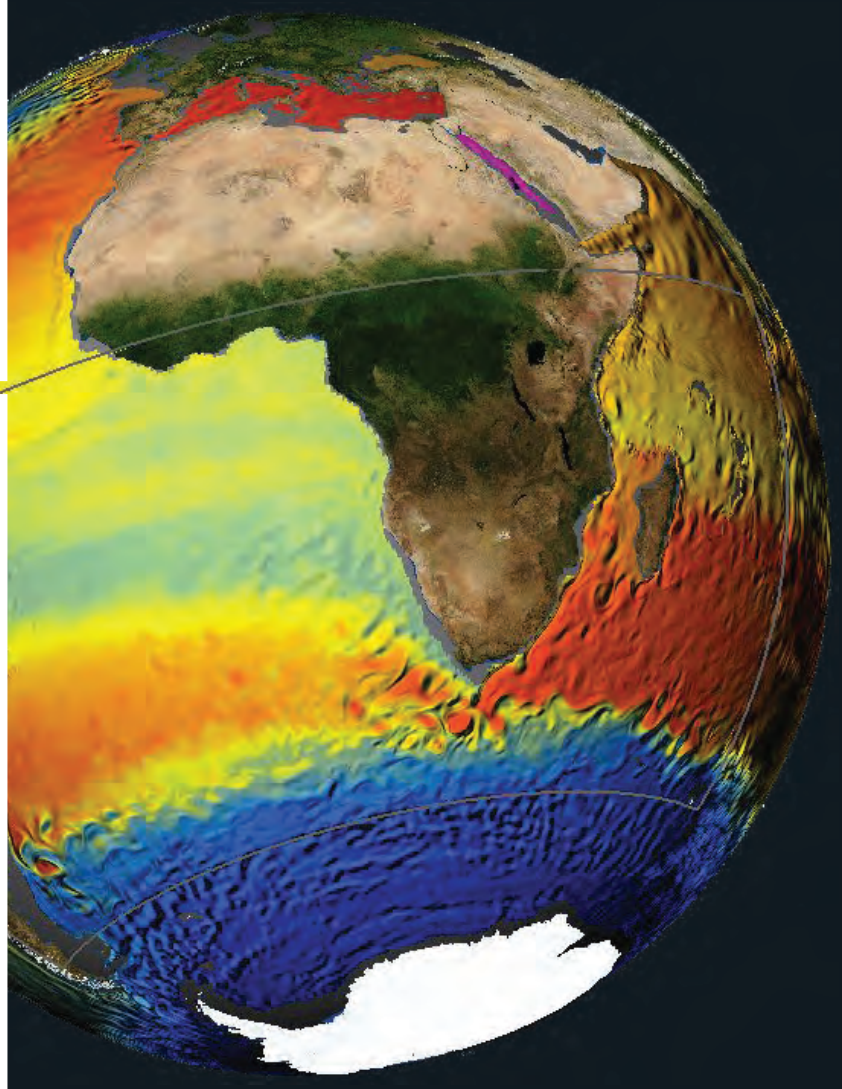
The Agulhas System and its Role in Changing Ocean Circulation, Climate, and Marine Ecosystems



American Geophysical Union Chapman Conference

Stellenbosch, Western Cape, Africa

8 - 12 October 2012

AGU Chapman Conference on The Agulhas System and its Role in Changing Ocean Circulation, Climate, and Marine Ecosystems

Stellenbosch, Western Cape, Africa
8 - 12 October 2012

Conveners

Will de Ruijter, Utrecht University, The Netherlands
Rainer Zahn, Universitat Autònoma de Barcelona, Spain
Arne Biastoch, Helmholtz Centre for Ocean Research Kiel (GEOMAR), Germany
Lisa Beal, University of Miami, U.S.A.

Program Committee

SCOR WG 136 Members and Associate Members:
Meghan Cronin, NOAA PMEL, Seattle, U.S.A.
Francis Marsac, IRD, France
Juliet Hermes, SAEON, Cape Town, South Africa
Graham Quartly, NOCS, Great Britain
Tomoki Tozuka, University of Tokyo, Japan
Ian Hall, Cardiff University, Great Britain
Pierrick Penven, IRD, France
Herman Ridderinkhof, NIOZ, The Netherlands
Michael Roberts, DEA Oceans and Coasts, South Africa

Local Organizing Committee

David Vousden, ASCLME, Grahamstown, South Africa
Juliet Hermes, SAEON, Cape Town, South Africa
Michael Roberts, DEA Oceans and Coasts, South Africa

Cover photos

Top photo: Table Bay from RV Meteor as she leaves for a pre-site survey of an ODP/IODP drilling transect in January 2001. Photo credit: Rainer Zahn.

Lower photo: Local school children visit RV Knorr in Cape Town during mobilization for the first Agulhas Current Time-series (ACT) cruise in April 2010. Photo credit: Clement Rousset.

Figure: Snapshot of temperature and velocity gradients (15-Jun-2006) from the nested ocean model, INALT01, illustrating the Agulhas Current system. Credit: Jonathan Durgadoo, GEOMAR.

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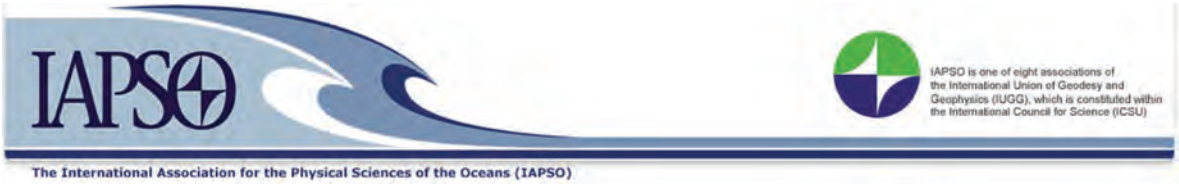

AGU Chapman Conference on The Agulhas System and its Role in Changing Ocean Circulation, Climate, and Marine Ecosystems

Meeting At A Glance

Sunday, 7 October 2012

1600h – 1900h	Registration
1700h – 1900h	Welcome Reception

Monday, 8 October 2012

0830h – 0900h	Opening Remarks The Deputy Minister of Science and Technology, Derek Hanekom
0900h – 1220h	Session 1: The Agulhas System, present and Past
1040h – 1100h	Coffee Break
1100h – 1220h	Session 1: The Agulhas System, present and Past
1220h – 1250h	Plenary Discussion - The Agulhas System, present and Past
1300h – 1400h	Group lunch and Welcoming Remarks Lawrence Mysak, Immediate Past President of International Association for the Physical Sciences of the Oceans
1400h – 1700h	Organized Activity: Lawn Games 1
1700h – 1730h	Session 1: The Agulhas System, Present and Past (cont.)
1530h – 1945h	Poster Session 1 The Agulhas System, Present and Past
2000h – 2200h	Reception Dinner at Moyo

Tuesday, 9 October 2012

0900h – 1220h	Session 2: Effects of Agulhas System Variability on Regional Weather, Climate, Ecosystems, and Fisheries ('regional interactions')
1040h – 1100h	Coffee Break
1220h – 1250h	Plenary Discussion - Effects of Agulhas System Variability on Regional Weather, Climate, Ecosystems, and Fisheries ('regional interactions')
1300h – 1400h	Lunch
1400h – 1700h	Organized Activity – Hike on Helderberg
1700h – 1730h	Session 2: Effects of Agulhas System Variability on Regional Weather, Climate, Ecosystems, and Fisheries ('regional interactions') (cont.)
1730h – 1945h	Poster Session 2 - Effects of Agulhas System Variability on Regional Weather, Climate, Ecosystems, and Fisheries ('regional interactions')
2000h – 2200h	Dinner on Your Own in Stellenbosch

Wednesday, 10 October 2012

0900h – 1245h	Group Discussions: Future Research Directions and Implementation of Sustained Observations
0900h – 0905h	Group Discussions: Introduction - de Ruijter
0905h – 0915h	Group Discussions: Ongoing/Necessary Observations - Beal, Zahn
0915h – 0925h	Group Discussions: Modelling - Biastoch, Tozuka
0925h – 0940h	Group Discussions: Implementation and the WIO Strategic Alliance - Vousden
0940h – 1100h	Breakout for Discussion Groups
1100h – 1120h	Coffee Break
1120h – 1245h	Group Reporting and Plenary Discussion
1300h – 1400h	Lunch
1400h – 2200h	Organized Activities – Township or Table Mountain Tours
1800h – 2200h	Dinner on Your Own

Thursday, 11 October 2012

0900h – 1040h	Session 3: Mechanisms that Link the Agulhas to Ocean Circulation and Climate ('controls')
1040h – 1100h	Coffee Break
1100h – 1210h	Session 3: Mechanisms that Link the Agulhas to Ocean Circulation and Climate ('controls')
1210h – 1250h	Plenary Discussion - Mechanisms that Link the Agulhas to Ocean Circulation and Climate ('controls')
1300h – 1400h	Lunch
1400h – 1700h	Organized Activity – Lawn Games 2
1700h – 1730h	Session 3: Mechanisms that Link the Agulhas to Ocean Circulation and Climate ('controls') (cont.)
1730h – 1945h	Poster Session 3 - Mechanisms that Link the Agulhas to Ocean Circulation and Climate ('controls') (cont.)
2000h – 2200h	Conference Dinner at the Spier Hotel

Friday, 12 October 2012

0900h – 1040h	Session 4: Impact of Agulhas Retroflection and Leakage on Large-scale Circulation and Climate ('global effects')
1040h – 1100h	Coffee Break
1100h – 1210h	Session 4: Impact of Agulhas Retroflection and Leakage on Large-scale Circulation and Climate ('global effects')
1210h – 1250h	Plenary Discussion - : Impact of Agulhas Retroflection and Leakage on Large-scale Circulation and Climate ('global effects')
1300h – 1400h	Lunch
1400h – 1530h	Poster Session - : Impact of Agulhas Retroflection and Leakage on Large-scale Circulation and Climate ('global effects')
1530h – 1600h	Lutjeharms Memorial Lecture
1600h – 1615h	Conference Outcomes: Summary and Points of Action Will de Ruijter, Lisa Beal, Arne Biastoch, Rainer Zahn and SCOR/IAPSO/WCRP WG 136
1615h – 1630h	Closing Remarks Michael McPhaden, President, American Geophysical Union
1700h – 2330h	Cape Town Excursion and Dinner on Your Own

SCIENTIFIC PROGRAM

SUNDAY, 7 OCTOBER

1600h – 1900h	**Registration**
1700h – 1900h	**Welcome Reception**

MONDAY, 8 OCTOBER

0830h – 0900h	**Opening Remarks** **The South African Deputy Minister of Science and Technology, Derek Hanekom**
	Session 1: The Agulhas System, Present and Past Spier Auditorium
0900h – 0930h	**Lisa M. Beal** | Introduction to Session 1: An introduction to the Greater Agulhas System
0930h – 1000h	**Sabrina Speich** | What We have Learned From the GoodHope and BONUS-GoodHope Projects and What we Plan Within the SAMOC International Programme ***(INVITED)***
1000h – 1020h	**Jeffrey W. Book** | Warm-core Agulhas Plateau Eddies
1020h – 1040h	**Motoki Nagura** | Dynamics of the Seychelles Dome Simulated by 34 Ocean-Atmosphere Coupled General Circulation Models
1040h – 1100h	Coffee Break
1100h – 1130h	**Gianluca Marino** | The Role of the Agulhas System in Abrupt Climate Change ***(INVITED)***
1130h – 1150h	**Jens Zinke** | Interannual and decadal variability in the greater Agulhas current region over the past 350 years from coral paleothermometry
1150h – 1220h	**Mathieu Rouault** | Ocean Atmosphere Interaction in the Agulhas Current System ***(INVITED)***
1220h – 1250h	**Plenary Discussion - The Agulhas System, Present and Past**
1300h – 1400h	**Group lunch and Welcoming Remarks** **Lawrence Mysak, Immediate Past President of International Association for the Physical Sciences of the Oceans**
1400h – 1700h	**Organized Activity - Lawn Games 1**

Session 1 (cont.) - The Agulhas System, Present and Past

Spier Auditorium

1700h – 1730h **Curtis W. Marean** | Early Modern Humans on the Edge of Land and Sea: The Dynamic Character of the Agulhas Paleoscape and its Impact on Modern Human Origins ***(INVITED)***

1730h – 1945h Poster Session 1 - The Agulhas System, Present and Past

Spier Auditorium

M-1 **Juliane Steinhardt** | Seasonal planktonic foraminifera assemblage changes in the Mozambique Channel

M-2 **Simon Josey** | What Do We Know About Air-Sea Exchanges In The Agulhas System?

M-3 **Johnny A. Johannessen** | New estimates of the greater Agulhas Current dynamics from high-resolution satellite sensor synergy

M-4 **Agatha M. De Boer** | The Subtropical Front and its relation to the windstress curl

M-5 **Jenny E. Ullgren** | In Situ Observations of Mozambique Channel Throughflow and Large Anticyclonic Eddies

M-6 **Lisa Hancke** | Characteristics of the surface circulation in the Mozambique Channel from satellite-tracked drifters

M-7 **Charine Collins** | Modelling the Comoros Basin using ROMS

M-8 **Ternon Jean-François** | New insight on the circulation in the Mozambique Channel from in-situ measurements (2005-2010)

M-9 **Conor Purcell** | Modelling the influence of Agulhas Leakage on the Atlantic Meridional Overturning Circulation during glacial-interglacial transitions

M-10 **Lisa M. Beal** | Preliminary results from the Agulhas Current Time-series Experiment (ACT)

M-11 **Graham Quartly** | Slippage in models: The impact of boundary conditions

M-12 **Graham Quartly** | The East Madagascar Current: Looking deeper than the superficial flow

M-13 **Michael J. Roberts** | Observations of shelf edge upwelling along the Mozambique shelf: the interaction of anticyclone-cyclone paired eddies with the continental slope

M-14 **Sebastian Kasper** | Stable hydrogen isotope composition of C37 alkenones as indicator for salinity changes in the Agulhas leakage area during Termination I and II

M-15 **Konstantina Rizopoulou** | The dynamics of the Agulhas Current by coastal altimetry

M-16 **Viviane V. Menezes** | Multi-scale Variability in the South Indian Upper Ocean Circulation: Impacts on the Agulhas Current System

M-17 **Kristina L. Arthur** | Fossil planktonic foraminifera from the Agulhas region over the last Glacial-Interglacial cycle: a study on temporal and spatial similarity

M-18 **Rosamma Stephen** | Copepods in the Agulhas Retroflection Front and adjacent waters : evaluation of 2004 and 1964 collections

M-19 **Lisa Guastella** | Influence of the Durban cyclonic eddy on the east coast of South Africa

M-20 **Monika Breitzke** | Morphology of the seafloor in the Southern Mozambique Channel: Evidence for long-term persistent bottom-current flow and deep-reaching eddy activity

M-21 **Gavin Louw** | Monitoring the dynamics of the Natal Pulse, Durban break-away eddy and the Agulhas Undercurrent with a single, real-time mooring off Port Edward

M-22 **Eric Chassignet** | Agulhas Current system representation in high horizontal resolution (1/12 and 1/25 degree) global HYbrid Coordinate Ocean Model (HYCOM) configurations

M-23 **Meghan F. Cronin** | NOAA Adopt-A-Drifter Program: Schoolchildren's Oceanographic Experiments

M-24 **Petra S. Dekens** | Increased Agulhas leakage during the early Pliocene, a time of sustained global warmth

M-25 **Warren Wood** | The nature and distribution of deep filaments in the strong mixing portions of the Agulhas Return Current – Observations from seismic oceanography

2000h – 2200h **Reception Dinner at Moyo**

TUESDAY, 9 OCTOBER

Session 2: Effects of Agulhas System Variability on Regional Weather, Climate, Ecosystems,and Fisheries ('regional interactions')

Spier Auditorium

0900h – 0930h **Francis Marsac** | Introduction to Session 2: Effects of Agulhas system variability on regional weather, climate, bio-physical interactions, marine ecosystems and fisheries

0930h – 1000h **Hisashi Nakamura** | Air-Sea interactions Associated with the Agulhas System: Regional, Basin-Scale and Hemispheric Impacts ***(INVITED)***

1000h – 1020h **Satyaban B. Ratna** | Simulation of extreme seasonal climate over South Africa using the high resolution Weather Research and Forecasting (WRF) model

1020h – 1040h **Martin Ziegler** | Development of modern human behaviour linked to rapid climate change

1040h – 1100h Coffee Break

1100h – 1130h **Chris Reason** | The Influences of the Agulhas Current on Regional Climate and Weather Patterns ***(INVITED)***

1130h – 1200h **Carl D. van der Lingen** | Effects of Agulhas System Variability on Small Pelagic Fish off South Africa ***(INVITED)***

1200h – 1220h **Francesca Porri** | From general patterns to individual mechanisms: oceanographic determinants of offshore larval dispersal

1220h – 1250h **Plenary Discussion - Effects of Agulhas System Variability on Regional Weather, Climate, Ecosystems,and Fisheries ('regional interactions')**

1300h – 1400h **Lunch (Tuesday)**

1400h – 1700h **Organized Activity - Hike on Helderberg**

Session 2 (cont.): Effects of Agulhas System Variability on Regional Weather, Climate, Ecosystems,and Fisheries ('regional interactions')
Spier Auditorium

1700h – 1730h **Ben P. Kirtman** | Global Climate Simulations with Ocean Eddy Resolving Resolutions ***(INVITED)***

1730h – 1945h **Poster Session 2 - Effects of Agulhas System Variability on Regional Weather, Climate, Ecosystems,and Fisheries ('regional interactions')**
Poster Hall

T-1 **Frank Kiwalabye** | Vulnerability And Effects Of Climate Change To Older People In Africa

T-2 **Mohammed Ngwali** | Impact of Climate Variability on Sea Level Change in East Africa

T-3 **Chaoxia Yuan** | Predictability of the Subtropical Dipole Modes in the Atlantic and Indian Oceans

T-4 **David Vousden** | A Global Network of Marine Hotspots: Understanding and adapting to Climate change in the Western Indian Ocean

T-5 **Takahito Kataoka** | A mechanism of the Indian Ocean subtropical modes simulated in the CMIP3 models

T-6 **David H. Vousden** | Evolving new Governance Approaches for the Agulhas and Somali Current Large Marine Ecosystems through Dynamic Management Strategies and Partnerships

T-7 **Larry Hutchings** | Drivers of primary productivity on the Agulhas Bank: which ones are likely to change in future and what are the consequences?

T-8	**Kerstin Braun** | Southern South African coastal climate: the influence of sea level, SST, orbital parameters and productivity as recorded in speleothem stable isotopic records
T-9	**Shaun Johnston** | Mixing estimates from sustained observations by underwater gliders
T-10	**Jennifer M. Jackson** | The bio-physical influence of Natal Pulses on the Agulhas Bank, South Africa
T-11	**Neil Malan** | Dynamic Upwelling on the Inshore Edge of the Agulhas Current
T-12	**Charles von der Meden** | BENTHIC-PELAGIC LINKS: EXPLAINING TOPOGRAPHICALLY-RELATED ADULT MUSSEL DISTRIBUTIONS
T-13	**Jenny A. Huggett** | Are Changes in the Copepod Community on the Agulhas Bank over the Last Two Decades Mediated by Environmental Factors or Predation?
T-14	**John G. Mungai** | A Numerical Investigation of Surface Currents of the Western Indian Ocean
T-15	**Graham Quartly** | The Madagascar Bloom – a serendipitous study
T-16	**Dierk Hebbeln** | Exploring the potential of cold-water corals as (palaeo-)environmental indicators for the Mozambique and Agulhas Current systems
T-17	**Bernardino S. Malauene** | Cool, elevated chlorophyll waters off northern Mozambique
T-18	**Tarron Lamont** | Phytoplankton production and physiology on the KwaZulu Natal Bight, South Africa
T-19	**Emma Khadun** | INCREASED RIVER DISCHARGE DURING THE YOUNGER DRYAS IN THE UPPER MOZAMBIQUE CHANNEL
T-20	**Kate Watermeyer** | Re-examining changes in SST on the Agulhas Bank as a driver of distributional change in small pelagic fish
T-21	**Yonss S. José** | Influence of mesoscale variability on the biogeochemical structure of the Mozambique Channel
T-22	**Christo P. Whittle** | Characterization of Agulhas Bank upwelling variability from satellite-derived sea surface temperature and ocean color products
T-23	**Agatha M. De Boer** | Lightning over the Agulhas Current
T-24	**Meghan F. Cronin** | Air-sea flux measurements by the NOAA surface mooring in the Agulhas Return Current
T-25	**Luc Rainville** | Coastal Trapped Waves and Internal Tides on the Agulhas Bank, South Africa

2000h – 2300h **Dinner on Your Own in Stellenbosch**

WEDNESDAY, 10 OCTOBER

0900h – 1245h	**Group Discussions: Future Research Directions and Implementation of Sustained Observations**
0900h – 0905h	**Group Discussions: Introduction - de Ruijter**
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0940h – 1100h	**Breakout for Discussion Groups**
1100h – 1120h	**Coffee Break**
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1300h – 1400h	**Lunch (Wednesday)**
1400h – 2000h	**Organized Activities - Township or Table Mountain Tour**
1800h – 2000h	**Dinner on Your Own**

THURSDAY, 11 OCTOBER

Session 3: Mechanisms that Link the Agulhas to Ocean Circulation and Climate ('controls')
Spier Auditorium

0900h – 0930h	**Wilhelmus de Ruijter** | Introduction to Session 3: Physical Mechanisms That Link the Agulhas to Ocean Circulation and Climate (controls)
0930h – 1000h	**Eric Chassignet** | Western Boundary Current Detachment in Numerical Model: A Review ***(INVITED)*** **<*i*/><*b*/>**
1000h – 1020h	**Benjamin Loveday** | Decoupling the Agulhas Current and Agulhas Leakage
1020h – 1040h	**Dewi Le Bars** | Why is the Indonesian Throughflow strenghtening the Agulhas Current leakage?
1040h – 1100h	Coffee Break
1100h – 1130h	**Bjorn Backeberg** | Impact of Intensified Indian Ocean Winds on Mesoscale Variability in the Agulhas System ***(INVITED)***

1130h – 1150h **Meghan F. Cronin** | Prevalence of Strong Bottom Currents in the Greater Agulhas Current System

1150h – 1210h **Robert M. Graham** | The response of the Subtropical Front to a shift in the Southern Ocean Westerlies

1210h – 1250h **Plenary Discussion - Session 3: Mechanisms that Link the Agulhas to Ocean Circulation and Climate ('controls')**

1300h – 1400h **Lunch (Thursday)**

1400h – 1700h **Organized Activity - Lawn Games 2**

Session 3 (cont.): Mechanisms that Link the Agulhas to Ocean Circulation and Climate ('controls')
Spier Auditorium

1700h – 1730h **Raleigh R. Hood** | Biogeochemical Impacts of Boundary Currents in the Indian Ocean with Special Reference to the Agulhas System and the Madagascar Bloom ***(INVITED)***

1730h – 1945h **Poster Session 3 - Mechanisms that Link the Agulhas to Ocean Circulation and Climate ('controls')**
Poster Hall

TH-1 **Yushi Morioka** | How to generate the Indian Ocean Subtropical Dipole in a coupled GCM

TH-2 **Ian R. Hall** | Weakened Agulhas Leakage as a Potential Trigger for Reduced AMOC Intensity Before the Onset of Heinrich Events

TH-3 **Tamaryn Morris** | Mozambique Channel eddies as a transport mechanism: The case of Red Sea Water

TH-4 **Steven Herbette** | Dynamics of a dipolar gyre on the beta-plane

TH-5 **Margit Simon** | Does upstream Agulhas Current variability reflect inferred changes in Agulhas Leakage?

TH-6 **Sarah Romahn** | Antarctic control on tropical western Indian Ocean sea surface temperature and productivity during the late Pleistocene

TH-7 **Jan Saynisch** | Ocean bottom pressure assimilation in the Agulhas region

TH-8 **Jonathan V. Durgadoo** | Atlantic warm-water route depends on the Westerlies

TH-9 **Tomoki Tozuka** | Interannual variations of the Seychelles Dome and its possible influence on the upstream of the Agulhas Current

TH-10 **Pierrick Penven** | Modeling the Recent Changes in the Agulhas Retroflection Region

TH-11 **Masami Nonaka** | Upper ocean heat content, SST, and surface heat flux in midlatitude oceanic frontal zones

	TH-12	**Lucy Scott** | Title: A long term monitoring network for the western Indian Ocean
	TH-13	**Emidio Andre** | Three years of current measurements outside Pemba, Northern Mozambique
	TH-14	**Emanuela Rusciano** | Interocean exchanges and the spreading of Antarctic Intermediate Water South of Africa
	TH-15	**Allison M. Franzese** | Assessing the role of the Subtropical Front in regulating Agulhas Leakage at the Last Glacial Termination
	TH-16	**Wonsun Park** | Spectrum of the Agulhas Current as simulated by a coupled atmosphere-ocean general circulation model
	TH-17	**Robert M. Graham** | Evidence for Southern Hemisphere Westerly Wind Changes during the Last Glacial Maximum
	TH-18	**Jeroen van der Lubbe** | Zambezi sediment dispersal over the last 20ka
	TH-19	**Wayne Goschen** | Upwelling in the coastal zone off Algoa Bay driven by wind and large episodic meanders in the Agulhas Current
	TH-20	**Gary S. Lagerloef** | Satellite Salinity and Velocity Measurements in the Agulhas Current System
2000h – 2200h	**Conference Dinner at the Spier Hotel**	

FRIDAY, 12 OCTOBER

	Session 4: Impact of Agulhas Retroflection and Leakage on Large-scale Ocean Circulation and Climate ('global effects') Spier Auditorium
0900h – 0930h	**Arne Biastoch** | Introduction to Session 4: Impact of Agulhas Retroflection and Leakage on Large-scale Ocean Circulation and Climate
0930h – 1000h	**Erik van Sebille** | Towards a Framework for Assessing Agulhas Leakage in the Real Ocean ***(INVITED)***
1000h – 1020h	**Edmo J. Campos** | Trends in the South Atlantic in a Numerical Simulation Forced with NCEP Reanalysis
1020h – 1040h	Coffee Break
1040h – 1100h	**Marjolaine Krug Rouault** | Intra- and Annual variability of the Agulhas Current from satellite remote sensing observations
1100h – 1130h	**Frank J.C. Peeters** | Fossil Planktic Foraminiferal Faunas: Silent Witnesses of Past Ocean Environments South of Africa ***(INVITED)***
1130h – 1150h	**Thibaut Caley** | Quantitative estimate of the Agulhas paleo-leakage
1150h – 1210h	**Joseph D. Ortiz** | An Indirect Estimate of the Impact of the Agulhas Leakage on the Atlantic Meridional Overturning Circulation During the Holocene

1210h – 1250h **Plenary Discussion - Impact of Agulhas Retroflection and Leakage on Large-scale Ocean Circulation and Climate ('global effects')**

1300h – 1400h **Lunch (Friday)**

1400h – 1530h **Poster Session 4 - Impact of Agulhas Retroflection and Leakage on Large-scale Ocean Circulation and Climate ('global effects')**
Poster Hall

F-1 **Arne Biastoch** | Fate and Impact of Anthropogenic Agulhas Leakage Increase

F-2 **Alan Foreman** | Linking Agulhas Leakage and Atlantic G. menardii Zonation: Glacial/Interglacial Abundances of G. menardii from a Depth Transect Along the Namibian Margin

F-3 **Marcio L. Vianna** | Pan-Atlantic Ocean Circulation Changes in the Bidecadal Climate Band and Relations to the Agulhas Leakage

F-4 **Paolo Scussolini** | Tracing the influence of Agulhas Leakage in the South Atlantic over glacial Termination II (MIS 6-5)

Lutjeharms Memorial Lecture
Spier Auditorium

1530h – 1600h **Arnold L. Gordon** | Retroflections and Bifurcations

1600h – 1615h **Conference Outcomes: Summary and Points of Action**
Will de Ruijter, Lisa Beal, Arne Biastoch, Rainer Zahn and SCOR/IAPSO/WCRP WG 136

1615h – 1630h **Closing Remarks**
Michael McPhaden, President, American Geophysical Union

1700h – 2330h **Cape Town Excursion and Dinner on Your Own**

ABSTRACTS

listed by name of presenter

Andre, Emidio

Three years of current measurements outside Pemba, Northern Mozambique

Gammelsrød, Tor[1]; Andre, Emidio[2]; Hoguane, Antonio M.[3]

1. Geophysical Institute, University of Bergen, Bergen, Norway
2. Environment, Instituto Investigacao Pesqueira, Maputo, Mozambique
3. School of Marine Sciences, Universidade Eduardo Mondlane, Quelimane, Mozambique

A Seaguard current meter was deployed at 954 m bottom depth in position 13 04'S, 040 42.3E. The instrument was located 100m above bottom. The imooring was deployed in November 2008 and recovered in December 2011. The average speed was 10 cm/s but with a large variability. Episodes occurring about 4 times a year showed current up to almost 60 cm/s. These episodes are believed to be associated with the large anti-cyclonic eddies in the Mozambican Channel. There are two competing theories how these eddies are formed; One by Harlander et al (2009) which indicate that they obtain their characteristics at the most narrow part in the Mozambican Channel which is about 400 km south of our mooring. The second theory was suggested by Backeberg and Reason (2010) who suggested that they are formed by anti-cyclonic vortices created at the northern tip of Madagascar. One way to resolve this dilemma is to compare with overlapping data from the LOCO-line (Ridderinkohof et. al, 2010) to learn if the eddies we observe at 13°S are the same which propagates southwards to 16 – 17°S where the LOCO moorings are located. Swart et al (2010) have indicated that the Mozambican Channel eddies are influencing the Aghulas Current system influencing both Natal Pulses and Aghulas Ring sheddings. In the region near our mooring there strong indications that enormous sub-ocean floor gas and oil reserves exist, and off-shore operations like exploratory ocean floor drillings are planned. Will currents up to 60 cm/s be any threats to such operations? Experiments with a ROMS model and comparisons with the LOCO mooring at the same depth further south indicate that surface current may be a factor 2 – 4 times the current at 800m depth, which means that surface current may reach as high as 2.5 m/s. This will make off-shore operations challenging and a system for predicting extreme current events necessary

Arthur, Kristina L.

Fossil planktonic foraminifera from the Agulhas region over the last Glacial-Interglacial cycle: a study on temporal and spatial similarity

Arthur, Kristina L.[1]; Peeters, Frank J.[1]; Simon, Margit H.[2]; Hall, Ian R.[2]; Caley, Thibaut[1]; Ziegler, Martin[2]

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2. School of Earth and Ocean Sciences, Cardiff University, Cardiff, United Kingdom

While bounded in the north by the African continent, the Indian-Atlantic water exchange, south of Africa, is controlled to a large extent by the dynamics and position of the Subtropical Front (STF). Past research has shown the STF is a migratory front, thought to restrict the Agulhas Leakage by way of northward migration during glacial periods. The position of the STF is not well constrained, and model results indicate a northward STF position is not necessarily accompanied by decreased leakage. In this study we aim to unravel the influence of the last glacial-interglacial cycle on the Agulhas fauna in the upstream region, the Agulhas Current, and the affect this has on the downstream Agulhas Leakage Fauna (ALF). We also aim to find out how the STF migration has affected the Agulhas Leakage over the last glacial-interglacial cycle. To resolve these aims we study planktonic foraminiferal assemblages, obtaining a record of environmental changes at two core sites – underneath the Agulhas Current in the south-west Indian Ocean (CD154 17-17K), and on the Agulhas Plateau further to the south (MD02-2588). Faunal proxy records for both cores span a period of ~100 ka and are compared with the last 100 ka of the Cape Basin Record (CBR) in the downstream leakage area. Planktonic foraminifer species are grouped into five categories: tropical, subtropical, transitional, sub-polar and polar. The glacial Agulhas Current fauna is dominated by subtropical-transitional dominated fauna, compared to a tropical-subtropical dominated fauna during interglacial periods. Using a fauna similarity index we compare these changes in the upstream region with the downstream ALF to estimate the efficiency of the leakage. This comparison also provides a downstream-calibrated record that enables the interpretation of the Agulhas Leakage while removing the effects of regional variation. The similarity index is also used to interpret Agulhas gateway geometry variation over the last glacial-interglacial cycle. Results show that the degree of similarity between up and downstream faunas varies, with a lower degree of similarity during the Last Glacial Maximum (LGM), followed by higher similarity during the Holocene, suggesting that leakage efficiency increased. The Agulhas Plateau record shows a decrease in sub-polar and polar species over the past ~20 ka, and an increase in transitional species. This indicates a northward position of the STF (relative to MD02-2588) during the LGM, followed by a southward position during the Holocene. Therefore variation in Agulhas Leakage efficiency points to a close link with the STF position, and changes in leakage link with

changes in the migration of the front. Furthermore, our data suggests that strengthening of the south-west Indian Ocean subtropical gyre may occur during periods in which the STF is positioned further to the north. Potentially increased vigour of this recirculation may add to a non-linear behaviour between leakage and the position of the STF as predicted by model simulations.

Backeberg, Bjorn

Impact of Intensified Indian Ocean Winds on Mesoscale Variability in the Agulhas System ***(INVITED)***

Backeberg, Bjorn[1]

1. Oceanography, Nansen-Tutu Centre, Rondebosch, Cape Tow, South Africa

South of Africa, the Agulhas Current retroflects and a portion of its waters flows into the South Atlantic, typically in the form of Agulhas rings. This flux of warm and salty water from the Indian to the Atlantic Ocean (the Agulhas leakage) is now recognized as a key element in global climate. An Agulhas leakage shutdown has been associated with extreme glacial periods, while a vigorous increase has preceded shifts towards interglacials. In the absence of a coherent observing system, studies of the Agulhas have relied heavily on ocean models, which have revealed a possible recent increase in Agulhas leakage. However, due to the high levels of oceanic turbulence, model solutions of the region are highly sensitive to their numerical choices, stressing the need for observations to confirm these important model results. Here, using satellite altimetry observations from 1993-2009, we show that the mesoscale variability of the Agulhas system, in particular in the Mozambique Channel and south of Madagascar, has intensified. This appears to result from an increased South Equatorial Current driven by enhanced trade winds over the tropical Indian Ocean. Overall, the intensified mesoscale variability of the Agulhas system is reflected in accelerated eddy propagation, both in source regions as well as the retroflection from which eddies propagate into the South Atlantic Ocean. This suggests that the Agulhas leakage may have increased from 1993-2009, confirming previous modelling studies that have further implied an increased Agulhas leakage may compensate a deceleration of Meridional Overturning Circulation associated with a freshening of the North Atlantic Ocean.

Beal, Lisa M.

Introduction to Session 1: An introduction to the Greater Agulhas System

Beal, Lisa M.[1]; Ridderinkhof, Herman[2]

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2. Royal Netherlands Institute for Sea Research (NIOZ), Den Burg, Netherlands

In this introductory talk we will review the character, strength, and variability of the greater Agulhas System. The Agulhas Current has an estimated mean transport of 70 Sv at 32 S and sub-annual variability that peaks around 60 days, associated with a meander mode and ring shedding. Satellite altimeter data suggest that there is also a seasonal signal, with stronger velocities in austral summer. The southward flow of water through the Mozambique Channel is dominated by eddies and its interannual variability is high, owing to shifting of the tropical and subtropical gyres related to the Indian Ocean Dipole mode. This interannual variability is thought to affect the Agulhas retroflection and leakage. The East Madagascar Current links to the Agulhas via dipoles, paired cyclones and anticyclones, which mutually advect to the southwest. The size and variability of Agulhas leakage, which is carried by highly stochastic rings, eddies, and filaments, are difficult to measure and hence highly uncertain, with estimates between 2 and 15 Sv. Associated heat and freshwater transports can vary by two orders of magnitude dependent on whether Agulhas leakage is perceived to exchange with South Atlantic thermocline or deep waters. Leakage feeds into both the Atlantic overturning and Southern Hemisphere super-gyre circulations in unknown proportions. The position of the retroflection has been relatively stable over the past 20 years, although there is increased sea surface temperature and eddy kinetic energy over the region which may be related to an expansion of the subtropical gyre with climate change and an increase in leakage. Palaeoceanographic data show that Agulhas leakage has varied dramatically in the past, tied to glacial-interglacial climate change, reaching its peak during glacial ice-volume maxima.

Beal, Lisa M.

Preliminary results from the Agulhas Current Time-series Experiment (ACT)

Beal, Lisa M.[1]; Leber, Greta[1]

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ACT is an experiment to produce a multi-decadal time series of Agulhas Current transport at 34 S, using three years of in situ velocity measurements from a full-depth current meter array, together with two decades of along-track altimeter data. Preliminary results show that the transport of the Agulhas Current between April 2010 and November 2011, estimated as the mean southwestward flow across the ACT line out to 180 km offshore, is 81 Sv with a standard deviation of 21.6 Sv. The mean current core has speed 1.2 m/s and is about 40 km from the coast in waters of 1200 m depth. An undercurrent is seen on the continental slope below 1200 m depth with mean speeds under 10 cm/s. Instantaneous maximum velocities can reach 2.5 m/s and are significantly correlated (r=0.6) with Eulerian transport. Transport variability is dominated by four meander events, except for a transport minimum in September 2011 which is not associated with an offshore displacement of the current. Direct velocity and hydrographic sections out to 300 km offshore, collected during the April 2010 and November 2011 cruises, captured the complete Current during a meander and non-meander state, respectively. Comparing these data shows that the structure of the Current changes little and its transport is similar (5 Sv difference) between the meander and non-meander cases. Hence, we expect the stream-wise Agulhas Current transport to be significantly higher, and its variability lower, than the Eulerian estimate above. In the future, we will synthesise the current meter measurements with dynamic height estimates from four

bottom moorings, which extend the array from 180 km to 300 km offshore, and with along-track altimeter data, in order to improve and extend the transport time series.

http://act.rsmas.miami.edu

Biastoch, Arne

Introduction to Session 4: Impact of Agulhas Retroflection and Leakage on Large-scale Ocean Circulation and Climate

Biastoch, Arne[1]; Zahn, Rainer[2]

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Owing to internal dynamics and external forcing factors the Agulhas Current Retroflection varies on wide range of time scales. The ensuing interoceanic transfer of mass, heat and salt, the 'Agulhas Leakage', modulates the modern horizontal gyre and overturning circulations at interannual-decadal time scales, while long paleoceanographic time series document variability and variation of Agulhas Leakage at centennial to multi-millennial scales. Paleo-proxy records compellingly demonstrate peak Agulhas Leakage maxima at the end of glacial climates as the ocean circulation transgressed to its full-strength interglacial mode. The proxy records also show recurrent shorter Agulhas Leakage events that coincided with perturbed states when the Atlantic overturning circulation was fundamentally different from today's. The data suggest strong interactions with abrupt switches between shallow and deep modes of the global conveyor belt circulation. The driving forces for these variations are similar even though they proceed on different time scales: changes in the Southern Hemisphere wind systems such as the trades and westerlies, some in response to far-field forcing from the Northern Hemisphere, figure prominently in defining the Agulhas Retroflection and strength of the Agulhas Leakage present and past. Amplified by anthropogenic factors these wind systems undergo current changes, causing observable migrations of oceanic fronts and substantial changes in Agulhas Leakage over the past decades. The complexity of the Agulhas Leakage with its multiple mesoscale features and a variability that occurs on a wide range of timescales calls for an integration of interdisciplinary expertise that combines paleo and modern observations with climate modelling. Such integrative views are needed to better understand the significance of the Agulhas Retroflection and Leakage and its embedding into the global ocean circulation and climate.

Biastoch, Arne

Fate and Impact of Anthropogenic Agulhas Leakage Increase

Biastoch, Arne[1]; Rühs, Siren[1]; Durgadoo, Jonathan[1]; Böning, Claus W.[1]

1. FB1-Theory & Modeling, GEOMAR, Kiel, Germany

Recent work suggests that the changes of the Southern Hemisphere (SH) winds led to an increase in Agulhas leakage and a corresponding salinification of the Atlantic. Climate model projections for the 21st century especially predict a progressive southward migration and intensification of the SH westerlies. The potential effects on the ocean circulation of such an anthropogenic trend in wind stress are studied here with a high-resolution ocean model. The model suggests an increase of ~4 Sv in Agulhas leakage in response to the wind changes, associated with a southward expansion of the subtropical supergyre. The northward transport in the upper branch of the Atlantic Meridional Overturning Circulation (AMOC) gradually increases by up to 1.5 Sv at 20°-25°S; about 0.5-1 Sv of this dynamical signal crosses the equator, concentrated along the western boundary of the South Atlantic. The main effect of the increasing inflow of Indian Ocean waters is the salinification and densification of upper-thermocline waters in the Atlantic Ocean. Timescales and pathways of Agulhas leakage are studied with a Lagrangian analysis using virtual floats. Consistent among different model resolutions, typical timescales of 6-8 years arise for the advective pathway into the equatorial Atlantic, and 15 years into the subtropical North Atlantic.

Book, Jeffrey W.

Warm-core Agulhas Plateau Eddies

Book, Jeffrey W.[1]; Rice, Ana E.[2]; Wood, Warren T.[1]; Barron, Charlie[1]; Ansorge, Isabelle[3]; Roman, Raymond[3]

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Anticyclonic eddies over the Agulhas Plateau have been previously documented, (e.g., see Lutjeharms and Valentine, 1988, and Boebel et al., 2003), however the persistence, magnitude, and role of these eddies have received less attention than other aspects of the Agulhas Current System. Gridded solutions for sea-surface height for the region, based on the 19 years of altimeter measurements, suggest that an anticyclonic eddy over the plateau is often present and may be part of the mean structure. These eddies can interact with both the east and west sides of the Agulhas Return Current as it loops around the Plateau. 2011/2012 offers an opportunity to examine one of these eddies and its interaction with the main current in great detail based on the observations made during the Agulhas Return Current 2012 cruise aboard R/V Melville in Jan./Feb. A large anticyclone over the southern Plateau can be observed in the satellite data during December 2011. This eddy may have at least partially originated from a detached anticyclone formed many months earlier to the east of the Plateau. In late January, 2012, just as an Agulhas Ring detaches into the Atlantic, the Return Current portion of the system appears to shift slightly eastwards towards the Plateau and directly interacts with the Agulhas Plateau eddy which has shifted to the western side of the Plateau. The cruise captured this interaction through detailed surveys of the eddy and current system. From an eddy radial crossing survey performed on Feb. 2-3, 2012, the eddy was observed to have a radius of more than 120 km, carry an upper 800 m transport exceeding 57 Sv, and have a maximum velocity exceeding 1.4 m/s. The band of core velocities around the eddy (speeds

greater than 0.5 m/s) was centered at about 60 km radius and was 90-100 km wide down to a depth of 350 m and 50 km wide to a depth of 600 m. These new observations provide a basis to begin to re-examine the role of such large warm-core anticyclones inside the Agulhas Current System. What role do they play in mixing of subtropical and subantarctic waters? Do they have a recurrent role in the shedding of rings to the Atlantic through indirect interactions with currents to the west of the Plateau? How important is it for models to resolve these eddies and properly account for their interactions with the main current?

Braun, Kerstin

Southern South African coastal climate: the influence of sea level, SST, orbital parameters and productivity as recorded in speleothem stable isotopic records

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4. Institut de Ciencia i Technologia Ambientals, Universitat Autònoma de Barcelona, Barcelona, Spain
5. Institute of Earth Sciences, Hebrew University of Jerusalem, Jerusalem, Israel

Located at the intersection of sub-tropical and temperate climatic regions, the climate in South Africa is marked by steep gradients. During summer, tropical easterly trade winds bring rainfall from the Agulhas region to the east coast. In winter, the trade winds shift north and temperate westerlies bring frequent rainfall to the south west. The central south coast receives rainfall from both systems. Different sources of rainfall result in seasonal variations in rainfall amount and isotopic composition. In Mossel Bay, rainfall in July has a δ18O of about -6‰ (SMOW), whereas in January, the δ18O is ~0.13 ‰ (SMOW, 1). Such variations are recorded in speleothem's δ18O. On longer timescales, δ18O variations in speleothems also record changes in air temperature and sea surface conditions. The strong spatial variations in the rainfall and temperature result in differences in the vegetation. In the summer rainfall region C4 grasses dominate, while in the winter rainfall region C3 plants are more common. These differences are recorded in the speleothem δ13C. Speleothems have been sampled from caves along the southern coast of South Africa. Crevice and Staircase Cave are situated at Pinnacle Point (Mossel Bay) few meters from the coast line the intermediate rainfall region, and yield isotopic records of the periods between ~111 – 53 ka and ~320 – 130 ka. The E-Flux Cave record, situated ~ 90 km inland from Pinnacle Point, covers the time between 117 – 20 ka, and Robertson Cave in the winter rainfall region yields a record between ~550-250 ka. Large differences in the amplitude and range of the δ18O and the δ13C between speleothems from the different caves reflect differences in vegetation, rainfall systems and physical sea-atmosphere-land processes. The isotopic records of the Pinnacle Point caves show a close correlation with changes in relative sea level (RSL, 2). Records of E-Flux cave speleothems show a high similarity to the SST record from the Agulhas Corridor (3). The isotopic record from Robertson Cave speleothems shows a strong correlation to both SST and TOC of a marine core situated further east which reflecting changes in the the strength of the Agulhas current (4). Steep differences in climate of South Africa are related to: RSL, SST, position of the subtropical front and the Agulhas current and atmospheric circulation. The influence of each process varies on an east to west axis along the south coast of South Africa.

1. Bar-Matthews, M., et al. (2010). Quat. Sci. Rev. 29(17-18): 2131 - 2145. 2. Waelbroeck, C., et al. (2002). Quat. Sci. Rev. 21(1–3): 295-305. 3. Martínez-Méndez, G., et al. (2010). Paleoceanography 25 (PA4227): doi:10.1029/2009PA001879. 4. Bard, E. & R. E. M. Rickaby (2009). Nature 460(7253): 380-383.

Breitzke, Monika

Morphology of the seafloor in the Southern Mozambique Channel: Evidence for long-term persistent bottom-current flow and deep-reaching eddy activity

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New high-resolution bathymetric and sub-bottom profiler data collected in the Southern Mozambique Channel along a grid of 16 parallel, non-overlapping lines show a large variety of bedforms which were formed by strong bottom currents. They are visually classified into four main microtopographic zones and several sub-zones which divide the study area into regions with (1) smooth seafloor, (2) undulating bedforms, (3) seamounts and islands, and (4) the Zambezi Channel. A smooth seafloor occurs on the Mozambican continental slope together with downslope mass-wasting processes, north and south of Bassas da India, on the eastern levee of the Zambezi Channel and in the Zambezi cone. Undulating bedforms of some kilometres wavelength and several tens of metres height cover most of the southern, central and northeastern study area. The most spectacular bedforms are numerous, closely spaced, giant erosional scours of up to ~450 m depth, more than ~20 km length and ~3 - 7 km width in the southwestern part of the study area. Here, northward flowing Antarctic Bottom Water (AABW) is topographically blocked to the north and deflected towards the east due to the shallowing bathymetry of the Mozambique Channel. SW-NE trending undulating bedforms aligned parallel to the deflected AABW and interpreted as small contourite mounds allow to trace the AABW flow path eastwards. An ~100 km long W-E trending contourite channel indicates the northernmost extension of the AABW. NW-SE oriented undulating bedforms in the

west, hummocky bedforms in the east and arcuate, cross-cutting features in-between reflect a completely different current regime in the central study area. Comparisons with LADCP sections show, that the western part lies in the range of deep-reaching anticyclonic Mozambique Channel eddies (MCEs), so that the undulating bedforms are again considered to be small contourite mounds aligned parallel to a part of the swirl. The cross-cutting features in the middle mark the eastern boundary of the MCEs, where a northbound flow direction prevails. The hummocky bedforms in the east may have developed under the influence of seasonally variable cyclonic East Madagascar Current (EMC) eddies simulating at least two different flow directions. The origin of arcuate bedforms, sediment ridges and circular or elongate depressions in the northeastern study area is not clear. Bottom currents which interact with the topography of the Bassas da India complex and the Zambezi Channel may contribute to their formation. All morphological features are draped with sediments indicating that the present-day current velocities are not strong enough to erode sediments. This agrees with published LADCP bottom-current velocities of 0.1 m/s. Hence, the microtopography must originate from a time when bottom-current velocities were stronger. Assuming a published sedimentation rate of 20 m/Myrs and a drape of at least 50 m thickness the microtopography may have developed during Pliocene times or earlier.

http://www.geo.uni-bremen.de/sensorik/

Caley, Thibaut

Quantitative estimate of the Agulhas paleo-leakage

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An accurate estimate of the Agulhas paleo-leakage is important to modelling studies, which aim to quantitatively understand its role in the global ocean's overturning circulation. Our attempt to provide a quantitative assessment of this inter-ocean exchange is based on planktonic foraminiferal proxy records from two marine sediment archives; one in the upstream and the other in the downstream region of the Agulhas Current. The influence of glacial-interglacial climate changes on the upstream "source composition" of the foraminiferal assemblages is used to quantitatively estimate the downstream leakage record over the past 620 kyrs. Our results indicate an Holocene leakage of 24 ± 7%, which is in the range of modern inter-ocean exchange obtained from flots seeded experiments (Biastoch et al., 2008). During the Last Glacial Maximum (19-23 kyr), however, our results indicate a reduced leakage of 12 ± 10%. The most significant reduction occurs during marine isotopic stage 12, for which we infer an extremely reduced leakage of 2 ± 8%, yielding the conclusion that the Agulhas leakage may have been entirely shut down for this period. Our results provide part of the necessary boundary conditions which could be used in modelling exercises to validate and quantitatively understand the climatic role of the leakage. Citation: Biastoch, A., J. R. E. Lutjeharms, C. W. Böning, and M. Scheinert (2008), Mesoscale perturbations control inter-ocean exchange south of Africa, Geophys. Res. Lett., 35, L20602, doi:10.1029/2008GL035132.

Campos, Edmo J.

Trends in the South Atlantic in a Numerical Simulation Forced with NCEP Reanalysis

Campos, Edmo J.[1]; Gramcianinov, Carolina B.[1]; Carvalho, Jessica[1]

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A 1/4-degree, 22-layer implementation of HYCOM to the Atlantic-Indian Ocean basins (98W-114E, 65S-60N) was forced with monthly means of the NCAR/NCEP was run for the period 1948 to 2010. Analyses of the results show good agreement with other numerical experiments and satellite-based observations. These include salinity and temperature changes in the mixed-layer for the entire modeled area. The spatial distribution of regions of cooling and warming in the southern part of the domain, particularly in the Brazil-Malvinas Confluence and in Agulhas retroflection area, are in general agreement with previous studies. The zonally averaged transport for two different periods (1960-1978 and 1992 – 2010) shows a slight poleward shift, suggesting a widening of the gap between the Indian and Atlantic Ocean basins. Time-series of the mean barotropic transport, averaged between 10E and 30E, and of the latitude of the zero-streamline on 20E show increase in the westward transport and a poleward displacement of the subtropical convergence on 20E. In the Atlantic basin, the difference between the averaged MOC for 1992-2010 and 1960-1978 (Figure 1) show an overall weakening in the volume transport. Time-series plots in different latitudes show negative trends in the upper limb of the MOC in the South Atlantic. The northward heat-transport calculated from the model's results across 34.5S has a mean value of approximately 0.6 pW, with a clear negative trend for the entire period. At 26.5N, the model results do not show a significant trend in heat transport, except for the past decade, when a slight negative trend is seen, in the plots, in the last 10 years. In the western South Atlantic, the results present a southward displacement of the Brazil-Malvinas confluence and an increase in temperature and salinity in the subtropical region. Ongoing analyses are investigating the causes for the weakening of the model's MOC. It is also underway a higher resolution experiment (1/12-degree) with the same model implementation.

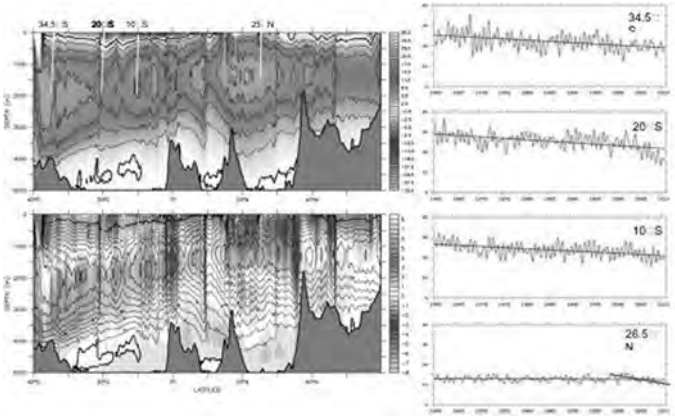

Figure 1: The upper-left panel depicts the AMOC streamfunction, in Sverdrups, averaged for the period 1960-1978. The white lines indicate were the integrated values of the MOC time-series were computed. The difference between the periods 1992-2010 and 1960-1978 is plotted in the lower-left panel in shades of blue (negative) and red (positive) colors, over the contour lines of the AMOC averaged for 1992-2010. The plots on the right are the time-series for the MOC on different latitudes. All three plots for the South Atlantic present a clear negative trend.

Chassignet, Eric

Agulhas Current system representation in high horizontal resolution (1/12 and 1/25 degree) global HYbrid Coordinate Ocean Model (HYCOM) configurations

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The representation of the Agulhas Current system is evaluated in several high horizontal resolution (1/12 and 1/25 degree) global HYbrid Coordinate Ocean Model (HYCOM) configurations with and without data assimilation. The increase in resolution does lead to levels of eddy kinetic energy similar to drifter observations (Thoppil et al., 2012, GRL). There are still, however, significant model-data discrepancies in the generation of Agulhas Current rings in the non-assimilative simulations. The rings are shed at regular intervals which then follow a northwestward track with little dissipation. This is a fairly common problem in eddy-resolving simulations and we will attempt to summarize diagnostics that may help unravel the issues behind this inaccurate representation of the rings' pathways.

Chassignet, Eric

Western Boundary Current Detachment in Numerical Model: A Review ***(INVITED)*** ***<i/><b/>***

Chassignet, Eric[1]

1. Florida State Univ-COAPS, Tallahassee, FL, USA

An accurate depiction of currents and associated features, such as mesoscale eddies, fronts, and jets, is essential to any eddy-resolving ocean model when modeling the global ocean circulation. Identifying the dynamics responsible for western boundary current separation has been a long-standing challenge. It is fair to say that a proper western boundary current separation in a numerical model is the result of many contributing factors and that the separation mechanism remains very sensitive to choices made in the numerical model for subgrid scale parameterizations. There is yet no single recipe that would guarantee a correct separation of all western boundary currents in a global model. Much of the focus in the literature has been on achieving a proper Gulf Stream separation, but each western boundary current (including the Agulhas) presents its own challenge and will respond differently to the chosen numerical algorithms and forcing functions. This talk will attempt to summarize our current understanding of western boundary current detachment, especially as it relates to the Agulhas Current.

Collins, Charine

Modelling the Comoros Basin using ROMS

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The dynamics of the Comoros Basin and especially the 'Comoros Gyre', could be an important contributor to the dynamics of the Agulhas Current, in particular the meso-scale variability. However, little is understood of the characteristics and oceanic processes in this region. Limited studies have suggested that the 'Comoros Gyre' is a semi-permanent, anti-cyclonic eddy, located in the region 5°S-10°S between the east coast of Mozambique and to the north west of Madagascar. In this study the general circulation of the Comoros Basin and its impact on eddy formation is investigated using the Regional Ocean Modelling System (ROMS), as well as data from a dedicated research cruise The 1/12° ROMS simulation covers the domain 6°S-24°S and 30°E-55°E and is forced with surface fluxes derived from the Comprehensive Ocean-Atmosphere Data Set (COADS), sea surface temperatures based on Pathfinder Advanced Very High Resolution Radiometer (AVHRR) data, and windstress obtained from QuikSCAT. The model suggests that the circulation in the Comoros Basin is highly dynamic and consists of multiple meso-scale eddies (cyclonic and anti-cyclonic). At times these eddies merge to form a larger recirculation cell and this is what is often considered as the semi-permanent gyre feature. The recirculation consists, in the north, of the northern branch of the East Madagascar Current, and in the west of a relatively strong poleward current along the coast of Africa which bifurcates at about 14°S. One part of the poleward current turns east forming the southern boundary of the recirculation cell and the other branch continues south through the narrows of the channel where an anti-cyclonic eddy is formed. During the SW monsoon there is an intensification of the northern branch of the East Madagascar Current and multiple meso-scale eddies in the Comoros Basin is a more frequent occurrence. The vertical structure of the meso-scale eddies in the Comoros Basin are similar to that of Mozambique Channel eddies. The eddies in the Comoros Basin are surface intensified and have a deep vertical extension. Idealised simulations have been performed and results are presented here.

Cronin, Meghan F.

NOAA Adopt-A-Drifter Program: Schoolchildren's Oceanographic Experiments

Cronin, Meghan F.[1]; Ansorge, Isabelle[2]; Bretteny, Mark[3]; Dolk, Shaun[4]; du Toit, Santjie[5]; Hermes, Juliet[6]; Lumpkin, Rick[7]; Mtontsi, Thomas[6]; Stander, Johan[5]; Stanitski, Diane[8]; Stapley, James[9]

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7. NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami, FL, USA
8. NOAA Climate Programs Office, Silver Springs, MD, USA
9. Agulhas and Somali Current Large Marine Ecosystems Project, Grahamstown, South Africa

Schoolchildren in South Africa and the USA are performing oceanographic experiments in the greater Agulhas Current system using surface drifters provided by the NOAA Adopt-A-Drifter program. In a "surface dispersion" experiment, classes adopt a pair of surface drifters that are then deployed in the Agulhas Current east of South Africa, while it is still a western boundary poleward current. Prior to deployment, the schoolchildren develop hypotheses for whether and why the drifters might drift into the Atlantic, Indian, Southern, or Pacific Oceans, and hypotheses as to when and where the two drifters will separate. The schoolchildren also sign stickers that are placed on their drifters. Several months after their drifters have been deployed, a researcher discusses the results with the schoolchildren. A pair of drifters adopted by elementary school children in George, Western Cape SA and Bethesda MD USA, and by secondary school children in Mossel Bay SA had a very interesting outcome: one drifter ended up in the Atlantic Ocean, while the other drifted into the Indian Ocean. In contrast, a pair of drifters adopted by elementary school children in Seattle WA USA retroflected into the Agulhas Return Current, but died before it was clear whether they would end up in the Indian Ocean or Southern Ocean. Researchers are studying these data to better understand the dispersion properties of the surface currents in this very dynamic region of the greater Aghulas Current system. Data from these drifters contribute to the Global Drifter Program, a component of the Global Ocean Observing System, and can be viewed from both the Global Drifter Program webpage and the NOAA Adopt-A-Drifter Program webpage:
http://www.adp.noaa.gov/track_drifting_buoys.html

Cronin, Meghan F.

Air-sea flux measurements by the NOAA surface mooring in the Agulhas Return Current

Cronin, Meghan F.[1]; Sutton, Adrienne J.[2]; Sabine, Christopher L.[1]; Reason, Chris[3]; Rouault, Mathieu[3]; Vousden, David[4]

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On 30 November 2010, a NOAA moored buoy was deployed at 38.5S, 30E on the edge of the warm Agulhas Return Current (ARC) southeast of South Africa. The site was located in a region where climatologically the ocean releases a large amount of heat to the atmosphere, making this a region of intense air-sea interaction. The site was also located at the southern boundary of the Agulhas and Somali Current Large Marine Ecosystems (ASCLME). The mooring carried sensors to monitor air-sea exchanges of heat, moisture, momentum, and CO2; and several subsurface sensors to monitor near surface currents, temperature and salinity. While the site was located in a region where climatologically there is large CO2 uptake, the mooring observed a large CO2 outgassing event during early December 2010, and weak CO2 uptake during the remainder of the record. On 16 January 2011, the mooring line broke at about 1400 m below the buoy. Roughly 3 months later, on 8 March 2011, the buoy and all its sensors were fortuitously recovered by the R/V Marion Dufresne over 1500 km east of the deployment site. As the drifting buoy was swept eastward by the strong ARC jet, the upper 30 m of the ocean cooled by 1.8C. The average net surface heat flux measured by the buoy during this period was -64 W/m2. If acting upon a 30-m layer, this heat flux could cause the layer to cool by 1.6C, suggesting that much of the cooling of the ARC current as it leaves the western boundary region of the South Indian Ocean is due to surface heat loss to the atmosphere. Comparisons with the ECMWF Reanalysis Interim (ERA-I) and NCEP-2 reanalysis products show overall good agreement with the buoy measurements, with the exception of sea surface temperature. These large biases in the reanalyses' sea surface temperature result in biases in the products' heat flux values. Lessons learned from the buoy deployment will be discussed.

Cronin, Meghan F.

Prevalence of Strong Bottom Currents in the Greater Agulhas Current System

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The deep ocean is not quiescent. While the ocean current system can be thought of roughly as wind-driven gyres in the upper ocean and slow creeping thermohaline flow in the deep ocean, very strong currents and benthic storms can occur in the deep ocean as well. In this analysis, historical deep current meter data, and output from the OFES model and the INALT01 model are used to map the prevalence of strong bottom currents that exceed 0.2 m/s in the greater Agulhas Current system. The two models and historic current meter data are remarkably consistent, showing that these strong bottom currents occur in the Agulhas retroflection region more than 20% of the time. Furthermore, beneath the mean Agulhas Current, including in the retroflection region, the bottom currents can exceed 0.2 m/s more than 50% of the time. In contrast, on the flanks of the Agulhas Plateau, bottom currents appear to rarely exceed 0.2 m/s, perhaps due to stabilization by the bottom topography. The models also show evidence of bottom intensification in the currents. The Rossby and Reynolds numbers are estimated in order to compare these bottom currents to storms in the atmosphere.

De Boer, Agatha M.

The Subtropical Front and its relation to the windstress curl

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3. Bert Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden

The latitudinal position of the Southern Ocean Subtropical Front (STF) is thought to affect the amount of Agulhas leakage from the Indian to the Atlantic Ocean. This leakage, in the form of Agulhas Rings, provides a salt flux to the Atlantic that may strengthen the Atlantic Thermohaline Circulation and ultimately contribute to Western Europe warming. The position of the STF has often been linked to the windstress curl in the Southern Ocean. The theory argues that the STF is analogous to the North Atlantic Current which separates the Subtropical gyre and the Subpolar gyre in the North Atlantic. In this context the STF should line up with the position of zero windstress curl and thus zero meridional Sverdrup transport. Others have argued that the STF is more often found where the windstress curl has its maximum negative value and the Ekman transport convergence is at a maximum. Here we investigate how the STF relates to the windstress curl by comparing the published compilations of Southern Ocean fronts from hydrographic measurements (Orsi, 1995) and satellite observations (Sokolov and Rintoul, 2009) with windstress observed by satellite scatterometry (Risien and Chelton, 2008). The windstress products and the ocean front observations are not representative of the exact same time periods or the same resolution. We therefore also consider the how well the STF and zero and peak winds stress curl positions correspond in the 1/3 degree resolution coupled climate model HiGEM wherein the oceanic and atmospheric fields are dynamically consistent. To determine how well Sverdrup theory can be used to estimate and predict the circulation in the Southern Ocean, we also calculate the southern limit of where the ocean is in linear vorticity balance. The implication of the non-linearity of the Southern Ocean for the STF position is discussed. In a companion abstract, also submitted to the Agulhas System Chapman conference, Graham et al. show how the STF (and other fronts in the ACC) responds to meridional shifts in the windstress curl on decadal and longer timescales.

De Boer, Agatha M.

Lightning over the Agulhas Current

De Boer, Agatha M.[1, 2]; Collier, Andrew B.[3, 4]

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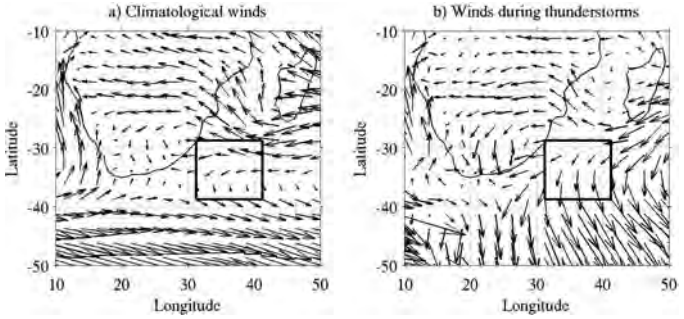
Subtropical and mid-latitude oceanic lightning occurs predominantly over warm waters to the east of continents. Here we present an analysis of lighting over one such region, the warm Agulhas Current off the south-east coast of South Africa. The seasonal and interannual variability is derived from two distinct lightning datasets, the satellite Lightning Imaging Sensor for years 1996-2007, and the terrestrial World Wide Lightning Location Network for 2005-2011. Favourable climatic conditions for lighting are investigated using wind and surface air temperature data from the NCEP reanalysis. We find peak lighting in autumn over the Agulhas Current but with low seasonality. While the prevailing winds over the region are easterly, most of the lightning occurs when the winds are northerly and north-northeasterly. In particular, lightning is more frequent when winds blow from warm to cold air regions. This contradicts traditional wisdom that thunderstorms over the Agulhas Current are induced by cold dry continental air blowing over the warm water or that they are a result of cold fronts. A global extension of the analysis indicates that the more frequent occurrence of lighting, when winds blow from warm to cold regions, holds for most of the subtropical oceans. In contrast lighting is largely independent of wind direction over continents and in the tropics. Winds most often blow from warm to cold air over the Agulhas Current in the later winter and spring months when lightning frequency is low. The peak autumn lightning therefore

cannot be simply explained by wind direction and requires further investigation.



Annual surface wind field from NCEP reanalysis data for the wider Southern Africa region (a) and mean wind direction for days in which there are more than 15 strokes in the gridbox. Climatological winds here refer to the average of the 7 year period of study. Note that the prefered direction for lighting is calcuate for each gridbox so that the picture on the right does not represent a synoptic view of the windfield on any given day. The black rectangle is the Agulhas Current regions evaluated the analysis

de Ruijter, Wilhelmus

Introduction to Session 3: Physical Mechanisms That Link the Agulhas to Ocean Circulation and Climate (controls)

de Ruijter, Wilhelmus[1]; Hermes, Juliet[2]

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The Agulhas retroflection system is a critical region for both the subtropical 'supergyre' and the global overturning ocean circulation. Retroflection and leakage depend on the subtle interplay of far field forcing and local nonlinear dynamics, in particular the position of maximum Westerlies and the inertia and stability of the Agulhas as it separates from the African continental slope. To simulate Agulhas leakage and its dIstribution over the gyre and overturning circulation it is therefore essential that these nonlinear dynamics are correctly resolved. In this introduction we will discuss the controlling dynamics and their modeling.

Dekens, Petra S.

Increased Agulhas leakage during the early Pliocene, a time of sustained global warmth

Dekens, Petra S.[1]; Wojcieszek, Dominika[2]; Kynett, Kathryn[1]

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2. College of Marine Science, University of South Florida, St Petersburg, FL, USA

The Agulhas Leakage (AL) is a returning branch of the meridional overturning circulation that closes up the loop of the conveyor belt and therefore plays an important role in Earth's climate. The strength of AL is controlled by the position of the sub-tropical front; a southward shift of the front widens the Agulhas corridor and allows increased AL into the Atlantic Ocean. But the question of how the AL will respond to sustained global warmth remains unanswered. The early Pliocene (3-5 Ma) is the most recent time in the Earth's history when climate was significantly warmer than today (3-4°C). In this study, we investigate changes in AL as climate cooled from the early Pliocene warm period to the cooler Pleistocene. We present Mg/Ca and δ18O records from 4 species of planktonic foraminifera (*G. ruber* , *G. sacculifer* , *G. tumida* , and *G. crassiformis*) from ODP site 1264 (28.53°S; 2.85°E, 2505 m water depth) located on the Walvis Ridge in the southeastern Atlantic, within the influence of the AL. The combined Mg/Ca and δ18O measurements on species with different depth habitats allow us to reconstruct temperature and changes in salinity throughout the upper water column. The Mg/Ca record of *G. sacculifer* , a surface dwelling species, shows no long-term trend in sea surface temperature (SST) over the past 4 Ma. The δ18O record indicates that sea surface salinity (SSS) gradually decreased from the early Pliocene to today. Mg/Ca and δ18O of subsurface species show a similar pattern: no long-term trend in temperature, but a marked freshening from the early Pliocene to today. Although the SSS could be related to local changes in precipitation/evaporation, the fact that the subsurface records show the same trend indicates a larger scale process is affecting salinity throughout the water column in the south Atlantic. Increased salinity could also be due to increased Agulhas leakage, which delivers relatively salty water to the region. The Pliocene-Pleistocene salinity decrease corresponds to decreased nannofossil and increased foraminifera content in the core. High abundance of nannofossils in the Pliocene indicates well-stratified, chlorophyll-rich AL waters. At the same time, the high productivity of the Agulhas rings represent conditions unfavorable for foraminifera, and explains the relatively low foraminifera abundance at ODP site 1264 during the early Pliocene. A sub-Antarctic SST record displays ~4°C Pliocene-Pleistocene cooling [Martinez-Garcia et al., 2010], indicating the expansion of the Southern Ocean into its modern position. Therefore, during the early Pliocene, the Agulhas corridor was wider, allowing for increased AL. Given the abundance of evidence for increased AL during the early Pliocene, and the lack of evidence for changes in precipitation patterns in the subtropical gyres, we conclude that the Mg/Ca SST and δ18O records and the sediment composition at ODP site 1264 reflect an increased AL during the early Pliocene warm period and a decreasing influence of the AL as climate cooled over the past 4 Ma.

Durgadoo, Jonathan V.

Atlantic warm-water route depends on the Westerlies

Durgadoo, Jonathan V.[1]; Biastoch, Arne[1]

1. Helmholtz Centre for Ocean Research Kiel (GEOMAR), Kiel, Germany

The Atlantic warm-water route, constituting primarily of Agulhas Leakage (AL), is showing a contemporary increasing trend, occurring as a result of changing wind patterns in the Southern Hemisphere that is associated with climate change. The precise mechanisms behind this dependency between the AL and the wind field are studied within a suite of ocean/sea-ice models. A series of simulations have been designed to carefully and independently detangle the influence of the intensity and position of the Trades and Westerlies on the AL. Slight perturbations are applied to the realistic wind-stress, effectively altering the momentum input to the ocean towards a different mean state. Results show that contrary to

previous work, the magnitude of AL is largely decoupled from upstream variations induced by changes in Trades. Instead, it significantly responds to changes in the Westerlies. The portion of the westerly winds acting locally over the Agulhas Current System proportionally and symmetrically modulates the leakage magnitude. Conversely, outside the System, the Westerlies influence not only the leakage but also the adjacent currents and these responds differently over time.

Foreman, Alan

Linking Agulhas Leakage and Atlantic G. menardii Zonation: Glacial/Interglacial Abundances of G. menardii from a Depth Transect Along the Namibian Margin

Foreman, Alan[1]; Charles, Chris[1]; Slowey, Niall[2]

1. Scripps Institution of Oceanography, La Jolla, CA, USA
2. Oceanography, Texas A&M, College Station, TX, USA

The correlation between the Atlantic abundance history of Globorotalia menardii and glacial/interglacial cycles is one of the oldest observations in paleoceanography. Recent explanations of this correlation have focused on the cessation and resumption of Agulhas leakage, with 're-seeding' of Atlantic G. menardii populations accomplished by interocean exchange south of Africa (Caley et al, 2012). Other evidence, however, links G. menardii abundance in the Atlantic to thermocline ventilation processes (Sexton and Norris, 2011). Thus, the relevance of Atlantic G. menardii zonation to Agulhas leakage is still open to question, despite the seemingly obvious chain of logic that connects the sediment record to Agulhas input. Here we present evidence of G. menardii abundance from a depth transect of cores located along the Namibian margin between 19°S and 24°S, south of the Walvis Ridge. The cores span water depths of 3700 to 500 meters, with sedimentation rates ranging from 5-10 cm/kyr. More than a dozen cores in this transect capture the last full ice age cycle (to ~150 ka) and have been densely sampled for other paleoceanographic tracers, including radiocarbon. Thus, this depth transect of cores provides an ideal test of the temporal relationship between G. menardii abundance in the Benguela region and various other tracers that are sensitive to surface and interior (subthermocline) flow. We find that the abundance of G. menardii in these cores exhibits a highly complex pattern, as opposed to operating as a simple glacial-interglacial switch. Direct comparison with carbon isotopic records helps delineate possible influences of thermocline ventilation by high-latitude sources, but, collectively, the observations suggest the strong influence of local processes on G. menardii abundance in the Benguela region—even during the interglacial intervals. These observations in turn provide significant constraints on the limits of the Agulhas "re-seeding" hypothesis.

Franzese, Allison M.

Assessing the role of the Subtropical Front in regulating Agulhas Leakage at the Last Glacial Termination

Franzese, Allison M.[1]; Goldstein, Steven L.[1]

1. Earth and Environmental Sciences, Columbia University, Palisades, NY, USA

It has long been thought that north-south migrations of the Subtropical Front (STF) south of Africa might strongly regulate the Agulhas Leakage on glacial-interglacial timescales, and recent papers have argued that such migrations play a key role in glacial climate and in global climate transitions due to that regulation (e.g. Bard and Rickaby 2009; De Deckker et al. 2012). As the STF is a zone of high meridional sea surface temperature (SST) and sea surface salinity (SSS) gradients, changes in the location of the STF can be addressed by measurements of SST and SSS proxies in appropriate deep sea cores. Although many proxy records from the Southern Hemisphere show variability consistent with reduced Agulhas Leakage and/or a more northern position of the STF during glacial times, there are currently no high resolution reconstructions of changes in the SST and SSS gradients that define the STF in this key region south of Africa. Our current study aims to do just that. Our project fills in a significant geographical gap in glacial reconstructions of the STF by using a meridional transect of cores from the western flanks of the Agulhas Plateau, between the latitudes of 38°S and 42°S. We are using paired measurements of planktonic Mg/Ca and $\delta^{18}O$ as proxies for SST and SSS, to explicitly reconstruct the position of the STF over the past 25,000 years, covering the time period of the Last Glacial Termination, and we plan to combine these with measurements of proxy tracers of particles and water mass. We will present high temporal resolution records of the SST and SSS gradients associated with the STF immediately south of the Agulhas Retroflection over the last 25,000 years. This represents a step in testing the hypothesis that southward migrations of the STF allowed for increased Agulhas Leakage, which helped to trigger enhanced NADW formation and increased the meridional overturning circulation associated with glacial terminations. *References: Bard, E. and R. E. M. Rickaby (2009). "Migration of the subtropical front as a modulator of glacial climate." Nature 460(7253): 380-383. De Deckker, P., M. Moros, K. Perner and E. Jansen (2012). "Influence of the tropics and southern westerlies on glacial interhemispheric asymmetry." Nature Geosci 5(4): 266-269.*

Gordon, Arnold L.

Retroflections and Bifurcations

Gordon, Arnold L.[1]

1. Lamont-Doherty Earth Observatory of columbia University, Palisades, NY, USA

My involvement with Agulhas Research started with a RV Knorr 1983 cruise, which included Johann Lutjeharms, Will deRuijter and Rana Fine. What an adventure; it brought me to the fascinating world of the Agulhas Retroflection, opening a window to a regional oceanographic phemenona with major global impact. The Agulhas leakage of Indian

Ocean water into the South Atlantic not only affects the South Atlantic heat/freshwater inventories, but also the appears to be directly linked to the Atlantic overturning circulation, so central to the Earth's climate system. The Agulhas Retroflection and its leakage are coupled to the upstream Indian Ocean conditions and to the far away Indonesian throughflow (it was the Agulhas that directed me to the Indonesian throughflow, which forms a focus of my present research) and 'Tassie leakage', making for a global network of interocean exchange. The work we achieved during the 1980s led into the 'cottage industry' of the 1990s and continues today. What controls the form of the Agulhas Retroflection and its leakage is a fascinating topic of dynamical oceanography. But it also brings attention to a class of regional oceanographic features with large-scale impact: Retroflections and Bifurcations. The ocean circulation/climate regimes, e.g. the subpolar and subtropical gyres, exchange water across their boundaries in rather confined regions. Retroflections, usually associated with western boundary currents are quite common, as a current curls back to its 'own' regime, but in the process leaks water by eddies or streamers into the neighboring system. Similarly, as a broad ocean current crossing the ocean reaches a western or eastern boundary, it splits, some of its content flowing northward, some southward, in a bifurcation pattern. Both retroflections and bifurcations promote exchange between ocean regimes, closing the large-scale ocean heat and freshwater budgets. Variability of the retroflection leakage or relative position of a bifurcation have profound global consequences.

Goschen, Wayne

Upwelling in the coastal zone off Algoa Bay driven by wind and large episodic meanders in the Agulhas Current

Goschen, Wayne[1]

1. SAEON, Roggbaai, South Africa

The emergence of cold water is frequently observed in Algoa Bay and along the coast north to Port Alfred, on the Eastern Cape coast, South Africa. It was found that upwelling in this area was driven by both wind and the Agulhas Current. Wind-driven upwelling appears to be initiated at Woody Cape/Cape Padrone, the northeastern promontory of Algoa Bay, and then spreads into Algoa Bay and north towards Port Alfred during northeasterly component winds. Cold water is upwelled along the shoreline at inertial periods and greater after the wind changes to northeasterly, although uplifting of the isotherms in the bottom layer begins with the wind change. During wind-driven upwelling the winds, currents, sea level, and sea temperatures are highly correlated, with the local response of currents and sea level signifying the activity of coastal trapped waves. When four large solitary meanders in the Agulhas Current (so-called "Natal Pulses") propagated past Algoa Bay in 2009 and 2010, enhanced upwelling was observed along the shoreline and in the coastal zone. Two such events occurred in autumn and winter during mainly southwesterly, downwelling favourable winds, but the currents had strong southwestward (downstream) components, as with wind-driven upwelling although there was little correlation between winds and currents. The role of large solitary meanders in the Agulhas Current in causing these strong currents, and their contribution to coastal upwelling off Algoa Bay, are investigated.

Graham, Robert M.

The response of the Subtropical Front to a shift in the Southern Ocean Westerlies

Graham, Robert M.[1, 2]; de Boer, Agatha M.[1, 3]; Heywood, Karen J.[2]; Chapman, Mark R.[2]; Stevens, David P.[4]

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2. Environmental Sciences, University of East Anglia, Norwich, United Kingdom
3. Geological Sciences, Stockholm University, Stockholm, Sweden
4. Mathematics, University of East Anglia, Norwich, United Kingdom

A number of recent studies have highlighted the importance of the latitudinal position of the Subtropical Front (STF) for modulating the volume flux of Agulhas Leakage into the Atlantic. This flux of warm saline water promotes the formation of North Atlantic Deep Water. However, little is understood about the dynamics of this system on multi-decadal timescales. The high resolution data that is required to resolve frontal features in the Southern Ocean is only available from Satellites, and thus the time series only extends ~20 years. Here we present output from two 100 year simulations on the high resolution coupled global climate model HiGEM, with an oceanic resolution of 1/3 degree. The resolution is sufficient to represent frontal features in the Southern Ocean well. Agulhas rings can be observed in the monthly output files and strong correlations between wind stress curl and SST gradients are found, as in observations from satellite data. One simulation was forced with 4xCO2 leading to an intensification and 1.3 degree southward shift of the Southern Hemisphere Westerlies, allowing the response of fronts to changes in the wind field to be investigated. The STF is shown to shift south in the Atlantic and Indian basins, even over steep topographic ridges. In contrast, fronts further south within the ACC do not move, even in the Pacific Sector where the model topography is flat. We find that the fronts which move are surface intensified and therefore decoupled from the topography below whereas fronts within the ACC are more barotropic and so sensitive to the underlying topography.

Graham, Robert M.

Evidence for Southern Hemisphere Westerly Wind Changes during the Last Glacial Maximum

Graham, Robert M.[3, 4]; Kohfeld, Karen E.[1]; Sime, Louise C.[2]; de Boer, Agatha[3, 4]; Wolff, Eric W.[2]; Le Quéré, Corrine[5]; Bopp, Laurent[6]

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2. British Antarctic Survey, Cambridge, United Kingdom
3. Bert Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden
4. Geological Sciences, Stockholm University, Stockholm, Sweden
5. Environmental Sciences, Univeristy of East Anglia, Norwich, United Kingdom
6. Centre National de la Recherche Scientifique, Saclay, France

The Southern Hemisphere westerlies are a key component of the global climate system. It is hypothesized that during glacial periods equatorward excursions of the westerlies cut off the flux of Agulhas Leakage from the Indian Ocean to the Atlantic. This shift of winds is also believed to have brought about a ~90 ppm drawdown of atmospheric CO2. Here we bring together paleo-observational data from aeolian transport, terrestrial moisture, sea surface temperature and ocean export production. We place these data within the context of other paleo-evidence in order to test which hypothesized changes in westerly winds could have occurred during the Last Glacial Maximum. We interpret the data to show that the most likely changes in winds would have involved either an overall strengthening or an equatorward displacement of winds. However, other changes cannot be ruled out. To improve our understanding detailed analysis of multi-model climate simulations are performed. These alongside the new database of moisture observations yield new insights into Southern Hemisphere westerly wind behavior. Interestingly the model simulations do not show large latitudinal shifts between the pre-industrial and the Last Glacial Maximum (LGM). Furthermore, we show that paleo-observations of moisture change, previously interpreted as evidence for an equatorward shift, can be simulated without a large latitudinal shift in the position of the westerly winds.

Guastella, Lisa

Influence of the Durban cyclonic eddy on the east coast of South Africa

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2. Bayworld Centre for Research & Education (BCRE), Cape Town, South Africa
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The Durban eddy is a lee-trapped, semi-permanent, cold core cyclonic eddy that occurs off the east coast of South Africa south of Durban (29.87°S, 31.03°E). It is driven by the Agulhas Current which moves offshore of a regressing shelf edge near Durban. The eddy is a mesoscale feature, extending approximately 60-90 km alongshore and 30-50 km offshore. ADCP data indicate consistently strong south-westward Agulhas Current flow 40 km offshore of Durban, while the inshore regions are characterised by frequent current reversals. These current reversals are characterised by strong north-eastward flows associated with eddy spin-up, which is followed by a return to weaker south-westward flow after the eddy breaks away from the Durban area and dissipates to the south. Analysis of the ADCP data together with satellite imagery shows that the eddy is present offshore of Durban approximately 55% of the time, with an average lifespan of 8.6 days, and "inter-eddy" periods of 4-7 days. A thermistor array and ship CTD data indicate upward doming of the thermal structure in the centre of the cyclone associated with cooler water and nutrients higher up the water column; this clearly stimulates primary production. Satellite-tracked surface drifters released in the eddy showed that the nutrient-rich eddy water can be transported northwards along the inshore regions of the KwaZulu-Natal (KZN) Bight (an area extending some 150 km north of Durban where the continental shelf widens), supporting the KZN Bight ecosystem. Of increasing importance, is the influence of the Durban eddy on the southern KZN and Transkei shelf regions. Roberts et al. (2010) has shown that short-term current reversals (2-3 days) observed in ADCP data measured off Port Edward (31.08°S, 30.22°S), some 150 km south of Durban, corresponds with downstream propagation of the Durban breakaway eddy. Associated with these reversals is a decrease in bottom temperature as a result of shelf edge upwelling. The Durban break-away eddy is therefore a transient (southward propagating) mechanism for the upslope movement of cold water rich in nutrients, which may well be capable of stimulating primary production. The eddy generally becomes more elongate in shape and flattens against the shelf as it propagates downstream, ultimately dissipating into lateral waves in the inshore boundary of the Agulhas Current near Port Alfred (33.60°S, 26.90°E), a further 600 km south of Durban. The downstream influence of the southward propagating breakaway eddy on the Agulhas current system is examined in more detail in this presentation. References: Roberts, M.J., van der Lingen, C.D., Whittle, C and M van den Berg, 2010: Shelf currents, lee-trapped and transient eddies on the inshore boundary of the Agulhas Current, South Africa: their relevance to the KwaZulu-Natal sardine run, Afr. J Mar Sci 32(2): 423-447.

Hall, Ian R.

Weakened Agulhas Leakage as a Potential Trigger for Reduced AMOC Intensity Before the Onset of Heinrich Events

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Interocean exchange of heat and salt around South Africa - the so called 'Agulhas Leakage' - is thought to be a

key link in the maintenance of the Atlantic meridional overturning circulation (AMOC). It takes place at the Agulhas Retrflection, largely by the intermittent shedding of enormous rings that penetrate into the South Atlantic Ocean. Recent palaeoceanographic studies suggest that variability in the latitudinal position of the subtropical front (STF) in the Southern Ocean, acts as a gatekeeper for the Agulhas retrflection and moreover, that a variable northward migration of the STF potentially modulated the severity of glacial periods by altering the amount of Agulhas leakage with consequences for the AMOC. Here we present a high-resolution record of ice rafted debris (IRD) from the southern Agulhas Plateau (sediment core MD02-2588, 41'19,90 S and 25'49,70 E, 2907 m water depth) covering the last 350,000 years. We find distinct millennial-scale events with high abundances of IRD. These IRD events are indicators for a northward shift of the Southern Ocean frontal system, thereby allowing sufficient cooling and iceberg survivability as far north as the Agulhas Plateau. Our proxy record suggests significant millennial scale variability of the frontal movements throughout the last three glacial cycles. Largest IRD peaks occur during marine isotope stage 8 (~300,000 years BP) and hence during a period for which an extreme northward shift in the STF has been identified previously. We compare our IRD record with records of millennial scale climate variability in the North Atlantic after careful synchronization of individual age models using benthic oxygen isotopes. In general, IRD peaks recorded on the Agulhas Plateau occur during globally cold conditions but in anti-phase with coldest events (Heinrich events) in the North Atlantic, which systematically occur at the culmination of large reductions in AMOC. This observation is in line with the concept of a bipolar seesaw behaviour of the glacial Atlantic. As IRD peaks recorded in MD02-2588 tend to precede IRD peaks in the North Atlantic we speculate that the events in the South may have been active in triggering a reduced AMOC intensity that has been observed to occur before the onset of ice rafting events in the North. A reduced salt export into the Atlantic ocean associated with the southern IRD events may have augmented the destabilization of AMOC activity in the North Atlantic triggering feedbacks in that region, such as basin-wide subsurface warming, increased basal melt rates under an ice shelves fronting the Laurentide Ice Sheet, subsequent collapse allowing ice flow surges and eventually iceberg and freshwater discharge into the Labrador Sea that further amplfied weakening of the AMOC.

http://www.cardiff.ac.uk/earth/

Hancke, Lisa

Characteristics of the surface circulation in the Mozambique Channel from satellite-tracked drifters

Hancke, Lisa[1]; Roberts, Michael J.[2]; Ternon, Jean-Francois[3]

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2. Oceans and Coasts, Department of Environmental Affairs, Cape Town, South Africa
3. UMR 212 EME, Institut de Recherche le Developpement, Le Port, Reunion

The surface circulation of the Mozambique Channel is described from 82 satellite-tracked drifters present in the channel between 2000 and 2010. Drifter trajectories provide in situ measurements of the surface currents, while coincident satellite altimetry verifies the position of drifters in relation to the mesoscale eddy field. Anticyclonic eddies were mostly present along the western boundary of the channel, while the eastern boundary of the channel and the region southwest of Madagascar were characterized by increased cyclonic activity. Results show that water can be isolated in eddies for extended periods and thus be transported towards the source region of the Agulhas Current. However, horizontal mixing between adjacent counter-rotating eddies was also observed. The study demonstrates the complexity of the surface circulation in this eddy dominated environment and highlights the importance of frontal zone transport for biological connectivity between geographically isolated regions in the Mozambique Channel.

Hebbeln, Dierk

Exploring the potential of cold-water corals as (palaeo-)environmental indicators for the Mozambique and Agulhas Current systems

Hebbeln, Dierk[1]

1. MARUM, Univ Bremen, Bremen, Germany

An expedition with the German RV SONNE, planned for 2015, will focus on the first dedicated investigation of scleractinian cold-water corals along the Southeast African continental margin. The overall aim is to get first insights into the distribution, appearance and biodiversity of these so far largely unexplored ecosystems of the Southwest Indian Ocean, and to identify the most important environmental forcing factors controlling their development. The occurrence of these ecosystems in this region in water depths of 200 m to 700 m has been proven e.g. by earlier dives with the German submersible JAGO as well as by scientific reports compiled for the global cold-water coral database of the UNEP World Conservation Monitor Centre (UNEP-WCMC). These data reveal that cold-water corals live off NW- and S-Madagascar and along the South African continental margin from South Africa as far north as Tanzania. From this region a total of 36 azooxanthellate scleractinian cold-water corals have been reported. Among these are the important framework- or even reef-building species Lophelia pertusa, Madrepora oculata, Solenosmilia variabilis and some dendrophylliid corals. To assess their distribution, their relation with the ambient environmental

conditions and their imprint on the sea floor (note the up to ~350 m high coral carbonate mounds off Ireland) detailed video-based characterisation of the facies and fauna (JAGO/ROV) supplemented by an extensive sampling programme will be conducted. As proven also for other ocean basins, geochemical signatures in the cold-water coral skeletons can provide very valuable palaeo-archives of past water mass characteristics. Thus, skeletal material from living as well as of fossil scleractinian cold-water corals will be collected and analysed for their paleoceanographic potential. With sufficient planning time being left, involvement of new colleagues in this expedition is still possible.

http://www.marum.de/AG_Hebbeln.html

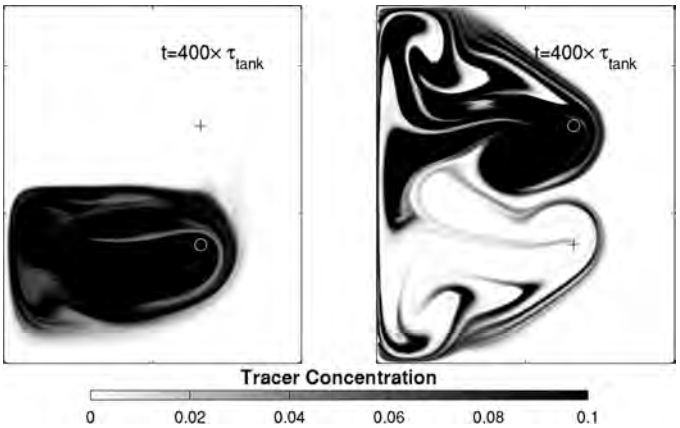
Herbette, Steven

Dynamics of a dipolar gyre on the beta-plane

Herbette, Steven[1]; Hochet, Antoine[1]; Colin de Veridère, Alain[1]; Huck, Thierry[1]

1. Physique, University of Brest, Brest, France

The behavior of a dipolar gyre forced by a localized source and sink is studied in the framework of a shallow-water beta plane model. A linear analytical solution is found. It consists of a dipolar gyre, composed of one central zonal jet that connects to two external zonal jets through western boundary currents. Non linear numerical experiments are performed varying the intensity of the forcing, inverting the position of the source and sink, and changing the distance between the source and the sink. Results confirm qualitative observations found in previous laboratory experiments: i) When the central zonal jet is directed westward, the system becomes unstable and water mass is exchanged between the two gyres; ii) When the central zonal jet is eastward, the system remains stable, even at high pumping/injection rates, and the two gyres remain isolated from each other. We investigate the origin and the dynamics of that instability using potential vorticity arguments. Results show that within the unstable configurations, the necessary condition for instability (PV-gradient inversion) derived by Charney and Stern (1962) is always verified inside the westward zonal jet. On the other hand, stable configurations do not complete the criteria. Although the western boundary currents can in some cases fulfill the criteria, our simulations do not seem to show any instabilities originating from the latter. To discriminate whether the observed instability comes from the perturbations released by the source and the sink or whether it is linked to the intrinsic instability of the zonal central jet, a linear stability analysis of the mean state is performed. The role played by the western boundary currents and their connection to interior zonal jets also retain particular attention. Understanding the stability of these simple circulations is probably an important prerequisite to rationalize the much more complex eddy and wind driven mean gyres of the ocean.



Tracer concentration after reaching statistical equilibrium in a stable central eastward jet (left) and an unstable central westward jet (right) configuration)

Hood, Raleigh R.

Biogeochemical Impacts of Boundary Currents in the Indian Ocean with Special Reference to the Agulhas System and the Madagascar Bloom ***(INVITED)***

Hood, Raleigh R.[1]

1. UMCES/HPL, Univ of Maryland, Cambridge, MD, USA

Boundary currents mediate the transfer of global and regional forcing to local coastal scales. In this process, they fundamentally alter biogeochemical fluxes and ecosystem processes. In the Indian Ocean, several boundary current systems are seasonally reversing (e.g., the Somali Current, West and East India Coastal Currents, and the Java Current). These reversing surface currents are unique to monsoon-driven systems and they have profound biogeochemical impacts. The southern currents (Agulhas and Leeuwin) both flow poleward throughout the year. In general, the biogeochemistry and ecology of southern hemisphere currents have been less comprehensively studied than their northern counterparts and significant uncertainties still exist regarding their dynamics and interactions. The poleward flow of the Leeuwin Current is unique among eastern boundary currents of the southern hemisphere and it has many unusual biogeochemical attributes. Although the physical dynamics of the Agulhas Current and its source waters are reasonably well understood, the biology is relatively understudied. The two major source regions for this current are from the north through the Mozambique Channel and from the east via the East Madagascar Current. On average, the Agulhas retroflects south of the continent to return eastward and the deep mesoscale eddies (rings) generated there have strong impacts on the ecology and biogeochemistry of the marine ecosystem. Anomalous large-scale open ocean phytoplankton blooms are observed extending southeastward from the southern tip of Madagascar in the southern hemisphere summer in satellite chlorophyll data. These globally significant blooms are clearly associated with the source waters of the Agulhas Current and they appear to be advected eastward by the recently discovered Southern Indian Ocean Countercurrent. There is compelling evidence that they are fueled to some degree by nitrogen inputs from diazotrophic cyanobacteria.

Huggett, Jenny A.

Are Changes in the Copepod Community on the Agulhas Bank over the Last Two Decades Mediated by Environmental Factors or Predation?

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3. Marine Research Institute, University of Cape Town, Cape Town, South Africa

Copepods comprise 90% of zooplankton carbon on the Agulhas Bank, and provide an important food source for pelagic fish and juvenile squid. A single large species of copepod, Calanus agulhensis, dominates this copepod community in terms of biomass, and has a centre of distribution associated with the semi-permanent ridge of cool, upwelled water south of Mossel Bay. Zooplankton abundance and species composition on the Agulhas Bank has been monitored annually in austral spring since 1988, during routine acoustic surveys of pelagic fish, providing a time-series of over two decades. This time of year coincides with peak spawning by anchovy. To investigate interannual and long-term zooplankton variability on the Agulhas Bank, mean copepod biomass was calculated using data from stations sampled across the shelf in the vicinity of Danger Point (western Agulhas Bank) and Mossel Bay (central/eastern Agulhas Bank). Mean copepod biomass on the western Agulhas Bank has declined by 36% since 1988, from 1.11 g C m-2 over the first half of the time-series (1988-1999) to 0.72 g C m-2 over the second half (2000-2010). Both the biomass and proportion of Calanus agulhensis also declined over the time-series, although interannual variability was high. There was a more marked decline in total biomass of copepods, as well as that of Calanus agulhensis, on the central/eastern Agulhas Bank, with less interannual variability. Here, mean copepod biomass declined by 59%, from 1.24 g C m-2 over the period 1988-1999, to 0.51 g C m-2 over the period 2000-2010. Mean biomass of C. agulhensis declined by 68% over the time-series, from 52% of total copepod biomass during 1988-1999, to 39% during 2000-2010. This decline in C. agulhensis on the Agulhas Bank corresponds with a gradual shift towards to a smaller copepod-dominated community. Long-term changes in zooplankton communities may be influenced by environmental forcing (bottom-up control), by predation (top-down control), or a combination of the two. In this study, long-term variability in remotely-sensed temperature and chlorophyll, and in acoustically-estimated pelagic fish biomass, on the Agulhas Bank are investigated to explore possible linkages with the observed changes in the copepod community.

Hutchings, Larry

Drivers of primary productivity on the Agulhas Bank: which ones are likely to change in future and what are the consequences?

Hutchings, Larry[1, 2]; Lamont, Tarron[2]; Barlow, Ray[1, 2]

1. MA-RE, UCT, Cape Town, South Africa
2. Dept Environment, Oceans and Coasts, Cape Town, South Africa

Drivers of primary productivity on the Agulhas Bank: which ones are likely to change in future and what are the consequences? Larry Hutchings*, Ray Barlow* and Tarron Lamont#. * Ma-Re Institute, UCT, larry.hutchings@gmail.com #DEA, Oceans and Coasts Abstract The Agulhas Bank is a broad shelf area which is a crucial subcomponent of the Benguela Large marine Ecosystem, as it is the major spawning ground upstream of the wind-driven upwelling prevalent on the west coast, which acts as the major nursery ground for many of the important fish species in the southern Benguela. The Agulhas Bank is moderately productive compared to the west coast but more efficient trophic coupling and energy reserves accumulated on the west coast allow it to support large biomasses of fish, particularly during spring, summer and autumn. Productivity is driven by a number of different mechanisms, including: The classic temperate zone cycle of mixing and stratification; Episodic wind mixing The passage of internal waves; Coastal wind-driven upwelling; Divergence driven upwelling Shelf edge upwelling Meanders and eddies in the Agulhas Current; The cold ridge; Diffusion through the thermocline. These mechanisms may alter under future climate change scenarios driven by changes in the Current itself and by changes in ocean-atmosphere coupling around the southern tip of Africa. This presentation will examine each of these mechanisms and try to understand in which direction the change will occur and some biological consequences in terms of enrichment, retention, transport and concentration.

Jackson, Jennifer M.

The bio-physical influence of Natal Pulses on the Agulhas Bank, South Africa

Jackson, Jennifer M.[1]; Rainville, Luc[1]; Roberts, Mike J.[2]; McQuaid, Christopher D.[3]; Porri, Francesca[3]; Durgadoo, Jonathan[4]; Biastoch, Arne[4]

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2. Department of Environmental Affairs, Cape Town, South Africa
3. Department of Zoology and Entomolgy, Rhodes University, Grahamstown, South Africa
4. Helmholz Centre for Ocean Research, Kiel, Germany

Little is known about mesoscale interactions between the Agulhas Current and the shelf waters of the Agulhas Bank or how these processes influence the biology of the bank. In this study, physical and biological data collected during a dedicated cruise in September 2010 allowed the identification of several mesoscale features and indicate a strong effect of the current on the bank, including a Natal Pulse that forced the Agulhas Current onto the Agulhas

Bank as an Agulhas Current meander. Once on the Agulhas Bank, this strong flow entrained many particles, including phytoplankton and coastal benthic larvae, that were then advected offshore as the Agulhas Current moved off the continental shelf. Results from a high-resolution nested ocean model, INALT01, suggest that Natal Pulse-forced Agulhas Current meanders always occur downstream of Natal Pulses. Since Natal Pulses occur several times per year, the advection of particles offshore by the Agulhas Current likely has a significant effect on eastern Agulhas Bank ecosystems and fisheries. A proposal of future bio-physical studies, which include ocean modeling and in-situ observations, of the eastern Agulhas Bank will be emphasized.

Jean-François, Ternon

New insight on the circulation in the Mozambique Channel from in-situ measurements (2005-2010)

Jean-François, Ternon[1]; Mike, Roberts[2]; Tammy, Morris[3]; Lisa, Hancke[3]; Bjorn, Backeberg[4, 5]

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2. Ocean and Coast Research, Department of Envirnomental affairs, Cape Town, South Africa
3. Bayworld Centre for Research and Education, Cape Town, South Africa
4. Department of Oceanography, University of Cape Town, Cape Town, South Africa
5. Nansen-Tutu Centre for Marine Environmental Research, University of Cape Town, Cape Town, South Africa

Circulation and the related biological production have been studied during five cruises conducted in the Mozambique Channel (MZC) between 2005 and 2010 in the framework of MESOBIO, a multidisciplinary programme focusing on the biological signature of the eddy dynamics at different trophic levels. The circulation in the MZC is known to be highly turbulent, favouring both enhanced primary production due to the eddy dynamics, biological organisms concentration at frontal areas and connectivity across the channel due to the currents associated with (migrating) eddies. This presentation will focus on the results of in-situ measurements that characterize the horizontal and vertical current distribution in the surface and subsurface layers (0 to 500m). They were obtained at different location and time period during MESOBIO which allowed sampling different configurations of the eddy field, regarding notably the global energy of the system (periods of strong versus weak mesoscale dynamics). The measurements are analysed together with the eddy field observed from satellite altimeter measurements. Different circulation scenarios were sampled, including the "classical" anticyclonic eddy generation at the narrows (16°S) of the channel, the enhancement of southward migrating eddies by structures (both cyclonic and anticyclonic) formed in the east of the channel and the presence of a fully developed cyclonic eddy at the narrows. The observations confirm the predominance of the anticyclones in the west of the MZC and provide, however, evidence of multiple alternative scenarios in the eddy distribution and signature in the MZC. The comparison between in situ measurements (ADCP and velocities derived from surface drifters) and the geostrophic current derived from sea surface height measurements indicate a good quantitative description of the eddy driven circulation from altimetry while the calculated currents are weaker by up to 30%. It is also shown that the wind driven component of the circulation may be significant when considering biological issues. Finally, our observations highlight that a-geostrophic currents need to be considered in future research to facilitate a more comprehensive description of the circulation in this area and its potential biological impact.

Johannessen, Johnny A.

New estimates of the greater Agulhas Current dynamics from high-resolution satellite sensor synergy

Johannessen, Johnny A.[1]; Chapron, Bertrand[2]; Collard, Fabrice[3]

1. Nansen Environmental and Remote Sensing Center, Bergen, Norway
2. IFREMER, Brest, France
3. CLS, Brest, France

The Agulhas Current is among the strongest western boundary currents in the world's oceans. It is highly important for the Indo-Atlantic inter-ocean exchange and recently its role in the global thermohaline circulation has also been addressed with emphasis on quantitative knowledge of the seasonal to interannual current and transport variability. Doppler-derived ocean surface velocities manifest the intensity of the greater Agulhas Current and demonstrate the capability to use this new method provided by the ESA Envisat Advanced Synthetic Aperture Radar (ASAR) as a "speed-gun" in space. Building on more than 1300 synoptic wide coverage acquisitions since 2007, new high-resolution gridded maps (12.5 km x 12.5 km) of the greater Agulhas Current have been routinely produced. In this paper we will demonstrate that this Doppler based method, in combination with surface drifter data, satellite altimetry and sea surface temperature measurements, can resolve circulation patterns and variability that may have important implications for the understanding of the dynamics of the greater Agulhas Current regime.

Johnston, Shaun

Mixing estimates from sustained observations by underwater gliders

Johnston, Shaun[1]; Rudnick, Daniel L.[1]

1. Scripps Institution of Oceanography, La Jolla, CA, USA

Glider sections through the eddy-rich region off the southwest coast of Africa could provide sustained observations of mesoscale and finescale variability. To demonstrate glider capability, existing observations from 2005-2012 in the California Current System, an eastern boundary current, are used to estimate mixing from finescale parameterizations based on shear and strain. Spray gliders measure temperature, salinity, fluorescence, and currents with CTD and acoustic Doppler profilers from 0-500 m and are typically deployed for ~3 months at a time. Each glider typically covers 1 cross-shore section in ~3

weeks. To sustain sections, typically 3 or 4 glider missions are needed each year.

http://www-pord.ucsd.edu/~shaunj/

José, Yonss S.

Influence of mesoscale variability on the biogeochemical structure of the Mozambique Channel

José, Yonss S.[1]; Aumont, Olivier[2]; Machu, Eric[2]; Penven, Pierrick[2, 1]; Moloney, Coleen[3]; Maury, Olivier[4, 1]

1. Oceanography, University of Cape Town, MA-RE Institute, Cape Town, South Africa
2. LPO (UMR 6523 CNRS, Ifremer, IRD, UBO, ICEMASA), Brest, France
3. Zoology, University of Cape Town, MA-RE Institute, Cape Town, South Africa
4. IRD - UMR 212 EME, Sete, France

The mesoscale activity in the Mozambique Channel has a significant impact on the ecosystem, from phytoplankton to top predators (Weimerskirch et al., 2004; Tew-Kai and Marsac, 2010). The way this mesoscale activity controls the first trophic levels, as well as the influence of physical and biogeochemical processes on the upper trophic levels are not fully understood. In on attempt to bridge this gap in knowledge and to investigate the impact of mesoscale features on the ecosystem of the Mozambique Channel, an eddy resolving oceanic model (Shchepetkin and McWilliams, 2005), is coupled with a biogeochemical model PISCES (Aumont and Bopp, 2006) to simulate the marine ecosystem of the Mozambique Channel. We quantify the part of the production related to the mesoscale activity and the relative contribuition of the production advected from the coastal zone by the eddies. The backward tracking of cyclonic and anticyclonic eddies pointed out the phytoplankton growth within these mesoscale features (both cyclonic and anticyclonic eddies) occurred in response to nutrients being injected into the euphotic zone by advection and subsequent retention of surrounding nutrient-rich waters within the eddies. Offshore nutrient distributions depended strongly on lateral advection of nutrient-rich water from the coastal regions, induced by eddy activity. The environmental conditions at the places where the eddies were generated had an important effect on nutrient concentrations within these structures.

Josey, Simon

What Do We Know About Air-Sea Exchanges In The Agulhas System?

Josey, Simon[1]

1. NOC, Southampton, United Kingdom

Current understanding of the air-sea exchanges of heat and freshwater (E-P) in the Agulhas System will be reviewed using a wide range of observation-based datasets and model analyses. The strong air-sea temperature and humidity gradients associated with the Agulhas current, coupled with significant wind forcing, drive major latent and sensible heat losses (that are exceeded only by the Gulf Stream and Kuroshio amongst major current systems). However, previous research by Rouault et al. (2003) has shown that early versions of the NCEP and ECMWF atmospheric model reanalyses tend to underestimate these fluxes as they are unable to adequately represent the air–sea fluxes over the warmest waters in the core of the current. This issue will be revisited in the context of the new generation of higher resolution atmosphere only and coupled ocean-atmosphere model reanalyses. In particular, new results will be presented which examine the dependence of these heat loss terms on the grid resolution used in the reanalysis with reference to other observation based datasets. Furthermore, temporal variability in the net heat exchange (and its components) will be examined at decadal to centennial timescales using output from the NOAA-CIRES 20th Century Reanalysis V2 (20CR) which spans the period 1871-2008. Variability in both the heat and freshwater fluxes at these timescales will be related to changes in the major atmospheric modes influencing the Agulhas System, with particular reference to the trend in the Southern Annular Mode in recent decades.

https://noc.ac.uk/people/sxj

Kasper, Sebastian

Stable hydrogen isotope composition of C37 alkenones as indicator for salinity changes in the Agulhas leakage area during Termination I and II

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2. Department of Marine Geology, Royal Netherlands Institute for Sea Research, 1790 AB Den Burg (Texel), Netherlands
3. Institut de Ciència I Tecnologia Ambientals, Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain

At the southern tip of the African shelf the Agulhas Current retroflects back into the Indian Ocean whereby so called 'Agulhas rings' spin off and release warmer and more saline water into the South Atlantic Ocean. The magnitude of the Agulhas leakage, therefore, has a strong impact on the Atlantic Meridional Overturning Circulation and hence the entire meridional heat flux. Thus, glacial – interglacial fluctuations of the Agulhas leakage into the Atlantic Ocean can affect global temperatures (1). Reconstructions of the dynamics of the Agulhas current based on geochemical proxies for sea surface temperatures and salinity could help to understand the link between the magnitude of the Agulhas current and global temperatures. Although there are a number of proxies available for reconstructing sea surface temperatures, few tools are available for salinity reconstructions. It has been suggested that alkenone hydrogen isotope composition (δDalkenones) is strongly related to salinity and δDsea water and therefore could be used as a tool for sea surface salinity estimations (2, 3). During glacials, i.e. Marine Isotope Stage (MIS) 6 and MIS3/2, the subtropical front is thought to have moved northwards (4) thereby weakening the exchange between the Indian and Atlantic Ocean resulting in a build-up of warm saline water at the tip of South Africa. During early MIS 5, and similarly during the Holocene, the exchange is thought to increase again resulting in a decrease in salinity. We generated long term δDalkenone records of two sediment

cores to examine temporal variations in salinity in the Agulhas system with focus on the transition from MIS 6 to 5, Termination II and the transition from MIS 3/2 to the Holocene, Termination I. These results show that there is a shift to more negative δDalkenone values of approximately 13‰ from MIS 6 to 5 and of approximately 12‰ from MIS3/2 to the Holocene. The observed shifts cannot be explained by changes in ice volume only or other factors and suggest a shift in salinity, from relatively high salinities during the glacials to lower salinities during intergacials. Our results are in agreement with the proposed changes in ocean circulation in the time intervals studied (4). To further establish the δDalkenone as a salinity proxy, we are currently analyzing the hydrogen isotope composition of alkenones from core tops along a North-South gradient through the Mozambique Channel and the Agulhas current. 1.C. S. M. Turney, R. T. Jones, Journal of Quaternary Science 25, 839 (2010). 2.S. Schouten et al., Biogeosciences 3, 113 (2006). 3.M. T. J. van der Meer et al., Earth and Planetary Science Letters 262, 594 (2007). 4.G. Martinez-Mendez et al., Paleoceanography 25, (2010).

Kataoka, Takahito

A mechanism of the Indian Ocean subtropical modes simulated in the CMIP3 models

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The Indian Ocean subtropical dipole (IOSD) is one of the climate modes in the Southern Hemisphere and peaks in austral summer (December-February). The positive (negative) IOSD is characterized by a dipole pattern in the sea surface temperature (SST) anomaly in the southern Indian Ocean with a warm (cold) southwestern pole located in the greater Agulhas system and a cold (warm) northeastern pole off Australia. Southern African rainfall with its seasonal maximum in austral summer is influenced by SST anomalies associated with the IOSD events. Toward an accurate prediction of the IOSD, the generation mechanism of the IOSD is investigated using observation data and outputs from the "twentieth-century climate in coupled models" (20c3m) control runs of coupled general circulation models (CGCMs) submitted to the Coupled Model Intercomparison Project, phase 3 (CMIP3). It is found that the mixed-layer over the southwestern (northeastern) pole becomes anomalously shallow (deep) during the pre-mature phase of positive events. This results in an enhanced (a suppressed) warming of the mixed-layer by the climatological shortwave radiation. As a consequence, positive (negative) SST anomalies develop. This contribution from the shortwave radiation is the most dominant in the growth of the IOSD.

Khadun, Emma

INCREASED RIVER DISCHARGE DURING THE YOUNGER DRYAS IN THE UPPER MOZAMBIQUE CHANNEL

Khadun, Emma[1]; Wang, Yiming[1]; van der Lubbe, Jeroen[1]; Schneider, Ralph[1]

1. Geology, CAU University of Kiel, Kiel, Germany

Positive sea surface temperature (SST) anomalies are an important control on coastal rainfall in Madagascar in the present day. Positive SST anomalies in the southwest Indian Ocean, result in increased precipitation over southeastern Africa and northern Madagascar. It is still under debate as to whether local insolation changes, such as the movement of the intertropical convergence zone (ITCZ), are the dominant control on rainfall at millennial timescales, and whether Northern hemisphere cold events such as the Younger Dryas (YD) also occurred in the southern hemisphere. NW Madagascar is located at the southern extent of the ITCZ during austral summer and positioned at the mouth of the Mozambique Channel, a key pathway of the Agulhas Current, which transports warm saline waters from the tropical western Indian Ocean southwards. The temperature variability of this current probably has a large impact on the local precipitation regime. Marine sediment cores located at river mouths allow for the simultaneous reconstruction of both oceanic and continental climate changes over time, and thus help to elucidate whether river runoff, reflecting rainfall, can be related to SST anomalies in the Mozambique Channel at millennial timescales. Here we present bulk sediment compositional data and SST data from marine sediment core GIK 16168-2 off northwest Madagascar, located at 1326m water depth between the mouth of the Betisboka and Mahajamba river deltas and at the southern extent of the ITCZ. An age chronology for GIK 16168-2 has been developed by correlation between the data show in this study and other dated SST and XRF records along the southeast African coast. Bulk sediment records, including XRF derived elemental ratios, organic carbon to nitrogen ratio (Corg/N), reflect terrestrial versus marine input to the core site. SST has also been reconstructed using the UK'37 index. A sharp decrease in SST of 2°C is observed during the YD, which is in contrast to the low SST variability characterising the Holocene. Low Ti/Ca and Corg/N ratios (8-10) indicate that terrigenous input was low during the Holocene. There is a positive correlation between the Ca/Ti, total carbonate and the sea level curve from Siddall et al. (2003), suggesting a reduction of terrigenous supply with the change in the proximity of the core location to the river mouth due to sea level rise. Corg/N ratios (10-12) and high Ti/Ca indicate increased terrigenous supply during the YD in comparison to the Holocene. At the YD, Zr/Rb indicates a greater input of fine-grained material, reflecting an increase in riverine clay relative to sands. Our bulk sediment data therefore suggests an increase in river runoff at the end of the YD, probably due to increased precipitation over Madagascar, associated with a decrease in SSTs. As such, increased river runoff from northwest Madagascar during the YD may be associated with increased precipitation caused by a southwards shift in the ITCZ. More direct palaeoprecipitation reconstructions using deuterium isotopes from n-alkanes will be conducted to confirm this

conclusion, along with comparison to river discharge reconstructions from East Africa to investigate the effect of latitudinal movements of the ITCZ.

Kirtman, Ben P.

Global Climate Simulations with Ocean Eddy Resolving Resolutions ***(INVITED)***

Kirtman, Ben P.[1]

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The current literature provides compelling evidence suggesting that an eddy-resolving (as opposed to eddy permitting) ocean component model will significantly impact the simulation of large-scale climate, although this has not been fully tested to date in multi-decadal global coupled climate simulations. The purpose of this talk is to document how increased ocean model resolution impacts the simulation of the large-scale climate variability with a particular focus on coupled processes in the Agulhas region . The model used for this study is the NCAR Community Climate System Model version 4. Two experiments are reported here. The first experiment (i.e., control, referred to as LRC) is a 155-year present-day climate simulation of the 0.5^0 atmosphere (zonal resolution 0.625^0 meridional resolution 0.5^0) coupled to ocean and sea-ice components with zonal resolution of 1.2^0 and meridional resolution varying from 0.27^0at the equator to 0.54^0 in the mid-latitudes. The second simulation is carried out in two phases with the same atmospheric model coupled to 0.1^0 ocean and sea-ice component models. The initial condition for the first phase (referred to as HRC03) is the same as the control simulation, except that the ocean state has been interpolated to the 0.1^0 grid. The second phase (referred to as HRC06) begins at year-102 of HRC03 using the same resolution and parameters except in this case the polar winds have been filtered to reduce computational instability. This phase of the experiment extends to year-155. The simulations are compared in terms of how ocean eddies impact the mean and variable climate. Emphasis is placed on the Agulhas region, with particular emphasis on how the resolved eddies impact air-sea feedbacks.

Kiwalabye, Frank

Vulnerability And Effects Of Climate Change To Older People In Africa

Kiwalabye, Frank[1]

1. YCWU, Kampala, Uganda

Climate change affects the fundamental requirements for health clean air, safe drinking water, sufficient food and secure shelter. It not only affects the older people but the entire human race. The aim of this presentation is to examine the impact of climate change on population mainly older people from and within Africa. It attempts to gauge the extent of loss of livelihood in the affected areas due to climate change. Social and economic factors are a great factor in increasing the vulnerability of some older people who are exposed to the negative impacts of climate change. Socioeconomic disadvantages restrict the capacity of individuals to avoid the negative health impacts of climate change, mitigate those impacts, or cope with them if they cannot be mitigated or avoided. Older populations are among the most at risk due to decreased mobility, changes in physiology, and more limited access to resources, all of which may limit adaptive capacity among older and more vulnerable people. Older, vulnerable populations face adaptive challenges to their new environments, with potentially far-reaching implications for health as well as for societal strategies to cope with climate change effects at both the population and policy level.

Krug Rouault, Marjolaine

Intra- and Annual variability of the Agulhas Current from satellite remote sensing observations

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2. Oceanography, University of Cape Town, Cape Town, South Africa
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4. Laboratoire d'Océanographie Spatiale, IFREMER, Brest, France

More than 6 years of high frequency Sea Surface Temperature (SST) imagery as well as current observations derived from 18 years of altimetry are combined to study the variability of the Agulhas Current at the intra-annual and annual time-scales. Algorithms to track the position of the Agulhas Current are developed and applied to the altimetry and SST records. Time-series of the Agulhas Current's path show no seasonality in the position of the Agulhas Current and confirm that large excursions in the Agulhas Current's path are dominated by the intermittent passage of offshore meanders. The front detection analysis conducted on the SST dataset in the northern Agulhas reveals that Natal Pulses are complex features of the circulation associated with a range instabilities. During their southward progression Natal Pulses can evolve rapidly to either dissipate, re-merge with the initial Natal Pulse or in some rare occasion, detach from the Agulhas Current. From the northern to the southern Agulhas Current regions the number of Natal Pulses decreases, with on average only 1.6 Natal Pulses per year reaching the southern Agulhas. South of Port Elizabeth, fluctuations in the position of the Agulhas Current core estimated from altimetry and the SST are in very good agreement, allowing us to use the 18-year altimetry records to study the variability of the southern Agulhas Current. While the position and width of the Agulhas Current do not display an annual cycle, the geostrophic current speed at the current's core exhibits distinct seasonal variations, with a stronger flow observed in austral summer. The annual cycle dominates the frequency spectra of the current's core geostrophic velocities. Results presented in this paper suggest that a stream-coordinate characterization of the Agulhas Current is necessary to better capture its intrinsic variability at the annual time-scale.

Lagerloef, Gary S.

Satellite Salinity and Velocity Measurements in the Agulhas Current System

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The Aquarius salinity sensor was launched on the Aquarius/SACD satellite 10 June 2011 and has been collecting data since 25 August 2011. This paper gives an overview of the first year of global sea surface salinity (SSS) data and measurement uncertainties. Between the time of this writing and the conference, several processing updates will be implemented and tested, and the most recently reprocessed data will be presented. We then focus on the Agulhas current system and document the SSS patterns and variability resolved by the satellite data. OSCAR surface current (SC) data are then applied to examine surface transports and eddy variability in the Agulhas system, including multi-year animations of the regional SC variability. Lastly, we examine the relationship between the SSS and SC variations and provide preliminary estimates of salinity advection by currents and eddies. The figure shows an overlay for a 1-week period in November 2011 as an example. SSS (grayscale) and SC (vector) data are interpolated to 1/3 degree grid. Intense SSS variations adjacent to the coast are likely spurious artifacts due to the signal contamination from land and the incomplete correction for that. Away from the coast, one can see examples where SSS variations correspond with SC meanders and eddies. These Aquarius SSS data are quite preliminary and higher quality results will be presented at the conference.

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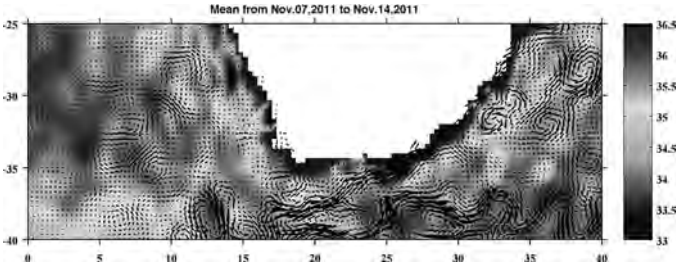

Lamont, Tarron

Phytoplankton production and physiology on the KwaZulu Natal Bight, South Africa

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3. Marine Research Institute, University of Cape Town, Cape Town, South Africa

During January 2010, time series studies of primary production (PP) and physiology were conducted at selected sites on the KwaZulu Natal (KZN) Bight. These sites were located in the vicinity of the Durban lee eddy, in the mid shelf region of the central part of the Bight, off the Tugela Mouth, and to the north and south of Richard's Bay. At most sites, phytoplankton biomass ranged from 0.10 – 1.44 mg m-3, and integrated PP ranged between 0.35 and 2.58 g C m-2 d-1. The highest biomass and PP was observed at the mid shelf site, varying between 0.26 – 4.27 mg m-3 and 7.22 – 9.89 g C m-2 d-1, respectively. Environmental conditions at each of the sites differed substantially and were primarily driven by short-term fluctuations in the position of the inshore edge of the Agulhas Current. Phytoplankton adaptation to varied environmental conditions was characterised by decreased αB and increased PsB with elevated temperatures and reduced irradiance conditions. Elevated biomass levels were associated with a temperatures ranging between 20 – 25 °C, suggesting that this was the optimal temperature range for primary production.

Le Bars, Dewi

Why is the Indonesian Throughflow strenghtening the Agulhas Current leakage?

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1. IMAU, Utrecht, Netherlands

The relation between the Indonesian Throughflow and the Agulhas Current (AC) leakage is explored using numerical experiments. In a strongly eddying global ocean model (Parallel Ocean Program, 0.1 degree horizontal resolution), we compare an upper ocean flow for a closed Indonesian Seaway experiment with that of a control simulation. Most of the volume transport from the Indonesian Throughflow flows through the Mozambique Channel into the AC. Import of warm and fresh water from the Pacific leads to increasing temperature of the upper Indian Ocean and decreasing salinity of the AC. Both the effect of increased AC transport and increased stratification at the Agulhas retroflection lead to strenghten the leakage to the South Atlantic. The dynamical relation between Indonesian Throughflow and Agulhas leakage is analyzed using a regional idealized model at high resolution (Hallberg Isopycnal Model). Sensitivity experiments are performed to isolate the specific impact of the Indonesian Throughflow water and of local stratification on the retroflection. These idealized simulations allow us to understand the physical mechanisms that explain the results of the global simulations, this represents an important step towards the understanding of the physics of the AC retroflection.

Louw, Gavin

Monitoring the dynamics of the Natal Pulse, Durban break-away eddy and the Agulhas Undercurrent with a single, real-time mooring off Port Edward

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Between September and December 2010, a single real-time mooring was deployed on the slope off Port Edward in 1000 m in anticipation of monitoring key features of the Agulhas Current in real-time in the future. A position in a depth of 1000 m was apparently well in the core of the

current. The mooring comprised of a uniquely manufactured large (76" diameter) Flotation Technologies buoy hosting two 75 kHz RDI ADCPs (upward and downward looking) positioned at a depth mid-way in the water column (500 m). The hourly data were transited from the mid water buoy via acoustic modem to a surface buoy some 4 km away then send via GPRS into a cellular network to a server based in Cape Town. Data showed dominant south-westward current reaching speeds of > 1.5 m/s in the upper 500 m which is consistent with previous in situ measurements. Also dominant in the data set was the Agulhas Undercurrent which showed strong pulsing. Of interest however, were current reversals observed every few weeks lasting for several days. In a subsequent experiment designed to help interpret the single 1000 m mooring, extra moorings were placed either side of the real-time mooring, one in 200 m - the other in 2000 m. Combine these data not only showed the Agulhas Current and the Undercurrent, but also showed that the current reversals were caused by the Natal Pulse, the Durban break-away eddies and interestingly deep ocean eddies which caused substantial slope upwelling.

Loveday, Benjamin

Decoupling the Agulhas Current and Agulhas Leakage

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Inter-basin exchange of thermocline waters at the southern tip of Africa is a key component of the global thermohaline circulation. Mediated by the dynamics of the Agulhas retroflection, warm and saline waters, carried southward along the east coast of South Africa by the Agulhas Current, are injected into the turbulent Cape Basin. Here the majority of the Agulhas Current transport retroflects back into the Indian Ocean as the Agulhas Return Current, while waters entering the South Atlantic, collectively termed the Agulhas Leakage, are incorporated into the upper branch of the Meridional Overturning Circulation, exerting a climatic influence on decadal to millennial timescales. Evidence gathered from observations and ocean-only model simulations suggest that this leakage has increased in the past 30 years. However, while upstream mesoscale variability, caused by source region eddies or solitary meanders, is known to influence the timing of the occlusion of Agulhas rings (the predominant leakage mechanism), hindcast simulations suggest contradictory results with regard to the leakage response to changes in the wind driven Agulhas Current transport. Further, paleoclimatic proxy records point to a significant reduction in inter-ocean exchange during glacial terminations, with changes in the Southern Hemisphere winds as the driving factor. However, the ability of hindcast simulations to disentangle the effects of variations in trade and westerly wind systems is limited. To better assess the greater Agulhas Current system response to possible past and future climatic shifts, a systematic series of idealised experiments is performed here. Climatological reference runs are performed using an eddy-permitting configuration of the regional ocean modelling system (ROMS), spanning the Indian and southeast Atlantic. A tandem simulation includes a high-resolution, eddy-resolving nest over the Agulhas Retroflection. Anomalies, developed from the reference-run derived mean zonal wind-stress are applied in subsequent sensitivity runs. These are designed such that the strength and meridional extent of the trade- and mid-latitude westerly winds can be independently modified. For robust Eulerian quantification of the Agulhas Leakage, a passive tracer is introduced, which explicitly labels Indian Ocean waters, allowing both diffusive and advective processes to be captured. For comparison, Agulhas Leakage transport calculations are also performed using an offline Lagrangian package. Results suggest that while the transport of the Agulhas Current varies greatly with changes in trade wind strength and latitude, there is little or no response in the downstream inter-ocean flux. This result is consistent with a parallel series of experiments produced with coarse and eddy-resolving OGCM experiments. Further, due to the apparent lack of a dynamical connection between Agulhas Current and Leakage transports, we suggest that the previously published correlations (or anti-correlations) between the two may artificially arise from the differing forcing fields used in those studies and that, at large scale, the changes in leakage are principally governed by changes in the westerlies.

Malan, Neil

Dynamic Upwelling on the Inshore Edge of the Agulhas Current

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The presence of upwelling inshore of the Agulhas Current at the extreme eastern side of the Agulhas Bank (near Port Alfred) was first described by Lutjeharms et. al. (2000) using remote sensing and historical cruise data. These data indicated that, although intermittent, upwelling occurred 40% of the time with surface temperatures dropping 4-6°C at times over the width of the shelf and extending as far north as East London (i.e. ~150 km). This observed upwelling was ascribed to divergence as a result of an increase in the shelf width. Episodic shelf edge upwelling events have also been observed in other western boundary currents (WBC), e.g. the Florida Current/Gulf Stream and the East Australian Current. Proposed mechanisms for the upslope intrusion of deeper water included Ekman pumping at the base of the WBC (requires direct contact between the WBC and slope bottom) possibly enhanced by wind driven offshore Ekman transport at the surface (Pearce, 1980), oscillations (meanders) in the WBC as a result of instabilities (Csanady (1989, 1990), geostrophic adjustment which does not require direct contact with bottom (Condie, 1995), and offshore eddies (Middleton et al., 1994). This study aims to understand the mechanism underlying the observed upwelling off Port Alfred. Data are examined from three current meter moorings deployed across the shelf for a period of 12 months, as well as hydrographic and S-ADCP data collected from four cruises. Trends in bottom

temperature data (extent and duration) across the shelf are correlated with the mesoscale dynamics of the Agulhas Current including the Natal Pulse - determined from the moorings and high-resolution satellite-derived sea surface temperature, ocean colour and altimetry products. Ultimately, this study will be supplemented by a modeling experiment (ROMS) that will investigate the topographical effects of the widening shelf and test the hypothesis that the upwelled slope water near Port Alfred is the source of the cold nutrient-rich bottom water on the Agulhas Bank.

Malauene, Bernardino S.

Cool, elevated chlorophyll waters off northern Mozambique

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2. Instituto Nacional de Investigacao Pesqueira, Maputo, Mozambique
3. Oceanography, University of Cape Town, Cape Towm, South Africa
4. Oceans and Coasts, Department of Environment Affairs, Cape Towm, South Africa

In-situ observations from an underwater temperature recorder and a shipboard oceanographic survey are combined with satellite sea surface temperature and chlorophyll-a measurements derived from MODIS to assess the temporal and spatial variability of temperature and chlorophyll in the Mozambique Channel near Angoche, 16°S. Intermittent, cool surface water and elevated chlorophyll signatures were found along the northern coast between 15-18°S, suggesting upwelling off Angoche, covering an area of approximately 68 000 km2. The region displayed seasonal variations between persistent "non-cool" events from April to July and intermittent cooler events from August to March. Generally, periods of increased cooling events occurred every two months, but shorter period re-occurrence (8-30 days) of cool events were also observed. Two possible forcing mechanisms were determined: firstly from satellite blended sea surface winds derived from NOAA/NCDC, and secondly, offshore sea level anomalies from AVISO altimetry. It is suggested that the cool, elevated chlorophyll surface signal is partly wind-driven, responding to weak alongshore northeasterly monsoon winds which blow between August and March, combined with southward propagating anti-cyclonic eddies. An analysis of the near coastal temperature time series from 2002 to 2007 shows both seasonal and shorter term variability associated with fluctuations of the wind direction during the austral spring/summer. It is not clear which mechanism dominates.

Marean, Curtis W.

Early Modern Humans on the Edge of Land and Sea: The Dynamic Character of the Agulhas Paleoscape and its Impact on Modern Human Origins ***(INVITED)***

Marean, Curtis W.[1]

1. Institute of Human Origins, Arizona State University, Tempe, AZ, USA

Genetic and anatomical evidence suggests that Homo sapiens arose in Africa between 200 and 100 thousand years (ka) ago, and recent evidence suggests that complex cognition may have appeared between ~164-75 ka. This evidence directs our focus to marine isotope stage 6, when from 195-125 ka the world was in a fluctuating but predominantly glacial stage when much of Africa was cooler and drier, and when dated archaeological sites are extremely rare. The archaeological research at Pinnacle Point showed that humans expanded their diet to include marine resources by ~164 ka at site PP13B on the south coast of South Africa, perhaps as a response to these harsh environmental conditions. The associated material culture documents an early use and modification of pigment, likely for symbolic behavior, and there is now intriguing evidence for complex pyrotechnology in the form of heat treatment of lithics. PP13B also includes a later sequence of MIS5 occupations that extends to 90 ka, and documents an adaptation that increasingly focuses on coastal resources. Recent excavations at site PP5-6 extend the sequence at Pinnacle Point to 48 ka, making a composite Pinnacle Point sequence our longest Middle Stone Age record for the coast of South Africa. Our research group working at Pinnacle Point (South African Coast Paleoclimate, Paleoenvironment, Paleoecology, Paleoanthropology Project - SACP4) is taking a multi-proxy approach to modern human origins, and attempts to embed the human origins record in a detailed and continuous reconstruction of the Paleoscape. To that end, we developed the first 3D model of the changing South African coastline over the last 420 ka and the first high resolution long continuous sequence speleothem of Quaternary climate and environmental change on the south coast. Other proxy studies of micro-mammals and macro-mammals sharpen the environmental reconstructions. During glacials a flat and featureless coastal plain emerged in front of the caves and a grazing migration ecosystem developed on it. Early in the MSA during marine isotope stages 6 and early 5, while the coastline was within 10 km of Pinnacle Point and populations were rather small, hunter-gatherers used caves and rockshelters on this neo-coastline (the current coastline) on a regular basis, but when sea levels dropped sufficiently to move the coast beyond 10 km, they rarely used the neo-coastal sites and focused their residential bases on the now-submerged paleo-coastline. As populations increasingly expanded during the later MSA, people were forced to relax their focus on the sea and move into less desirable habitats and fully terrestrial adaptations. During MIS4 these populations expanded further and packed the landscape. The speleothem sequence suggests that the south coast received a greater amount of summer rain, and grasses using the C4 photosynthetic pathway expand in the region, but particularly on that plain resulting in a rich grazing ecosystem that, together with the coastal resources and

geophytes of the Cape flora, created a rich but ever-changing environment through this crucial phase of modern human origins.

Marino, Gianluca

The Role of the Agulhas System in Abrupt Climate Change ***(INVITED)***

Marino, Gianluca[1]; Zahn, Rainer[2, 3]

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2. Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona, Spain
3. Departament de Física, Universitat Autònoma de Barcelona, Bellaterra, Spain

The paleoceanographic record provides compelling examples of abrupt reorganizations of the Atlantic meridional overturning circulation (AMOC) that occurred repeatedly in the past and acted as an oceanic control on interhemmispheric climate variability and CO2 partitioning between the deep ocean and the atmosphere. One notable expression of this variability is the recurrent pattern of abrupt cold-warm transitions in the North Atlantic, the so-called Dansgaard-Oeschger events. The cold phases are commonly ascribed to freshwater perturbation in the northern North Atlantic that caused the AMOC and its associated northward heat transport to weaken, thereby cooling the mid to high latitude North Atlantic for centuries to millennia. The cold phases then abruptly (within decades) terminated and the region warmed by up to 16°C. There is broad consensus that the warming was caused by a resumption of the AMOC, while the underlying mechanisms that kick-started the AMOC to full strength remain enigmatic. Traditionally, the trigger for these abrupt events has been sought in ocean-atmosphere processes taking place either in the high-latitude North Atlantic or in the tropics. But new paleoceanographic proxy-data that were generated in the GATEWAYS project point to a very different mechanism: the inter-ocean salt transport from the Indian Ocean to the Atlantic, by means of the so-called Agulhas Leakage, may have acted as a trigger of sudden AMOC resumptions and, in turn, of abrupt climate changes. An ensemble of high-resolution paleoceanographic time series from the Indian-Atlantic oceanic gateway demonstrates a one-to-one coupling between abrupt climate swings in the North Atlantic and transient salt transport events from the Indian Ocean to the Atlantic. Peak maxima in the inter-ocean salt transfer coincided with the accelerated warming that terminated the North Atlantic cold phases. This finding lends credence to the model simulations that have long speculated that the Indian-to-Atlantic salt-leakage may indeed act as a driving force of abrupt climate change via its influence on the AMOC. We place these new results into a framework of previous paleo-reconstructions and model simulations to derive a fuller picture of the Agulhas System dynamics in the course of millennial-scale AMOC events and glacial-interglacial climatic transitions during the Late Pleistocene.

Marsac, Francis

Introduction to Session 2: Effects of Agulhas system variability on regional weather, climate, bio-physical interactions, marine ecosystems and fisheries

Marsac, Francis[1]; Cronin, Meghan F.[2]

1. Oceanography, IRD / University of Cape Town, Rondebosch, South Africa
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The Greater Agulhas System is highly dynamical, leading to intense air-sea fluxes that affect storms/cyclones formation and rainfall over the African continent. It also exhibits a strong mesoscale activity which induces biological responses throughout the trophic pathways, from the tiniest (plankton) to the largest (top predators) marine organisms. The structuring role of mesoscale eddies on the distribution of phytoplankton has been well described in the literature using the sea color satellite imagery. In addition, recent in-situ measurements of planktonic communities have led to insights into processes involved. At the intermediate and upper levels of the ecosystem, data collected from inshore and offshore fisheries, and from dedicated sampling experiments, are used to depict major distribution patterns in the South West Indian ocean region. The Agulhas current acts as a conveyor belt for migrating tropical species and a clear example is shown of a tropical tuna taking advantage of this western boundary current to undertake feeding migrations in subtropical to temperate latitudes off South Africa. We shall also discuss the observed and modeled changes in fish communities in a warmer Agulhas current.

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Menezes, Viviane V.

Multi-scale Variability in the South Indian Upper Ocean Circulation: Impacts on the Agulhas Current System

Menezes, Viviane V.[1]; Vianna, Marcio[2]; Phillips, Helen[1]

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It is presently recognized that the greater Agulhas system and the Atlantic-Indian inter-ocean exchanges of heat and salt are key drivers of the global climate variability. Despite the currently growing number of studies focusing on this subject, the regional long scales of space-time variability of the Agulhas circulation system are still poorly known. Recently, it has been shown that the Agulhas eddy shedding is controlled by upstream processes due to the southwestward propagating eddy trains both from the Mozambique Channel (MC) and from the East Madagascar Current (EMC) slope region. On the other hand, some studies suggest that these eddy trains could be triggered by westward-propagating planetary wave fields evolving across the Subtropical South Indian Ocean (SIO) at the semiannual band. Recent studies showed the presence of a shallow and persistent cross-gyre eastward flow, the South Indian Counter Current (SICC) and the absence of a Mozambique western boundary current. In the present work, we analysed 18 years of satellite altimeter data, satellite-derived geodetic

Mean Dynamic Topographies (MDTs based on GRACE and GOCE data) and the CARS Climatology to characterize the mean upper-ocean circulation and the regional variability in multiple scales. The altimetry data used here belongs to the AVISO delayed time, reference series that was separated into 14 time-period bands from intra-seasonal to non-linear trend using Singular Spectrum Analysis and Maximum Entropy Methods. Analysis of the geodetic MDTs and CARS dynamic height confirm that the Subtropical Gyre is better described as a double-cell structure: the northern cell is centered around the east side of Madagascar (22S-60E) and the southern at 35S-35E, being connected with the EMC. The SICC flow appears very clearly with mean velocity of 10 cm/s, originating in the partially EMC retroflection, which at 70E form several branches with some closing the northern cell. Two branches of the westward South Equatorial Current (SEC) reach the east of Madagascar: one at 18S (20 cm/s) and other at northern tip (35 cm/s). Analysis of the CARS suggests that the SICC is associated with a density front at surface, with salinity playing a very important role in the definition of this front at the eastern side of the basin. Period bands show the intra-seasonal (<160 days) explaining 34% of the variance, annual (18%), bi-annual (14%), semi-annual (14%) and non-linear trend band (6%). At the intra-seasonal band the upstream circulation of the Agulhas system is forced remotely by planetary waves originating from the Australian coastal region (Indonesian Throughflow and South Australia). The trend band exhibit maximum variability in 3 areas: in the SICC, Agulhas Retroflection and Indonesian Throughflow. Both SG cells have expanded and intensified from 1992 to 2011 with the northern cell having expanded from 75E to 90E. Changes in the SICC current speed were striking: west of 60E it more than doubled (from 8-12 cm/s to 20-26 cm/s), while the SEC branch reaching the northern tip of Madagascar decreased from 29-35 cm/s to 25-30 cm/s and the SEC branch at 18S has intensified.

Morioka, Yushi

How to generate the Indian Ocean Subtropical Dipole in a coupled GCM

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2. The University of Tokyo, Tokyo, Japan

Based on experiments using a coupled general circulation model, forcing mechanisms of the Indian Ocean Subtropical Dipole (IOSD) are investigated. As in the observation, the IOSD simulated in the control experiment is characterized by a dipole pattern of sea surface temperature (SST) anomalies in the northeastern and southwestern parts of the southern Indian Ocean, and it is associated with the variations in the Mascarene High during austral summer. In the second experiment, where the SST outside the southern Indian Ocean is nudged toward the monthly climatology of the simulated SST, only one type of the IOSDs occurs owing to the anomalous Mascarene High. This is associated with the zonal wavenumber four pattern of equivalently barotropic geopotential height anomalies in the mid-latitudes, suggesting an interesting link with the Antarctic Circumpolar Wave. This result indicates that even without atmospheric teleconnections from air-sea coupled modes outside the southern Indian Ocean, the IOSD may develop in association with the atmospheric climate mode in the Southern Hemisphere. However, the IOSD occurs much less frequently in this experiment as compared to the control experiment. In the third experiment, where the SST outside the southern Indian Ocean and the tropical Pacific is nudged toward the monthly climatology of the simulated SST, two types of both positive and negative IOSDs occur. Since the frequency of occurrence of the IOSDs significantly increases as compared to that in the second experiment, this result indicates that atmospheric teleconnections from air-sea coupled modes in the tropical Pacific such as El Niño/Southern Oscillation may also play an important role in inducing the variations in the Mascarene High that generate the IOSD. Since the present study benefits the better understanding of the interannual variations in the Mascarene High, it may also lead to better understanding of the variations in the Agulhas Current system.

Morris, Tamaryn

Mozambique Channel eddies as a transport mechanism: The case of Red Sea Water

Morris, Tamaryn[1]; Ternon, Jean-Francois[2]; Roberts, Michael J.[3, 1]

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Red Sea Water (RSW) is an intermediate water mass formed in the Red Sea which enters the Gulf of Aden between 500 and 800 m then the Mozambique Channel between 900 and 1200 m. RSW is defined by high salinities (34.8 – 34.9 PSU), low temperatures (5.5 – 7.0° C), low oxygen levels (1.0 – 2.1 ml/l) and densities between 27.2 and 27.6 sigma-θ. RSW is thought to be a dominant component of the salt budget for the intermediate waters of the Western Indian Ocean (as opposed Indonesian Throughflow Water and diapycnal mixing) as well as a significant salt contribution to the South Atlantic through the shedding of Agulhas Rings at the Agulhas Retroflection. Historically, it was thought that the most efficient mechanism of transporting RSW through the Mozambique Channel was by means of mesoscale eddies with the back-ground flow a lesser contribution. This paper analyzes eight years of Argo float data in the Mozambique Channel and compares the positive RSW profiles to an automatic eddy detection scheme using ¼° delayed time SLA product (updated AVISO product with RIO9 processed mean dynamic topography) to analyze the transport potential of mesoscale eddies. Contrarily, results show that both cyclonic and anti-cyclonic mesoscale eddies combined only account for 44 % of the transport potential through the Mozambique Channel with the remaining positive RSW Argo float profiles occurring outside of these mesoscale perturbations. Ten events are noted whereby a RSW positive Argo float becomes entrapped within either a mesoscale anti-cyclonic or cyclonic eddy (i.e. > four weeks). These are analyzed further to determine whether eddy kinetic energy (EKE) plays a role in the transport of RSW. Results confirm neither a seasonal signature for the distribution of RSW within the

Mozambique Channel, nor mesoscale eddies being the preferred mechanism for transport as suggested in previous studies of the Mozambique Channel. This paper forms a base for future projects planned for the region using Argo floats deployed strategically within mesoscale eddies to monitor the dynamics of the thermocline (i.e. aging and decay of mesoscale eddies).

Mungai, John G.

A Numerical Investigation of Surface Currents of the Western Indian Ocean

Mungai, John G.[1]

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In this paper, the variability of the Somali Current due to the monsoonal transition is investigated using a numerical ocean model. The monsoon is characterized by wind reversals and seasonality in the precipitation of a region. The surface circulation of the western Indian Ocean during the summer (JAS) and winter (JFM) monsoon winds is investigated using the Regional Ocean Modelling System (ROMS). ROMS is forced with the Comprehensive Ocean Atmosphere Data Sets (COADS) while the initial and lateral boundary conditions are derived from the World Ocean Atlas. The domain area of the model study is constrained by 10S to 15N and 35E to 65E. An overview of the surface circulation of the Somali basin is given, discussing the Somali Current, East African Coastal Current, South Equatorial Counter Current, Southern Gyre, and the Great Whirl. The motivation of this study is to improve the understanding of the poorly understood circulation patterns within the Somali Basin from intra-seasonal to seasonal timescales, using the ROMS model. The model results suggest a seasonally reversing Somali current with a sub-surface counter current, consistent with observations. Other prominent features such as the Great Whirl, which occurs during the Southwest monsoon and the Southern Gyre, are also apparent in the simulation. The East African Coastal Current (EACC) and the South Equatorial Counter Current (SECC) are also major features of the Somali basin circulation that are equally apparent from the model simulation. The model equally reproduces the equatorial jets as expected during the transition period of April/May and October/November with the net result of mass transport from the western end of the basin towards the east.

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Nagura, Motoki

Dynamics of the Seychelles Dome Simulated by 34 Ocean-Atmosphere Coupled General Circulation Models

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The simulated upwelling domes in the southern Indian Ocean are examined, using outputs from 34 ocean-atmosphere coupled general circulation models (CGCMs) including those from the phase five of the Climate Model Intercomparison Project (CMIP5). In observations, the upwelling dome, which is referred to as the Seychelles Dome, is generated by local Ekman upwelling and located in the southwestern tropical Indian Ocean. In 12 out of the 34 CGCMs, the upwelling domes are misplaced in the eastern half of the basin (Figure 1). The annual mean Ekman pumping velocity is almost zero in the southern off-equatorial region in these models, due to the easterly wind biases prominent in boreal summer and fall to the north of 7°S. Also, the easterly biases along the equator cause shallow thermocline biases along the Java and Sumatra coasts via Kelvin wave dynamics, which are radiated to the southeastern Indian Ocean and result in the upwelling dome there. As a result, the upwelling domes originate from the eastern boundary in these models, rather than being forced by local winds. It is also discussed that the biases in CMIP5 models are comparable to those in CMIP3 models regarding zonal position of the upwelling domes and periodicity of thermocline depth in the dome regions.

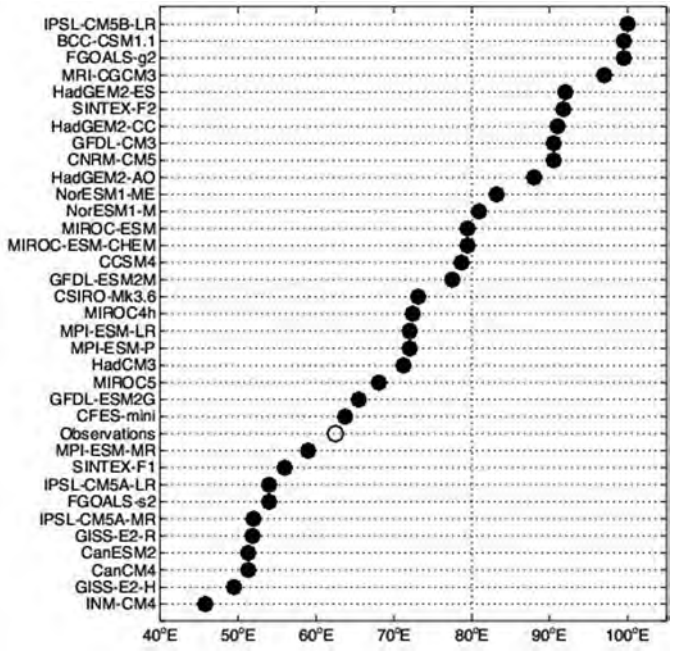

Figure 1: The longitudes of the shallowest annual-mean D20 in 5°S-12°S. The open and filled circles are for observations and CGCMs, respectively.

Nakamura, Hisashi

Air-Sea interactions Associated with the Agulhas System: Regional, Basin-Scale and Hemispheric Impacts ***(INVITED)***

Nakamura, Hisashi[1, 2]; Miyasaka, Takafumi[1]; Nishii, Kasuaki[1]; Ogawa, Fumiaki[1]; Nonaka, Masami[2]; Komori, Nobumasa[2]; Taguchi, Bunmei[2]; Tanimoto, Youichi[3, 2]

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The Agulhas System, especially its Return Current, accompanies pronounced meridional sea surface temperature (SST) contrasts in the midlatitude South Indian Ocean, being confluent with much cooler water associated with the Antarctic Circumpolar Current (ACC). The tight SST gradient along this oceanic frontal zone helps form a

well-defined surface baroclinic zone, where distinct cross-frontal contrasts in heat release from the ocean on the passage of weather systems effectively restore tight meridional gradient in surface air temperature (SAT). In addition to moisture supply from the warm Return Current, the SAT gradient thus maintained allows recurrent development of cyclones, leading to the formation of a storm track and a well-defined rain band, especially in the cold season. With the surface baroclinic zone maintained continuously by the Agulhas System, transient eddy activity remains high throughout the year, forming the core region of the Southern Hemisphere (SH) storm track. Local influence of transient eddies that amplify baroclinically in the Agulhas region is not limited to the formation of the rainband. The strong eddy activity maintains a well-defined core region of the subpolar jet stream (or polar-front jet: PFJ), which accompanies the strong surface westerlies maintained by poleward eddy heat flux to drive the ACC and Agulhas Current. The slight enhancement of the storm-track activity in winter drives the surface westerlies even strongly to maintain the Mascarene High, a surface subtropical anticyclone that develops in winter over the western portion of the basin in winter. In recognition of its summertime counterpart develops farther to the east under the strong land-sea thermal contrast across the west cost of Australia, we argue that the distinct east-west seasonal displacement of the surface subtropical high over the South Indian Ocean reflects the seasonal transition in the primary forcing on the subtropical high. The variability of the eddy-driven PFJ manifests itself as the Southern Hemisphere annular mode (SAM), which exerts significant impacts in the SH climate system. From this viewpoint, the oceanic frontal zone is essential for the presence of the SAM and the maintenance of its activity, as suggested by an atmospheric general circulation model experiment under the aqua-planet setting.

Ngwali, Mohammed

Impact of Climate Variability on Sea Level Change in East Africa

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The study focuses on the analyses of the of the sea level variations along the East African Coast during the 1997/1998 El Niño and the 2000/2001 La Niña periods. The data used for this study were the observed tide gauge measurements from Zanzibar and Lamu tide gauge stations collected for the period of nine (9) years from 1996 to 2004 and satellite data obtained from various sources for the periods of 1997/1998 and 2000/2001. The investigated datasets revealed that the inter-annual variation of sea level data in East Africa is influenced by the El Niño Southern Oscillation (ENSO) and the Indian Ocean Zonal Dipole Mode (IOZDM) events in the tropical western Indian Ocean. The 1997/1998 was the period associated with positive IOZDM and ENSO events in the western Indian Ocean was also associated with higher Sea surface temperatures, leading to rising of sea levels along the East African coast. These conditions in turn led to development of strong convection and severe weather conditions over the East African region. By contrast, The 2000/2001 was associated with negative IOZDM and ENSO events in the Western Indian Ocean and low sea surface temperatures which led to lower sea level along the East African Coast. These conditions in turn led to reduction of moist air from the ocean and stabilized the atmosphere, leading to relatively fine weather and reduced rainfall over the East African region.

Nonaka, Masami

Upper ocean heat content, SST, and surface heat flux in midlatitude oceanic frontal zones

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In studies of midlatitude air-sea interaction, increasing attention has been paid to oceanic frontal zones where oceanic variability can induce sea surface temperature anomalies (SSTAs) that may be able to exert some feedback onto the overlying atmosphere. This strongly contrasts with broader regions in the midlatitude ocean basins where SSTAs are mainly caused by atmospheric thermal forcing. Agulhas return current and its eastward extension are among such oceanic frontal zones, and at least for climatological field influences of its strong SST gradient onto atmospheric circulation have been suggested in several studies. To understand impacts of oceanic variability on the atmosphere and climate, many studies have been conducted on atmospheric responses to SSTAs. There is, however, a concern that even in oceanic frontal zones, SSTAs are affected by atmospheric variability and thus can be not only the cause for but also a response to atmospheric variability. Then, in this study, we propose to use sea surface height (SSH) and/or upper ocean heat content, which is defined as vertically integrated temperature from the surface to 700-m depth, rather than SST as variables representing oceanic variability as their variability is dominantly influenced by thermocline depth variations. In the subarctic frontal zone in the western North Pacific, high SSTAs tend to be associated with enhanced turbulent heat release from the ocean to the atmosphere. This relation is found more clearly between the upper ocean heat content and surface latent heat flux. This is probably because the heat content is less likely to be influenced directly by atmospheric thermal forcing than SST and thus more likely to represent ocean to atmosphere feedback. Furthermore, lag-correlation analysis between monthly anomalies of sea level pressure (SLP) and upper ocean heat content suggests atmospheric responses to oceanic variability in the subarctic frontal zone, whereas the counterpart between SLP and SST indicates atmospheric forcing on underlying SST on interannual time scale. These results indicate that upper ocean heat content can better represent oceanic variability than SST and thus be useful for investigating air-sea interaction in midlatitude. In midlatitude in the Southern Hemisphere, unfortunately historical subsurface temperature observations are limited, and upper ocean heat content cannot be used and satellite observed SSH is used to represent oceanic variability, although its period is limited to after 1992. In the frontal

zone associated with the Agulhas return current and its eastward extension, surface heat flux and either SST or SSH are positively correlated, suggesting ocean-to-atmosphere feedback. Also, as in the western North Pacific, the latter correlation is slightly higher than the former. Due to limited length of the time series, robust atmospheric response is difficult to detect based on satellite observation and atmospheric reanalysis data. Coupled models are also necessary to investigate further atmospheric response to variability in these oceanic frontal zones in the South Indian Ocean.

Ortiz, Joseph D.

An Indirect Estimate of the Impact of the Agulhas Leakage on the Atlantic Meridional Overturning Circulation During the Holocene

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The leakage of Agulhas rings from the Indian Ocean to the South Atlantic represents an important contribution to the global heat budget as part of the thermohaline circulation. Beal et al. (2011) discuss the importance of the Agulhas leakage to the Atlantic Meridional Circulation (AMOC), stressing the need for additional observationals and modeling studies to elucidate how anthropogenic forcing will influence the linkage between the Agulhas Leakage and the AMOC. Here we employ a time-dependent version of the Sandal-Nof analytical model to explore variation in the AMOC during the Holocene. The model is an application of the modified island rule and consists of six equations that represent the conservation equations for heat and salt, transport from the Southern Ocean to the North Atlantic, transport from the Arctic to the North Atlantic, the sinking flux due to convection in the North Atlantic, and constraints on North Atlantic convections and air-sea heat exchange in the North Atlantic. We invoke the slowly varying approach, where a steady model solution is taken to be valid when the forcing varies on a time scale much longer (~1000 yr) than the advective timescale (~10 yr). The simplicity of the model, which incorporates only the fundamental physics needed to model the interaction of the wind-driven and the thermohaline circulation enables us to run the model with 100-year time steps for a period of 12,000 years. The model is forced with paleoceanographic proxies for the Southern Ocean Winds and the flux of water into the world ocean due to the melting of ice sheets on land and the resulting change in sea level. Comparison of model output with published Pa-Th records from the South and North Atlantic indicates that the model record of sinking flux, W, is positively correlated with Pa-Th in the North Atlantic at depths influenced by the NADW (r = 0.77) and inversely correlated with Pa-Th records from the South Atlantic at depths associated with the AABW (r = -0.45). Pa-Th records at transitional depths between these water masses produced minimal correlation with W. Because the model does not incorporate eddy fluxes arising from the shedding of Agulhas rings into the South Atlantic along the retroflexion region, we can use the magnitude of the linear correlation between the paleoceanographic Pa-Th proxies (which must be influenced by the Agulhas eddies as well as other processes) as a first order measure of the non-linear impact of the Agulhas rings on the AMOC, assuming that the Agulhas Rings are the dominant process related to the AMOC that is excluded from the model. These results suggest on upper limit on the contributions of the Agulhas eddies to the AMOC variation during the last 12,000 years of 40 to 80% at depths associated with the cores of the NADW and AABW respectively. Changes of this magnitude are comparable to estimates of the impact of 20th century anthropogenic forcing on the Agulhas leakage as inferred from simulations with the NCAR Community Climate System Model version 3 (Lee et al., 2011).

Park, Wonsun

Spectrum of the Agulhas Current as simulated by a coupled atmosphere-ocean general circulation model

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The Agulhas Current, a warm western boundary current, feeds waters as a part of the Greater Agulhas System that consists of the retroflection flowing back to subtropical gyre and the leakages providing salty water into the Atlantic basin. Stronger air-sea interaction over the western boundary current is known to affect the ocean-land moisture flux, and thus important in the climate over the Southern Africa as well as over the current region. Due to its wide involvement of different processes, it will be useful to investigate a spectrum of the Agulhas current and relationship to climate variability. Here, we analyze a multi-millennial control simulation with a fully coupled atmosphere-ocean model (Kiel Climate Model) to illustrate internal variability and compare with proxy data. Rich spectrum exists from interannual, decadal, multi-decadal and multi-centennial time scales, of which relations are to other ocean basins, e.g. Tropical Pacific, North Pacific, North Atlantic and Southern Ocean. In particular, on longer time scales, competing roles of the North Atlantic and Southern Ocean may exist. Relative roles of the warm-water route compared with the cold-water route are further investigated on different time scales with a help of higher resolution simulations with an ocean-sea ice model.

Peeters, Frank J.C.

Fossil Planktic Foraminiferal Faunas: Silent Witnesses of Past Ocean Environments South of Africa ***(INVITED)***

Peeters, Frank J.C.[1]

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Planktic foraminifera are unicellular marine microscopic amoebae that build a calcite shell. At the end of their life cycle their shells swiftly settle to the ocean floor where they become part of the marine geological record. Because of their widespread distribution and high abundance in ocean sediments, these microfossils are arguably the most

important carriers of palaeoclimate information available to scientists, often aiding in the reconstruction of the ocean's temperature, salinity or biological productivity. A significant part of our understanding on past upper-ocean conditions has been obtained from the analyses of the fossil assemblages. In general, the fossil species composition found in surface sediments mirrors the composition of living assemblages collected in the upper part of the water column. It is therefore that fossil assemblages from core-top sediments are considered to well reflect water masses and modern hydrographic conditions. The assemblages and their diversity clearly change as a function of latitude: from a high diverse warm water fauna in the tropics / sub-tropics, to a low diverse cold water fauna in the (sub)polar regions. Large-scale regional oceanic features, such as boundary currents, frontal zones or upwelling regions, often result in the mixing of water masses and their corresponding faunas. South of Africa, Indian Ocean waters collide and mix with the Atlantic and Southern Ocean waters and their characteristic faunas, resulting in peculiar assemblages, which appear characteristic for specific hydrographic conditions. The fossil planktic faunas from the marine geological archives underlying the Agulhas Current system can be considered as 'silent witnesses' of its past dynamics. In my presentation I will discuss observations on modern planktic foraminiferal faunas in relation to different water masses and hydrographic features, and how these observations may be used to make the silent witnesses 'speak'.

http://www.falw.vu/~peef/

Penven, Pierrick

Modeling the Recent Changes in the Agulhas Retroflection Region

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3. Nansen-Tutu Center for Marine Environmental Research, UCT, Cape Town, South Africa

The Agulhas Current is now recognized as a key element for the Climate of the Earth. In particular, the Agulhas Leakage, the flux of relatively warm and salty waters entering the South Atlantic from the Agulhas Retroflection, can have an impact on the Meridional Overturning Circulation. This region is one of the most turbulent regions of the world Oceans, and the Agulhas Leakage is linked to the propagation of large coherent structures into the South Atlantic Ocean: The Agulhas Rings. Recent observations from satellite altimetry have shown that the level of eddy kinetic energy in the Agulhas Retroflection, in the Mozambique Channel and South of Madagascar (i.e. in 3 regions known for the presence of mesoscale eddies) have increased significantly over the last two decades. This has been related to a wind forced increase of the South Equatorial Current. In particular, eddies are now moving faster, implying a possible increase in Agulhas Leakage. A new ocean model simulation based on the Regional Ocean Modeling System (ROMS) has been designed to reproduce this increase in energy. It uses an ocean reanalysis (SODA) at its lateral boundaries and an atmospheric reanalysis (CFSR) for its surface conditions. This simulation is analyzed to quantify over the water column the changes in eddy properties and propagations speeds, as well as the causes of these changes and their effects on the Agulhas Leakage.

Porri, Francesca

From general patterns to individual mechanisms: oceanographic determinants of offshore larval dispersal

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2. Applied Physics Laboratory, University of Washington, Seattle, WA, USA
3. South African Environmental Observation Network, Egagasini Node, Cape Town, South Africa

Larval connectivity is central to understanding population dynamics of marine organisms and is profoundly influenced by hydrodynamics at multiple spatial scales. Here we provide a regional scale study that identifies mesoscale oceanographic mechanisms linked to the distribution of invertebrate larvae. We surveyed the distribution of mussel larvae along 12 onshore to offshore transects within an alongshore distance of about 700km along the Agulhas Bank. Several oceanographic parameters were measured simultaneous to larval collection to identify the physical variables correlated with larval distribution. A strong pattern of high densities of mussel larvae being restricted to the nearshore was observed with most larvae restricted within a mean of 3.7 km of the coast. Multivariate analysis and individual regressions failed to identify a strong, common physical predictor variable, or combination of variables, that could explain this pattern. Instead, four different oceanographic mechanisms were identified that could explain onshore distribution of larvae on separate parts of the coast. These were: a Natal Pulse, an Agulhas Current meander, an anomalous southward current along transect seven, and the accumulation of larvae in a region with known internal wave activity. In addition, an Agulhas Current meander downstream of the Natal Pulse swept large numbers of recently "spawned" larvae up to 30km offshore, acting as a corridor for dispersal and loss of viable larvae into the Agulhas Current. Importantly, no single oceanographic phenomenon could explain the broad pattern of larval distribution along this coast, rather different mechanisms drove the same result in different places.

Purcell, Conor

Modelling the influence of Agulhas Leakage on the Atlantic Meridional Overturning Circulation during glacial-interglacial transitions

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2. Paleoclimate Dynamics, Alfred Wegener Institute, Bremerhaven, Germany

It has been proposed that the influence of the Indian-Atlantic warm water exchange route on the Atlantic Meridional Overturning Circulation (AMOC) has been subject to changes in the past. In particular, the dynamics of the Agulhas system appears to be severely impacted by meridional shifts in the subtropical front. Here we use a fully coupled Earth System Model (COSMOS), employing an adapted ocean grid that locates the model's south pole over South Africa in order to maximise the grid's spatial resolution up to ~40km in the Agulhas region and throughout the Atlantic basin. This allows us to simulate more of the complex dynamics that governs the Agulhas system. In order to investigate the influence of Agulhas dynamics on the AMOC during glacial-interglacial transitions, Last Glacial Maximum (LGM) boundary conditions have been applied to the model set-up using Paleoclimate Modelling Intercomparison Project Phase III (PMIP3) criteria. Initial results suggest that the adapted ocean grid set-up is capable of realistically simulating transport throughout the Agulhas region. The model simulates reasonable pre-industrial rates of Agulhas Leakage in the range of 15-25Sv, coherent with other high resolution ocean models. Moreover, our model set-up produces a maximum pre-industrial AMOC of 13.5Sv, some 2.5Sv lower than in the standard grid set-up. This decrease in AMOC strength could be related to the simulated reduction of Agulhas Leakage. Our LGM simulations suggest that the global average sea surface temperature decreased by approximately 3C relative to pre-industrial levels. The AMOC was characterised by intensified poleward surface flow and stronger deep water convection in the North Atlantic, which results in a higher maximum stream-function relative to pre-industrial levels. Freshwater perturbation experiments have been performed on the pre-industrial and LGM states. A pre-industrial 0.2Sv perturbation to the North Atlantic region reduces the maximum AMOC strength to ~7Sv after 150 years, with a contemporaneous increase of salinity levels in the South Atlantic. After these 150 years Agulhas Leakage increased in the range of 2-6Sv relative to initial pre-industrial levels. The LGM 0.2Sv perturbation simulated an increased Agulhas Leakage in the range of 1-3Sv after 150 years. This bi-polar response is consistent with the notion of a southward shift of the STF (subtropical front). Further sensitivity studies involving greenhouse gas and solar insolation forcing are under way. Of particular interest is the investigation of the active-passive role of Agulhas Leakage on the evolution of millennial scale climate change associated with glacial-interglacial transitions.

http://www.cardiff.ac.uk/earth/research-staff/mr-conor-purcell/

Quartly, Graham

Slippage in models: The impact of boundary conditions

Quartly, Graham[1]; de Cuevas, Beverly[1]; Coward, Andrew[1]

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Even global ocean models can have lateral boundaries. In particular Z-level models require lateral boundary conditions wherever the ocean points meet the step-like topography. NEMO, which uses a C-grid formulation, provides a choice of no-slip or free-slip lateral boundary conditions for the velocity components and the option selected will affect the dynamics of the flow further offshore. Although the no-slip condition is formally the correct condition to apply, it is clear that the molecular processes responsible for arresting flow in the close proximity to solid boundaries are not represented in the turbulent closure parameterisations. In this analysis we compare runs of the NEMO code on a global ORCA 0.25 degree grid with both no-slip and free-slip lateral boundary conditions. A particular area of contrast between the two is the Mozambique Channel, where the standard free-slip run produces a strong southward-flowing western boundary current, whilst the no-slip one generates large anticyclonic eddies, as are noted in real world observations. What is particularly intriguing is that the time mean of these two regimes is similar, whereas their variability is very different. Surprisingly the frequency spectrum of the transport is similar in both realizations.

Quartly, Graham

The East Madagascar Current: Looking deeper than the superficial flow

Quartly, Graham[1]

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Ocean colour and infra-red imagery of the waters around the southern tip of Madagascar show complex patterns of intense currents, coastal upwelling and convoluted contortions of the flow. No quasi-steady state persists for long with eddies being advected along the southeastern flank of Madagascar and disturbances (Rossby waves and/or eddies) propagating westward into the region from the south Indian Ocean. These combine to wrap tendrils of warm low chlorophyll water into retroflection-like patterns. But what of the flow below? This presentation will cover the analysis of a 14-month mooring section across the westward extension of the East Madagascar Current, noting the deep fast flow of the main core of the current plus an eastward-flowing undercurrent close to the coast. At the southern end of the section the surface waters do, on average, head east; however, below 200 metres the flow is westward apart from during a few major events when anticyclones passed through the array. The moorings were laid along the ground track of the orbit occupied by the TOPEX and Jason altimeters; the near-surface flows from the moorings do correlate well with altimetric height

gradient. Thus the mooring data can be used to correct for the poorly known geoid permitting a 20-year time series of absolute currents across this section.

Quartly, Graham

The Madagascar Bloom – a serendipitous study

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The late summer (February-April) phytoplankton bloom that occurs east of Madagascar, exhibits significant interannual variability and at its largest extent covers ~1% of the world's ocean surface area. The bloom raises many intriguing questions about how it begins, is sustained, propagates to the east, exports carbon and ends. It has been observed and studied using satellite ocean colour observations, but the lack of in situ data makes it difficult to address these questions. Here we describe observations that were made on a cruise in February 2005 serendipitously. These show clearly for the first time the existence of both a deep chlorophyll maximum at ~70-100m depths (seen in SeaSoar fluorimeter data) and a surface chlorophyll signature (seen in SeaWiFS satellite ocean colour data). The observations also show the modulation of biological signature both at surface and at depth by the eddy field. In situ observations indicate that Trichodesmium dominates the bloom nearer to Madagascar, while the diatom Rhizosolenia (and its symbiont Richelia intracellularis) dominates further from the island. In addition, SeaSoar Optical Plankton Counter (OPC), temperature and salinity data suggest that the surface bloom seen in the SeaWiFS data is confined to the shallow (~30m) mixed layer.

Rainville, Luc

Coastal Trapped Waves and Internal Tides on the Agulhas Bank, South Africa

Rainville, Luc[1]; Jackson, Jennifer[1]; Roberts, Michael[2]

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2. Department of Environmental Affairs, Cape Town, South Africa

Using a set of moored and ship-based measurements, we explore the high frequency variability of the temperature and velocity structures on the Agulhas Bank. In particular, large coastal trapped waves (CTWs) with periods of 3 to 5 days are found to be associated with temperature fluctuations of several degrees, particularly near the bottom, and velocities of the order of 10 cm/s. As reported in previous studies, the currents associated with CTWs are mostly barotropic. The variability in their period, amplitude, and phase are examined in relation to the wind forcing, both local and remote, as well as to the oceanographic conditions. Intrusions of the Agulhas Current onto the Bank in particular are believed to play a significant role in setting the properties of the CTWs. In addition, temperature fluctuations of several degrees over a few hours are observed in these data, consistent with vertical displacements associated with internal waves. Wind-generated inertial waves are likely to be a dominant source of high-frequency variability on the shallow Agulhas Bank, but semidiurnal internal tides are also present. The propagating waves are found to have an impact on the distribution of nutrients and organisms: in a shipboard survey, high phytoplankton concentrations were observed at the crests of presumed semidiurnal internal waves. This presentation will explore the consequences of this short-time scale variability on the Biology of the Agulhas Bank.

Ratna, Satyaban B.

Simulation of extreme seasonal climate over South Africa using the high resolution Weather Research and Forecasting (WRF) model

Ratna, Satyaban B.[1]; Behera, Swadhin[2, 1]; Ratnam, J. V.[2, 1]; Ndarana, Thando[3]; Rautenbach, Hannes[4]; Takahashi, Keiko[5, 1]; Yamagata, Toshio[1]

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2. Research Institute for Global change, JAMSTEC, Yokohama, Japan
3. South African Weather Service, Pretoria, South Africa
4. University of Pretoria, Pretoria, South Africa
5. Earth Simulator Center, JAMSTEC, Yokohama, Japan

The austral summer (December-January-February, DJF) seasonal rainfall over South Africa during 2010/2011 was above normal in relation to its climatology. A series of heavy rainfall episodes that occurred during this season caused devastating floods over the region. In order to avoid such flood damage to agriculture and society, accurate predictions of extreme seasonal rainfall is regarded as very important for South Africa. In this study an attempt is made to simulate the 2010/2011 austral summer season rainfall using the high resolution Weather Research and Forecasting (WRF) regional model. To achieve this, the model was configured with two way interacting nested domains of horizontal resolutions of 27 km and 9 km, respectively. Initial and boundary conditions for the simulations were provided from ERA-Interim data that are available at a 1.5 degree resolution, from where the model was integrated from 1 November 2010 to 1 March 2011. Sea surface temperature values from ERA-Interim were interpolated to the model's grid to obtain lower boundary conditions. Sensitivity simulations were performed with three different cumulus parameterization schemes viz Kain-Fritsch (KF), Betts-Miller-Janjic (BMJ), and Grell-Devenyi Ensemble (GDE). The simulated rainfall from the KF scheme is overestimated throughout the country. The GDE scheme shows a better rainfall distribution over the eastern coast of the country, although it underestimates rainfall over the Limpopo Province, the Northwest Province and the eastern parts of the Northern Cape Province. Rainfall simulated by the BMJ scheme, however, has a good agreement with the observed rainfall in terms of both spatial distribution and intensity. Analysis of area averaged daily rainfall from the observed and model simulated data over different regions of South Africa shows that the model could successfully capture the intra-seasonal variability observed during DJF 2010/11. It was observed that the main source of moisture for the excess seasonal rainfall is the Indian Ocean, as easterly winds enter the continent from the eastern oceanic region adjacent to the African continent. Convergence of

moisture is observed over the Mozambique Channel and the Agulhas Current regions. The easterly flow over those regions helps to transport moisture from the Indian Ocean to the southern African continent. Stronger heat flux, resulting from the higher ocean temperature and strong surface wind, enhances low level instability along the coast. The WRF model accurately simulates the SST induced strong surface winds that lead to higher heat fluxes over the Mozambique Channel. The warm Agulhas Current flowing poleward along the east coast of southern Africa is known to influence the South African climate to some extent. The simulated rainfall and circulation patterns are consistent with previously hypothesized features of ocean-atmosphere interaction for the Agulhas current region.

Reason, Chris

The Influences of the Agulhas Current on Regional Climate and Weather Patterns ***(INVITED)***

Reason, Chris[1]

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The Agulhas Current is the most intense western boundary current in the Southern Hemisphere and exerts a strong influence on climate and weather patterns not just in southern Africa but also downstream over parts of Australasia. By virtue of its core temperature being considerably warmer than the ambient ocean, from which it is separated by marked frontal gradients, strong air-sea interaction occurs over the Agulhas Current, particularly south of South Africa and when the prevailing low level winds are westerly or southerly. Experiments with atmospheric general circulation models suggest that its influence on regional weather occurs through enhancing the local instability of the atmosphere and its moisture content which then impacts most obviously on the neighbouring landmass when low level onshore wind jets occur such as during cut-off low events. Cut-off lows have caused most of South Africa's flooding disasters yet they are not well understood and are often poorly forecast. A suite of experiments with a regional atmospheric model shows that the influence of the Agulhas Current on severe weather systems over South Africa is generally stronger than the effect of topography. In terms of climate, the Agulhas Current region manifests substantial interannual and interdecadal variability as well as a warming trend in recent decades. Neighbouring southern Africa also experiences substantial rainfall variability on these scales, some of which can be linked with that in the Agulhas Current. Evidence for these linkages will be presented from observational and modelling analyses. However, as yet, there is less evidence of any significant trend in regional rainfall. Some potential causes for this apparent de-coupling will be discussed.

Rizopoulou, Konstantina

The dynamics of the Agulhas Current by coastal altimetry

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The Agulhas Current (AC) is the western boundary current of the South Indian Ocean and has a crucial role on ocean circulation and climate. In this study AC is observed and characterized by coastal altimetry. AC flows down the east coast of Africa following very closely the continental shelf. The continental shelf is very steep which makes the AC flowing most of the time very stably unlike other western boundary currents. Using reprocessed along-track altimeter data with specific data editing and processing strategies, more data can be retrieved near the coast with better spatial coverage and improved quality, compared to standard altimetry datasets. Jason track #96, which crosses the AC nearly orthogonally and on which ACT (Agulhas Current Time-series) array is located, and the Envisat track #343 which is also almost coincident with a slightly different orientation have been used in this study to demonstrate our methodology. Time-series of geostrophic surface velocity anomalies (GSVA) every 10 days from Jason #96 and a complementary dataset of GSVA's every 35 days from Envisat have been derived over one year (2010), which include a Natal Pulse event. This study evaluates the ability of coastal reprocessed altimetry data to capture the current variability as well as the mesoscale features.

Roberts, Michael J.

Observations of shelf edge upwelling along the Mozambique shelf: the interaction of anticyclone-cyclone paired eddies with the continental slope

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In 2002 a UTR (Underwater Temperature Recorder) was deployed at a depth of 18 m on Zambia Reef (near Inhambane) in southern Mozambique. Surprisingly, the data showed strong shelf edge upwelling to occur commonly throughout the 4 year record with no apparent seasonality. Physical principles dictate two well-known mechanisms possibly responsible for such upwelling - northerly winds (offshore Ekman transport) and/or Ekman veering in the bottom boundary layer of a strong southward-bound current. It is now well established that the Mozambique Current in the form of a western boundary current does not exist. Instead anticylonic eddies are seen to move southwards down the Mozambique Channel at a rate of 3–5 per annum. In April 2005, a research vessel (FRS Algoa) which had just

serviced the UTR observed a strong southerly current off the adjacent shelf. SSH data downloaded to the ship showed an anticyclone-cyclone eddy pair (dipole) positioned in the immediate vicinity. The anticyclone was north of the cyclone, a configuration referred to as an A-C dipole. The region was surveyed using an onboard S-ADCP and CTD lines. The data showed strong (1.5 m s-1) southward currents adjacent to the shelf and significant upwelling between the dipole and the shelf with concomitant enhanced nutrient levels. This upwelling was also clearly evident in the Zambia Reef UTR data. Retrospective analysis of SSH data showed the dipole to have moved southwards down the Mozambique Channel and taken a few weeks to pass the Zambia Reef area. During this time it was clearly responsible for several significant and closely spaced (clustered) upwelling events. These ceased as the dipole moved further southwards into the South West Indian Ocean and away from the Inhambane Terrace. This observation was taken as firm proof that upwelling on the Inhambane Terrace was induced by transient dipoles eddies, and that such eddies are a significant means of pumping nutrients into the shallow shelf ecosystem. Another A-C dipole was similarly sampled in 2007 this time further north off the Sofala Bank near Biera. This too had strong rotating currents with upwelling on the shelf edge. A third A-C dipole, similarly located off the Inhambane Terrace was sampled in 2010 by the FRS Antea (French). The data confirmed yet again that shelf edge upwelling occurs on the western side of these dipoles contrary to classical theory. However, analysis of the UTR time series found that dipole eddies off the Inhambane Terrace could only be associated with 50% of the upwelling events; with some events having occurred in the total absence of eddy induced geostrophic flows. This indicates another mechanism at work here, possibly wind. A satellite-tracked surface drifter released in the active shelf edge upwelling zone of a dipole moved swiftly offshore highlighting huge potential for loses of egg and larval material from the Mozambican shelf when dipoles move through the region.

Romahn, Sarah

Antarctic control on tropical western Indian Ocean sea surface temperature and productivity during the late Pleistocene

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We reconstructed water column structure and surface productivity in the tropical western Indian Ocean to identify to what extent changes in surface water temperature and paleoproductivity are atmospherically controlled by the East African monsoon system or controlled by the ocean via subsurface water masses of Antarctic origin. For this purpose we analyzed proxy records of a 14C-AMS dated sediment Core GeoB12615-4 off Tanzania (07°08.30'S / 39°50.45'W, 446 m water depth) that spans the last 40 kyr. The hydrography at this site is influenced by a northwestern branch of the South Equatorial Current, the East African Coastal Current, which receives its water mainly via the Indonesian Throughflow and by equatorial upwelling of Subantarctic Mode Water (SAMW) at 5-10°S [Schott and McCreary, 2001]. The East African Monsoon may affect primary productivity and water mass stratification via nutrient and fresh water influx, respectively, from Rufiji River into the Indian Ocean. We used Mg/Ca ratios of the planktic foraminifer Globigerinoides ruber white (s.s.) for past sea surface temperature (SST) reconstructions and stable carbon isotope ratios of G. ruber white (s.s.) and the benthic foraminifer Planulina ariminensis for paleoproductivity calculations. We find strong correlations between paleoproductivity and SST. In addition, high δ13C values of bottom water coincide with low SST on centennial timescales. Most important, however, the SST pattern during the deglaciation resembles temperature records from continental Antarctic ice cores, with an early SST increase at ~19 kyr BP and a distinct temperature setback, simultaneous to the Antarctic Cold Reversal. We suggest SAMW to be the most likely thermal link between western tropical Indian and Antarctic Oceans during the past 40 kyr and, moreover, to be the main control on marine primary productivity. Our conclusion corroborates earlier studies suggesting the SST in the Western Indian Ocean to be controlled by SAMW and thereby modulated by Antarctic temperature [Kiefer et al., 2006; Naidu and Govil, 2010]. Kiefer, T. McCave, I.N. and Elderfield, H. (2006). Antarctic control on tropical Indian Ocean sea surface temperature and hydrography, Geophys. Res. Lett, 33, L24612. Naidu, P. D., and P. Govil (2010). New evidence on the sequence of deglacial warming in the tropical Indian Ocean, Journal of Quaternary Science, 25(7), 1138-1143. Schott, F. A., and J. P. McCreary (2001). The monsoon circulation of the Indian Ocean, Progress In Oceanography, 51(1), 1-123.

Rouault, Mathieu

Ocean Atmosphere Interaction in the Agulhas Current System ***(INVITED)***

Rouault, Mathieu[1, 2]

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Oceans gain heat mainly at the Equator and in upwelling areas and lose it largely in western boundary currents. This loss of energy is due to a sea surface temperature contrast between western boundary currents and their surroundings, leading to a high evaporation rate and substantial turbulent latent and sensible heat fluxes. In that respect, the Agulhas Current system has an important role to play in global climate on top of its role on the exchange of heat and salt between the Indian and Atlantic Oceans. Measurements in the Agulhas Current have shown substantial transfers of water vapour in the marine boundary layer, a deepening of the marine boundary layer due to intense mixing, and unstable surface atmospheric stability created by the advection of colder and drier air above the current (Rouault et al, 1995, 2000). The intensity of mixing in the local boundary layer is such that cloud lines can often be observed above the current (Lee-Thorp et al., 1998). Rouault et al (2002) have provided evidence of the influence of the Agulhas Current on the evolution of a

severe convective storm over southern South Africa. That particular storm, in December 1998, led to severe flooding and a tornado in Umtata that nearly killed President Nelson Mandela when the winds in the town caused a building to collapse. The most important change is found in the Agulhas Current system, which has warmed by up to 1.5 °C since the 1980s. Rouault et al. (2009) have shown that the Agulhas Current system has warmed by up to 1.5 °C since the 1980s and that this warming was due to an intensification of the Agulhas Current system in response to an increase in wind stress curl at relevant latitudes in the Indian Ocean. A numerical model that reproduces the observed SST relatively well showed that the transport of the Agulhas Current system had increased since the 1980s leading to the observed warming. This also led to substantial increase in evaporation rate of up to 1 mm per day per decade in the Agulhas Current system and a 50% increase in the leakage of Agulhas water into the South Atlantic. A cooling of up to 0.5 °C per decade occured in the dynamic upwelling cell of Port Alfred and Port Elizabeth where it seems to spread into the Agulhas Current itself and to the west. Upwelling favourable wind could have contributed to the cooling but an intensification of the Agulhas Current and concurrent intensifying of the dynamic upwelling could be the principal reason of the cooling in that region.

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Rusciano, Emanuela

Interocean exchanges and the spreading of Antarctic Intermediate Water South of Africa

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Argo hydrographic profiles collected from 2004 to 2009 in the southeast Atlantic sector of the Southern Ocean are used in combination with hydrographic transects to describe the characteristics of Antarctic Intermediate Water (AAIW) in the region. Making use of the recently developed ANDRO velocity dataset, we estimate the evolution of the dynamical properties of different AAIW varieties along their pathways within the isoneutral layer ($27.1 < \gamma n < 27.6$). Three different regional varieties of intermediate water converge in the southeast Atlantic: Atlantic AAIW (characterized by $S<34.2$), Indian AAIW ($S>34.3$), and a newly detected Indo-Atlantic intermediate watermass ($34.2<S<34.3$). The collected Argo salinity profiles show a quasi-zonal distribution of the salinity minimum values computed within AAIW on the isoneutral surfaces. The zonal distribution of AAIW matches fairly well with the location of the Southern Ocean fronts. The Indian AAIW flowing within the Agulhas Current separates into two portions when it enters the South Atlantic. One portion retroflects following the Agulhas Return Current (13.4 Sv) and proceeds back to the Indian Ocean. While the other branch separates from the Agulhas Current, flows within cyclonic eddies and mixes with waters from the Atlantic Ocean at 12°E-23°E. The Atlantic AAIW enters our study domain between the Subtropical Front and the Subantarctic Front (36 Sv). The portion of the Atlantic AAIW that is not involved in the mixing processes moves into the Indian Ocean (28 Sv). After the formation of the Indo Atlantic AAIW, which is discovered and described in this study, the watermsass separates into two branches due to the turbulent environment. One portion moves westward (7.4 Sv) and subducts along the Northern Subtropical Front, and the other moves eastward (7.4 Sv) to contribute a sizeable volume of fresh and oxygenated water to the Indian Ocean. As the Indian Ocean has a comparatively high salt content and low oxygen values, the input from the AAIW type identified by this study could contribute significantly to the properties of the region and thus have a significant infleuence on the global thermohaline circulation.

Saynisch, Jan

Ocean bottom pressure assimilation in the Agulhas region

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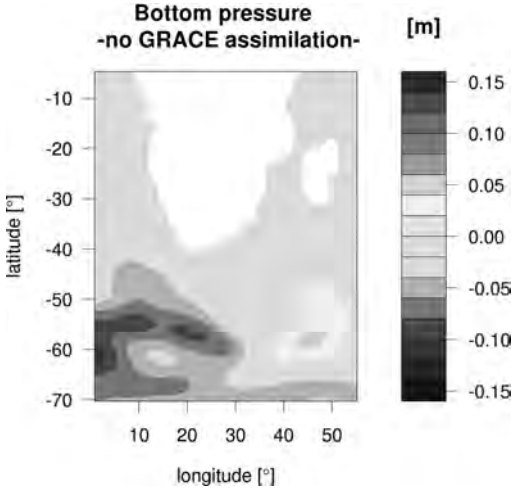
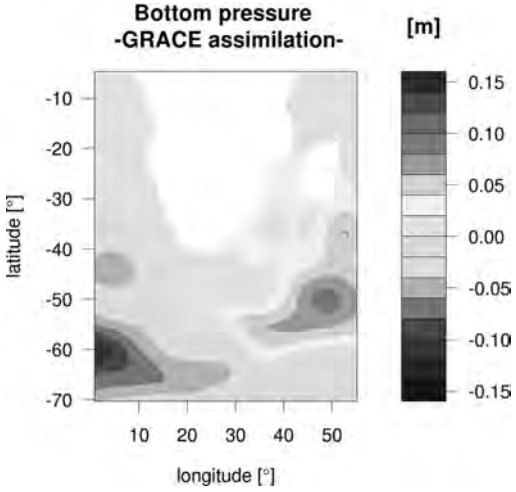
We assimilate daily ocean bottom pressure observations with a coarse scale ocean model. The observations are derived from GRACE satellite data and the resultant simulation is studied with respect to the induced changes in the Agulhas system. We report on the impact of the assimilation on transport and shape of the current as well as sea surface slope. Finally we discuss the errors in the observations due to the vicinity of the coast.



Ocean bottom pressure in meter of equivalent water height of the reference simulation without assimilation of observations.



Ocean bottom pressure in meter of equivalent water height of the assimilation simulation. This field is very close to the respective observations (not shown).

Scott, Lucy

Title: A long term monitoring network for the western Indian Ocean

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The oceanography of the Western Indian Ocean is driven by various influences of the seafloor bathymetry, continental masses, input of water from surrounding oceans, and interaction with the atmosphere. Variability of ocean currents, mesoscale eddy systems, and other large scale processes (including ocean-atmosphere interactions), anthropogenic influences on the health of the LMEs and their subsequent effects, have an influence on the resilience and sustainability of goods and services provided to coastal populations. Several projects and programmes throughout the western Indian Ocean region are currently engaged, together with nation states, in improving the understanding of the functioning of the Agulhas and Somali Large Marine Ecosystems. Past research and new surveys are being used to establish the current state of knowledge and baselines where they did not previously exist. In order to manage an ecosystem, an understanding of natural variability and long term trends, indicating directional change, must also be known. To this end, the Western Indian Ocean Sustainable Ecosystem Alliance is undertaking the coordination of an inclusive network for the long term monitoring of the Agulhas and Somali Current LMEs, focused on ecological, socio-economic and governance parameters, at appropriate spatial and temporal scales, linked to a suite of indicators. The long term monitoring framework which will be inclusive of global indicator sets, process studies and existing monitoring programmes, will strive to serve critical information needs for management and governance, guided by the ASCLME Transboundary Diagnostic Analysis. This presentation outlines the process of development of the long term monitoring network, and progress to date.

Scussolini, Paolo

Tracing the influence of Agulhas Leakage in the South Atlantic over glacial Termination II (MIS 6-5)

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The Indian Ocean waters that enter the South Atlantic via the Agulhas Leakage (AL) are considered to have a stabilizing effect on the Atlantic Meridional Overturning Circulation. Models suggest that AL and overturning circulation are well correlated in the present-day ocean. Paleoceanographic evidence indicates that episodes of increased inter-ocean Agulhas transfer have accompanied the past major glacial terminations. We explore the influence that the AL exerted in the South Atlantic thermocline during the penultimate termination (T-II). For this scope we produced planktic foraminifer δ18O and Mg/Ca proxy time series from a sediment record underlying the present-day path of northwestward migrating Agulhas rings, on the central Walvis Ridge. The surface species Globigerinoides ruber s.l. reveals gradual SST increase starting at the end of MIS 6 until after T-II, with both SST and (qualitative) SSS peaking during the early MIS 5e; the "deep"-dwelling Globorotalia truncatulinoides sin. is considered to reflect conditions around 400-600m in the water column, and shows an abrupt warming just after T-II, concomitant with a high salinity anomaly. The residuals of foraminiferal δ18O and Mg/Ca temperature estimations between the surface and the "deep" layers are interpreted as proxies for the thermal stratification of the upper ocean. They indicate that stratification started to increase during the late MIS 6, and reached a maximum at the beginning of MIS 5. This shift is supported by the rise in the relative abundance of the right coiling morphotype of G. truncatulinoides from the mid-MIS 6 to MIS 5e, which we interpret as an index of thermocline shoaling. The development of stratification parallels the pattern of the AL as obtained from another record from the east of the Cape Basin. We also show that the single specimen δ18O variability of G. truncatulinoides sin. is largest in coincidence with the strongest release of AL, and we propose that this is a consequence of the perturbation of warmer "deep" waters intermittently carried by paleo-Agulhas rings over the Walvis Ridge. We conclude that during T-II the AL increases the temperature of the subsurface upper ocean on the trajectory of the Agulhas rings across the South Atlantic.

http://www.falw.vu.nl/nl/onderzoek/earth-sciences/marine-biogeology/staff/paolo-scussolini.asp

Simon, Margit

Does upstream Agulhas Current variability reflect inferred changes in Agulhas Leakage?

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Some 4-5 times per year the Atlantic Ocean receives warm, saline waters from the Indo-Pacific Ocean through ring shedding events of the Agulhas Current (AC) around the southern tip of Africa. This transfer of heat and salt through the Indo-Atlantic Gateway, the so called 'Agulhas Leakage (AL)', is believed to influence the Atlantic Meridional Overturning Circulation (AMOC) and thus may affect climate in the North Atlantic region and beyond. While paleoceanographic investigations have been crucial in highlighting the important role of the AL for the climate system on orbital timescales, studies identifying trigger mechanisms of AL on shorter timescales are scarce. Furthermore, reconstructions focusing on the potential connection between AL and the upstream dynamics of the AC are still limited due to a lack of climate records extracted from the main trajectory of the current itself. Here we use high–resolution multi-proxy reconstructions from a sediment core located in the main flow of the Agulhas Current (CD154 17-17K), offshore Eastern Cape Province, South Africa to reconstruct sea-surface temperature (SST) and other environmental conditions over the last 100 kyrs with the aim to unravel changes in the upstream dynamics

of the AC on orbital to millennial scale timescales. We find that surface and sub- surface water temperature variations in the AC appear synchronous with temperature changes recorded in the central Antarctic ice cores. Warmer upper water column temperatures during the Holocene, MIS 3 and 5 are associated with an increased abundance of subtropical planktonic foraminiferal marker species (Agulhas Leakage fauna, ALF). Colder surface water conditions during the LGM and MIS 4 coincide with higher abundances of Globorotalia inflata and Neogloboquadrina pachyderma (dex.) species, which are mostly found in waters of the southern subtropical to subantarctic zones. The occurrence of these transitional species in the AC during Southern Hemisphere cold intervals, when other evidence shows the Southern Ocean frontal system was shifted several degrees northward compared to today suggest that a stronger and/or reorganised Agulhas Return Current Circulation likely had a significant impact on the upper water column properties of the AC itself. Superimposed on longer-term changes we find millennial-scale warm, saline episodes in the AC that are synchronous with cold Heinrich Stadials in the Northern Hemisphere and inferred reductions in the AMOC strength. These warm/saline intervals also coincide with similar warm intervals observed in the Mozambique Channel, the Indonesian Throughflow (ITF) and south of Australia. Together these reconstructions could shed new light on the temperature/salinity variability reported in the Cape Basin area and its interpretation in terms of varying leakage, implying that the records of AL at the Agulhas Bank may potentially reflect temperature/salinity shifts of the AC as a whole.

Speich, Sabrina

What We have Learned From the GoodHope and BONUS-GoodHope Projects and What we Plan Within the SAMOC International Programme ***(INVITED)***

Speich, Sabrina[1]

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South of Africa, the Southern Ocean provides the export channel for North Atlantic Deep Water (NADW) to the global ocean and the passage for heat and salt from the Indian and Pacific oceans to the North Atlantic. This region is influenced by the largest turbulence observed in the ocean. The eastward flowing Antarctic Circumpolar Current, the South Atlantic Current and NADW meet with the westward flow of Indian waters carried by the Agulhas Current, leading to water masses exchanges through jets, meanders, vortices, and filaments interactions. These local mesoscale and submesoscale interactions and the derived meridional fluxes constitute a major link between the Southern Ocean and the global meridional overturning circulation (MOC). At the same time, mixing and air-sea interactions are responsible for significant water masses properties modifications. Owing to the relative isolation of the region, few modern observations time series existed in this sector of the global ocean before 2004. This was the main reason to foster an international cooperation to monitor regularly this oceanic sector. The project has been named GoodHope (GH hereafter) by the Cape of Good Hope. The international partnership is gathering together means (in terms of human, observing platforms, ship time and general financial support) from 11 different institutions and six countries (France, South Africa, United States, Germany, Russia and Spain). It has been approved in 2003 by the International CLIVAR panel and endorsed by SCAR and CliC . With the relatively important number of full-depth hydrographic cruises, of high resolution XBT sampling, of deployed profiling floats and satellite altimetry in complement with numerical simulation analyses we have been able to improve quantitatively the knowledge on regional dynamics and water properties exchanged south of Africa. Important progresses on the understanding and quantifying particular aspects of the regional dynamics have been made, among others, on the estimate of the ACC variability; on oceanic mesoscale turbulence responsible of properties exchange across frontal region with important consequence on heat and fresh water budgets, biogeochemical cycles and air-sea; on the regional mixing layer heat budget, on the Indo-Atlantic Antarctic Intermediate Water exchanges; on global estimates of halothermosteric variability in connection with sea-level changes. I will describe some of the results we obtained within the GoodHope project, the special IPY BONUS-GoodHope action and introduce the objectives and field programs of the new SAMOC international Project.

Steinhardt, Juliane

Seasonal planktonic foraminifera assemblage changes in the Mozambique Channel

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Key words: Planktonic foraminifera, sediment trap, diversity Recent findings suggest that the Agulhas leakage is an essential element of the climate system. The Agulhas leakage from the Indian to the Atlantic Ocean occurs via ring-shedding, four to six times a year. This mechanism is thought to be controlled upstream in the Mozambique Channel area - one of the most influential source areas of the Agulhas Current. A better understanding of the variability in the Mozambique Channel will help to better understand long-term changes in the Agulhas Current and its leakage. Since distribution patterns of modern planktonic foraminifera in upper water column have been associated with many oceanographic variables (e.g. e.g. SST, SSS, light intensity or food availability), changes can be identified and tracked by faunal distribution changes over time. Using sediment traps, we intended to discover whether the ecological signals present contain information on both seasonal and inter-annual processes and how the information could be transferred into data from sediment cores to link the biological and hydrographical variability in the past. We present novel census counts for a sediment trap mooring deployed at 2231 m depth, located upstream the Agulhas current in the Mozambique Channel at 16°42.69'S and 40° 51.32'E. Particle component compositions were investigated and planktonic foraminifera species diversity, fluxes and relative abundances were determined for individual size fractions with a three-week resolution over one and a half years.

Stephen, Rosamma

Copepods in the Agulhas Retroflection Front and adjacent waters : evaluation of 2004 and 1964 collections

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3. Marine Biolpogy, Zoological Survey of India, Kolkatta, India

The Agulhas current 27 0 to 40 0S flowing southward along the east coast of Africa is the western boundary current in the Indian Ocean transporting high saline warm water of the tropics towards the Antarctic. The Agulhas upwelling system along the coast of south Africa in both Indian and Atlantic Ocean has been well studied . A portion of the westerly flowing current reverses course at the tip of Africa and retroflects eastward forming the Agulhas return current. This flow exihibits a quasi-stationary meandering pattern and remain as Agulhas Retroflection Front (ARF) at 400.15S -410.15 S. During the International Indian Ocean Expedition(IIOE,1960-65) a few samples in this vicinity of ARF are available during the cruises of the year1964 . In 2004 as part of the Southern Ocean study the Centre for Marine Living Resource and Ecology, Government of India had conducted a multidisciplinary cruise during January-February onboard Sagar Kanya (Jasmine et al., 2009). The southern ocean is known as high nutrient low chlorophyll area. Zooplankton samples were taken with Multiple Plankton Net(Hydrobios) with mouth areaO.25m2. Samples were taken from 5 strata between 0- 1000m. An account of the copepods in the Agulhas retoflection front is presented here. The stations were along 450 E meridian from 300S to 500S and both hydrographical and biological observations were made across the major fronts and zones between the subtropical and polar regions including the ARF. The zooplankton biomass was very low (0.010ml/m3) in this front when compared with the other fronts. Copepods formed only 53.5% while chaetognaths constituted 42.86% of the population. Surprisingly the adjacent Sothern Subtropical Front (SSTF) sustained the highest biomass of the study area namely1.28ml/m3 in the mixed layer where euphausids contributed 68.16% and copepods contributed only 31.8% of the total zooplankton. The copepod species observed in ARF are Nannocalanus minor, Neocalanus gracilis, N tonsus, Canthocalanus pauper, Eucalanus longiceps, E mucronatus, Mecynocera clausi, Calocalanus spp and Clausocalanus spp. Metridia lucens, Pleuromamma spp were also present. In the deeper strata Lucicutia curta and Heterostylitis longicornis and Disseta palumboi were recorded.Oncaeidae, Corycaeidae and Harpacticoids were well represented. Agesthes mucronatus was frequent in the strata below thermocline. In the IIOE collections Nannocalanus minor Canthocalanus pauper, Neocalanus robustior and Megacalanus princeps were present . Species of Calocalanus and Mecynocera were abundant in the region.The hydrographical features during 1964 are also compared with the data of 2004 from the mixed layer and thermocline layer since the IIOE represented only the epipelagic plankton. Comparison of copepod composition in an interval of four decades will give an insight into alterations if any . Marked increase in the percentage of carnivorous components was evident in the collections of 2004. Future intensive investigations in this line canreveal the impact of recent climate change on most impotant pelagic community, the copepods

Tozuka, Tomoki

Interannual variations of the Seychelles Dome and its possible influence on the upstream of the Agulhas Current

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The Seychelles Dome (SD) in the southwestern tropical Indian Ocean is located in the upstream of the Greater Agulhas System. Interannual variations of the SD are investigated using outputs from an ocean general circulation model. It is found that the interannual variability is locked seasonally to boreal winter, and the SD becomes anomalously weak (strong) owing to anomalous local Ekman downwelling (upwelling) and arrival of downwelling (upwelling) Rossby waves excited in the southeastern Indian Ocean. Also, the interannual variation of the SD is related to that of the coastal current along Tanzania and Mozambique; the coastal current is anomalously southward during weak SD years compared with strong SD years.

Ullgren, Jenny E.

In Situ Observations of Mozambique Channel Throughflow and Large Anticyclonic Eddies

Ullgren, Jenny E.[2, 1]; van Aken, Hendrik M.[2]; Ridderinkhof, Herman[2]; de Ruijter, Will P.[3]

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2. NIOZ, Texel, Netherlands
3. IMAU, Utrecht University, Utrecht, Netherlands

The flow through the Mozambique Channel, which feeds into Agulhas Current, is characterized by an abundance of mesoscale eddies. At the narrowest part of the Channel, large anticyclones dominate. These eddies carry warm, saline water masses in their cores, and further downstream they can trigger the formation of Agulhas Rings. Here, in situ data from an array of eight deep-sea moorings across the narrowest cross section of the Channel in the years 2003-2009 are analysed to present a census of directly observed Mozambique Channel anticyclones and determine their mean properties. Ensemble means of anticyclones reveal the typical features of eddies throughout all phases of their passing the mooring section and enable us to explore in detail their generation and propagation through the Channel. We also compare the interannual variability in eddy frequency and characteristics with the multi-year record of volume transport to establish whether mesoscale eddy activity is linked on interannual time scales with the strength of the total throughflow through the Channel.

van der Lingen, Carl D.

Effects of Agulhas System Variability on Small Pelagic Fish off South Africa ***(INVITED)***

van der Lingen, Carl D.[1, 2]

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Anchovy (Engraulis encrasicolus) and sardine (Sardinops sagax) are small pelagic fish that are of both economic and ecological importance to South Africa. Distributed in shelf waters around almost the entire South African coast, they are the main targets of the county's purse-seine fishery and are also important prey for a variety of predators including other fish species, marine mammals and seabirds. Their planktivorous diet, short life span and reliance on transport to or retention within suitable nursery areas of their pelagic eggs and larvae makes these species highly responsive to environmental forcing. As a consequence they are characterized by substantial interannual variability in recruitment success and show both annual and decadal scale fluctuations in population size. How variability in the Agulhas system may impact on these small pelagic fish species is illustrated in this presentation using three examples. These include (i) how changes in cross-shelf gradients in sea surface temperature over the Agulhas Bank appear to influence the distribution of anchovy spawners during summer; (ii) the role that Natal pulses and break-away eddies play in enabling sardine to overcome their habitat restrictions and undertake their annual spawning migration during the sardine run off South Africa's east coast; and (iii) how Agulhas rings shed into the south Atlantic may negatively impact anchovy (and sardine) recruitment. Conjectures on how future variability in the Agulhas system arising from global climate change may impact these species are also given.

van der Lubbe, Jeroen

Zambezi sediment dispersal over the last 20ka

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The Zambezi River drainage area covers most of the southeastern African continent along the southern limit of the Intertropical Convergence Zone (ITCZ). Therefore, discharge of the Zambezi River is thought to be linked to precipitation changes related to latitudinal shifting of the ITCZ. The Zambezi River discharges high amounts of terrigenous material that accumulates along the western margin of the Mozambique Channel and the upstream Agulhas system. Therefore, the Zambezi Margin forms a key location to study possible interactions between terrestrial climate variations integrated over the large Zambezi catchment area and paleoceanographic changes in the southwestern Indian Ocean. We performed sedimentary analysis of grain-size, XRF bulk chemistry and magnetic susceptibility on a series of piston cores collected along a north-south depth transect close to the Zambezi River mouth. The relative terrigenous contribution as reflected by Ca/Ti ratios shows a substantial decrease during the last deglacial due to the sea-level rise and the subsequent transgressive migration of the river mouth system. In addition, the deposition of fine grained Zambezi sediments shifted from in front of the Zambezi mouth towards the deeper, northern piston coring sites during the last deglacial. Under glacial sea-levels, the Zambezi River was incised into the shelf and sediments were released to the continental slope in front of the Zambezi mouth. After the flooding shelf (at about 9ka), Zambezi sediments are transported northwards along the Mozambique coastline prior to be redirected towards the continental slope. Further, the supply of the terrigenous material was enhanced to the deeper, northern cores during the Younger Dryas and Heinrich event 1. In combination to high sedimentation rates along the transect, we interpret the Younger Dryas and the Heinrich event 1 as periods of increased Zambezi sediment input induced by enhanced rainfall over the Zambezi catchment. This supports recent reconstructions of wet conditions due to a more southern extent of the ITCZ in the East-Africa during these 'Atlantic cold events'.

van Sebille, Erik

Towards a Framework for Assessing Agulhas Leakage in the Real Ocean ***(INVITED)***

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Changes in the magnitude of Agulhas leakage, the thermocline water flowing from the Indian to the Atlantic Ocean, can be related to changes in the North Atlantic circulation a few decades later. This relation means that a sustained monitoring of Agulhas leakage could be used to potentially identify large-scale climate change signals at an early stage. However, estimating the magnitude of Agulhas leakage in the real ocean is extremely difficult, both because of the intermittent nature of the leakage and because of the vigorous mixing in the Cape Basin. Agulhas leakage can best be assessed in a Lagrangian framework, using the trajectories of floats that start in the Agulhas Current and end in the Atlantic Ocean. In the real ocean, unfortunately, not nearly enough floats can be released to get even an estimate of the leakage. Within a numerical model context, on the other hand, millions of float trajectories can yield a high-resolution time series of Agulhas leakage. In a modelling context, we use such a time series to identify proxies of Agulhas leakage based on quantities observable in the real ocean. Here, for the first time, we will show how a combination of many available proxies is able to constrain Agulhas leakage in the real ocean. We will discuss what it would take to set up a monitoring framework for Agulhas leakage in the real ocean and how that might help predict changes in the Atlantic Meridional Overturning Circulation.

Vianna, Marcio L.

Pan-Atlantic Ocean Circulation Changes in the Bidecadal Climate Band and Relations to the Agulhas Leakage

Vianna, Marcio L.[1]; Menezes, Viviane[2]

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Recently reported computer simulation experiments with high-resolution Global Coupled models (GCMs) for prediction of regional sea-level (RSL) rise have shown that root mean square distributions of RSL variability are concentrated mostly in narrow zonal bands dominated by eastward currents in the Subtropical Southern Hemisphere (e.g. Suzuki et al., 2005). It is also known that RSL variability in the multidecadal band may be decomposed in two components: wind-forced thermocline depth and the buoyancy-forced steric height changes. It is also known that the spectral energy of atmosphere/ocean multidecadal variability presents a large peak in the 20-30 year band, as demonstrated by analysis of air temperature derived from Greenland ice-cores, Sr/Ca-based SST reconstructions from Pacific tropical coral reef data, South Atlantic sea surface temperatures and OGCM simulations. However, high-resolution RSL spatial distributions and dynamics (propagation patterns) in the bidecadal band are still poorly known. We present here a comprehensive data-driven analysis of the evolution of North and South Atlantic Circulation structures in the bidecadal band. Known North Atlantic evolving structures are reproduced and new ones are found in the South Atlantic, including the role of the Agulhas Leakage driving a northward propagation of the RSL signal. The spatial patterns of RSL variability are obtained by analysis of 17 years of AVISO Sea Level Anomaly data. The analysis is done by using EOF, Singular Spectrum Analysis, and Maximum Entropy methods suggests that the well-known altimeter-derived steep trend in SL in the Atlantic Ocean is actually nonlinear, with a minimum in 1994 and maximum in 2006-2008, resembling a half cycle of a 20-year-scale oscillation. This was confirmed by analysis of long Tide Gauge (TG) time series from the North and South Atlantic, including the TG from Mossel Bay in the Agulhas region, which are locally consistent with the altimeter-derived SL trend from nearby grid points. The same analysis is applied to the Ishii data set and the SODA (Simple Ocean Data Assimilation) output data version 2.2.4 from 1871 to 2008 to obtain a more complete picture. A Complex EOF analysis (CEOF) of the SODA Bidecadal band is performed to determine the evolving space-time distributions and propagation of the RSL and Subsurface Temperature signals. Results suggest that the spatial distributions of altimetry-derived SL trend peaks largely over eddy-dominated eastward currents at frontal areas in the 30-40 latitude bands are consistent with those obtained from the lower resolution but longer time span of SODA data. The propagation patterns of the bidecadal RSL and Subsurface Temperature are analyzed following the Liu (1998) Non-Doppler Mode (wind-driven thermocline depth) and Advective Mode (Subsurface Density) 3D Planetary Wave theory. One interesting finding relates to a northward cross-equatorial propagation of Agulhas Leakage signals well into the North Atlantic.

von der Meden, Charles

BENTHIC-PELAGIC LINKS: EXPLAINING TOPOGRAPHICALLY-RELATED ADULT MUSSEL DISTRIBUTIONS

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The importance of total life-history pattern has long been recognised, particularly in terms of differentiating between single or multi-stage population regulation. Knowledge of total life-history is therefore critical to ecological predictions of population dynamics. Working from a previously established pattern in intertidal mussel populations (bay adult cover > open-coast), this study tracked larval distribution and settlement patterns in relation to coastline topography and distance from shore to determine which stage(s) and mechanisms are responsible for the adult distribution. Sampling was carried out in relation to 2 bays and 2 open-coast areas on the east coast of South Africa. Onshore larval settlement was monitored using plastic collectors. The adjacent nearshore larval distribution was assessed using 4 grids (each within 2km of shore). Proximate large-scale transects, extending perpendicular to the shore into the large-scale Agulhas Current, sampled offshore larval distribution. Several predictions were made: 1) Onshore settlement will be strongly related to coastline topography with greater numbers of settlers in the bays; 2) Nearshore larval distribution will remain tied to topography, but with open-coast areas being more variable; 3) Offshore larval abundances should be the lowest, with distributions having little connection to coastline topography. Here, abundances should decrease with distance from shore, particularly at stations within the Agulhas current. Understanding these benthic-pelagic links will help to identify the mechanisms regulating intertidal populations.

Vousden, David

A Global Network of Marine Hotspots: Understanding and adapting to Climate change in the Western Indian Ocean

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Marine natural resources, such as fisheries, provide significant social and economic benefits globally, and early warning of changes in resource availability is required to minimise social tensions (e.g. increased poverty and changes in resource allocation) and societal costs (e.g. income redistribution and government restructuring). Additionally, prior knowledge of how and when resources may alter will

also facilitate the development, application and evaluation of adaptation options for fisheries. Based on identification of the world's marine climate change hotspots we are coordinating a global network of researchers, managers and policy makers. By sharing information currently emerging on climate change impacts in regional global warming 'hotspots', typified by predicted above average ocean temperature increases, we will provide the potential for early warning and evidence of the biological response by natural resources to climate change. While water temperature is only one variable responding to climate change, it is the major driver of distribution, abundance, phenology & life history of marine organisms. Based on historical (last 50 years) and projected (next 50 years) rates of ocean warming, 24 regional hotspots were identified that were warming faster than 90% of the oceans. These included areas of the western Indian Ocean, with the 1998 bleaching event the main driver of change in the region.Examination of hotspots provides us with the first opportunities to detect the nature and pace of climate change induced impacts on our marine ecosystems, separate the impacts of synergistic stressors like climate and fishing, and also offers the strongest prospect for validating species or ecosystem model projections against reality. With sufficient interdisciplinary research and information, these hotspots will also provide the first opportunity for evaluation of adaptation options in fishery systems. A network of scientists working in global marine hotspots, where information is integrated and synthesized, contrasted and compared across locations, can best address the challenges of climate change. Collaboration at a global scale is necessary to develop knowledge for managers to make decisions and for increased community understanding of the need for these decisions, including increased confidence in the models and adaptation options being proposed.

Vousden, David H.

Evolving new Governance Approaches for the Agulhas and Somali Current Large Marine Ecosystems through Dynamic Management Strategies and Partnerships

Vousden, David H.[1]; Scott, Lucy[1]; Ngoile, Magnus[1]; Sauer, Warwick[1]

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Up until very recently, the western Indian Ocean region and its Large Marine Ecosystems were poorly understood. In the last 4-5 years, detailed coastal and offshore observations have revealed a wealth of information on the role of current behaviour, ocean-atmosphere interactions, habitat and species distribution, and their impacts on the sustainable livelihoods of dependent coastal and inland communities within the region. This new information has provided the countries of the western Indian Ocean with a baseline from which to measure changes within the ecosystem and to predict the likely impacts on living marine resources and dependent human populations. Most recently, the countries and their partners (NGOs, IGOS, international and regional scientific bodies, etc) have started to forge an Alliance within the region (the Western Indian Ocean Sustainable Ecosystem Alliance). This Alliance aims to maintain a long-term ecosystem monitoring programme to identify the aforementioned changes in the baseline; to strengthen skill-sets in the region through focused training programmes; to build stronger capacity for modelling and predicting the effects of change; and, of highest priority, to translate the scientific conclusions and the outputs of high-resolution models and their predictions into pragmatic adaptive management actions and policy decisions. To this effect, the Alliance is exploring and evolving a new 'dynamic management' approach that will advise action on the basis of a peer-reviewed 'weight-of-evidence' that adopts the validity of trends in the data in terms of management needs and actions, even in the absence of 95-99% confidence limits. This approach has many advantages both to the scientific community and to the management and decision-making sectors of government. The evolving mechanism and its advantages and shortfalls are explored in this paper.

http://www.asclme.org

Watermeyer, Kate

Re-examining changes in SST on the Agulhas Bank as a driver of distributional change in small pelagic fish

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3. Oceans and Coasts, Department of Environmental Affairs, Cape Town, South Africa

The sudden and persistent increase in the proportion of Cape anchovy Engraulis encrasicolus spawner biomass found east of Cape Agulhas in 1996 is thought to be environmentally mediated. Based on concurrent changes in cross-shelf temperature gradients on the Agulhas Bank, atmospheric surface pressure, and zonal wind-speed, earlier work hypothesised increased wind-induced coastal upwelling as the primary driver. The data used to establish these concurrent physical changes were previously analysed using decadal means based on a priori hypotheses of when shifts occurred. Here Reynolds SST data are reanalysed using the sequential t-test algorithm for detecting regime shifts (STARS) method to statistically identify shifts. Results are considered in terms of recent work regarding other possible long-term shifts in the southern Benguela, and confirm previous findings. Additionally previously unidentified positive shifts in cross-shelf SST gradient on the western Agulhas Bank were detected in the mid-1990s. Cooling of the inshore region of the Agulhas Bank and resultant increases in the cross-shelf temperature gradient due to changes in upwelling intensity occurred simultaneous to the increase in easterly anchovy biomass and may have led to improved conditions for small pelagic fish on the south coast.

Whittle, Christo P.

Characterization of Agulhas Bank upwelling variability from satellite-derived sea surface temperature and ocean color products

Whittle, Christo P.[1, 2]

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South of Africa the Agulhas Bank forms a roughly triangular-shaped, broad extension of the continental shelf, ranging from Cape Point in the west to East London 800km further along at its eastward extreme. It is a complex oceanic region influenced by coastal upwelling processes typical of the Benguela Upwelling System, as well as shelf-edge dynamic upwelling resulting from the variable presence of the Agulhas Current. During summer intermittent easterly winds drive coastal upwelling at several promontories along the South African southern coast. On the eastern Agulhas Bank divergent upwelling is observed as the Agulhas Current follows the edge of a widening continental shelf. Further southward intermittent, intense shear-edge eddies, driven by a meandering Agulhas Current, upwell cold water in their cores which may be advected onto the Agulhas Bank. A subsurface ridge of cool water, extending along the 100 m isobath, appears to be a quasi-permanent feature of the large scale thermal structure along the eastern and central Agulhas Bank during spring and summer. These upwelling processes promote high primary production at preferred locations on the Agulhas Bank. Consequently the Agulhas Bank provides both a spawning ground and nursery area, and is the centre of abundance of numerous commercially exploitable species. The mesoscale surface signatures associated with these upwelling events are readily observed on sea surface temperature and chlorophyll-a concentration images. An analysis of the large scale climatology and variability of sea surface temperature (SST) and surface chlorophyll on the Agulhas Bank has previously been performed using 4.5km AVHRR and SeaWiFS data, but this study did not address variability on shorter space and time scales. Cloud-free high resolution SST data from the Multiscale Ultrahigh Resolution (MUR) blended product presents the opportunity for a detailed analysis of upwelling at the event scale, thereby allowing for the identification of upwelling contributions from various locales on the Agulhas Bank. MODIS Aqua 1km data provide coincident SST and chlorophyll-a data that not only serves to confirm the quality of the blended product, but also allows for the characterization of the chlorophyll response to upwelling events.

Wood, Warren

The nature and distribution of deep filaments in the strong mixing portions of the Agulhas Return Current – Observations from seismic oceanography

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In January and February of 2012 the U. S. Naval Research Laboratory, Geomar, University of Cape Town, and Cambridge University surveyed the Agulhas Return Current (ARC) and a large warm-core eddy over the Agulhas Plateau using the relatively unconventional method of seismic oceanography. The ARC12 cruise acquired nine seismic transects corroborated with 204 simultaneous XBT casts. Between seismic deployments, 18 CTD, 39 underway CTD (UCTD), and 41 microstructure profiles were acquired. Ship-board ADCP (75kHz), and meteorological data were acquired continuously throughout the cruise. The high lateral resolution of the seismic technique allowed us to observe deep, thin filaments - sheets of water 10-20m thick persisting for many 10s of km, and depths of up to 1200m. The filaments, which were also detected in the XBTs, are most prominent in an East-West transect that crosses the northward flowing ARC in the West and Southward flowing portion of the anticyclonic eddy in the East. The filaments extend below the ARC, are shallow throughout the hyperbolic zone between the ARC and eddy, and end abruptly at the edge of the eddy. The eddy edge manifests as a sharp lateral change in reflectivity that occurs over just a few meters, corresponding to the eastern edge of the cold dome between the ARC and eddy. We observed similar filaments and abrupt reflectivity changes in several transects over the ARC and eddy, indicating that at least the character of the features (if not each actual filament) is persistent over a period of at least hours to days. The seismic reflectivity of the water is due mostly to sharp vertical temperature contrasts, but it is not clear why the particular temperature contrasts would form laterally extensive filaments, or sharp lateral edges.

Yuan, Chaoxia

Predictability of the Subtropical Dipole Modes in the Atlantic and Indian Oceans

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Prediction of climate modes inducing abnormal weather and extreme events over the globe is useful for mitigating the societal impacts. Many studies have been devoted to predicting El Niño/Southern Oscillating (ENSO) over the

past decades. Since the discovery of the Indian Ocean Dipole (IOD), predictability of the tropical Indian Ocean climate has also received much attention. In contrast to these climate modes in the tropical oceans, prediction of climate modes in the extratropics is considered to be a more difficult task owing to large internal variability of the atmosphere and weak ocean-atmosphere coupling. Hence, very few studies to date have examined predictability of climate modes in the extratropics. In this study, we focus on the Indian Ocean Subtropical Dipole (IOSD) and South Atlantic Subtropical Dipole (SASD), and evaluate their predictability for the first time using ensemble seasonal predictions of a CGCM. A positive IOSD (SASD) is associated with positive SST anomalies over the southwestern pole and negative SST anomalies over the northeastern pole in the southern Indian Ocean (South Atlantic). Both the IOSD and SASD are known to influence precipitation over the southern African region in austral summer at their height of evolution. Anomalous southeasterlies between the two SST anomaly poles carry extra moisture from the subtropical Indian Ocean to the southern Africa and enhance the moisture convergence and precipitation there. On the other hand, the SST anomalies of SASD modulate the westerly jet in the mid-latitudes and influence the zonal moisture exchange between the South Atlantic and southern Africa, and thus the southern African rainfall. Also, the positive IOSD and SASD are linked to an atmospheric circulation condition that favors the development of tropical temperate troughs in the continent-based South Indian Convergence Zone, giving rise to a high rainfall rate over the southeastern southern Africa and southwestern Indian Ocean. Therefore, successful predictions of the IOSD and the SASD with sufficient lead-time in a CGCM may contribute to better predictions of the southern African summer precipitation. Here, predictability of the subtropical dipole modes is assessed using the SINTEX-F coupled model that has high prediction skills on both the ENSO and IOD. Despite the known difficulty in predicting subtropical climate, it is shown for the first time that the model can successfully predict the IOSD and the SASD at lead time of up to 1 to 2 seasons with a prediction barrier in austral autumn due to the seasonal locking of the IOSD and the SASD to austral summer. The overall prediction skills of the IOSD are higher than those of the SASD. Also, the predictability of SST anomalies in the north¬eastern pole of the IOSD is higher than that of the southwestern pole, whereas no significant difference is found in the predictability for the two poles of the SASD.

Ziegler, Martin

Development of modern human behaviour linked to rapid climate change

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The development of modernity in human populations in Africa has been linked to pulsed phases of technological and behavioral innovation within the Middle Stone Age (MSA) of South Africa, which are associated with early evidence for symbolic behaviour, personal ornaments, complex tools and sophisticated hunting techniques. However, the trigger for these intermittent and sometimes very short-lived (<1000 years) pulses of technological innovation is an enigma, as is the reason for sudden abandonments of occupational sites and reoccupation thousands of years later. Here we show that, contrary to some previous studies, these intervals of innovation were tightly linked to local climatic ameliorations. We demonstrate that major MSA innovational pulses occurred at times when South African climate changed rapidly towards humid conditions while northern sub-Saharan Africa experienced widespread 'megadroughts' as the Northern Hemisphere entered phases of extreme cooling. These millennial-scale teleconnections result from a southward shift in the austral summer position of the Intertropical Convergence Zone (ITCZ) in combination with warmer conditions in the Agulhas Current regime during North Atlantic cold events. Humid pulses in South Africa contributed to the creation of a refugium with favorable environmental conditions. This strongly implies that innovational pulses of early modern human behaviour were climatically forced, linked to the adoption of new refugia. These required adaptive change, but also subsequently provided favourable conditions for population growth, supporting models linking such pulses with changes in demography.

Zinke, Jens

Interannual and decadal variability in the greater Agulhas current region over the past 350 years from coral paleothermometry

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Sea surface temperature (SST) in the Agulhas Current region has increased considerably since the early 1980's (Rouault et al, 2009) and strong interannual and decadal variability is superimposed on the long-term trend. Consistently, the southwestern Mozambique Channel has experienced one of the highest rates in ocean warming across the southern Indian Ocean since 1950 (McClanahan et al., 2008). Here, we use a multi-century long reconstruction to show interannual and decadal variability of SST, which include 350 years (1658-2008) long monthly coral proxy data and a 3-core annual composite Sr/Ca and oxygen isotope record from the Ifaty and Tulear reefs off southwestern Madagascar. The coral record is extended from previous analysis (Zinke et al., 2004), showing a non-stationary relationship of SST with the El Nino/Southern Oscillation (ENSO), a link with the Pacific Decadal Oscillation (Cueger et al., 2009) and SST variations strongly coupled to the greater Agulhas Current region and the southern Madagascar return flow (Fig.1). The Ifaty SST proxy record shows also skill in the reconstruction of southern African late summer rainfall influenced by large-scale climate modes (Fig.1). References Crueger, T., Zinke, J. and Pfeiffer, M. 2009. Dominant Pacific SLP and SST variability recorded in Indian Ocean corals. International Journal of Earth Sciences 98, Special Volume. doi:10.007/s00531-008-0324-1. McClanahan, T. R., Ateweberhan, M., Omukoto, J. & Pearson, L. Recent seawater temperature histories, status, and predictions for Madagascar's coral reefs. Marine Ecology Progress Series 380, 117-128 (2008). Rouault, M., Penven, P. & Pohl, B. Warming in the Agulhas Current system since the 1980's. Geophysical Research Letters 36, doi:10.1029/2009GL037987 (2009). Zinke, J., Dullo, W.-C., Heiss, G. A. & Eisenhauer, A. ENSO and Indian Ocean subtropical dipole variability is recorded in a coral record off southwest Madagascar for the period 1659-1995. Earth and Planetary Science Letters 228, 177-194 (2004).

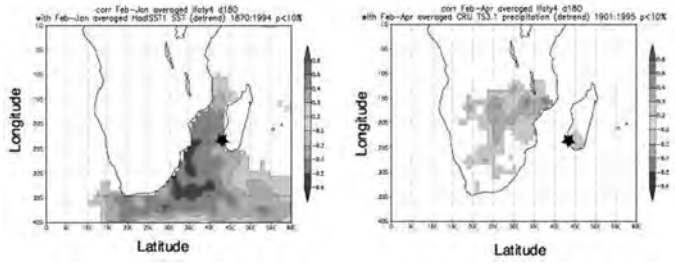

Fig. 1 – Correlation maps between Ifaty coral oxygen isotope record (star) and (left) SST from HadSST1 and (right) precipitation from CRU TS3.1. Correlation is calculated with the detrended annual mean values. Note that oxygen isotopes are negatively correlated with SST. Correlations and data retrieved from http://climexp.knmi.nl/