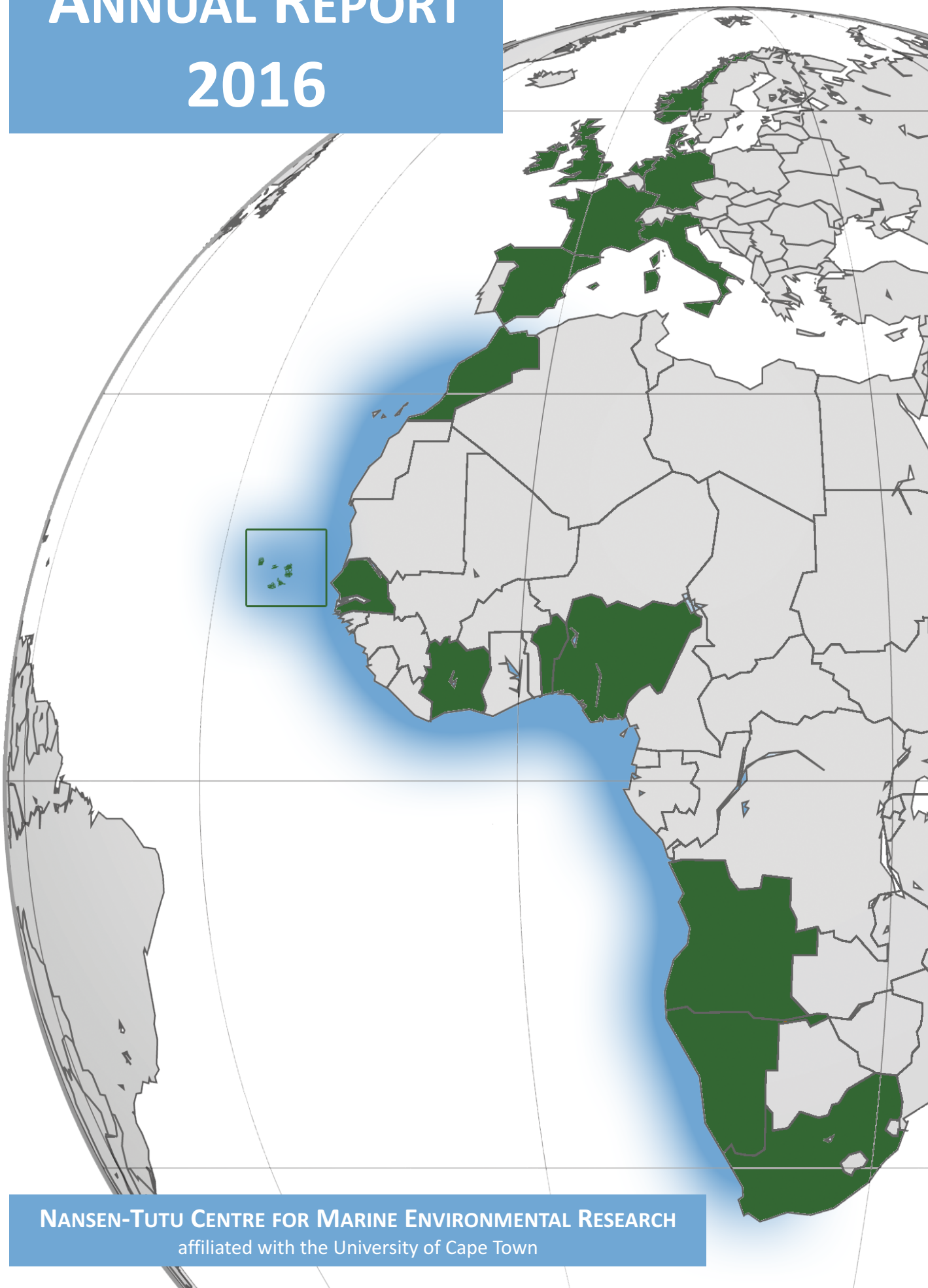


ANNUAL REPORT 2016



NANSEN-TUTU CENTRE FOR MARINE ENVIRONMENTAL RESEARCH
affiliated with the University of Cape Town

2016 – REPORT FROM THE BOARD

VISION

The vision of the Nansen-Tutu Centre for Marine Environmental Research is to serve Africa through advancing knowledge of the marine environment and climate system in the spirit of Nobel Peace Laureates Fridtjof Nansen and Desmond Tutu.

The priority research activities at the Centre are:

- Ocean modeling and prediction
- Ocean-atmosphere, climate and regional impact
- High resolution satellite remote sensing of the regional shelf seas
- Regional sea level variability and global change
- Capacity building and education

ACKNOWLEDGEMENT

The Nansen-Tutu Centre's activities are enabled through financial contributions. In 2016 the Centre received funding from the Nansen Environmental and Remote Sensing Center, the Nansen Scientific Society, University of Bergen, Institute for Marine Research and the Department of Oceanography at University of Cape Town. In addition in kind contributions were received from all the partners.

ORGANISATION

The Nansen-Tutu Centre (NTC) is a non-profit research centre hosted at the Marine Research Institute and the Department of Oceanography at the University of Cape Town (UCT). The administrative and legal responsibilities reside with the University of

Cover image: Partner countries of the EU-FP7 "Enhancing PRediction of Tropical Atlantic Climate and its Impacts" (PREFACE) project in which the Nansen-Tutu Centre is a partner. Image courtesy of Mathieu Rouault.

Cape Town. It is a joint venture agreement between the signatory partners from South Africa, Norway, France and the United States. In 2016, the signatory partners from South Africa include the Marine Research Institute (MaRe)/Department of Oceanography, University of Cape Town, the African Centre for Climate and Earth System Studies (ACCESS), the Council for Scientific and Industrial Research (CSIR), and the South African Environmental Observation Network (SAEON). From Norway the signatory partners included the Nansen Environmental and Remote Sensing Center (NERSC) and the Nansen Scientific Society, from France the International Centre for Education, Marine and Atmospheric Sciences over Africa (ICEMASA), and from the USA the Geosciences Department at the Princeton University. The extension of the joint venture for 3 years (Phase II) was initiated in July 2013, with seed funding commitments from NERSC and the Nansen Scientific Society. Additional external funding for projects is applied from South African and Norwegian funding bodies, bilateral funding agreements, the European Union's Framework Programmes, space agencies, industry and private sponsors.

Phase II of the joint venture agreement was extended from June 2016 to December 2016 to prepare for the launch of Phase III, which included the Department of Environmental Affairs (DEA) – Oceans and Coasts Branch, the South African Weather Service (SAWS), the Cape Peninsula University of Technology (CPUT) and the Nelson Mandela Metropolitan University's (NMMU) Institute for Coastal and Marine Research as additional signatory partners from South Africa, and the replacement of ICEMASA as a signatory partner with the Institut de recherche pour le Développement

(IRD) and Université de Bretagne Occidentale. The Institute of Marine Research (IMR) and the University of Bergen (UiB) re-joining the agreement as signatory partners. Funding for this bridging period was made available from NERSC, IMR and UiB.

STAFF

Nansen-Tutu Centre staff consists of partially funded and seconded associate researchers and administrators from the partner institutes, as well as fully or co-funded MSc, PhD students and Post-doctoral research fellows. During 2016, the Nansen-Tutu Centre comprised 20 persons, including 3 MSc students, 5 PhD students, 4 researchers, 7 associate researchers and 1 administrator from its founding partners, including the Marine Research Institute and the Department of Oceanography at the University of Cape Town, the Council for Scientific and Industrial Research, South African Environmental Observation Network, and the Nansen Environmental and Remote Sensing Center.

SCIENTIFIC PRODUCTION, CAPACITY BUILDING AND TEACHING

A total of 11 publications emanated from the Centre in 2016, which included: 7 papers published in peer-reviewed journals and 4 articles in peer-reviewed conference proceedings.

In 2016, the Nansen-Tutu Centre supported the students listed below. They either received a full bursary, top-up funding towards their bursaries or travel support for research exchanges and conference attendance.

- Rodrigue Anicet Imbol Koun-gue (full bursary: NTC and ACCESS) – PhD, Cameroon
- Georges-Noel Tiersmon-do Longandjo (full bursary: PREFACE and ACCESS) – PhD, Democratic Republic of Congo
- Arielle Stella Nkwinkwa

- Njouado (full bursary: AIMS and WRC) – PhD Cameroon
- Juliano Dani (top up: NTC) PhD Madagascar
- Mr. Bernardino Nhantumbo (full bursary: NTC and ACCESS) – PhD, Mozambique
- Mr Tharone Rapeti (project funded: NRF) – MSc, South Africa
- Mr Mark Hague (project funded: SANAP; travel support: SCAMPI) – MSc, South Africa
- Ms Estee Vermeulen (project funded: NRF; travel support: SCAMPI)

Congratulations to Daniel Shilperoort, Marc de Vos and Khushboo Jhugroo who graduated in 2016. They were all funded by the Nansen-Tutu Center and visited Bergen in 2015 to work on their thesis dissertations under supervision of NERSC scientists.

Additionally, NTC staff and associates were involved in the co-supervision of Honours, MSc and PhD students registered at the University of Cape Town and the University of Bergen, as well as teaching in the Department of Oceanography's undergraduate and post-graduate programmes, the Applied Marine Science MSc programme and the African Climate and Development Initiative MSc programme.

During 2016, the Centre facilitated seven international research exchanges to Bergen, Norway, including 3 Ph.D. students, 2 MSc students and two senior scientists: Prof Mathieu Rouault and Dr Bjorn Backeberg visited Bergen. Bernardino Nhantumbo visited NERSC for 3 months, Rodrigue Anicet Imbol Kounge visited UiB for 3 months and Arielle Stella Nkwinkwa Njouado visited UiB and NERSC for three months. The 3 PhD students worked on their thesis dissertations under supervision of Norwegian scientists. The two MSc students, Marc Hague and Estee Vermeulen, also

attended semester courses at UiB for 6 months. 3 senior scientists, Johnny Johannessen, Thomas Toniazzo and Marek Ostrowski from partner institutes in Bergen (respectively NERSC, UiB, and IMR) visited the Nansen-Tutu Centre in 2016.

NATIONAL COOPERATION

The Centre actively participates in national research and development activities, including the projects funded through the National Research Foundation, the Department of Science and Technology, the South African National Antarctica Programme, the Water Research Commission (WRC) and ACCESS. ACCESS is a consortium of several agencies, researcher councils, research programmes, universities and research groups who have combined efforts to deliver a range of outputs aligned to the Department of Science and Technology's Global Change Grand Challenge. It is a platform for integrated and end-to-end research and education, services and training outputs and outcomes related to the opportunities and challenges emanating from a varying and changing environment, collectively referred to as Earth Systems Science. The Water Research Commission (WRC) project "Role of the Ocean on Climate" investigates mainly the impact of the Agulhas Current on weather and climate of Southern Africa, decadal variability of climate and the role of El Nino on drought in Southern Africa. In 2016 we experienced one of the most severe droughts in South African history. The drought has now persisted for 2 years. As in 2015, the Centre played a key role in providing early warning of the impending drought and also in explaining the physics behind it. This included participation at high level national workshops and various TV appearances. UiB and NERSC are partners in the WRC project.

INTERNATIONAL ACTIVITIES

The Centre facilitated two PhD students' attendance at the international Climate Summer School in Bergen. In addition four PhD students from the Department of Oceanography at the University of Cape Town were sponsored by NERSC to attend the Indo-Norwegian Winter School in Hyderabad. Bjorn Backeberg attended the 1st BRICS Workshop on Operational Oceanography which took place from September 26 – 28 hosted by the Institute of Atmospheric Physics, Chinese Academy of Sciences with the attendance of representatives from China, South Africa, Russia and Brazil. Bjorn Backeberg was also invited to attend the GODAE OceanView Science Team annual meeting in Kochi, India in November 2016. Mathieu Rouault and Bjorn Backeberg together with the directors of the Nansen Centre in Bangladesh, India, Russia, South Africa and China gathered in Bergen for the celebration of the 30th anniversary of the NERSC in November 2016. Mathieu Rouault and Anicet Imbol Kounge each gave a presentation at the Benguela Symposium held in Cape Town in November 2016. The Nansen-Tutu Center was also involved in organising a workshop in Cape Town during the South Africa - Norway Science Week focusing on "Value Creation in Ocean Space - New Opportunities in the Blue Economy" in November 2016 where Phase III of the Nansen-Tutu Center was launched.

The Centre contributed to a number of international projects. These include 2 European Seventh Framework Programmes, the Marie Curie Actions project "The role of the Southern Ocean carbon cycle under climate change" (SOCCLI), and the project "Enhancing prediction of Tropical Atlantic climate and its impacts" (PREFACE). PREFACE is a climate

change project with 28 partners across 18 countries in Europe including UIB, IMR from Norway and NTC from Africa, and 3 associate partners directly involved in the sustainable management of the three Eastern boundary large marine ecosystems of the Tropical Atlantic. The centre is a partner in a project funded under South Africa - Norway Research Co-operation on Climate Change, the Environment and Clean Energy, entitled "Seasonal to decadal Changes Affecting Marine Productivity: an Interdisciplinary investigation" (SCAMPI). SCAMPI aims to carry out interdisciplinary research in the marine environment, addressing different scales of variability in the oceans off southern Africa and providing knowledge that allows impacts of future climate change to be anticipated and adaptation strategies developed. The project spans the "Environment" and "Climate System" thematic areas of the SANCOOP call. It builds on the already-established, strong relationships between the University of Cape Town's Marine Research Institute (including the Nansen-Tutu Centre), the Nansen Environmental and Remote Sensing Center in Bergen, and the University of Bergen and the Centre for Ecological and Evolutionary Synthesis at the University of Oslo.

FINANCIAL SITUATION

A total of 859 000 ZAR (500 000 NOK) seed funding for the Centre was made available from Norwegian partners in 2016: 434 277 ZAR (250 000 NOK) from NERSC; 176 865 ZAR (100 000 NOK) from NSS; 161 371 ZAR (100 000 NOK) from UiB and 86 565 ZAR (50 000 NOK) from IMR. In addition to this, the Department of Oceanography at UCT contributed 50 000 ZAR and almost 2.4m ZAR was raised through project funding in 2016. These include

projects funded by the South African National Research Foundation, ACCESS, the Water Research Commission, the South Africa - Norway Research Co-operation SANCOOP Program, the European Framework 7 Programme and the ESA's GlobCurrent project. A significant challenge faced by the Centre is that projects often predominantly fund travel, running and student bursaries, while it is very difficult to raise funding for salaries.

PHASE II (2014–2016) MILESTONES ACHIEVED

During Phase II, the Centre supported 5 MSc and 7 PhD students from South Africa and Africa. Of those, 5 students (4 MSc and 1 PhD) graduated from the University of Cape Town between 2014 and the end of 2016.

Between 2014 and 2016 the centre contributed towards the following summer schools and workshops:

- Intergovernmental Oceanographic Commission of UNESCO, Summer School on Application of Ocean Coastal Data and Modelling products, Accra, 9 – 13 June 2014
- NTC Summer School on Ocean, Climate and Marine Ecosystem, Cape Town, 1 – 8 December 2014
- PIRATA-PREFACE-CLIVAR Tropical Atlantic Variability Conference, Cape Town, 24 – 28 August 2015

A total of 32 research exchanges were facilitated through the Centre, with 3 South African researchers and 11 African students visiting IMR, UiB and NERSC in Norway while 8 Norwegian researchers and 2 Norwegians student visiting the Nansen-Tutu Centre in South Africa.

A total of 33 publications emanated from the Centre of which 27 were in scientific peer-reviewed

journals, 10 in peer reviewed conference proceedings and 2 chapters in book. 13 peer reviewed papers, 5 peer reviewed conference proceedings and one chapter in book had Norwegian co-authors. Through the Centre's collaboration and activities in the Global Ocean Data Assimilation Experiment OceanView (GOV), South Africa continues to act as an observer in its science team.

PROSPECTS FOR 2017

Finalise Phase III joint venture agreement

Host GODAE OceanView Coastal Ocean and Shelf Sea Task Team annual meeting

Continue to support existing PhD students.

Appoint new MSc and PhD students depending on available funding.

Enhance and formalise institutional collaborations.

Improve science outreach through popular articles, social media and newsletters.

Contribute to the new course in operational oceanography at UCT

Approved by The Board
Cape Town, July 2017

THE BOARD

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Mrs. S. Bosma, Marine Research Institute, University of Cape Town

SCIENCE REPORT FOR 2016

The Centre's research activities are grouped into 4 overarching themes:

Ocean modelling and prediction coordinated by Bjorn Backeberg,

Ocean-Atmosphere interaction, climate variability and change, regional impacts coordinated by Mathieu Rouault,

High resolution ocean satellite remote sensing coordinated by Marjolaine Krug

Regional sea level variability and global change coordinated by Frank Shillington.

OCEAN MODELLING AND PREDICTION

The group supported 2 MSc students, and published 1 paper in an international peer-reviewed journal and 2 peer-reviewed conference proceedings. de Vos et al. (2016) use an eddy-tracking algorithm and compare the derived eddy characteristics of an assimilated (ASSIM) and an unassimilated (FREE) simulation experiment in HYCOM with gridded satellite

altimetry-derived SLA data. Using an eddy tracking algorithm they were able to quantitatively evaluate whether the assimilation improves the dynamical properties of the model and isolates the remaining limitations or flaws in the dynamical model, inappropriate assumptions in the assimilation scheme, or artifacts of the eddy tracking scheme. Overall, ASSIM yields improvements over FREE in eddy density distribution and dynamics; particularly amplitude, rotational speed and eddy kinetic energy (Figure 1). In contrast, eddy radii appear degraded by the assimilation, which is likely due to the local Gaussian tapering applied during assimilation. The non-linear properties of the flow are degraded by the assimilation as a consequence of incompatibility between assimilation and eddy tracking scheme. The threshold for the maximum eddy propagation velocity is often exceeded when data assimilation relocates an eddy, causing the algorithm to interpret the discontinuity as eddy genesis, which directly influences the eddy count, lifetime and propagation velocity, and indirectly influences oth-

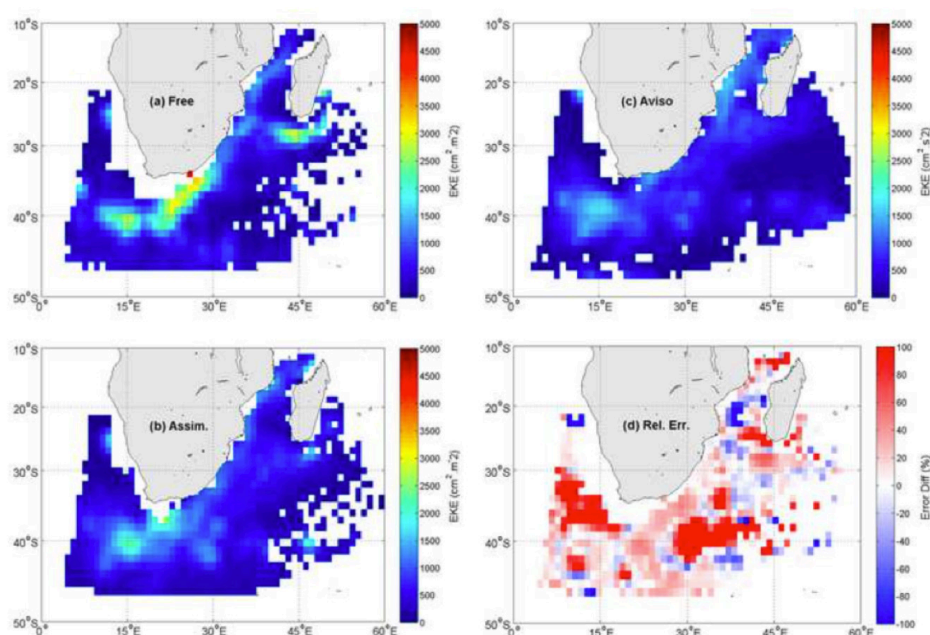


Fig. 1. Eddy kinetic energy for a) FREE, b) ASSIM and c) AVISO. d) Shows relative error, with redder tones indicating closer adherence of Assim. to Aviso, and bluer areas indicating closer adherence of Free to Aviso.

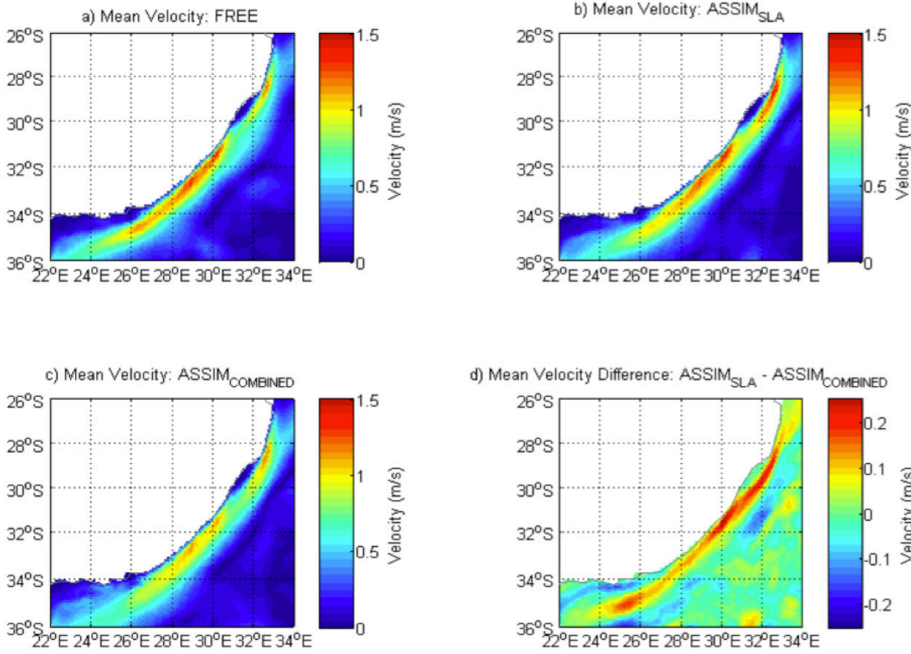


Fig. 2. (a) 2008 – 2009 mean velocity map from the FREE; (b) mean velocity map from $ASSIM_{SLA}$; (c) mean velocity map from $ASSIM_{combined}$; (d) Difference map, of mean velocities, $ASSIM_{SLA}$ minus $ASSIM_{combined}$. Red colours indicate where $ASSIM_{SLA}$ has higher velocities than $ASSIM_{combined}$ while blue indicates the opposite.

er metrics such as non-linearity. The regional HYCOM simulation significantly underestimates the number of eddies south of Madagascar compared to gridded altimetry. Assimilating along-track SLA generates eddies south of Madagascar. However, they decay rapidly within the assimilation cycle, highlighting the models' limitation in sustaining mesoscale activity in this region. Finally, the eddy tracking algorithm allowed us to separate the contributions from mesoscale eddies to the total eddy kinetic energy (EKE), with residual EKE being contributed by meandering currents. The result indicates that the assimilation of SLA more strongly impacts mesoscale eddies, with only limited impact on current meanders. The work is based on the MSc thesis of de Vos (2016).

The MSc study by Rapeti (2016) compared two assimilation experiments using the Ensemble Optimal Interpolation (EnOI) data assimilation scheme in a regional implementation of the Hybrid Coordinate Ocean Model (HYCOM). In the first experiment we assimilated

late along-track satellite sea level anomaly (SLA) data only, and in the second experiment we assimilate both along-track sea level anomaly (SLA) as well as OSTIA sea surface temperature (SST) data. The objectives of the study are to investigate the impacts of assimilating SST along with SLA into the regional HYCOM model, with the hopes of improving the model performance. The long-term aim of this experiment is to develop a regional ocean prediction system. The additional assimilation of SST along with SLA into the HYCOM model, has improved upon the representation of the SST field across the region by reducing the error. However, with regards to velocity (Figure 2), surface eddy kinetic energies (EKE), as well as subsurface velocities, the updated SST model performs poorly in comparison to the previous SLA only assimilation experiment. Increases in error, as well as the frequent production of mesoscale features along the Agulhas Current and South of Madagascar were noted. Water masses are also inaccurate-

ly represented in the combined SLA-SST assimilation; the model underestimates salinity in the upper 500 m. The assimilation of SST has improved upon the SST-SSH correlation in the model, an improvement over FREE and $ASSIM_{SLA}$. The work was published in a peer-reviewed conference proceeding in 2016 (Rapeti and Backeberg, 2016). The benefit of assimilating OSTIA SSTs remains unclear, further work suggested that assimilating SST anomalies would be beneficial, but this is the subject of further investigation (pers. comm. Backeberg).

OCEAN-ATMOSPHERE INTERACTION, CLIMATE VARIABILITY AND CHANGE AND REGIONAL IMPACT

The Ocean-Atmosphere group had two papers published in 2016. Rouault et al. (2016) used Sea surface temperature (SST) estimated from the Advanced Microwave Scanning Radiometer E onboard the Aqua satellite and GlobCurrent altimetry derived sea level anomalies and geostrophic current are used south of the Agulhas Current to identify warm-core mesoscale eddies presenting a distinct SST perturbation superior to 1°C to the surrounding ocean. The analysis of twice daily instantaneous charts of equivalent stability neutral wind speed estimates from the SeaWinds scatterometer onboard the QuikScat satellite collocated with SST during the lifespan of for those six identified eddies show stronger wind speed above those warm eddies than surrounding water at all wind directions. However, only half of the case show higher wind above the eddies than surrounding water at the instantaneous scale. 20% of the cases had incomplete data due to partial global coverage of the scatterometer path. For cases when the wind is stronger above warm eddies, there is no relationship between the increase in surface

wind speed and the SST perturbation but we do find a linear relationship between the decrease in wind speed from the center to the eddy border downstream and the SST perturbation from warm eddy to cold surrounding ocean. SST perturbations range from 1°C to 6°C for a mean eddy SST of 15.9°C and mean SST perturbation of 2.65°C. Diameter of eddies range from 100 to 250 km. Mean background wind speed is about 12 m/s mostly southwesterly to northwesterly and ranging mainly from 4 m/s to 16 m/s. Mean wind increase is about 15% at 1.8 m/s. Wind speed increase of 4 to 7 m/s above warm eddies is not uncommon (Figure 3). Cases where the wind did not increase above the eddies or did not decrease downstream had higher wind speeds and happen during cold front associated with intense cyclonic low pressure systems suggesting certain synoptic conditions need to be met to allow for the development of wind speed anomalies over warm core ocean eddies or that change in wind speed above eddies was masked by a large-scale synoptic wind speed deceleration/acceleration affecting part of the eddies.

In the second paper, Dieppois et al. (2016) studied the decadal variability of rainfall in South Africa. Year-to-year variations in rainfall across Southern Africa have major consequences for human livelihoods and ecosystems through their impact on drought, temperature, water supply, vegetation and agriculture. Interannual variability of summer Southern African rainfall is known to be primarily influenced by El Niño Southern Oscillation (ENSO), with dry and wet seasonal anomalies during El Niño and La Niña respectively. Decadal fluctuations have also been found in summer Southern African rainfall. Of particular importance is the so-called Interdecadal 18.6 year

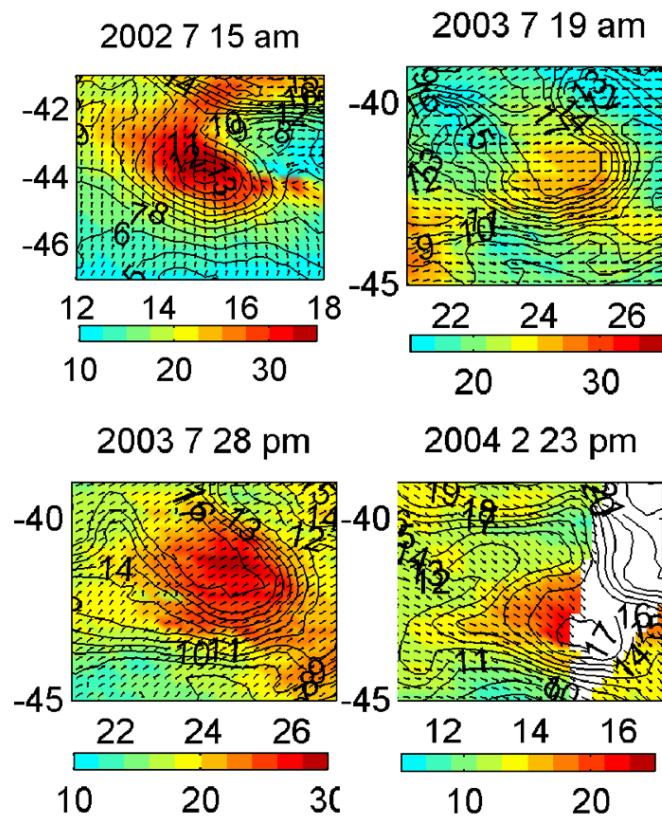


Fig. 3. Clockwise from top left, Instantaneous estimate of QuikScat wind speed in m/s (color) and directions (arrows) and AMSR microwave sea surface temperature (contours) south of the Agulhas Current system on the 15 07 2002 (morning path) 19 07 2003 (morning path), 23 02 2004 (evening path) and 28 07 2003 (evening path) showing strong and homogeneous increase and decrease in wind speed collocated with increases and decrease of sea surface temperature.

Dyer-Tyson cycle. However, until now, discussions about potential mechanisms of these decadal fluctuations were limited. For instance, most of the studies were based on comparisons between two periods of approximately 10-years, which are too short to capture the decadal signals (i.e., roughly two $\frac{1}{2}$ cycles). They are thus likely to describe changes in interannual variability between two decades that are not necessarily related to decadal signals. Using an approach based on spectral analysis, the study aims to address these gaps, by defining the changing characteristics of summer and winter Southern African rainfall, and their specific teleconnections for the main timescale of climate variability. As determined

by wavelet analysis (Figure 4), the austral summer and winter rainfall indices exhibit three significant time scales of variability over the twentieth century: Interdecadal (15–28 years), quasi-decadal (8–13 years), and interannual (2–8 years).

Teleconnections with global sea surface temperature and atmospheric circulation anomalies are established here but are different for each time scale. Tropical/subtropical teleconnections emerge as the main driver of austral summer rainfall variability. Shifts in the Walker circulation are linked to the El Niño–Southern

Oscillation (ENSO) and, at decadal time scales, to decadal ENSO-like patterns related to the Pacific Decadal Oscillation and the Interdecadal Pacific Oscillation. These global changes in the upper zonal circulation interact with asymmetric ocean-atmospheric conditions between the South Atlantic and South Indian Oceans; together, these lead to a shift in the South Indian Convergence Zone and a modulation of the development of convective rain-bearing systems over southern Africa in summer. Such regional changes, embedded in quasi-annular geopotential patterns, consist of easterly moisture fluxes from the South Indian High, which dominate southerly moisture fluxes from the South Atlantic High. Austral winter rain-

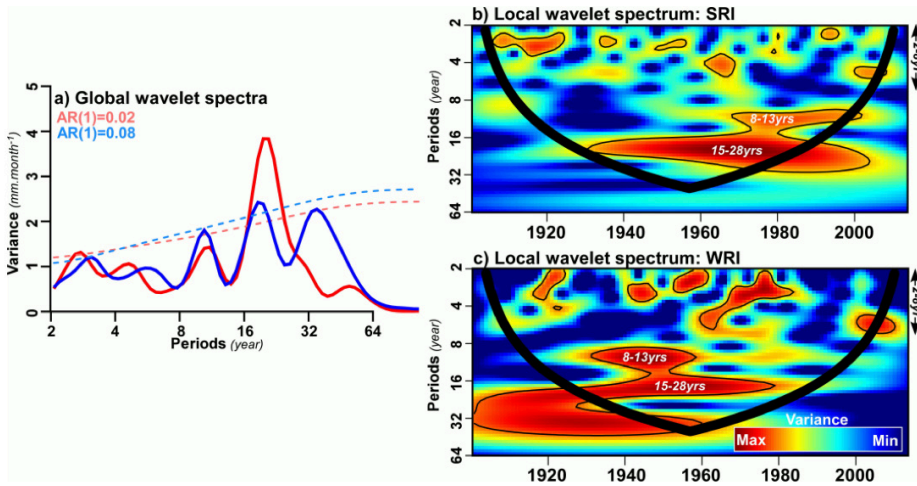


Fig. 4. Time-scale patterns of variability in summer and winter southern African rainfall. *a* Global wavelet spectra of the SRI (blue) and the WRI (red). The dashed blue and red lines indicate the red noise spectra with regard to the first order autoregressive (SRI-AR[1] = 0.02; WRI-AR[1] = 0.08). *b-c* Continuous wavelet power spectrum of the SRI and the WRI. Bold lines (the so-called cone of influence) delineate the area under which power can be underestimated as a consequence of edge effects, wraparound effects and zero padding; thin contour lines show the 95% confidence limits based on 1000 Monte-Carlo simulations of the red noise background spectrum.

fall variability is more influenced by midlatitude atmospheric variability, in particular the Southern Annular Mode. The rainfall changes in the south-western regions of southern Africa are determined by asymmetrical changes in the midlatitude Westerlies between the Atlantic and Indian Oceans.

HIGH RESOLUTION OCEAN SATELLITE REMOTE SENSING

The High resolution ocean satellite remote sensing had three papers and a master thesis. In his Master's thesis, Daniel Shilperort Master student co advised by Marjolaine Krug, Mathieu Rouault and Morten Hansen and who spent three months in Bergen at NERSC in 2015 used, 5 years (987 swaths) of high resolution wind speeds, derived from Advanced Synthetic Aperture Radar data collected over the Agulhas Current region to investigate the effect of warm, high intensity currents on the ocean's surface roughness and resulting derived wind fields (Figure 5). The wind data are derived using the CMOD5.n GMF with CFS reanalysis wind data as

direction input. The CFS direction data are validated using ASCAT derived wind observations GlobCurrent ocean current velocity data is used to investigate the difference between the satellite derived wind speeds compared to

surface velocities of the current and the true wind speed. The current relative effect on the wind is investigated for different wind direction regimes, namely: upcurrent, downcurrent, crosscurrent west and crosscurrent east. The analyses are conducted for 6 locations of interest, evenly spaced along the Northern Agulhas Current. MODIS, SEVIRI and OSTIA SST data are used as proxy for locating the core of the Agulhas and its temperature fronts, as well as to investigate wind speed modifications as a result of ocean-atmosphere energy transfer. It is found that higher resolution SAR derived winds have a greater ability to represent higher intensity and smaller scale wind features in comparison to winds derived from Scatterometer. A combination of the current relative effect and SST-atmospheric heating for upcurrent wind directions results in a sharp increase in mean wind speeds over the inshore boundary of the current of between 5m/s and 7m/s (50–60%). Individual events can reach as high as 15m/s

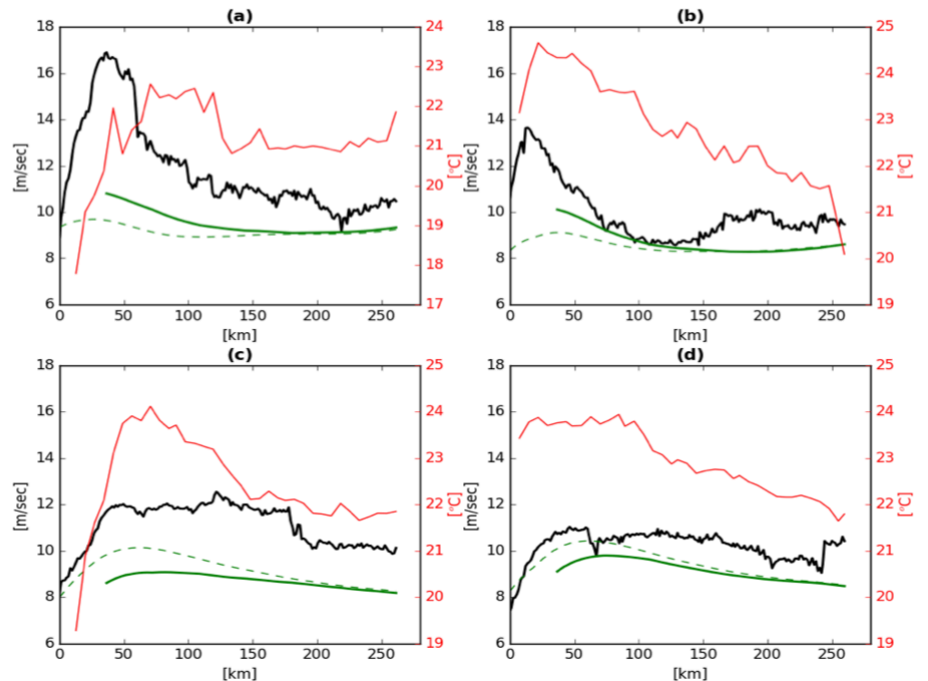
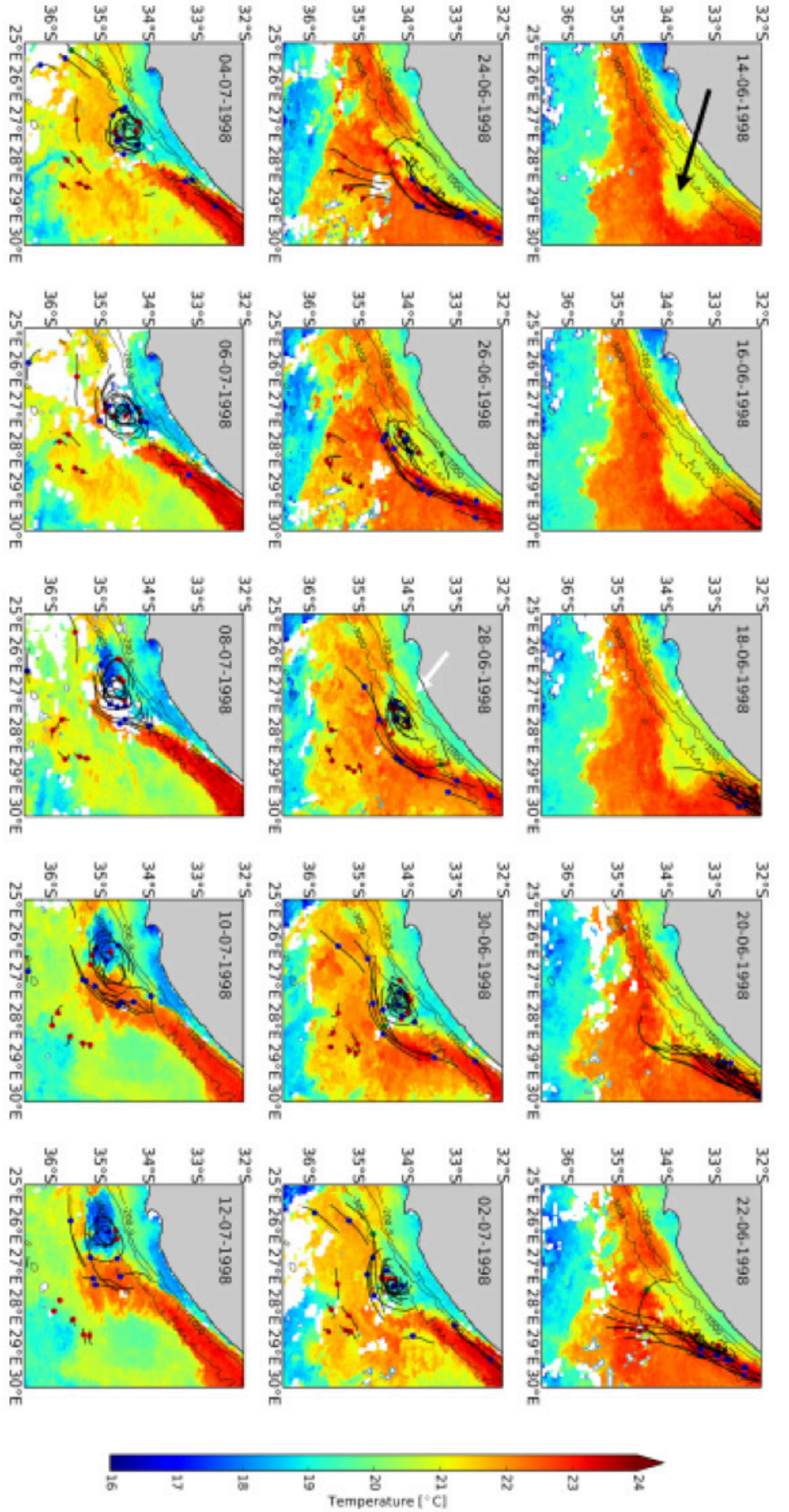


Fig. 5. Effect of the Agulhas Current velocity and temperature on surface wind speed. Left panels: Transect A; top: wind against current; bottom: Wind with current. Right panels same for Transect B. Red line Sevir SST, black line ASAR relative surface wind speed; green solid line CFSR absolute surface wind speed; dashed green line CFSR relative wind speed.

(100%) over 10's of kilometers. For downcurrent winds, the expected current relative effect is overridden by increased wind speeds of up to 5m/s (40%) across the entire current due to the influence of SSTs. The mean effect of SSTs on wind speeds has a stronger effect than the current relative effect on wind speed changes over the current. The wind speed differences are best represented under moderate wind speeds, between 5–15m/s. In the first paper of the group, Pivan et al (2016) reinvestigates the work of Lutjeharms et al. (2001, 2003) who documented the properties of a Natal Pulse using isopycnal Lagrangian floats. He combined Lagrangian analyses and Eulerian maps derived from objective analysis to better describe the evolution of a Natal Pulse (Figure 6) along three density surfaces referred to as the surface (satellite-observed), shallow (isopycnal 1026.8 kg m⁻³), and deep (isopycnal 1027.2 kg m⁻³) layer. The observations show that this Natal Pulse extended to a depth of 1000 m and was associated with cyclonic relative vorticity values of about $6.5\text{--}8.5 \times$

Fig. 6 Southward progression of the Natal Pulse as seen in the SST imagery. Eight days SST composites are centered on the annotated date (day/month/year). Red and blue dots show the respective positions of the shallow and deep floats. A thick black line marks the path followed by the floats over a period of 4 days. The 200, 1000, and 3000 m isobaths are represented with thin black lines. The black and white arrows indicate, respectively, the Natal Pulses and the warm recirculating plume. The shallow Float 526 is a green point. GEBCO_081, with a spatial resolution of 30 arc sec grid, is used for the bathymetry in all maps.



$10\text{--}5 \text{ s}^{-1}$ in the surface and shallow layer and $4 \times 10\text{--}5 \text{ s}^{-1}$ in the deep layer. This Natal Pulse contributed to cross-shelf exchange through the offshore advection of Eastern Agulhas Bank water near

the surface, onshore advection of South Indian Central Water and/or Indian Equatorial Water in the shallow layer, and Antarctic Intermediate Water in the deep layer. Sea surface temperature maps

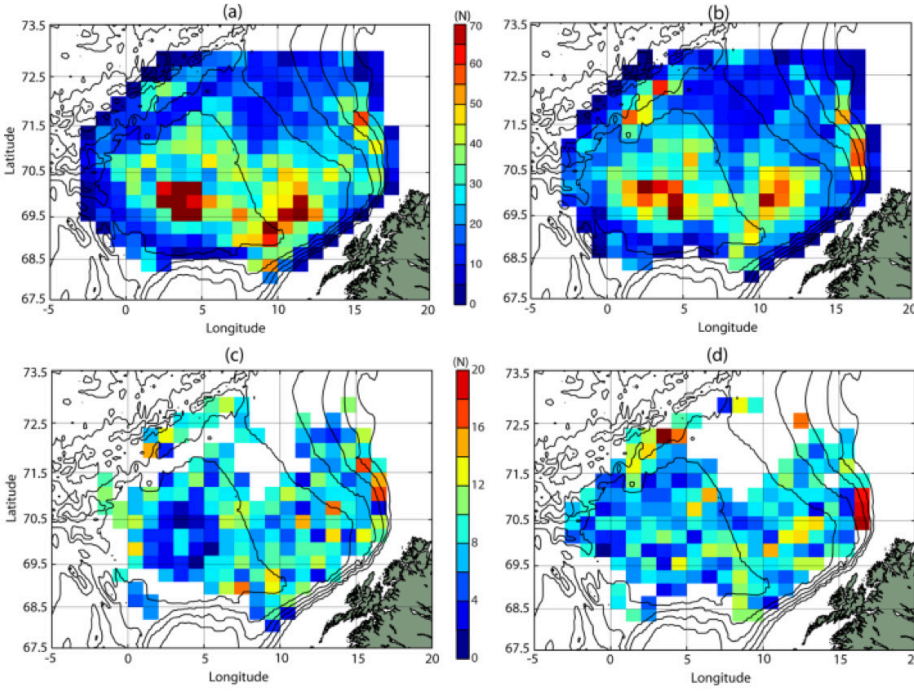


Fig. 7. (a, b) Total number of eddy occurrences and (c, d) total number of eddy genesis of (a, c) anticyclonic and (b, d) cyclonic eddies in every 1° longitude and 0.3° latitude bins in the Lofoten Basin. Number of eddy genesis in bins with low number of eddy occurrences is not plotted. Black lines are isobaths drawn for every 500 m.

showed that the downstream progression of the Natal Pulse along the 3000 m isobaths was related to a readjustment of its rotation axis. This readjustment advected Eastern Agulhas Bank water into the Natal Pulse eddy and triggered a SST cooling of about 3°C in the cyclonic area. The importance of a warm recirculating Agulhas plume originating from the Natal Pulse was highlighted. This warm water plume extended to a depth of 700 m and was associated with onshore velocities exceeding those experienced within the Natal Pulse eddy by a factor of 2. Our observations indicate that the June/July 1998 Natal Pulse and its associated plumes enhanced cross-shelf exchanges. The two next papers, Raj et al. (2016a) and Raj et al. 2016b, study the Lofoten Basin, one of most eddy rich region in the Norwegian Sea. In this paper, the characteristics of these eddies are investigated from a comprehensive database of nearly two decades of satellite altimeter data (1995–2013) together with Argo profiling floats and surface drifter

data. An automated method identified 1695 and 1666 individual anticyclonic and cyclonic eddies respectively in the Lofoten Basin (Figure 7) from more than 10,000 altimeter-based eddy observations. The eddies are found to be predominantly generated and residing locally. The spatial dis-

tributions of lifetime, occurrence, generation sites, size, intensity, and drift of the eddies are studied in detail. The anticyclonic eddies in the Lofoten Basin are the most long-lived eddies (>60 days), especially in the western part of the basin. Observations reveal two hotspots of eddy occurrence on either side of the Lofoten Basin. Furthermore, a cyclonic drift of eddies is inferred in the western Lofoten Basin. Barotropic energy conversion rates reveals energy transfer from the slope current to the eddies during winter. An automated collocation of surface drifters trapped inside the altimeter-based eddies are used to corroborate the orbital speed of the anticyclonic and cyclonic eddies. Moreover, the vertical structure of the altimeter-based eddies is examined using collocated Argo profiling float profiles. Combination of altimetry, Argo floats, and surface drifter data is therefore considered to be a promising observation-based approach for further studies of the role of eddies in transport of heat and biomass from the slope current to the Lofoten Basin.

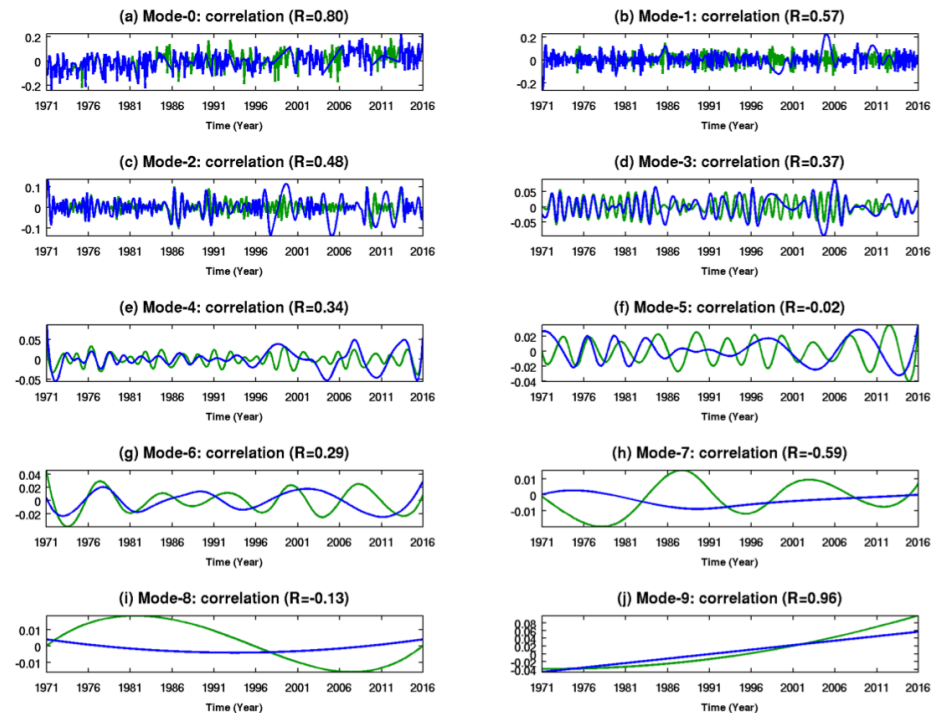


Fig 8. Comparison of the EMD modes derived from sea level data with no gaps (green) and with gaps. The missing values in the data with gaps were filled using a linear interpolation method.

REGIONAL SEA LEVEL VARIABILITY AND GLOBAL CHANGE

The regional sea level variability and global change group supported 1 PhD student. Mr Nhantumbo has pioneered this research for the Nansen-Tutu Centre, and it is expected that his PhD research will yield new findings to a severely under-capacitated research niche in South Africa. Sea level variability and rise in the context of coastal vulnerability and management is a crucial topic, and its importance and worldwide awareness has increased significantly in the context of the rising of sea levels, due to natural variability and anthropogenic forcing. Particularly, sea level variability and rise is of great concern in the coastal areas, where a significant part of the population is settled in many countries around the world. Therefore, understanding regional and local long-term sea level variability as well as its trend is critical. To date, around the southern Africa coast, there has been no detailed study to better understand the drivers of sea level variability at interannual to multi-decadal time scales. Mr Nhantumbo's PhD focus is to separate time scales of variability within sea level records in order to determine and study their characteristics. Separating these timescales is one of the greatest challenges in sea level research due to the absence of a consensus in the suitable method to be applied. The Empirical Mode Decomposition (EMD) is a new method for analysing a sea level records and it was chosen as a suitable method to extract time scales of variability from the sea level record, and notably it is the first time that this method is applied to southern African tide gauge records. A critical component of analyzing sea level records using the EMD is understanding the impact that data gaps have on the modes of varia-

bility identified by the EMD, and sea level records in southern Africa have a lot of gaps. Therefore, to understand how the EMD method works it was compared with other methods, and the impact of data gaps was tested by introducing gaps in a sea level time series derived from satellite altimetry. The impact of different gap filling methods was also tested to provide more insight into the how the separated oscillatory modes are affected under each tested gap filling method (Figure 8).

The comparisons show that the EMD method is advantageous over other spectral methods as it fragments the time series into a set of embedded sub-time series frequencies. This ability to display the energy-frequency-time distribution in such way is critical to understanding drivers of sea level variability for the region. The sensitivity of the EMD when dealing with data gaps was tested by comparing the output for different gap filling methodologies, including the linear interpolation, average value and linear trend value. Results suggest that, with minor exceptions, filling the gaps with the linear trend value is not appropriate. Significant effort has been made in finding alternative methods of filling these data gaps, including studying the relationship between neighboring tide gauges and satellite altimetry data.

PUBLICATIONS IN 2016

PEER-REVIEWED PAPERS

Braby, L., **Backeberg, B.C.**, Anson, I., Roberts, M.J., **Krug, M.** and Reason C.J.C. (2016). Observed eddy dissipation in the Agulhas Current, *Geophys. Res. Lett.*, 43, 8143–8150, doi:10.1002/2016GL069480.

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Pivan, X., **Krug, M.**, and Herbette, S., (2016). Observations of the vertical and temporal evolution of a Natal Pulse along the Eastern Agulhas Bank, *J. Geophys. Res. Oceans*, 121, doi:10.1002/2015JC011582

Raj, R.P., **Johannessen, J.A.**, Eldevik, T., **Nilsen, J.E.** and **Halo, I.**, 2016. Quantifying mesoscale eddies in the Lofoten Basin. *Journal of Geophysical Research: Oceans*. DOI: 10.1002/2016JC011637

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PEER-REVIEWED CONFERENCE PROCEEDINGS

de Vos, M., B. Backeberg and F. Counillon (2016). Towards understanding the impact of assimilating along-track SLA data on simulated eddy characteristics in the Agulhas System, 32nd Annual conference of the South African Society for Atmospheric Science, Cape Town 31 October 1 November 2016, 21-24, ISBN 978-0-620-72974-1.

Longandjo, G. T. and M. Rouault How does well ECHAM simulate central Africa rainfall seasonal cycle 32nd Annual conference of the South African Society for Atmospheric Science, Cape Town 31 October 1 November 2016. ISBN 978-0-620-72974-1, pp 116-118.

Rapeti, T. and B. Backeberg (2016). Preliminary investigation into the impacts of assimilating SST and SLA on the surface velocities in a HYCOM of the Agulhas Current. 32nd Annual conference of the South African Society for Atmospheric Science, Cape Town 31 October 1 November 2016, 112-115, ISBN 978-0-620-72974-1.

Rouault, M., Verley, P. and Backeberg, B., (2016). Wind changes above warm Agulhas Current eddies. 32nd Annual conference of the South African Society for Atmospheric Science, Cape Town 31 October 1 November 2016. ISBN 978-0-620-72974-1, pp 73-76.

GRADUATION IN 2016

Daniel Schilperoort – M.Sc.: The Effect of the Agulhas Current on SAR derived wind fields. Supervised by Marjolaine Krug, Mathieu Rouault and Morten Hansen

Marc de Vos – M.Sc.: The Impact of Assimilating Along-Track SLA Data on Simulated Eddy Characteristics in the Agulhas System.

Supervised by Bjorn Backeberg and Francois Counillon.

Khushboo Jhugroo – MSc.: Regional features of the phytoplankton bloom cycle in the Sub-Antarctic Zone of the Atlantic. Supervised by Marcello Vichi, Morten Hansen and Anton Korosov.

STAFF IN 2016

SCIENTISTS

Dr. Bjorn Backeberg (Co-director, 20% salary from NERSC) – Ocean modeling and prediction

Assoc. Prof. Marcello Vichi (Co-director until April 2016, seconded) – Ocean modeling and prediction

Assoc. Prof. Mathieu Rouault (Research director and Co-director since April 2016, 50% salary) – Ocean-atmosphere, climate and regional impact

Dr. François Counillon (Associate researcher, seconded) – Ocean modelling and prediction

Dr. Issufo Halo (Associate researcher, seconded) – Ocean modelling and prediction

Dr. Morten Hansen (Associate researcher, seconded) – Satellite remote sensing of regional shelf seas

Prof. Johnny A. Johannessen (Associate researcher, seconded) – Satellite remote sensing of regional shelf seas

Dr. Anton Korosov (Associate researcher, seconded) – Satellite remote sensing of regional shelf seas

Dr. Marjolaine Krug (Associate researcher, seconded) – Satellite remote sensing of regional shelf seas

Dr. Jan-Even Nilsen (Associate researcher, seconded) – Regional sea level variability and global change

Dr. Annette Samuelsen (Associate researcher, seconded) – Ocean modelling and prediction

Emeritus Prof. Frank Shillington (100% stipend) – Satellite remote sensing of regional shelf seas

PHD STUDENTS

Mr. Rodrigue Anicet Imbol Koun-gue – Ocean-atmosphere interaction and climate

Mr. Georges-Noel Tiersmondo Longandjo – Ocean-atmosphere interaction and climate

Ms. Arielle Stella Nkwinkwa Njouado – Ocean-atmosphere interaction and climate

Mr. Bernardino Nhantumbo – Regional sea level variability and global change

Mr. Juliano Dani – Satellite remote sensing of regional shelf seas

MSC STUDENTS

Mr. Tharone Rapeti – Ocean modelling and prediction

Mr. Mark Hague – Ocean modelling and prediction

Ms. Estee Vermeulen – Ocean modelling and prediction

ADMINISTRATIVE AND TECHNICAL STAFF

Sharon Bosma (Associate staff, seconded) - Finances

USEFUL LINKS

Nansen-Tutu Centre
<http://www.nansen-tutu.org>

Marine Research Institute
<http://ma-re.uct.ac.za/>

Department of Oceanography
<http://www.sea.uct.ac.za/>

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<http://mathieuroault6.wix.com/nansentutusummer>



Directors of the Bangladesh, India, Russia, South Africa and China "satellite" Nansen Centers gathered in Bergen for the celebration of the 30th anniversary of the Nansen Environmental and Remote Sensing Center in November 2016.



Nansen-Tutu Centre for Marine Environmental Research

Department of Oceanography, Marine Research, University of Cape Town

Rondebosch, Cape Town, 7700
South Africa

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