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Session 1 – Ocean Processes

Title: Eastern boundary circulation and hydrography off Angola – building Angolan oceanographic capacities

Authors and affiliations: Pedro C.M. Tchipalanga [1], Marcus Dengler [2], Peter Brandt [2,3], Robert Kopte [2], Marisa Macuéria [4], Paulo Coelho [4], Marek Ostrowski [5] and Noel S. Keenlyside [6]

[1] Instituto Nacional de Investigação Pesqueira, Departamento do Ambiente e Ecossistemas Aquáticos, Moçâmedes, Angola

[2] GEOMAR Helmholtz Centre for Ocean Research Kiel, FB1: Ocean Circulation and Climate, Physical Oceanography, Kiel, Germany

[3] Christian-Albrechts-Universität zu Kiel, Mathematisch-Naturwissenschaftliche Fakultät, Kiel, Germany

[4] Instituto Nacional de Investigação Pesqueira, Luanda, Angola

[5] Institute of Marine Research, Oceanography and Climate, Bergen, Norway

[6] Geophysical Institute, University of Bergen, & Bjerknes Center for Climate Research, Norway

Abstract: The eastern boundary region off Angola encompasses a highly productive ecosystem important for the food security of the coastal population. The fish-stock distribution, however, undergoes large variability on intraseasonal, interannual and longer time scales. These fluctuations are partly associated with large-scale warm anomalies that are often forced remotely from the equatorial Atlantic and propagate southward reaching the Benguela upwelling off Namibia. Such warm events, named Benguela Niños, occurred in 1995 and in 2011. Here we present results from an under-explored extensive in-situ dataset that was analysed in the framework of a capacity strengthening effort. The dataset was acquired within the Nansen Programme executed by the Food and Agricultural Organization of the United Nations and funded by the Norwegian government. It consists of hydrographic and velocity data from the Angolan continental margin acquired bi-annually during the main downwelling and upwelling seasons over more than 20 years. The mean seasonal changes of the Angola Current from 6°S to 17°S are presented. During austral summer the southward Angola Current is concentrated in the upper 150 m. It strengthens from north to south reaching a velocity maximum just north of the Angola Benguela Front. During austral winter the Angola Current is weaker, but deeper reaching. While the southward strengthening of the Angola Current can be related to the wind forcing, its seasonal variability is most likely explained by coastally trapped waves. On interannual timescales, the hydrographic data reveals remarkable variability in subsurface upper ocean heat content. In particular, the 2011 Benguela Niño was preceded by a strong subsurface warming of about 2 year duration.

Title: Role of Equatorial Basin-Mode Resonance for the Seasonal Variability of the Angola Current at 11°S

Authors and affiliations: Robert Kopte [1], Peter Brandt [1,2], Martin Claus [1,2], Richard J. Greatbatch [1,2] and Marcus Dengler [1]

[1] GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Kiel, Germany

[2] Christian-Albrechts-Universität zu Kiel, Kiel, Germany

Abstract: Multi-year moored velocity observations of the Angola Current near 11°S reveal a weak southward mean flow superimposed by substantial intraseasonal to seasonal variability, including annual and semiannual cycles with distinct baroclinic structures. In the equatorial Atlantic these oscillations are associated with basin-mode resonances of the fourth and second baroclinic modes, respectively. Here, the role of basin-mode resonance and local forcing for the Angola Current seasonality are investigated. A suite of linear shallow-water models for the tropical Atlantic is employed, each model representing a single baroclinic mode forced at a specific period. The annually and semiannually oscillating forcing is given by 1) an idealized zonally uniform zonal forcing restricted to the equatorial band corresponding to a remote equatorial forcing or 2) realistic, spatially-varying Fourier components of wind stress data that include local forcing off Angola, particularly alongshore winds. Model-computed modal amplitudes are scaled to match moored velocity observations from the equatorial Atlantic. The observed annual cycle of alongshore velocity at 11°S is well reproduced by the remote equatorial forcing. Including local forcing slightly improves the agreement between observed and simulated semiannual oscillations at 11°S compared to the purely equatorial forcing. However, the model-computed semiannual cycle lacks amplitude at mid-depth. This could be the result of either underestimating the strength of the second equatorial basin-mode of the fourth baroclinic mode or other processes not accounted for in the shallow-water models. Overall, our findings underline the importance of large-scale linear equatorial wave dynamics for the seasonal variability of the boundary circulation off Angola.

Title: Sources and Propagation Pathways of Water Masses to the Northern Benguela Upwelling System

Authors and affiliations: Martin Schmidt [1], Lydia Siegfried [1], Volker Mohrholz [1], Tim Junker [1], Anja van der Plas [2], Pascal Nardini [3], Gerik Scheuermann [3] and Michael Böttinger [4]

[1] Leibniz-Institute for Baltic Sea Research Warnemünde, Germany

[2] National Marine Information and Research Centre, Namibia

[3] Universität Leipzig, Institute for Computer Science, Germany

[4] Deutsches Klimarechenzentrum GmbH, Germany

Abstract: We investigate sources and propagation pathways of water masses determining the hydrographic conditions in the Northern Benguela Upwelling System (NBUS). Our results challenge the common view on the water mass variability in the NBUS as derived from a classical water mass analysis and limited field data. From in-situ temperature and salinity measurements two major source water masses are well known, South Atlantic Central Water (SACW) and Eastern South Atlantic Central Water (ESACW). Both have different oxygen and nutrient characteristics. Mooring data have shown the direct relation between poleward SACW transport with a coastally trapped undercurrent and the oxygen conditions in the NBUS. Hence, the coastal wave guide is considered as the major pathway and direct link for poleward spreading SACW from the equatorial area into the NBUS. Based on a numerical tracer release experiment, we present a more comprehensive view on the origin of the water mass variability in the NBUS. We could identify three major source areas for water masses determining the hydrographic, oxygen and nutrient variability in the NBUS. In addition to the coastal wave guide, the South Equatorial Counter Current (SECC) and the South Equatorial Under Current (SEUC) reveal as major pathways of tropical SACW into the NBUS. Near the northern rim of the NBUS in the Kunene upwelling cell, south-eastward extensions of the SECC merge with the coastal flow (Angola current) and feed the poleward undercurrent. Away from the coast and on a decadal scale the simulated ocean current field partly resembles a Sverdrup balanced flow, indicating the importance of the large scale wind stress curl over the south-eastern Atlantic for the variability of the water mass composition, oxygen and nutrient conditions in the NBUS. We discuss seasonal cycle and interannual variability of conservative model tracers, oxygen and nutrient conditions in the NBUS in response to the wind field variability.

Title: Coastal trapped wave propagation along the southwest African shelf as revealed by moored observations

Authors and affiliations: Tim Junker [1], Volker Mohrholz [1], Martin Schmidt [1], Lydia Siegfried [1] and Anja van der Plas

[1] Leibniz-Institut fur Ostseeforschung Warnemünde (IOW), Germany

[2] National Marine Information and Research Centre (NatMIRC), Swakopmund, Namibia

Abstract: Coastal trapped waves (CTWs) that propagate poleward along the south west African shelf potentially leak energy from lower latitudes into the Benguela Upwelling System (BUS). Thus, in addition to the local winds, these waves provide an important remote forcing mechanism for the upwelling region.

The present study aims at elucidating the basic nature of CTWs in the northern BUS. To this end we make use of unique, multi-site velocity observations from the Namibian shelf (18°S, 20°S, 23°S). By means of wavelet methods, we examine the alongshore velocity signal for signatures of CTWs. We found that a substantial amount of energy is concentrated within a sub monthly to sub seasonal frequency band (10-50 d). Based on the coherence and phase spectra of the alongshelf currents, we provide evidence for a predominant southward phase propagation and establish typical time and length scales of CTWs in the region. It turns out that their properties differ significantly within a few hundred kilometres along the coast. A comparison of the results with theoretical dispersion curves shows that this difference is most likely explained by variations in the cross-shelf topography. Finally, we investigate the coupling of the alongshore currents with the coastal and equatorial wind stress and highlight regions of potential wave generation.

Title: Benguela Niño and Niña events from 1958 to 2015

Authors and affiliations: Rodrigue Anicet Imbol Koungue [1,2], Serena Illig [1,3], Mathieu Rouault [1,2]

[1] Department of Oceanography, MARE institute, University of Cape Town, South Africa

[2] Nansen-Tutu Centre for Marine Environmental Research, University of Cape Town, South Africa

[3] Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES, CNRS, IRD, UPS, Toulouse, France; part of the International Mixed Laboratory ICEMASA

Abstract: Benguela Niños and Niñas are intermittent, extreme warm and cold events that develop near the border between Angola and Namibia. These extreme events have been intensively studied these past years because of their significant impacts on the regional rainfall and the local marine ecosystem. Recently, Imbol Koungue et al. [2017], evidenced the role played by the Interannual Equatorial Kelvin waves during the onset of Benguela Niños and Niñas over 15 years (1997-2012). The present study is an update of the recent paper by Imbol Koungue et al. [2017]. We aim to revisit most of the Benguela Niños and Niñas developing before 1998 along the Angolan and Namibian coastlines using monthly averaged from an Ocean General Circulation Model (OGCM) for the period 1958 - 2015 which has been validated using available observation datasets. Preliminary results show the occurrences of 55 anomalous coastal events (29 warm and 26 cold) over the period 1958 – 2015. In agreement with recent studies, most of these anomalous coastal events are remotely forced via Interannual Equatorial Kelvin Wave (IEKW) propagations at interannual timescales with equatorial variability leading coastal SST variability by 1 month. Meridional transport anomalies across the ABF seem to contribute to the development of these anomalous coastal warm events. We show that October to April appears to be the favourable season in which anomalously warm or cold coastal events in the South-east Atlantic Ocean peak and are also linked to the remote oceanic forcing (IEKW).

Title: How does the low-frequency Equatorial Kelvin Wave activity, local ocean stratification, and coastal winds modulate the south-eastern interannual Atlantic variability?

Authors and affiliations: Marie-Lou Bachèlery [1,2], Serena Illig [1,3,4] and Mathieu Rouault [1,2]
[1] Department of Oceanography, University of Cape Town, Cape Town, Rondebosch, South Africa
[2] Nansen-Tutu Centre for Marine Environmental Research, University of Cape Town, South Africa
[3] Laboratoire d'Etude en Géophysique et Océanographie spatiale (LEGOS), CNRS/IRD/CNES, Toulouse, France
[4] MARE Institute, LMI ICEMASA, University of Cape Town, Cape Town, Rondebosch, South Africa

Abstract: The objective of this study is to describe the low-frequency modulation of the Equatorial Kelvin Wave (EKW) activity in the tropical Atlantic as well as the low-frequency modulation of the local stratification and coastal winds along the coast of south-western Africa. We aim at investigating the control of these forcings in modulating the oceanic interannual variability off the coasts of Angola/Namibia and the phenomenology of Benguela Niño/Niña events. The methodology is based on the development of a high resolution (1/12°) long-term (1958 - 2008) numerical simulation of the South-Atlantic Ocean using the Regional Ocean Modeling System (ROMS). The evaluation of the model performances show that the model is skilful in reproducing the mean state and the interannual variability. The evaluation of the equatorial forcing reveals a low-frequency modulation of the EKW activity with a significant reduction of the EKW energy from 1958 to 1990, then re-energized up to 2008. Variations are associated with change in EKW baroclinic mode contribution to interannual sea level anomalies: from 1958 the second baroclinic mode dominate, and is then balance by the third baroclinic mode after the late 1990's. Concomitantly, further analyses show a decrease of the wind stress forcing and a modulation of the magnitude of wind projection coefficients according to the oceanic baroclinic modes in the Guinea gulf with in particular a strong increase of the third EKW mode. Changes are associated with the increase (decrease) of the intensity (maximum depth) of the equatorial stratification. Our results suggest that the change in the remote equatorial forcing may play an important role in the modulation of the variability off the coasts of south-west Africa. These results will be confronted to the low frequency modulation of local wind variations and Coastal Trapped Waves (CTW) signature due to different stratification state along the south-eastern coast of Africa. Indeed, modulation of the coastal stratification will most likely impact the characteristics of CTW propagation and their efficiency to imprint the coastal interannual variability in the Benguela Upwelling System.

Title: Monitoring Rossby waves along 6 degree south in the tropical Atlantic

Authors and affiliations: Mathieu Rouault [1,2], Rodrigue Anicet Imbol Kounge [1,2] and Serena Illig [1,3]

[1] Department of Oceanography, MARE Institute, University of Cape Town, South Africa

[2] Nansen Tutu Center for Marine Environmental Research, Ma-re Institute, University of Cape Town, South Africa

[3] ICEMASA, LEGOS, IRD, France

Abstract: The PREFACE program allowed the deployment and annual maintenance of an ATLAS mooring at 6° S, 8° E during PREFACE cruises. A first mooring was bought by South Africa in 2006 and was deployed successfully for a year during a pilot project. PREFACE allowed to buy a second mooring needed to establish a permanent location as one replaced a mooring by a complete calibrated one. This is an extension of the PIRATA array of moorings in the tropical South-East Atlantic and an African contribution to the global observing system. PREFACE acquired an ATLAS mooring which is equipped with an extra currentmeter at 10 m depth and an extra short wave radiation sensor which allows calculation of the radiative flux and the net heat budget at a 10 minute temporal resolution. Turbulent sensible and latent heat fluxes can also be calculated at a 10 minute resolution. Sensible and Daily average is available in real time. A CO2 sensor is also deployed on the mooring. The strategic location of the mooring in the stratocumulus deck which is a problem to coupled models, offshore of the Congo River plume and upstream of the Angola Current make this mooring a unique measuring platform which has continuously worked in real time since May 2013. Mooring data and satellite remote sensing estimates of salinity indicates numerous intrusions of low salinity water from the Congo River since 2013. While the air and sea surface temperature (SST) distribution is unimodal, the upper ocean subsurface temperature and dynamic height is bi-modal and seems to be a seasonal Rossby wave triggered by a seasonal kelvin waves along the equator. PIRATA mooring, altimetry and SST allow monitoring the passage of Rossby waves all the way to Brazil modifying the SST in a region that is known to impact the regional Brazilian climate.

Rouault, M., Servain J., Reason C.J.R., Bourles B., Rouault M.J., Fauchereau N., 2009: Extension of PIRATA in the tropical South-East Atlantic: an initial one-year experiment. African Journal of Marine Science 2009, 31(1): 63–71

Title: Equatorial Deep Jets in the Atlantic Ocean studied by observations and ocean general circulation models

Authors and affiliations: Peter Brandt [1,2], Richard J. Greatbatch [1,2], Martin Claus [1,2], Jan-Dirk Matthießen [1], Franz Philip Tuchen [1], François Ascani [3], Marcus Dengler [1], John Toole [4], Christina Roth [1] and J. Thomas Farrar [4]

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany

[2] Christian-Albrechts-Universität zu Kiel, Germany

[3] Department of Oceanography, University of Hawai`i, Hawai`i, USA

[4] Woods Hole Oceanographic Institution, Woods Hole, MA, USA

Abstract: With the first few years of full-depth moored velocity observations in the central equatorial Atlantic at 23°W at hand showing the upward energy propagation of high vertical mode interannual zonal velocity oscillations, an impact of these so called Equatorial Deep Jets (EDJs) on sea surface temperature and climate was suggested. Much effort was devoted during the PREFACE period to the understanding of the dynamics, the energy sources and maintenance as well as the upward influence of EDJs. Here we will summarize the knowledge gained from the analysis of observational data and model output on the intricate chain of mechanisms and processes starting with the generation of intraseasonal equatorial waves by the instability of the mean wind-driven circulation via their downward energy propagation, the transfer of intraseasonal energy to maintain EDJs and the upward energy propagation of the EDJs. EDJs are composed of high vertical mode equatorial Kelvin and Rossby waves forming resonant equatorial basin modes. In the observational record of the Atlantic Ocean, oscillations of these basin modes have a quasi-steady period of about 4.5 years. EDJs are maintained against dissipation due to energy supply from intraseasonal variability with time scales of tens of days via the convergence of the meridional flux of intraseasonal zonal momentum. The energy transfer observed in the central equatorial Atlantic at 23°W is associated with downward and eastward beams of intraseasonal Yanai waves generated by Tropical Instability Waves (TIWs) near the surface west of 23°W. These Yanai waves interact with the pre-existing EDJs resulting in the energy transfer from high to low frequency variability. This observational evidence confirms results obtained by idealized and realistic simulations with ocean general circulation models. Moreover, model simulations show the quasi-steady oscillation of EDJs with a decadal modulation and an upward influence at the sea surface manifesting in enhanced variability of the North Equatorial Counter Current (NECC) with the same time scale.

Title: Deep Intraseasonal Variability in the Central Equatorial Atlantic

Authors and affiliations: Franz Philip Tuchen [1], Peter Brandt [1,2] and Martin Claus [1,2]

[1] Geomar Helmholtz Centre for Ocean Research Kiel, Kiel, Germany

[2] Christian-Albrechts-Universität zu Kiel, Germany

Abstract: Besides the zonal flow that dominates the seasonal and long-term variability in the equatorial Atlantic, energetic intraseasonal meridional velocity fluctuations are observed in large parts of the water column. 15 years of full-depth velocity data from an equatorial mooring at 23°W are used to investigate intraseasonal variability and specifically the downward propagation of intraseasonal energy from the surface into the deep ocean. Near the surface (20 to 50 m), intraseasonal variability at 23°W peaks at periods between 30 to 40 days. It is associated with westward propagating Tropical Instability Waves, which undergo an annual intensification in August. Enhanced energy levels of equatorial intraseasonal variability are observed down to about 2000 m. A frequency-vertical mode decomposition shows that meridional velocity fluctuations are more energetic than the zonal ones for periods < 50 days. The energy peak at 30 to 40 days and vertical modes 2 to 5 excludes equatorial Rossby or gravity waves and suggests Yanai waves to be associated with the observed intraseasonal energy. Yanai waves that are considered to be generated by Tropical Instability Waves propagate their energy from near the surface west of 23°W down- and eastward to eventually reach the mooring location. The distribution of intraseasonal energy depends largely on the dominant frequency and the time, depth, and longitude of excitation with the dominant vertical mode of the Yanai waves playing only a minor role. Observations also indicate the presence of weaker intraseasonal variability at 23°W below 2000 m that is not associated with Tropical Instability Waves.

Title: Inertial wave induced mixing in the tropical Atlantic: observations, parameterizations and impacts

Authors and affiliations: Markus Jochum [1]

[1] NBI, Denmark

Abstract: The strength of inertial wave induced mixing is estimated from the PIRATA array in the tropical Atlantic, and its impact is parameterized in the two different mixed layer models of CESM and NorESM. Despite the differences in their mixed layer models, the climate response is quite similar in both models: a northward shift of the Atlantic ITCZ, which represents a significant improvement for both models. A surprising challenge, however, is the exact quantification of the mixing: it turns out that most of the mixing is done during a few short events, which makes for rather poor statistics even with record lengths of several years. Based on our experience we provide some strategies with which future observational campaigns can improve our understanding of inertial wave induced mixing.

Title: Mixed Layer Heat Budget in the North-eastern Tropical Upwelling System: Two paradoxes of the temperature control in the Senegalese upwelling

Authors and affiliations: Saliou Faye [1], Alban Lazar [2] and Gregory Foltz [3]

[1] Centre de Recherche Océanographique Dakar-Thiaroye (CRODT/ISRA), Dakar, Senegal

[2] Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN/UPMC), Paris, France

[3] NOAA/Atlantic Oceanographic and Meteorological Laboratory, Miami, FL USA

Abstract: An oceanographic and meteorological buoy has been set up and dedicated to monitoring and analysis of the short and long-term changes in climate, atmosphere and marine environment within the Senegal coastal upwelling. The buoy ""MELAX"" was deployed early 2015 in the heart of the Senegalese upwelling by 35m-depth at (14,20'N, 17,14'W). Data collected are, for the atmosphere, surface wind, solar radiation, humidity and rain, and for the ocean, temperatures, salinity, and currents (from the surface to the bottom) and oxygen.

We present the first two years of observations, in particular the relationship between wind, sea surface temperature and currents. We also show the reconstruction of the heat budget which highlights the relative role of oceanic and atmospheric processes in the evolution of sea surface temperature. Buoy and model mixed layer budget are compared to provide a better understanding of thermodynamics within Senegalese upwelling.

Session 2 – Climate variability and teleconnections

Session 2.1 – Atlantic variability : ITCZ and atmosphere-ocean feedbacks

Title: Do SST gradients drive the monthly climatological surface wind convergence over the tropical Atlantic?

Authors and affiliations: Moussa Diakhaté [1,2], Alban Lazar [2], Gaëlle de Coëtlogon [3] and Amadou T. Gaye [1]

[1] Laboratoire de Physique de l'Atmosphère et de l'Océan-Siméon Fongang (LPAO-SF), Université Cheikh Anta Diop, Dakar, Senegal.

[2] Laboratoire d'Océanographie et Climat, Expérimentations et Approches Numériques (LOCEAN), Université Pierre et Marie Curie, France

[3] Laboratoire Atmosphère, Milieux, et Observations Spatiales (LATMOS), Université Pierre et Marie Curie, France

Abstract: We present a climatological study of the tropical Atlantic surface wind convergence, one of the main drivers of the marine intertropical convergence zone (ITCZ) precipitations, including coastal northeastern Brazilian and West African rainfalls. Climatological monthly mean surface wind convergence budget, as well as that of their month-to-month variations, is analysed over the 2000–2009 decade, using ocean–atmosphere reanalyses and satellite-derived data sets. Sea surface temperature (SST) influence is particularly investigated via comparison of its Laplacian with that of sea level pressure. Results for monthly means reveal that the Lindzen-Nigam paradigm does hold in regions of deep convection but only on their flanks. In deep convection regions, the budget analysis suggests the entrainment due to elevated heating by cumulus convection as the leading term. Elsewhere, over the 'open ocean ITCZ' meridional flanks, as well as over the 'coastal one' (Gulf of Guinea and northeastern Brazilian coasts), the pressure contribution is positive and largely dominated by its component below the boundary layer closely related to the SST. Horizontal advection is also found important over these areas, but with the pressure as the first-order driver. Otherwise, month-to-month variations of ITCZ are controlled by the geostrophy within the pressure contribution tightly dominated by the free tropospheric component.

Title: Equatorial Atlantic interannual variability and its relation to dynamic and thermodynamic processes

Authors and affiliations: Julien Jouanno [1], Olga Hernandez [2,1] and Emilia Sanchez-Gomez [3]

[1] LEGOS, Université de Toulouse, CNES, CNRS, IRD, UPS, Toulouse, France

[2] Mercator-Océan, Ramonville Saint Agne, France

[3] CECI-CERFACS, Toulouse, France

Abstract: The contributions of the dynamic and thermodynamic forcing to the interannual variability of the equatorial Atlantic sea surface temperature (SST) are investigated using a set of interannual regional simulations of the tropical Atlantic Ocean. The ocean model is forced with an interactive atmospheric boundary layer, avoiding damping toward prescribed air temperature as is usually the case in forced ocean models. The model successfully reproduces a large fraction (R2 = 0.55) of the observed interannual variability in the equatorial Atlantic. In agreement with leading theories, our results confirm that the interannual variations of the dynamical forcing largely contribute to this variability. We show that mean and seasonal upper ocean temperature biases, commonly found in fully coupled models, strongly favour an unrealistic thermodynamic control of the equatorial Atlantic interannual variability.

Title: The coupling between the ocean and the atmosphere in the equatorial Atlantic seasonal cycle

Authors and affiliations: Lander R. Crespo [1], Noel Keenlyside [1] and Shunya Koseki [1]

[1] Geophysical Institute, Bjerknes Centre for Climate Research, University of Bergen, Norway

Abstract: We investigate the ocean-atmosphere interactions in driving the seasonal cycle of the atmosphere in the tropical Atlantic basin. We force an atmospheric general circulation model with three different sea surface temperature (SST): (1) globally observed daily-climatological SST, (2) globally annual-mean SST, and (3) annual-mean SST in the equatorial Atlantic and daily-climatological SST elsewhere. The comparison between the three atmospheric model runs show that seasonal variations in SST strongly influence the seasonal evolution of the West African Monsoon and ITCZ over the equatorial Atlantic Ocean. Forcing the model with annual mean SST (globally and in the equatorial Atlantic) considerably reduces the seasonal variance in the atmosphere, except for the zonal winds in the central and eastern equatorial Atlantic. Equatorial Atlantic SST contributes to the seasonal cycle in precipitation and meridional winds over the entire equatorial Atlantic, but only strongly influences zonal winds in the western equatorial Atlantic. We conclude that the coupling between ocean and atmosphere is stronger in the western than in the eastern equatorial Atlantic. We are now using the output of the atmospheric model simulations to force an ocean general circulation model. We will use this to assess the role of active ocean-atmosphere interaction in the seasonal cycle in the equatorial Atlantic.

Title: Sea Surface Salinity signature of the tropical Atlantic interannual climatic modes

Authors and affiliations: F. Mesmin Awo [1,2,4], Gael Alory [2], Casimir Y. Da-Allada [1,3,4,5], T. Delcroix [2], Julien Jouanno [2], Ezinvi Baloïtcha [1]

[1] CIPMA, Université d'Abomey Calavi, Cotonou, Bénin.

[2] LEGOS, UMR CNES, CNRS, IRD, Université de Toulouse, Toulouse, France.

[3] IRD/LOPS, IFREMER, CNRS, Université de Brest, IUEM, Brest, France.

[4] LHMC/IRHOB, IRD, Cotonou, Benin.

[5] ESTBR/UNSTIM, Abomey, Benin

Abstract: A consistent Sea Surface Salinity (SSS) signature of the tropical Atlantic meridional and equatorial interannual modes is extracted from in situ observations and a regional numerical simulation, by a statistical analysis on the 1980-2012 period. Oceanic and/or atmospheric processes responsible for the signature of each mode are identified through a mixed-layer salt budget in the validated model. The meridional mode is associated in spring with a meridional SSS dipole in the equatorial band, due to changes in fresh water flux related to a meridional shift of the Inter-Tropical Convergence Zone (ITCZ). It is also associated with large SSS anomalies in the north and south west tropical Atlantic, due to advection of relatively fresh equatorial waters by strengthened western boundary currents, and off the Congo River where both meridional and vertical advection are involved. The equatorial mode is associated in summer with 3 zonal bands of alternating SSS anomalies between 5°S and 10°N. The southernmost band is due to vertical advection and diffusion at the mixed layer base, the two others to a shift of the ITCZ-related rainfall maximum, with additional contribution of meridional advection in the northernmost band. The equatorial mode also leads to large SSS anomalies in the North Brazil Current retroflection region, mainly due to horizontal advection of equatorial SSS anomalies. The SSS signatures of the meridional and equatorial modes are well captured by the SMOS satellite during particular events.

Title: Climates in oceanic regions characterized by low-level clouds

Authors and affiliations: Carlos R. Mechoso

Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles

Abstract: This presentation focuses on the tropical climate and addresses the fundamental subject of the influence of low-level (MLB) clouds over the oceans. Studies based on observational data and numerical models suggest that warmer sea-surface temperature (SST) reduces overlying cloudiness, thereby acting as a positive feedback on SST by increasing the amount of solar radiation reaching the ocean surface. Colder SST enhances MBL cloudiness, which similarly acts as a positive feedback. The clouds are generated and sustained by complex interplays among microphysical, radiative and turbulent processes, which are very challenging to parameterize in comprehensive global climate models (CGCMs).

We start by demonstrating that MLB clouds may amplify modes of interannual to interdecadal climate variability by means of a positive cloud-SST feedback. Typical summertime patterns of SST variability over the North Atlantic and Pacific and springtime patterns of interhemispheric SST variability over the tropical Atlantic in the observation are associated with co-located anomalies of shortwave cloud radiative effect, low-level cloud fraction, SST, and estimated inversion strength. These associations are consistent with a positive cloud-SST feedback. The simulation of such a feedback varies widely among CGCMs participating in phase 5 of the Coupled Model Intercomparison Project (CMIP5). We examine the impact of the feedback on model-to-model differences in the representation of patterns of coupled atmosphere-ocean variability. Models that simulate a cloud feedback magnitude that is too weak compared to that estimated from observations substantially underestimate the amplitudes of SST and cloudiness associated with these patterns of variability. Such models also underestimate the amplitude of atmospheric circulation associated with typical interhemispheric tropical Atlantic variability. Models with a more realistic feedback magnitude generally produce higher and more realistic amplitudes. The amplitudes of patterns of coupled atmosphere-ocean variability in simulations, therefore, are sensitive to the simulation of MLB cloud processes.

Next, we narrow down on the case of the anomalous high-magnitude warming of SST in the subtropical northeast Pacific, the marine low cloud region off Baja California, between January 2014 and September 2015, when SST sharply increased and the PDO shifted to its warm phase. It is shown that anomalously positive cloud-induced radiative flux was the dominant component of the energy budget of the ocean mixed layer during this period of warming off Baja California.

Title: Characterization of Rainfall Extreme Events by Dry Spell and Wet spell Analysis in Senegal - Cancelled

Authors and affiliations: Cheikh Modou Noreyni Fall [1], Amadou Thierno Gaye [1], Christophe Lavaysse [2], Cheikh Dione [3] and Mamadou Simina Dramé [4]

[1] Laboratory of Atmospheric and Oceanic Physics Simeon FONGANG, UCAD, Senegal

[2] JRC European commission, Ispra, Italy

[3] Laboratoire d'aérologie/Centre de recherches atmosphériques, Toulouse, France

[4] Department of physics, UCAD, Senegal

Abstract: In West Africa, rainfall is a a mean socio-economic factor for the people. For example in Senegal, we have 60% of the people who live from agriculture. At this time, the World Food Program (WFP) in his 2018 report said that Senegal is one of the seven Sahelian countries where the number of food-insecure people will increase significantly, from 314,600 people currently to 548,000 people during the 2018 lean season. While in this area, the water cycle has a high variability on all spatial and temporal scales and depends on the dynamics of the complex system of the West African monsoon. Rainfall is generated by Mesoscale convective systems and squall lines (Mesoscale convective systems multicellular) but also with local storm systems of any size, such as isolated thunderstorms. The spatial and temporal distribution of the seasonal cumulative rainfall depends on the number of occurrence of these various convective systems.

This work highlights the rainfall intraseasonal characteristics of Senegal. Using the synoptic observation network of ANACIM (National Agency of Civil Aviation and Meteorology) to and IRD (Institute of Research for Development) with 86 stations in Senegal, from 1990 to 2010. We have analysed many descriptors of the rainy season including wet and dry spells.

This high spatiotemporal variability is observed between stations separate by a few kilometres. Indeed, Diourbel recorded a rain deficit in 2007 season, while for the same year was in surplus Kaolack. The high frequency character with spatial variability of short Dry spell DS1 (1 to 3 days) an DS2 (4 to 7 days) is shown at the South of Senegal. While the DS3 (8 to 14 days) and the extreme dry spell DS4 (up to 14 days) show a low occurrence at the North but with more spatial variability. We have also observed that DS3 and DS4 reflect often the false start and early end of the season, while for the wet spell we have shown a dipolar shape, with a South-North gradient. The strong and long Wet Spell modulate meanly the seasonal accumulation rain but with a high spatial variability.

Title: Interdecadal changes in ocean teleconnections with the Sahel. Modulating role of the multidecadal SST background

Authors and affiliations: Roberto Suárez-Moreno [1], Belén Rodríguez de Fonseca [1,2], Jesús A. Barroso [1] and Andreas H. Fink [3]

[1] Universidad Complutense de Madrid (UCM), Department of Geophysics and Meteorology, Madrid, Spain

[2] Instituto de Geociencias, IGEO-CSIC, Madrid, Spain

[3] Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT), Germany

Abstract: The atmospheric response to global sea surface temperatures (SSTs) is the leading cause of rainfall variability in the West African Sahel. On interannual periodicities, the El Niño-Southern Oscillation, the Atlantic equatorial mode and Mediterranean warm/cold events primarily drive variations of summer rainfall over the Sahel. Nevertheless, the rainfall response to these modes of interannual SSTs variability has been suggested to be unstable throughout the observational record. This study explores changes in the leading patterns of co-variability between Sahel rainfall and SSTs, analysing the dynamical mechanisms at work to explain the non-stationary relationship between anomalies in these two fields. A new network of rain-gauge stations across West Africa is used for the first time to investigate these instabilities during the period 1921-2010. A hypothesis is raised that the underlying SSTs background seems to favour some interannual teleconnections and inhibit others in terms of the cross-equatorial SSTs gradients and associated impacts on the location of the Inter-tropical Convergence Zone. Results of this study are relevant for improving the seasonal predictability of summer rainfall in the Sahel.

Session 2.2 - External drivers of tropical Atlantic variability

Title: A warming hole in the equatorial Atlantic cold tongue region during the satellite era

Authors and affiliations: Hyacinth C. Nnamchi [1] and Mojib Latif [1]

[1] GEOMAR - Helmholtz Centre for Ocean Research Kiel, Düsternbrooker Weg 20, 24105 Kiel, Germany

Abstract: The equatorial Atlantic cold tongue is characterized by intense seasonal upwelling peaking during the boreal summer, which plays import roles in regional and global climate fluctuations. However, climatic trends in the cold tongue remain poorly understood due to poor observational coverage and biases in climate models. Here we analyse the past 35 years with generally improved observations, including satellite data, to show cooling trends in the cold tongue. Consistent with the annual cycle of the upwelling, the cooling trends are seasonally phase-locked to the summer months. The trends are associated with shifts in the latitudinal location of the inter-tropical convergence zone and consequently summer precipitation over West Africa. The underlying mechanism for the cooling trends appears linked to the intrusion of cold waters from beneath the thermocline. Greenhouse forcing experiment with a high-resolution version of the Kiel Climate model, with substantially reduced biases in the cold tongue, suggests that the cooling may be related to increases in atmospheric greenhouse gases.

Title: South Atlantic Anti-Cyclone as a driver of Atlantic Niño variability

Authors and affiliations: Noel Keenlyside [1,2], William Cabos Narvaez [3], Dmitry Sein [4], Shunya Koseki [1,2], Hyacinth Nnamchi [5]

[1] Geophysical Institute, University of Bergen, Norway

[2] Bjerknes Center for Climate Research, Bergen, Norwayand Bjerknes Centre, Bergen, Norway

[3] University of Alcalá, Alcalá de Henares, Madrid, Spain

[4] Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

[5] University of Nigeria, Nsukka, Nigeria

Abstract:

Atlantic Niño variability remains poorly understood and predicted, despite exhibiting some apparent similarities to the El Niño Southern Oscillation. Here we show that extra-tropical influences play a dominant role in driving Atlantic Niño variability, bringing a new dimension to our understanding. We assess the role of extra-tropical atmospheric variability in driving observed Atlantic variability by comparing ensemble simulations with two configurations of a regional coupled climate model. In one case the South Atlantic Anticyclone is prescribed at the southern boundary of the regional atmospheric model, while in the other it is simulated within the domain. In both configurations, atmospheric reanalysis drive the global ocean model outside of the coupled domain and are prescribed as boundary conditions to the regional atmospheric model. Extra-tropical southern hemisphere variability can explain around 50% of the observed Atlantic Niño variability. The greatest impact is from boreal spring and autumn. Comparing models different resolution and parameterisations shows the importance of representing the link between SAA and equatorial Atlantic variability in capturing the observed Atlantic Niño variability. The link between the two regions appears related to thermodynamic ocean-atmosphere interaction.

Title: Conciliating tropical Atlantic impact on ENSO

Authors and affiliations: Belén Rodríguez de Fonseca [1,2], Irene Polo [3], Elsa Mohino [1], Teresa Losada [1], Marta Martín del Rey [1,2], Noel Keenlyside [4] and C. Roberto Mechoso [5]

[1] Dto Fisica de la Tierra y Astrofisica, UCM, Madrid, Spain

[2] IGEO, Madrid, Spain

[3] Department of Meteorology, University of Reading, Reading, UK

[4] University of Bergen and Bjerknes Centre for Climate Research, Bergen, Norway

[5] Department of Atmospheric and Oceanic Sciences, UCLA, Los Angeles, USA

Abstract: Recent studies have found, in observations, windows of enhanced ENSO predictability from the tropical Atlantic variability. Thus, during some periods, Atlantic Niño is able to influence from previous summer in the atmospheric processes that trigger Pacific Niño. Other studies point to decades in which is the spring north tropical Atlantic anomalous sea surface temperature the optimal predictor of ENSO. These windows of predictability occur at multidecadal timescales, and studies put forward the Atlantic Multidecadal Variability as modulator. Nevertheless, no physical explanation has been found so far to explain the mechanisms behind this modulation. Here we analyse both connections in observations and Pi-control simulations from Phase 5 of the Climate Modelling Intercomparison Project (CMIP5). Results show how both, observations and CMIP5 models presents multidecadal modulation of the Atlantic-Pacific interbasin connection. Nevertheless, models are not realistic at reproducing the north tropical Atlantic-ENSO teleconnection and overestimated the influence on ENSO on equatorial Atlantic. While north tropical Atlantic –ENSO connection enhances 2-yr cycle El Niño, the Atlantic Niño-ENSO teleconnection presents a 4 year cycle. This last feature is also shown in models. For those periods in which the connection is enhanced, simulations present an negative interhemispheric gradient of sea surface temperature in the Atlantic and an meridional shifts of tropical rainfall. It has been concluded that the switch for the interbasin connections coincides with displacements of the Intertropical Convergence Zone, which can be associated with Atlantic Multidecadal Oscillation but also to other factors. Despite in models ENSO influence on the Atlantic is stronger than in observations and the Atlantic leading on the Pacific is weaker, the shift is found for all models. The present study confirms the existence of this connection, its periodicity and the causes leading to its emergence. Our results are of great interest for the seasonal to decadal prediction system.

Title: Role of the ocean dynamics in ENSO-tropical Atlantic teleconnection under warmer climate

Authors and affiliations: Marta Martín-Rey [1], Christophe Cassou [1] and Emilia Sanchez-Gómez [1]
[1] CECI-CERFACS, Toulouse, France

Abstract: El Niño-Southern Oscillation (ENSO) is the leading air-sea coupled mode of inter-annual variability in the tropical Pacific with worldwide climate impacts. Recent studies have reported that the Global Warming (GW), induced by GHG external forcing, could affect the ENSO phenomena in a long-term future climate (i.e. the frequency, intensity, spatial pattern) and consequently the ENSO teleconnections and impacts. In addition, the role of the internal climate variability seems to be crucial to amplify or attenuate the GW effect in the near-term horizon.

In the present study, we use a pacemaker protocol in a perfect model framework by using the coupled model CNRM-CM5 to investigate the influence of the mean background state (pre-industrial vs RCP85) on the ENSO teleconnection over the tropical Atlantic (TA). Two pacemaker experiments have been performed by restoring the SSTs anomalies, issued from a pre-industrial control simulation, over the eastern Tropical Pacific. Both experiments, consisting of an ensemble of 30 members each, only differ in the prescribed GHG forcing: Pre-industrial versus RCP85.

In a warmer climate, the mean Walker circulation is debilitated in the tropical band, causing anomalous subsidence over the eastern equatorial Atlantic during winter-spring. Additionally, the Atlantic Subtropical Highs are weakened and the ocean surface-subsurface connection is enhanced in the tropical Atlantic basin. Under the RCP85 scenario, the ENSO-TA teleconnection is reinforced, activating the ocean wave activity. In particular, the El Niño event originates a negative NAO-like pattern and in turn an anomalous reduction of the north-eastern trades in TA. This wind pattern at the surface is able to excite an oceanic Rossby wave north of equator that is reflected in the western boundary and propagates as an equatorial Kelvin wave from boreal spring to summer. The latter ENSO-TA teleconnection mechanism is much more prominent in a warmer climate, suggesting the importance of the background state in modulating the atmospheric ENSO signal and TA mean conditions, key elements for the effectiveness of the ENSO impact.

Session 3 – Climate Prediction

Title: Reducing climate model systematic error in the tropical Atlantic sector by enhancing atmospheric resolution: implications for seasonal to interannual variability and predictability

Authors and affiliations: Mojib Latif [1], Jan Harlaß [1], Sebastian Steinig [1] and Wonsun Park [1]

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany

Abstract: We investigate the influence of atmosphere model resolution on tropical Atlantic sector mean climate, seasonal to interannual variability and its predictability in the Kiel Climate Model (KCM). Biases typical for state-of-the-art climate models such as large errors in the sea surface temperature (SST) over the eastern tropical Atlantic can be strongly reduced in the KCM by employing high atmospheric resolution, horizontal and vertical. At high atmospheric resolution, simulation of the mean three-dimensional atmospheric circulation over the tropical Atlantic and the adjacent continents is much enhanced, which in turn improves simulation of tropical Atlantic ocean circulation and SST. Companion uncoupled atmosphere model simulations with observed SST reveal that the errors in the mean atmospheric circulation are systematic to the atmosphere model.

The enhanced mean state and seasonal cycle improves the simulation of tropical Atlantic interannual SST variability and its seasonal phase locking. Further, monthly to seasonal predictability of tropical Atlantic SST is enhanced at high atmospheric circulation, as well as the representation of the West African Monsoon and its relationship to the cold tongue development in the tropical Atlantic. We conclude that sufficiently high atmospheric resolution is a prerequisite to reduce climate model biases in the tropical Atlantic sector.

Title: Prediction of Short-term Tropical Atlantic Climate Fluctuations using A Coupled Climate Model with Different Atmosphere Model Resolutions

Authors and affiliations: X. Li [1,2], M. H. Bordbar [1], Mojib Latif [1,3], W. Park [1] and Jan Harlaß

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany

[2] Physical Oceanography Laboratory, Ocean University of China, Qingdao, China

[3] Excellence Cluster "The Future Ocean" at Kiel University, Kiel, Germany

Abstract: The Tropical Atlantic features several competing modes of climate variability such as those fluctuations which are similar to the El Niño/Southern Oscillation (ENSO) but with weaker amplitude and different seasonal phase locking. In contrast to the tropical Pacific, climate models generally fail to realistically simulate the climate mean state and the ENSO-like variability in the Tropical Atlantic due to model bias. The crucial role of atmosphere model resolution in refining ocean–atmosphere exchanges and thus improving climate mean state and variability over the Tropical Atlantic has been previously shown. However, the impact on the predictive skill is still under debate. Utilizing three commonly used approaches to predict short-term climate fluctuations, we examine the skill in predicting sea surface temperature anomalies (SSTAs) over the tropical Atlantic in a fully coupled climate model with identical oceanic model but different atmospheric resolutions.

In perfect model experiments, i.e. when predicting the model SSTAs, our analysis reveals a significant skill over much of the tropical Atlantic at lead times of one to two seasons and up to three seasons in the western Tropical Atlantic for forecasts initialized in boreal summer and fall, whereas it is the most skilful over the eastern sector when initialized in boreal spring.

Overall, our findings suggest that, in the presence of identical oceanic component, the skill in predicting Tropical Atlantic SSTAs is significantly enhanced when using high resolution in the atmospheric component which can be potentially related to the enhanced representation of ENSO-like dynamics in the model version with higher atmospheric resolution. This further supports the widespread efforts to refine the spatial and temporal resolutions in the climate models.

Title: Relationships among Inter-model Spread and Biases in Tropical Atlantic sea surface temperatures

Authors and affiliations: Elsa Mohino [1], Belén Rodríguez de Fonseca [1,2], Teresa Losada [1], Irene Polo [1,3] and C. Roberto Mechoso [4]

[1] Dto Fisica de la Tierra y Astrofisica, UCM, Madrid, Spain

[2] IGEO, Madrid, Spain

[3] Department of Meteorology, University of Reading, Reading, UK

[4] Department of Atmospheric and Oceanic Sciences, UCLA, Los Angeles, USA

Abstract: In this work we explore the reasons for spread in the simulation of monthly-mean sea surface temperature (SST) in the Tropical Atlantic (70ºW-20ºE; 20ºS - 20ºN) by 24 models participating in CMIP5. We use the output of piControl simulations and estimate the modes of inter-model variability by applying Principal Component (PC) analysis to the long-term climatological SSTs simulated in the Atlantic Ocean for the selected region. The first mode of inter-model variability is related to generally cooler SSTs, especially over the southern basin. A regression between the PC of this mode and the global SST field reveals worldwide connections with same-signed loads over most of the tropics, especially in the eastern Pacific. The mode is also connected with higher low cloud cover over the main upwelling regions of the world. The second mode of inter-model variability is restricted to the Atlantic basin with a north-south dipole of SST (defined by negative and positive loads to the north and south of the equator, respectively), with strongest loads in the subpolar gyre region. This mode is connected to a too weak Atlantic Meridional Overturning Circulation. The third mode is related to the double Intertropical Convergence Zone bias in the Pacific and to an interhemispheric asymmetry in the net radiation at the top of the atmosphere. Our results suggest that the main contributor to the mean bias pattern in the Tropical Atlantic is the second mode. Accordingly, those models that simulate weaker AMOCs tend to show stronger biases in the Tropical Atlantic. For those models, particular attention should be paid to the correct simulation of the Antarctic sea ice, as its underrepresentation is a potential cause for weakening the upwelling branch of the AMOC.

Title: The April Transition between Easterly and Westerly Wind Bias in the Tropical Atlantic in Hindcasts Using the ECMWF IFS

Authors and affiliations: Jon Shonk [1], Teferi Demissie [2] and Thomas Toniazzo [2]

[1] University of Reading, UK

[2] Uni Research Climate and Bjerknes Centre for Climate Research, Bergen, Norway

Abstract: Seasonal forecasting using coupled general circulation models is heavily affected by model drift that can dominate the forecasts. This is the case in the tropical Atlantic where equatorial westerly errors have a large impact particularly on the representation of coastal upwelling in the Benguela region (Voldoire et al. 2018).

Operational and non-operational forecasts with ECMWF's Integrated Forecasting System (IFS) atmosphere model, used in System 4 and EC-Earth, show that equatorial westerlies appear during a sudden transition in boreal spring corresponding to the establishment of a spurious southern ITCZ in the Atlantic. We analyse this transition in System 4, in parallel uncoupled (atmosphere-only) hindcasts prescribing observed SSTs, and in hindcasts run using EC-Earth version 2.3.

We find that the initial easterly and the subsequent westerly "bias regimes" are very different in terms of how the biases interact, and also that they originate from different components of the coupled model. The easterly regime shows strong trade winds that are associated with the development of a cold tongue bias and a double ITCZ, that develop in all models independent of the presence of coupling. The sharp weakening of the trade winds in the westerly regime occurs during April and is associated with the intensification of rainfall in the erroneous southern branch of the ITCZ in the coupled models. The excess convergence steers the trade winds away from the equatorial band, creating a windless zone between the two branches of the ITCZ. The establishment of a double ITCZ in the Atlantic is not dependent on a cold model bias over the Equator, and it cannot be explained by a traditional wind-induced surface heat exchange mechanism (Xie and Philander 1994) or by excessive convection over land (Richter and Xie 2008). We speculate that excessive boundary-layer stability in the transitional regime between marine stratocumulus and trade cumulus (Schreier et al. 2014), together with the geometry of the basin, tends to favour moisture convergence south of the Equator (Pauluis 2004) and associated convective precipitation in the tropical Atlantic.

Title: Role of wind stress in driving coupled model SST biases in the Tropical Atlantic

Authors and affiliations: Aurore Voldoire [1], Teferi Demissie [2], Anna-Lena Deppenmeier [3], Eleftheria Exarchou [4], Claudia Frauen [1,10], Katerina Goubanova [5,9], Noël Keenlyside [6], Shunya Koseki [6], Chloé Prodhomme [4], Emilia Sanchez-Gomez [5], Mao-Lin Shen [6], Jon Shonk [7], Thomas Toniazzo [2], Abdoul-Khadre Traoré [8]

[1] CNRM, France
[2] Uni Klima, Uni Research AS, Bergen, Norway
[3] Wageningen University, The Netherlands
[4] Barcelona Supercomputing Center, Spain
[5] CERFACS, France
[6] University of Bergen, Norway
[7] Reading University, UK
[8] LMD, France
[9] CEAZA, Chile
[10] IOW, Germany

Abstract: Coupled climate models used for long-term future climate projections as well as seasonal forecasts models share a systematic warm sea surface temperature (SST) bias in the tropical Atlantic. One of the objectives of the EU-FP7 PREFACE project is to better understand physical mechanisms responsible for the development of such systematic biases in the Tropical Atlantic using the Transpose-CMIP protocol. Six climate models have participated to the coordinated analysis: CNRM-CM-LR (CNRM), CNRM-CM-HR (CERFACS), EC-Earth v3.1 (WU, BSC), ECMWFS4 (UREAD), IPSL-CM (IPSL), and NorESM (UiB). Seasonal hindcasts simulations have been run starting in May and February over the period 2000-2009. In all models, 80% of the long term bias is reached in 6 months, confirming the rapid development of Atlantic warm SST biases. From these control experiments, it is shown that the equatorial SST bias is not driven by surface heat fluxes biases in all models whereas in the southeast the solar heat flux could explain the set-up of an initial warm bias in the first days.

Several sensitivity experiments to the wind stress allow disentangling the role of wind in driving the SST bias. These confirm the leading role played by wind stress bias in driving the equatorial SST bias, even if the amplitude of the bias depends on the model. The reduced SST bias lead to reduced precipitation locally but there is no remote effect on the West African Monsoon rainfall. Over the southeast, the local wind biases tend to have a local impact on the SST bias (except in the higher resolution model). However, there is also a non-local effect of equatorial wind correction in 2 models explained by sub-surface advection of water from the equator that is colder when the equatorial wind stress is corrected. It is also shown that improving the mean state in the equatorial Atlantic lead to an intensification of the Bjerknes feedback loop.

Title: Bias development and its impact on prediction skill as examined from daily mean output of a full-field initialization hindcast

Authors and affiliations: Ingo Richter [1] and Takeshi Doi [1]

[1] APL, JAMSTEC, Japan

Abstract: Current prediction systems struggle to skilfully predict sea-surface temperature (SST) variations in the tropical Atlantic, particularly in the equatorial and coastal upwelling regions. It is often assumed that this poor prediction skill is due to the severe SST biases that most models feature there. Some recent studies, however, indicate that the role of biases maybe less important than previously thought and that inherent predictability limits are one major reason for the poor skill in the tropical Atlantic compared to the tropical Pacific.

The present study uses a hindcast experiment with the SINTEX-F coupled general circulation model (GCM) for the period 1983-2016 to examine both the impact of biases on prediction skill and the root causes of the model biases in the tropical Atlantic. For this purpose, we analyse the bias evolution (the forecast drift) and its relation to prediction skill at daily time-scales. Since the model is initialized with the observed state, the forecast starts out with zero bias and gradually drifts towards its biased attractor during the forecast period.

Preliminary results suggest that the link between drift and prediction skill is not very strong. A good example is the Angola-Benguela upwelling region off the coast of southwestern Africa, were SST biases of up to 5 K gradually develop over the 6-month forecast period but the prediction skill often deteriorates within a few weeks. Other regions, such as the equatorial Atlantic and the northern tropical Atlantic, also exhibit relatively little sensitivity to SST bias. This suggests that forecast drift is not the main reason for the poor tropical Atlantic prediction skill of SINTEX-F.

Regarding the origins of eastern equatorial Atlantic SST biases, we find that, irrespective of initialization month, there are two periods of rapid development: July through August and December through February. The former period appears related to westerly wind biases in the western equatorial Atlantic, while the latter period is associated with a weakening of the local cross-equatorial winds.

Title: Seasonal prediction skill in the tropical Atlantic using anomaly coupling

Authors and affiliations: Lea Svendsen [1], Francois Counillon [1,2], Noel Keenlyside [1,2], Shunya Koseki [1], Teferi Demissie [3], Thomas Toniazzo [3], Yiguo Wang [2] and Ingo Bethke [3]

[1] Geophysical Institute, University of Bergen, and Bjerknes Centre for Climate Research, Bergen, Norway

[2] Nansen Environmental and Remote Sensing Center and Bjerknes Centre for Climate Research, Bergen, Norway

[3] Uni Research Climate and Bjerknes Centre for Climate Research, Bergen, Norway

Abstract: Current state-of-the-art models exhibit large climatological errors in the tropical Atlantic. To what extent this contributes to the poor seasonal prediction of these models in the tropical Atlantic remains unclear. Here we investigate this issue by comparing seasonal predictions with a standard and an anomaly coupled configurations of the Norwegian Climate Prediction Model (NorCPM), which aims at providing seasonal-to-decadal prediction by assimilating data into the Norwegian Earth system model (NorESM) with the Ensemble Kalman Filter. In the anomaly coupled configuration the climatological errors are reduced and the mechanisms for equatorial Atlantic variability are better represented. We also find significant prediction skill of equatorial Atlantic SSTs in August in the anomaly coupled configuration. Here we discuss the possible mechanisms for the improved prediction skill in August, and why the skill has not improved earlier in the year when Atlantic Niño events are initiated.

Title: Impact of Tropical Atlantic variability on Tropical Pacific predictability

Authors and affiliations: Eleftheria Exarchou [1], Maria Belén Rodríguez de Fonseca [2], Irene Polo [2,3] and Teresa Losada [2]

[1] Barcelona Supercomputing Centre, Bercelona, Spain

[2] Universidad Complutense de Madrid, Facultad de Físicas, Geofísica y Meteorología, Madrid, Spain

[3] National Centre for Atmospheric Science Department, Department of Meteorology,

University of Reading, Reading, UK

Abstract: Previous studies indicate the influence of Atlantic variability on ENSO frequency and variability (Wu and Kirtman, 2004; Dommenget et al. 2006; Jansen et al., 2009). Rodriguez-Fonseca et al (2009) shows that summer equatorial Atlantic anomalous SSTs are highly anticorrelated with the equatorial Pacific in the next winter months. The mechanism of the Atlantic/Pacific teleconnection involves an anomalous Walker circulation triggered by the anomalous SST over the eastern Tropical Atlantic, which results in anomalous easterly winds over western Pacific and thermocline perturbations that propagate eastward thus favouring the development of ENSO conditions (Losada et al., 2010; Polo et al., 2015).

Here, we use the NMME and EUROSIP multi-model seasonal prediction systems for the period 1981-

2014. In order to investigate the impact of the summer Atlantic variability on the predictability of ENSO, we compare retrospective forecasts initialized in February to forecasts initialized in June. We find that the June initialized forecasts have consistently higher skill in predicting ENSO than the February initialized at longer lead times, indicating a source of ENSO predictability in the initialization of June. We further find that models with high prediction skill over the summer Tropical Atlantic tend to both better reproduce the connection between the summer Tropical Atlantic SST and the winter Tropical Pacific SST, and also have higher skill in predicting the winter Tropical Pacific SST. Given that the Tropical Atlantic is an area of large and systematic biases and poor prediction skill (i.e. Richter et al., 2017) this study emphasizes the importance of correctly representing the Tropical Atlantic mean state and variability in order to improve Tropical Pacific predictability.

Title: Quantifying systematic climate model errors in the simulation of interannual and decadal climate variability in the tropical Atlantic region

Authors and affiliations: Davide Zanchettin [1], Carlo Gaetan [1], Maeregu Woldeyes Arisido [1,2], Jorge Lopez Parages [1,3], Angelo Rubino [1]

[1] University Ca'Foscari of Venice, Dept. of Environm. Sc., Informatics and Statistics, Mestre, Italy

[2] University of Milano Bicocca, School of Medicin and Surgery, Milano, Italy

[3] Universidad Complutense de Madrid, Departamento de Física de la Tierra, Astronomía y Astrofísica, Madrid, Spain

Abstract: The climatology simulated by current coupled climate models is affected by systematic errors compared to observations regarding mean state, seasonal cycle and interannual internal variability. Of these, the warm bias affecting south-eastern tropical Atlantic sea-surface temperatures is among the most critical.

In this contribution, we will illustrate two state-of-the-art statistical models for the quantification of the impact of climate model biases on the simulation of interannual and decadal climate variability in the tropical Atlantic region. Both models were developed within Work Package 10 of PREFACE and build on the state-space approach and share a Bayesian hierarchical framework, but are targeted at different aspects of the problem: The first model is focused on estimation of the purely temporal component of systematic model errors through structural decomposition, and uses the evolution of sea-surface temperature drifts in the Tropical Atlantic region from decadal climate predictions as a test bed; the second model is focused on the spatio-temporal assessment of the bias in a multi-model ensemble, and uses near-surface air temperatures over the Tropical Atlantic region from CMIP5 historical simulations as a test bed.

We will provide illustrative examples to demonstrate how the proposed methodology can help improving the characterization and understanding of the temporal as well as spatio-temporal evolution of systematic climate model errors, and hence for a more reliable interpretation of simulated interannual-to-decadal tropical climate variability.

Title: Revisiting the CMIP5 Thermocline in the Tropical Pacific

Authors and affiliations: Antonio Castaño-Tierno [1], Elsa Mohino [1], Belén Rodríguez de Fonseca [1] and Teresa Losada [1]

[1] Universidad Complutense de Madrid, Madrid, Spain

Abstract: The thermocline is defined as the ocean isotherm in which the vertical thermal gradient is maximum. In the Pacific Ocean, observations have led to the use of the 20 degree Celsius isotherm as an estimate of the thermocline. Nevertheless, such estimate is not necessarily as good a proxy in coupled models as in observational datasets. This work presents a comparison of the depth of the 20 °C isotherm and the depth of the layer of maximum temperature gradient for the equatorial Pacific Ocean. It is shown that there are significant differences between them in the CMIP5 preindustrial simulations. This is due to the 20 °C isotherm not being able to follow the thermocline correctly, mainly in the eastern region of the Pacific, where the cold tongue develops. A strong correlation between the depth of the 20 °C isotherm and the model sea surface temperature is found in the eastern boundary of the ocean, while in the western region the 20 °C isotherm is located below the thermocline. It is found that using the depth of the 20 °C isotherm as a proxy for thermocline depth for the whole of the Pacific Ocean might lead to errors in the assessment of the model ability to reproduce ocean-atmosphere interactions. These results might have implications in the study of model thermocline biases and their relationship with model sea surface temperature bias.

Session 4 – Marine ecosystems, fisheries management and climate change

Title: Spatial and temporal variability of primary production in the north-west African upwelling: A modelling approach.

Authors and affiliations: Pierre-Amaël Auger [1,3], Thomas Gorgues [3], Eric Machu [3], Timothée Brochier [5], Patrice Brehmer [2] and Olivier Aumont [4]
[1] Millenium Institute of Oceanography, Concepción, Chile
[2] Laboratoire des sciences de l'Environnement MARin, Brest – France
[3] Laboratoire d'Océanographie Physique et Spatiale, Brest – France
[4] Laboratoire d'Océanographie et du Climat : Expérimentations et Approches Numériques, Paris – France
[5] UMMISCO, Bondy, France

Abstract: An analysis based on a multi-decadal physical–biogeochemical hindcast simulation (1980–2009) was conducted to characterize the drivers of the spatial distribution of phytoplankton biomass and production in the north-west (NW) African upwelling system. To that end, a comparative box analysis representing homogeneous sub-regions in the NW African upwelling system has been conducted. The sub-regions have been defined using the near-surface horizontal circulation patterns. In each box, we analysed the dynamics of primary productivity and nutrients with regard to advective and diffusive matter fluxes at the boundaries and local biological production and/or uptake. The nature and variability of the matter exported from the coastal margin to the adjacent open ocean were also subsequently depicted. This variability of the primary production may impact the distribution and abundance of fish populations, and their associated fisheries, on a large range of timescales.

Title: Synthesis of prey field dynamics and the analysis of tuna dynamics to qualitatively evaluate the prospect for future fisheries in the tropical eastern central Atlantic

Authors and affiliations: Heino O. Fock [1], Stephanie Czudaj [2], Ivanice Monteiro [2] and Péricles Silva [2]

[1] Thünen-Institute (TI), Institute of Sea Fisheries, Federal Research Institute for Rural Areas, Forestry and Fisheries, Palmaille 9, 22767 Hamburg, Germany

[2] Instituto Nacional de Desenvolvimento das Pescas (INDP) and Ocean Science Centre Mindelo (OSCM), Mindelo, Sao Vincente, Cabo Verde

Abstract: The evaluation is based on the analysis of prey length spectra and biomass size spectra on the one side and tuna catch rate dynamics on the other side. The production of tuna is determined by the amount of primary production PP transferred to higher trophic levels TL by PP × TE (TL − 1), where TE is trophic efficiency. TE is determined by TE=exp((b-0.25)*lg PPMR), where b is the slope of biomass spectrum and PPMR is the size ratio of predators to prey. The analysis of prey dynamics revealed no change in minimum or maximum sizes of the species indicating no change in PPMR. However, significant differences in size structure were indicated in 20 out 28 species. Slopes of normalized biomass size spectra steepened in 2015 for the tropical (-0.88 to -1.4) and subtropical region (-1.08 to -1.28). The slope for the temperate region was -0.44 in 1966-79. Maximum sizes for all species were smaller in the oxygen minimum region, associated with significant changes in size structure.

Local dynamics of Yellowfin tuna (*Thunnus albacares*, YFT) catch rates covering the area 10-20°N latitude and 10-30°W longitude indicate a positive dependency on cooling in the tropical North Atlantic in springtime and a weakening of autumn winds in September and October. The evaluation shows that negative effects due to changes in TE can be counterbalanced by improved stock management.

Title: Yellowfin tuna catch opportunities in Cape Verde – coping with uncertainties of local CPUEs

Authors and affiliations: Ivanice Monteiro [1], Pericles Silva [1] and Heino O. Fock [2]

[1] Instituto Nacional de Desenvolvimento das Pescas (INDP) and Ocean Science Centre Mindelo (OSCM), Mindelo, Sao Vincente, Cabo Verde

[2] Thünen-Institute (TI), Institute of Sea Fisheries, Federal Research Institute for Rural Areas, Forestry and Fisheries, Palmaille 9, 22767 Hamburg, Germany

Abstract: One of the aims of the PREFACE project (EU FP7 GA. N. 603521) work package WP12.1 is to analyse Yellowfin tuna (*Thunnus albacares*, YFT) catch opportunities in the waters of Cabo Verde and to investigate the effect of climate. Local catch-per-unit-effort (CPUEl) is treated as a function of stock size, Ns, and environmental factors, Vi, the latter at local scale or in terms of climate indices. For tuna stocks, no fisheries independent information is available. This limits the potential to calculate unbiased abundance and distribution indices. We analyse local YFT catches with different statistical models to account for uncertainty in local abundance data. Catch data both from artisanal and industrial fisheries were acquired for the area 10-20°N latitude and 10-30°W longitude to indicate catch opportunities in Cape Verde waters. In this presentation, we emphasize on the assumptions underlying the calculation of local CPUE and model weighting to take account of for instance aggregation behaviour both of fishermen and tuna.

Title: Hydrographic control on larval fish assemblages: Lessons from the Canary Current Ecosystem

Authors and affiliations: Maik Tiedemann [1,2,6], Heino Fock [1], Patrice Brehmer [2], Julian Döring [3], Gregor Börner [4], Shawn Dove [5], Werner Ekau [3], Christian Möllmann [6]

[1] Thünen-Institute (TI), Institute of Sea Fisheries, Federal Research Institute for Rural Areas, Forestry and Fisheries, Palmaille 9, 22767 Hamburg, Germany

[2] Institut de Recherche pour le Développement (IRD), Dpt Ocean, UMR 195 Lemar, IRD Délégation Régionale Ouest, Campus Ifremer, 29280, Plouzané, France

[3] Leibniz Centre for Tropical Marine Research (ZMT), Fahrenheitstraße 6, 28359 Bremen, Germany

[4] Humboldt University, Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences, 12587 Berlin, Germany

[5] GEOMAR, Helmholtz Centre for Ocean Research Kiel, Düsternbrooker Weg 20, 24105 Kiel, German

[6] Institute for Hydrobiology and Fisheries Science, Center for Earth System Research and Sustainability (CEN), Klima Campus, University of Hamburg, Grosse Elbstrasse 133, D-22767 Hamburg, Germany

Abstract: Fronts, eddies, and upwelling shape larval fish habitats in the Canary Current Ecosystem. In the last five years, five sea-going expeditions have been undertaken to investigate the influence of these ocean processes on the life of fishes and their early life stages. The use of different sampling techniques (e.g. midi/maxi multinet, GULF VII, and CTD) allowed us to understand horizontal and vertical larval fish distribution patterns. Frontal zones that function as natural barrier for plankton drift were identified enabling the formation of spatially segregated larval fish assemblages. Mesoscale eddies compensated an offshore drift of water masses during the upwelling process retaining fish larvae at the shelf break. An upwelling intensity driven spatio-temporal niche partitioning was observed between larval round sardinella (*Sardinella aurita*) and larval European sardine (*Sardina pilchardus*). While climate models predict a change of the upwelling intensity in upwelling ecosystems, we suggest that dominance relationships of small pelagic fishes will fluctuate according to upwelling intensity variation. The results of our studies improve the understanding of how fishes avail the dominant physical features in upwelling ecosystems and aid to comprehend population dynamics.

Title: *Sardinella aurita* growth parameters variability under the balanced effects of climate change and fishing pressure

Authors and affiliations: Bocar Sabaly Balde [1,2,3,4], Fambaye Ngom Sow [2], Kamarel Ba [2], Werner Ekau [3], Justin Kantoussan [5], Massal Fall [2], Patrice Brehmer [4], Malick Diouf [1]

[1] Université Cheikh Anta Diop (UCAD), Institut Universitaire de Pêche et d'Aquaculture, UCAD II Bâtiment Pédagogique / Rez-de-chaussée, BP 45784, Dakar–Fann, Sénégal

[2] Institut Sénégalais de Recherche Agricole (ISRA), Centre de Recherche Océanographique de Dakar-Thiaroye (CRODT), BP 2241, Centre PRH, Dakar, Senegal

[3] Leibniz Center for Tropical Marine Ecology (ZMT), GmbH- Fahrenheitstraße 6, 28359 Bremen, Germany

[4] Institut de Recherche pour le Développement - France (IRD), UMR 195 Lemar, BP 1386, Dakar, Sénégal

[5] Université Gaston Berger (UGB), Unité de Formation et de Recherche des Sciences Agronomiques, de l'Aquaculture et des Technologies Alimentaires (UFR S2ATA), Saint-Louis, Senegal

Abstract: *Sardinella aurita* is an overexploited small pelagic fish and a key species in Senegal at socioeconomics level, nevertheless the growth parameters which is a good indicator of fish stressors, have not been updated since 30 years. In this work, we analysed *S. aurita* (n = 32 300) age and growth in Senegal taking into account the tropical seasonality. Growth parameters are then compared with those previously obtained in the literature on the same geographical area (since 60 to 34 years) and more widely in different locations in tropical North Atlantic and Mediterranean Sea. The results show a significant difference of growth parameters in Senegal since thirty years, indeed growth of *S. aurita* became slower and its maximum size has significantly decreased. The comparison of *S. aurita* variability in growth performance reported in Mauritania-Senegal coast, as well as in Mediterranean Sea and Eastern/Western Atlantic Ocean reveals a significant influence of environmental parameters and/or the level of exploitation. In one hand in tropical Atlantic, *S. aurita* growth in Eastern Central is similar to the one reported in Western Central, while *S. aurita* growth is rather slow in Mediterranean Sea where, vs tropical Atlantic, Sea temperature and prey availability are lower. On the other hand, in the Atlantic Western Central, where the fishing pressure on the stock is lower over the last decade vs Atlantic Eastern Central, an increase in asymptotic length is observed, while in the Mediterranean Sea and Atlantic Eastern Central, where the fishing pressure is higher, the asymptotic length has drastically decreased. We assume that the fishing pressure and the climate change, or a combination of both, have an effect on the biological parameters of *S. aurita*.

Title: On the role of equatorial warm events in expanding the southward range of *Sardinella aurita* along Angolan coast.

Authors and affiliations: Marek Ostrowski [1], Antonio Barradas [2] and Jens Otto Krakstad [1]

[1] Institute of Marine Research, Nordnesgaten 50, 5817 Bergen, Norway

[2] Instituto Nacional de Investigacaõ Pesqueira, C.P.2061, Luanda, Angola

Abstract: Sardinella caught in Angolan waters belongs the southeastern sardinella stock inhabiting coastal waters from Cape Lopez in Gabon (0.5°S) to the Angola Benguela Front (ABF,17°). Since mid 2000s, a growth of the sardinella biomass is observed in the southernmost regions of Angola, in the Central Region (9°-13°S) where recently 70% of the stock is observed compared to 30 % during 1990s and in the ABF region (13°-17°) where there had not been a full annual life cycle presence of sardinella before 2006. The analysis of fish length data suggests that the observed biomass increase occurs due the migration of adult fish from the more northerly, warmer areas along the coast. A hypothesis is proposed that warm equatorial events increase availability of *S. aurita* to fisheries along the southern Angolan coast. Austral summer (October to March) is the season prompting southward migrations of sardinella in Angolan waters. Coastally trapped waves of equatorial origin depress the thermocline inhibiting upwelling. The Congo River flooding waters that have been accumulated in the open ocean during past fluvial discharge events intrude onto the Angolan shelf driven by the seasonally accelerated Angolan Current. With the upwelling inhibited, poor feeding conditions set in and cue the southward fish migration. The period 1995-1999 was characterized by a strong interannual equatorial activity with a seasonally locked episodes occurring every summer, but then stock was dominated by the climate resistant *S. maderensis*. Seasonal migrations along the coast were observed but these did not expand the geographical range of the stock. In 2004, *S. aurita* first appeared in significant numbers in Angolan waters, coincident to the decadal minimum of the Congo River discharge (2004-2005). *S. aurita* reacts to the summertime food scarcity with a much longer migration range compared to *S. maderensis*. In 2006, it expanded to the ABF region (13°-17°S); at the same time its numbers were substantially reduced along the Gabonese and Congolese coasts (0.5°-5°S). In the summer 2012, one year after the major 2011 Benguela Niño event, the biomass of *S. aurita* in the ABF contributed the highest proportion to the total biomass in Angola.

Title: A promising effect of El Niño on sardinella distribution along the northwest African coast: a potential source of seasonal predictability?

Authors and affiliations: Jorge López-Parages [1], Belén Rodríguez de Fonseca [1], Timothée Brochier [2], Pierre-Amael Auger [3], Davide Zanchettin [4], Angelo Rubino [4], Carlo Gaetan [4] and Noel Keenlyside [5]

[1] Dpto. de Física de la Tierra y Astrofísica, UCM-IGEO, Complutense University of Madrid, Spain

[2] Institute of Research for Development, Paris, France

[3] Milenio Oceanographic Institute, Valparaíso, Chile

[4] Dpto di Scienze Ambientali, Informatica e Statistica, Ca Foscari University of Venice, Italy

[5] Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway

Abstract: Many questions remain open concerning the effect of environmental variability on abundance and distribution dynamics of round sardinella (*Sardinella aurita*) over the Canary upwelling system. This issue is of special relevance due to the great role that sardinella plays in northwest African fisheries and marine ecosystems. Here, the possible climate drivers of sardinella population migration along the northwest Africa are addressed. To this aim, we have used data provided by the coupled model compounded by the Regional Oceanic Modelling System ROMS, configured for the northwest African upwelling system, and by the biogeochemical model PISCES, which simulates plankton productivity and carbon biomass based upon the main nutrients. This coupled model has been run over the period 1980-2009 using an atmospheric reanalysis and consistent oceanic boundary conditions. Finally, an evolutionary individual-based Lagrangian model has been used to simulate the spatio-temporal behaviour of sardinella according to the environmental constraints obtained from ROMS-PISCES. Strikingly, a robust anomalous increase (decrease) of sardinella biomass has been identified from early to late winter off Cape Blanc (Saharan coast) in response to the Pacific El Niño conditions. This dipolar pattern reflects an alteration of the normal migration of sardinella between the Saharan and the Mauritanian waters and seems to be primarily mediated by the effect that El Niño-related anomalous winds has on the meridional currents along the northwest African coast. This sardinella response to El Niño is reinforced in late winter through an anomalous warming of the Mauritanian waters due to an anomalous weakening of coastal upwelling also forced by the aforementioned El Niño-related anomalous winds. According to our results this anomalous response of sardinella biomass might be predicted, for El Niño years, few months in advance from the El Niño-related SST patterns. This fact opens the possibility to the development of predictive tools, which should be necessarily assessed in further works.

Title: Intense warming causes a spatial shift of small pelagic fish: early warning for food security in North-West Africa

Authors and affiliations: Abdoulaye Sarre [1], Hervé Demarcq [2], Noel Keenlyside [3], Jens-Otto Krakstad [4], Saliou Faye [1], Djiga Thiao [1], Salaheddine El Ayoubi [5], Ould Taleb Mohamed Ahmed [6], Ebou Mass Mbaye [7], Adama Mbaye [1], Patrice Brehmer [8]

[1] Centre de Recherche Océanographique de Dakar-Thiaroye, BP 2241, Dakar, Senegal

[2] Institut de Recherche pour le Développement, UMR-248 MARBEC, Centre de Sète, Avenue Jean Monnet, CS 30171, 34203 Sète cedex, France

[3] Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway,

[4] Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway

[5] Institut National de Recherche Halieutique (INRH), Casablanca, Morocco

[6]Institut Mauritanien de Recherche Océanographique et des Pêches (IMROP), BP 22, Nouadhibou, Mauritania

[7] Fisheries department (FD), Banjul, The Gambia

[8] Institut de Recherche pour le Développement, Campus IRD-UCAD, UMR-195 LEMAR, BP 1386, Hann, Dakar, Senegal

Abstract: Along the coast of North-West Africa, fish supply is important at both socio-economic and cultural levels. Reports by fishermen emphasise changes in the distribution of fish species important for food security. Northward shifts in the distribution of sardinella and other species have been attributed to a warming trend and the redistribution of upwelling intensity and productivity. As a result, the abundance of sardinella along the coast has increased in the subtropics and fallen in the intertropical region. Independent observational time series confirm a robust northward shift in *Sardinella aurita* since 1995, which we attribute to the intense warming of this region, where the greatest increase in sea surface temperature of all tropical regions is found. The spatial shifts in biomass of several hundred kilometres observed during the last 20 years are of the same order of magnitude as those recorded for surface isotherms in the sub-regional pelagic habitat of sardinella. Such changes are an important policy consideration for food security management in several West African countries.

Title: Climate change and seasonality of small pelagics: impacts on their value chain in Senegal

Authors and affiliations: Adama Mbaye [1], Aliou Ba [2], Jörn Schmidt [3], Fambaye Ngom [1], Modou Thiaw [1], Patrice Brhemer [2], Abdoulaye Sarré [1], Djiga Thiao [1]
[1] ISRA/CRODT/Sénégal
[2] IRD/France/Sénégal
[3] Kiel université/Germany

Abstract: Factors influencing landed prices and those of processed products (fish and processed) are mainly landed quantities and product quality. The latter are in turn influenced by the seasonality of sardinella conditioned by the temperature of the water. It is usually in cooroon periods (April to June) that sardinella landings are more important and it is at this time also that the prices of fresh fish and processed products are the lowest. On the other hand sardinella is rare in lolli most often (October to December) and it is at this period also that the prices are generally higher. Nevertheless, depending on whether one is on the Petite Côte or on the Grande Côte, fishermen's appreciations of the periods of abundance of sardinellas differ. However, from the analysis of fishermen's knowledge on sardinella migration and bioecological models, it appears that sardinella are present on Senegalese coasts during periods of low temperature. As the cold water periods are later and shorter, the sardinella will be increasingly rare on the coast in Senegal, its higher price, accessibility is more difficult and consequently the animal protein deficit of the populations more accentuated.

Title: The economic impacts of Marine Protected Area on Senegalese small pelagic fisheries

Authors and affiliations: Aliou Ba [1,5], Christian Chaboud [2], Jörn Schmidt [3], Malick Diouf [4], Massal Fall [5], Moustapha Dème [5], Patrice Brehmer [1,5]

[1] Institut de Recherche pour le Développement - France (IRD), UMR 195 Lemar, BP 1386, Dakar, Sénégal

[2] Institut de Recherche pour le Développement - France (IRD), UMR Marbec, Sète, France

[3] University of Kiel (CAU), Department of Economics, Wilhelm-Seelig-Platz 1, 24118, Kiel, Germany

[4] Université Cheikh Anta Diop (UCAD), Institut Universitaire de Pêche et d'Aquaculture, UCAD II, BP 45784, Dakar, Sénégal

[5] Institut Sénégalais de Recherche Agricole (ISRA), Centre de Recherche Océanographique de Dakar-Thiaroye (CRODT), BP 2241, Centre PRH, Dakar, Sénégal

Abstract: In the early 2000s, Senegal set up several Marine Protected Areas (MPAs) along its coastal zone for the purpose of biodiversity conservation and the sustainably of fisheries. However, the impact of MPAs may vary depending on the types of fishing. In Senegal, the sardinella fishing accounts for 70% of total catches. This fishery is of crucial for food security and employment. Given this importance, it is necessary to evaluate the impact of the MPAs often considered as a tool for fisheries management. An analytical, dynamic and spatial bio-economic model of sardinella fishery has been developed and simulations over 40 years were carried out. The model takes into account the migration of the resource and that of fishermen. The main results show that the fishery is economically overexploited and that the society loses about 15 billion CFA over 40 years of exploitation, i.e. 375 million CFA per year. To reach an optimal level of exploitation, it would be necessary to halve the current fishing capacity. The closure rates of 10, 20 and 30% lead to increases in biomass (8 to 28%) and rent (5 to 11%). Spatio-temporal closure measures lead inevitably to overcapacity in unclosed areas. The objective 11 of the Aichi Convention will have a reserve effect on the resource but also weak improvements in economic indicators for this fishery. Lastly we show that if we expect that the MPAs provide a significant impact on sardinella fishery in Senegal, they should be accompanied by a limitation of fishing capacity.

Title: Empirical bio-economic modelling of small-scale artisanal fisheries under climate change: A new approach and application to the Senegalese purse-seine fishery

Authors and affiliations: Kira Lancker [1], Lorena Fricke [1], Jörn Schmidt [1]

[1] Department of Economics, Christian Albrechts University of Kiel, Wilhelm-Seelig-Platz 1, 24118 Kiel, Germany

Abstract: Artisanal open access fisheries are an important source of protein in many developing regions, and they provide livelihoods for millions of people. They are, however, challenged by changing environmental and local market conditions. Quantitative bio-economic models of such fisheries are needed to inform resource management and climate adaptation policies. The empirical estimation of model parameters faces issues of endogeneity, as local markets provide significant links between quantities and prices, and data is often scarce and of poor quality.

Here, we present a bio-economic model based on standard resource economics assumptions, which is able to explain non-linear impacts of environmental variations (climate and catchable biomass) on output and prices. We present an estimation approach that efficiently utilizes scarce data by directly estimating dynamic model equations and that averts endogeneity bias by means of a two-step estimation procedure. The ensuing exogenous environmental impact estimates can be used for robust prediction beyond the currently observed environmental state. In addition, the approach is able to analyse a fisheries vulnerability to environmental variations by disentangling regional supply and demand particularities. An application to the Senegalese purse seine fishery targeting small pelagics illustrates the link between environmental impacts and economic outcomes. An analysis of welfare effects quantifies consequences for livelihoods and food security.

Title: Managing environmental impacts and decrease in Marine Fish Catch: perceptions and strategies by fisher folks in coastal Nigeria

Authors and affiliations: Nnaemeka Andegbe Chukwuone [1], Jorn Schmidt [2], Kira Lancker [2] and Ebele Chinelo Amaechina [3]

[1] Centre for Entrepreneurship and Development Research (CEDR) and Department of Agricultural Economics, University of Nigeria, Nsukka, Enugu State, Nigeria

[2] University of Kiel, Germany (CAU), Department of Economics

[3] Department of Agricultural Economics, University of Nigeria, Nsukka, Enugu State, Nigeria

Abstract: Despite the significant level of dependence on the resources from Nigeria coastal areas, it has become highly degraded due to lack of proper management and the additional threat of environmental and climate variability. There has been unprecedented decline in fish stocks, over harvesting and over fishing in Nigeria coast. In fact, catch by artisanal fishermen manifest the degrading stock as landings are dominated by juveniles while certain valued species are disappearing. For example, the result of a short day survey in areas of Nigeria's coastal waters under the Gulf of Guinea Large Marine Ecosystem survey revealed a high proportion of under-sized fish species or juvenile to the tune of 70-90% in each haul, less than 15 cm in size. This situation persists despite the fact that one of the central goals of the government is to achieve a substantial, but sustainable increase in production. In order to find ways to reverse this ugly situation, this study determined the perceptions and strategies employed by artisanal fisher folks in coastal Nigeria in managing environmental impacts and decline in fish catch and estimated the socioeconomic factors that influence management strategies. A total of 1105 fishermen from 17 core fishing grounds in eight coastal states across Nigeria, 65 fishermen in each fishing ground, were interviewed. Weights were applied to the fishermen in the artisanal sector and in the semi-industrial sector to reflect the population of fishermen in coastal Nigeria. Descriptive statistics and multinomial logit model was applied in achieving the objectives. The findings revealed that petroleum pollution was the major environmental issue that impacts on fish and fishing gear causing death of fish resources. The major coping strategy to petroleum pollution was changing fishing grounds or doing nothing. The findings also revealed that the majority of the fishermen experienced decrease in fish catch in the last 10 years. The major reason for decrease in demersal and pelagic species catch was due to encroachment by industrial fleet and petroleum pollution. Reduction of expenditure on household consumption, increase in income from non-fishing activities and using savings as buffer were the main financial management strategies employed by fishermen in coping with decline in fish catch. Some socioeconomic and social capital factors influenced the management strategies employed by the fishermen. We recommend that policies to check petroleum pollution of the marine area; and increased surveillance to check the encroachment of industrial fleet in areas within the five nautical miles as in Nigeria fisheries regulation should be encouraged. Also providing financial incentives to the fisher folk especially middle aged and poorer ones through their associations would help them cope with decline in catch and also reduce their extent of fishing as they would invest in non-fishing activities and thus help in ensuring sustainable fisheries.

POSTER PRESENTATIONS

Session 1 – Ocean Processes

Title: Mixed layer heat/salt budget and Equatorial Under-Current dynamics in the tropical Atlantic from a joint model-observations approach

Authors and affiliations: Olivia Kom [1], Gaël Alory [2], Casimir Da-Allada [1] and Julien Jouanno [2]

[1] CIPMA, Benin

[2] LEGOS, France

Abstract: Climatological mixed layer heat/salt budget terms derived from a NEMO 1/4° forced model simulation and from a PREFACE observation-based product are compared in the eastern tropical Atlantic. Mean spatial patterns of mixed layer depth, SST and SSS are in good agreement despite some local biases. For the annual mean heat balance, atmospheric fluxes are quite different along the coasts, while horizontal advection mostly differs around the equator, maybe due to the low resolution of the observations (2.5°) that cannot resolve small meridional scales. The seasonal heat balance is compared in boxes off Angola, in the northeast Gulf of Guinea and in the Atlantic cold tongue. Seasonal variations of heat fluxes are correlated except in the last box, while advection is everywhere poorly correlated. For the annual mean salt balance, model and observations show similar freshwater fluxes, with larger spatial contrasts in the model, while advection mostly differs around the ITCZ. In the Benguela region, model and observations roughly agree on freshwater fluxes and advection seasonal variations. Off Angola, SSS variations are uncorrelated. The observed product does not explicitly resolve vertical diffusion, an important process for the heat/salt balance in the Gulf of Guinea.

The seasonal characteristics of the simulated EUC transport are compared to observations based on cruises and moorings at 23°W. In the model, the EUC transport is slightly larger than observed on average, while its seasonal cycle is of comparable amplitude and shows a maximum around September and minimum in November, leading the observations by one month. The maximum velocity is also biased high but seasonal cycles are consistent and roughly phased with the transport seasonal cycle. The EUC core in the model is shallower than observed but with a similar seasonal cycle and coinciding maxima in depth and transport. Its latitudinal position is more south of the equator, with a seasonal cycle opposite in phase and larger than observed. A test simulation with interannual wind forcing but climatological fluxes forcing is compared to the reference simulation to identify the respective role of dynamic and thermodynamic forcing on the EUC characteristics, in particular its salinity maximum.

Title: Seasonal variations of tidally generated internal waves in the eastern boundary upwelling system off Angola

Authors and affiliations: Peter Brandt [1,2], Kevin Lamb [3], Marcus Dengler [1], Robert Kopte [1], Volker Mohrholz [4], Pedro Tchipalanga [5], Marek Ostrowski [6]

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany

[2] Christian-Albrechts-Universität zu Kiel, Germany

[3] Department of Applied Mathematics, University of Waterloo, Canada

[4] Leibniz-Institut für Ostseeforschung, Rostock, Germany

[5] Instituto Nacional de Investigação Pesqueira, Departamento do Ambiente e Ecossistemas Aquáticos, Moçâmedes, Angola

[6] Institute of Marine Research, Oceanography and Climate, Bergen, Norway

Abstract: The eastern boundary upwelling system of the South Atlantic Ocean is one of the most productive marine ecosystems. It is separated by the Angola-Benguela frontal zone at about 16°S into a permanent wind-driven upwelling system to the south and a tropical upwelling system to the north. Here we study the seasonal upwelling at 11°S using shipboard hydrographic and current data, microstructure data as well as temporally high-resolution moored velocity data acquired during several field experiments since July 2013. Additionally we use hydrographic data taken in the frame of the Norwegian Nansen Programme during biannual cruises covering the main downwelling and upwelling seasons over more than 20 years. The seasonal upwelling is strongly influenced by the propagation of semiannual coastally trapped waves leading to a dynamical change in the stratification at the shelf. Local wind forcing plays only a minor role in driving the near-coastal upwelling. Moored velocity observations at the shelf break at about 500 m water depth show a seasonal enhancement of internal wave energy near the buoyancy frequency during the main upwelling system. An on-shore propagation of internal waves as observed during the field campaigns implies enhanced mixing on the shelf, which is in general agreement with sparse microstructure measurements. To better understand the processes at work, a 2-D very high-resolution non-hydrostatic model is applied to simulate the generation of internal waves at the shelf break by a barotropic tidal flow and their onshore propagation. Simulations performed using mean observed stratifications of the main upwelling and downwelling seasons show significant differences in the onshore propagation of internal waves induced by both differences in slope criticality and near surface stratification.

Title: An elevated turbulent mixing event caused by a near-inertial wave in the mixed layer

Authors and affiliations: Marcus Dengler [1], Rebecca Hummels [1], Tim Fischer [1], Gerd Krahmann [1], Willi Rath [1] and Peter Brandt [1]

[1] GEOMAR Helmholtz Centre of Ocean Research Kiel, Kiel, Germany

Abstract: Between 2005 and 2016, an extensive shipboard and autonomous microstructure measurement program was carried out in the proximity of PIRATA sites in the central and northeastern tropical Atlantic. The data reveal regional variability of upper ocean mixing processes from diurnal to seasonal time scales. Here, we discuss an elevated turbulent mixing event below the mixed layer caused by surface near-inertial waves and address the impact of these mixing events on the mixed-layer heat balance at the PIRATA site at 11.5°N, 23°W. Altogether, microstructure data at this site was collected during 8 different cruises. During one incident, sampling was conducted during the presence of an elevated near inertial wave. Velocities associated with the NIW were above 0.6m/s in the mixed layer and decreased to near zero below the stratification maximum at 30m depth. Mixing during the presence of the NIW was strongly elevated and dissipation rates of turbulent kinetic energy exceeded 1x10^(-5) m^3 s^(-2) in the stratified region below the mixed-layer in some profiles. Associated cooling of the sea surface temperature was also elevated. Diapycnal heat flux was above 140Wm^(-2) 10m below the mixed layer and more than 300Wm^(-2) in the region 5m below the mixed layer. Near-Inertial wind stress magnitude (NIWSM) during the period war particularly high. Using the PIRATA winds, it was found that in general, the seasonal cycle of NIWSM has a very similar shape as the residual from the heat balance. Wind energy flux to NIWs from a slab ocean model is used to estimate the frequency of the occurrence of the elevated NIW ocean velocity.

Title: The variability of the Cape Boujdor upwelling and its relationship with the cape Blanc frontal zone

Authors and affiliations: A. Makaoui [1], A. Agouzouk [1], Bessa Ismail [1,2], J. Larissi [1], M. Idrissi [1], Y. Belebchi [1], O. Ettahiri [1] and K. Hilmi [1]

[1] Oceanography Department, National Institute of Fisheries Research, Casablanca, Morocco

[2] Laboratory of Engineering and Materials, Faculty of Sciences Ben M'Sik, Hassan II Casablanca University, Morocco

Abstract: The southern zone is in permanent supply of water enriched in nutrient, allowing a high primary productivity of its marine ecosystem. However, inputs of hot water deficit in dissolved oxygen, deriving from the south, are manifested exceptionally from one year to another under the effect of global warming on the ocean. Using in situ data and a model data from marine Copernicus with a resolution of 0.083-degree x 0.083 degree, we evaluated the relationship between ocean mixed layer depth (MLD), the sea surface temperature, sea surface salinity, and sea surface chlorophyll-a concentration. In our study, we found that coastal areas are related generally to a shallower MLD all the year in the Cape Boujdor region. In addition, we proved that the source of the upwelling is between 25°N and 26°N, and it is permanent in this region except during the fall season when the northern east wind are weaker in the north of Dakhla. However, we observed that the sea surface chlorophyll richness is located in the region between 24.5°N and 22°N, and corresponding to the south of cape Boujdor. We suggested that the upwelled water is derived to the south by a coastal south current forming a filament in this region. When upwelling is relatively active in the south of Dakhla, the area is fed more by mineral-enriched South Atlantic Central Waters (SACW). These waters (ECSA) are accompanied, exceptionally by waters less saturated in dissolved oxygen and can be an indicator of the impact of climate change on the area.

Session 2 – Climate variability and teleconnections

Title: Boreal spring equatorial Sea Surface Salinity as a potential predictor of Atlantic Cold Tongue events

Authors and affiliations: Casimir Y. Da-Allada [1,2,3], Julien Jouanno [4], Nicolas Kolodziejczyk [5], C. Maes [1], Bernard Bourlès [4], Gael Alory [4] and F. Gaillard [6]

[1] IRD/LOPS, IFREMER, CNRS, Univ. Brest, IUEM, Brest, France

[2] LHMC/IRHOB, IRD, Cotonou, Benin

[3] ESTBR/UNSTIM, Abomey, Benin

[4]Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES, CNRS, IRD, UPS, Toulouse, France, Brest, France

[5] IUEM/LOPS, IFREMER, CNRS, IRD, Univ. Brest, Brest, France

[6] IFREMER/LOPS, CNRS, IRD, Univ. Brest, IUEM, Brest, France

Abstract: The link between the boreal spring sea surface salinity (SSS) and the May-June-July (MJJ) sea surface temperature (SST) in the equatorial Atlantic Cold Tongue (ACT) region is investigated at interannual time scales from 1990-2012 using observations and model. Results reveal a significant correlation between April-May-June (AMJ) interannual SSS anomalies (SSSA) and the MJJ SST anomalies (SSTA). Most of extreme interannual SSSA appear the years of extreme interannual SSTA in the ACT region. Thus, major salty and desalted ACT events are followed by 1-month major warm and cold ACT events and confirms the idea that boreal spring SSSA could be used as a predictor of ACT events. Based on the model mixed-layer salinity budget and sensitivity experiments, we found that the interannual variability of the SSS is mainly controlled by horizontal advection during salty and desalted ACT events and changes in the horizontal advection are largely due to changes in winds.

Title: Oceanic Forcing on Interannual Variability of Sahel Heavy and Moderate Daily Rainfall Events

Authors and affiliations: Moussa Diakhate [1], Belén Rodríguez de Fonseca [2], Iñigo Gómara [2], Elsa Mohino [2], Abdou Lahat Dieng [1] and Amadou Thierno Gaye [1]

[1] Université Cheikh Anta Diop, BP 5085, 10700 Dakar, Senegal

[2] Universidad Complutense de Madrid, Madrid 28040, Spain

Abstract: Sahelian rainfall variability is strongly influenced by atmospheric teleconnections triggered by anomalous sea surface temperatures (SST). The remote SST forcing on seasonal precipitation rainfall over West Africa has been extensively analysed in the literature. However, their impact on the variability of Sahelian daily rainfall events, stratified by intensity, has received little attention so far. This article analyses SST remote forcing on Sahel summer months (June to September) moderate (below 75th percentile) and heavy (above 75th percentile) daily precipitation events interannual variability during the period 1981-2016. Evidence is given that interannual variabilities of these events are markedly different. Occurrence of moderate daily rainfall events appears to be enhanced by positive SST anomalies over the Tropical North Atlantic and Mediterranean, which act to increase low-level moisture advection towards the Sahel from the adjacent oceanic waters (the opposite holds for negative SSTs anomalies). While heavy/extreme daily rainfall events seem to be linked to El Niño-Southern Oscillation (ENSO) and Mediterranean variability. Under La Niña conditions and a warmer Mediterranean, vertical atmospheric instability is increased over the Sahel and low-level moisture supply from the Equatorial Atlantic is enhanced over the area (the reverse is found for opposite sign SST anomalies). Attending to the total rainfall index, these results indicate that interannual variability of Sahel rainfall is mainly dominated by the extreme events. These results may have strong implications on seasonal forecasting of Sahel moderate and heavy/extreme precipitation events based on SST predictors, as significant predictability has been found from 1-4 months in advance.

Title: Longitudinal variations of SST event characteristics in the tropical Atlantic and Pacific oceans

Authors and affiliations: Tina Dippe [1], Richard J. Greatbatch [1] and Joke F. Lübbecke [1]

[1] GEOMAR Helmholtz Center for Ocean Research Kiel, Germany

Abstract: Sea surface temperature (SST) variability in the tropical Atlantic and Pacific oceans is characterized by strong, interannual modes, whose warm and cold events are referred to as Atlantic and Pacific Niños and Niñas, respectively. While the basins are comparable in terms of their principal physical set-up, the characteristics of their SST events differ substantially from each other. One well-researched aspect of the Pacific El Niño-Southern Oscillation (ENSO) is its asymmetry. Although the term refers to a number of known non-linearities within the ENSO phenomenon in general - such as differences in the spatial and temporal evolution between warm and cold events -, we focus here specifically on the length and strength of events. We use a simple event identification method that isolates events within a time series of anomalies, relative to a threshold that is based on its standard deviation. We then apply this method along the equator and quantify how length and strength asymmetries between warm and cold events vary in dependence of longitude, both in the tropical Atlantic and Pacific. We show that for the period 1958-2016, events tend to be of statistically indistinguishable length in the entire tropical Pacific, while warm events are significantly longer than cold events in the Atlantic cold tongue region. In agreement with previous research, we find that the strength of events is highly asymmetrical in the Pacific, with cold events being significantly stronger than warm events in the western basin and vice versa in the eastern basin, where mean magnitudes differ by roughly 1K. In contrast, event strengths are statistically equal in the entire tropical Atlantic.

Title: Abrupt transitions in the NAO control of explosive North Atlantic cyclone development

Authors and affiliations: Iñigo Gómara [1,2,3], Belén Rodríguez de Fonseca [1,2], Pablo Zurita-Gotor [1,2], Sven Ulbrich [4] and Joaquim G. Pinto [5]

[1] Dept. of Geophysics and Meteorology, Universidad Complutense de Madrid, Madrid, Spain

[2] Instituto de Geociencias (IGEO), UCM-CSIC, Madrid, Spain

[3] CEIGRAM, AgSystems, Universidad Politécnica de Madrid, Madrid, Spain

[4] Institute for Geophysics and Meteorology, University of Cologne, Cologne, Germany

[5] Institute of Meteorology and Climate Research (IMK-TRO), Karlsruhe Institute of Technology (KIT), Germany

Abstract: Explosive cyclones are intense extra-tropical low-pressure systems featuring large deepening rates. In the Euro-Atlantic sector, they are a major source of life-threatening weather impacts due to their associated strong wind gusts, heavy precipitation and storm surges. The wintertime variability of the North Atlantic cyclonic activity is primarily modulated by the North Atlantic Oscillation (NAO). In this study, we investigate the interannual and multi-decadal variability of explosive North Atlantic cyclones using track density data from two reanalysis datasets (NCEP and ERA-40) and a control simulation of an atmosphere/ocean coupled General Circulation Model (GCM—ECHAM5/MPIOM1). The leading interannual and multi-decadal modes of variability of explosive cyclone track density are characterized by a strengthening/weakening pattern between Newfoundland and Iceland, which is mainly modulated by the NAO at both timescales. However, the NAO control of interannual cyclone variability is not stationary in time and abruptly fluctuates during periods of 20–25 years long both in NCEP and ECHAM5/MPIOM1. These transitions are accompanied by structural changes in the leading mode of explosive cyclone variability, and by decreased/enhanced baroclinicity over the sub-polar/sub-tropical North Atlantic. The influence of the ocean is apparently important for both the occurrence and persistence of such anomalous periods. In the GCM, the Atlantic Meridional Overturning Circulation appears to influence the large-scale baroclinicity and explosive cyclone development over the North Atlantic. These results permit a better understanding of explosive cyclogenesis variability at different climatic timescales and might help to improve predictions of these hazardous events under present and projected greenhouse gas forcing scenarios.

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Title: Equatorial Atlantic interannual variability in a CGCM

Authors and affiliations: Shunya Koseki [1,2], Noel Keenlyside [1, 2]

[1] Geophysical Institute, University of Bergen, Norway

[2] Bjerknes Center for Climate Research, Bergen, Norway

Abstract: We have investigated the CGCM-simulated equatorial Atlantic interannual variability in sea surface temperature (SST) focusing on its dynamical and thermodynamical processes. We compare an anomaly-coupled model, with its mean state corrected to observations by prescribing the observed air-sea flux correction of climatology to a standard model with large biases in the tropical Atlantic. A benchmark simulation of the CGCM (without the anomaly coupling) overestimates the equatorial SST variability from summer to early winter and the area of high variability extends more westward compared to the observations. The Bjerknes Feedback is held in the standard simulation as observed, but the coupling between zonal wind and Atlantic SST anomalies and its seasonality is poorly represented. While the anomaly coupling somewhat underestimates the amplitude of SST interannual variability with respect to the observations, there are some improvements in seasonality and location of the SST variability. The Bjerknes Feedback loop is also ameliorated; in particular, the communication between zonal wind stress and SST anomalies shows a better seasonal march in the western basin. Additionally, the thermodynamical process for the SST variability is also well reproduced with the anomaly coupling. Lag-composite analysis elucidates that the anomaly coupling leads to a more realistic evolution in the Atlantic modes and better symmetry between the SST warm and cold SST anomalies. On the other hand, both experiments without and with the anomaly coupling fail to simulate the South Atlantic Anticyclone variability in February to April, which possibly triggers and enhances the equatorial Atlantic SST anomalies. We conclude that the anomaly coupling can improve the equatorial mechanism for the SST variability. Such improvement of the processes responsible for the variability should influence the skill of seasonal prediction.

Title: Is the boreal spring Tropical Atlantic SST variability a precursor for the Equatorial Mode?

Authors and affiliations: Marta Martín-Rey [1,2] and Alban Lazar [2]

[1] CERFACS, Toulouse, France

[2] Université Pierre et Marie Curie (UPMC), Sorbonnes Universités, Paris, France

Abstract: The boreal spring-to-summer tropical Atlantic variability is driven by two air-sea coupled modes: the Meridional (MM) and Equatorial Mode (EM), respectively. Previous studies have suggested a possible interaction between them, but without reaching a consensus about its existence, type (destructive or constructive) and frequency (inter-annual to decadal). Here, we present a set of sensitivity experiments with the medium-resolution regional ocean model NEMO-ATLTROP025, aimed to investigate the air-sea and ocean processes responsible of the development of the MM and its connection to the equatorial SST anomalies.

The reference experiment is forced with a 1.5-year composite air-sea fluxes associated with a typical Meridional Mode event from July (year -1) to December (year 0). It confirms that during the growing phase, the reduction (intensification) of the trades in NTA (STA) activate the latent heat fluxes, warming (cooling) the underneath region. In contrast, ocean processes are crucial to generate the equatorial SST signal.

North and close to the equator, the wind anomaly excites a downwelling equatorial Rossby wave that propagates from winter to spring. It is reflected at the western boundary, becoming a downwelling Kelvin wave traveling and warming up the equator from July to September. Two additional sensitivity experiments have been performed to isolate the contribution of the oceanic waves vs the local wind forcing at the equator.

The present study suggests that the oceanic wave connecting the MM and the EM is modulated by the local wind forcing, establishing a competition between both phenomena. Depending on the constructive or destructive nature of this interaction, the EM event will take place after a MM event.

Title: Atlantic control of the late-19th century Sahel humid period.

Authors and affiliations: Julián Villamayor [1,2], Elsa Mohino [1], Myriam Khodri [3], Juliette Mignot [3] and Serge Janicot [3]

[1] Universidad Complutense de Madrid (UCM), Madrid, Spain

[2] Instituto de Geociencias (IGEO), Spain

[3] LOCEAN/IPSL, Sorbonne Universités, UPMC-CNRS-IRD-MNHN, Paris, France

Abstract: Precipitation regime shifts in the Sahel have dramatic humanitarian and economic consequences such as during the 1970's and 1980's severe droughts. Though Sahel precipitation changes during the late 20th century have been extensively studied, little is known about the decadal variability prior to the 20th century. Some evidences suggest that during the second half of the 19th century the Sahel was as much or even more rainy than during the 1950's and 1960's. Here, we reproduce such anomalous Sahel humid period in the late-19th century by means of climate simulations. We show that this increase of rainfall was associated with an anomalous supply of humidity and higher-than-normal deep convection in the middle and high troposphere. We present evidence suggesting that Sea Surface Temperatures (SSTs) in the Atlantic basin played the dominant role in driving decadal Sahel rainfall variability in this early period.

Title: The coupling between tropical Pacific and Atlantic basins in a recharge oscillator framework

Authors and affiliations: Lander R. Crespo [1], Belen Rodríguez de Fonseca [2,3], Irene Polo [4] and Noel Keenlyside [1]

[1] Geophysical Institute, Bjerknes Centre for Climate Research, University of Bergen, Bergen, Norway

[2] Departamento de FTAAI, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Madrid, Spain

[3] Instituto de Geosciencias (CSIC-UCM), Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Madrid, Spain

[4] NCAS-Climate, Department of Meteorology, University of Reading

Abstract: We implement a conceptual recharge oscillator model for the tropical Pacific coupled with a linear damped model based on tropical Atlantic SST anomalies to study the interbasin teleconnections. The parameters of the model are fit to the observations for the first and the second half of the 20th century and for the following two cases: (1) non-seasonally, non-interannually varying parameters and (2) seasonally, non-interannually varying parameters. The simulated Pacific thermocline and SST show a strong coupling for the period 1951-2001 with the thermocline and SST leading by 12 and 10 months, respectively, with a correlation of 0.5, while in the observations they lead by 10 and 8 months, respectively. For the period 1900-1950, the thermocline leads the SST by 5 months both in the model and observations but the SST does not feedback onto the thermocline. The comparison between the simple recharge oscillator model with and without Atlantic feedback shows that the Atlantic SST does not affect the coupling between Pacific thermocline and SST, but clearly impacts the Pacific SST. Observations show that Atlantic SST leads Pacific SST by 8 months, while in our model the correlation maximum occurs for a leadtime of 15 months. The impact of Atlantic SST on Pacific SST is stronger for the second period of the study, in agreement with the observations. The leadtime of Atlantic SST onto Pacific SST is slightly reduced, and hence, closer to the observed when we fit the model for seasonally varying parameters.

Title: Large scale mechanisms associated with heat wave occurrences in Senegal

Authors and affiliations: Marie Jeanne Gnacoussa Sambou [1], Serge Janicot [2], Benjamin Pohl [3], Daouda Badiane [1], Amadou T. Gaye [1] and Abdou L. Dieng [1]

[1] LPAOSF/ ESP / Univ. Cheikh Anta Diop, Dakar,Senegal

[2] LOCEAN, UMR7159 Sorbonne Univ. UPMC-CNRS-IRD-MNHN, Paris, France

[3] CRC, UMR6282 Biogéosciences, CNRS / univ. Bourgogne Franche-Comté, Dijon, France

Abstract: The coastal location of the Senegal induces specific heat wave (HW) events. HWs are defined as daily temperature (daily maximum or minimum temperature, or mean apparent temperature) higher than the 95th moving percentile during at least three consecutive days over the boreal spring period (Mars-April-May, 1979-2014). A hierarchical classification enables to define three homogeneous regions in terms of HW occurrences over Senegal (Zone #1, #2 and #3, from West to East). In order to study how atmospheric circulation is linked to these HW occurrences, composites of anomaly fields of ERA-Interim reanalysis have been computed using as reference date the starting day of each HW detected in GSOD (Global Summary of the Day) observations database. Results show that two patterns control the occurrence of HWs: regional-scale positive pressure anomalies centred around 35°N-10°W, and more local negative anomalies around 20°N-15°W. This structure leads to enhanced north-easterly winds advecting higher temperatures and moister air over the three zones of Senegal, and lower temperatures and drier air over the central Sahel. The intensity of this relationship is the largest for Zone #1, intermediate for #2 and the weakest for #3. The increased moisture signal over Senegal is highest for the composites associated with minimum and apparent temperature. Indices linked to this structure can be used to evaluate the predictability of such HW events.

Title: The connection between Atlantic multi-decadal variability and the Indian summer monsoon in CMIP5 models

Authors and affiliations: Lea Svendsen [1], Feifei Luo [2], Shuanglin Li [2,3], Yongqi Gao [2,4], Noel Keenlyside [1,4], Tore Furevik [1]

[1] Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Bergen, Norway

[2] Nansen-Zhu International Research Centre and Climate Change Research Center, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

[3] Department of Atmospheric Science, China University of Geoscience, Wuhan, China

[4] Nansen Environmental and Remote Sensing Center and Bjerknes Centre for Climate Research, Bergen, Norway

Abstract: Instrumental records show a significant positive correlation between the Atlantic multi-decadal variability (AMV) and the Indian summer monsoon (ISM) rainfall, where warm (cold) sea surface temperatures (SSTs) in the North Atlantic are associated with more (less) ISM rainfall on multi-decadal timescales. However, discrepancies among the models make the robustness of this link debated. We have analysed the link between AMV and ISM rainfall in 66 historical 20th century all-forcing simulations from 22 models from the Coupled Model Intercomparison Project Phase 5 (CMIP5). There is a considerable range in the correlation between AMV and the ISM in the CMIP5 between -0.39 to 0.66, and only 10 out of 66 members (~ 15%) show a significant positive correlation close to the observations. The ensemble members with positive AMV-ISM correlations show an AMV-related atmospheric teleconnection that involves an extratropical-tropical SST gradient in the North Pacific, as well as a regional temperature difference between the Indian subcontinent and the tropical Indian Ocean. Moreover, the models with higher climatological precipitation over the tropical Atlantic and smaller SST biases the North Pacific and the tropical Atlantic better reproduce the observed teleconnections. Further analyses of the preindustrial control simulations of the only two models that capture these teleconnections across all the historical ensemble members (HadGEM2-ES and GFDL-CM3), reveal that the while both these models capture the AMV-ISM teleconnection in externally forced simulations, only HadGEM2-ES reproduces a link in the preindustrial control simulation, where the concurrent SST anomalies in the Pacific seem to be pivotal in reproducing the AMV-ISM link.

Title: Meridian Seasonal Variability of the Tropical Atlantic Warm Pool Associated with the Inter-Tropical Convergence Zone (ITCZ)

Authors and affiliations: Dahirou Wane [1], Alban Lazar [2], Malick Wade [3] and Amadou T. Gaye [1]

[1] Laboratoire de Physique de l'Atmosphère et de l'Océan Siméon-Fongang, ESP/UCAD

[2] Laboratoire d'océanographie et du climat: expérimentations et approches numériques (LOCEAN) / UPMC, Sorbonne Universités

[3] Laboratoire des sciences de l'atmosphère et des océans (LSAO) / UGB

Abstract: The Atlantic Warm Pool (AWP) is an ocean system strongly coupled to the Marine Inter-Tropical Convergence Zone (ITCZ) and its precipitation, and to a lesser extent to adjacent coastal precipitation. In our study, the Ocean Mix Layer (MLD) heat budget equation is used to identify and quantify the mechanisms controlling seasonal AWP meridional migration. We define the latter as the region with SST ≥ 27 ° C, and identify the terms of the budget that explain the migrations of the two isotherms 27 ° C north and south (respectively FN and FS).

The results show that north-side meridional migration (FN) is mainly controlled by air-sea flux, while oceanic processes are opposed. The ocean plays an important role in the meridional migration of the FS in the west except in the Gulf of Guinea, where movement is controlled by air-sea flux.

We will present a detailed analysis of the mechanisms of these migrations, detailing the contributions of ocean processes and heat fluxes at the air-sea interface.

Session 3 – Climate Prediction

Title: Influence of sea surface temperature (SST) bias in North West Africa upwelling system in CMIP5 models

Authors and affiliations: Antonio Castaño-Tierno [1], Belén Rodríguez de Fonseca [1,2], Teresa Losada [1] and Elsa Mohino [1]

[1]Departamento de Física de la Tierra, Astronomía y Astrofísica I, Geofísica y Meteorología. UCM, Av. Complutense s/n, 28040 Madrid (Spain)

[2] Instituto de Geociencias (CSIC-UCM), Facultad de CC. Físicas, Plaza de Ciencias 1, 28040 Madrid (Spain)

Abstract: Using different diagnostic variables, we study the relation between SST bias in CMIP5 PI control simulations and the representation of North West Africa upwelling. Upwelling variability is studied using the meridional wind stress, temperature profiles and thermocline depth defined as the depth of maximum temperature vertical gradient.

Both seasonal cycle and interannual variability are analysed. Applying regression analysis and Empirical Orthogonal Functions (EOFs), a link is stablished between the global SST bias and coastal upwelling representation. Consistence between thermocline depth and wind stress divergence is assessed.

Title: Climate projections with bias-reduced CGCMs in Tropical Atlantic

Authors and affiliations: Teferi Demissie [1], Noel Keenlyside[2], Shunya Koseki[2], Thomas Toniazzo[1] and Ingo Bethke[1]

[1] Uni Research Climate and Bjerknes centre for climate research, Bergen, Norway

[2] Geophysical Institute, University of Bergen and Bjerknes centre for climate research, Bergen, Norway

Abstract: Current state-of-the-art models exhibit large climatological errors in the tropical Atlantic. The consequence of these errors for climate projections is undocumented. Here we compare climate change projections with a standard and an anomaly coupled configurations of the Norwegian Climate Prediction Model (NorCPM). Anomaly coupling greatly reduces the simulated climatological errors. This leads to greatly differing climate change projections (present to 2100). The standard model shows a rather uniform warming of around 2.5 degrees Celsius over the equatorial Atlantic. In contrast, the corrected model shows greater warming in the east, reaching 3 degrees Celsius in the eastern equatorial Atlantic. These changes are reflected in quite different rainfall response patterns. The standard model shows that climate change will lead to wetter conditions over central Africa and the western Atlantic, and drier conditions over eastern equatorial South America and the south equatorial Atlantic. The corrected model, in contrast, shows greater rainfall changes in the east and over central Africa, and less drying over South America. The underlying mechanisms causing these differences will be discussed. This result illustrates the potential impact of mean state errors in future climate change in this region.

Title: Impact of dynamical regionalization on precipitation biases and teleconnections over West Africa

Authors and affiliations: Iñigo Gómara [1,2,3], Elsa Mohino [1], Teresa Losada [1], Marta Domínguez [1], Roberto Suárez-Moreno [1,2] and Belén Rodríguez de Fonseca [1,2]

[1] Dept. Geophysics and Meteorology, Universidad Complutense de Madrid, Madrid, Spain

[2] Instituto de Geociencias (IGEO), UCM-CSIC, Madrid, Spain

[3] CEIGRAM, AgSystems, Universidad Politécnica de Madrid, Madrid, Spain

Abstract: West African societies are highly dependent on the West African Monsoon (WAM). Thus, a correct representation of the WAM in climate models is of paramount importance. In this article, the ability of 8 CMIP5 historical General Circulation Models (GCMs) and 4 CORDEX-Africa Regional Climate Models (RCMs) to characterize the WAM dynamics and variability is assessed for the period July-August-September 1979–2004. Simulations are compared with observations. Uncertainties in RCM performance and lateral boundary conditions are assessed individually. Results show that both GCMs and RCMs have trouble to simulate the northward migration of the Intertropical Convergence Zone in boreal summer. The greatest bias improvements are obtained after regionalization of the most inaccurate GCM simulations. To assess WAM variability, a Maximum Covariance Analysis is performed between Sea Surface Temperature and precipitation anomalies in observations, GCM and RCM simulations. The assessed variability patterns are: El Niño-Southern Oscillation (ENSO); the eastern Mediterranean (MED); and the Atlantic Equatorial Mode (EM). Evidence is given that regionalization of the ENSO–WAM teleconnection does not provide any added value. Unlike GCMs, RCMs are unable to precisely represent the ENSO impact on air subsidence over West Africa. Contrastingly, the simulation of the MED–WAM teleconnection is improved after regionalization. Humidity advection and convergence over the Sahel area are better simulated by RCMs. Finally, no robust conclusions can be determined for the EM–WAM teleconnection, which cannot be isolated for the 1979–2004 period. The novel results in this article will help to select the most appropriate RCM simulations to study WAM teleconnections under current and future climate scenarios.

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Title: Impact of the anomaly coupling in the simulation of the interannual variability of the Tropical Atlantic Ocean in a simulation

Authors and affiliations: Teresa Losada [1,2], Antonio Castaño-Tierno [1], Elsa Mohino [1], Belén Rodríguez de Fonseca [1,2], Carlos R Mechoso [3]

[1] Departamento de Física de la Tierra, A. A. I, Facultad de Ciencias Físicas, UCM. Madrid (Spain)

[2] Instituto de Geociencias (CSIC-UCM), Facultad de Ciencias Físicas, UCM. Madrid (Spain)

[3] Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, (USA)

Abstract: It is well known that coupled global climate models show important systematic errors that can preclude our confidence in their results. One important open question in this regard, is the relation between biases and variability in global climate models.

In this work, we evaluate the impact of the implementation of an anomaly coupling technique, in which the only information exchanged by the atmospheric and oceanic components of the model is the anomalous part of the fluxes and the SST, in the simulation of the interannual variability in the UCLA CGCM model.

Title: Impact of the reduction of the southern extratropical incoming radiation on the simulation of the tropical Atlantic variability

Authors and affiliations: Teresa Losada [1,2], Belén Rodríguez de Fonseca [1,2], Antonio Castaño-Tierno [1] and Carlos R. Mechoso [3]

[1] Departamento de Física de la Tierra, Astronomía y Astrofísica I, Facultad de Ciencias Físicas, UCM. Plaza de las Ciencias 1, 28040 Madrid, Spain

[2] Instituto de Geociencias (CSIC-UCM), Facultad de Ciencias Físicas, UCM. Plaza de las Ciencias 1, 28040 Madrid, Spain

[3] Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, CA, 90095, USA

Abstract: Coupled global climate models (CGCMs) show important biases in the simulation of SST, not only in the tropics, but also over the Southern Ocean. A recent work has shown that improving the errors in the Southern Ocean SST can result in an improvement of the tropical biases in the UCLA CGCM.

In this work, we analyse how this model simulates the tropical Atlantic Niño mode in a control run and we compare the results with the variability of a second simulation in which we apply an idealized reduction of the incoming shortwave radiation over the Atlantic sector of the Southern Ocean.

Our results show an improvement of the simulation of the tropical Atlantic variability at interannual timescales in the idealized simulation. The representation of the Atlantic Equatorial Mode is improved and the variability in the tropical Atlantic is enhanced.

Title: Relationship between inter-annual tropical variability and mean state in CMIP5 models

Authors and affiliations: Irene Polo [1,2], Belén Rodríguez de Fonseca [1], Elsa Mohino [1], Teresa Losada [1], Julian Villamayor [1] and Carlos R. Mechoso [3]

[1] Dto Fisica de la Tierra, Astronomia y Astrofisica I, UCM, Madrid, Spain

[2] Department of Meteorology, University of Reading, Reading, UK

[3] Department of Atmospheric and Oceanic Sciences, UCLA, Los Angeles, USA

Abstract: Previous studies on systematic errors of coupled atmosphere-ocean general circulation models have generally focused on long-term-averaged features. The way in which these mean errors impact the variability of the coupled system has received less attention. The present study examines the relationships in CMIP5 models among inter-model differences in the simulation of the mean climate and the individual models' success in reproducing the observed tropical climate variability at inter-annual time-scales. Our approach is based on comparing the leading inter-annual modes of sea surface temperature (SST) variability for each model, and on correlating defining characteristics of these modes with their representations of the mean state. In the tropical Pacific, the success in simulating the spatial structure of the first mode of inter-annual variability (El Niño) is higher in models that capture the observed location of mean convection over the western Pacific and Maritime Continent. This appears together with a southward shift of the Intertropical Convergence Zone in both the Pacific and Atlantic basins. Such a shift is noted in models for which the mean SST is warmer than average over the southern hemisphere and the equatorial Pacific and Atlantic. In the Tropical Atlantic, the success with the first mode of inter-annual variability (Atlantic Niño) is higher in models that are able to reproduce the intensity of observed westerly winds around 40S as well as the cooler SST/lower Ocean Heat Content over 40S and the Southern Ocean, which are themselves linked to the deep ocean circulation and Atlantic Meridional Overturning Circulation. A stronger North Brazil Current is associated with reduced explained variance by the Atlantic Niño, through the increased ocean heat transport convergence in the deep tropics and the warming of the subsurface in the equatorial Atlantic. Thus, this work contributes to set metrics for assessment of predictions of inter-annual variability in climate projections by CMIP5 models.

Title: Impact of the ocean stochastic parameterization on the simulated mean state and variability of a coupled model

Authors and affiliations: Emilia Sanchez-Gomez [1], Marta Martin del Rey [1], G. Ruggiero [2] and R. Msadek [1]

[1] CECI-CERFACS, Toulouse, France

[2] Mercator-Ocean, Toulouse, France

Abstract: The ocean component in state-of-the-art coupled models operates in general at a coarse horizontal resolution (~100 km) that does not allow resolving the ocean mesoscale dynamics. These unresolved processes provide a great degree of uncertainty in forced ocean and also coupled simulations. To tackle with this uncertainty, parameterisations emulating the average effect sub-grid scale processes have been developed. These parameterisations are implemented either on the advection terms or in the equation of state of the primitive equations of the ocean model. In a recent work, Brankart 2013 has developed a new parameterization aimed at simulating the uncertainties in the computation of the large-scale horizontal density gradient from the large-scale temperature and salinity fields. On this purpose, a stochastic term was added in the seawater equation of state to mimic the sub-grid random fluctuations of temperature and salinity fields. In a ocean forced simulation, they showed that this parameterization has a considerable impact on the ocean large-scale circulation, especially in the regions of intense mesoscale activity (i.e. the western boundary currents).

Following this idea, in this work we study the impact of the stochastic parametrization in the low-resolution coupled model CNRM-CM6 (1.4o for the atmosphere, and 1o for the ocean). Given the uncertainties related to this parameterization, we built 3 ensembles of 3 members each in which different values of the stochastic parameters have been tested. The effect of the stochastic ocean on the mean state and variability is analysed in the ensembles. Preliminary results show slight, but significant impacts over the heat and salt content in the Atlantic Ocean (North Atlantic and Tropical Atlantic), associated with the Subpolar and Subtropical gyres transports, and also over the mixed layer and deep convection the Labrador and Greenland-Irminger-Norwegian seas.

Title: Tropical Atlantic low-cloud biases in CNRM-CM6: evaluation of the new atmospheric physics

Authors and affiliations: Florent Brient [1], Romain Roehrig [1] and Aurore Voldoire [1]

[1] CNRM, Météo-France/CNRS, Toulouse, France

Abstract: Most state-of-the-art coupled general circulation models have serious biases in the tropical Atlantic, which strongly impact their representation of the regional climate. The CMIP5 version of CNRM-CM has been shown to suffer from these typical biases, namely a westerly wind bias over the Equatorial Atlantic and a excess of solar radiation in the southeastern region.

Since CMIP5, a new atmospheric physics has been developed and implemented in the CNRM-CM model. It includes a new boundary-layer scheme based on a TKE prognostic equation, a detailed microphysics scheme prognostically describing liquid and ice cloud condensates as well as liquid and solid precipitating hydrometeors, and a new convective scheme aiming at representing in a continuous way dry, shallow and deep convection. The representation of clouds and convection in the tropics is strongly impacted. In the present study, its realism is further assessed in the south-eastern part of the tropical Atlantic.

Low-level cloud biases in the new version of CNRM-CM are first assessed in AMIP-type simulations. We focus on how the model represents the vertical development of boundary-layer clouds and the transition from stratus to cumulus regimes, using a zonal transect between the Namibian coast and South America. In particular, the representation of this transition is related to biases of the surface energy budget. Then, short-term hindcasts (Transpose-AMIP framework) are used to better understand the mechanisms at play. Low-level cloud biases are shown to be associated with fast processes (a few hours to a few days). Specifically, the drivers for this low-cloud underestimate are further discussed to show that they are likely to arise from errors in cloud scheme input coming from the boundary-layer thermodynamics (e.g. turbulence) and structural errors from the cloud parameterization itself (e.g. assumptions of sub-grid variance of thermodynamical variables). This study provides guidance for future improvements of stratocumulus representation in the CNRM-CM model.

Section 4 – Marine ecosystems, fisheries management and climate change

Title: Variabilité hydrobiologique de la région de Dakhla (24°N-23°30°N et 23°N) et biodiversité du micro-phytoplancton

Authors and affiliations: Tarik Baibai [1]

[1] Institut National de Recherche Halieutique, Casablanca, Maroc

Abstract: La présente étude concerne la zone située au large de la région de Dakhla (23° - 24°N). C'est une synthèse des paramètres du milieu (volets océanographie physique et océanographie biologique) des campagnes océanographiques réalisées par l'INRH durant les périodes estivales 2000-2015, tout en mettant l'accent sur la période juillet 2015 (en terme de production et de biodiversité du microphytoplancton).

Cette zone de la région de Dakhla (23° - 24°N) connaît une variabilité hydrologique et biologique dans l'espace et dans le temps. Elle dépend étroitement des résurgences des eaux situées au niveau du Cap Boujdor dont les origines se situent au large, entre 250 à 300 m de profondeur.

En terme de biodiversité du phytoplancton (période juillet 2015), la zone située à 23°-23°30' et 24°N, révèle la présence de six groupes rituels des côtes atlantiques marocaines (diatomées, dinoflagellés, silicoflagellés, raphidophycés et coccolithophoridés), dominés quasiment par le groupe des diatomées avec un pourcentage d'abondance relatif de 88%.

La majorité des taxons dominants le peuplement microalgal durant cette période estivale en 2015 sont fréquemment abondants au niveau des côtes atlantiques marocaines et connus comme indicateurs ou accompagnateurs de l'activité des upwellings, tels Pseudonitzschia, Leptocylindrus danicus, Thallassiosira et Gymnodinium. Toutefois, d'autres taxons, habituellement observés avec une faible fréquence et abondance au niveau de ces radiales, se sont rencontrées fréquemment avec une abondance élevée, tels : Lithodismium (11%) et Cochlodinium (5%).

Title: Modelling and management options in a context of increase fishing effort and efficiency: Case of *Ethmalosa fimbriata* in Southern Senegal

Authors and affiliations: Bocar Sabaly Balde [1,2,3,4], Patrice Brehmer [4], Fambaye Ngom Sow [2], Werner Ekau [3], Justin Kantoussan [5], Massal Fall [2], , Malick Diouf [1]

[1] Université Cheikh Anta Diop (UCAD), Institut Universitaire de Pêche et d'Aquaculture, UCAD II Bâtiment Pédagogique / Rez-de-chaussée, BP 45784, Dakar–Fann, Sénégal

[2] Institut Sénégalais de Recherche Agricole (ISRA), Centre de Recherche Océanographique de Dakar-Thiaroye (CRODT), BP 2241, Centre PRH, Dakar, Senegal

[3] Leibniz Center for Tropical Marine Ecology (ZMT), GmbH- Fahrenheitstraße 6, 28359 Bremen, Germany

[4] Institut de Recherche pour le Développement - France (IRD), UMR 195 Lemar, BP 1386, Dakar, Sénégal

[5] Université Gaston Berger (UGB), Unité de Formation et de Recherche des Sciences Agronomiques, de l'Aquaculture et des Technologies Alimentaires (UFR S2ATA), Saint-Louis, Senegal

Abstract: The bonga shad (*Ethmalosa fimbriata*) is the third exploited of the small pelagics (after *Sardinella aurita* and *S. maderensis*) in the Senegalese waters and is commonly consumed locally. This fishery is mainly practiced by artisanal fishermen and is of great importance for the Senegalese economy as for food security in the region. Our investigations are aimed to inform the selection of management tools based on the dynamics of bonga shad exploitation to increase the likelihood of fishermen. The current rate of exploitation (E) was estimated (0.8), updating current statute (fully exploited) and indicating that the bonga shad in Senegal is over-fished. Moreover, we report a seasonal variability in recruitment and biomass of the Senegalese bonga shad, and a downward trend over the study period as well as a maximum size decrease of -8.8 cm (18 %) in 63 years. Such changes are attributed to increase in fishing capacity. To reverse the overexploitation status of the bonga shad stock, it is necessary to put the mesh of encircling nets from 40mm to 60mm, to reduce the fishing effort drastically, apply regulations on the capture, sale and processing of juveniles and exclusion of seiners and monofilaments on the Senegalese Southern Coast.

Title: Estimating dynamics of population fecundity to understand spawning tactics in *Ethmalosa fimbriata* (Bowdich, 1825) in an upwelling environment

Authors and affiliations: Bocar Sabaly Balde [1,2,3,4], Julian Döring [3], Saliou Faye [2], Werner Ekau [3], Patrice Brehmer [4], Malick Diouf [1]

[1] Université Cheikh Anta Diop (UCAD), Institut Universitaire de Pêche et d'Aquaculture, UCAD II Bâtiment Pédagogique / Rez-de-chaussée, BP 45784, Dakar–Fann, Sénégal

[2] Institut Sénégalais de Recherche Agricole (ISRA), Centre de Recherche Océanographique de Dakar-Thiaroye (CRODT), BP 2241, Centre PRH, Dakar, Senegal

[3] Leibniz Center for Tropical Marine Ecology (ZMT), GmbH- Fahrenheitstraße 6, 28359 Bremen, Germany

[4] Institut de Recherche pour le Développement - France (IRD), UMR 195 Lemar, BP 1386, Dakar, Sénégal

Abstract: Fluctuations in abiotic factors, e.g., temperature, salinity, food availability, will result in specific spawning tactics. This drives some populations to create reproductive strategies to ensure the survival of their offspring. The analysis of comparative functional responses can be used in different contexts to improve the understanding and prediction of the environmental impact on small pelagic population fecundity (PF). Successful recruitment into a population is subject to variations in fecundity. Significant seasonal and inter-annual differences in PF of *Ethmalosa fimbriata* in southern Senegalese coastal waters could be observed. Here we show that the population is able to fit its spawning tactic to variable conditions in an upwelling environment. It appears that *E. fimbriata* aims at spawning in water temperatures of around 24°C and at an upwelling intensity of 3 m3 s-1 m-1. Understanding the spawning tactics of an highly exploited fish species is important in the context of climate change to get efficient forecast in countries where fisheries is crucial at socio-economical level, in order that decision maker can provide ad hoc adaptation plan for the fisheries sector.

Title: The effect of oceanographic factors on micronektonic acoustic density in the three African Atlantic large marine ecosystems

Authors and affiliations: Patrice Brehmer, Hervé Demarcq, Anne Mouget, Chloé Migayrou, Najib Chouraki, Vamara Kone, Uatjavi Uani, Abdoulaye Sarré, Ahmed Taleb, Aka Marcel Kouassi, Yannick Perrot, Nolwenn Behagle, Jens-Otto Krakstad, Ibrahima Diallo and Ndague Diogoul

Abstract:

Title: Micronektonic acoustic density variations along Canary Current Large Marine Ecosystem over 20 years

Authors and affiliations: Nolwenn Behagle, (IRD, France), Abdoulaye Sarré, Ahmed Taleb, Salahedine El-Ayoubi, Anne Mouget, Yannick Perrot, Chloé Migayrou, Jens-Otto Krakstad,Ndague Diogoul, EbouMass Mbye, Patrice Brehmer

Abstract:

Title: Change in micronektonic diel vertical migration behavior over the three Atlantic Africans large marine ecosystems: internanual variability and effect of bathymetric partition

Authors and affiliations: Patrice Brehmer, Maik Tidemann, Anne Mouget, Salahedine El Ayouni, Vamara Kone, Najib Chouraki, Uatjavi Unavi, Nolwenn Behagle, Yannick Perrot, Abdoulaye Sarre

Abstract:

Title: Alternative sampling strategy for the assessment of the Arguin bank impact on the western African small pelagic fish population's resilience

Authors and affiliations: Timothée Brochier, Thomas Gorgues, Patrice Brehmer, Serge Stinckwich, Eric Chenin, Moustapha Elmoustapha Bouzouma, Ebaye Sidina

Abstract:

Title: Complex small pelagic fish population patterns arising from individual behavioural responses to their environment

Authors and affiliations: Timothée Brochier [1,2], Pierre-Amaël Auger [3], Laure Pecquerie [4], Eric Machuc [5], Xavier Capet [6], Modou Thiaw [7], Baye Cheikh Mbaye [5], Cheikh-baye Braham [8], Omar Ettahiri [9], Najib Charouki [9], Ousseynou Sene Ndaw [10], Francisco Werner [11], Patrice Brehmer [2,4]

[1] IRD, Unité de Modélisation Mathématique et Informatique des Systèmes COmplexes (UMMISCO), UMI 209, Univ Paris 06, Sorbonne Universités, Bondy, France
[2] IRD, Laboratoire des sciences de l'Environnement MARin (Lemar), UMR 195, F-93143, ISRA-CRODT, BP 1386, Hann, Dakar Sénégal
[3] IRD, Laboratoire d'Océanographie Physique et Spatiale (LOPS), UMR 6523 CNRS/IFREMER/IRD/UBO, Technopole Brest Iroise, 29280 Plouzané, France; Present address: Instituto Milenio de Oceanografia (IMO), Escuela de Ciencias del Mar, Pontificia Universidad Católica de Valparaíso, Av. Altamirano 1480, Valparaíso, Chile
[4] IRD, Laboratoire des sciences de l'Environnement MARin (Lemar), UMR 195, IUEM, rue Dumont d'Urville, 29280 Plouzané, France
[5] UCAD, Laboratoire de Physique de l'Atmosphère et de l'Océan Siméon Fongang (LPAO-SF), BP 5085 Dakar-Fann, Senegal
[6] CNRS, Laboratoire d'Océanographie et du Climat Expérimentation Et Approche Numériques (LOCEAN), Université Pierre et Marie Curie, Paris, France
[7] Centre de Recherche Océanographique de Dakar-Thiaroye, ISRA-CRODT, BP 2241, Hann, Dakar, Senegal
[8] Institut Mauritanien de Recherche Océanographique et des Pêche (IMROP), BP 22, Nouadhibou, Mauritania
[9] Institut Nationale de Recherche Halieutique (INRH), Bd Sidi Abderrahmane 2, Ain Diab 20180 Casablanca, Morocco
[10] Groupe Interdisciplinaire de Recherche sur l'Éducation et les Savoirs (GIRES), Dakar, Senegal
[11] NOAA Fisheries, 1315 East West Highway, Silver Spring, MD 20910, USA

Abstract: Small pelagic fish (SPF) species are heavily exploited in eastern boundary upwelling systems (EBUS) as their transformation products are increasingly used in the world food chain. Management relies on regular monitoring, but there is a lack of robust theories for the emergence of the populations' traits and their evolution in highly variable environments. This work aims to address existing knowledge gaps by combining physical and biogeochemical modelling with an individual life-cycle based model applied to round sardinella (*Sardinella aurita*) off northwest Africa, a key species for regional food security. Our approach focused on the processes responsible for seasonal migrations, spatio-temporal size-structure, and interannual biomass fluctuations. Emergence of preferred habitat resulted from interactions between natal homing behaviour and environmental variability that impacts early life stages. Exploration of the environment by the fishes was determined by swimming capabilities, mesoscale to regional habitat structure, and horizontal currents. Fish spatio-temporal abundance variability emerged from a complex combination of distinct life-history traits. An alongshore gradient in fish size distributions is reported and validated by in situ measurements. New insights into population structure are provided, within an area where the species is abundant year-round (Mauritania) and with latitudinal migrations of variable (300 to 1200 km) amplitude. Interannual biomass fluctuations were linked to modulations of fish recruitment over the Sahara Bank driven by variability in alongshore current intensity. The identified processes

constitute an analytical framework that can be implemented in other EBUS and used to explore impacts of regional climate change on SPF.

Title: Spatial Environmental trends in the three Atlantic African Large Marine Ecosystems in a context of global warming

Authors and affiliations: Hervé Demarcq, Abdoulaye Sarré, Aka Marcel Kouassi, Uatjavi Uanivi, Mohamed Ahmed Jeyid, Salahedine El Ayoubi, Idriss Lamine Bamy and Patrice Brehmer

Abstract:

Title: Occurrence spatiale et biodiversité des méduses dans l'écosystème Atlantique marocain entre (35°N) et (21°N)

Authors and affiliations: Hounaida Farah Idrissi, Souad Keffani, Hamid Chffiri, Abdekrim Kalmoni, Najib Charouki

[1] Institut National de Recherche Halieutique (INRH), Boulevard Sidi Abderrahmane, Ould Jmel-Casablanca, Morocco

Abstract: Les méduses figurent parmi les premiers métazoaires apparus dans l'hémisphère bleu. En Atlantique marocain entre les parallèles (35°N) et (21°N), durant la période allant du 1998 à 2017, les apparitions massives de ce macro-plancton gélatineux sont de plus en plus fréquentes et qui inclus divers groupes, comme les cténaires, les méduses et les tuniciers.

Dans la zone d'étude, l'occurrence des méduses calculée dans les stations de pêche a été pondérée par rapport au nombre moyen des stations par campagne en mer de chaque navire de recherche déployé. A l'échelle spatiale, le poids total des méduses capturées cumulé sur toute la série des campagnes disponibles montre que le maximum des captures a été enregistré entre les latitudes 22°N et 23°N, suivi par une apparition bien prononcée au niveau de la zone centrale entre 33, 50°N et 31°N pendant les années 2007, 2009, 2011, 2015 et 2016.

Cette présente étude dresse en partie l'éventuelle interaction entre l'abondance des méduses et la variabilité de la concentration de l'oxygène dissous (O2) en (mol/l) dans toute la colonne d'eau à l'échelle spatiale et aussi interannuelle.

En terme de biodiversité du macro-plancton gélatineux, l'écosystème atlantique marocain a révélé la présence de six groupes (Salpes, Cténaires, Pyrosomes, Rhizostomes, Siphonophores, et scyphozoaires), représentés par 15 espèces identifiées et recensées.

Title: Water mass physico-chemical parameters effect on acoustic layers spatial structuration in the Canary Current Large Marine Ecosystem

Abstract and affiliations: Chloé Migayrou, Abdoulaye Sarré, Ahmed Taleb, Anne Mouget, Nolwenn Behagle, Salahedine El Ayoubi, Ndague Diogoul, Elizandro Rodriguez, Ebou Mass Mbye, Yannick Perrot, and Patrice Brehmer

Abstract:

Title: Application of functional classification on high resolution oceanographic data in Canaries current large marine ecosystem: toward fine scale analysis

Authors and affiliations: Mamadou Ndiaye, Sophie Dabo-Niang, Mohamed Salem Ahmed, Ndague Diogoul, Salahedine El Ayoubi, Abdoulaye Sarré, Ahmed Taleb, Elizandro Rodriguez, Ebou Mass Mbye, Maik Tiedemann, Yannick Perrot, Chloé Migayrou, Nolwenn Behagle, Louis Marié, Eric Machu, Xavier Capet and Patrice Brehmer

Abstract: The management of the marine biology requires, among other, knowledge of the functioning of the ecosystem. In particular, in the context of fisheries resources, an in-depth knowledge of the marine environment and interspecific interactions within it is essential. It should be noted that major disturbances in the marine ecosystem are the result of climate change. These latter greatly affect the fishery resource. The spatio-temporal analysis of the environmental factors or fishing pressure that influence the evolution of the resource and its production is therefore of paramount importance. In the scope of geostatistics, number of methods has been developed to study the abundance of a particular stock, in climate change setting. Many of these are based on kriging models as kriging and co-kriging. The present study is an ecosystem approach based essentially on a spatio-temporal analysis of data concerning the coastal fisheries and demersal resources of Senegal. This will be done using spatial modelling over time, which involves spatial statistical methods of possibly infinite nature (functional data).

The non-parametric approach is particularly suitable for modelling some functional data. Indeed, it considers very broad models to characterize and quantify the factors influencing the spatio-temporal evolution of the resource within the marine ecosystem, while taking into account the spatial structure of data. We extend nonparametric spatial prediction method, in the functional setting for monitoring the effect of climate change on abundance of demersal fish. Numerical studies were carried out in order to illustrate the behaviour of the proposed methodology both for simulated and bio-ecological dataset.

Title: Methanogenic potential of aquaculture waste a smart initiative for green aquaculture in the framework of blue growth

Authors and affiiliations: NDeye Aida Ndiaye [1], Halima Magouzou Diagne [1], Hamet Diaw Diadhiou [2], Waly Ndiaye [2], Fulgence Diedhiou [2], Mamadou Niang [2], Matar Sylla [3], Mouhamed Lamine Gaye [4], Saliou Fall [1], and Patrice Brehmer [5,2]

[1] Institut Sénégalais de Recherche Agricole (ISRA), LCM, Bel air, Dakar, Sénégal

[2] Institut Sénégalais de Recherche Agricole (ISRA), Centre de Recherche Océanographique de Dakar Thiaroye (CRODT), BP 2221, Dakar, Sénégal

[3] Programme Nationale de Biogaz du Sénégal (PNB Sn), Dakar, Sénégal

[4] Université Cheikh Anta Diop (UCAD), Département de Chimie, Dakar, Sénégal

[5] Institut de Recherche pour le Développement (IRD), Délégation régionale France Ouest, UMR Lemar (UBO-CNRS-IRD-Ifremer), BP70, 29 280, Plouzané, France

Abstract: All predictions agree that tilapia is destined to become the major aquaculture species of tomorrow. Tilapia is grown in more than 100 countries and production reaches 4.3 million tonnes making this fish group the second largest for global aquaculture, after that of carp. The modern development of its breeding requires energy for production systems e.g. to supply oxygen equipment or automatic food vending machines or the heating of livestock ponds. This work proposes to valorise the waste resulting from the activities in fish farming by the processes of anaerobic digestion to produce energy. For this, faeces of Tilapia *Oreochromis niloticus* were sampled periodically and their methanogenic potential (BMP test) determined and compared to a reference substrate (poultry droppings); with or without inoculum. The μCG analysis made it possible to determine the relative proportions of methane (CH4) in the biogas as a function of the duration of production. Biochemical methane potential (BMP) tests showed rapid kinetics of biogas production of fish faeces in the presence of inoculum (+ inoculum) compared with the production of biogas in faeces alone. This kinetics of biogas production is reversed between the third and fourth week. In both cases, the proportion of methane is generally greater than 60% from the second week of incubation, which shows the quality of the biogas produced. The composition of CH4 and CO2 does not change with or without inoculum. However, there is a significant difference in total CH4 volume which is twice as large with inoculated fish faeces than uninoculated fish or poultry droppings. Our results show that fish droppings are good methanogenic substrates and the use of the inoculum allows for a quick start of biogas production and avoids MO losses. Realized on a large scale, the valorisation of aquaculture fish faeces could constitute a source of green energy for the development of fish farming in Africa. And thus a smart initiative to fight against climate impact on small pelagic fish stock displacement in tropical areas.

Title: Matecho: an open-source tool for processing fisheries acoustics data to facilitate collaborative development

Authors and affiliations: Yannick Perrot, Patrice Brehmer, Jérémie Habasque, Gildas Roudaut, Nolwenn Behagle, Abdoulaye Sarré, Ndague Diogoul, Anne Lebourges-Dhaussy

Abstract:

Title: Echo level segmentation on echo-integration of fisheries acoustics data.

Authors and affiliations: Yannick Perrot, Patrice Brehmer, Nolwenn Behagle, Anne Mouget, Chloe Migayrou, Jérémie Habasque, Gildas Roudaut, Ndague Diogoul, Abdoulaye Sarré

Abstract:

Title: Analysing tortuosity in diving behaviour of yellowfin tuna, *Thunnus albacares*, in CABO VERDE

Authors and affiliations: Pericles Silva [1], Ivanice Monteiro [1], Victor Stiebens [2], Matthias Schaber [3] and Heino O. Fock [3]

[1] Instituto Nacional de Desenvolvimento das Pescas (INDP) and Ocean Science Centre Mindelo (OSCM), Mindelo, Sao Vincente, Cabo Verde

[2] Marine Biological Consultancy - Cape Verde

[3] Thünen-Institute (TI), Institute of Sea Fisheries, Federal Research Institute for Rural Areas, Forestry and Fisheries, Palmaille 9, 22767 Hamburg, Germany

Abstract: Habitat quality changes with climate change, affecting water temperature and oxygen contents, and this change in habitat quality could trigger a shift in spatial distributions of the tuna species, i.e. yellowfin (YFT) and bigeye tuna (BET), in Cabo Verde with subsequent effects for the fisheries. The aim of WP 12-2 is to investigate habitat use of these species. In 2016 and 2017, five specimens of YFT were tagged with External pop-up satellite tags (WildlifeComputers MiniPAT). Diving depth rarely was deeper than 80 m. No deep dives were undertaken. Tags were deployed at the islands of Maio, São Vincente, São Nicolau and Boa Vista of Cabo Verde.

We developed 2 different approaches to analyse tortuosity in diving behaviour. The index $\tau 1$ describes the ratio between depth difference to vertical swimming speed for 9 consecutive time steps, i.e. about 10 minutes. The index $\tau 2$ is the inverse of the depth difference weighted by the swimming speed.

Values for $\tau 1$ range from 0 – 1, and values ~ 1 indicate straight diving and searching. Intermediate values are assumed to indicate hunting activities with a series of short up and downward directed strokes, and low values would indicate horizontal activities only. Whereas $\tau 1$ is a relative measure, $\tau 2$ is indicative of absolute activity levels. Relatively high levels indicate low absolute vertical activity and could indicate either horizontal moves or resting.

In particular the specimens associated with dolphins showed a significant difference for $\tau 2$ during night-time.