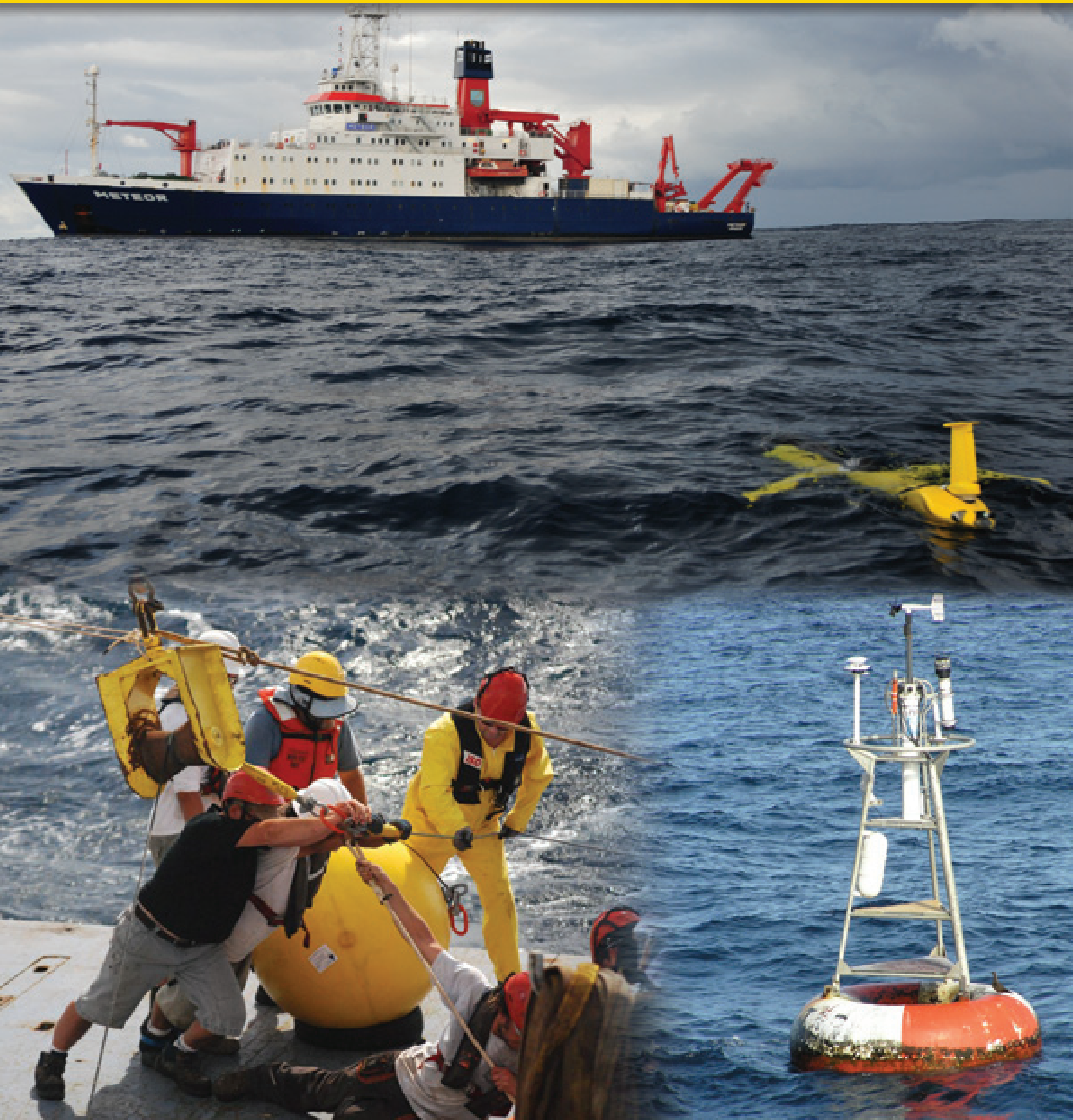
Climate Variability & Predictability
CLIVAR
World Climate Research Programme

Exchanges

CLIVAR Endorsed Projects

No. 61 (Vol 18 No.1) March 2013



CLIVAR is an international research programme dealing with climate variability and predictability on time-sales from months to centuries. CLIVAR is a component of the World Climate Research Programme (WCRP). WCRP is sponsored by the World Meteorological Organization,the International Council for Science and the Intergovernmental Oceanographic Commission of UNESCO.

WCRP
World Climate Research Programme

Editorial

Roger G. Barry, Director ICPO

CLIVAR ENDORSED PROJECTS

CLIVAR's Panels and Working Groups have generated a range of activities, which receive formal endorsement through the normal course of CLIVAR business. From time to time, however, the CLIVAR Scientific Steering Group (SSG) is asked to endorse research (and other activities such as conferences and workshops) and to consider including new research foci in its portfolio which have grown up externally from its Panels and WGs as independent national or international efforts. The objectives of these requests are varied but include:

- Helping a project/activity to obtain national recognition and funding;
- Establishing a formal mechanism to enable the representatives of a project/activity to engage discussions with a CLIVAR panel or WG, or the ICPO to assist co-ordination;
- Broadening CLIVAR's scientific remit to include new emerging areas of science, for example the La Plata research area (The La Plate Basin Continental Scale Experiment (LPB) was the subject of Exchanges number 57 in October 2011).

This issue of Exchanges presents reports of six CLIVAR-endorsed projects that have operated for a number of years and one associated research cruise. Each project is independent and they are not necessarily closely related, but their reports provide a window on wider CLIVAR activities.

The projects reported on in this issue are:

- Intra-American Study of Climate Processes (IASCLiP)
- Mediterranean Climate Variability and Predictability (MedCLIVAR)
- Madden-Julian Oscillation Task Force (part of the Dynamics of the MJO (DYNAMO) project)
- Northwestern Pacific Ocean Circulation and Climate Experiment (NPOCE)
- Southwest Pacific Ocean Circulation and Climate Experiment (SPICE), including a SPICE Pandora Research Cruise Report
- Tropical Atlantic Climate Experiment (TACE)

I would like to thank the authors for their contributions to this issue and ICPO Staff Scientist Dr. Jennifer Riley for editing the articles.

A Review of Recent Research Activities within the Intra-Americas Science Climate Processes Program (IASCLiP)

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Introduction

The Intra-Americas Science Climate Processes Program (IASCLiP) is a WCRP CLIVAR/GEWEX program focused on the climate of the Intra-Americas Sea region. IASCLiP seeks to improve and expand the observational network across the warm water pool region of the Americas as a promising avenue towards improving the accuracy of both operational models and regional forecasts across the 41 nation domain of the Intra-Americas Seas (IAS). This report highlights selected research efforts from 2012 and 2013 which demonstrate the impact and interaction of the Intra-Americas Seas (IAS) regional climate on broadscale fluctuations in weather and climate across both North America and South America. The modeling studies presented here clearly demonstrate the need for enhanced climate monitoring within the IAS region with direct pay offs relative to the prediction of seasonal rainfall anomalies in the North America Monsoon region and spring time tornado activity in the United States. The Prospectus, Monitoring and Modeling plans for IASCLIP can be accessed directly at: http://www.eol.ucar.edu/projects/iasclip/ .

The IASCLiP program follows previous VAMOS investigations of the North American and South American monsoon systems. A major goal of IASCLiP is to develop a better understanding of the inter connections between these monsoon systems and the climate of the Caribbean Basin. An important NOAA CPO ARC data collection effort in the Dominican Republic has yielded a long time series of rainfall and temperature records extending back into the 1930s. In a preliminary analysis of these data sets by Art Douglas and Phil Englehart at Creighton University, a strong linkage was found between Caribbean rainfall and the monsoon systems of Mexico (Figure 1). This correlation analysis indicates that the mid summer drought of the Caribbean is systematically connected with mid summer drought (Canicula) in southern Mexico, but rainfall in these two southern regions are out of phase with the summer monsoon in northwest Mexico. A final link in the broad teleconnections in rainfall across the Americas is drawn between monsoon rainfall in Northwest Mexico and summer precipitation in the Midwest. It was this latter relationship that became a major focal point of the NAME program in the early 2000s.

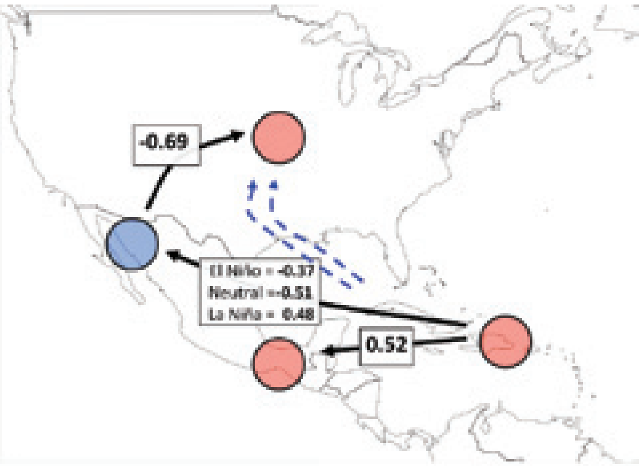

Figure 1. Broad teleconnections between summer rainfall (JJA) in the Dominican Republic, Mexico and the central United States. Correlations are based on more than 65 years of GHCN-NCDC based climate division data. The relationship between monsoon rainfall in northwest Mexico and the Dominican Republic is strongly based on the phase of ENSO.

Links between Summer Rainfall in the Equatorial Amazon and Subsequent SST Anomalies in the Intra Americas Seas.

Misra and DiNapoli analysis (2012) shows that enhanced austral summer rainfall (DJF) over the equatorial Amazon is followed by cooler SSTs in the Intra America Seas (IAS) region during the boreal summer (JJA; Fig. 2). The authors propose that the physical mechanisms responsible for this teleconnection are found in remote ENSO forcing of the north-south migration of the western Atlantic ITCZ. In warm (cold) ENSO years, the equatorial Amazon is invariably drier (wetter) than normal in the austral summer because the ITCZ is displaced to the north (south) of the equatorial Amazon Basin. In subsequent seasons the ITCZ continues to be displaced farther to the north (south) following the mature phase of a warm (cold) ENSO event. These ENSO controlled fluctuations in the latitudinal position of the western Atlantic ITCZ lead to anomalous surface energy fluxes over the IAS region. In cold ENSO years (ITCZ displaced anomalously southward), the descending branch of the Hadley Circulation is directed towards the central IAS region with associated anomalous desiccation of the atmospheric column across the Caribbean. This drying results in an increase in the upwelling longwave energy flux. The enhanced longwave flux leads to the development of cold SST anomalies across the IAS (Figure 2). Misra and DiNapoli note that the upwelling long wave flux is a dominant term in the surface energy balance of the IAS region. IASCLiP research continues to focus on the importance of understanding the interaction of IAS climate with both the South American and North American monsoons. These links between the position and the strength of the austral summer monsoon in the Amazon and subsequent SST anomalies in the Caribbean influence the ability of models to predict tropical cyclone activity in the IAS region, including the vulnerable coastal waters of eastern Mexico and the southeastern United States.

Impact of Land Surface Conditions on the North American Monsoon.

Feng et al. (2013) investigated the impact of land surface conditions on the development of the North American monsoon (NAM) system using two ensemble simulations conducted with a General Circulation model from May to September in 2004. Both ensemble runs consisted of six members forced with the same observed sea surface temperature but with different initial atmospheric conditions. The control run used a fully interactive land surface model, whereas the sensitivity ensemble run was prescribed with land surface state variables from the Global Land Data Assimilation System. Soil moisture in the sensitivity run was significantly lower than the control run over the core NAM region, including Arizona-New Mexico (AZNM) and northwestern Mexico (NWM), with maximum negative values along the Sierra Madre Occidental foothills (Fig. 3a). The authors found that a reduction in soil moisture resulted in less precipitation over AZNM and northern NWM (Fig. 3b) due to a positive feedback primarily controlled by the local recycling mechanism. Over these regions, the reduced soil moisture led to a decrease in latent heat flux/evaporation and higher Bowen ratio and surface temperature. These changes resulted in the development of a deep (warm and dry) boundary layer, which suppressed convection and hence reduced precipitation. In western Sinaloa (central coastal plain bordering the Gulf of California) soil moisture decreases had the opposite effect on precipitation. Soil moisture reduction changed the surface fluxes and consequently the surface pressure gradients and the large-scale wind fields. These changes resulted in an increase in moisture convergence in the coastal zone which favored enhanced convection and increased precipitation.

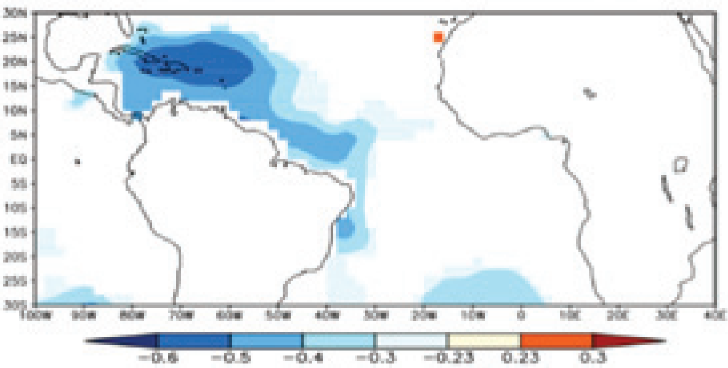

Figure 2. The correlation of the mean boreal summer (JJA) seasonal SST anomalies with the mean preceding December-January–February (DJF) rainfall from Climate Research Unit (CRU) over Equatorial Amazon (7_S– 7_N and 65_W–50_W). These correlations are computed over the period from 1950–2004. Only significant values at 90 % confidence interval according to t test are shown. The linear trends in rainfall and SST are removed before the correlation is calculated. Adapted from Misra and DiNapoli (2012).

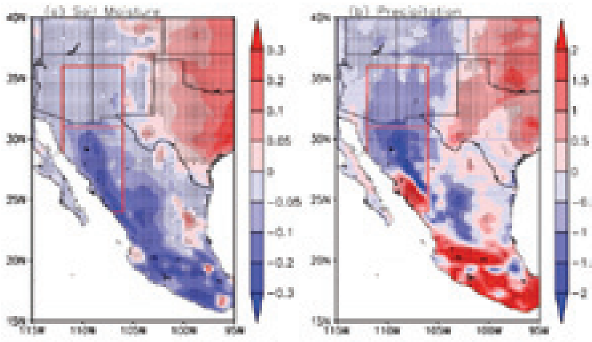

Figure 3. JuneJulyAugust 2004 difference between sensitivity and control ensemble simulations of a) mean top-layer (01.7 cm) soil moisture (percentage of saturation) and b) precipitation (mm day-1). Regions where differences are statistically significant at the 90% confidence level are indicated by the black hyphen. The red solid lines designate the monsoon region including ArizonaNew Mexico (31-36N, 112-106W) and northwestern Mexico (24-31N, 112-106W). Figure is from Feng et al. (2013).

Moisture Transport from the IASCLiP region and Tornado Activity in the United States

Lee et al. (2013) examined the ten years of highest tornado activity for the United States during the spring (April-May, 1950-2010). They determined that these years were associated with significantly enhanced moisture transport from the Inter-American Seas region into the United States. Enhanced moisture transport from the IAS is accompanied by increased convective available potential energy over the central and eastern United States, as well as greater lower-level (0 ~ 1 km) vertical wind shear. These changes provided large-scale atmospheric conditions conducive to intense tornado outbreaks over the United States (Fig. 4). This study also ties enhanced moisture transport from the IAS region into the United States with a distinct pattern of tropical Pacific SST anomalies set up during the transitional phase of ENSO in the boreal spring. This SST pattern which is linked to tornado outbreaks is known as the positive phase Trans-Niño. SST distribution in the positive phase is characterized by colder-than-normal SSTs in the central tropical Pacific (Nino4) and warmer-than-normal SSTs in the eastern tropical Pacific (Nino1&2). This IASCLiP research effort highlights the importance of understanding IAS moisture transport and its role in the development of severe weather events in the United States. The new NSF Caribbean COCONet GPS Precipitable Water array and the long standing NOAA TAO array in the equatorial Pacific offer real time monitoring across two ocean regions which show important links to tornado activity in the United States.

IASCLiP Climate Bias in CMIP5 models

Kozar and Misra (2013) examined the 20th century simulations of the CMIP5 suite of models for their rendition of the Atlantic Warm Pool (AWP) climatology and variability. Their work concentrates on the areal distribution of the AWP warm water core (> 28.5°C). They find a pervasive cold bias in most models over the IAS region in the Aug-Sep-Oct (ASO) season (Fig. 5). In the observational record they note that for the ASO season, over 70% of the area in the northwest tropical Atlantic Ocean exhibit mean SSTs between 26°C and 29°C. In contrast, in a majority of the CMIP5 models examined, over 70% of the northwest tropical Atlantic area is characterized by cooler SSTs, in the range of 24-28°C as shown in Fig. 5.

Kozar and Misra note that the seasonal cycle of the AWP is well defined with its peak in the late boreal summer and early fall with a comparatively rapid onset and demise. In the ERSSTv3 climatology the AWP ramps up in July, reaches a peak in September, and then rapidly diminishes in size and strength in November. In 10 of the 17 CMIP5 models, the AWP reaches its peak size in August, which is a month too early when compared to observations. Many of the CMIP5 models that exhibit a severe cold bias over the IAS (BCC-CSM1-1, CCSM4, CanESM2, GFDL-CM3, INMCM4, IPSL-CM5A-LR, NorESM1-M) weaken their modest AWPs much too quickly (as compared to the climatological cycle). By October less than 20 % of the AWP's area remained in place with respect to its peak monthly size (compared to 41% of the area observationally). The models with less severe cold bias, however, have an entirely different problem in that they fail to exhibit the sharp changes in the AWP's seasonal cycle. Four models—CSIRO-Mk3.6, GISS-E2-R, GISS-E2-H and HadGEM2-ES—have well-defined AWPs of over 200,000 km^2 into November (compared to 70,000 km^2 in the observations). The development of the AWP is much too gradual in these models in comparison to the sudden onset of warming found in the observations. The HadGEM2-ES in particular overestimates the average size of the warm pool during the spring and winter months, when the AWP is expected to be undefined (SSTs <28.5°C). This research effort by Kozar and Misra highlights the need to improve AWP prediction across the IASCLiP region. In many cases model

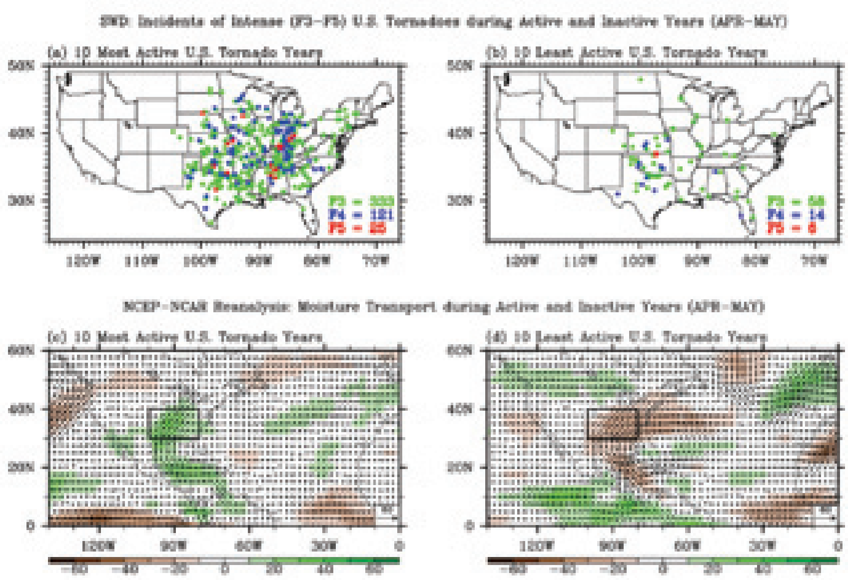

Figure 4. Incidents of intense (F3-F5) U.S. tornadoes in April-May for (a) the ten most active U.S. tornado years and (b) ten least active U.S. tornado years. Green color is for F3, blue color for F4 and red color for F5 tornadoes. Anomalous moisture transport for (c) the ten most active U.S. tornado years and (d) ten least active U.S. tornado years in April-May during 1950-2010 obtained from NCEP-NCAR reanalysis. The units are kg m-1sec-1 for moisture transport. The small box in (c) and (d) indicates the central and eastern U.S. region frequently affected by intense tornadoes (30oN-40oN, and 100oW-80oW).

Bin	ERSST v3	BCC-CSM1-1	CanESM2	CCSM4	CNRM-CM5	CSIRO-Mk3.6	GFDL-CM3	GFDL-ESM2G	GFDL-ESM2M
20-21 °C	1.4%	1.2%	1.1%	0.6%	1.0%	1.4%	1.4%	0.9%	1.1%
21-22 °C	1.1%	1.6%	1.3%	1.2%	1.3%	1.6%	2.2%	1.3%	1.4%
22-23 °C	1.3%	2.1%	1.9%	2.0%	1.6%	3.7%	3.0%	2.1%	2.1%
23-24 °C	2.1%	2.9%	4.1%	2.9%	3.2%	6.8%	4.2%	5.2%	4.4%
24-25 °C	3.3%	6.3%	10.6%	4.7%	7.4%	11.3%	8.7%	10.7%	10.3%
25-26 °C	7.5%	18.5%	17.6%	14.9%	16.5%	16.4%	15.2%	15.5%	17.4%
26-27 °C	15.3%	27.3%	23.4%	26.6%	27.1%	17.3%	23.7%	26.5%	27.9%
27-28 °C	29.4%	20.6%	27.9%	33.2%	26.4%	16.7%	29.3%	27.4%	25.5%
28-29 °C	26.3%	2.3%	7.6%	10.7%	6.4%	12.9%	6.3%	4.3%	4.2%
29-30 °C	4.1%	0.1%	0.2%	0.3%	0.4%	3.3%	0.7%	0.3%	0.4%
>30°C	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%

Bin	GISS-E2-H	GISS-E2-R	HadGEM 2-ES	INM-CM4	IPSL-CM5A-LR	MIROC5	MPI-ESM-LR	MRI-CGCM3	NorESM1-M
20-21 °C	2.1%	1.6%	0.6%	1.3%	1.6%	1.2%	1.0%	1.9%	0.0%
21-22 °C	2.0%	2.6%	0.8%	2.2%	2.3%	1.6%	1.4%	2.3%	0.0%
22-23 °C	2.9%	3.2%	1.9%	3.3%	4.9%	3.9%	2.1%	3.7%	0.0%
23-24 °C	4.9%	4.4%	4.2%	3.0%	13.1%	10.4%	4.9%	4.8%	5.8%
24-25 °C	7.3%	6.3%	10.8%	7.3%	20.3%	16.9%	9.7%	9.8%	24.5%
25-26 °C	10.2%	8.2%	16.9%	15.1%	23.0%	22.0%	12.9%	16.7%	39.9%
26-27 °C	15.4%	12.4%	27.4%	33.4%	16.6%	22.4%	16.9%	25.6%	22.0%
27-28 °C	40.0%	34.0%	23.3%	25.1%	7.9%	13.8%	34.4%	22.9%	3.4%
28-29 °C	19.0%	27.6%	9.1%	0.6%	0.9%	2.3%	17.2%	4.3%	0.0%
29-30 °C	0.1%	3.3%	1.4%	0.0%	0.0%	0.2%	1.8%	0.2%	0.0%
>30°C	0.0%	0.0%	0.3%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%

Figure 5. Frequency distribution of 1909–2005 ASO averaged SSTs across the Atlantic Basin in one-degree bins. Each value is shown in percent area of the total domain (0_N–45_N and 40_W–100_W), and is accompanied by a bar graph. The bins that contribute to the AWP (SST>28.5C) are shown in red. From Kozar and Misra (2012).

based seasonal tropical cyclone prediction continues to be hindered by the cold bias in IAS SSTs and the colder-drier atmosphere of the models over the IAS has direct implications with respect to the seasonal prediction of moisture transport into the North American continent. IASCLiP is focused on identifying and correcting these well documented model errors.

Response of Freshwater Flux and Salinity to Variability of the Atlantic Warm Pool

Wang et al. (2013) investigated the response of freshwater flux and sea surface salinity (SSS) to variations in the Atlantic Warm Pool from seasonal to multidecadal timescales. Their research employed various reanalysis products and observations. All data sets demonstrated a consistent response for all of the timescales: A large (small) AWP is associated with a local freshwater gain (loss) to the ocean (Fig. 6, less (more) moisture transport across Central America and a local low (high) SSS. Their moisture budget analysis demonstrates that the freshwater change is dominated by the atmospheric mean circulation dynamics, while the effect of thermodynamics is of secondary importance. Further decomposition points out that the contribution of the mean circulation dynamics primarily reflects the divergent wind change at low levels as a result of the SST change. In association with a large (small) AWP, warmer (colder) than normal SST over the tropical North Atlantic can induce anomalous low-level convergence (divergence), which favors anomalous ascent (decent) and thus the generation of more (less) precipitation. On the other hand, a large (small) AWP weakens (strengthens) the trade winds and their associated westward transport of moisture towards the eastern tropical Pacific across Central America. This reduction of moisture transport into the eastern tropical Pacific favors more (less) moisture residing in the Caribbean and hence more (less) precipitation.

These results of Wang et al. (2013) suggest that variability of freshwater and ocean salinity associated with the AWP may have the potential to affect the Atlantic meridional overturning circulation (AMOC). On one hand, as the AMOC weakens, its northward heat transport is reduced and thus, the North Atlantic cools and the AWP becomes small. On the other hand, a small AWP decreases rainfall in the tropical North Atlantic and this leads to an increase in the cross-Central American moisture export to the eastern North Pacific. Both of these factors tend to increase salinity in the tropical North Atlantic Ocean. Advected northward by the wind-driven ocean circulation, the positive salinity anomalies may increase the upper-ocean density in the deep-water formation regions and thus strengthens the AMOC. Therefore, the AWP plays a negative feedback role that acts to restore the AMOC after it is weakened or shut down. This hypothesis has been tested and confirmed by numerical model experiments (Zhang et al. 2013). Enhanced monitoring of the IAS warm pool per the addition of surface and subsurface salinity and temperature

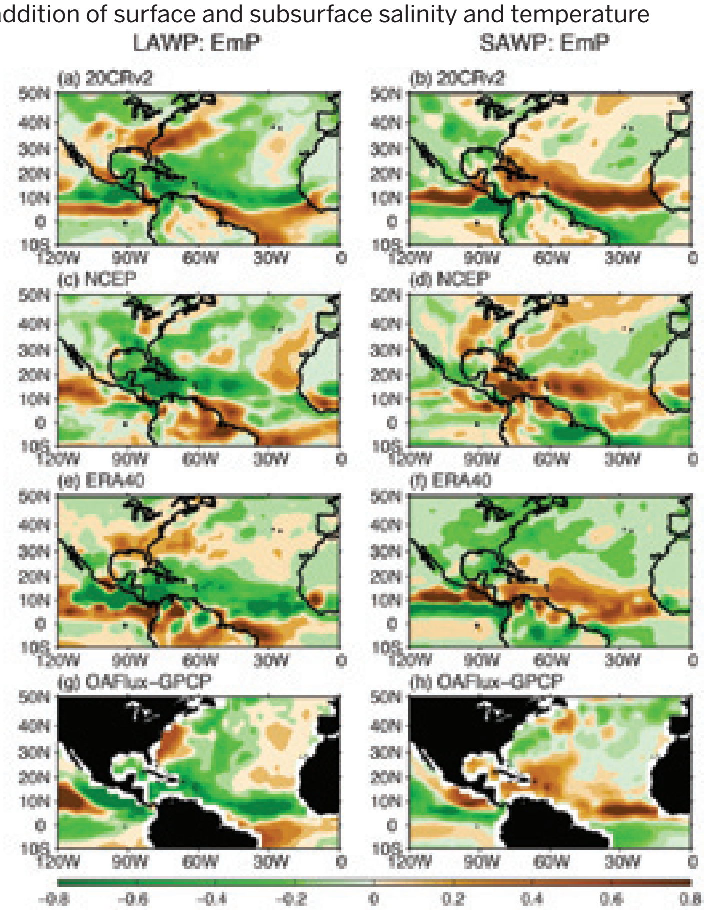

Figure 6. Composites of the EmP (Evaporation minus Precipitation) anomalies (mm/day) on interannual timescales during the summer (JJA). Shown are for large AWP (left panels) and small AWP (right panels) from various data sets of (a, b) 20CRv2, (c, d) NCEP, (e, f) ERA40 and (g, h) OAFlux-GPCP.

measurements on preexisting NOAA buoys in the IAS could provide a means for detecting developing changes in the AMOC. The IASCLiP community strongly supports this type of long term monitoring activity within the IAS region.

Summary

IASCLiP is an integrated ocean-atmosphere research program focusing on the prediction of weather and climate impacts of the warm water pool of the Intra-Americas Seas. As illustrated in the above summaries of recent research within IASCLiP a main goal of the program is to develop a better understanding of the climate processes within the region and adjacent land masses. Partnerships between the research community and federal agencies within the more than 40 plus nation domain are critical to the success of the program as it seeks to improve operational modeling within the region Research emphasis continues to be placed on the structural development of the warm water pool and its associated impacts on climate extremes and the development and transition of the monsoon systems in South and North America.

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Climate Variability and Mediterranean Predictability (MedCLIVAR)

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Objectives and history

MedCLIVAR (www.medclivar.eu) goals are to coordinate and promote research on the climate of the Mediterranean region, covering its past evolution, its present space-time variability, trends and future climate scenarios. It aims at a comprehensive vision of the regional climate system, including its atmospheric, marine and terrestrial components, and considering the effects of climate changes on human activities and ecosystems. Therefore, MedCLIVAR includes a broad spectrum of topics: reconstruction of the climate's past evolution, description of patterns and mechanisms characterizing its space-time variability, identification of present trends, understanding of the forcing parameters responsible for the observed changes, production of future climate scenarios at regional scale and analysis of climate change impacts.

The first official MedCLIVAR meeting was an exploratory workshop held in Rome (16-19 May 2004). This workshop was supported by the European Science Foundation (ESF) and led to the MedCLIVAR "white paper", which provided the ground for the CLIVAR endorsement (January 2005) and the approval of the MedCLIVAR-Research Network Project by ESF. The ESF MedCLIVAR-RNP (Research Networking Programme) was launched in May 2006 and, thanks to the support of funding agencies in 12 countries (which made available about 920 Keuros in 5 years), has held 6 workshops, 1 major conference, 2 summer schools, assigned 31 young scientist exchange grants and sponsored or co-sponsored 11 scientific meetings. Since its launch, MedCLIVAR has acted as an independent platform for scientific discussion, exchange of information among scientist and promotion of scientific research on the climate of the Mediterranean region. Three main factors contribute to the remarkable interest this relatively small region raises among climatologists:

- A peculiar and rich phenomenology. The Mediterranean region presents a large spectrum of mesoscale processes that are relevant for the description of the regional climate, for both its marine and atmospheric components. Complexity and richness of phenomena are caused by the morphology of the Mediterranean region and by its geographical location in a transition region, which is under the influence in part of subtropical and in part of mid-latitude climate regimes.
- A well-developed cultural background in most Mediterranean countries. The traditionally high cultural level of this region, which has been a cradle of civilization and has been strongly involved in the development of the modern world, provides cultural resources and highly educated scientists for studying regional climate. Education and research (supported by many universities and institutions) have traditionally been in a strong position in most countries around the Mediterranean Sea and provide the basis for the existing large number of scientific publications.
- Vulnerability of ecosystems and human societies to climate change. Impacts on society and environment determine a growing set of questions and demands being posed to scientists by citizens and politicians. In the Mediterranean region, climate variability and change act as new source of problems that can trigger very negative scenarios in a situation already environmentally problematic.

During the existence of MedCLIVAR, the climate science of the Mediterranean region has progressed on many aspects. New or extended digitalized time series and an increased number of natural and documentary proxies have contributed to improve the reconstruction of past climate variability. A wide spectrum of hydrological, ecological and even socio-economic impacts of climate variability have been described in recent scientific studies. Key processes of the Mediterranean Sea circulation, such as deep water formation, have been accurately modeled. Sea level trends and the factors causing them during the last decades (atmospheric, steric and mass changes) have been estimated. Regional climate models have been improved in term of resolution and complexity, recently including the coupling to a high resolution model of the Mediterranean Sea circulation, and provide now a more accurate information than before on the response of the Mediterranean regional climate (including extreme climatic events) to global climate change. The two books published by MedCLIVAR in 2006 and 2012 provide a comprehensive view of this evolution

Networking and publications

MedCLIVAR has put together expertise covering different subjects and created a forum to exchange results and facilitate synergies among groups. The network that MedCLIVAR has established is based on groups of scientists mainly from Austria, France, Germany, Greece, Italy, Israel, Portugal, Spain, Switzerland, Turkey, U.K., and includes also participants from North Africa countries such as Libya, Tunisia, Egypt and Morocco. The Network has organized six strategic workshops that were managed directly by the Steering Committee: 2006 in Carmona (Spain) convened by R. Garcia-Herrera, 2007 in Toulon (France) convened by L. Li, 2008 in Rhodes (Greece) convened by A. Theocharis, 2009 in Sesimbra (Portugal) convened by F. Abrantes and R. Trigo, 2010 in Trieste (Italy) convened by F. Giorgi, 2011 in Tel Aviv (Israel) convened by P. Alpert and H. Saaroni. Further, MedCLIVAR has supported the organization of 11 workshops/conferences in cooperation with other projects and initiatives. Two Summer Schools, which have attracted a large numbers of young scientists and students from both developing and developed countries, were organized in Rhodes in 2008 and in Trieste in 2010. In addition, every year, MedCLIVAR has held a "Mediterranean Climate Variability" session at the European Geosciences Union general assembly. The 2011 MedCLIVAR Conference "Mediterranean Climate: From past to the future", held in Lecce (Italy) on June 6-9th 2011, has been followed by the 2012 MedCLIVAR conference "The climate of the Mediterranean region: understanding its evolution and effects on environment and societies" held in Madrid (Spain) on September 26-29th 2012.

Participation of young scientists (percent) to the MedCLIVAR grant exchange programme in term of country of provenience of the grant holder (left) and of hosting institutions (right). Abbreviation denotes the countries that contributed to the programme; Bulgaria (BG), Croatia (HR), France (FR) Germany (DE), Greece (GR), Israel (IL), Italy (IT), Portugal (PT), Spain (ES), Switzerland (CH), Tunisia (TN). This figure has been extracted from "Mediterranean Climate Variability", Elsevier, Amsterdam, developments in Earth and Environmental Sciences, vol.4 ISBN: 9780080460796

The new book "The climate of the Mediterranean region: from the past to the future" has been written five years after the previous book "Mediterranean Climate Variability". These two books are main outcomes of the MedCLIVAR programme and are meant to represent the results of a community effort. In fact, both books are multi-authored manuscripts written by a team of scientists actively working on Mediterranean climate research. In a coordinated sequence of chapters they describe the status of the knowledge on different aspects of the Mediterranean climate. They contain very useful reviews of the present research, overviews of recent developments and new research interests. They are meant to provide not only scientists, but also environmentalists and policymakers with clear and correct information on climate variability and change at the regional Mediterranean scale. The comparison of the second book with the first one shows the progresses of the MedCLIVAR programme and of the Mediterranean climate research during the period between their publication. The most evident differences include more material on climate modeling and projections, a wider treatment of sea level issues, a larger contribution from the paleo-climate component, and an extended discussion on climate extremes in the second book. The main results of the programme are also documented in four special issues:

- "Mediterranean climate: trends, variability and change", Global and Planetary Change, Volume 63, Issues 2–3, Pages 87-282, 2008, P.Lionello, S.Planton and X.Rodó eds.
- "Oxygen isotopes as tracers of Mediterranean variability: linking past, present and future" Global and Planetary change, Volume 71, Issues 3–4, Pages 135-270 , 2010, M.D. Jones, C.N. Roberts and G. Zanchetta eds.
- "Venetia and Northern Adriatic Climate" Physics and Chemistry of the Earth, Volume 40-41, pages 1-106, 2012, P.Lionello ed.
- "Understanding dynamics and current developments of climate extremes in the Mediterranean region", NHESS, http://www.nat-hazards-earth-syst-sci.net/special_issue112.html, R. Garcia-Herrera, P.Lionello, U. Ulbrich eds.)

Ongoing activities

MedCLIVAR activities are continuing after the termination of the ESF support. Since December 2011 MedCLIVAR publishes a newsletter twice a year (M.Marcos, K.Schröder, S.Somot, A.Toreti, eds), as a tool for distributing information on the MedCLIVAR activities and on initiatives that are important for the Mediterranean Climate. A special Issue of

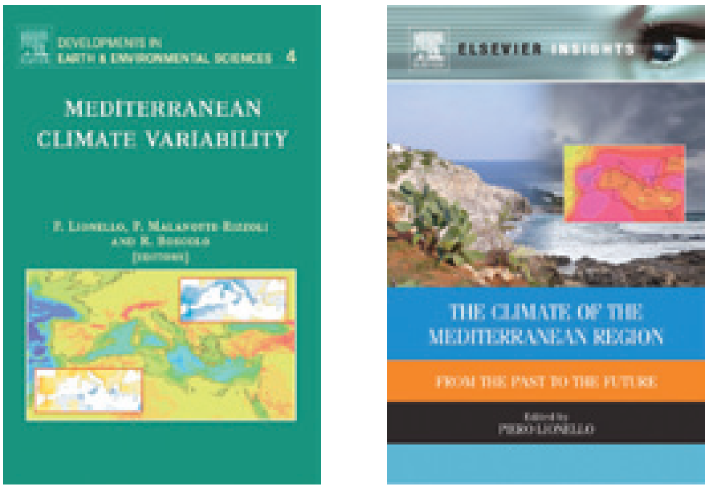

Figure 1: The covers of the two MedCLIVAR books, published in 2006 (left) and 2012 (right)

Regional Environmental Changes with title "The climate of the Mediterranean region: recent progresses and climate change impacts" is presently being finalized (P.Lionello, F.Abrantes, M. Gacic, S. Planton, R. Trigo, U. Ulbrich eds). MedCLIVAR has initiated also a major effort for a systematic archiving of observations and model data on the Climate of the Mediterranean region at the World Data Center for Climate (WDCC), in order to share data among scientific community (contact piero.lionello@unisalento.it for further information and for submitting data sets). Finally, the third MedCLIVAR Conference will be held in the second half of 2014 in Istanbul (Turkey). Topics will include modeling and understanding of regional climate extremes, climate variability on decadal, multi-decadal and centennial time-scales, circulation, strait exchanges, recent developments and applications of regional climate models, discussion of climate change impacts on ecosystems and human civilizations. The conference is expected to promote exchange of information between climatologists, on one hand, and social scientists, economists, agronomists on the other hand.

In the future MedCLIVAR aims further develop the cross-disciplinary discussion and the dissemination of results, and continue acting as an open bottom-up organization of scientists, which offers a neutral forum for scientific discussion and coordination of research. Indeed, the present financial situation and, sometimes political differences hamper this type of initiative. It is initiatives such as MedCLIVAR which are extremely important for optimizing the use of regional resources and for overcoming some of the political and cultural differences across this region.

Acknowledgement

MedCLIVAR acknowledges the European Science Foundations and its member organizations, which supported the programme

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Chapter 2. A review of 2000 years of paleoclimatic evidence in the Mediterranean (Luterbacher J. et al.)

Chapter 3. Circulation of the Mediterranean sea and its variability (Schroeder K. et al.)

Chapter 4. Sea level rise and its forcing in the Mediterranean sea (Gomis D. et al.)

Chapter 5. Climate of the Mediterranean: synoptic patterns, temperature, precipitation, winds and their extremes (Ulbrich U. et al.)

Chapter 6. Large-scale atmospheric circulation driving extreme climate events in the Mediterranean and related impacts (Xoplaki E. et al.)

Chapter 7. Modeling of the Mediterranean climate systems (Li L. et al.)

Chapter 8. The climate of the Mediterranean region in future climate projections (Planton S. et al.)

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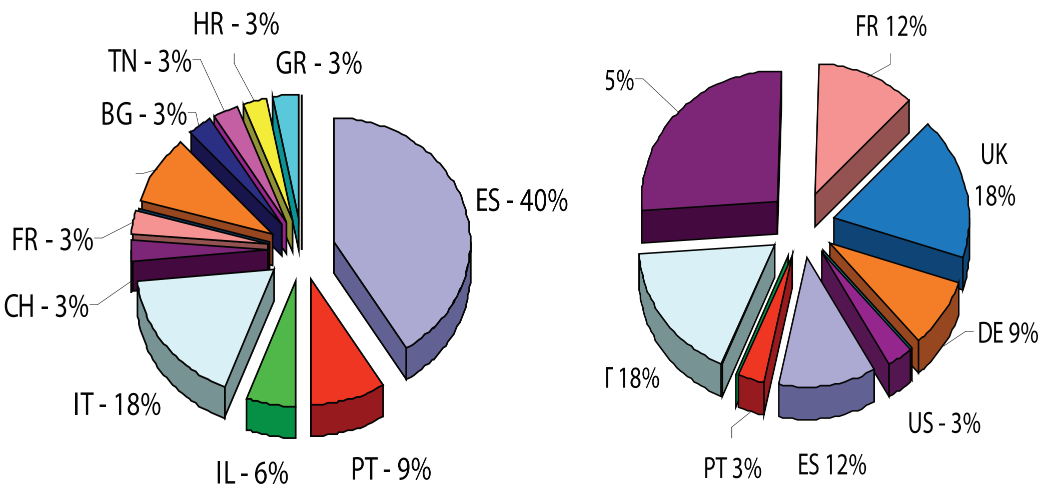

Figure 2: Participation of young scientists (percent) to the MedCLIVAR grant exchange programme in term of country of provenience of the grant holder (left) and of hosting institutions (right). Abbreviation denotes the countries that contributed to the programme; Bulgaria (BG), Croatia (HR), France (FR) Germany (DE), Greece (GR), Israel (IL), Italy (IT), Portugal (PT), Spain (ES), Switzerland (CH), Tunisia (TN). This figure has been extracted from "Mediterranean Climate Variability", Elsevier, Amsterdam, developments in Earth and Environmental Sciences, vol.4 ISBN: 9780080460796'

Madden-Julian Oscillation (MJO) Task Force: a joint effort of the climate and weather communities

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Background

It is widely recognised that improved understanding and prediction of the Madden Julian oscillation (MJO) and related tropical intraseasonal variability (ISV) is crucial for both the climate and weather communities, and the decisions they support. Because simulating and predicting this variability in global numerical models has been difficult, a 'task force' of 15 scientists was formed in early 2010 to foster further improvements in this area following the earlier success of the US CLIVAR MJO Working Group (from 2006-2009). Programmatically, the MJO Task Force (MJO-TF) sits within the framework of the joint WCRP/WWRP/THORPEX Year of Tropical Convection (YOTC)[1] activity, and is endorsed by CLIVAR. This article provides a summary of MJO-TF activities and accomplishments and its future plans. With the initial term of the MJO-TF coming to an end in December 2012, plans have been made for its continuation for another 3 years.

Overall goal

The overall goal of the MJO-TF has been to facilitate improvements in the representation of the MJO in weather and climate models in order increase the predictive skill of the MJO and related weather and climate phenomena.

Membership and contributors

The initial membership of the MJO-TF (in 2010) was Duane Waliser (initial co-chair), Matthew Wheeler (co-chair), Ken Sperber, Eric Maloney, Xiouhua Fu, Jon Gottschalck, Richard Neale, Chidong Zhang, Daehyun Kim, Augustin Vintzileos, Masaki Satoh, Hai Lin, Harry Hendon, Frederic Vitart, and David Raymond. The last three researchers have since stepped down and been replaced by Prince Xavier, June-Yi Lee, and Steve Woolnough. Eric Maloney replaced Duane Waliser as co-chair in 2011. Important contributions to the MJO-TF have also been made by Xianan Jiang, Nicholas Klingaman, Jim Benedict, Mitch Moncrieff, and Min-Seop Ahn.

Communication and web-page

The MJO-TF has had 14 teleconferences and 3 face-to-face meetings. Meeting minutes and other information is disseminated through the web page at www.ucar.edu/yotc/mjo.html.

1 For a description of YOTC, see http://www.ucar.edu/yotc/index.html.

Subprojects

The previous version of this group, the US CLIVAR MJO Working Group, had success in three main areas: (1) Development of a set of MJO simulation diagnostics (Waliser et al. 2009); (2) Application of these diagnostics to a set of climate model simulations (Kim et al. 2009); and (3) Development and implementation of an MJO forecast metric for operational prediction models (Gottschalck et al. 2010). The support of these three areas by the MJO-TF has been ongoing, such as the continual evaluation of the operational model MJO forecasts. However, the new focus has expanded to four subprojects.

Subproject 1: Process-oriented diagnostics and metrics for MJO simulation

The MJO simulation diagnostics developed by the predecessor group assess whether models are successfully able to simulate the MJO. However, they provide limited insight into why models exhibit varying levels of success with their MJO simulations. The aim of this subproject is to explore and develop diagnostics that provide this insight. That is, what are the processes operating in a model that determine its MJO simulation fidelity?

Previous observational results indicate that a strong relationship exists between tropical precipitation and tropospheric humidity, such that heavy rainfall preferentially occurs in atmospheres that are relatively moist (e.g. Bretherton et al. 2004). Studies have also argued that the dynamics of the MJO are regulated by the processes that control tropospheric moisture (e.g. Benedict and Randall 2007). Further, many model convection parameterization schemes have been shown to be too insensitive to the effects of free tropospheric humidity (e.g. Derbyshire et al. 2004), and models in which the sensitivity of convection to that humidity has been increased tend to produce a more robust MJO (e.g. Hannah and Maloney 2011). This knowledge has led the MJO-TF to develop and test a set of process-oriented diagnostics based on interactions between convection and moisture.

One diagnostic based on this concept looks at the relationship between precipitation rate and column saturation fraction (e.g. Bretherton et al. 2004). In observations, precipitation rate is a strong non-linear function of saturation fraction. While work with a limited set of models suggested that models able to capture the strong non-linearity between precipitation and saturation fraction produce better MJO simulations (Zhu et al. 2009), further investigations by the MJO-TF have demonstrated that this diagnostic appears to be a necessary, but not sufficient, condition for a good MJO simulation.

The MJO-TF has also considered diagnostics that assess the vertical distribution of relative humidity as a function of precipitation rate (e.g. Kim et al. 2009). An idea underlying several bodies of MJO theory is that before the enhanced convective phase of the MJO can begin, a period of gradual moistening occurs (e.g. Blade and Hartmann 1993). In observations, this moistening process is characterized by a gradual deepening of the tropospheric moist layer. Thus, diagnostics have been developed that characterize the relationship between the vertical profile of relative humidity and precipitation rate (e.g. Thayer-Calder and Randall 2009, Xavier 2012). Although a strong relationship with MJO simulation strength has not been found, preliminary work of the MJO-TF has found that models which reproduce the observed moistening behaviour tend to produce a more robust MJO simulation.

Another diagnostic of the processes that control tropospheric moisture is gross moist stability (GMS). Under the assumption of weak tropical temperature gradients, GMS becomes equivalent to the efficiency with which convection discharges moisture from the atmospheric column. It has been hypothesized that for an MJO moisture anomaly that supports convection to be sustained, GMS must be small or negative (Raymond and Fuchs 2009; Hannah and Maloney 2011). Thus, the MJO-TF has also been actively studying the utility of the GMS for understanding model MJO behaviour. Indeed, an initial assessment of 3 pairs of good/poor model simulations (Figure 1), shows that for each model pair the version with an improved (i.e. stronger) MJO is characterized by a lower normalized GMS (Benedict et al. 2013, in preparation).

Through increased understanding of the processes that each of these diagnostics highlights, improvements to models should ensue. In the same way as the MJO Working Group provided analysis code to the community for the calculation of the simulation diagnostics, the MJO-TF plan to provide code for these new diagnostics.

Subproject 2: Boreal summer monsoon ISV monitoring and forecast metrics

One of the successes of the predecessor group, in conjunction with the Working Group on Numerical Experimentation (WGNE), was the development and implementation of the MJO forecast metric as displayed at http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml. This display allows users to quickly and easily see the current state of the MJO and the prediction of its future evolution in each of the ~16 participating models. Daily model output is projected onto a pair of empirical orthogonal functions (EOFs) that describe the MJO's large-scale structure as derived from observations by Wheeler and Hendon (2004). Focussing on this pair of EOFs has proven useful for making forecasts of MJO impacts out to a lead of several weeks, as well as for assessing the real-time performance of the models (Gottschalck et al. 2010). However, by concentrating on the eastward MJO signal along the equator, they provide little information on the important northward propagating variability of the boreal summer monsoon. Therefore, the MJO-TF has worked to develop and implement a new forecast metric for the boreal summer ISV.

To achieve this, a new set of EOFs have been derived that capture the unique characteristics of ISV during boreal summer (Lee et al. 2012). This has been done using combined EOFs computed with daily maps of 850-hPa zonal wind and satellite outgoing longwave radiation (OLR) over the domain 10°S-40°N, 40°E-160°E. The first two EOFs show many of the important characteristics of the boreal summer intraseasonal oscillation (BSISO), including the northwest-southeast tilted rainband (OLR anomaly) and implied northward propagation from the quadrature phasing of the associated time series (Figure 2). We call this component of variability BSISO1. EOFs 3 and 4 are associated with the pre-monsoon and onset component, which we call BSISO2 (not shown).

As with the MJO forecast metric activity, the support of WGNE has been obtained to coordinate the implementation of the new metric within the operational forecast centres, and discussions have occurred to find a host of the new metric. The eventual goal is to have a web page depicting model forecasts of BSISO1 and BSISO2 in real time that can aid impacts forecasting and encourage further model improvement.

Subproject 3: Simplified MJO metrics and CMIP5 analysis

Following on from the predecessor group's effort on MJO simulation diagnostics, discussed above, this subproject has two thrusts: to create simplified metrics of the MJO that distil the information of the full set of diagnostics into 1 or 2 numbers; and to apply the full set of MJO diagnostics to the current generation of climate models that are included in the Coupled Model Intercomparison Project phase 5 (CMIP5).

The first of these thrusts was at the request of the Working Group on Coupled Modelling/WGNE Climate Model Metrics Panel. A simplified metric of the MJO, described in Sperber and Kim (2012), was defined from the lag correlation analysis of a pair of principal component time series (PCs), where the PCs are obtained by projecting maps of simulated 20-100 day bandpass filtered daily OLR onto the two leading EOFs of observed MJO variability. The metric has two components: the maximum positive correlation at any lag; and the lag at which this maximum correlation occurs. For observations this correlation is 0.69 at a lag of 11 days. Most models have a lower maximum correlation than observed, indicating less coherent large-scale propagation, and some of the poorer models have a negative lag, indicating an incorrect predominance of westward propagation. Further, it is shown that the maximum positive correlation from the many

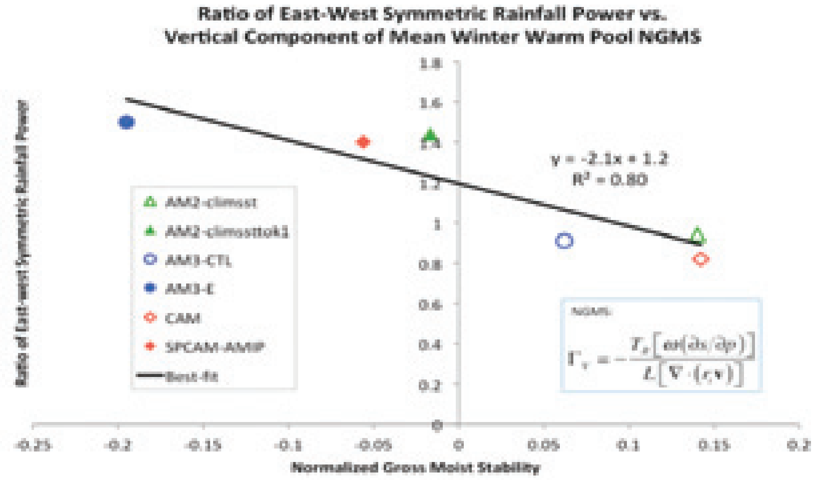

Figure 1. Ratio of east-west symmetric rainfall power (30-96 days, wavenumbers 1-3) versus vertical component of normalized gross moist stability (NGMS) averaged over the Indo-Pacific warm pool during boreal winter. The definition of NGMS is shown at the lower right, where s is moist entropy, r_t is the water vapor mixing ratio, and T_R is a reference temperature. The observed east-west symmetric rainfall power is 2.4 estimated from the TRMM satellite.

models is significantly correlated with the ratio of eastward to westward precipitation power at MJO time and space scales, indicating that it is a good indicator of coherent eastward propagation in the models. The east/west power ratio is another commonly used metric of the MJO in models (e.g. Figure 1).

The second thrust of this subproject is a comprehensive analysis of the MJO in CMIP5 simulations. Although some analysis of the MJO in CMIP5 models has already been performed (e.g. Hung et al. 2012), an analysis with the full set of MJO simulation diagnostics has not. With the help of graduate student Min-Seop Ahn from Seoul National University, this work is now under-way.

Subproject 4: Vertical structure and diabatic processes of the MJO
This subproject is being conducted jointly with the GEWEX Global Atmospheric Systems Study (GASS) panel. It was conceived by members of the MJO-TF when it was noticed how different the vertical structure of the MJO diabatic heating was between different satellite and reanalysis products (e.g. Jiang et al. 2011), and the realisation that understanding of this very important quantity for the MJO is quite limited despite its relevance to a number of theories. For example, to what extent is the vertical structure in reanalysis products determined by the model cumulus parameterization, and to what extent is this structure essential for realistic MJO representation? Therefore, with the process modelling and parameterization expertise of GASS, this global model intercomparison project, focussing on the physical processes associated with the MJO, was launched (Petch et al. 2011).

The experimental framework of the project takes advantage of the known relationships between biases in short-range model forecasts and long-term simulations. It also considers how biases in the representation of the MJO may change with forecast lead time. Three different types of model runs have been sought: (1) 20-year climate simulations with 6-hourly global output that characterize each model's intrinsic MJO and related variability; (2) A series of daily 48 hour forecasts initialized during a few different case periods, with time-step output over the Indo-Pacific Ocean region; and (3) A series of daily 20-day lead forecasts with 3-hourly global output during the same case periods. A very detailed list of model outputs has been requested focussing on vertical structure and complete tendency terms for temperature, humidity and momentum, and additional quantities essential to diabatic and other important physical processes. The full specifications of the experimental framework are provided at http://www.ucar.edu/yotc/mjodiab.html. Two of the case periods selected occurred in 2009/10 during YOTC, and planning for a third case during the Dynamics of the MJO (DYNAMO)/ Cooperative Indian Ocean Experiment on Intraseasonal Variability (CINDY) field program is underway. As of September 2012, runs from 20 different models had been received for (1); from 9 models for (2); and from 11 models for (3). The deadline for model submissions for inclusion in the initial set of publications was December 2012. Drafts of these initial publications are expected to be available by June 2013, with full community access to the model data allowed soon afterwards.

Objectives of the subproject are to provide information that helps model developers to make improvements to their physical parameterization schemes and to provide feedback to the satellite formulation and algorithm communities regarding strengths, shortcomings and gaps in satellite products. The outcome of this initial multi-model experiment may be utilized by GASS to develop a follow-on process modelling study for one or more of the most important yet uncertain processes identified in this subproject. Synergies exist with all of the other MJO-TF subprojects.

Conferences and workshops

Together with the CLIVAR Asian-Australian Monsoon Panel (AAMP), the MJO-TF organised the Monsoon ISV Modelling Workshop in June 2010 at the APCC in Busan Korea (Hendon et al. 2011). The MJO-TF also provided input to sessions at the WCRP Open Science Conference in Denver USA (October 2011), and the 1st Pan-GASS conference in Boulder USA (September 2012).

Other activities

Besides these defined projects and conferences, the MJO-TF has also been active in promoting coordinated MJO-related research and development among other scientific groups and projects. Two examples are MJO-TF involvement in guiding aspects of the multi-institutional ISV Hindcast Experiment (ISVHE; http://

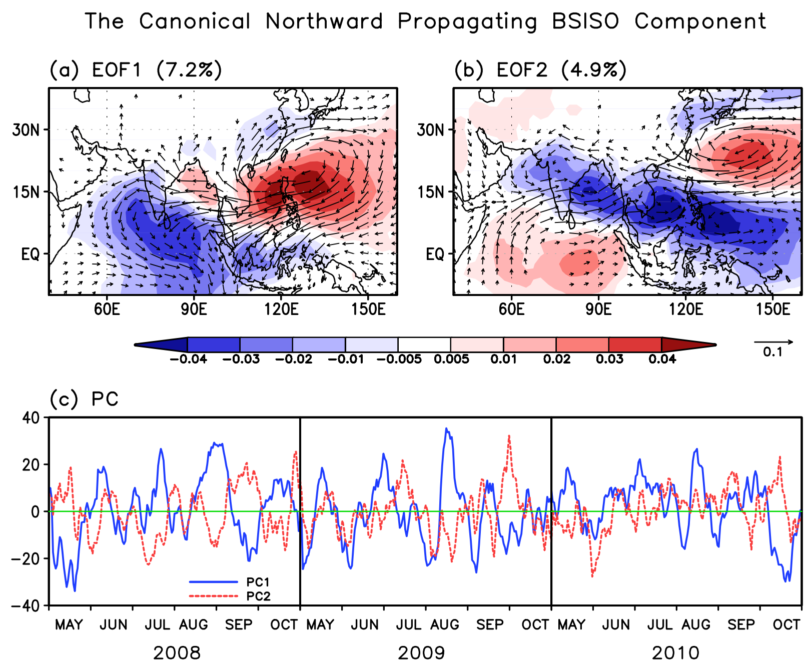

Figure 2. Results from a combined EOF analysis of 850hPa zonal wind and OLR over the latitude/longitude domain as shown, as discussed by Lee et al. (2012). (a) and (b) show the spatial structure of the leading 2 EOFs with OLR shaded and the winds displayed as vectors. Note that the meridional component of the wind, which was not used in the EOF analysis, was reconstructed for this figure using regression against the PC time series. (c) Example PC time series for the leading 2 EOFs for the boreal summer monsoon months during 2008-2010.

iprc.soest.hawaii.edu/users/jylee/clipas/), and in asking US CLIVAR to add the intraseasonal timescale to their draft mission statement for 2013 and beyond.

Future plans

For its second 3-year term, the MJO-TF plans to continue its work on the 4 defined subprojects and also establish one new subproject. Of the 4 subprojects listed above, the 1st and 4th will require significant and continued effort to complete. The difficulty arises from the complexity of the relationship of the MJO to the physical processes involved with moisture and convection. To bring in new and additional expertise to address these difficult problems, a rotation of 5 members of the current membership is occurring. A new subproject on MJO air-sea interaction will also be established. One of the aims of the latter will be to develop a process-oriented diagnostic that may be able to relate MJO simulation capability to the processes of air-sea coupling.

Coordination of the MJO-TF activities with other research programs is essential for its continued success. As well as the links already mentioned, coordination has occurred with DYNAMO/CINDY groups and will likely continue, especially for verifying the time-step model output being generated and archived for a November 2011 case in subproject 4. Dialogue has also occurred with the planning group of the Sub-seasonal to Seasonal Prediction Initiative (S2S; Vitart et al. 2012). The MJO-TF is well positioned to be the MJO (and other tropical ISV) research arm of the S2S project.

The research of the MJO-TF will also likely contribute to two of the recently-defined WCRP Grand Challenges: on the provision of skilful future climate information on regional scales, which includes an intraseasonal prediction component; and on clouds and climate sensitivity. For the latter, the importance of model cloud and convection parameterizations has been highlighted, consistent with the goals of the MJO-TF subprojects 1 and 4.

When appropriate, the MJO-TF plans to continue to help organise conferences and workshops. On our horizon is the WWRP International Workshop on Monsoons (IWM-V) planned for Macau in October 2013. The MJO-TF has accepted the role of co-sponsor of the workshop and will organise a full day of the scientific program, as well as one or two training lectures on intraseasonal monsoon prediction.

Linking the climate and weather scales and communities, the MJO-TF hopes to continue making steps towards its overall goal.

Update

Since preparing this article, WCRP and WWRP have confirmed the extension of the MJO-TF for another 3 years, with its official reporting now going through WGNE.

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Report on Northwestern Pacific Ocean Circulation and Climate Experiment (NPOCE)

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Brief introduction to NPOCE

The Northwestern Pacific Ocean Circulation and Climate Experiment (NPOCE) program is a multi-national, multi-institutional program, designed to observe, simulate, and understand the dynamics of the Northwestern Pacific (NWP) ocean circulation and its role in low-frequency modulations of regional and global climate. The primary GOAL of NPOCE is to understand the dynamics of the NWP circulation and its roles in warm pool maintenance and low-frequency variability, and modulation of ENSO cycle, East Asian Monsoon (EAM) variability, and NWP tropical cyclones.

NPOCE was founded on a series of workshops since 2004. Several large-scale projects within NWP region have been launched in the past few years. With participating scientists from nineteen institutions in eight countries, including Australia, China, Germany, Indonesia, Japan, Korea, the Philippines and the USA, NPOCE was endorsed by CLIVAR as an international joint program in April, 2010 and successfully inaugurated in May of the same year in Qingdao, China. The background and organization of NPOCE can be found on the project's website: http://npoce.qdio.ac.cn/.

The NPOCE program is conducted under the leadership of its Scientific Steering Committee (SSC). The SSC had 12 members when NPOCE inaugurated, but was adjusted and expanded to 18 members based on decisions of two successive SSC meetings. The NPOCE SSC is currently constituted as follows:

Chair

Dunxin Hu	Institute of Oceanology, Chinese Academy of Sciences (IOCAS), China

Members

Rameyo Adi	BRKP, Ministry of Marine Affairs and Fisheries, Indonesia
Dake Chen	Second Institute of Oceanography, State Oceanic Administration (SIO/SOA), China
Minhan Dai	Xiamen University, China
Arnold Gordon	Columbia University, US
Dongchull Jeon	Korea Institute of Ocean Science and Technology (KIOST, formerly named as KORDI), Korea
Yuji Kashino	Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan
William S. Kessler	National Oceanic and Atmospheric Administration, US
Jae-Hak Lee	Korea Institute of Ocean Science and Technology, Korea
Yukio Masumoto	Japan Agency for Marine-Earth Science and Technology, Japan
Bo Qiu	University of Hawaii, US
Tangdong Qu	University of Hawaii, USA
Stephen Riser	University of Washington, US
Andreas Schiller	Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
Cesar Villanoy	University of the Philippines, Philippines
Fan Wang	Institute of Oceanology, Chinese Academy of Sciences, China
Lixin Wu	Ocean University of China, China
Dongliang Yuan	Institute of Oceanology, Chinese Academy of Sciences, China

The NWP features a complicated ocean circulation system with intensive multi-scale air-sea interactions (Figure 1). The region is a crossroads and major pathways for different water masses from mid and high latitudes and the southern hemisphere to

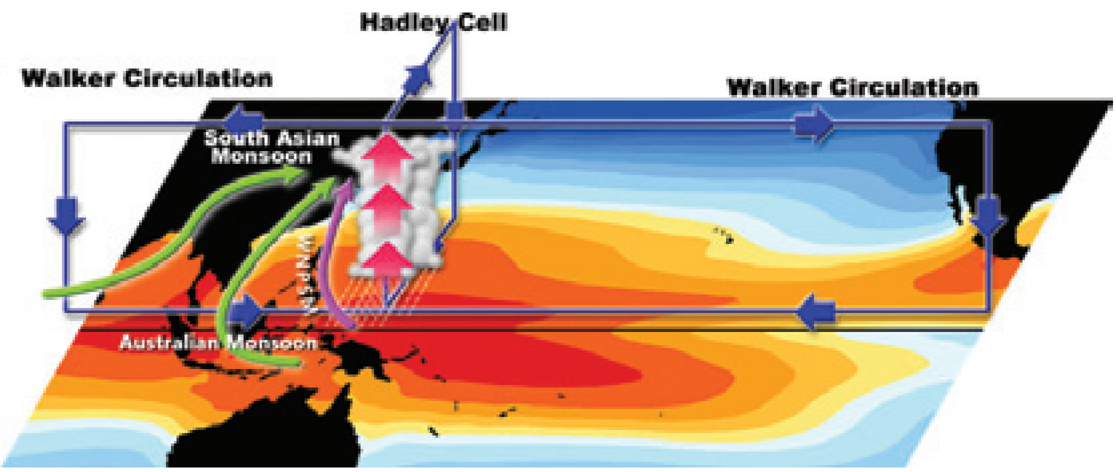

Figure 1. Roles of the tropical NWP Ocean in global and regional climate systems: ENSO, monsoons, the Walker circulation and Hadley Cell, etc. (Hu et al., 2011)

enter the equatorial thermocline. Several currents originate in the NWP, including Kuroshio (KC), Mindanao Current (MC), North Equatorial Countercurrent (NECC), Indonesian Throughflow (ITF), and the South China Sea Throughflow (SCSTF). Consequently the NWP strongly interacts with the ambient oceans and seas, and participates in the recharge-discharge process of the warm pool. The changes in the NWP water properties and ocean circulation can influence the heat and freshwater budget and hence the atmospheric deep convection over the warm pool; thereby playing a role in modulating ENSO cycles and the EAM variations, as well as in the development and evolution of the NWP cyclones.

Even with significant advances over the past several decades, our understanding of some issues on the NWP still remains incomplete. The origins of Mindanao Undercurrent (MUC), Luzon undercurrent (LUC), the water exchanges between the NWP and the SCS via the Luzon Strait, the low latitude western boundary currents (LLWBCs), etc., are still poorly understood owing to scarce and inadequate observations. Lack of in-situ observations severely hinders our understanding of subtropical-tropical water and heat exchanges, and their roles in decadal and long-term changes of the tropical ocean-atmospheric circulations. Few observations in the NWP provide reliable information to validate model capability in simulating oceanic heat and freshwater transport; both of which are crucial to warm pool maintenance and low-frequency variability.

Therefore, the coordinated observational program and modeling analysis of NPOCE will provide a more complete description of structure and variability of the ocean circulation in the NWP, help improve prediction of the climate drivers discussed above, and provide a projection of local/regional ocean and climate conditions.

Progress and highlights

NWP observations

A series of cruises to the NPOCE domain have been carried out since its inauguration (figure 2). Korean scientists from the Korea Institute of Ocean Science and Technology (KIOST) have so far set up one surface buoy at 10°N, 152°E and three subsurface moorings along a JASON 2 satellite track in the mid Philippine Sea, to monitor the North Equatorial Current (NEC). Chinese scientists from the Institute of Oceanology, Chinese Academy of Sciences (IOCAS) have deployed and replaced three subsurface moorings to measure western boundary currents (WBCs) at 8°N and 18°N since 2010, and deployed one more mooring at Maluku Strait in November 2012. One of these moorings was successfully deployed and retrieved at the water depth of 6100m off the Mindanao coast, obtained the first two year direct current observation data in this region, and measured remarkable strong undercurrent even at 1000m depth, indicating a complicated 3D circulation structure of NWP WBCs. In addition, many CTD casts were made and 18 ARGOS drifters were deployed. Scientists from SIO of SOA have deployed 26 Argo floats, including 16 two-way communication floats for the purpose of observing the ocean response to tropical cyclones. Japanese scientists from the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) also deployed two subsurface moorings off Mindanao, to measure the variability and dynamics of MC and MUC system. US Scientists from University of Washington deployed some profiling floats equipped with SeaBird surface temperature/salinity sensor (STS) and Passive Acoustic Listener (PAL) unit in the Western Pacific Ocean (WPO) for the measurements of wind speed, rainfall, and near-surface temperature and salinity. With these efforts, the observation system in the WPO is enriched, and valuable data featuring long period and a diversity of variables are expected.

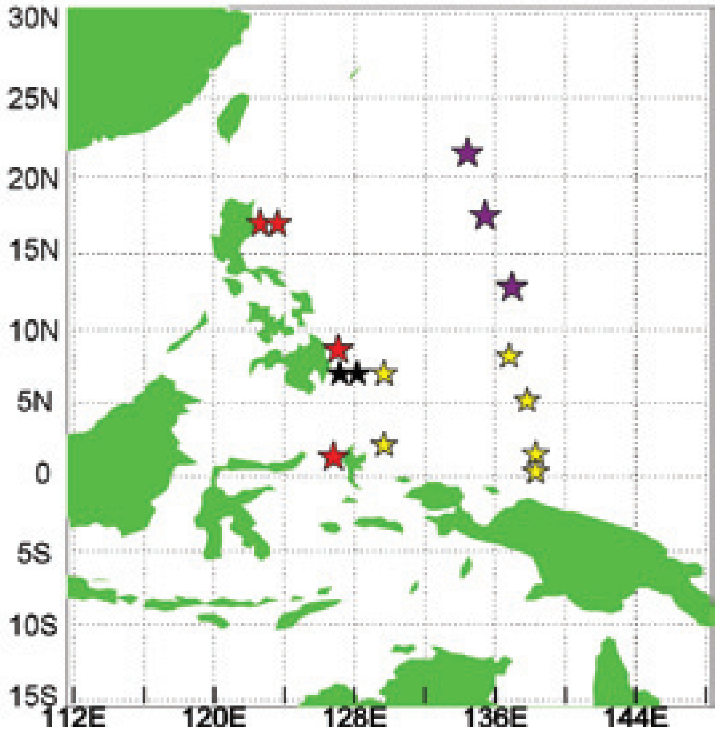

Figure 2. Mooring observations in NPOCE domain (2010-2012) IOCAS: 4 moorings (Red stars), POSEIDON: 3 moorings (Purple stars), JAMSTEC: TRITON Buoy (Yellow stars), 2 moorings (Black stars).

Models and process studies

A hierarchy of ocean circulation and climate models with focus on the NPOCE domain is being developed, including high resolution global ocean circulation model, high resolution regional coupled ocean-atmosphere model, and high resolution regional model nested in large-scale model. Such model developments enable numerical study on multi-scale processes including Typhoon, WBCs, ENSO and long-term climate variability.

Process studies of NWP ocean circulation and climate are conducted through modeling and data analysis. For example, some new features of MUC and LUC are found from direct current observations (Hu et al., 2013) and OFES GCM results (Qu, et al., 2012). The water source of LUC is simulated using different models (Wang and Hu, 2012; Gao et al., 2012). It has been noticed that in the tropical WPO, the linear trend of sea level rise based on satellite altimeter measurements exceeds 10 mm yr^{-1}. This is more than three times the rate of the global mean sea level rise and is largely attributable to the upper ocean water mass redistribution caused by the surface wind stresses of the recently strengthened atmospheric Walker circulation (Qiu and Chen, 2012). Variability of NEC-KC-MC (NMK) system and NEC bifurcation are also intensively studied.

New projects

Besides the major research projects that keep contributing to NPOCE, such as POSEIDON/KIOST, GAIA/KIOST, TOCS/JAMSTEC and several major Chinese projects (973 projects, NSFC Major Project, and CAS major project), four more major projects closely related to NPOCE have been funded by Ministry of Science and Technology of China. Two five-year projects were launched in 2012: the National Basic Research Program (973 program) "Structure, Variability and Climatic Impact of Ocean Circulation and Warm Pool in the Tropical Pacific Ocean" (2012-2016) led by Dr. Fan Wang; and the National Basic Research Program in Global Change "Response of Ocean to Global Warming and its Impact on East Asian Climate and China Seas Carbon Storage" (2012-2016) led by Dr. Dongliang Yuan. Two more projects were newly funded in 2012: the 973 program "Mechanisms of upper ocean response to and modulation on typhoon" (2013-2017) led by Dr. Dake Chen; and the Global Change program "Multiscale variability processes, mechanism and predictability in the Northwestern Pacific" (2013-2017) led by Dr. Lixin Wu.

Important Meetings

Jointly organized by NPOCE and Southwest Pacific Ocean Circulation and Climate Experiment (SPICE), the Open Science Symposium (OSS) on Western Pacific Ocean Circulation and Climate was successfully held on October 15-17, 2012 in Qingdao, China (website: http://oss2012.csp.escience.cn). More than 200 scientists and students from 13 countries, including China, France, United States, Australia, Germany, Philippines, Korea, Fiji Islands, and Japan, participated in the OSS. The areas of the symposium covered a variety of subjects including: the western Pacific Ocean circulation and its roles in the maintenance and low frequency variability of the warm pool; the relationship between the warm pool and the low-frequency variability of the climate; the long-term evolution of the ENSO cycles and its mechanisms; variability of the EAM system; climatic evolution and predictability of tropical cyclones in the NWP; and the Western Pacific Ocean's role in, and impacts on the carbon cycle, biogeochemical process, ocean acidification, ecosystem, and paleo-oceanography etc.

Participants that gave speeches at the opening of the OSS included: Chinese Academy of Science (CAS) Academician Guanhua Xu, chair of Scientific Committee of 973 Program; Prof. Martin Visbeck, co-chair of WCRP/CLIVAR SSC; Dr. Susan Wijffels, co-chair of International Argo Steering Team; Dr. Yucheng Chai, Deputy director of Geoscience Division of National Natural Science Foundation of China (NSFC); SAS academician Deliang Chen, Former Executive Director of International Council for Science (ICSU), and Prof. Hui Wang, vice Director of IOCAS. Co-chair of CLIVAR Pacific Panel Dr. Wenju Cai, CAS Academicians Jilan Su, Congbin Fu, and Mu Mu also attended the symposium.

The NPOCE SSC meeting-2012 was also held on October 16 in Qingdao, presided by the SSC Chair, CAS Academician Dunxin Hu. Eight SSC members from China, United States, Korea and Japan, as well as Prof. Martin Visbeck, Dr. Wenju Cai and chair of SPICE SSC Dr. Alexandre Ganachaud attended the meeting. Four candidates were approved as new SSC members on the SSC meeting.

Prospect

With efforts and cooperation of all the participants, NPOCE is, so far, running well and smoothly. In the future, a further integration of efforts from various nations and institutions in field experiment is needed. NPOCE shall promote coordination with other regional programs, such as SPICE and ITF Gateway, to seek a well-organized study in the whole western Pacific Ocean. We believe that a new era for ocean circulation and climate study in the western Pacific will come soon.

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Advances from the Southwest Pacific Ocean circulation and climate experiment (SPICE)

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Endorsed by CLIVAR in 2008, the Southwest Pacific Ocean Circulation and Climate Experiment (SPICE) is an international research project which aims to understand the southwest Pacific Ocean circulation, as well as its direct and indirect influence on both regional and basin-scale climate, and the South Pacific Convergence Zone (SPCZ). SPICE was designed to measure and monitor the ocean circulation, and to validate and improve numerical models.

South Pacific thermocline waters are transported in the westward flowing South Equatorial Current (SEC), from the subtropical gyre centre toward the southwest Pacific Ocean - creating a major circulation pathway that redistributes water from the subtropics to the equator and to the southern ocean (Figure 1). The transit in the Coral, Solomon and Tasman Seas is potentially of great importance to the climate system. Changes in either the temperature or the amount of water arriving at the equator have the capability to modulate the El Niño Southern Oscillation (ENSO) and produce basin-scale climate feedbacks. The southward thermocline pathways are, comparably, of major influence on Australia and New Zealand areas, affecting climate and biodiversity.

At the outset of SPICE in 2005, few observations were available to diagnose the processes and pathways through the complicated geography of the southwest Pacific. The region is remote, and the large temporal variability and strong narrow currents in a complex bathymetry posed serious challenges to both observation and numerical modelling. This led scientists from France, Australia, USA, New Zealand, Japan and several Pacific Island countries to develop a coordinated program, including intensive observations and focussed modelling experiments (Ganachaud et al. 2007, 2008a). Since its inception, the SPICE modelling and regional field studies have addressed many aspects of the Southwest Pacific: heat and mass transports; properties and dynamics of the strong boundary currents and jets; and water mass transformations.

SPICE provides a platform to stimulate international collaboration and funding from national programs (http://www.obs-mip.fr/spice). Data collected during SPICE are shared following the CLIVAR data policy, and distributed through existing national facilities.

While SPICE is regionally focused, it integrates basin-scale studies of the ocean-atmosphere system. Those, including the South Pacific circulation and its connection with equatorial processes and climate variability, are more broadly addressed within CLIVAR.

We summarize here the recent progress, following two major meetings: a SPICE special session at the 10th International Conference on Southern Hemisphere Meteorology and Oceanography, Nouméa, April 2012; and the Western Pacific Ocean Circulation and Climate, Qingdao, October 2012 which allied SPICE and the Northwestern Pacific Ocean Circulation and Climate Experiment (NPOCE) scopes.

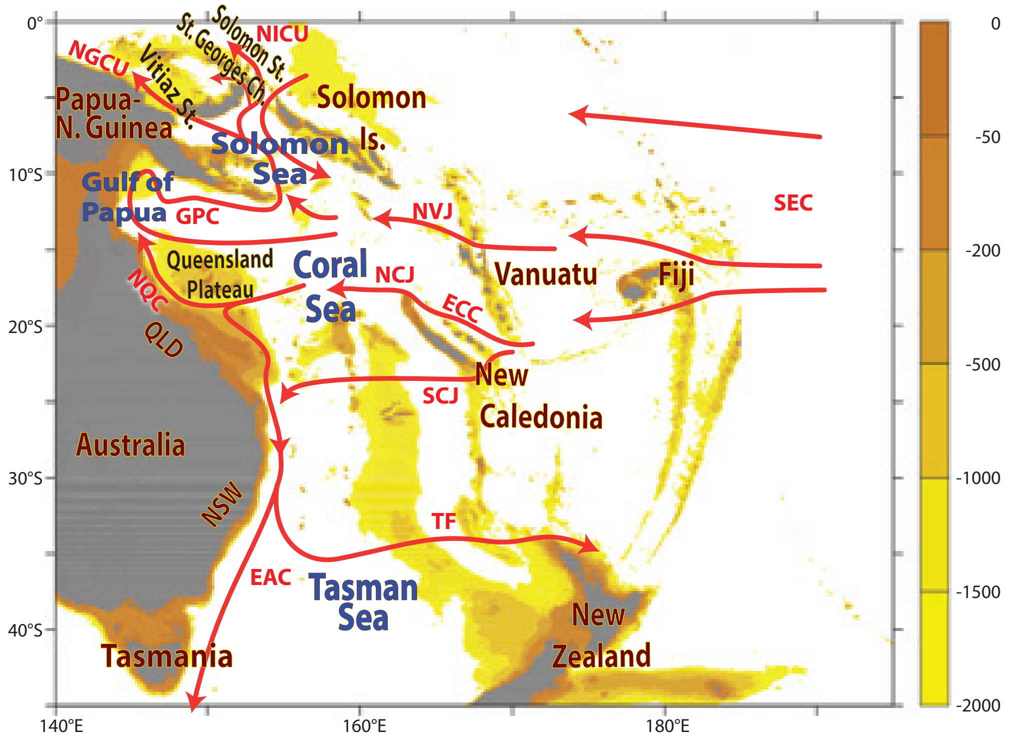

Figure 1. Topography of the southwest Pacific, where only depths shallower than 2000 meters are shaded (QLD=Queensland; NSW=New South Wales). Red arrows denote the main thermocline currents (SEC=South Equatorial Current; NVJ=North Vanuatu Jet; ECC= East Caledonian Current; NCJ=North Caledonian Jet; SCJ=South Caledonian Jet; NQC=North Queensland Current; GPC=Gulf of Papua Current; NGCU=New Guinea Coastal Undercurrent; NICU=New Ireland Coastal Undercurrent; EAC=East Australia Current; TF=Tasman Front). Surface counter currents are not represented for clarity.

Modelling groups and efforts

To unravel the dynamics of basin-scale climate variability in this ecologically sensitive region, SPICE researchers use global and regional models, at eddy-resolving spatial scales (10km and less), to explore mesoscale activity, multi-decadal climate trends and link coastal impacts to regional and global phenomena such as ENSO, the South Annular Mode (SAM) and Pacific Decadal Oscillation (PDO). Furthermore, there is an increasing synergy between climate modelling and operational oceanography efforts such as those pursued by MERCATOR Ocean and BLUElink. Combining observations and models enables the exploration and analysis of;

- The jet-like structures in the SPICE area;
- The eddy dynamics in boundary currents such as the East Australian and the Gulf of Papua Currents;
- The shelf-scale upwelling processes
- The dynamical drivers of sea surface temperature (SST) anomalies in the Coral Sea and associated coral bleaching events.

Despite successful simulations and model-based analyses of ocean dynamics in the SPICE region, many model-related challenges remain. Eddy-resolving models covering the whole SPICE domain still do not have the spatial and vertical resolution necessary to fully resolve all key features such as narrow jets between islands, sub-mesoscale phenomena of the western boundary currents (WBC), reefs and straits which dominate large parts of the region, e.g., the Great Barrier Reef. High resolution (1/36°) nested regional simulations are presently analyzed, but the computational burden to run these at basin-scale over multiple decades is still prohibitive and –if pursued- would require a truly major international effort. Other related issues include inaccurate or missing topography at high spatial resolution, and lack of accurate multi-scale coast-to-shelf-to-open ocean sub grid-scale parameterisations, for both vertical and horizontal mixing, (including effects by tides). Algorithms capable of fully parameterising such modelling challenges are under active development but it will take some time before they become available to the broader scientific community.

In situ observations

The SPICE field program (Figure 2) aimed to:

- Complete large-scale surveys of the Coral, Solomon, and Tasman Sea inflows and outflows with special attention to the WBC;
- Test large scale monitoring of key climate quantities such as the thermocline inflows and outflows and air-sea fluxes;
- Observe simultaneously in different parts of the basin to accomplish regional mass, heat, and freshwater budgets;
- Achieve island-scale process studies to address local specificities.

High-resolution hydrographic surveys of the water column provide temperature, salinity and dissolved oxygen down to at least 2000 m. When possible, nutrient and geochemical data were collected, in collaboration with the GEOTRACES programme. Glider measurements first served to demonstrate the application of recent technology with lines in the Solomon Sea; across the western boundary currents off Queensland and New South Wales; and two coastal jets near New Caledonia. Since 2007 gliders have monitored the transport across the Solomon Sea, with four to eight crossings annually . Moorings and Pressure Inverted EchoSounders (PIES) deployed across the entrance of the Solomon Sea have provided horizontal integrals of mass transport, with high temporal resolution. EXpandable bathyThermograph (XBT) probes were deployed at high resolution across key sections, providing a temperature survey of the upper water column and associated oceanic transports. Sections, initiated in 1991 across the “Tasman box” were continued, in conjunction with the onset new sections. Argo floats seeded in southwest Pacific during SPICE increased the number of temperature and salinity profiles from 50 per year in 2005 to 1700 per year in 2011. Surface drifters were released on cruise or XBT lines with an enhanced focus on the Eastern Australian Current (EAC).

Main scientific advancements

With a partition of each group's efforts into geographic or topical sector (Figure 1), numerous observations were collected, greatly improving numerical simulations.

Coral Sea

The bulk of the South subtropical gyre water enters the Coral Sea in the broad South Equatorial Current (SEC; Figure 1). It then divides into jets that were pointed out in early numerical simulations and data-deficient climatologies. In situ SPICE observations confirmed the circulation schematics and revealed its vertical structure, with a broad and shallow North Vanuatu Jet (NVJ) and a narrow and deep North Caledonian Jet (NCJ) (Gourdeau et al. 2008, Ganachaud et al. 2008b), which both have a strong surface signature as shown by drifter observations (Choukroun et al 2010). The NCJ sources from East Caledonia Current (ECC) waters (Maes et al. 2007, Gasparin et al. 2011). Limited observations suggest the presence of a South Caledonian Jet (SCJ), and further characterization will come from new glider data. Against the coast of Australia, the NCJ bifurcates feeding the boundary currents; the East Australian Current (EAC) to the south and North Queensland Current (NQC) to the north, (Choukroun et al. 2010).

The NQC waters flow clockwise against the Gulf of Papua coast, leading the community to name it the Gulf of Papua Current (SPICE community, 2012), and eventually feed into the Solomon Sea. In the lee of Vanuatu Islands, and just south of the NVJ, a counter current was discovered, the Coral Sea Counter Current (Qiu et al. 2009). Similarly, a Fiji Basin Counter Current was found to the west of Fiji. More accurate bathymetry has greatly improved currents in numerical simulations in the Coral Sea (Schiller et al. 2008). Previously these dynamically important straits between islands were not well represented in simulations, resulting in spurious jets to the north of south of the islands.

The Coral Sea jets and counter currents result in dynamical instabilities and high variability, generating westward-moving Rossby waves (Maharaj et al. 2007, 2009, Qiu et al. 2009). At seasonal to decadal timescales, the SEC, the jets and WBCs respond to large scale forcing, either locally or remotely depending upon latitude and timescale (Qiu and Chen 2006, Kessler and Gourdeau 2006, 2007, Roemmich et al. 2007). An El Niño event generally enhances the SEC transport and the transport entering into the Solomon Sea (Kessler and Cravatte 2013; Davis et al., 2012; Melet et al., 2010b, 2013), particularly in the NVJ.

Tasman Sea

The EAC provides both the western boundary of the South Pacific Gyre and the linking element between the Pacific and Indian Ocean gyres. Climatology shows that the EAC strengthens southward along the coast and then separates into filaments that are northeastward (STCC), eastward Tasman Front (TF, Figure 1), and a residual "Tasman Outflow" to the south. This circulation was identified as part of a supergyre that flows westward around Tasmania and connects the south Pacific subtropical gyre with the Indian Ocean, thereby redistributing waters amongst the major oceanic basins (Ridgway and Dunn 2007).

In situ measurements were intensified with the start of the Australian Integrated Marine Observing System (IMOS) programme in 2007 (Figure 2) and the deployment of hydrography and mooring arrays in the Tasman Front and subtropical boundary current around New Zealand (Sutton and Bowen 2011). Along with new ocean simulations and ocean state estimates (Schiller et al 2008, Brassington et al. 2007), they permitted major new documentation of the average circulation, its variability and corresponding mechanisms in the region. Combined satellite and in situ data showed that net poleward flow across the Tasman Sea has a strong variability on eddy scale; seasonal and interannual to decadal scales that affect seawater properties (Ridgway 2007a, Ridgway et al. 2008,

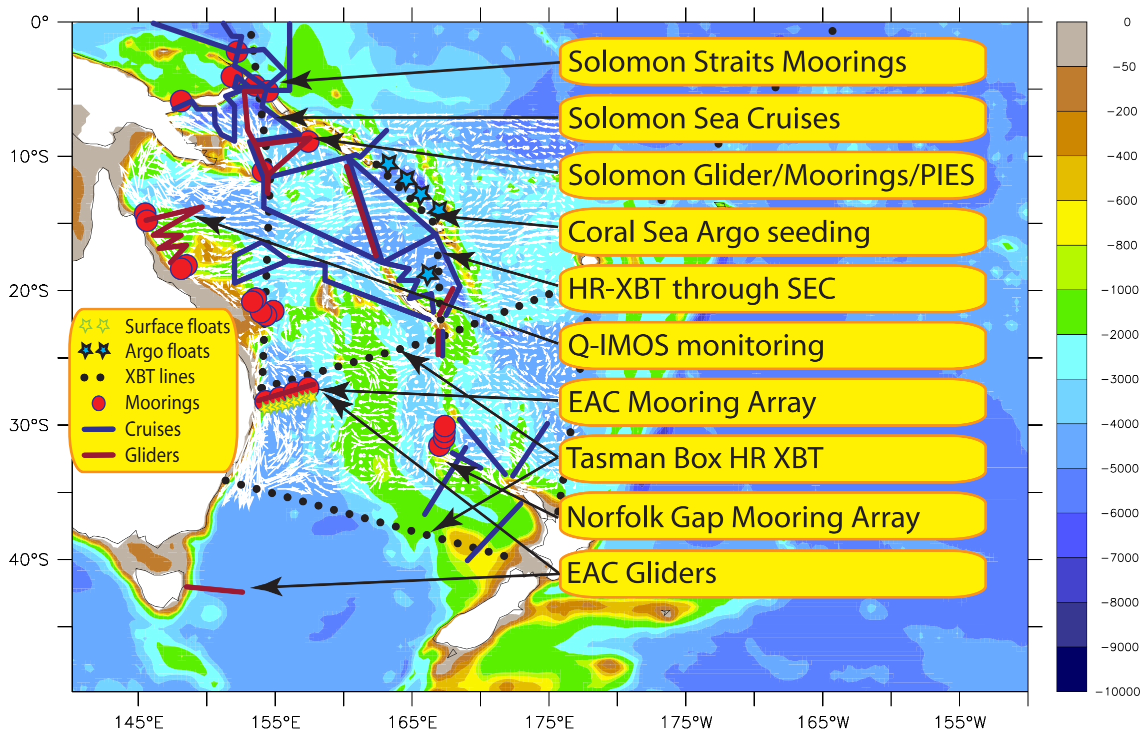

Figure 2. SPICE field program. White arrows indicate the 0-1000m integration of CARS geostrophic velocities referenced to velocities from Argo float trajectories (Kessler and Cravatte, 2013).

Holbrook and Maharaj 2008). The decadal variations were related to basin wide wind stress increases, consistent with linear dynamics, with increases in the EAC and decreases in the Tasman Front flow (Hill et al. 2008).

Over long time scales, the supergyre spin-up revealed by Argo data and altimetry (Roemmich et al 2007) implies an enhanced EAC, resulting in observed warmer, saltier waters near Tasmania (Ridgway 2007a,b, Hill et al. 2008) and higher sea level near Sydney (Holbrook et al 2010).

Solomon Sea

The Solomon Sea is a necessary transit for WBC waters on their way to the equator, where intense flows encounter complex and steep topography. This is by far the less documented sea of the southwest Pacific, and before 2007, there were very few in situ measurements besides scattered ADCP and XBT data collected during ship transits. Only very high-resolution numerical models (>1/12°) were able to simulate the flow through the narrow straits. Along with climatologies of shipboard-ADCP data and surface drifters, they revealed a first description of the inside circulation, pointing out the partition of the New Guinea Coastal Undercurrent (NGCU) into Vitiaz and Solomon straits (Melet et al. 2010a; Cravatte et al. 2011, Hristova and Kessler 2011). The inflow from the Coral Sea was estimated by a dedicated cruise, continuously repeated glider transects and Argo floats (Gasparin et al. 2012, Davis et al. 2012, Zilberman et al. in press).

The Solomon Sea was found to be the region of highest sea level variability of the subtropical South Pacific. From sea surface height satellite data, drifters and simulations, the seasonal variations of thermocline waters were described in relation with subtropical and equatorial dynamics, and the local wind influence (Melet et al. 2010a,b, Hristova and Kessler 2011, Zilberman et al. in press). Large interannual transport variations were observed by gliders (Davis et al. 2012) and in numerical simulations. El Niño events increase equatorward transport, and because the flow becomes saturated in Vitiaz Strait, more water is diverted through Solomon Strait (Melet et al. 2013).

Link to the equator and high latitudes

Subtropical to Equator and high latitudes pathways:
North of the Solomon Sea, waters join the equatorial warm pool at the surface, and the equatorial undercurrent (EUC) just below. Numerical simulations, corroborated by existing observations, suggest that ~70% of EUC water comes from the combined Vitiaz and Solomon straits, the partition of which controls their route and fate (Grenier et al. 2011). In upper layers, the western boundary currents vary in opposition to the equatorial warm water volume (Melet et al., 2010b; Lengaigne et al. 2012), which is a predictor of ENSO characteristics (Bosc and Delcroix 2008, Singh et al. Eastern and central Pacific ENSO and their relationships to the recharge/discharge oscillator paradigm, submitted to Deep-Sea Research). Intermediate waters roughly follow the boundary currents of the southwest Pacific, with different geographic origins and partition among the straits (Qu et al. 2009; Gao et al. 2011, Grenier et al. 2011). These tropical-equatorial dynamics point to the importance of southwest Pacific transports to both climate predictability (e.g. Cheng et al. 2007, McGregor et al. 2007, 2008) and equatorial productivity (Slemons et al. 2010; Grenier et al., 2013).

Generation and motion of spiciness anomalies

The increasing coverage of Argo data allowed detection of large scale spiciness anomalies, formed during winter in the thermocline of the south subtropical gyre and subject to interannual ENSO variations (Qu et al. 2008, Sato and Suga 2009, Kolodziejczyk and Gaillard 2012). Numerical simulations suggest these anomalies advect westward, reaching the western boundary in about 5 years with greatly weakened amplitudes. In the Tasman Sea, strong interannual variability was observed in mode water formation (Tsubouchi et al. 2007, Holbrook and Maharaj 2008).

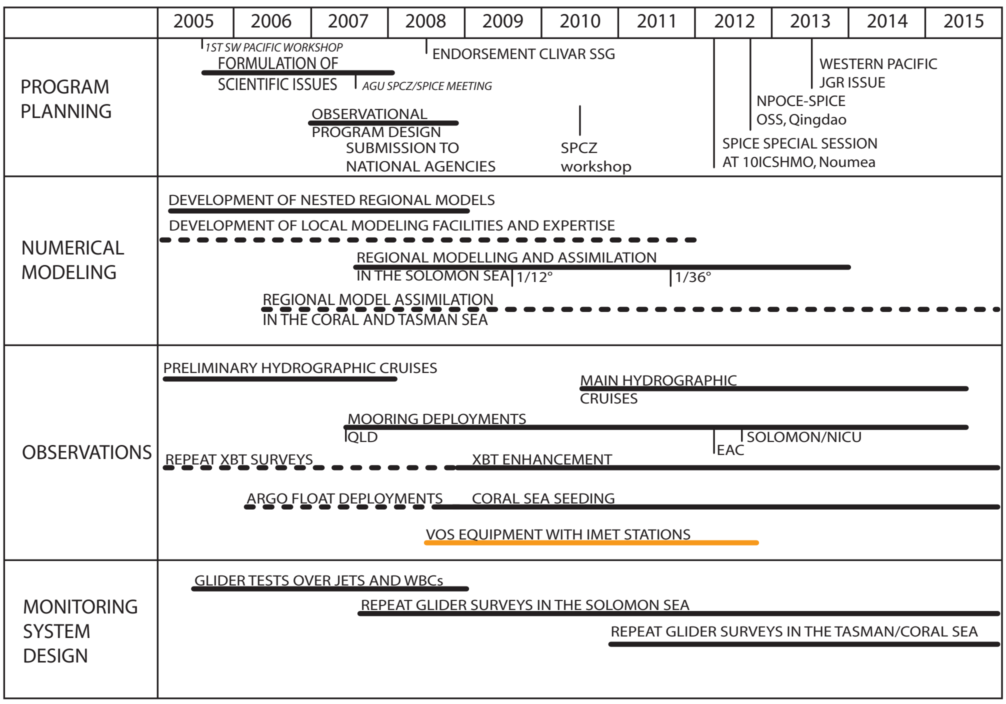

Figure 3. SPICE operation chronology since 2005.

Equatorward pathways
The fate and influence of equatorward anomalies is yet not clear. In the Solomon Sea historical data showed a strong erosion of the salinity maximum, which is reproduced in a model incorporating a specific tidal-mixing scheme (Melet et al. 2011); In addition, an alternative numerical simulation suggests that important diapycnal mixing also occurs downstream of the Solomon straits (Grenier et al. 2011). The recent new in situ data in the Solomon Sea will help understanding these different mechanisms.

Likewise, large interannual and decadal variations are observed in measurements and models of the southwest Pacific transports and properties (Kessler and Cravatte 2013, Zilberman et al. in press, Gasparin 2013). Such variations are associated with substantial changes in the boundary current system, and temperature and salinity as they feed the warm pool and EUC (Melet et al. 2013).

Poleward pathways
Substantial variations are observed in the Tasman Sea, influencing local conditions from Sydney to Tasmania and New Zealand with measureable consequences on ecosystems (Roemmich et al. 2007, Ridgway 2007a, Hill et al. 2008, 2011, Holbrook et al. 2010). The repercussions on local climate, through the EAC/TF modulation (Sasaki et al. 2008, Hill et al. 2011), or on global climate via the supergyre acceleration are not yet clear.

South Pacific Convergence Zone

The South Pacific Convergence Zone (SPCZ) is the largest rainband in the Southern Hemisphere and this rainfall is oriented adjacent to SST gradients in the tropical (Lintner and Neelin 2008) and subtropical South Pacific (Widlansky et al. 2010). Regional SST gradients determine the basin-scale wind structure that supports SPCZ-related moisture convergence and was identified as a key driver of equatorial and boundary ocean currents (e.g. Melet et al. 2013). Hence, a SPICE objective is to better understand climate interaction with regional ocean circulations through study of the SPCZ formation, variability, and the southward tilt with longitude.

Progress towards understanding the SPCZ came from remote sensing data, climate model experiments, and oceanic in situ measurements such as sea surface salinity which is correlated with SPCZ associated rainfall (Delcroix et al. 2011). The tilted orientation of the SPCZ is explained by the blocking influence of the East Pacific subtropical high (Takahashi and Battisti 2007a,b) and associated accumulation of eastward-moving synoptic disturbances, which propagate from south of Australia into a jet-exit region over the central South Pacific where mean westerly winds are weaker (Widlansky et al. 2010; Matthews 2012).

On interannual timescales, four typical structures of the SPCZ position were identified, each influenced by the slowly varying SST pattern associated with ENSO (Vincent et al. 2009). During extreme El Niño events, the SPCZ collapses onto the equator as the meridional SST gradient vanishes between the equator and 15°S. Uneven future warming of the tropical Pacific may increase frequency of these 'zonal-SPCZ' events (Cai et al. 2012), possibly changing the mean rainfall pattern (Widlansky et al. 2012).

Further research and SPICE legacy

Although much recent scientific progress has been made understanding the circulation and dynamics of the SPICE region, numerous observational and modelling operations continue (Figure 3), and there are many remaining science questions.

Continuing SPICE operations

Mooring arrays are presently in the water; the Solomon Sea inflow and outflow will be monitored until 2014; the NQC array will continue although with less moorings; but budget restrictions will bring an early end to the EAC array. An experiment combining mooring, glider, XBT and along track altimetry is taking place in the ECC. Monitoring continues with gliders, moorings and Pressure Inverted EchoSounders (PIES) in the Solomon Sea, high-resolution XBT lines and Argo float deployments. Repeat glider transects are being conducted from the Central to the Northern Great Barrier Reef across the Queensland Trough. Modelling efforts are also taking a new step, with two very high-resolution simulations at 1/36° ongoing (NEMO/ROMS codes).

Outstanding science issues

The combined effect of spiciness and transport anomalies on equatorial and Tasman Sea conditions is confirmed to be potentially large; the potential effect of spiciness anomalies is questioned, given the strong salinity erosion into and downstream of the Solomon Sea; however, results need to be evaluated in light of the SPICE regional measurements combined with basin-scale data.

Despite great progress towards understanding the SPCZ shape and behaviour, the current generation of coupled climate models still poorly simulates the diagonal extension of the rain band towards southern latitudes. Model deficiencies limit the capacity to reproduce and predict rain, winds, and the ocean circulation in the South Pacific and—through teleconnections—over the whole basin.

The successful alliance of geochemistry and physics during SPICE operations suggests developing further multidisciplinary approaches to unravel the dominant impact of southwest Pacific waters on equatorial and high latitude geochemistry and ecosystems.

Basis for new developments

Pacific Island countries and territories are extremely sensitive to oceanic and atmospheric conditions. Sea level rise, rainfall variability, temperature changes greatly impact their resources and lifestyle (Bell et al. 2011, 2013, Australian Bureau of Meteorology 2011), thus regional evolution and projection of such variable is of great interest to policy makers. SPICE efforts, along with the Pacific-Australia Climate Change Science and Adaptation planning Program (PACCSAP) helped assess projections for oceanic conditions and the SPCZ (Brown JN et al. 2012, Brown JR et al. 2012, Widlansky et al. 2012; Ganachaud et al. 2012; Sen Gupta et al. 2012). Recent assessments suggest new and more integrated programs are needed in which training and capacity building can directly utilize scientific expertise and evolving predictive capabilities of the ocean and atmosphere in the region.

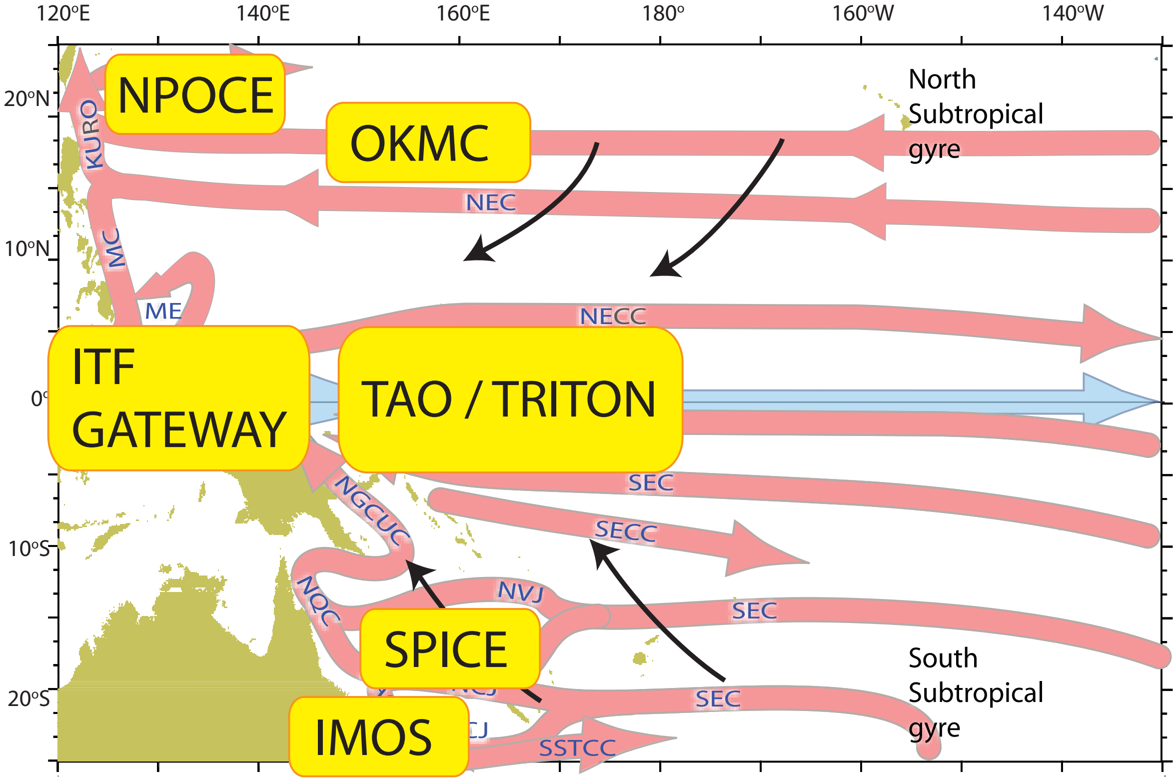

Figure 4. Concurrent CLIVAR programs in the western Pacific. With the equatorial TAO/TRITON array, the Indonesian Throughflow (ITF Gateway), the Northwestern Pacific Ocean Circulation and Climate Experiment (NPOCE), Origins of the Kuroshio and Mindanao Currents (OKMC) and SPICE, all oceanic pathways to the equator will be measured.

Western Pacific Coordination

The CLIVAR Pacific Panel provides a platform to coordinate international programs. This is illustrated in Figure 4, where the quasi-simultaneous occurrence of CLIVAR West Pacific programs is expected to provide an unprecedented understanding of the warm pool, along with EUC sources and dynamics. A special JGR issue on the Western Pacific Ocean Circulation and Climate, planned for 2014, will include many SPICE contributions.

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Pandora cruise provides an unprecedented description of the Solomon Sea

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Introduction

The climatic variability in the equatorial Pacific at decadal time scales could be linked to water supply from the subtropical gyres toward the equator. Improving our knowledge of water masses transformations and pathways through the South-West Pacific is one of the main objectives of SPICE (Ganachaud et al. this issue). In addition to dynamical transformations, water masses undergo nutrient and micronutrient enrichment when entering into contact with the coasts; impacting the productivity of the Equatorial Pacific Cold Tongue and its climatic role. Quantifying these land/ocean exchanges is a priority of the international GEOTRACES program.

The Pandora Cruise

A multidisciplinary cruise was completed in July 2012 through a France-USA collaboration, to document physical and geochemical water properties in the Solomon Sea and adjacent areas, believed to be a key location for SPICE studies. Data obtained during the cruise and associated mooring deployments are expected to substantially improve our understanding of the area, both in terms of climate and ecosystems.

The main objectives of the cruise were:

- To provide a quasi-synoptic description of surface and subsurface circulation in the Solomon Sea and in the straits connecting it to the equator;
- To deploy a series of moorings in the straits and on both sides of the Solomon Sea, to obtain the temporal variability of the circulation;
- To document water masses transformations and mixing, as well as ocean-margins exchanges, in particular through sampling of Trace Elements and Isotopes (TEI) at selected locations in the area.

Therefore the experimental approach combined physical, chemical and geochemical experiments, to access a wide range of space and time scales of the circulation.

The cruise track included both classical hydrology sections, including macro-nutrients, and 24-48h time-series stations, the latter allowing TEI sampling and providing information on short term hydrology variability, and its impact on geostrophic calculations (Figure 1). The cruise, carried out on French R/V L'Atalante, departed from Nouméa, New Caledonia, on June 28 2012 and ended at the same port on August 6. A first meridional section along 163E documented the incoming flows of the South Equatorial Current. Following sections were obtained across the

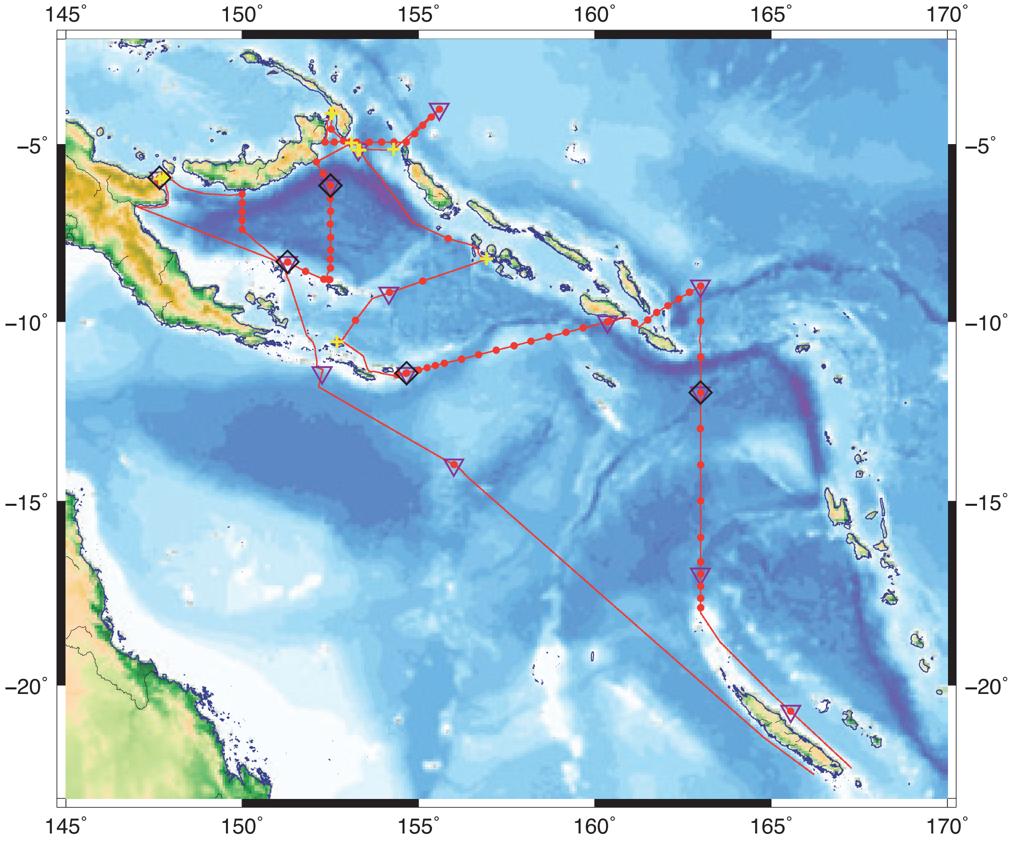

Figure 1. Pandora cruise track. Red dots, CTD stations; triangles, "clean" CTD stations; diamonds, in-situ pumps deployments; yellow crosses, moorings.

southern entrance of the Solomon Sea, in its interior, and across the straits at its northern exit. Two SeaBird CTDO2/Rosette systems were used, comprising a "clean" (titanium structure, Kevlar cable, courtesy of C. Measures, U. of Hawaii) for trace metals sampling and "dirty" system. Overall 83 multiple-cast stations were achieved for a total of 134 casts, most to 2000m or more, including 93 LADCP profiles. During the whole cruise, 2 shipboard RDI ADCPs recorded the current field to 1000-1500m depth. Nine moorings were deployed in the straits, in the frame of a consortium agreement between LEGOS, Scripps Institution of Oceanography (SIO) and University of Papua-New Guinea. Two "end points" moorings were also deployed in the Solomon Sea to monitor total geostrophic flow, as a collaboration between LEGOS and SIO.

Data is still in a preliminary analysis phase. However, some qualitative features seem to already emerge:

- The very deep extension (with a significant speed to more than 1500 m depth) of the western boundary current (New Guinea Coastal Undercurrent, NGCU) at its entrance into the Solomon Sea is confirmed, its core being located at 300-800 m. Its transport during Pandora was probably in the upper range of what was estimated from glider data by Davis et al., (2012); this is consistent with their finding of a stronger flow during El-Niño episodes. However, the slight warming of summer 2012 did not even reach the NOAA definition of El Niño (NOAA/NWS/CPC). It is noteworthy that measured transports through the Solomon Sea and straits were generally stronger than previous observations or model results (Figure 2).
- The existence of a Solomon Island Current (SICU), flowing north-westwards along the eastern coast of the Solomon Islands has been suggested by some modeling studies. During Pandora, only a shallow coastal flow was measured.
- A peculiar increase in dissolved oxygen content, deep into the Solomon Trench (4000-5600m) is currently being investigated.
- Preliminary geochemistry results show that; dissolved iron concentrations only slightly increase across the Solomon Sea transit; radium activities are higher close to the coast; and toxic methyl-mercury can be produced in situ in the open ocean and not only at margins.

A turnover cruise is planned in 2014 to maintain the moorings. The final mooring recovery will take place in 2015, for a total transport time series of 3 years.

This cruise and related work are made possible through funding by Agence Nationale de la Recherche (ANR-09-BLAN-0233-01), Institut National des Sciences de l'Univers, Institut de Recherche pour le Développement in France, the National Science Foundation in the USA and the University of Papua New Guinea.

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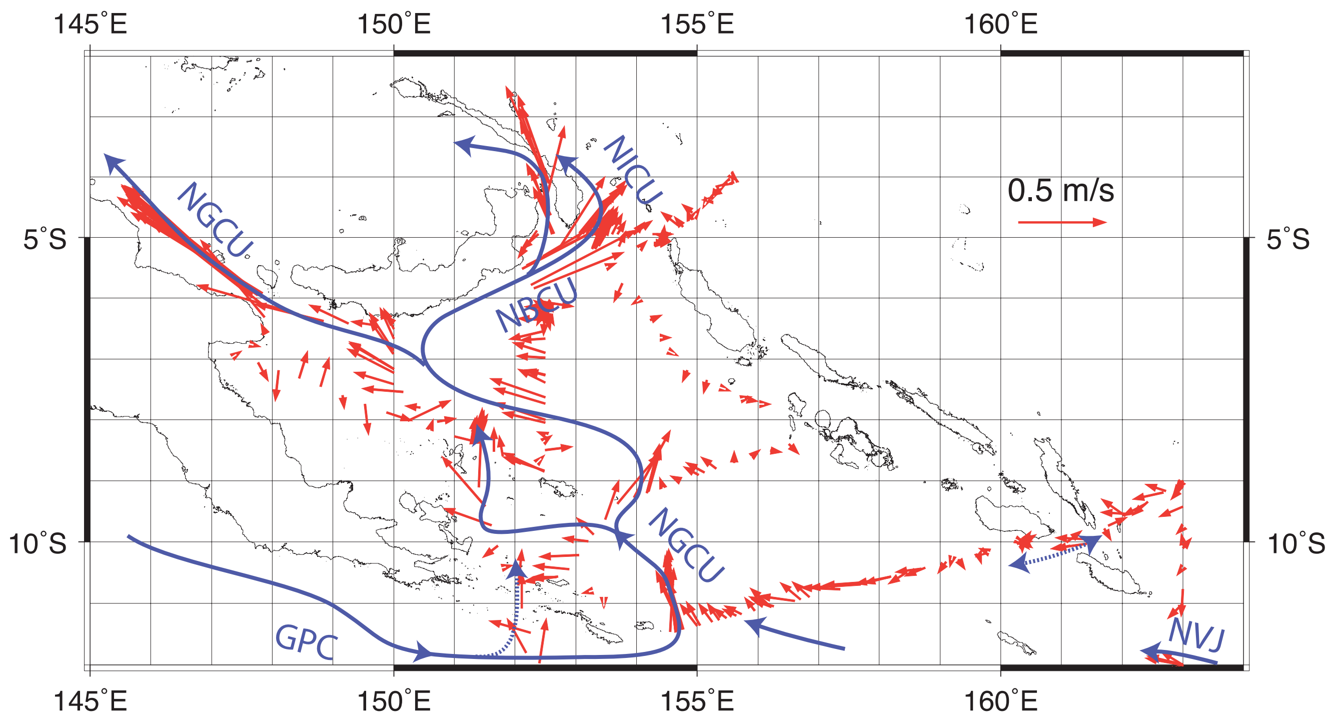

Figure 2. Hourly-averaged, 50-700m depth currents from shipboard ADCP in the Solomon Sea (red arrows), scale is shown on map. Overlayed are the main currents pathways in the Solomon Sea (in blue). GPC: Golf of Papua Current; NVJ: North Vanuatu Jet; NGCU: New Guinea Coastal Undercurrent; NBCU: New Britain Coastal Undercurrent; NICU: New Ireland Coastal Undercurrent.

Tropical Atlantic Climate Experiment (TACE)

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Introduction

More than 10 years ago it was recognized that there was a need for a focused observational and modeling effort in the tropical Atlantic, to advance the predictability of climate variability in the surrounding region and to provide a basis for assessment and improvement of coupled models. The scientific foundation of such an effort was developed in the Tropical Atlantic Climate Experiment (TACE) white paper by Fritz Schott and co-authors in 2003. The TACE implementation workshop in February 2005, held in Miami marked the starting point of a truly international five-year (2006 – 2011) research program under the auspices of CLIVAR. TACE with its backbone, the Prediction and Research Moored Array in the Tropical Atlantic (PIRATA), was closely linked to other initiatives in the tropical Atlantic like the French EGEE (Etude de la circulation océanique et de sa variabilité dans le Golfe de Guinée) program and the African Monsoon Multidisciplinary Analyses (AMMA).

One of the main goals of TACE was to improve the observational database and to carry out dedicated process studies enhancing our understanding of the tropical Atlantic climate system. The regional focus of TACE was on the central and eastern equatorial Atlantic (Fig. 1) characterized by the development of the Atlantic cold tongue (ACT) during boreal summer. The year-to-year variability of the ACT sea surface temperature (SST) is linked to climate variations including the strength and onset date of the West African Monsoon; however, its prediction is strongly limited by large biases in coupled climate models.

Here we report about the 2012 Tropical Atlantic Variability (TAV) meeting that was held jointly with the PIRATA-17 meeting from 10th to 13th September 2012 in Kiel, Germany. The meeting focused on advances in observing, simulating, understanding and predicting TAV and provided an opportunity to assess progress toward achieving TACE's goals. The meeting was organized around five themed sessions:

1) Climate Variability and Change in the Tropical Atlantic

2) Tropical Atlantic Teleconnections

3) Predictability, Coupled and Uncoupled Model Biases

4) Oceanic and Atmospheric Processes Affecting Climate Variability

5) Physical-Biogeochemical Interaction

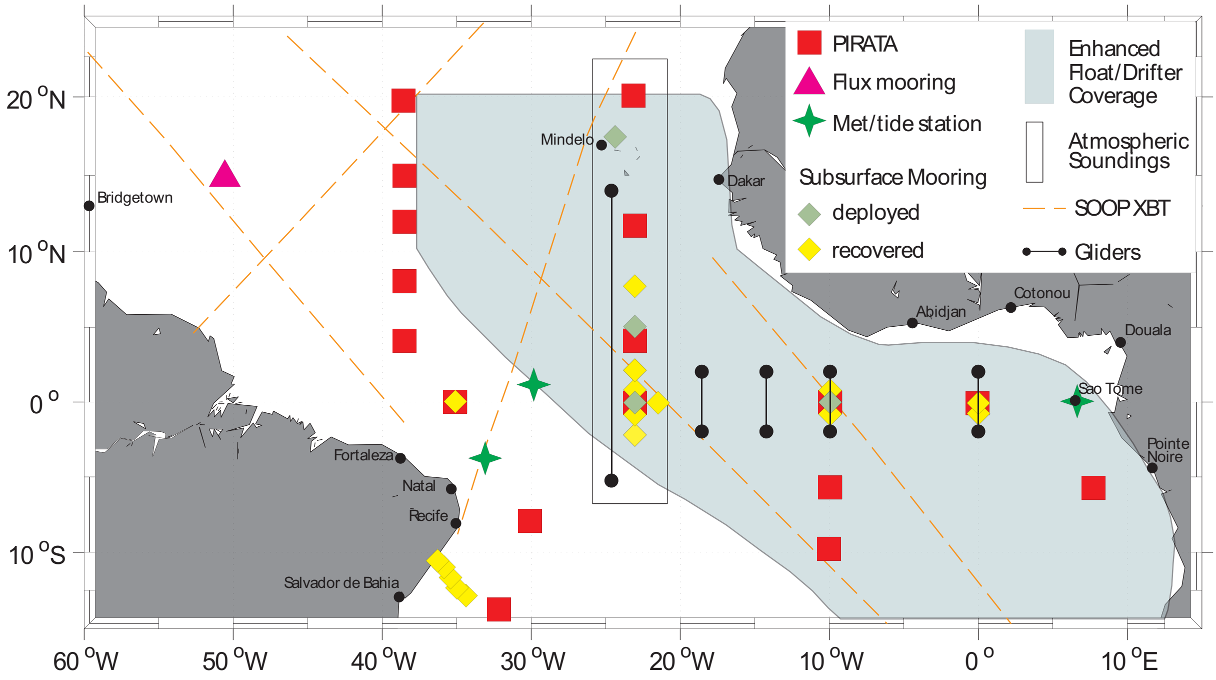
This report summarizes the progress to date in TACE based on the presentations at the conference. Highlights from the first three sessions are grouped together in the following section, followed by a summary of Session 4. We also briefly describe the status of the biogeochemistry in the tropical Atlantic, despite not being formally part of TACE, because it points toward the increasing importance of multidisciplinary research in the tropical Atlantic for understanding and predicting climate. The scientific program, abstracts as well as most presentations are available at the meeting website: https://conferences.geomar.de/conferenceDisplay.py?ovw=True&confId=0.

Tropical Atlantic Climate Variability and Teleconnections, Predictability and Model Biases

Climate Variability and Change in the Tropical Atlantic

Session 1 on climate variability and change in the tropical Atlantic centered around the recent progress in documenting and understanding of modes of variability and long-term climate change within the region. Enhanced observations and modeling studies during the TACE period have led to some new understanding of underlying physical processes governing modes of TAV. For example, Lumpkin (2012) showed, using a synthesis product of the surface geostrophic circulation, that the interannual variability of the North Equatorial Countercurrent is linked to the appearance of the Atlantic meridional mode and zonal mode. Lübbecke (2012) analyzed stability properties of the Atlantic zonal mode and concluded that it is more strongly damped compared to its counterpart in the Pacific – ENSO. Rouault (2012) presented observational evidence that the development of Benguela Niños is closely linked to the advection of warm Angolan water in the Northern Benguela region across the Angola-Benguela Front (ABF), suggesting that anomalous advection of heat near the ABF can be a key process during the onset of Benguela Niños. Queiroz (2012) presented a multi-dataset analysis of surface ocean variability along the West African coast that revealed a significant surface ocean warming trend in the region since 1982. This coastal warming trend appears to be a part of a larger scale warming pattern over the entire Eastern tropical Atlantic basin as shown by Servain (2012). Servain (2012) further showed that the warming trend is most significant during the warm season. The warming features are consistent with earlier studies by Deser et al. (2010) and Tokinaga and Xie (2011). Subsequent discussions focused on potential causes of the warming trend. One possible cause, as

Figure 1. Observational network in the tropical Atlantic during TACE.



suggested by Tokinaga and Xie (2011), may be related to the aerosol forcing, while the other may be related to slow changes in ocean circulations, such as the Atlantic Meridional Overturning Circulation. The latter is supported by a modeling study by Campos (2012) who showed an increase in the Agulhas leakage and a poleward shift of the oceanic Subtropical Convergence Zone. Finally, Treguier (2012) presented some intriguing modeling results on Congo River plume dynamics. Interannual variations of sea surface salinity (SSS) along the equator and the Gulf of Guinea coast are found to be independent on river discharge variations, but are the result of larger scale advection anomalies.

Tropical Atlantic Teleconnections

Session 2 on teleconnections focused on the influences of the Pacific El Niño/Southern Oscillation (ENSO) and other modes of climate variability on the tropical Atlantic as well as the impact of tropical Atlantic climate variability on surrounding oceans and continents. It is well known that ENSO has an impact on the surface layer of the tropical Atlantic; Kröger (2012) elaborated on these impacts by describing how the details of wind stress teleconnections from the Pacific affect the tropical and subtropical cells in an ocean model. Keenlyside (2012) showed, through seasonal prediction experiments with a climate model, that equatorial Atlantic SST could significantly improve the prediction of major El Niños across the boreal spring predictability barrier by impacting the Equatorial Pacific atmospheric circulation during this critical development phase of ENSO events. Subsequent discussion emphasized the need to quantify the relative importance of tropical Atlantic vs. tropical Indian Ocean impacts on the ENSO cycle, both of which have been highlighted by independent groups.

Predictability, Coupled and Uncoupled Model Biases

Section 3 focused on the coupled models' SST bias over the eastern equatorial and SE tropical Atlantic and their impacts on predictability. Latif (2012) showed that the reduction of coupled model systematic errors is essential for the generation of useful predictions. Voldoire (2012) showed that the systematic errors that eventually lead to large SST biases over the eastern equatorial Atlantic, are already present during the early stages of the CNRM-CM5 coupled model integrations. Nobre (2012) showed that SST error growth in INPE's (Instituto Nacional de Pesquisas Espaciais) coupled model was insensitive to increased atmospheric CO_2 concentration. Richter (2012) examined the outputs of CMIP5 model pre-industrial control simulations, reporting that one of the major reasons for the reversed SST gradient over the equatorial Atlantic appears to be the weaker than observed equatorial easterlies in March-April-May. Toniazzo (2012) showed that the development of coupled model errors evolves from several time-scales, from days to years, and that the fully developed error patterns appear very similar in different models. Finally, Chang (2012) showed for a high-resolution ocean model that in addition to the contributions of atmospheric model biases, systematic oceanic errors also make a significant contribution to the bias problem. In particular, (1) a strong warm bias at the ABF front, maintained by the local wind and the convergence of Angola and Benguela Current, is caused by an overshooting of the Angola Current in ocean models and (2) an alongshore warm bias to the south of the front is caused by the model deficiencies in simulating the sharp thermocline along the equator, the strong thermal gradient beneath the Angola current, and the complex circulation system within the Benguela upwelling zone.

Process studies

TACE was designed to better understand processes relevant for the mean climate system including seasonal mixed layer heat and freshwater budgets, interannual variations in the tropical circulation, and its underlying dynamics. The observational program consisted of improved profiling float and surface drifter coverage, glider measurements, high-density XBT lines, subsurface moorings along the equatorial wave-guide, and repeated research cruises during different seasons with hydrographic, microstructure, and biogeochemical measurements. Studies analyzing the large amount of new data acquired during the TACE period together with data from the pre-existing PIRATA buoy array, remote-sensing data and a new

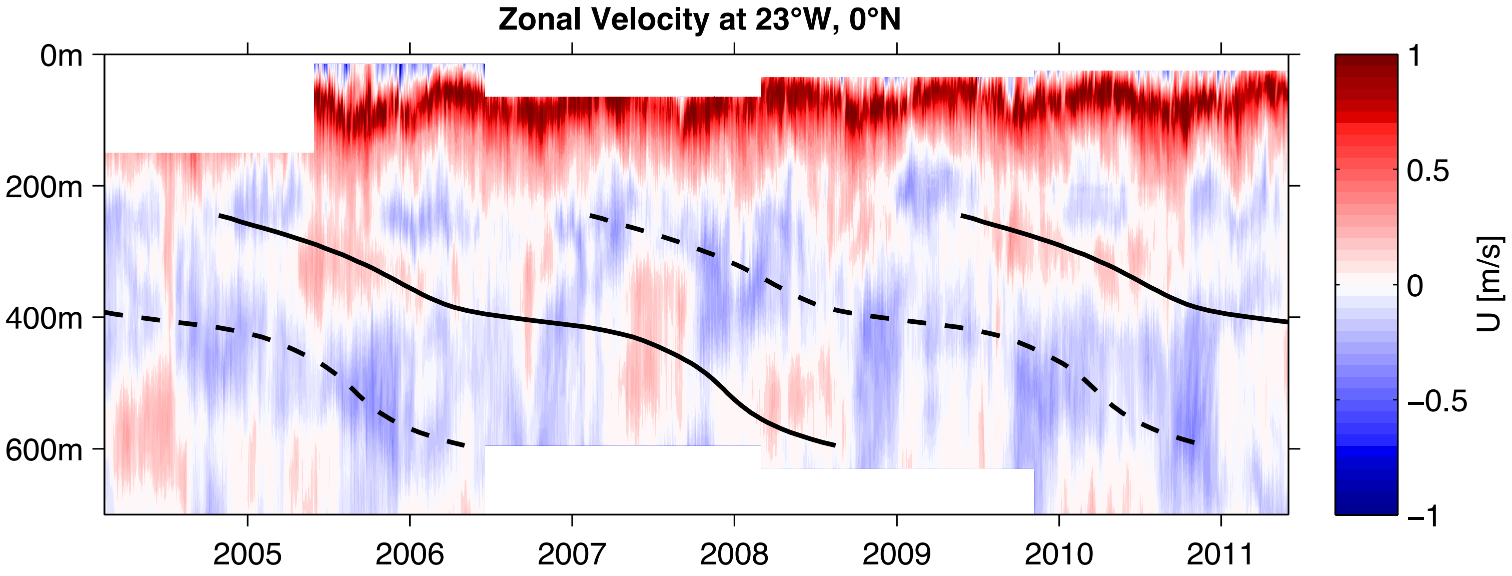


Figure 2. Zonal velocity measured at the equator, 23°W with moored ADCPs. The eastward flow of the EUC at about 80 m depth is characterized by a strong seasonal cycle. Below the EUC, the phase propagation of EDJ is marked by solid and dashed lines that are obtained from a 4.5-year harmonic fit (update from Brandt et al., 2011).

generation of high-resolution model simulations were mostly presented within session 4: "Oceanic and Atmospheric Processes Affecting Climate Variability". The session was split into two sub-sessions: a) Surface mixed layer heat budgets and mixing processes and b) Tropical Atlantic circulation and dynamics.

Surface mixed layer heat budgets and mixing processes

Seasonal and interannual variations in the mixed layer heat and freshwater budget were addressed in several presentations using different observational and modeling methods. Particularly, microstructure measurements carried out during different cruises as part of TACE and on autonomous gliders provided a much-improved understanding of mixed layer budgets. Hummels (2012) presented the mixed layer heat budget from observations and concluded that the observed diapycnal heat flux contributes crucially to the budget within the ACT (equator, 23°W, 10°W and 0°), while the budget is dominated by atmospheric forcing in the southern ACT region at 10°S. An extensive measurement program within the ACT region was carried out during the ACT onset in boreal summer 2011 (mid-May and mid-July). Two consecutive cruises complemented by a glider-swarm experiment delivered an unprecedented number of contemporaneous microstructure profiles, hydrographic and current data. Dengler (2012) presented an analysis of observations taken near the PIRATA buoy at the equator, 10°W. The strong SST cooling from end of May to mid-July, from 26°C to below 22°C, could be largely explained by strong bursts of turbulence extending from the mixed layer into the upper thermocline. These turbulent bursts occurred predominately, but not exclusively, during nighttime. Vertical shear of horizontal velocity was particularly enhanced in the upper 40m of the water column with the shear caused by zonal flow variability playing a dominant role. The results contrasted with results from the Pacific cold tongue (PCT) presented by Moum (2012) showing a much more pronounced role of tropical instability waves and associated meridional flow variability in producing a diapycnal heat flux that could alone maintain the PCT.

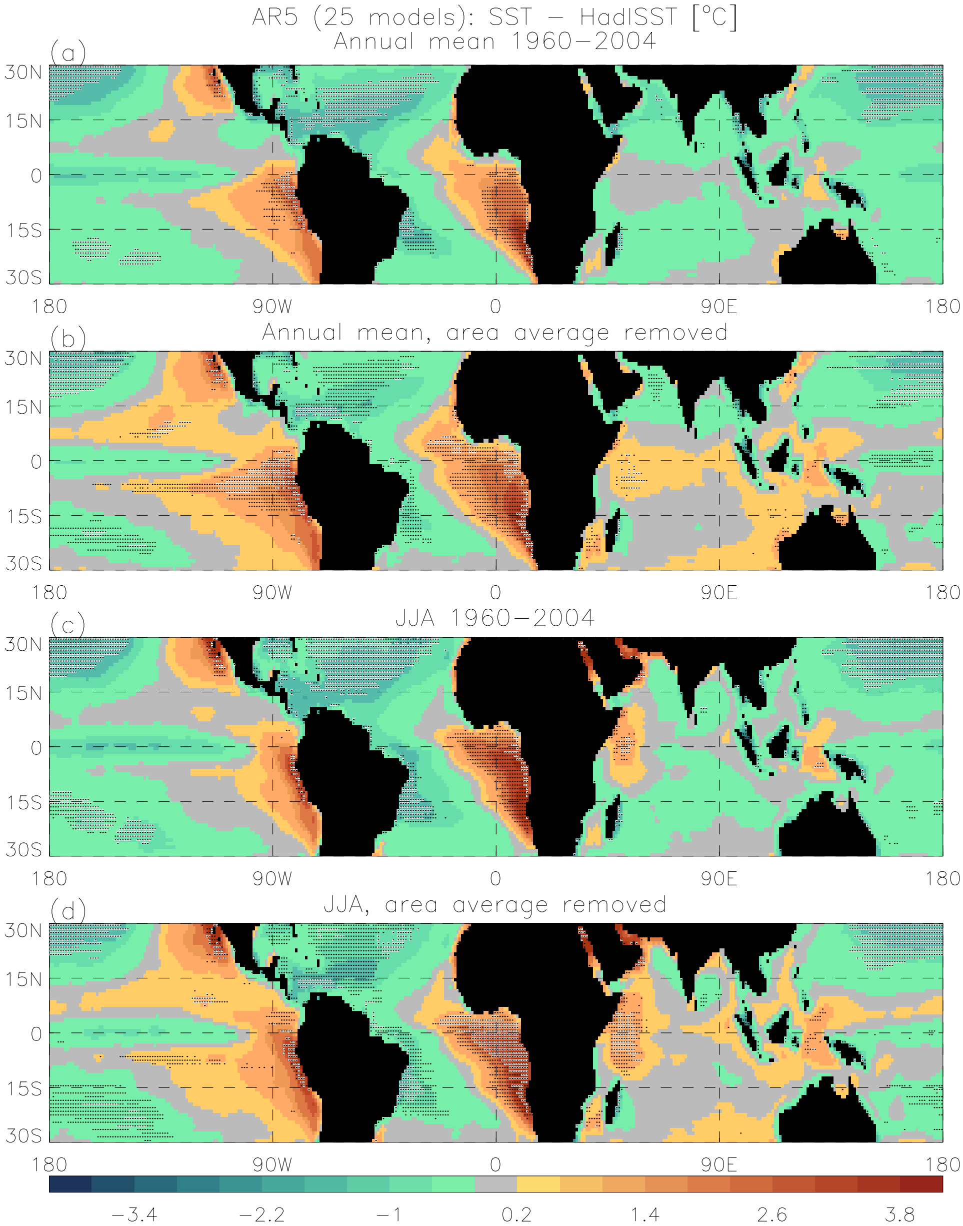
High-resolution model simulations were employed to study the effect of different types of intraseasonal equatorial waves in causing cooling events in the ACT, and to study the role of vertical velocity in the ACT formation. Simulations by Jouanno (2012) suggest that intraseasonal waves significantly contribute to the mixed layer heat budget. Cooling events due to diapycnal mixing are particularly strong in the shear zone above the Equatorial Undercurrent (EUC) and during boreal summer when the westward surface flow is strongest. The vertical shear above the EUC is similarly modulated by different types of intraseasonal waves, including wind-generated mixed Rossby gravity waves, inertia-gravity waves, and equatorial Kelvin waves. An investigation of the Ekman balance in the ACT was presented by Caniaux (2012), where the equatorial upwelling was found to be an indirect response to the wind forcing. The associated vertical velocity preconditions the oceanic mixed layer for the strong diapycnal mixing occurring later during the onset of the ACT.

The session also underlined the growing focus on salinity in the community. In terms of datasets, Xie (2012) presented a new SSS monthly blended product from NOAA, that enriches significantly the existing in-situ and satellite datasets. Hernandez (2012) described the current efforts at Mercator to keep providing a global ocean reanalysis, ongoing since 1992. In terms of processes, Lazar (2012) focused on the North Atlantic Warm Pool barrier-layer, detailing how the remarkable winter subsurface temperature inversions resulted from fresh water capping and yearlong penetrative solar radiations. A mixed layer salinity budget over the ACT during the ACT onset in 2011 was computed from observations by Schlundt (2012), indicating that alike heat budget subsurface mixing processes were of paramount importance to close the freshwater budget.

Tropical Atlantic circulation and dynamics

Subsurface moorings and repeated shipboard observations were used to observe circulation variability during the TACE period. Current meter mooring arrays were installed at different longitudes focusing in particular on the strength of the EUC supplying the upwelling within the ACT. Brandt (2012) presented moored velocity observations from 23°W carried out between 2005 and 2011 and analyzed the relation between EUC

Figure 3. Difference between simulated and observed mean SST. The warm bias is pervasive (stippled areas is where all models have the same bias) in CMIP5 just as it was in CMIP3 (Toniazzo and Woolnough, 2012).



transport variations and TAV. Interannual transport anomalies are found to be seasonally dependent with maximum variability during boreal summer. Regression of wind and SST anomalies onto EUC transport anomalies revealed northward wind anomalies in June (i.e., early onset of the African monsoon), and colder SSTA in the ACT associated with a strong EUC. Further, November EUC transport vs. the next April SST and winds showed warm SSTA in the Tropical North Atlantic (TNA) region, consistent with Okumura and Xie (2006) who argued that Atlantic Niño tends to evolve into a meridional mode event.

A joint analysis of the 23°W mooring data and similar moored current observations at 10°W and 0° were presented by Johns (2012). The variability of the EUC transport is more semiannual at 23°W and more annual at 0°E. In boreal spring, during the annual wind relaxation, the EUC transport is approximately the same across the basin while in fall there is a sharp decrease toward the east. Year-to-year variability was associated with a stronger reduction of the EUC in July/August particularly at the eastern mooring sites during 2009 compared to 2010. In 2010, the ACT was anomalously weak; while in 2009 the ACT was normal (or slightly cooler than normal). Unfortunately, the experiment did not sample a strong Atlantic Niño event.

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Three other talks presented new results regarding equatorial deep jets (EDJ). These jets, that are characterized by small vertical wavelength, downward phase and upward energy propagation and an oscillation period of about 4.5 years, were recently observed at the equatorial 23°W mooring site (Fig. 2) and analyzed with respect to their possible effect on SST and climate in the tropical Atlantic region (Brandt et al. 2011). Ascani (2012) presented idealized simulations for the generation of EDJ as well as latitudinally alternating zonal jets (Equatorial Intermediate Current System, EICS). Both current systems are found to originate from intraseasonal fluctuations generated by the instabilities of the tropical wind-forced, near-surface current system. The analysis of the meridional and vertical structure of EDJ using observations, reduced gravity modeling and theory were presented by Didwischus (2012) and Greatbatch (2012). Greatbatch (2012) were able to explain the increased meridional width of the EDJ compared to inviscid theory by isopycnal mixing of momentum.

The large number of research cruises in the Gulf of Guinea was used by Bourlès (2012) to draw a new summary of the circulation and its variability in the northern part of the Gulf. A special focus was on the Guinea current system, including an eastward flowing undercurrent under the Guinea current that is fed by salty subtropical waters.

Summary and Outlook

TACE has provided important contributions to the understanding of the seasonal to interannual circulation of the tropical Atlantic, the interannual ACT variability, and the role of various processes in climate model biases. Using a large number of new observations performed during TACE, the seasonal mixed layer heat budget along the equator could finally be closed and interannual circulation variability could be observed and related to different climate patterns. Following the increasing importance of multidisciplinary research in the tropical Atlantic for predicting climate, ocean-atmosphere pCO_2 sensors have been installed on two PIRATA sites since 2006 (6°S, 10°W and 8°N, 38°W), and shipboard underway pCO_2 measurements and/or sea water sampling for the measurement of the CO_2 system have been performed in the tropical Atlantic as part of the PIRATA cruises since 2006. Oxygen sensors were also included at two PIRATA sites (23°W, 4°N and 11.5°N). These time series are being used to investigate physical-biogeochemical interactions - an important aspect of ongoing tropical Atlantic climate research.

Several open questions remain after TACE:

- What are the contributions of different processes (e.g. diapycnal mixing, equatorial wave processes) to interannual variations in the mixed layer heat budget?
- What is the role of internal ocean variability in setting up large –scale ocean atmosphere interactions?
- Is there a need for a better representation of small meridional and vertical scale flow features (like EDJ and EICS) or shelf and near-coastal processes in coupled climate models?

One important outcome from TACE was the investigation of many different factors that contribute to climate model SST biases. State-of-the art climate simulations still show strong biases in the tropical Atlantic climate system, which limits climate predictability in the region. The largest SST bias is found in the Benguela upwelling region (Fig. 3). Hypotheses for the cause of this bias that involve ocean dynamics include possible misrepresentation of the connectivity between equatorial and coastal upwelling regions in climate models. The advective water transport from the equator to the Benguela region, as well as wave processes along the equatorial and coastal wave-guide are of particular importance. Unrealistic stratification or wave processes in conjunction with unrealistic local forcing in the coastal upwelling region could lead to too warm SST in the eastern tropical Atlantic. However, atmospheric processes (atmospheric convection, cloud processes) may also contribute. With the end of TACE, the focus of ongoing research programs is shifting more toward the tropical Southeast Atlantic, which is presently a region of exceptional low ocean data availability. This new focus has led to the establishment of the US CLIVAR Eastern Tropical Oceans Synthesis Working Group (http://www.usclivar.org/working-groups/etos) that is aimed at enhancing cooperation between groups focusing on the different tropical oceans, and between observationalists/modelers and ocean/atmospheric scientists, to gain a better understanding of the key oceanic, atmospheric, and coupled processes occurring in this region.

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The CLIVAR Exchanges is published by the International CLIVAR Project Office
ISSN No: 1026-0471

Editor: Jennifer Riley
Layout & Printing: Indigo Press, Southampton, UK

CLIVAR Exchanges is distributed free of charge upon request (email: icpo@noc.ac.uk)

The ICPO is supported by the UK Natural Environment Research Council and NASA, NOAA and NSF through US CLIVAR.
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International CLIVAR Project Office
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European Way, Southampton, SO14 3ZH,
United Kingdom
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