OS11M HC: 319 B Monday 0830h

Indian Ocean and Indonesian Throughflow Variability From Models and Observations I

Presiding: **R Murtugudde,** ESSIC/Univ of Maryland**; J T Potemra,** University of Washington

OS11M-01 0830h

The Monsoon as a Self-regulating Coupled Ocean-Atmosphere System

Peter John Webster (303 492 4423; pjw@oz.colorado.edu)

Webster, Peter John, Program in Atmospheric and Oceanic Sciences, University of Colorado, Boulder, Boulder, CO 80309, United States

Observational studies have shown that the Asian-Australasian monsoon system exhibits variability over a wide-range of space and time scales. These variations range from intraseasonal (20–40 days), annual, biennial (about 2 years), longer term interannual (3–5 years) and interdecadal. Despite this range of variability, the South Asian monsoon (at least as described by Indian precipitation) exhibits a smaller range of variability during its summer pluvial phase than variability exhibited in other climate systems of the tropics. For example, drought or flood rarely extend to multiple years, with rainfall oscillating biennially from slightly above average to slightly below average precipitation.

We argue that variability of the monsoon is regulated by negative feedbacks between the ocean and the atmosphere. The annual cycle of the heat balance of the Indian Ocean is such that there is an ocean heat transport from the summer hemisphere from the summer hemisphere resulting principally from wind-driven Ekman transport. Given the configuration of the low-level monsoon winds, the Ekman transport is in the opposite sense to the lower tropospheric divergent wind. The cross-equatorial ocean heat transport is large with amplitudes varying between +2 PW (northward) in winter and –2 PW (southward) in summer compensting, almost exactl;y, an atmospheric heat flux of –2PW and +2PW, resepctively. Thus, the wind-induced heat transport works to cool the ocean of the summer hemisphere upper ocean while warming the winter hemisphere. Similar regulation occurs on interannual time scales. For example, during anomalously strong northern hemisphere monsoon summers (typically a La Nina), strong winds induce a stronger than average southward flux of heat. When the monsoon is weak (typically an El Nino), the wind-driven ocean heat flux is reduced. In this manner, the monsoon regulates itself by reducing summer hemisphere sea-surface temperatures during strong monsoon years and increasing it during weak years. In this manner, the monsoon is self regulating.

It is noted, however, that the ocean heat transport theory of monsoon regulation does not necessarily allow heat anomalies to persist from one year to the next. Furthermore, the theory does not include the Indian ocean dipole as a dynamic entity. Finally, we develop a more general theory in which the slow dynamics of the dipole are integral components of a sequence of processes that regulate the monsoon, thus minimizing radical year to year departures of the monsoon from climatology.

OS11M-02 0845h

Structure and Mechanisms of South Indian Ocean Climate Variability

Shang-Ping Xie[1] (808-956-6758; xie@soest.hawaii.edu)

H. Annamalai[1]

Friedrich A. Schott[2]

Julian M. McCreary[1]

[1]University of Hawaii, IPRC/SOEST, 2525 Correa Road, Honolulu, HI 96822, United States

[2]University of Kiel, Institut fr Meereskunde, Kiel, Germany

A unique open-ocean upwelling exists in the tropical South Indian Ocean (SIO), a result of the negative wind curl between the southeasterly trades and equatorial westerlies, raising the thermocline in the west. Analysis of in-situ measurements and a model-assimilated dataset reveals a strong influence of subsurface thermocline variability on sea surface temperature (SST) in this upwelling zone. El Nino/Southern Oscillation (ENSO) is found to be the dominant forcing for the SIO thermocline variability, with SST variability off Sumatra also making a significant contribution. When either an El Nino or Sumatra cooling event takes place, anomalous easterlies appear in the equatorial Indian Ocean, forcing a westward-propagating downwelling Rossby wave in the SIO. In phase with this dynamic Rossby wave, there is a pronounced co-propagation of SST. Moreover, a positive precipitation anomaly is found over, or just to the south of, the Rossby wave-induced positive SST anomaly, resulting in a cyclonic circulation in the surface wind field that appears to feedback onto the SST anomaly. Finally, this downwelling Rossby wave also increases tropical cyclone activity in the SIO through its SST effect.

This coupled Rossby wave thus offers potential predictability for SST and tropical cyclones in the western SIO. Our results suggest that models that allow for the existence of upwelling and Rossby-wave dynamics will have better seasonal forecasts than ones that use a slab ocean mixed layer. Our lagged-correlation analysis shows that SST anomalies off Java tend to precede those off Sumatra by a season, a time lead that may further increase the Indian Ocean predictability.

URL: http://iprc.soest.hawaii.edu/~xie

OS11M-03 0900h

On Dipole-like Variability in the Tropical Indian Ocean

Astrid Baquero-Bernal[1] (49-40-41173318; baquero@dkrz.de)

Mojib Latif[1] (49-40-41173248; latif@dkrz.de)

[1]Max-Planck Institut fuer Meteorologie, Bundesstr. 55, Hamburg 20146, Germany

The interannual variability of the tropical Indian Ocean sea surface temperature (SST) is studied with observational data and a hierarchy of coupled general circulation models (CGCMs). Special attention is given to the question whether an oscillatory dipole mode exists in the tropical Indian Ocean region with centers east and west of 80°E. Our observational analyses indicate that dipole-like variability can be explained as an oscillatory mode only in the context of ENSO (El Niño/Southern Oscillation).

A dipole-like structure in the SST anomalies independent of ENSO was found also. Our series of coupled model experiments shows that ocean dynamics is not important to this type of dipole-like SST variability. It is forced by surface heat flux anomalies that are integrated by the thermal inertia of the oceanic mixed layer, which reddens the SST spectrum.

OS11M-04 0915h

Indian Ocean Dipole-Indian Monsoon Rainfall-ENSO: changing relationships

Ashok Karumuri[1,2] (+81-45-778-5585; ashok@jamstec.go.jp)

Zhaoyong Guan[1,3] (+81-45-778-5584; guan@jamstec.go.jp)

Toshio Yamagata[1,4] (+81-3-5841-4297)

[1]Climate Variations Program, Frontier Research For Global Cgange/Institute for Global Change Research, 3173-25, Showamachi, Kanazawa-Ku, Yokohama 236-0001, Japan

[2]Indian Institute of Tropical Meteorology, Pashan, Pune 411 008, India

[3]Department of Atmospheric Sciences, Nanjing Institute of Meteorology, Nanjing 210044, China

[4]Department of Earth and Planetary Science,, Graduate school of Science,The university of Tokyo, Tokyo 113 0033, Japan

The Indian Ocean Dipole (IOD) and the El Nio/Southern Oscillation (ENSO) have complementarily influenced the Indian Summer Monsoon Rainfall (ISMR) during the last four decades of the twentieth century. Whenever the ENSO-ISMR correlation is low (high), the IOD-ISMR correlation is high (low). Our study shows that the Indian Ocean Dipole caused the recent decline in the ENSO-ISMR correlation. We conclude, from the analysis of the observed data (1958-1997) and from the AGCM sensitivity studies, that the ENSO-induced anomalous circulation over the Indian region is either countered or supported by the IOD-induced anomalous meridional circulation cell, depending upon the phase and amplitude of the two major tropical phenomena in the Indo-Pacific sector.

OS11M-05 0930h

The Intrinsic Variability of the Indian Ocean in a Constrained Coupled Climate Model

Albert S. Fischer[1] (+33-1-44-27-27-11; asf@lodyc.jussieu.fr)

Eric Guilyardi[2] (ericg@met.reading.ac.uk)

Pascal Terray[1] (lea@lodyc.jussieu.fr)

Jean-Philippe Boulanger[1] (jpb@lodyc.jussieu.fr)

Pascale Delecluse[1] (pna@lodyc.jussieu.fr)

[1]Laboratoire d'Océanographie Dynamique et de Climatologie, UPMC, 4 place Jussieu - boîte 100, Paris 75005, France

[2]CGAM, Dept. of Meteorology, U. of Reading, Reading RG6 6BB, United Kingdom

The links between Indian Ocean variability and El Niño-Southern Oscillation (ENSO) variability in the Pacific are studied using a coupled atmosphere-ocean general circulation model. A 200 year reference run of the model (SINTEX: ECHAM-ORCA, Gualdi et al., 2001) exhibits a reasonable ENSO cycle in the Pacific, and Indian Ocean variability that has features similar to the 'dipole mode' (Saji et al., 1999, *Nature*). The development of cold SST anomalies along the coast of Sumatra in the southeastern tropical Indian Ocean (SETIO) is accompanied by anomalous easterly winds, associated with warm anomalies to the west, and strongly tied to the seasonal cycle.

A statistical analysis of the reference run reveals some modes of variability in the Indian Ocean that are tightly linked with the model ENSO cycle, and some that appear to have greater independence. The dominant non-homogeneous mode of variability of Indian Ocean SST, a zonal equatorial mode with opposing SST anomalies in the east and west, has strong links with ENSO. Variability of the cold pole in the SETIO has greater independence from ENSO variability. The reference run generally has stronger zonal Walker-type circulations than observed.

In order to study the intrinsic variability of coupled phenomena in the Indian Ocean, a novel experiment is undertaken with the coupled model, with tropical Pacific wind stresses felt by the ocean constrained to a mean seasonal cycle. The variability of the Indian Ocean, without the influence of ENSO, is then isolated in the model, and investigated. This is a first step towards an understanding of how ENSO events affect the interannual variability of the Indian Ocean, and what natural variability is intrinsic to the coupled system involving the Indian Ocean.

OS11M-06 0945h

Coupled Dynamics in the Indian Ocean: Externally or Internally forced?

Annamalai H[1] ((808) 956 5646; hanna@soest.hawaii.edu)

Raghu Murtugudde[2] ((301) 314 2622; ragu@vinsanto.essic.umd.edu)

James Potemra[1] ((808) 956 2737; jimp@soest.hawaii.edu)

Shang-Ping Xie[1] ((808) 956 6758; xie@soest.hawaii.edu)

Bin Wang[1] ((808) 956 2563; bwang@soest.hawaii.edu)

[1]International Pacific Research Center (IPRC/SOEST) University of Hawaii , 2525 Correa Road, Honolulu, HI 96822, United States

[2]ESSIC, University of Maryland, Room 2201, CSS Bldg, University of MD, Collge Park,, Maryland, MD 20742, United States

A long and consistent atmosphere and ocean assimilated analyses products have been diagnosed to elucidate possible physical mechanism through which ENSO initiates the coupled air-sea interaction over the equatorial eastern Indian Ocean (EEIO).

The main conclusion emerges from the present work is that the Indian Ocean has its own coupled mode of variability that is weak on its own but grows under the influence of external forcings. There exists a time window (boreal spring/early summer) in the annual cycle of convection and thermocline depth over the EEIO and Indonesian Throughflow (ITF), during which the ocean-atmosphere system is relatively fragile and susceptible to external forcings. In the majority of the events examined in the present study, El Nino like conditions in the western Pacific emerge as a potential candidate to initiate air-sea interaction in the EEIO, through both atmospheric and oceanic links.

OS11M-07 1020h

ENSO influence on the preconditioning, onset, growth, mature and decay phases of the Indian Ocean events

Raghu G Murtugudde[1] ((301) 314-2622; ragu@essic.umd.edu)

Annamalai Hariharasubramanian[2] ((808) 956 5646; hanna@soest.hawaii.edu)

James Beauchamp[1] ((301) 405-0050; vajim@essic.umd.edu)

[1]ESSIC/Univ of Maryland, ESSIC/Univ of MD, CSS Bldg Room 2207, College Park, MD 20742

[2]IPRC/SOEST, University of Hawaii at Manoa Department of Meteorology & IPRC 2525 Correa Road, Honolulu, HI 96822

The strongest El Nino-Southern Oscillation (ENSO) event of the last century was accompanied by anomalous conditions in the Indian Ocean which had historic regional climatic impacts. The debate continues about whether these zonal modes in the Indian Ocean (IOZM) need an external trigger or can be initiated internally within the Indian Ocean. An ocean GCM coupled to an advective atmospheric mixed layer model and forced with NCEP reanalyses winds for the period of 1949-2001 is employed to analyze each IOZM event to understand their preconditioning, onset, and growth phases with respect to ENSO events. The composite analyses of the weak, strong, and aborted IOZM events clearly demonstrate that the atmospheric circulation changes associated with the onset of ENSO events in the Pacific are crucial for triggering the initial anomalous cooling off Java after which the coupled IOZM events can grow. The MJO activity and the Indonesian throughflow also play crucial roles not only in preconditioning the Indian Ocean but also in the growth phase. The ENSO-IOZM interactions underwent interdecadal changes centered around 1976, the well known climate shift. The details of the intercomparisons of the IOZM events and the mechanism of the ENSO trigger for each event is presented including the role of the 1976 shift on IOZM.

OS11M-08 1035h

Roles of the Indian Ocean in decadal ENSO variations

Jin-Yi Yu[1] ((310)206-3743; yu@atmos.ucla.edu)

James C. McWilliams[1] ((310)206-2829; jcm@atmos.ucla.edu)

[1]University of California Los Angeles, Department of Atmospheric Sciences 405 Hilgard Ave., Los Angeles, CA 90095-1565, United States

The fundamental physical processes that give rise to El Nino-Southern Oscillation (ENSO) are believed to be within the tropical Pacific. However, climate features external to the tropical Pacific may be capable of affecting ENSO behaviors. In this study, we perform experiments with a coupled atmosphere-ocean GCM (CGCM) to examine the roles of the Indian Ocean-Monsoon system in the decadal modulation of ENSO. In the control simulation, the oceanic component of the CGCM includes only the tropical Pacific Ocean (i.e., the Pacific Run). In the second CGCM simulation, both the Indian and Pacific Oceans are included in the ocean model component (i.e., the Indo-Pacific Run).

Our CGCM experiments show that the Indian Ocean-Monsoon system can modulate the amplitude and frequency of ENSO and produce interdecadal ENSO variations. The strong and weak ENSO decades are very different in their thermocline depths and Walker circulation strengths. In this talk, we will examine the major differences between the strong and weak ENSO decades in their atmospheric and oceanic mean states. Focus will be placed on the relative importance of the Indonesian throughflow and Asian Monsoon variation in allowing the Indian Ocean to affect decadal ENSO variations.

OS11M-09 1050h

How Does the Indo-Pacific Region Affect the Interannual Variability of the Tropical Oceans?

Simona Masina[1] (+39-051-6398015; masina@ingv.it)

Silvio Gualdi[1] (+39-051-6398060; gualdi@ingv.it)

Antonio Navarra[1] (+39-051-6398014; navarra@ingv.it)

Eric Guilyardi[2] (+44-118-987-5123; ericg@met.reading.ac.uk)

[1]Istituto Nazionale di Geofisica e Vulcanologia, Via Gobetti 101, Bologna 40129, Italy

[2]University of Reading, Centre for Global Atmospheric Modelling PO Box 243 Earley Gate, Reading RG2 2BB, United Kingdom

The influence of anomalous conditions in the tropical Indo-Pacific region on the interannual variability in the tropical Indian Ocean is investigated both in observations and a series of numerical simulations. The simulations have been carried out with a coupled atmosphere-ocean model at different resolutions and an ocean only general circulation model which appear to reproduce realistic modes of variability of the tropical oceans. Evidence of significant correlations between wind anomalies in the Indonesian throughflow region and sea surface temperature anomalies in the tropical Indian and Pacific Oceans have been found both in observations and simulations. Our studies suggest a possible role of the Indo-Pacific region in the onset of interannual variability in both the tropical Indian and Pacific Oceans. The role of air-sea coupled processes and upper ocean dynamics on the evolution of the Indian Ocean interannual varibility is also investigated.

OS11M-10 1105h

Remote Response Of The Indian Ocean To Interannual SST Variations In The Tropical Pacific

Toshiaki Shinoda[1] (3034974295; ts@cdc.noaa.gov)

Mike A Alexander[1] (3034976030; maa@cdc.noaa.gov)

Harry H Hendon[2] (610396694120; hhh@bom.gov.au)

[1]NOAA-CIRES Climate Diagnostics Center, 325 Broadway, Boulder, CO 80303, United States

[2]Bureau of Meteorology Research Centre, BMRC, PO Box 1289K, Melbourne 3001, Australia

Coupled model experiments are used to investigate Indian Ocean SST variability associated with ENSO via an "atmospheric bridge". An ensemble of 16 atmospheric general circulation model (AGCM) simulations are performed in which observed SSTs are specified in the central and eastern tropical Pacific Ocean over the period 1950-1999. The remainder of the global oceans are simulated using a grid of 1-dimensional mixed layer models

Composites of SST and surface fluxes for warm and cold ENSO events for the period 1950-1999 are formed. The coupled model simulates some aspects of the observed Indian Ocean SST anomalies associated with ENSO including the basin-wide warming and development of a zonal dipole structure in Northern autumn. Surface flux anomalies associated with ENSO in the eastern tropical Indian Ocean agree with NCEP reanalysis fluxes reasonably well. AGCM and coupled model experiments suggest that a large portion of surface flux amomalies in the eastern tropical Indian Ocean associated with ENSO is remotely forced by the SST variation in the eastern tropical Pacific. The remotely forced SST in the eastern tropical Indian Ocean significantly contributes to the dipole variation.

OS11M-11 1120h

The Roles of Rainfall and High Frequency Wind on the Interannual Variability of the Indian Ocean-Atmosphere Climate

Kate Q. Zhang[1] ((818)393-3839; katez@pacific.jpl.nasa.gov)

Claire Perigaud[1] ((818)354-8203; cp@pacific.jpl.nasa.gov)

[1]MS 300-323, Jet Propulsion Lab, 4800 Oak Grove Dr, Pasadena, CA 91109, United States

The roles of rainfall and high frequency wind on the interannual variability of the Indian Ocean-Atmosphere Climate are examined with data (XBT temperature profiles, TOPEX sea level, AVHRR SST, FSU or Quickscat wind stress, and GEWEX rainfall) and a nonlinear reduced-gravity thermodynamic model forced by observed atmospheric conditions. In the control run (CR), the ocean is forced with FSU interannual monthly winds over 1980-2000 and climatological monthly rainfalls. In experiment R, wind remains unchanged, but rainfall is prescribed to their interannual monthly values observed over 1980-2000. Results show that the interannual anomaly in salinity-rainfall has a major impact on the surface and subsurface temperature distribution. The simulated SST in experiment R is in much better agreement with the observed SST. However, the amplitude of SST anomalies is smaller than the observed. One possible explanation is that the monthly averaging of wind and rainfall is inappropriate. This possibility is examined over 1999-2000 by experiments Q and RQ, where the daily wind variability observed by Quickscat is superimposed on FSU monthly average of experiments CR and R. Because of the nonlinear nature of the mixing induced by wind and rainfall, this study highlights the role of high-frequency processes in the Indian Ocean climate.

OS11M-12 1135h

Anomalous Surface Currents in the tropical Indian Ocean

Semyon A Grodsky[1] (senya@atmos.umd.edu)

James A Carton[1] (301-405-5365; carton@atmos.umd.edu)

Raghu Murtugudde[2] (raghu@essic.umd.edu)

[1]Meteorology, Univ. MD, Computer and Space Sci. Bldg Stadium Dr., College Park, MD 20742, United States

[2]ESSIC, Univ. MD, Computer and Space Sci. Bldg Stadium Dr., College Park, MD 20742, United States

An anomalous climate event occurred in 1997 in the Indian Ocean with severe consequences for the surrounding continental areas. In response to an intensification of the trade winds, a westward gradient of SST and an anomalous reversal of the eastward surface currents with peak velocity anomalies exceeding 1 m/s were evident in the boreal autumn. A similar but weaker event took place in 1994. In this study we examine the observational record during the 1990s including surface drifter velocities, SST and altimeter sea level to confirm these dramatic changes. We examine the key momentum balance between wind-induced momentum flux and the pressure gradient force as well as the important role of horizontal temperature advection in the mixed layer heat response.

URL: http://www.meto.umd.edu/~senya/HTML/io_vel/io_vel.html

MON

OS11N HC: 323 A Monday 0830h

Low-Latitude Boundary Currents

Presiding: **T Qu,** University of Hawaii; **R Lukas,** University of Hawaii

OS11N-01 0830h INVITED

Pacific Low-Latitude Western Boundary Currents

Peter Chu (831-656-3688; chu@nps.navy.mil)

Naval Postgraduate School, 833 Dyer Road, Monterey, CA 93943, United States

Recent observational and modeling studies on the Pacific low-latitude western boundary currents and their connection to the Indian Ocean are reviewed. The topics include the water mass characteristics, the current structure and their effects on the global thermohaline circulation, determination of the currents using inverse method and numerical modeling.

OS11N-02 0850h

Variabilities of the New Guinea Coastal Current and Undercurrent

Yoshifumi Kuroda[1] (+81-468-67-9458; kuroday@jamstec.go.jp)

Iwao Ueki[1] (+81-468-67-9468; uekii@jamstec.go.jp)

Yuji Kashino[1] (+81-468-67-9459; kashinoy@jamstec.go.jp)

[1]JAMSTEC, 2-15 Natsushima, Yokosuka 237-0061, Japan

The seasonal and interannual variabilities of the New Guinea Coastal Current (NGCC) and the New Guinea Coastal Undercurrent (NGCUC) were examined based on the 3-5 year-long time series of current data from subsurface ADCP moorings and hydrographic data from the ship. The change of the Antarctic Intermediate Water (AAIW) was also discussed. As seasonal reversal of the surface NGCC was clearly observed. In boreal summer characterized by the southeasterly monsoon, northwestward current was dominant in the surface layer. At that time, the warm low-salinity layer thickened and sloped down toward the New Guinea coast from the equator. That surface water accumulation may be caused by onshore Ekman drift at the New Guinea coast, combined with weak Ekman upwelling at the equator. In the boreal winter, southeastward surface current developed extending down to 100 m depth in response to the northwesterly monsoon. Coastal upwelling was indicated in that season and the surface water accumulated at the equator due to Ekman convergence. Year-around northwestward NGCUC whose core speed was about 60 cm/s was observed around 200 m depth, and apparently intensified in boreal summer. The characteristics of the AAIW around sigma-theta = 27.2 in that region also varied seasonally, as the temperature and salinity of the AAIW in boreal summer were lower than those in boreal winter. The water mass change was consistent with the variability of the NGCUC, as the intensified NGCUC in boreal summer could advect much volume of the AAIW from the source region. The seasonal change of the NGCUC was mainly induced by basin scale wind change. It was because the time series of volume transport at the western boundary, which were estimated from Sveldrup flow based on the basin scale wind field, correlated highly with the time series of depth averaged NGCUC. The most significant feature in the ENSO time scale was that the reversal of surface current disappeared in the boreal winter from late 1997 to early 1998 in the height of the strongest El Nino on record, and the southwestward current from surface to the NGCUC core depth dominated. The NGCUC core depth coincided with the salinity maximum layer of the south Pacific tropical