Collaboration Opportunity for Observational Enhancements in Indian Ocean Dynamics and Tropical Cyclone Forecasting

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MM/OM - Site Visit Report News Headlines Local Experts Rally for observational enhancements to Tropical Cyclone Forecasting in the South West Indian Ocean. Project Proposed for comparisons studies and the generation of new validation sets for selective enhancements to the Global Climate Observing System.

INTRODUCTION

The Office Of Naval Research International Field Office (ONRIFO) conducted collaboration discussions with Mark R Jury, from the Environmental Science Dept, University of Zululand, South Africa, during the IOGOOS conference held in Grand Bay, Mauritius 2-9 Nov 2002. A cooperative research project between the Environmental Science Dept, University of Zululand and the Mauritius Meteorological Services, and ONR/NRL/ONRIFO is proposed, entitled "Indian Ocean Dynamics and Tropical Cyclone Forecasting". Its purpose is to build local expertise on how the Northeast monsoon and ocean dynamics interact with tropical cyclones in the Southwest Indian Ocean, through modeling and observational studies involving graduate student research. The Indian Ocean is the third largest Ocean in the world and it is unique in many ways. U.S. Naval vessels that sail across the Indian Ocean rely on current models that are data sparse, and do not always accurately reflect the state of the environment. Indian Ocean tropical cyclones develop at rapid rates, and put our sailors at risk. This proposed project provides a unique opportunity for scientists to address the impact of Indian Ocean environmental factors on cyclogenesis. This knowledge would benefit forecasts of extreme weather and sea state, making them more reliable and strategically valuable to user groups. The Newsletter is designed to inform national and international scientists, research and governmental institutions and international organizations about potential research collaboration.

LONG TERM GOALS

To enhance the marine meteorological network in the tropical western Indian Ocean through the provision of additional observing capability; coordinated through local application centers where communications infrastructure and technical expertise will be upgraded.

OBJECTIVES

An improved understanding of the causes of inter-seasonal weather variability over the SW Indian Ocean is the main scientific objective. Reliance is placed on the Global Climate Observing System (GCOS to investigate the influence of the Indian NE monsoon on regional climate.). However data voids are typical in mid-ocean regions, so numerical simulations cannot be validated. Selective enhancements to the GCOS network should be guided through comparative studies and the generation of validation data sets.

A number of parallel research objectives will be pursued:

1. Describe the spatial structure and temporal variability of the Indian NE monsoon at intra-seasonal to inter-decadal time scales using historical data;
2. Assess the stability of monsoon - cyclone interactions and perform studies leading to predictability;
3. Gather surface data sets for verification of numerical simulations and prediction products, and analyse errors contributed by observational inconsistencies;
4. Evaluate reanalysis products for adequacy and reliability, and assess which additional observations will lead to improvements in climate prediction;
5. Improve the ability to predict extreme weather events at 5-30 day lead times;
6. Identify the processes linking ocean heat anomalies with monsoon circulations over the SW Indian Ocean;
7. Establish the capability to predict tropical Indian Ocean SST through various modeling techniques;
8. Perform diagnostic studies and numerical simulations to relate oceanic dynamics, diabatic heating and coupling mechanisms to circulation changes over the SW Indian Ocean;
9. Quantify the impacts of tropical cyclones on a wide array resources in socio-economic context;
10. Expand the ocean weather modelling capabilities of weaker institutions in the region, with suitable expertise, and collaborate with these centres to ensure on-going operational research.

APPROACH

Key scientific questions to be addressed in this project:

For the oceans –

1. What are the oceanic characteristics resulting in adjustments to the monsoons and the associated circulation systems across the SW Indian Ocean?
2. What are the time and space structures and dynamics of: currents and transient waves, heat storage, vertical motion and mixing, surface fluxes, subtropical gyres, and warm pools in the SW Indian Oceans?

For the monsoons –

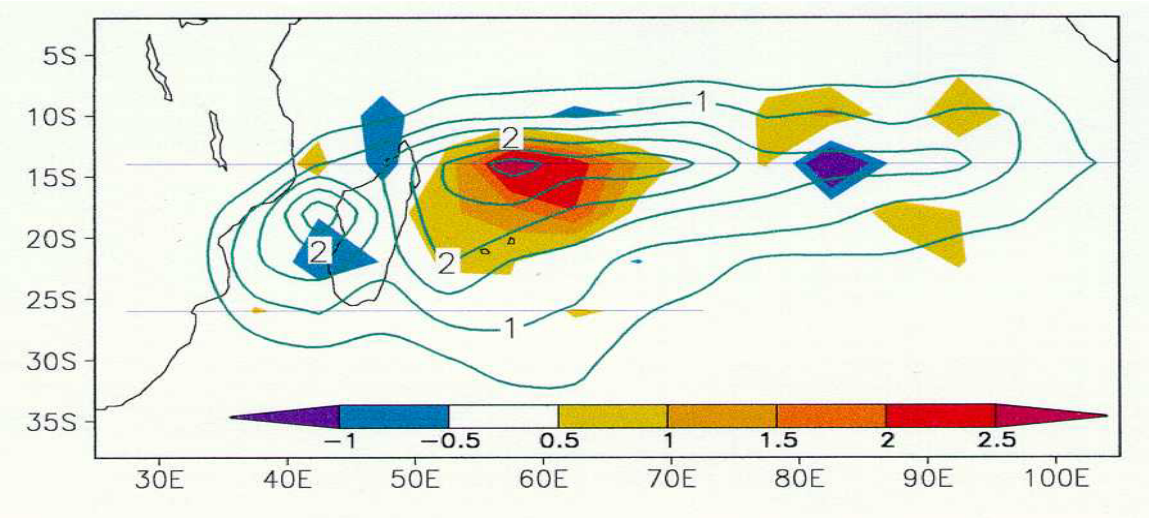
1. What atmospheric fluxes of surface heat/moisture/momentum affect the cellular structure of monsoon circulations around the SW Indian Ocean?
2. What dynamics of tropical zonal flow (Walker Cells and Madden Julian Oscillation - MJO) and southern hemisphere flows enable tropical-high latitude interactions?

Key questions on predictability and user uptake -

1. How can we better predict the track and intensity of tropical cyclones in the SW Indian Ocean prior to their formation?
2. What are the respective roles of monsoon forcing and remote ocean variability in the genesis of tropical cyclones?
3. What is the monsoon response to SST variation in key areas? What are the preferred response frequencies in the intra-seasonal domain?
4. How can forecast users best utilise environmental predictions to plan a sustainable livelihood?

The tropical cyclones of the SW Indian Ocean interact with the surrounding Indian monsoon system and global modes of variability to produce large fluctuations in number, track and intensity; and associated socio-economic impacts. There is a need to better understand the mechanisms responsible for these two-way teleconnections. This work will involve the study of monsoon fluxes and ocean dynamics, particularly in:

1) The thermocline 'ridge' southeast of the Seychelles, and
2) The Mozambique Channel and Agulhas Current.



Tropical cyclone days in the WIO: solid lines are historical mean numbers of TC days per degree square in the December to March season; shading is the increase in TC days caused by a deeper thermocline in the north (from Xie et al 2001).

Project activities will consist of graduate studies toward MSc / PhD degrees at the three cooperating universities, coupled with internships at operational institutions involved in ocean and weather prediction. The training seeks to mix South African graduate students with counterparts from the SW

Indian Ocean. Theoretical and practical training and thesis supervision will be given by the project leaders and visiting post-doctoral scientists.

Specific research activities will be tackled according to student interest, guided by the timetable below. They include -

- Ocean influences on climatic patterns and events: key Sea Surface Temperature (SST) indices will be 'mapped' onto gridded tropical cyclone data, and statistical relationships will be analysed at various lags to determine the extent and seasonality of influence.
- Understanding SST variability: environmental factors forcing composite warm and cool events will be analysed: including radiative fluxes, surface heat exchanges, wind stress patterns, thermocline depth and ocean currents.
- Understanding ocean evolution:
  - ⇒ Investigate sensitivity of ocean circulation to various wind stress and 'surface heat flux forcing' using ocean general circulation models.
  - ⇒ Assimilate insitu and satellite measurements into a numerical model to study the evolution of SST and gradients across ocean gyres.
- Monsoon - cyclone interactions: analyse station and re-analysis data to characterise the annual cycle of convection, particularly shifts in extent and intensity from the equatorial Indian Ocean and Mozambique Channel. Study how Rossby wave disposition perturbs the behaviour of tropical cyclones.
- Composite analysis of tropical cyclone formation in the context of the MJO:
  - ⇒ Perform a composite analysis of tropical cyclones and their precursor patterns
  - ⇒ Analyse the time evolution of monsoon wind bursts using daily atmospheric profile data from equatorial stations and compare with reanalysis data.
- Validate remote sensing data: compare station, satellite and gridded data; and develop locally tuned diagnostic models to overcome error budgets, with particular attention given to new microwave and ocean products.
- Quantify economic impacts of climate: analyse climatic elements and economic data by sector and country to better define appropriate mitigating strategies.

Implementation Time-table

Capacity Building:
Intake of 1st group of MSc / PhD bursars
Graduate degree prog. & Internship 2004-2005
Intake of 2nd group of MSc / PhD bursars
Graduate degree prog. & Internship 2006-2007

Tropical cyclones and ocean dynamics
Annual cycle and ocean coupling processes 2004
Monsoon - cyclone interaction 2005
Composite analysis of tropical cyclogenesis 2006
Remote sensing data and ocean assimilation 2007

Formulation of predictive models
Upgrading of existing models 2004

Development of weather predictions 2005
Development of ocean predictions 2006
Dissemination of products 2007

IMPACT / APPLICATIONS

The project will create new local insights into severe weather processes underlying the prediction of tropical cyclone impacts. Such innovation is likely to see scientists from the project providing important advice for decision makers across the SW Indian Ocean.

ASSESSMENT

This proposed project is consistent with the S&T thrust of ONR/NRL Marine Meteorology programs. Department of the Navy high interest areas related to Marine Meteorology S&T in Indian Ocean are: (1) Research projects related to the onset and location of major circulations: monsoon onset, behavior of the onset vortex, and interactions of SW Asian monsoon system with the SE Asian monsoon system, and (2) Projects addressing the behavior and prediction (track, intensity, structure) of Indian Ocean cyclones. The proposed project will aim to:

- Create the ability to dynamically model key aspects of the intra-seasonal weather oscillation, particularly ocean coupling and responses to monsoon surges.
- Increase the number and quality of graduate theses, peer-reviewed publication outputs and conference presentations within the SW Indian Ocean.
- Enhance the accuracy, reliability and uptake of long-range (5-30 day) weather forecasts.
- Provide guidance on how to mitigate part of the economic losses resulting from tropical cyclone events.

Annual reports to sponsors will be provided. With a 'track record' of training operational weather forecasters to a sophisticated level, the project builds on current momentum. The Indian Ocean and associated seas are regions of high naval interest, characterized as environmental "data sparse" areas per NAVOCEANO and CNMOC databases. The lack of good observation data in the Indian Ocean, both in situ, and satellite for data assimilation over this region, will be mitigated by the onset of observational enhancements to tropical cyclone forecasting in the South West Indian ocean. This project is consistent with USN objectives. The proposal's budget is projected to be $60,000.00 U.S. dollars per year. The Naval International Cooperative Opportunities in Science & Technology Program (NICOP) is a grant funding mechanism by which ONRIFO supports USN objectives through international S&T collaborations. Collaborations are sought which match complementary strengths between US & International S&T providers for the mutual benefit of all participants. Interested U.S. Sponsors, or principle investigators should contact the author to coordinate the submission of a NICOP proposal. This S&T collaboration initiative will facilitate future naval operations in the Indian Ocean, Arabian Gulf, and Red Sea by potentially providing real-time environmental data for assimilation into Navy Models and prediction systems.

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