Ocean and Climate Change Institute
2012 Funded Project

Project Title: Indo-Pacific connectivity on decadal timescales: Remote Pacific impacts on eastern Indian Ocean variability

PIs: Caroline Ummenhofer

What were the primary questions you were trying to address with this research? (Or, if more appropriate, was there a hypothesis or theory that you were trying to prove or disprove?)
How can we combine information from high-resolution numerical ocean models and paleo proxy reconstructions from coral records to understand long-term variability in the Indo-Pacific climate system? Does the Pacific Ocean affect variability in Indian Ocean temperatures on decadal timescales? Does the connection between the Pacific and Indian Ocean vary over time?

What have you discovered or learned that you didn't know before you started this work?
It has been well-described that the Indian Ocean has sustained robust surface warming in recent decades, with warming rates exceeding those of other tropical ocean basins. However, assessment of Indian Ocean heat content since the 1950s suggests extensive (subsurface) cooling for much of the tropical Indian Ocean. Ocean model experiments reveal that subsurface cooling trends in Indian Ocean heat content since the mid-1960s to the late 1990s are largely driven by remote Pacific winds associated with the Pacific Decadal Oscillation.

What is the significance of your findings for others working in this field of inquiry and for the broader scientific community?
Significant trends in Indian Ocean sea surface temperatures and heat content – both in observations and projections for the 21st Century – have the potential to impact regional climate, through changes in the monsoon circulation and hydroclimate across the wider Indo-Pacific region. However, it remains unclear what role decadal to multi-decadal variability in upper-ocean Indian Ocean thermal characteristics play in these trends. Our results have implications for seasonal monsoon forecasts and are of interest for decadal predictions and paleoclimate studies.

What is the significance of this research for society?
The Indian Ocean has been described as "one of the last great frontiers of oceanographic research" and appears to be particularly sensitive to climate change. However, our understanding of long-term changes in its properties is very limited. This is despite the Indian Ocean's large influence on regional rainfall and drought in surrounding countries, where largely agrarian societies are highly dependent on sufficient rainfall. Our research helps to develop a dynamic understanding how Indian Ocean properties have changed over time, with implications for regional climate, water resources, and, ultimately, society through impacts on agriculture and health.

What were the most unusual or unexpected results and opportunities in this investigation?
Multi-decadal (Pacific) winds seem to have masked increases in Indian Ocean heat content due to thermal forcing since the 1960s. However, wind and thermal forcing both contribute positively to Indian Ocean heat content since 1999. Thus, drastic increases in Indian Ocean heat content in coming decades are likely, with implications for regional climate and vulnerable societies in Indian Ocean rim-countries.

What were the greatest challenges and difficulties?
Sparse observational records hamper the detection (and attribution) of changes in Indian Ocean characteristics. In contrast, paleo proxy reconstructions, for example from corals, offer crucial

insights into Indian Ocean long-term variations, but they lack spatial coverage. Interpretation of coral proxy records is challenging in light of mixed temperature and salinity signals being recorded by corals in different locations. Ongoing work and comparison with high-resolution model output will help towards a more dynamically based interpretation of the signals recorded by corals.

When and where was this investigation conducted? (For instance, did you conduct new field research, or was this a new analysis of existing data?)
Research was conducted in collaboration with colleagues at the GEOMAR Helmholtz Centre for Ocean Research in Kiel, Germany. The Theory and Modeling Group at GEOMAR has extensive expertise in running and interpreting high-resolution ocean model simulations. As part of this project, PI Ummenhofer spent several weeks at GEOMAR to obtain and collate relevant high-resolution model output to bring back to WHOI for further analysis.

What were the key tools or instruments you used to conduct this research?
State-of-the-art numerical high-resolution ocean model simulations were key tools for this research. Only very few, isolated extended, high-quality observational records exist for the Indian Ocean. To understand long-term changes in the Indian Ocean region, it was necessary to use computer simulations, so-called ocean hindcasts, which provide a comprehensive set of oceanographic variables with very fine horizontal resolution over the last 60 years.

Is this research part of a larger project or program?
Evolving from this OCCI-funded research, PI Ummenhofer was awarded a prestigious Fellowship from the German Alexander von Humboldt Foundation that sponsors foreign scientists to conduct cutting-edge research at host institutions in Germany. Over the next three years, PI Ummenhofer will spend three months each year at GEOMAR in Germany. There she will obtain state-of-the-art ocean model output and participate in tailored sensitivity experiments to better understand long-term changes in Indian Ocean properties and how they are influenced by the Pacific. Model output will be available for follow-up analysis at WHOI by PI Ummenhofer, postdocs, and students becoming involved in the project.

What are your next steps?
The remote forcing mechanisms driving multi-decadal variability in sub-surface Indian Ocean heat content will be further evaluated with a series of ocean model sensitivity experiments. The implications of decadal variations in sub-surface heat content will be investigated for long-term sea surface temperature changes in the Indian Ocean. The results will help towards an improved understanding of decadal predictions for the Indian Ocean region.

Have you published findings or web pages related to this research? Please provide a citation, reprint, and web link (when available).

Ummenhofer CC, Biastoch A, Böning C (2015) Indian Ocean heat content changes masked by multi-decadal variability: Is the Indian Ocean warming or not? Geophysical Research Abstracts, 17, EGU General Assembly, April 12-16, 2015, Vienna, Austria

Ummenhofer CC (2014) The Indian Ocean – Oceanographer's "Stepchild", Oral presentation at Alexander von Humboldt Foundation Network Meeting, November 26-28, 2014, Würzburg, Germany

Please provide photographs, illustrations, tables/charts, and web links that can help illustrate your research.
http://web.whoi.edu/ummenhofer/indian-ocean-variability-regional-impacts/
http://www.whoi.edu/fileserver.do?id=196184&pt=10&p=91553
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