Kimberley Marine Research Program

WAMSI Project 2.2.7

Knowledge integration and predicting biophysical response to climate change

The impact of climate change on the Kimberley marine environment is still not well understood because not enough is known about continental shelf processes and ocean boundary currents. In this project, CSIRO researchers use historical data and numerical modelling to investigate how sensitive the coastal marine waters off the Kimberley are to changes in ocean temperature, sea level, and shelf circulations that may be caused by human activity and natural climate drivers in the Indo-Pacific Ocean.

Background

The Kimberley region lies in tropical northwestern Australia and is directly influenced by the Australian monsoon and El Niño-Southern Oscillation (ENSO) - an irregularly periodical variation in winds and sea surface temperatures over the tropical Pacific Ocean.

Sea surface temperatures off the Kimberley coast appear to be warmer during El Niño, compared to the rest of the west coast of Australia.

The continental shelf off the Kimberley coast is between 200-500 kilometres wide and located at the pathway of the Pacific to Indian Ocean connection, at an intersection of ocean circulation of regional and global relevance, so that shelf currents may also be influenced by monsoon and ENSO variability.

Over the past six decades, ocean temperatures off the Kimberley coast have been rising at a moderate rate of about 0.05 to 0.1°C per decade, lower in comparison to waters off the southwest coast of Australia.

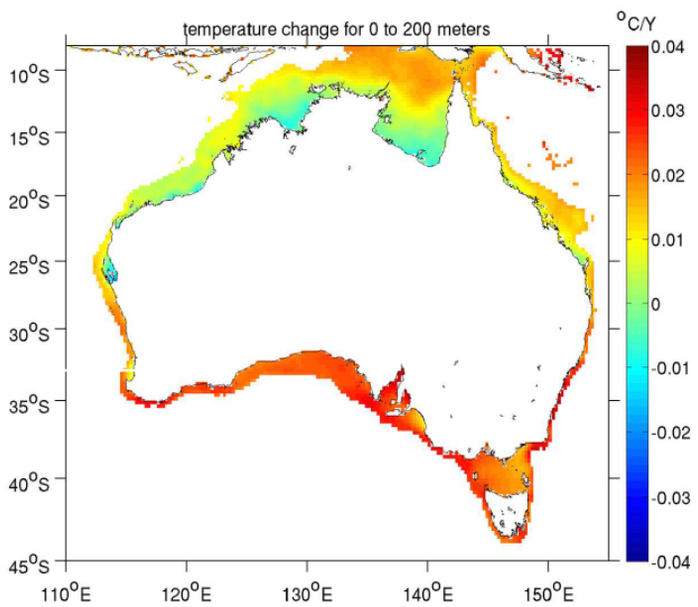

Figure 1. Linear trends of sea surface temperature of shelf regions (<200 m depth) around Australia from 1981 to 2014.

Over the past 30 years, satellite observations have also revealed that the Kimberley coast appears to experience more frequent extreme hot temperatures during summer.

It is believed that ocean temperatures and marine species off the Kimberley coast are highly sensitive to future climate change. There is however, a lack of knowledge on interannual and longer term variability in the region.

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Poor historical data coverage, rough topography and strong tidal currents have prevented us from gaining a better understanding of the seasonal dynamics and thermodynamics in the region.

The Kimberley coastal region is a semi-diurnal macrotidal (tidal range >4 m) environment experiencing two high and two low tides of approximately equal size every day with local areas that are mesotidal (2–4 m tidal range). Tidal mixing is likely to play a key role in regional heat balance and biochemical processes.

Ocean models for the region are either coarse resolution that do not include tides, or fine resolution but developed for process studies. So far, there is no dedicated modelling study to resolve both shelf circulation and tides, nested within large-scale forcing, that can be used to understand the interannual variability and long-term changes of the marine environment in the region.

Research Objectives

Understanding the temperature variations and changes off the Kimberley coast, over different time scales, is crucial to the future management of the Kimberley marine environment. To help address this, a team of researchers led by CSIRO have instigated a study with three key research objectives:

- conduct a detailed analysis and review of influences of the past climate variability and change on ocean temperature, salinity, sea levels, and shelf current off the Kimberley coast;
- generate a model/predictions of projected future changes in the physical environment off the Kimberley coast using a downscaled numerical model; and
- deliver an improved understanding of climate change impacts on key biophysical indicators such as coastal water mixing and dispersal off the Kimberley coast.

To help deliver these objectives, the project team are making use of historical and satellite observation datasets and ocean model experiments for diagnostic studies of regional climate sensitivity, including the response of shelf temperature, salinity, current, and mixing characteristics to climate variability and change of the Indo-Pacific Ocean.

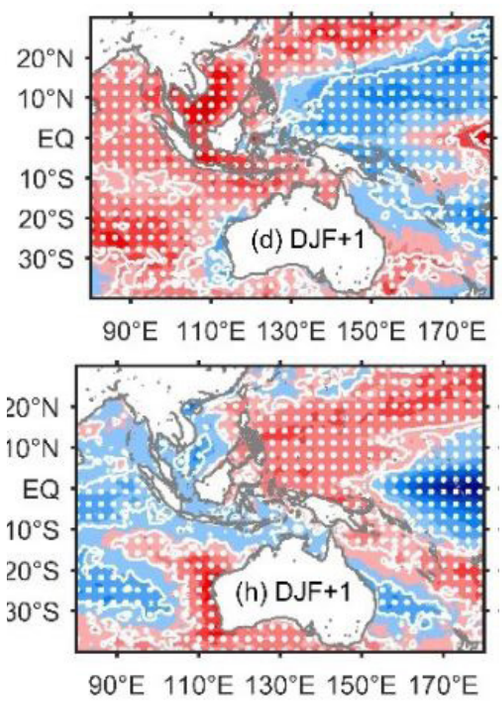

Figure 2. Sea surface temperature anomaly composites in austral summer during (top panel) El Niño and (lower panel) La Niña events.

The Approach

Global Climate Models are an effective tool for projecting our environment's response to rising greenhouse gases in the atmosphere.

Due to the complexity of climate physics (i.e. a range of scales from individual clouds to global patterns and strong interactions across the scales), the models are formulated at relatively low spatial resolution (typically 100 km) and smallscale processes (that are present in coastal waters) are poorly determined and characterised. So while they are suitable for global applications, such as projections of global averaged temperature, they do not provide sufficient spatial resolution to make useful regional climate change projections.

The challenge for this research has been to provide climate change projections with more realistic resolution and ocean dynamics in the regional marine environment.

A modelling approach is being used by CSIRO to downscale future changes of the physical environment such as ocean temperature and ocean circulation for the Australian region using Bluelink OFAM-3 model at 10 km resolution.

To generate projected future changes, a Regional Ocean Modeling System (ROMS) (at ~2 km resolution) has been nested within OFAM-3.

The main focus of the nested modelling is to assess how changed wind regimes and other air-sea forces are likely to impact shelf circulation off the Kimberley coast in the future.

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For our regional downscaling, the 2009 to 2012 time period has been used for the model simulation under the current climate to capture some extreme climate events as well as have the IMOS mooring data (to validate the model performance).

For the future climate simulation, a four year period during 2060's was used to carry out the same downscaling model.

Particle tracking models can be embedded in the hydrodynamic model to study coastal water retention and dispersal off the Kimberley coast under current and future climate change scenarios in an attempt to understand how water salinity, temperature and wind changes would affect the dispersal of marine animal and plant life in other WAMSI projects.

What we've found

Ocean temperatures

Off the Kimberley coast, sea surface temperatures are higher during summer and cooler during winter, with the seasonal ranges between 4 to 5°C in monthly climatology, which is less than the Pilbara coast.

Unlike ocean temperatures off the west coast, sea surface temperatures off the Kimberley coast are warmer during El Niño events, not La Niña events (Figure 2), despite coastal sea levels tending to be higher during La Niña. This may indicate that ocean temperatures on the shelf are predominantly influenced by the air-sea exchanges, instead of coastal currents.

Coastal salinity

Simulations from the OFAM model, during the extended La Niña conditions (after the 2010-11 event), indicated that the Indonesian Throughflow waters and the coastal waters off the Kimberley coast became very fresh (Figure 3).

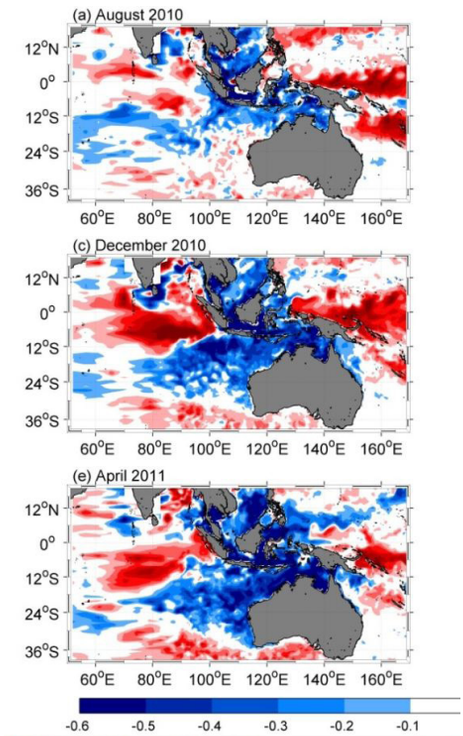

Figure 3. Sea surface salinity anomalies (psu) derived from Bluelink BRAN 3p5 model output during the 2010-2011 La Niña event.

The freshening of the Kimberley coastal waters was mostly due to the unusual rainfall rates in the region, particularly in the Indonesian seas and off the north coast of Australia.

The freshening change is carried southward by the Leeuwin Current. There appeared to be a decadal freshening trend in the region, influenced by the large-scale Pacific climate. The strong interannual variations of ocean salinity may have implication for marine biota.

Marine heatwaves

There has been an increase in frequency of marine heatwaves off the Kimberley coast in austral summer in the past 30 years, and most of the marine heatwaves at Scott Reef and at the Kimberley coast tend to occur during El Niño events (Figure 4), due to weaker Australian monsoons and reduced air-sea heat losses to the atmosphere, as well as reduced cloud coverage.

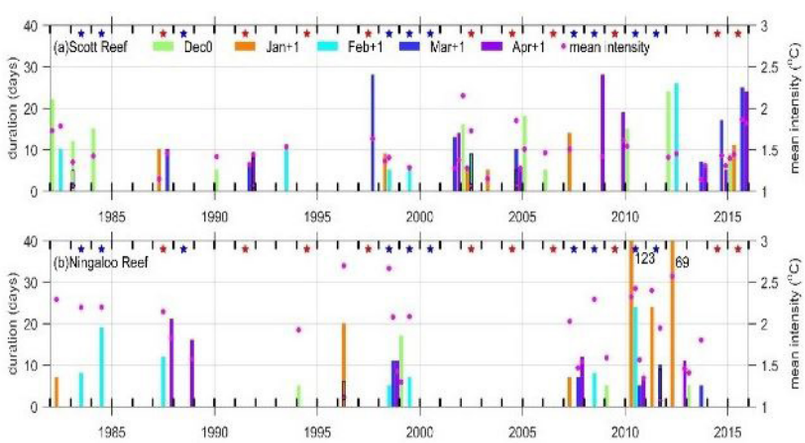

Figure 4. Marine heatwave duration and intensity for the events identified at Scott Reef and Ningaloo Reef over the past 30 years.

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Future climate projections

OFAM downscaling model output shows enhanced warming in the northern Kimberley coastal marine region in the future climate projections. This warming is most likely to be influenced by the fast warming trend of the land mass.

The warming rates near the coast during winter months tended to be higher.

Although the coastal model simulation results are still being assessed, the initial results suggest that the simulated warming trends of the Kimberley coast are consistent with the OFAM downscaling model.

Expected project outcomes

Although the project is not due to conclude until September 2017 it is expected it will deliver an improved understanding of the climate sensitivity of the Kimberley coast physical environment, including ocean temperature, salinity, and shelf current, based on historical observation, numerical modelling, and a comprehensive literature review.

The project will also improve our knowledge on climate change impacts on the Kimberley coast, including future temperature and sea level rises, changes in shelf current, which has implications on mixing characteristics of water masses along the coast.

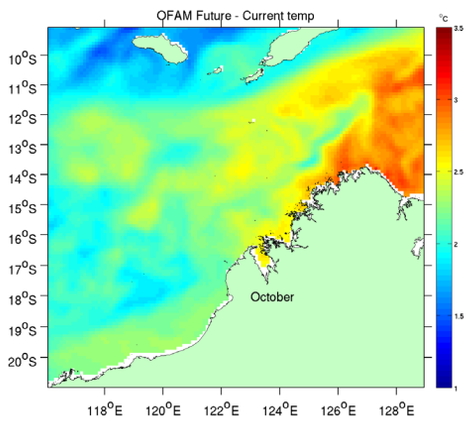

Figure 5. Projected future changes in sea surface temperatures from OFAM simulations in the 2060s

Who will use this information?

The project outputs are being incorporated into the ecosystem modelling and management strategy evaluation project (Kimberley Marine Research Program project 2.2.8) to evaluate the biological impacts of climate change in the Kimberley region.

The model outputs will also be used by researchers from state and commonwealth government agencies and universities to better understand the impact of climate change off the Kimberley coast.

It's expected that the baseline knowledge of climate sensitivity off the Kimberley coast generated as part of this research will be of relevance to the Kimberley Science and Conservation Strategy, and the proposed Great Kimberley Marine Park network.

It is intended that the projections of future changes in the biophysical environment off the Kimberley coast will help guide decision-making, planning and monitoring in the region.

Type of data collected

Data produced in this project will be the 2-km resolution shelf model simulation outputs.

Data available in:

The metadata associated with this project can be viewed via the AODN metadata catalogue. Data will be available via the CSIRO Data Access Portal after the embargo period for the project.

Project Team

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