Coastal diurnal warming – a study of the Great Barrier Reef

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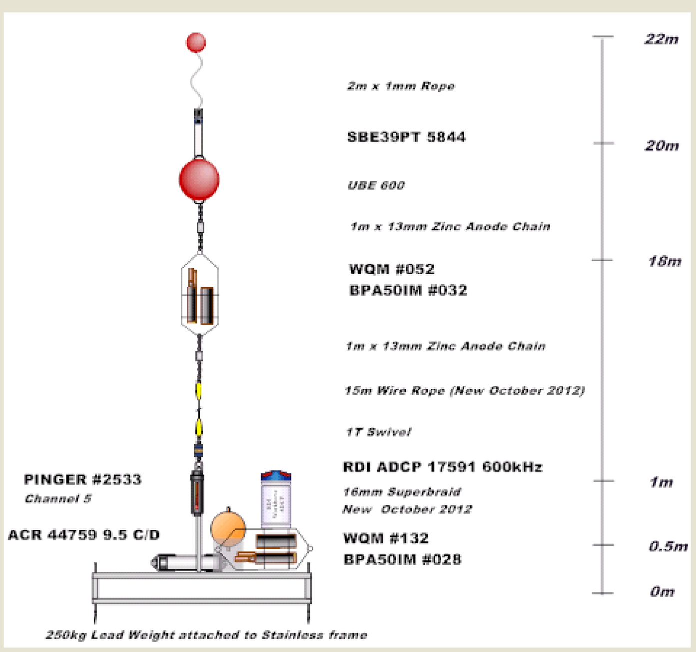
Abstract

The Australian Great Barrier Reef (GBR) is the world's largest coral reef system; it supports growth, reproduction and shelter for fish and invertebrates and is a major component in the local economy. But, it is vulnerable to the effects of climate change. Coral bleaching is predicted to become more frequent and more severe in coming decades. Understanding coastal diurnal warming could help improve assessing short-term thermal stress on the corals, and coral reef bleaching prediction. We developed a traditional deterministic hydrodynamic model and a stochastic and uncertainty quantification model to investigate effects of the variations in the shallow bottom topography on tidal flows. The model provides the relationships between diurnal heating and tidal flows in GBR shallow waters region. We use the temperature time series and acoustic Doppler current profiler data provided by the Australian Institute of Marine Science (AIMS) to validate the model predictions. The in-situ data can also characterize the interactions between tidal flows with complex bathymetry and diurnal heating. Our study will contribute to our understanding of the coral reef bleaching. The objective is to be able to use satellite-derived SSTs (Zhu et al., 2014; Ditri et al, 2018) to asses better the thermal stress imposed on corals.

1. Data

In-situ datasets:

- Current speed: Understanding how water currents move across the GBR is essential. Vertical and horizontal ADCP-based current and wave transport monitoring data in different stations were provided by the Australian Institute of Marine Science (AIMS).
- Temperature data: Sea-Bird SBE39 temperature sensors data was also provided by AIMS through Australian Ocean Data Network (AODN) portal.
- Wind speed and air temperature: Provided by Facility for Automated Intelligent Monitoring of Marine Systems (FAIMMS) of the Australian 'Integrated Marine Observing System' (IMOS) project.
- Surface Radiation: From NASA Modern-Era Retrospective analysis for Research and Applications Version 2 (MERRA-2)



The left panel shows the ADCP-based current and wave monitoring system and the attached SBE39 temperature sensor. The right panel shows the AIMS FAIMMS station.

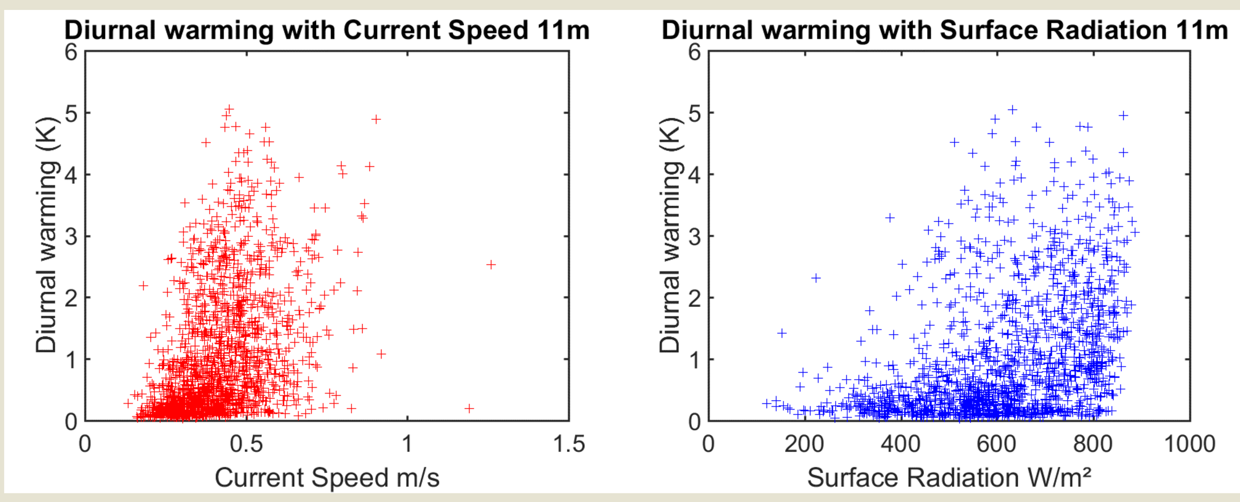
GBRTides Model input:

- Multi-scale Ultra-high Resolution (MUR) Sea Surface Temperature data: Spatial resolution:1km, Area: Global, Temporal resolution: Daily.
- Tidal input: Oregon State University Tidal Inversion Software#(OTPS), it includes accurate maps of tidal currents or elevations. The tides are provided as complex amplitudes of earth-relative sea-surface elevation for five primary (M2, S2, N2, K1, O1 see Table below), harmonic constituents, on a 1440x721, 1/4 degree resolution full global grid.
- Bathymetry: Provided by NOAA National Centers for Environmental Information (NCEI) ETOPO1 model, a 2 arc-minute global model of Earth's surface that integrates land topography and ocean bathymetry.

Notation	Frequency	Period (hours^{-1})	Amplitude (m)
M2	2w=28.9841	12.4206	0.9081
S2	2w=30.0000	12.0000	0.4229
N2	2w=28.4397	12.6583	0.1739
K1	2w=15.0410	23.9345	0.1682
O1	2w=13.9430	25.8193	0.3769

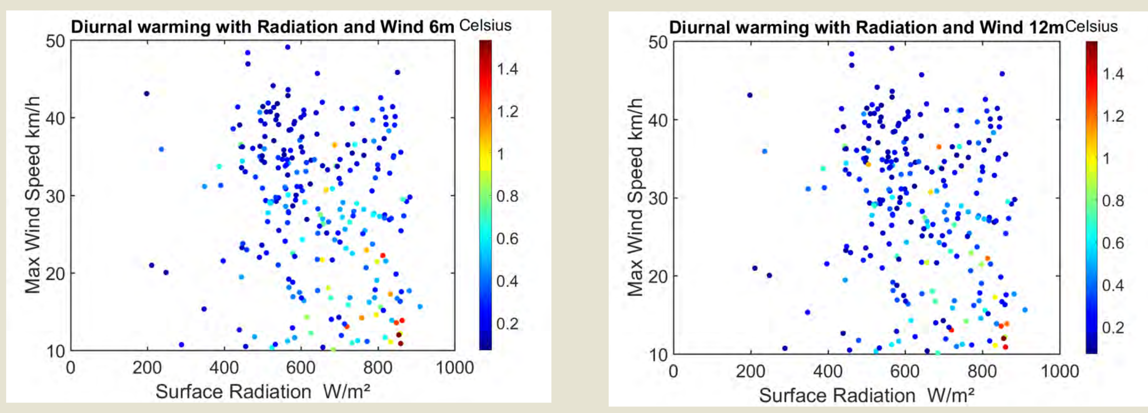
Tidal Information, M2 N2 S2 as Semi-diurnal tides and K1 O1 as diurnal tides.

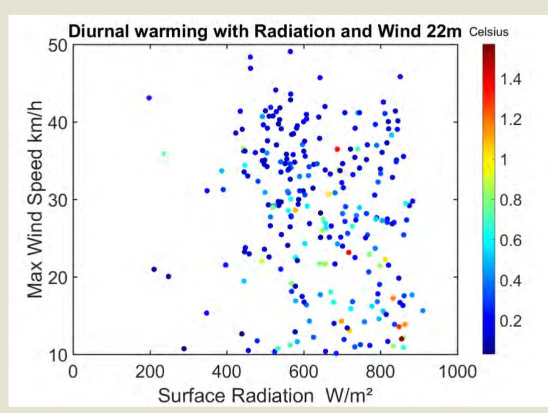
2. GBR Diurnal Warming with Wind/Solar



Data from the GBRPPS station (18.18° S 147.09° E), period: Oct 24 2012 to Mar 27 2017. The ADCP depth is 68 m and the SBE39 temperature is at 11 m depth. Left figure shows the relationship between the diurnal warming, defined as the temperature range in 24-hour periods, and the maximum current in the same intervals. Right figure shows the relationship between the diurnal warming and surface radiation.

3. GBR Diurnal Warming with Depth



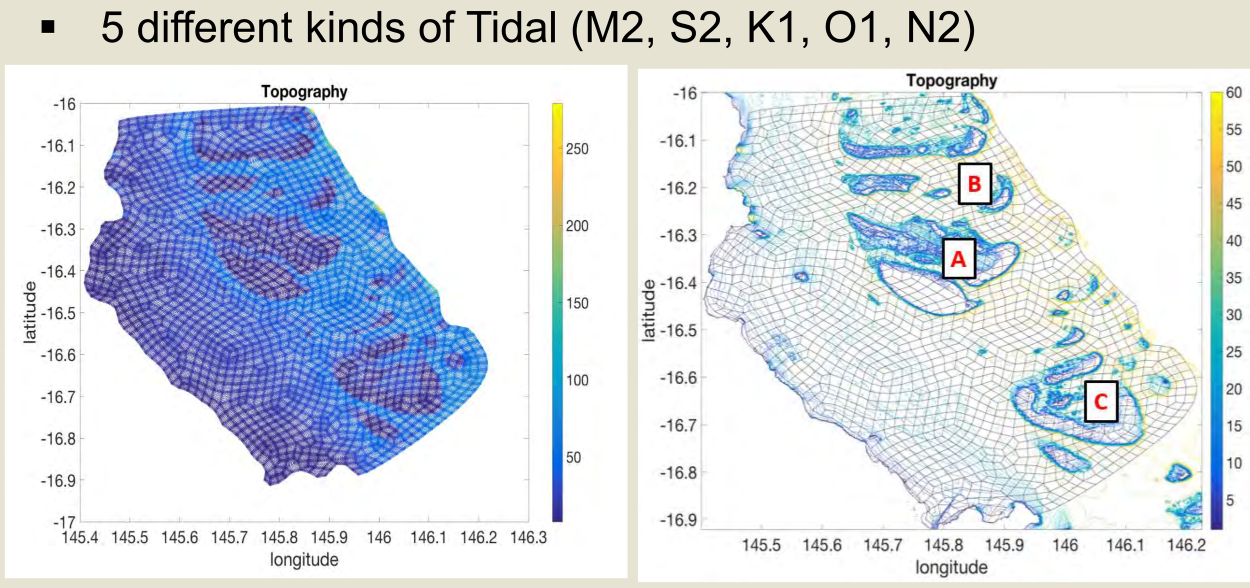


Data from the GBRLSH station(14.42°S 145.38°E), period: May 8 2013 to May 21 2014. The ADCP depth is 31m and the SBE39 temperatures are at 6m 12m 22m depths.

At 6m depth the relationship between the maximum current and the amplitude of the diurnal temperature signals is more pronounced than at 22m. Indicating that the signal is not just heating from above. To resolve the relative importance of diurnal heating and advection of temperature variability by tidal flow we use hydrodynamic modelling.

4. GBR Tides Model Simulation

- Run for 4 weeks.
- First 2 weeks to spin-up; second 2 weeks data for analysis
- Viscosity = 50 g/(cm·sec) and Diffusion = 25 m^2/sec
- Move interval set as every 600 seconds (10min)
- Bottom drag as 2.5*10^{-3} N
- 5 different kinds of Tidal (M2, S2, K1, O1, N2)

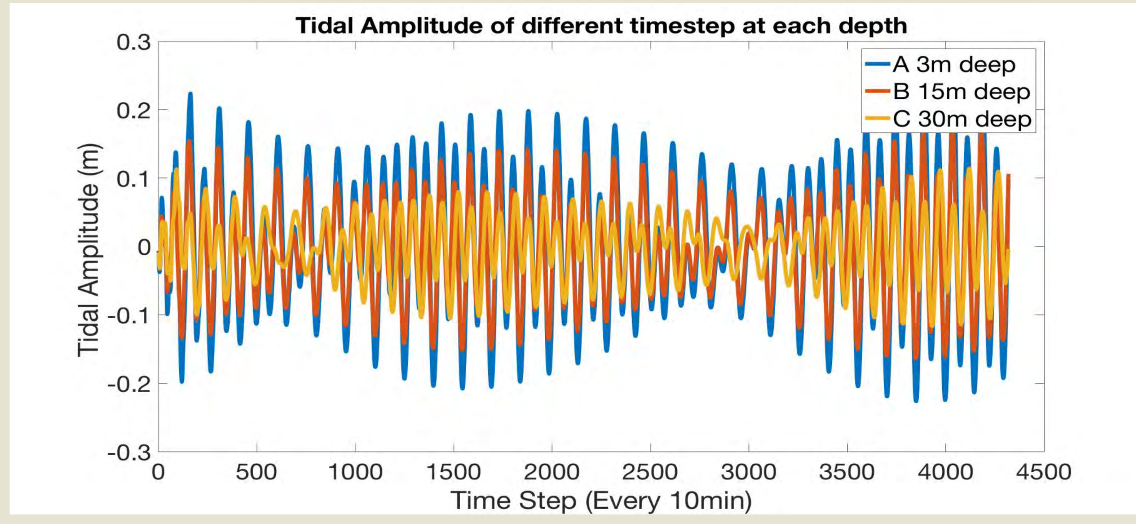


The left panel shows the full spectral element grid including the interior interpolation points. The right panel shows the 1596 elements partition of the domain. Locations of three positions at different depths in the model domain are shown.

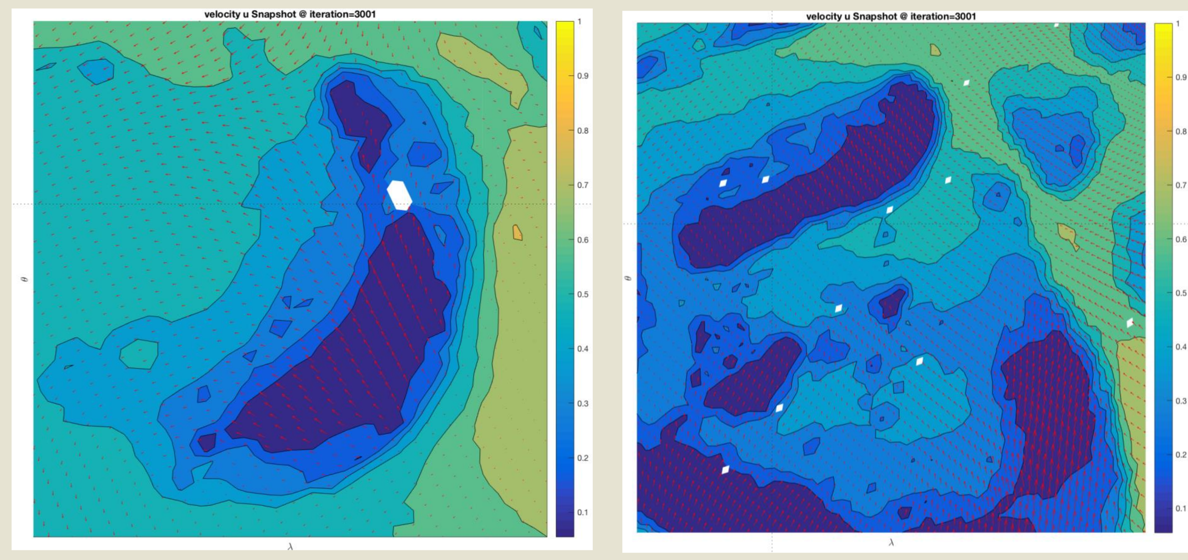
5. Results

Point	Latitude	Longitude	Depth	N
A	-16.3233	145.8439	3.093m	25247
B	-16.6625	145.9107	14.993m	29269
C	-16.7657	146.0277	30.010m	3189

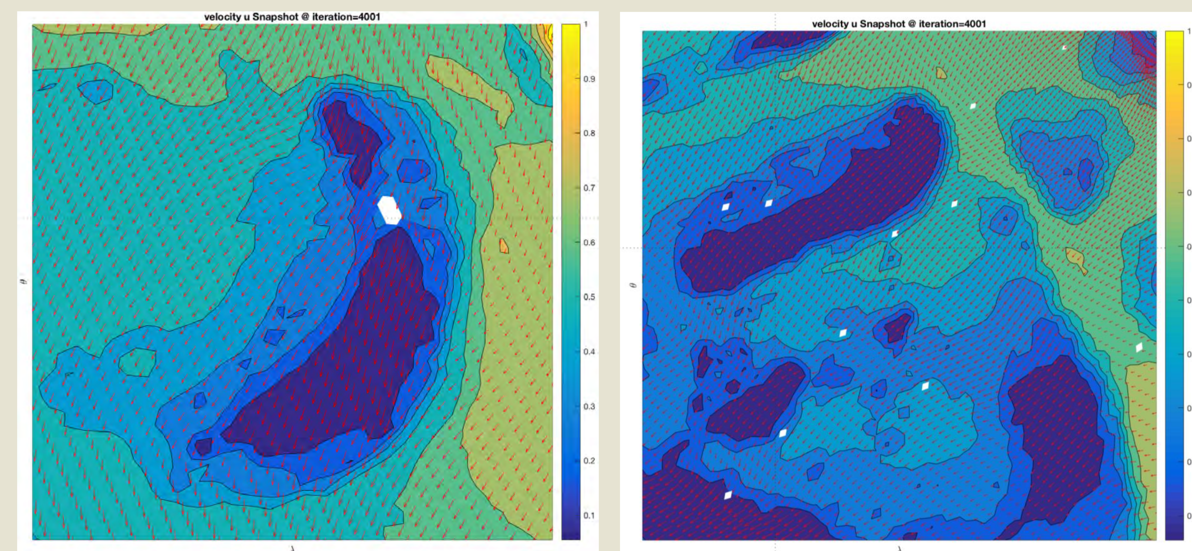
Table: Locations and depths of three selected positions in the model domain as shown in the figures in section 4.



Time series of pressure fluctuations at three locations at model grid point at different depths, indicating larger amplitudes of the tidally induced variations in shallower water.



Arrows show flow velocity time 27.78 days, after the model has spun-up. The right panel shows a close-up of a reef system with northward currents at the top and southwest-ward current. Note that the visualization was performed by interpolating the model output on a regular structured before contouring. The contours are bathymetric depth.



The flow velocity at time 34.85 days. The current flow is driven by tidal forcing. Initial results show that the tidal currents are strongest in shallower water, not supporting the “sticky water” hypothesis of Wolanski & Spagnol. (2000). Additional simulations are needed to resolve and understand the physical causes of the signals.

6. Affiliations & Acknowledgement

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7. References

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