# Quantifying Chemical Changes in the "Heartbeat" of a Coral Reef on Tetiaroa Atoll, French Polynesia

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## Motivation: Why Tetiaroa?

Global projections of ocean acidification suggest that coral reefs will enter a stage of net dissolution by 2100. Tetiaroa Atoll, French Polynesia offers an ideal setting (relatively constrained biogeochemistry, historically-limited anthropogenic influences, and easy access) in which to address the following:

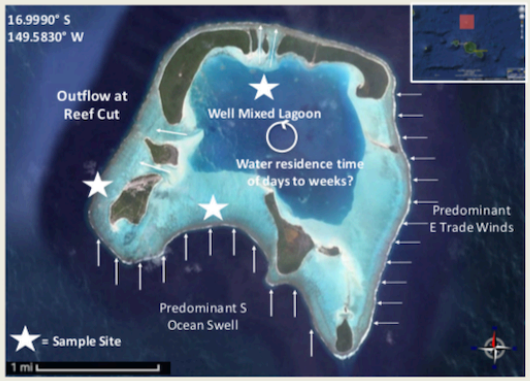
**1). How will whole atoll biogeochemistry respond to OA?**
Approach: Map and measure the dynamic biogeochemical processes governing calcification/dissolution *in situ* in a pristine and mature reef ecosystem.

**2). Can we predict when atoll processes will reach a tipping point?**
Approach: Develop a mechanistic model of the atoll that integrates data across diurnal, seasonal, decadal, and even millennial timescales from which net ecosystem calcification can be obtained.

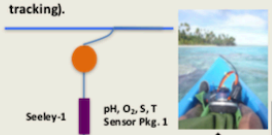
**3). Can we develop chemical tools that monitor shifts in reef biogeochemistry and act as leading indicators of whole atoll changes?**



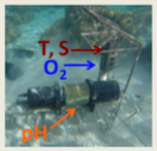
## Methodologies




Lagoon: Mooring of sensors for seasonal monitoring (temperature, salinity, dissolved $O_2$, pH…) + microSWIFTs (current tracking).





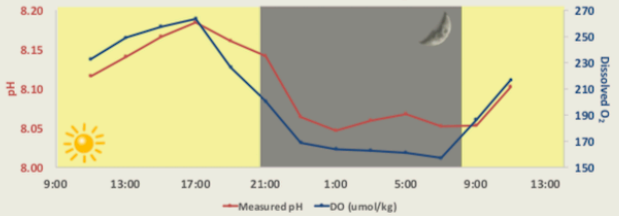




Reef: Sensor measurements (temperature, salinity, dissolved $O_2$, pH…) + diel bottle samples (alkalinity, DIC, nutrients, trace metals).

Additional measurements include: modern sea level, paleo-sea level (coral U/Th), ADCP, water isotope analysis (D/H), and weather station.

## The Daily "Heartbeat" of the Reef

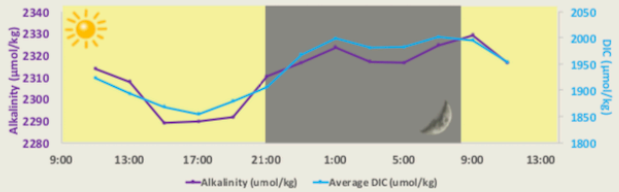
May 2014 – Diurnal pH & $O_2$




*pH measured with SAMI-pH (Sunburst) & $O_2$ measured with CTD (Seabird) and Winkler titrations.

| | pH | $O_2$ |
|---|---|---|
| Photosynthesis/Respiration | ✓ | ✓ |
| Calcification/Dissolution | ✓ | X |
| Gas Exchange | ✓ | ✓ |

May 2014 – Diurnal Alkalinity and DIC

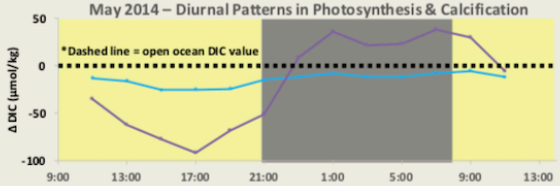



*Alkalinity measured by open-cell titration; DIC measured by coulometer. Precision = ± 2 µmol/kg for both instruments.

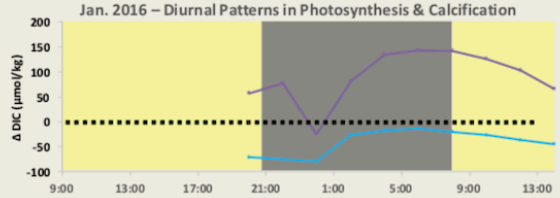
$$Net\ Calcification\ (\frac{\mu mol\ DIC}{kg}) = \frac{\Delta Alkalinity}{2}$$

$$Net\ Photosynthesis\ (\frac{\mu mol\ DIC}{kg}) = \Delta DIC - \frac{\Delta Alkalinity}{2}$$

May 2014 – Diurnal Patterns in Photosynthesis & Calcification




Jan. 2016 – Diurnal Patterns in Photosynthesis & Calcification

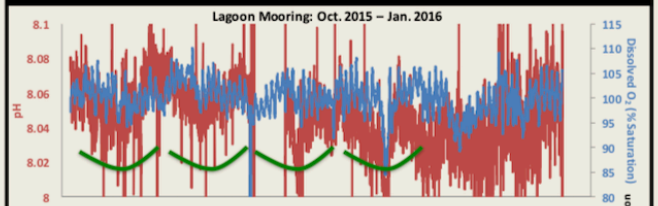




- Net calcification with seasonal rates despite low temperature seasonality.
- Photosynthesis/Respiration dominant control of reef pH?
- Calcification/Dissolution modulates at onset of photosynthesis/respiration?

## Recent Observations: A Record of Entire Atoll Biogeochemistry

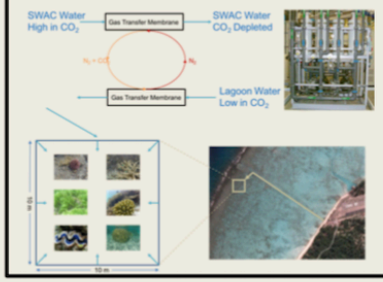
Lagoon Mooring: Oct. 2015 – Jan. 2016




Bottle Alkalinity Measurements from Various Points throughout Lagoon


- Lagoon represents integrated atoll signals of biogeochemistry!
  - Longer residence time → smaller amplitude changes
  - Fortnightly tides reflected in dataset (green brackets).

## Next Steps: How will the reef respond to a high $pCO_2$ world?




Free Ocean Carbon Enrichment (FOCE)!

- Use SWAC infrastructure to redirect 1000 µatm $CO_2$ deep waters to surface.
- Simulate conditions proposed for 2100 A.D.

## Next Steps: Which class of organisms is responsible for calcification/dissolution?

$$D_{Me} = \frac{Me/Ca_{Precip}}{Me/Ca_{Seawater}}$$


$D_{Sr\ (Aragonite)}$ = 1.1 – 1.2 $D_{Sr\ (Calcite)}$ = 0.28 – 0.45

Measure Sr/Ca ratios of reef and lagoon seawater on diel scale – because of partition coefficient ($D_{Sr}$) differences, reef waters may be recording changes in *what* is calcifying/dissolving!

- Reef → Daily/seasonal changes in calc./diss.
- Lagoon → Seasonal/decadal changes in calc./diss.

## Acknowledgements

This ongoing project would not be possible without the generous support of Jim and Marsha Seeley. Special thanks to David Seeley for bringing the opportunity to explore the chemical oceanography of Tetiaroa to our attention. We are also grateful for the logistical support provided by the Tetiaroa Society and the Brando Resort in French Polynesia. Thanks also to Seabird for instrumental support. Additional graduate support supplied by the University of Washington-hosted NSF IGERT Program on Ocean Change and the Achievement Rewards for College Scientists Fellowship.