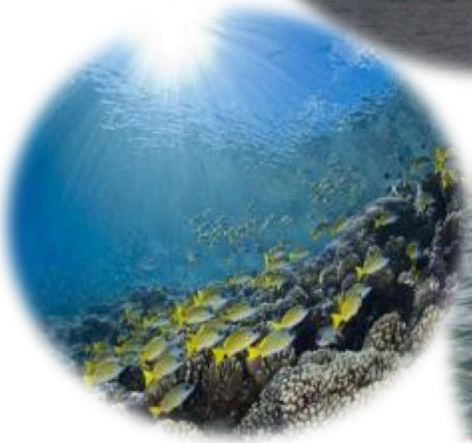
Oceans and Ecosystems Research

Quantifying Climate Change and Ocean Acidification Impacts to US Coral Reefs



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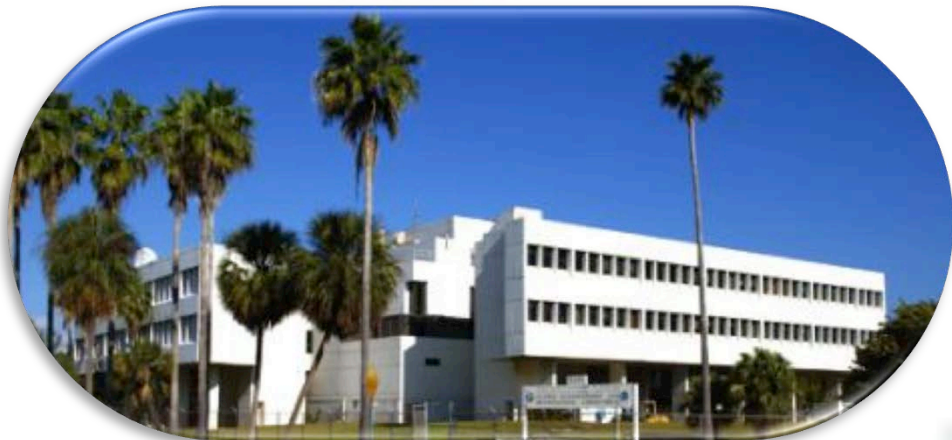
R. van Hooidonk



Project Overview

- **Major Science Questions**
  - ***What is the impact of climate change and ocean acidification on US coral reefs?***
    - What are the spatiotemporal trends in temperature and ocean acidification on US coral reefs?
    - What are the ecosystem impacts of ocean acidification on US coral reefs?
    - How will climate change and ocean acidification alter the physical environment of coral reefs in the future?
- Links to goals of the NOAA strategic plan
  - Improved scientific understanding of the changing climate system and its impacts
  - Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions
- Links to other Authorizing Language
  - **FOARAM Act of 2009** – *To provide for ocean acidification research and monitoring*

Partnerships and Stakeholders

- NOAA and CIs:
- Non-NOAA Govt:
- Academic:
- NGO and Private Industry:

I. What are the spatial and temporal trends in temperature and ocean acidification on US coral reefs?

- NCRMP/OAP's

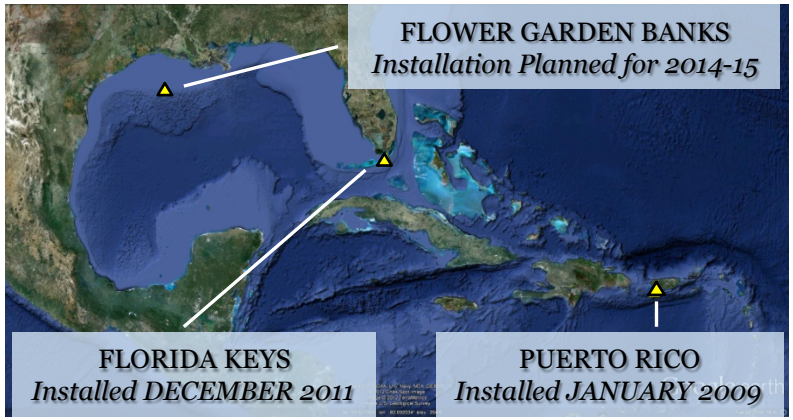
  Class III or 'Sentinel' Climate Monitoring Sites (n = 3)

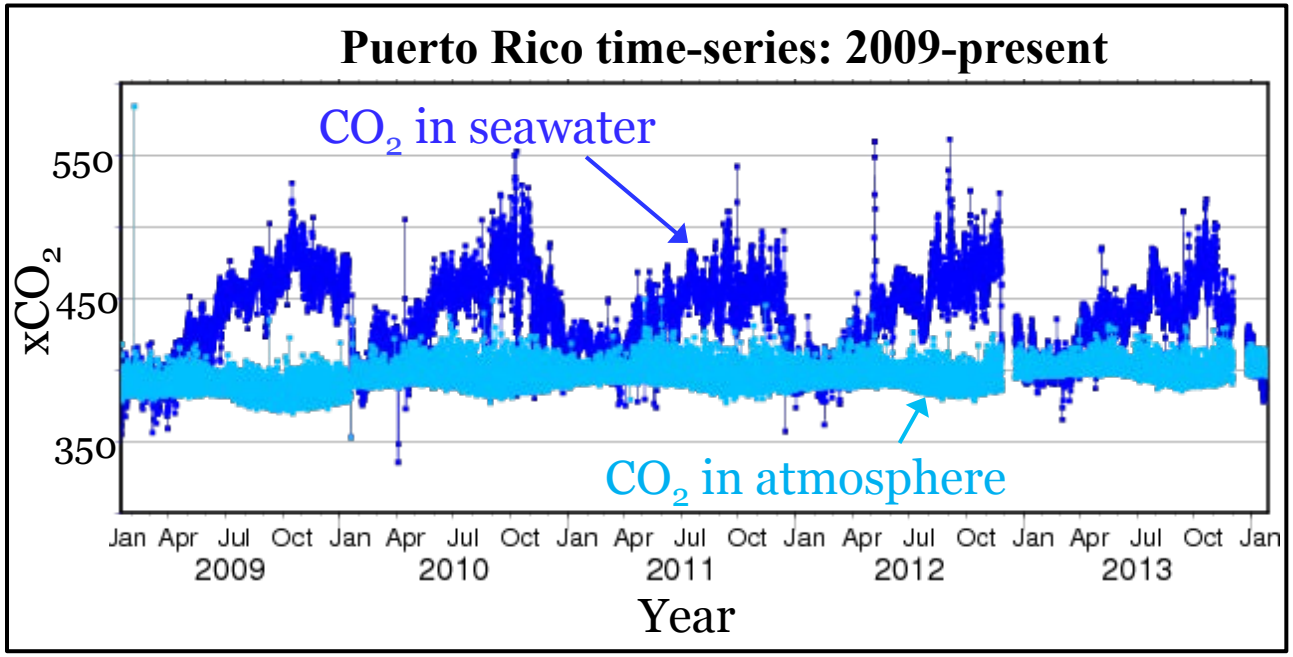
  - CO_2 time-series

    AND

  - Ecosystem response

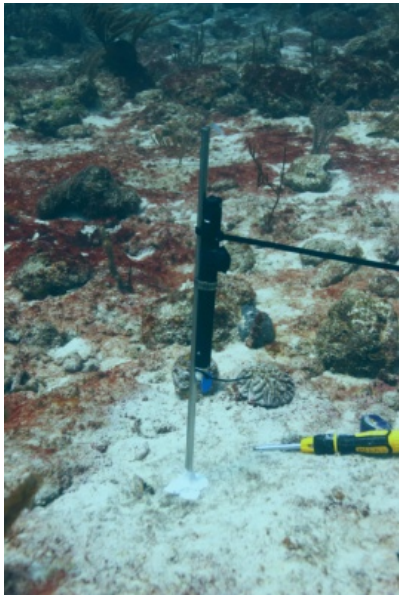
Class III sites in Atlantic



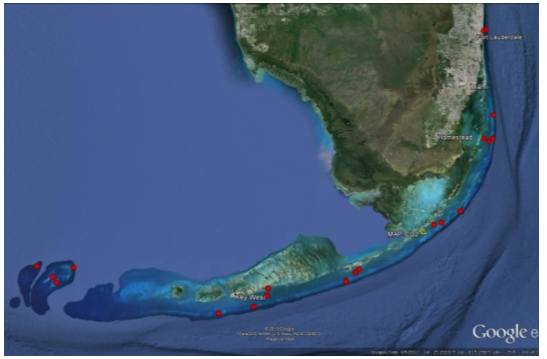


I. What are the spatial and temporal trends in temperature and ocean acidification on US coral reefs?

- **NCRMP/OAP**
- **Class II (n = 3 sites in Atlantic)**
  - 48-hr diurnal sampling of TCO_2 and total alkalinity (TA)
  - Ecological Response (Calcification, Bioerosion etc.)
- **Class I (n = 27 transects, 108 sites in Atlantic)**
  - Each transect is an array of four thermistors across a depth gradient
  - Temperature measurements obtained every 5 minutes
- **Class O (n = 150/year in Atlantic)**
  - Randomized bottle sampling for TCO_2 and TA
  - Highest spatial resolution, least temporal resolution
  - US coral reef sites in Virgin Islands, Puerto Rico, Florida, Flower Garden Banks
  - Each region sampled once every three years



Class I Lang Bank, St Croix



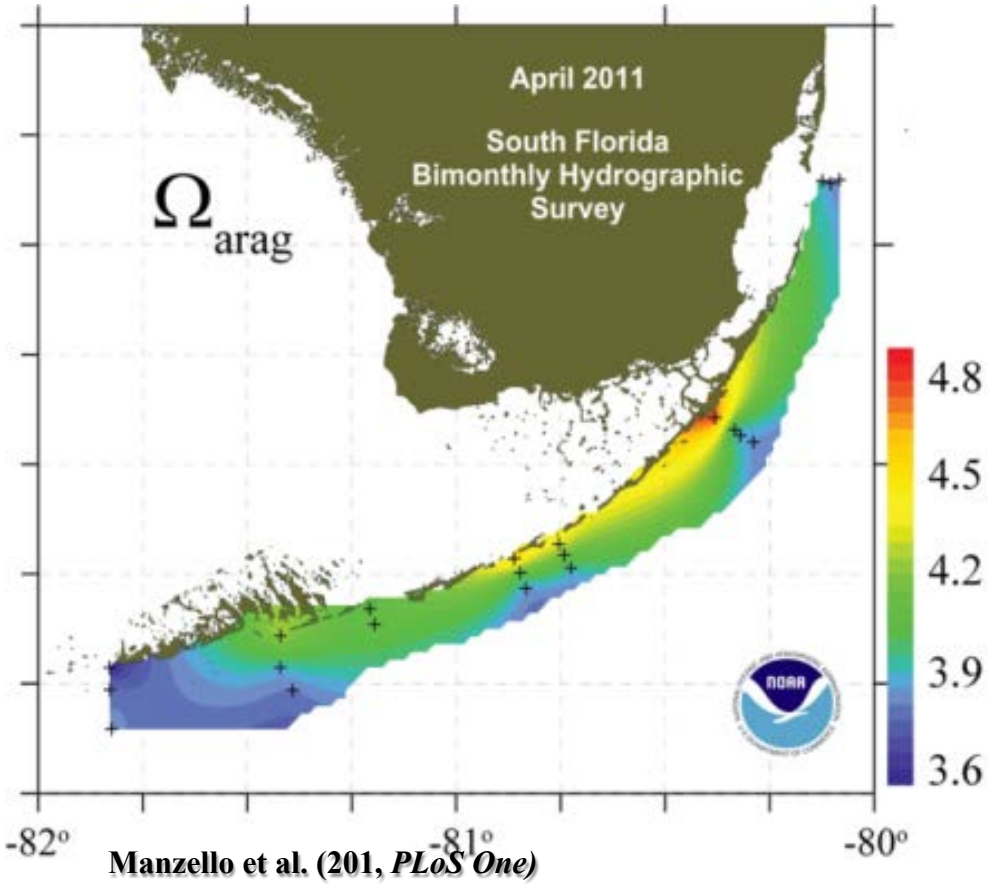
Class I sites on Florida Reef Tract

I. What are the spatial and temporal trends in temperature and ocean acidification on US coral reefs?

Spatial and Temporal Trends of Ω_{arag} on Florida Reef Tract

Key Findings of Study:

- Seagrasses may create OA refugia
- Resilient patch reefs on Florida Reef Tract spatially co-occur with largest CO_2 drawdown
- Low CO_2 and elevated Ω_{arag} at these sites may be contributing to resilience

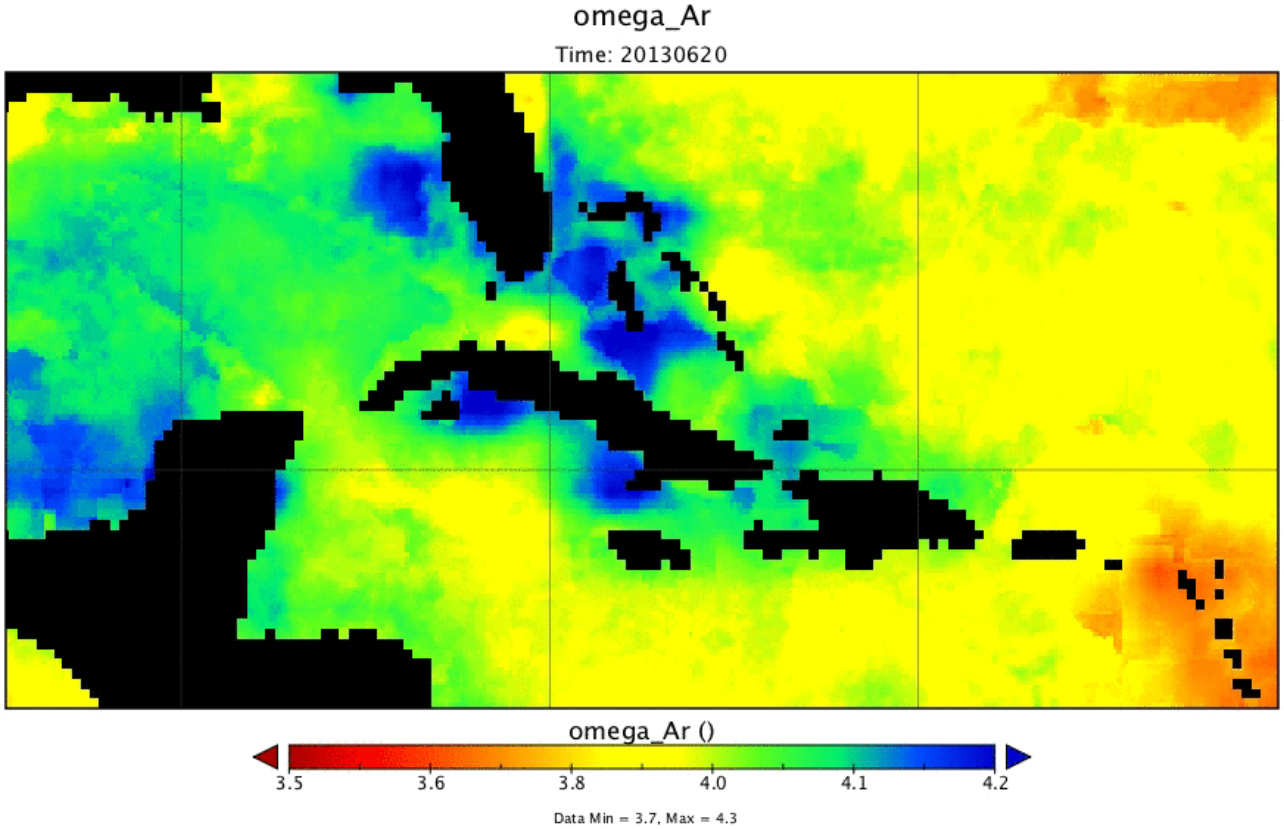


Manzello et al. (201, *PLoS One)*

I. What are the spatial and temporal trends in temperature and ocean acidification on US coral reefs?

Ocean Acidification Product Suite

Near-real-time daily estimate of Ω_{arag}

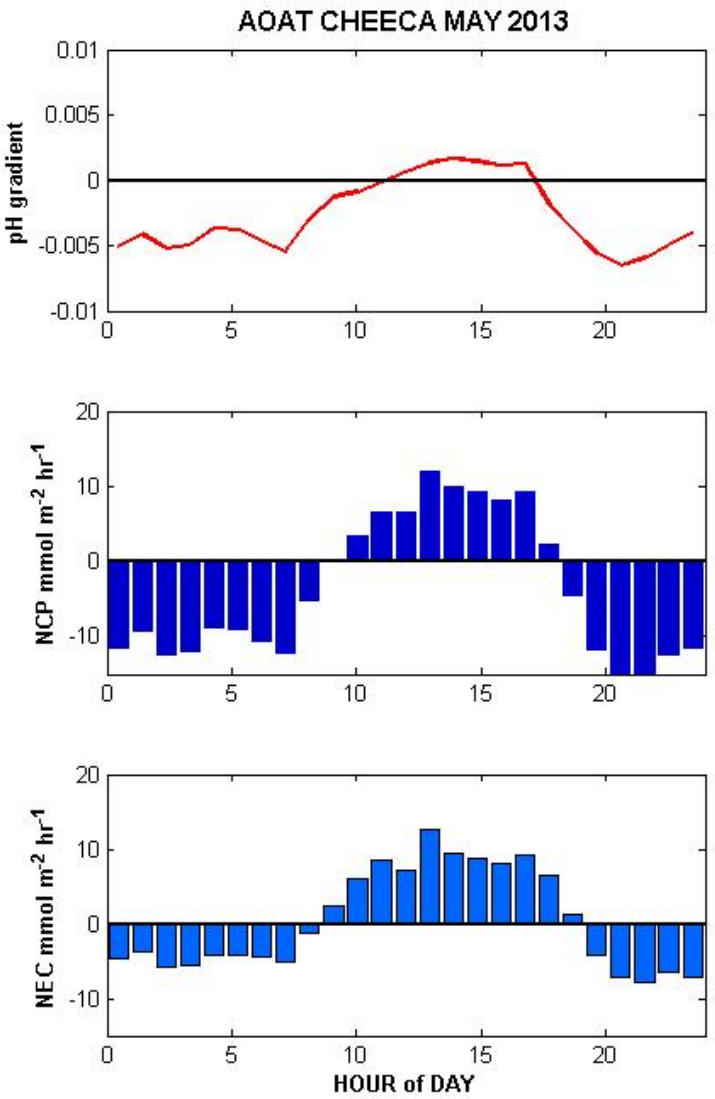


Next Generation Ocean Acidification Product Suite, Created by R. van Hooidonk

II. What are the ecosystem impacts of ocean acidification on US coral reefs?

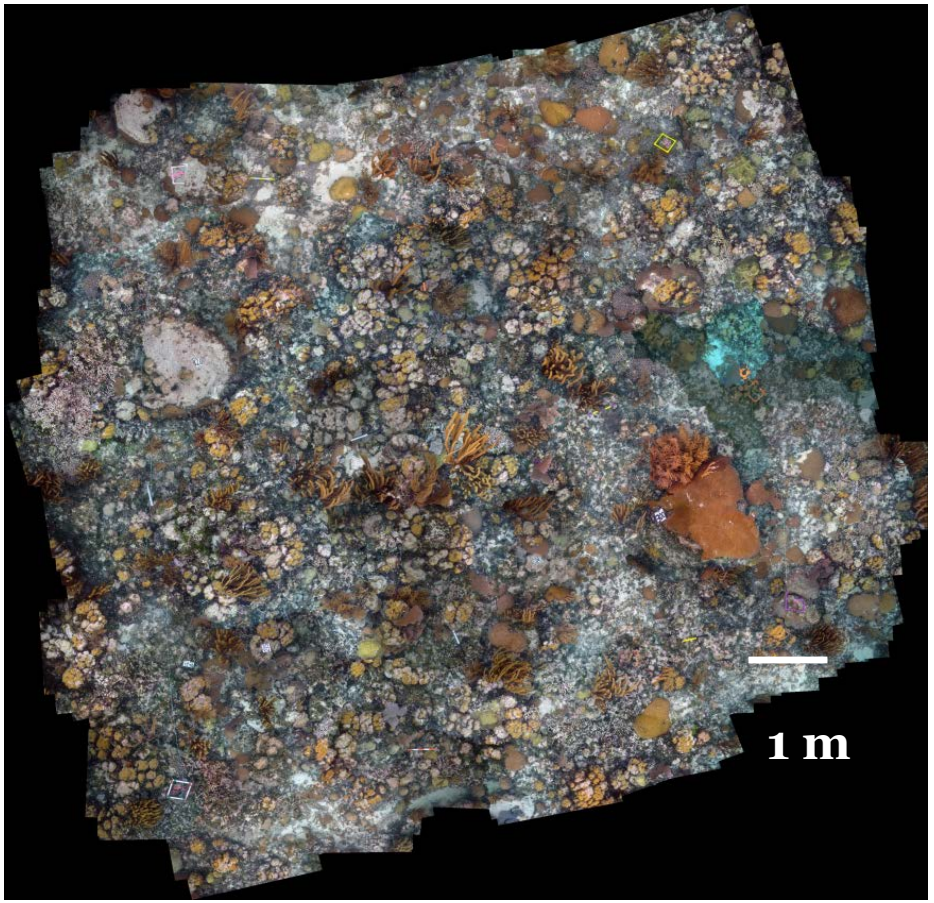
- Net Ecosystem Calcification (NEC) and Net Community Productivity (NCP)
  - Temporal frequency: 3-4 times per year, 1 week duration
  - Rotate annually between class III sites

CROSS (Coral Reef Oxygen Sensing System) at Cheeca Rocks, Florida Reef Tract Class III NCRMP/OAP monitoring site



II. What are the ecosystem impacts of ocean acidification on US coral reefs?

- **High-resolution benthic characterization**
  - Visual archive posted on web
  - Measure any metric of interest (coral cover, H', etc)
  - Rotate annually between class III sites



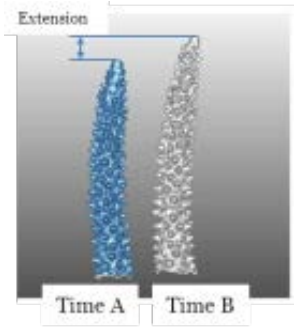
Landscape Mosaic
Cheeca Rocks Class III, FL Keys

II. What are the ecosystem impacts of ocean acidification on US coral reefs?

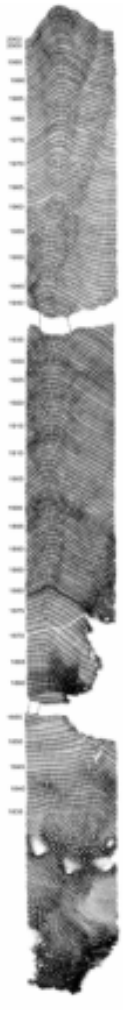
- **Techniques to measure species-specific coral growth and calcification**

Alizarin Stain

Buoyant weighing



3-D scanner

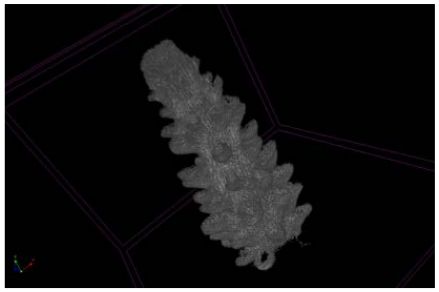


Large coral cores

Up to 100+ yrs of growth

Image courtesy K. Helmle

Small cores
~10 yr record



Micro-CT

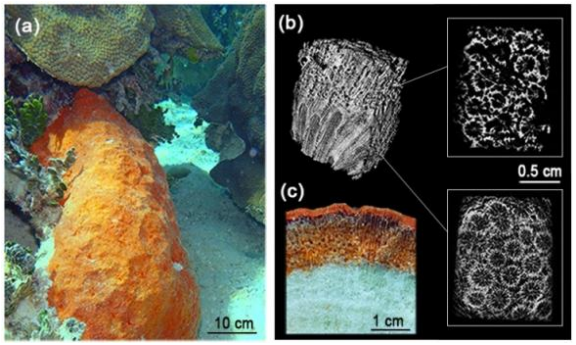
<u>Monitoring coral calcification</u>

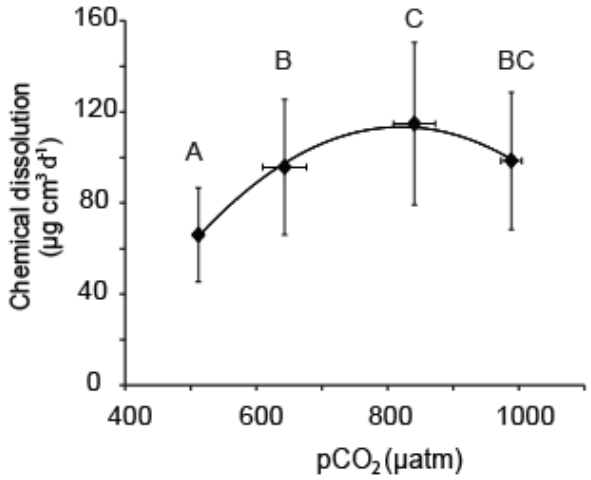
- Initial collection of Large coral cores at class III sites to establish baseline
- Small cores every 5-10 yrs to monitor calcification
- Buoyant weight/3D scanning when collection restricted (i.e., ESA-listed species)

II. What are the ecosystem impacts of ocean acidification on US coral reefs?

Bioerosion

- Both field and lab studies show increase in bioerosion with acidification
- Field studies in naturally high-CO_2 environments
  - Upwelling
  - Volcanic CO_2 seeps
- Laboratory experiments
  - Biologically-mediated chemical dissolution increases with high-CO_2
    - Endolithic Algae
    - Clionaid sponges



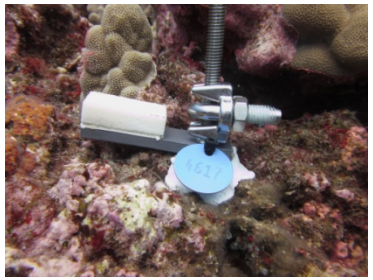


Enochs et al. In prep

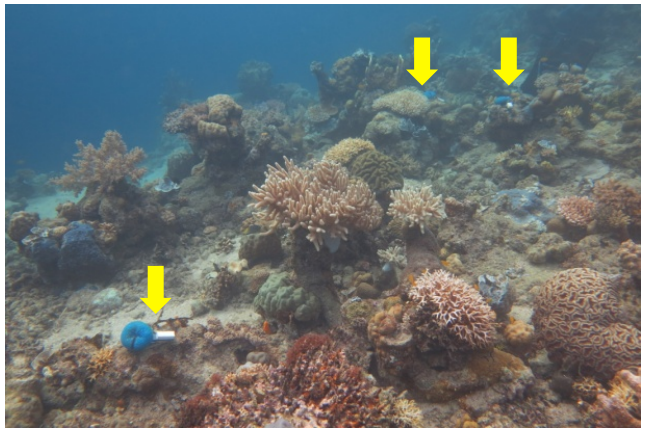
II. What are the ecosystem impacts of ocean acidification on US coral reefs?

- **How do we monitor bioerosion?**
  - **BMUs (B**ioerosion **M**onitoring **U**nits,

    Developed by I. Enochs of AOML)
    - Deployed at all class II and III sites, collected /analyzed every 3 yrs
  - Community census of bioeroders
    - Rotate annually between class III sites

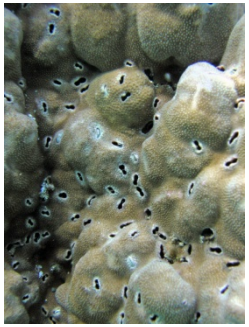


BMU
-Clean coral block used to measure euendolithic bioerosion
-CT before/after deployment
-Deployed in NW Hawaiian Is.



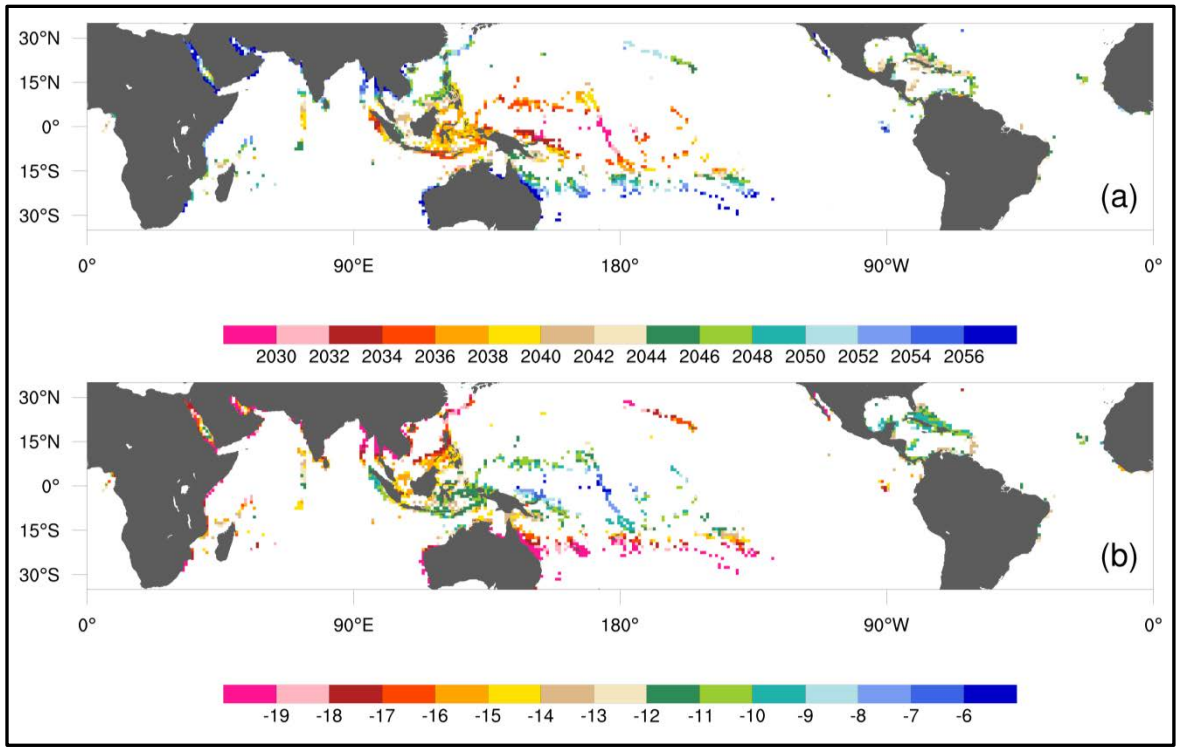
BMUs
Deployed at CO_2 vent site in Papua New Guinea. Collaborative effort with K. Fabricius of Australian Institute of Marine Sciences

Different agents of reef bioerosion



III. How will climate change and ocean acidification alter the physical environment of coral reefs in the future?

Coral Reef futures with warming and OA



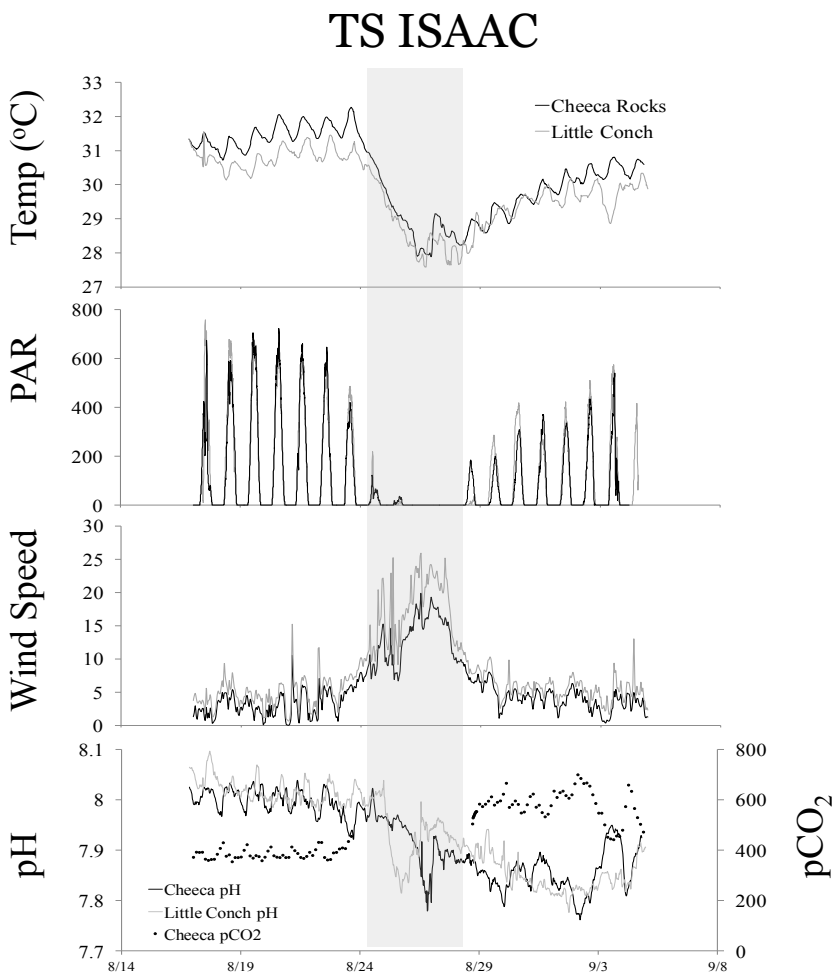
van Hooidonk et al. (2013, *Global Change Biol.*)

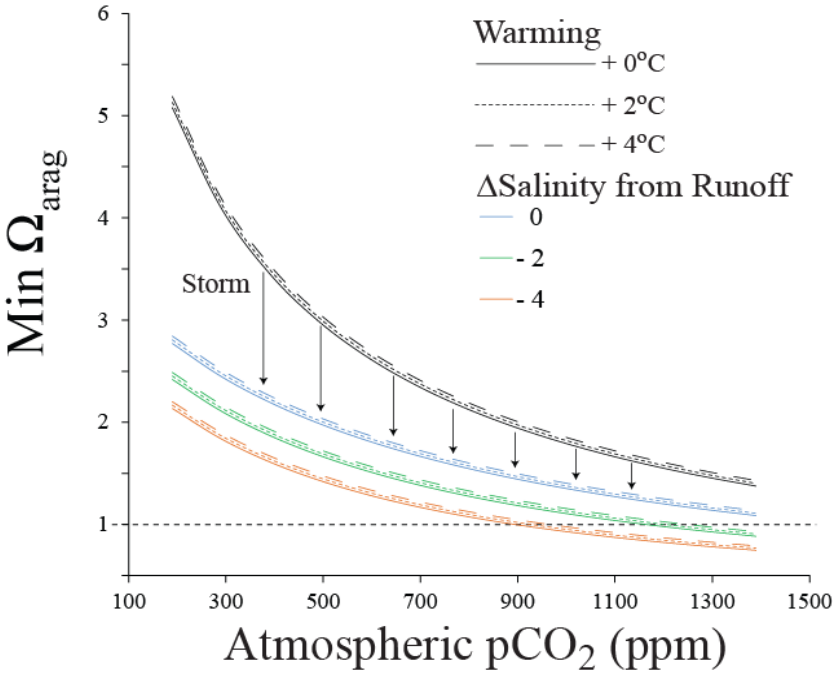
Major Finding

-Locations that will serve as temporary refugia from bleaching will be most impacted by acidification

III. How will climate change and ocean acidification alter the physical environment of coral reefs in the future?

Tropical Cyclones, Warming, and Ocean Acidification





-Ω_{arag} depressed by -1.0 for full week after impact of TS Isaac
-Undersaturation occurs from tropical storms with OA by end of the century

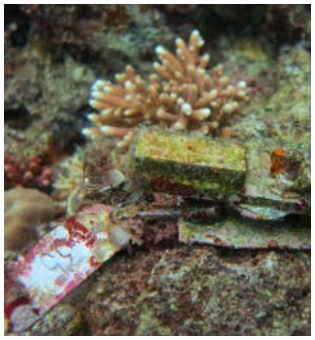
Manzello et al. (2013, *JGR-Oceans)*

Collaborative Research

- Climate change and ocean acidification are global threats

- Primary focus is US coral reefs, but we engage with partners to address these questions across international borders

-Participation in 8 missions from Galápagos to New Caledonia
-Data from remote locations never before studied
-CO_2 and coral calcification



BMU after 4 months of deployment , May 2013. CO_2 vent site in Papua New Guinea

Australian Institute of Marine Science

Looking Ahead

- **When is the next milestone?**
  - Climate/OA monitoring Network fully operational by end of FY15
- **What are the expected deliverables?**
  - High-quality time-series of CO_2 data to discern rate/magnitude of OA to US coral reefs
  - Time-series of $CaCO_3$ production/destruction on US coral reefs
  - Predictions of reef futures based on improved understanding of global change and its impacts
  - Delivery of report card to US congress on impact of climate change and OA to US reefs
  - AOML is a leader in these efforts
  - No other agency, domestic or foreign, is doing this research at this scope/scale
- **Known risks and issues**
  - Time and Labor Intensive
  - Requires long-term, committed investment because will be difficult to discern effects of OA due to other disturbances (coral bleaching, coral disease, land-based sources of pollution etc.)
- **What are the immediate next steps?**
  - Installation of class III sites at Flower Garden Banks, Saipan, American Samoa
  - Complete deployment of all class I, class II and class III sites in Atlantic

Questions?