Guiding Our Sampling: Using ocean models in ocean acidification observing system network design.

Thomas Oliver PhD, Ocean Acidification Program Manager
Coral Reef Ecosystem Division, PIFSC NOAA
WESTPAC Training Workshop
Phuket, Thailand, 19-21 January 2015
Cost of Data Collection Programs

Temporal Resolution/Coverage

Minutes
Days
Seasons
Years
Decades

Spatial Resolution/Coverage

One Site
10s of Sites
100s of Sites
1000s of Sites

Cost ($)

Ridiculously Expensive
Prohibitively Expensive
Expensive
Costly
Cheap

Spatial Resolution/Coverage

Temporal Resolution/Coverage
Cost of Data Collection Programs

Temporal Resolution/Coverage

Spatial Resolution/Coverage

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Water Sampling Program (GLODAP)
Cost of Data Collection Programs

- Water Sampling Program (GLODAP)

- Cost ($)
  - Ridiculously Expensive
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  - Expensive
  - Costly
  - Cheap

- Spatial Resolution/Coverage
  - Days
  - Minutes

- Data Collection Programs
  - Spatial
  - Temporal

- Sites
  - 10s
  - 100s
  - 1000s

- Yeas

- Days

- Hours

- Minutes

- Seconds

- Water
Low Temporal Coverage

High Spatial Coverage
Cost of Data Collection Programs

Temporal Resolution/Coverage

Minutes
Days
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Years

Spatial Resolution/Coverage

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10s of Sites
100s of Sites
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"Wide Net"

Water Sampling Program (GLODAP)

Spatial Resolution/Coverage
Cost of Data Collection Programs

- Minutes
- Days
- Seasons
- Years

Spatial Resolution/Coverage

Temporal Resolution/Coverage

Automated Instrument (MApCO₂)

- One Site
- 10s of Sites
- 100s of Sites
- 1000s of Sites

Cost ($)

- Ridiculously Expensive
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- Expensive
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Temporal Resolution/Coverage vs. Spatial Resolution/Coverage
Cost of Data Collection Programs

Automated Instrument (MApCO₂)

Minutes
Days
Seasons

Spatial Resolution/Coverage
Temporal Resolution/Coverage

100s of Sites
1000s of Sites

Cheap
Costly
Prohibitively Expensive
Expensive
Ridiculously Expensive

Cost ($)
Temporal Cycles in Hawai'i MApCO2 data (pCO2-2009)

Spectral Density

Cycle of X Days (Period)
Temporal Cycles in Chuukk MApCO2 data (pCO2-2012)
High Temporal Coverage

Low Spatial Coverage
“Deep Anchors”

Cost of Data Collection Programs

Minutes
Days
Seasons
Years
Decades

Spatial Resolution/Coverage

Temporal Resolution/Coverage

One Site
10s of Sites
100s of Sites
1000s of Sites

Automated Instrument (MapCO₂)

Cost ($)

Ridiculously Expensive
Prohibitively Expensive
Expensive
Costly
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Spatial Resolution/Coverage

Temporal Resolution/Coverage

"Deep Anchors"
Cost of Data Collection Programs

Temporal Resolution/Coverage

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Spatial Resolution/Coverage

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Automated Instrument (MapCO₂)

“Deep Anchors”

Water Sampling Program (GLODAP)

“Wide Net”
Cost of Data Collection Programs

Temporal Resolution/Coverage
- Minutes
- Days
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Spatial Resolution/Coverage
- One Site
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Automation Instrument (MapCO₂)

“Deep Anchors”

“Wide Net”

Water Sampling Program (GLODAP)

Cost ($)
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Spatial Resolution/Coverage

Temporal Resolution/Coverage
Cheap
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Cost ($)

Spatial Resolution/Coverage

Temporal Resolution/Coverage

Integrated OA Monitoring Program

Automated Instrument (MapCO$_2$)

Water Sampling Program (GLODAP)

Ocean Models

Spatial Resolution/Coverage

Temporal Resolution/Coverage

Years

Seasons

Days

Minutes

One Site

10s of Sites

100s of Sites

1000s of Sites

Spatial Resolution/Coverage

Temporal Resolution/Coverage

Cheap

Costly

Expensive

Prohibitively

Expensive

Ridiculously

Expensive

Cost ($)
DATA

MODELS GUIDE
DATA COLLECTION:
• WHERE?
• WHEN?
• HOW?
MODELS GUIDE
DATA COLLECTION:
• WHERE?
• WHEN?
• HOW?

“GOOD” DATA BUILD MORE ROBUST MODELS
**Where? When? How?**

• *Get Good Representation:*  
  – Sample oceanographically distinct areas.

• *Deep Anchors:*  
  – Document temporal variability in a few places.

• *Wide Net:*  
  – Minimize temporal variability across samples in many places.

• *Share Sampling Protocols:*  
  – Collect comparable data for a global perspective.
CT-ROMS
Coral Triangle - Regional Ocean Model System

Dynamical downscaling at 5-km resolution
Produces PHYSICAL oceanographic fields
Sea Surface Temperature

CT-ROMS [Castruccio et al., 2013].
Degree Heating Weeks
Surface Currents
Connectivity: Drifter Simulations

CT-ROMS [Castruccio et al., 2013].
Modeling Ocean Acidification requires coupling to a Biogeochemical Model.
WHERE? WHEN? HOW?

• **Get Good Representation:**
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Cost of Data Collection Programs

- **Automated Instrument (MapCO₂)**
- **Water Sampling Program (GLODAP)**
- **Ocean Models**

**Spatial Resolution/Coverage**
- **Minutes**
- **Days**
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**Temporal Resolution/Coverage**
- **One Site**
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**Cost (\(\text{\$}\))**
- **Cheap**
- **Costly**
- **Expensive**
- **Prohibitively Expensive**
- **Ridiculously Expensive**
Observations

**PACIFICA** (PACIfic ocean Interior CArbon)
- Merged datasets of ship-based hydrographic observations

Time-series stations
1. **SEATS** (SouthEast Asian Time-series Station)
2. **TAO-TRITON site**
   - with MAPCO2 buoy

**NOTE THE PAUCITY OF OBSERVATIONS IN ISLAND and REEF AREAS**

Coral reef locations are in pink
Modeling

Future projection of aragonite saturation state from CMIP5 models show declines in the western tropical Pacific

BUT

Global models do not resolve details of the Indonesian region

Solution: develop a high resolution model with ability to calculate carbonate chemistry
When?

• Sample to Maximize Variability:
  – Document Temporal Variability In Few Places

• Sample to Minimize Variability:
  – Control for Spatial Comparability In Many Places

• Correct Spatial Data for Temporal Variability
Where?

- Demonstrate Spatial Variability
- Sample to Maximize Variability:
  - Document Temporal Variability In Few Places
- Sample to Minimize Variability:
  - Control for Spatial Comparability In Many Places
- Correct Spatial Data for Temporal Variability
What Do We Need To Observe?

Establish key baselines & commit to long-term observations of key indicators to robustly detect relevant long-term trends

<table>
<thead>
<tr>
<th>Reef Assessment &amp; Monitoring (Macro)</th>
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<td>Benthic cover (hard &amp; soft corals), fish, macroinvertebrates...</td>
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<th>Seawater carbonate chemistry</th>
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<td>Spatial patterns across environmental &amp; human gradients</td>
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<td>Temporal-long-term changes, shorter-term processes.</td>
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<td>Calcification rates</td>
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<tr>
<td>Coral coring - provide history of past</td>
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<td>Crustose Coralline Algae - reef building cement</td>
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<td>Net Ecosystem Calcification</td>
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<td>Standardized indices of biodiversity - resilience?</td>
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<td>Bioerosion</td>
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<td>Microbial composition/diversity - adaptation?</td>
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<td>Habitat structure - Link to fisheries</td>
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Long-term Impacts of OA

Need long-term observations to detect changes & impacts of OA
Simple, systematic, achievable and relevant to societal values!

Atmospheric CO$_2$ at Mauna Loa Observatory

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory

Research needed to understand finer-scale processes of OA
Ocean Acidification Monitoring

Example: NCRMP/CROAMP

Northwestern Hawaiian Islands

Main Hawaiian Island

Mariana Archipelago

Pacific Remote Island Areas

American

Observing across gradients of environmental conditions, biodiversity, human impacts
Island-scale Survey Design

Sampling for DIC, TA, T, S, Chl a, nutrients.
Surface & Reef
Onshore-offshore
2-3 year sampling
Derive pH, Ω, NEC, NEP

Upstream DIC/TA sampling
Site-scale Sampling Design
Designing an Observing System Network: Sampling Across Variability

Chuukk MApCO2 Site

Date (2011-2012)

Omega_A(P,T,ALK,DIC) @ CTDPRE [DBAR]=first

Takahashi, 2014