Use of High Frequency Water Quality Data to Scale Ecological Processes in Estuaries

Michael C. Murrell
Jim Hagy, Johh Lehrter, Chenfeng Le,
Jane Caffrey

U.S. Environmental Protection Agency
Office of Research and Development
Gulf Ecology Division, Gulf Breeze, FL, USA

National Water Monitoring Conference, Cincinnati OH, 29 April 2014
Background

And...

- Continuous water quality monitoring technology has facilitated the acquisition of unprecedented volumes of water quality data in aquatic ecosystems

- Satellite imagery is another data trove for evaluating coastal water quality
  - Florida coastal criteria (Schaeffer et al. 2013)
  - Effect of land use and climate on chlorophyll (Le et al. 2009, 2013a,b,c)

- Monitoring programs are increasingly relying on such data sources to supplement or replace field sampling
  - Cost effective
  - Potentially vast information content
Background (cont)

But

• A question remains how and whether these high volumes of data have increased our understanding of aquatic systems
  – Data ≠ Information

• State variables (i.e. chlorophyll, CDOM, salinity, water clarity) are useful but do not predict ecological rate processes

• Process rate measurements provide an integrated way of evaluating the “health” or trophic state of an ecosystem
  – Growth Rates, Grazing Rates, Trophic Transfer Rates, etc.
  – Labor intensive

• Methods that estimate process rates from water quality time series are a promising “value-added” use of high frequency datasets
  – Ecosystem Gross Production, Respiration, NEM
Purpose of Study

Therefore

• Compare and evaluate methods of measuring ecological processes
  – Ecosystem vs Plankton Metabolism
  – Channel vs Shoal

• Compare and evaluate methods of measuring water optical properties
  – Satellite vs. Point sampling
  – Channel vs Shoal
Study Design 2013

• Satellite imagery
  – MERIS time series (2002-2012)
  – Chlorophyll and CDOM products

• In situ WQ instruments (Apr-Sept 2013)
  – Shoal (seagrass) vs Channel (bare bottom)
  – Ecosystem gross production and respiration

• Point sampling (~Weekly)
  – CTD profiles
  – Chlorophyll, CDOM, Part Abs.
  – Plankton Primary Production, Respiration
Satellite spatial resolution of Pensacola Bay
WQM’s and Weather Station

\[
\frac{dC}{dt} = P - R + D
\]

\[
D = k_a (C_s - C)
\]
**Plankton Experiments**

**Graph and Equation:**

\[ P = P_{\text{max}} \left(1 - e^{\alpha / P_{\text{max}}} \right) - R \]

- \( P \): Primary Production
- \( P_{\text{max}} \): Maximum Primary Production
- \( \alpha \): Slope
- \( R \): Respiration

**Graph Details:**
- **Y-axis:** DO (mmol O\(_2\) m\(^{-3}\))
- **X-axis:** Time (hr)
- **Legend:**
  - Initial
  - Final
  - 0 screens
  - 1 screen
  - 2 screens
  - 3 screens
  - 4 screens
  - dark

**Legend Image:**
- Initial vs. Final DO levels
- Time (hr) vs. DO levels for different irradiance levels (0 screens, 1 screen, 2 screens, 3 screens, 4 screens, dark)
MERIS CDOM and chlorophyll products from study site show interannual variability.

- MERIS died in 2012!
- Data from 2013 are similar to MERIS record.
How do in situ optical properties compare between shoal and channel?

- $a(T) = a(g) + a(d) + a(ph)$

- Shoal and Channel sites have virtually identical absorption properties based on weekly point samples

- Extrapolating RS products to shallow waters (i.e. seagrass habitat) is supported
What ‘happened’ during 2013 study?
Time series show low salinity water intrusion in July
Chlorophyll increased after low salinity water intrusion
Open water metabolism shows influence of low salinity intrusion

- Shoal >> Channel
- Shoal
  - High > Decrease
- Channel
  - Low > Increase
Plankton metabolism also influenced by low salinity intrusion

- Shoal and Channel sites similar response

- Low > Increase
Plankton vs. Ecosystem Metabolism
Channel vs Shoal Environment

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ecosystem</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoal</td>
<td>114</td>
<td>110</td>
</tr>
<tr>
<td>Channel</td>
<td>33</td>
<td>36</td>
</tr>
<tr>
<td><strong>Plankton</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoal</td>
<td>29</td>
<td>16</td>
</tr>
<tr>
<td>Channel</td>
<td>26</td>
<td>13</td>
</tr>
<tr>
<td><strong>% Plankton</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoal</td>
<td>28%</td>
<td>16%</td>
</tr>
<tr>
<td>Channel</td>
<td>83%</td>
<td>47%</td>
</tr>
</tbody>
</table>

Plankton P and R (mmol O₂ m⁻³ d⁻¹)

Ecosystem P and R (mmol O₂ m⁻³ d⁻¹)

-50 0 50 100

Shoal
Channel
1:1
Summary

• Both remote sensing and continuous WQ data provide unique perspectives on ecosystem dynamics
• Allows for ‘scaling up’ and extrapolation of limited point samples
• Shows HF features ‘missed’ by point samples, expands temporal scale
• Channel and Shoal comparison
  – Identical optical properties
  – Vastly different process rates
Thank You!

Funding support:
NASA ROSES program

SPAM Team:
Jessica Aukamp, David Beddick, George Craven, Ally Duffy, Brandon Jarvis, Mike Marcovich, Diane Yates
Future Directions
Open Water Metabolism

- **Odum 1956**
  - Diel changes in dissolved oxygen used to infer rates of daytime apparent net production and night-time respiration
  - Air-sea exchange estimated using wind speed and departures from saturation
  - Daily integration yields estimates of gross production and respiration

\[
\frac{dC}{dt} = P - R + D
\]

\[
D = k_a (C_s - C)
\]
CDOM fluorescence (from WQM, daily average) and ag_350

$y = 0.233x - 0.199$

$R^2 = 0.881$

CDOM fluorescence (from WQM, daily average) and ag_350
$y = 38.504x - 0.066$

$R^2 = 0.780$
The graph shows the relationship between CDOM (Chlorophyll a, Dissolved Organic Matter) and CDOM_ctd (Corrected Dissolved Organic Matter) over the months of April to October. The data is separated into two categories: Shoal and Channel. The graph includes a linear regression line with the equation:

\[ y = 3.171x - 0.472 \]

The coefficient of determination, \( R^2 \), is 0.947, indicating a strong correlation between the variables.
K-Z Model

\[ I_z = I_0 e^{-kz} \]

Caroon depicting a boat with CTD and water column

\( k = \text{log slope} \)
River flow during study

The graph shows the river flow over time, with data from 1934 to 2013. The shaded area represents the average flow over that period. The black line indicates the flow for the year 2013, and red dots mark the sampling dates.
Net Ecosystem Metabolism

![Graph showing Net Ecosystem Metabolism from April to October with data points for Shoal and Channel.](image-url)
CTD time series