Representer-based observing system design in the New York Bight

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Outline of the presentation

1. Background and motivations
2. IS4DVAR Data assimilation result
3. Set-up of the representer system
4. Observing system design
5. Summary
Background

New York Bight:

- biologically active
- complicated but interesting dynamics
- affected by both local forces (wind, river discharge, topography, etc.) and remote forces (large-scale circulation, tides, etc.)
- one of best observed coastal areas around the world
Observations: spring 2006

(from Rutgers COOL webpage)
Motivations

- To improve the estimation of the ocean state and prepare for real-time ocean forecast
- To evaluate existing observation pattern and help design targeted observations
- Towards building an integrated modeling and observation system
ROMS IS4DVAR result

– improvement of the analysis and forecast

\[
\text{skill} = 1 - \frac{\text{RMS}_{\text{afterDA}}}{\text{RMS}_{\text{beforeDA}}}
\]

- substantial improvement of temperature and salinity forecast (~15 days)
- velocity forecast is improved for 2-3 days
Representer-base observing system design

- **Question**: where should we deploy the gliders to better predict the salt flux with the Hudson Shelf Valley in 2 days
Observing system design ---- background

seasonal average of salinity and current at 20m
(simulated with ROMS)
Observing system design ---- background

Salt flux time series

Salt flux in the Hudson Valley:

- strong shoreward intrusion in winter and spring
- little net flux in summer
the representer-based system

\[ J = \frac{1}{\Delta t} \int \int \int \left[ \nu S - \overline{\nu S} \right] dtdzdx \]

- The representer of \( y_i \),
  \[ \text{HRB}^{-1} R^T \delta_{i,t_0} = \text{HRB}^{-1} R^T \frac{\partial \Phi(x_i,t_0)}{\partial \Phi(x,t_0)} \]
  tells the covariance between \( \Phi(x_i,t_0) \) and \( H\Phi(x,t) \).

- \( \text{RB}^{-1} R^T \frac{\partial J}{\partial \Phi} \) gives the covariance between \( J \) and model state \( \Phi(x,t) \).

- Assuming no other observation available around the targeted area.

<table>
<thead>
<tr>
<th>time</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>day</th>
</tr>
</thead>
</table>

control run

adjoint \( \partial J/\partial \Phi \)

tangent linear

representer
Observing system design

\[ J = \frac{1}{\Delta t} \int_{L H} \int_{\Delta t} \int \left[ vS - \bar{v}S \right] dtdzdx \]

RMS of the correlation of \( J \) with salinity at 20m

- **Summer**
- **Winter-spring**
Observing system design

\[ J = \frac{1}{\Delta t} \int \int \int \left[ vS - \bar{v}S \right] dt dz dx \]

RMS of the correlation of \( J \) with salinity at 20m

**RMS of the correlation of \( J \) with salinity at 20m**

- **summer**
- **winter-spring**

**Optimal**

**Traditional**
Set-up of the DA twin experiments

- control run
- tangent linear
- representor
- perturbed run
- forecast
- adjoint
- B
- J_t
- J_b
- J_a
- obs.

Time progression:
0 1 2 3 4 5 6 7 8 9 day
DA twin experiments

\[
\text{skill} = 1 - \frac{|J_{\text{after DA}} - J_{\text{true}}|}{|J_{\text{before DA}} - J_{\text{true}}|}
\]

- For both seasons, the DA system assimilated data from optimally positioned gliders gives better 2nd-day prediction of \( J \).
- The big improvement in winter-spring season is presumably caused by the strong landward intrusion in the valley and then clear identification of dynamical upstream.
Observation comparison – glider vs. mooring

Assuming: model error ~ ocean state anomaly

\[ J = \frac{1}{V \Delta t} \int_V \int_{\Delta t} \left[ \frac{(T - \overline{T})^2}{O_T} + \frac{(S - \overline{S})^2}{O_S} \right] dtdV \]

- a glider has broader influence area and a mooring has stronger influence around the observation location
Observing system design — upwelling vs. downwelling

\[ J = \frac{1}{V \Delta t} \int \int \left[ \frac{(T - \bar{T})^2}{O_T} + \frac{(S - \bar{S})^2}{O_S} \right] dtdV \]
Summary and future work

- ROMS IS4DVAR has been applied in the NYB area and improved analysis and forecasts

- The representer system provides guidance on the design of targeted observation and has been used to compare different types observations and same observation in different dynamical regimes

- The newly developed observation sensitivity module in ROMS can be used to check the influences of observations in a data assimilation and forecast system.