ECOSYSTEM MODELLING: TOWARDS THE DEVELOPMENT OF A MANAGEMENT TOOL FOR A MARINE COASTAL SYSTEM

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Agenda

- Pagasitikos eutrophication problem
- Description of the Ecosystem Model
- Data Assimilation
Subject: Ecosystem Description

The eutrophication problem

- In 1982 dense mucilage
- This phenomenon was greatly reduced and it returns with greater severity in 1987, the worst year ever recorded
- Since then it has become an almost periodic phenomenon.
- The areas affected are the shallow north parts of the gulf where agricultural and domestic runoff are entering
**Subject:** Ecosystem Description

**Field data**

- **Velocity Fields**
  - (cm/sec)
  - **November**
  - **July**
  - **November**

- **Field data**
  - **T, S, O₂, u-v**
  - **NH₄**, **NO₃**, **NO₂**, **PO₄**, **SiO₄**, **Chl-a**
Subject: Description of the Ecosystem Model

Computational area

39° - 39.43°, 022.8125° - 023.3025° E
50 x 44 boxes, (1/100 x 1/100 deg)
~ 900 x 900m.

25 σ levels
Logarithmic distribution
Subject: Description of the Ecosystem Model

ERSEM
Forcing

Initial conditions

- ECMWF 6 hours data
  - Wind stresses
  - Temperature and air humidity
  - Cloud cover
  - Heat fluxes
  - Solar radiation

- Precipitation Jaeger (horizontal resolution 5°x2.5°)

- Initial conditions - March analyzed fields
Almost stable dipole significantly affecting the ecology and in particular the anticyclone which transport organisms and detritus to the deeper parts of the gulf which are trapped.
Subject: Description of the Ecosystem Model

Model results

Nitrate Concentrations (µM)
& Vertical Velocity Profiles (May)

Phosphate Mean Concentrations (µM)

Mean Chlorophyll Concentrations (µg/l)

August

May

April
Subject: Validation of the Ecosystem Model


\[ C_{x,t} = \frac{M_{x,t} - D_{x,t}}{sd_{x,t}} \]

\( C_{x,t} \) normalised deviation between model & data for box \( x \) and season \( t \),
\( M_{x,t} \) mean value of the model results within box \( x \) and season \( t \),
\( D_{x,t} \) mean value of the \textit{in situ} data within box \( x \) and season \( t \), and
\( sd_{x,t} \) standard deviation of the \textit{in situ} data within box \( x \) and season \( t \).

The lower the value of the cost function the better the agreement between model and data:
- \(<1\) Very good,
- \(1<2\) = Very good,
- \(2<5\) = Good,
- \(2<5\) = Reasonable,
- \(>5\) = Poor.

Holt, J \textit{et al.} (2005)

\[ x^2 = \frac{1}{n\sigma_o^2} \sum (A_m - A_o)^2 \Rightarrow x = \sqrt{\frac{\sum (A_m - A_o)^2}{n\sigma_o^2}} \]

\( A_m \) and \( A_o \) are the model and observed variable, \( n \) is the number of observations and \( \sigma_o \) is the standard deviation of the observations. We might expect values of \( x<1.0 \) to be required for the model to have any predictive skill.


Model Efficiency

\[ ME = 1 - \frac{\sum (D - M)^2}{\sum (D - \bar{D})^2} \]

Is a measure of the ratio of model error to variability in observational data. The squaring of the error rewards a good fit and punishes a poor fit. Performance levels are categorised as:
- \(>0.65\) excellent,
- \(0.65-0.5\) very good,
- \(0.5-0.2\) good,
- \(<0.2\) poor.
The Low-Rank Kalman Filter(s)

- Singular Evolutive Kalman (SEEK) filters, low-rank (r) square-root KFs

\[ P = LUL^T \rightarrow N \times r \]

\[ L_k = M_k L_{k-1} \]

Forecast

Analysis

\[ \tilde{x}_{k/k-1} = M(\tilde{x}_{k-1}) \]

\[ \tilde{x}_k = \tilde{x}_{k/k-1} + G_k [y_k - H(\tilde{x}_{k/k-1})] \]

\[ G_k = L_k U_k \left( H_k L_k \right)^T R_k^{-1} \]

\[ U_k^{-1} = \rho U_{k-1}^{-1} + \left( H_k L_k \right)^T R_i^{-1} H_k L_k \]

- A “collection” of SEEK filters:
  - **SEEK**: \( M \equiv M \)
  - **SEIK**: Ensemble variant
  - **SFEK**: \( M \equiv I_d \)
### TWIN EXPERIMENTS

<table>
<thead>
<tr>
<th>FILTER</th>
<th>$\rho$</th>
<th>rank</th>
<th>OBSERVATIONS TYPE</th>
<th>STATE VECTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFEK</td>
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<td>35</td>
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Subject: Data Assimilation

Twin Experiments

SFEK, SEEK AND SEIK PERFORMANCE (35 modes, $\rho=0.65$)
Assimilation into POM-ERSEM

- **Model** = 1/100° Pagasitikos configuration with 25 layers
- **Downscaling** = from 1/30° Aegean, from 1/12° Mediterranean

Downscaling model solutions: a problem of proper OBCs (nesting) and initialization

- Interpolate coarse model solution and add constraints in order to dump spurious oscillations and propagating waves
  - VIFOP (a variational initialization method, Auclair 1999)
- Nesting techniques developed within MFSPP, MFSTEP and POSEIDON projects
Assimilation into POM-ERSEM

- **Observations** = SeaWiFS 2003 on a weekly basis
- **SEEK Filter with rank 40**
- **Initialization** = EOFs computed from 2-days outputs of 2001-2002 model integration, explaining 95% of the variance
- **Amplification factor** = 0.5
Experiment Setup

- **Model** = 1/100° Pagasitikos Gulf with 25 layers

1. **Initialization**: starts from the state of 31/12/2002
2. **Free-run**: run without assimilation starting from mean state
3. **Evaluation**: RMS misfit relative to the misfit from mean state
Assimilation into ERSEM
CONCLUSIONS

The ecosystem model simulates adequately the major characteristics and the seasonal cycle of Pagasitikos Gulf.

The use of Kalman filtering techniques for DA into POM-ERSEM was successful despite concerns about its complex internal structure.

The SEIK filter is shown to perform better than the SEEK where strong nonlinearities appear.
Thank You