Initial biogeochemical modeling at NOAA/NCEP: Using VIIRS ocean color data for validation and data assimilation

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Project Descriptions
(Background)

• The NOAA Ecological Forecasting Roadmap (EFR) for 2015-2019 states that its objective is “to provide dependable, higher quality forecast products, derived from the successful transition of research and development into useful applications....”

• In support of the NOAA-approved roadmap, this project proposes to evaluate approaches and develop a prototype foundational global biogeochemical modeling capability for NOAA’s operational Real-Time Ocean Forecast System (RTOFS) for reliably providing the global modeling fields required to support the ecological forecasts of the EFR technical teams.
Project Descriptions
(Background)

• Specifically,
  ➢ to establish a component for the national modeling ‘backbone’ that will generate global predictions of the common physical and biogeochemical variables used by ecological forecasts
  ➢ to address key linkages and gaps within the EFR infrastructure framework via JPSS VIIRS ocean color data and physical-biogeochemical numerical modeling because ocean color data from VIIRS provides a unique path toward ecological forecasting through biogeochemical (BGC) analyses and forecasts, facilitating both real-time and scenario-based marine ecosystem applications
Project Descriptions
(Identification of Users)

• Targeted users within NOAA:
  ➢ Ecological Forecasting Roadmap technical teams (harmful algal blooms, hypoxia, habitats),
  ➢ Those explicitly involved with numerical modeling and prediction in conjunction with the NOAA Ecological Forecasting Infrastructure and Process team

• The external user community:
  ➢ Local, state, federal governments, non-governmental organizations (NGO's), and academic and industry entities using derivative analyses and predictions.
Scientific Objectives

• Employing coupled BGC-physical modeling to improve NWS forecasting skill at short-term and seasonal scales
  ➢ by including the effects of biological heating on upper-ocean thermal structure
  ➢ by exploring the direct assimilation of VIIRS products ($K_{d490}$) in conjunction with radiative transfer (RT) computations using existing validated algorithms (Lee, 2006; Gregg, 2002).
• Providing scenario-based forecasting
  ➢ to predict system responses to potential changes by drivers (natural or through ecosystem management decisions)
• Assessing the effects of carbon dynamics between the atmosphere and the ocean and subsequent changes in the acidity of the global ocean
• Exploring BGC model to support for upper-trophic-level modeling
Approaches
(Ocean Model: RTOFS-Global)

• RTOFS-Global
  ➢ Hybrid Coordinate Ocean Model (HYCOM) based system with 1/12° and 41 layers
  ➢ iso- pycnal (deep ocean), z-levels (surface), σ (coasts)
  ➢ Tripole grid (1 at South Pole and 2 from Arctic bipole)
  ➢ Recti-linear (<47°N) and curve-linear (>47°N)

• RTOFS-Global
  ➢ NAVOCEANO daily initialization with MVOI (now 3DVAR) data assimilation from NCODA (Navy Coupled Ocean Data Assimilation)
  ➢ KPP for vertical mixing
  ➢ 2-day nowcast (GDAS) and 6-day forecast (GFS)
Approaches
(Ocean Model: RTOFS-Global)
Approaches
(NOBM: NASA Ocean Biogeochemical Model)

Approaches
(Data Assimilation: 2DVAR)

• Step 1. Integrate model for a certain period with no nudging from t=0 (beginning of cycle) to t=T. Initial condition is X(t=0). End condition is X(t=T).
• Step 2. Carry out CHL analysis at 0-hr and at T-hr.
• Use CHL from X(t) as a background X_b.
  ➢ X_a=X_b+K(y_0-H(X_b))
where X_a: analysis; X_b: background; K: Kalman gain; y_0: observations (VIIRS); H: observation operator; [y_0-H(X_b)]: innovation, distance between model and observation.
  ➢ Data points will be assimilated (e.g., VIIRS) with a certain time window for data pooling.
• Step 3. Create linearly interpolated CHL field between the two consecutive CHL analyses X_a (t=0) and X_a (t=T).
• Step 4. Integrate model for T hours with nudging from t=0 (beginning of cycle) to t=Thrs. Initial condition is X(t=0). End condition is X(t=T).
• Next cycle: re-label end condition of integration with nudging as the initial condition if the next cycle.
Approaches
(Data Assimilation: NCODA)

Stage 1: Preliminary data sensitivity error checks

Ocean Obs

- SST: NOAA (GAC, LAC), METOP (GAC, LAC)
- GOES, MSG, AATSR, AMSR-E, Ship/Buoy
- Profile Temp/Salt: XBT, CTD, Argo Float, Fixed/Drifting Buoy
- Altimeter SSH: Jason-1, Jason-2, ENVISAT
- Sea Ice: SSM/I, SSMIS
- Glider: Slocum, Sea-Glider, Spray CTD

Stage 2: External data error checks

Ocean Data QC

- Innovations

Stage 3: Internal data error checks

3DVAR

- Forecasts Fields + Prediction Errors
- First Guess

Stage 4: Adjoint sensitivities

Adaptive Sampling Data Impacts

Analysis Components (QC + 3DVAR)

HYCOM

Forecast Component

Cummings (2011)
Milestones

• Year 1:
  ➢ Use VIIRS-derived $K_{d\text{PAR}}$ and $K_{d490}$ with a two-band scheme (Lee et al., 2006)

• Year 2:
  ➢ Implement coupling of the modified BGC model with online HYCOM/RTOFS-Global
  ➢ Modify NOBM (Gregg, 2002; 2003) biogeochemical module to include air-sea oxygen dynamics

• Year 3:
  ➢ Implement simple data assimilation techniques (2DVAR) to nudge model values to better represent VIIRS observations
  ➢ Validate model-derived Chl-a against independent *in situ* observations (e.g., BIO-Argo) and VIIRS data.
Thanks!