The US West Coast Component of the Coastal Ocean Modeling Testbed (COMT)

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US West Coast:

- fisheries
- navigation
- coastal populations (Seattle, Portland, San Francisco, Los Angeles, San Diego)

http://www.wired.com/2010/01/global-shipping-map/
Coastal Ocean Circulation Models

- Predict currents, temperature, salinity

**Coupled physical-biological models:**

- biological properties (nutrients, phytoplankon, zooplankton)

**Data assimilation**

- Optimally combine models and observations to obtain the best estimate of the ocean (initial conditions for accurate forecasts)

**Support:**
- Fisheries management
- Search & Rescue
- Environmental hazard response
- Navigation
- Recreation
WC COMT participating groups:

IOOS RAs:
CenCOOS
SCCOOS
NANOOS

Circulation models, data assimilation:
(a) Edwards, Moore: WC Regional model, 10-km res. + 4DVAR
(b) Chao: CA 3-km res. + 3DVAR | new: EnKF (w/ B. Cornuelle)
(c) Kurapov: OR+WA 2-km res. + 4DVAR

Coupled bio-chemical modeling:
NEMURO (11 components) w/ WC regional model
CoSINE (13 components) w/ CA model– F. Chai
NPZDO (6 components) w/ WA model (N. Banas, UW)
Intercomparisons:

- Bio-chemical models (coupled with the same ocean circulation model) (Edwards, Banas, Chai)

- Data assimilation: 4DVAR vs. hybrid ensemble-variational method (Kurapov, Cornuelle)

- Data assimilation: 3DVAR vs. EnKF (Chao, Cornuelle)

- Data assimilation: new metrics for observational impact assessment based on 4DVAR (Moore)

Transition to operations:

WC COMT  

NOAA West Coast Ocean Forecast System (WCOFS)  
(PI: Kurapov, OSU – NOAA NOS, NESDIS, JCSDA)
3 Biogeochemical Models

NPZD (Cascadia)
- biomass and species composition from microscopy (Lessard)
- biomass and species composition from microscopy (Kudela)
- POC:PON:chl stoichiometry (Kudela)
- benthic flux parameterization based on historical, local benthic oxygen consumption data (Hartnett and Devol 2003)
- satellite and bottle chl (Kudela)
- nitrate primary productivity (Kudela)
- dilution experiments (Lessor)
- dilution experiments (Lessor)
- deckboard incubations and growth kinetics expts (Kudela)
- attenuation–chl–salinity relationships from CTDs (Hickey, Kudela)

Banas et al.
- calibrated CTD oxygen (Hickey/Connolly)
- benthic flux parameterization based on historical, local benthic oxygen consumption data (Hartnett and Devol 2003)
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Chai et al.
- satellite and bottle chl (Kudela)
- POC-PON-chl stoichiometry (Kudela)
- biomass and species composition from microscopy (Lessard)
- calibrated CTD oxygen (Hickey/Connolly)

CoSiNE
- dilution experiments (Lessard)
- 14C primary productivity (Kudela)
- deckboard incubations and growth kinetics expts (Kudela)
- attenuation–chl–salinity relationships from CTDs (Hickey, Kudela)
- biomass and species composition from microscopy (Lessard)
- biomass and species composition from microscopy (Lessor)
- POC-PON-chl stoichiometry (Kudela)
- satellite and bottle chl (Kudela)
- nitrate primary productivity (Kudela)
- dilution experiments (Lessor)
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surface chlorophyll in reference vs best in ensemble

<table>
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<tr>
<th>SATELLITE OBS</th>
<th>CASCADIA</th>
<th>NEMURO</th>
<th>CoSiNE</th>
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<td><strong>Initial, reference runs</strong></td>
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<td><strong>Optimized</strong></td>
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Optimized = best in ensemble

2000, annual mean
The cost function $J(\theta)$ summarizes model performance in one number.

$$J(\theta) = \frac{1}{3} \frac{J_{nut}(\theta)}{J_{nut}(\theta_{ref})} + \frac{1}{3} \frac{J_{coastal}(\theta)}{J_{coastal}(\theta_{ref})} + \frac{1}{3} \frac{J_{offshore}(\theta)}{J_{offshore}(\theta_{ref})}$$

**NO₃-based contributions:**

$$J_{nut}(\theta) = \frac{1}{4} \sum_{t \in \{\text{JFM,AMJ,JAS,OND}\}} \frac{1}{2} \left( \frac{1}{n_t} \left| \sum_{i=1}^{n_t} m_{i,t}^{\text{NO}_3}(\theta) - \sum_{i=1}^{n_t} o_{i,t}^{\text{NO}_3} \right| + \sqrt{\frac{1}{n_t} \sum_{i=1}^{n_t} (m_{i,t}^{\text{NO}_3}(\theta) - o_{i,t}^{\text{NO}_3})^2} \right)$$

$$J_{coastal}(\theta) = \frac{1}{\#G_{\text{coastal}}} \sum_{x \in G_{\text{coastal}}} \frac{1}{12} \sum_{t=1}^{12} \log \left( \frac{\bar{m}^{\text{chl}}_{x,t}(\theta)}{\bar{o}^{\text{chl}}_{x,t}} \right)^2$$

$$J_{offshore}(\theta) = \frac{1}{\#G_{\text{offshore}}} \sum_{x \in G_{\text{offshore}}} \frac{1}{12} \sum_{t=1}^{12} \log \left( \frac{\bar{m}^{\text{chl}}_{x,t}(\theta)}{\bar{o}^{\text{chl}}_{x,t}} \right)^2$$

(Edwards et al.)
Sensitivity of different models to variation in biological parameters

NPZD: 4 variables 9 biological parameters varied
NEMURO: 11 variables 44 (+4) biological parameters varied
Cascadia: 5 variables 13 biological parameters varied
CoSiNE: 10 variables 33 (+1) biological parameters varied
Testing new metrics for data assimilation impact assessment, based on the adjoint algorithm (Moore)

Example: Observation Impacts on 37N Transport

\[ x_a = x_b + K^\phi (y - H(x_b)) \]

\text{posterior} = \text{prior} + \text{gain} \times \text{innovation}

Consider a scalar function:

\[ I(x) \]

(transport at 37N, coast to 127W, 0-500m in this case)

Change in \( I \) due to 4D-Var:

\[ \Delta I = I(x_a) - I(x_b) \]

\[ \Delta I = I(x_b + K^\phi e) - I(x_b) \approx d^T K^\phi (\partial I / \partial x)|_{x_b} \]

\[ = (y - H(x_b))^T K^\phi (\partial I / \partial x)|_{x_b} \]

Change in \( I \) can be uniquely attributed to each obs \( y_i \), the transpose (adjoint) of the gain matrix \( K^T \)
RMS annual means:
Total

RMS Initial Conditions
RMS annual means:
Initial conditions

RMS Surface Forcing
RMS annual means:
Surface forcing

RMS Open Boundary Conditions
RMS annual means:
Open boundary conditions
COMT => Transition to operations

WCOFS:

- Approx. 2-km horizontal resolution
- Atm. forcing: NOAA NAM (grid 218)
- Boundary conditions: Navy Global HYCOM (w/ data assimilation)

Products:
- Long run without assimilation (testing, model climatology)
- Real-time forecasts (3-7 days), w/ data assimilation (SSH, SST, in-situ obs.)
SST, Feb 2009

multisat OSTIA

WCOFS

OSTIA 01-Feb-2009 ... 01-Mar-2009

ROMS ../Exp03/Sample/Surf/
notes:  
(1) upwelling off OR and Northern CA,  
(2) warming in S. CA, just along the coast
SST, Nov 2009

multisat OSTIA

WCOFS
OSTIA 01-Feb-2010 ... 01-Mar-2010

SST, Feb 2010
← multisat OSTIA

WCOFS →

ROMS ./Exp03/Sample/Surf/

-140 -130 -120

-140 -130 -120
Daily averaged SST (31 May 2009)

Multisat OSTIA SST product (5-km res.)

WCOFS (2-km res.)

note:
- narrow shelf (black line is H=200 m)
- a warm tongue along the slope, colder water farther offshore
- colder water over shelf (Mexico), local upwelling?
Area-averaged, daily-averaged surface current components off Oregon: WCOFS vs. HF radar (Kosro)

OCT 2008 – DEC 2009

u: cross-shore (eastward)

v: alongshore (northward)

winter downwelling  summer upwelling  winter downwelling
Area-averaged, daily-averaged surface current components off Oregon: WCOFS vs. HF radar (Kosro)

OCT 2009 – DEC 2010

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winter downwelling  summer upwelling  winter downwelling
ROMS SSH vs. coastal tide gauge (44.65N, South Beach, OR)

TG: low-pass filtered (40-hr half ampl.), inverted barometer correction using NAM $P_{\text{AIR}}$

ROMS: daily-ave
SUMMARY:

- Bio-chemical model intercomparison and optimization: improved parameters, guiding choice for the WCOFS bio-chemical model component

- Data assimilation intercomparisons: exploring synergies between methods, testing impact of different data on the ocean estimates

- Transition to operations: WCOFS
  (successful initial runs, preparation for data assimilation)
  (tests of WCOFS+NEMURO are in COMT yr. 3-5 plans)