Assimilation of satellite SSH in coastal ocean circulation models

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I will address the following topics of interest for this session:
- Multi-mission, multi-scale mapping of SWOT SSH and nadir altimetry SSH
- Multi-captor, multi-scale mapping of SWOT velocity and nadir altimetry, SST, ocean color, S3 SAR velocities
- Data assimilation

(I will talk about coastal ocean applications; many techniques discussed would be relevant to data assimilation on regional, basin, and global scales)
The model domain:

Model: ROMS (3-km res.)

real-time forecasts
(using Jason, Cryosat and AltiKa altimetry,
+ GOES SST, HF radar surface currents)
4DVAR = dynamically based **time-** and **space-** interpolation of data

**Hourly GOES SST (NOAA-CoastWatch D. Foley)**

- Assimilate data in a 3-day interval (TL&ADJ AVRORA)
- Correct initial conditions in the recent past
- Run forecast model (ROMS) with improved initial conditions
The real-time coastal ocean forecast model: variational DA in a series of sliding time windows

To find correction to initial conditions (and possibly, BC and forcing) using 4DVAR: the tangent linear (TL) model and its adjoint (ADJ) are needed

The ADJ model: propagates observed information backward in time

(We use our own TL&AD AVRORA codes: stand-alone codes, dynamically and algorithmically consistent with ROMS)
Examples of alongtrack altimetry and model forecasts (red):

(We assimilate SSH minus the mean along the track)
The optimum correction is obtained as a series of several ADJ and TL model runs:

\[ \lambda = \text{Sensitivity to ini conditions} \]

ADJ

(a linear combination of impulses at obs locations/times)

TL

\[ C \lambda \]

linearized solution ...

A covariance for initial condition errors \((C)\) has to be specified:
(1) provides smoothing
(2) may include dynamical constraints on the correction (Weaver, 2005)
Multivariate data assimilation:

Due to the TL dynamics and initial error covariance (C),

- assimilation of SSH affects not only SSH model fields, but also \((u,v), T, S\)
- assimilation of other sources (SST, surface \((u,v)\)) will affect SSH
- information from surface observations will be propagated to 3D

Does assimilation of SSH improve or degrade accuracy of ocean estimates at depth?

What combination of surface observations will provide the best constraint on 3D fields?

What would be the impact of SWOT data, compared to the impact of existing data sets?

Does assimilation of surface data (including SWOT) help to extend the impact of subsurface observations (mooring, glider)?
Variational assimilation of satellite observations in a coastal ocean model off Oregon

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Figure 3. Locations of AVISO along-track satellite altimeter data available in a series of several 6 day assimilation windows, 1 June to 30 July 2005, TOPEX (black), Jason (white), and Envisat (gray). The bathymetric contour shown is 200 m.
Figure 4. Observed AVISO absolute dynamic topography (black) and model SSH (gray) along Jason track 206, June–October 2005 (see Figure 3 for the track location); each line is demeaned independently.
9/28/2009: SSH (contours), SST (color)

Assimilation of SSH impacts (improves) SST
Meridional sections of T, 126W (9/28/2005): assimilation of SSH changes the slope of isotherms.

no DA

DA: SSH

DA: SSH + SST
Correction in SST due to DA is consistent with verification $T(\text{lon}, z)$

A shallower thermocline in the DA case

(sections at 44.65N)
Cross-shore sections (T and meridional velocity v) extended to 128W:

(Jason, model SSH)
The advantage of variational DA: **time-interpolation** of data
Ongoing efforts:

- a larger domain
- a better (2-km) resolution
- include the Columbia R. discharge
- include tides
- include assimilation of shelf mooring and glider T and S transects
- improved ini error covariance

**NS OOI gliders (starting in 2014, J. Barth et al.)**
SWOT data coverage (day 1-21):

(orbit info provided by C. Ubelmann, B. Chapron)
SUMMARY:

Variational DA: dynamically consistent data interpolation in space and time.

Assimilation of SSH: impacts velocities, T, S (in 3D).

SWOT altimetry: will be a revolution in ocean prediction (coastal, regional, global)