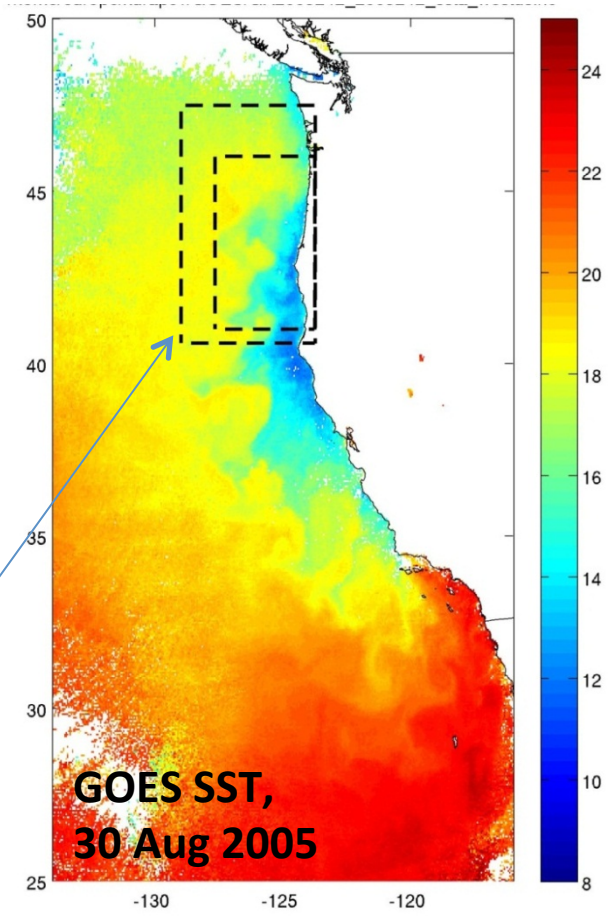
# Coastal-interior ocean flux estimates from a high-resolution data assimilative model

Alexander Kurapov,
College of Oceanic and Atmospheric Sciences
Oregon State University

*in collaboration with* P. Yu, S. Erofeeva,
P. T. Strub, G. D. Ebgert, J. S. Allen, P. M. Kosro,
D. Foley (NOAA-CoastWatch), L. Miller (NOAA)

***ONR*, *NOAA (incl. CIOSS support)*, *NSF***




*Our coastal ocean model domains*

**As seen in this satellite SST image, there is intensive exchange between coastal and interior ocean:**

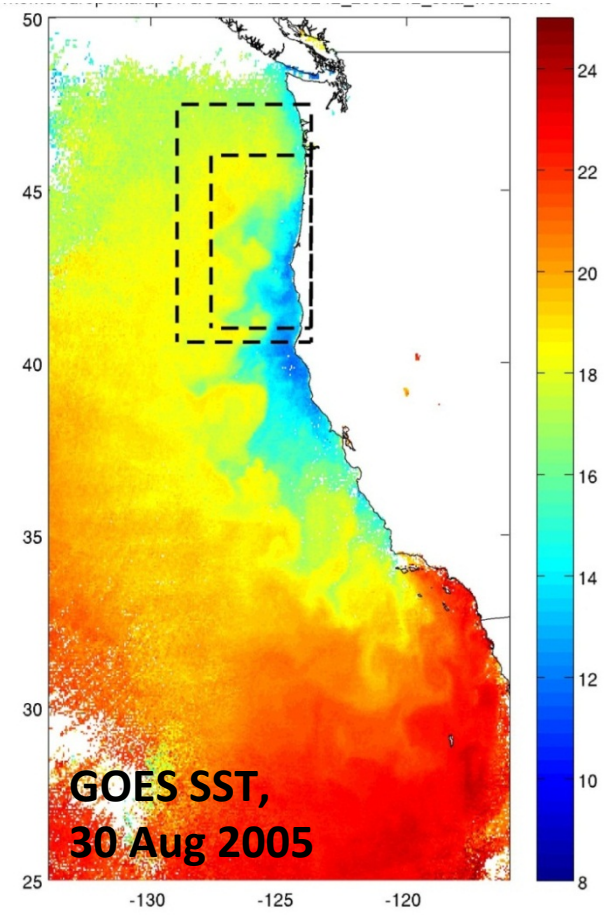
- volume, momentum, heat, material

Processes governing this exchange are generally not resolved by climate (global, coupled) models

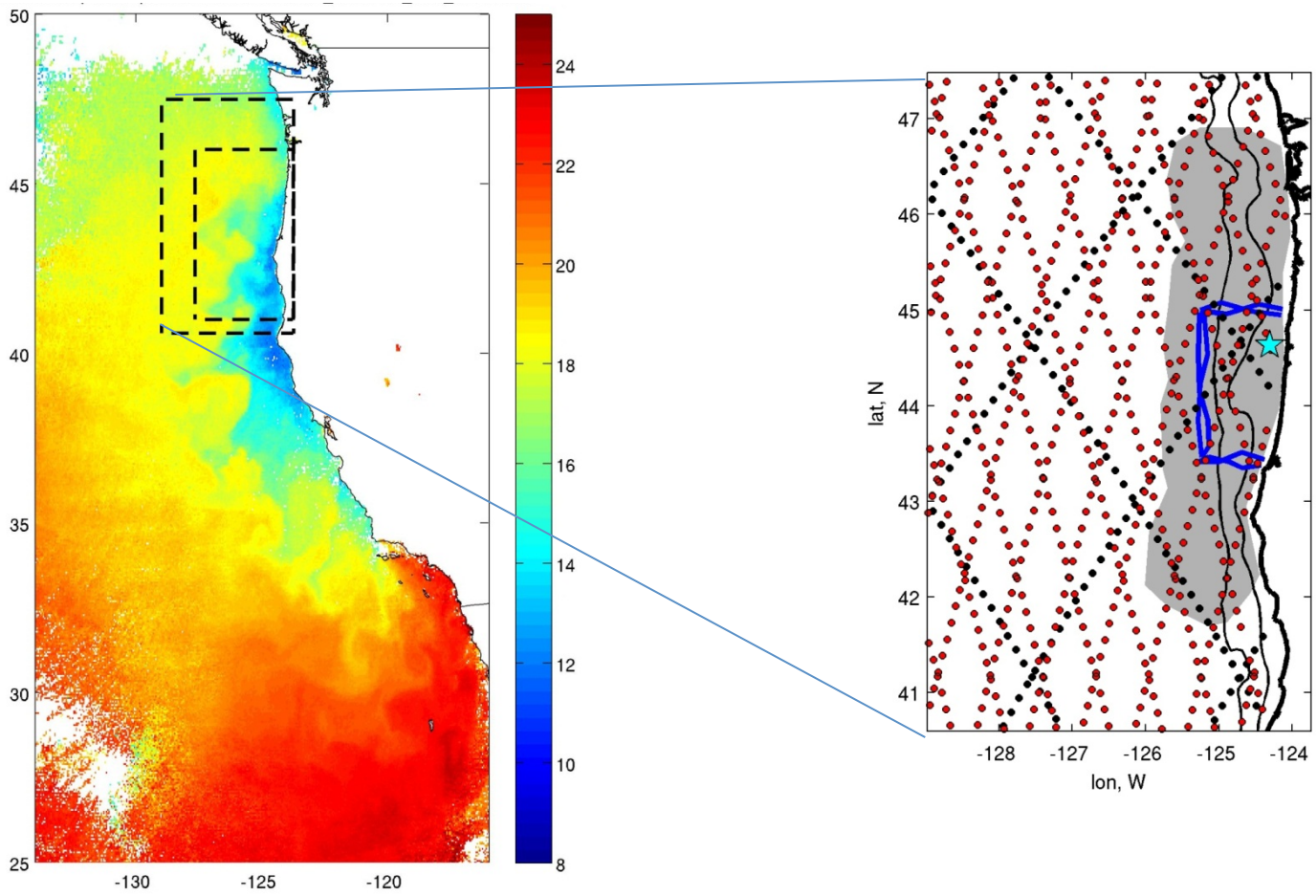
Regional models can provide estimates of the transports and exchange rates

Data assimilation =
synthesis of models and observations

⇒ improved estimates of the transports



**Assimilated data:** satellite SST, **HF radar**, along-track altimetry



**Model details (configuration for real-time forecasts):**

***(shown: forecast SST & SSH, Sept. 20, 2010)***

Regional Ocean Modeling System (ROMS)
400 x 800 km
3-km horizontal resolution, 40 vertical layers

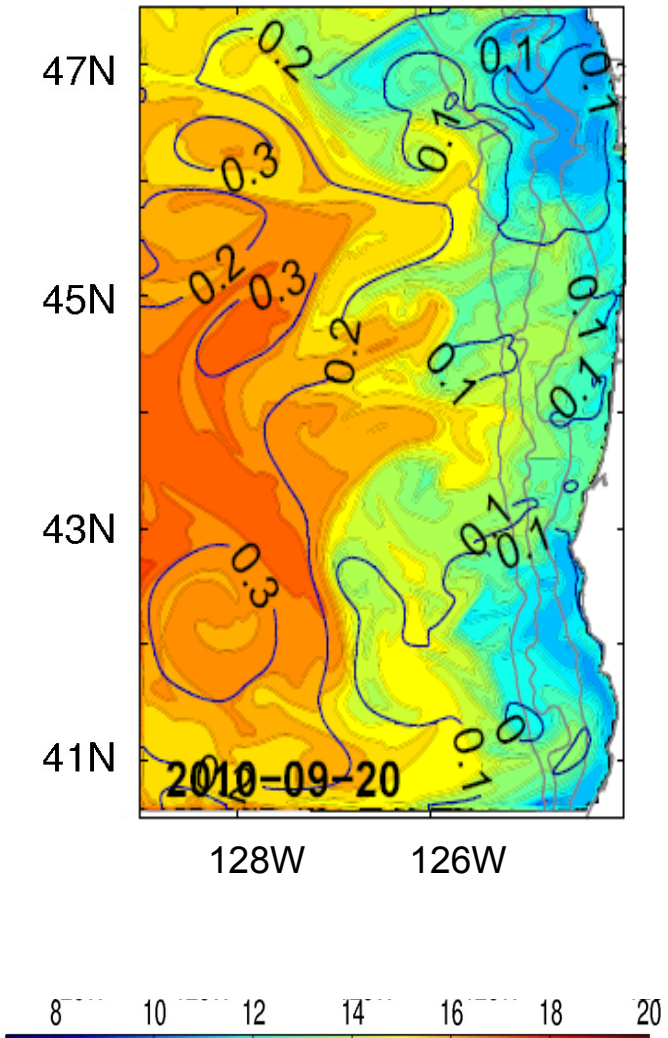
<u>Atmospheric fluxes:</u> NOAA –NAM forecasts

<u>Boundary conditions:</u> NCOM-CCS climatology

- Since 8/2010:
assimilation of HF radar surface currents
+ hourly GOES SST

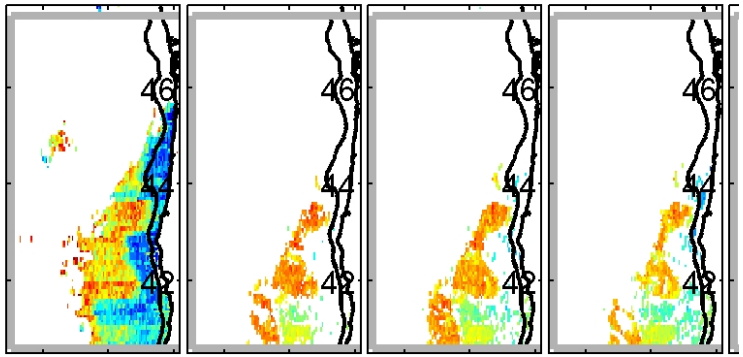
- Since April 2011:
assimilation of HFR currents
+GOES SS
+RADS alongtrack SSH

(assimilate at 6-km resolution, correction then interpolated to the 3-km grid)

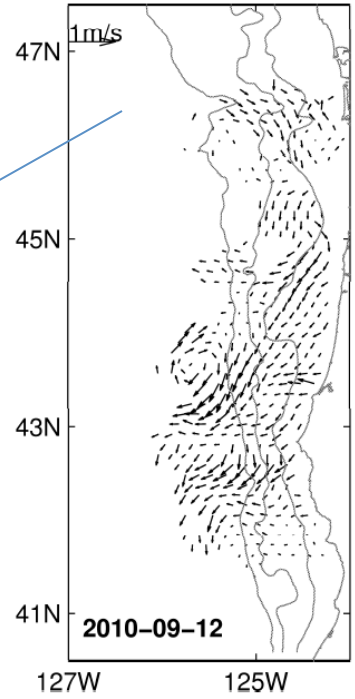


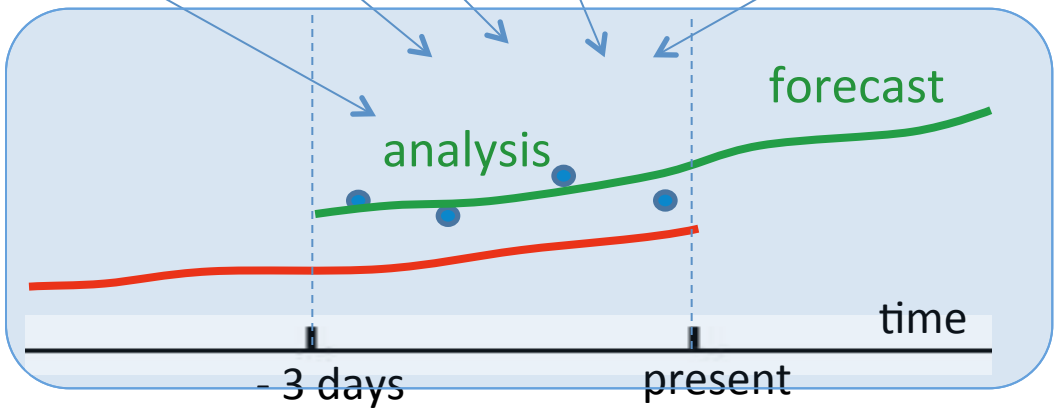
## 4DVAR = dynamically based time- and space- interpolation of data

*GOES hourly data*



*HF radar daily ave maps*




$$J(u) = (u(0) - u_0^B)^T C_0^{-1} (u(0) - u_0^B) + (d - Lu)^T C_d^{-1} (d - Lu) \rightarrow \min$$

$u(0)$ = {SSH, u, v, T, S}

$u^B$ : prior (background) state

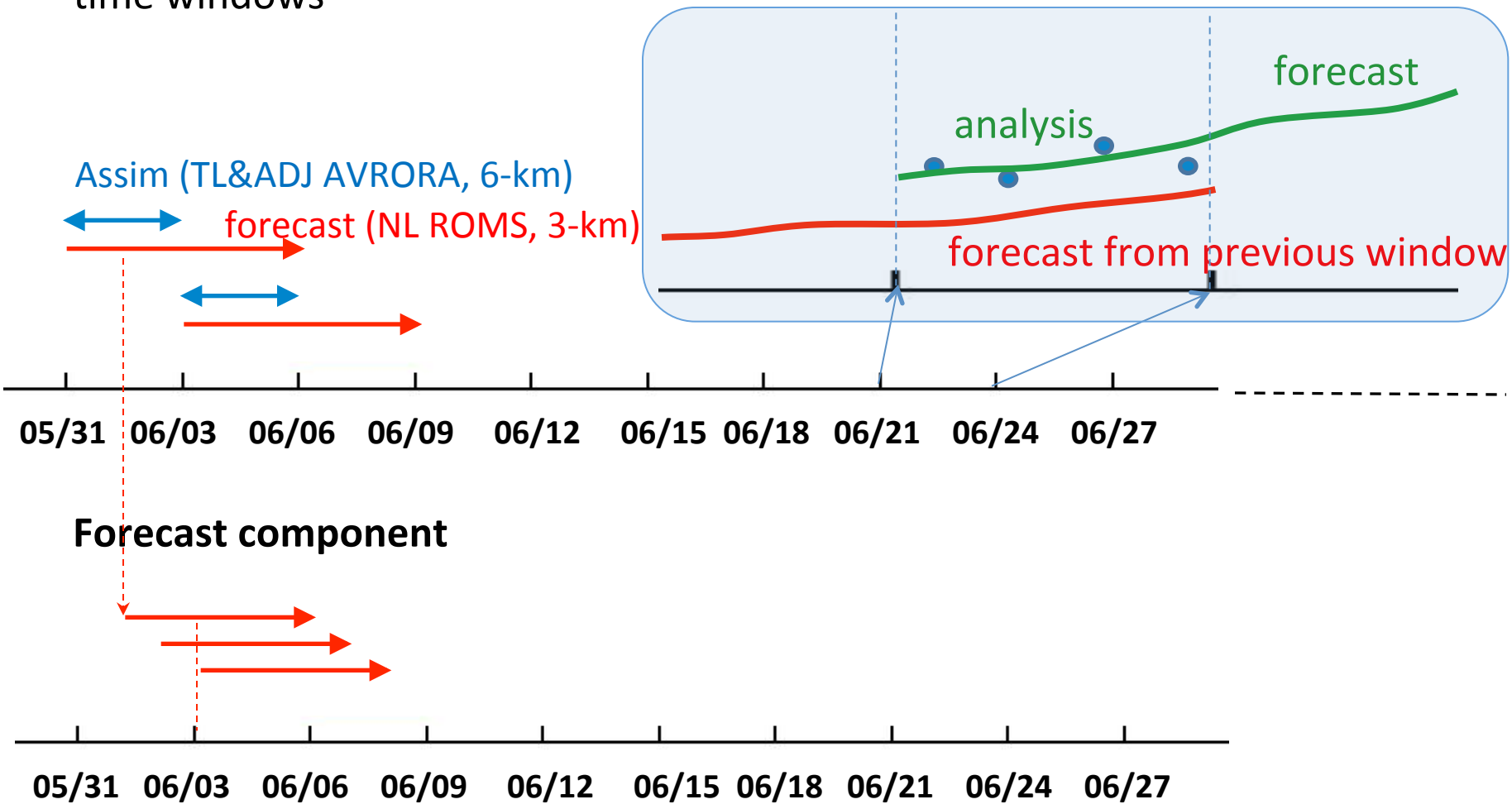
$d$ : data vector

$C_0$ : the initial condition error covariance

$C_d$ : the data error covariance

L : operator matching model output and the data (data functionals)

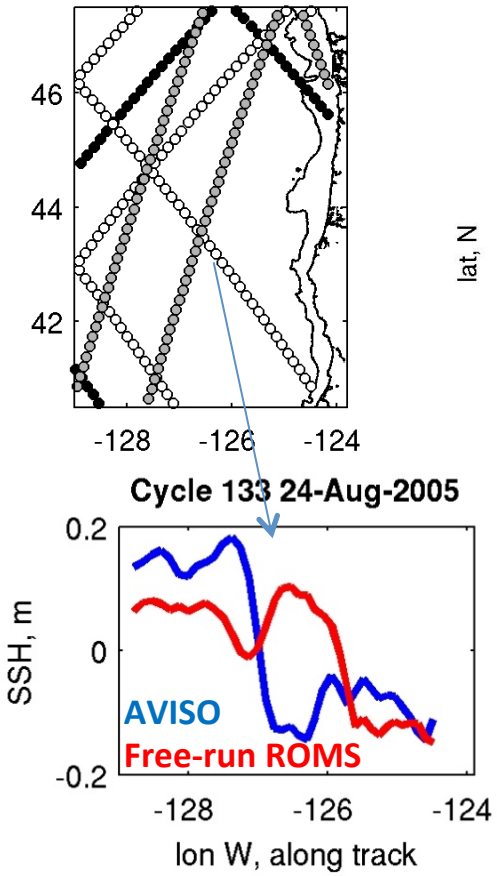
**Real-time coastal ocean forecast model:** variational DA in a series of sliding time windows



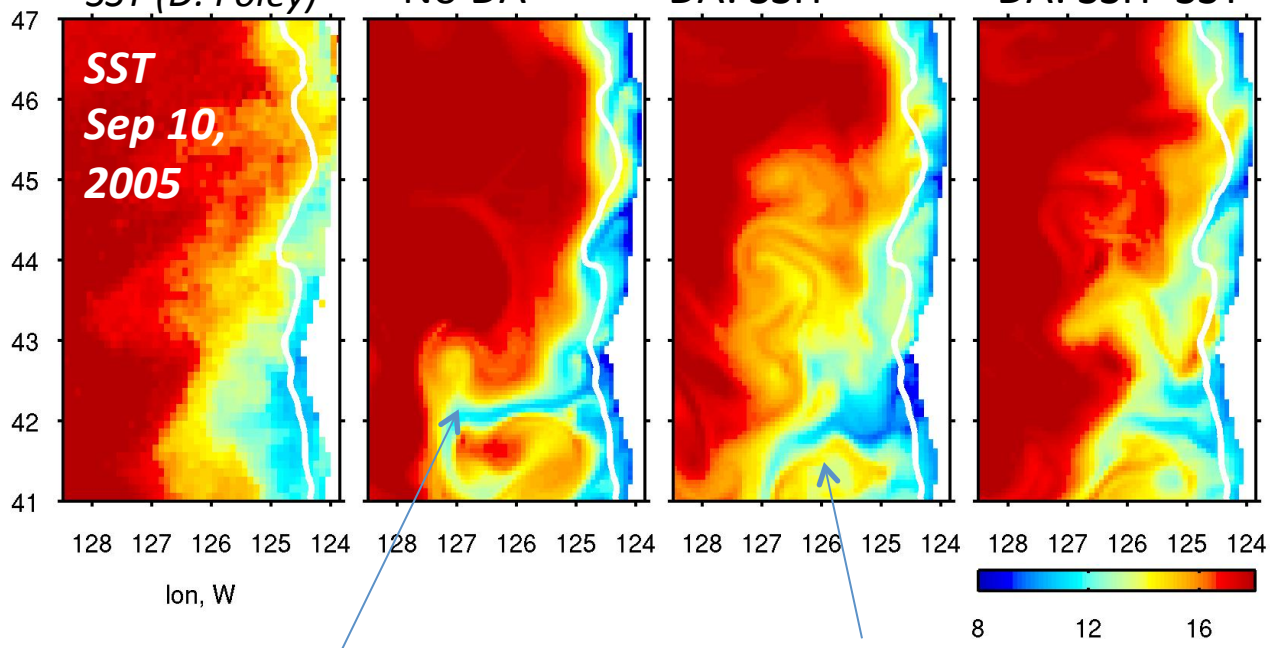
## Effect of SSH assimilation of near-surface transports

Along-track SSH assimilation improves the geometry of the SST upwelling front (Kurapov et al., JGR, 2011)

*Example of SSH data in a 6-day window*




*multisat. blended SST (D. Foley)*



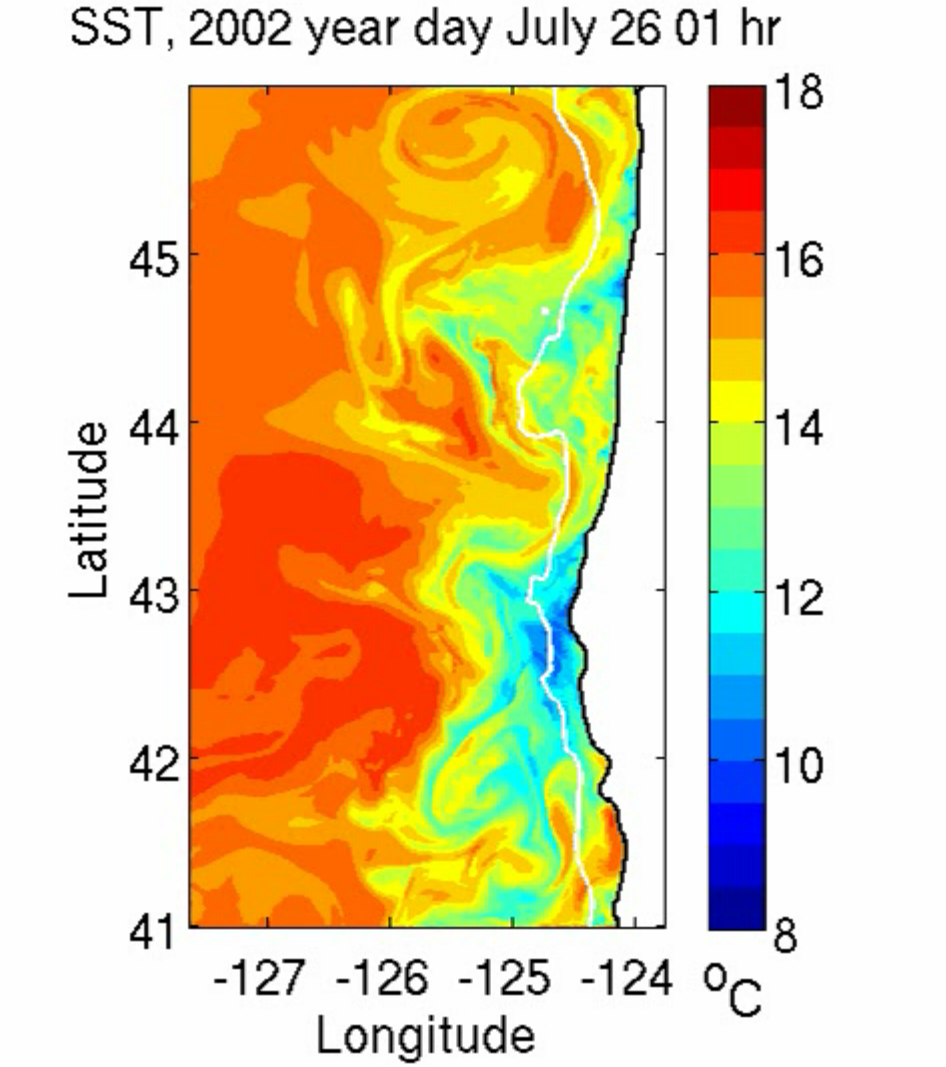

No DA: separation as a narrow jet

DA SSH: a wider area of colder water offshore transport (more comparable to observed SST)

**Qualitatively, westward front propagation in the 6-km DA model is similar to that in the 1-km free-run model**

Importance of smaller scales:

- flow over topography
- submesoscale dynamics
- high-frequency motions (incl. internal tides)



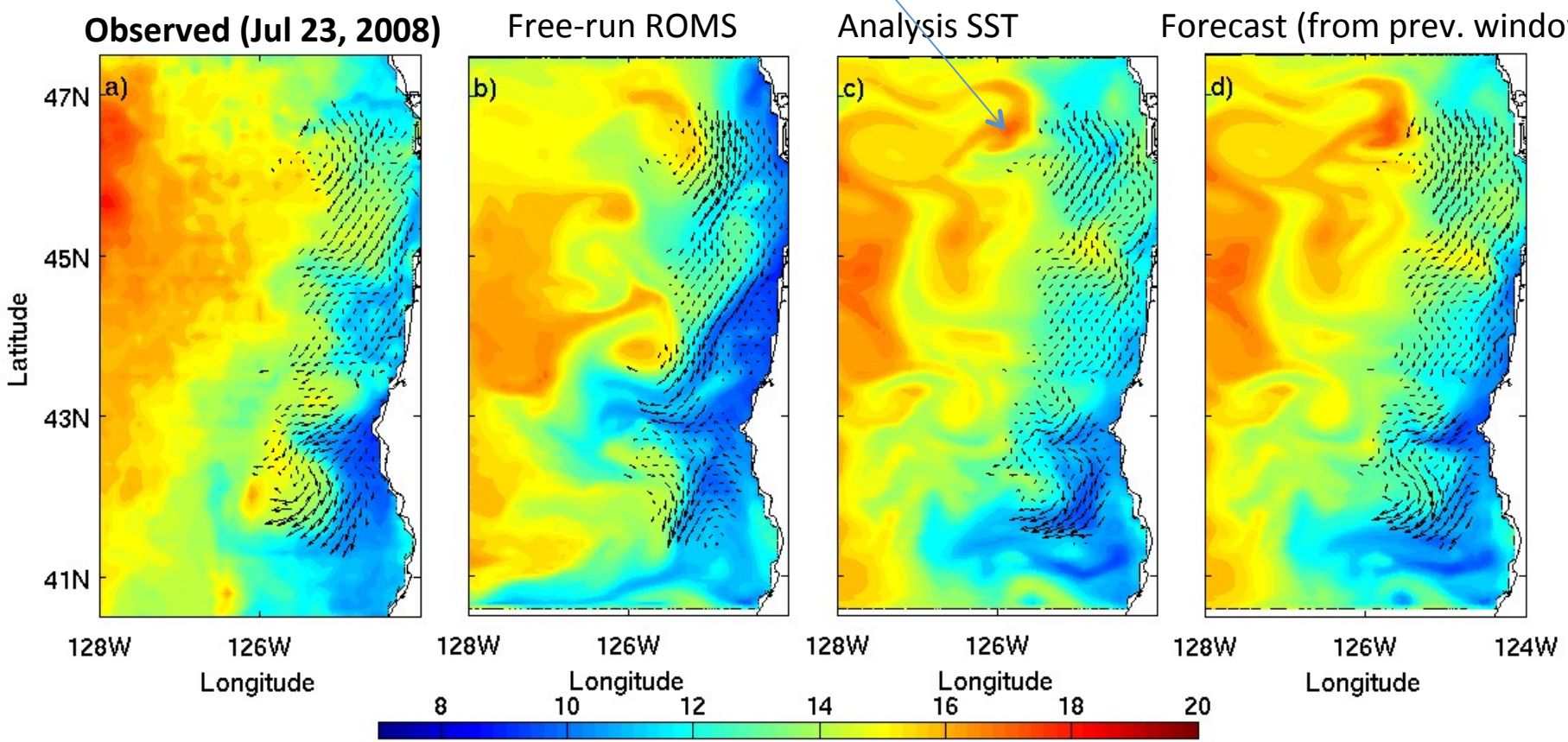

[model described in: ***Osborne, Kurapov et al., JPO, in press***]

**Impact of assimilated HF radar surface current data:**

(hindcast study, summer 2008, *Yu et al., ms in prep*.):

- **geometry of the SST front is improved**

(HFR currents are assimilated alone)

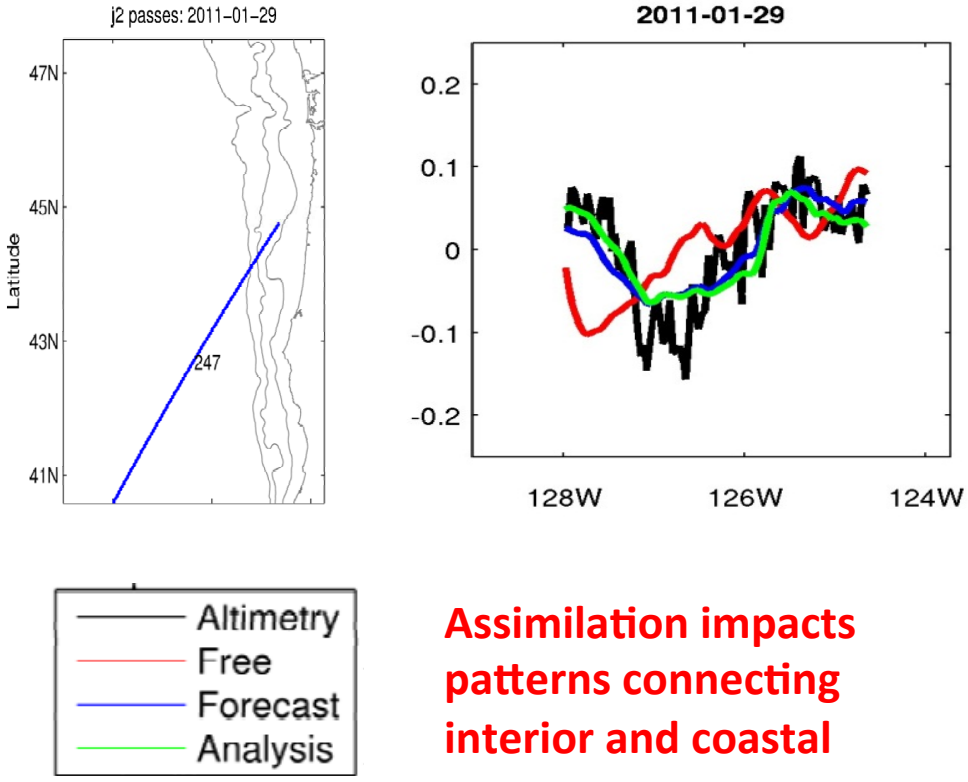



HF radar data: P. M. Kosro

**Assimilation of GOES SST + HF radar surface currents has helped to improve the slope of SSH (geostrophic currents)**

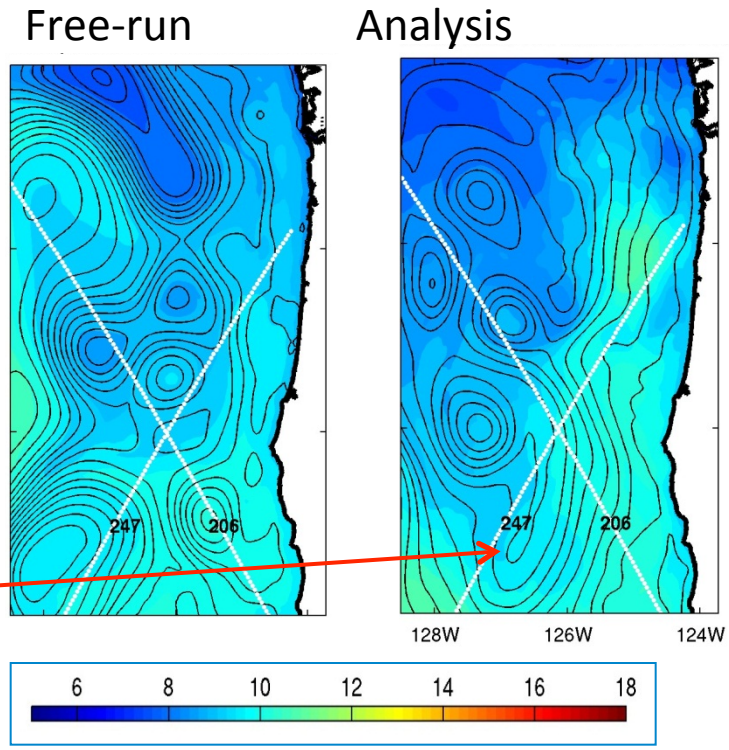
*(note: alongtrack SSH is not assimilated in this case, only used for verification)*

***SSH along J2 track 247:***




**Assimilation impacts patterns connecting interior and coastal ocean areas**

***Monthly averaged SST (color), SSH (contours) – January 2011***



# Data assimilation ⇒ Heat (as well as volume, momentum, material) is added or removed during re-initialization

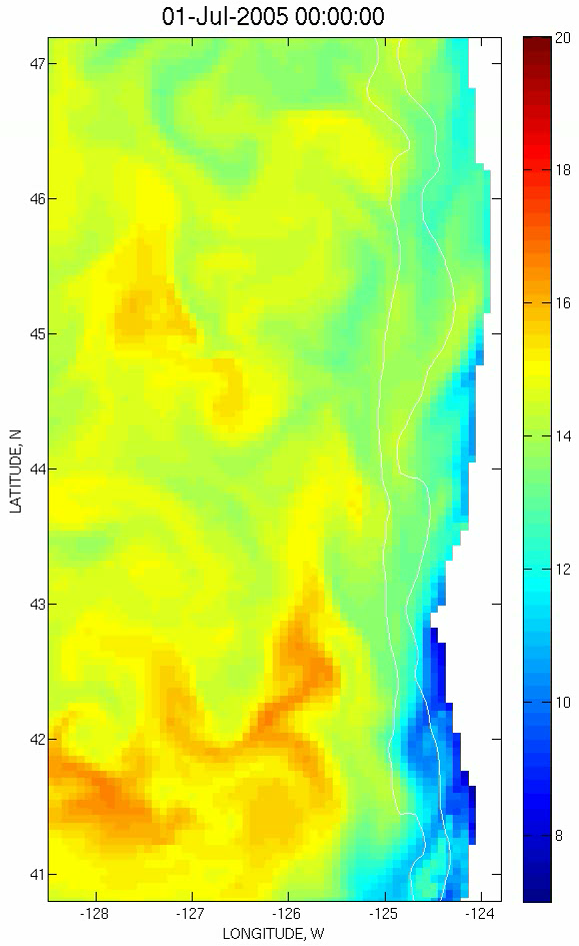
**DATA ASSIMILATION = MODELS + OBSERVATIONS**

**This model of coastal ocean circulation off Oregon has assimilated the sea surface height measured by 3 satellites (model state is corrected every 6 days to better fit the data)**

**Aplications:**
- **accurate estimate of shelf / interior ocean fluxes**
- **estimate of model errors**
- **short term (3-7 day) forecasts of ocean currents**

**Shown: sea surface temperature ($^{o}$C)**
- **Development of upwelling near coast in summer**
- **Offshore transport of coastal waters**

*(ocean bottom contours: 200 and 1000 m)*



**Volume-integrated heat equation:**

$$c_p \rho_\circ \frac{d}{dt} \int_V T \, dV =$$

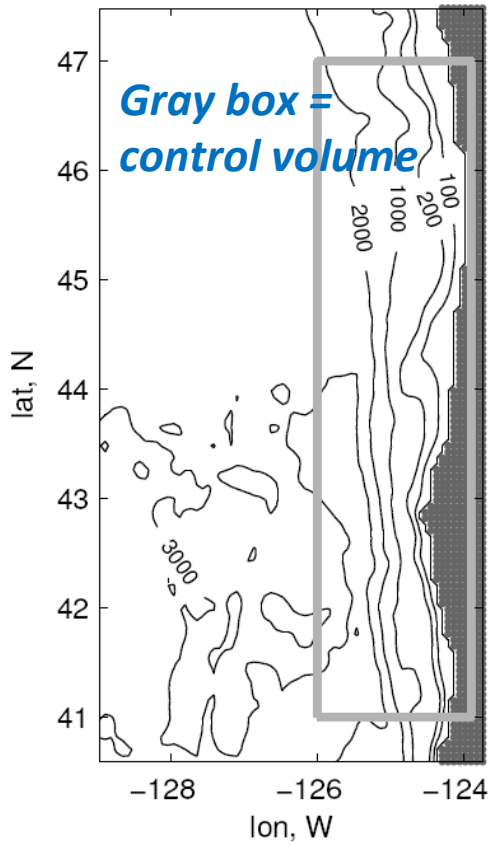
$$-c_p \rho_\circ \int_B T \mathbf{u} \cdot \mathbf{n} \, dB + \int_A Q_{atm} \, dA +$$

***advective flux through side boundaries***

***atmospheric heat flux***

$$+ c_p \rho_\circ \sum_k \delta(t - t_k) \int_V \delta T_k \, dV,$$

***series of instantaneous DA corrections at times $t_k$***



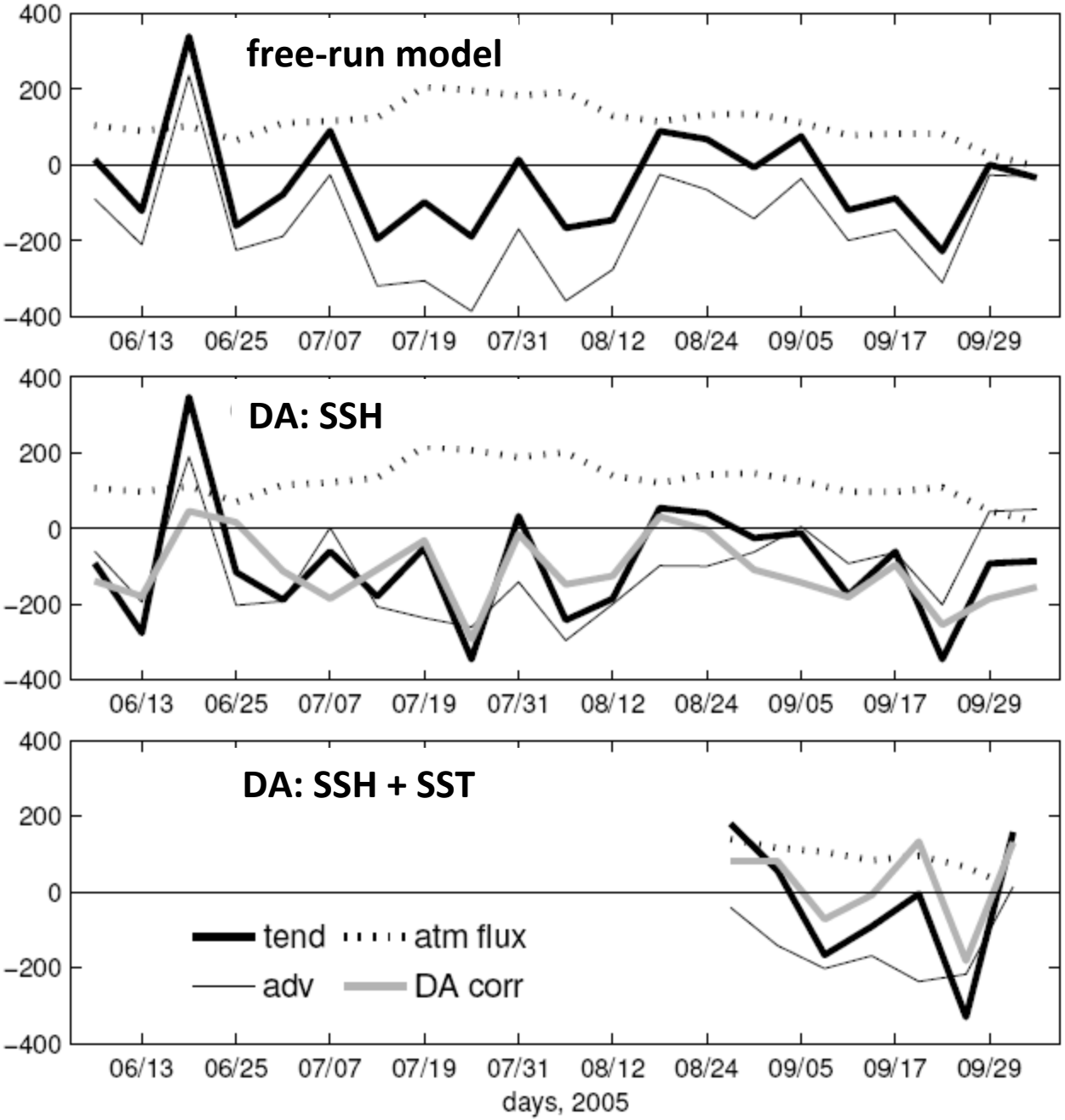

To present these terms, we average the terms over 6 day intervals, each centered on the time of correction

**Time-series of volume-integrated terms in the heat equation** (*scaled to obtain units of W/m²*)

- Variability in tendency is dominated by advection

-DA correction term is comparable in magnitude to other terms

- Correction term: DA SSH – cooling DA SSH+SST closer to 0 on average



SUMMARY:

4D variational data assimilation (DA) provides a tool for synthesis of data from different platforms, filling gaps, and filtering noise

Multivariate capabilities of DA:
- SSH assimilation improves the geometry of the upwelling front
- HFR surface current assimilation improves the geometry of the upwelling front
- Combined SST - HFR surface current assimilation

Alongtrack SSH, SST, and HF radar surface currents provide a constraint on the coastal-interior ocean transports

Estimates of the heat (and other) fluxes from a data assimilative model must be taken with caution, since heat is added or removed during re-initializtion.

Monitoring the DA contribution to the heat balances (e.g., bias, variance compared to other terms) is a useful metrics of a DA system performance

Simulations and analyses using high-resolution models help to understand the nature of the error in DA models