Mapping the ocean's surface circulation from altimetry

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Extended objective mapping

- The traditional objective mapping technique of Bretherton, Davis and Fandry (1976) is extended to include additional constraints
- We focus here on the development to the equatorial problem. The degeneracy of geostrophy there has long posed a problem for velocity estimation near the equator.

Beta geostrophy

- Start with normal geostrophy:

$$u_g = -\frac{g}{f}\frac{\partial \eta}{\partial y}$$

  - Leads to singularity at the equator as f -> 0.
- The traditional solution is to use “Beta Geostrophy” near the equator.
- Second derivative via L’Hôpital’s rule:

$$u_\beta = -\frac{g}{\beta}\frac{\partial^2 \eta}{\partial y^2}$$

Combining the two

- How do we combine the 2 estimates of velocity in a way that is continuous.
- Define a weighted velocity (Lagerloef et al. 1999):

$$u = -W_f \frac{g}{f}\frac{\partial \eta}{\partial y} - W_\beta \frac{g}{\beta}\frac{\partial^2 \eta}{\partial y^2}$$

- Where the weights are:

$$W_f = \frac{f^2}{f^2 + \beta^2 L^2} \qquad W_\beta = \frac{\beta^2 L^2}{f^2 + \beta^2 L^2} \qquad W_f + W_\beta = 1$$

Velocity equations

- The full equations for u & v become:

$$u = -\frac{1}{f^2 + \beta^2 L^2}\left(fg\frac{\partial \eta}{\partial y} + \beta L^2 g\frac{\partial^2 \eta}{\partial y^2} \right)$$

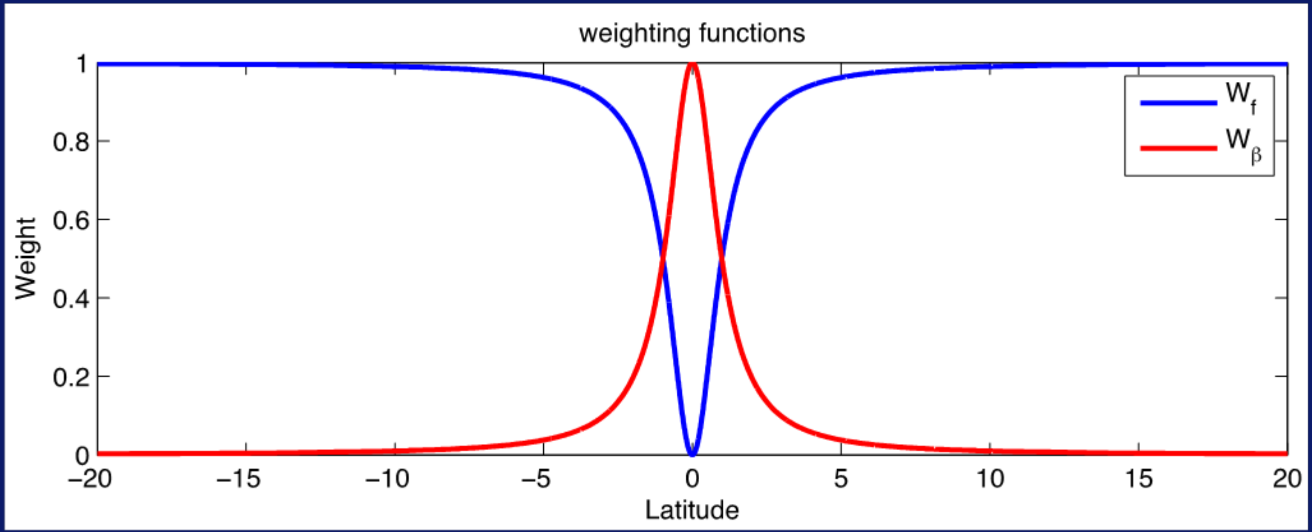
$$v = \frac{1}{f^2 + \beta^2 L^2}\left(fg\frac{\partial \eta}{\partial x} + \beta L^2 g\frac{\partial^2 \eta}{\partial x \partial y} \right)$$

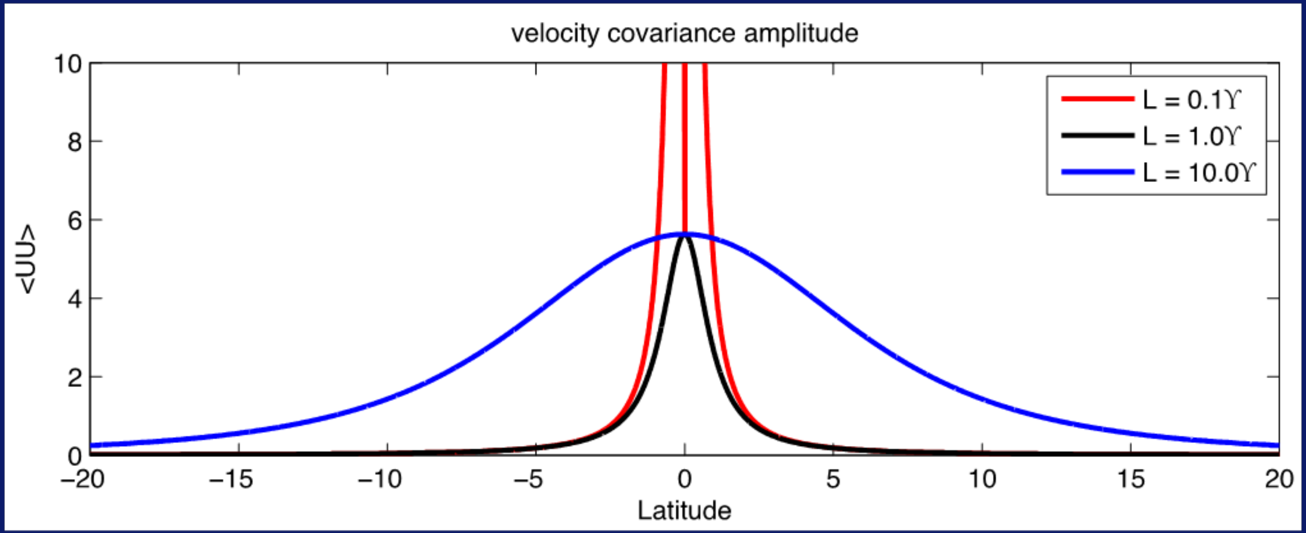
- There is no longer a singularity as f -> 0, and the velocity is finite at the equator.
- These relations are used to form the velocity and pressure covariance functions.

L

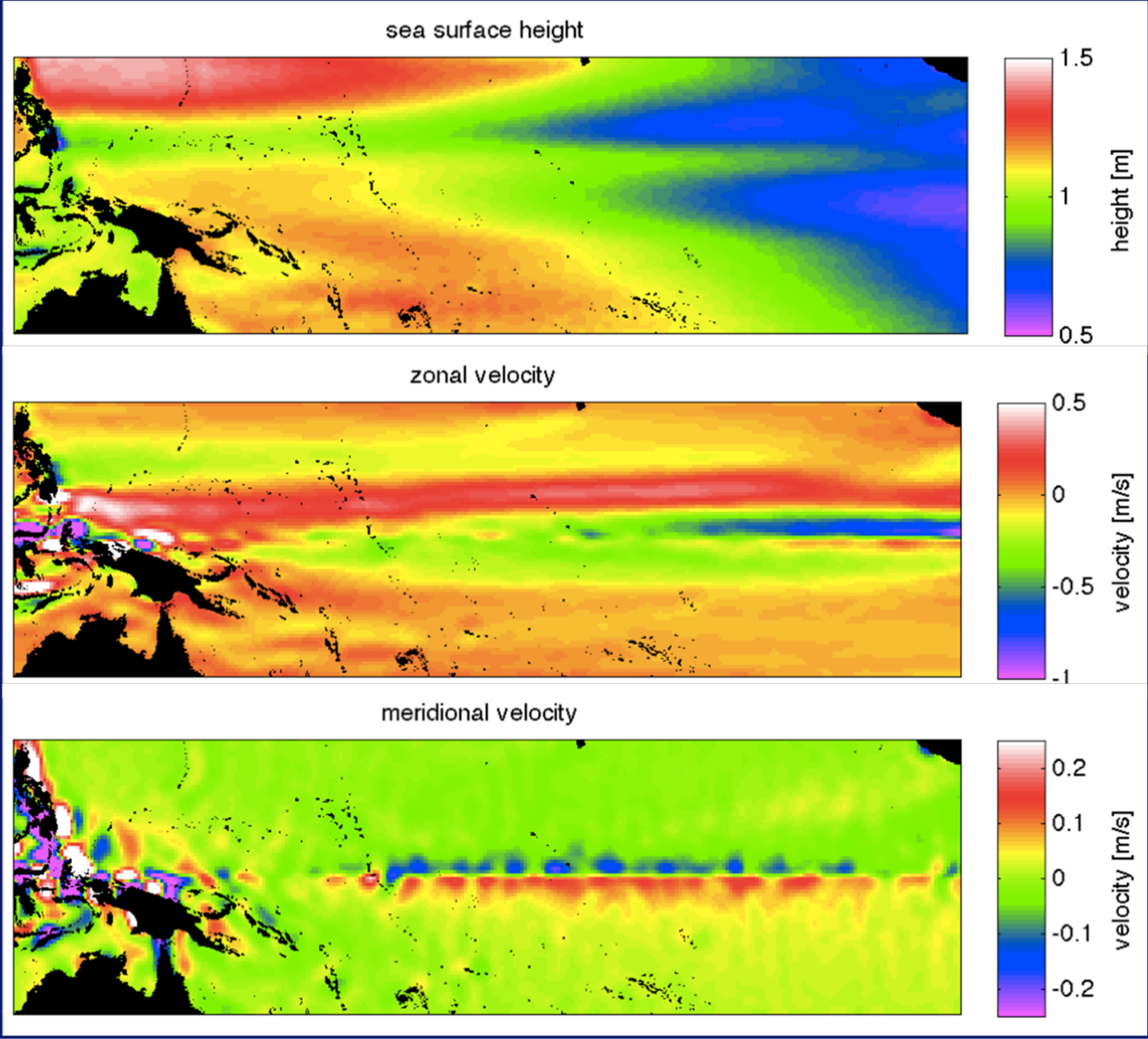
- What is the parameter L?
- Defines the meridional scale over which the beta geostrophic.
  - Too small a value leads to too large a signal covariance near the equator which leads to noisy estimates.
  - Too large a value leads to beta geostrophy being applied too far outside the equatorial zone.
- In practice L = 1° appears to work well.

Weight function and covariance





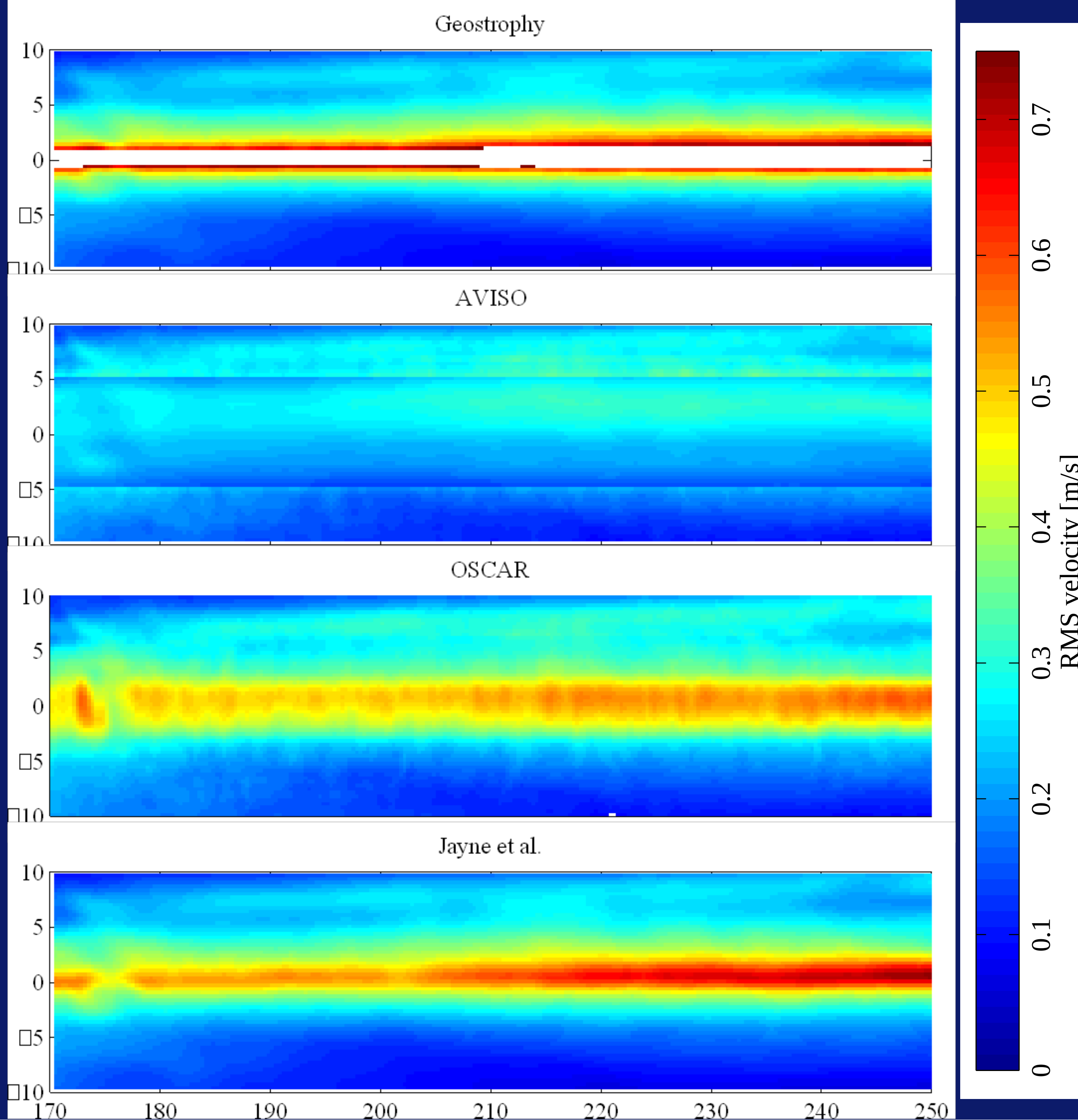
Mean surface velocity



Velocity variance

RMS velocity in the equatorial Pacific Ocean:

1. Using classic geostrophy
2. As in AVISO (note discontinuity at ±5°)
3. OSCAR
4. This methodology

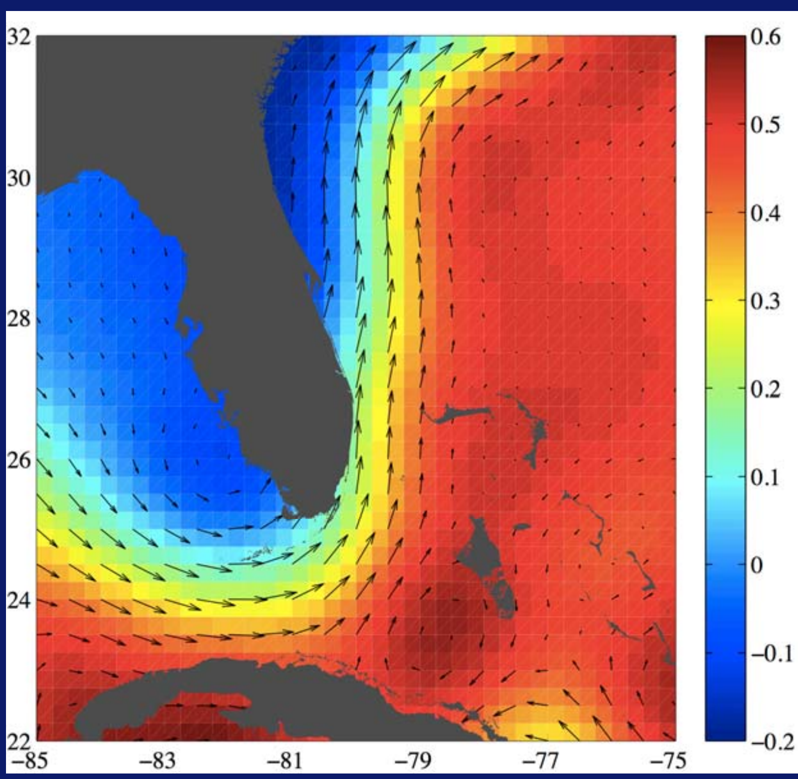


Constraint on flow thru topography

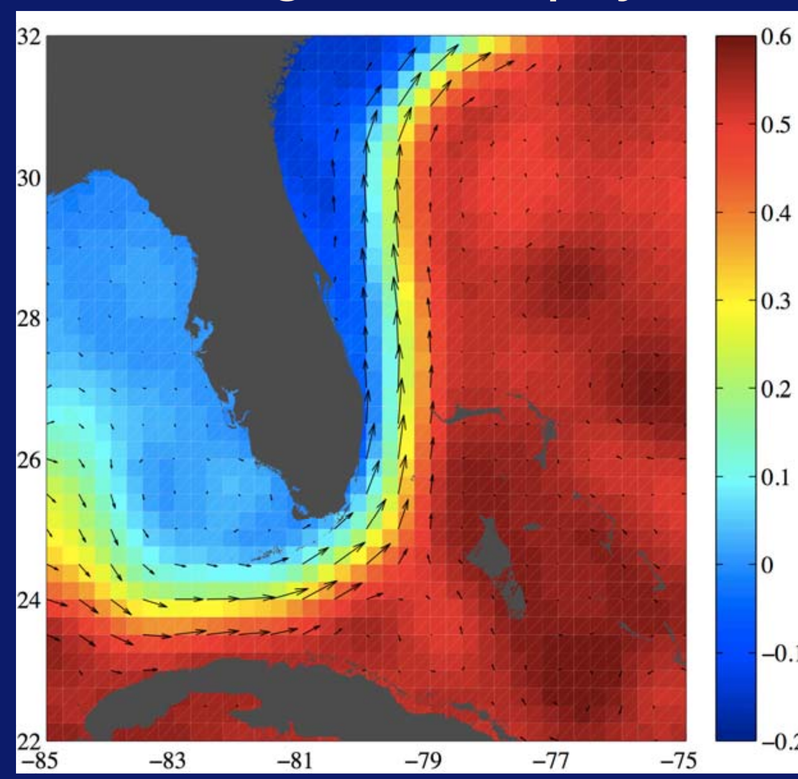
- There is a long-standing problem with dynamic ocean topographies calculated from sea surface height and the geoid
- Omission of the short wavelengths in the geoid create strong gradients at the coast where there is a sharp cutoff
- The primary constraint we will use is a soft constraint limiting flow *normal* to topography but leaving the *tangential* flow unchanged

The Florida Current

Computation of the velocity directly from the dynamic ocean topography yields unphysical flow into and out of the coastline.



The addition of a soft constraint for no normal flow through the coast modifies the calculated velocity field, rendering it more physical.



Other constraints & considerations

- Decorrelation of observations blocked by topography has been implemented
- Ageostrophic pressure gradient along the equator
- Revisiting the Ralph & Niiler drifter Ekman layer correction to accommodate the equator
- Efficient algorithms for global estimation

Summary

- Demonstrated an extended objective mapping technique that shows promise
- Velocity data has important value
- The goal is to have a physically realistic estimate of the upper ocean circulation, pressure, and tracer fields that relies strongly on the data and weakly on the underlying model