Using multiple tracers to improve submesoscale signal

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More than altimetry

Different datasets exist at the same time
- ex: SST and SSH
  - SST and Geostrophic kinetic energy
- ex: SSS and SSH
- different SST products at different resolutions between mars 31 and april 2: 10 images

⇒ More insight on dynamics compared to 1 sensor only
⇒ Extract “balanced” motions
Salinity (SMOS) and velocity (altimetry)

SMOS SSS (color) + currents (vector) from 04/06 to 18/06 2012

- Cold and Fresh slope & shelf waters
- Warm & salty eddies
- Labrador current
- Cross-frontal exchanges
- Cold & Fresh eddies
- Warm and Salty Central Atlantic Waters
- Gulf Stream
**SWOT at scales below 50km**

- SSH variance at large scales (1000km)
- SSH error only at small scales (10km)
  
  with weak influence on total signal
SWOT at scales below 50km

- Kinetic energy ($KE = k^2 |SSH|^2$) at all scales: preferentially at mesoscales, but also at submesoscale
- Significant error at submesoscales with important contribution on total signal

SWOT signal alone not sufficient for scales below 50km? ⇒ Need to use different sensors to improve signal ⇒ Assimilation of these different datasets
Ex: Surface Quasi-Geostrophy

No potential vorticity anomalies (Blumen, Held...)
⇒ solution in Fourier space

\[ \widehat{SSH} = \gamma \frac{\widehat{\rho}_s}{|k|} \] with \( k \) horizontal wavenumber

\[ \widehat{SSH} \approx \alpha \gamma \frac{\widehat{SST}_s}{|k|} \quad \text{if} \quad \rho_s \approx \alpha \ SST \]

\[ \widehat{\psi}(k, z) = \widehat{\psi}(k, z = 0) \exp(N|k|z/f_0) \]

- horizontal and vertical motions from geostrophy and frontogenesis equation

valid down to 15km and 400m depth (Lapeyre et al. 2006)
Reconstitution of vorticity field at surface (Klein et al. 08)

- Relative vorticity \( (s^{-1}) \)
- SQG prediction
How to reconstruct submesoscale SSH?

- SSH and horizontal velocity signal at scales larger than 100km
- High resolution SST with gaps (clouds)
- AMSRE SST at low resolution

Reconstruct submesoscale SSH from
- submesoscale SST (Lagrangian tracer)
- Surface Quasi-Geostrophy
How to create submesoscale tracers?

- Evolution of patches of tracer in mesoscale eddy field

\[ \frac{\partial C}{\partial t} + u \cdot \nabla C = 0 \]

- Lagrangian advection of tracers allows filamentation

- Low resolution tracers ⇒ high resolution at later time
**Lagrangian technique: “Reverse Domain Filling”**
used in atmospheric sciences since 1994

Equivalence between

\[
\frac{\partial C}{\partial t} + \mathbf{u} \cdot \nabla C = 0 \quad \text{and} \quad \frac{D\mathbf{x}}{Dt} = \mathbf{u}(\mathbf{x}, t) \quad \frac{DC}{Dt} = 0
\]

Reverse Domain Filling (RDF)

- Step 1
  Run a back trajectories starting with a regular gridded array
- Step 2
  Interpolate observations to back trajectory points
- Step 3
  Copy values forward to regular grid
Infrared SST at 1km

Microwave SST at 80km

from low-resolution SST

velocity from SSH
(by geostrophy)

Lagrangian SST
Test in idealized numerical simulation

tracer advected by low-res SSH

SST gradients

relative vorticity
Future work

Potential for new inversion techniques to improve SWOT signal at submesoscale (e.g. relative vorticity)

- Advection of SST by SWOT or NADIR altimetry \( \Rightarrow \) submesoscale fronts in SST

- Use dynamical models to assimilate Microwave/Infrared SST and SWOT SSH to improve submesoscales

- Surface Quasi Geostrophy (relating \( (u, v, w) \) to SST and SSH) could help to infer vertical motions
Is there a dynamical link between SST and SSH at meso and submesoscales?

- Improve SSH at 1km using SST at 1km and SSH at 50km?