Lateral stirring of surface tracer fields by satellite altimetry

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Lagrangian lateral advection with altimetric geostrophic velocities can be used to stir large scale tracer fields at the ocean surface, and reconstruct mesoscale fronts and eddies.

Technique tested in the energetic N. Atlantic (Despres et al. 2011) & Southern Ocean region south of Tasmania (Dencausse et al., 2013) & in the tropical and subtropical Pacific Ocean (Rogé et al. 2014)

Discussion implications for SWOT – technique & validation
Technique: passive horizontal stirring of tracer fields with altimetric velocities.

- Lagrangian advection in 3 stages:
  - **Initial conditions**: large-scale gridded tracer field (CORIOLIS in-situ or SMOS)
  - **Calculate advection field** from altimetric currents, interpolated onto a fine-scale grid (AVISO / DUACS currents)
  - **Validate with ORE-SSS TSG data** and satellite SST data

*Despres et al. 2011; Dencausse et al. 2013; Rogé et al., 2014*
Validation data

4 zones tested:

1) W tropical Pacific
2) Subtropical S Pacific
3) E tropical Pacific
4) Southern Ocean

1) ORE-SSS Ship Themosalinograph (TSG) data

2) 2D- AMSRE- satellite SST data
Lagrangian advection with altimetry

Illustration of fine scale development

Coriolis Initial Conditions

Coriolis at T-6 days

Coriolis at T-13 days

Coriolis at T-27 days

Advected fields of Coriolis SST

AVHRR SST

Coriolis SST
Choice of advection time: tracer fields advected with altimetry

Ex: Southern Ocean region:

- **Coriolis** – weaker energy at all space scales
- Satellite **AMSRE-AVHRR**
  - similar energy > 300 km
  - AVHRR > AMSR-E at shorter scales

- Coriolis fields advected with altimetry – fine-scale energy increases with advection time

But is it realistic?

~ 14 days is a good compromise
2-way advection to reduce bias

Technique only uses passive stirring of the tracer field

With increased advection times, biases are introduced due to missing physics (air-sea fluxes, mixing, diffusion, …)

• 2-way method reduces overall bias
• Intermediate filtering needed – can lose data close to coasts

Comparison with in-situ TSG data

South of Tasmania

(Dencausse et al, in prep)
Interannual changes in SW Pacific SST structure

Westward propagating mesoscale SST structures recreated by altimetric stirring

ICs: CORIOLIS  1-way 10d advection  2-way 10d advection  AMSRE SST
Interannual changes in Eastern Pacific SST structure

ICs: CORIOLIS
1-way advection
2-way advection
AMSRE SST

Red: Hovmöller line
Black contour: AMSRE front
=> 1- or 2-way geostrophic stirring shows no real improvement

Fast TIWs in AMSRE data not observed with altimetry & so not recreated
Correlation mesoscale SSH - SST

Technique works well in regions with a good SSH-SST mesoscale correlation

SSH, SST filtered 70-250 km

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Implications for SWOT

- Temporal evolution of the larger mesoscale signal (AVISO/DUACS maps) can be used to reconstruct finer scales at mid latitudes … used for any surface tracer field (SST, SSS, nutrients, carbon, …)
- Only the fronts/filaments generated by geostrophic convergence are represented - not filaments generated by other processes.
- Works well in regions where SSH-SST mesoscales are well correlated
- Need to explore additional dynamics in tropical and high-latitude regions (Ekman, ML frontogenesis, …)
- Same caveat for dynamical interpolation and sQG … tests are needed in different dynamical regions…
Thank you
Finite-Time Lyapunov Exponents (FTLEs):

$1/\tau$ : For a finite time of 15 days, measures the rate of separation of lagrangian particles, based on altimetric velocities.

Typical advection times:

- $0.2 = 5$ days
- $0.1 = 10$ days,
- $0.05 = 20$ days

~ 10 - 14 days

Waugh & Abraham, GRL 2008
2) Difficulties with validation

Many in-situ observations measure surface mixed layer processes at specific depths (TSG – (SST, SSS, 5-15 m), surface drifters (15 m), mooring data, ADCP currents, …)

Altimetry (nadir & SWOT) measures surface slopes & geostrophic currents – can respond to deeper signals

⇒CalVal for SWOT, and validation of SWOT-derived currents, will need careful work to understand mixed-layer vs depth-intergrated geostrophic processes.

Thank you!