Preparing for future fine-scale ocean observations of surface topography and surface currents

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Altimetric surface currents usually calculated from mapped sea surface height fields using the geostrophic approximation:
- Includes the $\beta$-plane approx across the equator (Picaut, Lagerloef, etc)
- Can include a cyclogeostrophic correction (eg Penven)

Satellite total current products often combine mapped altimetric geostrophic currents with « ageostrophic » Ekman, SST gradients, Stokes drift, etc.

Mapped SSH data only detects larger mesoscale processes (> 200 km, > 15 days)

J. Sudre
Altimetry tracks deep-reaching eddies and currents

Altimetric SSH reflects the surface pressure field – responds to depth-integrated ocean changes

Large mesoscale eddies can be tracked for years across ocean basins with altimetry

Colocated altimetric geostrophic currents and Argo data in South Atlantic

Eddy’s core subducts under warmer subtropical waters, but deep signature is still tracked by altimetry

Surface currents reflect the mixed layer processes – may be very different

Laxenaire et al. 2019 JGR (in revision)
Limits of nadir altimetry for surface currents

- Provides 1-D SSH slices across ocean dynamics
- Large distances between groundtracks.
- Instrument noise hides structures < 70 km (Jason-class) and 35-50 km (Saral or Sentinel-3) \cite{Dufau2016, Vergara2019}
- Interpolation for 2D mapped data: structures > 200 km \cite{Chelton2011}
- Not observing small, rapidly evolving ocean dynamics – high latitudes, coasts and regional seas nor ageostrophic motions
From SSH gradients to currents & vorticity

Chelton et al, PO, 2019

Modelled 500 m resolution

Snapshots of SSH, Current Speed and Vorticity in Rotated Model Coordinates
(ROMS Model with 0.5 km x 0.5 km Grid Resolution)

AVISO resolution

Space-Time Smoothed SSH, Current Speed and Vorticity Present Capabilities from AVISO SSH Fields
(Geostrophic with 200 km x 1 month Smoothing)
Key seasonal ocean processes from 20-200 km

Mesoscale processes
Horizontal Transport & mixing
(Heat, carbon, nutrients)

(Sub) mesoscale Fronts & eddies
50 % vertical transport
Predominant in deep winter mixed layers
Ocean Scientific objectives

• The primary oceanographic objectives of the SWOT mission are to observe the 2D ocean mesoscale and submesoscale circulation at spatial resolutions of 15 km and larger, providing the missing link between 15 and 200 km for ocean climate studies.

• The mission is also designed to observe coastal/estuarine dynamics and tides, and high-latitude tides and internal tides, important in the ocean’s energy budget, and for ocean mixing & dissipation

Technological objective - set a new standard for future altimetry missions. (2D fields, lower noise)
SWOT - 2D measurement of surface water topography

Ocean Data Products:
(after onboard processing)

- Basic oceanographic SSH product (2 km posting / resolution) over 50 km wide swath (0.6 GB/day)
- Expanded products (2 km):
  - Full corrections (2.4 GB/day)
  - Wind/waves/\sigma_0 (0.6 GB/day)
- Expert high resolution product: SSH & SAR images (250m posting / 500m resolution) (37 GB/day)
Synergestic use of SWOT’s 2 km SSH & 250 m backscatter for surface current detection

Gulf Stream simulation

Simulated SWOT SSH & currents (left)
Backscatter & currents (right)

Credit: Ifremer
Resolution of SSH (& currents) above the noise

SWOT’s effective resolution depends on sea-state (signal > noise)

Wang & Fu, JPO, 2018

These structures will not be observable everywhere
→ depends on measurement noise & sea-state
Barotropic tides in SSH & improved tidal currents

Swot will provide 3 yrs of improved SSH and tidal currents – like tide gauges at 250 m resolution

Coastal tidal currents
High-latitude tidal currents (ice-free zones to 78° latitude)

=> Improved tidal currents for in-situ currents & all other satellite missions (eg nadir altimetry, SKIM, ADCPs, ...)

Assessment of the FES2014 Tidal Currents on the shelves around Australia, Cancet et al., 2017
Internal tides occur at scales < 200 km in SSH, and can dominate in low energy regions.

Ocean stratification changes or currents & eddies can scatter internal tides → incoherent (unpredictable).

**Challenge**: Internal tides to be removed before calculating geostrophic currents. Coherent (predictable) internal tides may be corrected. How to remove incoherent tides?

**Opportunity**: Interaction of mesoscale & internal tides → mixing & dissipation.

**Modelled coherent internal tides**

**Transition scale (km)**: where balanced motions dominate IGWs in $k$-spectra.

Qiu et al., 2018, JPO

J. Shriver

Altimetric SSH includes baroclinic tides
SWOT and fine-scale surface currents

- SWOT observes SSH and SAR images ... need careful processing to remove noise, and separate coherent & incoherent internal tides

- Expecting good observations of anisotropic 2D structure of small mesoscales, and derived balanced currents, vorticity and strain

- Balanced flow currents can be derived from SSH gradients down to 15-40 km wavelength, depending on SWH conditions & internal tide/waves editing. Complementary to SKIM total surface currents

- SWOT will provide greatly improved tides and tidal currents after 3 years ... useful for all past and future missions & model validation

- SWOT will provide unique observations of the interactions between balanced flow and internal gravity waves (incl internal tides)

http://swot.jpl.nasa.gov

- SWOT science team will be renewed soon – next ROSES/TOSCA call in June 2019
Ocean Data Products:
- basic oceanographic SSH product (2 km resolution/posting)
- Expanded low resolution product – full corrections, wind/waves (2 km)
- expert high resolution product: SSH & SAR images (500m resolution/ 250m posting)
SWOT orbits

Nominal Launch date: Sept 2021

First 6 months: 1-day orbit:
  1st 3 months – instrument checkout
  2nd 3 months – mid-Dec to mid-Mar 2022 – Science orbit
  ➢ Ideal for ocean studies of rapidly evolving small mesoscales and submesoscales

3-year 21-day repeat orbit
Nominally: Mar 2022 to Mar 2025
Full global coverage
1-day and 10-day sub-cycles for better mesoscale coverage

Global coverage to 78° latitude
Applications of SWOT SSH (global: pixels at 250 m / 2 km)

2D surface height images for ...

Meso & sub-mesoscale ocean SSH & currents
Coastal SSH & currents
High-latitude Currents in leads & Sea Ice Freeboard

Coastal, high latitude & Internal Tides & Internal waves

250 m open ocean Bathymetry
Currents derived from altimetric sea surface height (SSH)

Altimetric SSH reflects the surface pressure field – responds to depth-integrated ocean changes:

- Large scale ocean circulation, ENSO, Planetary waves, large mesoscales

Surface currents/jets in the surface mixed layer may be spatially offset from depth-integrated gradients detected by altimetry

Oceanographers need to understand both