Mesoscale resolution capability of altimetry: present and future

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Abstract

Wavenumber spectra computed from along-track Sea Surface Height Anomalies exhibit linear slope between large and small scales linked to the geostrophic turbulence and its energy cascades in the mesoscale band (Le Traon et al., 2008). At small scales, altimeter measurements are affected by instrumental noise preventing the observation of small scales processes. This paper determines the length scales of ocean dynamics following DOG theory reachable with along-track 1Hz altimeter data. It relies on a joint analysis of (i) the spectral slope in the mesoscale band and (ii) the noise level observed for scales lower than 20km. Maps of mesoscale capability of the on-flight altimeter missions (Jason-2, SARAL/Altika, Cryosat-2) are discussed at global scales. Finally, a prediction of the future 2D mesoscale resolution capability of the SWOT mission is computed using a simulated SWOT error level.

Methodology

The mesoscale capability of an along-track altimeter 1Hz data depends locally on its small-scales error level and on the mesoscale spectral slope (geostrophic turbulence cascade theory).

The geographical description of this mesoscale capability relies on SSH wavenumber spectral characteristics of on-flight altimeter missions. SSH is corrected from all altimeter corrections and from the Mean Sea Surface CNES-CLS 2011.

Wavenumber spectra are calculated following Le Traon et al. (1990) from March to October 2013 and averaged over 10°x10° boxes as Xu and Fu 2011, 2012. A SSH wavenumber spectrum obtained in one of these boxes is illustrated in black in Figure 1.

At high wavenumbers, between 20km and 12km, the noise level is estimated as the mean value of energy in this band.

To estimate the spectral slope in the mesoscale band, between 250km and 90km, by a least square regression, we first remove the error (white noise) effect on the spectrum shape (red curve on Figure 1). The mesoscale capability is the wavelength of the crossing point.

Impact of MSS accuracy error on non-repetitive altimeter mission

For non-repetitive altimeter missions such as Cryosat-2, or for new altimeter orbits with uncharted ground-tracks such as Sentinel-3 or the future SWOT mission, the SSH anomalies are referenced to a gridded mission instead of an along-track precise mean profile.

The overlapping periods of the Jason-1/Jason-2 repeat missions and the geodetic phase of Jason-1 are used here to infer the gridded MSS error away from gridded tracks. We compute the mean global PSD over 2 subsequent 1-year periods: • when Jason-1 is on its interleaved orbit, i.e. a charted ground track (May 10–June 11) • when Jason-1 is on an uncharted geodetic ground track (May 12–June 13)

The extra energy in the Jason-1 PSD between these two periods infers the MSS errors along the uncharted ground-tracks: the PSDs show a substantial difference in energy levels from 25-110 km wavelength over these two periods. The ratio of these PSDs over the PSD calculated with Jason-2 (as a reference) for the two periods confirms that there is up to 17% of additional energy during the non-repetitive phase (orange curve on Figure 5b). This means that using the gridded MSS slightly degrades the mesoscale resolution capability of new altimeter orbits or geodetic orbits.

In the future, reduced MSS errors are expected over the 25-110 km wavelength band from the recent most MSS products, such as DTU 2015 (Andersen et al., 2015) or CNES-CLS 2015 (Schaeffer, personal communication), which include full cycles of CryoSat-2 and Jason-1 geodetic data.

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SWOT, future resolution capability to sample mesoscale dynamics

Considering the spectral slopes spatial distribution estimated from current altimetry missions (Figure 3), the mesoscale resolution capability of the future mission SWOT has been estimated by taking into account simulated noise level of its instrument KaRIN.

To date, the error level of the SWOT mission is expected to have a mean value of 2.5 cm RMS for a 1km resolution, with a modulation of the mean across-swath error level by the SWH: ranging from 2.6 cm RMS for SWH less than 2m, it increases up to 5.6 cm RMS for SWH of around 8 m (Peral et al., 2015).

Using this spatial distribution of SSH obtained from Jason-2 observations from March to October 2013 and the relationship between SWH and error in KaRIN, a map of future SWOT noise error level has been simulated. Together with the Jason-2 spectral slopes distribution (Figure 3a), it permits to estimate the SWOT mesoscale resolution capability (Figure 6). It leads to a mesoscale resolution capability strongly improved compared to current missions. Even compared to SARAL/Altika, SWOT would greatly improve the observability of fine mesoscale and submesoscale processes, at high western boundary currents systems (Kuroshio, Gulf Stream, Agulhas Current) where wavelength lower than 20km seem to be reachable.

Although its mesoscale resolution capability will vary seasonally and geographically, with such performances this future 2D SSH mission is expected to reveal unprecedented observations of the small-scale features of the ocean.