Influence of the high-frequency MOG2D corrections on the surface velocity field

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Established in 1989, the Centre de Topographie des Océans et de l'Hydrosphère is a French Observational Service dedicated to satellite altimetry, and part of the national network of observational services sponsored by the Institut National des Science de l'Univers (INSU).

The principal objective of the Centre de Topographie des Océans et de l'Hydrosphère is to maintain an up-to-date, homogeneous altimetric data base for studying long-term sea level change with emphasis on its impact on climate.

In 2000, this objective was expanded to include the developing altimetric applications on the continents and hydrosphere, in particular to monitor changes in lake and river levels and on the cryosphere. This expanded Observation Service is now known as the Centre de Topography des Oceans et de l'Hydrosphère (CTOH).

Ocean SLA product – with FES2002 tides and MOG2D barotropic correction

As part of the Jason SWT validation in 2003, we are developing and testing an improved alongtrack sea level anomaly product which includes a new mean sea surface (CLS MSS001), the latest tides (FES2002 and GOT2000) and a high-frequency correction based on the response to atmospheric forcing (using MOG2D). These corrections are applied to Topex-Poseidon and Jason-1 data (see Table 1). In addition, a 16.4 cm bias has been removed from the Jason-1 data.

SLA =	Topex/poseidon	Jason-1
+ Altitude	sat_alt (NASA)	altitude
- Altimeter Range	h_alt	range_ku
- Ionospheric correction	iono _corr or iono_dor	iono_corr_alt_ku
- Wet tropospheric correction	wet_h_rad or wet_corr	rad_wet_tropo_corr
- Dry tropospheric correction	dry_corr	model_dry_tropo_corr
- Sea State Bias corr. (Ku)	ssb_corr_k1	sea_state_bias_ku
- Solid earth tide	solid_earth_tide	solid_earth_tide
- Geocentric pole tide	h_pol	pole_tide
- Elastic tide & loading effect	ocean_tide_FES2002	ocean_tide_FES2002
- Inverse barometer correction	ib_MOG2D or inv_bar	ib_MOG2D or inv_bar_corr
- Mean sea surface height	mss_cls_01	mss_cls_01

Table 1: Sea Level Anomaly computed for T/P or J-1

Influence of the high-frequency MOG2D corrections on the surface velocity field

Here we test the sensitivity of the surface geostrophic velocity estimates to the MOG2D barotropic correction (Carrere and Lyard, 2003). We use 2 test cases:

Test case 1 : Alongtrack surface geostrophic velocities are calculated using Topex-Poseidon and Jason-1 data from the tandem mission, with and without the MOG2D correction. We calculate the velocities from the T/P and Jason SLAs along parallel groundtracks, which are separated by < 7 minutes in time. The MOG2D correction is calculated from global 6-hourly ECMWF atmospheric pressure and wind fields, so the two parallel groundtracks are essentially subject to the same large-scale atmospheric forcing.

Test case 2 : Mapped surface geostrophic velocities are calculated from Topex/Poseidon + Jason-1 sea level anomalies mapped onto a regular 0.5°x0.5° regular grid. Geostrophic velocities are calculated between neighbouring grid points over a 10-day cycle, irrespective of the time difference between them. The mapping technique (GMT – "near neighbor") uses only the closest points in space, with no additional horizontal smoothing.

Test case 1: Alongtrack Surface Geostrophic velocities : the data

The alongtrack surface geostrophic velocities are calculated using the technique of Stammer and Dieterich, 1999. For each pair of T/P and Jason tandem tracks, points at the same latitude will be separated by ~ 410 secondes. Figure 1c) shows the alongtrack SLA for the pair of groundtracks (track 001) from the first tandem cycle (Jason Cycle 028; Topex Cycle 371). This groundtrack passes through the southern Indian Ocean. The raw alongtrack data (Figure 1a) shows that Jason data is on average 163.7 mm higher than Topex data for this cycle. Before calculating the velocities, we reduce the alongtrack noise using a 7 point running mean filter, and remove a mean 163.7 mm bias from all of the Jason data (Figure 1b).

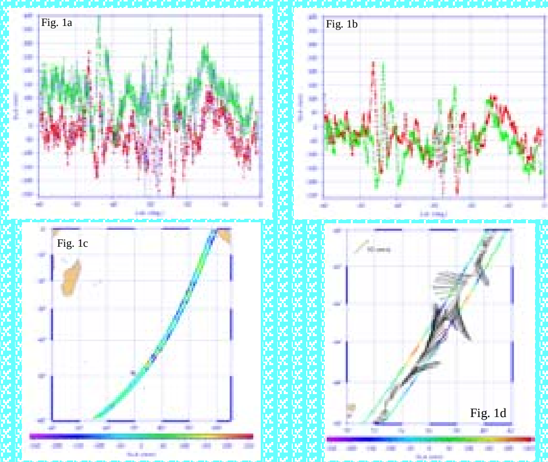


Figure 1:

a) Raw alongtrack sea level anomaly data for track 001 for Jason cycle 028 (green line) and Topex cycle 371 (red line).

b) Filtered alongtrack data with a 16.37 cm bias removed from the Jason data.

c) SLA along Topex and Jason groundtracks for track 001.

d) Zoom of alongtrack velocity vectors for track 001, using the Stammer and Dieterich methodology.

Alongtrack Surface Geostrophic velocities : methodology

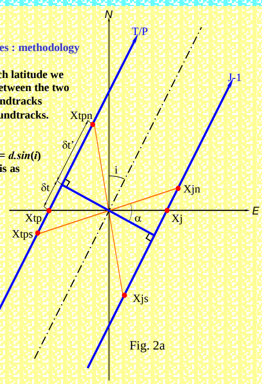
Following the methodology of Stammer and Dieterich (1999): at each latitude we calculate the inclination angle of the groundtracks, *i*, the distance between the two groundtracks, *2d*, and choose 4 points on the Topex and Jason groundtracks which are at an angle α=45° from the axis perpendicular to the groundtracks.

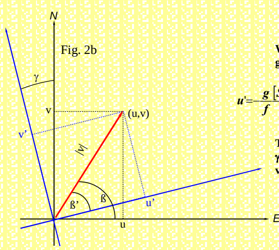
We define (see Figure 2a) :

- **the distance between the latitude and the perpendicular axis as $\delta t = d.sin(i)$**
- **the distance between each of the 4 points and the perpendicular axis as $\delta t' = d.cos(i).tan(\alpha)$**

Then :

- **latitude (Xjn) = $(\delta t' - \delta t)$ * cos(*i*) + lat (Xj)**
- **latitude (Xjs) = $-(\delta t' + \delta t)$ * cos(*i*) + lat (Xj)**
- **latitude (Xtpn) = $(\delta t' + \delta t)$ * cos(*i*) + lat (Xtp)**
- **latitude (Xtps) = $-(\delta t' - \delta t)$ * cos(*i*) + lat (Xtp)**





We calculate 2 orthogonal velocity vectors from the gradient between pairs of SLAs at these 4 points:

$$u' = \frac{g}{f}\,\frac{[SLA(Xtpn) - SLA(Xjs)]}{dist(Xtpn - Xjs)} \qquad v' = \frac{g}{f}\,\frac{[SLA(Xjn) - SLA(Xtps)]}{dist(Xjn - Xtps)}$$

These orthogonal vectors are then rotated by an angle γ = (α-*i*) into north-east coordinates (see Figure 2b) via the following calculation :

$$|v| = \sqrt{u'^2 + v'^2} \qquad \beta' = arcsin\left(\frac{v'}{|v|}\right)$$

$$\beta = \beta' + \gamma \qquad u = |v|\cos\beta \qquad v = |v|\sin\beta$$

The result is an alongtrack series of velocity vectors located mid-point between the Topex and Jason groundtracks (Figure 1d).

Intercomparaison between alongtrack and mapped velocity field

Figure 3 shows the results comparing the alongtrack velocities (test case 1 - left panel) and the mapped velocities (test case 2 - right panel). As expected, for the tandem velocity calculation, the large-scale MOG2D barotropic correction has only a small influence on the velocity field, and mainly in the high latitude regions shown by Carrère and Lyard, 2003.

For the mapped data (right panel) the background EKE is slightly higher (fig.s 3d, 3e) since there are more high-frequency variations between neighbouring non-tandem tracks. Note that the large number of missing tracks (North and South Atlantic and western Pacific oceans) introduce a groundtrack pattern into the mapped SLAs and EKE field (Figs 3d, 3e) which is reduced in the difference map (Fig 3f). The difference map shows clearly the regions where the MOG2D correction produces large changes in EKE. On average, MOG2D reduces the alongtrack EKE by 13 cm^2/s^2 in the latitude bands from 20-65°N and 20-65°S. The spatial smoothing inherent in the mapped data increases the variance and so the EKE reduction is only 5.7 cm^2/s^2 .

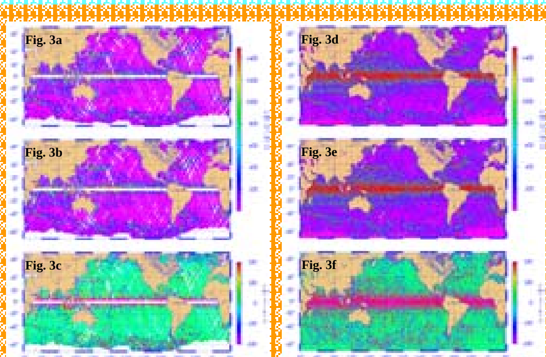


Figure 3 : (left panel) Alongtrack EKE for 2 different cases:

a) including the MOG2D barotropic correction,

b) without the MOG2D correction,

c) the difference between the two fields.

Figure 3 : (right panel) EKE calculated from the SLA mapped onto a regular 0.5°x0.5° grig:

d) including the MOG2D barotropic correction,

e) without the MOG2D correction,

f) the difference between the two fields.

Conclusion:

This validation study shows that using the MOG2D high-frequency barotropic correction can improve the EKE field, for both the alongtrack and mapped velocity data.

The MOG2D correction has only a minor effect at mid-latitudes when calculating velocities from the tandem mission parallel groundtracks, mainly because the same large-scale atmospheric forcing is applied to both tracks at the same time. There is more improvement at high latitudes where the small-scale barotropic ocean response is more important.

References :

- Carrère, L., Lyard, 2003: Modeling the barotropic response of the global ocean to atmospheric wind and pressure forcing – comparaisons with observations. GRL, 30(6), 1275.
- Stammer, D., C. Dieterich, 1999: Space-Borne Measurements of the Time-Dependent Geostrophic Ocean Flow Field. JAO Tech., 16,1198-1207.

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