A Mean Sea Surface Dedicated to Ocean Studies : Global Estimation

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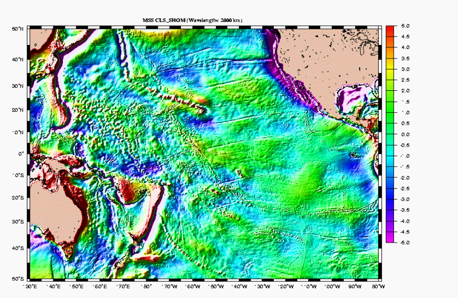
ABSTRACT

Topex/Poseidon (T/P), GEOSAT, and ERS-1 improved altimetric dataset are used to estimate a mean sea surface (MSS). This MSS is dedicated to oceanography, focusing on the accuracy of the mean sea height along the satellite ground tracks. The 3-years T/P accurate (1.2 cm rms) mean profile is processed to reference the MSS. A two-year ERS-1 mean profile is calculated by merging phase C and G dataset, with a 1.6 cm rms accuracy. The two-year GEOSAT mean profile is 2 cm rms accurate. These two profiles are adjusted to T/P. The data of the two 168-day ERS-1 geodetic cycles are also used, to provide a global high resolution to the MSS. For all the ERS-1 data, the ocean variability is removed from the sea surface height by subtracting the T/P sea level anomaly (SLA), then the orbit error are also reduced by spline-fitting with T/P arcs, allowing a 6.5 cm rms accuracy. EGM96 geoid is removed to the data. A suboptimal inverse technique is applied to estimate the MSS from these residuals, on a 1/16° grid. This technique takes into account the long wavelength biases on altimetric arcs and also the oceanic variability noise. The MSS is validate first by analyzing discrepancies with the mean profiles ; e.g., less than 1.3 cm rms and 0.11 cm/km rms with the T/P mean profile in a global evaluation. Its accuracy is improved compared to other MSS, particularly at small scales. And there are about 3.6 and 5.1 cm rms discrepancies with OSU95 MSS and the GRGS MSS respectively. The second validation is based on differences between the three MSS, and the standard deviation is below 11 cm. A final test show that to use the MSS to reference altimetric Sea Level Anomalies (SLA) is valuable: its allows a merging of several satellite data set reducing systematics biaises.



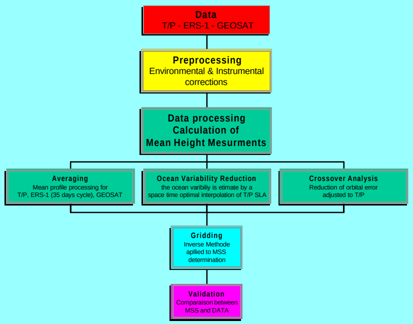
OBJECTIVE

- **The MSS must be accurate along and close to the satellite track pattern (e.g., T/P, ERS1-2, GEOSAT... JASON,Envisat,GFO)**
- **The MSS must be contains the short wavelength of the geoid undulations at the vicinity of the satellite ground tracks.**
- **The MSS should be the reference for calculating and merging homogeneously Sea Level Anomalies from differents satellites.**

DATA

- ***Three-year T/P mean profile***
  Cycles 11 to 121 (january 93 to january 96), NASA-JGM-3 orbit.
- ***Two-year ERS-1 mean profile***
  Merging phases C (7-17, nov. 92 to nov. 93) and G (2-12, mai 95 to mai 96) to get two full years of data with the DPAF orbit
- ***Two-year GEOSAT mean profile***
  Cycles 1 to 44 (years 87 and 88)
- ***ERS-1 geodetic phase***
  2 Cycles (april 94 to march 95)

Mean Sea Surface Determination



Data
T/P - ERS-1 - GEOSAT
Preprocessing
Environmental & Instrumental corrections
Data processing
Calculation of
Mean Height Mesurments
Averaging
Mean profile processing for
T/P, ERS-1 (35 days cycle), GEOSAT
Ocean Variability Reduction
the ocean varibiliy is etimate by a
space time optimal interpolation of T/P SLA
Crossover Analysis
Reduction of orbital error
adjusted to T/P
Gridding
Inverse Methode
apllied to MSS
determination
Validation
Comparaison between
MSS and DATA

PREPROCESSING & PROCESSING

	Mean profile T/P	Mean profile ERS-1	Mean profile GEOSAT	ERS-1 geodetic phase
period	1993-94-95 cycles 11 to 121	92/11 - 93/11 7-17 phase C 95/05 - 96/05 2-12 phase G	87/11 - 88/11 cycles 1-44	94/04 - 94/09 phase E 94/10 - 95/03 phase F
Resolution at the equator	315 km	~ 80 km	160 km	~ 8 km
coverage	66°	82°	72°	82°
Remark	référence for all observations	-2 phases mixing - Orbite DPAF	-introduce interannual variability	provide the hight resolution
particularity		-adjustements of E/E crossover differences -removing oceanic variability -adjustement to T/P mean profile	-adjustement to T/P mean profile	-adjustements of E/E crossover differences removing oceanic variability adjustement to T/P mean profile
RMS of crossover differences before processing	1.66 cm	2.55 cm	6.54 cm	~13 cm
Internal accuracy between 66°N et 66°S	1.2 cm	1.6 cm	2 cm	6.5 cm
accuracy related from T/P between 66°N et 66°S	1.2 cm	2 cm	3.2 cm	6.5 cm
accuracy related from T/P over 66°		4.8 cm	3.2 cm	10 cm

GRIDDING or ESTIMATION METHOD

Inverse method, taking into account large scale errors along the satellite tracks (Le Traon et al., 1997)

OBSERVATIONS :

- Residuals of the Mean Heights to the EGM96 geoid
- Data noise :

- Mesurement errors
- Large scale errors (e.g. residual orbit error)
- Residuals of oceanic variability

METHOD :

For each grid point in the first calculation grid (0.25° x 0.25°) :

- *Data are collected in the 200 km-radius influence bubble*
- *The mean is calculated and subtracted, to center the observations*
- *The observation covariance matrix is inverted*
- *A subgrid estimation (1/16° x 1/16°) is processed, using this covariance matrix, providing estimates and errors*

The bubble mean and the EGM96 are added back to the estimates

P.-Y. Le Traon, F. Nadal and N. Ducet, 1997 : An Improved mapping method of multi-satellite altimeter data, in press to Journal of Atmospheric and Oceanic Technologie.

VALIDATION

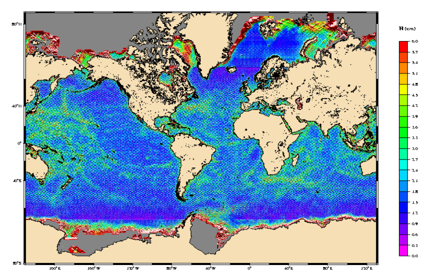
In order to validate and improve the MSS calculation, several tests are scheduled :

- Look at the differences between the T/P, ERS-1 and GEOSAT mean profiles heights and corresponding interpolated values of the MSS.
- Compare the grid gradients with the along track mean profiles to verify the restitution of the shorts wavelengths of the geoid.
- Comparing our MSS to MSS calculated with other dataset (e.g., the GEOSAT Geodetic dataset), in particular the OSU95 MSS (Yi, 1995) and the GRGS MSS (Mazzega et al., 1996).

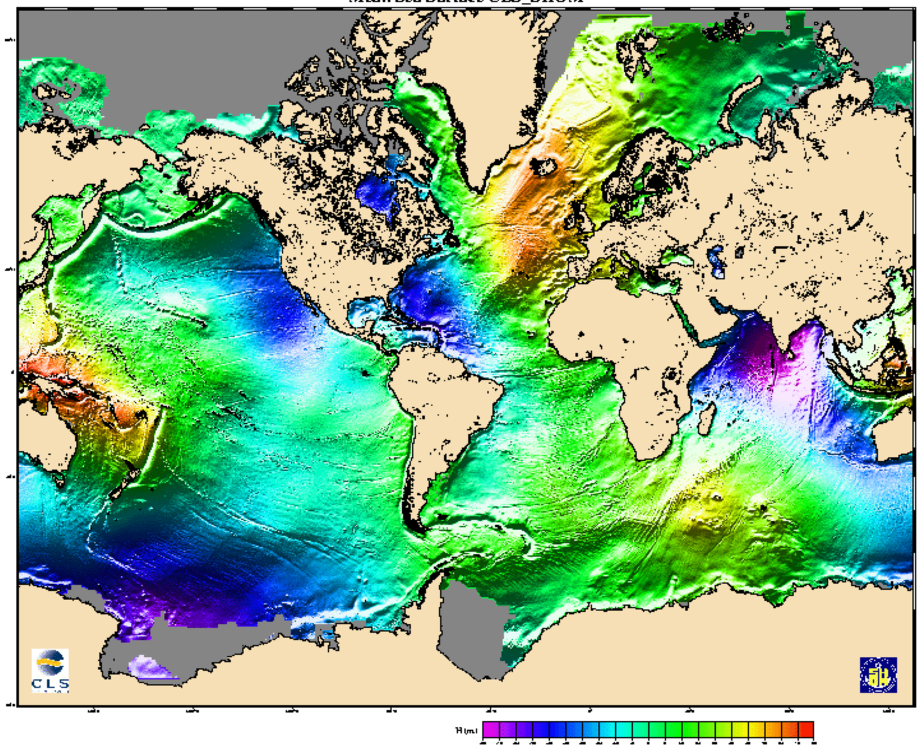
Surfaces	Satellites	DH (cm)	Standar Deviation (cm)	DH/ds (cm/km)	Standar Deviation (cm/km)
OSU95	T/P ERS-1 GEOSAT 168 (1) 168 (10)	-0.39 0.12 -0.20 -0.49 0.70	3.64 5.34 4.94 8.80 9.68	0	0.15 0.29 0.28 0.86 0.87
GRGS	T/P ERS-1 GEOSAT 168 (1) 168 (10)	-2.21 -2.73 -2.26 -1.95 -2.00	5.11 6.65 6.72 8.95 9.44	0	0.42 0.48 0.49 0.91 0.91
CLS_SHOM	T/P ERS-1 GEOSAT 168 (1) 168 (10)	-0.13 -0.17 -0.27 0.05 0.29	1.29 2.08 4.06 7.12 7.26	0	0.11 0.15 0.18 0.80 0.78

Différence between MSS	Mean(cm)	Standard-deviation (cm)
OSU95 - GRGS	-3.32	10.68
CLS_SHOM - OSU95	0.05	10.43
CLS_SHOM - GRGS	-3.09	10.18

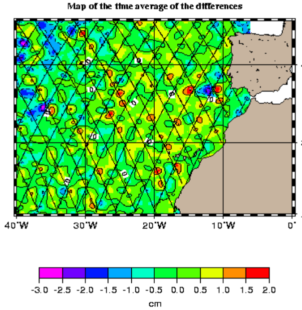
Error of the Mean Sea Surface CLS_SHOM



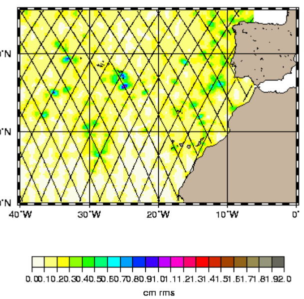
Mean Sea Surface CLS_SHOM



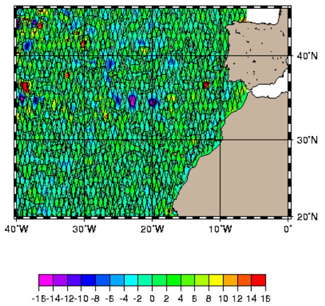
Map of the time average of the differences



Map of the time standard deviation of the differences

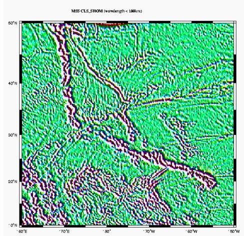


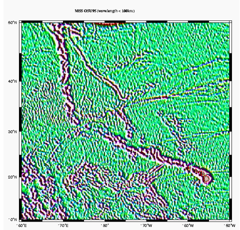
Difference of variance maps (cm²)



Using the MSS to calculate Sea Level Anomalies

Two set of SLA have been calculated: first by subtracting the mean profiles, and second by subtracting the MSS to the altimetric height. Then the SLA mapping have been performed every ten days (each T/P cycle) during 1993, separetely with the two SLA dataset. At each cycle, maps of differences have been calculated. The time average of these differences exhibits 1-2 cm anomalies related to the difference between the MSS and the T/P mean profile. These anomalies are related to 1) geographically correlated errors contaminating the MSS and 2) better precision of the MSS (near the coast). The time standard deviations are assumed to show the geoid cross-track errors not well corrected in the SLA referenced to the mean profiles (anomalies of ~1cm rms). The MSS is also dedicated to improve homogeneity between T/P and ERS-1 dataset. The difference of T/P and ERS-1 SLA maps ref. mean profile, are compared to the difference of T/P and ERS-1 SLA maps ref. to the MSS. The map of the difference of time variance of the two types of SLA shows anomalies in strong geoid height variability areas. Positive/negative values are related to a «noisier» MSS/Mean profile reference resp. Thus, there is no strong negative impact in using the MSS as the reference for SLA.





CONCLUSION

- The precision along the mean profiles is keeped (e.g; 1.3, 2.1, 4.1 cm RMS with T/P, ERS-1, and GEOSAT profiles respectively) and comparable with the crossover differences (e.g; 1.6, 2.5, 3.7 cm RMS).
- A sensitivity study of the error show that errors are coherent with mean profile discrepancies.
- The mapping of the differences between the 3 MSS show that the CLS_SHOM MSS is not degraded by a trackiness (data noise).
- Compared to other MSS the CLS_SHOM estimates MSS provides better resolution of the short wavelength along the mean profiles.
- Comparisons between SLA calculated with MSS and with mean profiles show that the use of the MSS would pollute the SLA mapping by only 1-2 cm RMS at short scales.

PERSPECTIVE

- The CLS_SHOM MSS will be used for merging present altimeter data and futur data of Jason1, ENVISAT, and GFO.
- The MSS corresponds to the mean oceanic level from 1993 to 1995. The MSS should be determined over a longer period by a reference to 5 year T/P mean profile.
- Our processing and gridding method may be adapted for gravity anomaly and vertical deflection calculations.