The CLS01 Mean Sea Surface: A validation with the GSFC00.1 surface

Fabrice Hernandez and Philippe Schaeffer

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1. Introduction

Mean Sea Surfaces (hereafter MSS) are essentially satellite altimetry by-products. They correspond to the geoid undulations and the mean dynamic topography (hereafter MDT) averaged over a selected period. A detailed description of MSS development and uses by oceanographers and geodesists is given by (Rapp, 1997 ; Cazenave and Royer, 2001 ; Tapley and Kim, 2001). MSS are necessary in satellite oceanography for correcting the cross-track geoid errors in the repeat orbit method (e.g., Brenner et al., 1990). They are also useful to reference the altimetric Sea Surface Height (hereafter SSH), and therefore to compute the Sea Level Anomalies (hereafter SLA) that are free of the geoid height and its uncertainties. In particular, to provide a common reference to distinct satellite dataset, like TOPEX/Poseidon (hereafter T/P), ERS-2 and GEOSAT Follow On (hereafter GFO), and in a near future Jason-1 and EnviSat. Subsequently, the corresponding SLA can be combined to map the ocean circulation because the expected bias between these dataset would be reduced.

A particular attention has been paid in recent MSS determinations to reduce the short scale noise level, and also to homogenise the MDT overall content (i.e., to ensure that the MDT near T/P or ERS-2 ground tracks is related to the ocean topography time-averaged over the same period). A comparison between four MSS has been conducted in preparation of the Jason-1 SWT (Science Working Team) by Hernandez and Schaeffer (2000) (hereafter called HS2000) which concluded that the GSCF00 and the CLS_SHOM98.2 MSS were the most accurate surfaces.

Recently, the Goddard Space Flight Center has slightly modified its MSS, whereas a new MSS has been computed at CLS –called CLS01– benefiting from longer altimetric dataset and improved mapping technique. This note is summarising the comparison that have been carried out in order to evaluate the respective accuracy and interest of these two MSS as scientific products for the Jason-1 and EnviSat missions. Section 2 describes shortly the CLS01 MSS determination, comparison to altimetric data are presented in section 3, and section 5 ; and direct comparisons between surfaces in section 4. Conclusions are given in section 6.

2. The CLS01 MSS

The frame of the CLS01 determination is the same than the one designed for the CLS_SHOM98.2 MSS (HS2000). The first goal is to offer a mean height (MH) high precision along the T/P, ERS-1 and GEOSAT groundtracks, the second is to provide an homogeneous MDT content. Both are necessary for using the CLS01 MSS as the Jason-1, EnviSat and GFO referencing surface, and combine these three types of SSH to map the ocean mesoscale circulation.

2.1. Data processing

T/P data over the 1993-1999 seven years period have been selected, because is the longest full-year dataset available at the time of the MSS computation. T/P SSH were processed with the most recent geophysical corrections. In particular, the GOT99.2 tidal model (Ray, 1999), and tailored inverse barometer corrections (Dorandeu and Le Traon, 1999). Due to the T/P SSH accuracy, the resulting mean profile is the most precise ever computed (Table 1). It is 30% more accurate than the T/P mean profile used to compute the CLS_SHOM98.2 MSS. Thus, this mean profile is chosen to reference the MSS CLS01.

Both ERS-1 and ERS-2 35-day repeat orbit data were selected to compute a mean profile (see Table 1). ERS data ("ERS" refer to both ERS-1 and ERS-2) are first corrected with the same altimetric correcting model than T/P SSH whenever it is possible. In particular, the Scharroo and Visser (1998) precise orbit determination is used. Then, ERS SSH are adjusted to T/P to reduce orbit error using the Le Traon and Ogor (1998) method. To remove the ocean variability, and derive MH from ERS SSH, the technique proposed by Hernandez (2000) is applied. It allows to minimise the seasonal/interannual aliasing effects caused by the mean profile computation using non-continuous ERS time series. Then, the ERS mean profile is adjusted to the T/P mean profile –using the Le Traon and Ogor (1998) adjustment method– to reduce the last biases. Due to longest ERS time series, and the specific data processing applied, the ERS mean profile is 40% more accurate than the one used to determine the CLS_SHOM98.2 MSS.

A GEOSAT mean profile is also computed, to provide accurate MH short wavelengths at the vicinity of the GFO groundtracks. Unfortunately, 17-repeat GEOSAT SSH correspond to a previous period (i.e., 1986 to 1989) Thus, the MDT contained in the GEOSAT mean profile is not consistent with the T/P and ERS one. Like in the CLS_SHOM98.2 MSS computation, GEOSAT SSH over the most complete 2-year period are selected (i.e. 1987-1988) to compute a mean profile. To reduce the MDT differences, ands also altimetric biases (due to altimetric errors or correction inconsistencies) the GEOSAT mean profile is adjusted to both T/P and ERS mean profile, using the Le Traon and Ogor (1998) method. From 16 ± 8 cm rms height differences at mean profile crossovers, the adjustment conduct to 0 ± 4 cm rms discrepancy level. Next, short scales discrepancies exhibited through the crossovers are directly subtracted to the GEOSAT mean profile, to finally lead to a 3 cm rms differences with the T/P and ERS mean profiles.

ERS-1 geodetic data are necessary to provide everywhere the geoid shortest scales. Geodetic SSH are processed like 35-day repeat orbit data (see above). However, the MH value cannot be obtained from a time averaging. Instead, the method proposed by Hernandez (2000) is again used. By the way, Geodetic SSH are consistent with the T/P mean profile. The resulting MH provide a ~6 cm rms accuracy.

	T/P mean profile	ERS mean profile	GEOSAT mean profila	ERS-1 geodetic data
Selected time period	1993-1999 7 years (cycles 11-280)	1993-1999 5 years 64 cycles - ERS-1 phase C (6-18) - ERS-1 phase G (1-2) - ERS-2 phase A (1-49)	1987-1988 2 years (cycles 1-44)	1994-95 - ERS-1 phase E - ERS-1 phase G
Orbit inclination	66°	98°	108°	98°
Groundtracks limits in latitude	66°S-66°N	82°S-82°N	72°S-72°N	82°S-82°N
Groundtracks spacing	320 km	~80 km	160 km	~8 km
Groundtracks number	254	1002	488	~9500
Total of used points	553094	1866041	853288	14705902
Remarks	Used to reference the MSS	Merging non-continuous phases and data from 2 satellites (ERS-1 and ERS-2)	Data referenced to a distinct period (ocean interannual changes)	Provide the shortest wavelength. Accuracy reduced by the ocean variability
Data processing		- Altimetric corrections consistent with T/P - Reduce the ocean variability - Mean profile adjustment to T/P	- Reduce the ocean seasonal variability - Mean profile adjustment to T/P and ERS (>66° lat.) - Remove the medium scales crossover discrepancies with T/P and ERS	- Altimetric corrections consistent with T/P - Reduce the ocean variability
Accuracy	~1 cm rms	~1.5 cm rms	~2.8 cm rms	~6 cm rms
Relative precision to T/P		~1.1 cm rms	~3 cm rms	~5.4 cm rms

Table 1: Description of the data used and the relevant processing. Accuracy are deduced from crossover analysis of height differences.

2.2. Least square collocation technique

Table 2 summarises the CLS01 characteristics. Again, the estimation technique developed to determine the CLS_SHOM98.2 MSS (HS2000) has been improved to compute the CLS01 MSS. The grid resolution is refined to 2’ (1/30°). The local least square collocation technique (see Bretherton et al., 1976 ; Tarantola and Valette, 1982) uses altimetric data in a 200 km radius ; is weighted by their respective error level ; and is constrained by the MSS a-priori spatial covariance models in the considered area. The error budget separates specifically instrumental noises, ocean residual variable signal, and along-track long wavelength errors (based on the method proposed by Le Traon et al., 1998). It allows to reduce the so-called “trackiness” effect, and also to lower the short wavelength noise generated by the less accurate ERS-1 geodetic MH. A remove/restore technique is applied to get rid of the largest scales, using the EGM96 geoid model (Lemoine et al., 1998). The technique provides an estimation error value, associated with the quality of the data used, and their sparseness. The MSS is determined oceanwide between 80°S and 82°N. On continents, the MSS is filled up with the EGM96 geoid. The connection between the MSS and the EGM96 geoid on continents has been carefully examined, in order to minimise the gaps, and provide a smoothed gradient surface on coastal areas.

Name	CLS01
Reference ellipsoid	T/P
Referencing time period	1993-1999 (7 years)
Domain	Global (80°S to 82°N) – Oceanwide where altimetric data are available. EGM96 elsewhere and on continents.
Spatial resolution	Regular grid with a 1/30° (2 minutes) spacing (i.e. ~4 km)
Grid	10800 points in longitudes / 4861 points in latitude
MSS Determination technique	Local least square collocation method on a 6' grid where altimetric data in a 200-km radius are selected. Estimation on a 2' grid based on SSH-EGM96 values (remove/restore technique to recover the full signal). The inverse method uses local isotropic covariance functions that witness the MSS wavelength content.
Estimation error level	YES (in m) – Negative values are flagging coastal areas where the smoothed junction with the continental EGM96 geoid is computed.
Altimetric dataset	T/P 7 years mean profile ERS-1/2 5 years mean profile GEOSAT 2 years mean profile ERS-1 geodetic data

Table 2: The CLS01 mean sea surface.

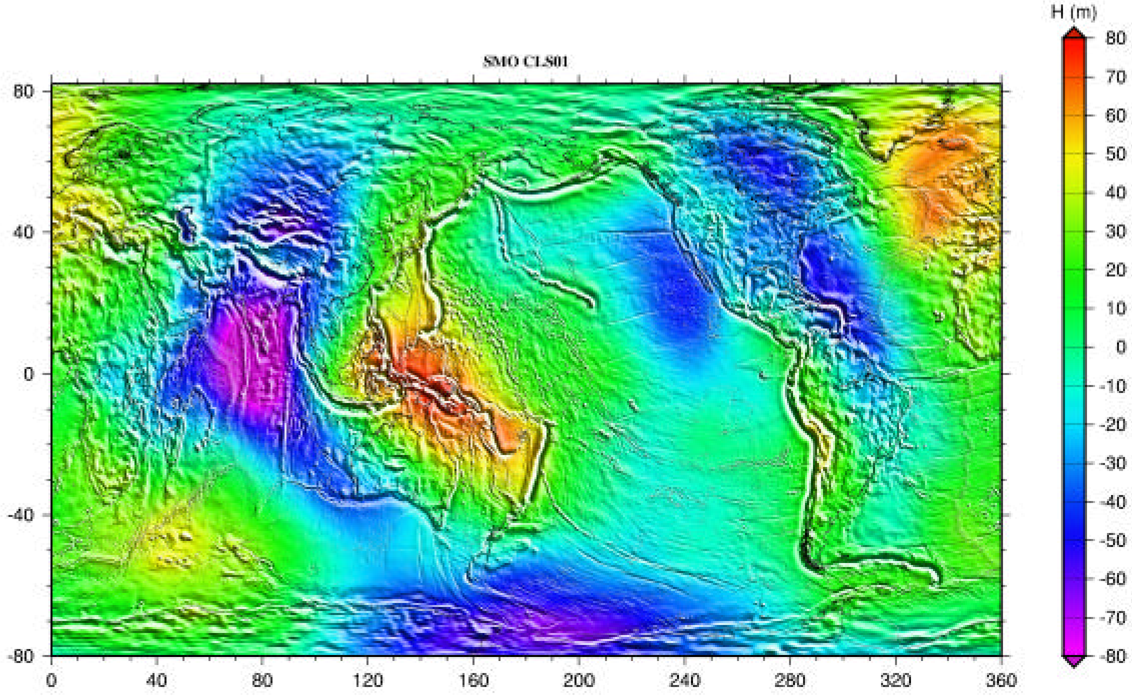

Figure 1: Global map of the MSS CLS01 (units in m). On continents, the EGM96 geoid.

3. Validation using mean profiles

As already mentioned in HS2000, mean profiles can be used to validate MSS. We compare the T/P (7 years) and the ERS (5 years) mean profiles to the CLS01 and GSFC00.1 MSS. The main reason is that they are the most precise profile available (see Table 1). Comparing the CLS01 MSS with the mean profiles used to determine it, essentially gives the reliability level of our estimation technique. The drawback is that the MSS and the profile are not independent. However, assuming that these T/P and ERS mean profiles are the most accurate representation of any mean height deduced from satellite altimetry, one can discuss:

?? The geoid wavelength content of the CLS01 and GSFC00.1 MSS, in particular the short scales and also over coastal areas.

?? The MDT content of each MSS, and the homogeneity of this content along the T/P and ERS groundtracks.

In practice, MSS and mean profiles are compared in term of height differences and also along-track gradient differences. Table 3 and Table 4 are summarising the statistics. Such comparison had already been presented at the T/P and Jason-1 Science Working Team meeting in November 2000 in Miami, USA. The GSFC00 and CLS_SHOM98.2 MSS had been compared to the same T/P and ERS mean profiles. Statistics are computed for different coastal areas, and also the 66°S-66°N area where T/P (and Jason-1) are measuring the SSH. Thresholds in height and slope differences are also taken into account. The 10 m threshold exclude erroneous points either in the surfaces or the mean profiles. The three depth limits are defined to characterise the coastal areas, the continental shelves, and the deep ocean. In the present comparison, there is a slight change concerning the along-track slope computations: they are performed only if successive points along the groundtracks are separated by a distance of less than 0.3 degree, to avoid artefacts caused by along track gaps, islands and continental areas. Moreover, comparisons between the GSFC00.1 and CLS01 MSS versus the T/P and ERS mean profiles are based on a common set of valid points along the profiles. The GSFC00.1 is limited to 80°S/80°N, then the 80-82°N band is not included in the comparisons with ERS.

The number of mean profile points compared to the CLS01 MSS is larger than with the CLS_SHOM98.1 MSS. The CLS01 surface is better determine close to the coast, because more altimetric data are available. Moreover, large areas of the Arctic and Antarctic oceans, and semi-enclosed sea (e.g., the Hudson Bay) are also mapped, because ERS-2 data are available.

Comparison between the CLS_SHOM98.1 and GSFC00.1, and the mean profile exhibit a 2.5-3.5 average difference in height. The two main reason are:

?? The T/P and ERS SSH are corrected using a new inverse barometer correction using the average pressure (~1011 mbar), instead of a constant value (1013 mbar, see Dorandeu and Le Traon, 1999) that generates a ~2 cm bias on the mean profiles. Consequently, this bias appears in the height differences with MSS computed with altimetric data not corrected with this new correction.

?? The MDT, by definition, is averaging the interannual ocean variations, that can represent several centimetres. The CLS_SHOM98.1 MSS is referenced to the 3-year –1993-95– period. The GSFC00.1 MSS is referenced to the 6-year –1993-1998– period. And the mean profiles (and thus the CLS01 MSS) are referenced to the 7-year (1993-99) period. Consequently, MH systematic differences appears between these products.

Limits (height threshold and bathymetry)	# points (% of points)	RMS height differences (mean/std) in cm	Slope Diff. std (mm/km) # pts
	T/P 7 ans vs CLS_SHOM98.1 (pts 529 628)		
All / (50 cm)	528 744 (99.83%)	04.42 (3.15 / 03.09)	02.17
0-100 m / (10 m)	014 380 (02.72%)	**12.03** (3.46 / 11.53)	06.21
100-500 m / (10 m)	019 555 (03.69%)	13.60 (4.12 / 12.96)	06.09
> 100 m / (10 m)	515 248 (97.28%)	05.64 (3.17 / 04.66)	01.96
> 500 m / (50 cm)	495 157 (93.49%)	04.09 (3.12 / 02.64)	01.60
	T/P 7 ans vs CLS01 (common pts 552 130)		
All / (50 cm)	549 903 (99.60%)	1.57 (0.05 / 01.57)	0.58 (548 575)
0-100 m / (10 m)	020 637 (03.74%)	11.09 (0.34 / 11.08)	2.03 (020 014)
100-500 m / (10 m)	023 004 (04.17%)	5.52 (0.27 / 05.51)	1.30 (022 628)
> 100 m / (10 m)	528 320 (95.69%)	1.44 (0.05 / 01.44)	0.45 (528 121)
> 500 m / (50 cm)	505 837 (91.62%)	**0.83** (0.04 / 00.83)	0.36 (505 417)
	T/P 7 ans vs GSFC00.1 (common pts 552 130)		
All / (50 cm)	547 032 (99.08%)	3.91 (3.20 / 02.25)	1.12 (545 767)
0-100 m / (10 m)	019 131 (03.46%)	**21.37** (4.89 / 20.80)	2.51 (018 519)
100-500 m / (10 m)	022 436 (04.06%)	8.83 (3.45 / 08.13)	1.95 (022 060)
> 100 m / (10 m)	527 815 (95.60%)	4.01 (3.18 / 02.44)	1.04 (527 016)
> 500 m / (50 cm)	505 244 (91.51%)	3.56 (3.18 / 01.59)	0.98 (504 829)

Table 3: Statistics of the along-track differences between MSS and the T/P 7 years mean profile. Comparisons with the CLS_SHOM98.1 MSS were carried out last year. The two others were performed for this study with a common number of points. Height statistics (in cm) are given in Root Mean Square, Mean, and Standard deviations. Standard deviations are reported for slopes differences (in mm/km).

Differences between the mean profiles and the CLS01 MSS (height differences of 1.6 / 2.2 cm rms respectively with T/P and ERS) are consistent with the a-priori error levels prescribed for the mean profiles (see Table 1), whereas slope differences are rather low. This is a confirmation of the robustness of our MSS estimation technique, since the shortest wavelengths present in the mean profiles seem to be contained in the CLS01 MSS.

Between the CLS_SHOM98.1 and the CLS01, the improvements appear:

?? Near the coast where more points are available (the slope differences are strongly reduced. It means that the noise level is lowered near the coast).

?? Over the continental shelves (with T/P, the MH differences are 80% reduced).

?? On the deep ocean, where the resolution (1/30° for CLS01 instead of 1/16° for CLS8HOM98.2) helps to better describe the shortest scales present in the mean profiles.

Statistics of height and slope differences with respect to the mean profiles are higher for the GSFC00.1 MSS than for the CLS01 MSS. Near the coast and the continental shelves, the MH discrepancy levels between the GSFC00.1 MSS and the T/P and ERS mean profiles are not of the same order. They are also larger by more than a factor of two with the CLS01 statistics. Over the deep ocean, which represent ~90% of the compared values, the CLS01 MSS stays closer to the mean profiles. At high latitudes (statistics with the ERS mean profile), differences are also amplified with the GSFC00.1, but mean profiles are less accurate, and conclusions more difficult to establish.

Considering both the discrepancy level of the CLS01 and GSFC00.1 MSS with respect to the T/P or ERS mean profile. It appears that the differences between the CLS01 and T/P, or CLS01 and ERS (~20%) are more consistent that the differences between the GSFCC00.1 surface and the two profiles (~70%). In other terms, the CLS01 MDT content is more homogeneous than the GSCF00.1 one.

Limits (latitudes, height threshold and bathymetry)	# points (% of points)	RMS height differences (mean/std) in cm	Slope Diff. std (mm/km) # pts
	ERS 5 years vs CLS_SHOM98.1 (pts 1 560 674)		
66° / (50 cm)	1 493 054 (95.67%)	04.67 (3.30 / 03.30)	01.94
0-100 m / (10 m)	044 721 (02.87%)	**10.64** (3.57 / 10.02)	04.87
100-500 m / (10 m)	064 107 (04.11%)	08.70 (4.03 / 07.72)	04.10
> 100 m / (10 m)	1 515 953 (97.13%)	04.85 (3.30 / 03.56)	01.84
> 500 m / (50 cm) / 66°	1 411 212 (90.42%)	04.44 (3.25 / 03.02)	01.67
	ERS 5 years vs CLS01 (pts communs 1 849 961)		
All / (50 cm)	1 840 750 (99.50%)	2.16 (0.04 / 02.16)	0.93 (1 835 116)
66° / (50 cm)	1 650 631 (89.23%)	1.44 (0.04 / 01.44)	0.78 (1 646 701)
0-100 m / (10 m)	108 381 (05.86%)	10.20 (0.44 / 10.19)	2.09 (0 105 353)
100-500 m / (10 m)	102 667 (05.55%)	5.10 (-0.02 / 5.10)	1.44 (0 101 575)
> 100 m / (10 m)	1 730 446 (93.54%)	1.76 (0.03 / 01.76)	0.81 (1 727 667)
> 500 m / (50 cm) / 66°	1 525 529 (82.47%)	**0.91** (0.03 / 00.91)	0.65 (1 524 081)
> 500 m / (50 cm)	1 627 463 (87.97%)	1.16 (0.03 / 01.16)	0.75 (1 625 781)
	ERS 5 years vs GSFC00.1 (pts communs 1 849 961)		
All / (50 cm)	1 813 784 (98.04%)	5.71 (2.86 / 04.94)	1.84 (1 809 046)
66° / (50 cm)	1 637 884 (88.54%)	4.25 (3.21 / 02.78)	1.72 (1 634 352)
0-100 m / (10 m)	98 332 (05.32%)	**28.58** (0.53 / 28.58)	3.43 (0 095 341)
100-500 m / (10 m)	99 440 (05.38%)	14.07 (1.75 / 13.96)	2.48 (0 098 348)
> 100 m / (10 m)	1 723 897 (93.19%)	6.20 (2.86 / 05.41)	1.74 (1 721 118)
> 500 m / (50 cm) / 66°	1 524 301 (82.40%)	3.80 (3.19 / 02.07)	1.59 (1 522 872)
> 500 m / (50 cm)	1 621 864 (87.67%)	4.52 (2.97 / 03.41)	1.61 (1 620 330)

Table 4: Statistics of the along-track differences between MSS and the ERS 5 years mean profile. See table caption of Table 3.

Excluding the impact of the inverse barometer bias, or the interannual variations, the CLS01 MSS exhibit more consistency with the mean profiles than the GSFC00.1 MSS. Assuming that these profiles offer a never achieved precision, we can conclude that the CLS01 MSS is more accurate, on the overall than the GSFC00.1 surface. However, differences on the deep ocean evidence that these two surfaces offer a good level of precision. While continental shelves and coastal areas seem to be better described by the CLS01 MSS.

4. CLS01 and GSFC00.1 grid comparison

As was done in HS2000, the CLS01 MSS is directly compared to the GSFC00.1. But instead of comparing the surfaces at each grid points, which are not the same anyway, because the CLS01 surface is determined on a 1/30° node registration grid, and the GSFC00.1 MSS on a 1/30° pixel registration grid, the comparisons are carried out along the T/P, ERS and GEOSAT mean profiles. In other terms, we want to analyse the MSS differences where we do know that both surfaces benefited from altimetric data to be determined.

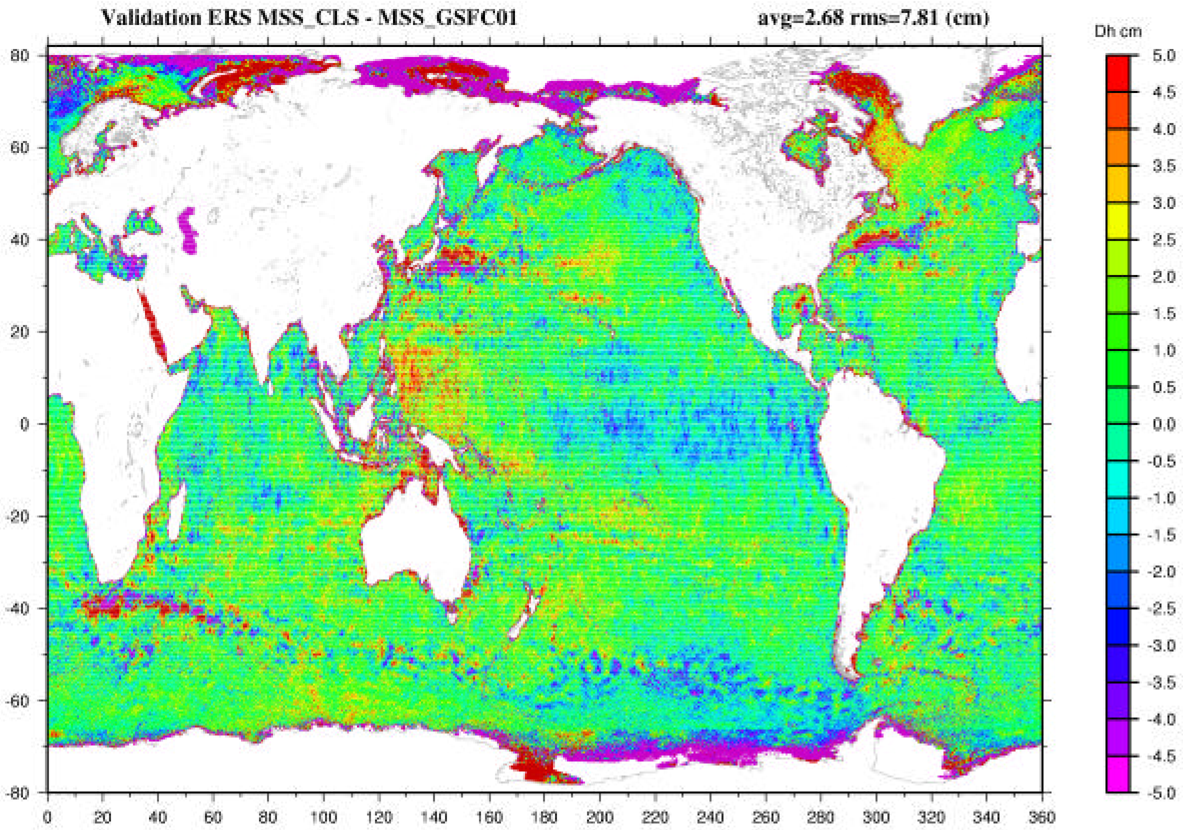

Figure 2: Map of the height differences between the CLS01 and GSFC00.1 MSS along the ERS mean profile groundtracks. Units in cm.

The CLS01 and GSFC00.1 MSS are interpolated along the groundtracks of the T/P (7 years), ERS (5 years), and GEOSAT (2 years) mean profiles. The statistics of the interpolated MH differences are presented in Table 5. There is a systematic height difference between the two surfaces, characterised by mean difference of the order of 2.5-3 cm rms. As explained above, this bias is caused by the different models used to correct the altimetric data, and also by the interannual ocean variability averaged over distinct periods for the two MSS, that modifies their respective MDT.

Along the T/P mean profile, where the two surfaces benefited from the most accurate data, the standard deviation of the MH differences is reduced to 3.35 cm rms. Along the GEOSAT mean profile, which is –at the opposite– the dataset that has been less adjusted either by the GSFC or the CLS team, the two surfaces are also close. Whereas along the ERS groundtracks, the differences are more important. This comes from the distinct processing applied by the

CLS and GSFC team to the ERS SSH. Figure 2 illustrates these differences. Large and coherent patterns of MH differences appear, that are linked with the interannual variability of the ocean. At the vicinity of the western boundary currents, and also the Circumpolar Antarctic Current shorter scale discrepancies are seen. They typically correspond to energetic ocean mesoscale features that were not removed in the MSS. Because the ocean variability has been reduced prior the CLS01 computation, we are suspecting residual errors in the GSFC00.1 surface. More carefully, one can note that along the Kuroshio or the Gulf Stream systems, a latitudinal positive/negative difference is observed. This might be caused by the meridional displacement of these current systems between the 1993-1998 and the 1993-1999 periods. Finally, this map show high MH differences (more than 5 cm rms) on the polar areas, caused by the partial coverage of ERS-2 and geodetic data.

Mean profile groundtracks Used for the comparisons	# compared points	Height différences RMS (mean / standard deviation)
Along T/P	551 374	4.59 (3.13 / 3.35)
Along ERS	1 845 854	7.81 (2.68 / 7.34)
Along GEOSAT	841 653	4.42 (3.07 / 3.18)

Table 5: Statistics of the height differences between the CLS01 and GSFC00.1 MSS along mean profile groundtracks

Because we are here comparing the two MSS along the mean profile groundtracks, the GSFC00 trackiness affects observed against the CLS_SHOM98.2 MSS (HS2000) are not discussed here. However, some regional grid comparisons between CLS01 and GSFC00.1 witnessed again these trackiness effect that contaminate the GSFC00.1 MSS.

5. ERS-2 and T/P SSH during the year 2000

SLA obtained by subtracting either the CLS01 or the GSFC00.1 MSS to ERS and T/P SSH, can be used to validate these MSS. The analysis is performed using ERS-2 and T/P SSH from the year 2000, because these altimetric data are not used to determine the GSFC00.1, neither the CLS01 MSS. T/P SSH from cycle 269 (starting the 3/1/00) to cycle 309 (ending the 12/2/01), and ERS-2 data from cycle 49 (starting the 20/12/99) to 59 (ending the 8/1/01) are processed using the same corrections that we used for determining the CLS01 MSS. Then two set of SLA are computed by subtracting respectively the GSFC00.1 and the CLS01 MSS.

For each T/P (resp ERS-2) cycle, that is, 10 (resp. 35) days of data, height and along track slope statistics (mean and standard deviations) are computed. Again, bathymetric criteria (100-m depth) are defined to analyse separately coastal areas and open ocean.

Figure 3 and Figure 4 show a systematic bias between GSFC00.1 SLA and CLS01 SLA (the difference between the mean values remains quasi constant), in both the open ocean and the coastal areas. Again, this is caused by the systematic bias between the two MSS (see §3). Over the open ocean, the cycle SLA standard deviations are of the order of 10-11.5 and 11-12.5 for T/P and ERS-2 respectively. ERS-2 data are noisier than T/P data. The values are fluctuating consistently between GSFC00.1 and CLS01 SLA. Variations are caused by the ocean variability, and SSH errors and distributions.

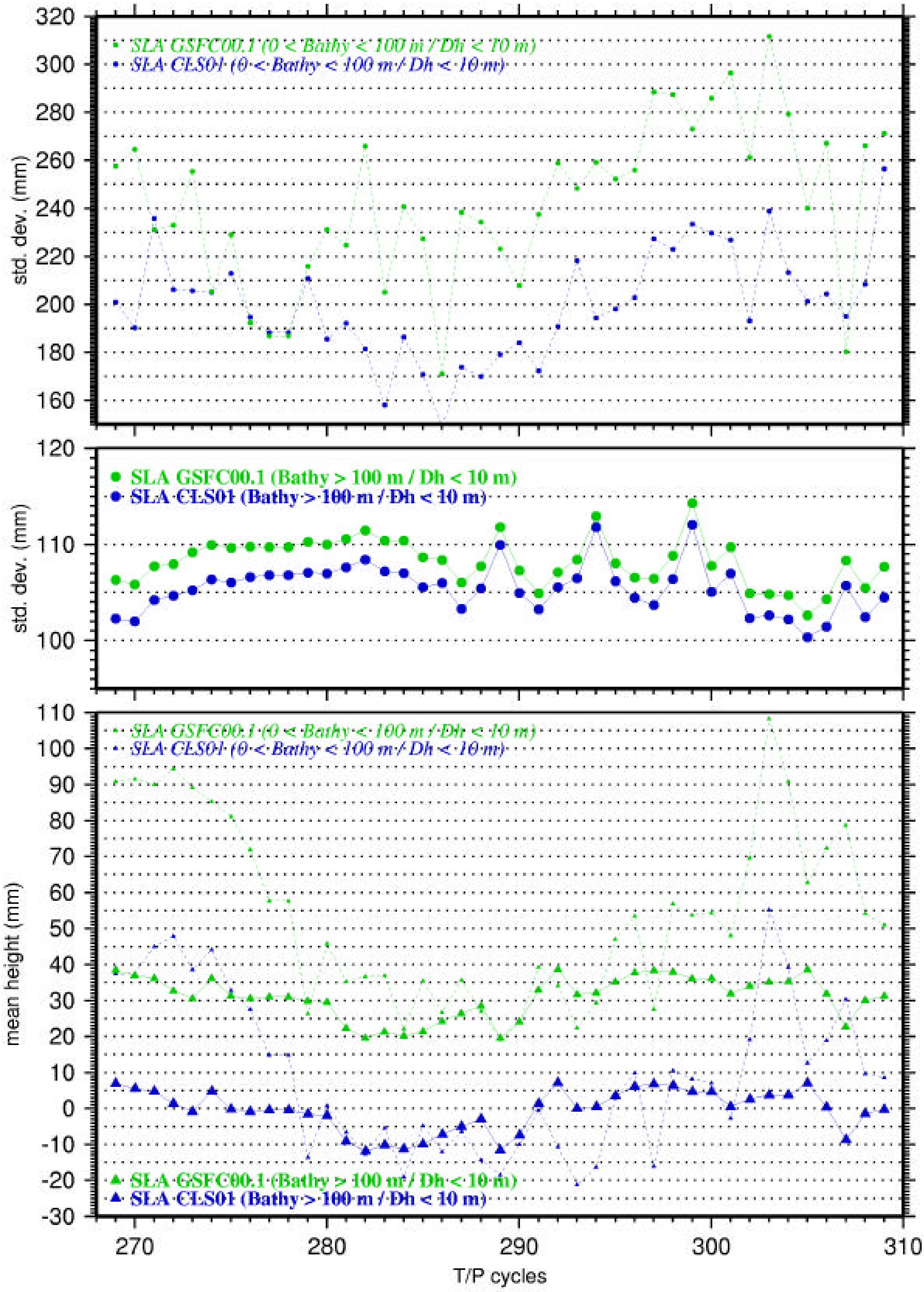

Figure 3: Cycle per cycle height statistics (in mm) for T/P SLA. The cycle mean values (bottom). The cycle standard deviations for open ocean (middle) and for coastal areas (top). SLA larger than 10 m are excluded.

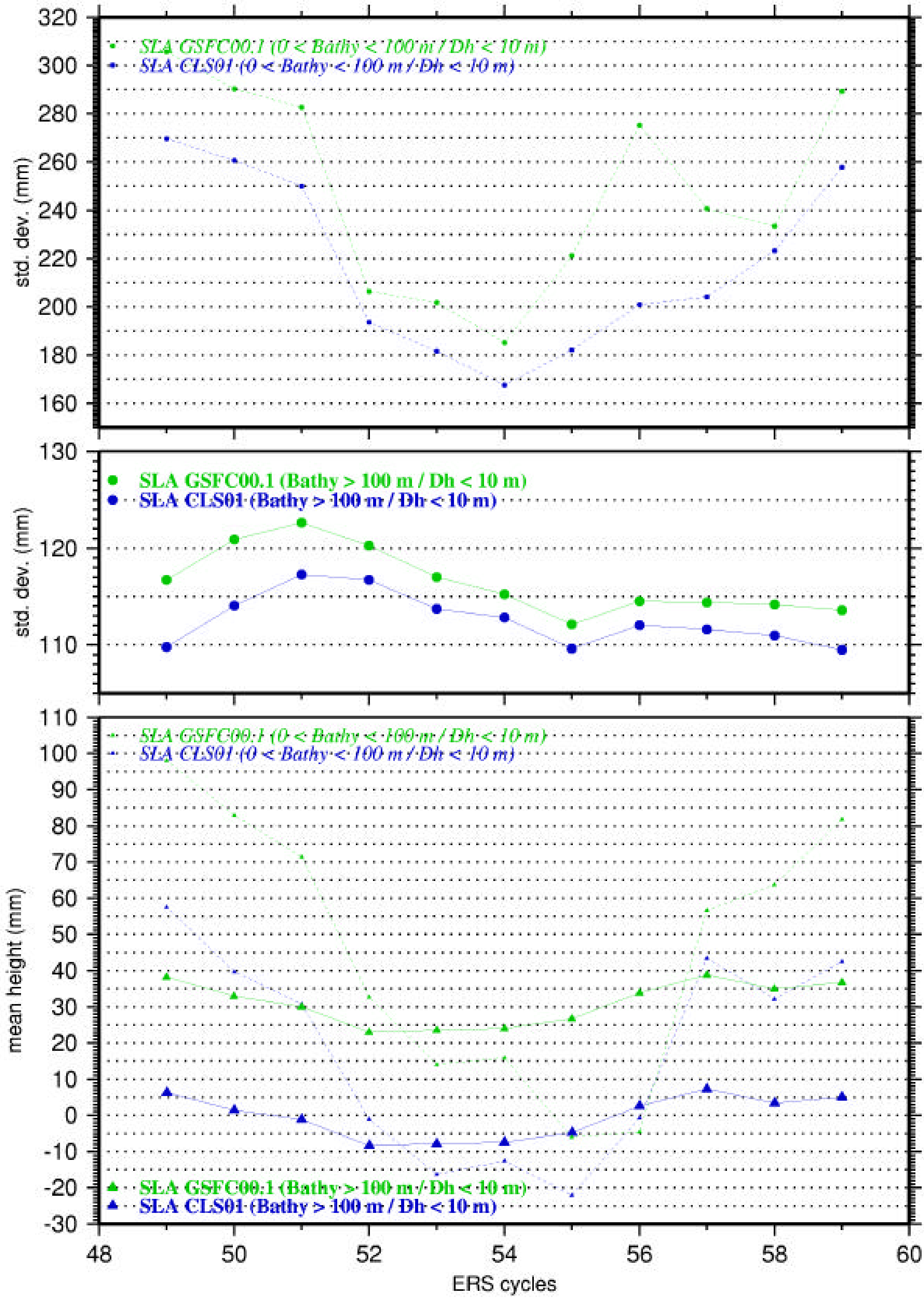

Figure 4: Statistics for ERS-2 cycle. See Figure 3 caption.

Standard deviation time series for GSFC00.1 SLA are always larger than for CLS01 SLA. If we assume no error correlation between SSH and the MSS, and also no error correlations between successive along track SSH, the SLA variance is expected to reveal the SLA noise. Thus the difference between the two series should represent the relative noise level due to the MSS used as a reference. Which implies that the noise level caused by the CLS01 MSS is lower than the noise level due to the GSFC00.1 MSS.

On coastal areas, our conclusions remain the same, although time series can be closer for T/P SLA (cycles 276-280 or 307). The SLA standard deviations are larger than over the open ocean. We primarily suspect the SSH noise level (e.g., inaccurate tidal corrections) rather than the MSS uncertainties.

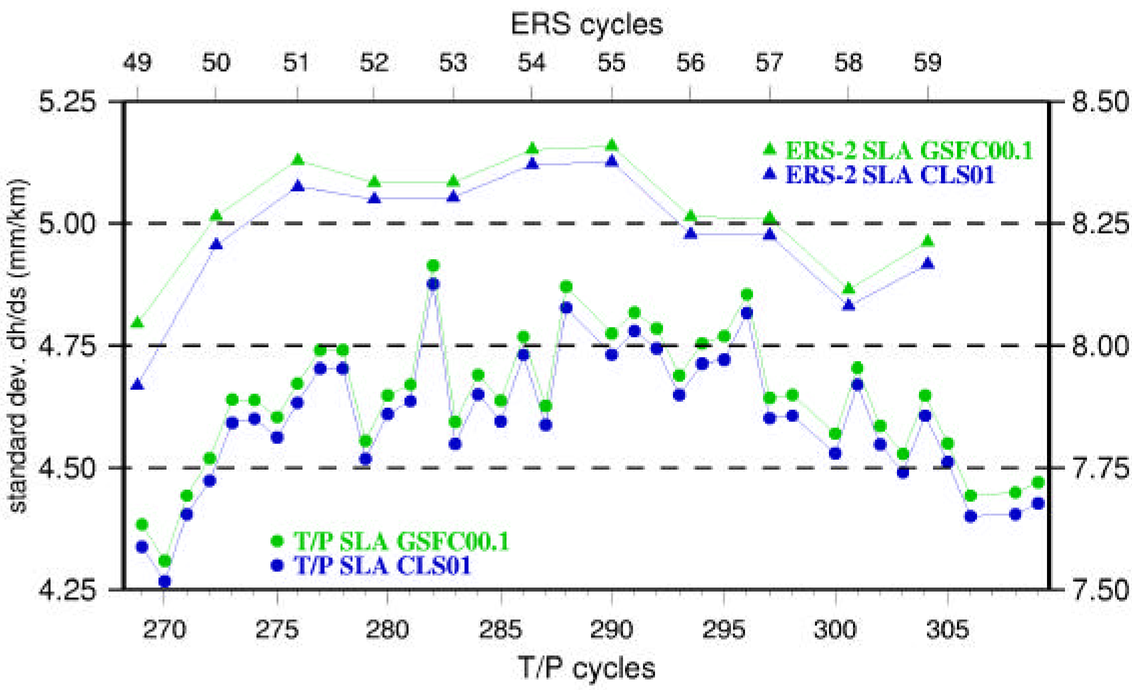

Figure 5: Cycle per cycle standard deviations of the along track slope. T/P cycles are referenced on the bottom axis, and the standard deviations values on the left axis. While ERS-2 cycles are referenced on the top axis, and the values on the right axis (units in mm/km). SLA along track slopes larger than 100 mm/km are excluded.

A complementary approach consist in analysing the SSH along-track slopes, that correspond to the shortest scales of the geoid and the short scale geostrophic currents. Once the MSS are subtracted to the SSH, the variance of the SLA along-track slopes should represent 1) the MSS noise level at short scales, and 2) the altimetric noise, plus 3) the ocean short scale variability.

Figure 5 shows that between T/P and ERS-2 SLA, the slope variance is tripled (~4.5 compared to ~8.25 mm/km rms). Again, this is largely caused by the altimetric noise of the ERS-2 data. However, we have demonstrated that the MSS shortest scales accuracy along the T/P mean profile is larger than along the ERS mean profile.

For both ERS-2 and T/P, the SLA referenced to the CLS01 MSS are less noisy than those referenced to the GSFC00.1. Thus, the along track slope statistics confirm the height statistics that showing the lower noise impact of the CLS01 MSS.

6. Conclusions

We are here comparing the CLS01 and the GSFC00.1 MSS, to infer their respective interest for the ongoing satellite altimetry (Jason-1, then EnviSat). A similar study was conducted last November 2000, comparing the CLS_SHOM98.2 and the GSFC00 MSS. The CLS01 is based on longer altimetric dataset and determined globally over a 2' grid, matching the resolution level provided by the GSFC00.1 MSS.

The CLS_SHOM98.2, CLS01 and GSFC00.1 MSS are compared to the T/P 7-year and ERS 5-year mean profiles. These two profiles offer a never achieved accuracy, but they were used to determine the CLS01 MSS (meaning that the comparison are not independent). However, comparisons show that the CLS01 MSS outclass the CLS_SHOM98.2 MSS (former MSS determination), in particular in coastal areas, and does better than the GSFC00.1 MSS. Over the open ocean CLS01 and GSFC00.1 differences are of the order of 3 cm rms. There is also a 2.5-3 cm bias between the two surfaces caused by the ocean interannual variability that modifies the respective MDT, but particularly by the more recent altimetric corrections we used to determine the CLS01 MSS. Because altimetric height will be corrected this way in the future, it is important to note that this bias would remain if the GSFC00.1 is used to reference altimetric data.

At small wavelengths, the MSS CLS01 stays closer to the mean profiles, which means that the short scales of the geoid undulations are better mapped than in the GSFC00.1 MSS. Trackiness effect are noticeable in the GSFC00.1 (which is the same MSS than GSFC00 with some gaps corrected).

The MSS might be used to reference simultaneously altimetric data from distinct satellites (e.g., Jason-1, EnviSat and GFO). In that case, we expect some MSS global homogeneity in terms of MDT and noise level. Comparisons show that the CLS01 MSS is much more homogeneous under the T/P and ERS ground tracks than the GSFC00.1 MSS.

Alternatively, we have used ERS-2 and T/P data from year 2000 to investigate in a total independent way the two MSS accuracy. Assuming no along track error correlation between SSH, and no correlated errors between SSH and MSS, we can conclude that the CLS01 MSS generates less noise when referencing the altimetric heights. That is, the CLS01 MSS is globally more accurate than the GSFC00.1 MSS.

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