Error Estimation of the global and regional mean sea level trends from Jason-1&2 and T/P data

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Overview

- Purpose : estimation of the different errors which can impact the global and regional MSL trends

- This presentation is divided into 3 parts:
  - 1) MSL description derived from Jason-1&2 and T/P altimeter missions
  - 2) MSL trend uncertainties for each correction and for orbit calculation
  - 3) Estimation of total error budget

1.1 – MSL description : definition and standards

- Reference Global MSL is calculated from Jason-1, Jason-2 and T/P data :
  - T/P : M-GDR products have been updated with GSFC0809 orbit (ITRF2005, GRACE), non parametric sea state bias (Labroue), and same standards as Jason-1 for other geophysical corrections
  - Jason-1 : Both GDR-B / GDR-C releases are used, a SSH map bias is applied to link each MSL time data series together
  - Jason-2 : GDRs data are used

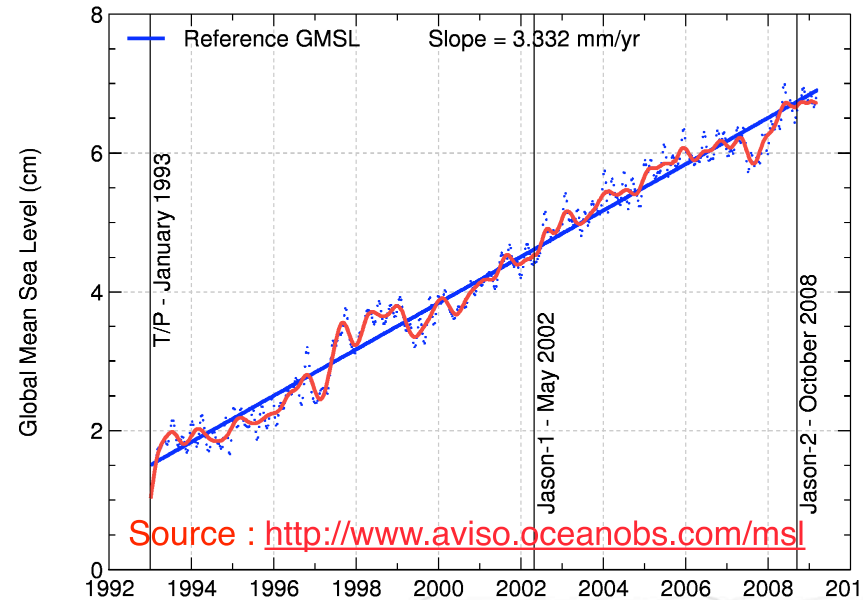
- Each MSL data series are linked together accurately thanks to the T/P&Jason-1 and Jason-1/Jason-2 formation flying phases :
  - T/P/Jason-1 : global bias (7.55 cm); Jason-1 cycle 11, May 2002
  - Jason-1/Jason-2 : global bias (6.51 cm); Jason-2 cycle 11, October 2008

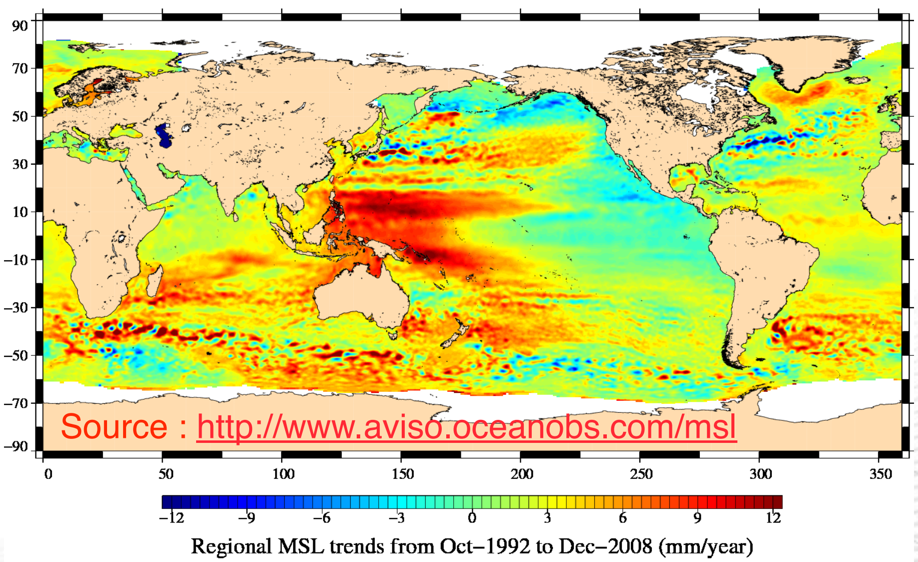
- Wet troposphere correction, inverse barometer correction, GIA (-0.3 mm/yr) are applied to calculate the MSL

⇒ For more details, see MSL Aviso Website: http://www.aviso.oceanobs.com/msl

1.2 – MSL description : global and regional MSL trend

- After removing annual, semi-annual signals, the GMSL trend is 3.33 mm/yr (with GIA) from January 1993 to May 2009

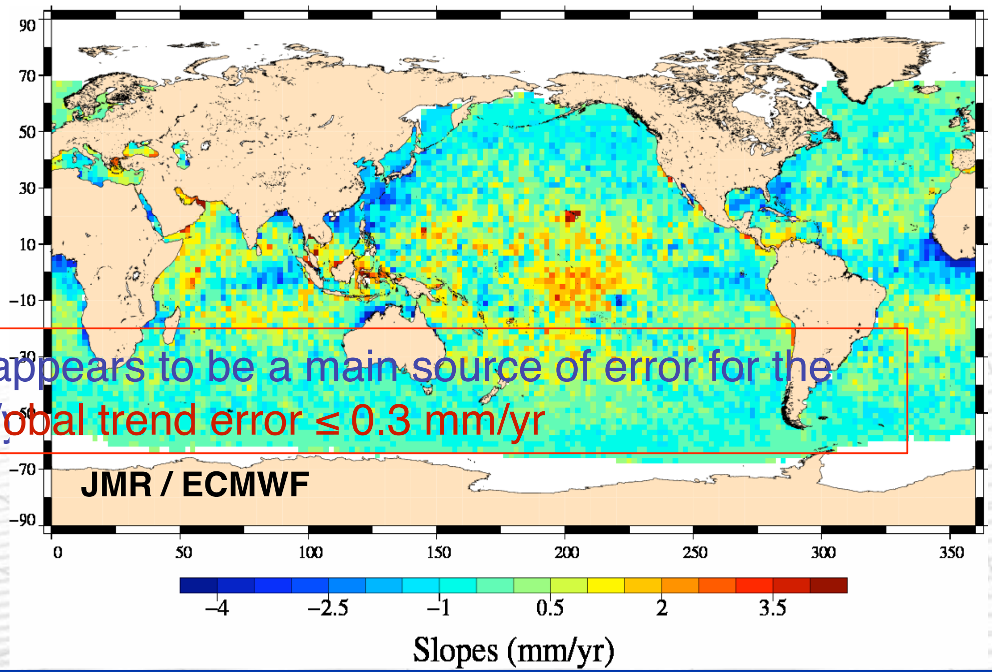




- Regional MSL trends are estimated from multi-mission grids (DUACS products)
- Inhomogeneous repartition of the ocean elevation is highlighted : +/- 10 mm/yr

2.1 – MSL trend uncertainties: Wet troposphere correction

- Radiometer Wet troposphere corrections (Jason-1, T/P, and Envisat) can be impacted by long term instrumental drifts (component ageing, thermal effects, yaw maneuvers, instrument turned off, …)
- Natural targets are used for calibration but this assumes they are independent of any long-term evolution
- Comparisons with meteorological model fields or radiometer correction together is a way to estimate the drift uncertainty



- Regional MSL slope differences (Radiometer/Model) : 0.3 to 0.5 mm/yr in wet areas
- The Wet troposphere correction appears to be a main source of error for the

→ 0.2 mm/yr ≤ global trend error ≤ 0.3 mm/yr

2.2 – MSL trend uncertainties: orbit calculation

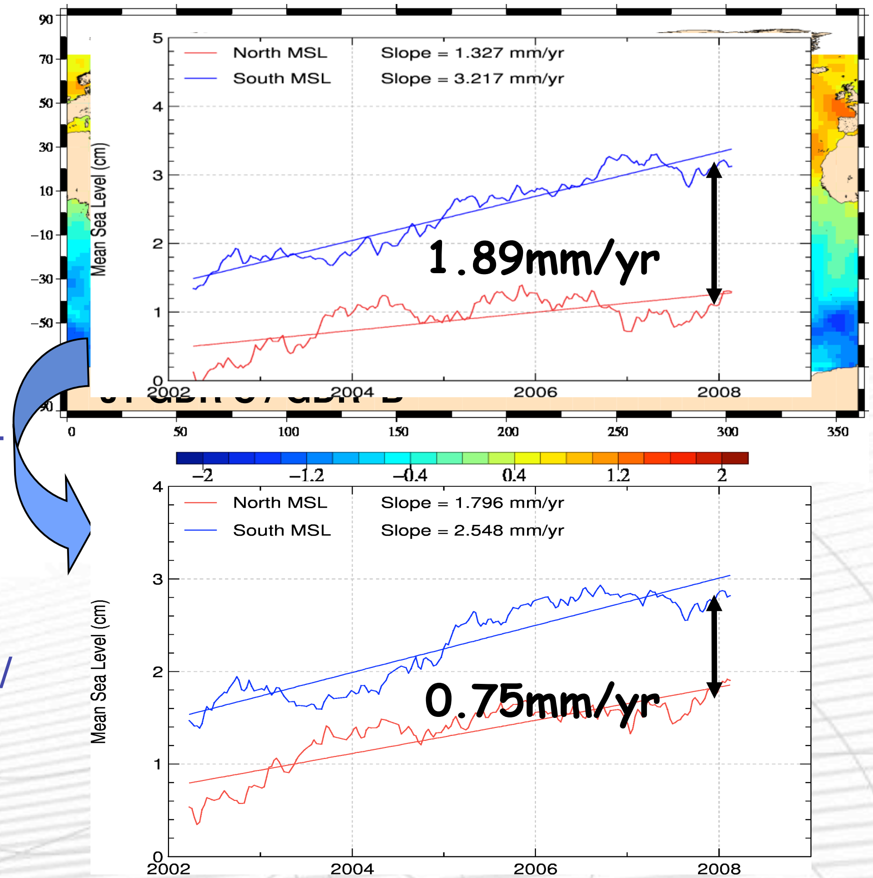
- The impact of orbit solutions on the MSL trends is linked to the reference frames and gravity models applied, especially between hemispheres

- For Jason-1, hemispheric differences using GDR-C orbits instead of GDR-B orbits are also observed close to +/- 1 mm/yr

⇒ due to the change from ITRF2000 to ITRF2005 reference frame

- Using GDR-C release, the hemispheric MSL trends are in better agreement

- A similar behavior have been observed for T/P using last GSFC orbit solution with ITRF2005



2.2 – MSL trend uncertainties: orbit calculation

- Last orbit solutions modify the hemispheric MSL trends significantly, but the difference is questionable:

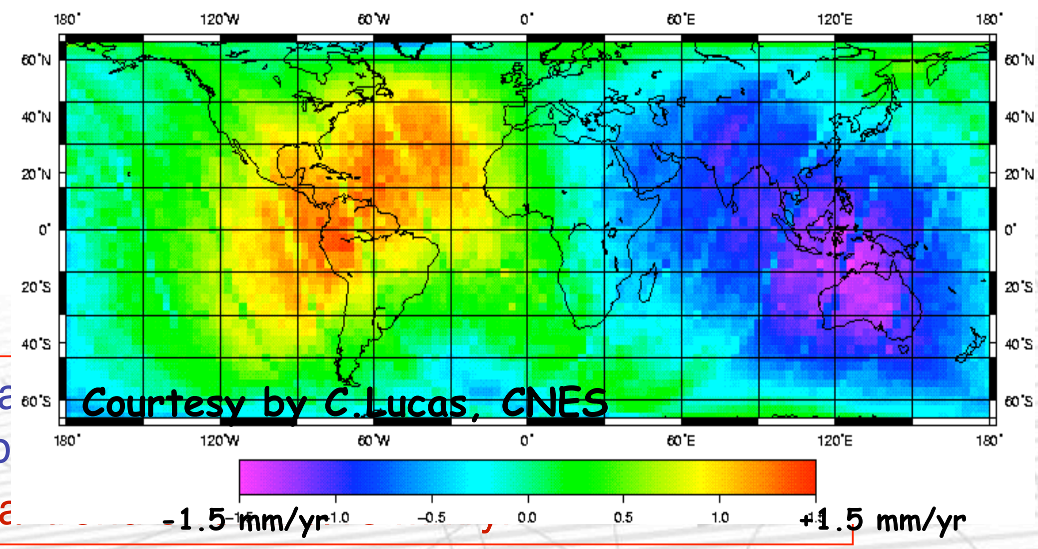
⇒ Do hemispheric MSL trend differences can be explained by physical processes

⇒ It's not easy to assess them with external sources :

  - ⇒ tide gauges : they are few TG in high latitudes (studies on going …)
  - ⇒ Argo profiles + GRACE data could also be used

⇒ Finally, we can consider at the moment these hemispheric differences as an uncertainty although ITRF2005 improves the orbit calculation

- In addition, the gravity fields have an impact : for instance the omission of long term variations leads to 1.5 mm/yr differences on basin scales.



⇒ As a result of the unequal ocea… the error budget due to the orb…

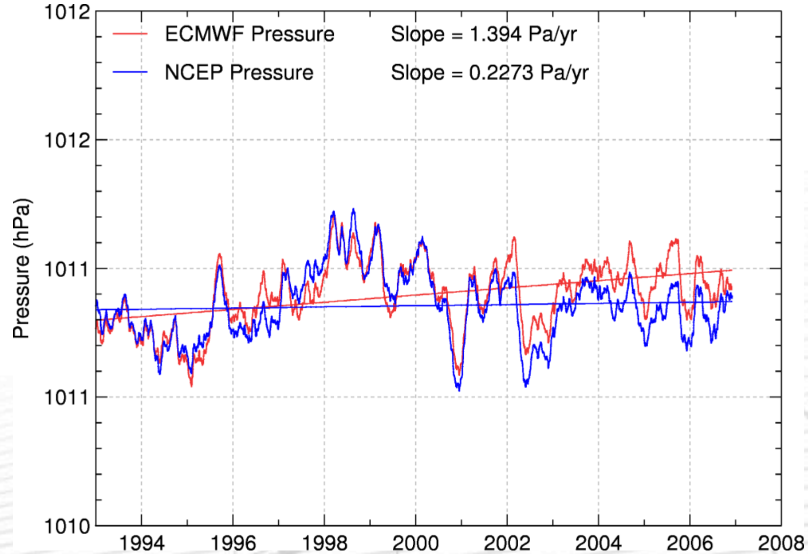
0.1 mm/yr ≤ globa…

2.3 – MSL trend uncertainties: pressure fields

- Operational ECMWF pressures fields could impact the long-term sea level estimate through the inverse barometer and the dry troposphere corrections.

- Differences between NCEP (reanalysis) and ECMWF models highlight a relative weak long term trend difference :
  ⇒ about ~1 Pa/yr ⇔ impact on the global MSL trend is ≤ 0.05 mm/yr

- Inconsistencies between pressure and mean pressure fields (ECMWF) have been also detected in Jason-1 GDR products :
  ⇒ both jumps (+20Pa in 2004 and -20Pa 2006 ⇔ 2.5 mm on the SSH) impact the global MSL trend by 0.2 mm/yr over the Jason-1 period
  ⇒ Other similar errors could be present on T/P time data series



⇒ The error budget due to pressure fields on the global MSL trend is :

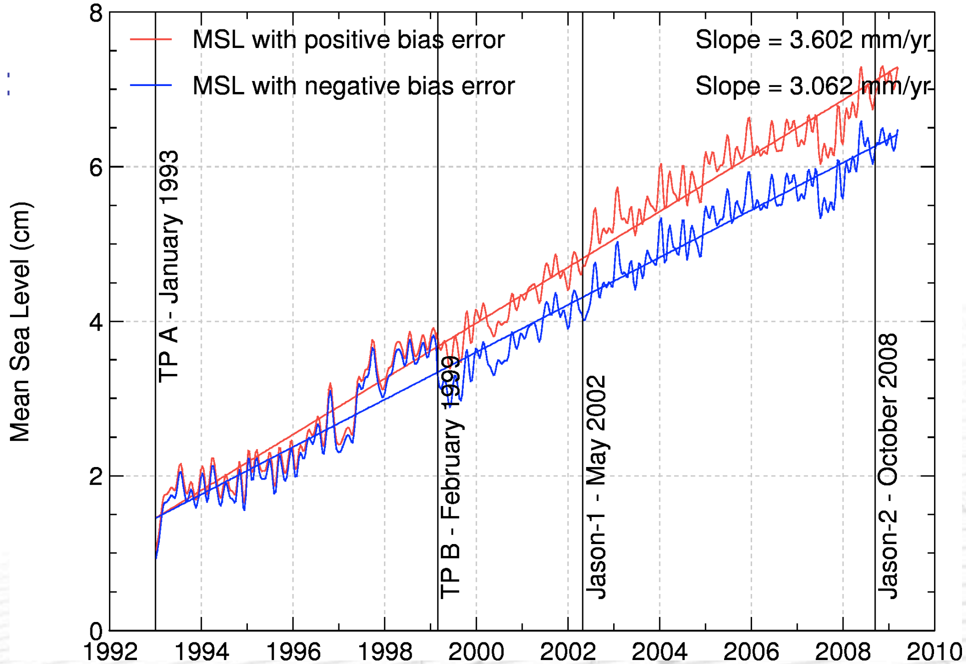
0.05 mm/yr ≤ global trend error ≤ 0.1 mm/yr

2.4 – MSL trend uncertainties: bias error between each data series

- MSL reference derived is split into 4 altimeter series : Topex A, Topex B, Jason-1, Jason-2

⇒ In order to connect them correctly, SSH biases have to be applied

- SSH bias uncertainties are estimated :
  - ⇒ 1.0 mm ≤ TP A / TP B ≤ 2.0 mm
  - ⇒ 0.5 mm ≤ TP / J1 ≤ 1.0 mm
  - ⇒ 0.25 mm ≤ J1 / J2 ≤ 0.5 mm



- These uncertainties impact directly the global MSL trend between ±0.10 and ±0.25 mm/yr considering minimal or maximal errors.

⇒ The error budget due to SSH bias uncertainties on the GMSL trend is :

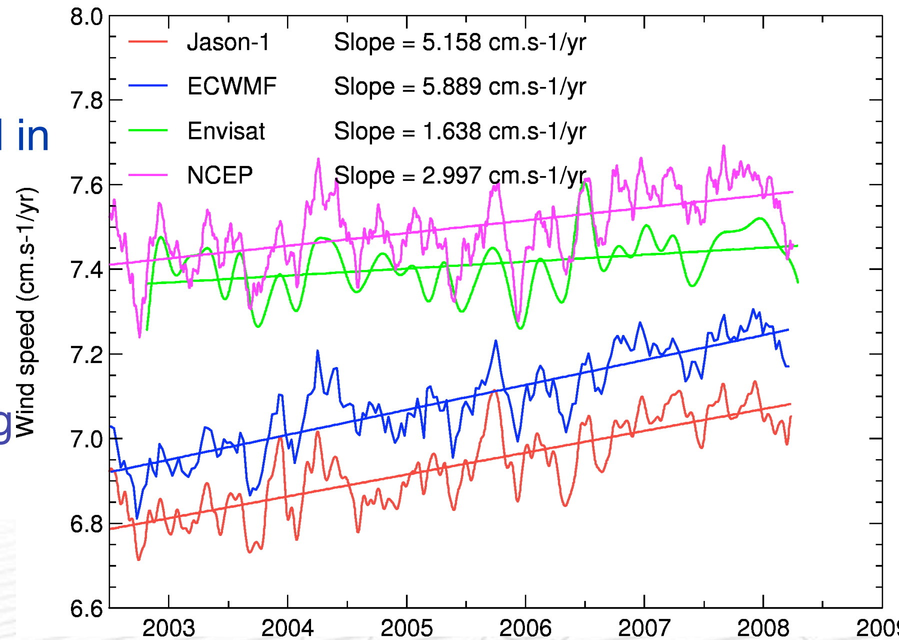
0.10 mm/yr ≤ global trend error ≤ 0.25 mm/yr

2.5 – MSL trend uncertainties: altimetric parameters

- Altimeter parameters are precisely monitored over all the mission life-time to detect intrumental anomalies (due to ageing for instance)

- However, a potential drift has been detected in the altimeter wind speed (computed from SWH and SIGMA0)

- An uncertainty varying between 2 and 4 cm.s-1/yr can then be considered comparing models (ECMWF, NCEP) and Jason-1 and Envisat



⇒ The error budget due to the sigma0 (through the SSB) on the GMSL trend is : 0.05 mm/yr ≤ global trend error ≤ 0.1 mm/yr

3.1 – Total error budget : summary

Source of error for the MSL calculation	MSL trend uncertainties from 1993 to 2009	
	Minima	Maxima
Orbit : Cnes POE (GDR B) for Jason-1 and GSFC (ITRF2000) for T/P.	0.10 mm/yr	0.15 mm/yr
Radiometer Wet troposphere correction: JMR (GDR B) & TMR (with drift correction).	0.20 mm/yr	0.30 mm/yr
Dynamical atmospheric and dry troposphere corrections using ECMWF pressure fields.	0.05 mm/yr	0.10 mm/yr
Sigma0 drift impacting altimeter wind speed and sea state bias correction	0.05 mm/yr	0.10 mm/yr
Bias uncertainty to link TP A / TP B, TOPEX and Jason-1, Jason-1 and Jason-2	0.10 mm/yr	0.25 mm/yr

Upper Bound of GMSL Trend Error < 0.9 mm/yr

3.2 – Total error budget : global MSL trend error

- A 0.9 mm/yr total error budget is a pessimistic point of view : we assume errors are additional (not negatively correlated)
- The quadratic sum leads to value close to 0.45 mm/yr
  - ⇒ This method do not take into account the true correlation of error together
- Finally, we used an inverse method to estimate a more realistic error :

$$x_{est} = R_{xx} H^T (H R_{xx} H^T + R_{vv})^{-1} z$$

- Thanks to this formalism, the covariance of observations can be described in Rvv matrix:
  - ⇒ According to the time period (T/P, Jason-1, …)
  - ⇒ According to their nature (jump, drift, …)

- The error can be directly deduced in a confidence interval from the formal error multiplied by the adapted student coefficient

⇒ Finally the total error budget of GMSL is :

0.6 mm/yr in a confidence interval of 90%

Conclusion

- This study allows us to describe the global MSL error budget :
  - ⇒ GMSL trend = 3.32 mm/yr ± 0.6 mm/yr in a confidence interval of 90%

- Global MSL trend error is in agreement with tide gauge studies (In-Situ Calval session) :
  - ⇒ T/P+Jason-1 / Tide gauge drift = ± 0.7 mm/yr

- But this MSL error description has to be refined :
  - ⇒ Thanks to new altimeter standards : MSL trend error should be reduced
  - ⇒ Thanks to supplementary studies in order to estimate altimeter uncertainties better

- For instance, we do not consider any drift on altimeter range in this study :
  - ⇒ It might be more realistic considering a drift on TOPEX-A period as highlighted with tide gauge in-situ comparison and in relationship with TOPEX retracked data (see Labroue's poster).