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# Error Characterization of altimetry measurements at Climate Scales

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# Overview

- The purpose of this study is to characterize errors of altimetry at climate scales

- Description of errors for global Mean Sea Level Trend has been already performed from 1993 to 2008 (Ablain et al, 2009):

⇒ It's interesting to revisit this error over the 1993-2012 time period

⇒ Other spatial and temporal scales are also of great interest for climate studies

⇒ Such errors could reduce the accuracy of the observation of the MSL and can make it difficult to provide interpretation of geophysical mechanisms.

| Spatial Scales | Temporal Scales |
|---|---|
| Global MSL (10-day averaging) | Long-term evolution ( > 10 years ⇔ trend) |
| | Inter annual signals (2- 5 years) |
| Regional MSL (2x2 deg boxes and 10-day averaging) | Periodic signals (Annual, 60-days,…) |

# Overview

- Data used :

⇒ TOPEX, Jason-1 and Jason-2 data using the level-2 products (GDR,..)

⇒ Updated with the latest altimeter standards available in the frame of SALP (CNES) and Sea-Level CCI (ESA) projects, e.g. :

  - Latest orbit solutions (CNES-GDR-C)
  - DAC and dry troposphere corrections derived from ERA-interim
  - …

- **Outlines**

⇒ Description of sources of errors :

  - Orbit calculation
  - wet troposphere correction
  - altimeter instrumental parameter
  - Other errors

⇒ MSL budget error at climate scales

⇒ Comparisons with users requirements (scientific goals)

# Orbit solutions

- These last years, orbit solutions have been improved at climate scales

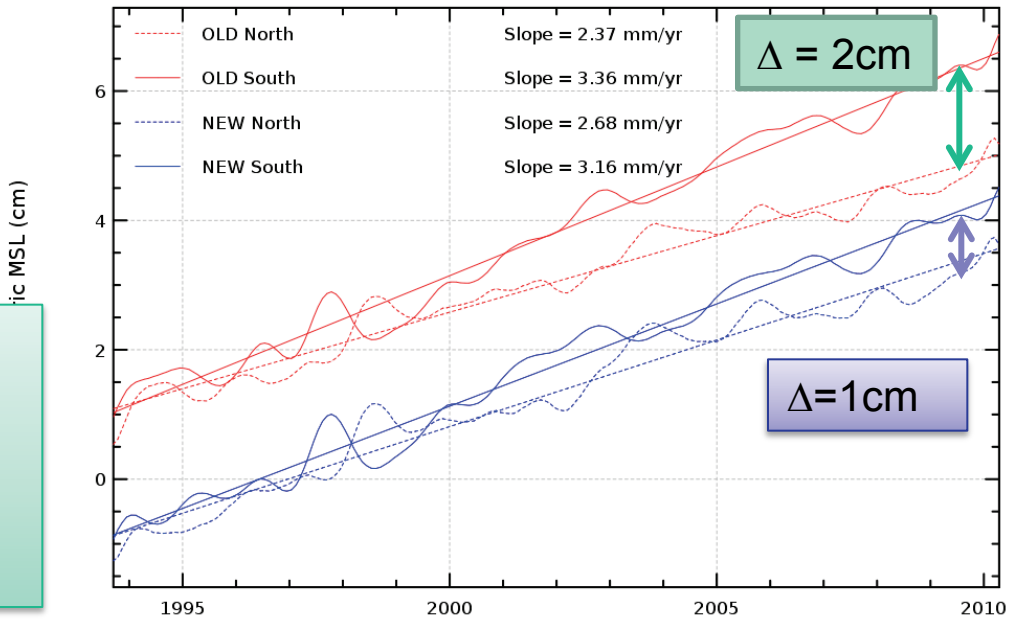
- Latest ITRF solutions reduced the heterogeneity between hemispheric MSL

⇒ Reduction of regional MSL trend differences between Northern and Southern Hemispheres

- Impact of ITRF2008 (blue) / ITRF2005 (red) on hemispheric MSL

⇒ Δ=0.5 mm/yr instead of 1 mm/yr

- These hemispheric differences provide an upper bound of error :
  - error ≤ 0.5 mm/yr at basin scale
  - higher at high latitudes



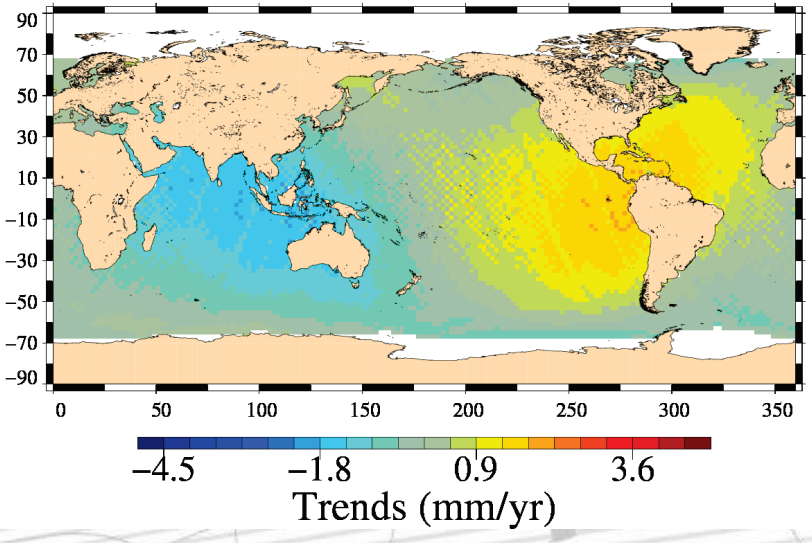
# Orbit solutions

- New time-variable gravity field models used in orbit calculation have significantly reduced the errors of MSL trends at basin scales

⇒ For instance regional MSL trend differences between Envisat and Jason-1 have been significantly reduced using CNES-GDR-D orbit / CNES-GDRC [Ollivier et al., 2012]

⇒ On Jason-1, the impact is close to +/- 1.5 mm/yr at basin scales.

Impact of new CNES GDR-D / GDR-C orbit solutions for Jason-1 on regional MSL trends




- However, errors on gravity field modelization are still observed and impact orbit calculation at climate scales:

⇒ For instance, on the first decade of altimetry on TOPEX-era (from 1992 to 2002), GRACE data are not available.

# Orbit solutions

- Other source of errors have been also identified :

⇒ For instance, no more GPS data on Jason-1 : orbit is slightly degraded with potential impact at climate scale

- Budget errors of orbit solution versus climate scales

| Spatial Scales | Temporal Scales | Orbit solutions errors |
|---|---|---|
| GMSL | Long-term evolution | ≤ 0.1 mm/yr |
| | Inter annual signals | ≤ 1 mm |
| | Periodic signals | ≤ 0.5 mm for annual |
| RMSL | Long-term evolution | ≤ 2 mm/yr |
| | Periodic signals | ≤ 5 mm for annual |

For more details: L.Cerri presentation (The Precise Orbit and the Challenge of Long Term Stability, on last Monday 24th, 2012)

# Instrumental altimeter parameters

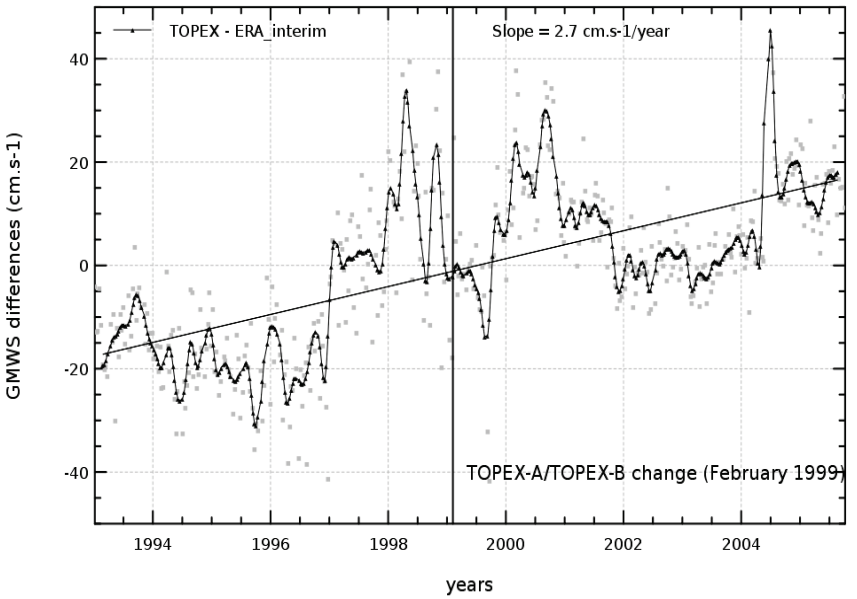
- Altimeter instrumental parameter errors can be due to the instrumental ageing, instrumental anomalies or error in ground processing.
- Altimeter parameters are precisely monitored over all the mission life-time to detect, monitor and correct these instrumental anomalies.
- However, instrumental parameter instabilities have been detected especially on the first altimetry decade on TOPEX data

- Detection of long-term instabilities on altimeter backscatter coefficients has been highlighted studies [Ablain et al, 2012] :

⇒ -0.03 dB for Jason-1 from mid-2004 to 2005

⇒ -0.1 dB from 1993 to 2002 for TOPEX with strong inter-annual signals

⇒ overestimation of the GMSL trend of about 0.1 mm/yr over the 1993 to 2011 period



# Instrumental altimeter parameters

- Other errors have been identified on TOPEX data:

⇒ Strong SWH drift during the 1996-1999 period (30 cm) impacting the estimation of the SSB during this period => inter-annual error

⇒ 58.77~day signal error on TOPEX range (OSTST, Lisbon 2010) ~3 mm

⇒ Geographical MSL bias on TOPEX-A and TOPEX-B : North/South/Ascending/Descending

- Budget errors of instrumental parameters versus climate scales

| Spatial Scales | Temporal Scales | Instrumental parameter errors |
|---|---|---|
| GMSL | Long-term evolution | ≤ 0.1 mm/yr |
| | Inter annual signals | ≤ 2 mm |
| | Periodic signals | ≤ 3 mm for 60-day signal |
| RMSL | Long-term evolution | ≤ 0.5 mm/yr |
| | Periodic signals | ≤ 1 cm for 60-day signal |

# Wet troposphere corrections

- Wet troposphere correction is a main contribution of error for the Global MSL trend:

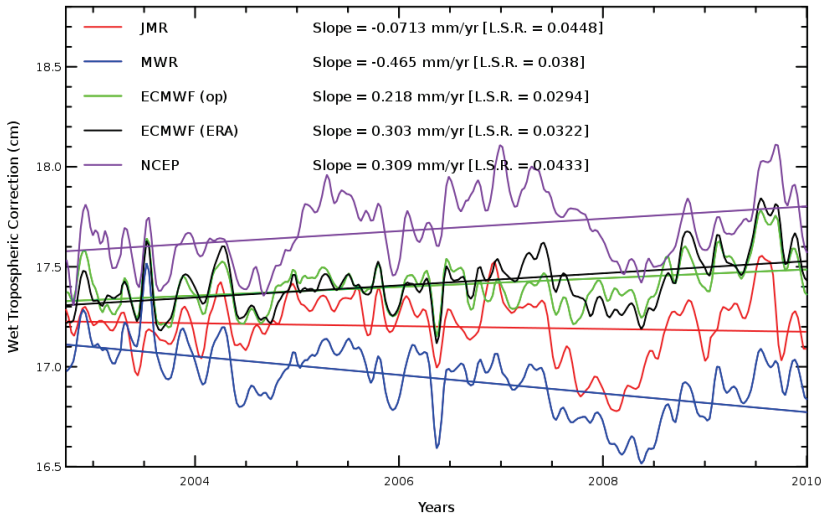
⇒ 0.3 mm/yr [Ablain et al, 2009] : this error is still the same on 1993-2012 period !

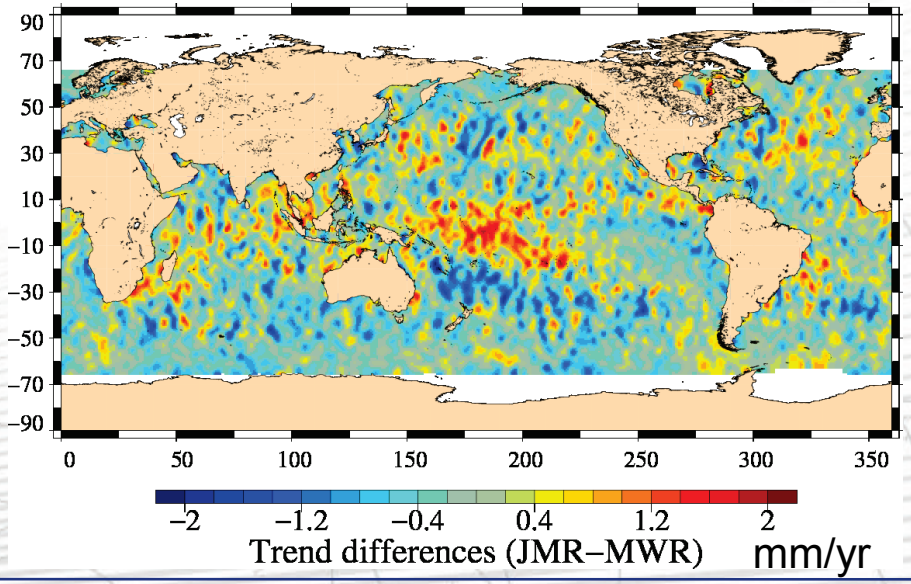
- Errors at inter-annual scales are also significant

⇒ During ENSO event (Niña event) Model and radiometer do not observe the same signal

- Regional MSL trend differences are also significant

⇒ Radiometer or/and model comparison highlight 2 mm/ differences in tropical band



# Wet troposphere corrections

- 60-day signal errors TOPEX and Jason-1 radiometers due to yaw maneuvers

⇒ Corrections have been performed a posteriori but errors ≤ 3 mm of amplitude remain

- Budget errors of wet troposphere correction versus climate scales

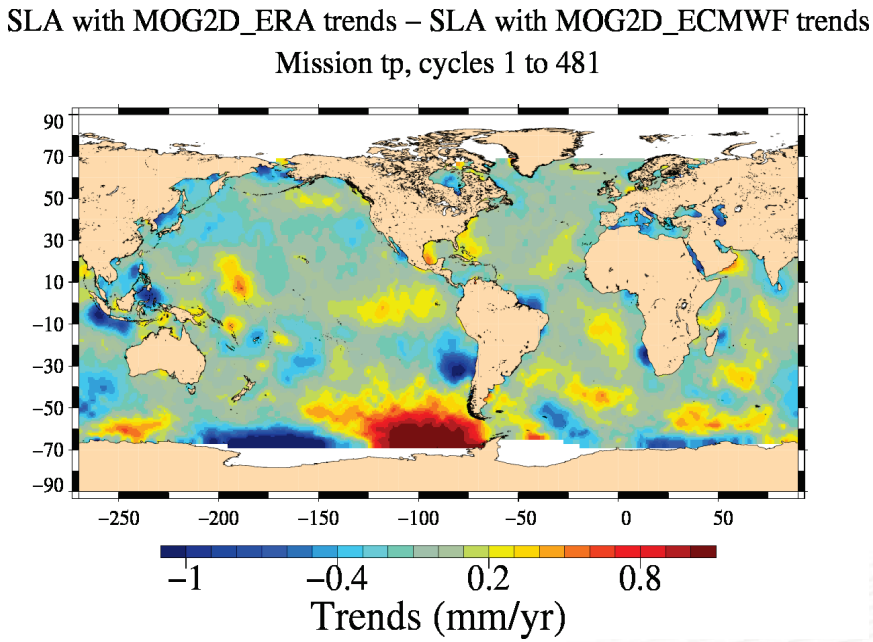
| Spatial Scales | Temporal Scales | Wet tropo. errors |
|---|---|---|
| GMSL | Long-term evolution | ≤ 0.3 mm/yr |
| | Inter annual signals | ≤ 2 mm |
| | Periodic signals | ≤ 3 mm for 60-day signal |
| RMSL | Long-term evolution | ≤ 2 mm/yr |
| | Periodic signals | Not evaluated |

See S.Brown's presentation (Is There a Drift in the Radiometer? 20 Years of Progress in Developing a Climate Quality Wet Troposphere Correction, on last Monday 24th, 2012)

# Other errors

- Atmospherical fields : impact of high frequency variability on regional MSL trends

⇒ Using ERA-interim pressure fields in DAC and dry troposphere correction improve the estimation of the MSL evolution at regional scales




RMSL trend differences between DAC derived from ERA-interim and ECMWF operational pressure fields on TOPEX: RMSL trends reach 1 mm/yr in high latitudes

⇒ Remaining errors are difficult to be estimated…

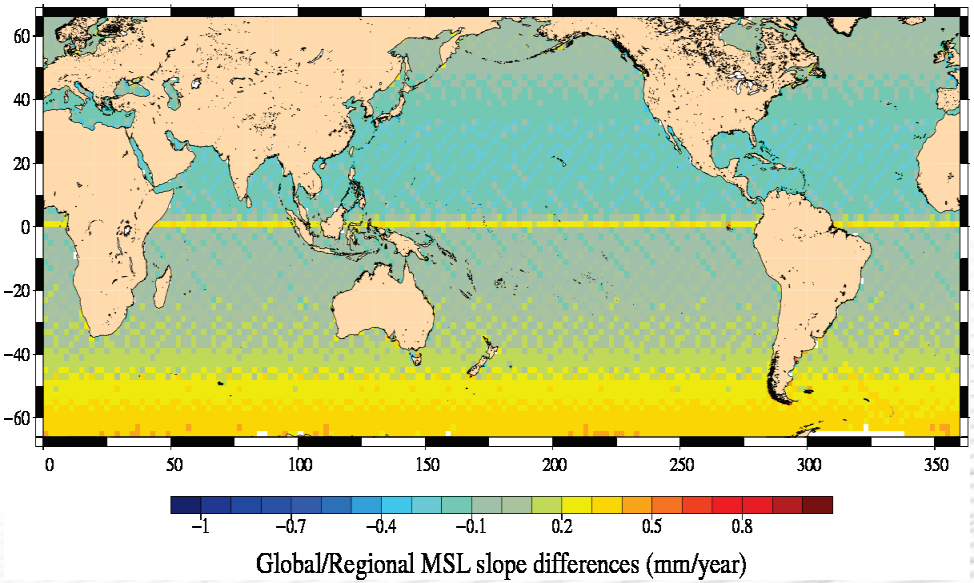
⇒ Upper bound errors can be given by the impact of ERA-interim pressure fields in comparison with ECMWF operational pressure fields

# Other errors

- SSH biases to link altimetry together have been accurately estimated:
- at global scale : TP/JA1 (+/- 1mm) , JA1/JA2(+/- 0.5 mm) & TP-A/TP-B (+/- 2 mm)
- At regional scale : TP/JA1, J1/JA2 (not corrected for TP-A &TP-B)
- However, it remains uncertainties which impact the MSL evolution:

⇒ +/-0.2 mm/yr for the GMSL trends and +/-0.5 mm/yr on the regional MSL trends

⇒ Impact on the determination of MSL variations at inter-annual scale mainly in 1999 during the TP-A/TP-B change and during the strong El-Niño event




Impact of regional SSH bias corrections (between TP/JA1 and JA1/JA2) on regional MSL trends from 1993 to 2010

# Other errors

- Sea State Bias correction : see D. Vandemark's presentation "Continued Progress towards A Next-generation Sea State Bias", on last Monday 24th, 2012

- Altimeter data coverage at high latitudes is reduced due to sea ice :

⇒ uncertainties on annual signals, trends, … are higher on these areas (Prandi et al, 2012).

- Oceanic tidal models :

⇒ Periodic signal errors have been highlighted: 58.77 days, ….

⇒ Long-term trend errors ?

# MSL budget error at climate scales

- Thanks to the accurate analysis of each source of error in the sea-level calculation, we are able to estimate the MSL error budget at climate scales

⇒ Global error is defined by an upper bound

⇒ In-situ comparisons (Tide Gauges, Argo profiles) are also used to defined this budget error

| Spatial Scales | Temporal Scales | Altimetry errors |
|---|---|---|
| Global Mean Sea Level (10-day averaging) | Long-term evolution (> 10 years ) | ≤ 0.5 mm/yr |
| | Inter annual signals ( 2-5 years) | ≤ 3 mm |
| | Periodic signals (Annual, 60-days,…) | Annual ≤ 1 mm<br>60-day ≤ 5 mm |
| Regional Mean Sea Level (2x2 deg boxes and 10-day averaging) | Long-term evolution (trend) | ≤ 3 mm/yr |
| | Inter annual signals (> 1 year) | Not evaluated |
| | Periodic signals (Annual, 60-days,…) | Annual ≤ 1 cm<br>60-day ≤ 2 cm |

# Altimetry data budget error at climate scales

- User requirements have been defined in Sea-level CCI project and last GCOS report.
- Comparing these scientific goals with altimetry errors allow us to qualify the level of altimetry errors at climate scale: null, low or strong

⇒ altimetry errors are systematically higher than these scientific goals (when they are defined)

| Spatial Scales | Temporal Scales | Altimetry errors | User Requirements |
|---|---|---|---|
| Global Mean Sea Level (10-day averaging) | Long-term evolution (> 10 years ) | ≤ 0.5 mm/yr | 0.3 mm/yr |
| | Inter annual signals ( 2-5 years) | ≤ 3 mm | 0.5 mm over 1 year |
| | Periodic signals (Annual, 60-days,…) | Annual ≤ 1 mm<br>60-day ≤ 5 mm | Not defined |
| Regional Mean Sea Level (2x2 deg boxes and 10-day averaging) | Long-term evolution (trend) | ≤ 3 mm/yr | 1 mm/yr |
| | Inter annual signals (> 1 year) | Not evaluated | Not Defined |
| | Periodic signals (Annual, 60-days,…) | Annual ≤ 1 cm<br>60-day ≤ 2 cm | Not Defined |

# Summary & Conclusions

- Current altimetry errors at climate scales are higher than user requirements although altimetry system is in agreement with mission specifications :

⇒ TOPEX reprocessing is needed to improve stability of altimeter instrumental parameters

⇒ Future orbit solutions should continue to improve regional MSL

⇒ Wet troposphere corrections remain the main source of errors and should be improved

- The link between altimeter systems and climate community should be enhanced:

⇒ To improve or refine user requirements

⇒ To better specify future altimeter system for climate applications

⇒ To reprocess older missions beyond their original specifications