Error Characterization of altimetry measurements at Climate Scales

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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
- **Global MSL**
  - (10-day averaging)

### Temporal Scales
- Long-term evolution ( > 10 years ⇔ trend)
- Inter annual signals (2- 5 years)
- Periodic signals (Annual, 60-days,...)
• 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)
These last years, orbit solutions have been improved at climate scales.

Latest ITRF solutions reduced the heterogeneity between hemispheric MSL, leading to a reduction of regional MSL trend differences between Northern and Southern Hemispheres.

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

- \( \Delta = 0.5 \text{ mm/yr} \) instead of \( 1 \text{ mm/yr} \)

These hemispheric differences provide an upper bound of error:
- \( \text{error} \leq 0.5 \text{ mm/yr} \) at basin scale
- higher at high latitudes
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 \(\pm 1.5\) mm/yr at basin scales.

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

<table>
<thead>
<tr>
<th>Spatial Scales</th>
<th>Temporal Scales</th>
<th>Orbit solutions errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMSL</td>
<td>Long-term evolution</td>
<td>≤ 0.1 mm/yr</td>
</tr>
<tr>
<td></td>
<td>Inter annual signals</td>
<td>≤ 1 mm</td>
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<tr>
<td></td>
<td>Periodic signals</td>
<td>≤ 0.5 mm for annual</td>
</tr>
<tr>
<td>RMSL</td>
<td>Long-term evolution</td>
<td>≤ 2 mm/yr</td>
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<tr>
<td></td>
<td>Periodic signals</td>
<td>≤ 5 mm for annual</td>
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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
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

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<td>Periodic signals</td>
<td>≤ 3 mm for 60-day signal</td>
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<td>≤ 1 cm for 60-day signal</td>
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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

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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)
• Atmsphrical 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

SLA with MOG2D_ERA trends – SLA with MOG2D_ECMWF trends
Mission tp, cycles 1 to 481

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
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 24\textsuperscript{th}, 2012.

- Altimeter data coverage at high latitudes is reduced due to sea ice:
  \Rightarrow uncertainties on annual signals, trends, … are higher on these areas (Prandi et al, 2012).

- Oceanic tidal models:
  \Rightarrow Periodic signal errors have been highlighted: 58.77 days, ….
  \Rightarrow Long-term trend errors?
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 define this budget error

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<td>Regional Mean Sea Level (2×2 deg boxes and 10-day averaging)</td>
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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)

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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