Sea Level Monitoring from Satellite Altimetry for Climate Studies
- improve the precision of the global mean sea level trend***
  → Reduce the current uncertainty (of 0.5-0.6 mm/yr) to <0.3 mm/yr

- improve the precision of the interannual variability***
  → Reduce current uncertainty of +/- 2 mm to <1 mm

- improve the precision of the regional variability***
  → Reduce current uncertainty of >2 mm/yr to <1 mm

(Also requirements from GCOS, OCEANOBS09, ...)
For What Purposes?

- Detect an acceleration in the rate of sea level rise and for sea level budget studies
- Determine the processes causing the interannual variability
- Improve estimates of the total ‘absolute’ sea level change in selected areas
- Estimate precisely the respective roles of thermal expansion and salinity changes
- Perform detection/attribution studies
- Extract the fingerprint of the solid Earth’s response to last deglaciation and present-day land ice melt.
Estimate of the GMSL derived from ERS-1, ERS-2 and Envisat needs to improved using other altimetry missions and the new CCI standards.

⇒ the GMSL trend is now 2.5 mm/yr with CCI standards instead of 1.9 mm/yr
⇒ The GMSL trend based on ERS and Envisat missions is now consistent with that derived with T/P, Jason-1, Jason-2
The ‘reference’ missions (T/P, Jason-1, Jason-2)

➔ **Important differences between the altimetry processing groups**

*Masters et al., Marine Geodesy, 2012*
Sea_Level_CCI

Detrended global mean sea level
Data from CLS and University of Colorado

Difference between the two
Sea_Level_CCI

1992-2011

Mean Sea Level from CLS/LEGOS and Colorado University

- **CU**
  - Trend: 3.1 mm/yr

- **AVISO**
  - Trend: 3.2 mm/yr

2005-2010

Mean Sea Level from CLS/LEGOS and Colorado University

- **AVISO**
  - Trend: 2.8 mm/yr

- **CU**
  - Trend: 2.1 mm/yr
# Sea Level Budget (2005-2010) (mm/yr) -IPCC AR5-

<table>
<thead>
<tr>
<th></th>
<th>Thermosteric Sea level</th>
<th>Glaciers</th>
<th>Ice sheets</th>
<th>Total Climatic Contributions</th>
<th>Observed (Altimetry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Leuliette &amp; Willis 2011 (0-700m)</td>
<td>0.5 +/- 0.5</td>
<td></td>
<td></td>
<td>(1) + (3) \rightarrow 2.4</td>
<td></td>
</tr>
<tr>
<td>(2) Von Schuckmann &amp; Le Traon 2012 (0-1500m)</td>
<td>0.75 +/- 0.15</td>
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<td></td>
<td>(2) + (3) \rightarrow 2.6</td>
<td></td>
</tr>
<tr>
<td>(3) Kaser, Cogley Allison, Rignot, etc</td>
<td>0.92 +/- 0.05</td>
<td></td>
<td>0.93 +/- 0.27</td>
<td></td>
<td>2.1</td>
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<tr>
<td>(4) Jacob et al 2012 (2003-2010)</td>
<td>0.41 +/- 0.08</td>
<td></td>
<td>1.06 +/- 0.19</td>
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<tr>
<td>NOAA/AVISO</td>
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<td>2.8</td>
</tr>
<tr>
<td>Univ Colorado/GSFC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.1</td>
</tr>
</tbody>
</table>
Sea_Level_CCI

Short-term trends computed over successive 6-year time spans

6 yr GMSL trends from AVISO / CLS and University of Colorado
Regional sea level trends (1993-2010)

Regional sea level due to GIA (effect on satellite altimetry)
Effects on regional sea level due to solid Earth deformation and self gravitation in response to ongoing (& future) land ice melt

Mitrovica, 2009; Milne et al., 2009

Greenland melting

Antarctica melting

Negative values ← 0  +1mm/yr  +1.4 mm/yr

(colour scale in mm/yr if melting rate = 1 mm/yr equivalent sea level rise)
Sea_Level_CCI

Onboard Instruments

Ionosphere

Wet tropo

Dry tropo

Multi-satellite merging

Orbit

Atmospheric loading

Sea state correction

Ocean tides

Coastal and high latitudes

$h_d = H - h - h_g$

altimeter range measurement $h$

dynamic sea surface topography

reference ellipsoid

globoid height $h_g$

sea surface height

geoid

sea surface

H satellite orbit

(reference ellipsoid)
Sea_Level_CCI

Masters et al, Marine Geodesy, 2012