The SEA LEVEL "Essential Climate Variable":

A key indicator of human-induced global climate change & internal climate variability

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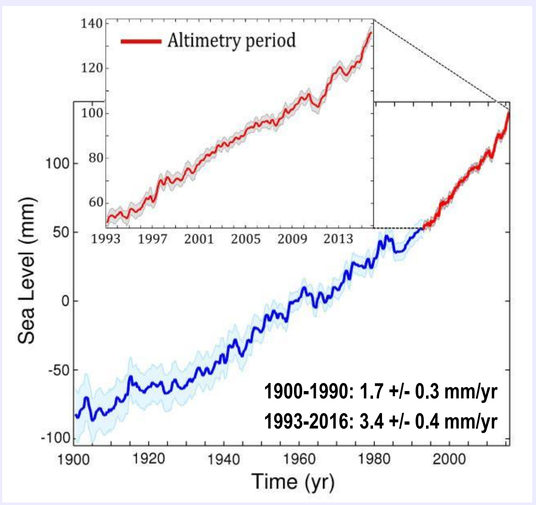
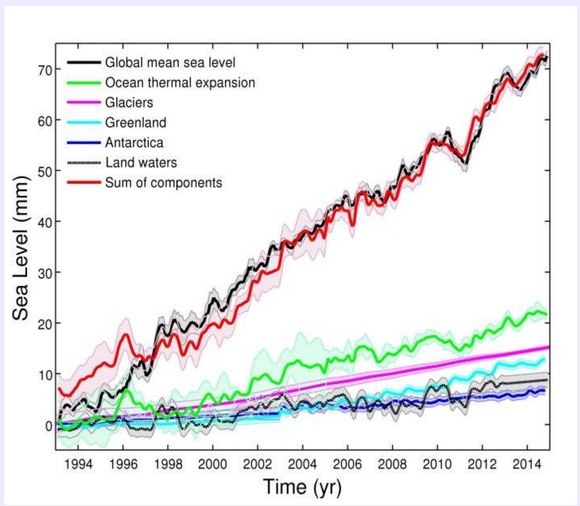
The WCRP Grand Challenge Group 'Regional sea level variability and change'*;
The ESA 'Climate Change Initiative Sea Level' ** and 'Sea level closure budget'*** projects

Present-day sea level changes

Anthropogenic global climate change causes ocean warming and land ice melt, resulting in global mean sea level rise

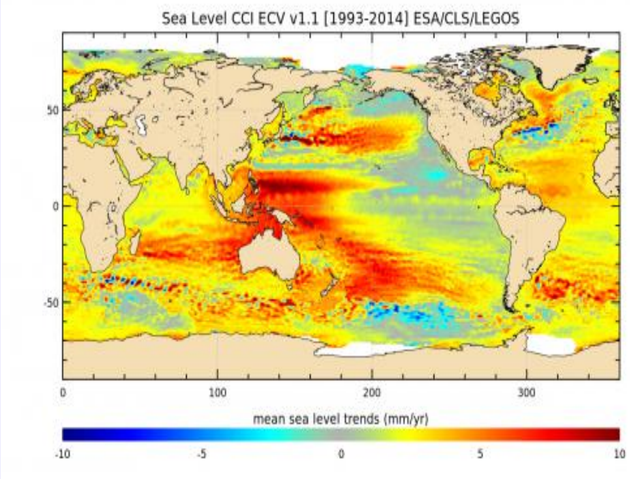


Observed global mean sea level rise since the year 1900 (from tide gauges, blue curve, data from Church & White, 2011; from satellite altimetry, red curve; mean of 6 different data sets)

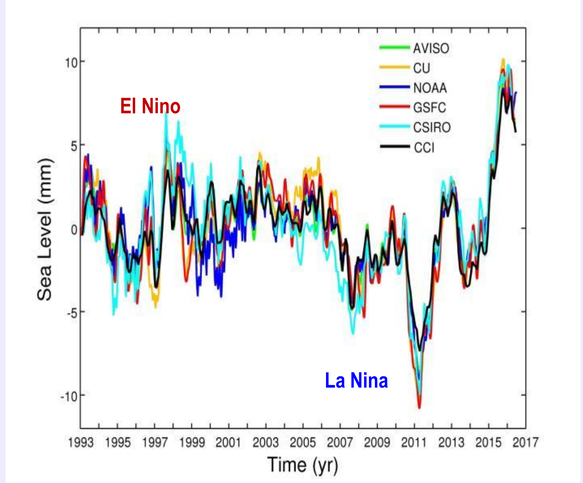


Observed global mean sea level and contributions from ocean thermal expansion, land ice melt (glaciers, Greenland and Antarctica) and land water storage changes since 1993 (altimetry era; means of several data sets) (source: LEGOS)

Internal climate variability (e.g., Pacific Decadal Oscillation/PDO, El Niño-Southern Oscillation/ENSO, North Atlantic Oscillation/NAO) is mostly responsible for present-day regional trends in sea level and interannual variability of the global mean sea level

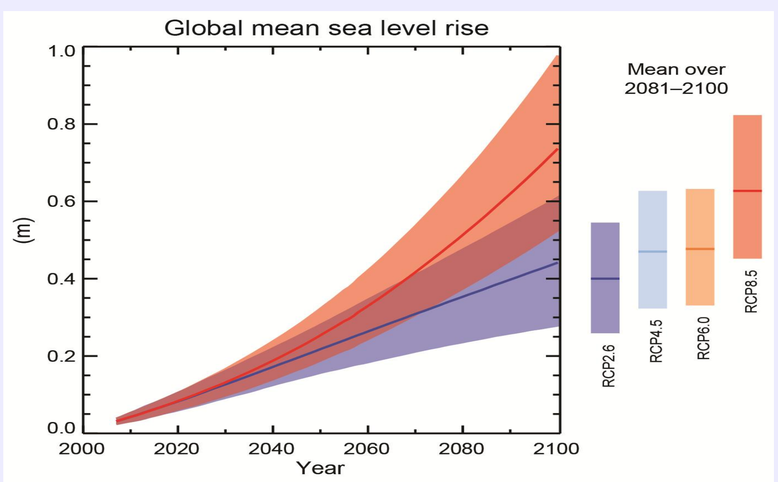


Regional sea level trends over the period 1993-2014 (data from CCI)



Detrended global mean sea level (1993-2016) (global mean rise of 3.4 mm/yr removed; data from 6 processing groups)

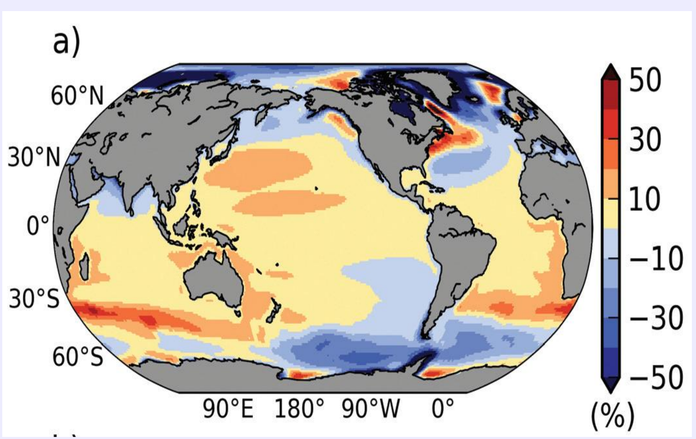
Future sea level changes



Process-based model projections for RCP 2.6 AND 8.5 scenarios (IPCC, Church et al., 2013)

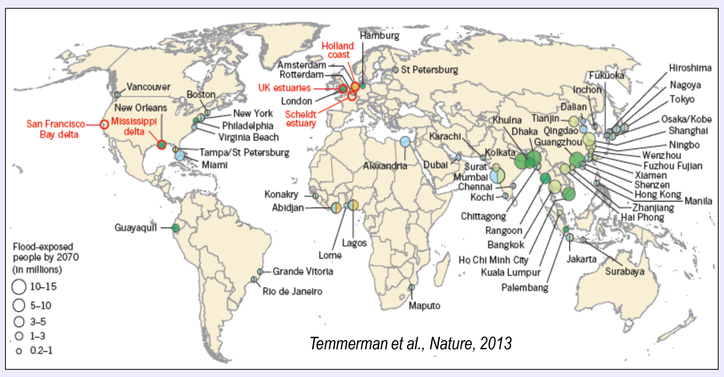
Whatever the future trajectories of green house gas emissions, sea level will continue to rise in the future decades and even centuries;. For a given warming scenario, main projection uncertainties come from uncertainty on future ice sheets dynamics

Future regional sea level rise due to anthropogenic global warming will depart from the global mean rise because of non uniform thermal expansion and deformations of ocean basins (& gravitational changes) in response to past and future land ice melt



Percentage of deviation of regional sea level change between 1986–2005 and 2081–2100 from the global mean; same % for all warming scenarios.(IPCC, Church et al., 2013)

Coastal sea level rise



Temmerman et al., Nature, 2013

Future sea level rise: a major threat of global climate change for low-lying, highly-populated coastal regions; will aggravate coastal flooding during extreme events

What counts at the coast is the TOTAL RELATIVE sea level rise, i.e., the sum of the global mean rise + the regional variability + small-scale local oceanic processes + vertical land motions

Ground subsidence due to natural processes (e.g., tectonic movements, sediment loading) and/or human activities (e.g., water and oil extraction, offshore sand dredging, coastal engineering, etc.) amplify the negative impacts of climate-related sea level rise

Observational and modelling issues

- **Considering that the global mean sea level rise is an integrator of changes occurring in the climate system and a major consequence of current Earth's Energy Imbalance, sustained & accurate monitoring of sea level and components is an imperative**
- **Reducing uncertainties on global mean sea level projections (e.g., due to ice sheet dynamics) and providing local sea level projections accounting for all processes acting at the coast are major goals**
- **Studying the sea level budget using different observing systems (satellite altimetry, Argo, space gravimetry, etc.) allows tracking temporal changes of the components, offers constraints on « missing contributions » (e.g. deep ocean warming) or poorly known components (e.g., ground water depletion in aquifers); allows cross- validation of observing systems used to estimate the components.**

Closure of the sea level budget

- **Closing the global sea level budget by precisely estimating all single components entering into the budget remains a challenge**
  - → **Significant work still needed to reduce uncertainties of all components of the sea level budget**
  - → **Progress can be achieved via a concerted international effort**
  - → **It is proposed to develop a community-based synthesis of the sea level budget using data sets from different observing systems and different approaches, to be regularly published (yearly basis) in the *Earth System Science Data* journal (as done for the « Global Carbon Project » and the « Global Earth Energy Budget »).**

- * www.wcrp-climate.org/grand-challenges/gc-sea level
- ** www.esa-**sealevel-cci**.org/
- *** Martin Horwath & partners

References

- Church, J. A., P. U. Clark, A. Cazenave, J. M. Gregory, S. Jevrejeva, A. Levermann, M. A. Merrifield, G. A. Milne, R. S. Nerem, P. D. Nunn, A. J. Payne, W. T. Pfeffer, D. Stammer and A. S. Unnikrishnan, 2013: Sea Level Change. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Church, J. A., and N. J. White , 2011. Sea-Level Rise from the Late 19th to the Early 21st Century, *Surveys in Geophysics*, *32*(4-5), 585-602.
- Temmerman S. et al., 2013. Ecosystem-based coastal defence in the face of global change, *Nature*, 504, 79-83.