Key Climate Change Indicators from the Ocean; 2017 Update

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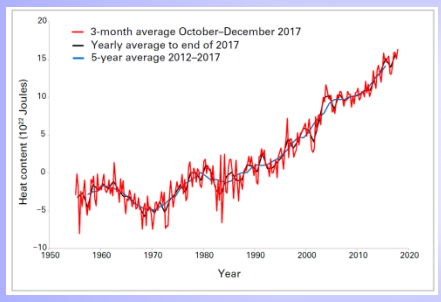
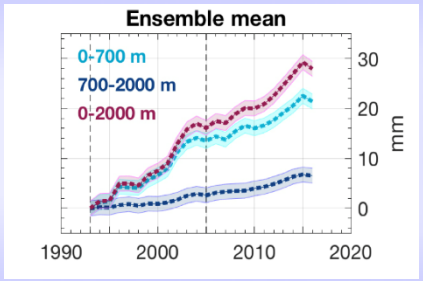
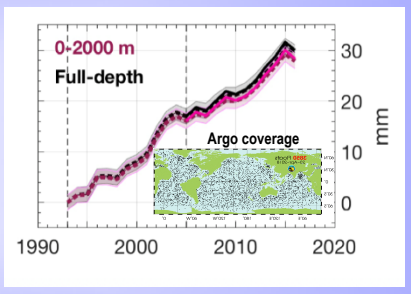
Abstract: The Earth is currently in a state of energy imbalance because of anthropogenic green house gas emissions, with 93% of the accumulated heat excess being stored in the ocean. The remaining 7% warms the atmosphere and continents, and melts sea and land ice. Because of ocean warming and land ice mass loss, sea level rises. Together with global mean Earth's temperature, ocean heat content (OHC) and global mean sea level (GMSL) are key indicators of global climate change. In effect, the rate of change of energy storage in the climate system can be directly derived from OHC change . Besides, the GMSL is an integral of changes occurring in the climate system in response to unforced climate variability as well as natural and antropopogenic forcing factors. Study of the sea level budget provides constraints on missing contributions, such as the unsurveyed deep ocean heat storage.

OCEAN WARMING



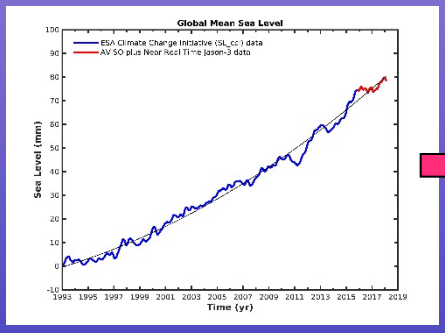
Global Ocean Heat Content change (x10^{22}J) for the 0-700 m layer (source: WMO Statement on the State of the Global Climate 2017)



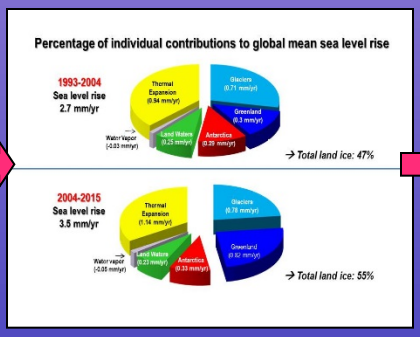


Ocean Thermal Expansion change since 1993 (in mm equivalent sea level) for different depth layers; Ensemble mean estimates from different data sets (Source: Global sea level budget 1993-present, the WCRP Global Sea Level Budget Group, 2018)

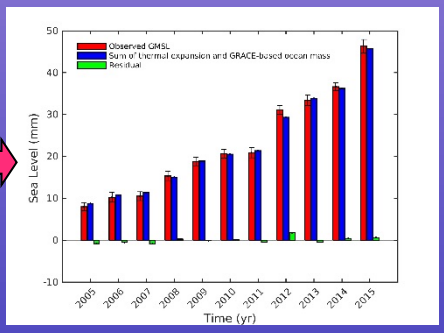
GLOBAL MEAN SEA LEVEL RISE AND SEA LEVEL BUDGET



Global mean sea level from multi mission satellite altimetry (1993-present). Data from the ESA Climate Change Initiative Project extended with Jason-3 satellite data from AVISO



Percentage of individual components to the GMSL in 1993-2004 and 2004-2015; The acceleration of the GMSL mostly comes from accelerated Greenland ice mass loss (from Dieng et al., 2017)



Annual sea level budget (2005-2015) estimated from Argo-based thermal expansion and GRACE-based ocean mass . The sea level budget is almost closed (source the WCRP Sea Level Budget Group, 2018)

What do we need for science?

- A long accurate full depth ocean heat content record for monitoring the Earth's energy imbalance (von Schuckmann et al., 2016) → *sustained Argo network with global coverage + deep Argo*
- A long accurate global and regional sea level record → *sustained altimetry missions*
- Regular estimates of closure of the sea level budget at global and regional scales → *process understanding, constraints on missing contributions and Earth Energy Imbalance, detection & attribution studies, validation of climate models…*
- A global, multi-mission Coastal Altimetry data set (does not exist yet) → *important for studying coastal impacts of global change and developing adaptation strategies*

References: WMO Statement of the State of the Global Climate 2017, WMO report n° 1212, 2018; Global Sea Level Budget 1993-present, The WCRP Global Sea Level Budget Group, ESSD, submitted, 2018; Von Schuckmann et al., An imperative to monitor Earth's energy imbalance, Nature Climate Change, 6, 138-144, 2016; Dieng H. et al., New estimate of the current rate of sea level rise from a sea level budget approach, *Geophysical Research Letters*, 44, doi:10.1002/ 2017GL073308, 2017.