CASE STUDY 2

SEA-LEVEL RISE AND IMPACT ON COASTAL REGIONS

SUMMARY

Title
Sea-level rise and impact on coastal regions

Service
Global, regional, and coastal sea-level change information (trends, rates of change, spatial patterns); and associated uncertainties

End users
Policymakers (government to coastal city authorities), state offices, coastal management agencies, stakeholders, general public

Intermediate users
Scientific community, international bodies (WCRP, IPCC)

Application(s)
Climate change monitoring, coastal management, adaptation to extreme events (storm surges and flooding), urban development, recreation and tourism

Models used
- Earth gravity fields models for orbit computations
- Solid earth and ocean tide models, ionospheric and wet/dry tropospheric models
- Mean sea-surface (marine geoid) models
- Glacial isostatic adjustment models
- Global hydrological models

Climate data records used
- Sea-level record from satellite altimetry (multi-sensor gridded time series at 0.25° daily resolution, 1993–present)
- Ocean temperature and salinity records from Argo and XBT devices
- Glaciers and ice-sheet mass balance records
- Atmospheric and oceanic reanalyses 30-year average of historical sea-ice edge locations

Satellite observations used
- Topex/Poseidon, Jason-class, ERS-1/-2, Envisat ASAR, SARAL/AltiKa, Cryosat (altimetry)
- GOCE, GRACE (gravimetry)

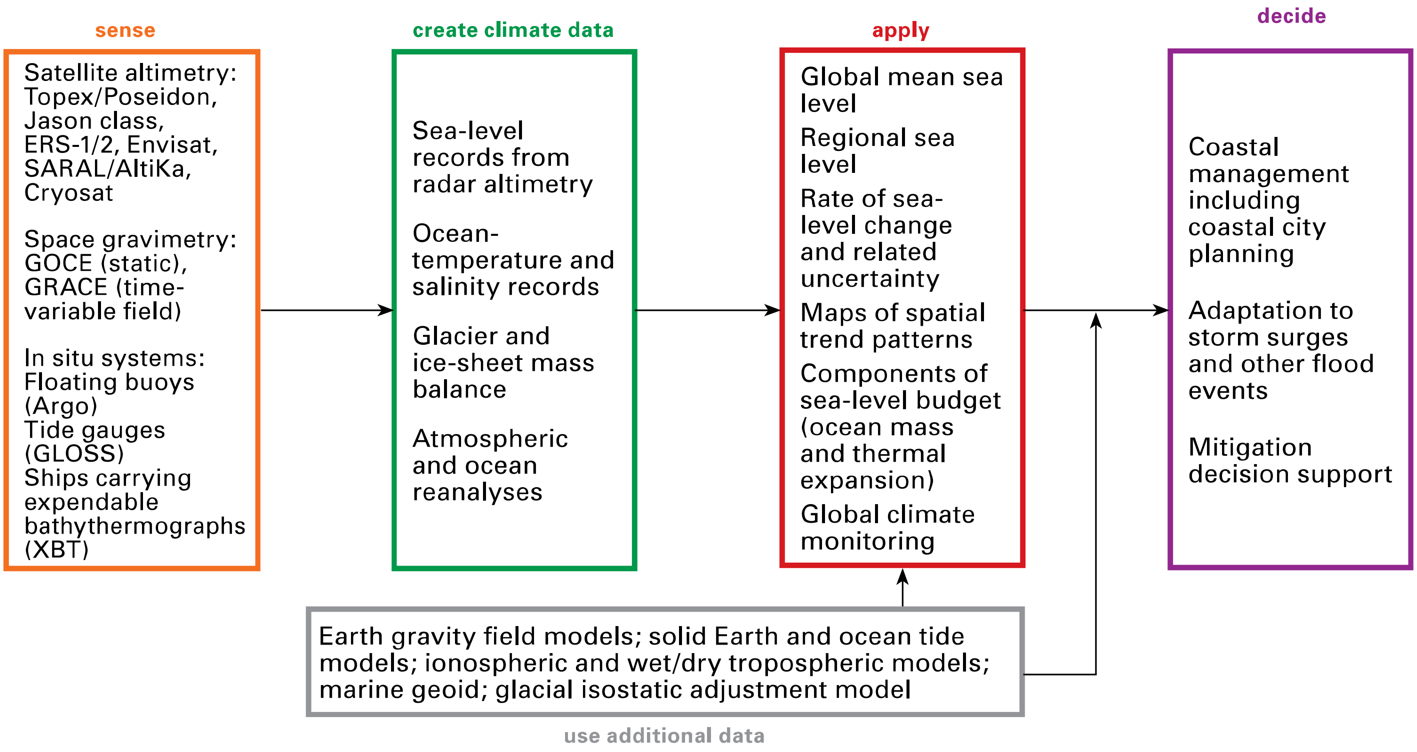
Agencies that produce records
- CNES/AVISO, ESA (CCI), NASA (GRACE), NOAA, CSIRO, University of Colorado (USA)
- Copernicus Marine Service, Climate Change Service (Europe)

Sustainability of service (demonstration or ongoing)
Ongoing service (partially operational)

FLICKR

Stilt houses, Pulau Sibuan, Sabah, Malaysia

INFORMATION FLOW



DESCRIPTION

Sea levels are presently rising at a sustained rate. They will continue to do so in future decades and centuries in response to anthropogenic climate change. Sea-level rise is one of the most threatening consequences of global warming and a major concern for populations living in low-lying coastal regions (about 25% of the world's population). Sea-level rise causes in permanent inundation, shoreline erosion, wetland loss, saltwater intrusion into surface water bodies and aquifers, and rising water tables. Figure 1 (IPCC SREX, 2012) shows current and future population exposure to inundation in low-level coastal areas in the case of a 1-in-100-year extreme storm for different sea-level rise scenarios. Moreover, in many coastal regions of the world, the impact of sea-level rise is exacerbated by other natural and/or anthropogenic factors (for example, decreased rate of fluvial sediment deposition in deltaic areas, ground subsidence due to tectonic activity or ground-water pumping and hydrocarbon extraction).

Monitoring sea-level variations from global to local levels is essential to estimate how fast sea levels are rising, to understand the physical processes at work and to validate climate models used for projecting future changes. This is a major goal and an essential need for the development of coastal adaptation to climate change. The service therefore consists of:

- Sea-level records at global, regional and coastal levels (with associated uncertainties);
- Secondary products:
  - Rate of sea-level rise with associated uncertainties;
  - Maps of spatial trend patterns in sea levels with associated uncertainties;
  - Components of the global mean sea-level budget (ocean mass based + ocean thermal expansion changes) with associated uncertainties.

Background

Sea level is the height of the sea surface expressed either in a geocentric reference frame (absolute sea level) or with respect to the moving Earth's crust (relative sea level). Absolute sea-level variations result from changes in the volume of water filling ocean basins (either due to water density or mass changes). Relative sea-level variations denote sea-surface height changes with respect to the ground (thus accounting for both absolute sea-level changes and vertical ground motions). Sea-level variations occur on a very broad range of spatio-temporal timescales. Sea level is a very good indicator of climate change and variability. As the ocean heats up in response to global warming, sea waters expand, which causes sea levels to rise. Mountain-glacier melting and ice-mass loss from the ice sheets also

Figure 1. For low-elevation coastal areas, current and future (2050) population exposure to inundation in the case of the 1-in-100-year extreme storm for a sea-level rise of 0.15 m and for a sea-level rise of 0.50 m due to the partial melting of the Greenland and West Antarctic Ice Sheets (Handmer et al., 2012; data from Lenton et al., 2009)

cause sea levels to rise. In addition, modifications of the land hydrological cycle due to climate variability and direct anthropogenic forcing lead to sea-level variations.

Since the early 1990s, satellite altimetry has become the main tool for precisely and continuously measuring absolute sea level with quasi-global coverage and a few days' revisit time. The concept of satellite altimetry measurement is simple: an on-board radar altimeter transmits microwave radiation towards the sea surface, which partly reflects back to the satellite. Measurement of the round-trip travel time provides the height of the satellite above the instantaneous sea surface (called 'range'). The relevant measurement is the sea-surface height above a fixed reference surface (e.g. the mean sea surface). Sea-surface height is obtained by calculating the difference between the altitude of the satellite above the reference surface (deduced from precise orbitography) and the range measurement. The estimated sea-surface height needs to be corrected for various factors due to atmospheric delays, instrumental drifts and bias between successive altimetry missions. Other corrections due to geophysical effects, such as solid-Earth, pole and ocean tides are also applied.

High-precision satellite altimetry started with the launch of Topex/Poseidon in 1992, followed by several other missions. The precision of an individual sea-surface height measurement has now reached 1–2 cm, allowing the global mean rate of rise to be estimated to within ~0.4 mm/yr. The temporal evolution of the global mean sea level from satellite altimetry since early 1993 shows an almost linear increase, at a mean rate of 3.2 ±0.4 mm/yr (Figure 2). For the altimetry period, rises in the sea level result from ocean thermal expansion (~38%), land-ice melt (~50%) and land-water storage change (~12%, mostly due to ground-water pumping). As evidenced by satellite altimetry, sea levels are not rising uniformly (Figure 3). The regional variability in sea-level trends is dominated by large-scale changes in the density structure of the oceans (mainly temperature changes). Those changes are a response to forcing factors (e.g. heat and fresh water exchange at the sea-air interface and wind stress) and their interactions with the ocean circulation.

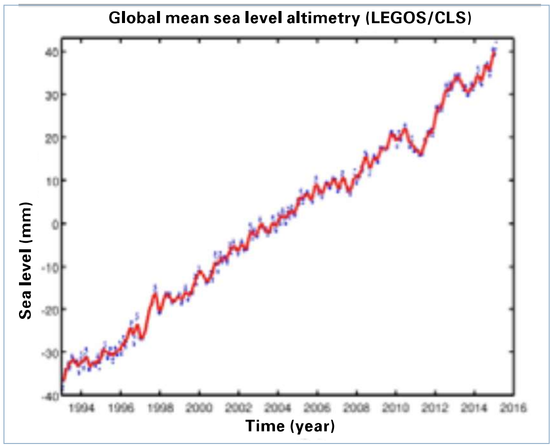


Figure 2. Global mean sea-level evolution from multi-satellite altimetry (1993–2015)

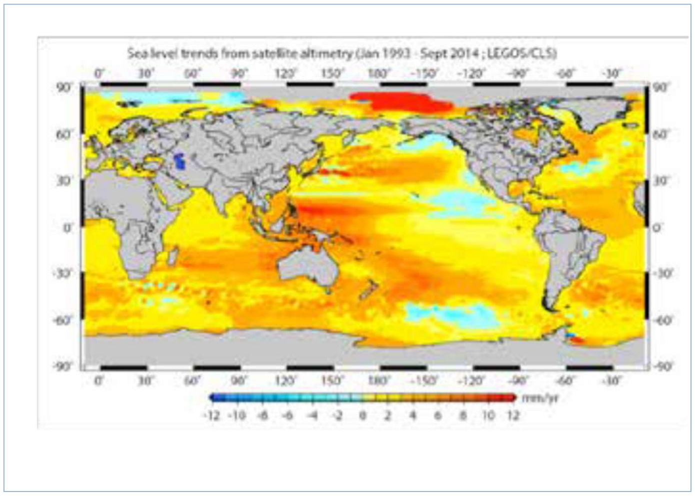


Figure 3. Spatial trend patterns in sea level from multi-satellite altimetry, 1993–2014 (mm/yr)

Figure 4. Maeslant storm surge barrier (near Rotterdam) and the Eastern Scheldt barrier (Rijkswaterstaat, 2009 and Jonkman et al., 2013)

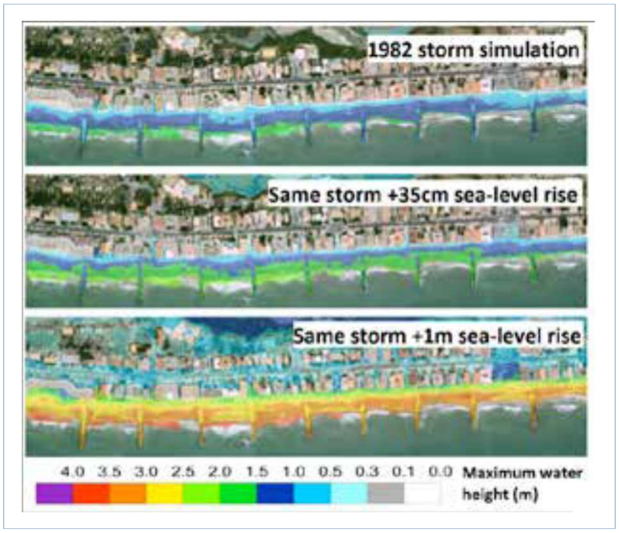


Figure 5. Simulation of local coastal flooding in a low-lying area of the north-western Mediterranean (Languedoc-Roussillon, France) during a storm surge event (the 1982 storm) for different sea-level rise scenarios; maximum water height (m) reached for each scenario is shown (By permission, BRGM; Pedreros et al., 2011)

Coastal cities adapting to sea-level rises

With sea-level rise adding to the risk of coastal inundation, in particular during storm surges events, a number of cities have decided to reinforce their coastal protection schemes. An illustration is given in Figure 4 of the Netherlands coastline near Rotterdam (Jonkman et al., 2013). More generally, as concerns grow over sea-level rise impacts in coastal areas (temporary and permanent submersion, shoreline erosion), more precise information on projected sea-level rises and the probability of storm surges need to be developed to better inform coastal planning policies. Available simulations show that sea-level rises drastically increase storm surge-related flooding in low-lying coastal areas (Figure 5, Pedreros et al., 2011). For efficient and timely adaptation planning, coastal managers require a range of advanced sea-level products based on observations and modelling, including regional and/or probabilistic projections and global to local observations.

References

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