Summary of the NCK symposium "Regional sea level change"

Museum Volkenkunde, Leiden, 28 September 2017, co-sponsored by ENW/NWO, organized by Theo Gerkema and Aimée Slangen (NIOZ, EDS, Yerseke)

Speakers:

Session 1
Chair: Stefan Aarninkhof (Delft University of Technology)
- **Roderik S.W. van de Wal** (Utrecht University):
  Evolution of the Greenland and Antarctic Ice Sheets
- **Thomas Frederikse** (Delft University of Technology):
  Closing regional sea level budgets with geodetic observations
- **Aimée Slangen** (NIOZ, EDS, Yerseke):
  Regional sea-level projections and sea-level allowances
- **Martin Verlaan** (Deltares):
  Modelling of storm surges and extreme levels worldwide

Session 2
Chair: Kathelijne Wijnberg (University of Twente)
- **Dewi Le Bars** (KNMI):
  Probabilistic projections of sea level rise
- **Cornelis Slobbe** (Delft University of Technology):
  Onshore and offshore vertical reference frames
- **Sally Brown** (University of Southampton):
  Determining impacts and adaptation to sea-level rise at regional and local scales

Discussion session
Chair: Torbjörn Törnqvist (Tulane University, New Orleans)
Panel:
- **Renske de Winter** (Utrecht University)
- **Bert Vermeersen** (Delft University of Technology/NIOZ)
- **Sally Brown** (University of Southampton)

Research in recent decades has demonstrated that the change in sea level is far from uniform around the globe: at some locations it rises faster than the global mean, at others there may even be a drop. These regional characteristics need to be considered when developing policies and measures of coastal defense and adaptation. In this symposium, a comprehensive overview was given of the state-of-the-art knowledge on regional sea level change and lacunae in our understanding were identified.

The volume of water in the oceans can change in two ways: by the addition (or removal) of water mass and by changes in the density of seawater. Since 2003, the former can be accurately determined from satellite gravimetry; over that period its contribution has been about twice as large as the effect of thermal expansion (referred to as a *steric* effect), as inferred from Argo float measurements. They add up to a net sea-level rise that corresponds well with the global mean sea level rise determined from satellite altimetry. Thus, the sources that account for the global mean sea-level rise over the last decades have been identified.

The contributing factors to the oceanic mass change can be split into glaciers, the Greenland ice sheet, the Antarctic ice sheet and liquid water storage on land. With the use of satellite gravimetry, these factors can be ranked. During the last decades, the dominant factors have been the glaciers and the Greenland ice sheet. However, the largest potential for sea-level rise lies in the Antarctic ice sheet, and scientists are still debating how much it will contribute to sea level changes in the coming centuries. In particular, the ice sheet dynamics is still poorly understood and forms the dominant source of uncertainty in projections. Possible mechanisms of ice sheet instability have been identified but probabilities, magnitudes and time scales are still hard to quantify.

Determining regional trends in sea level change in coastal areas involves many more factors than for the global mean trend. What matters most in terms of flooding risks is the relative sea level change (the quantity measured by tide gauge stations): the net effect of geocentric sea level change and vertical land motion (e.g. due to glacial isostatic adjustment, tectonics, and gas or groundwater extraction). This requires an understanding of the local magnitude of these movements of the crust and their expected development for projections. Estimates of local relative sea level change derived from tide gauges require an accurate vertical datum. At this moment, however, operational techniques are lacking to connect the height network at the Wadden islands to that on the mainland. Model-based hydrodynamic leveling offers perspectives for a possible method. Another outstanding issue is that estimates of vertical movements of the Pleistocene layer derived from leveling between the primary markers of NAP differ from those derived from absolute gravimetry.

There are also factors that affect the local geocentric sea level. An important one is the gravitational attraction that ice sheets exert on the surrounding water. If they lose mass, the attraction becomes weaker and as a result, the local sea level drops. This happens to within a distance of about 2200 km from the ice sheet. Beyond that point, sea level rises and at distances larger than about 6700 km the rise even exceeds the global mean. The North Sea area is a case in point: changes in the relatively nearby Greenland ice sheet are almost neutral in terms of relative sea level (here post-glacial rebound also plays a role), whereas melting of the remote Antarctic ice sheet produces a rise that exceeds the global mean. The Antarctic ice sheet thus forms the major source of uncertainty for projections of the North Sea area, because of its high potential for adding mass to the ocean combined with the quantitatively poorly understood mechanisms of ice sheet instability.

Adaptation measures for future sea level rise involve a diversity of strategies. In sparsely populated areas one could decide to accept a certain risk of flooding and damage or anticipate a possible future necessity of moving elsewhere and accept that areas become uninhabitable. Areas that cannot afford to be flooded need large-scale protection and adaptation schemes. The inequity of protection measures implies that there will be winners and losers. Small islands will feel the effects of climate change and sea-level rise first. They will take longer to overcome extreme events.

For flood risk prediction worldwide (operational forecasting and calculation of return periods of extreme levels), a global tide and surge model has recently been developed.

Finally, it is important to realize that at a temperature rise of 1.5 or 2.0 C the problem of sea-level rise and its subsequent impact will not go away. This also makes the common reference year of 2100 somewhat shortsighted: if the rise of sea-level turns out to be higher than previously expected by that date, though perhaps still manageable, subsequent decades would correspondingly experience even more severe conditions. The existing uncertainty in projections poses problems for long-term designs of dikes etc., which have to be based on specific numbers and requirements. For the foreseeable future, this incompatibility – between what we know scientifically and need to know from a coastal management point of view – is likely to remain.

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