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Facing the Third Dimension in Coastal Flatlands

Global Sea Level Rise and the Need for Coastal Transformations

Owing to global warming, imminent losses at polar ice sheets will entail several meters of highly unpredictable sea level rise. Merely carrying on with bulwarks for defense against a rising sea will exacerbate the fate of coastal flatlands such as the subsiding North Sea Wadden Coast. The mighty dimension of the rising sea requires debates on a wider conceptual horizon. It is time to initiate stepwise coastal transformations toward growing with a rising sea.

Karsten Reise

Facing the Third Dimension in Coastal Flatlands. Global Sea Level Rise and the Need for Coastal Transformations
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Due to global sea level rise (SLR), over the next centuries up to half a billion people now living in coastal plains will have to either relocate to higher terrain, exist on floating cities or, by mischance, may even drown. In an attempt to rectify a dearth of public awareness for coastal consequences of SLR triggered by anthropogenic climate change, workshops with experts and concerned citizens of the North Sea Wadden Coast held at Hanse-Wissenschaftskolleg in Delmenhorst (northern Germany) proposed a set of long-term, no-regret adaptations (Reise 2015). Here, reasons are put forward why public debates on systemic and incremental coastal transformations should no longer be postponed.

Sea Level Rise in the Anthropocene

Three key processes are driving SLR: thermal expansion of a warming ocean, melting of mountain glaciers and polar ice caps, and the disintegration of Greenland and Antarctic ice sheets. The latter is potentially the most threatening and also the least understood (DeConto and Pollard 2016, Hvidberg 2016). In the warm interglacial period prior to the last glaciations with temperature similar to today, sea level rose within a few centuries by four to six meters, reaching up to nine meters above the present level (O'Leary et al. 2013). Large chunks of ice had slipped from Antarctica into the ocean. In our time the same could happen again.

Long-term scenarios suggest a SLR up to 25 or even 52 meters (figure 1, p. 90). Clark et al. (2016) warn that decisions on global greenhouse gas emissions taken in the next decades will determine SLR over the next thousands of years. Coastal societies are likely to face an almost irreversible rise of several meters over the course of the next centuries. However, rates and magnitudes are hard to predict because of inherent complexity and still unknown processes. Small temperature changes can trigger extreme responses through feedbacks between ice, ocean, and atmosphere.

Nevertheless, the perceived time horizon for SLR tends to be far beyond political and lifetime decisions.[1] It remains in the shadow of climate debates because it is lagging behind atmospheric warming: water needs more time to warm and ice longer time to melt. In human history, mean sea level remained almost constant (figure 1), an anthropogenic signal in SLR is evident only for the period since 1970 (Slangen et al. 2016). Thus, a rise is essentially unfamiliar to coastal people and often parodied as a return to a biblical flood scenario.

Another issue hindering the awareness of the problem is that annual rates of SLR are reported in millimeters, while tidal range and storm surge heights are given in meters.[2] As a consequence, SLR appears harmless. Coastlines reliably fortified against storm surges are also perceived as safe enough against SLR within this century and beyond. In the Netherlands and Germany, trust in coastal defense has grown because disasters with major dike failures have not happened for 64 and 55 years, respectively. Further- >

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1 Projections beyond this century seem irrelevant to most people (Görg 2016).
2 Sea level has risen about three millimeters per year from 2002 to 2014 (Rietbroek et al. 2016).

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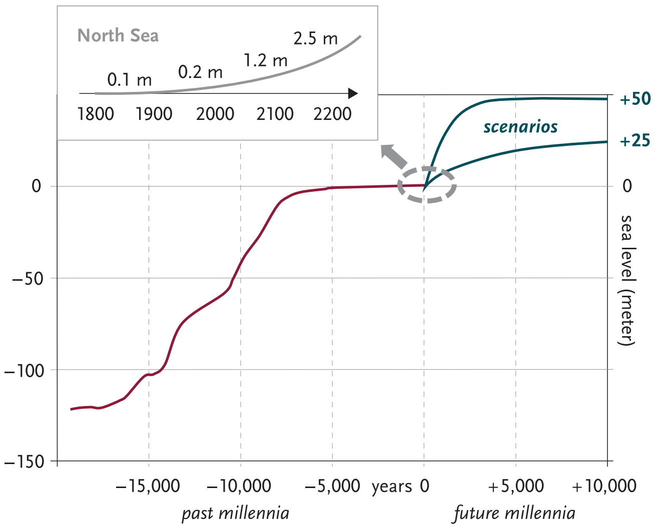

FIGURE 1: Rapid postglacial sea level rise (SLR) had slowed down over the last 7,000 years but will resume to high rates in scenarios presented by Clark et al. (2016). Inset: centennial SLR measured from 1800 to 2000 and as upper projections for 2100 and 2200 in the inner North Sea (based on Wahl et al. 2013, Katsman et al. 2011, Slangen et al. 2014).

more, scientific controversies about rates of SLR have thrust aside high agreement on upward direction. For the sake of credibility, sea level scientists tend to avoid overestimates more than risking underestimates. As shown below, such attitudes towards SLR are misguided when it comes to necessary coastal adaptations.

Wadden Coast: Inherited Burden

Worldwide, coastal plains have emerged over the past seven millennia when sediment deposition outbalanced a slow rise of the sea. Along the southern North Sea coast, sedimentation processes remained undisturbed when dwelling mounds were piled up to hold out storm surges.[3] These hillocks were likened to ship wrecks by the Roman, Plini the Elder, when visiting this flat, amphibious land- and seascape two millennia ago (Fischer et al. 2005). He pitied the miserably drenched occupants, but was thoroughly mistaken. This Wadden Coast became densely populated, was productive and has grown with the sea (box 1).

Since the Middle Ages, Frisian and other people laboured hard on their wet terrain. They claimed land, built dikes and dug ditches, and sluiced excessive rainwater through their dikes into the sea. However, soils shrink when drained dry and their organic matter is oxidized to CO_2. In the adjacent bogs, peat was excavated for fuel, and then clay and manure were added to gain more arable land. Excavating, draining, and blocking sediment deposition by dikes caused polders to sink below the level of the sea. The resultant inverse coastal topography became liable to disaster when fierce storm tides broke feeble dikes, and wadden often took over where once people ploughed their fertile land (Kabat et al. 2012). An arms race began. Dikes were built stronger and higher, but also floods reached higher levels because space to accommodate storm-tide water masses decreased as more land was claimed from the sea. The stronger the coastal defense structures were perceived, the more lives and values were entrusted to them – another viscous cycle. Modern dikes are now nine meters high or more (figure 2).

Intensified draining and removal of the last coastal moors aggravated subsidence. In addition, tectonic rebound to Scandinavian uplift in the wake of deglaciation has subtracted half a meter of land since medieval times, while sea level has risen by one meter since then (Vink et al. 2007). Near the mouth of the Elbe, total subsidence reached 3.5 meters below mean sea level, corresponding to five meters below mean high tide and nine meters below the highest storm tide recorded in that area. Farm houses will be completely submerged if dikes fail. An unsustainable coastal topography has developed, particularly in the face of faster SLR in the coming centuries.

For a long time, the wadden were dismissed as lost land, but in the 1960s, a mind shift began. Their natural values were recognized as outstanding and unique. In 2009/2014, the UNESCO listed the Wadden Sea as a *World Heritage Site*. It comprises the largest coherent belt of intertidal mud and sand flats with spectacular flocks of coastal birds. Claiming of new land from the sea had already ceased for economic reasons. The Netherlands, Germany and Denmark now formally cooperate in the conservation of Wadden Sea natural dynamics and have adopted common environmental targets. This transboundary cooperation is continually improved and also extends to cultural values and sustainable development. Today, this success story is in danger of being curtailed by a dawning new dimension of SLR.

Managing the Third Dimension at the Wadden Coast

Entrenched in German mentality is a fight against excess water (Blackbourn 2006), and the Dutch are even called a hydraulic society. Fighting the sea with ever stronger coastal architectures is seen in the height of dikes and massive storm surge barriers. However, unwanted side-effects of water control and climate change led a commission in 2008 to present to the Dutch government a new spatial adaptation strategy of integrating as far as possible natural dynamics of water and sediments (Secretariaat Deltacommissie 2008, see also van Koningsveld et al. 2008, van Weesenbeeck et al. 2014). This turnaround from the fight against to an alliance with the sea was approved by the government. However, implementation was hampered by a political crisis and was met by local resistance (Schmitt 2015). Apparently, coastal transformations to accommodate accelerating SLR will need decades of public debates and planning, and even more decades for stepwise implementation and lifestyle adjustments. Below, this is illustrated by suggestions for sustainable adaptations at the Wadden Coast (see also Reise 2015).

3 In Dutch and German known as *Tjerpen*, *Wurten* or *Warften*.

BOX 1: Coastal Terms

Intertidal mud and sand flats – where one can wade across – are termed *Wadden* or *Watten* at the southern North Sea coast. The *Wadden Sea* extends from Den Helder peninsula in the Netherlands through the German Bight to Skallingen peninsula in Denmark, comprising salt marshes, tidal flats (wadden), deep gullies, sand bars, and islands. Linked to the Wadden Sea are the tidal reaches of entering rivers, the *estuaries*, where fresh and marine waters mix. Land protected by earthen walls *(dikes)* against flooding are called *polders* (regionally *Groden* or *Koog*). The entire region of the southern North Sea coast comprising the polder land (embanked land) and the Wadden Sea including the estuaries is here named the *Wadden Coast*.

FIGURE 2: Farm houses in Westermarsch, northern Germany, crouch behind a tall dike facing seawards with groynes on the mudflats to enhance sediment aggradation. For more aerial photographs on coastal change see Reise (2015) and *www.alexmaclean.com*.

Unburden Estuaries from ever Larger Vessels

At the Wadden Coast with shallow tidal waters, increasing vessel size led to new ports at the outer coast (e.g., Bremerhaven, Eemshaven), and to ever deeper dredging of shipping lanes where ports remained upstream in the estuaries (e.g., Hamburg, Papenburg). Diking and dredging has transformed wide estuaries into narrow and deep funnels which constitute an enhanced risk with SLR. While in estuarine port cities various adaptations are already under way (Stokman et al. 2009, Bolstad and Meyer 2014), solutions for the battered estuarine environment are more difficult to find. Probably, this could only be achieved by a floating ship terminal positioned in the North Sea for cargo transfer from mega-vessels to barges with less draught, which would commute further to coastal ports. Estuaries could then recover and the effects of SLR could be defused. Obdurate societal conflicts over this issue call for an open debate (Veit 2017, Hintz and Schuldt 2014).

Rewetting the Coastal Hinterland and Tide Polders for Growing with the Sea

Hinterland polders were embanked first, and thus, have sunk lower than more seaward polders. Due to this inverted wedge profile, managed retreat (so-called coastal realignment) in response to SLR is not a sensible option at the Wadden Coast. However, if drainage would cease in low hinterland polders, high costs spent on pumping residual rainwater up to sea level for discharge could be saved (Ahlhorn and Meyerdirks 2010), and rather spent on lifting homesteads onto traditional dwelling mounds and roads onto dams. Aiming for a "waterland" would not only stop subsidence and store atmospheric CO_2 similar to former peat bog areas, but might also lead to economically viable options. For example:

- high storage capacity for rainwater could mitigate effects of summer drought and heavy rainfall as projected in regional climate scenarios, while floating vacation homes and stilt houses accessible by water taxi could attract tourism;
- a grid of causeways could allow for a mosaic of different water levels where revenues could be generated from floating gardens and greenhouses or with aquaculture partly roofed by photovoltaic panels, in addition to agriculture;
- reed grass for traditional thatched roofs could be cultivated, or farmers could cultivate exotic wetland plants such as Asian lotus with showy flowers and rhizomes regarded as a delicacy.

In the Netherlands, a concept of *Growing with the Sea* has been developed (Helmer et al. 1996, Temmerman and Kirwan 2015). Polders flushed with tidal waters rich in suspended sediment grow by clay aggradation. This natural process could be employed to keep up with SLR. Near Bremerhaven, agricultural land has been transformed into a bird reserve in an attempt to compensate for habitat loss that occurred while extending a container terminal (figure 3). A sluice in the dike was rebuilt for tidal exchange, creating a tide polder with high silt deposition. This example of nature restoration could serve as a model for sites where it could be combined with various wetland uses (see above). However, a reversal from subsidence toward growing with a rising sea would take about a century, and it would need successful examples before such transformations could spread from polder to polder community. >

Sand Nourishments for Keeping up with Sea Level Rise

The chain of wave- and wind-shaped sand dune barrier islands of the Wadden Sea is gradually driven landward by storm surges and SLR (figure 4). Nonetheless, immobile tourism infrastructures have been built close to eroding beaches (mobile homes would have been more appropriate). Defense with stone, steel and concrete to hold island positions has often aggravated sand deficiencies. Therefore, sand replenishments are now preferred to compensate for shore erosion (CWSS 2010, De Vriend and Van Koningsfeld 2012).[4]

The bottom of the North Sea holds huge amounts of sand which were deposited by a big river delta two to four million years ago. However, facing an accelerating SLR, sand resources of the North Sea should be reserved for coastal nourishments and not be used for land filling or concrete production. Offshore sources of sand can be tapped by suction hopper vessels that ship sand inshore to compensate for beach erosion and supplement coastal sand budgets once SLR exceeds natural sedimentation rates. In northern Germany, coastal defense and nature protection agency representatives recently decided for a common strategy which aims to maintain the wadden area as a coastal defense absorbing wave energy and also to preserve wadden biodiversity (Hofstede and Stock 2016). Sand nourishments should be applied in subtle doses to minimize ecological impacts. This requirement can be better met with precautionary sediment supply rather than by compensation of losses.

Conclusions and Recommendations

In the past, the wadden coastline has either shifted landward by storm surges, shifted seaward by land claim, or remained in place by coastal bulwarks. Coastal management was essentially driven by two-dimensional concepts. With the rising sea in the Anthropocene, a third dimension will challenge coastal plains. Ideas for accommodating more water and natural dynamics contrast with traditional thinking (Fischer and Reise 2011, Schmitt 2015), and the perceived time scale of SLR conflicts with short-term pressures. Thus, the transfer of inconvenient scientific knowledge to society will need long dialogues and support by cultural efforts including artistic research (Wirth et al. 2014, Hermville 2016, van Renssen 2017).

Important are no-regret and economically viable steps of coastal transformation. A timely stop to dredging estuaries ever deeper, testing polders for living with more water, and subtle sand nourishments around islands are recommended for learning by experience. Small island and polder communities, with their sense for local integrity and intergenerational solidarity, may be predestined for transdisciplinary systemic transformation projects. For them, SLR may even offer a chance for more sustainable, improved economic and demographic development. An early start to coastal transformations into the third dimension will be essential to avoid disaster, and could allow for a smooth transition.

FIGURE 3: Tide polder, Luneplate, at the River Weser, Lower Saxony. Tides swing in and out through a wide sluice in the outer dike (left). The polder also serves as a water reservoir after heavy rainfall via a sluice at the inner dike.

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References

Ahlhorn, F., J. Meyerdirks. 2010. *Speichern statt pumpen.* Wilhelmshaven: Nationalpark- und Biosphärenreservatsverwaltung Niedersächsisches Wattenmeer.

Blackbourn, D. 2006. *The conquest of nature. Water, landscape, and the making of modern Germany.* London: W.W. Norton.

Bolstad, J., W. Meyer. 2014. Resiliency for the city and the sea. *Topos* 87: 64–69.

Clark, P.U. et al. 2016. Consequences of twenty-first-century policy for multi-millennial climate and sea-level change. *Nature Climate Change* 6: 360–369.

CWSS (Common Wadden Sea Secretariat). 2010. *Coastal protection and sea level rise. Wadden Sea Ecosystem 28.* Wilhelmshaven: CWSS. www.waddensea-secretariat.org/sites/default/files/downloads/cpsl_third_report.pdf (accessed March 30, 2017).

DeConto, R.M., D. Pollard. 2016. Contribution of Antarctica to past and future sea-level rise. *Nature* 531: 591–597.

De Vriend, H.J., M. van Koningsveld. 2012. *Building with nature: Thinking, acting and interacting differently.* Dordrecht: EcoShape.

Eggermont, H. et al. 2015. Nature-based solutions: New influences for environmental management and research in Europe. *GAIA* 24/4: 243–248.

Fischer, L. et al. (Eds.). 2005. *Das Wattenmeer. Kulturlandschaft vor und hinter den Deichen.* Stuttgart: Theiss.

Fischer, L., K. Reise (Eds.). 2011. *Küstenmentalität und Klimawandel. Küstenwandel als kulturelle und soziale Herausforderung.* Munich: oekom.

Görg, C. 2016. Zwischen Tagesgeschäft und Erdgeschichte. Die unterschiedlichen Zeitskalen in der Debatte um das Anthropozän. *GAIA* 25/1: 9–13.

Helmer, W., P. Vellinga, G. Litjens, H. Goosen, E. Ruijgrok, W. Overmars. 1996. *Growing with the sea.* Zeist, NL: World Wide Fund for Nature (WWF).

Hermville, L. 2016. Climate change as a transformation challenge. A new climate policy paradigm? *GAIA* 25/1: 19–22.

Hintz, K., E-O. Schuldt (Eds.). 2014. *Wahr-Schau zur geplanten Elbvertiefung.* Norderstedt: Books on Demand.

Hofstede, J.L.A., M. Stock. 2016. Climate change adaptation in the Schleswig-Holstein sector of the Wadden Sea: An integrated state governmental strategy. *Journal of Coastal Conservation.* doi.org/10.1007/s11852-016-0433-0.

Hvidberg, C.S. 2016. Ice sheet in peril. *Science* 351: 562–563.

4 Growing by sand nourishment constitutes a compromise, but may be seen as a nature-based solution (see Eggermont et al. 2015).

FIGURE 4: Groynes on the beach combat losses of sand at the barrier island of Wangerooge, Lower Saxony, to save a resort built too close to shore. Lost sand is also shuttled back by truck from the downstream end of the island. A better solution would be sufficient replenishment of sand taken from an offshore seafloor.

Kabat, P. et al. 2012. The Wadden Sea region: Towards a science for sustainable development. *Ocean and Coastal Management* 68: 4–17.

Katsman, C. A. et al. 2011. Exploring high-end scenarios for local sea level rise to develop flood protection strategies for a low-lying delta – the Netherlands as an example. *Climatic Change* 109: 617–645.

O'Leary, M. J. et al. 2013. Ice sheet collapse following a prolonged period of stable sea level during the last interglacial. *Nature Geosciences* 6: 796–800.

Reise, K. (Ed.). 2015. *Kurswechsel Küste: Was tun, wenn die Nordsee steigt?* Kiel: Wachholtz.

Rietbroek, R., S-E. Brunnabend, J. Kusche, J. Schröter, C. Dahle. 2016. Revisiting the contemporary sea-level budget on global and regional scales. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* 113: 1504–1509.

Schmitt, L. 2015. *Klima, Raum und Zeit im Wandel. Eine ethnographische Untersuchung von Adaptionen und Konflikten auf der westfriesischen Insel Ameland.* Munich: oekom.

Secretariaat Deltacommissie. 2008. *Working together with water. A living land builds for its future. Findings of the Deltacommissie.* www.deltacommissie.com/doc/deltareport_full.pdf

Slangen, A. B. A. et al. 2014. Projecting twenty-first century regional sea-level changes. *Climatic Change* 124: 317–332.

Slangen, A. B. A. et al. 2016. Anthropogenic forcing dominates global mean sea-level rise since 1970. *Nature Climate Change* 6: 701–705.

Stokman, A., H. von Seggern, S. Rabe. 2009. Designing tidal landscapes. *Topos* 68: 88–93.

Temmerman, S., M. L. Kirwan. 2015. Building land with a rising sea. *Science* 349: 588–589.

Van Koningsveld, M., J. P. M. Mulder, M. J. F. Stive, L. van der Valk, A. W. van der Weck. 2008. Living with sea-level rise and climate change: A case study of the Netherlands. *Journal of Coastal Research* 24: 367–379.

Van Renssen, S. 2017. The visceral climate experience. *Nature Climate Change* 7: 168–171.

Van Wesenbeeck, B. K. et al. 2014. Damming deltas: A practice of the past? Towards nature-based flood defenses. *Estuarine, Coastal and Shelf Science* 140: 1–6.

Veit, S.M. 2017. Der Realitätsverweigerer. *die tageszeitung*, 15.02.2017. www.taz.de/Rueckschlag-fuer-Hamburger-Buergermeister/!5381724 (accessed March 30, 2017).

Vink, A., H. Steffen, L. Reinhardt, G. Kaufmann. 2007. Holocene relative sea-level change, isostatic subsidence and radial viscosity structure of the mantle of northwest Europe (Belgium, the Netherlands, Germany, southern North Sea). *Quaternary Science Reviews* 26: 3249–3275.

Wahl, T. et al. 2013. Observed mean sea level changes around the North Sea coastline from 1800 to present. *Earth-Science Reviews* 124: 51–67.

Wirth, V., A. Prutsch, T. Grothmann. 2014. Communicating climate change adaptation. State of the art and lessons learned from ten OECD countries. *GAIA* 23/1: 30–39.

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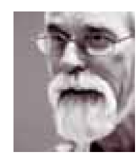

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