Institute of Coastal Research

Research Unit 1: System Analysis and Modelling

PACES II / Topic 2

RU 1

Helmholtz-Zentrum Geesthacht

Centre for Materials and Coastal Research

Natural and Anthropogenic Contributions to Sea Level Change

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Baltic Sea coast Prerow, April 2014 (photo: R. Weisse)

Topic 2

Introduction

Sea level and its evolution in time are of great interest for at least two reasons:

- The potential impact on coastal populations and ecosystems is large.
  Extreme Sea Levels

- The imprint of the physical climate system on sea level may make it an indicator of climate change.
  Mean Sea Levels

Wave overtopping, Nössedeich, Sylt (photo: Kühl)

Detection and Attribution

For both cases it is important to distinguish between ***anthropogenic*** and ***natural*** contributions because any anthropogenic effect will be superimposed on the background "noise" of natural ***climate variability***.

- ***Detection*** is the process of demonstrating that an observed change in climate is highly unusual in a statistical sense, although a reason for the change is not necessarily provided.

- ***Attribution*** is the process of establishing the cause of a particular change in climate, including the testing of competing hypotheses.

(http://glossary.ametsoc.org/)

Objective

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As a contribution to detection and attribution of anthropogenic signals in sea level:

- Investigate the degree to which GMSL rise may be explained by random natural variations in addition to deterministic processes
  (upper limits of natural contributions to GMSL rise)

- Investigate the extent to which there are robust detectable signals in extreme North Sea sea levels
  (consistency among extreme sea level climate projections)

Upper Limits of Natural Contributions

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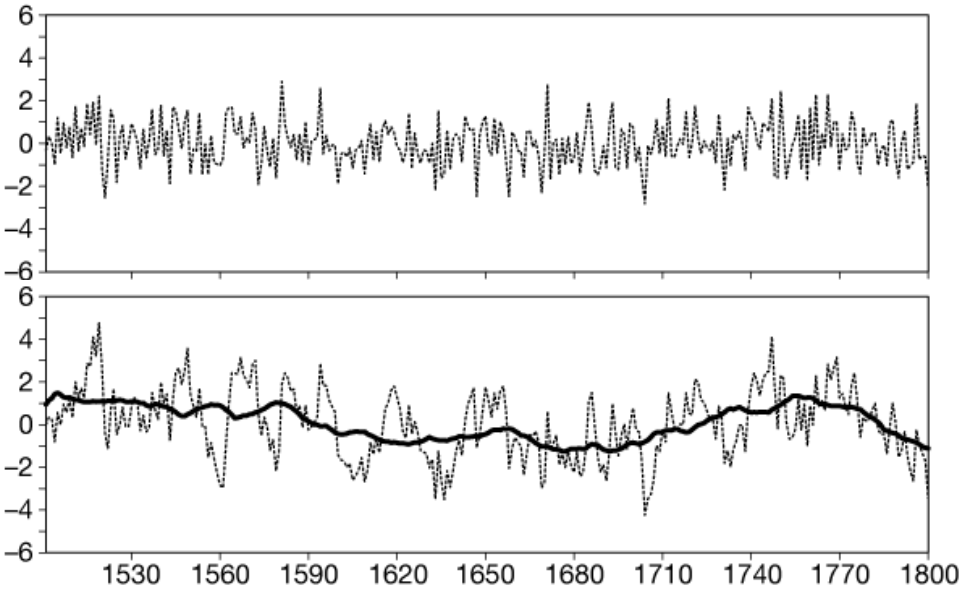
- In any coupled system with different time scales (memory) the system with longer memory will integrate short-term (random) fluctuations (***Stochastic climate model***, Hasselmann 1976)

- Observed sea-level records exhibit such ***long-term persistence*** apart from the anthropogenically forced upward trend.



Response of a simple stochastic climate model (bottom) to white noise (random) forcing (top) (Weisse and von Storch, 2009)

Upper Limits of Natural Contributions

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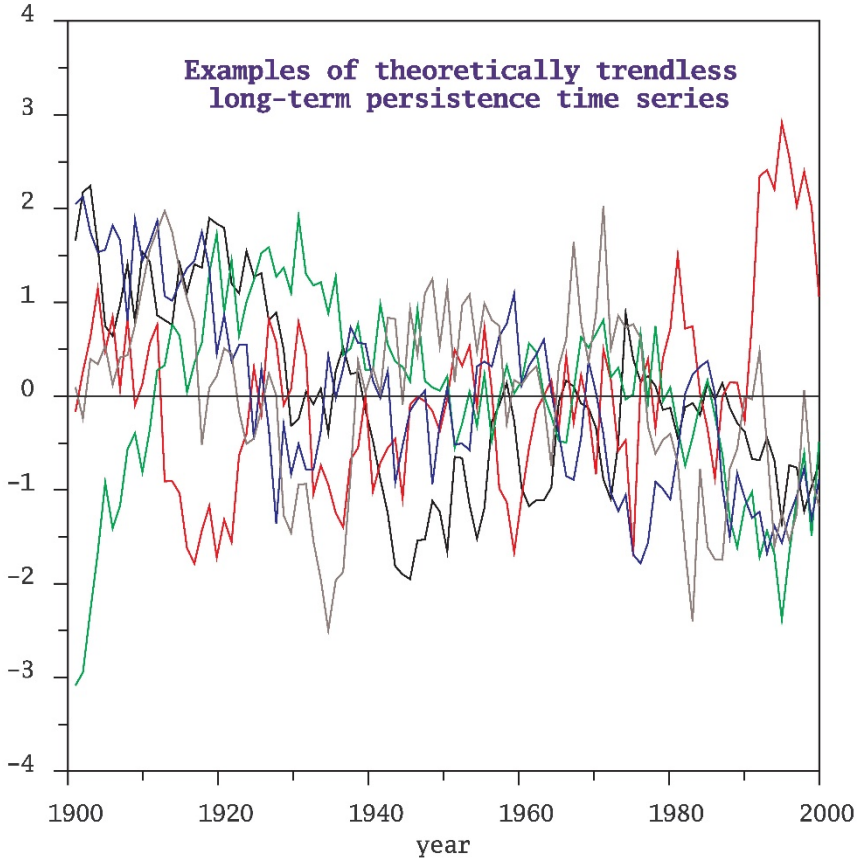
- Observed sea-level records exhibit such ***long-term persistence*** apart from the anthropogenically forced upward trend.

- **How much can these trends contribute?**



(Zorita, 2018, pers. comm.)

Two Approaches

Starting from the sea level equation which has the form of a stochastic process in which the ocean integrates random variations and other (deterministic) forcing

- Derive statistical properties of the forcing contributions and GMSL reconstructions using whenever available, at least two for each of them, that are either differ substantially from or are obtained by different methods or models taking reconstruction errors into account (Ocaña et al., 2016)

- Derive the statistical properties from GMSL reconstruction based on regional estimates (Dangendorf et al., 2015)

Use Monto Carlo techniques to simulate an ensemble of theoretical trendless artificial GMSL estimates from which upper limits of natural contributions can be assessed.

Upper Limits of Natural Contributions

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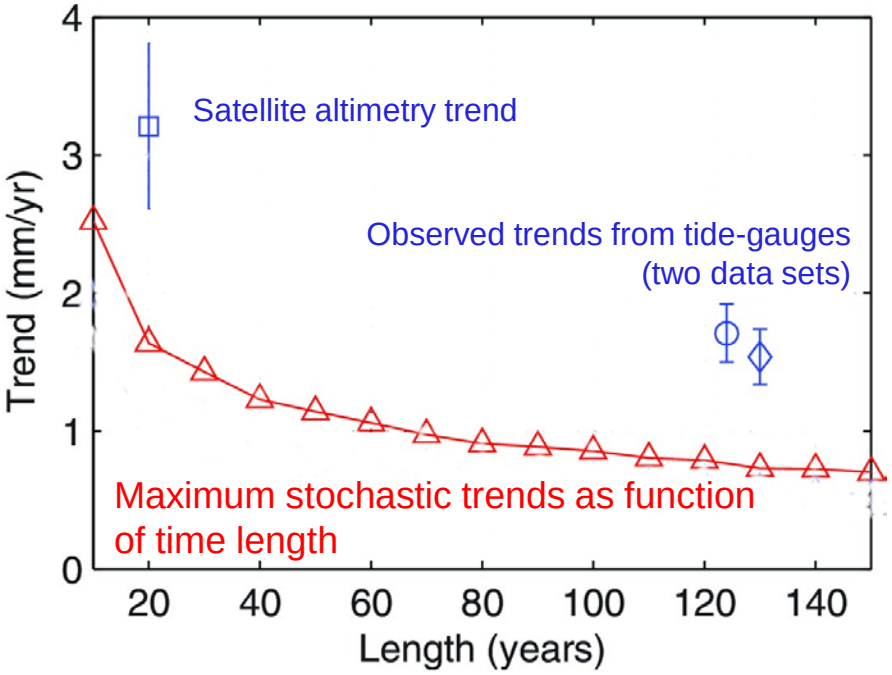
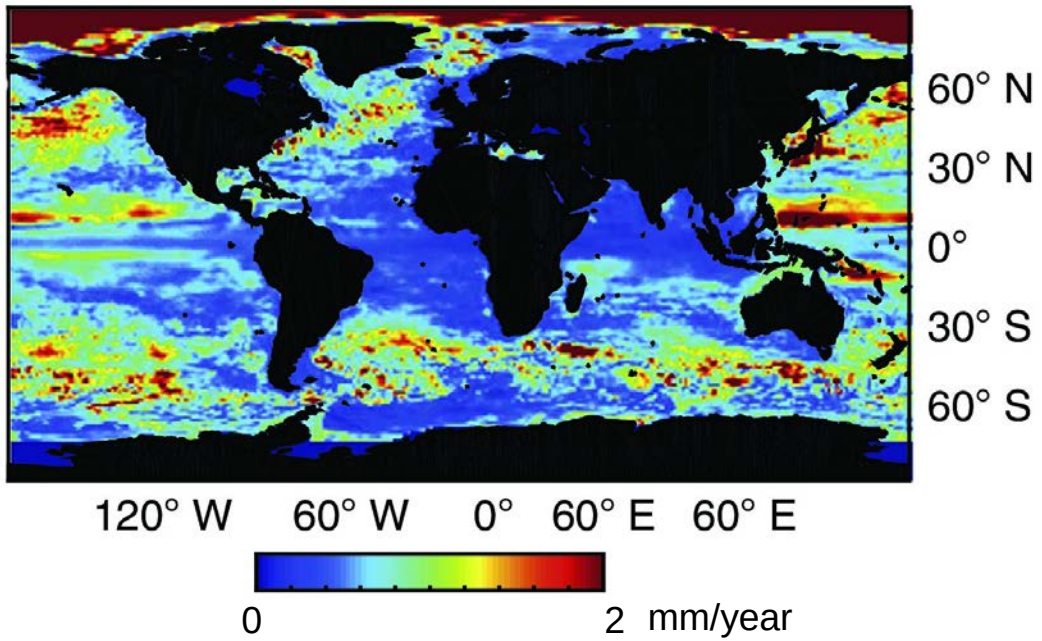


(Ocaña et al., 2016)

Maximum local stochastic trend over 100 years



(Dangendorf et al., 2015)

Results from the analysis of global and regional sea-level records:

At most, 50% of the observed trends could be natural

Consistency among ESL projections

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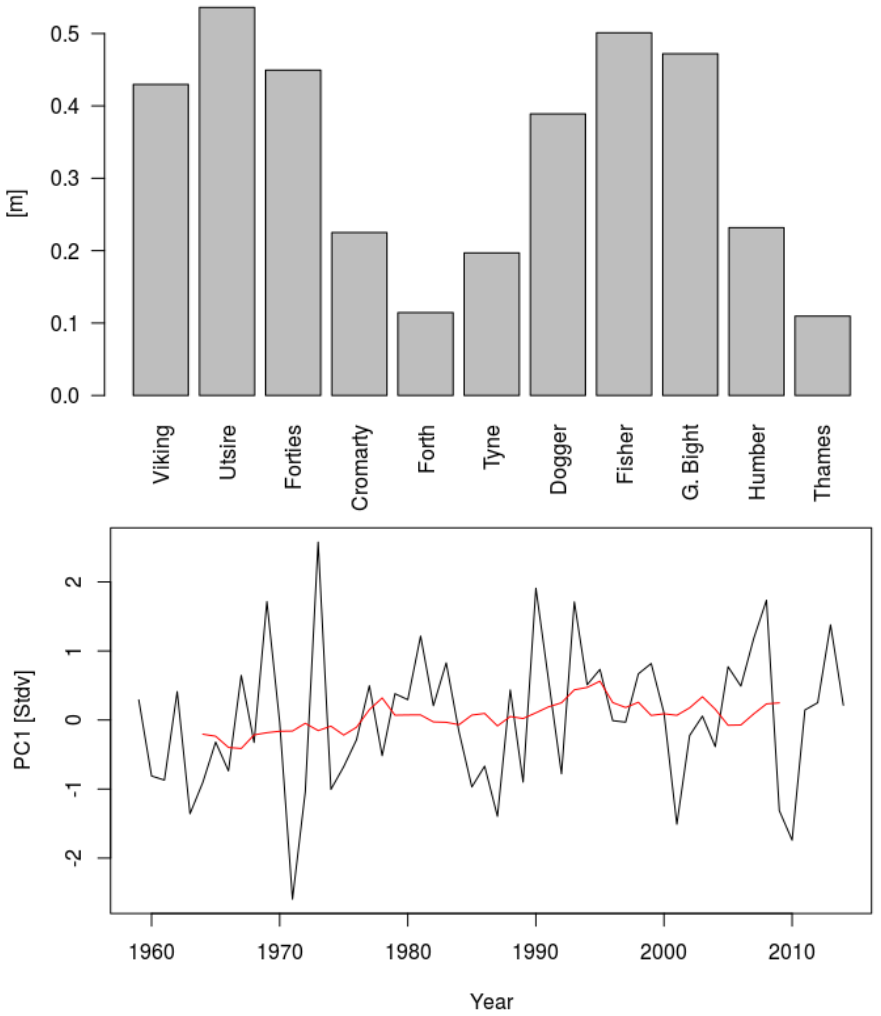
- While for GMSL a clear trend (signal) is obvious, for extreme North Sea sea levels (ESL) such a signal is absent.
- **Is there any robust detectable signal in future climate projection that we may look for in the observations?**



EOF 1 of annual 99%-tile significant wave height (Teich et al., in prep.; Data from Groll et al., 2017)

Consistency among ESL projections

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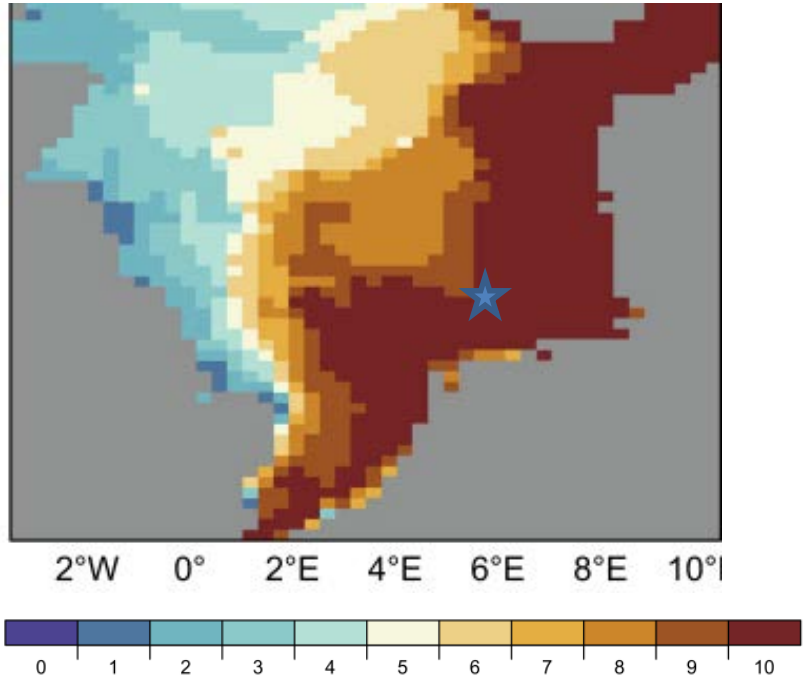
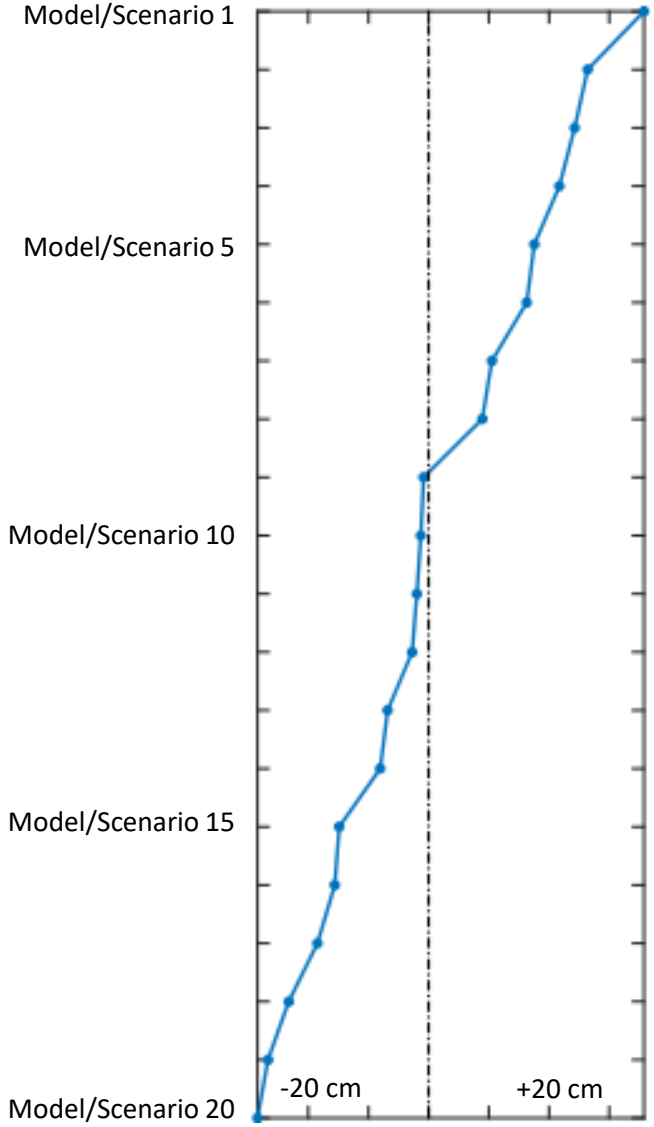


*Number of **dynamical** wave climate projections (out of 10) showing positive sign of change 2071-2100./.1961-1990 in the southern North Sea (Grabemann et al., 2015)*



*Number of **statistical** wave climate projections (out of 20) showing at least the same sign of change 2071-2100./.1961-1990 at station Fino 1 in the southern North Sea (Bisling and Weisse, in prep.)*

Results from the analysis of downscaled regional wave projections:

So far no indication of a robust and detectable signal.

Conclusions

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As a contribution to detection and attribution of anthropogenic signals in sea level we found:

- As a results from the analysis of global and regional sea-level records that at most 50% of the observed trends could be natural

- As a result from our analysis of wave climate projections that for waves in the North Sea there is so far no indication on the existence of a robust and detectable signal.

References

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