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Annual mean sea level and its sensitivity to wind climate

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Changes in relative mean sea level affect coastal areas in various ways, such as the risk of flooding, the evolution of barrier island systems, or the development of salt marshes. Long-term trends in these changes are partly masked by variability on shorter time scales. Some of this variability, for instance due to wind waves and tides (with the exception of long-period tides), is easily averaged out. In contrast, inter-annual variability is found to be irregular and large, of the order of several decimeters, as is evident from tide gauge records. This is why the climatic trend, typically of a few millimeters per year, can only be reliably identified by examining a record that is long enough to outweigh the inter-annual and decadal variabilities.

In this presentation we examine the relation between the annual wind conditions from meteorological records and annual mean sea level along the Dutch coast. To do this, we need reliable and consistent long-term wind records. Some wind records from weather stations in the Netherlands date back to the 19th century, but they are unsuitable for trend analysis because of changes in location, height, surroundings, instrument type or protocol. For this reason, we will use only more recent, homogeneous wind records, from the past two decades. The question then is whether such a relatively short record is sufficient to find a convincing relation with annual mean sea level. It is the purpose of this work to demonstrate that the answer is positive and to suggest methods to find and exploit such a relation.

We find that at the Dutch coast, southwesterly winds are dominant in the wind climate, but the west-east direction stands out as having the highest correlation with annual mean sea level. For different stations in the Dutch Wadden Sea and along the coast, we find a qualitatively similar pattern, although the precise values of the correlations vary. The inter-annual variability of mean sea level can already be largely explained by the west-east component of the net wind energy vector, with some further improvement if one also includes the south-north component and annual mean atmospheric pressure. Knowledge of these local correlations can then be used to correct values of annual mean sea for these atmospheric effects. This halves the margin of error (expressed as 95\%-confidence interval) for linear trends in a 20-year sea level record.

The sensitivity on wind direction has a regional variability, even on a small scale like the Dutch Wadden Sea. Model results illustrate the detailed spatial patterns in inter-annual variability of annual mean sea level.

This study also implies that climatic changes in wind direction, or in the strength of winds from a specific direction, may affect local annual mean sea level quite significantly.