Regional storm climate and related marine hazards in the last decades

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Storms represent a major environmental threat. They are associated with abundant rainfall and excessive wind force. Wind storms cause different types of damages on land and on sea; on land, houses and other constructions may be damaged; also trees may break in larger numbers in forests. In the sea, wind pushes water masses towards the coasts, where the water levels may become dangerously high, overwhelm coastal defense and inundate low-lying coastal areas; also the surface of the sea is affected – wind waves are created, which eventually transform into swell. Obviously, ocean waves represent a major threat for shipping, off-shore activities and coastal defense.

Different types of storm prevail in different parts of the world. In the tropics taifuns or hurricanes are frequent and threatening phenomena; at mid latitudes mainly baroclinic storms form along the polar front; in subpolar regions so-called polar lows form emerge when polar air masses move across relatively warm ocean water. These different types of storms are generated by different dynamical mechanisms.

In this contribution we deal only with windstorms in the North East Atlantic and Northern European region.

We review a number of questions, namely

1. *How to determine decadal and longer variations in the storm climate?* The methodical problem is that many variables, which seem to be well suited for this purpose, are available only for a too short period or suffer from *inhomogeneities*, i.e., their trends are contaminated by trends related to the observation process (instrumentation, practice, or environment). From air pressure readings at a weather station and characteristics of storm surge levels at a tide gauge useful indicators may be derived.
2. *How has the storm climate developed in the last few decades and last few centuries?* It turns out that an increase in storm activity over the considered region (NE Atlantic, N Europe) took place for a few decades since about the 1960s, which had replaced a downward trend since about 1900. When considering air pressure readings at two stations in Sweden since about 1800 no significant changes could be found.
3. *How is storm climate variability linked to hemispheric temperature variations?* Usually it is argued that a general warming would lead to an increase of water vapor in the atmosphere, thus a warming would provide more "fuel" for the formation of storms. This hypothesis is examined in the framework of a millennium simulation with a state-of-the-art climate model, which was run with reconstructed natural and anthropogenic forcing since 1000 bp, and extended until the year 2100 assuming scenarios for future greenhouse gas emissions. It turns out that during preindustrial and industrial times (i.e., until about the end of the 20century), the hypothesized link could not be detected, even if significant temperature fluctuations were simulated;

only when greenhouse gas concentrations strongly increased, a parallel development of NE Atlantic storm intensity and hemispheric temperature emerged.

4. *How did wind storm impact on storm surges and ocean waves develop in the past decades, and what may happen in the expected course of anthropogenic climate change?* Regionally detailed reconstructions of surface winds since about 1960 have been used to run dynamical models of water levels, currents and ocean waves in the North Sea. Changes were found to be consistent with the changes of storm activity, namely a general increase since 1960 to the mid 1990s and thereafter a decline – apart of the Southern North Sea, where the upward trend is still going on. Scenarios prepared by a chain of assumed emissions, global and regional climate models point to a slightly more violent future of storminess, storm surges and waves in the North Sea. For the end of the century an intensification of a bout 10% is envisaged, mostly independent of the emission scenario used. When not only the change in windiness but also the enlarged volume of the ocean is considered, then an increase of 20 cm in 2030 and of 70 cm in 2085 along the German Bight are reasonable guesses for future conditions.

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