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Modelling the variability of midlatitude storm activity on decadal to century time scales

GKSS FORSCHUNGSZENTRUM in der HELMHOLTZ GEMEINSCHAFT

Introduction & Motivation

- Storms are a characteristic of the maritime weather at midlatitudes.
- It is particularly difficult to homogeneously "measure" storm intensities:
  - Observations depend on subjective decisions
  - Long series of direct wind observations often suffer from inhomogeneities
- It seems that Northern European storm climate has been relatively stable during the last two hundred years *(Bärring and von Storch 2004)*. However, in history many people have experienced storms as having become more severe *(von Storch and Stehr 2000)*.
- From proxy data we know that past climate has undergone significant variations:
  → Medieval Warm Period, Little Ice Age, Late Maunder Minimum (LMM, 1675-1710)
- The spatial extent of these episodes is still a subject for debate. But there is little doubt that significant temperature deviations prevailed during these times in large areas.

Are these temperature variations associated with significant changes of storminess?

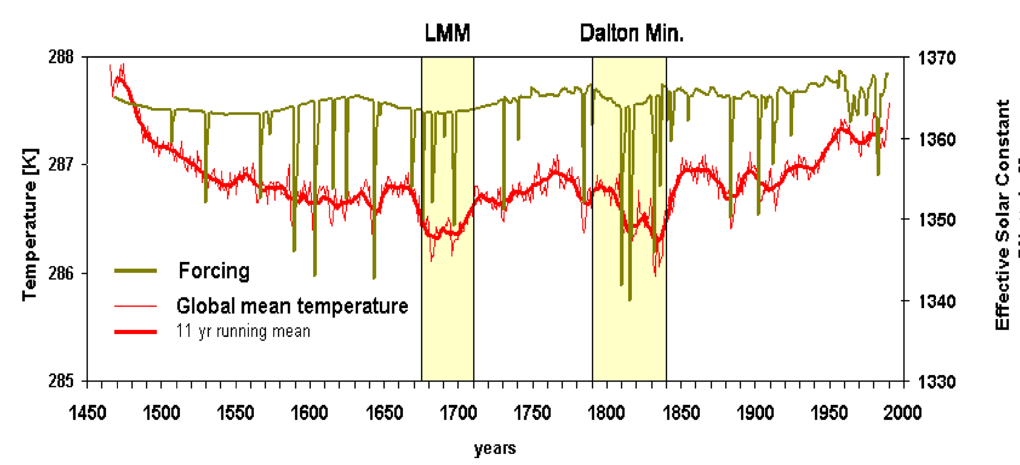
Climate Model

Coupled Global **O**cean-**A**tmosphere **G**eneral **C**irculation **M**odel **ECHAM4/HOPE-G**
Atmosphere: horizontal resolution 3.75°x3.75° (T30), vertical: 19 layers.
Ocean: horizontal resolution 2.8°x2.8°(T43), refining to 0.5° near equator, vertical: 20 layers.

Flux correction is applied. *(e.g. Roeckner et al. 1996)*

Simulations

- 2 realizations of a **historic climate change simulation** (time dependent solar, volcanic, and anthropogenic GHG forcing). **One simulation is shown exemplarily.**
- 3 **transient climate change simulations** with idealized forcing simulating a future climate state (CMIP2, SRES A2/B2 scenarios). **The A2/B2 scenarios are shown exemplarily.**
- a control simulation (present day conditions) *(Zorita et al, 2004)*



Effective solar forcing and annual global mean temperature. The temperature shows two distinct minima: one during the LMM and one during the Dalton Minimum.

References

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Zorita E, H von Storch, JF Gonzales-Rouco, U Cubasch, J Luterbacher, S Legutke, I Fischer-Bruns, U Schlese (2004) Climate Evolution in the Last Five Centuries Simulated by an atmosphere-ocean model: Global Temperatures, the North Atlantic Oscillation and the Late Maunder Minimum. Meteor Z, 13, 4, 271-289

Roeckner E et al. (1996) The atmospheric general circulation model ECHAM4: Model description and simulation of present-day climate. Report No. 218, MPI Meteorology, Hamburg

von Storch H, Stehr N (2000) Climate change in perspective. Our concerns about global warming have an age-old resonance. Nature 405:615

Methods

- Analysis of the simulations with respect to global storm activity
- Characteristic parameter: Frequency of **maximum wind speed events**. Lower limit on the Beaufort wind speed scale of **8 Bft** is used as threshold (17.2 ms^{-1}).
- Determination of 2 simple indicators describing the frequency and regional shift of storm activity:

- **Storm frequency index**: Simple count of storm days per grid point
- **Storm shift index**: PC obtained by projection of storm frequency data onto dominating EOF of storm frequency in pre-industrial times

Conclusions

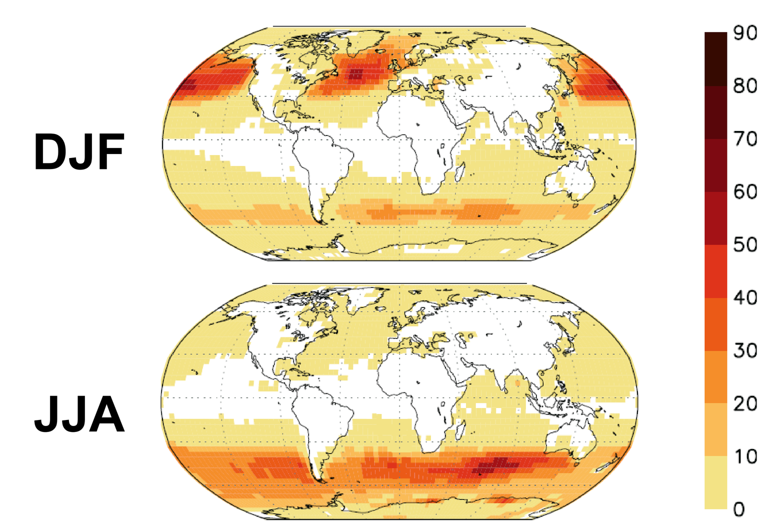
Historical times and industrially influenced period:

- Variations of the external forcing are not directly related to variations in storm activity, neither in historical times, nor in the industrially influenced period.
- In pre-industrial times, storm activity is decoupled from hemispheric mean temperature.
- Anomalous temperature regimes (like the LMM) are not associated with systematic storm conditions.
- The storm indices show no trend until recently (except for SH in 20th century).

Future climate change scenario:

- Poleward shift of regions with maximum storm intensity for N-Atl, N-Pac and SH.
- Storm intensity is constant over the NH as a whole, but increasing in the N-Atl and decreasing in the N-Pac region.
- Parallel increase of storm indices and temperatures over the N-Atl region and Southern Ocean. *(Fischer-Bruns and von Storch, 2005)*

Results

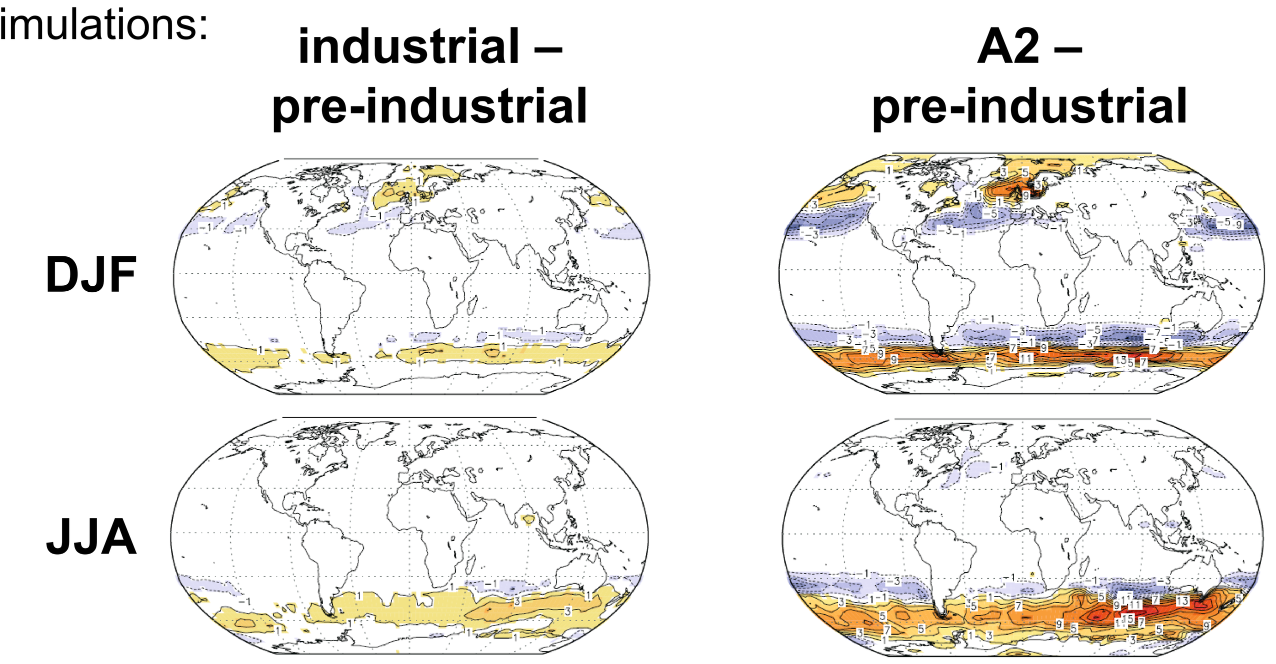


Storm frequency and future shift

Frequency of storm days for DJF and JJA for the pre-industrial period 1551–1850 in one of the historical simulations

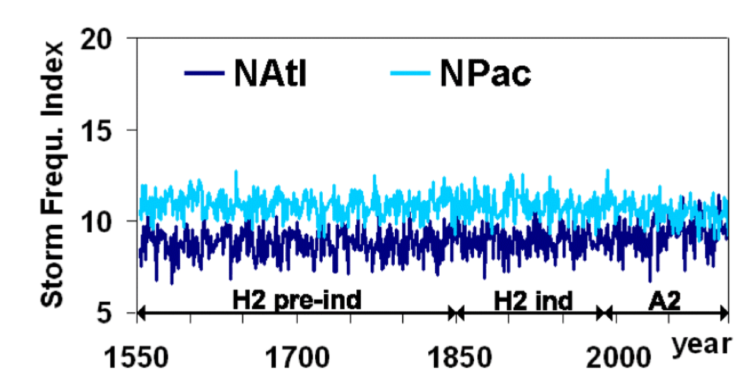
Storm frequencies for the industrially influenced period hardly differ from pre-industrial maps, even though significant temperature anomalies temporarily emerge in the historical simulations:

In the climate change simulations, a poleward shift of storm activity is found in all three storm track regions. Here results are shown for the IPCC scenario A2:



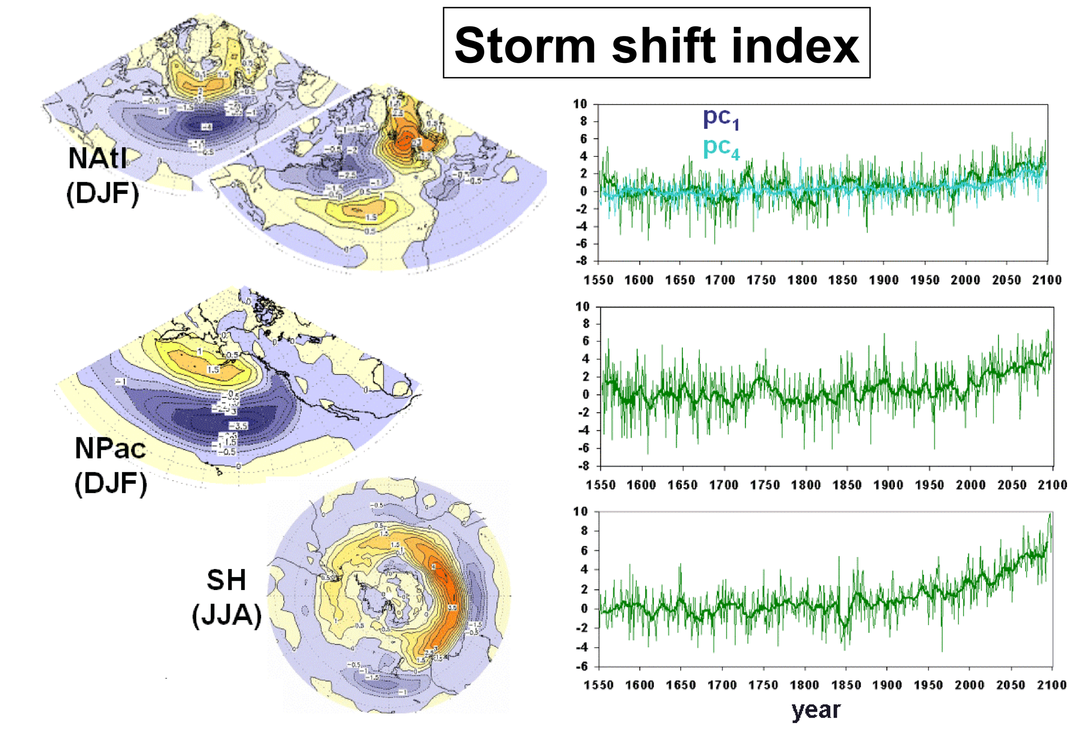
Differences in storm frequency between industrial and pre-industrial period and differences between future period and pre-industrial period

Storm frequency index



Storm intensity index for DJF averaged over the N-Atl and N-Pac region. The pre-industrial, industrial and future periods (scenario A2) are indicated.

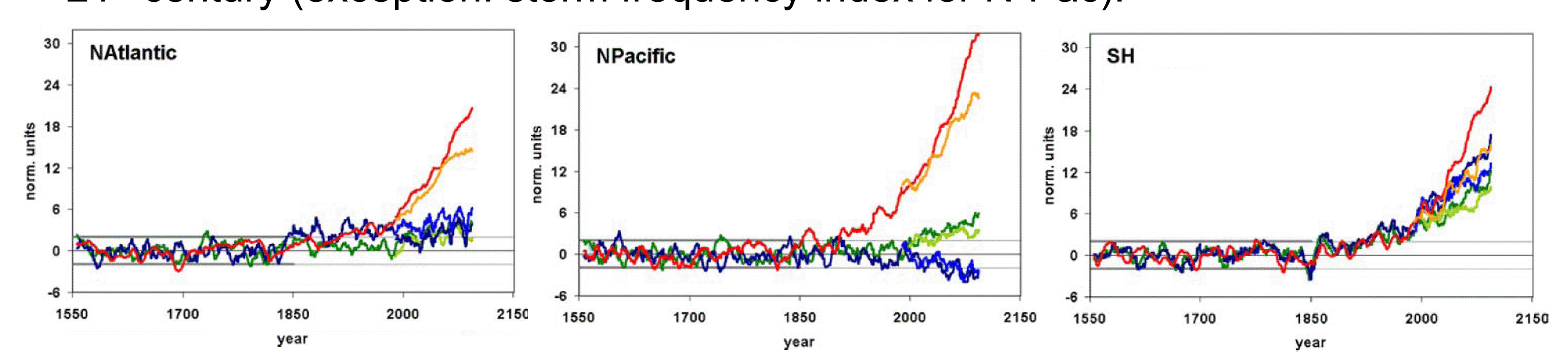
Storm shift index



Pre-industrial period: dominating EOFs of storm frequency for different domains and corresponding PC time series (obtained by projection of the 1551–2100 data on these EOFs) *)

Temperature and storms

In contrast to the historical runs, the storm indices parallel the development of temperature, exceeding the 2 σ-range of pre-industrial variations in the early 21st century (exception: storm frequency index for N-Pac):



2m temperature (red/orange), storm frequency index (blue) and storm shift index (green) for one historical simulation (until 1990) and both SRES scenarios (after 1990): A2 (red, dark blue and green), B2 (orange, light blue and green). The bold gray lines indicate ±2 σ for the pre-industrial period, continuing as thin gray lines. *) (11-yr running mean, standardized to unit variance and zero mean in the pre-industrial period)

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