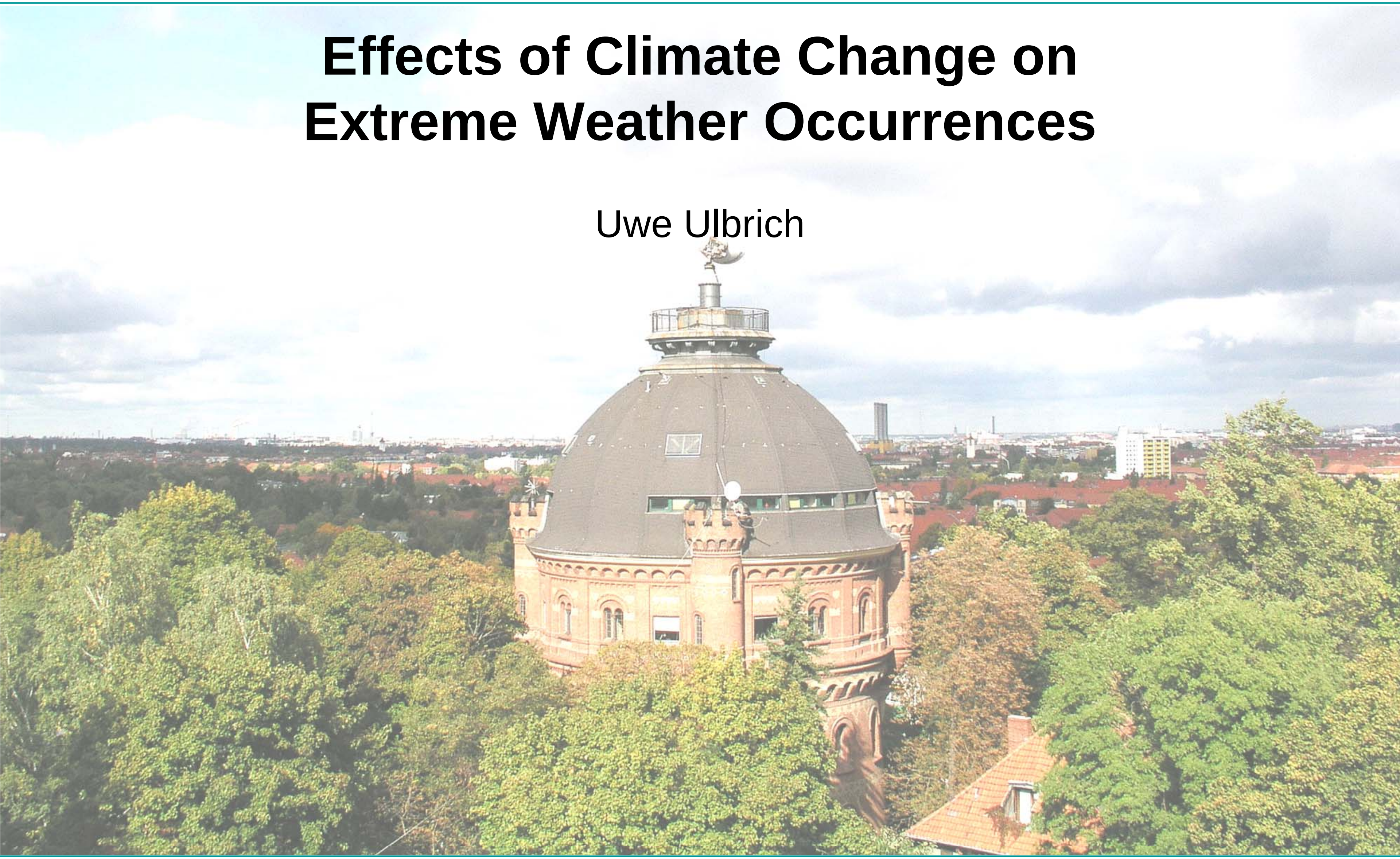
Effects of Climate Change on Extreme Weather Occurrences

Uwe Ulbrich



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Outline

- Damage from extreme meteorological events
- Observed climate changes
- Numerical modelling of the earth system response to rising greenhouse gas concentrations
- Selected model results
- Convective events and air traffic

Impacts of meteorological extreme events

Heavy Precipitation

→ Floods

Dry periods

→ Drought

Extreme Temperatures

→ Heat waves

Extreme Lows

→ Storm damage

Convective events

→ Hail

1995
Überschwemmung, Köln, Deutschland

2002
Überschwemmungen, Europa

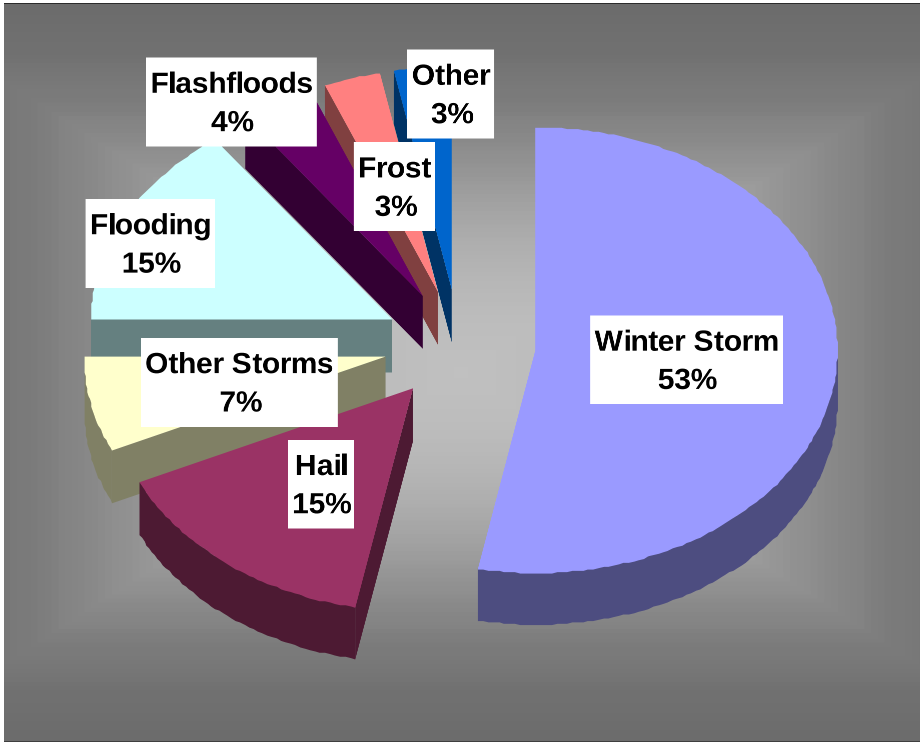
2003
Hitzewelle, Europa

1976
Wintersturm Capella, Europa

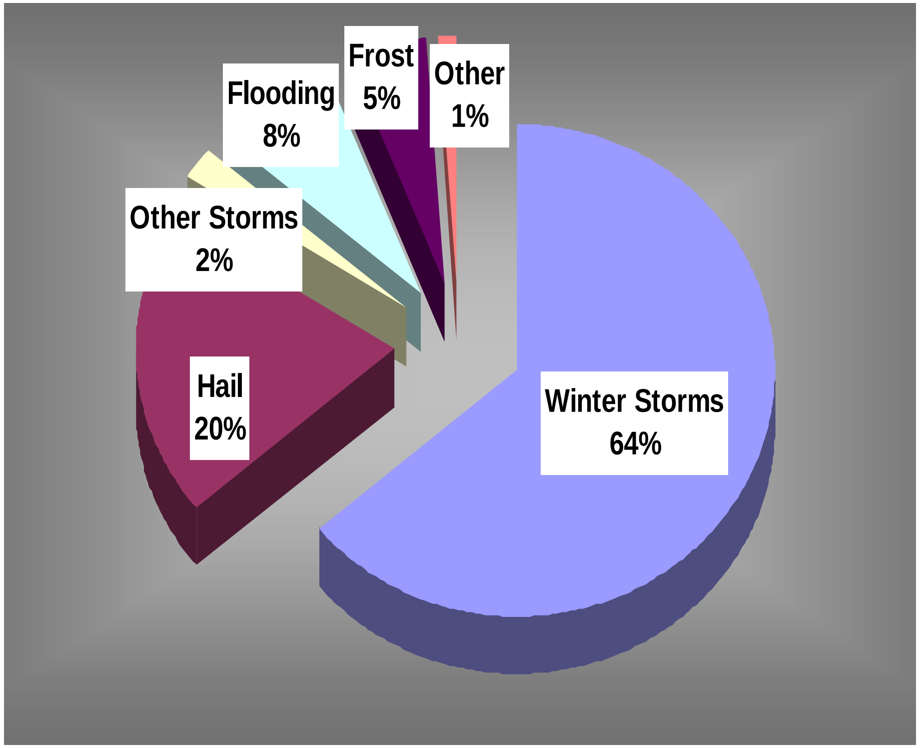
1999
Wintersturm Lothar, Europa

Loss distribution Germany, 1970-1998

Total loss



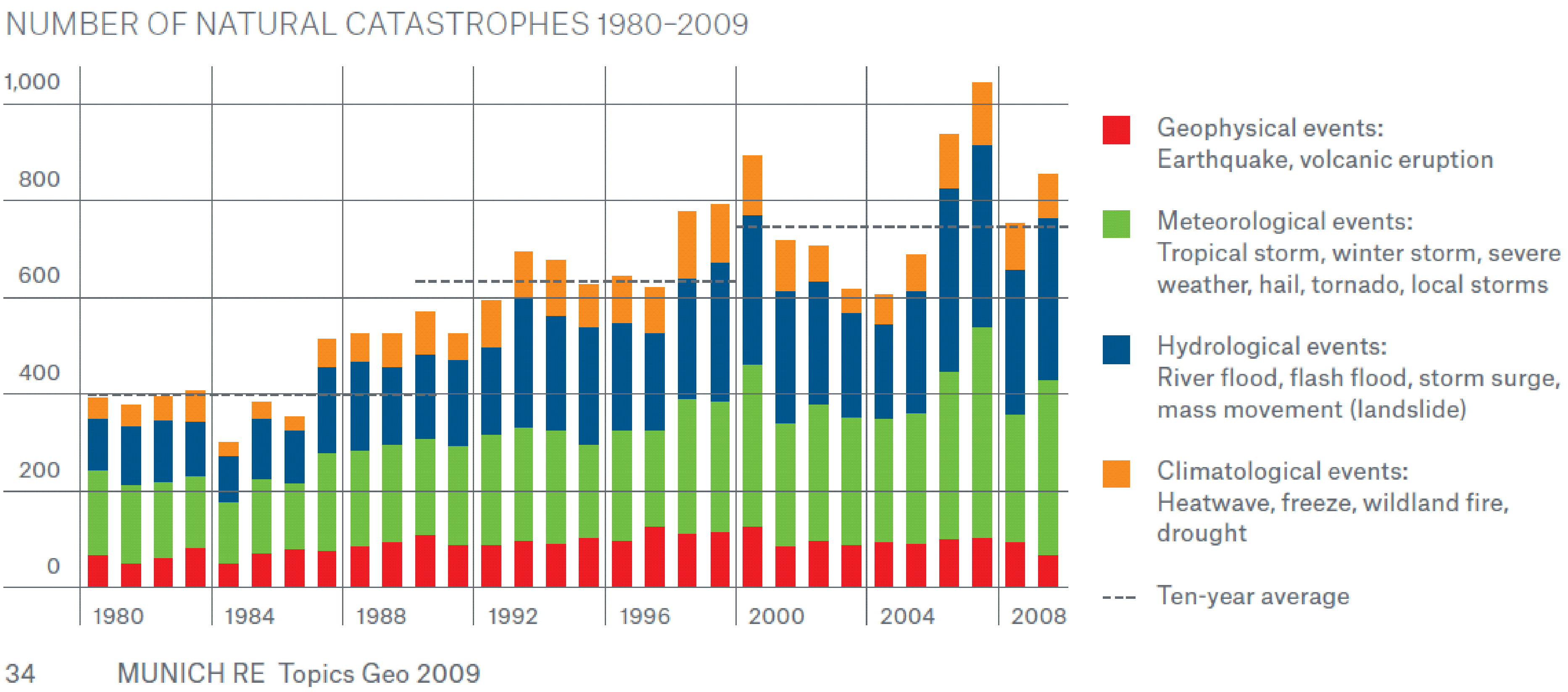
Insured loss



Source: Munich Re: Naturkatastrophen in Deutschland.

Schadenerfahrungen und Schadenpotentiale, München 1999

Number of Natural Catastrophes 1989-2009 distinguishing event types



Source: Munich Re Topics Geo 2009

Central European Temperature Anomalies 1761-2009 (De Bilt, Potsdam, Basel, Wien)

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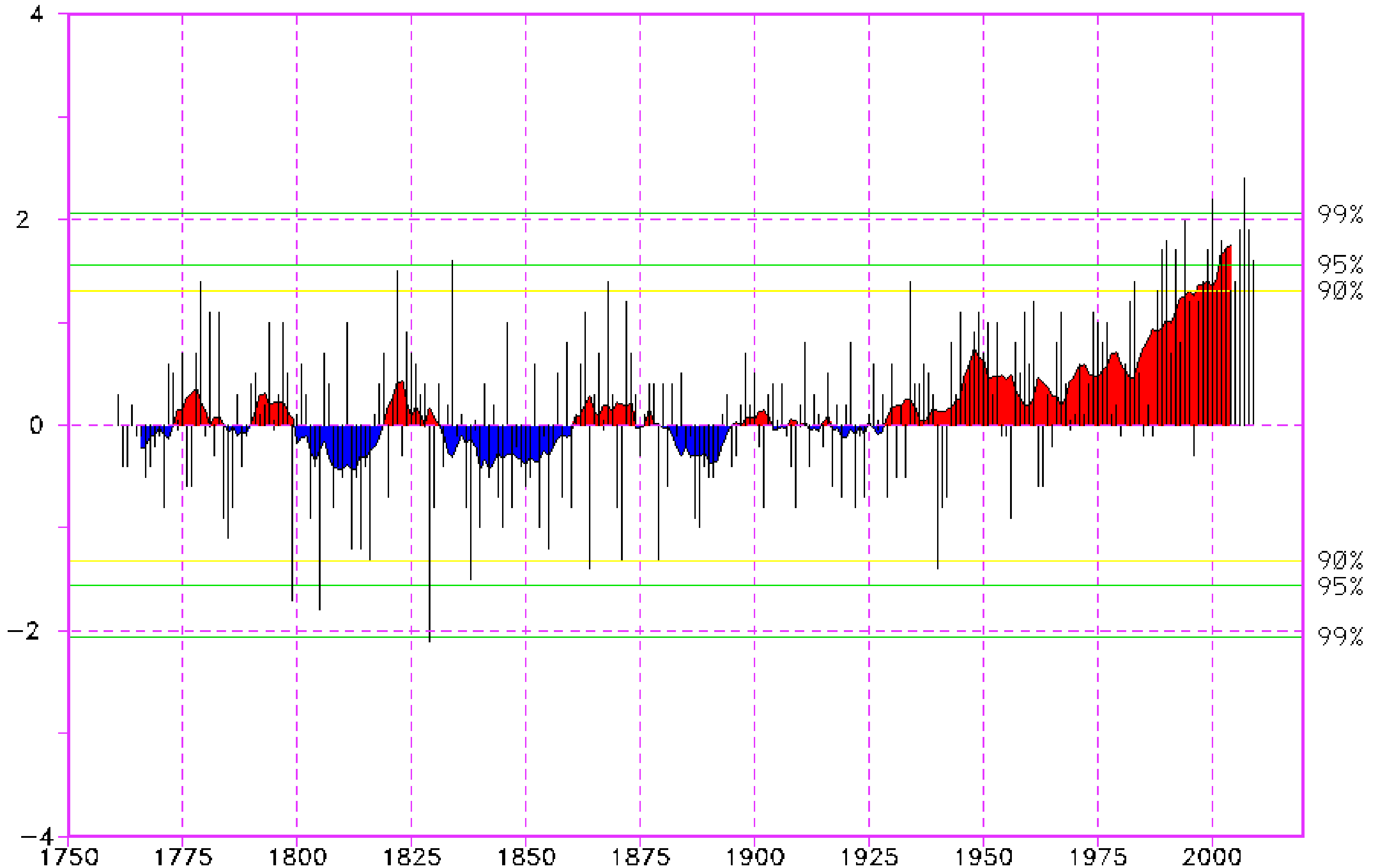
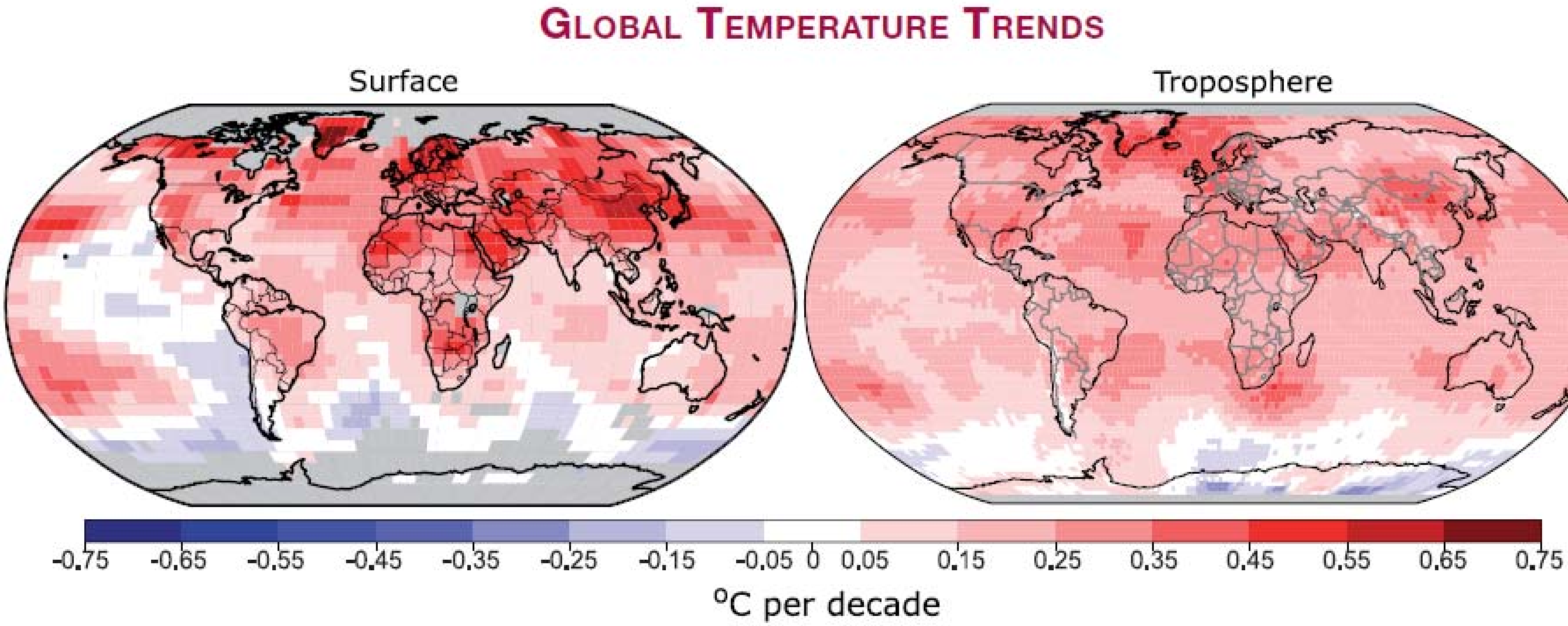


Smoothed curve: 11−year running mean

Source: Universität zu Köln, Institut für Meteorologie

Temperature Trends 1979-2005



Source: IPCC 2007

Observed Storm Trends using SLP data

Wang et al.,
Climate Dynamics, 2009

DJF

JJA

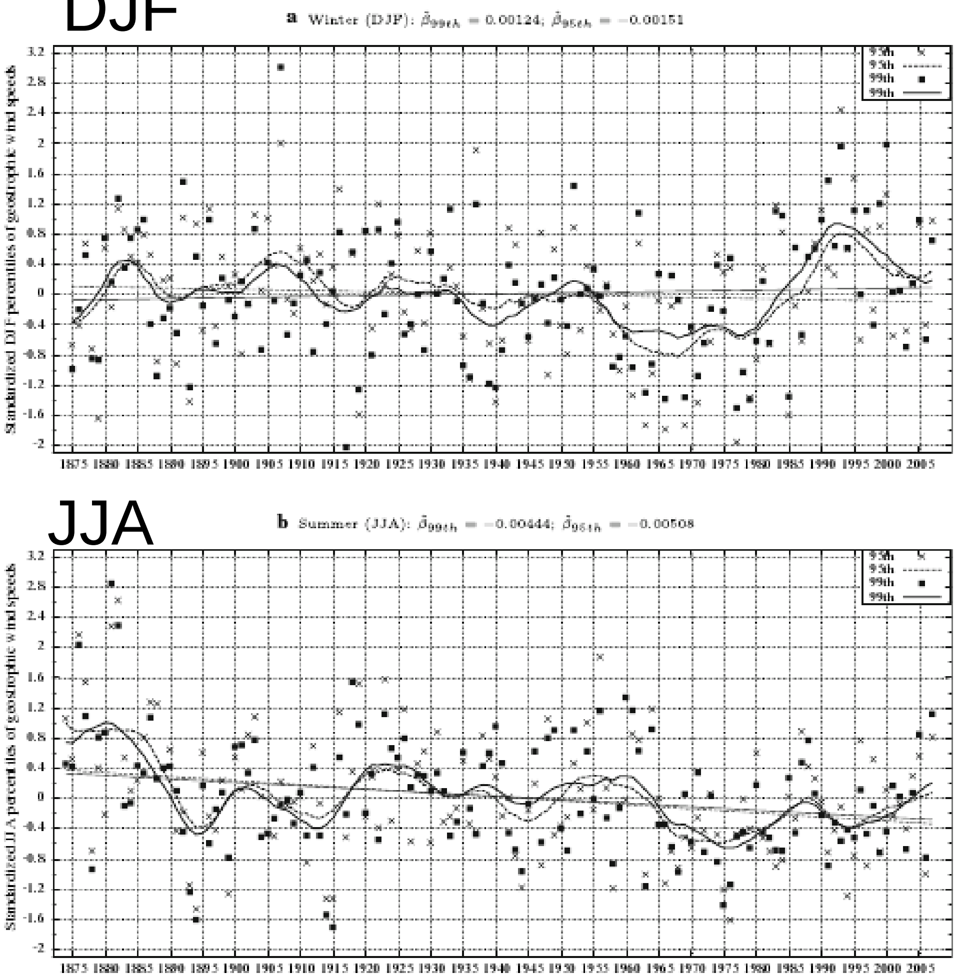
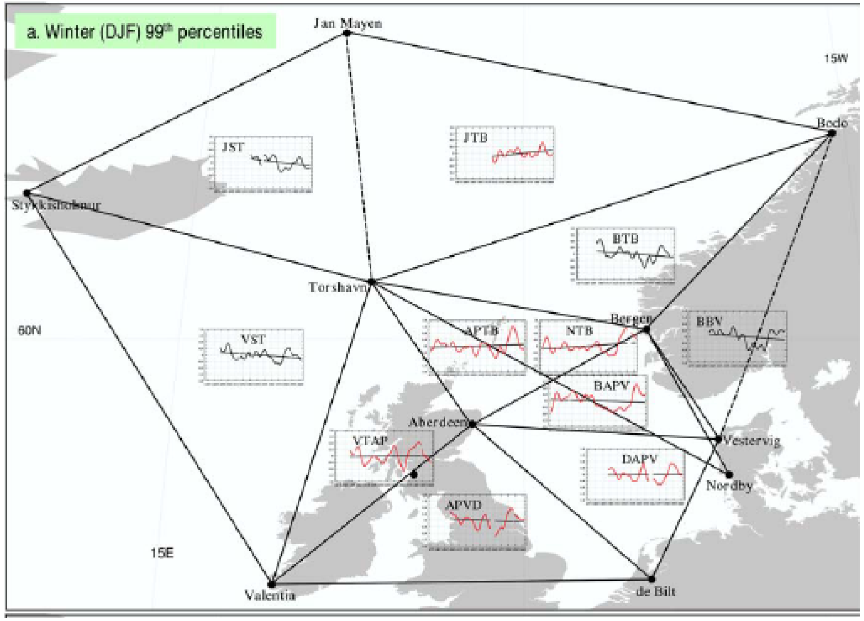
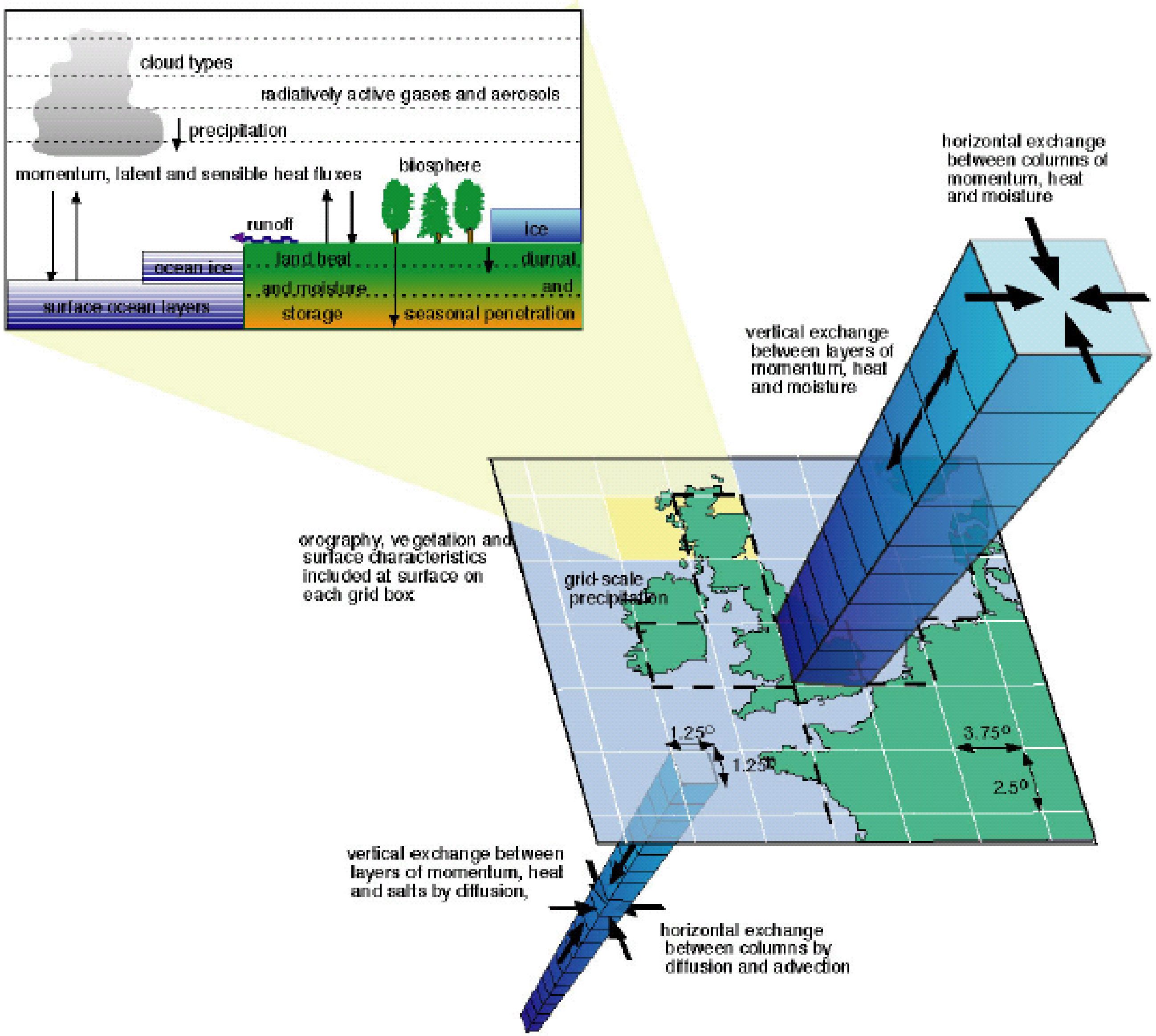


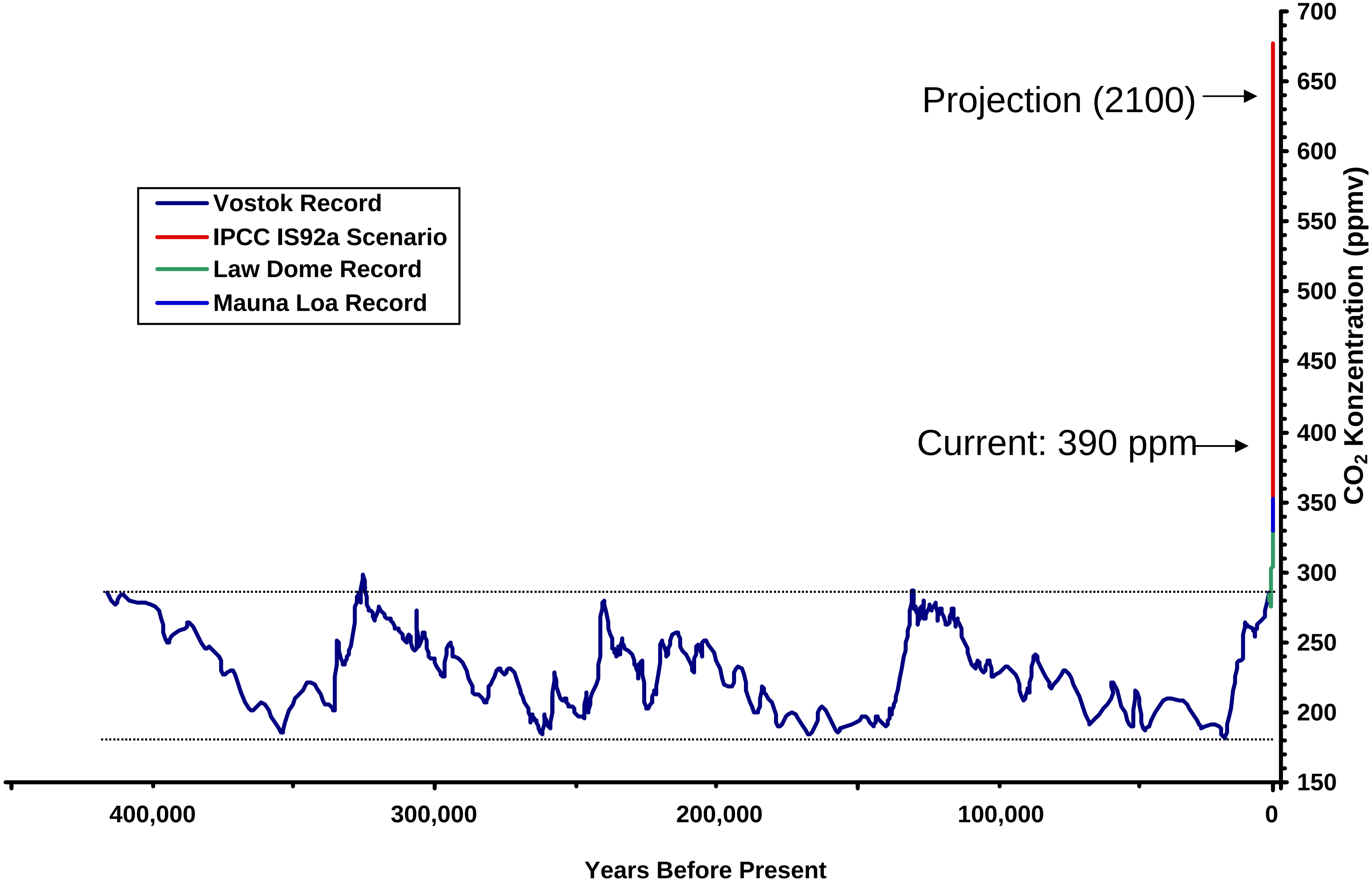
Fig. 4 The same as in Fig. 2 but for area averages of the standardized seasonal 99th and 95th percentiles of geo-winds in the North Sea area (APTB+BAPV+DAPV+NTB)



How to assess climate change, and extremes? Numerical climate models

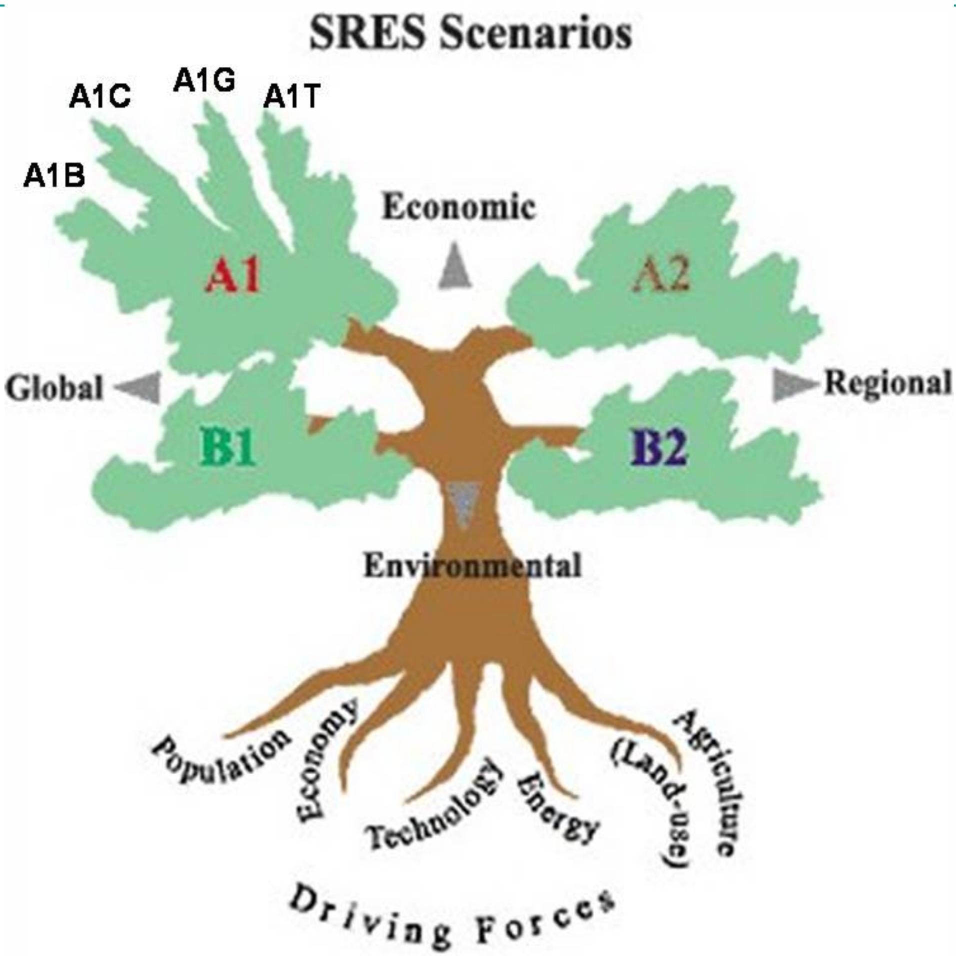


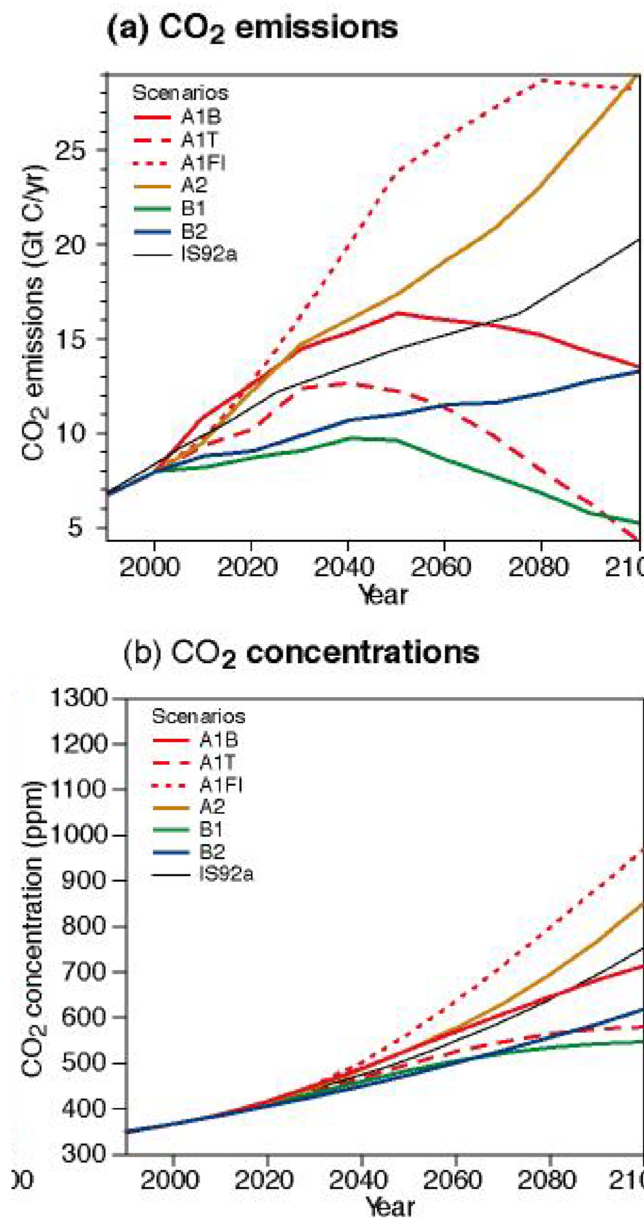
CO_2 concentration in in ice core samples, atmospheric CO_2, projection 2100



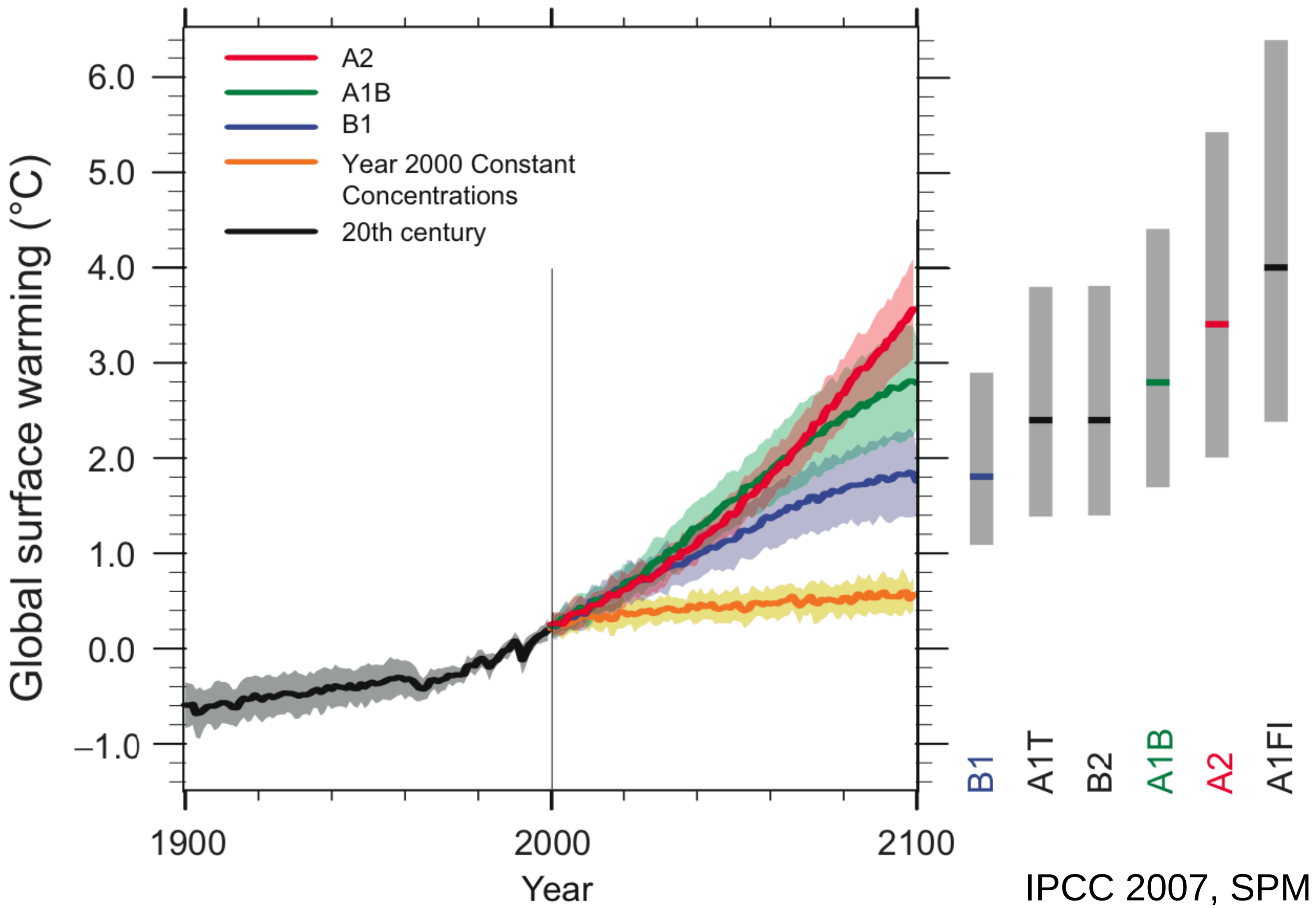
Quelle: C. D. Keeling and T. P. Whorf; Etheridge *et.al.;* Barnola *et.al.;* *(PAGES* / IGBP); IPCC

Socio-economic scenarios





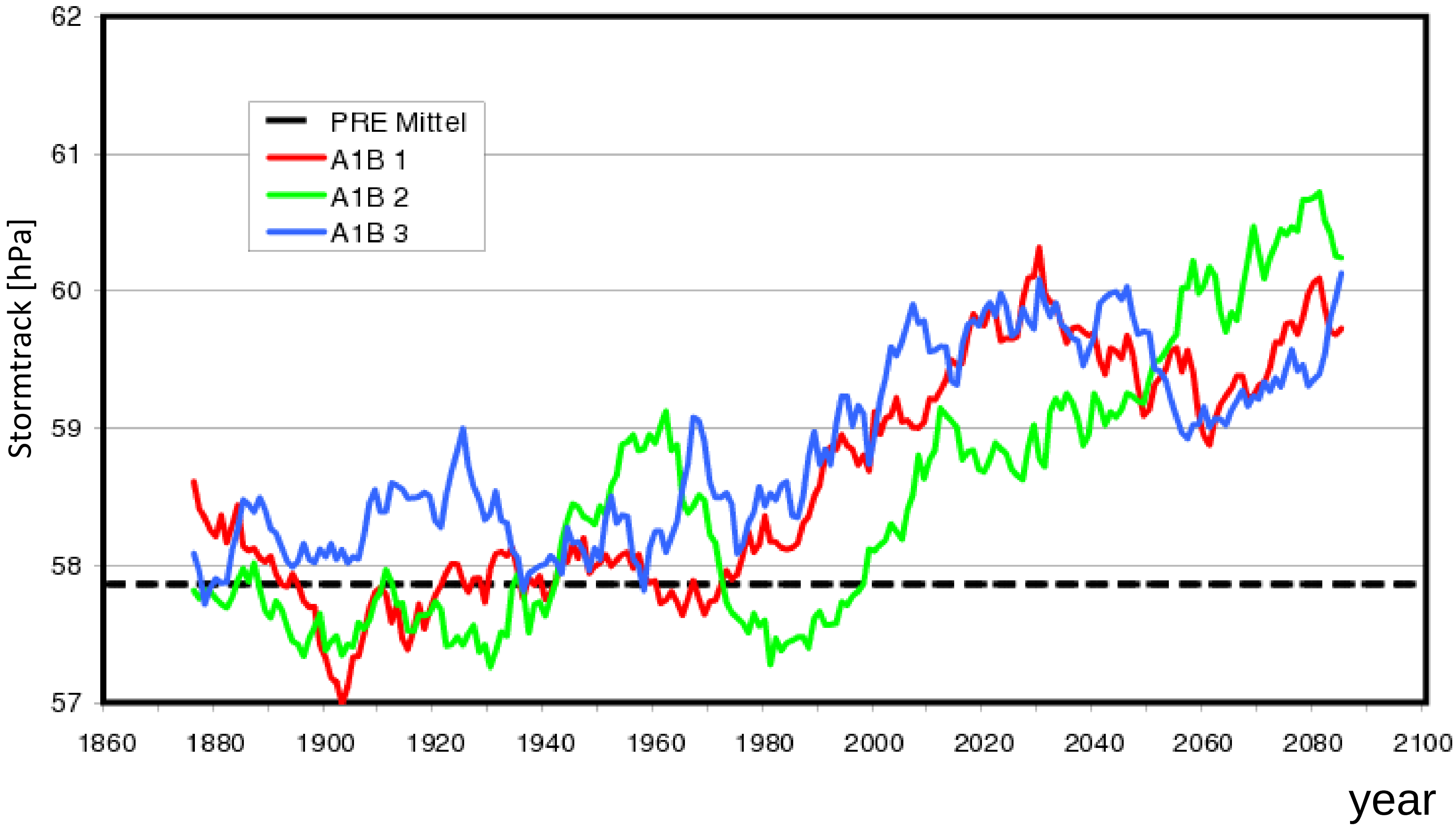
Multi-model Averages and Assessed Ranges for Surface Warming



IPCC 2007, SPM

Internal climate variability in model runs

ECHAM5/OM1 North Atlantic storm track activity

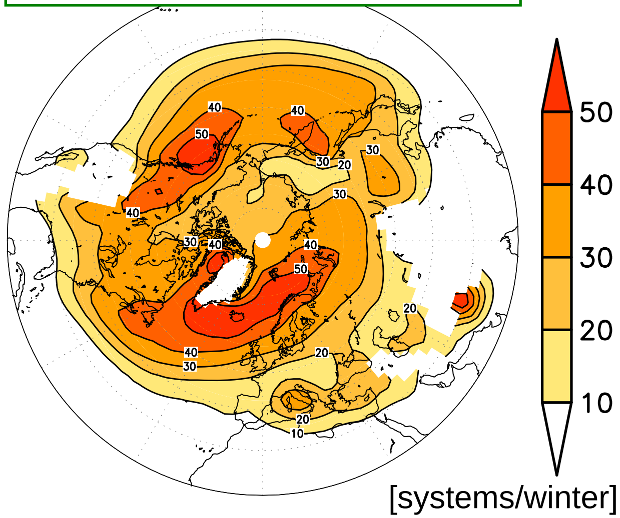


31y running means

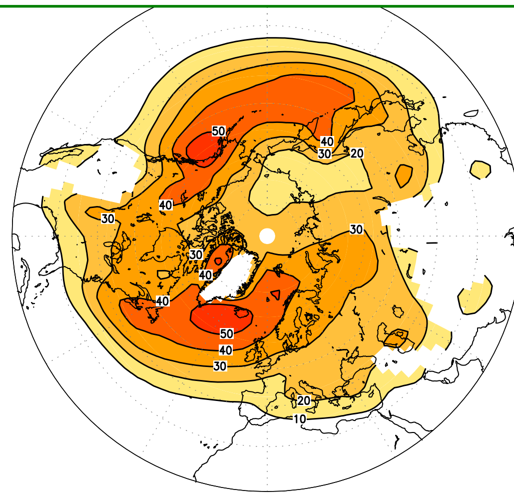
Cyclone Tracks

(cyclone identification and tracking based on Murray and Simmonds, 1991)

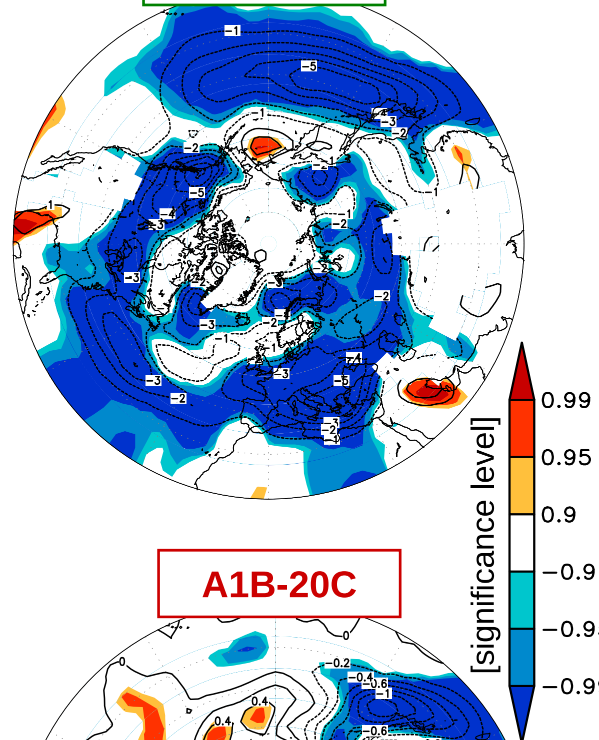
ERA40 all systems



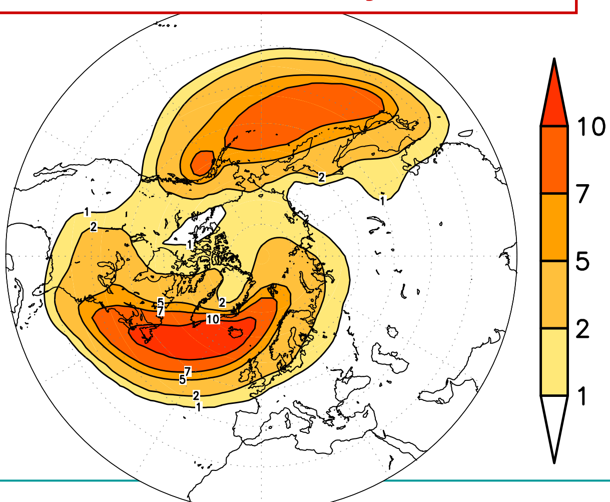
ENSEMBLE all systems



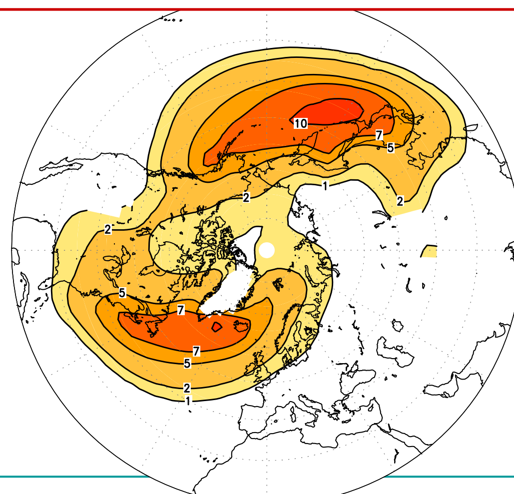
A1B-20C



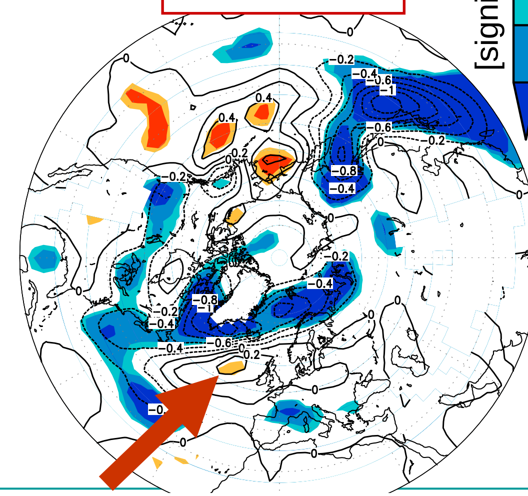
ERA40 extreme cyclones



ENSEMBLE extreme cyclones



A1B-20C

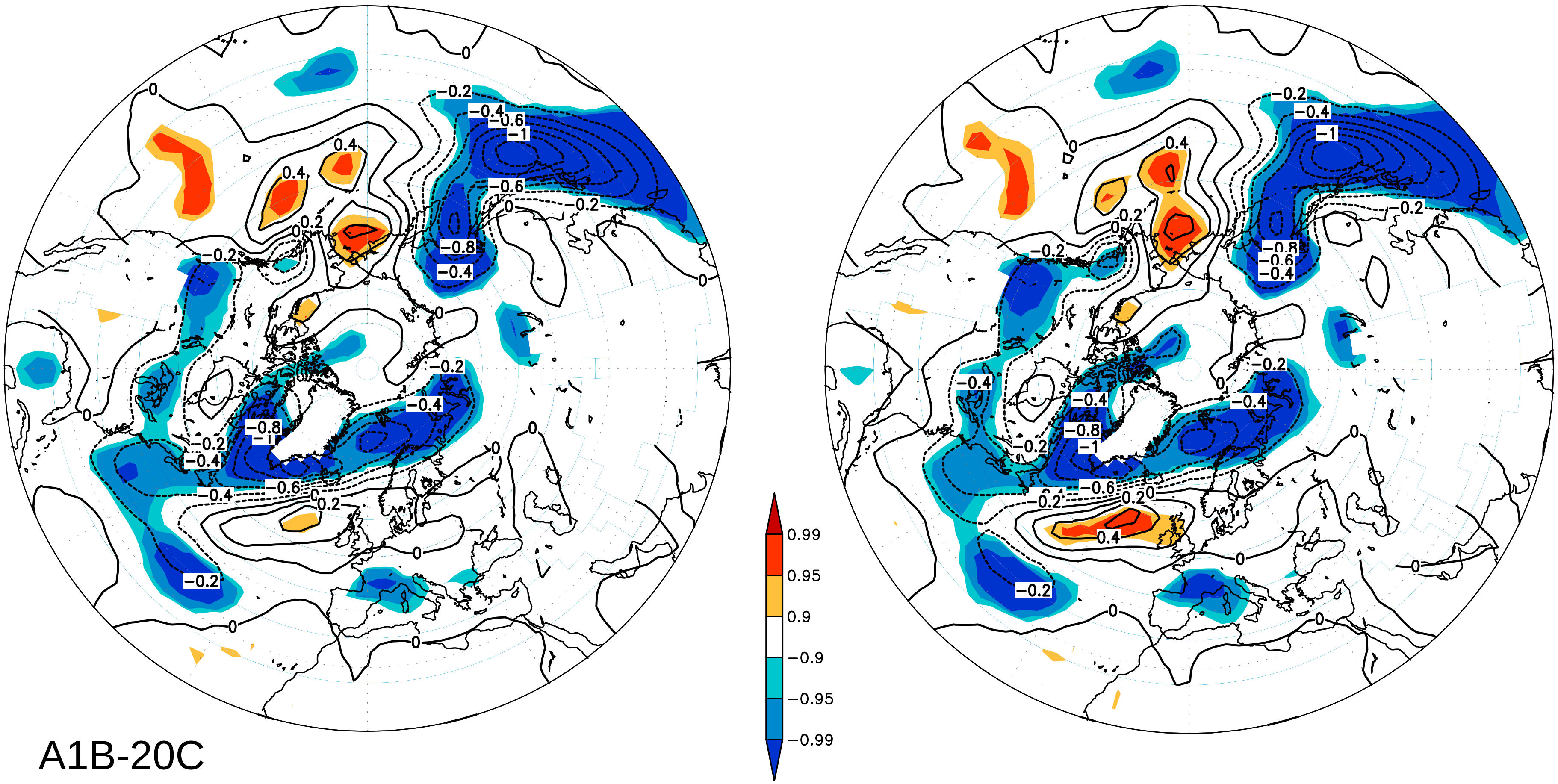


(Leckebusch et al., 2008)

Ensemble mean: weighting of models (extreme cyclones)

equal weights

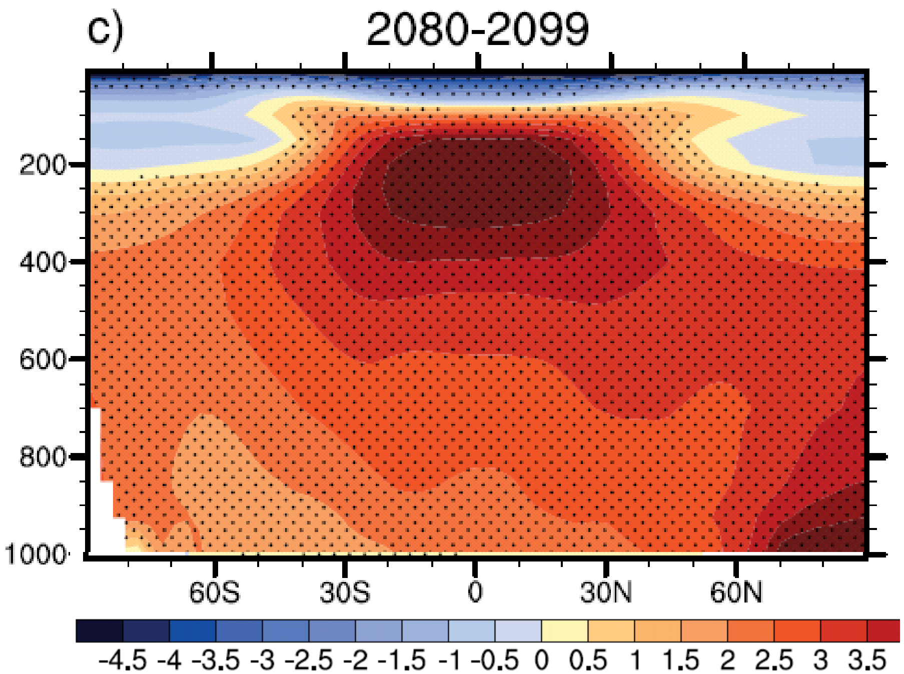
weighted based on ability to reproduce observed cyclone climatology pattern

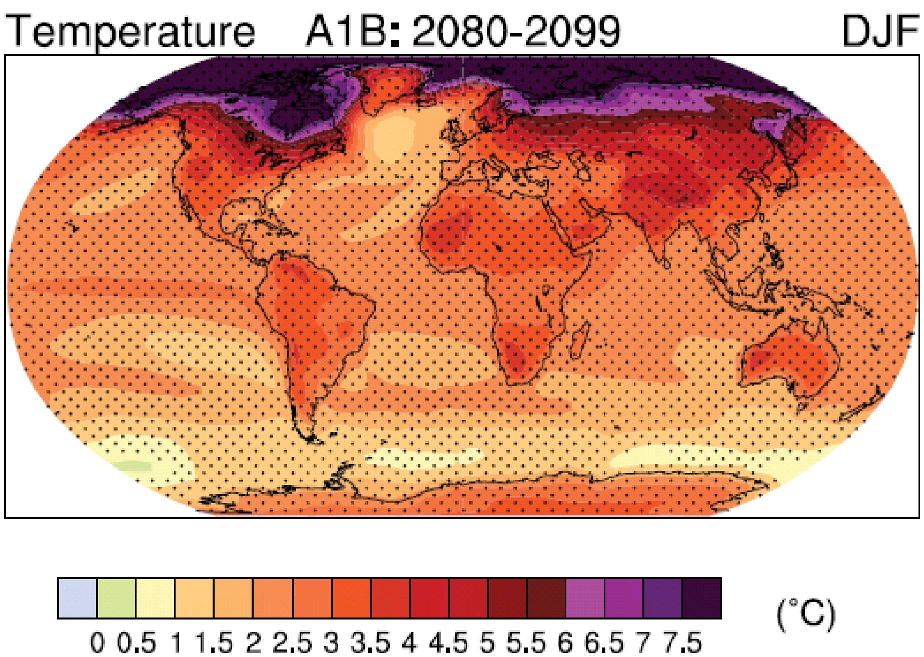


A1B-20C

Leckebusch et al, CLIVAR Exchanges, 2008

Temperature signals
2080-2099 vs. 1980-1999 forcings



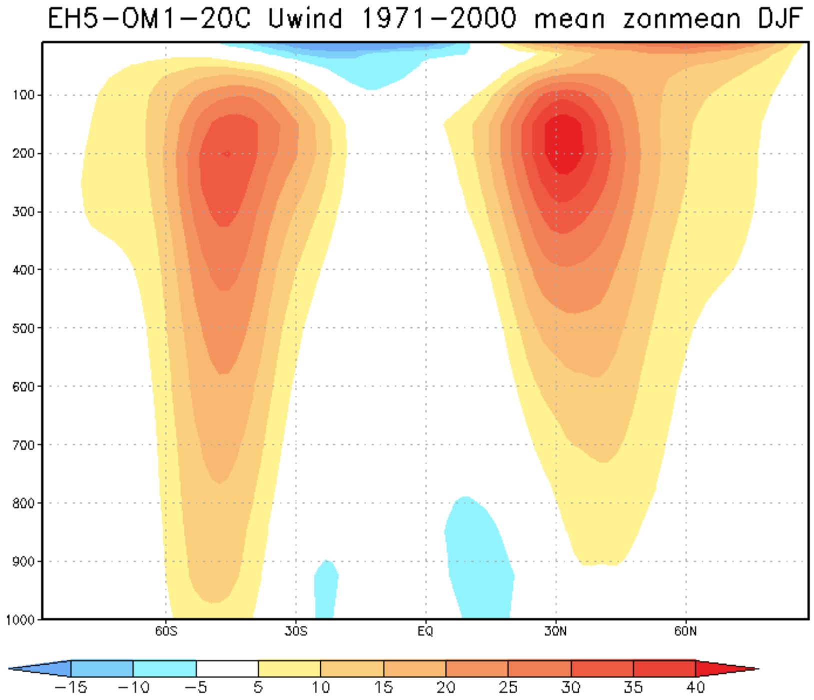


Dotted areas:
multi-model ensemble mean signal exceeds
the multi-model standard deviation

IPCC 2007, SPM

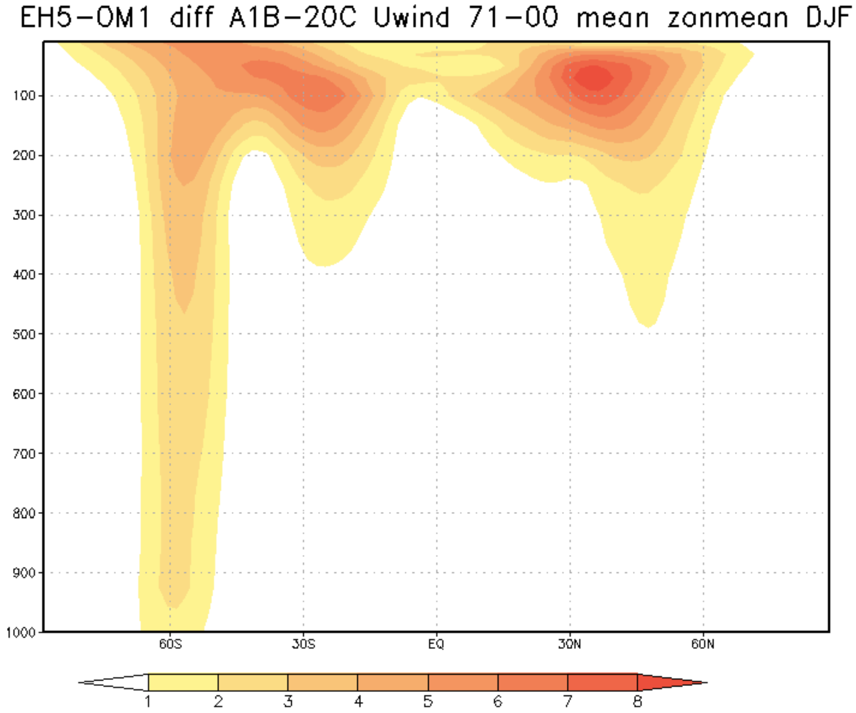
A1B Climate Signal DJF, Zonal Mean Zonal Wind

Present day GHG forcing (1971-2000)



in m/s

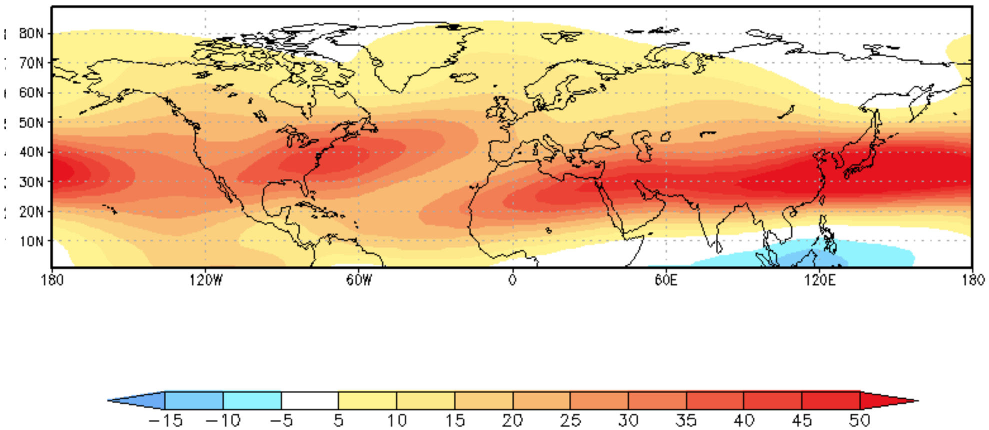
A1B GHG signal (2071-2100 vs. 1971-2000)



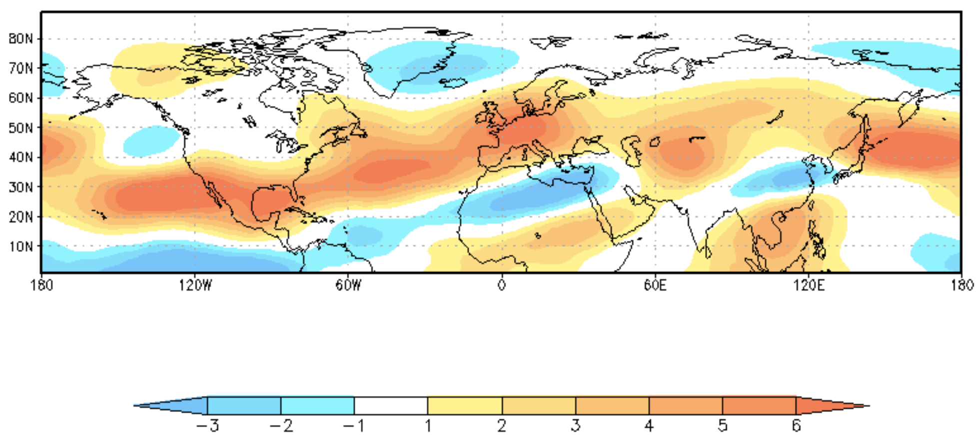
in m/s

Model: ECHAM5

Zonal wind at 200 hPa DJF



Present day climate
(1971-2000 forcing)



Climate signal
(2071-2100 vs. 1971-2000)

ulbrich@met.fu-berlin.de

Variance of vertical wind speed at 200 hPa

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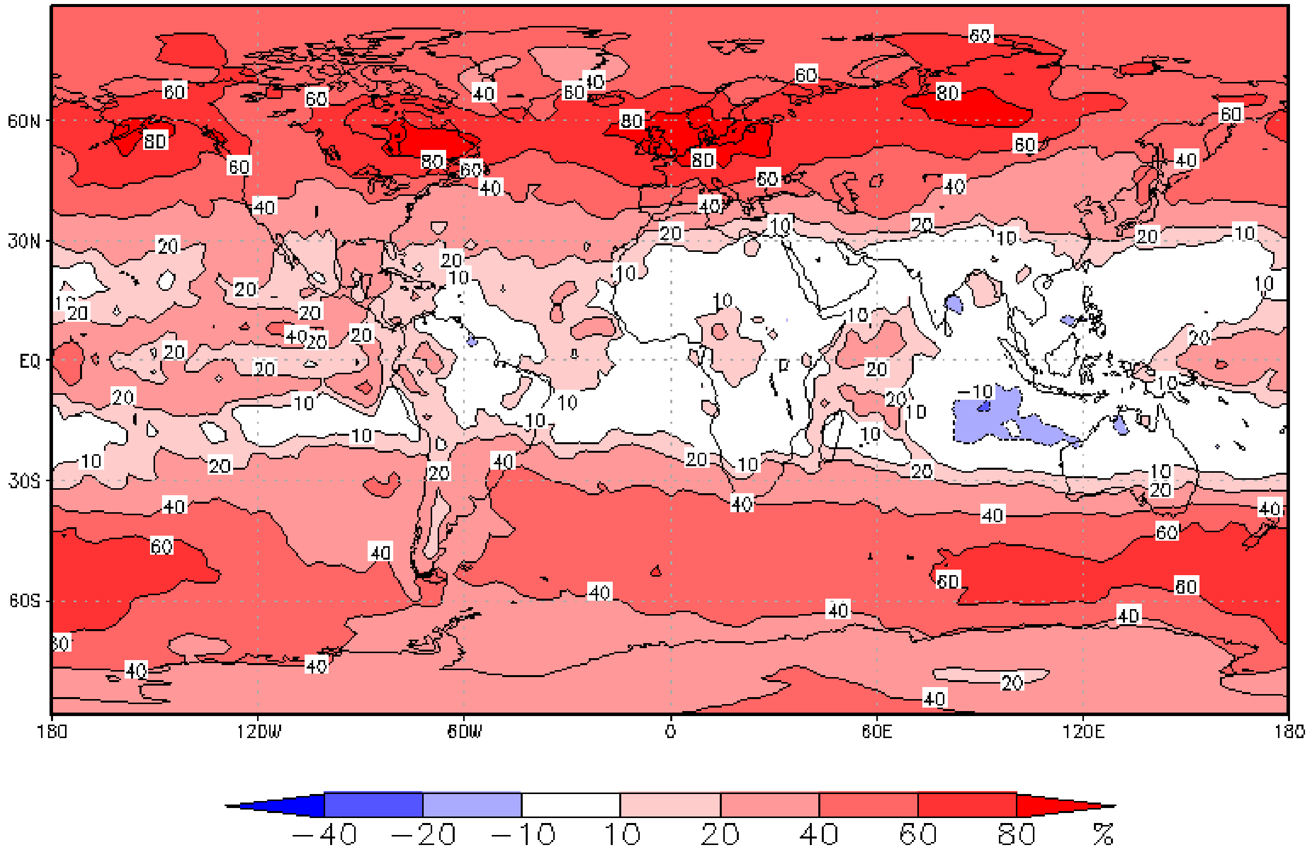
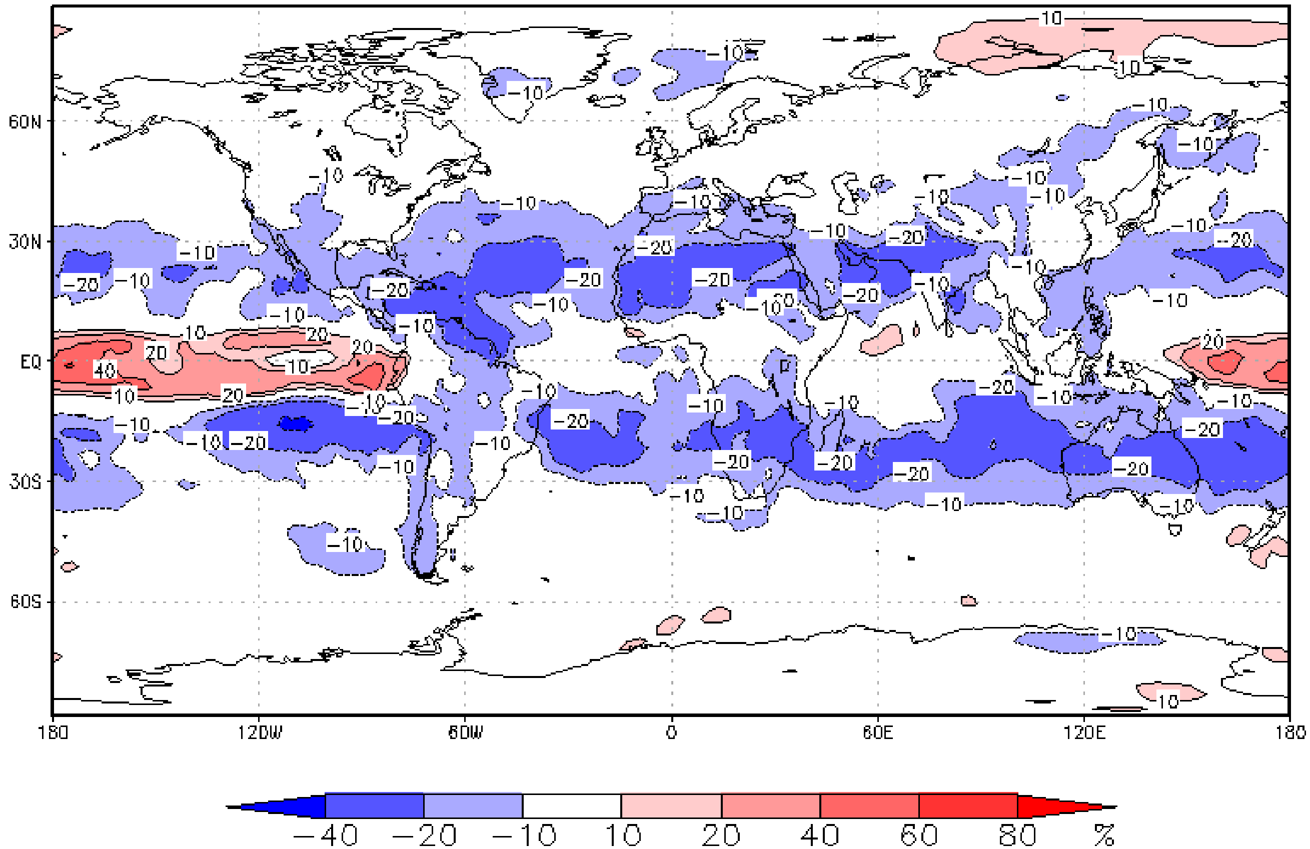


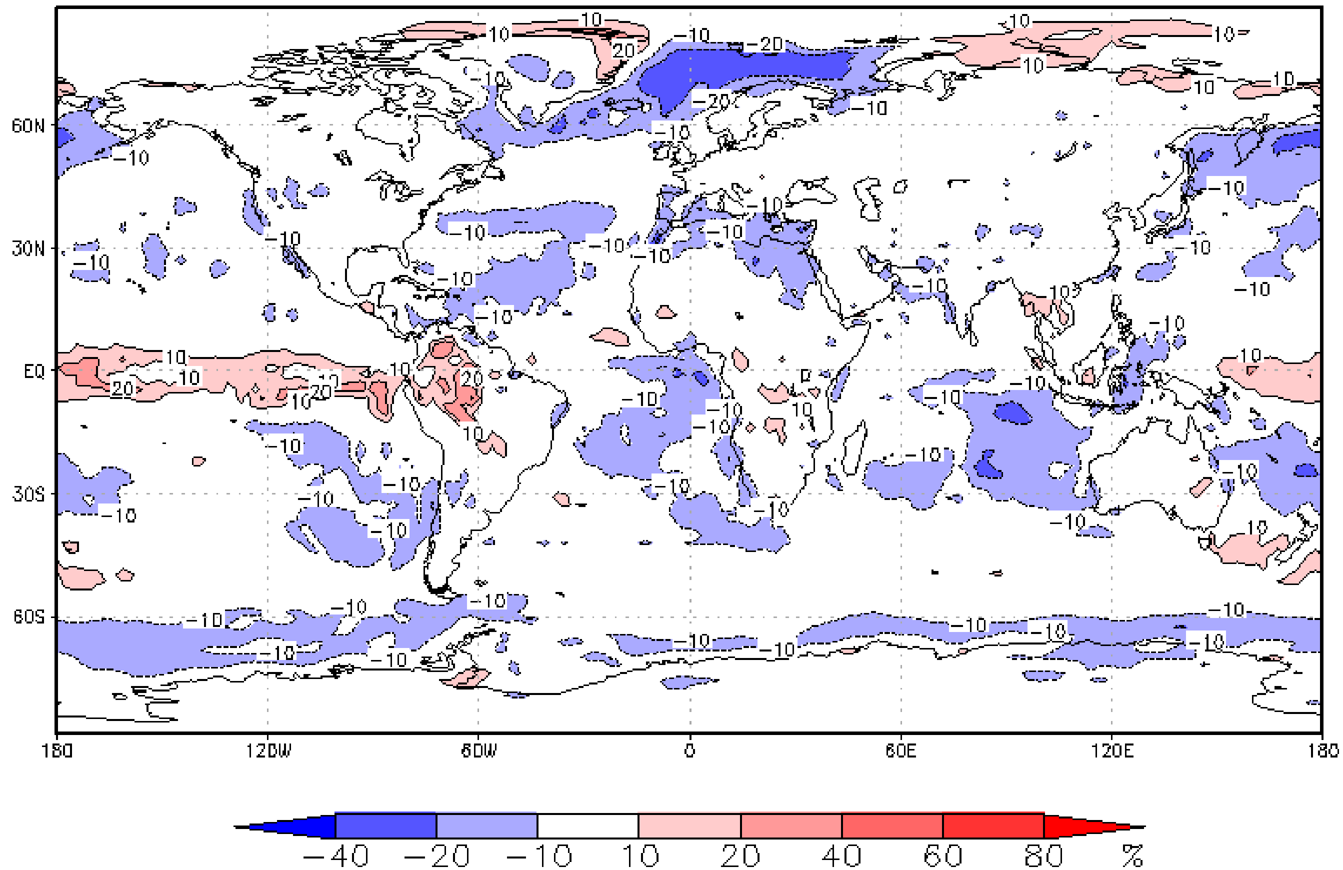
Model ECHAM5 A1B (2070-2100) – 20C (1970-2000)

Variance of vertical wind speed at 500 hPa



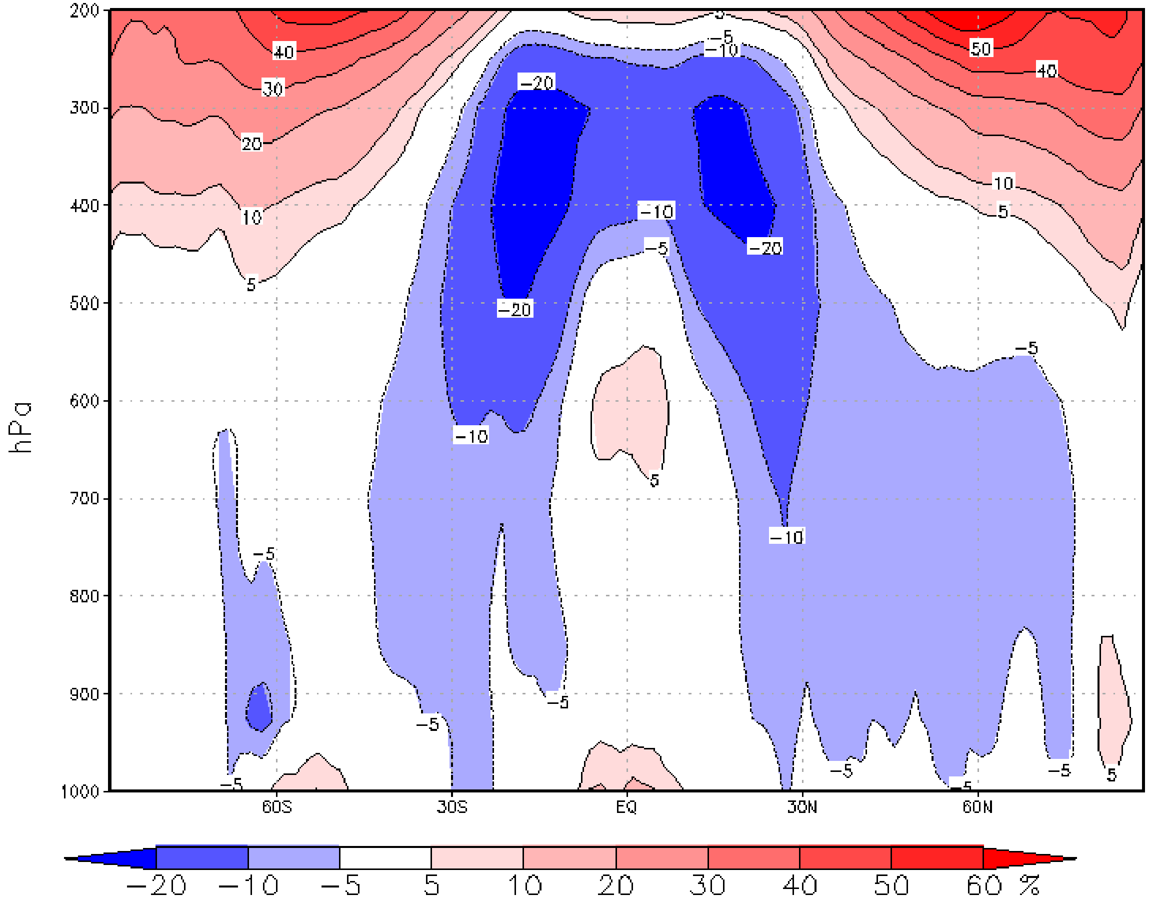
Model ECHAM5 A1B (2070-2100) – 20C (1970-2000)

Variance of vertical wind speed at 925 hPa



Model ECHAM5 A1B (2070-2100) – 20C (1970-2000)

Variance of vertical wind speed, zonal mean



Model ECHAM5 A1B (2070-2100) – 20C (1970-2000)

Potential effects of changing extreme events on air traffic safety and comfort

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- Turbulence
- Downdrafts
- Tornadoes
- Hail
- Lightning
- Heavy local rainfall induced effects

RegioExAKT

(2006-2010)

Regional Risk of
convective extreme weather events
Applied concepts for trend assessment and adaptation

Joint 11 partner project, coordinated by Nikolai Dotzek, DLR

How much do we know about present day convective event climatology in Europe?

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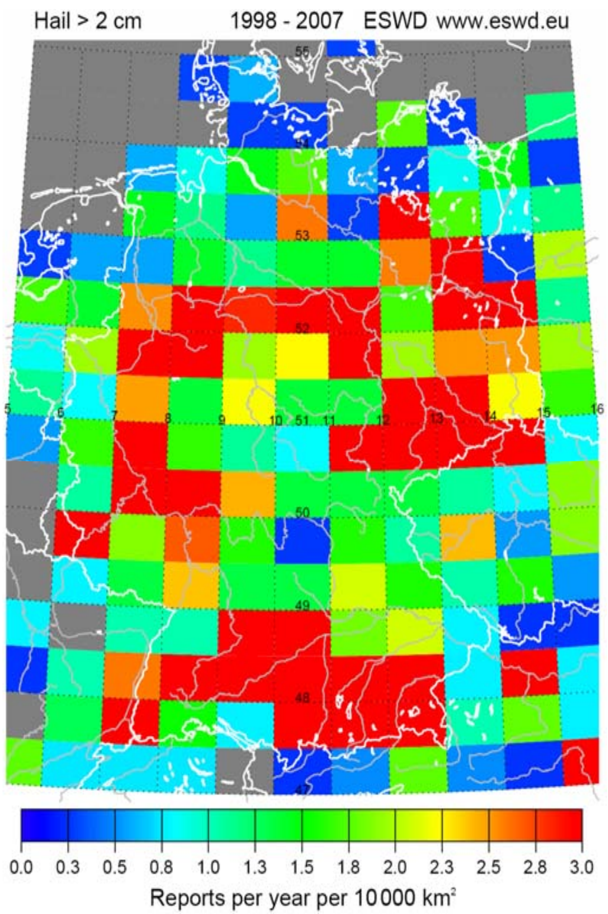
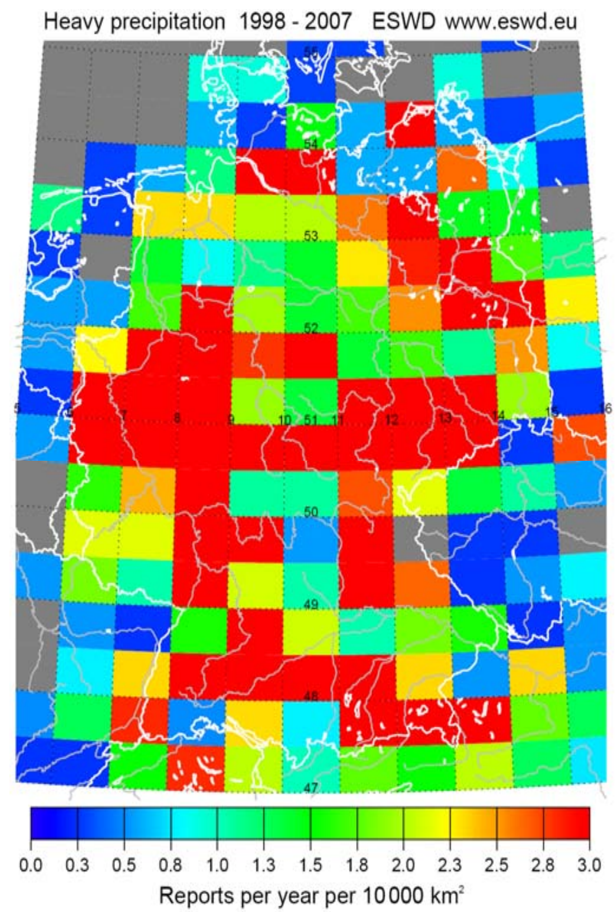
Reports per year
and 10000 km²
1998-2007



Hail



Heavy precip.

How can we assess convective event probability?

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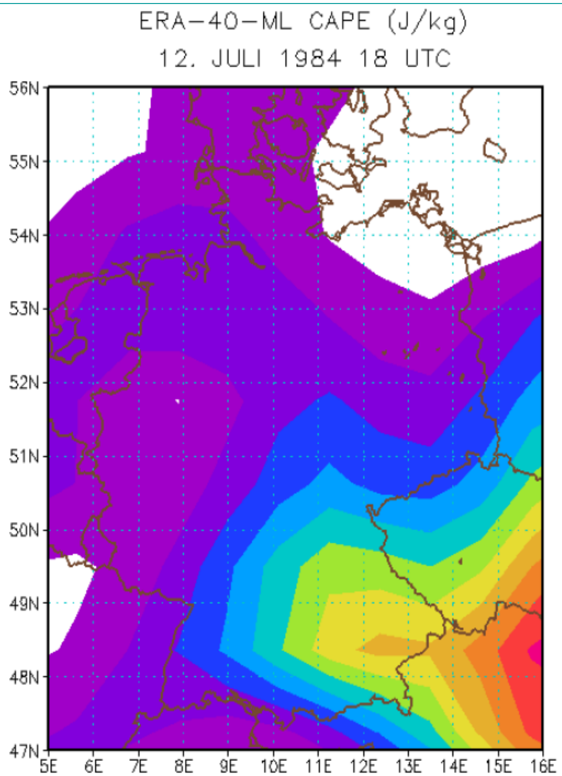
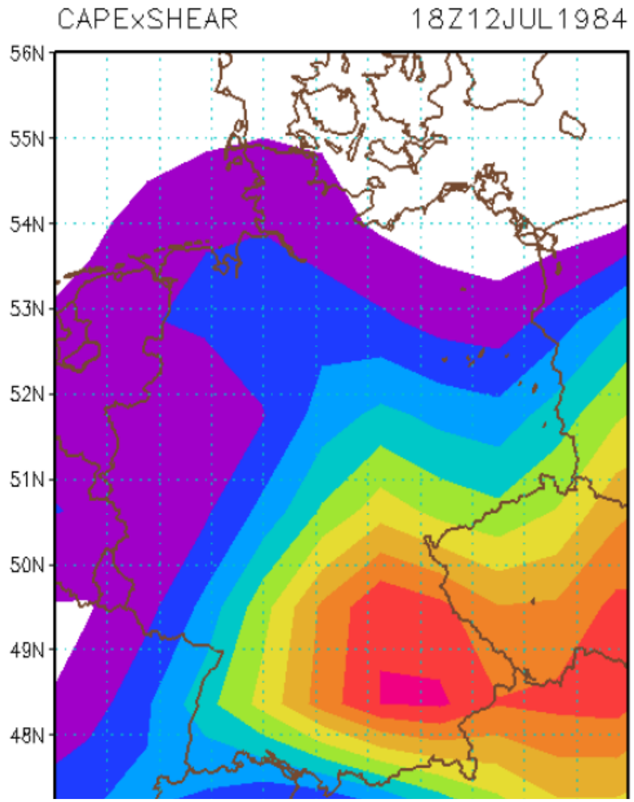
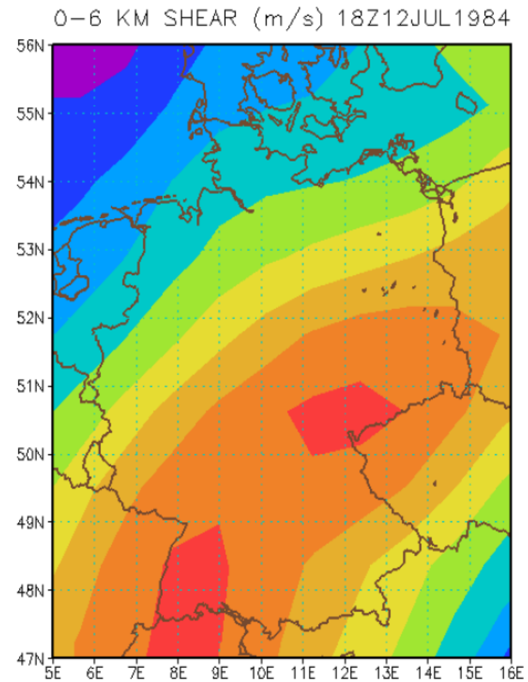


CAPE
=
Buoyancy energy

CAPE x Shear
=
Extreme event potential

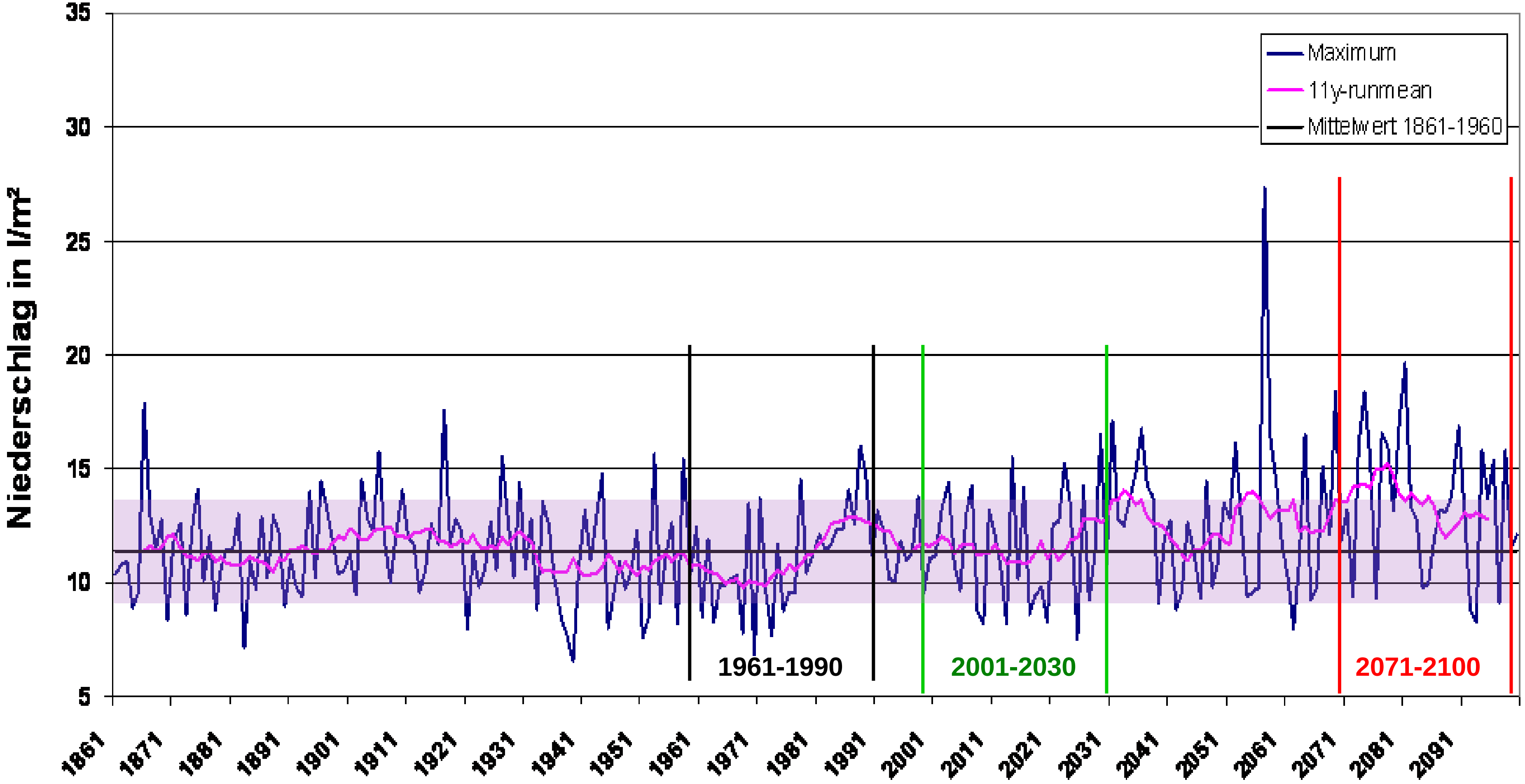




Shear
=
Forcing for organised intense thunderstorms

Develop complex parameters based on coarse grid atmospheric data, and compare with event occurrence

Evaluate model output and perform spatial/temporal downscaling



Maximum annual convective daily precipitation, Munich region (ECHAM5-OM1, A1B scenario)

Conclusions I

- Changes in severe weather occurrences are difficult to detect in observations:

  Main reasons:

  - extreme events are rare – effect on statistical significance
  - climate variability

  Consequence

  - need to collect more historical data, new data
  - estimating changing probability for local extremes from larger scales

Conclusions II

- Climate Change effects on extreme events are found in GHG simulations

- Confidence in model results must be gained from

  - agreement between ensembles of simulations

  - estimating risk for/magnitude of convective events from large scale parameters

  - statistical and dynamical downscaling

- Perform focused model evaluations, for example for air safety issues

Thank you for your attention!