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Variability in Extreme Events: How does Climate Change influence winter storms?

GC Leckebusch

Outline

1. **Motivation**: Focus on mid-latitude Cyclones (Winter Storms)
2. **The Climate System and Assessing Extremes**

   Natural Variability in the climate system; Storms on different time scales; Synoptic Scale: dynamical processes & growth factors
3. **Anthropogenic Climate Change and Extreme Storms**
   Growth factors, inter-annual variability, multi-decadal scale; ACC scale
4. **Uncertainty of Extremes**
   Discussion of sources of uncertainty; some quantification
5. **Summary / Take Home Message**

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1. Motivation: Open Questions for ETCs

Severe Storm series and flooding in the UK Winter 2013/14:

Severe events, e.g. on 27.10.13, 3.1.14, 8.2., 12.2., 14/15.2.

Event-ID	Event Name	Event Start Date	Peril	Captured Markets	Original Industry Loss*
20131223-1	**Dirk**	23 Dec 2013	Windstorm	FRA, GBR	**EUR 275 m** (first report, 03 Feb 14)
20131205-1	**Xaver**	05 Dec 2013	Windstorm	DEU, DNK, GBR, NLD, NOR, SWE	**EUR 727 m** (second report, 05 Mar 14)
20131027-1	**Christian**	27 Oct 2013	Windstorm	BEL, DEU, DNK, GBR, NLD, SWE	**EUR 1'068 m** (second report, 27 Jan 14)

Source: PERILS AG

1. Motivation: Open Questions for ETCs

Open Questions from Society and Industry

Question 1:

What drives the seasonal to decadal **variability** of events at the **extreme tail** of the severity distribution?

Question 2:

What is the probability of severe losses in the near-term future?

Question 3:

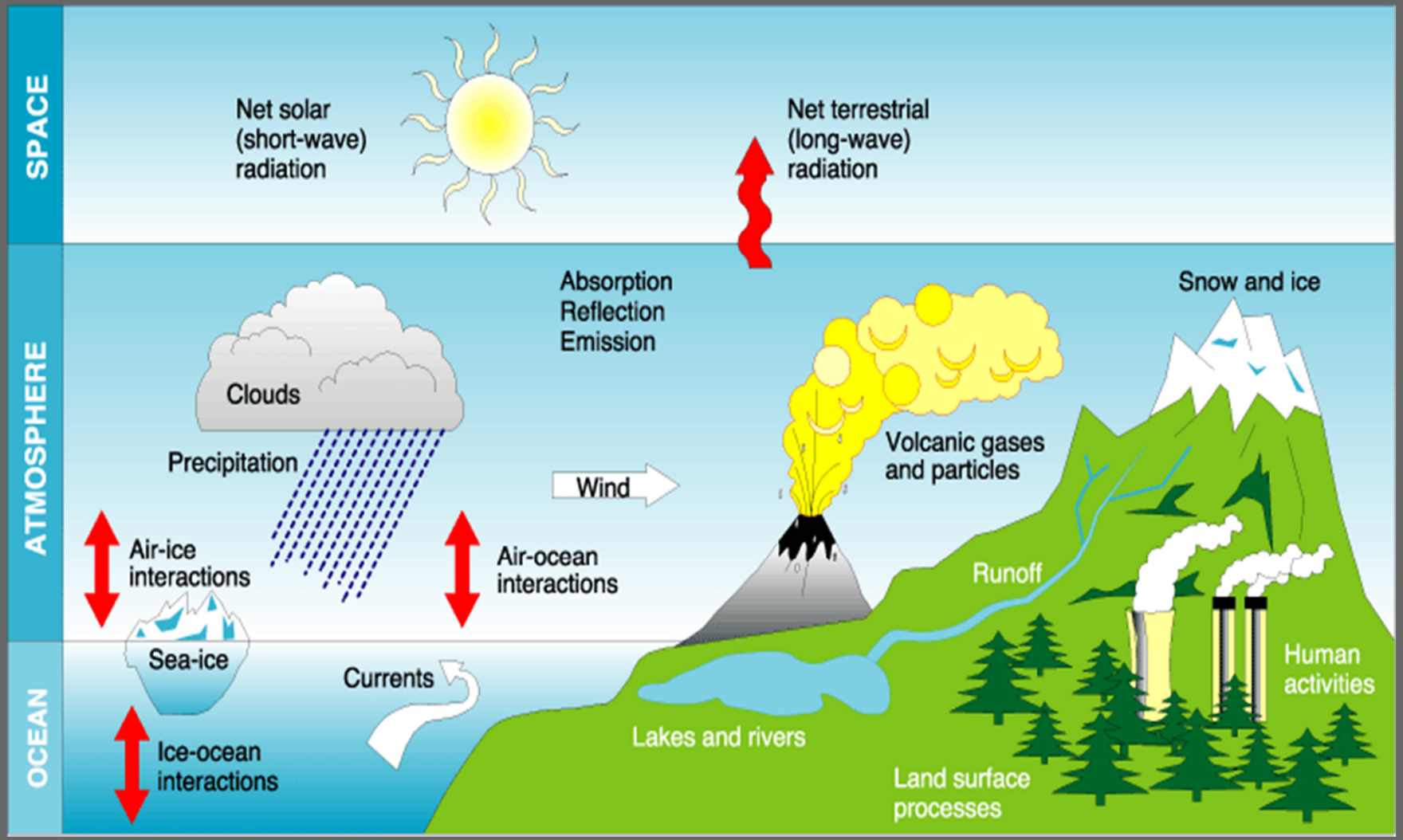
How do severe winter storms behave under ACC?

How certain are current assessments?

Part 2.1)

The climate system & natural variability

Natural greenhouse effect: +33 degrees Celsius

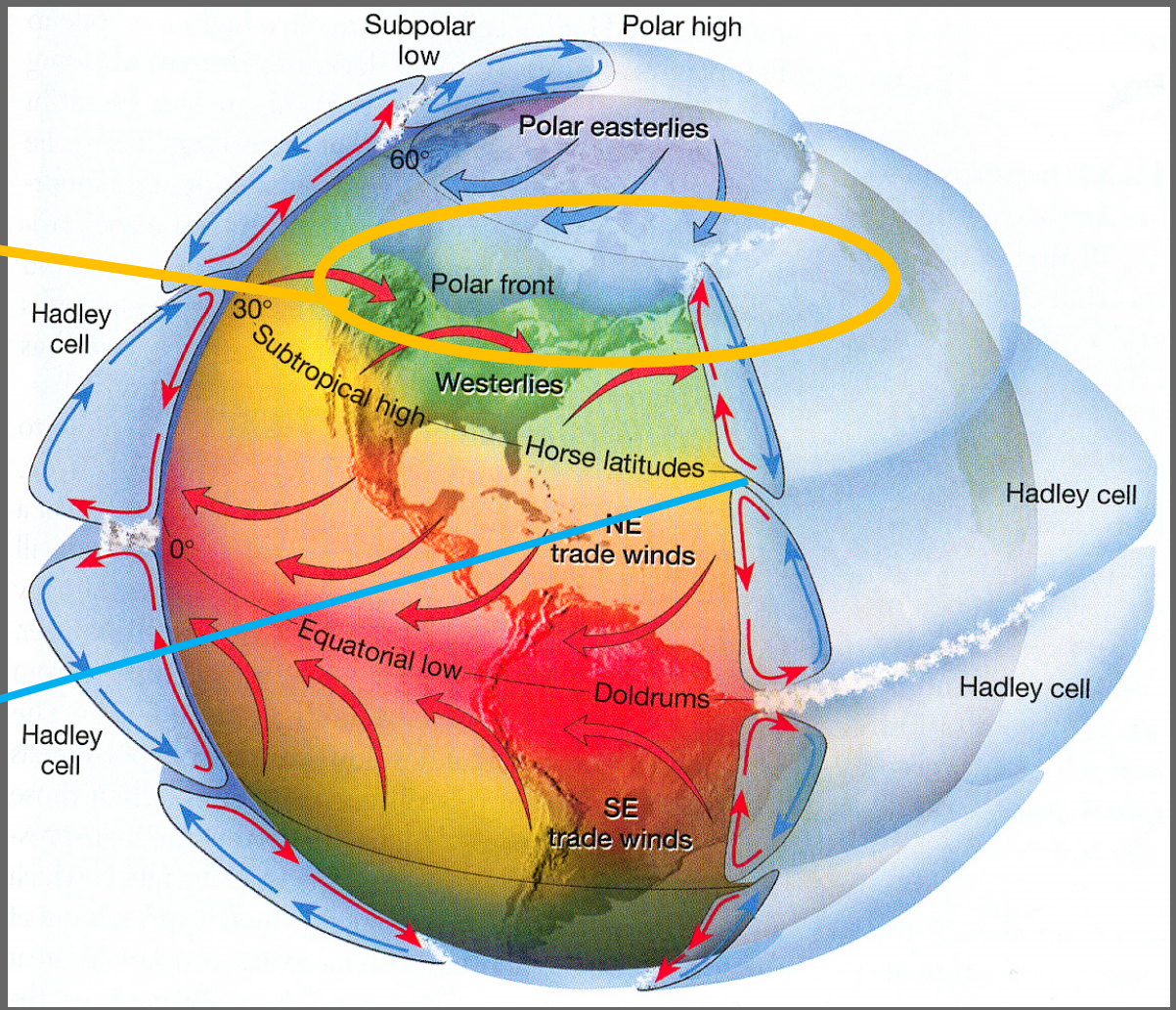


Modified from http://www.mpimet.mpg.de

General atmospheric circulation

Dominant feature of mid-latitude weather: Polar Front

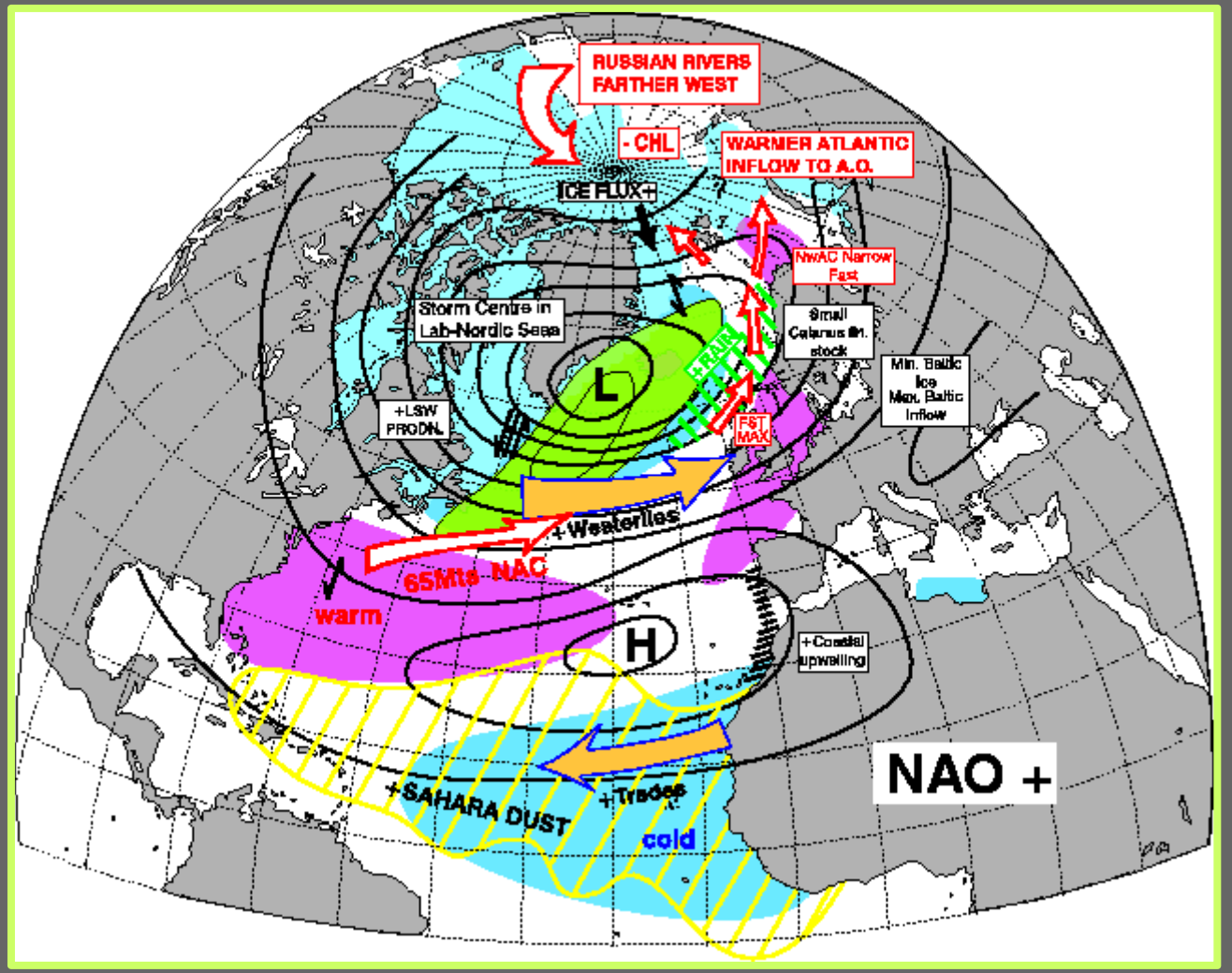
Subtropical Jet



(from Tarbuck and Lutgens, 2003)

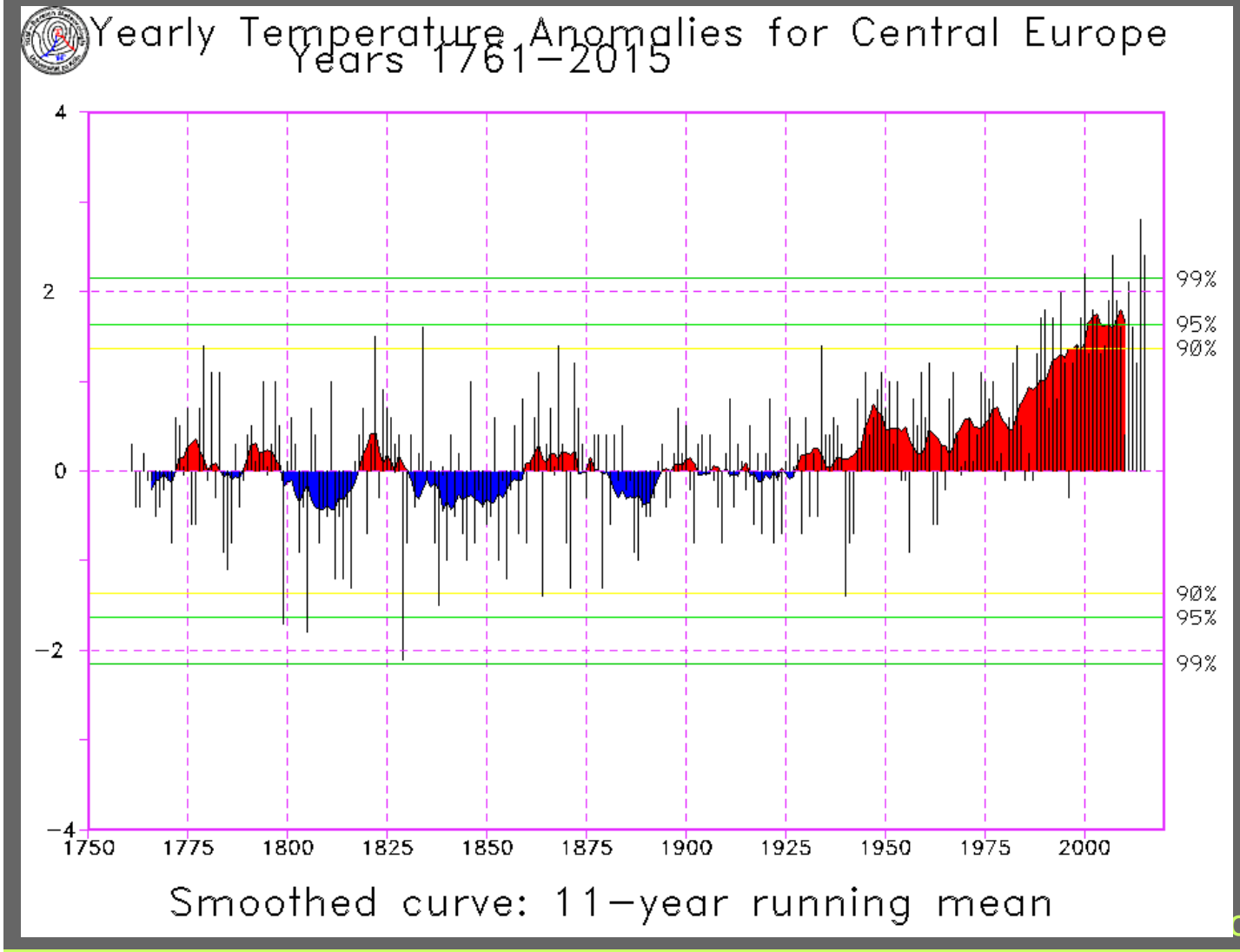
Positive Phase of the North-Atlantic Oscillation:

Example of an internal variability mode, acting on different time scales



Source: University of Exeter

Annual Temperature anomaly for Central-Europe since 1761

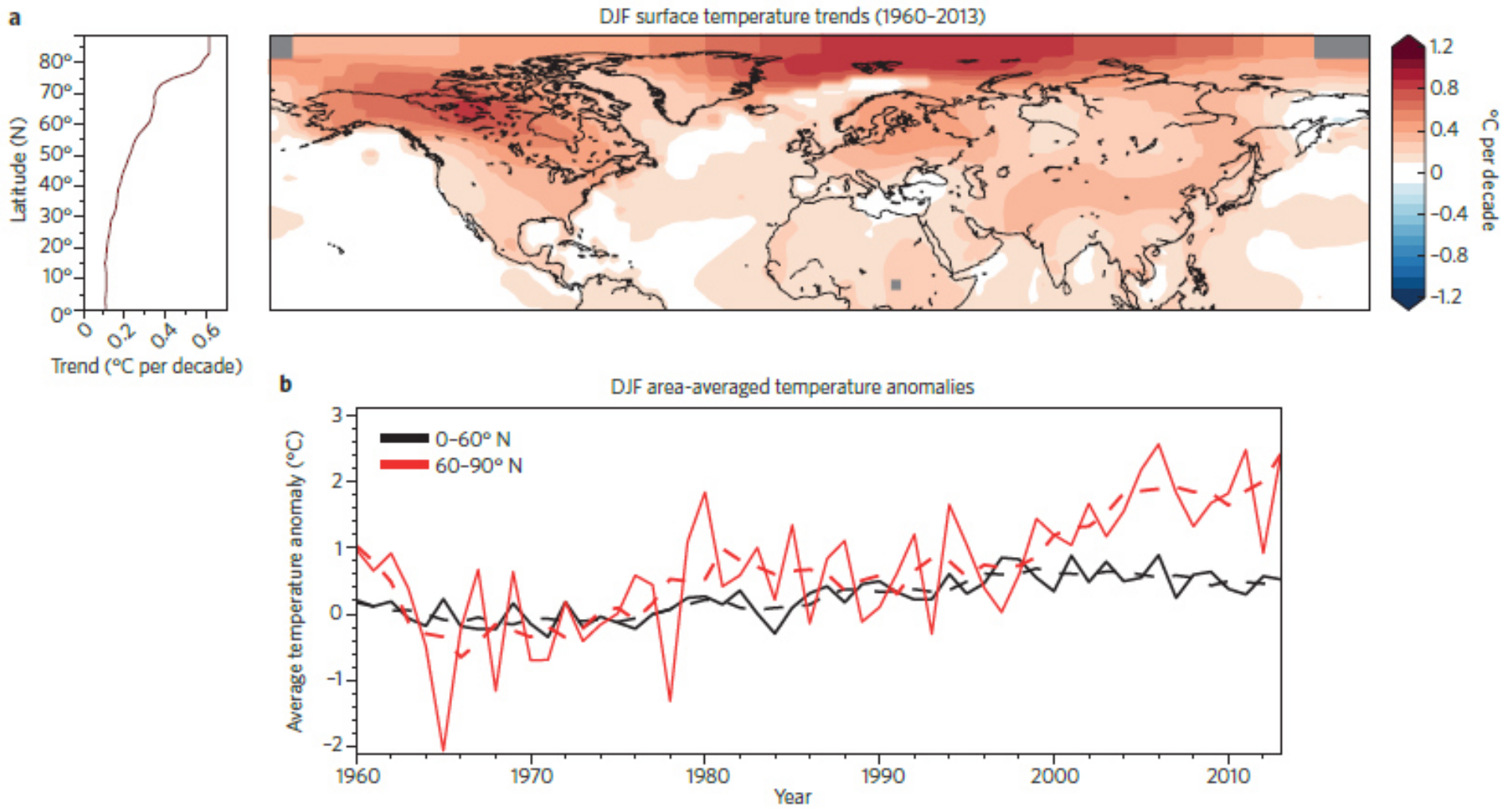


Stations:

De Bilt
Potsdam
Basel
Vienna

Source: Universität zu Köln

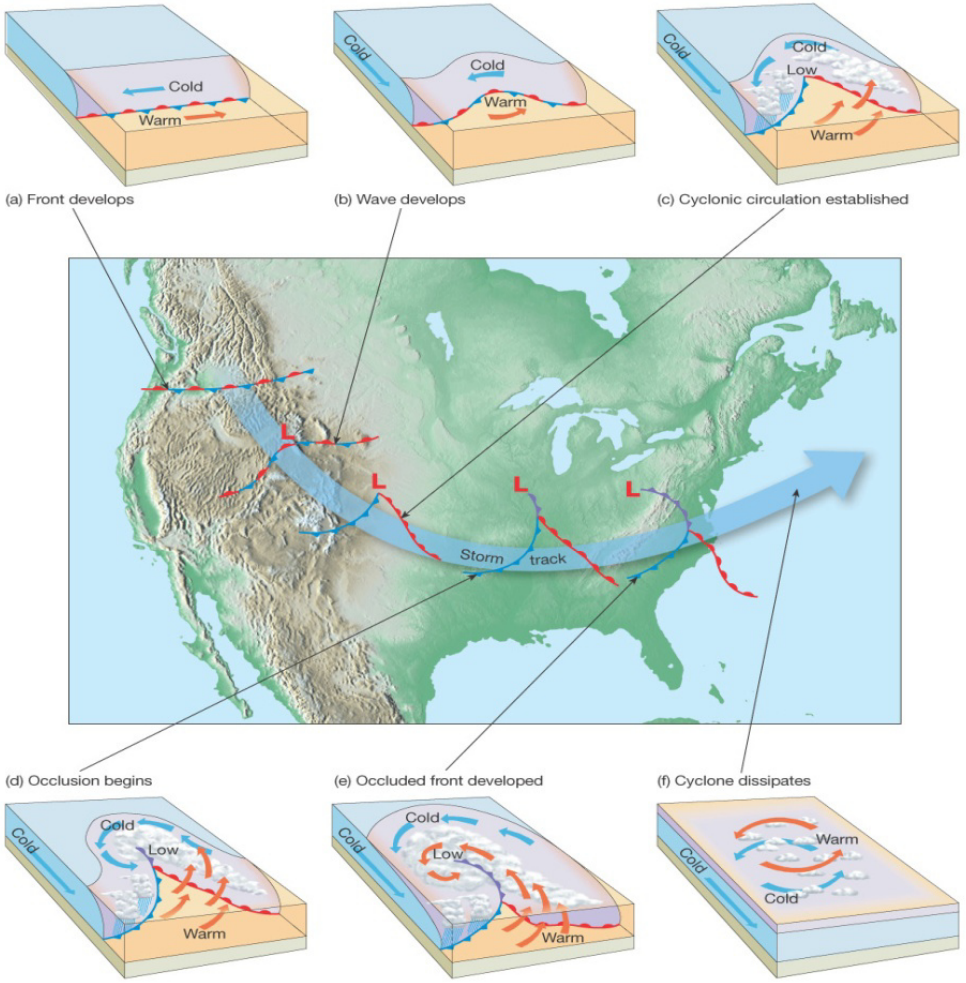
Observed Surface Temperature Trends since 1960:



Cohen et al. (2014)

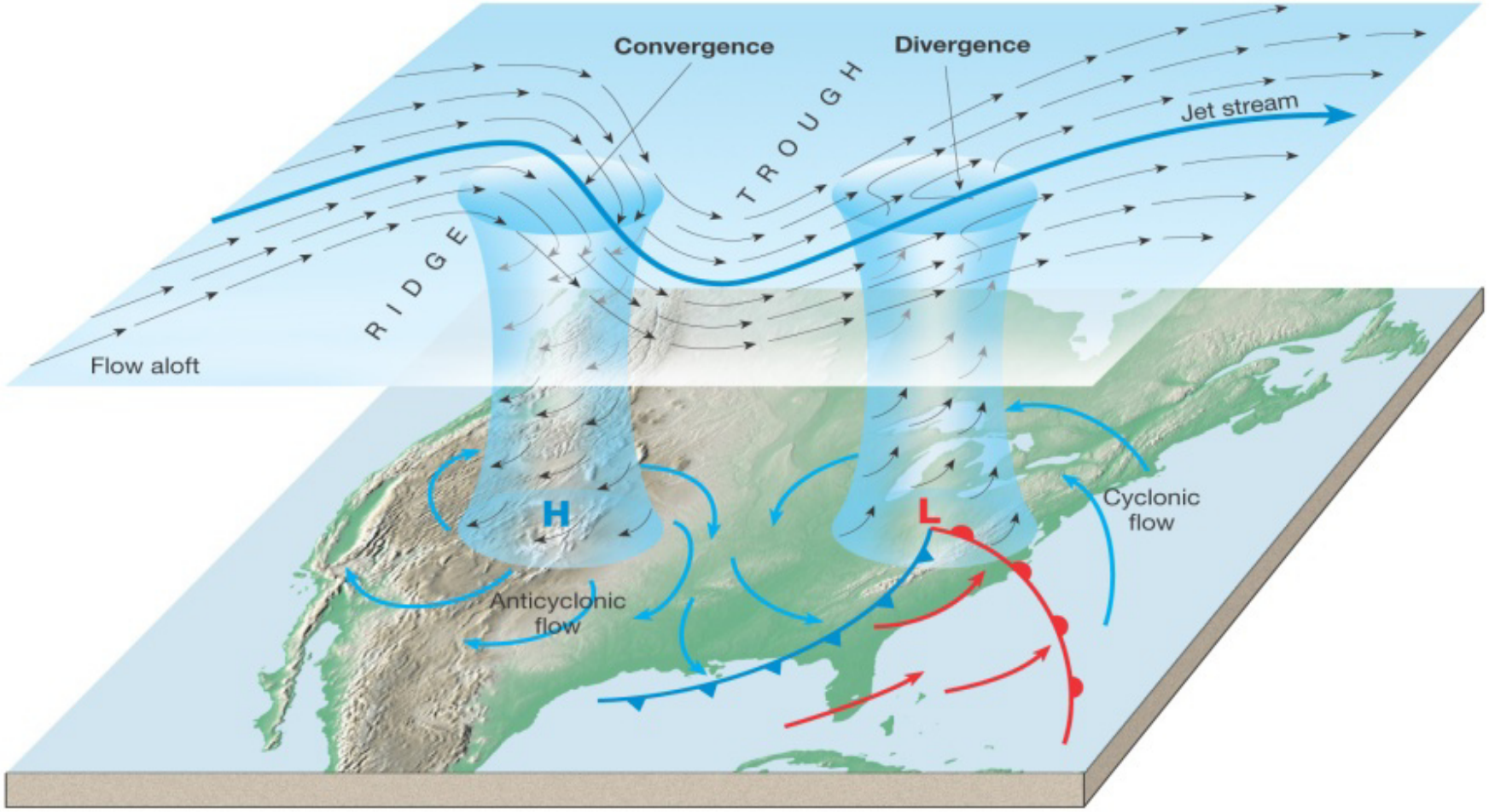
2.2 Assessing Extreme Cyclones

ETC Life Cycle



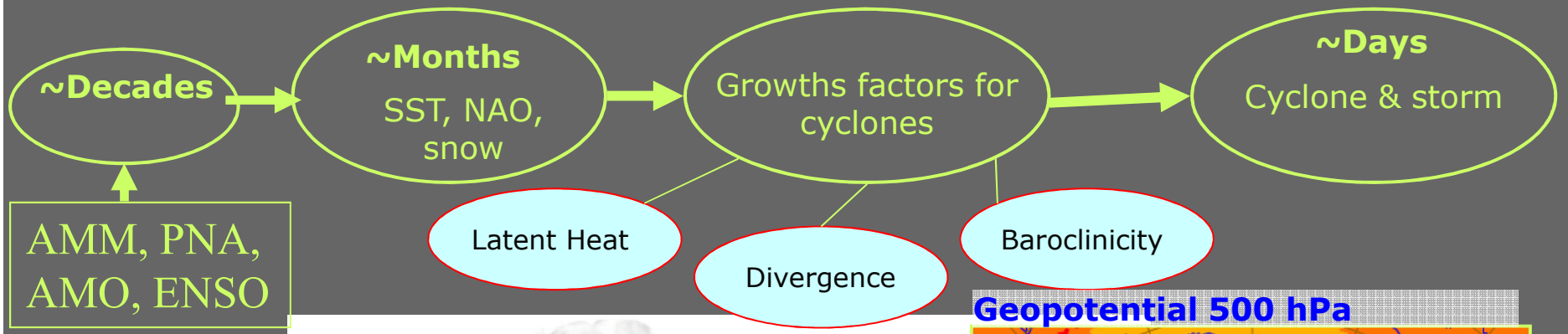
Graphics: Lutgens & Tarbuck

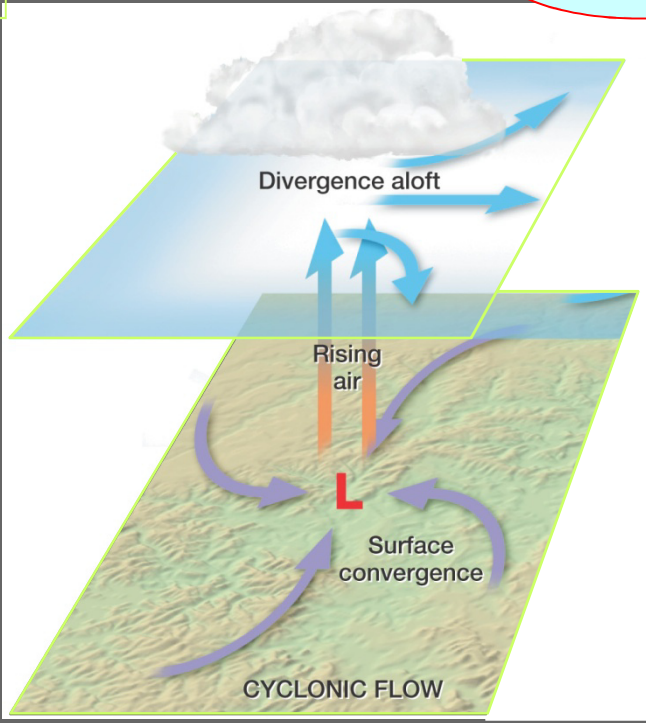
Dominating role of upper troposphere waves for cyclogenesis:



Graphics: Lutgens & Tarbuck

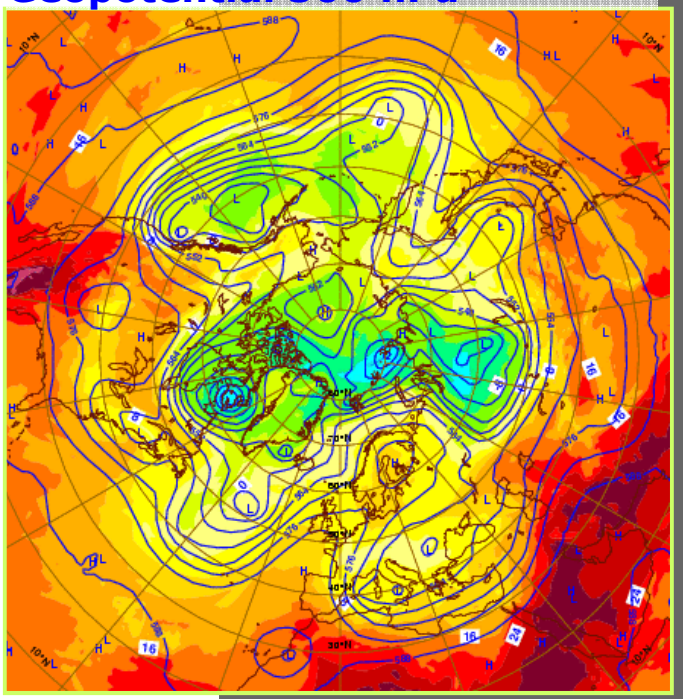
Potential Sources of Variability / Predictability





Adapted from Lutgens & Tarbuck (Eds., 2007)

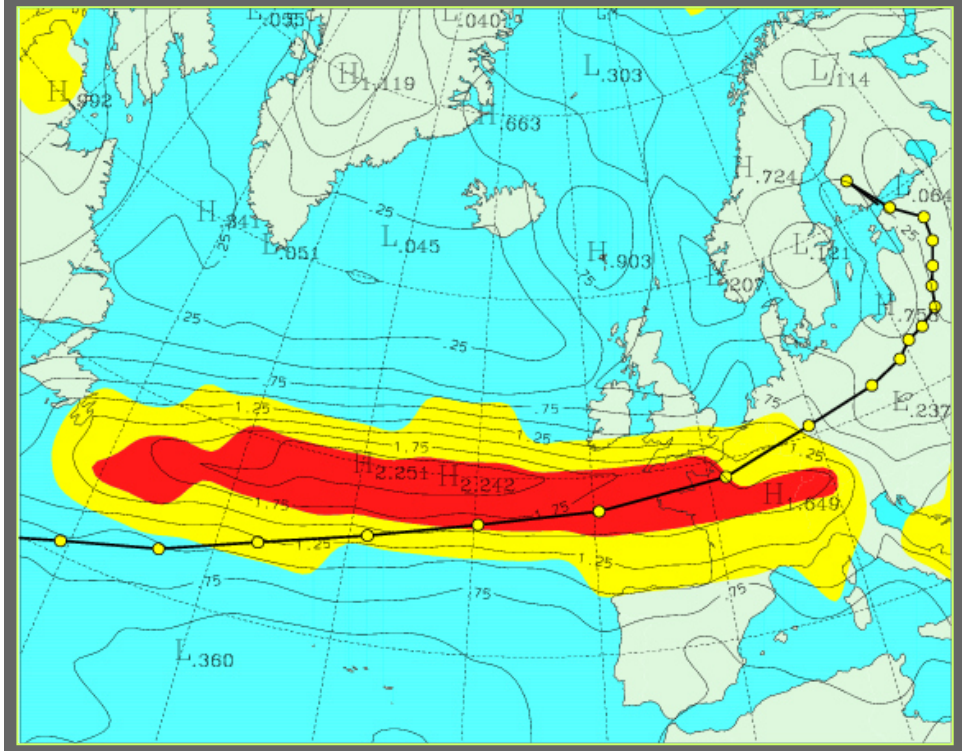
Geopotential 500 hPa



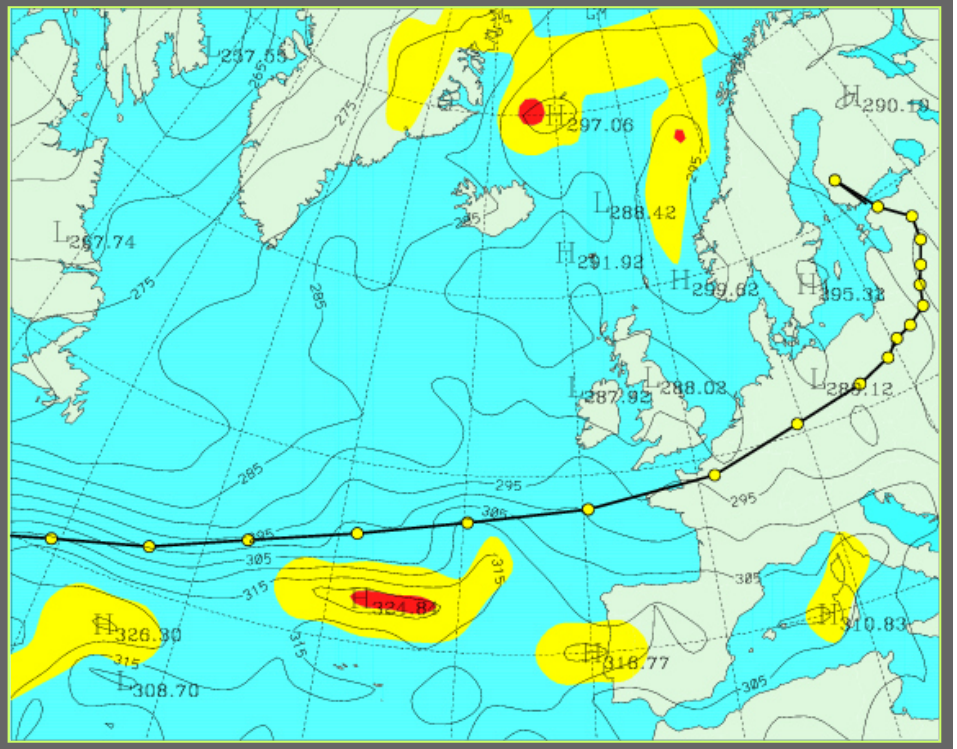
ECMWF Forecast for 20.05.2010 00 UTC

2. Synoptic Scale – Growth Factors
Lothar 26.12.1999

Baroclinic Instability: 24. - 26.12.1999

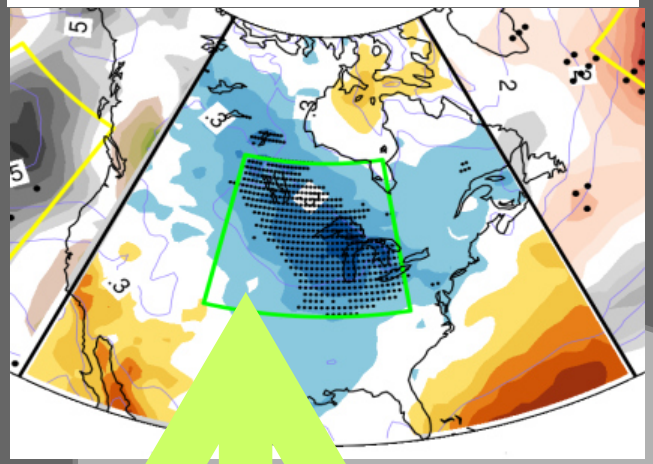


Latent Heat content Θ_e , 25.12.1999, 18 UTC



Coloured: Exceedance of the local 95th, 99th percentile

NA, Surface Temperature

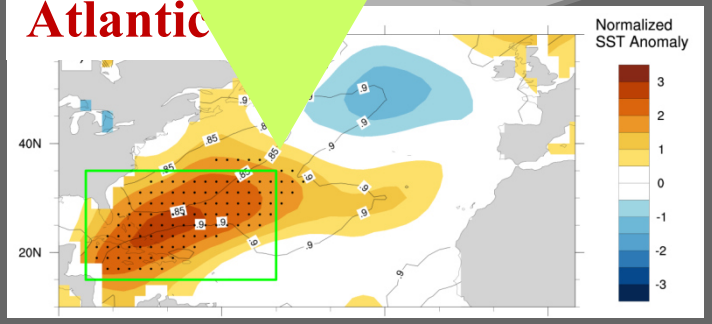


Explanatory factor for increased storm frequency in Winter 2013/14: Meridional temperature gradient

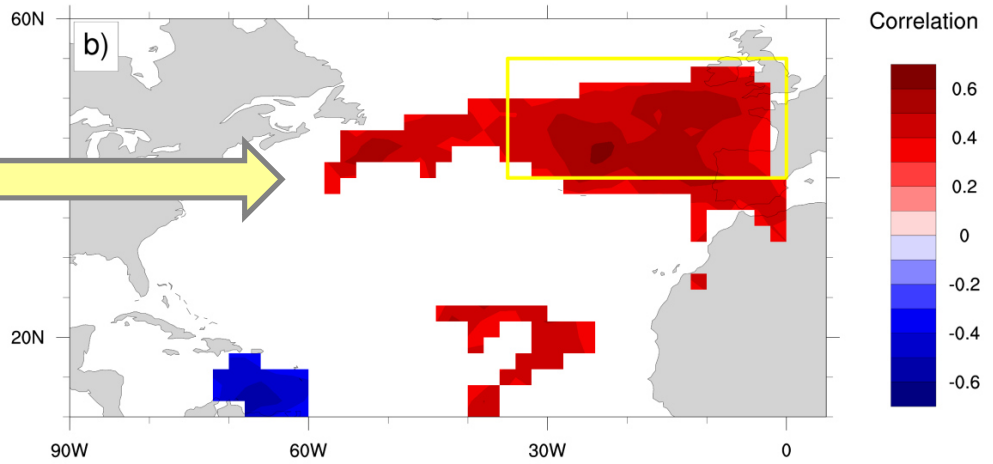
no correlation

Temp-gradient Index

Atlantic



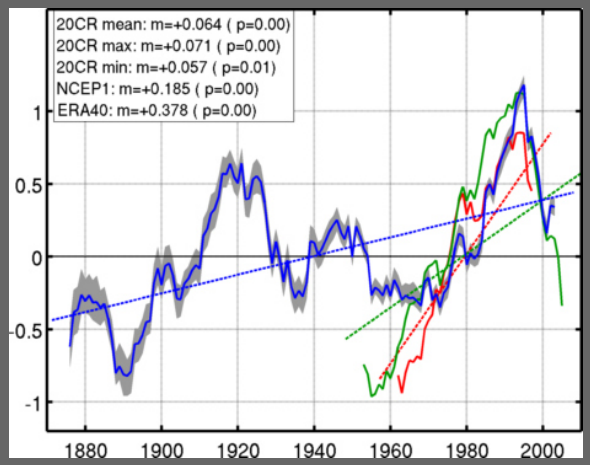
Correlation:
Meridional T-gradient index vs. wind storm frequency
(p>0.05 omitted)



Wild, Befort & Leckebusch, 2015 (BAMS)

20th Cen. Reanalyses comparison: NCEP vs. ECMWF

Decadal Variability shows large differences over certain regions

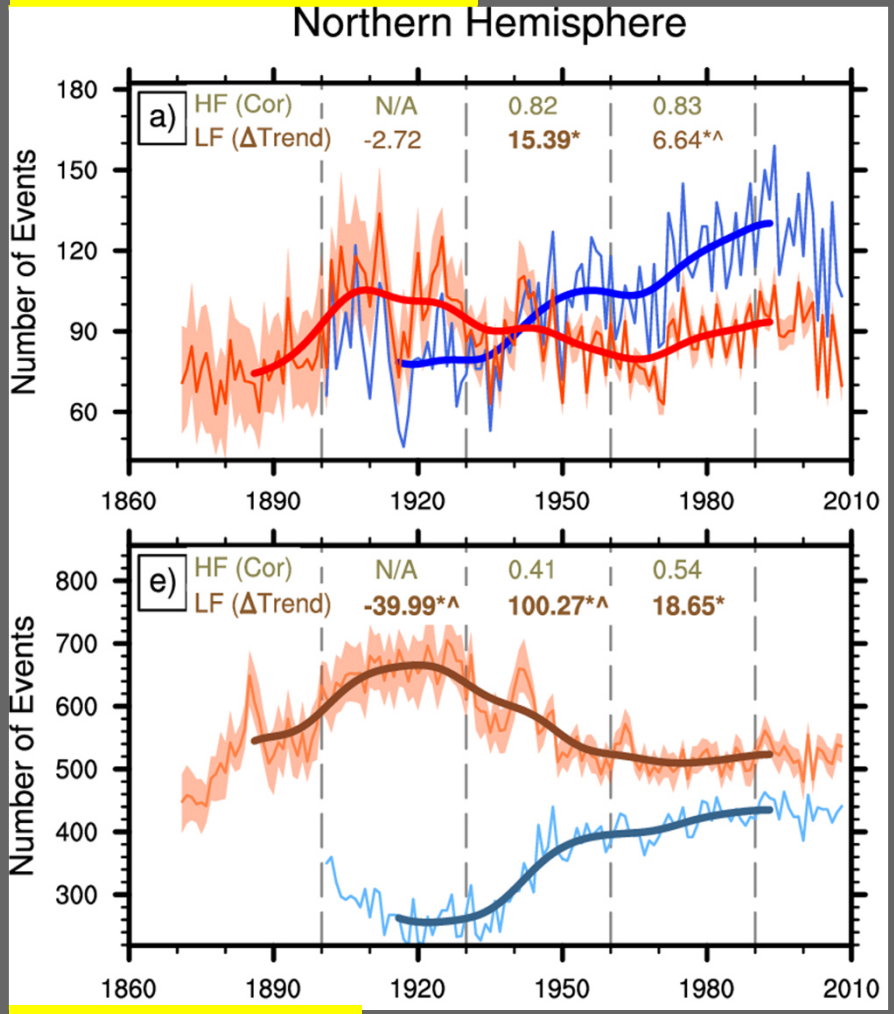


Donat,.., Leckebusch et al.. 2011 (GRL)

Befort,.., Leckebusch et al., 2016 (Atm. Sc. Let.), under review

Strong Cyclones

Blau: ECMWF



Windstorms

Rot: NCEP

3. ACC and Extreme Storms

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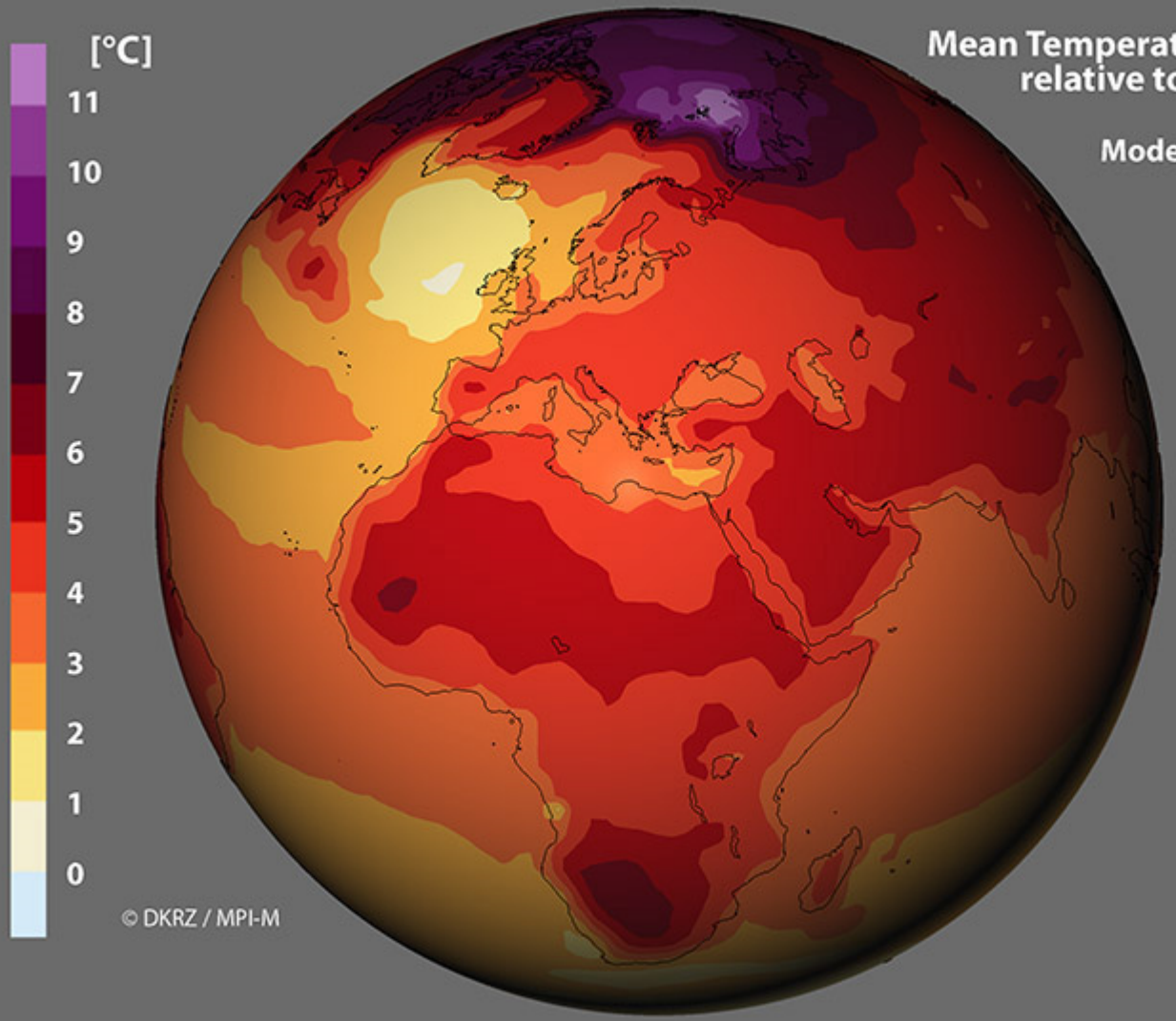
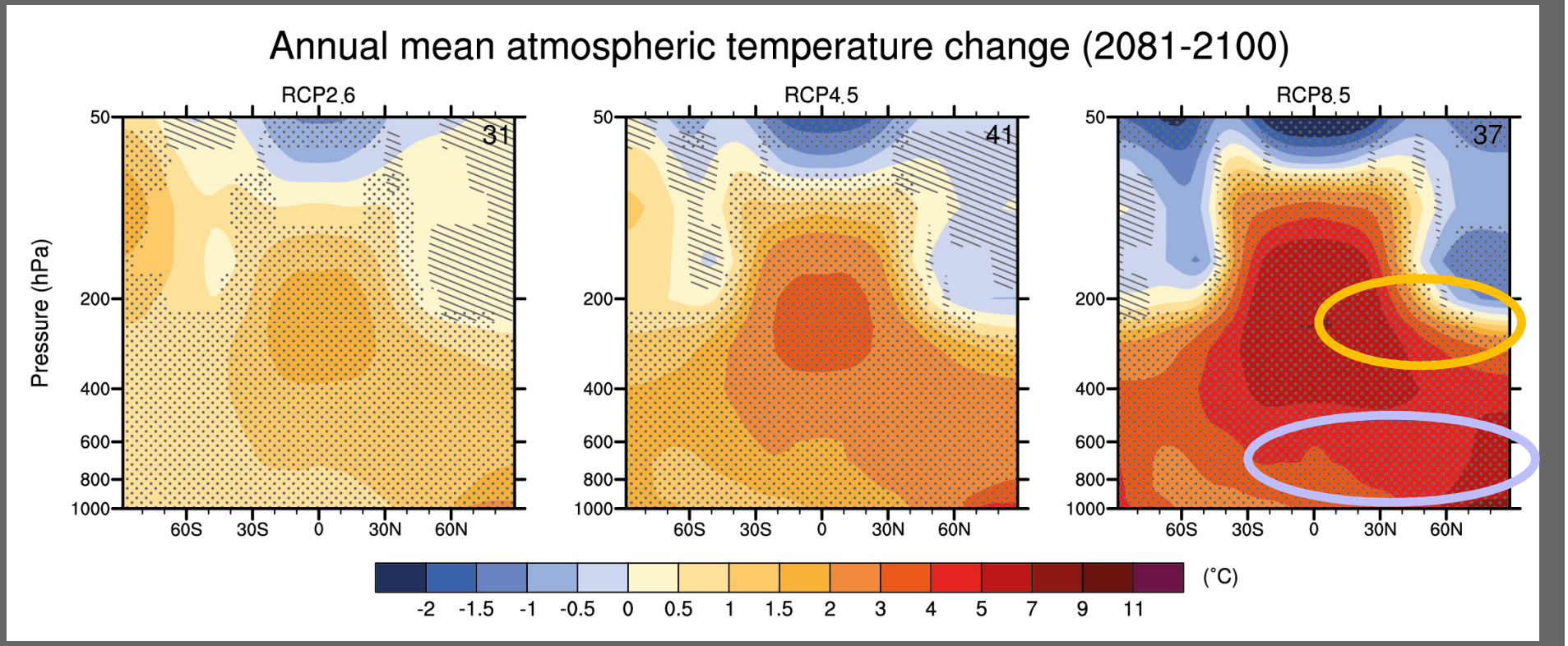
Projected late 21st century

annual mean surface **temperature** change



CMIP5 multi-model mean:

Vertical Cross Section of Temperature change

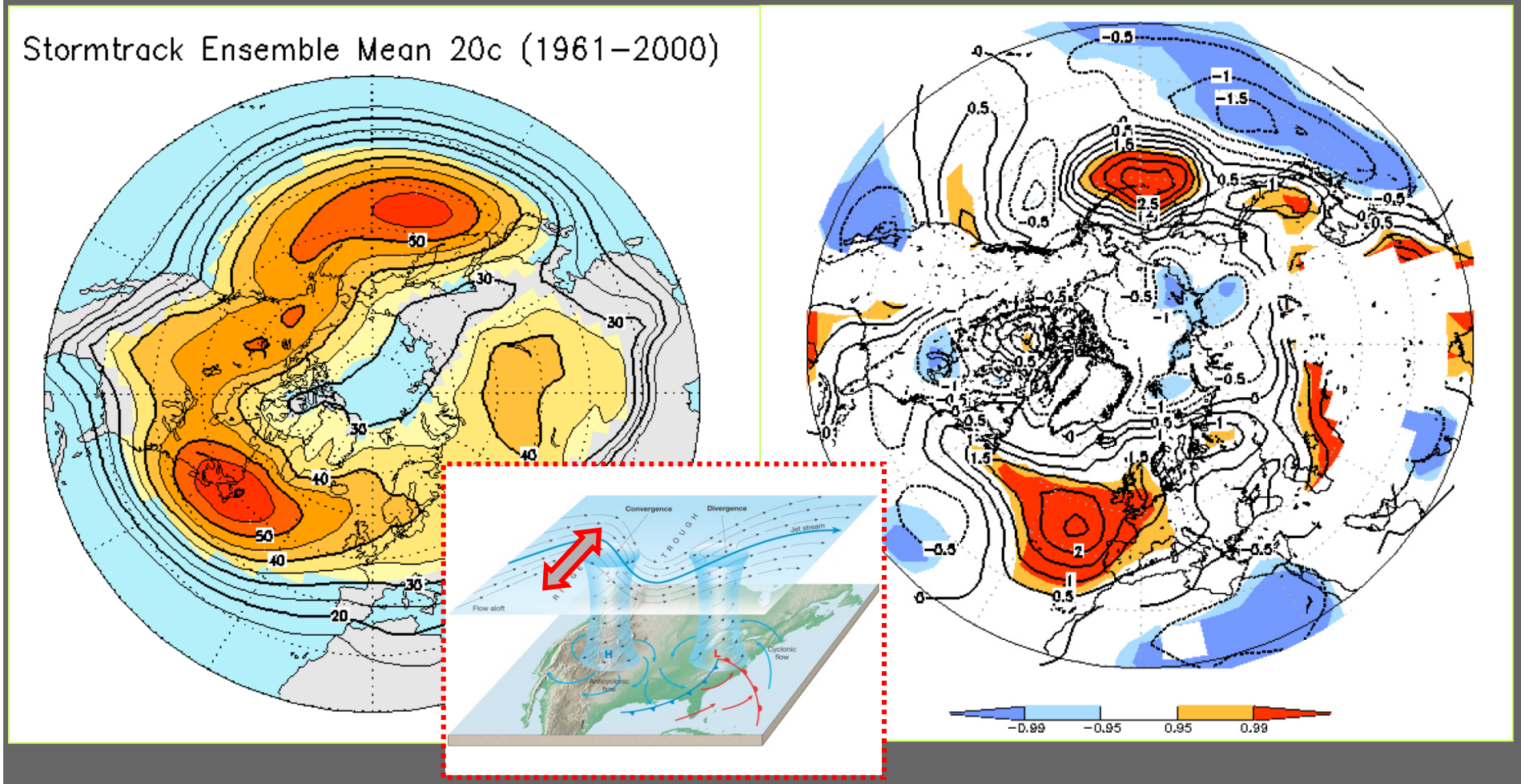


IPCC 2013, 5AR, WG1, Fig. 12.12

Projected:

➔ Different Temperature Change in upper vs. lower troposphere

1000 hPa Storm track: Climate Change Signal (SRES A1B)



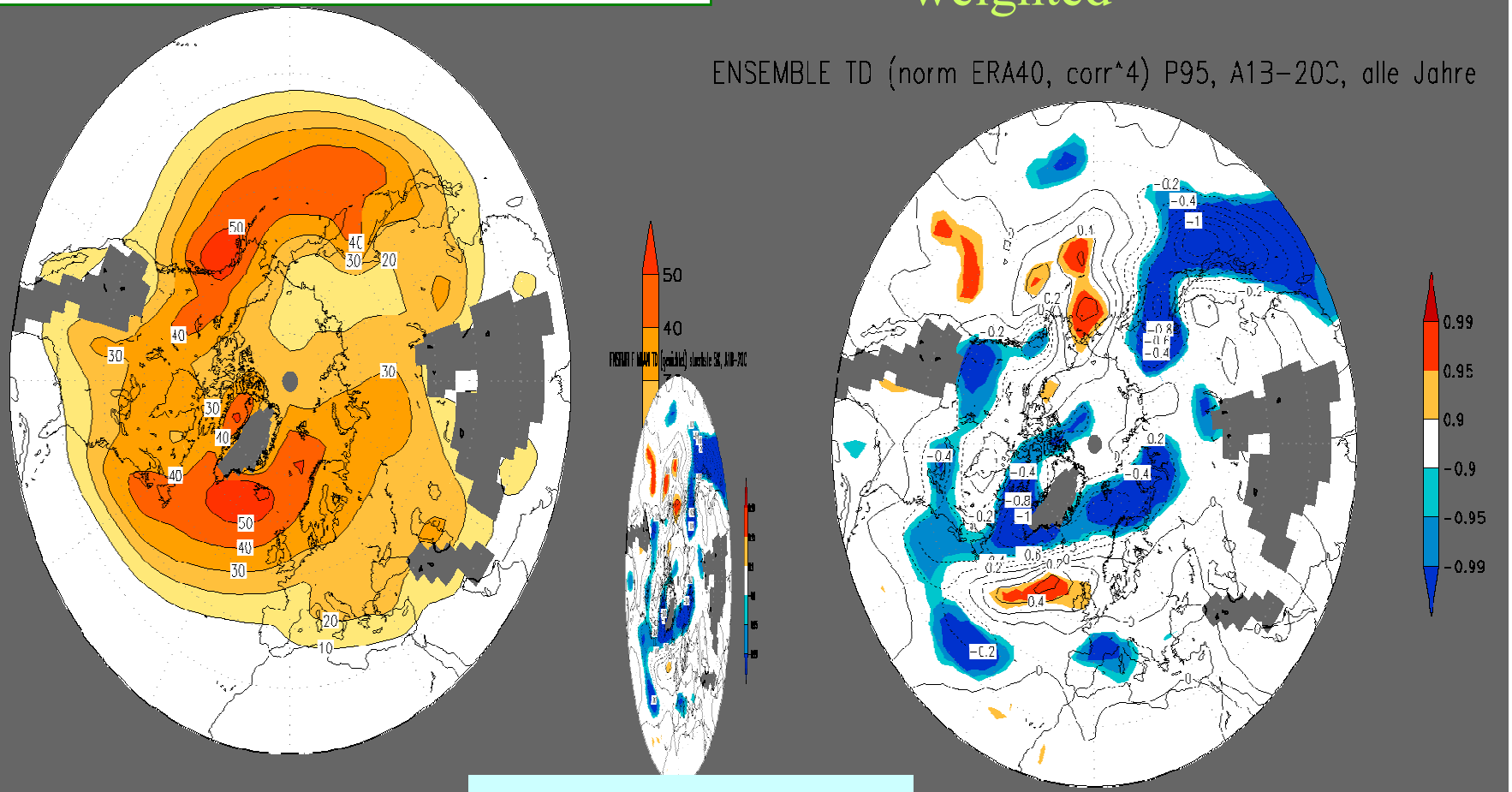
Changing Northern Hemisphere Storm Tracks in an Ensemble of IPCC Climate Change Simulations
Ulbrich, Pinto, Kupfer, Leckebusch, Spangehl, Reyers (2007), J Climate

Anthropogenic Climate Change Signal for Extreme Cyclones

(A1B Scenario 2071-2100 vs 1970-2000)

ENSEMBLE all systems

Extreme Cyclones; weighted



Leckebusch et al., 2008c

4. Uncertainties of Extremes

ACC Regional Impact assessment's main sources of uncertainty:

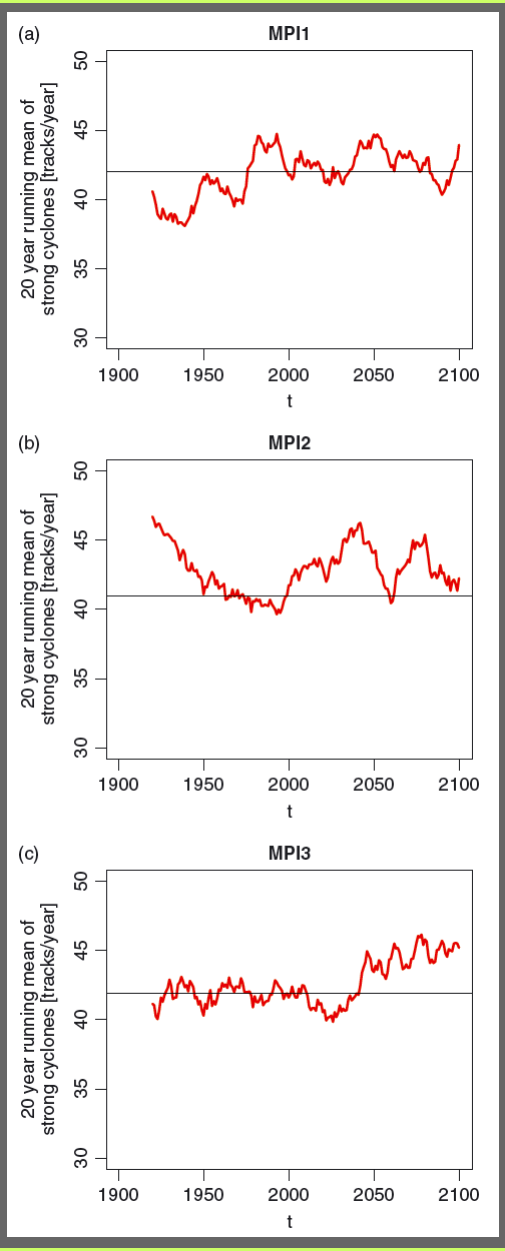
1. Uncertain future emission regulation and the subsequent emissions and concentration → **Scenario Uncertainty**
2. Uncertain response of the global climate dynamics on greenhouse gas emissions → **Model Uncertainty**
3. Initial value problem: is the present-day 30 years window representative in terms of its extreme value? → **Nat. Variability Uncertainty**
4. Uncertainty in downscaling → **Downscaling Uncertainty**
5. Uncertainty in statistical relation from the meteorological phenomenon to the economic loss → **Impact model Uncertainty**
6. Uncertainty in estimate of e.g. Generalized Pareto distribution due to finite length of time series. → **Statistical Model Uncertainty**

Initial Value/ Natural Variability Uncertainty

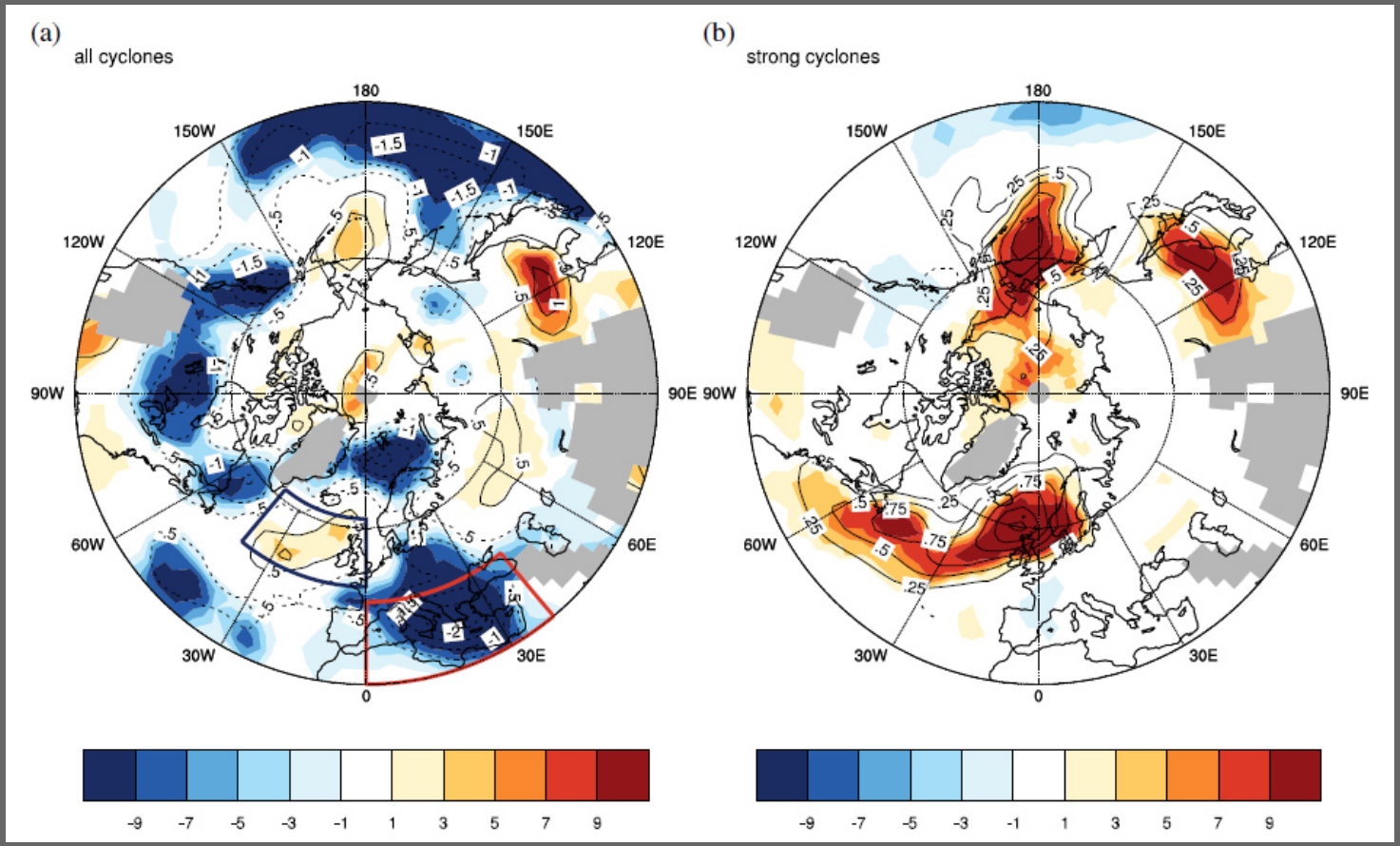
Transient development of strong SH cyclone in different realisations of the same model under identical forcing

➔ **Assumed solution**:
Investigate only ensemble mean

Grieger, Leckebusch et al., 2014 (Int J Climatology)

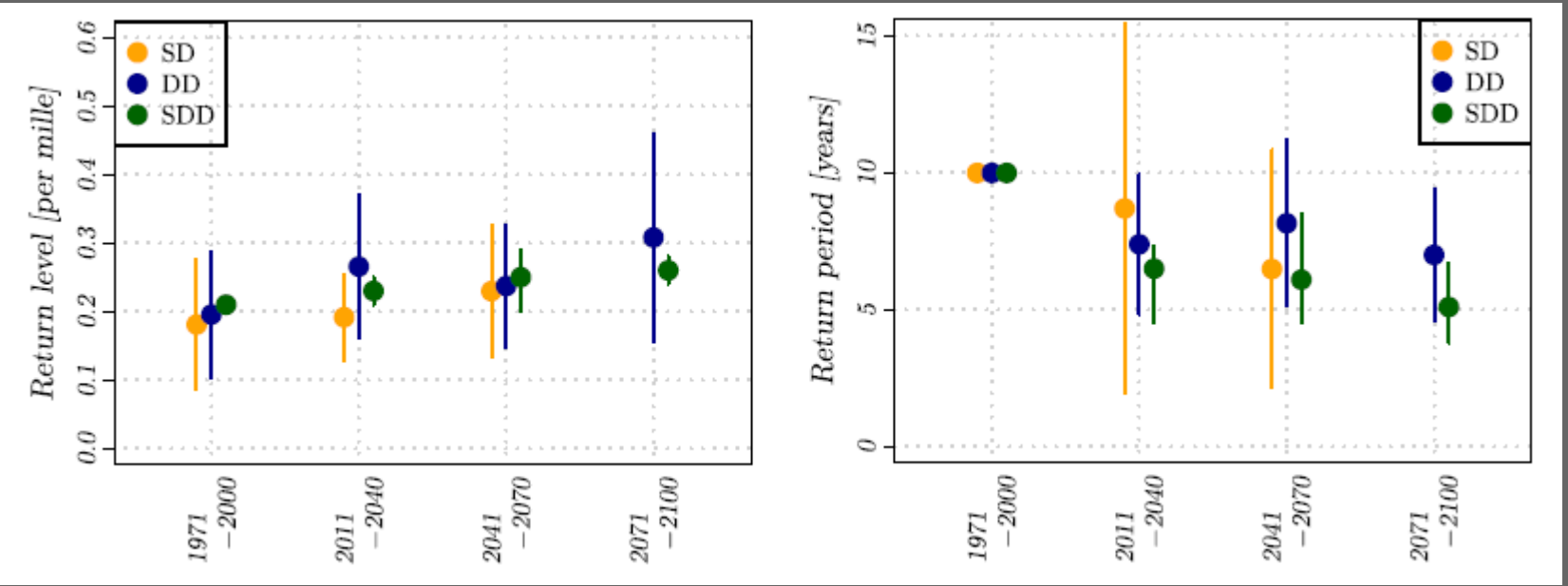


Method Uncertainty: **a) Diagnostic** ➔ Number of tracking methods showing a significant climate signal for a) all and b) strong cyclones.



Ulbrich, Leckebusch et al., 2013 (Met Z)

Method Uncertainty: b) Downscaling technique



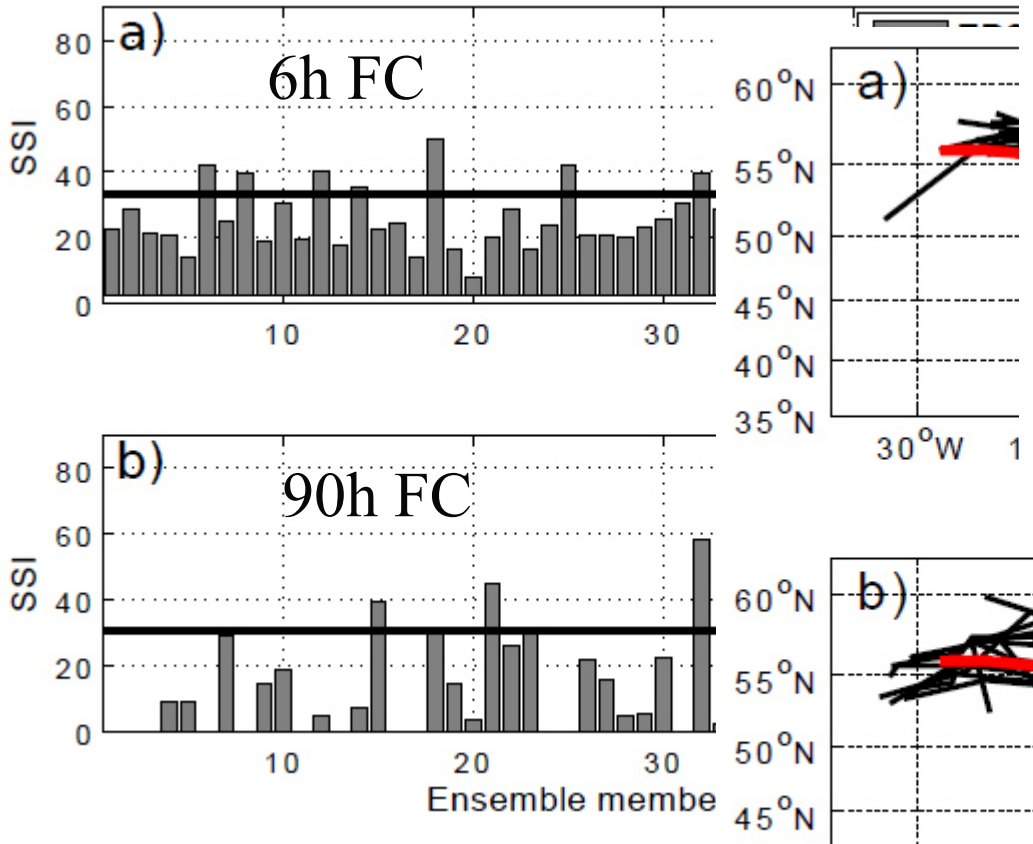
SD: Statistical Downscaling
DD: Dynamical Downscaling
SDD: Statistic-Dynamical Downscaling

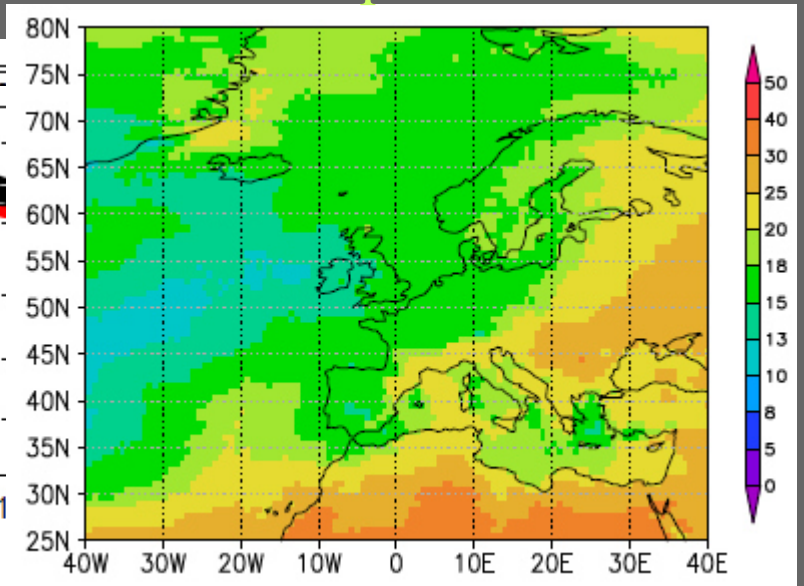
Held,.., Leckebusch et al., 2013 (Climatic Change)

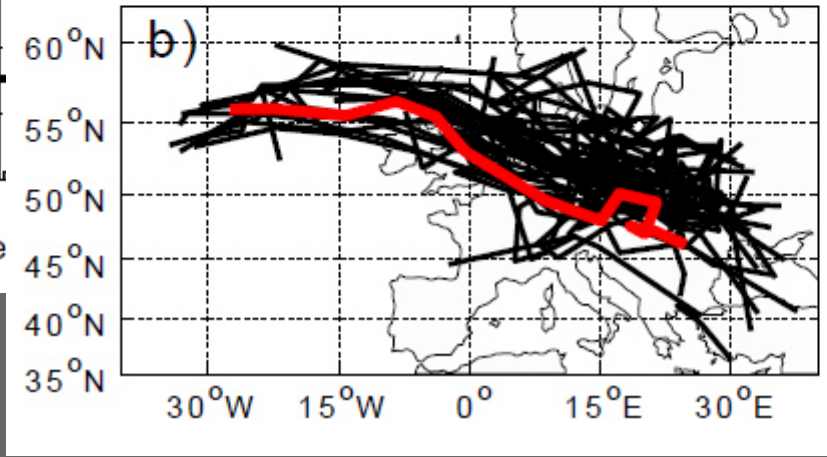
Statistical Sample Uncertainty: ECMWF EPS

Intensity of Winter Storm Daria

% of pure EPS storms



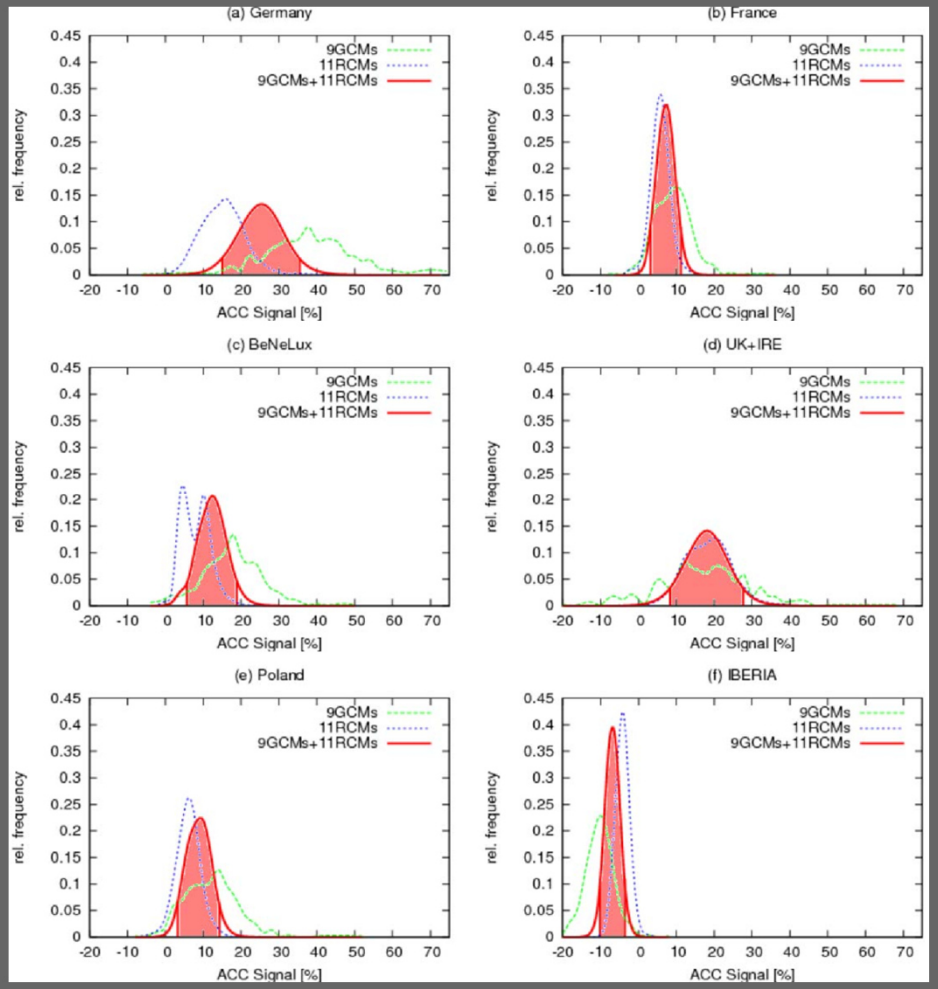




Osinski, .., Leckebusch et al., 2015 (NHESS)

Uncertainties of MME Mean perspectives (sample uncertainty)

ACC signal assessed by using MMCA method



MMCA method applied to GCM and RCM data)

MMCA: Multi-Model Combinatorics Approach

- Calculation of all possible multi-model ensemble means by using only a subset of all available simulations

- This gives information about the robustness of the **MME mean** signal for all available models

(Donat, Leckebusch et al., 2011

Summary / Take home Message:

- Extreme mid-latitude **winter storms** are am ajor threat for infrastructure and insured losses in Europe out of Natural Hazards and potentially affected by Climate Change
- The **Assessment** reveals gaps in our understanding of driving mechanisms leading to severe event frequency-intensity changes on different time scales from inter-seasonal to multi-decadal.
- Nevertheless: Good candidates for **Understanding** large-scale influences on the interannual variability of extreme cyclone occurrence
- **Uncertainties** are crucial to quantify for science and industry ➔ development of suitable policies and better risk assessment for industry


Thank you very much for your attention !!