A SEAMLESS APPROACH TO ASESSING MODEL UNCERTAINTIES IN CLIMATE PROJECTIONS OF SEVERE EUROPEAN WINDSTORMS

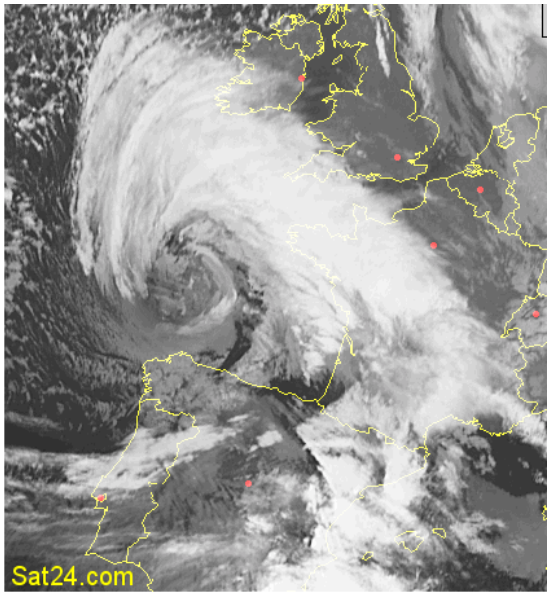
Peter Knippertz, Tomek Trzeciak, Jenny Owen

School of Earth & Environment
University of Leeds

Outline

UNIVERSITY OF LEEDS

- Risk and uncertainty
- Sources of uncertainty
- Approaches to quantify uncertainty
  – classical statistical
  – “seamless” case-study based
- Advantages and problems
- Conclusions



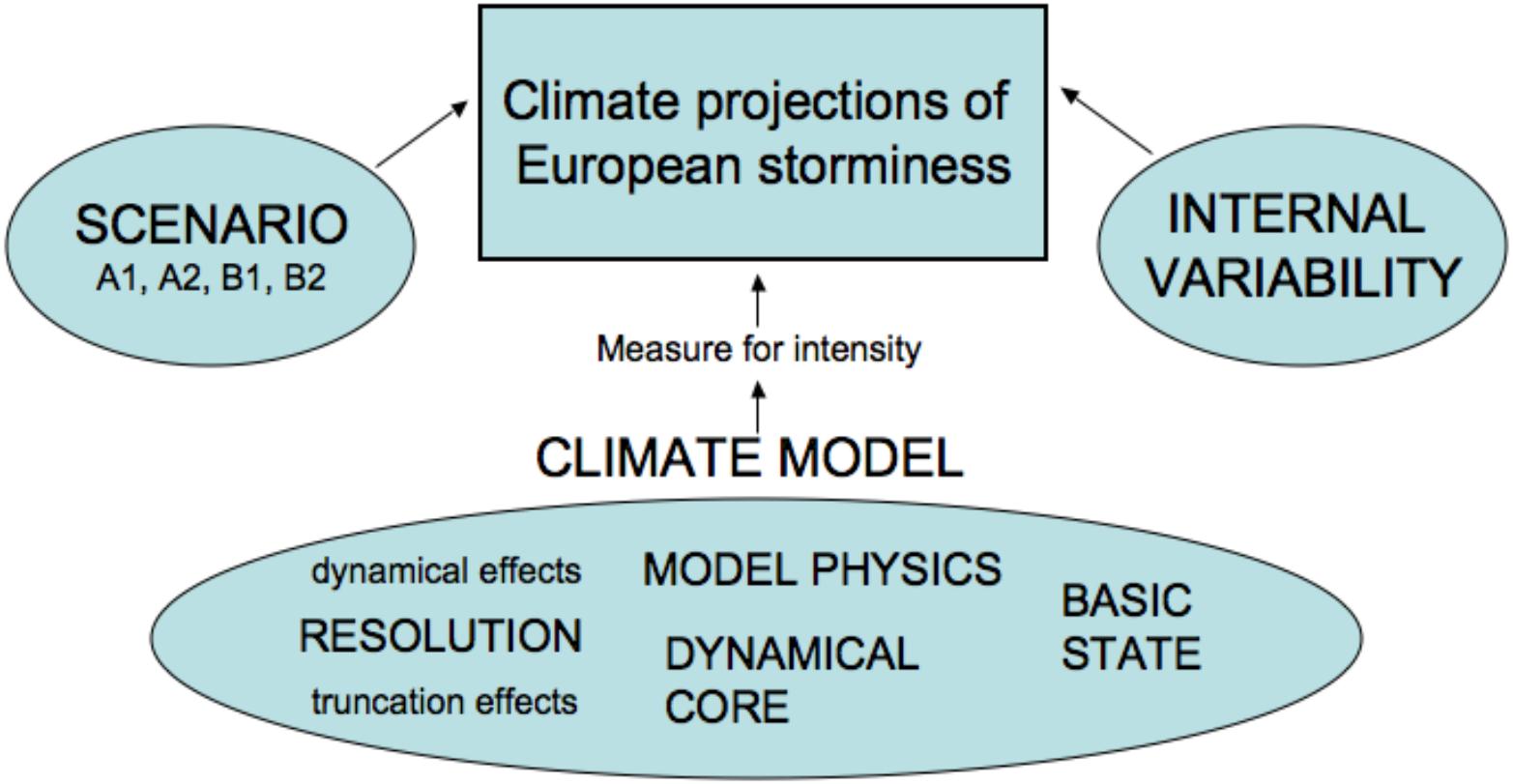
Risk and uncertainty

UNIVERSITY OF LEEDS

- Risk = frequency x consequences
- Frequency: here occurrence of a severe storm
- Consequences: e.g. insurance loss
- For past, both can be determined (typically with return periods)
- For future, seasonal prediction or climate models are needed to obtain projections for storm frequency
- These will have uncertainties!
- Quantified uncertainties can be build into insurance models.
- Unquantified uncertainties $\rightarrow$ danger of bad surprises

Sources of uncertainty

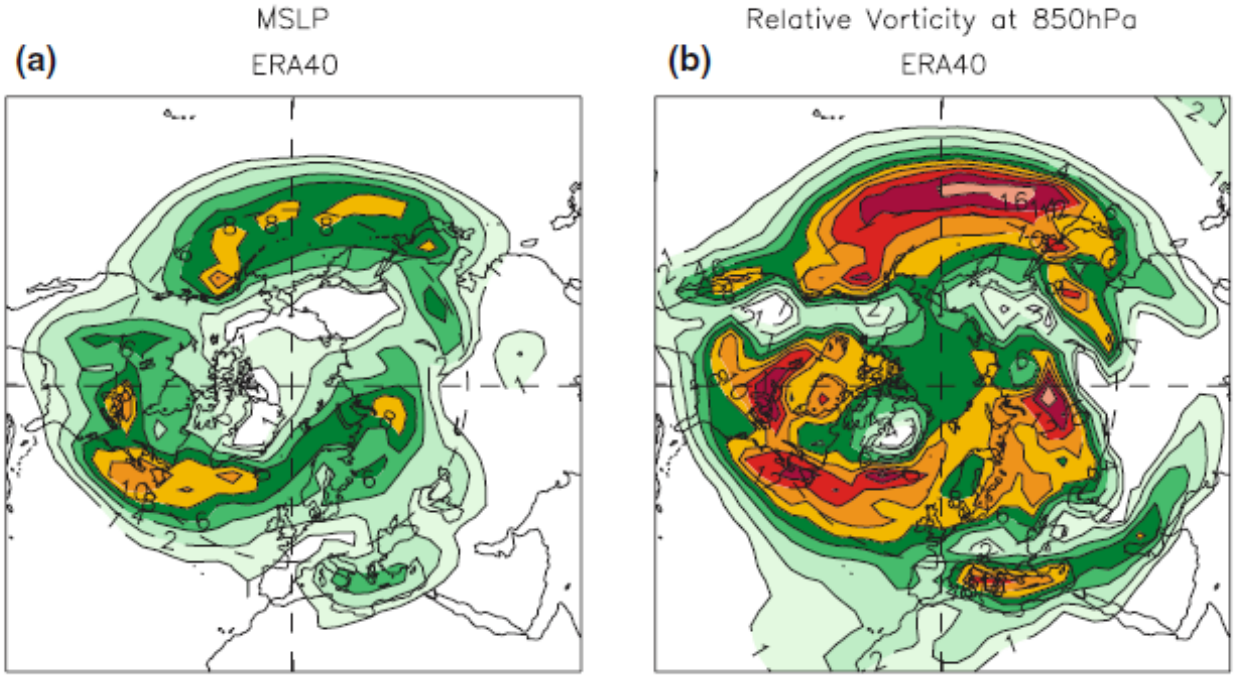
UNIVERSITY OF LEEDS



Measure of intensity

UNIVERSITY OF LEEDS

- Different studies in the past have used different metrics to measure storminess (*Ulbrich et al., TAC, 2009*).

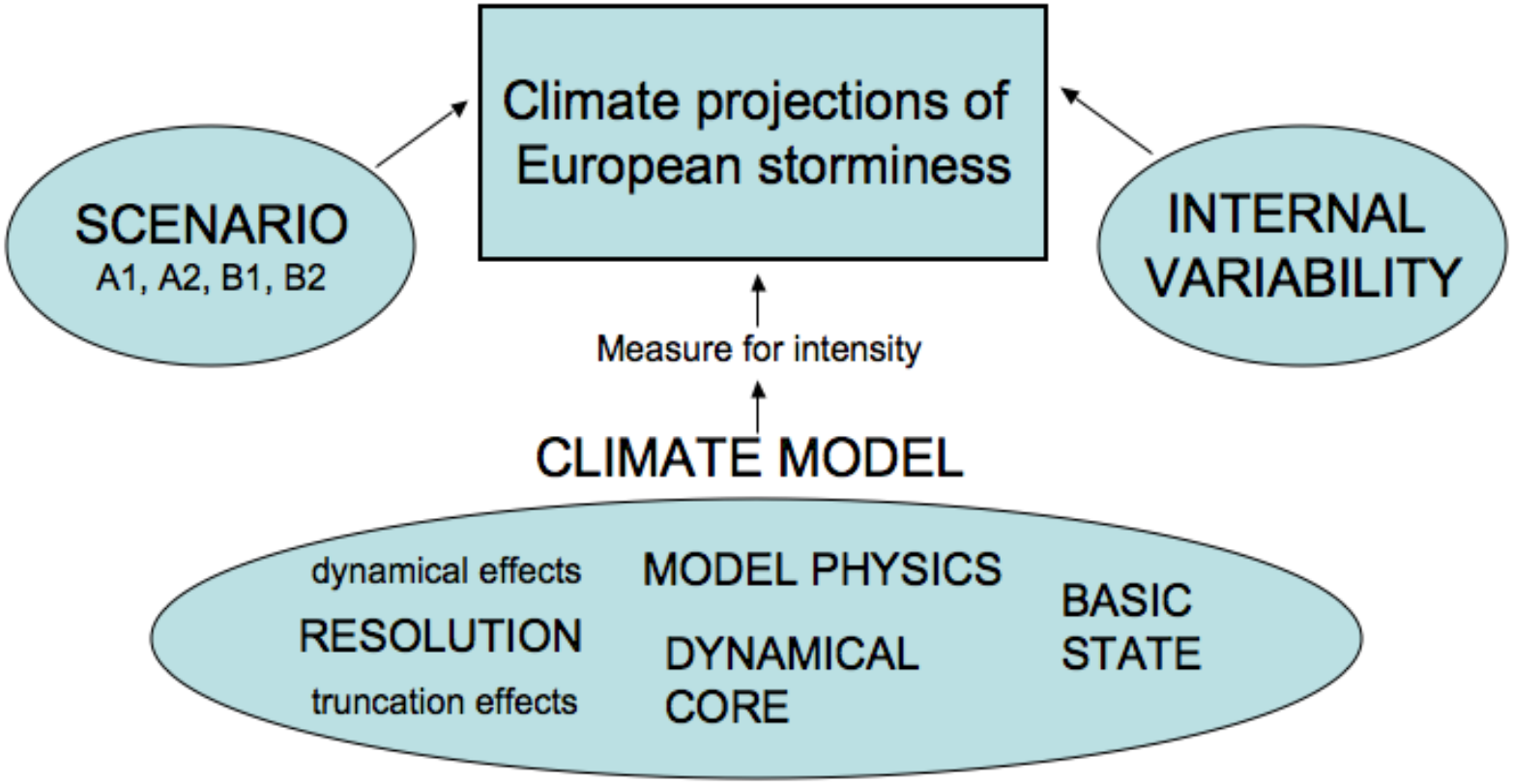


from Greeves et al., CD, 2007

- Which metric is optimal for impact assessment?
- More systematic comparisons needed!

Sources of uncertainty

UNIVERSITY OF LEEDS



Climate model

UNIVERSITY OF LEEDS

- Arguably biggest source of uncertainty
- Interpretation of model output and future developments require a thorough understanding of model deficits.
- Four aspects can be separated:

A) RESOLUTION

B) MODEL PHYSICS

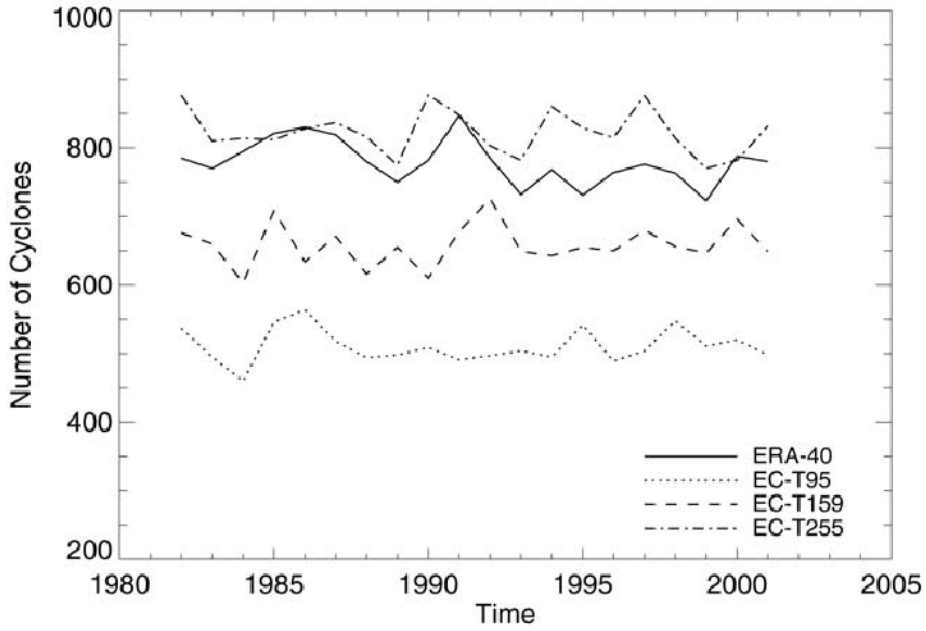
C) DYNAMICAL CORE

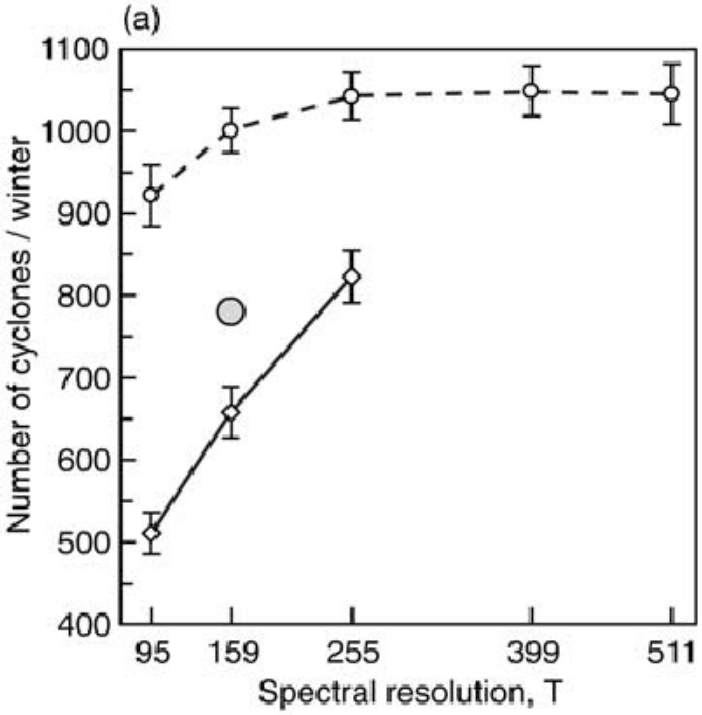
D) BASIC STATE

Resolution

UNIVERSITY OF LEEDS

Coarse resolution can lead to decreased storm counts due to
– insufficient representation of crucial dynamical processes
– failed capturing of storm centres (truncation effect)





from Jung et al., QJ, 2006

Model physics & dynamical core

UNIVERSITY OF LEEDS

- **DYNAMICAL CORE**
  – numerical treatment of main dynamical equations (time step, advection etc.)
  – not expected to be a major source of uncertainty
- **MODEL PHYSICS**
  – parameterizations of subgridscale processes (e.g. convection, energy fluxes from ocean, radiation)
  – can have a considerable influence on storm development
  – few systematic studies so far
- Generally, these uncertainties are assessed by running multi-model ensembles.
- Recent research suggests that IPCC models might be “too similar” (*Pennell & Reichler, JCL, 2011*) to represent true uncertainty.

Basic state

UNIVERSITY OF LEEDS

- Some climate models have substantial errors in their basic state
- This is reflected in biases in mean sea-level pressure, and the position and intensity of the jets and storm tracks
- What is the effect of this on the reliability of climate signals?
- Some people have suggested weighting of multi-model ensembles based on performance in current climate
- Politically difficult within IPCC
- What if model generates right answer for wrong reason?

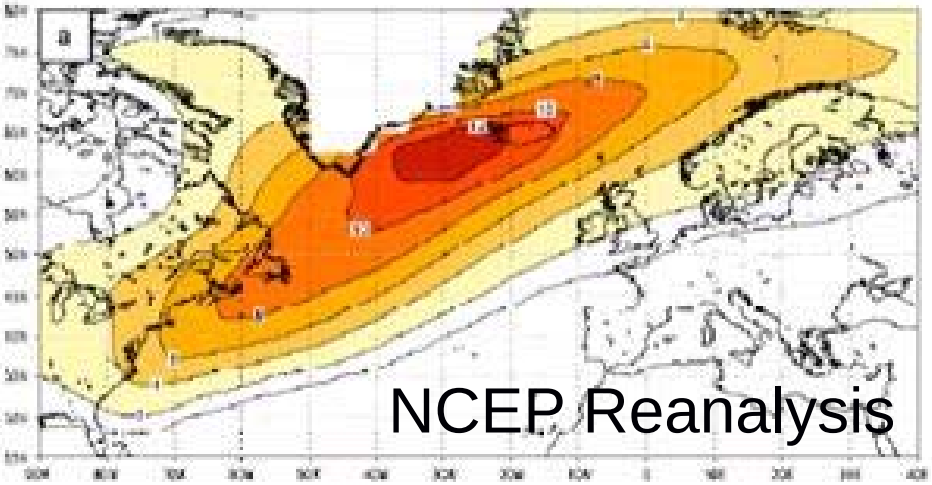
Assessing uncertainty

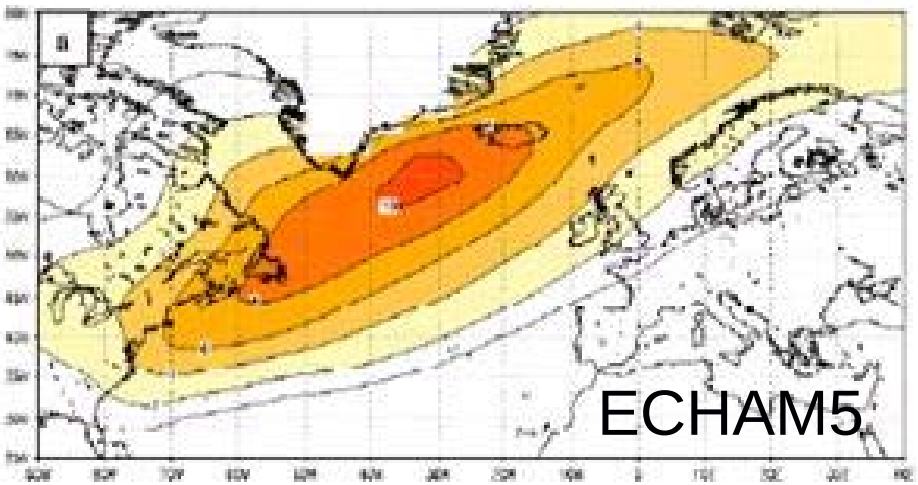
UNIVERSITY OF LEEDS

Statistical assessment

1) compare climate model output and re-analysis data
   → *plausibility check*

from Pinto et al.,CD, 2009





2) compare model output for current & future climate
   → *climate signal*

3) determine spread of multi-member multi-model ensemble
   → *uncertainty*

Advantages & problems

UNIVERSITY OF LEEDS

Advantages

- statistically robust, significances can be estimated
- vary greenhouse gas concentrations → **SCENARIO** uncertainty
- long ensemble simulations → **INTERNAL VARIABILITY** uncertainty
- multi-model approach → part of the uncertainty associated with **DYNAMICAL CORE** and **MODEL PHYSICS**

Problems

- Long runs → no rigorous testing of **RESOLUTION** and **MODEL PHYSICS** effects
- Difficult to separate effects of model errors and **BASIC STATE**
- E.g. model systematically underestimates cyclones and compensates this pressure bias → positive plausibility check for wrong reasons

Seamless approach

UNIVERSITY OF LEEDS

- Seamless approaches seek synergies between forecasting at weather (NWP), seasonal and climate timescales.
- Strategy of a recently started project at the University of Leeds funded by the AXA Research Fund.
- Investigation of about 20 historical extreme/severe European windstorms.
- Simulations with IPCC climate models in NWP mode (run at Leeds and Transpose-AMIP experiments)
- Comparison with operational weather predictions (deterministic & ensemble) and (re-)analyses
- Compare results with statistical results for CMIP5 climate model output.

Advantages & problems

UNIVERSITY OF LEEDS

Advantages

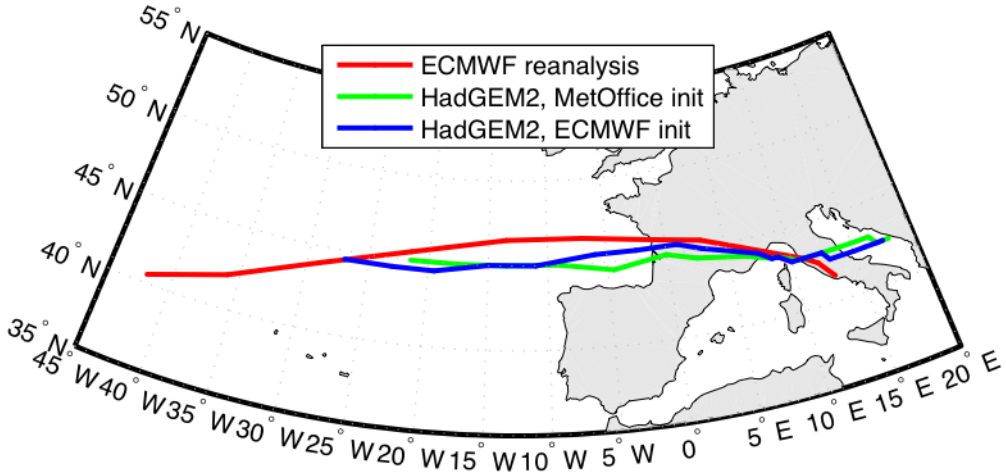
- separation of role of fast processes from that of **BASIC STATE** changes possible
- case study approach allows extensive testing of effects of **RESOLUTION**, **MODEL PHYSICS** & **DYNAMICAL CORE**
- determine systematic biases with regard to intensity and track
- might allow development of calibration procedures

Problems

- representativity of selected cases
- statistical robustness
- technical problems with porting models, spin-up etc.

A Transpose AMIP example

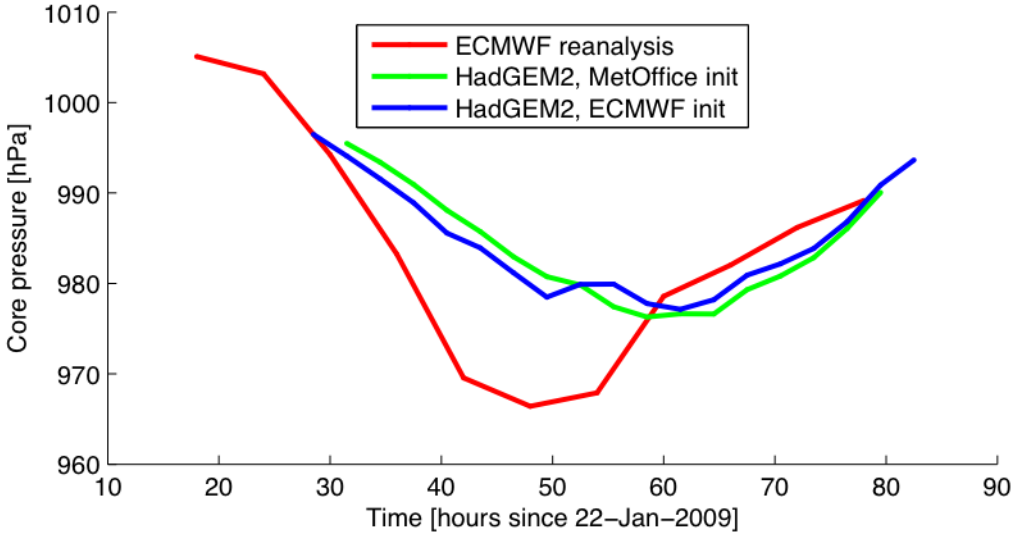
UNIVERSITY OF LEEDS



Track and core pressure of storm “Klaus”

All runs initiated at 1330 UTC 22 Jan. 2009

and interpolated to 0.5x0.5° ECMWF grid



Conclusions

UNIVERSITY OF LEEDS

- Uncertainties in climate projections of intense wintertime windstorms key to assessing potential impacts of climate change on Europe

- Most important sources of uncertainty associated with
  – emission scenarios
  – internal variability
  – metrics for storminess
  – climate models (physics, resolution, dynamical core)

- Classical approaches to quantify uncertainty:
  – statistically robust
  – but problems to separate out effects of single sources

- Seamless approaches combining weather and climate prediction will allow new insights.