Imperial College London

Grantham Institute for climate change

Department of Meteorology

The University of Reading

Modelling Climate Variability & Change

Brian Hoskins

Imperial College London

The University of Reading

Reasons for Confidence in Model Projections

- Models built on basic physics
- Success in simulating the mean climate with some accuracy
- General consistency of globally averaged T response from simplest to most complex
- Success in forecast/hindcast of weather, seasonal climate, impact of Pinatubo, past century
- Simulation of phenomena such as El Niño, storms

Reasons for Lack of Confidence in Model Projections

- Underestimation of natural variability? E.g. 1940s
- Uncertainty in forcing used for past century, e.g. solar, aerosols
- Only just starting to have interactive atmospheric chemistry & carbon cycle
- Uncertainty in cloud behaviour, aerosol effects, solar variability,…
- Poor representation of some phenomena particularly on smaller scales
- Behaviour too smooth?

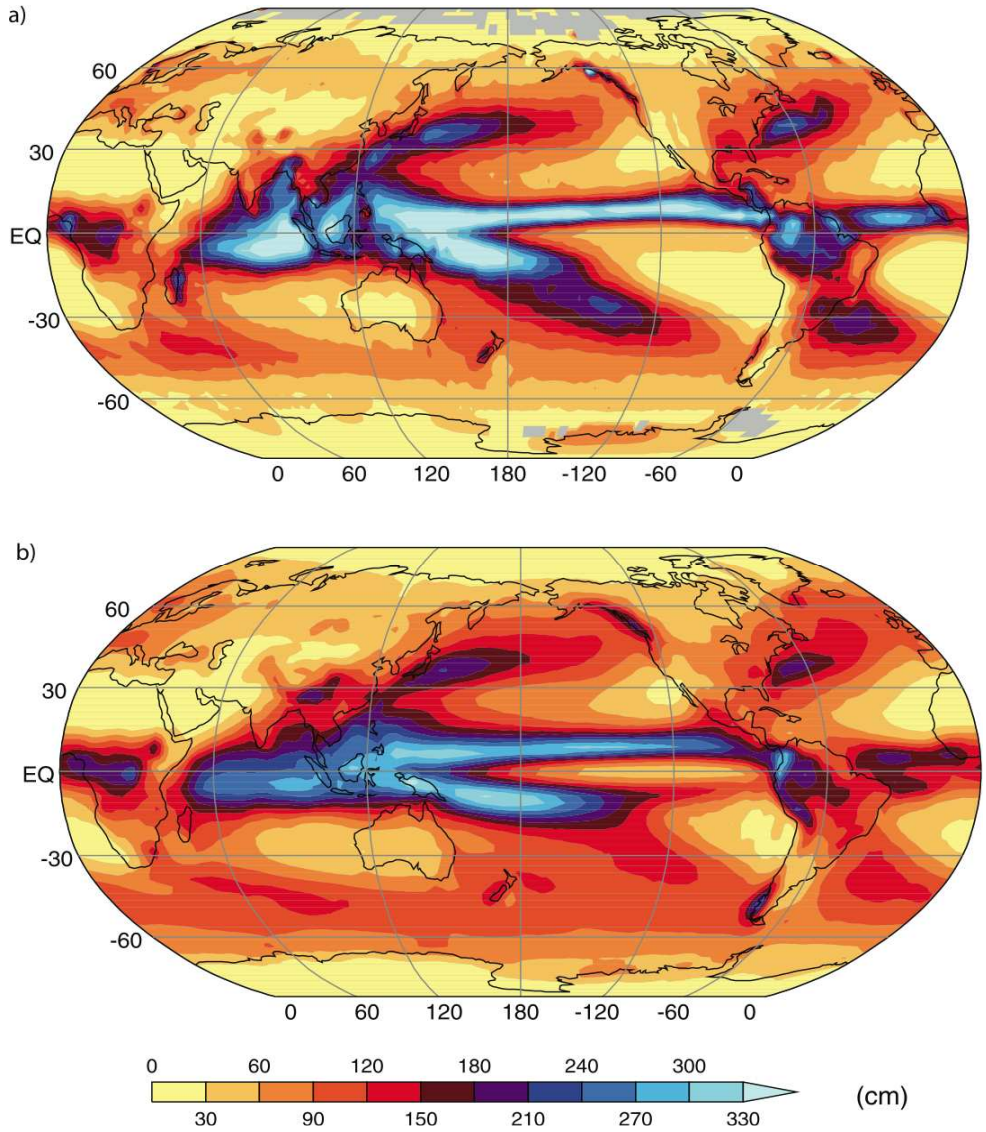
Imperial College London

The University of Reading

One test for models: Annual mean precipitation: 1980-1999

Observed

Climate model simulations

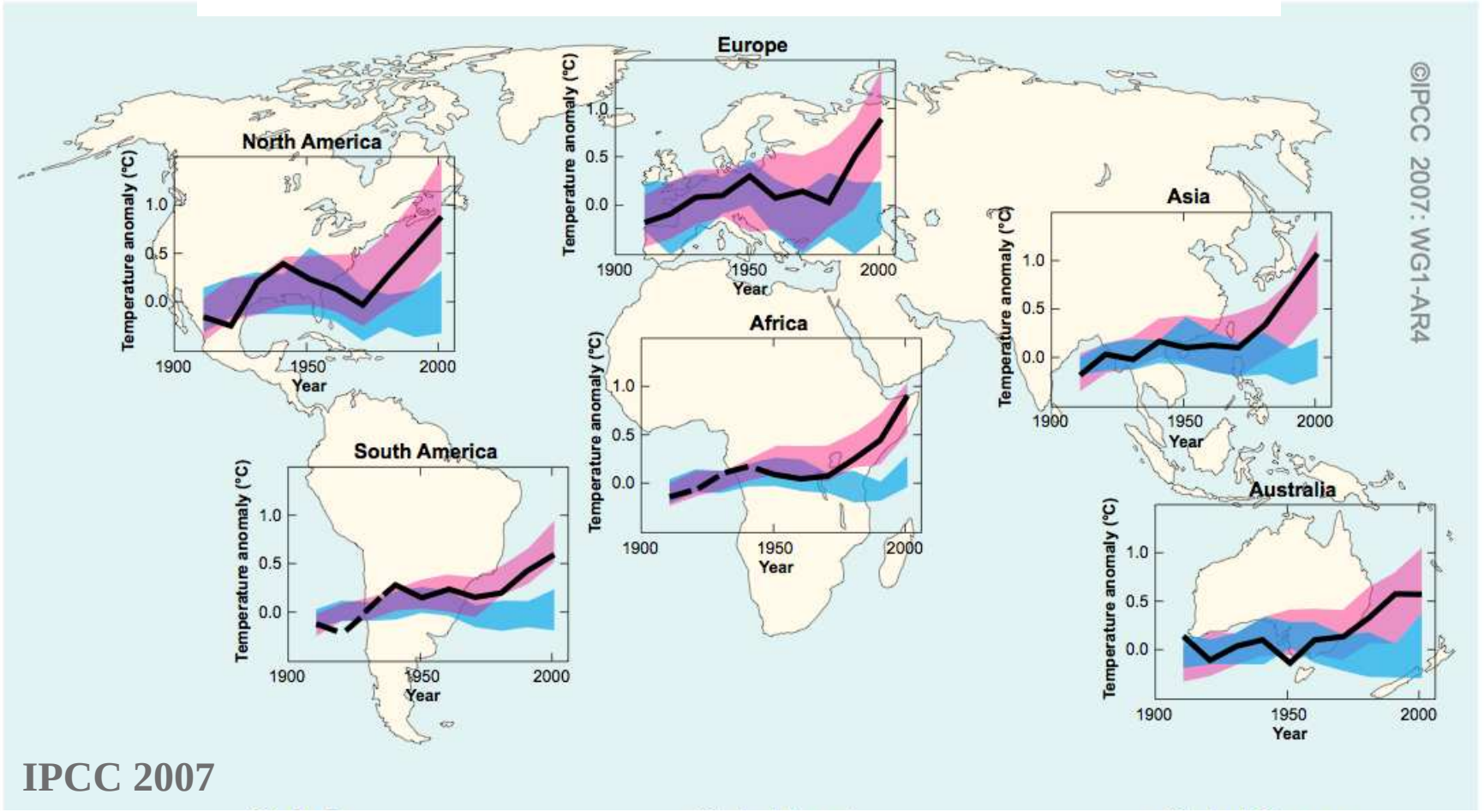


IPCC 2007

Imperial College London

The University of Reading

20th Century Continental Temperatures: Observed & Modelled with & without anthropogenic forcings

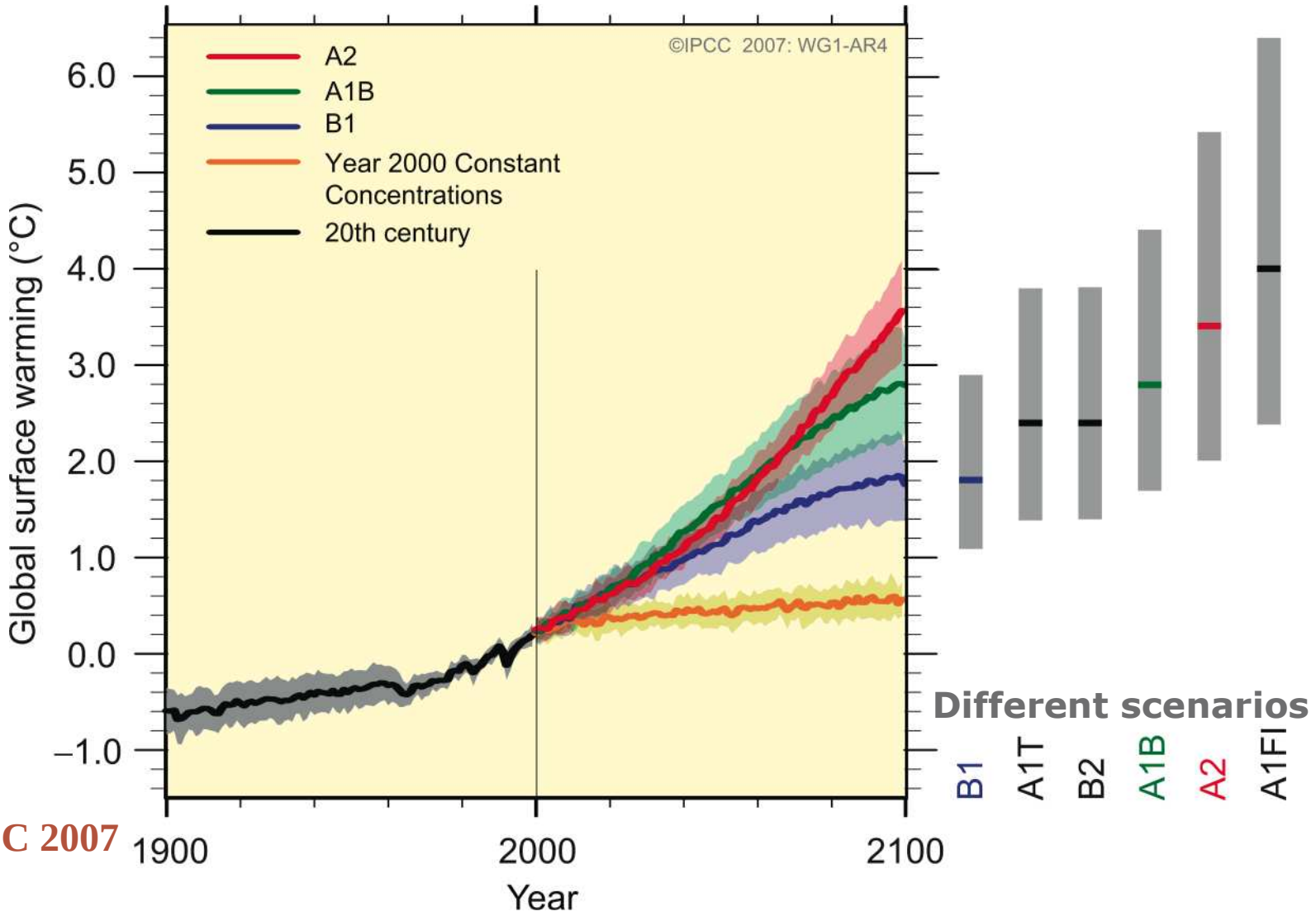


IPCC 2007

Imperial College London

The University of Reading

Projections of globally averaged surface warming

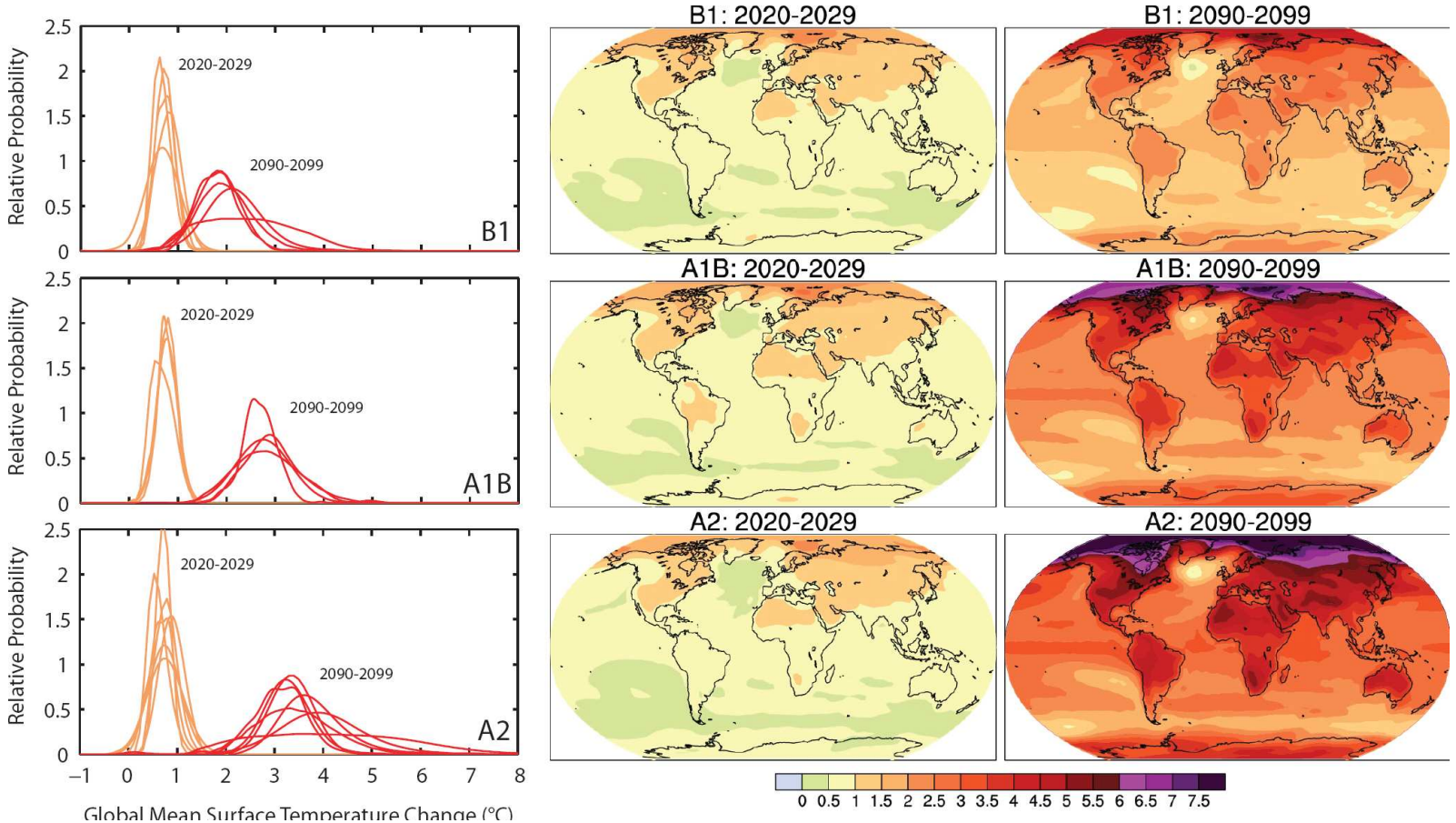


IPCC 2007

Imperial College London

The University of Reading

IPCC (2007) Surface Temperature Projections 2020s & 2090s relative to 1980-99



Global mean

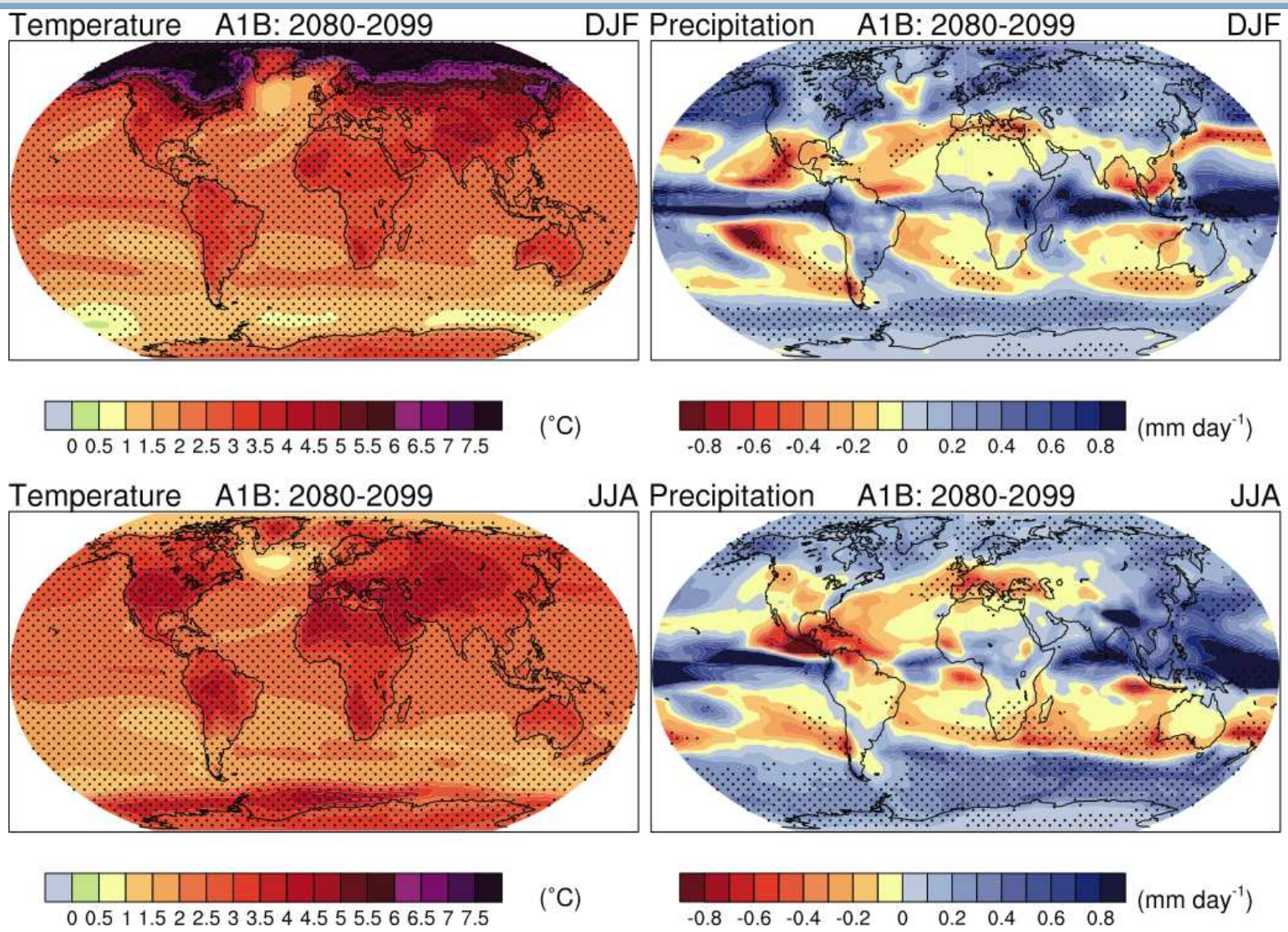
2020s

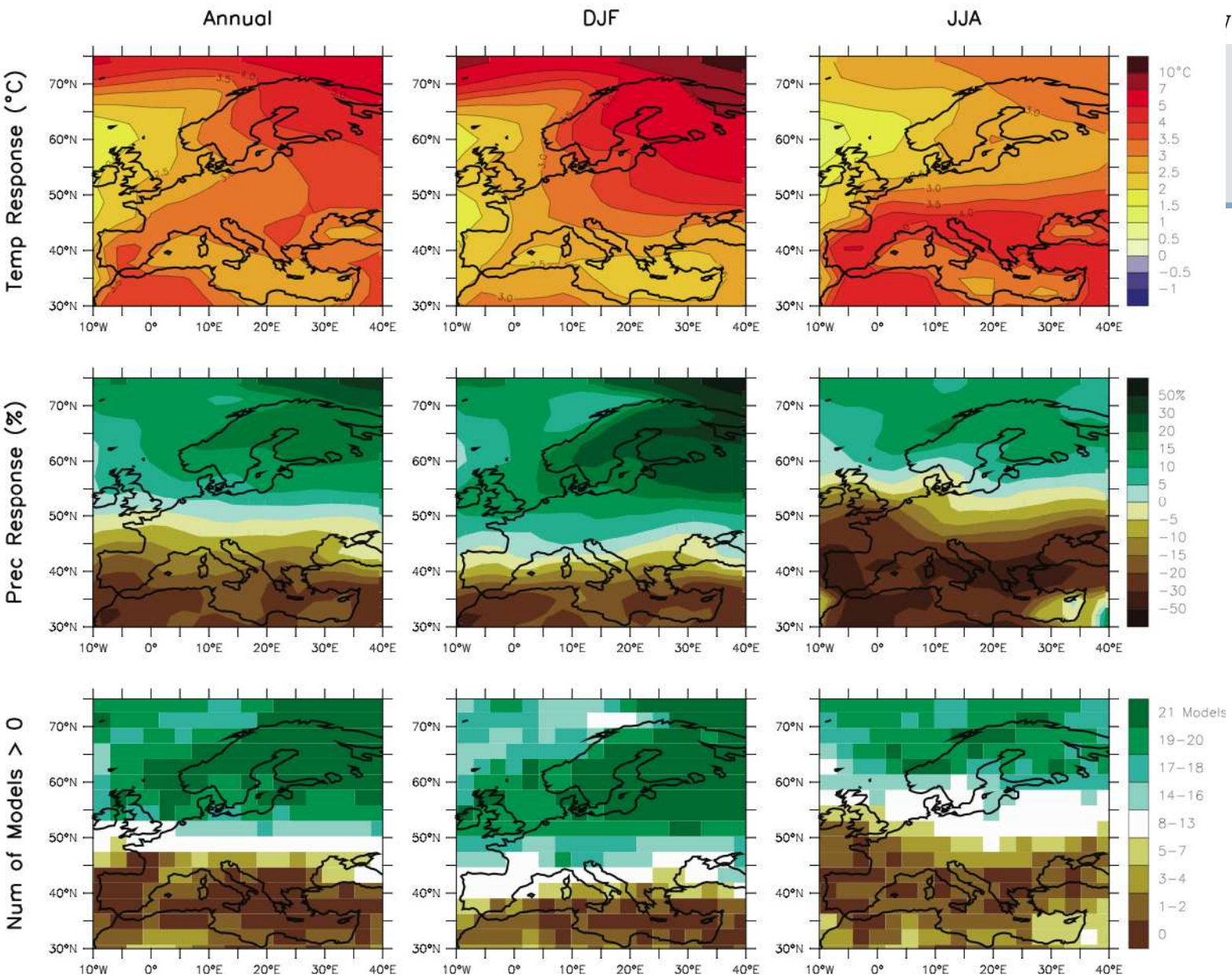
2090s

Imperial College London

The University of Reading

Surface Temperature & Precipitation Projections Dec-Feb and June-Aug: 2090s relative to 1980-99



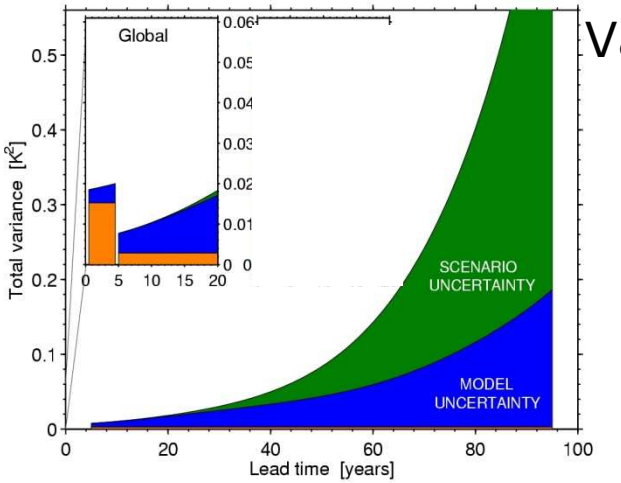

Annual
DJF
JJA
Temp Response (°C)
Prec Response (%)
Num of Models > 0
70°N
60°N
50°N
40°N
30°N
10°W
0°
10°E
20°E
30°E
40°E
10°C
7
5
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
50%
30
20
15
10
5
0
−5
−10
−15
−20
−30
−50
21 Models
19−20
17−18
14−16
8−13
5−7
3−4
1−2
0

Imperial College London

The University of Reading

Contribution to uncertainty in global decadal mean T

Hawkins & Sutton (2008)

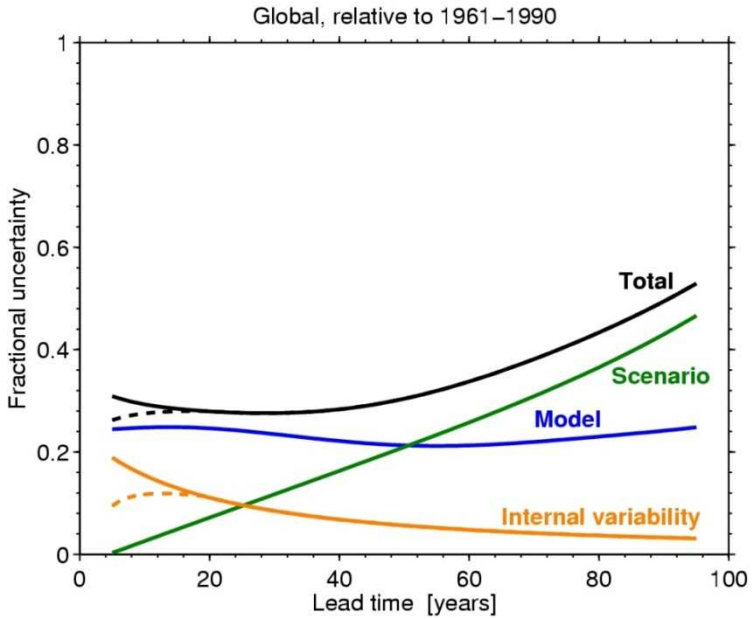


Variance

Internal variability

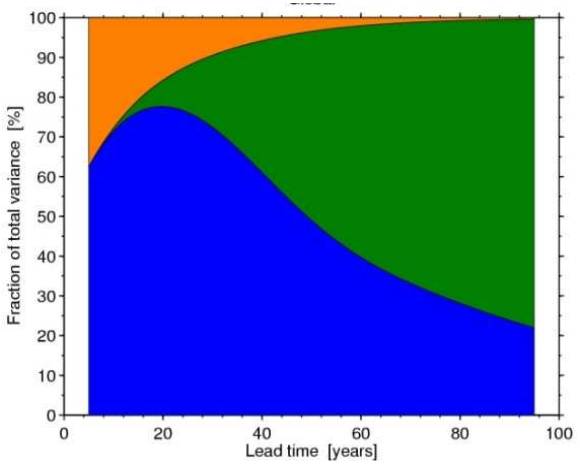
Model uncertainty

Scenario uncertainty

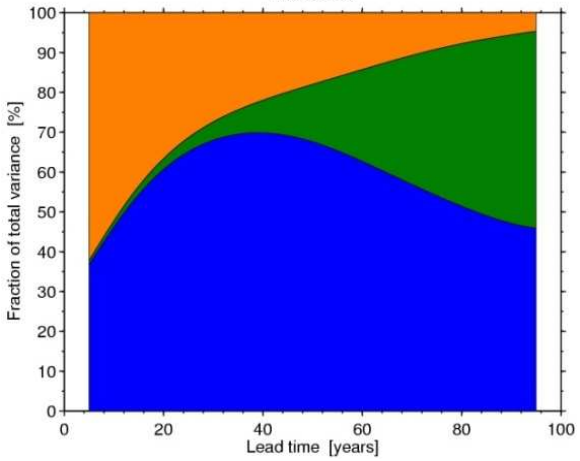


Fraction of total variance

Global



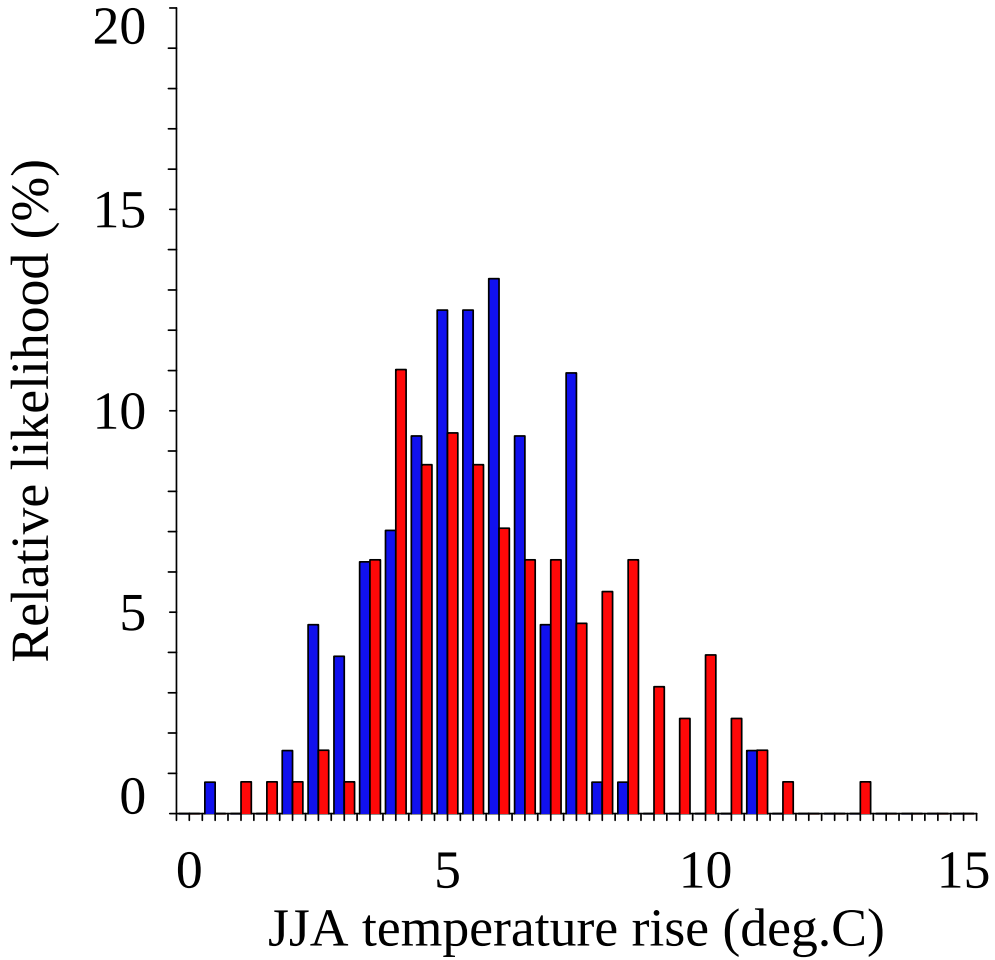
British Isles



Imperial College London

The University of Reading

Doubled CO_2: Projected changes in probability distributions for summer day temperatures in Southern England



Hottest day of summer

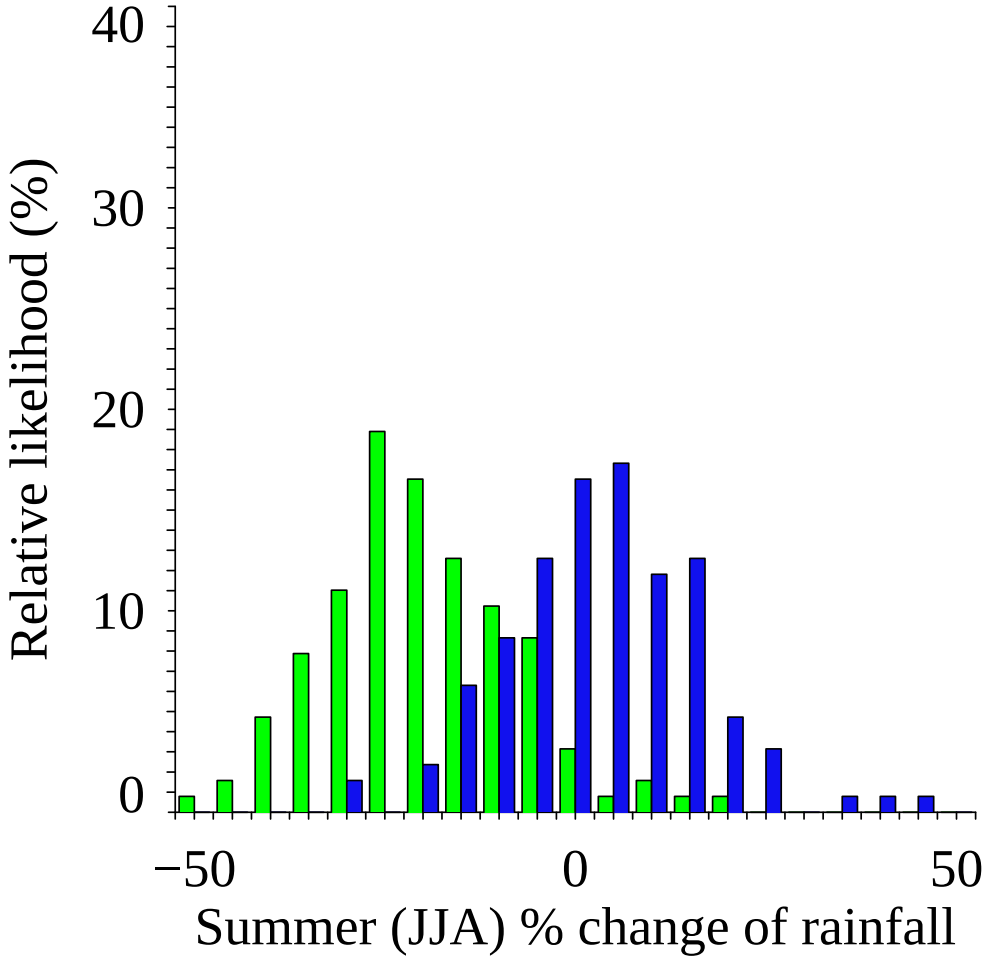
Average day of summer

Hadley Centre

Imperial College London

The University of Reading

Doubled CO_2: Changes in probability distributions for summer wet days in Southern England



Wettest day of summer

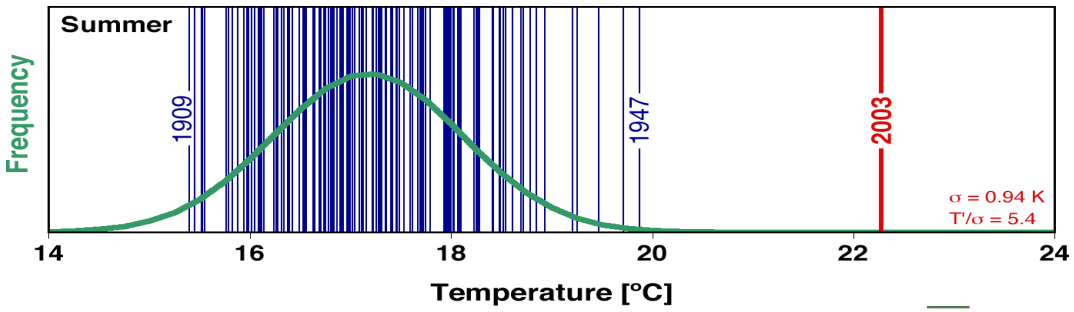
Average wet day of summer

Hadley Centre

Imperial College London

The University of Reading

Summer 2003: record European warmth

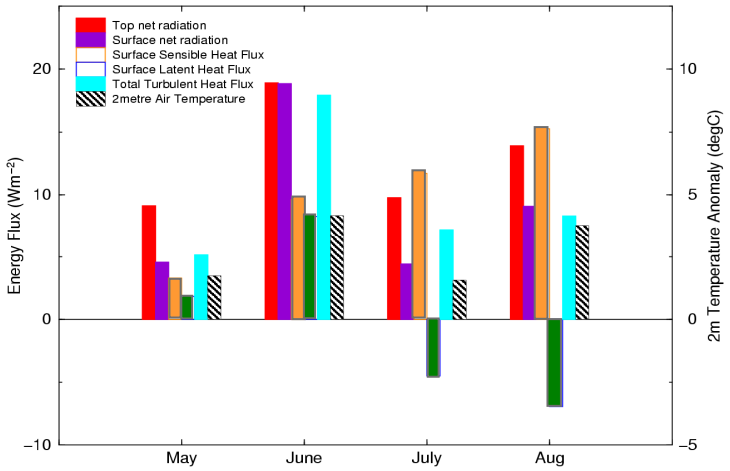


Swiss Temperature Series 1864-2003 (mean of 4 stations)

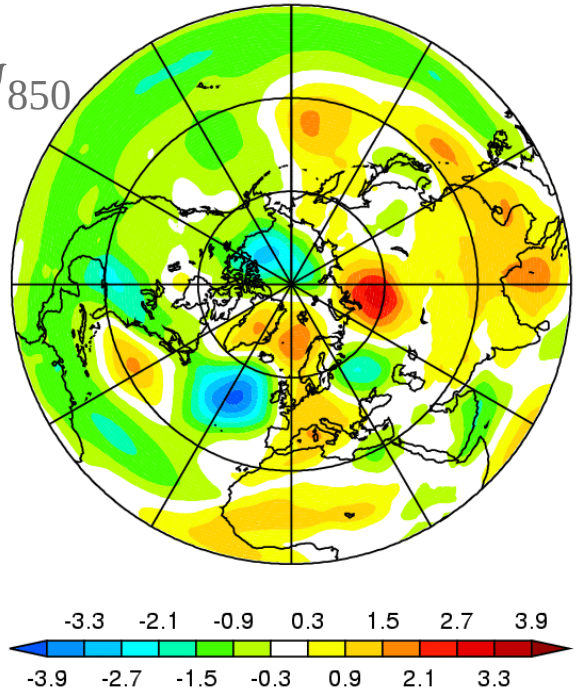
*Schär et al. 2004, Nature, **427**, 332-336*

Anomalies in Heat Budget over Europe

surface sensible heat flux
surface latent heat flux



JJA ψ_{850}

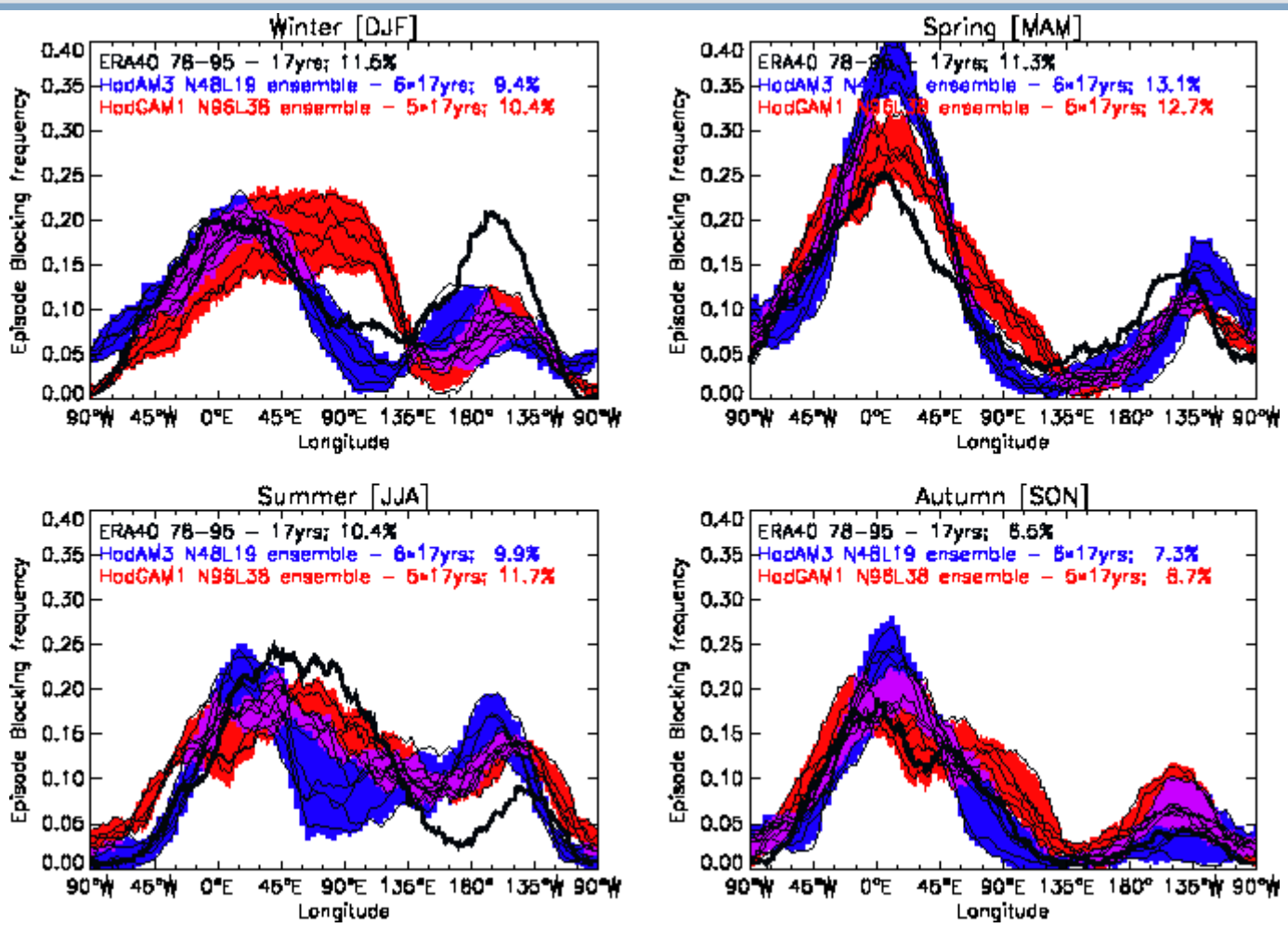


Black, Blackburn, Harrison, Methven & Hoskins (2004)

Imperial College London

The University of Reading

Blocking in 2 UKMO-Hadley Centre Climate models



Tim Henton (Met Office/HC)

Imperial College London

The University of Reading

The Cascade of Confidence

- Very high confidence in the occurrence of global warming due to human emissions of greenhouse gases

- Moderate confidence in aspects of continental scale climate change projections (depending on var & place)

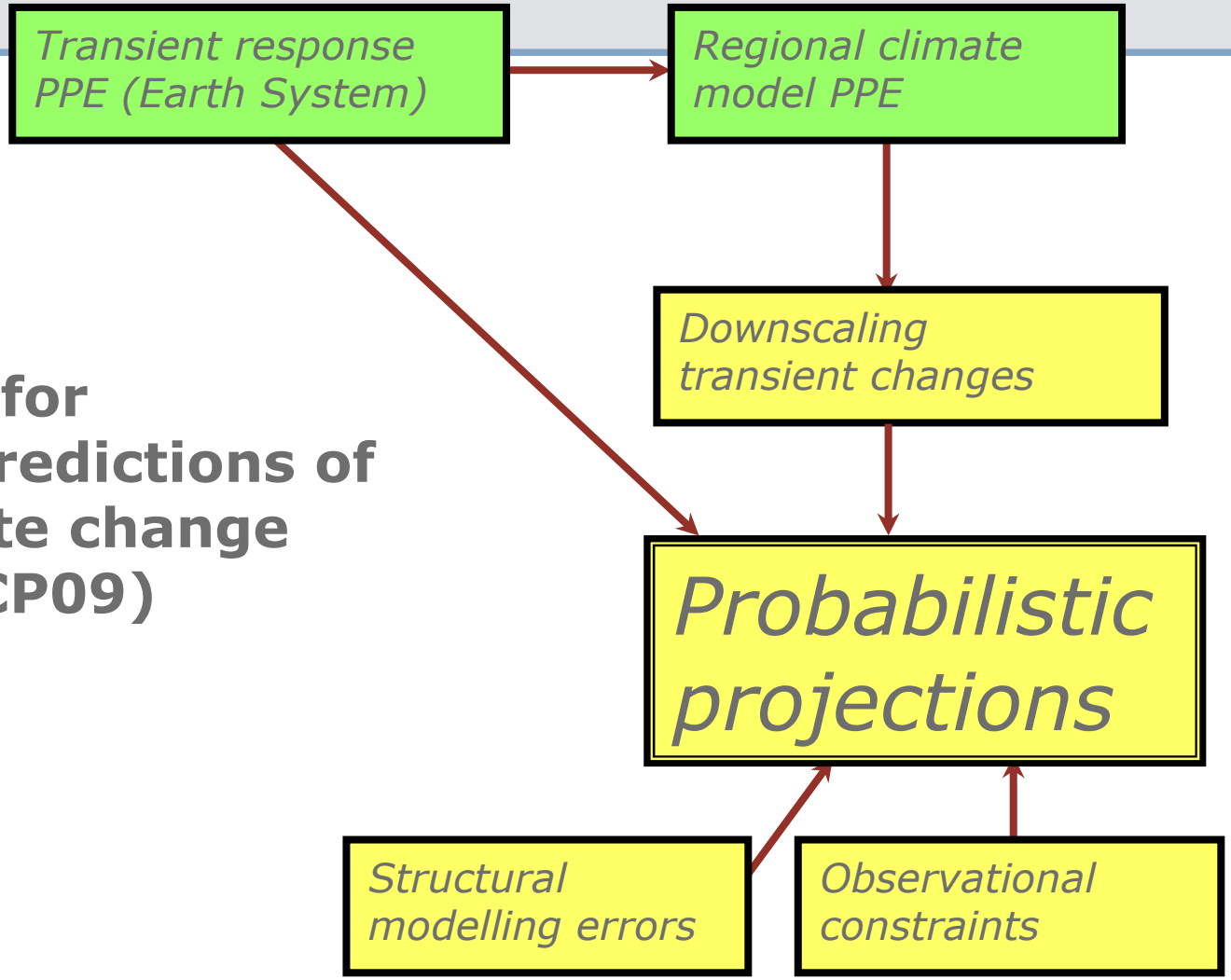
- Regional scale climate change information is indicative to the extent that it reflects the large-scale changes modified by local conditions

- There is no climate change information on local scales beyond that at the regional scale. All that can be produced is a range of examples of local climates consistent with current larger-scale model projections.

Imperial College London

The University of Reading

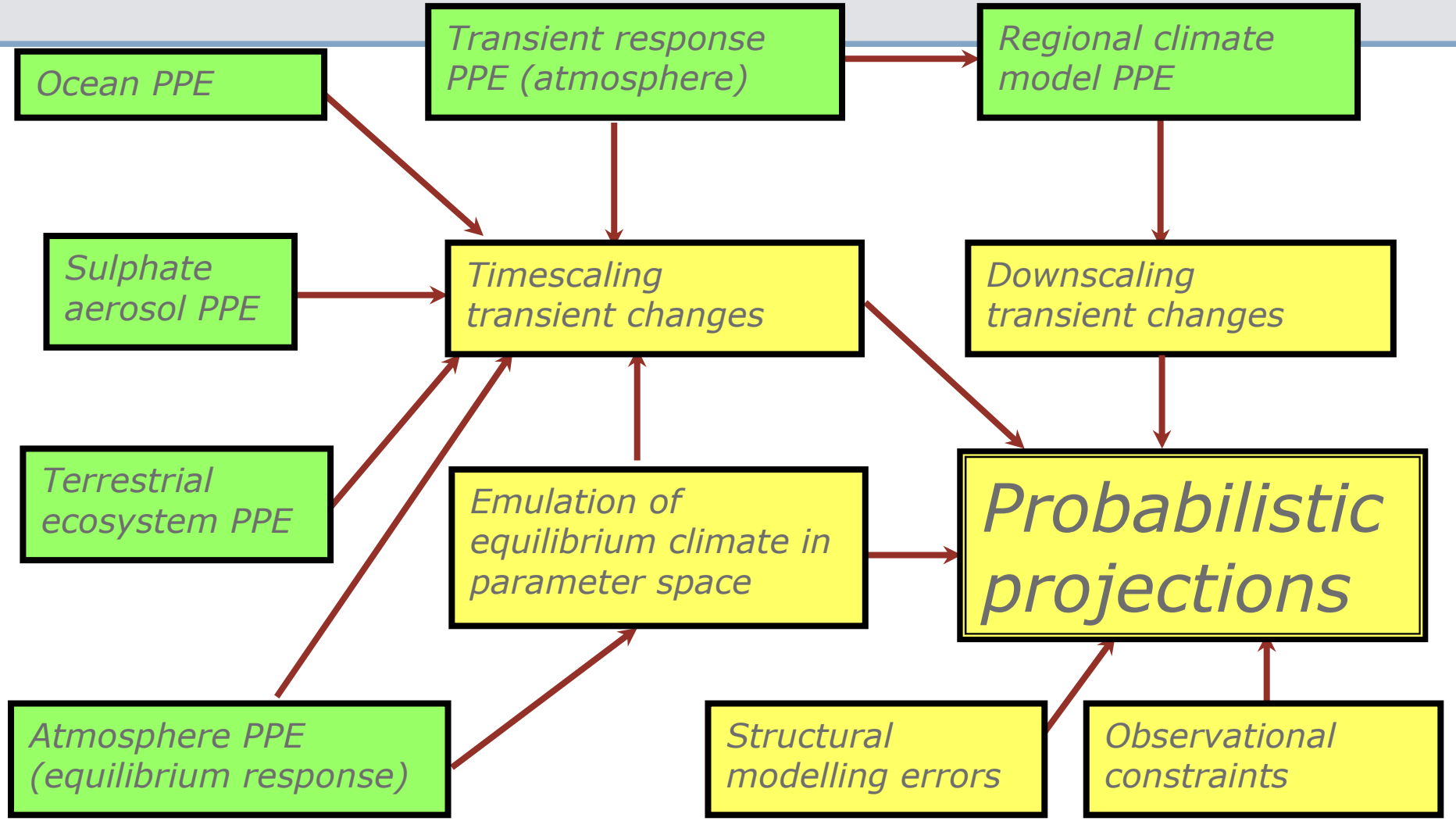
IDEAL system for probabilistic predictions of regional climate change (including UKCP09)



Imperial College London

The University of Reading

Actual method for UKCP09 probabilistic projections

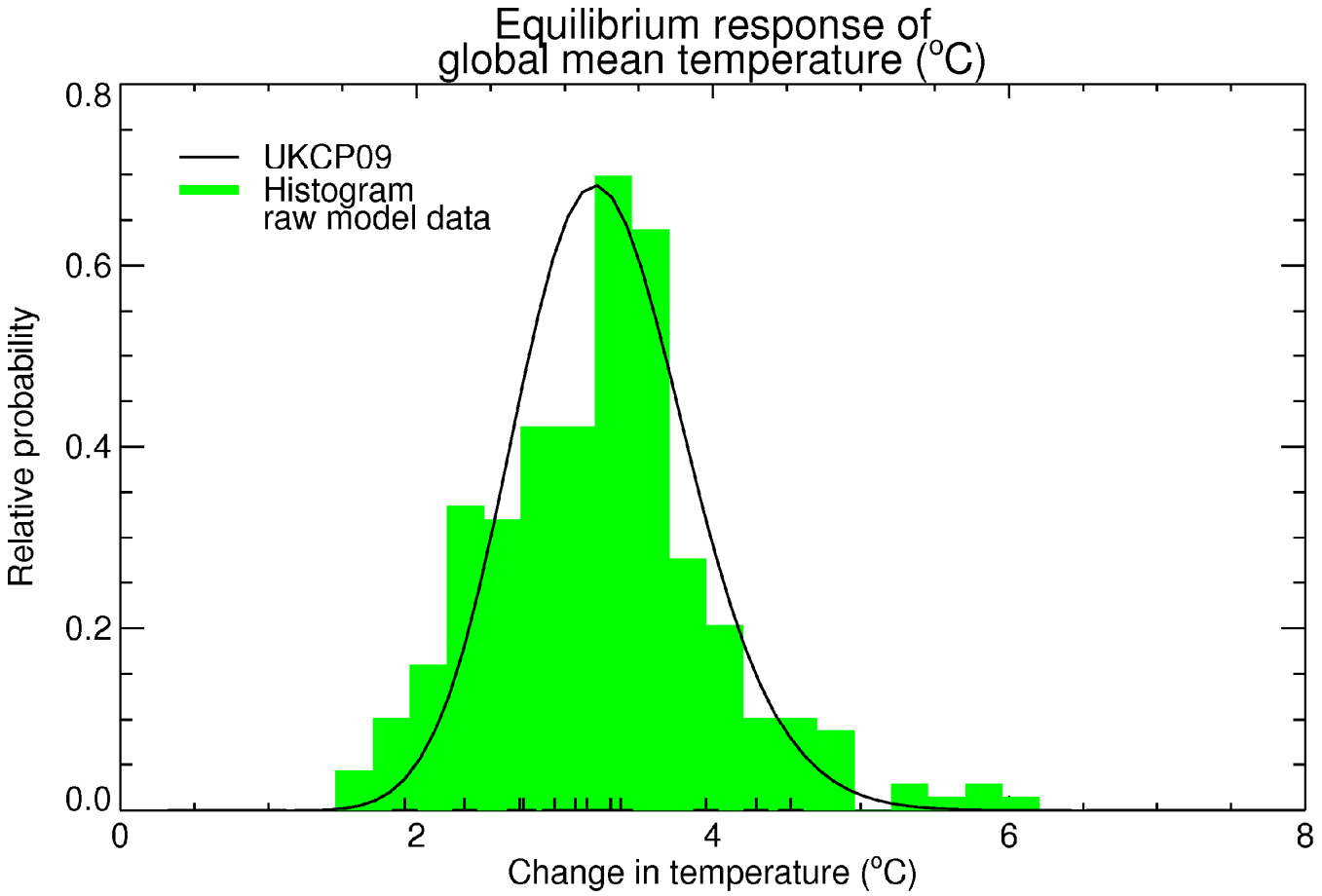


Imperial College London

The University of Reading

Equilibrium response to doubling of CO2

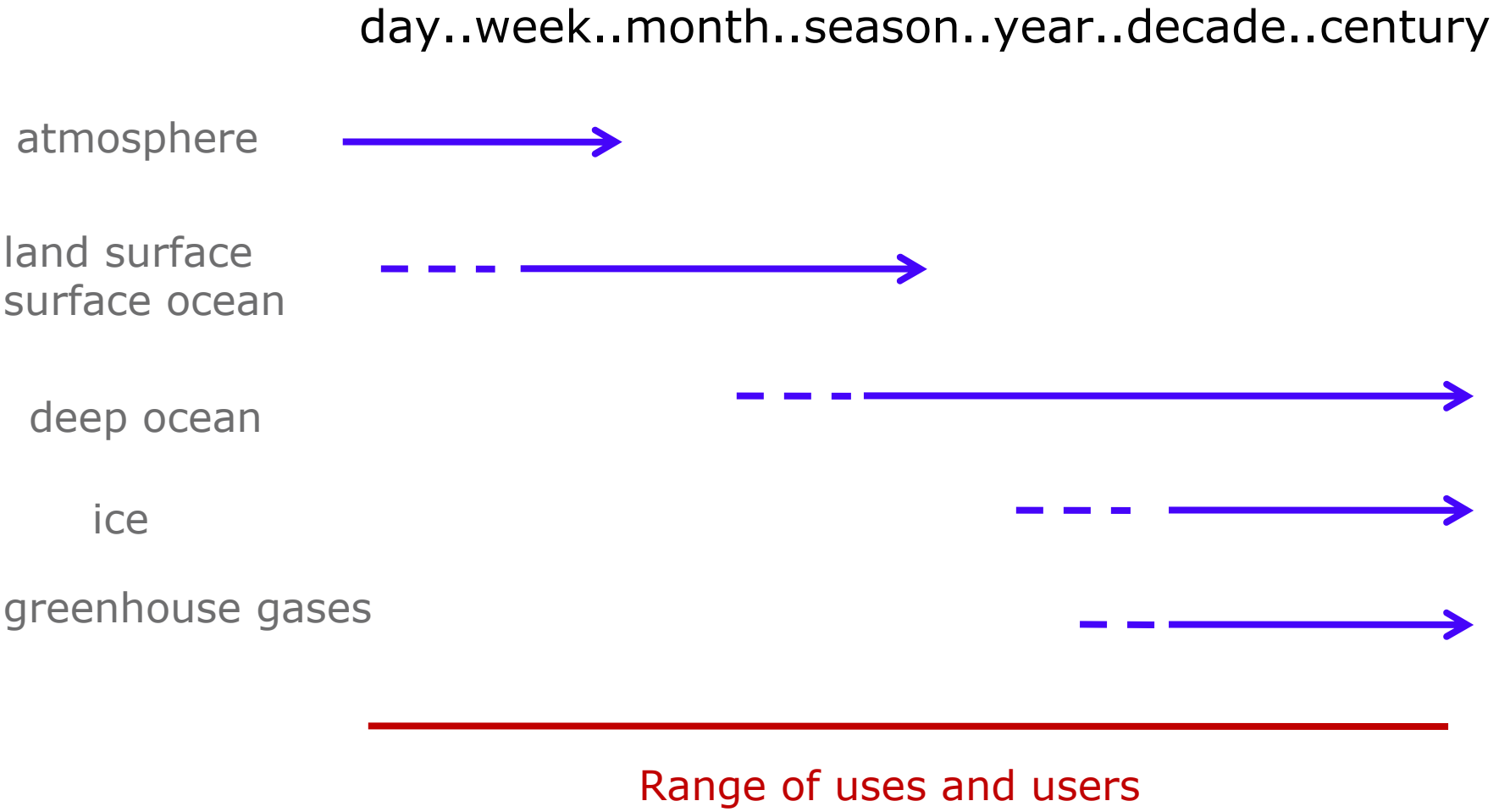
Results are combined with projections from other climate models and observations to produce probabilistic projections



Imperial College London

The University of Reading

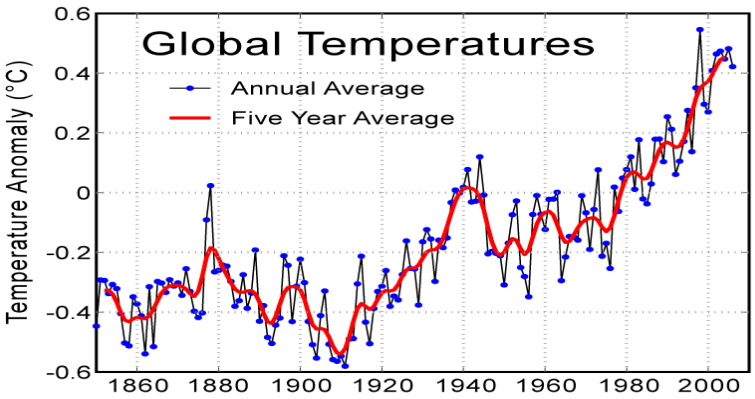
The seamless prediction problem

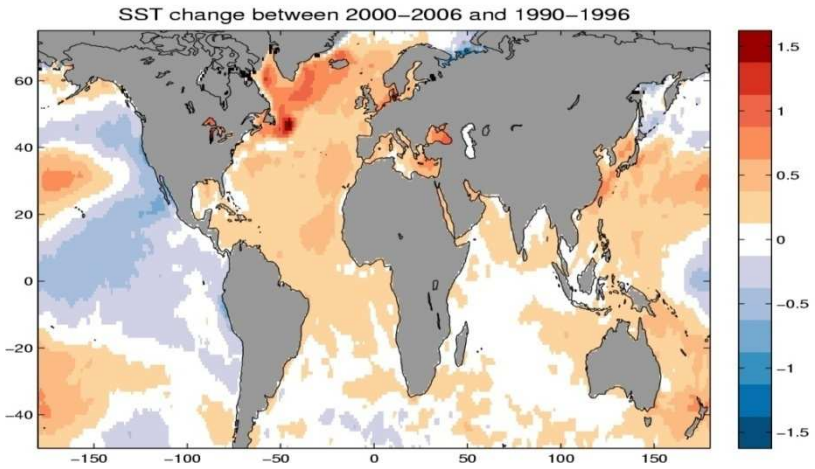


Imperial College London

The University of Reading

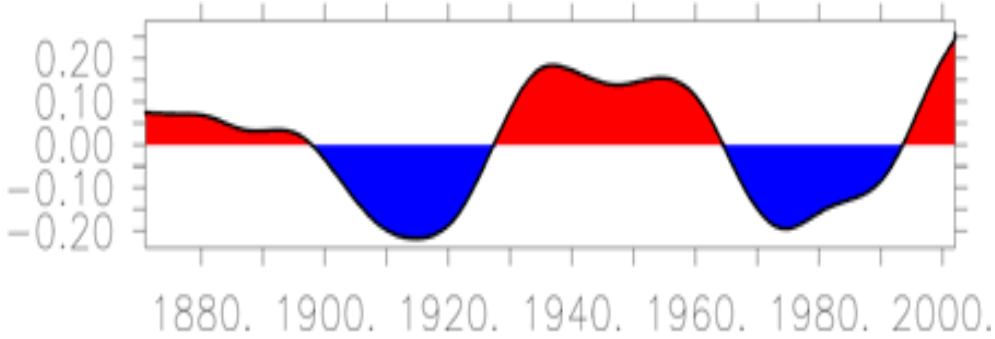
North Atlantic Multi-decadal Oscillation





Recent SST warming pattern

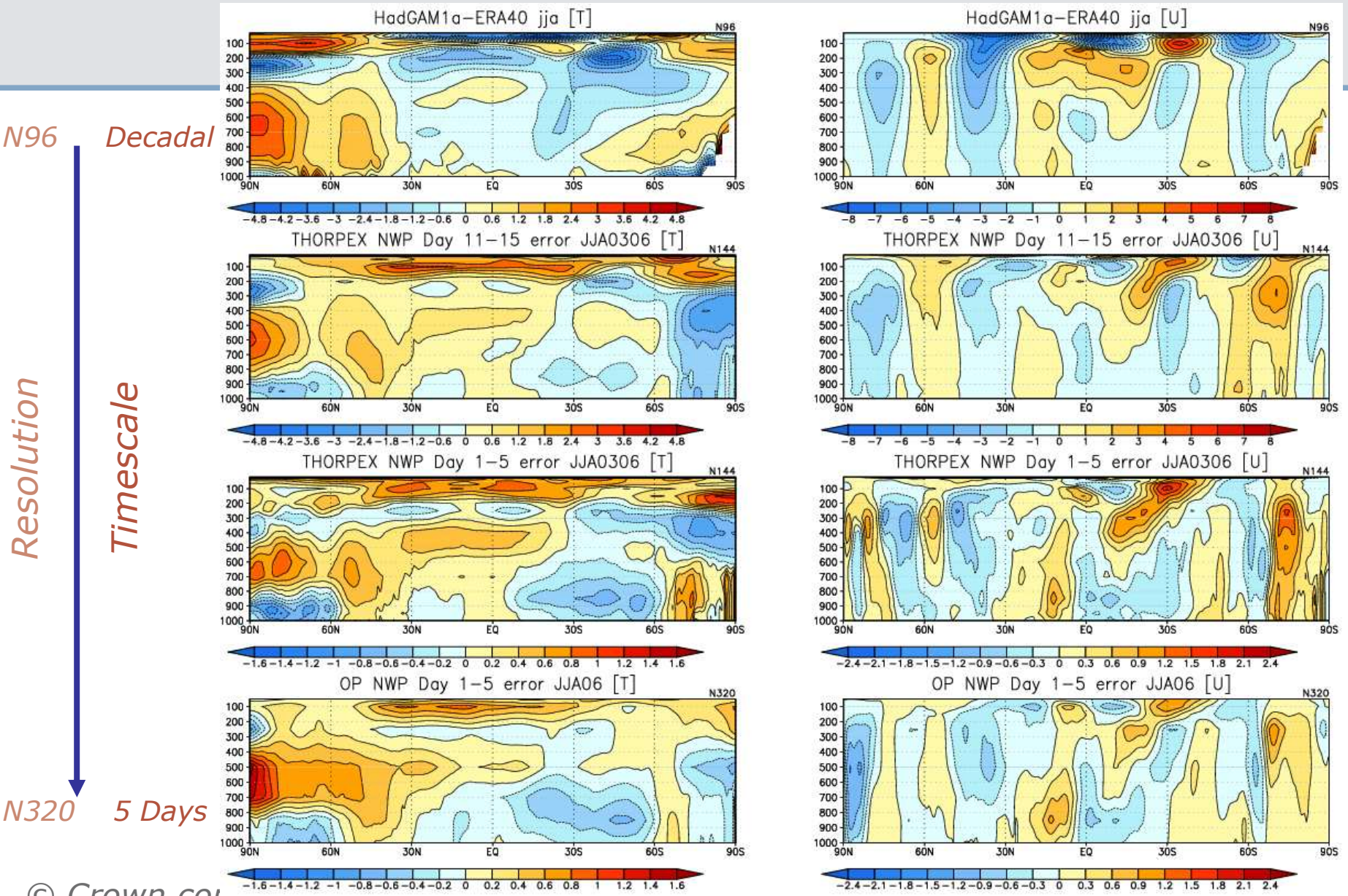
Smoothed North Atlantic sea surface temperature (long term trend removed)



Sutton & Hodson, 2005

Potential predictability of Atlantic SST, and hence impacts

Systematic Errors – NWP to Climate (UK MetO)



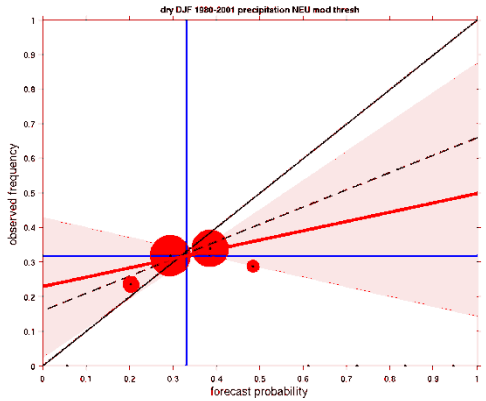
Imperial College London

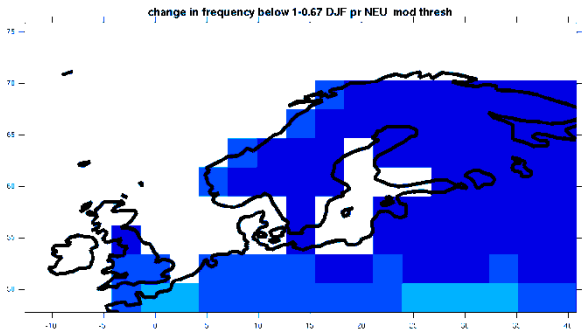
The University of Reading

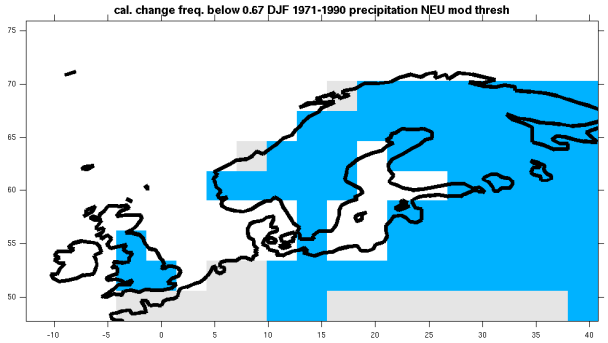
Calibration of climate projections using seasonal forecasting skill?

Palmer et al (2008)

Northern Europe dry DJF: Reliability of seasonal forecasts is poor, hence discount the strong AR4 probabilities



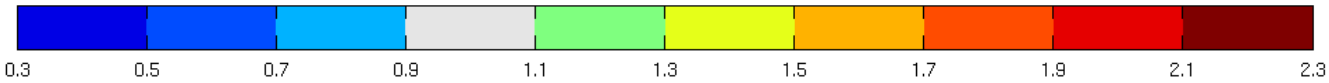




DEMETER Reliability

AR4 Uncalibrated

AR4 Calibrated



Imperial College London

The University of Reading

Met Office Unified Model suite 2011+

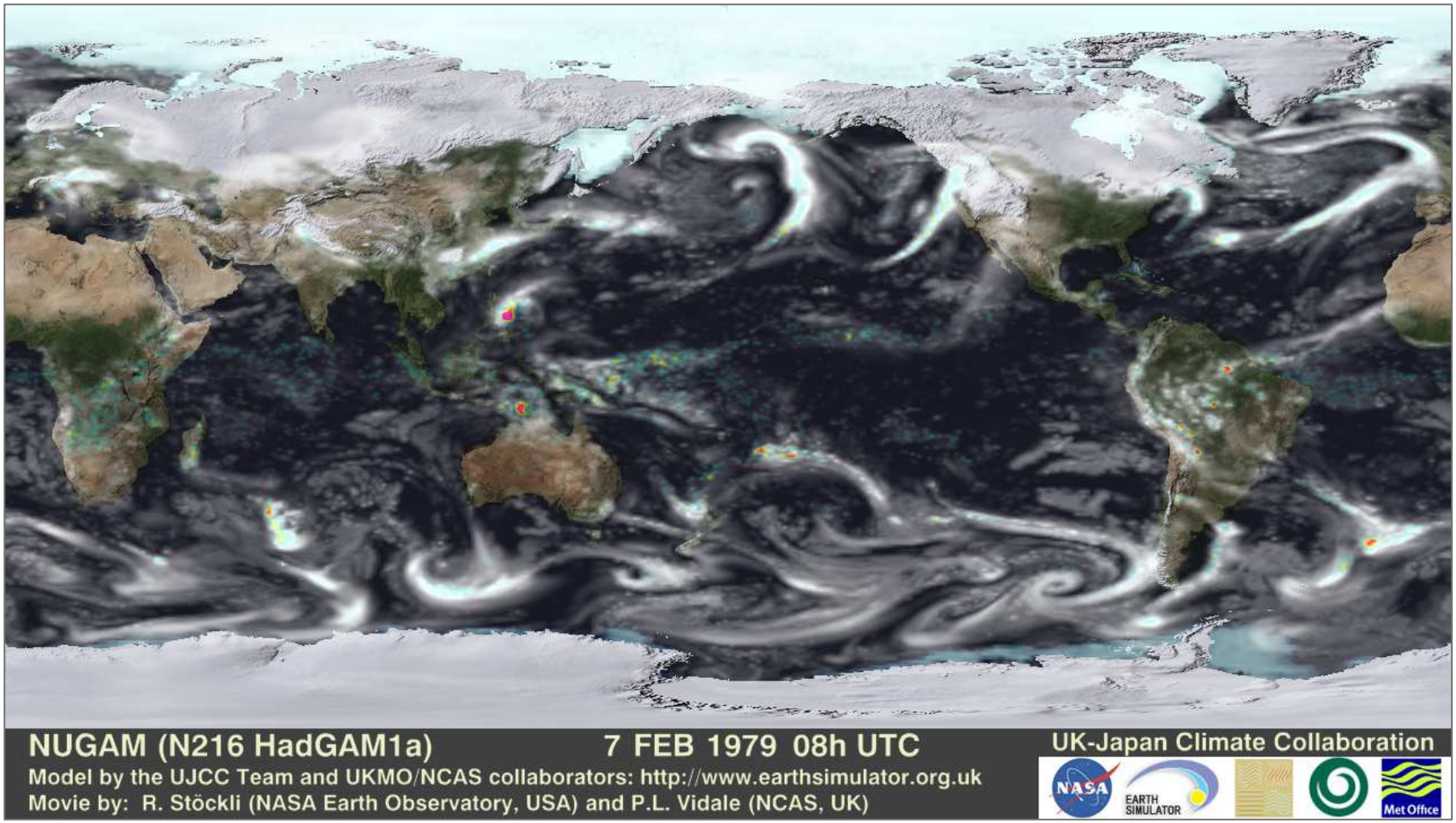
	Regional NWP NAE (2 days)	Global NWP (6 days)	THORPEX (15 days)	Seasonal 2 Decadal (GloSea)	Centennial	Regional Climate
Horizontal Resolution	12km	25km – N512	60km – N216	60km – N216	135km – N96	25km
Vertical Resolution	70 L	70 L	70 L	85L	63L 85L	63L 85L
Atmos Physics	HadGEM3-A + upgrades	HadGEM3-A + upgrades	HadGEM3-A + upgrades	HadGEM3-A + upgrades	HadGEM3-A	HadGEM3-A
Atmos. data assimilation	4D-Var (3h cycle) MOPS LH nudging	4D-Var	Reconfigured Global Analysis	Reconfigure Global Analysis	N/A	N/A
Soil moisture initialisation	Reconfigured daily from Global soil moisture	Soil nudging	Global “nudged” analy.	UM analysis.	N/A	N/A
Ocean	Persisted SST	Persisted SST	Persisted SST anomalies.	NEMO (0.25°)	NEMO (1°, 1/3° tropics)	Driven by HadGEM3-AO (NEMO) SSTs
Ocean data Assimilation	N/A	N/A	N/A	FOAM bias correction or 4D, multi-variate OI of salinity, sub surf.T, SST’s	N/A	N/A
Ensembles	MOGREPS 24 member ETKF 16km/70L	MOGREPS 24 member ETKF (Bowler(06)) N216/70L	24 member ensemble from MOGREPS perturbations	100 member	HadGEM3 PPE decadal ensemble	

Imperial College London

The University of Reading

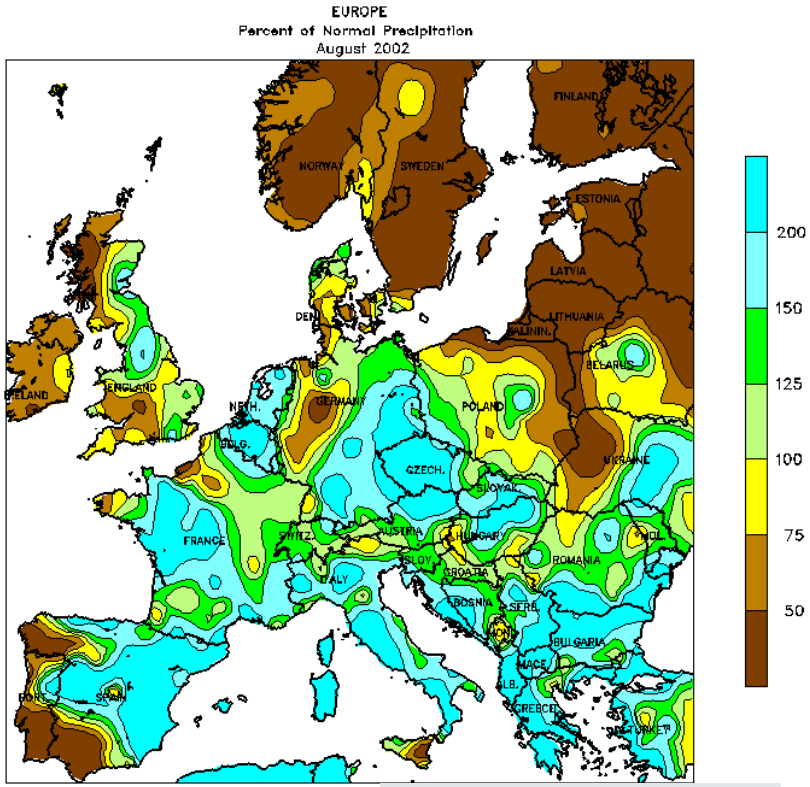
Much higher resolution

Putting the weather back into climate

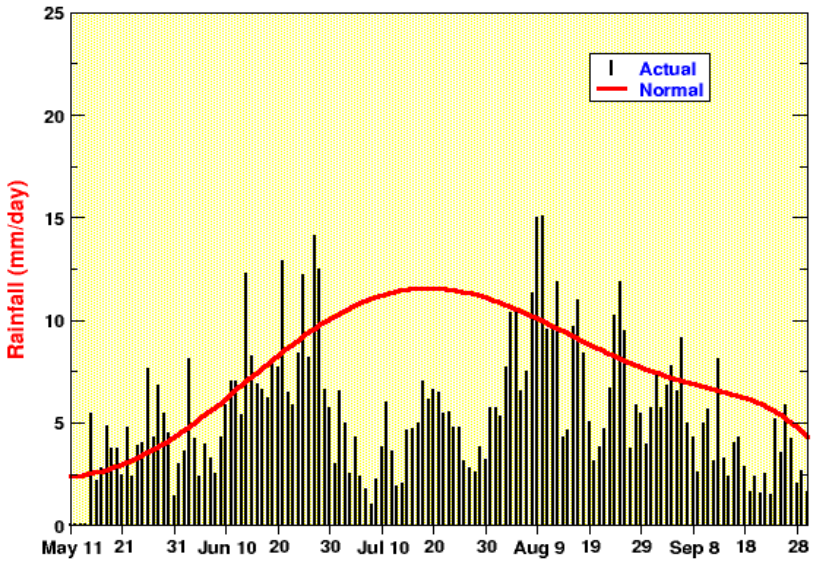


Summer 2002

Flooding in Central Europe



Drought in India



Blackburn & Hoskins (2006)

Imperial College London

The University of Reading

Progress in

NWP

Climate Projection

Achievements

- *Much greater skill on the large-scale*
- *Increasing ability high impact weather /meso-scale phenomena*
- *Probability information*
- *Better links with users*
- *Skill → 2^{nd} week, season*

- *Increased skill past/current climates*
- *More observations and better agreement of models with them*
- *Confidence GHG emissions are significantly perturbing climate system*
- *Simulation wider climate system w/o increased div of model projections*

Achieved through

- *Model numerics and resolution*
- *Parametrizations*
- *Computational power*
- *Data assimilation*
- *Observational system*
- *Ensembles*

- *Model resolution (some)*
- *Parametrizations*
- *Computational power*
- *Understanding of wider coupled ES*
- *Observations, but...*
- *Multi-model approach*

Conceptual bedrock

- *3-D adiabatic motion*

- *1-D thermodynamics*