The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1934-3

Fourth ICTP Workshop on the Theory and Use of Regional Climate Models: Applying RCMs to Developing Nations in Support of Climate Change Assessment and Extended-Range Prediction

3 - 14 March 2008

Uncertainty in RCM-based regional climate change projections.

Filippo Giorgi

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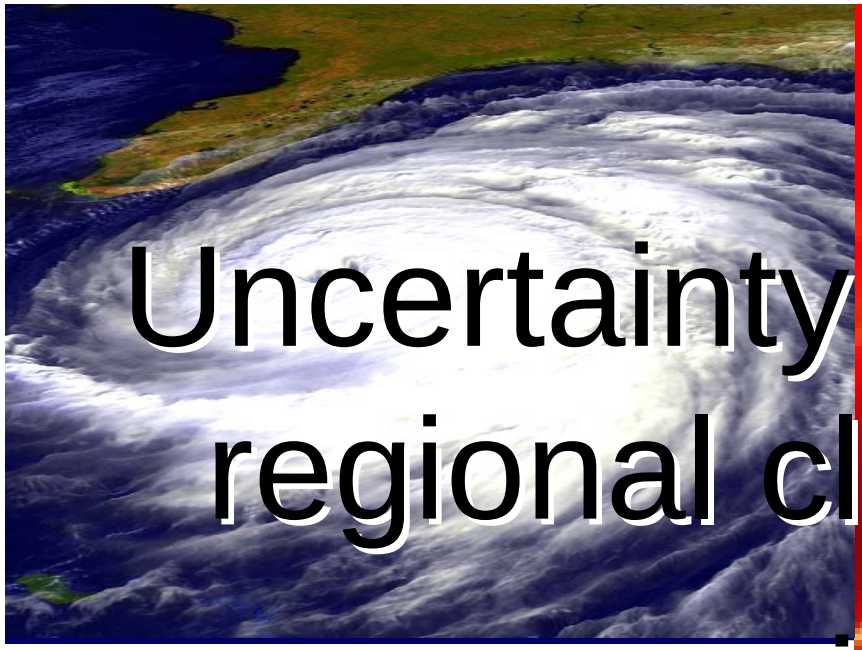
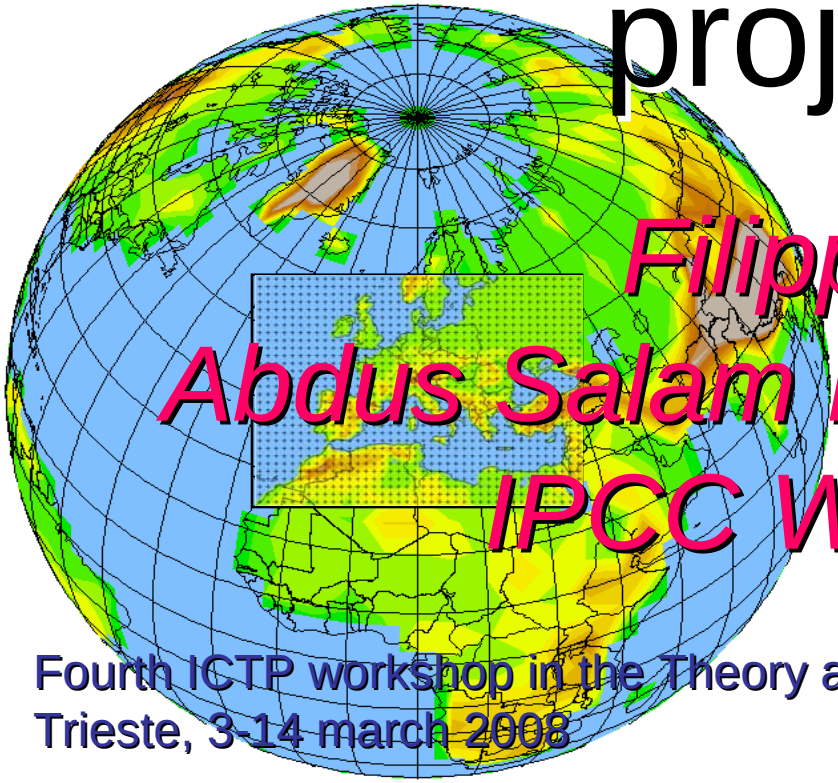
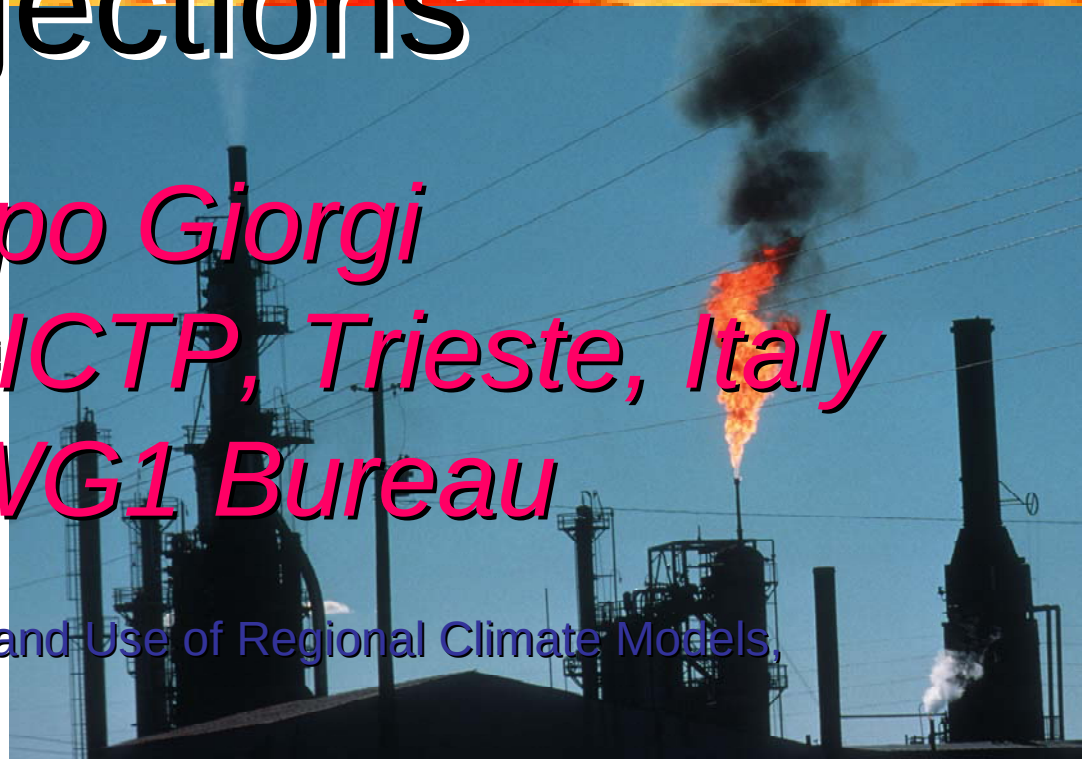


Uncertainty in RCM-based regional climate change projections

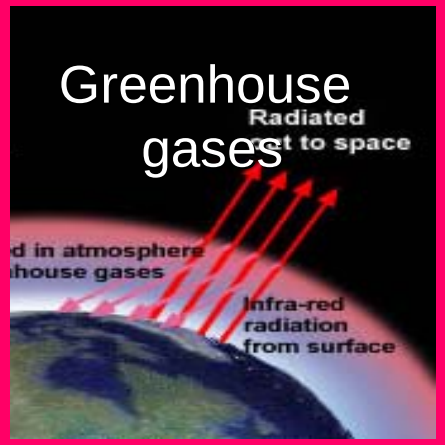


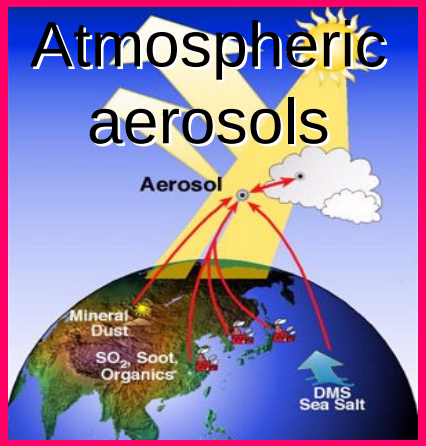
Filippo Giorgi
Abdus Salam ICTP, Trieste, Italy
IPCC WG1 Bureau

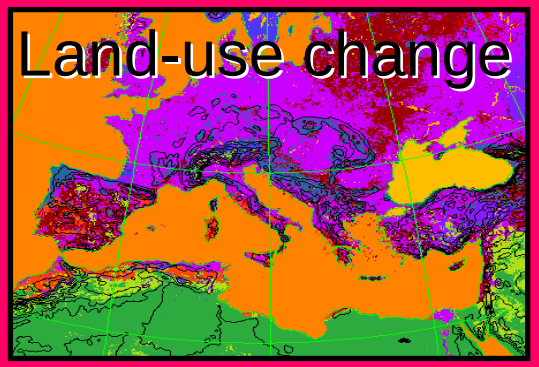


Fourth ICTP workshop in the Theory and Use of Regional Climate Models,
Trieste, 3-14 march 2008

Human factors

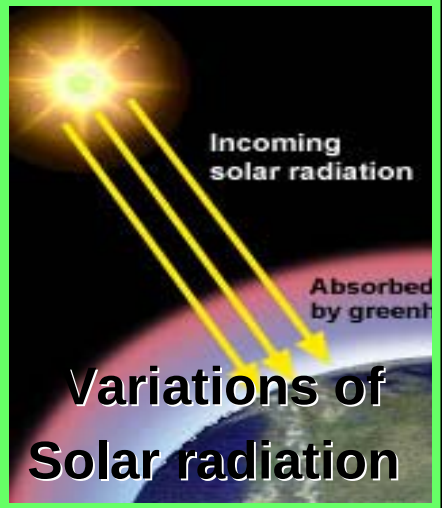


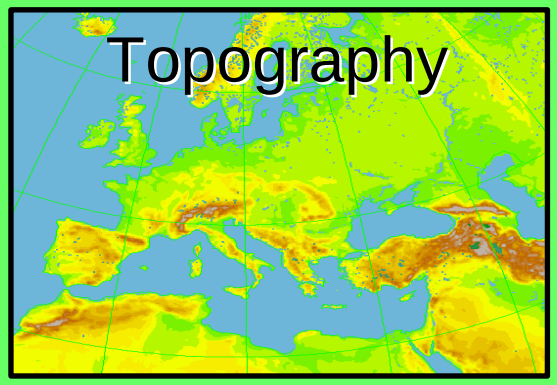




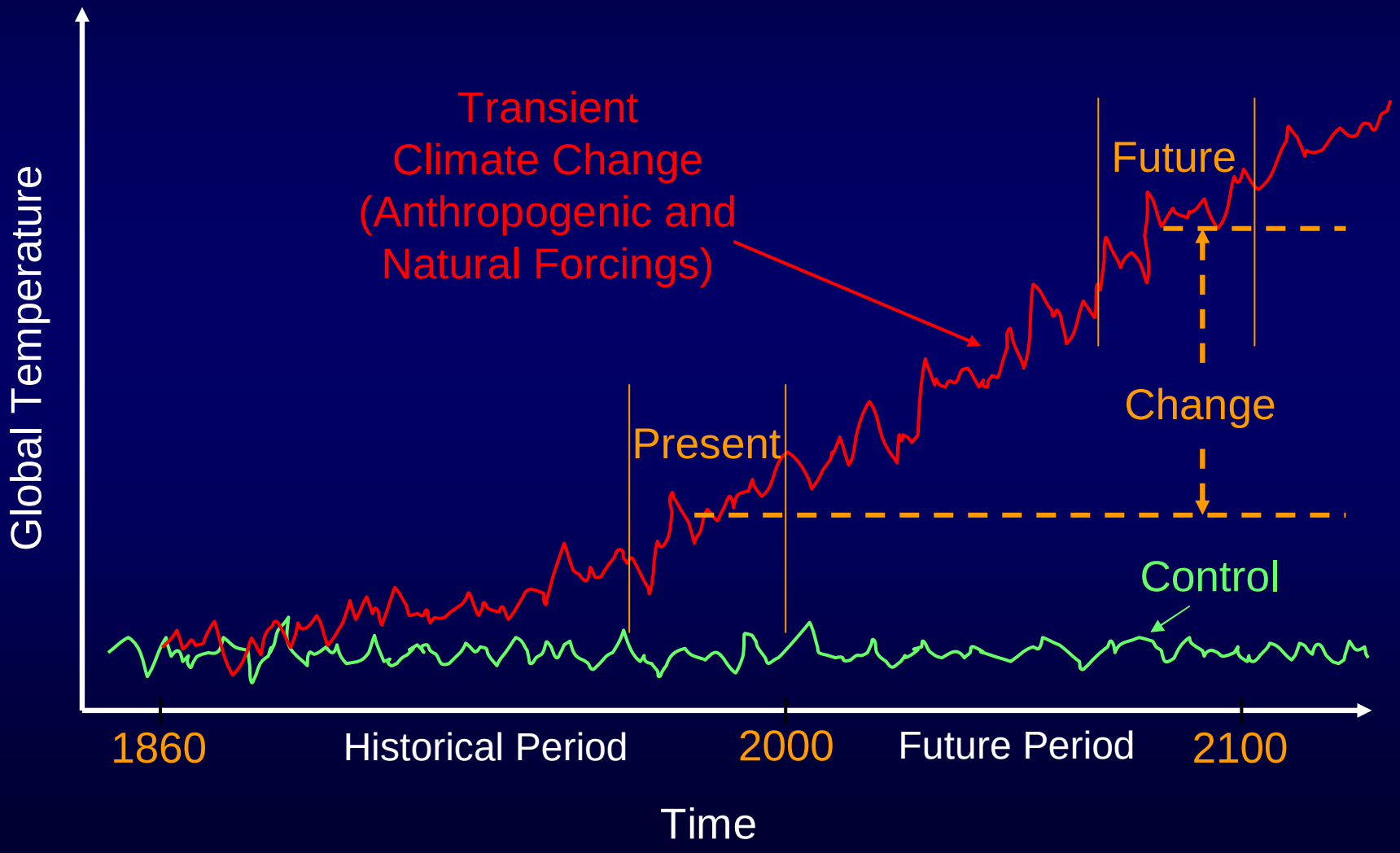
Different natural and human factors need to be accounted for in climate change studies

Natural factors



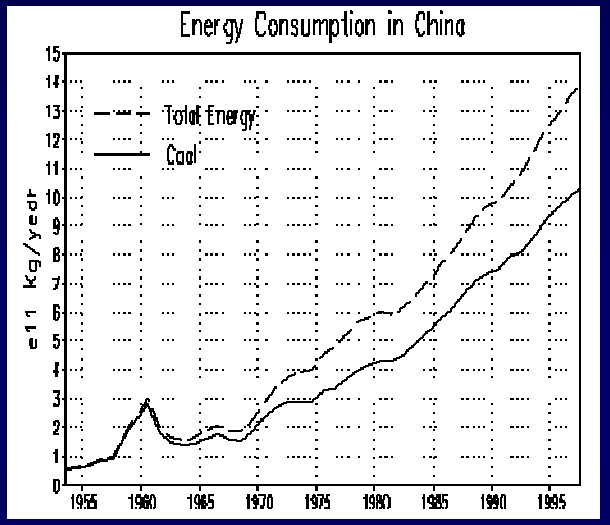


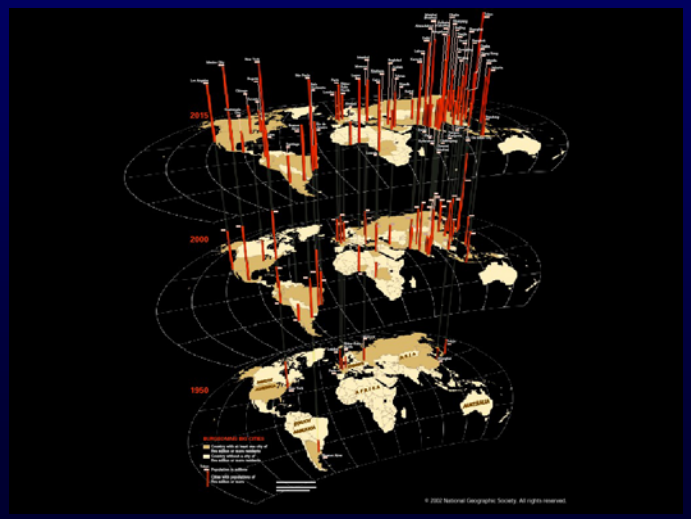
A Transient Climate Change Simulation



SOURCES OF UNCERTAINTY IN CLIMATE CHANGE PREDICTION

Intrinsic sources of uncertainty in climate change prediction: Unpredictability of natural and anthropogenic forcings

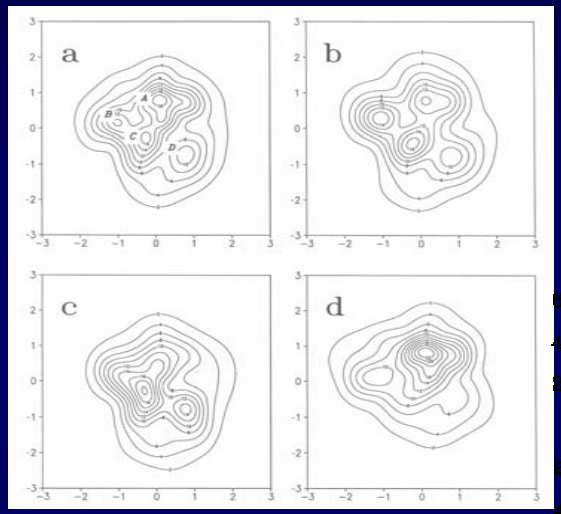




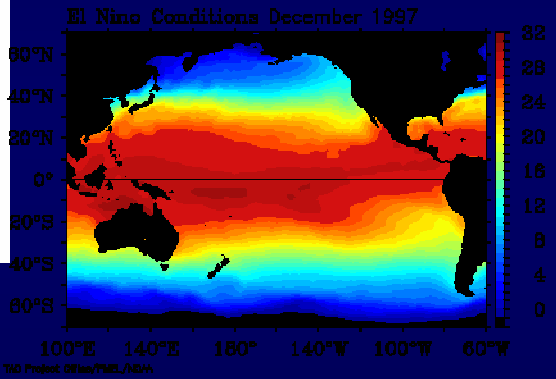
It is impossible to predict major volcanic eruptions or social/technological developments

(scenarios instead of predictions)

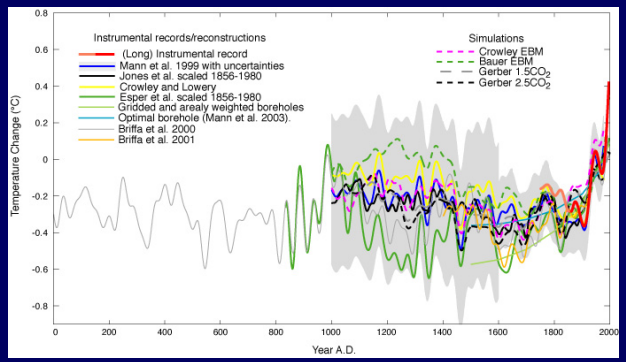
Intrinsic sources of uncertainty in climate change prediction: Nonlinearities in the climate system



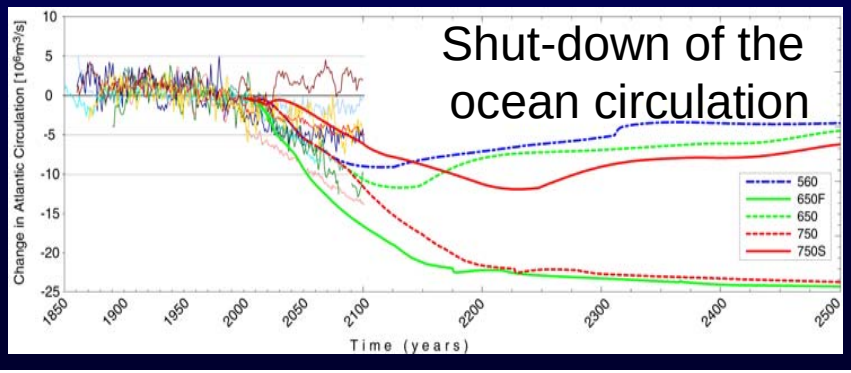
Internal modes and regimes

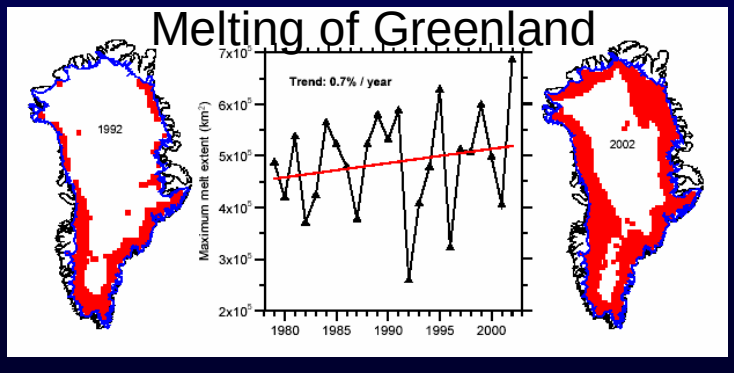


Natural climate variability

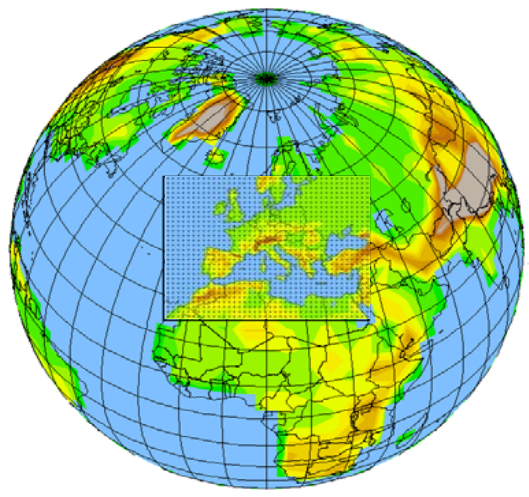


Threshold and feedback behaviors



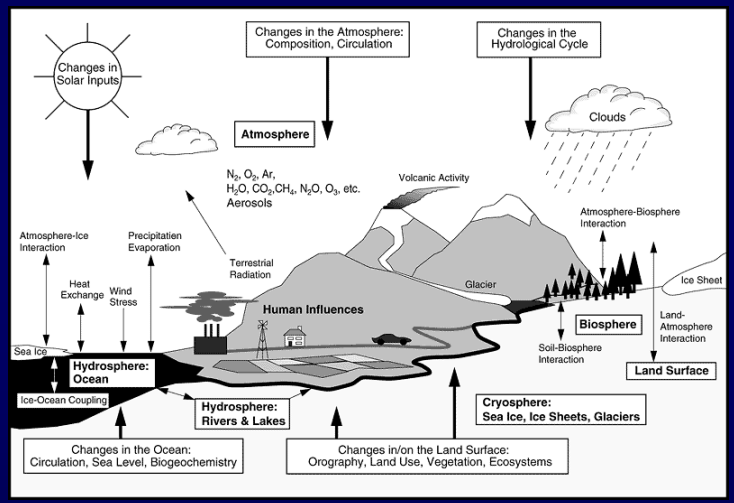


Added sources of uncertainty in climate change prediction: Imperfect knowledge



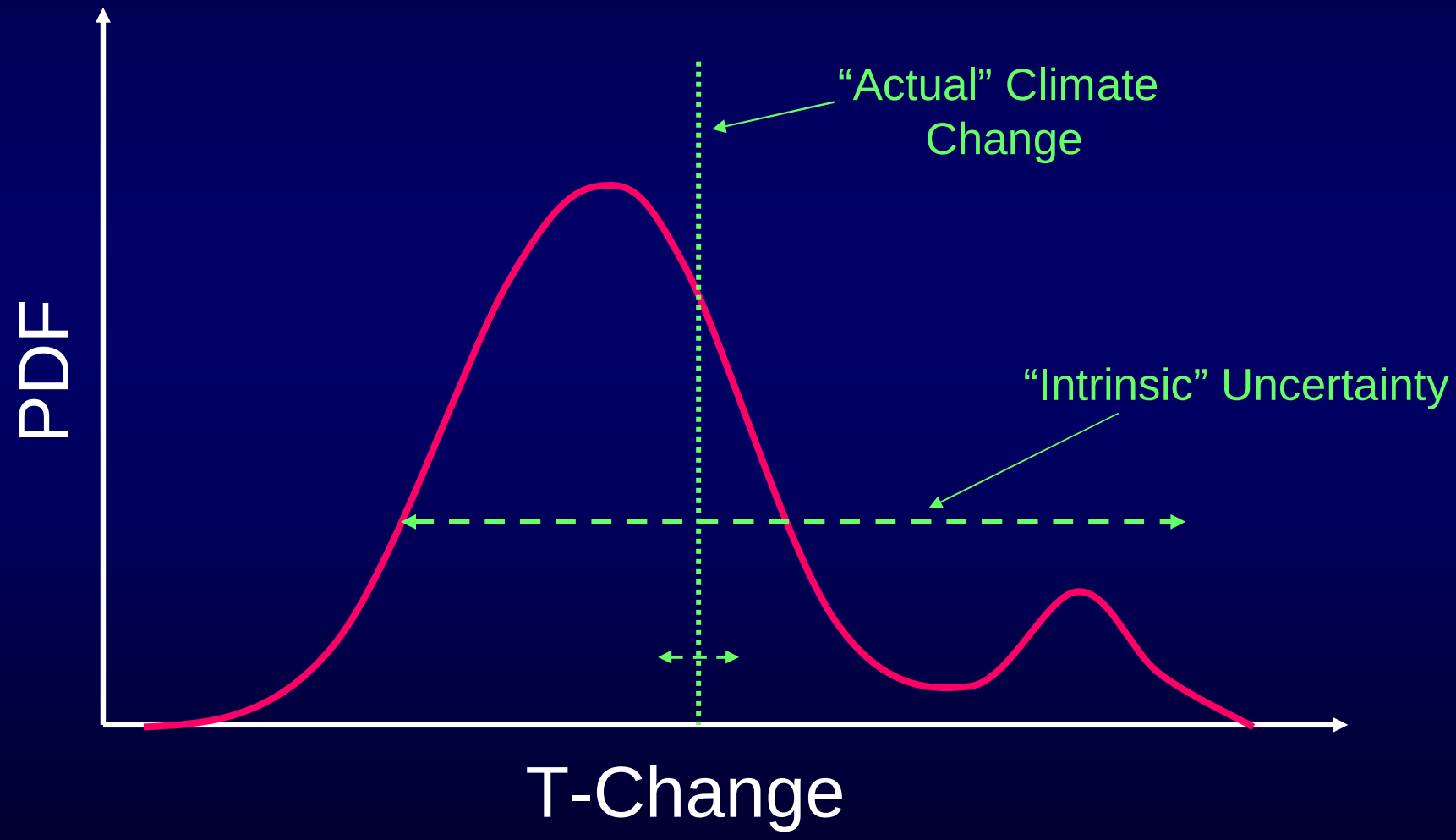
Models

Processes

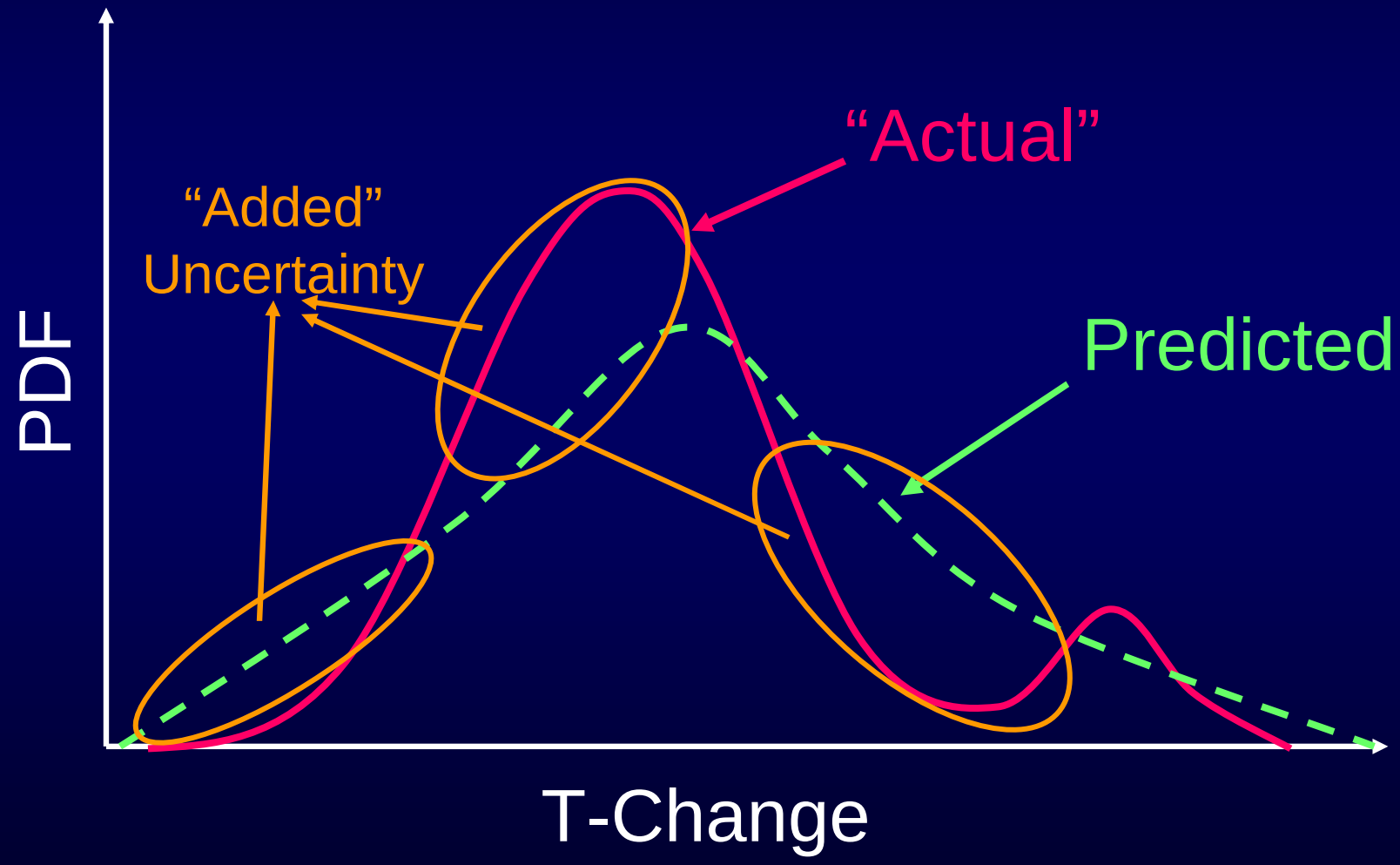


Observations
(model validation,
initial conditions)

“Actual” Climate Change PDF

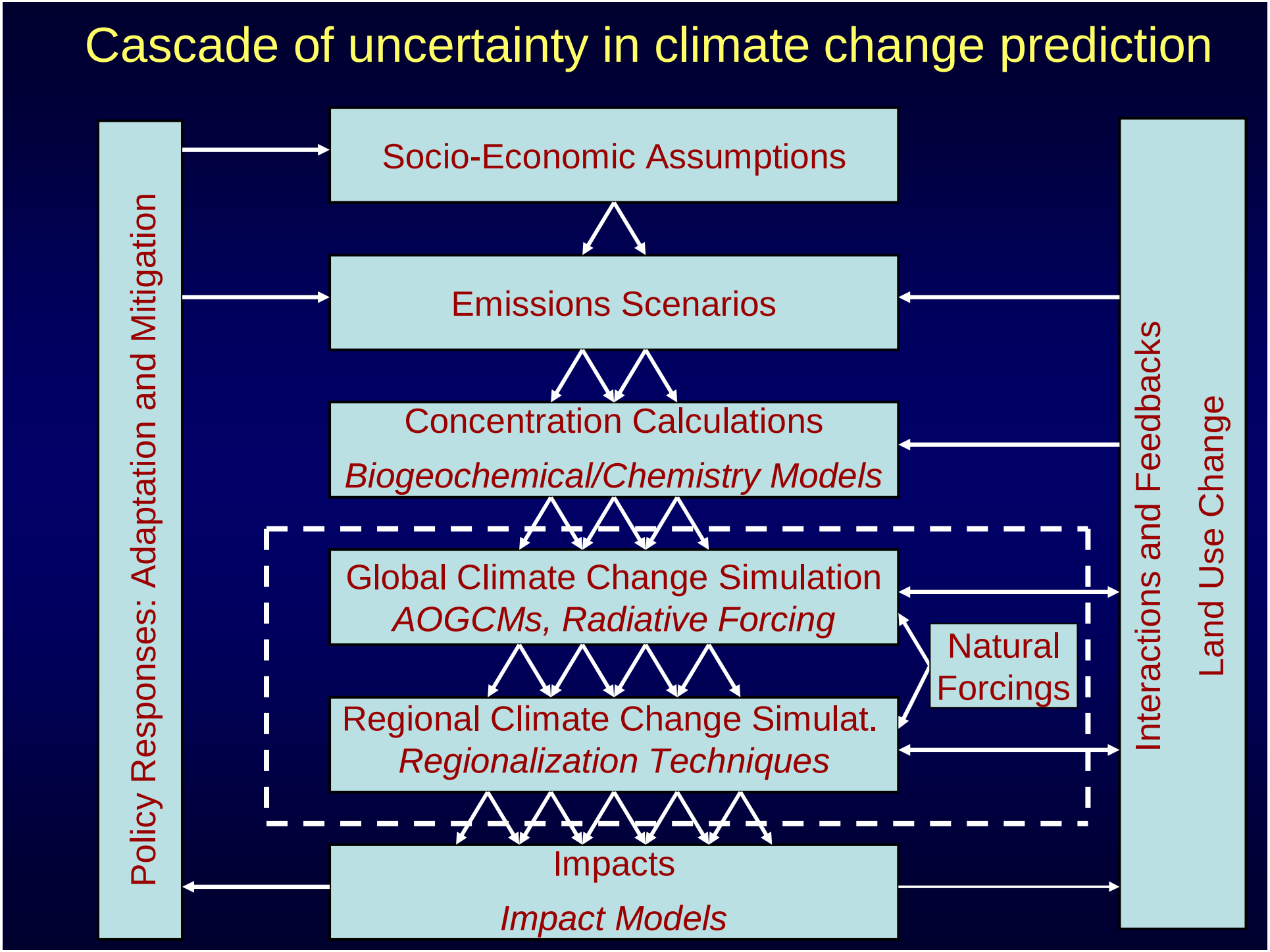


Predicted vs. “Actual” Climate Change PDF

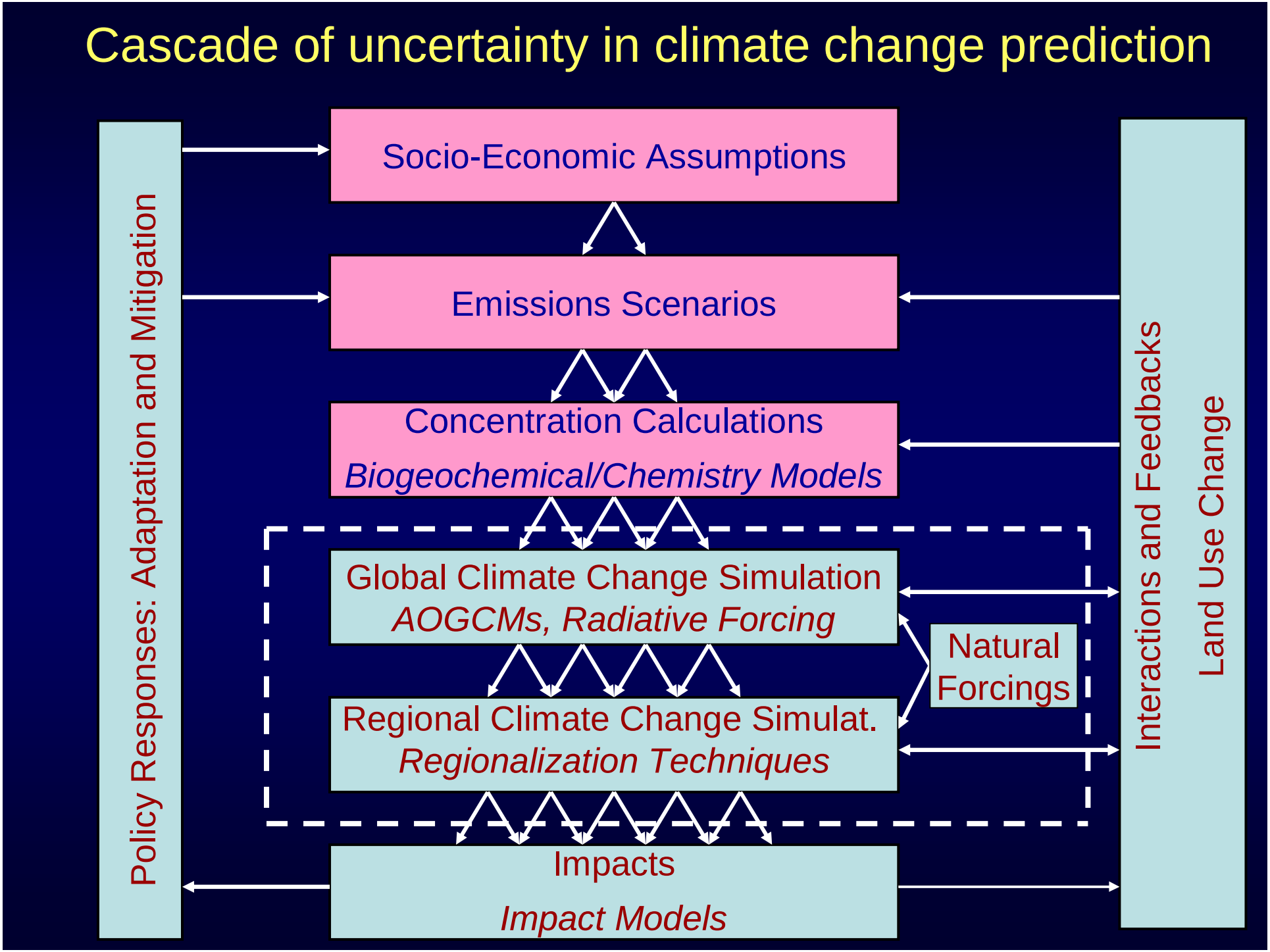


HOW DO WE CHARACTERIZE UNCERTAINTIES IN CLIMATE CHANGE PREDICTION

Cascade of uncertainty in climate change prediction

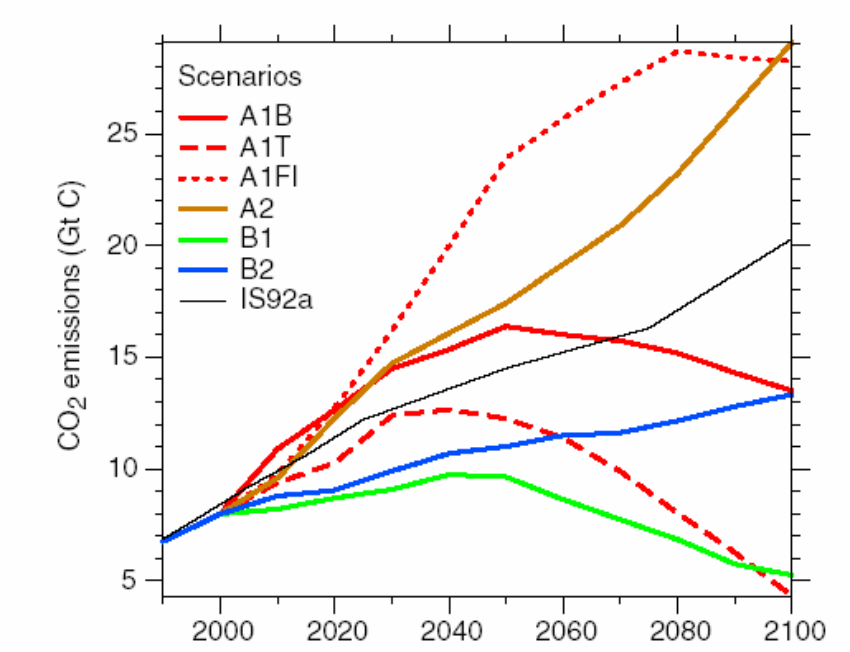


Cascade of uncertainty in climate change prediction

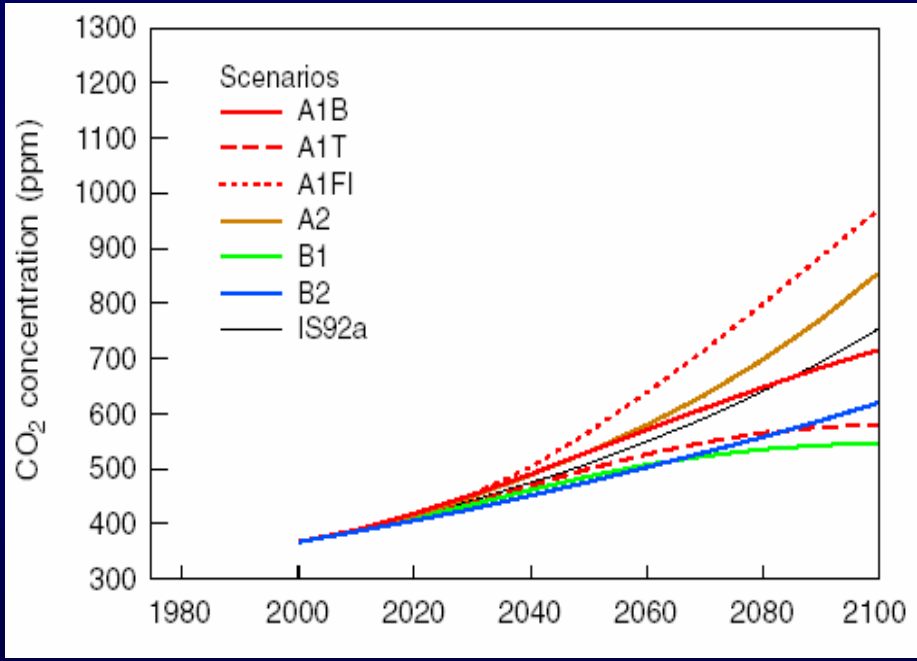


IPCC Emission and Concentration Scenarios

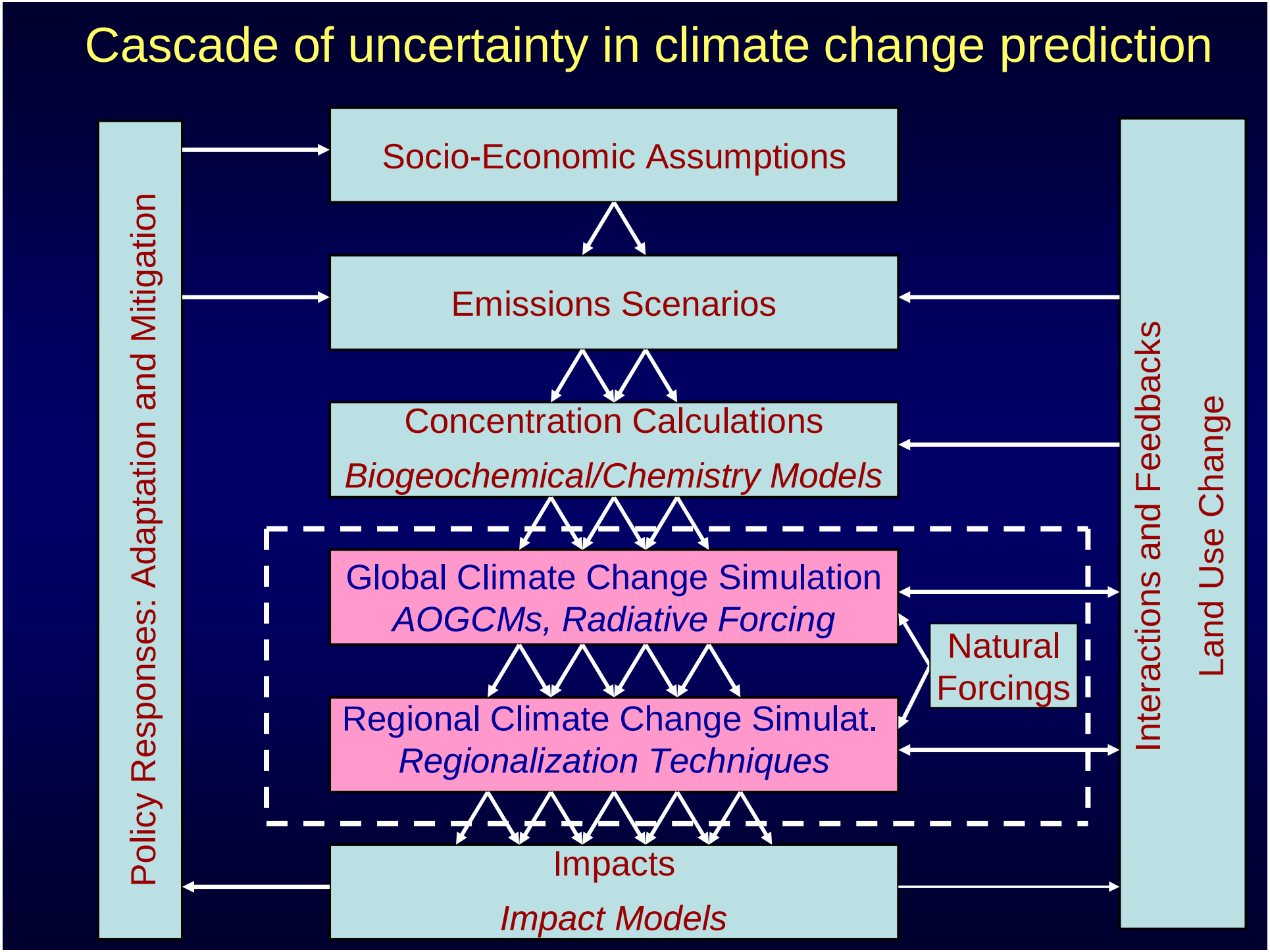
CO2 Emissions



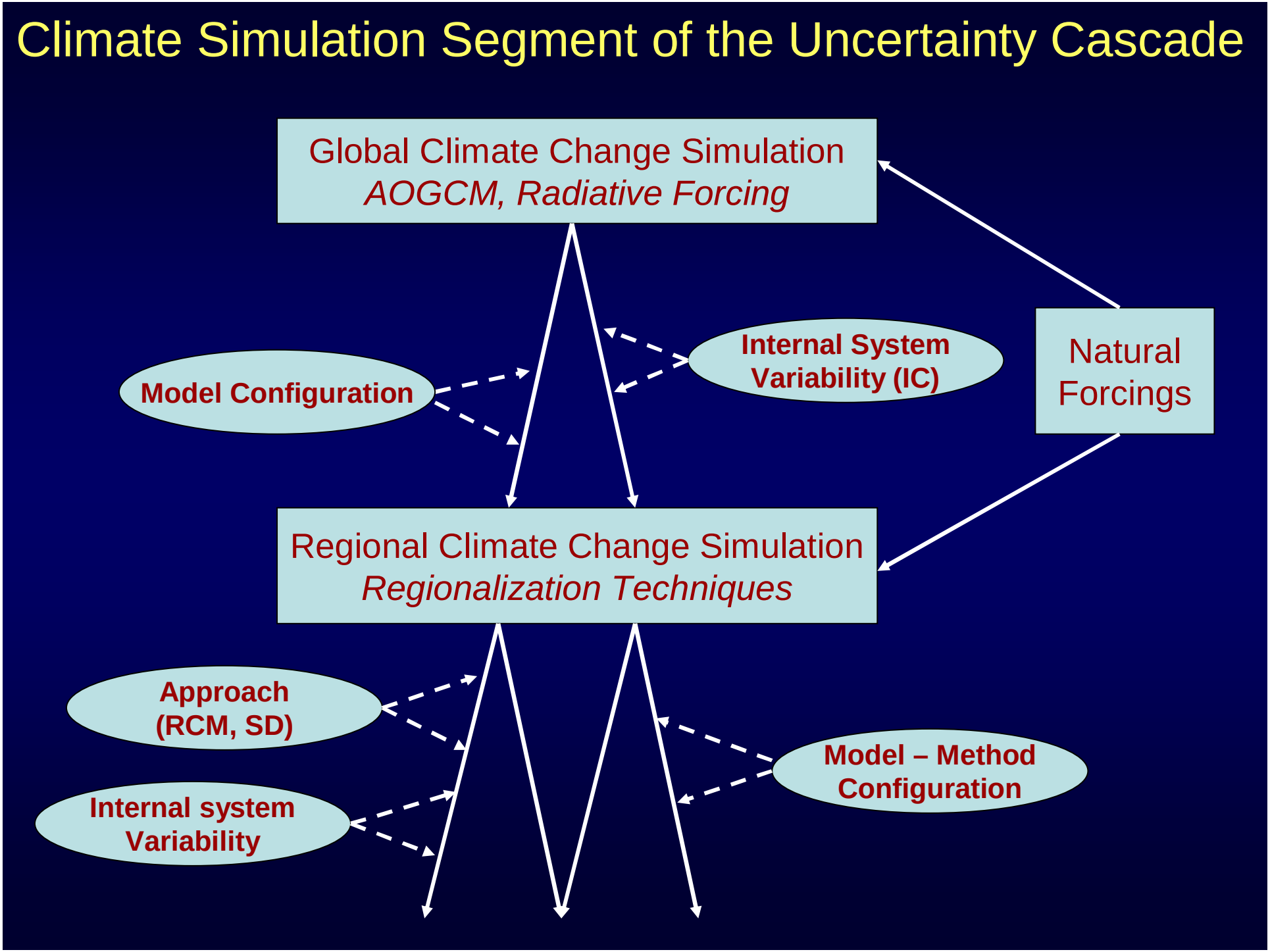
CO2 Concentrations



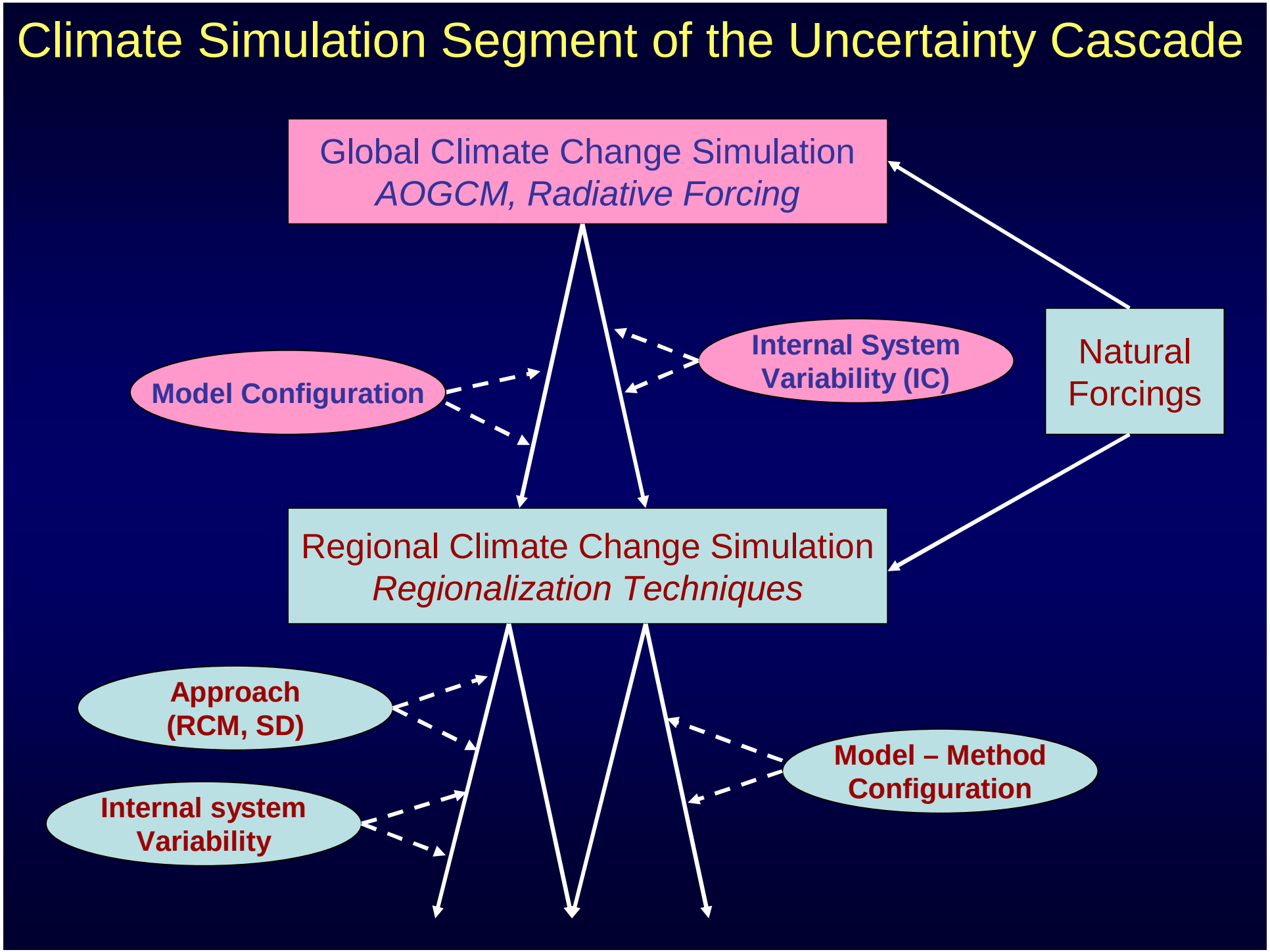
Cascade of uncertainty in climate change prediction



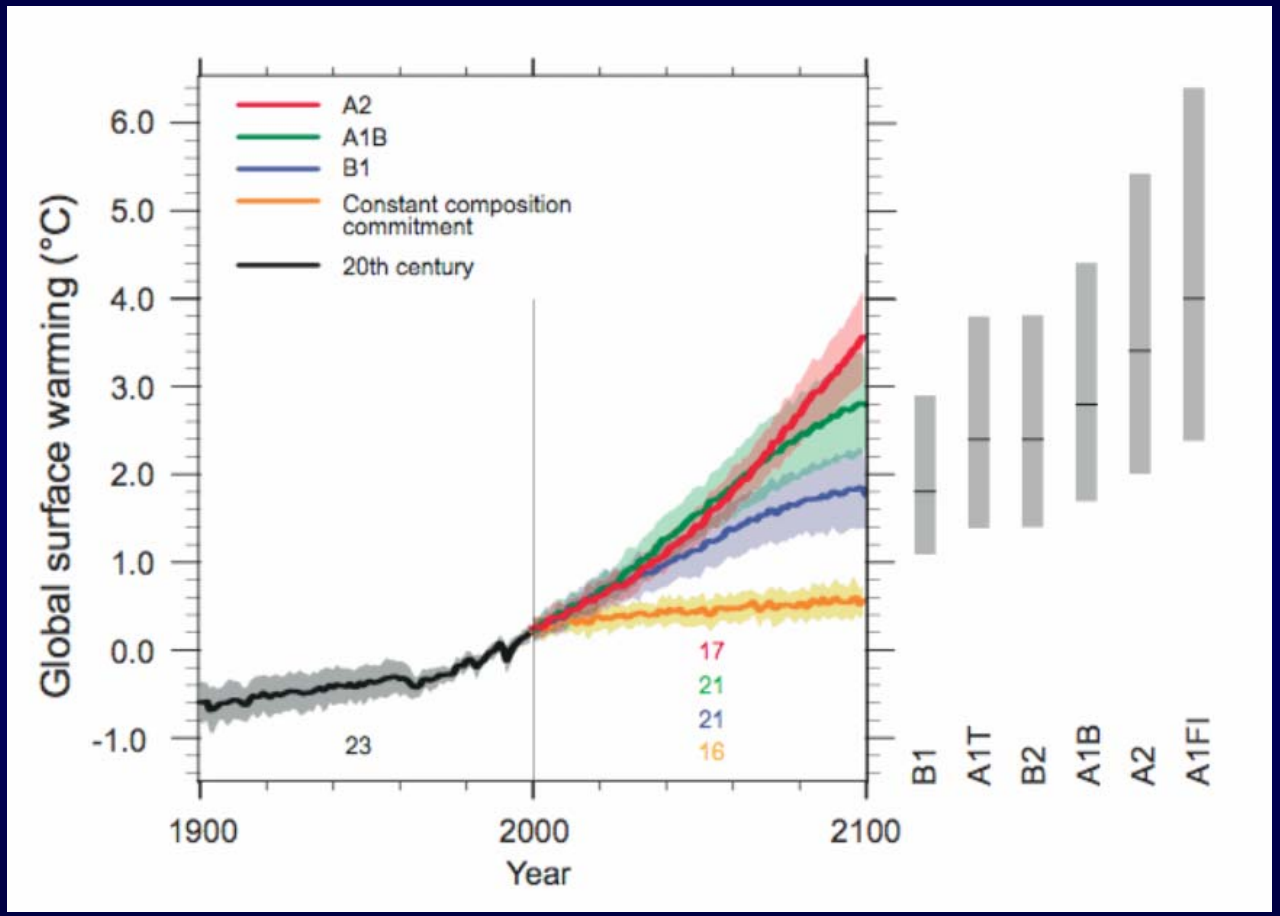
Climate Simulation Segment of the Uncertainty Cascade



Climate Simulation Segment of the Uncertainty Cascade

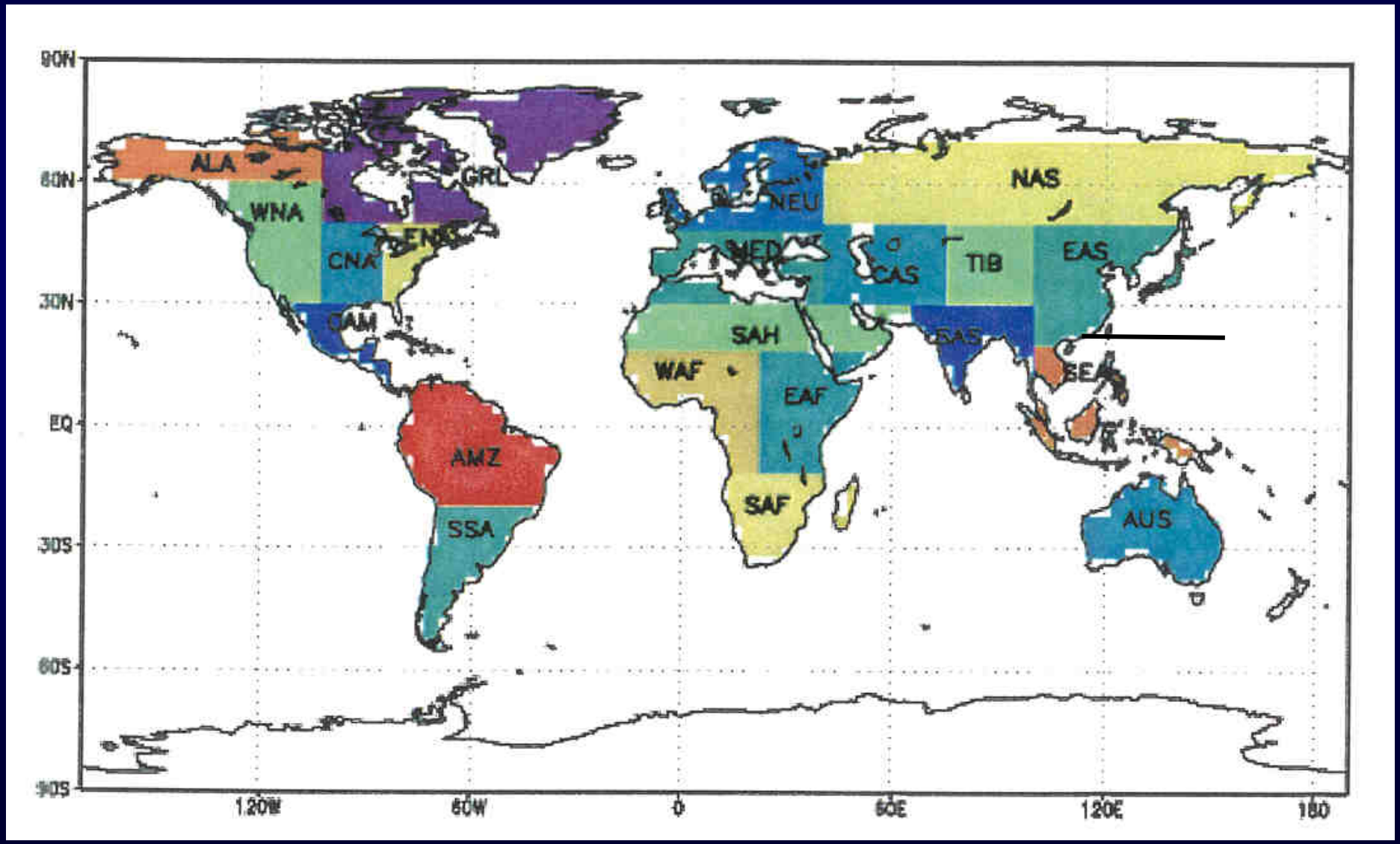


IPCC – 2007: Global temperature change projections for the 21st century

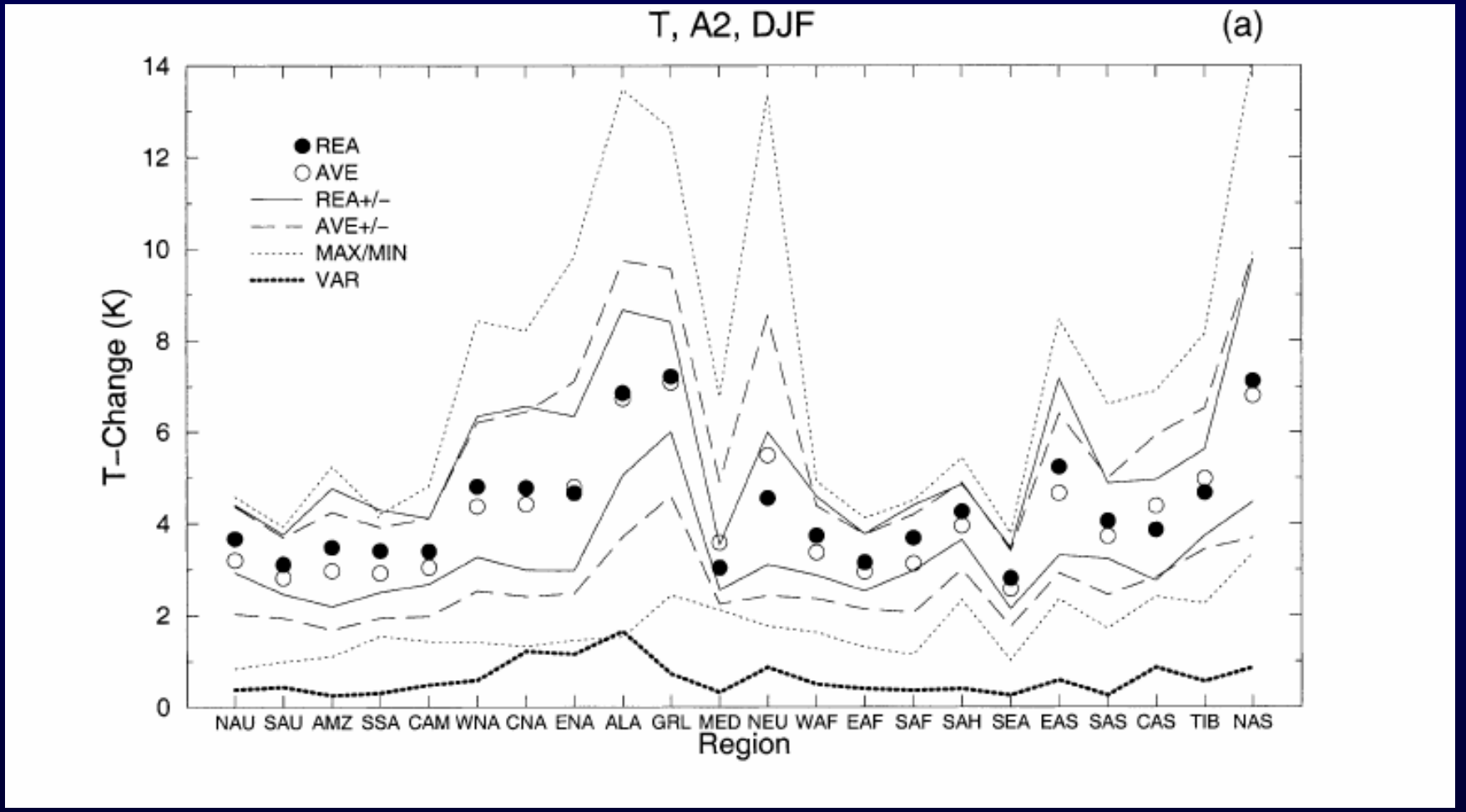


Model configuration and scenario uncertainty contribute approximately equally to the global warming projection uncertainty

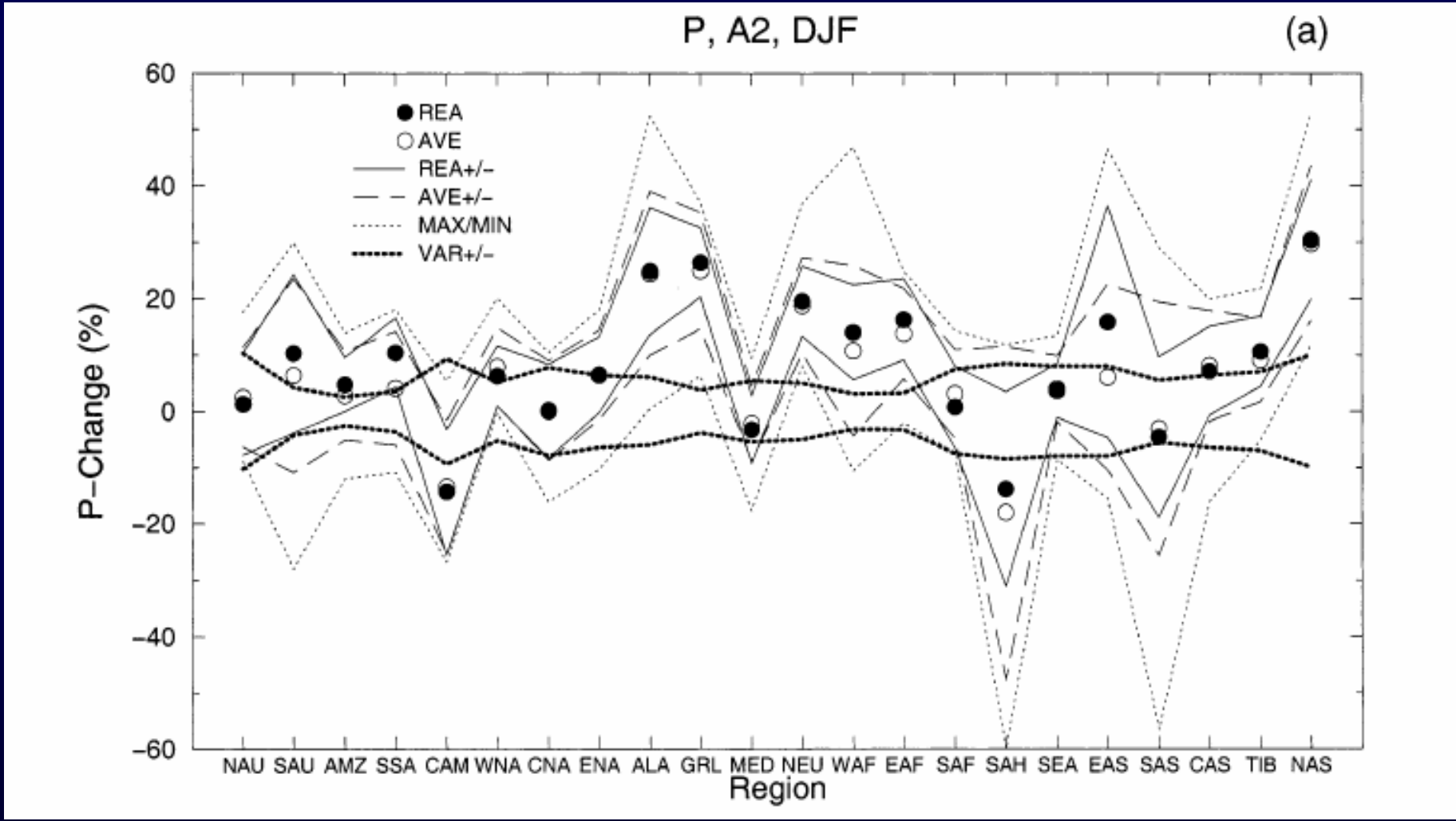
Model configuration uncertainty
Regional scale



Regional Temperature Change A2, DJF, 9 AOGCMs

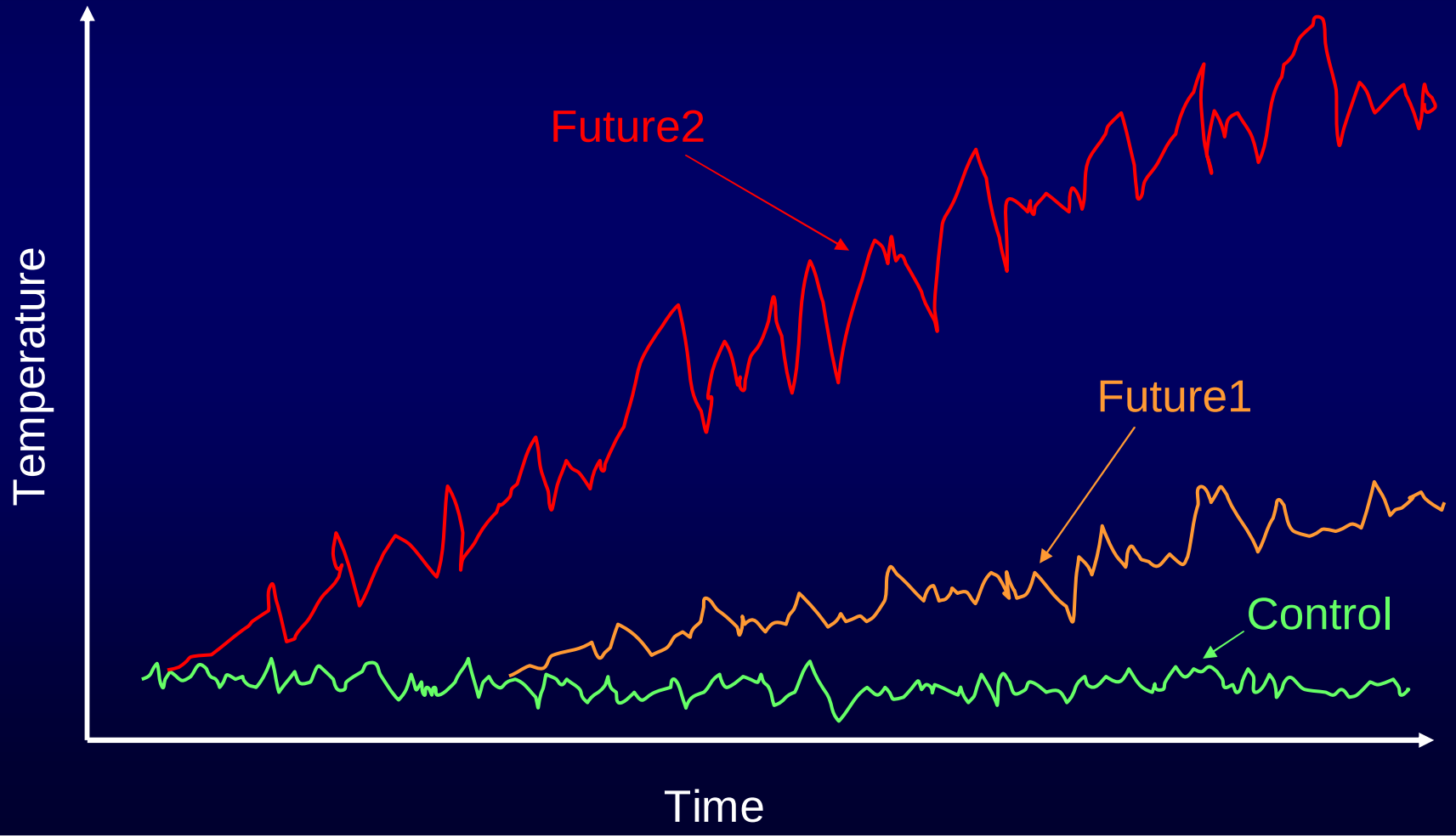


Regional Precipitation Change A2, DJF, 9 AOGCMs

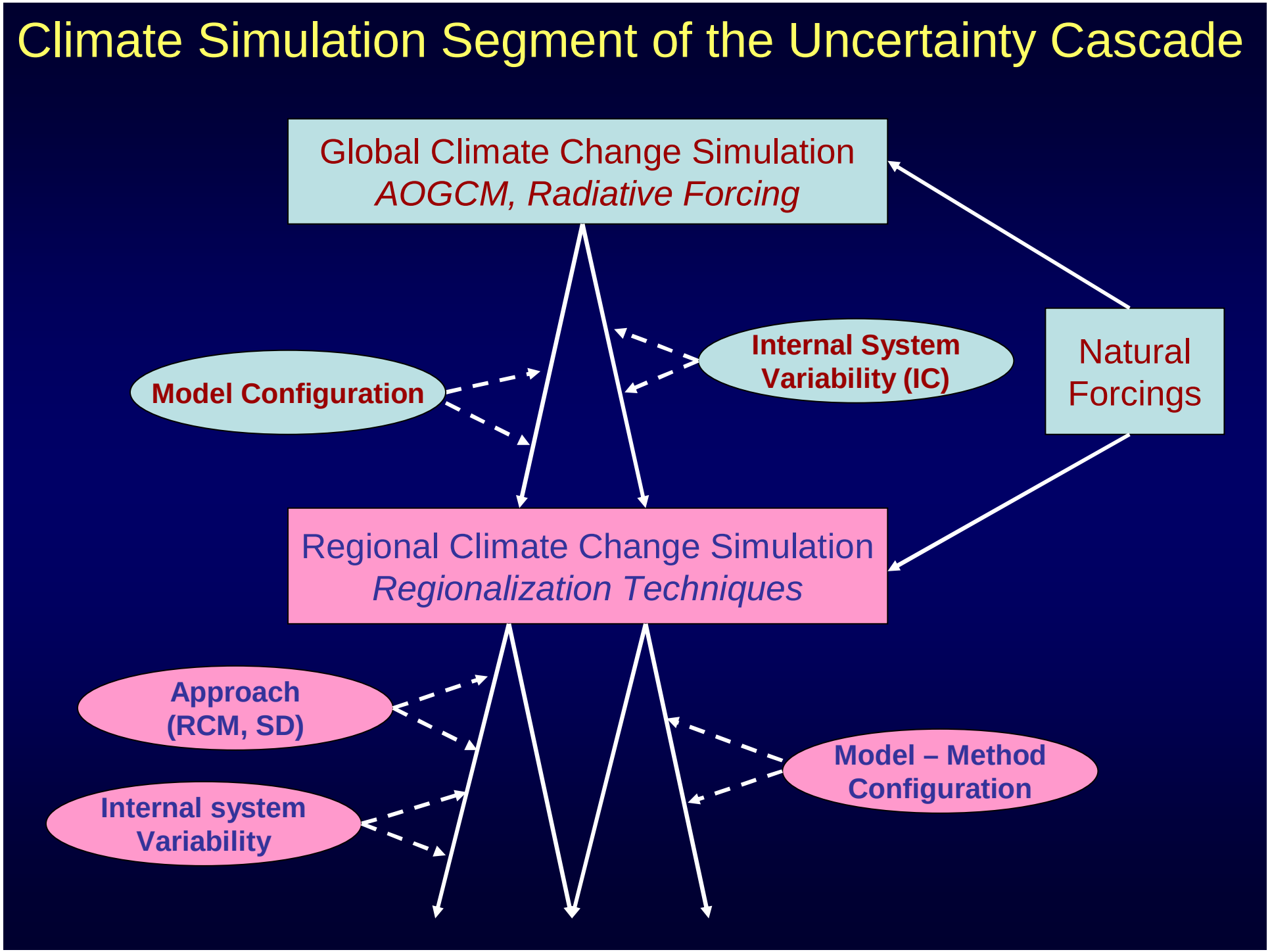


Internal system variability

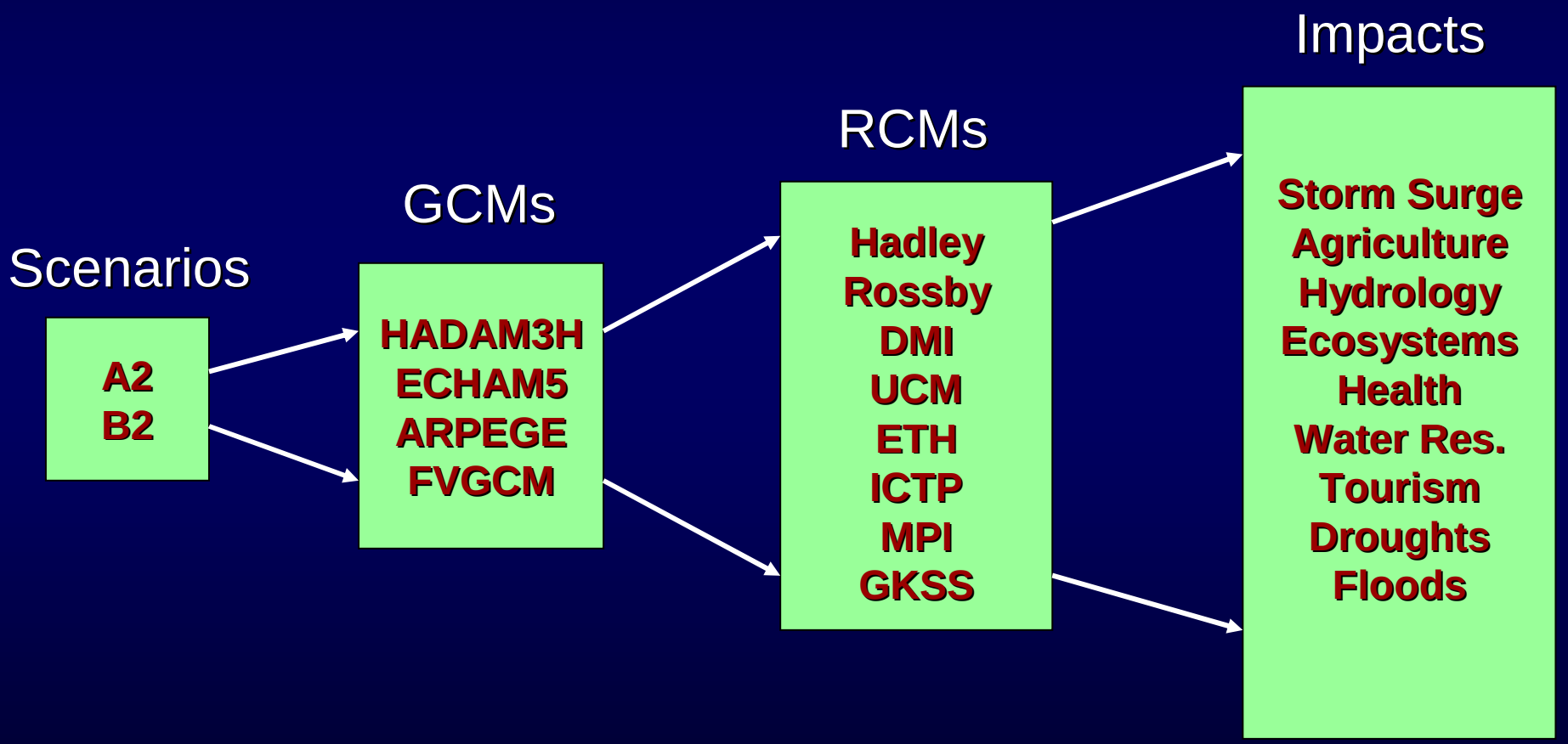
Climate can evolve differently depending on the initial conditions of its slow components (which we do not know with good accuracy)



Climate Simulation Segment of the Uncertainty Cascade

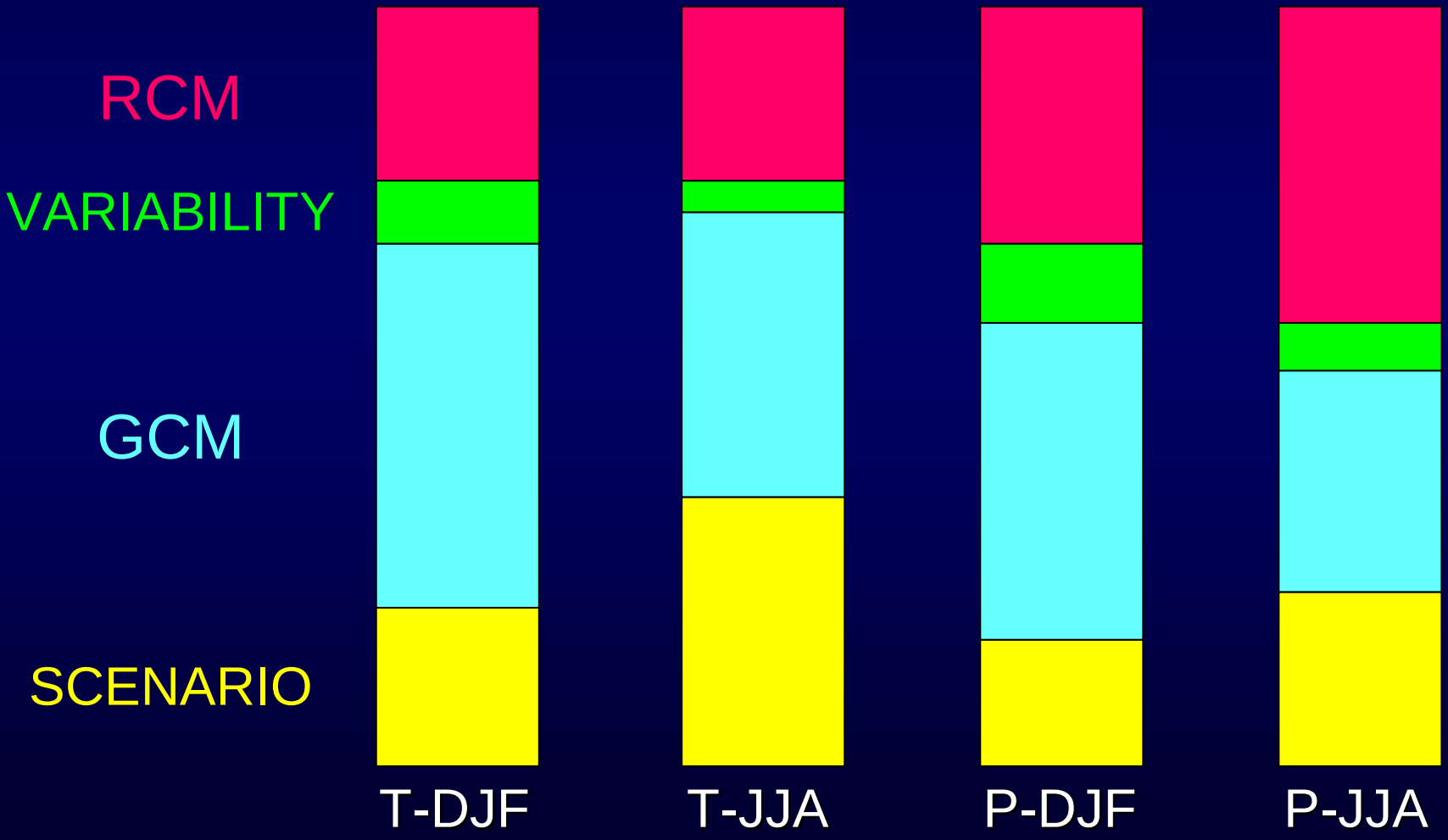


Uncertainties in regional climate change projections: The PRUDENCE strategy



Sources of uncertainty in the simulation of temperature and precipitation change (2071-2100 minus 1961-1990) by the ensemble of PRUDENCE simulations (whole Europe)

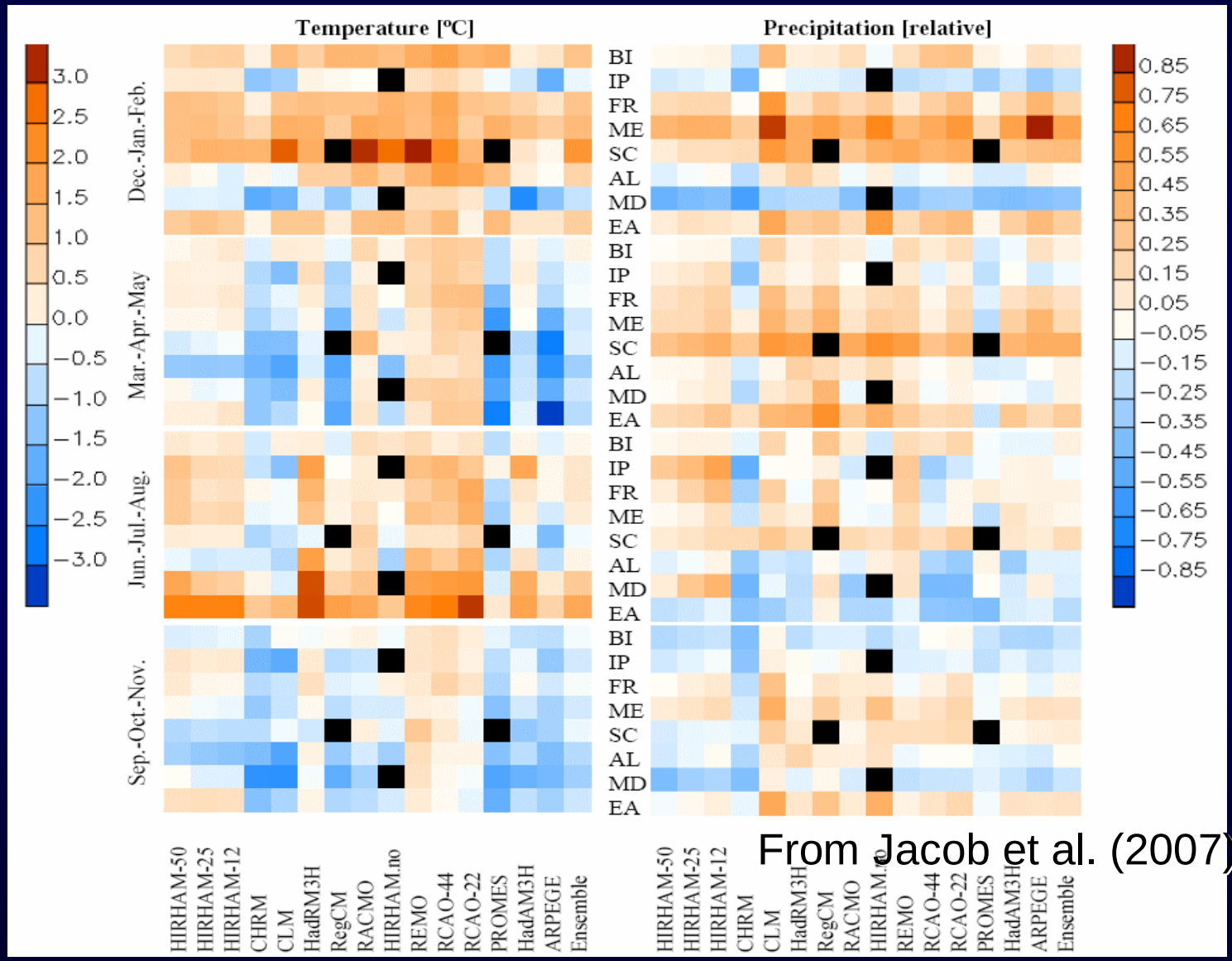
(Note: the scenario range is about half of the full IPCC range, the GCM range does not cover the full IPCC range) (Adapted from Deque et al. 2006)



Where does the RCM uncertainty bar come from?

- Use of different dynamics and physics schemes in the models
  - For the same set of LBC different physics schemes provide different simulations of precipitation and other variables
  - The effect is especially important in summer, when local processes are most effective

Performance of the PRUDENCE models over different European sub-regions



From Jacob et al. (2007)

Where does the RCM uncertainty bar come from?

- Internal variability of models
  - For the same set of LBC, small perturbations to the IC or LBC produce different simulations which constitute a background variability noise
  - Any physical signal should be outside this background noise

Internal variability experiments over East Asia (Giorgi and Bi 2000)

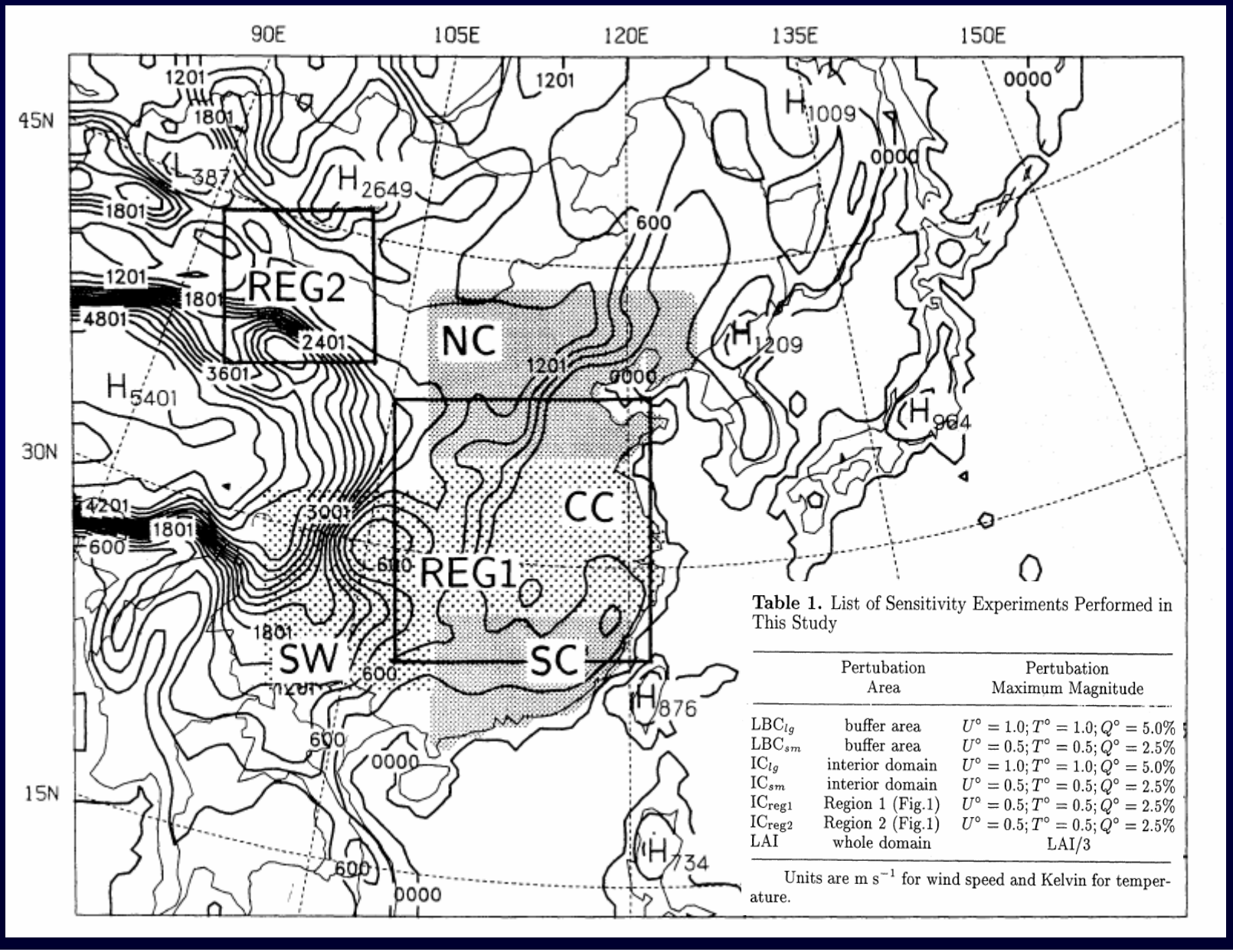
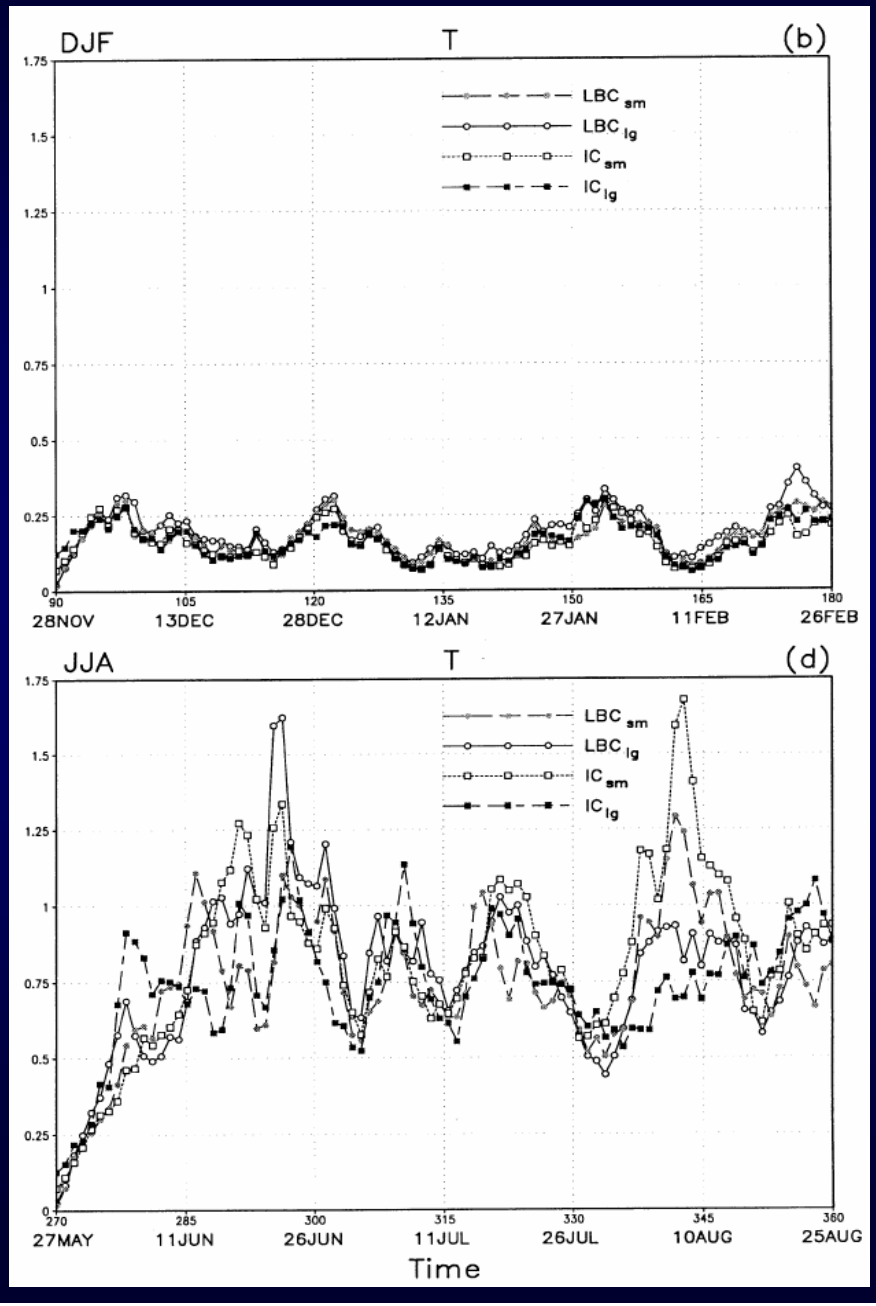


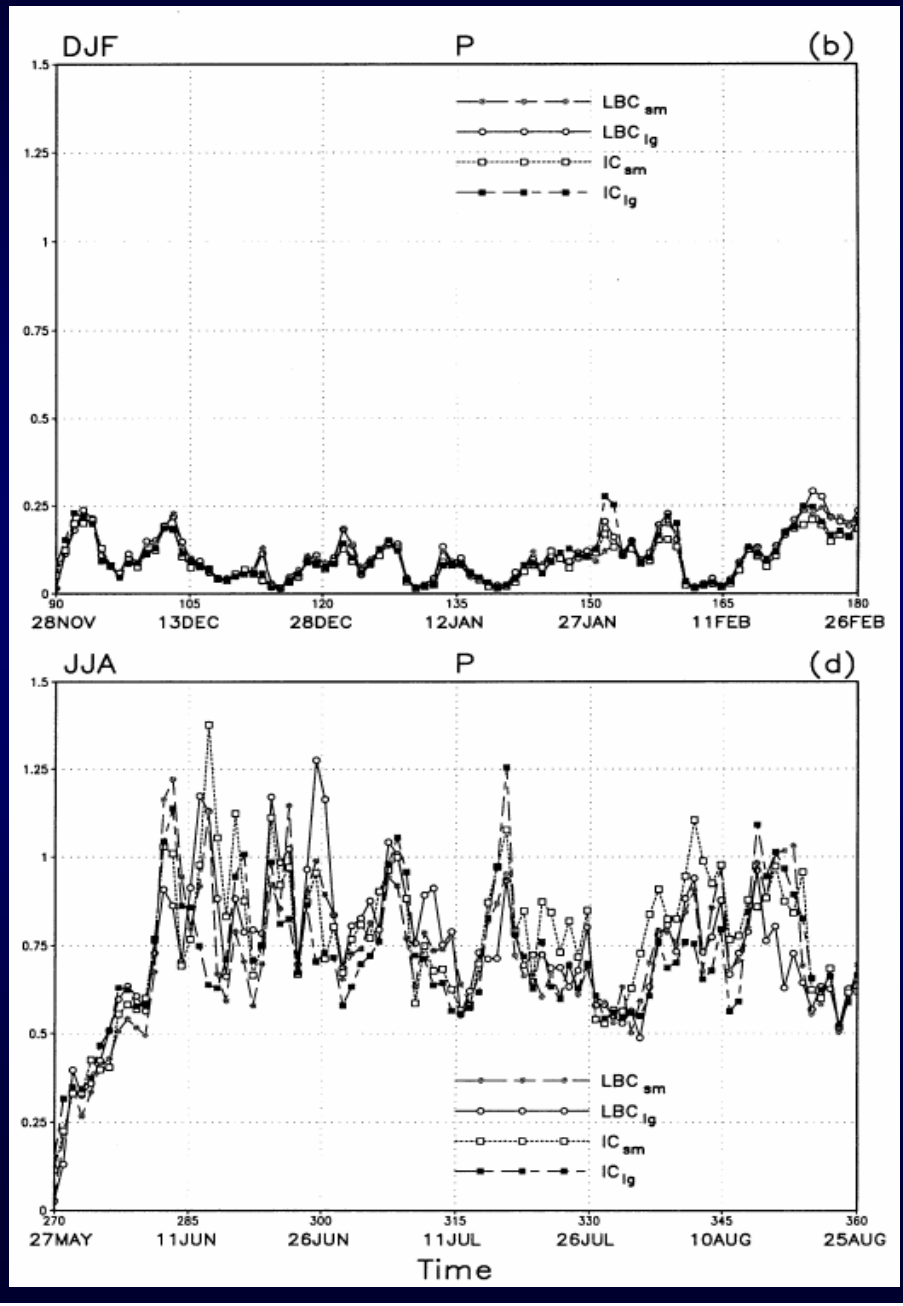
Table 1. List of Sensitivity Experiments Performed in This Study

	Pertubation Area	Pertubation Maximum Magnitude
LBC_{lg}	buffer area	$U^\circ = 1.0; T^\circ = 1.0; Q^\circ = 5.0\%$
LBC_{sm}	buffer area	$U^\circ = 0.5; T^\circ = 0.5; Q^\circ = 2.5\%$
IC_{lg}	interior domain	$U^\circ = 1.0; T^\circ = 1.0; Q^\circ = 5.0\%$
IC_{sm}	interior domain	$U^\circ = 0.5; T^\circ = 0.5; Q^\circ = 2.5\%$
IC_{reg1}	Region 1 (Fig.1)	$U^\circ = 0.5; T^\circ = 0.5; Q^\circ = 2.5\%$
IC_{reg2}	Region 2 (Fig.1)	$U^\circ = 0.5; T^\circ = 0.5; Q^\circ = 2.5\%$
LAI	whole domain	LAI/3

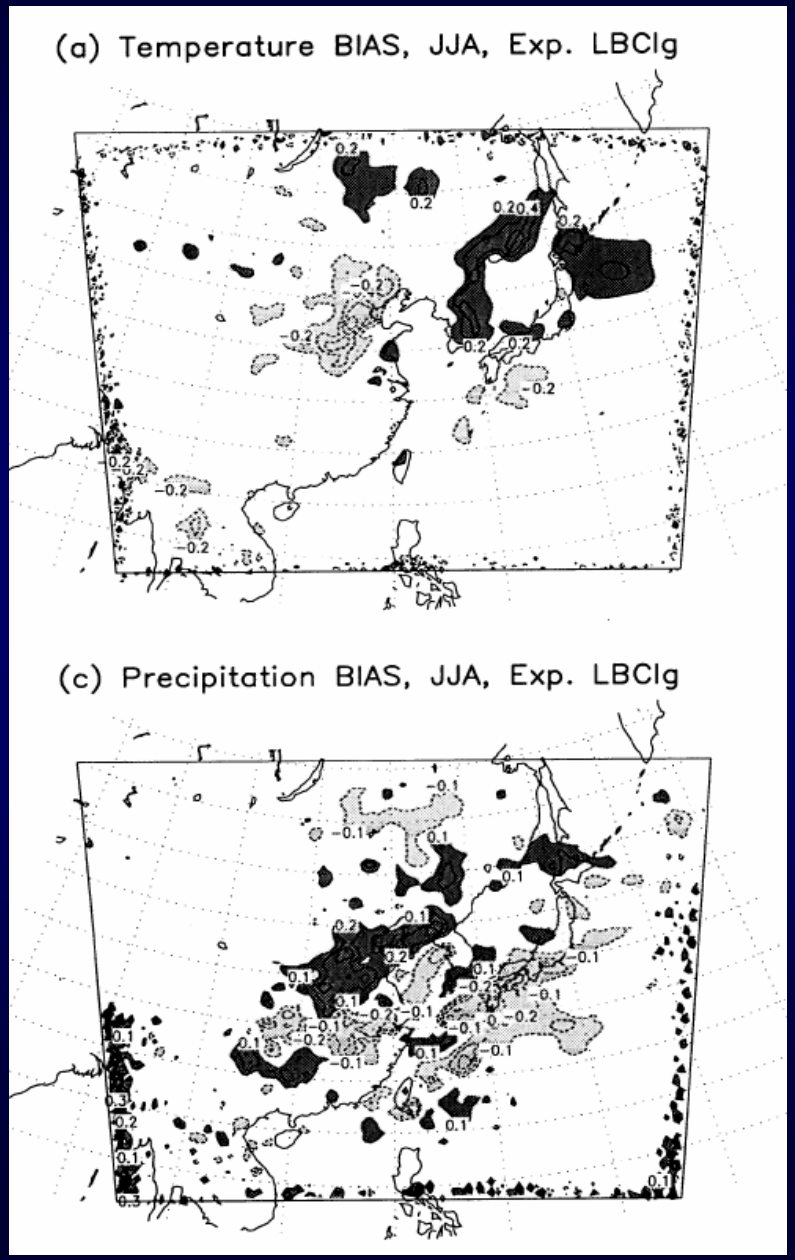
Units are m s^{-1} for wind speed and Kelvin for temperature.

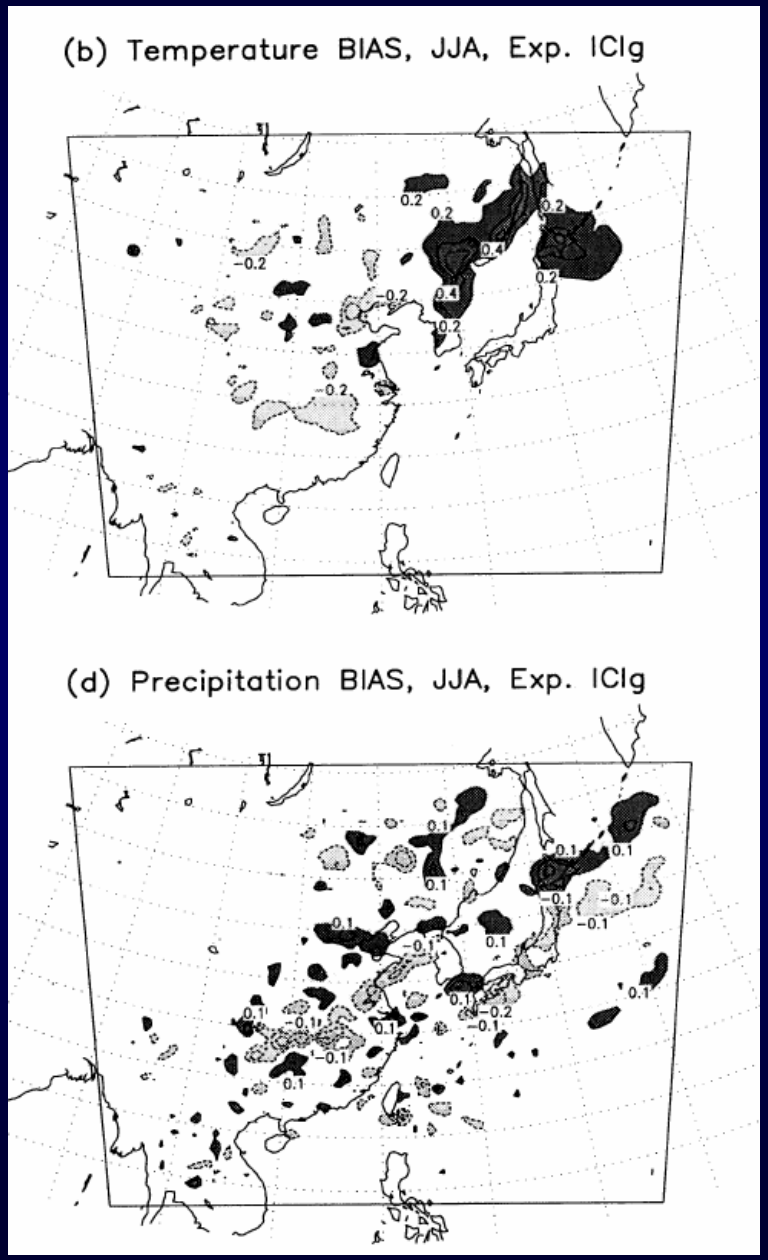
Sensitivity to initial and lateral boundary conditions





Sensitivity to initial and lateral boundary conditions





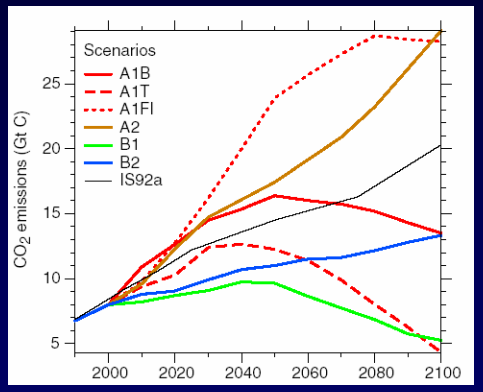
Where does the RCM uncertainty bar come from?

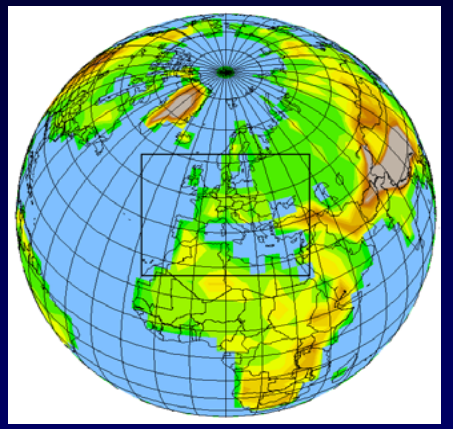
- LBC assimilation procedure
  - The LBC assimilation requires interpolation of driving fields in the lateral buffer zone, which is presumably done differently in different models
  - Different LBC assimilation techniques are used (e.g. relaxation vs. nudging)
  - Within the same procedure different set up may be used (width of buffer zone, exponential vs. linear relaxation function etc.)

Where does the RCM uncertainty bar come from?

- Choice of domain and configuration
  - Different models use different grid projections and configurations even at the same nominal resolution
  - The choice of domain and resolution generally affects an RCM simulation
  - Different models use different topography and land-use processing

The RCM Uncertainty "Hyper-matrix"





Experiment (i,j,k …)

GCMs

GCM Realizations

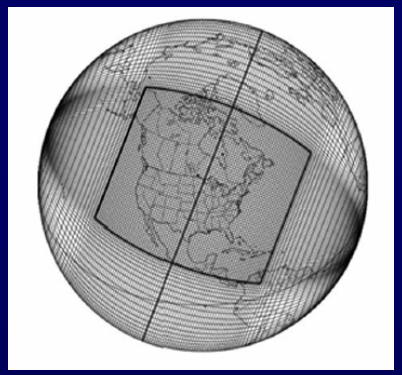
Regions

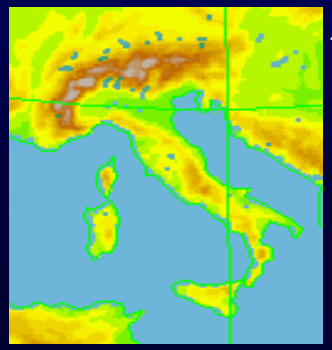
RCMs

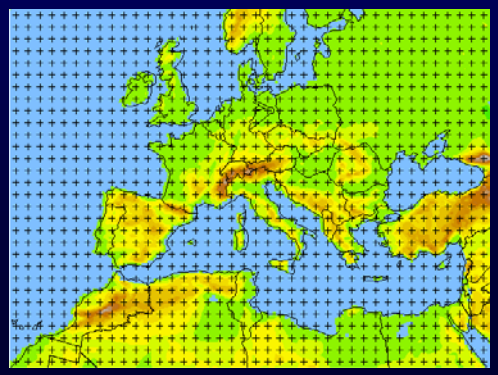
Resolution

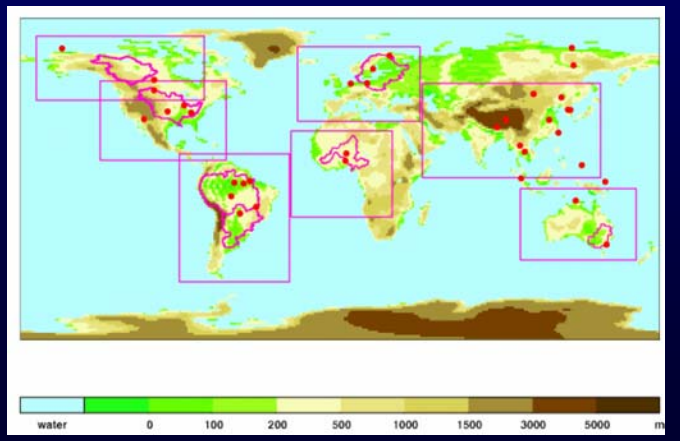
Other Techniques ?

Scenarios







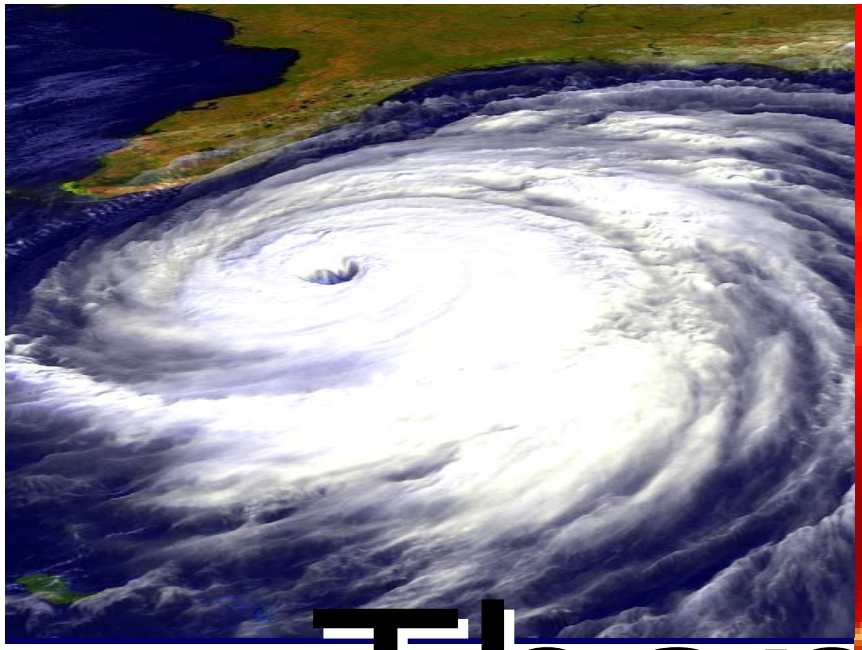


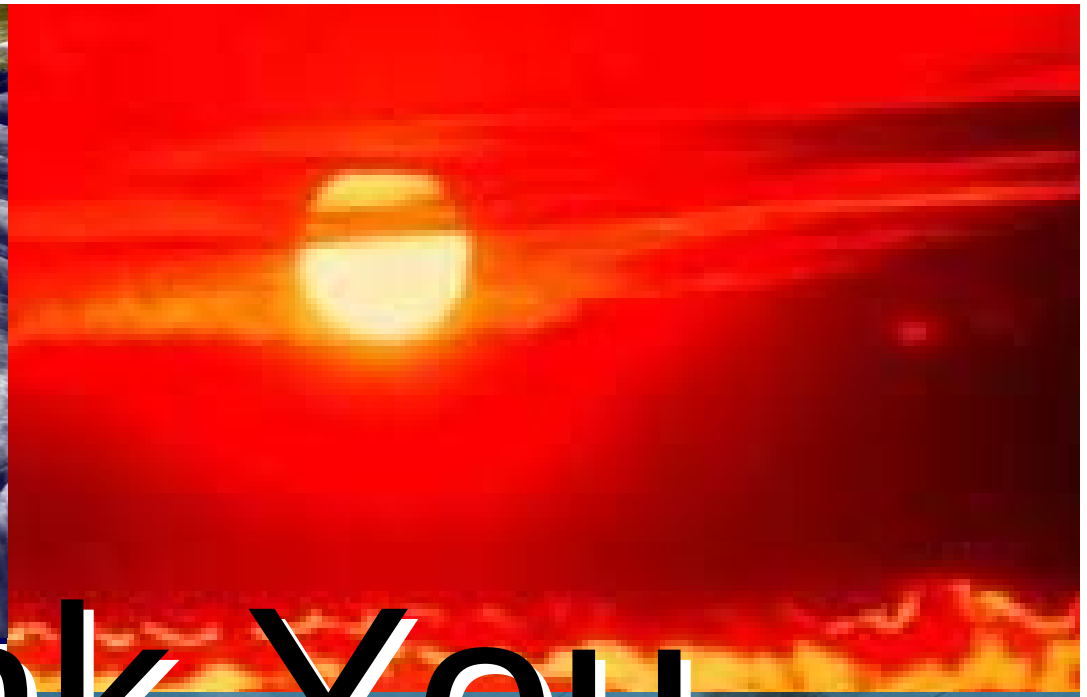
Conclusions

- The uncertainty associated with the use of RCMs (and other regionalization techniques) should be considered within the overall uncertainty cascade in the climate prediction process.
- Recent results from multi-model projects indicate that the uncertainty associated with the RCM process is higher than previously thought, especially at fine spatial scales
- A full characterization of the RCM-related uncertainty requires carefully designed experiments involving a multiplicity of models.
- The need is there of more coordinated and “recognized” multi-model projects (the current ones are still somewhat scattered), therefore …

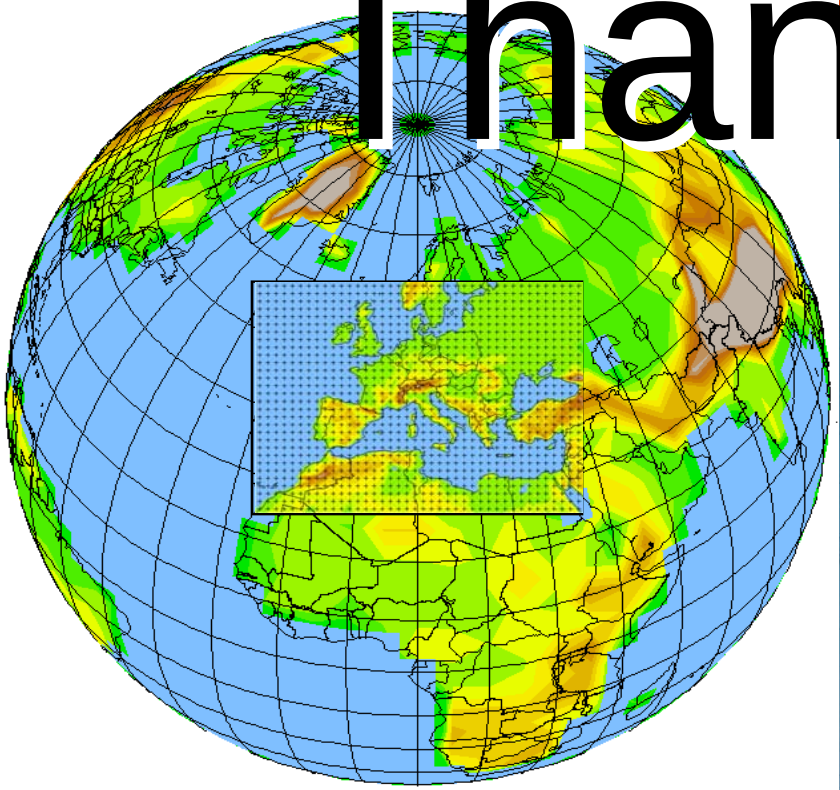
Should we approach WCRP to propose a CMIP-like framework to explore the RCM uncertainty Hyper-matrix ?

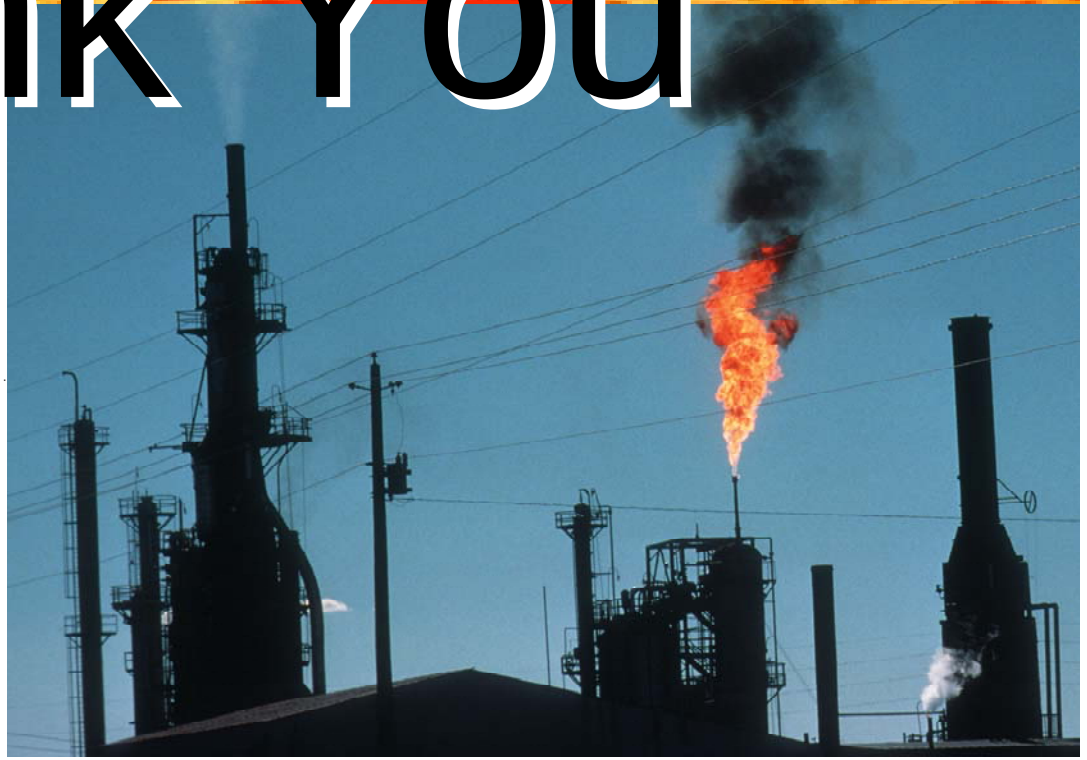
- Several “standard” domains (e.g. Europe, Africa etc.)
- Several “standard” resolutions (e.g. 50, km, 25 km, 10 km)
- Reference period(s) with perfect LBC (e.g. 10 yrs ERA40)
- Set of AOGCM fields for climate change simulations (e.g. 3 time slices, n models) for different scenarios
- Involve a wide community (climateprediction.net-type)
- Ask participants to carry out as many as possible of the experiments above to cover the Hyper-matrix
- Use different computing platforms (“grid” systems, Earth Simulator systems, etc.)
- Connection with the transferability and other intercomparison projects?
- Other regionalization techniques
- Input for AR5 (RCM-based input to AR4 was very limited)
- Do we write a proposal for suitable funding agencies?



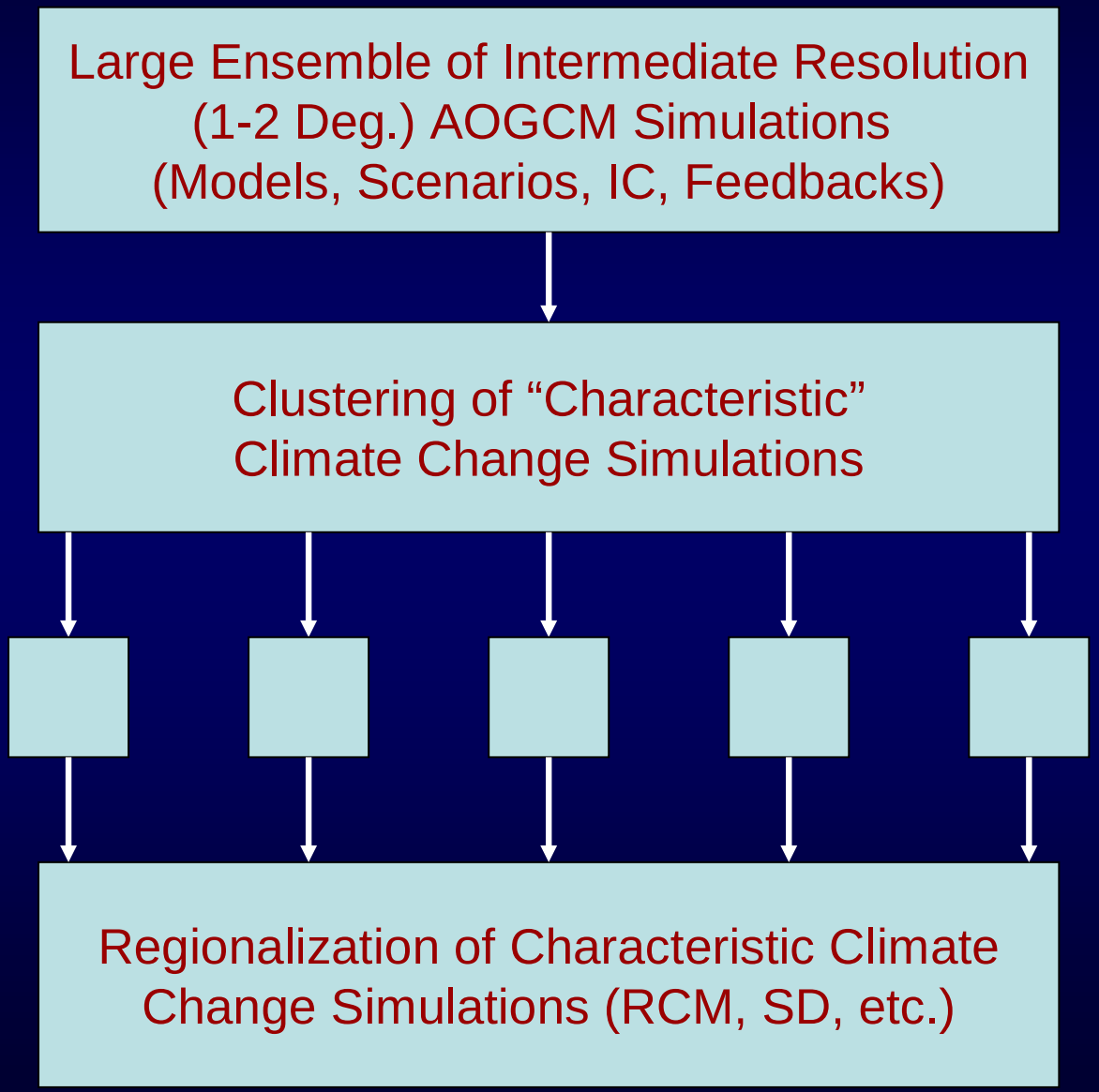


Thank You





A climate change prediction strategy



What makes a climate change simulation more reliable?

- Good model performance in reproducing observed features of the historical climate
- High inter-model agreement in the simulation of climate change features
- Good model performance in reproducing reconstructed features of past climates
- Physical soundness of the processes that lead to the simulated changes