GLOBAL CLIMATE MODELS & THEIR USE IN ASSESSMENTS, PREDICTIONS & PROJECTIONS

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American Society of Civil Engineers Workshop

Reston, VA
17 November 2011

Our starting point…

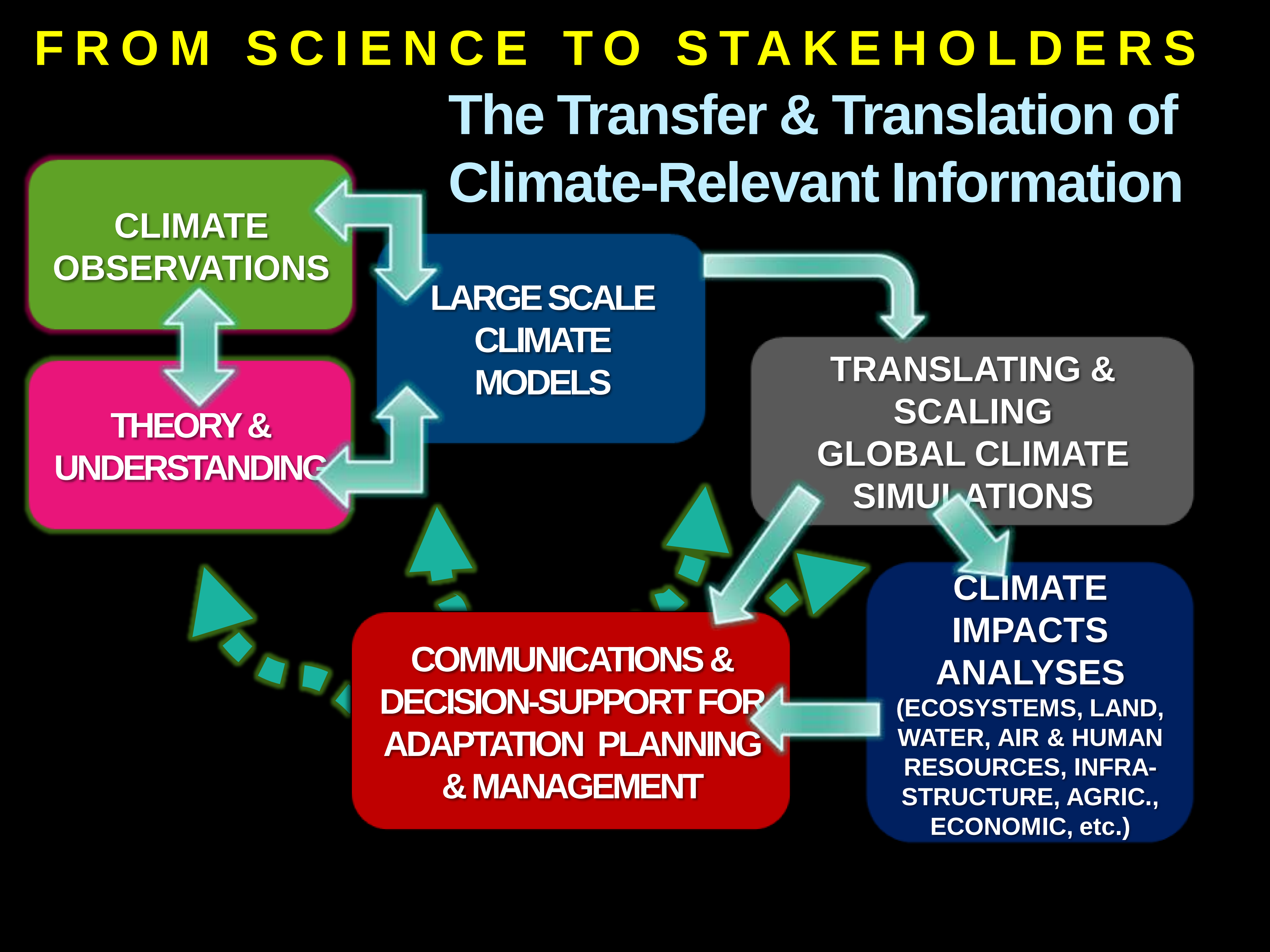
SOLID SCIENCE - OBS, THEORY, MODELS

LARGE SCALE , MULTI-DECADAL TO CENTURY

…this compelling evidence can put climate change on one's "personal radar"

OFTEN INTERESTED IN SMALLER SPATIAL SCALES, SHORTER TIME SCALES, & CLIMATE IMPACTS

…one may then ask, "what does it mean for me in my backyard?"


FROM SCIENCE TO STAKEHOLDERS
The Transfer & Translation of Climate-Relevant Information
CLIMATE OBSERVATIONS
THEORY & UNDERSTANDING
LARGE SCALE CLIMATE MODELS
TRANSLATING & SCALING GLOBAL CLIMATE SIMULATIONS
CLIMATE IMPACTS ANALYSES (ECOSYSTEMS, LAND, WATER, AIR & HUMAN RESOURCES, INFRA-STRUCTURE, AGRIC., ECONOMIC, etc.)
COMMUNICATIONS & DECISION-SUPPORT FOR ADAPTATION PLANNING & MANAGEMENT

Primary time scale of interest...

"Dec-Cen" = multi-decadal to century time scale

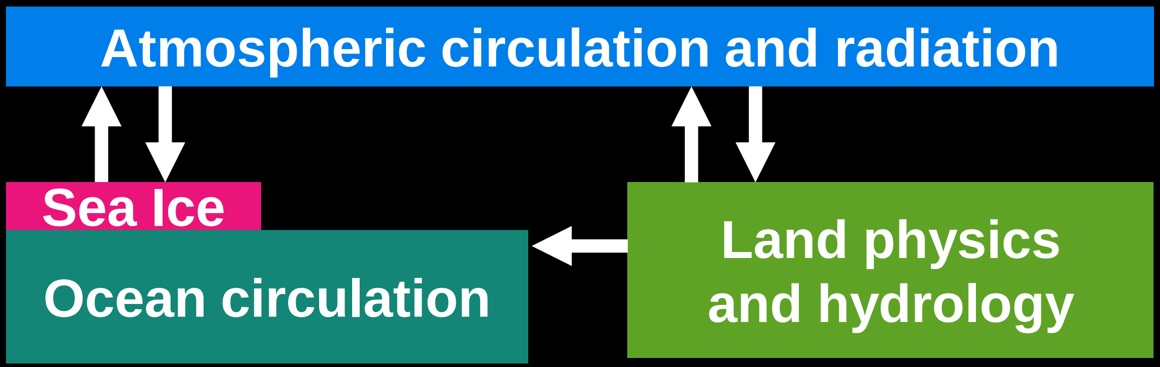
The most common period of interest when considering anthropogenically-induced climate change (*e.g.*, model simulations of the 20^{th} century and projections of 21^{st} century climate variability and change.)

1969 Results of the first coupled ocean–atmosphere general circulation model are published by Syukuro Manabe and Kirk Bryan, paving the way for later climate simulations that become a powerful tool in research on global warming.

AOGCMs represents the climate system's physical components. An Earth System Model (ESM) closes the carbon cycle.

Driven by CO2 concentrations

Climate Model (AOGCM)



Schmidt, G.,“The Physics of Climate Modeling”, Physics Today, Jan. 2007, pg 72.

Climate models can help quantify otherwise qualitative hypotheses and spur new ideas that can be tested against observations.

Categories of climate model physics

1) Fundamental Principles (*e.g.*, conservation of energy, momentum, & mass + orbital mechanics)
2) Well known physics that in practice are approximated (*e.g.*, radiation transfer, discretization of Navier-Stokes)
3) Empirical, sub-grid scale parameterizations (*e.g.*, formula for evaporation, cloud formation)

* emergent phenomena

State-of-the-Art Global Dynamical Climate Models

Divide the planet into millions of 3-D boxes (grid cells).

At the core are basic physics equations - solved at each grid box repeatedly to march ahead in time.

"Parameterizations" for processes smaller than the grid box.

Increasingly chemistry & biology

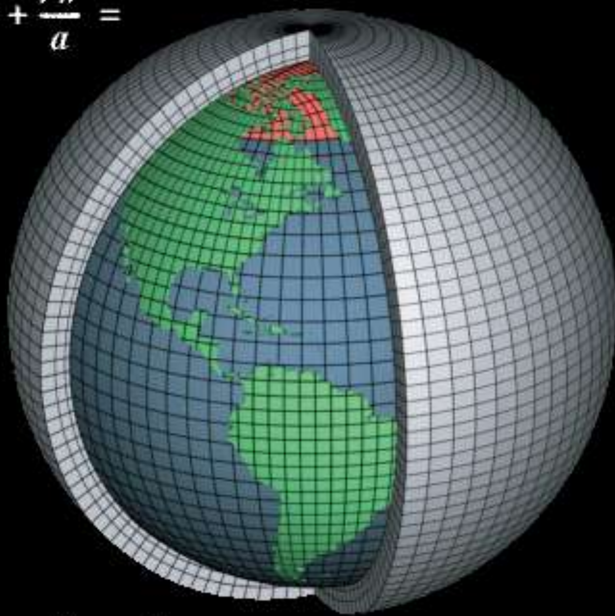
$$\frac{\partial v}{\partial t} + \frac{u}{a\cos\phi}\frac{\partial v}{\partial \lambda} + \frac{v}{a}\frac{\partial v}{\partial \phi} + w\frac{\partial v}{\partial z} + \frac{u^2\tan\phi}{a} + \frac{vw}{a} = -\frac{1}{\rho a}\frac{\partial p}{\partial \phi} - fu + F^{\phi}$$

Much more than a spreadsheet!

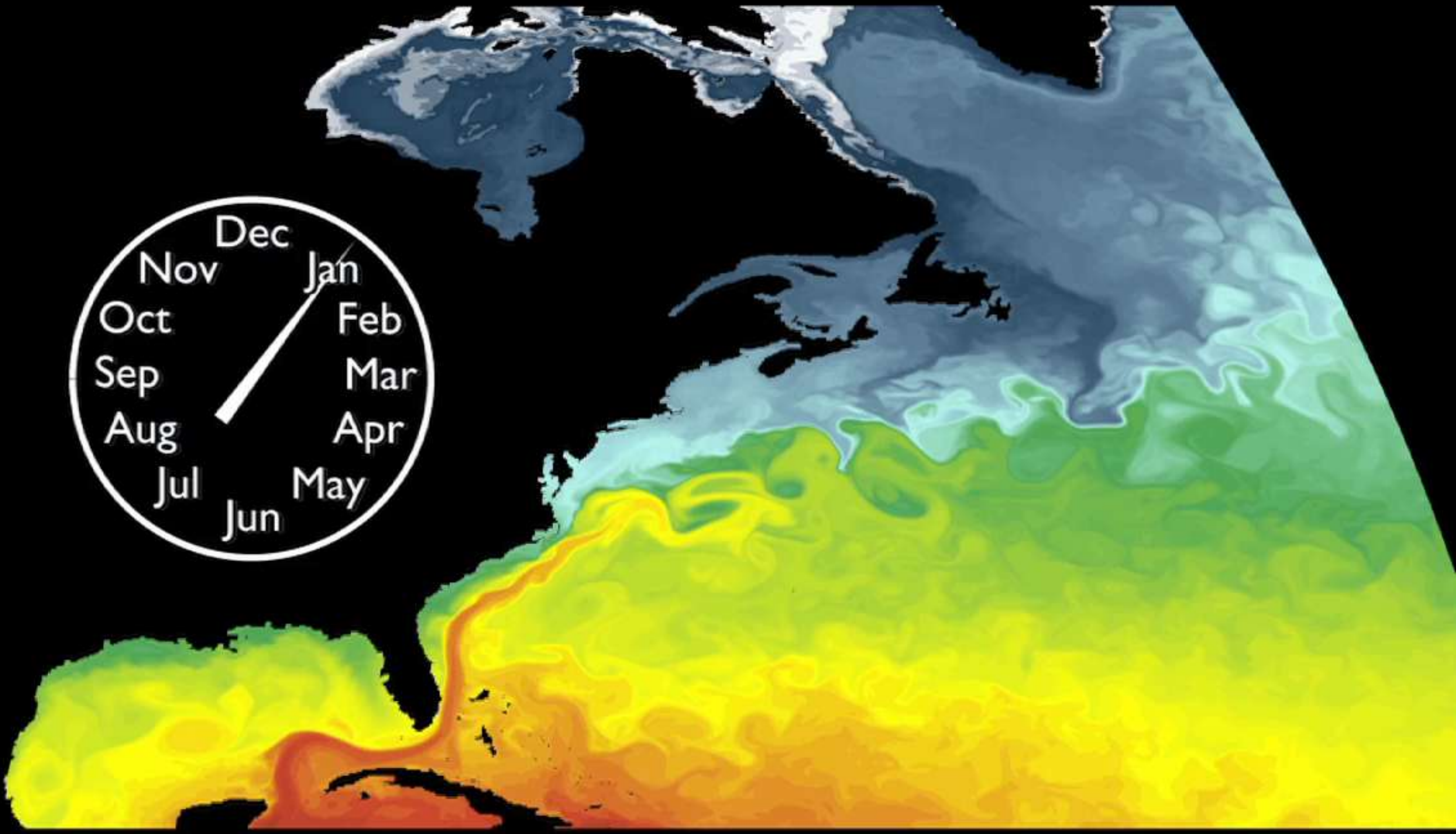
$$p(z) = \int_z \rho g\,dz + p_s$$

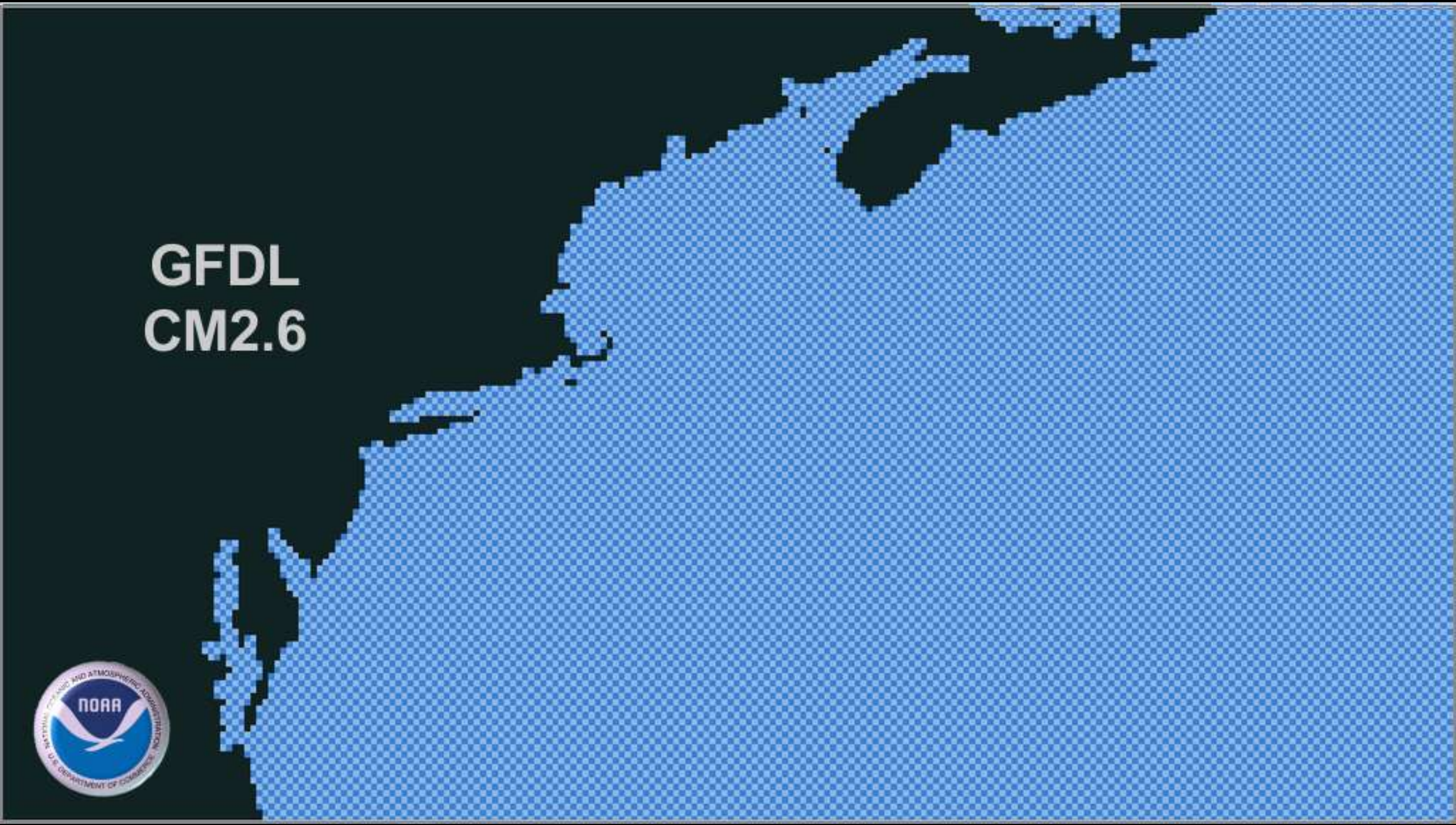
$$\frac{1}{a\cos\phi}\frac{\partial u}{\partial \lambda} + \frac{1}{a}\frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

$$\frac{dT}{dt} = \frac{u}{a\cos\phi}\frac{\partial T}{\partial \lambda} + \frac{v}{a}\frac{\partial T}{\partial \phi} + w\frac{\partial T}{\partial z} + D^{T\lambda} + D^{T\phi} + D^{Tz}$$

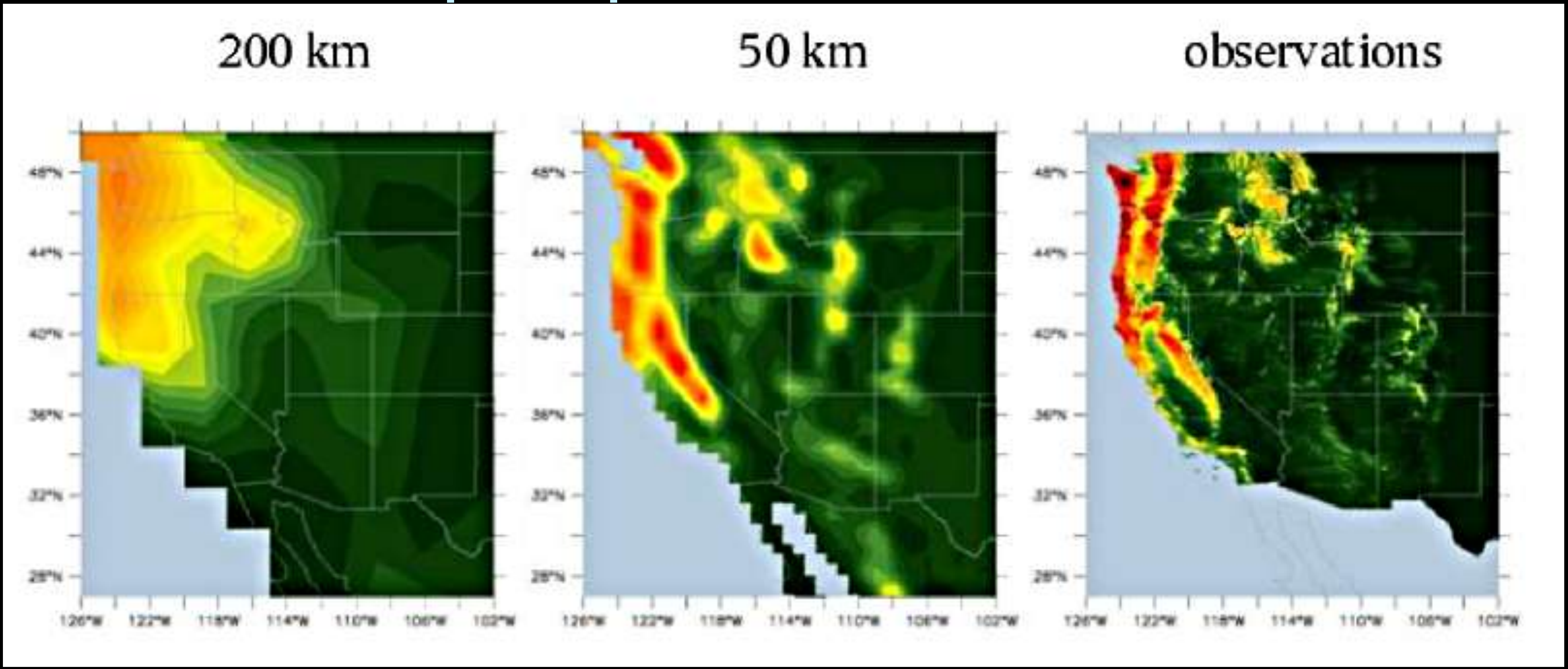


GFDL CM2.6 coupled AOGCM, Sea Surface Temperatures




GFDL
CM2.6

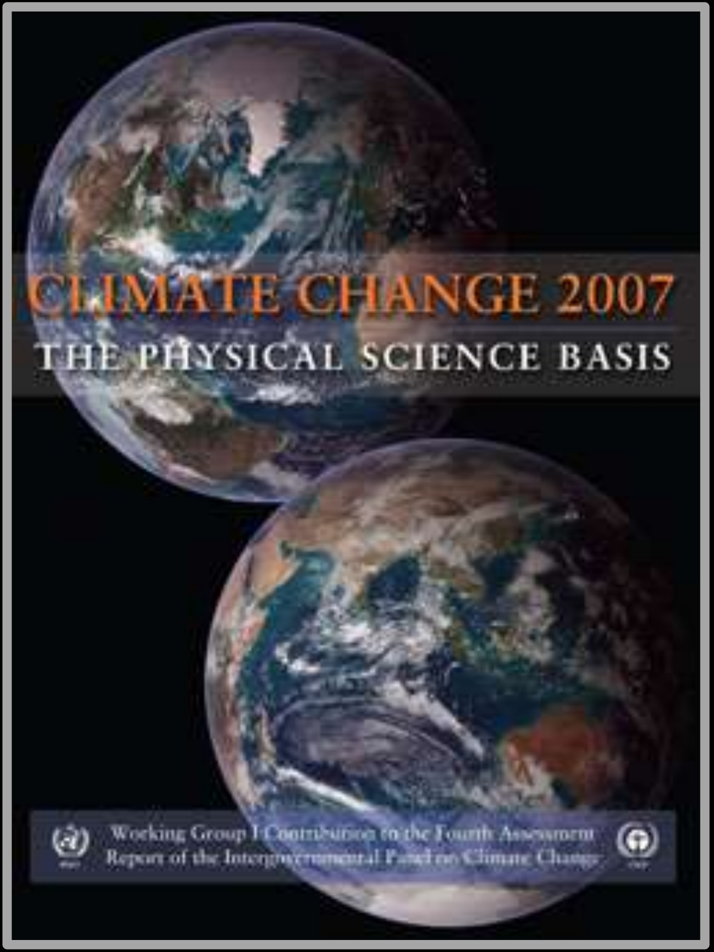
The effect of enhanced grid resolution on precipitation simulation



16 of the 50km (31 mile) on a side grid cells
fit inside each of the 200km (124 mile) cells

Today, for CMIP5, GFDL’s time slice experiments use an AGCM with a 25km grid.
Our newest AOGCM (GFDL CM2.5) uses an atmosphere with a 50km grid.

Intergovernmental Panel
on Climate Change (2007)
AR4 report, Working Group 1
Chapter 8: “Climate Models And Their Evaluation”, and
Chapter 10: “Regional Climate Projections”



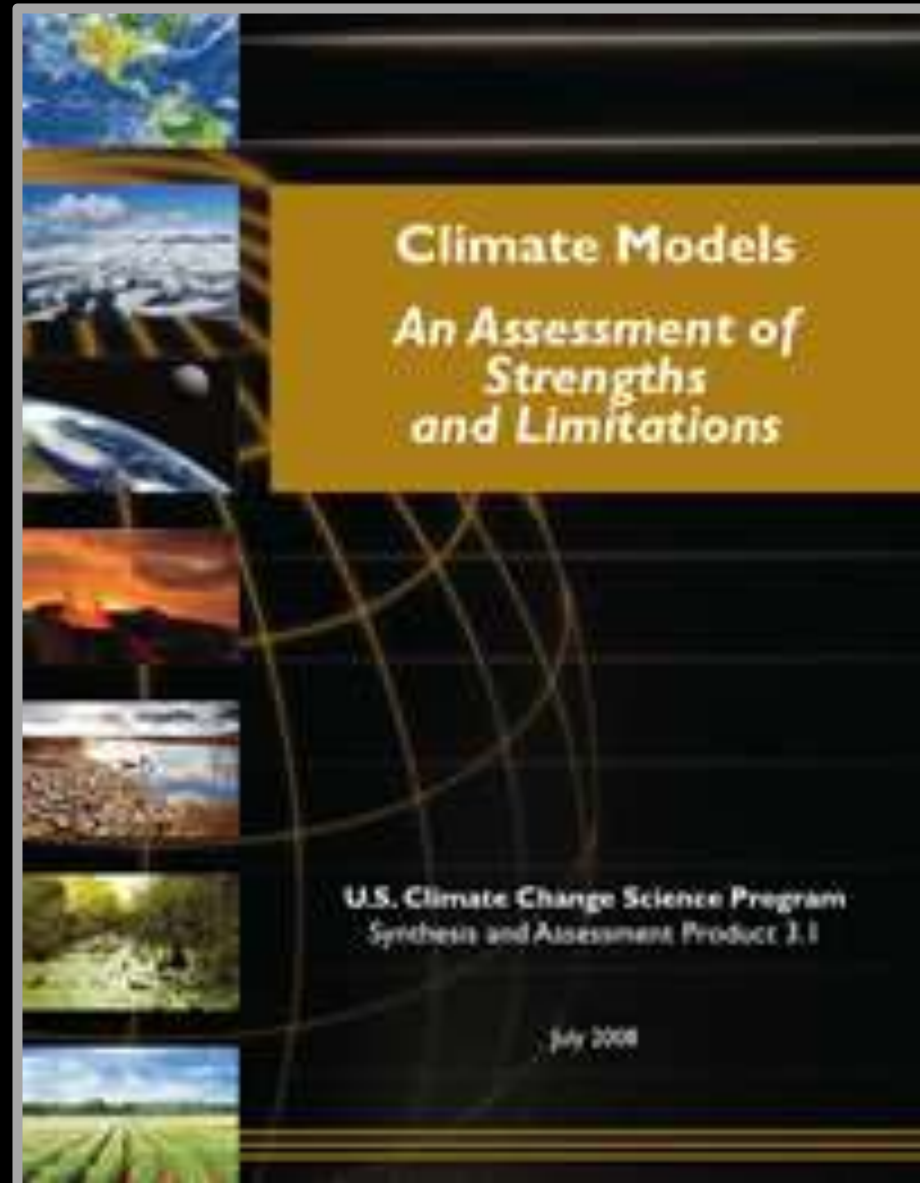
Regional climate change projections presented here are assessed drawing on information from four potential sources:

- AOGCM simulations
- Downscaling of AOGCM-simulated data to enhance regional detail
- Physical understanding of the processes governing regional responses
- Recent historical climate change

http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch8.html & ch10.html

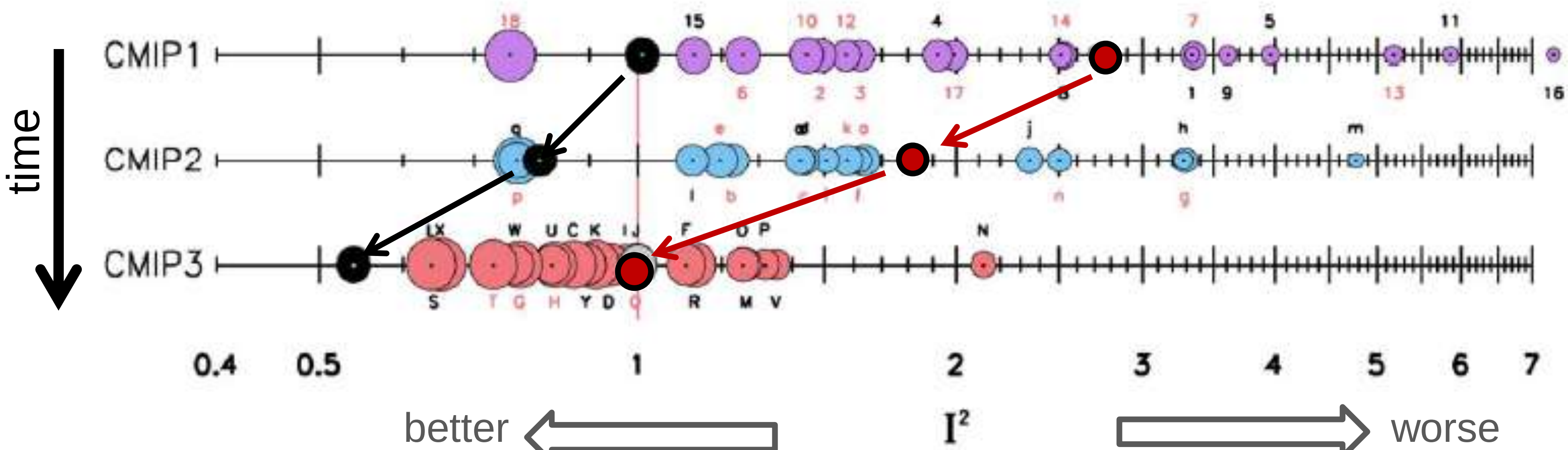
U.S. Climate Change Science Program (CCSP) Synthesis & Assessment Product 3.1

... [climate model] simulation strengths and weaknesses, vary substantially from model to model. From many perspectives, an average over the set of models clearly provides climate simulation superior to any individual model, thus justifying the multi-model approach in many recent studies.



www.**climates**cience.gov/Library/**sap/sap**3-1/final-report/

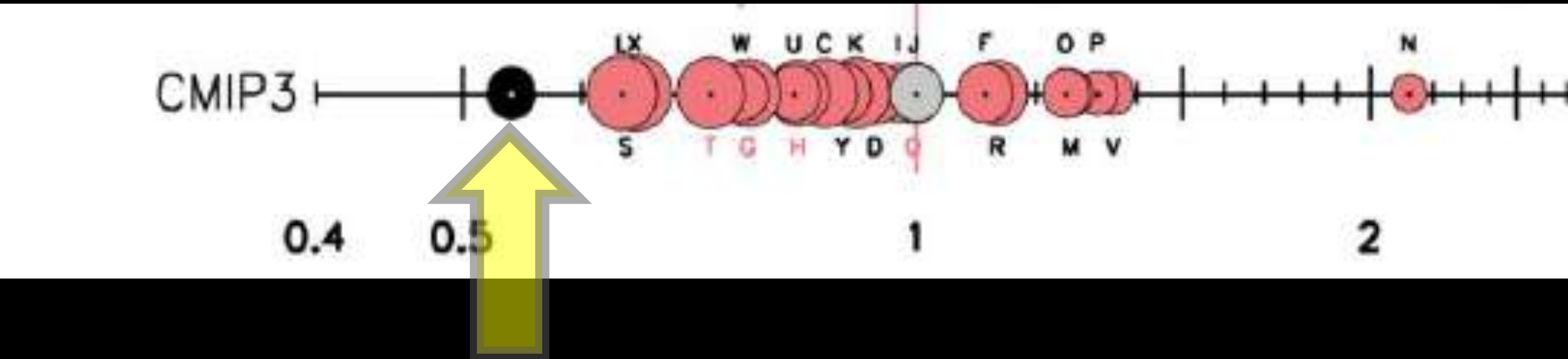
The Value of Multi-Model Ensembles



Reichler, T., and J. Kim (2008): How Well do Coupled Models Simulate Today's Climate? Bull. Amer. Meteor. Soc., 89, 303-311.

Performance error index of 14 metrics *for individual models (circles) and model generations (rows).* Black circles indicate the *index value of the multimodel mean taken over one model group.*
***Best performing* models have low index *values and are located toward the left. Circle sizes indicate the length of the 95% confidence* intervals.**

The Value of Multi-Model Ensembles



The multi-model ensemble mean (black circle) outperforms each of the individual models.

Analogous to how in a weather forecast contest it is difficult over the long term to beat the “consensus forecast” (the average of all the participating forecasters).

The Value of Multi-Model Ensembles … & Limitations

The end of model democracy?

An editorial comment

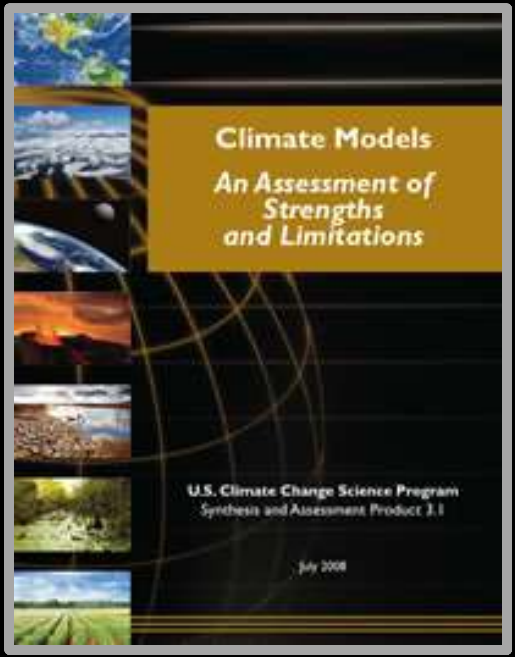
Reto Knutti

Knutti, R., The end of model democracy?, 2010, Editorial for *Climatic Change*, *102*, 395–404, doi:10.1007/s10584-010-9800-2
http://www.iac.ethz.ch/people/knuttir/papers/knutti10cc.pdf

- **The sample of models is neither random nor systematic.**
- **The models are not truly independent.**
- **Majority rules? Agreement across models does not guarantee correctness.**
- **What about structural uncertainties, etc. ?**
- **Averaging models leads to smoothing of spatially heterogeneous patterns… physically realistic?**

Related discussions also at … Knutti, et al., (2010) Challenges in combining projections from multiple models, *Journal of Climate*
UKCIP09 http://ukclimateprojections.defra.gov.uk/content/view/2088/500/
CCSP SAR 3.1 http://www.climatescience.gov/Library/sap/sap3-1/final-report/

U.S. Climate Change Science Program (CCSP) Synthesis & Assessment Product 3.1



In principle, using the direct output of climate models is desirable because these results represent a physically consistent picture of future climate … In practice this is rarely done.

Employing coarse-resolution global model output for regional and local impact studies requires two additional steps **- downscaling and bias removal**, or the adjustment of future projections for known systematic model errors.

www.**climates**cience.gov/Library/**sap/sap**3-1/final-report/

DOWNSCALING

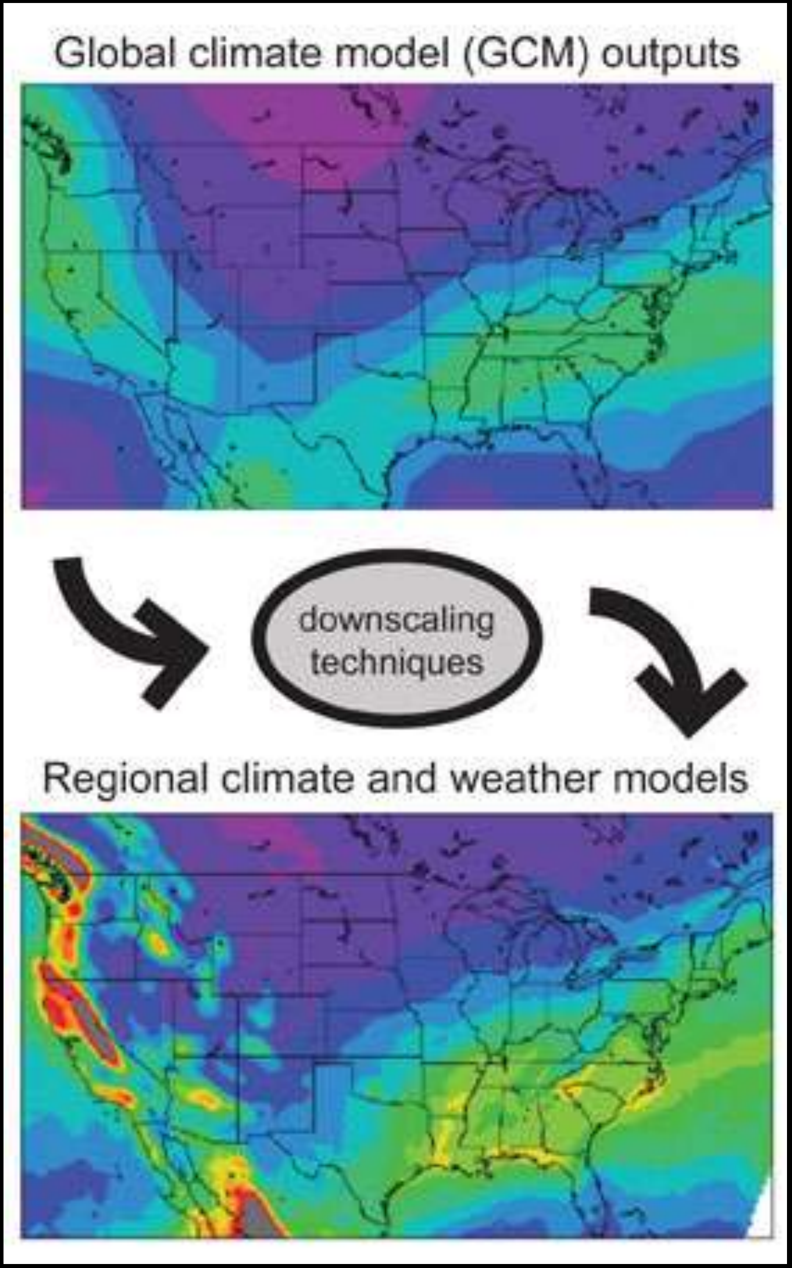
allows researchers to take coarse data from a global GCM and create regional predictions on a finer spatial scale.

2 types:

**** Dynamical***

**** Statistical***

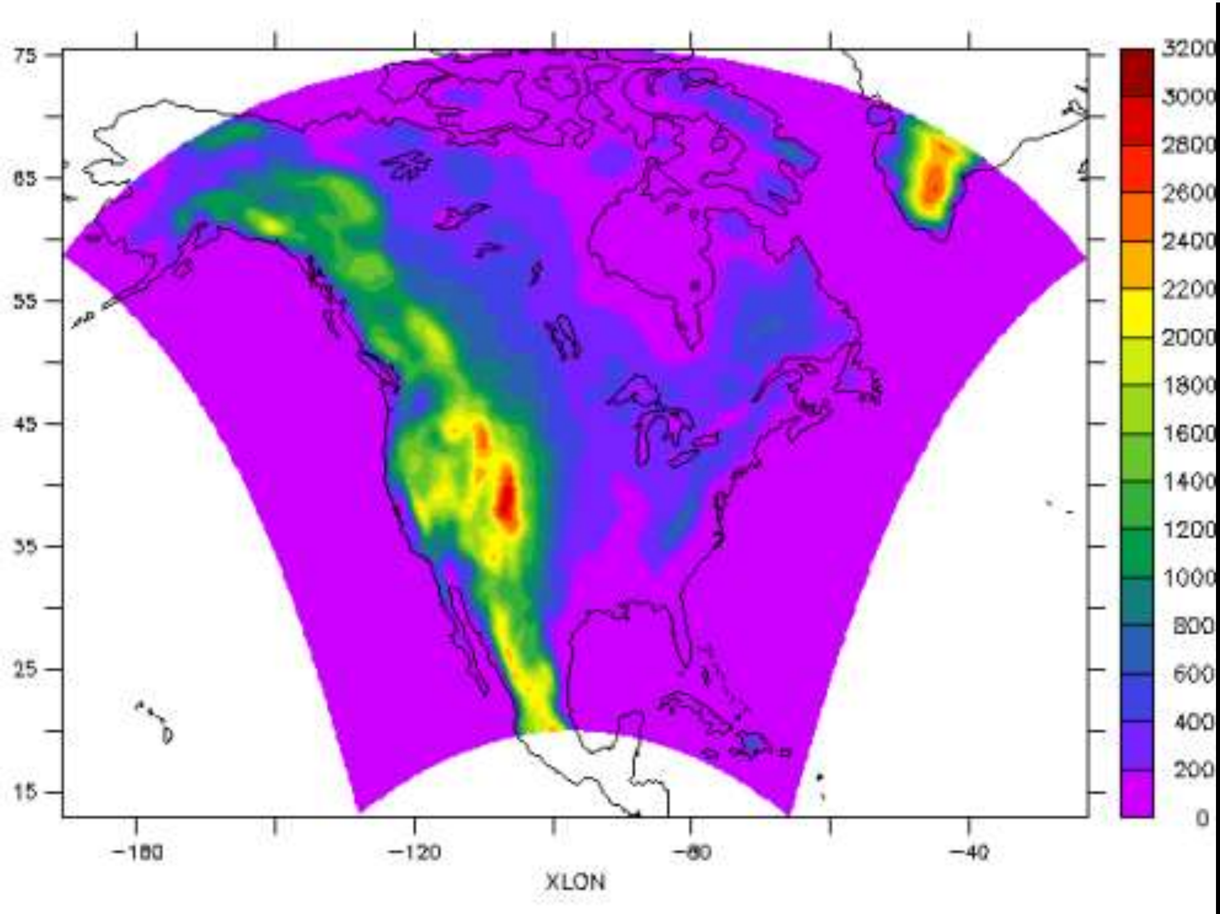
Image credit:The University Corporation for Atmospheric Research

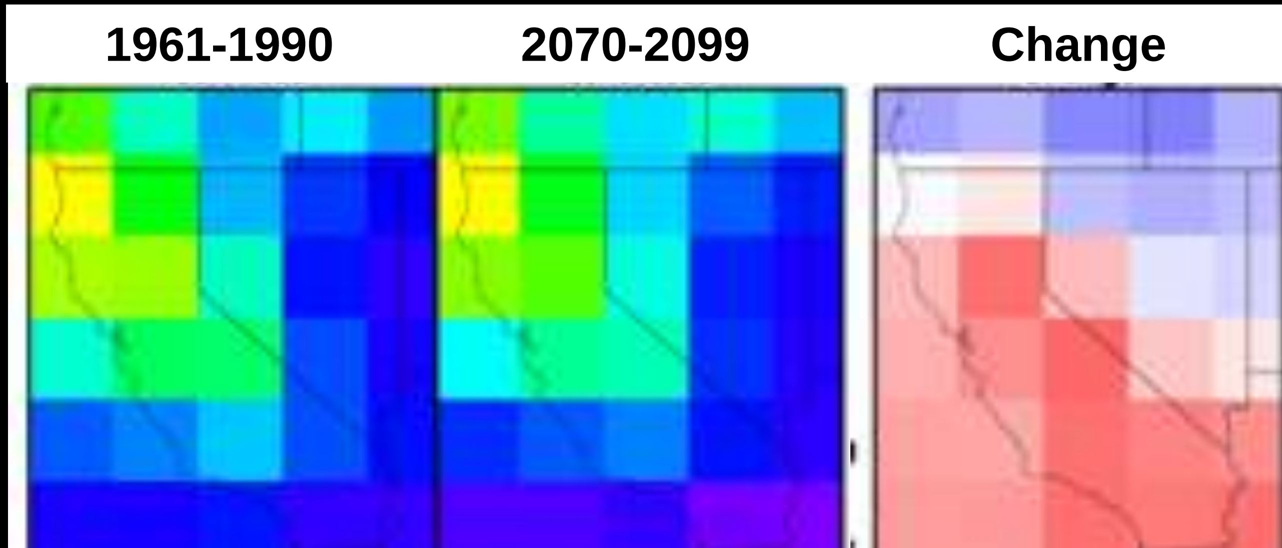


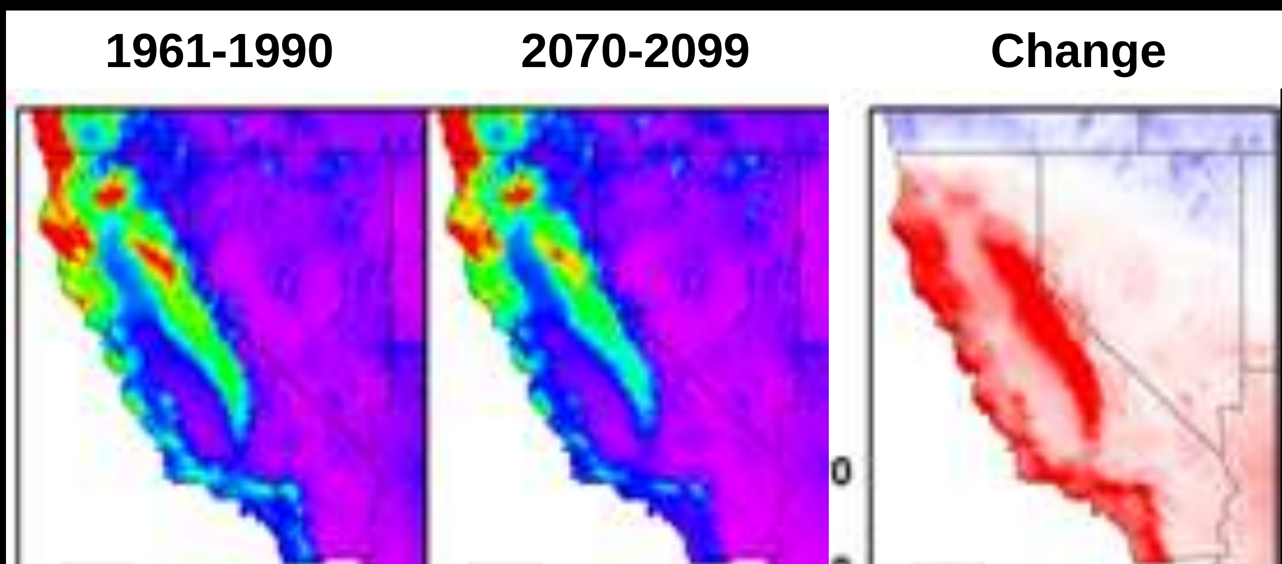
An example of Dynamical Downscaling: The North American Regional Climate Change Assessment Program

http://www.narccap.ucar.edu/

NARCCAP



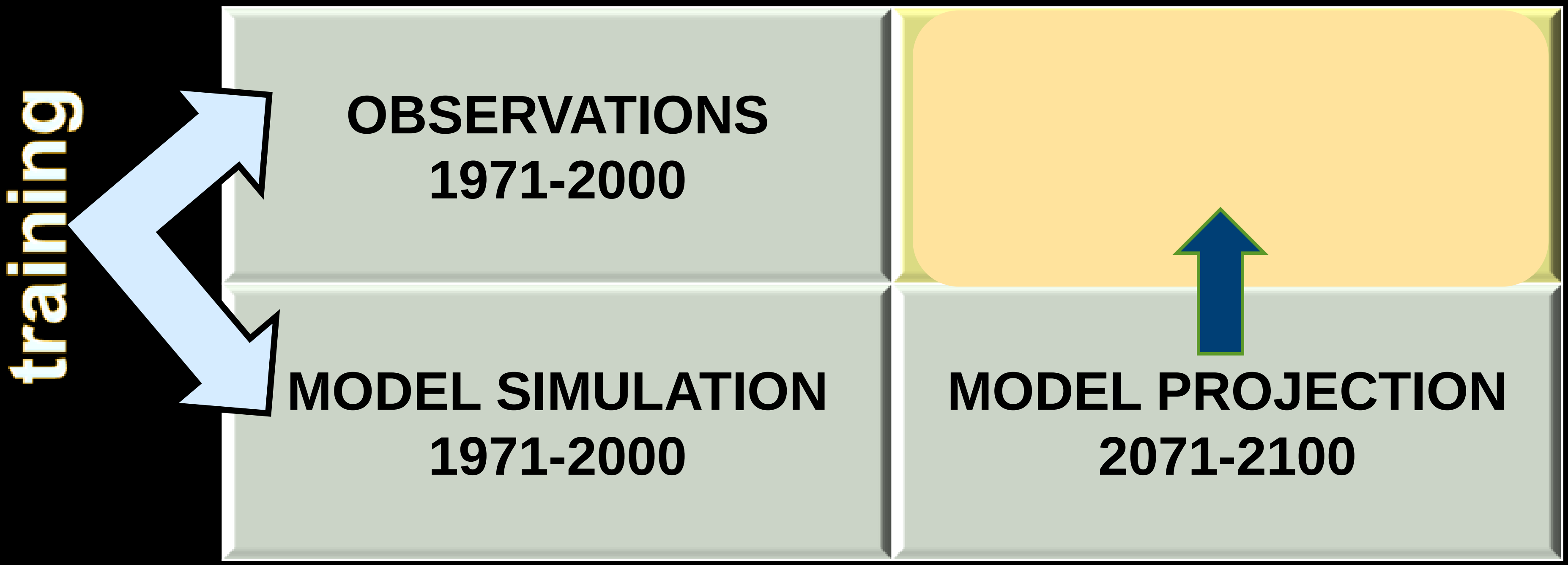




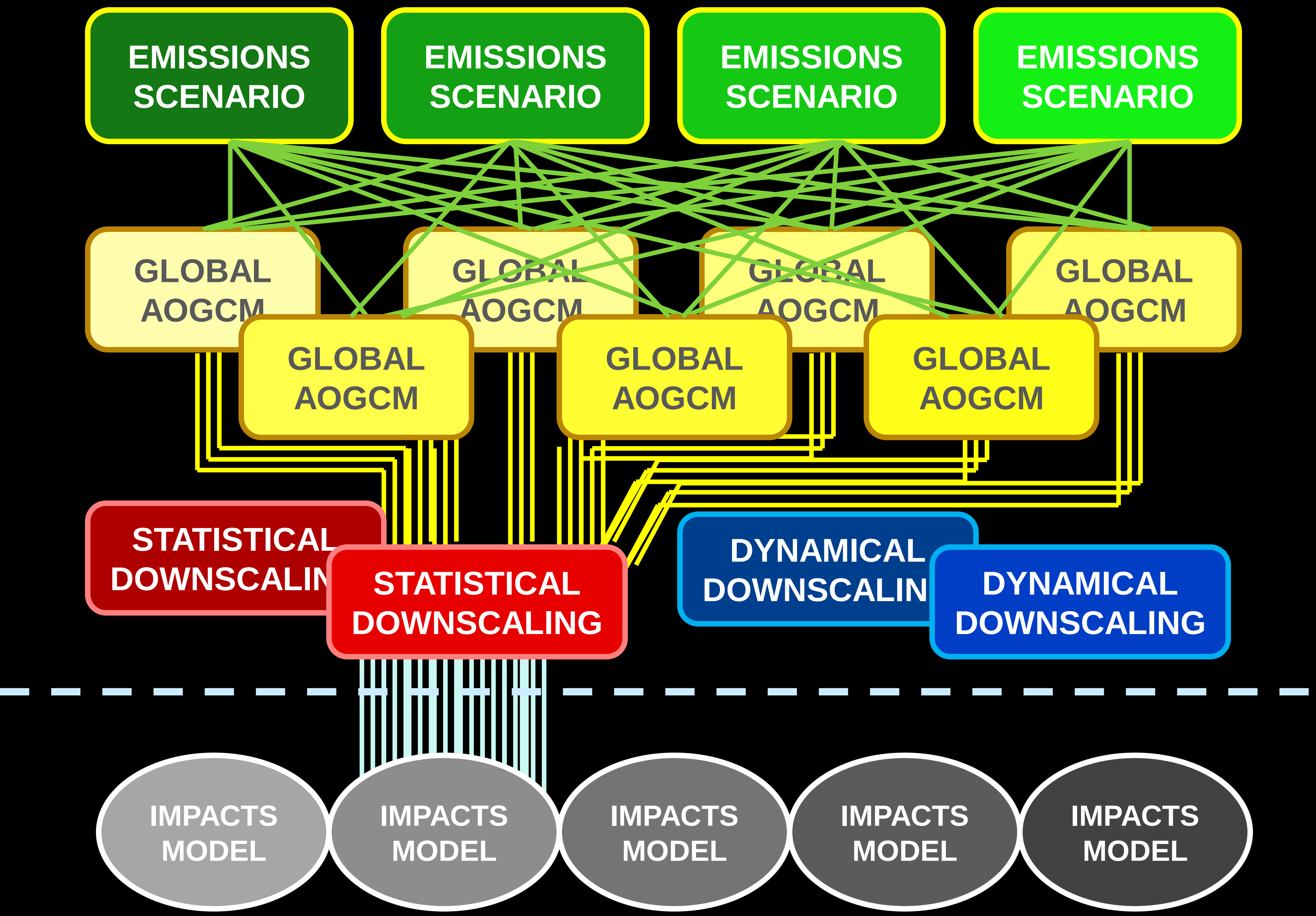
You can think of statistical downscaling as similar to the MOS

Source: http://www.engr.scu.edu/~emaurer/research.shtml

Statistical Downscaling: bias correction + higher resolution



There are numerous statistical downscaling techniques, varying from the very simple, to intermediate complexity, to neural network approaches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GLOBAL AOGCM
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STATISTICAL DOWNSCALING
STATISTICAL DOWNSCALING
DYNAMICAL DOWNSCALING
DYNAMICAL DOWNSCALING
IMPACTS MODEL
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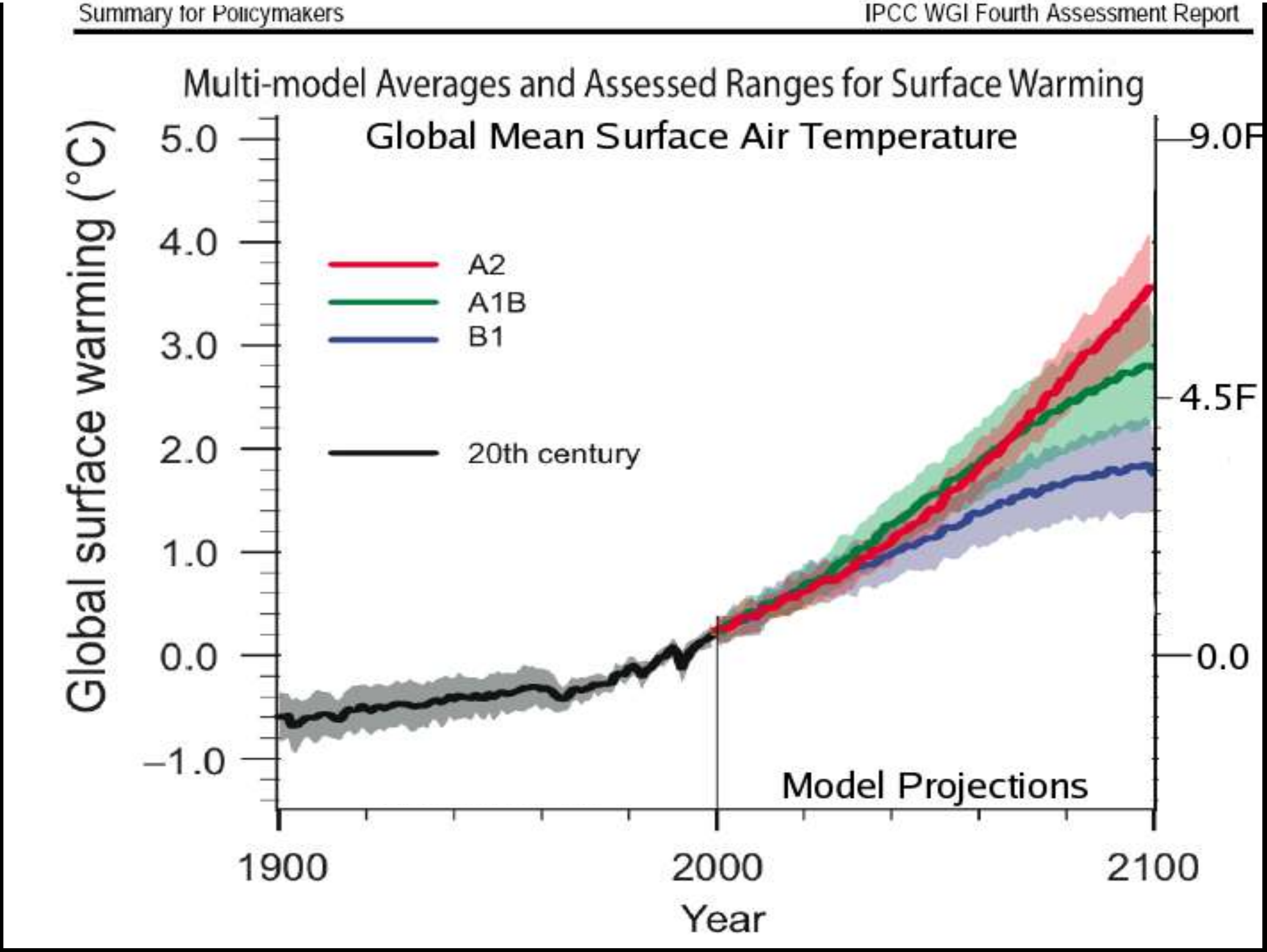
Multi-model means of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th-century simulation. Lines show the multi-model means, shading denotes the 1 standard deviation range of individual model annual means.



Source: IPCC 2007 WG1-AR4, Fig 10-4

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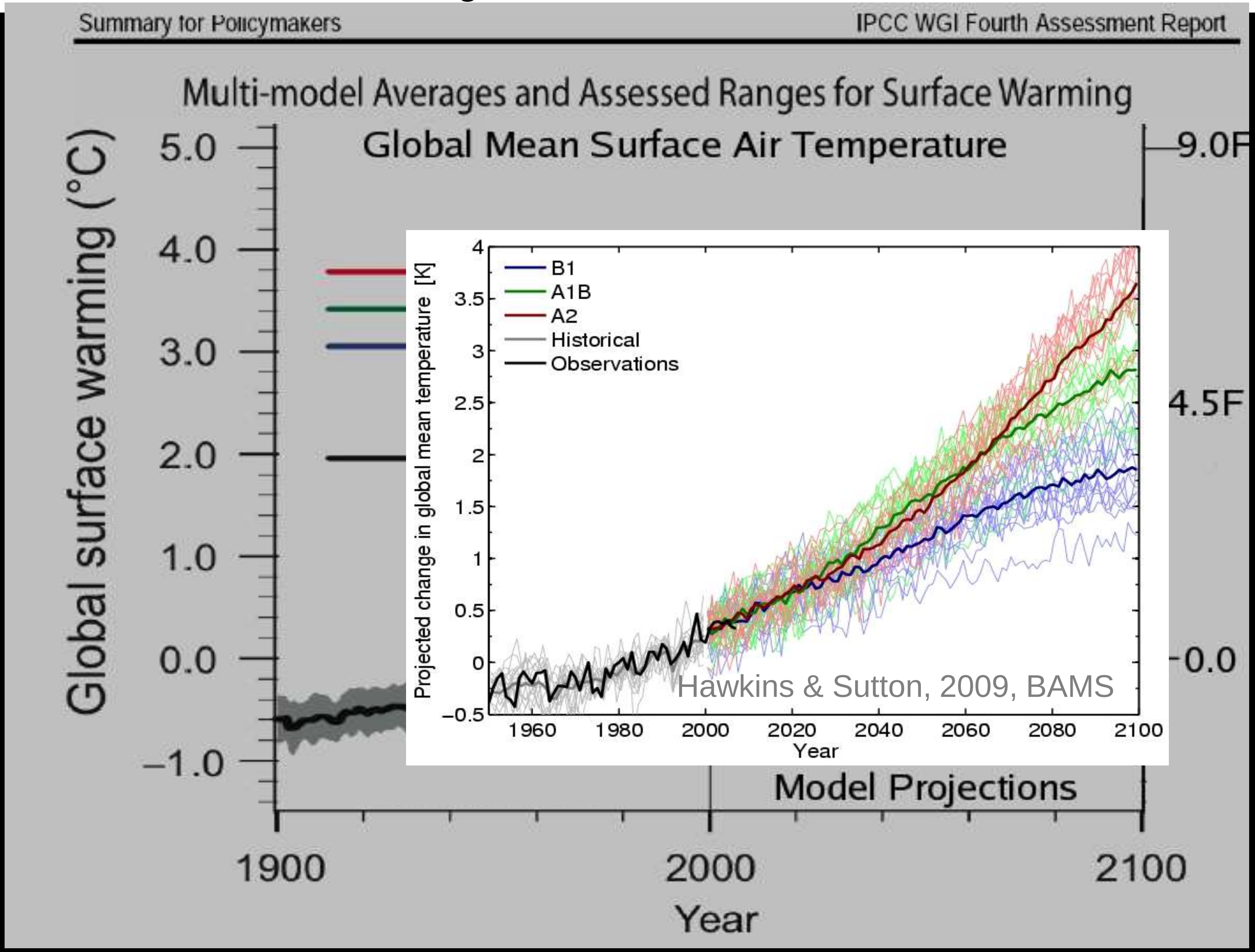

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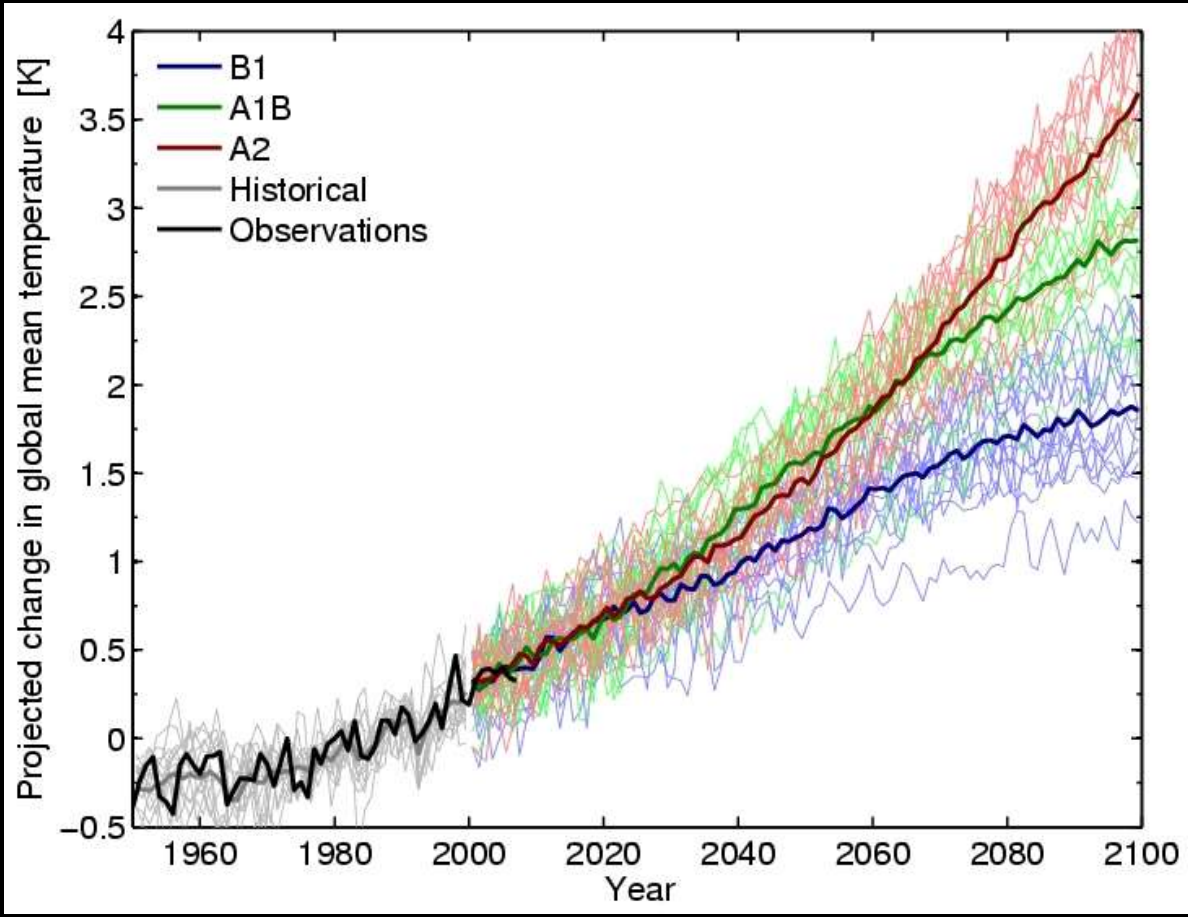


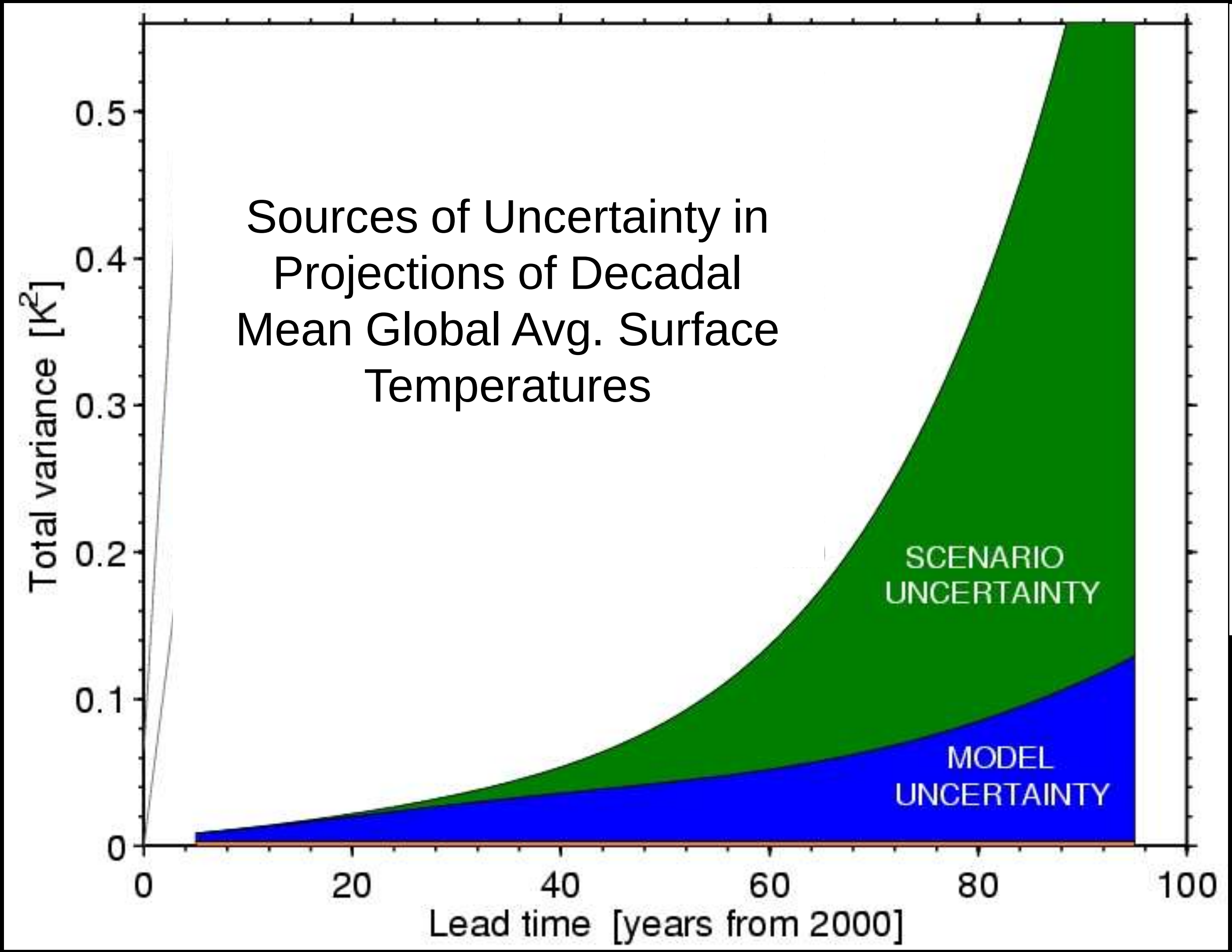
Global mean, annual mean, surface air temperature predictions from 15 global climate models under 3 different emission scenarios from 2000 to 2100.
The same models forced with historical forcings are shown as the thin gray lines.

Observed global mean temperatures from 1950 to 2007 (Brohan et al. 2006) are shown as the thick black line.

- Hawkins, Ed, and Rowan Sutton, 2009: The Potential to Narrow Uncertainty in Regional Climate Predictions. *Bull. Amer. Meteor. Soc.*, **90**, 1095–1107. doi: 10.1175/2009BAMS2607.1 (Aug. 2009)
- Related interactive web pages: http://climate.ncas.ac.uk/research/uncertainty/

From Hawkins & Sutton, 2009, BAMS

- **PARTITIONING UNCERTAINTY.** Uncertainty in climate projections arises from three distinct sources.
- First is the internal variability of the climate system: the natural fluctuations that arise in the absence of any radiative forcing of the planet. Appreciation of these fluctuations is an important matter, since they have the potential to reverse - for a decade or so - the longer term trends that are associated with anthropogenic climate change.
- Second is model uncertainty (also known as response uncertainty): in response to the same radiative forcing, different models simulate somewhat different changes in climate.
- Third is scenario uncertainty: uncertainty in future emissions of greenhouse gases, for example, causes uncertainty in future radiative forcing and hence climate. (Uncertainty in what people will do.)



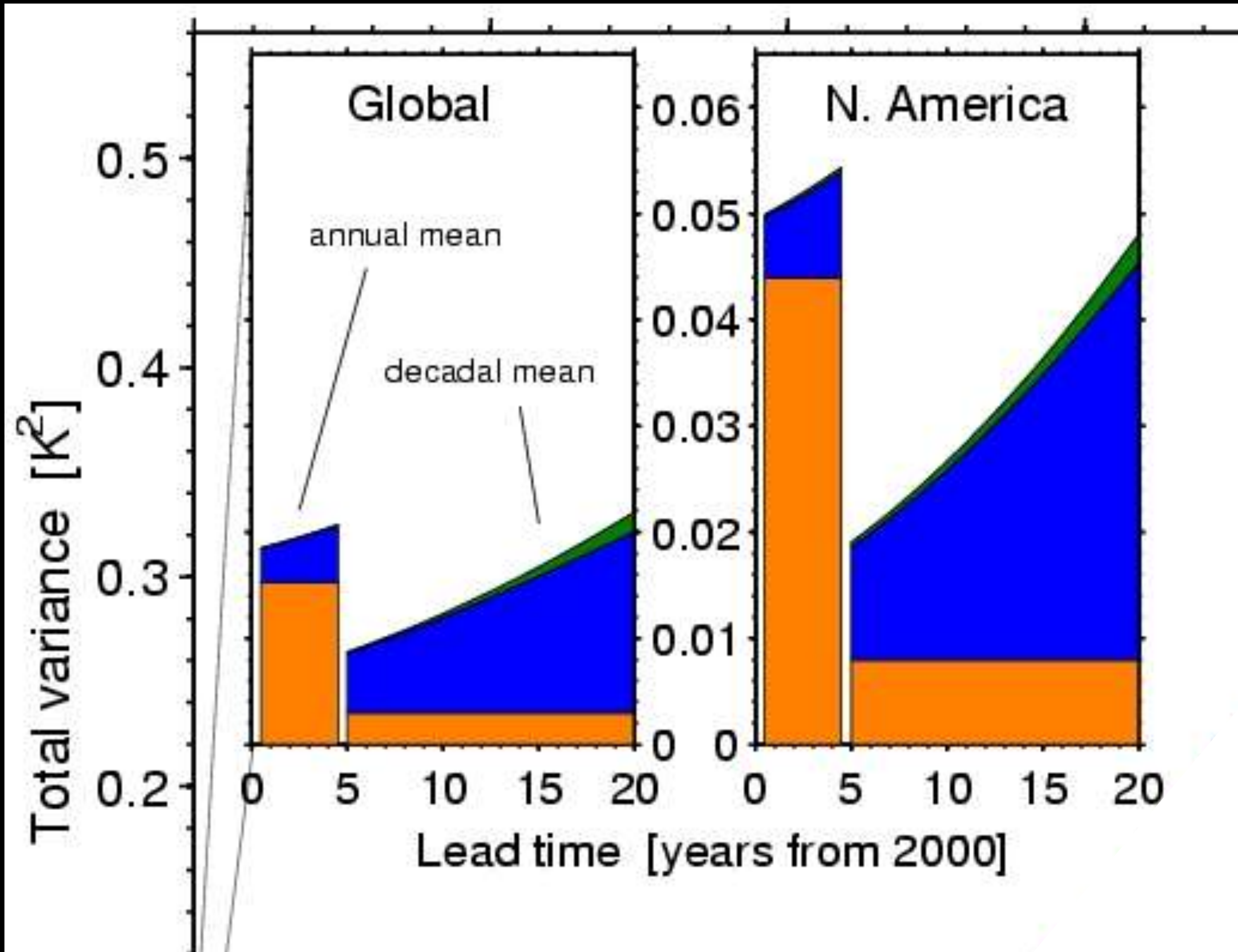
Green = scenario uncertainty

Blue = model uncertainty

Orange = internal variability

The relative importance of the three sources of uncertainty changes with region size and location, forecast/projection lead time, and the amount of time averaging applied. Total uncertainty is greater for smaller regions.

- Hawkins & Sutton, 2009, BAMS



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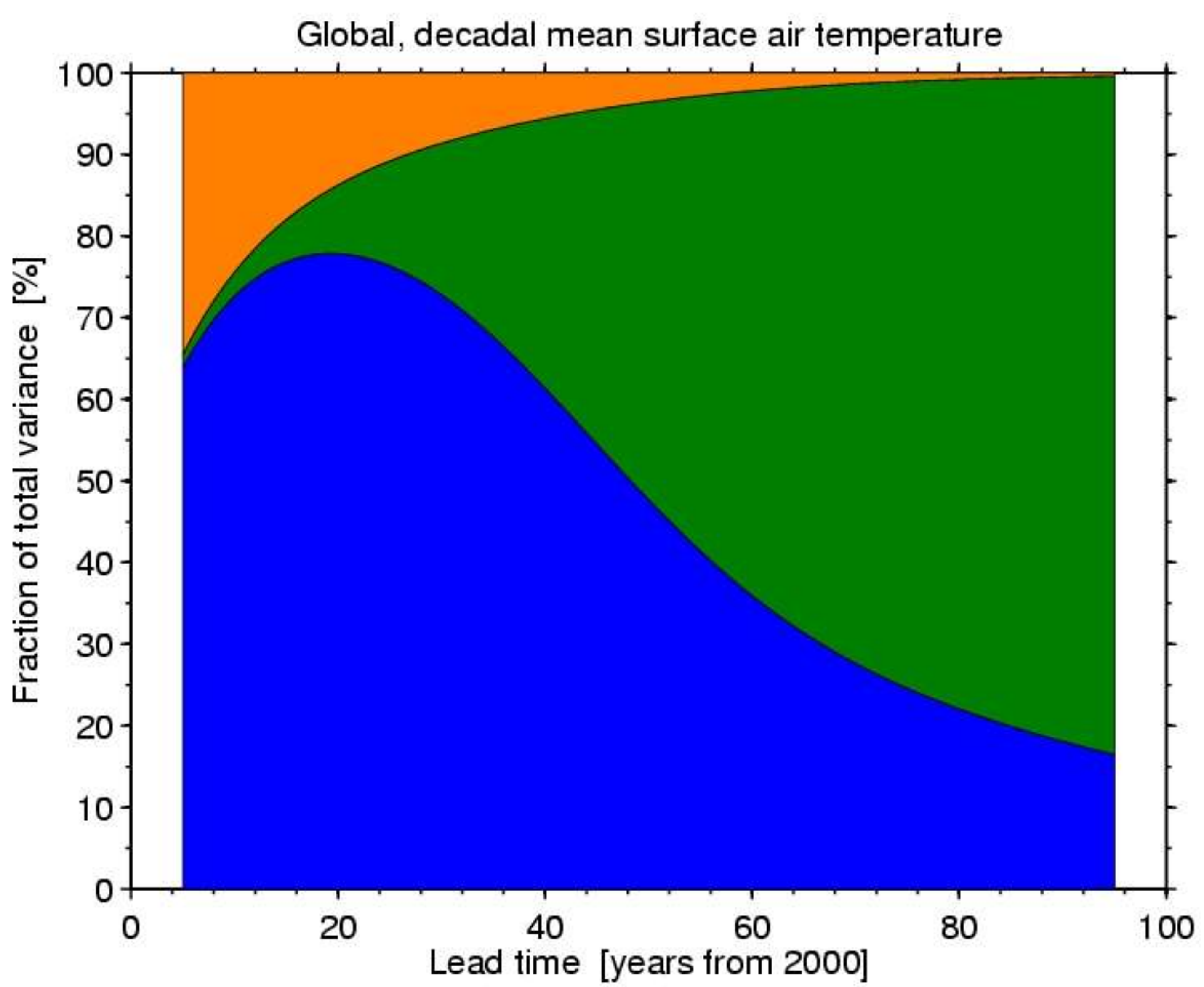

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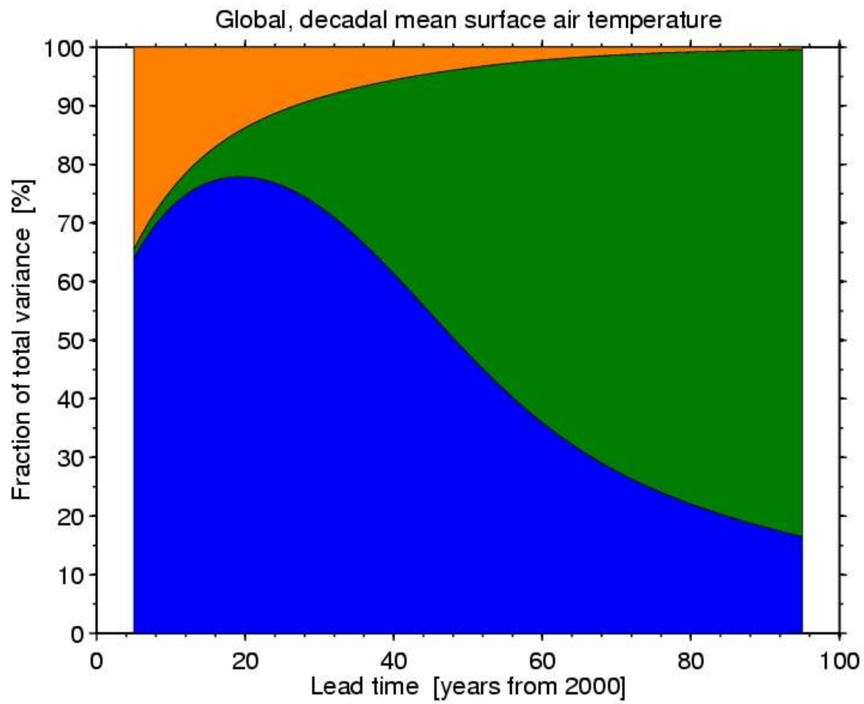
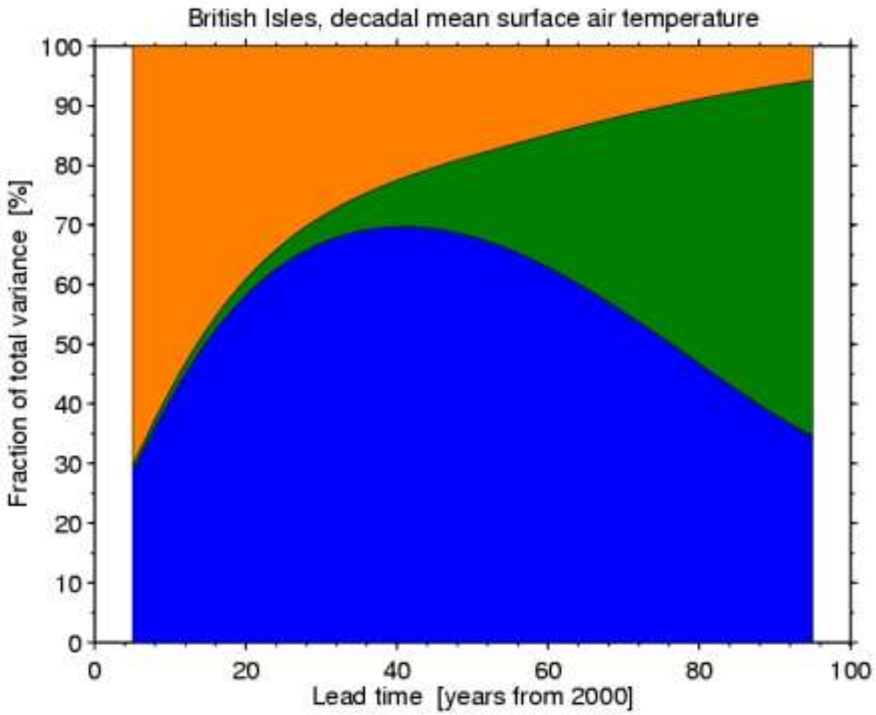


GLOBAL



BRITISH ISLES

Green = scenario uncertainty
Blue = model uncertainty
Orange = internal variability

Not only is total uncertainty is greater for smaller regions, the relative importance of different uncertainty components varies regionally and over time.

- Hawkins & Sutton, 2009, BAMS

Uncertainties In Climate Change Impacts Projections

1) **What will be the future emissions of greenhouse gases, etc. in the atmosphere?**
   (***these are climate model inputs***)

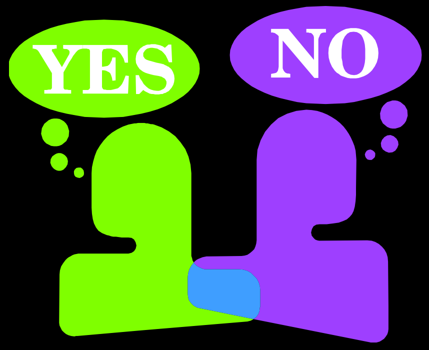
2) **How will the climate system respond to the changes in greenhouse gases, etc.?**
   (***these are climate model outputs*** *– they're valuable, but computer models are incomplete & are not perfect)*

3) **How will internal variability affect the emergence of climate change signals?**

4) **Downscaling uncertainties**

5) **How will changes in the climate affect crops, viruses, polar bears, coastal erosion, etc., etc., etc.?**
   (***climate change impacts*** *– some impacts researchers use climate model output as input to their own analyses)*

I don’t have the expertise to say what qualifies as “Best Practices”, but from my perspective there probably are some practices to avoid if the goal is to provide “actionable” decision-support info at the local level…



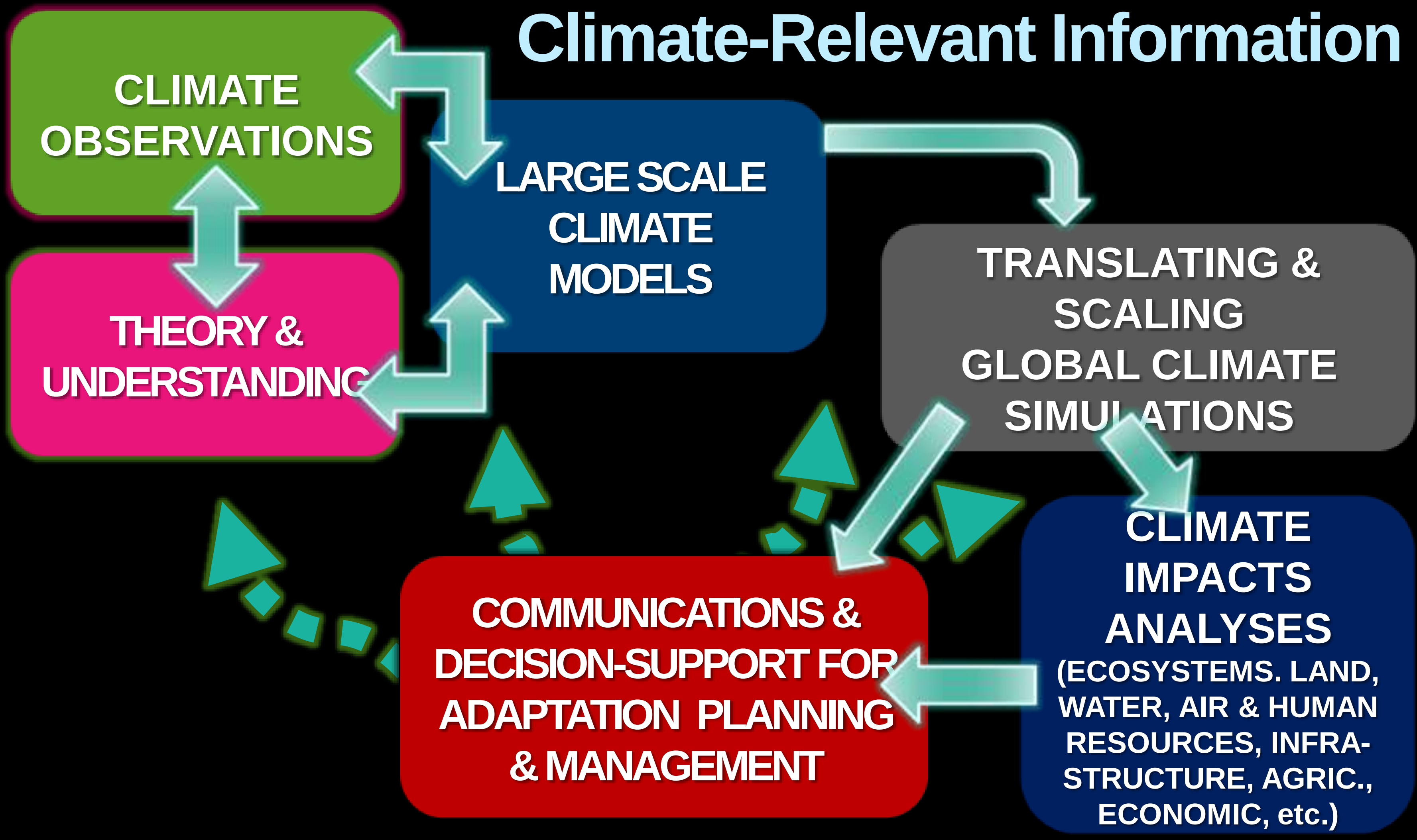
• Don’t rely on just one global climate model as input to your analyses if they are intended to support decision-making. (Avoid “Just tell me which one is the best model and I’ll use that one.”)

• If you use downscaling, might using more than one downscaling method have merit? Be aware of differences.

• Don’t just download model output to use as input and “turn the crank”, but instead identify and investigate the (regional) mechanisms involved to gain a better scientific understanding.

FROM SCIENCE TO STAKEHOLDERS

The Transfer & Translation of Climate-Relevant Information



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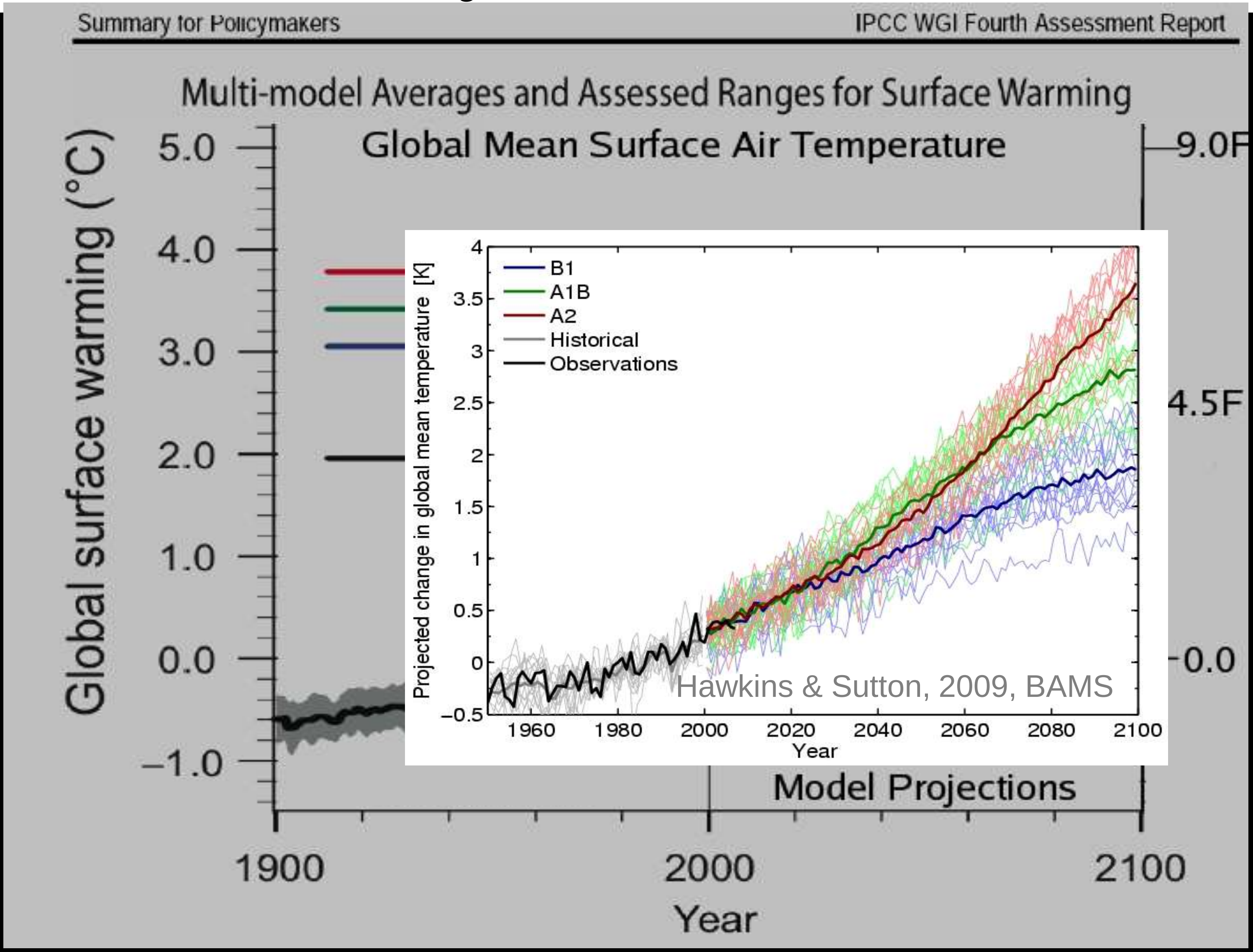
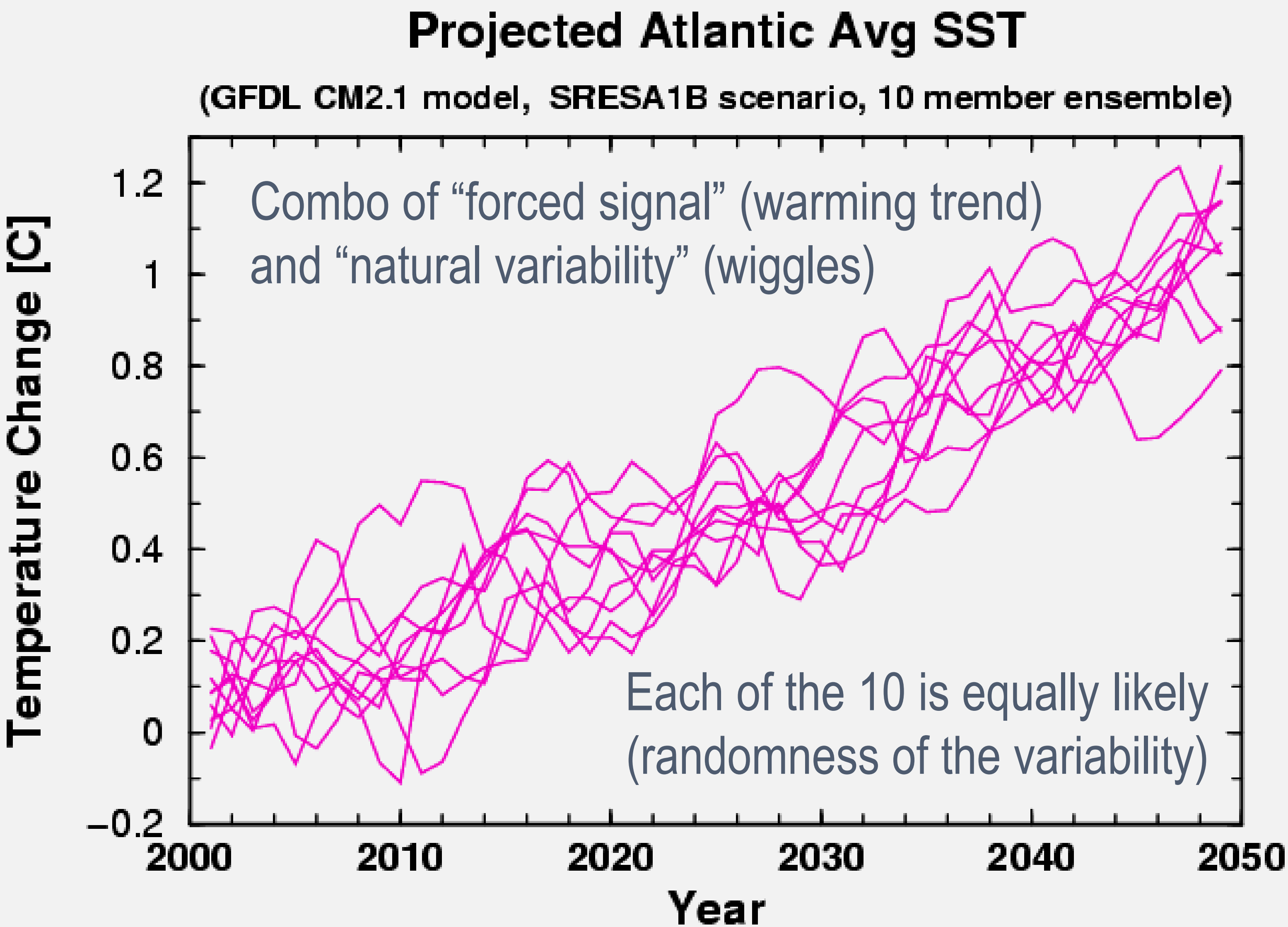
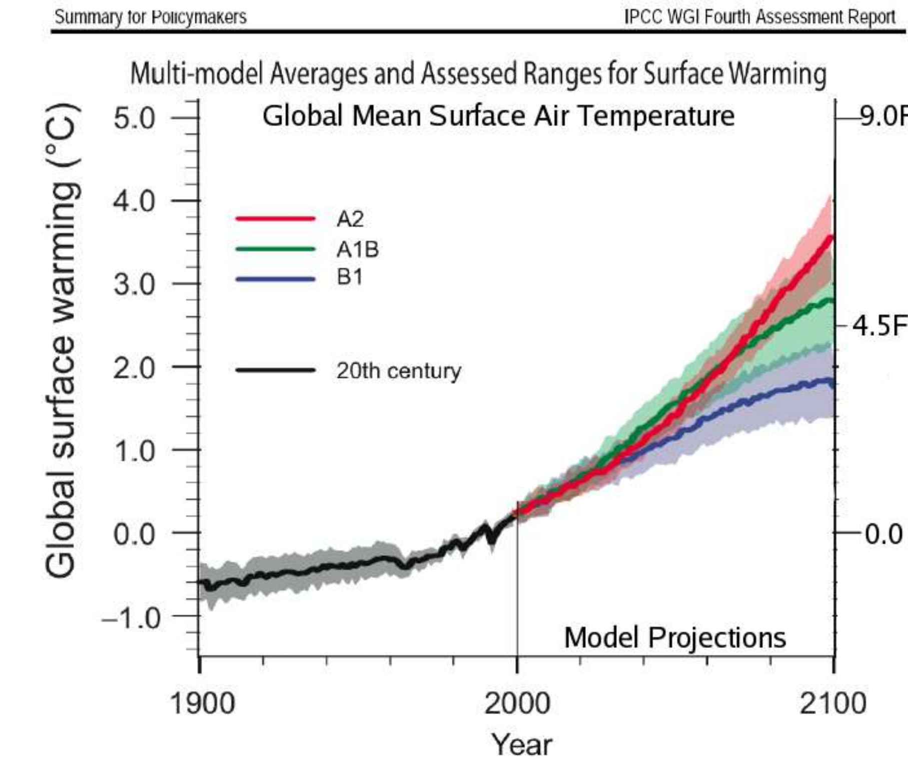


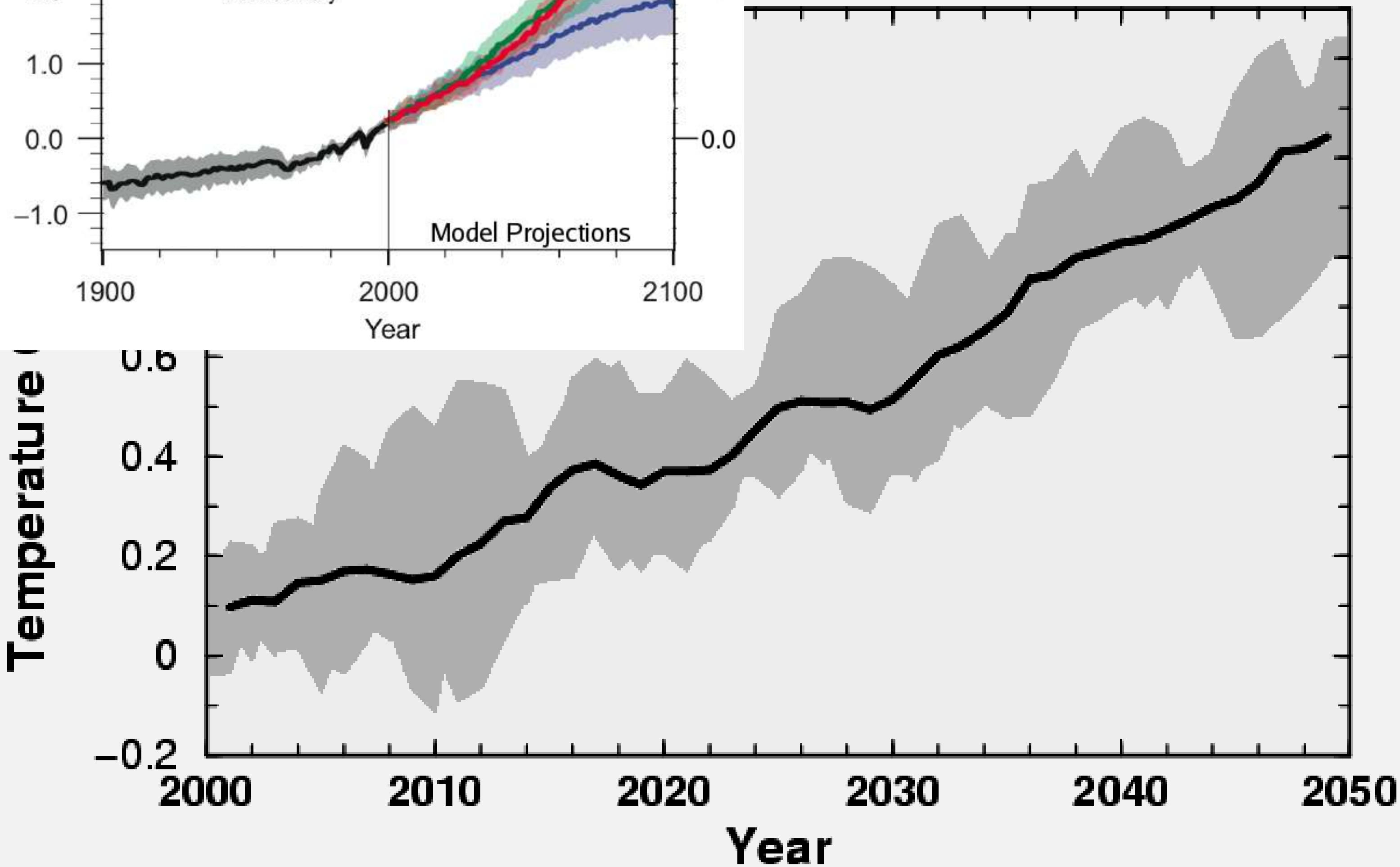
Source: IPCC 2007 WG1-AR4, Fig 10-4

Simplifying without Over-Simplifying



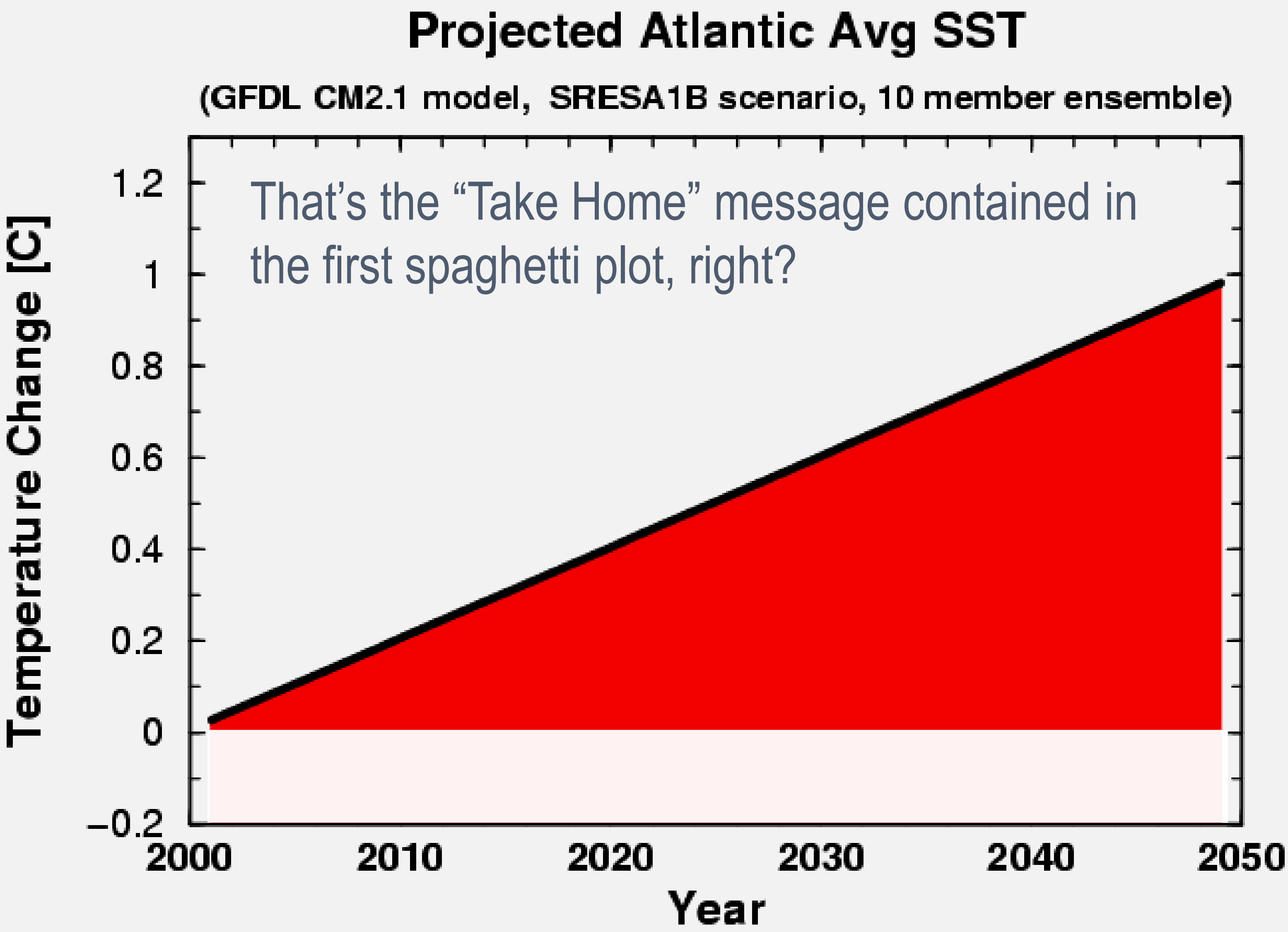


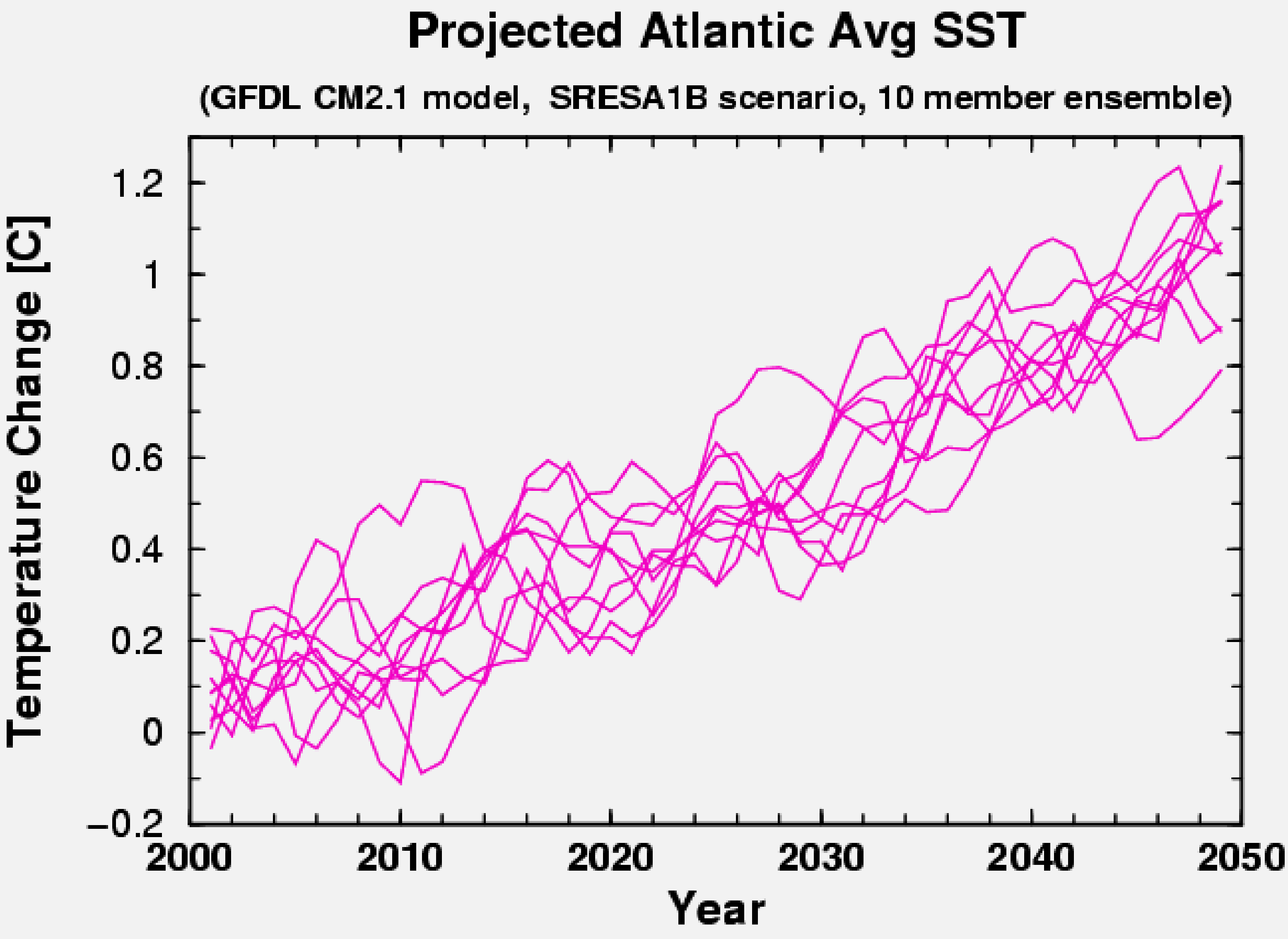
Summary for Policymakers
IPCC WGI Fourth Assessment Report
Multi-model Averages and Assessed Ranges for Surface Warming
Global Mean Surface Air Temperature
Global surface warming (°C)
5.0
4.0
3.0
2.0
1.0
0.0
–1.0
9.0F
4.5F
0.0
A2
A1B
B1
20th century
Model Projections
1900
2000
2100
Year

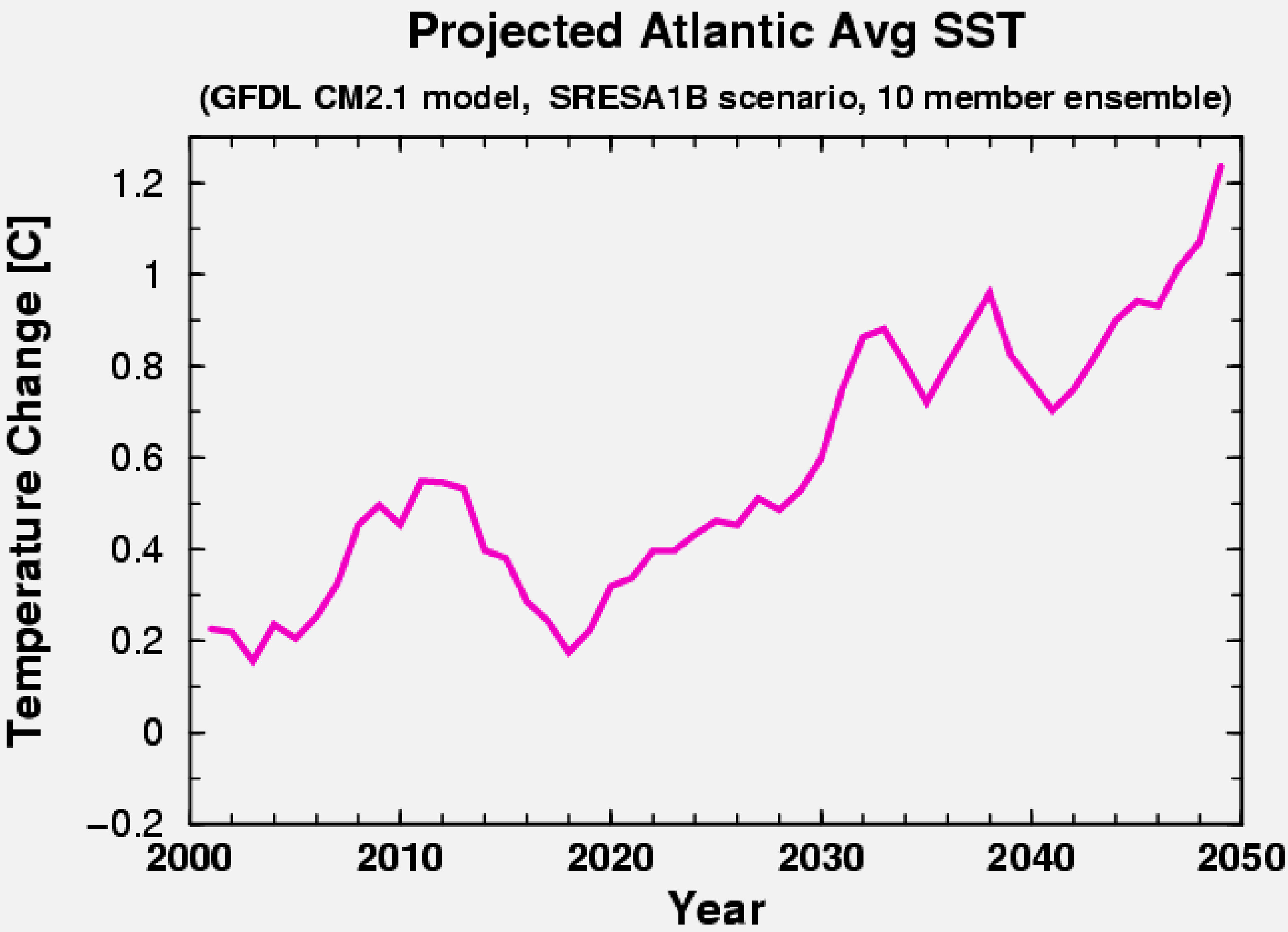


lantic Avg SST
B scenario, 10 member ensemble)
Temperature
0.6
0.4
0.2
0
–0.2
2000
2010
2020
2030
2040
2050
Year

Simplify by only showing the trend




Projected Atlantic Avg SST
(GFDL CM2.1 model, SRESA1B scenario, 10 member ensemble)
Temperature Change [C]
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
2000
2010
2020
2030
2040
2050
Year



Projected Atlantic Avg SST
(GFDL CM2.1 model, SRESA1B scenario, 10 member ensemble)
Temperature Change [C]
1.2
1
0.8
0.6
0.4
0.2
0
–0.2
2000
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2050
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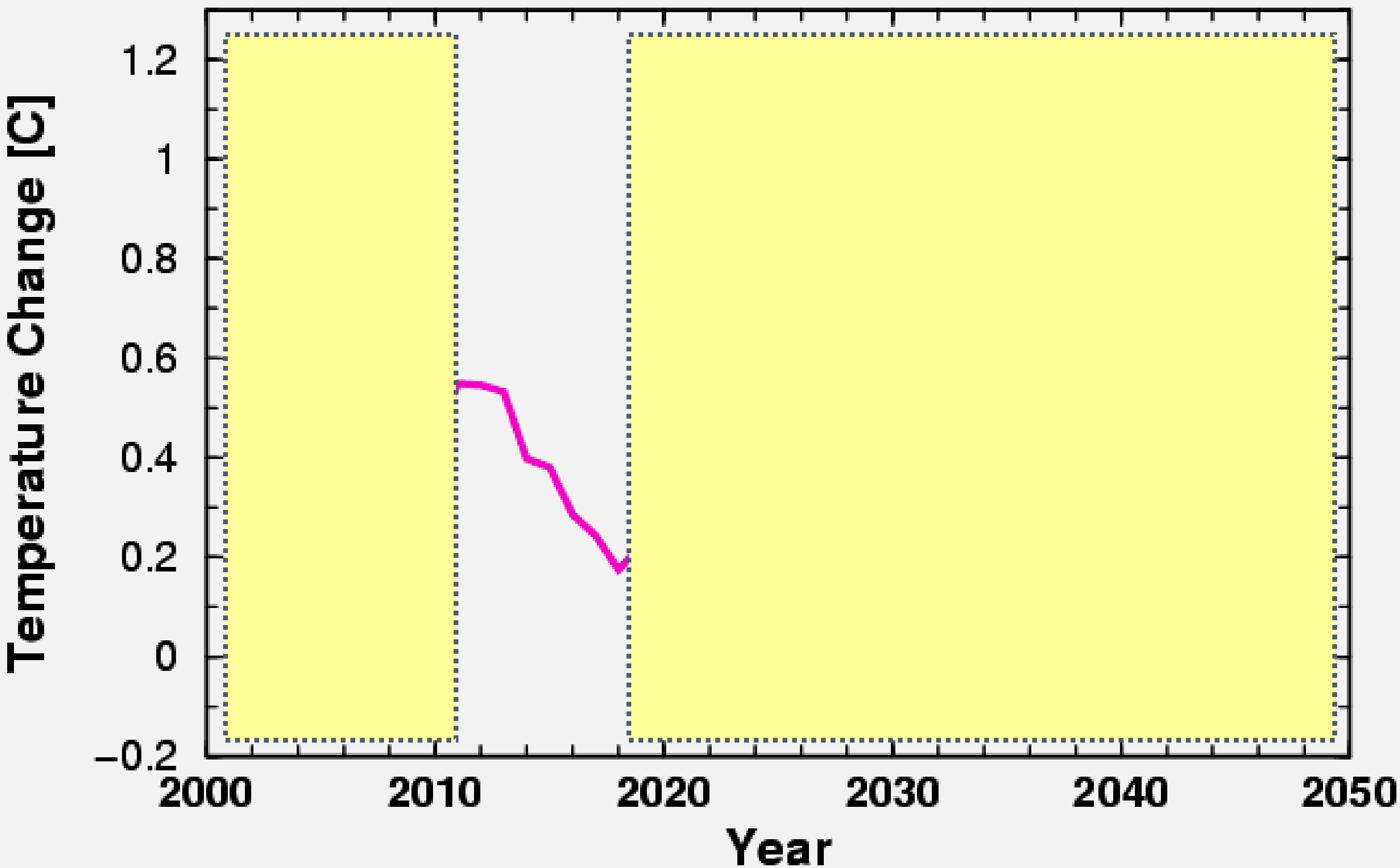
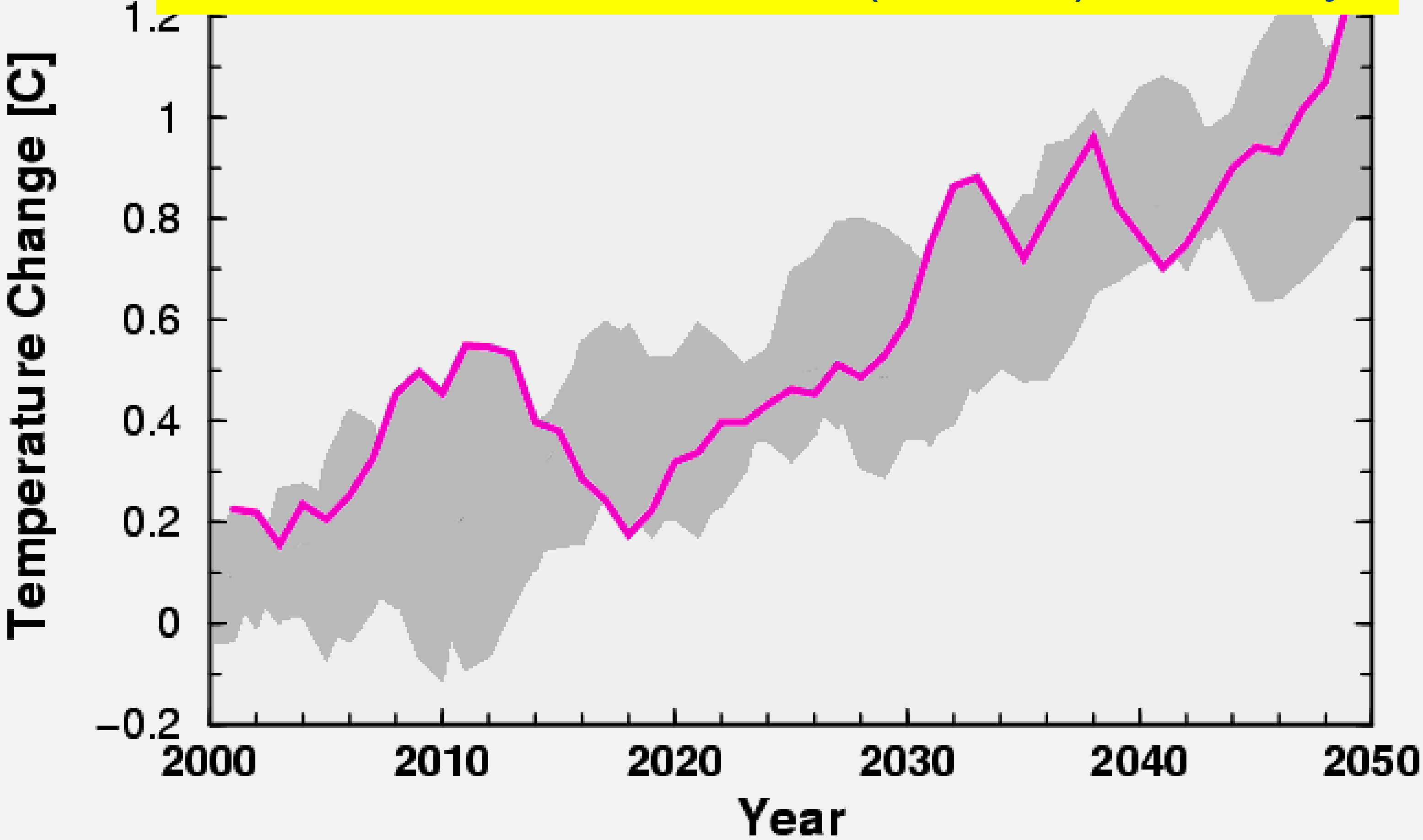


NOTE: Generally speaking, as one considers smaller geographic regions it takes longer for the force climate change “signal” to emerge from the “noise” of natural (internal) variability.



Fermenting Froth vs. Scientific Consensus

Sources of Scientific Info:

Individual peer-reviewed scientific papers… (typically journal articles are officially reviewed by relatively few people, as opposed to dozens or hundreds who are involved in the preparation of large "assessment" reports.)

The ideas contained in the individual papers are bits of the "fabulous fermenting froth*" of scientific investigation.

The assessment reports serve to distill the information and communicate the policy relevant bits that stand up.

(*paraphrase of Richard Alley during Congressional Hearing of 8 Feb 2007)

Intergovernmental Panel on Climate Change (2007) AR4 report, Working Group 1 Chapter 8: “Climate Models And Their Evaluation”

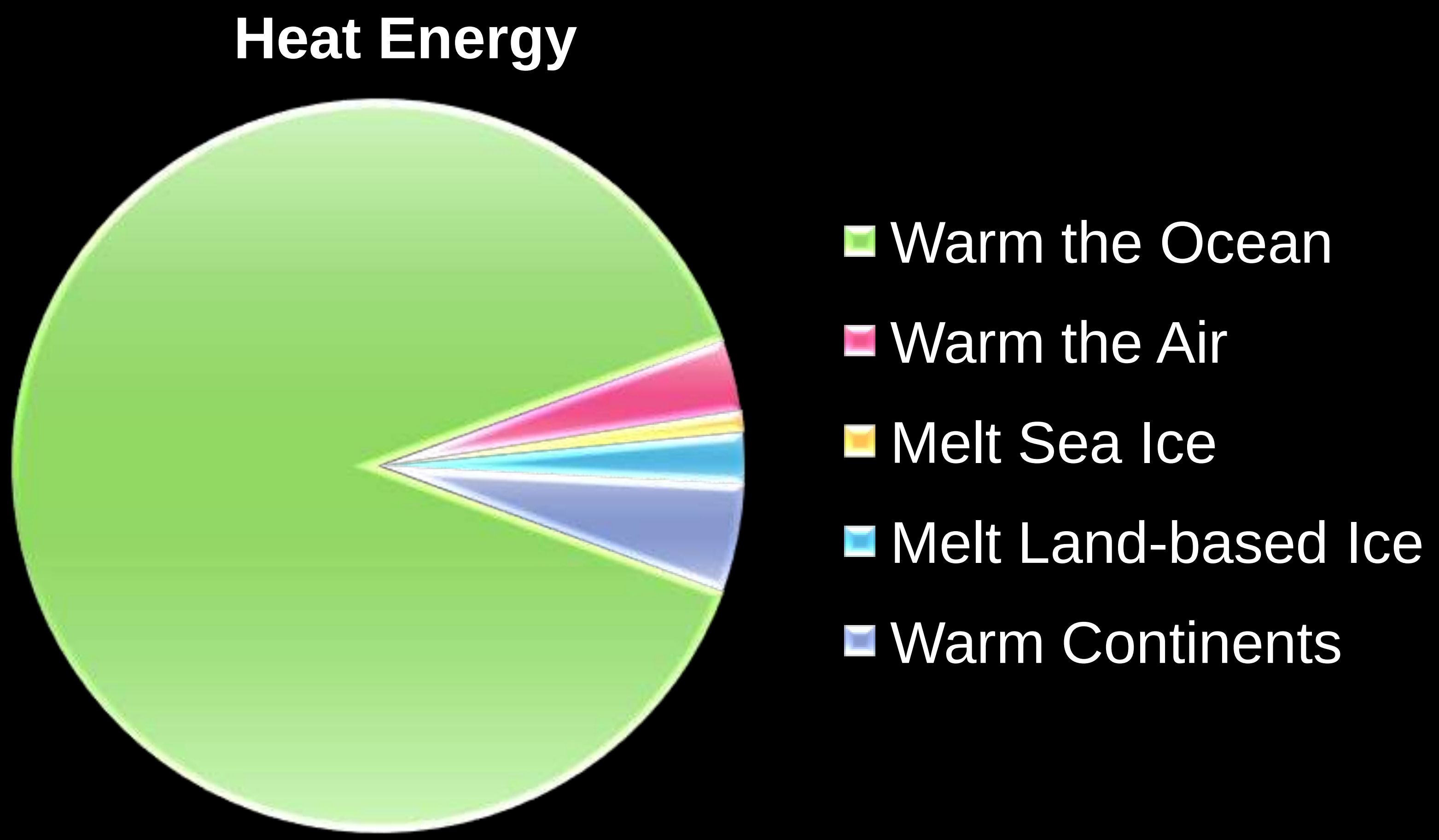
Frequently Asked Question 8.1

How Reliable Are the Models Used to Make Projections of Future Climate Change?

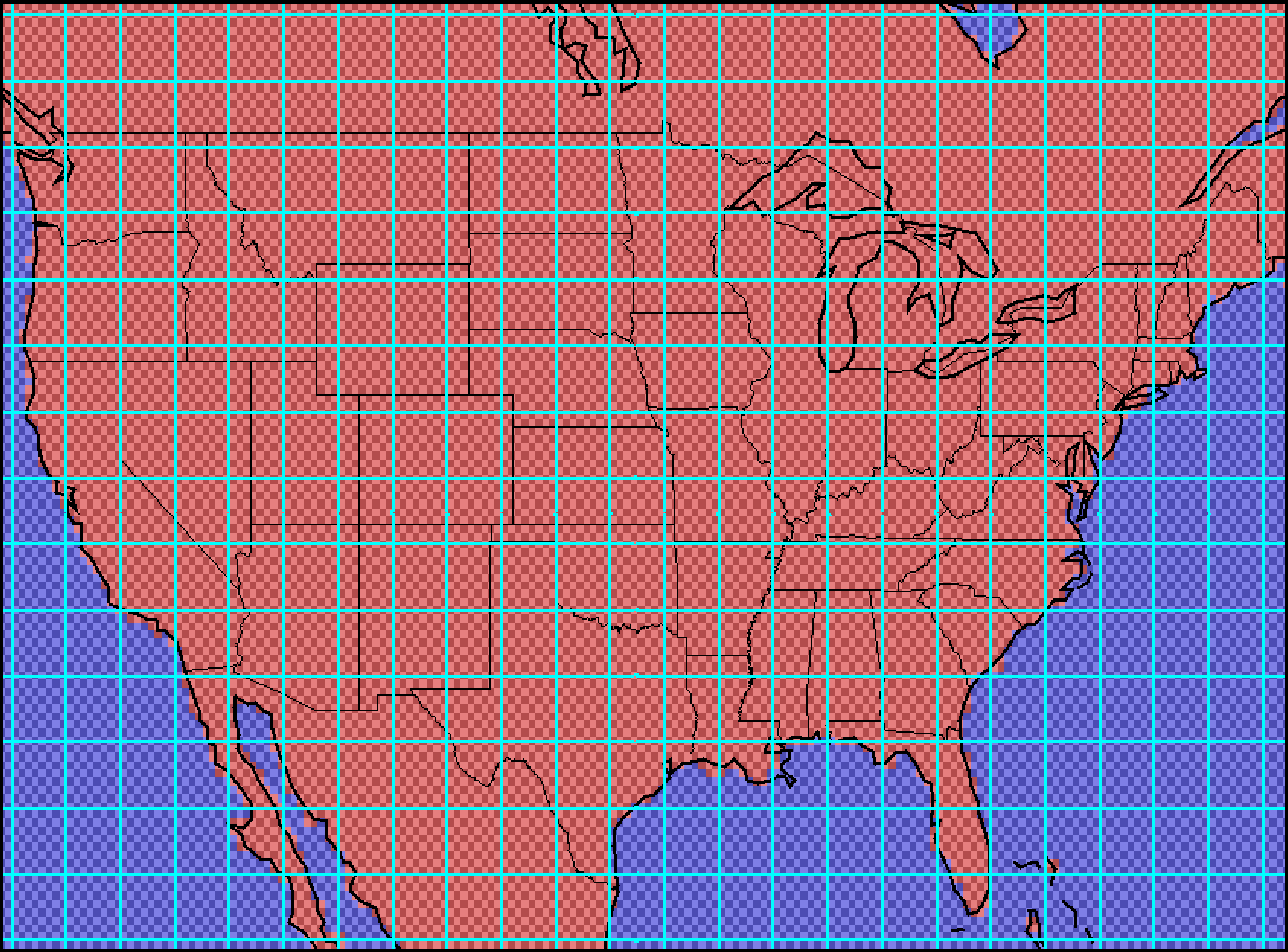
In summary, confidence in models comes from their physical basis, and their skill in representing observed climate and past climate changes. Models have proven to be extremely important tools for simulating and understanding climate, and there is considerable confidence that they are able to provide credible quantitative estimates of future climate change, particularly at larger scales. Models continue to have significant limitations, such as in their representation of clouds, which lead to uncertainties in the magnitude and timing, as well as regional details, of predicted climate change. Nevertheless, over several decades of model development, they have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases.

http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch8.html

Where has the additional heat energy gone? (1961-2003)



Data source:
IPCC 2007 WG1-AR4 , Fig. 5-4



Mitigation vs. Adaptation Strategies

LIMIT

- **MITIGATION**
  a human intervention that seeks to reduce the sources of greenhouse gases or enhance their sinks.

eg., increased fuel efficiency standards, car pools, setting % for renewables, cap & trade, CCS, planting trees, Δ land use practices, geo-engineering.

- **ADAPTATION**
  a human intervention that seeks to reduce the vulnerability of natural and human systems to climate change effects.

PREPARE

eg., build reservoirs, flood control projects, raise sea walls, change crops planted or develop new strains, move infrastructure or people, new Arctic Navy ships.

What role can climate model projections play in "decision support"?

…from "Best Available Science" To "Actionable Science"

LIMIT

MITIGATION

ADAPTATION

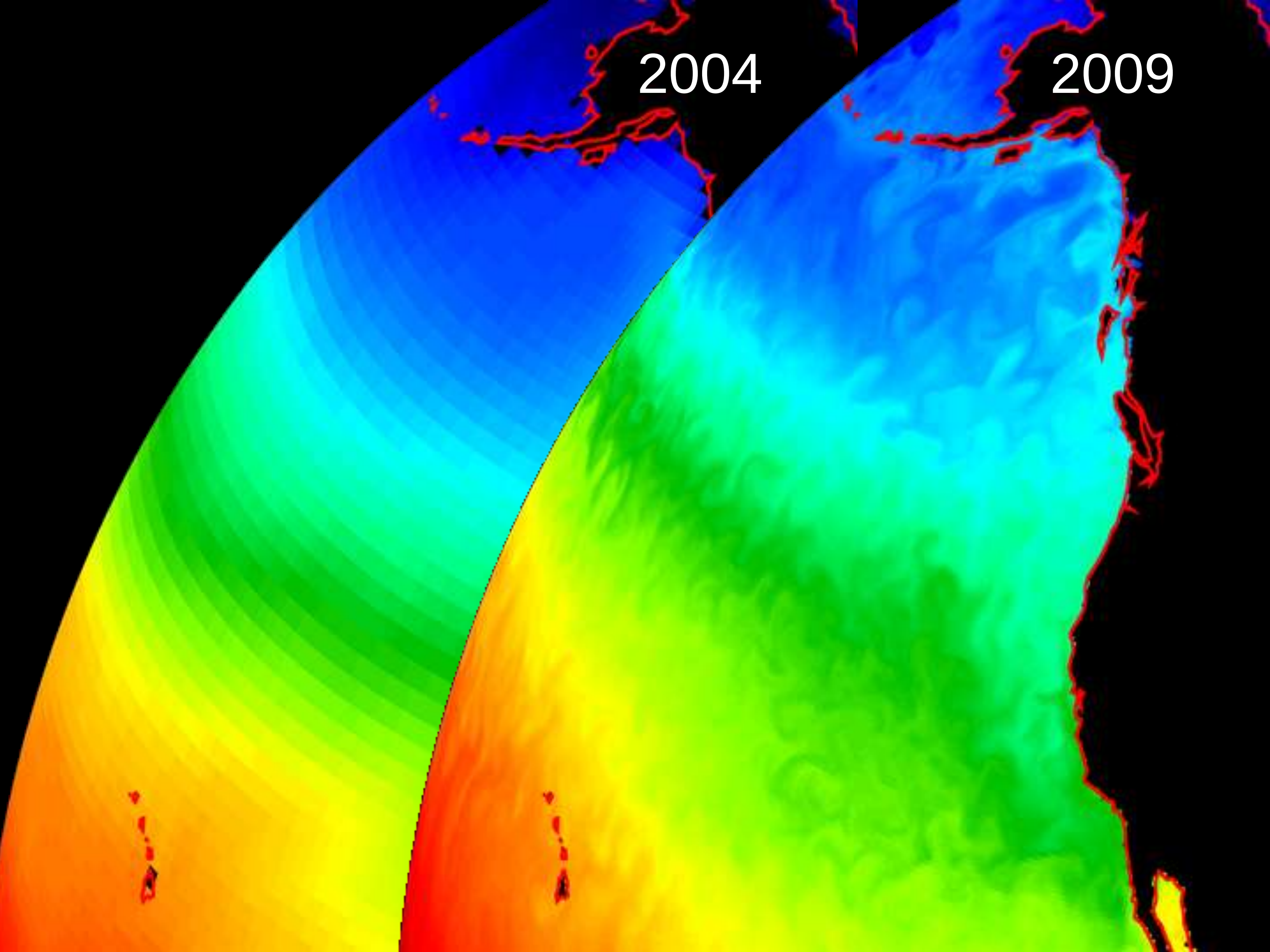
PREPARE

Large-Scale Science "Done"

By 2007, climate science had answered the main questions policymakers needed answered… Now it was up to policymakers to debate what the policy response should be.

Local-Scale Science "???"

By 2007, there was a need for higher-resolution climate change info to support adaptation planning… But could the science supply it at the levels desired to meet the demand?


2004
2009

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ARTICLES

DECADAL PREDICTION

Can It Be Skillful?

BY GERALD A. MEEHL, LISA GODDARD, JAMES MURPHY, RONALD J. STOUFFER, GEORGE BOER, GOKHAN DANABASOGLU, KEITH DIXON, MARCO A. GIORGETTA, ARTHUR M. GREENE, ED HAWKINS, GABRIELE HEGERL, DAVID KAROLY, NOEL KEENLYSIDE, MASAHIDE KIMOTO, BEN KIRTMAN, ANTONIO NAVARRA, ROGER PULWARTY, DOUG SMITH, DETLEF STAMMER, AND TIMOTHY STOCKDALE

A new field called “decadal prediction” will use initialized climate models to produce time-evolving predictions of regional climate that will bridge ENSO forecasting and future climate change projections.

The next Intergovernmental Panel on Climate Change (IPCC) report will contain a chapter on Decadal Predictability (aka Near-Term Climate)

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"The ability to provide meaningful decadal predictions using dynamical models has yet to be firmly established, but pioneering efforts at initializing coupled ocean-atmosphere 10-yr predictions have begun."

"…some unresolved questions remain regarding not only how to conduct decadal predictions, but also regarding the quality and usefulness of the results."

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"As we stand at the threshold of a new area of research, there are a variety of science questions that need to be addressed."

Physical Science Motivation: understanding mechanisms of variability
Societal Impacts Motivation: policy & decision-making support

Skill for "near term climate change" (decadal climate) predictions could come from:

- Climate Change Commitment (changes already in the pipeline due to atmospheric composition changes that have already occurred; the ocean's role)
- Climate Change Forced by Future Atmospheric Composition Changes (projections for atmospheric GHGs and aerosols)
- Knowledge of the Initial Conditions (observations of the climate system's "starting point")

Very Much An Active Research Topic

Why do we now think we can take a stab at tackling decadal climate prediction?

- **Better and more comprehensive observations** (especially of the ocean)

- **Improved global climate models**
  - Improved scientific understanding, leading to better climate models
  - More powerful computers, higher resolution

(a synthesis of observations, theory, & numerical modeling)

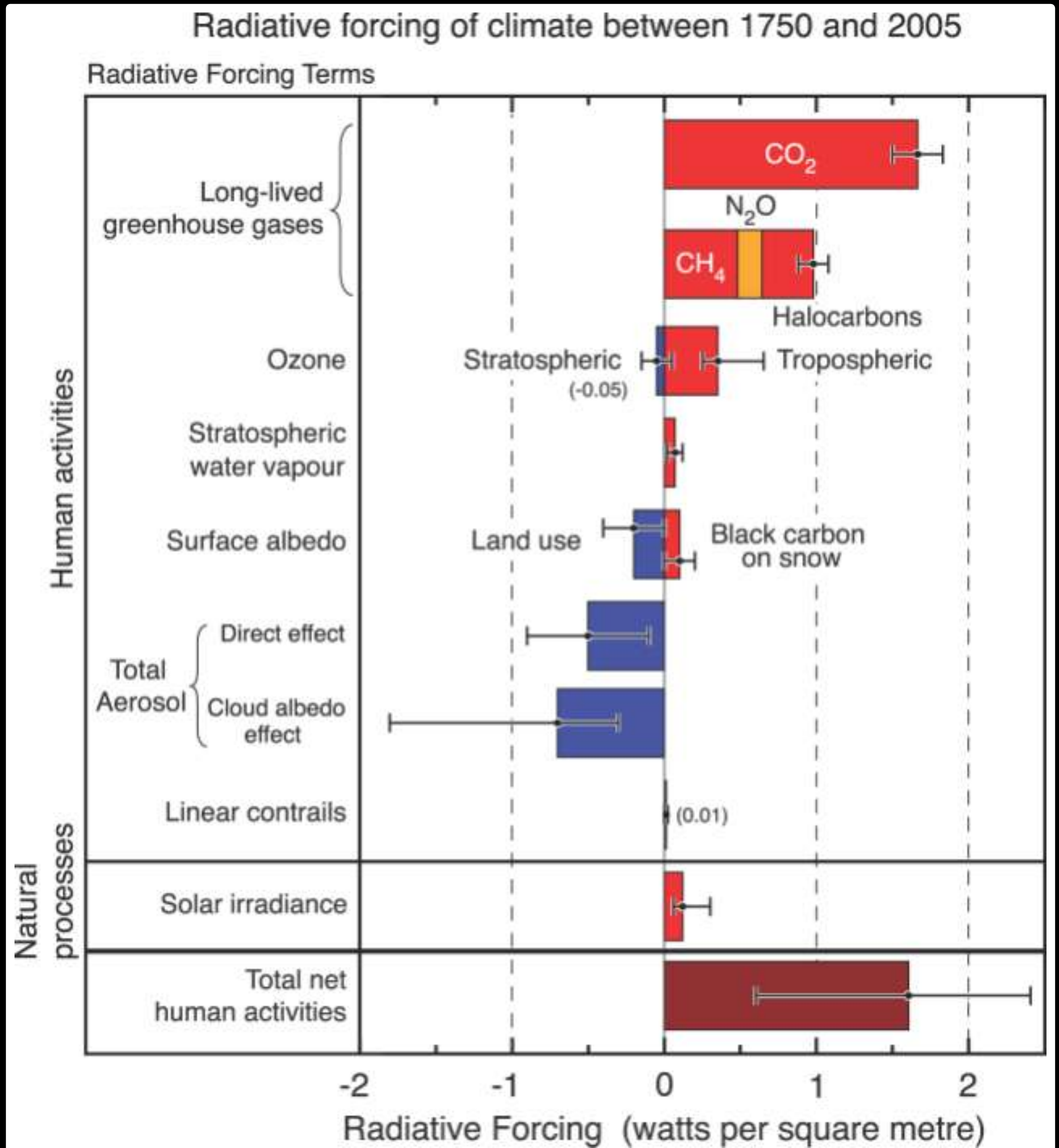
CMIP3 Climate Models

Last updated 17 July 2007

Originating Group(s)	Country	CMIP3 I.D.
Beijing Climate Center	China	BCC-CM1
Bjerknes Centre for Climate Research	Norway	BCCR-BCM2.0
National Center for Atmospheric Research	USA	CCSM3
Canadian Centre for Climate Modelling & Analysis	Canada	CGCM3.1(T47)
Canadian Centre for Climate Modelling & Analysis	Canada	CGCM3.1(T63)
Météo-France / Centre National de Recherches Météorologiques	France	CNRM-CM3
CSIRO Atmospheric Research	Australia	CSIRO-Mk3.0
CSIRO Atmospheric Research	Australia	CSIRO-Mk3.5
Max Planck Institute for Meteorology	Germany	ECHAM5/MPI-OM
Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA, and Model and Data group.	Germany / Korea	ECHO-G
LASG / Institute of Atmospheric Physics	China	FGOALS-g1.0
US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory	USA	GFDL-CM2.0
US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory	USA	GFDL-CM2.1
NASA / Goddard Institute for Space Studies	USA	GISS-AOM
NASA / Goddard Institute for Space Studies	USA	GISS-EH
NASA / Goddard Institute for Space Studies	USA	GISS-ER
Instituto Nazionale di Geofisica e Vulcanologia	Italy	INGV-SXG
Institute for Numerical Mathematics	Russia	INM-CM3.0
Institut Pierre Simon Laplace	France	IPSL-CM4
Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC)	Japan	MIROC3.2(hires)
Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC)	Japan	MIROC3.2(medres)
Meteorological Research Institute	Japan	MRI-CGCM2.3.2
National Center for Atmospheric Research	USA	PCM
Hadley Centre for Climate Prediction and Research / Met Office	UK	UKMO-HadCM3
Hadley Centre for Climate Prediction and Research / Met Office	UK	UKMO-HadGEM1

Page printed from:
http://www-pcmdi.llnl.gov/ipcc/model_documentation/ipcc_model_documentation.php

Radiative Forcing Agents: things that change the flow of solar & terrestrial (infrared) radiation though the climate system.



Source:
IPCC 2007 WG1-AR4 , Ch. 2, FAQ 2.1 Fig. 2

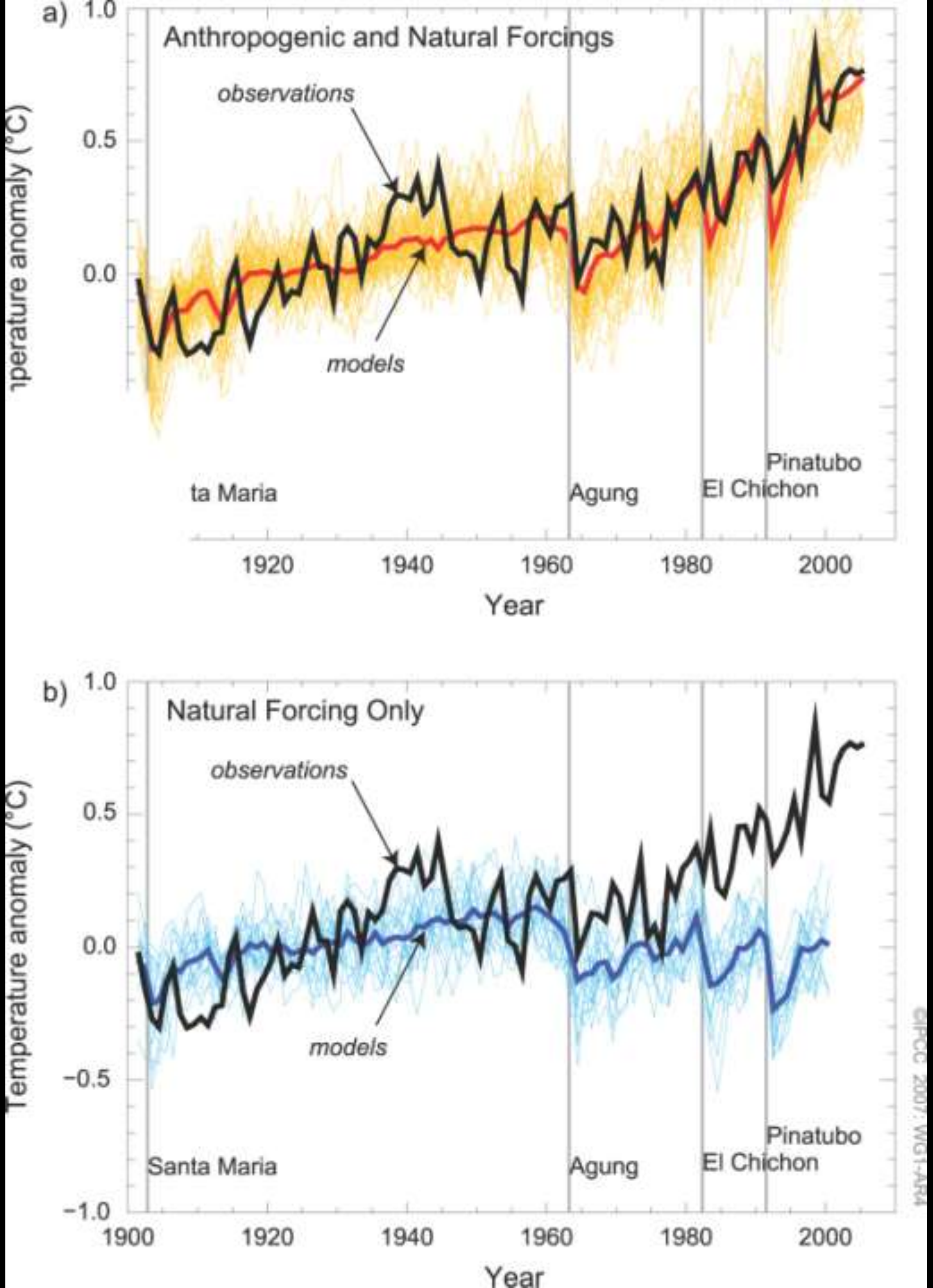
Simulating the 20th Century

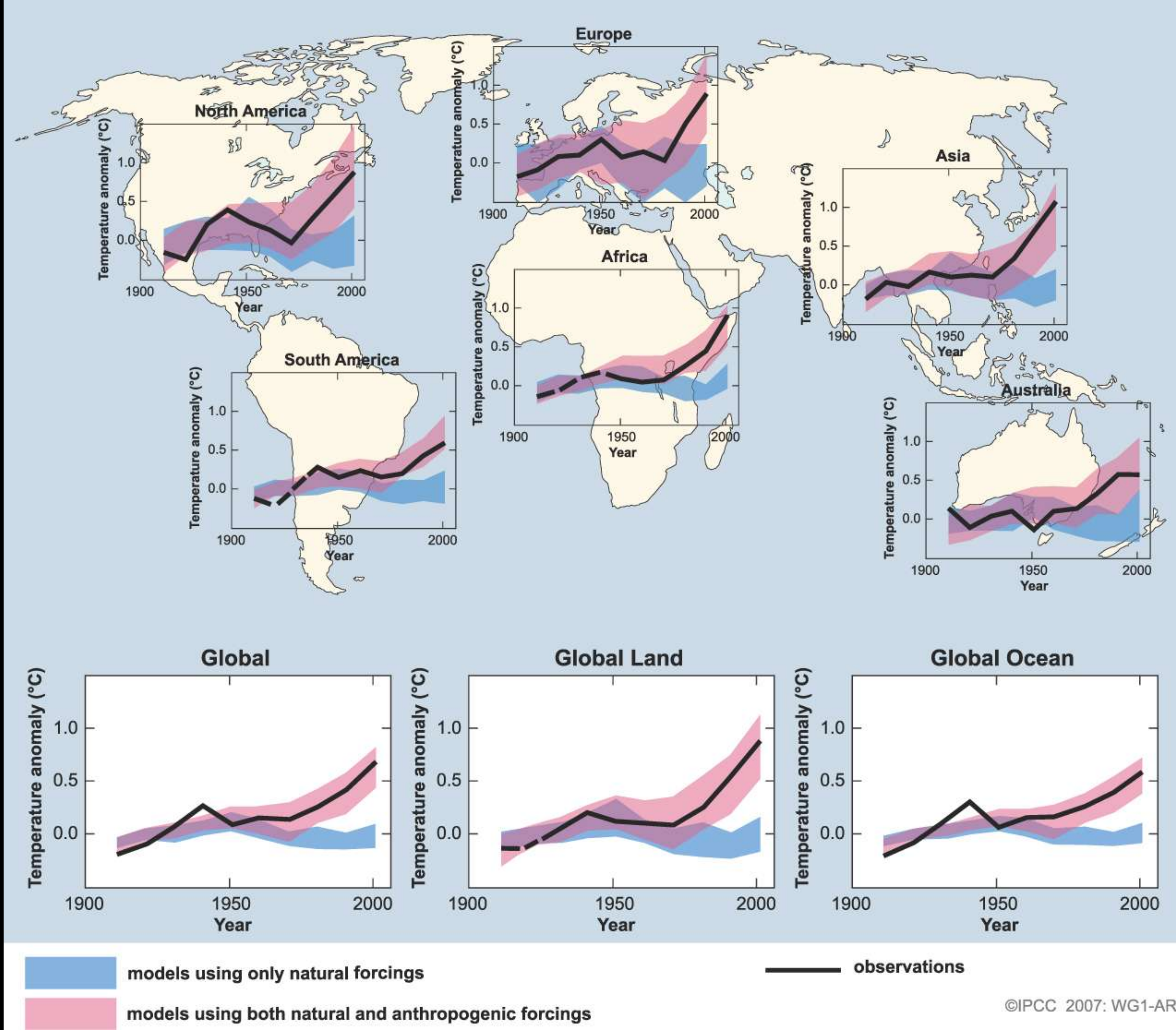
…asking "What if?" questions as part of Detection / Attribution studies

Anthropogenic Forcings = multiple GHGs, aerosols, land use, etc.

Natural Forcings = volcano & solar

Source: IPCC AR4 WG1 (2007) Technical Summary Fig 23





Europe
North America
Asia
Africa
South America
Australia
Global
Global Land
Global Ocean
Temperature anomaly (°C)
1.0
0.5
0.0
1900
1950
2000
Year
models using only natural forcings
models using both natural and anthropogenic forcings
observations
©IPCC 2007: WG1-AR4

Goldilocks' & The 3 Bears Attribution Conclusions:

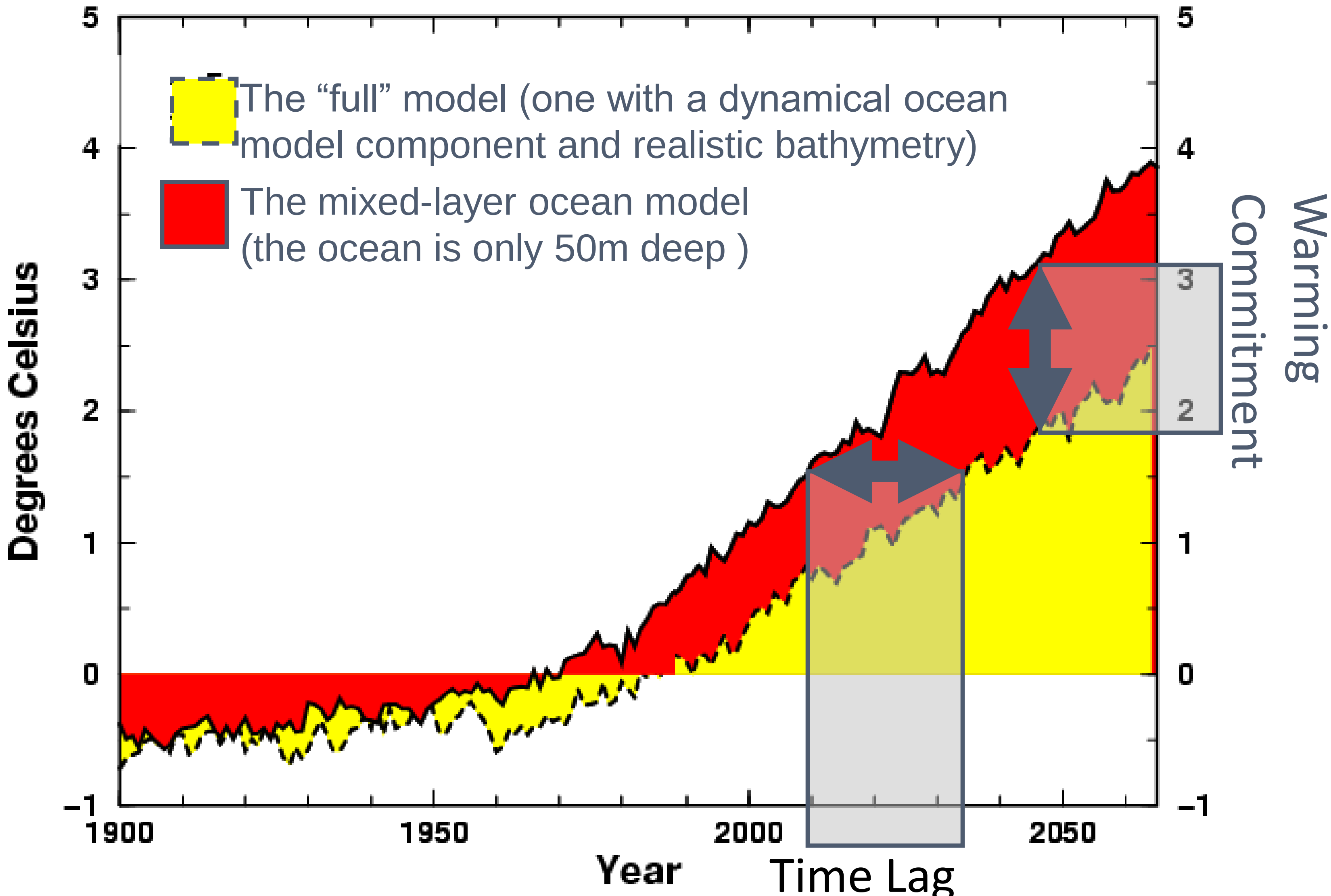
- If we consider only the natural forcings (solar and volcanic), the climate simulation is too cold (don't simulate the late 20th century warming signal).

- If we consider only the GHGs, the climate simulation gets too hot too fast.

- Considering together 4 types of changes (natural & human-induced) the model's 20th century global average temperature simulations are **just about right**.

(1) multiple GHGs (warming)
(2) Solar(+/-)
(3) Volcanic (cooling, few years)
(4) Tropospheric Aerosols (pollutants) (some + & some -, net -, short lived, days to week)

Ocean Heat Uptake Affects The Global Avg. Surface Air Temperature Transient Response



After Wetherald, Stouffer, & Dixon (2001), "Committed Warming and its implications for climate change", GRL.

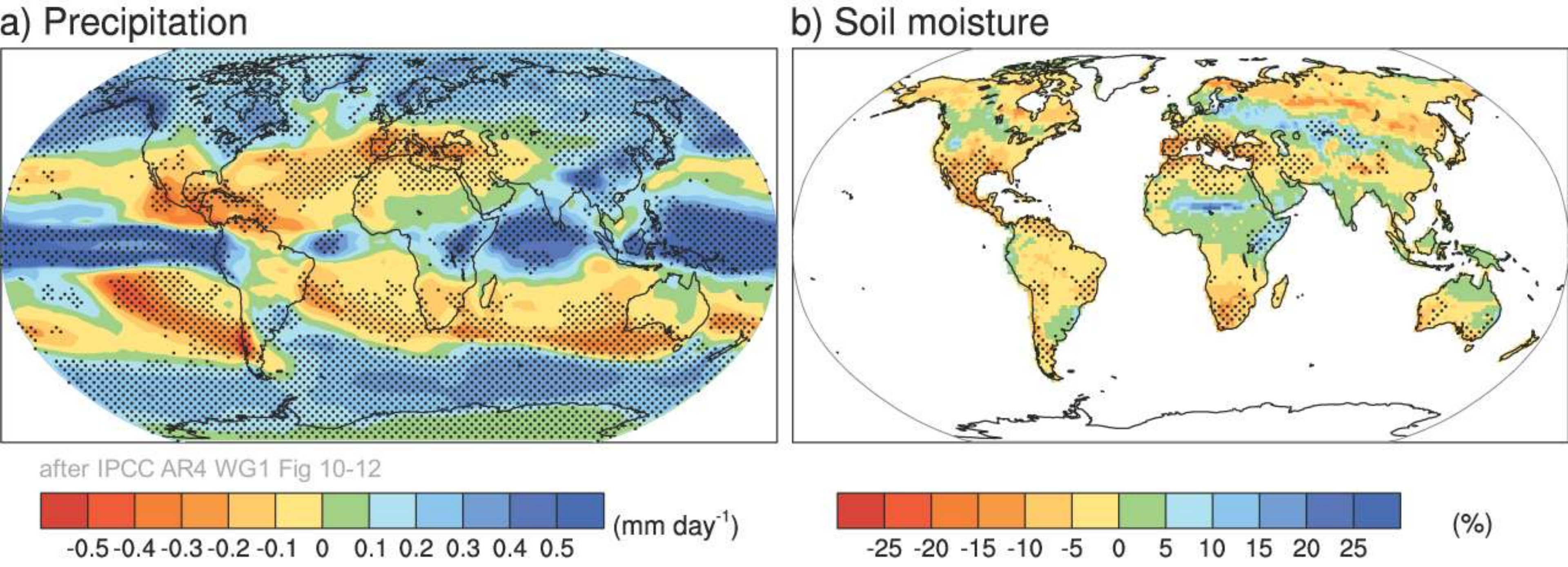
Some Implications

- Because of the ocean's heat uptake, the atmosphere is far from being in equilibrium with the present levels of atmospheric greenhouse gases.

- Even if atmospheric greenhouse gas concentrations were held constant at today's levels, the climate system would continue to warm for decades.

"Committed Warming" due to the ocean's thermal inertia…

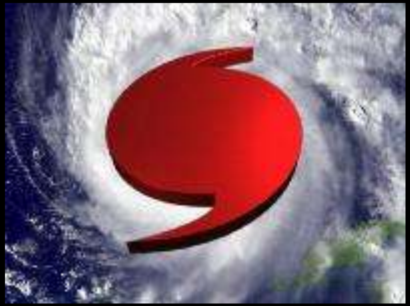
Precipitation & Soil Moisture: Multi-model 2080-2099 mean relative to 1980-1999. [A1B]



- Models simulate that global mean precipitation increases with global warming. Changes over the ocean between 10S & 10N account for about half of the total. However, there are substantial spatial and seasonal variations among the models. (Stippling shows where 80%+ of the models agree on the sign.) For soil moisture, there is some consistency in the sign of changes but magnitudes are quite uncertain.

WMO-related Tropical Cyclone Statements (2010)

www.nature.com/ngeo/journal/v3/n3/pdf/ngeo779.pdf
Knutson, *et al.*, "Tropical cyclones and climate change", Nature Geoscience, Vol 3, March 2010.



- **Detection / Attribution:** It remains uncertain whether past changes in any tropical cyclone activity (frequency, intensity, rainfall, and so on) exceed the variability expected through natural causes, after accounting for changes over time in observing capabilities.
- **Projections:** Tropical cyclone frequency is likely to either decrease or remain essentially the same. Despite this lack of an increase in total storm count, we project that a future increase in the globally averaged frequency of the strongest tropical cyclones is ***more likely than not*** — a higher confidence level than possible at our previous assessment.

Changes in severe weather environment

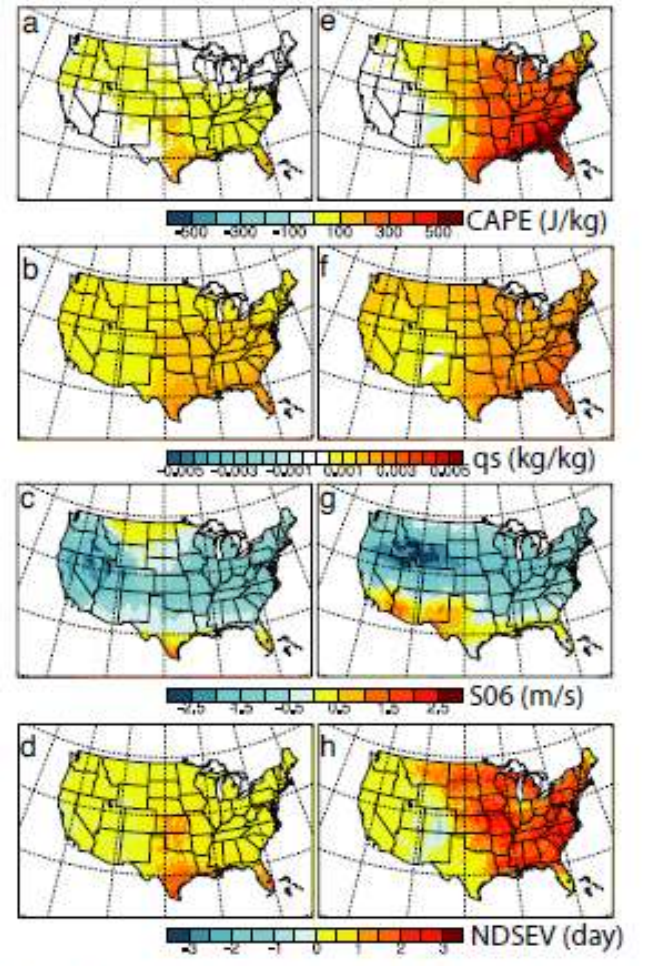
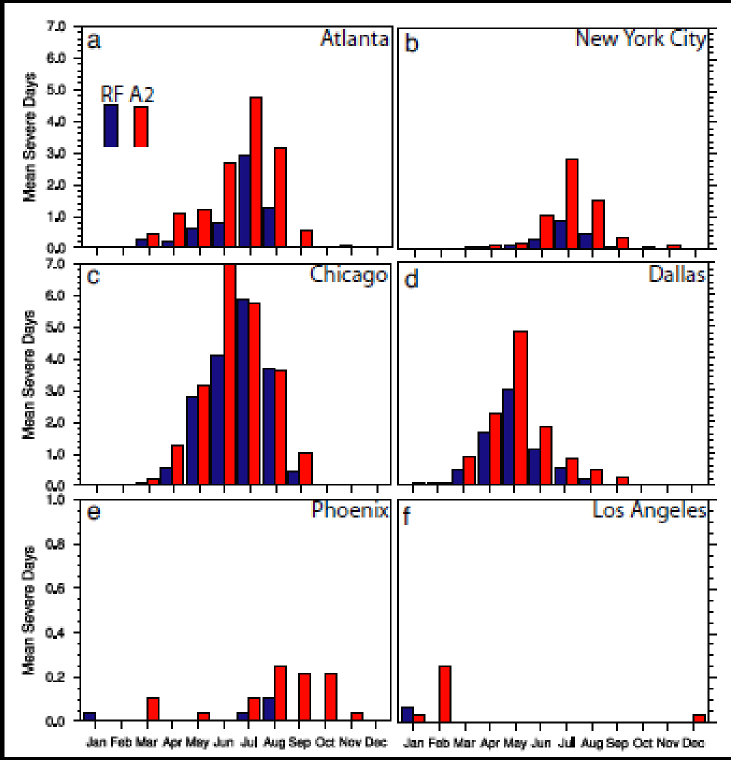


Fig. 1. Difference (A2 − RF) in mean CAPE, vertical wind shear over the surface to 6 km layer (S06), mean surface specific humidity (q_s), and severe thunderstorm environment days (NDSEV) for March–April–May (MAM) (*a–d*) and June–July–August (JJA) (*e–h*), respectively. The RF integration period is 1962–1989, and the A2 integration period is 2072–2099.

- CAPE and specific humidity increase
- Vertical wind shear decreases
- Net result: Increase in severe thunderstorm environment days



Source: Trapp et al. (2007, *PNAS*)

Statements from IPCC AR4 WG1 Technical Summary…

- The response of some major modes of climate variability such as ENSO still differs from model to model, which may be associated with differences in the spatial and temporal representation of present-day conditions.