CMIP5: A five year climate change modeling research strategy

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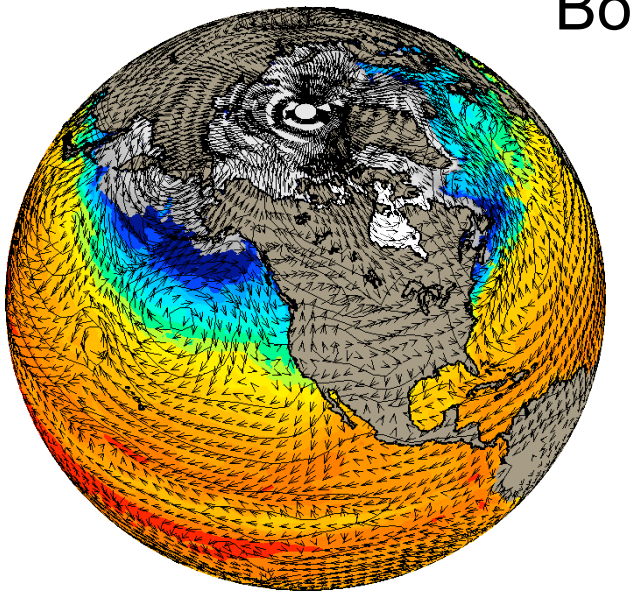


NCAR

The current round of climate change experiments for advancing our knowledge of climate variability and change and for assessment in the IPCC AR5:
Coupled Model Intercomparison Project phase 5 (CMIP5)

CMIP5 is the most ambitious coordinated multi-model climate change experiment ever attempted

CMIP5 is in progress (over 20 global climate change modeling groups around the world are participating)

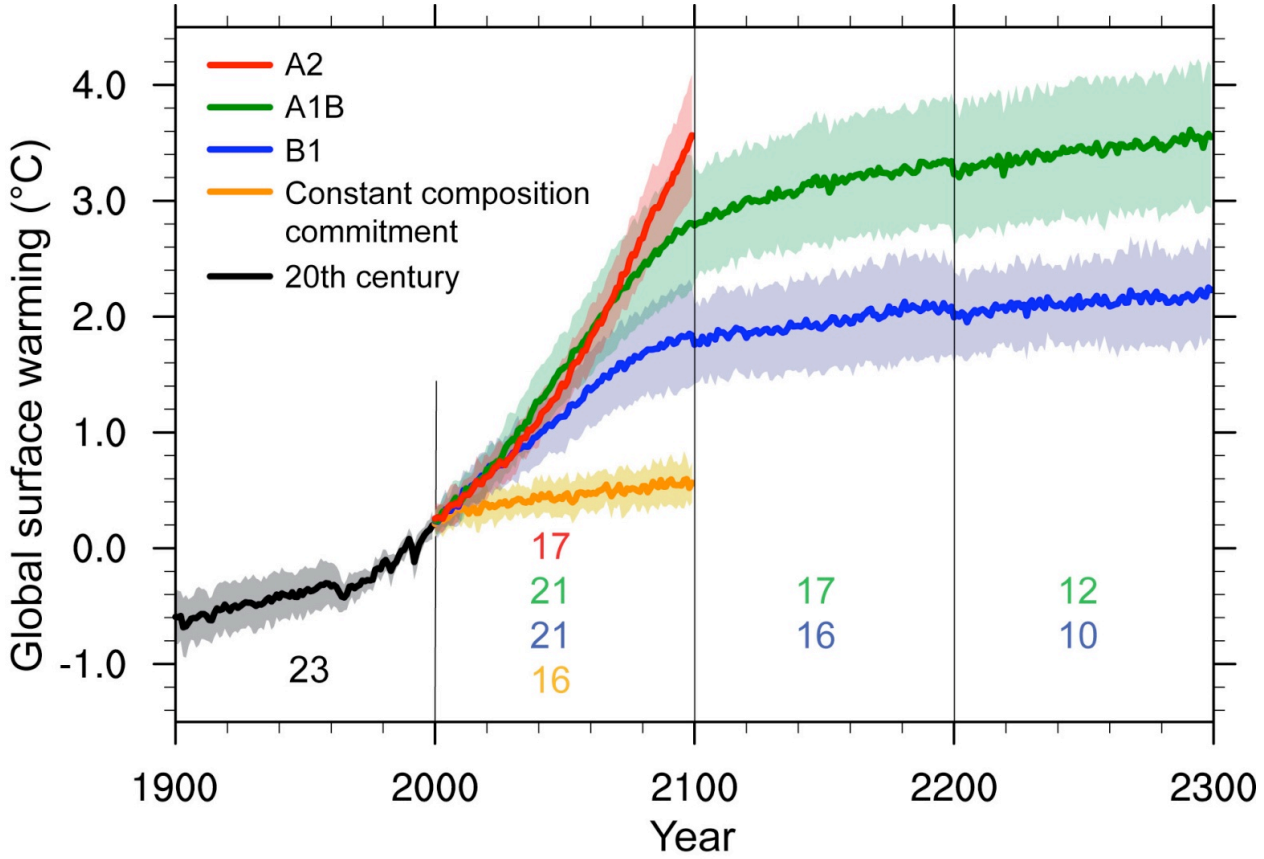
CMIP5 is being coordinated by the World Climate Research Program (WCRP) Working Group on Coupled Models (WGCM) in collaboration with AIMES (International Geosphere Biosphere Program--IGBP) and many other elements of the climate science community

What came before:

CMIP3

started in 2003; model data still being analyzed (CMIP4 was the 20th century single forcing experiments with the CMIP3 models)

Ch. 10, Fig. 10.4, TS-32



(Anomalies relative to 1980-99)

Unprecedented (up to that time) coordinated climate change experiments from 16 groups (11 countries) and 23 models collected at PCMDI (31 terabytes of model data), openly available, accessed by over 1200 scientists; hundreds of papers

Marked a “new era” in climate science research (Bulletin of the American Meteorological Society, 2007)

2007 IPCC AR4: “what if” SRES scenarios (no mitigation)

In 2006, it became clear that a profound paradigm shift for climate change science was about to happen, with direct implications for the emerging concept of climate services, and planning began for CMIP5

The IPCC AR4 in 2007 saw the end of the past 20 years of non-mitigation scenarios run in global climate models

Climate change science is now focusing on mitigation/ adaptation

New mitigation scenarios target certain levels of climate change that require policy actions

With different mitigation choices, what is the remaining time-evolving regional climate change to which human societies will have to adapt?

The new paradigm for climate change prediction:

decadal climate prediction with AOGCMs initialized with observations for near-term climate change over the next 30 years

In addition to **Atmosphere-Ocean General Circulation Models** (AOGCMs), first generation **Earth System Models** (ESMs) with coupled carbon cycle and intermediate resolution (~100 to150km) to study longer term feedbacks past mid-century with new mitigation scenarios

new **tangible linkages throughout the climate science community** WCRP, IGBP, IPCC Working Groups 2 (impacts/adaptation/vulnerability) and 3 (integrated assessment modeling and scenarios), and weather prediction community

A new set of climate change experiments: **CMIP5**

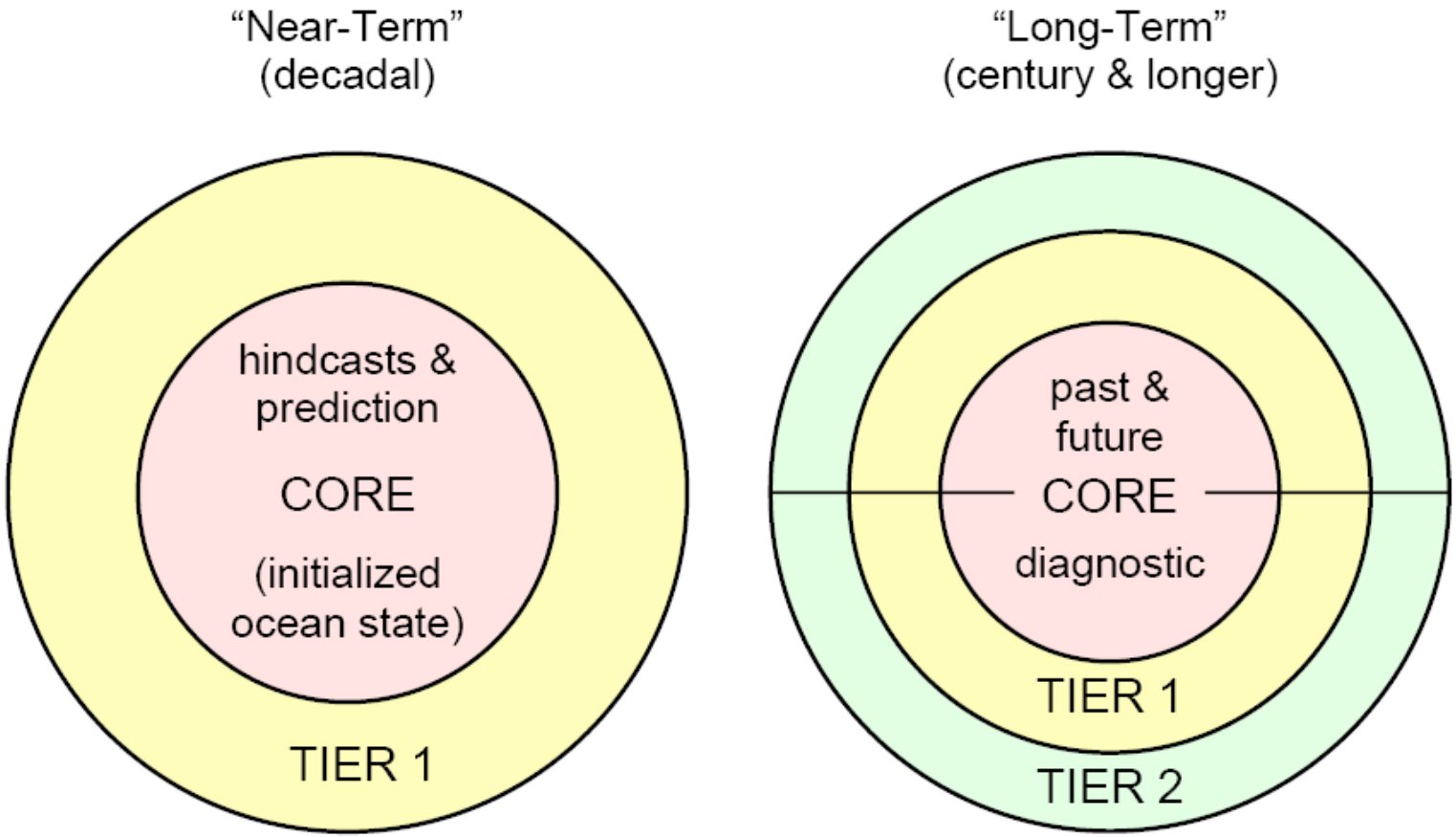
CMIP5 is an experimental design for a five year framework (2008-2013) for climate change modeling

CMIP5 is not dictated by IPCC, but formulated by the climate science community

experiments completed by July 2012 are being assessed in the IPCC AR5

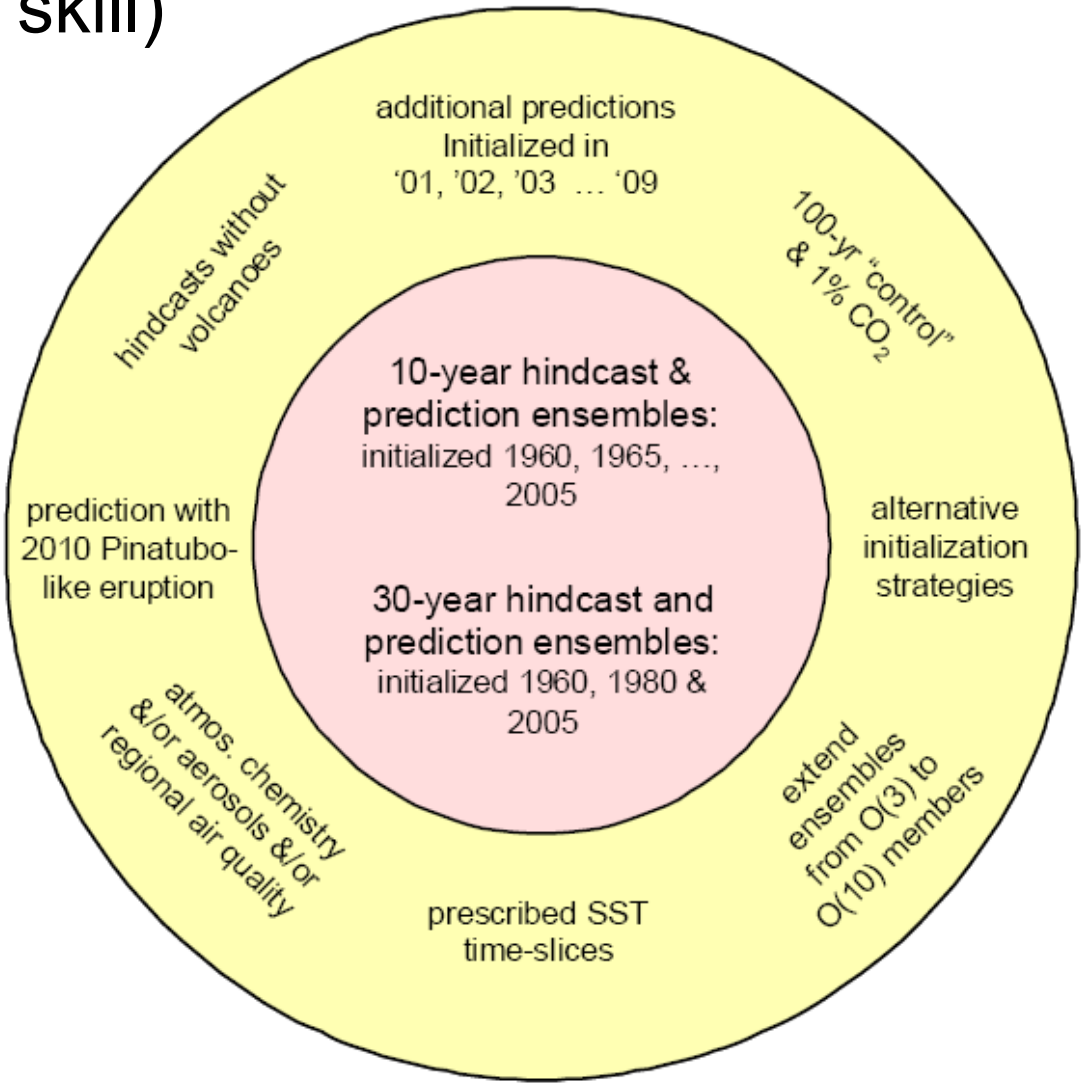
CMIP5 : conceptual experimental design

Two classes of models for two timescales and two sets of science problems

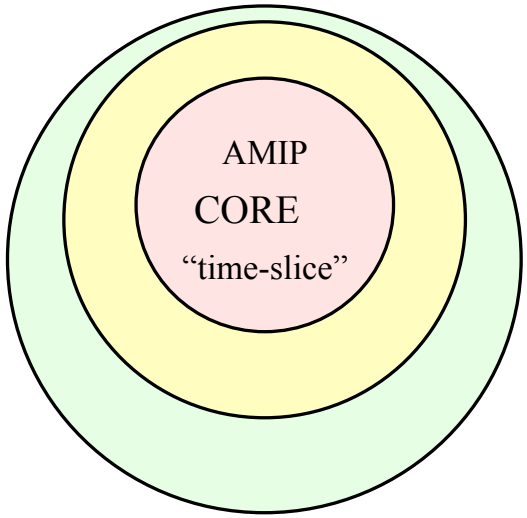


CMIP5 Decadal Prediction (out to 2035)

(Many experiments are hindcasts to quantify prediction skill)



CMIP5 time slice experiments with high resolution (~20 km) atmosphere-only models (to study changes in tropical cyclones, regional/local climate, etc.)



For computationally demanding models : very high resolution or very complex models, or new generation of climate models (e.g. global CRMs) :

Prescribed SST time-slices (1979-2008 + 2026-2035)

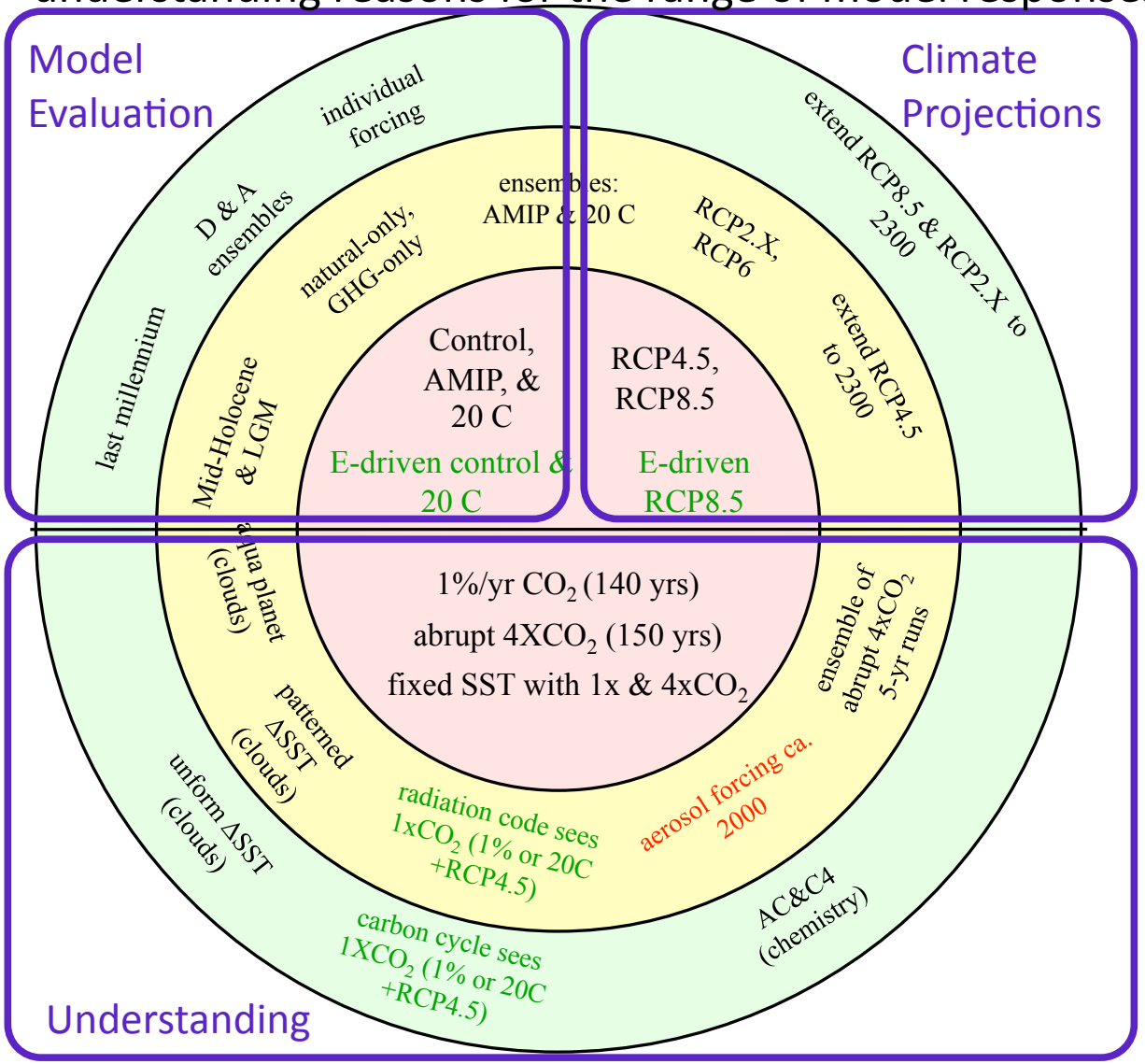
→ regional/local effects of climate change

→ hurricanes

→ explore the impact of higher resolution on climate simulations : mean & variability, extremes,
AND sensitivity to external perturbations.

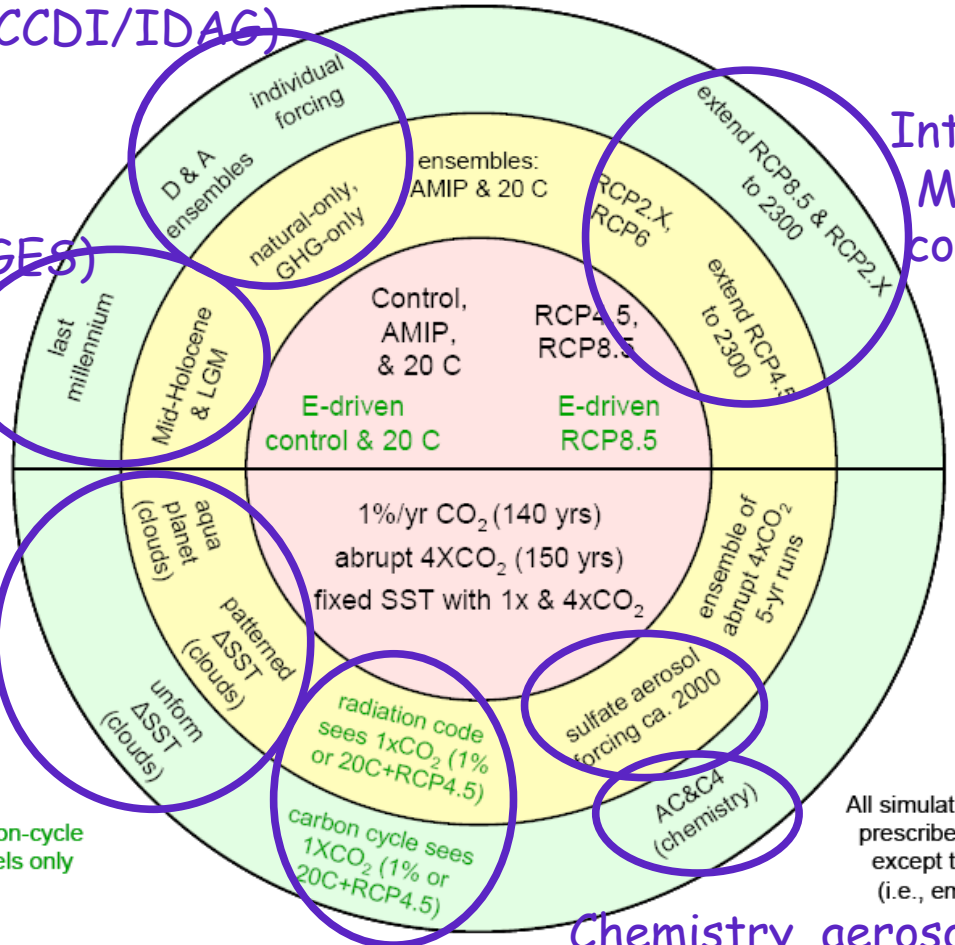
CMIP5 Long-Term Experiments

An important focus on model evaluation in comparison to observations and understanding reasons for the range of model responses



CMIP5 Long-Term Experiments

direct participation and collaboration with many communities



Detection-Attribution (ETCCDI/IDAG)

Paleo (PMIP, IGBP-PAGES)

Integrated Assessment Modeling Consortium, connection to WG-III

+ Satellite simulators & process diagnostics (CFMIP-GCSS)

Cloud and moist processes (CFMIP-GCSS WGNE)

Coupled carbon-cycle climate models only

All simulations are forced by prescribed concentrations except those "E-driven" (i.e., emission-driven).

Chemistry, aerosols (SPARC, AC&C)

Carbon-climate feedbacks (C4MIP, IGBP-AIMES)

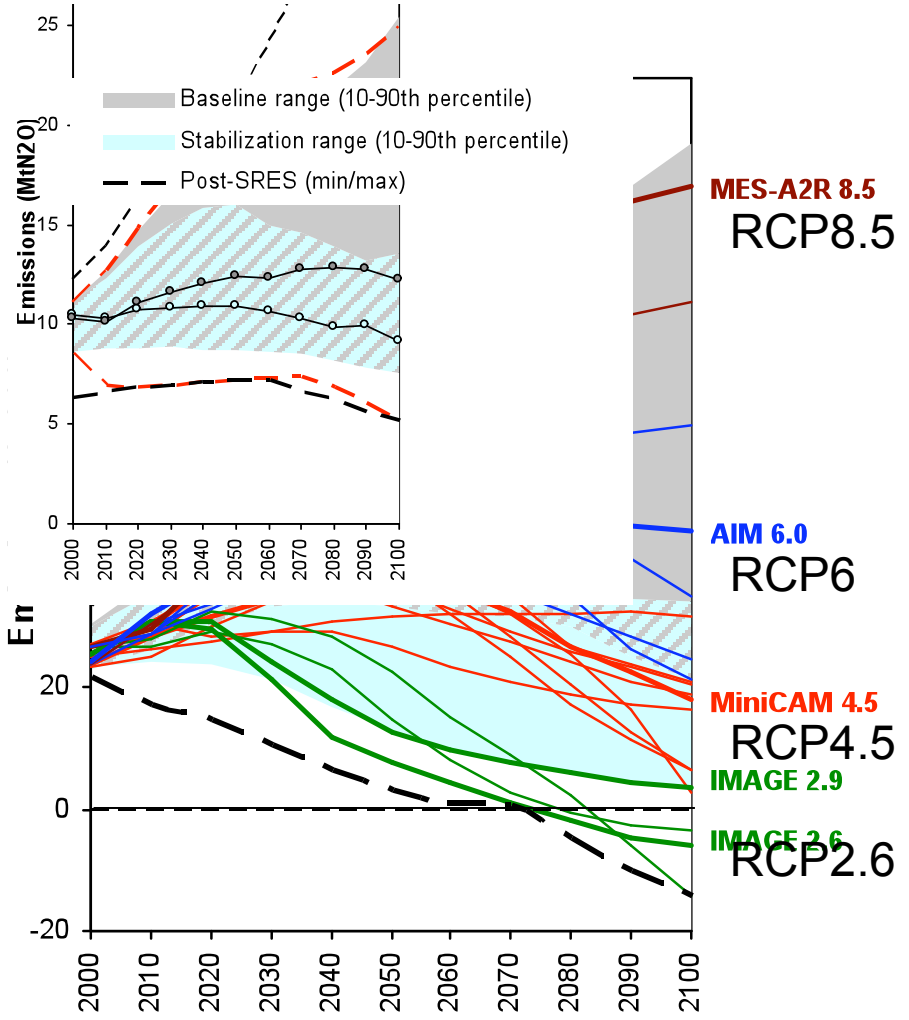
Crucial science questions are being addressed in CMIP5

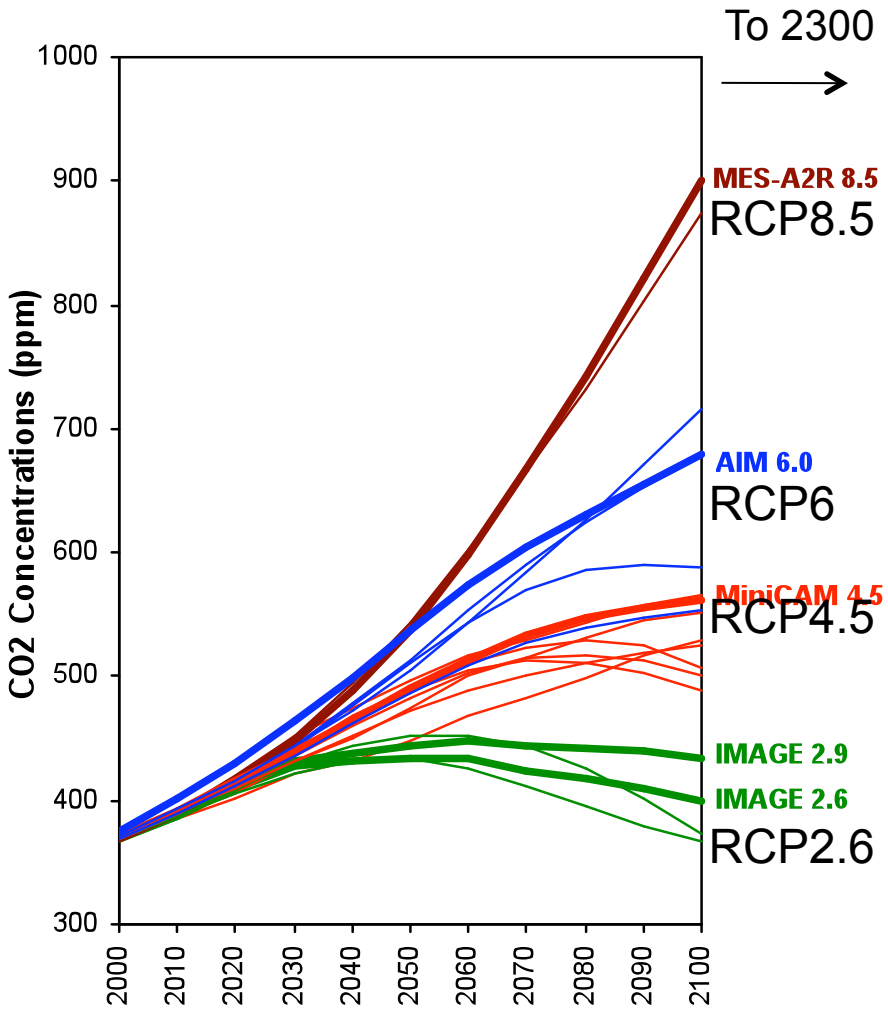
For example:

For decadal climate prediction:
what are the time-evolving changes in regional climate and extremes over the next few decades? (requires credible simulation of statistics of weather systems)

For long term climate change projections:
what are the size and nature of carbon cycle and other feedbacks in the climate system, and what will be the resulting magnitude of climate change for different mitigation scenarios? (requires credible interaction and feedbacks among all elements of the climate system)

New mitigation scenarios: representative concentration pathways (RCPs)



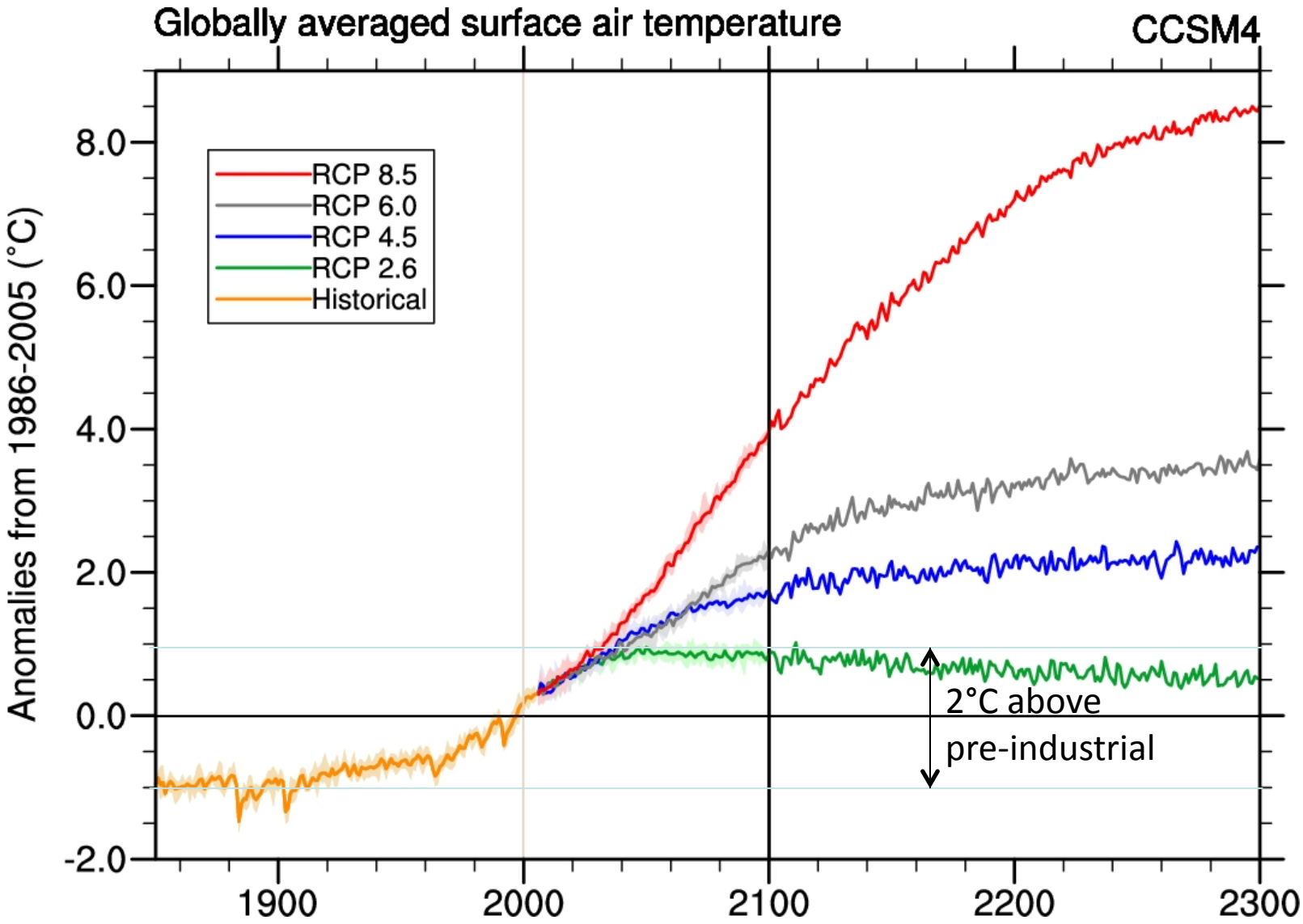


(Moss et al., 2010, Nature)

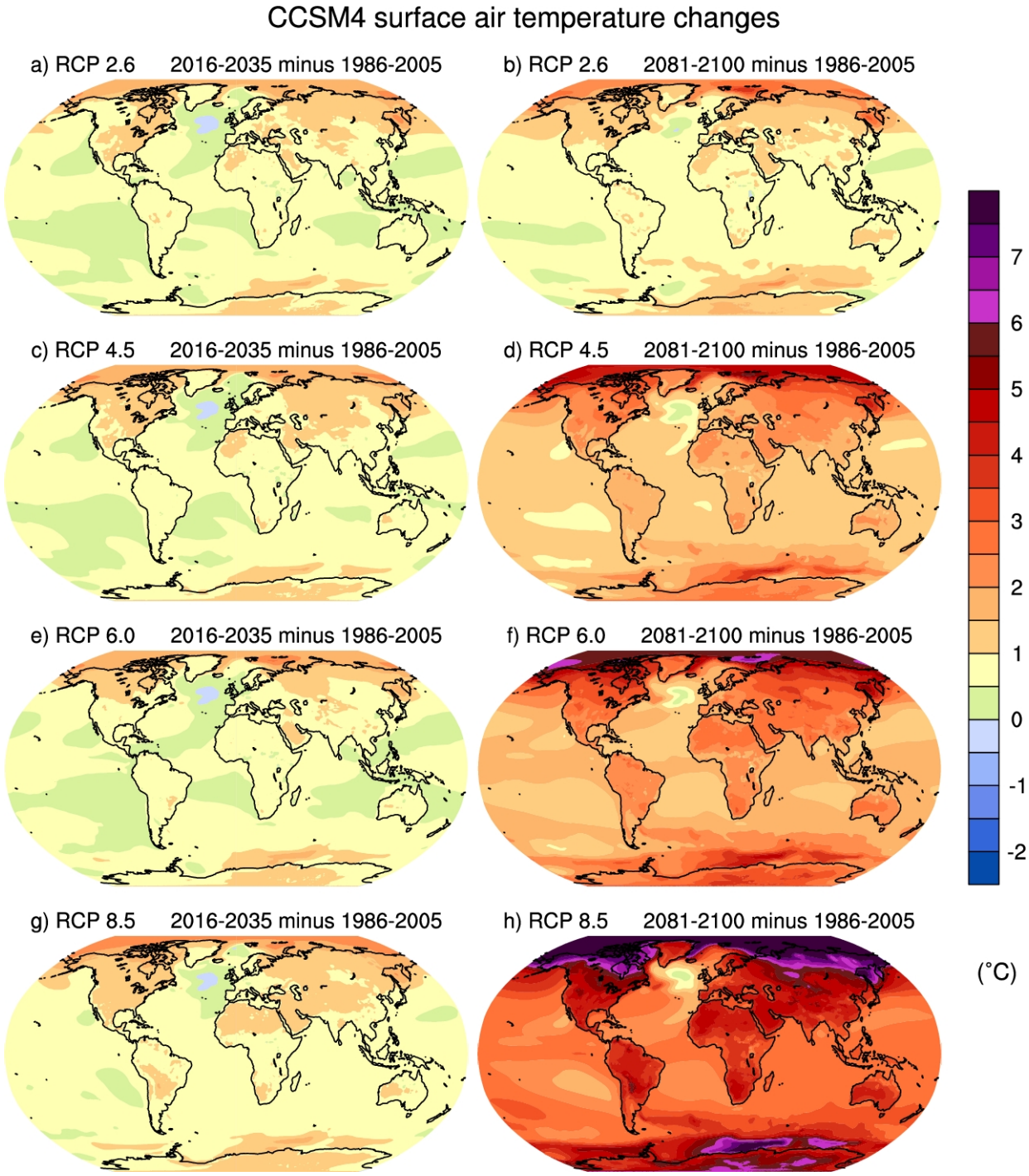
One way to achieve negative CO2 emissions in RCP2.6 by around 2070 in terms of the energy policy contribution (in addition to economic and demographic considerations):

--by 2070, about 45% fossil fuel with carbon capture and storage (CCS),
20% fossil fuel without CCS,
and 35% renewables (some of that includes biomass and CCS as well) and nuclear.

In contrast, RCP8.5 with little mitigation implies, by 2070, 80% fossil fuels without CCS, no fossil fuel with CCS, and 20% renewables and nuclear



(Meehl et al., 2012, J. Climate)



Warming in the near-term (2016-2035, left column) is similar no matter what scenario is followed—near term climate change is an adaptation problem

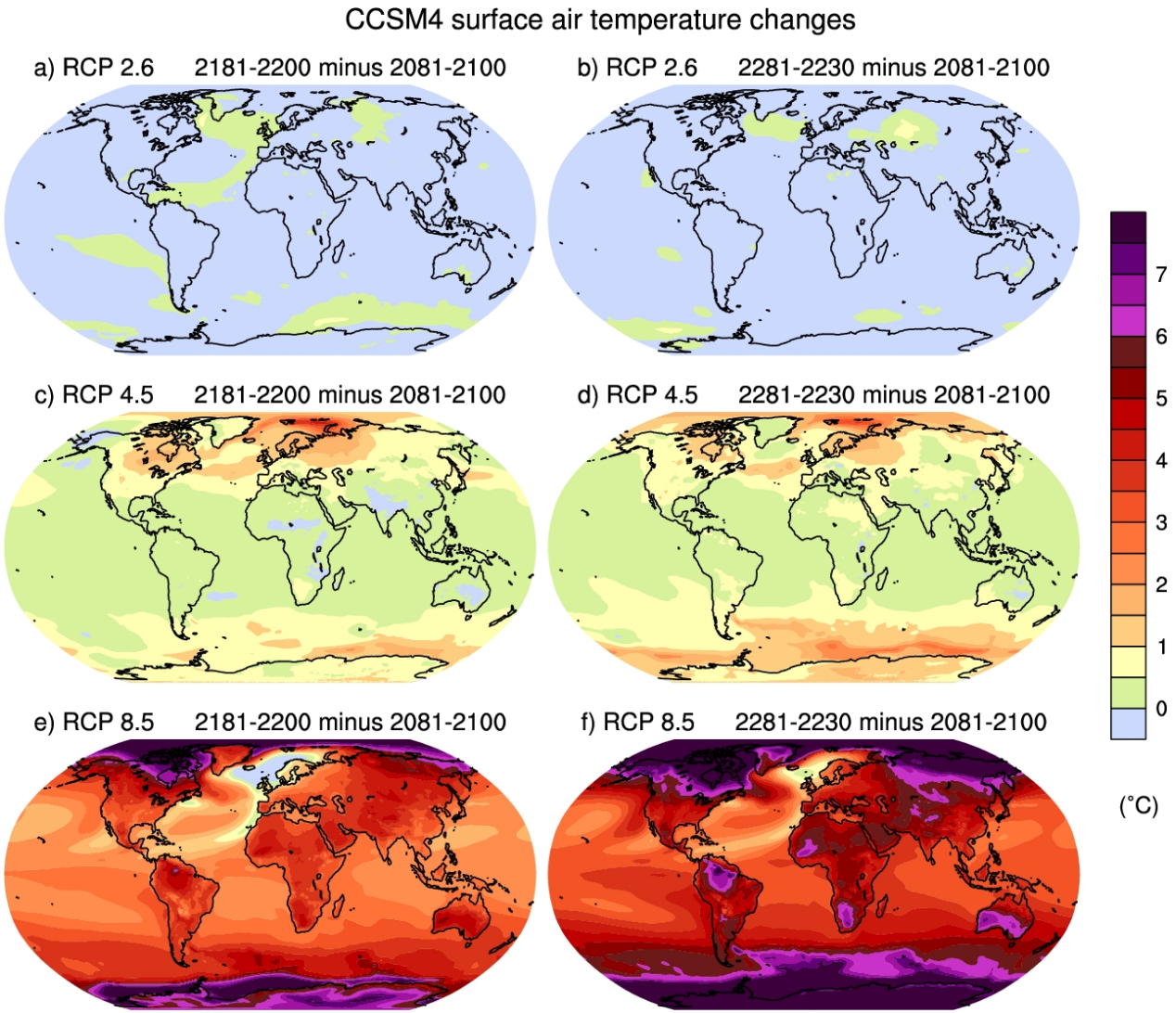
Magnitude of the warming later in the century (2081-2100, right column) depends a lot on what scenario is followed—the mitigation path we follow makes a big difference after mid-century

(Meehl et al., 2012, J. Climate)

Climate change doesn't stop at 2100

Aggressive mitigation in RCP2.6 produces cooling after 2100 (top) but little mitigation in RCP8.5 results in onging large warming to 2300 (bottom)

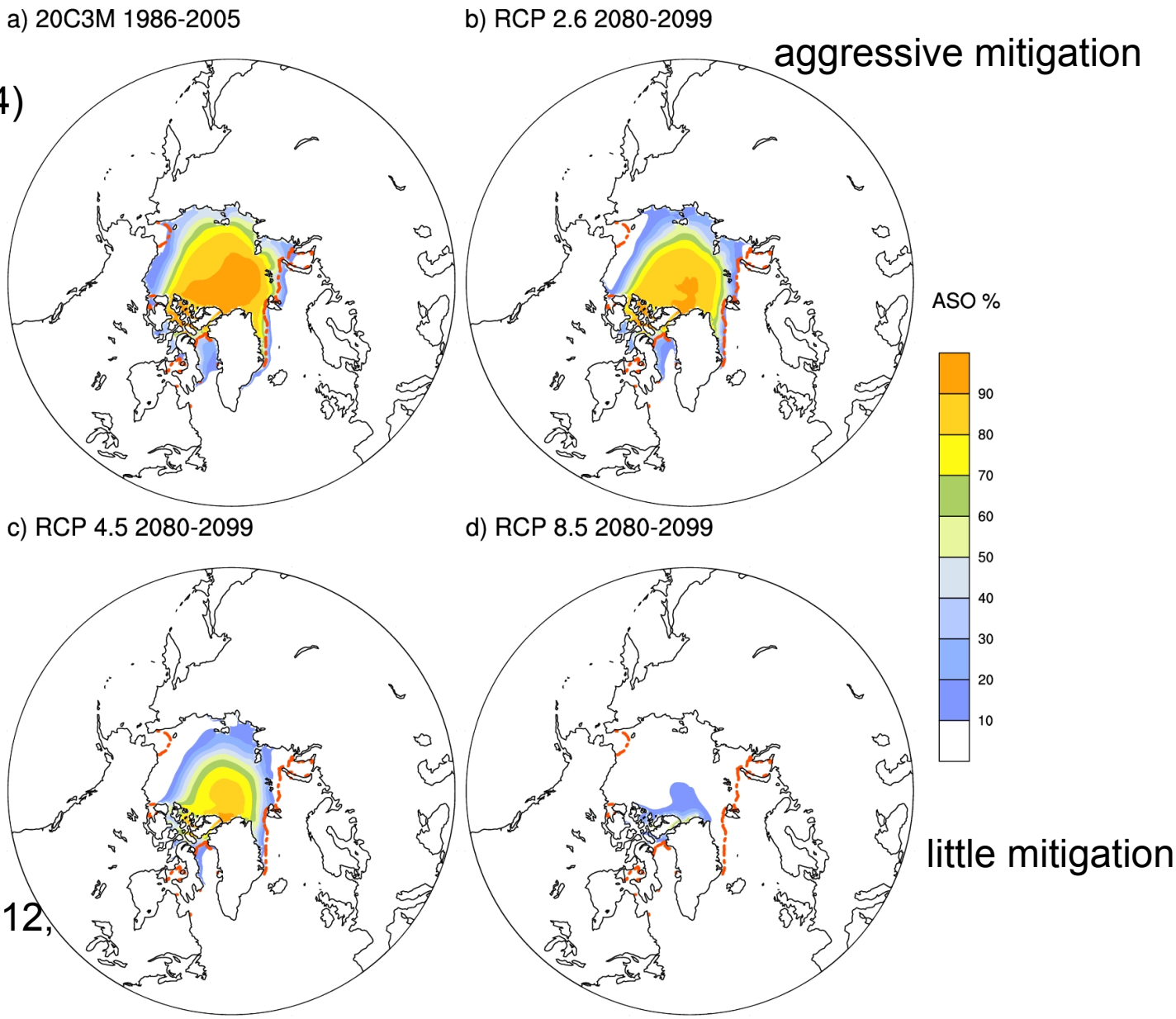
22nd century 23rd century



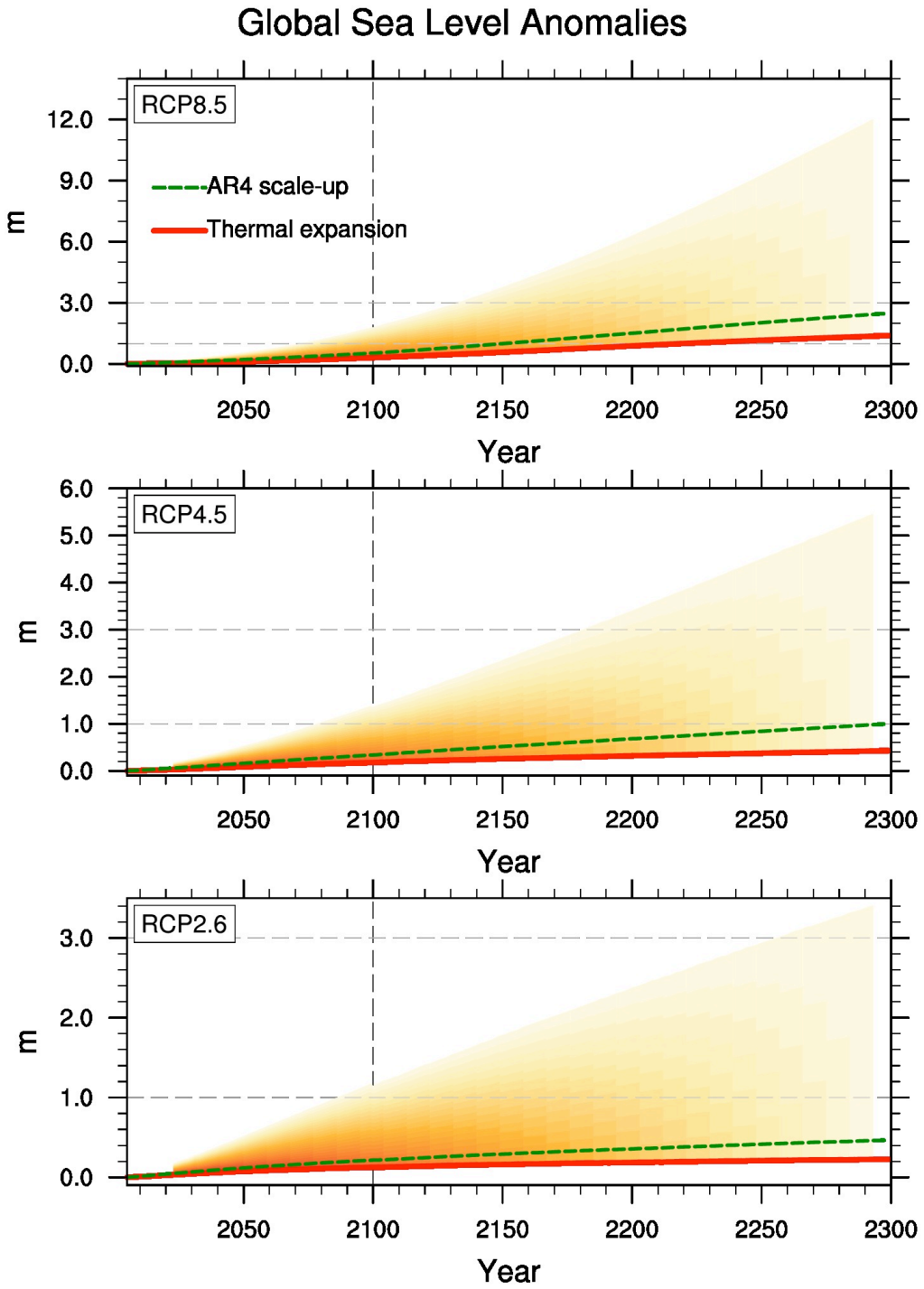
(Meehl et al., 2012, J. Climate)

What difference can mitigation make for adaptation? Much more Arctic sea ice would be retained, particularly in summer

(from CCSM4)



(Meehl et al., 2012, J. Climate)

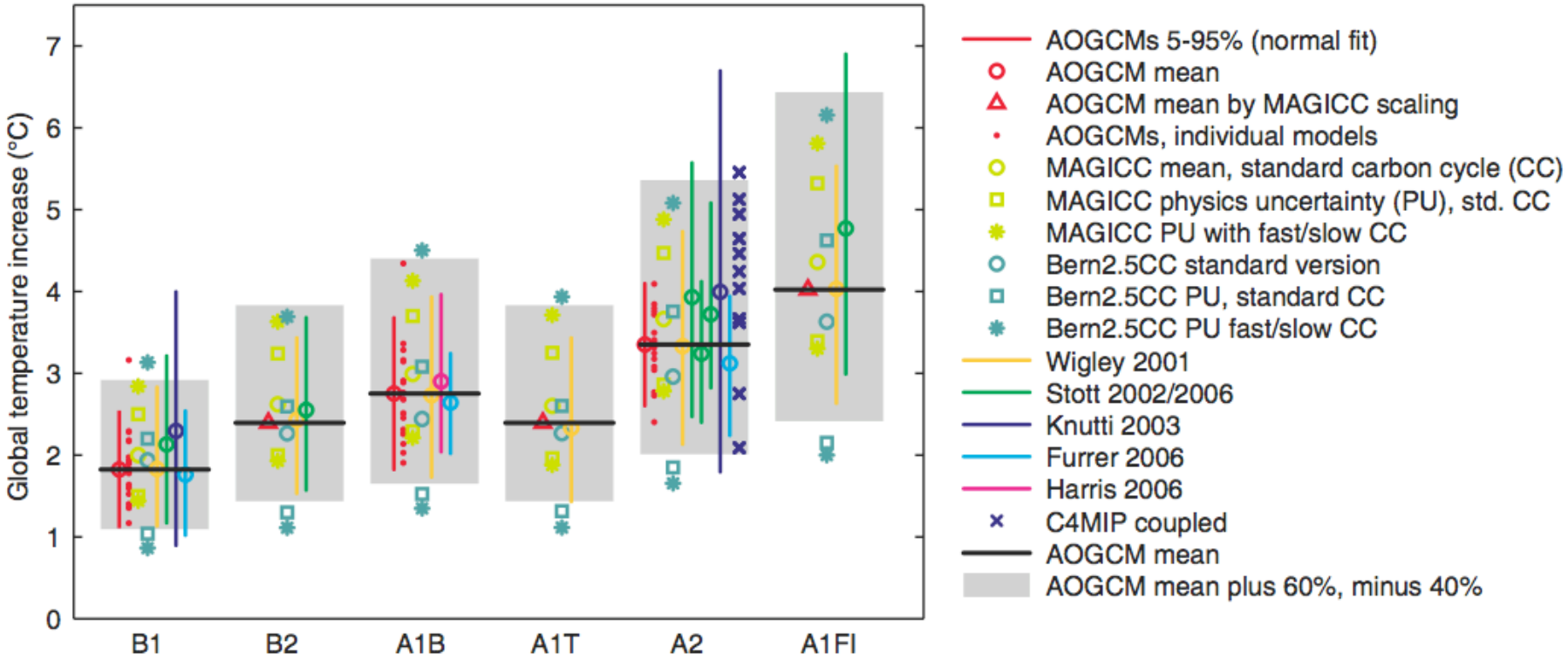


Even with aggressive mitigation in RCP2.6, sea level continues to rise at least until 2300 due to climate change commitment and ongoing thermal expansion, but at a slower rate than with less aggressive mitigation in RCP4.5 or RCP8.5

Large uncertainties remain regarding how much and how fast the ice sheets will melt

(Meehl, et al., 2012, Nature Climate Change)

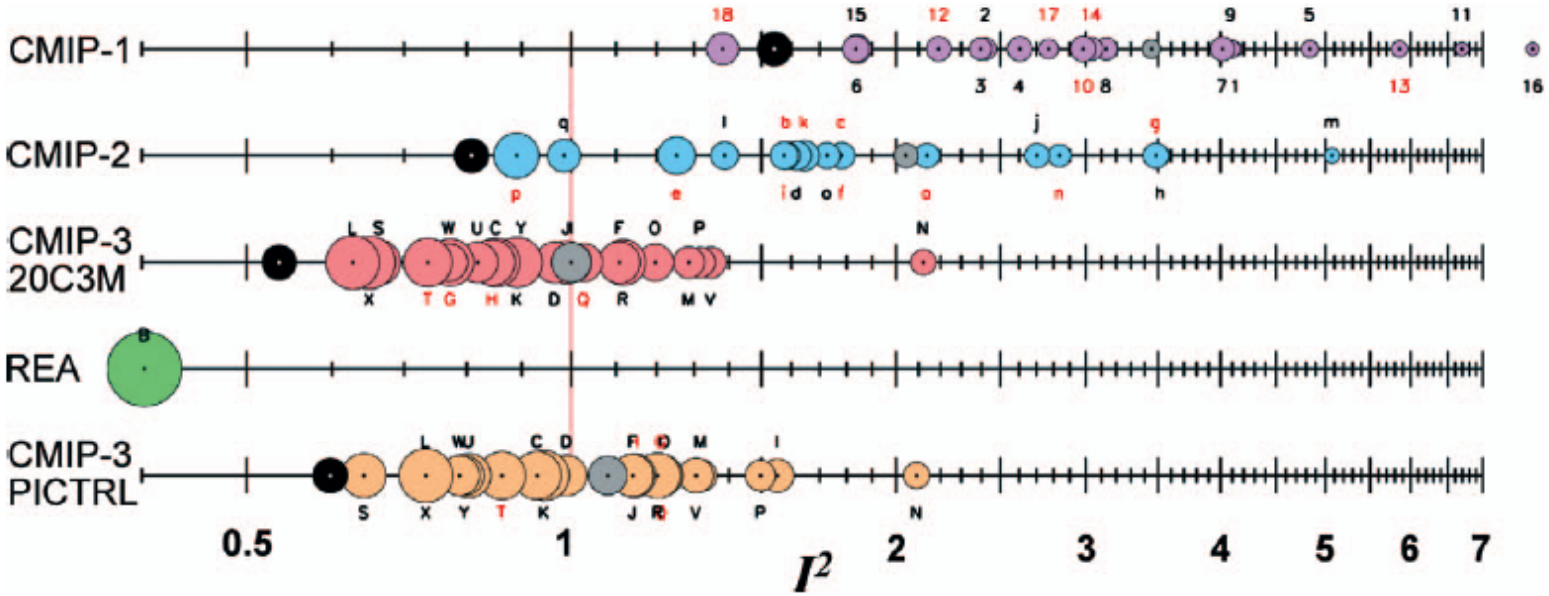
Why is there a spread among model projections? Part of the answer involves differences in the simulation of feedbacks



IPCC AR4 Fig. 10.29

Uncertainty in the size and nature of the feedbacks: carbon cycle, cloud, snow/sea ice

Multi-model ensembles generally out-perform any single model



(Reichler and Kim, 2008, BAMS)

- **CMIP5 data currently available from 25 modeling groups from 14 countries with 60 models**
  (CMIP3 had 16 groups from 11 countries with 23 models).

http://esgf.org/wiki/Cmip5Status/ArchiveView
http://cmip-pcmdi.llnl.gov/cmip5/availability.html

~1.4 Pb so far (already more than 44 times all the model data in CMIP3)

• Model outputs are accessed via the Earth System Grid Federation (ESGF, a distributed grid technology), and data are archived on local or regional nodes; some groups will send their model data directly to PCMDI where it will be archived on their ESGF node; all CMIP5 data can be accessed from the PCMDI web page with registration

• An extensive documentation of the models and of model experiments will be available for CMIP5 through EU Metafor (standardized vocabulary and documentation), and US Earth System Curator projects (web-based tools for ingesting metadata).

•For the modeling groups, the large volume of model data means that submissions were more of a “process”, rather than an “event”

Beyond 2013:

Higher resolution ESMs (25 km atmosphere, 0.1 degree ocean; coupled carbon cycle, prognostic chemistry and aerosols, dynamic vegetation)

Fully coupled Greenland and Antarctic ice sheet models in ESMs

IAMs routinely merged with ESMs

initialized decadal predictions with 10 km AOGCMs

Time slice experiments with 5 km resolution atmospheric models and even higher resolution possible

Summary:

The current round of climate change modeling simulations is CMIP5, coordinated by WGCM in collaboration with AIMES and many other elements of climate science community

CMIP5 is the most ambitious coordinated multi-model climate change experiment ever attempted

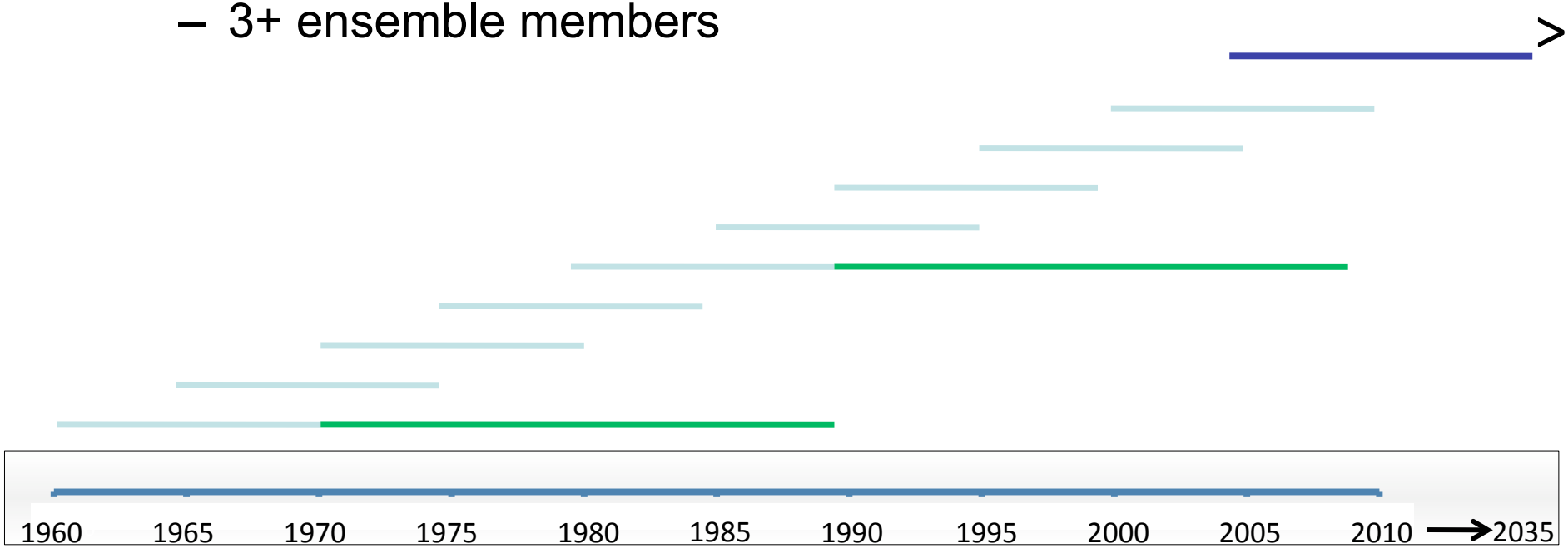
Climate change science is now focused on mitigation/ adaptation: new RCP mitigation scenarios imply policy decisions and options for targeted climate change stabilization at different levels

Challenge for climate science: What is the regional, time-evolving climate change to which society will have to adapt?

Countries: China, Italy, France, Australia, Denmark, Holland, Spain, Russia, Japan, U.K., Germany, USA, Norway, Korea

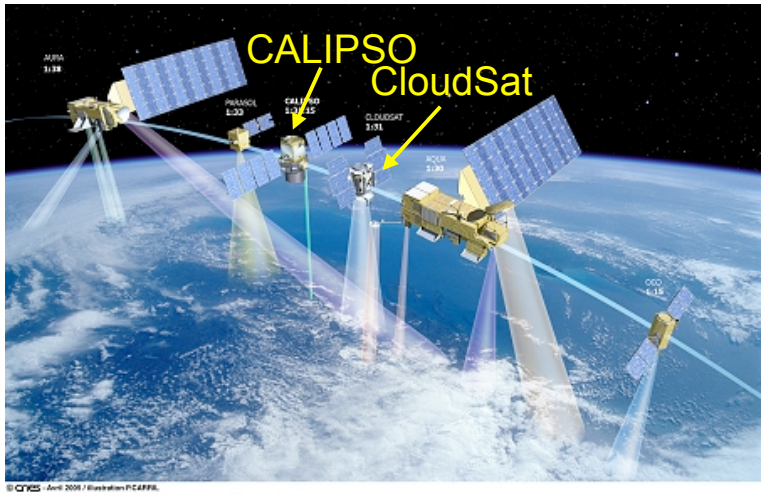
Decadal prediction – Core experiments

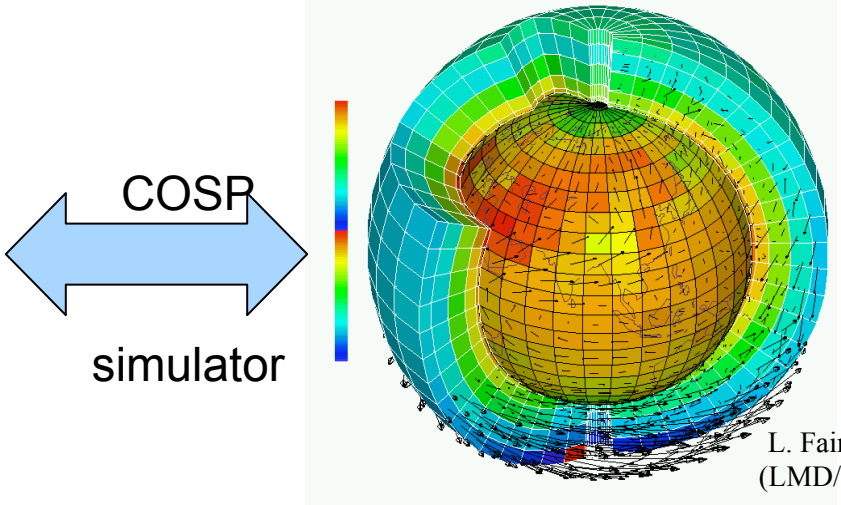
- 10 year hindcasts
  - Initialized at 1960, 1965, 1970 …
  - 3+ ensemble members
- 30 year hindcasts and one 30 year prediction
  - Initialized at 1960, 1980, 2005
  - 3+ ensemble members



WGCM/CFMIP activities on clouds : model evaluation and feedback analysis

- The cloud cover derived from satellites is not directly comparable to model outputs (due to vertical cloud overlap, instruments' sensitivity, attenuation, etc)





- **WGCM/CFMIP (Cloud Feedback Model Intercomparison Project, www.cfmip.net) has developed "satellite simulators" (COSP) to diagnose from model outputs the quantities that would be observed by satellites** (e.g. radar reflectivities for CloudSat, lidar backscattered signals for CALIPSO) as if the satellites were flying above an atmosphere similar to that predicted by the model.

- COSP is used by many climate models; **CMIP5** outputs will include COSP outputs.

- It will thus be possible to evaluate the distribution of clouds simulated by CMIP5 models, **including over the cryosphere.**

The huge effort involved with CMIP5 requires tangible connections:

WGCM (climate change modeling; coordinator of connections to others)

CLiC (ice sheets, sea ice, permafrost)

IGBP (AIMES) for carbon cycle, chemistry, aerosols and dynamic vegetation

IAM Consortium for new mitigation scenarios (RCPs) and WG2 TGICA

WGSIP (initialization for decadal prediction)

WGNE and GCSS (atmospheric model improvement, processes and parameterizations)

SPARC (ozone chemistry)

AC&C (chemistry and aerosols)

WGOMD (ocean model improvement)

Regional Modeling Task Group (embedded regional models and downscaling)

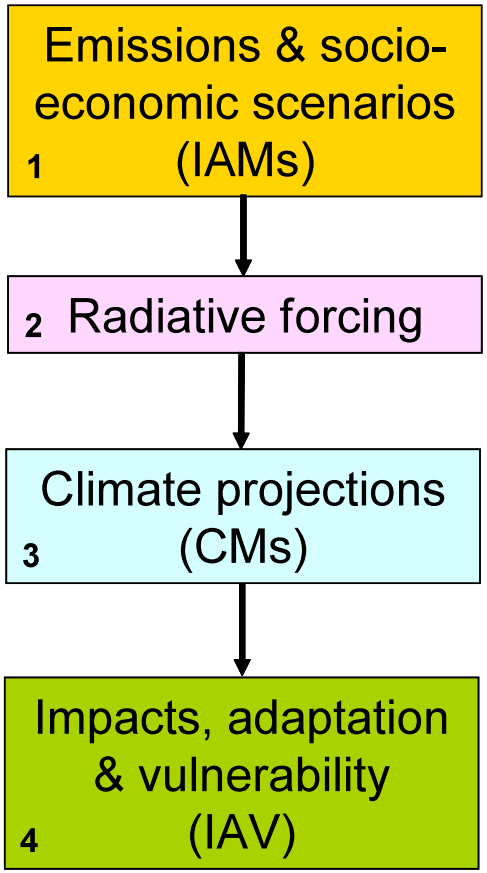
WCRP Metrics Panel (how to evaluate skill of predictions)

WOAP (observational data for model evaluation and initialization)

New way of producing/using scenarios devised by WG1, WG2 and WG3 communities (not IPCC)

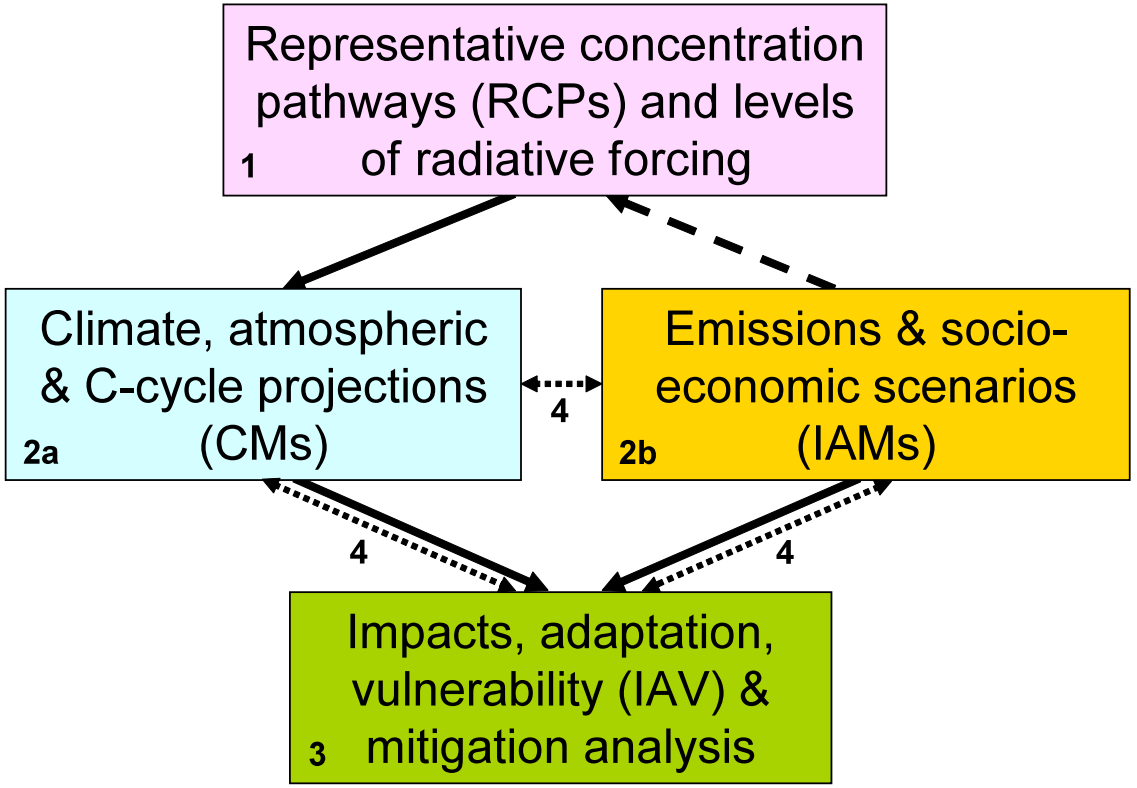
pre-AR4:

(a) Sequential approach



post-AR4:

(b) Parallel approach



(Moss, R., et al., 2010: Representative Concentration Pathways: A New Approach to Scenario Development for the IPCC Fifth Assessment Report. *Nature*)