Introduction to scenarios run with global climate models for CMIP6

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To obtain probabilistic information on potential future climates, global climate modeling groups must be persuaded to run their models with future emission scenarios and generate appropriate model output.

How has the global climate modeling community approached running scenarios in the models in the past, and how is that instructive for CMIP6?

The various phases of the CMIP started in the early 1990s

Organized by the World Climate Research Programme
Working Group on Coupled Models (WGCM, began in 1990)

Progress on information regarding future climate change marked by CMIP phases and IPCC assessments

…in the beginning, there was 1% per year compound CO2 increase

(in the First IPCC Assessment, 1990, two global coupled climate models, GFDL and NCAR, and only GFDL got the 1% run completed in time for the assessment)

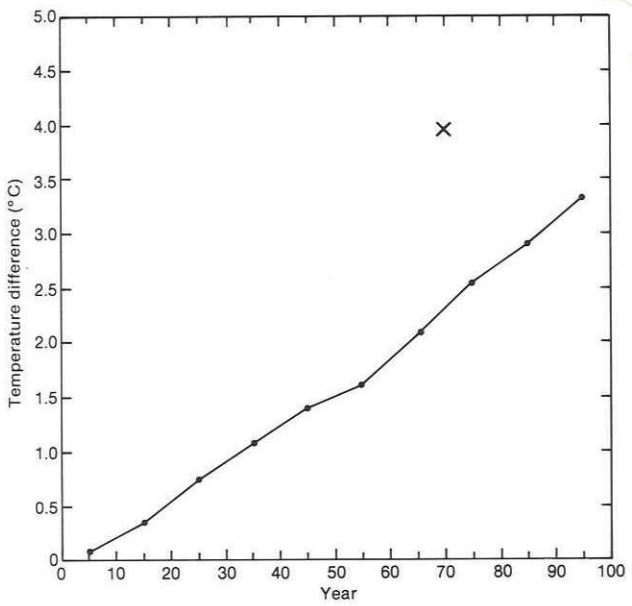

Figure 6.4: The temporal variation of the difference in globally averaged, decadal mean surface air temperature (°C) between the perturbation run (with 1% /year increase of atmospheric CO_2) and the control run of the coupled ocean-atmosphere model. For comparison, the equilibrium response of global mean surface air temperature of the atmosphere-mixed layer ocean model to the doubling of atmospheric CO_2 is also indicated by x-symbol at 70th year when the gradually increasing CO_2 doubles.

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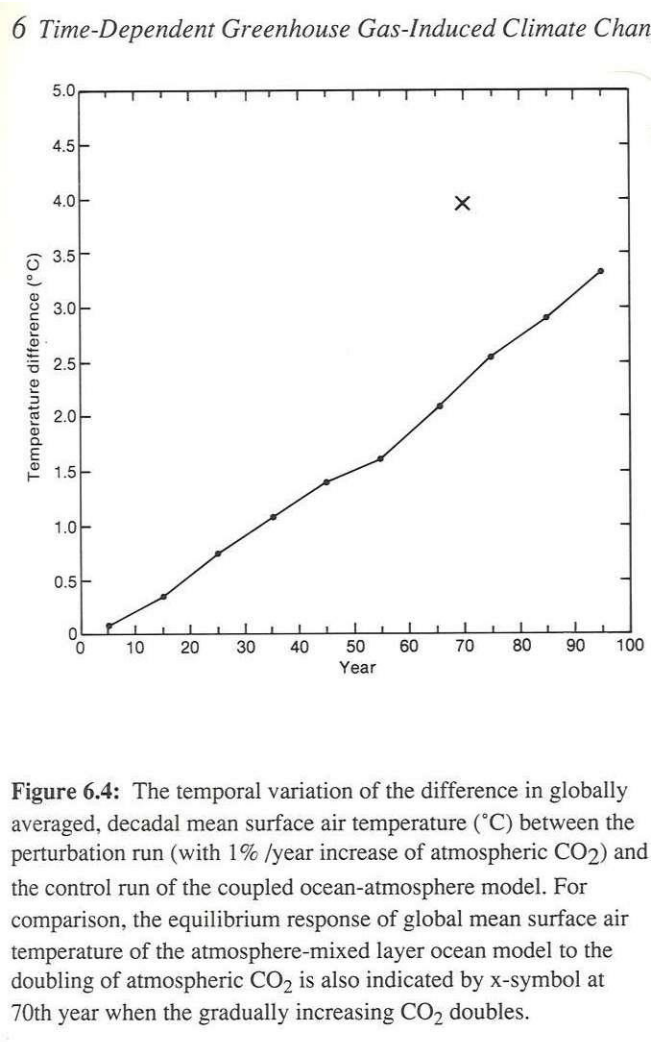

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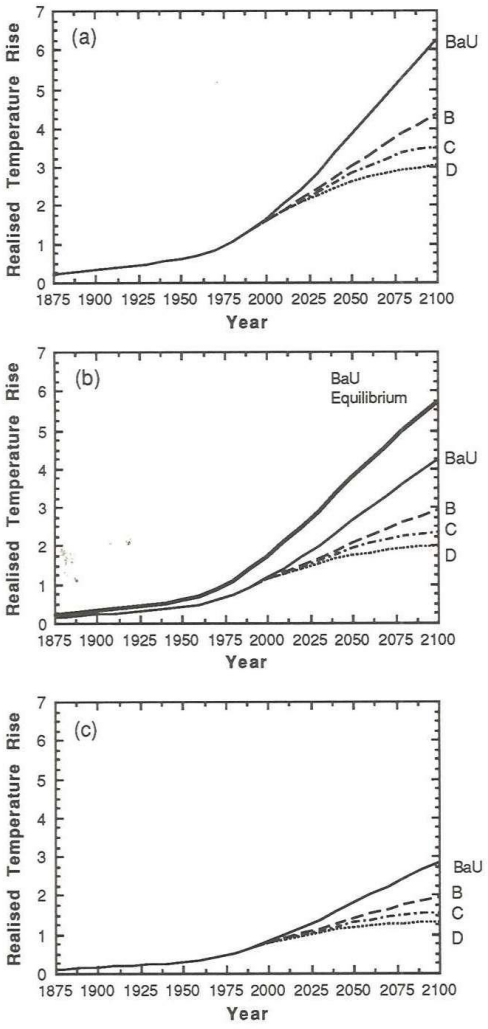
But more “IPCC scenarios” were run with Wigley’s simple climate model



The 1992 IPCC “update”, prepared for the Earth Summit in Rio,
was done in part to include new results from four global coupled climate models run with 1% per year CO2 increase
(compared to “IPCC 1990 Scenario A” from simple climate model)

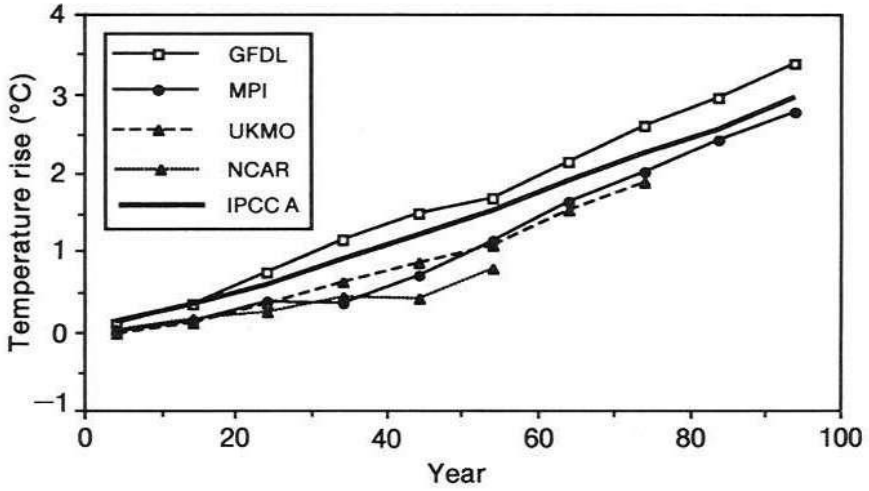


Figure B1: Decadal mean changes in globally averaged surface temperature (°C) in various coupled ocean-atmosphere experiments. (see Table B1). Note that the scenarios employed differ from model to model, and that the effect of temperature drift in the control simulation has been removed. Open boxes = GFDL; solid circles = MPI; triangles with dashed line = UKMO; triangles with dotted line = NCAR (sea temperatures only); solid line = IPCC 1990 Scenario A “best estimate”.

More global coupled climate models for the IPCC Second Assessment Report in 1995 with 1% CO2 (CMIP1)

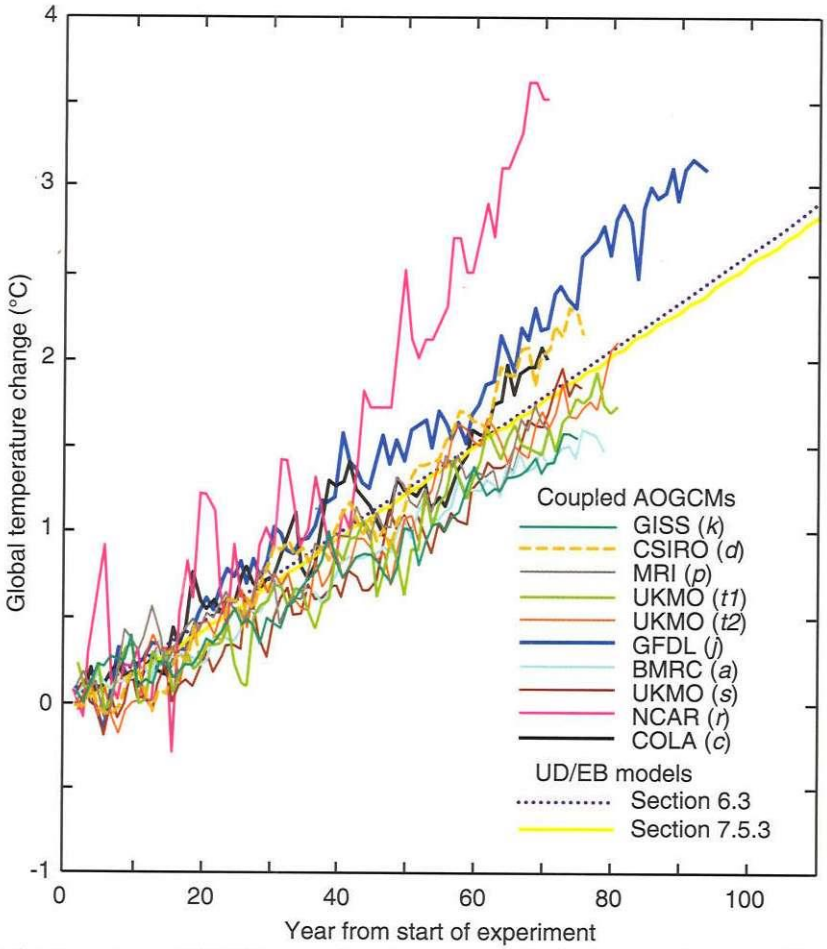


Figure 6.4: Comparison between several AOGCM simulations (climate sensitivities between 2.1 and 4.6°C), the UD/EB model of Section 6.3 (climate sensitivity 2.5°C) and the simple climate model of Section 7.5.3 (climate sensitivity of about 2.2°C). All models were forced with 1%/yr (compound) increase of atmospheric CO_2 concentration from equilibrium or near-equilibrium in 1990.

The new IS92 scenarios were run with Wigley's simple model for the IPCC SAR, 1995

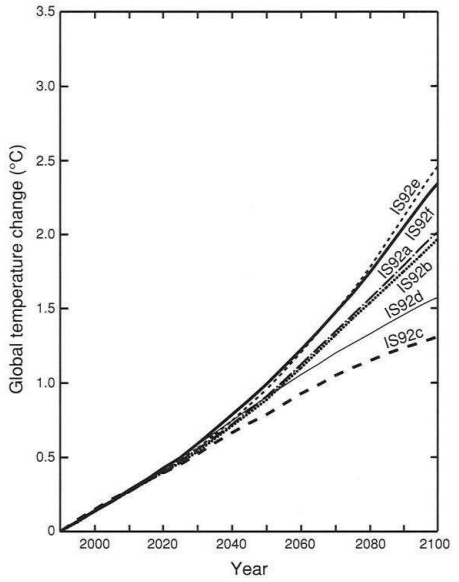


Figure 6.22: The effect of the IS92 emission scenarios on future global mean temperature changes. This is the full aerosol forcing case, with the climate sensitivity set to 2.5°C.

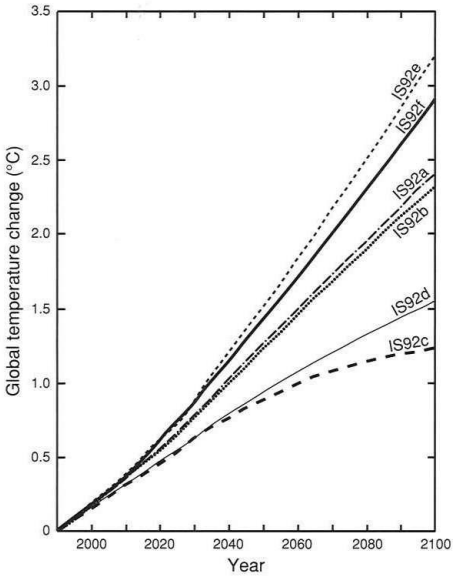


Figure 6.23: The effect of the IS92 emission scenarios on future global mean temperature changes, assuming constant aerosol concentrations beyond 1990. Results are for a climate sensitivity of 2.5°C.

(1990 to 2100 warming ranges from 0.8°C for IS92c to 1.0°C for IS92f). The different emission cases, however, give rapidly diverging temperature projections in the second half of the 21st century: for the changing aerosol case, the range of values spans 1.2°C by the year 2100. This behaviour illustrates the long-term nature of the climate change problem. There are two areas where there are appreciable lags in the system; between emission changes and concentration changes for CO_2 (and hence radiative forcing), and between radiative forcing changes and climate response. Inertia in both the carbon cycle and the climate system leads to a very long lag between CO_2 emissions changes and their eventual effect on climate.

Finally, Figure 6.24 shows an extreme range of possible warmings for the IS92 emission scenarios, together with results for the central case (IS92a) with and without changing aerosol forcing post-1990. To obtain a near-upper-limit projection, we take IS92e with a constant (1990) aerosol contribution (which maximises the forcing over 1990 to 2100) and use a climate sensitivity of $\Delta T_{2\times} = 4.5$°C; while to give a near-lower-bound projection we use IS92c, also with no post-1990 aerosol contribution (which in this

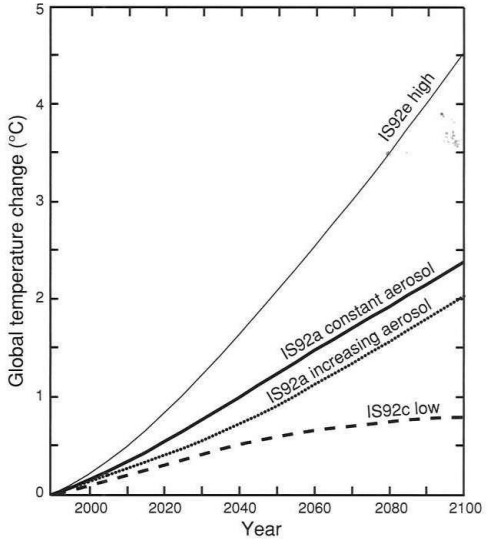


Figure 6.24: Extreme range of possible changes in global mean temperature. The topmost curve is for IS92e assuming constant aerosol concentrations beyond 1990 and a high climate sensitivity ($\Delta T_{2\times} = 4.5$°C); the lowest curve is for IS92c, also assuming constant aerosol concentrations beyond 1990, but with a low climate sensitivity ($\Delta T_{2\times} = 1.5$°C). Results for IS92a are shown for comparison, both with and without changing aerosols.

A new wrinkle in the IPCC Third Assessment Report in 2001, separating greenhouse gas and sulfate aerosol forcing from the IS92a scenario

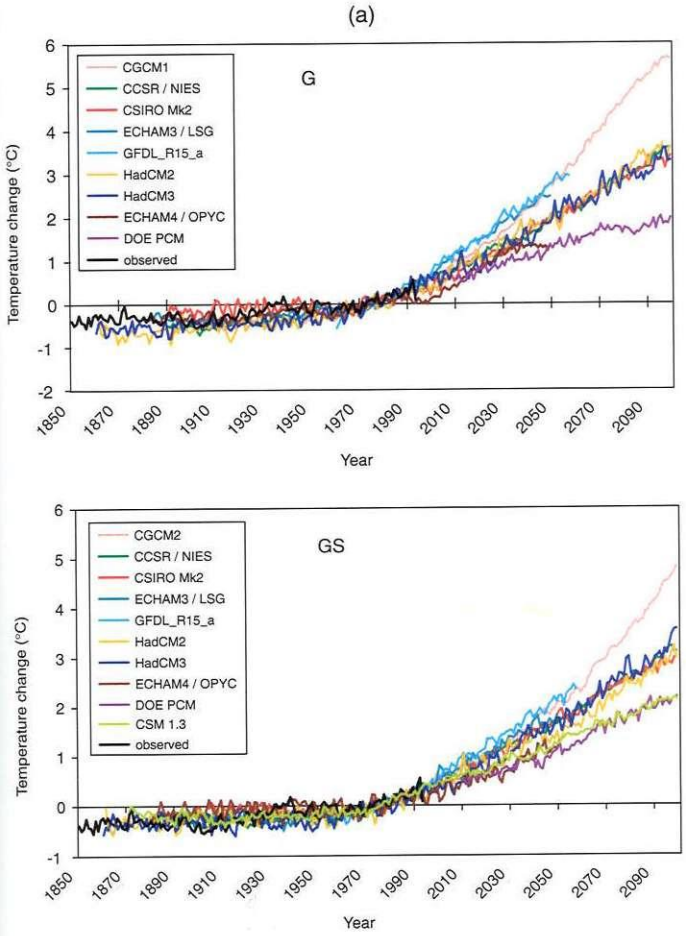


Figure 9.5: (a) The time evolution of the globally averaged temperature change relative to the years (1961 to 1990) of the DDC simulations (IS92a). G: greenhouse gas only (top), GS: greenhouse gas and sulphate aerosols (bottom). The observed temperature change (Jones, 1994) is indicated by the black line. (Unit: °C). See Table 9.1 for more information on the individual models used here. (b) The time evolution of the globally averaged precipitation change relative to the years (1961 to 1990) of the DDC simulations. GHG: greenhouse gas only (top), GS: greenhouse gas and sulphate aerosols (bottom). (Unit: %). See Table 9.1 for more information on the individual models used here.

Also new for the IPCC Third Assessment Report in 2001—the SRES scenarios (run at the last minute; this figure barely made it into the report, and almost was deleted due to late-arriving, little-understood outliers from the two Japanese modeling groups)

Initial resistance from the modeling groups: SRES scenarios had little perceived science value for them

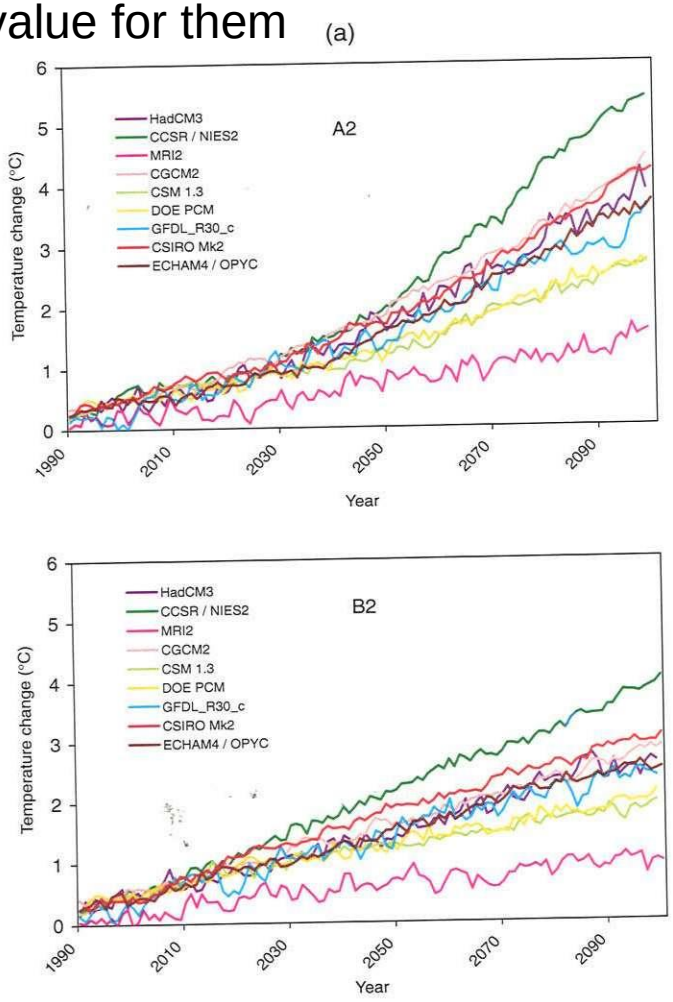
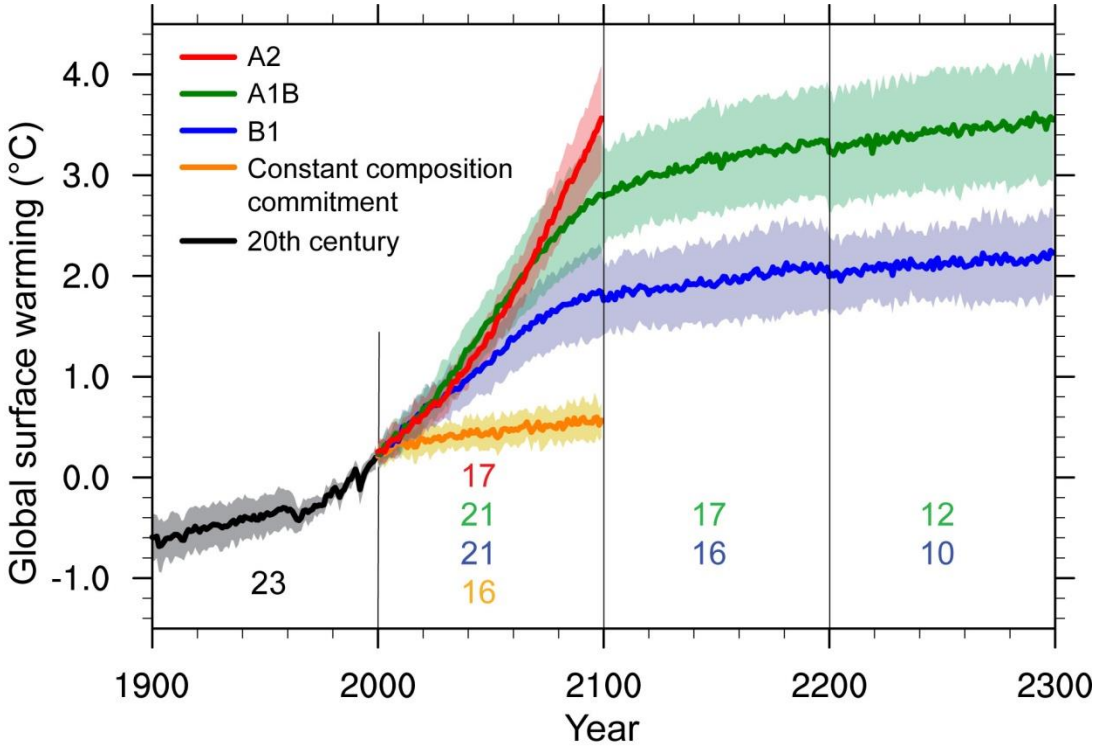


Figure 9.6: (a) The time evolution of the globally averaged temperature change relative to the years (1961 to 1990) of the SRES simulations A2 (top) and B2 (bottom) (Unit: °C). See Table 9.1 for more information on the individual models used here. (b) The time evolution of the globally averaged precipitation change relative to the years (1961 to 1990) of the SRES simulations A2 (top) and B2 (bottom) (Unit: %). See Table 9.1 for more information on the individual models used here.

A “new era in climate change research”, CMIP3 using the SRES scenarios
Assessed in the IPCC Fourth Assessment Report, 2007
--science concept of climate change commitment; SRES scenarios widely accepted



IPCC AR4 Ch. 10,
Fig. 10.4, TS-32

Unprecedented coordinated climate change experiments from 16 groups (11 countries) and 23 models collected at PCMDI (31 terabytes of model data), openly available, over 1300 scientists with analysis projects; over 200 papers

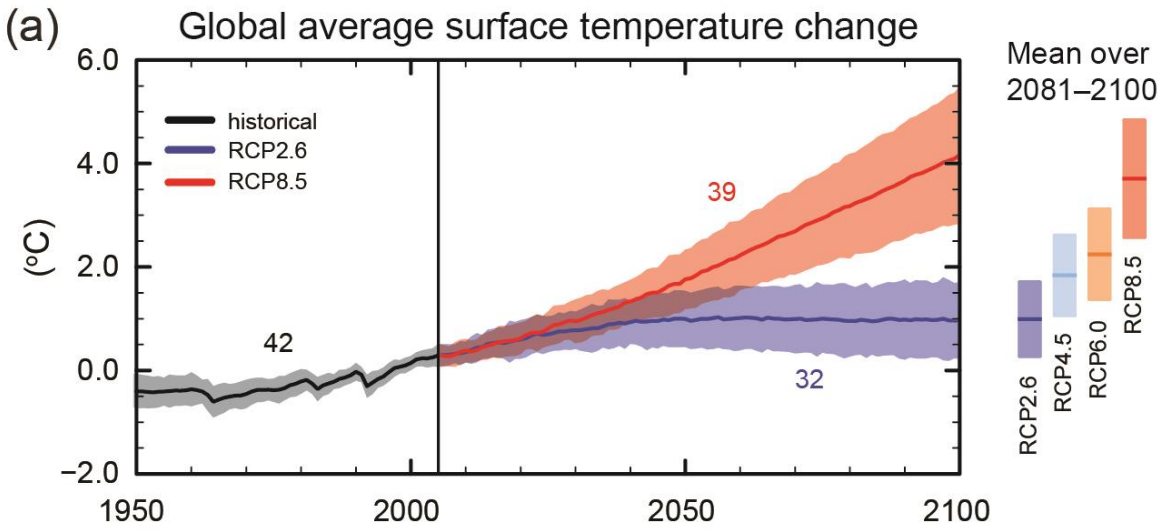
At the very end of the AR4 process, a last-ditch attempt to communicate a mitigation scenario from WGIII to be run by global climate models in WGI; but time ran out, and a WGI co-chair resistant to mitigation scenarios because “WGI is not about policy”

Realization that IAM and global climate modeling communities should work together

IAM and global climate modeling communities finally make contact (at EMF and AGCI, 2006)

RCPs and “parallel process” emerge as a consequence, and global climate models run mitigation scenarios for the first time

CMIP5, massive effort for the modeling groups,
over 40 global coupled climate models, nearly 3 petabytes of data; modeling groups taxed to the limit in completing all the CMIP5 simulations



From Summary for Policymakers, IPCC AR5, 2013

In IPCC AR5 (2013), highest and lowest RCPs were highlighted, implying “no mitigation” and “a lot of mitigation” (not quite “best case—worst case”, but headed in that direction)

Where we were a year ago at EMF Snowmass:

What's needed from this session:

--Recommendation of emission scenarios or land use scenarios to be run with ESMs for CMIP6 (no more than four total) to be carried forward to next week's AGCI CMIP6 session in Aspen

--duration: 2015-2100, with extensions to 2300 for at least a couple of the scenarios

--Perhaps reduce the total number of scenarios run to 2100 in favor of a couple of additional scenarios run for shorter periods (e.g. to 2050)

-- endorsement to use RCP8.5 as a "calibration" scenario for the new ESM versions to provide continuity with CMIP5?

CMIP6 Proposal: Scientific Focus

- It is proposed to use as the **scientific backdrop** for CMIP6 the six **WCRP Grand Challenges**, and an additional theme encapsulating questions related to **biospheric forcings and feedbacks**.
  1. Clouds, Circulation and Climate Sensitivity
  2. Changes in Cryosphere
  3. Climate Extremes
  4. Regional Climate Information
  5. Regional Sea-level Rise
  6. Water Availability
  7. AIMES theme for collaboration: biospheric forcings and feedbacks
- The specific experimental design would be focused on **three broad scientific questions**:
  1. How does the Earth System respond to forcing?
  2. What are the origins and consequences of systematic model biases?
  3. How can we assess future climate changes given climate variability, predictability and uncertainties in scenarios?

Meehl et al., EOS, 2014

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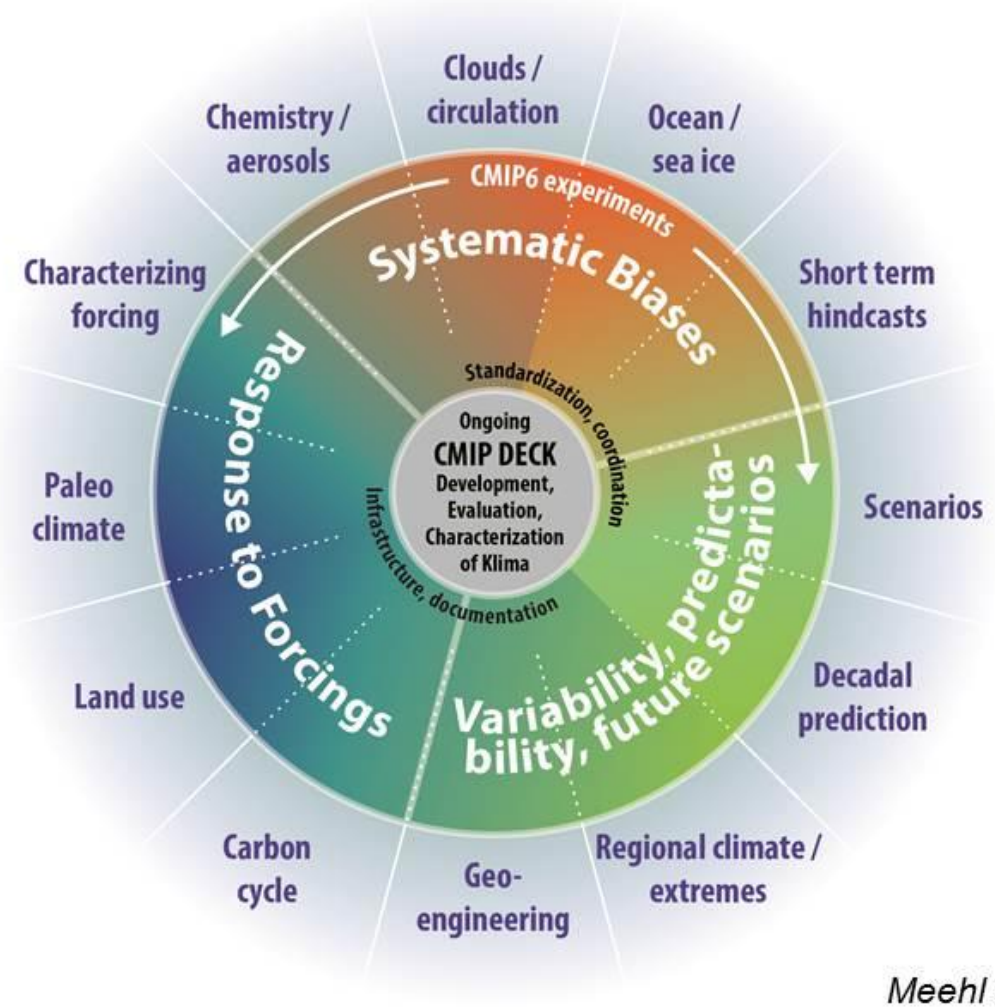
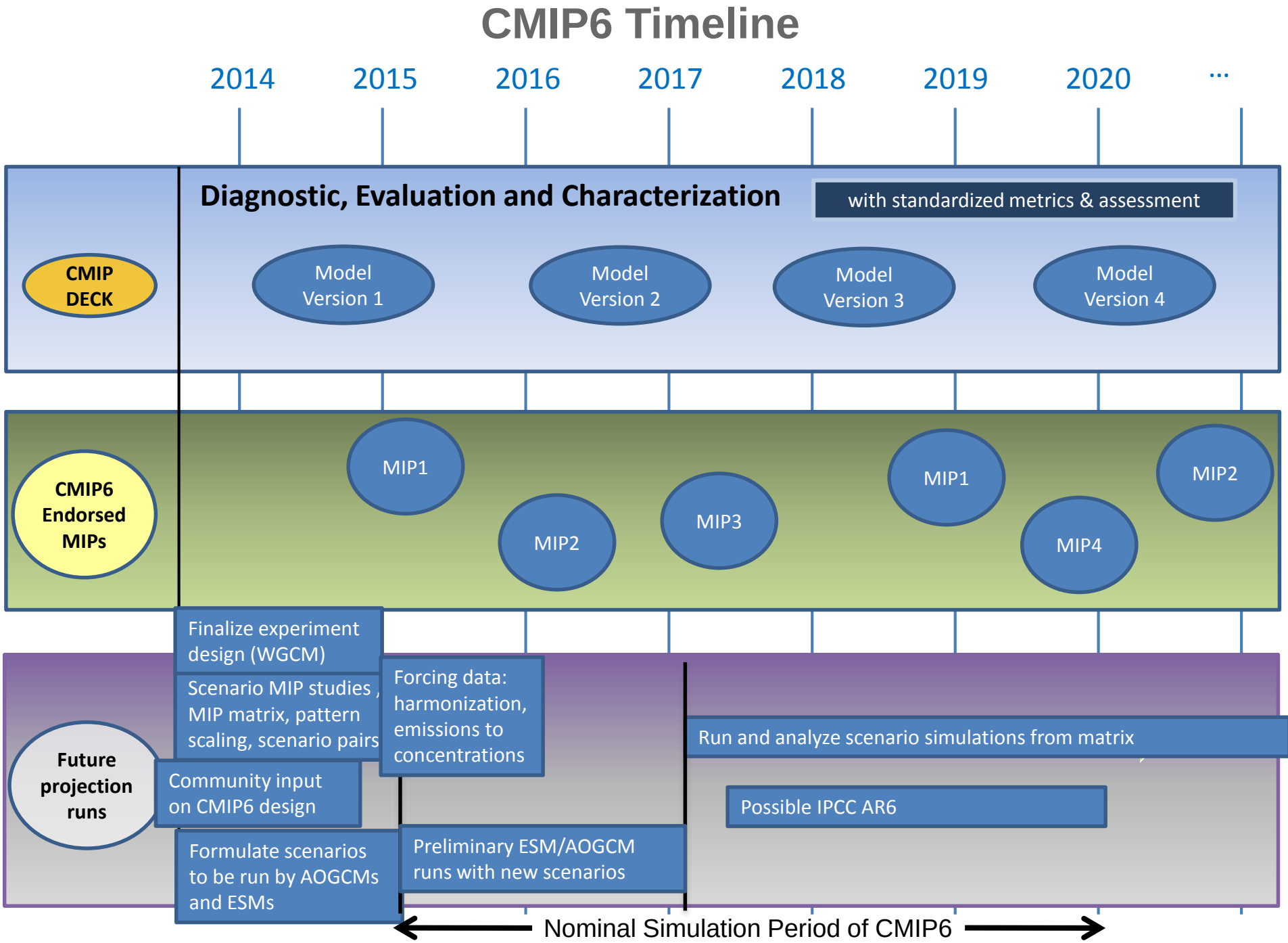
May be able to get them to run a new pair and an overshoot:
-- “worst case” (higher than RCP8.5—the path we’re on?—concept of “business as usual”?)
--“best case” (maybe a bit higher than RCP2.6—is RCP2.6 totally out of the realm of any feasible outcome?)
--An overshoot pathway to connect the two

WCRP Grand Challenges: (1) Clouds, circulation and climate sensitivity, (2) Changes in cryosphere, (3) Climate extremes, (4) Regional climate information, (5) Regional sea-level rise, and (6) Water availability, plus an additional theme on "biospheric forcings and feedbacks"



Meehl et al., EOS, 2014


CMIP6 Timeline
2014
2015
2016
2017
2018
2019
2020
...
Diagnostic, Evaluation and Characterization
with standardized metrics & assessment
CMIP DECK
Model Version 1
Model Version 2
Model Version 3
Model Version 4
CMIP6 Endorsed MIPs
MIP1
MIP2
MIP3
MIP1
MIP4
MIP2
Finalize experiment design (WGCM)
Scenario MIP studies , MIP matrix, pattern scaling, scenario pairs
Forcing data: harmonization, emissions to concentrations
Run and analyze scenario simulations from matrix
Future projection runs
Community input on CMIP6 design
Possible IPCC AR6
Formulate scenarios to be run by AOGCMs and ESMs
Preliminary ESM/AOGCM runs with new scenarios
Nominal Simulation Period of CMIP6