# CMIP5: Overview of the Coupled Model Intercomparison Project Phase 5

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## Background

- 25th IPCC session (Mauritius, 2006):
  - Recommendations for development of new scenarios
- Aspen Global Change Institute (2006):
  - Earth System Models: the Next Generation
- WCRP Informal Report (2007):
  - A Strategy for Climate Change Stabilization Experiments with AOGCMs and ESMs (Meehl, Hibbard, and others).

## Early Guidance and Objectives

- Guidance for new scenarios, from 25th IPCC Session (2006)
  - *Consistency* between scenarios used to study climate change, climate change impacts and adaptation, and climate change mitigation (Working Groups I, II, and III)
  - *Compatibility* of scenarios (comparable definitions and assumptions)
  - *Transparency* of development process

- Outcomes of Aspen workshop
  - Identified new ESM components in play for AR5
  - Established communication among WCRP, IGBP, IPCC, Integrated Assessment Modeling (IAM), Impacts Adaptation and Vulnerability (IAV) communities.
  - Proposed experimental design for 21st century climate change experiments
  - Specified forcing requirements for new models (time series of constituents)

## Summary of new capabilities in ESMs

- Prognostic carbon cycle (some with prognostic nitrogen)
- Ocean biogeochemistry, micronutrient limitation, trophic structure
- Emerging capability for land use change and dynamic fire modeling
- Emerging capability for biogeography and successional processes
- Expanded treatment of aerosols and atmospheric chemistry
- (Interactive ice sheets)

## CMIP5 Objectives

- Agreement on design (September 2008)
- Address outstanding scientific questions arising from IPCC AR4
- Improve understanding of climate
- Provide estimates of future climate change of use to those considering its possible consequences
- Not intended to be comprehensive – other experiments will emerge along the way

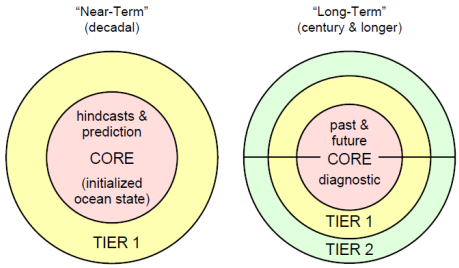
From “A summary of the CMIP5 Experiment Design”, Taylor, Stouffer, and Meehl, 2011

# CMIP5 Objectives (cont'd)

- Evaluate model simulated climate for the recent past
- Provide projections of future climate on two time scales:
  - Near term (2005-2035)
  - Long term (2005-2100 and beyond)
- Understand differences in model projections, including quantification of cloud and carbon cycle feedbacks

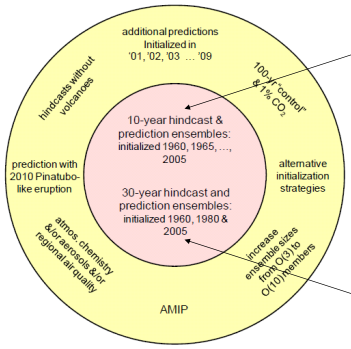
From "A summary of the CMIP5 Experiment Design", Taylor, Stouffer, and Meehl, 2011
Also, Hibbard et al. (2007): A strategy for climate change stabilization experiments. *EOS*, **88**, 217,219,221

# CMIP5 Design Summary




- All models perform CORE experiments (basis for intercomparison)
- Models perform Tier 1 and Tier 2 experiments as interests and resources dictate: these explore specific aspects of model forcing, response, and process

# Near term (decadal) experiments

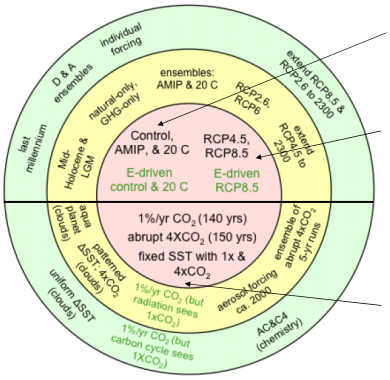



Assess model skill on time scales where initial state may exert some influence

At least 3 ensemble members for each run

Assess model skill on time scales where GHG forcing expected to exert some influence

# Long term experiments



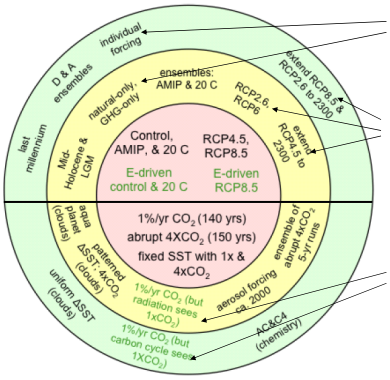

Pre-industrial control (ca. 1850) and 20th century, forced by concentrations and by **emissions**

Future scenarios (RCPs) forced by concentrations and by **emissions**

"Diagnostic" runs to assess transient climate response, equilibrium climate sensitivity

**Green font** indicates experiment performed only by models *with carbon cycle* representation

# Long term experiments, cont'd




Partial-forcing and single-forcing factor experiments to quantify C-climate feedbacks

Additional RCPs and multi-century simulations

And many other simulations…

"Diagnostic" runs to assess C-climate feedbacks and allowable (fossil fuel + land use) emissions

**Green font** indicates experiment performed only by models *with carbon cycle* representation

| | # | Experiment | Core | Tier 1 | Tier 2 |
|---|---|---|---|---|---|
| ALL MODELS | 3.1 | Coupled model, pre-industrial control | ≥500 | | |
| | 3.2 & 3.2-E | historical (1850- at least 2005) ensemble | ≥156 | (≥2)x (≥)156 | |
| | 3.3 & 3.3-E | AMIP ensemble (1979- at least 2008) | ≥30 | ≥2x(≥30) | |
| | 3.4 | Mid-Holocene (6 kyr ago) | | ≥100 | |
| | 3.5 | Last Glacial Maximum (21 kyr ago) | | ≥100 | |
| | 3.6 | Last Millennium (850-1850) | | | 1000 |
| | 4.1, 4.2, 4.3, & 4.4 | Projected responses to concentrations based on RCPs 4.5 & 8.5 (core) and RCPs 2.6 & 6 (tier 1) | 2x95 | 2x95 | |
| | 4.1-L | Extension of RCP4.5 through year 2300 | | 200 | |
| | 4.2-L & 4.3-L | Extension of RCP8.5 and RCP2.6 through year 2300 | | | 400 |
| | 6.1 | Idealized 1%/yr simulations | 140 | | |
| | 6.2 a&b | Prescribed SST expts. to diagnose "fast" responses to 4x pre-industrial $CO_2$ | 2x(≥30) | | |
| | 6.3 | Diagnosis of climate system "slow" responses to abrupt quadrupling of $CO_2$ | 150 | | |
| | 6.3-E | Ensemble of 5-year simulations to diagnose "fast" responses to abrupt 4x pre-industrial $CO_2$ increase | | 11x5 | |
| | 6.4a & 6.4b | Prescribed SST expts. to diagnose "fast" responses to all anthropogenic aerosols and to sulfate aerosols alone (for the year 2000) | | ≥2x30 | |
| | 6.5, 6.6 & 6.8 | Prescribed change in $CO_2$ concentration (tier1), and "patterned" (tier1) and uniform (tier 2) changes in SST for diagnosing cloud responses. | | 2x≥30 | ≥30 |
| | 6.7a&b&c | Aqua-planet cloud responses (control, 4x$CO_2$ and +4K experiments) | | 3x5 | |
| | 7.1 & 7.2 | historical runs with only natural forcing and only GHG forcing | | 2x(≥)156 | |
| | 7.3 | historical runs forced by individual agents | | | ≥1x≥156 |
| | (7.1-7.3)-E | Additional ensemble members of 7.1-7.3 | | | (≥1)x(≥2)x (≥)156 |
| | | SUBTOTALS: | ≥1226 | ≥1592 | ≥1898 |

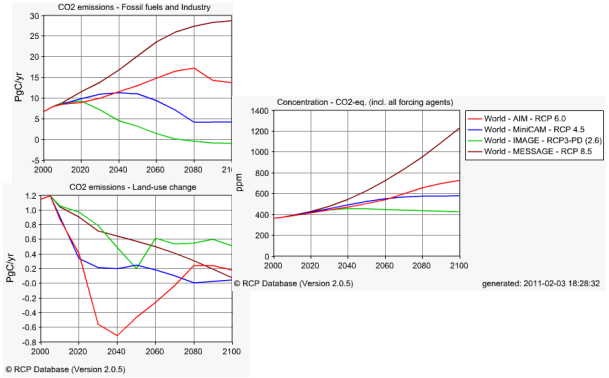
All models:
Control, historical, and paleo
Future scenarios (RCPs)
Diagnostic simulations (feedbacks)
Attribution runs (single and multi-factor)

## Simulations only performed by ESMs…

| | | | | | |
|---|---|---|---|---|---|
| ESMs | 5.1 | Pre-industrial control with $CO_2$ concentration determined by model | ≥251 | | |
| | 5.2 & 5.3 | Emission-driven historical and RCP8.5 simulations. | 251 | | |
| | 5.4 & 5.5 | Diagnosis of carbon-climate feedback components in prescribed $CO_2$ experiments (following "idealized" or more "realistic" pathways) in which $CO_2$ surface fluxes are saved and allowable emissions computed. | | 140 or 251* | 140 or 251* |
| | | **TOTALS:** | **≥1718** | **≥1727** | **≥2038** |

Forced by fossil fuel emissions and land use changes, as opposed to concentrations

## RCPs (from Integrated Assessment Models)




http://www.iiasa.ac.at/web-apps/tnt/RcpDb/dsd?Action=htmlpage&page=compare

## "Vanguard" components and experiments

- CMIP5 defines the common experiments
- Many other focused model components and simulations are anticipated, e.g.
  - Model evaluation efforts at multiple spatial and temporal scales
  - Feedback analysis at multiple time scales
  - Model uncertainty estimation
  - Nutrients, biogeography, fire
  - Integrated IAM + ESM (explore consistency issues)

## Connections to NACP

- CMIP5 provides raw material, but AR5 depends on assessment:
  - Robust process understanding
  - Observational constraints at site, regional, and continental scales
  - Offline evaluation of participating models
  - Assessment of coupled model uncertainties
  - Synthesis of policy-relevant information from multi-model x multi-scenario database