Climate Research at PCMDI and the Climate Model Intercomparison Project (CMIP)

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with input from Steve Klein and others at PCMDI

Program for Climate Model Diagnosis and Intercomparison (PCMDI)
Lawrence Livermore National Laboratory

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Overview

- PCMDI's dual mission:
  - Perform research
  - Enable research through infrastructure support of modeling (e.g., CMIP)
- Not included in this briefing are PCMDI's contributions to:
  - CSSEF (Dave Bader)
  - IMPACTS (Bill Collins)
  - HiRes (Jim Hack)
  - Integrated assessment (John Weyant)
  - Research supported by projects outside of climate modeling, e.g.
    - ASR-funded
    - BES-funded
    - NASA-funded
    - LLNL-funded (LDRD)

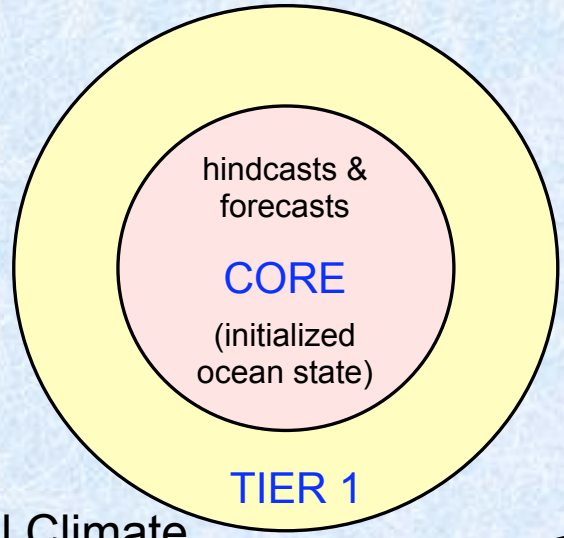
Leadership & infrastructure support for modeling activities

- Model intercomparison (CMIP, AMIP, CFMIP, PMIP, GeoMIP, etc.)
  - Standardized experiments for model evaluation, projections and understanding climate behavior
- CAPT: Cloud-Associated Parameterization Testbed
  - Test climate models under a weather-forecasting approach
- COSP: CFMIP Observation Simulator Package
  - Develop and promote diagnostic software to make more direct comparisons of models and satellite observations

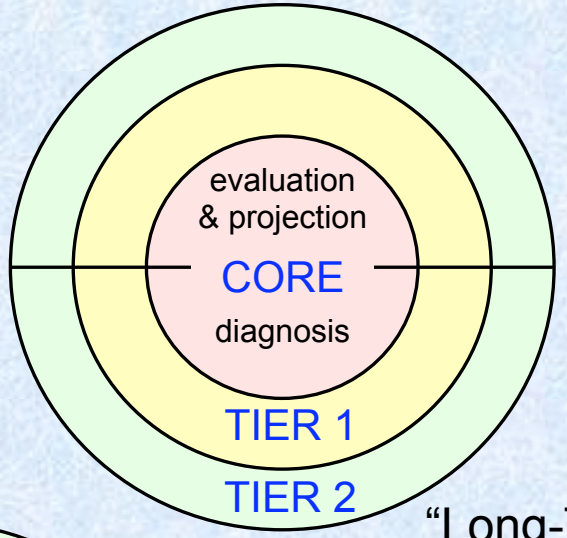
PCMDI's CMIP5 activities (some of this is described in a special edition of the CLIVAR Exchanges Newsletter)

- Mediate competing interests to optimize experiment design
- Develop a list of standard model output, considering the diverse interests of a broad community of scientists
- Coordinate and promote efforts to standardize model and experiment documentation
- Establish and provide software support for data standards
  - CF conventions
  - CMOR software to facilitate compliance
- Promote development of observational datasets in support of CMIP5 model evaluation ("obs4MIPs")
- Lead effort to develop software infrastructure to make data available to users from a distributed archive (ESG – Dean Williams)

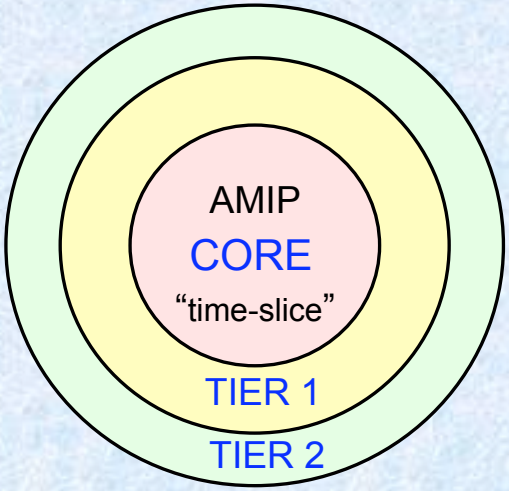
CMIP5 is organized around three types of simulations



Decadal Climate Prediction



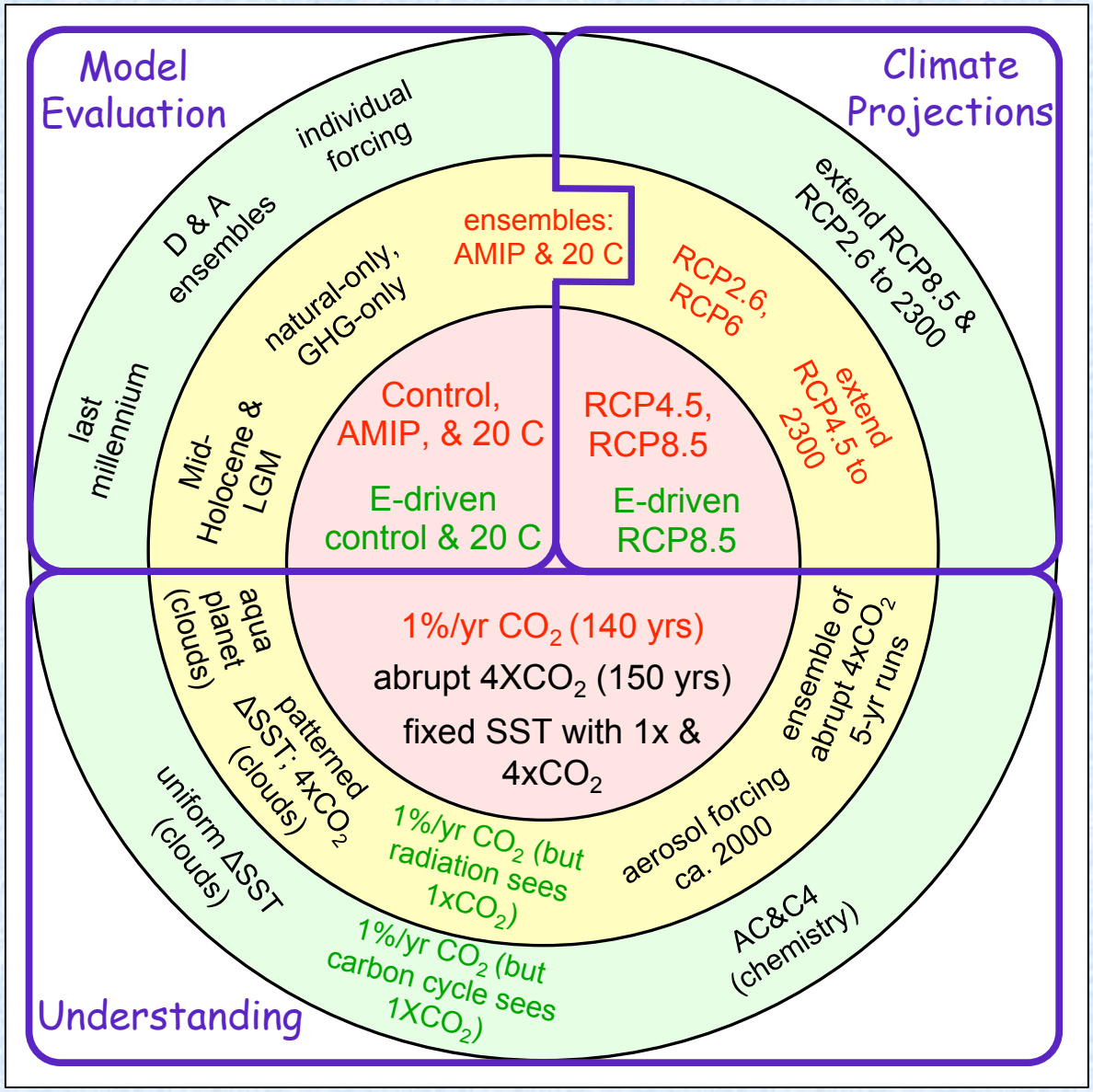
"Long-Term" Projections (century & longer)



Atmosphere-Only Simulations

(for computationally demanding and NWP models)

A rich set of CMIP5 experiments, drawn from several predecessor MIPs, focuses on model evaluation, projections, and understanding



Red subset matches the entire CMIP3 experimental suite

Green subset is for coupled carbon-cycle climate models only

Taylor, Stouffer & Meehl, BAMS, submitted 2011

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CMIP5 output fields requested (goes well beyond what was available from CMIP3)

- Domains (number of monthly variables*):
  - Atmosphere (60)
  - Aerosols (77)
  - Ocean (69)
  - Ocean biogechemistry (74)
  - Land surface & carbon cycle (58)
  - Sea ice (38)
  - Land ice (14)
  - CFMIP output (~100)
- Temporal sampling (number of variables*)
  - Climatology (22)
  - Annual (57)
  - Monthly (390)
  - Daily (53)
  - 6-hourly (6)
  - 3-hourly (23)

*Not all variables will be saved for all experiments and time-periods

http://cmip-pcmdi.llnl.gov/cmip5/output_req.html

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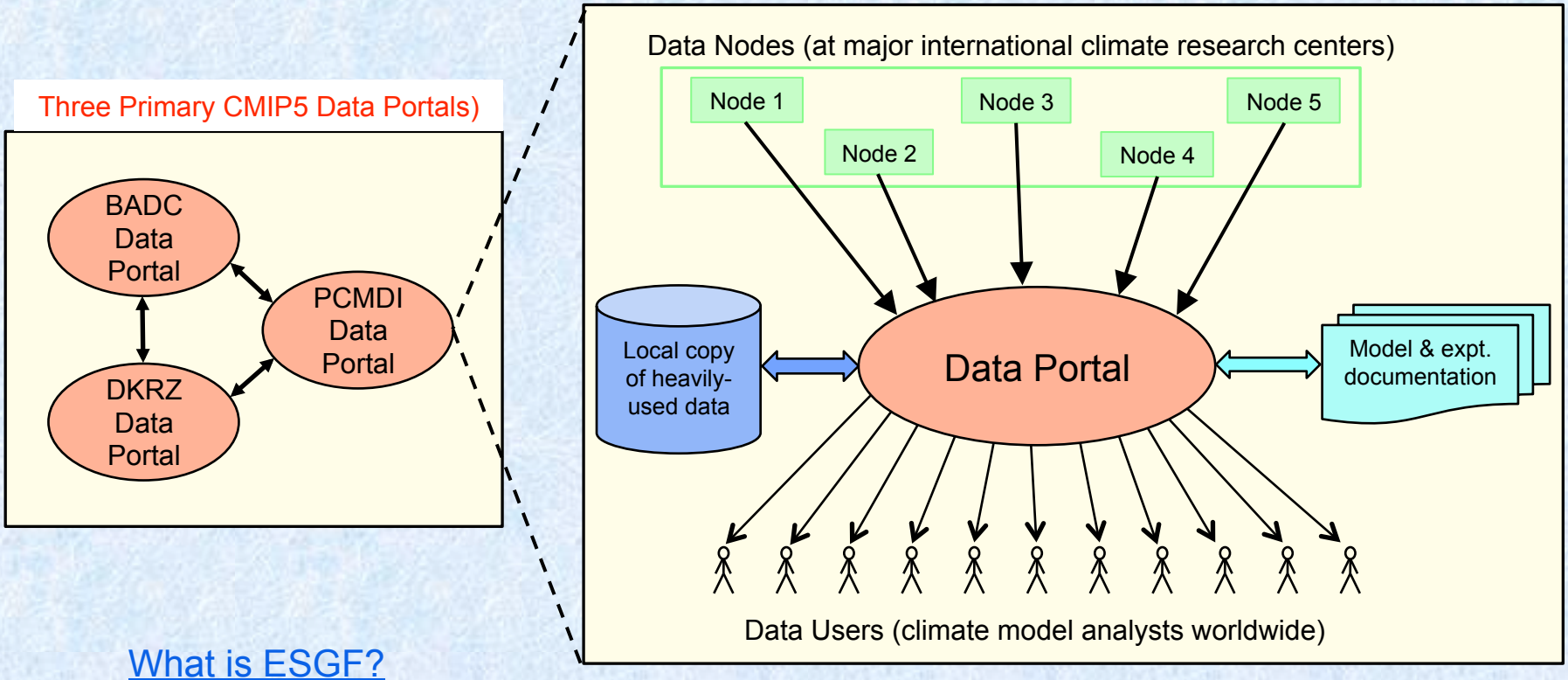
LLNL-led Earth System Grid Federation (ESGF) serves climate simulation output to analysts worldwide



What is ESGF?

- ESGF links together all major climate centers and provides access to climate simulations
- Currently expanding from 10's to 1000's of Tbytes
- Serves 1000's of researchers

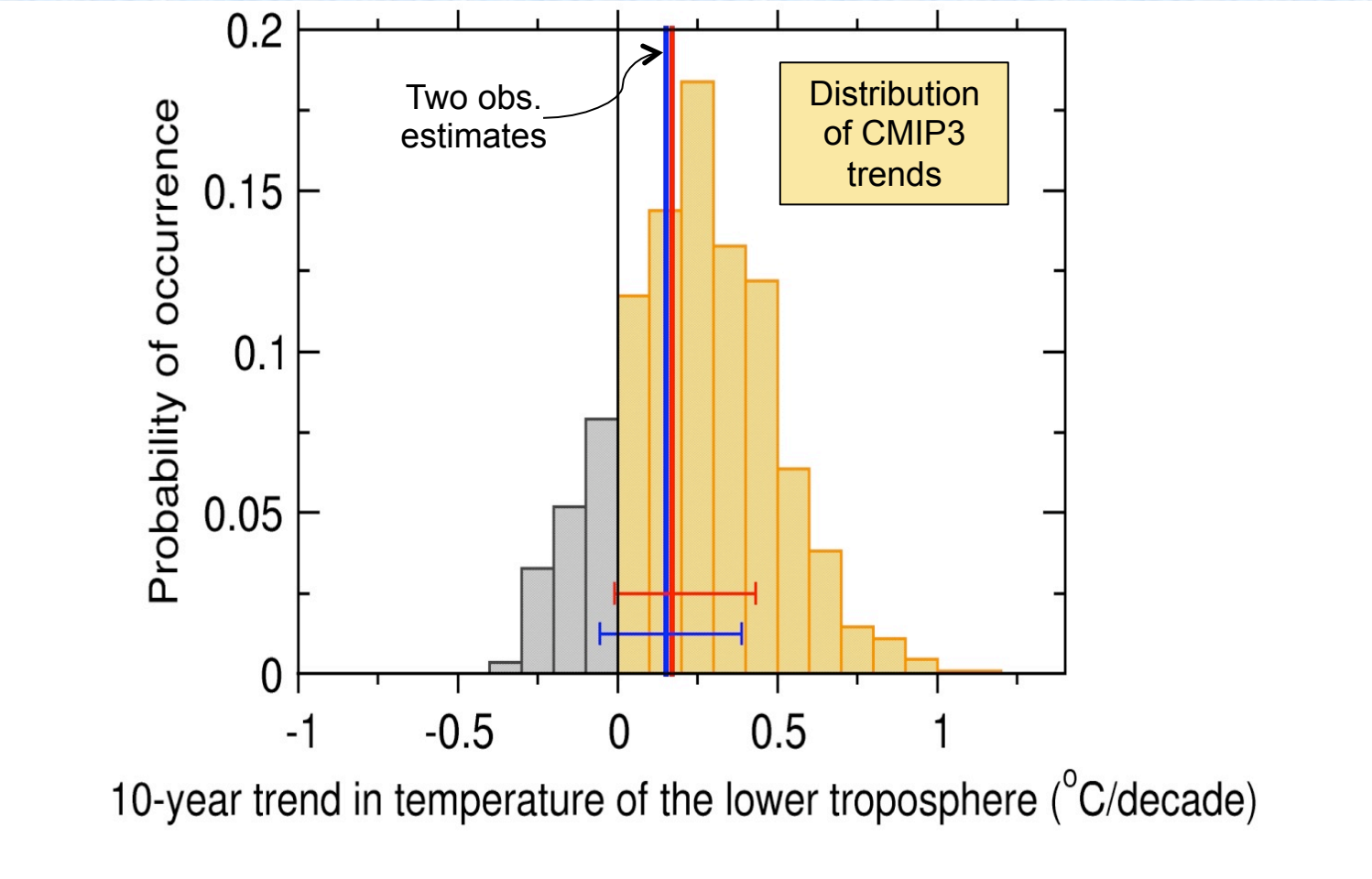
CMIP5 participating groups (23 groups; 50+ models; 18 Sept 2011: 15 models available from 10 centers)

Primary Group	Country	Model
CAWCR	Australia	ACCESS
BCC	China	BCC-CSM1.1
GCESS	China	BNU-ESM
CCCMA	Canada	CanESM2, CanCM4, CanAM4
CCSM	USA	CESM1, CCSM4
RSMAS	USA	CCSM4(RSMAS)
CMCC	Italy	CMCC- CESM, CM, & CMS
CNRM/CERFACS	France	CNRM-CM5
CSIRO/QCCCE	Australia	CSIRO-Mk3.6
EC-EARTH	Europe	EC-EARTH
LASG, IAP	China	FGOALS- G2.0, S2.0 & gl
FIO	China	FIO-ESM
NASA/GMAO	USA	GEOS-5
GFDL	USA	GFDL- HIRAM-C360, HIRAM-C180, CM2.1, CM3, ESM2G, ESM2M
NASA/GISS	USA	GISS- E2-H, E2-H-CC, E2-R, E2-R-CC, E2CS-H, E2CS-R
MOHC	UK	Had CM3, CM3Q, GEM2-ES, GEM2-A, GEM2-CC
NMR/KMA	Korea / UK	HadGEM2-AO
INM	Russia	INM-CM4
IPSL	France	IPSL- CM5A-LR, CM5A-MR, CM5B
MIROC	Japan	MIROC 5, 4m, 4h, MIROC- ESM, ESM-CHEM
MPI-M	Germany	MPI-ESM- HR, LR
MRI	Japan	MRI- AGCM3.2H, AGCM3.2S, CGCM3, ESM1
NCC	Norway	NorESM1-M, NorESM-ME, NorESM1-L

A focus of some PCMDI research: CMIP simulations. For example:

- Model evaluation & performance metrics
  - Suite of metrics to provide summaries
  - Encourage contributions from international panels and working groups to provide diverse perspectives and more complete characterization (more on this from Gleckler)
- Variability and major climatic features (MJO, ENSO, monsoons, etc.)
- Detection and attribution studies relying on multi-model ensemble (Ben Santer)

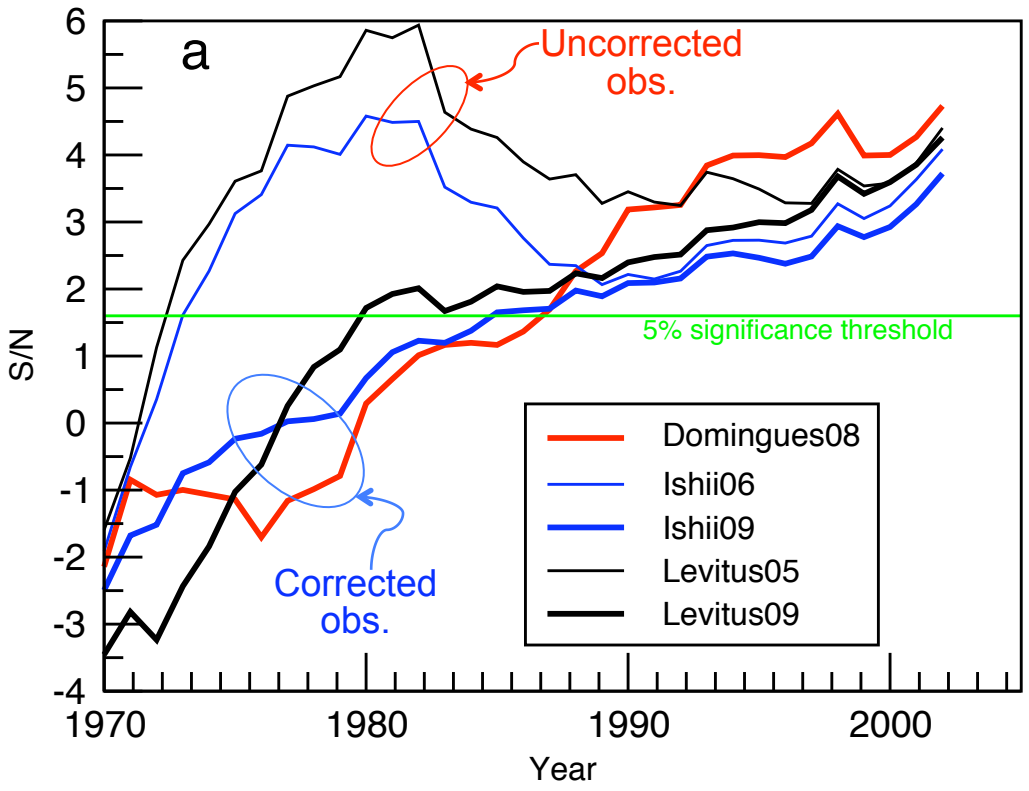
Recent ten-year trends in temperature simulated by realistically-forced models are consistent with obs.



Santer *et al.*, *J. Geophys. Res.*, 2011

Correction of observational biases has implications for identification of a human-caused ocean warming signal

S/N ratios of trends for periods starting in 1960



- Recent corrections to XBT measurements reduce '70's warming anomaly, delaying detection of projected heat content changes in observed record
- S/N on 40 year timescale is large (>3)

Gleckler et al., 2011

PCMDI has developed the CAPT: Cloud-Associated Parameterization Testbed

- Test new climate models with a weather-forecast approach (in collaboration with and building on earlier work by Williamson and others)

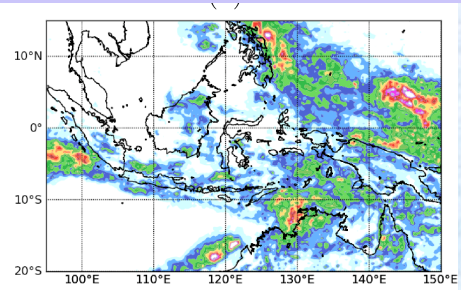
- Applications:
  - Evaluate new parameterizations. Example: Modification of the cloud physics parameterization in CAM5 (Peter Caldwell's poster)
  - Impact of increased model resolution
  - Evaluation of processes: Example: Tropical precipitation variability

Increased CAM4 resolution improves simulations, as revealed in CAPT day-2 forecasts of tropical precip.

- Improvements in:
  - Precipitation statistics (intensity, intermittency)
  - Land-sea breezes (diurnal cycle)
  - Resolved-scale heating rates
- Seasonal-mean precipitation insensitive to resolution
- But increased resolution can produce excessive local precipitation events (consistent with Williamson)

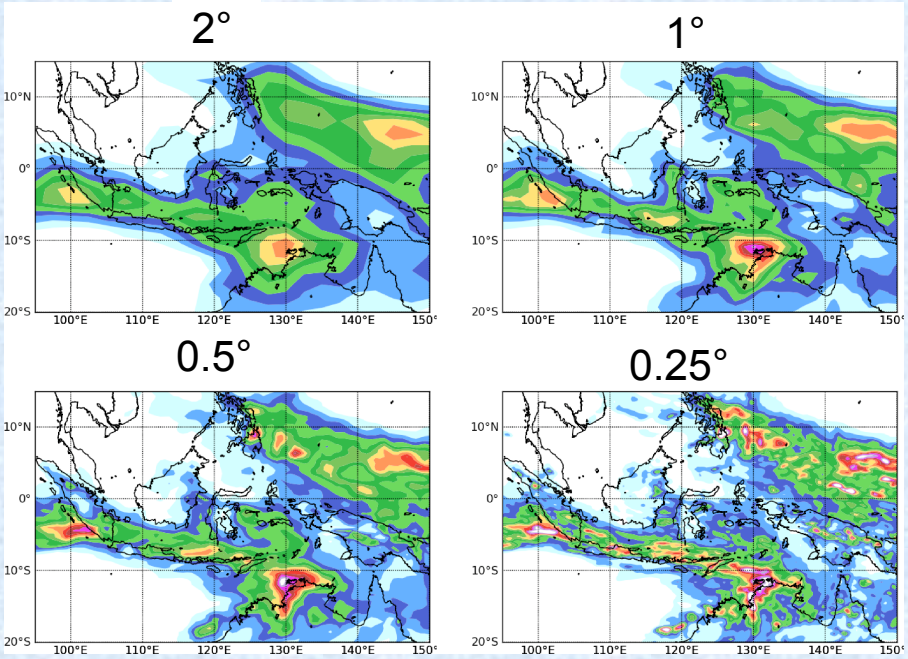
Boyle & Klein, JGR, 2010

Mean Precipitation for January 20-25, 2006



← TRMM obs.

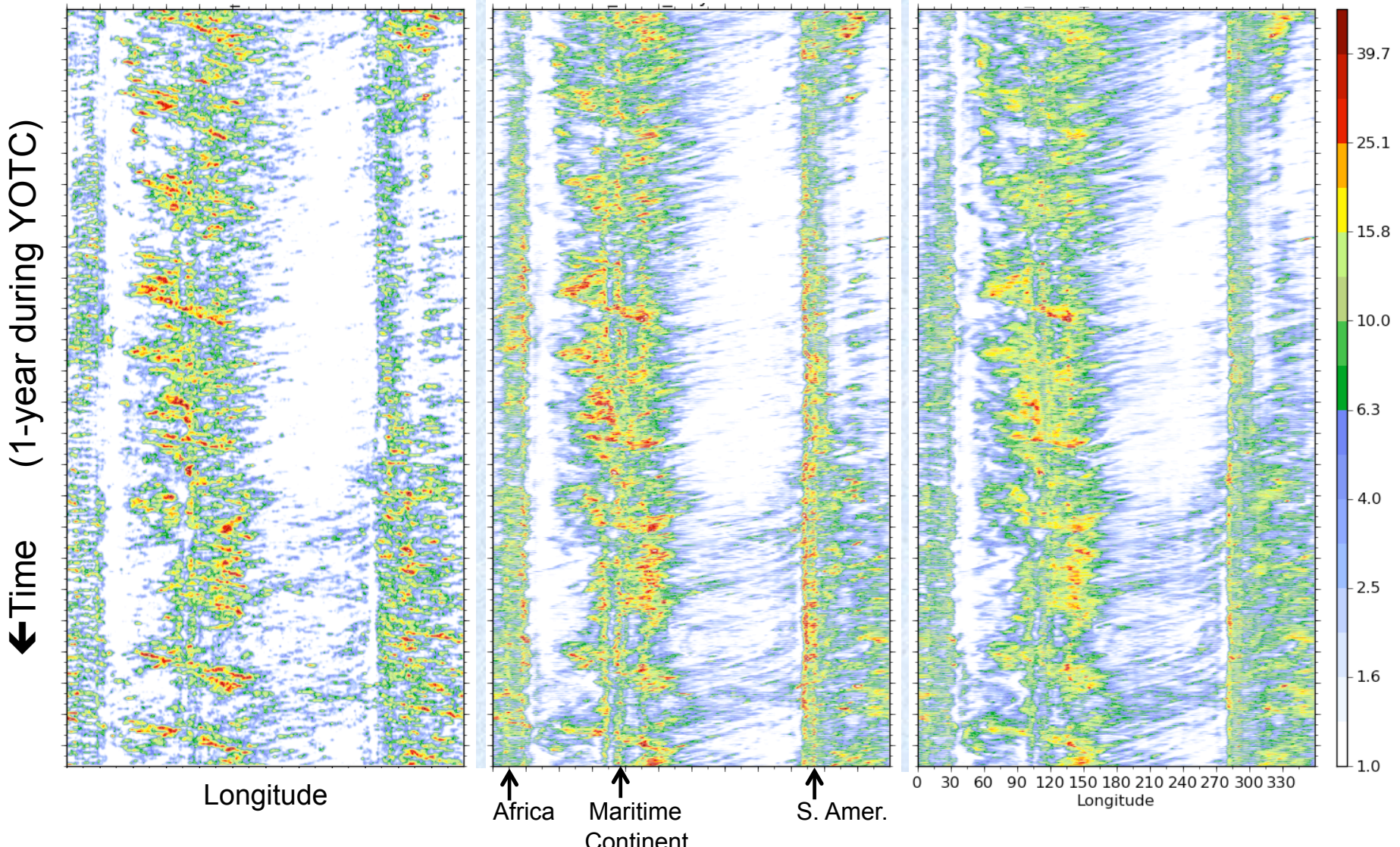
CAM4 at different horizontal resolutions



PCMDI has developed the CAPT: Cloud-Associated Parameterization Testbed

- Test new climate model cloud parameterizations with a weather-forecast approach
- Applications:
  - Evaluate new parameterizations. Example: Modification of the cloud physics parameterization in CAM5 (Peter Caldwell's poster)
  - Impact of increased model resolution
  - Evaluation of processes: Example: Tropical precipitation variability

Day-2 CAPT forecasts of tropical rainfall for YOTC period
(For more information see 2 posters: Shaocheng Xie and Hsi-Yen Ma

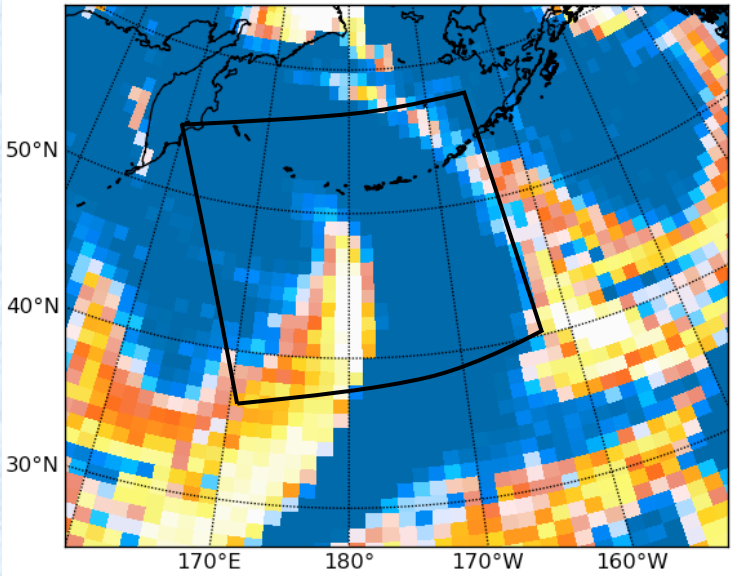


PCMDI develops and applies "satellite simulator" diagnostic codes

- Making key contributions to development of COSP (CFMIP Observation Simulator Package)
  - Enables direct comparison of model-simulated clouds and cloud observations
  - Includes ISCCP, MISR, MODIS, CLoudSat and Calipso satellite instruments
  - COSP is now imbedded in all major climate models, permitting accurate inter-model comparison of clouds
- Co-authored a recent BAMS article describing COSP
- Involved with implementing COSP option in CAM
- More information on COSP can be found in poster by Yuying Zhang

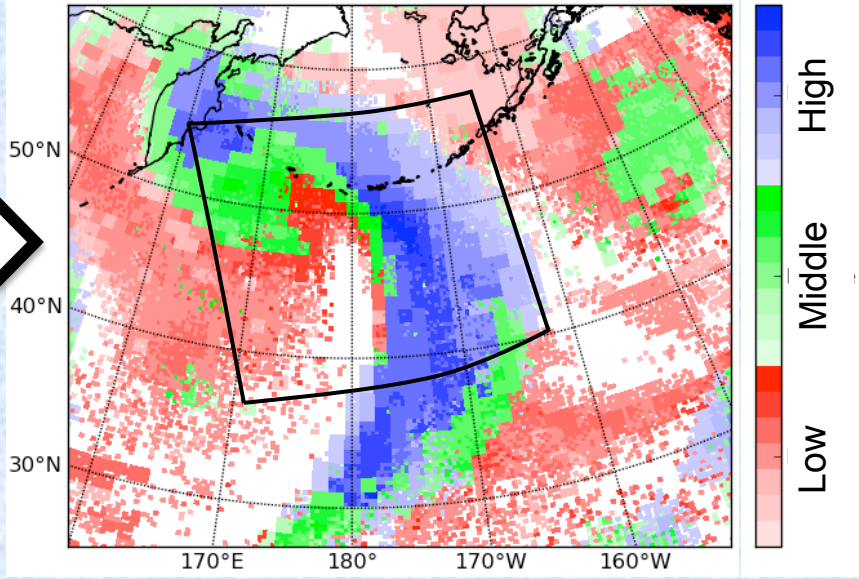
Day-2 CAPT forecast of frontal cloud systems

Climate model cloud fraction



COSP Processing

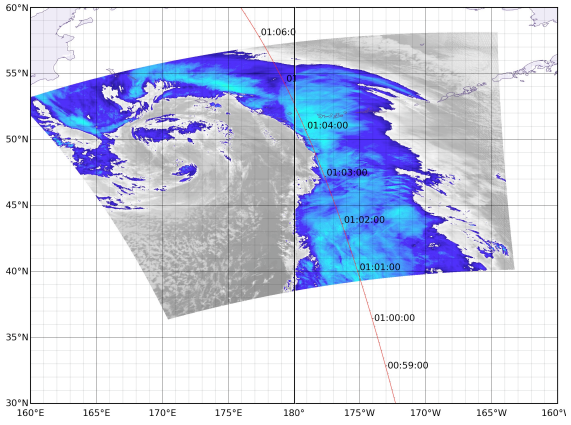
COSP ISCCP product



What would a satellite see if the atmosphere had the 3-D spatial distribution and cloud properties of a climate model?

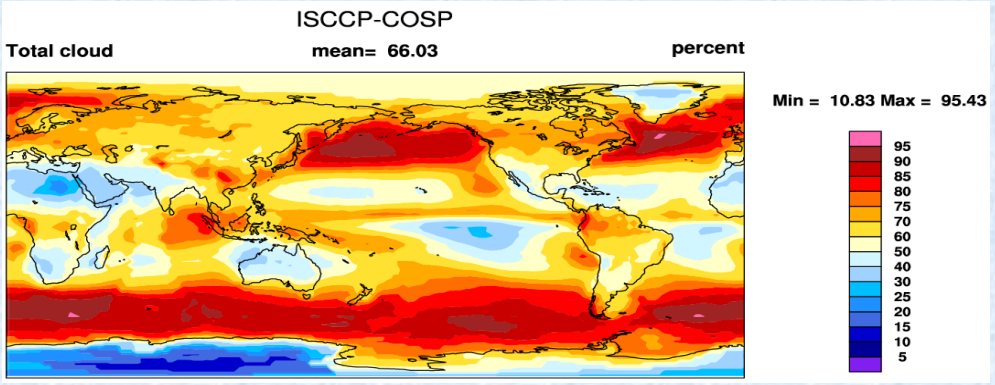
Bodas-Salcedo et al., BAMS, 2011

MODIS cloud-top temperature



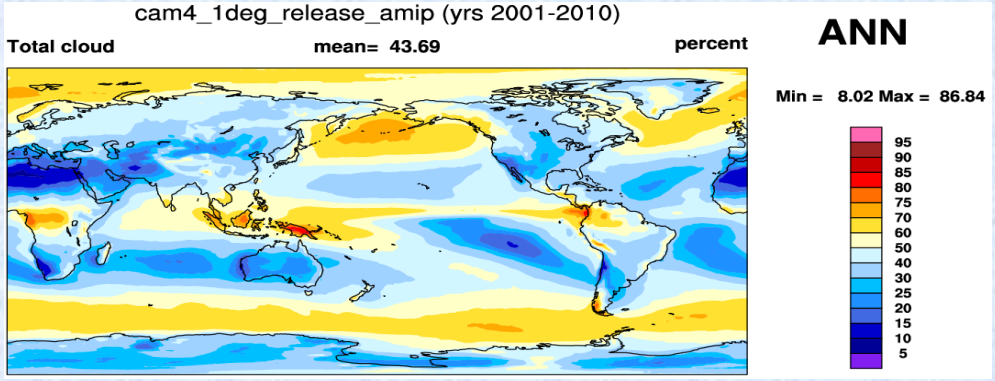
Use of COSP in evaluation of CAM shows improvement in mid-latitude clouds in CAM5, relative to CAM4.

Obs: ISCCP total cloud cover

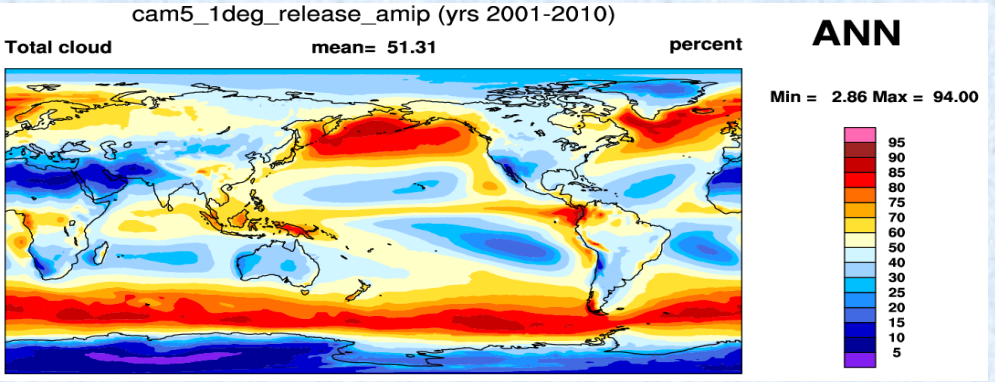


Model output processed by COSP to produce clouds seen by ISCCP

CAM4



CAM5



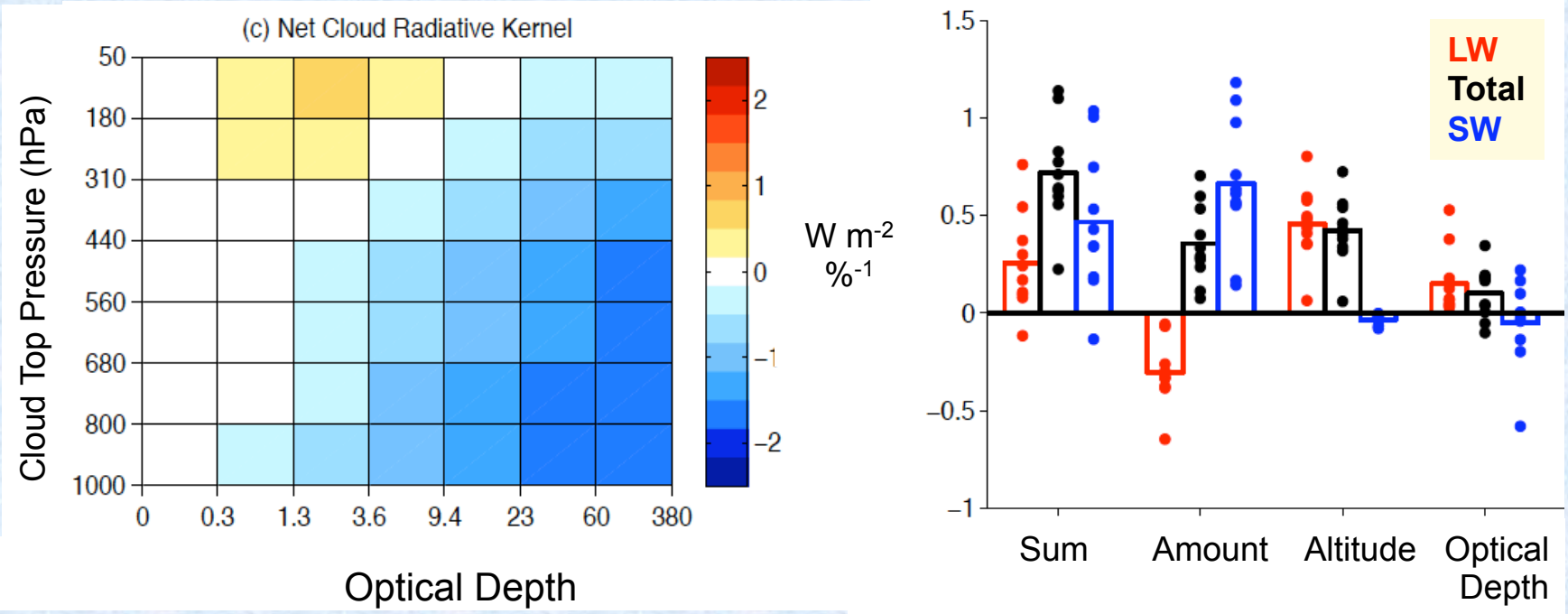
Contributions by Zhang, Klein and Boyle reported in Kay *et al.*, *J. Clim.*, submitted

PCMDI's cloud feedback studies

- Year-old RGCM project to study cloud feedbacks (in collaboration with Alex Hall and Joel Norris)
- Goal 1: to identify and understand which cloud feedbacks exhibit time-scale invariance
- Goal 2: to reduce uncertainty in cloud feedback predictions by climate models
- Recent result: Quantified contributions of different cloud types to cloud feedback
- Additional results: talks and poster this week
  - Neil Gordon's talk: Cloud optical depth feedbacks
  - Posters by Caldwell/Zhang/Klein and Xin Qu/Alex Hall: focused on marine stratocumulus cloud feedbacks

Zelinka et al. (J. Clim.) have developed a new method to diagnose different contributions to cloud feedbacks in models

- Using a radiative transfer model, sensitivity of TOA radiation to changes in cloud fraction of ISCCP cloud-types is calculated (producing "cloud radiative kernels")
- Radiative kernels multiply cloud fraction changes in diagnosed (using ISCCP simulator) in CMIP3 models
- Calculate contributions to cloud feedback from amount, altitude, and optical depth



Summary: DOE supports PCMDI's dual mission

- "Infrastructure" to support research
  - Model intercomparison activities
  - Software for handling and analyzing large distributed scientific data sets
  - CAPT – weather forecast approach to climate model evaluation
  - COSP – for evaluation of models against satellite data
- Research focuses
  - Around CMIP
  - Detection and attribution
  - Cloud processes
  - Performance metrics
  - Modes of variability
  - Etc.

PCMDI CMIP infrastructure support activities described in CLIVAR Exchanges Newsletter

- "CMIP5 Long-term experimental design" (co-author: Taylor)
- "CFMIP: Towards a better evaluation and understanding of clouds and cloud feedbacks in CMIP5 models" (co-author: Klein)
- "Climate response to aerosol forcings in CMIP5" (co-author: Taylor)
- "The Earth System Grid Federation: Software Framework Supporting CMIP5 Data Analysis and Dissemination" (Williams, Taylor & others)
- "Satellite Observations for CMIP5 Simulations" (co-author: Gleckler)

"Long-term" experiments: planned contributions

** Core simulations* *(# available as of 18 Sept 2011)*

Experiment(s)	# of models
* Control & historical	35 (10)
* AMIP	26 (8)
* RCP4.5 & 8.5	29 (9)
RCP2.6	18 (6)
RCP6	13 (6)
RCP's to year 2300	10 (?)
* 1% CO2 increase	28 (7)
* Fixed SST CO2 forcing diagnosis	16 (4)
* Abrupt 4XCO2 diagnostic	22 (7)

Experiment(s)	# of models
Fast adjustment diagnostic	9 (?)
Aerosol forcing	9 (2)
*ESM control, historical & RCP8.5	18 (3)
Carbon cycle feedback isolation	9 (2)
Mid-Holocene & LGM	11 (2)
Millenium	7 (0)
CFMIP runs	7-9 (1-4)
D & A runs	15 (6)

"Decadal" experiments: planned contributions

** Core simulations* *(# available as of 18 Sept 2011)*

Experiment(s)	Number of models
*Hindcasts and predictions	18 (4)
AMIP	3 (1)
Volcano-free hindcasts	3 (0)
2010 "Pinatubo-like" eruption	1 (0)
Initialization alternatives	5 (?)
Pre-industrial control	10 (1)
1% CO2 increase	9 (1)

CMIP5 timeline

- Late 2013: IPCC AR5 published
- Journal articles accepted – 15 March 2013
- Journal articles submitted – 31 July 2012
- April 2012: Data not already in the CMIP5 archive will probably not be included in publications cited by the AR5
- March 2011: First model output became available to users