

CMIP5 Update

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

Presented to the WCRP Working Group on Coupled Modelling

Hamburg, Germany
24 September 2012

Outline

- Models participating and simulations performed
- Output archive and user support
- Scientific impact
- Remaining priorities
- What about the future of CMIP?

CMIP5 participating groups

22 models available from 13 groups

17 Oct. 2011:

Primary Group	Country	Model
CSIRO-BOM	Australia	ACCESS 1.0, 1.3
BCC	China	BCC-CSM1.1, 1.1(m)
GCESS	China	BNU-ESM
CCCMA	Canada	CanESM2, CanCM4, CanAM4
DOE-NSF-NCAR	USA	CCSM4, CESM1 (BGC), (CAM5), (CAM5.1,FV2), (FASTCHEM), (WACCM)
RSMAS	USA	CCSM4(RSMAS)
CMCC	Italy	CMCC- CESM, CM, & CMS
CNRM/CERFACS	France	CNRM-CM5
CSIRO/QCCCE	Australia	CSIRO-Mk3.6.0
EC-EARTH	Europe	EC-EARTH
LASG-IAP & LASG-CESS	China	FGOALS- g2, s2, & gl
FIO	China	FIO-ESM
NASA/GMAO	USA	GEOS-5
NOAA 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-LR
MIROC	Japan	MIROC 5, 4m, 4h, ESM, ESM-CHEM
MPI-M	Germany	MPI-ESM- HR, LR, P, ESM-P
MRI	Japan	MRI- AGCM3.2H, AGCM3.2S, CGCM3, ESM1
NCC	Norway	NorESM1-M, NorESM-ME
NCEP	USA	CFSv2-2011
NICAM	Japan	NICAM-09
INPE	Brazil	BESM OA2.3



CMIP5 participating groups

3 March 2012

41 models available from 20 groups

Primary Group	Country	Model
CSIRO-BOM	Australia	ACCESS 1.0, 1.3
BCC	China	BCC-CSM1.1, 1.1(m)
GCESS	China	BNU-ESM
CCCMA	Canada	CanESM2, CanCM4, CanAM4
DOE-NSF-NCAR	USA	CCSM4, CESM1 (BGC), (CAM5), (CAM5.1,FV2), (FASTCHEM), (WACCM)
RSMAS	USA	CCSM4(RSMAS)
CMCC	Italy	CMCC- CESM, CM, & CMS
CNRM/CERFACS	France	CNRM-CM5
CSIRO/QCCCE	Australia	CSIRO-Mk3.6.0
EC-EARTH	Europe	EC-EARTH
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FIO	China	FIO-ESM
NASA/GMAO	USA	GEOS-5
NOAA 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-LR
MIROC	Japan	MIROC 5, 4m, 4h, ESM, ESM-CHEM
MPI-M	Germany	MPI-ESM- HR, LR, P, ESM-P
MRI	Japan	MRI- AGCM3.2H, AGCM3.2S, CGCM3, ESM1
NCC	Norway	NorESM1-M, NorESM-ME
NCEP	USA	CFSv2-2011
NICAM	Japan	NICAM-09
INPE	Brazil	BESM OA2.3



CMIP5 participating groups

59 models available from 24 groups

22 Sept. 2012:

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BCC	China	BCC-CSM1.1, 1.1(m)
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EC-EARTH	Europe	EC-EARTH
LASG-IAP & LASG-CESS	China	FGOALS- g2, s2, & gl
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NASA/GMAO	USA	GEOS-5
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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-LR
MIROC	Japan	MIROC 5, 4m, 4h, ESM, ESM-CHEM
MPI-M	Germany	MPI-ESM- HR, LR, P, ESM-P
MRI	Japan	MRI- AGCM3.2H, AGCM3.2S, CGCM3, ESM1
NCC	Norway	NorESM1-M, NorESM-ME
NCEP	USA	CFSv2-2011
NICAM	Japan	NICAM-09
INPE	Brazil	BESM OA2.3



CMIP5 timeline retrospective:

- 2006: Planning began in earnest.
- Fall 2008: Experiment design approved by WGCM
- January 2010: Experiment details in place
- March 2011: Output requirements and list of requested output finalized
- April 2011: **First model output available**
- August 2011: RCP forcing datasets finalized
- March 2012: A petabyte of data stored in 2,000,000 files
- July 2012: More than **200 publications** based on CMIP5 output in some stage of publication
- Now: 59 models available from 24 modeling centers; 1.7 PB in 4×10^6 files
- CMIP5 research just beginning

↑
15
months
↓

"Long-term" experiments: output available, as of (March 3 and) Sept. 22, 2012

Experiment(s)	# of models	Experiment(s)	# of models
* Control & historical	(29) 48	Fast adjustment diagnostic	?
* AMIP	(18) 28	Aerosol forcing	(6) 9
* RCP4.5 & 8.5	(24) 40	*ESM cntrl, hist. & RCP8.5	(8) 13
RCP2.6	(21) 29	Carbon cycle feedback isolation	(7) 10
RCP6	(15) 22	Mid-Holocene	(11) 13
RCP's to year 2300	?	LGM	(4) 7
* 1% CO2 increase	(21) 32	Millenium	(6) 7
* Fixed SST CO2 forcing diagnosis	(10) 12	CFMIP runs	(6) 10
* Abrupt 4XCO2 diagnostic	(20) 30	D & A runs	(16) 17

"Decadal" experiments: Output available, as of (March 3 and) Sept. 22, 2012

** Core simulations simulations*

Experiment(s)	Number of models
*Hindcasts and predictions	(14) 18
AMIP	(7) ?
Volcano-free hindcasts	(1) 2
2010 "Pinatubo-like" eruption	(1) 3
Initialization alternatives	?
Pre-industrial control	(12) ?
1% CO2 increase	(7) ?

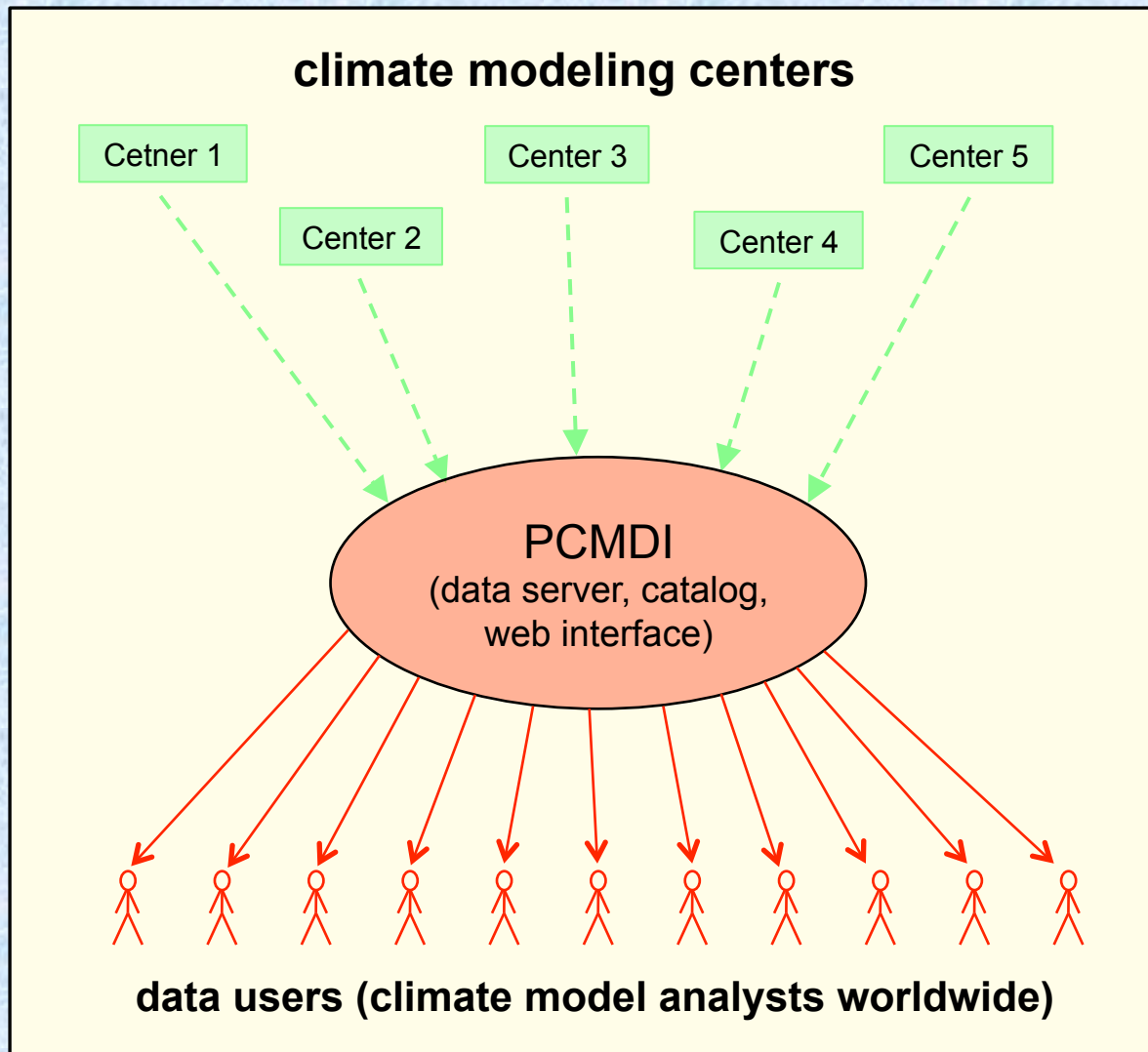
Data from providers to users: Modeling group

- Save/calculate CMIP-requested variables
- Rewrite data in conformance with CMIP-imposed data standards
- Place data on a server
- Install "Earth System Grid" (ESG) software to make data uniformly accessible from all models
- "Publish" data to the CMIP5 distributed database

Data from providers to users: PCMDI & the ESG Federation

- Provide CMOR software and tables:
 - For rewrite of model output
 - Enforce conformance with standards
 - Perform first-order QC
- Provide software to modeling groups and data centers:
 - "Publish" data
 - Installs protocols allowing external users to download data (http, gridftp, opendap??)
 - Enable replication
- Provide "portal" software where user can
 - Search distributed archive
 - Download CMIP output (either point-and-click, or with wget scripts)

Evolution of operational ESG: CMIP3



- Data shipped to PCMDI on hard disks
- Delayed availability
- Hindered corrections

- Search through web gateway
- Download from single location (ftp, http)

Evolution of operational ESG: CMIP5 (until recently)

- ESG software architecture similar to CMIP3, but
 - Data distributed worldwide at “data nodes”
 - Catalogs of data were hosted at gateways
 - Gateways shared catalog information
 - Users accessed data through gateways
- ESG limitations
 - Search engine hopelessly slow
 - Gateways often inaccurate in reporting data holdings
 - Overly monolithic structure of gateway software impaired timely
 - Modification to correct performance issues and bugs
 - Implementation of enhancements needed for CMIP5 (e.g., model documentation)
- ESG Federation formed (spring of 2010) to develop alternative

Evolution of operational ESG: CMIP5 peer-to-peer ESGF

- P2P timeline
 - Spring 2010: conception
 - Spring 2011: unanimous decision to transition to p2p system for CMIP5 (when ready)
 - Fall 2011: Prototype system ready for testing
 - August 2012: user comment -- “The new portal is wonderful! In one afternoon work achieved more than several weeks work with the old system.”
 - September 2012: Old gateways deprecated; P2P now operational
- Peer-to-peer (p2p) architecture is designed to be
 - Scalable to data needs of future
 - Simplified and modularized to enable nimble modification
 - Open-source to attract contributions and resources across the community
 - Easy to interface to (by API's)
 - Multiple, fast search options (including simple http inquiry outside user interface)

Additional resources available for users

- Model documentation (Eric Guilyardi's talk)
- CMIP5 website - see "Guide to CMIP5"
(http://cmip-pcmdi.llnl.gov/cmip5/guide_to_cmip5.html)
- Table of forcings used in each historicalMisc
- Links to modeling centers
- CMIP5 journal publications recorded and searchable
(<http://cmip.llnl.gov/cmip5/publications/allpublications>)

Record of CMIP5 publications

CMIP Coupled Model Intercomparison Project World Climate Research Programme



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- >> By Experiment
- >> By Variable
- >> By Keyword
- >> By Sampling Frequency

All Publications

Author	Article Title	Journal
?eparovi? L. , A. Alexandru, R. Laprise, A. Martynov, L. Sushama, ...	Present climate and climate change over North America as simulated by the fifth-generation Canadian Regional Climate Model (CRCM5); (Citation) (More Information)	Climate Dynamics
Ahlström A. , G. Schurgers, B. Smith	Robustness and uncertainty in terrestrial ecosystem carbon response to CMIP5 climate change projections; (Citation) (More Information)	Environmental Research Letters
Ahmed C. B. , S. Sensoy	Assessment of climate change effects on agriculture in the Mediterranean countries; (Citation) (More Information)	
Alan I. , M. Demircan, S. Sensoy	Trends in Turkey climate extreme indices from 1971 to 2004; (Citation) (More Information)	
Anav A. , P. Friedlingstein, M. Kidston, L. Bopp, P. Ciais, ...	EVALUATING THE LAND AND OCEAN COMPONENTS OF THE GLOBAL CARBON CYCLE IN THE CMIP5 EARTH SYSTEM MODELS; (Citation) (More Information)	Journal of Climate
Andrews T. , J. M. Gregory, M. J. Webb, K. E. Taylor	Forcing, feedbacks and climate sensitivity in CMIP5 coupled atmosphere-ocean climate models; (Citation) (More Information)	Geophysical Research Letters
Anstey J. A. , P. Davini, L. J. Gray, T. J. Woollings, N. Butchart, ...	Multi-model analysis of Northern Hemisphere winter blocking and tropospheric jet variability; (Citation) (More Information)	Journal of Geophysical Research
Arblaster J. M. , L. V. Alexander	The impact of the El Nino Southern Oscillation on maximum temperature extremes; (Citation) (More Information)	Geophysical Research Letters
Armour K. C. , C. M. Bitz, G. H. Roe	Time-varying climate sensitivity from regional feedbacks; (Citation) (More Information)	Journal of Climate
Arora V. , G. Boer, P. Friedlingstein, M. Eby, C. Jones, ...	Carbon-concentration and carbon-climate feedbacks in CMIP5 Earth system models; (Citation) (More Information)	Journal of Climate
Balan Sarojini B. , P. Stott, E. Black, D. Polson	Fingerprints of Changes in Annual and Seasonal Precipitation from CMIP5 Models over Land and Ocean; (Citation) (More Information)	Geophysical Research Letters



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Andrews T. , J. M. Gregory, M. J. Webb, K. E. Taylor	Forcing, feedbacks and climate sensitivity in CMIP5 coupled atmosphere-ocean climate models; (Citation) Andrews T. , J. M. Gregory M. J. Webb K. E. Taylor null : " Forcing, feedbacks and climate sensitivity in CMIP5 coupled atmosphere-ocean climate models" , <i>Geophysical Research Letters</i> 39 , doi:10.1029/2012GL051607 , http://www.agu.org/pubs/crossref/2012/2012GL051607.shtml (More Information)	Geophysical Research Letters
<u>Experiments</u>	<u>Models</u>	<u>Variables</u>
abrupt4xCO2	CanESM2	land area fraction
piControl	CNRM-CM5	surface temperature
sstClim	CSIRO-Mk3.6.0	toa incoming shortwave flux
sstClim4xCO2	GFDL-CM3	toa outgoing longwave flux
	GFDL-ESM2G	toa outgoing longwave flux
	GFDL-ESM2M	toa outgoing longwave flux assuming clear sky
	HadGEM2-ES	toa outgoing shortwave flux
	INM-CM4	toa outgoing shortwave flux assuming clear sky
	IPSL-CM5A-LR	toa outgoing shortwave flux
	MIROC-ESM	toa outgoing shortwave flux assuming clear sky
	MIROC5	
	MPI-ESM-LR	
	MPI-ESM-P	
	MRI-CGCM3	
	NorESM1-M	
		<u>Keywords</u>
		WG1 (physical climate system)
		Abrupt change
		Globe
		Energy budget
		Radiative forcing
		Clouds
		Radiation
		Feedbacks
		Climate sensitivity

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- » [By Experiment](#)
- » [By Variable](#)
- » [By Keyword](#)
- » [By Sampling Frequency](#)

Click on "citation" and "more information" to expand to:

Forcing, feedbacks and climate sensitivity in CMIP5 coupled atmosphere-ocean climate models; (Citation)

Andrews T. , J. M. Gregory M. J. Webb K. E. Taylor null : " Forcing, feedbacks and climate sensitivity in CMIP5 coupled atmosphere-ocean climate models" , *Geophysical Research Letters* 39 , doi:10.1029/2012GL051607 , <http://www.agu.org/pubs/crossref/2012/2012GL051607.shtml>

(More Information)

Experiments

abrupt4xCO2
piControl
sstClim
sstClim4xCO2

Models

CanESM2
CNRM-CM5
CSIRO-Mk3.6.0
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
HadGEM2-ES
INM-CM4
IPSL-CM5A-LR
MIROC-ESM
MIROC5
MPI-ESM-LR
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MRI-CGCM3
NorESM1-M

Variables

land area fraction
surface temperature
toa incoming shortwave flux
toa outgoing longwave flux
toa outgoing longwave flux assuming clear sky
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Keywords

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Climate sensitivity

Different subsets of information can be displayed.

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Publications analyzing model: ACCESS1.0

Author	Article Title	Journal
Bathols J. , C. Heady, I. G. Watterson	Are climate models more skillful in their home continent?; (Citation) (More Information)	Bulletin of the American Meteorological Society
Bracegirdle T. J. , D. B. Stephenson	On the robustness of emergent constraints used in multi-model climate change projections of Arctic warming; (Citation) (More Information)	Journal of Climate
Brown J. R. , A. F. Moise, R. A. Colman	The South Pacific Convergence Zone in CMIP5 simulations of historical and future climate; (Citation) (More Information)	Climate Dynamics
Brutel-Vuilmet C. , M. Menegoz, G. Krinner	An analysis of present and future seasonal Northern Hemisphere land snow cover simulated by CMIP5 coupled climate models; (Citation) (More Information)	The Cryosphere
Ceppi P. , Y. Hwang, D. M. Frierson, D. L. Hartmann	Southern Hemisphere jet latitude biases in CMIP5 models linked to shortwave cloud forcing; (Citation) (More Information)	Geophysical Research Letters
Collier M. A. , L. D. Rotstayn, J. Kim, K. Kim	An assessment of central and eastern Pacific El Nino's in the CSIRO-Mk3.6, ACCESS1.0 and ACCESS1.3 CMIP5 coupled climate models and their impact on Australian Rainfall; (Citation) (More Information)	Journal of Climate
Dirmeyer P. A. , Y. Jin, B. Singh, X. Yan	Trends in land-atmosphere interactions from CMIP5 simulations; (Citation) (More Information)	Journal of Hydrometeorology
Dirmeyer P. A. , Y. Jin, B. Singh, X. Yan	Evolving land-atmosphere interactions over North America from CMIP5 simulations; (Citation) (More Information)	Journal of Climate
Du Y. , X. Shang-Ping, Y. Ya-Li, X. Zheng, L. Liu, ...	Indian Ocean variability in the CMIP5 multi-model ensemble: The basin mode; (Citation) (More Information)	Journal of Climate
DU Z. , R. HUANG, G. Huang	How Well can CMIP5 CGCMs Simulate the EAP/PJ Teleconnection Pattern and its Corresponding Summer Climate in the East Asian Monsoon Region; (Citation) (More Information)	Other
DU Z. , R. HUANG, G. Huang	How well can CMIP5 CGCMs simulate the Asian summer monsoon rainfall and its interannual variability and their future projections; (Citation) (More Information)	Advances in Atmospheric Sciences
Fettweis X. , B. Franco, M. ...	Estimating Greenland ice sheet surface mass balance contribution to future sea level rise using the regional atmospheric climate model MAR; (Citation)	The Cryosphere Discuss

Total Publications Count: 248

Model	Count
ACCESS1.0	45
ACCESS1.3	28
BCC-CSM1.1	94
BCC-CSM1.1-m	17
BESM-OA2.3	6
BNU-ESM	23
CanAM4	23
CanCM4	34
CanESM2	126
CCSM4	104
CCSM4-RSMAS	13
CESM-BGC	20
CESM1-CAM5	24
CESM1-CAM5.1.FV2	15
CESM1-FASTCHEM	17
CESM1-WACCM	18
CFSv2-2011	12
CMCC-CESM	15
CMCC-CM	25
CMCC-CMS	17
CNRM-CM5	120

Additional resources available for users

- Model documentation (Eric Guilyardi's talk)
- CMIP5 website - see "Guide to CMIP5"
(http://cmip-pcmdi.llnl.gov/cmip5/guide_to_cmip5.html)
- Table of forcings used in each historicalMisc
- Links to modeling centers
- CMIP5 journal publications recorded and searchable
(<http://cmip.llnl.gov/cmip5/publications/allpublications>)
- Obs4MIPs coordinated with CMIP5 (Peter Gleckler's talk)

What's being done to enhance CMIP5 data services?

Well along:

- p2p ESG interface to model and experiment documentation
- Replication of subset of data (redundancy, improved performance, server-side calculations)
- Additional methods to download (gridFTP, ftp of a subset)
- Service to inform users of availability of new datasets of interest

What's being done to enhance CMIP5 data services?

In development:

- Sub-setting and server-side computation
- Service to tell users whether their files have been withdrawn/replaced
- Method of recording provenance of data used in CMIP5 publications (e.g., doi assignment and other options)
- Scalable method of reporting/notifying users of errors in data, but at present:
<http://cmip-pcmdi.llnl.gov/cmip5/errata/cmip5errata.html>
- Improved automated QC

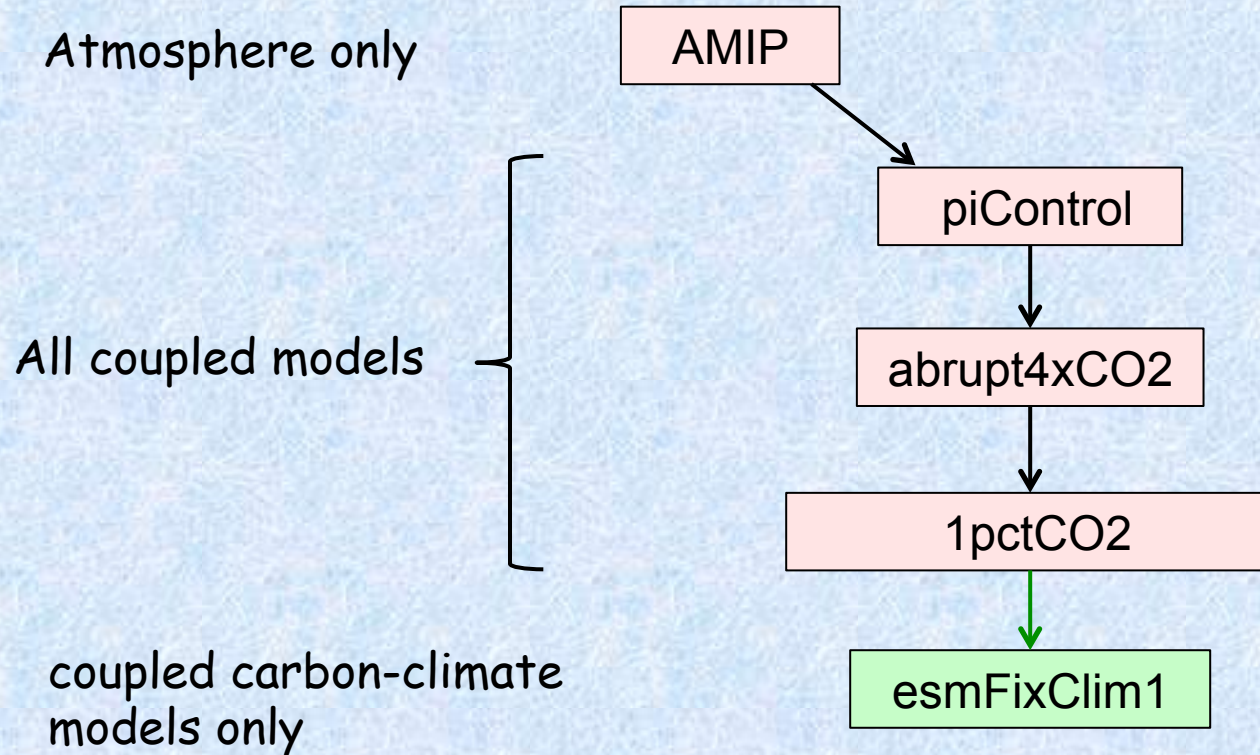
Remarks on CMIP's future

- Value of multi-model ensemble has been established
- CMIP has subjected models to wider scrutiny
- Resources devoted to CMIP tax modeling groups heavily

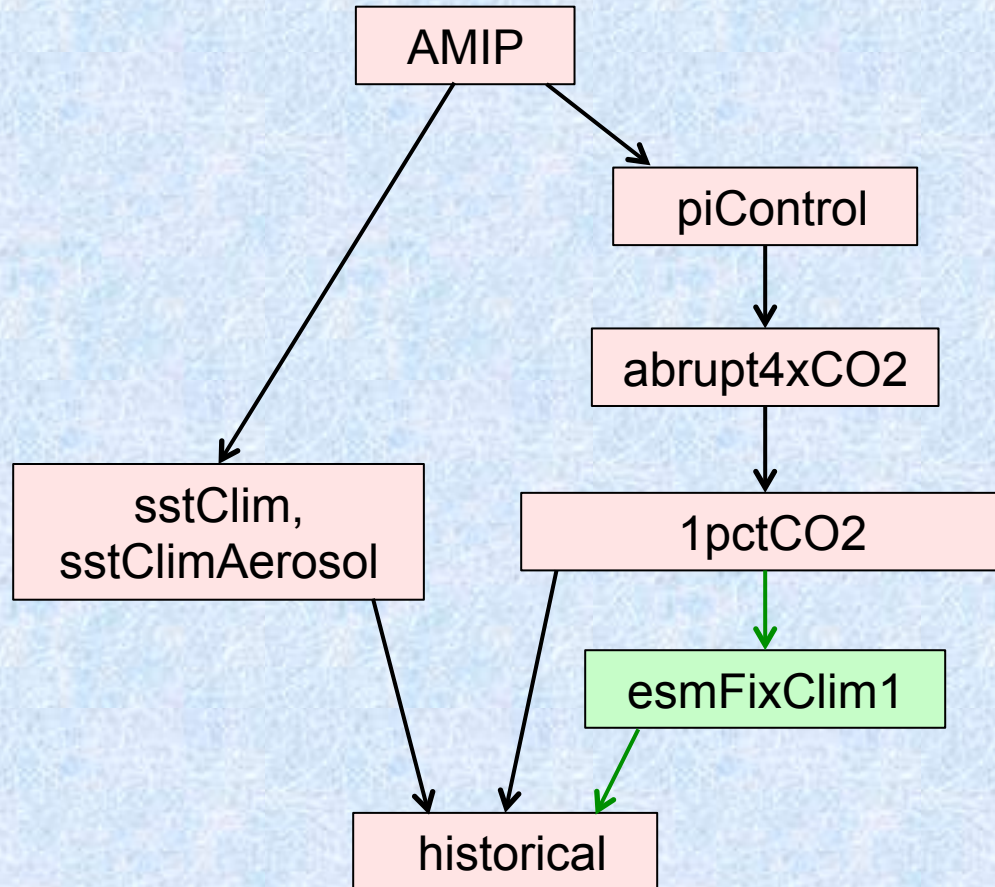
Suggestion:

- Establish a set of benchmark experiments that would
 - Be done anyway by most groups as part of the development cycle.
 - Evolve only slowly
 - Be revisited whenever a new model was developed
- Additional, specialized intercomparisons would build on these and make use of the same standards and infrastructure.

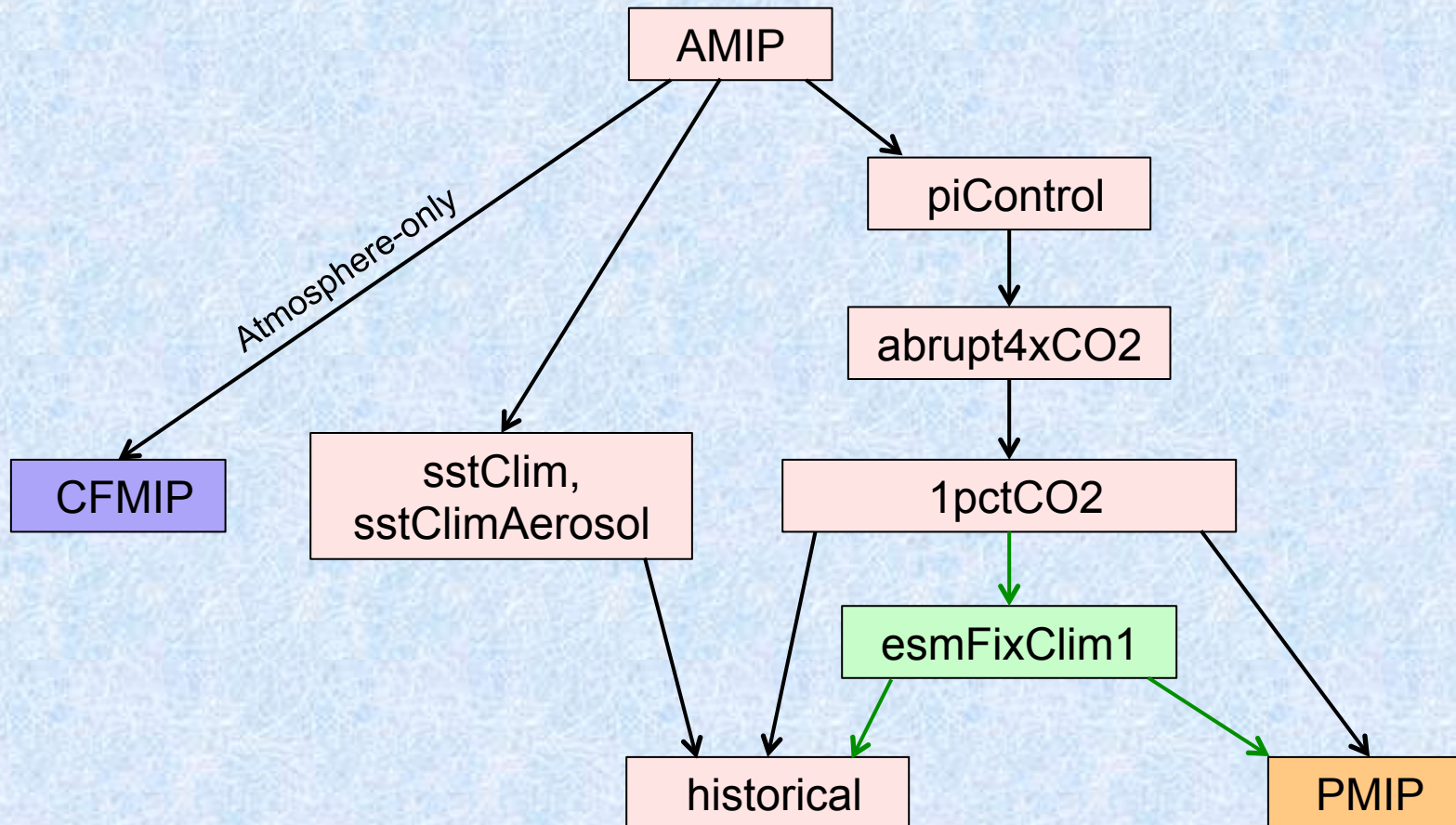
Start with essential CMIP benchmark experiments (omitting decadal prediction for now)



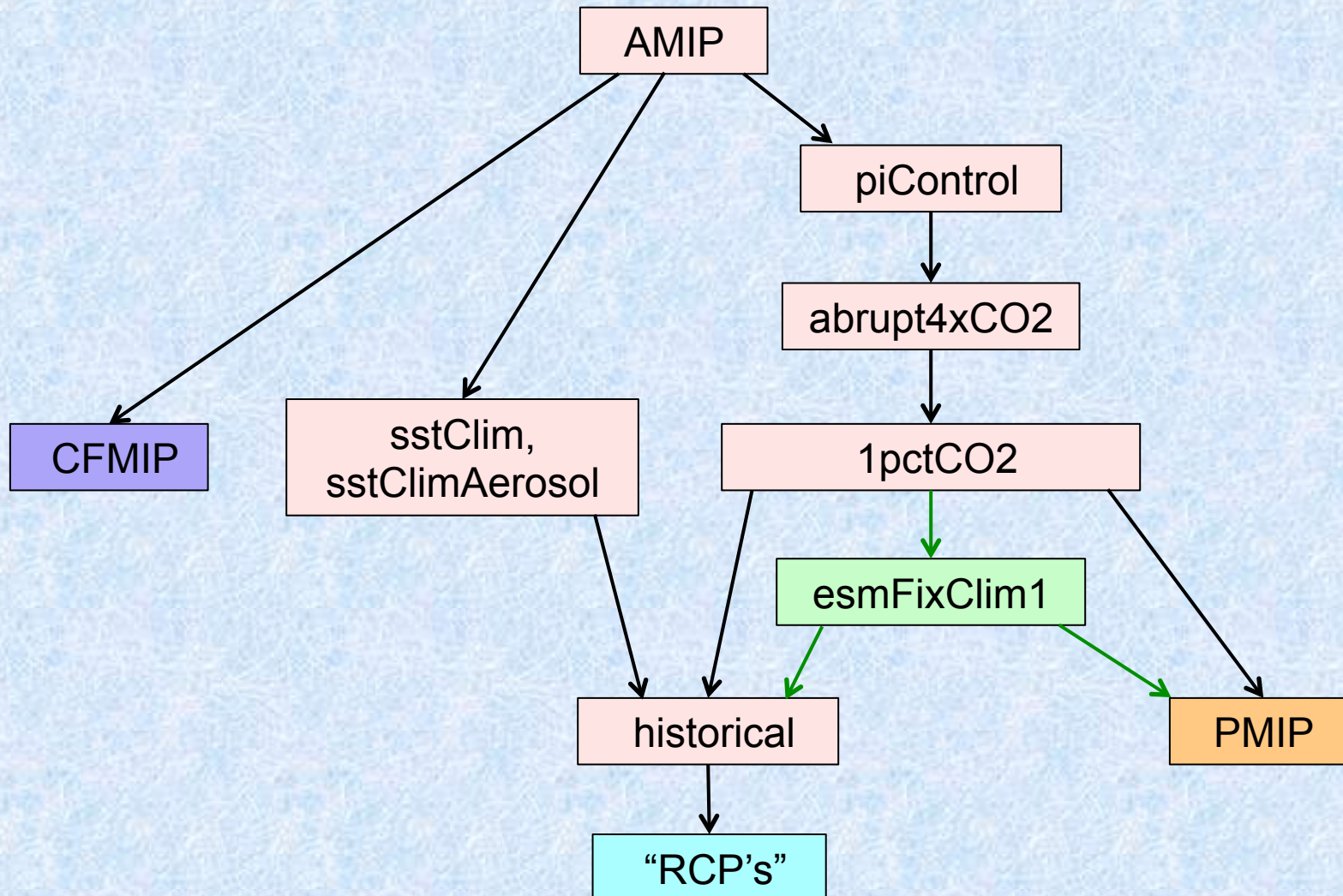
Include historical run for baseline detection & attribution experiments



Special interest MIP's would fit in but might not be revisited with every model version.



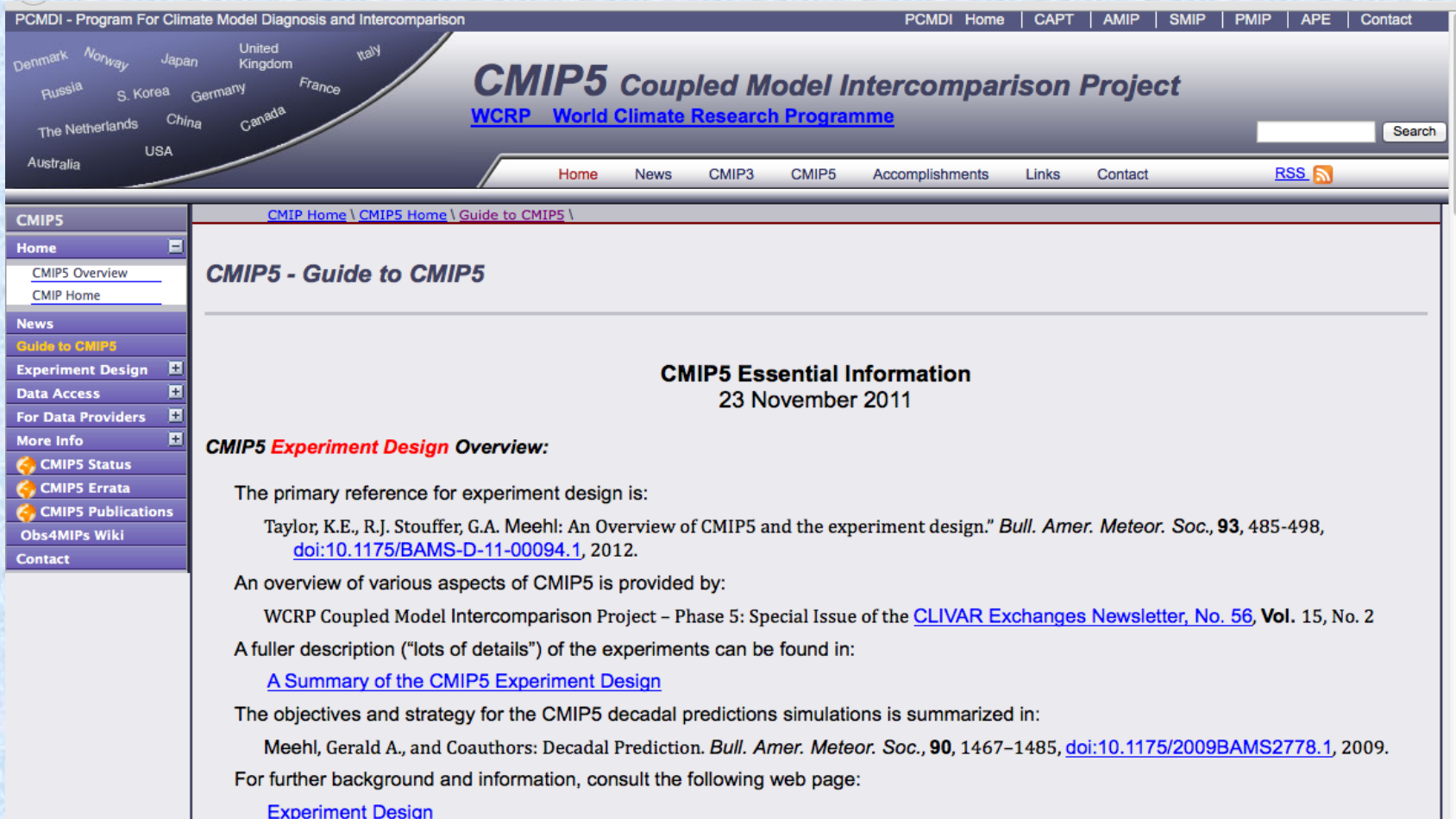
RCP runs (or their successors) would only be performed when needed for IPCC assessments



CMIP website:

<http://cmip-pcmdi.llnl.gov>

(or search on “CMIP5”)



PCMDI - Program For Climate Model Diagnosis and Intercomparison

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CMIP5 Essential Information

23 November 2011

CMIP5 Experiment Design Overview:

The primary reference for experiment design is:

Taylor, K.E., R.J. Stouffer, G.A. Meehl: An Overview of CMIP5 and the experiment design." *Bull. Amer. Meteor. Soc.*, **93**, 485-498, [doi:10.1175/BAMS-D-11-00094.1](https://doi.org/10.1175/BAMS-D-11-00094.1), 2012.

An overview of various aspects of CMIP5 is provided by:

WCRP Coupled Model Intercomparison Project – Phase 5: Special Issue of the [CLIVAR Exchanges Newsletter, No. 56](#), Vol. 15, No. 2

A fuller description (“lots of details”) of the experiments can be found in:

[A Summary of the CMIP5 Experiment Design](#)

The objectives and strategy for the CMIP5 decadal predictions simulations is summarized in:

Meehl, Gerald A., and Coauthors: Decadal Prediction. *Bull. Amer. Meteor. Soc.*, **90**, 1467–1485, [doi:10.1175/2009BAMS2778.1](https://doi.org/10.1175/2009BAMS2778.1), 2009.

For further background and information, consult the following web page:

[Experiment Design](#)

