The NCAR
Community Earth System Model
and the
IPCC Fifth Assessment Report

BESSIG meeting
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The Development of Climate Models Past to the Present

Mid-1960s	1970s-1980s	1990s	2000s	Present day
Atmosphere and land surface	Atmosphere, land surface, vegetation	Atmosphere, land surface, vegetation	Atmosphere	Atmosphere
Ocean	Ocean	Ocean	Ocean	Ocean
	Sea ice	Sea ice	Sea ice	Sea ice
		Sulfate aerosols	Sulfate aerosols	Sulfate aerosols
		Solar forcing, volcanic aerosols	Solar forcing, volcanic aerosols	Solar forcing, volcanic aerosols
			Carbon cycle	Carbon/Nitrogen cycle
			Dust, Sea Spray, & Mineral Aerosols	Dust, Sea Spray, & Mineral Aerosols
			Land surface, vegetation	Land surface, interactive vegetation
				Biogeochemical cycles
				Ice sheet

The Development of Climate Models

(From "History of climate modeling", by Paul Edwards; DOI: 10.1002/wcc.95)
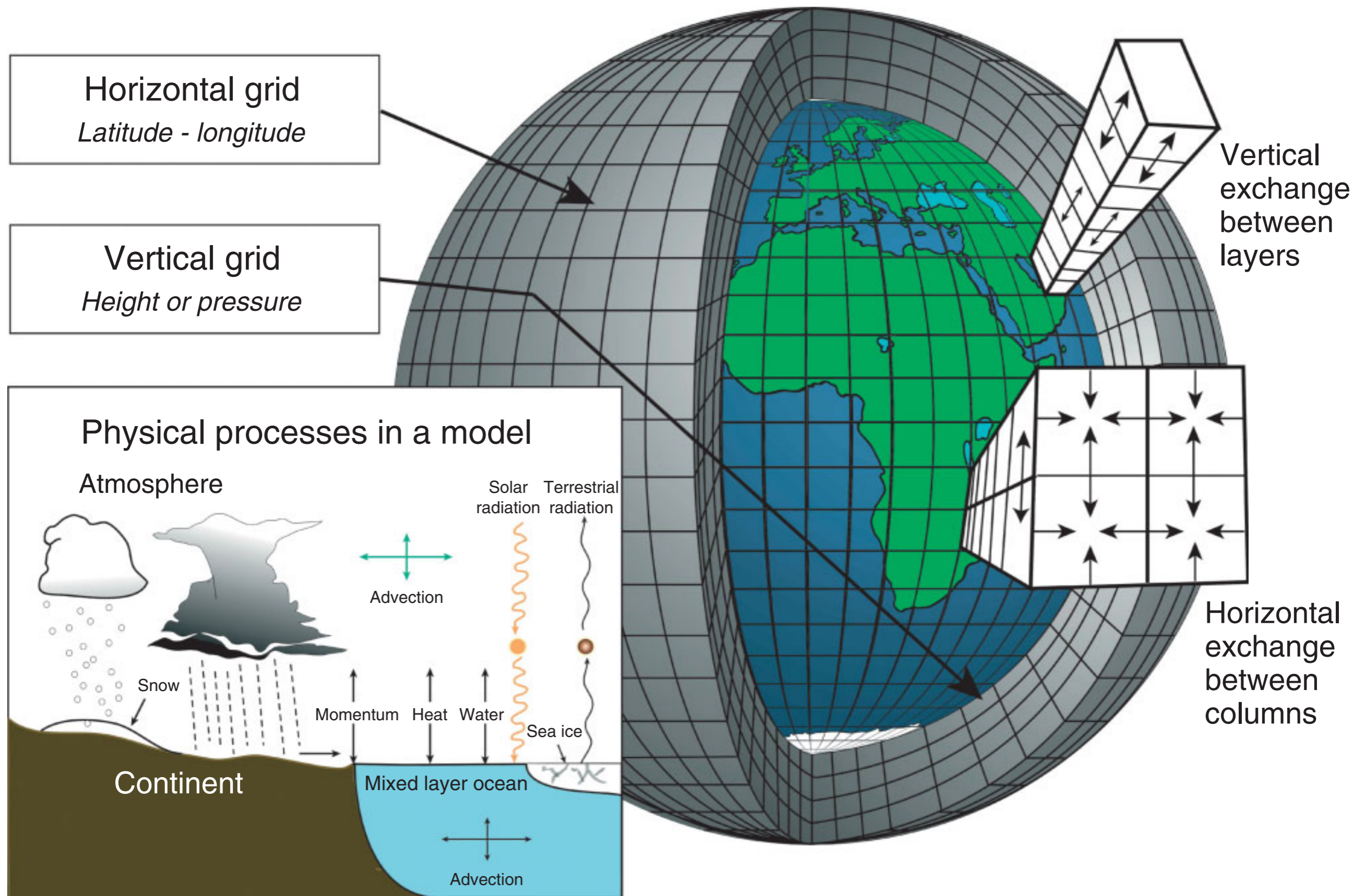
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ESM schematic (simple)

Horizontal grid
Latitude - longitude

Vertical grid
Height or pressure

Physical processes in a model

Atmosphere

Solar radiation   Terrestrial radiation

Advection

Snow

Momentum   Heat   Water

Sea ice

Continent

Mixed layer ocean

Advection

Vertical exchange between layers

Horizontal exchange between columns

(From "History of climate modeling",by Paul Edwards; DOI: 10.1002/wcc.95)
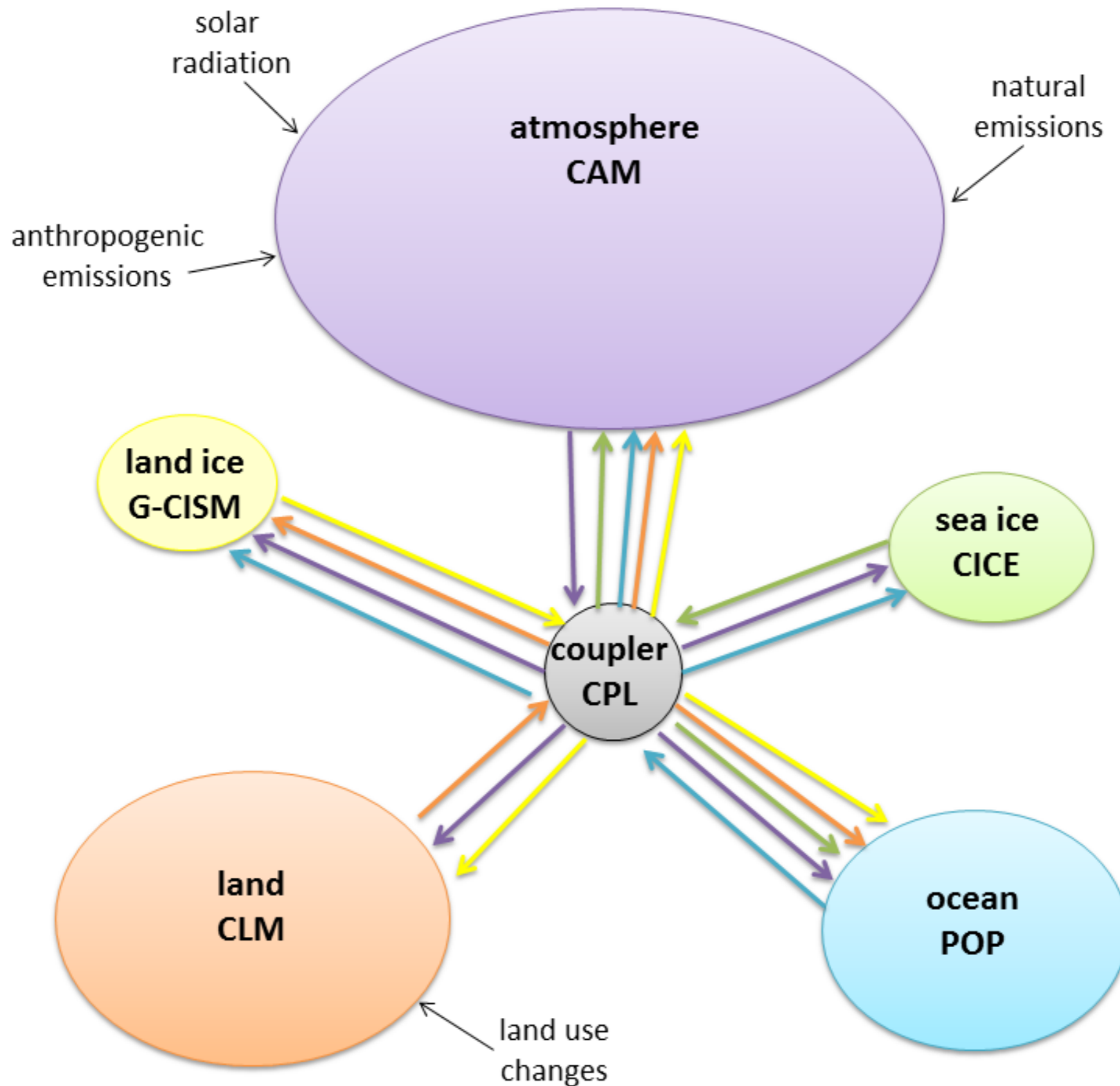
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CESM schematic (simple)

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CESM schematic (less simple)

Atmosphere Component	CAM DATM
CAM Modes: Multiple Dycores, Physics, Chemistry Options, WACCM/WACCMX, single column	
Data-ATM: Multiple Forcing/Physics Modes	

Land Component	CLM DLND
CLM Modes: no BGC, BGC, Dynamic or Prescribed Vegetation, Urban, Crop, RTM	
Data-LND: Multiple Forcing/Physics Modes	

Ice Component	CICE DICE
CICE Modes: Fully Prognostic, Prescribed	
Data-ICE : Multiple Forcing/Physics Modes	

Ocean Component	POP DOCN-(SOM/DOM)
POP Modes: Ecosystem, Fully-coupled, Ocean-only, Multiple Physics Options	
Data-OCN : Multiple Forcing/Physics Modes (SOM/DOM)	

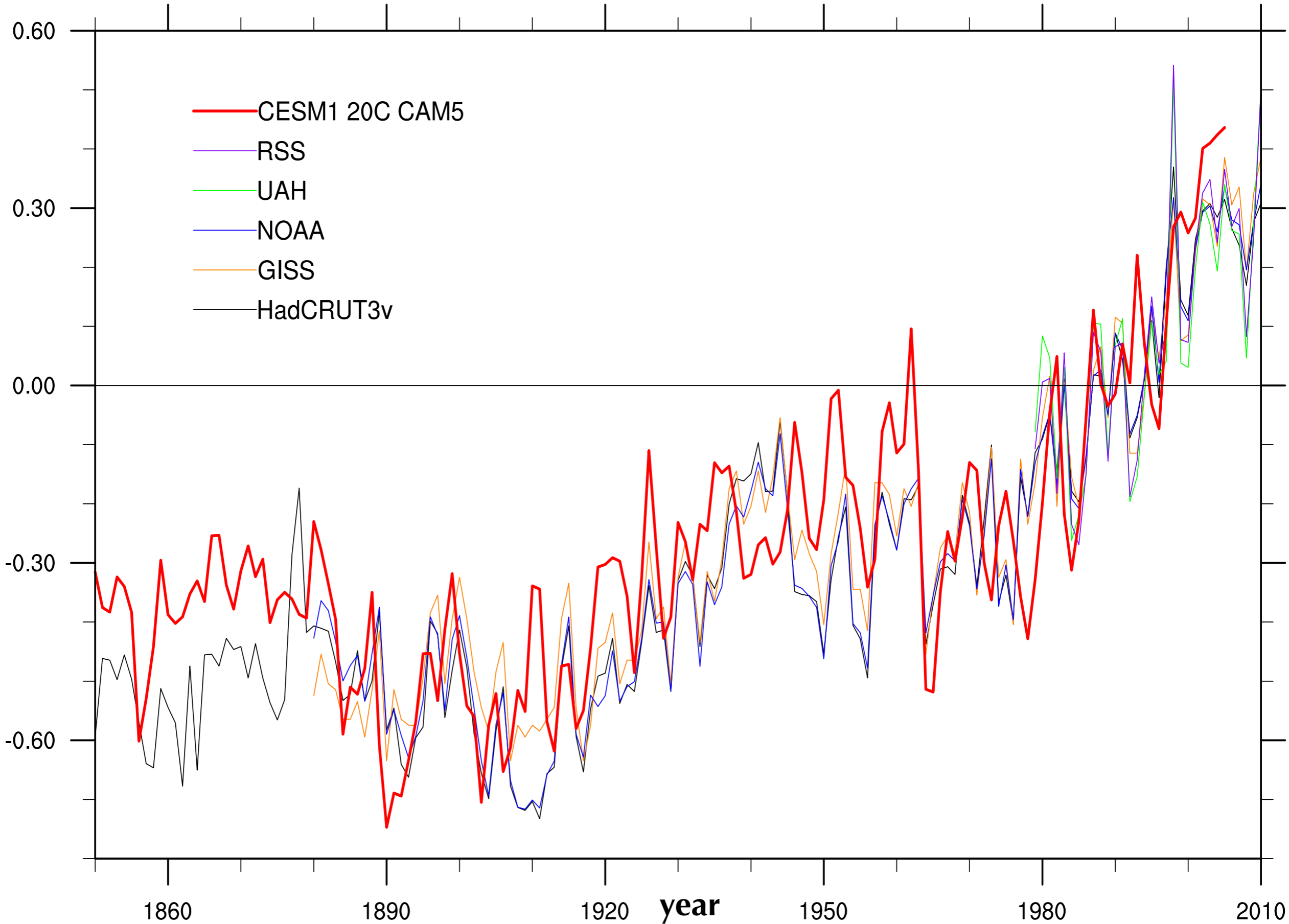| Land-Ice Component	Glimmer-CISM

New Wave Component	WW3 DWAV
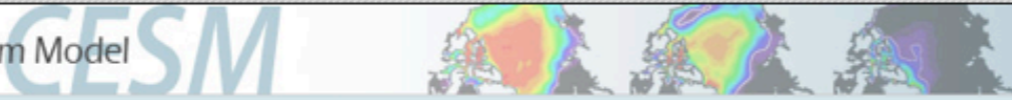
Coupler
Regridding, Merging, Calculation of ATM/OCN fluxes, conservation diagnostic

Replicates the past quite well!

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CESM infrastructure

Community Earth System Model **CESM**

CESM RUN DATABASE INTRAWEB

Select an experiment: -- select --   Add New Experiment   Manage Tables   -- search --   Go

Filter by: User	Status	Location	Machine	Resolution	Compset	Date Range	
--Select User--	--Select Status--	--Select Location--	--Select Machine--	--Select Resolution--	--Select Compset--	--Begin-- / --End--	Submit / Reset

Displaying experiments [1 - 25] out of 241

ID	Case Name	Type	Compset	Resolution	Machine	Request Date	Status	Assigned
248	a1.testing.add	CMIP5	B_1850-2000	f09_g16	copper	2011-07-15	Pending	Alice Bertini
249	a2.testing.add	CMIP5	H_PRESENT_DAY	f19_f19	hopper	2011-07-20	Pending	Chris Fischer
251	a3.testing.add	CMIP5	B_1850-2000	f09_g16	bluefire	2011-08-01	Running	Diane Feddema
265	a4.testing.add	CMIP5	H_PRESENT_DAY	f05_g16	jaguar	2011-08-13	Pending	Brian Eaton
267	a4.testing.clone	EXP	H_PRESENT_DAY	f05_g16	bluefire	2011-08-13	Running	Brian Eaton
26	B1850_TEST	EXP	B1850CN	f09_g16	bluefire	2011-03-01	Pending	Chris Fischer
226	b40.1850.2deg.tr1.waccm.001	EXP	B_WACCM_1850_TRACK1_CN	f19_g16	bluefire	2009-08-05	Paused	Chris Fischer
225	b40.1850.2deg.tr1.xlf11	EXP	B_1850_TRACK1_CN	f19_g16	bluefire	2009-08-07	Complete	Andrew Mai
224	b40.1850.2deg.tr1.xlf12	EXP	B_1850_TRACK1_CN	f19_g16	bluefire	2009-08-07	Complete	Andrew Mai
213	b40.1850.2deg.tr1.xlf12b	EXP	B_1850_TRACK1_CN	f19_g16	bluefire	2009-09-09	Complete	Andrew Mai
105	b40.1850.lgmco2.1deg.001	EXP	B1850CN	f09_g16	jaguar	2010-07-16	Pending	Nan Rosenbloom
116	b40.1850.lgmco2.track1.1deg.001	EXP	B_1850_CN	f09_g16	jaguar	2010-05-18	Stopped	Nan Rosenbloom
207	b40.1850.track1.009	EXP	B_1850_TRACK1_CN	f19_g16	bluefire	2009-10-14	Complete	Chris Fischer
227	b40.1850.track1.05deg.001	EXP	B_1850_TRACK1_CN	f05_g16	kraken	2009-07-29	Complete	Andrew Mai
216	b40.1850.track1.1deg.006	EXP	B_1850_TRACK1_CN	f09_g16	bluefire	2009-08-31	Complete	Andrew Mai
210	b40.1850.track1.1deg.006.ecosys	EXP	B_1850_TRACK1_CN	f09_g16	bluefire	2009-09-11	Complete	Keith Lindsay
38	b40.1850.track1.1deg.006a	EXP	B_1850_CN	f09_g16	bluefire	2010-12-29	Complete	Andrew Mai
4	b40.1850.track1.1deg.006b	EXP	B_1850_CN	f09_g16	bluefire	2011-03-17	Pending	Diane Feddema
215	b40.1850.track1.1deg.007	EXP	B_1850_TRACK1_CN	f09_g16	bluefire	2009-08-31	Complete	Andrew Mai
214	b40.1850.track1.1deg.008	EXP	B_1850_TRACK1_CN	f09_g16	bluefire	2009-09-08	Complete	Andrew Mai
212	b40.1850.track1.1deg.009	EXP	B_1850_TRACK1_CN	f09_g16	bluefire	2009-09-10	Complete	Andrew Mai
211	b40.1850.track1.1deg.010	EXP	B_1850_TRACK1_CN	f09_g16	bluefire	2009-09-10	Complete	Andrew Mai
203	b40.1850.track1.1deg.011	EXP	B_1850_TRACK1_CN	f09_g16	bluefire	2009-11-05	Complete	Andrew Mai
205	b40.1850.track1.2deg.001	EXP	B_1850_TRACK1_CN	f19_g16	bluefire	2009-10-22	Error	Diane Feddema
202	b40.1850.track1.2deg.002	EXP	B_1850_TRACK1_CN	f19_g16	bluefire	2009-11-05	Error	Diane Feddema

< View Prev 25 experiments   View 10, 25, or 50 experiments   View Next 25 experiments >

Questions or comments? email Alice Bertini or Gary Strand

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CESM infrastructure

t_experiments
- **id**
- ref_case_id
- case_name
- tag_name
- title
- description
- base_repo_tag
- compset_id
- ref_case_name
- request_date
- init_type
- requestor_id
- resolution_id
- scientific_id
- swLead_id
- expType_id
- queue
- current_year
- last_update
- charges_current
- charges_est
- throughput
- runscript_link
- case_dir
- run_length
- status_id
- runType_id
- historyFile
- yr_begin
- yr_end

t_exp_diag
- **diag_id**
- experiment_id

t_resolution
- **id**
- shortname
- longname

t_expType
- **id**
- tableName
- name
- description

t_cmip5
- **id**
- experiment_id
- CMIP5_id
- definition
- short_name
- ensembleNum
- ensembleSize

t_runType
- **id**
- name

t_diagnostics
- **id**
- experiment_id
- diagnostics_link
- description
- title
- status_id
- user_id
- plan

t_status
- **id**
- code
- description
- color

t_notes
- **id**
- note
- submitDate
- submitBy_id
- experiment_id
- status_id
- cat_id

t_compset
- **id**
- compset
- shortname
- components
- description

t_users
- **id**
- name
- email
- phone
- location_id

t_results
- **id**
- experiment_id
- description
- link
- user_id
- status_id
- cat_id

t_xml
- **id**
- mod
- experiment_id
- file_id

t_xml_file
- **id**
- filename

t_users_wg
- **user_id**
- wg_id

t_users_runStatus
- **user_id**
- experiment_id

t_hw_exp
- **hardware_id**
- experiment_id

t_category
- **id**
- name
- description

t_workingGroup
- **id**
- name
- lead_id

t_location
- **id**
- name
- description

t_hardware
- **id**
- name
- location_id

t_approvals
- **id**
- approver_id
- approvalDate
- experiment_id
- approvalRequestDate
- cat_id

Thursday, August 18, 2011

CMIP5/IPCC AR5

"The Intergovernmental Panel on Climate Change"

- 1990 - First Assessment Report
- 1995 - Second Assessment Report
- 2001 - Third Assessment Report
- 2007 - Fourth Assessment Report
- **2013 - Fifth Assessment Report**

CMIP5 experimental design

The second large-scale coordination of climate modeling efforts, data analysis, data management and data dissemination by the global climate modeling community: 20+ global coupled climate models from many modeling centers located around the world.
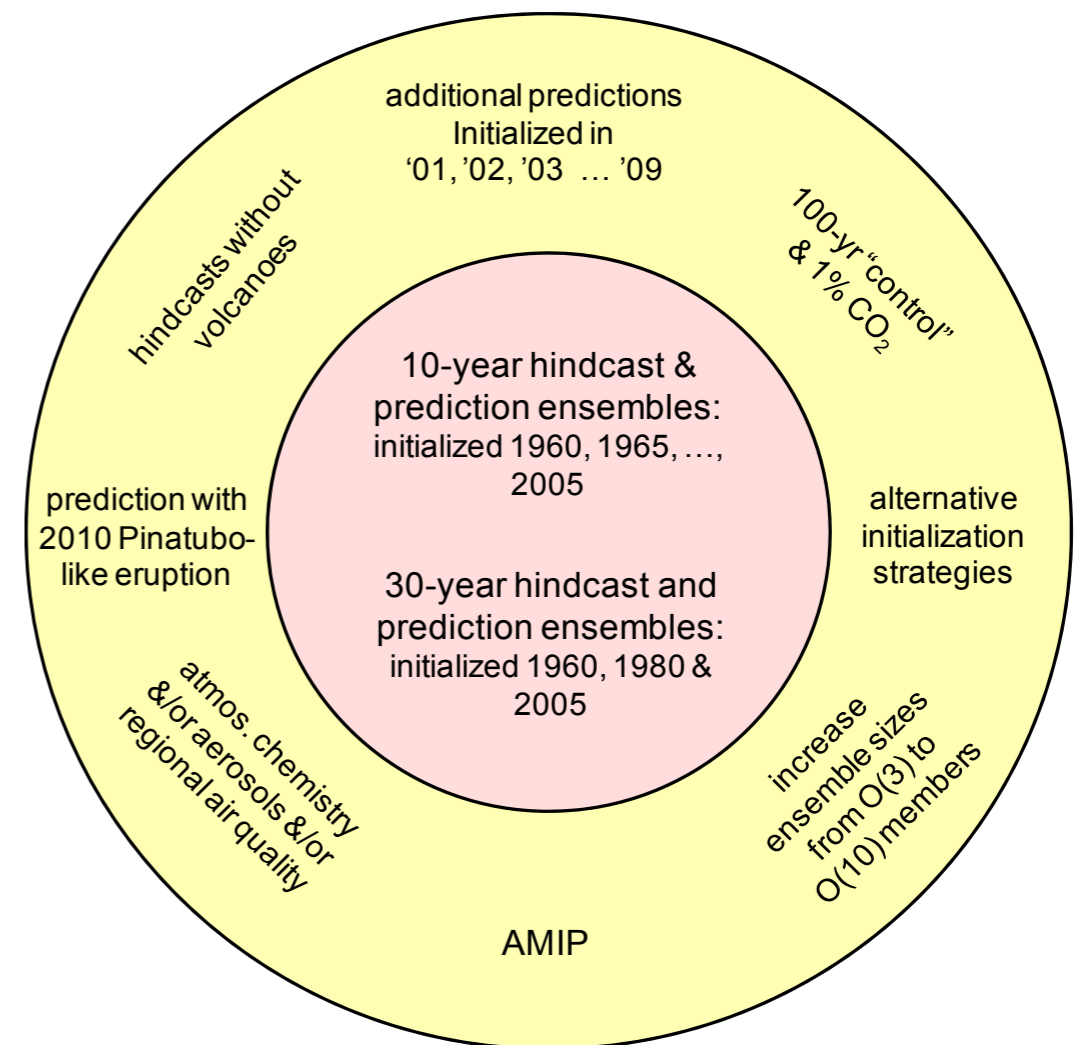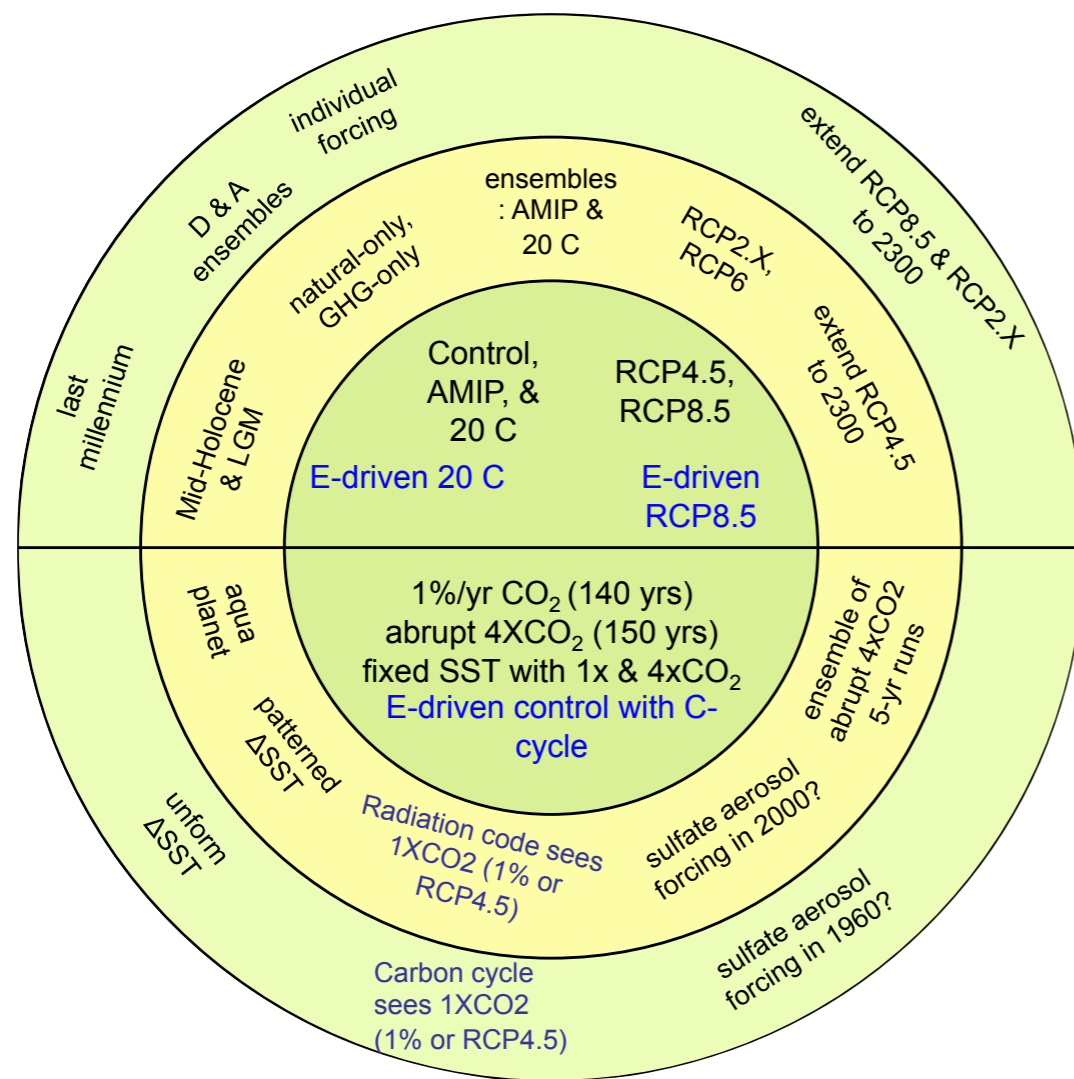
CESM CMIP5 simulations

| CMIP5 type	Description	#
piControl	pre-industrial control	3
1% CO2 increase	1 percent per year CO2	2
historical	Simulate 20th century climate and variations	20
historical variations	Single forcing runs, etc.	30
paleoclimate	Past climate (LGM, mid-Holocene, past 1000 years)	3
RCPs	RCPs 2.6, 4.5, 6.0, 8.5	34
Decadal predictions	Predictions (hindcast and forecast)	240
ESM	Earth System Model (BGC, carbon cycle, &c)	2
Other	Sensitivity and "idealized" Earths	6
Totals		**340**

# The NCAR CMIP5 model

"Community Earth System Model", version 1

- Fully-coupled global climate model
- Different resolutions and components, depending on experiment

	used for CMIP5		under development	
	2x1	**1x1**	**0.5x1**	**0.25x0.1**
atmosphere	144x96x26	288x192x26	576x384x32	1152x768x32
	(280 km x 200 km)	(140 km x 100 km)	(70 km x 50 km)	(35 km x 25 km)
land surface	144x96x15	288x192x15	576x384x15	1152x768x15
ocean	384x320x60	384x320x60	384x320x60	3600x2400x60
sea ice	384x320	384x320	384x320	3600x2400

CESM resolutions

FV 2°   FV 1°   FV ½°   FV ¼°
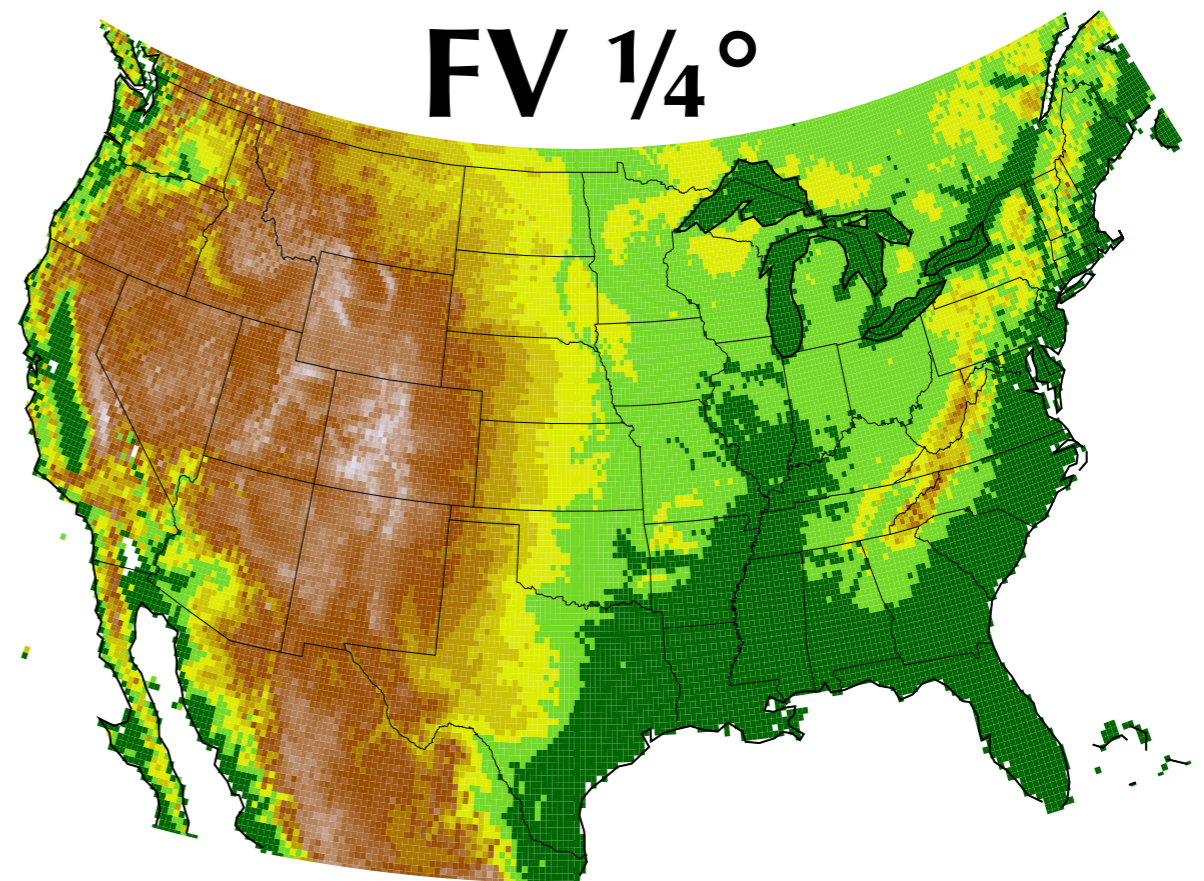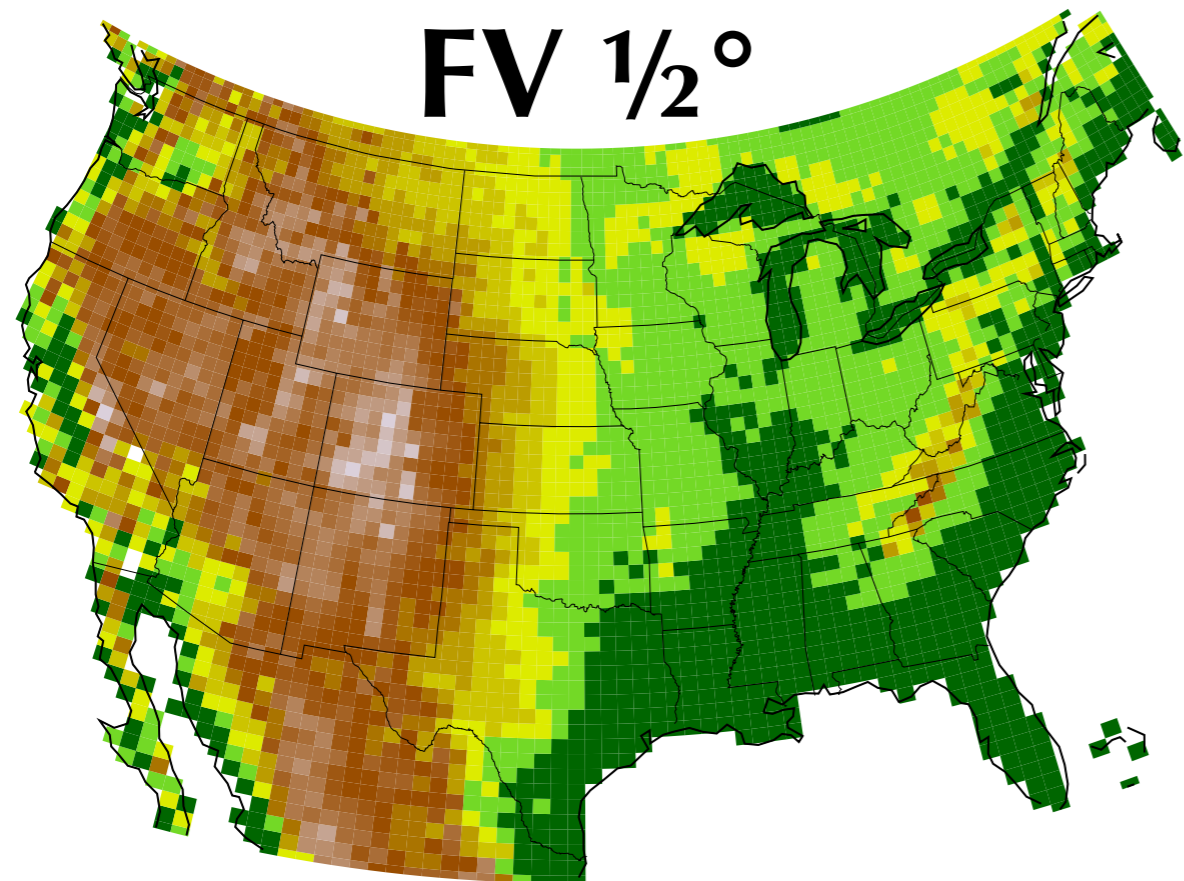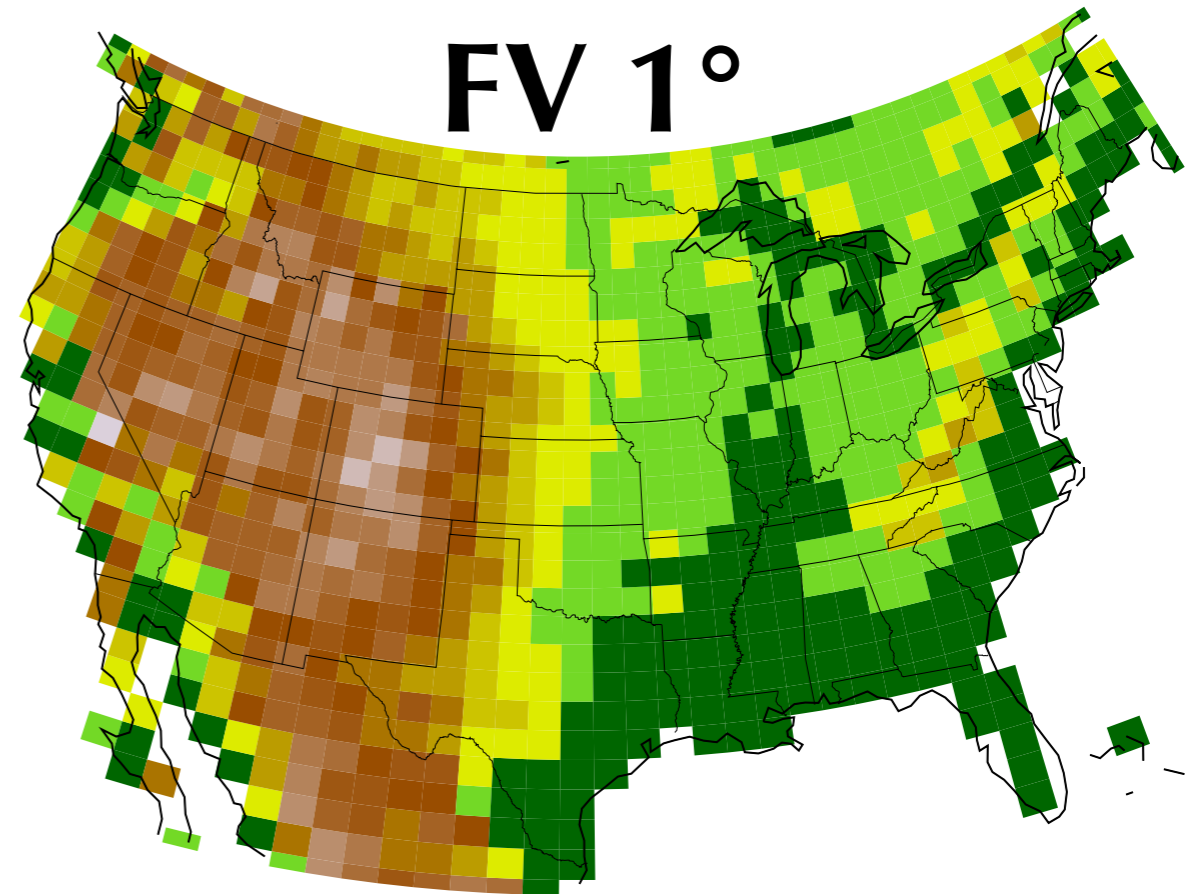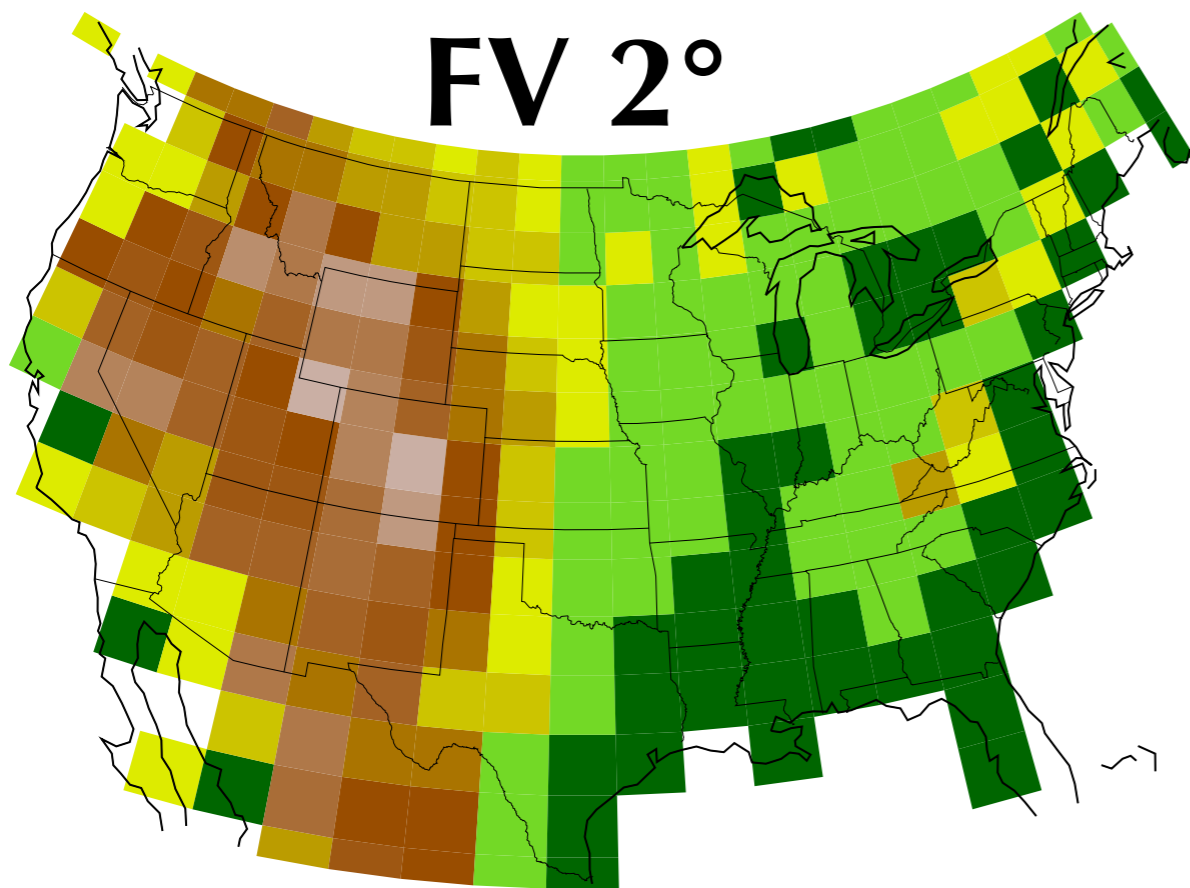
CESM output data arrangement
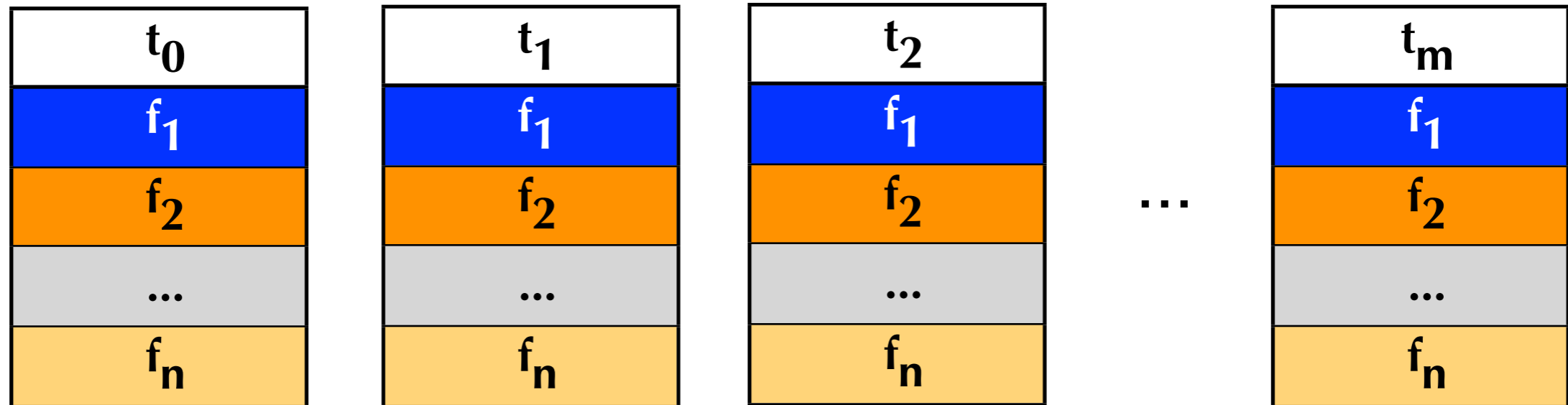
CMIP5 arrangement
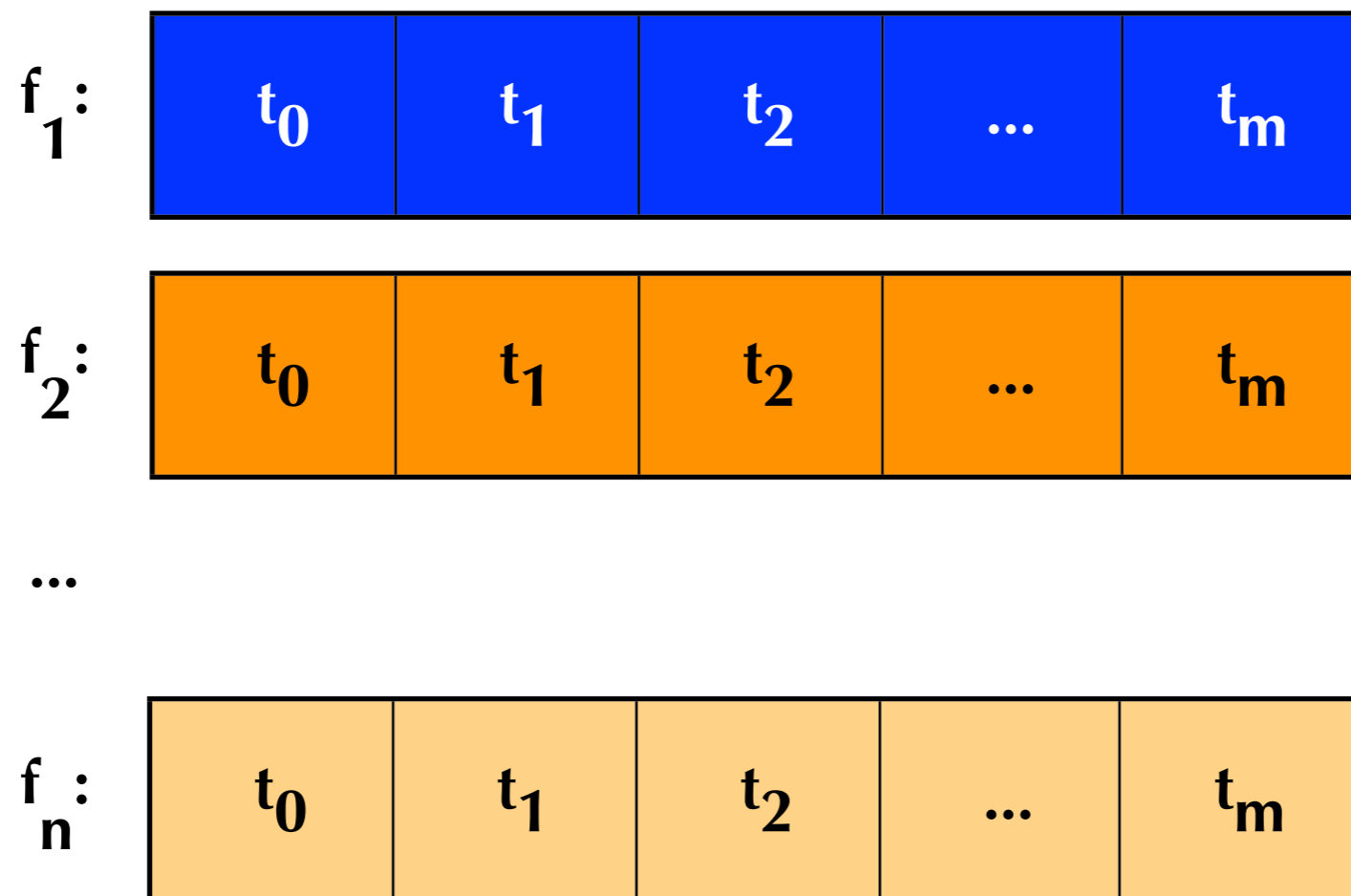
CMIP5 variable counts

	subdaily	daily	monthly	annual	totals
atmosphere	100	75	223	8	**406**
land surface	3	5	82	0	**90**
ocean	1	3	127	79	**210**
sea ice	0	4	40	0	**44**
totals	**104**	**87**	**472**	**87**	**750**

Archived CESM model data volume

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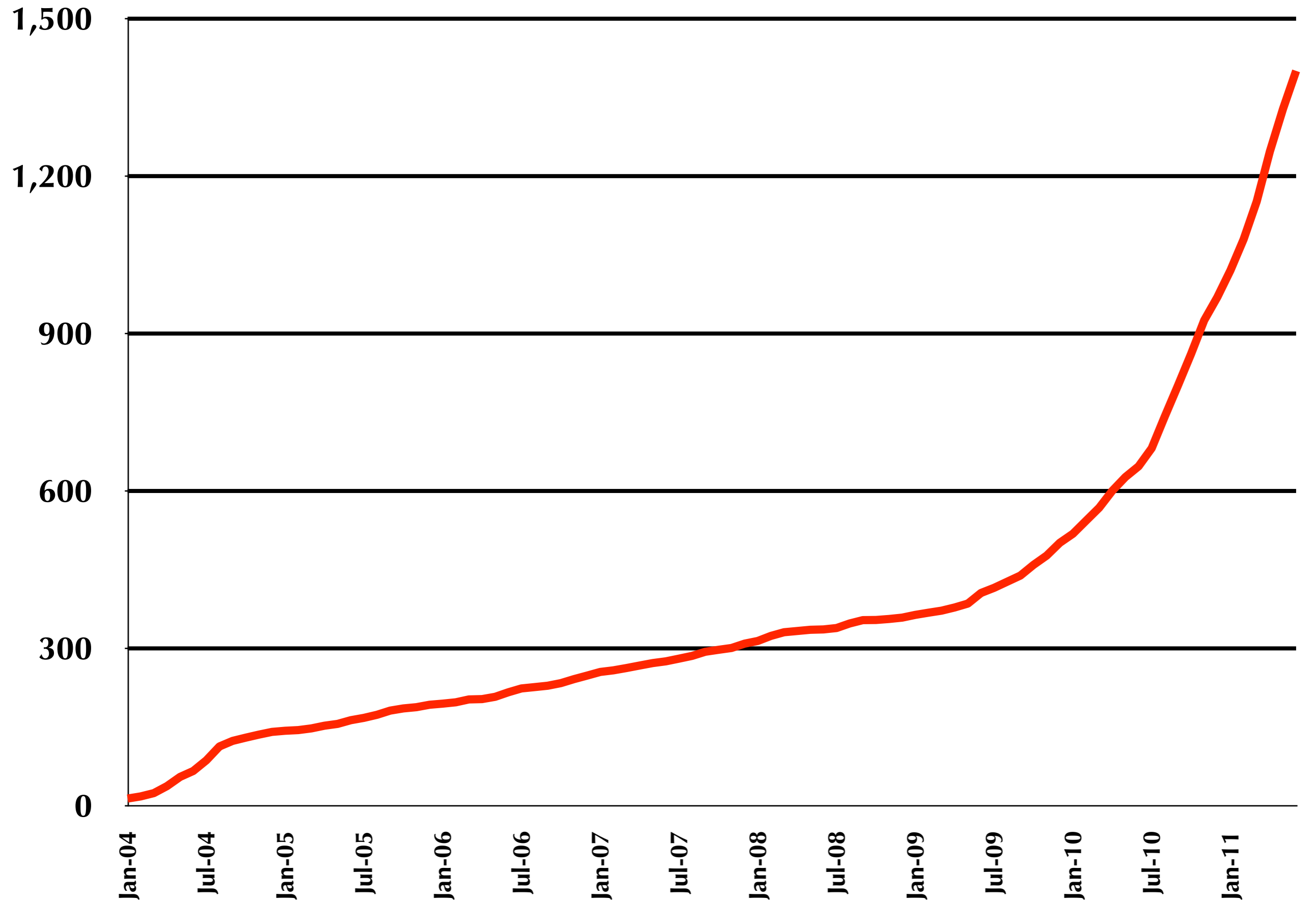
CMIP5 data requirements

Rather detailed (167 page PDF), including:

- Specific model fields, unchanged as well as derived
- From atmosphere, land surface, ocean and sea ice, aerosols, cloud feedbacks, and more
- Monthly averages, daily and sub-daily, annual averages, climatologies
- Single model field per netCDF-3 file, all time samples
- File sizes must be ~2-5 GB (as practical)
- Considerable amount of metadata required
- Defined horizontal and vertical resolutions
- Stringent data and metadata conventions, CF-compliant

Metadata requirements

Standard model output for specific variable

```
float TS(time, lat, lon) ;
        TS:units = "K" ;
        TS:long_name = "Surface temperature (radiative)" ;
        TS:cell_method = "time: mean" ;
```

As required by CMIP5

```
float ts(time, lat, lon) ;
        ts:standard_name = "surface_temperature" ;
        ts:long_name = "Surface Temperature" ;
        ts:comment = "\"\"skin\"\" temperature (i.e., SST for open ocean)" ;
        ts:units = "K" ;
        ts:original_name = "TS" ;
        ts:cell_methods = "time: mean (interval: 30 days)" ;
        ts:cell_measures = "area: areacella" ;
        ts:history = "2011-07-22T00:05:32Z altered by CMOR: replaced missing value
flag (-1e+32) with standard missing value (1e+20)." ;
        ts:missing_value = 1.e+20f ;
        ts:_FillValue = 1.e+20f ;
        ts:associated_files = "baseURL: http://cmip-pcmdi.llnl.gov/CMIP5/dataLocation
gridspecFile: gridspec_atmos_fx_CCSM4_historical_r0i0p0.nc areacella:
areacella_fx_CCSM4_historical_r0i0p0.nc" ;
```

Metadata requirements

Standard model global attributes

```
:Conventions = "CF-1.0" ;
:source = "CAM" ;
:case = "b40.20th.track1.1deg.006" ;
:title = "UNSET" ;
:logname = "mai" ;
:host = "be0809en.ucar.ed" ;
:Version = "$Name$" ;
:revision_Id = "$Id$" ;
:initial_file = "b40.1850.track1.1deg.006.cam2.i.0893-01-01-00000.nc" ;
:topography_file = "/fis/cgd/cseg/csm/inputdata/atm/cam/topo/USGS-gtopo30_0.9x1.25_remap_c051027.nc" ;
:nco_openmp_thread_number = 1 ;
```

As required by CMIP5

Metadata requirements
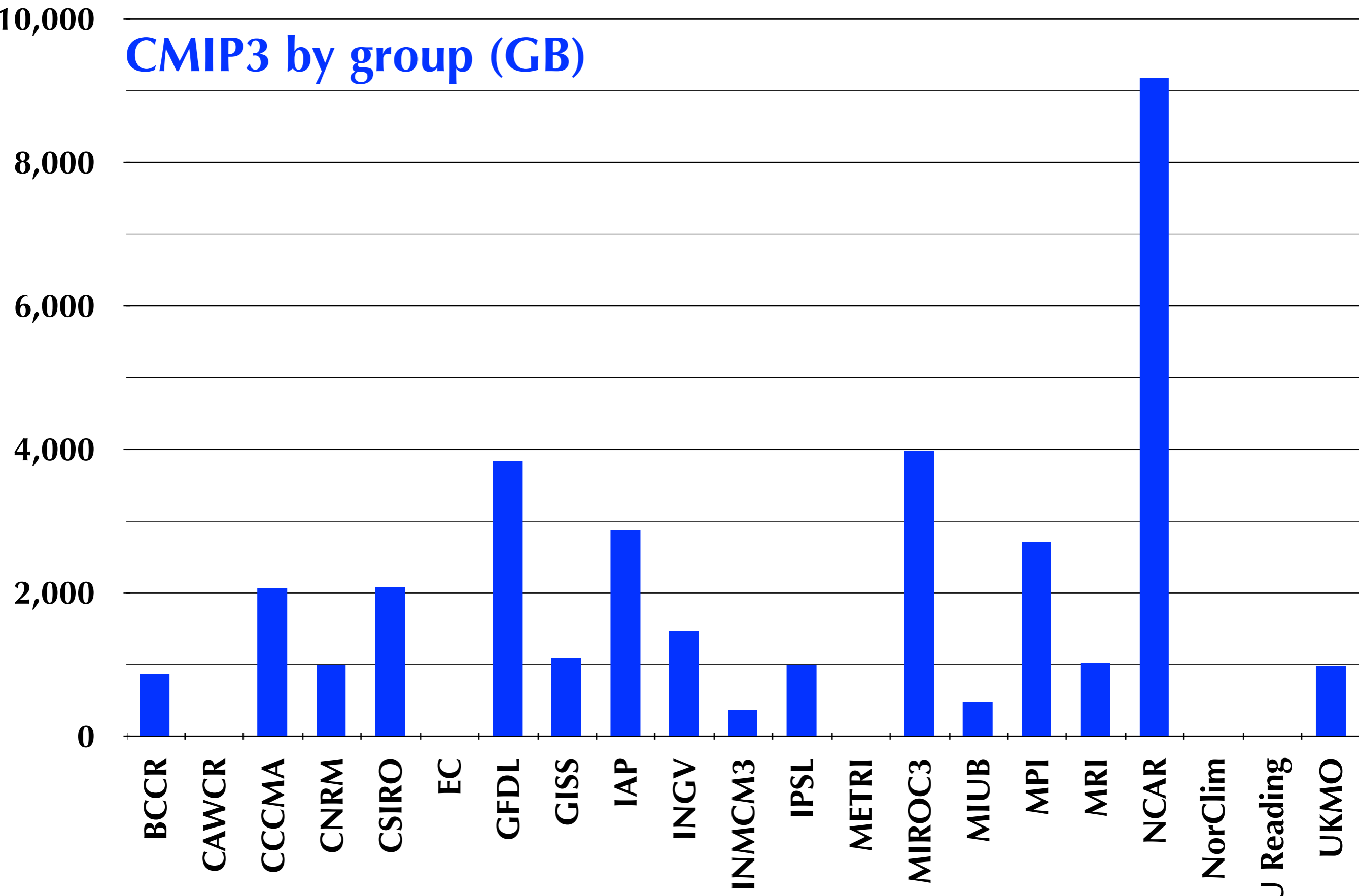
Standard model global attributes

```
:Conventions = "CF-1.0" ;
:source = "CAM" ;
:case = "b40.20th.track1.1deg.006" ;
:title = "UNSET" ;
:logname = "mai" ;
:host = "be0809en.ucar.ed" ;
:Version = "$Name$" ;
:revision_Id = "$Id$" ;
:initial_file = "b40.1850.track1.1deg.006.cam2.i.0893-01-01-00000.nc" ;
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:nco_openmp_thread_number = 1 ;
```
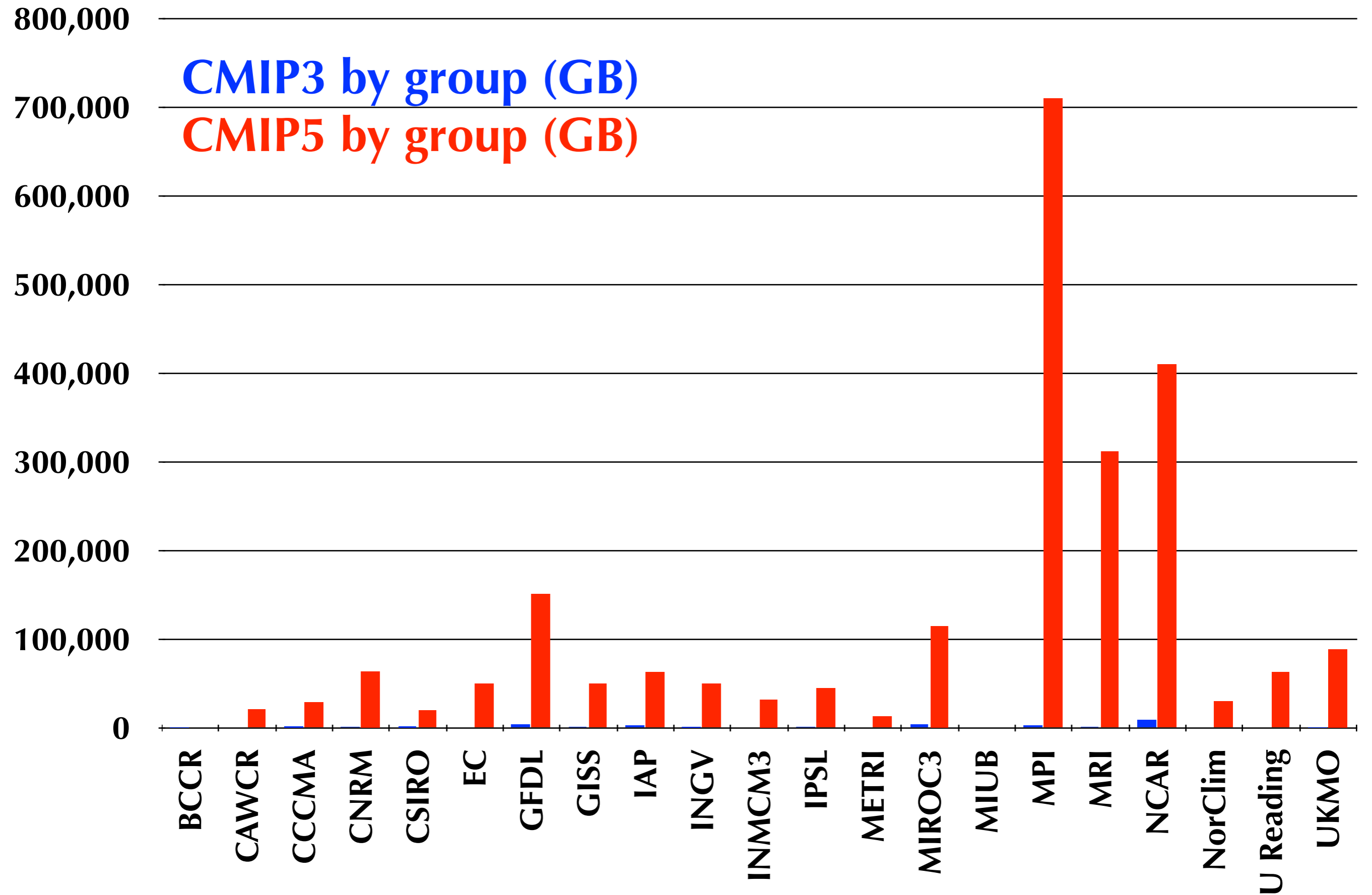
As required by CMIP5

```
:institution = "NCAR (National Center for Atmospheric Research) Boulder, CO, USA" ;
:institute_id = "NCAR" ;
:experiment_id = "historical" ;
:source = "CCSM4 (repository tag: ccsm4_0_beta43 compset: B20TRCN)" ;
:model_id = "CCSM4" ;
:forcing = "Sl GHG Vl SS Ds SD BC MD OC Oz AA LU" ;
:parent_experiment_id = "piControl" ;
:parent_experiment_rip = "r1i1p1" ;
:branch_time = 937. ;
:contact = "cesm_data@ucar.edu" ;
:references = "Gent P. R., et.al. 2011: The Community Climate System Model version 4. J. Climate, doi: 10.1175/2011JCLI4083.1" ;
:initialization_method = 1 ;
:physics_version = 1 ;
:tracking_id = "d33ccf77-a73c-4f55-8f02-3a0734d51151" ;
:acknowledgements = "The CESM project is supported by the National Science Foundation and the Office of Science (BER) of the U.S. Department of Energy.\n",
        "NCAR is sponsored by the National Science Foundation.\n",
        "Computing resources were provided by the Climate Simulation Laboratory at the NCAR Computational and Information Systems Laboratory (CISL),\n",
        "sponsored by the National Science Foundation and other agencies." ;
:resolution = "f09_g16 (0.9x1.25_gx1v6)" ;
:forcing_note = "Additional information on the external forcings used in this experiment can be found at\n",
        "http://www.cesm.ucar.edu/CMIP5/forcing_information" ;
:product = "output" ;
:experiment = "historical" ;
:frequency = "mon" ;
:creation_date = "2011-07-22T00:05:32Z" ;
:history = "2011-07-22T00:05:32Z CMOR rewrote data to comply with CF standards and CMIP5 requirements." ;
:Conventions = "CF-1.4" ;
:project_id = "CMIP5" ;
:table_id = "Table Amon (27 April 2011) a5a1c518f52ae340313ba0aada03f862" ;
:title = "CCSM4 model output prepared for CMIP5 historical" ;
:parent_experiment = "pre-industrial control" ;
:modeling_realm = "atmos" ;
:realization = 1 ;
:cmor_version = "2.7.1" ;
```

Data volumes by group

CMIP3 by group (GB)

Y-axis: 0, 2,000, 4,000, 6,000, 8,000, 10,000

X-axis categories: BCCR, CAWCR, CCCMA, CNRM, CSIRO, EC, GFDL, GISS, IAP, INGV, INMCM3, IPSL, METRI, MIROC3, MIUB, MPI, MRI, NCAR, NorClim, U Reading, UKMO

Thursday, August 18, 2011

Data volumes by group

CMIP3 by group (GB)
CMIP5 by group (GB)

Thursday, August 18, 2011

All over the globe...
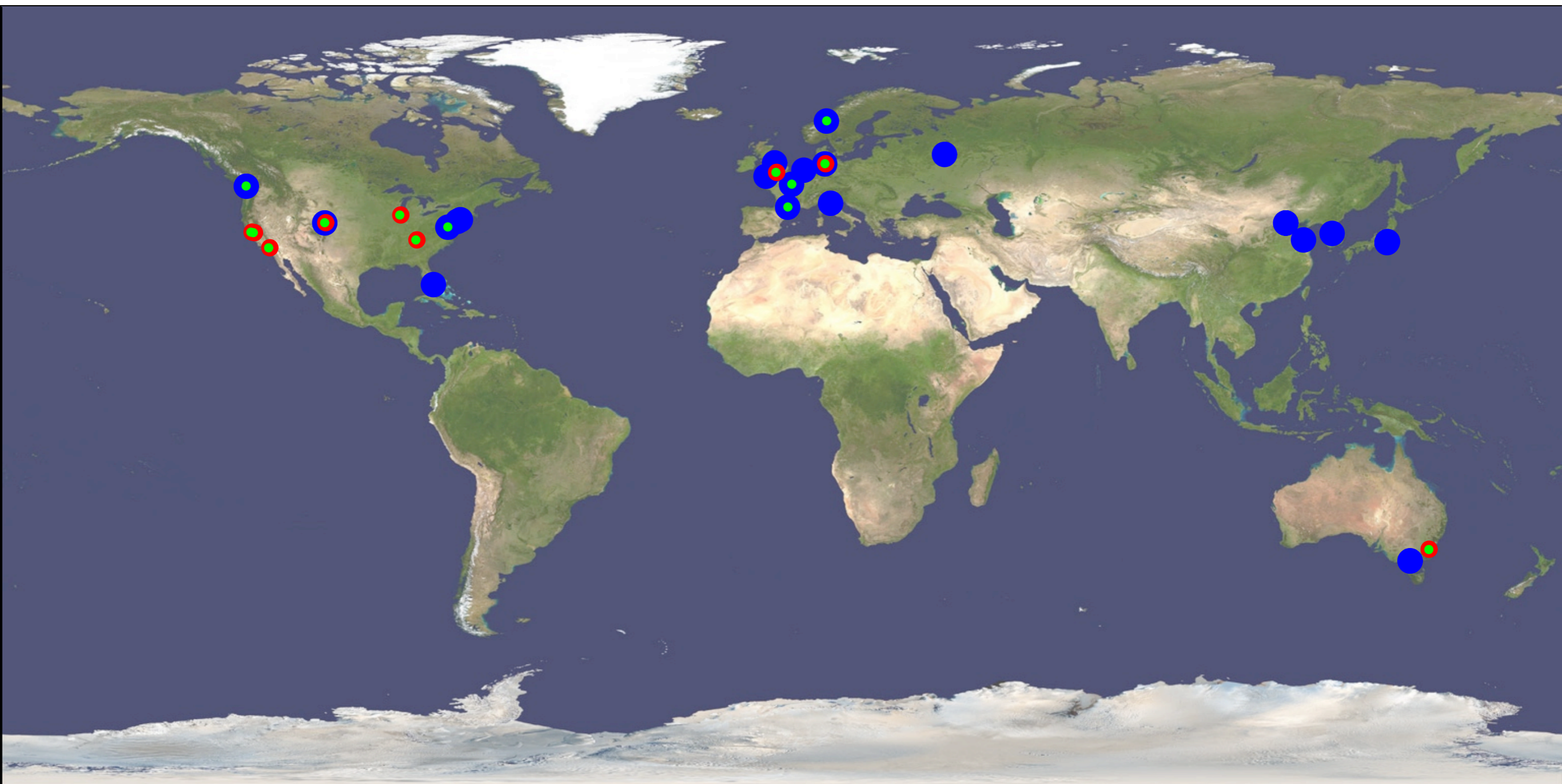
Modeling centers (24)

Gateways (9)

Nodes (14)

Thursday, August 18, 2011

The ESG federation

METAFOR

Data QC

Data Published > 10 PB
Data and **Metadata QC L1**

On globally distributed data nodes

Replicated:
Copied to PCMDI, BADC, WDCC & elsewhere ~ 1PB

Metadata QC L2 passed?

Data QC L2 passed?

To be replicated among ESGF?

Data QC L3 passed?

YES → YES → YES

NO

NO

NO

YES

Discard data

Data NOT formally citable *Modelling group control access manually.*

Data NOT formally citable Automatic access granted after filling in ESGF registration page.

DOI Assigned: Data formally citable Data can appear in IPCC-DDC

Automatic access granted after filling in ESGF registration page

(Informal citation still requested where formal citation not available)

Data QC

	QC Level 1	QC Level 2	QC Level 2
Description	CMOR2 and ESG publisher conformance checks	Data consistency checks	Double- and cross-checks of data and metadata and data publication as DataCite DOI
Data	preliminary; no user notification about changes; performed for all data; metadata may not be complete	no user notification about changes; performed for CMIP5 requested metadata and data	published and persistent data with version and unique DOI as persistent identifier; user notification about changes; performed for replicated data
Access	constrained to CMIP5 modeling centers	constrained to non-commercial research and educational purposes	constrained to non-commercial research and educational purposes, or open for unrestricted use (as specified by the modeling centers)
Access Control	PCMDI on behalf of WMO/WGCM	PCMDI, BADC, WDCC/DKRZ core data archives on behalf of WMO/WGCM	IPCC-DDC on behalf of TGICA
Citation	no citation reference	informal citation reference	formal citation reference
Quality Flag	"automated conformance checks passed"	"subjective quality control passed"	"approved by author" (in case of newer DOI available: "approved by author, but suspended")

Thursday, August 18, 2011

Some useful URLs

CESM

`http://www.cesm.ucar.edu`

CMIP5

`http://cmip.llnl.gov/cmip5`