NetCDF,
NCAR's climate model data,
and the IPCC

Gary Strand
NCAR/NESL/CGD

NCAR's climate model data

A bit of history...

1960s - 1990s

Self-designed self-implemented binary formats

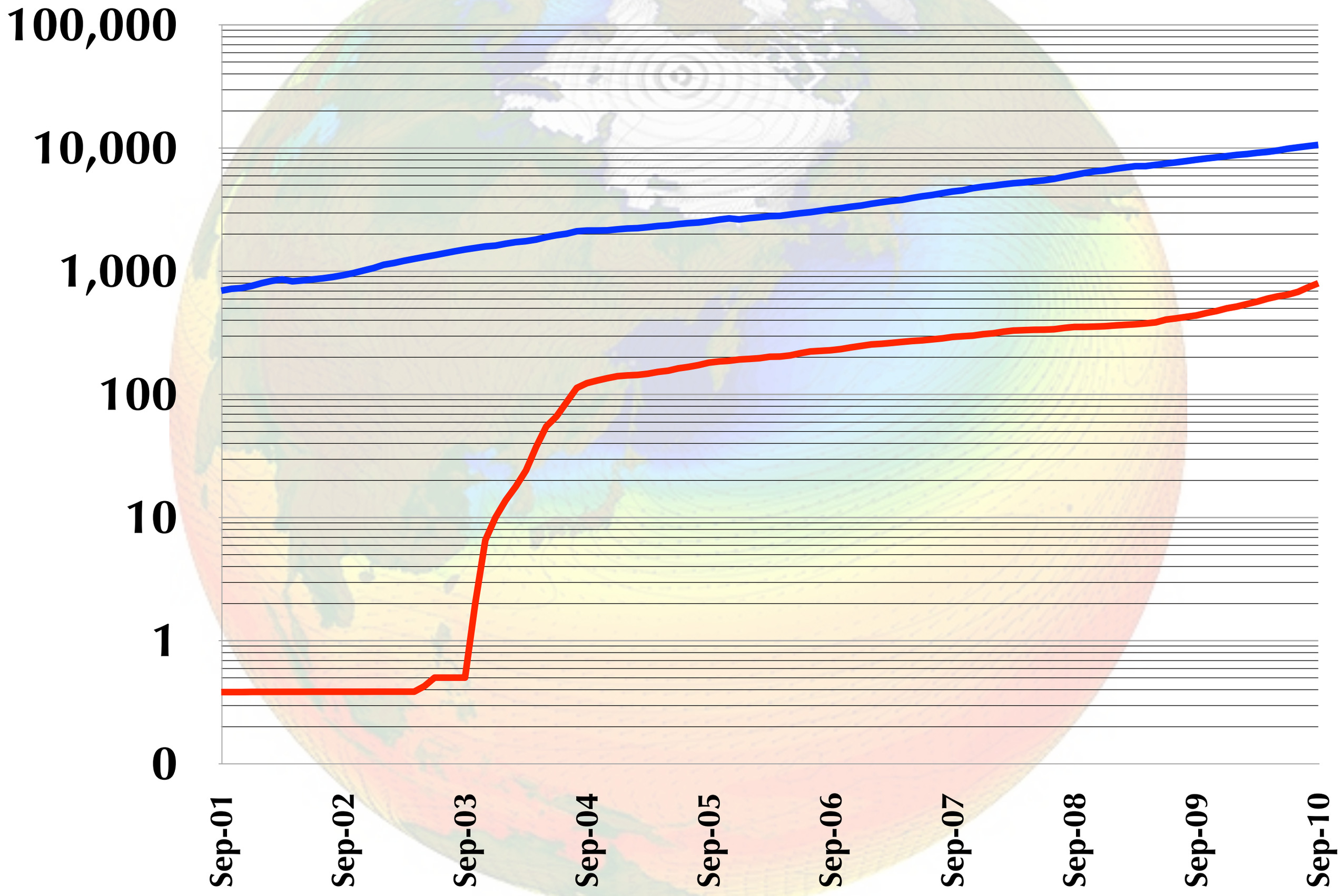
1990s-2000s

netCDF-3 for model output, some input

today

all netCDF, all the time

Total MSS and /CCSM volume (TB)



What is the IPCC?

The Intergovernmental Panel on Climate Change

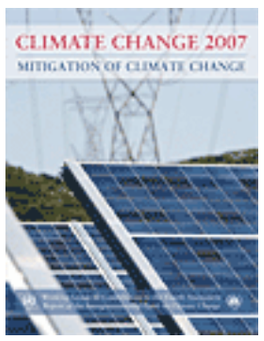
- 1990 - First Assessment Report
- 1995 - Second Assessment Report
- 2001 - Third Assessment Report
- 2007 - Fourth Assessment Report
- **2013 - Fifth Assessment Report**

What was the IPCC AR4?

"The 4th Assessment Report of the Intergovernmental Panel on Climate Change"

Working Group I Report:
"The Physical Science Basis"

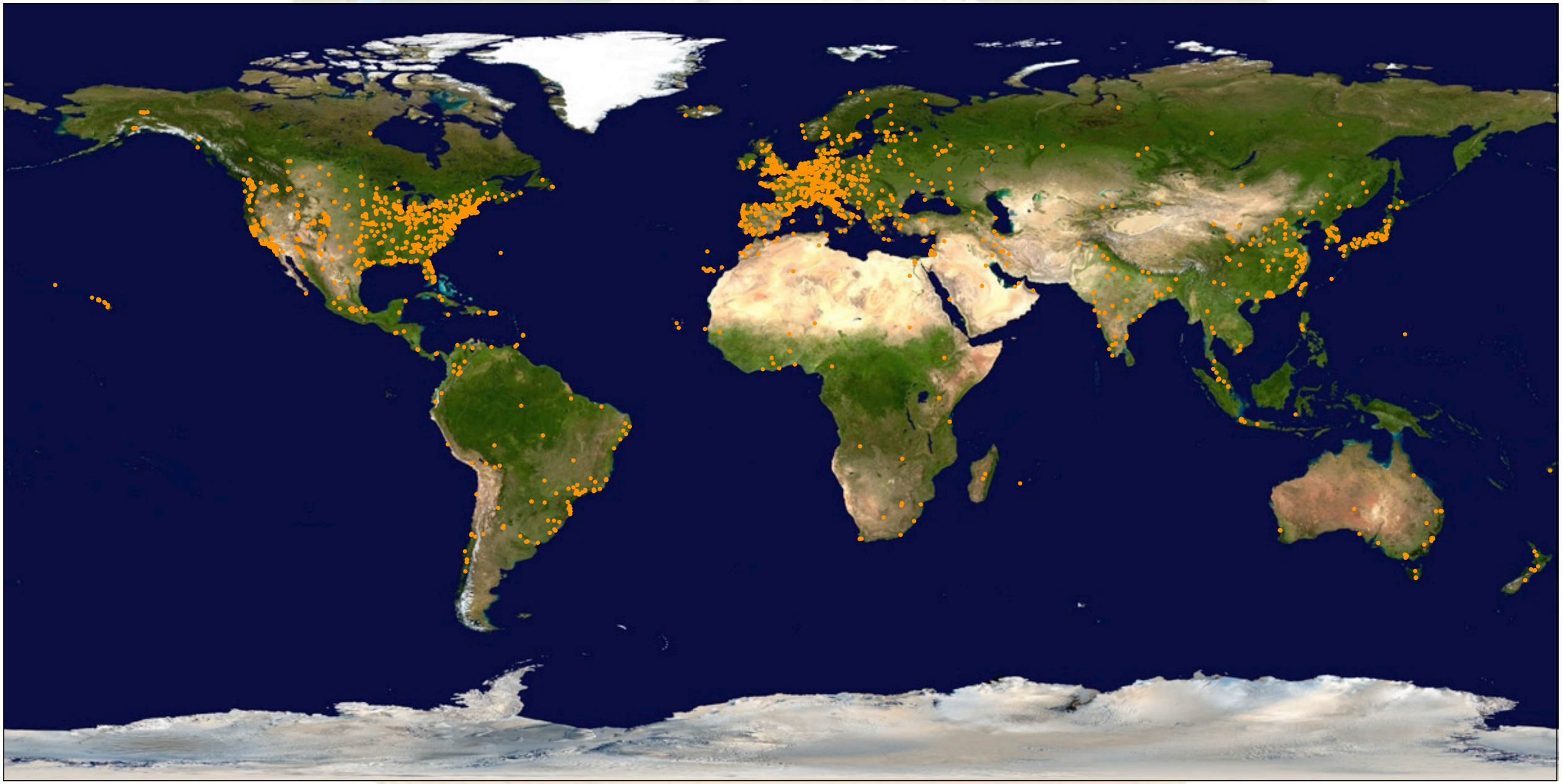
Working Group II Report:
"Impacts, Adaptation and Vulnerability"



Working Group III Report:
"Mitigation of Climate Change"

What was the IPCC AR4?

Distribution of users



~4,000 users, 130+ countries

What was the IPCC AR4?

The first large-scale coordination of climate modeling efforts, data analysis, data management and data dissemination by the global climate modeling community: 24 global coupled climate models from 16 modeling centers located around the world.

Types	Purpose	kinds	runs
"Control"	Assess model internal variability	2	3
CO2 increase	Determine climate sensitivity	2	4
20C3M	Simulate 20th century climate	1	14
SRES	Future scenarios (A1B, B1, A2, "commitment")	4	36
Other	Sensitivity and "idealized" Earths	3	6
Totals		**12**	**63**

Unprecedented in scale and scope

IPCC AR4 data requirements

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

IPCC AR4 data requirements

Metadata examples

From model output:

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

Required for IPCC AR4:

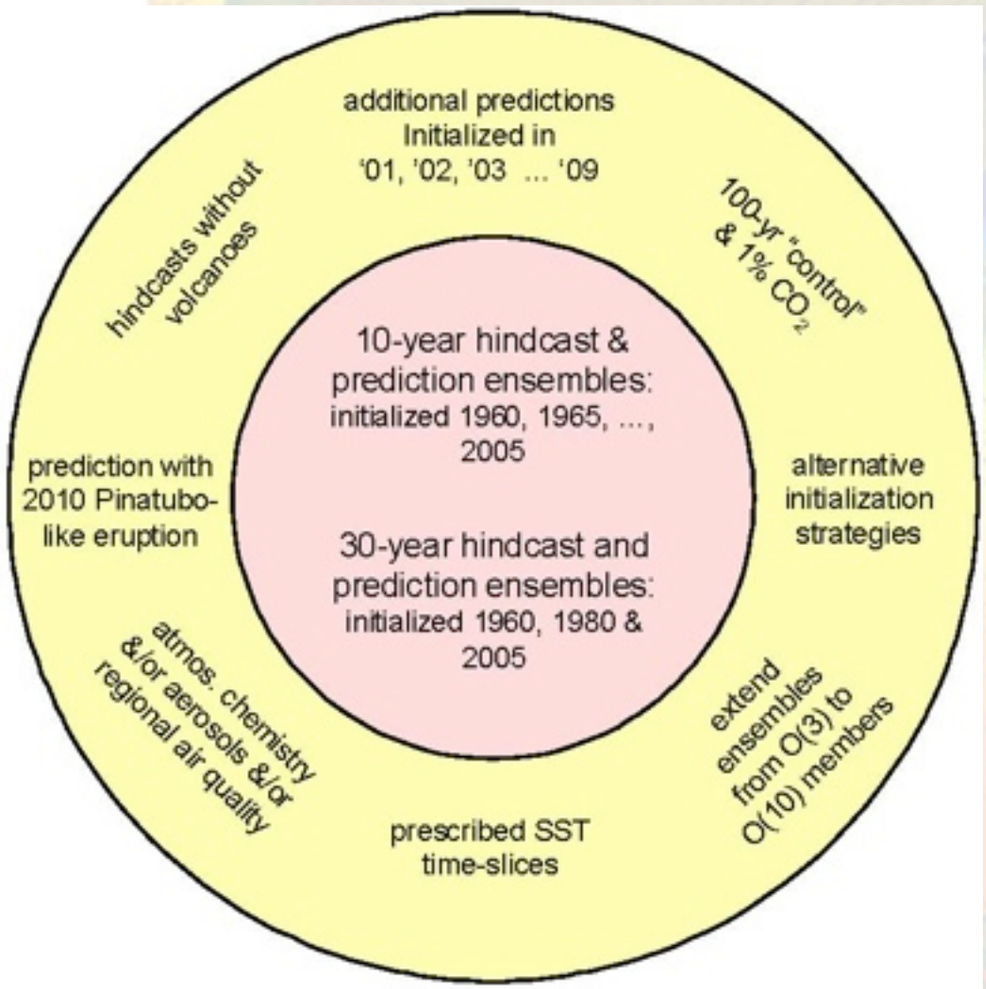
```
[...]
        float tas(time, lat, lon) ;
                tas:comment = "Created using NCL code CCSM_atmm_2cf.ncl on\n",
                        " machine mineral.cgd.ucar.edu" ;
                tas:missing_value = 1.e+20f ;
                tas:_FillValue = 1.e+20f ;
                tas:cell_methods = "time: mean (interval: 1 month)" ;
                tas:history = "Added height coordinate" ;
                tas:coordinates = "height" ;
                tas:original_units = "K" ;
                tas:original_name = "TREFHT" ;
                tas:standard_name = "air_temperature" ;
                tas:units = "K" ;
                tas:long_name = "air_temperature" ;
[...]
```

What is the IPCC AR5?

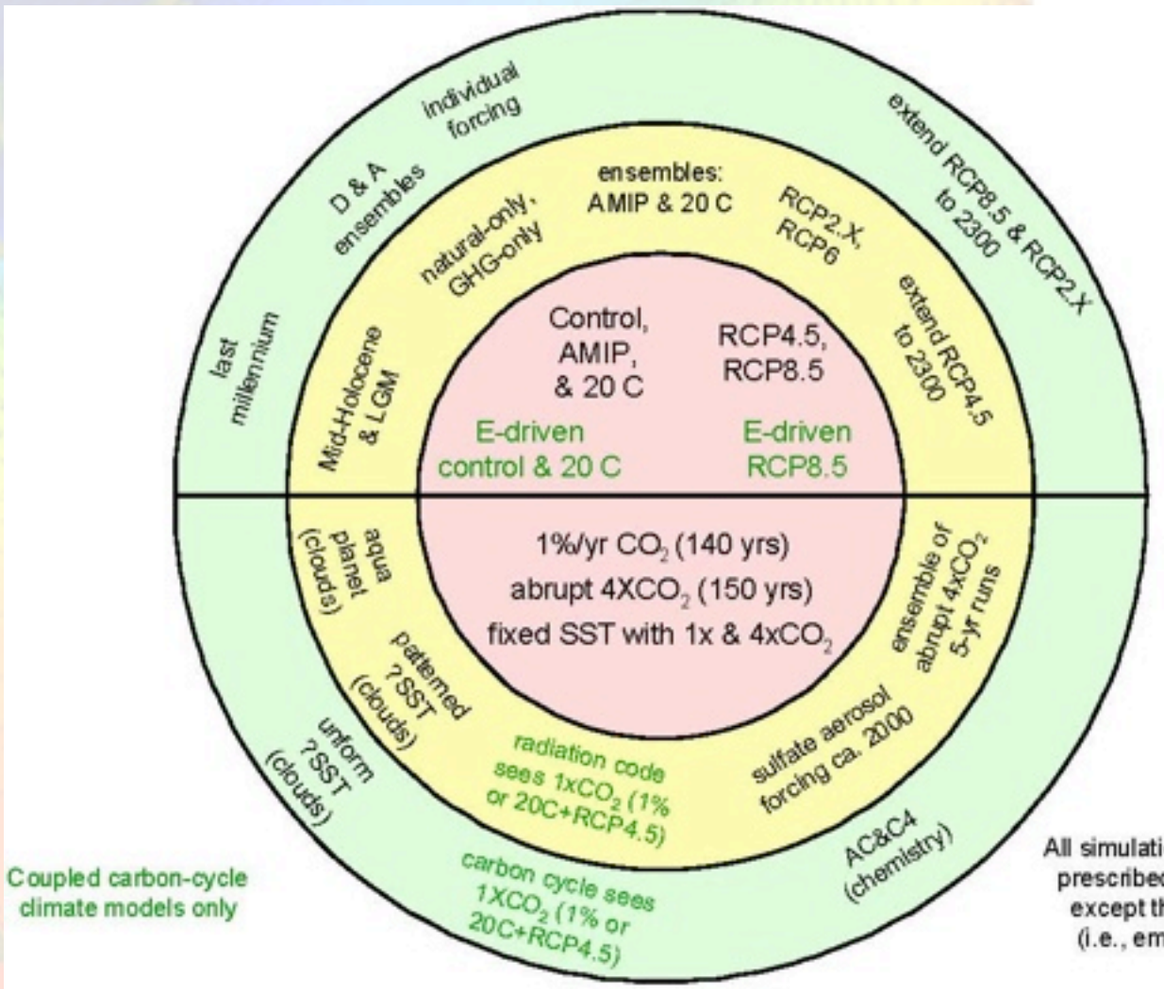
"The 5th Assessment Report of the Intergovernmental Panel on Climate Change"

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 15+ modeling centers located around the world

Many more experiments than AR4:



Decadal Prediction Experiments



Long Term Experiments

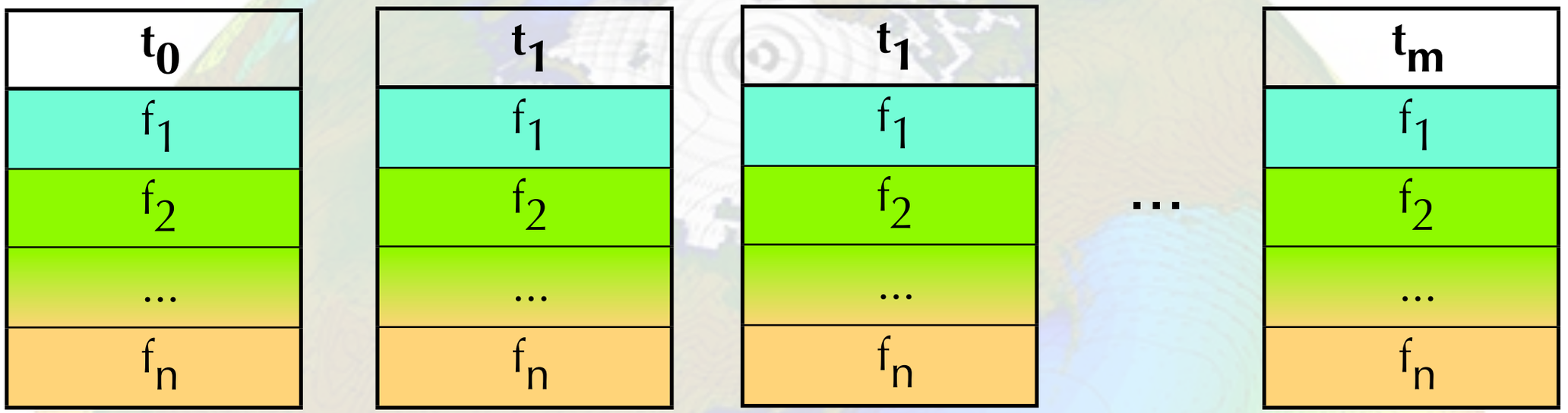
The NCAR CMIP5 model

CCSM4/CESM1

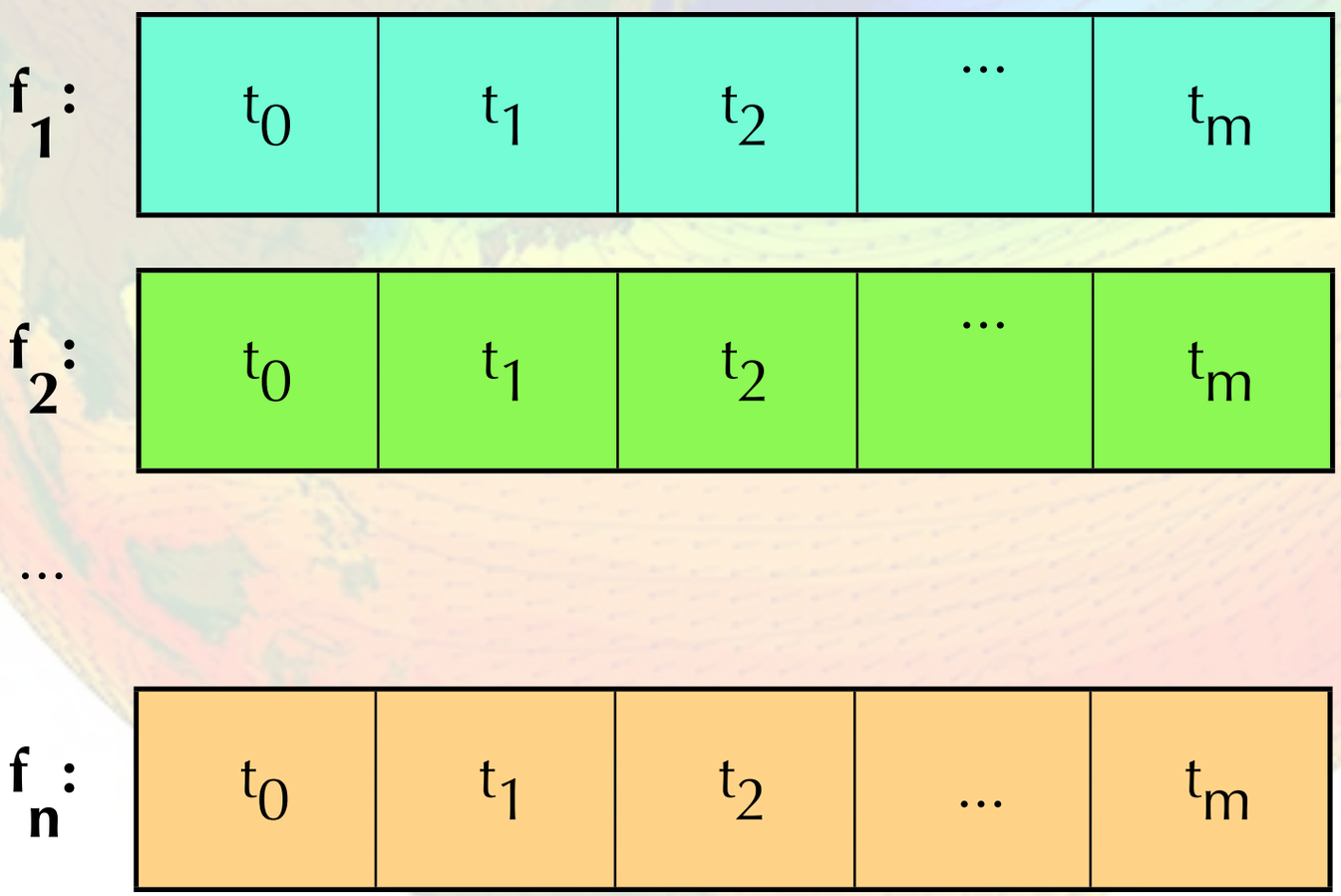
- Fully-coupled global climate model
- Different resolutions and components, depending on experiment

	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 output data arrangement



CMIPn arrangement



IPCC data AR5 requirements

- 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

What is the IPCC AR5?

Types	Purpose	kinds	runs
"Control"	Assess model internal variability	1	3
CO2 increase	Determine climate sensitivity	1	2
20C3M	Simulate 20th century climate and variations	9	45
RCPs	Future scenarios (2.6, 4.5, 6, 8.5)	4	28
Paleo	Past climate (LGM, mid-Holocene, past 1000 years)	3	3
Decadal	Predictions (hindcast and forecast)	30	150
ESM	Earth System Model (BGC, carbon cycle, &c)	5	24
Other	Sensitivity and "idealized" Earths	19	30
Totals		**72**	**285**

Unprecedented in scale and scope

What is the IPCC AR5?

Much more data than AR4:

	subdaily		daily		monthly		annual		**totals**	
	AR4	**AR5**	**AR4**	**AR5**	**AR4**	**AR5**	**AR4**	**AR5**	**AR4**	**AR5**
atmosphere	9	100	18	75	47	223	0	8	**74**	**406**
land surface	0	3	0	5	9	82	0	0	**9**	**90**
ocean	0	1	0	3	12	127	0	79	**12**	**210**
sea ice	0	0	0	4	4	40	0	0	**4**	**44**
totals	**9**	**104**	**18**	**87**	**72**	**472**	**0**	**87**	**99**	**750**

Really much more data!

Modeling group		AR4 volume (GB)
NCAR	USA	9,172.8
MIROC3	Japan	3,974.9
GFDL	USA	3,842.5
IAP	China	2,867.7
MPI	Germany	2,699.5
CSIRO	Australia	2,088.2
CCCMA	Canada	2,070.6
INGV	Italy	1,472.2
GISS	USA	1,096.8
MRI	Japan	1,024.5
CNRM	France	999.1
IPSL	France	997.7
UKMO	UK	972.8
BCCR	Norway	861.9
MIUB	Germany/Korea	477.2
INMCM3	Russia	368.2
Totals		**34,986.6**

Modeling group		AR5 volume (GB)
MPI	Germany	710,000
NCAR	USA	410,000
MRI	Japan	312,000
GFDL	USA	151,000
MIROC3	Japan	115,000
UKMO	UK	89,000
CNRM	France	64,000
IAP	China	63,000
U Reading	UK	63,000
EC	Europe	50,000
GISS	USA	50,000
INGV	Italy	50,000
IPSL	France	45,000
INMCM3	Russia	32,000
NorClim	Norway	30,000
CCCMA	Canada	29,000
CAWCR	Australia	21,000
CSIRO	Australia	20,000
METRI	Korea	13,000
Totals		**2,317,000**

The lessons from CMIPs

- Know your data - very well!
- Exploit the pre-existing standards for your data **AND** metadata!
- Metadata - the more, the better
- Make the lives of those who use your data easier - and that will make your life easier too

Some useful references

CMIP5 website:
http://cmip.llnl.gov

NetCDF Climate and Forecast (CF) Metadata Convention:
http://cf-pcmdi.llnl.gov

NetCDF Operators (NCO):
http://nco.sourceforge.net

Climate Data Operators (CDO):
http://www.mpimet.mpg.de/fileadmin/software/cdo