Big Data from CESM

Past, Present and the near Future

SEA Conference 2016

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(with the much-appreciated assistance of more than a few others)

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NSF NCAR U.S. DEPARTMENT OF ENERGY Office of Science

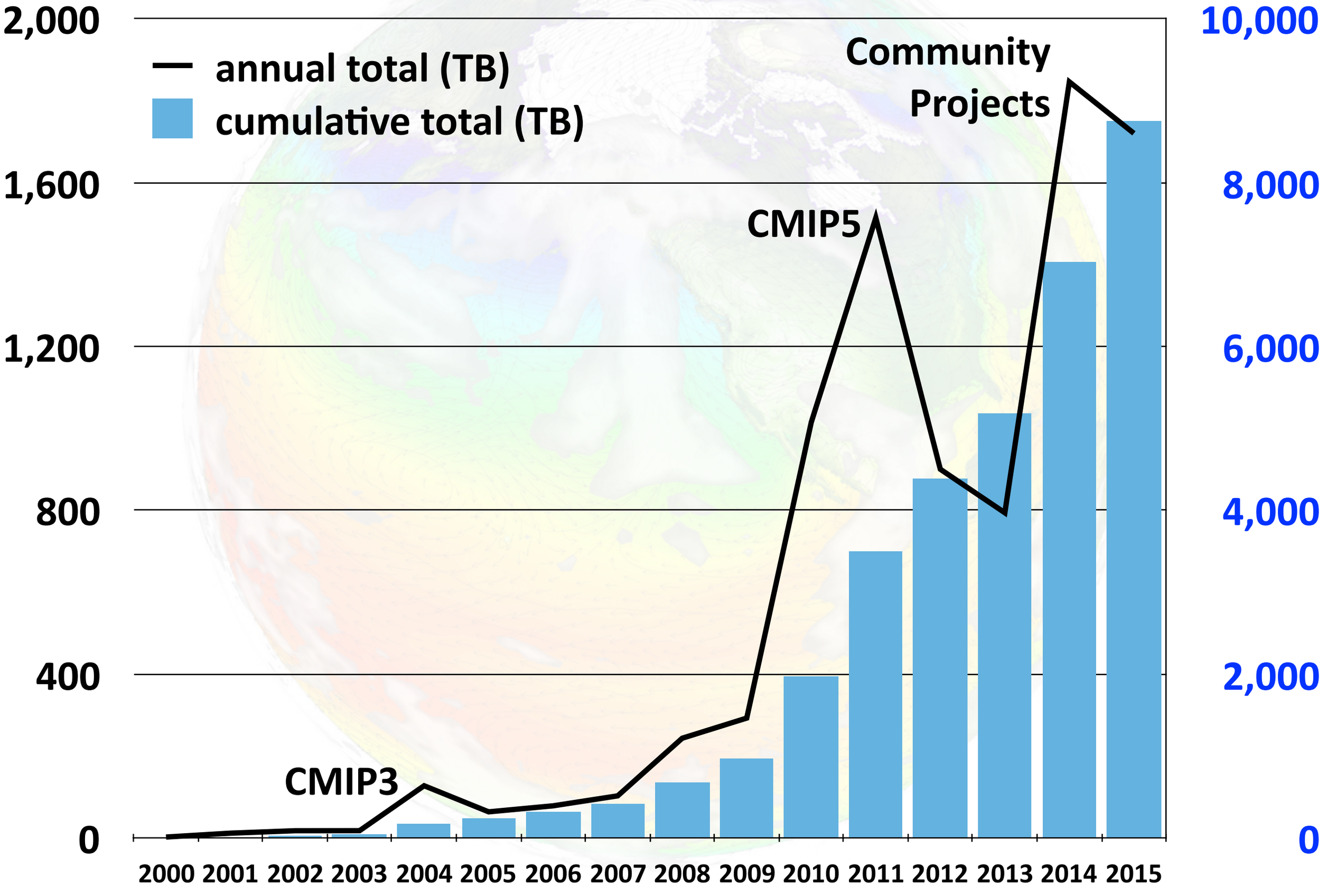
I should have known…

STUDENT ASSISTANT II - #0591

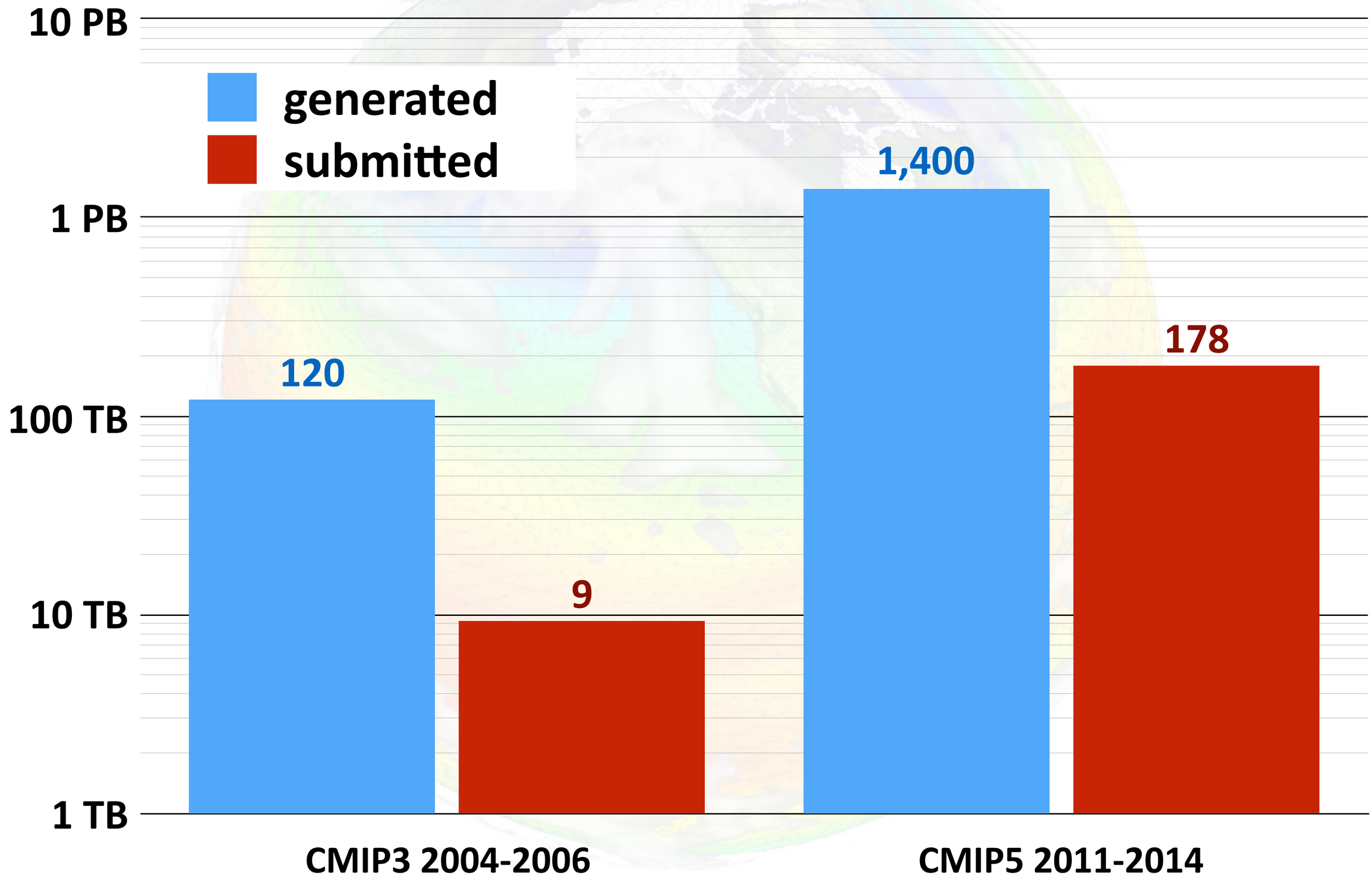
AAP - Global Climate Modeling Group
Flat Rate: $6.90/hour
DUTIES: Modifies existing atmospheric and ocean model computer programs to perform new functions and/or to improve their flexibility and ease of operation. Writes new utility computer programs for scientists which satisfy their requirements. Operates, as needed, computer programs for the storage and processing of data.
REQUIRES:
-- Basic FORTRAN programming skills
-- Skill in handling large data sets
-- Skill in transferring data between the computers, mass store, and physical tape
-- Skill in understanding scientists' requirements and translating these into workable programs
-- Successful completion of one year of college level physics, mathematics, or atmospheric science

Staff Notes 21 (35), 29 Aug 1986

Does CESM have big data?



Contributions to CMIPs



NCAR CMIP3 and CMIP5 comparison

Category	CMIP3		CMIP5	
Models used	**2:** CCSM3 & PCM		**5:** CCSM4, CESM1-CAM5, CESM1-BGC, CESM1-WACCM, CESM1-FASTCHEM	
Total volume submitted	**~ 9.2 TB**		**~178 TB**	
Total volume generated	**~120 TB**		**~1,400 TB**	
Total simulated years	**~14,900**		**~28,500**	
Number of model runs	107 total	73 (CCSM3)	555 total	91 (CCSM4 long-term)
				400 (CCSM4 DP)
		34 (PCM1)		64 (other configurations)
Experiments requested	12		37	
Output categories	6		19	
Number of requested fields	137		951	
Persons actively involved	10		15	
Months start-finish	36 (2004-2006)		48 (2010-2013)	

Recent big data CESM projects

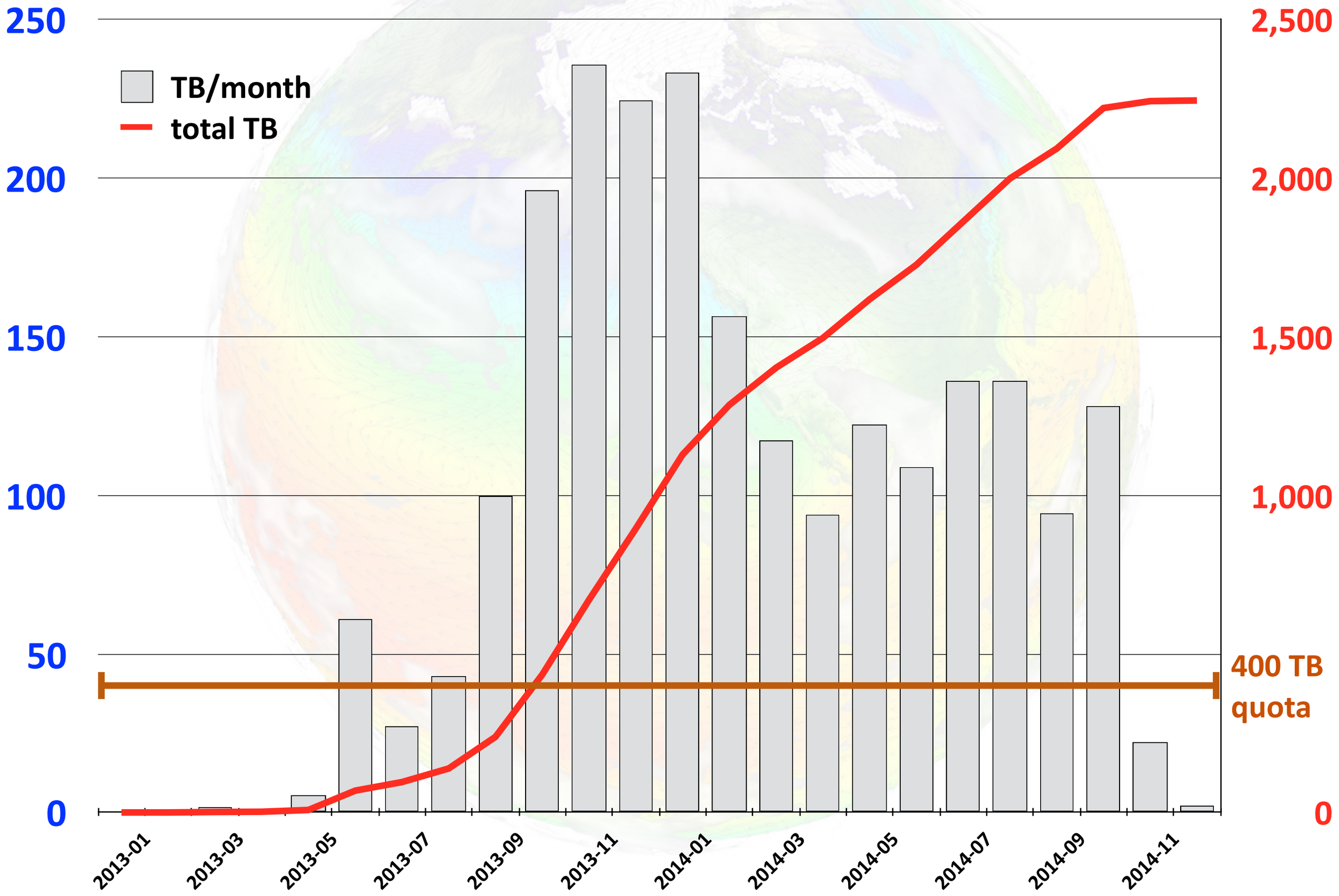
CESM1-CAM5 w/BGC Large Ensemble

- 70+ simulations:
  - "Control" runs (4300y), 1% CO2 (305y)
  - 40 20th century + RCP8.5 (1920-2100)
  - 15 RCP4.5 (2006-2100)
  - grand total 15,084y
  - 182,000 files, ~330 TB, all netCDF-4 with deflation

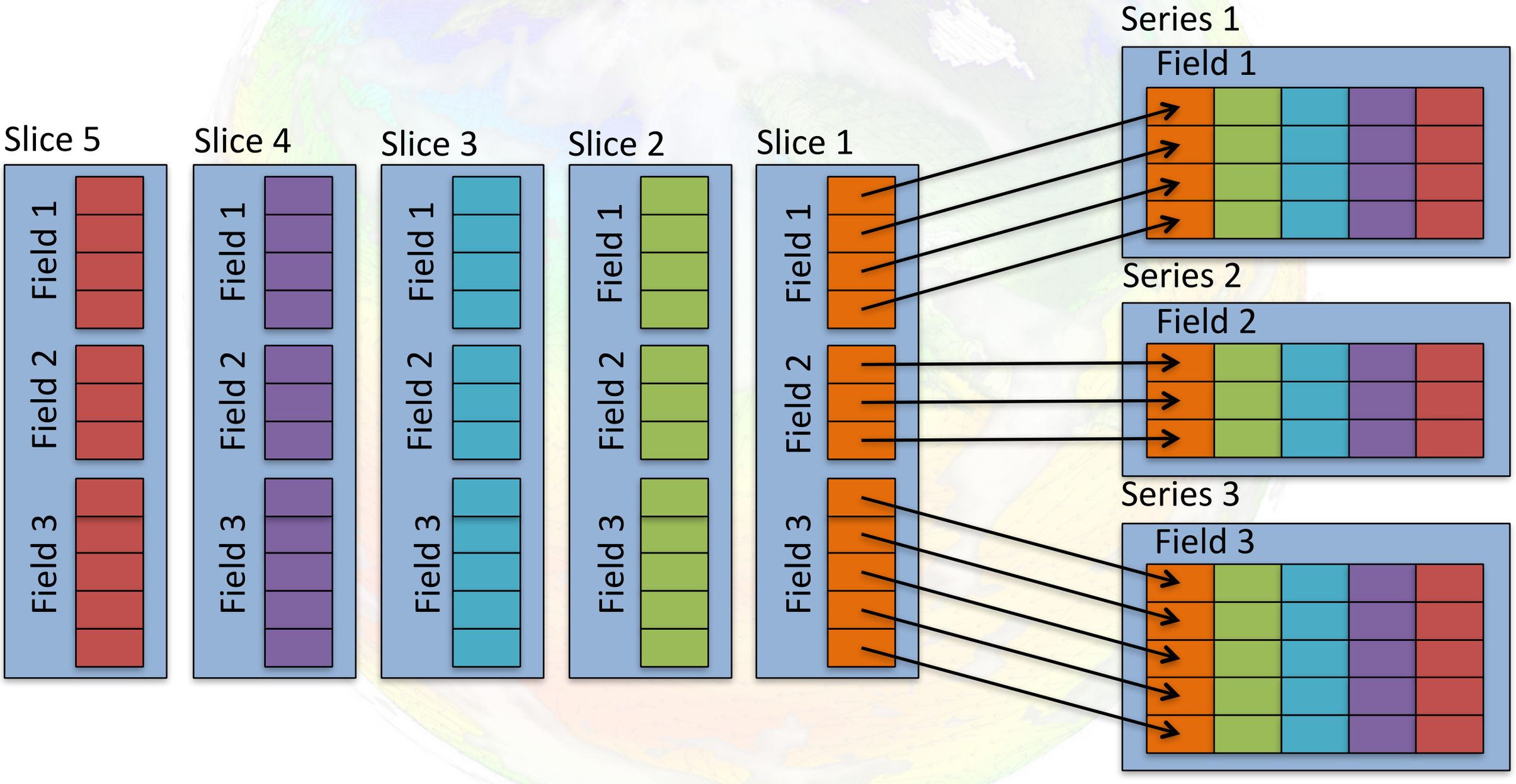
CESM1-CAM5 Last Millenium Ensemble

- 39 simulations
  - All forcings and variations, 850-2005 each
  - grand total 37,840y
  - 96,000 files, ~310 TB, all netCDF-4 with deflation

CESM1-CAM5 w/BGC Large Ensemble

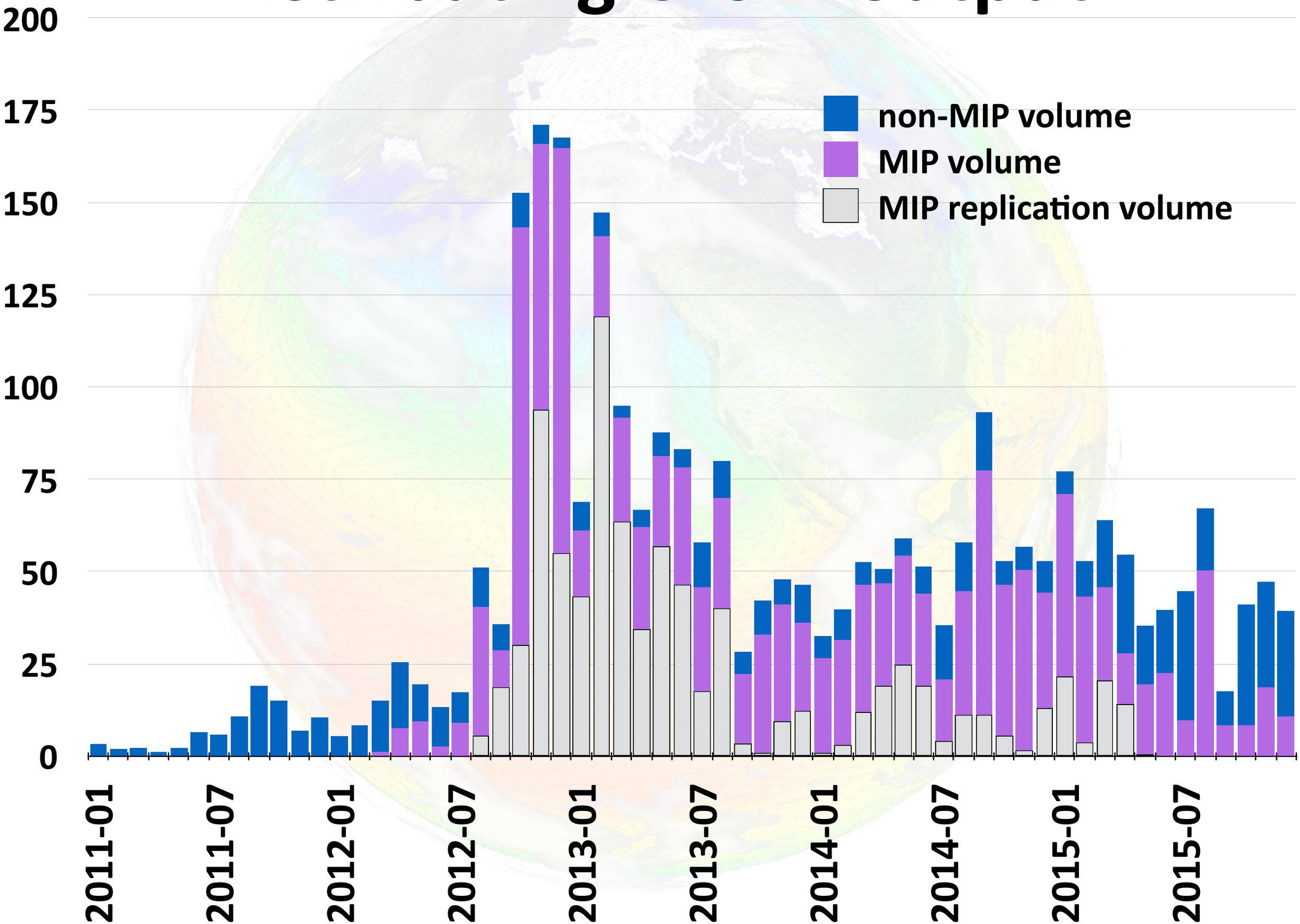


History Time-Slice to Time-Series Converter (Serial NCO)

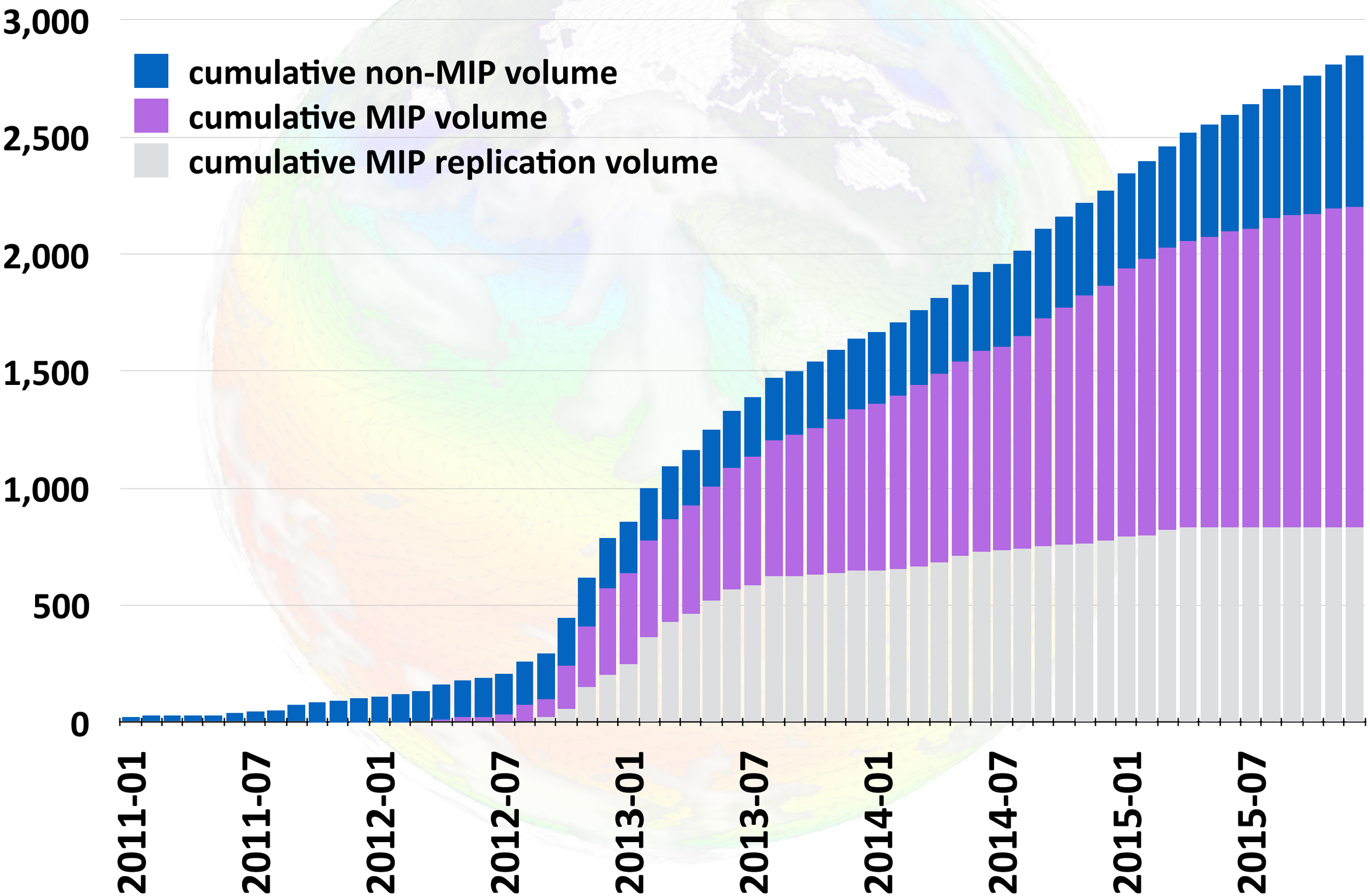


(Courtesy Sheri Mickelson, NCAR)

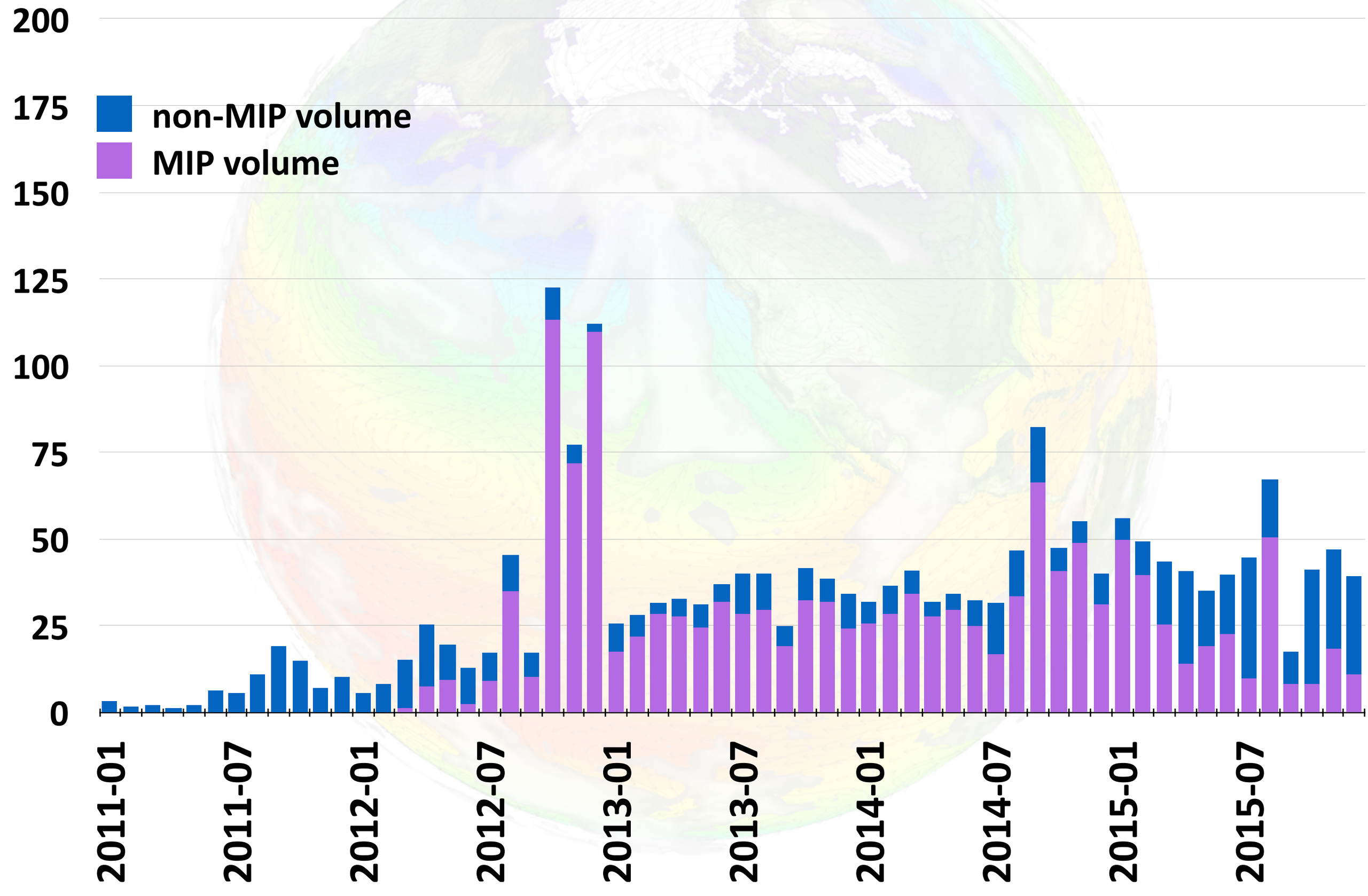
Distributing CESM output



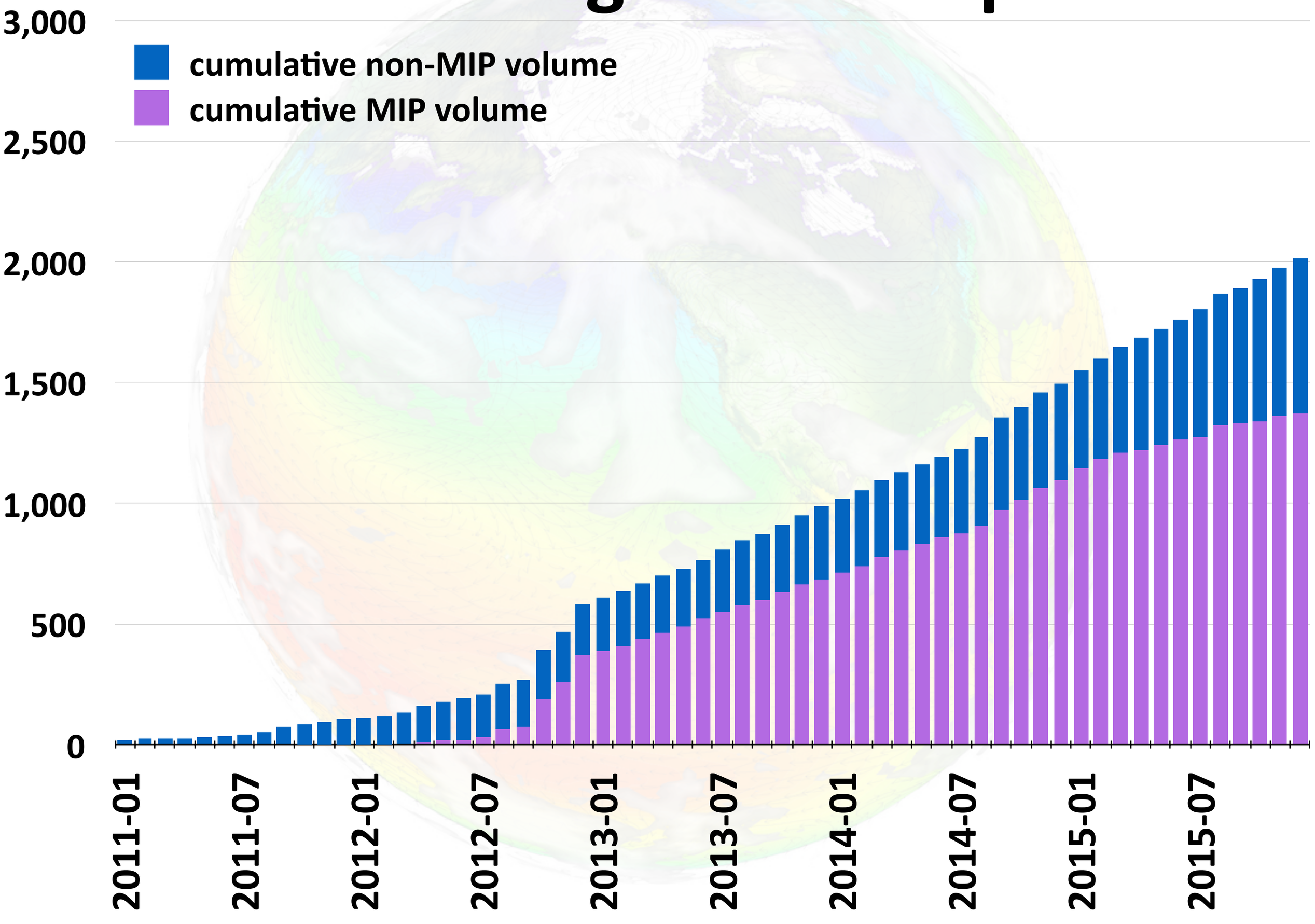
Distributing CESM output



Distributing CESM output



Distributing CESM output

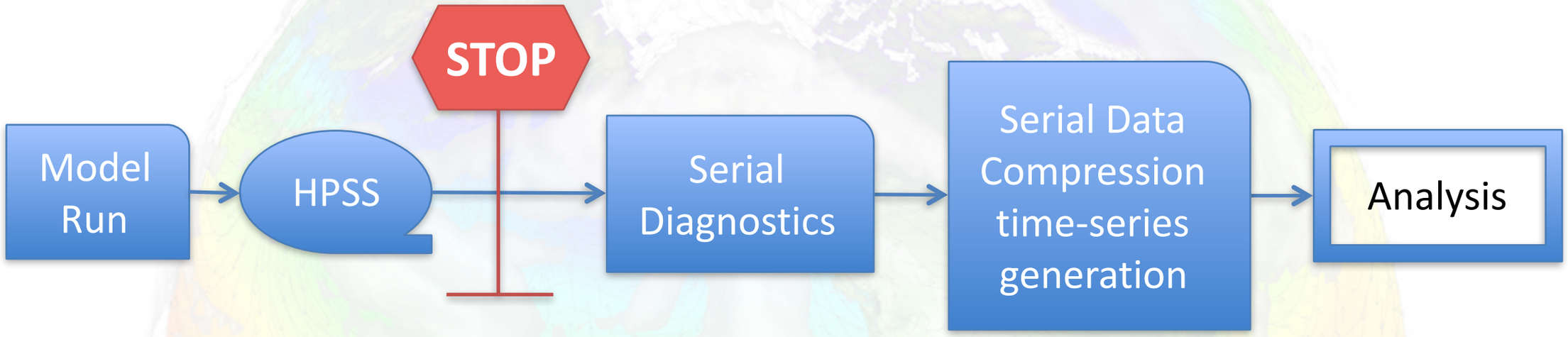


CESM/CSEG Workflow Re-engineering Project

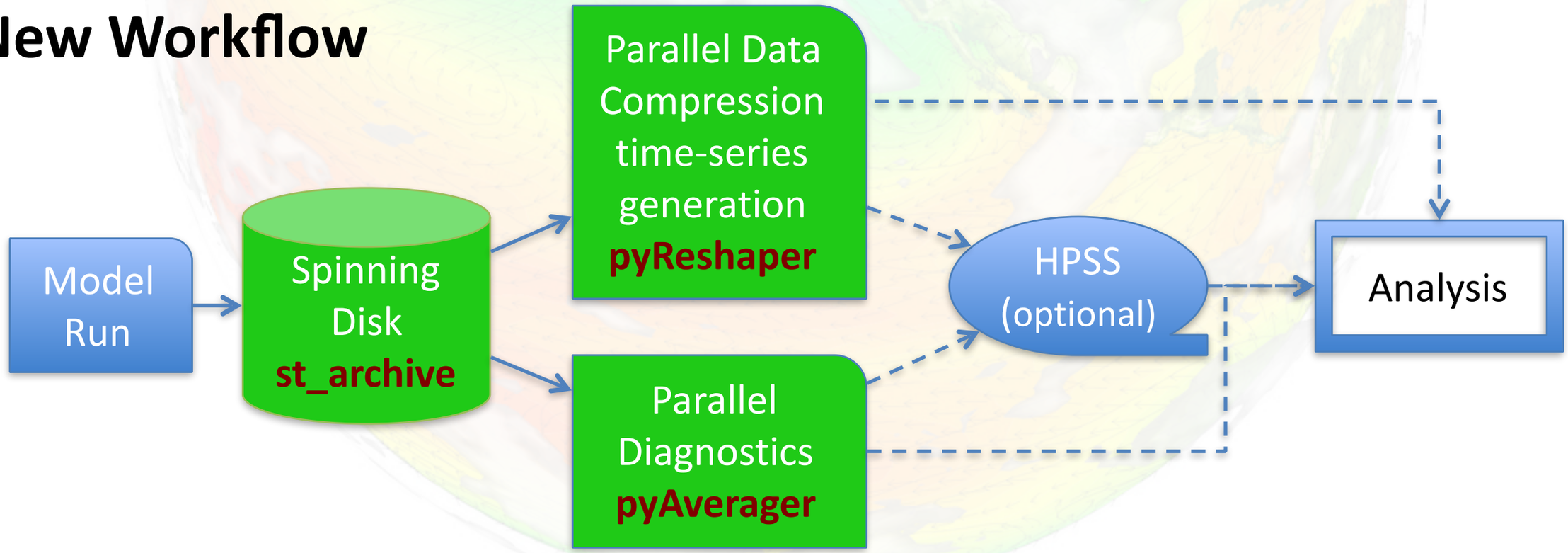
- Ben Andre
- Alice Bertini
- John Dennis
- Jim Edwards
- Mary Haley
- Jean-François Lamarque
- Michael Levy
- Sheri Mickelson
- Kevin Paul
- Sean Santos
- Jay Shollenberger
- Gary Strand
- Mariana Vertenstein

CESM/CSEG Workflow Re-engineering Project

Old Workflow



New Workflow

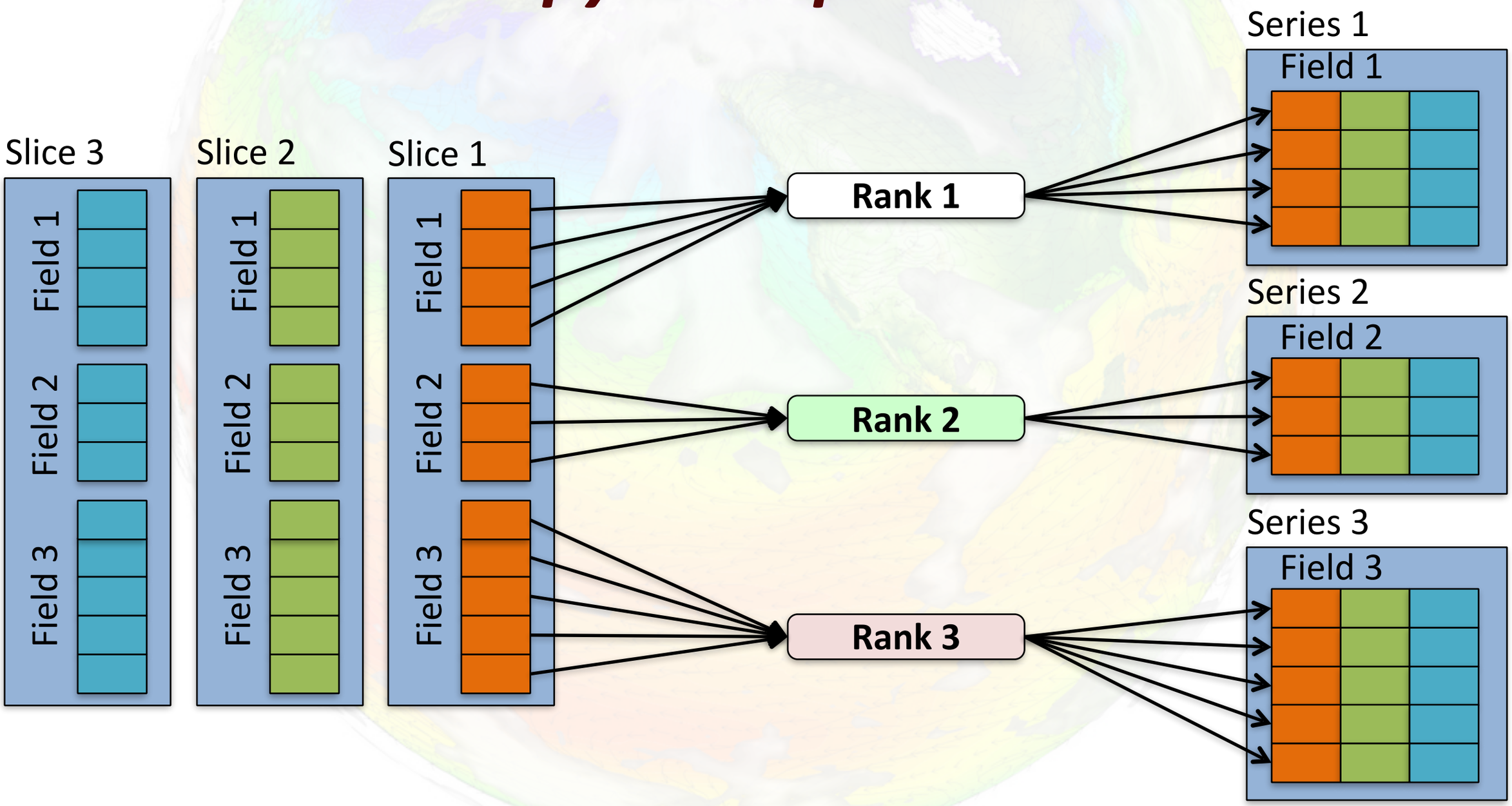


(Courtesy Sheri Mickelson, NCAR)

Task Parallelization Strategy

Each rank is responsible for writing one+ time-series variables to a file

pyReshaper



(Courtesy Sheri Mickelson, NCAR)

CESM1-CAM5/BGC decadal prediction

Start years from 1954 to 2014 (122 months)
Carried out on ‘edison’, at NERSC

610 simulations, 13 output streams each
9,108 timeslice files per simulation
1.103 TB per simulation - total 672 TB

<u>After transposition</u>
1,153 timeseries files per simulation
706 GB per simulation - total 430 TB (~33% less)
Max 25 TB processed in one day

Metrics for decadal prediction ensemble

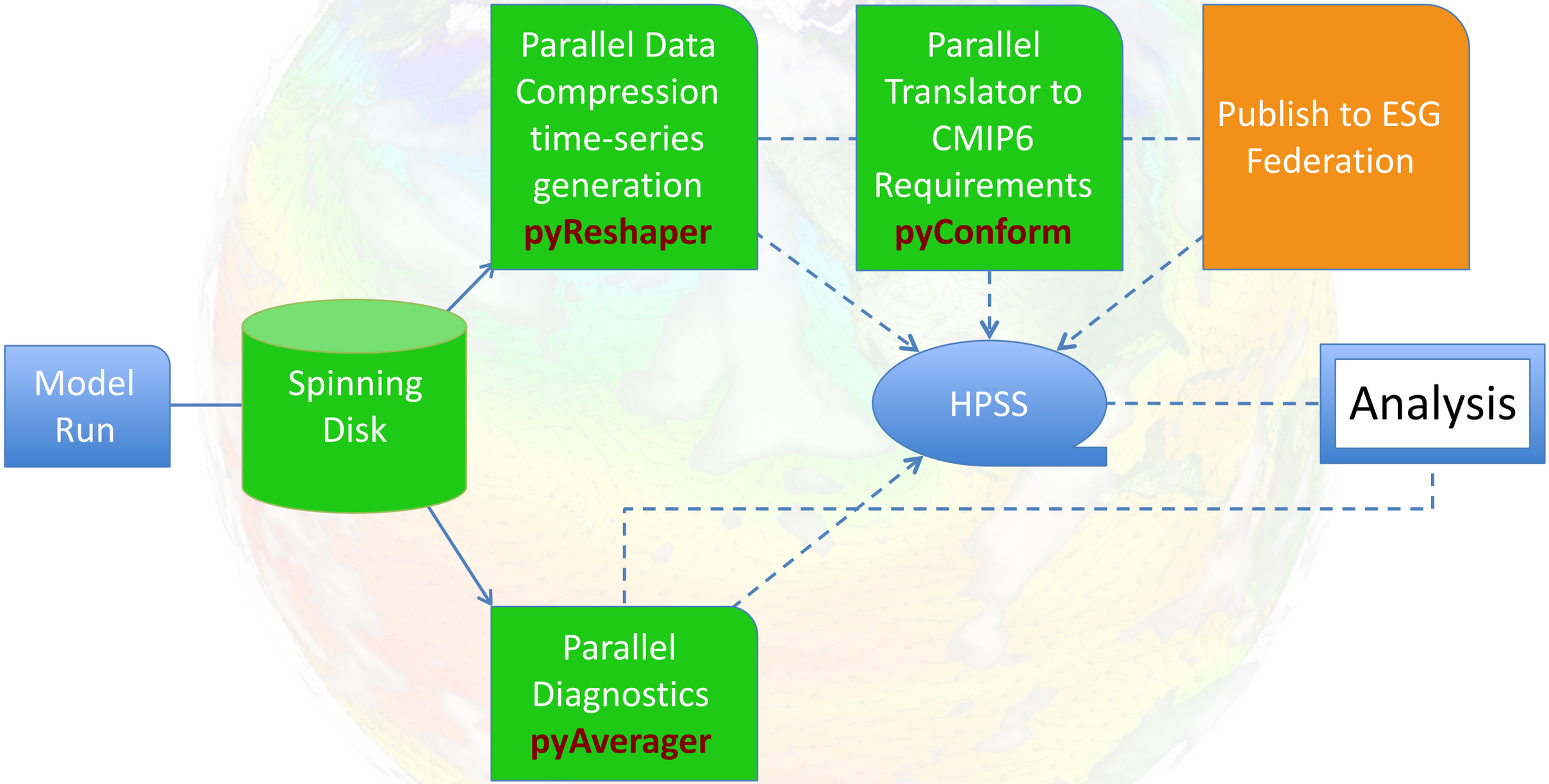
	atm			lnd		rof	
time sampling	mon	day	hr6	mon	day	mon	day
# fields	136	51	18	297	10	5	2
# times/file	1	365	1,460	1	365	1	365
model output volume per run (GB)	44.2	39.3	410.0	11.0	7.5	5.5	7.1
timeseries volume per run (GB)	21.7	41.4	410.1	3.5	1.8	0.1	2.3
compression ratio	2.0	0.9	1.0	3.1	4.2	55.0	3.1
mean serial wallclock time (s)	2,285	8,795	14,130	1,659	504	295	428
serial throughput (MB/s)	19.8	4.6	29.7	6.8	15.3	19.1	16.9
parallel #PEs used	144	72	24	312	24	24	24
mean parallel wallclock time (s)	193	8,942	19,082	120	864	66	876
parallel throughput (MB/s)	234.7	4.5	22.0	93.9	8.9	85.7	8.2
ratio parallel to serial (speedup)	11.9	1.0	0.7	13.8	0.6	4.5	0.5

Metrics for decadal prediction ensemble

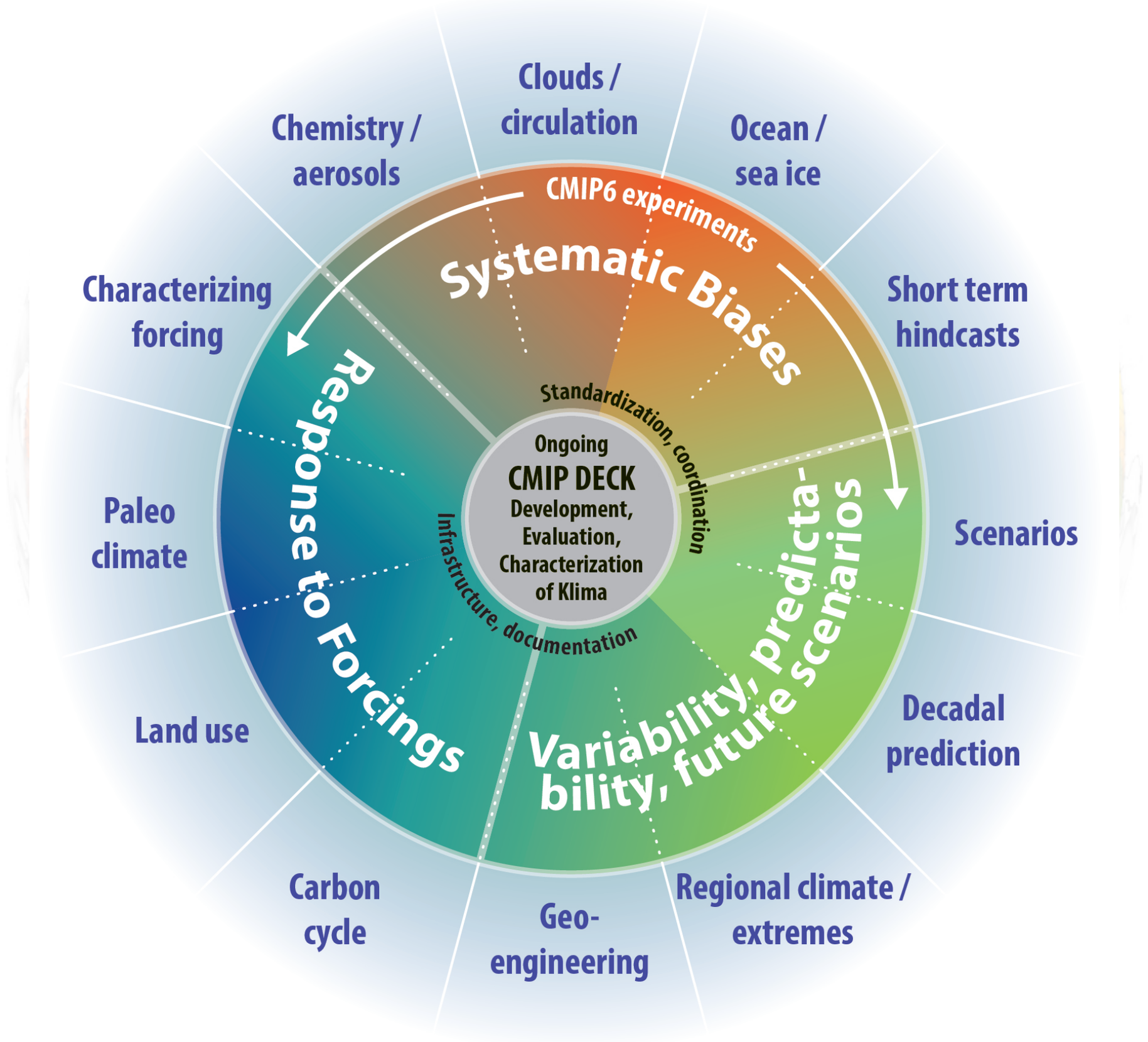
	ice		ocn			
time sampling	mon	day	mon	day	day	ann
# fields	111	34	272	10	17	45
# times/file	1	365	1	~30	~30	1
model output volume per run (GB)	8.0	66.6	431.0	24.0	35.9	12.9
timeseries volume per run (GB)	1.0	6.5	185.9	9.9	15.6	6.8
compression ratio	8.0	10.2	2.3	2.4	2.3	1.9
mean serial wallclock time (s)	3,610	6,920	10,120	578	1,980	600
serial throughput (MB/s)	2.3	9.8	43.6	42.5	18.6	22.1
parallel #PEs used	120	24	288	24	24	48
mean parallel wallclock time (s)	573	2,570	347	546	547	61
parallel throughput (MB/s)	14.3	26.5	1,272.8	45.0	67.2	217.4
ratio parallel to serial (speedup)	6.3	2.7	29.2	1.1	3.6	9.8

CESM/CSEG Workflow Re-engineering Project

CMIP6 Workflow



CMIP6 design schematic



CMIP6 Timeline

2014 2015 2016 2017 2018 2019 2020 …

Diagnostic, Evaluation and Characterization with standardized metrics & assessment

CMIP DECK

Model Version 1

Model Version 2

Model Version 3

Model Version 4

CMIP6 Endorsed MIPs

MIP1

MIP2

MIP3

MIP1

MIP4

MIP2

Future projection runs

Finalize experiment design (WGCM)

Scenario MIP studies , MIP matrix, pattern scaling, scenario pairs

Community input on CMIP6 design

Formulate scenarios to be run by AOGCMs and ESMs

Forcing data: harmonization, emissions to concentrations

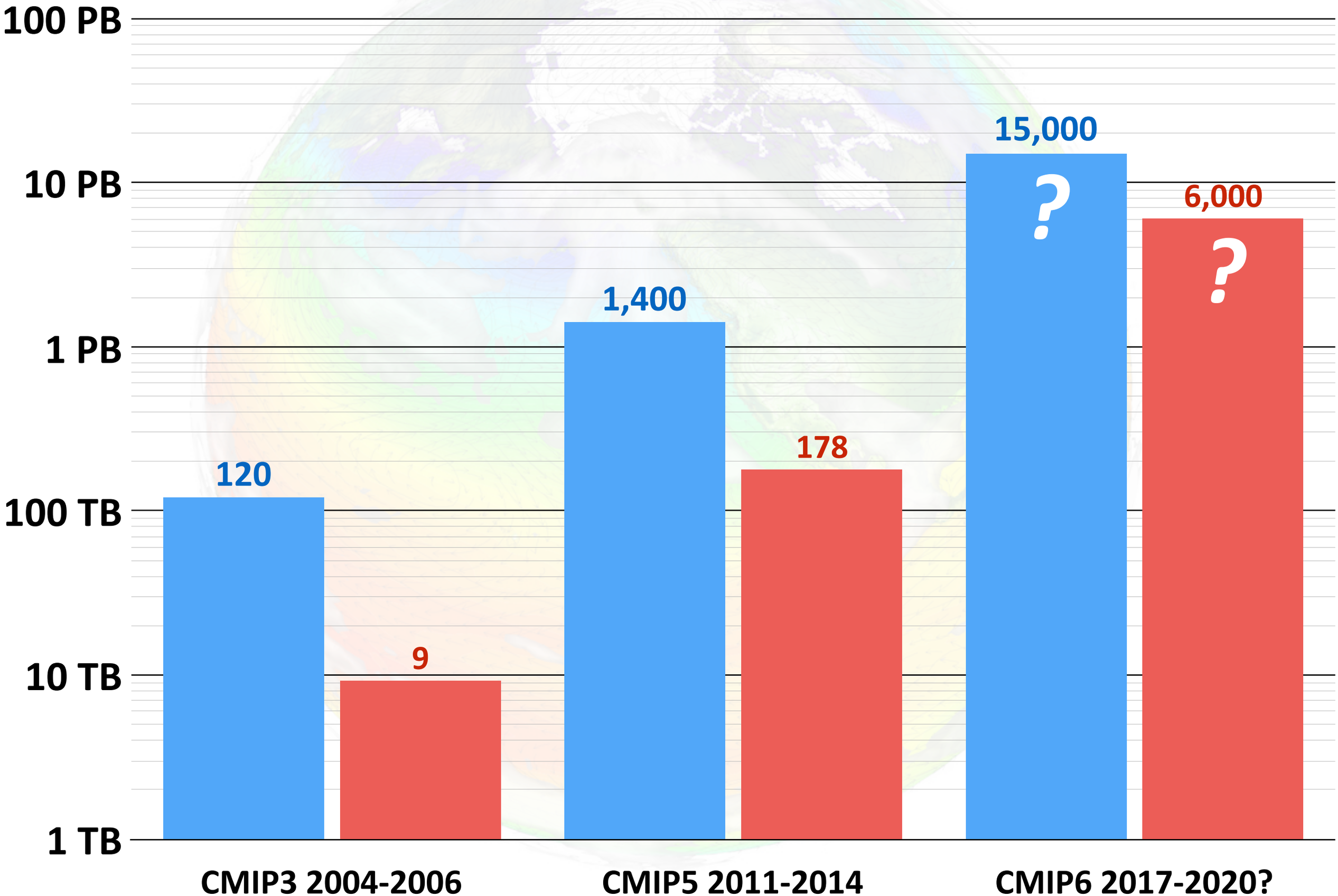
Preliminary ESM/AOGCM runs with new scenarios

Run and analyze scenario simulations from matrix

Possible IPCC AR6

Nominal Simulation Period of CMIP6

Contributions to CMIPs



Supporting all this…

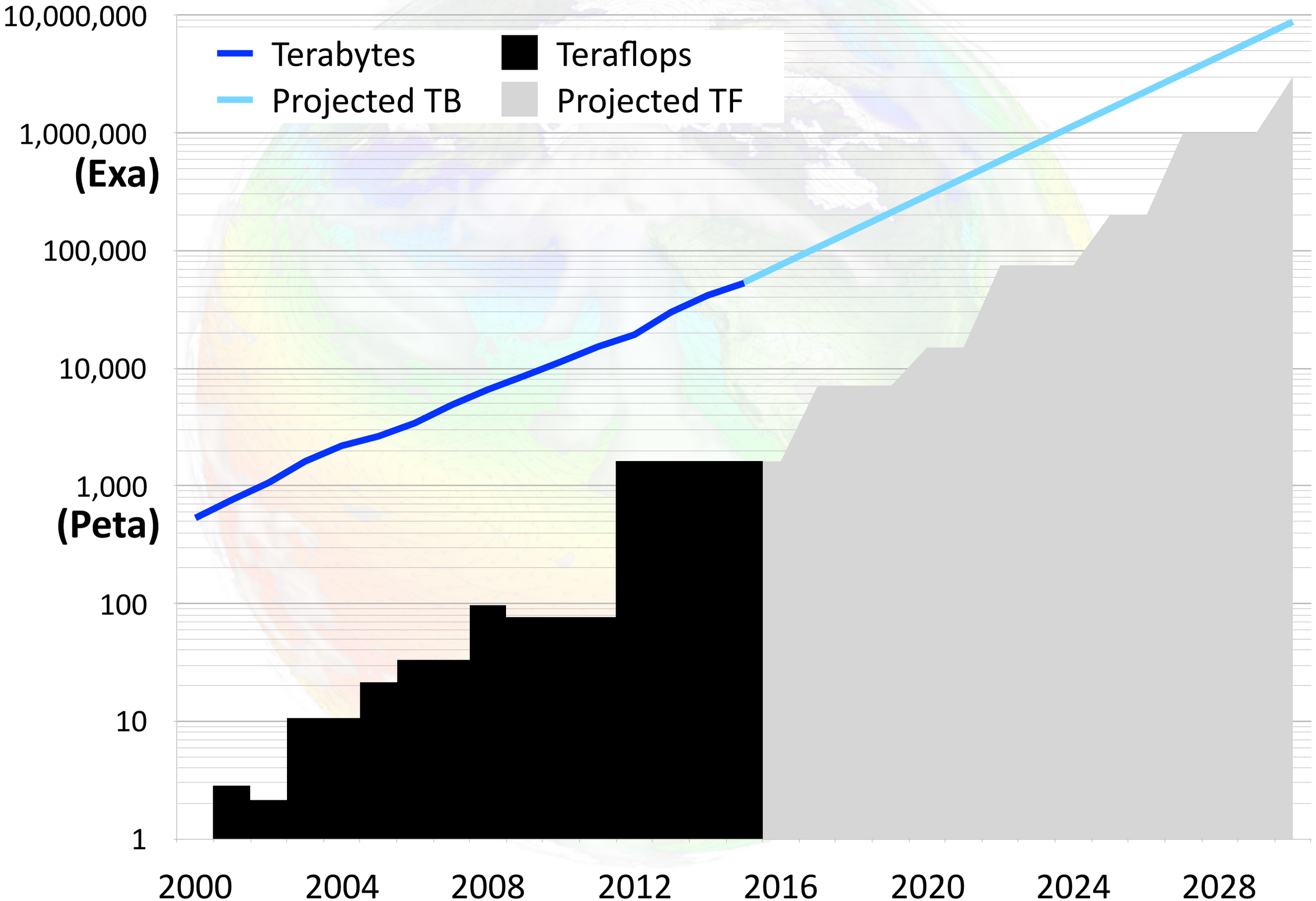
- *I am downloading some data but have been unable to find the definition of variables, e.g. QBOT, SNOWICE, FLDS,... (except for a few that agree with IPCC conventions). Also I have not found reports/articles defining the model and in particular the input to the model (where are time variations in ocean-land boundaries taken from, etc.)*
- *The metadata says that there is no coordinate reference system, which doesn't appear correct since it is obviously long and lat in degrees. What is the actual coordinate reference system and its spatial units? (ie meters, degrees)*
- *I downloaded two files and I couldn't open them on my PC, could you tell me what is the suitable program in order to open the files and I tried Adobe but it did not work.*
- *I'm new to the climate modeling world and don't understand why there are a number of runs for each experiment. I can't seem to find this information anywhere. I'm assuming that these runs are under the same initial conditions, but are maybe replicates to account somehow for model uncertainty.*
- *Some of the climate variables say that there are 17 levels when I brick the raster into R. I am assuming the levels have to do with the altitude, but the metadata does not address what the levels are. I really need to know what these levels are and how to determine this on my own. Can you tell me what the levels are and how to find that information for other files I might use with this problem?*

CESM and the nearish-future

Issues

- Meeting user community needs/wants drives all!
- Modeling and analysis ~concurrently to avoid memory -> disk latency and all the other issues
- Updating CESM data management policy to reflect workflow and other changes (DOIs, etc.)
- Longer-term viability of ESG/ESGF model - downloading PB isn't sustainable - or is it?
- Must have serious server-side analysis
- Possibility of rerunning for additional data

NCAR flops and bytes 2000-2030



References

CESM

http://cesm.ucar.edu

CESM Data Management Plan

http://cesm.ucar.edu/management/docs/data.mgt.plan.2011.pdf

ESG

http://www.earthsystemgrid.org

Thank you!