Development of a land model benchmarking system

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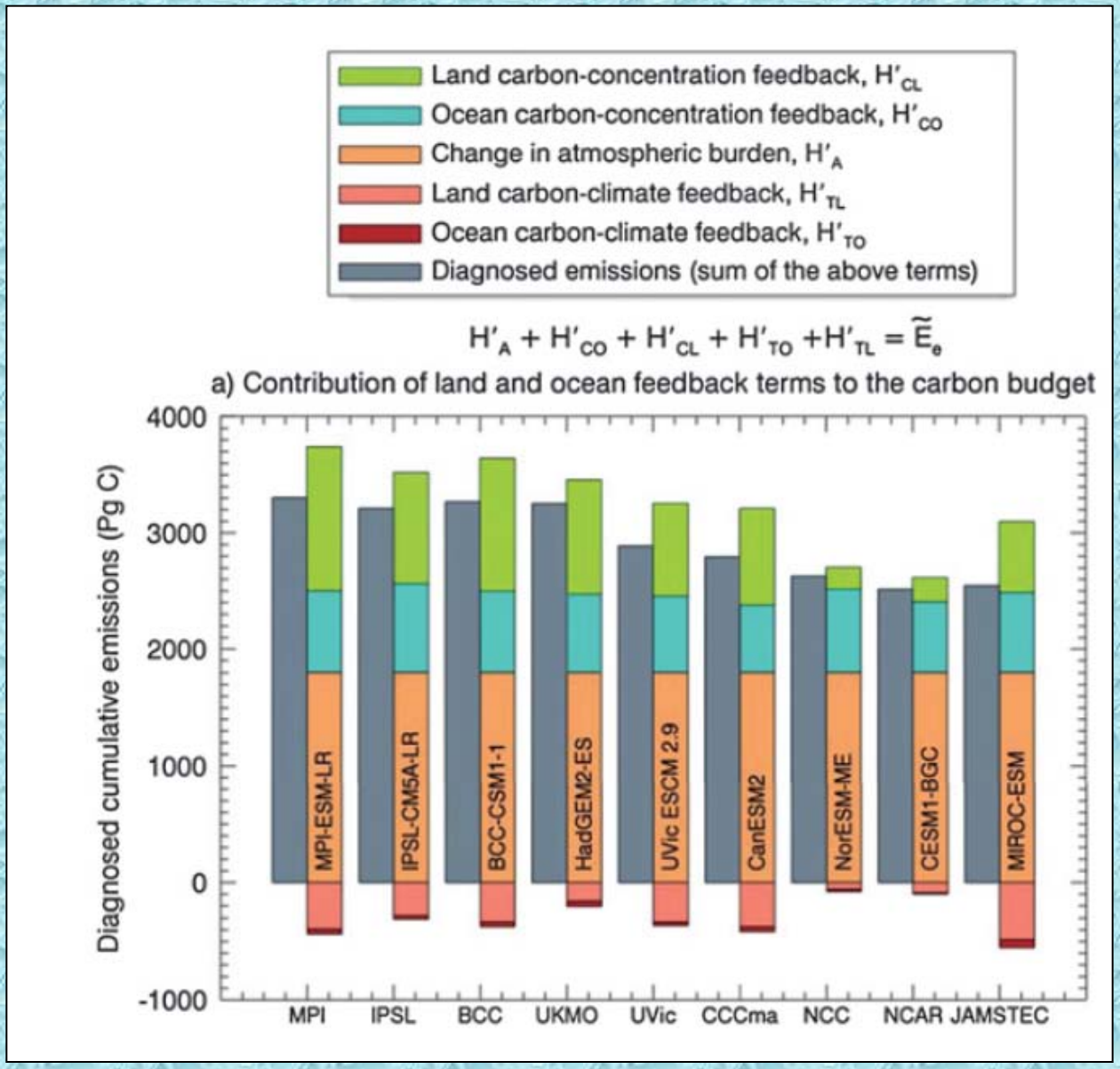
Background

- Representation of the carbon cycle is highly variable in different models.
- Benchmark is needed to reduce uncertainties related to carbon concentration and climate-carbon feedback.
- Rapid and systematic evaluation of land surface models is a crucial information source for model development.

Arora et al. (2013)



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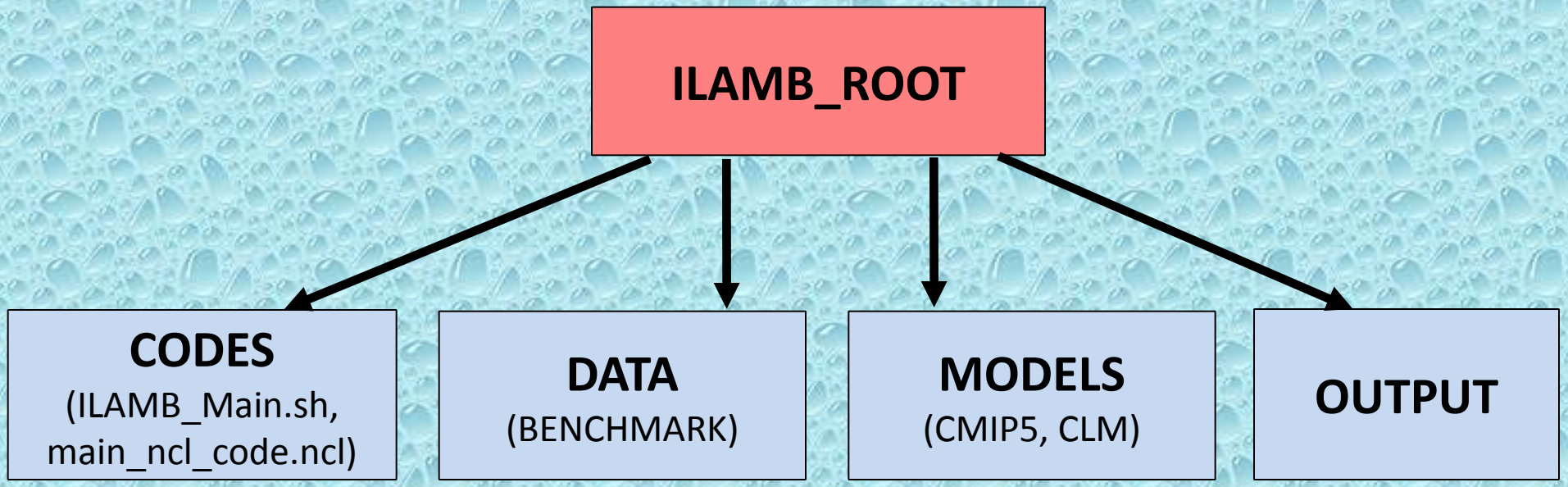
Objectives

- Describe a new benchmark system
- Compare CMIP5 models with benchmark
- Evaluate changes between CLM4.0 and CLM4.5

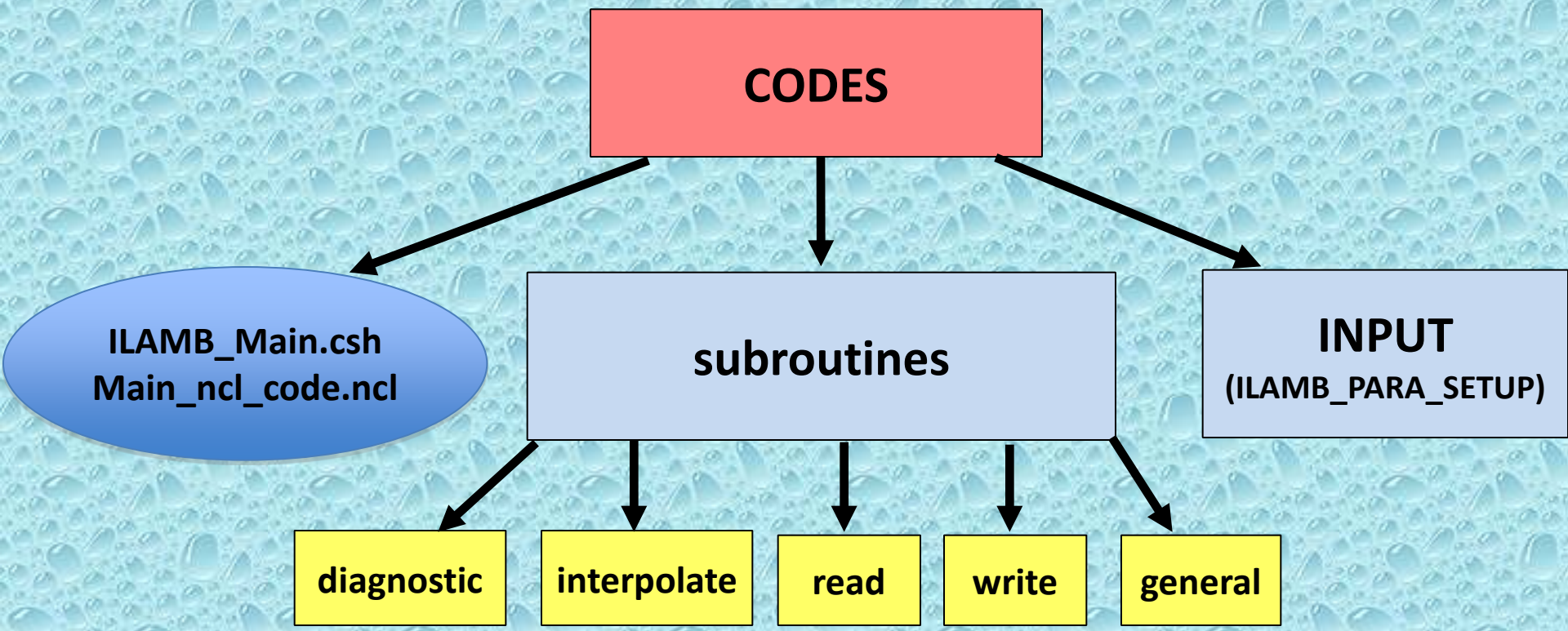
1. Benchmark System: Directory Structure



- The system is written in open source software, NCL (NCAR Command Language, http://www.ncl.ucar.edu), a publicly available language, and is designed for easy installation and use by scientists.

- A unique feature of this system is that it provides an overall performance evaluation for each model, for variables selected by the user.

1. Benchmark System: CODES



- This package is constructed with modular structures, so that new models, variables or benchmarks can be added.
- The software runs in a UNIX or LINUX, and it can be interactively run with other software, like R, IDL, MATLAB, etc.

1. Benchmark System: Control Parameter File

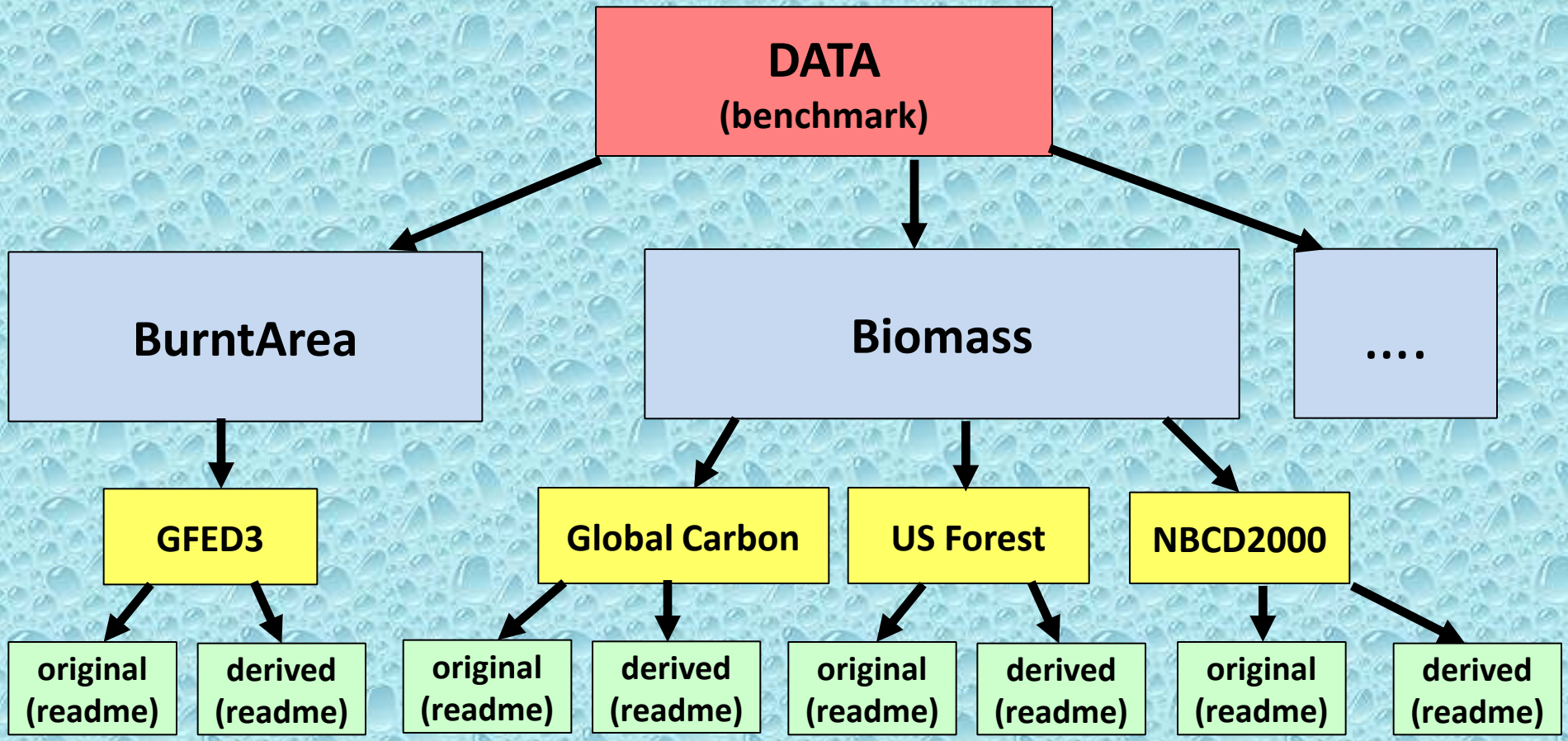
General Control Parameters

$ILAMB_ROOT/CODES/INPUT/ILAMB_PARA_SETUP

Models and # of ensembles			Here are Variables available for your choose										Diagnostic packages for your choose						
Model Name	cmipID	runID	burntArea	Biomass	NEE	GPP	Reco	albedo	LE	SH	Pr	tas	AM	Bias	RMSE	PS	TS	IS	OS
MeanModel	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
bcc-csm1-1	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
CanESM2	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
CCSM4	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
GFDL-ESM2G	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
HadGEM2-CC	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
HadGEM2-ES	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
inmcm4	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
IPSL-CM5A-LR	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
IPSL-CM5A-MR	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
MIROC-ESM	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
MIROC-ESM-CHEM	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
MPI-ESM-LR	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
NorESM1-M	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
CLM40cn	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
CLM45bgc	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1

Notes: This table (above) contains parameters for your choose to run ILAMB diagnostic package. The numbers shown above are default setup to run the diagnostic package. Based on your purpose, please change the numbers in the area from column 2 to 18 and row from 3 to 16. Please don't change the words shown in row 1 and 2 and column 1. In the future, you may add new models and new variables. But, in the current version, you can't do that. Here is the general information in each column. Column 1 shows the original CMIP5 model names (Don't make any change here). Column 2 (cmipID) is for your choose: which model you want to include in your diagnostics, 1: include this model, 0: exclude this model. Column 3 (runID) is for your choose: how many of ensembles you want to use, if you want to include all enembles, please enter 0 or a number larger its availibity; # of run for MeanModel actually has no meanful in this column. Columns 4-13 show variables that you want to include in the diagnostic package, 1: include, 0: not include. Columns 14-20 show the diagnostic packes that you can run, 1: include, 0: not include; AM: annual mean, Bias: bias between model and benchmark, RMSE: root mean square error between model and benchmark, PS: phase score, TS: spatial taylor score, IS: interannual variability score, OS: overall score.

1. Benchmark System: DATA

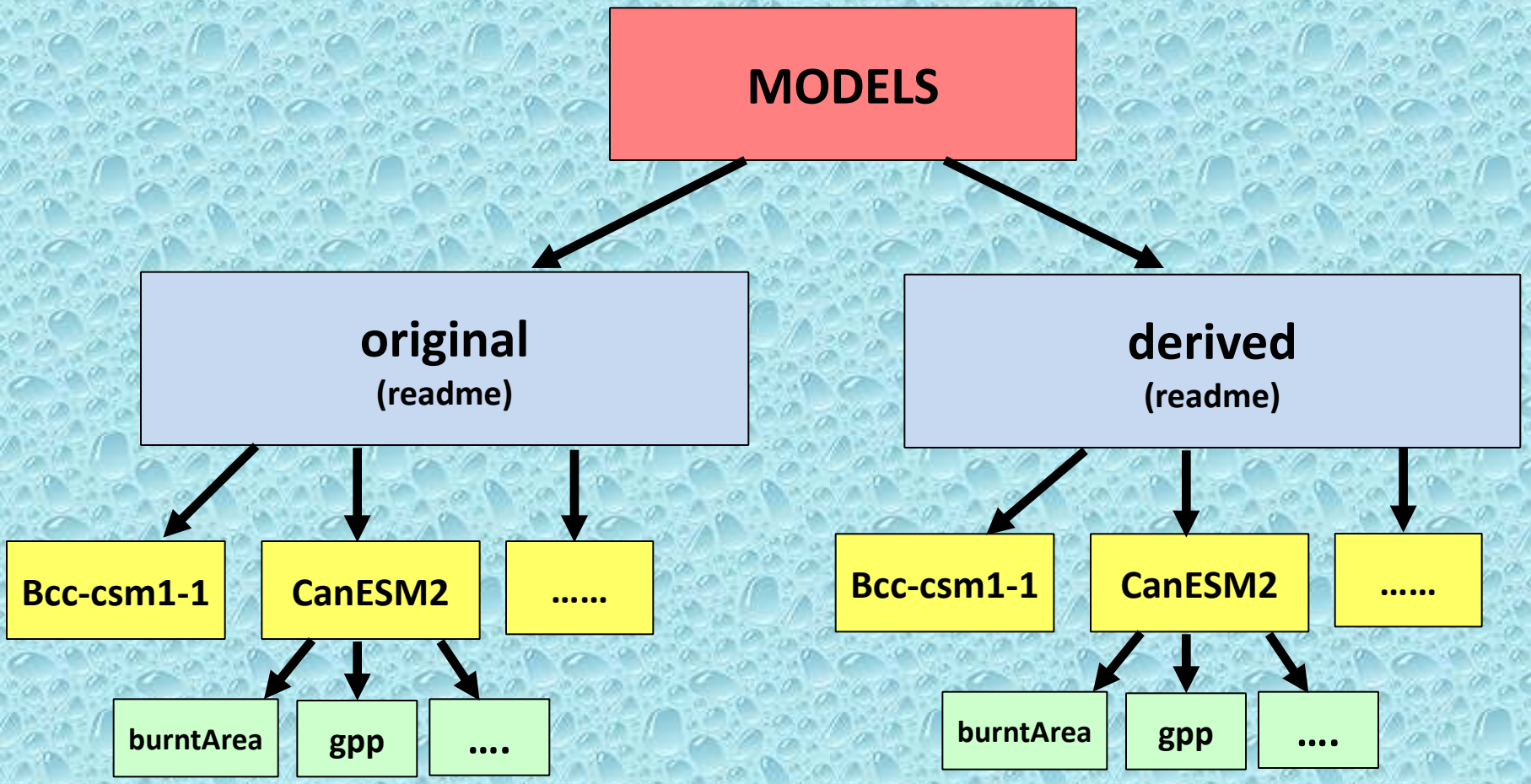


- We converted all grid benchmark data to standard 0.5x0.5 grid, and saved in NetCDF format.
- We also converted units of all benchmark data using CMIP5 standard.

1. Benchmark System: Current Datasets in the System

Variable Long Name (Short Name)	Source	Spatial resolution	Data Period
Burned Area (burntArea)	GFED3	0.5×0.5	1997-2005
Albedo (albedo)	MODIS (MCD43C3)	0.05×0.05	2000-2005
	CERES	1.0×1.0	2000-2005
Gross Primary Production (gpp)	Fluxnet	Station data	1996-2006
	Fluxnet-MTE	0.5×0.5	1982-2008
Net Ecosystem Exchange (nee)	Fluxnet	Station data	1996-2006
Total ecosystem Respiration (reco)	Fluxnet	Station data	1996-2006
Latent Heat (le)	Fluxnet	Station data	1996-2006
	Fluxnet-MTE	0.5×0.5	1982-2008
Sensible Heat (sh)	Fluxnet	Station data	1996-2006
Biomass Carbon (biomass)	US Forest (Blackard)	250m×250m	Annual
	US Forest (NBCD2000)	250m×250m	Annual
	Global Tropical Biomass	1km×1km	Annual
Leaf Area Index (lai)	MODIS	0.5×0.5	Annual
Precipitation (pr)	GPCP v2	2.5×2.5	1979-2012
Surface Air Temperature (tas)	CRU v3.21	0.5×0.5	1979-2012

1. Benchmark System: MODELS

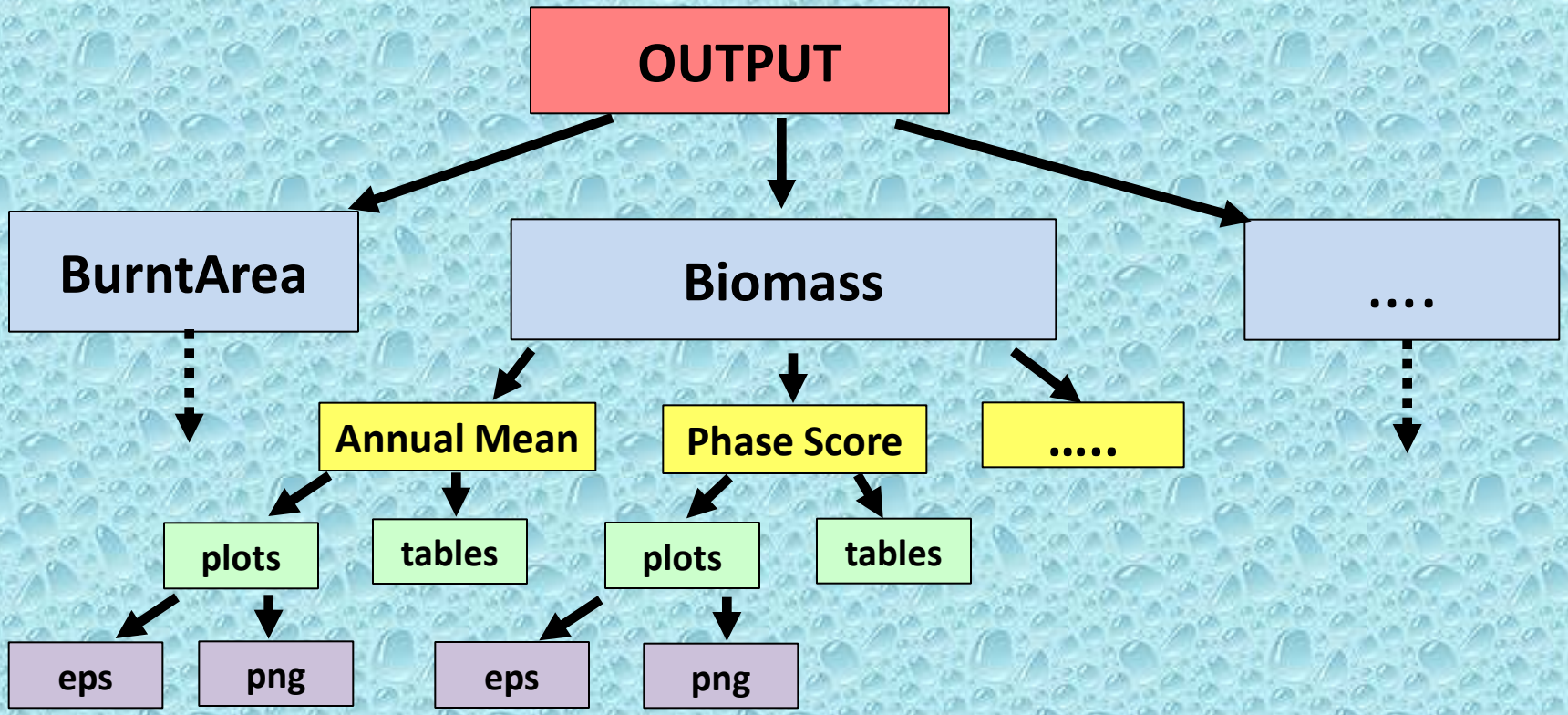


- We used CMIP5 file naming method in our system.
- Model data were converted to benchmark grid, i.e., 0.5x0.5, then compared with observations.

1. Benchmark System: CMIP5 Models Comparison (historical runs)

Model	Institution/Country	Resolution	No. of ensemles
bcc-csm1-1	Beijingl Climate Center/China	128×64	3
CanESM2	Canadian Center for Climate Modelling and Analysis/Canada	128×64	5
CCSM4	National Center for Atmospheric Research (NCAR)	288x192	6
GFDL-ESM2G	Geosphysical Fluid Dynamics Laboratory	144x90	3
HadGEM2-CC	Met Office Hadley Centre/UK	192×145	3
HadGEM2-ES	Met Office Hadley Centre/UK	192×145	4
Inmcm4	Insitute for Numerical Mathematics/Russia	180×120	1
IPSL-CM5A-LR	Institut Pierre Simon Laplace/France	96×96	5
IPSL-CM5A-MR	Institut Pierre Simon Laplace/France	144×143	1
MIROC-ESM	Japan Agency for Marine-Earth Science and Technology/Japan	640×320	3
MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology/Japan	128×64	1
MPI-ESM-LR	Max Planck Institute for Meteorology, Germany	192×96	3
NorESM1-M	Norwegian Climate Centre/Norway	144×96	3

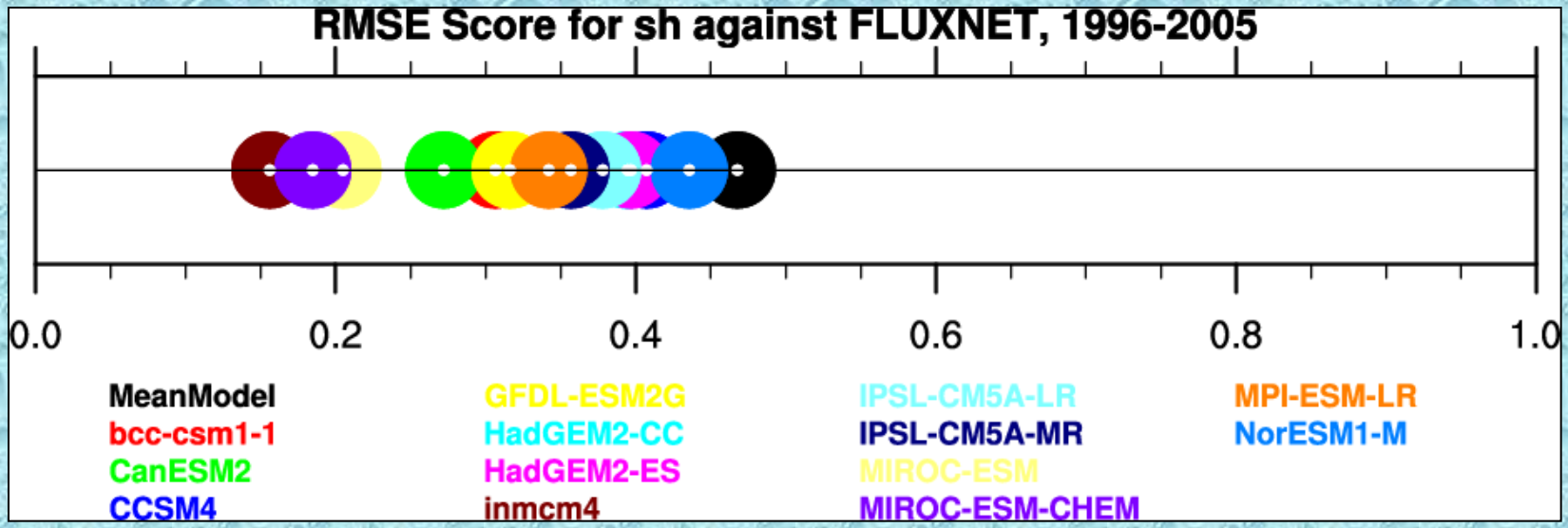
1. Benchmark System: OUTPUT



- High quality output files (encapsulated postscript files) can be used directly for publications or proposals.
- Output tables and files are written in HTML to facilitate viewing over the web.

System Scoring Metrics

RMSE Score

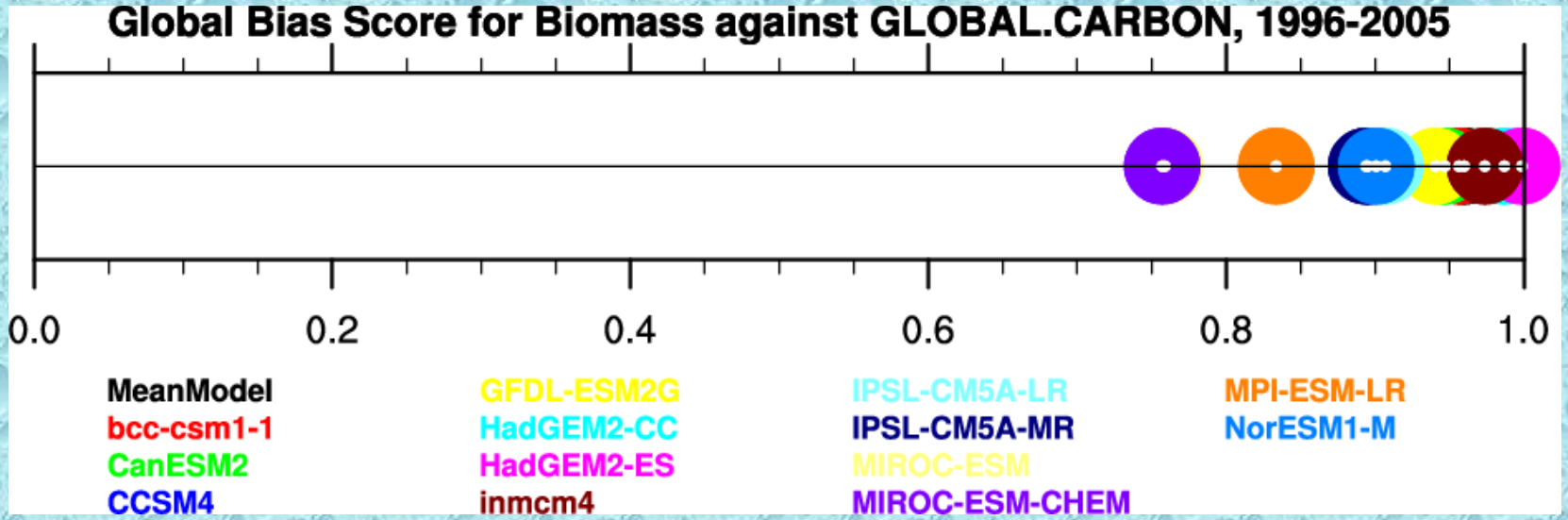


$$M = 1 - \frac{RMSE}{\sigma_{obs}}$$

Where σ_{obs} is the standard deviation of the benchmark and σ_{model} is the standard deviation of the model. RMSE is the root mean square error. *Ref: David Lawrence (personel Communication)*

System Scoring Metrics

Global Bias Score

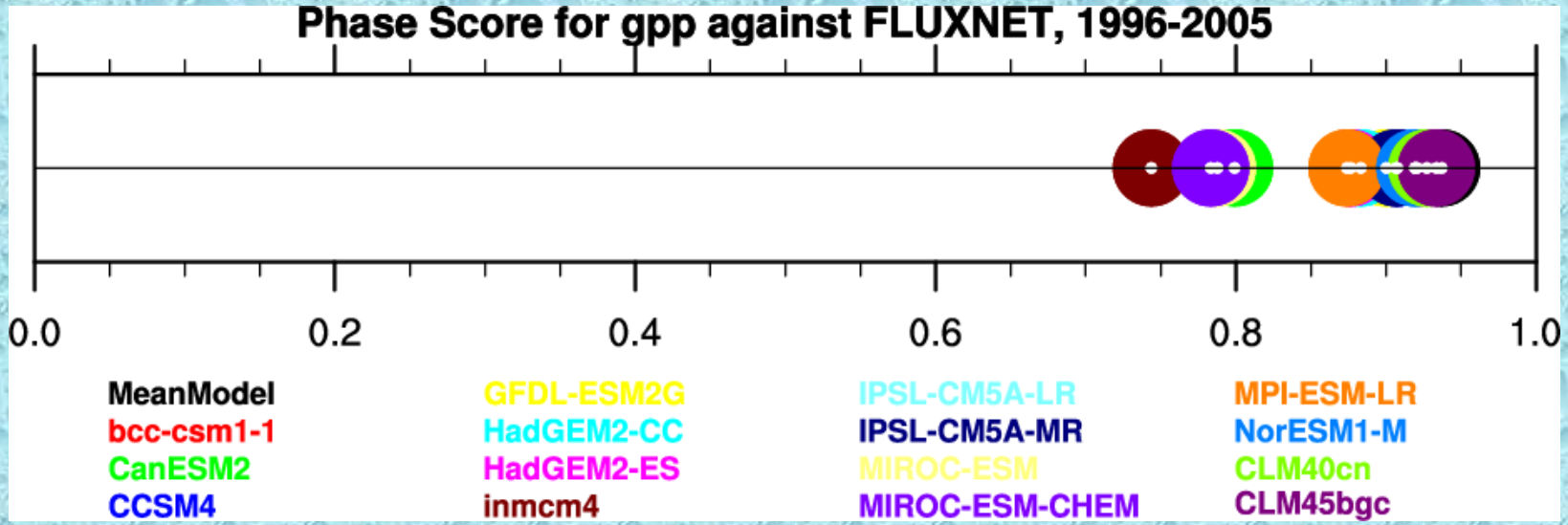


$$M = 1 - \frac{\left| AM_{model} - AM_{obs} \right|}{AM_{model} + AM_{obs}}$$

Where AM_{obs} is the global annual mean of the benchmark and AM_{obs} is the global annual mean of the model.

System Scoring Metrics

Phase Score

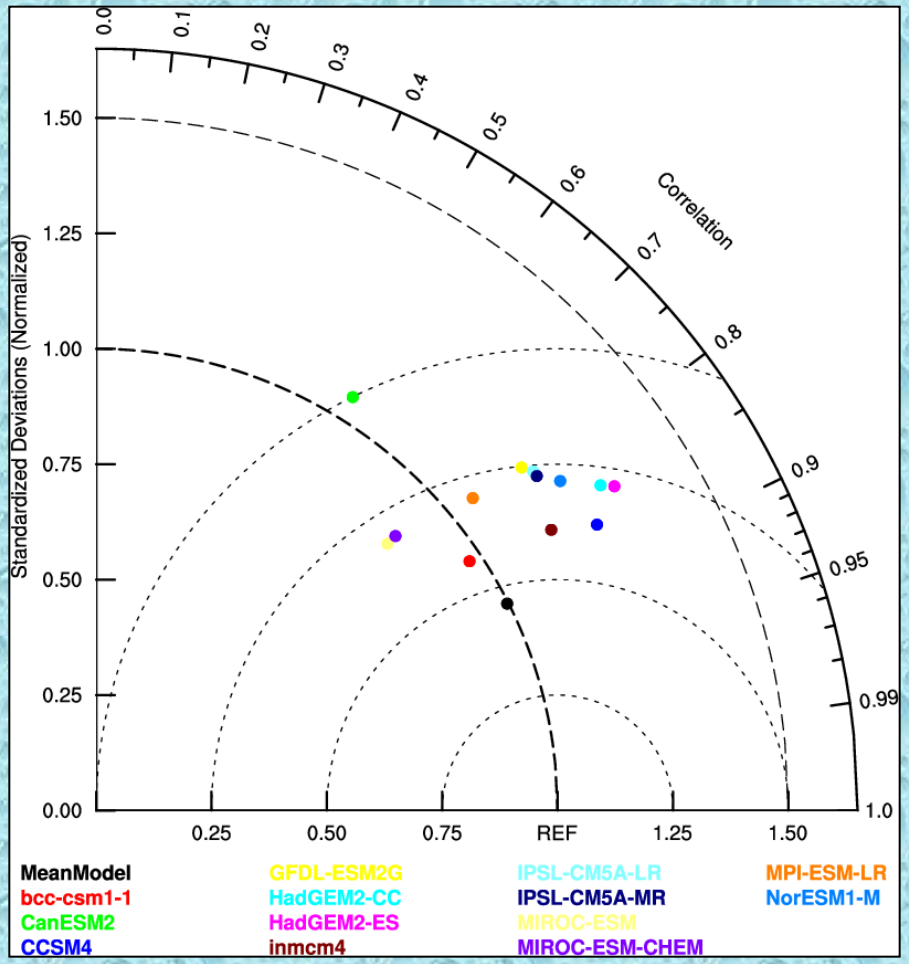


$$M = [1 + \frac{\sum A_j \cos \vartheta_j}{\sum A_j}] / 2$$

Where ϑ_j is the difference of the angle between the month of maximum values for the model and the month of maximum observations at each grid cell. This quantity was area-weighted over all the land grid cells in the model to obtain the global-scale metric. *Ref: Prentice, et al., GBC, 25, 2011*

System Scoring Metrics

Taylor Score



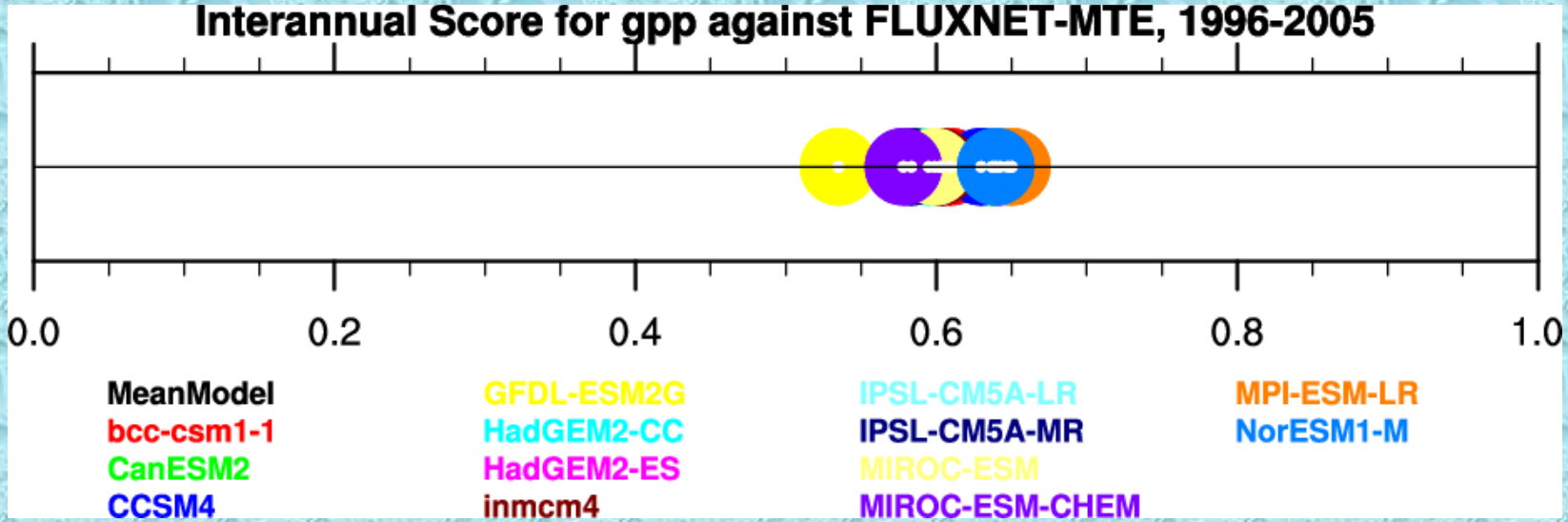
$$S = \frac{4(1+R)}{(\sigma_f + 1/\sigma_f)^2 (1+R_0)}$$

Where R_0 is the maximum correlation, R is the correlation coefficient between model and benchmark, and σ_f is the ratio of standard deviation for model and benchmark. This quantity was area-weighted over all the land grid cells in the model to obtain the global-scale metric .

Ref: Taylor, JGR, 106, 2001

System Scoring Metrics

Interannual Variability Score



$$M = 1 - \frac{\sum_{i=1}^{ncells} \frac{|m_i - o_i|}{m_i + o_i} \times A(i)}{TotalArea}$$

Where m_i is the model coefficient variation at the grid cell corresponding to the observation (o_i) and *ncells* is the number model grid cells. *Ref: Randerson, et al., GCB, 15, 2006*

2. Compare CMIP5 historical with benchmark

CMIP5 vs. Benchmark: Annual Mean

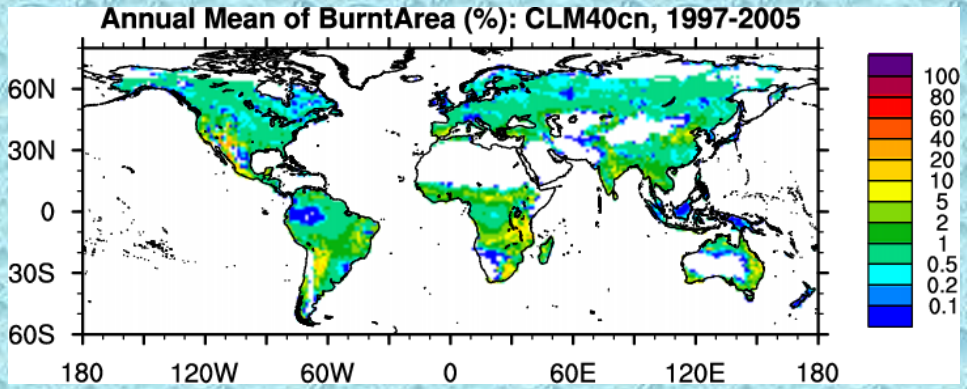
Model	Aboveground Biomass (PgC)	Burned Area (Mha/yr)	Gross Primary Production (PgC/yr)	Latent Heat (W/m^2)	Sensible Heat (W/m^2)
Benchmark	345	379	118	37	26
Mean Model	318	234	133	49	26
bcc-csm1-1	316		117	44	23
CanESM2	310		120	42	31
CCSM4	426	150	126	54	27
GFDL-ESM2G	388		156	50	16
HadGEM2-CC	336		129	50	26
HadGEM2-ES	344		134	51	26
Inmcm4	363		131	53	34
IPSL-CM5A-LR	286		156	44	27
IPSL-CM5A-MR	279		157	44	27
MIROC-ESM	211		113	55	27
MIROC-ESM-CHEM	211		114	55	27
MPI-ESM-LR	246	375	153	49	17
NorESM1-M	421	178	123	53	25

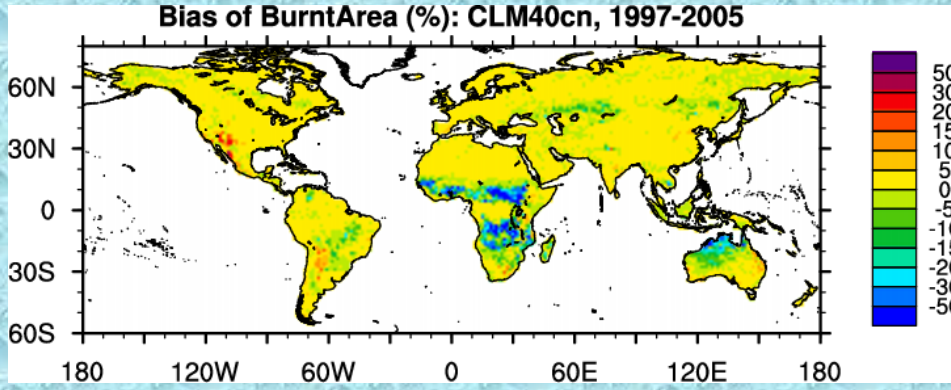
Click here to show more detail

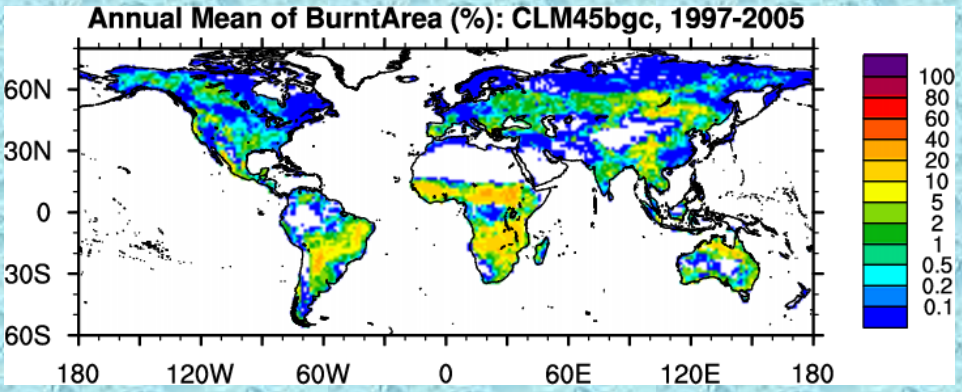
3. Evaluate change between CLM40cn and CLM45bgc

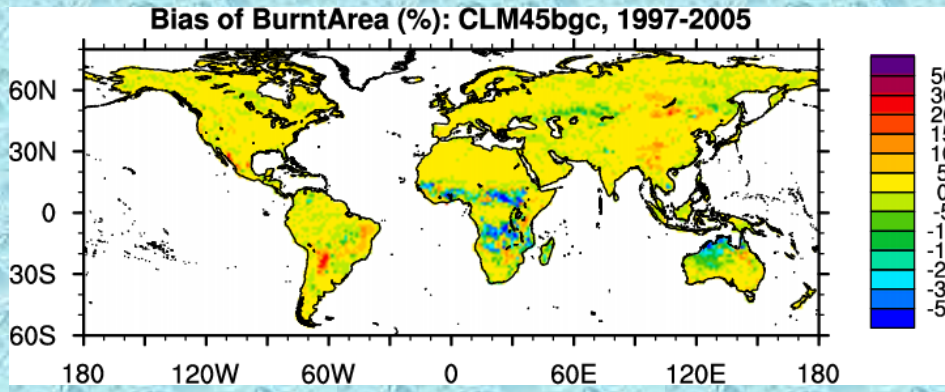
Annual mean for burned Area, 1997-2005

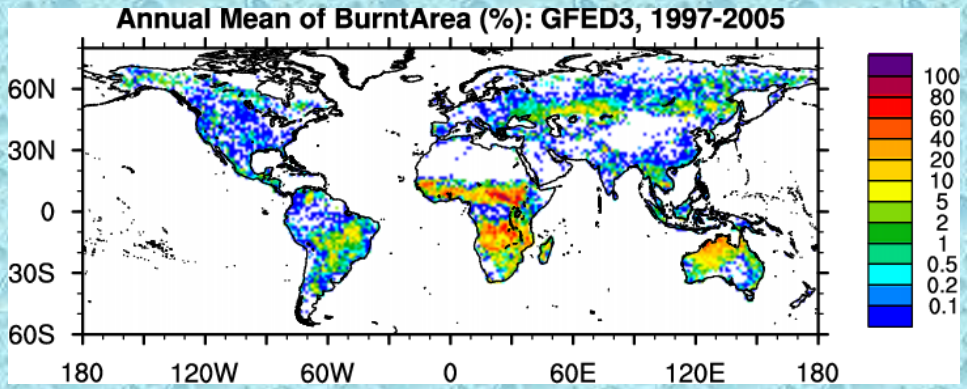
Bias, annual burned area (%), 1997-2005







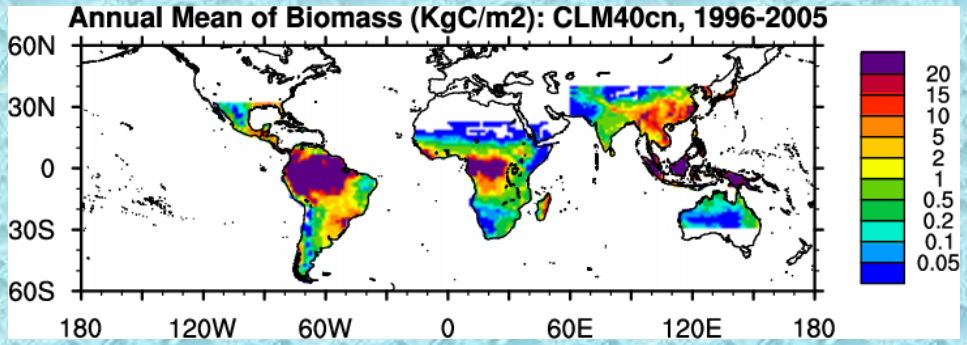


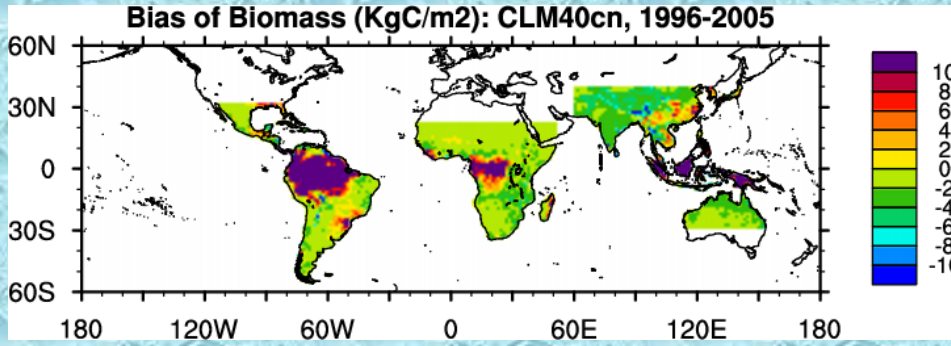


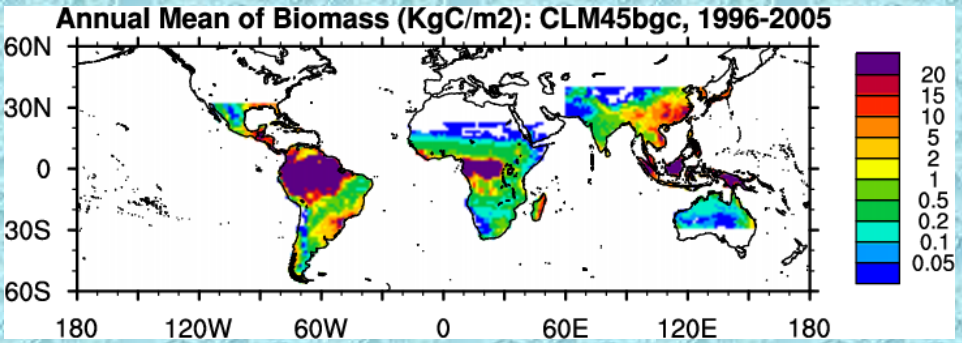
3. Evaluate change between CLM40cn and CLM45bgc

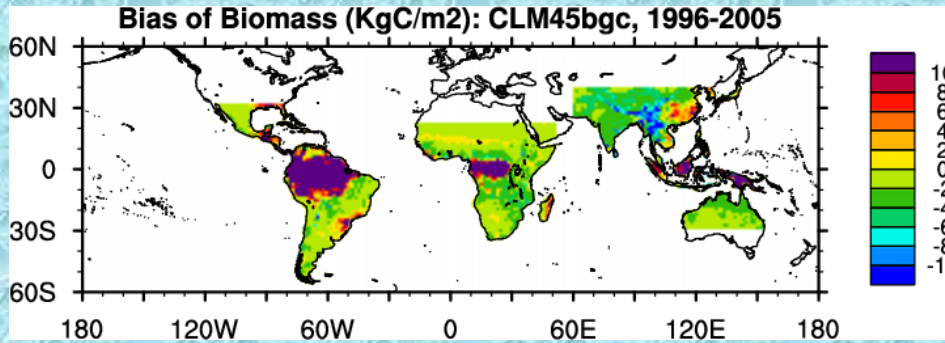
Annual mean, biomass, 1997-2005

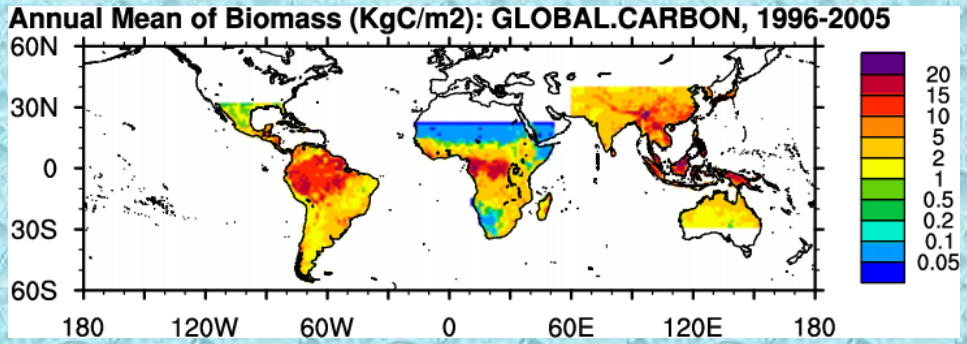
Bias, biomass, 1997-2005



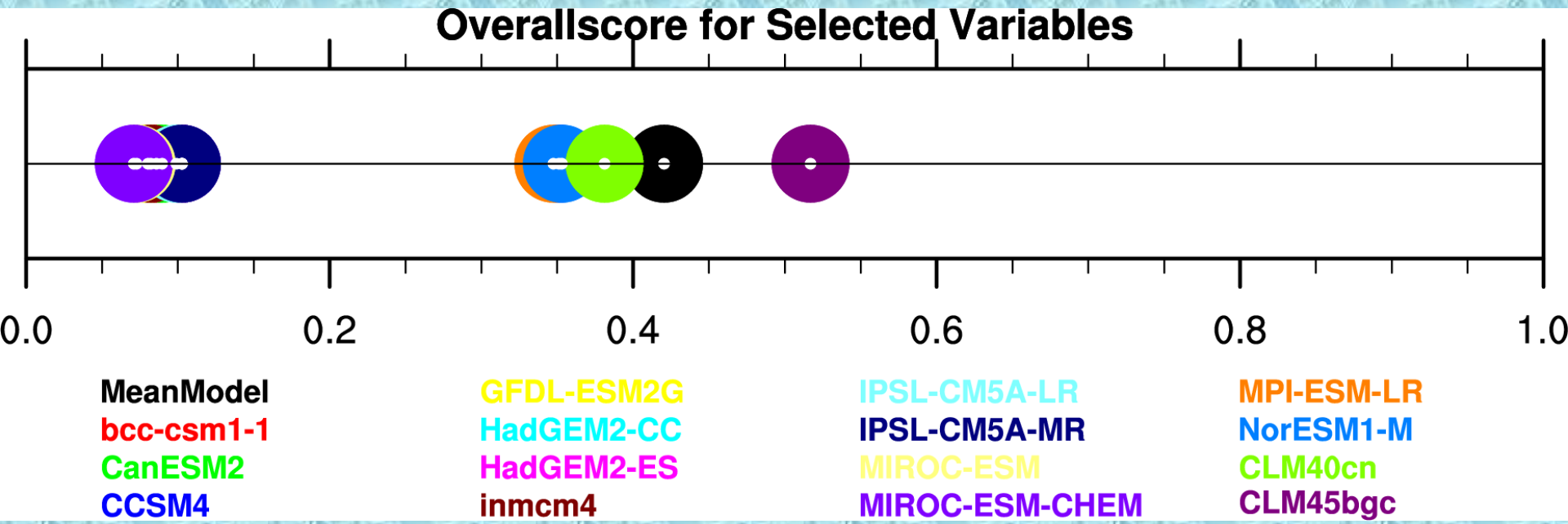








System Scoring Metrics



Acknowledgement

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Thank you!