Example Metrics and Diagnostics

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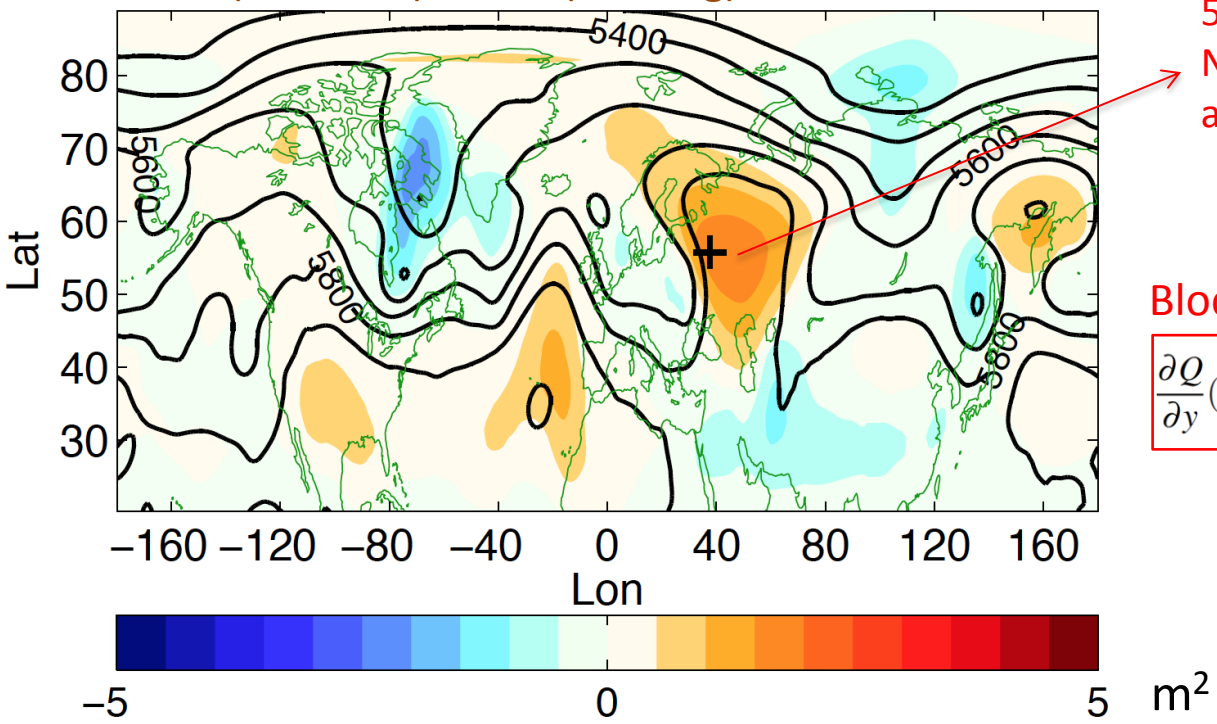
Example Atmospheric Blocking Diagnostic

Finite-amplitude wave activity for circulation extremes

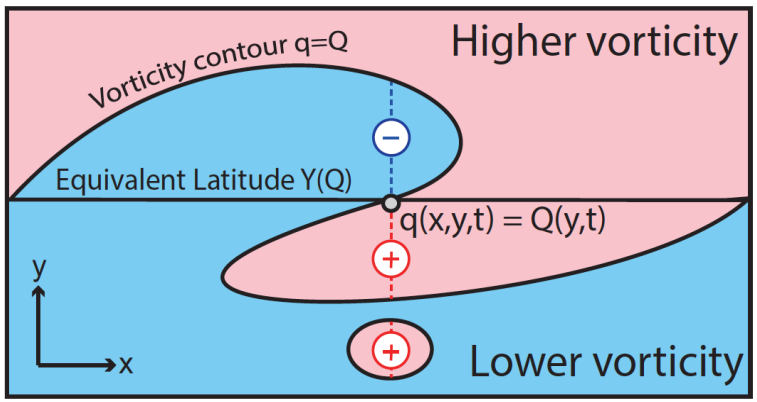
Z500 (contours) and A (shading) on Jul 29, 2010



5x the max of 1std NAO-induced wave activity

Blocking criterion:

$$\frac{\partial Q}{\partial y}(y,z) + \frac{\partial^2 \tilde{A}^*}{\partial y^2}(x,y,z,t) < 0.$$



$$\widetilde{A^*}(x,y,t) \equiv -\int_0^{\eta(x,y,t)} (q(x,y+y',t) - Q(y,t))dy'$$

$$\frac{\partial \widetilde{A^*}}{\partial t} + \nabla \cdot (\vec{F}_{advect} + \vec{F}_{E-P}) = 0$$

where

$$\vec{F}_{advect} = \begin{pmatrix} u_{REF}(y,t)\widetilde{A^*} - \int_0^{\eta}(u_e q_e)dy' \\ 0 \end{pmatrix} \text{ and } \vec{F}_{E-P} = \begin{pmatrix} \frac{v_e^2 - u_e^2}{2} \\ -u_e v_e \end{pmatrix}$$

Metric Scoring for ILAMB Prototype

Global Variables (Info for Weightings)

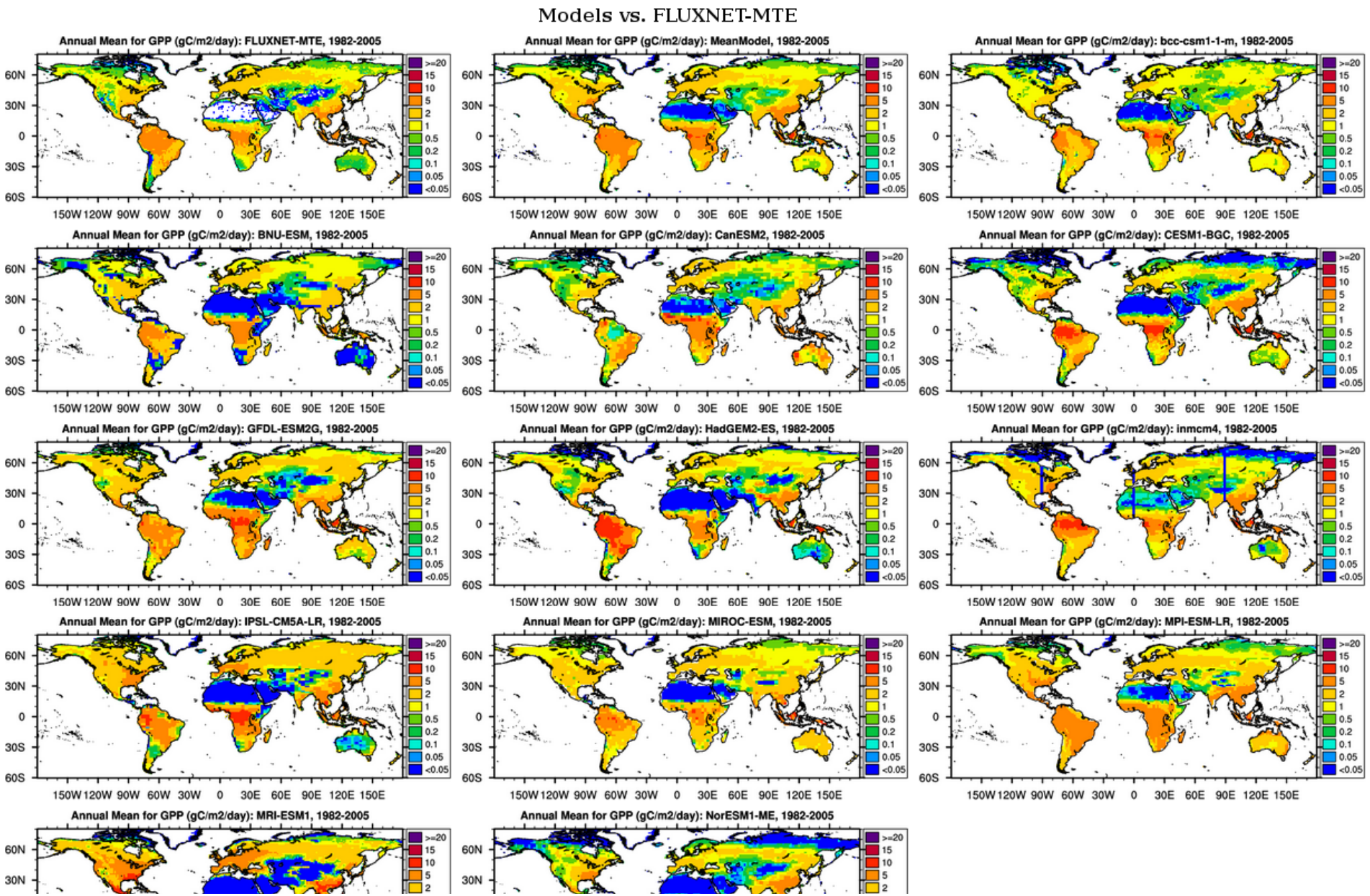
	MeanModel	bcc-csm1-1-m	BNU-ESM	CanESM2	CESM1-BGC	GFDL-ESM2G	HadGEM2-ES	inmcm4	IPSL-CM5A-LR	MIROC-ESM	MPI-ESM-LR	MRI-ESM1	NorESM1-ME
Aboveground Live Biomass	0.71	0.55	0.43	0.65	0.60	0.58	0.67	0.65	0.70	0.57	0.51	0.66	0.60
Burned Area	0.38	-	-	-	0.37	-	-	-	-	-	0.38	-	0.37
Carbon Dioxide	0.80	-	0.71	0.69	0.75	0.69	-	-	-	-	-	0.69	-
Gross Primary Productivity	0.77	0.72	0.73	0.64	0.71	0.67	0.69	0.70	0.66	0.69	0.69	0.52	0.70
Leaf Area Index	0.67	0.67	0.40	0.60	0.55	0.50	0.60	0.68	0.66	0.62	0.68	0.41	0.50
Global Net Ecosystem Carbon Balance	0.52	-	0.18	0.25	0.36	0.20	0.30	0.22	0.28	0.35	0.38	0.16	0.33
Net Ecosystem Exchange	0.49	0.48	0.45	0.39	0.48	0.48	0.47	0.44	0.53	0.47	0.50	0.48	0.48
Ecosystem Respiration	0.74	0.72	0.73	0.65	0.67	0.71	0.66	0.67	0.66	0.69	0.69	0.45	0.67
Soil Carbon	0.55	0.50	0.43	0.56	0.38	0.51	0.51	0.53	0.57	0.53	0.41	0.52	0.39
Summary	0.63	0.60	0.51	0.55	0.54	0.54	0.55	0.54	0.57	0.55	0.52	0.49	0.50
Evapotranspiration	0.75	0.73	0.72	0.72	0.73	0.70	0.74	0.69	0.75	0.71	0.72	0.74	0.71
Latent Heat	0.80	0.76	0.75	0.77	0.78	0.75	0.77	0.73	0.77	0.75	0.76	0.79	0.76
Terrestrial Water Storage Anomaly	0.53	0.46	0.37	0.54	0.48	0.43	0.44	0.52	0.45	0.52	0.56	0.47	0.45
Summary	0.69	0.65	0.61	0.67	0.66	0.63	0.65	0.64	0.65	0.66	0.68	0.67	0.64
Albedo	0.72	0.71	0.62	0.71	0.73	0.69	0.74	0.68	0.70	0.67	0.73	0.64	0.72
Surface Upward SW Radiation	0.77	0.73	0.66	0.74	0.76	0.74	0.76	0.73	0.73	0.71	0.75	0.66	0.75
Surface Net SW Radiation	0.84	0.85	0.84	0.84	0.86	0.86	0.85	0.84	0.82	0.83	0.87	0.85	0.86
Surface Upward LW Radiation	0.90	0.91	0.92	0.91	0.92	0.91	0.92	0.89	0.91	0.90	0.92	0.91	0.91
Surface Net LW Radiation	0.82	0.82	0.82	0.80	0.81	0.82	0.82	0.80	0.78	0.78	0.81	0.82	0.80
Surface Net Radiation	0.79	0.79	0.77	0.79	0.80	0.80	0.80	0.75	0.78	0.76	0.81	0.78	0.80
Sensible Heat	0.76	0.70	0.70	0.71	0.74	0.70	0.75	0.66	0.70	0.69	0.69	0.72	0.72
Summary	0.79	0.78	0.76	0.78	0.80	0.78	0.80	0.75	0.77	0.76	0.79	0.76	0.79
Surface Air Temperature	0.87	0.86	0.87	0.86	0.88	0.86	0.87	0.86	0.86	0.86	0.87	0.88	0.86
Precipitation	0.69	0.67	0.66	0.67	0.71	0.68	0.72	0.68	0.67	0.68	0.70	0.70	0.69
Surface Downward SW Radiation	0.86	0.87	0.88	0.87	0.88	0.88	0.87	0.86	0.83	0.86	0.88	0.87	0.88
Surface Downward LW Radiation	0.90	0.92	0.91	0.91	0.91	0.92	0.93	0.91	0.89	0.91	0.92	0.91	0.91
Summary	0.79	0.77	0.77	0.77	0.80	0.78	0.80	0.78	0.76	0.78	0.79	0.79	0.79
Overall	0.68	0.54	0.57	0.60	0.63	0.59	0.57	0.55	0.57	0.56	0.58	0.57	0.57

Gross Primary Production in ILAMB Prototype

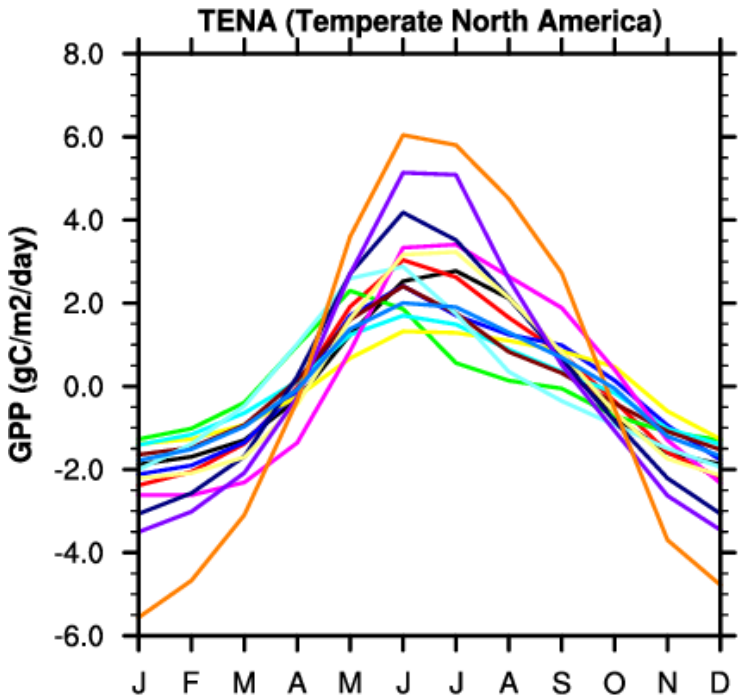
Diagnostic Summary for Gross Primary Productivity: Model vs. FLUXNET-MTE

	Global Patterns				Regional Patterns	Scoring (Info)				
	Annual Mean (PgC/yr)	Bias (PgC/yr)	RMSE (PgC/mon)	Phase Difference (months)	Regional Mean	Global Bias	RMSE	Seasonal Cycle	Spatial Distribution	Overall
Benchmark [Jung et al. (2009)]	118.4	-	-	0.0	access to plots	-	-	-	-	-
MeanModel	146.7	28.3	4.7	0.6	access to plots	0.77	0.73	0.79	0.94	0.79
bcc-csm1-1-m	112.6	-5.8	6.0	-0.2	access to plots	0.71	0.64	0.80	0.89	0.74
BNU-ESM	105.6	-12.8	6.2	-0.1	access to plots	0.69	0.66	0.79	0.83	0.73
CanESM2	129.7	11.3	7.3	0.8	access to plots	0.64	0.60	0.67	0.70	0.64
CESM1-BGC	129.0	10.6	5.7	0.5	access to plots	0.69	0.65	0.76	0.87	0.72
GFDL-ESM2G	168.6	50.2	9.3	0.6	access to plots	0.67	0.56	0.73	0.84	0.67
HadGEM2-ES	138.1	19.7	7.0	0.4	access to plots	0.67	0.60	0.78	0.83	0.70
inmcm4	136.9	18.5	5.7	0.3	access to plots	0.74	0.67	0.76	0.91	0.75
IPSL-CM5A-LR	168.1	49.7	9.0	0.4	access to plots	0.63	0.56	0.77	0.84	0.67
MIROC-ESM	129.2	10.8	6.1	0.3	access to plots	0.72	0.66	0.75	0.85	0.73
MPI-ESM-LR	169.7	51.3	7.5	0.4	access to plots	0.67	0.62	0.70	0.89	0.70

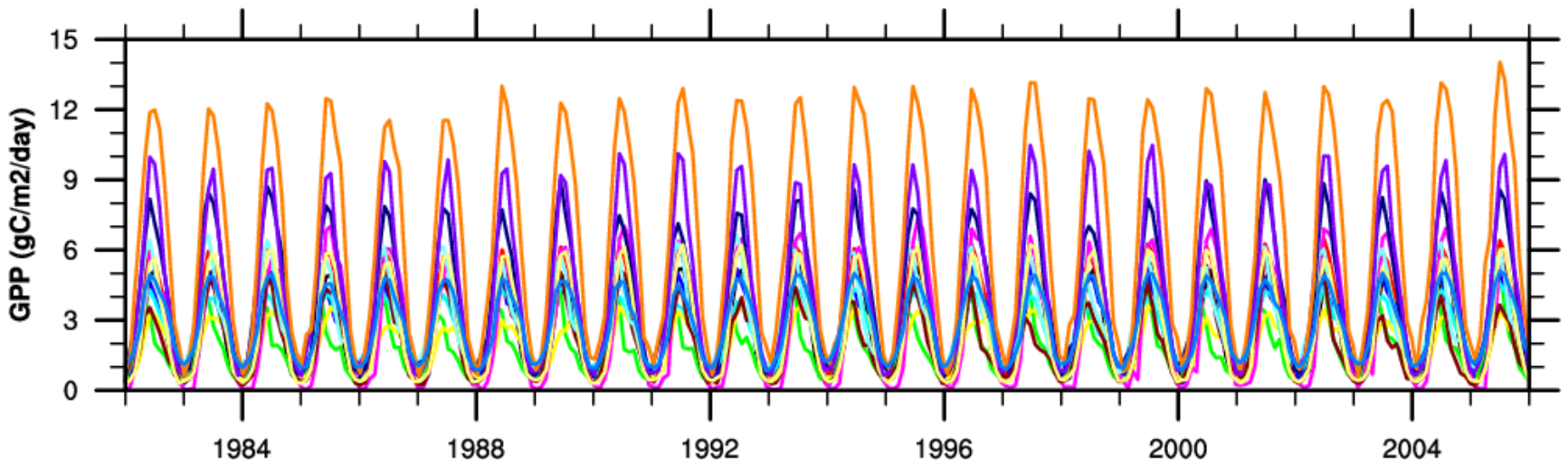
Annual Mean Gross Primary Production



Regional Gross Primary Production



Model	Annual	Bias	RMSE
FLUXNET-MTE	2.36	-999.00	-999.00
MeanModel	3.04	0.68	0.80
bcc-csm1-1-m	1.76	-0.60	1.32
BNU-ESM	2.53	0.17	0.63
CanESM2	1.83	-0.53	1.02
CESM1-BGC	2.41	0.05	0.75
GFDL-ESM2G	2.74	0.38	1.03
HadGEM2-ES	1.99	-0.37	0.84
inmcm4	3.06	0.70	1.20
IPSL-CM5A-LR	3.97	1.61	1.89
MIROC-ESM	2.58	0.22	0.47
MPI-ESM-LR	4.33	1.97	2.44
MRI-ESM1	6.50	4.14	4.86
NorESM1-ME	2.82	0.46	0.70



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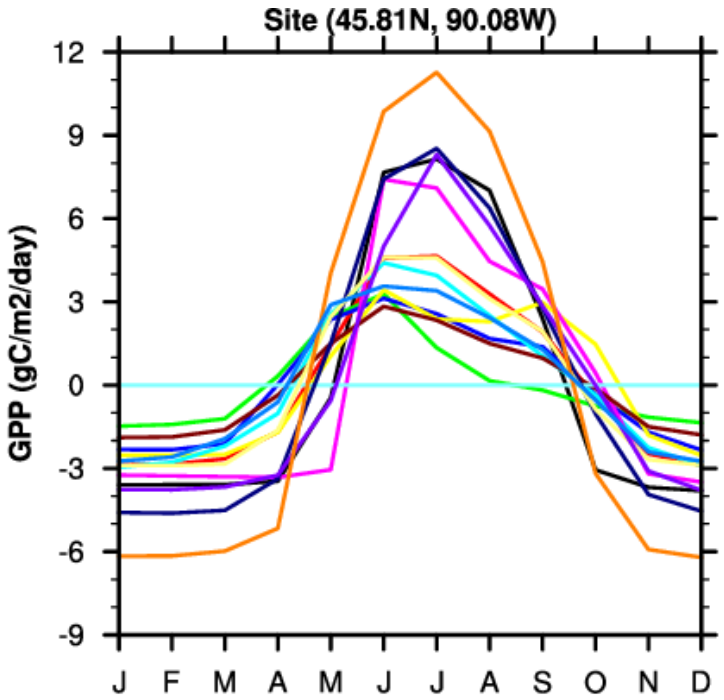
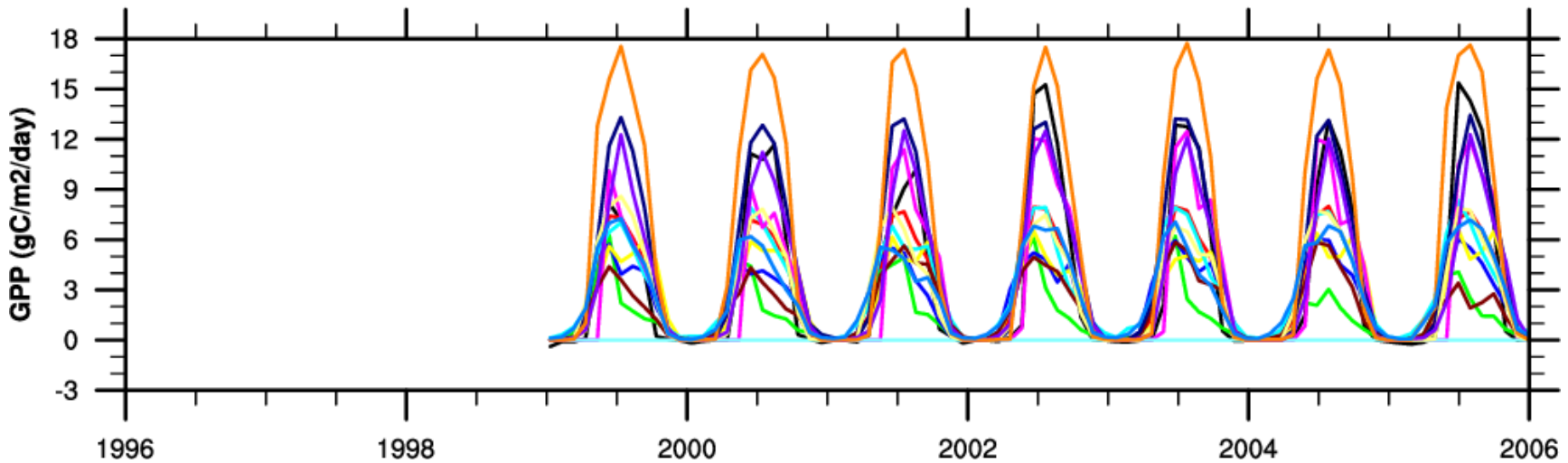
Site Gross Primary Production



Model	Annual	Bias	RMSE
FLUXNET	3.62	-999.00	-999.00
MeanModel	2.94	-0.68	2.61
bcc-csm1-1-m	1.52	-2.10	4.61
BNU-ESM	2.36	-1.26	3.71
CanESM2	2.57	-1.05	3.51
CESM1-BGC	3.13	-0.49	2.93
GFDL-ESM2G	3.38	-0.24	1.99
HadGEM2-ES	1.95	-1.67	4.03
inmcm4	0.00	-3.62	6.13
IPSL-CM5A-LR	4.63	1.01	2.10
MIROC-ESM	2.89	-0.73	2.82
MPI-ESM-LR	3.81	0.19	1.93
MRI-ESM1	6.19	2.57	3.92
NorESM1-ME	2.87	-0.75	3.23



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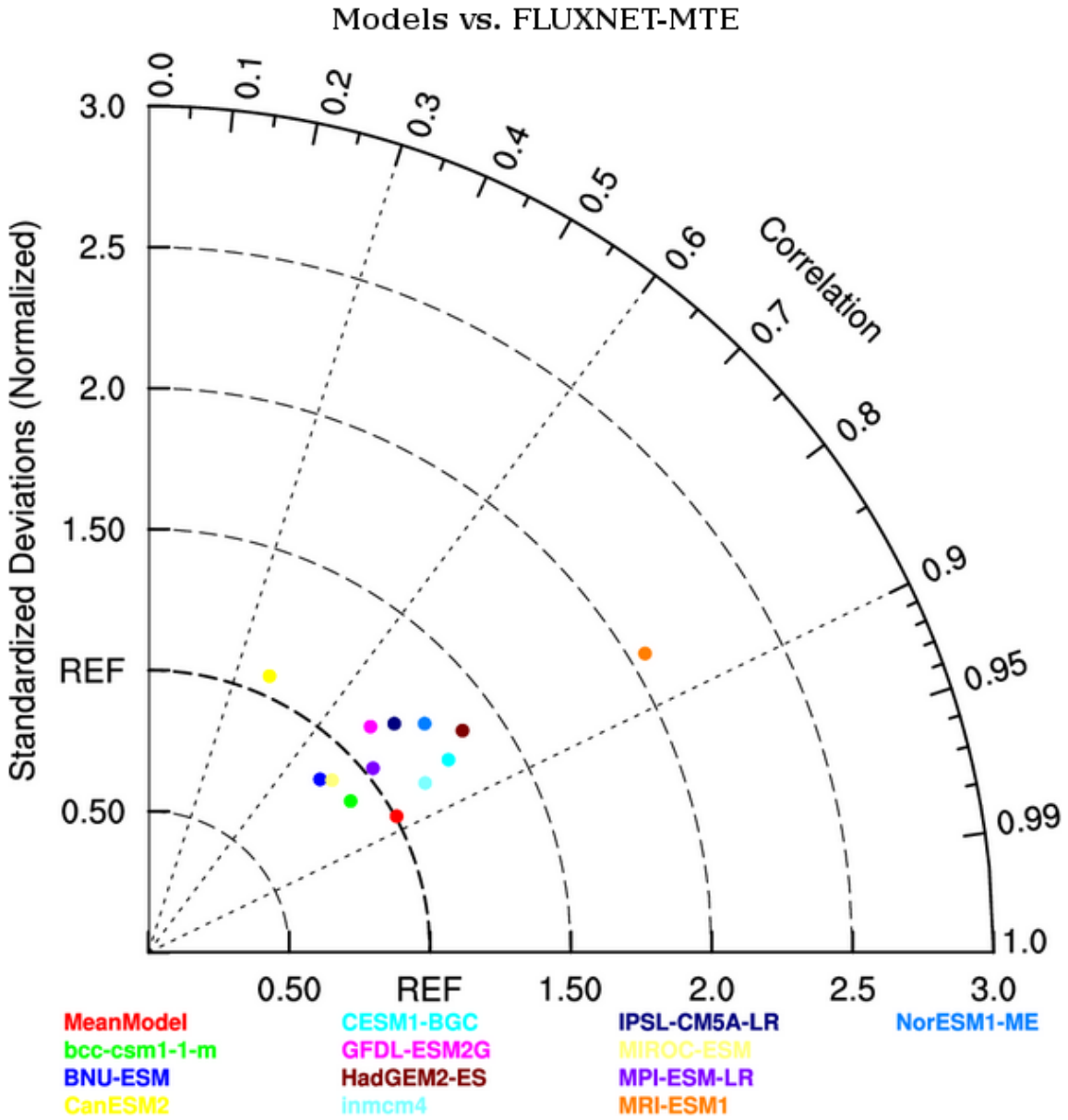
Spatial Correspondence of Gross Primary Production

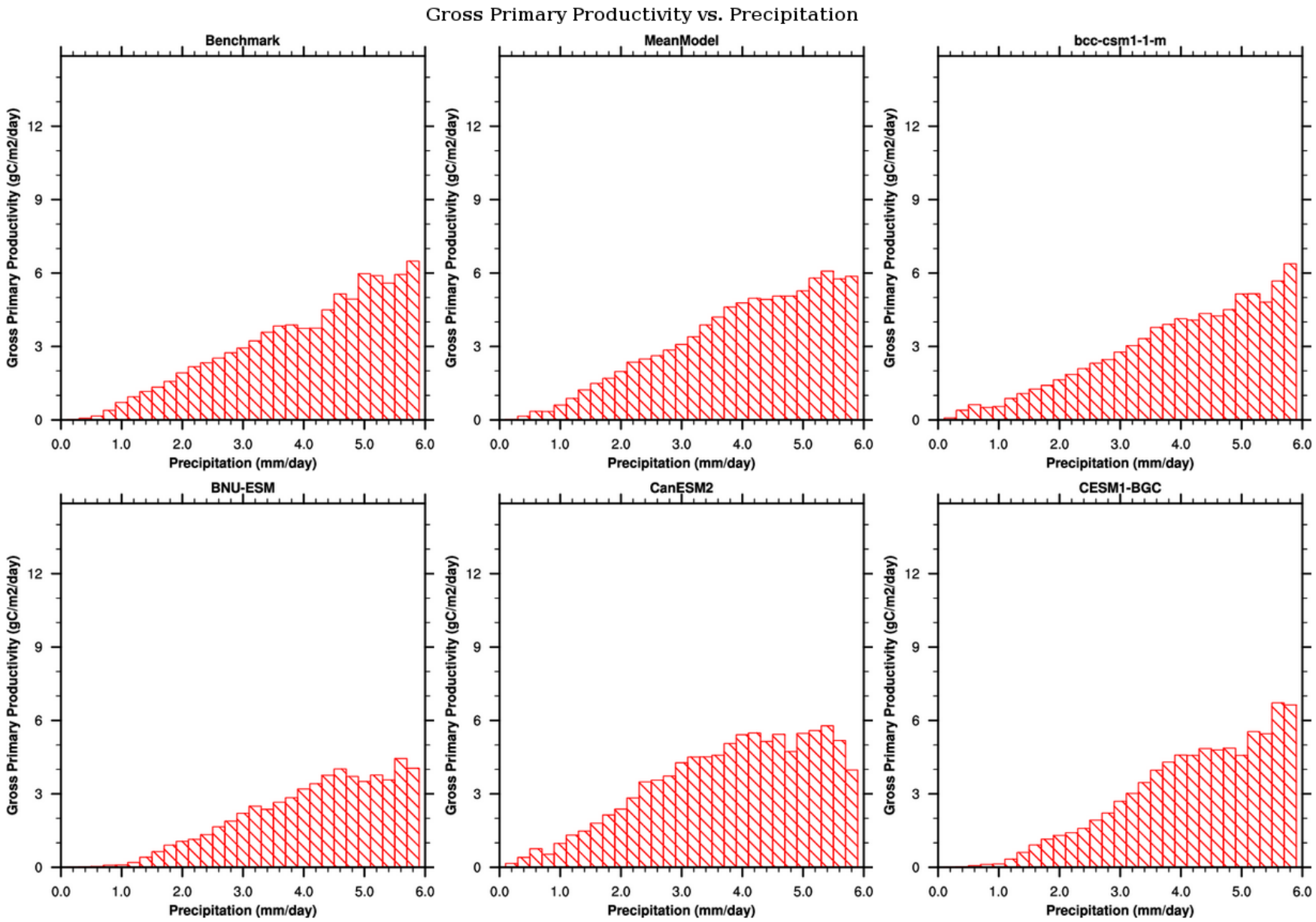


Variable to Variable Relationships

Variable to Variable Relationships (Info for Weightings)

	Relationship	Benchmark	MeanModel	bcc-csm1-1-m	BNU-ESM	CanESM2	CESM1-BGC	GFDL-ESM2G	HadGEM2-ES	inmcm4	IPSL-CM5A-LR	MIROC-ESM	MPI-ESM-LR	MRI-ESM1	NorESM1-ME
Evapotranspiration vs. Gross Primary Productivity	function_bar	1	0.82	0.79	0.62	0.85	0.73	0.89	0.83	0.76	0.86	0.74	0.88	0.60	0.69
Precipitation vs. Burned Area	function_bar	1	0.44	-	-	-	0.46	-	-	-	-	-	0.43	-	0.45
Precipitation vs. Evapotranspiration	function_bar	1	0.71	0.81	0.78	0.80	0.69	0.75	0.68	0.69	0.75	0.74	0.74	0.78	0.67
Precipitation vs. Gross Primary Productivity	function_bar	1	0.89	0.90	0.73	0.77	0.86	0.78	0.74	0.88	0.70	0.83	0.69	0.37	0.84
Precipitation vs. Leaf Area Index	function_bar	1	0.63	0.68	0.34	0.58	0.56	0.43	0.50	0.86	0.59	0.68	0.77	0.20	0.59
Surface Downward SW Radiation vs. Gross Primary Productivity	function_bar	1	0.74	0.79	0.77	0.65	0.72	0.59	0.68	0.66	0.48	0.67	0.53	0.28	0.69
Surface Net SW Radiation vs. Gross Primary Productivity	function_bar	1	0.77	0.82	0.62	0.68	0.76	0.66	0.78	0.74	0.60	0.64	0.59	0.40	0.74
Surface Air Temperature vs. Burned Area	function_bar	1	0.41	-	-	-	0.43	-	-	-	-	-	0.43	-	0.46
Surface Air Temperature vs. Evapotranspiration	function_bar	1	0.68	0.75	0.63	0.83	0.64	0.66	0.65	0.58	0.74	0.65	0.77	0.72	0.60
Surface Air Temperature vs. Gross Primary Productivity	function_bar	1	0.78	0.76	0.67	0.73	0.69	0.68	0.75	0.58	0.61	0.70	0.56	0.36	0.63
Overall			0.70	0.65	0.54	0.62	0.66	0.58	0.59	0.59	0.56	0.58	0.65	0.40	0.64

Gross Primary Production vs. Precipitation



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Metric Scoring for Next Generation System

Ecosystem and Carbon Cycle

	bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4	CESM1-BGC	GFDL-ESM2G	HadGEM2-CC	HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MRI-ESM1	NorESM1-M	NorESM1-ME
Biomass	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Burned Area	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Carbon Dioxide	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Gross Primary Productivity	0.53	0.57	0.52	0.47	0.52	0.52	0.52	0.51	0.51	0.05	0.50	0.52	0.55	0.55	0.55	0.45	0.54	0.54
Leaf Area Index	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Global Net Ecosystem Carbon Balance	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Net Ecosystem Exchange	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Ecosystem Respiration	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Soil Carbon	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~

Hydrology Cycle

	bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4	CESM1-BGC	GFDL-ESM2G	HadGEM2-CC	HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MRI-ESM1	NorESM1-M	NorESM1-ME
Evapotranspiration	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Latent Heat	0.39	0.39	0.43	0.36	0.44	0.44	0.41	0.42	0.42	0.40	0.44	0.42	0.43	0.43	0.40	0.41	0.45	0.45
Fluxnet-MTE (75.0%)	0.27	0.26	0.31	0.28	0.31	0.31	0.29	0.28	0.28	0.28	0.31	0.30	0.34	0.34	0.28	0.27	0.34	0.33
Fluxnet (25.0%)	0.77	0.76	0.78	0.60	0.83	0.83	0.78	0.86	0.85	0.77	0.83	0.78	0.71	0.71	0.76	0.82	0.79	0.78
Terrestrial Water Storage Anomaly	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~

Radiation and Energy Cycle

	bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4	CESM1-BGC	GFDL-ESM2G	HadGEM2-CC	HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MRI-ESM1	NorESM1-M	NorESM1-ME
Albedo	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Surface Upward SW Radiation	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Surface Net SW Radiation	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Surface Upward LW Radiation	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Surface Net LW Radiation	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Surface Net Radiation	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Sensible Heat	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~

Forcings

	bcc-csm1-1	bcc-csm1-1-m	BNU-ESM	CanESM2	CCSM4	CESM1-BGC	GFDL-ESM2G	HadGEM2-CC	HadGEM2-ES	inmcm4	IPSL-CM5A-LR	IPSL-CM5A-MR	MIROC-ESM	MIROC-ESM-CHEM	MPI-ESM-LR	MRI-ESM1	NorESM1-M	NorESM1-ME
Surface Air Temperature	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Precipitation	0.36	0.35	0.36	0.36	0.37	0.37	0.35	0.36	0.36	0.34	0.35	0.35	0.36	0.36	0.35	0.35	0.36	0.36
Surface Downward SW Radiation	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Surface Downward LW Radiation	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~

Gross Primary Production in Next Generation System

GPPFluxnetGlobalM

www.climatemodeling.org/~nate/ILAMB/GPP/GPPFluxnetGlobalMTE.html

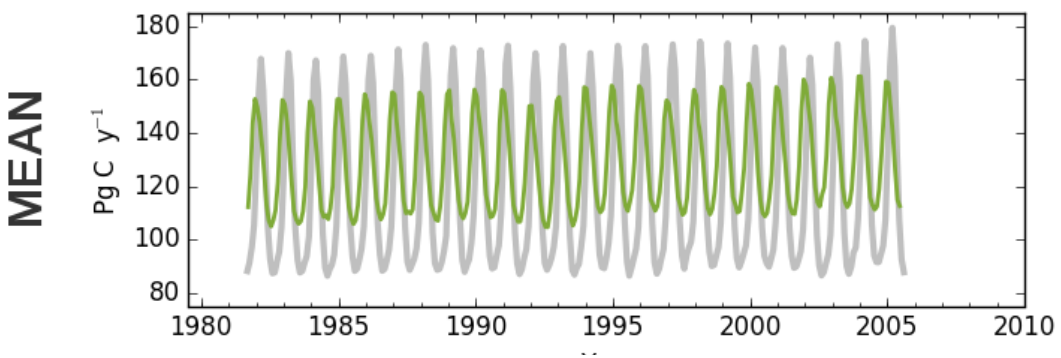
GPPFluxnetGlobalMTE / CESM1-BGC / global

global (global)

Model	Data	PeriodMean [Pg y^{-1}]	Bias [Pg y^{-1}]	RMSE [Pg y^{-1}]	PhaseShift [day]	BiasScore [-]	RMSEScore [-]	SeasonalCycleScore [-]	OverallScore [-]
bcc-csm1-1-m	[-]	112.727	-5.899	33.79	-50.776	0.951	0.758	0.409	0.719
BNU-ESM	[-]	105.936	-12.899	34.291	-53.531	0.897	0.755	0.395	0.701
CanESM2	[-]	130.126	11.341	25.989	-20.747	0.909	0.809	0.312	0.71
CESM1-BGC	[-]	129.312	10.542	30.063	-43.588	0.915	0.782	0.357	0.709
GFDL-ESM2G	[-]	169.109	50.129	66.266	-36.42	0.655	0.582	0.33	0.537
HadGEM2-ES	[-]	138.378	19.617	35.684	-42.434	0.848	0.747	0.329	0.668
inmcm4	[-]	137.359	18.594	35.237	-45.911	0.855	0.75	0.387	0.685
IPSL-CM5A-LR	[-]	168.765	49.83	76.518	-43.621	0.657	0.535	0.334	0.515
MIROC-ESM	[-]	129.69	10.816	40.742	-43.305	0.913	0.717	0.356	0.676
MRI-ESM1	[-]	244.217	125.162	138.38	-45.615	0.348	0.323	0.351	0.336
MultiModelMean	[-]	139.988	21.295	40.77	-41.101	0.836	0.716	0.305	0.643
NorESM1-ME	[-]	130.348	11.57	30.453	-39.748	0.907	0.78	0.37	0.709

Temporally integrated period mean

Spatially integrated regional mean



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Future Ocean Biogeochemistry Metrics

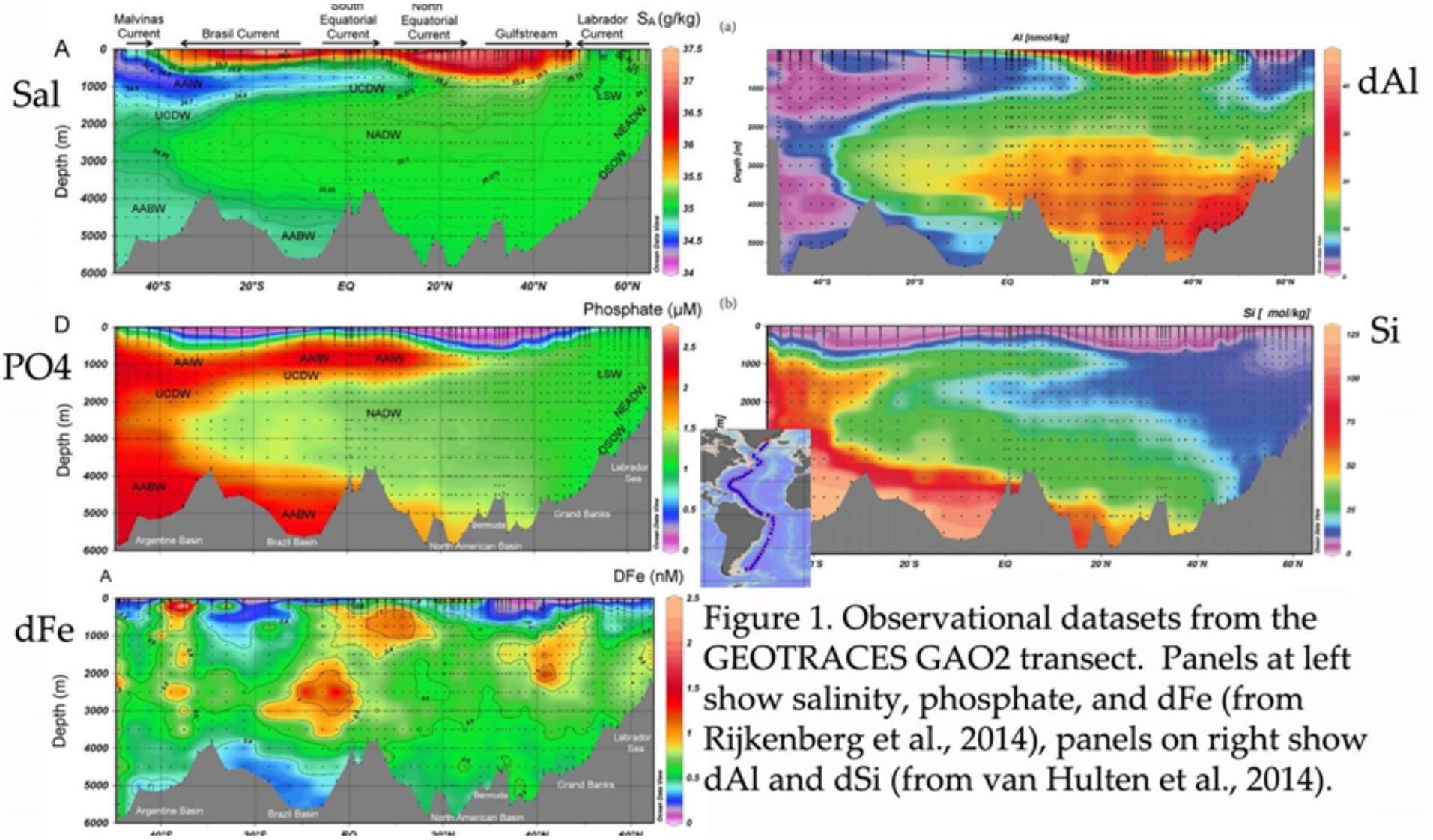
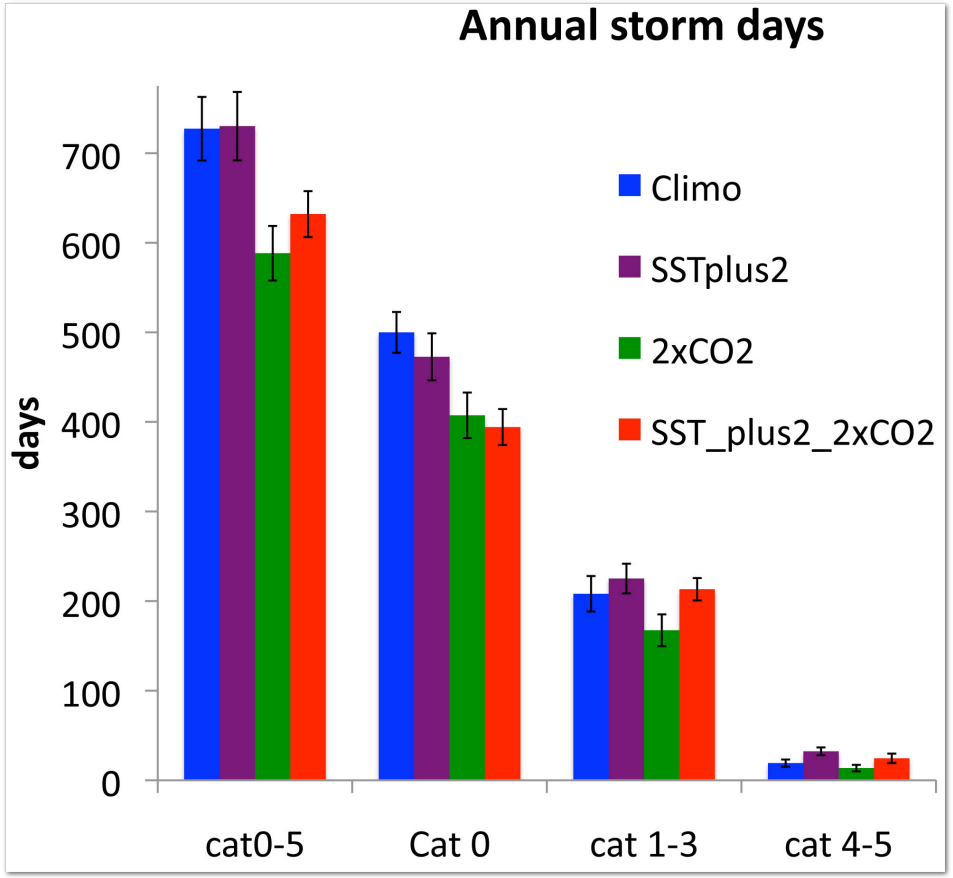


Figure 1. Observational datasets from the GEOTRACES GAO2 transect. Panels at left show salinity, phosphate, and dFe (from Rijkenberg et al., 2014), panels on right show dAl and dSi (from van Hulten et al., 2014).

Storm Metrics – Tropical Cyclones

- # of storms per year
  - global and by basin
  - fraction of Atlantic cyclogenesis in the Caribbean
- # of storm days per year
- Intensity distribution according to Sapphir-Simpson scale
  - S-S is a point wise measure
  - better alternatives would be characteristic of the whole storm
  - some alternate measures of storm properties at the surface:
    - accumulate cyclone energy
    - integrated kinetic energy
    - power dissipation index
    - cyclone damage potential
    - hurricane hazard index



Wehner et al. (2015)

- Future measures could characterize the vertical structure of TCs
- Size or radius is also important
- **Computationally intensive!**

Storm Metrics – Others

Extra-tropical Cyclones

- # of ETCs each year is presently unknown

Atmospheric Rivers

- AR on the west coast are well characterized
- not so much anywhere else
- definition is quite arbitrary in any event