Development and Scientific Simulations of the CAM Aquaplanet

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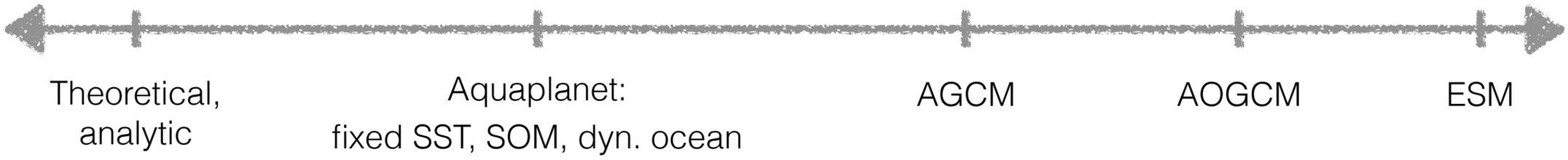
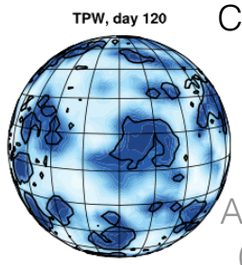
Introduction

- Held (2005, BAMS): Gap has developed between idealized models and comprehensive earth system models



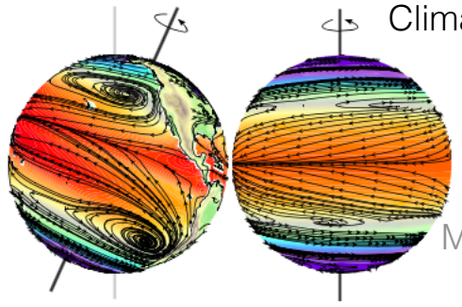
- Utility of aquaplanet models
  - Limitations: Loss of certain climate component interactions (ocean boundary currents, circulations driven by differential surface heat capacity or topography, etc.)
  - Strengths: "Clean" foundation for advancing hypotheses; testbed to develop and examine interactions of dynamics and parameterized physics
- Examples

Convection, MJO



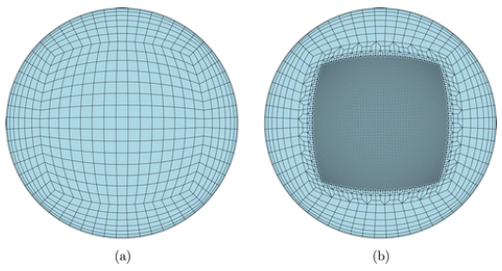
Arnold & Randall (2016, JAMES)

Climate Dynamics



Medeiros et al. (2015, CD)

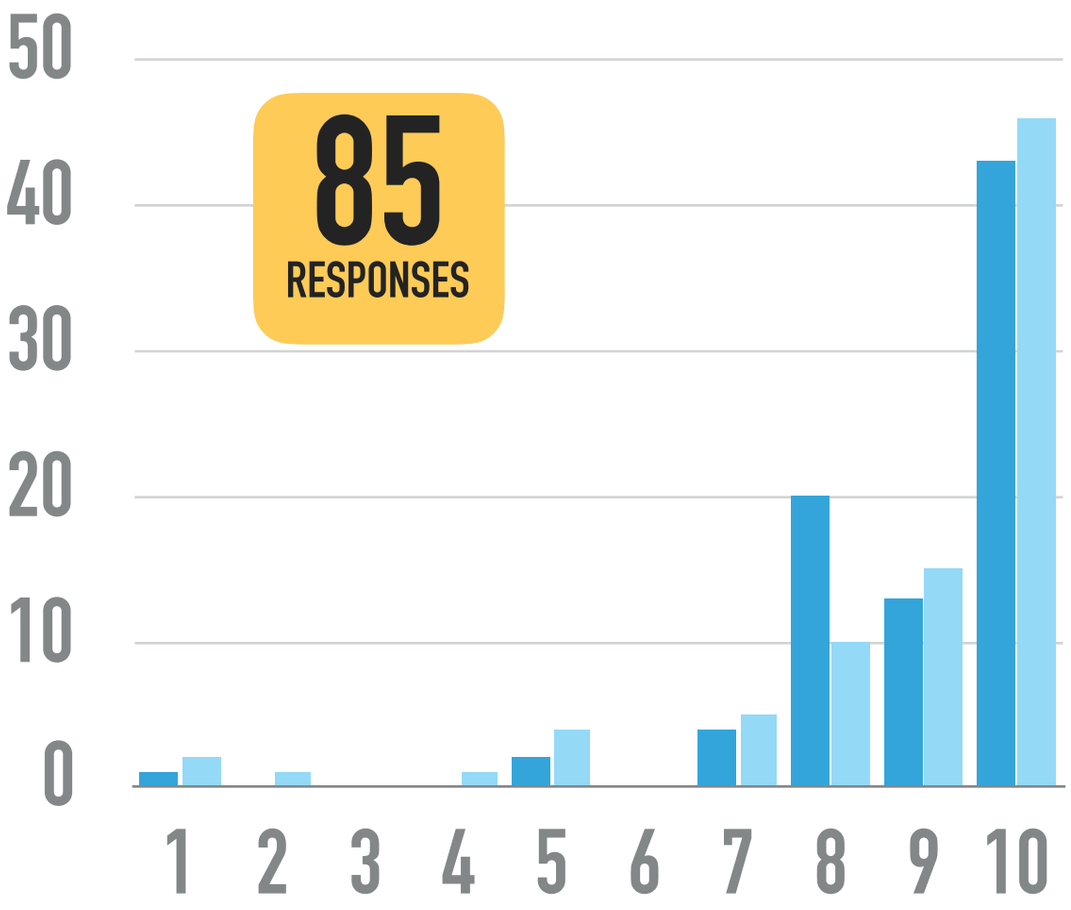
Grid, Parameterization Sensitivities



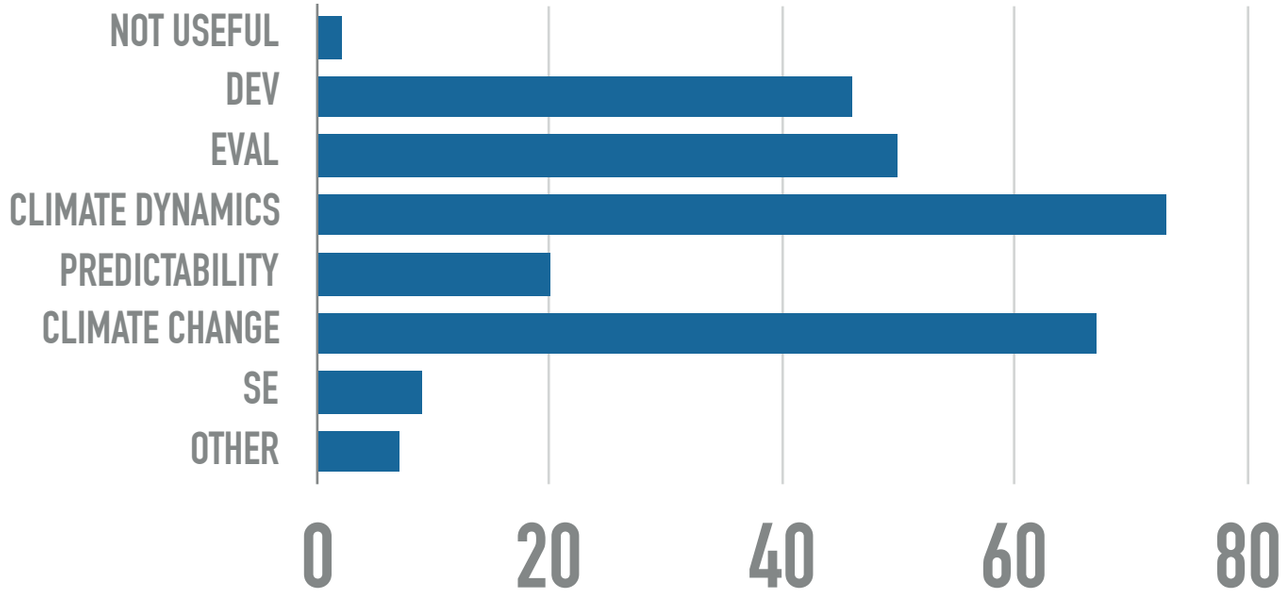
Zarzycki et al. (2014, JC)

- Community interest…

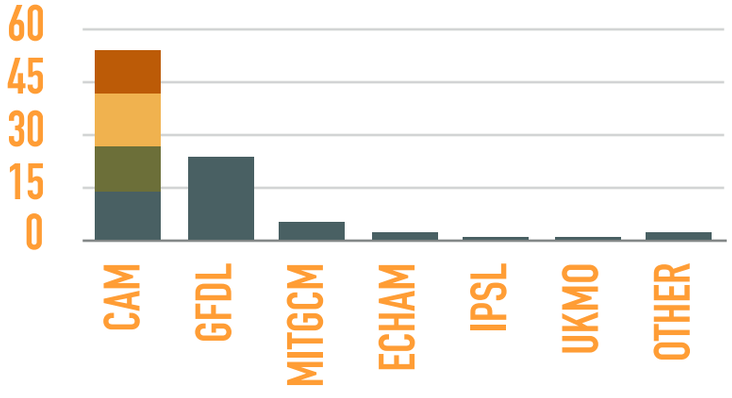
GENERAL INTEREST



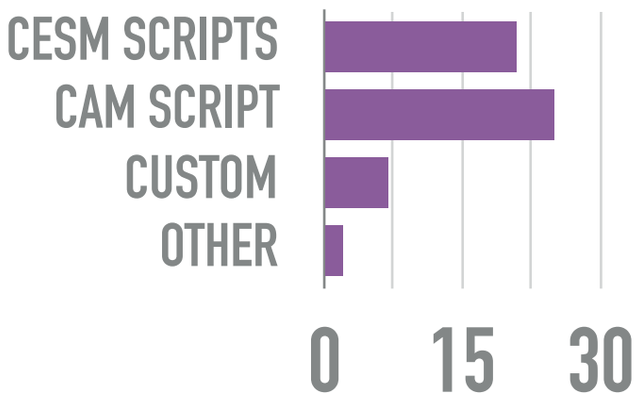
APPLICATIONS

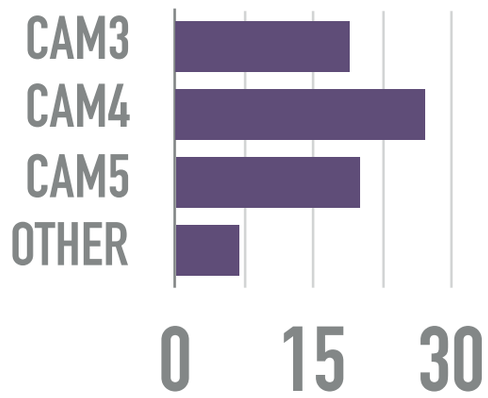


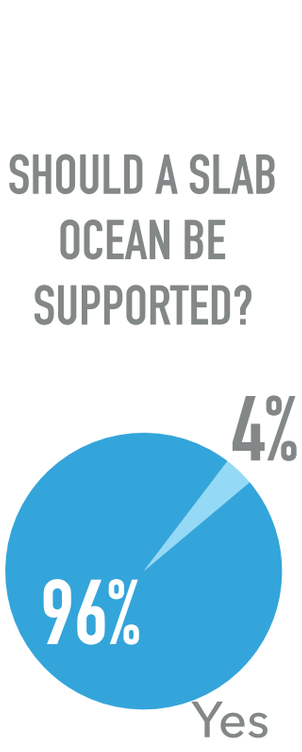
AQUAPLANET MODELS, PHYSICS

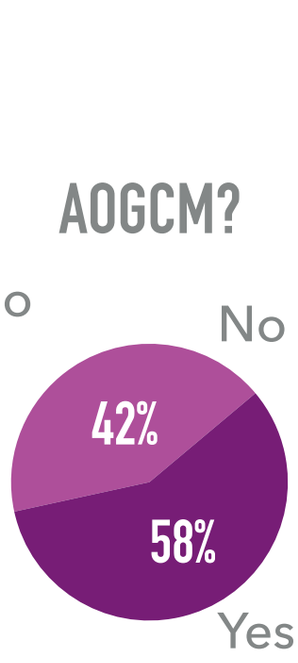


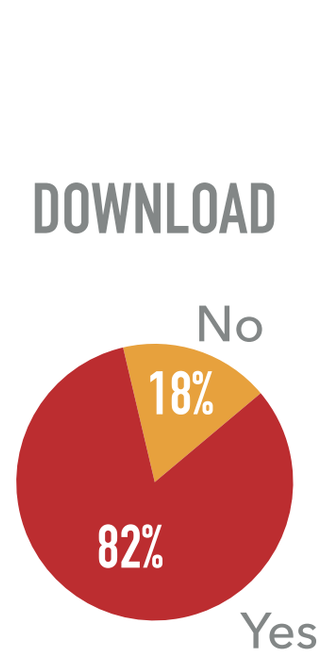
EXPERIENCE WITH CESM AQUAPLANET

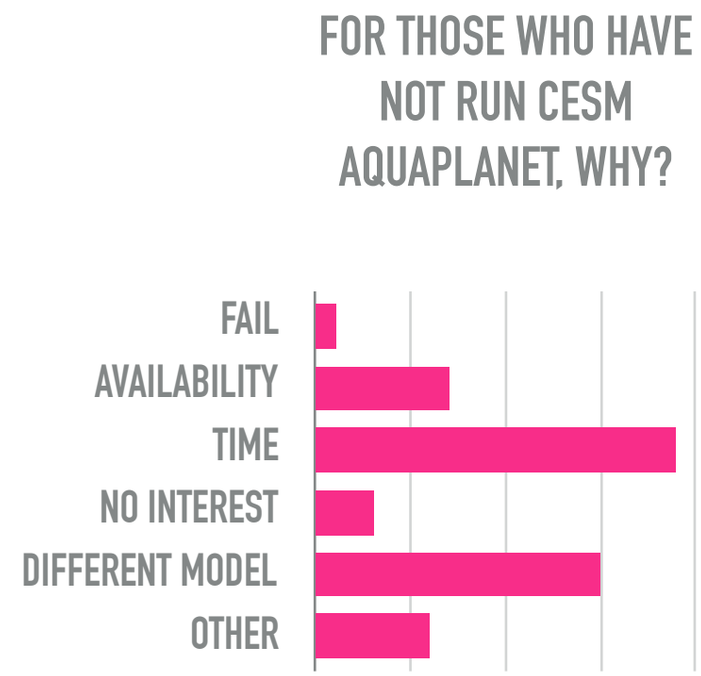


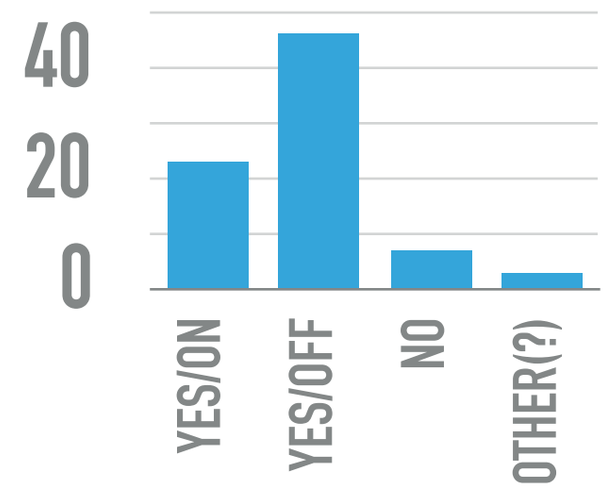












Introduction (cont.)

- Project goals (Year 1)
  - Test functionality of slab-ocean (SOM) aquaplanet in CAM 4, 5, & 6
  - Develop SOM compsets for CAM 4, 5, & 6 → CESM2
  - Provide scientific documentation and informal users guide
  - Deliver subset of “DECK” simulations as baseline reference (to be available on ESG)
  - Explore SOM configuration and resolution sensitivities, hydrocycle, and extremes

Aquaplanet Simulation Settings

CAM 4,
CAM 5.3,
CAM 6

Ocean	Run Type	Sim. Yrs
Fixed-SST	Development	20
Fixed-SST	Production: AMIP	21
Fixed-SST	Production: CMIP/CFMIP	12
SOM	Development	100
SOM	Production: “Baseline”	60+
SOM	Production: CO2 1%/yr	140
SOM	Production: 4x CO2	60+

Currently…

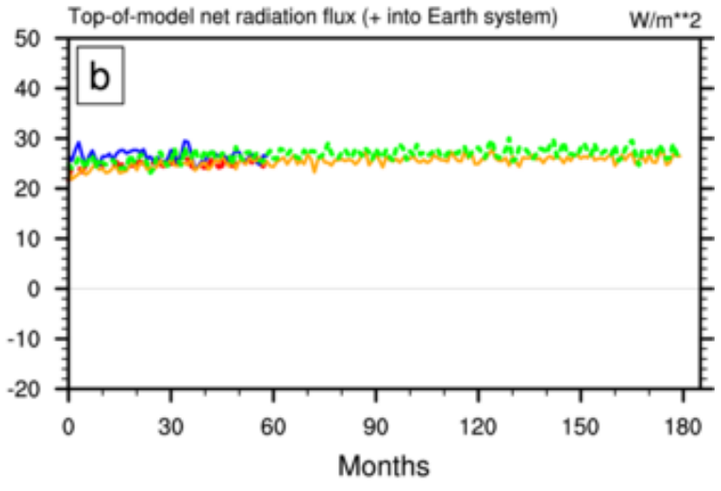
- Target horizontal resolution is 1°, some 2° runs will also be done
- All runs: FV dycore, no seasonality
- All fixed-SST runs forced by zonally symmetric “Qobs” SST profile
- All slab ocean runs use a zonally symmetric Q-flux and a globally constant 50 m oceanic mixed-layer depth

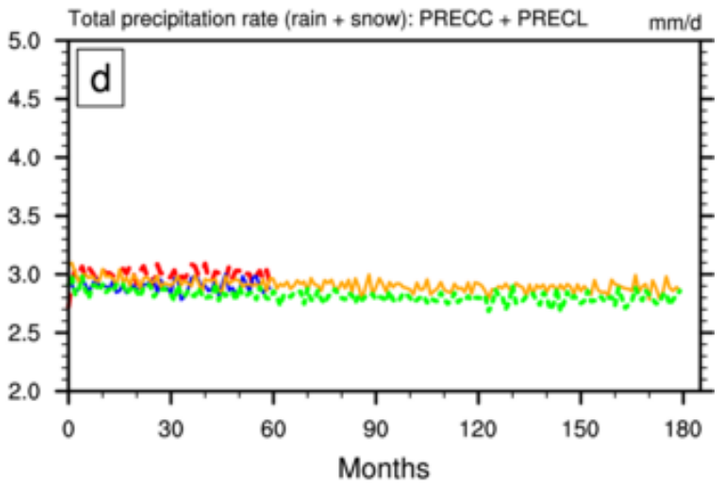
$$\rho_o c_p h \frac{\partial \mathrm{SST}}{\partial t} = F_{\mathrm{net}} + Q_{\mathrm{flx}}$$

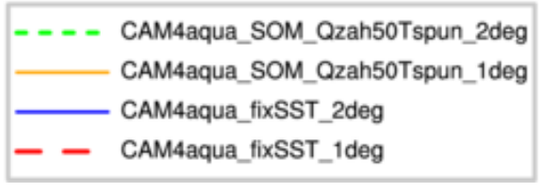
Kiehl at al. (2006, JC)

Results: Spin-up & Time Mean

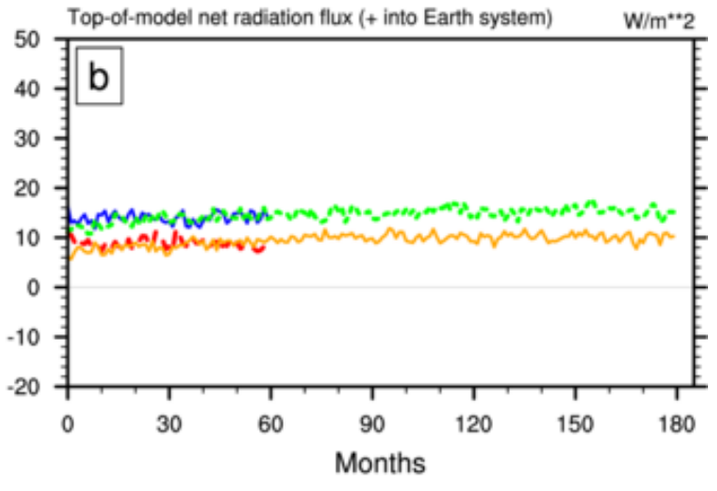
CAM 4

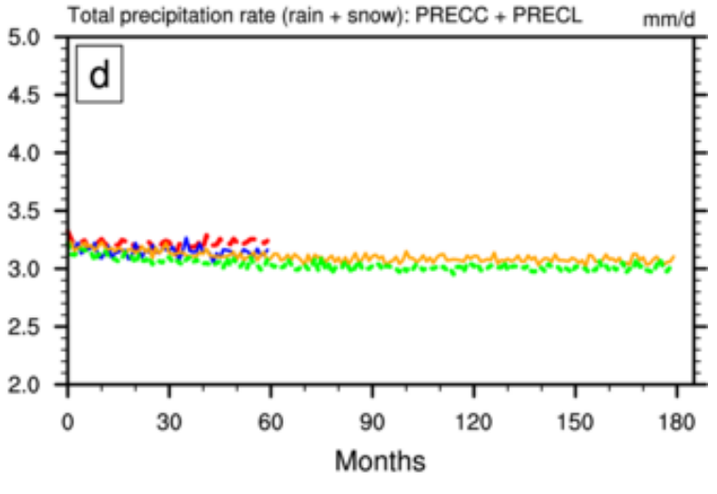


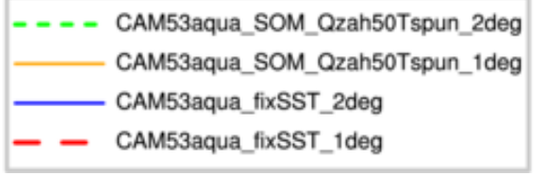


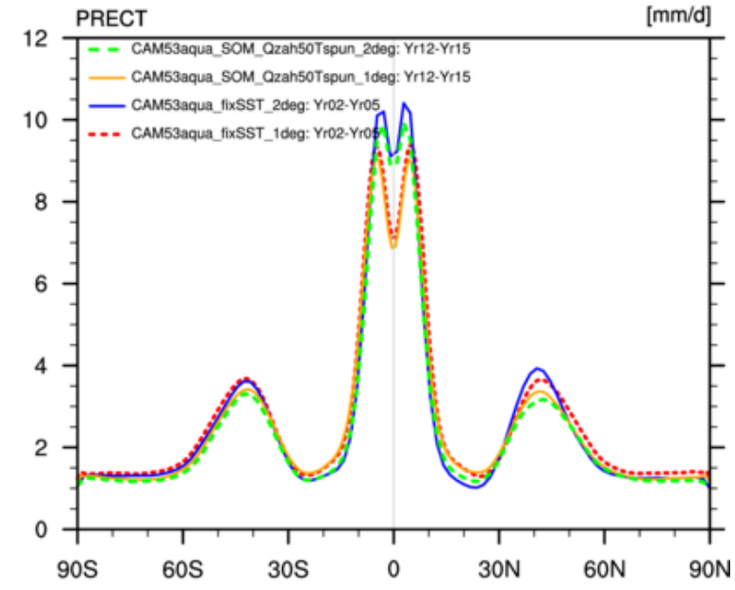


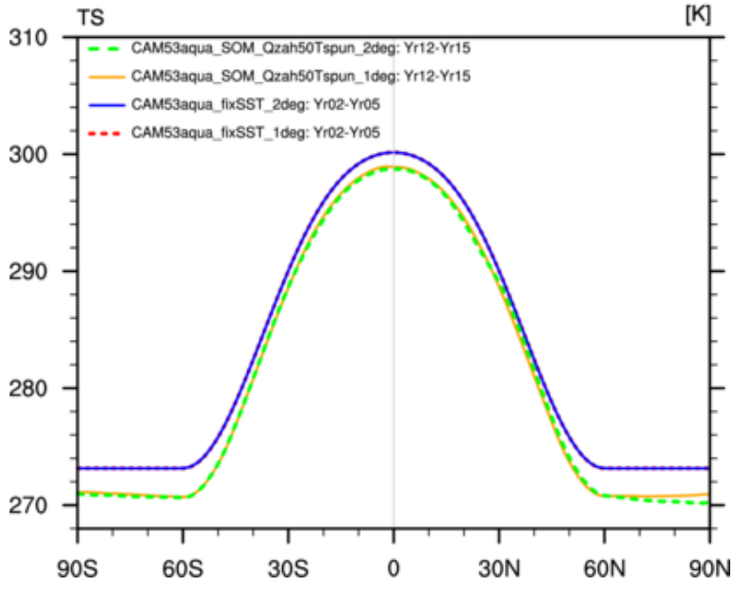
CAM 5.3









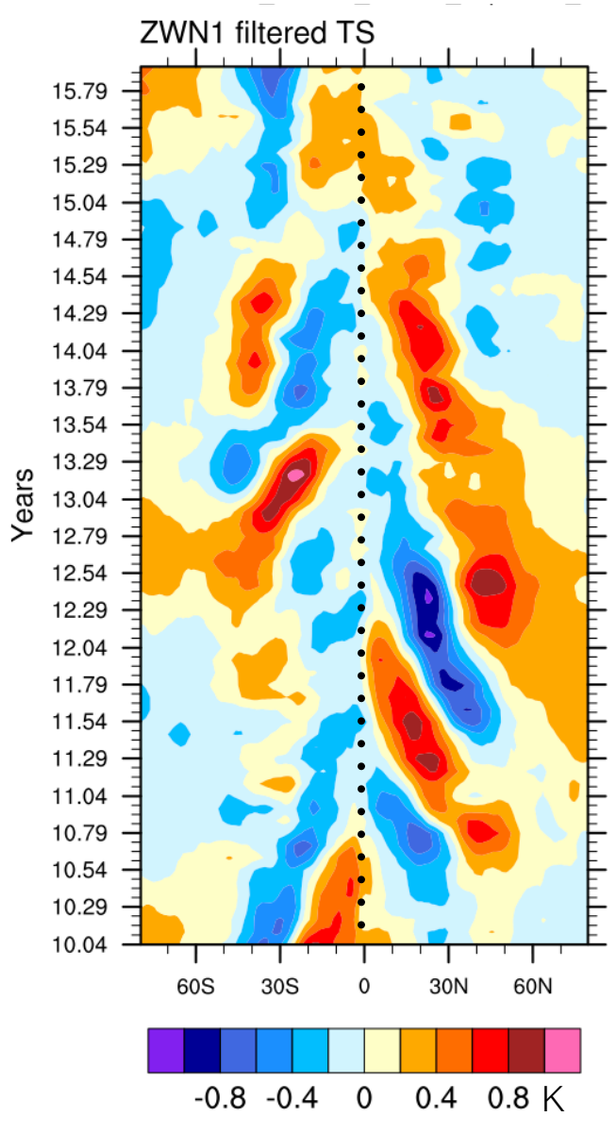


Results: Variability

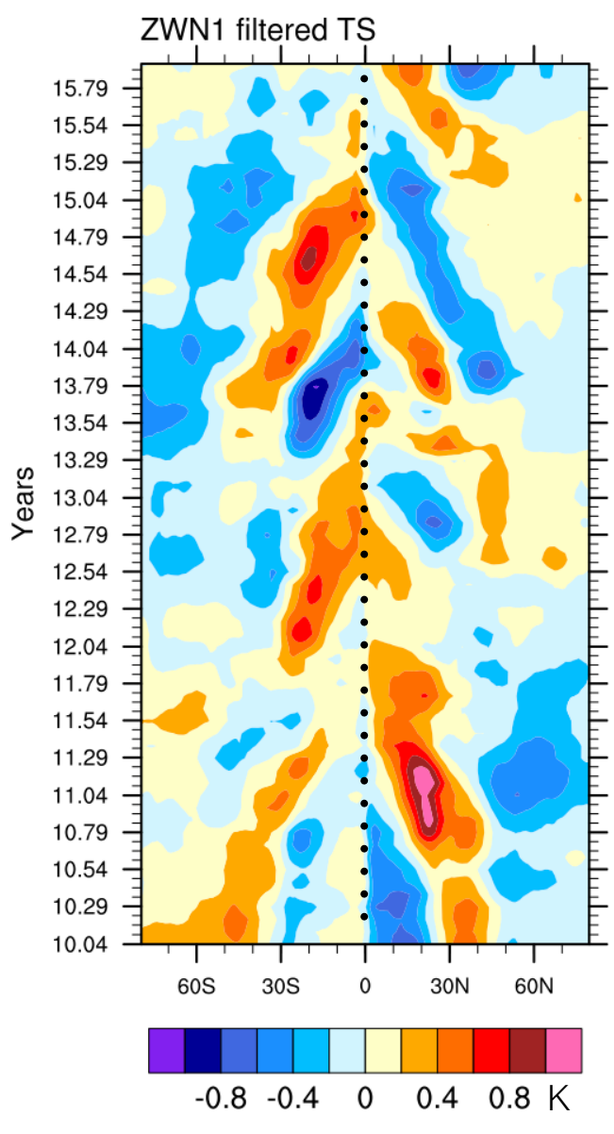
"Lollipop mode": Masked in the real world? Relevance?

Wang (2010, JAS); Zhang (2016, JC)

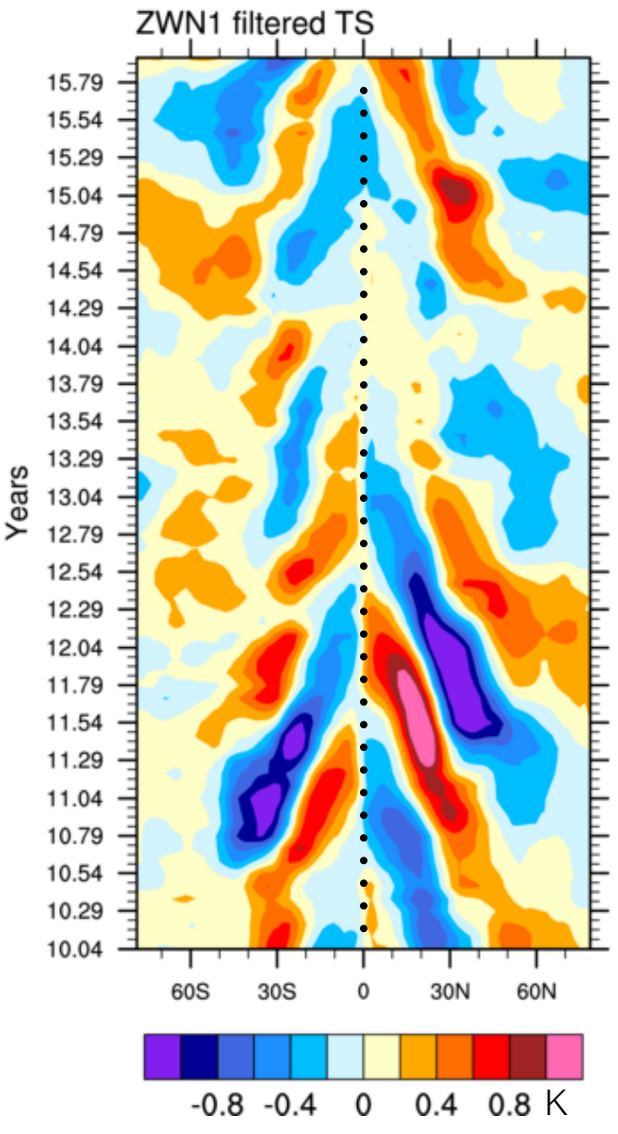
1° CAM 4 SOM



1° CAM 5.3 SOM



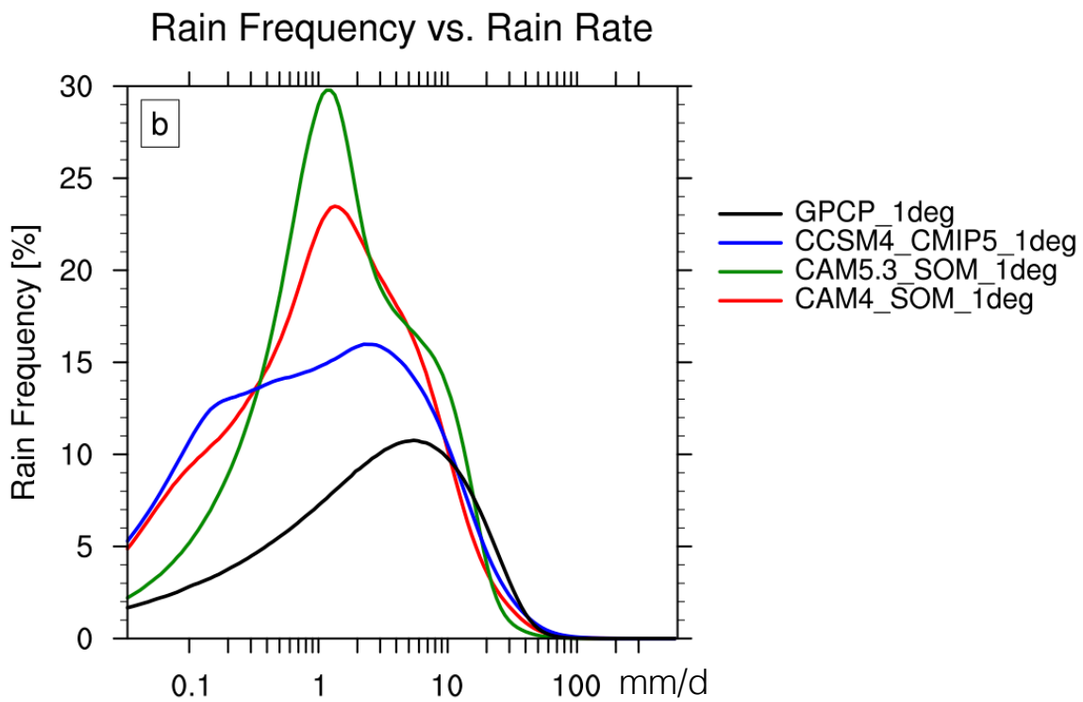
2° CAM 5.3 SOM

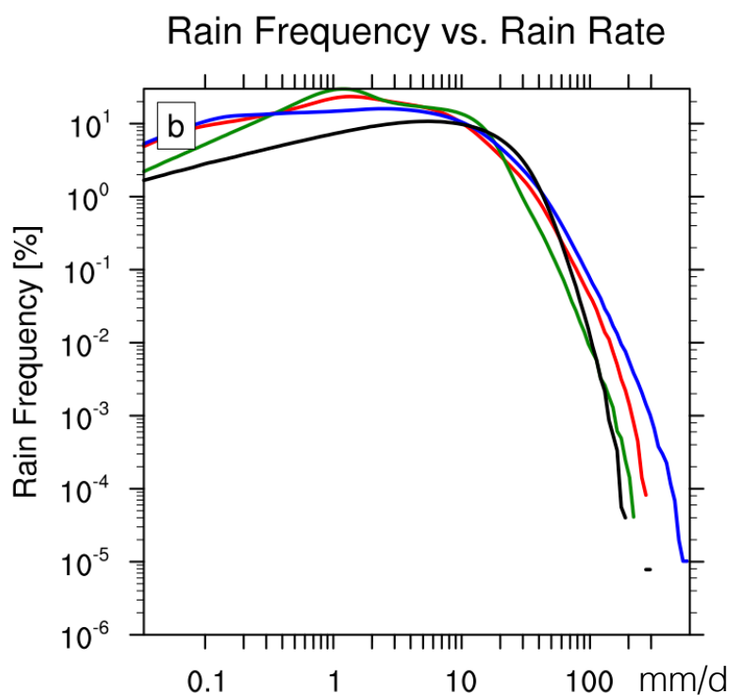


Results: Rain Distribution, Land-Sea Partitioning

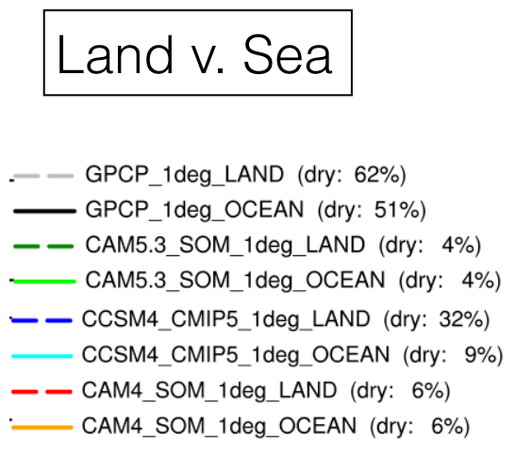
Analysis adapted from Pendergrass & Hartmann (2014, JC)

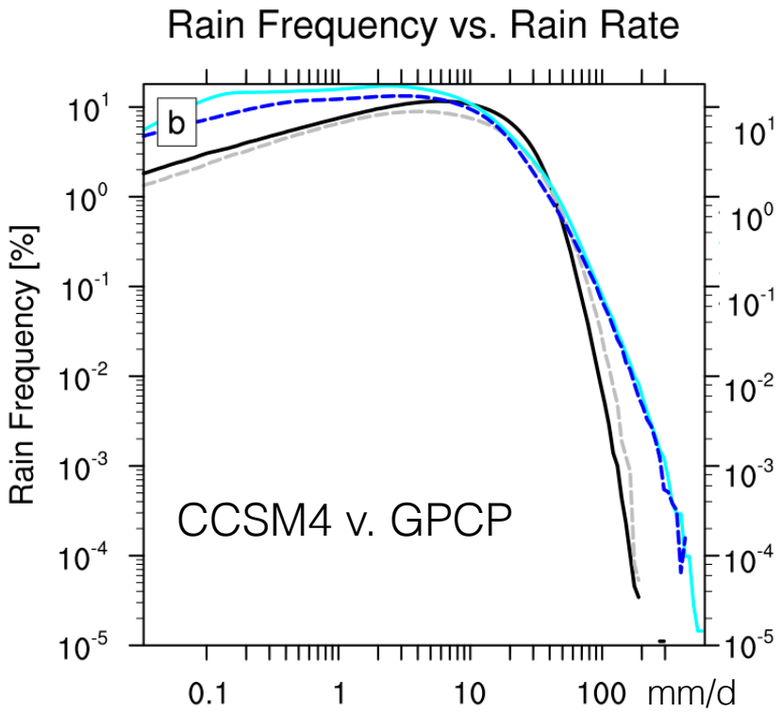
Global

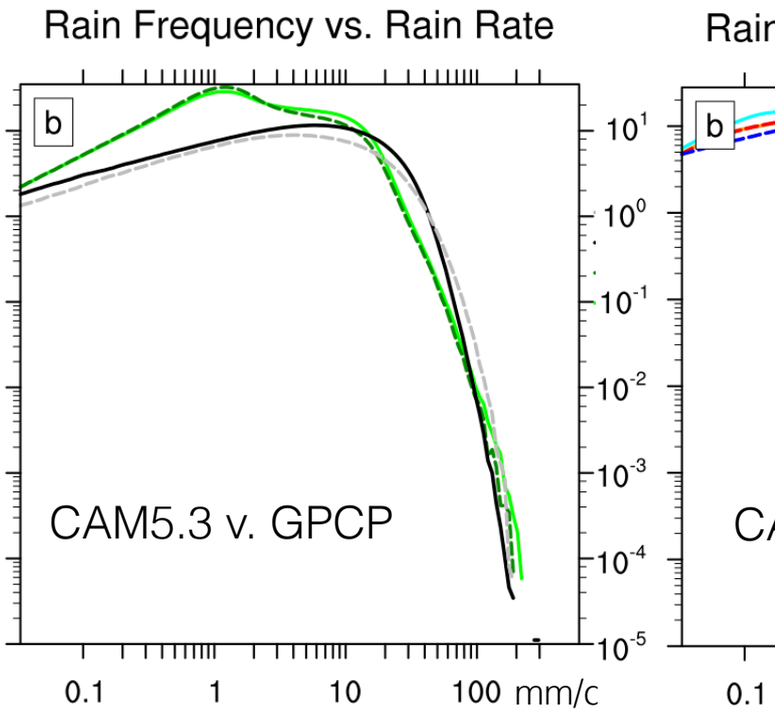


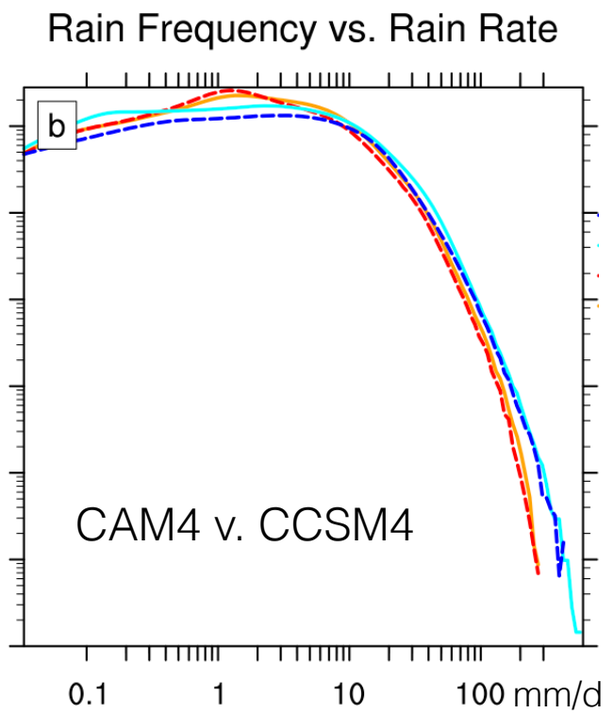


Land v. Sea

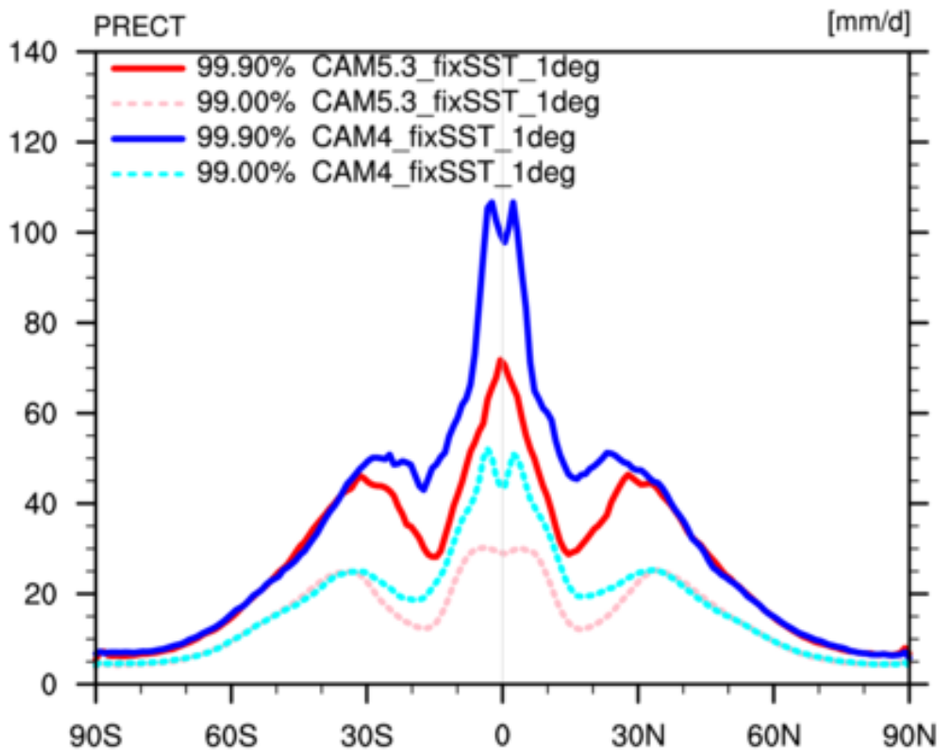


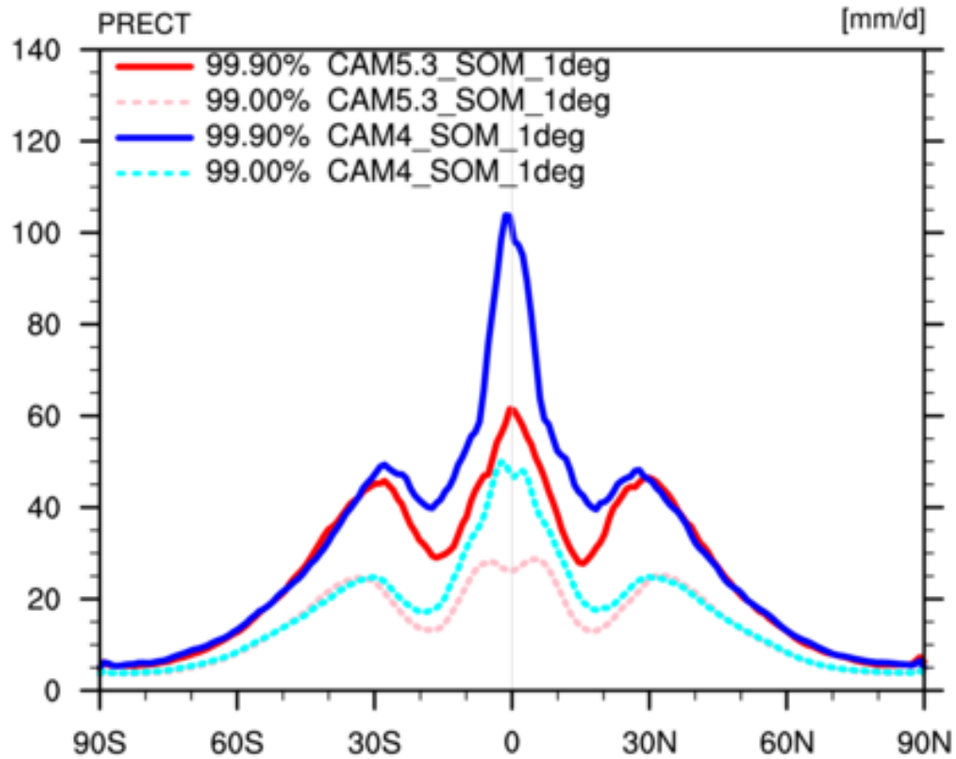






Results: Hydrocycle Extremes





Next Steps

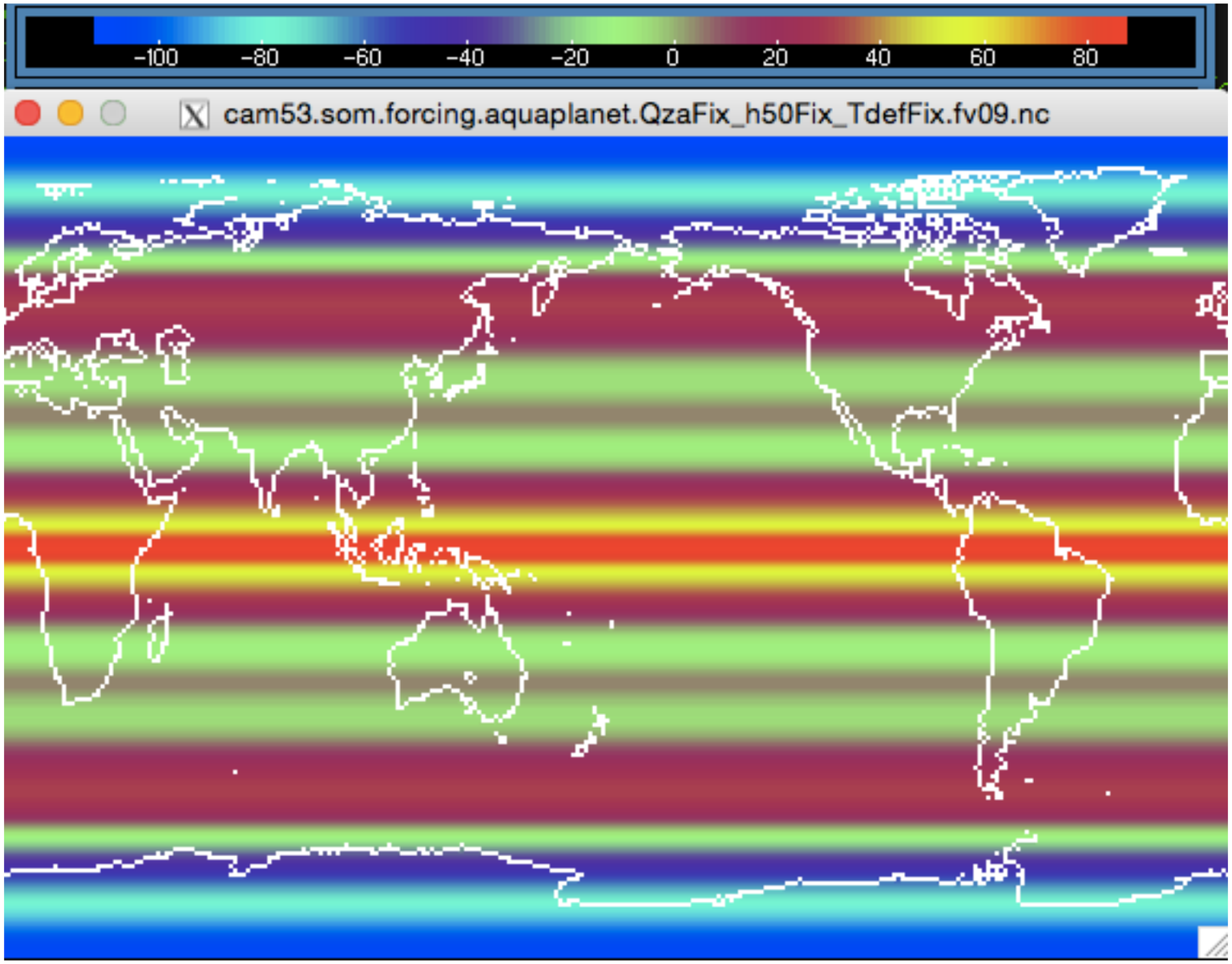
- Continued examination of:
  - Sensitivities of SOM to Q-flux, mixed-layer depth, physics, resolution
  - Large-scale modes of variability
  - Hydroclimate and extremes with increasing CO_2
- Beyond…
  - Bring in advanced, higher-resolution models: 0.25° “CESM-1dPOP”
  - Examine variability on other time scales

Summary

- Fixed-SST for FV CAM 4, CAM5.3, CAM6 already supported, out-of-box SOM versions for CAM5.3 and CAM6 coming online soon.
- Preliminary results explore modes of variability and hydrocycle
- User input welcomed for interactive ocean configurations!
  - Design of Q-fluxes?
  - Additional supported features? (Seasonality? Non-uniform oceanic mixed-layer depth? Sea ice?)

Extras

Zonally averaged Q-flux derived from fixed-SST “Qobs” run



Extras

Rainfall distribution statistics

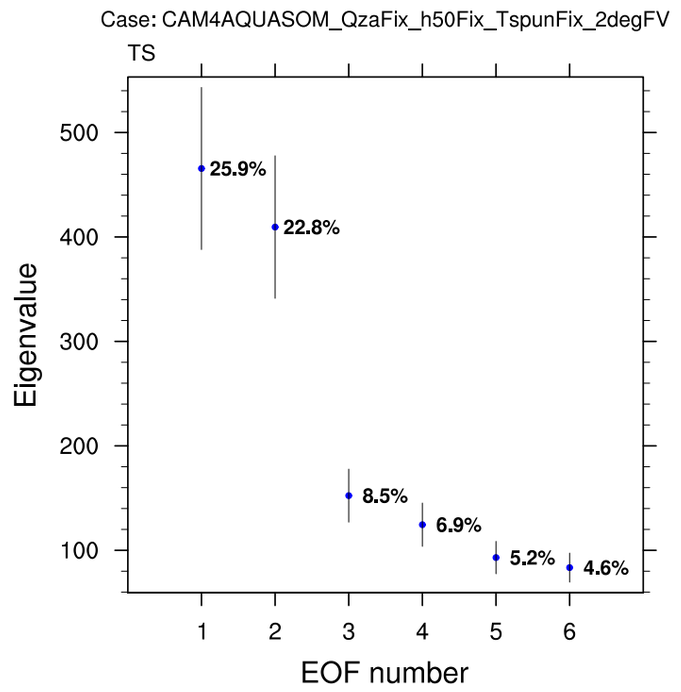
Simulation	Glb Avg P	P < 0	Zero P	Driest Bin	Max P
	[mm/d]	frac	frac	frac	[mm/d]
CAM4_SOM_2deg	2.791	0.000E+00	8.524E-05	4.238E-02	133.5
CAM4_SOM_1deg	2.881	0.000E+00	2.637E-04	6.118E-02	277.5
CAM5.3_SOM_2deg	3.008	5.514E-08	1.772E-06	2.291E-02	89.6
CAM5.3_SOM_1deg	3.077	1.203E-07	2.596E-06	3.579E-02	225.9
CAM4_fixSST_2deg	2.900	0.000E+00	1.083E-04	4.474E-02	145.8
CAM4_fixSST_1deg	3.003	0.000E+00	2.600E-04	6.130E-02	332.7
CAM4_fixSST_1deg-->2deg	3.003	0.000E+00	1.470E-05	3.553E-02	222.2
CAM5.3_fixSST_2deg_JJB_ctl	3.147	6.333E-08	1.704E-06	2.542E-02	121.2
CAM5.3_fixSST_1deg_JJB_ctl	3.217	6.207E-08	1.502E-06	3.579E-02	261.6
CAM5.3_fixSST_1deg-->2deg_JJB_ctl	3.217	0.000E+00	0.000E+00	2.213E-02	189.9
CAM5.3_fixSST_1deg_BPM_ctl	3.218	1.080E-07	2.390E-06	3.470E-02	283.5
CAM5.3_fixSST_1deg_BPM_aci	3.309	1.651E-08	2.398E-06	1.914E-02	332.0
CAM5.4_fixSST_1deg_BPM_micro	3.166	0.000E+00	6.748E-06	7.191E-02	242.4
CCSM4_CMIP5_1deg	2.970	0.000E+00	2.541E-02	1.605E-01	575.9
GPCP_1deg	2.673	0.000E+00	5.110E-01	5.436E-01	299.6

Extras

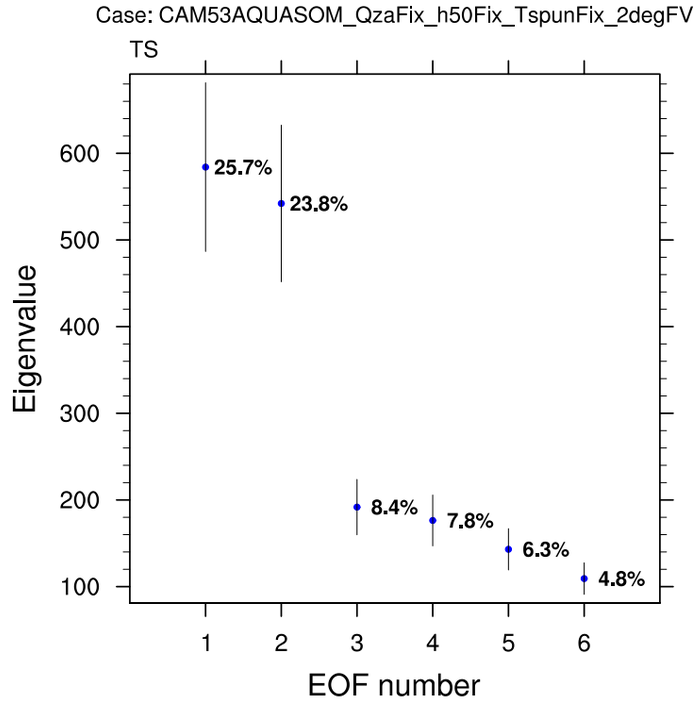
SST: ZWN 1 leading EOFs

2°

CAM4



CAM5.3



1°