Vegetation Feedbacks over the Global Monsoon Regions in CCSM3.5

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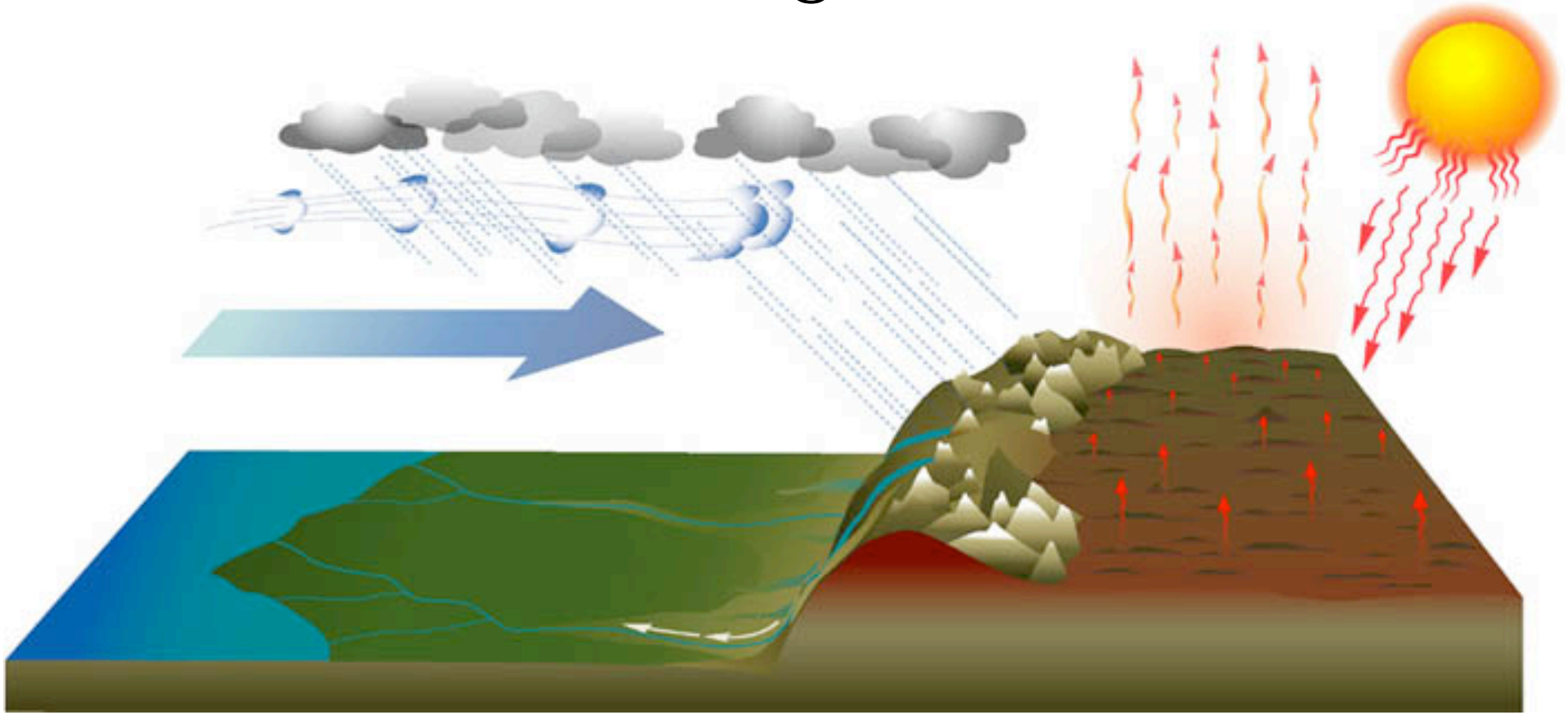


Acknowledgements

Funding Sources: NOAA CPPA and DOE NICCR

Drs. Sam Levis, Jon Wolfe, Feng He, Steve Vavrus: Assistance with CCSM3.5

Key Questions

1. How well does CCSM3.5 simulate the global monsoon systems?

2. How well does CCSM3.5 simulate global vegetation?

3. How does vegetation affect climate in the global monsoon regions?

Model Specifications and Experiments

NCAR CCSM3.5

Fully coupled - atm, ocean, land, ice

Dynamic vegetation (CLM-DGVM)

Finite Volume FV 1.9°x2.5°_gx1v5

B_PRESENT_DAY

Initial value ensemble experiments

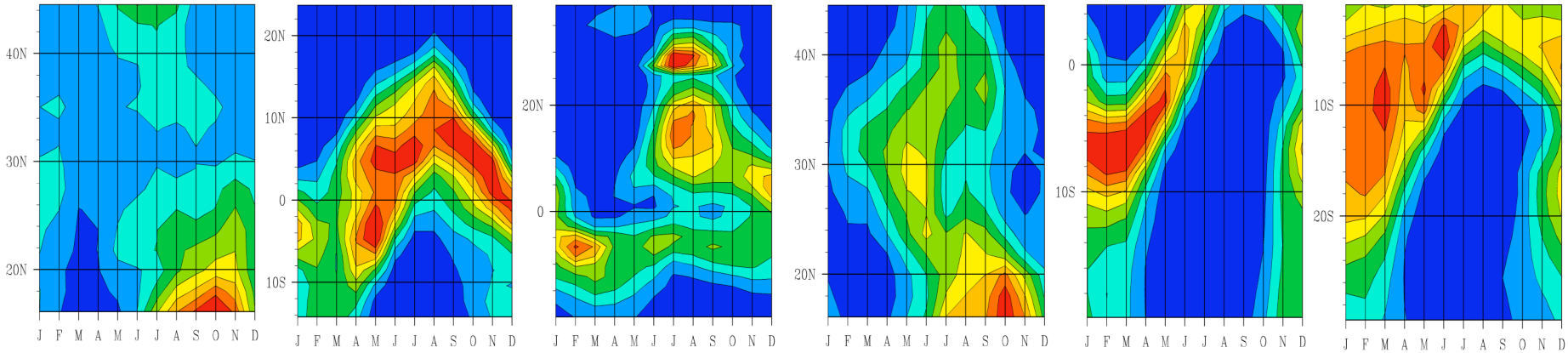
50 (1-yr) ensemble members

Reduced vegetation cover fraction by 0.2 over global monsoon regions

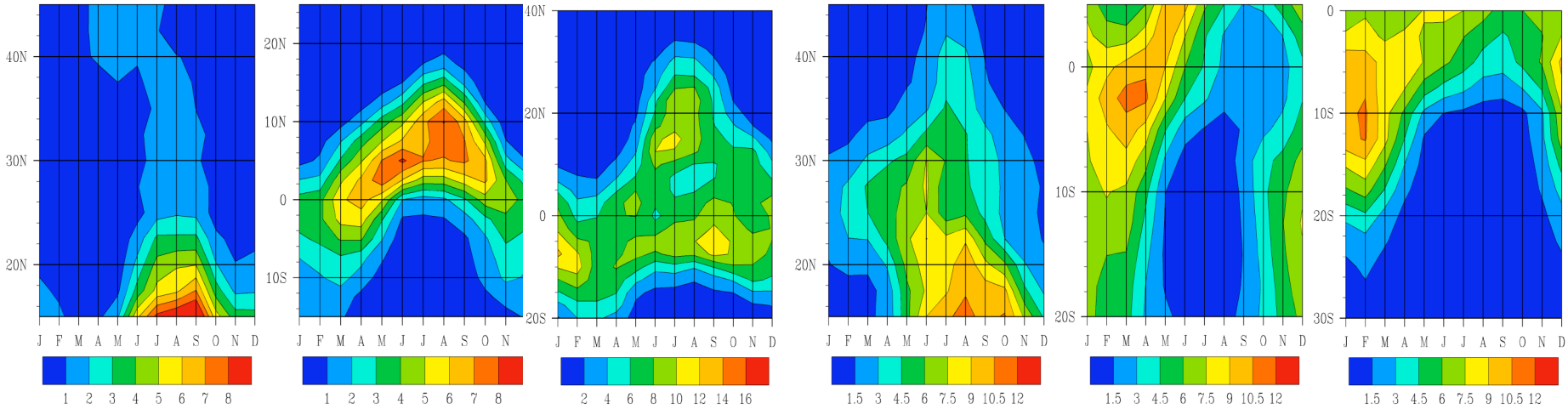
Mean Precipitation (mm/day)

North America | West Africa | India | China | South America | Northern Australia

(Simulated)



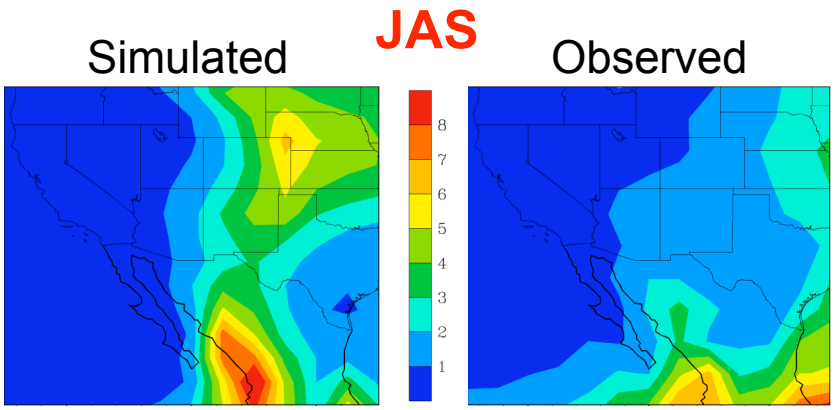
(Observed)

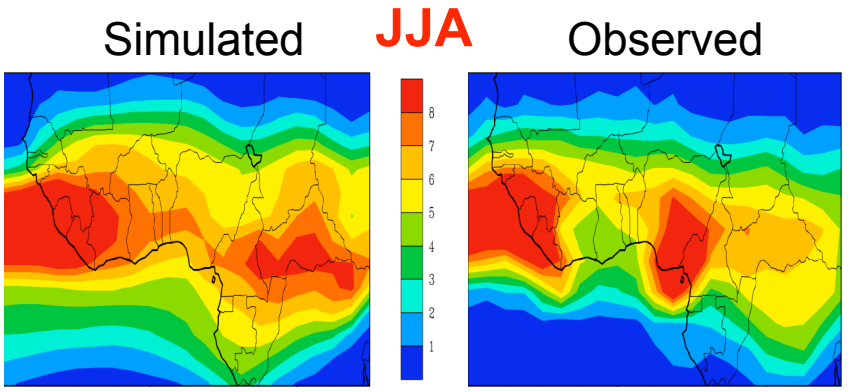


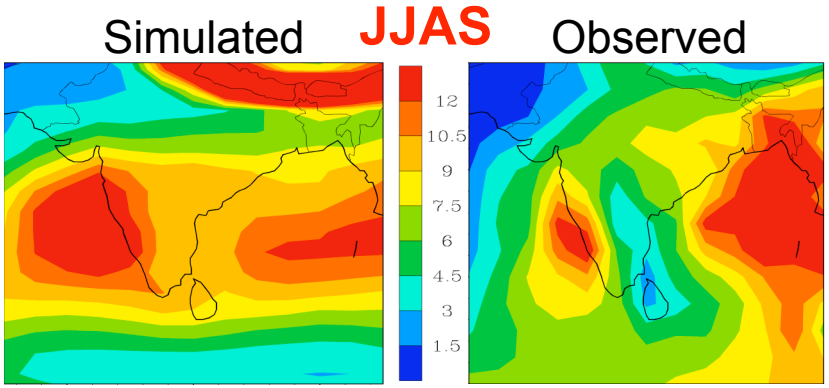
Obs = CMAP (Xie and Arkin) 1982-2000 2.5°x2.5°

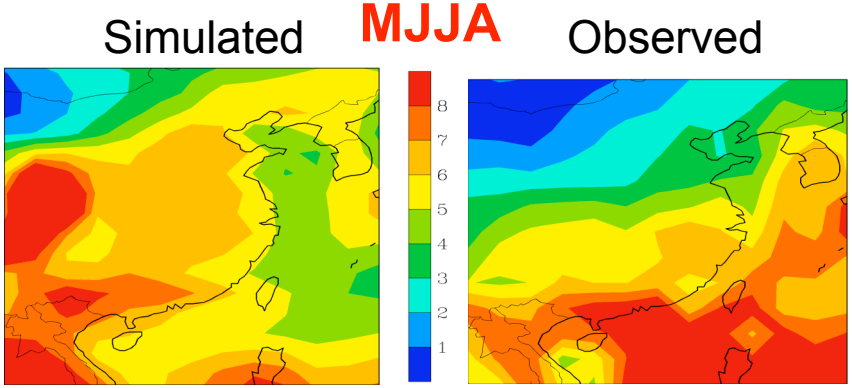
Too strong; 1 month late in Mexico and S. China;
Too far north into China and Australia

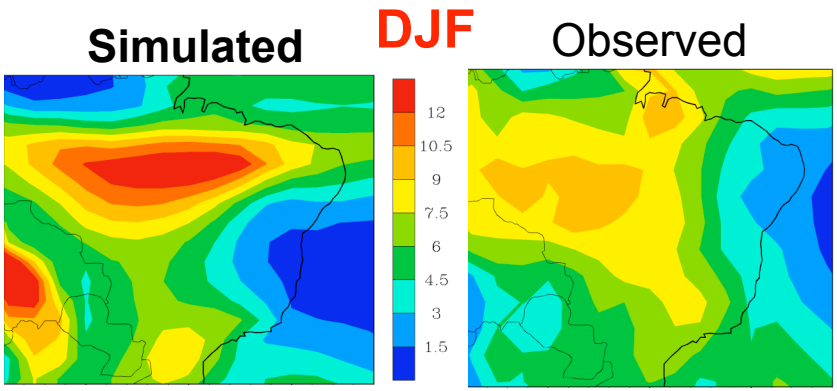
Mean Precipitation (mm/day)

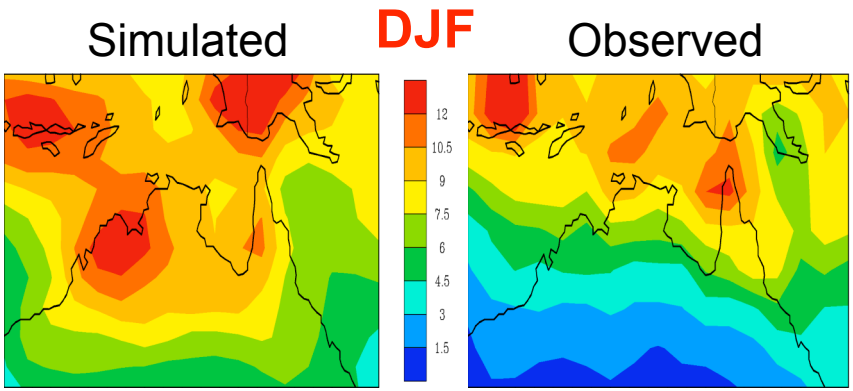




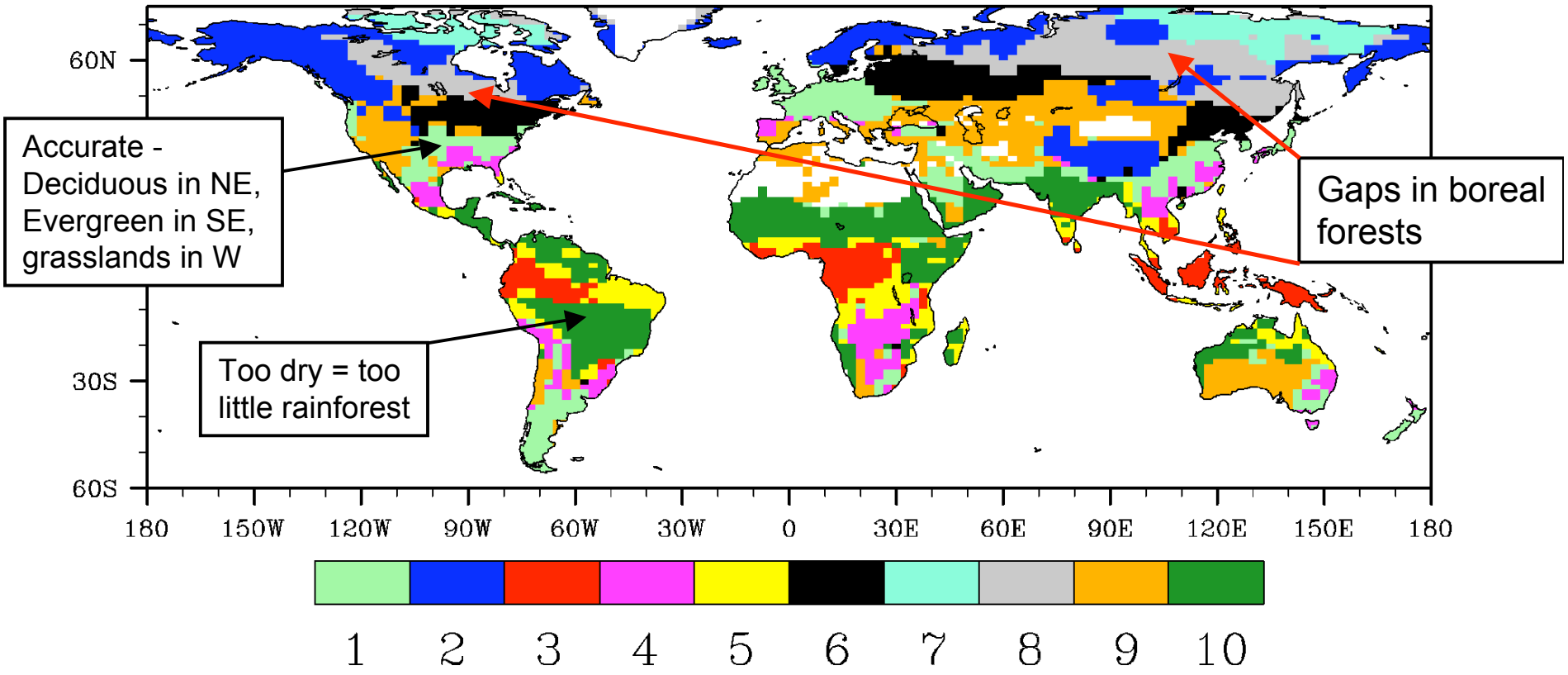








Simulated Biome Distribution (Max FPCGRID) for 50-Years



Cat 1 – Temperate Needleleaf Evergreen Forest

Cat 2 – Boreal Needleleaf Evergreen Forest

Cat 3 – Tropical Broadleaf Evergreen Forest

Cat 4 – Temperate Broadleaf Evergreen Forest

Cat 5 – Tropical Broadleaf Deciduous Forest

Cat 6 – Temperate Broadleaf Deciduous Forest

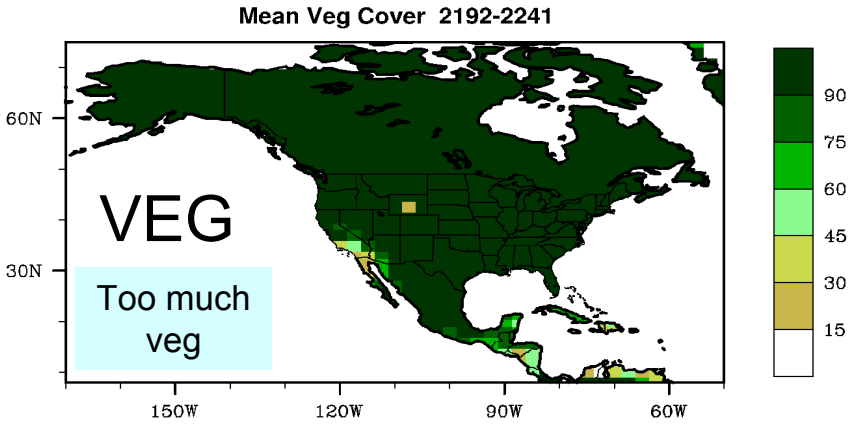
Cat 7 – Boreal Broadleaf Deciduous Forest

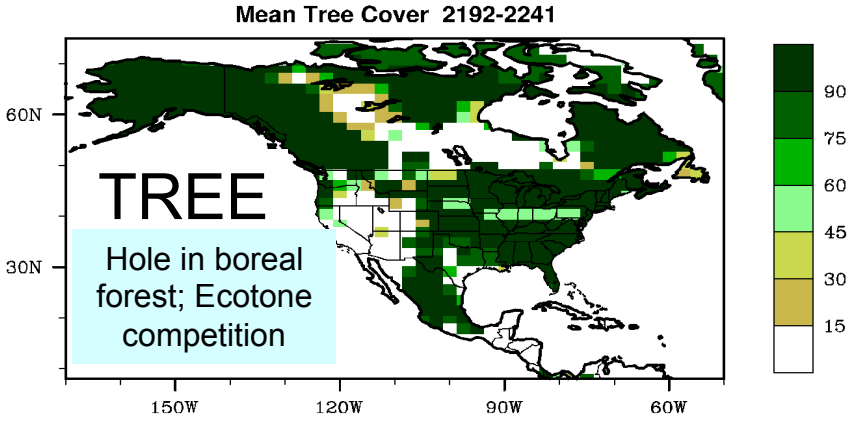
Cat 8 – C3 Arctic Grassland

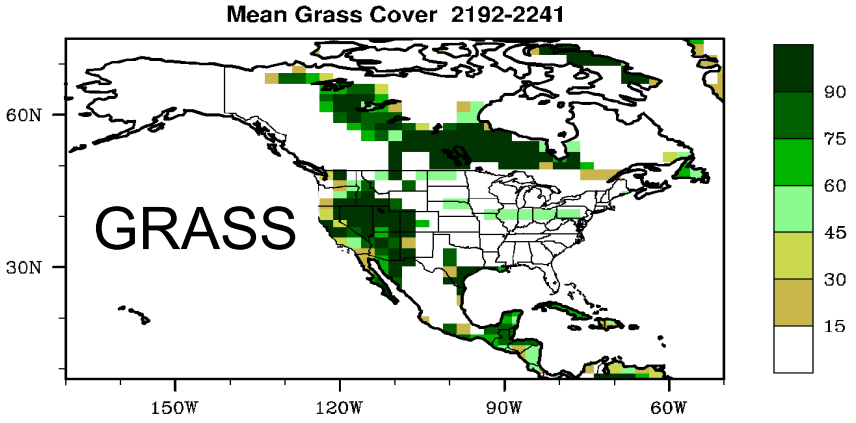
Cat 9 – C3 Grassland

Cat 10 – C4 Grassland

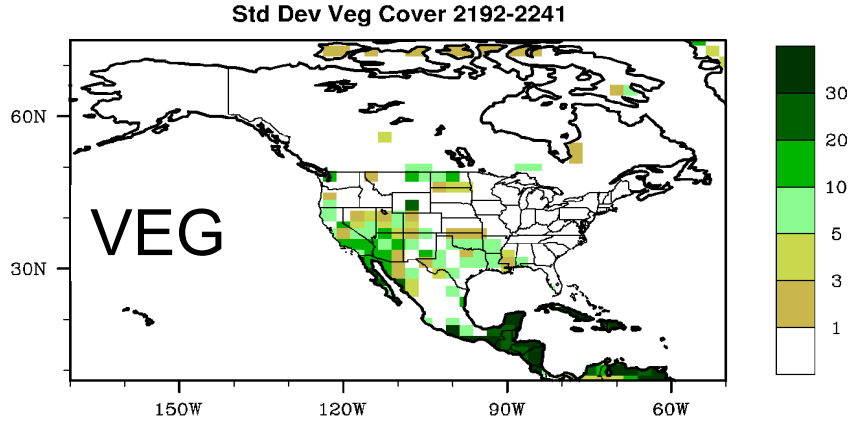
Simulated Mean

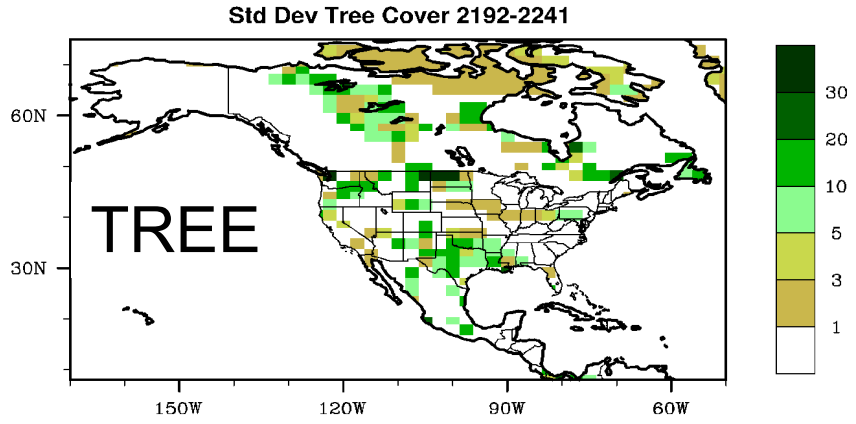


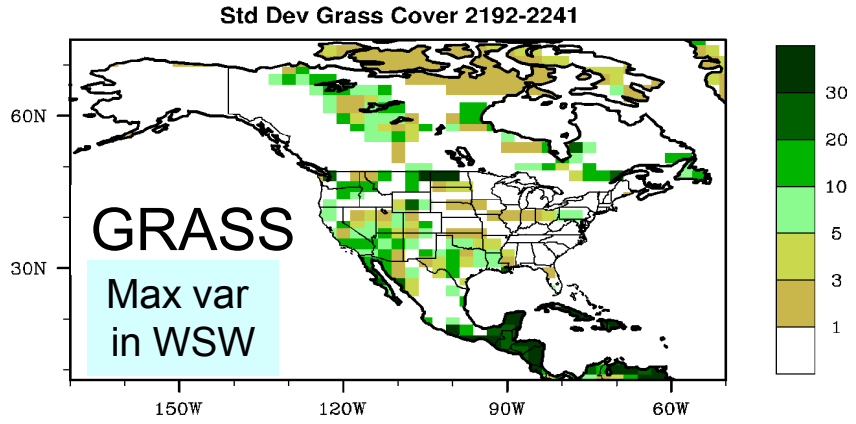




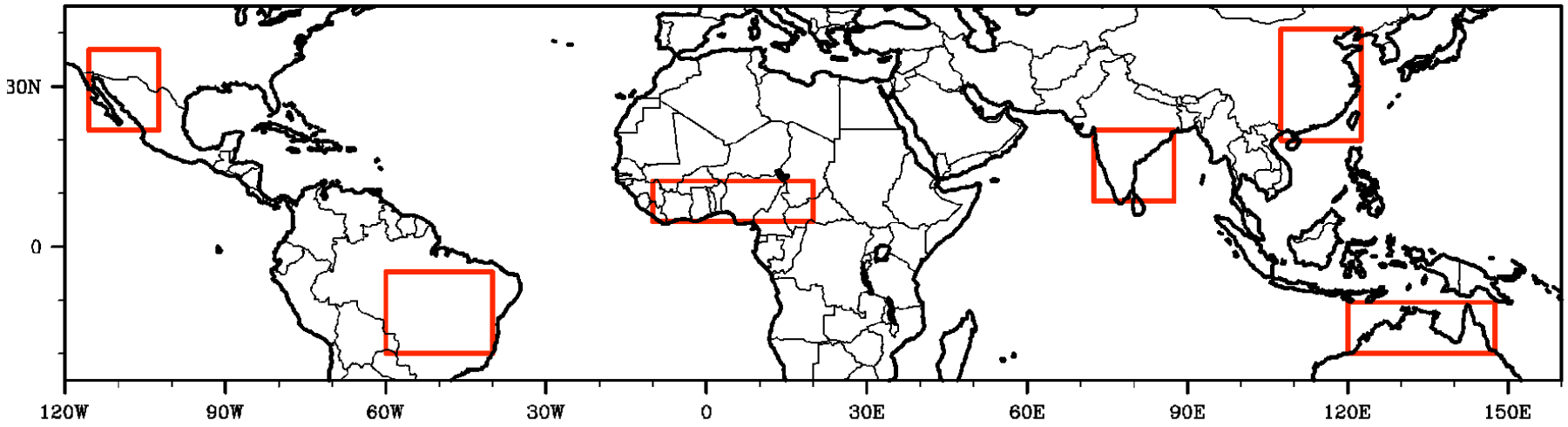
Simulated Standard Deviation



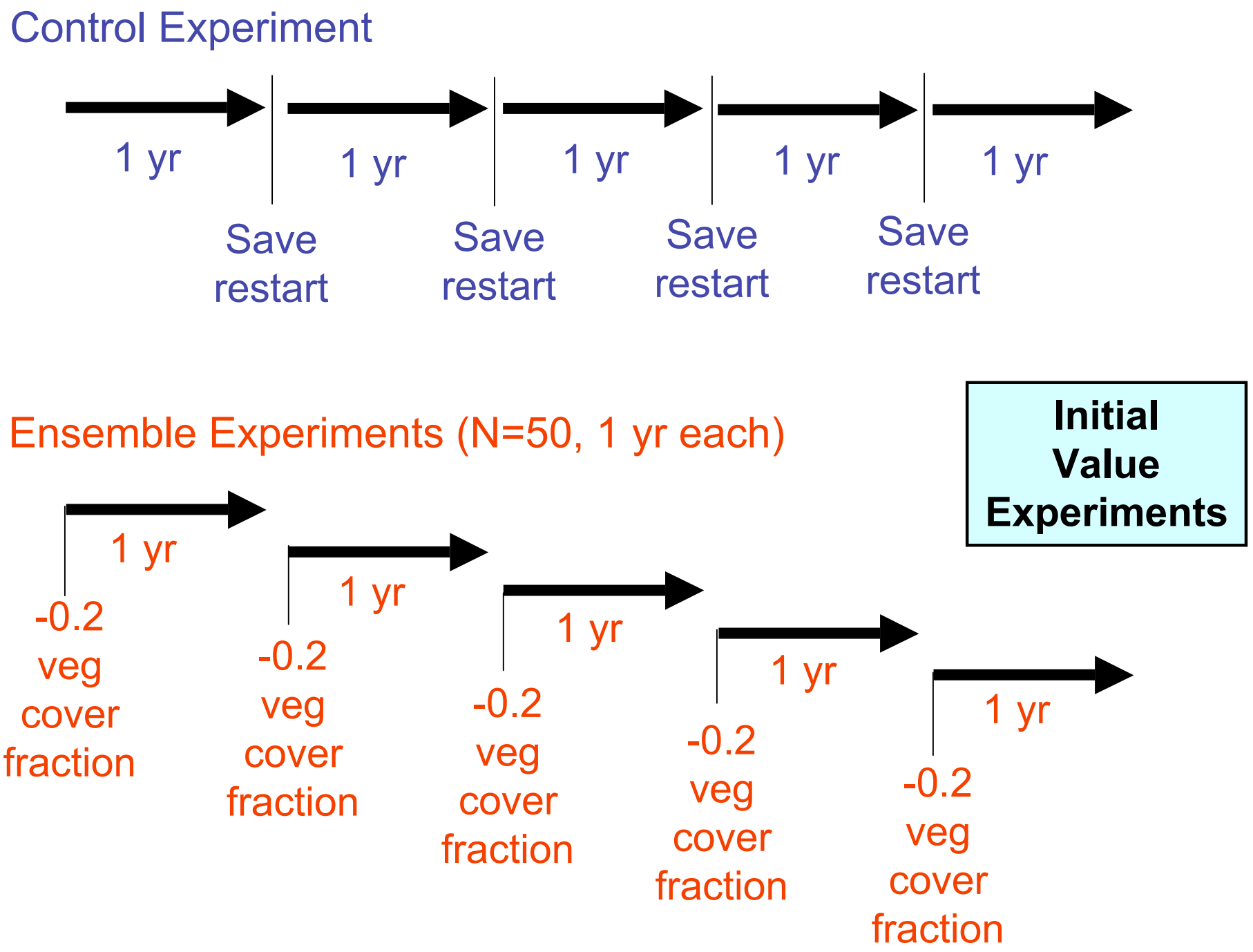


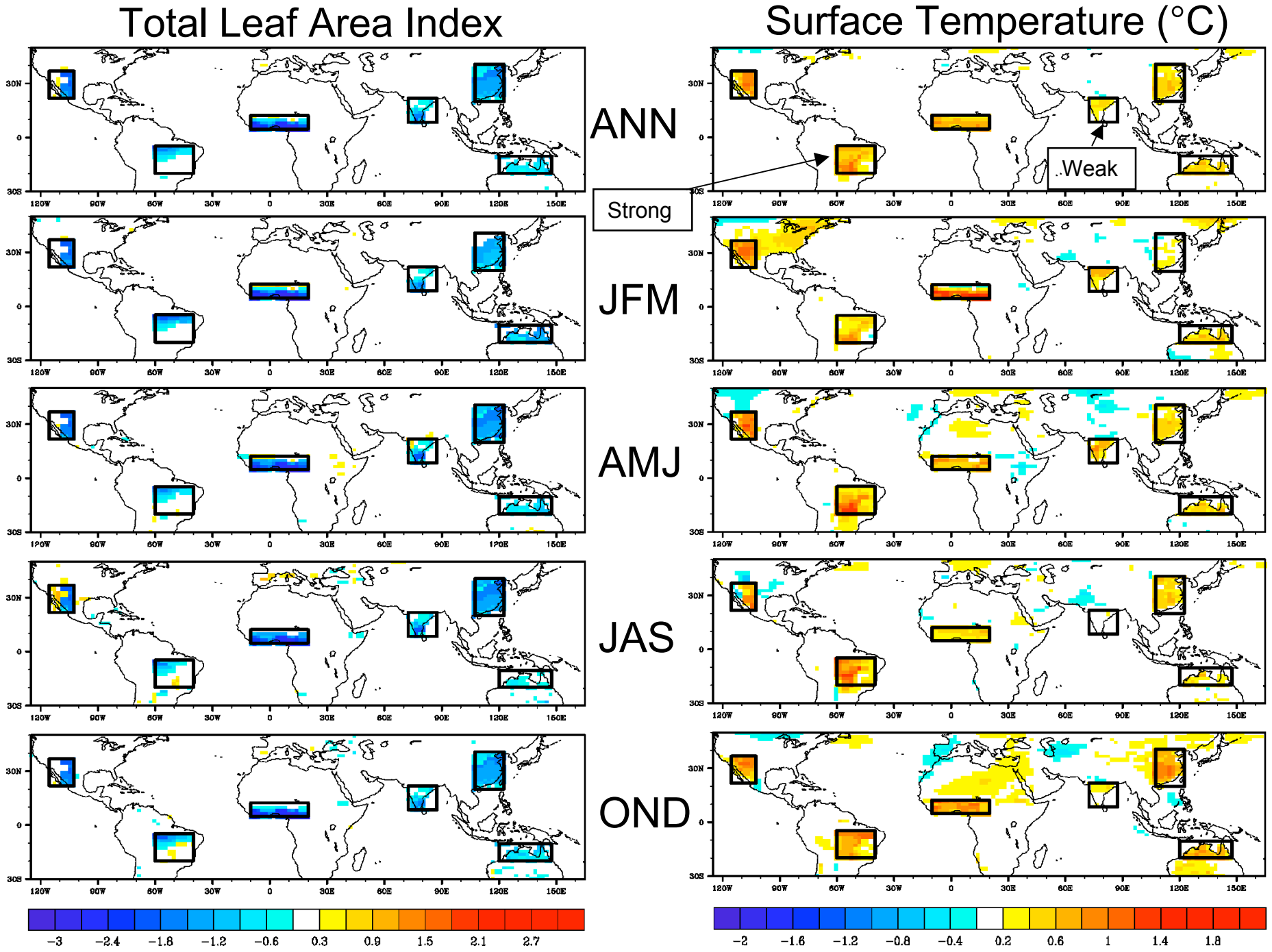


Areas of Altered Vegetation



1. North America
2. West Africa
3. India
4. China
5. South America
6. North Australia


Control Experiment
1 yr
1 yr
1 yr
1 yr
1 yr
Save restart
Save restart
Save restart
Save restart
Ensemble Experiments (N=50, 1 yr each)
Initial Value Experiments
-0.2 veg cover fraction
-0.2 veg cover fraction
-0.2 veg cover fraction
-0.2 veg cover fraction
-0.2 veg cover fraction
1 yr
1 yr
1 yr
1 yr
1 yr


Total Leaf Area Index
Surface Temperature (°C)
ANN
JFM
AMJ
JAS
OND
Strong
Weak
30N
0
30S
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
−3
−2.4
−1.8
−1.2
−0.6
0.3
0.9
1.5
2.1
2.7
−2
−1.6
−1.2
−0.8
−0.4
0.2
0.6
1
1.4
1.8

Surface Temperature (°C)	ANN	JFM	AMJ	JAS	OND
North America	+0.51	+0.64	+0.56	+0.31	+0.51
West Africa	+0.53	+0.63	+0.42	+0.36	+0.71
India	+0.15	+0.25	+0.23	+0.02	+0.11
China	+0.30	+0.08	+0.28	+0.33	+0.51
South America	+0.56	+0.38	+0.61	+0.66	+0.60
North Australia	+0.23	+0.25	+0.22	+0.13	+0.33

Less veg = warmer for all regions

Generally larger warming in autumn and smaller in summer

Greatest warming:
-W. Africa in autumn
-N. and S. America in winter

2-m Air Temperature (°C)	ANN	JFM	AMJ	JAS	OND
North America	+0.33	+0.48	+0.32	+0.13	+0.40
West Africa	+0.24	+0.27	+0.20	+0.17	+0.31
India	+0.10	+0.08	+0.19	+0.03	+0.09
China	+0.15	-0.05	+0.17	+0.14	+0.32
South America	+0.33	+0.14	+0.32	+0.46	+0.40
North Australia	+0.16	+0.17	+0.17	+0.04	+0.28

Less veg = higher sfc air T for all regions

Greatest warming in N. and S. America

Evaporation (W/m^2)

Evaporation (W/m^2)	ANN	JFM	AMJ	JAS	OND
North America	-0.13	+0.06	-1.48	+1.12	-0.24
West Africa	-1.73	-4.83	-0.58	-0.39	-1.14
India	-0.89	-2.25	-1.86	-0.56	+1.13
China	-0.24	-0.57	-0.62	+0.01	+0.22
South America	-1.35	-1.23	-0.57	-2.11	-1.49
North Australia	-1.18	-0.57	-0.25	-1.65	-2.27

Less vegetation = reduced evapotranspiration

Greatest reduction over West Africa

Generally larger reductions in winter-spring

Precipitation (cm/month)

Precipitation (cm/mon)	ANN	JFM	AMJ	JAS	OND
North America	-0.19	-0.27	-0.22	+0.19	-0.45 (-5%)
West Africa	+0.29	-0.16	+0.09	+0.55	+0.66 (+7%)
India	-0.02	-0.02	+0.36	+0.55	-0.98 (-7%)
China	-0.05	-0.23 (-4%)	+0.22	-0.19	-0.00
South America	-0.02	+0.08	+0.12	-0.11	-0.18
North Australia	-0.34	-0.24	-0.08	+0.07	-1.10 (-8%)

Only substantial annual responses in N. Australia (drying 4 cm) and West Africa (wettening 3.5 cm)

Large percent changes are autumn drying in N. Australia, India, and N. America and autumn wettening in W. Africa

The sign of the vegetation feedback varies per region

Sensible Heat Flux (W/m^2)

Sensible Heat Flux (W/m^2)	ANN	JFM	AMJ	JAS	OND
North America	-1.3	-1.5	-1.6	-2.6	+0.7
West Africa	-0.9	-1.2	-0.5	+0.4	-2.4
India	-0.5	-0.9	-1.2	+0.1	-0.1
China	-0.7	-0.8	-1.6	+0.1	-0.6
South America	-0.4	-0.9	-0.1	-0.2	-0.5
North Australia	-0.5	+0.5	-0.7	-2.1	+0.1

Less veg = reduced SH flux, especially in N. America

Reduction in SH greater in winter and lesser in summer

Regionally specific responses, including largest N. American reduction in summer and largest N. Australian reduction in winter

SH from ground increases and from vegetation decreases

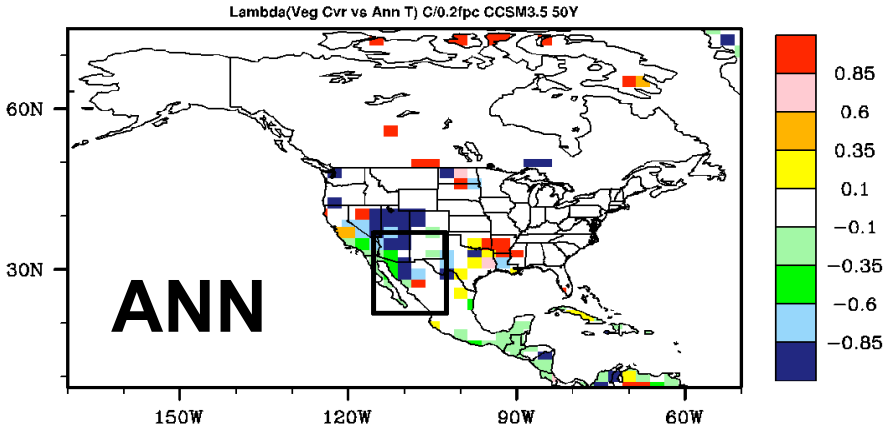
SH from Ground (W/m^2)	ANN	JFM	AMJ	JAS	OND
North America	+3.7	+3.1	+6.9	+2.2	+2.7
West Africa	+4.4	+5.6	+3.6	+3.9	+4.4
India	+5.3	+6.1	+8.5	+3.4	+3.4
China	+4.3	+4.8	+5.2	+4.1	+3.2
South America	+5.0	+3.4	+4.4	+6.9	+5.3
North Australia	+7.3	+4.0	+5.2	+9.9	+10.0

SH from Veget (W/m^2)	ANN	JFM	AMJ	JAS	OND
North America	-5.0	-4.7	-8.4	-4.8	-2.0
West Africa	-5.3	-6.8	-4.1	-3.5	-6.8
India	-5.9	-7.0	-9.8	-3.2	-3.5
China	-5.0	-5.6	-6.7	-4.0	-3.8
South America	-5.4	-4.4	-4.5	-7.1	-5.8
North Australia	-7.8	-3.5	-5.9	-12.0	-9.9

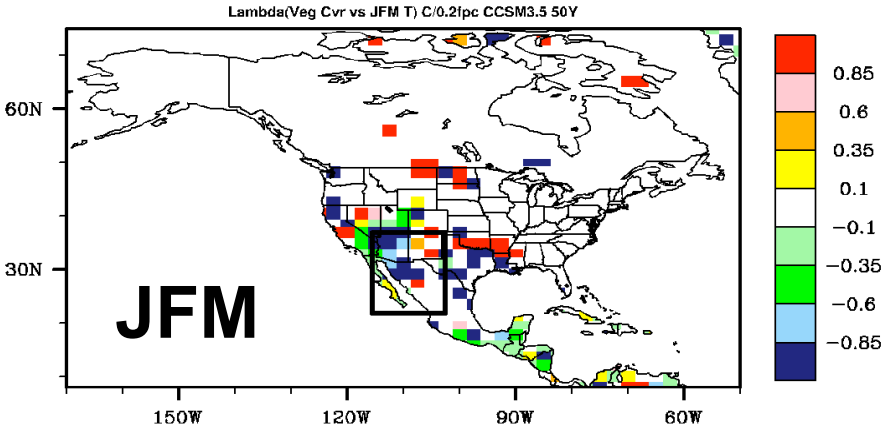
Statistical Feedback Parameter: Vegetation Cover Versus Air Temperature

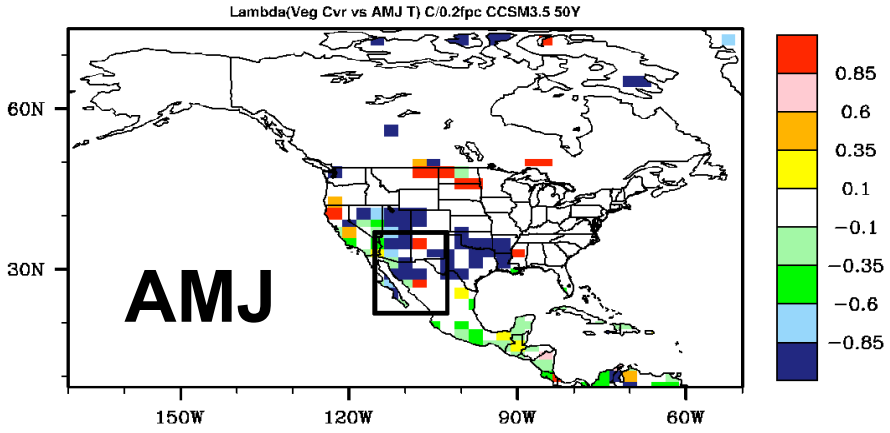
Statistical
Ann = +0.39°C/-0.2frac
JFM = +0.67°C/-0.2frac

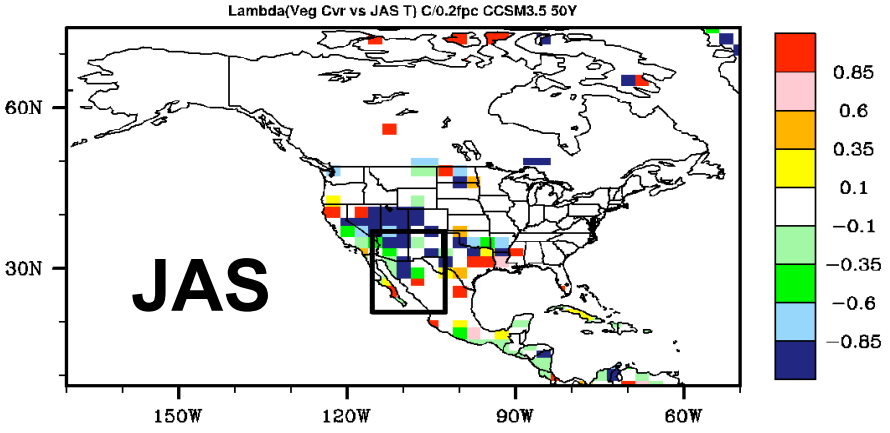
Dynamical
Ann = +0.33°C/-0.2frac
JFM = +0.48°C/-0.2frac

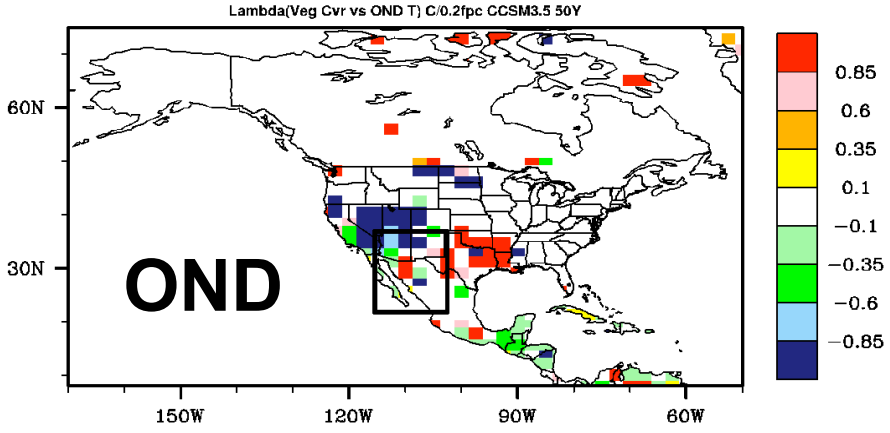


$$\lambda = \frac{\mathrm{cov}\,ariance[V(t-\tau)T(t)]}{\mathrm{cov}\,ariance[V(t-\tau)V(t)]}$$





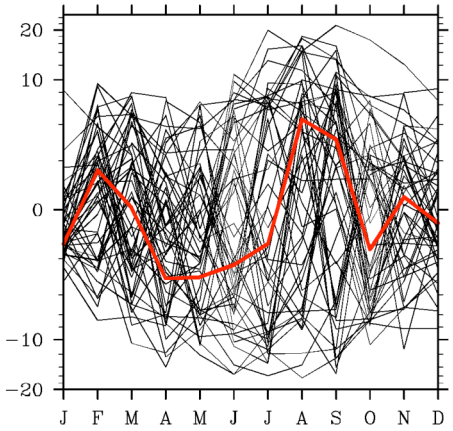




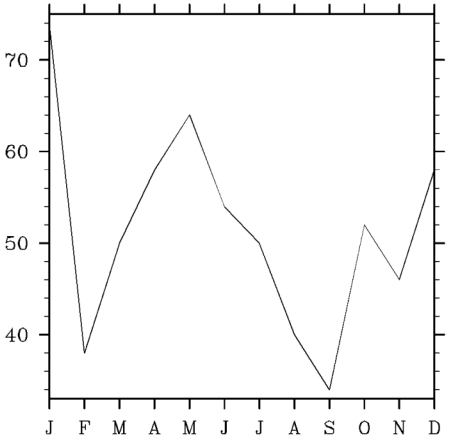
North American Monsoon Region

Spring reduction; Summer increase

Evaporation (W/m^2)

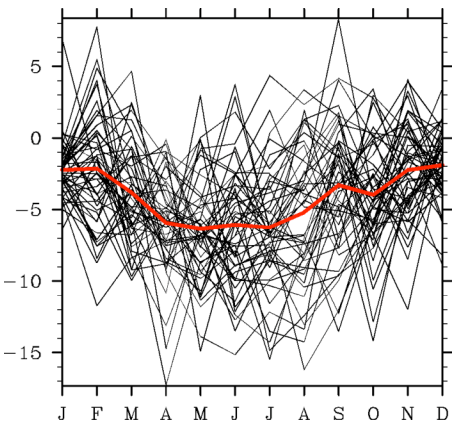


% of Ensemble Members < 0

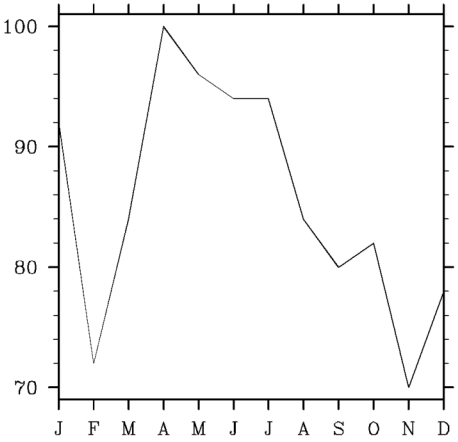


Largest reduction in spring

FCTR - Canopy Transpiration (W/m^2)

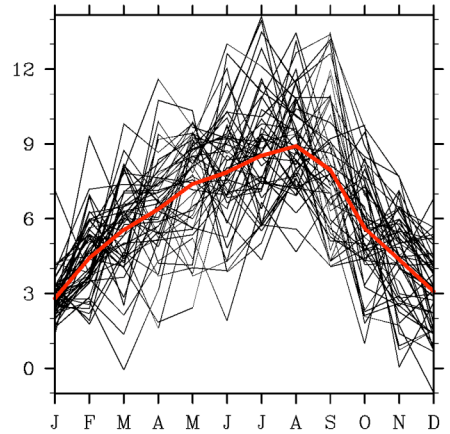


% of Ensemble Members < 0

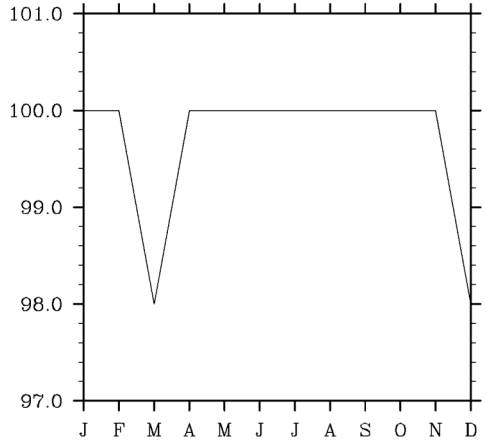


Largest increase in summer (robust)

FGEV - Ground Evaporation (W/m^2)

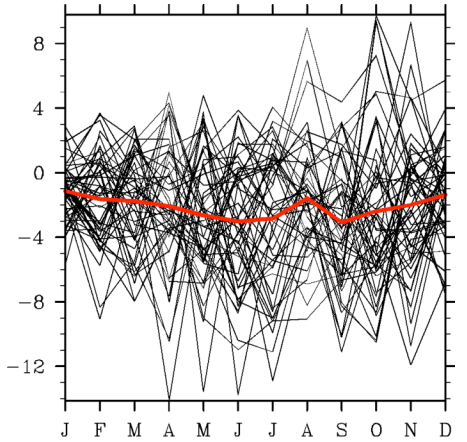


% of Ensemble Members > 0



Year-round reduction

FCEV - Canopy Evaporation (W/m^2)



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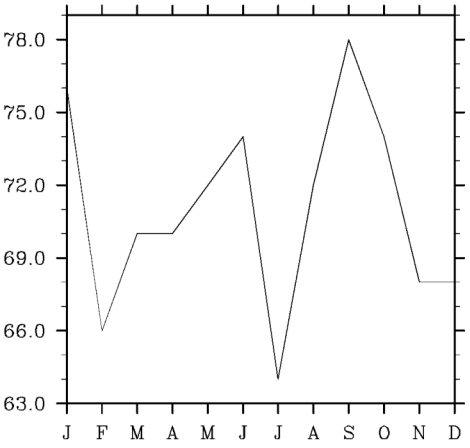

CONCLUSIONS

Monsoons: CCSM3.5 produces a reasonable seasonal onset of the global monsoons, although they are generally too strong and sometimes penetrate too far inland.

Vegetation: CCSM3.5 captures the global distribution of major biomes, although it oversimulates vegetation cover and has gaps in the boreal forests and Amazon rainforest.

Feedbacks: Reduced vegetation cover results in less SH and LH (evaporation) fluxes and higher temperatures. Precipitation responses vary but are generally reduced. Statistical estimates are reasonable over the N. American monsoon region.