Diagnosis of the Warm Bias Exhibited in CMIP5 AMIP Climate Simulations over ARM SGP site

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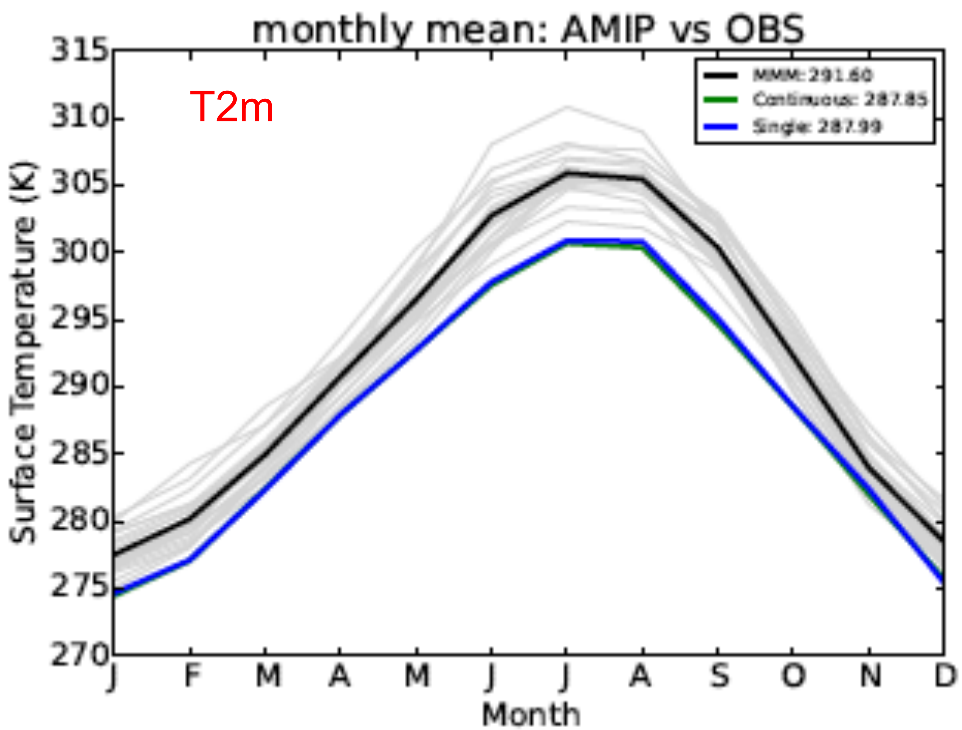
Warm bias exhibited in CMIP5 AMIP Climate Simulations over ARM SGP site

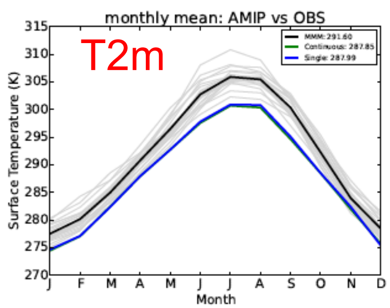


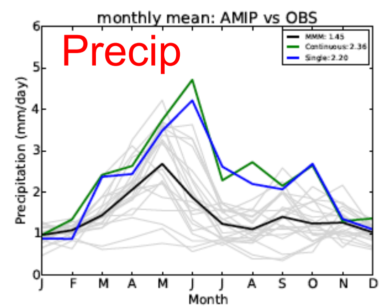
- **AMIP simulation:**
  Eliminate SST bias introduced
  by coupled simulations

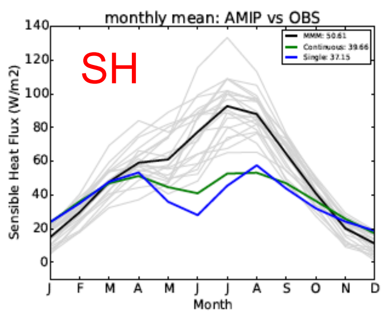
- Warm bias exhibits year around
  for most CMIP 5 models.
  ~ 3.6 K in Annual mean
  ~ 5.2 K in JJA

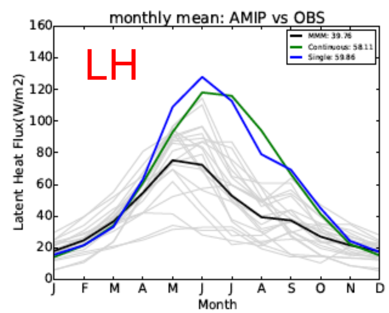
- Black: Multi-model mean
  Green: Continuous forcing
  (Variational analysis)
  3x3 Deg. domain mean
  Blue: Single point at central facility
  (ARMBE)

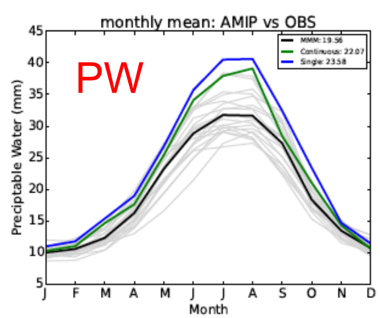
Statistical Summary of Bias patterns in Climate Simulation over SGP







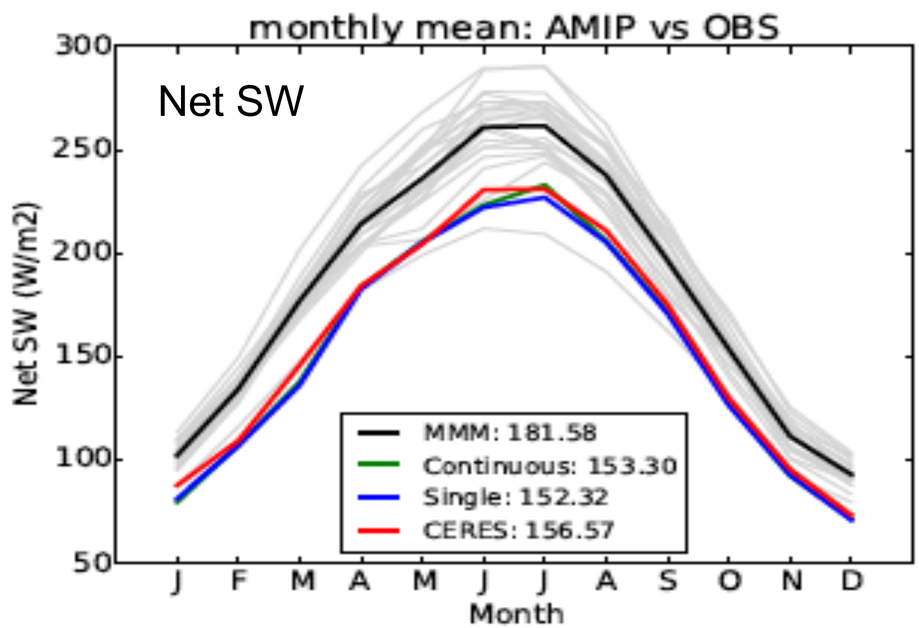




- Surface is too warm and dry.
  Bias is the highest during summer.
- Sensible heat is over-estimated
  latent heat is under-estimated in summer
- Precipitation peak bias
- The atmosphere column is too dry

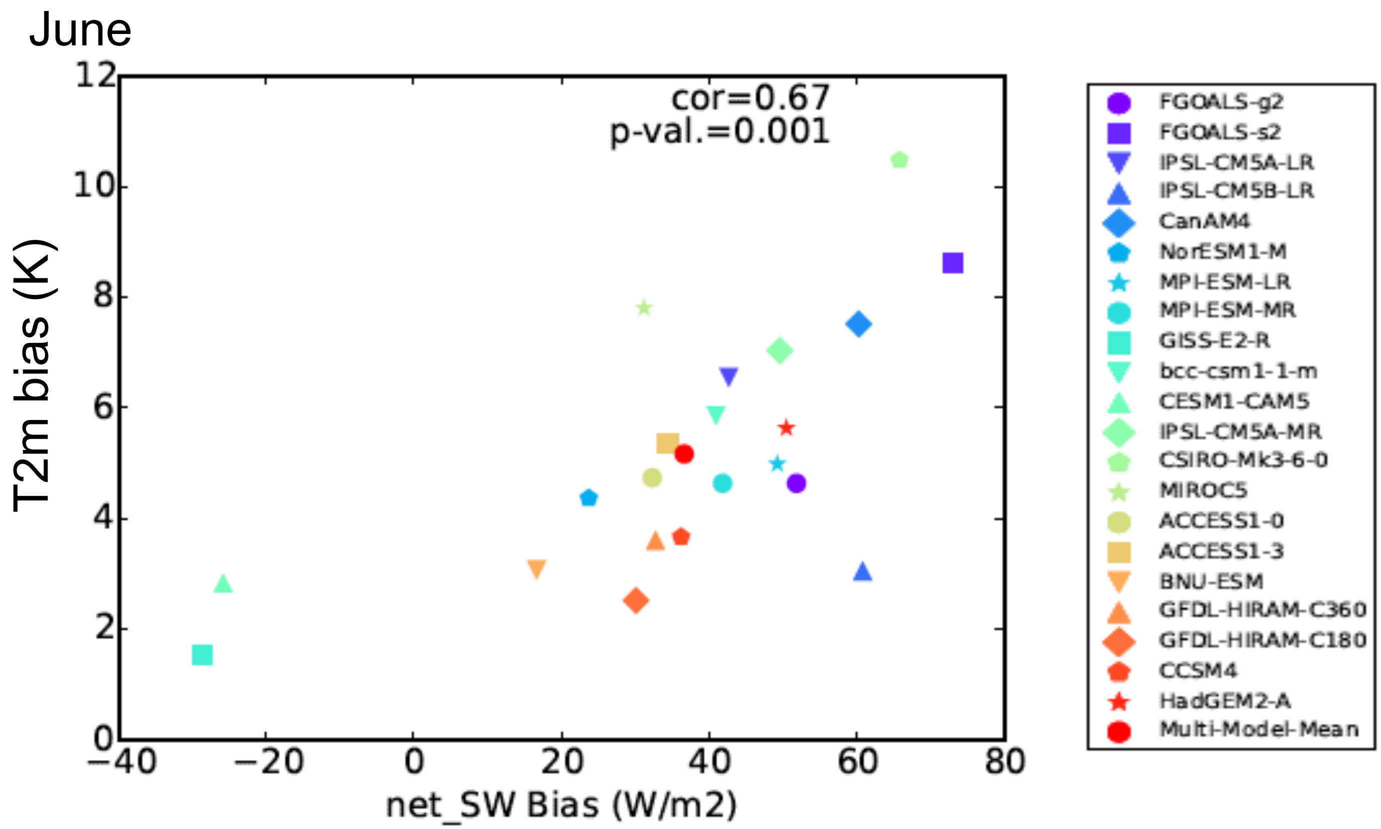
What contribute to the T2m bias?

Contribution of solar radiation error at surface



Based on both **CERES (Red)** and **ARM data (Blue and Green)**, models have strong net solar radiation bias (25~29 W/m^2 in annual mean)

Net SW bias correlates to T2m bias across models



Partition the surface net SW error

Net-SW error = $(1-\alpha_{mod})$*SWDN clr,error		SWDNclr error
	$+(1-\alpha_{mod})$*SWDN cre,error	SWDNcre error
	$+(\alpha_{mod} - \alpha_{obs})$*(SWDN clr+ SWDN cre)	Albedo error

Net SW error attribution (JJA mean):

CMIP5 Mean -Observation	Net-SW error (Wm-2)	Albedo error (Wm-2)	SWDN-clr error (Wm-2)	SWDN-cre error (Wm-2)
Based on ARM	32.68	6.26	4.84	21.54
Based on CERES	29.15	0.86	14.67	13.62

ARM vs CERES vs models

- The Radiative Flux Analysis product from ARM:

  Clear-sky fluxes are derived for identified clear-sky, empirical cosine fit based on solar angle to generate continuous data stream. It reflects ACTUAL Clear-sky fluxes.

- CERES and models:

  Clear-sky fluxes are calculated by removing the cloud but retaining aerosol and water vapor at cloudy time. Clear-sky fluxes are lower than ACTUAL clear-sky values.

  In order to evaluate climate models, CERES surface product is more suitable under definitional ground.

CMIP5 Mean -Observation	Net-SW error (Wm-2)	Albedo error (Wm-2)	SWDN-clr error (Wm-2)	SWDN-cre error (Wm-2)
Based on ARM	32.68	6.26	4.84	21.54
→ Based on CERES	29.15	0.86	14.67	13.62

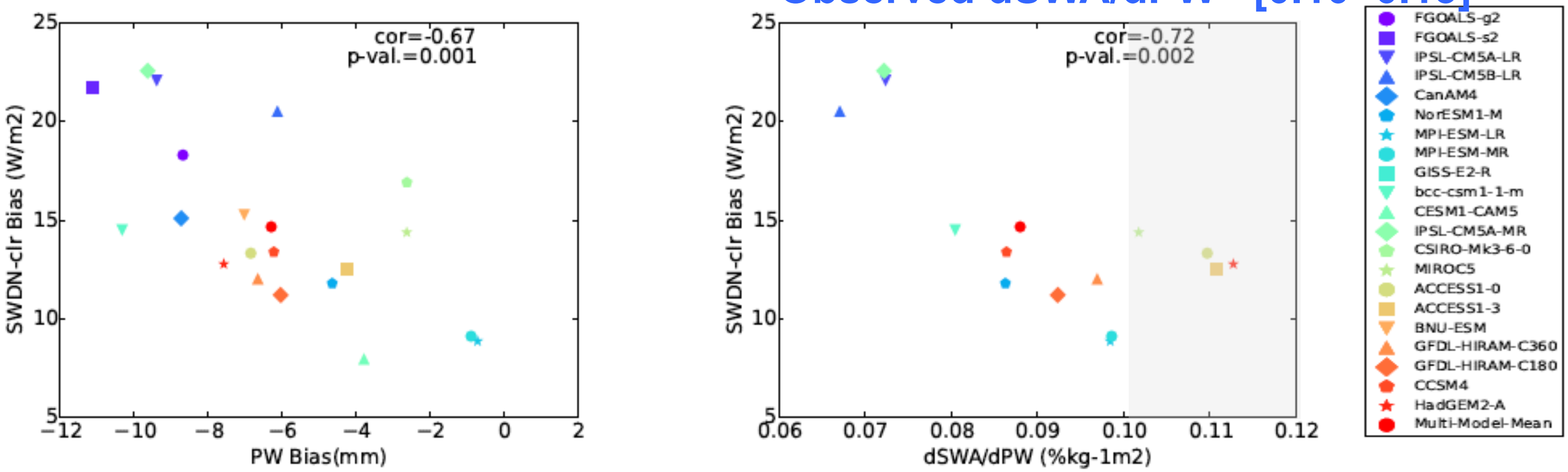
Thanks to Seiji Kato, David Rutan and Chuck Long for helping to understand.

PW and [dSWA/dPW] errors contribute to clear-sky SWDN error

PW : Precipitable water

dSWA/dPW: SWA (SW absorption) sensitivity to PW variation

Observed dSWA/dPW =[0.10~0.13]



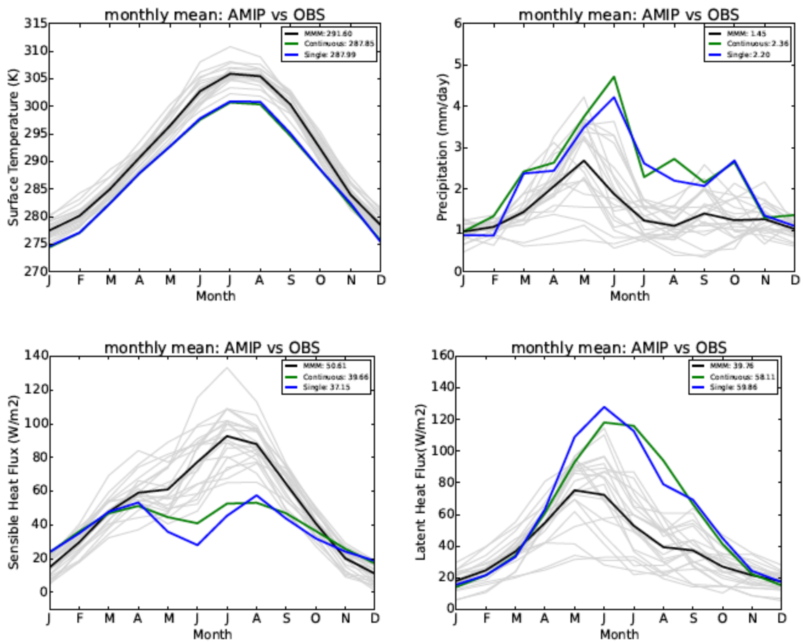
PW bias (mm)

dSWA/dPW ($\%kg^{-1}m^{-2}$)

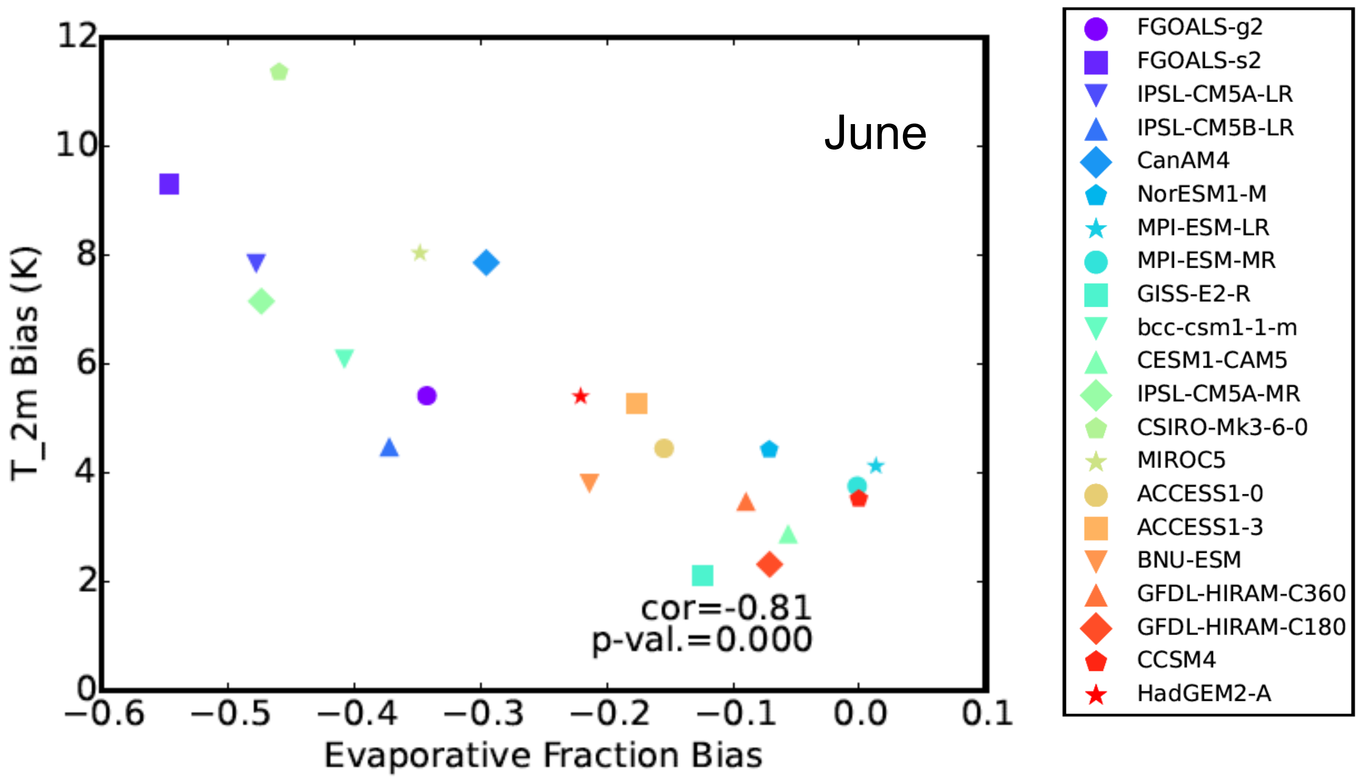
radiation transfer scheme deficiency (DeAngelis et al. 2016)

What contribute to the T2m bias?
Contribution from hydrological processes

Systematic bias in summer rainfall and evaporation is found in all GCMs.
Precipitation and evaporation are too low.

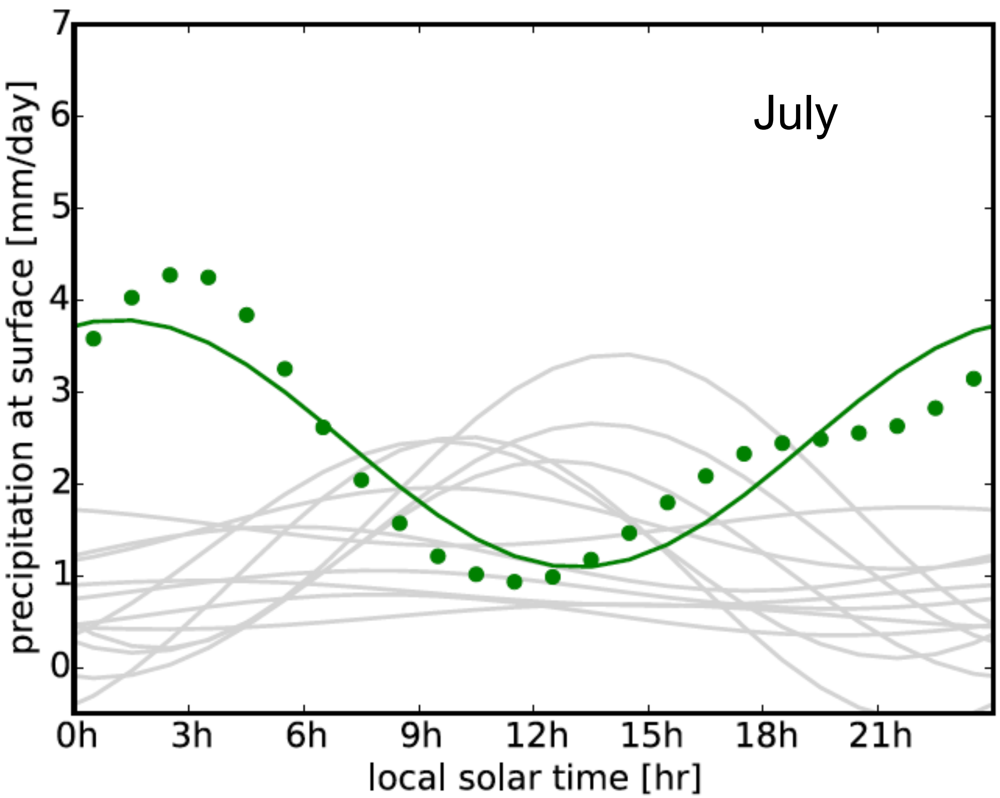


EF correlates to T2m bias across models



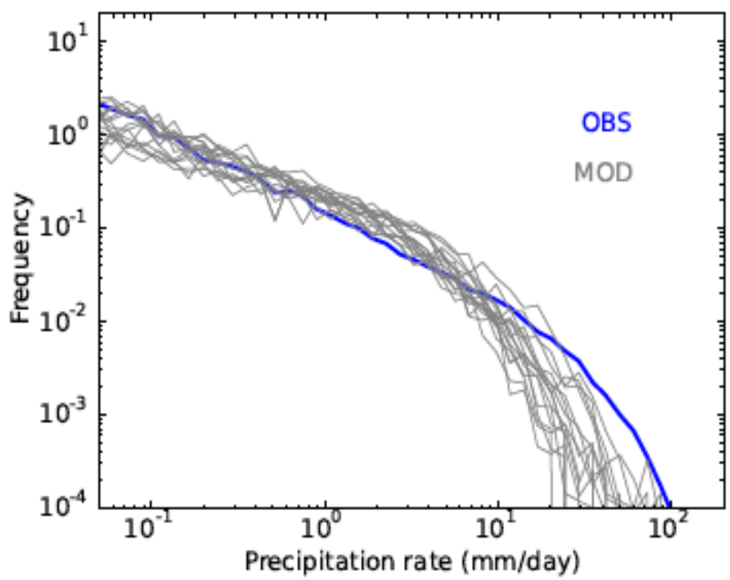
the partition of available energy at
the land surface: EF=LH/(SH+LH)

Diurnal cycle of precipitation

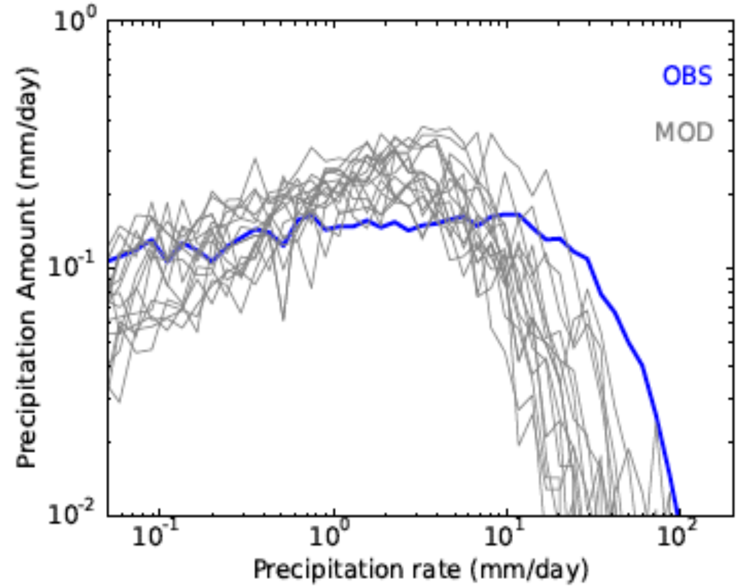


Models miss the nocturnal peak that is associated with eastward propagating convective episodes

PDF of precipitation



(a) Precipitation Frequency: JJA



(b) Precipitation Amount: JJA

- Models overestimate moderate precipitation occurrence, but underestimated light and heavy rainfall occurrence.
- This may relate to deficiencies in convective schemes in models

Summary and Discussion

- Warm bias over ARM SGP site is found in CMIP5 AMIP type of simulations
- Over-estimated net solar radiation and under-estimated Evaporative Fraction are responsible for the bias creation
- Both cloud radiative effect and clear-sky errors are important components in net solar radiation error*
- Process-oriented diagnosis using higher frequency model outputs
  - separate day time and night time processes
  - analyze what types of precipitation errors (nocturnal heavy rainfall?) that contribute most to the warm bias
- Large-scale circulation bias is inevitable: CAPT is a better tool to eliminate the large scale forcing bias and focus on the local physical processes

Extra slides

Prioritize the surface net SW error

Net-SW error =	$(1-\alpha_{mod})$*SWDN clr,error	SWDNclr error
	$+(1-\alpha_{mod})$*SWDN cre,error	SWDNcre error
	$+(\alpha_{mod}-\alpha_{obs})$*(SWDN clr+ SWDN cre)	Albedo error

Based on CERES_EBAF:

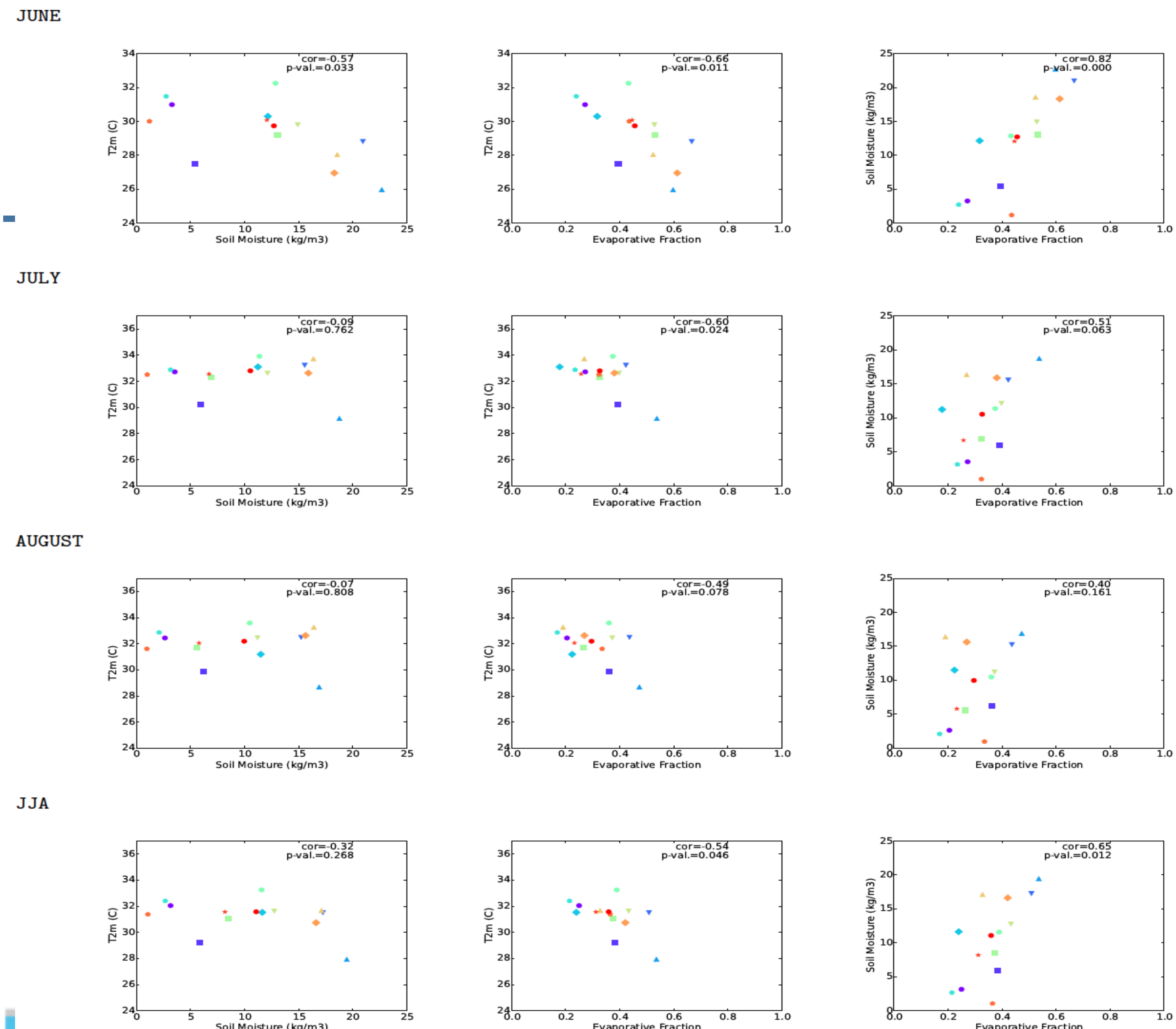
Model	Net-SWDN error (Wm-2)	Albedo error (Wm-2)	SWDN-clr error (Wm-2)	SWDN-cre error (Wm-2)
FGOALS-g2	19.11	-9.64	18.31	10.51
FGOALS-s2	38.18	-7.93	21.76	24.32
IPSL-CM5A-LR	26.86	0.07	22.09	4.79
IPSL-CM5B-LR	41.04	-1.48	20.53	22.07
CanAM4	41.78	-1.03	15.10	27.53
NorESM1-M	35.49	6.23	11.80	17.60
MPI-ESM-LR	19.46	-7.52	8.87	18.13
MPI-ESM-MR	17.20	-7.48	9.12	15.55
GISS-E2-R	-20.10	0.49	13.34	-33.99
bcc-csm1-1-m	18.24	-8.61	14.50	12.30
CESM1-CAM5	8.21	5.42	7.96	-5.11
IPSL-CM5A-MR	40.46	3.58	22.58	14.28
CSIRO-Mk3-6-0	54.00	10.08	16.92	26.76
MIROC5	36.65	7.67	14.39	14.64
ACCESS1-0	30.93	2.49	13.33	15.23
ACCESS1-3	44.42	10.77	12.55	21.25
BNU-ESM	56.40	20.63	15.28	20.44
GFDL-HIRAM-C360	22.81	0.03	12.03	10.81
GFDL-HIRAM-C180	12.97	-7.02	11.21	8.74
CCSM4	34.80	2.02	13.39	19.52
HadGEM2-A	33.21	-0.74	12.78	21.10
Multi-Model Mean	29.15	0.86	14.67	13.62

With out GISS : 31.6 0.88 14.73 16.00

Based on ARM: Radflux_Long

Model	Net-SWDN error (Wm-2)	Albedo error (Wm-2)	SWDN-clr error (Wm-2)	SWDN-cre error (Wm-2)
FGOALS-g2	22.65	-4.32	8.90	18.10
FGOALS-s2	41.72	-2.59	12.31	31.95
IPSL-CM5A-LR	30.39	5.46	12.27	12.71
IPSL-CM5B-LR	44.57	3.90	10.79	29.93
CanAM4	45.31	4.35	5.40	35.36
NorESM1-M	39.03	11.66	1.69	25.77
MPI-ESM-LR	22.99	-2.20	-0.60	25.77
MPI-ESM-MR	20.73	-2.15	-0.34	23.20
GISS-E2-R	-16.57	5.88	3.52	-26.06
bcc-csm1-1-m	21.78	-3.29	5.09	19.88
CESM1-CAM5	11.74	10.86	-2.06	2.97
IPSL-CM5A-MR	44.00	9.00	12.64	22.30
CSIRO-Mk3-6-0	57.53	15.60	6.77	34.91
MIROC5	40.18	13.13	4.24	22.82
ACCESS1-0	34.47	7.90	3.39	23.25
ACCESS1-3	47.95	16.25	2.26	29.56
BNU-ESM	59.93	26.19	4.61	29.05
GFDL-HIRAM-C360	26.35	5.42	2.22	18.72
GFDL-HIRAM-C180	16.50	-1.69	1.74	16.38
CCSM4	38.34	7.43	3.48	27.52
HadGEM2-A	36.74	4.65	3.04	28.97
Multi-Model Mean	32.68	6.26	4.84	21.54

With out GISS : 35.14 6.27 4.9 23.92

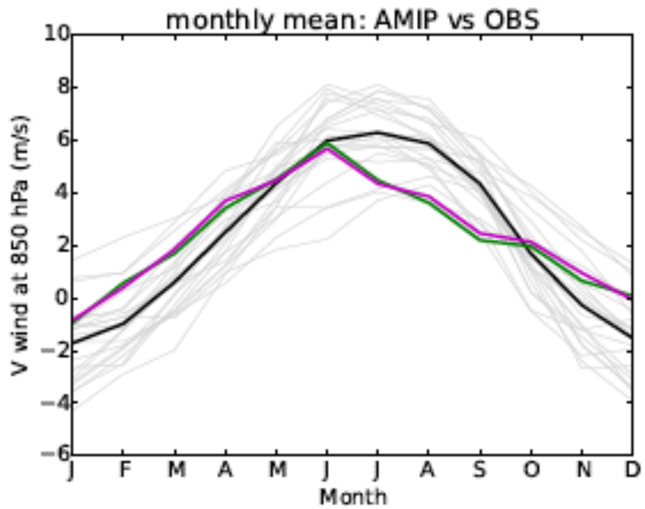


Soil moisture plays a central role in the partition of available energy at the land surface (EF=LH/(SH+LH)).

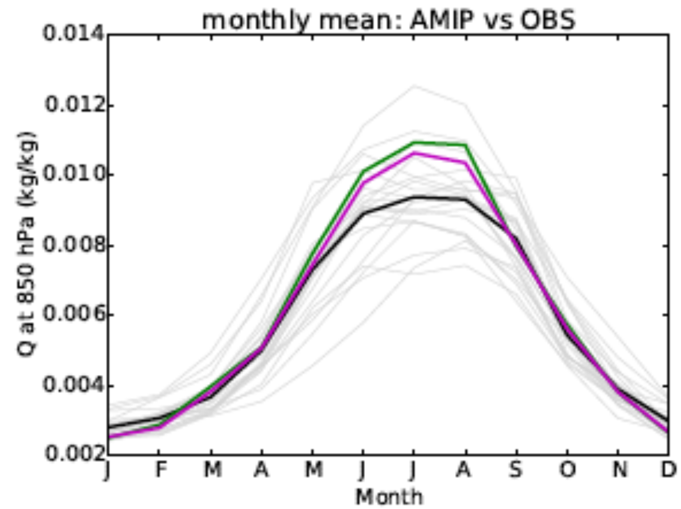
Soil moisture and EF coupling strength varies by months.

In June, coupling is strongest.

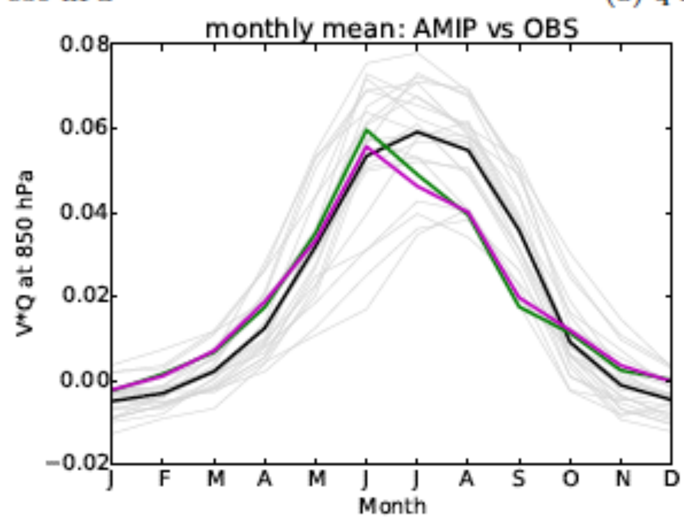
Onto moisture transport: Magenta (ECMWF) Green (Continuous Forcing)



(a) V at 850 hPa

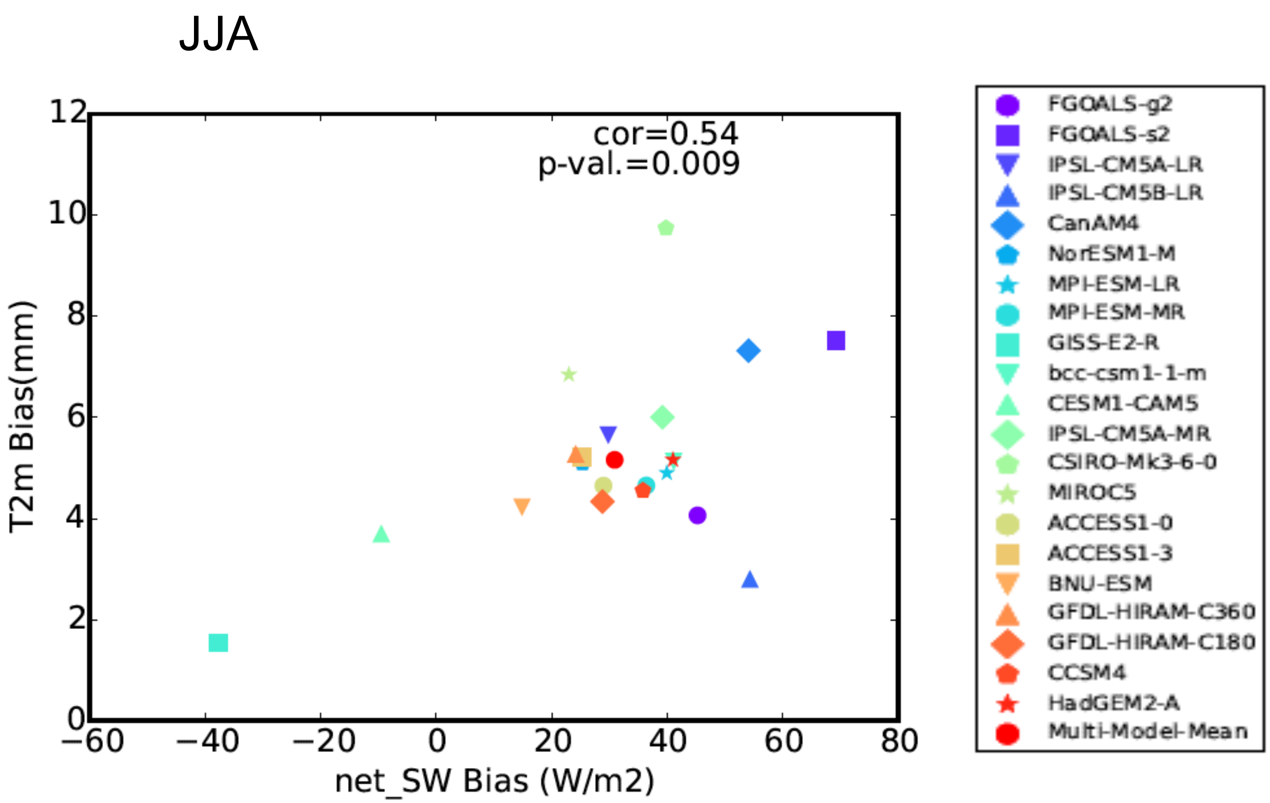


(b) q at 850 hPa

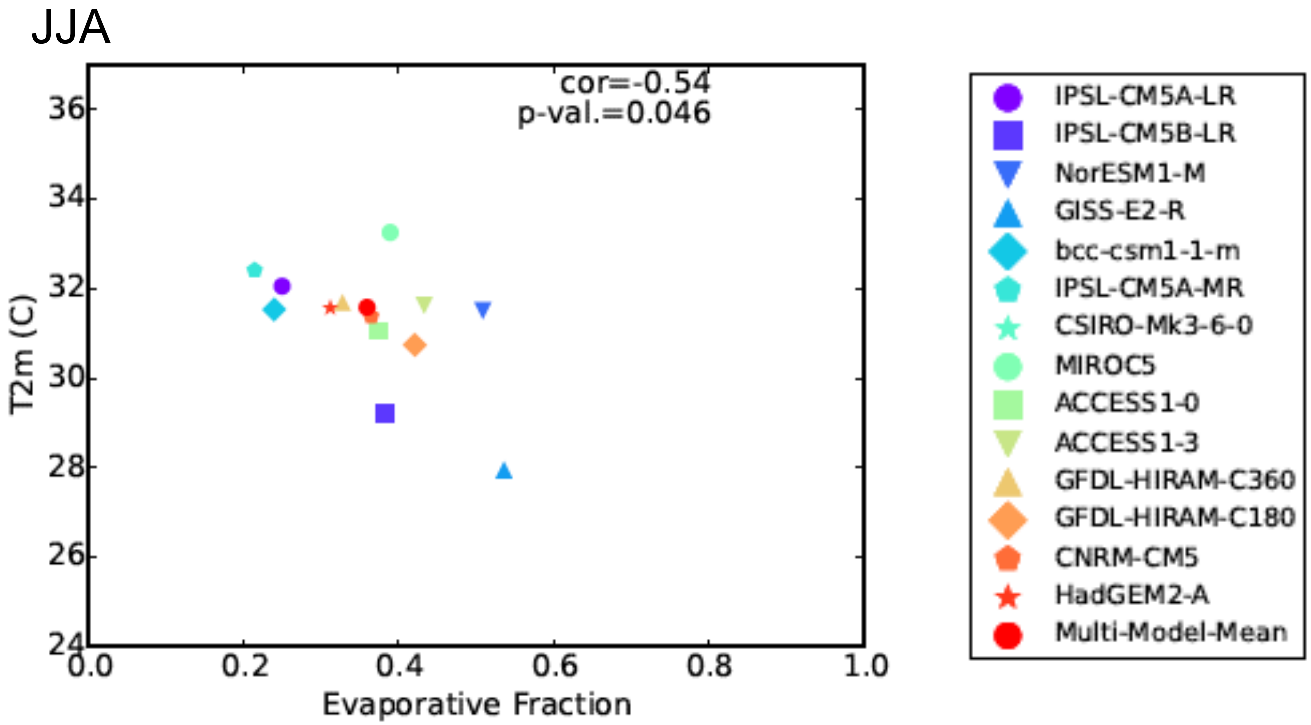


(c) Vq at 850 hPa

Net SWDN bias correlates to T2m bias across models

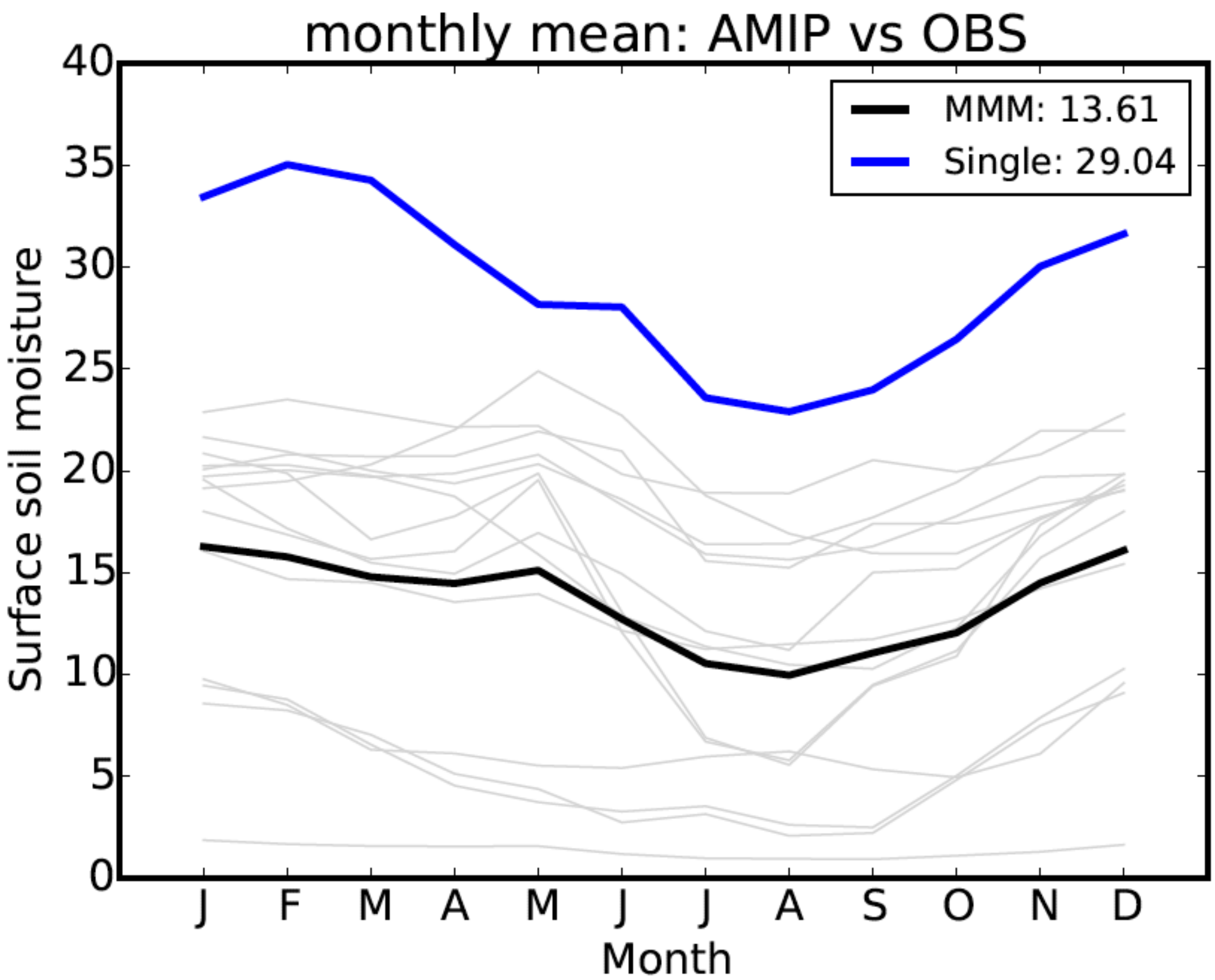


EF correlates to T2m bias across models

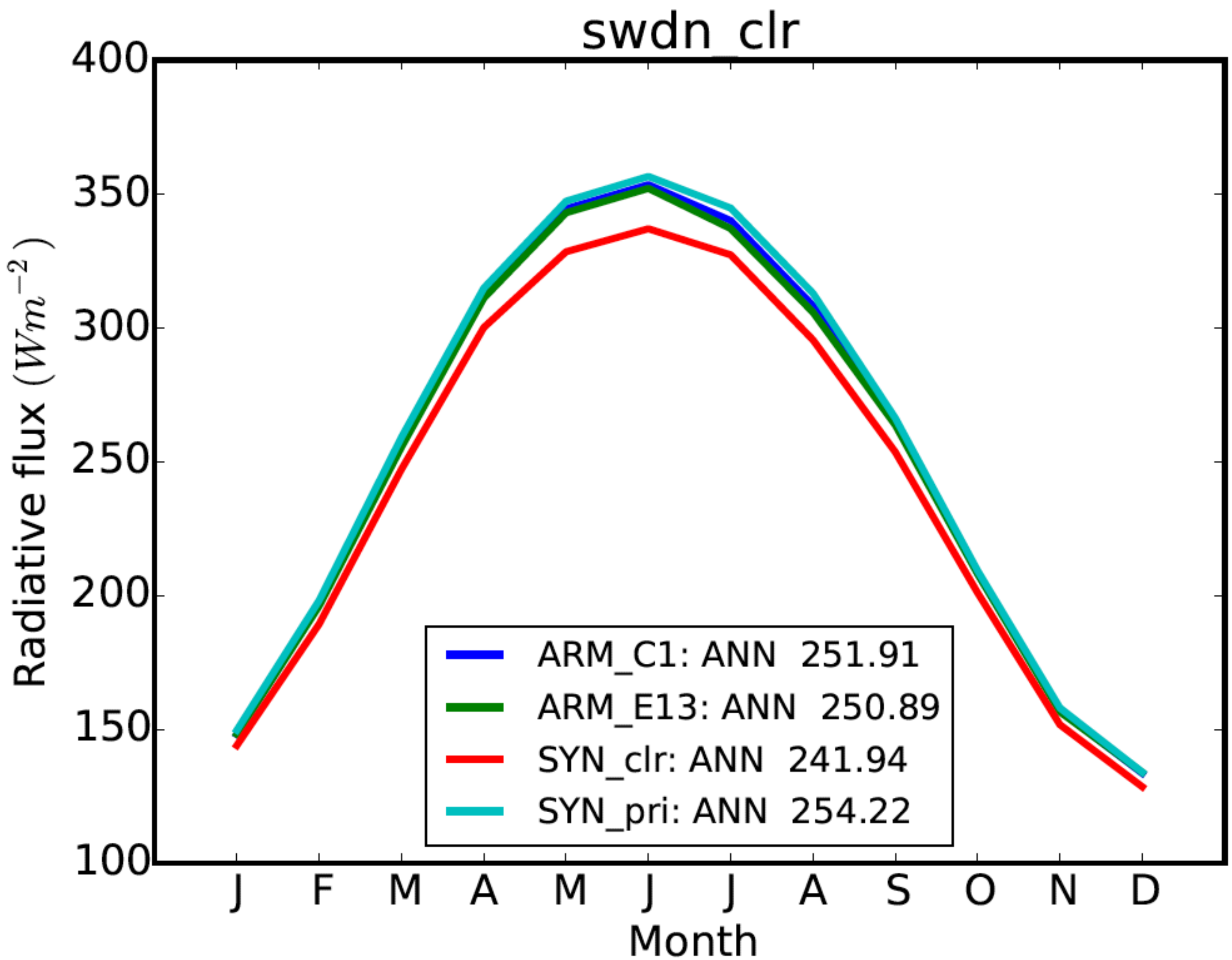


the partition of available energy at the land surface: EF=LH/(SH+LH)

Soil moisture



Clear-sky SW Down at two ARM sites E13 (36.66 N, 97.624 W) and C1 (36.60N, 97.485 W)



ARM Data stream:
sgpradflux1longC1 (1999~2011)
Sgpradflux1longE13 (1997~2008)

CERES Data stream:
CERES_SYN1deg (2000~2015)