Precipitation Intensity Trends and Changes in the Tropics from GPCP Observations and Climate Models

Robert Adler and Guojun Gu
University of Maryland

Use GPCP Monthly and AMIP/CMIP to examine rainfall intensity variations and trends in the 1988-2015 period and tease out effects of global warming (GW) and inter-decadal forcing (PDO). Gu and Adler, *J. Climate* 2018 (in press)

Examine tropical daily rainfall from TMPA (adjusted by GPCP Monthly) to examine intensity variations on inter-annual scale and compare with longer-term trends.

Data and Models

Monthly precipitation from the Global Precipitation Climatology Project (GPCP; Version 2.3)

Adler et al., 2018 *Atmosphere*

1979-present and on a global grid of 2.5°×2.5°

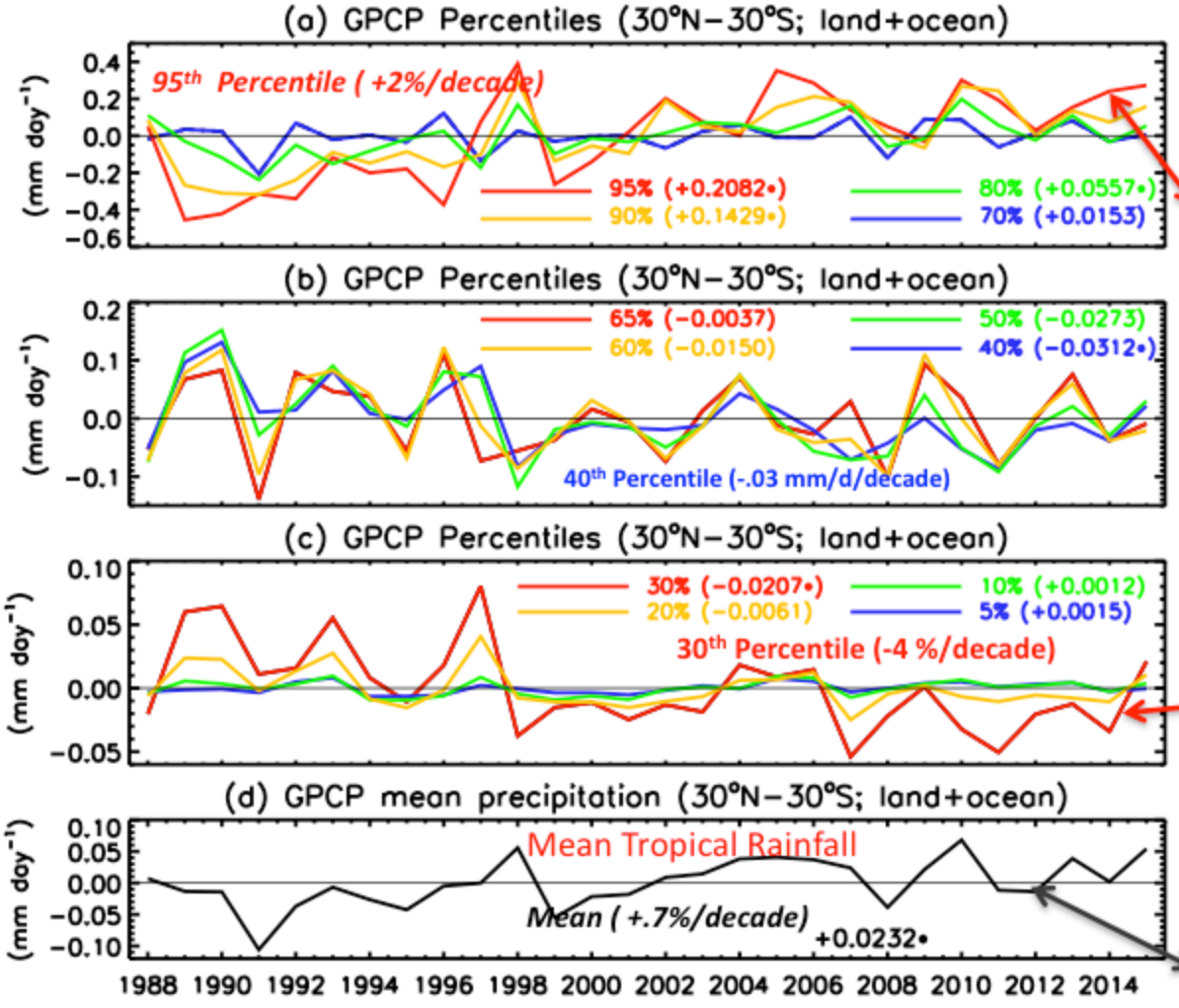
We focus on the period of 1988-2015 in which microwave-based precipitation estimates are available

CMIP5 monthly precipitation from ensemble of multiple climate models:

1) **AMIP**: AMIP-type simulations (driven by observed SST, ice extent, and historical radiative forcings) *Should simulate GW and PDO*

1) **CMIP:** Hist-Full; Coupled historical full radiative forcings simulations
Should simulate only GW and other long-term effects

Annual Anomalies of GPCP Percentiles (Pct) in the Tropics (30°N-30°S, Land+Ocean)



Positive trend, statistically significant for Pct ≥ 80th

95th Percentile: +2%/decade

Negative trend for the middle percentiles, significant for 30th - 40th (edge of moderate to dry regions)

30th Percentile: -4 %/decade

P_{mean} has positive trend, but smaller than high percentiles

Mean: +.7%/decade

Decadal-scale shift/change around 1998, coincident with the phase shift of the PDO

Signals stronger over ocean; weaker over land

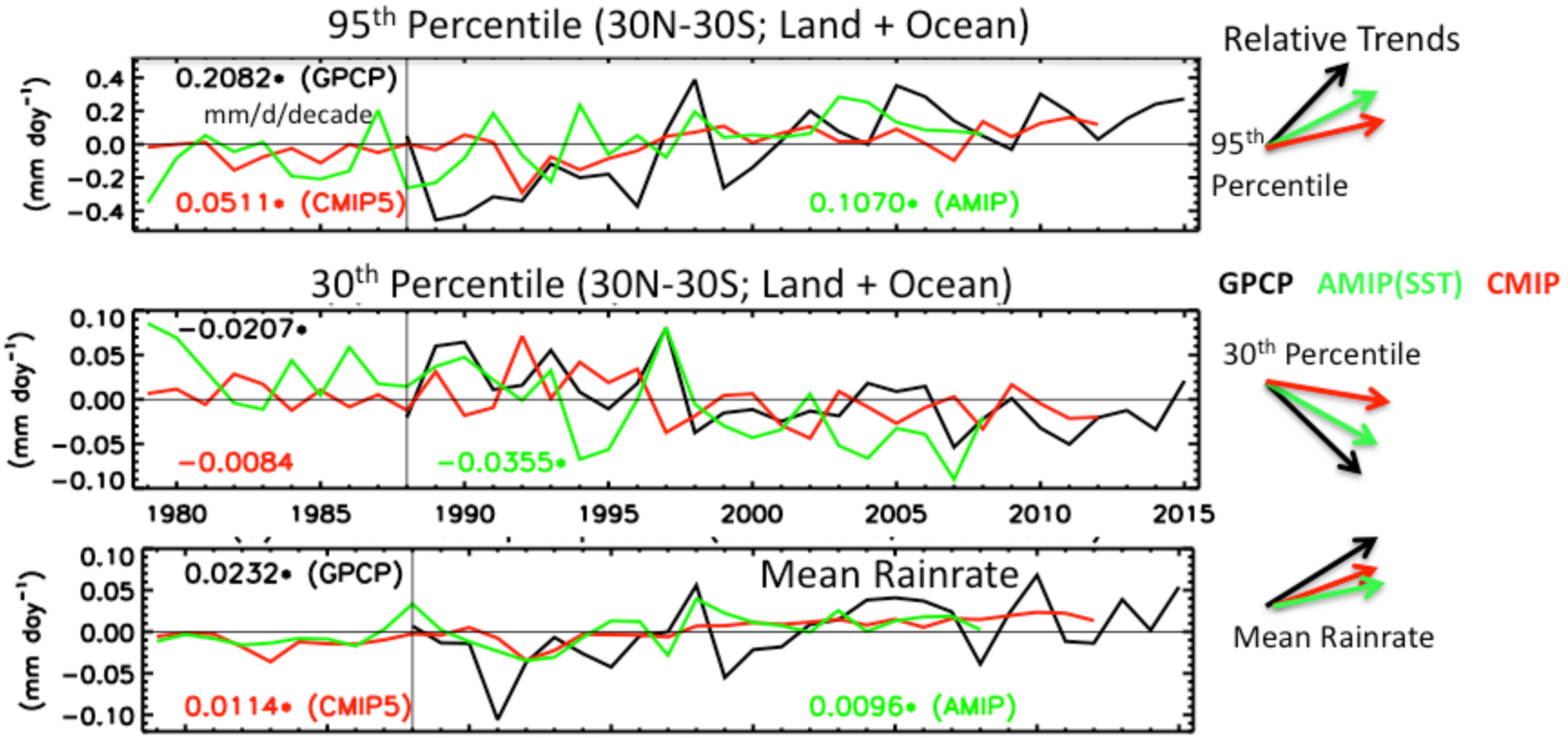
Mean Precipitation Percentiles in the Tropics (30°N-30°S, Land+Ocean) for GPCP, AMIP and Hist-Full)

Percentile	GPCP (1988-2015)	AMIP (1979-2008)	CMIP Hist-Full (1979-2012)
95th	10.47	10.14	9.70
90th	8.28	8.61	8.38
70th	3.87	4.91	4.65
30th	0.44	1.06	1.24
5th	0.026	0.19	0.20

mm/d

Differences in percentiles indicate the discrepancies of precipitation climatologies between models and GPCP

Percentile Changes/Trends: GPCP AMIP(SST) CMIP



- For Intense rain (90-95th Percentile) trend is up for observations (GPCP) and both model types, with trend magnitude GPCP>AMIP> CMIP.
- For Intermediate rain rates (e.g., 30th Percentile) trend is down for observations and models, with trend magnitude again GPCP>AMIP> CMIP.
- **Interpretations: 1) Models may be underestimating intensity changes related to warming; 2) AMIP>CMIP magnitudes may indicate relative GW+PDO vs. GW effects**

Variations/changes in Rainfall Intensity and the Size of Distinct Tropical Zones

Define Three precipitation categories and then distinct zones based on long-term mean percentiles (Pct) estimated from monthly rain-rates:

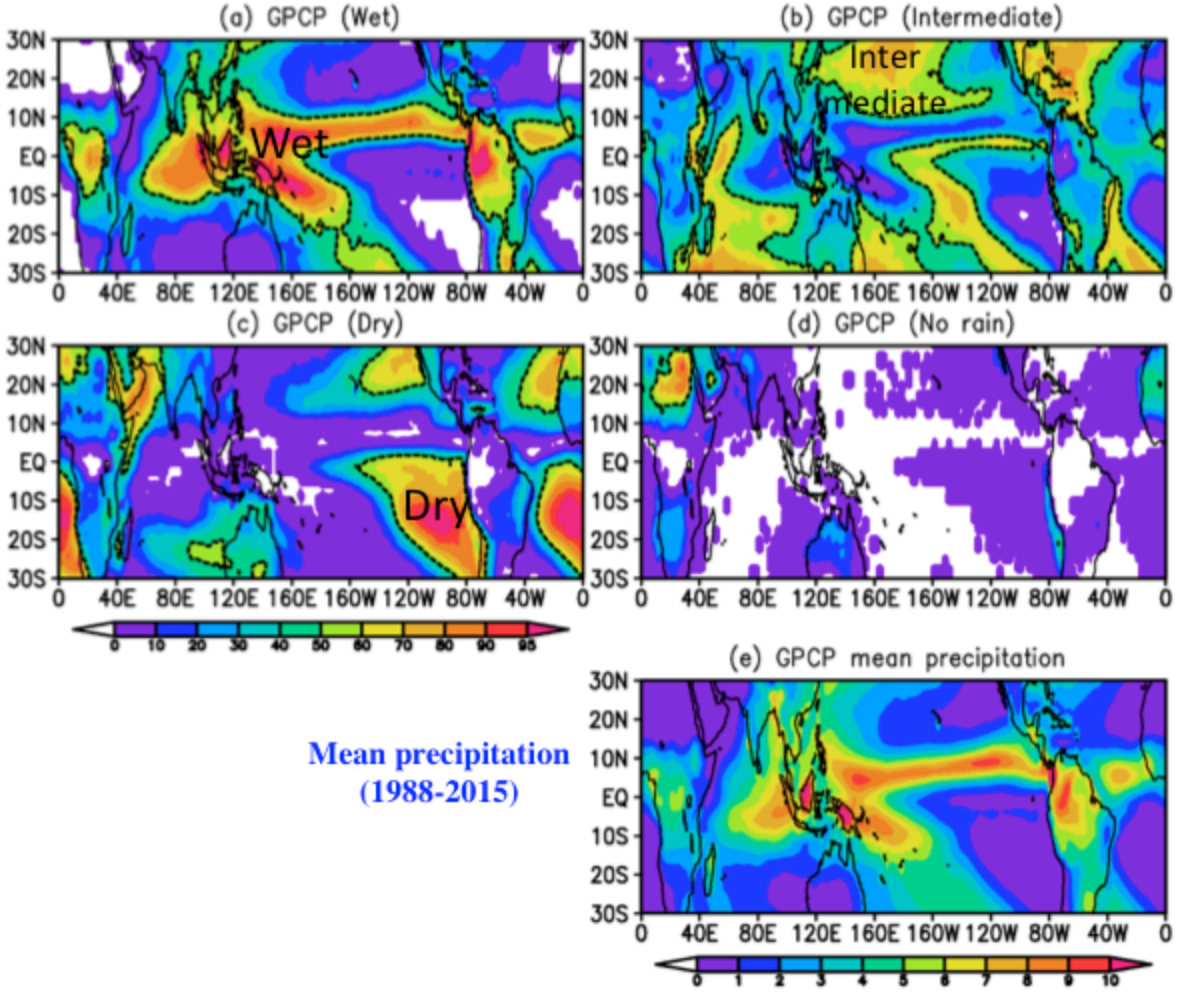
- Wet ($P \geq P_{Pct=70}^{th}$) [Zone above 70th Percentile]
- Intermediate ($P_{Pct=70th} > P \geq P_{Pct=30}^{th}$)[Zone between 70th and 30th Percentile]
- Dry ($P_{Pct=30th} > P \geq P_{Pct=5}^{th}$) [Zone between 30th and 5th Percentile]

Percentile	GPCP (1988-2015)	AMIP (1979-2008)	CMIP Hist-Full (1979-2012)
70th	3.87	4.91	4.65
30th	0.44	1.06	1.24
5th	0.026	0.19	0.20

Time series based on the classification of tropical (30°N-30°S) domain into four climatologically distinct zones for each month:

- Sizes of four tropical zones: S_{Wet}, S_{Inter}, and S_{Dry};
- Mean rain rates over wet and intermediate zones: P_{Wet} and P_{Inter}

Climatology of Occurrence Frequency (%) of four precipitation categories for GPCP



Mean precipitation (1988-2015)

Occurrence frequency = occurrence months (for each category)/total months

Four precipitation categories for defining tropical zones:

- Wet ($P \geq P_{Pct=70th}$),
- Intermediate ($P_{Pct=70th} > P \geq P_{Pct=30th}$),
- Dry ($P_{Pct=30th} > P \geq P_{Pct=5th}$),
- No rain ($P_{Pct=5th} > P \geq P_{pct=0th}$)

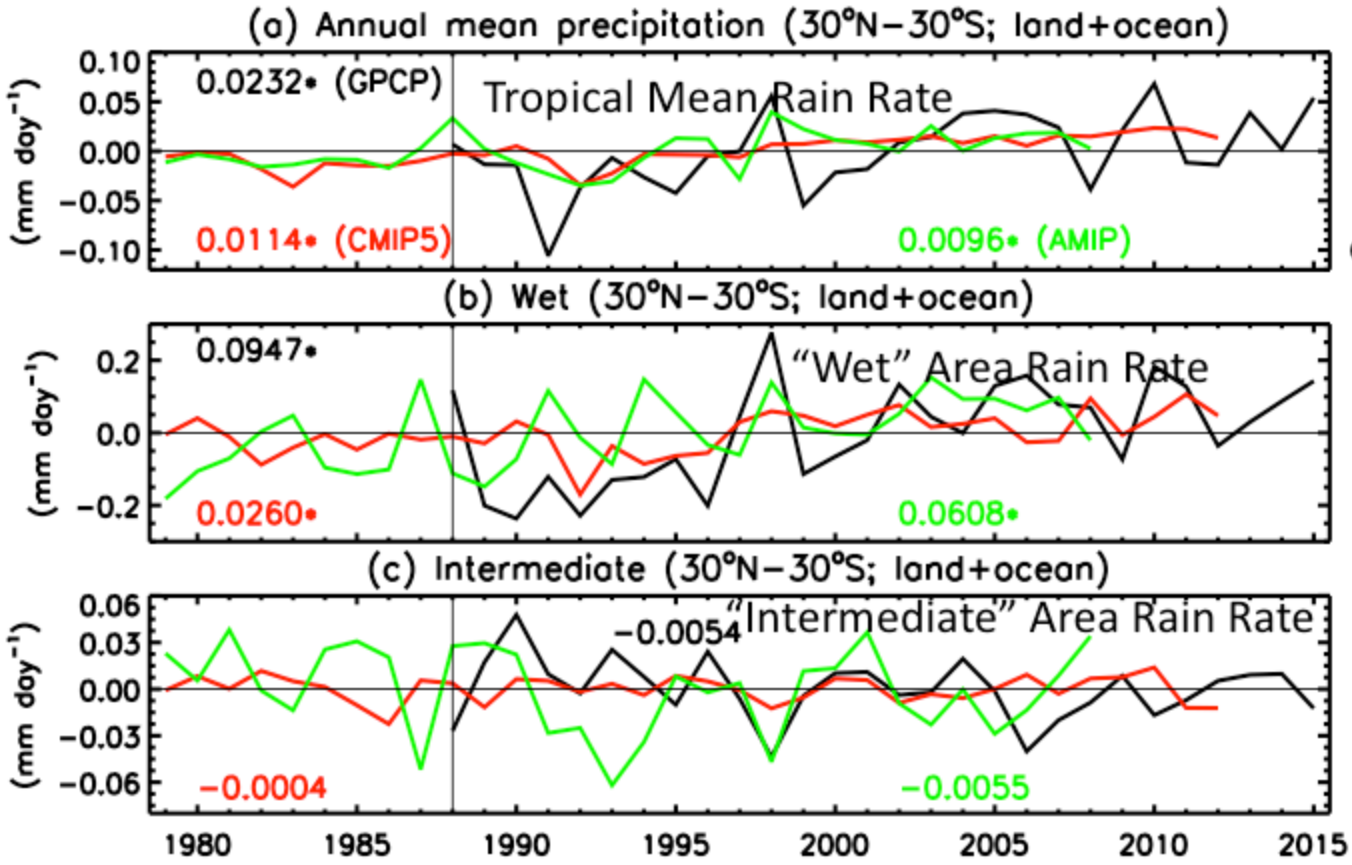
For GPCP monthly precipitation (1988-2015):

- $P_{Pct=70th}$ = 3.87 mm day^{-1}
- $P_{Pct=30th}$ = 0.44 mm day^{-1}
- $P_{Pct=5th}$ = 0.026 mm day^{-1}
- $P_{Pct=0th}$ = 0.0 mm day^{-1}

- "Wet" in general shows a similar spatial structure as mean precipitation, especially in the deep tropics, suggesting the dominance of deep convection;
- "Intermediate" occupies the regions between "Wet" and "Dry" as expected, and also contributes to the mean precipitation especially in the subtropics;
- "Dry" is generally located in the eastern basins and over several subtropical dry regions over lands

Trends in Annual Anomalies of Rain Rate in "Wet" and "Intermediate" Regions

GPCP AMIP(SST) CMIP



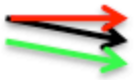
Relative Trends

Tropical Mean Rain Rate

GPCP AMIP(SST) CMIP

"Wet" Area Rain Rate

"Intermediate" Area Rain Rate

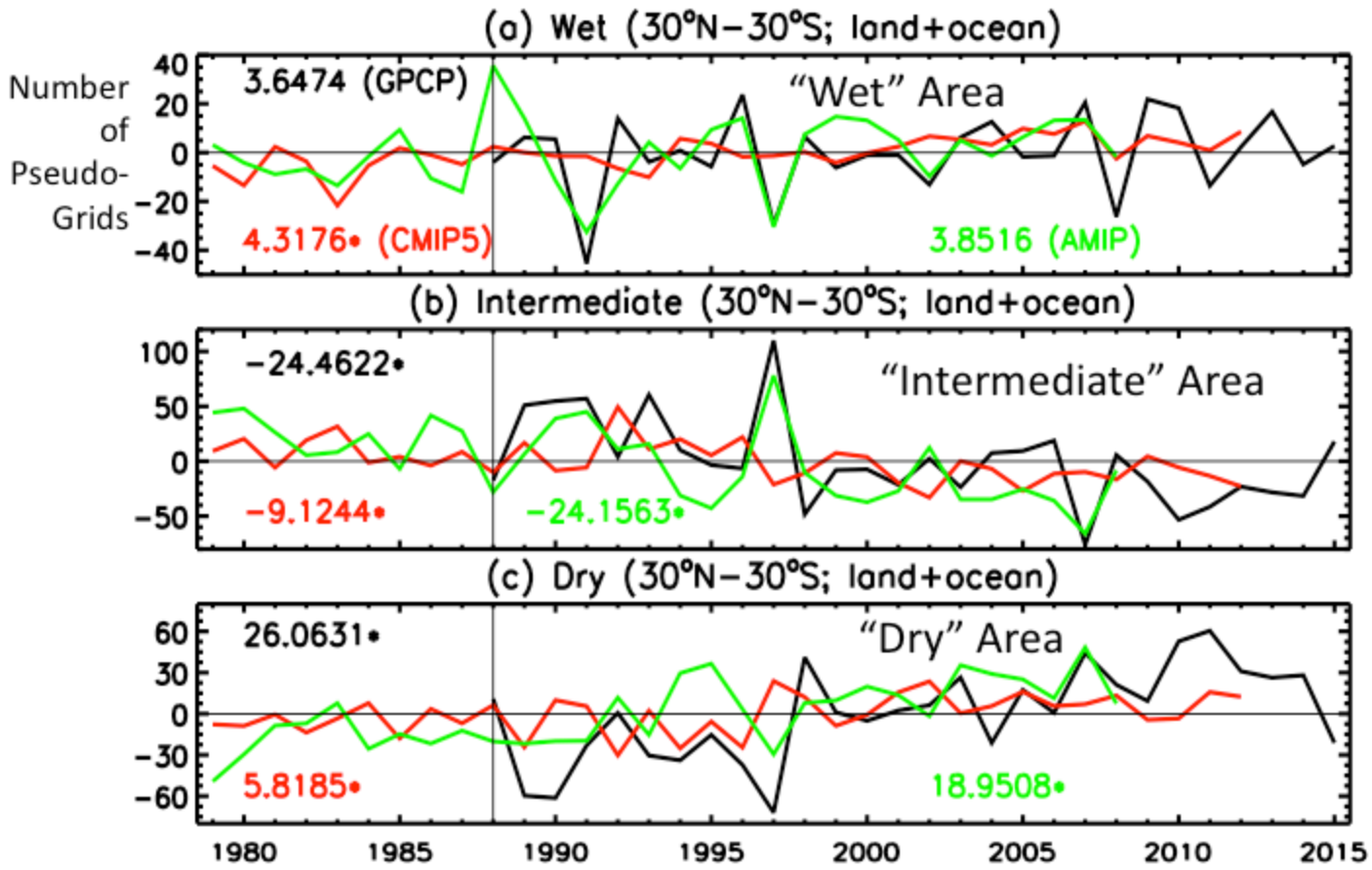


Not significant

- Mean tropical rain is increasing for observations and both model types; "Wet" area rainrate increasing quicker, with trend magnitude GPCP>AMIP> CMIP.
- "Intermediate" area rain rate trend is weakly down; not significant. "Dry" area changes not significant
- **Interpretation: Rain rate changes happening mainly in "Wet" areas, same as Percentiles**

Trends in Annual Anomalies of Areas of "Wet", "Intermediate" and "Dry" Regions

GPCP AMIP(SST) CMIP



Relative Trends

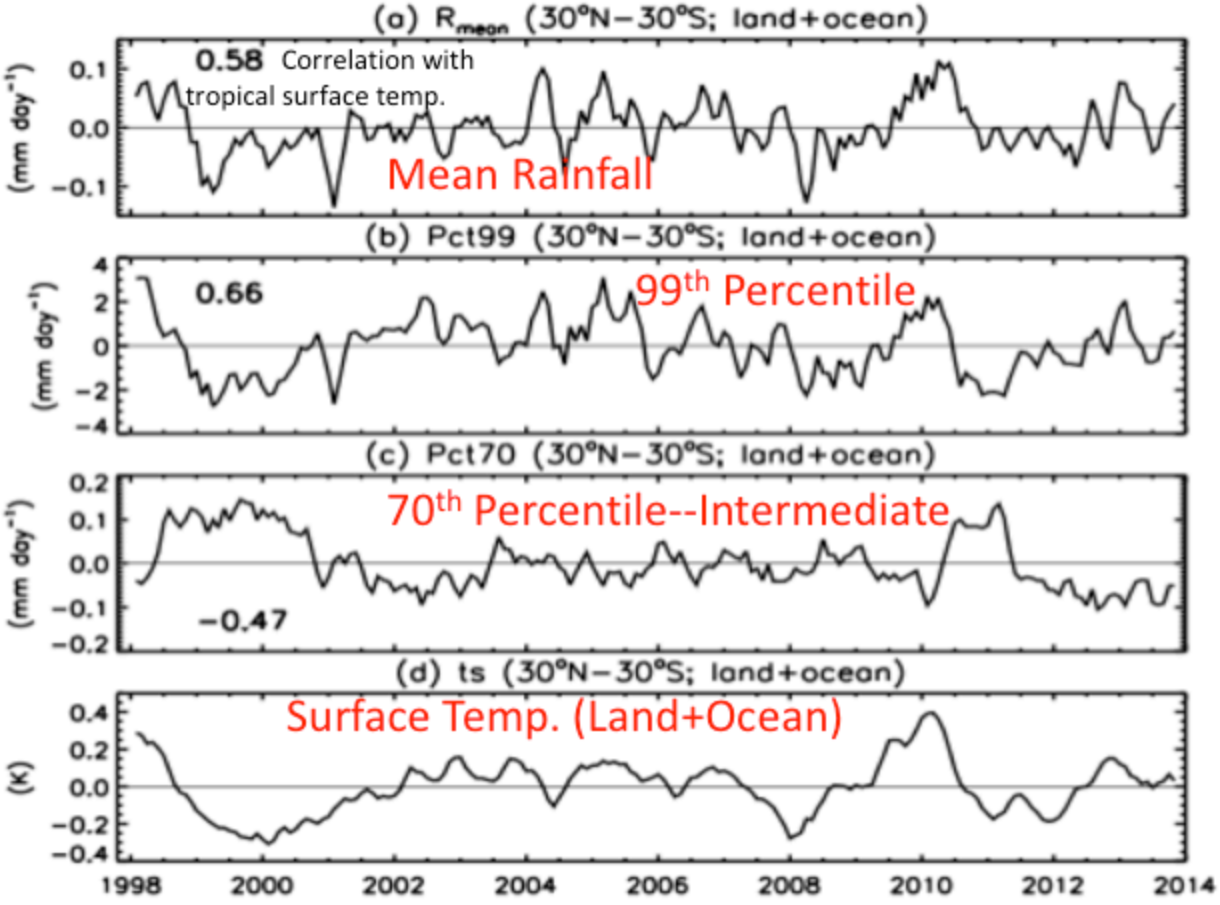
GPCP AMIP(SST) CMIP

- "Wet" area increasing slightly; "Intermediate" area decreasing strongly and "Dry" area increasing strongly with magnitudes GPCP>AMIP> CMIP.
- **Interpretation: Area changes happening mainly with "Intermediate" shrinking and "Dry" areas expanding**

Daily Rain Percentiles (30°N-30°S; Land+Ocean) Using TMPA (adjusted by GPCP Monthly)

1.0°x1.0° Lat. Long.

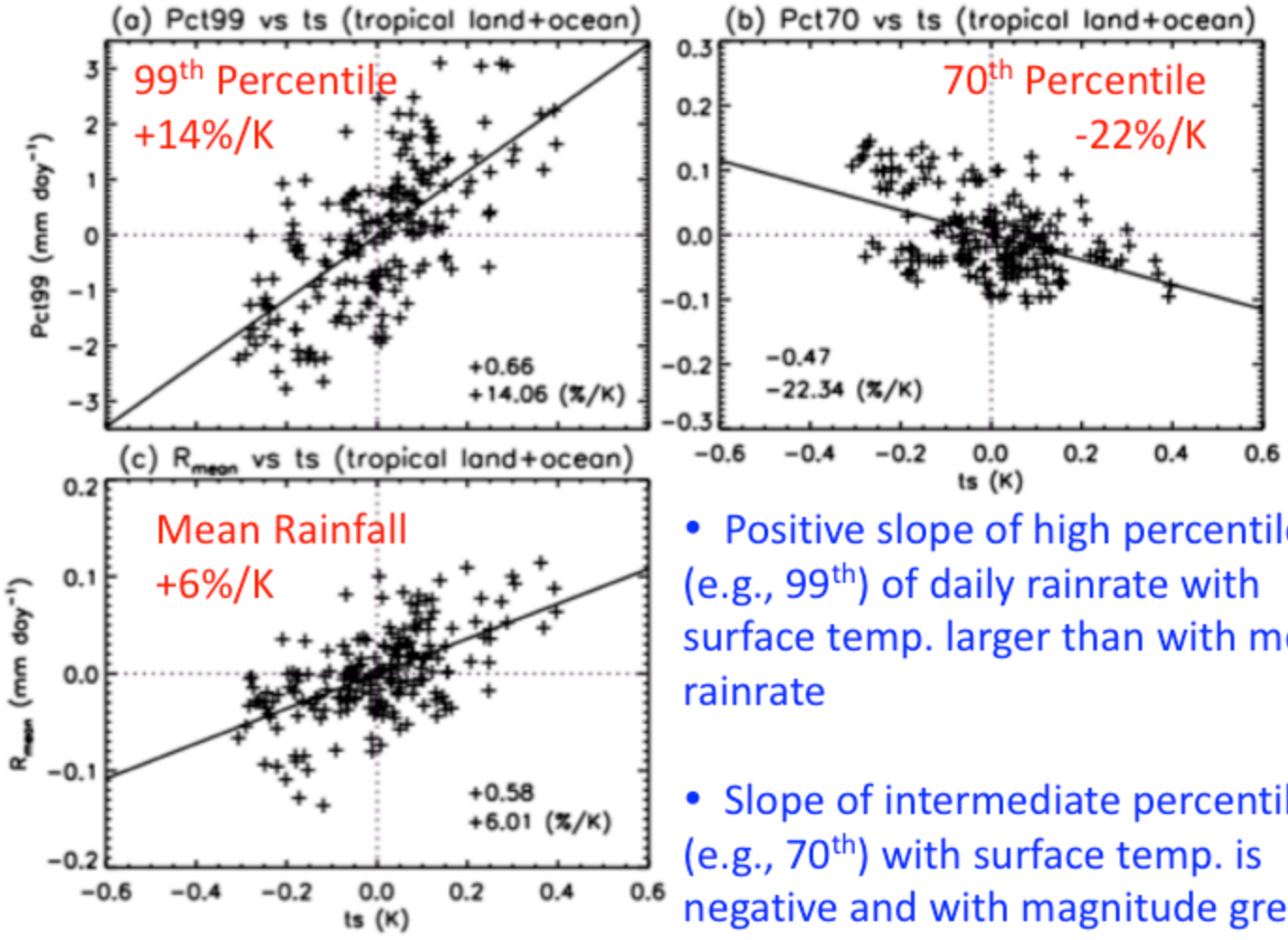
Inter-Annual Variations



Mean rainfall and high percentiles correlated positively with tropical surface temperature

Intermediate percentiles have negative correlation

Monthly Anomalies of Daily Rainfall Statistics vs. Surface Temp. Anomalies



- Positive slope of high percentiles (e.g., 99th) of daily rainrate with surface temp. larger than with mean rainrate

- Slope of intermediate percentiles (e.g., 70th) with surface temp. is negative and with magnitude greater than mean or 99th.

Comparison of Rainfall Intensity Variations in Relation to Surface Temperature Changes at Monthly and Daily Scales

	Mean Rainfall	High Percentile	Intermediate Percentile
Intensity Trends Monthly (1988-2015)	+5.0 %/K	+13.3 %/K *95th Percentile*	-31.4 %/K *30th Percentile*
Inter-annual Variations-Daily (1998-2013)	+6.0 %/K	+14.1 %/K *99th Percentile*	-22.3 %/K *70th Percentile*

Despite the different processes of the different temporal scales, the rainfall intensity changes have very similar statistics in relation to temperature changes

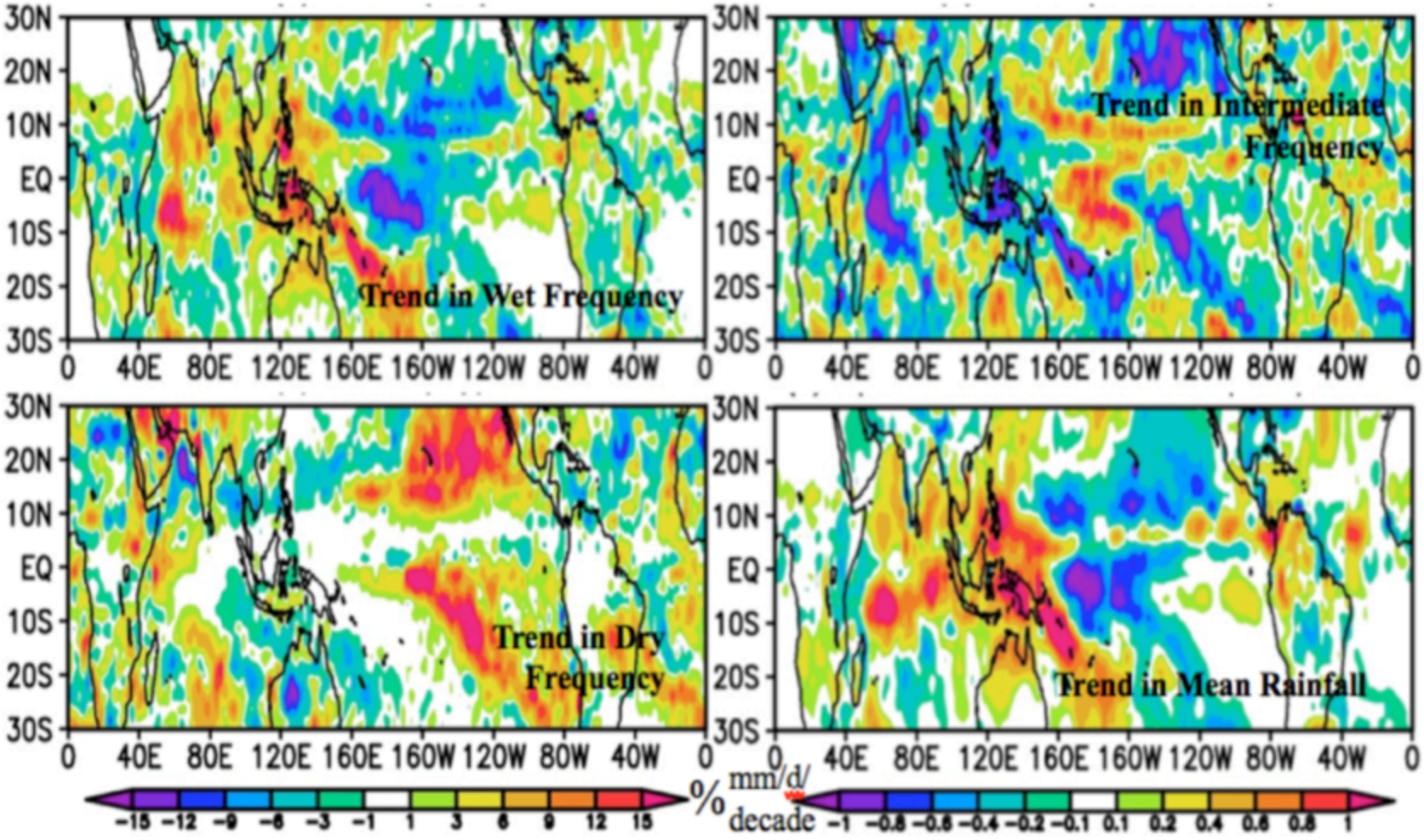
Summary of Monthly Intensity Changes/Trends

- Observations and Climate Models agree well in terms of sign of changes/trends in the mean and intensity categories over the satellite era
- Wet areas get **wetter**, i.e., rain rates in "Wet" areas and high Percentile thresholds increase, while "Dry" areas get **bigger.** "Intermediate" areas shrink
- AMIP trends/changes larger than free-running CMIP by factor of ~2. Interpretation: GW and PDO contribute about equally to changes during period
- Observational trends/changes larger than SST-forced AMIP runs by factor of ~1.5; Interpretation: Ensemble of models may be underestimating intensity changes related to GW by ~50%.

Connection of Monthly and Daily Changes to Surface Temp.

- Daily intensity statistics show high percentiles increasing with tropical inter-annual surface temp. changes at rate greater than mean rainfall, and with intermediate percentiles decreasing
- Despite the different processes of the different temporal scales, the rainfall intensity changes have very similar statistics in relation to temperature changes

EXTRA SLIDES


Trend in Wet Frequency
Trend in Intermediate Frequency
Trend in Dry Frequency
Trend in Mean Rainfall
30N
20N
10N
EQ
10S
20S
30S
0
40E
80E
120E
160E
160W
120W
80W
40W
−15 −12 −9 −6 −3 −1 1 3 6 9 12 15
%
mm/d/decade
−1 −0.8 −0.6 −0.4 −0.2 −0.1 0.1 0.2 0.4 0.6 0.8 1