Global Precipitable Water Trend and its Diurnal Asymmetry based on GPS, Radiosonde and Microwave Satellite Measurements

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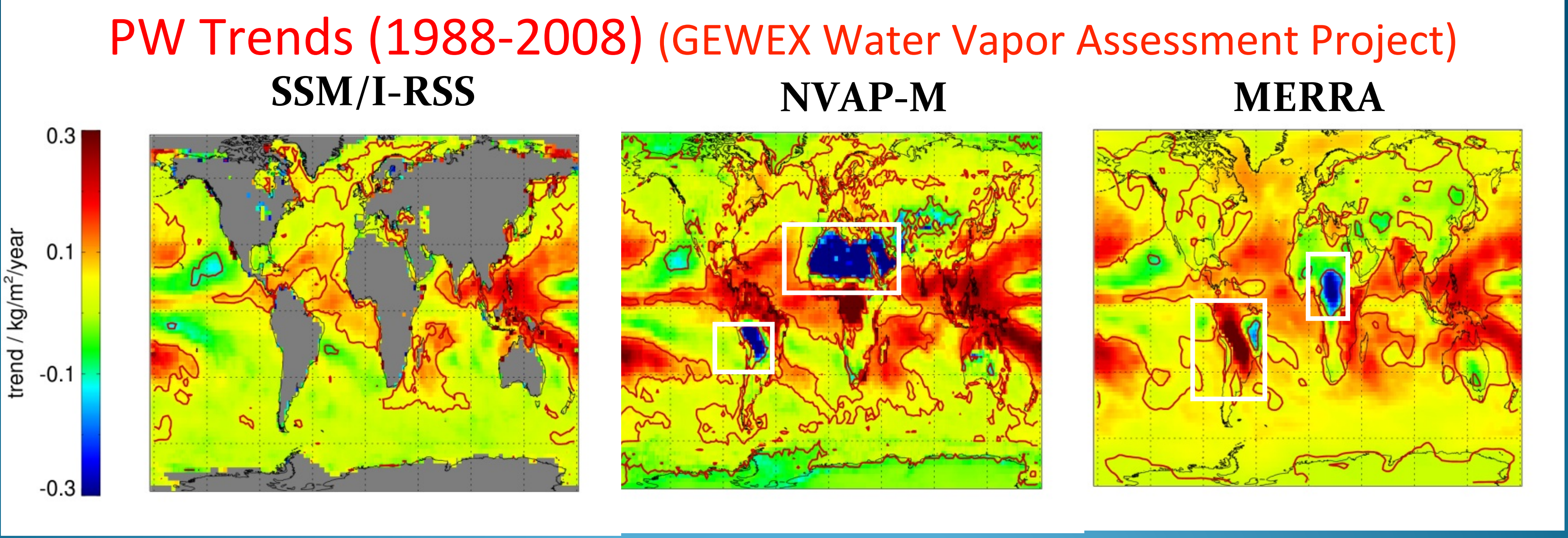
Motivation

1) Water vapor is the single most important greenhouse gas

2) Water vapor provides the water source for cloud formation and precipitation

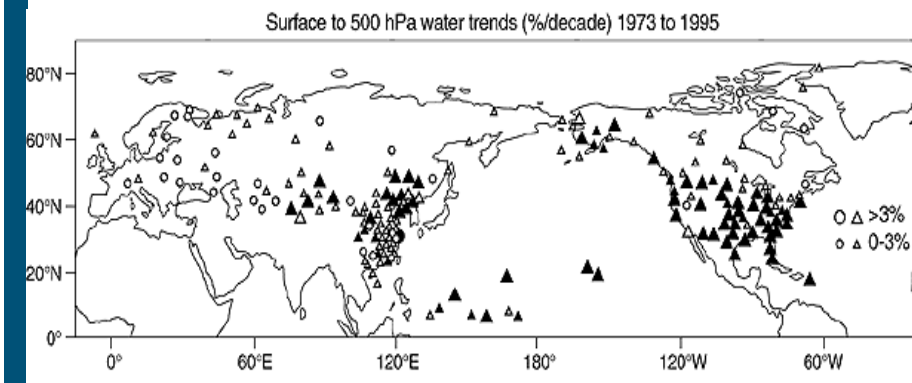
3) Significant disagreements in PW trends among different datasets and reanalysis products



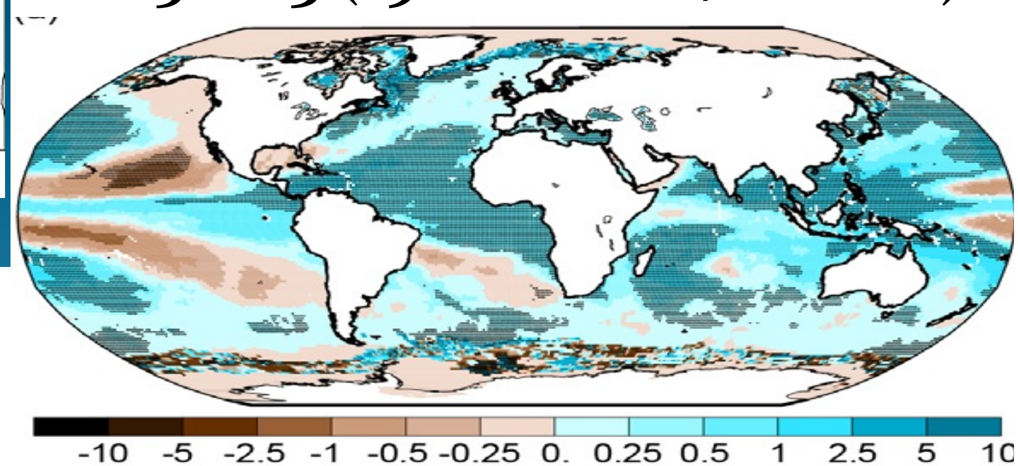
PW = total water vapor in the air column

IPCC Reports on PW trends

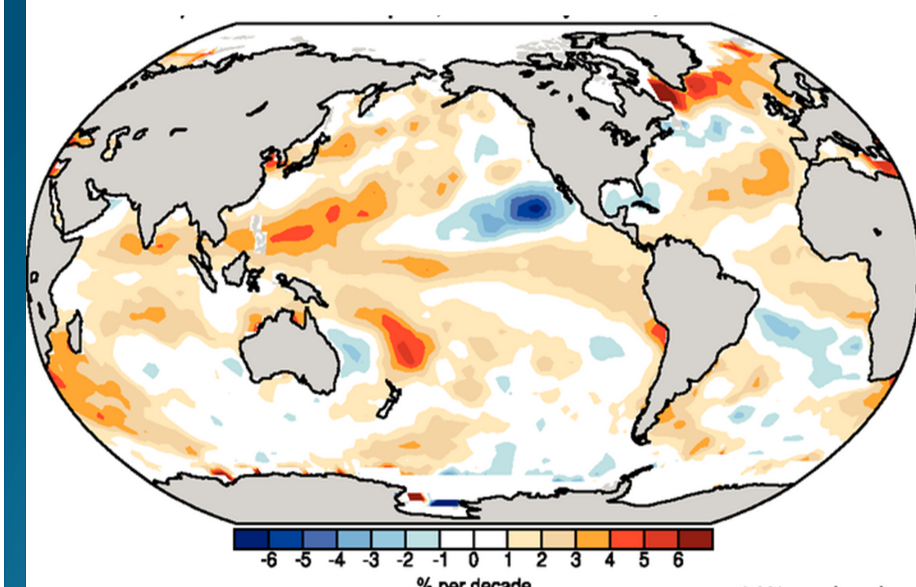
AR3 2001 (1973-1995 %/decade)



AR5 2013 (1988-2012 %/decade)



AR4 2007 (1988-2004 %/decade)



Questions:

1) What is the best estimate of global PW trends for recent years and its spatial variability over both land and ocean based on observations?

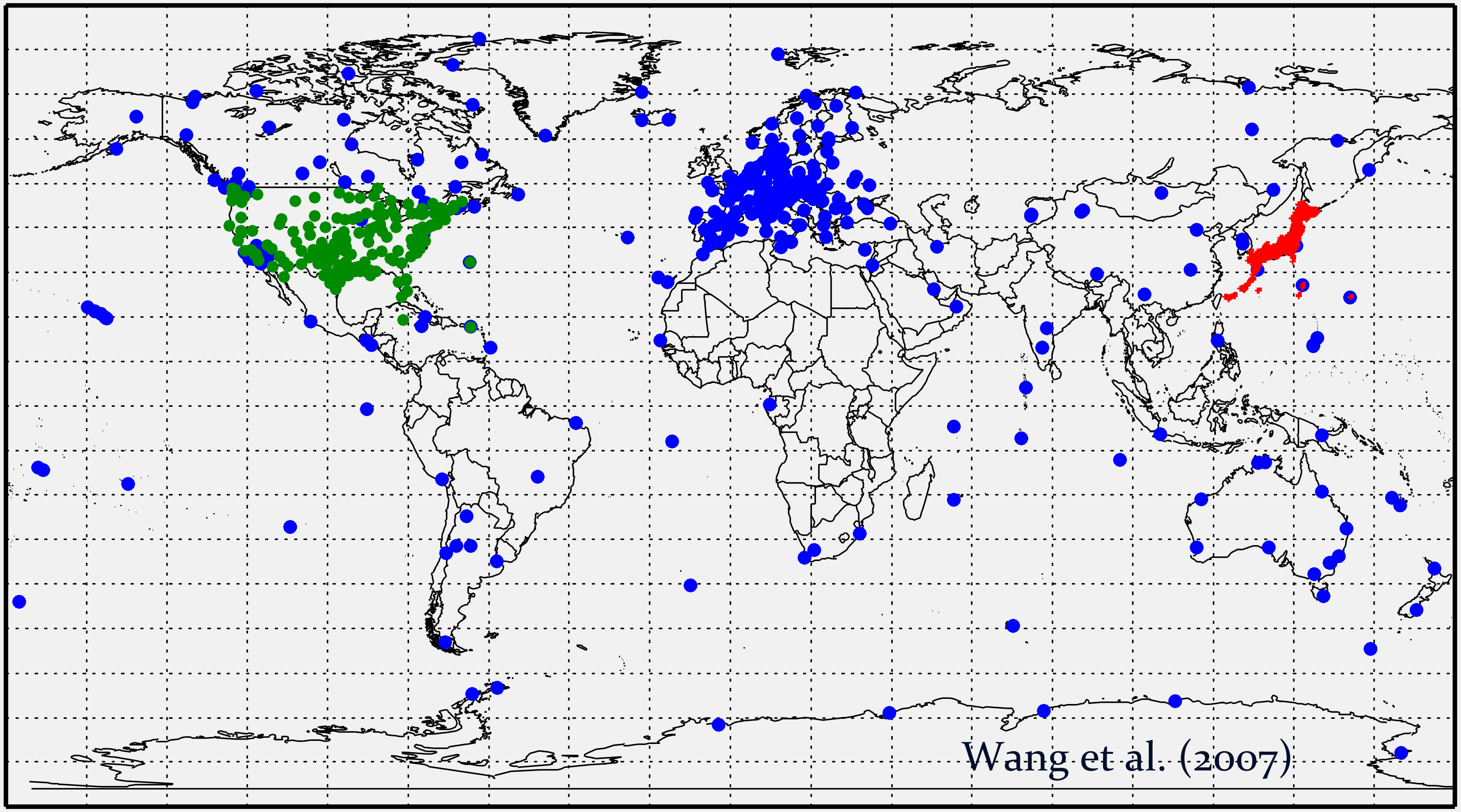
2) What is the diurnal asymmetry of PW variabilities and their relationship with T?

PW Datasets

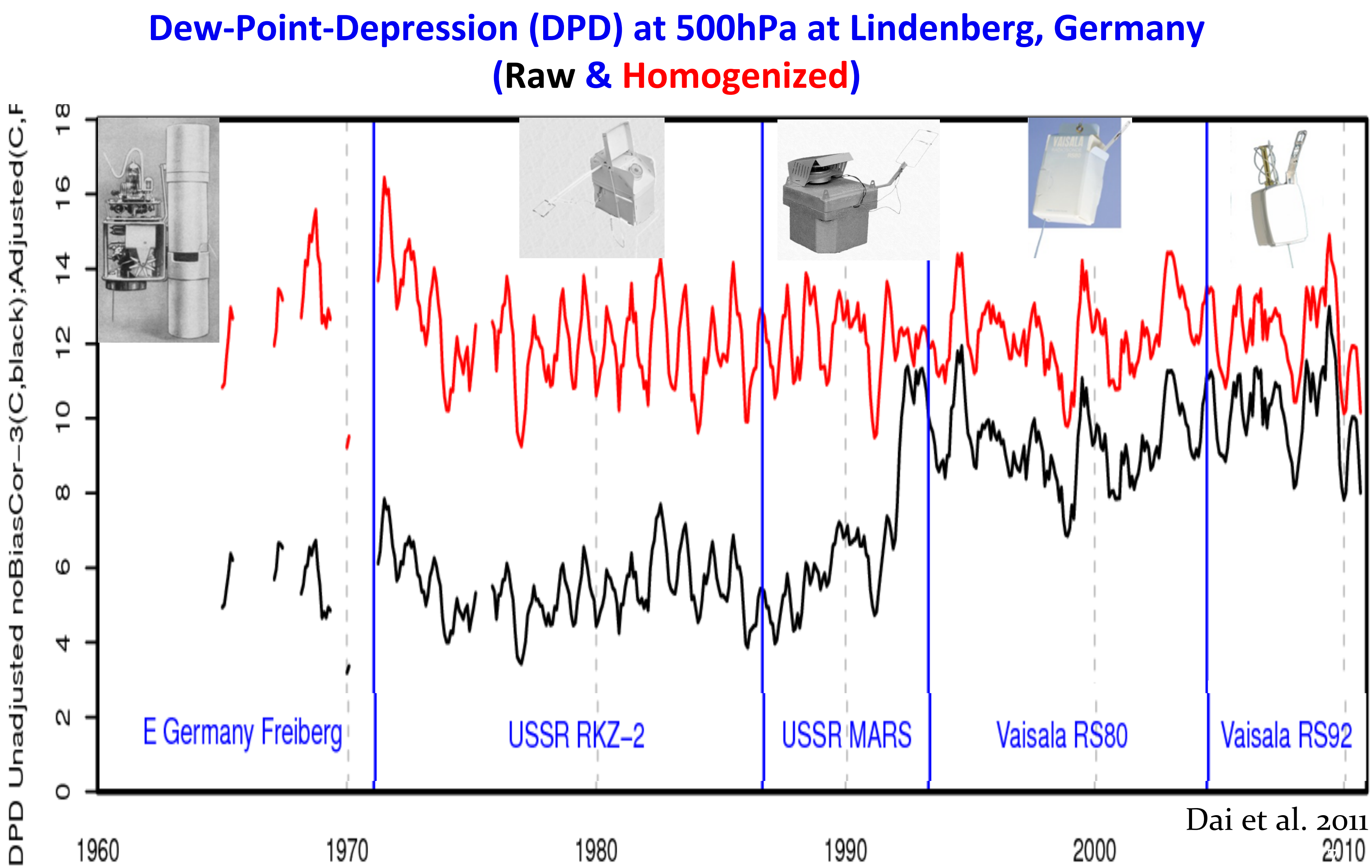
Name	Spatial Coverage	Temporal Resolution	Temporal Coverage	Sources
2-hrly GPS PW	Globe land ~400 stations	**2-hrly**	1995-2012	http://rda.ucar.edu/datasets/ds721.1/
Homogenized radiosonde data	Globe land ~900 stations	Twice daily	**1973-2011**	Request from June Wang
Satellite microwave radiometer (MWR) monthly mean PW data	**Ocean 1°x1°**	Monthly	1988-2013	ftp://ftp.remss.com/vapor/monthly_1deg/

NCAR global, 2-hourly GPS-PW dataset (1995-present)

- Jan. 1995 to Dec. 2012
- 2 hourly (0100, 0300, …, 2300 UTC)
- 380 IGS, 169 SuomiNet, 1223 GEONET
- Accuracy: < 3 mm
- Ps, Tm, ZHD and ZWD also available
- http://dss.ucar.edu/datasets/ds721.1/

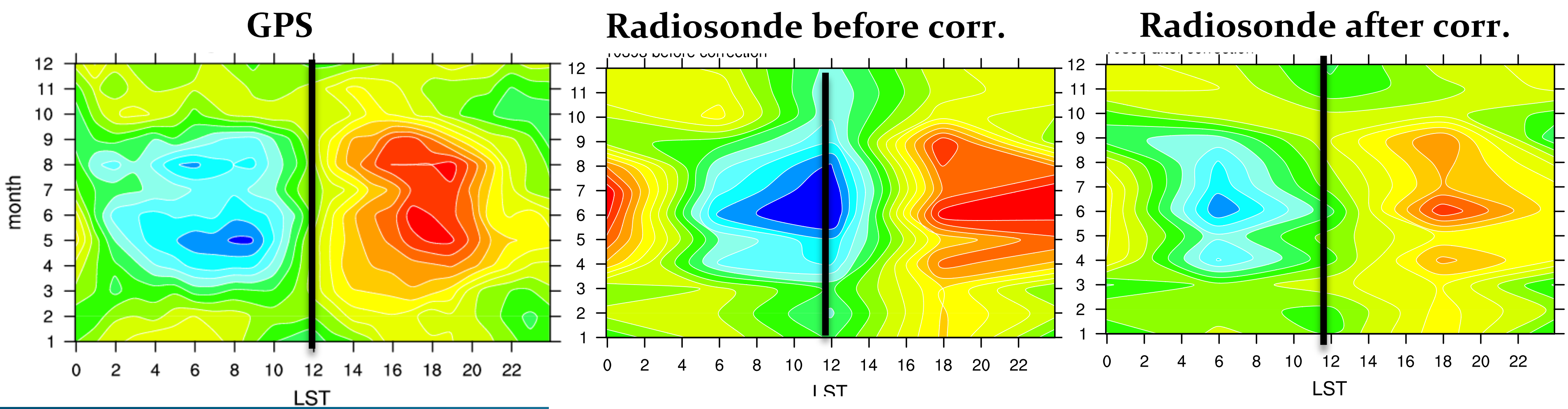


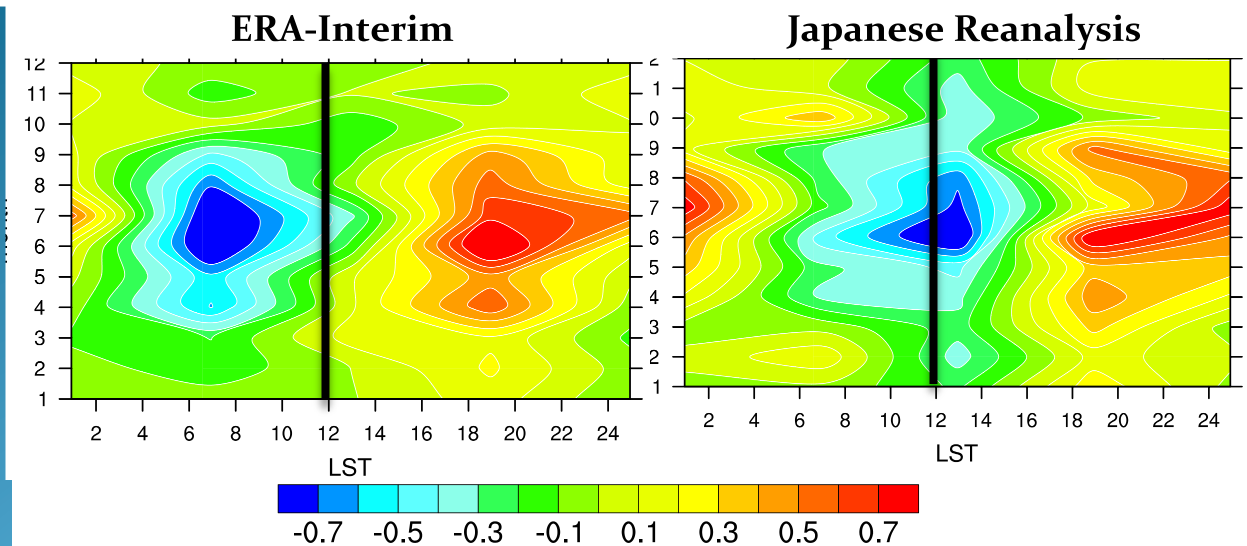
Impact of Homogenization



Dai et al. 2011

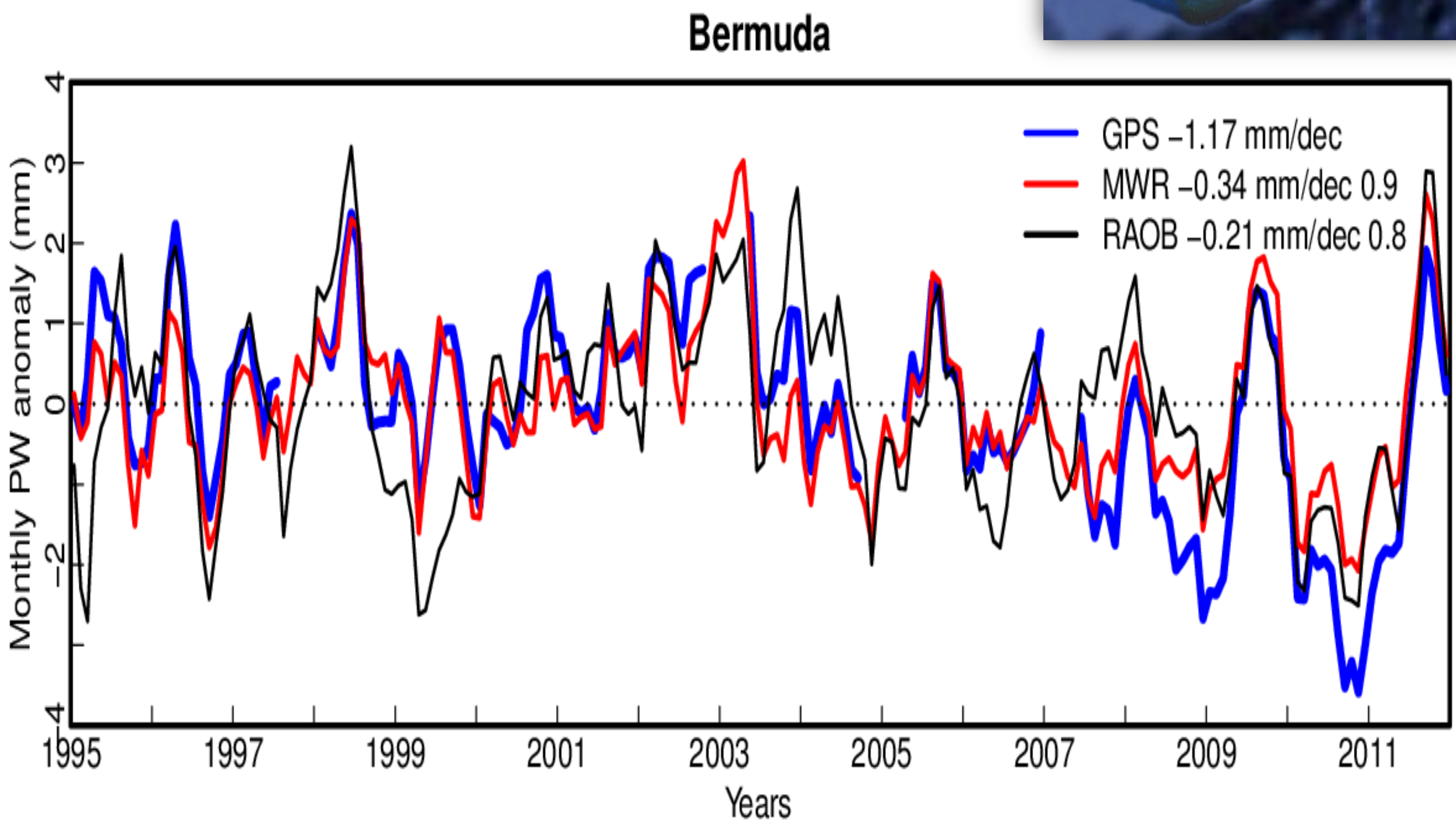
Impact on PW Diurnal Variations (Lindenberg)



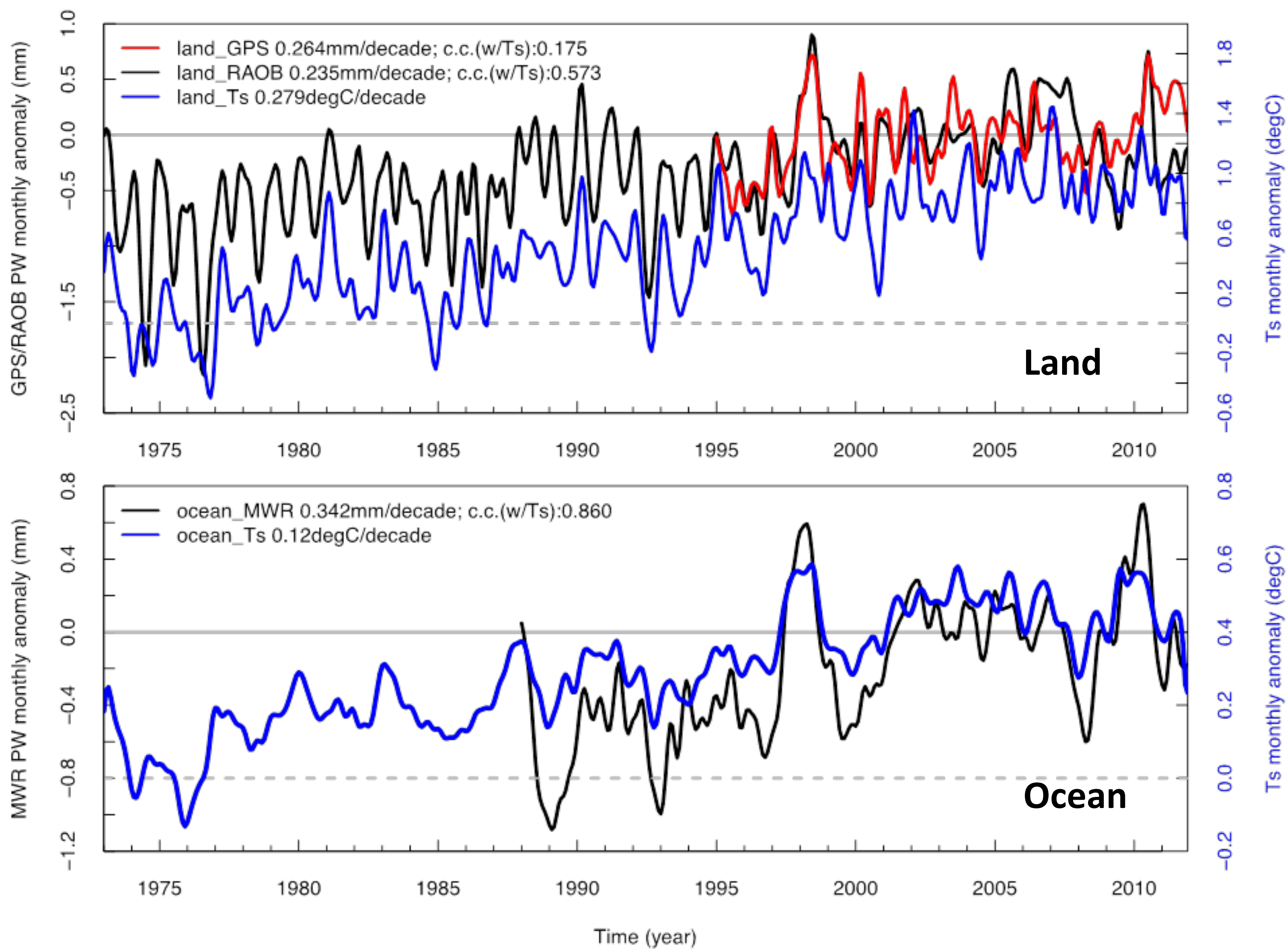


Wang et al. (2013)

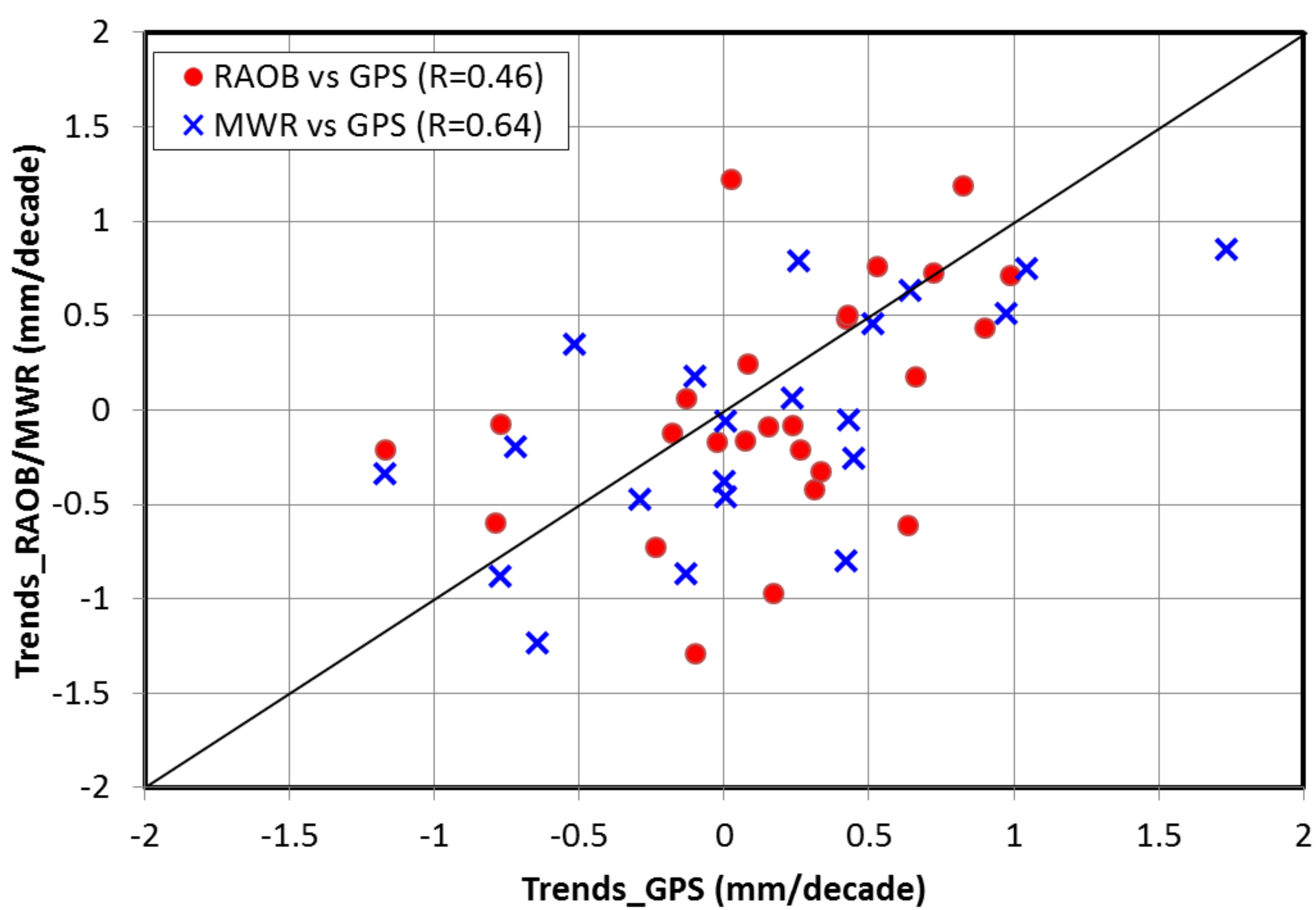
Comparisons of Three Datasets

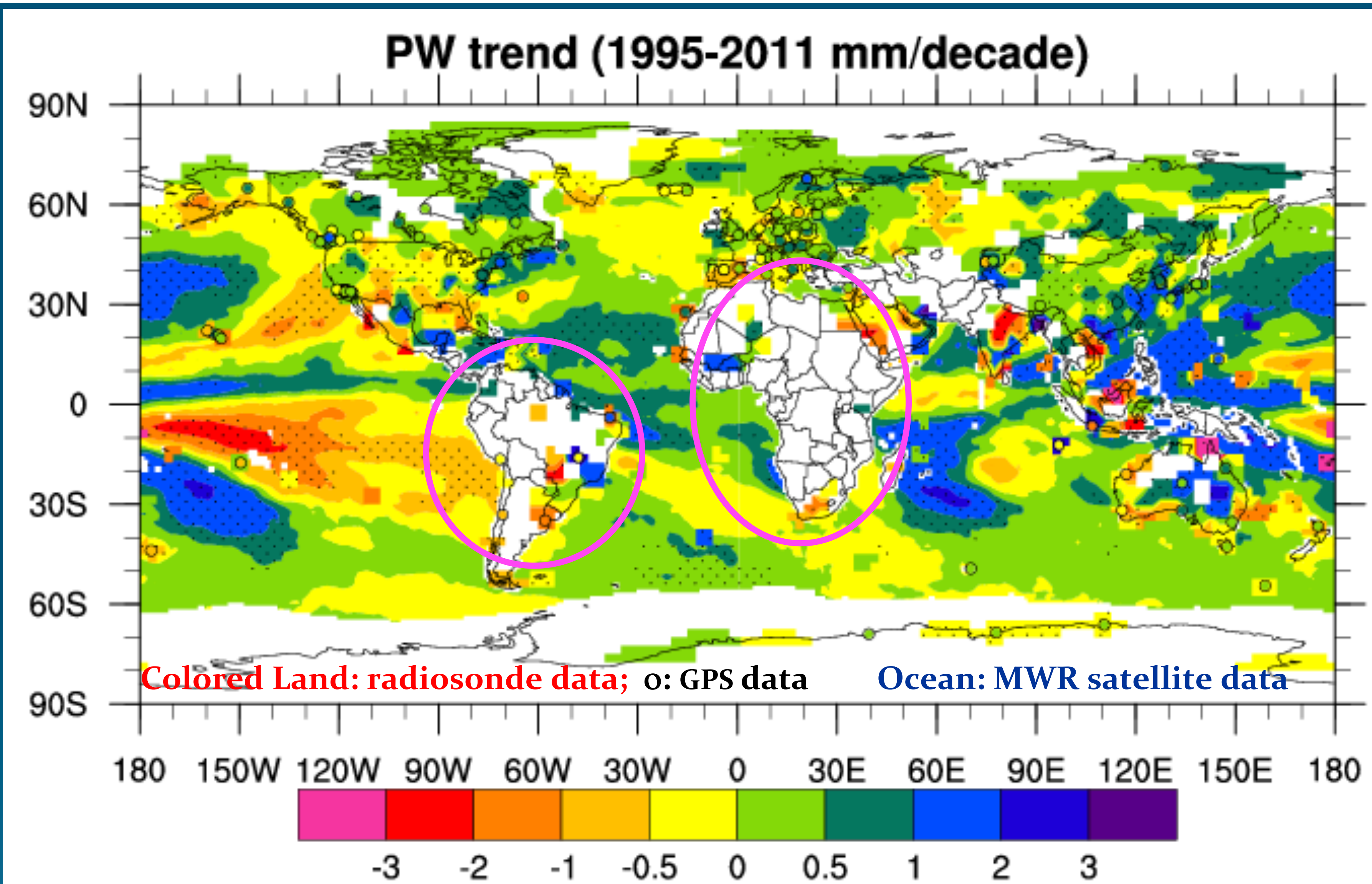


Global mean time series (PW and Ts)



Comparisons of trends

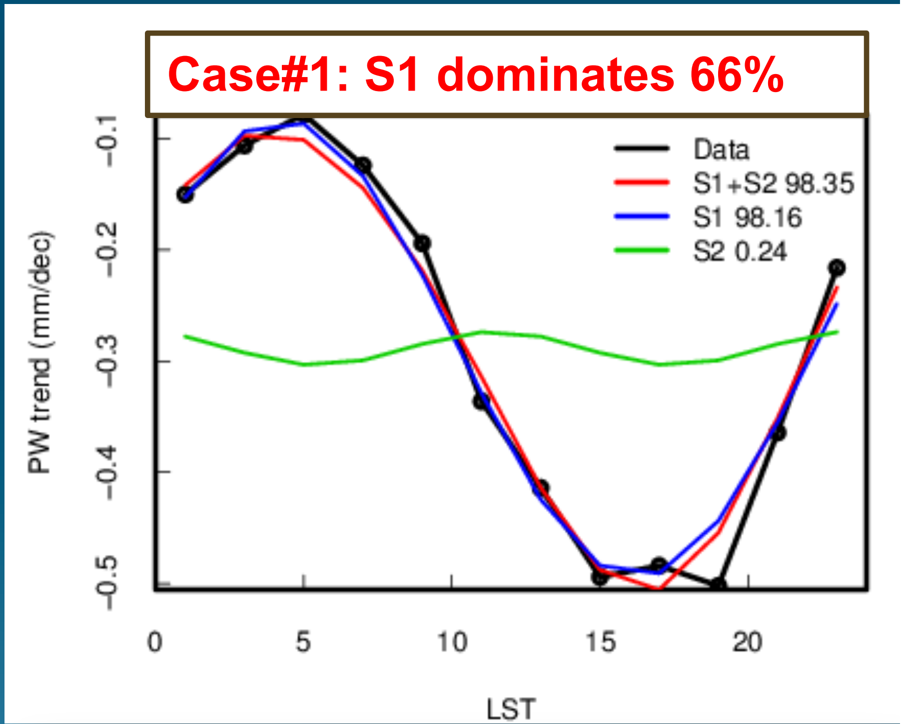


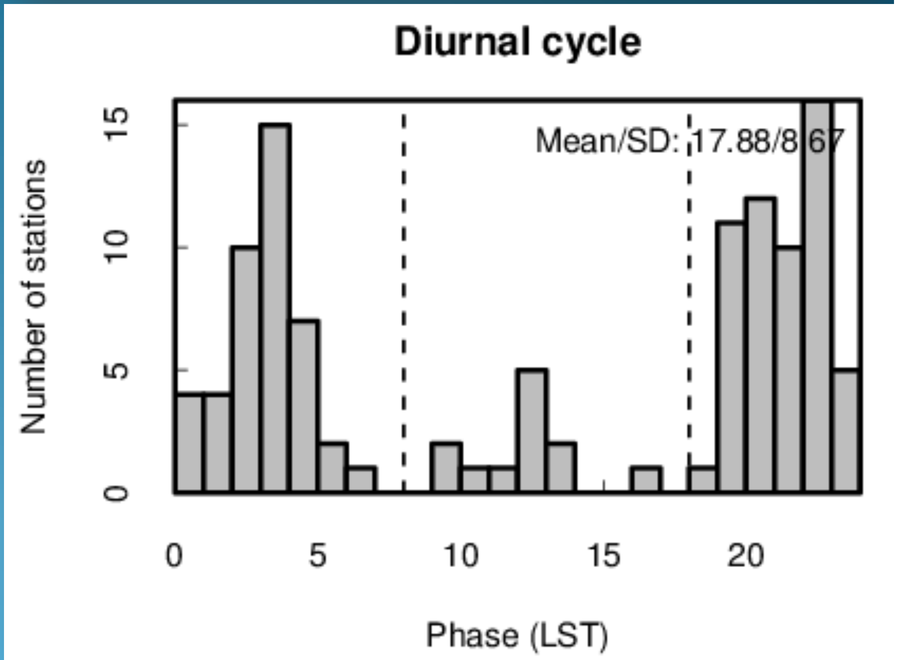


- General agreements among three datasets;
- Spatial coherence in homogenized radiosonde data;
- Unique spatial patterns over Ocean, and consistency for different time records.

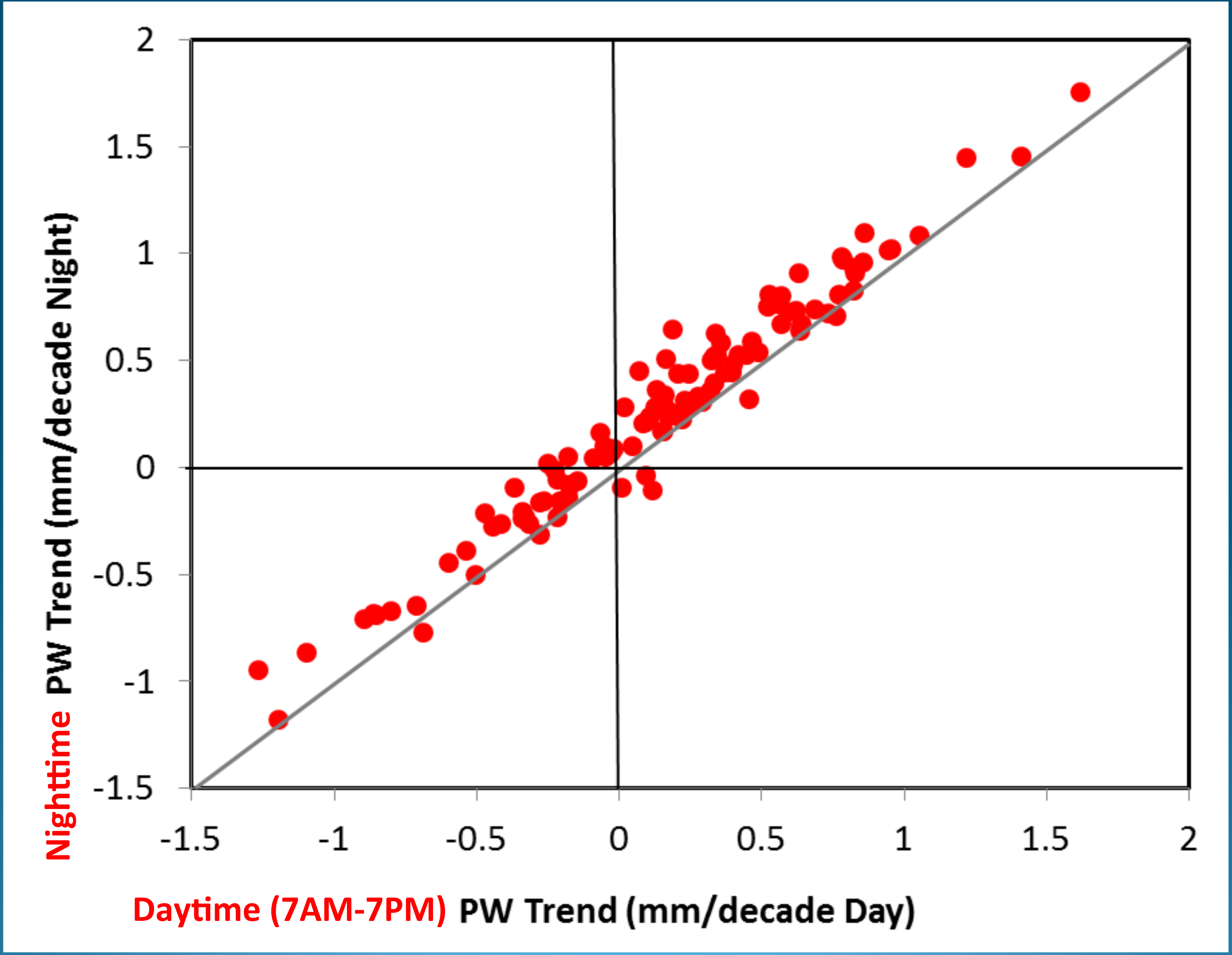
Diurnal cycle of PW trends

- At 66% of stations, the diurnal cycle dominates the sub-daily variability in PW trends;
- PW trends peak at night with a mean amplitude of ~0.2 mm/dec;
- On average , the diurnal cycle explains 42% of the variances (7% for semi-diurnal).

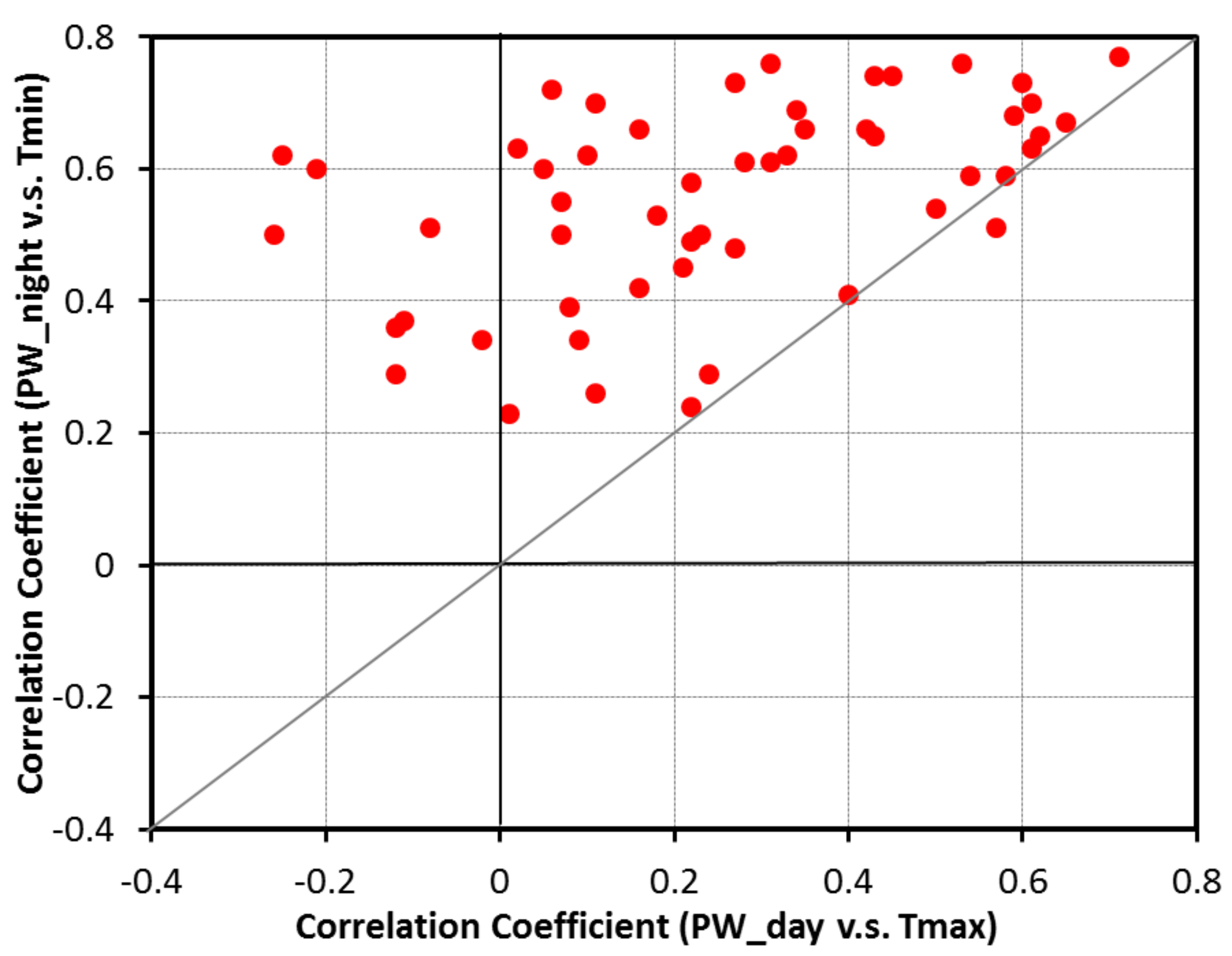




Diurnal Asymmetry of PW Trends (GPS Data)



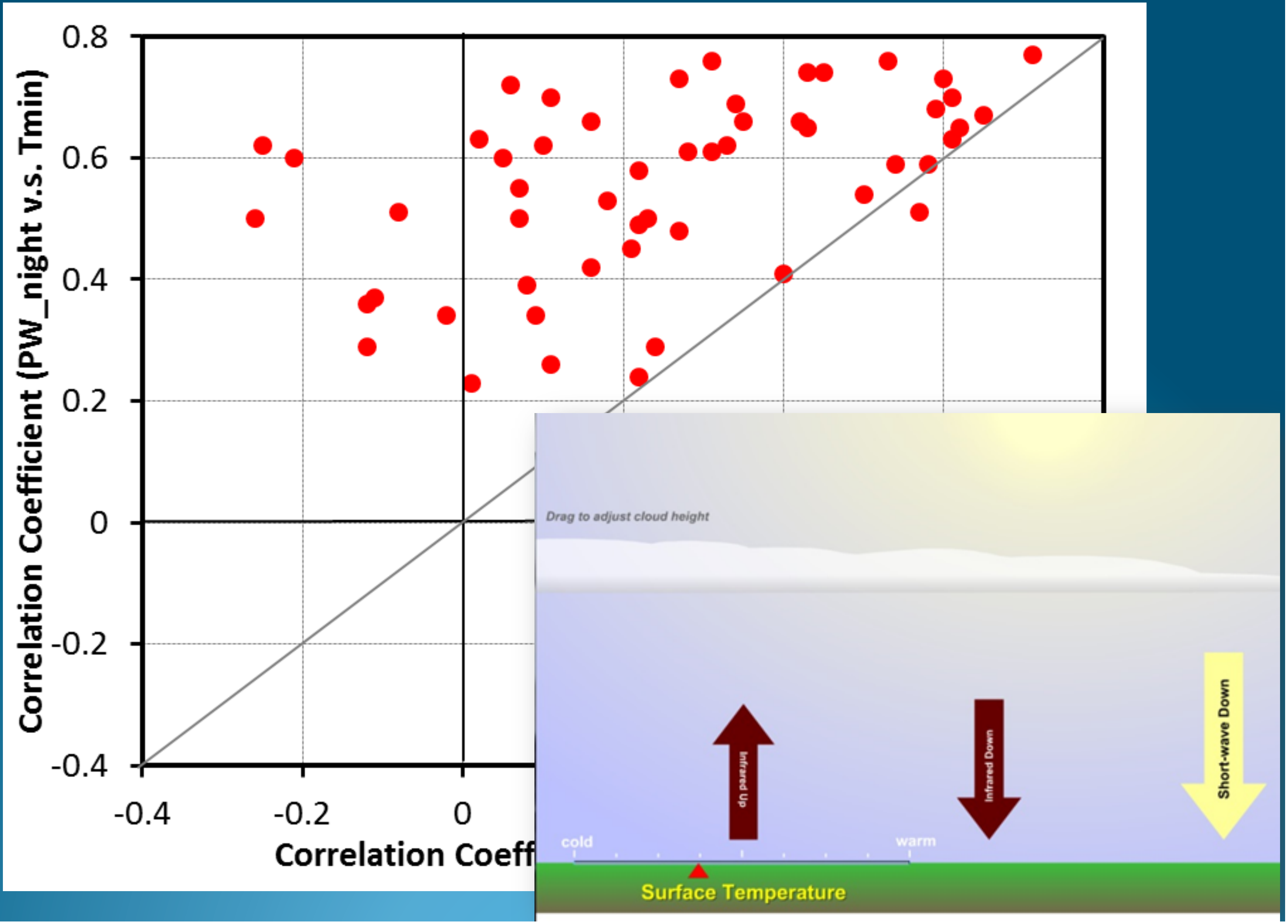
Diurnal Asymmetry of PW vs. Ts Correlation



Summary

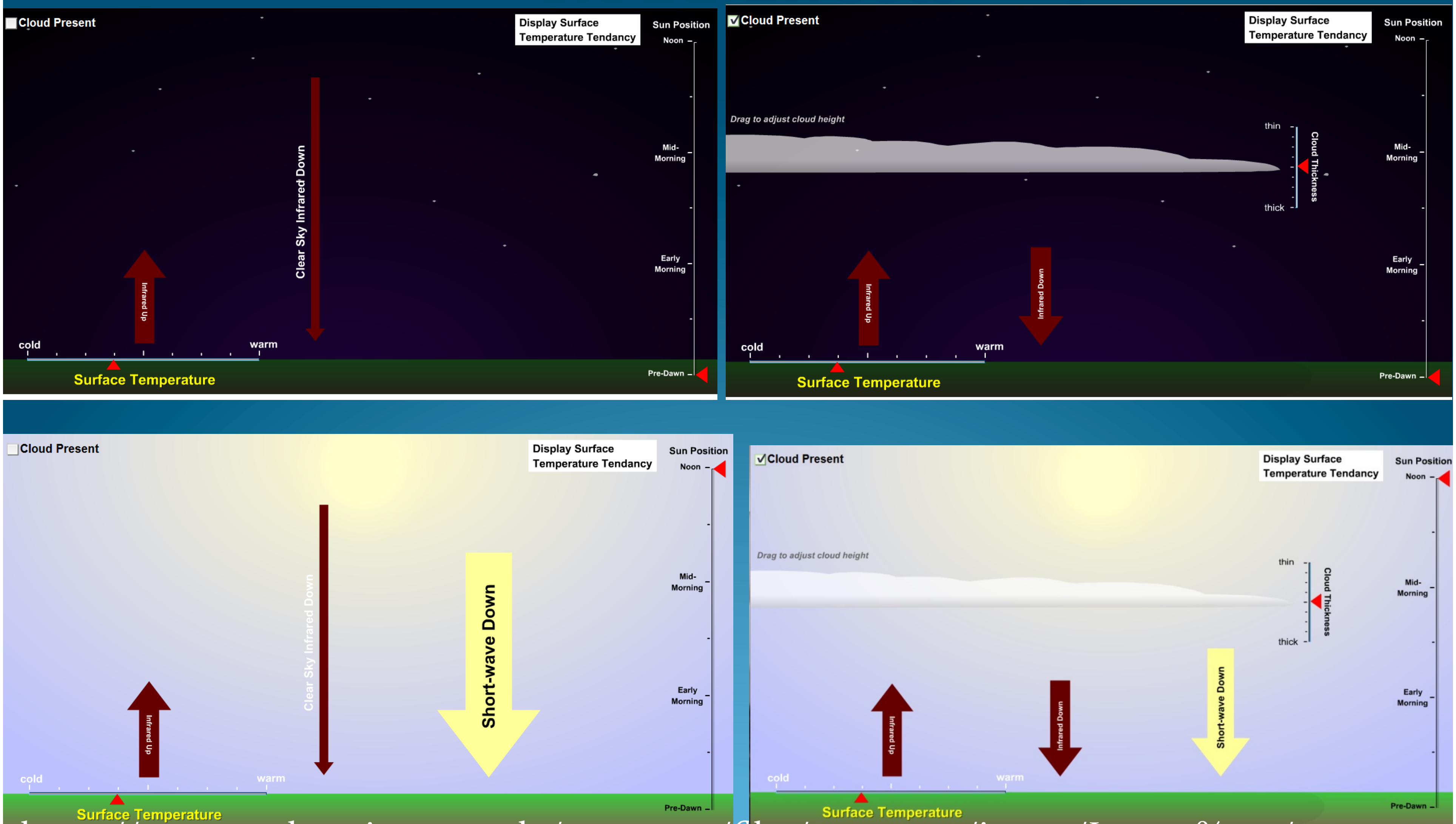
1. Global PW trends are analyzed using three datasets. The moistening trend is dominated over the globe, with larger trends over oceans than over land.
2. The atmospheric moistening rate is faster at night than during the day. PW has higher correlation with Tmin than Tmax as a result of clouds' effect on Tmax.
3. The result implies that the relationship of nighttime PW and Ts is a better indicator of water vapor feedback.

Diurnal Asymmetry of PW vs. Ts Correlation



Diurnal Asymmetry in Correlation

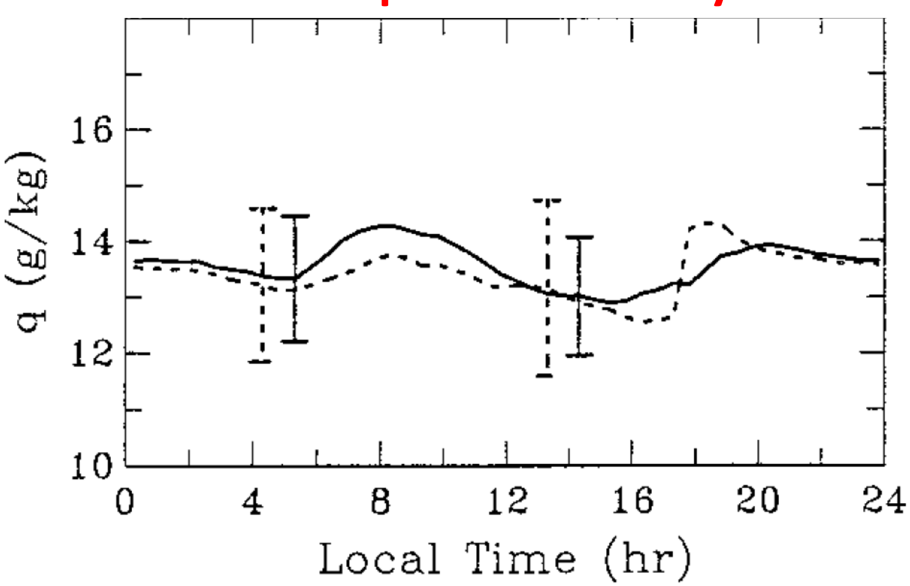
Cloud Effects



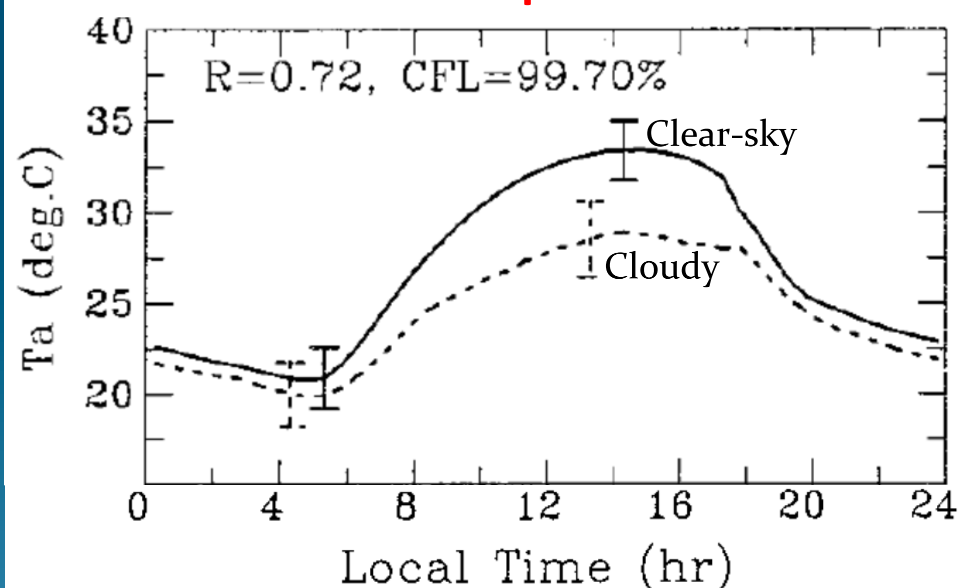
https://www.e-education.psu.edu/meteo003/files/meteo003/image/Lesson%202/L2_surf_rad.swf

Diurnal Asymmetry in Correlation: Cloud Effects

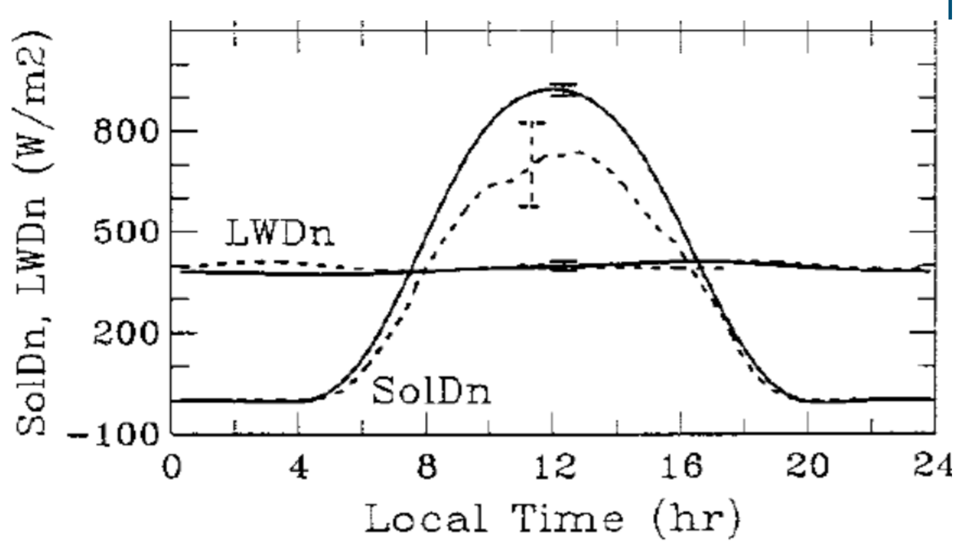
Surface specific humidity



Surface temperature



LW & SW downward radiation



Dai et al. 1999

How does PW change with T?

$$\frac{d \ln e_s}{dT} = \frac{L}{R_v T^2}$$

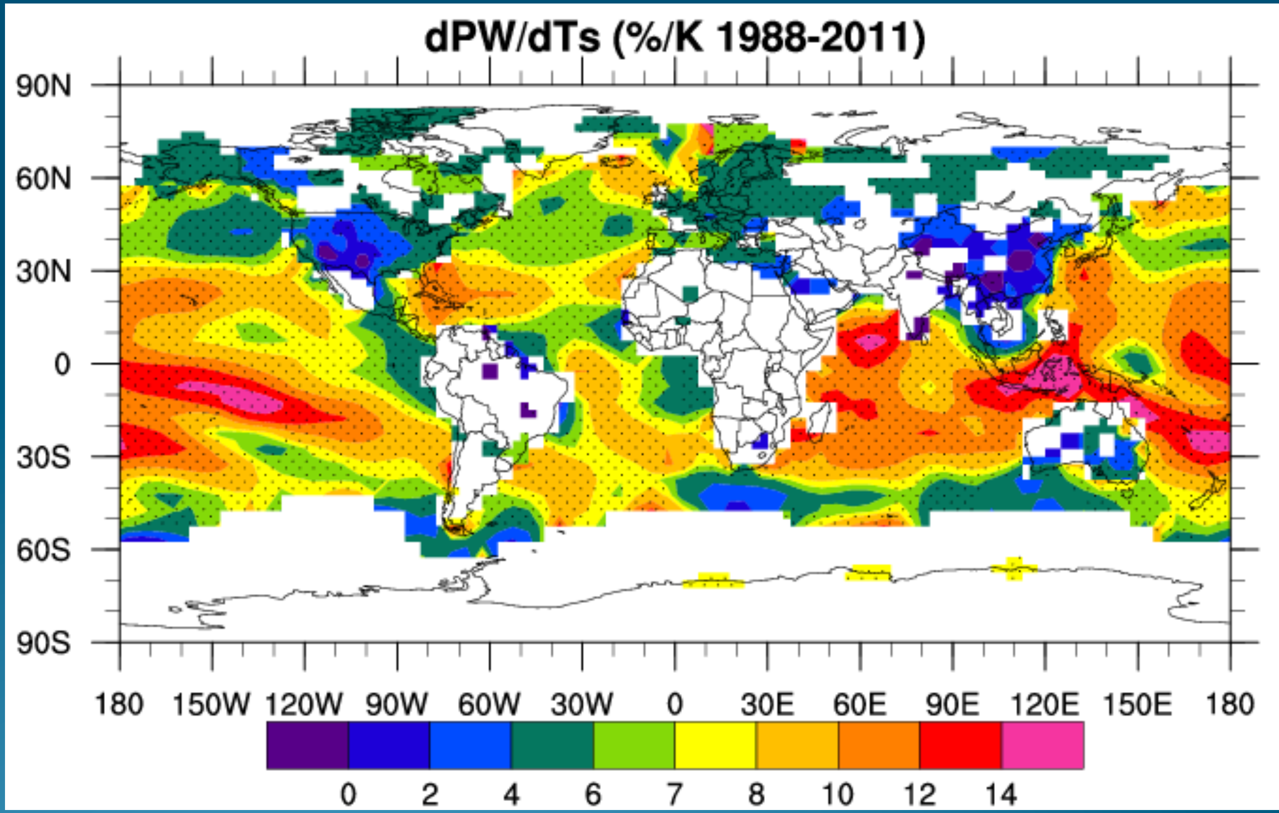
$q = 0.622 * RH * e_s / P$

$d(RH)/dT \approx 0$

$d(\ln q)/dT \approx L/(R_v T^2)$

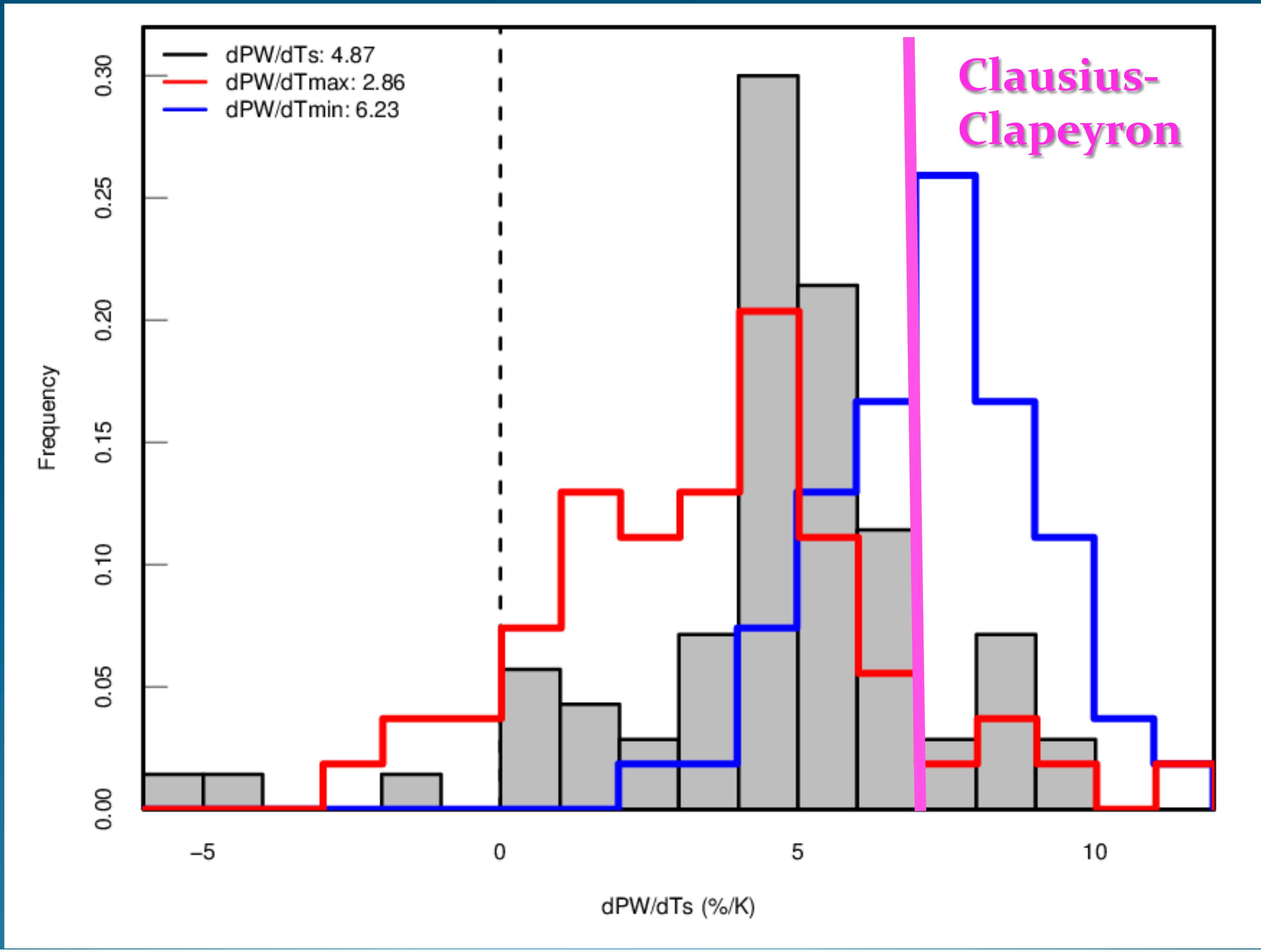
$PW = (1/g) \int q \, dp$

$d(\ln PW)/dT \approx L/(R_v T^2)$
(~7%/K)



- Statistically significant over most regions
- Larger than Clausius-Clapeyron rate (~7%/K) over Ocean, but smaller over Land

Diurnal Asymmetry of dlnPW/dT



Diurnal Asymmetry in PW Trends: Tmax, Tmin & RH

$$dPW/dt \propto RH*de_s/dt + e_s*dRH/dt$$

$$PW = (1/g) \int q \, dP$$

$$q = \varepsilon * RH * e_s/P$$

$RH * de_s/dt$

$de_s/dt \propto dT/dt$

$e_s * dRH/dt$

$dRH/dt \approx 0$