GPS Meteorological Networks for Process-Oriented Studies of Tropical Deep Convection

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OUTLINE

GPS Studies for Process-Oriented Studies

--What can be Observed (Single Station)

Shallow-to-Deep Convection Transition (Manaus)

--Dense Network (Manaus)

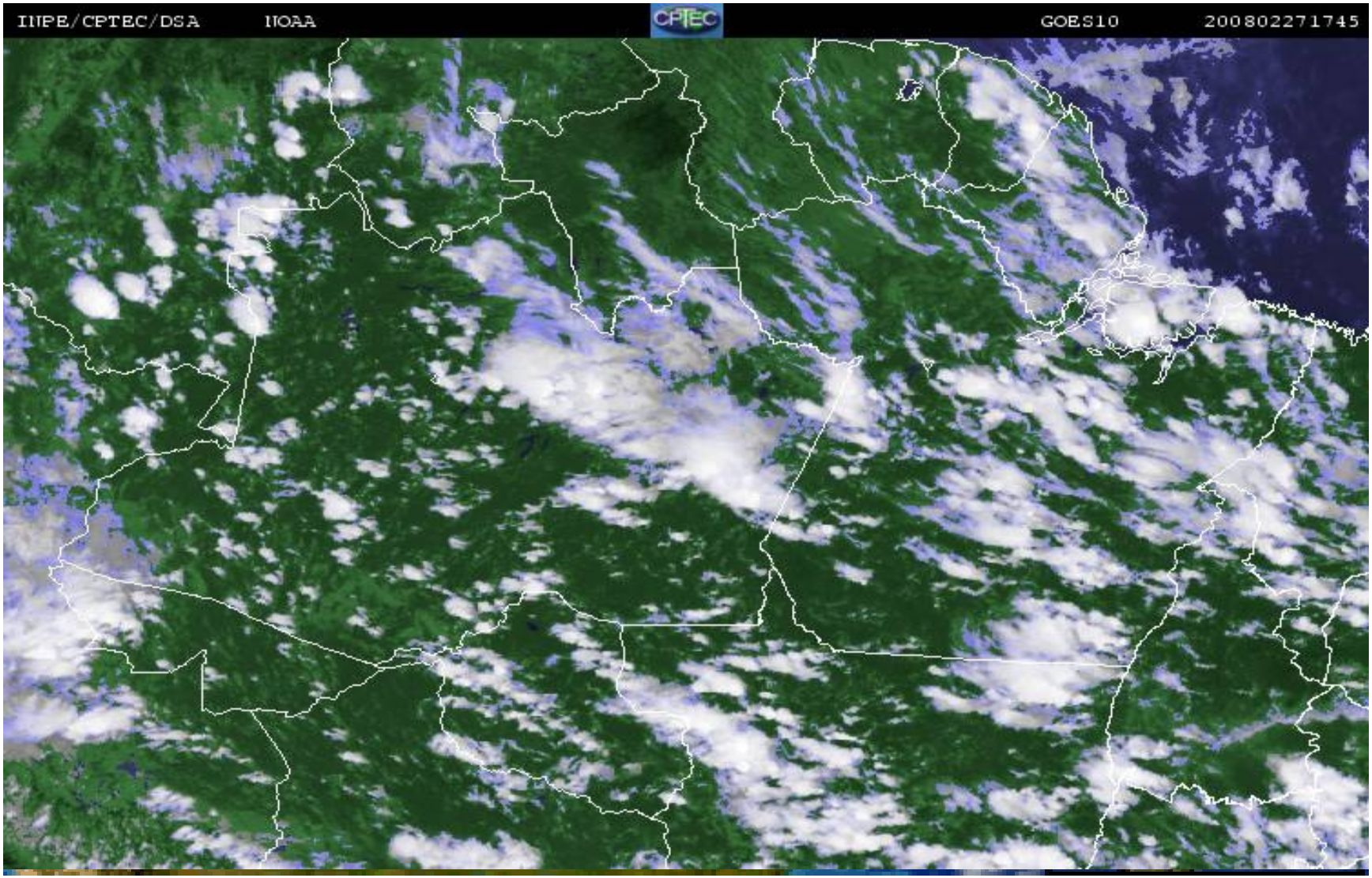
--Dense Network (Belem)

Propagating Squall Lines (Belem)

--The *GPS NAM Transect Experiment (2013)*

The Diurnal Cycle of Convection

Summary of GPS Networks in the IAS Region



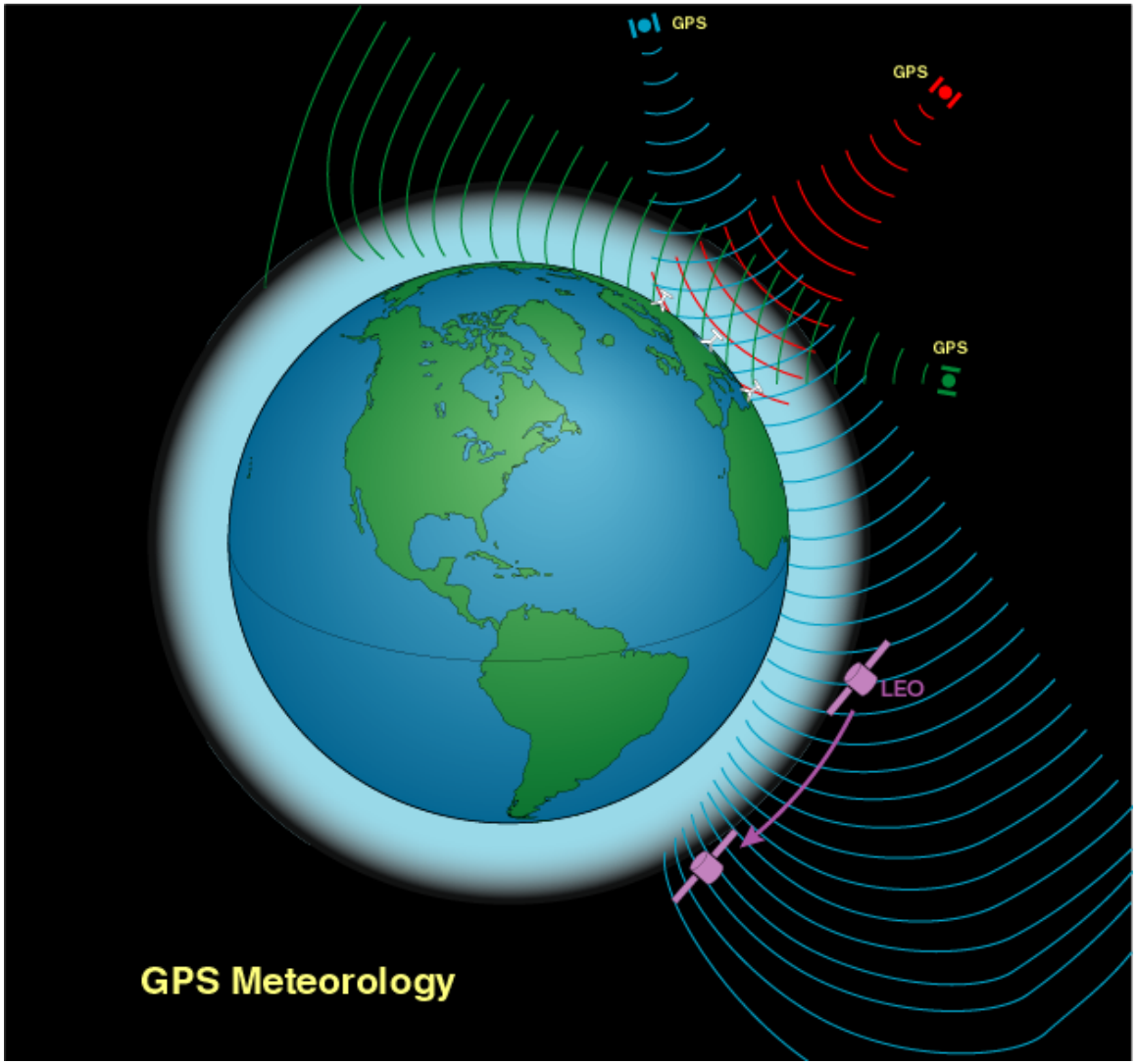
Strong tendency for convection to organize from individual cells to mesoscale convective systems (Hadley Cell, Hot Towers, Organized Convection)

Why is this important to understand?

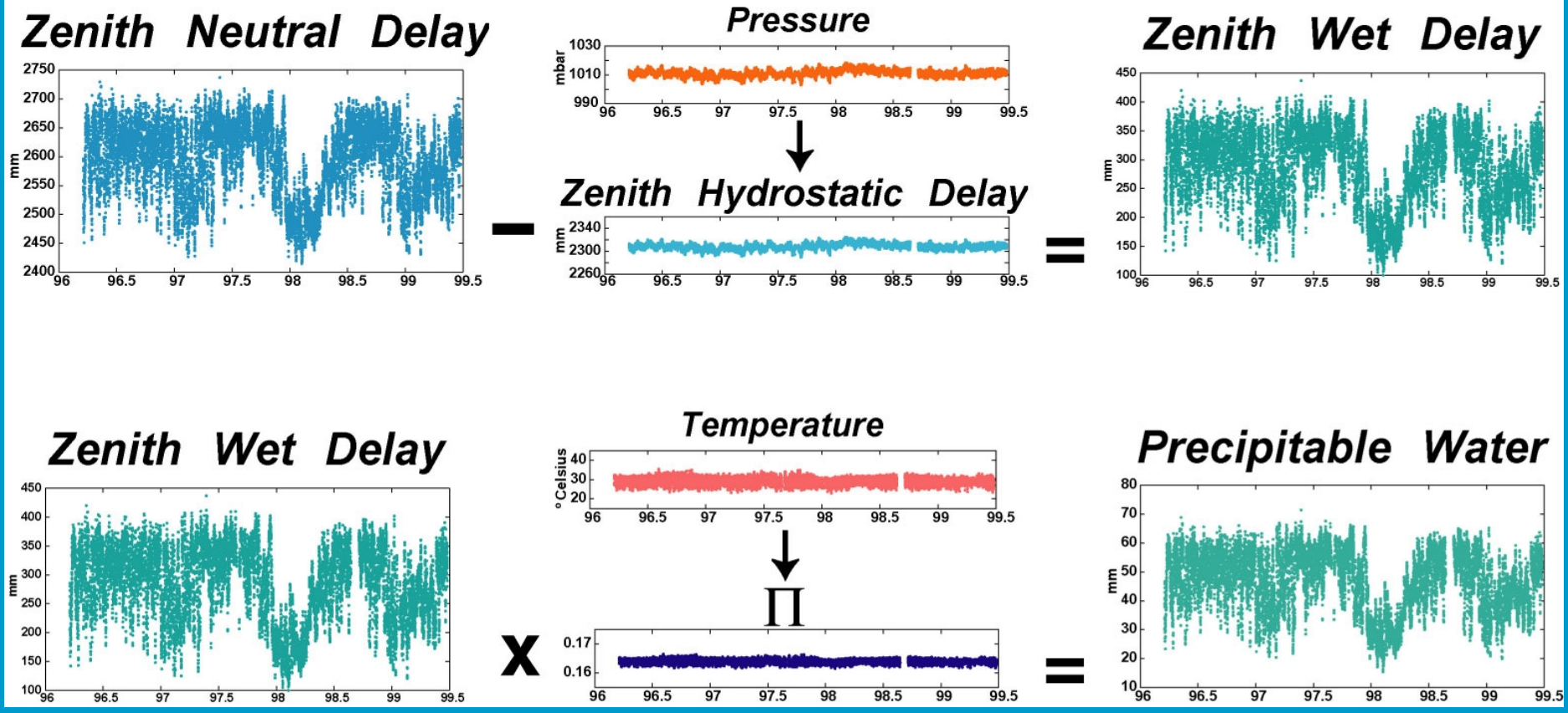
- Water vapor is most important greenhouse gas
- Deep Convection is the source of water vapor for the tropical free troposphere
- Organized Convection very efficient in upscale energy transfer (and transport)
- Multiscale Phenomenon (hard to parameterize, traditional paradigm e.g., Arakawa-Schubert)
- Convective Resolving Models Not A Panacea

(Entrainment and Microphysics)

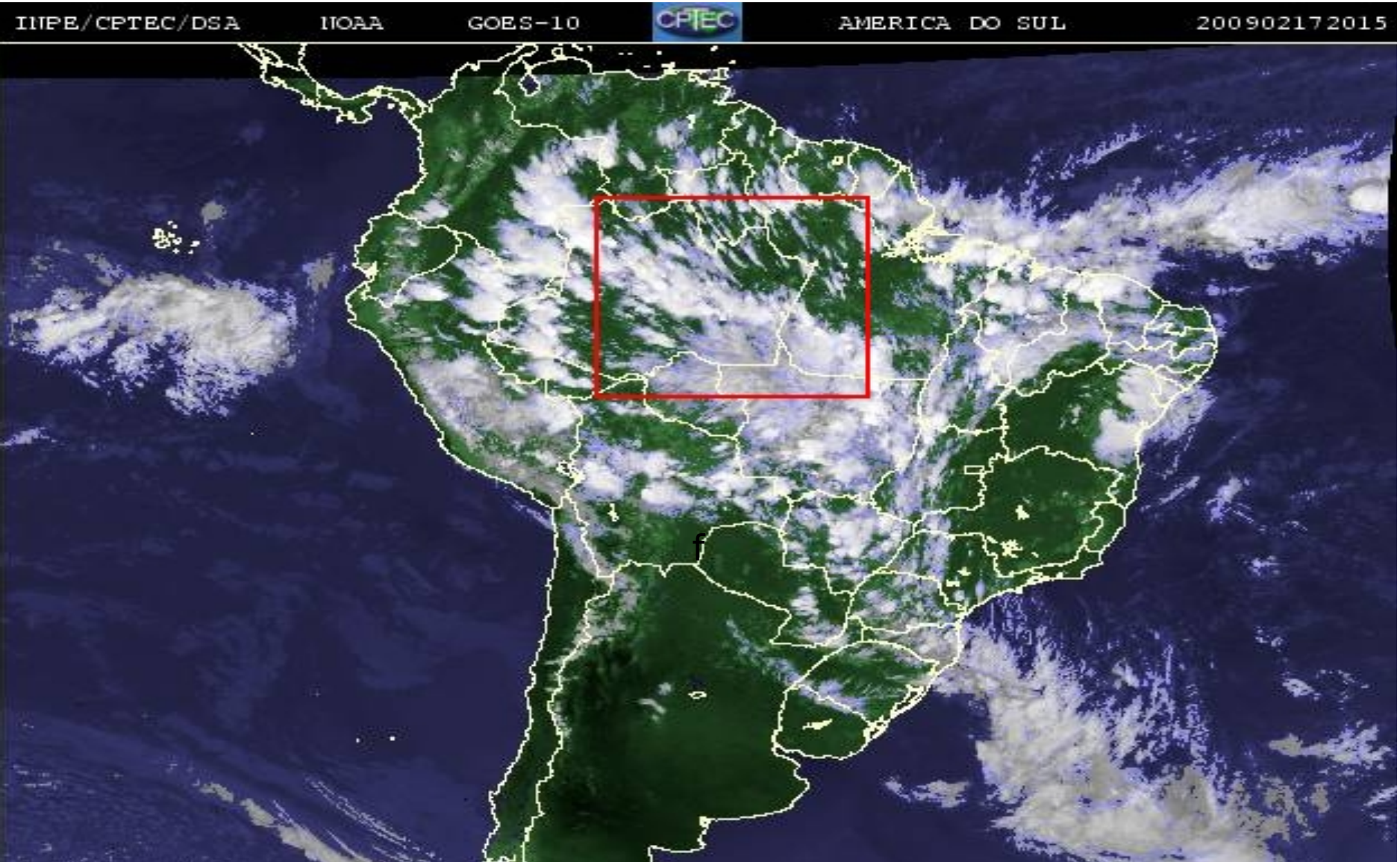
ATMOSPHERIC DELAY OF GPS SIGNALS IS THE BASIS OF GPS METEOROLOGY



Transformations of GPS Meteorology



GPS Meteorology in Brazil



GPS Meteorology Station from 07/08 to 1/2012 (*INPA*, NOAA/ESRL)

PWV (~5 minutes post processed, 30 minutes near real time)

Surface Met (p, T, RH, winds, precip) to develop convective climatology

Tropical Continental Regions: What controls the Shallow-to-Deep Convection Transition?

The Diurnal Cycle of Convection is poorly modeled in Large Scale Models (Betts and Jakob 2002 among others)

-The diurnal cycle, timing, and intensity is typically off

-Deep precipitating Convection triggered too early
And too often.

-Shallow-to-Deep Transition stage is often skipped.

GPS PWV can provide observational metrics that models should reproduce

3.5 year study using INPA GPS PWV, Surface Met. and Cloud Top Temperature (GOES 12).

Deep Convective Climatology Developed (320 Convective Events)

Shallow-to-Deep Convective Time scales examined (Adams et al. GRL 2013)

Water Conservation Equation

$$\frac{\partial}{\partial t}(IWV) + \frac{\partial}{\partial t}\int q_c \frac{dp}{g} + \nabla \cdot \int q\vec{V}\frac{dp}{g} = E - P.$$

Precipitable Water Vapor is Integrated (or Column) Water Vapor divided by the density of water

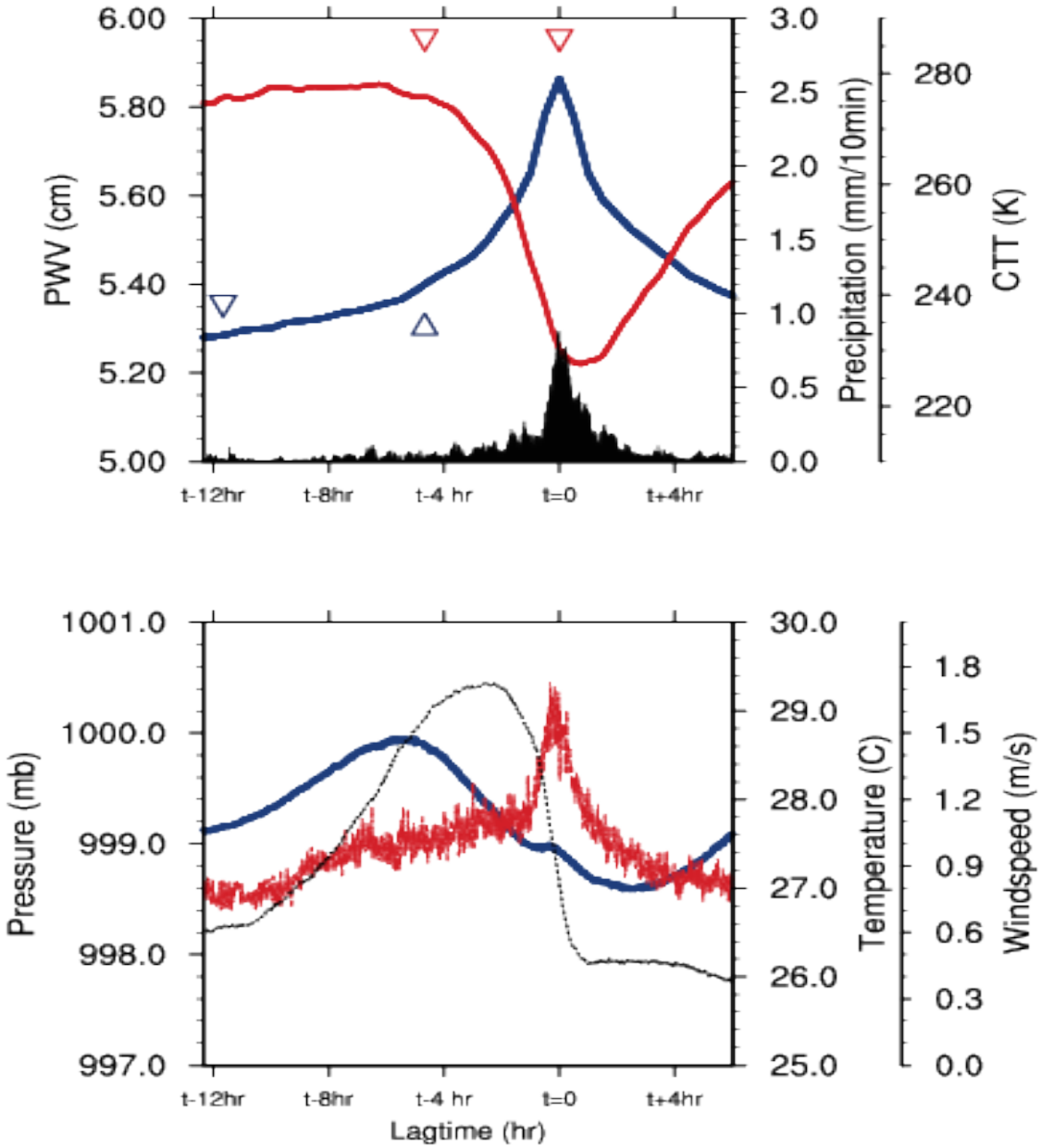
$$PWV = \frac{1}{\rho_w}\int q\frac{dp}{g} = \frac{IWV}{\rho_w}$$

To first order, the time-rate-of-change of PWV is simply moisture flux convergence:

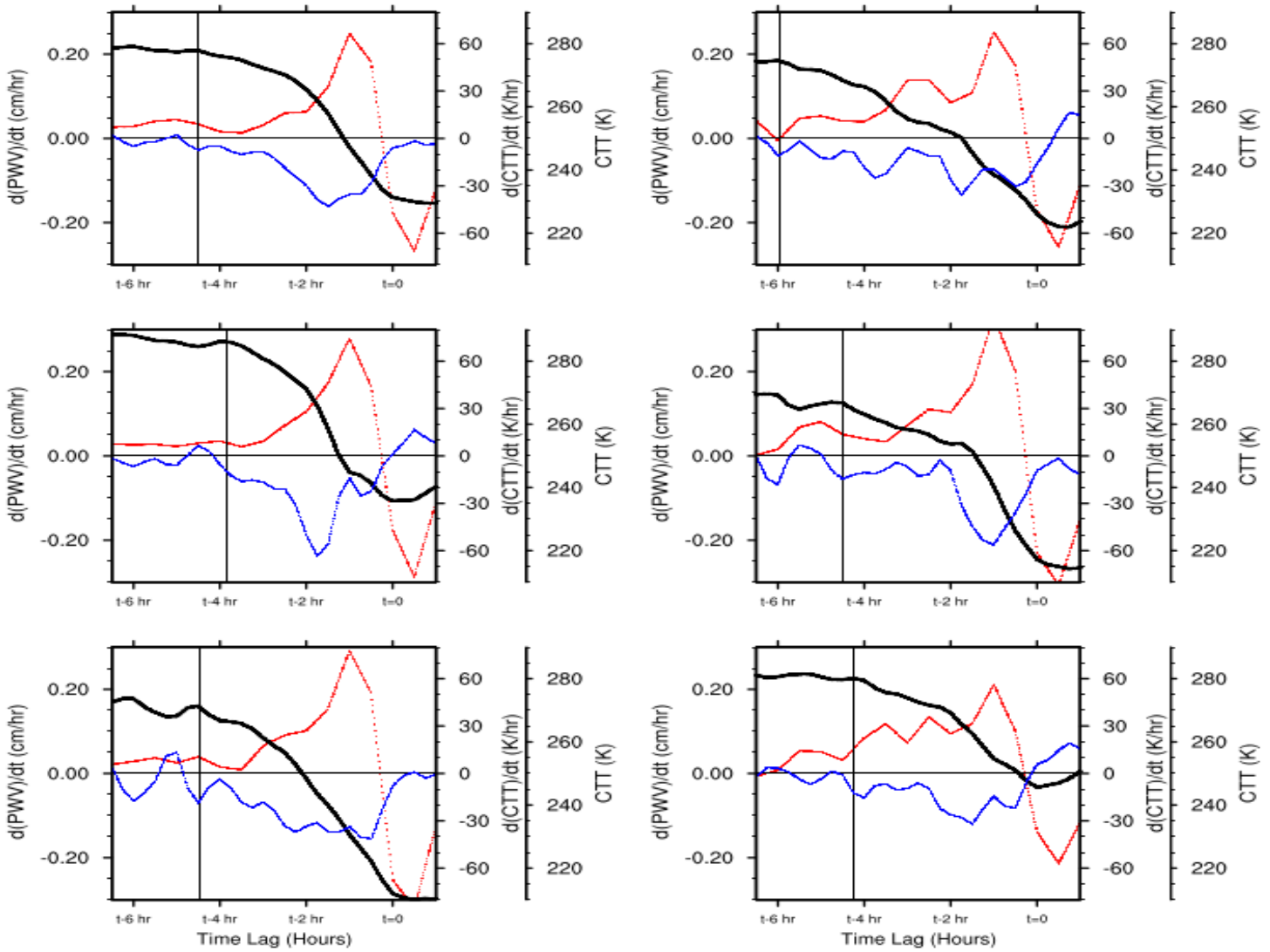
$$|\frac{\partial}{\partial t}(PWV)| \sim |\nabla \cdot \frac{1}{\rho_w}\int q\vec{V}\frac{dp}{g}|$$

Temporal Evolution of Convective Events INPA

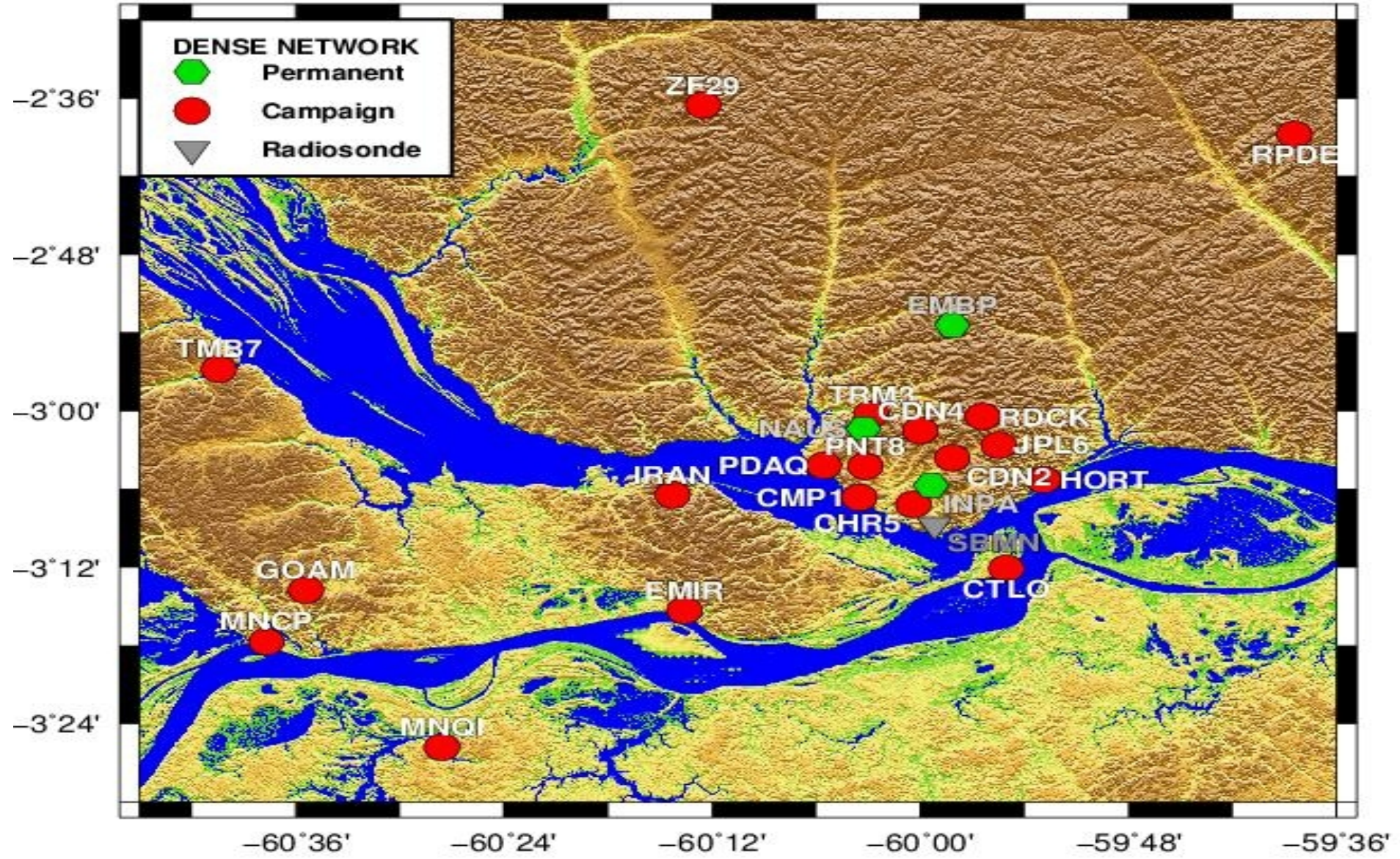
(3.5 years of data)



Approximately 4 hour shallow-to-deep water vapor convergence timescale observed regardless of criteria.

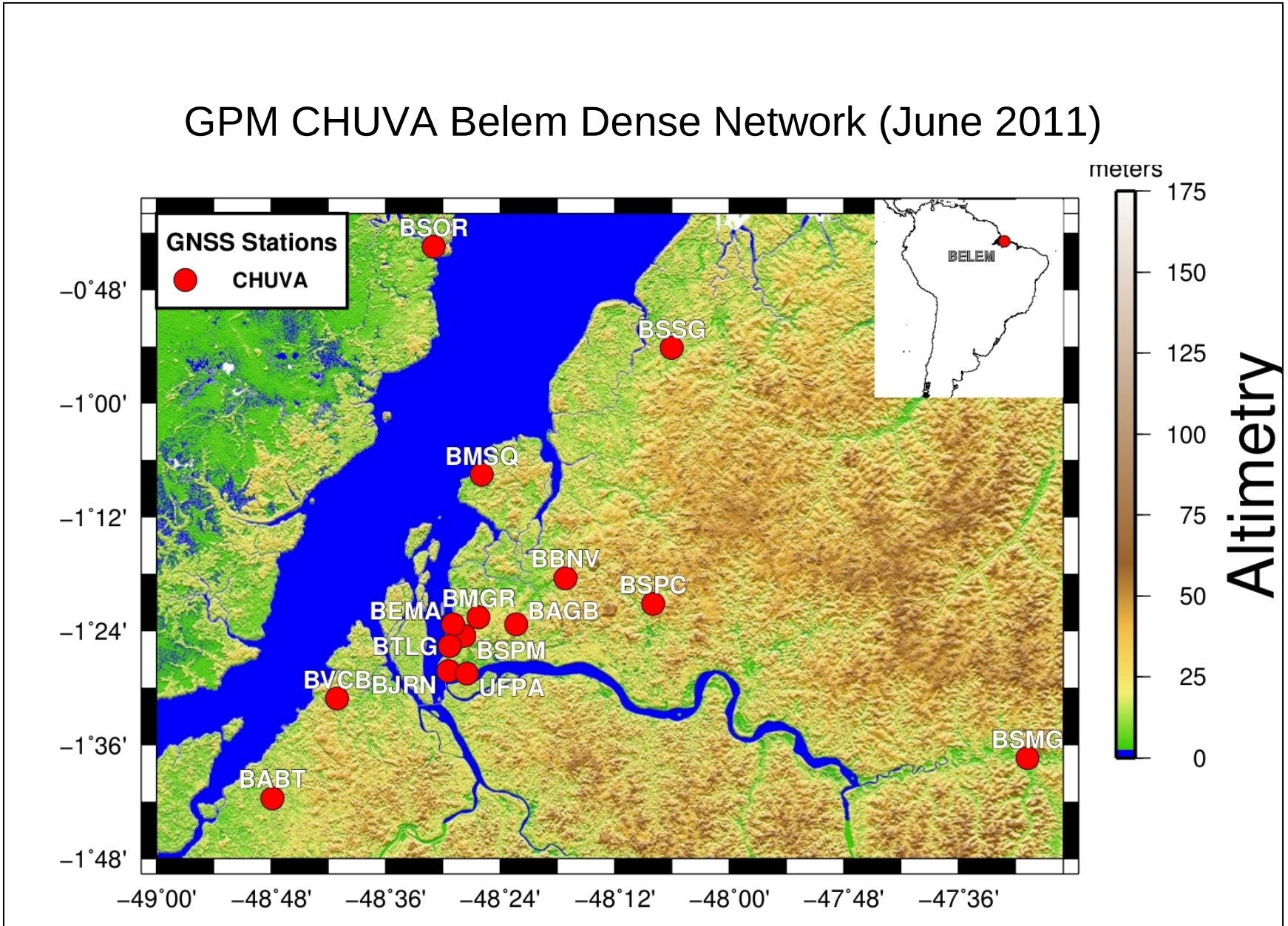


Dense GNSS Network in Manaus (April 2011-April 2012)
(Adams et al. 2015 BAMS)

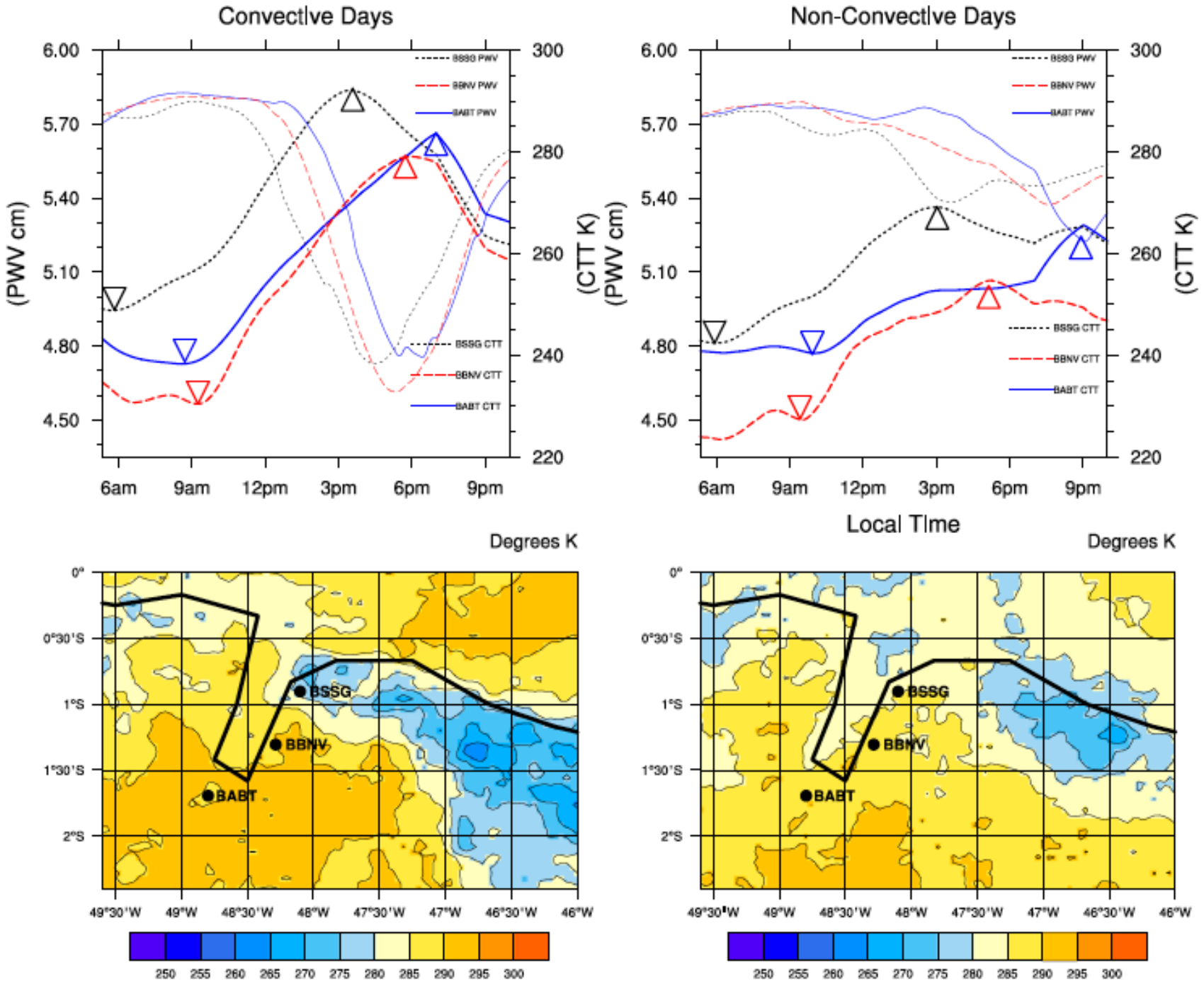


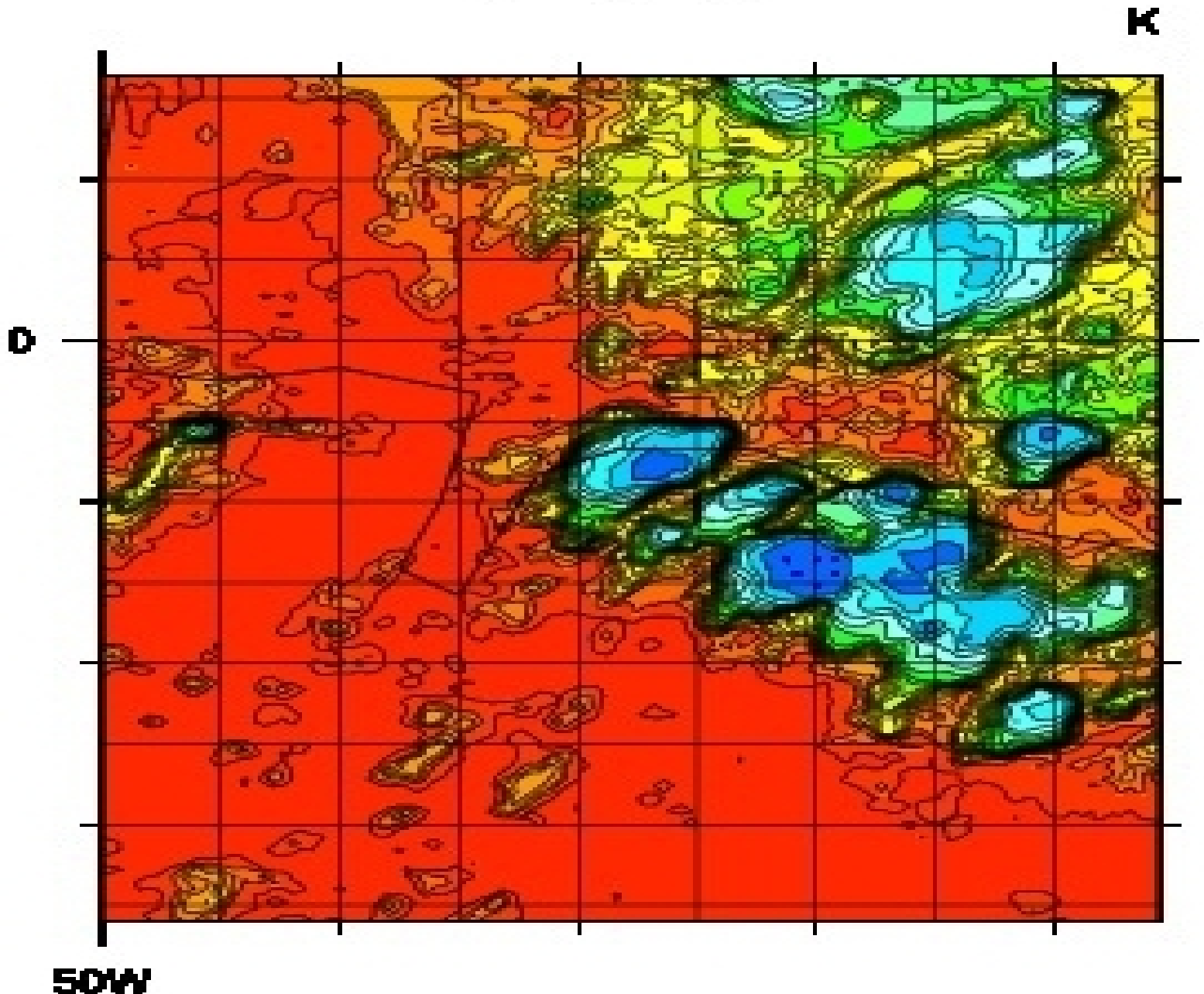
Site Logistics for GPS-Met are much more Flexible (Adams et al. 2011 JTECH, 2015 BAMS)

Global Precipitation Measurement (GPM)-CHUVA) June 2011 (Machado et al. 2014, BAMS)



A Squall Line Entering Belem from the Atlantic

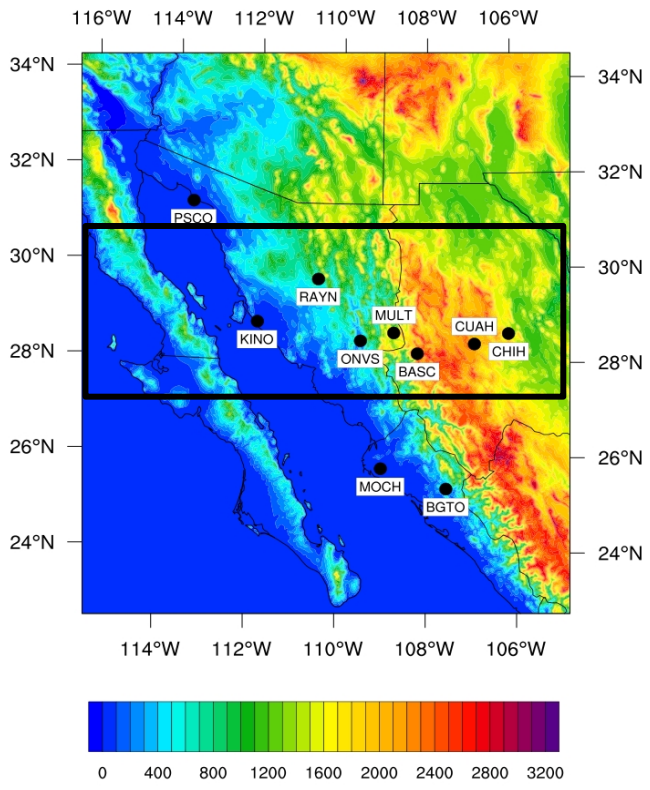

Convective Days
Non-Convective Days
(PWV cm)
(CTT K)
6.00
5.70
5.40
5.10
4.80
4.50
300
280
260
240
220
BSSG PWV
BBNV PWV
BABT PWV
BSSG CTT
BBNV CTT
BABT CTT
6am
9am
12pm
3pm
6pm
9pm
Local Time
Degrees K
0°
0°30'S
1°S
1°30'S
2°S
49°30'W
49°W
48°30'W
48°W
47°30'W
47°W
46°30'W
46°W
BSSG
BBNV
BABT
250
255
260
265
270
275
280
285
290
295
300

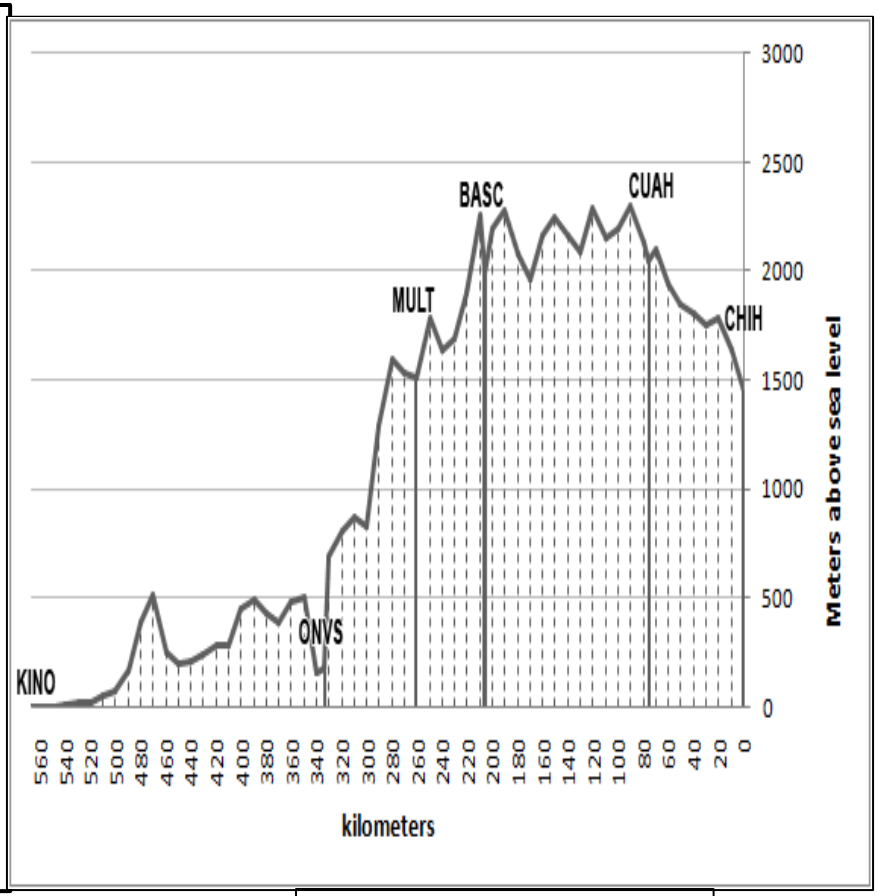

2011_07_04_1930
K
0
50W

Thermodynamic/Dynamic Parameters for Convective (22) vs Non Convective (19) days

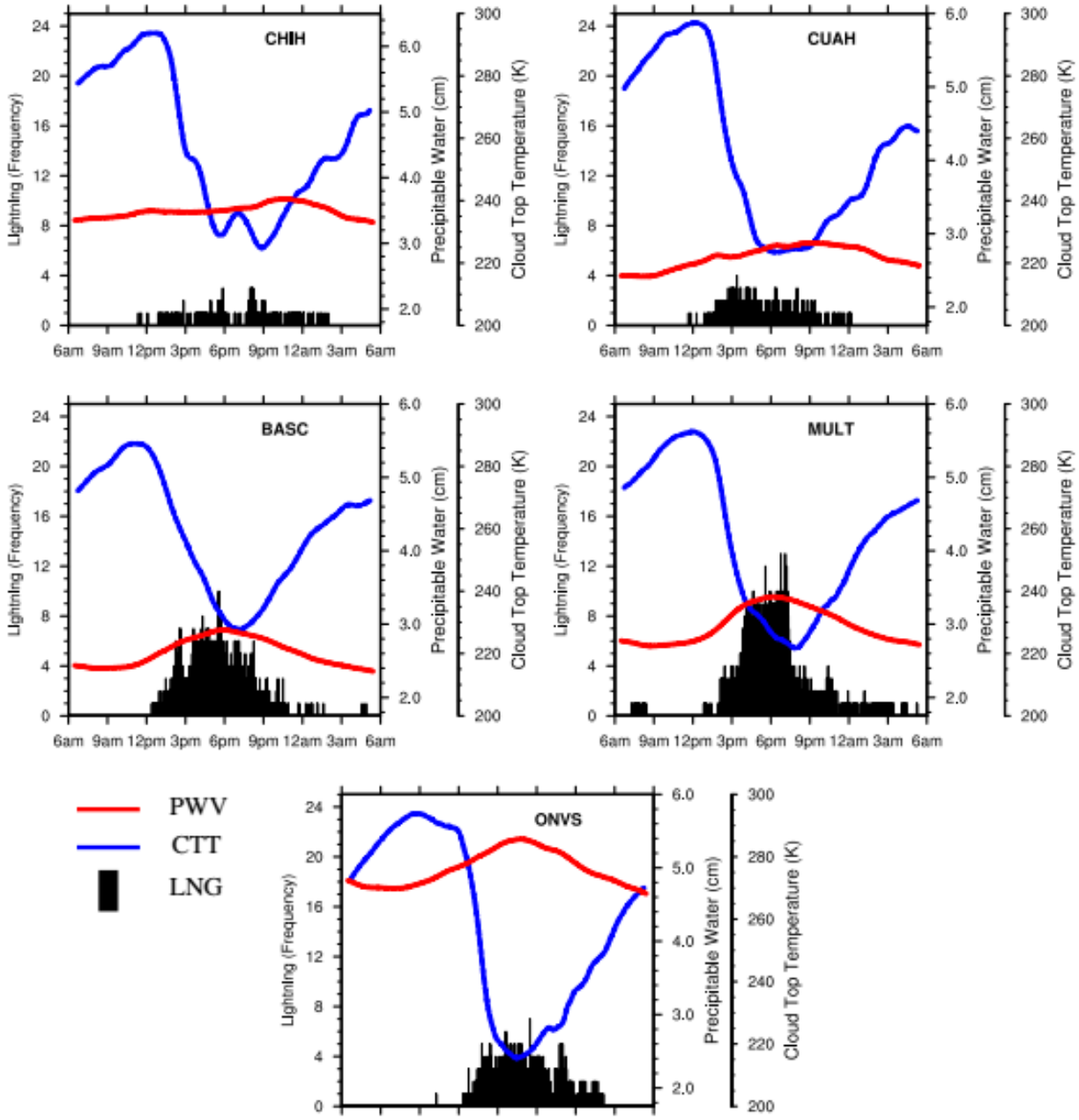
	CAPE Jkg^{-1}	CIN Jkg^{-1}	PWV cm	PWV 850 to 500mb cm	$\frac{\Delta PWV}{\Delta t}$ $cmhr^{-1}$	Propagation Speed. ms^{-1}	Shear $10^{-3}s^{-1}$
Convective (22 days)	1121.0	2.44	4.35	1.74	0.094	10.9	2.2
Non Convective (19 days)	549.0	3.32	4.23	1.77	0.064	5.8	1.9

The North American Monsoon GPS Transect Experiment 2013

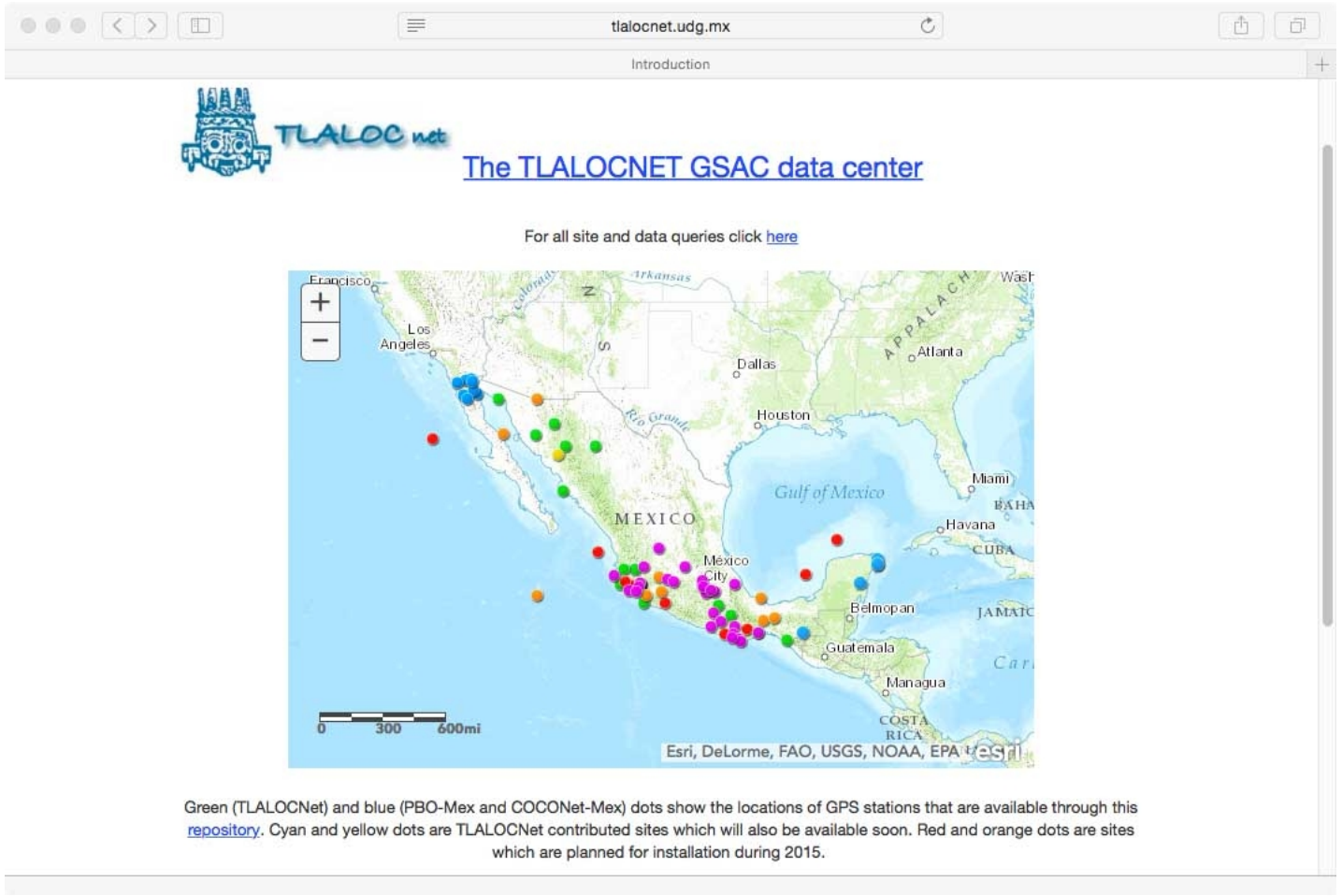




Moker et al. in preparation


CHIH
CUAH
BASC
MULT
ONVS
Lightning (Frequency)
Precipitable Water (cm)
Cloud Top Temperature (K)
6am 9am 12pm 3pm 6pm 9pm 12am 3am 6am
PWV
CTT
LNG

http://tlalocnet.udg.mx



TLALOCNet has real-time GPS PWV Distributed Throughout Mexico.

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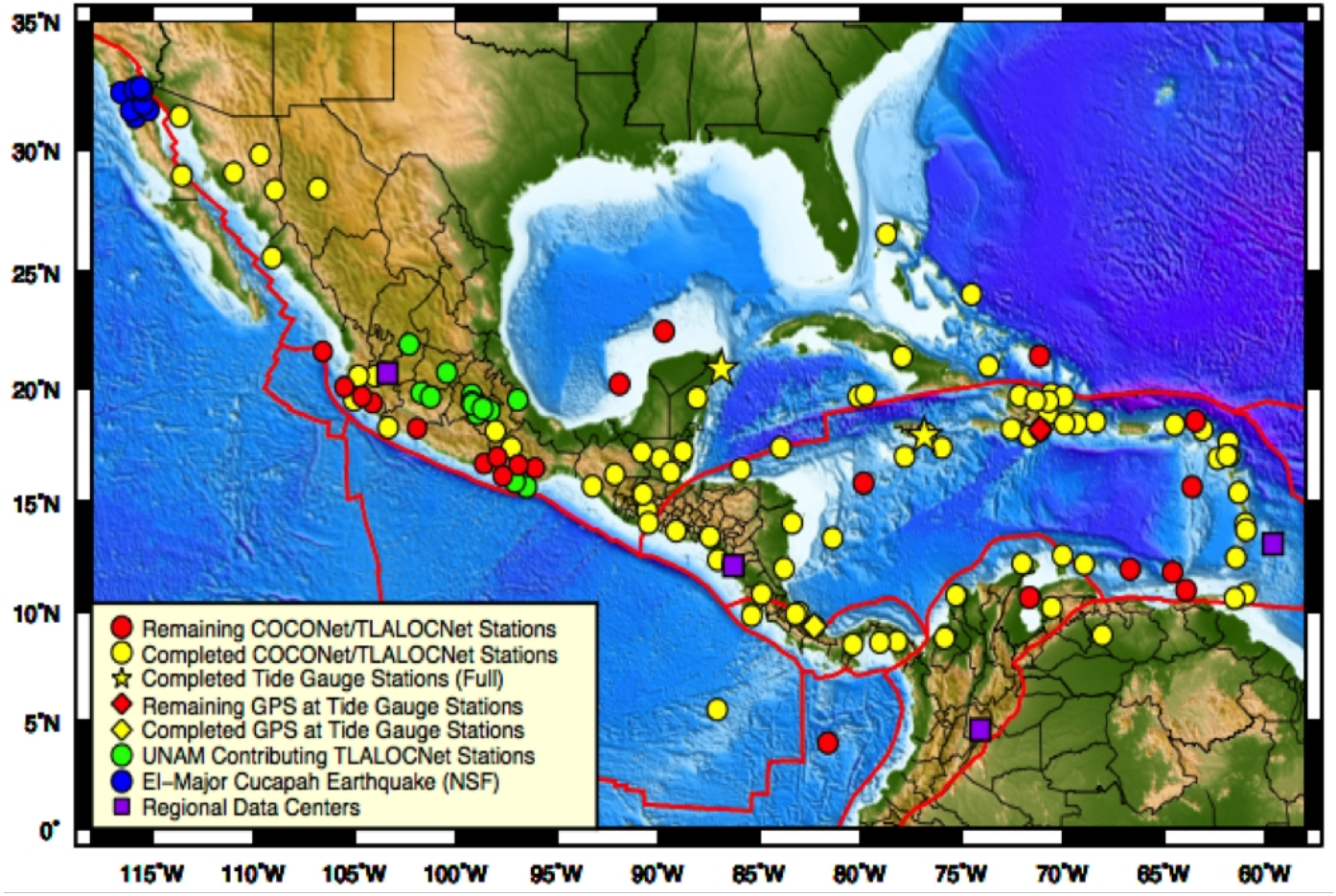
COCONet Provides real-time GPS PWV over much of the Caribbean



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Summary

--GNSS/GPS provides all weather, high frequency PWV with no instrumement drift

--3 Different Convective Regimes: Tropical Continental, Sea-Breeze, Monsoonal in Complex Topography

--Dense Networks supply information on Diurnal Cycle,

--Convection propagation, spatial/temporal scale of PWV perturbations and other characteristics

--Deep Tropical Continental Convection characterized by

4 hour wv convergence shallow-to-deep time scale

--New Networks provide Anchors for mesocale networks


Thank you
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