Deep Convection in the Deep Tropics and North American Monsoon

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Seminar Outline

Overview of Research

- Motivation: Important to Note Variability of Convection due to Topography, Landscape, Geographic position

- Most Theory for Tropical Convective Activity (e.g., Organization and Intensity) over Oceans

– Convection in the Amazon Region of Brazil
- Convection in the of NW Mexico/SW U.S. (NAM)



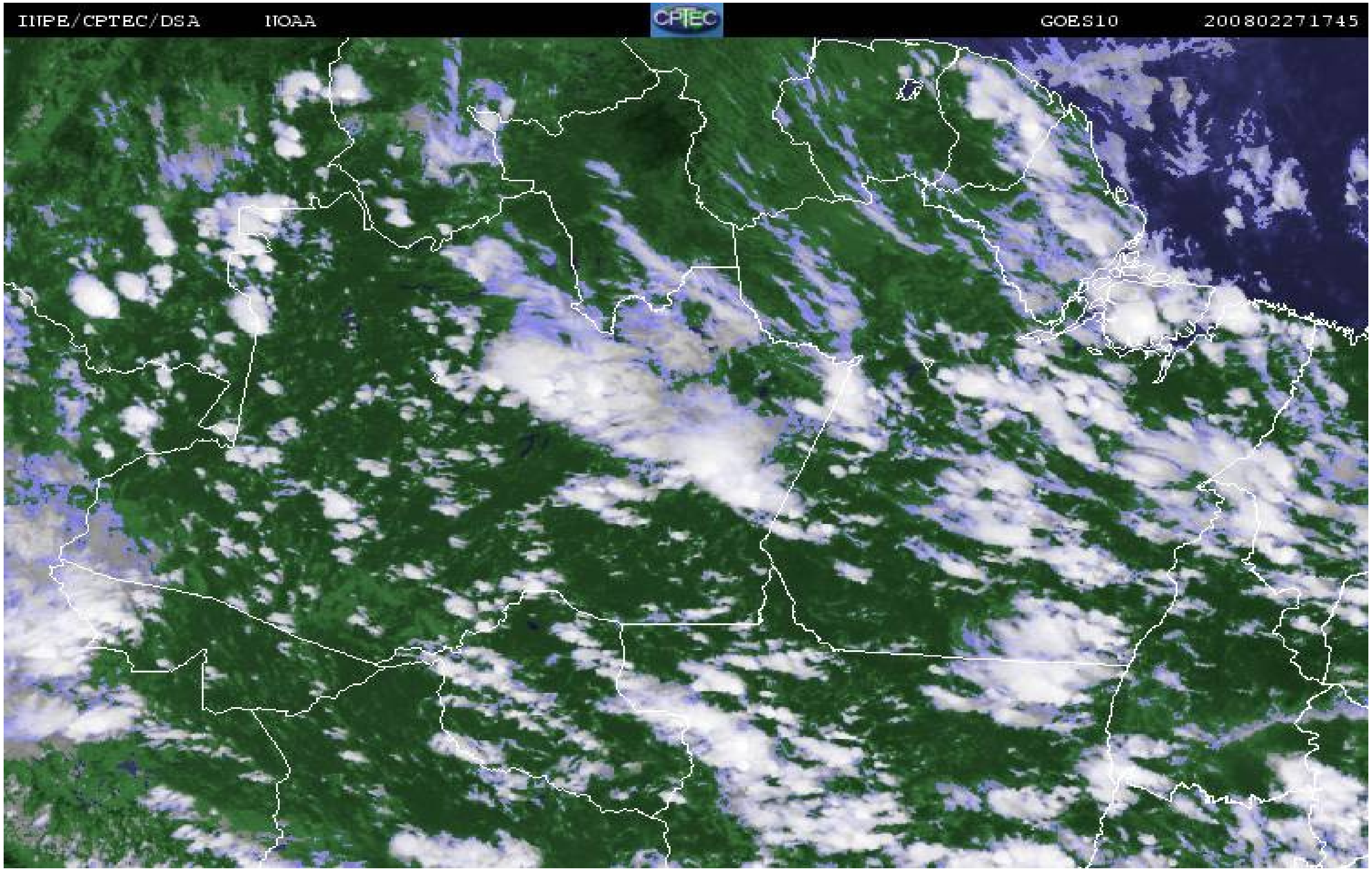
My Scientific Questions, Approaches and Goals

– **Questions**
- What Atmospheric Conditions determine the Intensity and Frequency of Tropical Convection?
– How do these Conditions vary Geographically?

– **Approaches**
- Remote Sensing: GOES IR, GPSmet, Vaisala GLD360
- Modeling (NWP, CRMs)
- Radiosondes, Eddy Covariance Flux Tower data

– **Goals**
- Create Metrics and Datasets to Challenge Models as well as for providing Data to Assimilate
- Assess Theory Relating Large and Convective Scales





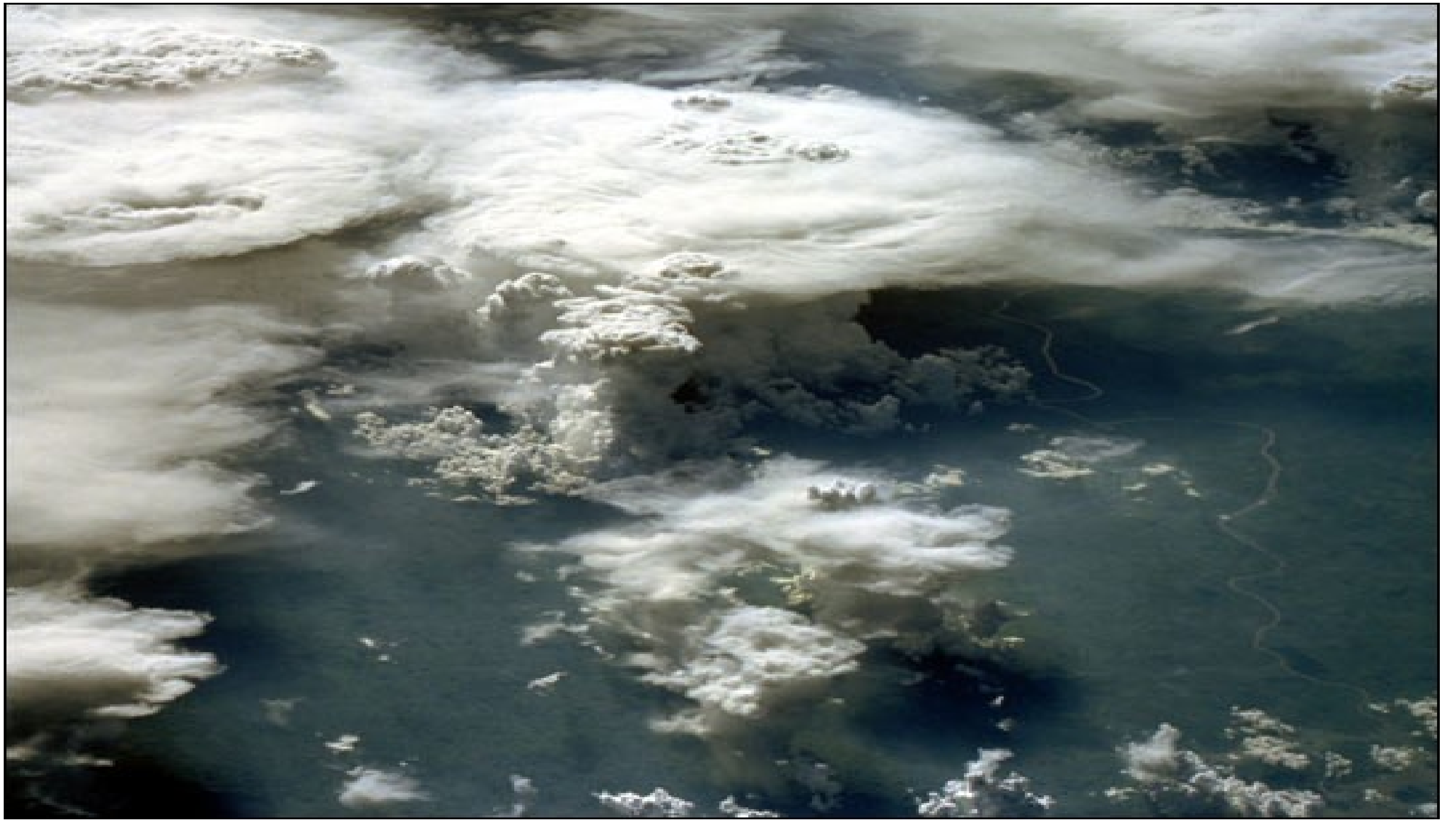
Fundamental Issue: How does Deep Precipitating Convection relate to Large-Scale Tropical Environment?

Convective Clouds grow from the Smallest Scales (~100m) to ~1000km (on the large end, but not beyond)

But only under certain thermodynamic and dynamic conditions

Most Theories of Convective/Large-scale Interactions have focused on oceanic regions; incluing small Tropical islands

Likewise, most modeling (Idealized and Experimental) studies of Convective/Large-scale Interactions assume sea-surface, or, minimally, very homogeneous surface conditions



However, at the convective-scale, continental regions greatly modify convective organization and intesity compared to oceanic regions. This is reflected in certain thermodynamic variables, particularly water vapor.

The complexity of convection over continents has motivated huge experimental campaigns (LBA, NAME, GOAmazon, Relampago)

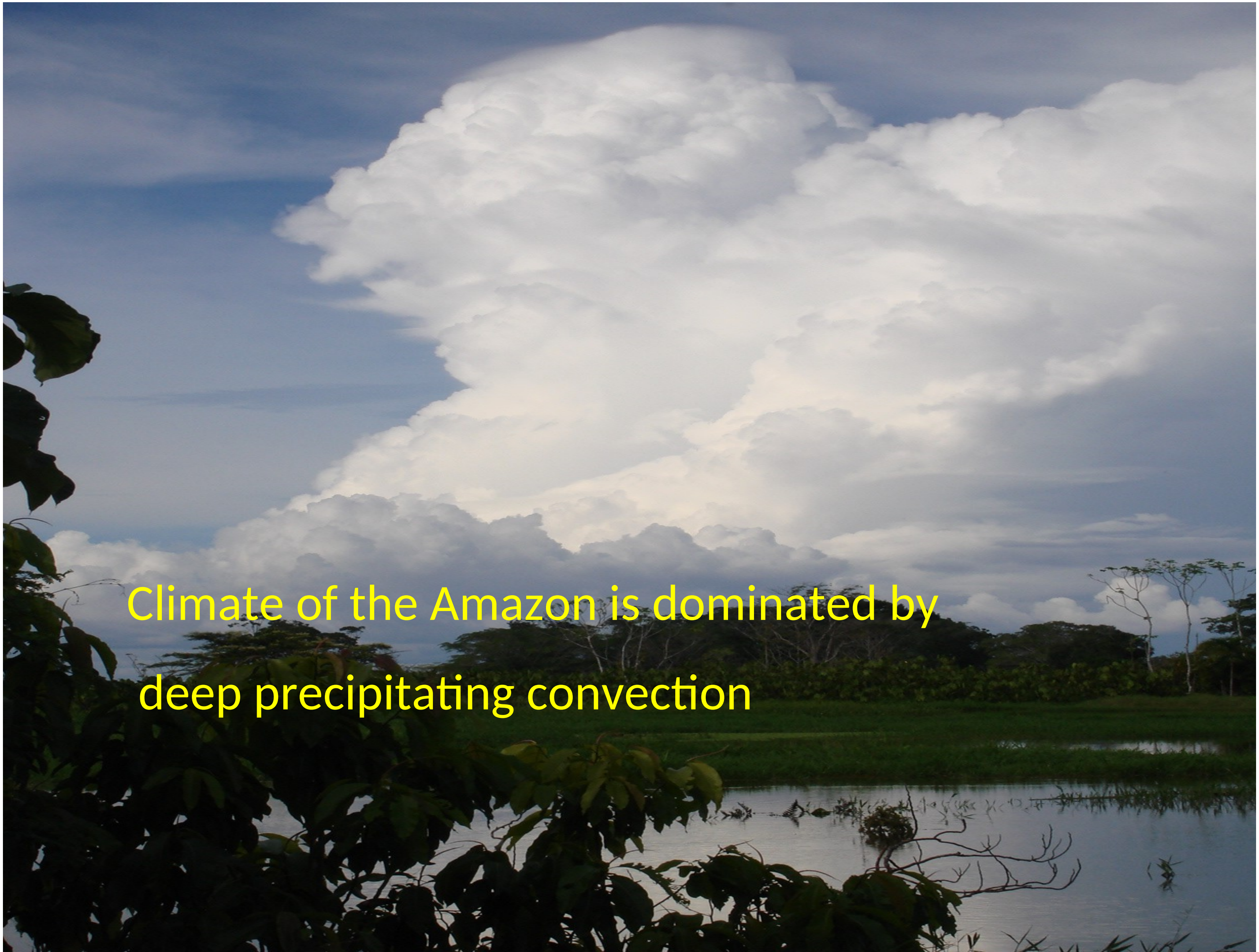
Theories and Observational Studies focusing on Deep Convection are based on Tropical Oceans

For example: Observations and Theories Offered For PWV-Precip Relationship
PWV/Column Relative Humidity and Precip. Reveals strong non-linear relationship (Xeng 1999, Bretherton et al. 2004 among others)

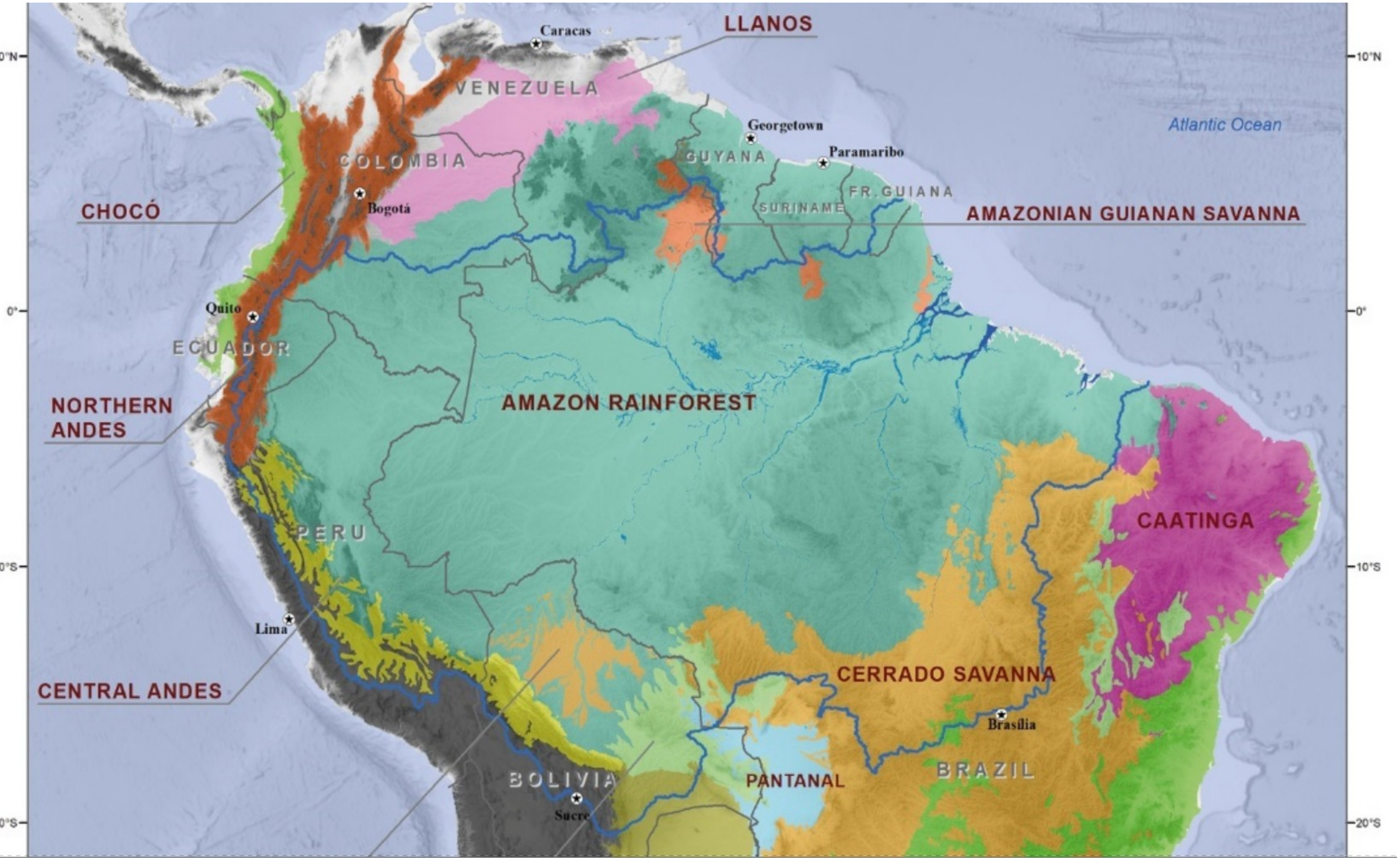
Self-Organized Criticality (SOC) (Peters et al. 2002, 2006,2010; Neelin et al. 2009; Holloway et al. 2009)

Thermodynamic Control (Raymond 2000; Raymond et al. 2009)

Gross Moist Stability (Neelin and Held 1987)


Climate of the Amazon is dominated by
deep precipitating convection

Coastal Amazon region is Sea-Breeze Dominant
The Central Amazon region topography is relatively homogeneous (a "Green Ocean")

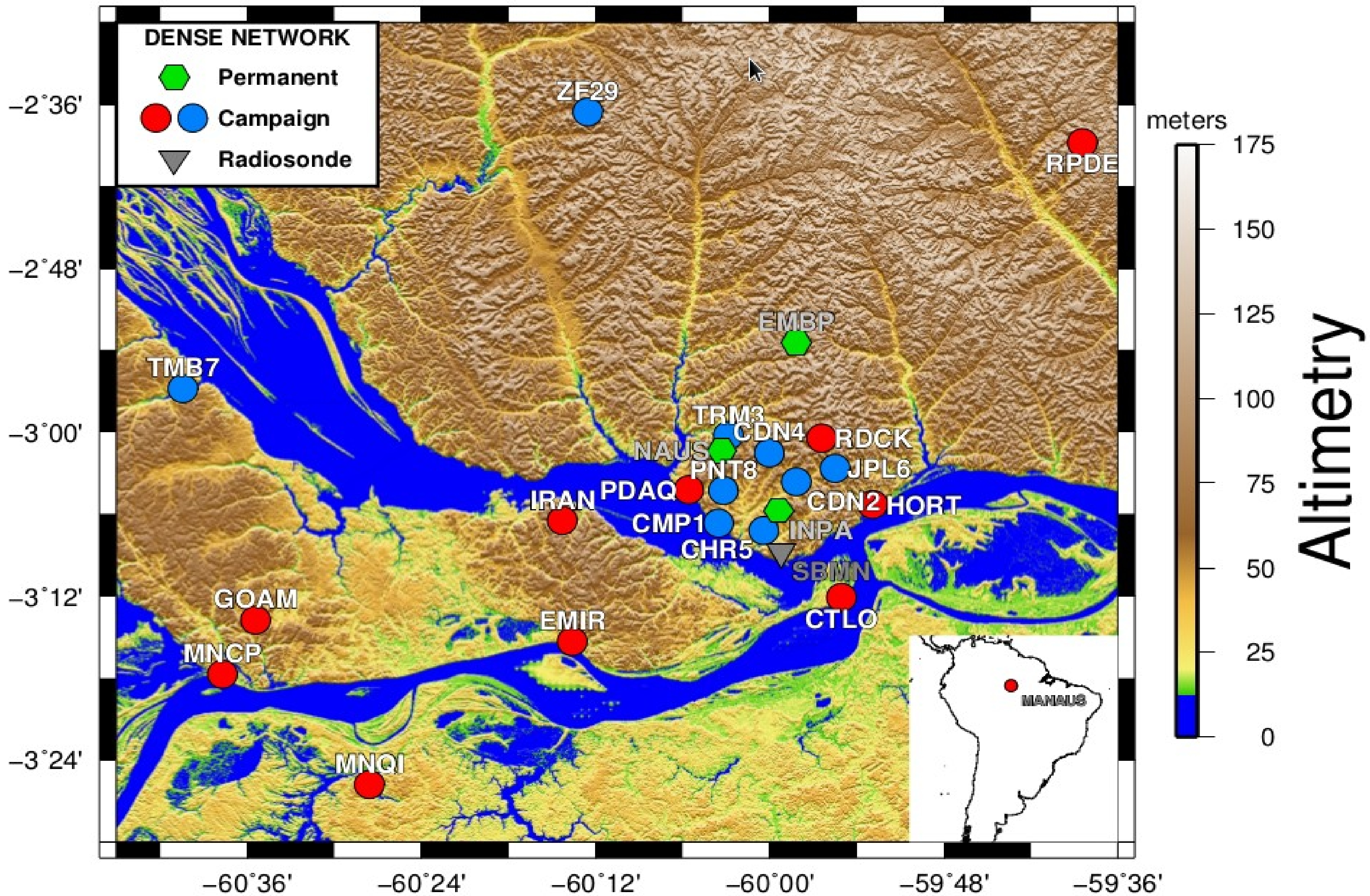


Changes in Surface Characteristics of Amazon River System, Annual Flooding and Retreat, Forest Canopy also Critical

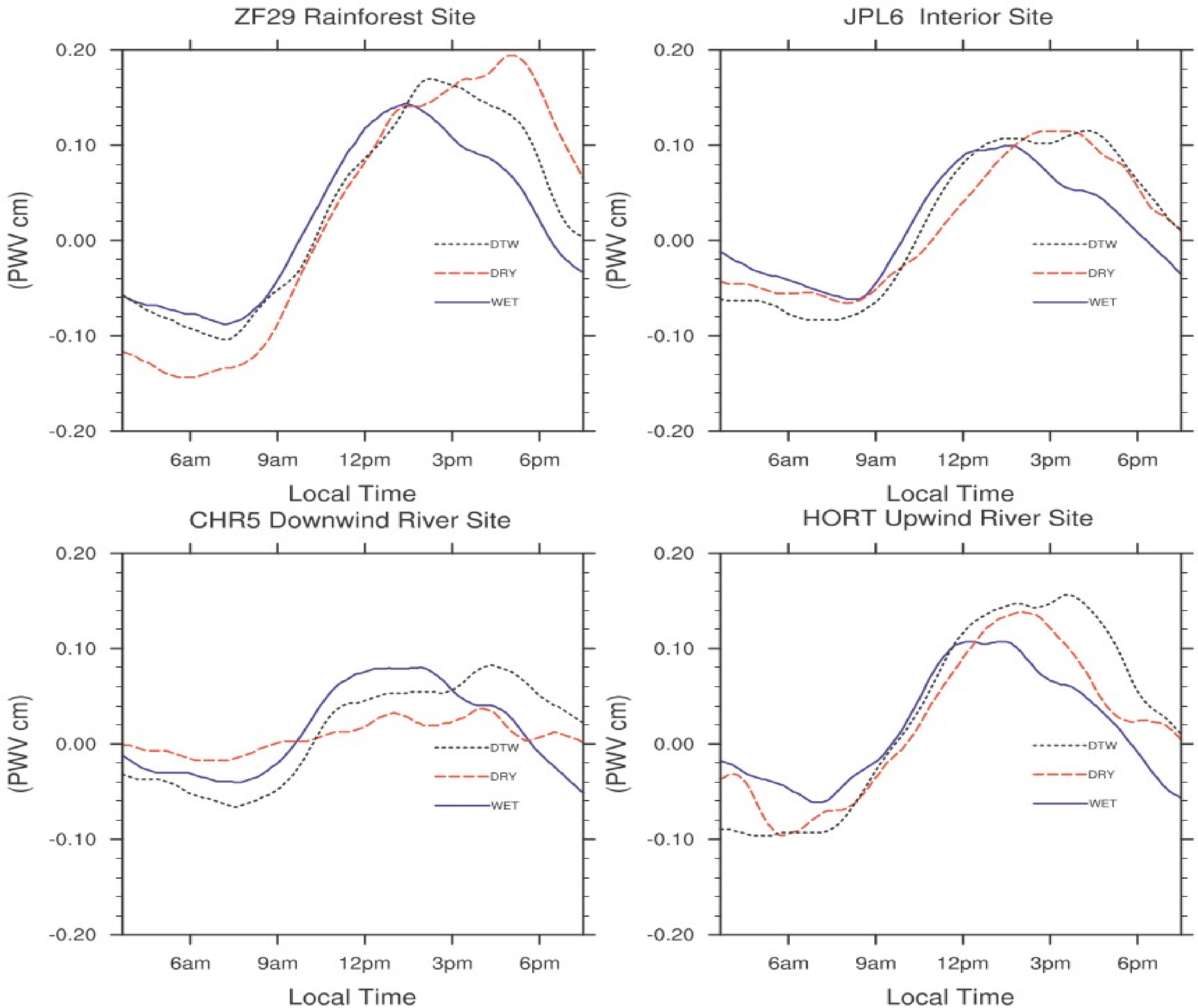
INPA (Brazil) and Max Planck Institute (Germany) created the 325m ATTO tower to examine rainforest influence on the atmosphere

The Amazon Dense GNSS Meteorological Network

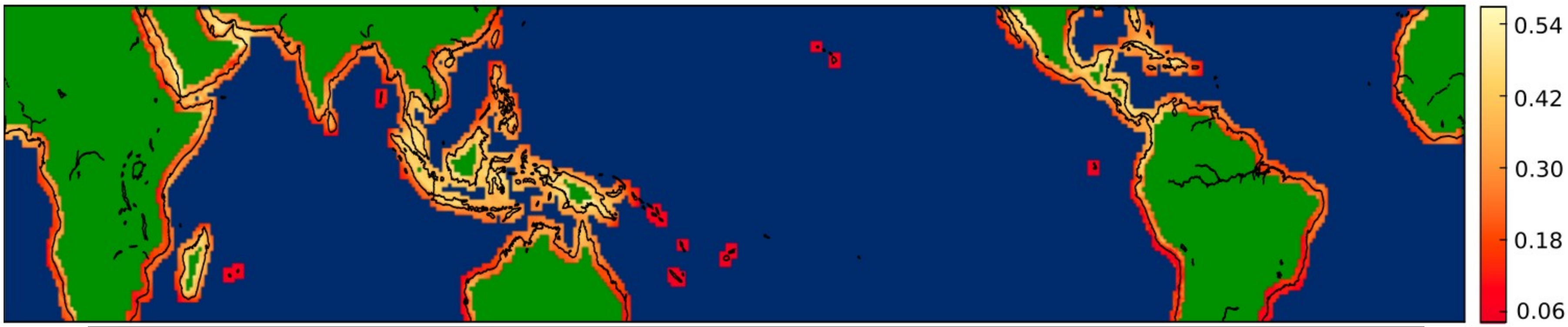
Continental Tropical (Manaus) (Adams et al. 2013, 2015, 2017)

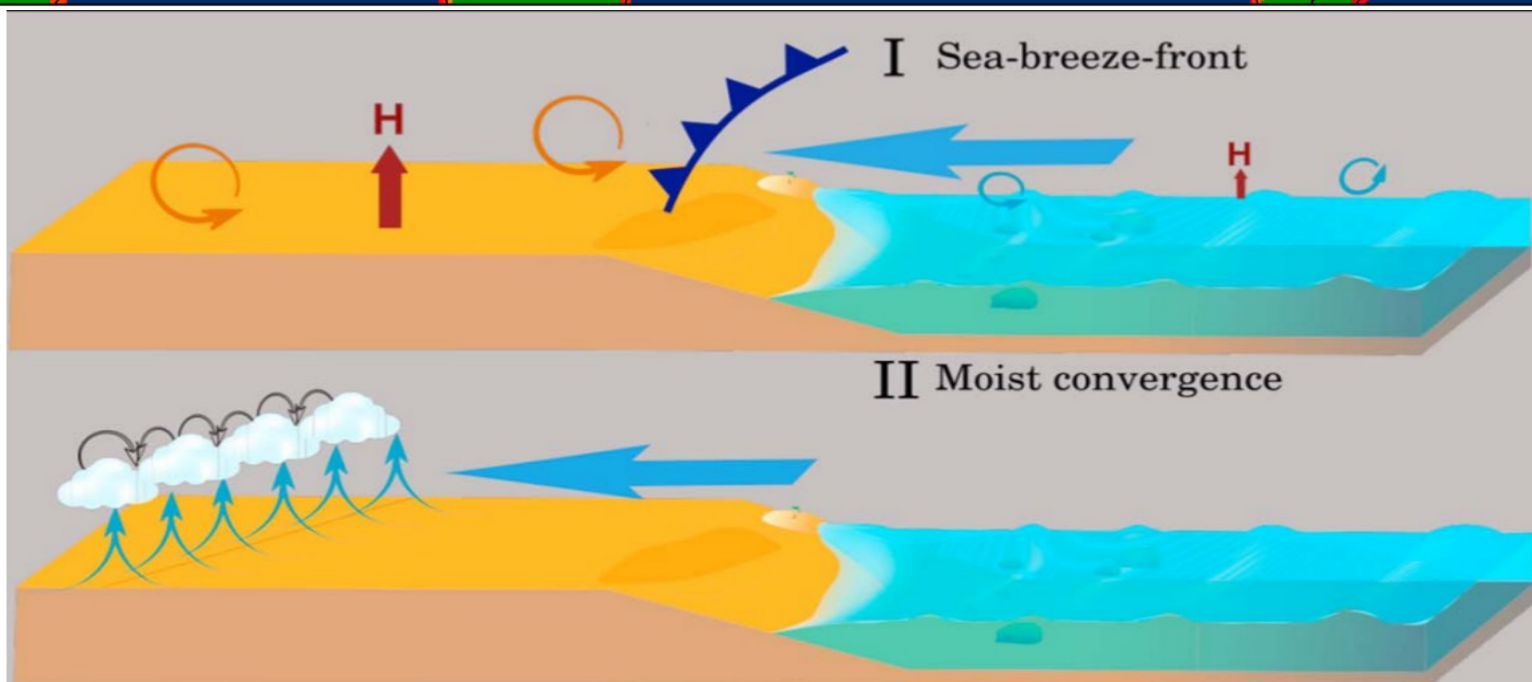


The strength of water vapor convergence has a dependence on location with respect to the Amazon River (Adams et al. 2015)

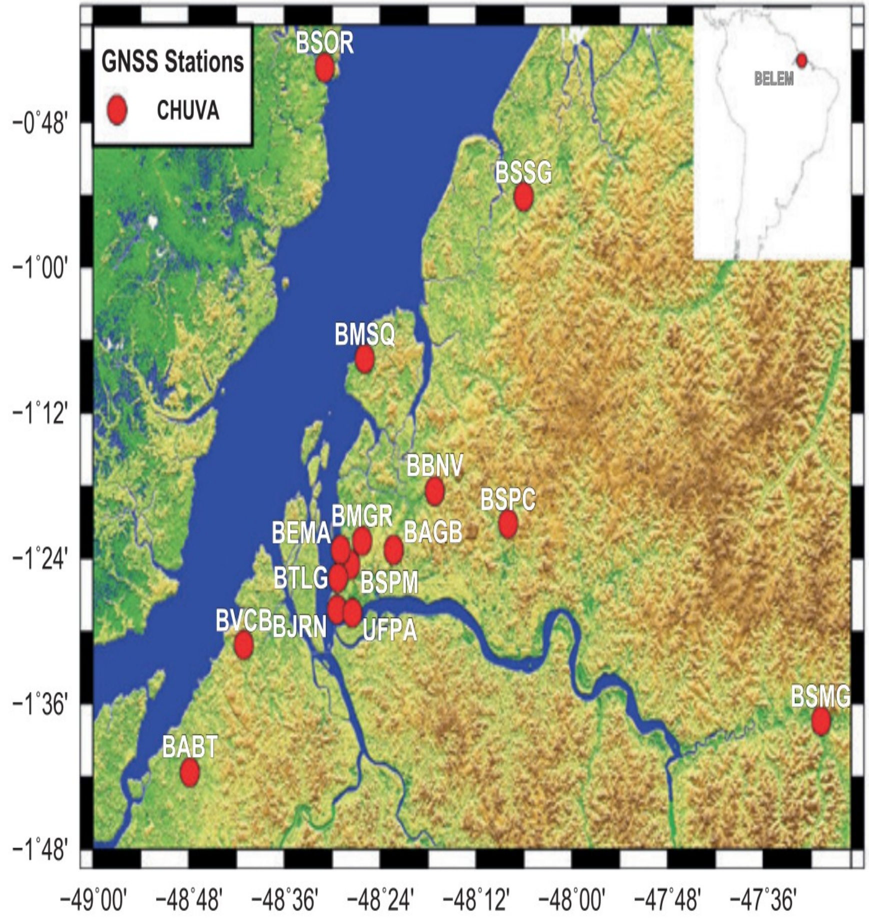


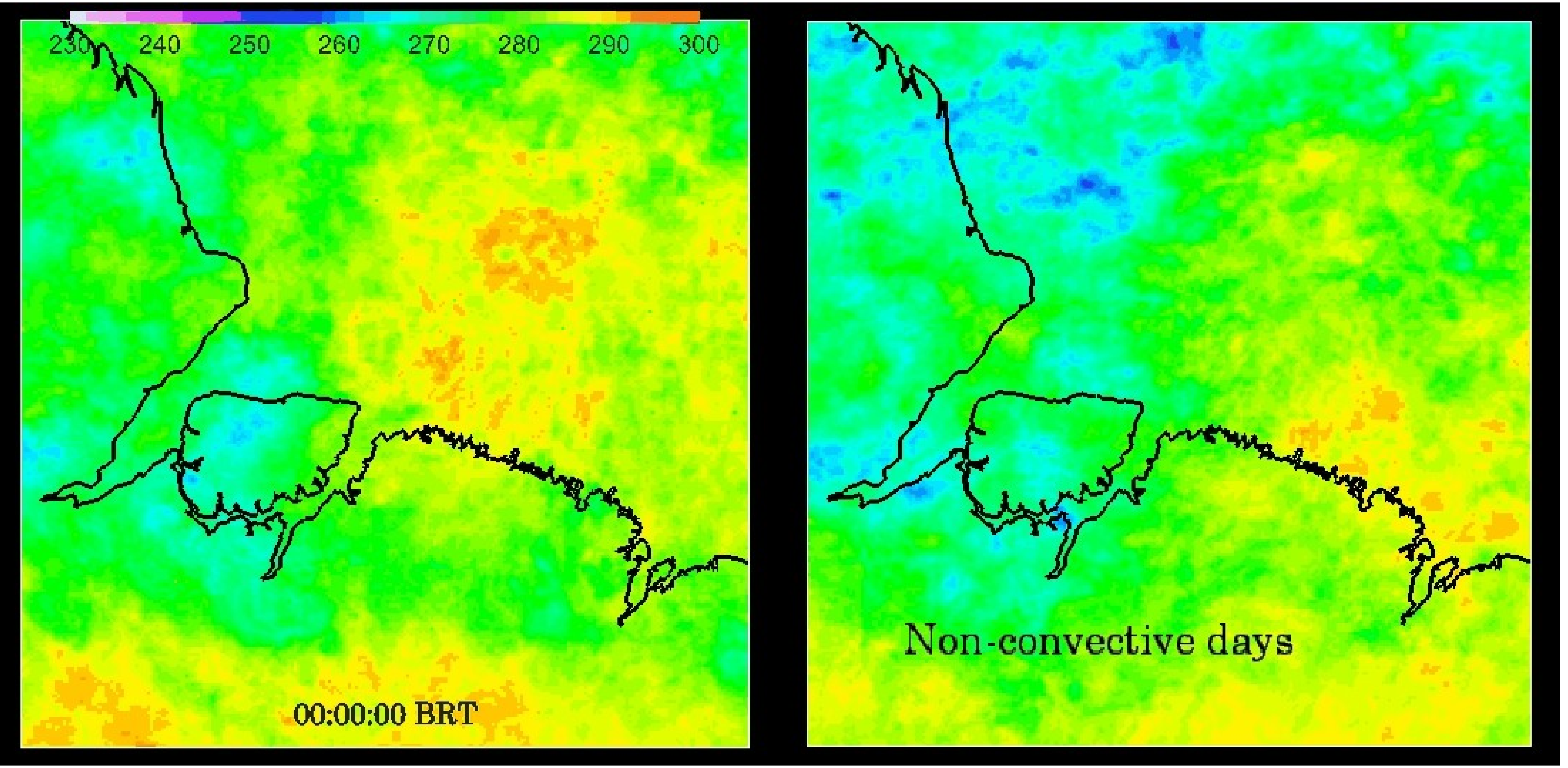
Within Tropical Meteorology, an important focus has been on Oceanic vs Continental Convection. The Sea-Breeze regime is Unique, but important across the Globe (Bergemann and Jakob 2016).



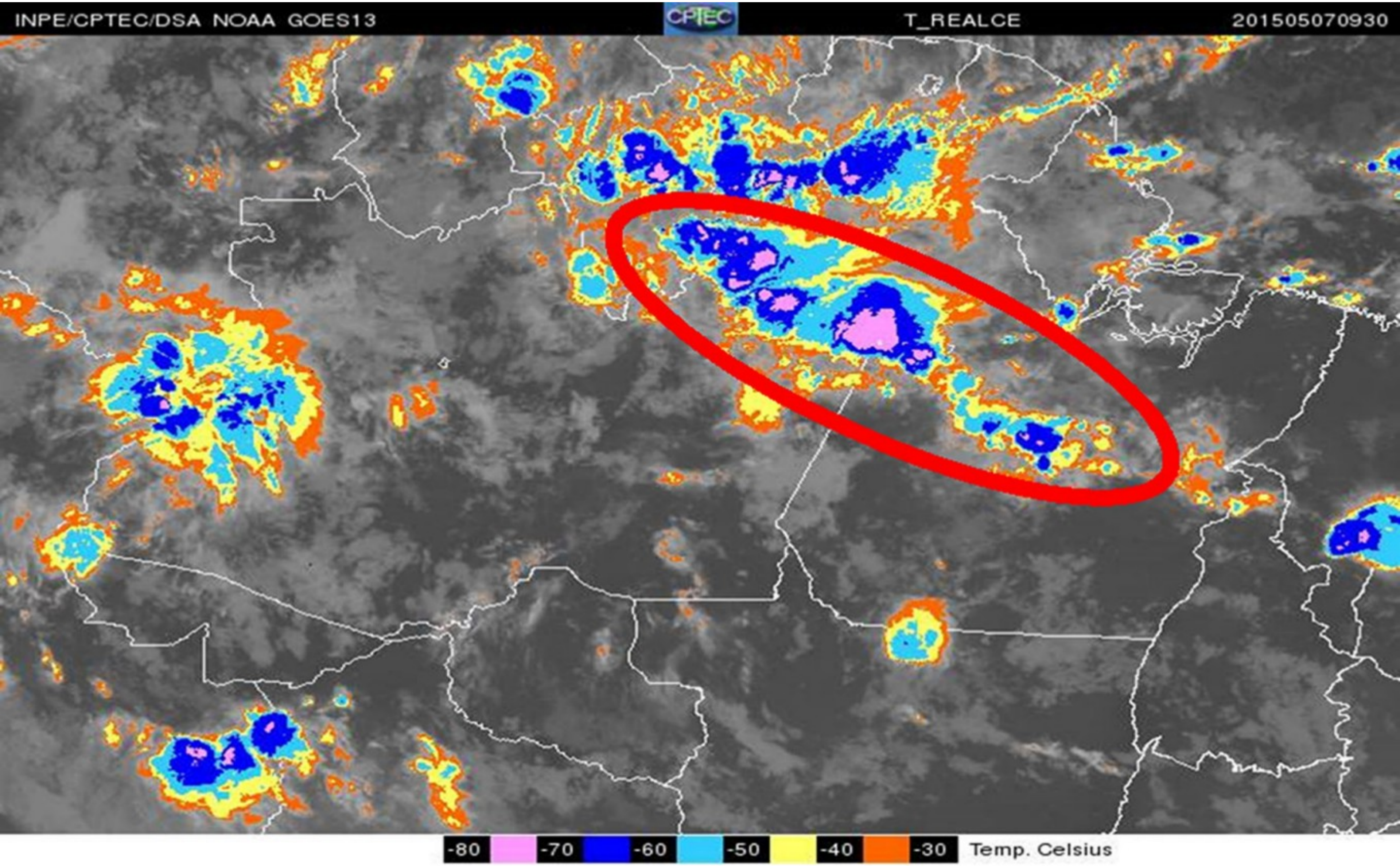


Land-sea contrasts cause sea breezes. This can lead to sea breeze-induced instability lines (CHUVA-GPM 2011, Dense GNSS Met. Network (2011-12)




230
240
250
260
270
280
290
300
00:00:00 BRT
Non-convective days

These Squall Lines can grow to 1000km and > 1 day lifetime (Gonçalves et al. 2022

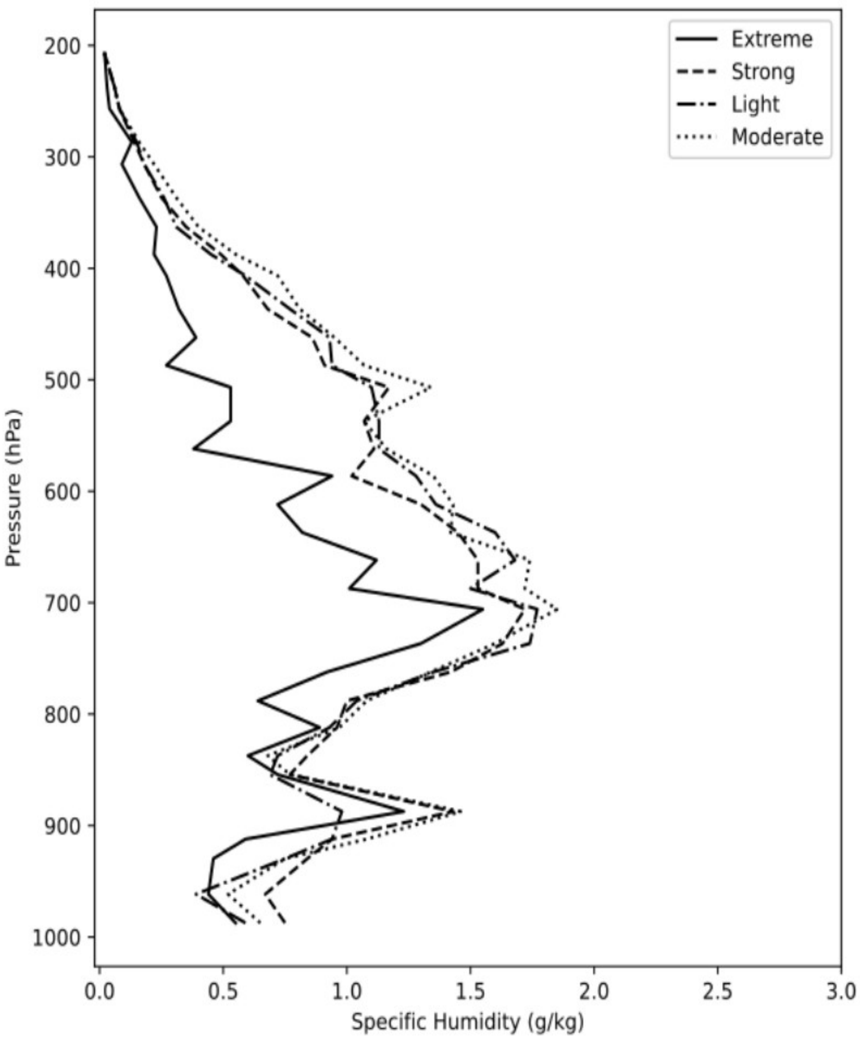


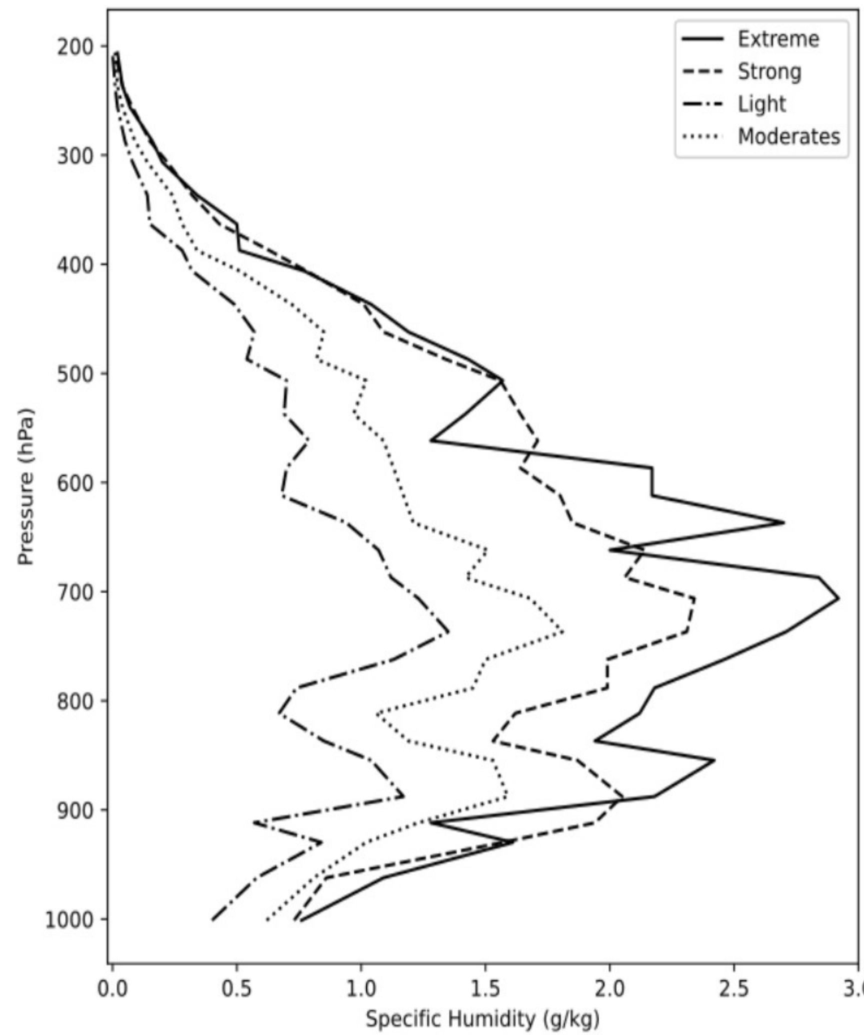
Belem Region Deep Convective Event Intensity was Determined Based on GLD360 data and local Precipitation from 2014 to 2019.

Table 1. Total events by lightning and precipitation category.

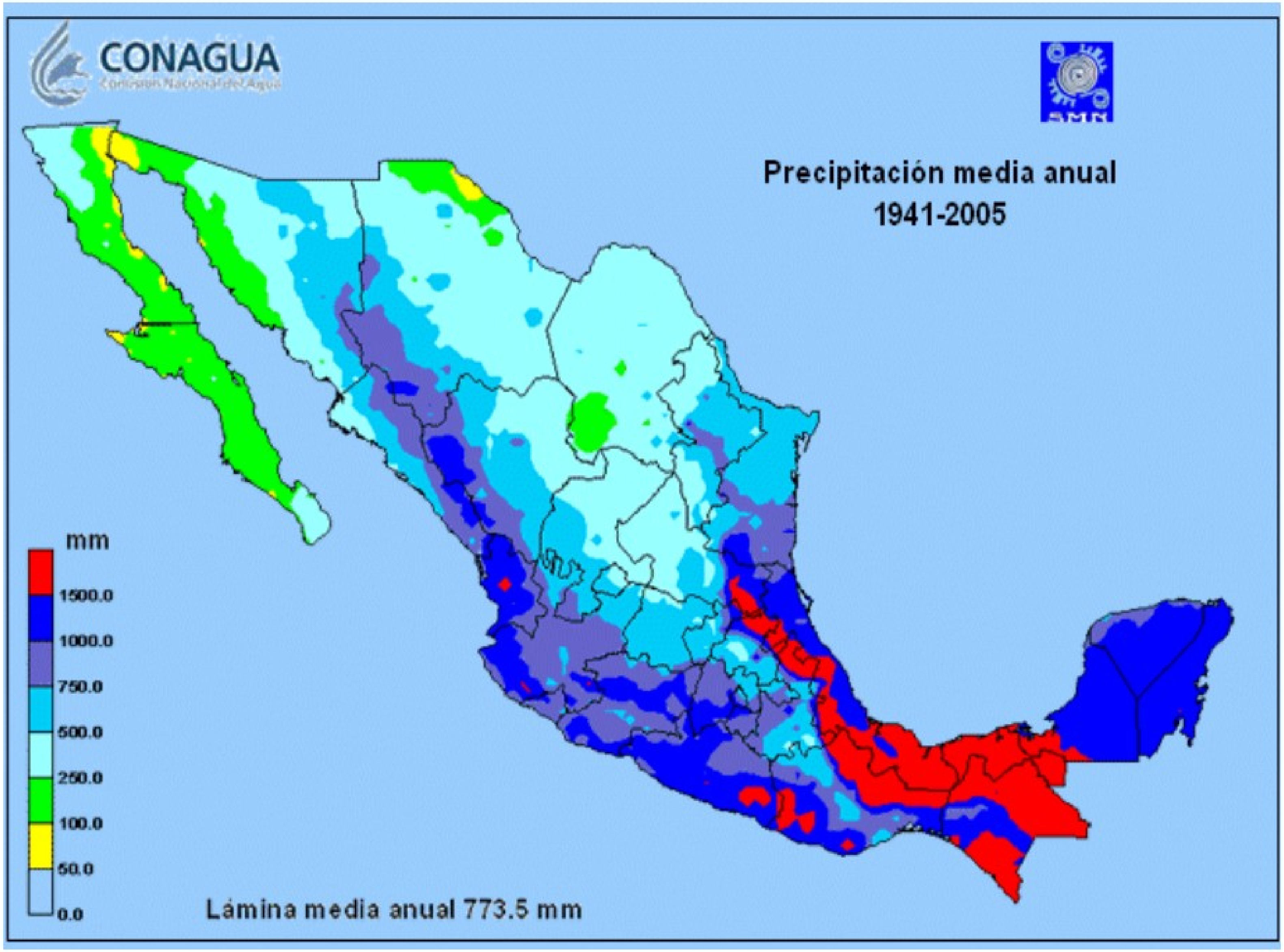
Category	Total days according to lightning	Total days according to precipitation	Match Percentage
Convective	1547	1600	86
Non Convective	345	567	70
Light	391	409	24
Moderate	770	791	44
Strong	308	320	25
Extreme	78	80	19

Water Vapor Profiles according to Intensity Category For Lightning and Precipitation-based Events.

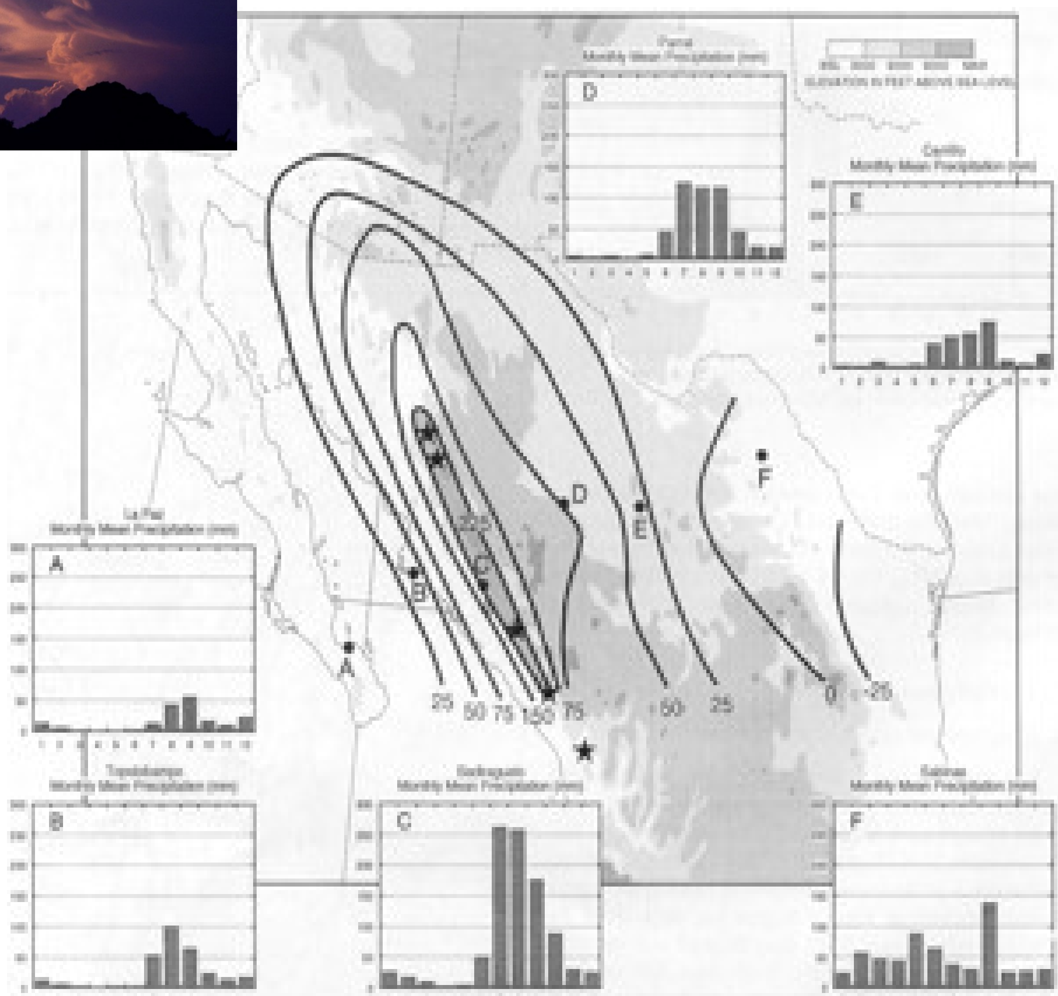




A Monsoon Thunderstorm SE California

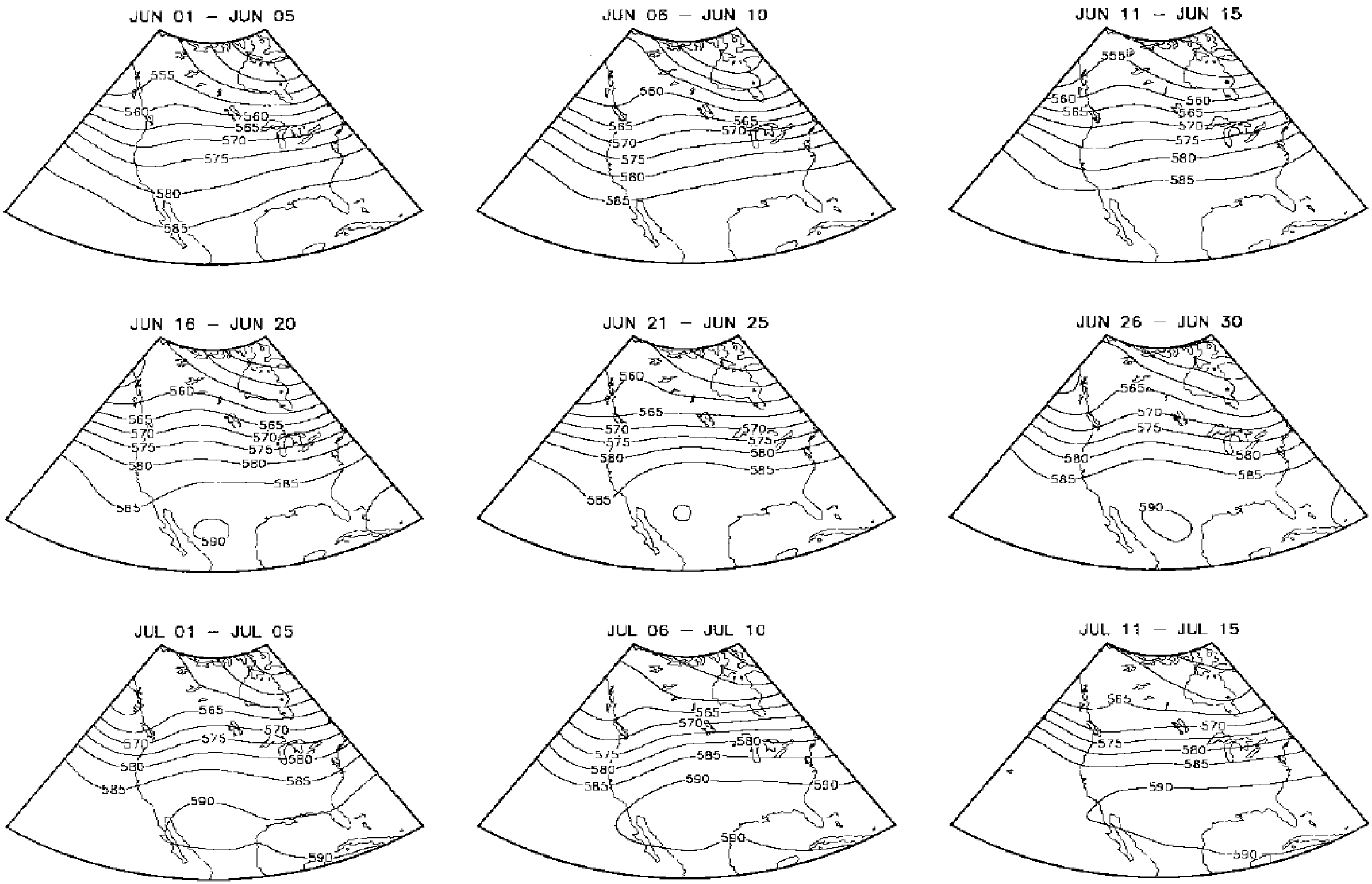

CONAGUA
Comisión Nacional del Agua
Precipitación media anual
1941-2005
mm
1500.0
1000.0
750.0
500.0
250.0
100.0
50.0
0.0
Lámina media anual 773.5 mm

North American monsoon (NAM)



- Commences in southern Mexico in late May/early June and spreads nortwestward along the western slope of the Sierre Madre Occidental
- The southwestern US (Arizona and New Mexico) is impacted by mid-to-late July
- Complex moisture source: Gulf of California/eastern Pacific (low levels) and the Gulf of Mexico (upper levels); potentially also the Great Plains

NAM begins with nortward movement of the Subtropical High (Adams and Comrie 1997)

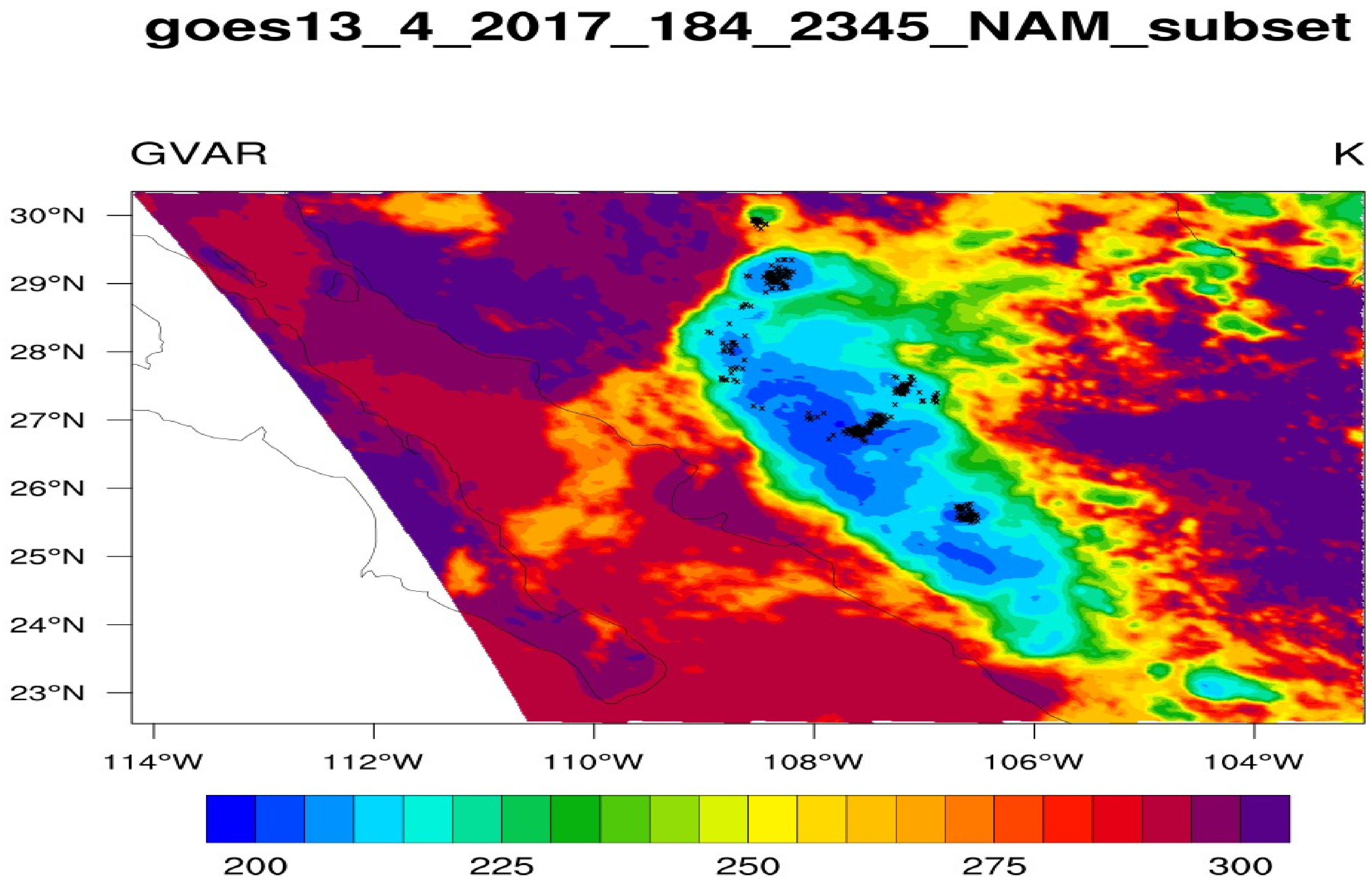


North American Monsoon

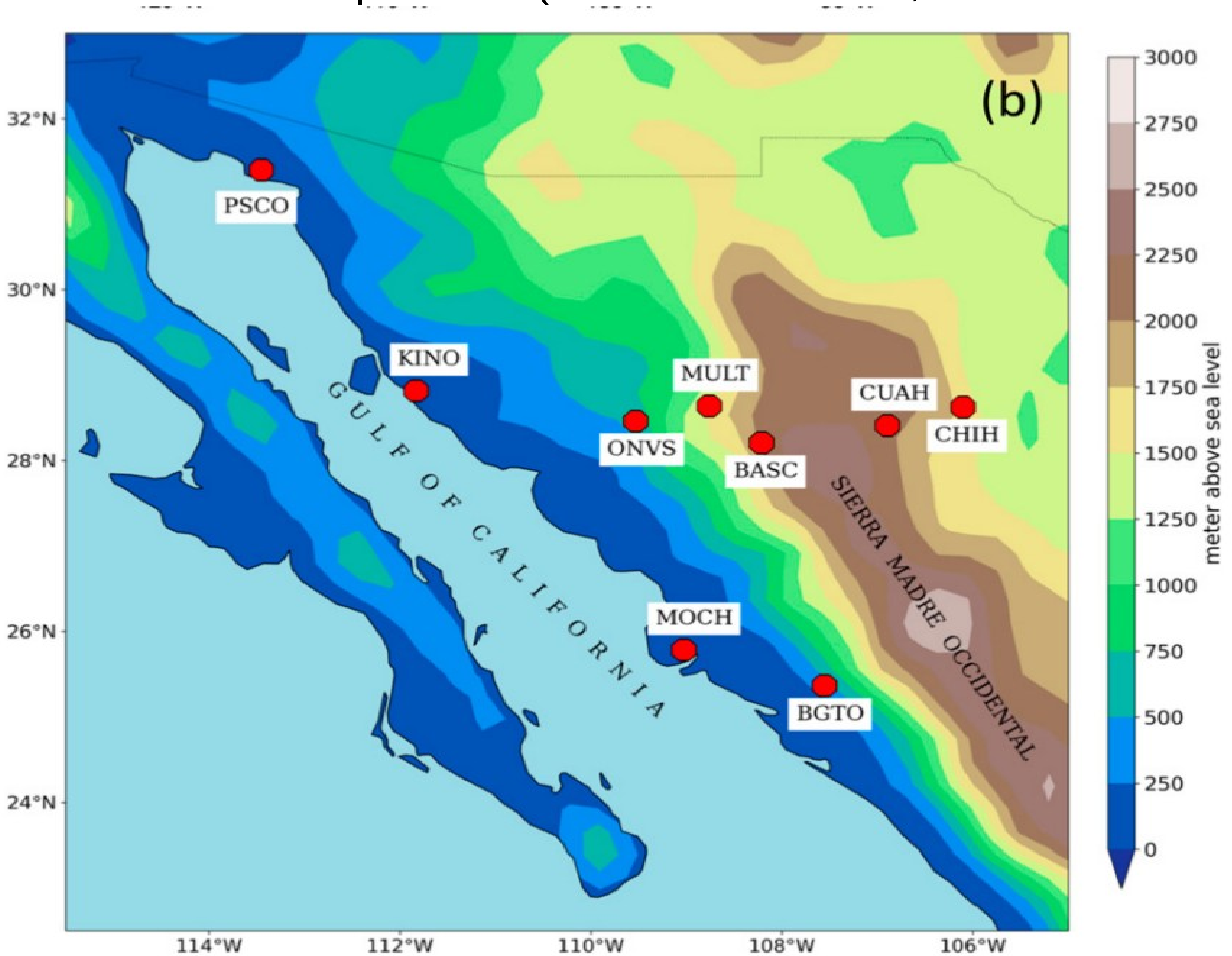
- The wet monsoon season occurs from late June-mid-September.
- Monsoonal rainfall totals are spatial heterogeneous, with the highest values found over the Sierra Madre Occidental
- A large portion of the rainfall is associated with Mesoscale Convective Systems

Near Rayón Sonora, mid August

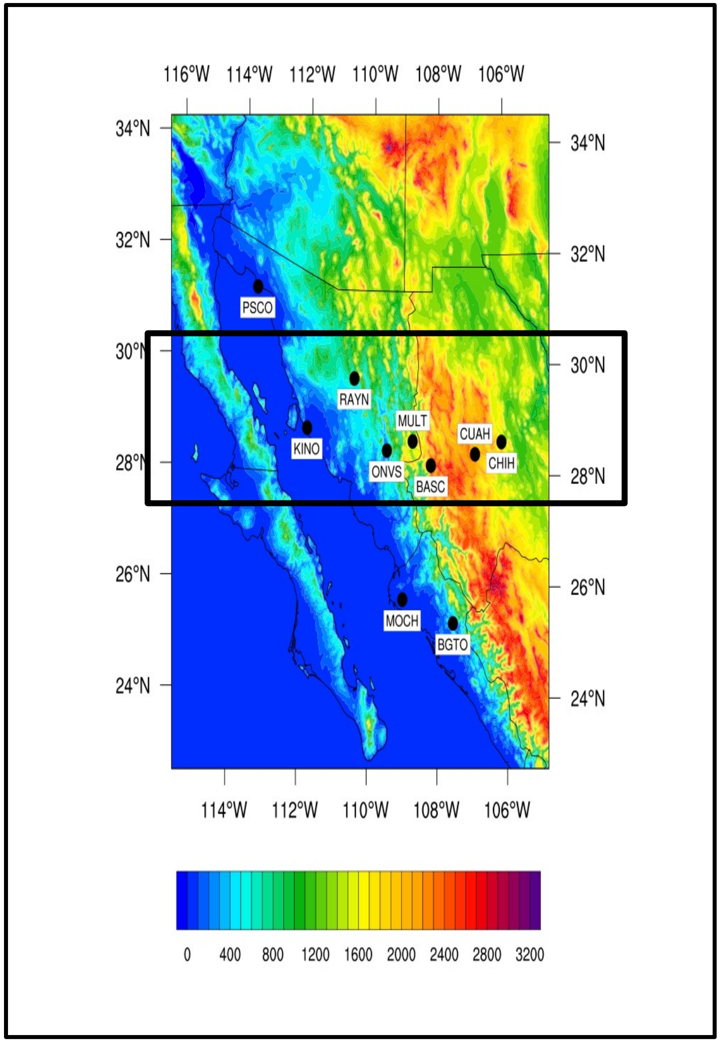
MCS contribute the largest precipitation events

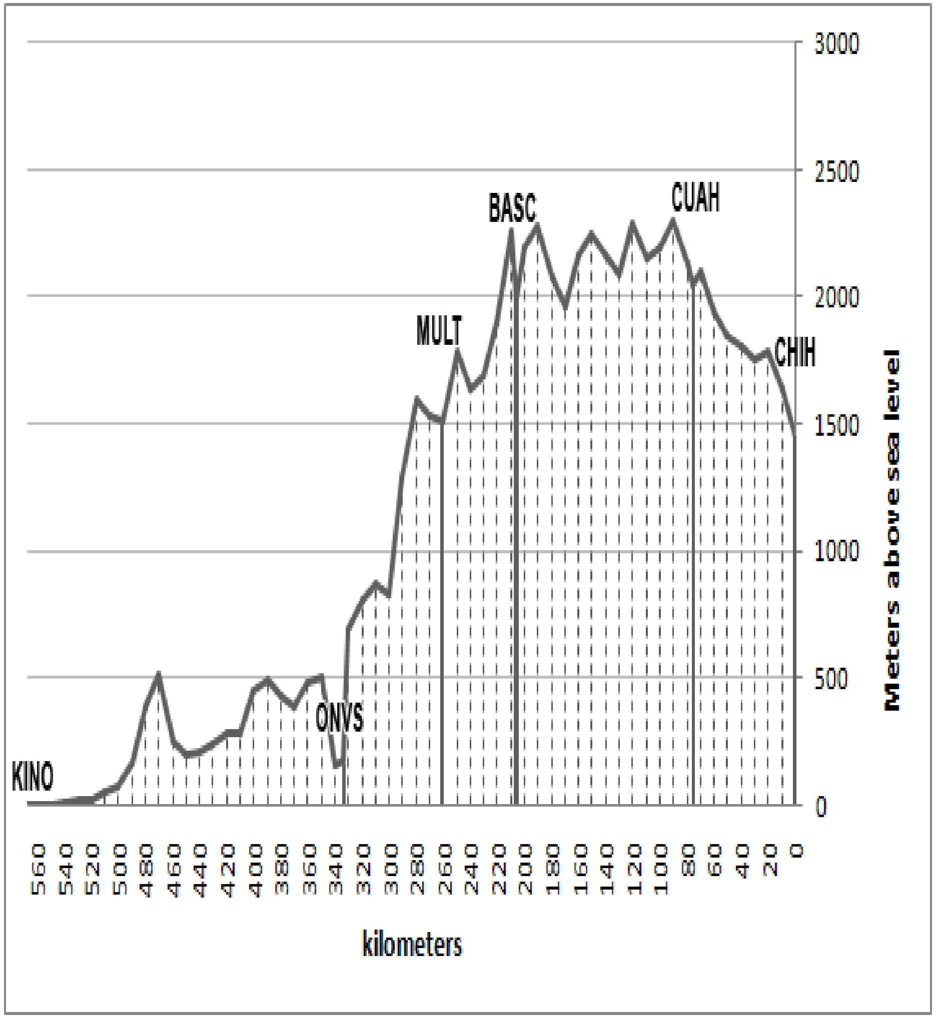


NAM GPS transect Experiment (Risanto et al. 2023, Serra et al 2016)



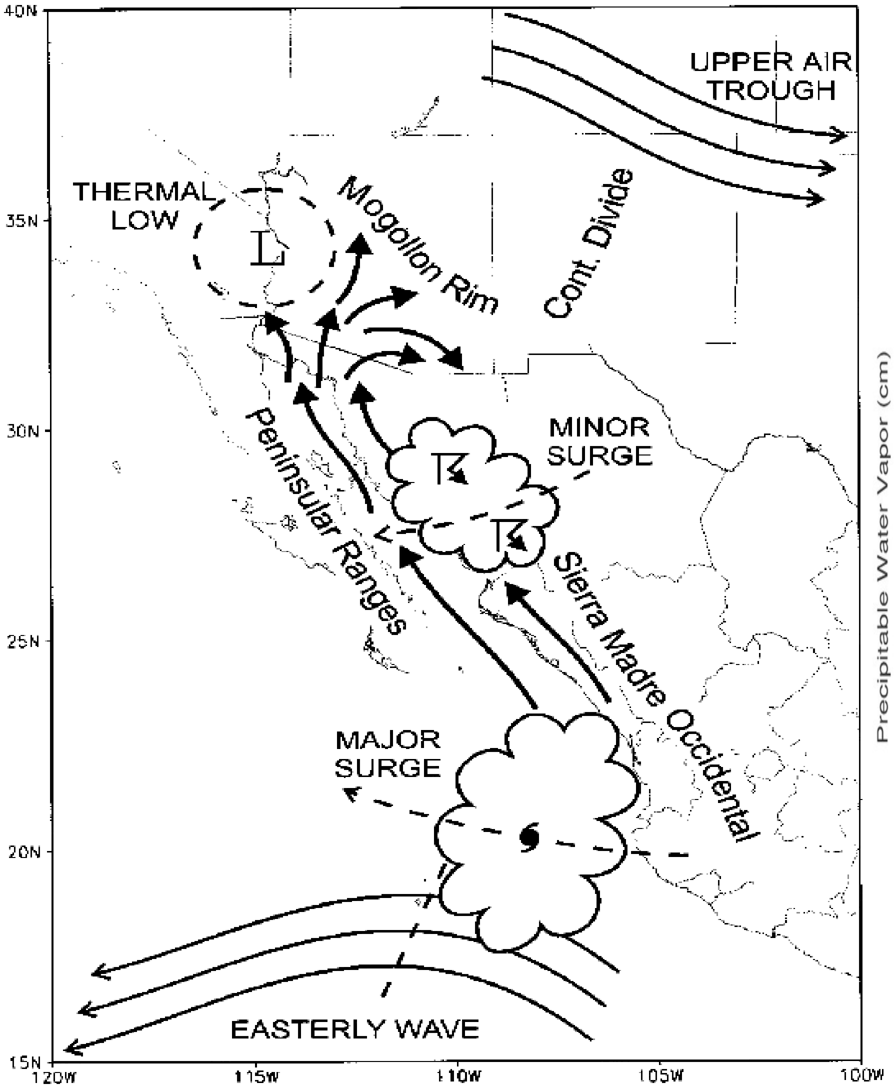
The Complex Topography of the Sierra Madre Occidental is particularly Challenging

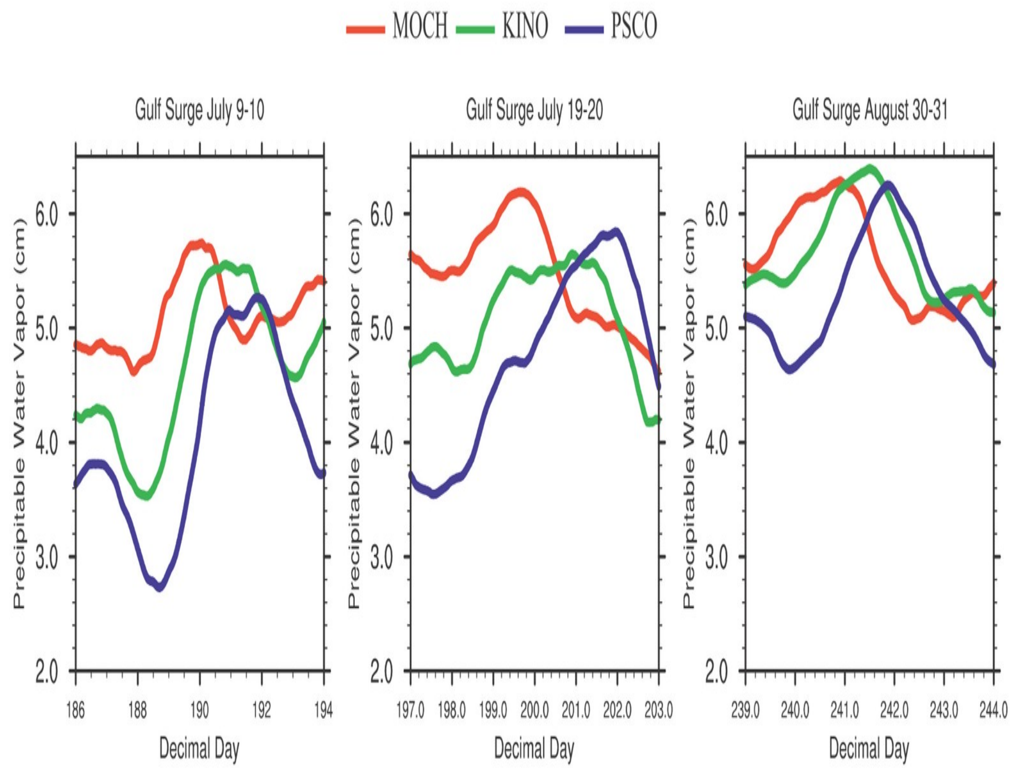




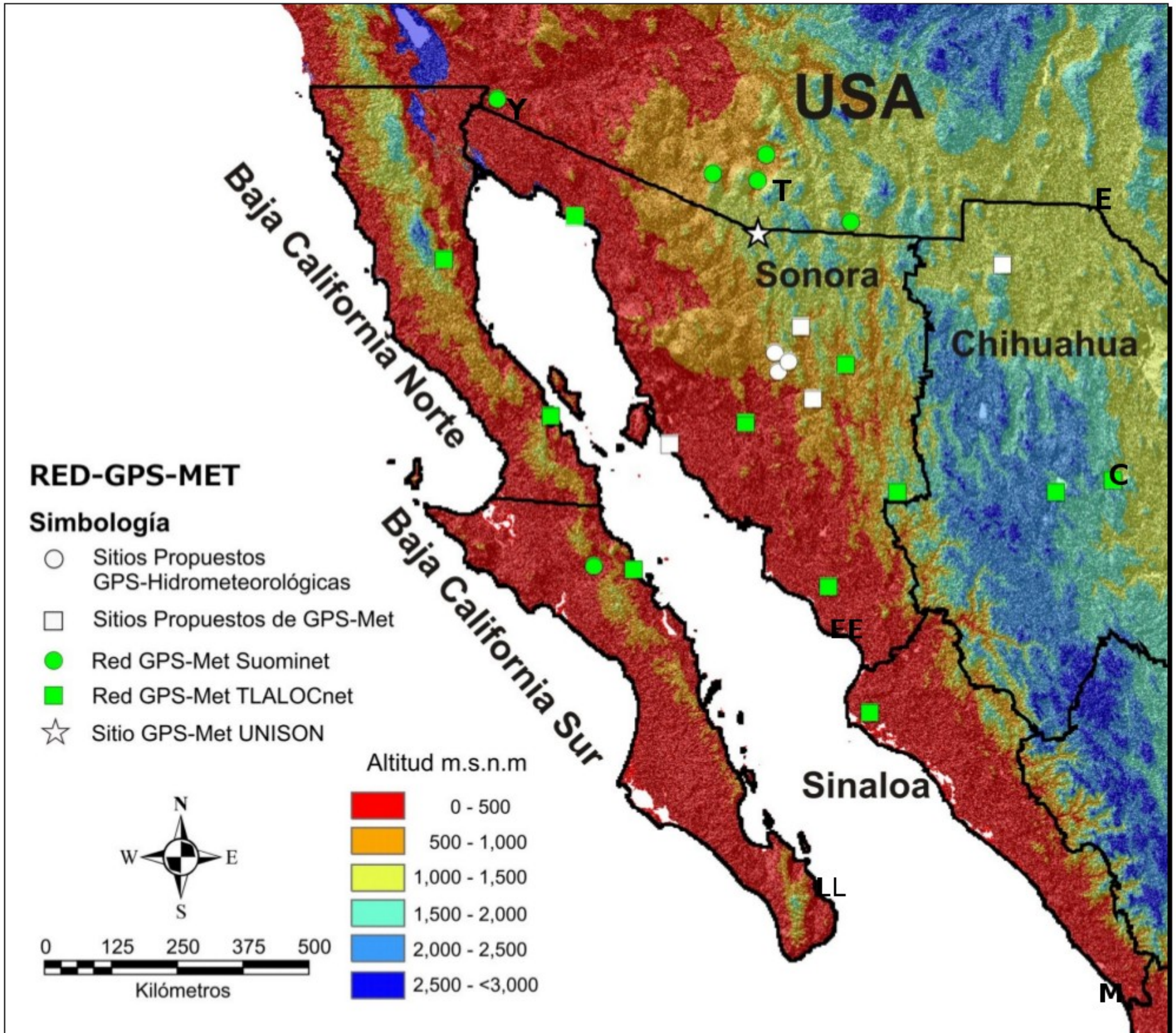


Gulf Surges can result in increases in convective precipitation in SE Califonia and Arizona





The GPS Hydromet Network (2017)



Within the Sierra Madre Occidental Ecosystems vary greatly

In the foothills, there radical changes in the vegetation between dry and wet seasons.

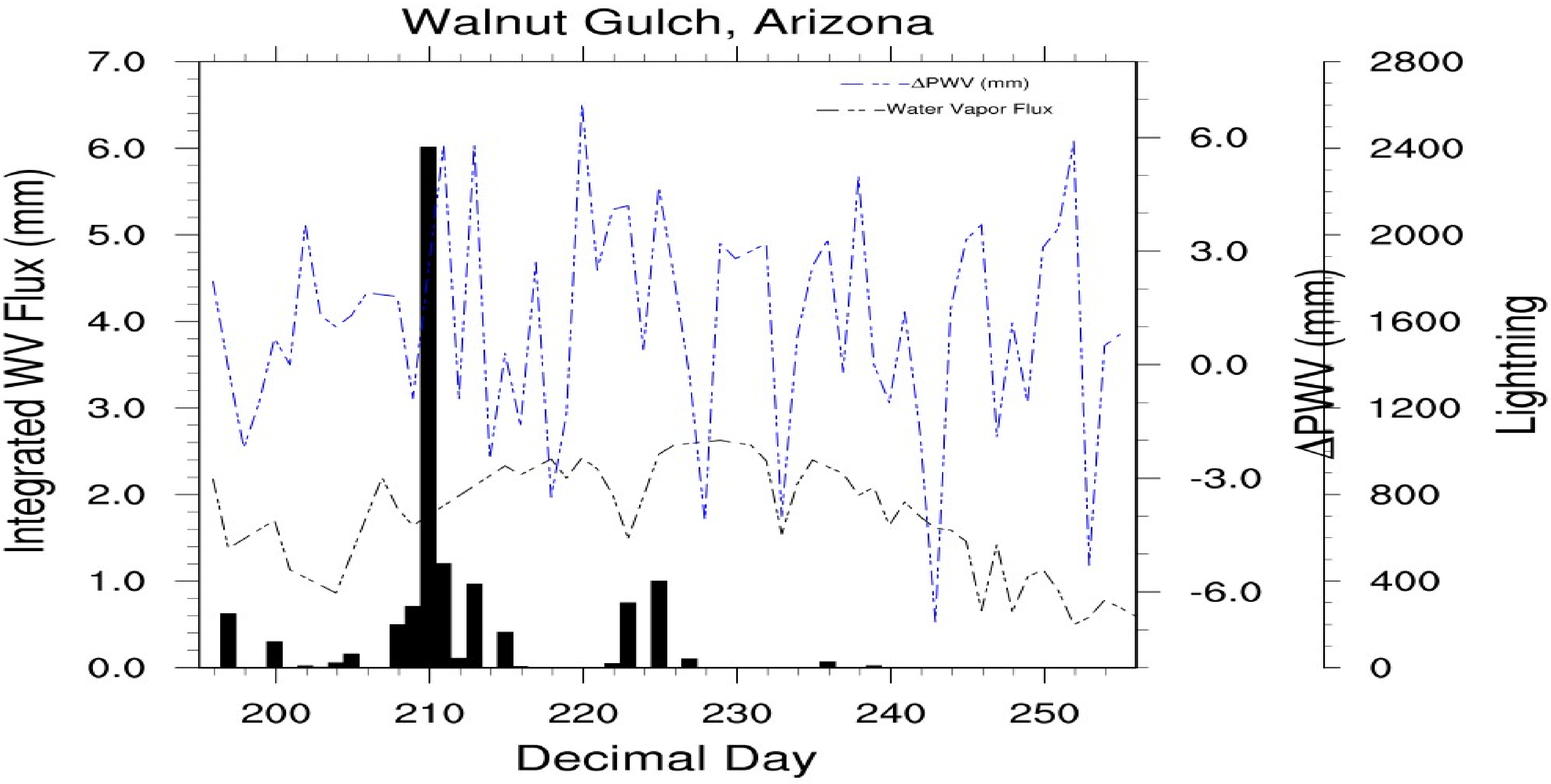
Road to Badiraguato, Sinaloa, dry and wet season.

NAM “Green Up”

- The Region of NW Mexico and the SW U.S. is Semi-arid to arid
- In Southern Sonora, Sinaloa and southward, vegetation green up is very quick, on the order of a few weeks.
- Some argue that the vegetation evapotranspiration is a source of water vapor for Monsoon Convection.

Green Up Southern Sonora, Lizarraga et al.

The local contribution of latent heat flux is not obvious (USDA site, Russ Scott)



Evolution and Intensity of MCS during the Monsoon (Omar Ramos Perez Ph.D. Thesis) (Ramos Pérez et al. 2022)

- Development of an MCS Climatology (GOES IR 1995-2017 and Lightning (Vaisala GLD360 2011-17)

- Geographic, Seasonal Variation, Diurnal Cycle were detemined (GOES IR data)

- MCS Morphology Determined from GOES IR

- Intensity and Trajectory determined from GLD360

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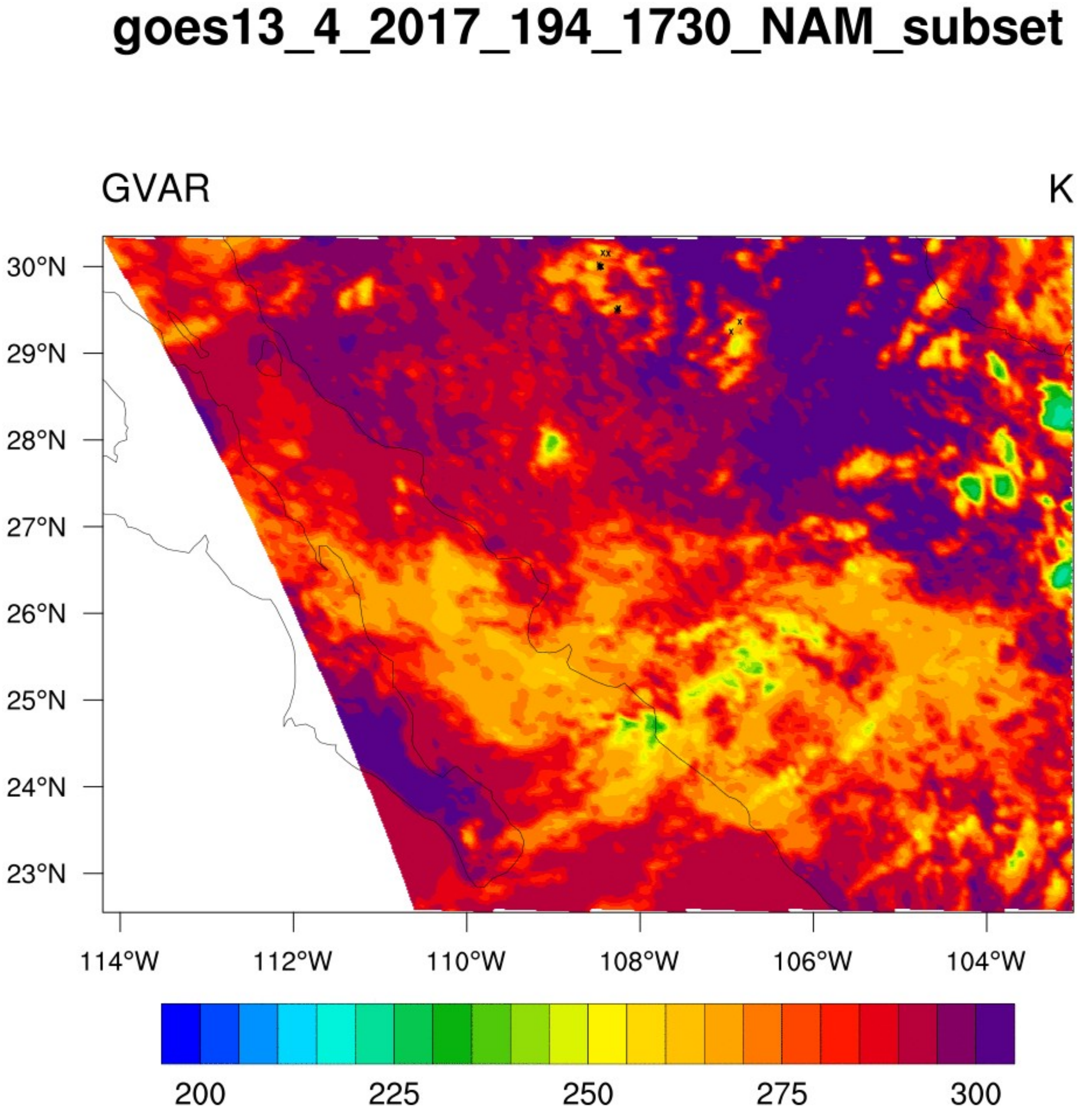
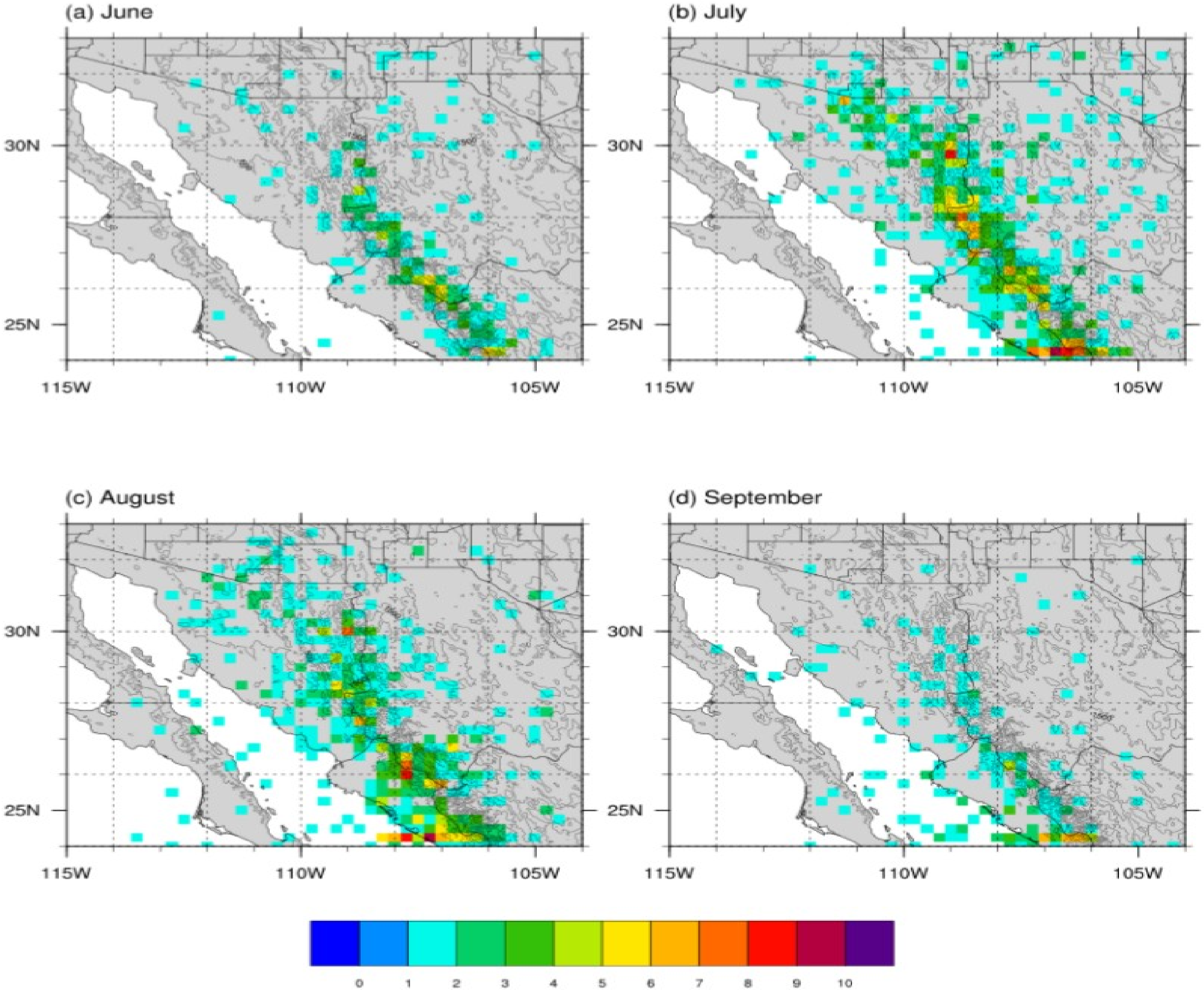

goes13_4_2017_194_1730_NAM_subset
GVAR
K
30°N
29°N
28°N
27°N
26°N
25°N
24°N
23°N
114°W
112°W
110°W
108°W
106°W
104°W
200
225
250
275
300

Deep Convective Growth over the SMO in the later afternoon/early evening

Monthly and Geographical distribution of MCS



Determining Trajectory and Intensity of MCS (Vaisala GLD360 y GOES IR) for 3 degrees latititude Bands

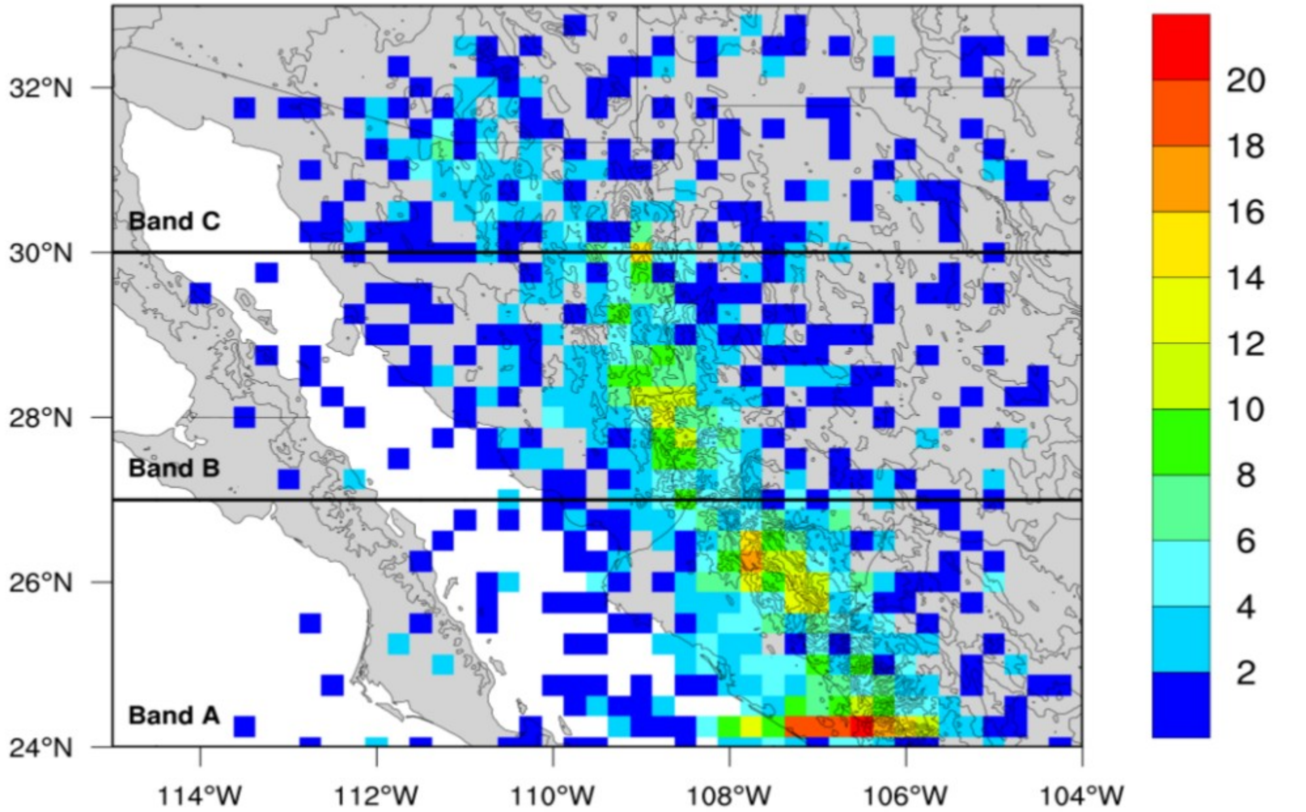
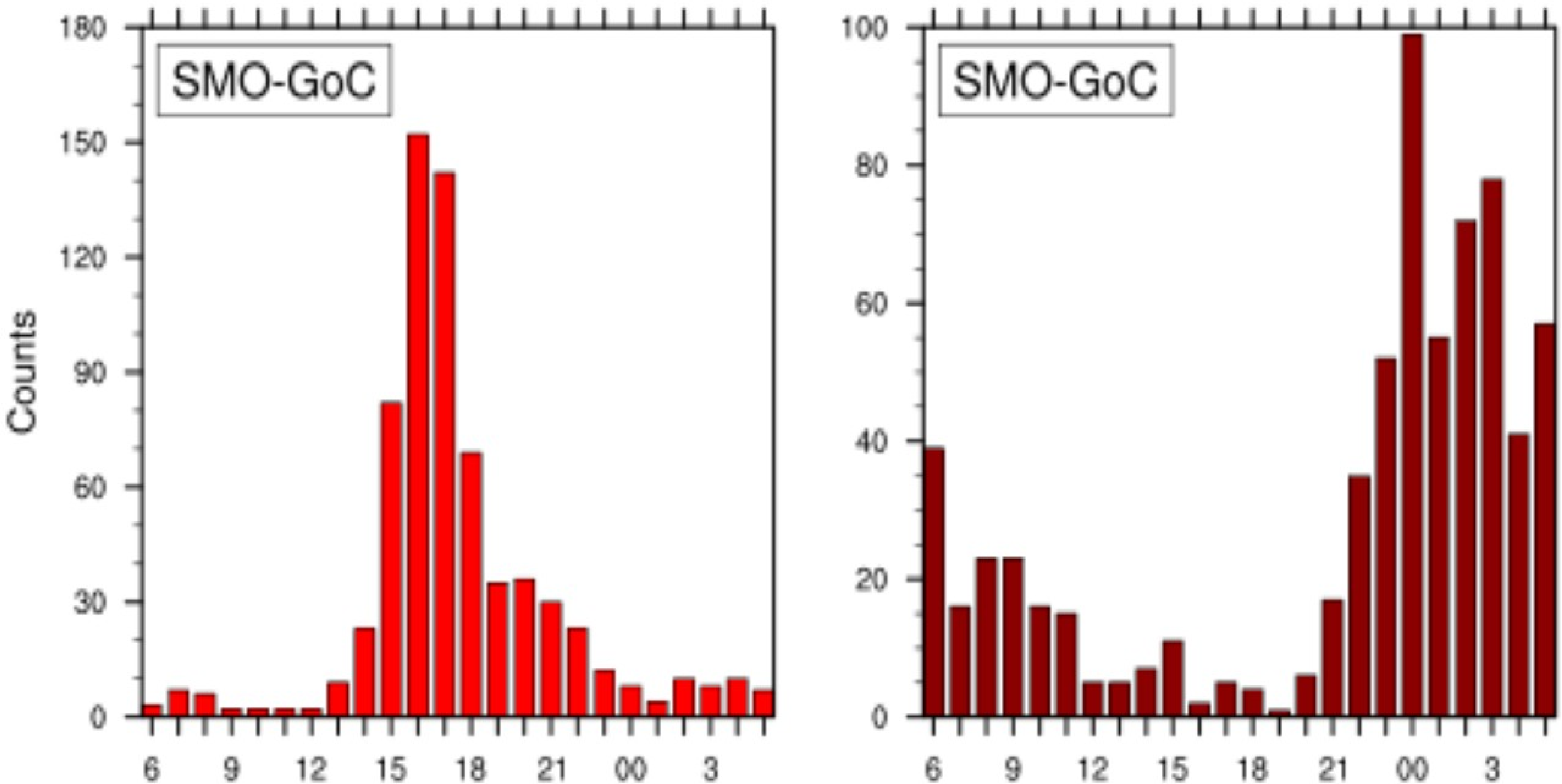
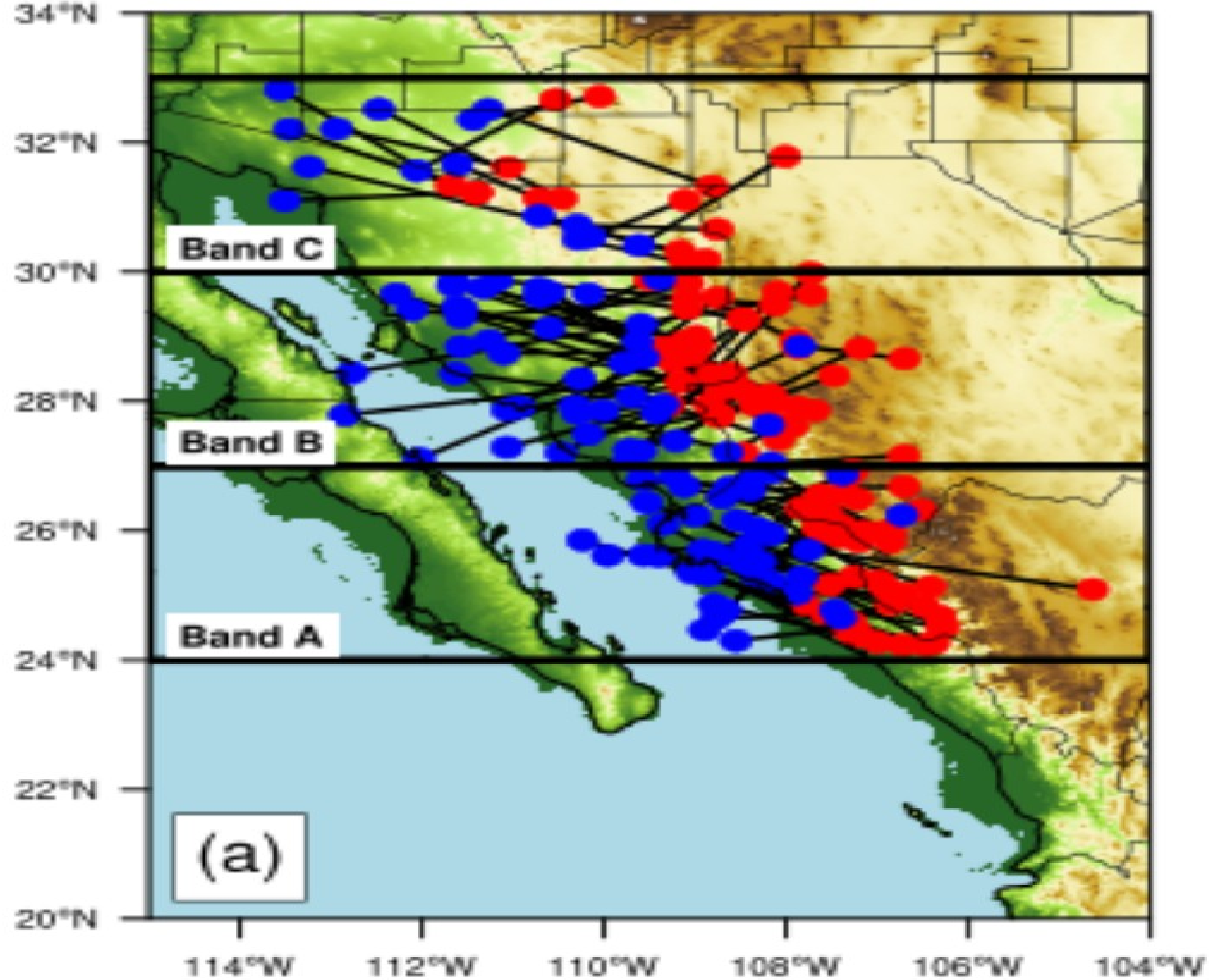


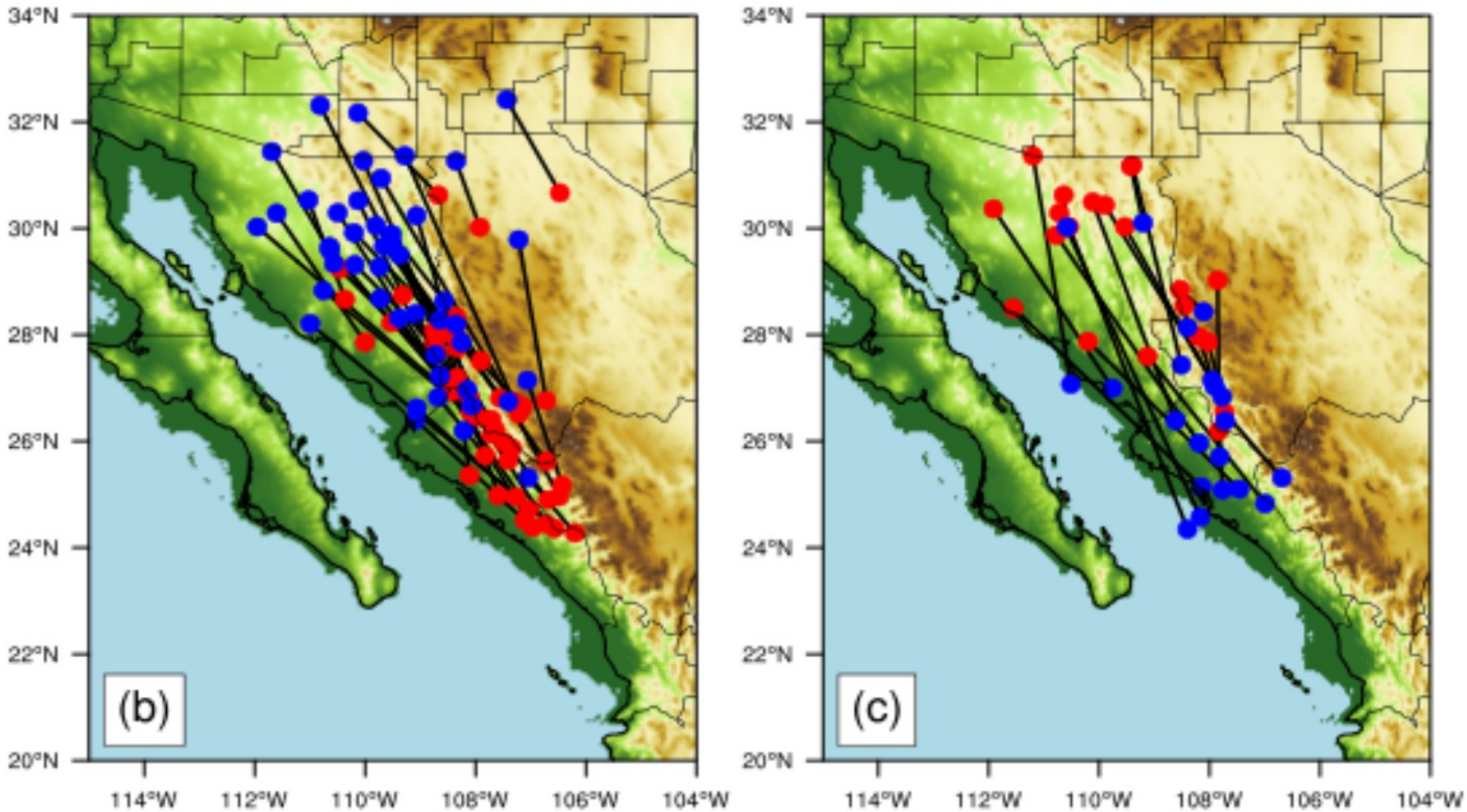
Figure 4. Geographic distribution of MCS counts during their initial stage based on the coordinates of the MCS centroid. The sums, indicated by the color bar, represent the total number of MCS (1995–1997) which initiated within a given 0.25° grid cell. The black line represents the border between the latitudinal bands called A, B, and C. The topography contours at intervals of 500 m are represented by the gray lines.

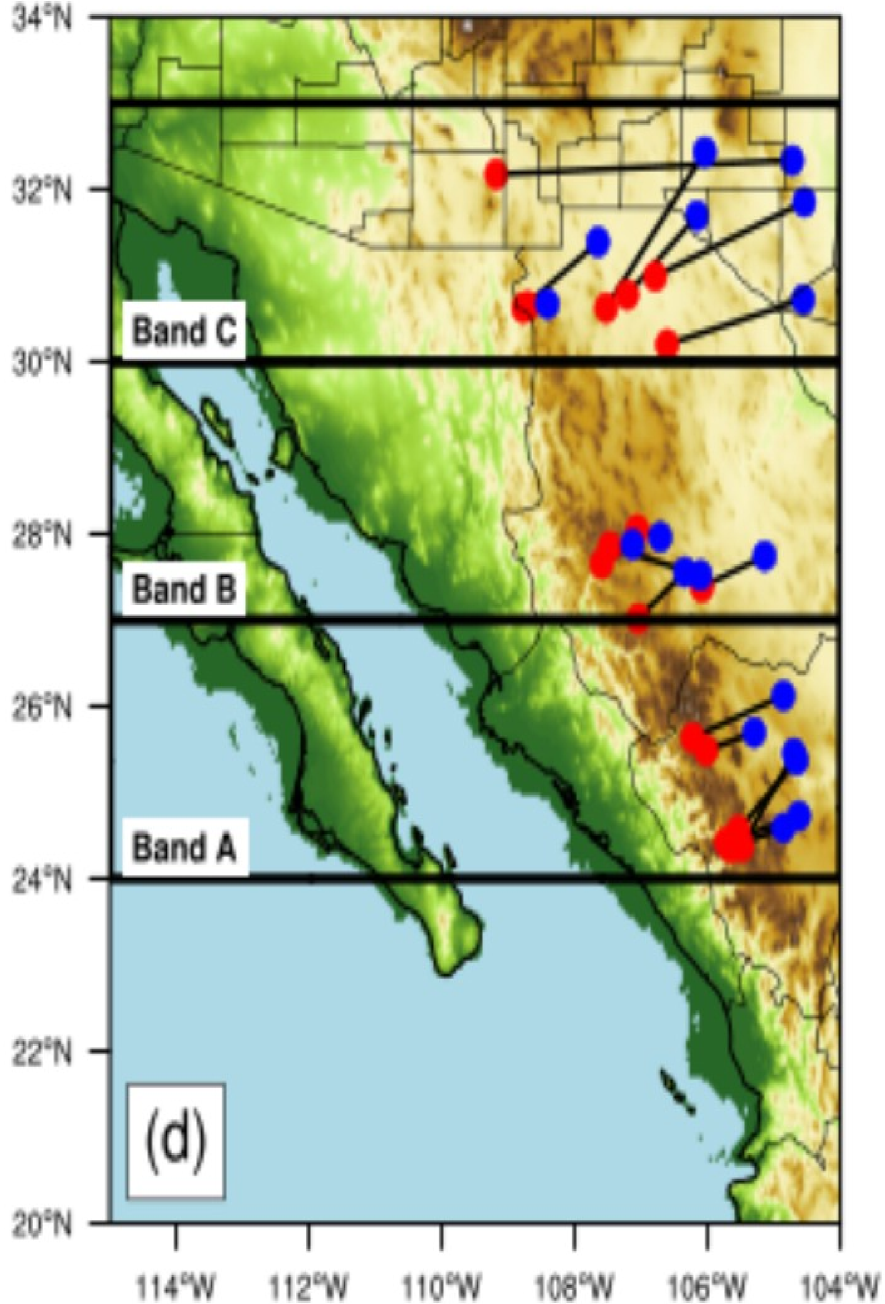
Diurnal Cycle of Initiation of MCS over the SMO and Dissipation over the Gulf of California



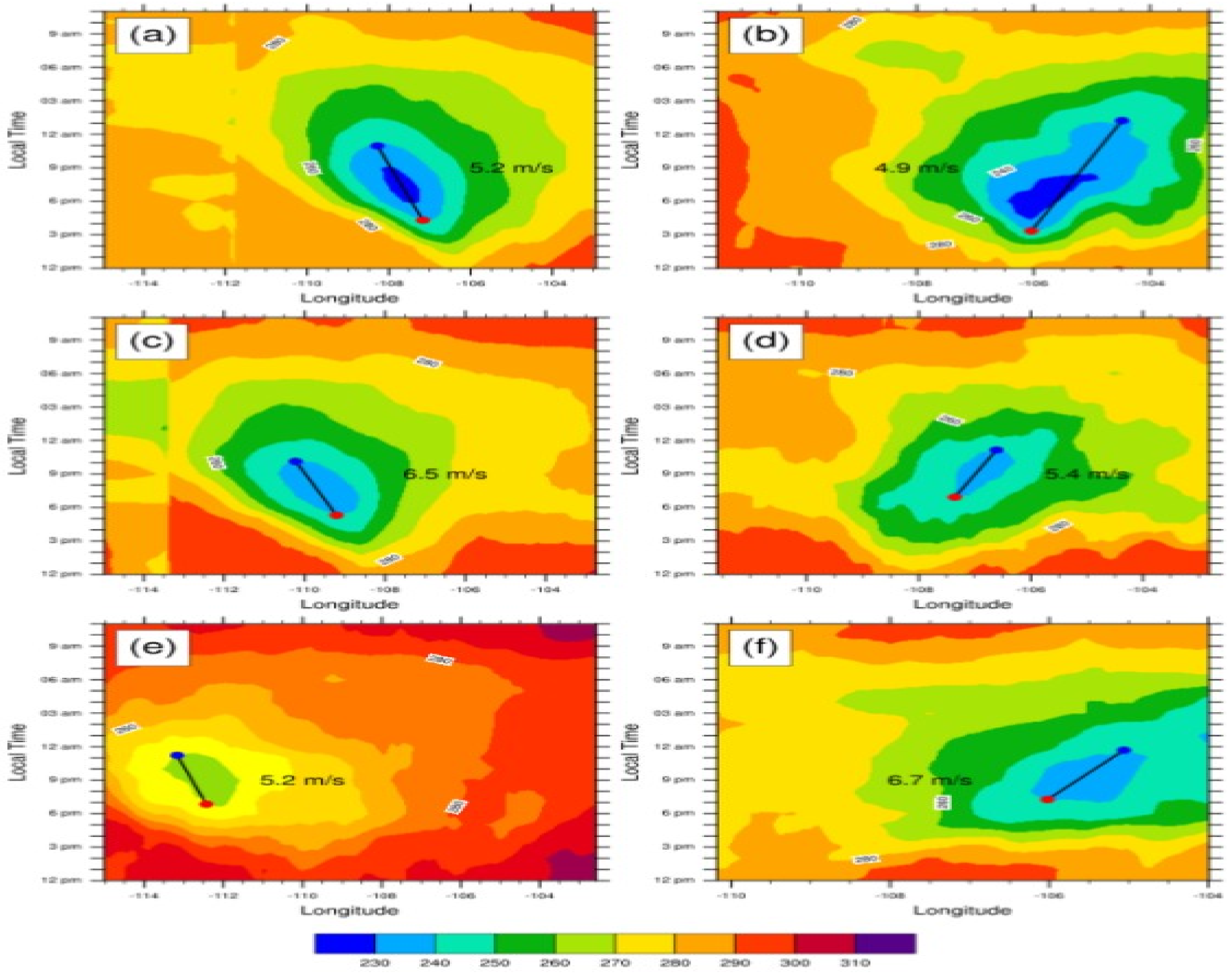


34°N
32°N
30°N
28°N
26°N
24°N
22°N
20°N
114°W
112°W
110°W
108°W
106°W
104°W
Band C
Band B
Band A
(a)


34°N
32°N
30°N
28°N
26°N
24°N
22°N
20°N
114°W
112°W
110°W
108°W
106°W
104°W
(b)
(c)


34°N
32°N
30°N
28°N
26°N
24°N
22°N
20°N
Band C
Band B
Band A
(d)
114°W
112°W
110°W
108°W
106°W
104°W

Propagation of MCS from Hovmoller Diagrams consistent with cold pool/density currents. Slow for gravity waves, and for advection processes.




Thank you
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