The influence of local evapotranspiration on deep convection activity during the North American Monsoon season

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EGU Leonardo, Ourense, España Octubre 25, 2016

This work has been funded by UNAM-PAPIIT IA103916

OUTLINE

1.The North American Monsoon

2.The 2013 GPS Transect Experiment
in Sonora and Sinaloa, Mexico.

3. Experimental design with WRF

4. Preliminary results

5. Future GPS met network for atmosphere-land interactions in Mexico

THE NORTH AMERICAN MONSOON (NAM)

FROM JULY, AUGUST AND SEPTEMBER NORTHWESTERN MEXICO AND THE SOUTHWESTERN UNITED STATES RECEIVE MORE THAN 70% OF THEIR TOTAL ANNUAL RAINFALL..

THE ANNUAL CHANGE IN CIRCULATION HAS BEEN TERMED THE NORTH AMERICAN MONSOON (**NAM**)

LARGE-SCALE CIRCULATION CHANGES DURING **NAM** CAN PRODUCE LARGE CHANGES IN PRECIPITATION FREQUENCY AND INTENSITY

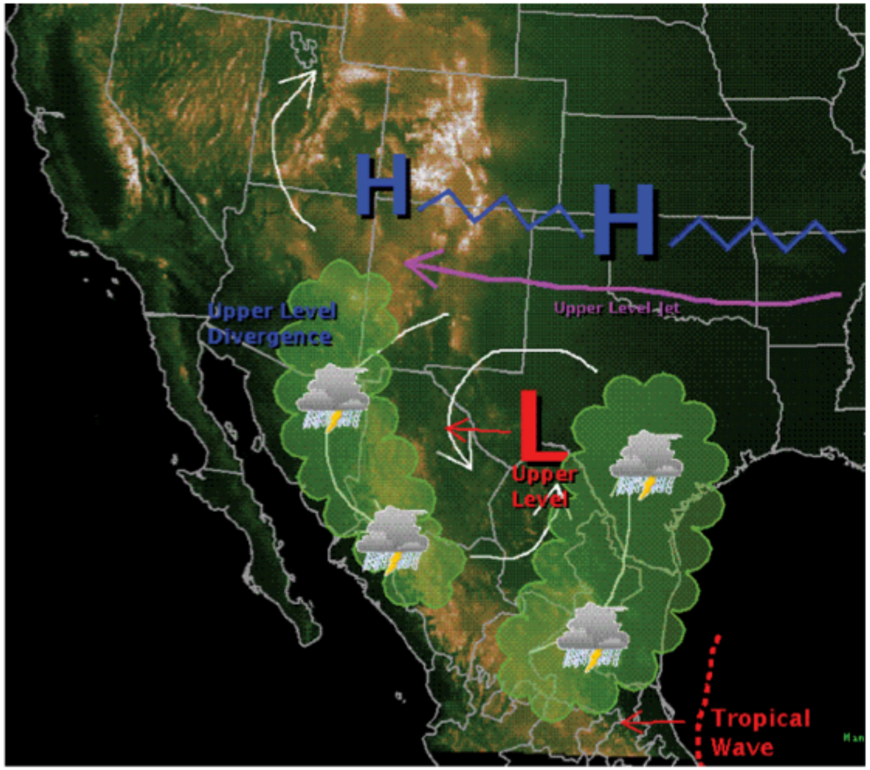
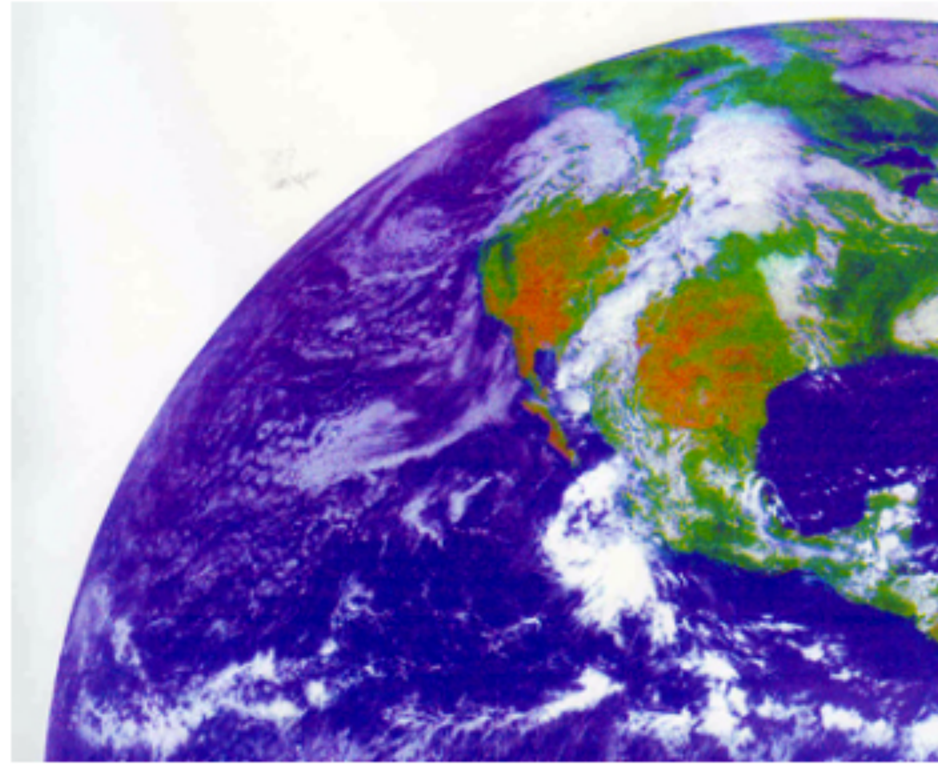


Figure 1: Idealized illustration of an inverted trough and its meteorological effects. This figure is similar to Figure 2 of Pytlak et al. (2005).



Satellite image showing a tropical easterly wave offshore of Mexico and strong surge from Gulf of California toward the southwestern US and further north.

TWO TYPES OF METEOROLOGICAL EVENTS ARE TRIGGERED IN THE NAME REGION BY LARGE-SCALE CONDITIONS AND SST GRADIENTS IN THE GULF OF CALIFORNIA:

1) INVERTED TROUGHS (IV s) AND 2) GULF COLD SURGES

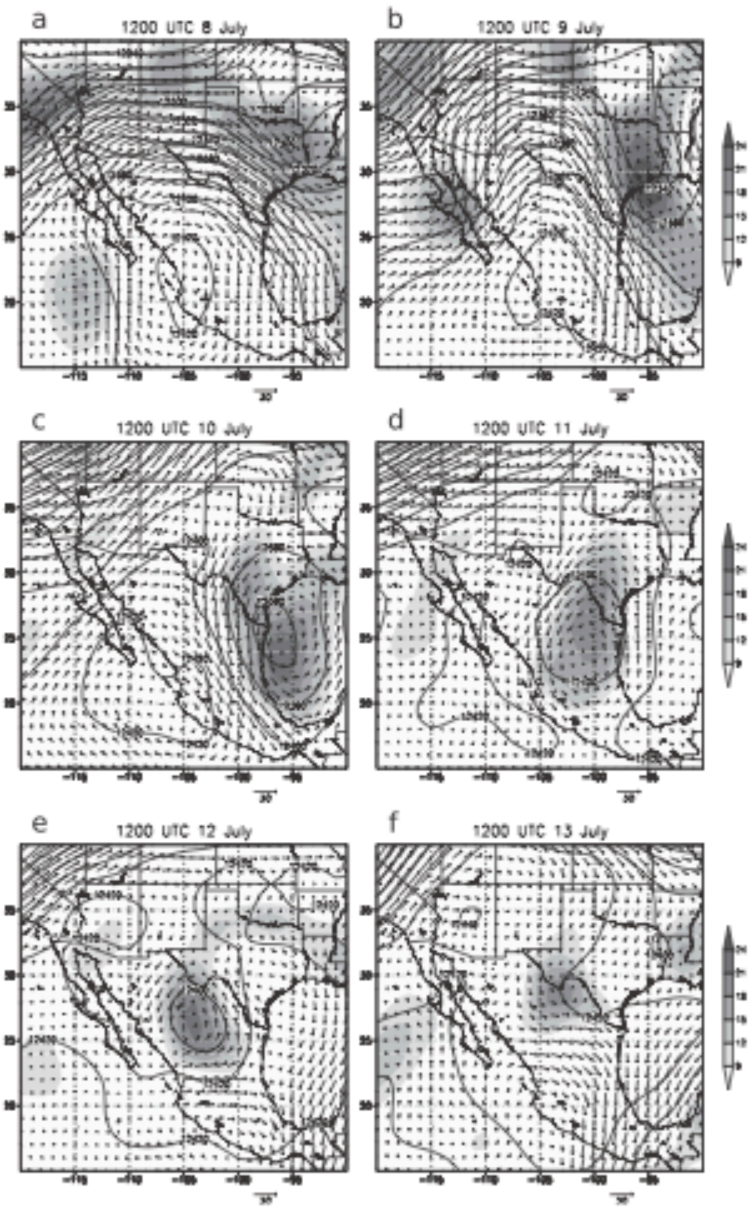


FIG. 2. 200-hPa heights (m, solid contours), wind (m s^{-1}, vectors), and absolute vorticity (10^{-5} s^{-1}, shaded contours) at 1200 UTC 8–13 Jul 2004.

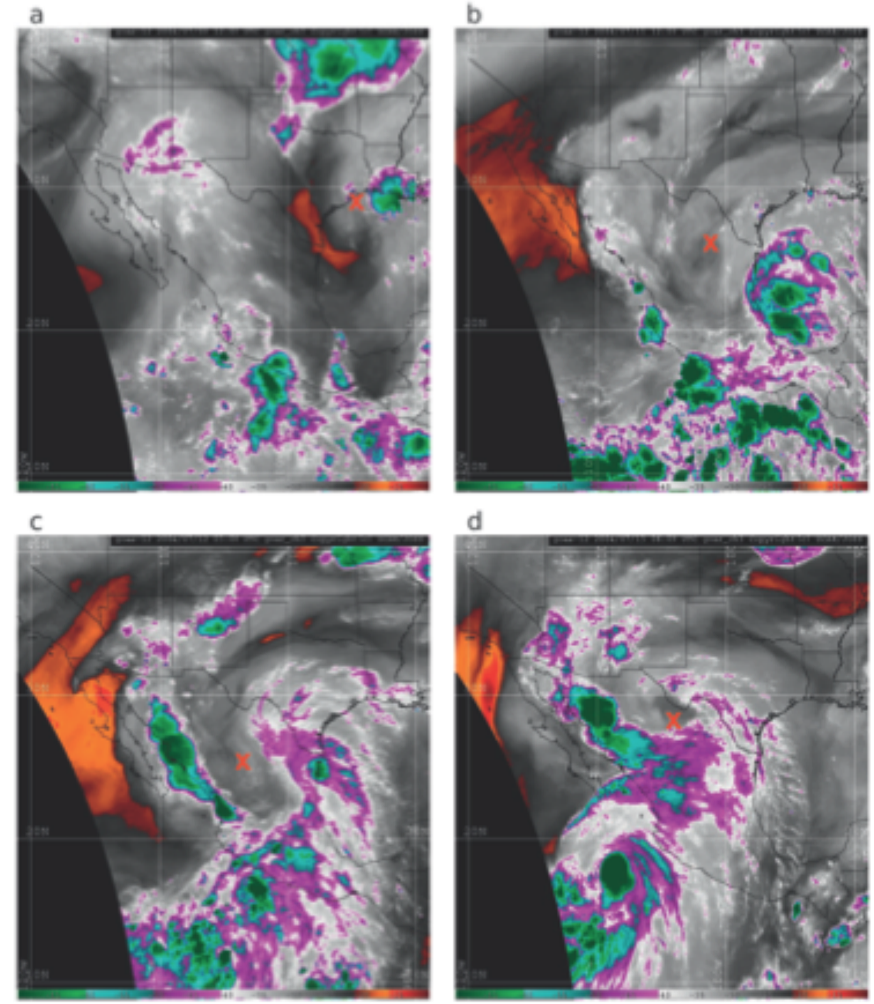


FIG. 3. *GOES-12* water vapor satellite imagery at (a) 1209 UTC 9 Jul, (b) 1209 UTC 11 Jul, (c) 0308 UTC 12 Jul, and (d) 0609 UTC 13 Jul 2004. The 200-hPa low center is denoted by "X."

INVERTED TROUGHS AND THEIR INFLUENCE ON MCS ORGANIZATION FINCH et al 2010

BASIC RESEARCH QUESTIONS IN THE NAM REGION

Let ***EVENT*** be (GULF SURGE, INVERTED TROUGH)

How does ***EVENT*** affect the distribution and timing of precipitation over the NAM region?

Where does ***EVENT*** moisture originate?
What moisture and thermodynamic characteristics differentiate the spatio-temporal evolution of high-precipitation ***EVENT*** and low-precipitation ***EVENT***?

Questions slightly modified from Schiffer and Nesbitt (2011

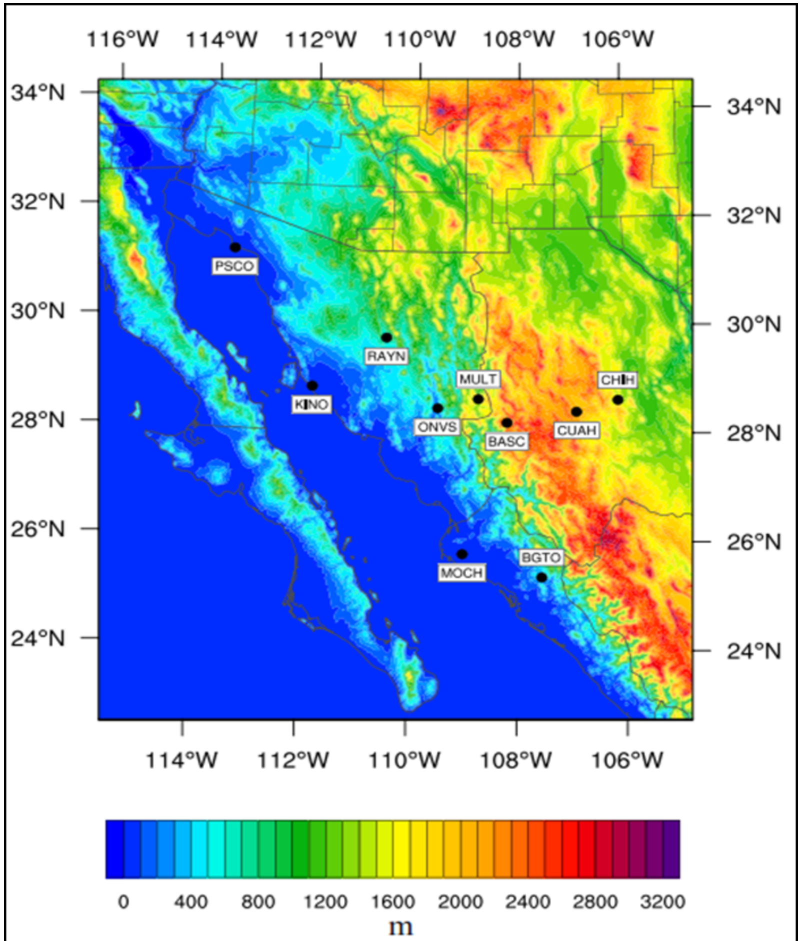
MORE BASIC RESEARCH QUESTIONS ARISED FROM NAME FIELD EXPERIMENT 2004

What is the relative importance of local surface forcing versus larger-scale dynamics for determining monsoon convection?

What is the relative importance of local water vapor sources versus larger-scale moisture transport?

Which processes are most critical in regional and weather forecast models for correctly representing monsoon rainfall?

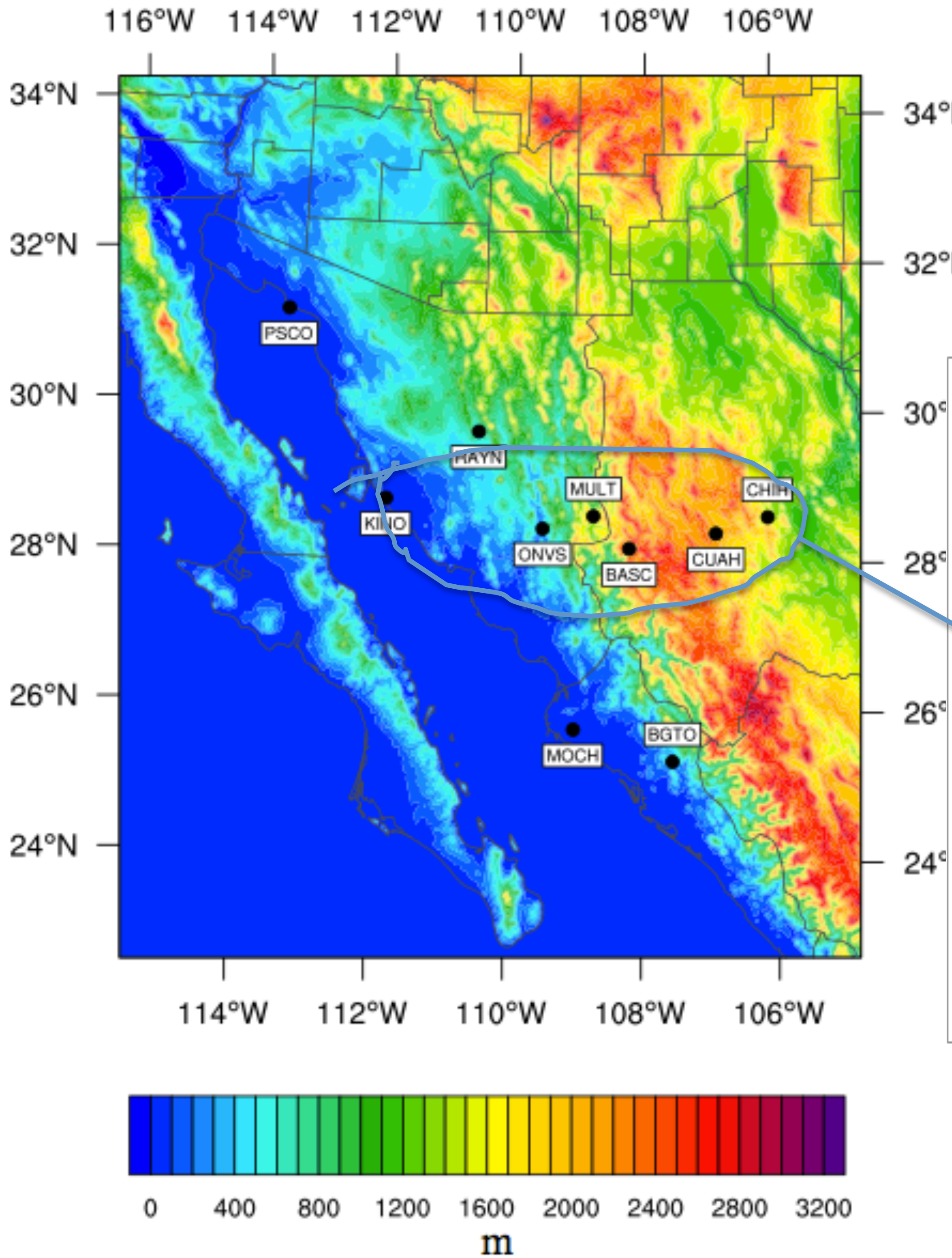
North American Monsoon GPS Transect Experiment 2013

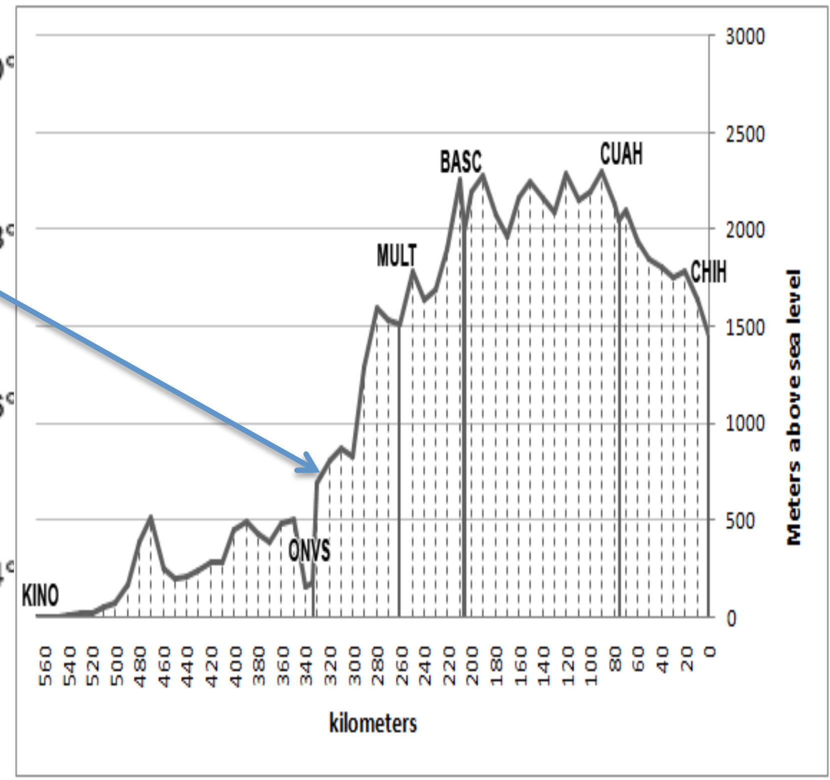


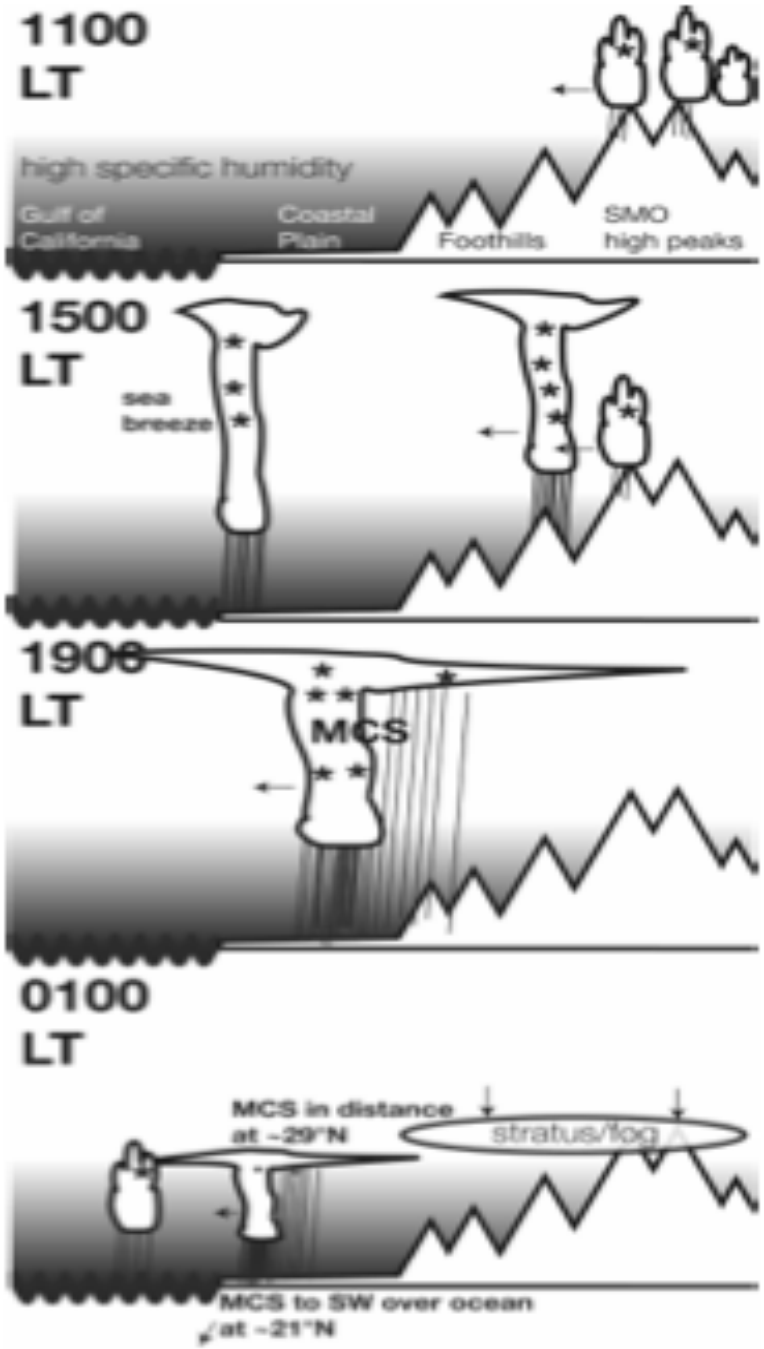
- Ten GPS-Met stations
- Three transects: Coastal, east-west (2)
- PWV each 5 min
- April to September 2013
- Look at the precipitation gradient over mountains

BAMS: Serra et al, 2016 (in press)

Transect Across SMO



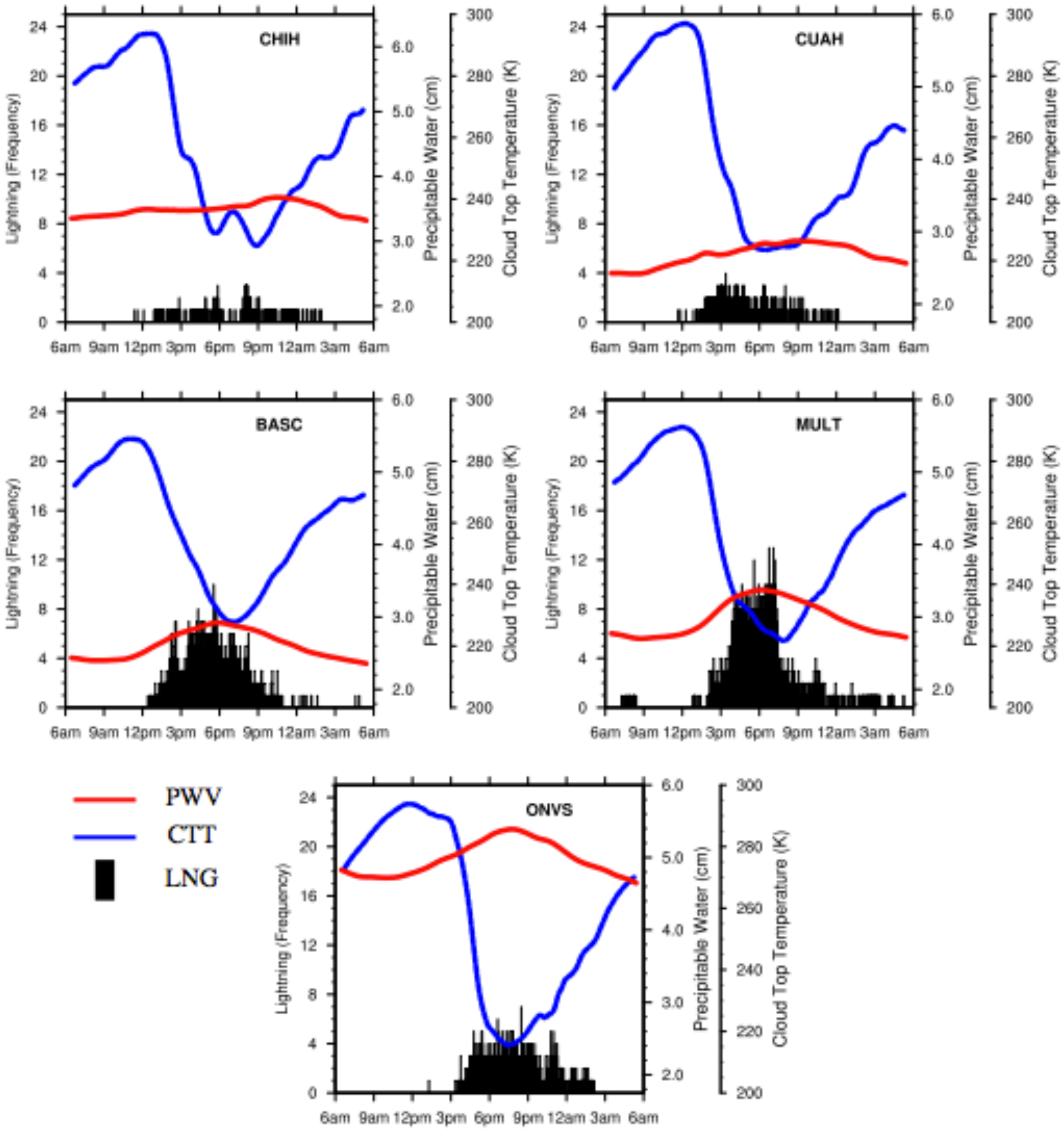




"Schematic of observed diurnal mechanisms along the SMO at 25°N. Cloud type indicates relative height attained by clouds, shading indicates specific (not relative) humidity contrasts, asterisks (*) indicate mixed-phase microphysical processes, and the density of the vertical streaks indicates the locations and relative intensities of the precipitation"

Nesbitt et al (2008)

FEATURES DEFINING CONVECTIVE DAYS FROM THE 2013 NAM GPS EXPERIMENT



NOTE: PRECIPITATION DATA UNRELIABLE THUS LIGHTINING DATA USED AS PROXY FOR PRECIPITATION AND DEEP CONVECTION DETECTION (Serra et al 2016)

Figure 2 – Composite diurnal cycles in PWV, CTT and lightning (LNG) for east west transect sites in order from east of SMO (CHIH) to the western slope (ONVS).

BUT WHAT ABOUT SEASONAL VARIABILITY IN PRECIPITATION INDUCED BY VEGETATION AND SOIL MOISTURE?.

HOW CAN WE SEPARATE LARGE-SCALE EFFECTS ON DEEP CONVECTION ORGANIZATION FROM SURFACE EVAPORATION AND EVAPOTRANSPIRATION?

LET US USE A REGIONAL MODEL WHERE WE TURN OFF EVAPORATION ALL TOGETHER AS A FIRST STEP AND SEE WHAT HAPPENS

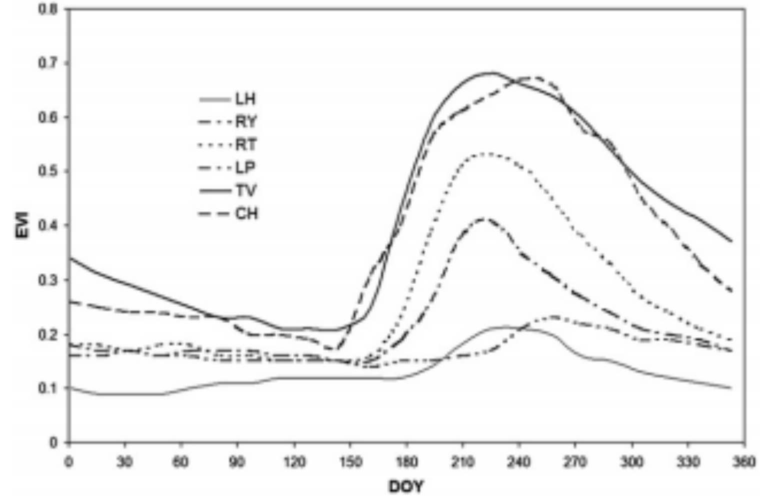
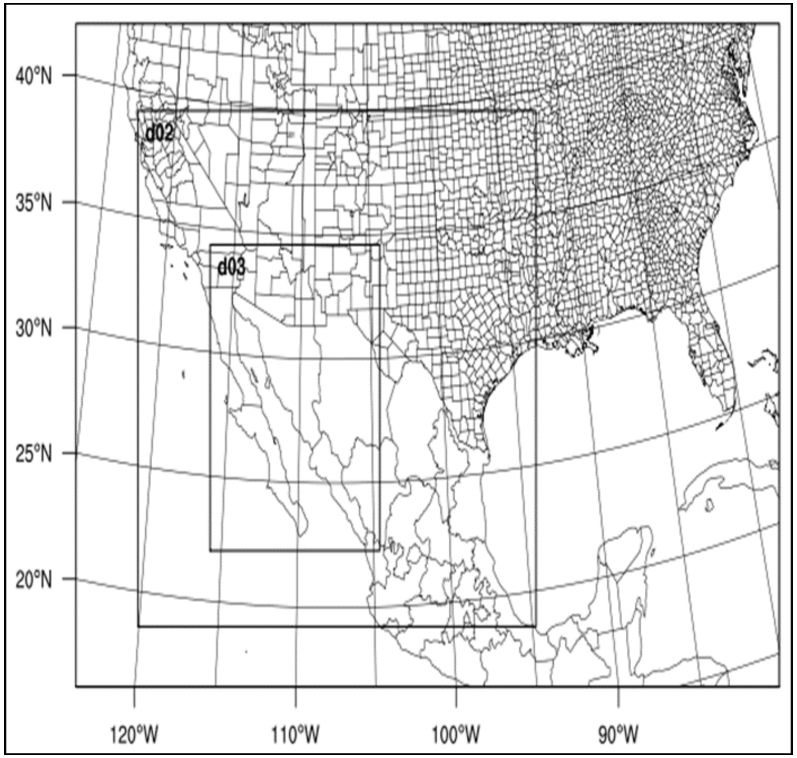


Fig. 2. The average seasonal variability of EVI versus DOY (day of year).

GREEN-UP TAKES PLACE IN A COUPLE OF WEEKS FROM MIDDLE TO LATE JUNE.
GREEN-UP NOT LIMITED TO AZ and SONORA. A LARGE FRACTION OF VEGETATION IN THE SOUTH WESTERN COAST OF MEXICO EXPERIENCES IT, ALBEIT AT DIFFERENT TIMES

Experiment Design with WRF



- Yonsei University PBL scheme
- Kain-Fritsch Cumulus (d01, d02)
- WSM6 Microphysics scheme
- Noah Land Surface model

- Weather Research & Forecasting (WRF) version 3.8.1
- 30 km, 10 km and 2.5 km spatial resolution
- 50 vertical levels
- IC & BC from ERA Interim
- 2012 MODIS Land Cover
- July 1st to September 13th 2013
- Spectral Nudging (from
- Level 39 to 49)
- 48 h spin-up time
- SSTs updated daily

(http://polar.ncep.noaa.gov/sst/rtg_high_res/)

METHODOLOGY IN WRF

$$E = E_t + E_{dir} + E_c$$ c

$$E_t = \sigma_f E_p B_c \left[1 - \left(\frac{W_c}{S}\right)^n\right],$$

$$E_{\mathrm{dir}} = (1 - \sigma_f)\beta E_p \quad \text{and} \quad \beta = \frac{\Theta_1 - \Theta_w}{\Theta_{\mathrm{ref}} - \Theta_w},$$

$$E_c = \sigma_f E_p \left(\frac{W_c}{S}\right)^n$$

***E* . TOTAL EVAPORATION**

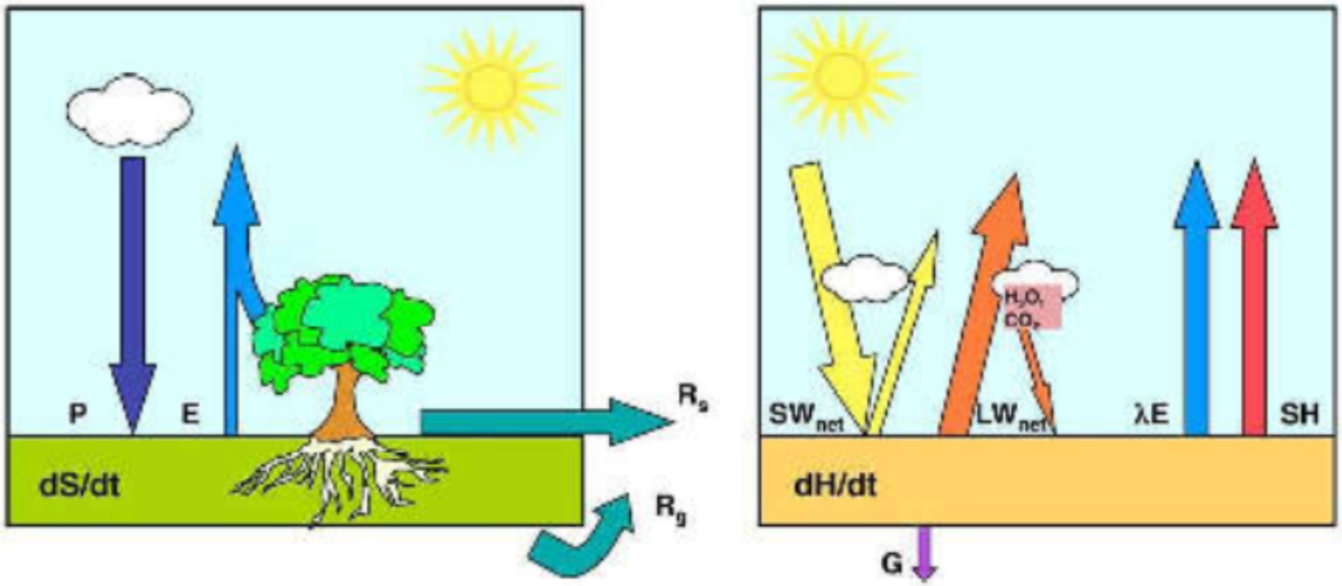
***E_c* : TRANSPIRATION VIA CANOPY AND ROOTS.**

***E_t* : EVAPORATION OF PRECIPITATION INTERCEPTED BY THE CANOPY**

***E_{dir}* : EVAPORATION FROM THE TOP SOIL LAYER**

BRUTE FORCE: SET E_p *= 0.0* IN ABOVE CODE ROUTINES OF NOAH LSM. EVAPORATION FROM OCEAN IS LEFT INTACT

Balance de agua y energía en una capa de suelo



$$\frac{d\Theta}{dt} = P - E - R_s - R_g$$ Razón de cambio de humedad de suelo (mm s^{-1})

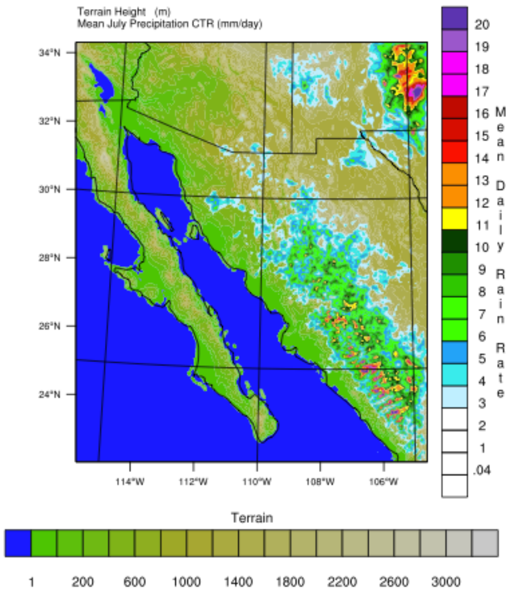
$$\frac{dH}{dt} = R_n - \lambda E - SH - G$$ Razón de cambio de energía (W m^{-2})

Humedad del suelo y evapotranspiración están acoplados a través del Las ecuaciones de balance de agua y energía ➔ la humedad del suelo **(Θ) . PERO EN EL EXPERIMENTO CON E_p = 0 LAS ECS. DE ENERGÍA Y LA HUMEDAD ESTÁN DESACOPLADAS.**

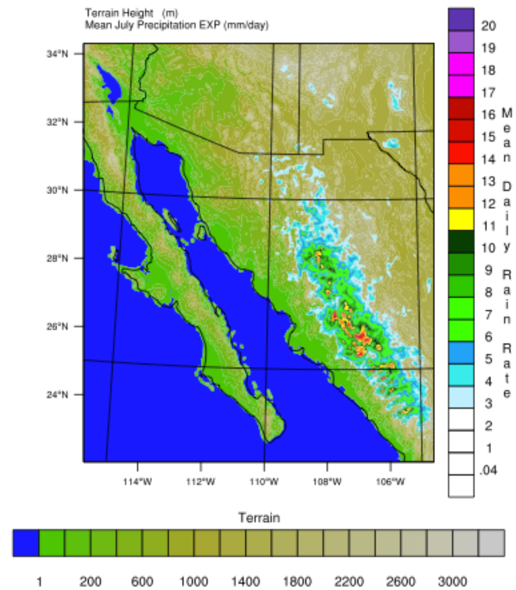
METHODOLOGY FOLLOWING ADAMS ET AL 2010 (cntd)

SEPARATE EVENTS INTO CONVECTIVE DAYS
AND NON CONVECTIVE,
REGARDLESS OF
LARGE-SCALE CONDITIONS
(NESBITT ET AL 2008 RECOMMENDATION)

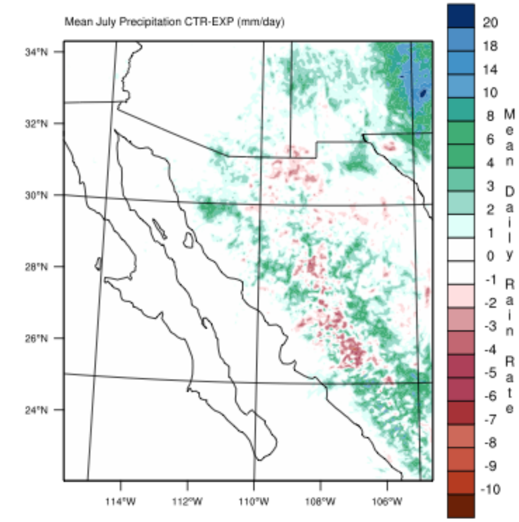
USING THE FOLLOWING RULE:
THE CLOUD TOP TEMPERATURE (CTT) DROPS BY 50 K IN TWO HOURS .AND. PRECIPITATION IS LARGER THAN 2 mm IN A 24 HOUR PERIOD.



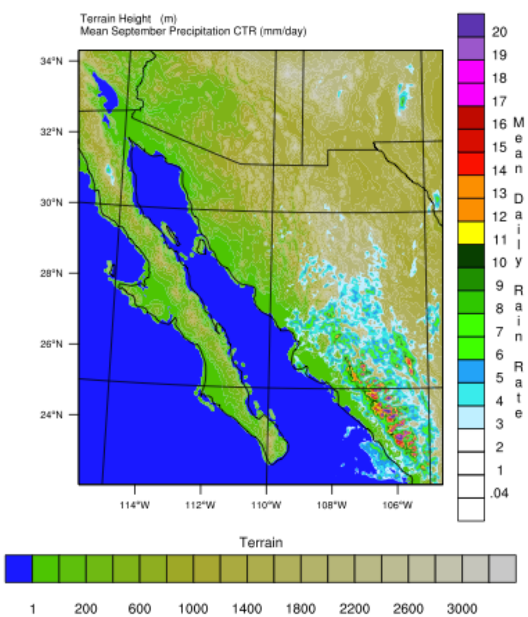
JULY: CTRL



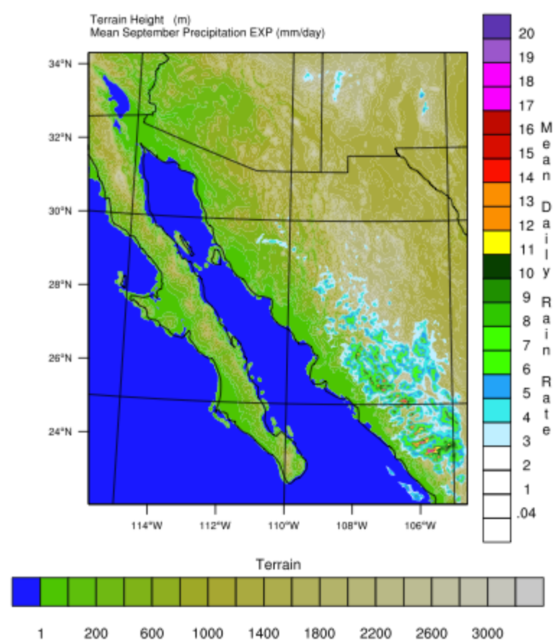
JULY: EXP



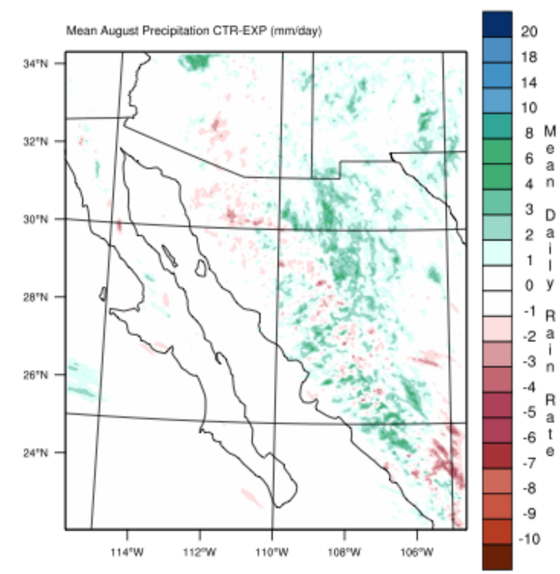
JULY: CTRL-EXP DIFF



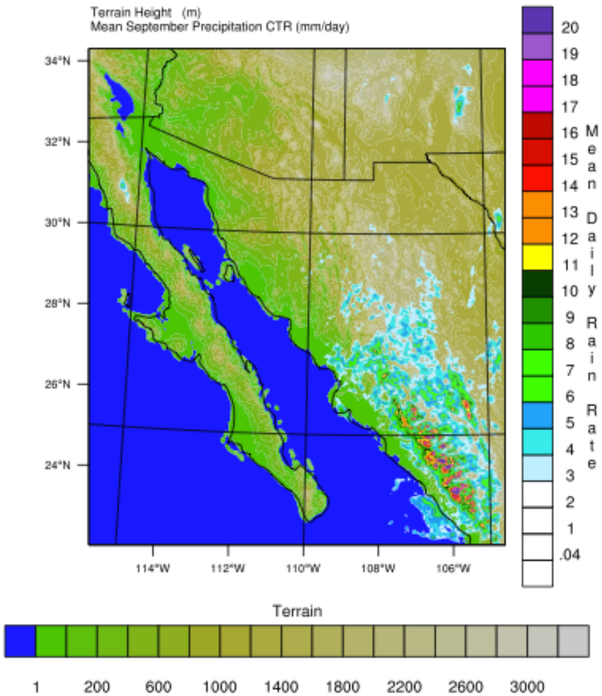
AUGUST: CTRL



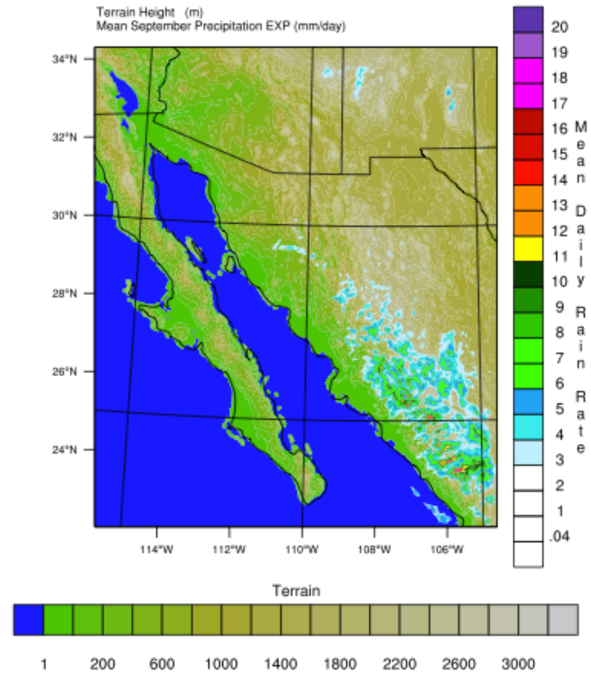
AUGUST: EXP



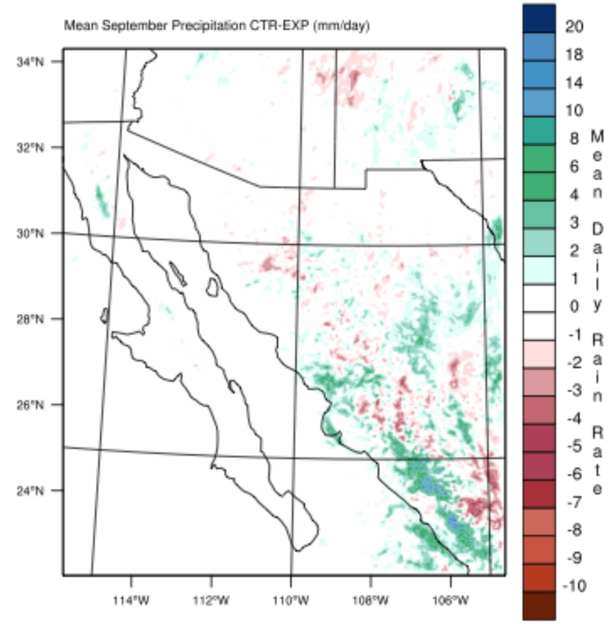
AUGUST: CTRL-EXP DIFF



SEPTEMBER: CTRL

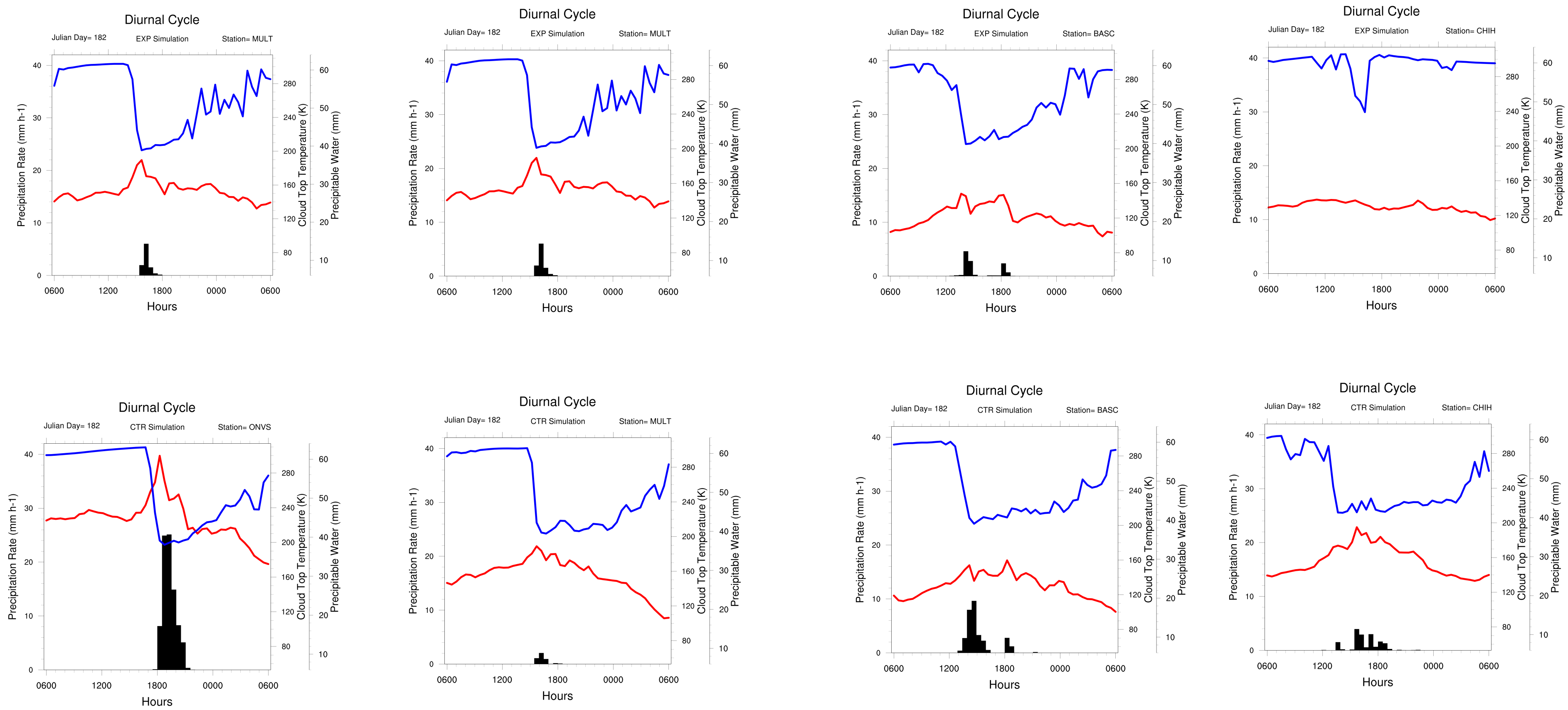


SEPTEMBER:EXP



SEPTEMBER:CTRL-EXP DIFF

TURNING OFF TOTAL EVAPORATION FROM THE SURFACE IMPACTS PRECIPITATION IN THE NAM REGION. PRECIPITATION DECREASES IN AREA AVERAGE SENSE IN THE **EXP** SIMULATION WHEN COMPARED WITH THE **CTRL** SIMULATION.



WEST >--→ EAST

GOC **SMO**

TURNING OFF EVAPORATION DECREASES PRECIPITATION AND DEEP CONVECTION DOES NOT DEVELOPS AS IN THE NESBITT ET AL (2008) SCHEMATIC EVOLUTION WITH DEEP CONVECTION EVOLVING TOWARDS THE COAST OF THE GOC

PRELIMINARY CONCLUSIONS:

1. PRECIPITATON RATES ARE DECREASED WHEN EVAPORATION IS TURNED OFF

2. THE EAST-WEST PROPAGATION AND DEVELOPMENT OF DEEP CONVECTION IS SEVERELY LIMITED UNDER AN EVAPORATION LIMITED ENVIRONMENT

THE MEXICAN NAM REGION NEEDS DESPERATELY HIGHER QUALITY METEOROLOGICAL AND HIDROLOGICAL NETWORKS TO CONSTRAINT CONVECTION-PERMITTING REGIONAL MODELS.

MULTIPLE APPLICATIONS FROM HIGHER QUALITY REGIONAL FORECASTS

TO THIS END, THE GROUP OF METEOROLOGY AND HIDROLOGY AT CCA-UNAM (ADAMS, QUINTANAR, OCHOA, ORDOÑEZ) SEEKS TO ESTABLISH A PERMANENT NETWORK FINANCED BY SEVERAL NATIONAL AND INTERNATIONAL ENTITIES (UNAM, UNISON, UA, ASU, CONACYT, NSF, IDR-FRANCE etc..).

NEED TO DEVELOP A MODEL FOR THE REST OF THE COUNTRY

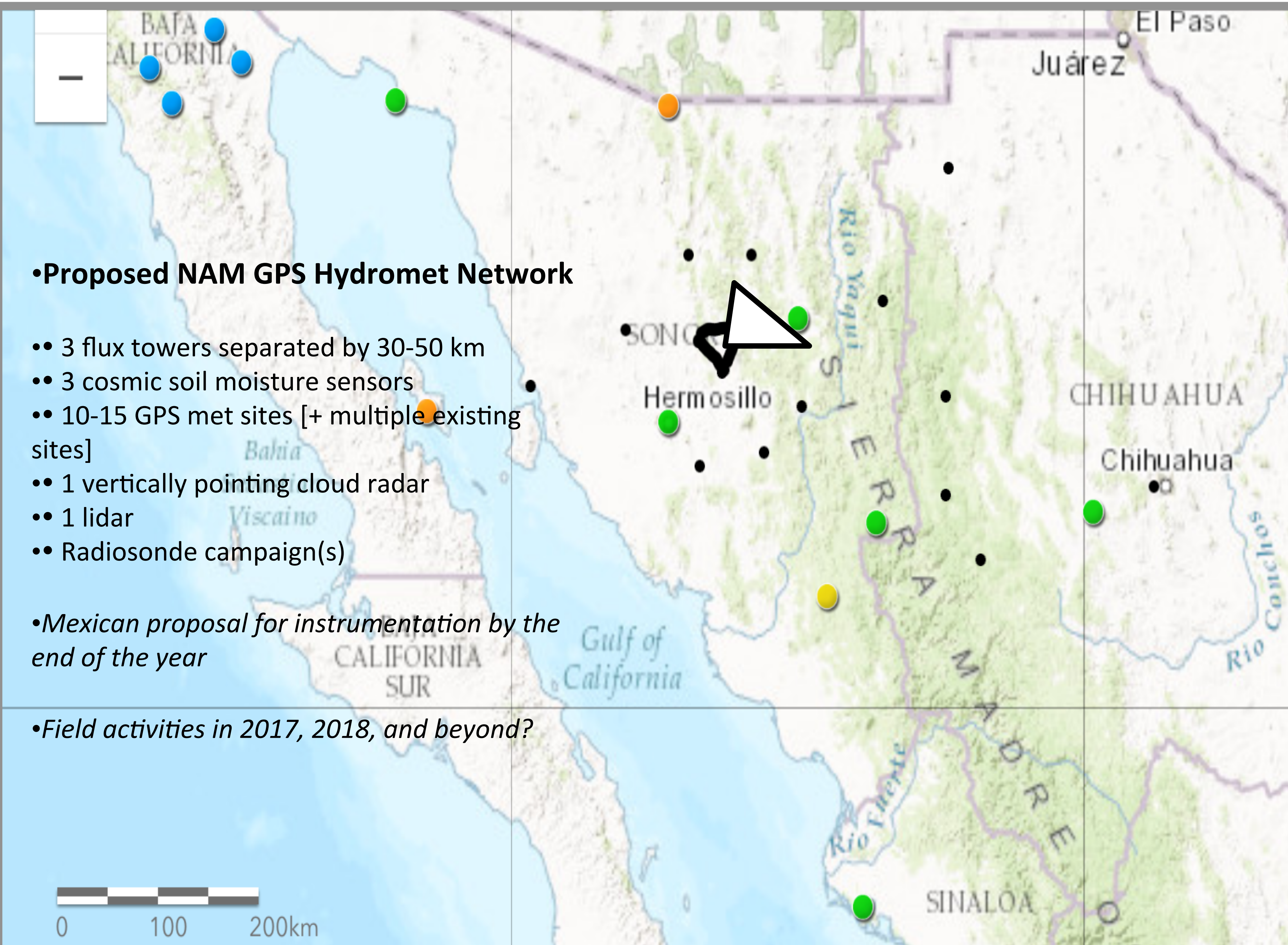
•*UC-MEXUS project --North American Monsoon GPS Hydrometeorological Network in Northwestern Mexico*

•**Proposed NAM GPS Hydromet Network**

•• 3 flux towers separated by 30-50 km
•• 3 cosmic soil moisture sensors
•• 10-15 GPS met sites [+ multiple existing sites]
•• 1 vertically pointing cloud radar
•• 1 lidar
•• Radiosonde campaign(s)

•*Mexican proposal for instrumentation by the end of the year*

•*Field activities in 2017, 2018, and beyond?*



•Possible Science Questions for Future Research

Quantification of Moisture Sources For Monsoon Precipitation (Land-vs-Ocean, Moisture Recycling)

Closing Local Hydrological Cycle (Data for Hydromet Models)

Large-scale Dynamical components of the NAM and their interactions with Atmospheric Convection

MCS Formation and propagation

Provide statistics of cloud fields and water vapor (particularly GPS PWV)

•An International Collaborative Effort

•**Participants**

•**Mexico**

•**UNAM, UNISON, UACJ,CICESE**

•**US**A

•UA,ASU, RUTGERS,UW,

UCSD,UICU,UCD,NCAR

THANK YOU !!!