Air-sea interaction in the Gulf of California and its effect on the North American Monsoon

Ehsan Erfani[1,2] and David L. Mitchell[1]

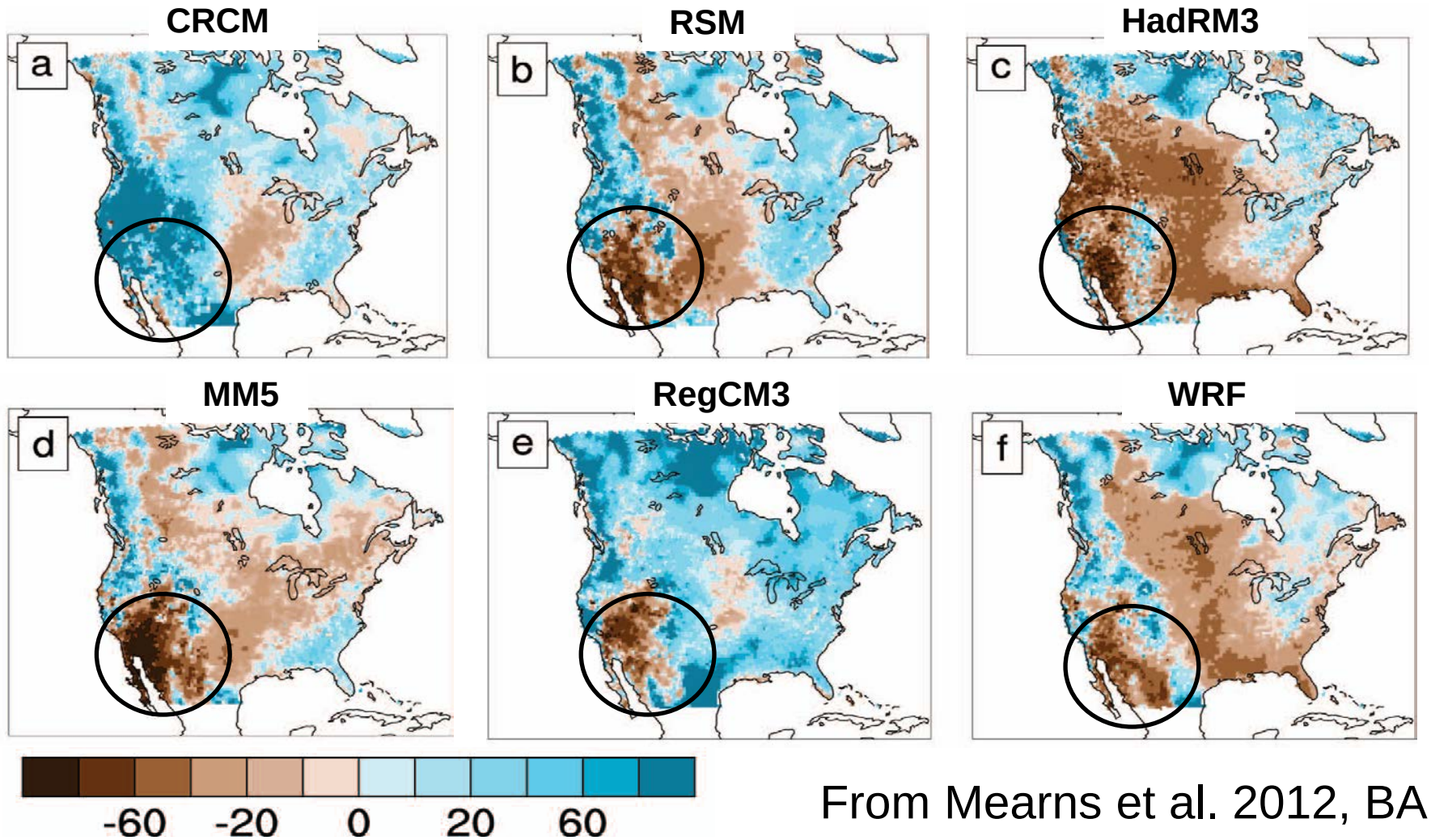
1.Desert Research Institute, Reno, Nevada

2. University of Nevada, Reno, Nevada

Thanks to:
John Mejia[1]

Why Care about NAM?

Summer precipitation bias (% difference; model – observed) for six regional models



From Mearns et al. 2012, BAMS

Poorest results over NAM region

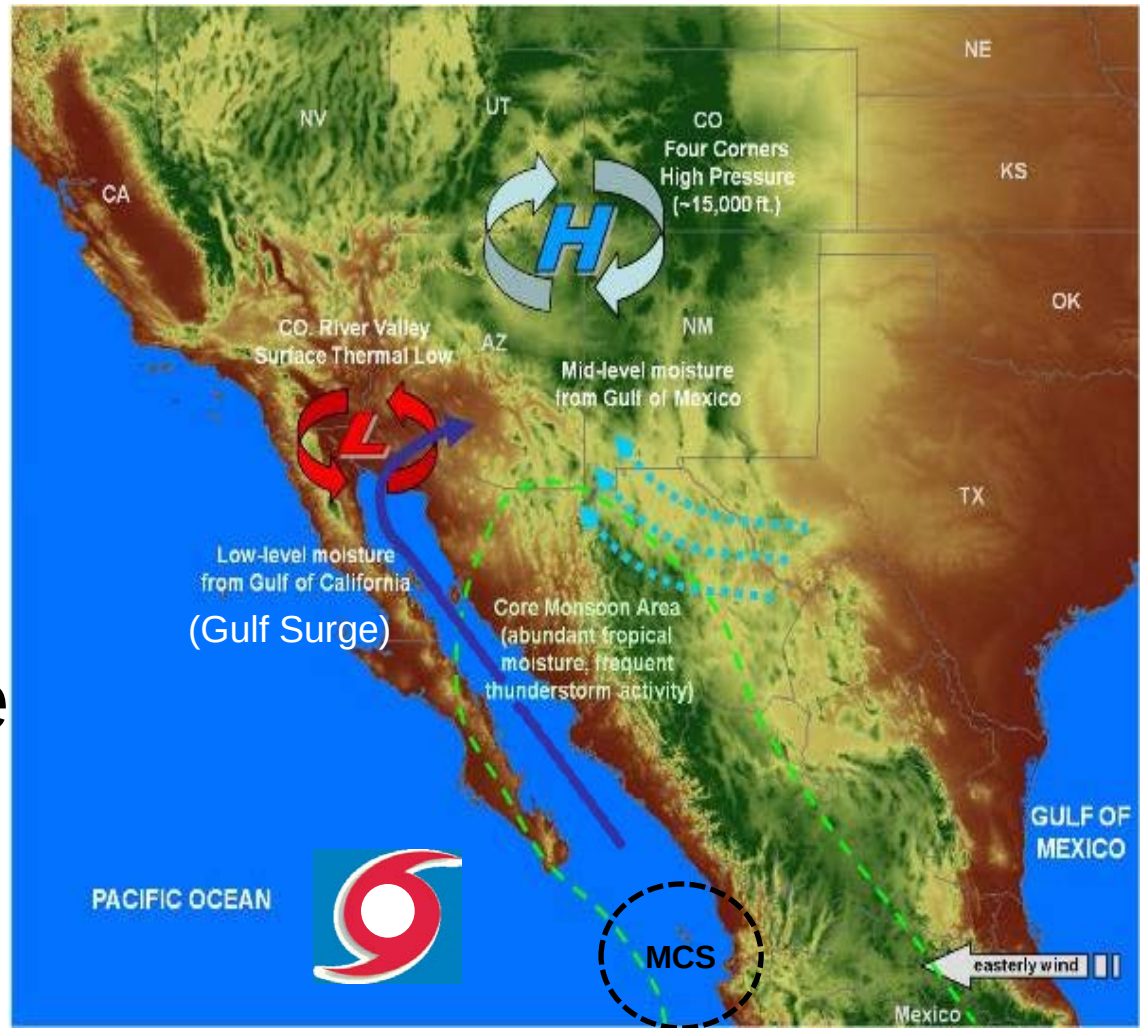
Factors contributing to NAM

Large-scale:

- Tropical Storms (TS)
- Monsoon Anticyclone
- MJO

Mesoscale:

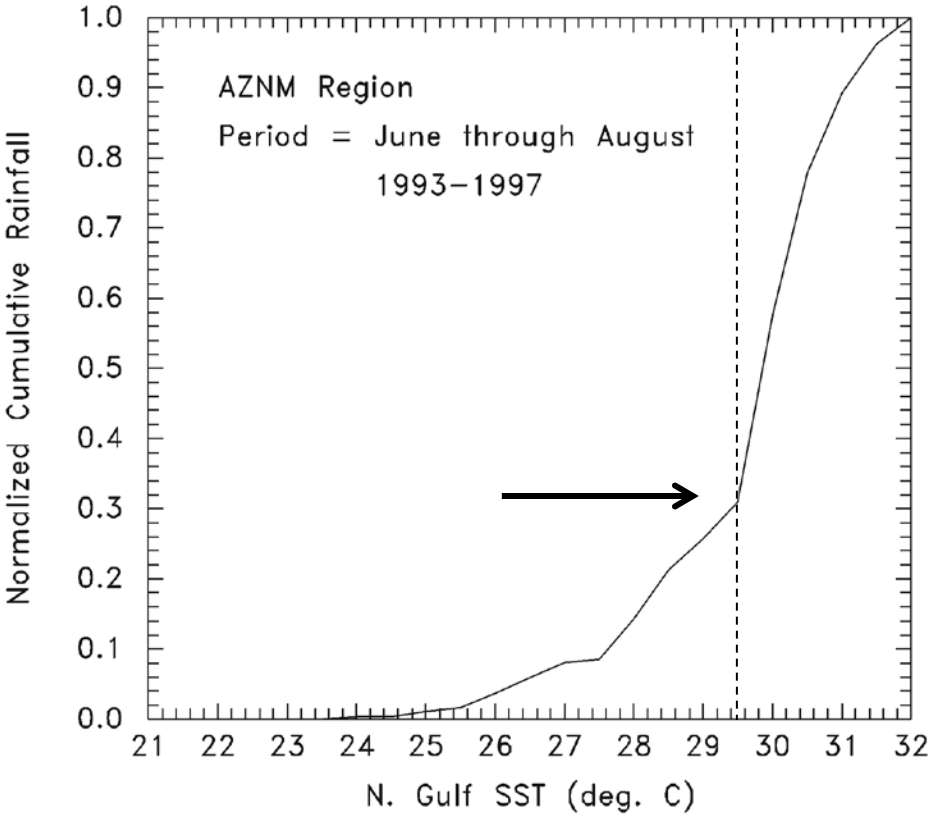
- Gulf Surges
- GC SSTs
- Mesoscale Convective Systems (MCS)



Adapted from UA College of Agriculture and Life Sciences: Climate Science Application Program.

Why should GC SSTs influence AZ rainfall?

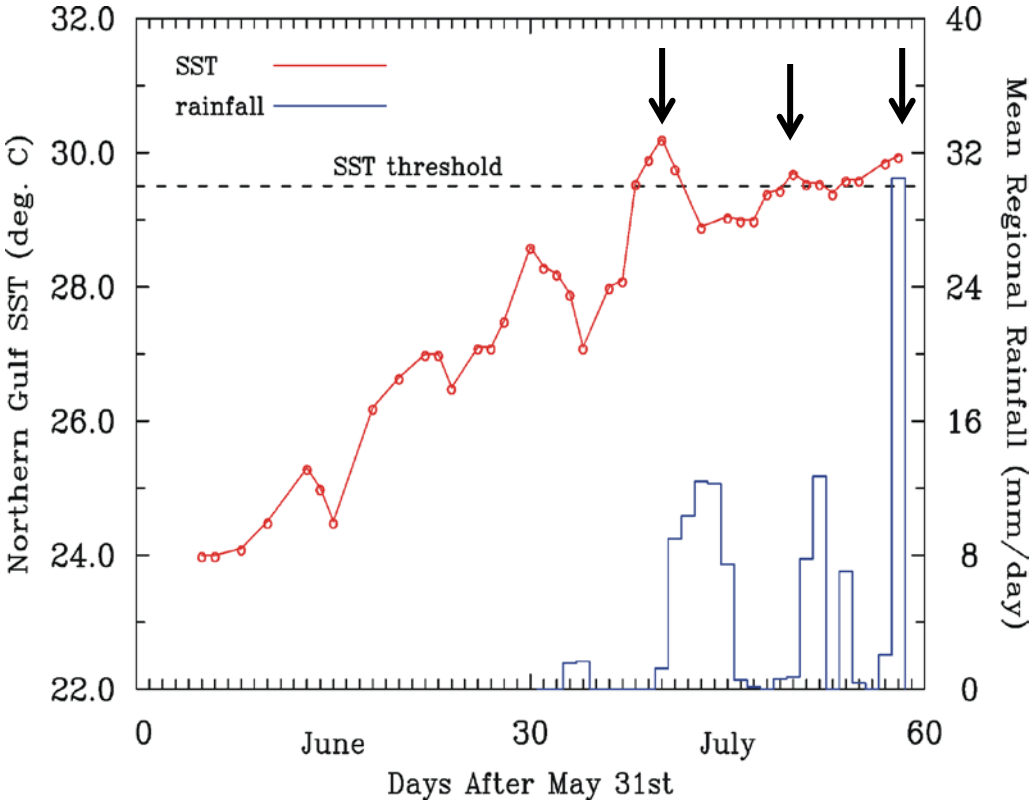
AZNM Monsoon, 1993-97



AZNM region cumulative normalized rainfall. Time is implicit with increasing SSTs. Based on five JJA seasons.

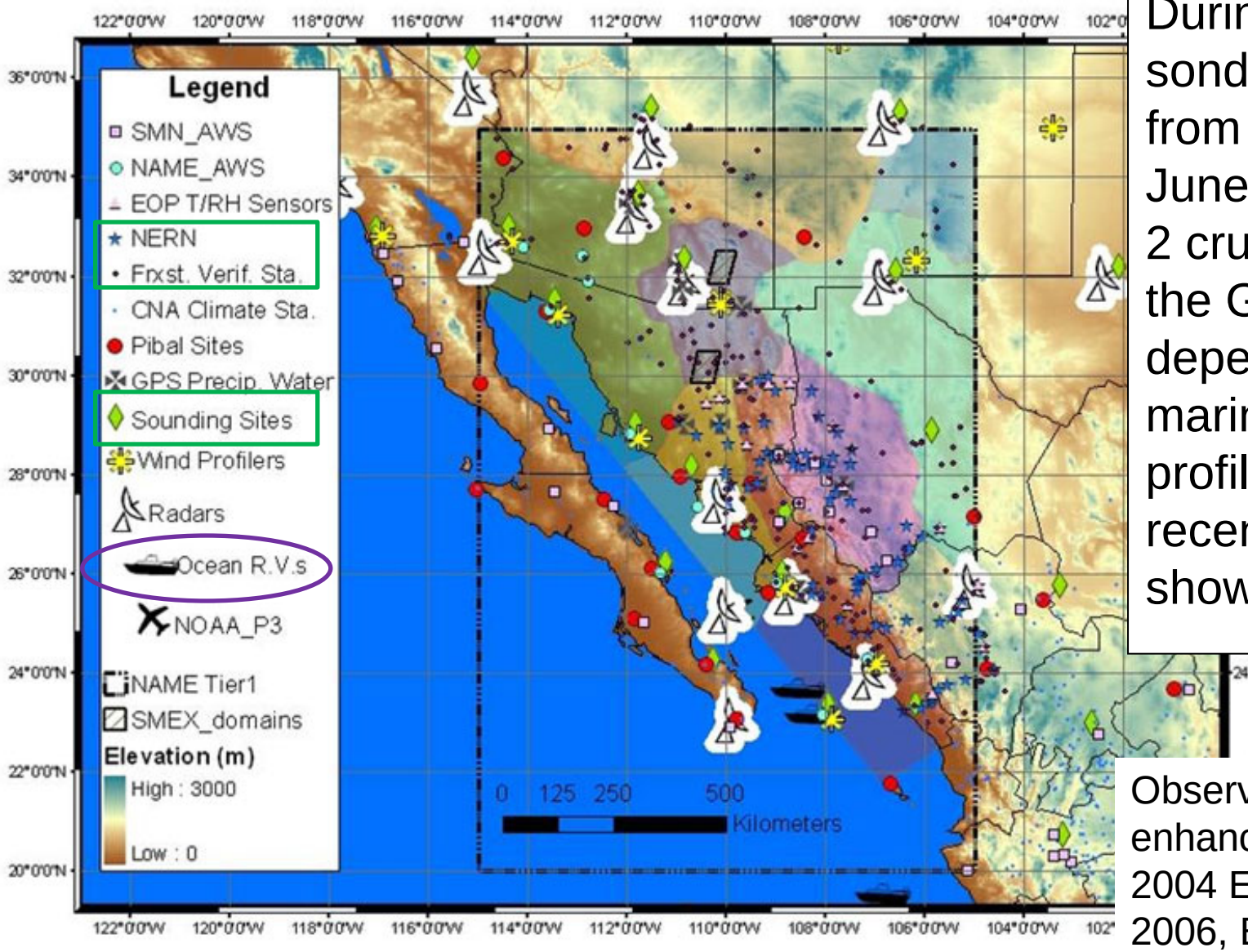
From Mitchell et al. 2002, J.Climate

The 2012 Arizona Monsoon



Relatively heavy rainfall begins after the N. GC SST exceeds 29.5°C.

North American Monsoon Experiment (NAME) 2004



During NAME, balloon sondes were released from a ship during June and August with 2 cruises up and down the GC axis. The dependence of the marine inversion & RH profile on GC SSTs was recently evaluated, as shown next …

Observing system enhancements for the NAME 2004 EOP (From Higgins et al, 2006, BAMS)

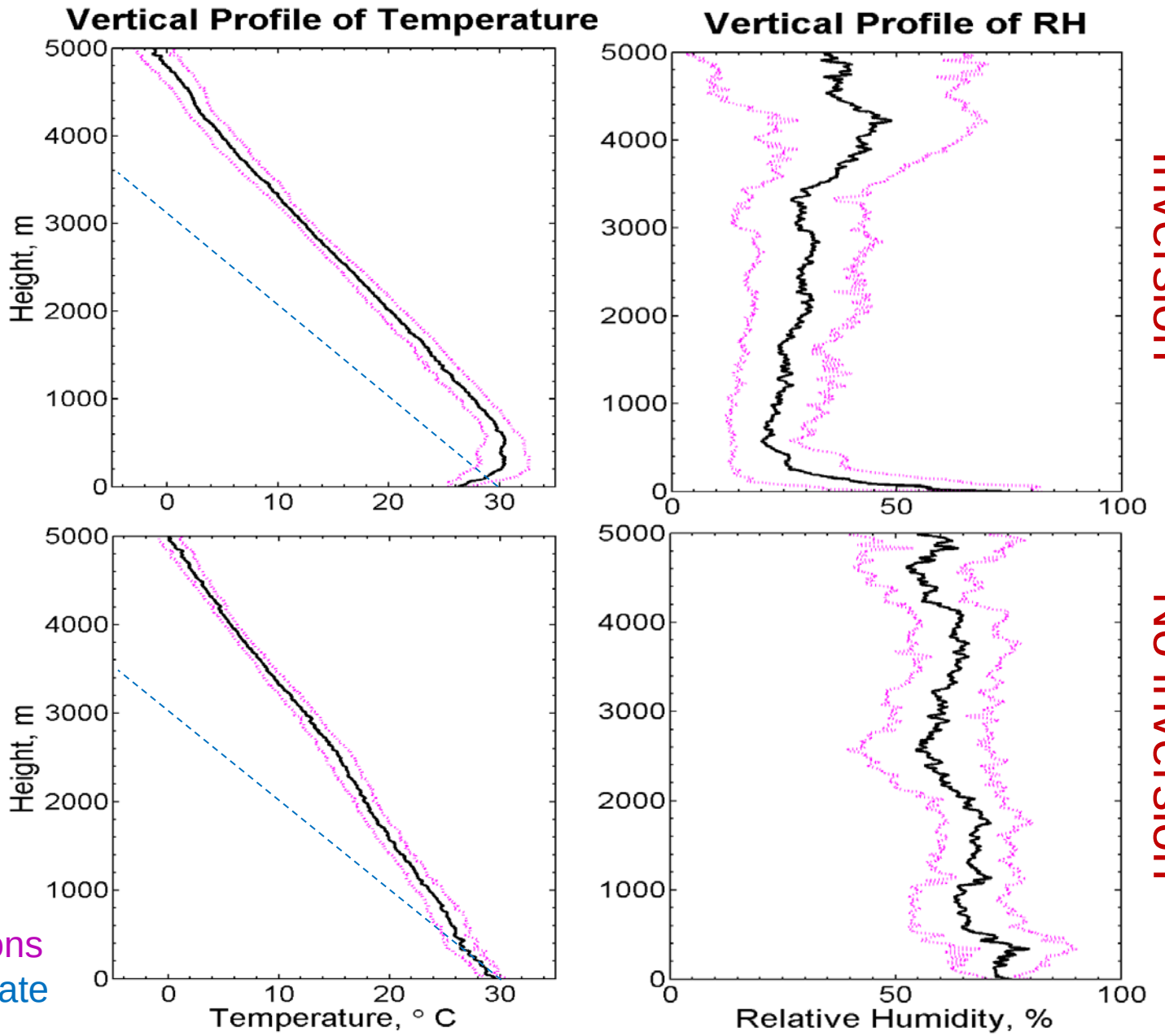
Dependence of MBL Inversion over GC on SSTs

10% of soundings having strongest inversion cap

Mean SST=25.3°C
σ_{SST}=0.9°C

10% of soundings having weakest inversion cap

Mean SST=29.9°C
σ_{SST} =0.9°C



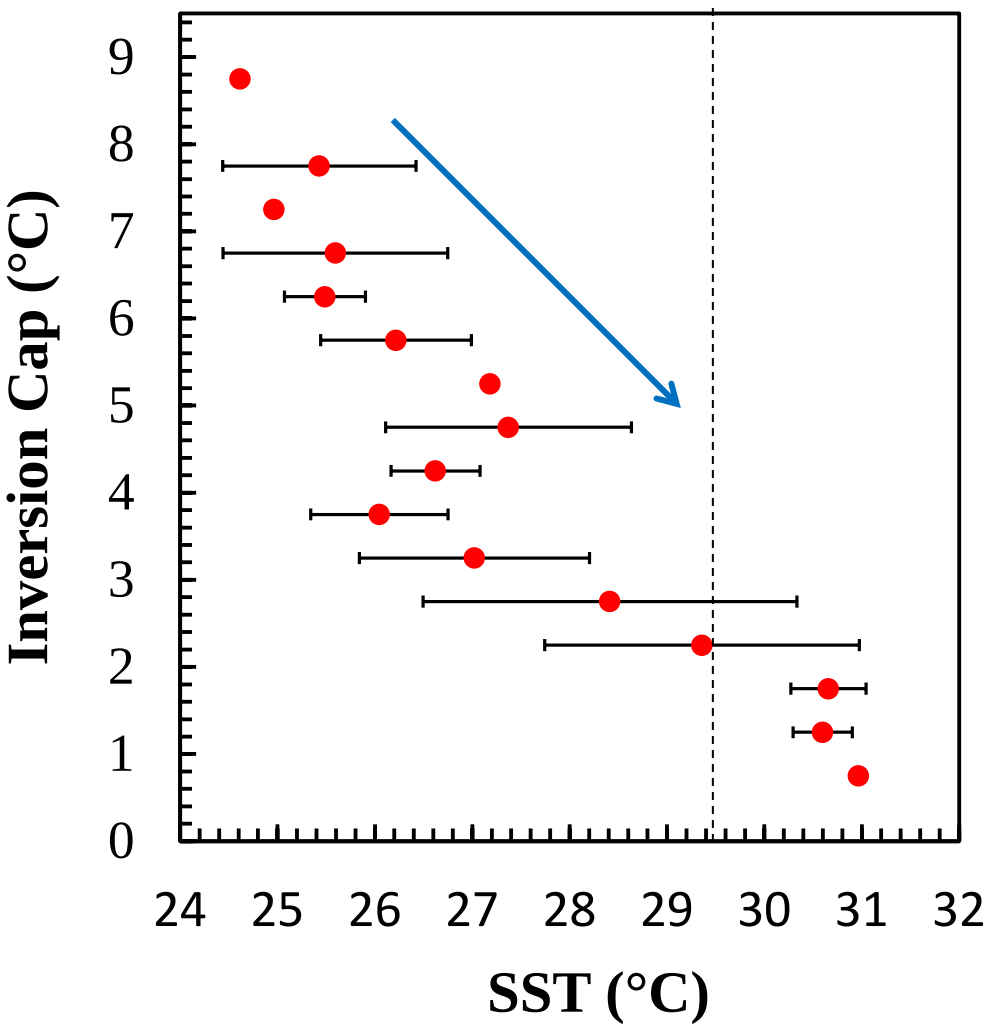
Black line: mean T or RH
Purple lines: standard deviations
blue line: dry adiabatic lapse rate

Blended SST: AVHRR and AMSR satellite data.

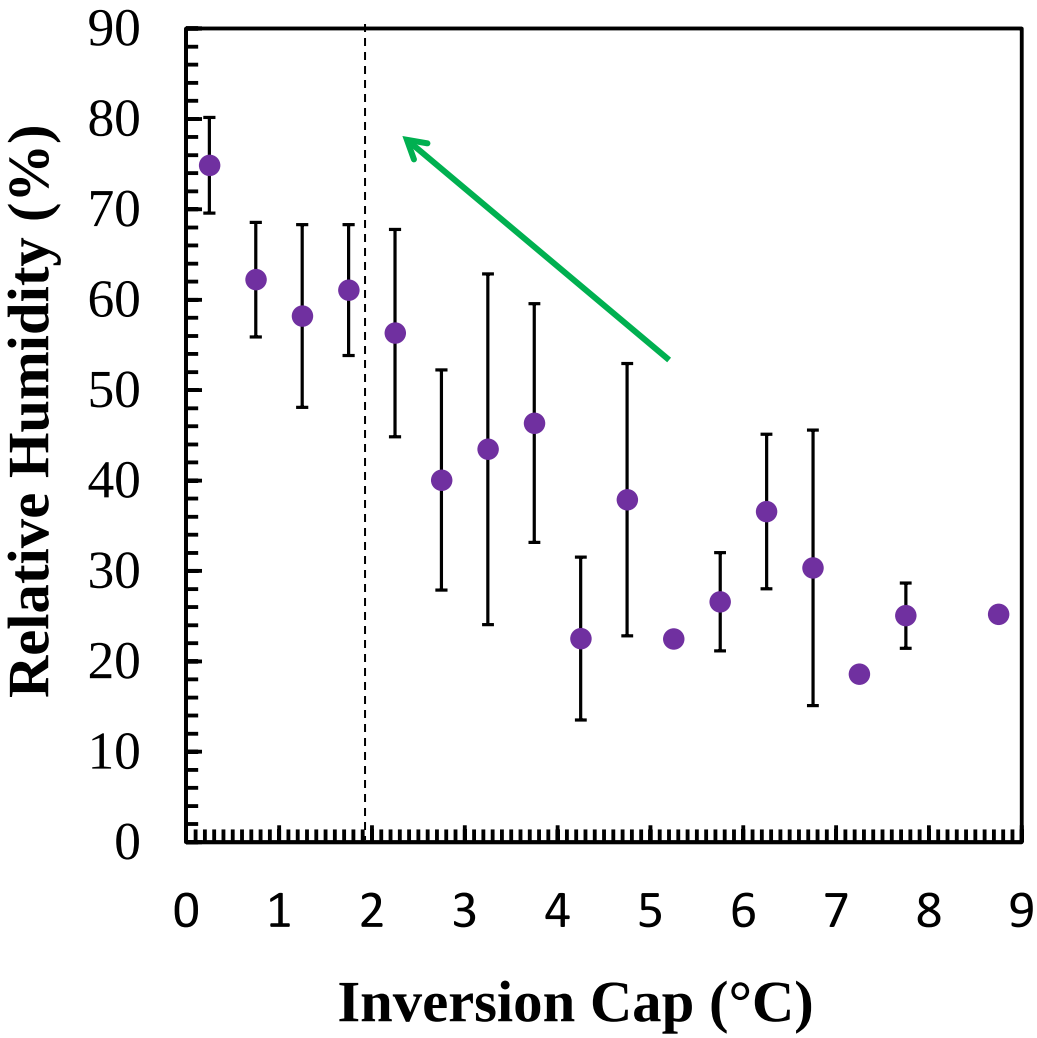
Dependence MBL Inversion over GC on SSTs

June & August 2004

Inversion cap vs. SST



Mean RH of lower 2000 m vs. inversion cap,

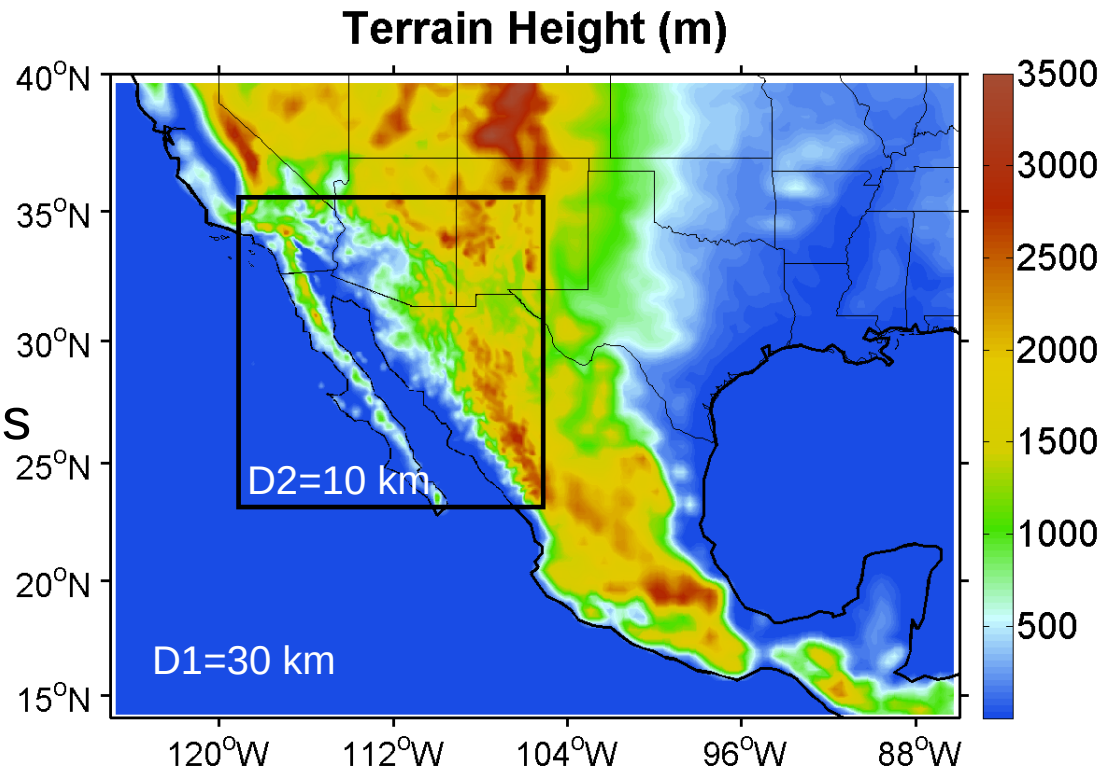


Model Setup and Domain

Time period: 8-17 JUL 2004
(includes monsoon onset)

{ 8 combinations of physics schemes
3 SST scenarios

Overall: 24 WRF runs



Model	No. of Domain	Main Domain Resolution	Nested Domain Resolution	Initial & Boundary Conditions	SST Scenario
WRF v3.4.1	2	30 km/L65	10 km/L65	NCEP/DOE reanalysis 2.5°x2.5°	MPM SST (Wang and Xie, 2007) NGC = 26 °C & SGC = 28 °C NGC = 30 °C & SGC = 30 °C

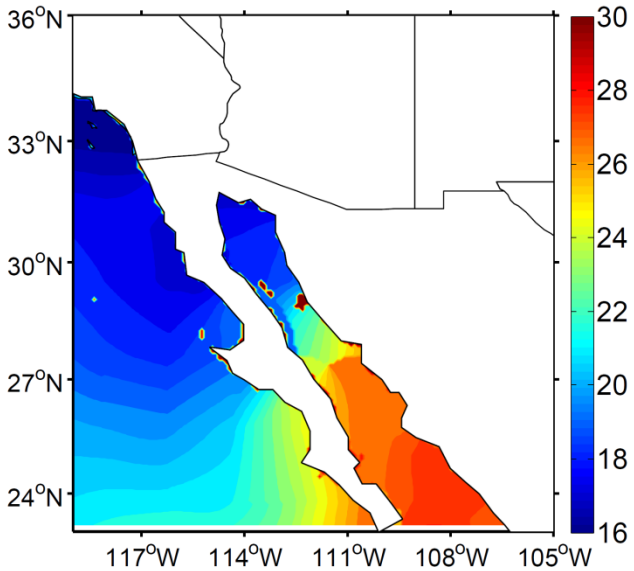
Model Setup and Domain

Combination of parameterization schemes used in each SST scenario

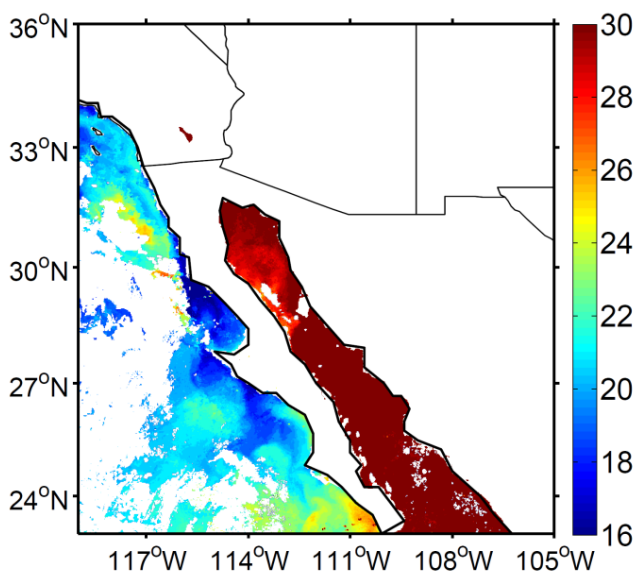
Experiment	Cumulus Physics	Boundary Layer Scheme	Land Surface Model	Microphysics Scheme	SW & LW radiation
1	Kain-Fritsch	YSU	Noah	WSM5	RRTM
2	Kain-Fritsch	YSU	RUC	WSM5	RRTM
3	Kain-Fritsch	MYJ	Noah	WSM5	RRTM
4	Kain-Fritsch	MYJ	RUC	WSM5	RRTM
5	BMJ	YSU	Noah	WSM5	RRTM
6	BMJ	YSU	RUC	WSM5	RRTM
7	BMJ	MYJ	Noah	WSM5	RRTM
8	BMJ	MYJ	RUC	WSM5	RRTM

Why GC SSTs important in modeling?

NCEP/ DOE Reanalysis

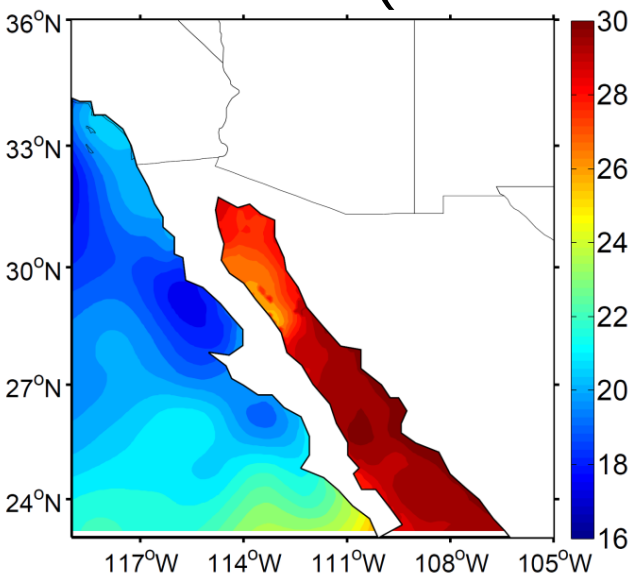


AVHRR Satellite

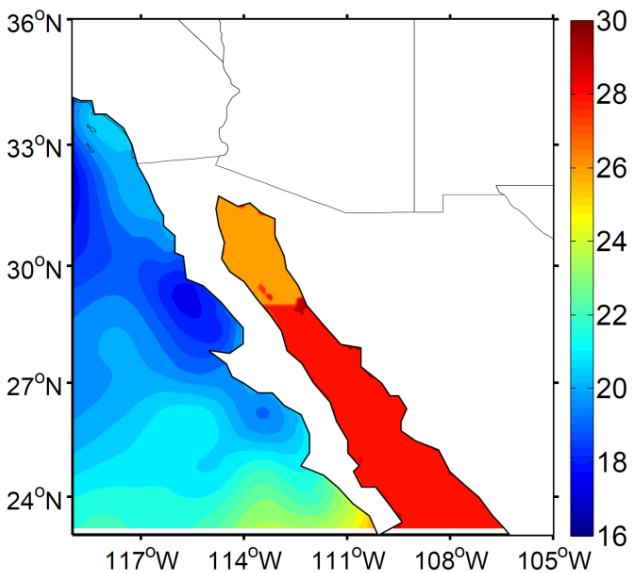


SST(°C),
8-17 July 2004

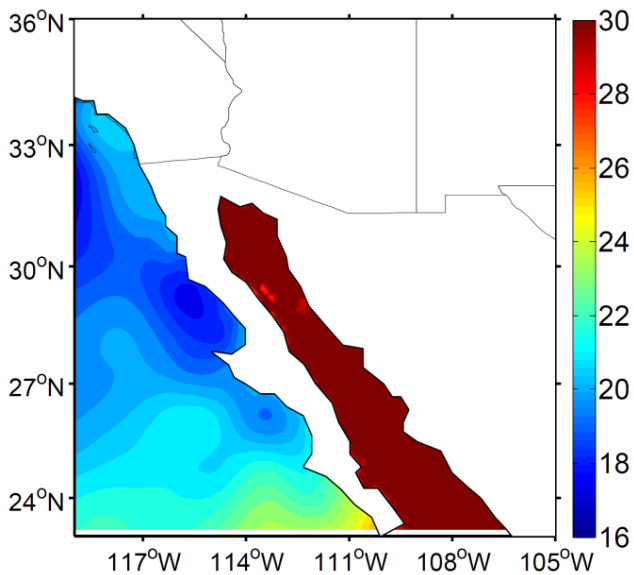
WRF Control (MPM SST)



WRF (SST: 26/28)

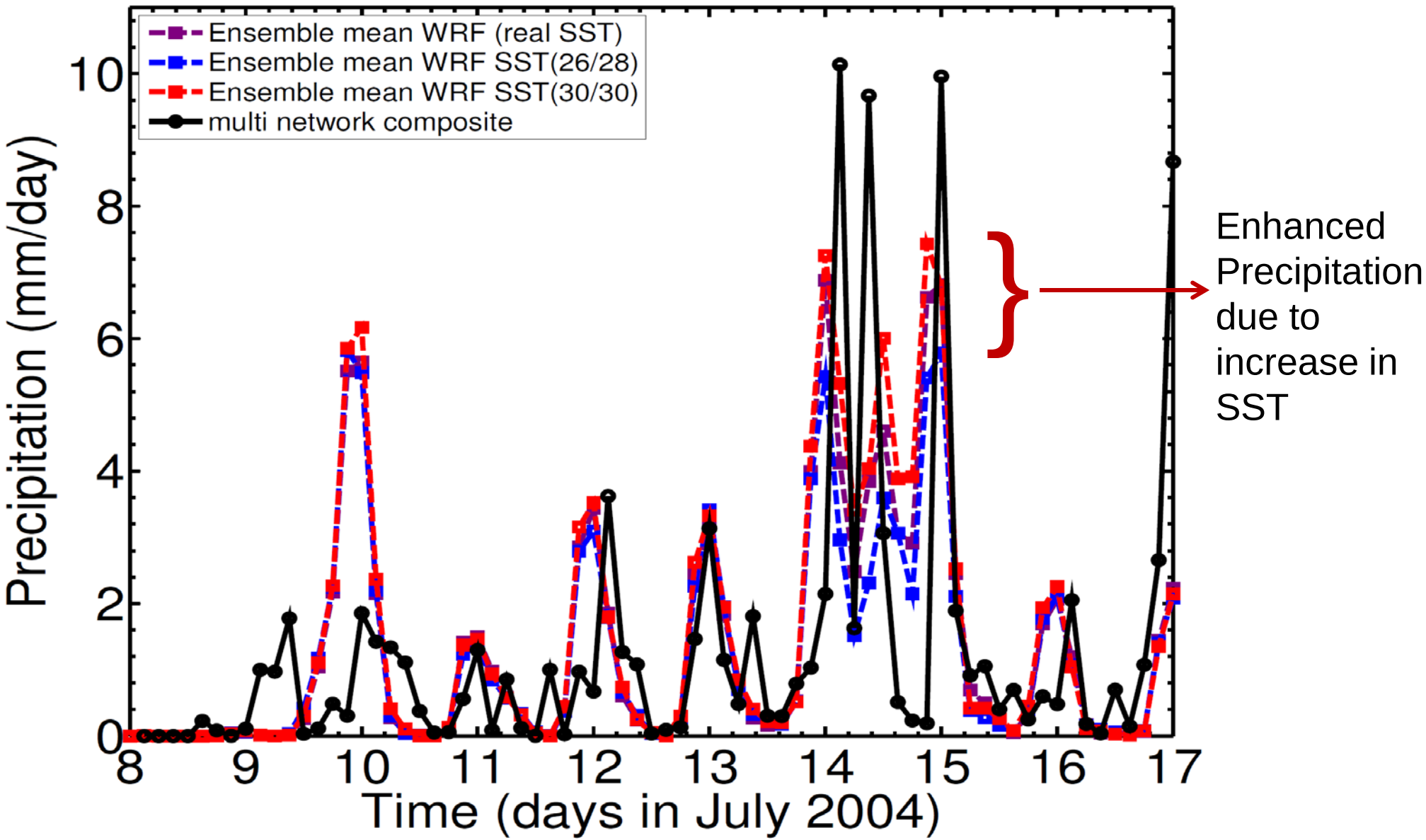


WRF (SST: 30/30)

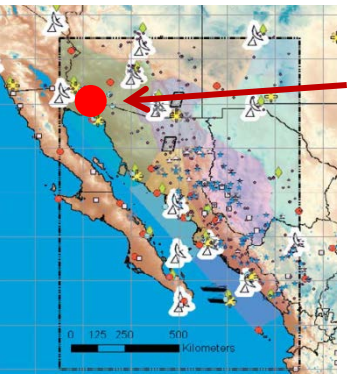


Precipitation Simulations

Time Series of Precipitation, Arizona Region, 8-17 July 2004



Time Series of Mixing Ratio Profile

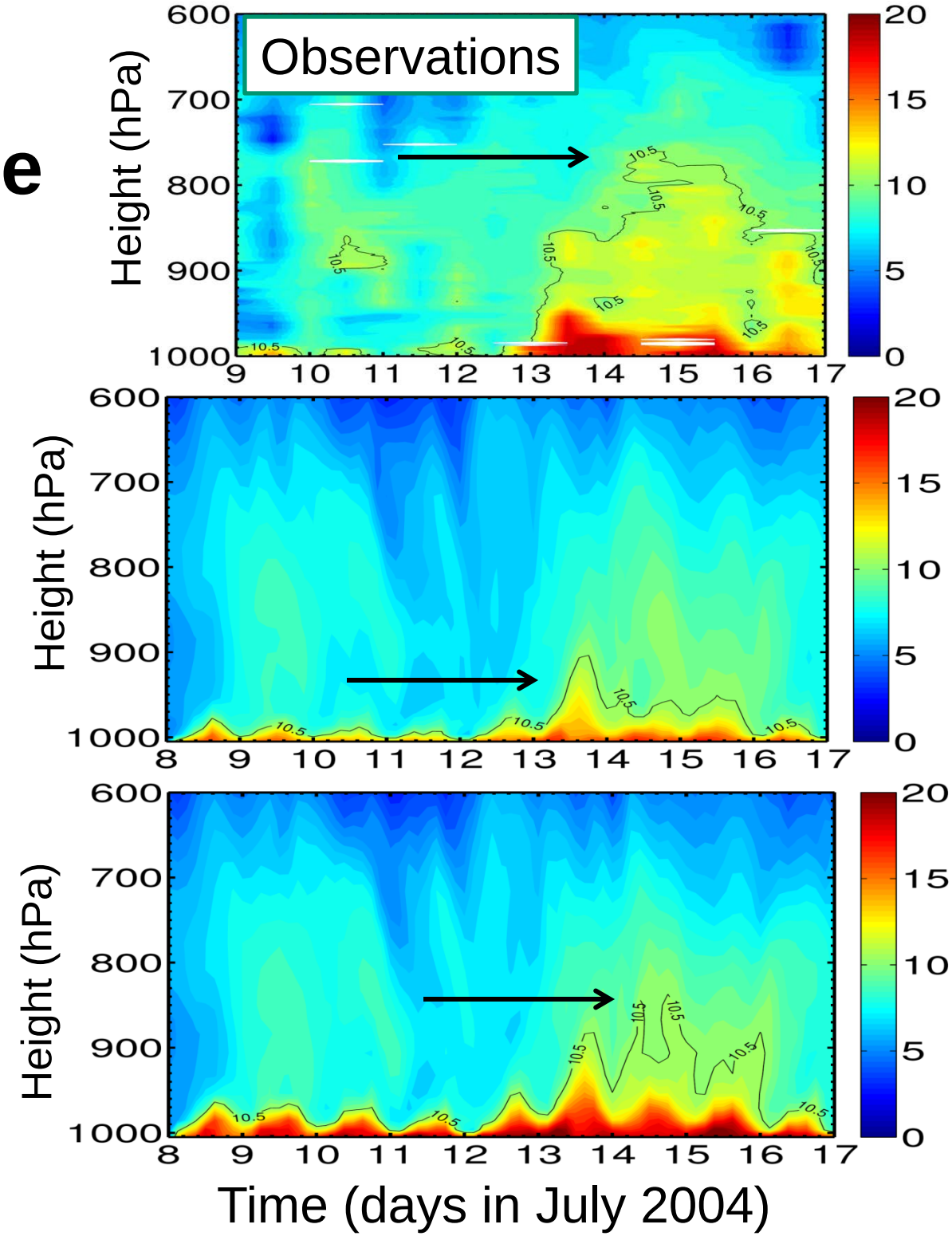


Puerto Penasco, 8-17 July 2004

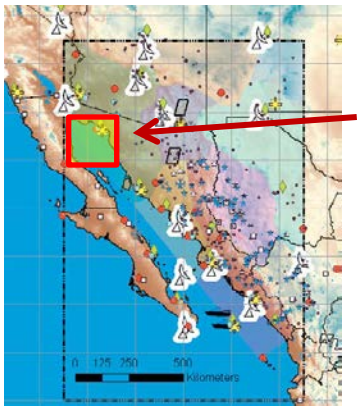
Ensemble Mean WRF (SST: 26/28)

r: mixing ratio (g/kg)

Ensemble Mean WRF (SST: 30/30)



Vertical Profiles, Mean over NGC

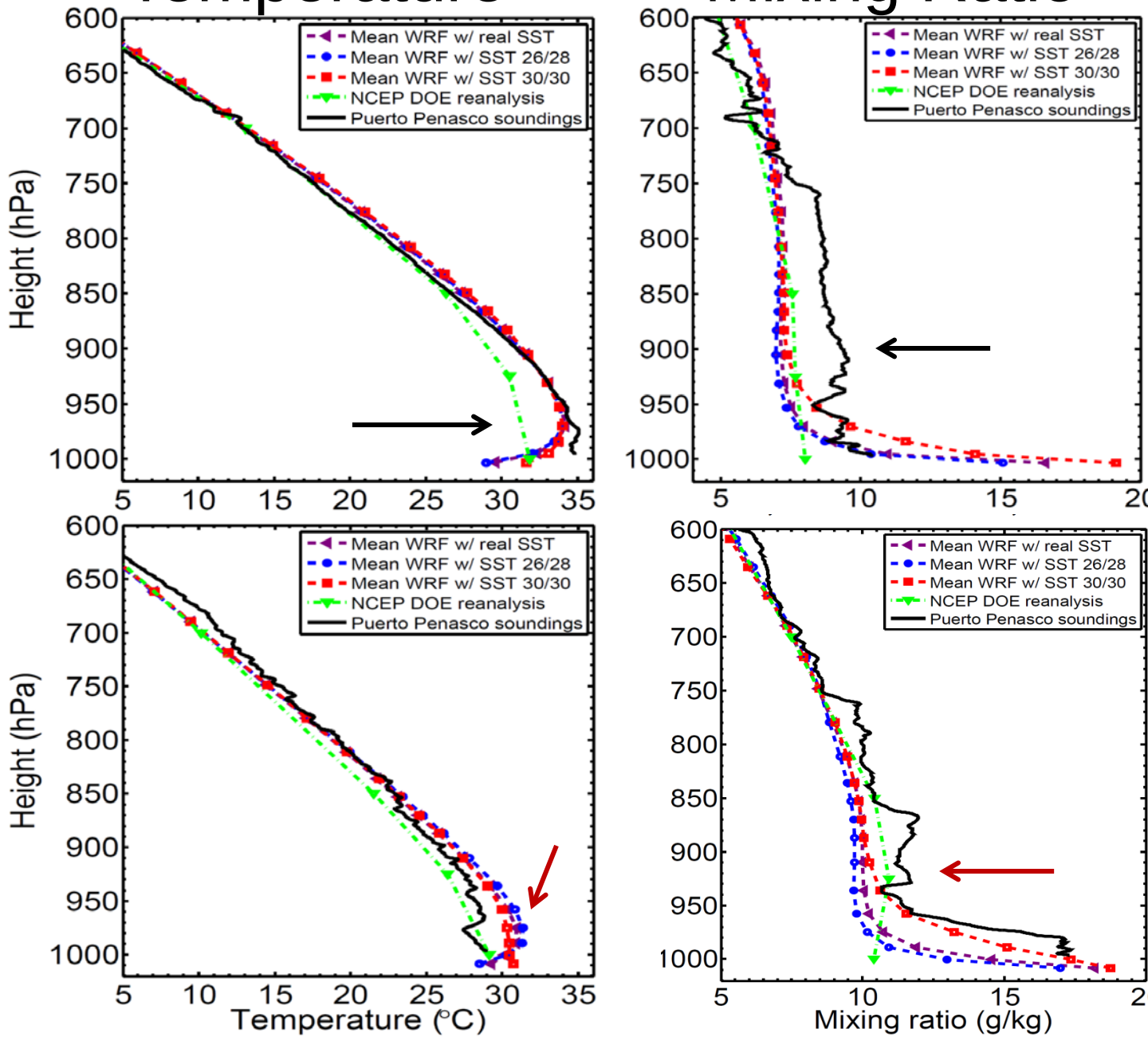


Averaged on
12 July 2004

Averaged on
14 July 2004

Temperature

Mixing Ratio



Conclusions

- In this study, we suggest a local scale mechanistic understanding of the NAM, which is related to the marine boundary layer (MBL) over the northern GC.

- The strong low-level inversion capping the top of shallow MBL weakens with increasing SSTs, allowing the trapped MBL moisture to mix with free tropospheric air. This leads to a deep moist layer that can be transported inland by low-level winds to enhance precipitation. These results are confirmed by WRF modeling.

- WRF simulates a stronger low-level inversion compared to sounding measurements, inhibiting the moistening of the lower troposphere.

Thanks!

North American Monsoon (NAM)

Summertime circulation that transports moisture from the tropics into the subtropical regions and controls summertime rainfall patterns.

Annual Rainfall Contributions of the NAM:

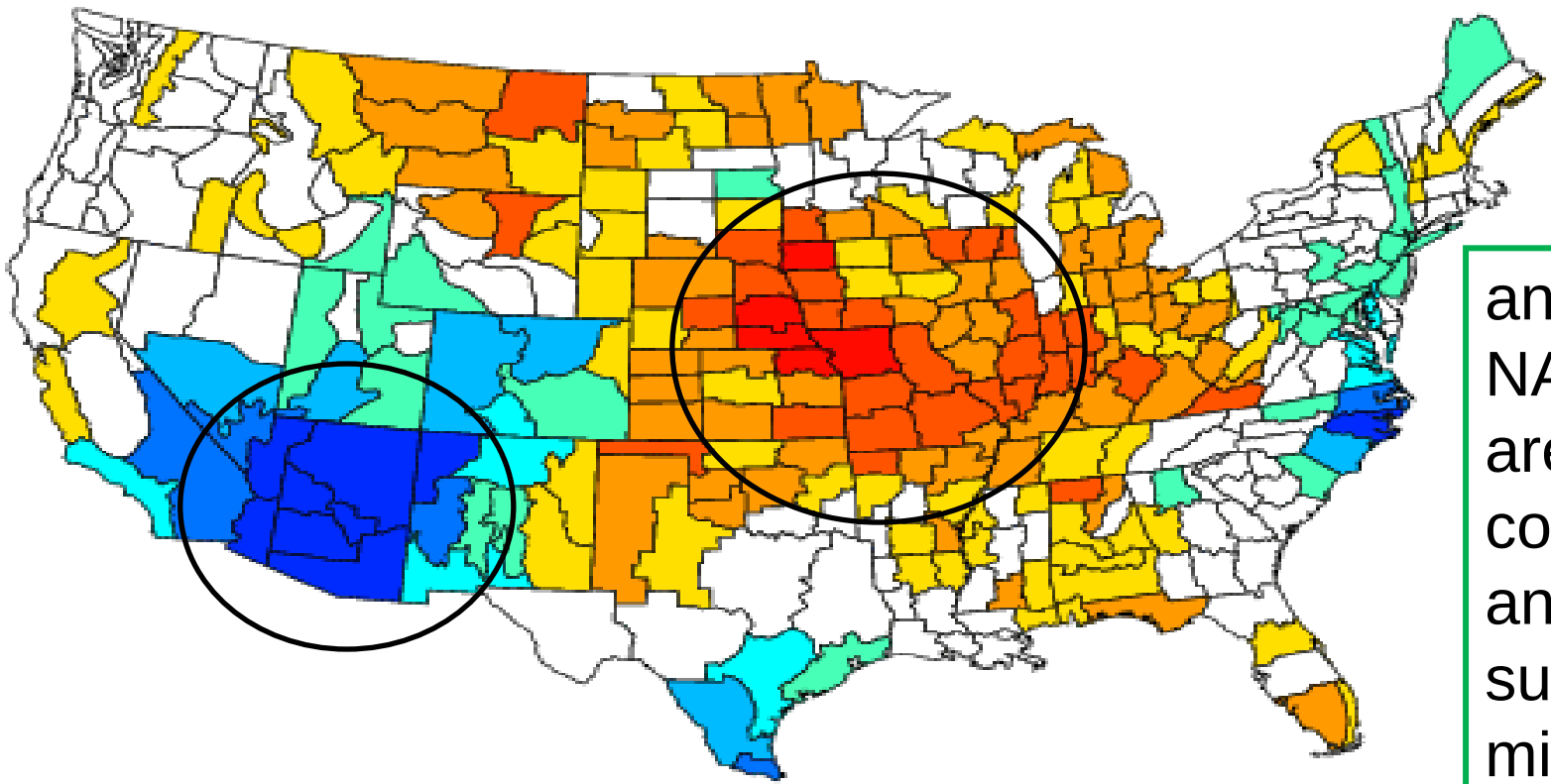
NW Mexico: 60-80%
Arizona: 35%
New Mexico: 45%

David Gochis, 2010, , NSF GPS Workshop

Why Care about NAM?

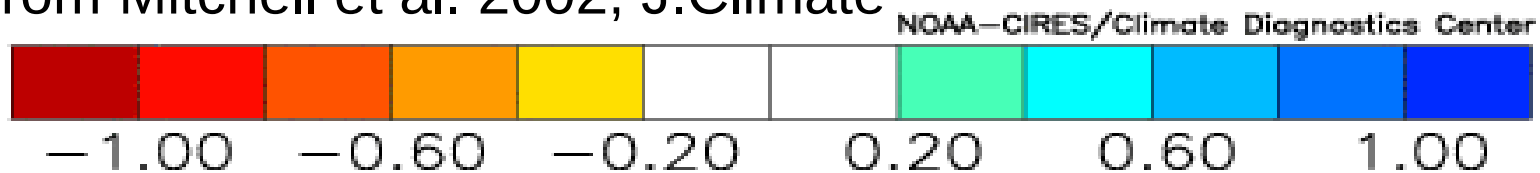
Composite Standardized Precipitation Anomalies

(deviation from normal for Jul-Sep precipitation), based on the 9 wettest AZ seasons for the period 1950-99, relative to the long-term mean 1950-95.



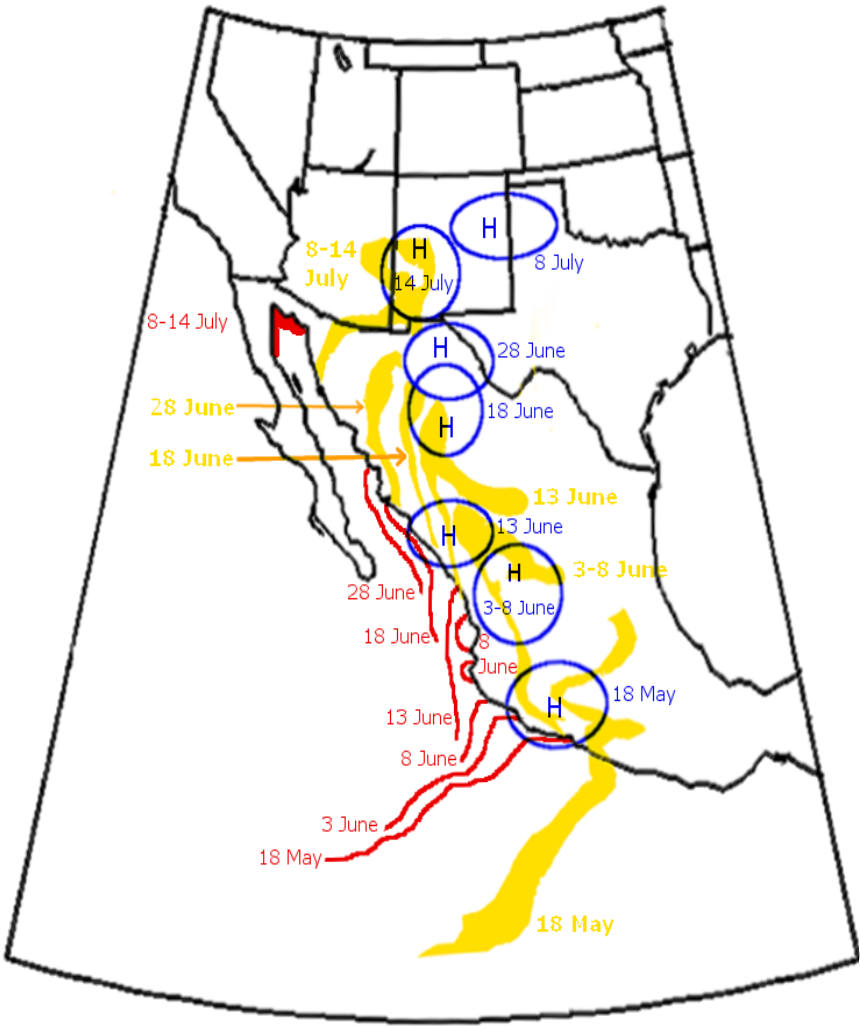
anomalously wet NAMs in Arizona are strongly anti-correlated with anomalously dry summers in the mid-west.

From Mitchell et al. 2002, J.Climate

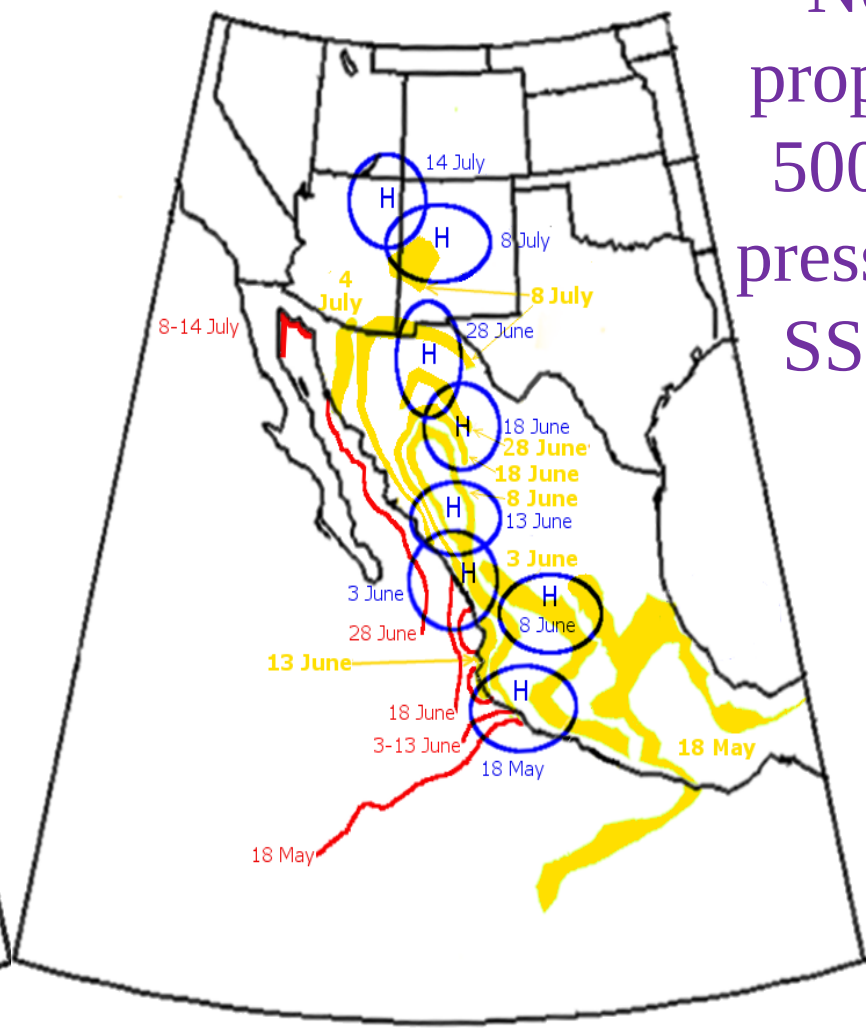


Relationship between NAM Anticyclone, SSTs & Deep Convection

Northward propagation of 500 hPa high pressure center, SST & OLR

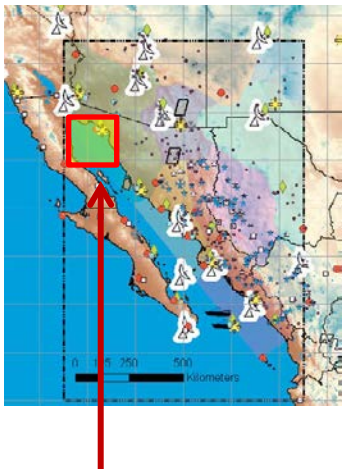


SST Climatology, 27.5 C isotherm : 1983-2000
OLR Climatology, 240-250 OLR gradient (W/m2):1983-2000
500 mb Geopotential Height Climatology: 1983-2000

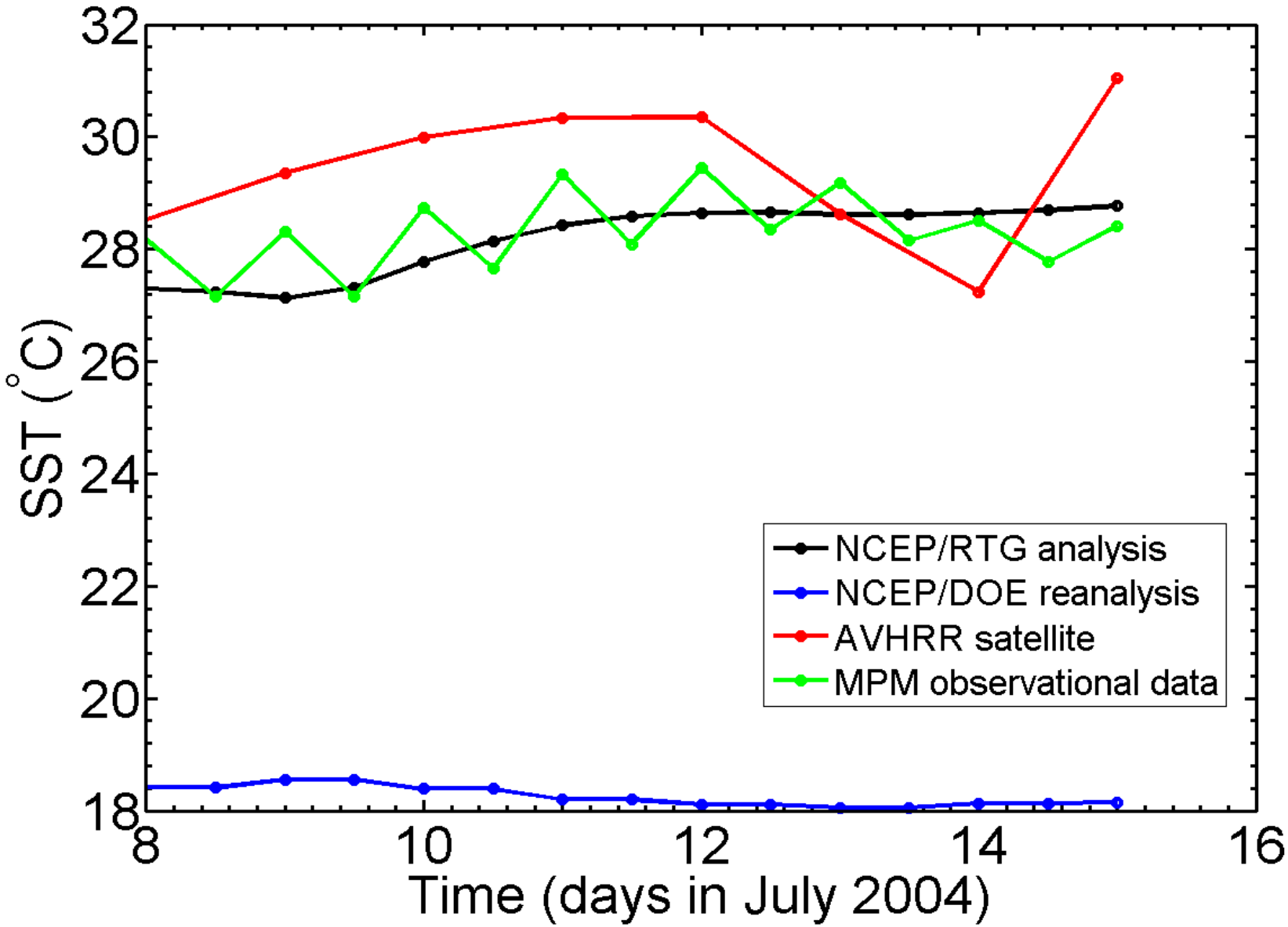


SST Climatology, 27.5 C isotherm : 2001-2010
OLR Climatology, 240-250 OLR gradient (W/m2):2001-2010
500 mb Geopotential Height Climatology: 2001-2010

Time Series of NGC SST

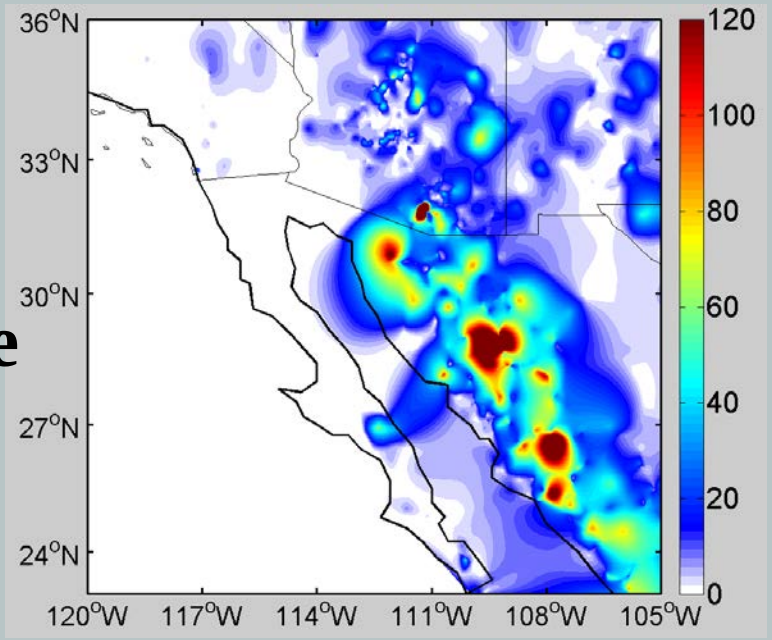


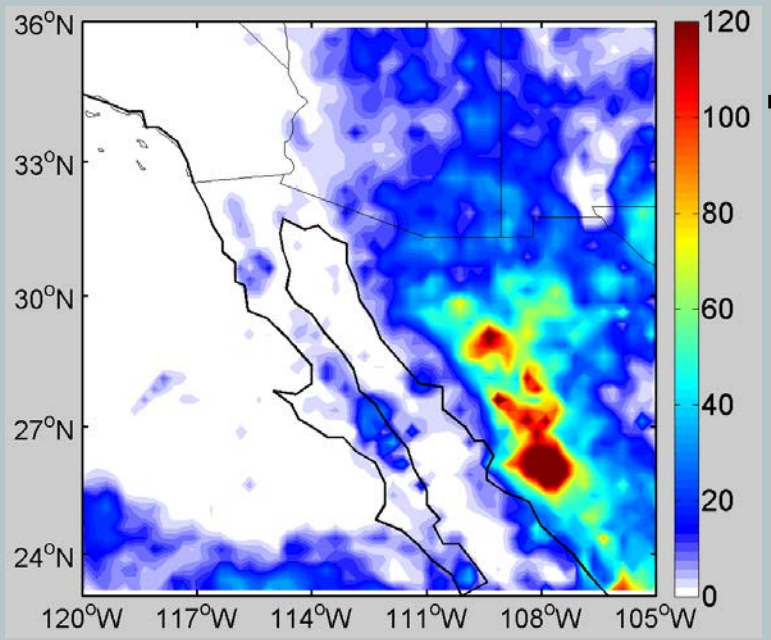
NGC



Precipitation Comparison, 8-17 JUL 2004

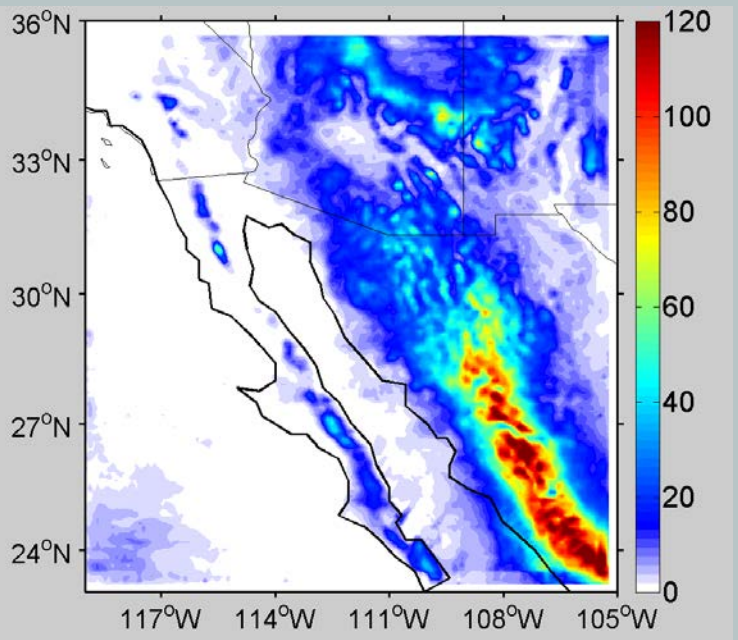
Multi-Network Composite





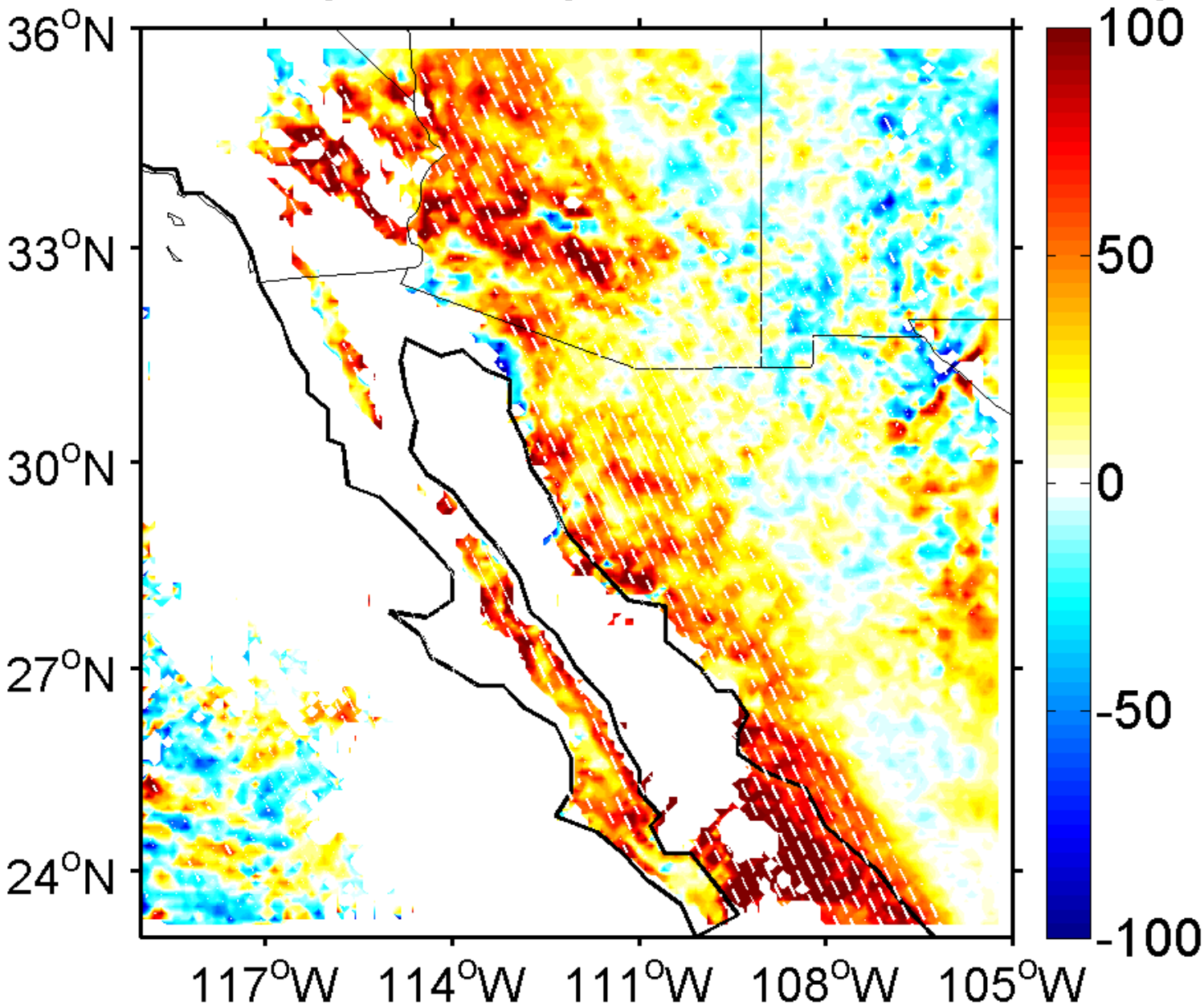
TRMM

WRF control run (MPM SST)



Precipitation Difference (%), 8-17 July 2004

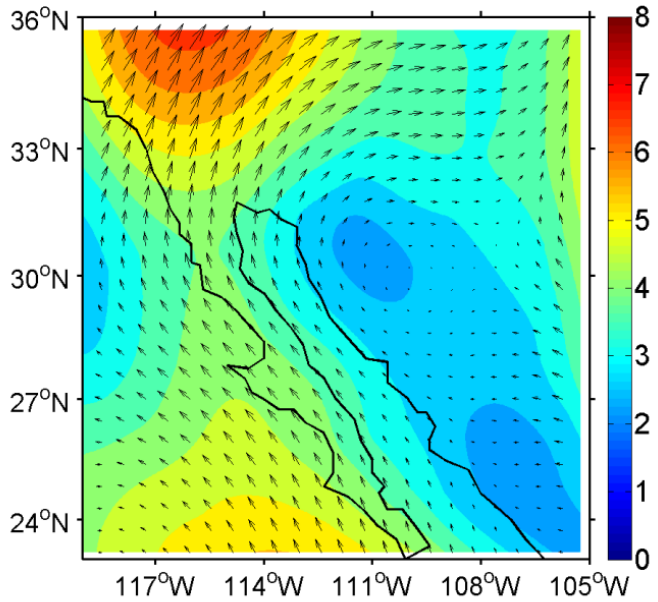
Ensemble Mean WRF (SST 30/30) – Ensemble Mean WRF (SST 26/28)



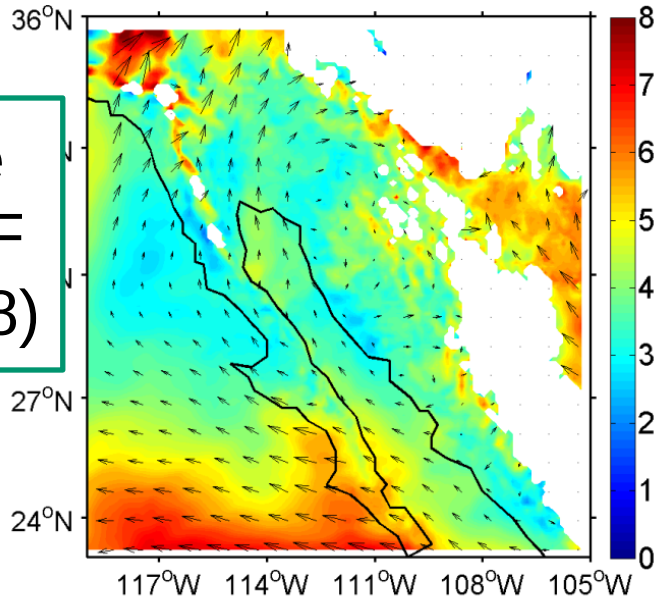
850 hPa Wind Speed & Vectors

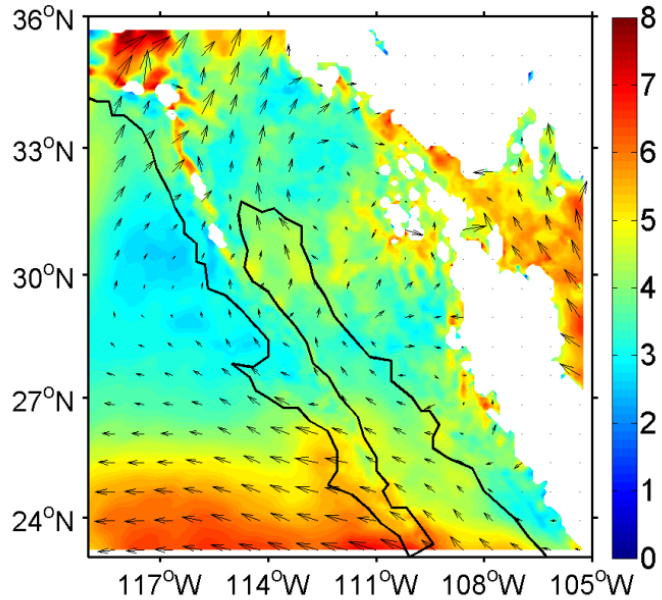
8-17 July 2004

met_em from NCEP/DOE reanalysis data



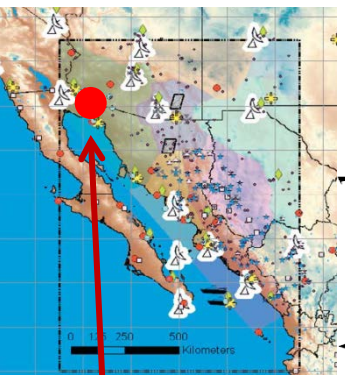
Ensemble Mean WRF (SST: 26/28)





Ensemble Mean WRF (SST: 30/30)

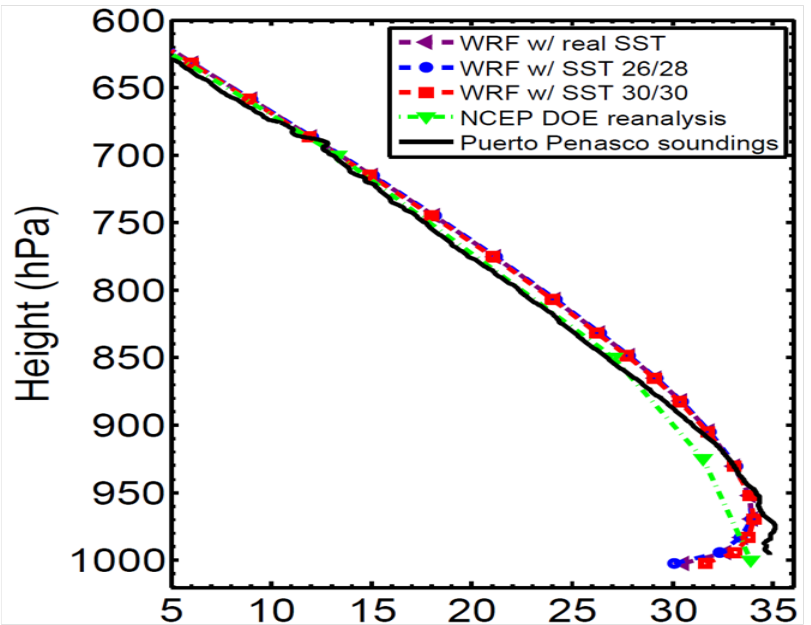
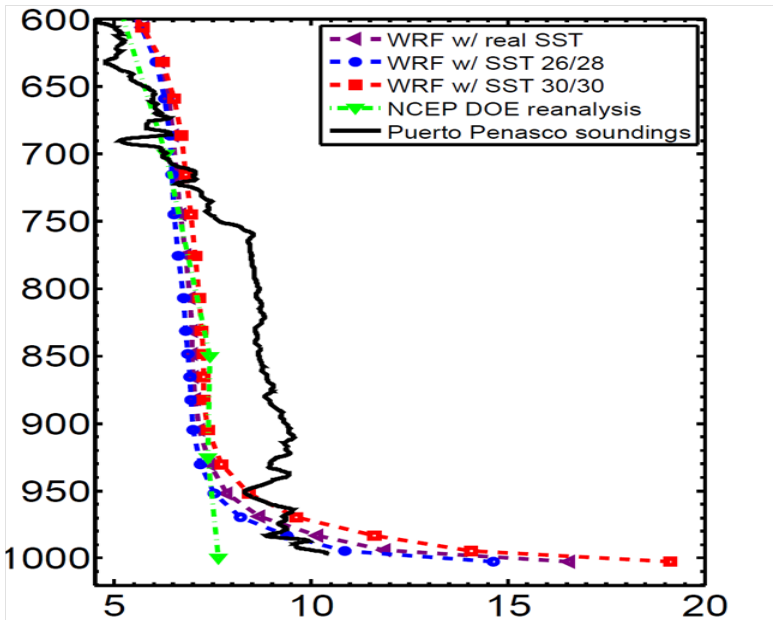
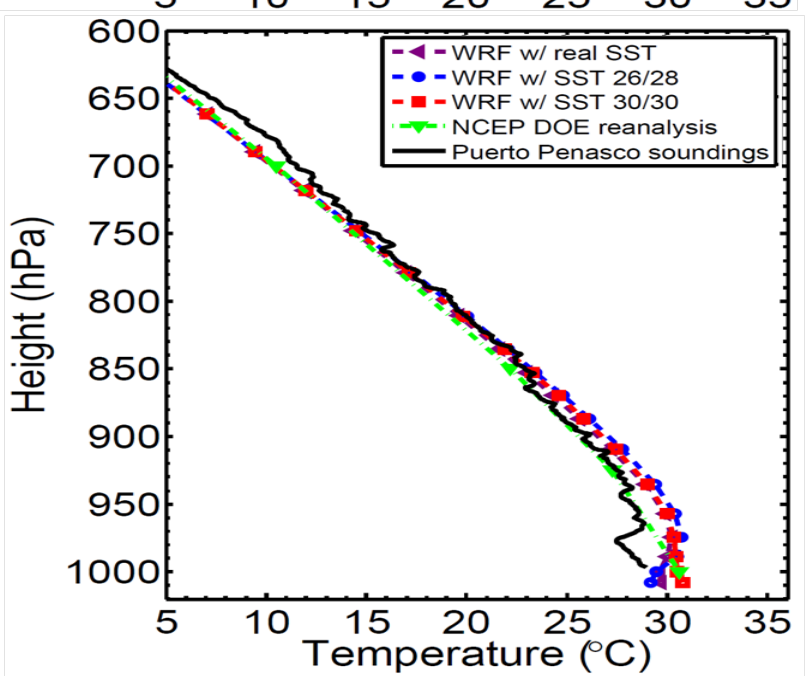
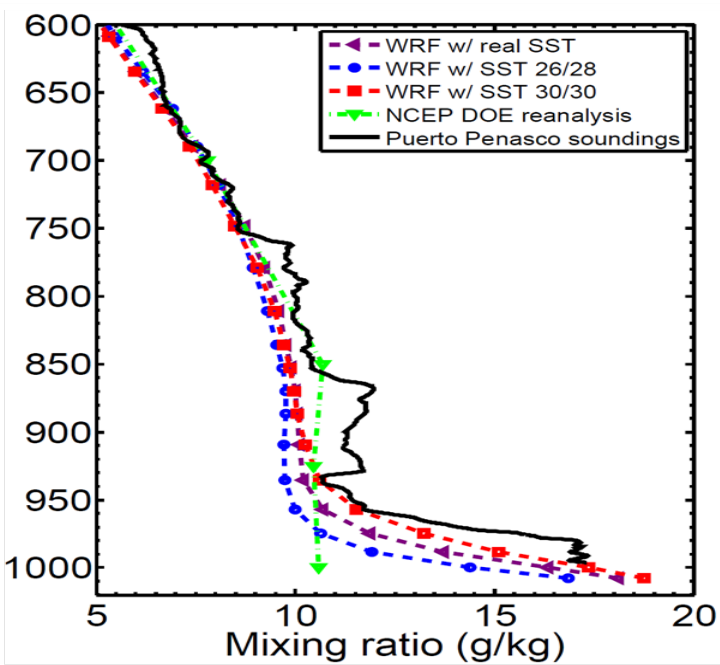
Vertical Profiles, Puerto Penasco



Puerto Penasco

Averaged on 12 July 2004

Averaged on 14 July 2004

Temperature

Mixing Ratio