A High-Resolution Simulation of Intensive Observing Period 2 during the North American Monsoon Experiment using the Weather Research and Forecasting (WRF) Model

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Presentation Outline

- Background on North American Monsoon Experiment (NAME) and Intensive Observing Periods (IOPs)
- Description of IOP 2 – Blas case
- WRF modeling of IOP 2 – signatures
- Concluding points
- Future work with adjoint sensitivity and data assimilation

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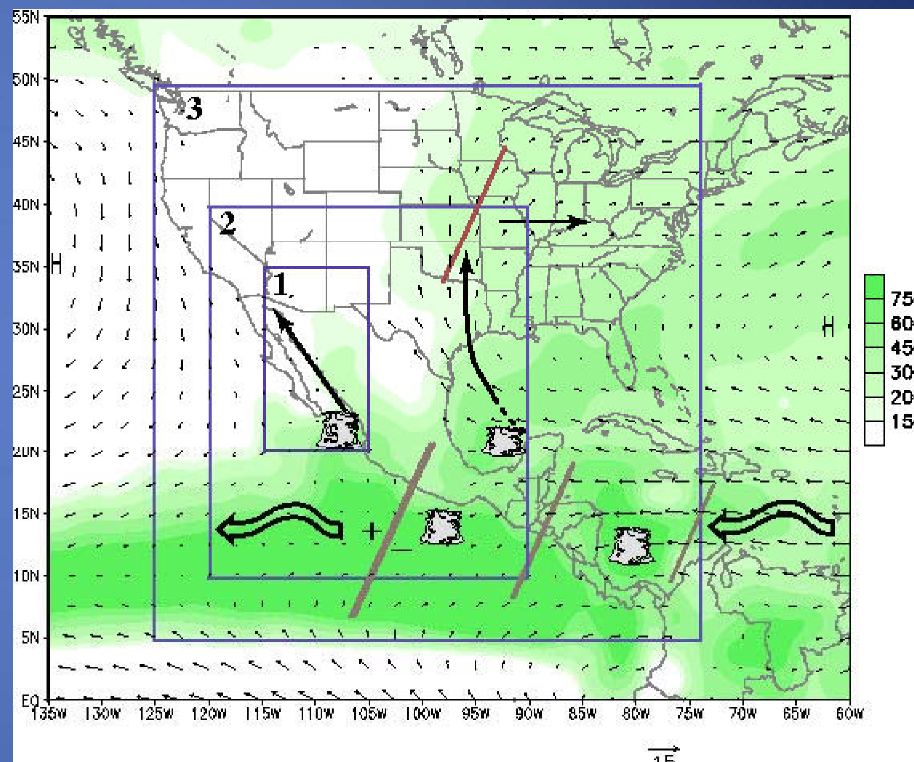
North American Monsoon Experiment (NAME)

- Intensive and extensive observations collected in the southwest U.S., northwest Mexico during summer 2004
- Tiered observational approach



Two Major NAME Goals

- Improved understanding of large-scale climate forcing factors that influence monsoon intraseasonal and interannual variability.

  →Improved climate forecasts

- Improved physical understanding and model representation of mesoscale processes that lead to monsoon rainfall.

  → Improved short term weather forecasts

Intensive Observing Periods (IOPs)

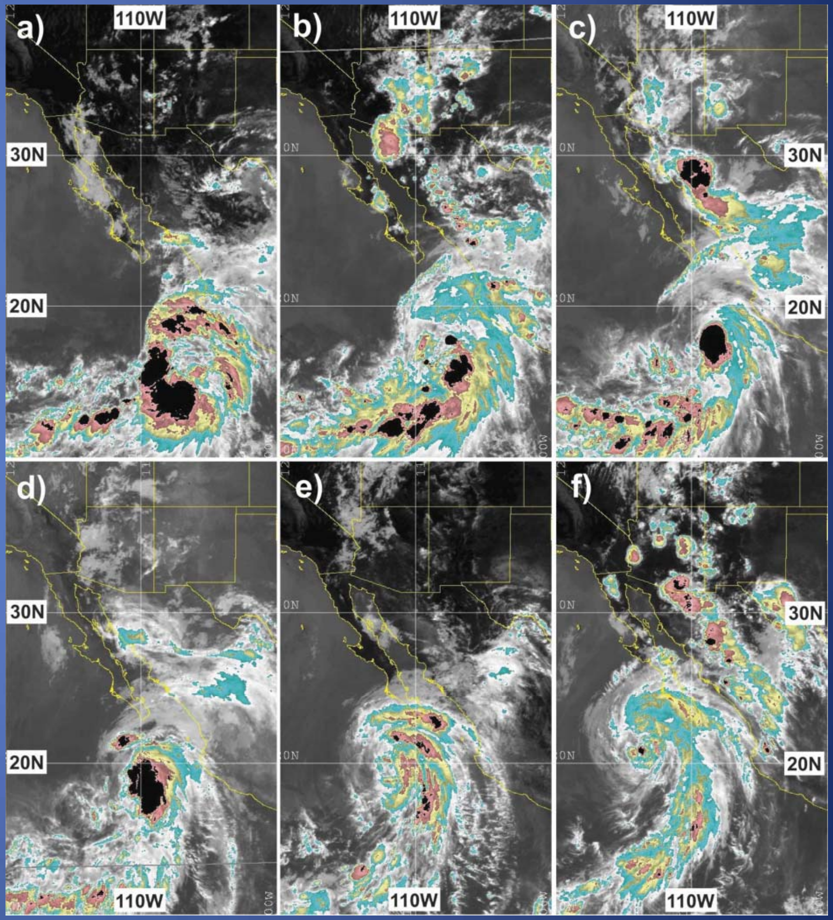
More intensive observations taken for a few days that targeted key meteorological phenomena of the monsoon (e.g. gulf surge, MCS development, etc.)

- Individual missions - ten in total
- Called when the phenomena were predicted
- Large amount of high resolution observations (satellite, surface, upper air, and radar)

IOP 2

- 00Z July 12 – 00Z July 15
- Gulf surge induced by

  the passage of TS Blas at southern end of the Gulf of California (GoC)
- Gulf surge and upper-level disturbance cause westward propagating MCSs off Sierra Madres and Mogollon Rim



Why use a regional model

- Gets near the scale of representing individual thunderstorms (and corresponding properties and effects: rainfall, organizations, outflow boundaries, etc)
- Hydrological implications – real time flash flood advisories, severe weather, etc. (e.g. UA Atmospheric Sciences performs high resolution monsoon forecasts for runs in cooperation with the Salt River Project.)
- Allows for determination of data sensitivity—which is important because of a lack of data in Mexico….will talk more about in future work.

WRF Lateral and Surface Boundary Forcing

Meteorological Data

- Global Forecast System (GFS) Reanalysis Data (FNL analyses)
- 18Z July 11 – 18Z July 15

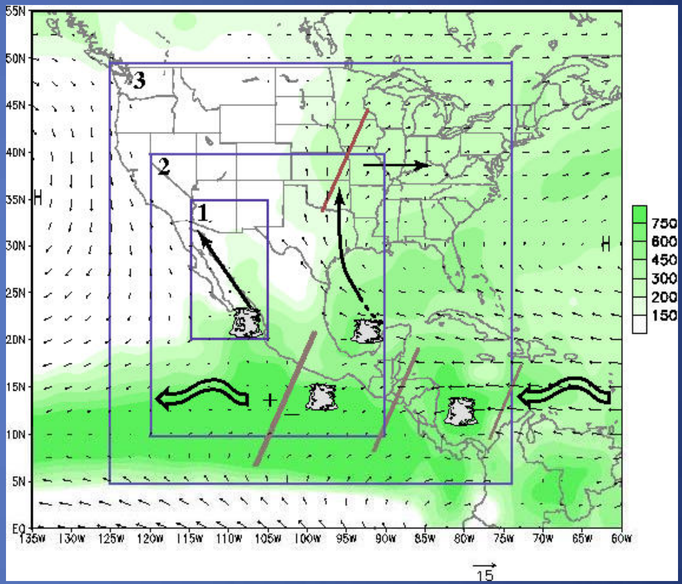
Soil Data Initialization from North American Regional Reanalysis (NARR)

WRF Domain Setup

(Approximately matches NAME Tier Regions)

Domain 3: Continental

132x134 at 30km resolution



Domain 2: Regional

265x262 at 10km resolution

Domain 1: Core monsoon region

573x345 at 2.5km resolution

*Scale of greatest interest since resolving convection.

WRF Physics for IOP-2 Experiment

(Similar to Current UA Operational NWP Forecasts with WRF)

- Microphysics: Lin et al Scheme
- LW and SW Radiation: CAM Scheme
- Surface Layer Physics: Eta similarity
- Land Surface Physics: Noah Land Surface Model
- PBL Physics: Mellor-Yamada-Janjic scheme
- Cumulus Parameterization: Kain Fritsch scheme
- *No cumulus parameterization on finest grid*

WRF Model Simulation Metrics

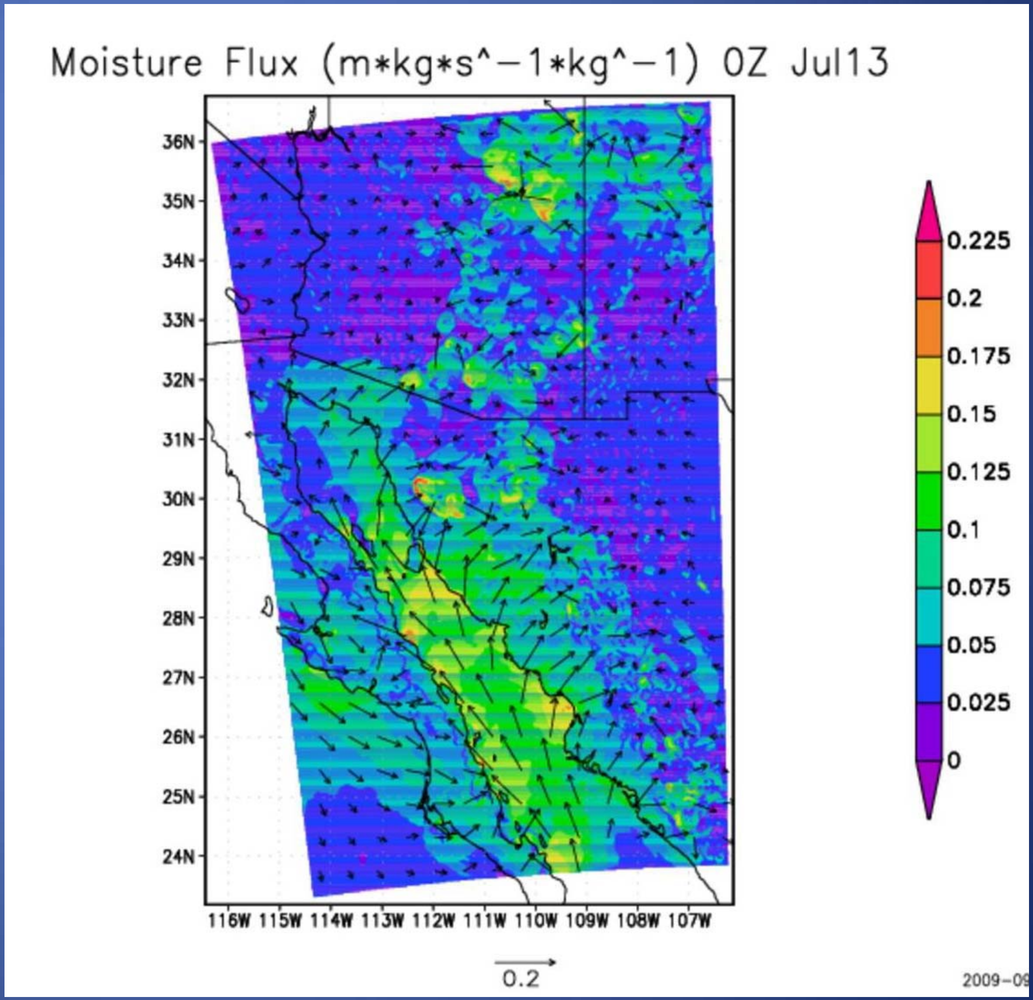
- Surface moisture flux associated with gulf surge
- Precipitation development, MCS organization and propagation
- Reasonable timing and geographic location of these salient meteorological features

Compare WRF results with Stage IV radar-derived rainfall, satellite imagery, and NAME ISS sounding data (Rogers and Johnson 2006)

Gulf Surge 5 PM July 12

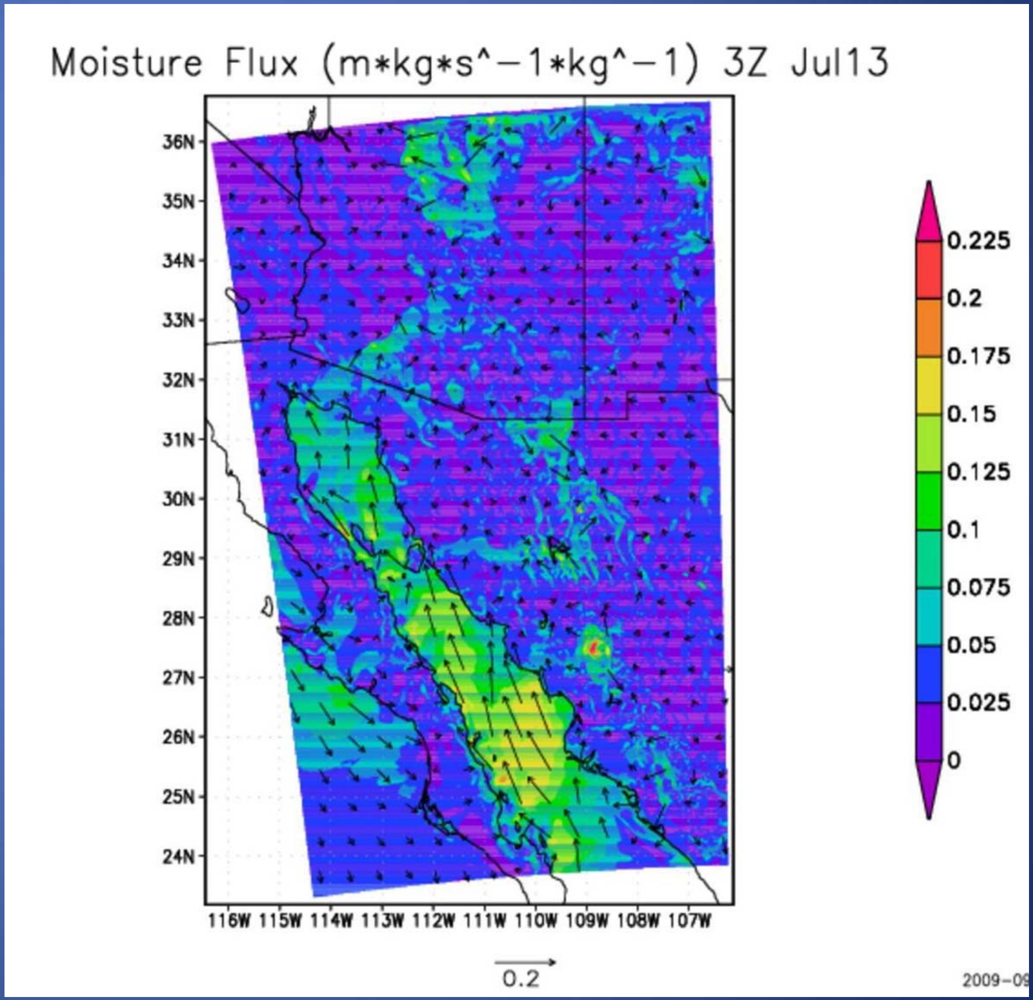
- Pre surge
- Surge signature located at the mouth of GOC

Note orientation of moisture flux vectors at the coast that indicate the strong diurnal cycle of convection



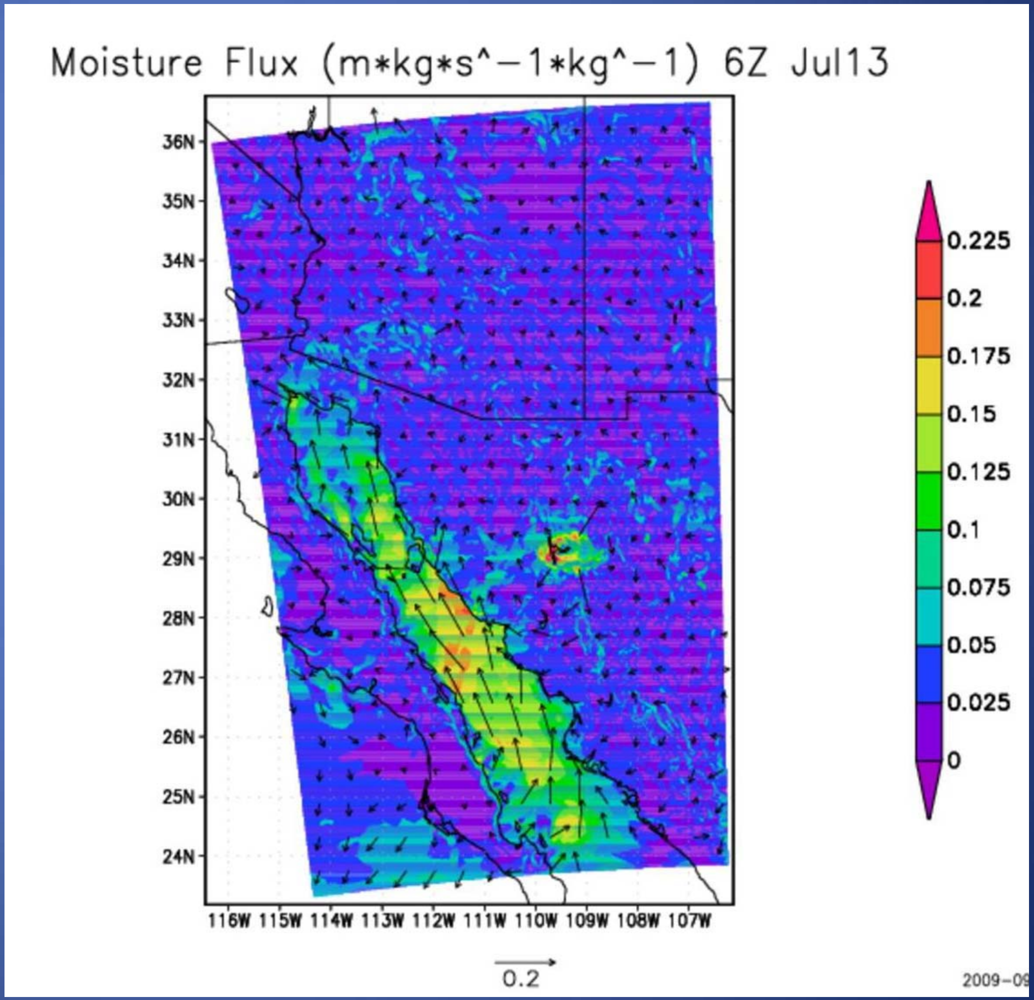
Gulf Surge 8 PM July 12

- Surge signature now present
  → Stronger flux
  → Vectors are parallel to the coast



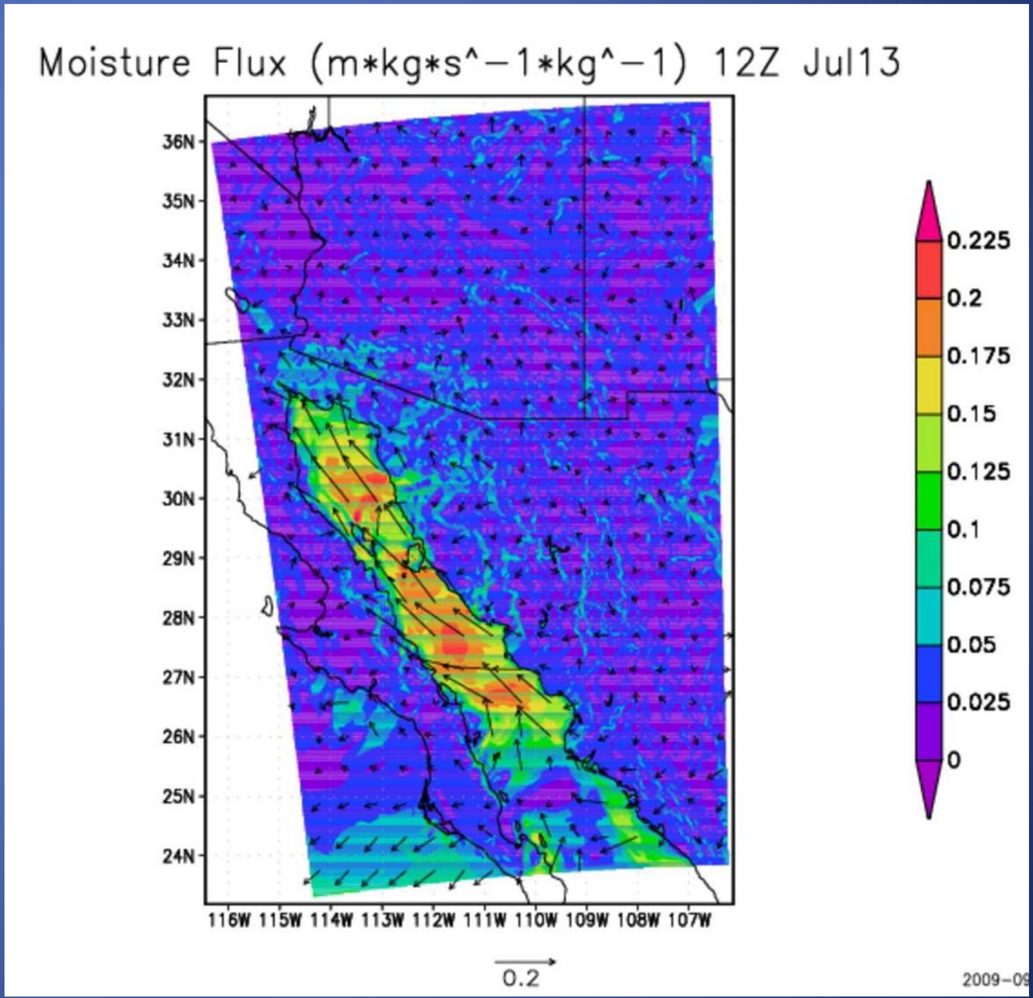
Gulf Surge 11 PM July 12

- Surge signature further north with stronger fluxes



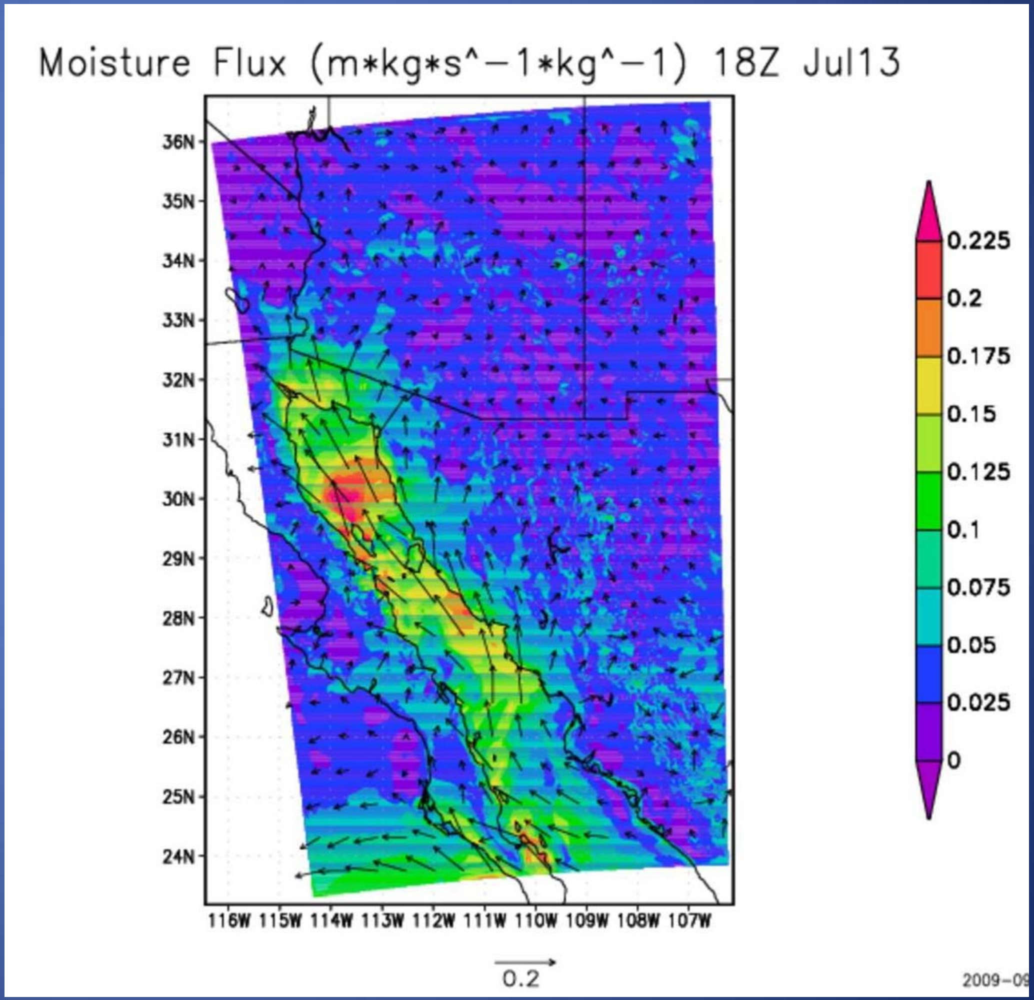
Gulf Surge 5 AM July 13

- Surge reaches northern gulf
- Positive moisture flux centered about Bahia Kino



Gulf Surge 11 AM July 13

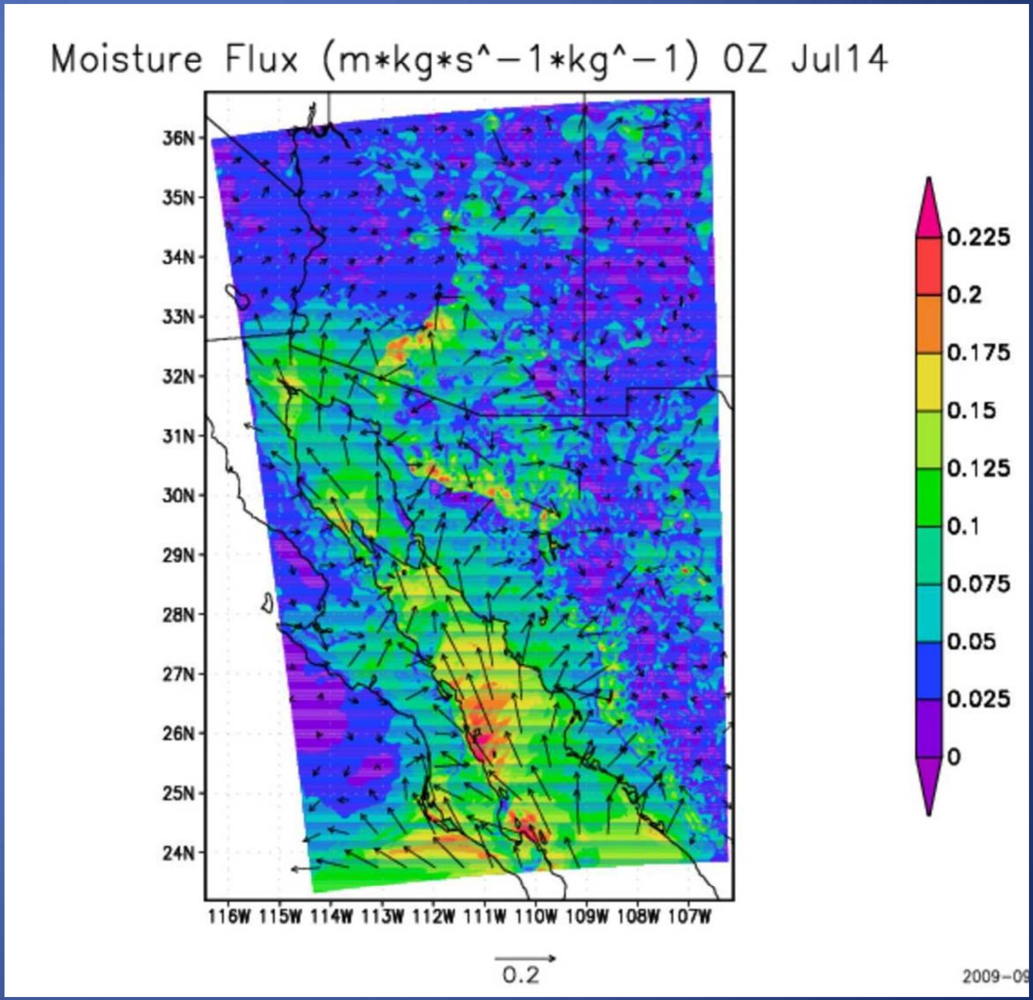
- Surge confined to northern gulf
- TS Blas starts to come into view



Note the fanning of the moisture flux at the northern end into low deserts of Arizona AND that moisture flux vectors parallel to coast. VERY difficult to simulate with coarser resolution using a cumulus parameterization!

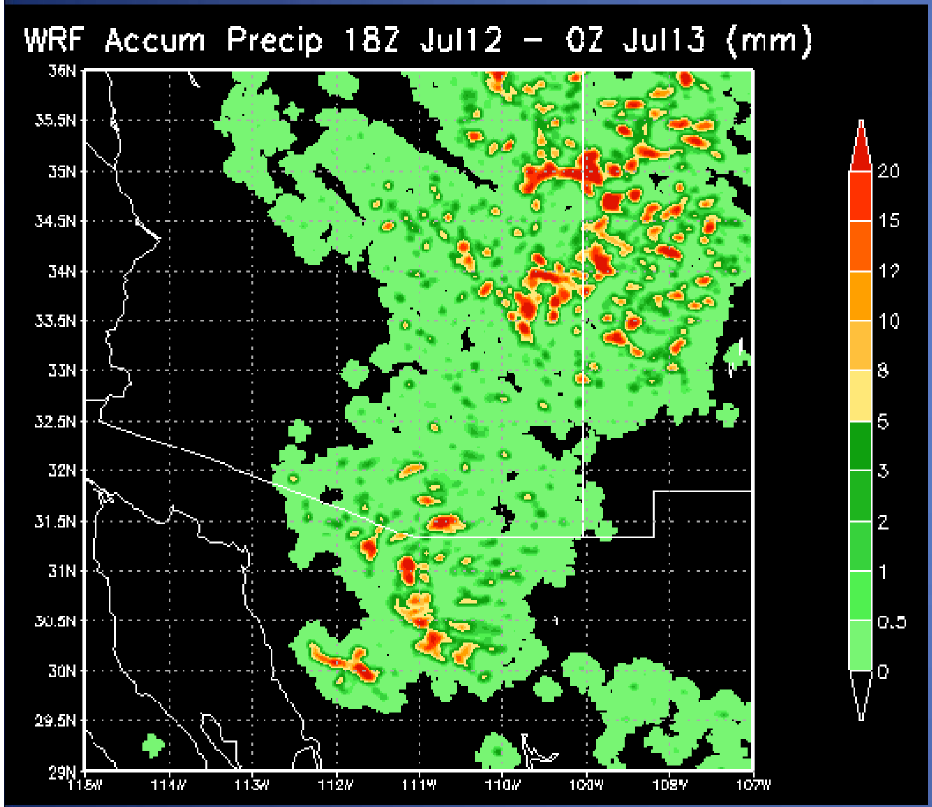
Gulf Surge 5 PM July 13

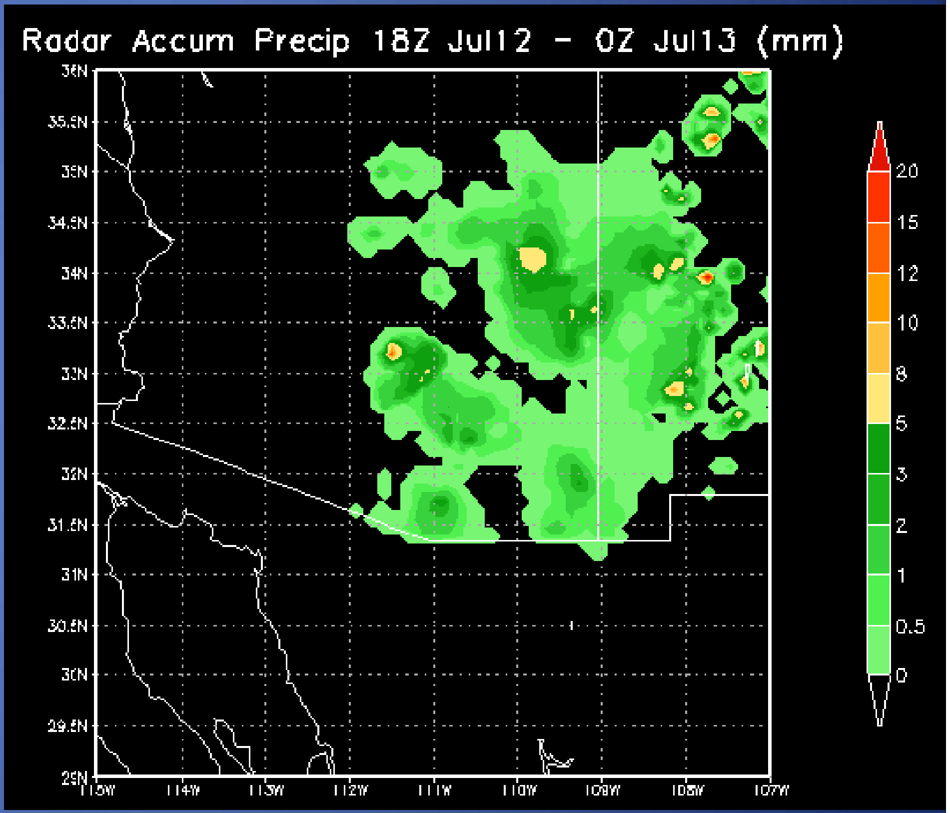
- Surge signature gone
- Moisture flux over south GoC result of Blas



WRF vs. radar-derived precipitation

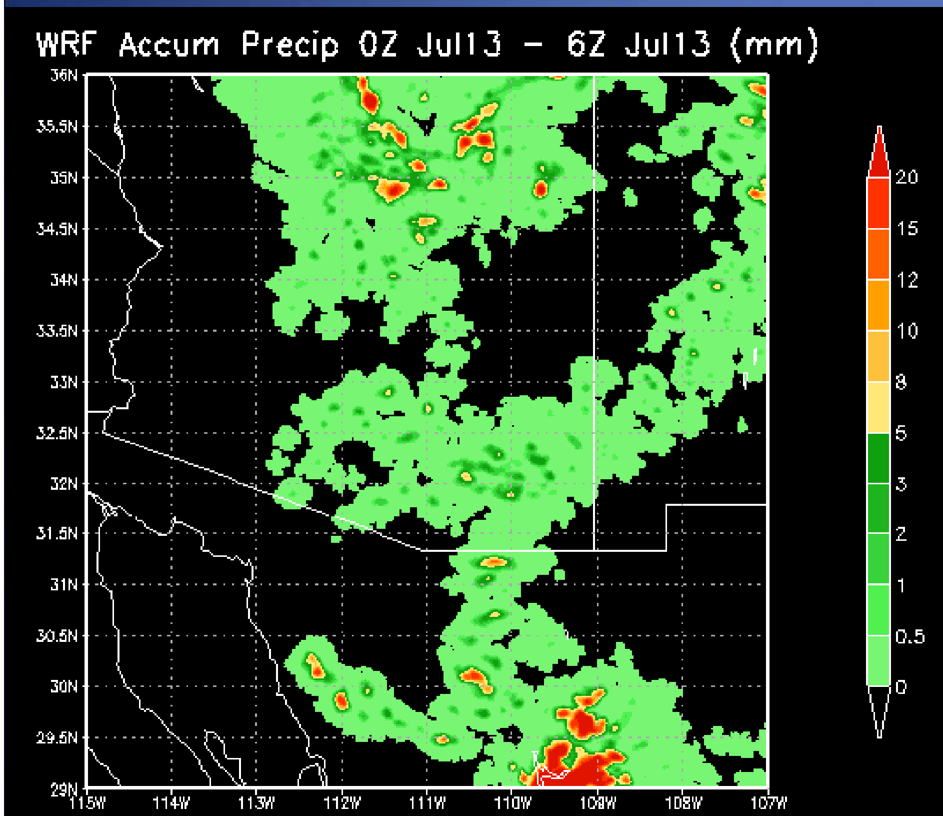
Late morning to late afternoon July 12

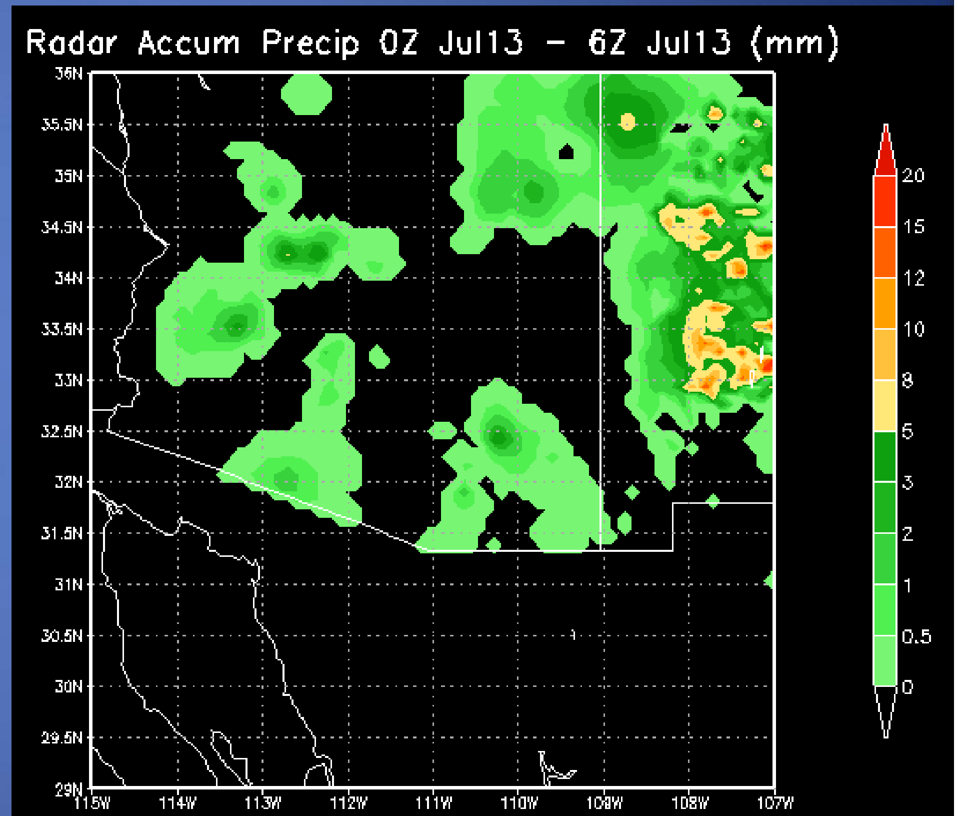




WRF vs. radar-derived precipitation

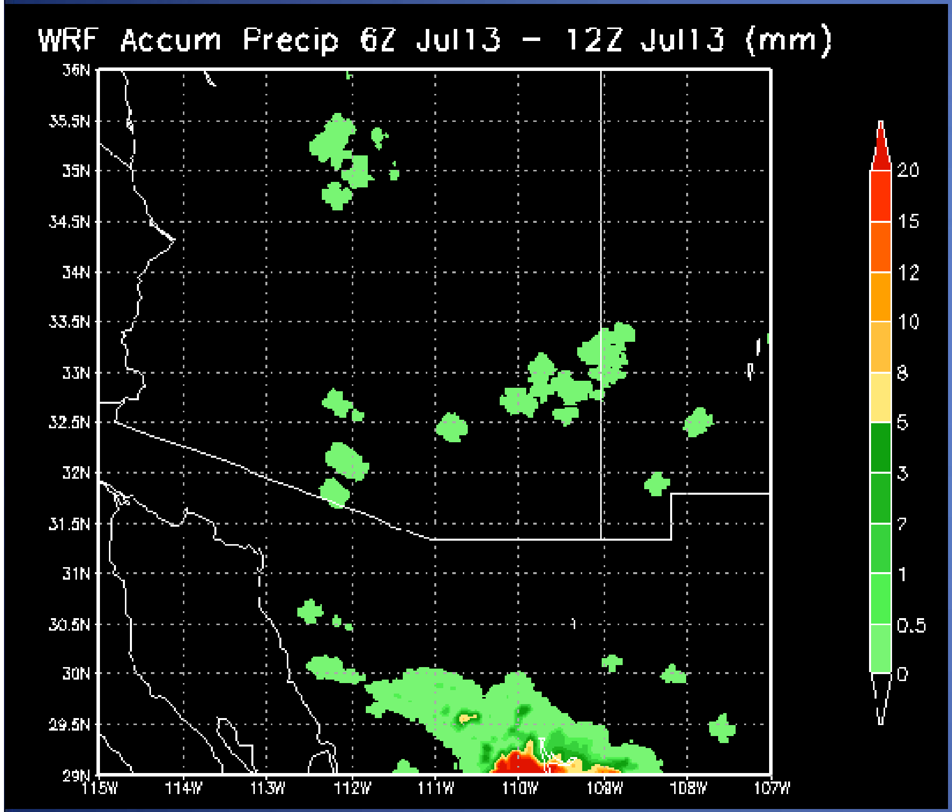
Late afternoon to late evening July 12

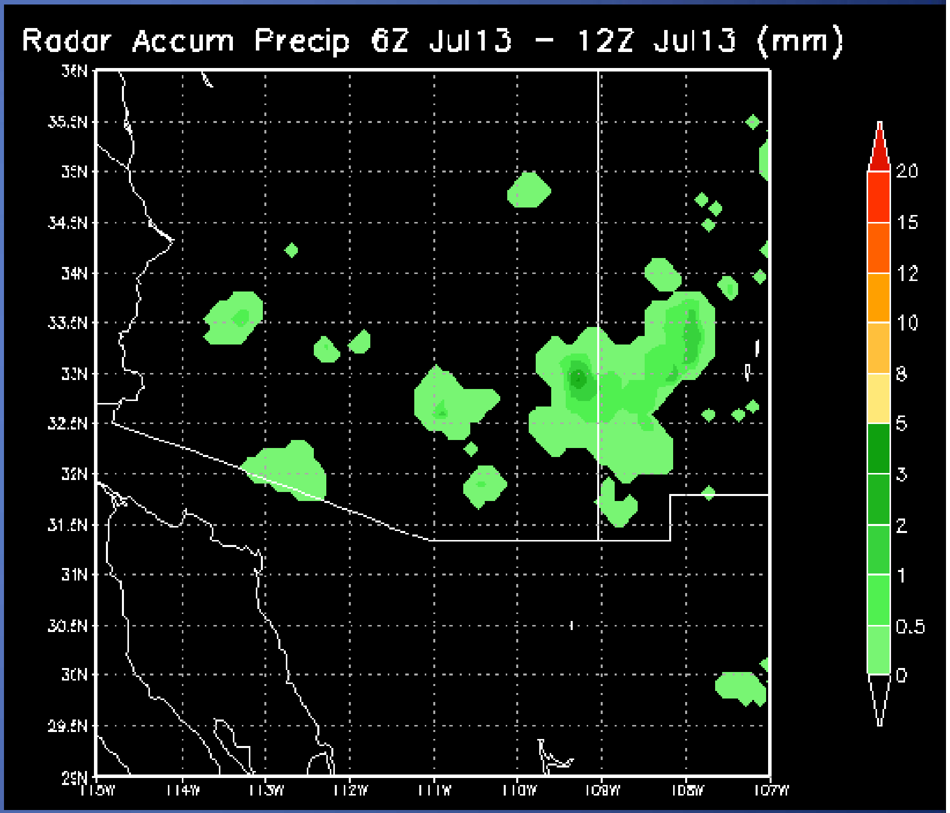




WRF vs. radar-derived precipitation

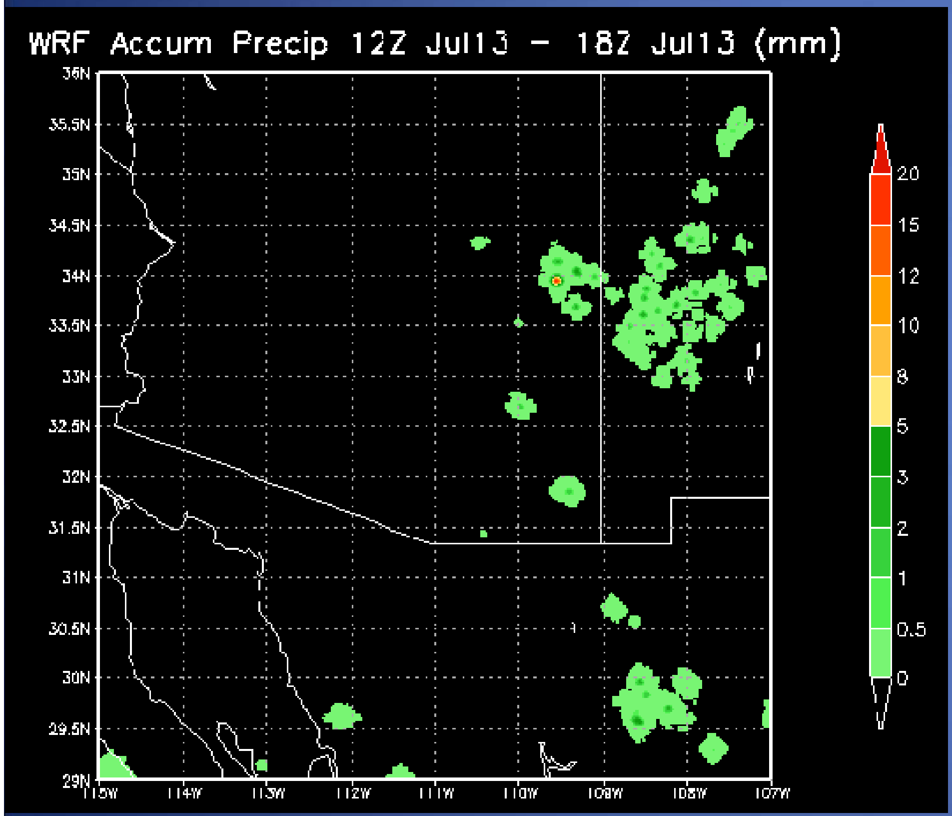
Late evening July 12 to early morning July 13

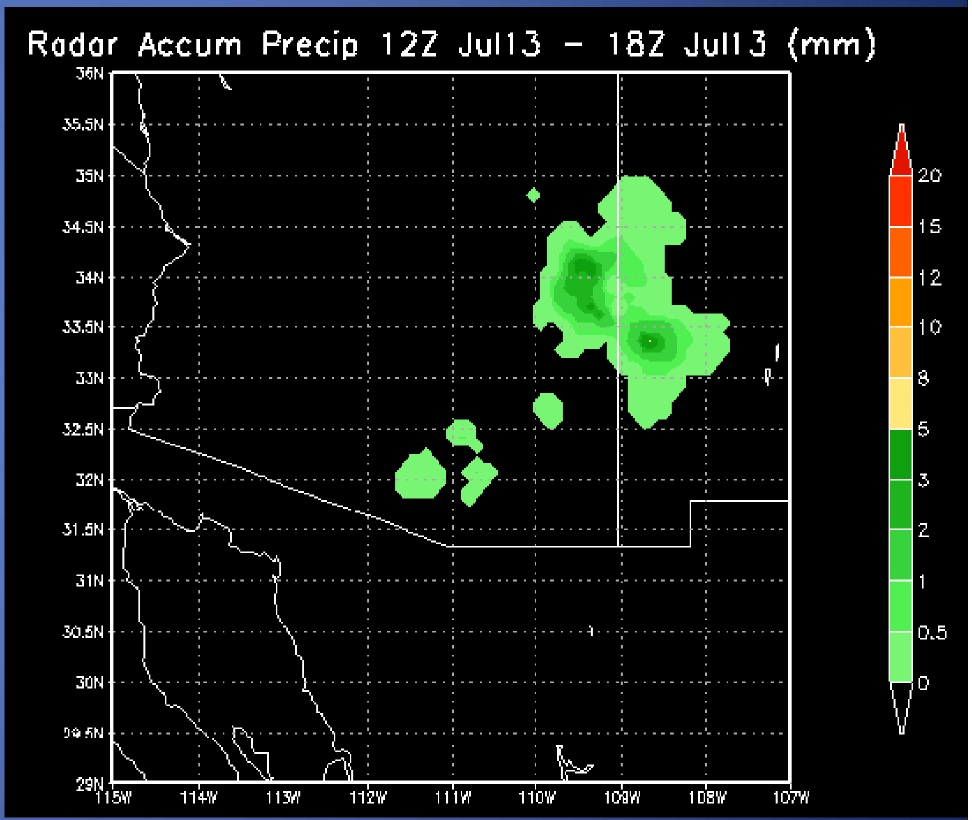




WRF vs. radar-derived precipitation

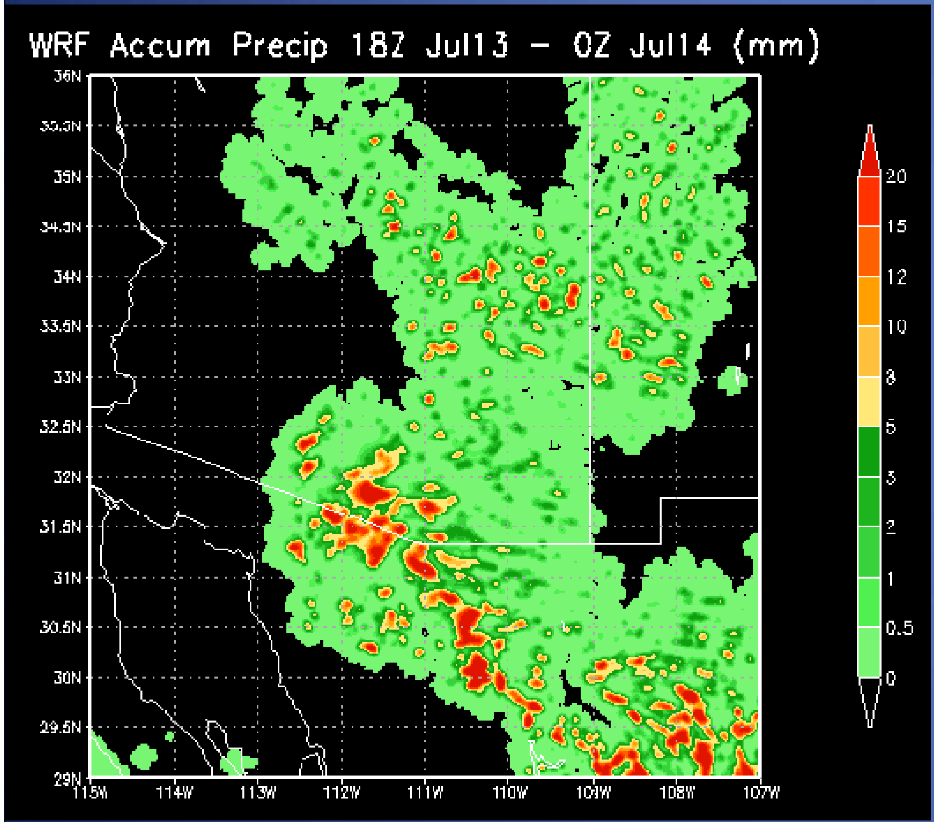
Early morning to late morning July 13

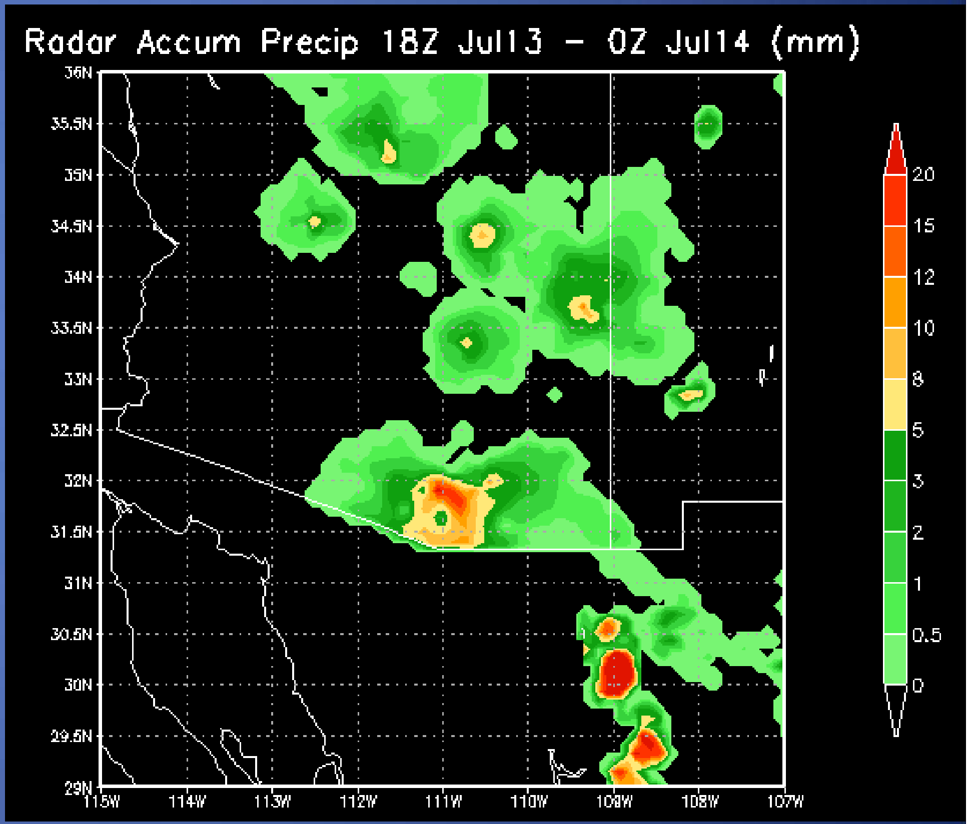




WRF vs. radar-derived precipitation

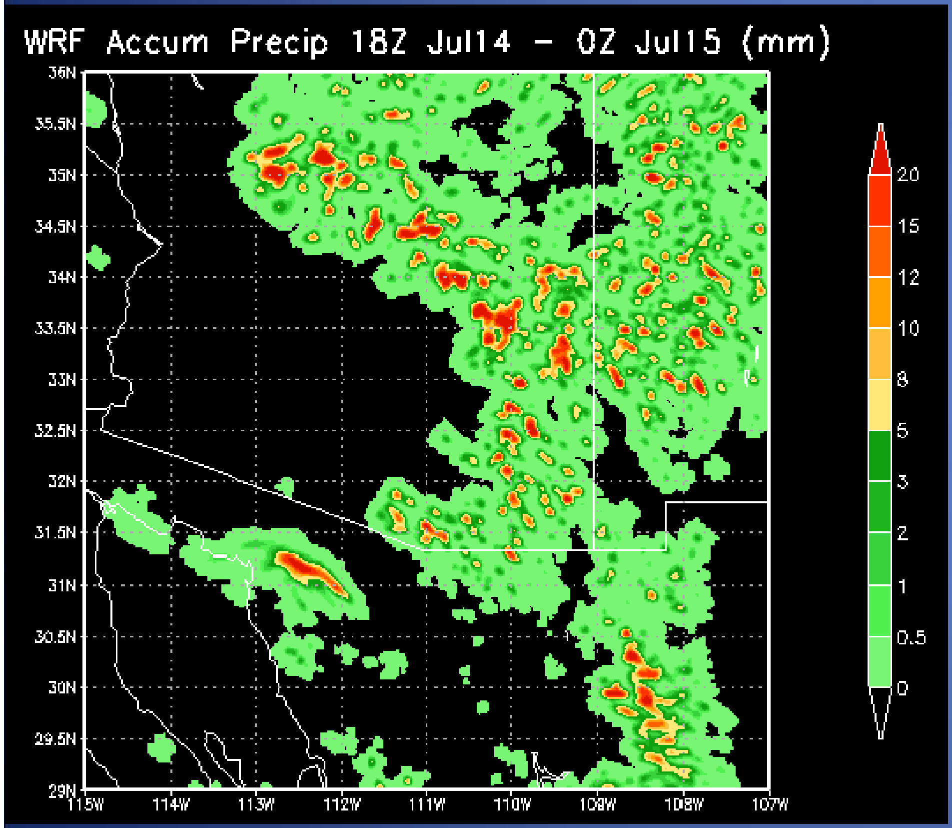
Late morning to late afternoon July 13

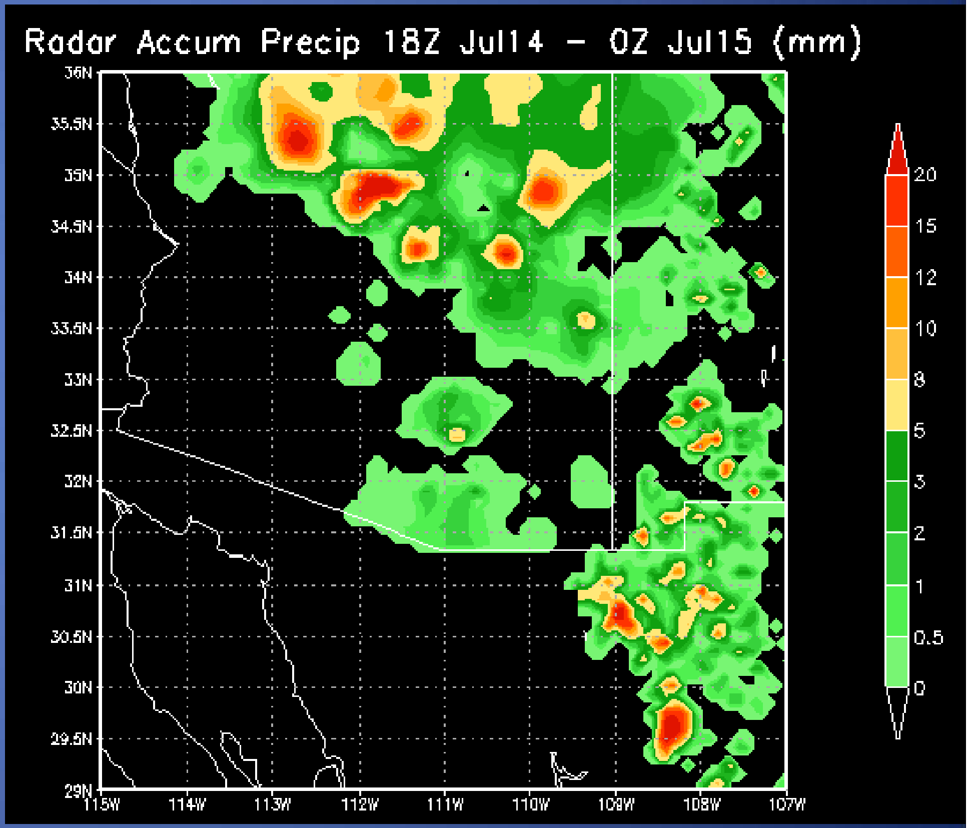




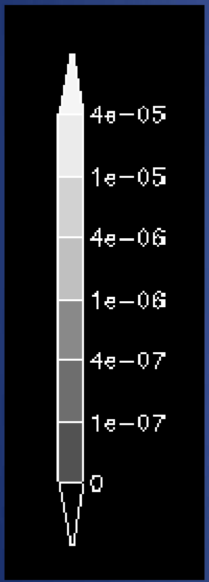
WRF vs. radar-derived precipitation

Late morning to late afternoon July 14

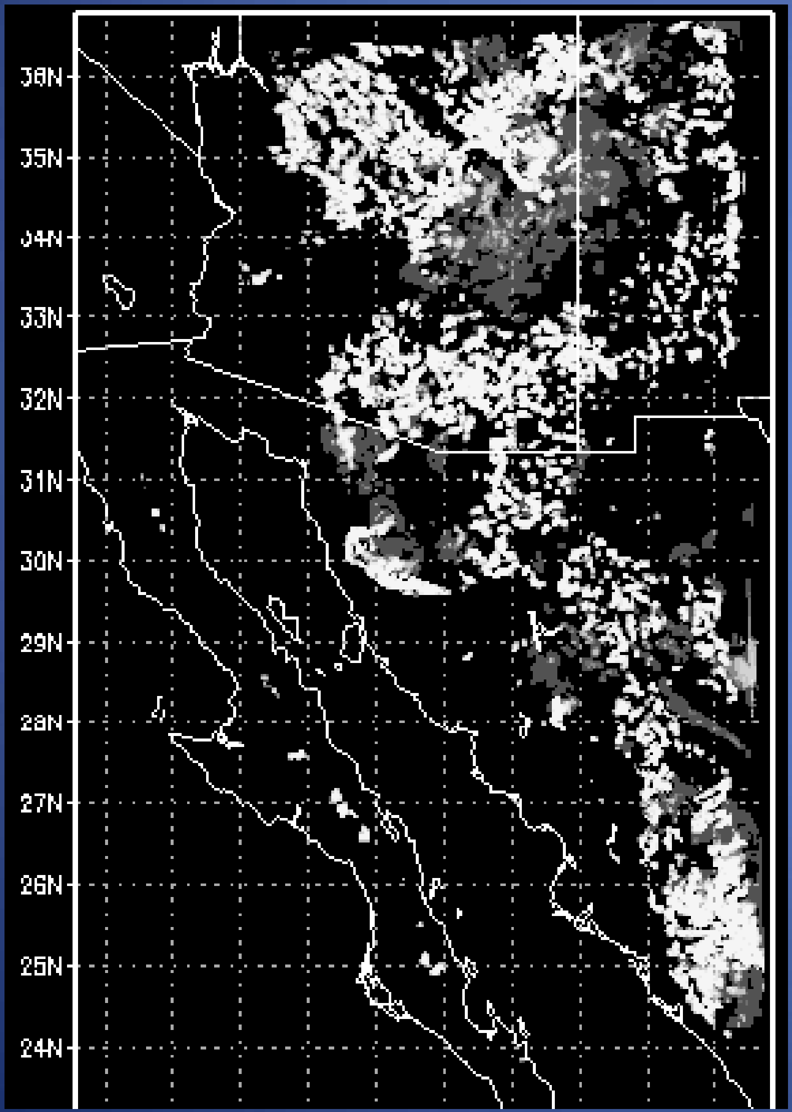


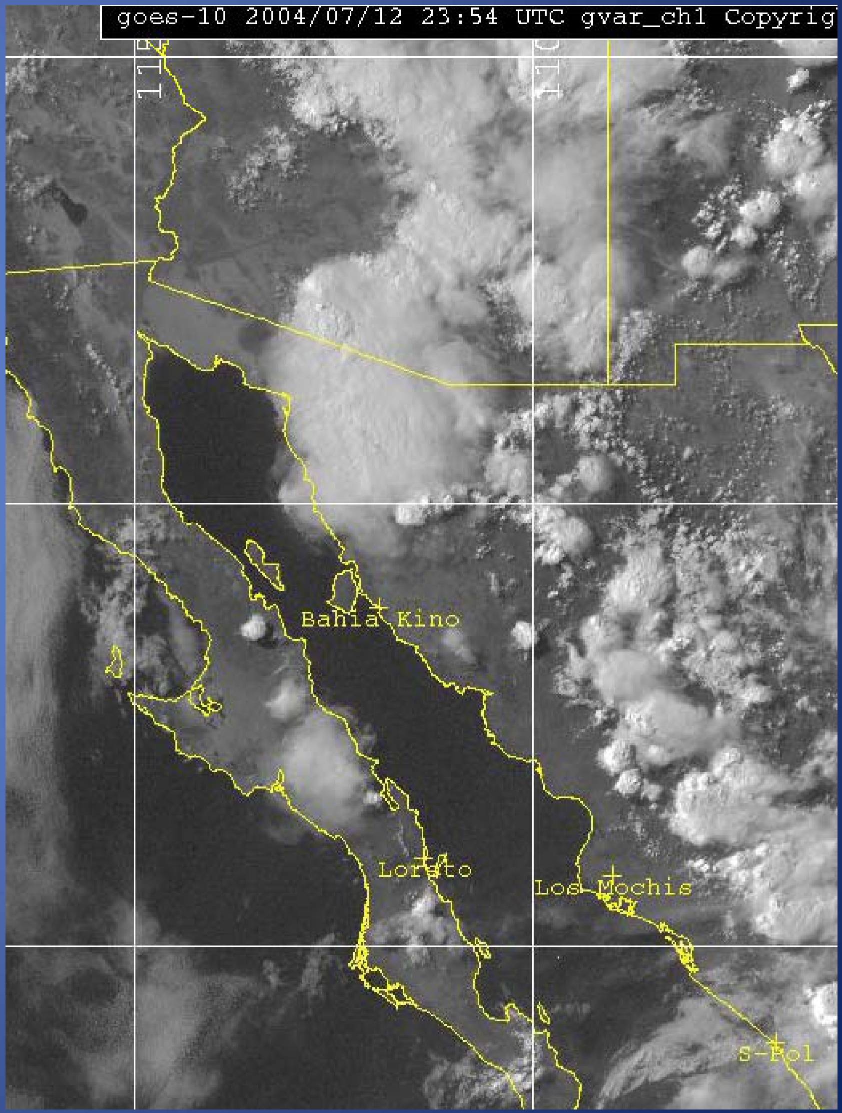


Cloud Mixing Ratio vs. GOES 10 Visible
5 PM July 12

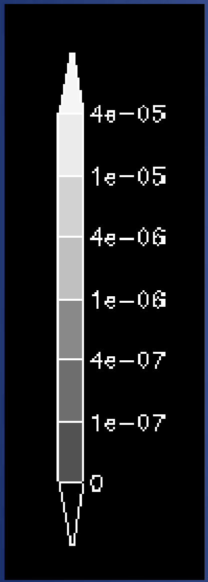


(kg/kg)





Cloud Mixing Ratio vs. GOES 10 Visible
8 AM July 13



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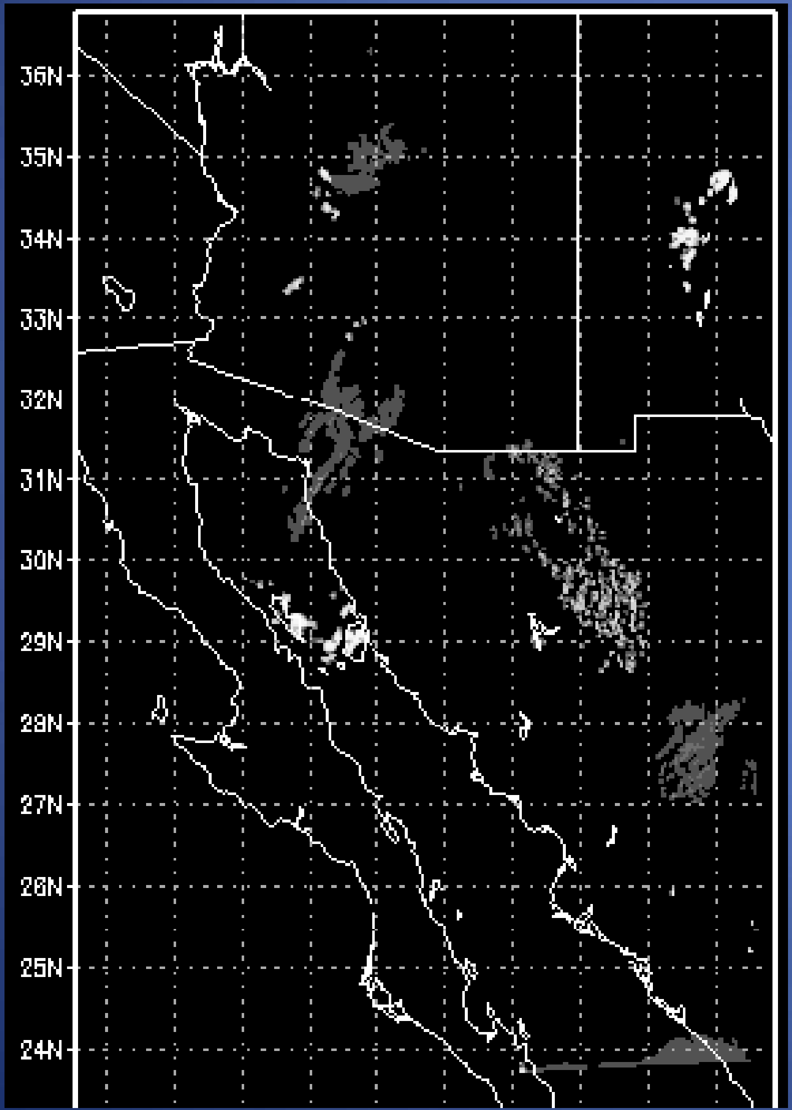
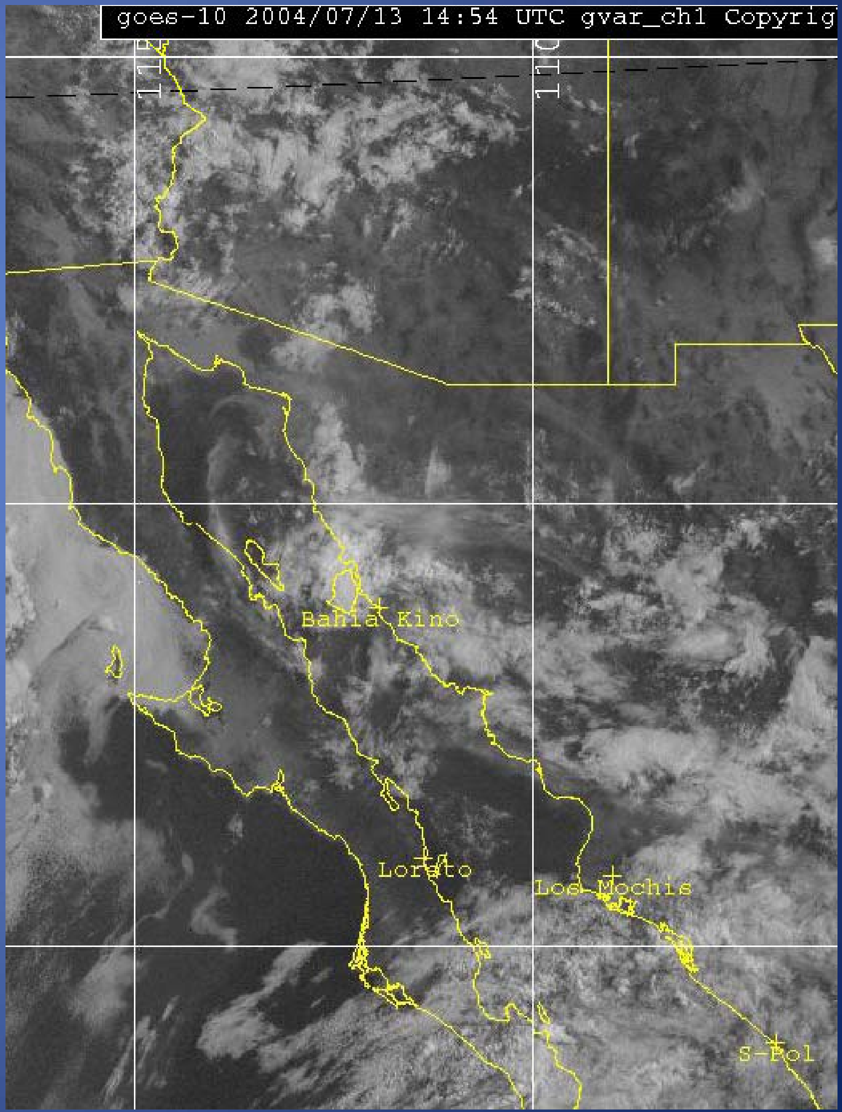
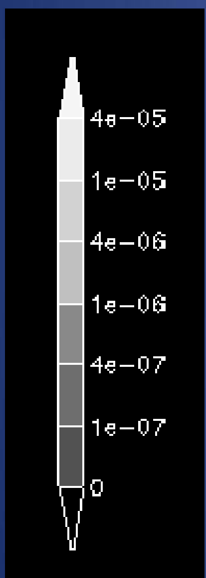
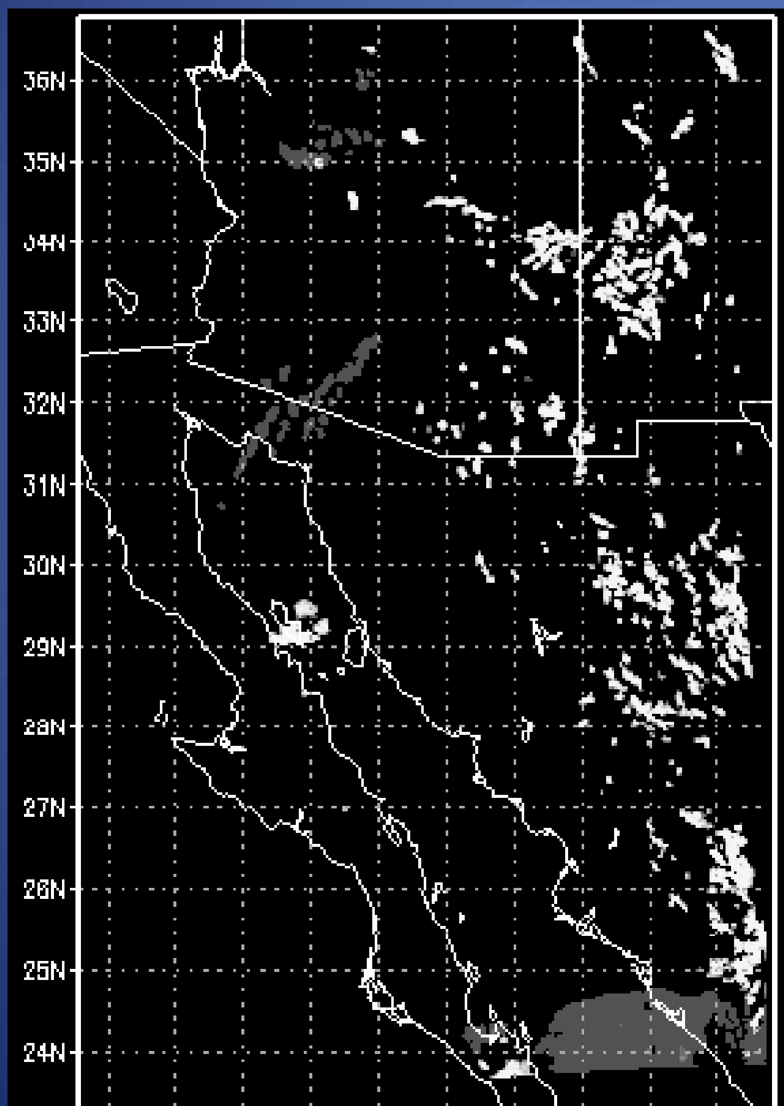


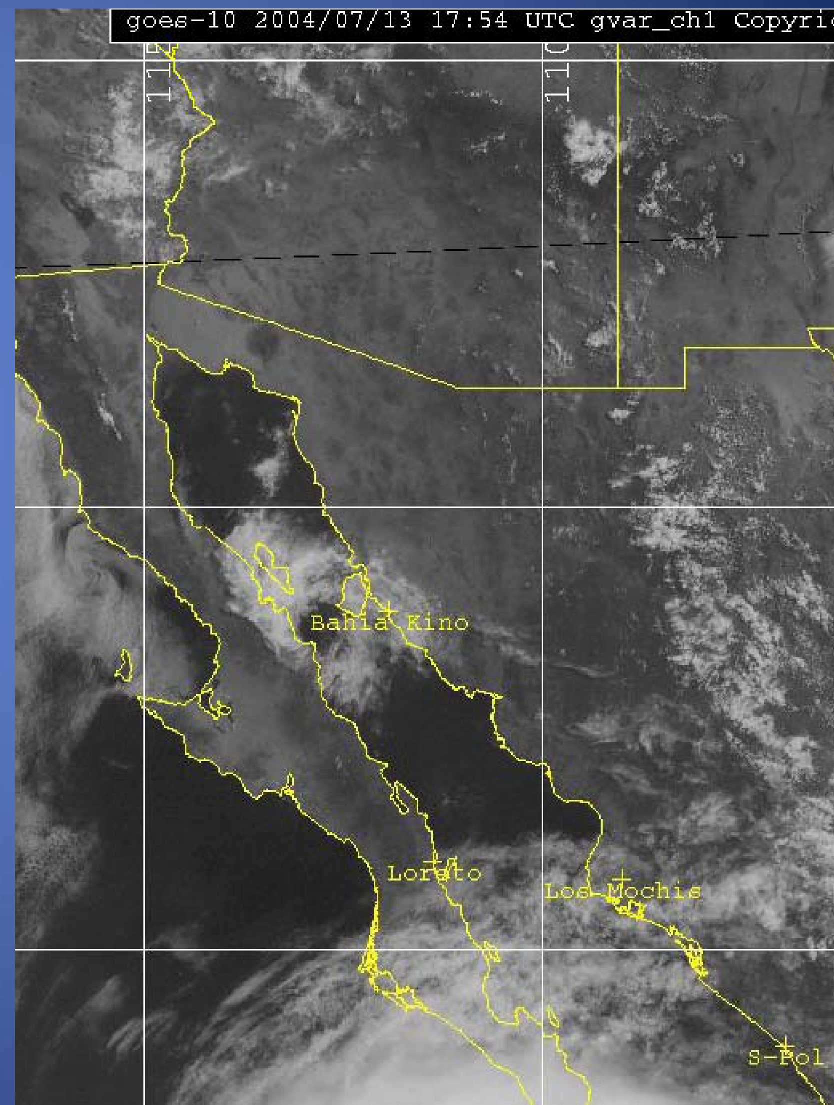


Cloud Mixing Ratio vs. GOES 10 Visible
11 AM July 13

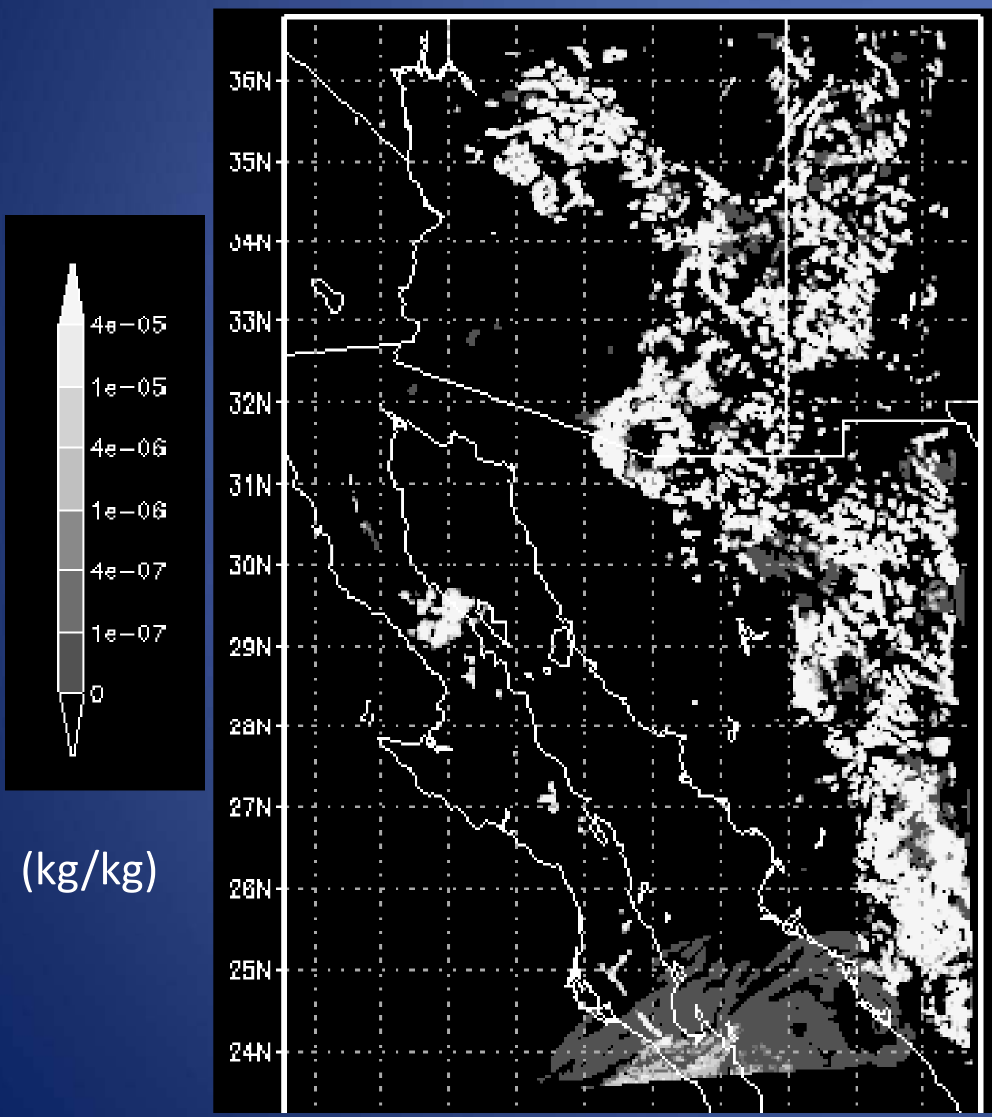


(kg/kg)

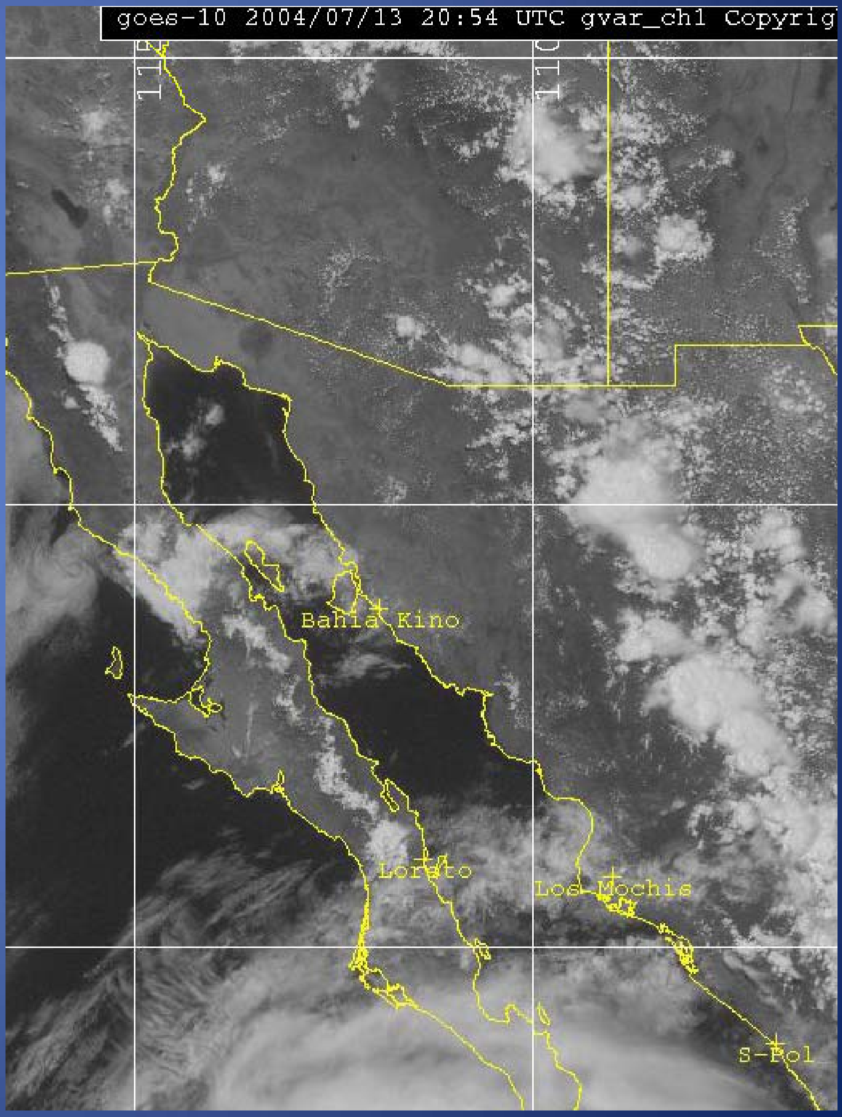




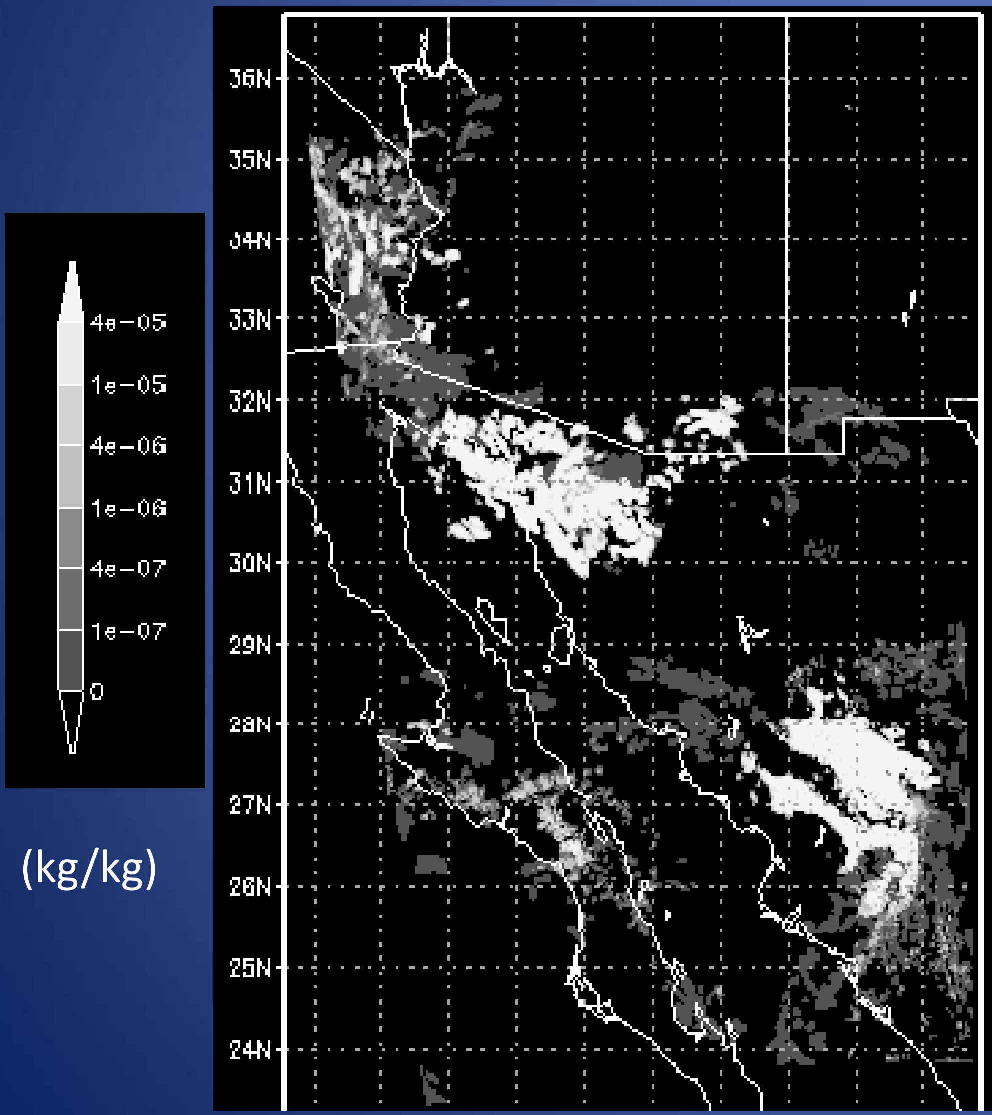
Cloud Mixing Ratio vs. GOES 10 Visible
2 PM July 13

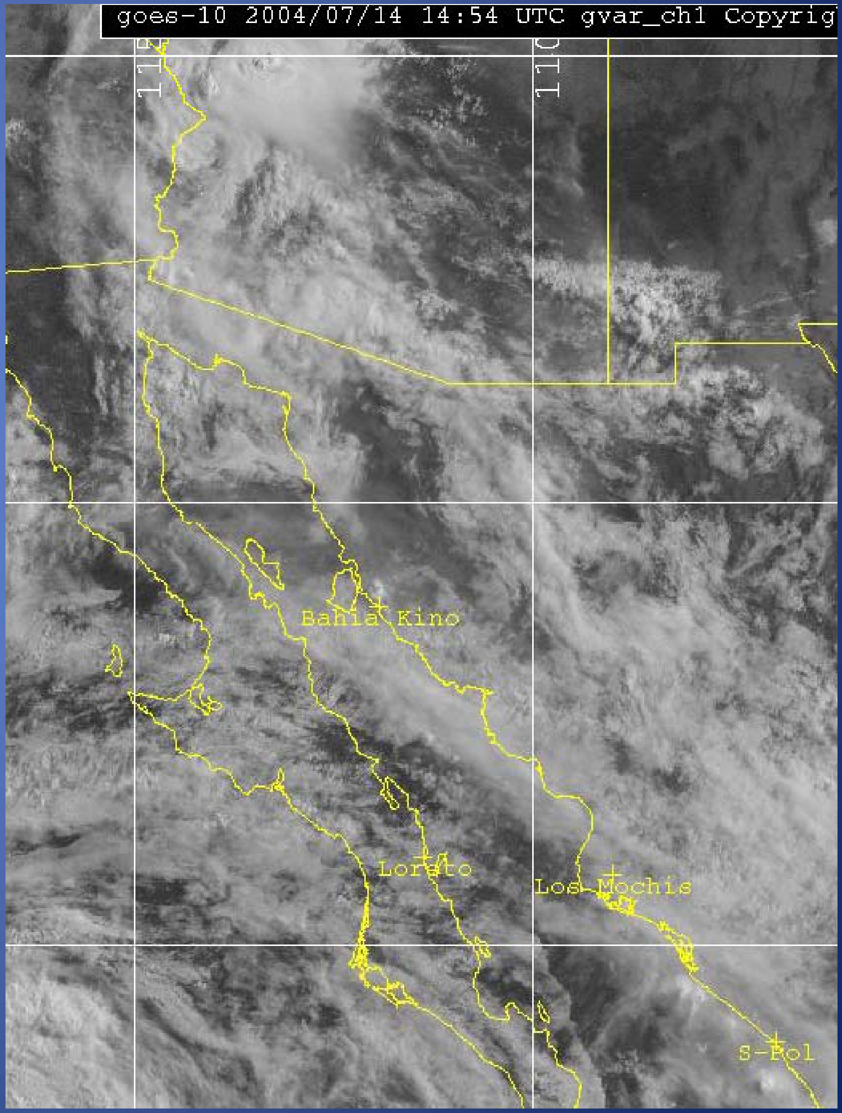


(kg/kg)

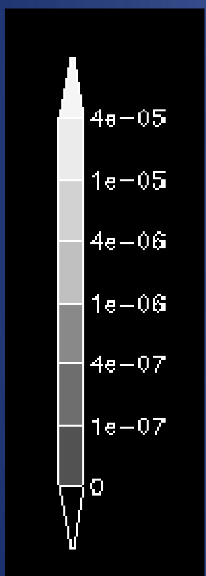


Cloud Mixing Ratio vs. GOES 10 Visible
8 AM July 14

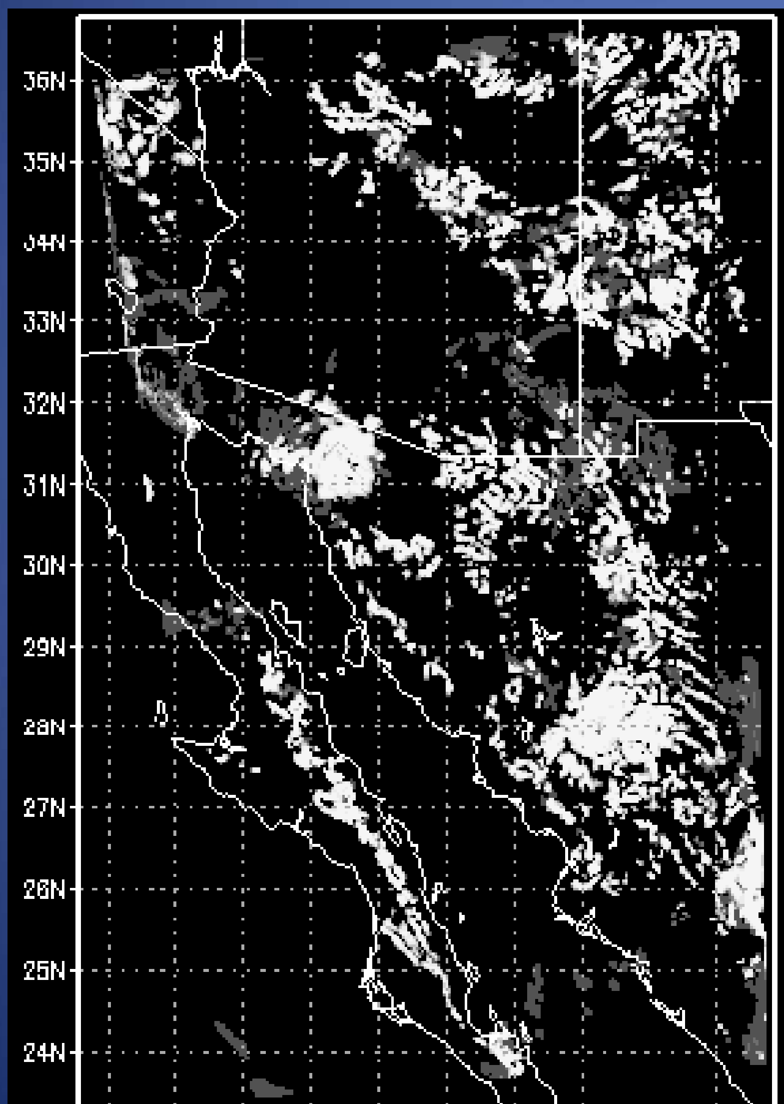


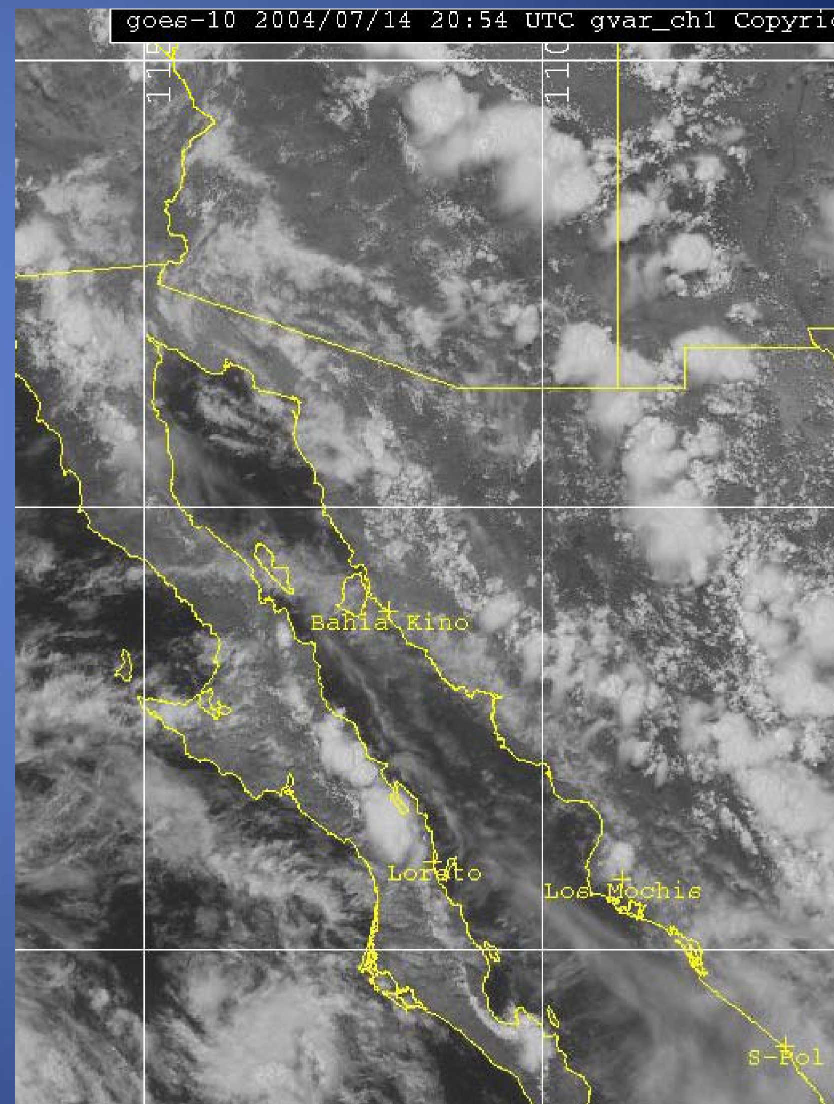


Cloud Mixing Ratio vs. GOES 10 Visible
2 PM July 14



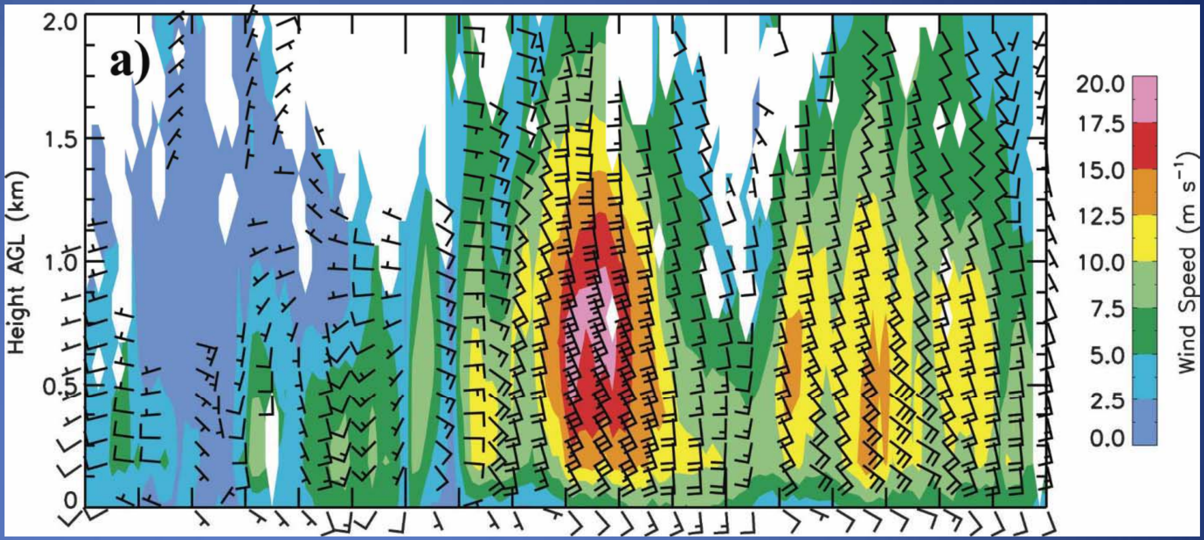
(kg/kg)



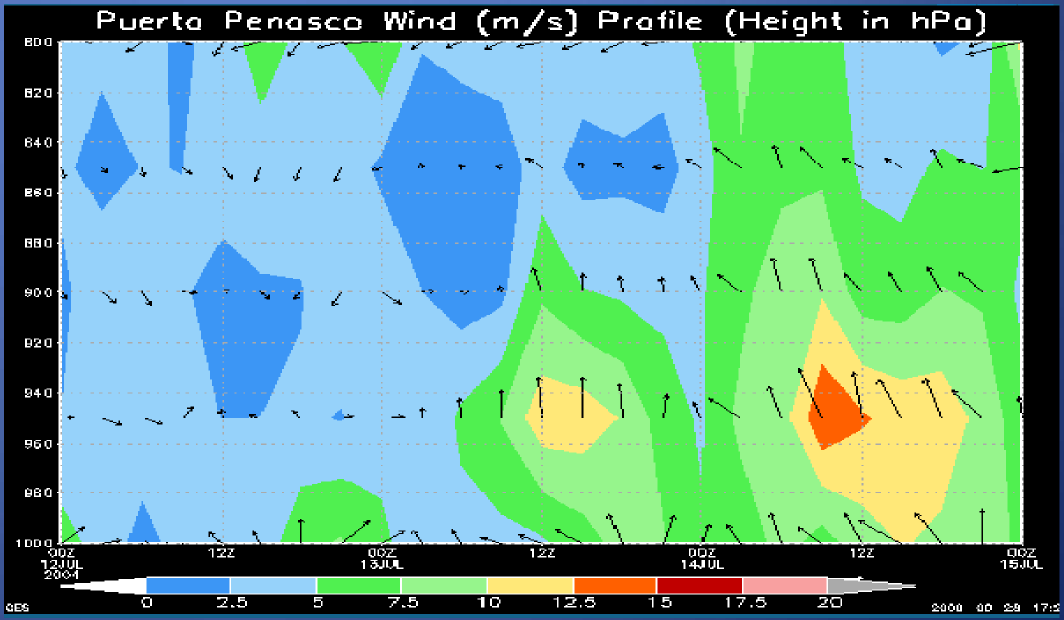


Puerto Peñasco Wind Profiles

- Provided by Rogers and Johnson:

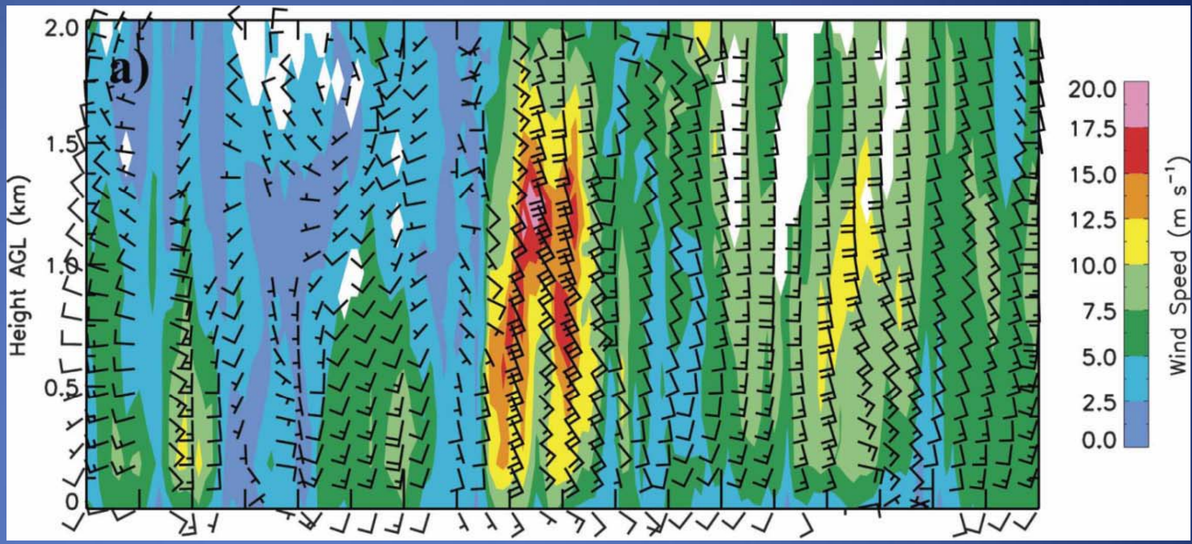


- Generated using WRF:



Bahia Kino Wind Profiles

- Provided by Rogers and Johnson:



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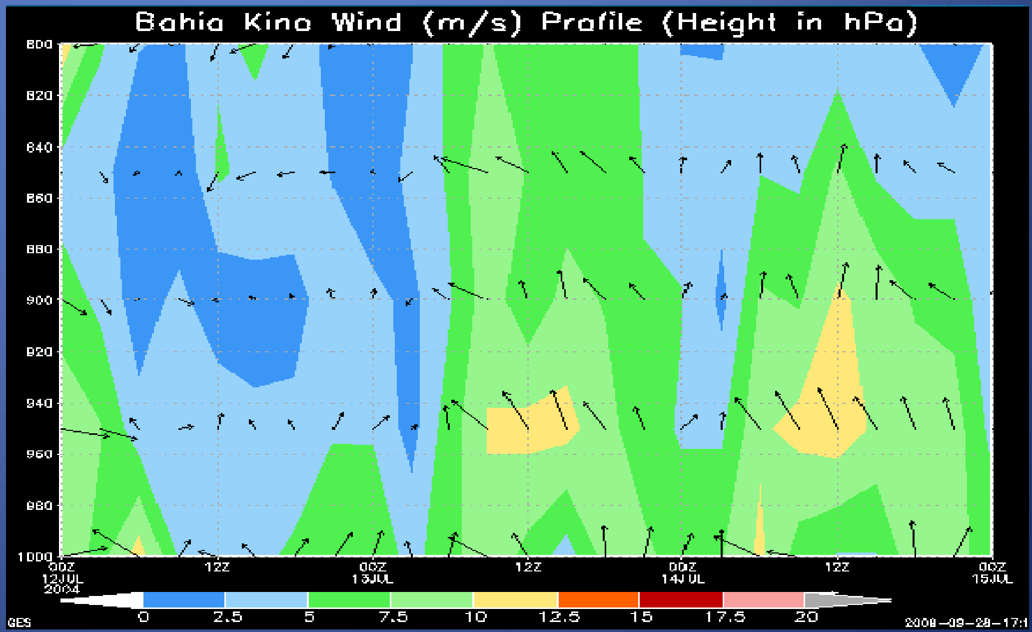


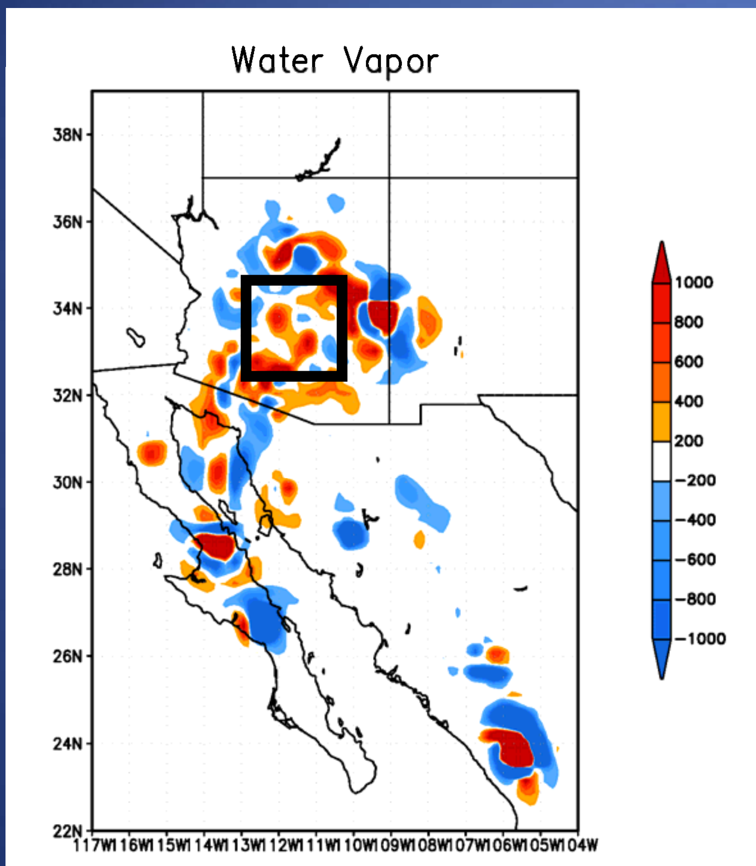
Concluding Points

- WRF does a reasonable job modeling the event according to the previously specified metrics.
- This run will serve as a starting point for improvement through eventual assimilation of NAME data (upper-air soundings)
- Long-term goal is improved real-time monsoon forecasts at high resolution.

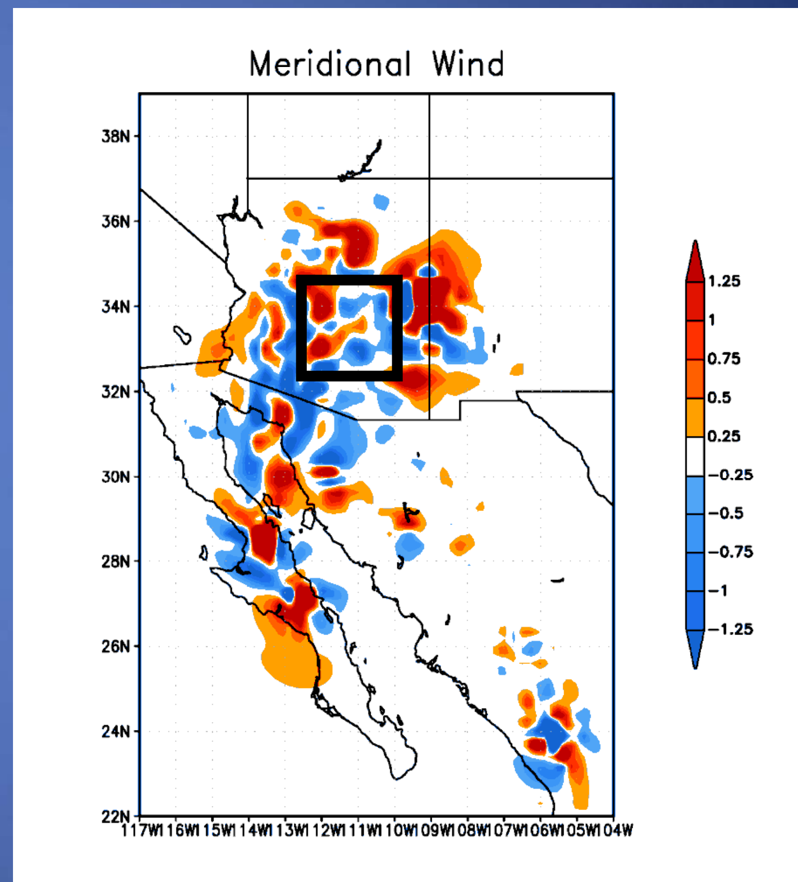
Future work

- Simulation of a few more IOPs and further analysis
- Determine sensitivity of the forecast to specification of initial conditions, through the use of new WRF adjoint model. Adjoint integrates a linearized version of the model backwards to determine areas of greatest sensitivity. Already done for a test case of severe monsoon weather event in Phoenix in August 2005.
- Use these results to guide assimilation of NAME upper-air data in IOP simulations and a long-term monsoon observing system.

Adjoint sensitivity of low-level winds in Phoenix area to initial conditions



Units: $m^2 s^{-2} kg kg^{-1}$



Units: $m s^{-1}$