A SURVEY OF NAME IOPS 2, 5, AND 6 USING WRF

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ATMOSPHERIC SCIENCES
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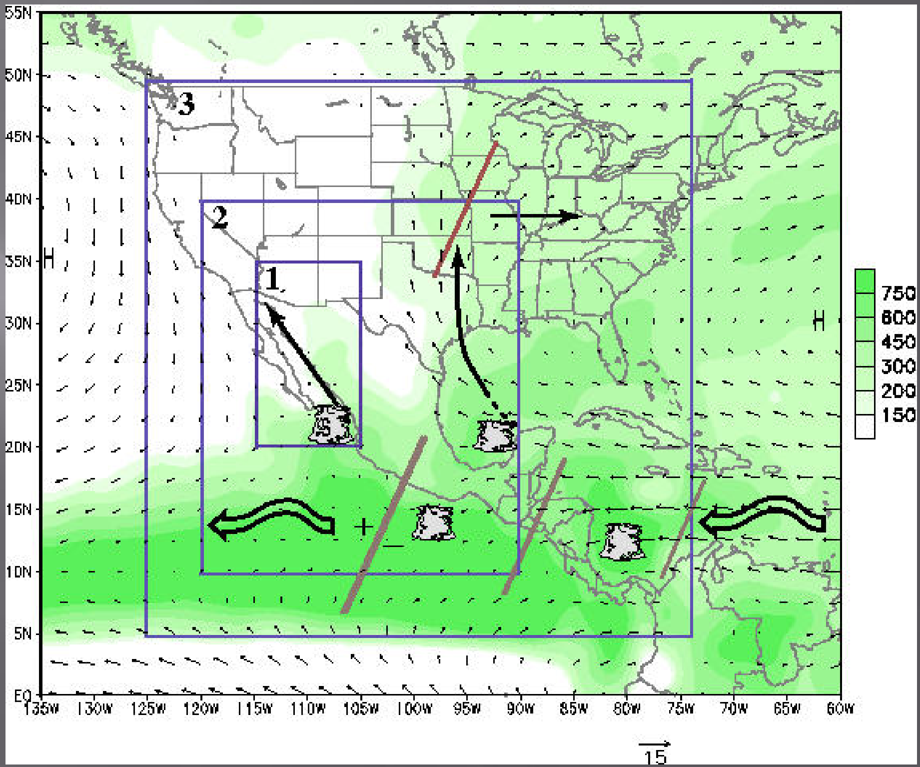
Presentation Outline

- Background on North American Monsoon Experiment (NAME) and Intensive Observing Periods (IOPs)
- Description and assessment of IOP 2 – Blas case
- Description and assessment of IOP 5
- Description and assessment of IOP 6
- Concluding points
- Future work

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)

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)

Soil Data Initialization from North American Regional Reanalysis (NARR)

WRF Domain Setup

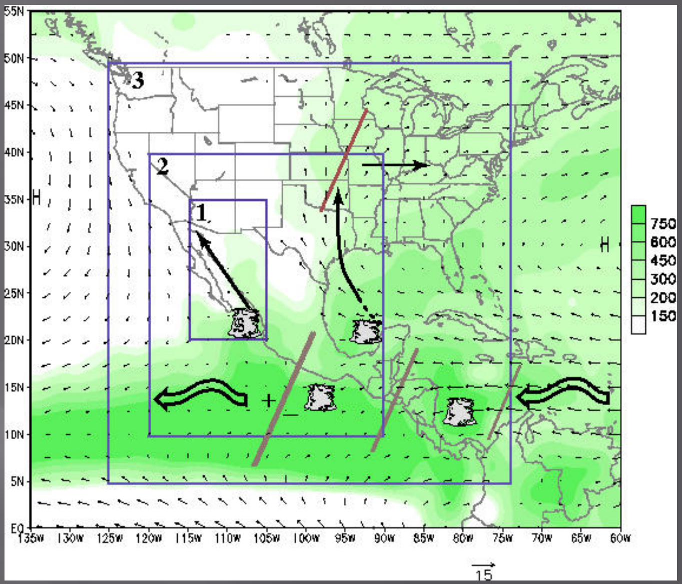
(Approximately matches NAME Tier Regions)

Domain 3: Continental

132x134 at 30km resolution

Domain 2: Regional

265x262 at 10km resolution



Domain 1: Core monsoon region

573x345 at 2.5km resolution

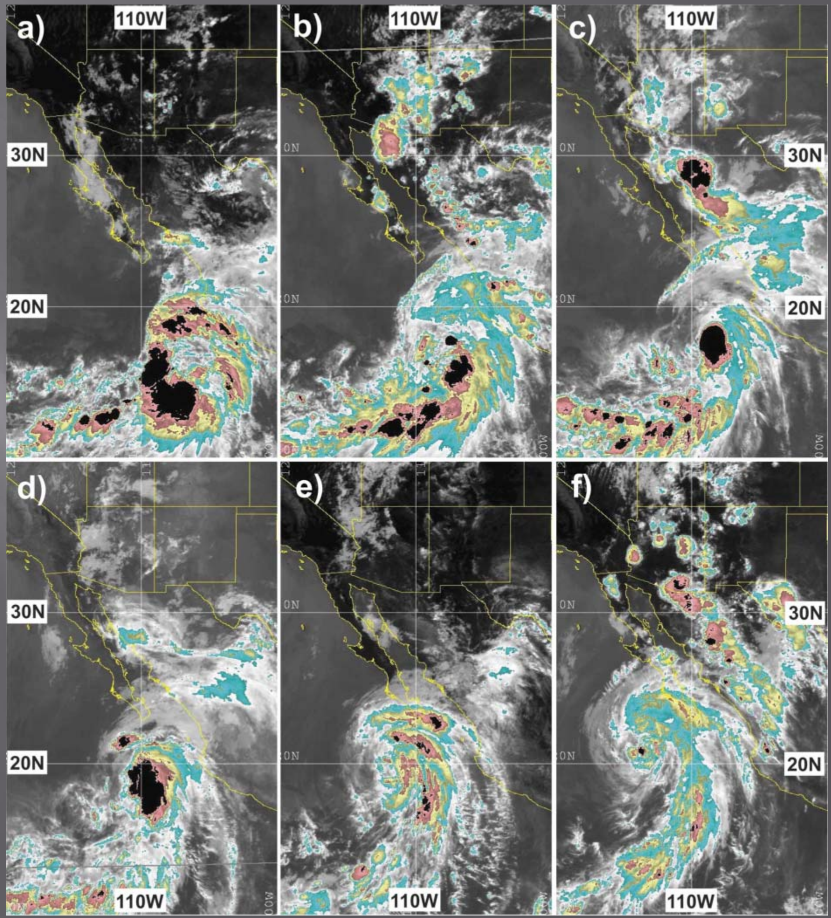
*Scale of greatest interest since resolving convection.

WRF Physics
(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*

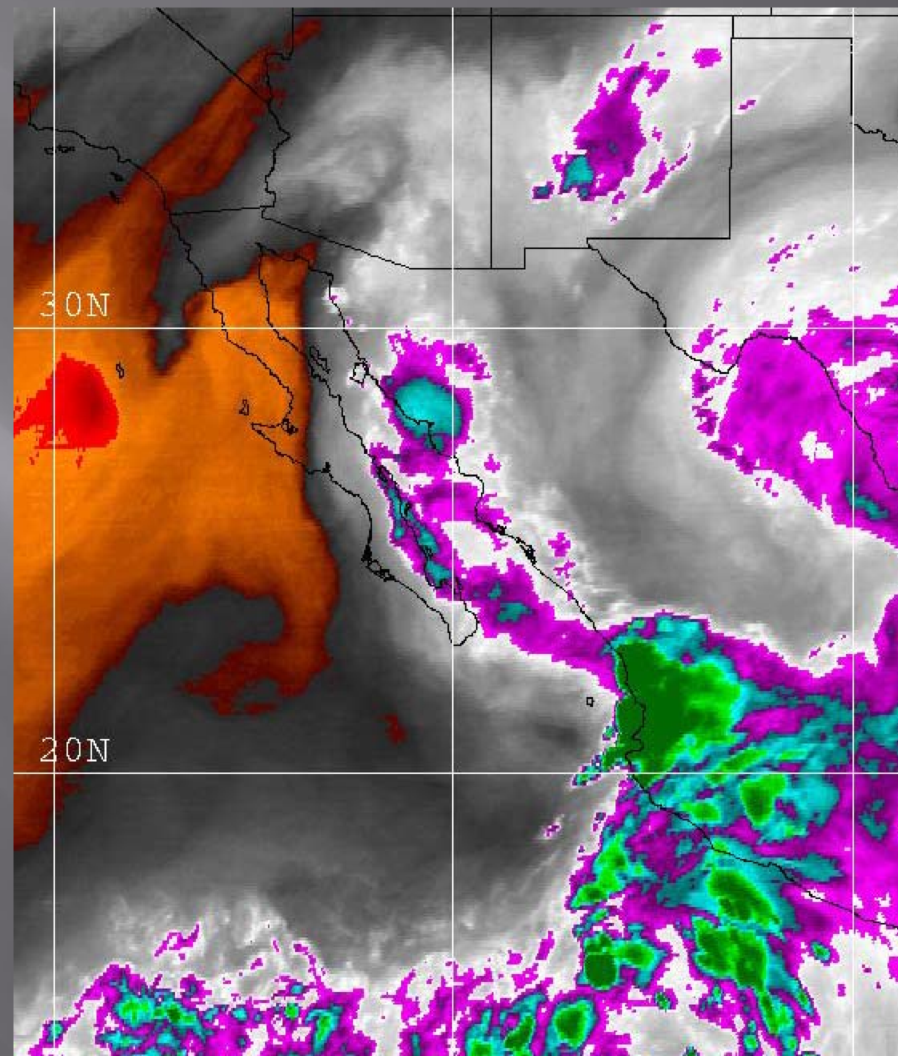
IOP 2

- 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



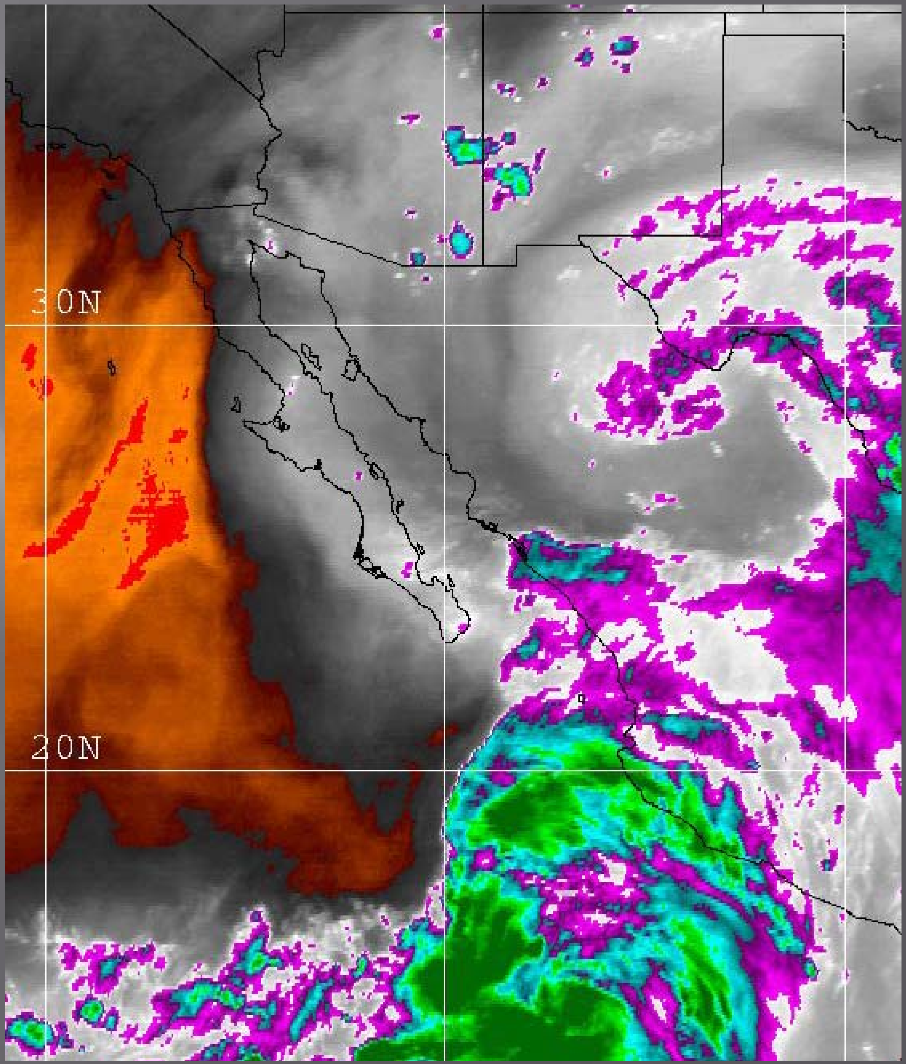
IOP 2
Sunday Night

- Diurnal convection develops
- Propagated west by strong midlevel easterly flow



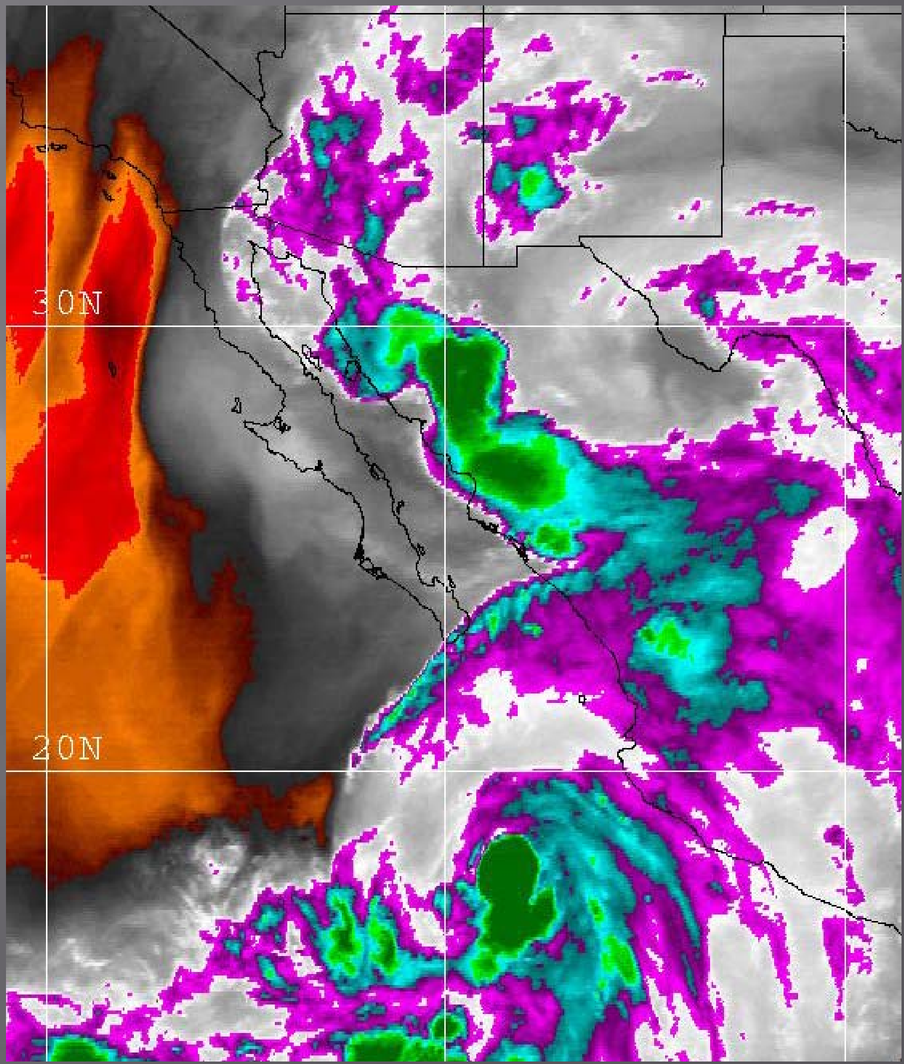
IOP 2
Monday Midday

- Convection dissipated
- No surge – may be due to weak pressure grad along gulf
- TS Blas developing



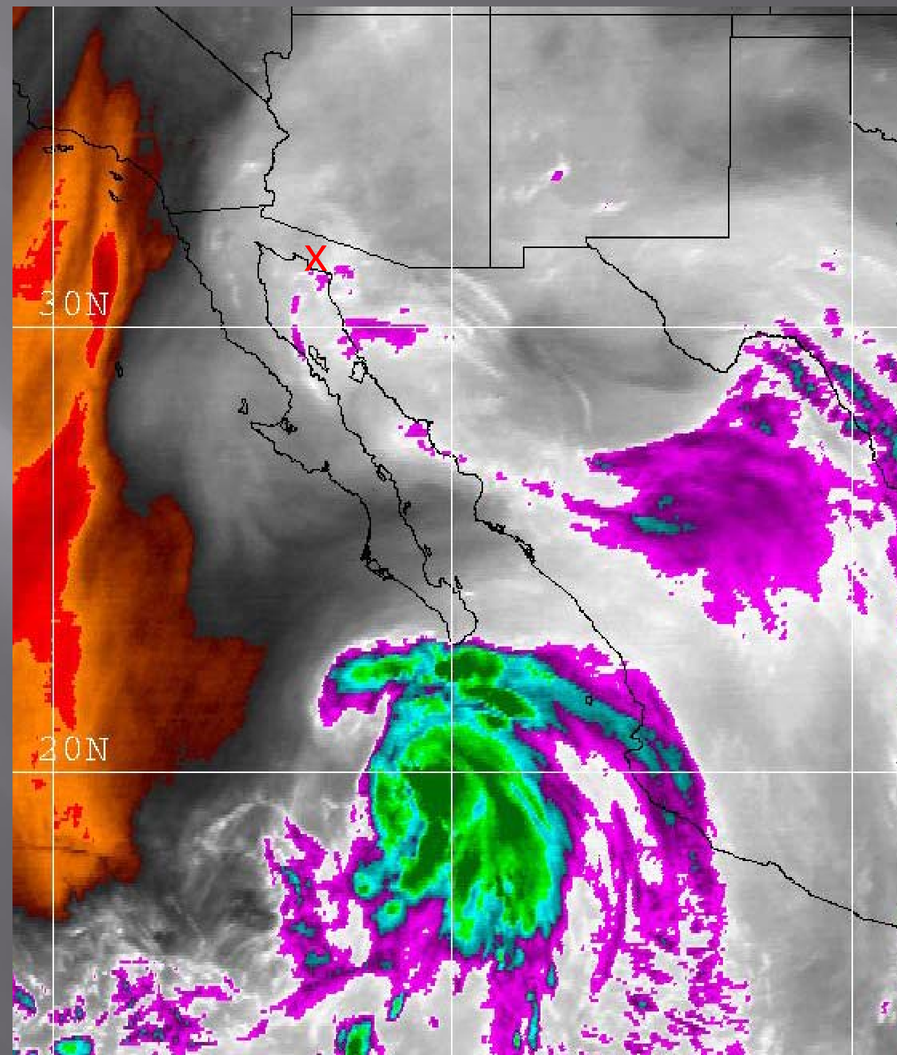
IOP 2
Monday Night

- Strong convection over coastal plains of Sonora
- Blas moving west – pressure rises in southern gulf



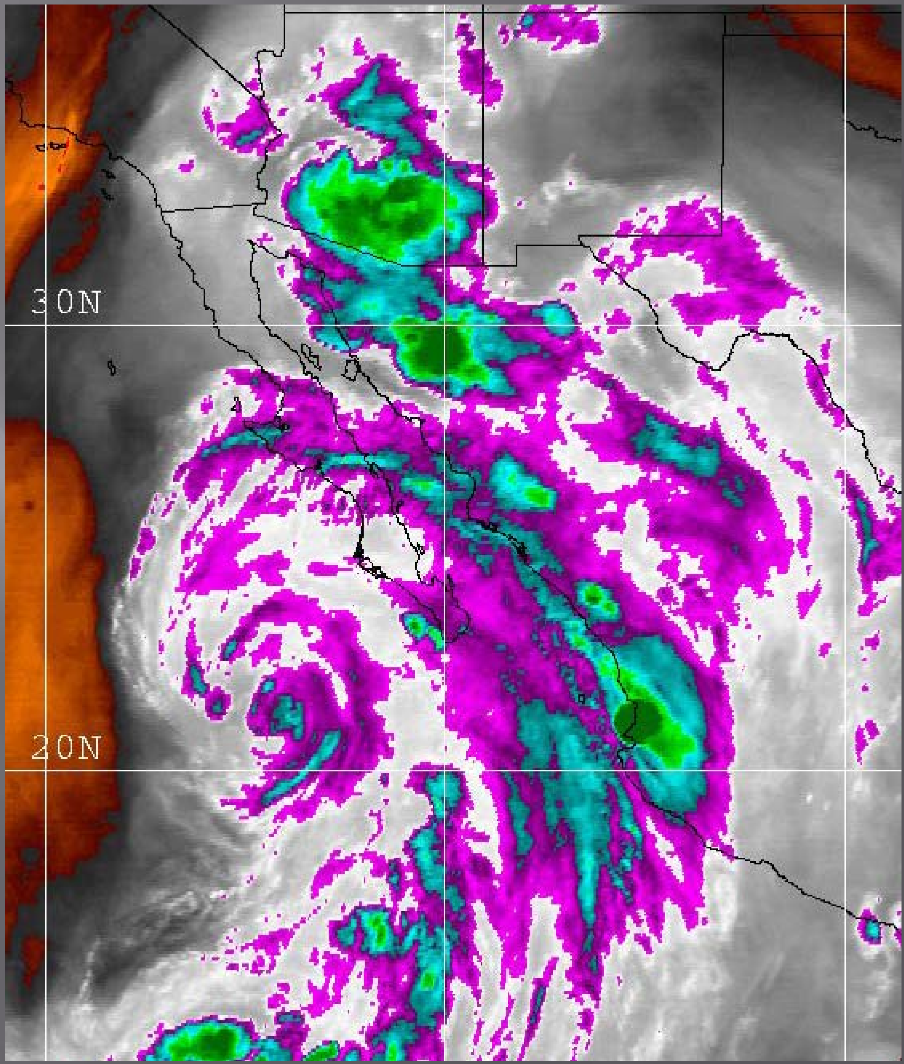
IOP 2
Tuesday Midday

- Dissipation of diurnal convection
- Surge moving up gulf
- Winds peak - Penasco



IOP 2
Tuesday Night

- Strong southerly winds at Yuma with increase in dewpoint
- Strong convection blow up in AZ



IOP 2 Simulation Metrics

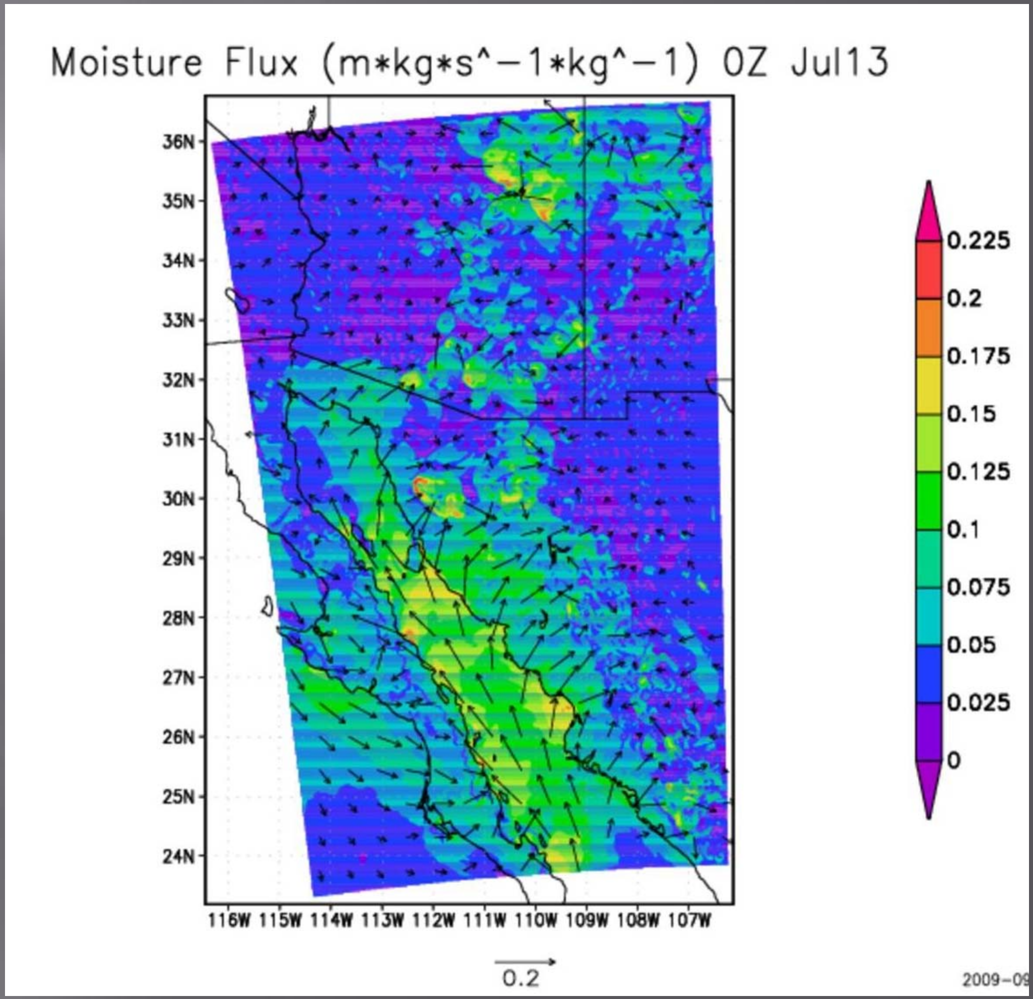
- Surface moisture flux associated with gulf surge
- Precipitation development, MCS organization and propagation
- Reasonable timing and geographic location of these salient meteorological features

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

Gulf Surge 5 PM July 12

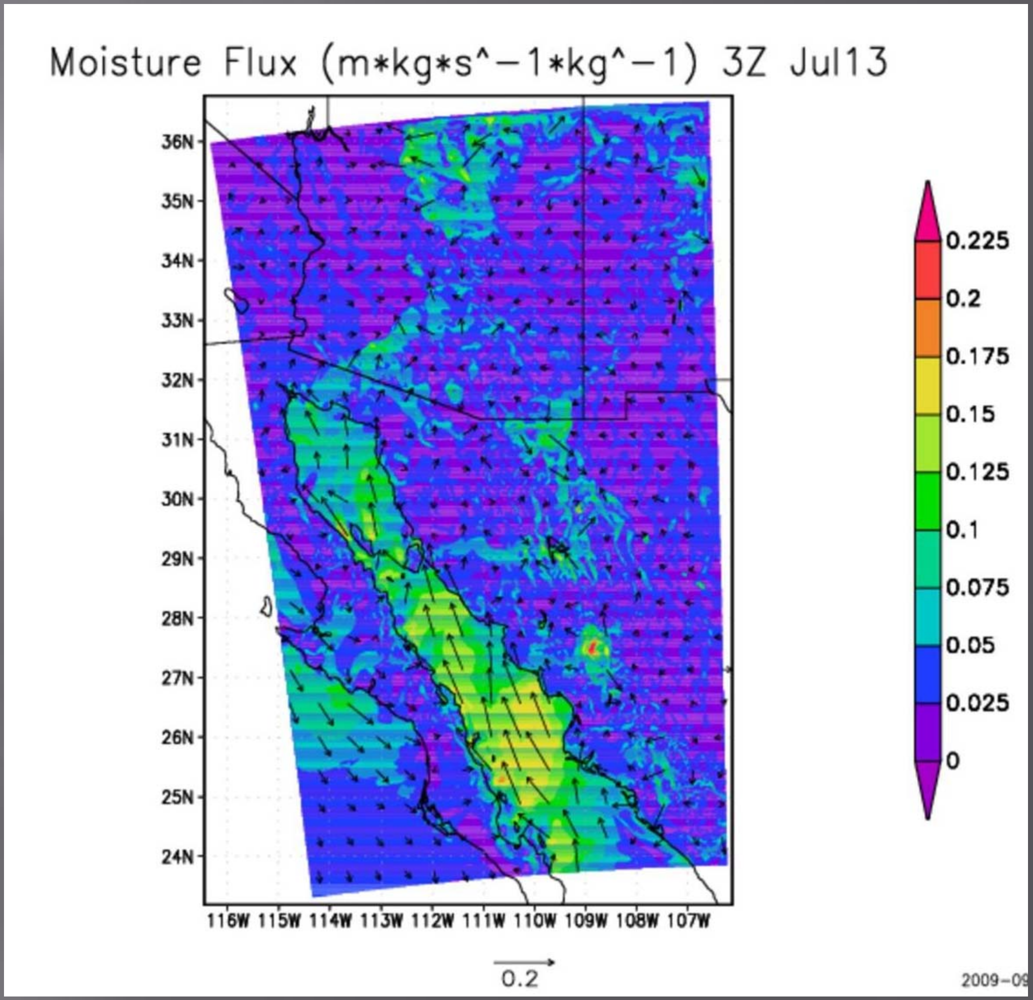
- Pre surge
- Surge signature located at the mouth of GOC

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



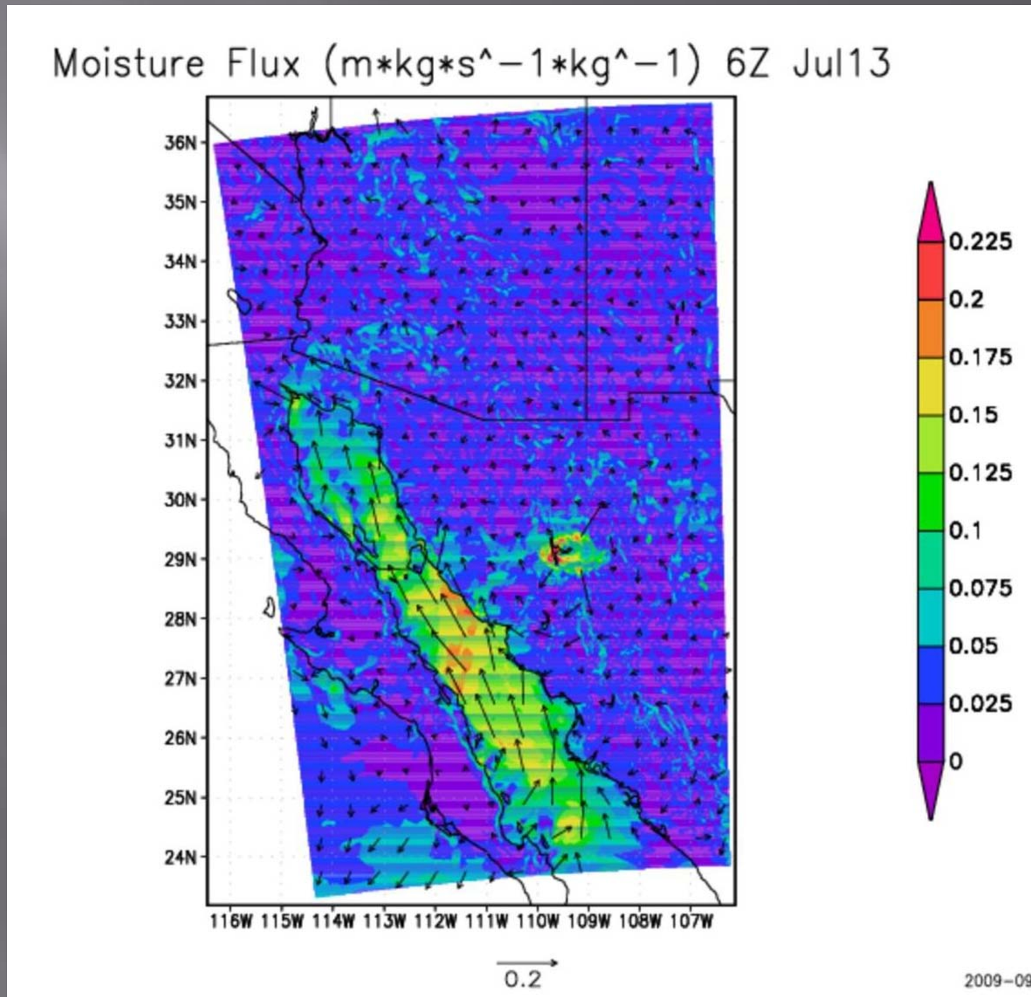
Gulf Surge 8 PM July 12

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



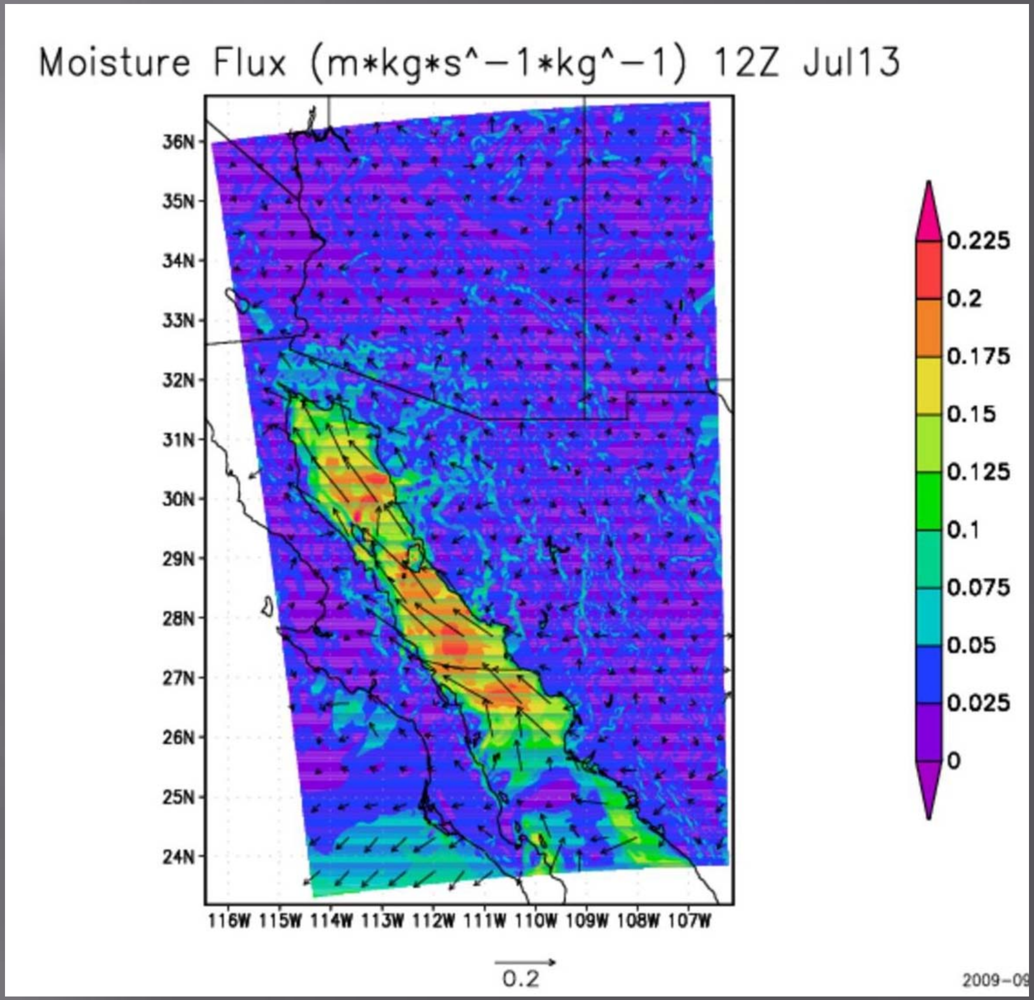
Gulf Surge 11 PM July 12

- Surge signature further north with stronger fluxes



Gulf Surge 5 AM July 13

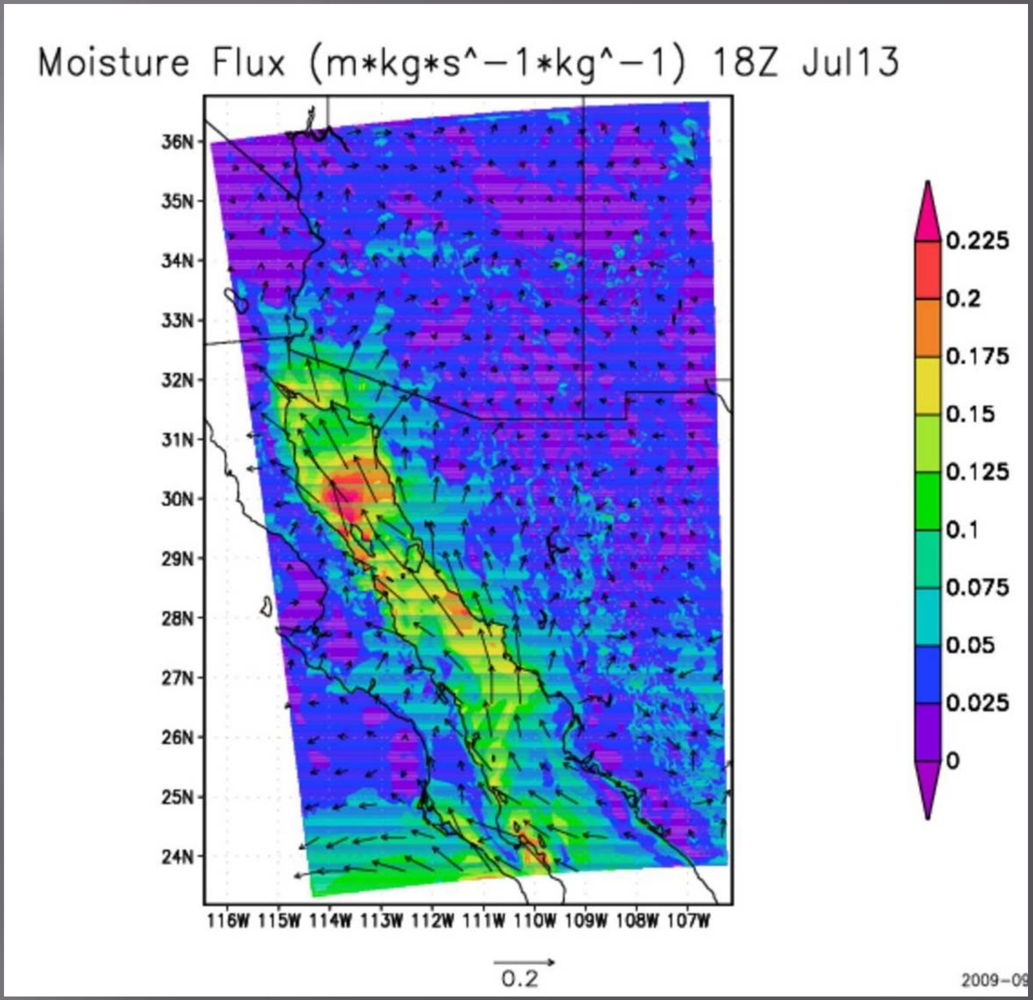
- Surge reaches northern gulf
- Positive moisture flux centered about Bahia Kino



Gulf Surge 11 AM July 13

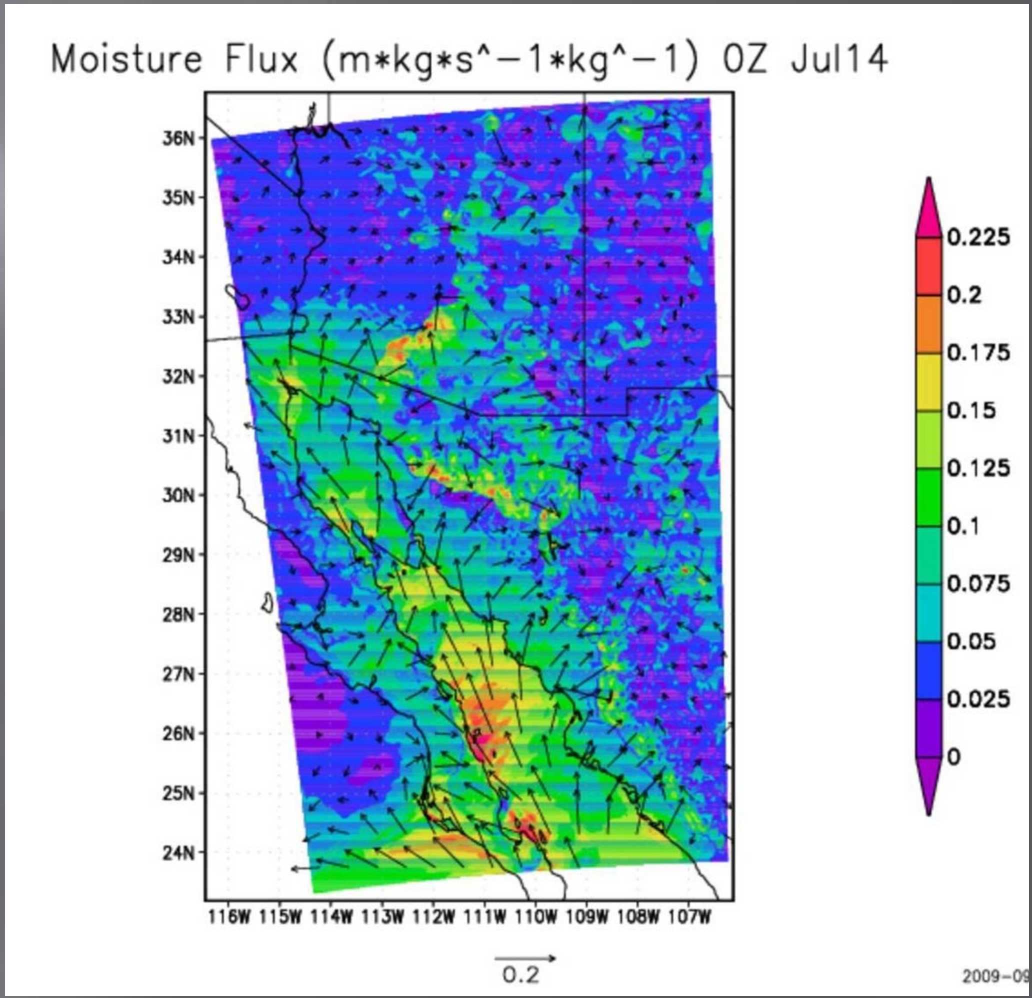
- Surge confined to northern gulf
- TS Blas starts to come into view

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!



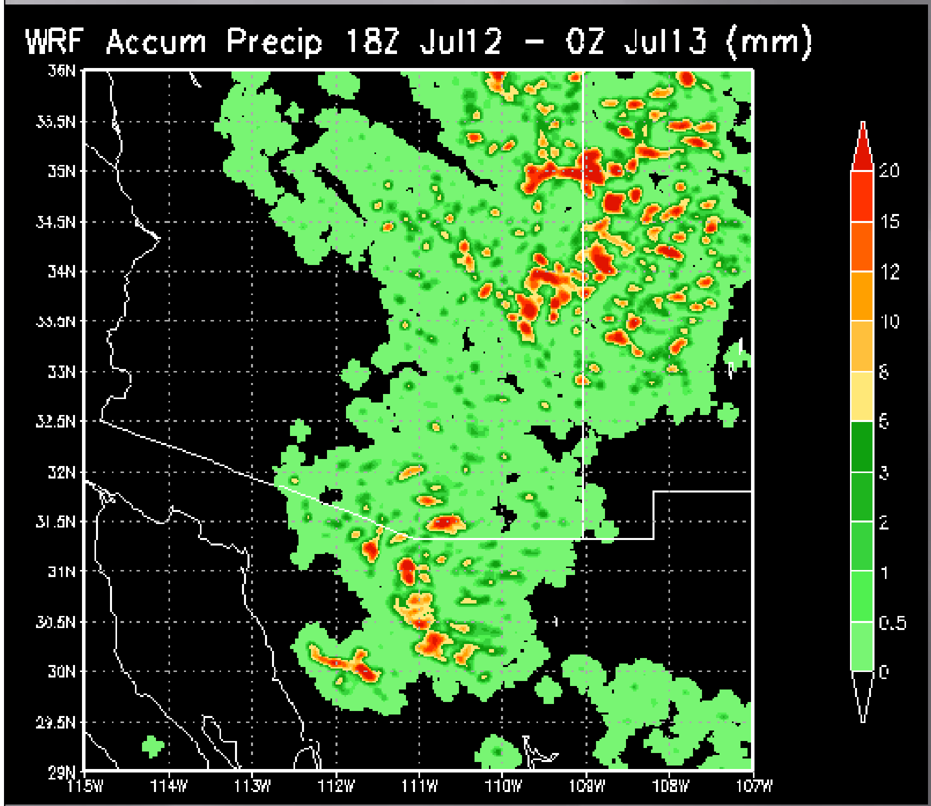
Gulf Surge 5 PM July 13

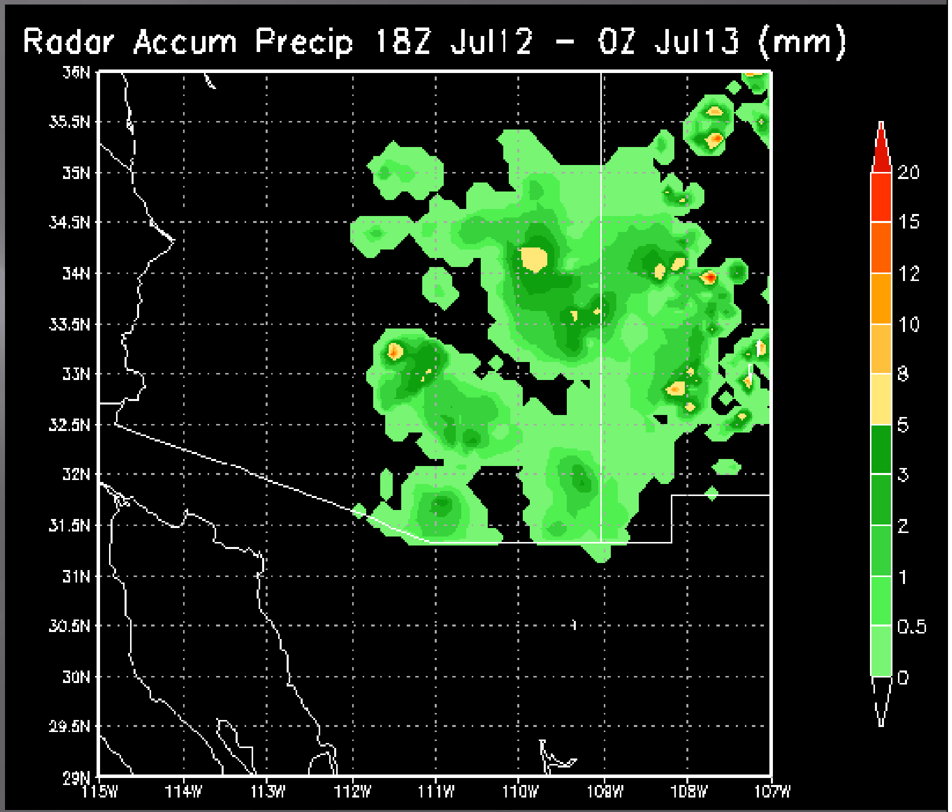
- Surge signature gone
- Moisture flux over south GoC result of Blas



WRF vs. radar-derived precipitation

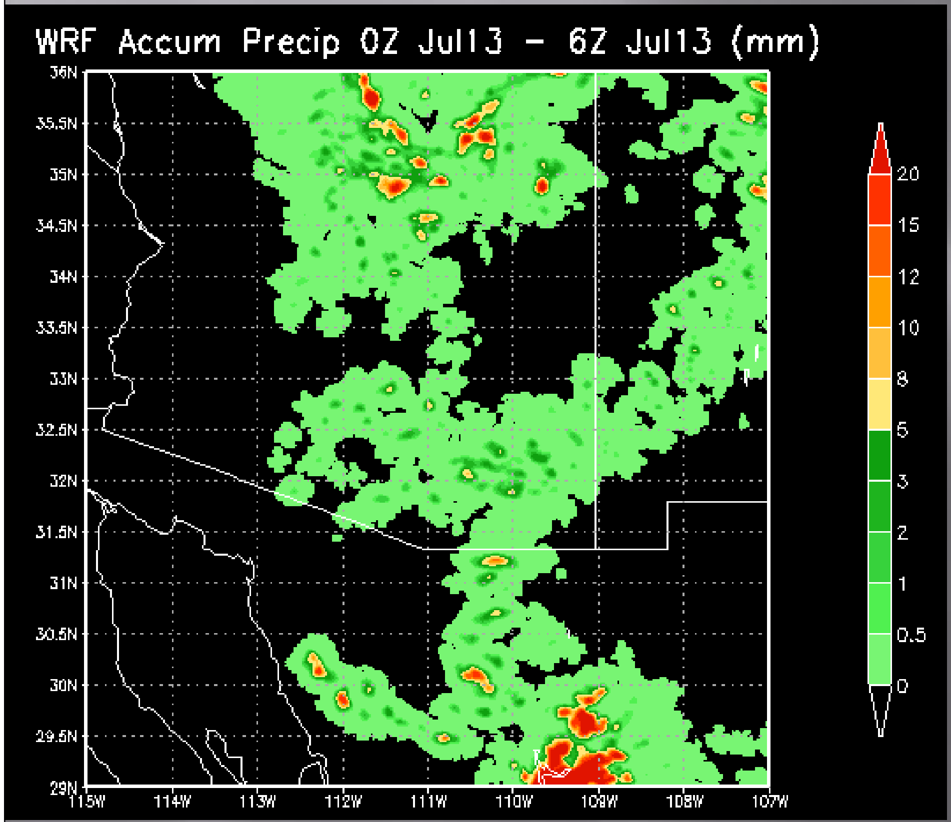
Late morning to late afternoon July 12

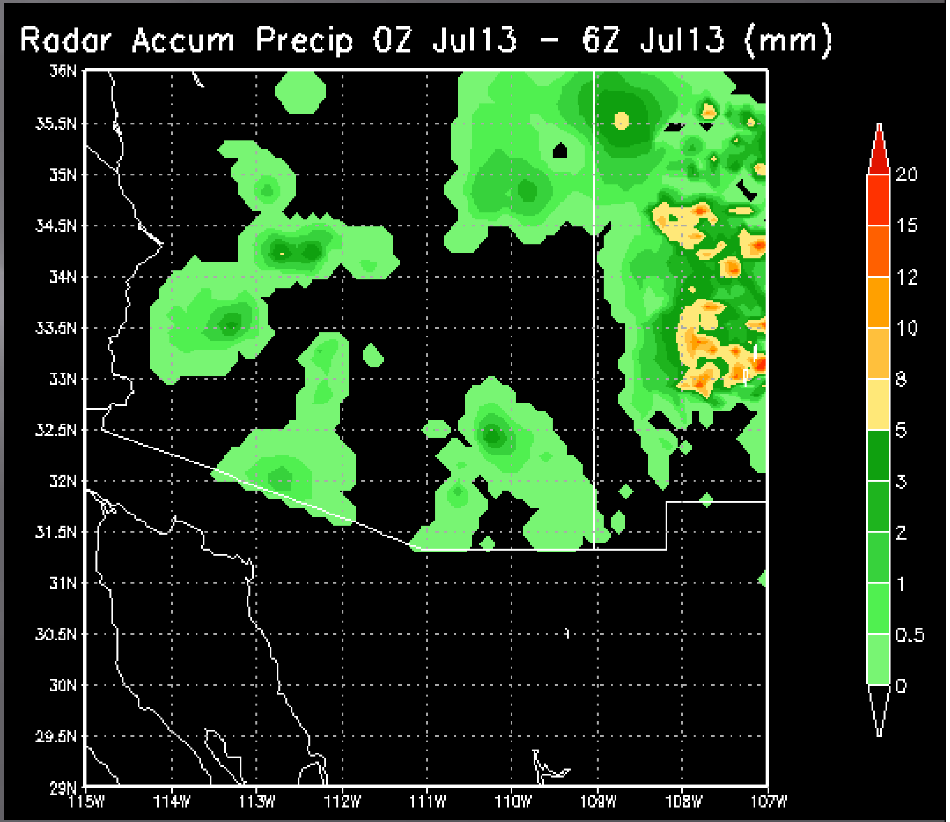




WRF vs. radar-derived precipitation

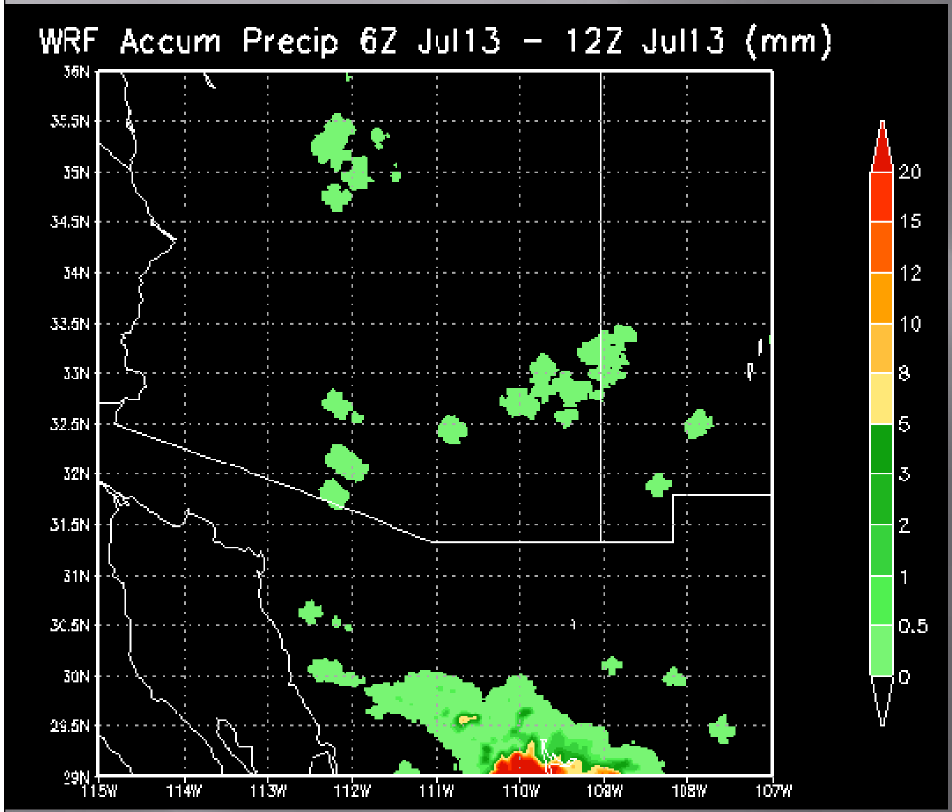
Late afternoon to late evening July 12

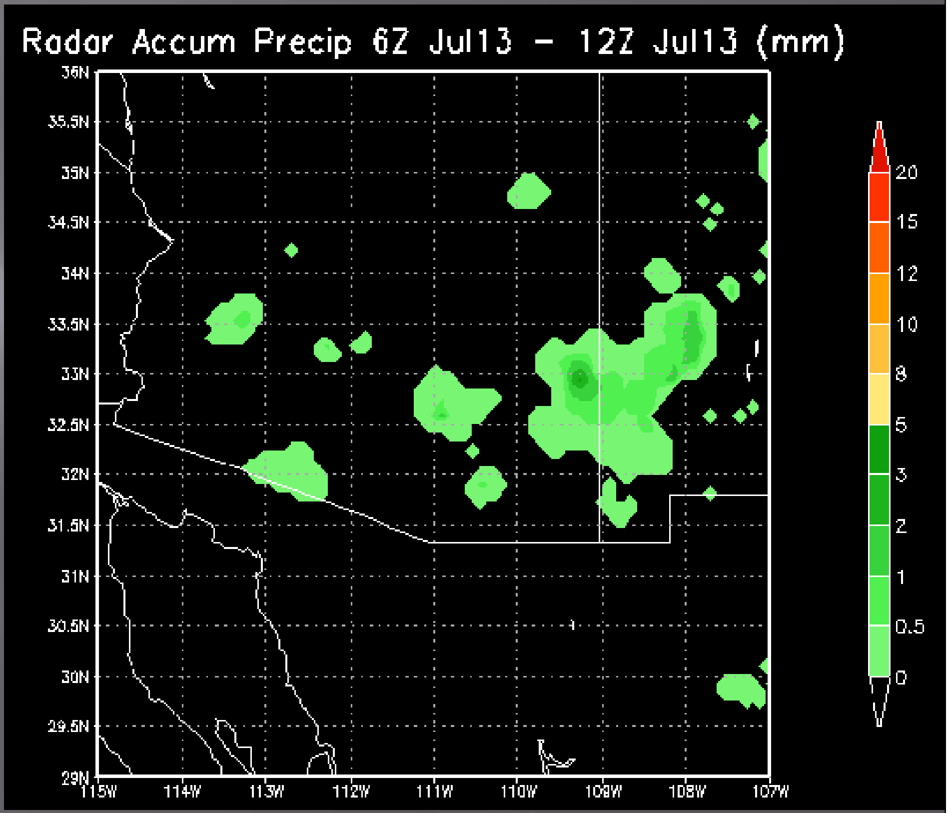




WRF vs. radar-derived precipitation

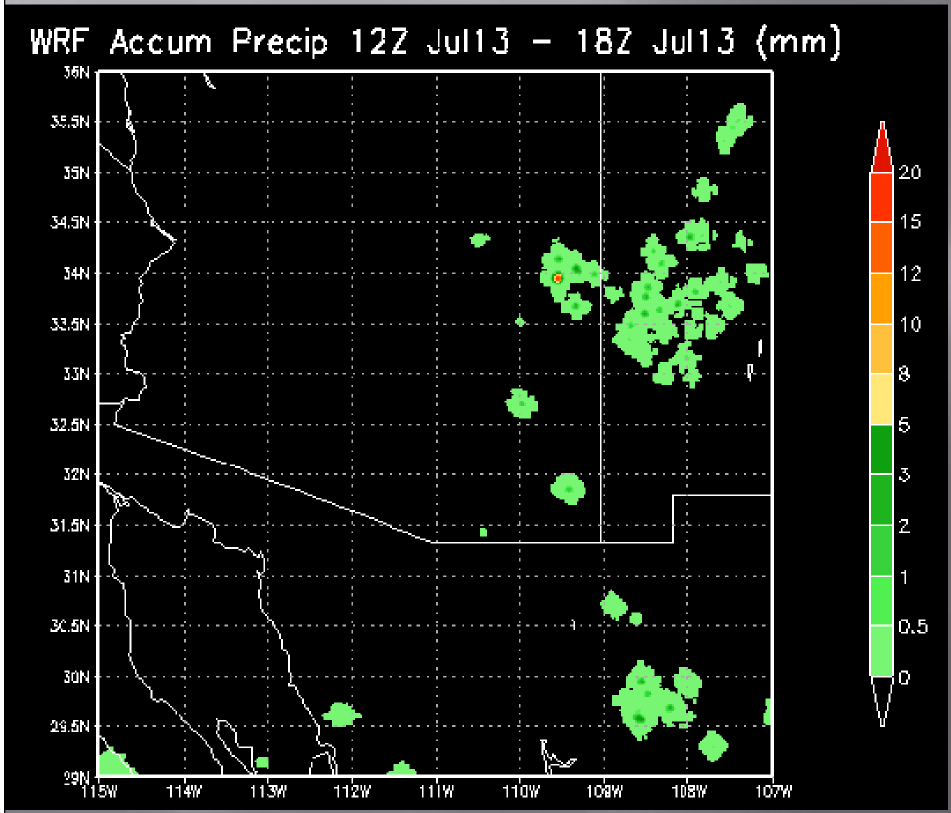
Late evening July 12 to early morning July 13

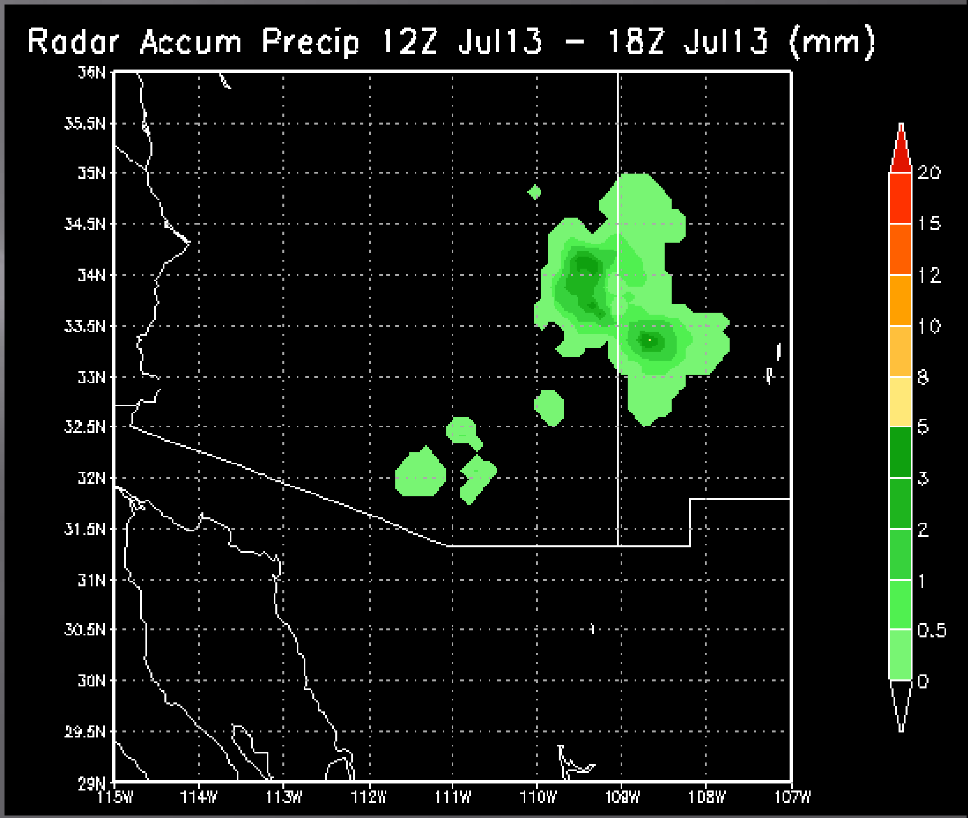




WRF vs. radar-derived precipitation

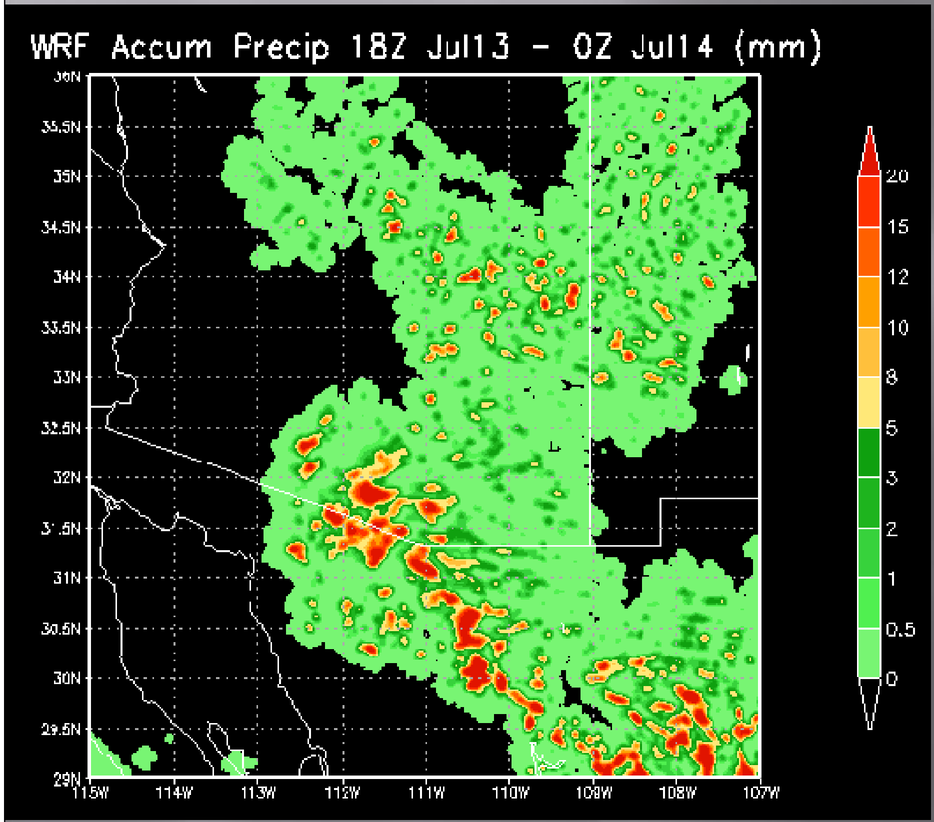
Early morning to late morning July 13

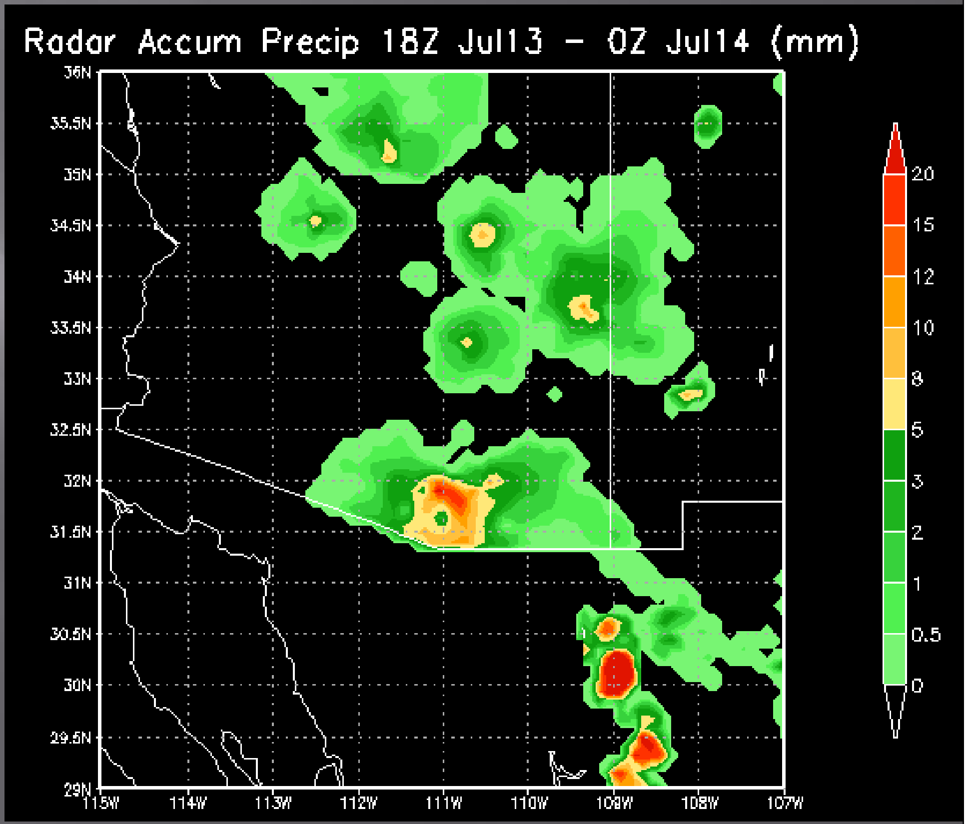




WRF vs. radar-derived precipitation

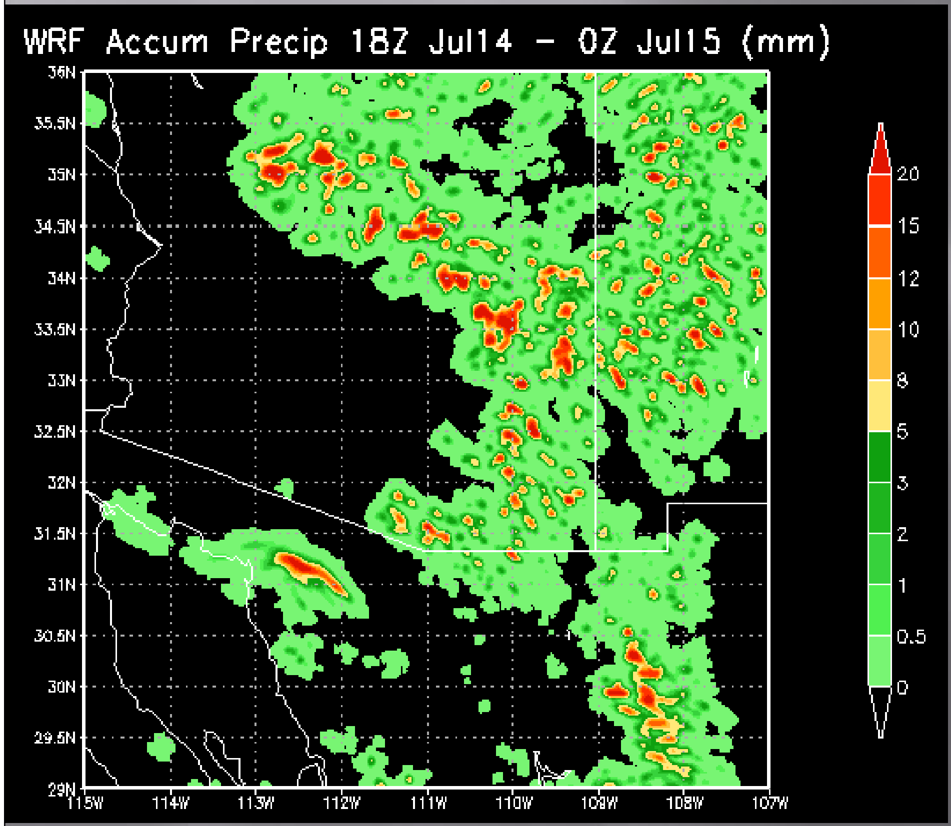
Late morning to late afternoon July 13

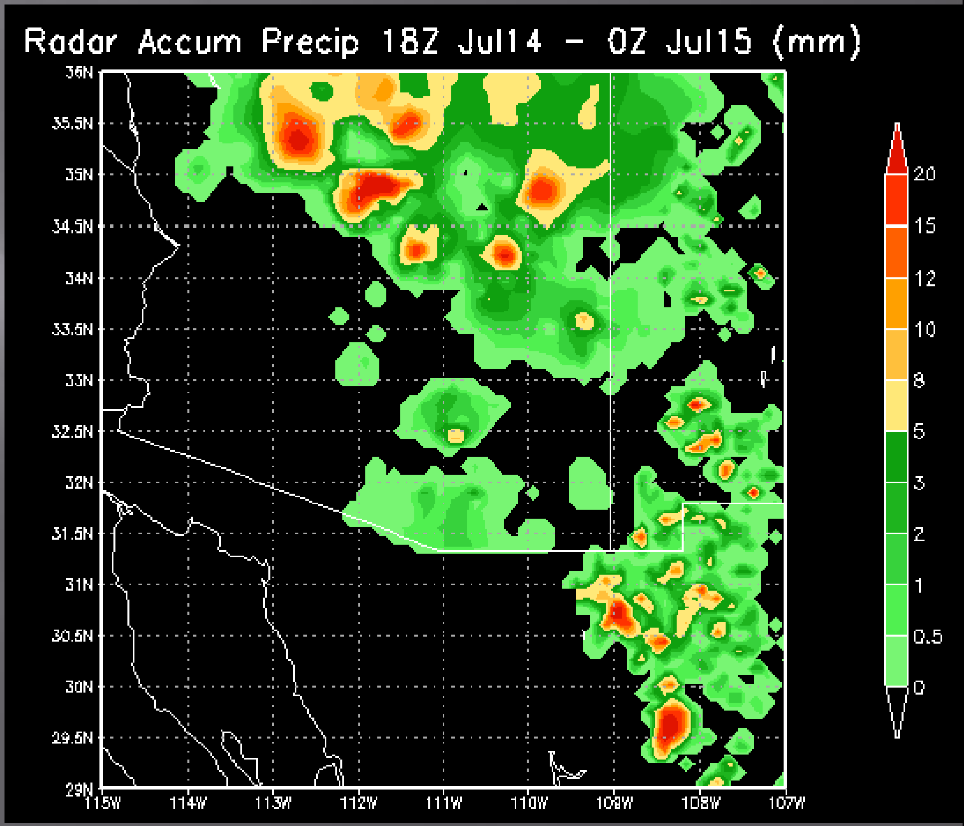




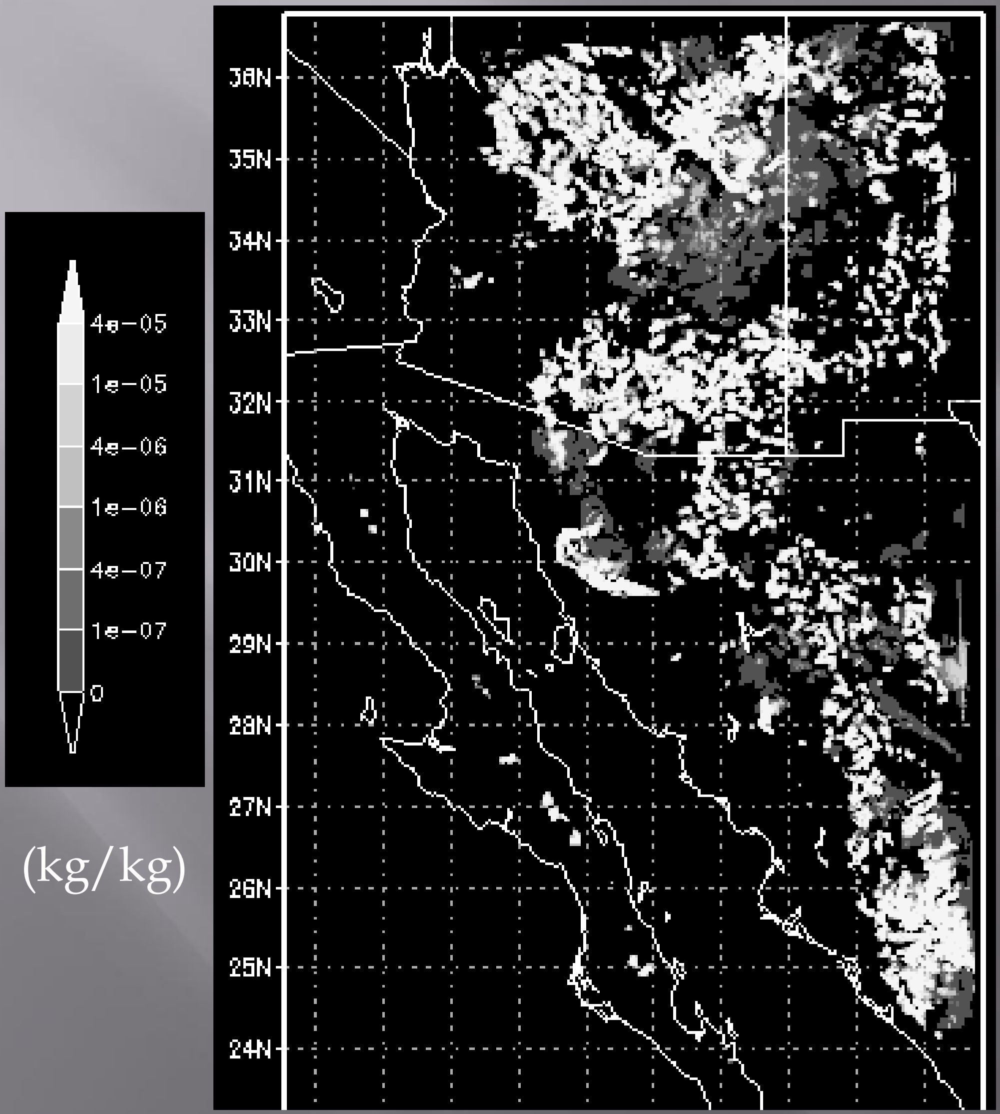
WRF vs. radar-derived precipitation

Late morning to late afternoon July 14

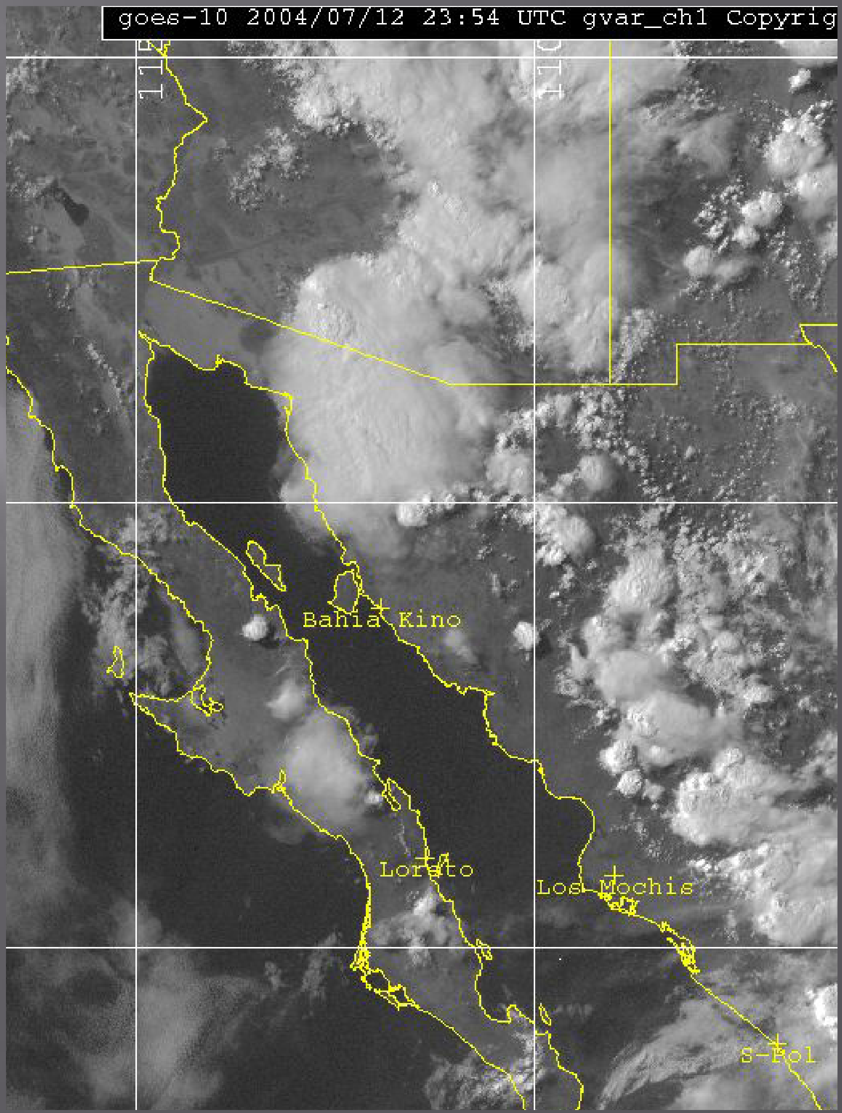




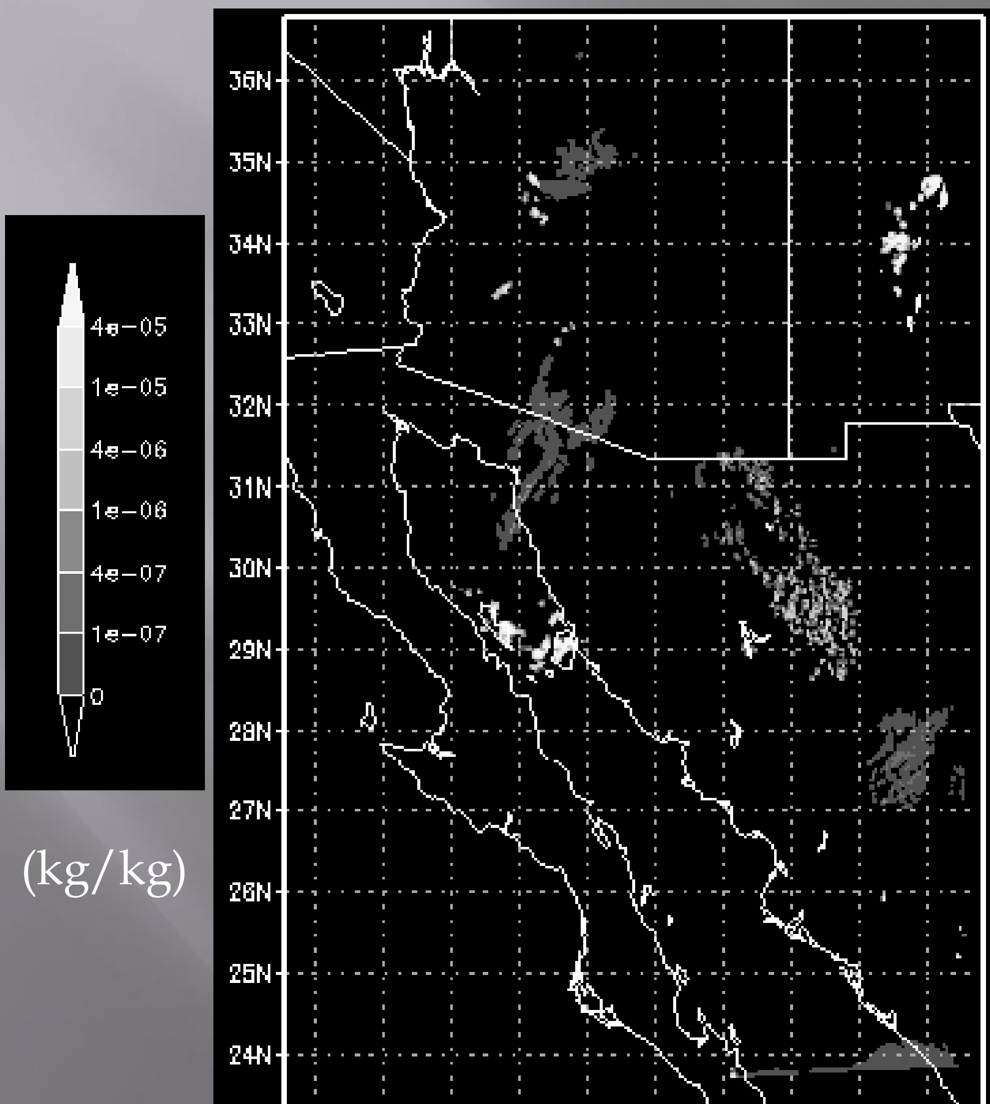
Cloud Mixing Ratio vs. GOES 10 Visible
5 PM July 12

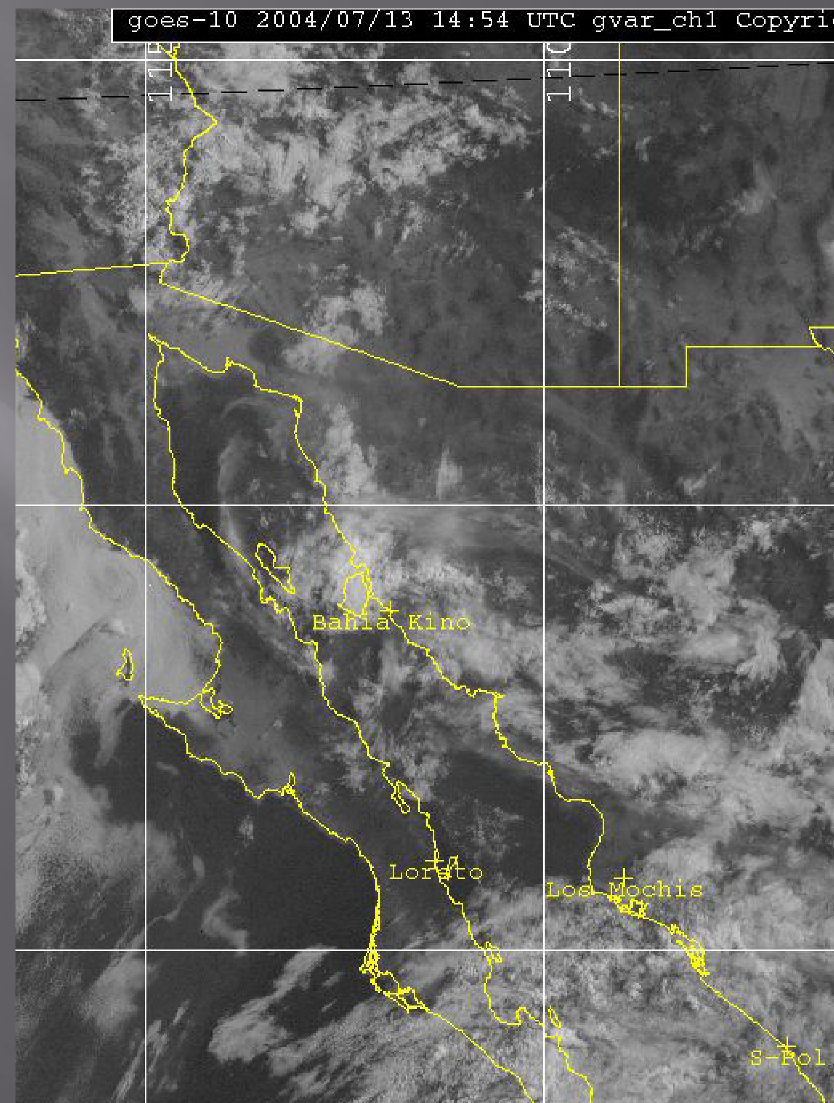


(kg/kg)

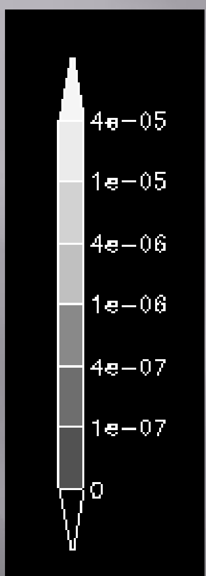


Cloud Mixing Ratio vs. GOES 10 Visible
8 AM July 13

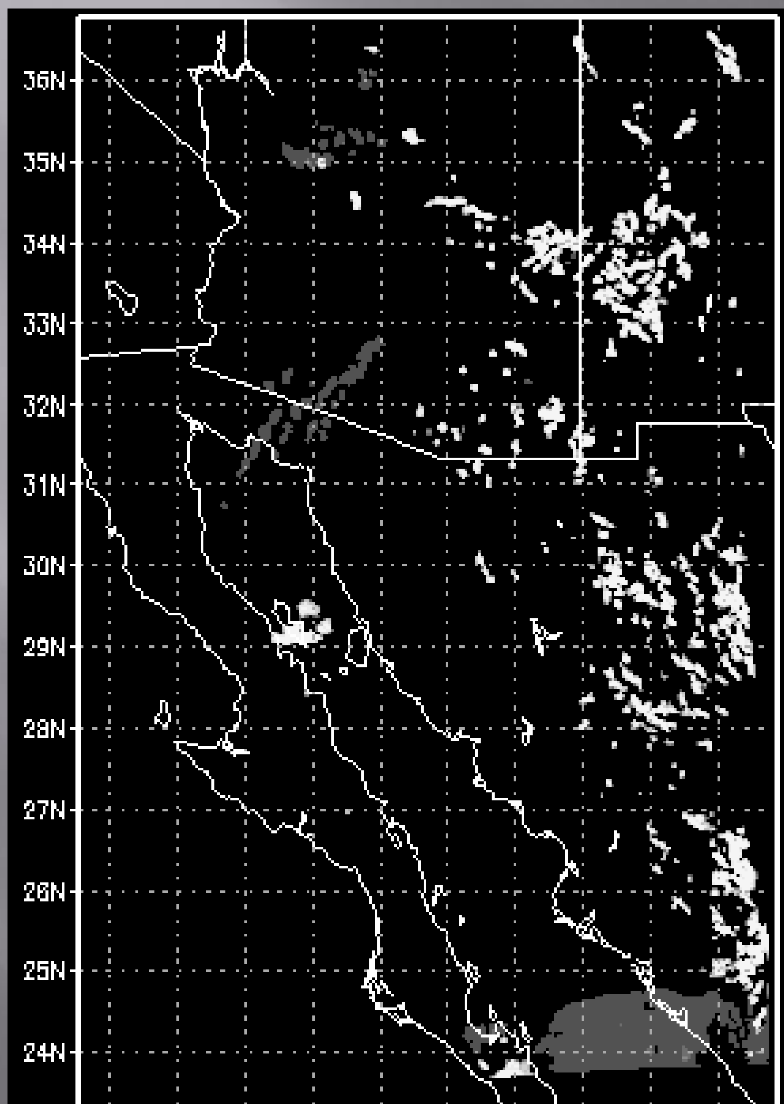


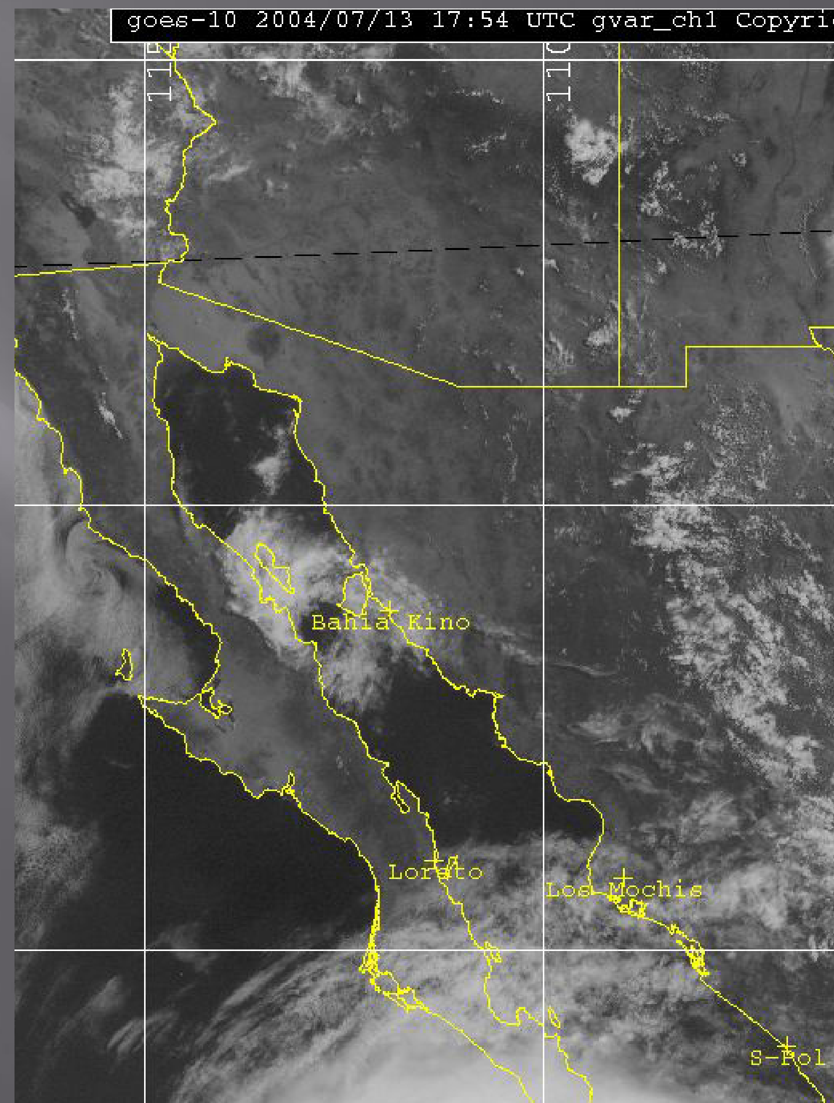


Cloud Mixing Ratio vs. GOES 10 Visible
11 AM July 13

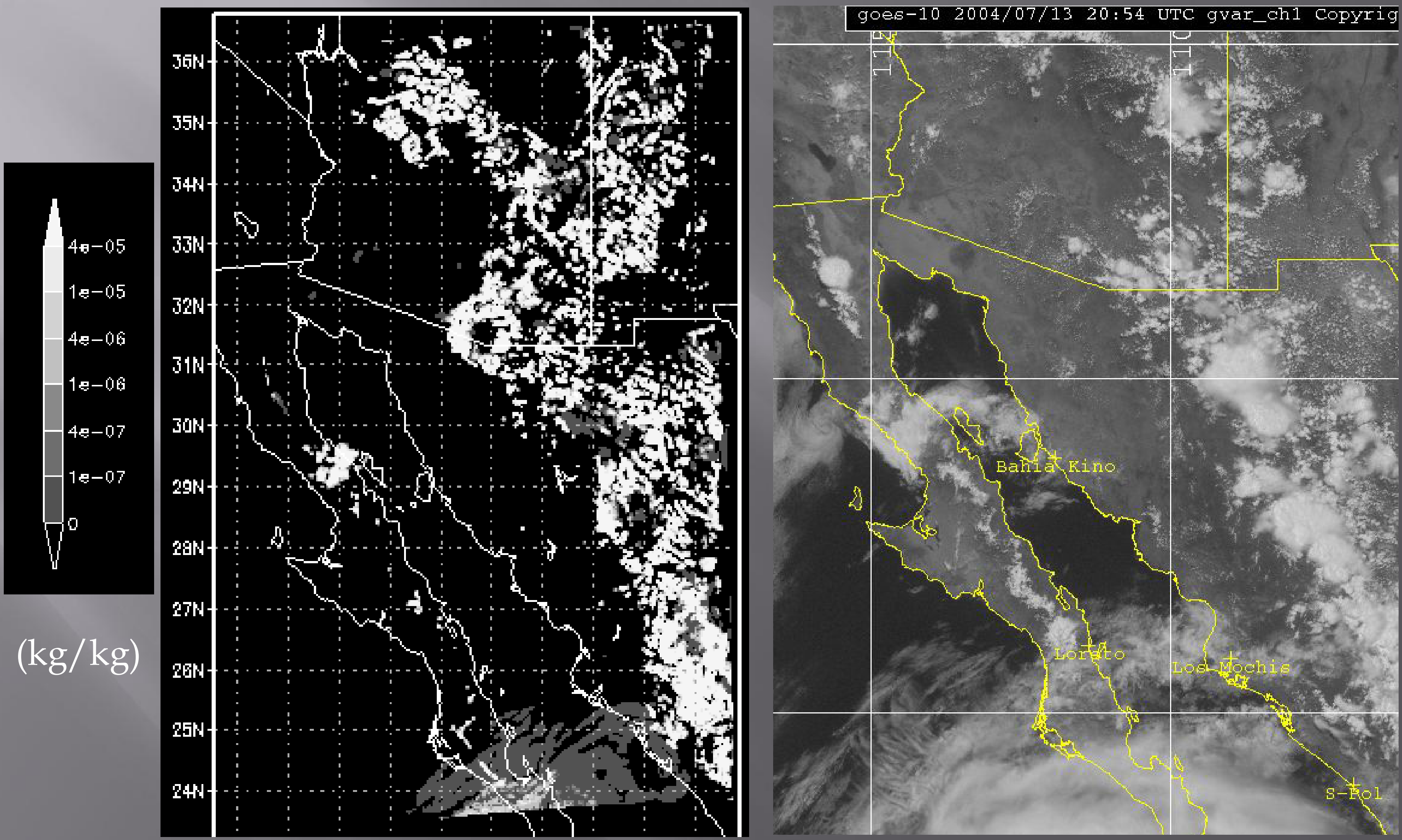


(kg/kg)

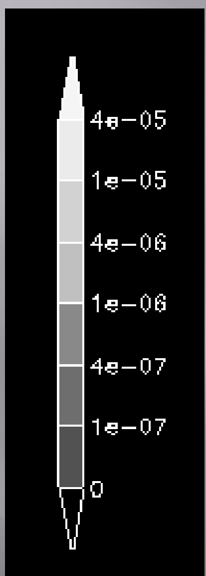




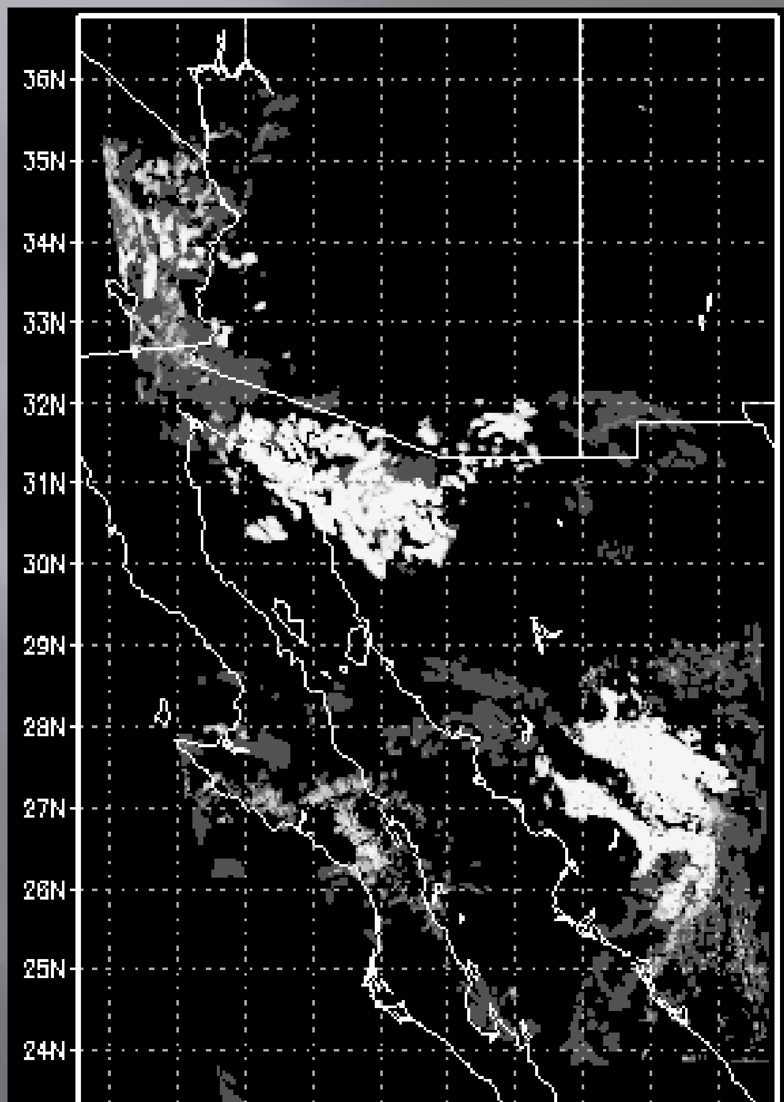
Cloud Mixing Ratio vs. GOES 10 Visible
2 PM July 13

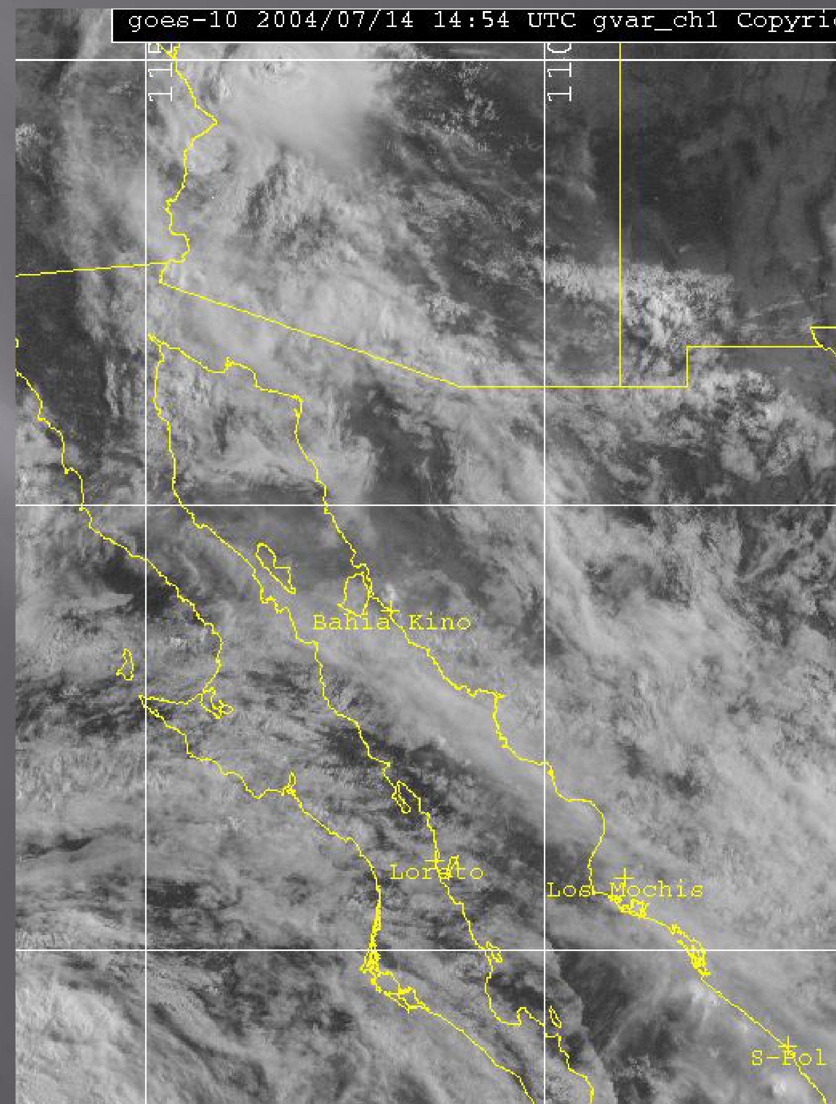


Cloud Mixing Ratio vs. GOES 10 Visible
8 AM July 14

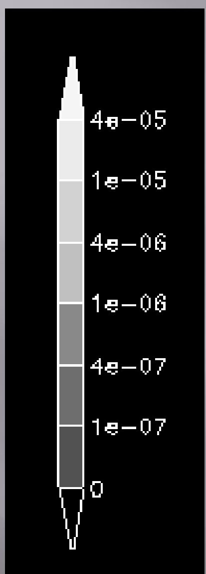


(kg/kg)





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



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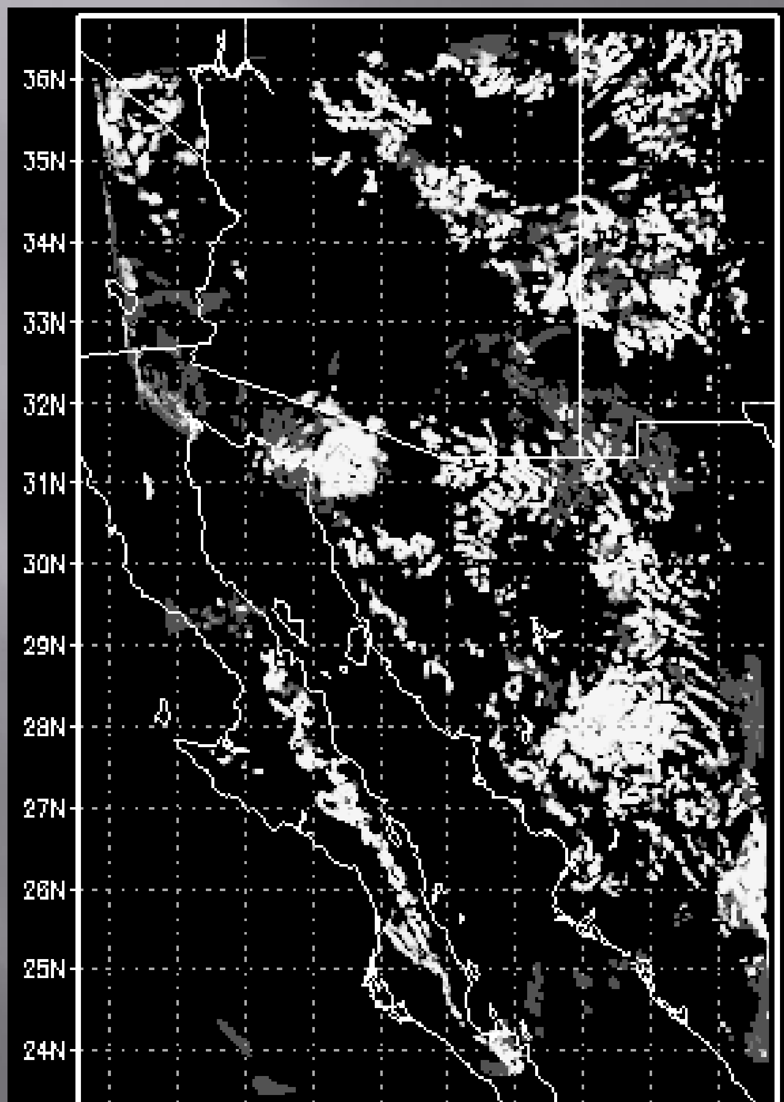
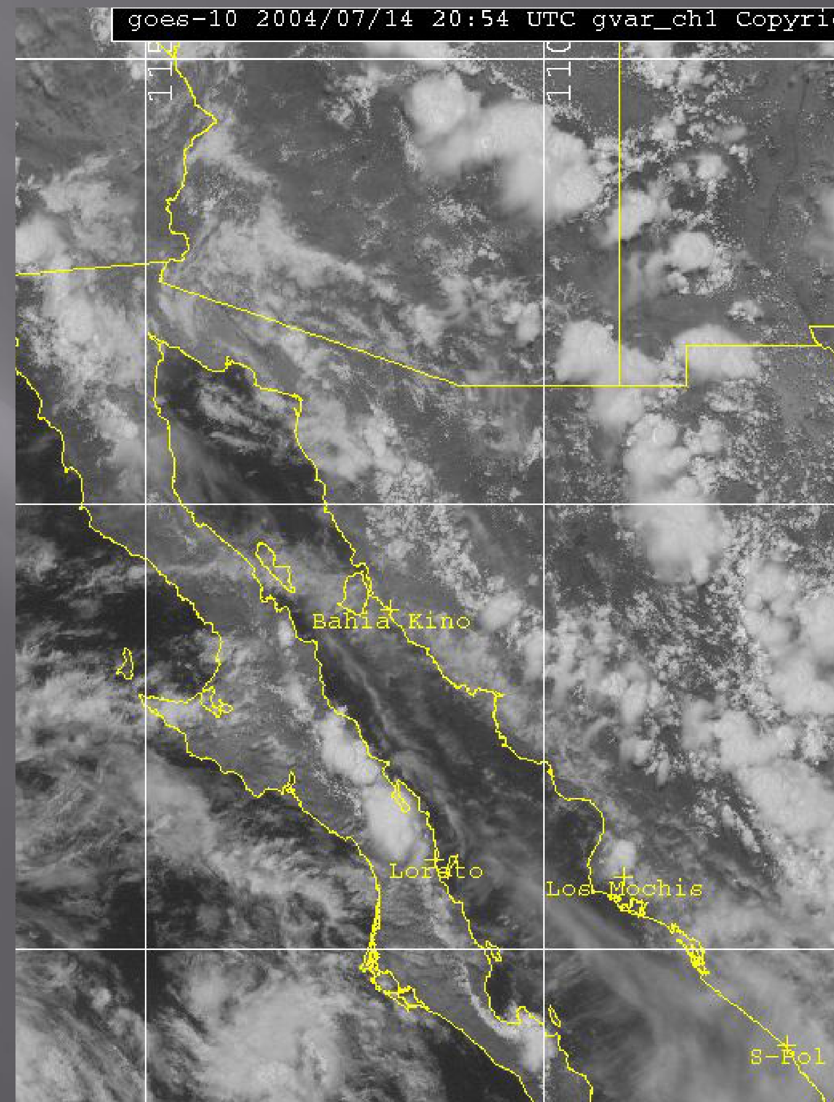
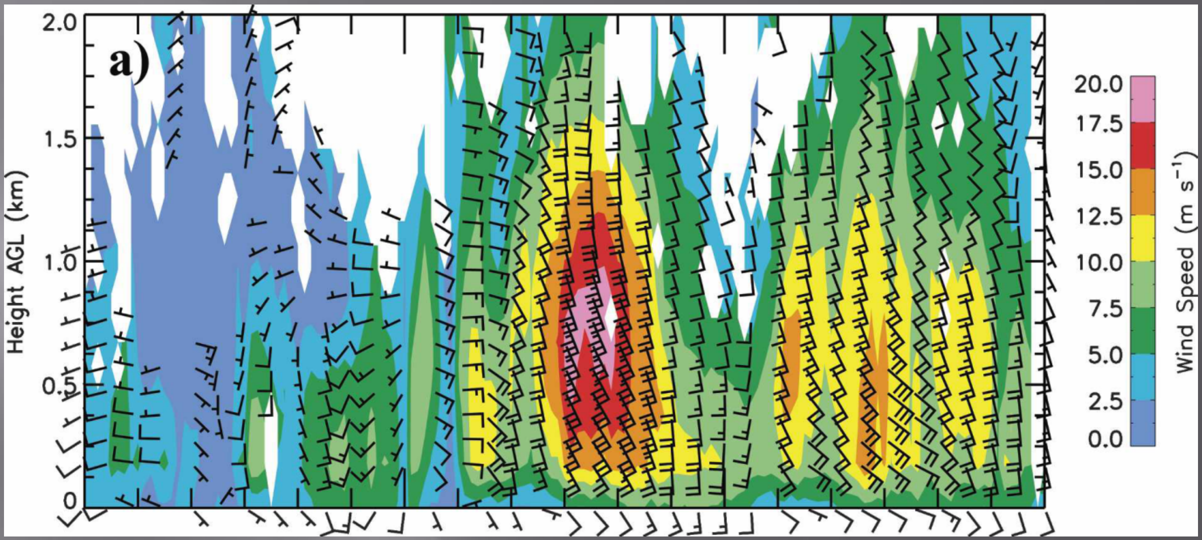


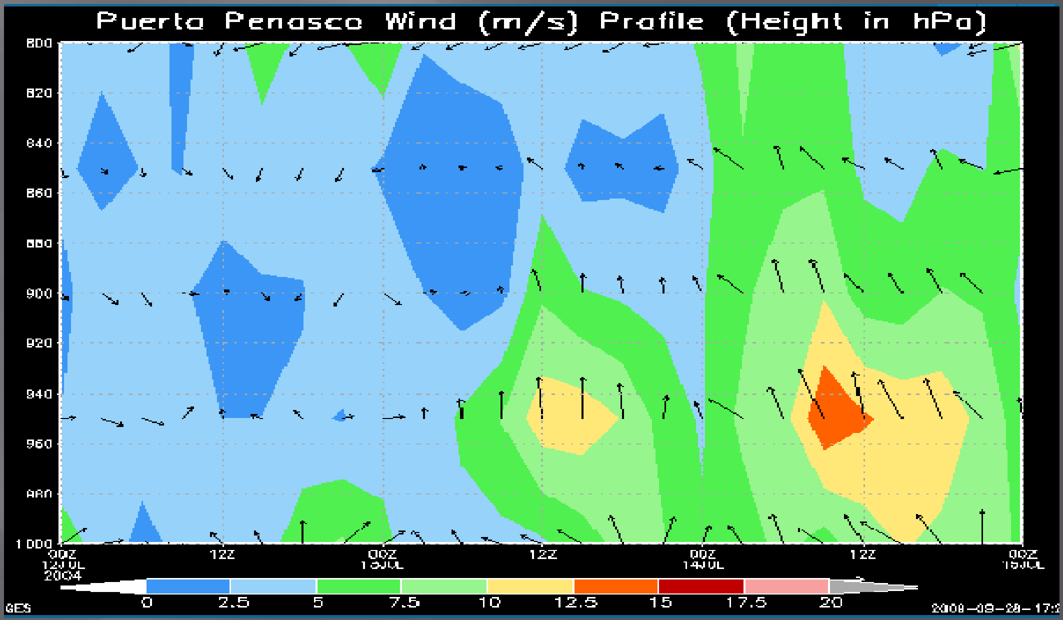


Puerto Peñasco Wind Profiles

- Provided by Rogers and Johnson:

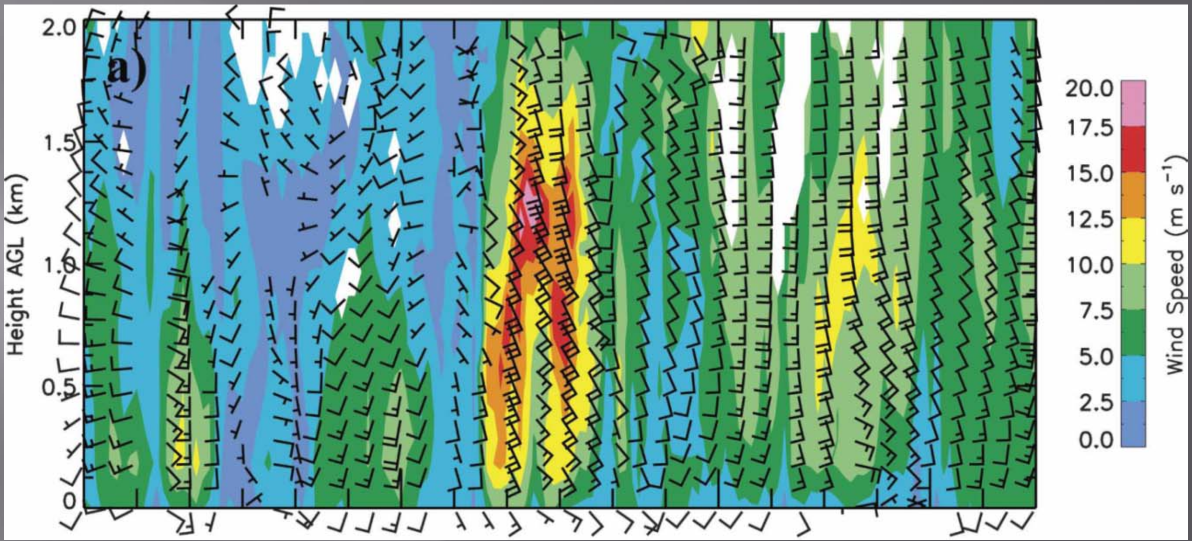


- Generated using WRF:



Bahia Kino Wind Profiles

- Provided by Rogers and Johnson:



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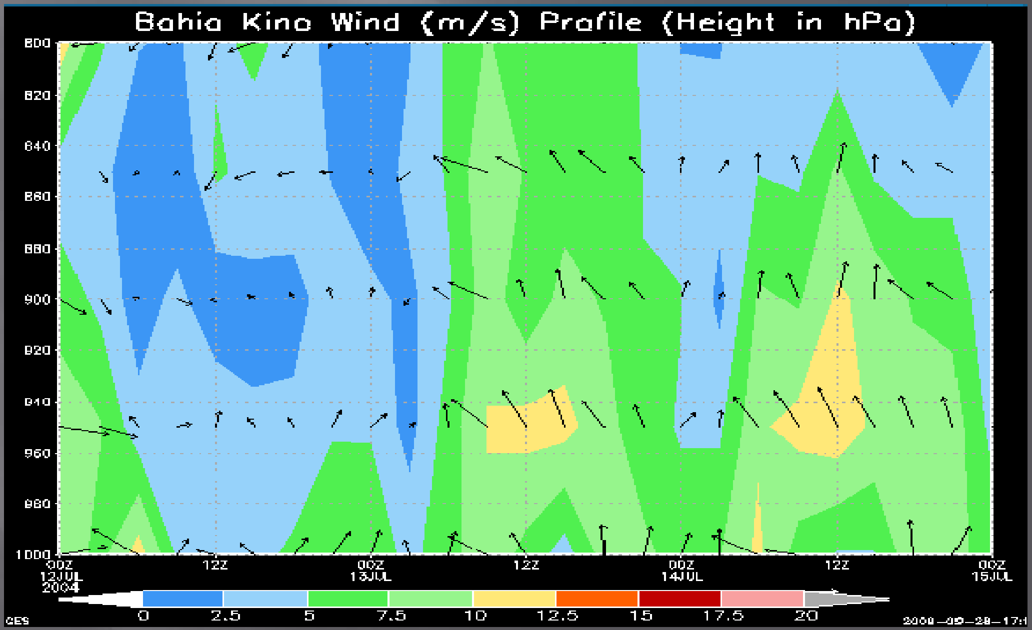
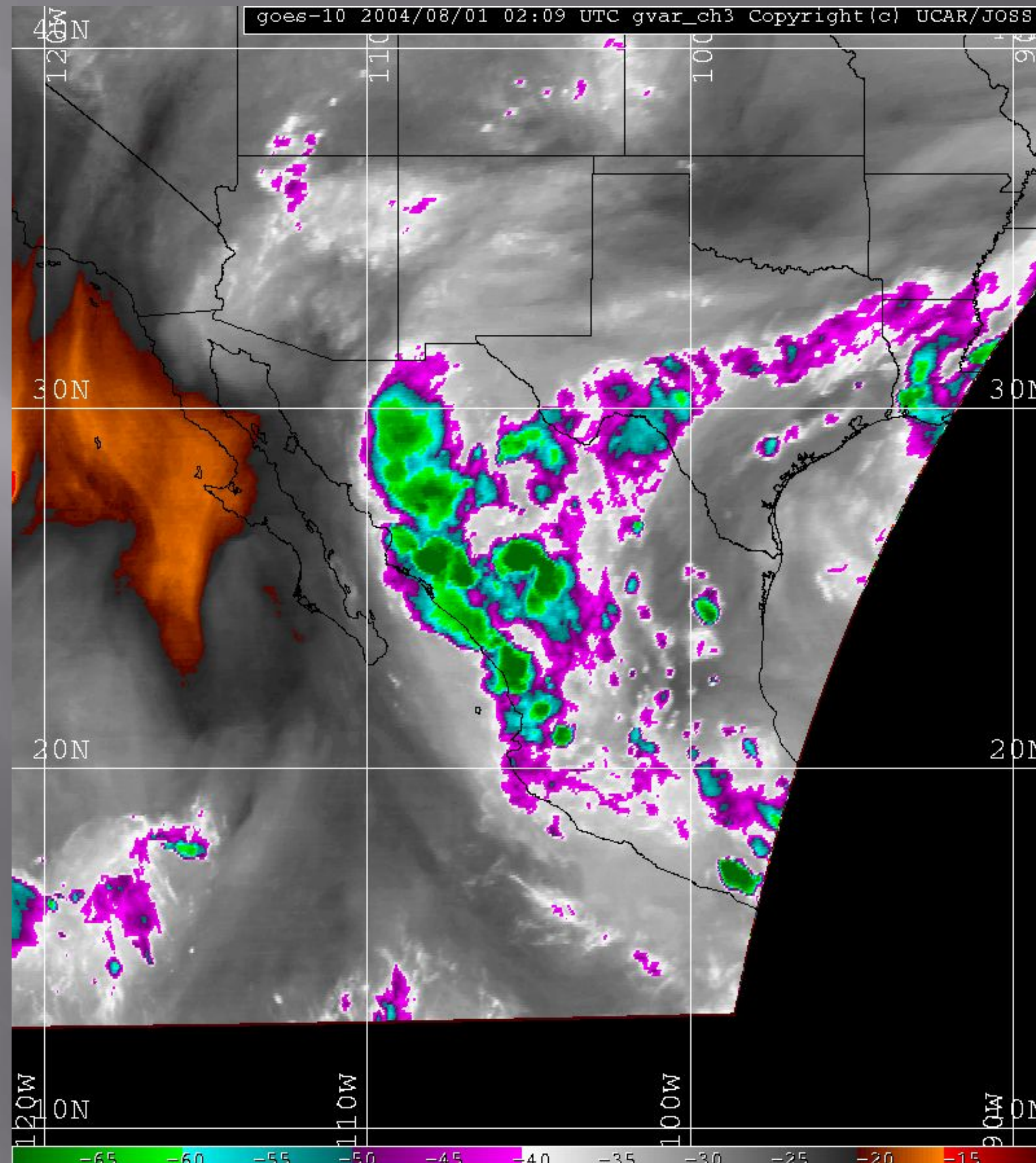


IOP 5

- Moisture flux IOP to capture strong monsoon circulation
- Strong tropical jet from NE Mexico to Gulf
  → strong divergence across central Gulf coast
- Trough to W, ST High to E
  → strong moisture advection from E
- MCV (TW 27) moves through area

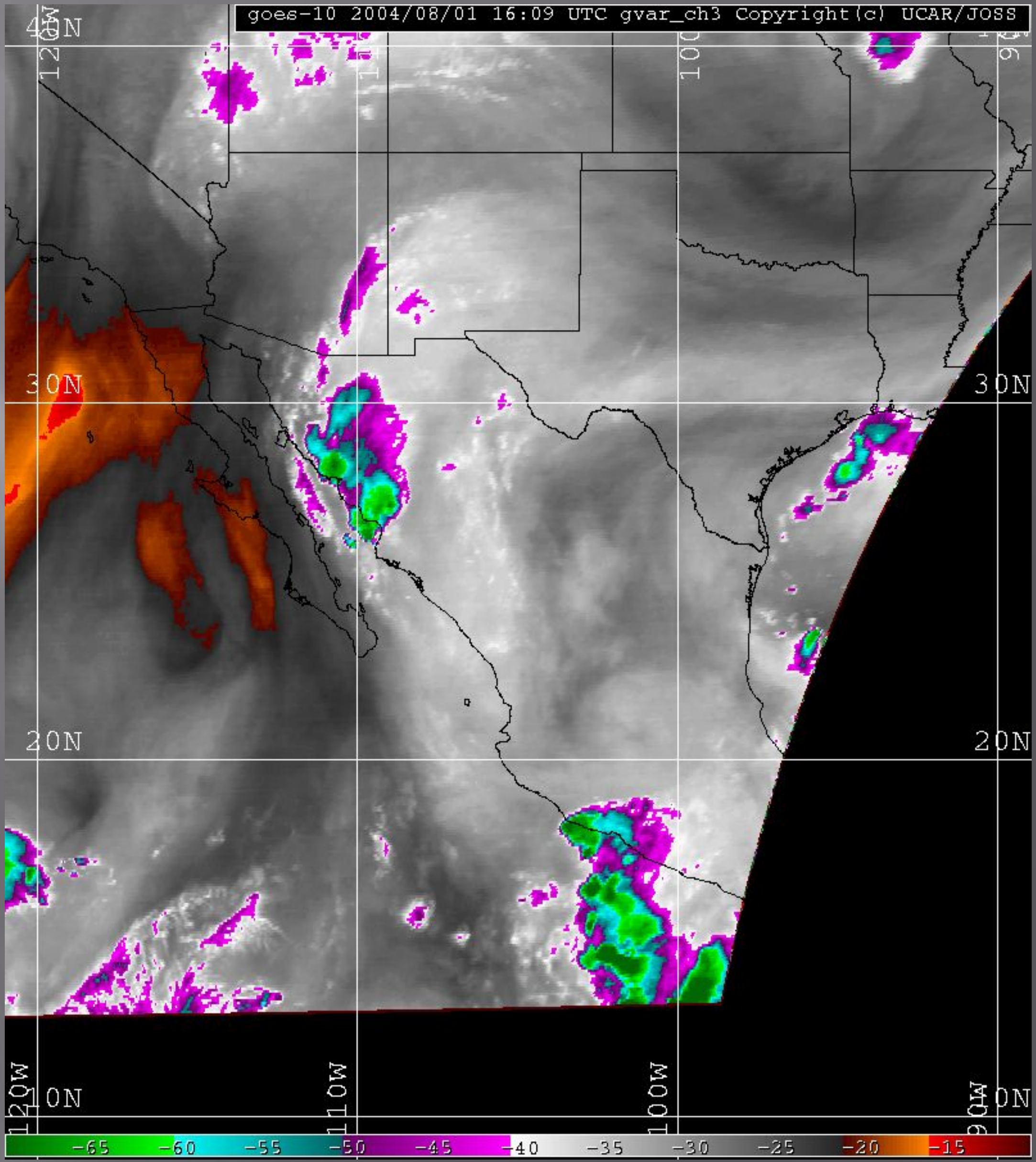
IOP 5
Jul 31 - Evening

- MCS active in three corners region (Durango, Sinaloa, Chihuahua)



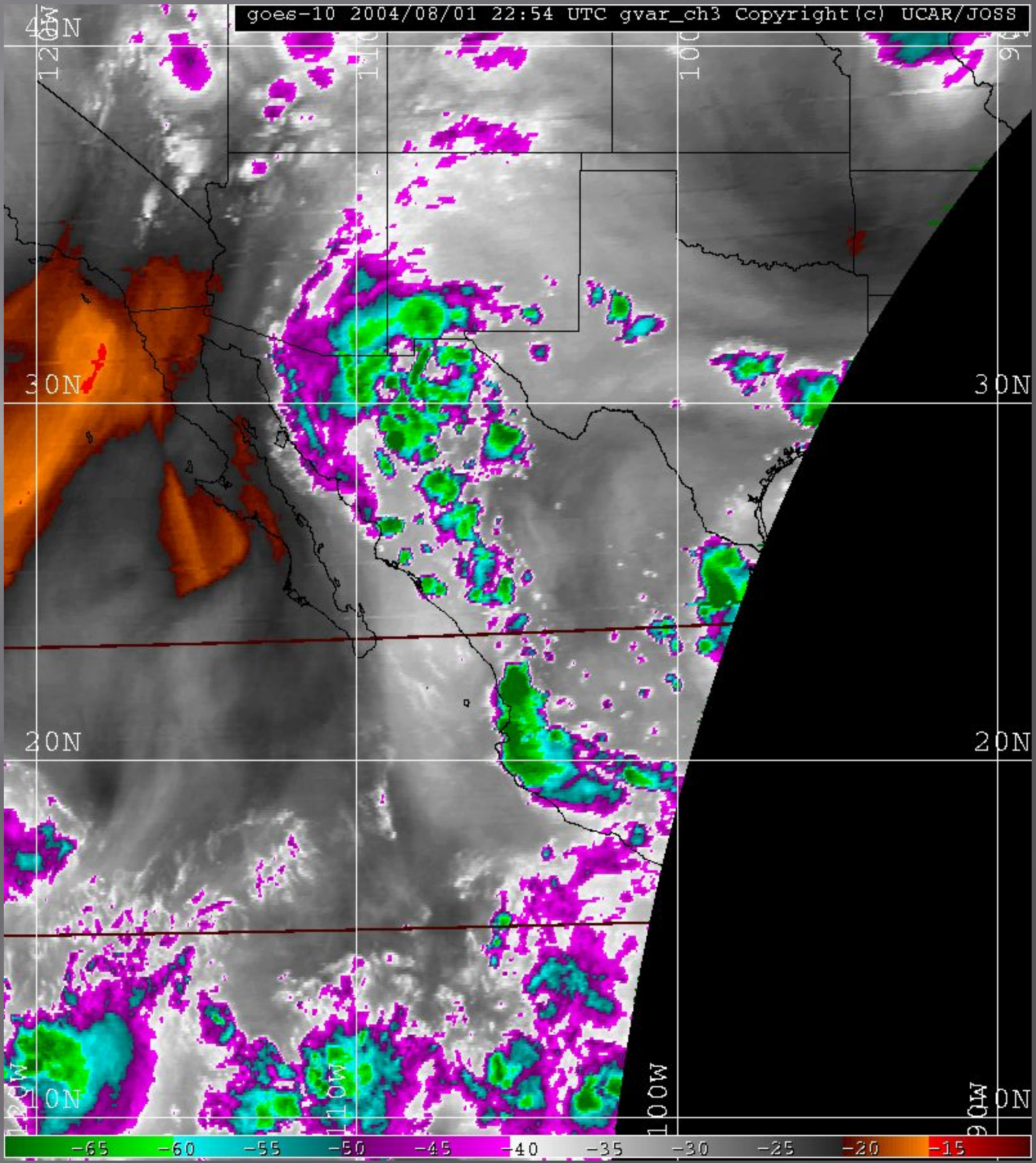
IOP 5
Aug 1 - Morning

- MCS decayed
- MCV moved north



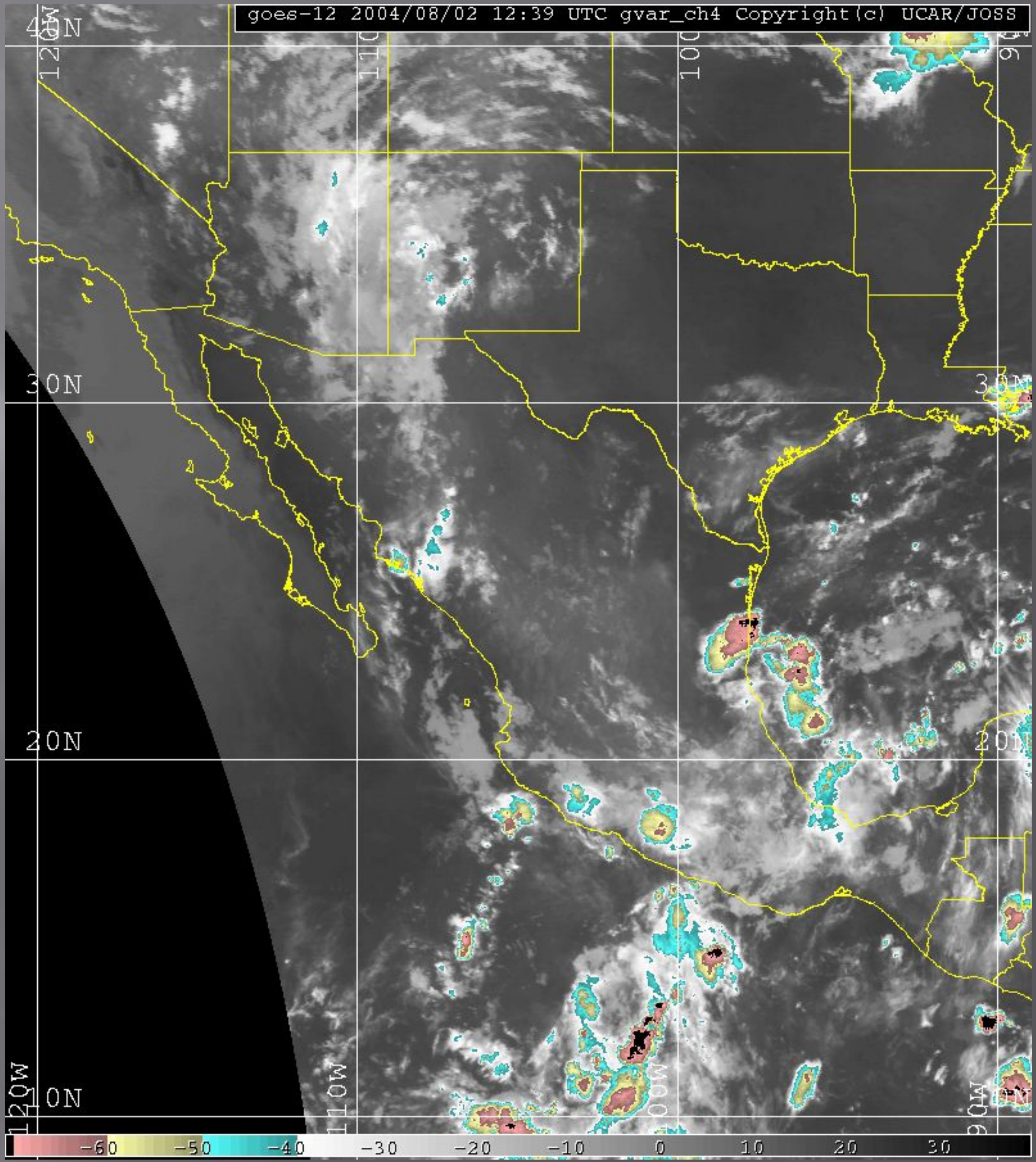
IOP 5
Aug 1 - Afternoon

- MCS redevelop NE Sonora, NW Chihuahua

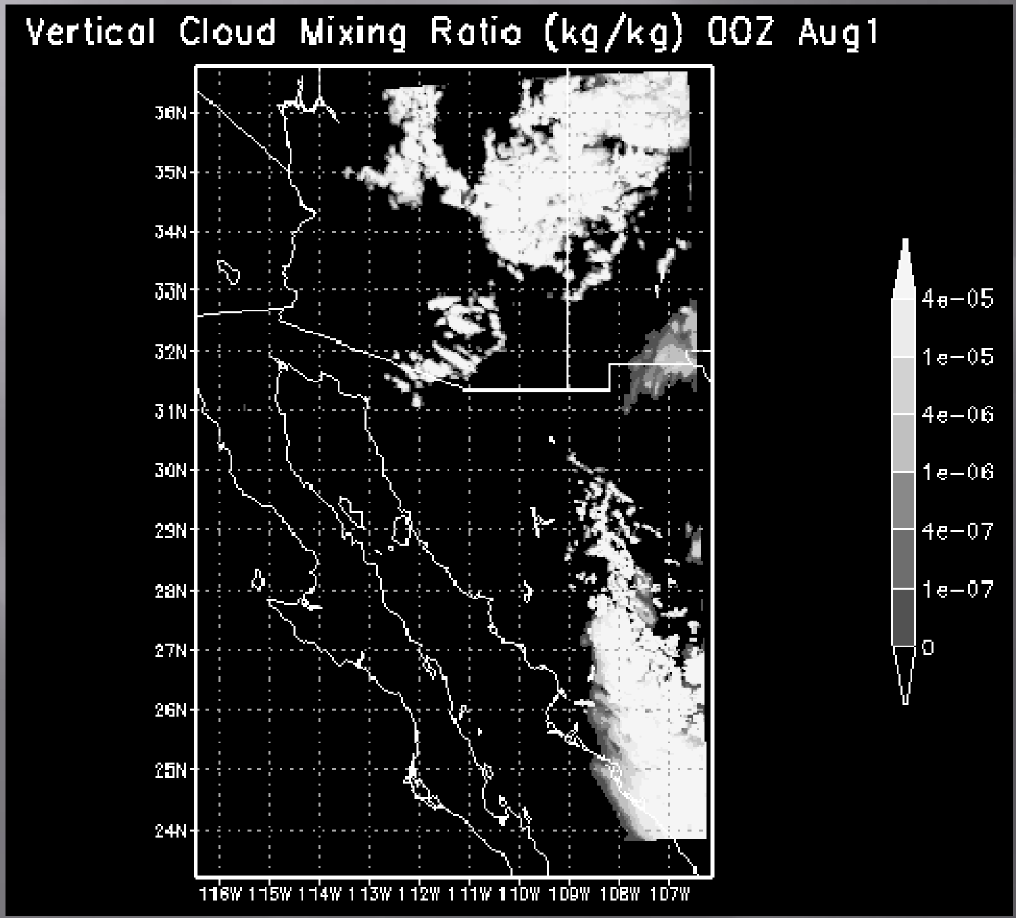


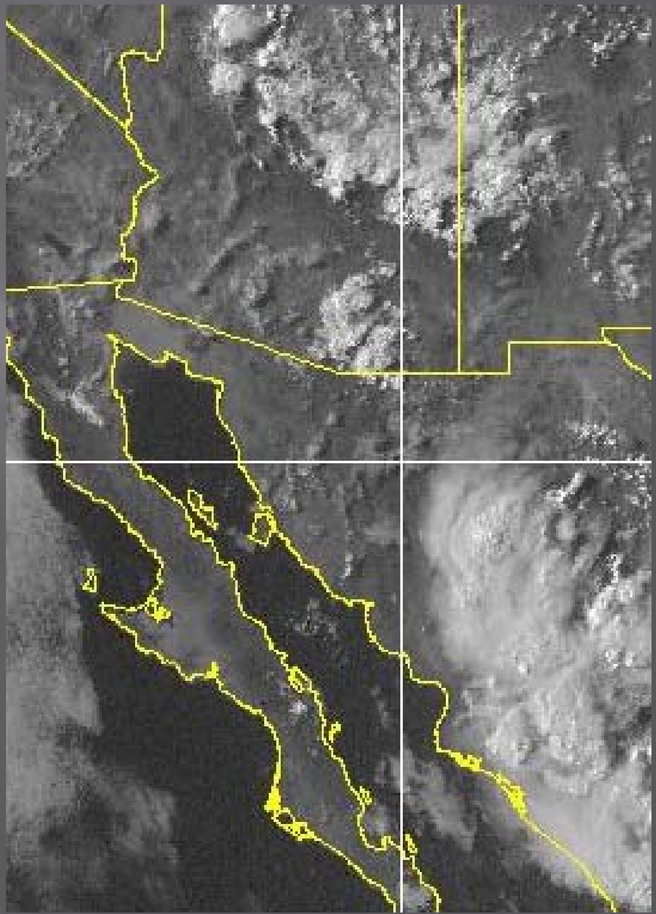
IOP 5
Aug 2 - Morning

- MCS dissipated
- MCV moves into Arizona



IOP 5 – Cloud Vapor





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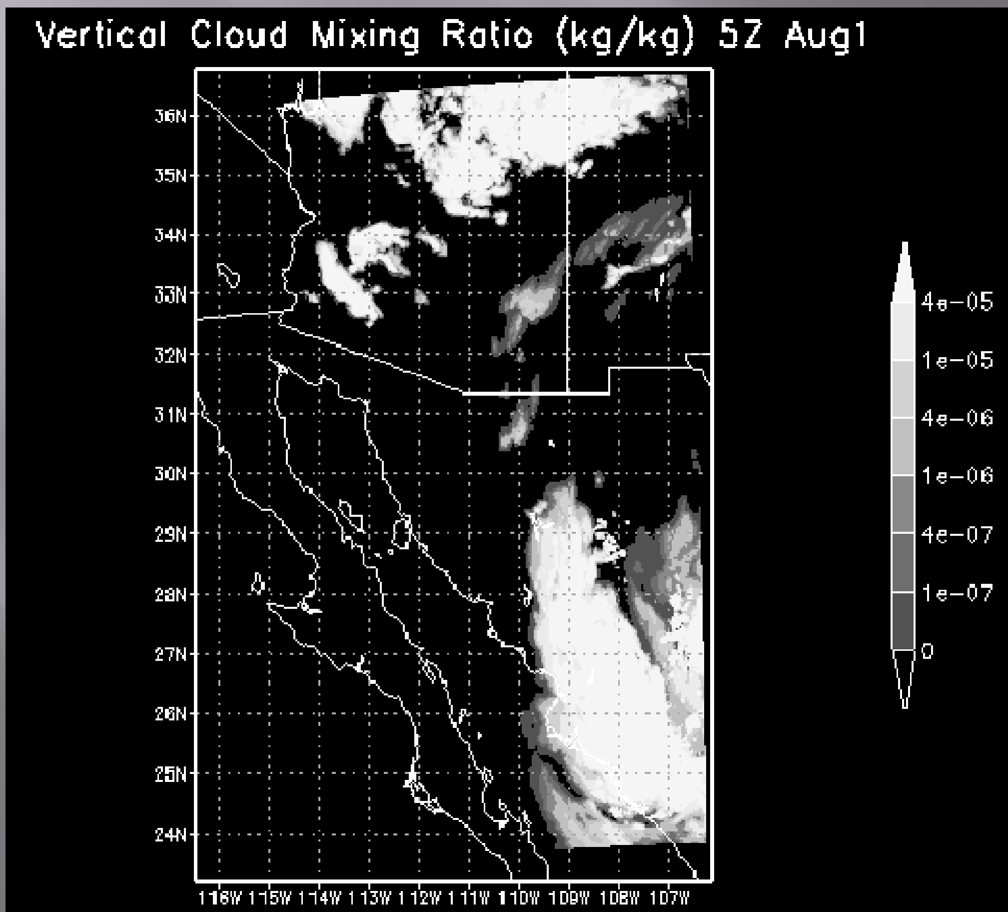

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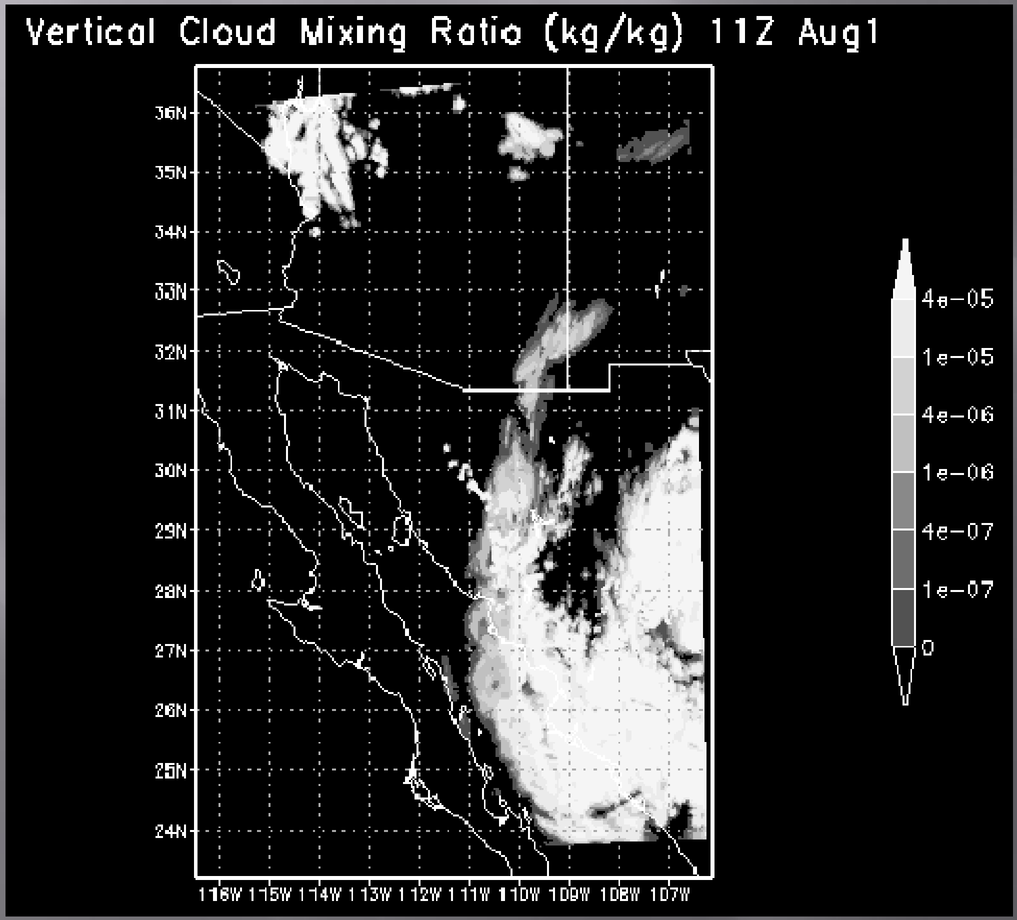

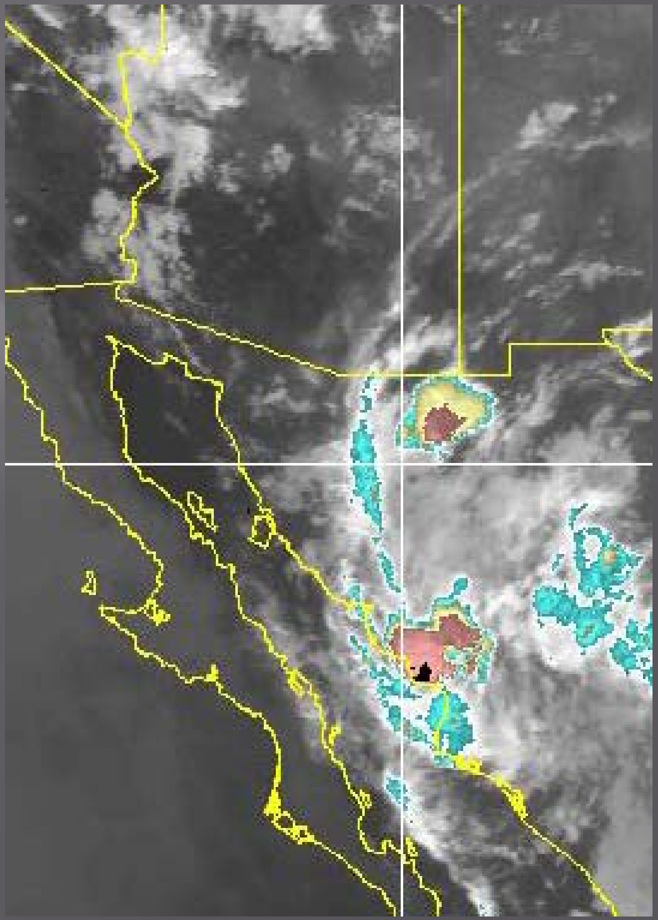

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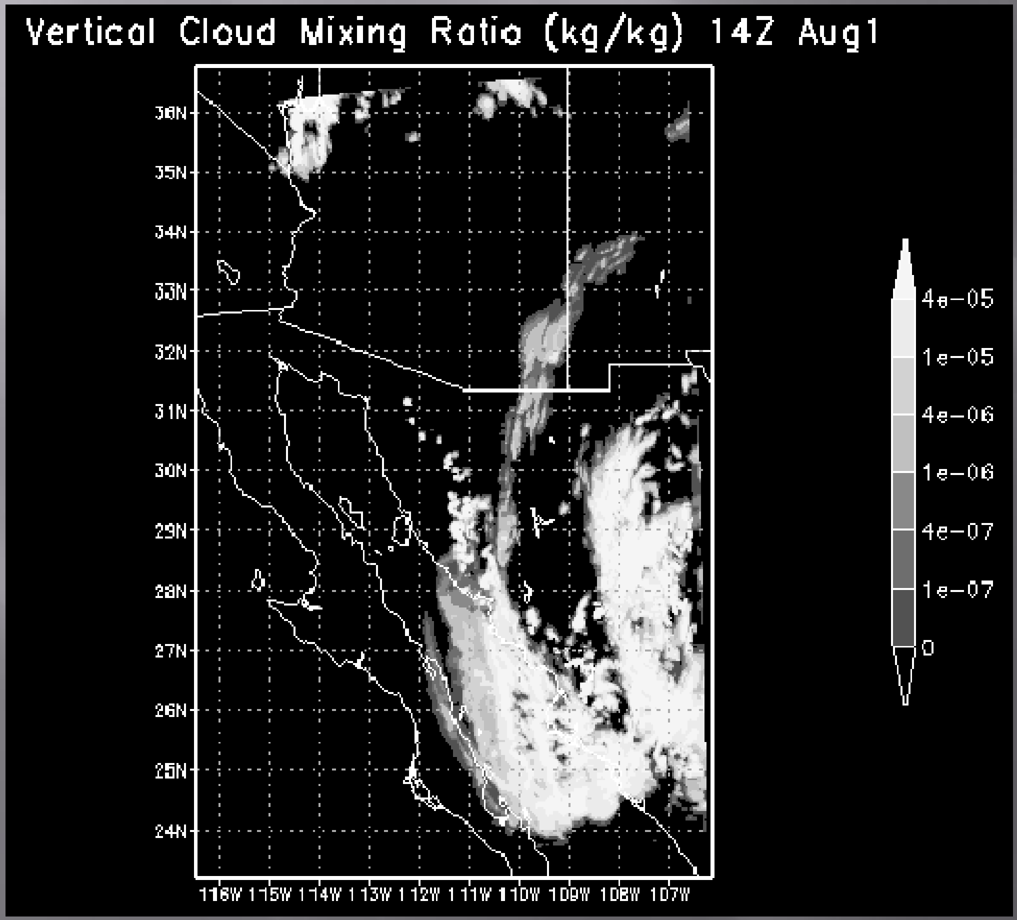

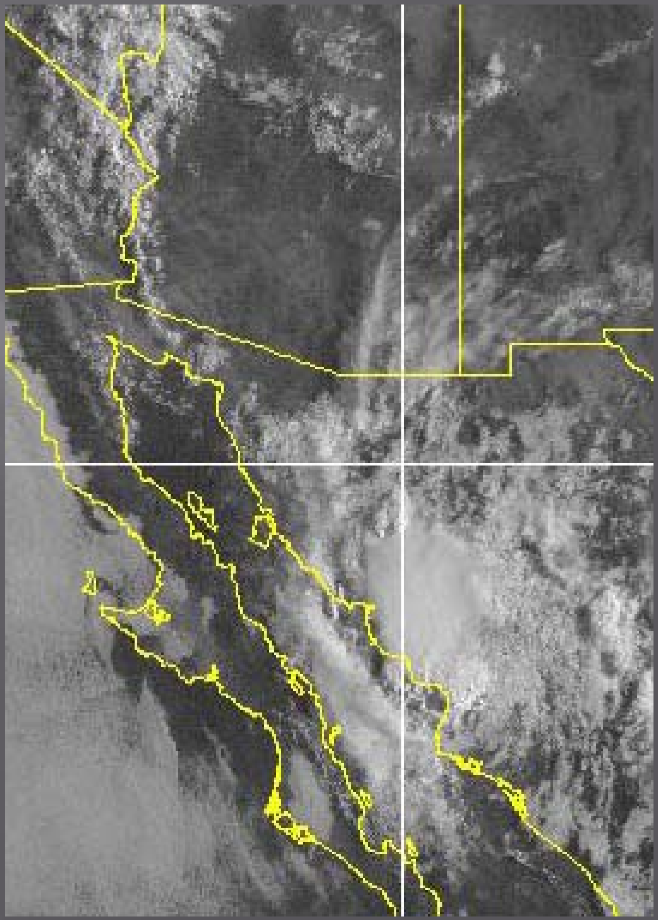

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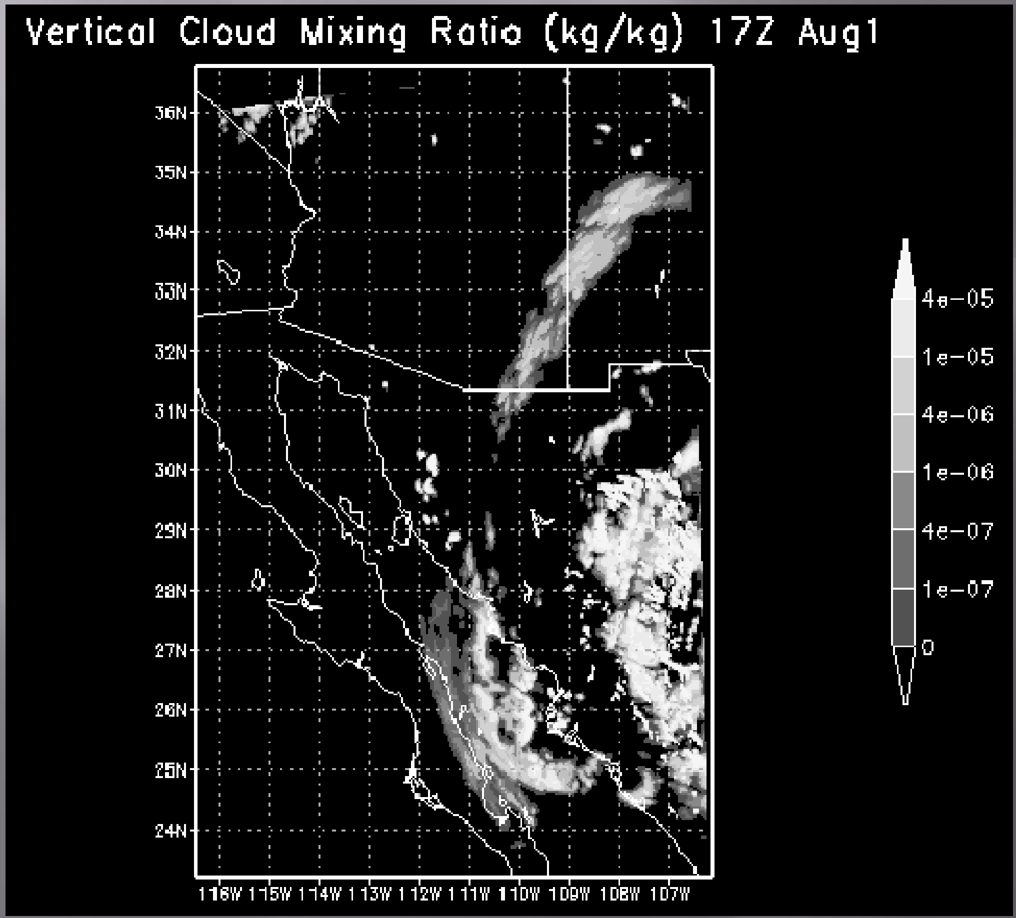

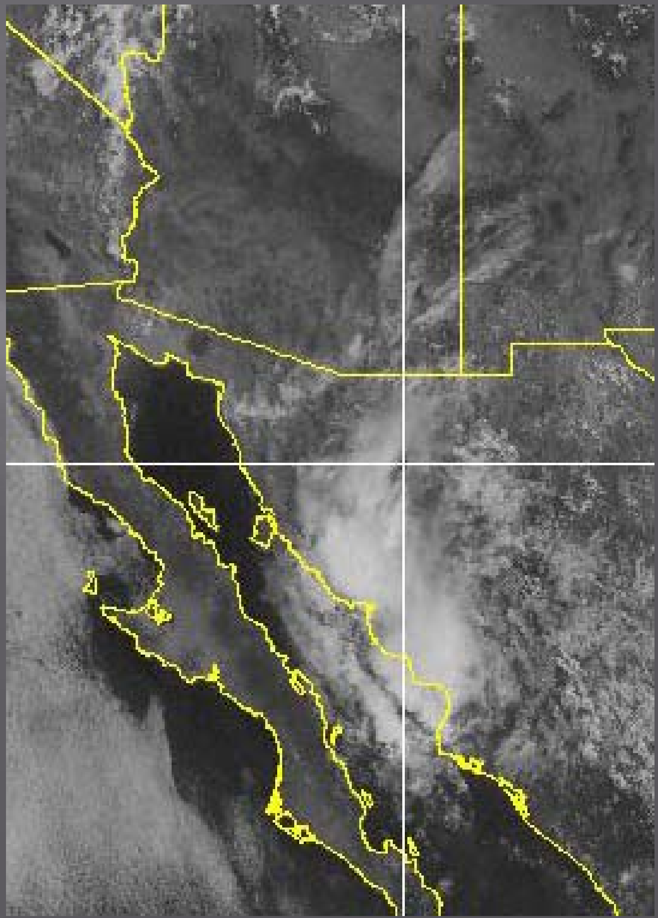

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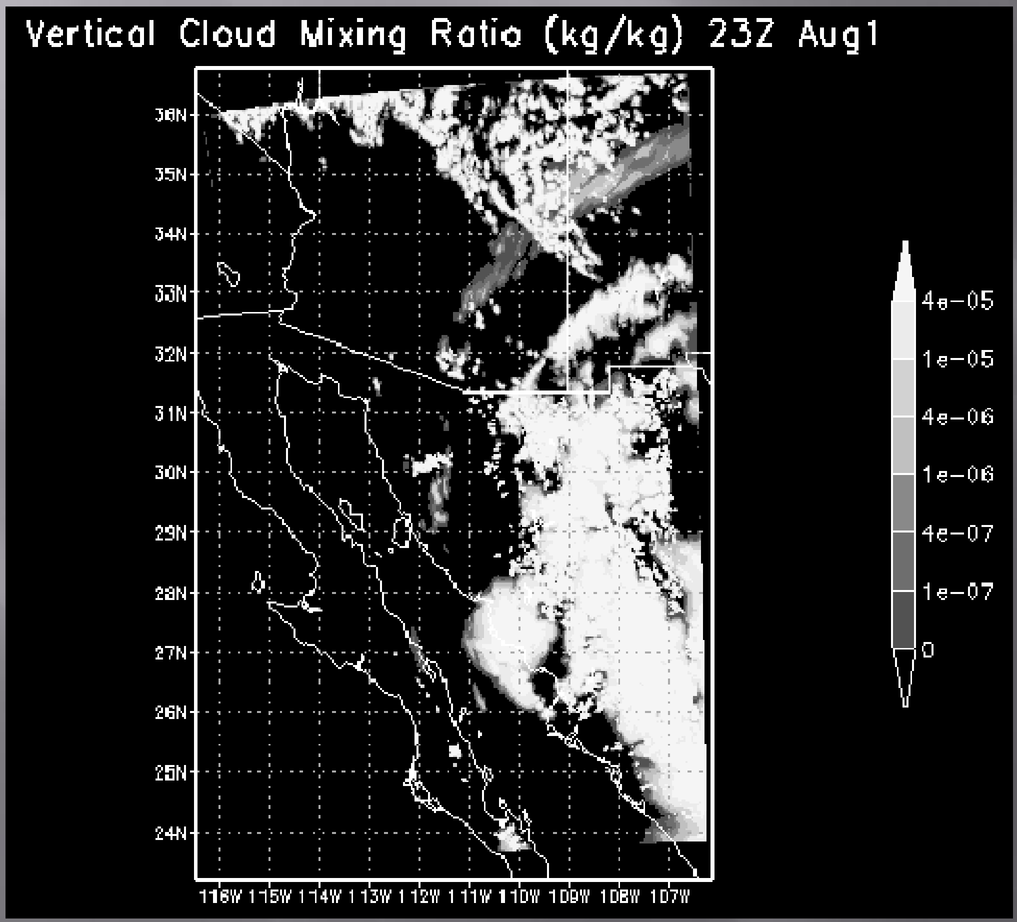
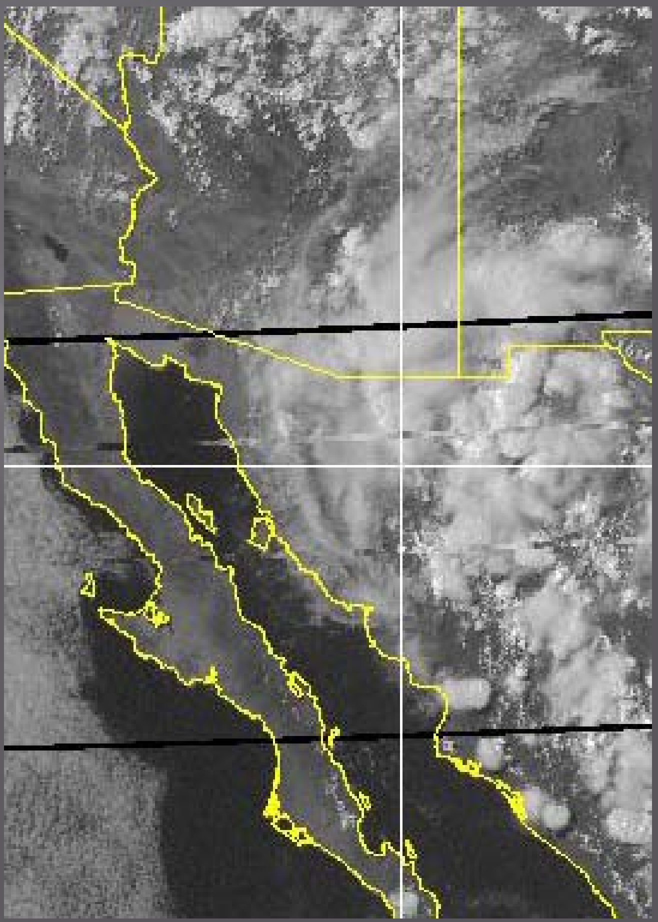
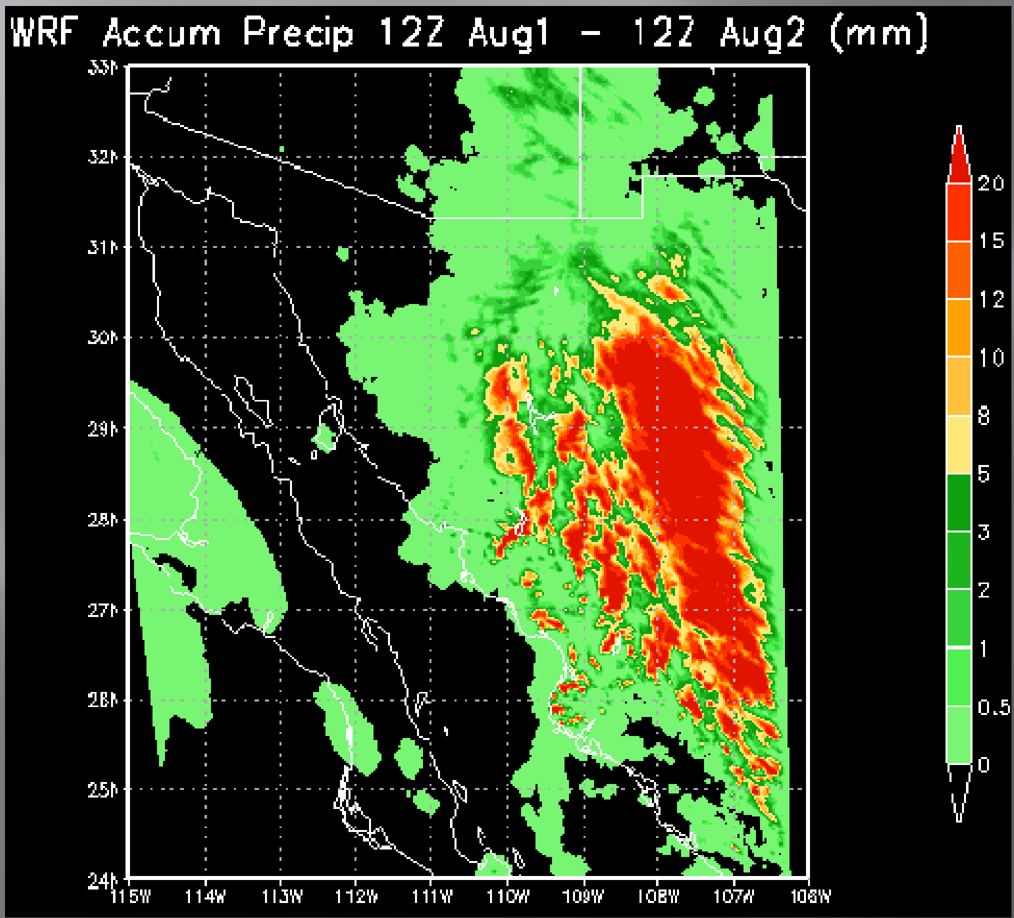
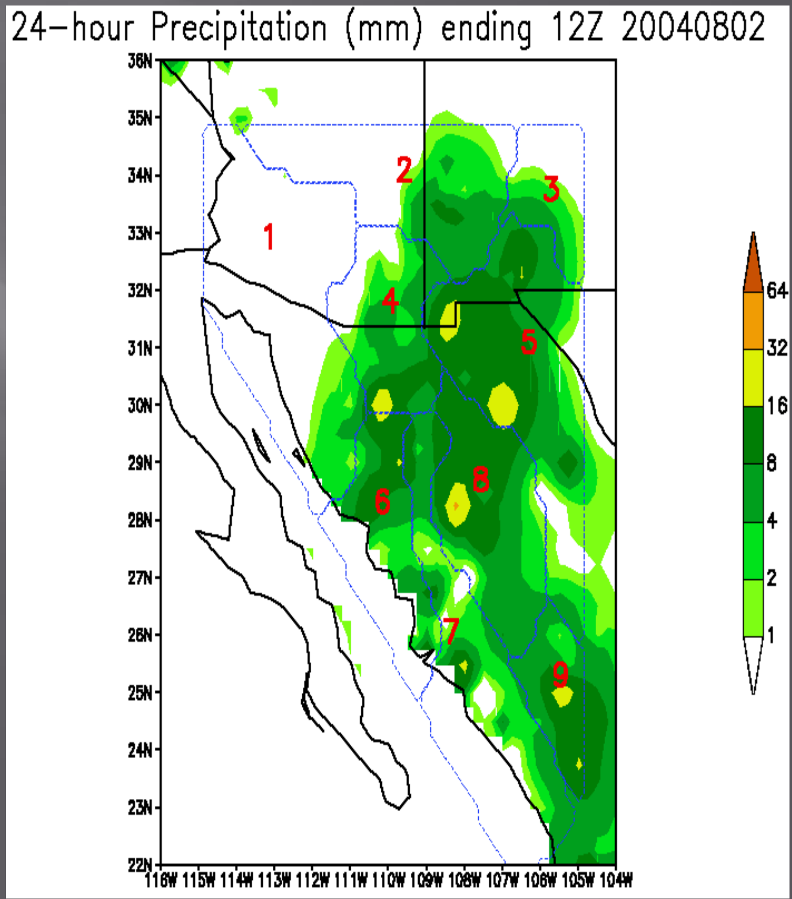




IOP 5 – Precip Comparison



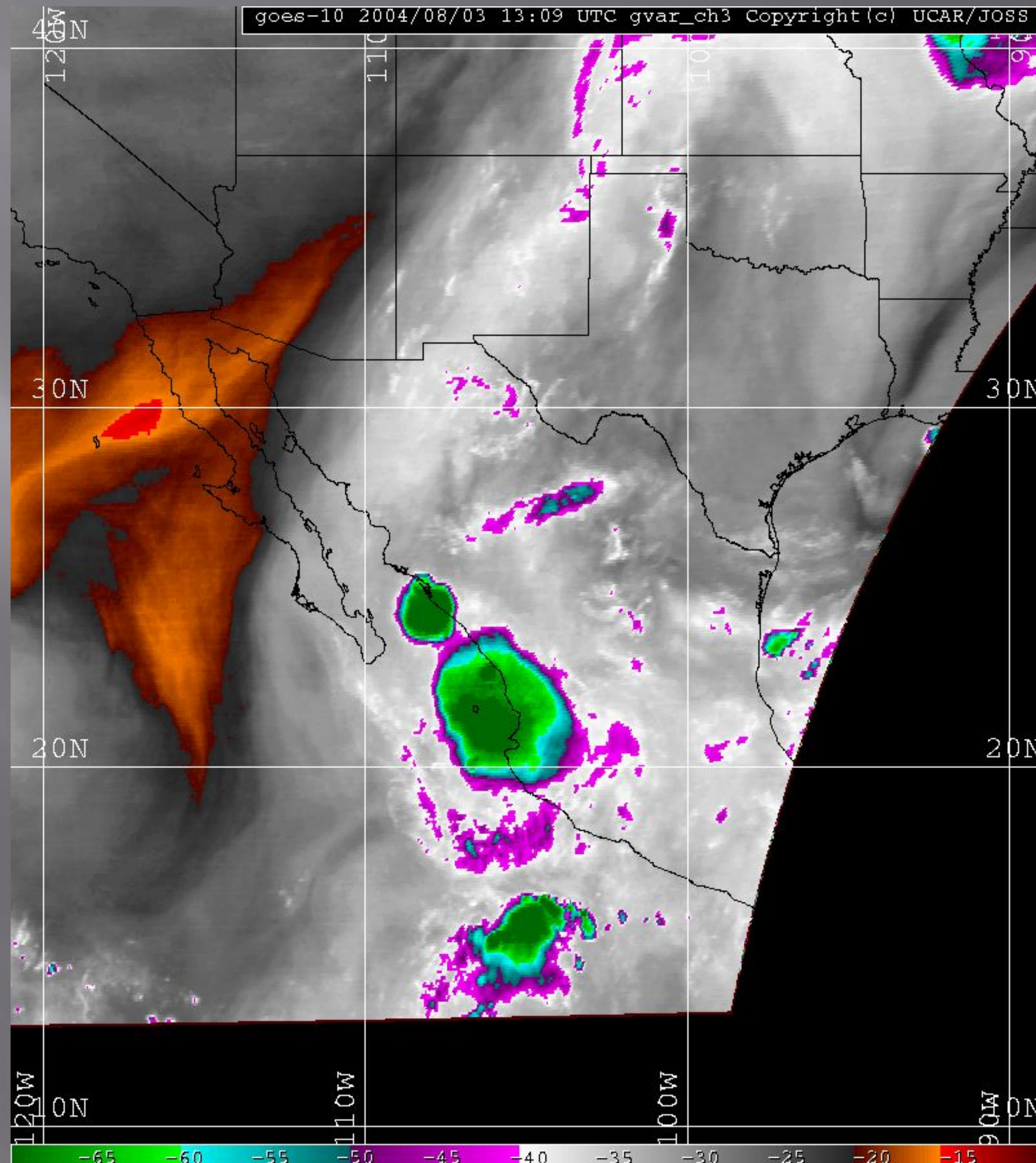


IOP 6

- MCS development and propagation
- From westward propagating TW 28
- MCC/MCS blow up to north
- Tropical jet left front exit at mouth of gulf – additional lift favorable for MCS development
- PGF weak – not conducive for gulf surge

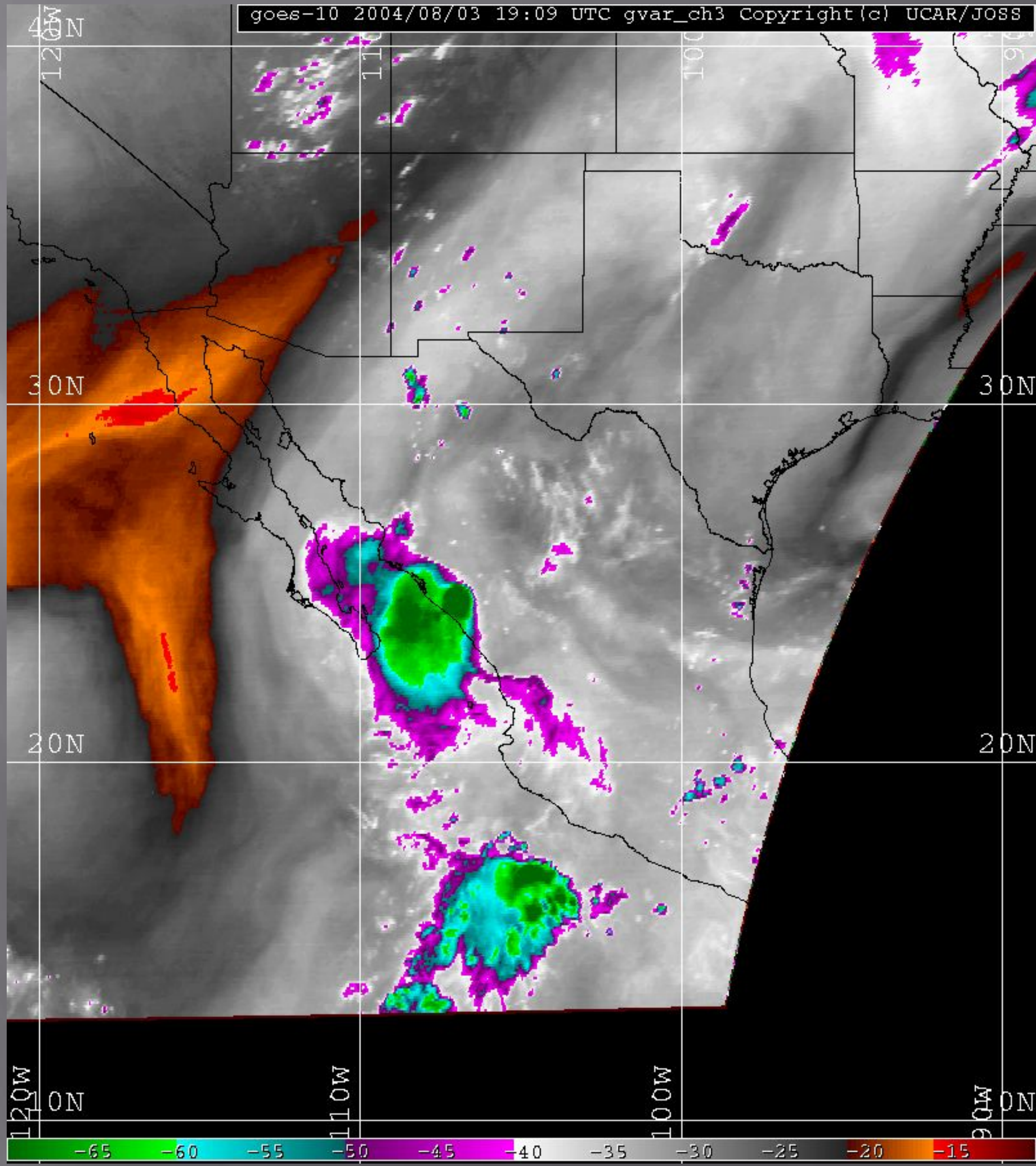
IOP 6
Aug 3 – Sunrise

- Formation of MCS in southern gulf
- Westward moving



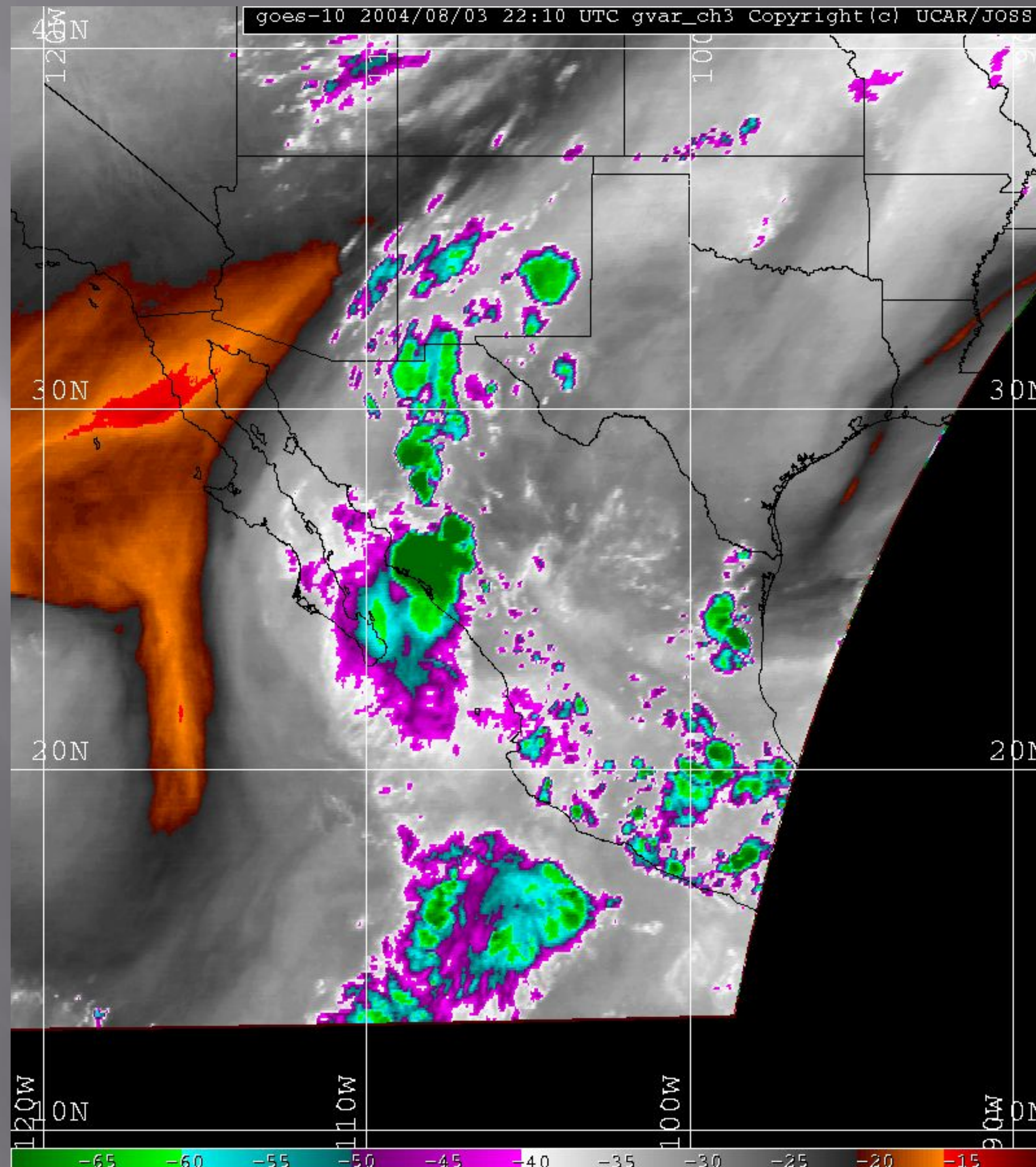
IOP 6
Aug 3 – Midday

- MCS continues to strengthen - unusual
- Moves NNW



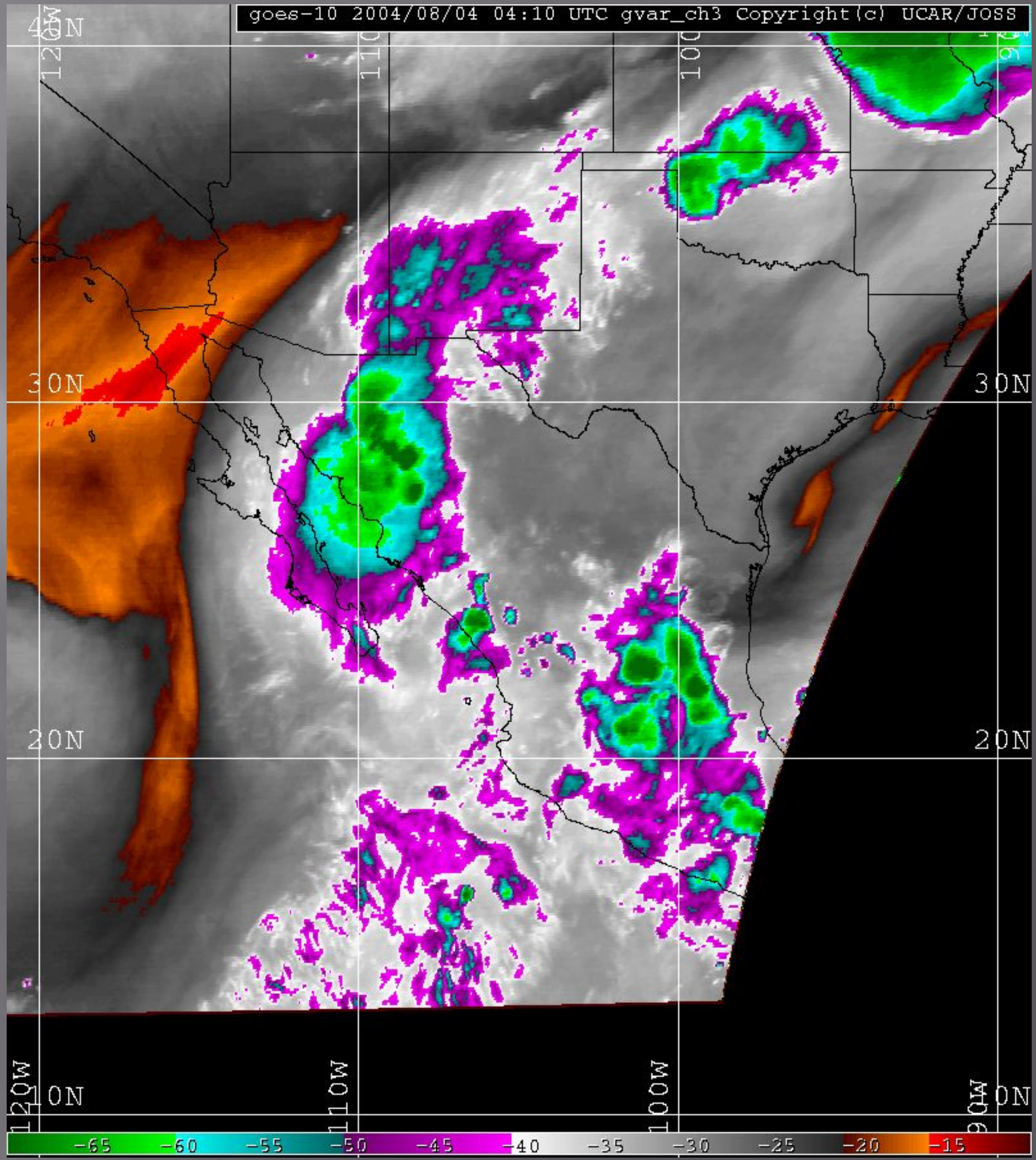
IOP 6
Aug 3 - Afternoon

- Convection (MCC) begins to develop north of MCS



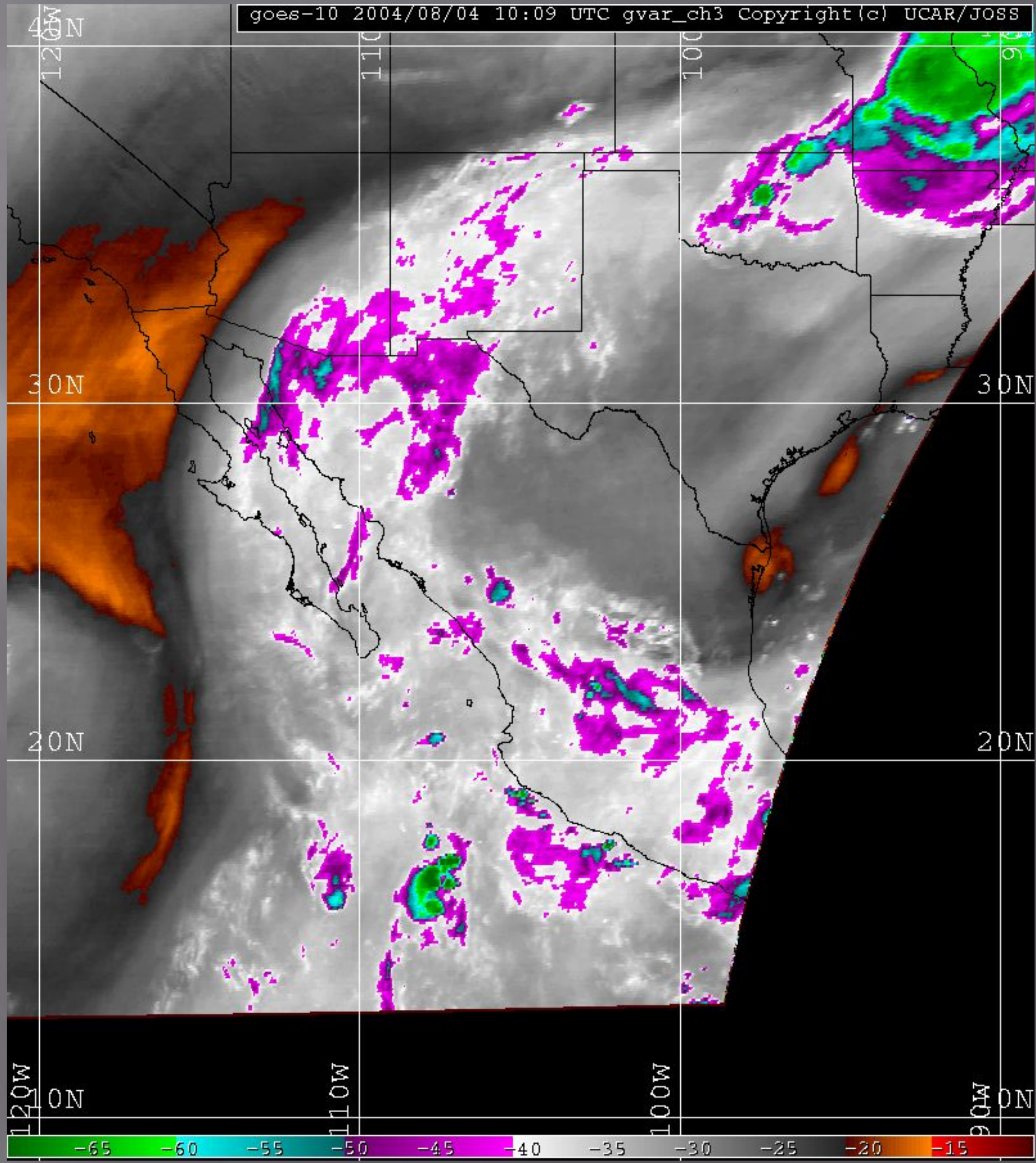
IOP 6
Aug 3 - Evening

- MCS blow up

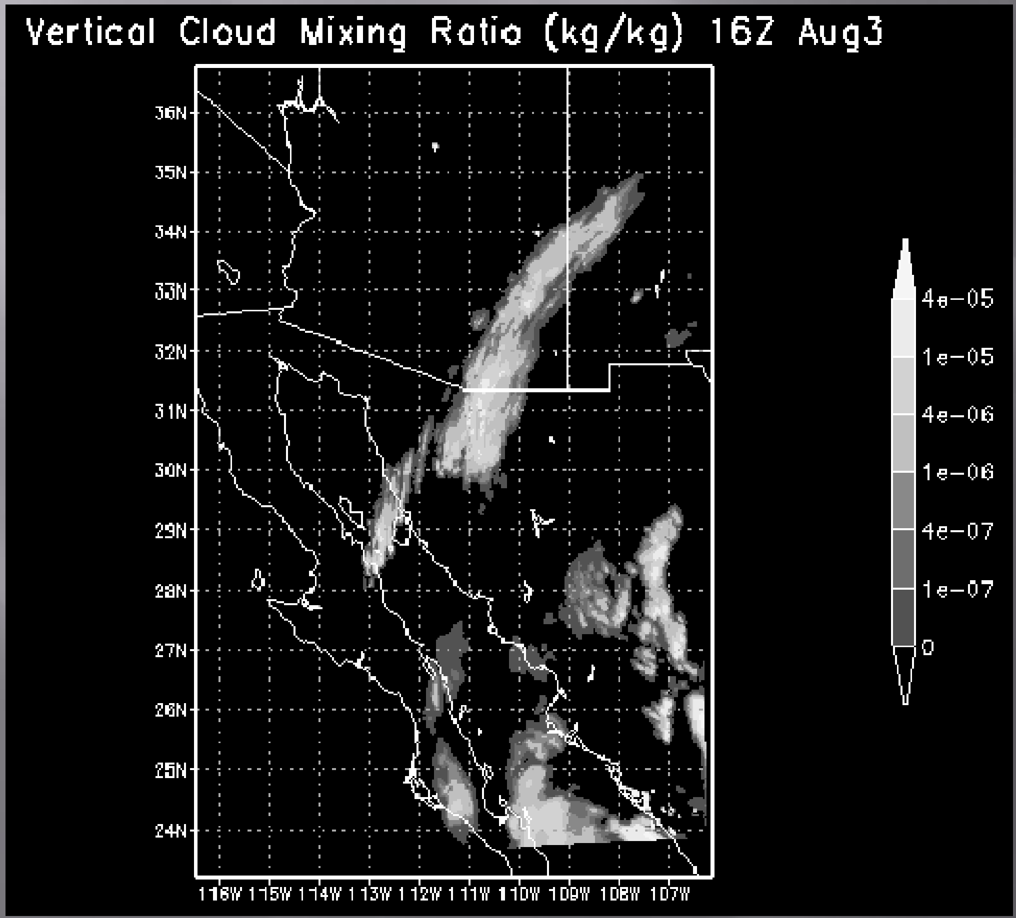


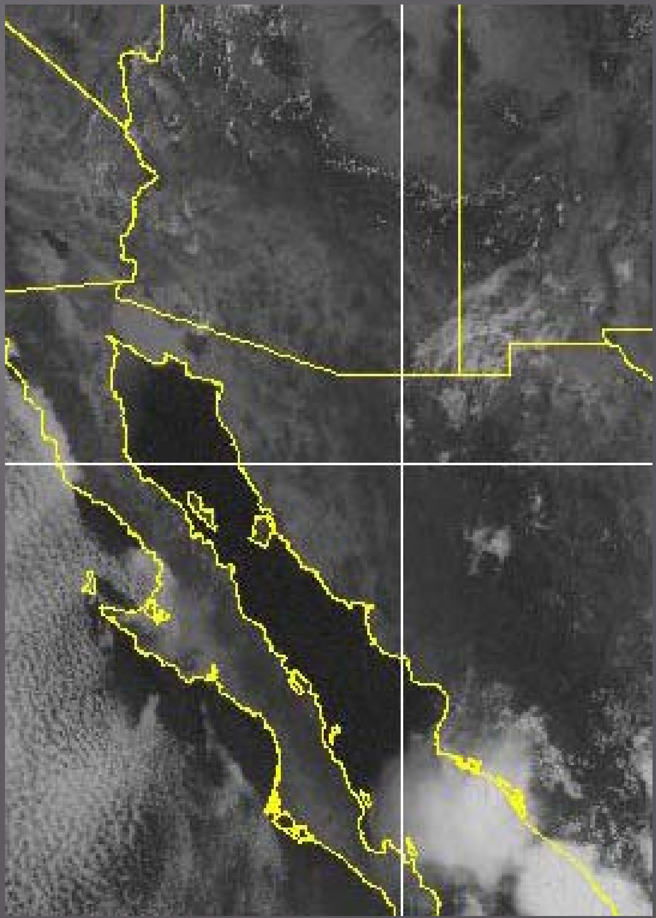
IOP 6
Aug 4 - Morning

- MCS/MCC decays and enters AZ

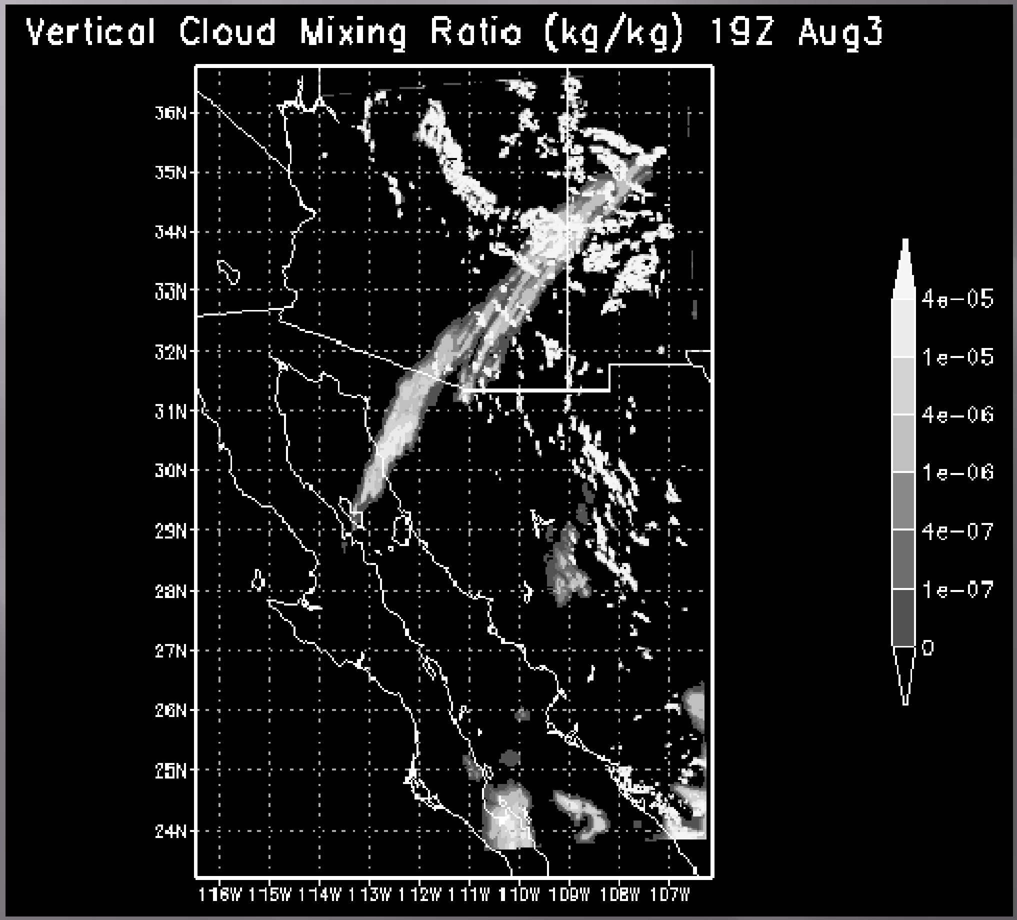


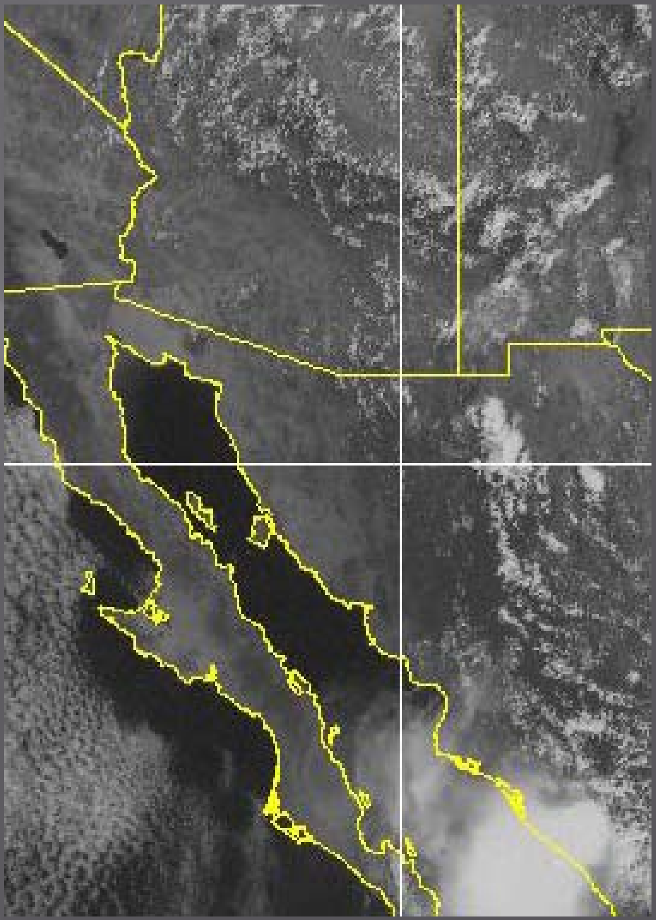
IOP 6 – First Look



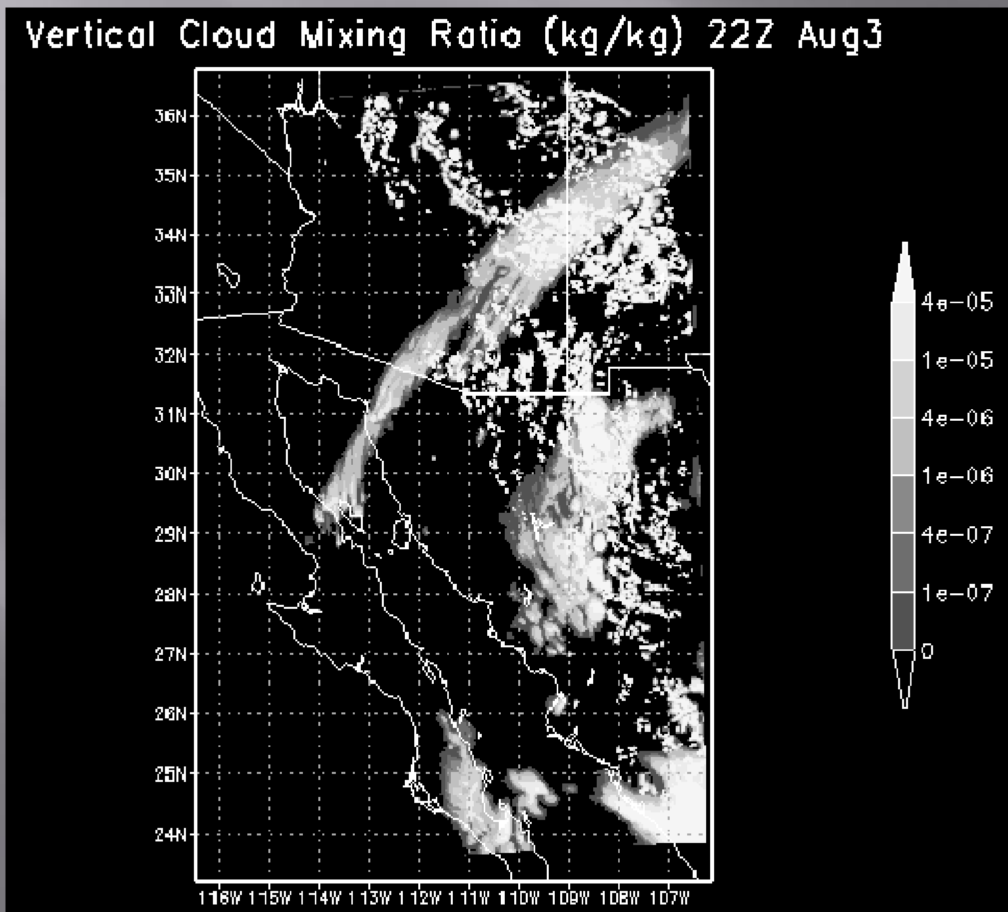


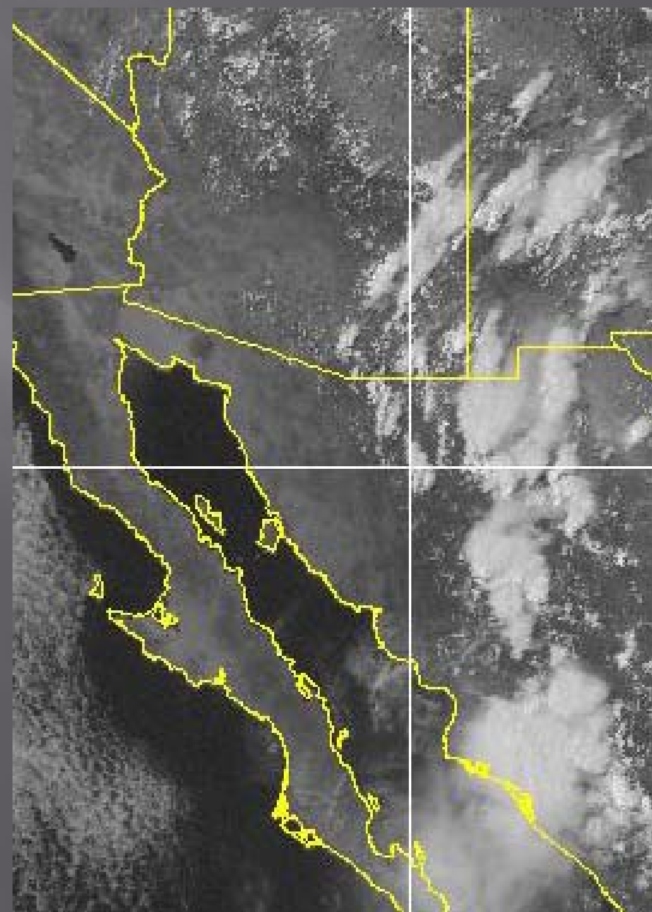
IOP 6 – First Look



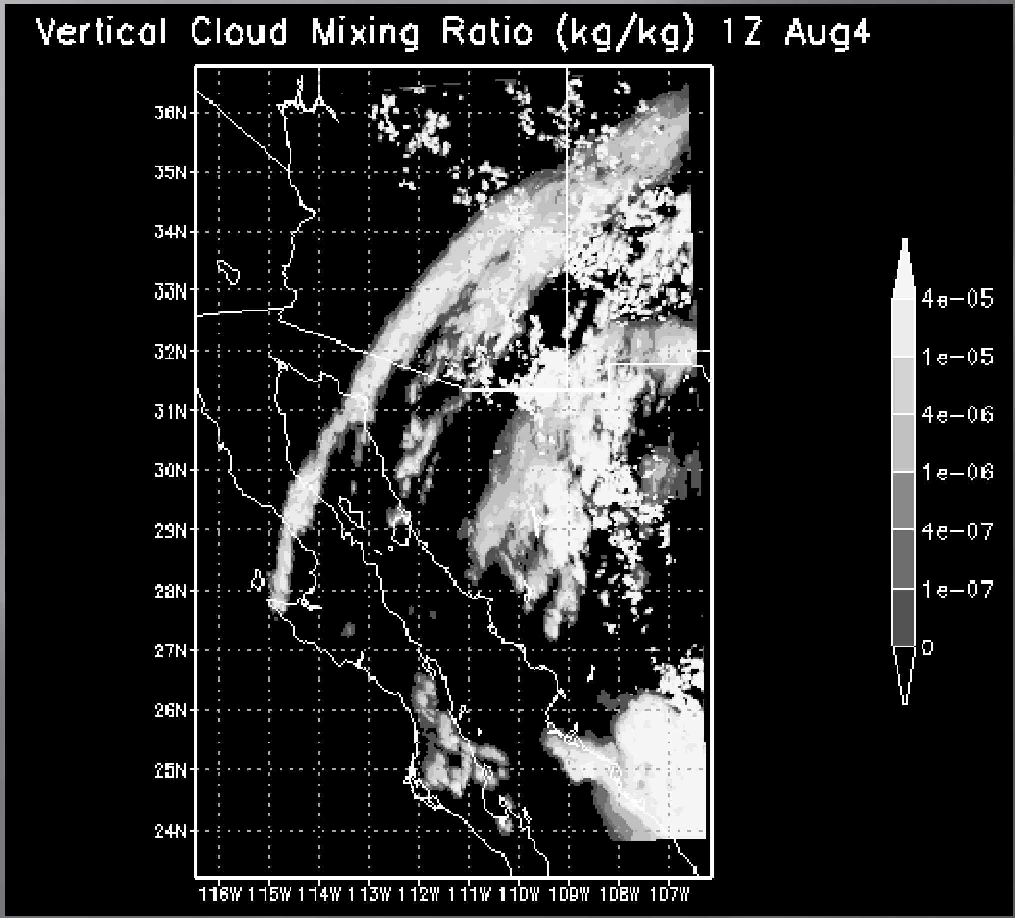


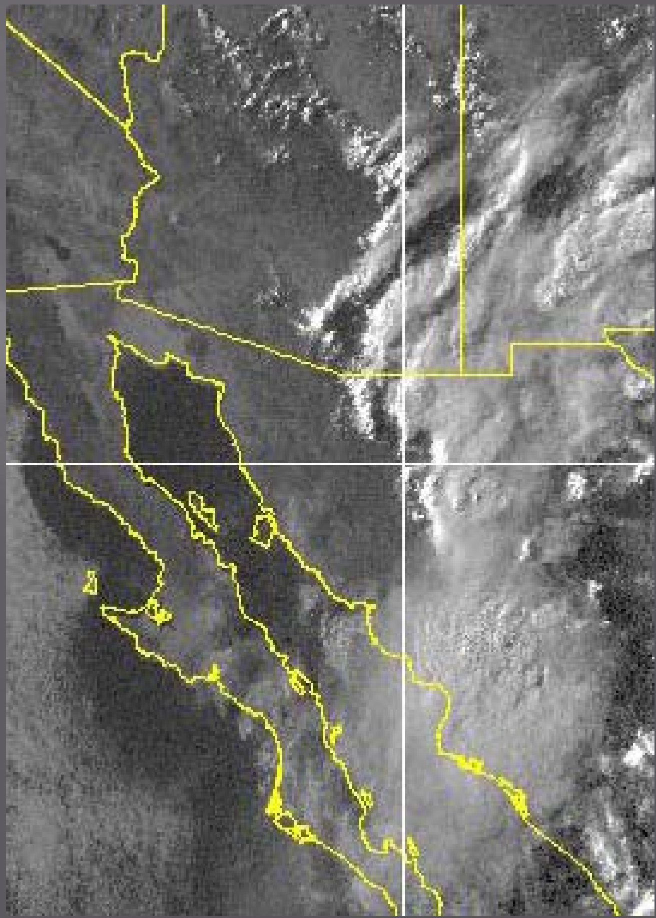
IOP 6 – First Look





IOP 6 – First Look





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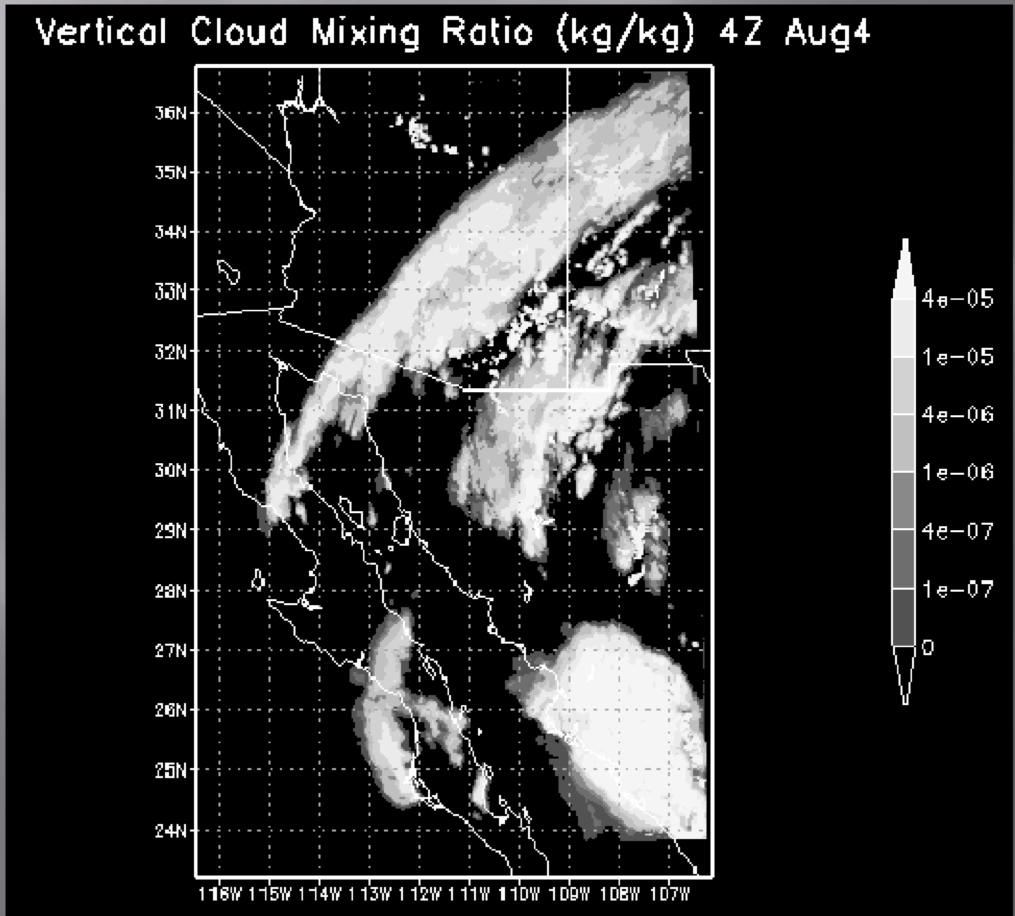
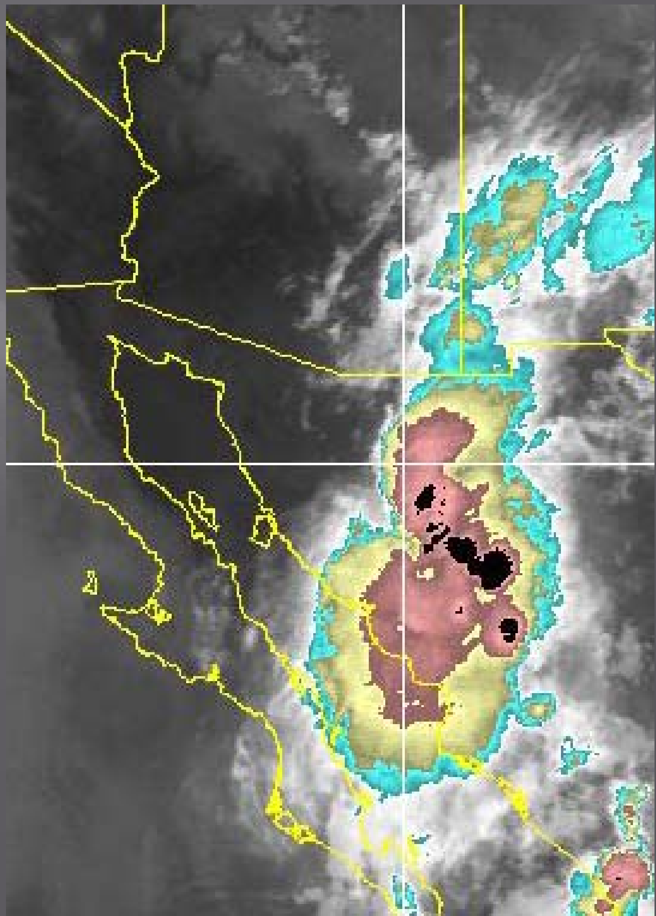
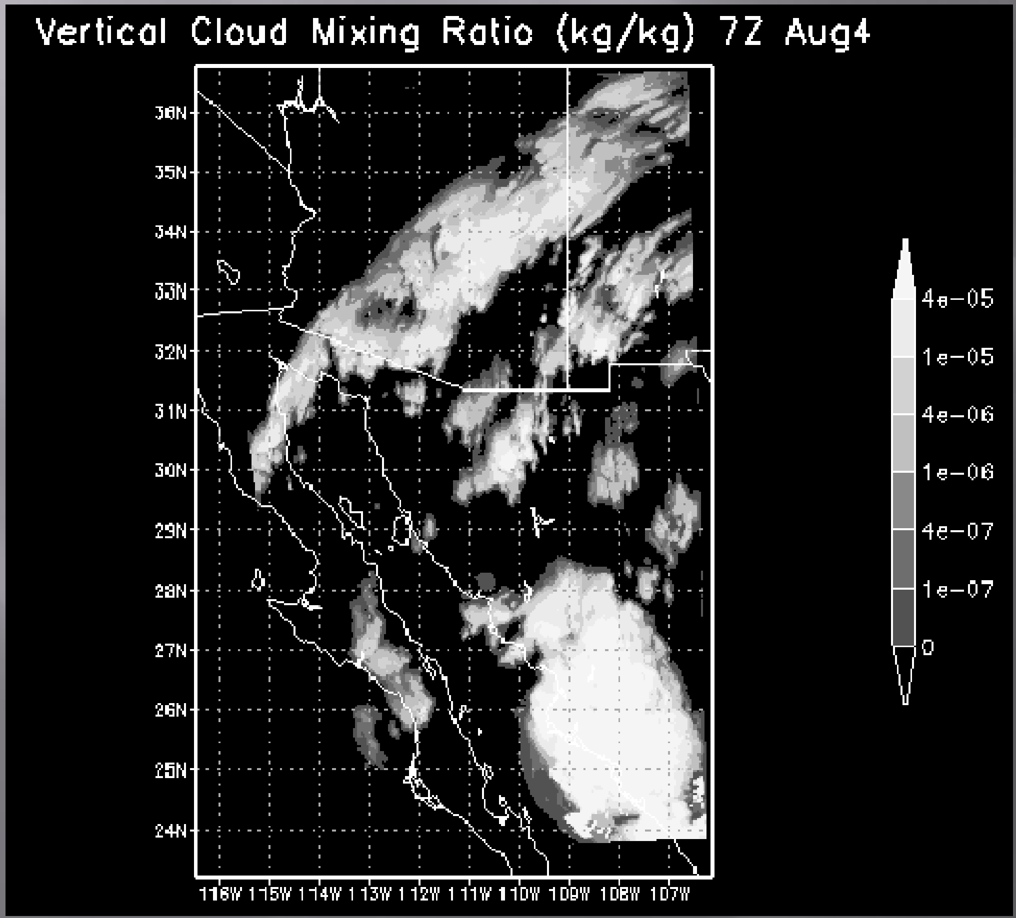
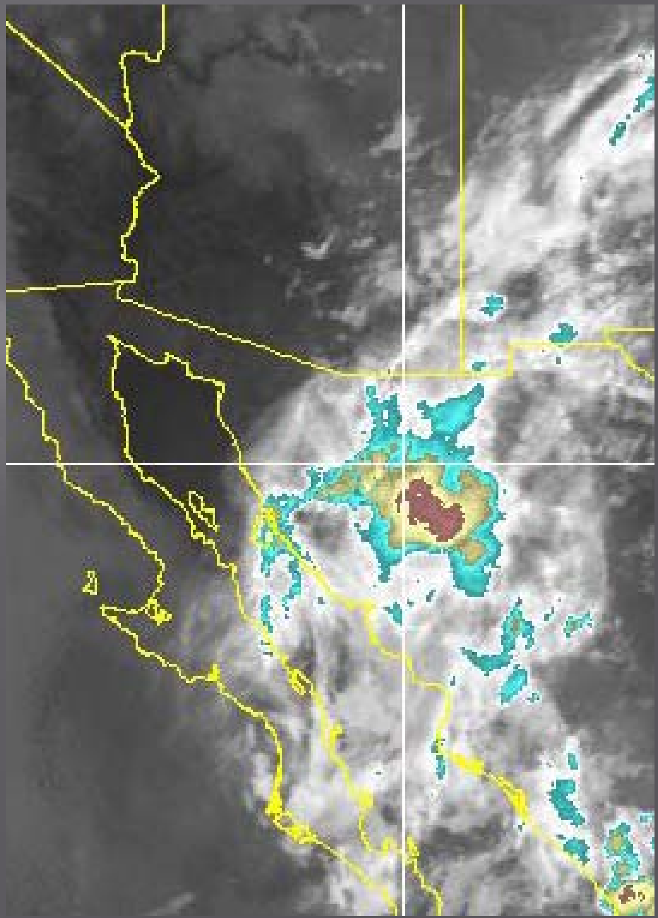


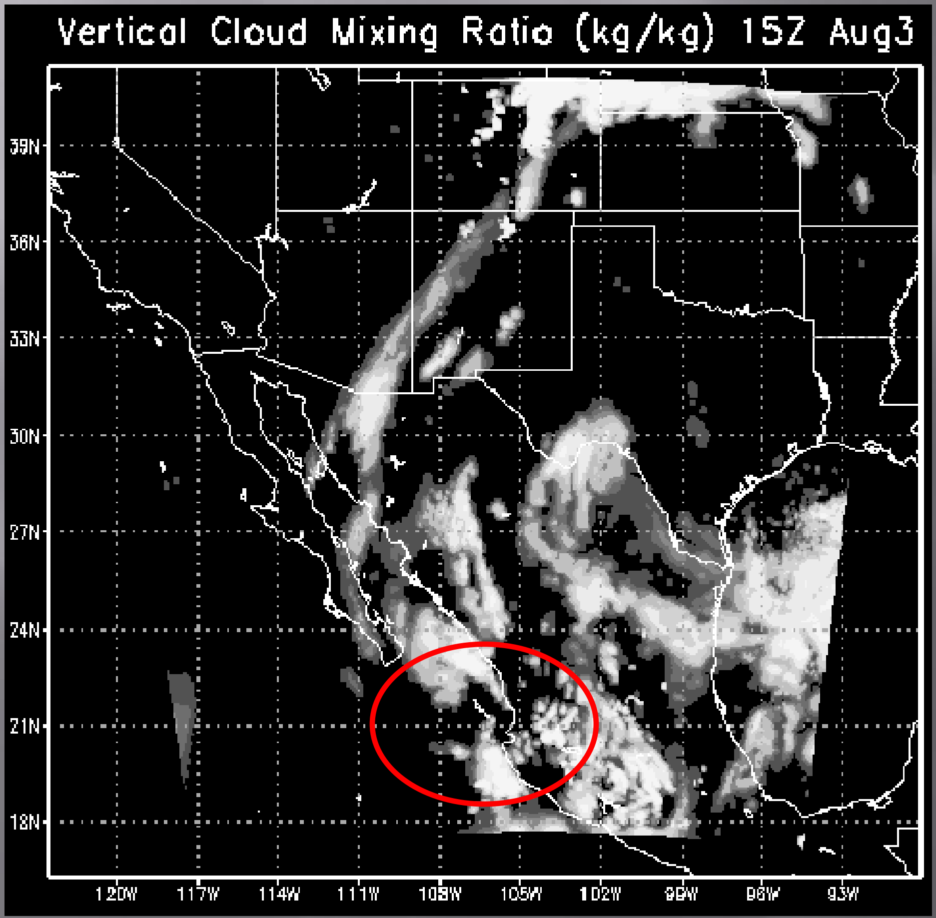


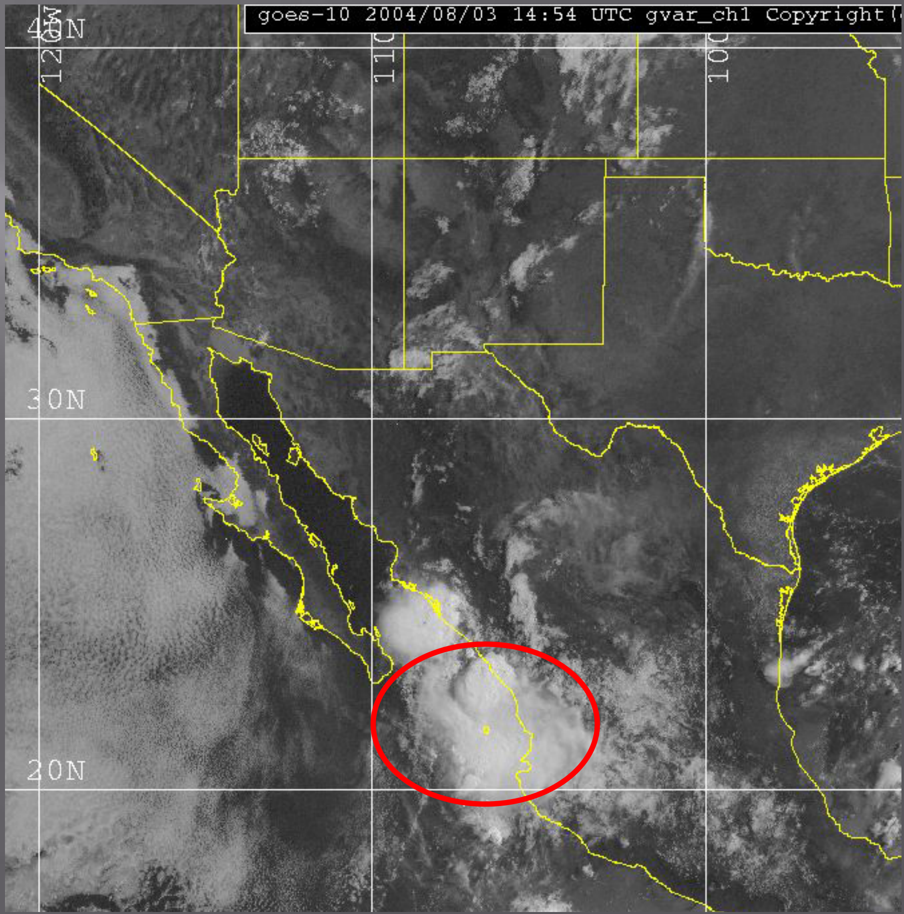
IOP 6 – First Look



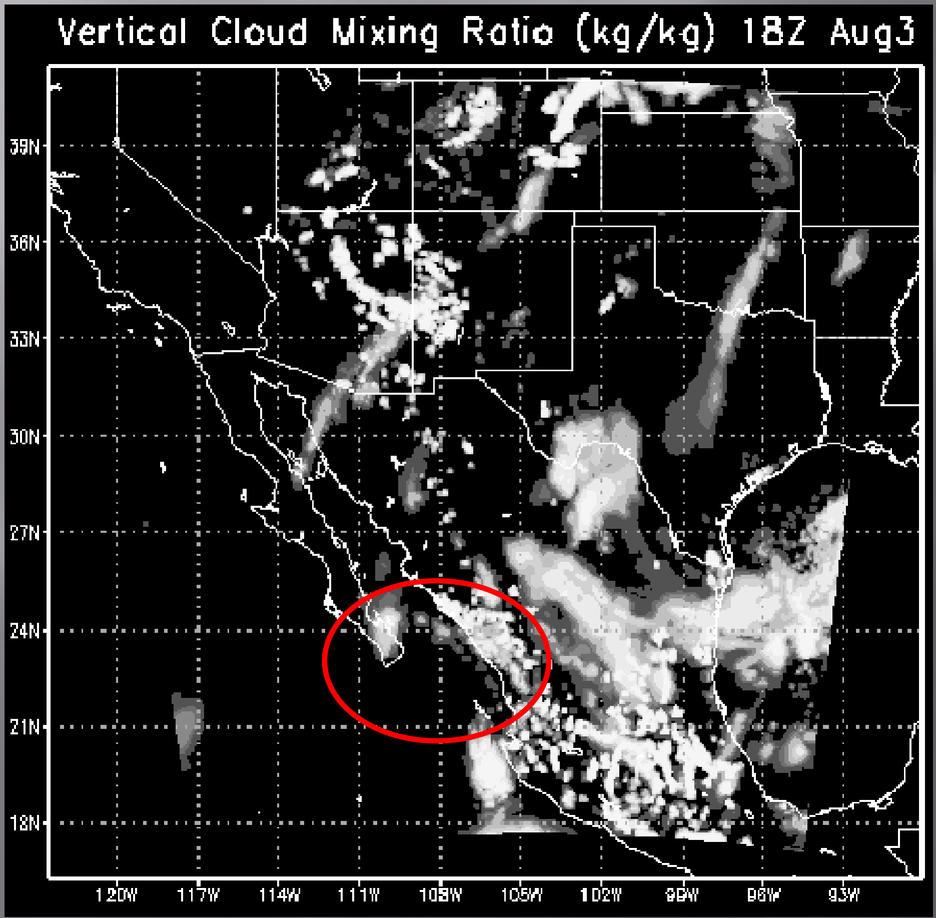


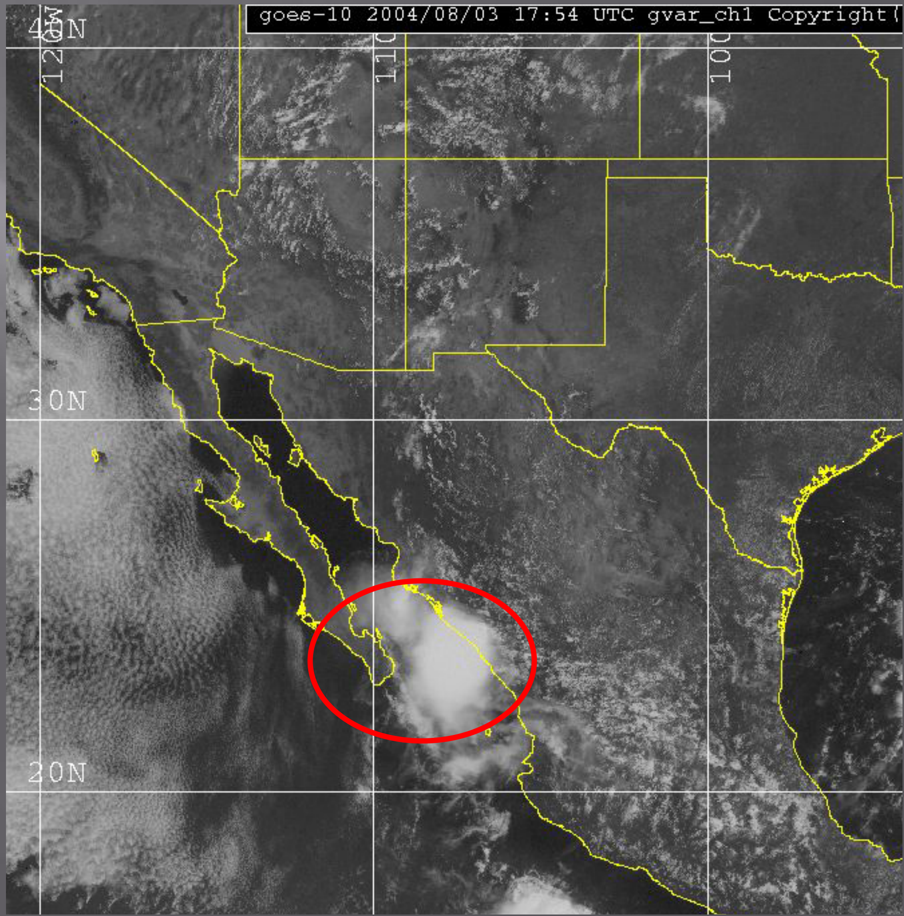
IOP 6 – Grid 2


Vertical Cloud Mixing Ratio (kg/kg) 15Z Aug3
39N
36N
33N
30N
27N
24N
21N
18N
120W
117W
114W
111W
108W
105W
102W
99W
96W
93W

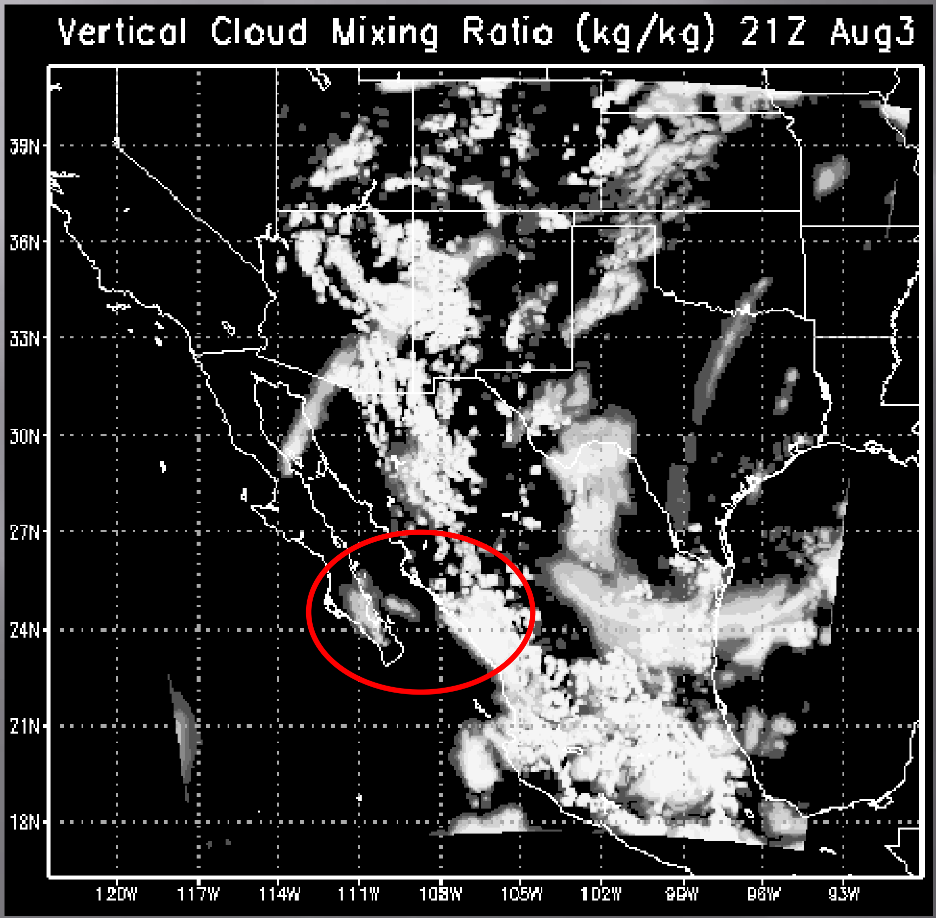

goes-10 2004/08/03 14:54 UTC gvar_ch1 Copyright
30N
20N
110
100

IOP 6 – Grid 2

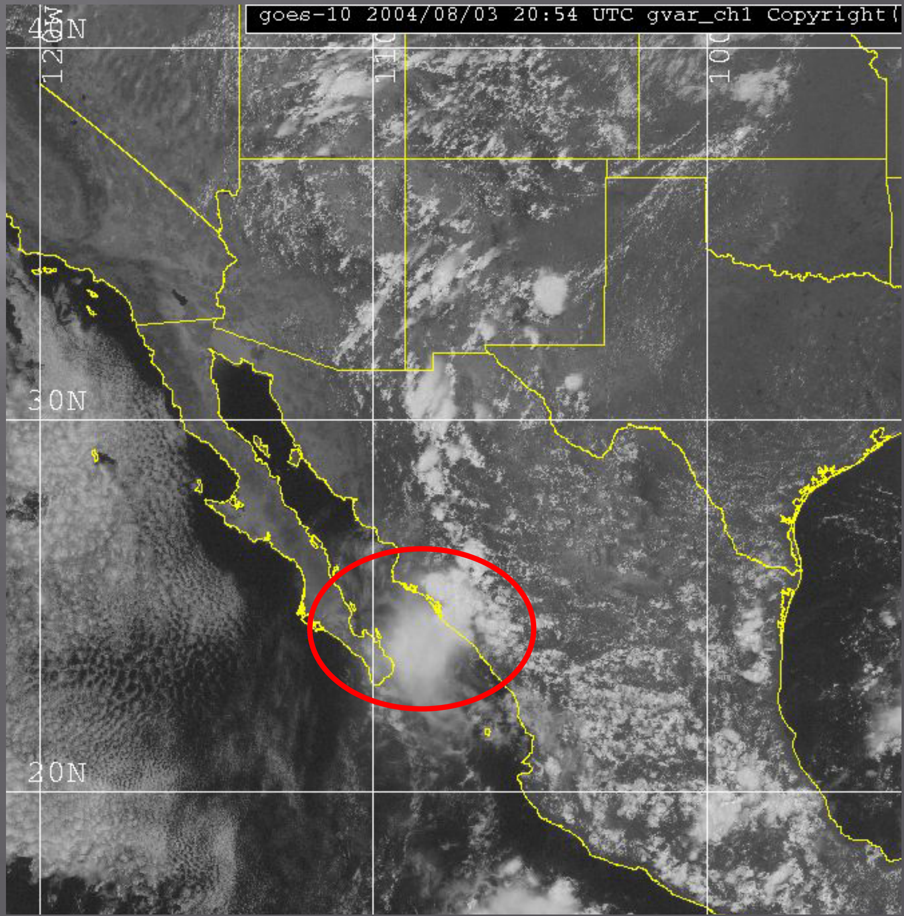

Vertical Cloud Mixing Ratio (kg/kg) 18Z Aug3
39N
36N
33N
30N
27N
24N
21N
18N
120W
117W
114W
111W
108W
105W
102W
99W
96W
93W


goes-10 2004/08/03 17:54 UTC gvar_ch1 Copyright(
40N
30N
20N
120W
110
100

IOP 6 – Grid 2



Vertical Cloud Mixing Ratio (kg/kg) 21Z Aug3
39N
36N
33N
30N
27N
24N
21N
18N
120W
117W
114W
111W
108W
105W
102W
99W
96W
93W



goes-10 2004/08/03 20:54 UTC gvar_ch1 Copyright(
30N
20N

IOP 6 – Potential solutions

- Extend out the finest domain
- Reduce the spin up time

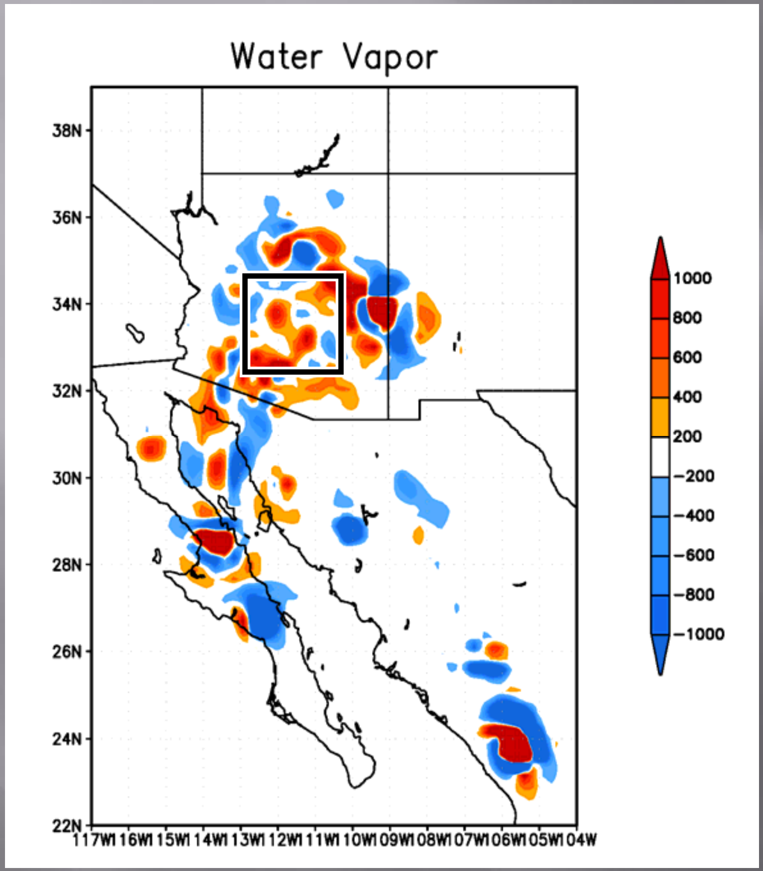
Concluding Points

- WRF does a reasonable job modeling IOPs 2 and 5. Modification will be needed to improve IOP 6.
- These runs 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.

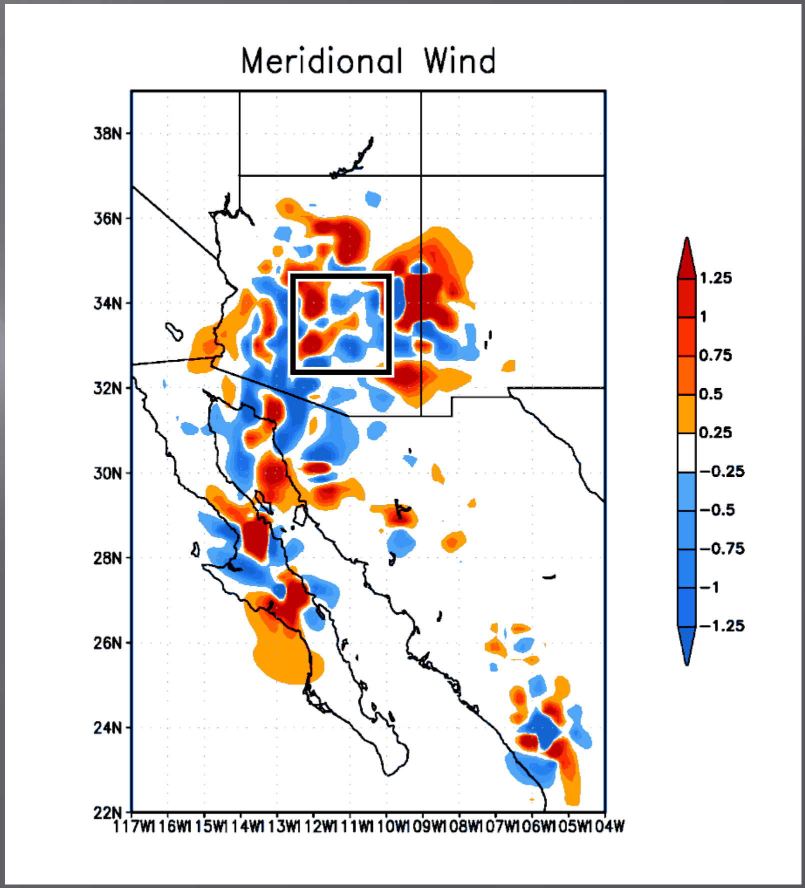
Future Work

- 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}