Summertime precipitation patterns associated with the sea breeze and land breeze in southern Mississippi and eastern Louisiana

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April 21, 2009

EGU General Assembly 2009, Precipitation Science Program

Sea (land) breeze and Convection

- The sea breeze is commonly observed along the northern coast of the Gulf of Mexico coast during the summer (June, July, August)
- Intersection of moist air over water with boundary layer perturbations (i.e. horizontal convective rolls) over land will trigger convection (Fovell 2005)
- The exact orientation and migration of the sea (land) breeze front, and the focus of associated convection, depends upon:
  - the temperature gradient between land and water
  - the prevailing boundary layer flow
  - land elevation
  - shape of the coastline

  (review by Medlin and Croft 1998)

Methodology

- Surface observations, upper air observations at KLIX, and NEXRAD data at KLIX collected for:
  June, July, and August of 2003 – 2005 (276 days)

- Reduced dataset to “sea/land breeze” (SLB) days with the following criteria:

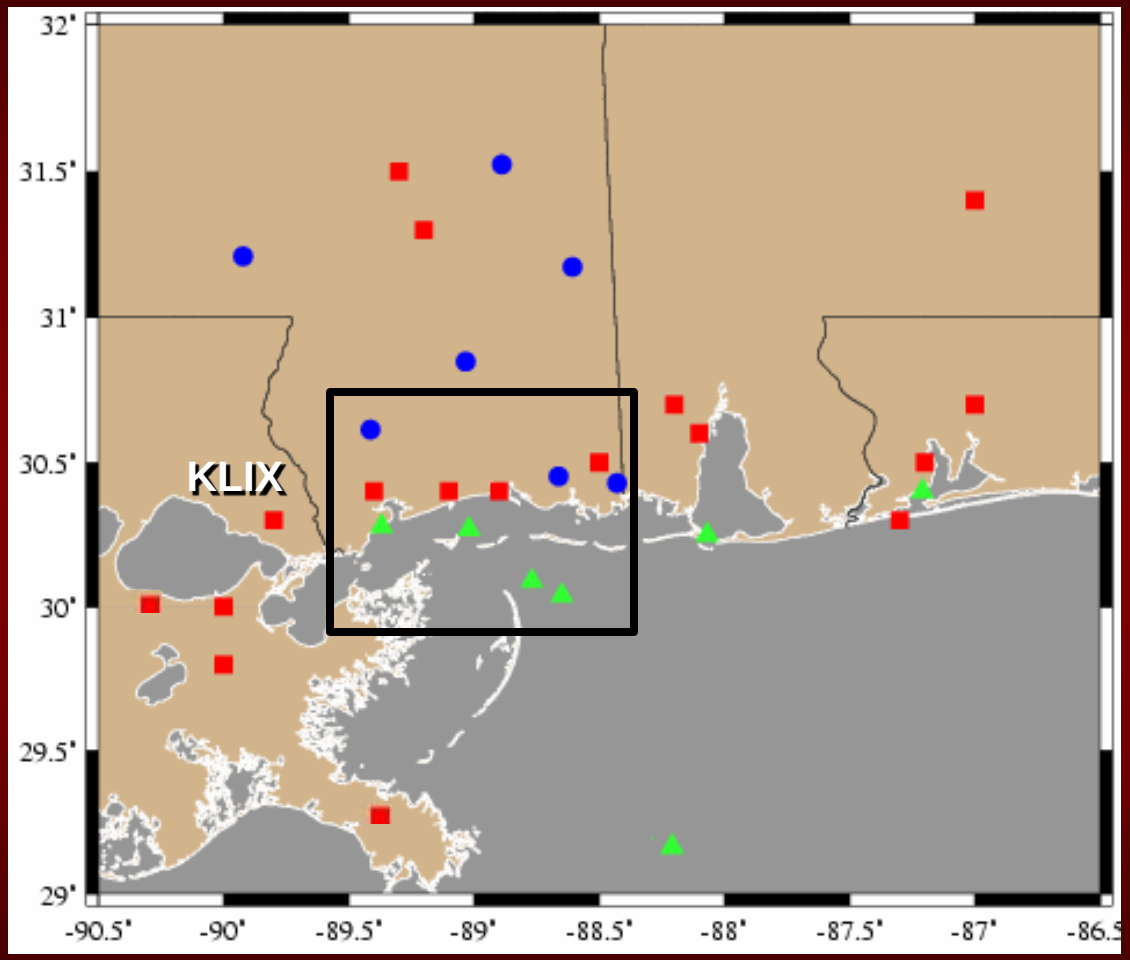
  – wind speed at land stations does not exceed 7.5 mph (or 3.4 m s^{-1}) at 00 UTC or 12 UTC

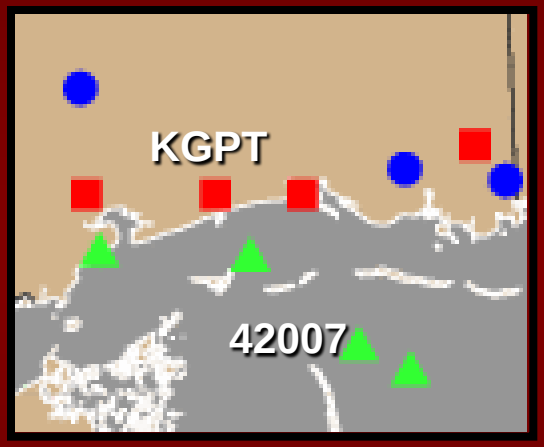
  – no precipitation event generated by:
    - a synoptic system, as discerned from archive of twice-daily UNISYS charts
    - widespread air mass thunderstorm activity, as discerned from NEXRAD data (possible synoptic forcing)

  – precipitation is primarily induced by the sea / land breeze

- 3-year averages of meteorological quantities computed for remaining days (102) by month

Observing stations





Red squares: NOAA stations Green triangles: buoys

Blue circles: Mississippi RAWS stations

Two typical case studies

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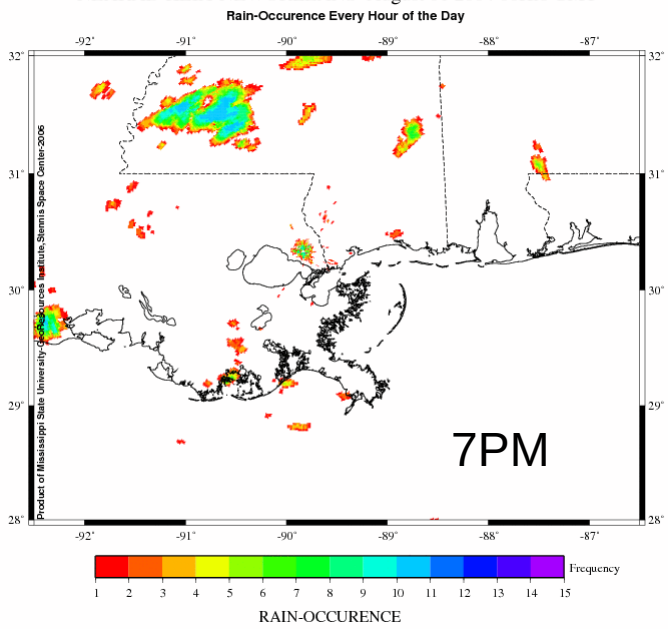

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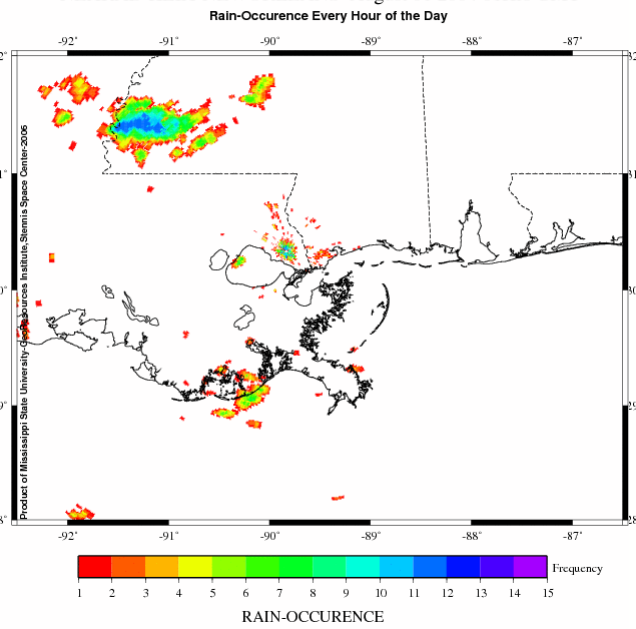

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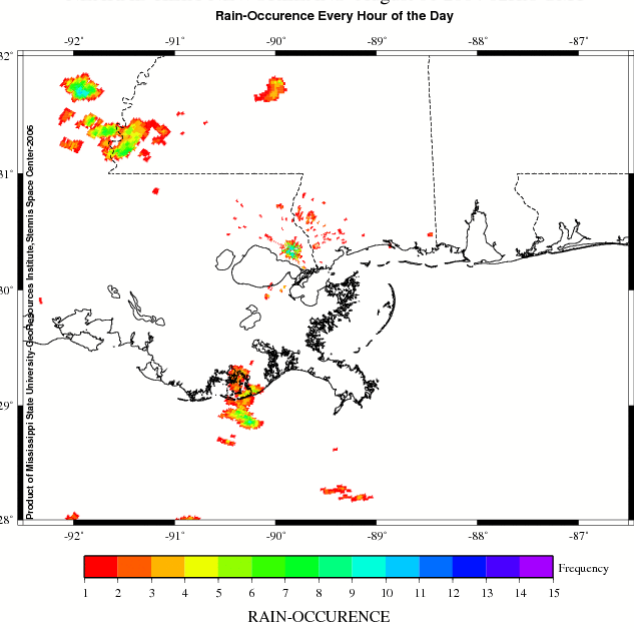

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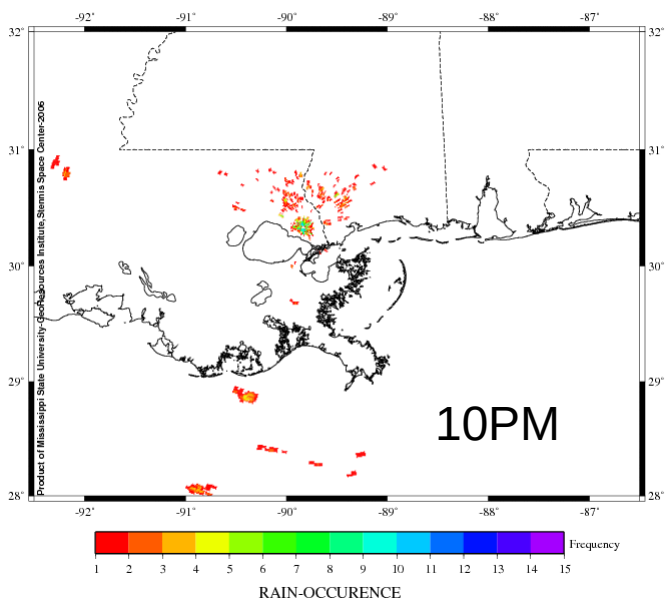

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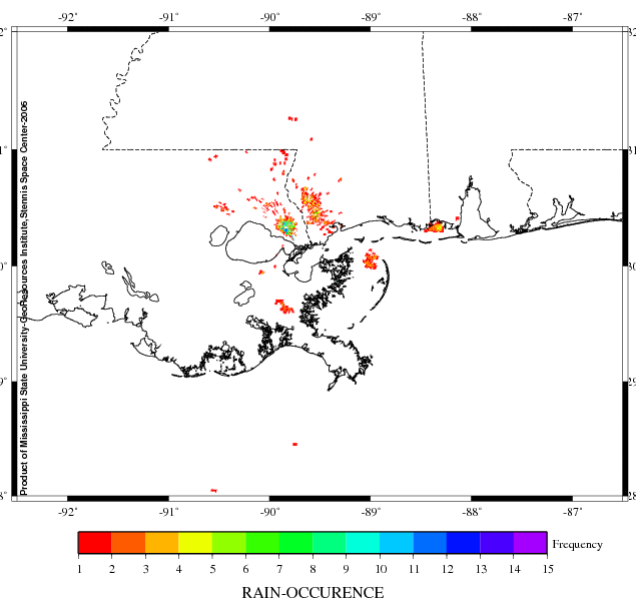

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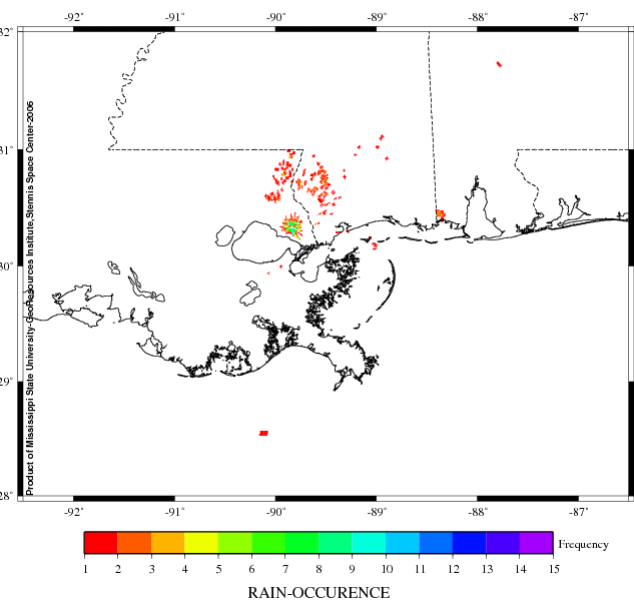

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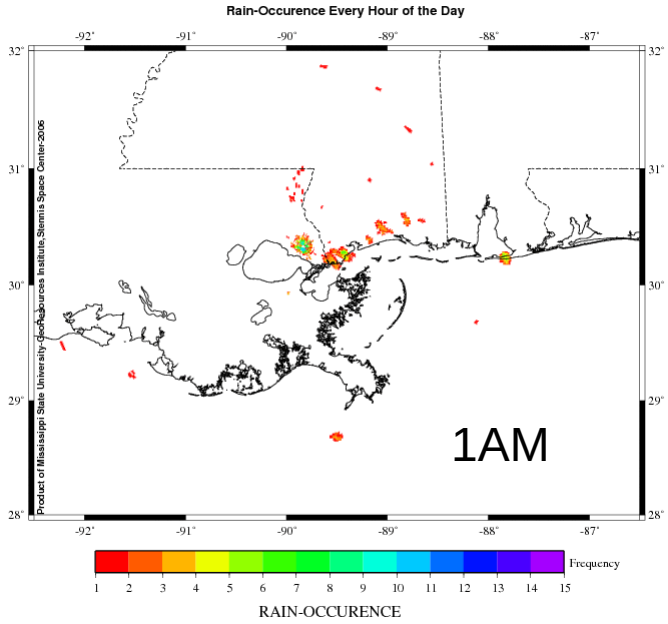

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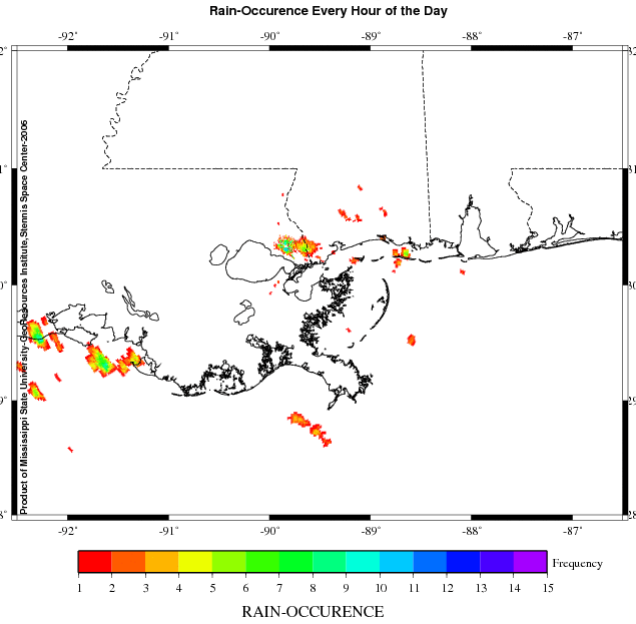

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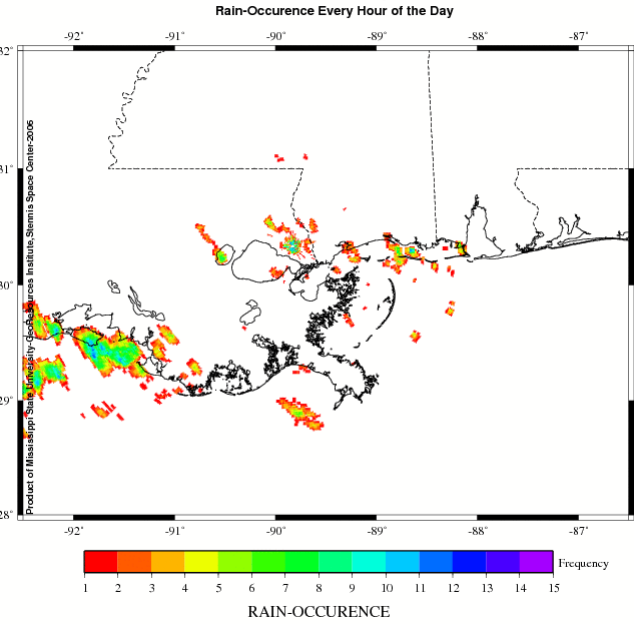

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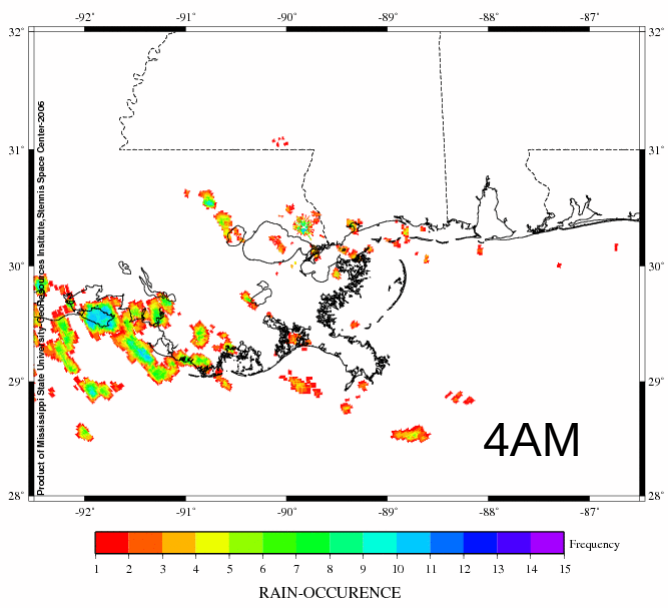

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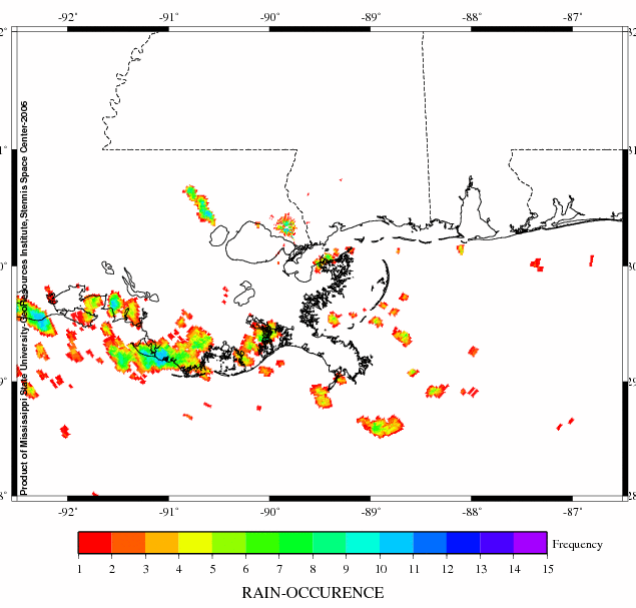

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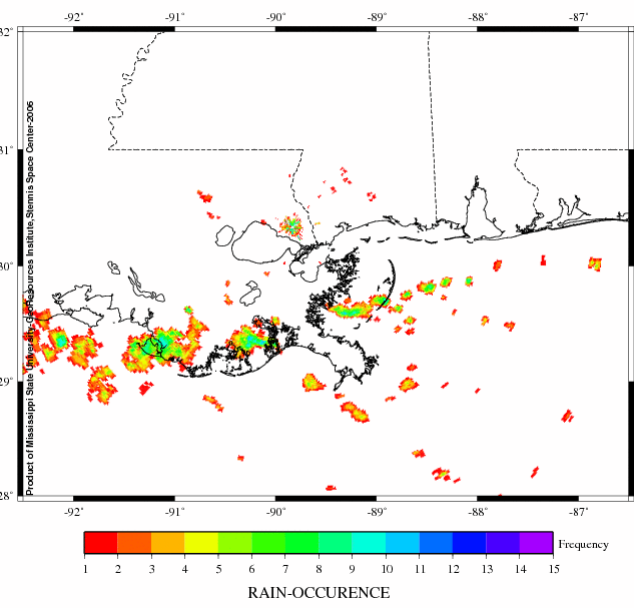

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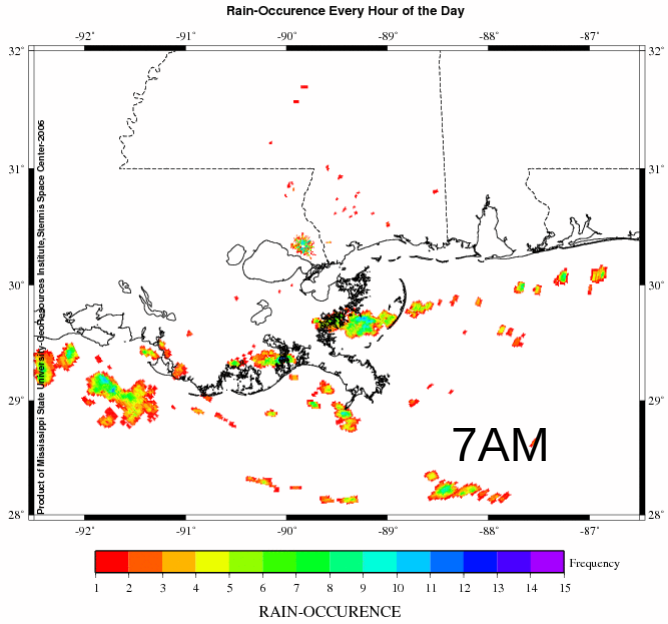

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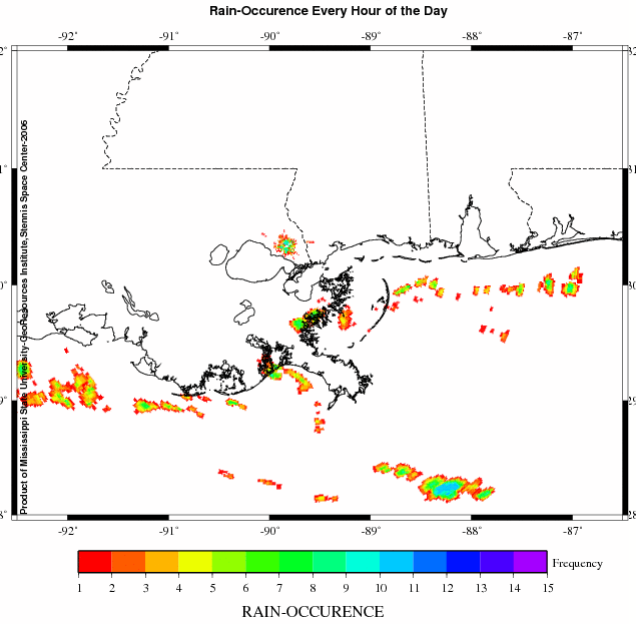

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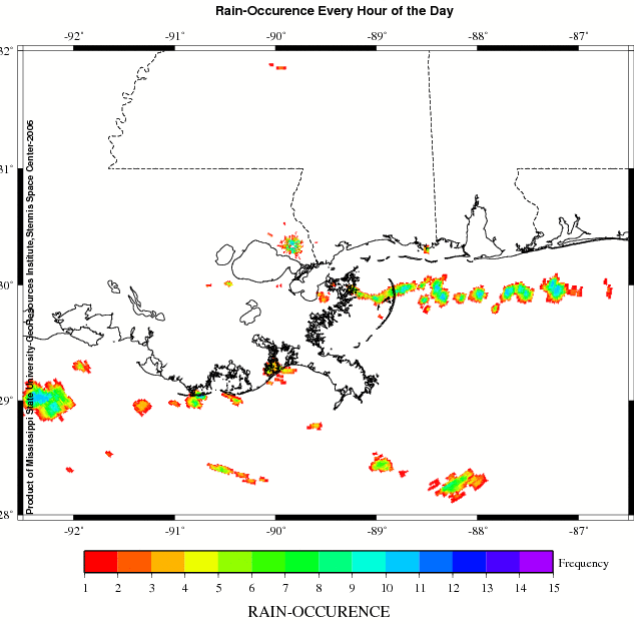

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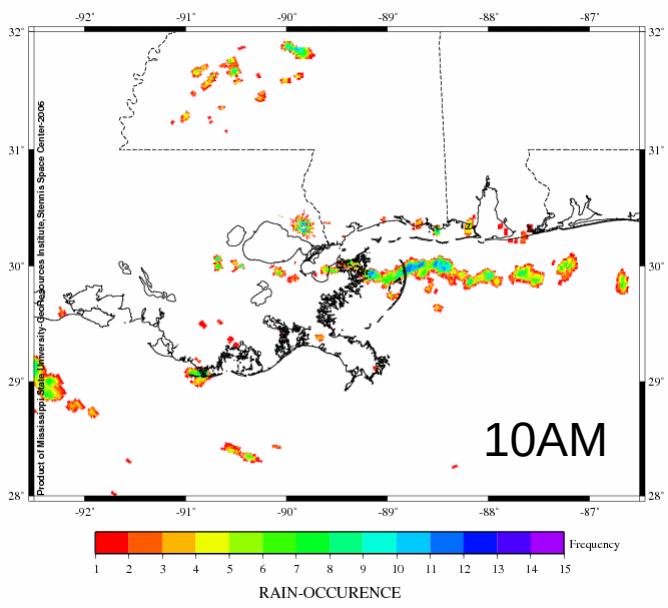

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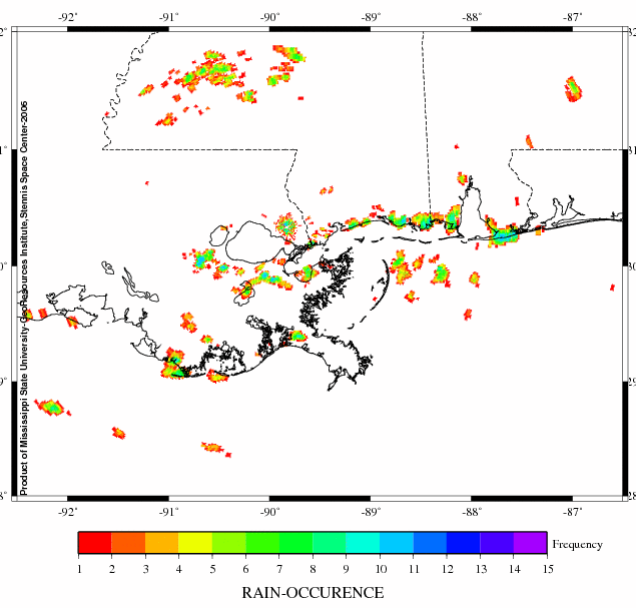

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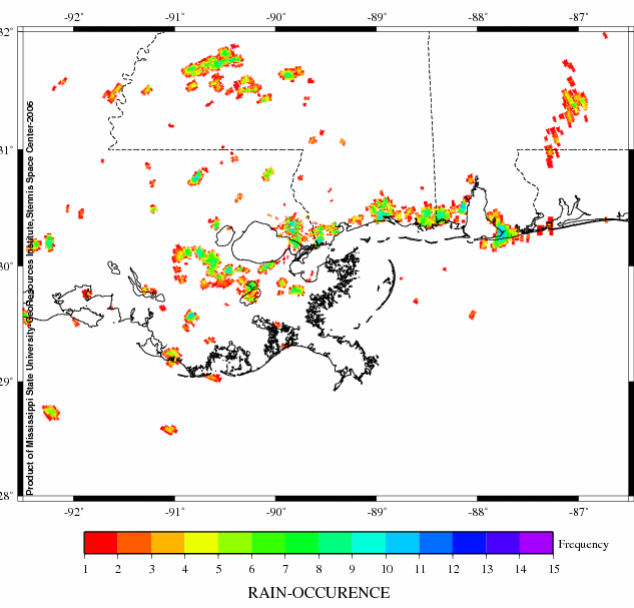

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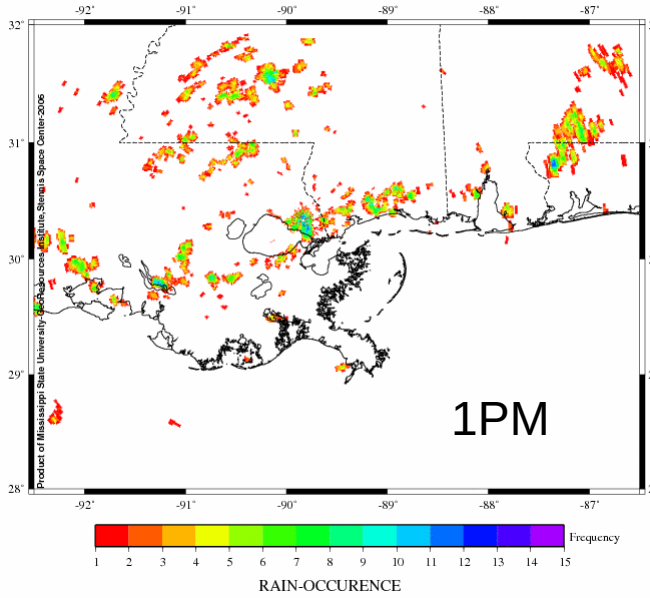

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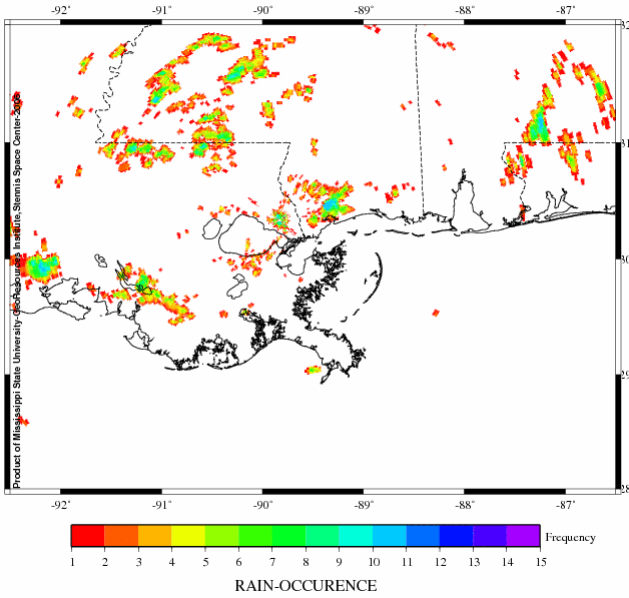

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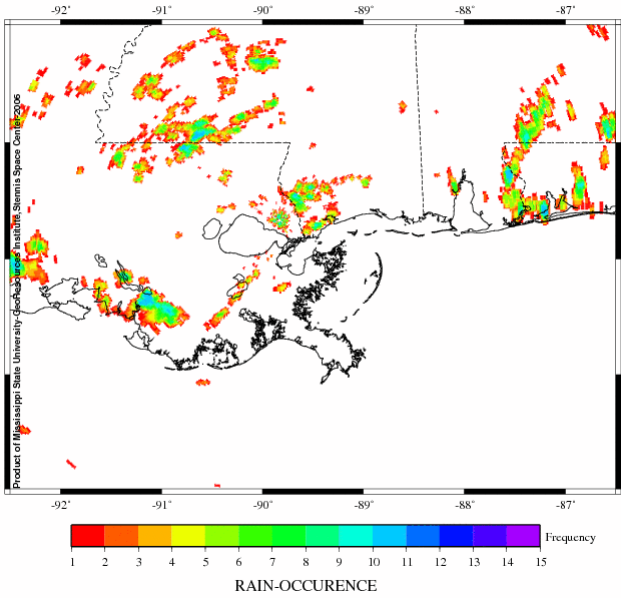

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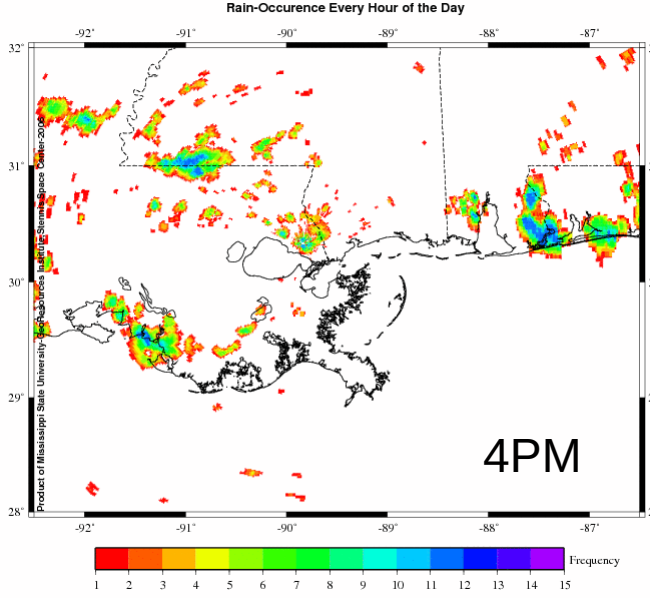

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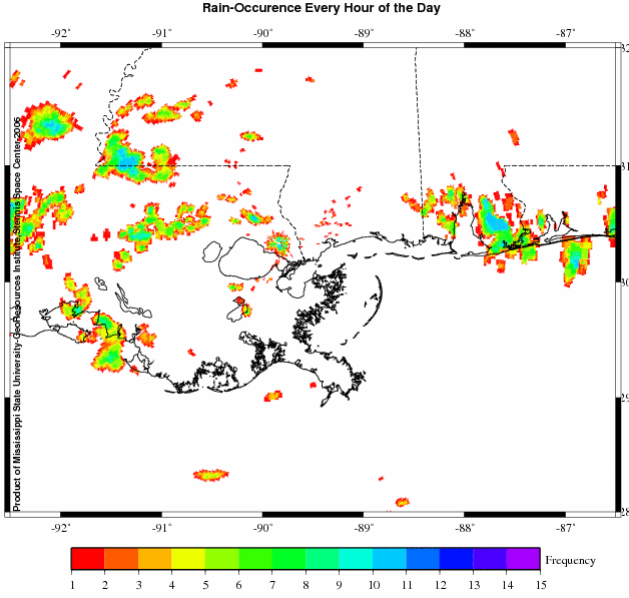

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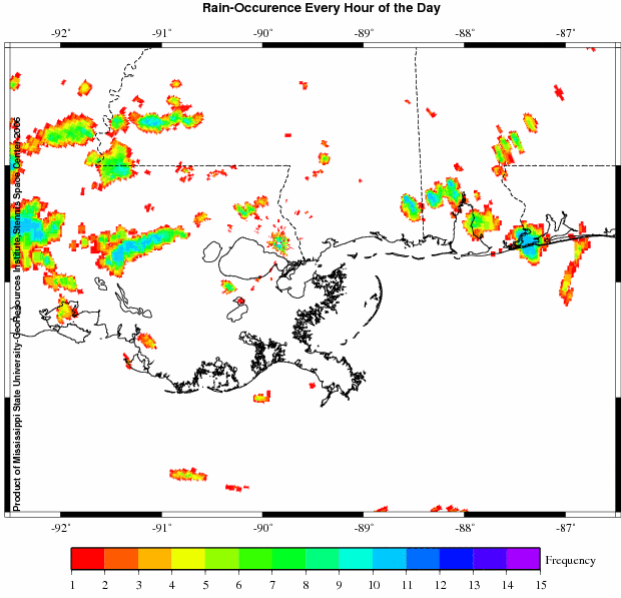

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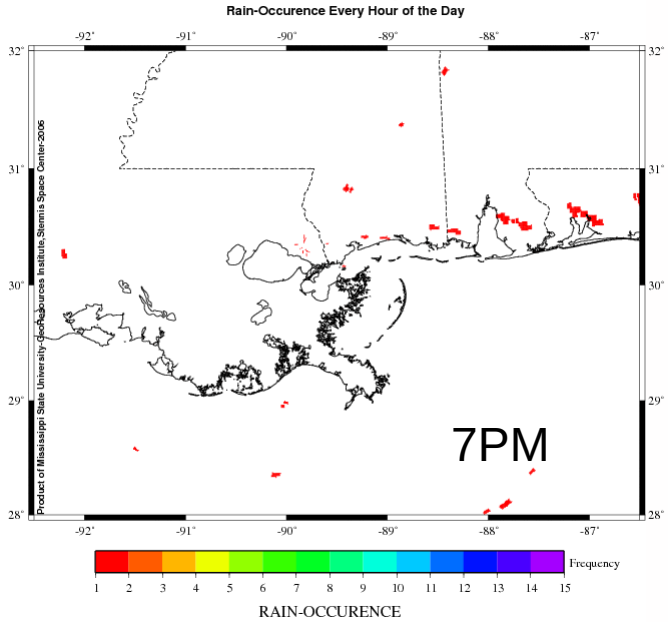

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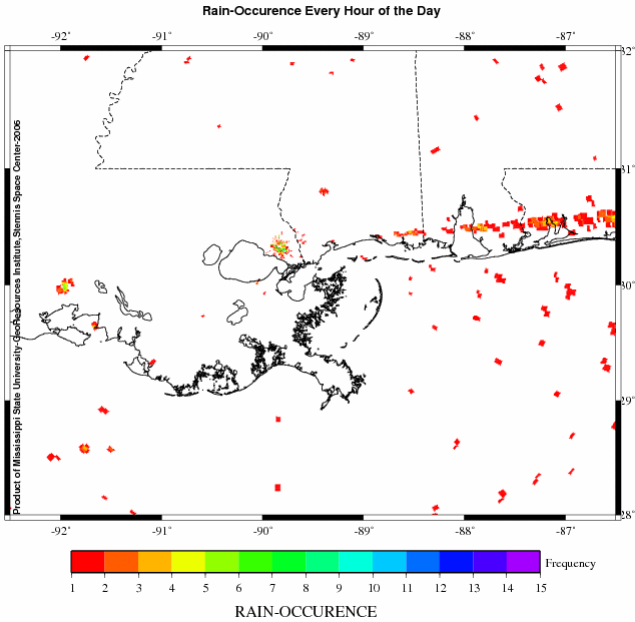

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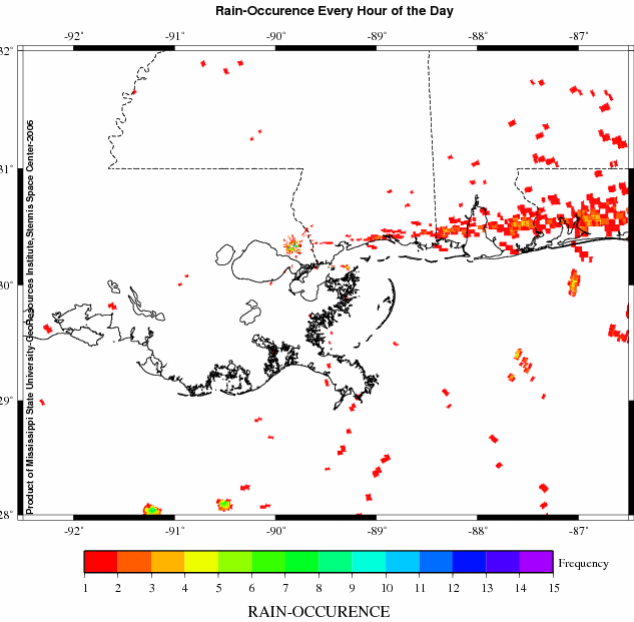

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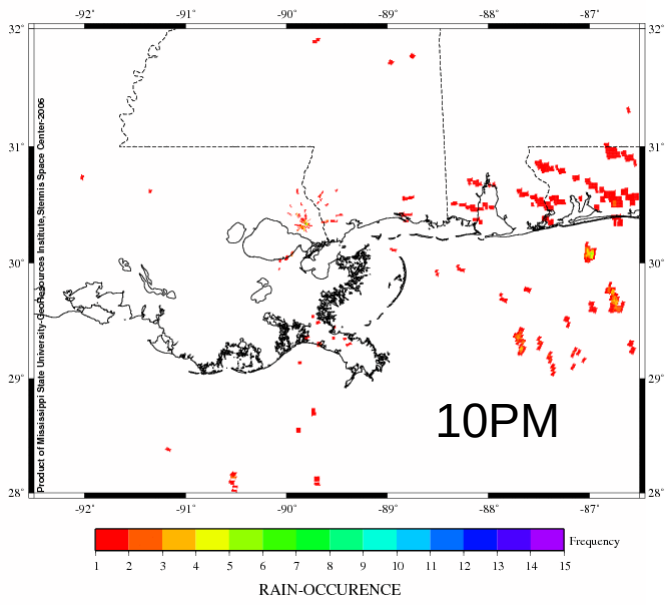

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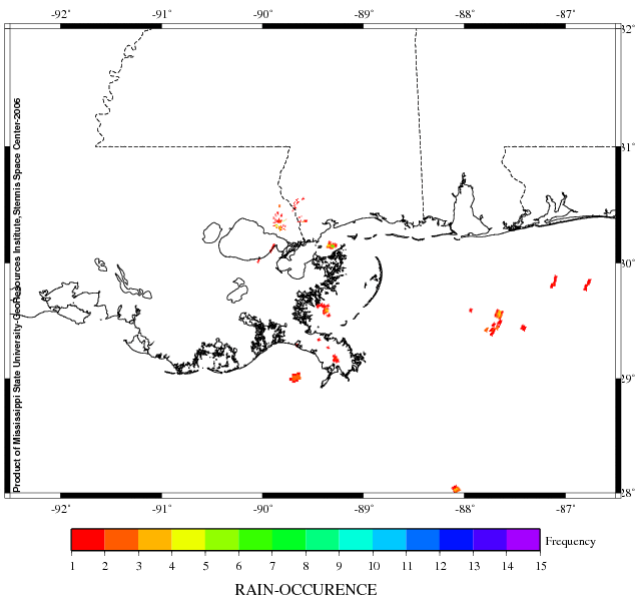

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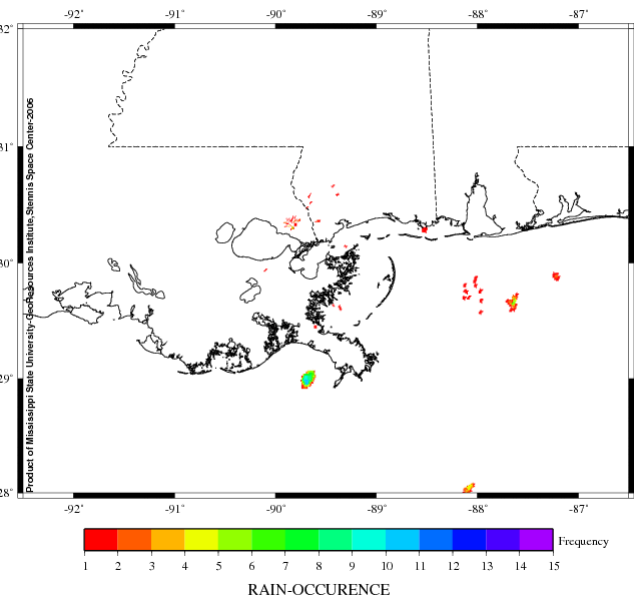

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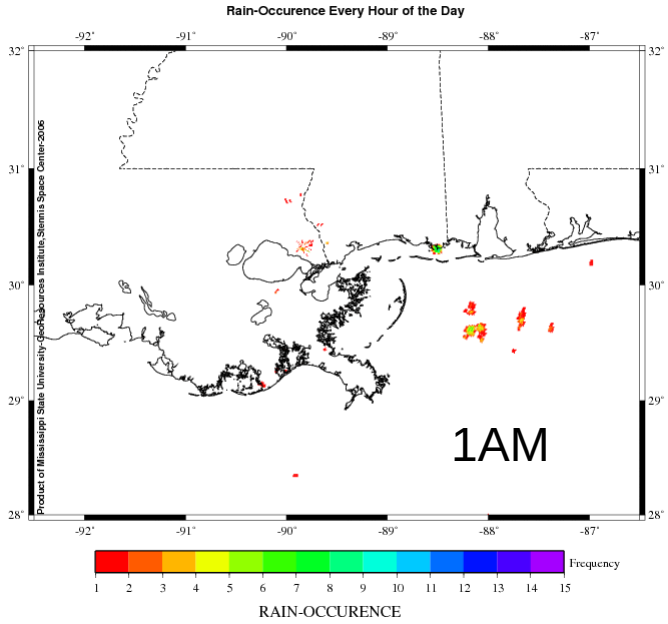

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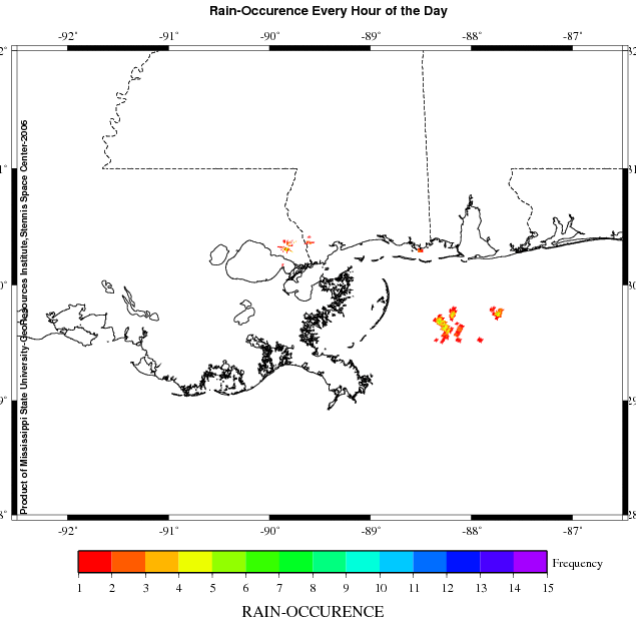

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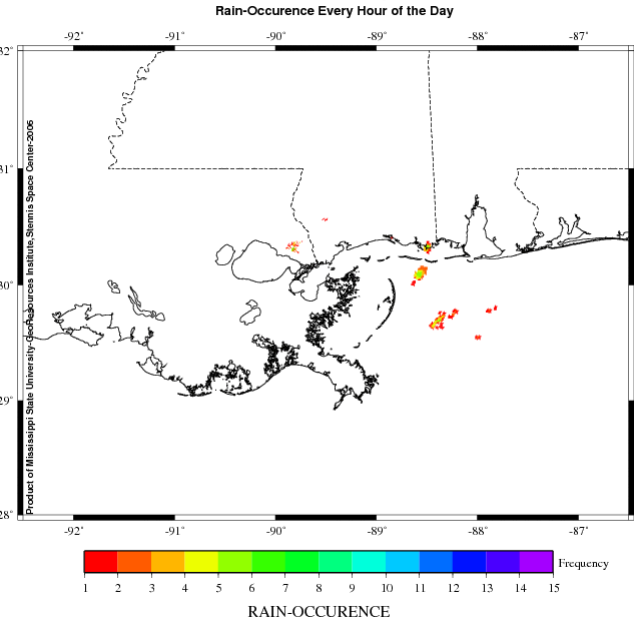

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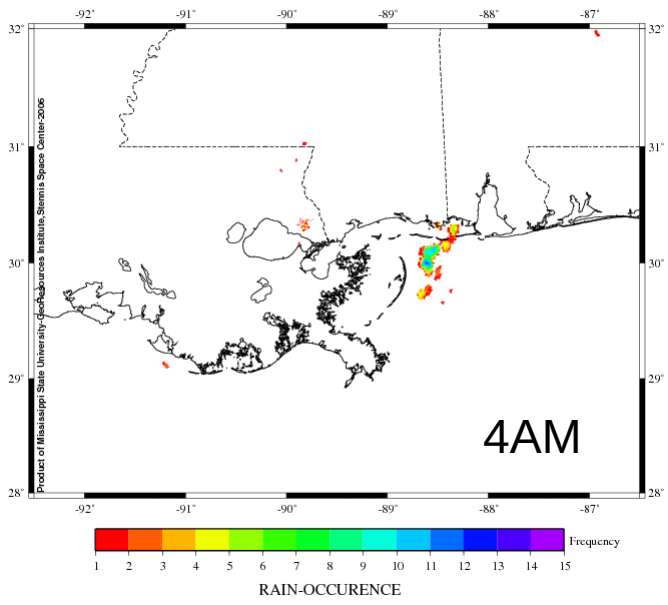

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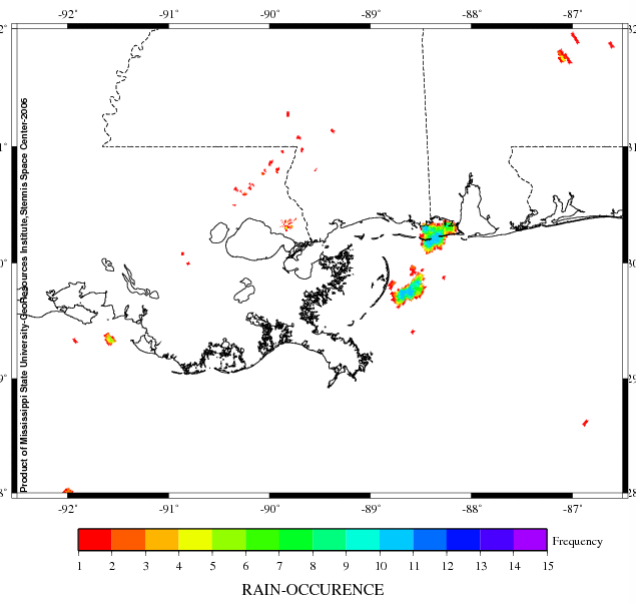

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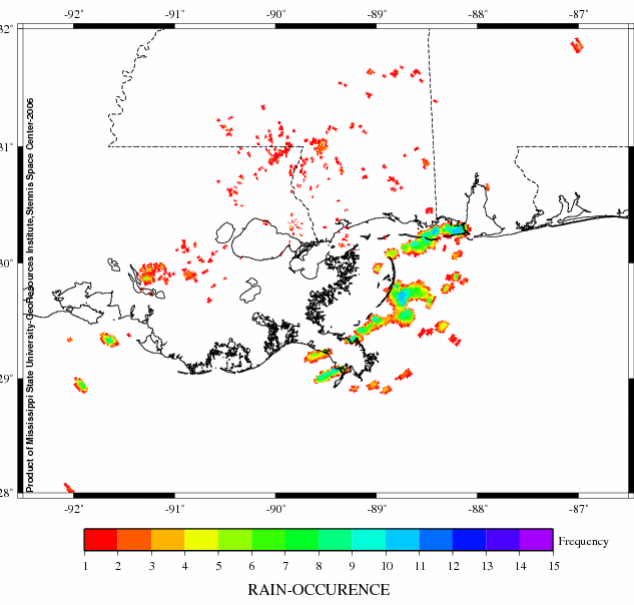

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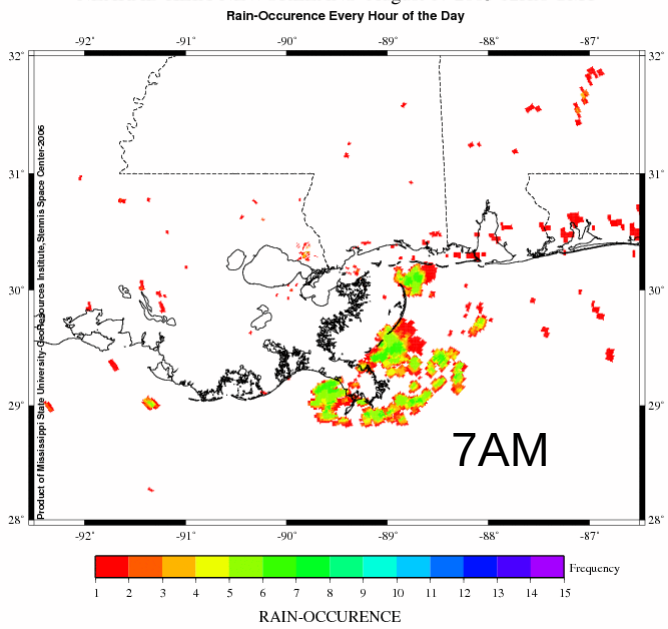

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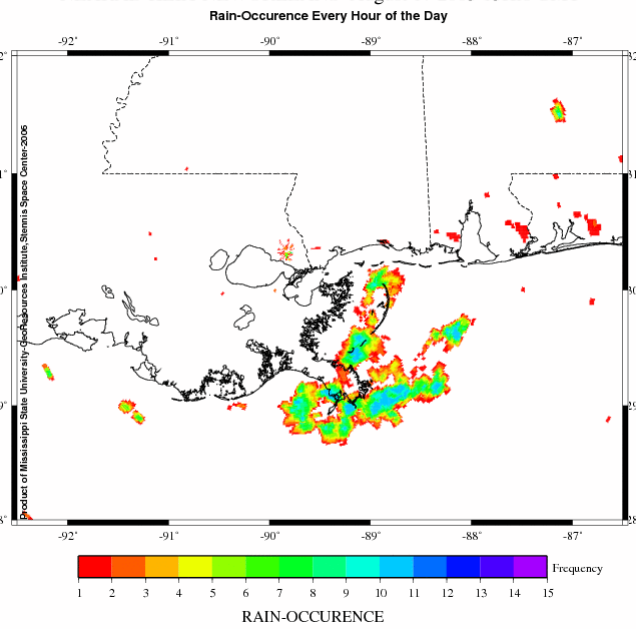

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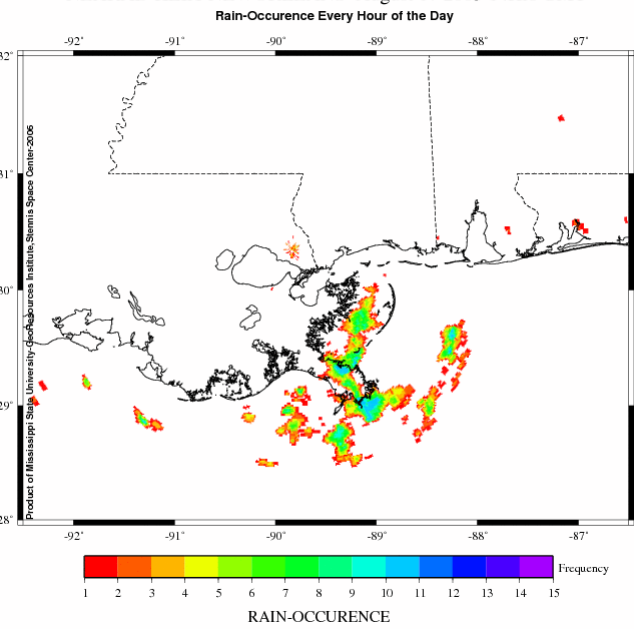

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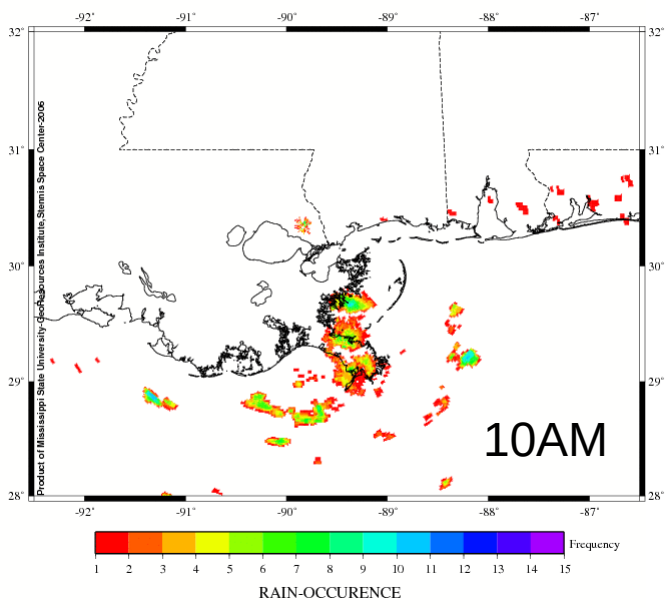

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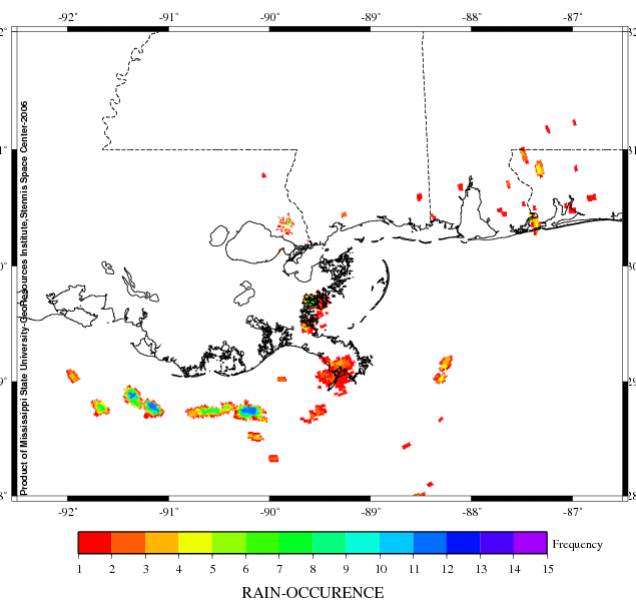

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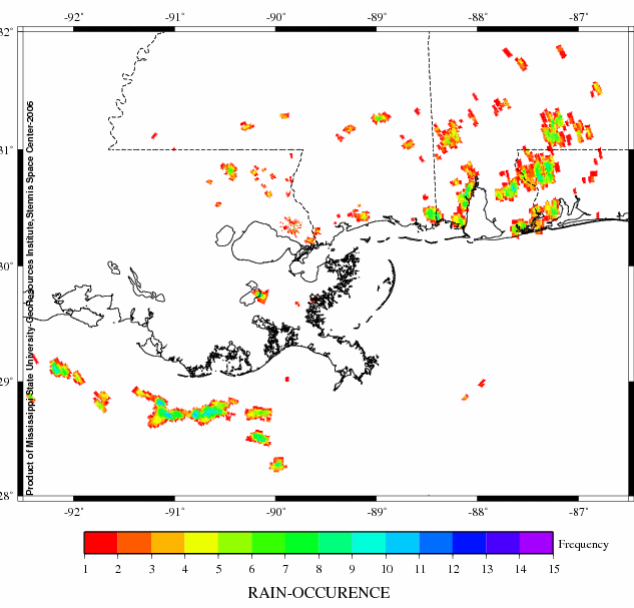

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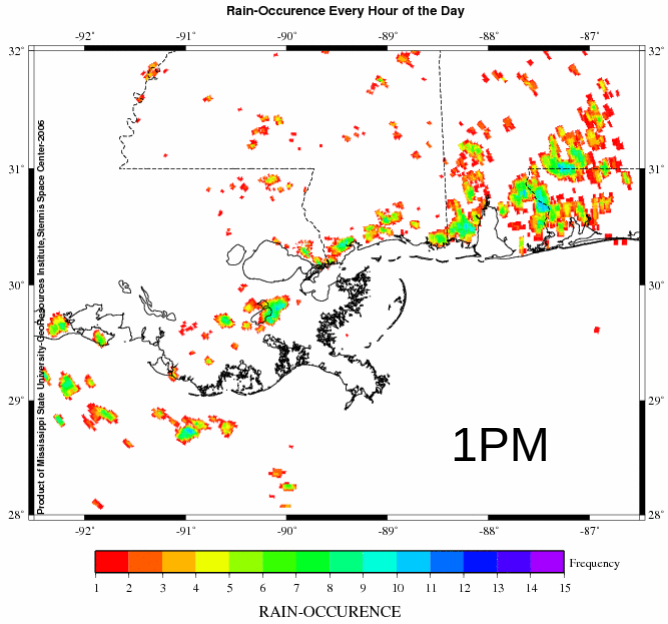

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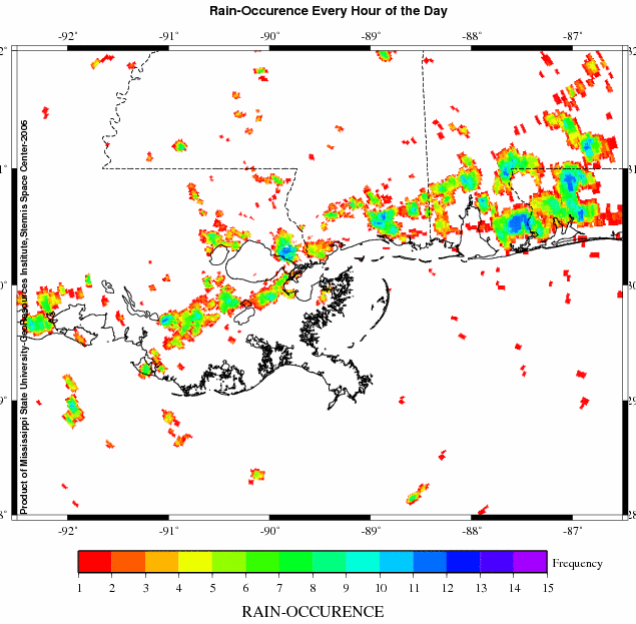

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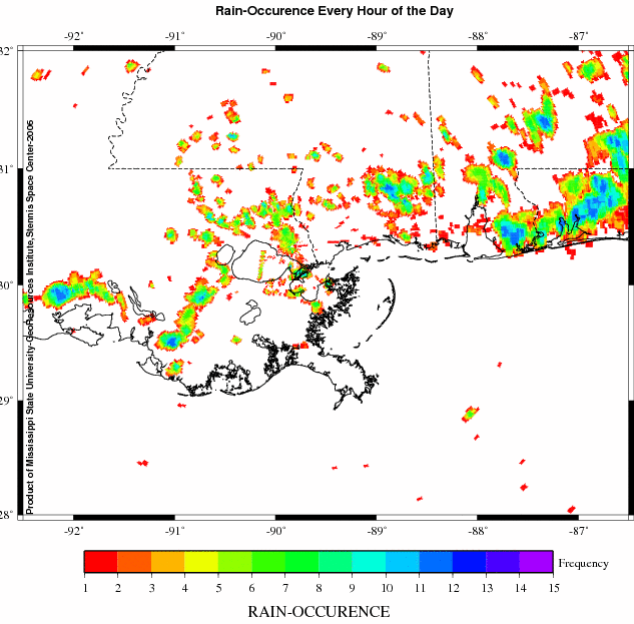

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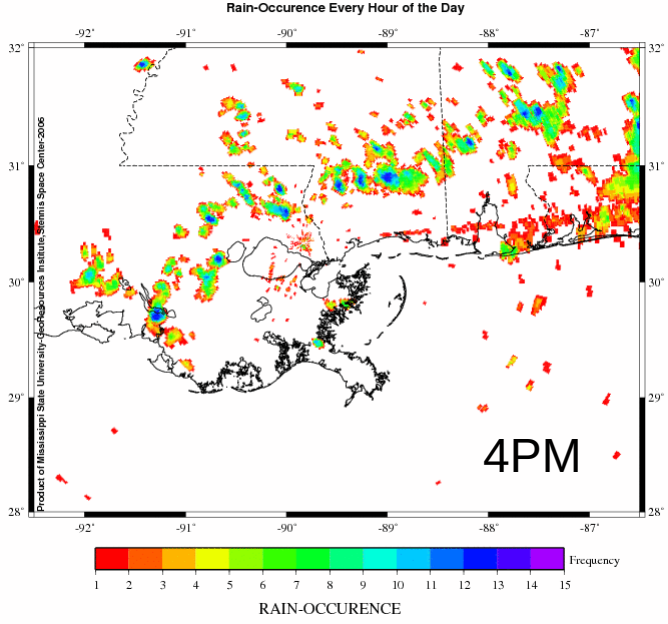

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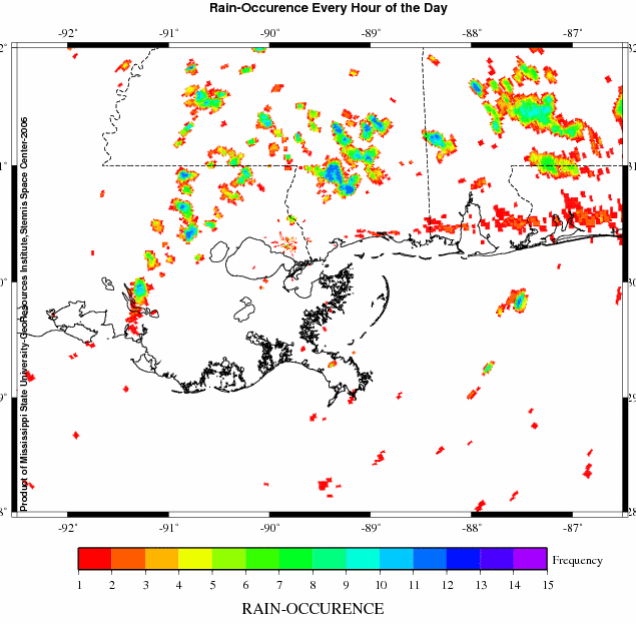

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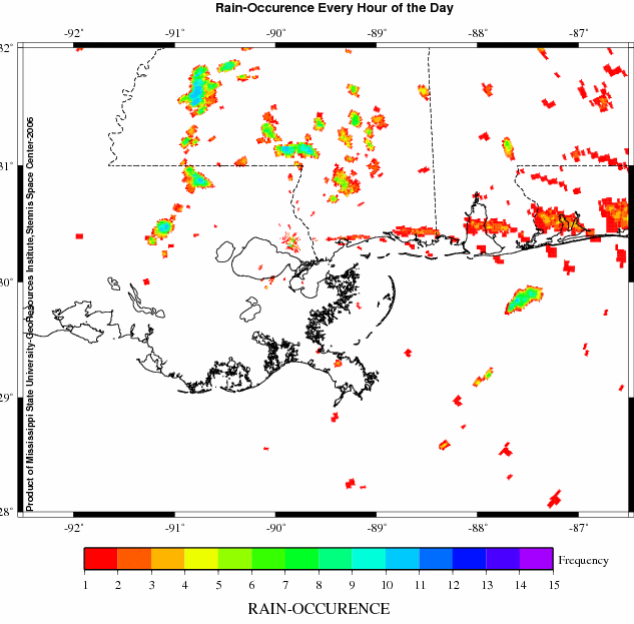
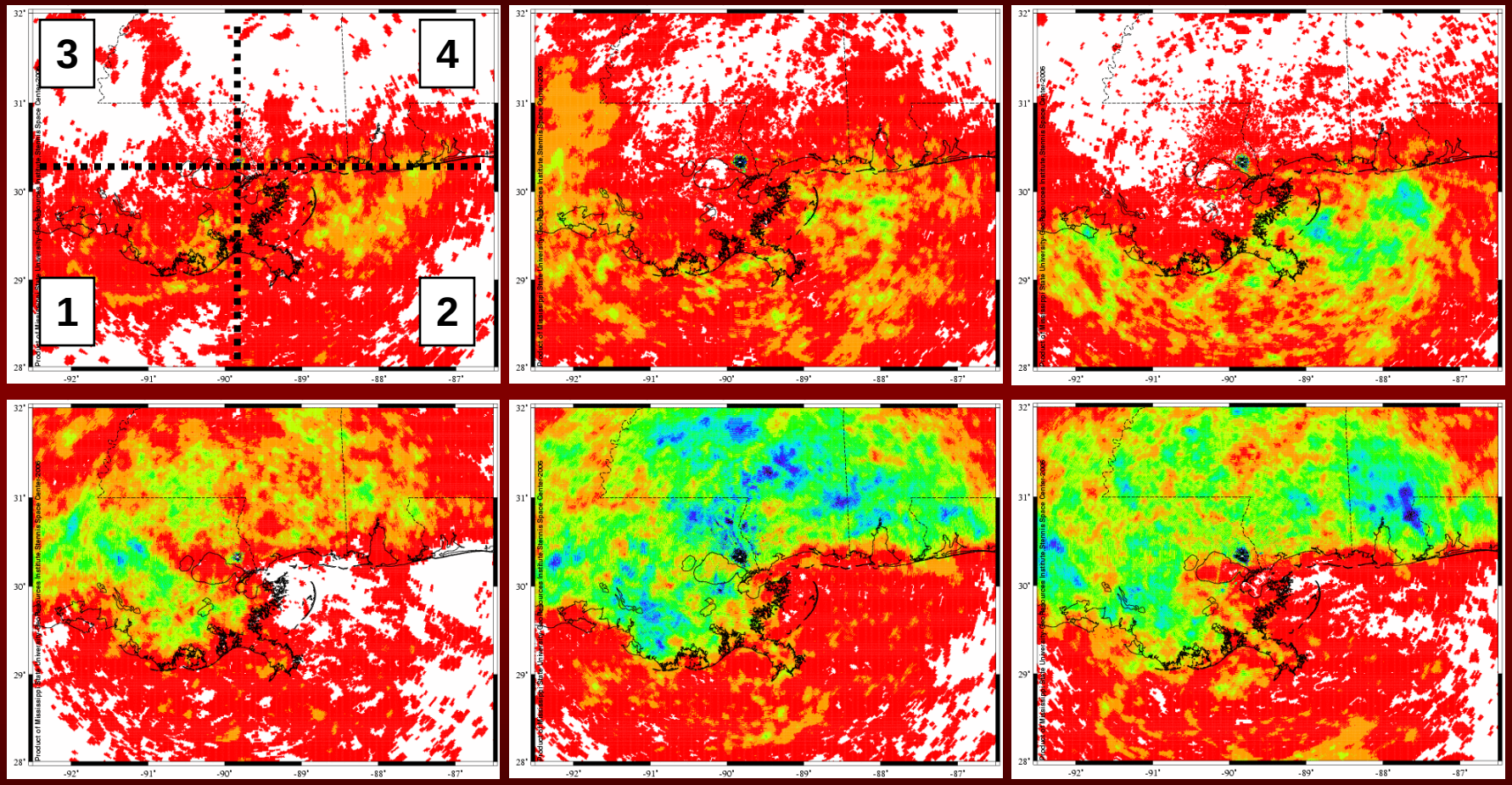


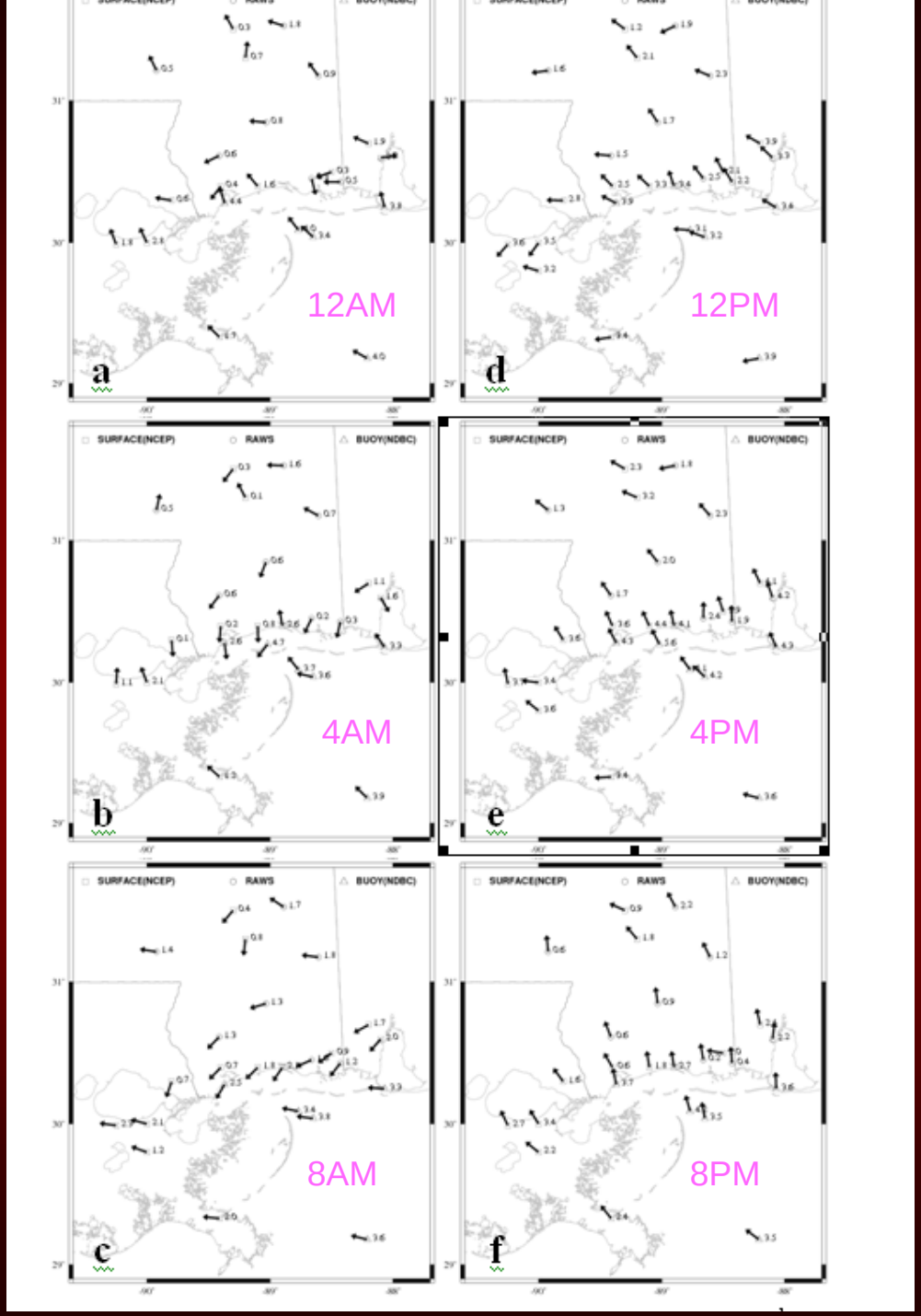
Monthly composites of convective rain pixels for 2003 – 2005

on SLB (102 of 276) days



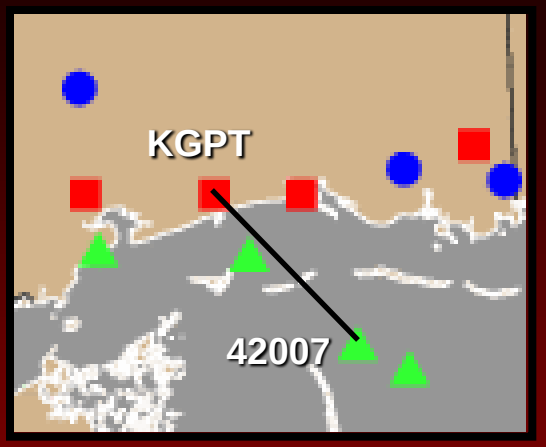
Wind composite
for Sea breeze days,
June.

July, August similar.

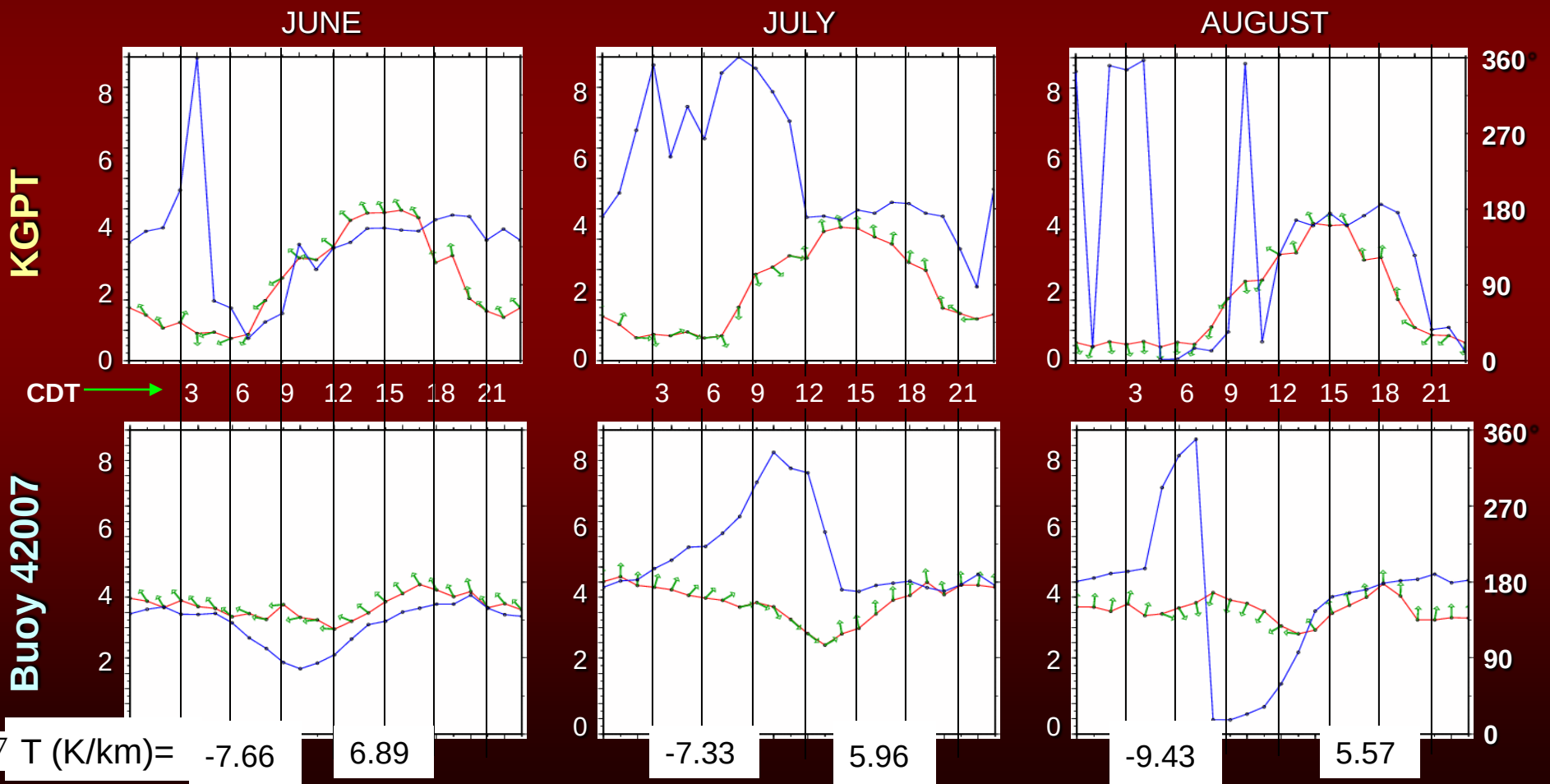


Average WIND DIR. and SPEED for 2003 – 2005

on SLB (102 of 276) days



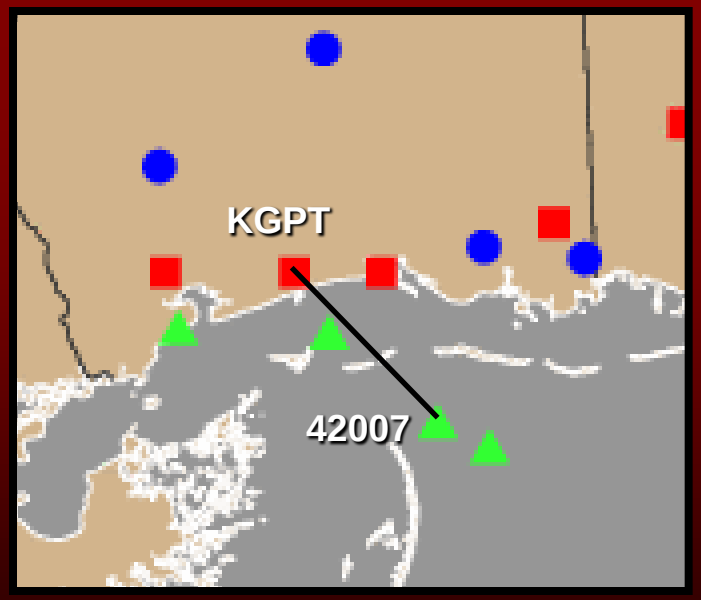
blue: wind direction red : wind speed (m / s)

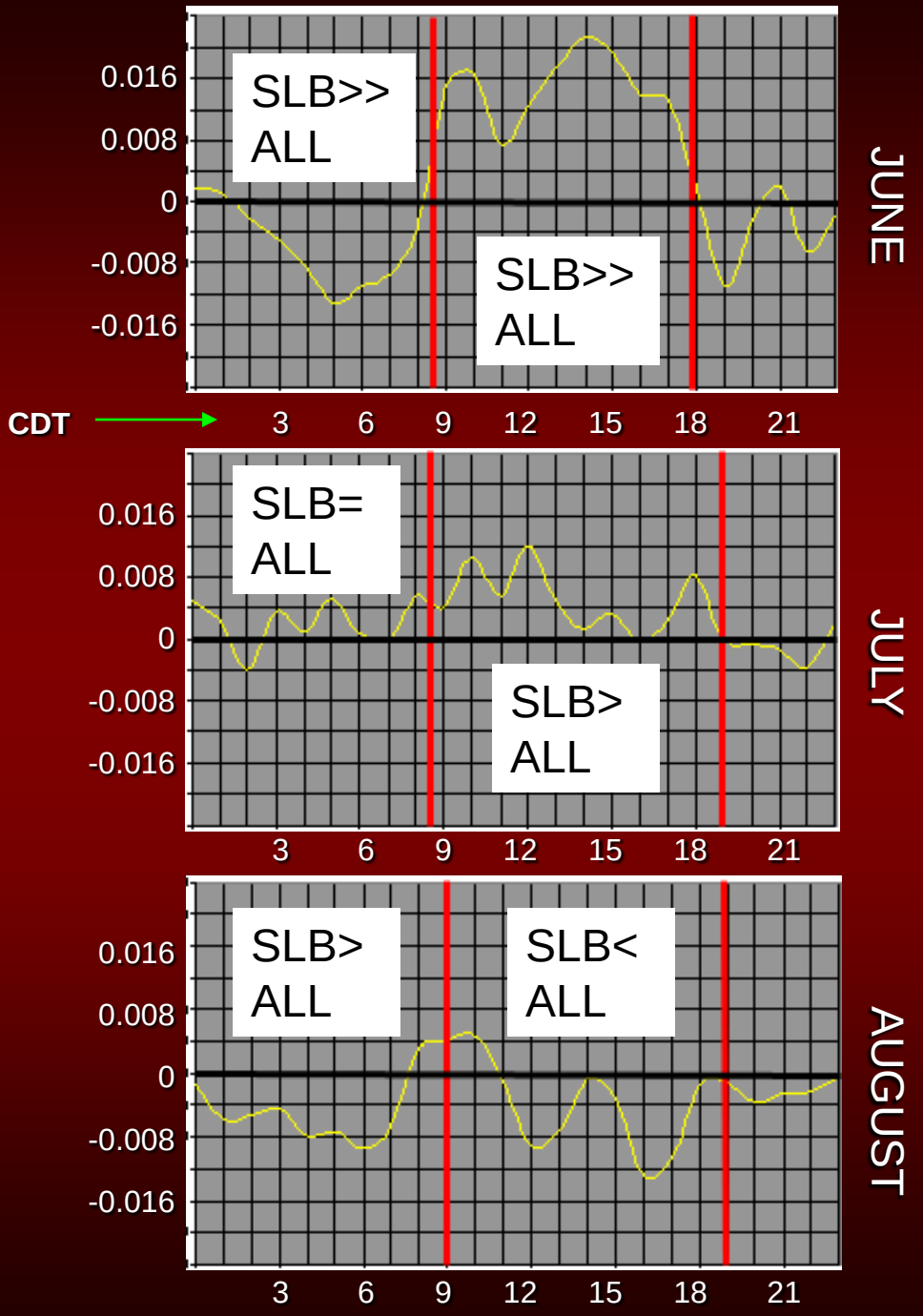


Average difference of **GRAD (T)** for SLB days vs. ALL days of JJA 2003 – 2005

GRAD (T) calculated in units of K km^{-1} between KGPT and Buoy 42007

red lines: times when SLB Grad (T) = 0





Methodology, cont.

- Assess predictive capability of upper-air parameters for areal precipitation coverage
  (APC = % of radar sector with convective precipitation in 4-h period)

Compare 4-hr composites of APC against
00 UTC and 12 UTC quantities of the following :

- K-index
  - 700-hPa Dew. Dep.
  - Γ (850 - 500 hPa)
- CAPE
- 850-hPa wind dir.
- PW (1000 - 300 hPa)

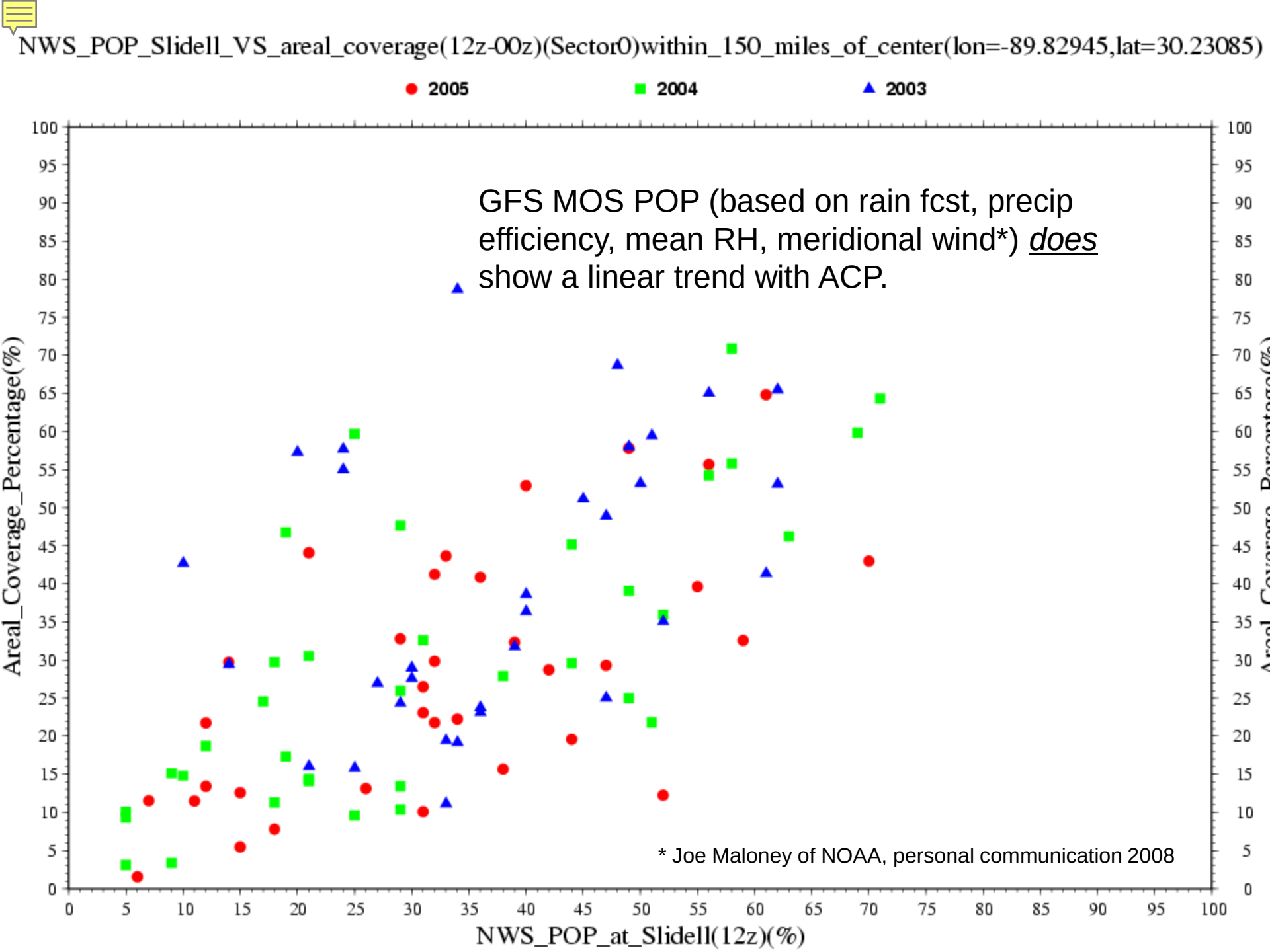
Also can assess effectiveness of K-Index

- Schaefer and Livingston (1990) showed that the Probability of Precipitation (POP) - typically stated as “20% chance of rain”, “30% chance of rain”, etc. - also represents the expected areal precipitation coverage (APC)
- K index (KI) predicts the POP of air mass thunderstorms (and, by association, APC):

$$KI=[(T850-T500)+Td850-(T700-Td700)]$$

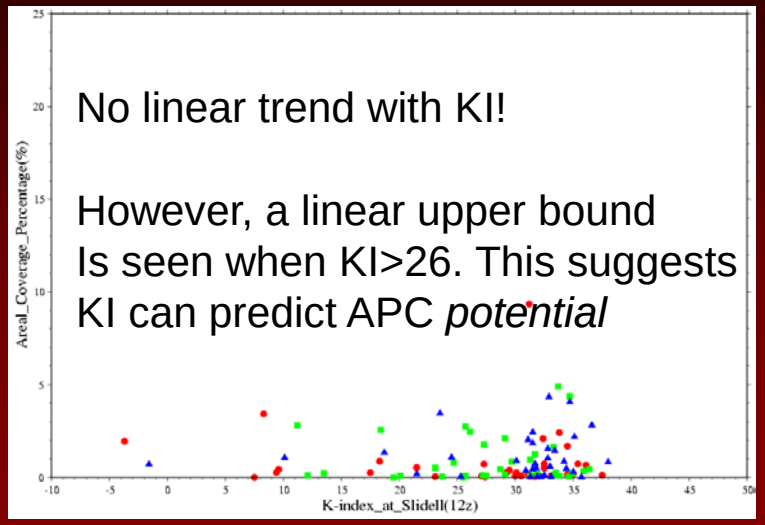
Developed by George (1950) in a qualitative fashion for an aeronautics textbook, KI is a positive integer measure of air-mass thunderstorm potential based on temperature lapse rate, moisture content of the lower troposphere, and the vertical extent of the moist layer.

As KI increases, the greater the likelihood of air mass thunderstorm development, with KI=15 associated with POP=20%, linearly increasing to 100% when KI reaches 40 or more. But how well does it really work?


NWS_POP_Slidell_VS_areal_coverage(12z-00z)(Sector0)within_150_miles_of_center(lon=-89.82945,lat=30.23085)
2005
2004
2003
GFS MOS POP (based on rain fcst, precip efficiency, mean RH, meridional wind*) does show a linear trend with ACP.
* Joe Maloney of NOAA, personal communication 2008
Areal_Coverage_Percentage(%)
NWS_POP_at_Slidell(12z)(%)

12 UTC (7AM) K-index versus 4-hr Areal Precipitation Coverage

NE sector (4)

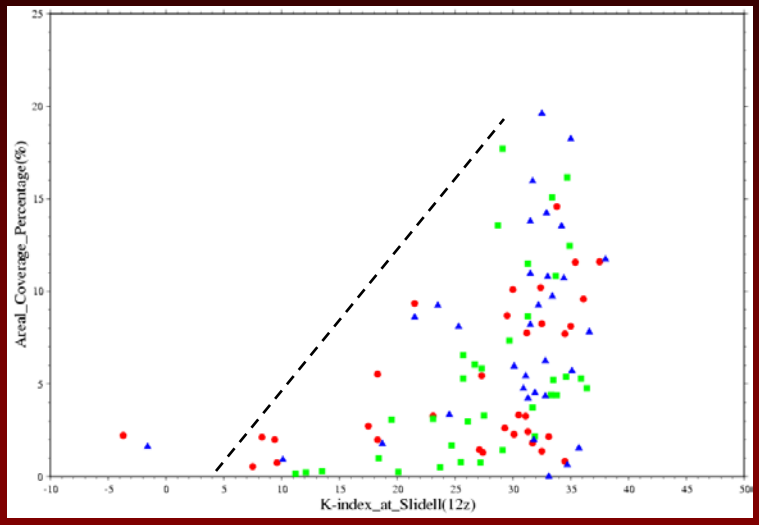


No linear trend with KI!

However, a linear upper bound
Is seen when KI>26. This suggests
KI can predict APC *potential*

12 UTC (7AM) K-index

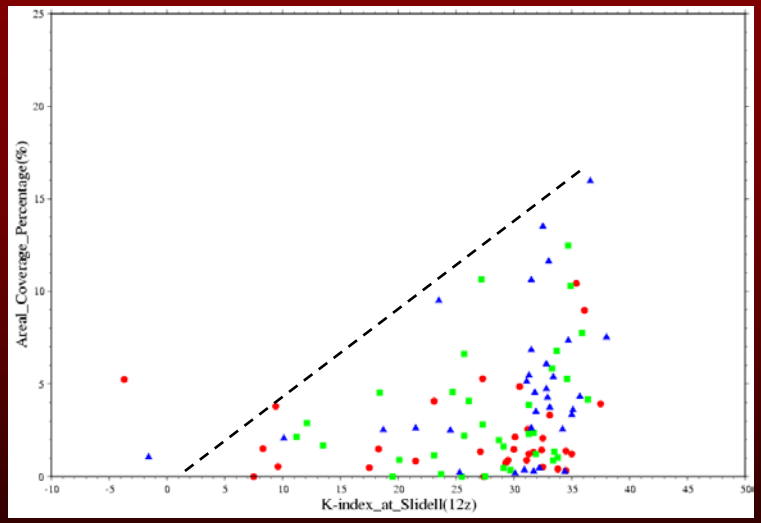
% area



12 UTC (7AM) K-index

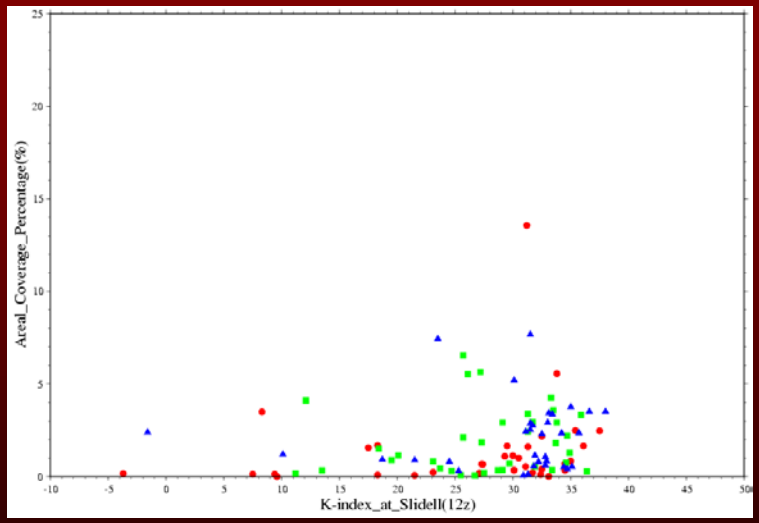
▲ 2003 ■ 2004 ● 2005

SE sector (2)



7-11 AM

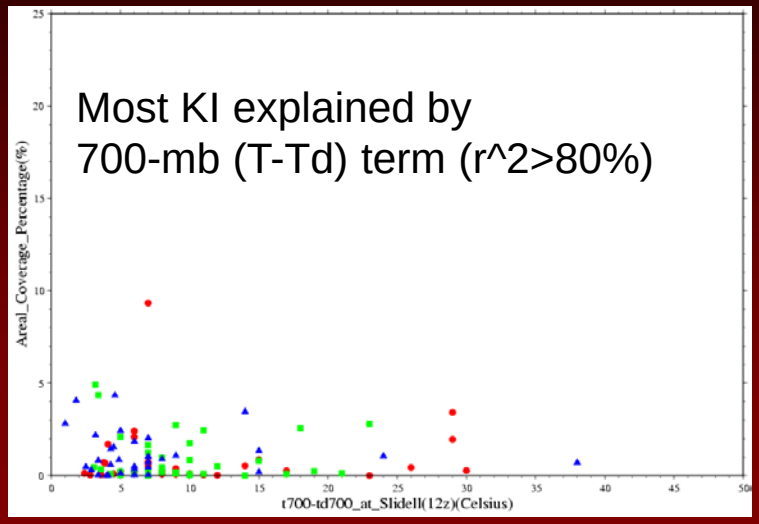
% area



3-7 PM

12 UTC (7AM) Dewpoint Depression at 700 hPa versus 4-hr Areal Precipitation Coverage

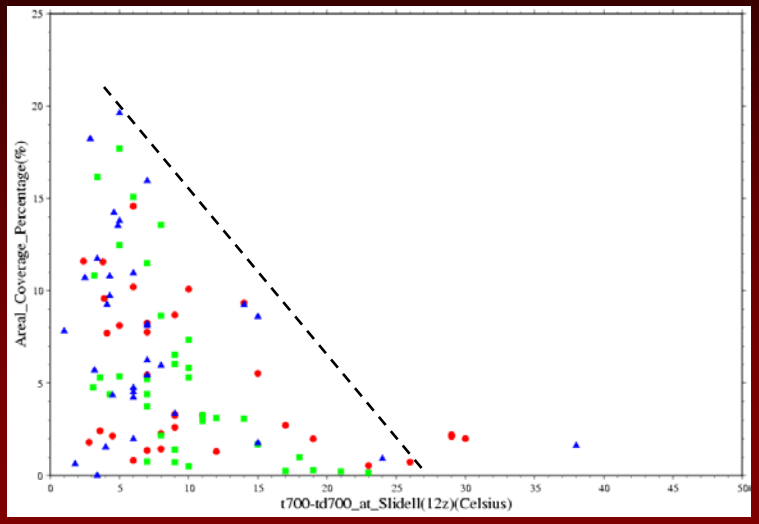
NE sector (4)



Most KI explained by
700-mb (T-Td) term (r^2>80%)

12 UTC (7AM) DD (K)

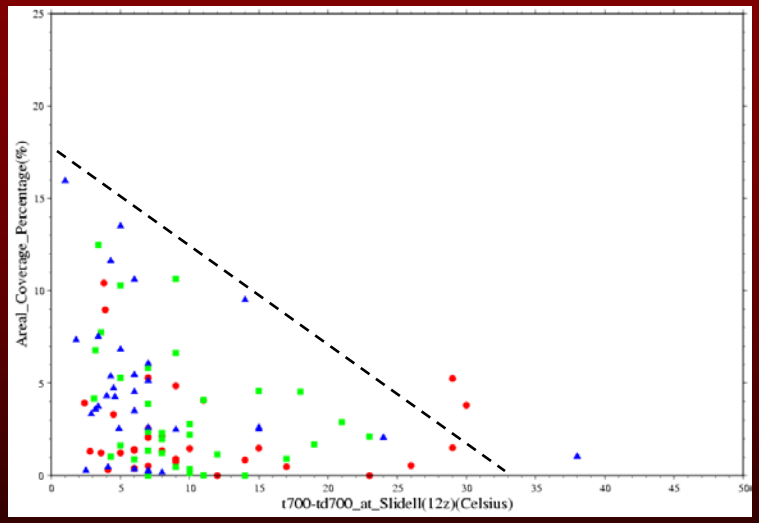
% area



12 UTC (7AM) DD (K)

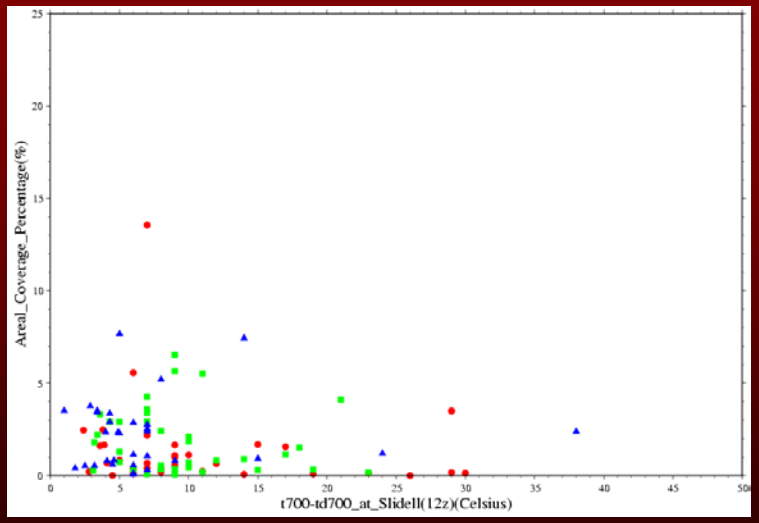
▲ 2003 ■ 2004 ● 2005

SE sector (2)



7-11 AM

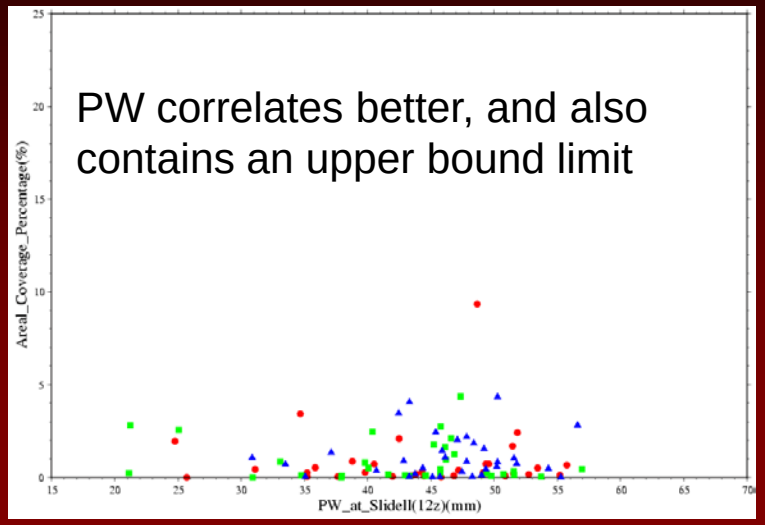
% area



3-7 PM

12 UTC (7AM) Precipitable Water versus 4-hr Areal Precipitation Coverage

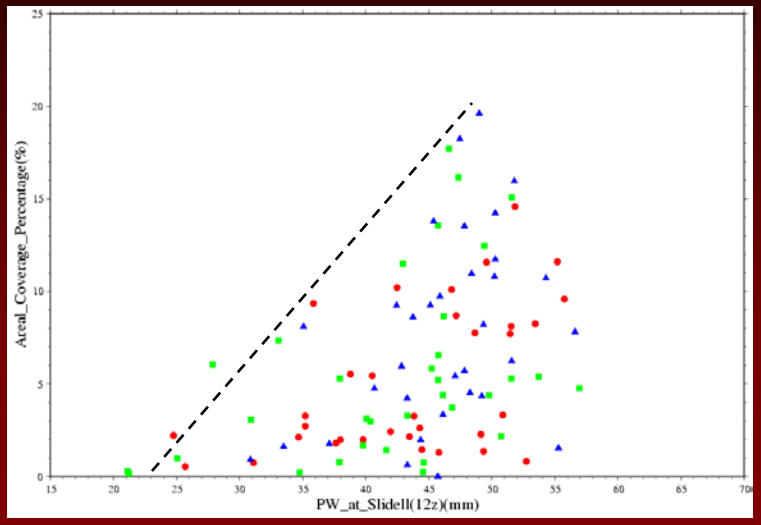
NE sector (4)



PW correlates better, and also contains an upper bound limit

12 UTC (7AM) PW (mm)

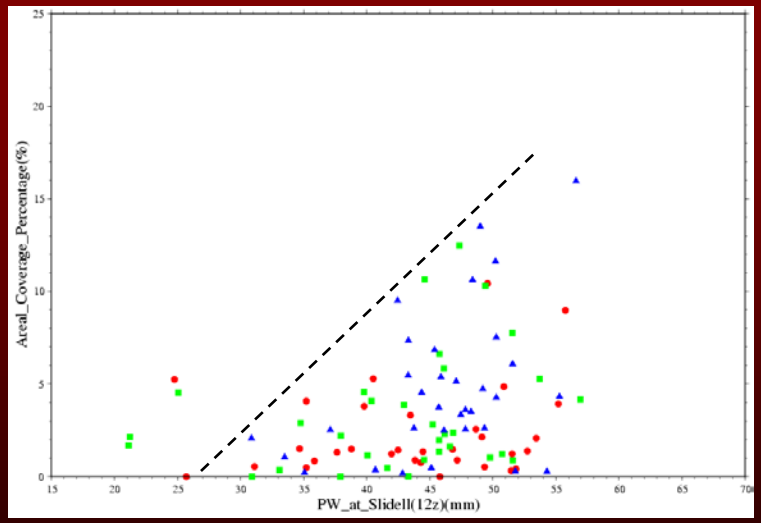
% area



12 UTC (7AM) PW (mm)

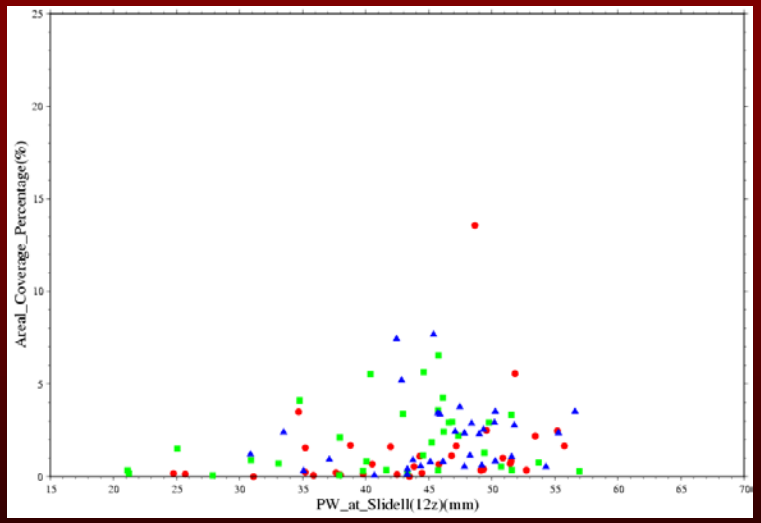
▲ 2003 ■ 2004 ● 2005

SE sector (2)



7-11 AM

% area



3-7 PM

Preliminary, Stepwise Multiple Regression Analysis:

Upper-air quantities correlated against Areal Precipitation Coverage

(yellow > 99% significant level)

	7 - 11 AM (land breeze convection)	3 - 7 PM (sea breeze convection)
NE sector (4) Land	R^2=4% 850-mb Wind direction=0.19	R^2=29% PW=0.48 CAPE=0.26 Td850=-0.18
SE sector (2) Water	R^2=19% PW=0.37 CAPE=0.29 T850-T500=-0.21 Td850=-0.16	R^2=6% PW=0.23 850-mb Wind direction=0.11

For all 24 cases (Sectors 1-4, 6 four-h periods), at 90-100% significance level, PW occurs 17 times, CAPE 11 times, wind direction 3 times, Td850 5 times, and lapse rate 4 times.

KI and 700-DD were only occasionally selected in stepwise routine, and rarely >90% significant

Conclusions

- June:
  - sea / land breeze signal strong with cross-shore T gradient
- July:
  - most sea breeze-induced precipitation
- August:
  - most land breeze-induced precipitation

- Offshore wind minimum occurs during sea breeze onset

- Regional land breeze comparable in strength to sea breeze
  - converges with prevailing flow over the Gulf during the early morning
  - provides focus for precipitation near barrier islands before sunrise through mid-morning.

- Regression shows PW and CAPE correlate best with areal precipitation coverage
  - KI not correlated with ACP, but provides an upper bound, and could be incorporated similar to the MPI concept used in tropical cyclone forecasting
  - PW also shows upper bound potential