HEAVY RAINFALL EVENTS PRECEDING THE ARRIVAL OF TROPICAL CYCLONES

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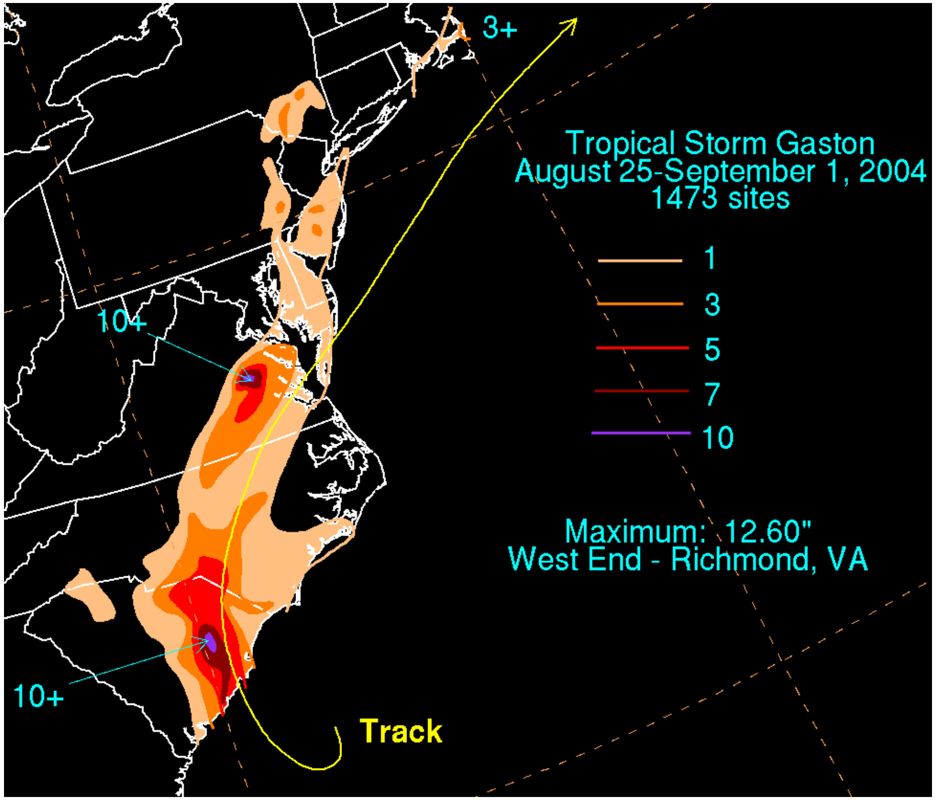
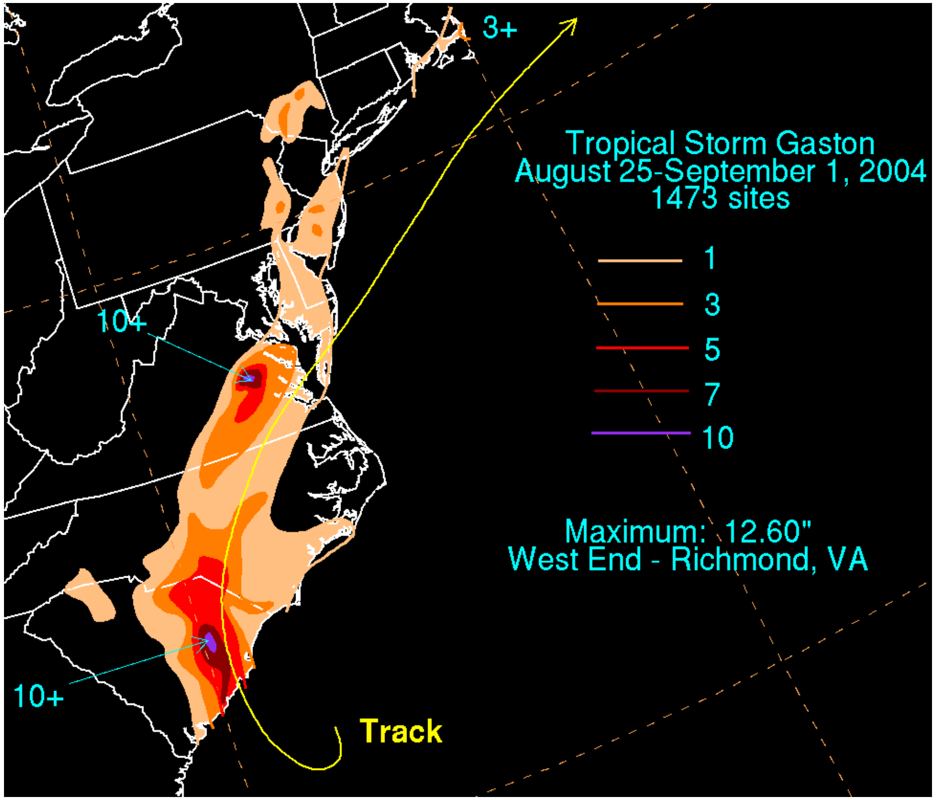
4 May 2007

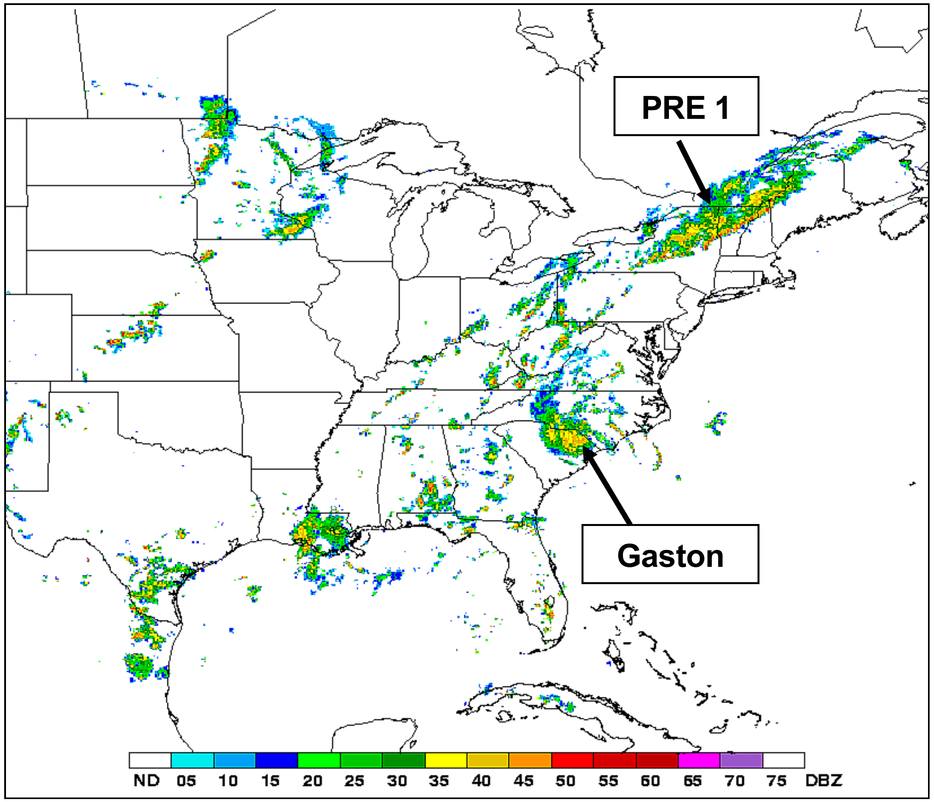
INTRODUCTION



- Nothing unusual about rainfall distribution at first glance
- Heaviest in SC and VA just left of the TC track
- A few scattered areas of heavy rain further north

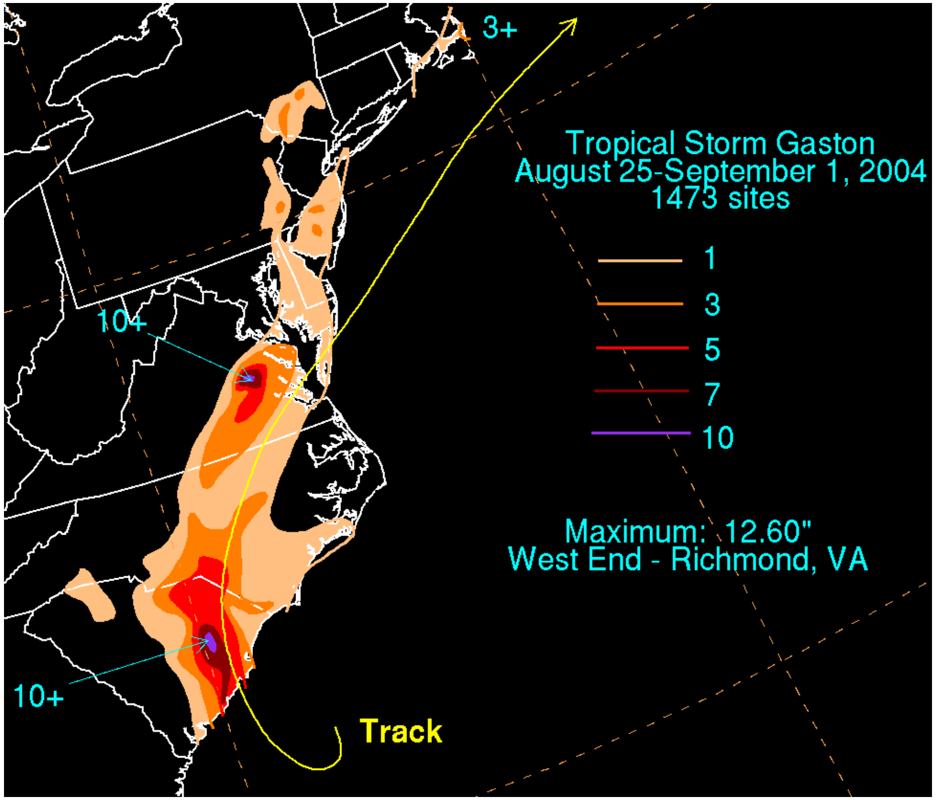
INTRODUCTION

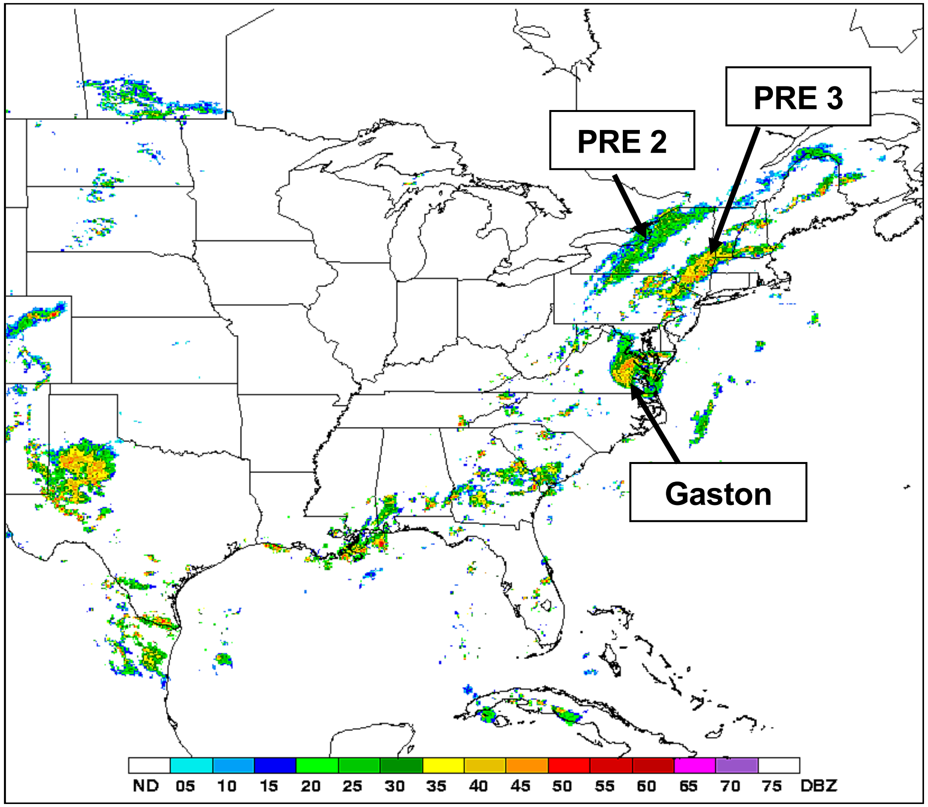




0000 UTC 040830 WSI NOWRAD Radar Mosaic

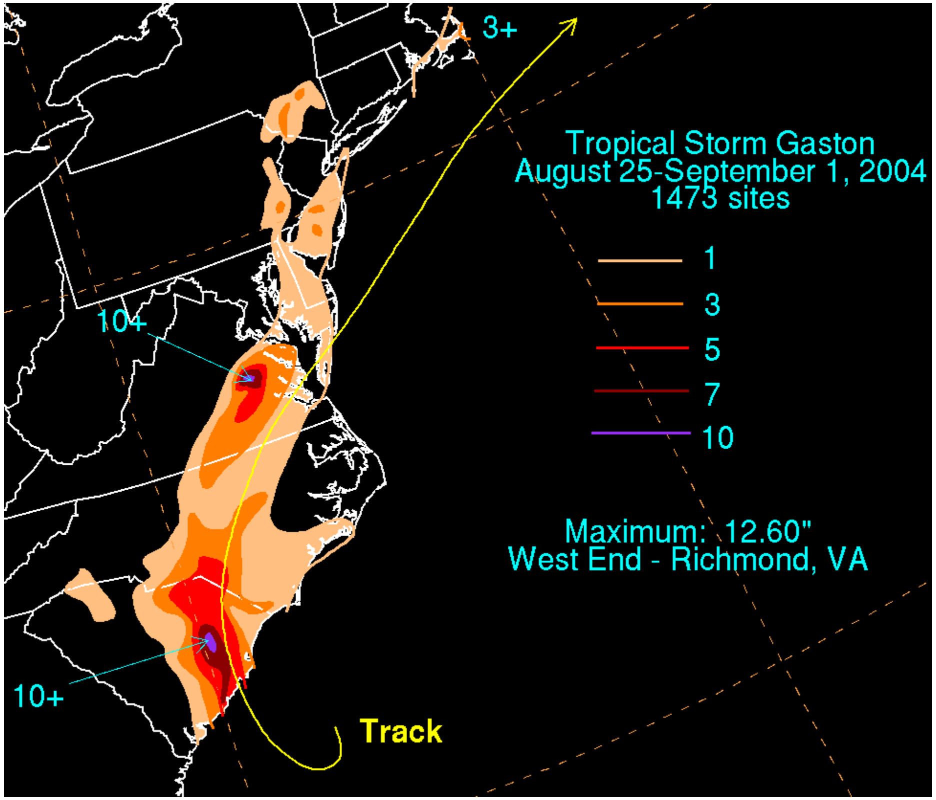
INTRODUCTION

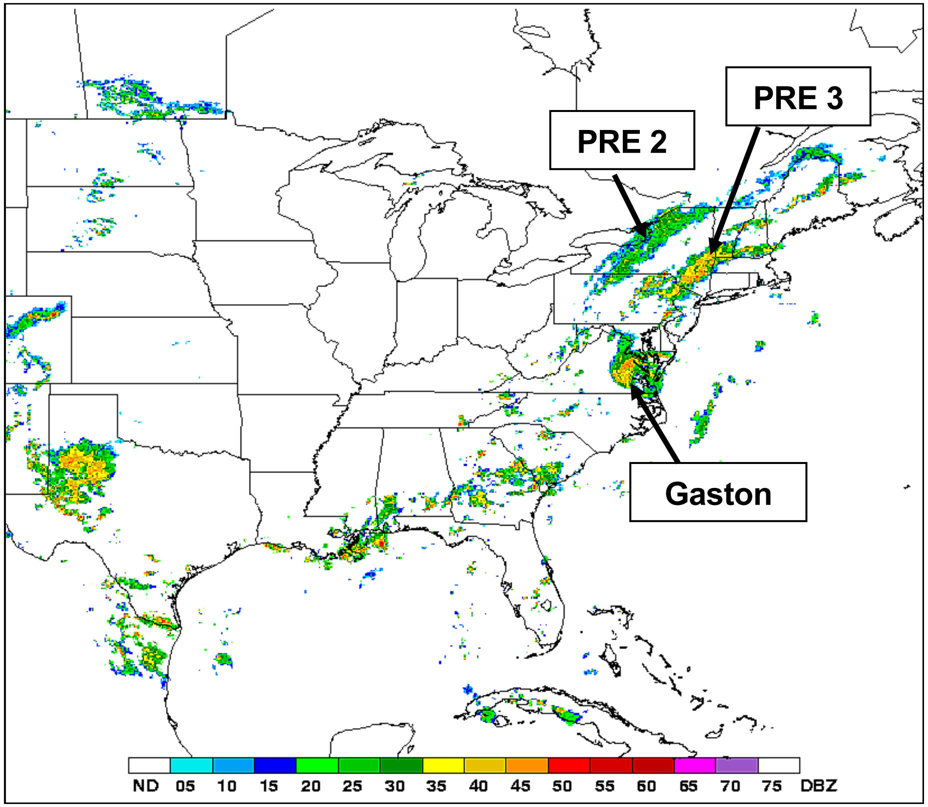




0000 UTC 040831 WSI NOWRAD Radar Mosaic

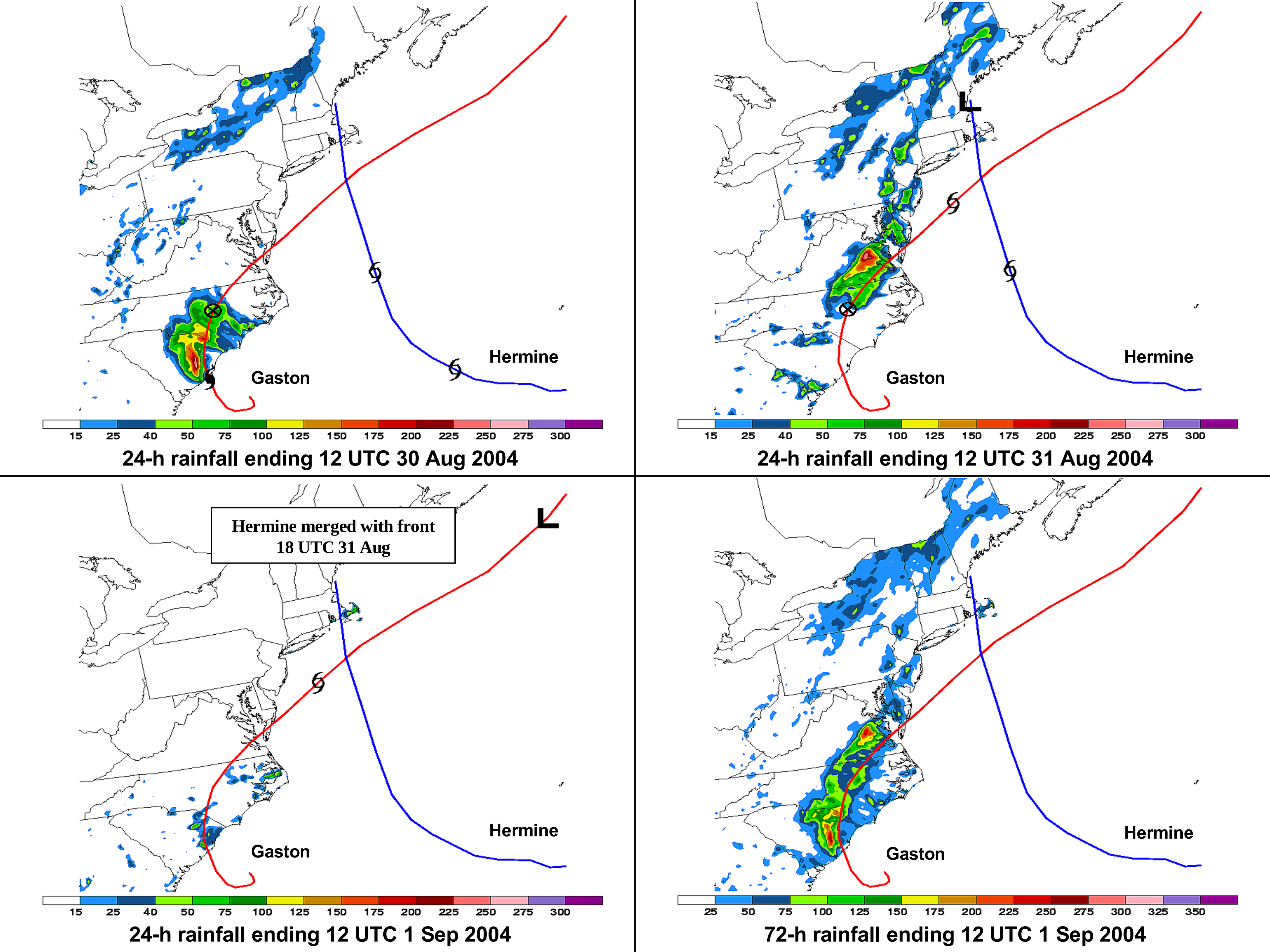
INTRODUCTION





0000 UTC 040831 WSI NOWRAD Radar Mosaic

How can we capture the downstream rainfall?


Hermine
Gaston
15 25 40 50 75 100 125 150 175 200 225 250 275 300
24-h rainfall ending 12 UTC 30 Aug 2004
L
Hermine
Gaston
15 25 40 50 75 100 125 150 175 200 225 250 275 300
24-h rainfall ending 12 UTC 31 Aug 2004
Hermine merged with front
18 UTC 31 Aug
L
Hermine
Gaston
15 25 40 50 75 100 125 150 175 200 225 250 275 300
24-h rainfall ending 12 UTC 1 Sep 2004
Hermine
Gaston
25 50 75 100 125 150 175 200 225 250 275 300 325 350
72-h rainfall ending 12 UTC 1 Sep 2004

DATA SOURCES

- NCDC and WSI NOWRAD radar imagery
- NHC best-track data
- NPVU QPE and NWS rainfall products
- NCEP/NARR gridded datasets
- NCEP/NCAR Global Reanalysis for compositing
- DATSAV and COADS surface data

IDENTIFYING PREs (1998–2006)

- Coherent area of rain displaced poleward of TC
- Maximum rainfall rates exceeded 100 mm in 24
- Moisture transport from TC toward PRE

IDENTIFYING PREs (1998–2006)

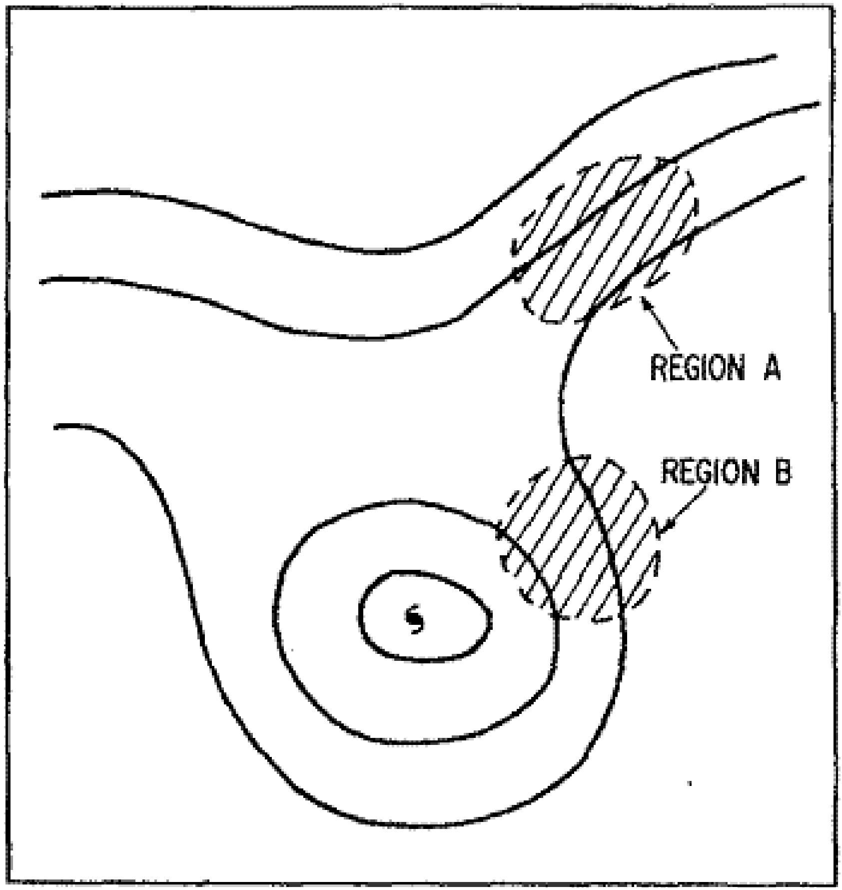
- Coherent area of rain displaced poleward of TC
- Maximum rainfall rates exceeded 100 mm in 24 h
- Moisture transport from TC toward PRE

47 PREs associated with 21 TCs were identified
(~ 2 PREs per TC)

~ 1/3 of all US landfalling TCs produced at least one PRE

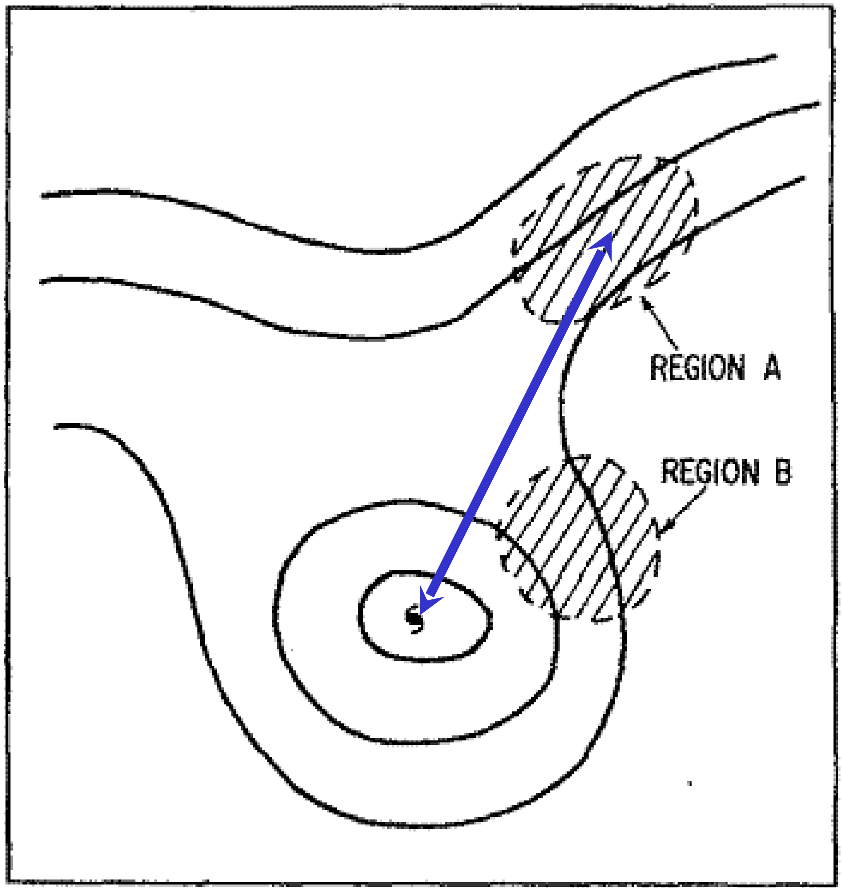
5 cases where TC did not make US landfall

PAST RESEARCH ON PRE WITH AGNES (1972)



Bosart and Carr (1978) conceptual model of antecedent rainfall

PRE STATISTICS



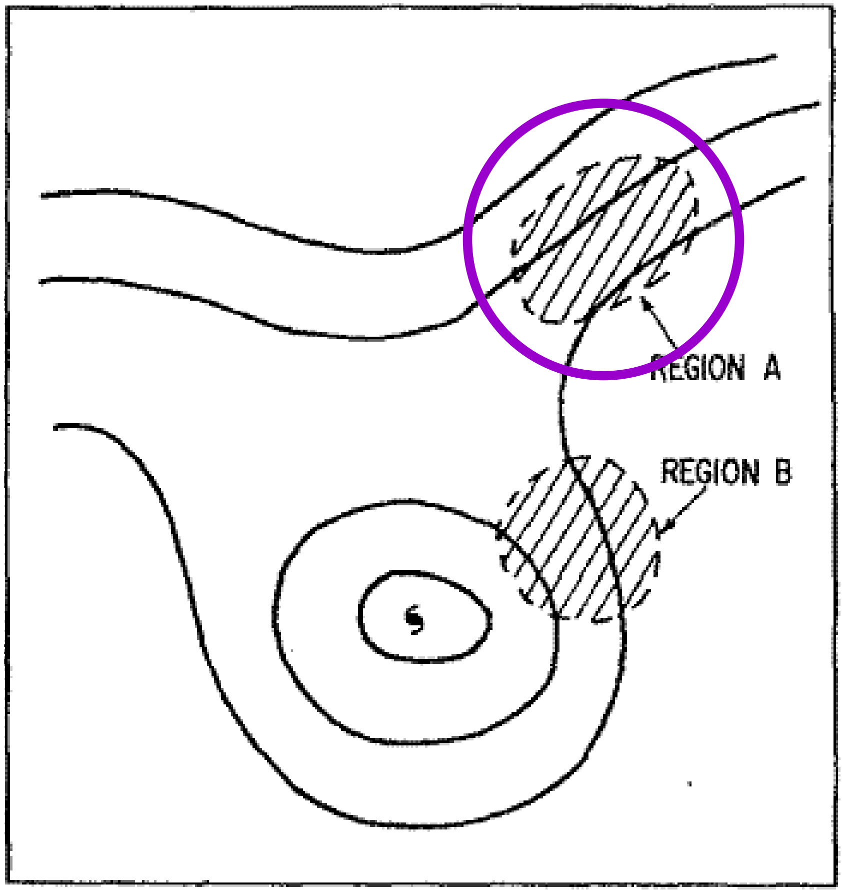
Bosart and Carr (1978) conceptual model of antecedent rainfall

Separation Distance

1086 ± 482 km

Median: 935 km

PRE STATISTICS



Bosart and Carr (1978) conceptual model of antecedent rainfall

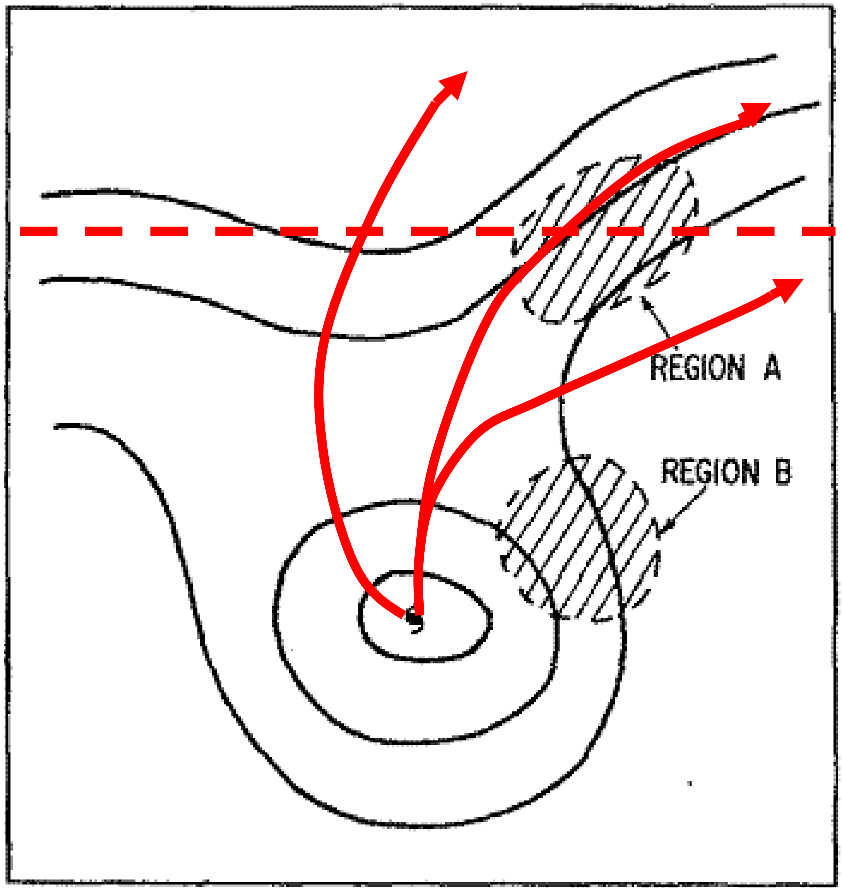
Separation Distance

1086 ± 482 km
Median: 935 km

Event Duration

14 ± 7 h
Median: 12 h

PRE STATISTICS



Bosart and Carr (1978) conceptual model of antecedent rainfall

Separation Distance

1086 ± 482 km
Median: 935 km

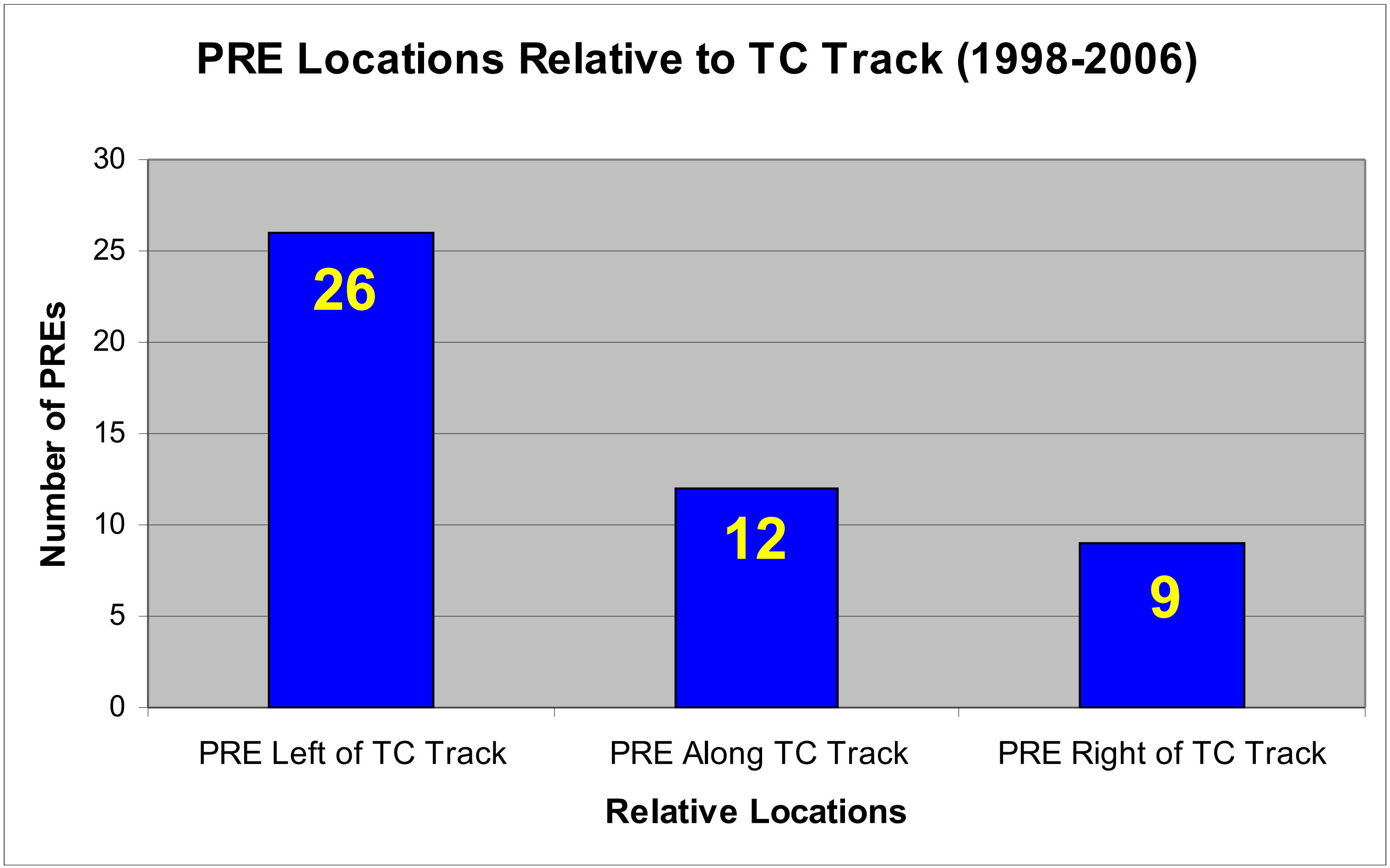
Event Duration

14 ± 7 h
Median: 12 h

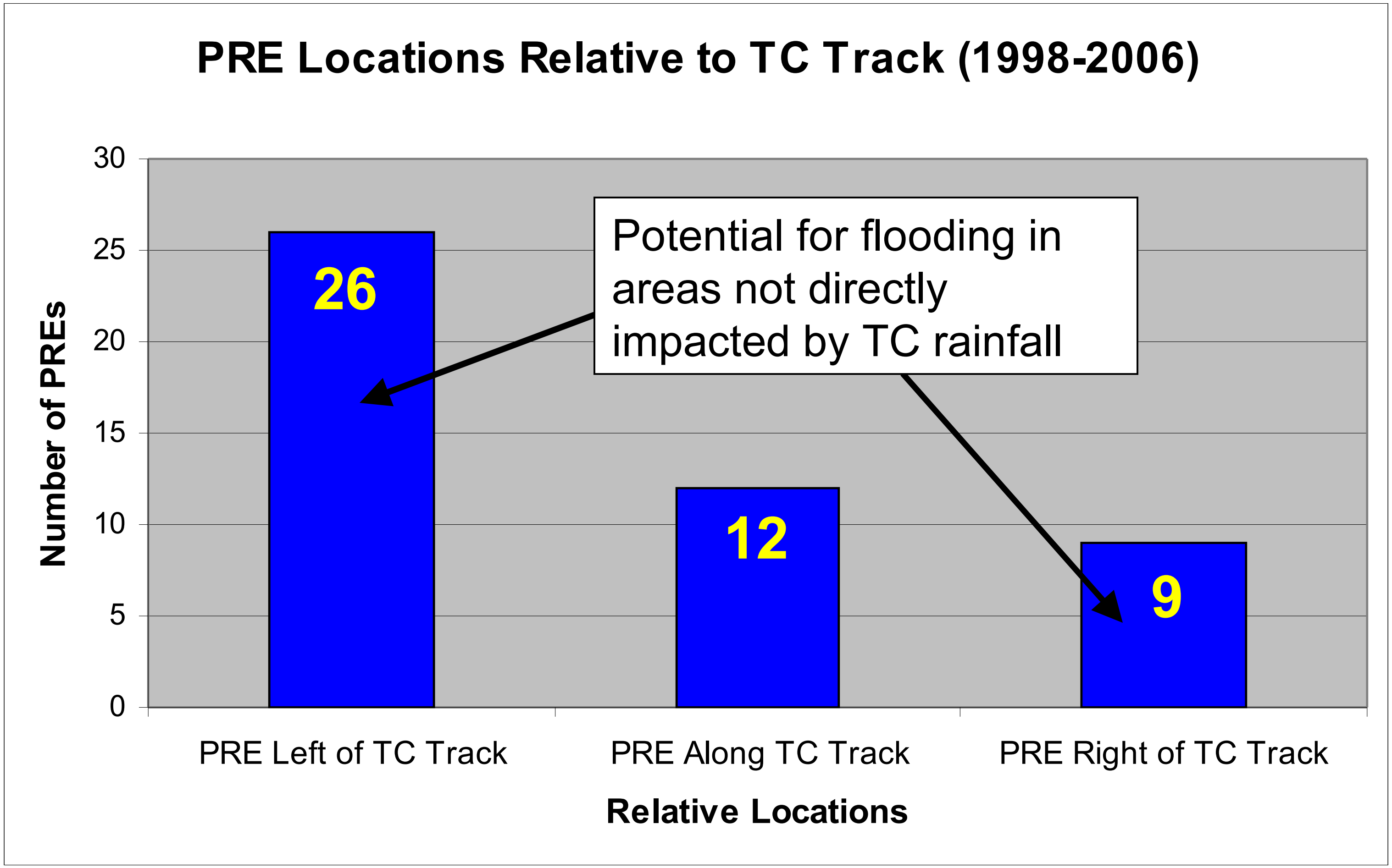
Time Lag

45 ± 29 h
Median: 36 h

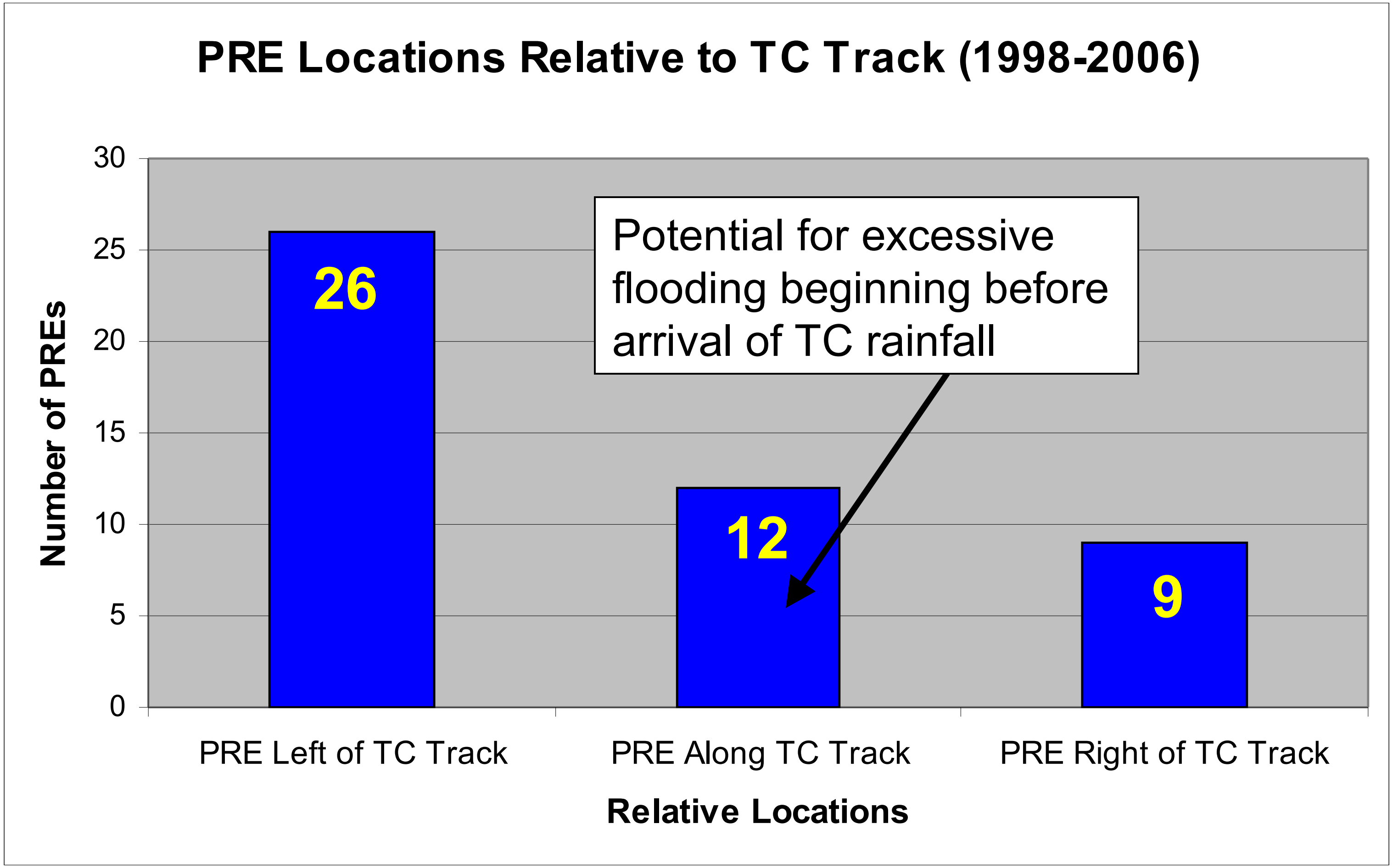
PRE TRACK-RELATIVE POSITIONS



PRE TRACK-RELATIVE POSITIONS



PRE TRACK-RELATIVE POSITIONS



PRE TRACK-RELATIVE POSITIONS

Type of PRE (Number in category)	24-h rainfall rate statistics (mm)			Mean PRE speed ($m\ s^{-1}$)
	Mean	Std. deviation	Maximum	
Left of Track (22)	185	70	340	10.7
Along Track (8)	245	100	410	12.9
Right of Track (7)	260	80	410	5.7

GREATEST RAINFALL

SLOWEST MOVEMENT

PRE TRACK-RELATIVE POSITIONS

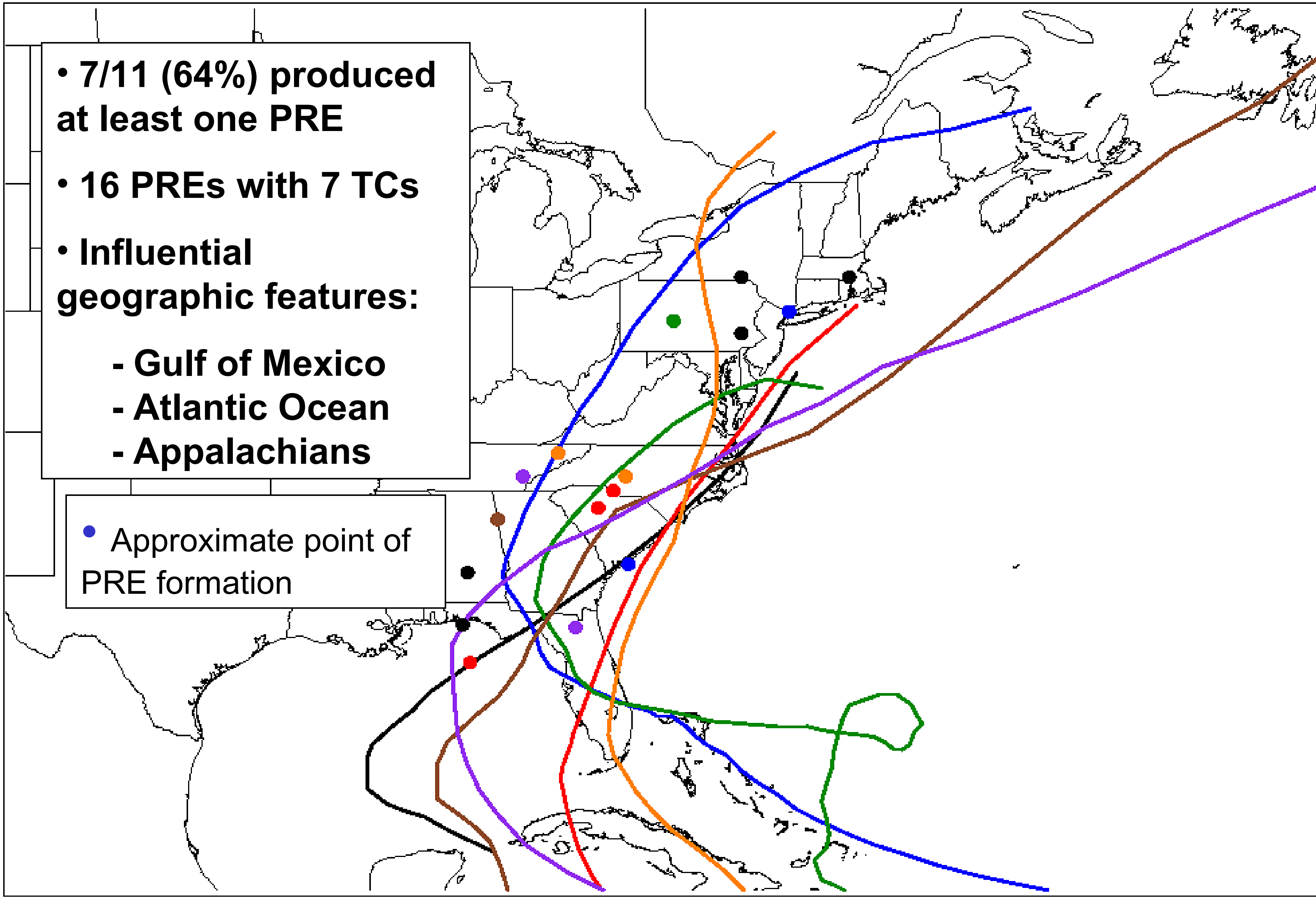
Type of PRE (Number in category)	24-h rainfall rate statistics (mm)			Mean PRE speed (m s^{-1})
	Mean	Std. deviation	Maximum	
Left of Track (22)	185	70	340	10.7
Along Track (8)	245	100	410	12.9
Right of Track (7)	260	80	410	5.7

HIGH RAINFALL

PREs MOVE TWICE AS FAST

SEPARATION BY TC TRACK SIMILARITY

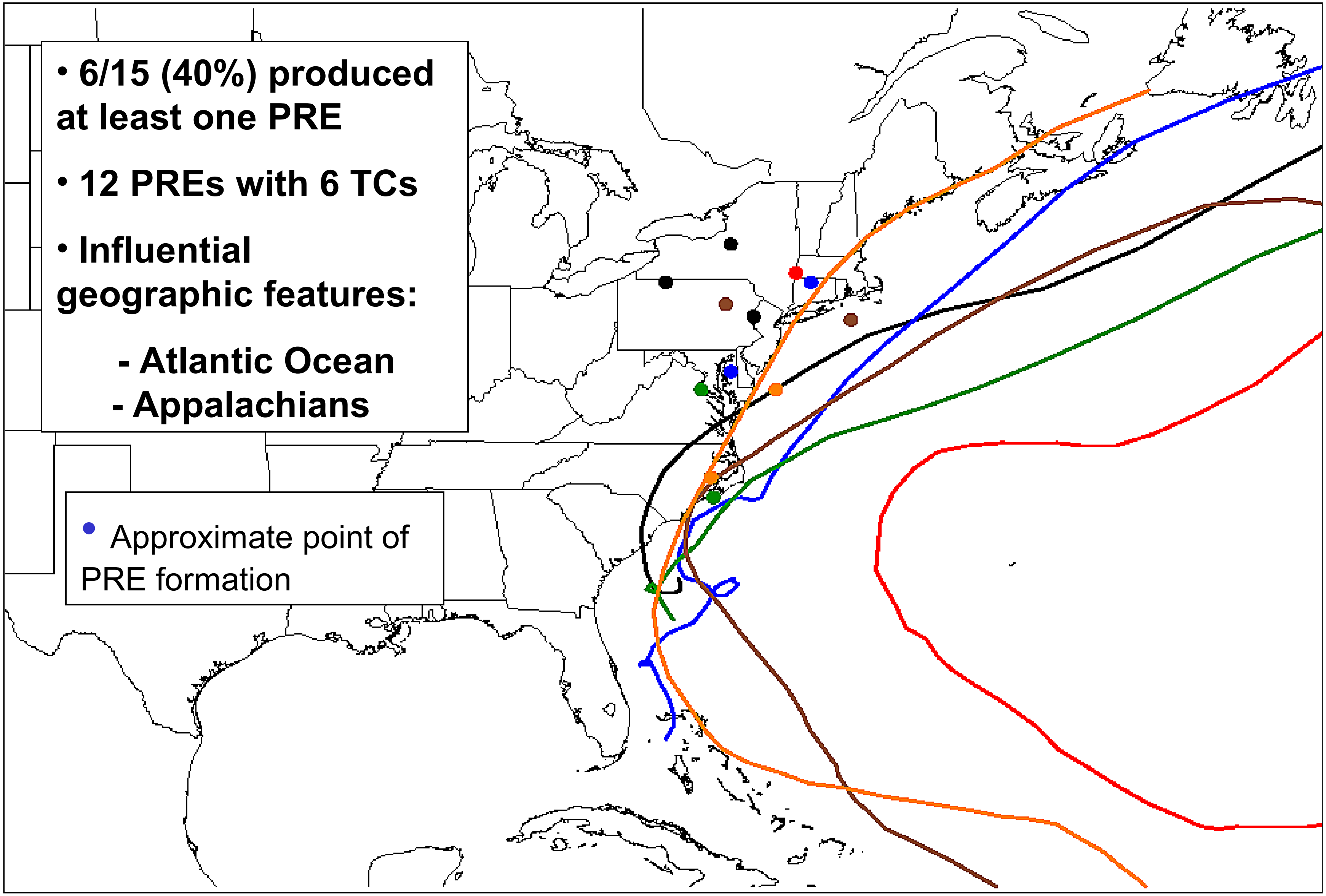
SOUTHEAST RECURVATURES



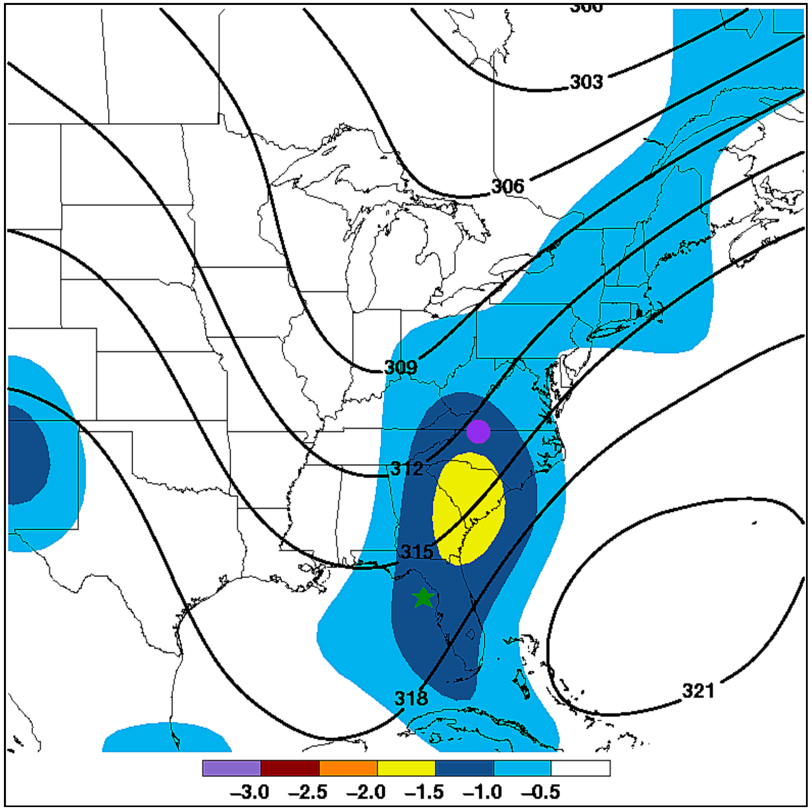
- 7/11 (64%) produced at least one PRE
- 16 PREs with 7 TCs
- Influential geographic features:
  - Gulf of Mexico
  - Atlantic Ocean
  - Appalachians

• Approximate point of PRE formation

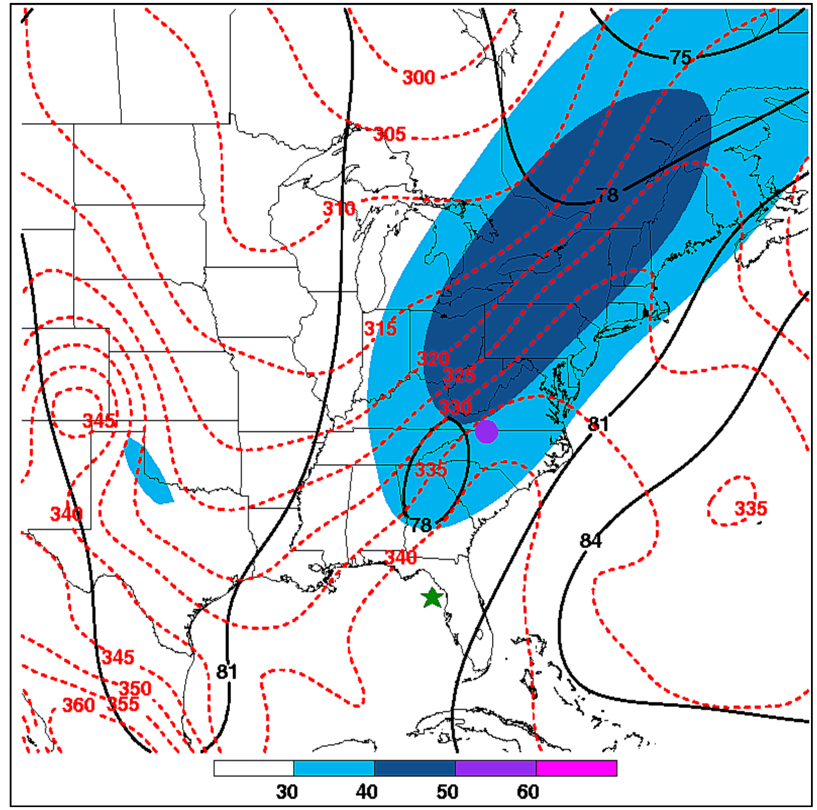
ATLANTIC RECURVATURES



SE RECURVATURE PRE COMPOSITE
TIME OF PRE INITIATION



700 hPa Ht (dam) and UVM (μb s^{-1})

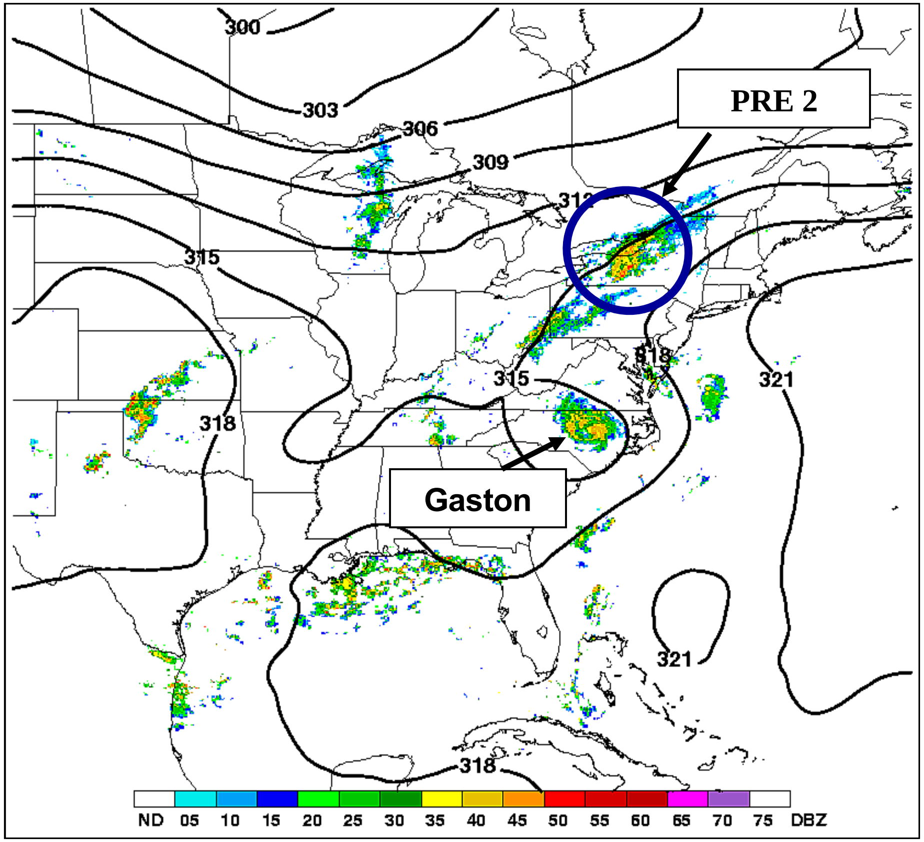


925 hPa Ht (dam), θ_e (K), and 200 hPa wind speeds (m s^{-1})

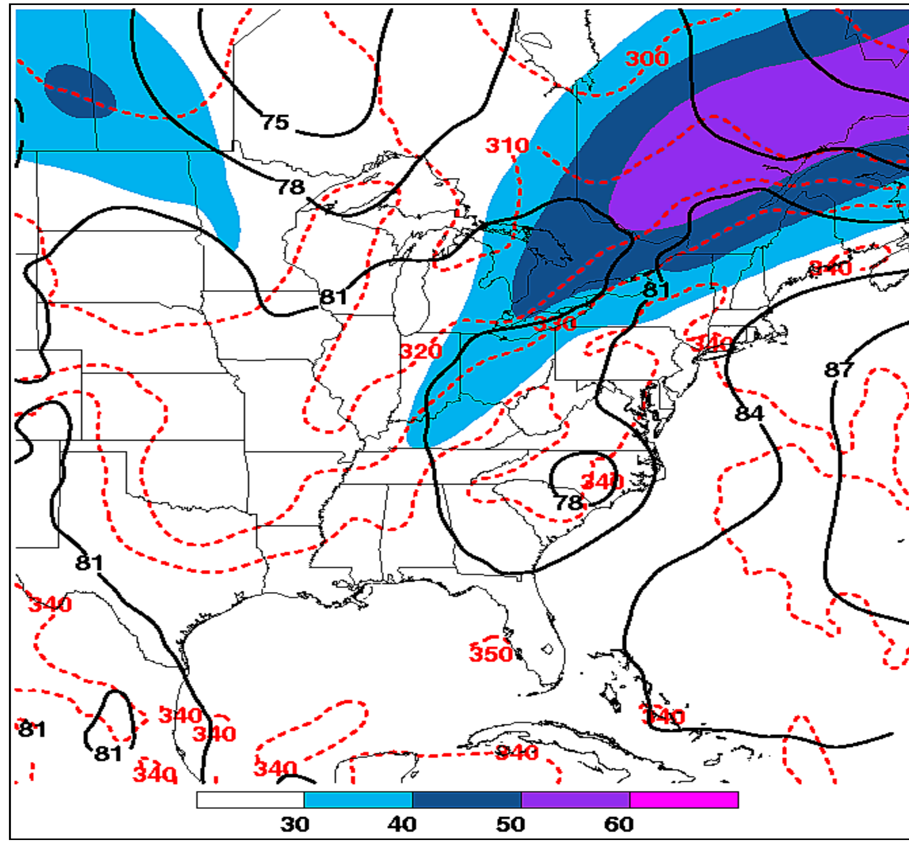
- Significant midlevel trough with weak UVM well poleward of TC
- Deep meridional flow transports tropical moisture up East Coast

- PRE forms:
  - in right-entrance region of intensifying upper-level jet
  - on western edge of θ_e ridge

GASTON (2004): SYNOPTIC FEATURES

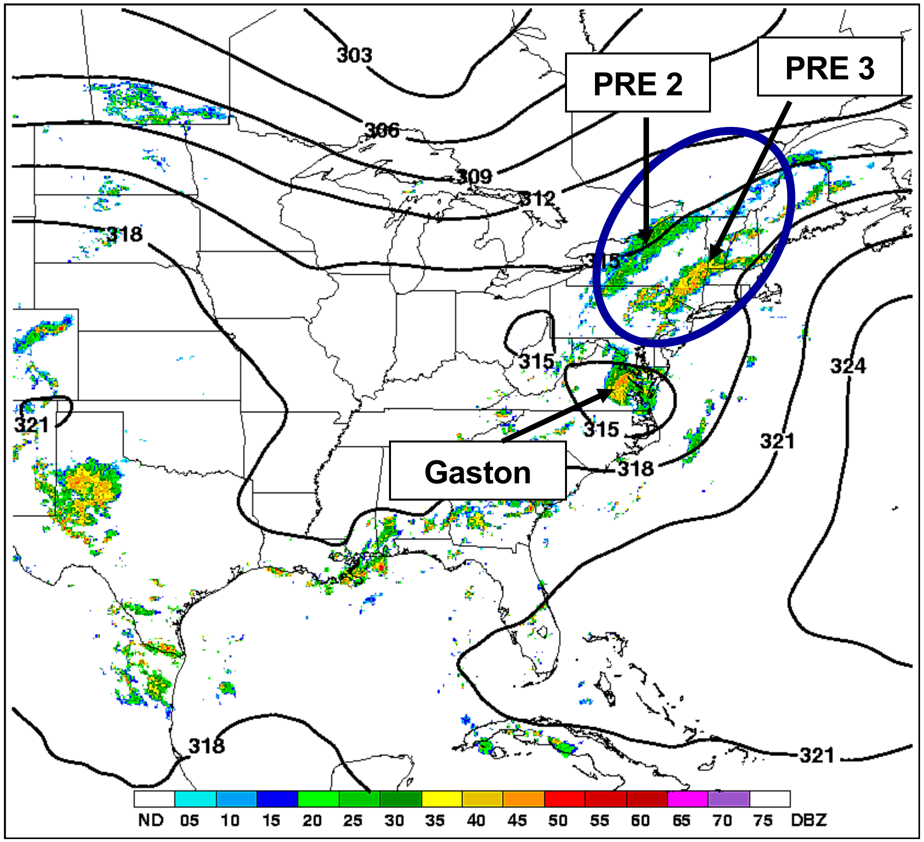


1200 UTC 040830 700 hPa Ht (dam) and WSI NOWRAD image



1200 UTC 040830 925 hPa Ht (dam), θ_e (K), and 200 hPa wind speeds (m s^{-1})

GASTON (2004): SYNOPTIC FEATURES



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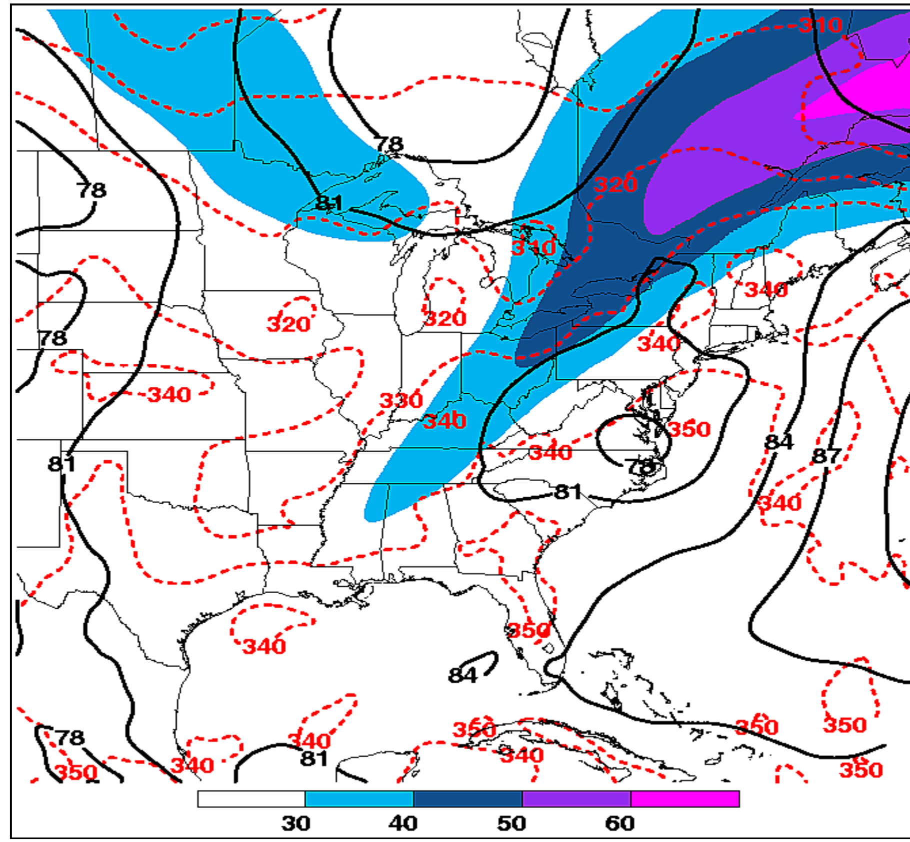
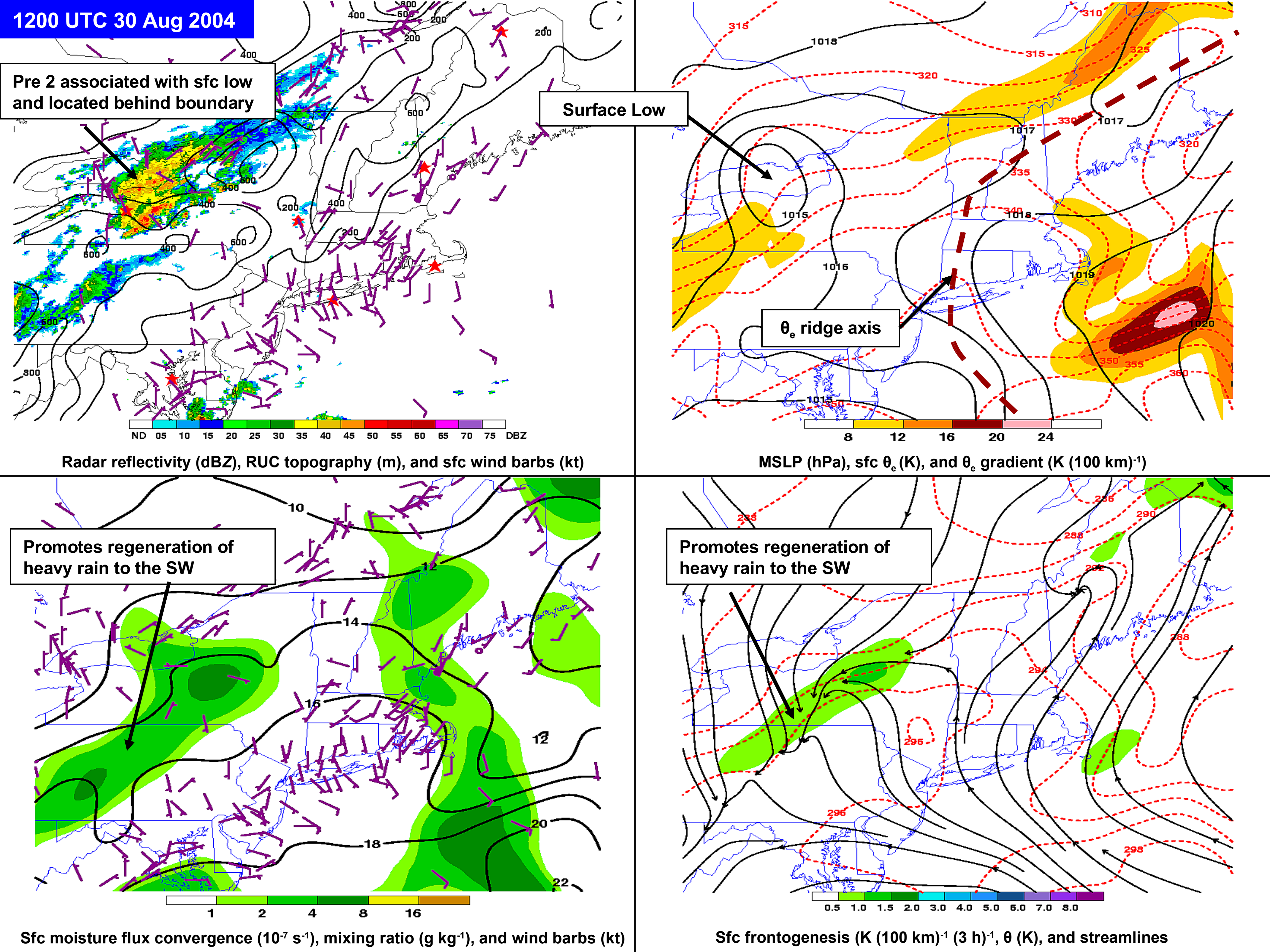
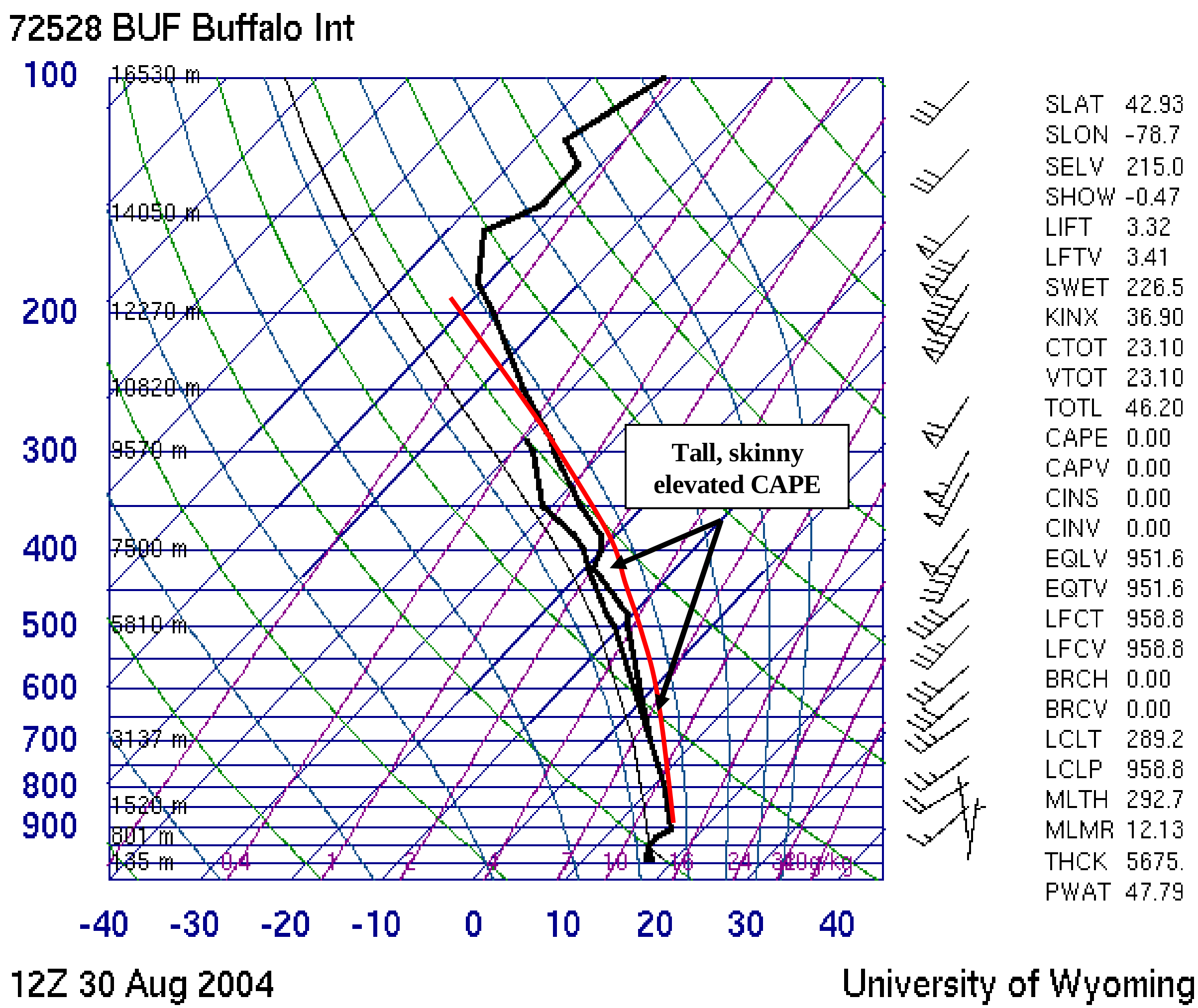


0000 UTC 040831 925 hPa Ht (dam), θ_e (K), and 200 hPa wind speeds (m s^{-1})

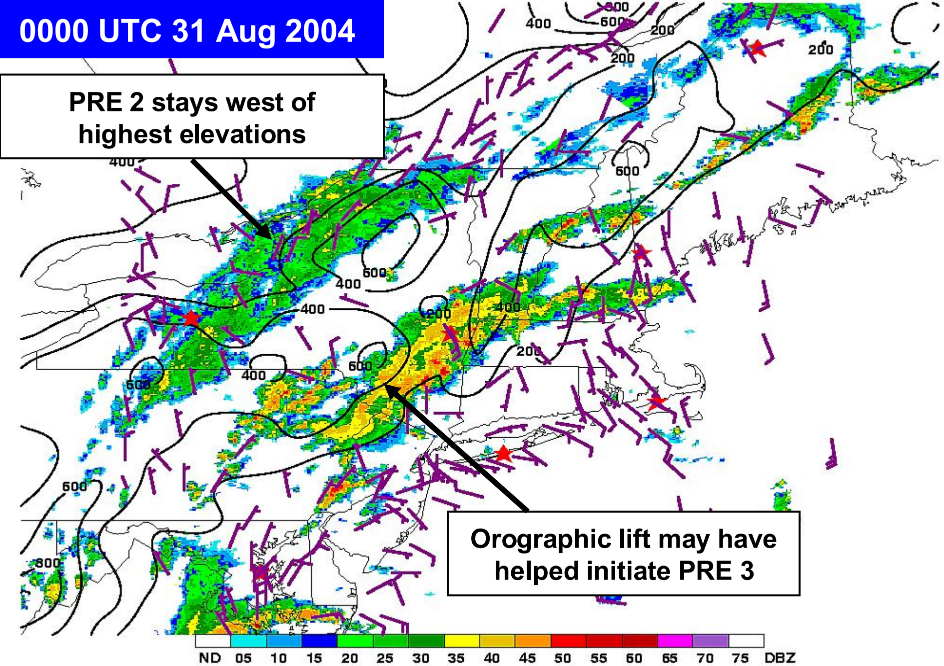
GASTON (2004)

MESOSCALE FEATURES

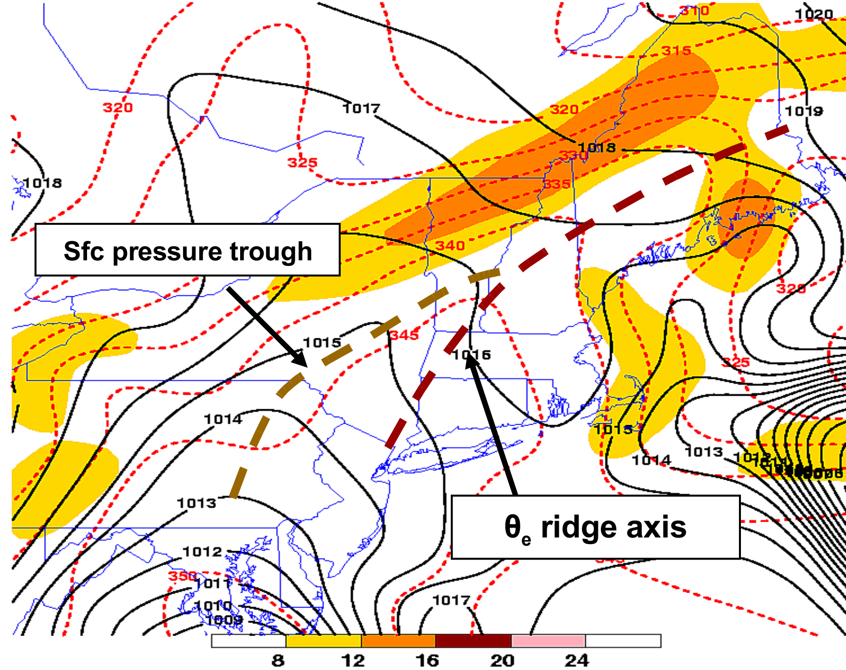

1200 UTC 30 Aug 2004
Pre 2 associated with sfc low and located behind boundary
Radar reflectivity (dBZ), RUC topography (m), and sfc wind barbs (kt)
Surface Low
θe ridge axis
MSLP (hPa), sfc θe (K), and θe gradient (K (100 km)-1)
Promotes regeneration of heavy rain to the SW
Sfc moisture flux convergence (10-7 s-1), mixing ratio (g kg-1), and wind barbs (kt)
Promotes regeneration of heavy rain to the SW
Sfc frontogenesis (K (100 km)-1 (3 h)-1, θ (K), and streamlines



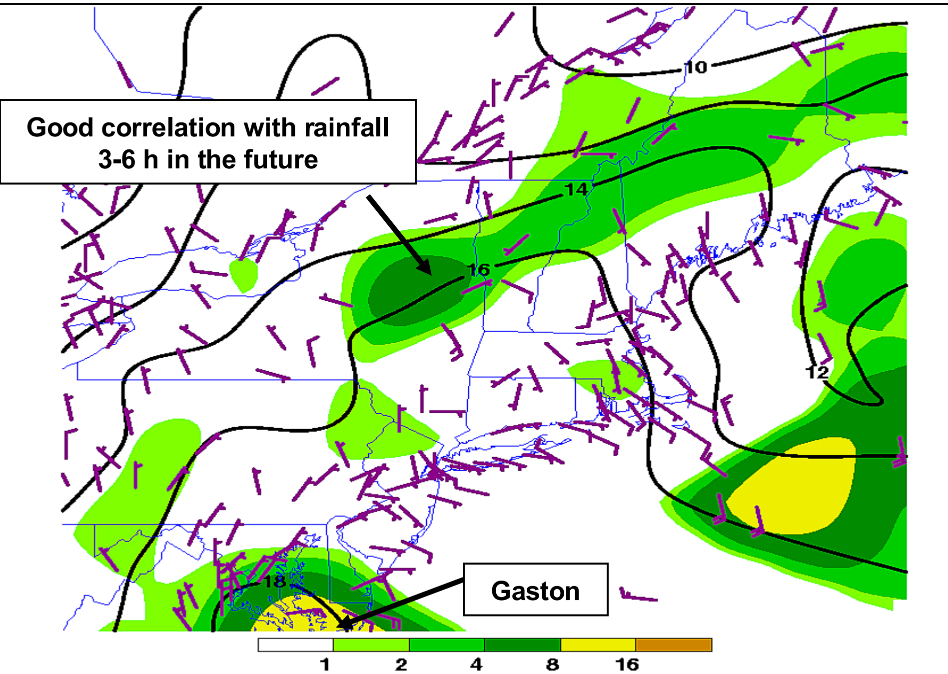
- **Saturated up through 600 hPa**
- **LL northerlies indicate BUF is behind the boundary**
- **850-200 hPa speed shear ~65 kt**
- **K-Index and SWI conducive to heavy convective rainfall**



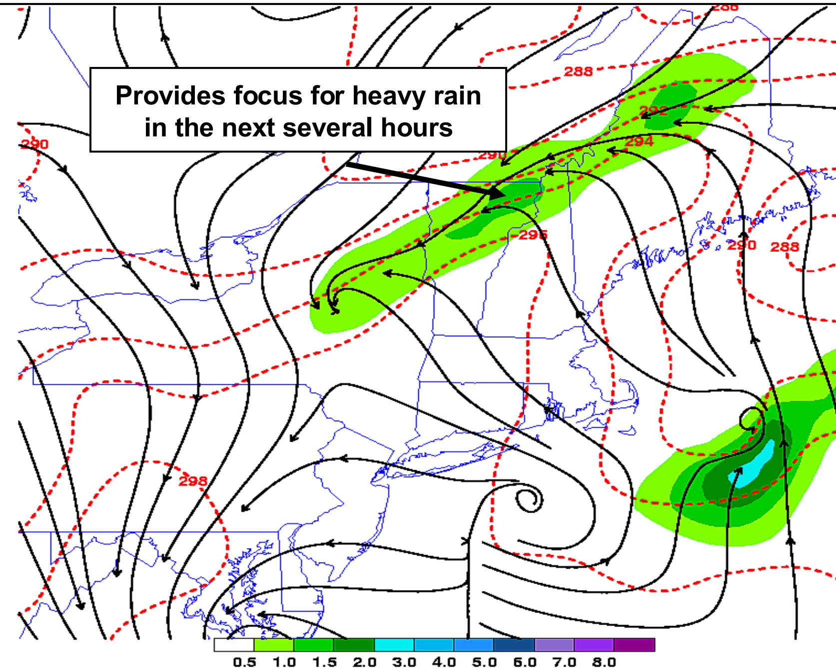
Radar reflectivity (dBZ), RUC topography (m), and sfc wind barbs (kt)



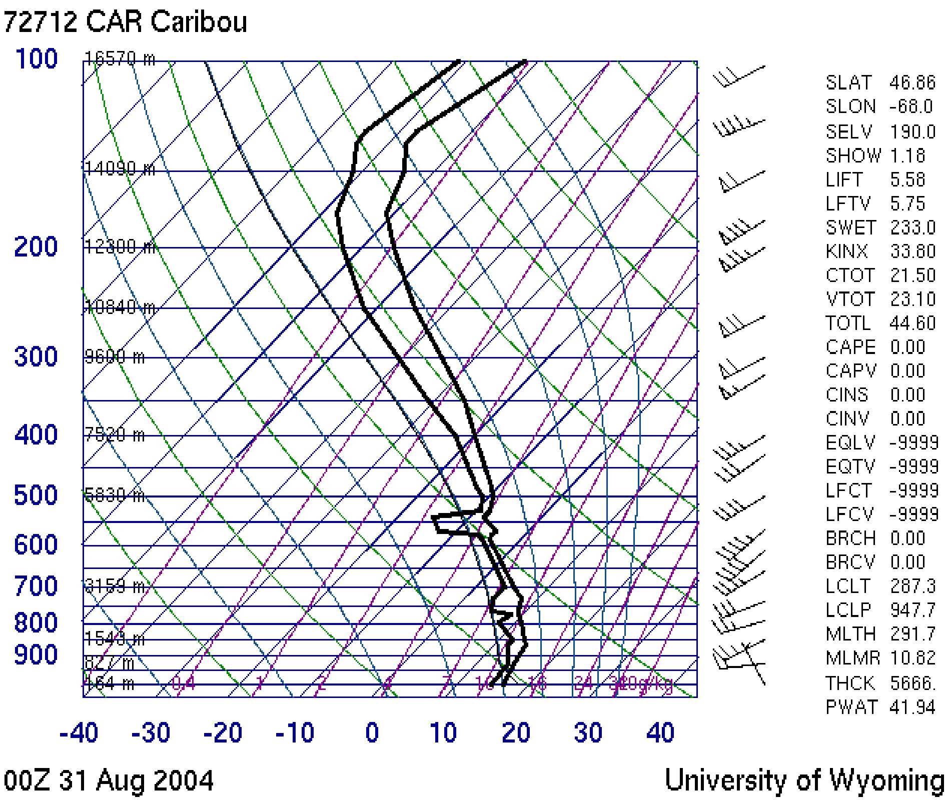
MSLP (hPa), sfc θ_e (K), and θ_e gradient (K (100 km)$^{-1}$)

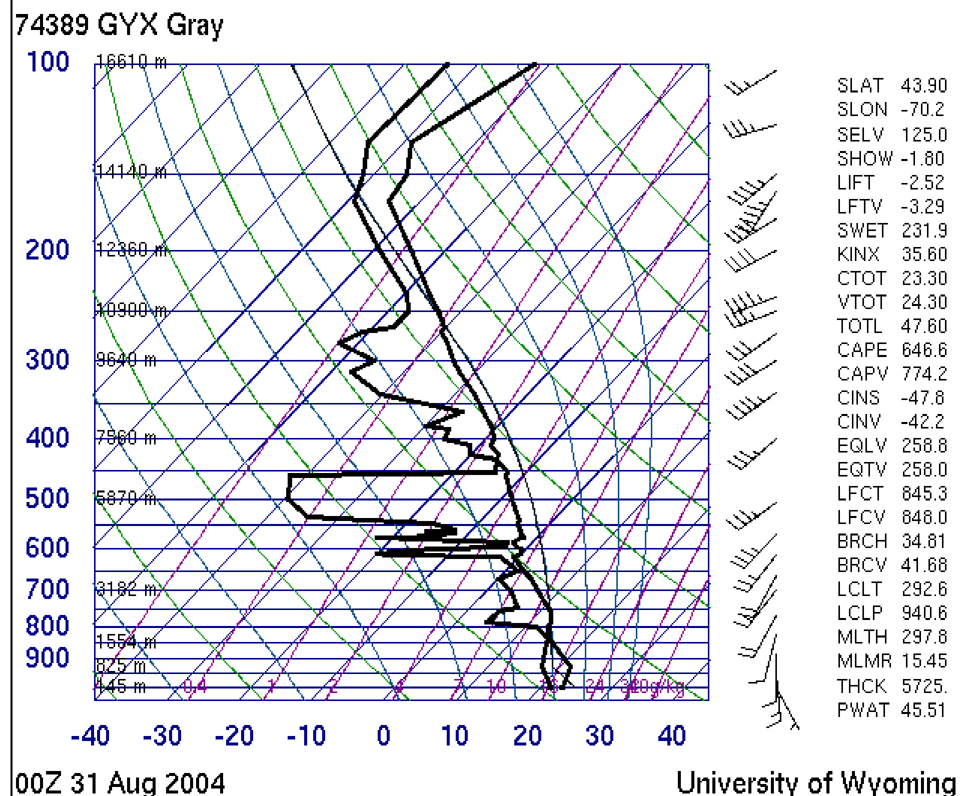


Sfc moisture flux convergence (10^{-7} s^{-1}), mixing ratio (g kg^{-1}), and wind barbs (kt)



Sfc frontogenesis (K (100 km)$^{-1}$ (3 h)$^{-1}$, θ (K), and streamlines





- **PRE 3 affects region several hours later**
- **Located behind θ_e boundary**
- **850-200 hPa speed shear ~50 kt**
- **K-Index still conducive to heavy convective rainfall**

- **Far eastern edge of PRE 3 affects region ~2 h later**
- **Located ahead of θ_e boundary**
- **LL veering winds with surface-based CAPE**

CONCLUSIONS

- ~ 1/3 of all US landfalling TCs produce at least one PRE, but landfall is not necessary
- PREs form on the order of 1000 km away from their parent TCs and about 1-2 days in advance
- LOT PREs are most common, but AT and ROT PREs produce the highest rain rates
- TCs recurving over the Southeast and along the East Coast have the greatest likelihood of producing PREs

CONCLUSIONS

PREs generally form:

- When persistent, deep meridional flow transports tropical air far from the TC

- In favored upslope regions or along synoptic/mesoscale boundaries:

  - Ahead of the boundary, where surface-based convection is favored
  - Immediately behind the boundary, where elevated convection is favored

CONCLUSIONS

PREs generally form:

- Along and just west of a low-level θ_e ridge, near the strongest gradient

- Near a midlevel jet-entrance region confluence zone

- Under favorable upper-level jet dynamics

TECHNOLOGY TRANSFER

GETTING THE WORD OUT

- Research presented at BGM Spring Workshop 27 March 2007
- Other conference presentations
- Possible NWS teletraining
- Eventual journal publication

TECHNOLOGY TRANSFER

INCORPORATING INTO OPERATIONS

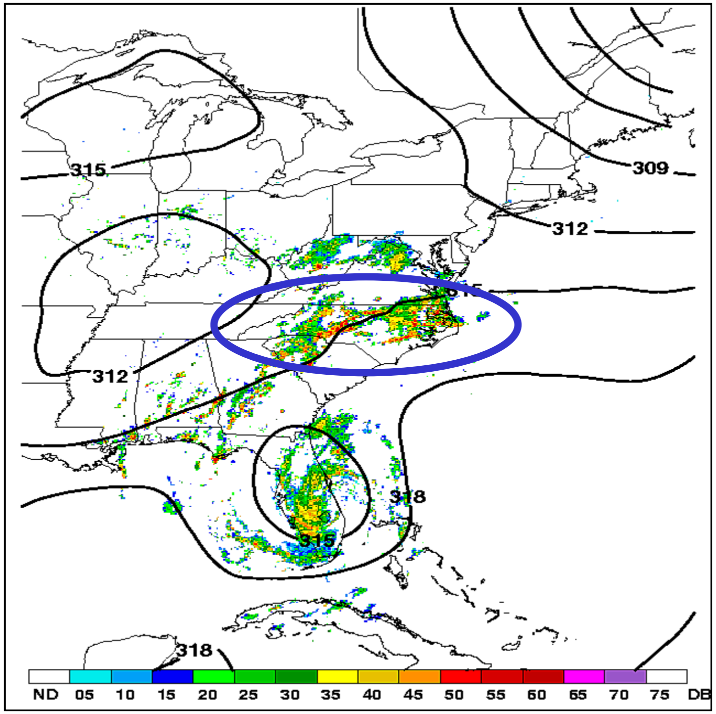
- 24-h track/precip technique for capturing rainfall downstream of TC
- TC track climatological maps
- Statistically modified Bosart and Carr (1978) conceptual model
- Ingredients-based methodology
- Construction of an “all-in-one” conceptual model

QUESTIONS?

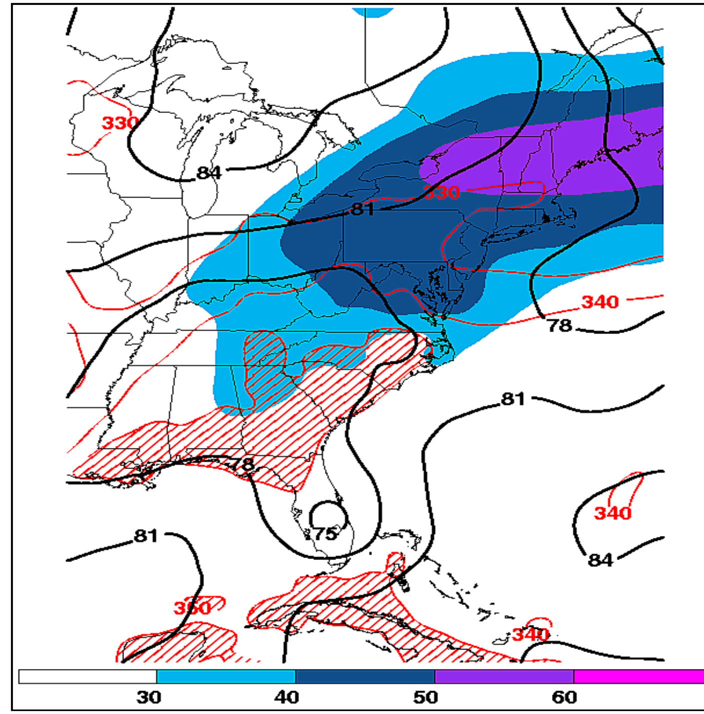
COMMENTS?

mcote@atmos.albany.edu

ALONG TRACK PREs



2100 UTC 060830 700 hPa Ht (dam) and WSI NOWRAD image

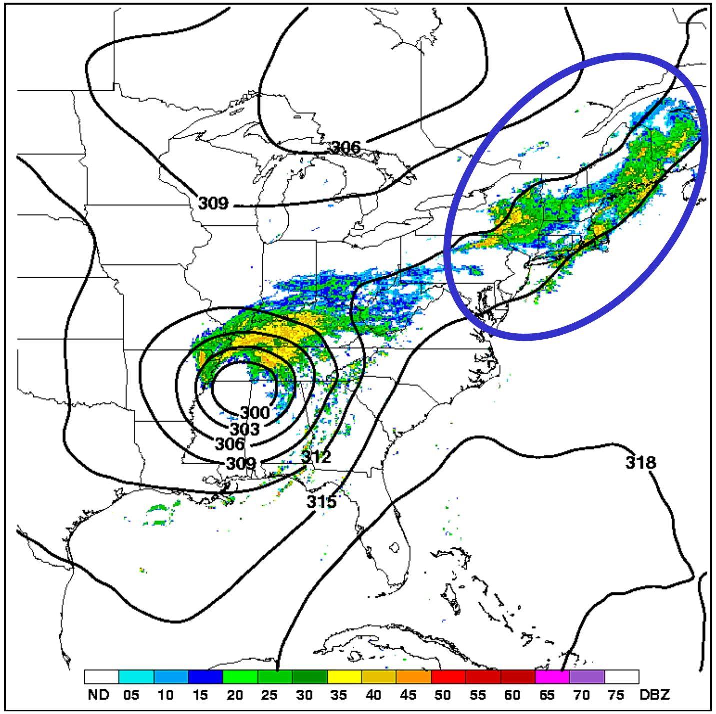


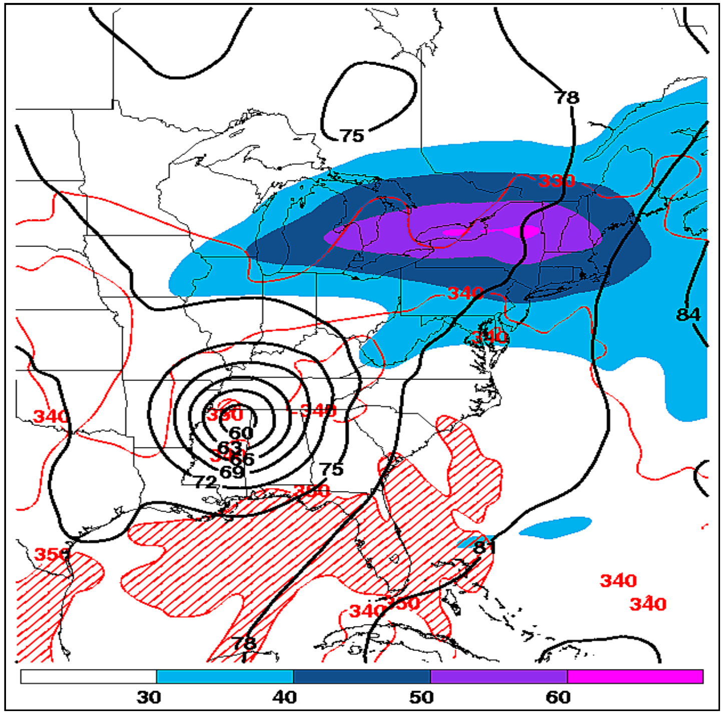
2100 UTC 060830 925 hPa Ht (dam), θ_e (K), and 200 hPa wind speed (m s^{-1})

Ernesto (2006)

- NW/SE oriented trough well to the northeast
- Closed midlevel low NW and flat ridge east of TC
- Broad upper-level jet to the north
- On western edge of θ_e ridge

RIGHT OF TRACK PREs





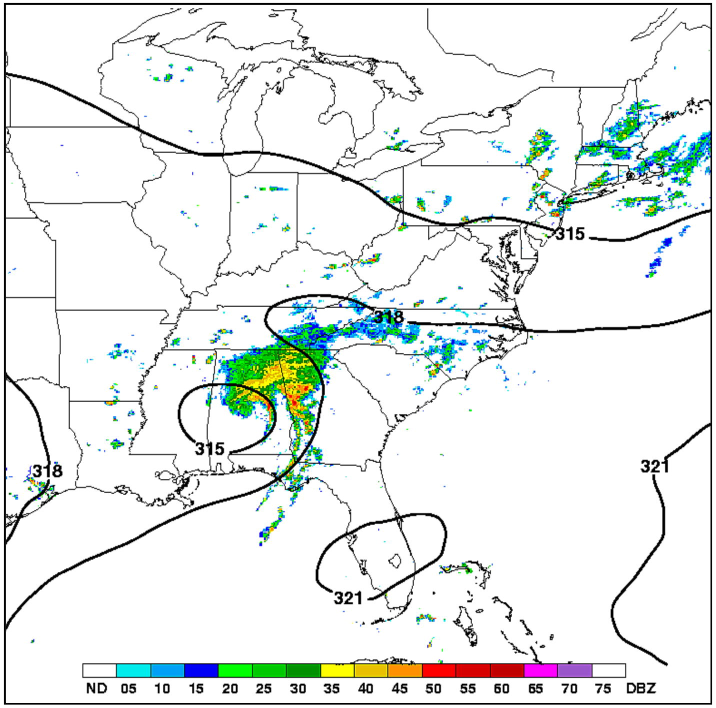
0900 UTC 050830 700 hPa Ht (dam) and WSI NOWRAD image

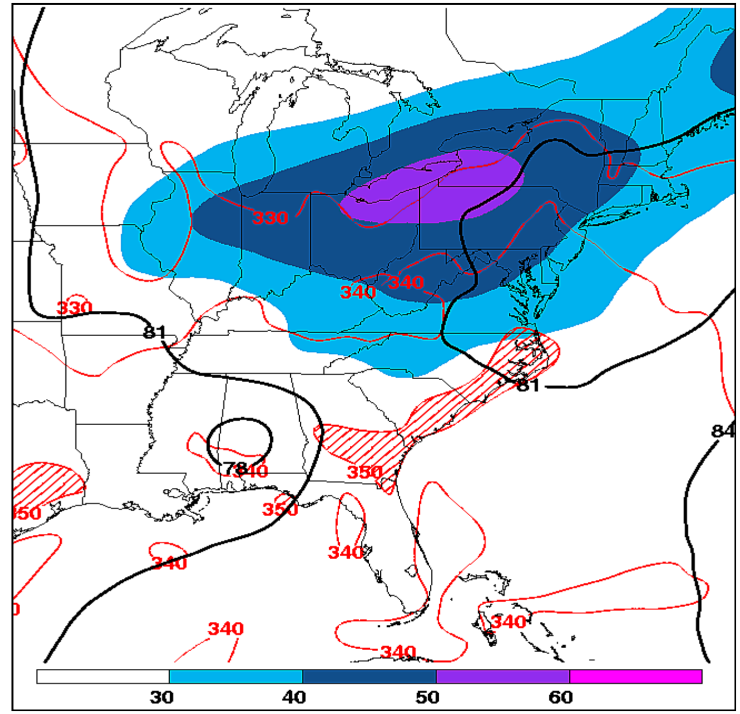
0900 UTC 050830 925 hPa Ht (dam), θ_e (K), and 200 hPa wind speed (m s^{-1})

Katrina (2005)

- Large midlevel low NNE and ridge SE of TC
- PREs a bit downstream of where model predicts
- Jet dynamics only partially explain the PREs
- No prominent low-level θ_e ridge or gradient near PRE

NULL CASE





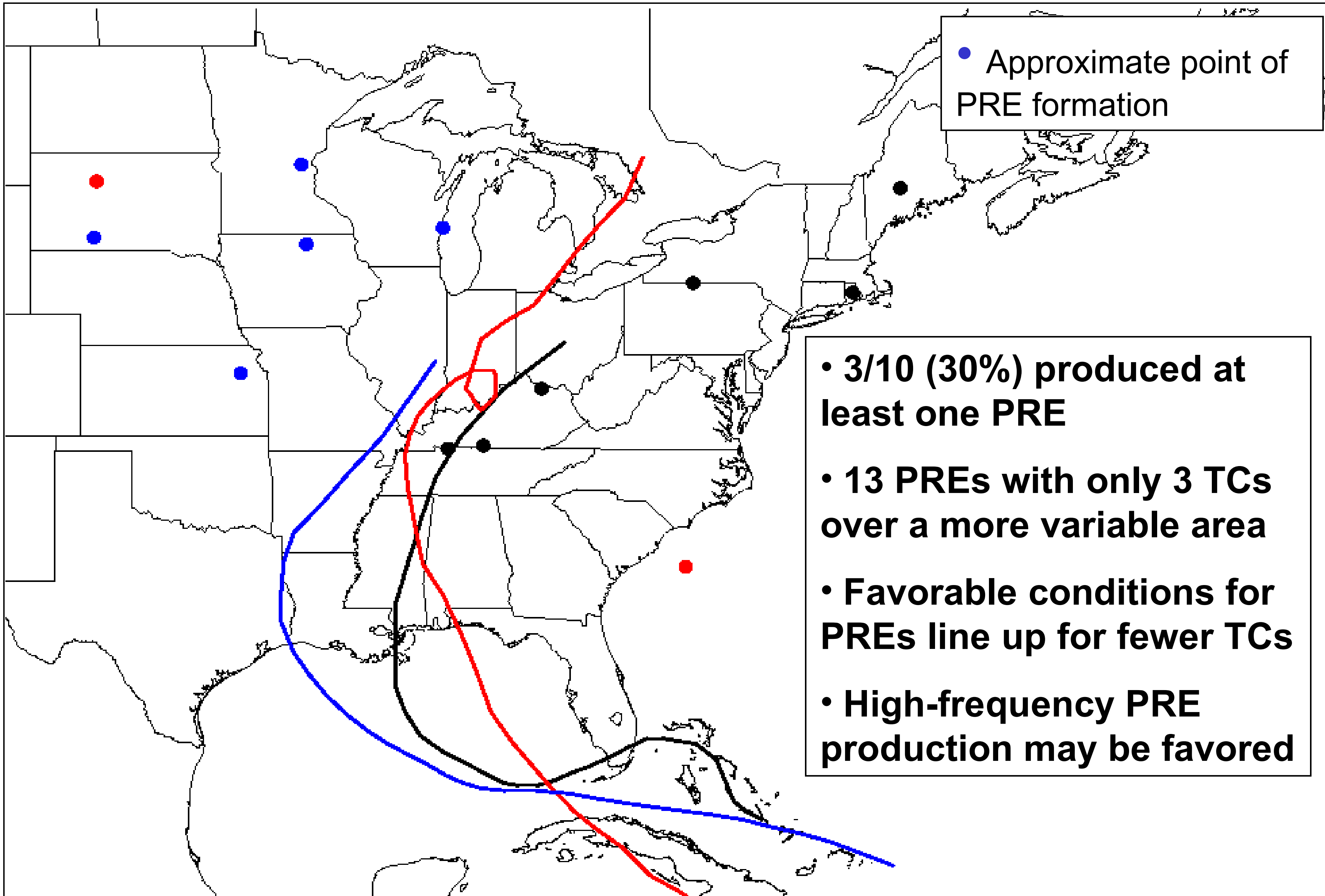
0000 UTC 050707 700 hPa Ht (dam) and WSI NOWRAD image

0000 UTC 050707 925 hPa Ht (dam), θ_e (K), and 200 hPa wind speed (m s^{-1})

Cindy (2005)

- WNW flow at midlevels
- Scattered rainfall over New England not related to Cindy
- Massive low-level ridge poleward of TC
- No rainfall near low-level θ_e ridge

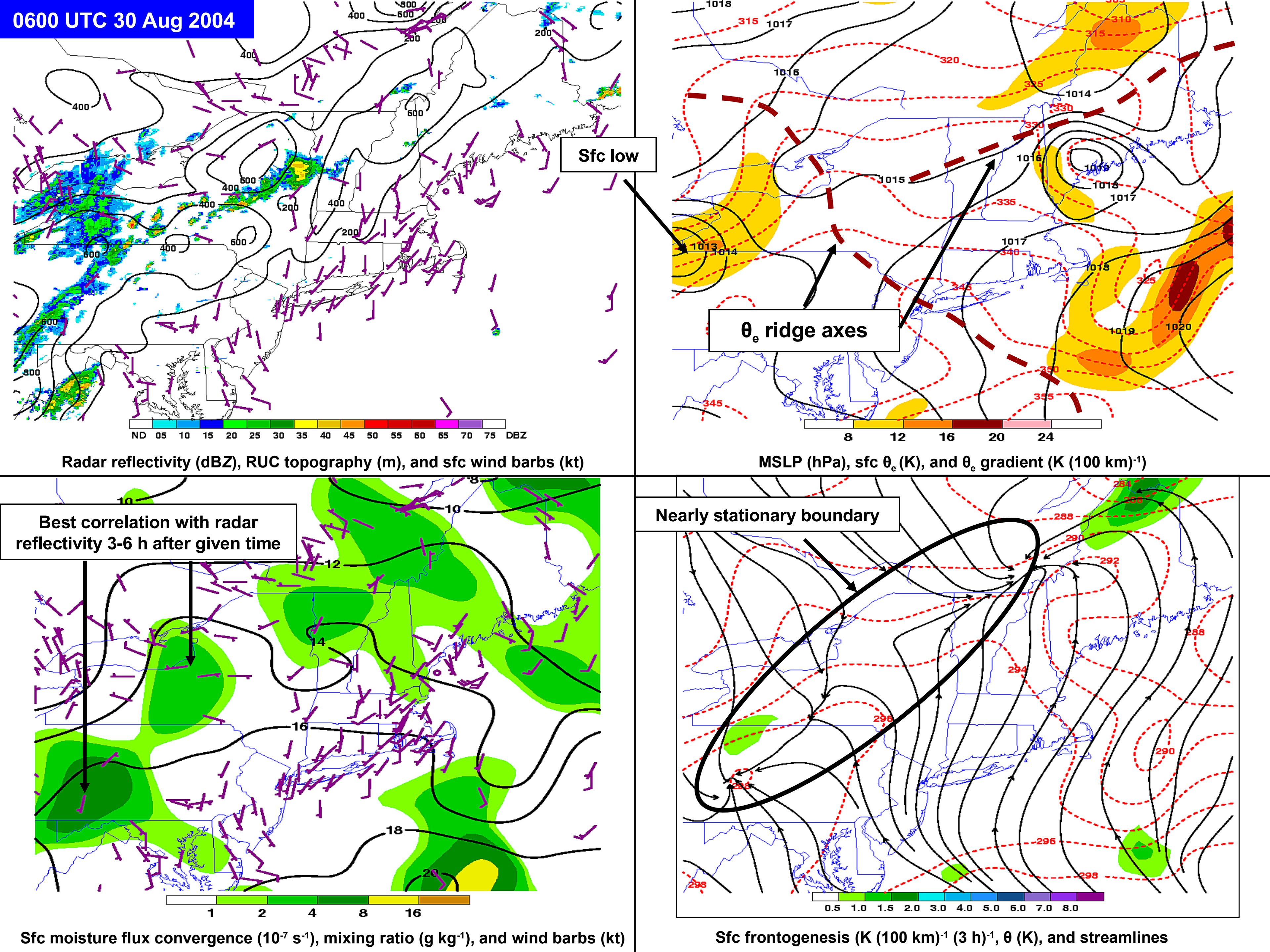
CENTRAL GULF LANDFALLS



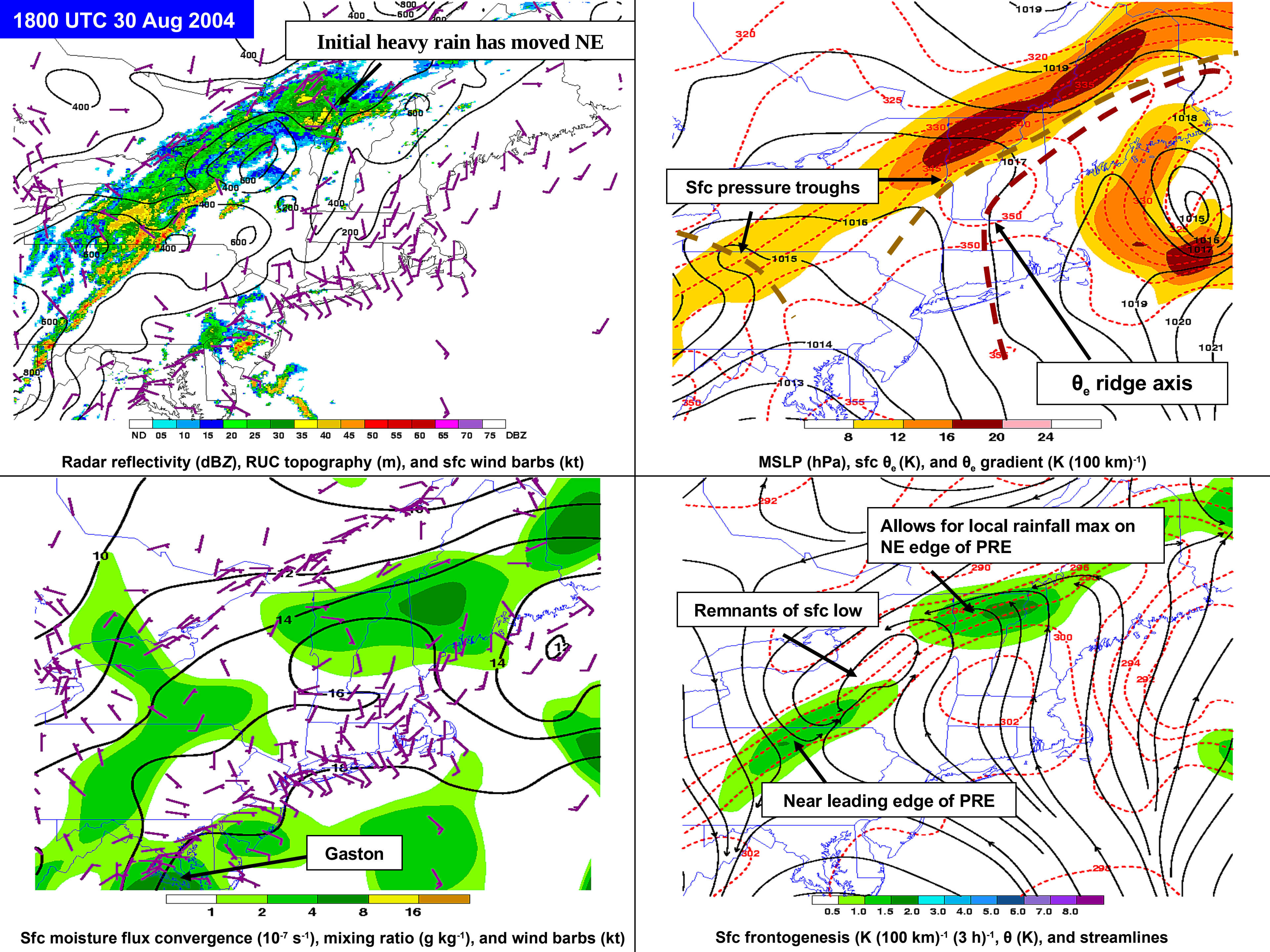
- 3/10 (30%) produced at least one PRE
- 13 PREs with only 3 TCs over a more variable area
- Favorable conditions for PREs line up for fewer TCs
- High-frequency PRE production may be favored

GASTON (2004)

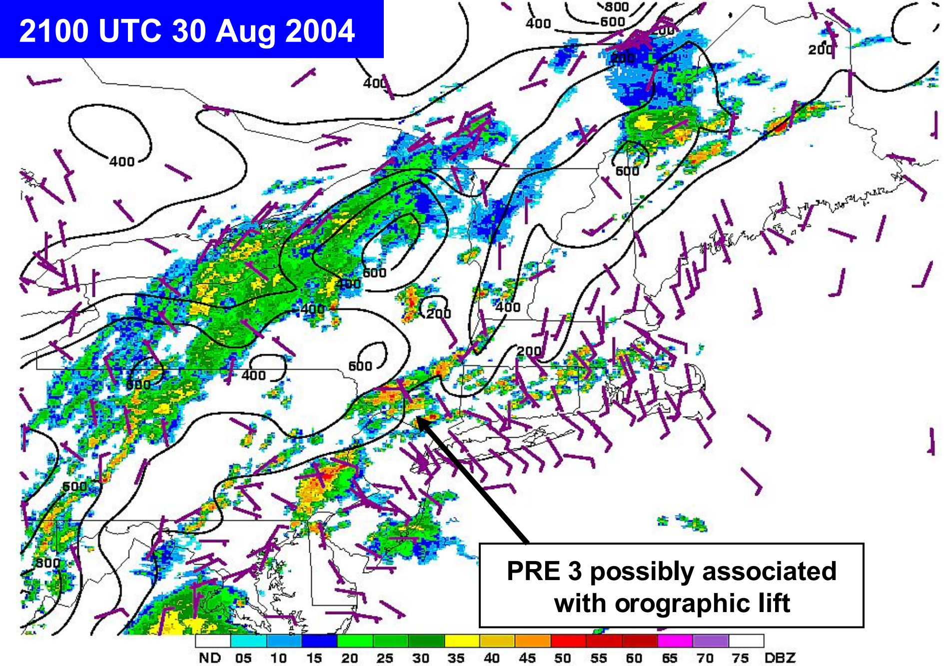
MESOSCALE DETAILS FROM ADDITIONAL TIMES



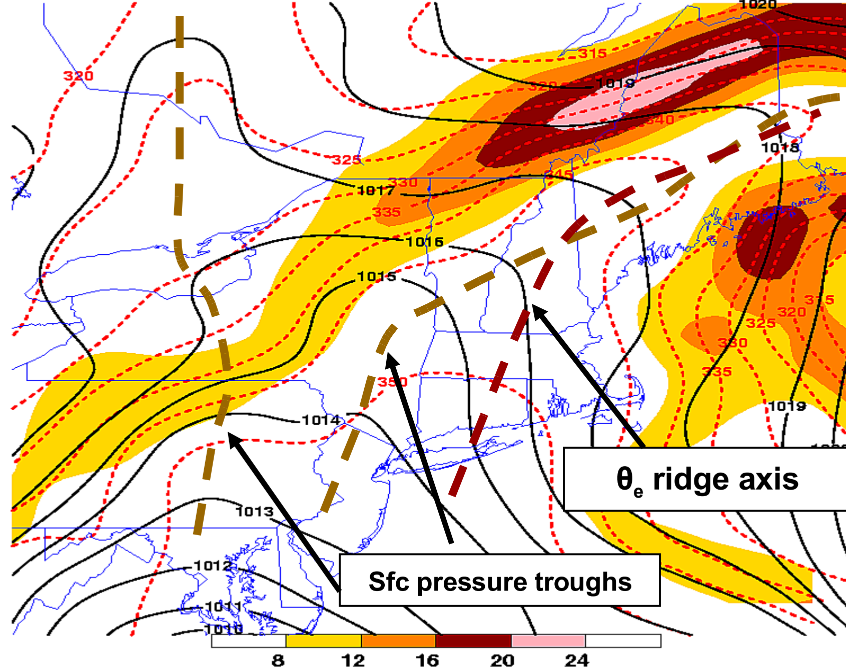
0600 UTC 30 Aug 2004
Sfc low
θe ridge axes
Radar reflectivity (dBZ), RUC topography (m), and sfc wind barbs (kt)
MSLP (hPa), sfc θe (K), and θe gradient (K (100 km)-1)
Best correlation with radar reflectivity 3-6 h after given time
Nearly stationary boundary
Sfc moisture flux convergence (10-7 s-1), mixing ratio (g kg-1), and wind barbs (kt)
Sfc frontogenesis (K (100 km)-1 (3 h)-1, θ (K), and streamlines



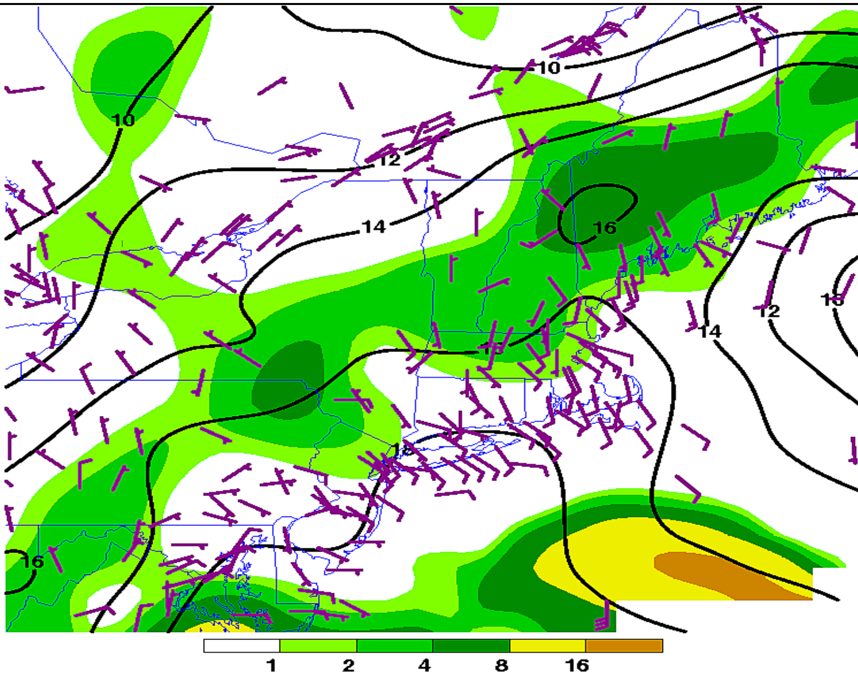
1800 UTC 30 Aug 2004
Initial heavy rain has moved NE
Radar reflectivity (dBZ), RUC topography (m), and sfc wind barbs (kt)
Sfc pressure troughs
θe ridge axis
MSLP (hPa), sfc θe (K), and θe gradient (K (100 km)-1)
Gaston
Sfc moisture flux convergence (10-7 s-1), mixing ratio (g kg-1), and wind barbs (kt)
Allows for local rainfall max on NE edge of PRE
Remnants of sfc low
Near leading edge of PRE
Sfc frontogenesis (K (100 km)-1 (3 h)-1, θ (K), and streamlines



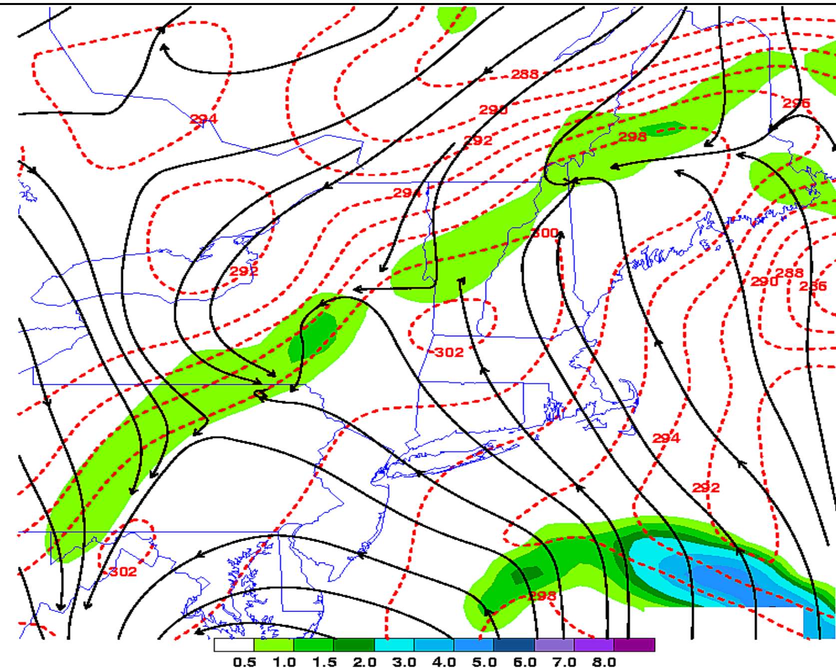
Radar reflectivity (dBZ), RUC topography (m), and sfc wind barbs (kt)



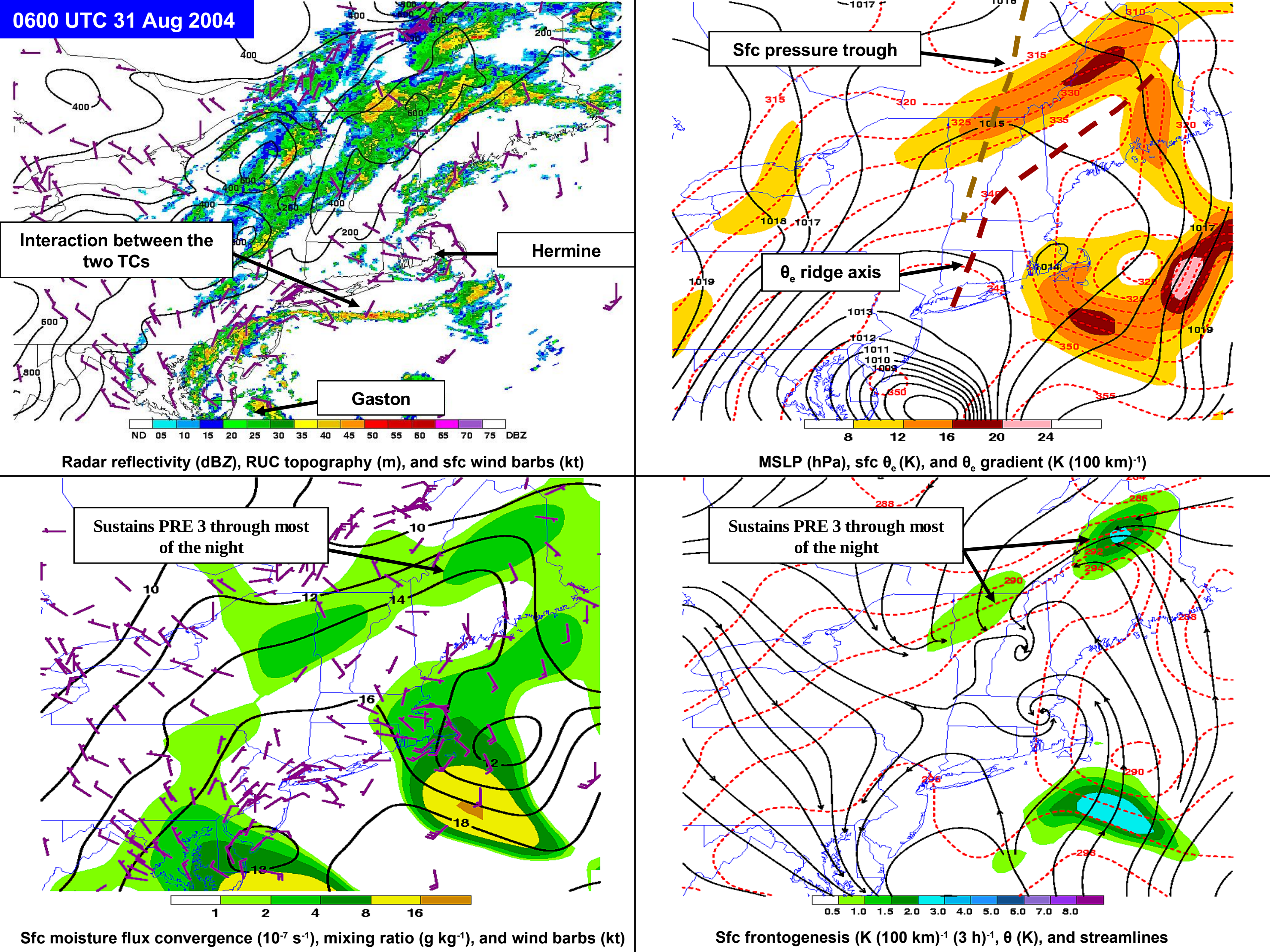
MSLP (hPa), sfc θ_e (K), and θ_e gradient (K (100 km)$^{-1}$)

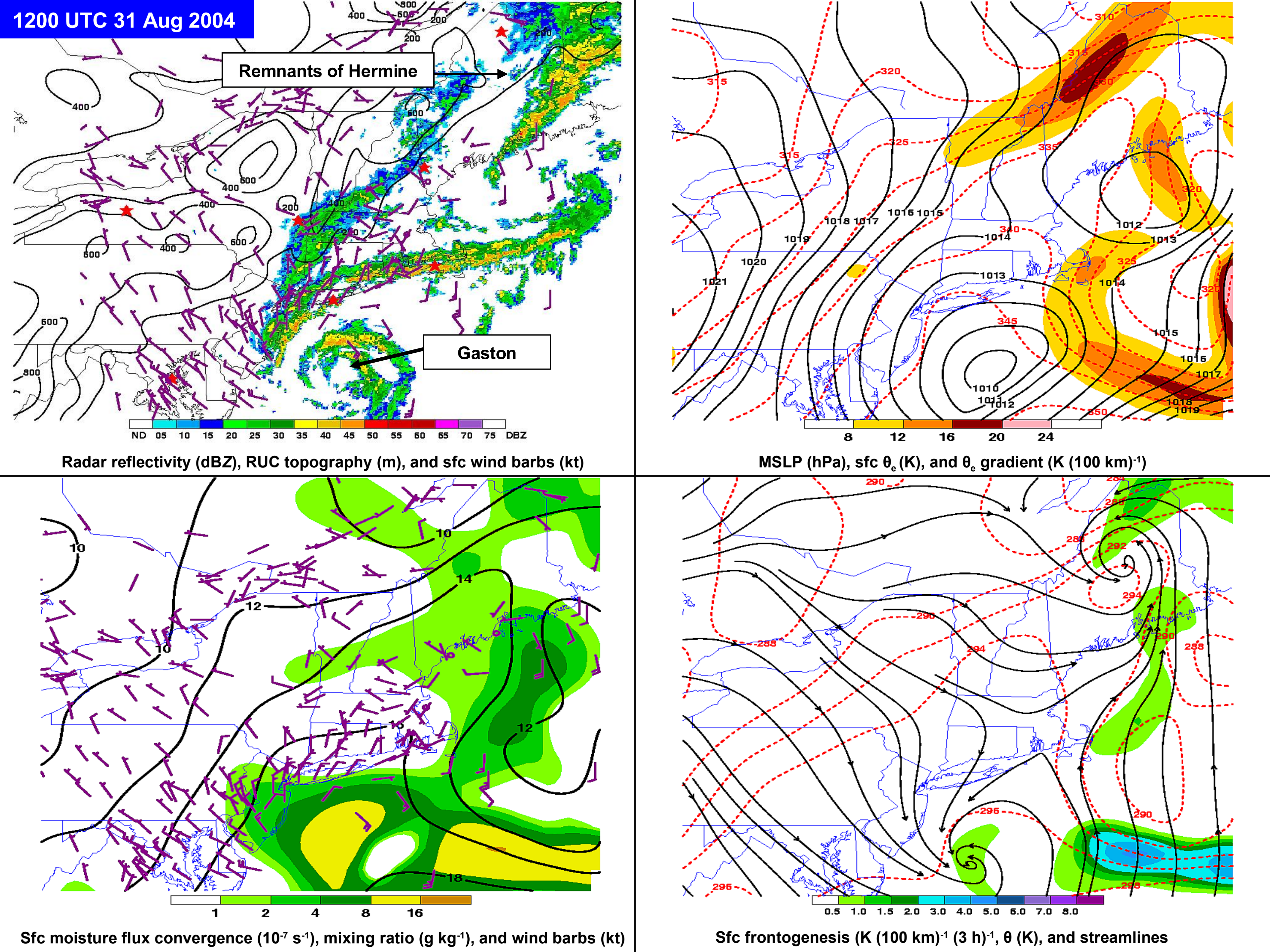


Sfc moisture flux convergence (10^{-7} s^{-1}), mixing ratio (g kg^{-1}), and wind barbs (kt)



Sfc frontogenesis (K (100 km)$^{-1}$ (3 h)$^{-1}$, θ (K), and streamlines


0600 UTC 31 Aug 2004
Interaction between the two TCs
Hermine
Gaston
ND 05 10 15 20 25 30 35 40 45 50 55 60 65 70 75 DBZ
Radar reflectivity (dBZ), RUC topography (m), and sfc wind barbs (kt)
Sfc pressure trough
θe ridge axis
8 12 16 20 24
MSLP (hPa), sfc θe (K), and θe gradient (K (100 km)-1)
Sustains PRE 3 through most of the night
1 2 4 8 16
Sfc moisture flux convergence (10-7 s-1), mixing ratio (g kg-1), and wind barbs (kt)
Sustains PRE 3 through most of the night
0.5 1.0 1.5 2.0 3.0 4.0 5.0 6.0 7.0 8.0
Sfc frontogenesis (K (100 km)-1 (3 h)-1, θ (K), and streamlines


1200 UTC 31 Aug 2004
Remnants of Hermine
Gaston
ND 05 10 15 20 25 30 35 40 45 50 55 60 65 70 75 DBZ
Radar reflectivity (dBZ), RUC topography (m), and sfc wind barbs (kt)
8 12 16 20 24
MSLP (hPa), sfc θe (K), and θe gradient (K (100 km)-1)
1 2 4 8 16
Sfc moisture flux convergence (10-7 s-1), mixing ratio (g kg-1), and wind barbs (kt)
0.5 1.0 1.5 2.0 3.0 4.0 5.0 6.0 7.0 8.0
Sfc frontogenesis (K (100 km)-1 (3 h)-1, θ (K), and streamlines