CONVECTIVE BURSTS DURING TROPICAL CYCLONE FORMATION AND INTENSIFICATION

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- 3-slide history of hurricane research

- Distribution of the potential for severe cells in tropical cyclones using CAMEX dropsondes

- Application to Tropical Storm Gabrielle (2001)

BRIEF HISTORY OF HURRICANE RESEARCH

Riehl and Malkus 1958: “hot tower” hypothesis

Upward mass flux in the tropics occurs in small tubes of intense updrafts. These hot towers play an essential role in tropical cyclones and in the tropical circulation in general.

When satellites first went into orbit, in order to forecast tropical cyclones, forecasters looked for convective towers

Emanuel (1986):

Too much emphasis on convection in tropical cyclones

Convection occurs most strongly over land, where tropical cyclones do not form

Key to tropical cyclone growth is a feedback between surface wind speed and fluxes of moist entropy from the ocean. Ocean temperature and mixed layer depth are what matter most

Emanuel produced full-fledged hurricanes in a numerical model without any pre-existing convective instability.

Hendricks et al. 2004, Montgomery et al. 2006:

Defined "vortical" hot towers (VHTs): back to hot towers, but with deep updrafts and rotation occurring together

They argued convincingly that VHTs were the building blocks of tropical cyclones in their model

This returns the emphasis to the convection, and the need to understand the nature of cells in tropical cyclones and their role in the vortex

Molinari and Vollaro (2008): used CAMEX sondes to evaluate the environment of intense local cells in Hurricane Bonnie (1998) using midlatitude convective parameters

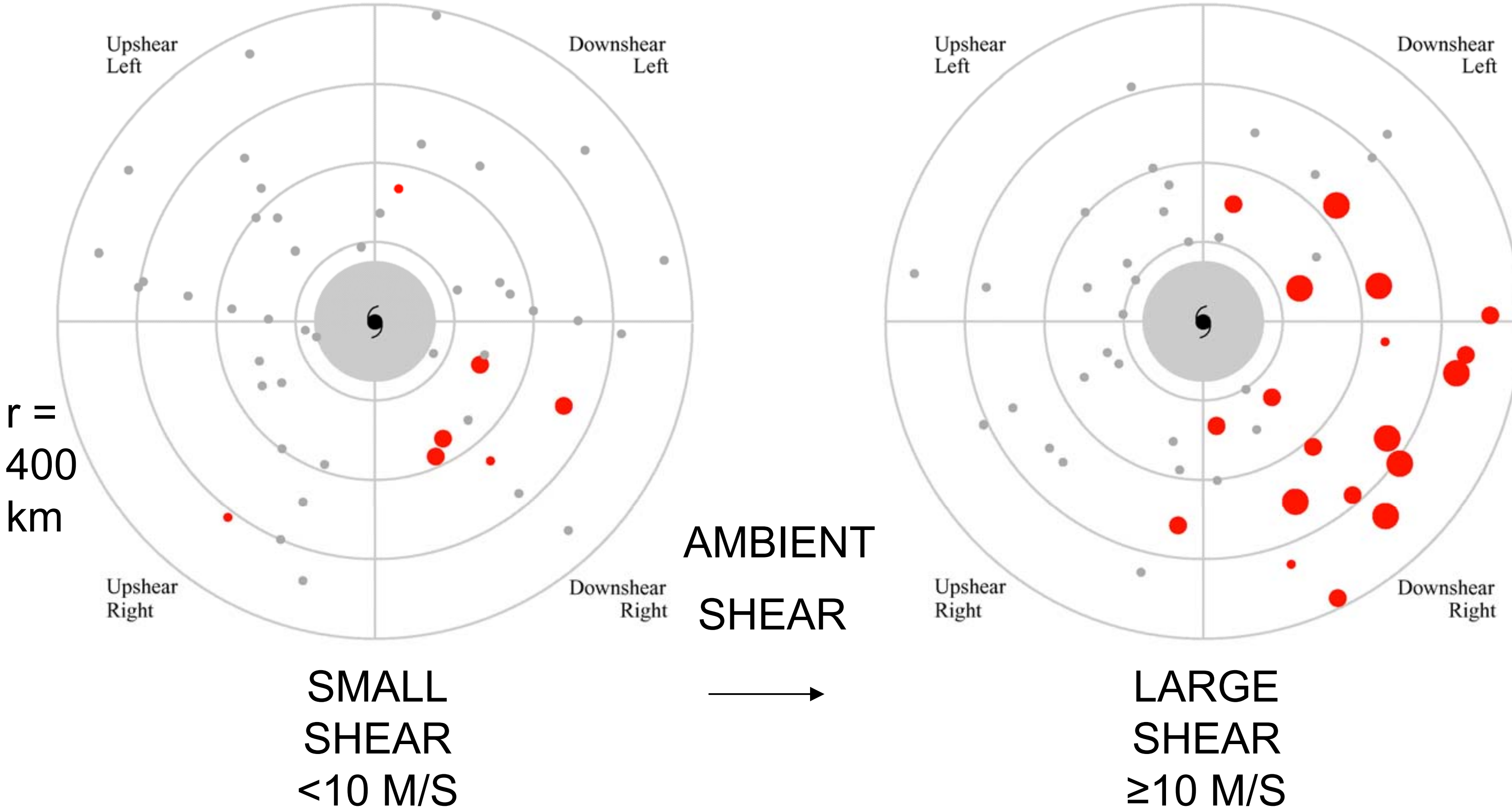
EHI: energy-helicity index

Empirical index for predicting supercells (and tornadoes) in midlatitudes

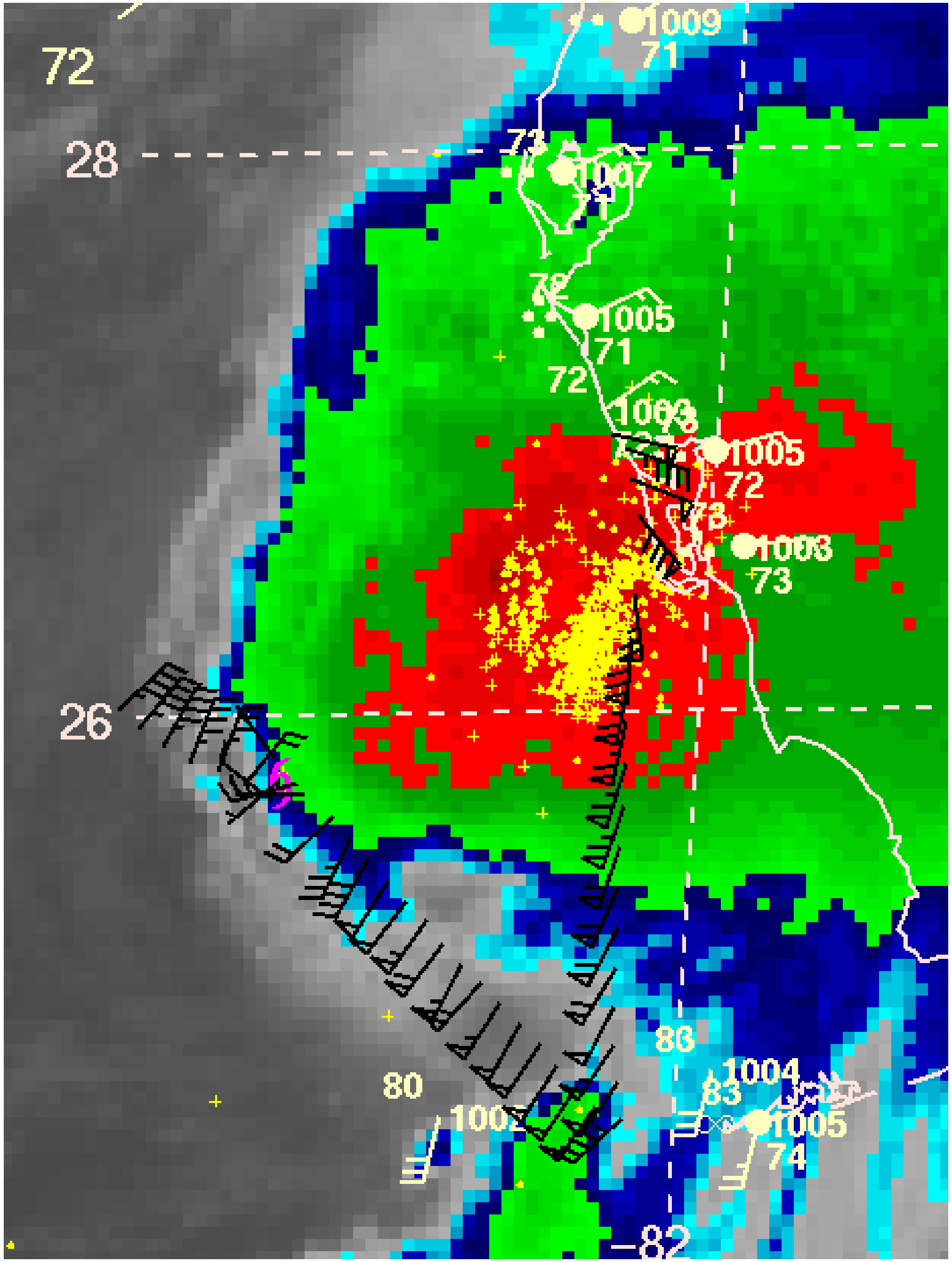
EHI is the product of normalized cell-relative helicity (0-3 km) and normalized CAPE

Hurricane Bonnie study has been repeated for all CAMEX storms

Next: distribution of EHI with respect to the center of all tropical cyclones sampled by dropsondes in the CAMEX experiments, rotated with respect to ambient vertical wind shear, for large and small ambient shear.

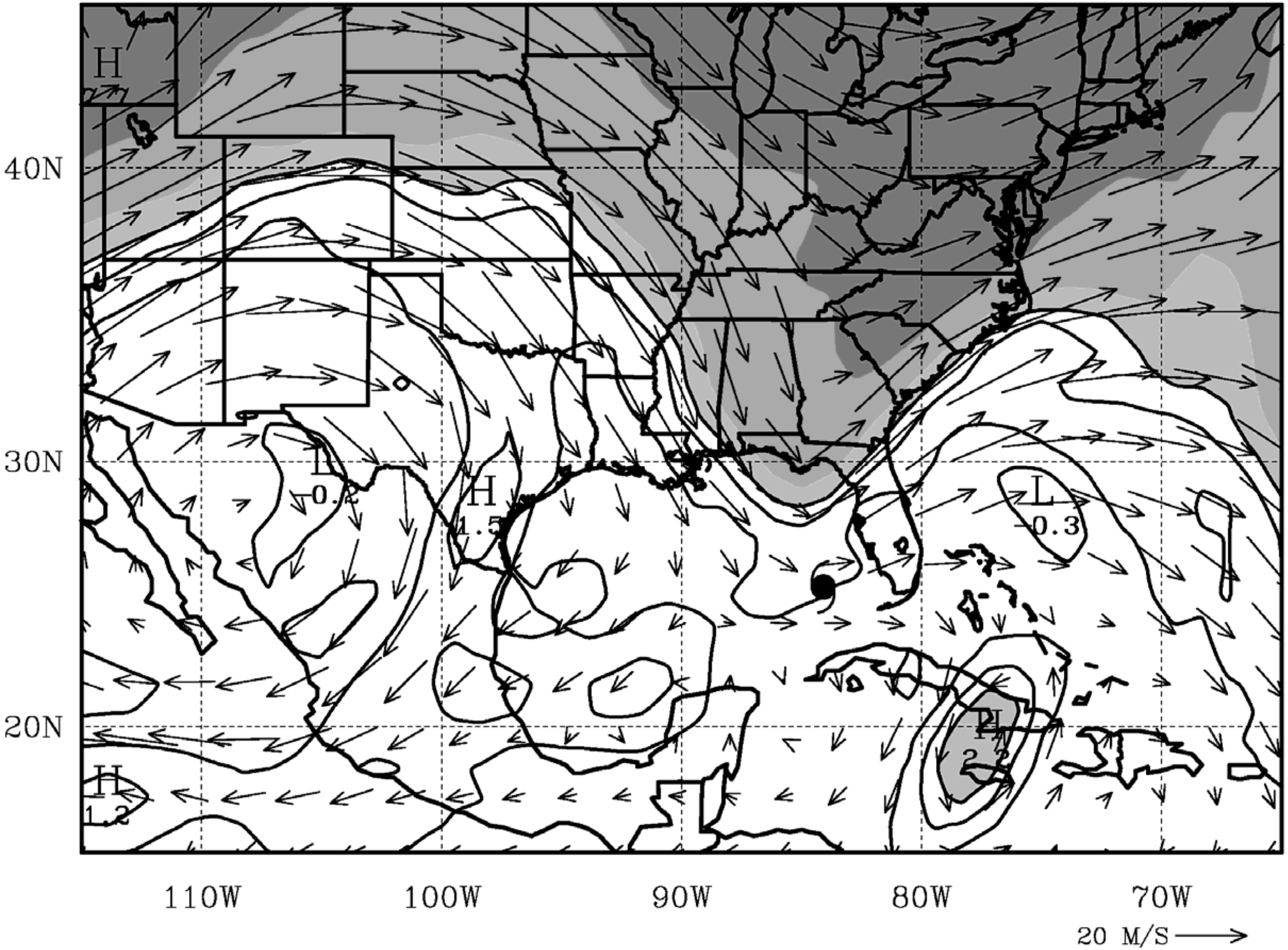


Distribution of EHI values with respect to ambient wind shear in CAMEX-observed tropical cyclones. Left panel: small ambient shear. Right panel: large ambient shear. Gray circles: severe cells unlikely. Red circles: likelihood grows with circle diameter.

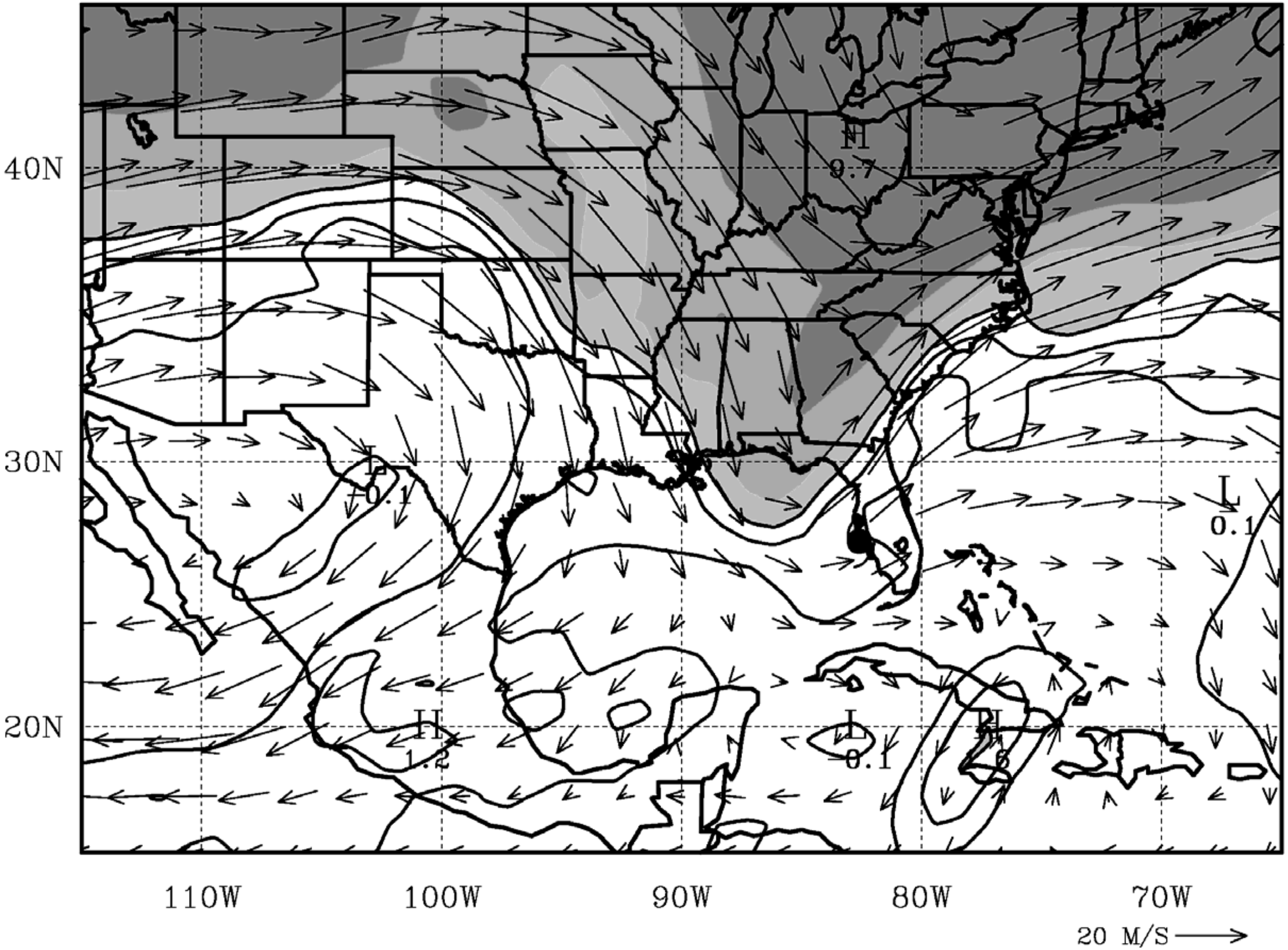


TROPICAL STORM GABRIELLE (2001)

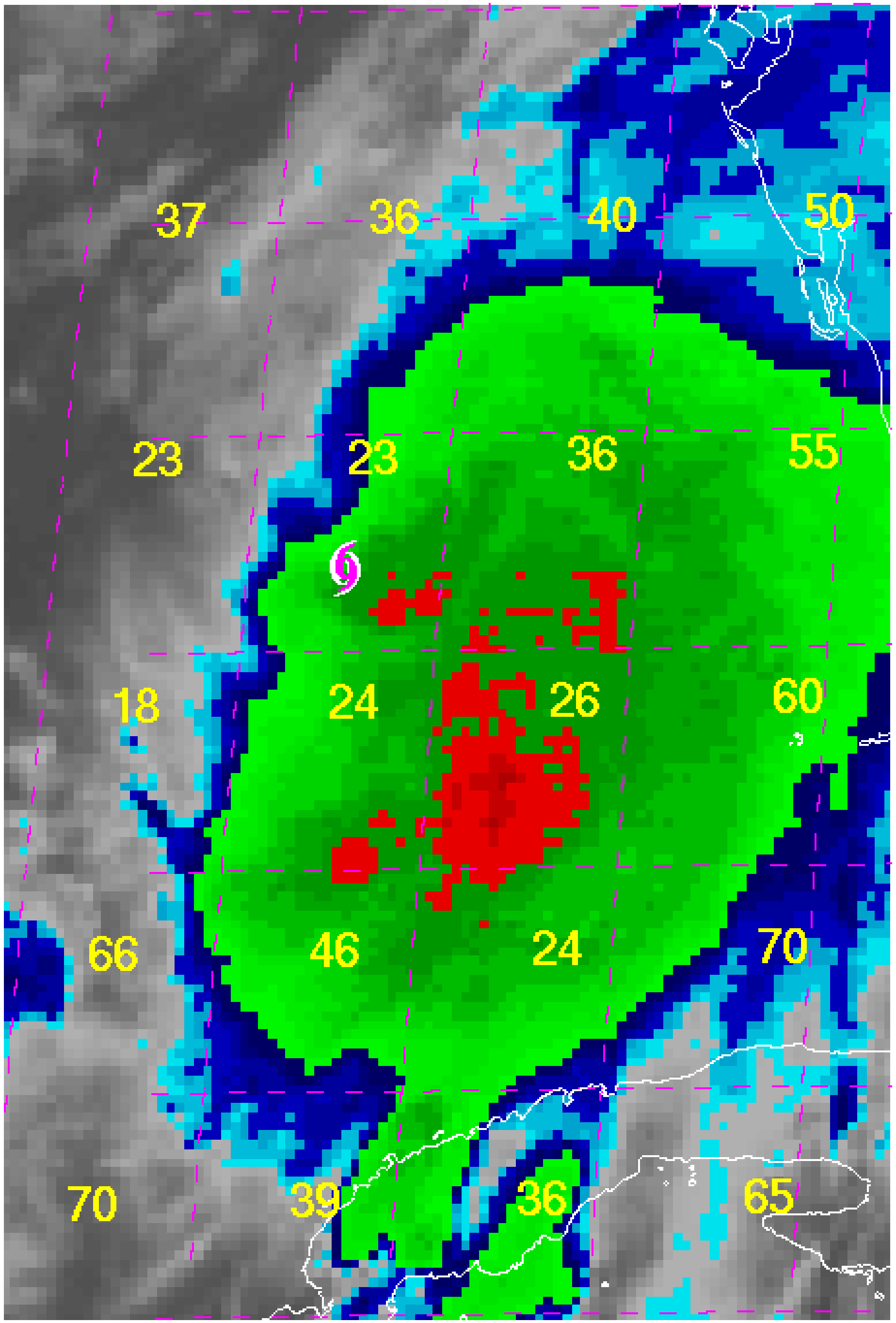
Infrared satellite image at 0715 UTC 14 September. Also shown are Air Force reconnaissance 850 hPa winds (0600-0730 UTC) and cloud-to-ground lightning flashes from 0530-0730 UTC. Surface winds are at 0700 UTC.



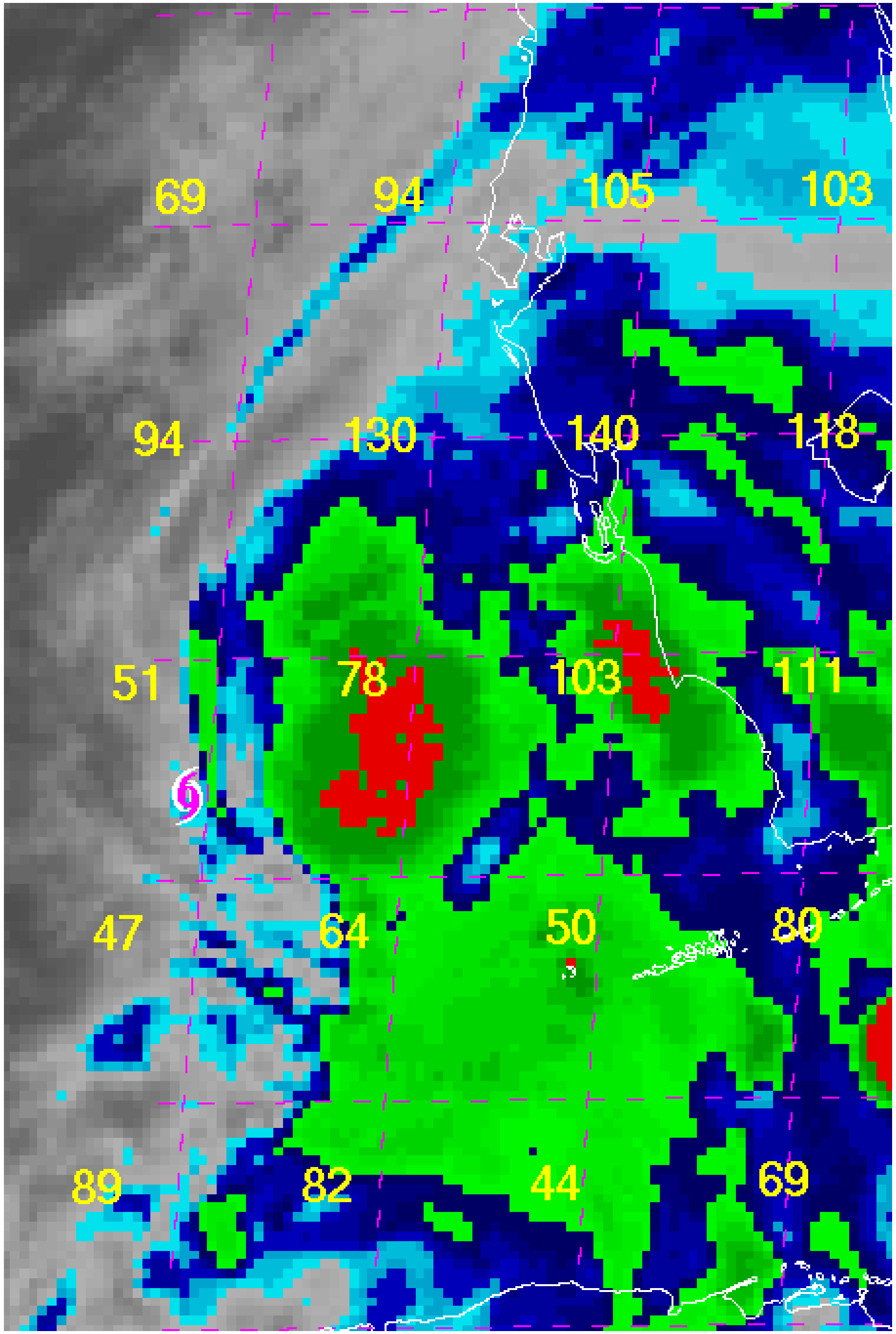
Potential vorticity and winds on the θ = 350K surface at 0000 UTC 14 September 2001.



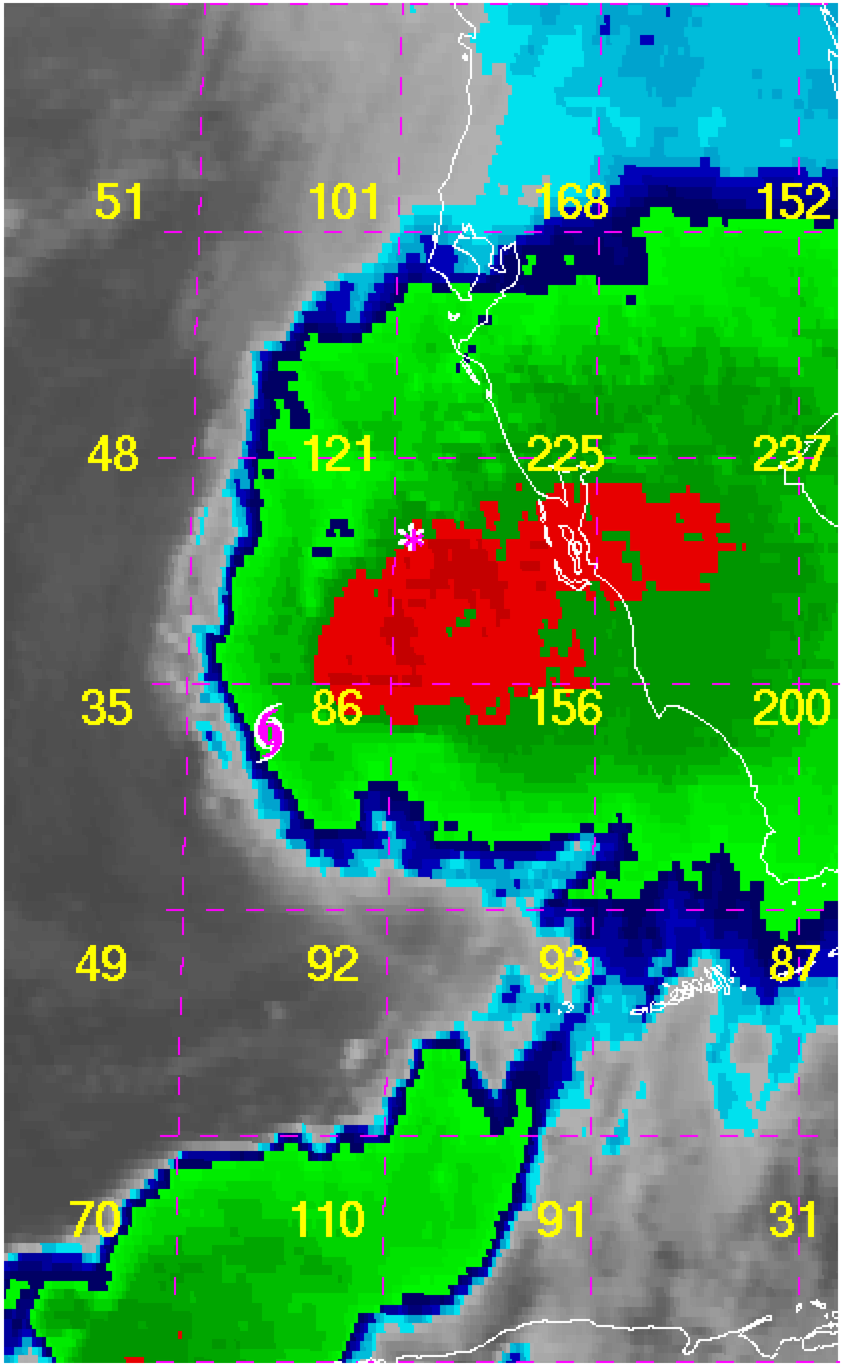
Potential vorticity and winds on the θ = 350K surface at 1200 UTC 14 September 2001.



Infrared satellite image (colors) at 1800 UTC 13 September 2001. Red shading indicates Tb < -72ºC. Yellow numbers indicate 0-3 km helicity values ($m^2\ s^{-2}$) calculated from ECMWF analyses at the same time. The hurricane symbol shows the best track center.



Same as previous, but for 6 hours later, at 0000 UTC 14 September.



Same as previous, but for an additional 6 hours later, at 0600 UTC 14 September. The asterisk indicates the location of center reformation less than three hours later. Reconnaissance aircraft found a 972 hPa pressure at that point, 20 hPa lower than 3 hours before.

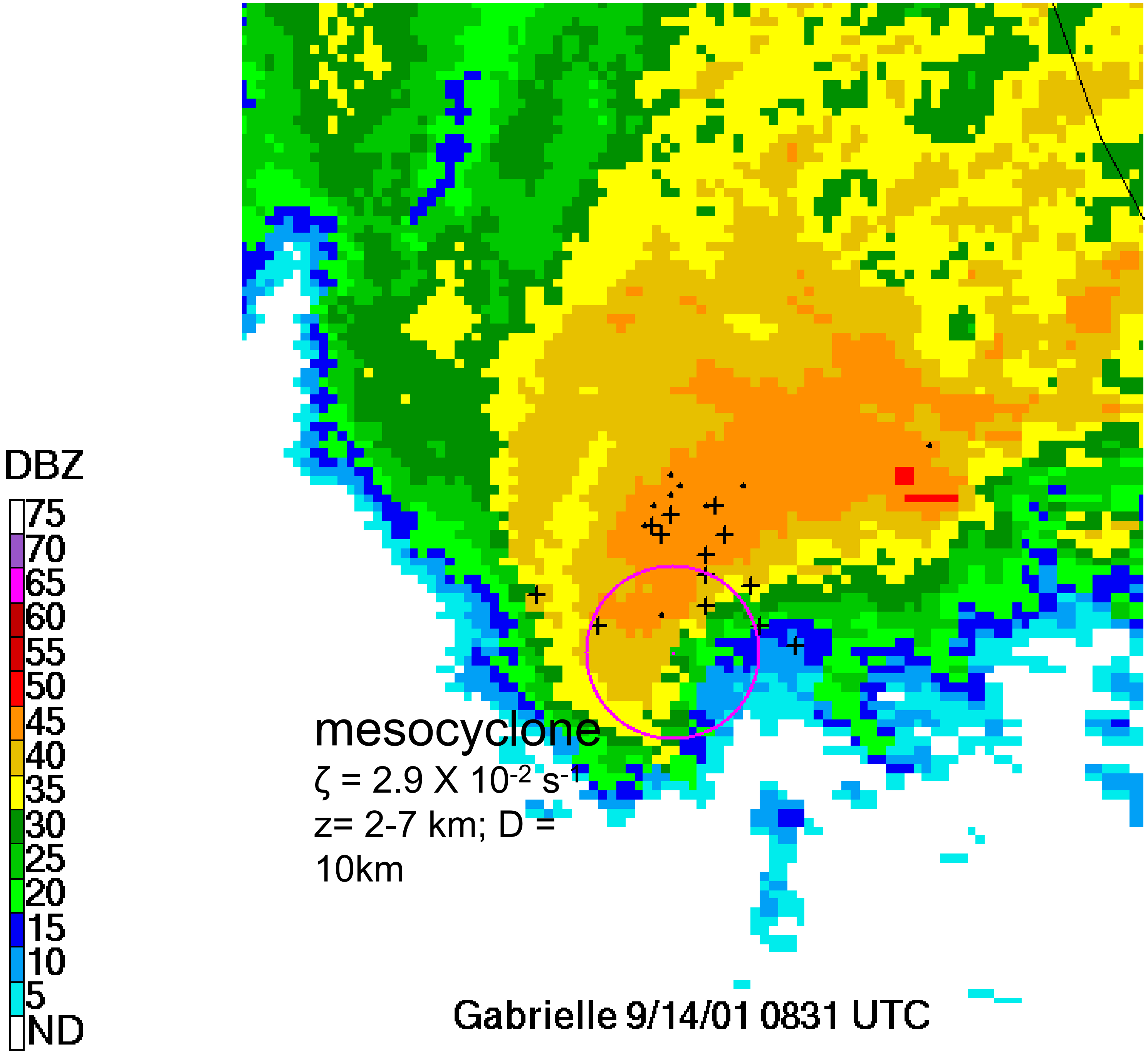
Next: radar reflectivity from Tampa, 70 km northeast of the newly developing center

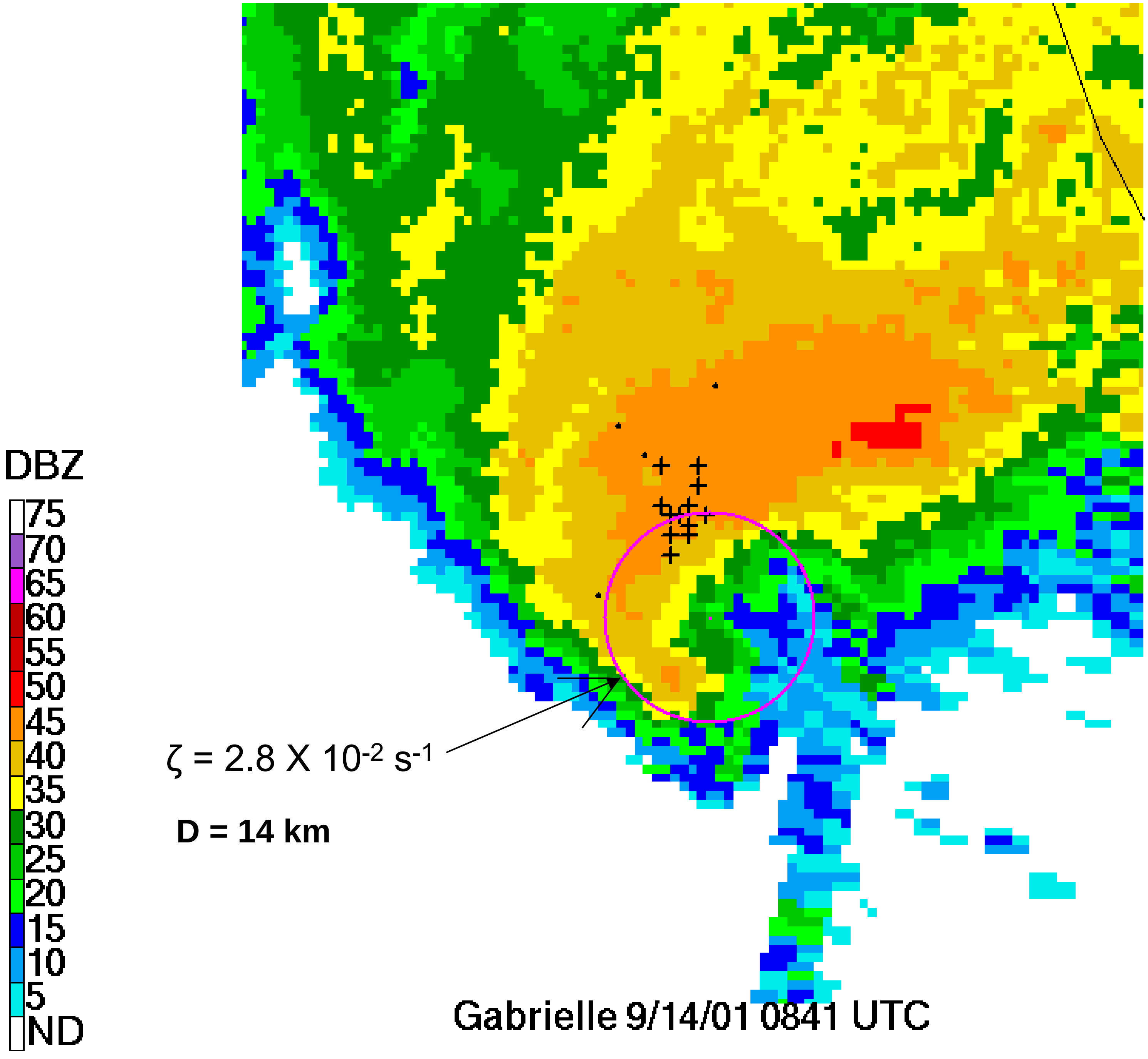
Focused on area of asterisk in previous image

Circles will indicate mesocyclones detected by the automated radar algorithm

Entire image is about 60 km across

5 minutes of lightning is shown by + signs (positive cloud-to-ground flash) and – signs (negative C-G flash)


DBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
ND
mesocyclone
ζ = 2.9 X 10-2 s-1
z= 2-7 km; D =
10km
Gabrielle 9/14/01 0831 UTC


DBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
ND
ζ = 2.8 X 10-2 s-1
D = 14 km
Gabrielle 9/14/01 0841 UTC

TS Gabrielle summary

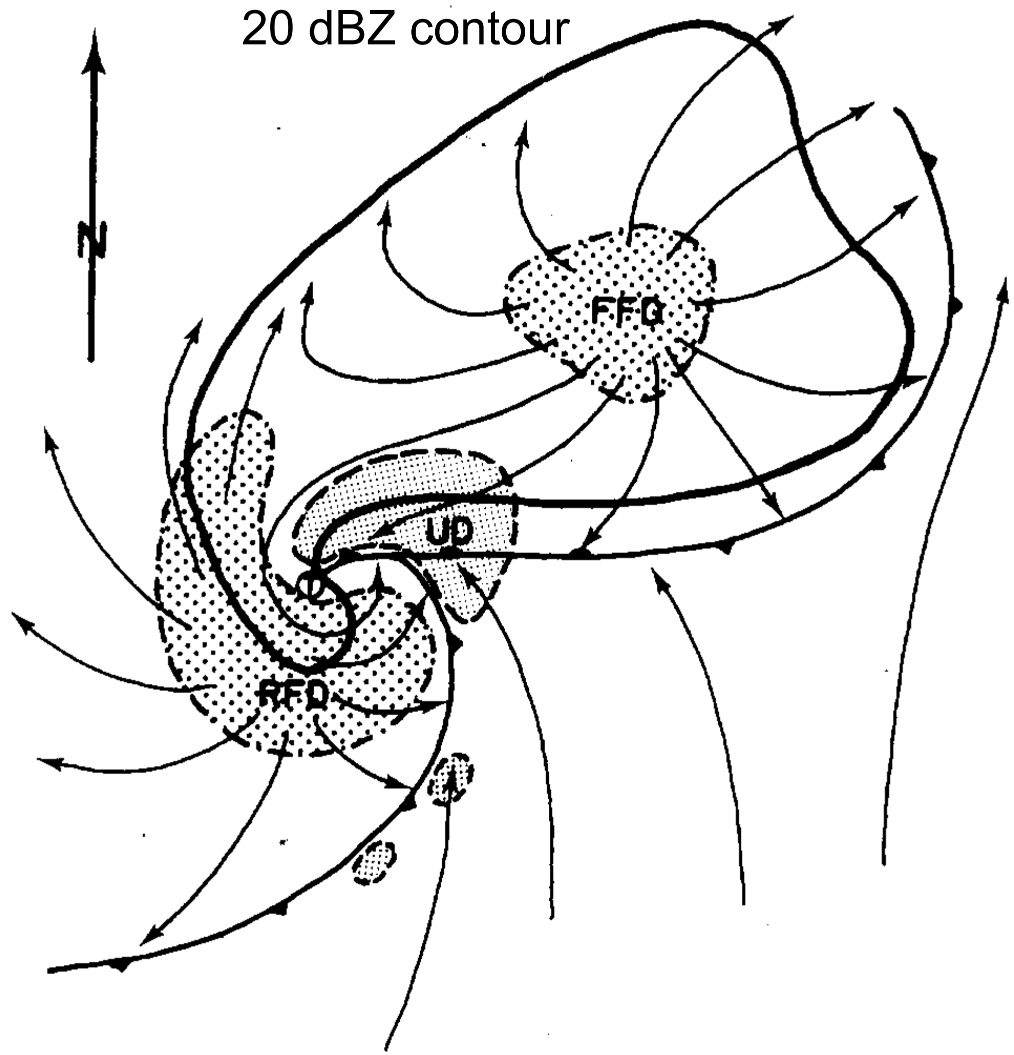
- Upper trough approached a weak tropical storm
- Ambient shear increased, and in-up-out flow strengthened downshear
- As a direct result, helicity rose downshear
- Long-lived cells developed in the same region
- One of these cells appeared to become the location of a center reformation

FINAL REMARKS

We need more observation of intense local cells in hurricanes: are they almost always like VHTs, are they sometimes like supercells, or do they take on other forms? What role do they play in vortex evolution?

To describe these cells and their role, we must have high time resolution, i.e., long residence time over the developing system

The Global Hawk with dropsondes would be a great tool!



Schematic supercell from Lemon and Doswell (1979)