Can the environment of maritime tropical cyclones support supercell thunderstorms?

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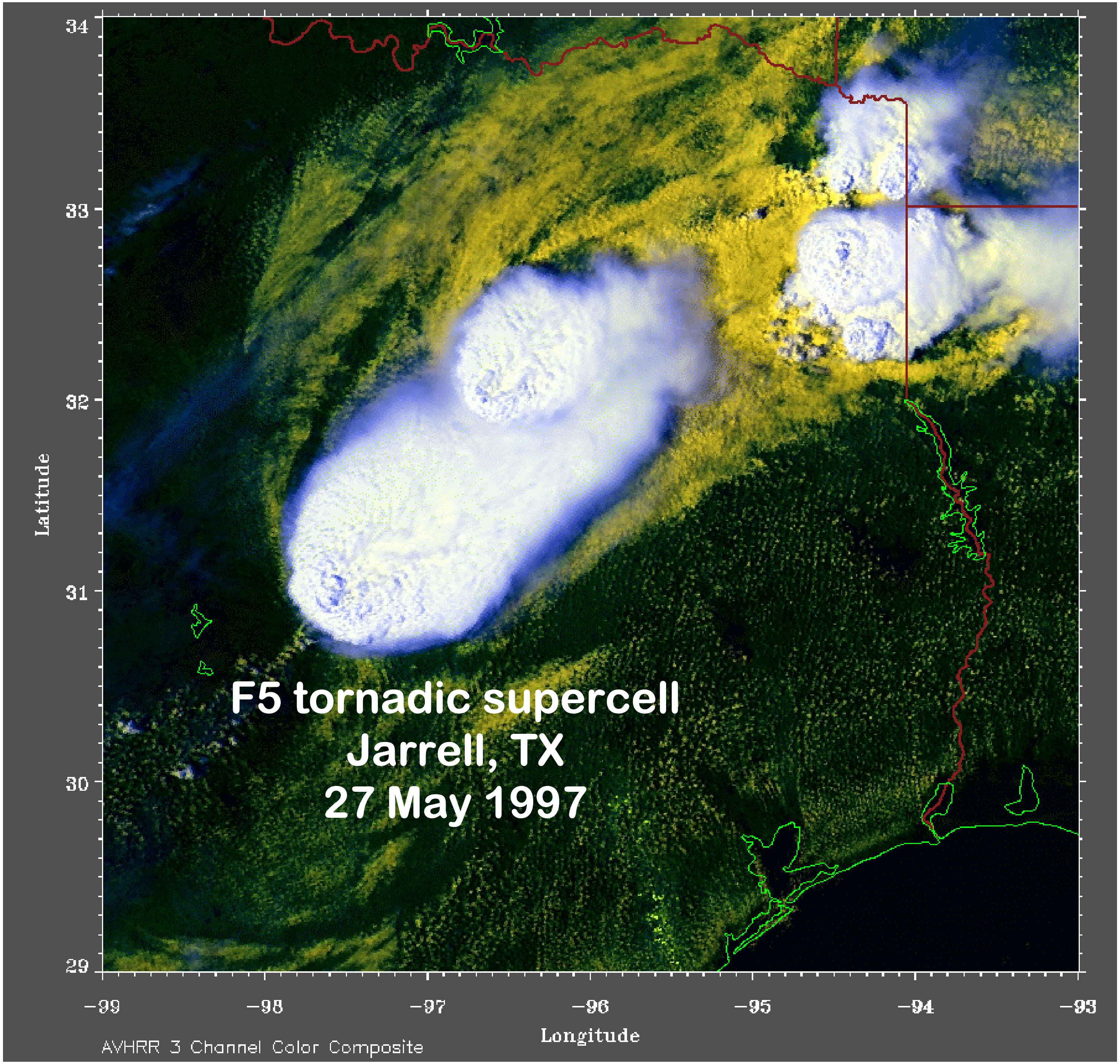
*** Talk was transferred from original transparencies**

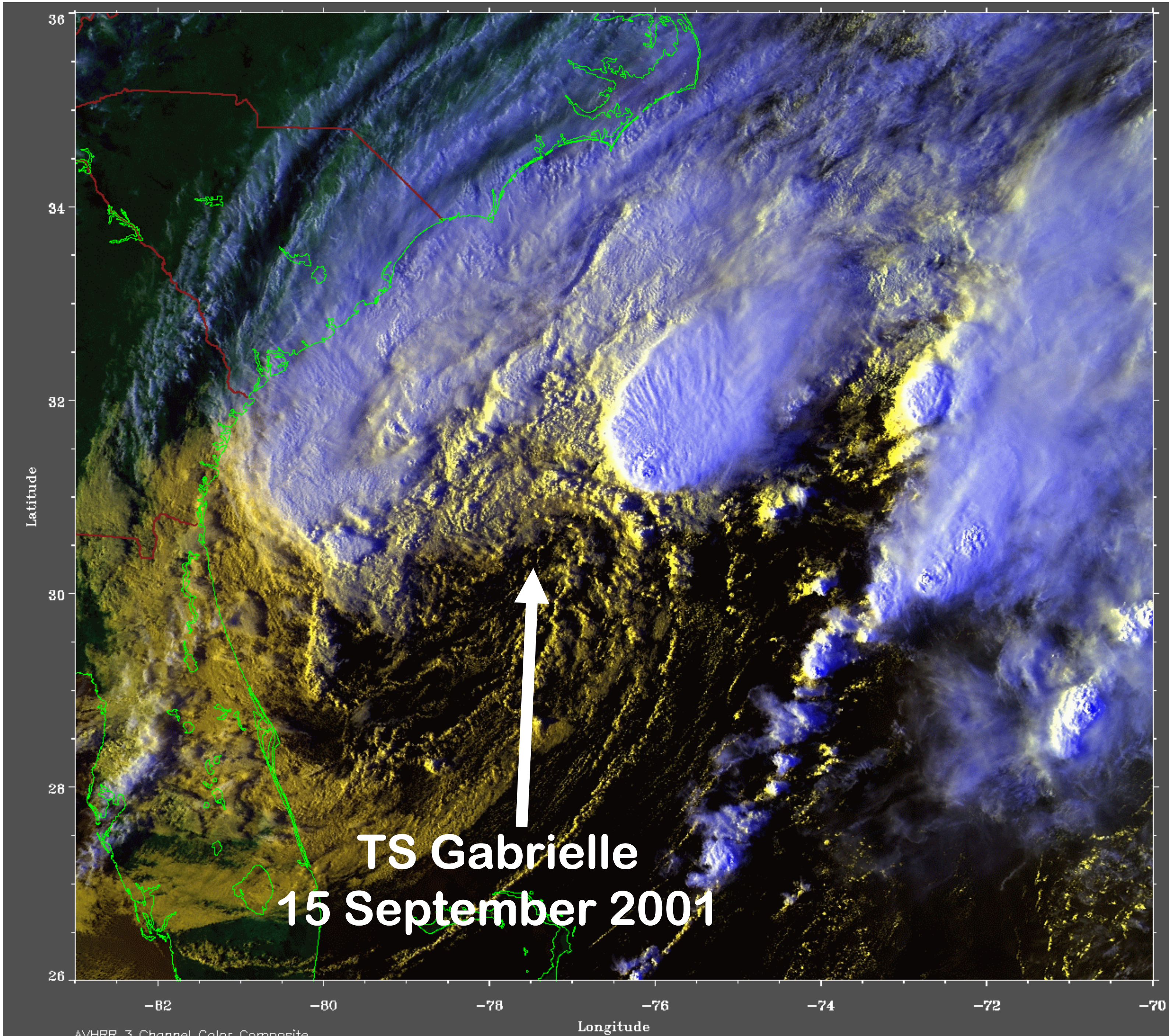
Abstract

Conventional thinking answers this question with a no. In general, the environment of tropical cyclones is thought of as containing copious amounts of moisture, but very little Convective Available Potential Energy (CAPE), and moist, neutral stability. However, careful study of the literature reveals that deep, circular convective exhaust clouds (CECs), similar to the overshooting tops and anvils of supercell thunderstorms, are frequently seen close to the eye of strengthening tropical storms (Gentry et al. 1970, Black et al. 1986). Moreover, Bogner et al. (2000) found that the area within 250 km of the hurricane center was favorable for supercell development, with bulk Richardson numbers (BRNs) in the 10-40 range.

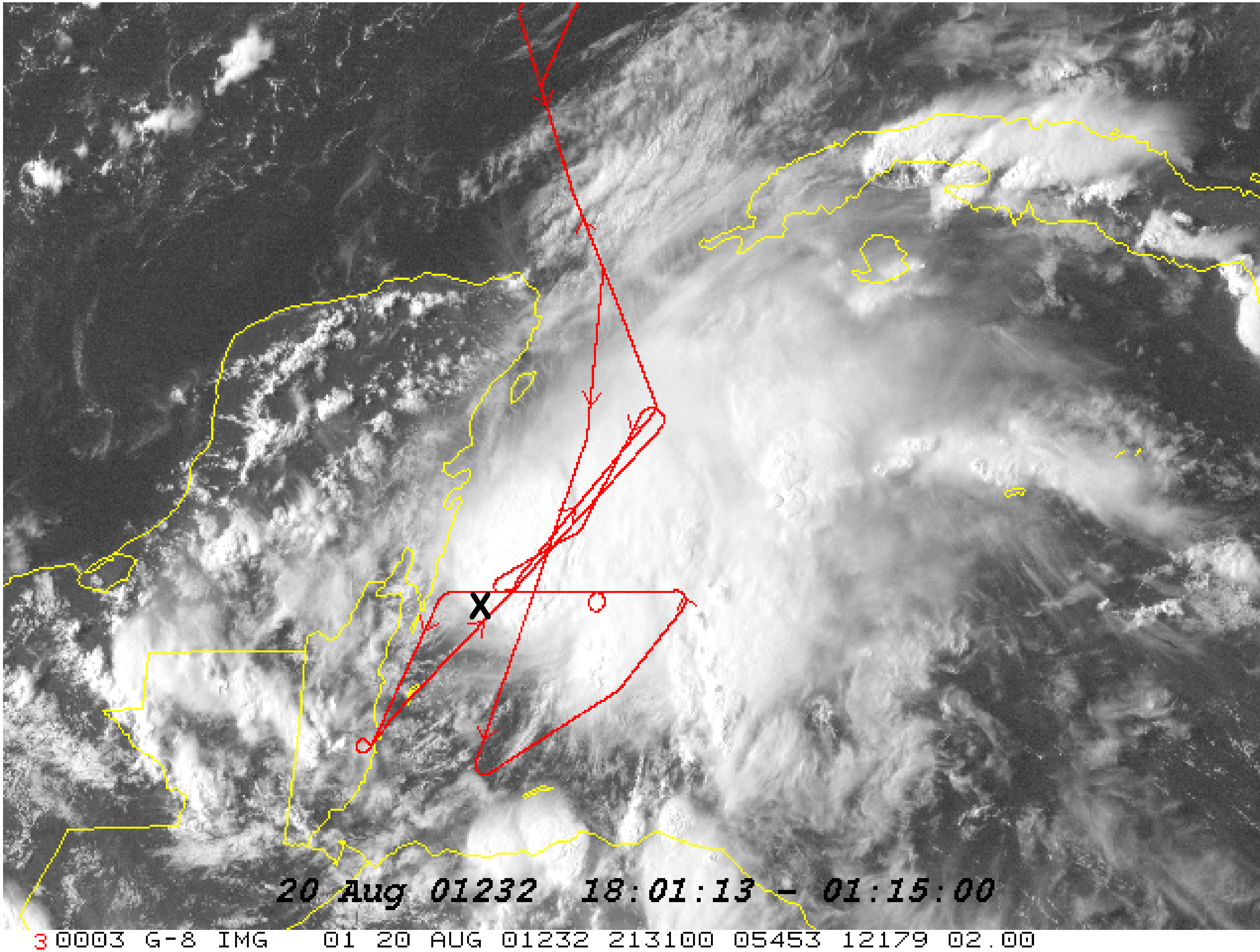
In this presentation, we shall examine the question using CAPE and shear values found in Tropical Storm Chantal (2001). As part of the fourth Convection and Moisture Experiment (CAMEX4), a NASA DC-8 flew into Tropical Storm Chantal on August 20th and deployed seven Omega dropwindsondes. At the time of the drops, Chantal was a strengthening tropical storm located just off the Yucatan Peninsula, with a deep, circular convective cell northeast (downshear) of the center. The center of Chantal was located just inside the southern edge of the main convective cell, on the cloudy side of this highly asymmetric storm.

Preliminary results show that the CAPE and shear values typically found around developing tropical cyclones, such as Chantal, are sufficient to support supercell thunderstorms. However, the BRNs were, in general, too small to support supercells as the directional shear was found to be much larger than the speed shear in the tropical cyclone environment.


F5 tornadic supercell
Jarrell, TX
27 May 1997
34
33
32
31
30
29
Latitude
−99
−98
−97
−96
−95
−94
−93
Longitude
AVHRR 3 Channel Color Composite



TS Gabrielle
15 September 2001
36
34
32
30
28
26
Latitude
-82
-80
-78
-76
-74
-72
-70
Longitude
AVHRR 3 Channel Color Composite



TS Chantal 20 August 2001

Could these be supercell thunderstorms?

- Conventional thinking: NO WAY
  - Moist neutral stability

- Research: YES, IT'S POSSIBLE
  - Gentry, Fujita and Sheets (1970)
    - ~ Circular Exhaust Clouds (CECs)
  - Bogner et al. (2000)
    - ~ Supercells possible within 250 km of the center

- Examine observations from Tropical Storms Chantal and Gabrielle (2001) collected during the NASA Fourth Convection and Moisture Experiment (CAMEX4)

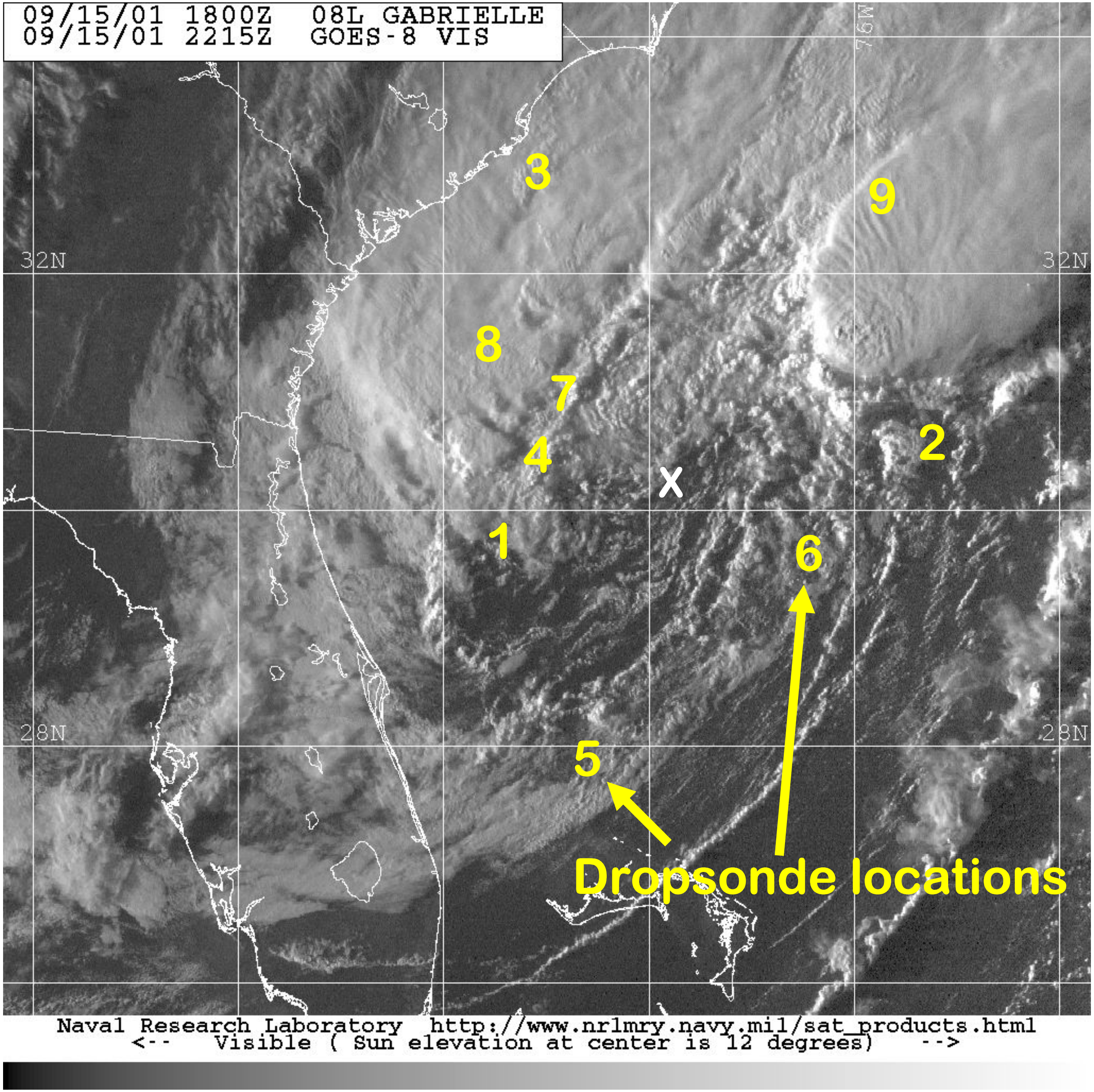
- 16 Omega dropwindsondes dropped from DC8 at 11 km (37,000 ft)

Severe weather parameters

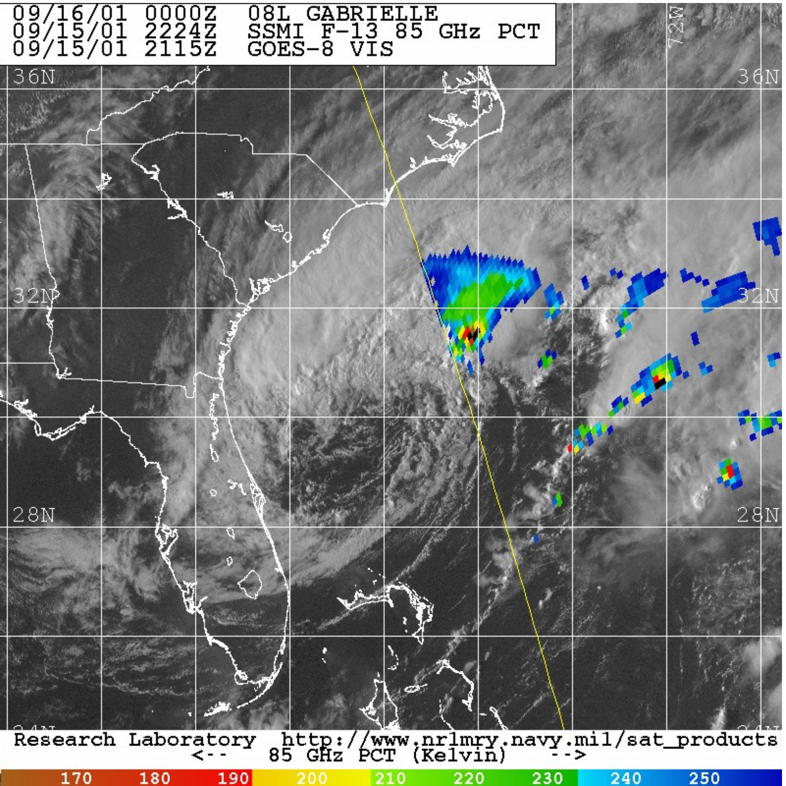
- **CAPE = g $\int$ ((θ(z) - θ(z)) / θ(z)) dz**
  ~ Buoyant energy taken over the vertical interval where the parcel is warmer than its environment

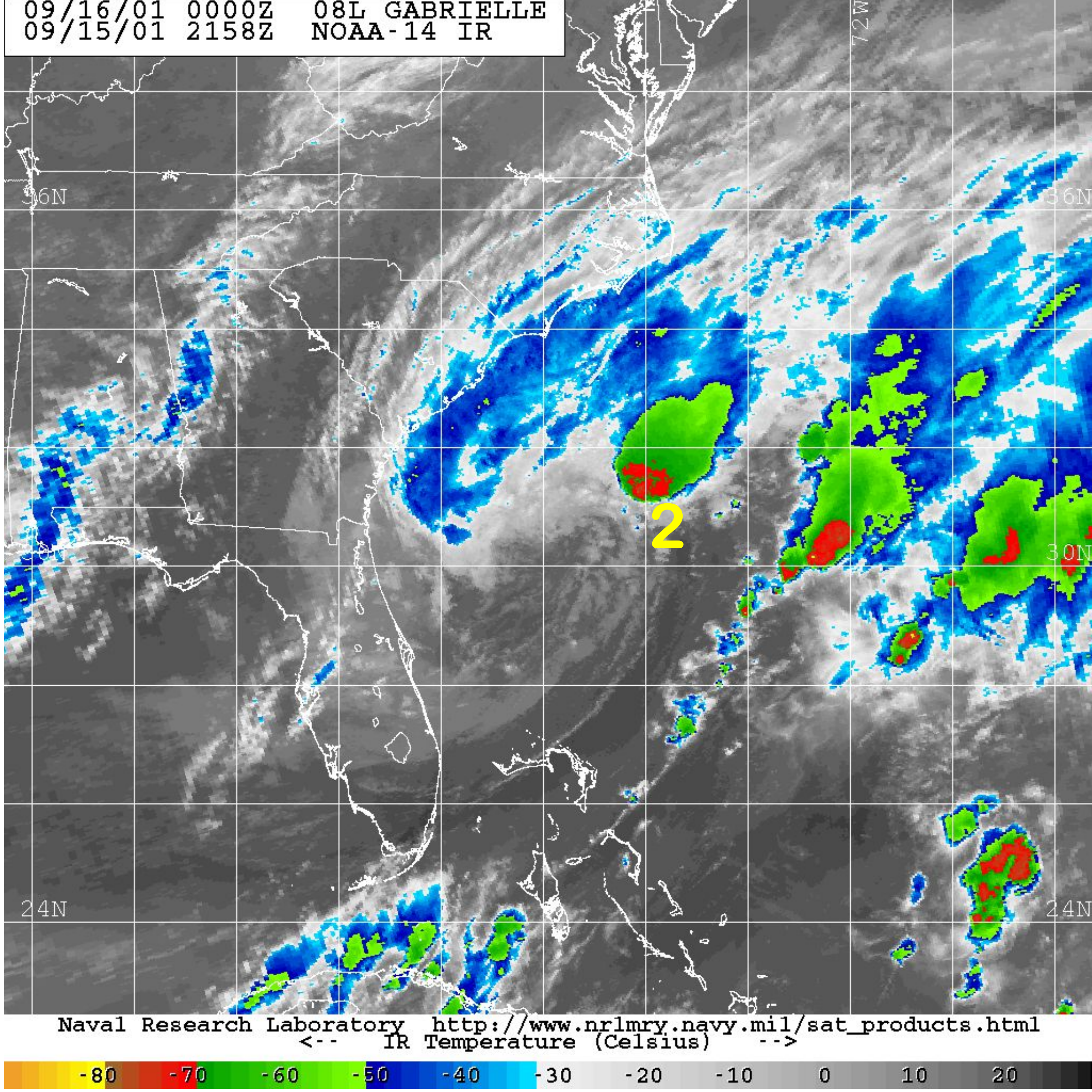
- **BRN = CAPE / (.5 ($V_{10\text{-}6000m}$ – $V_{10\text{-}500m}$)^2)**
  ~ Bulk Richardson Number
  ~ Weisman and Klemp (1982)
  ~10-40 for supercells

- **U_s = length of the hodograph**
  ~ Measure of environmental shear
  ~ > 30 m s^{-1} good for supercells


09/15/01 1800Z 08L GABRIELLE
09/15/01 2215Z GOES-8 VIS
76W
32N
32N
28N
28N
3
9
8
7
4
2
X
1
6
5
Dropsonde locations
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Visible (Sun elevation at center is 12 degrees) -->

Alternate views of the deep convective cell northeast of the center of TS Gabrielle 2001

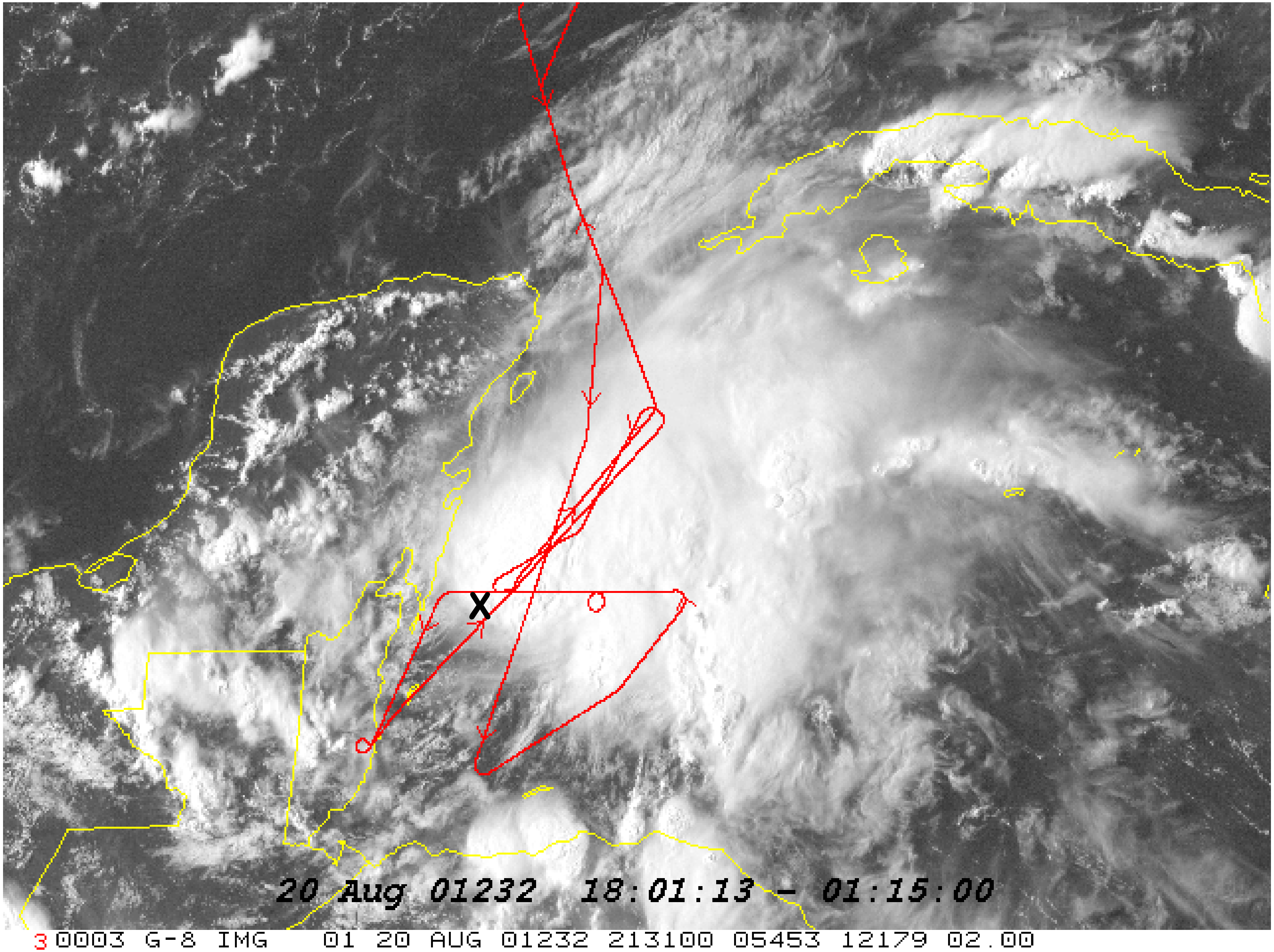




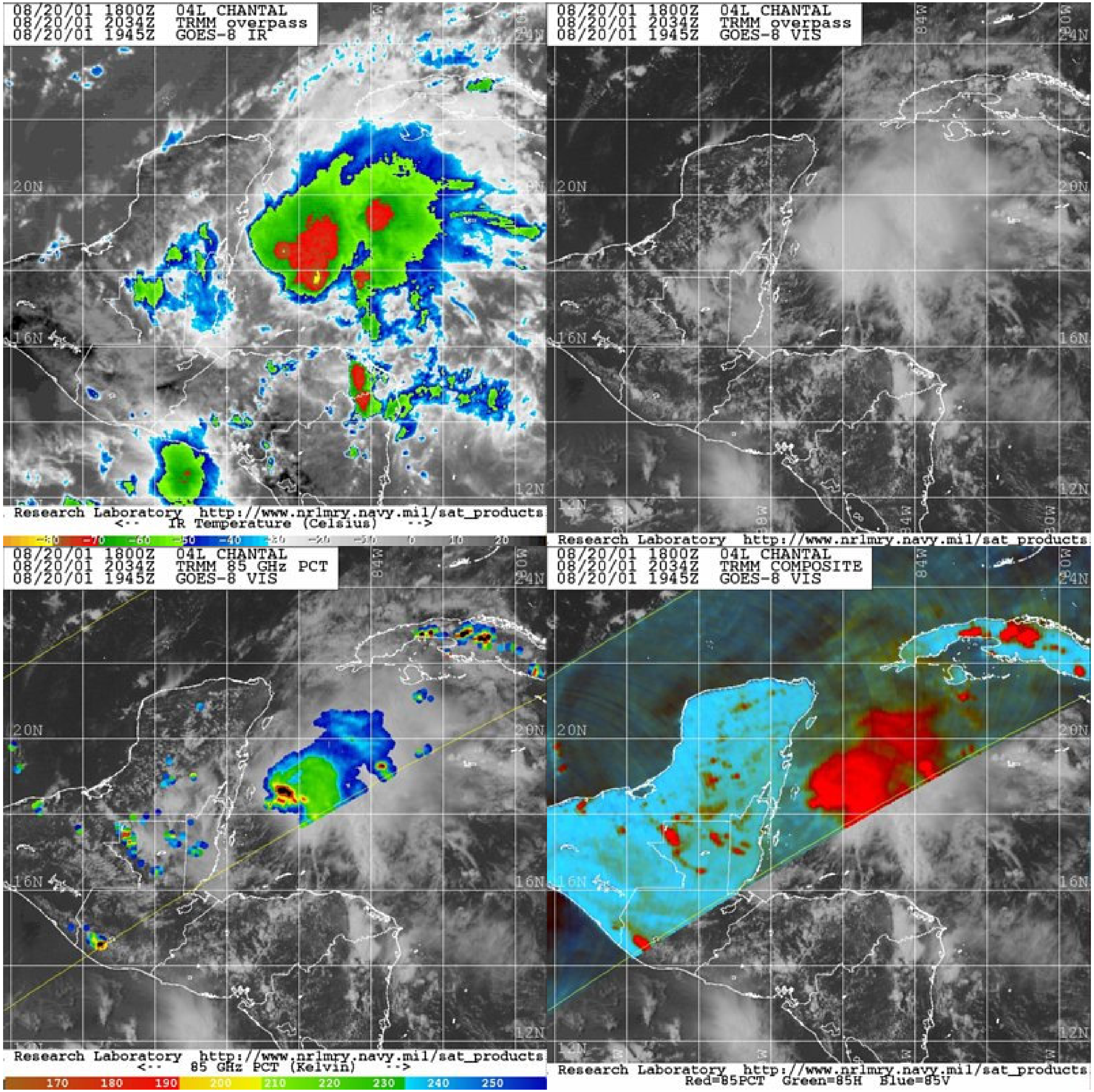
Drop 2 represents the air flowing into the deep convective cell

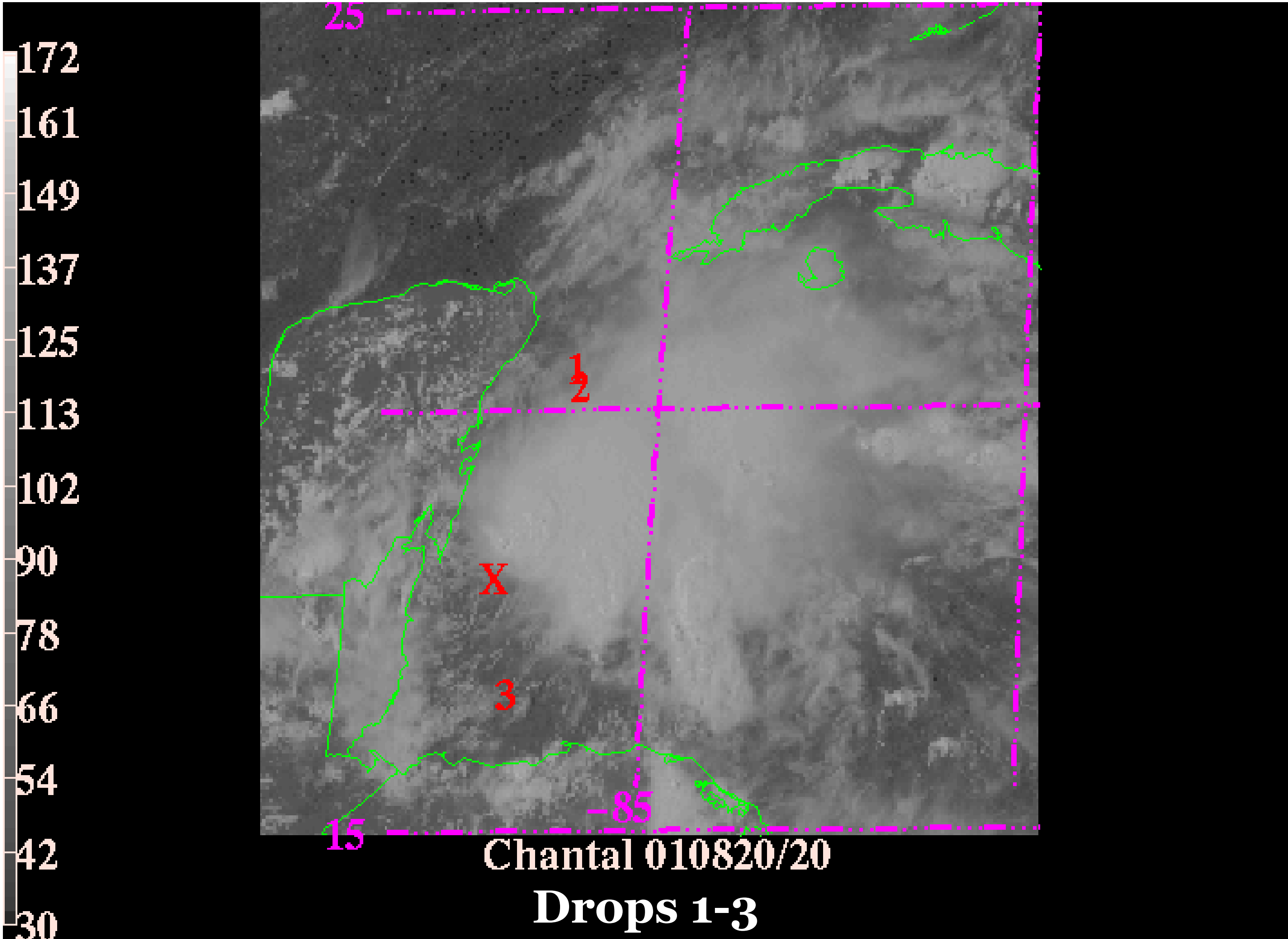
Drop Summary Table for Gabrielle (2001)

Drop #	Distance from the center (km)	LFC (hPa)	Layer of Maximum Buoyancy (hPa)	CAPE (J/kg)	500 hPa U_s (m s^{-1})	BRN
1	36	-	-	0	23.8	-
2	327	960	350-250	**1416**	37.8	**18**
3	332	-	-	0	40.6	-
4	70	965	350-300	729	34.7	62
5	258	960	400-350	**1092**	25.9	93
6	200	930	350-300	725	35.0	-
7	57	970	325-275	619	24.9	**27**
8	174	-	-	0	47.3	**1**
9	357	985	650-600	518	48.3	**8**



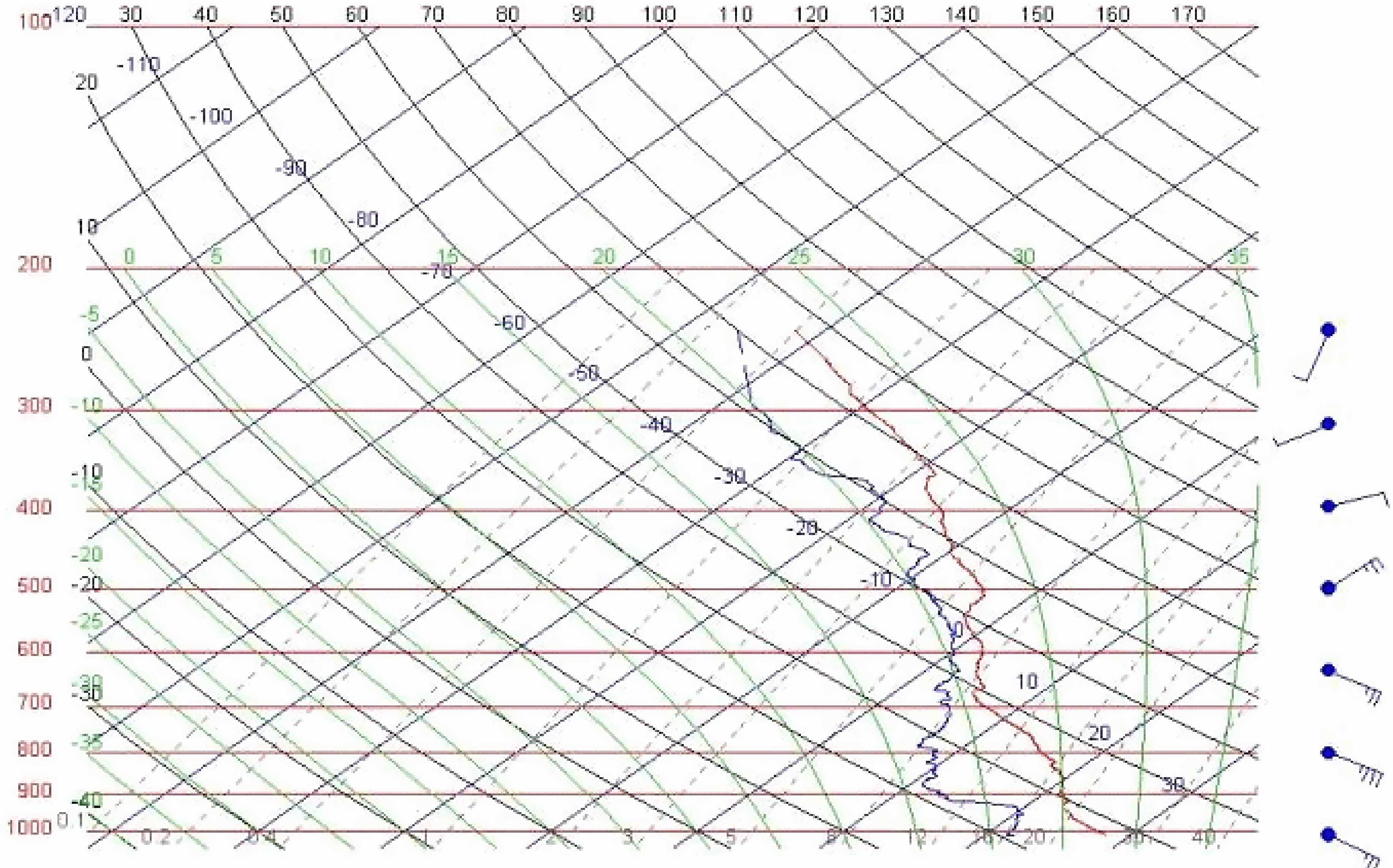
TS Chantal 20 August 2001


08/20/01 1800Z 04L CHANTAL
08/20/01 2034Z TRMM overpass
08/20/01 1945Z GOES-8 IR
20N
16N
12N
Research Laboratory http://www.nrlmry.navy.mil/sat_products
<-- IR Temperature (Celsius) -->
-70 -60 -50 -40 -30 -20 -10 0 10 20
08/20/01 1800Z 04L CHANTAL
08/20/01 2034Z TRMM overpass
08/20/01 1945Z GOES-8 VIS
84W
80W
24N
20N
16N
12N
Research Laboratory http://www.nrlmry.navy.mil/sat_products
08/20/01 1800Z 04L CHANTAL
08/20/01 2034Z TRMM 85 GHz PCT
08/20/01 1945Z GOES-8 VIS
84W
80W
24N
20N
16N
12N
Research Laboratory http://www.nrlmry.navy.mil/sat_products
<-- 85 GHz PCT (Kelvin) -->
170 180 190 200 210 220 230 240 250
08/20/01 1800Z 04L CHANTAL
08/20/01 2034Z TRMM COMPOSITE
08/20/01 1945Z GOES-8 VIS
84W
80W
24N
20N
16N
12N
Research Laboratory http://www.nrlmry.navy.mil/sat_products
Red=85PCT Green=85H Blue=85V


172
161
149
137
125
113
102
90
78
66
54
42
30
25
15
-85
1
2
X
3
Chantal 010820/20

Drops 1-3

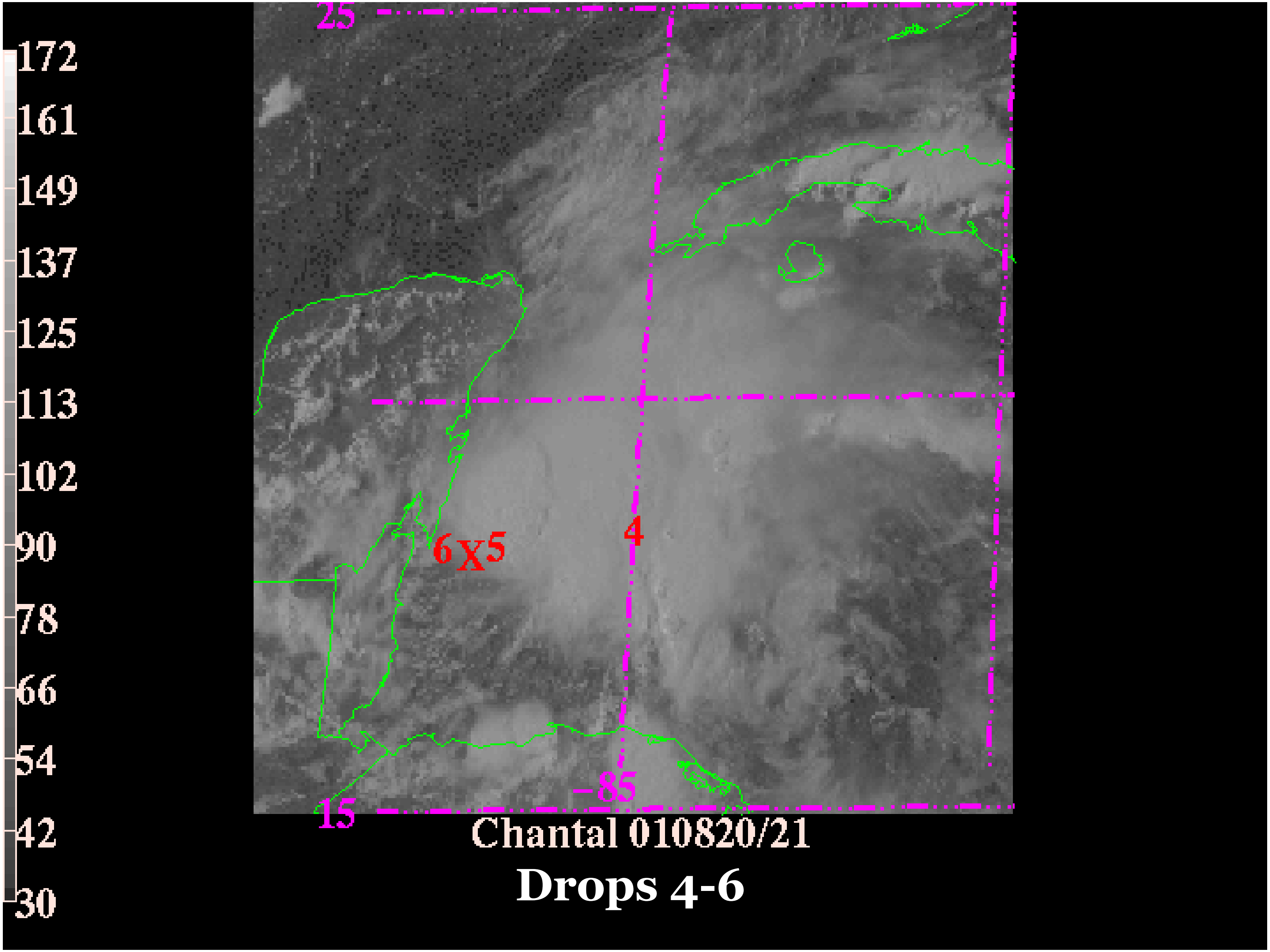
D20010820_195852.1 012615127 drop1 CAMEX 4, 010407 NASA DC-8,

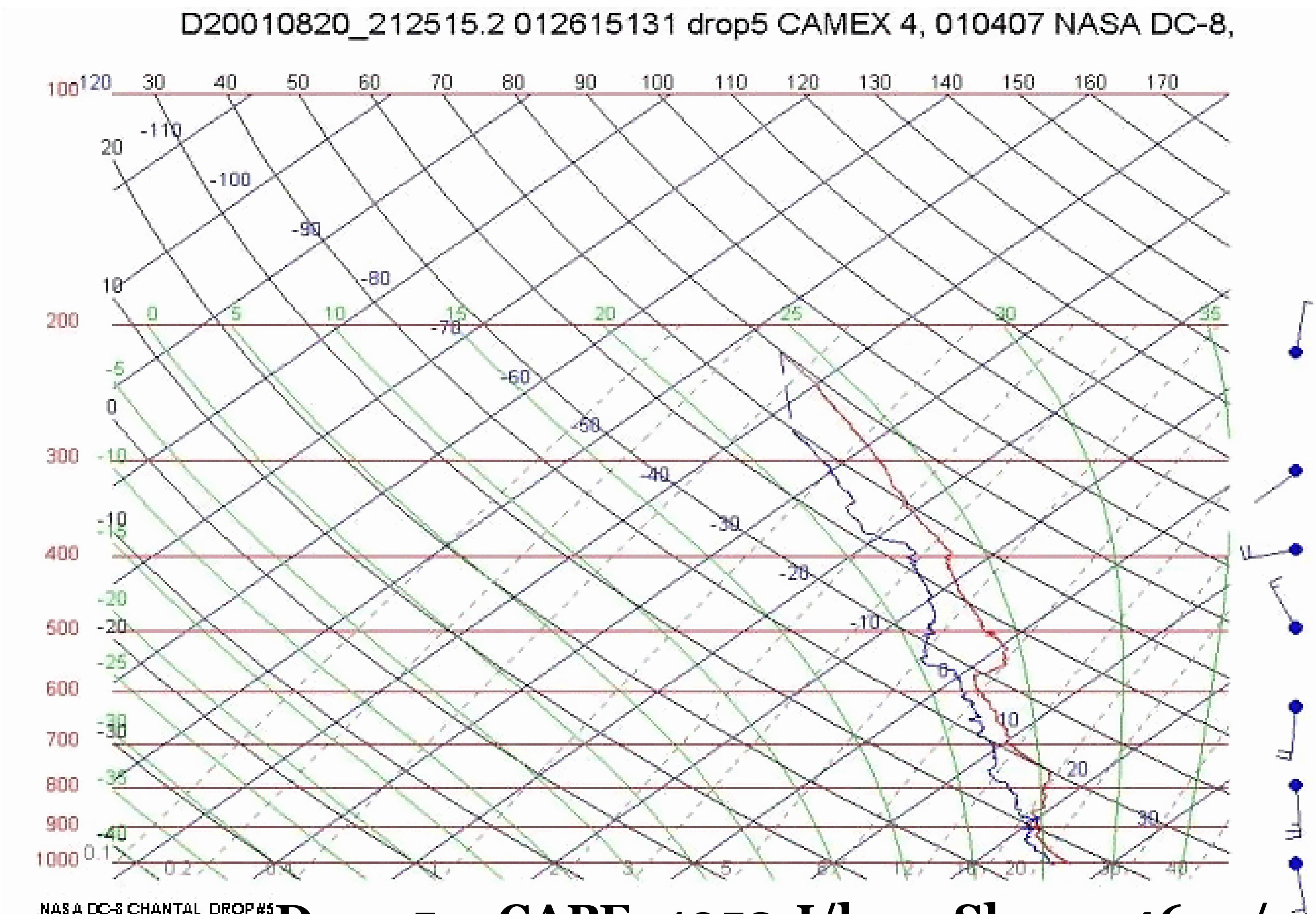


NASA DC-8 CHANTAL DROP#1

Drop 1 CAPE=563 J/kg Shear=48 m/s

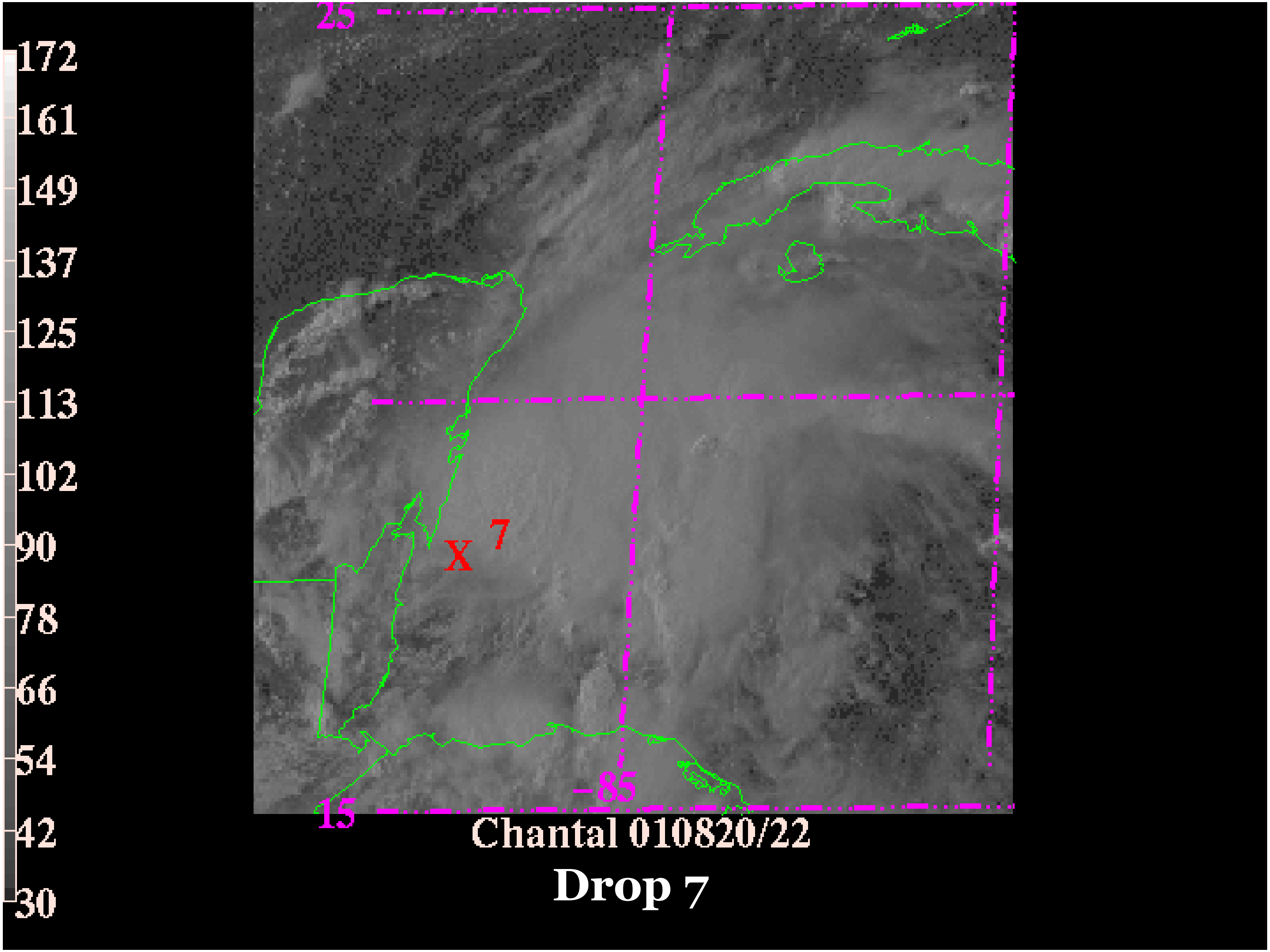
In deep convective outflow

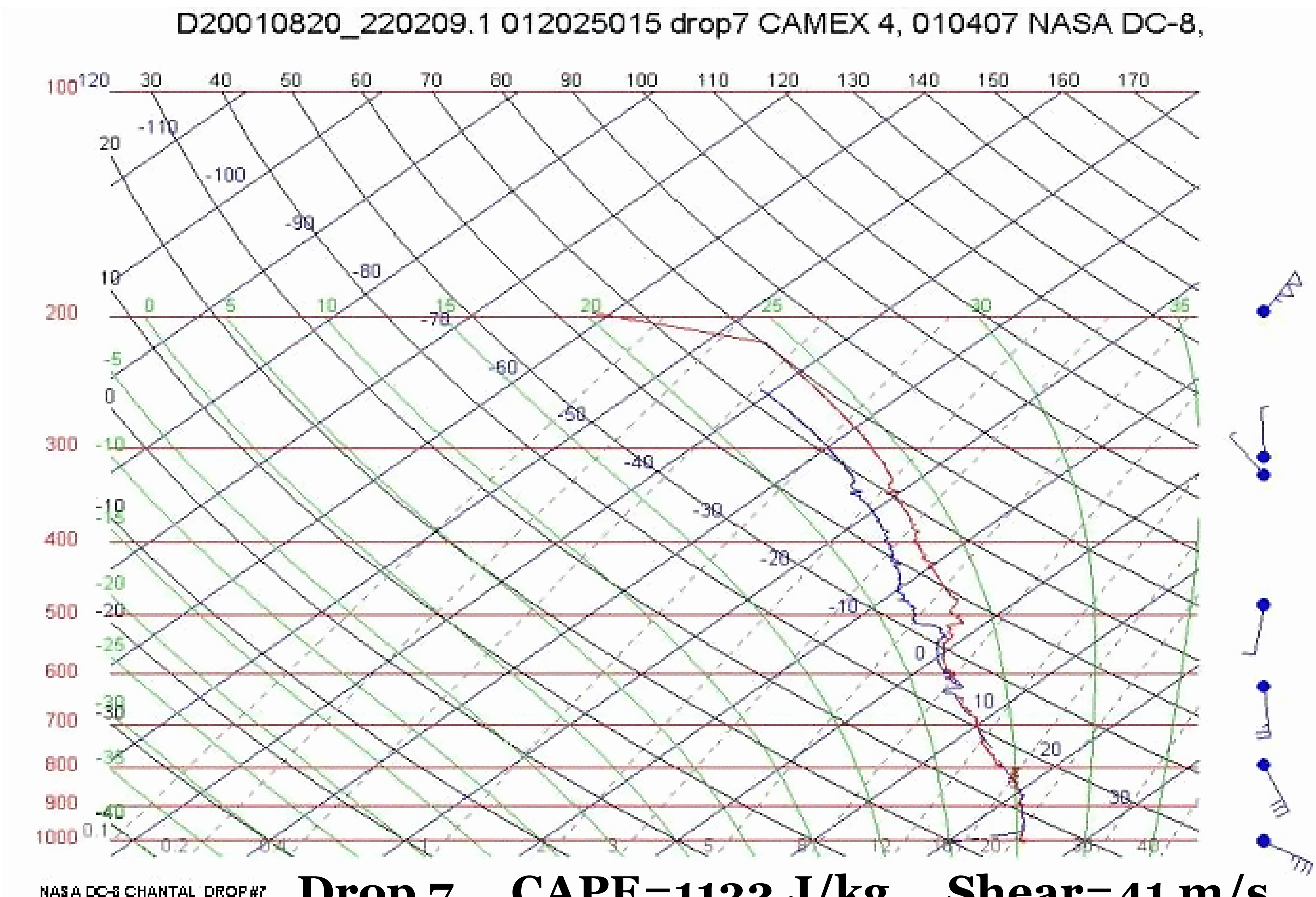

172
161
149
137
125
113
102
90
78
66
54
42
30
25
15
-85
4
6X5
Chantal 010820/21
Drops 4-6



Drop 5 CAPE=1952 J/kg Shear=46 m/s

In heart of deep convection


172
161
149
137
125
113
102
90
78
66
54
42
30
25
15
-85
X
7
Chantal 010820/22
Drop 7



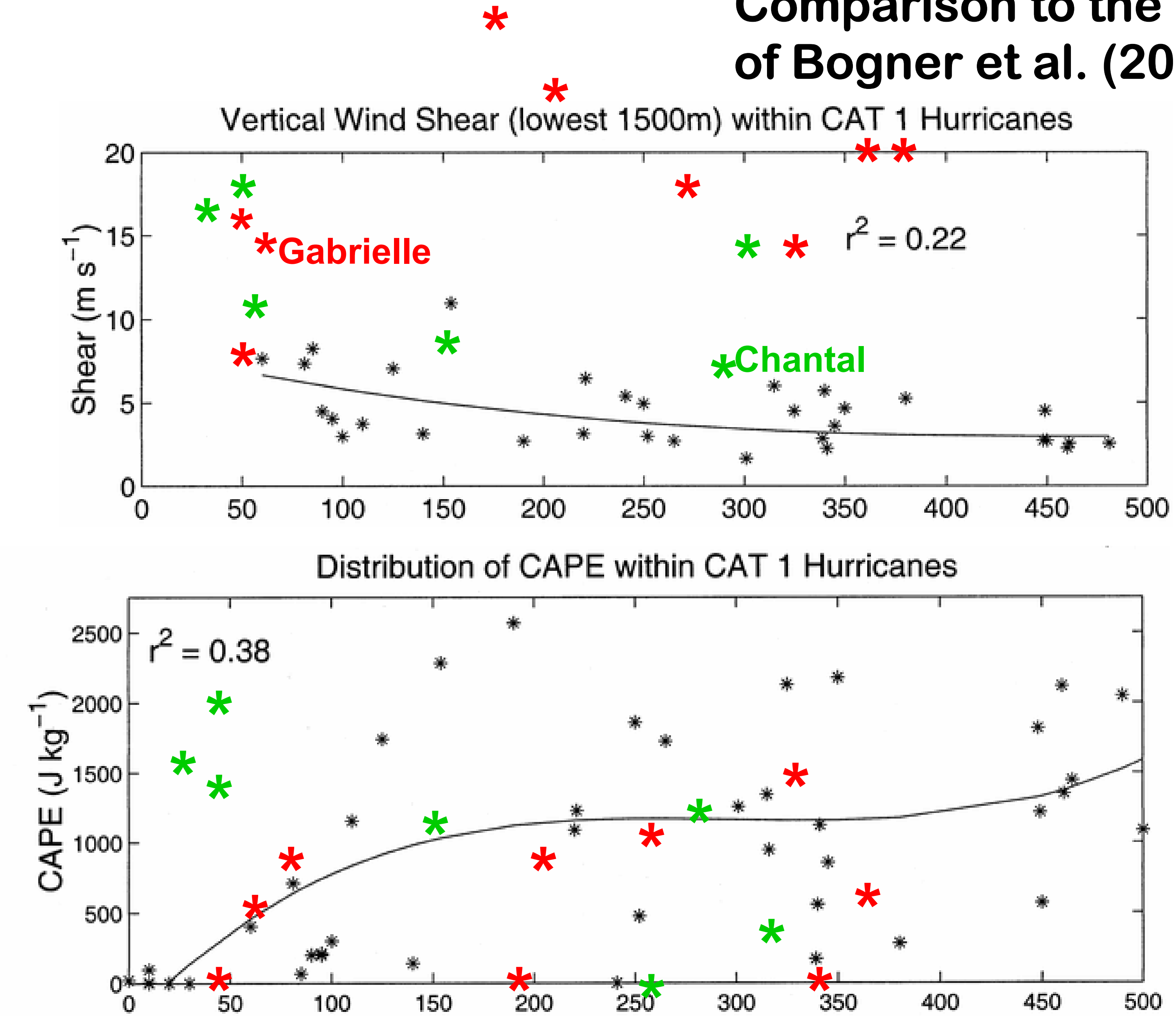
Drop 7 CAPE=1132 J/kg Shear=41 m/s

In deep convection

Drop Summary Table for Chantal (2001)

Drop #	Distance from the center (km)	LFC (hPa)	Layer of Maximum Buoyancy (hPa)	CAPE (J/kg)	500 hPa U_s (m s^{-1})	BRN
1	298	780	700-650	536	48.0	162
2	278	999	450-400	**1056+**	-	-
3	156	945	500-400	**1201**	21.7	95
4	251	-	-	0	48.3	-
5	48	987	325-275	**1952**	46.2	860
6	34	990	350-250	**1458**	31.5	**42**
7	47	963	350-300	**1132**	41.0	85

Comparison to the results of Bogner et al. (2001)



Summary & Conclusions

- CAPE and shear values are high enough to support supercells in the environment of tropical storms
- The standard BRN may not be appropriate for the tropical atmosphere
- Whether these and other CECs are supercells requires more detailed wind and circulation analyses
- Speculation that these CECs (or vortical hot towers ala M. Montgomery) are a crucial step in the tropical storm to hurricane transition in sheared storms