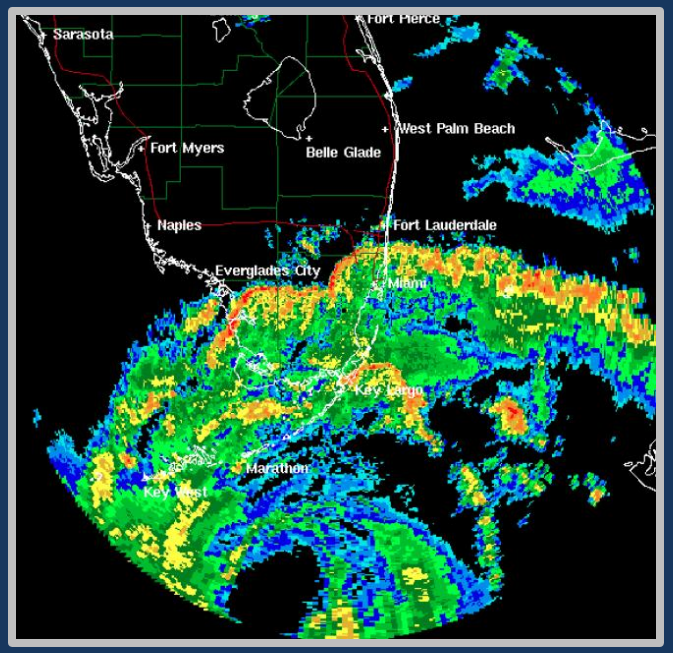
RAINEX:

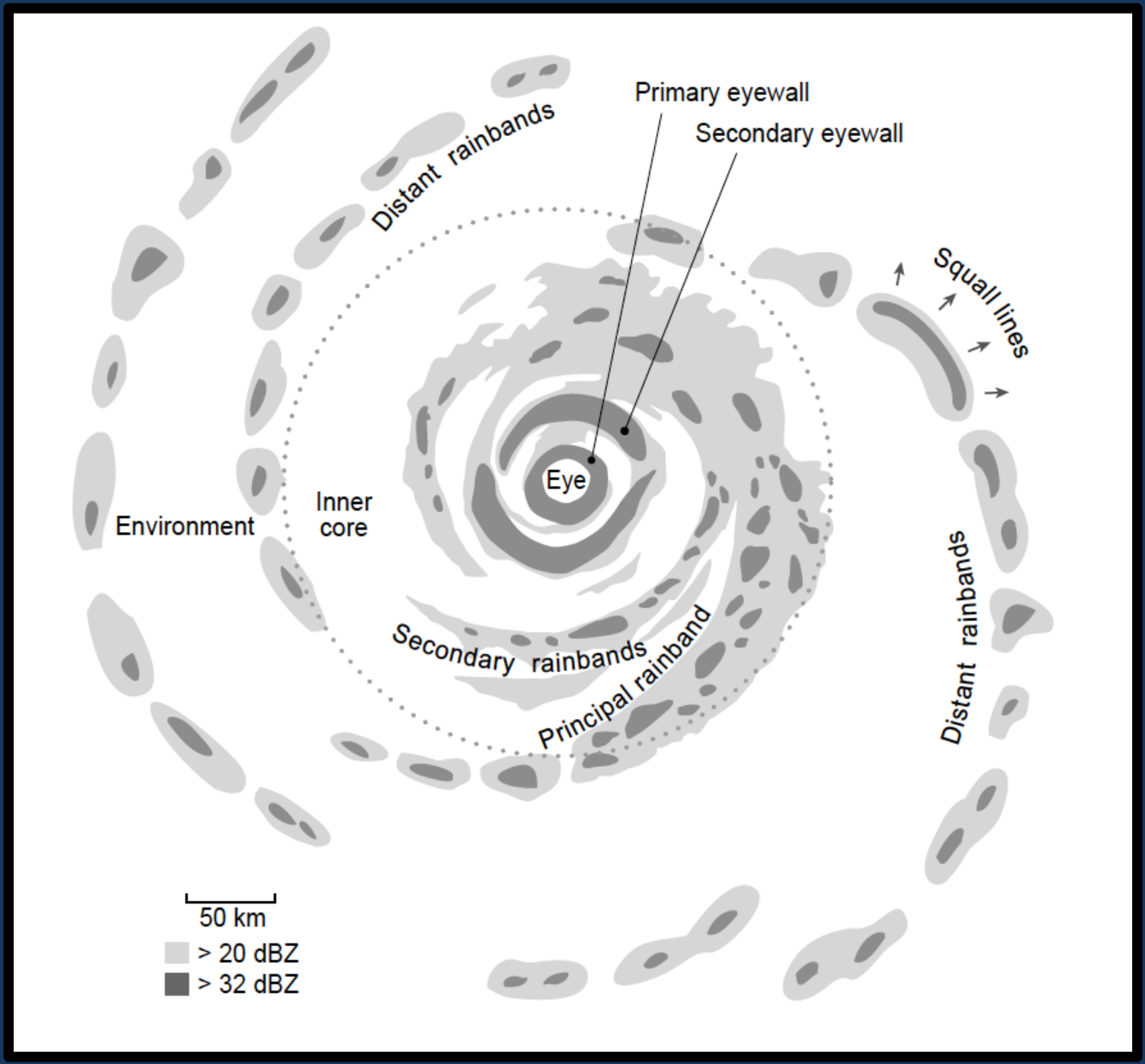
Convective Structures in Tropical Cyclones



Robert Houze
D. Hence, A. Didlake, B. Smull, W.-C. Lee, M. Bell

Hurricane Workshop NCAR Boulder 23 February 2010

Idealized hurricane structure

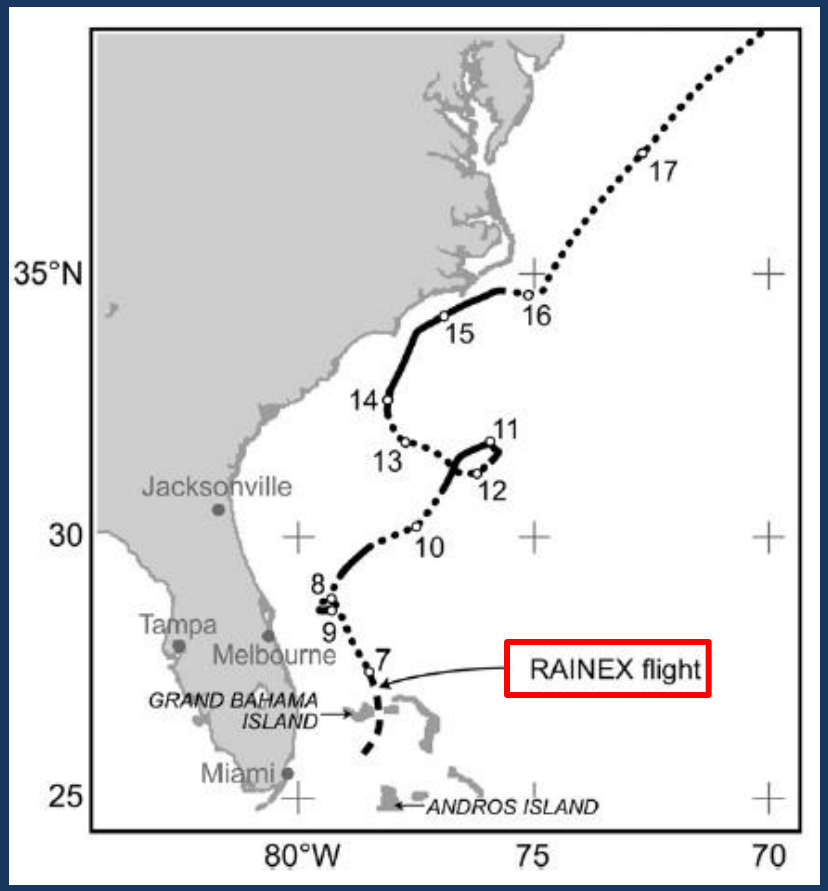


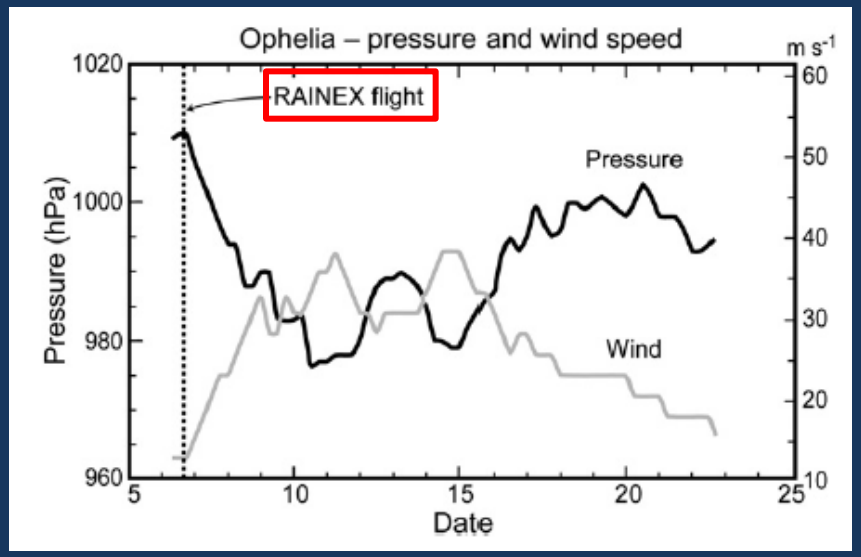
RAINEX (2005) Results

Ophelia—genesis case
Katrina—principal rainband
Rita—double eyewall and moat

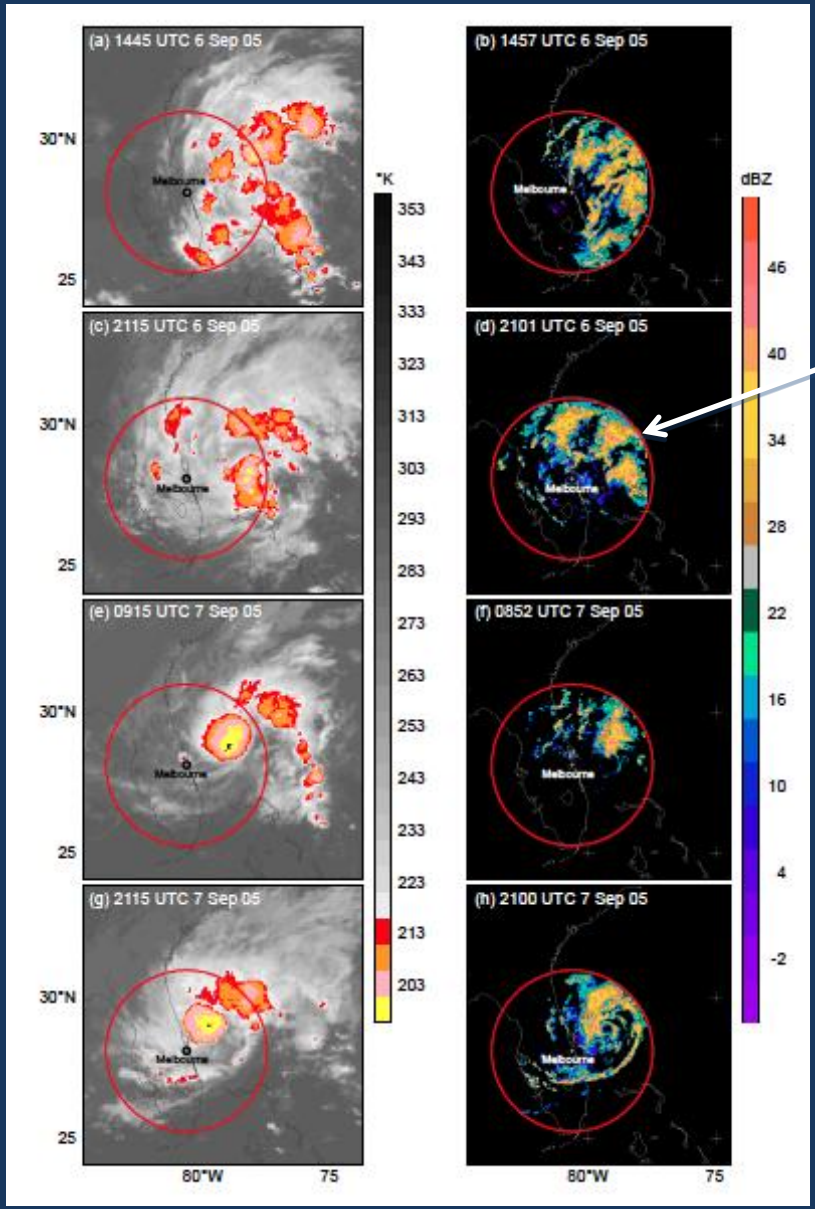
Ophelia

Ophelia


35°N
30
25
80°W
75
70
Jacksonville
Tampa
Melbourne
Miami
GRAND BAHAMA ISLAND
ANDROS ISLAND
RAINEX flight
7
8
9
10
11
12
13
14
15
16
17

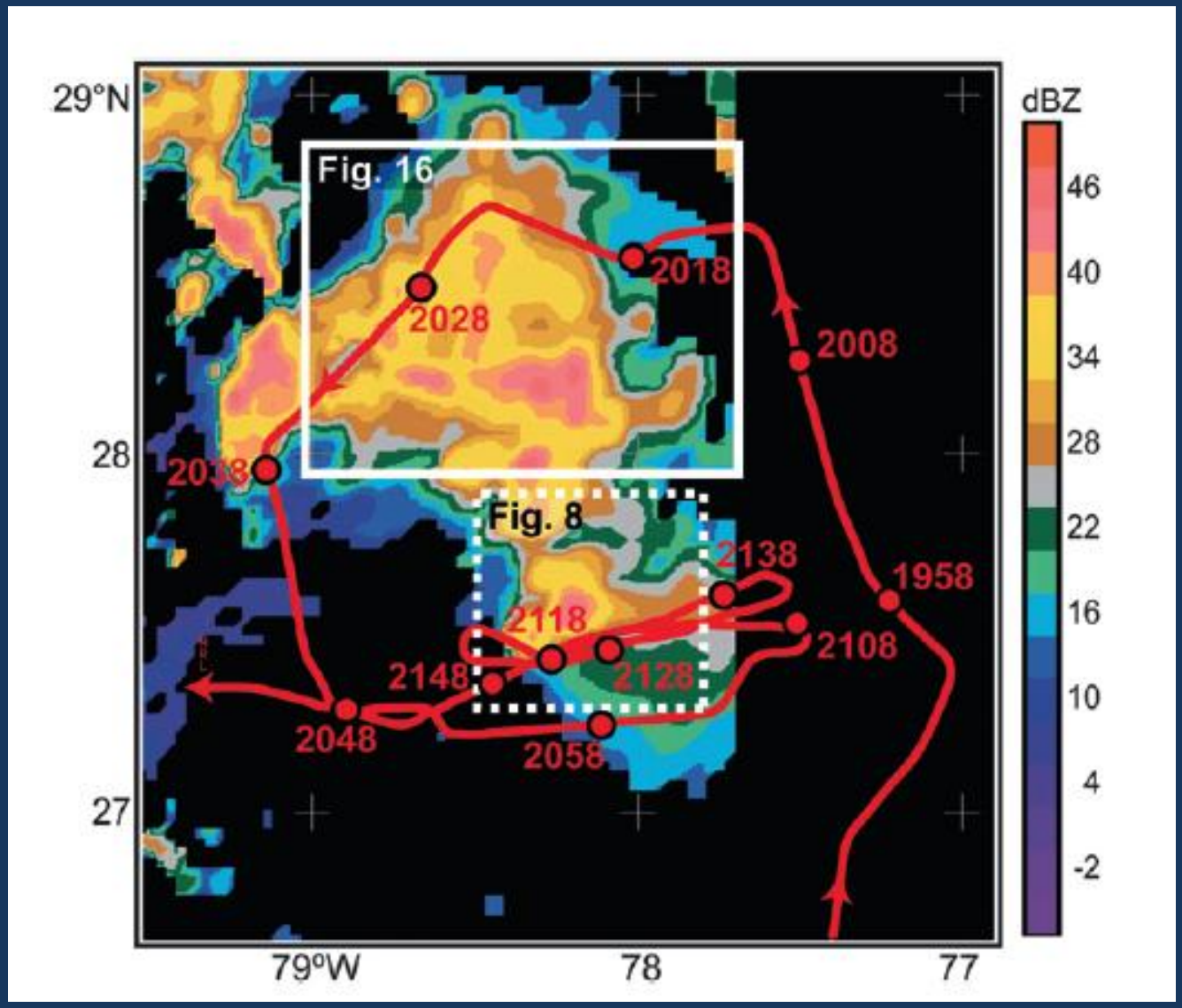

Ophelia – pressure and wind speed
RAINEX flight
Pressure
Wind
Pressure (hPa)
1020
1000
980
960
m s-1
60
50
40
30
20
10
5
10
15
20
25
Date

Convection During Ophelia Genesis

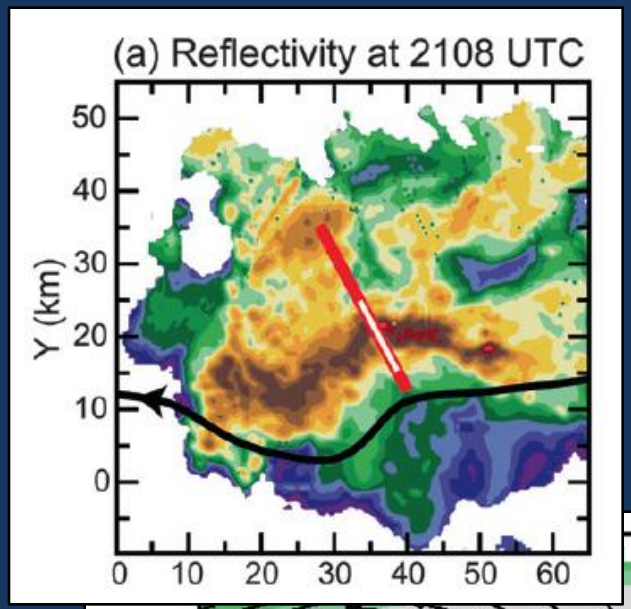


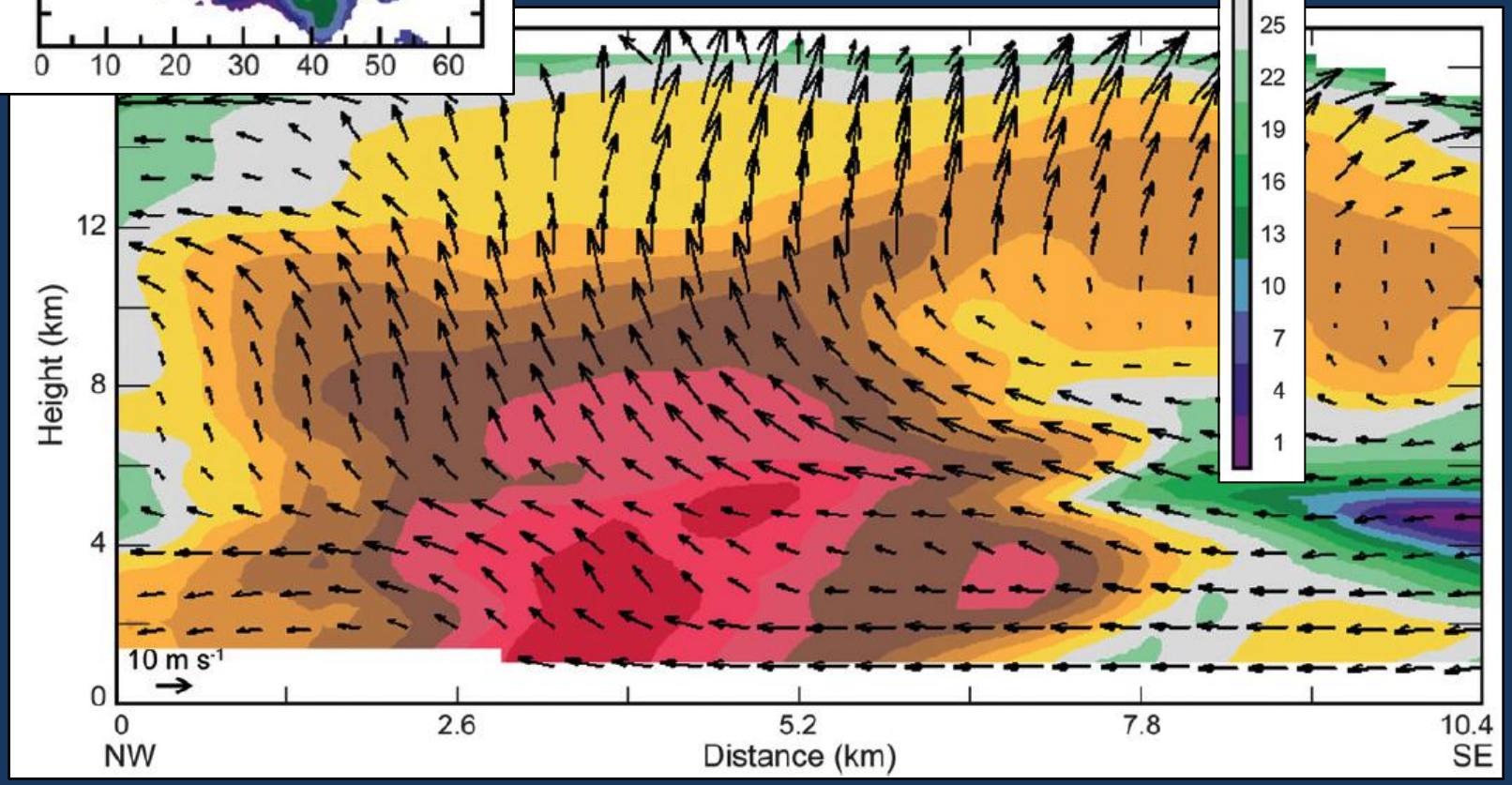
ELDORA flight

Flight track with ELDORA

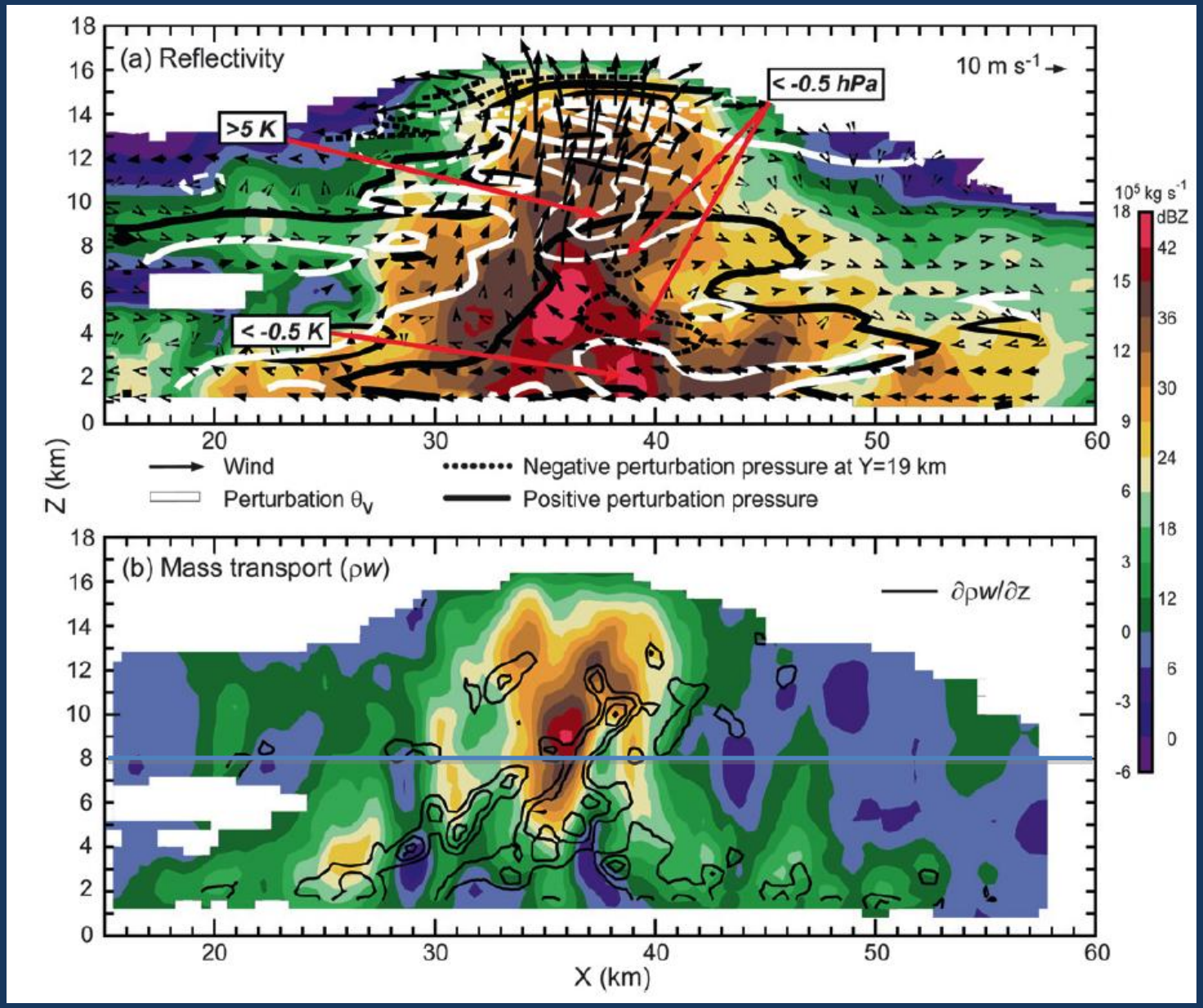


Convective Cell Shown by ELDORA

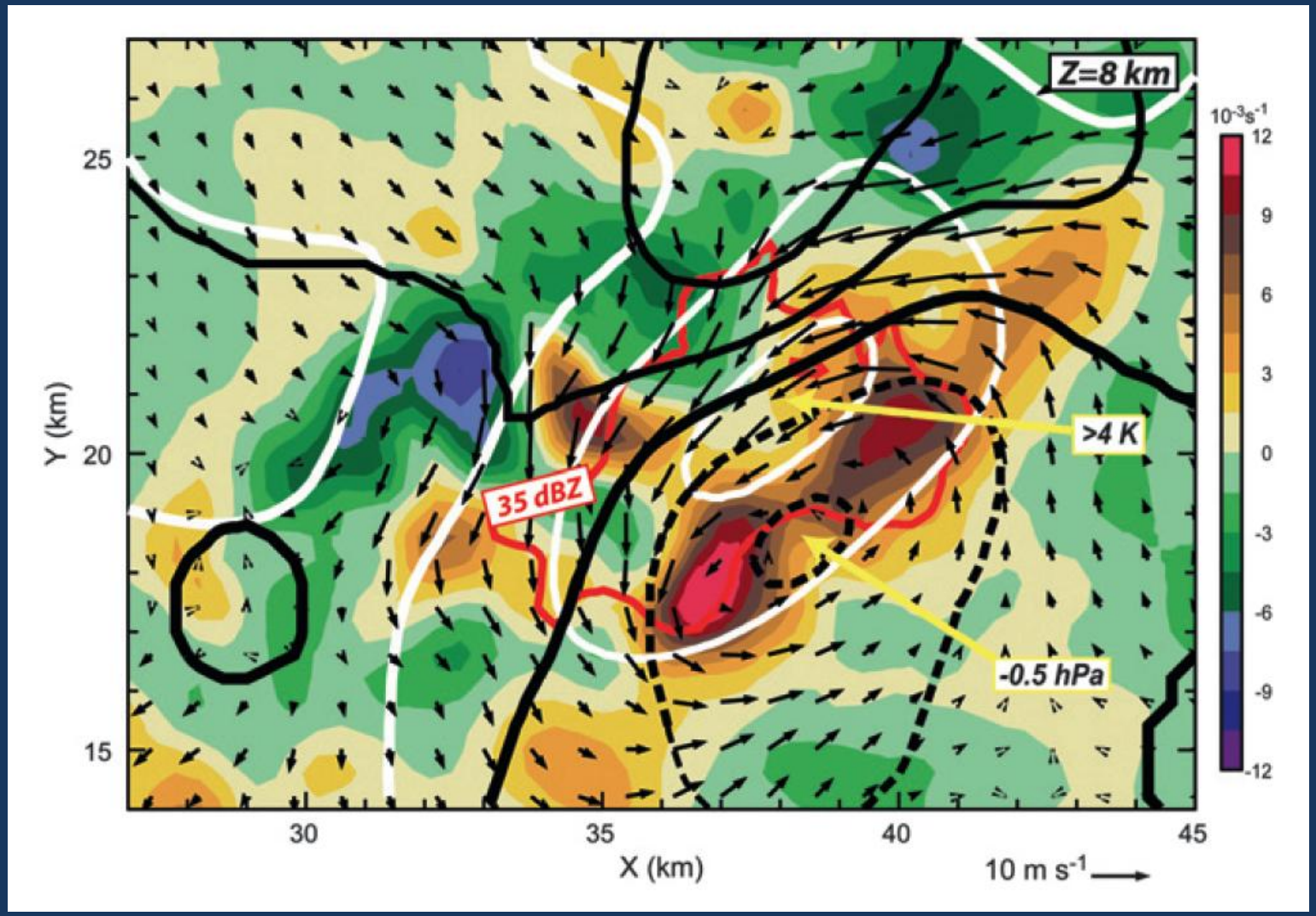




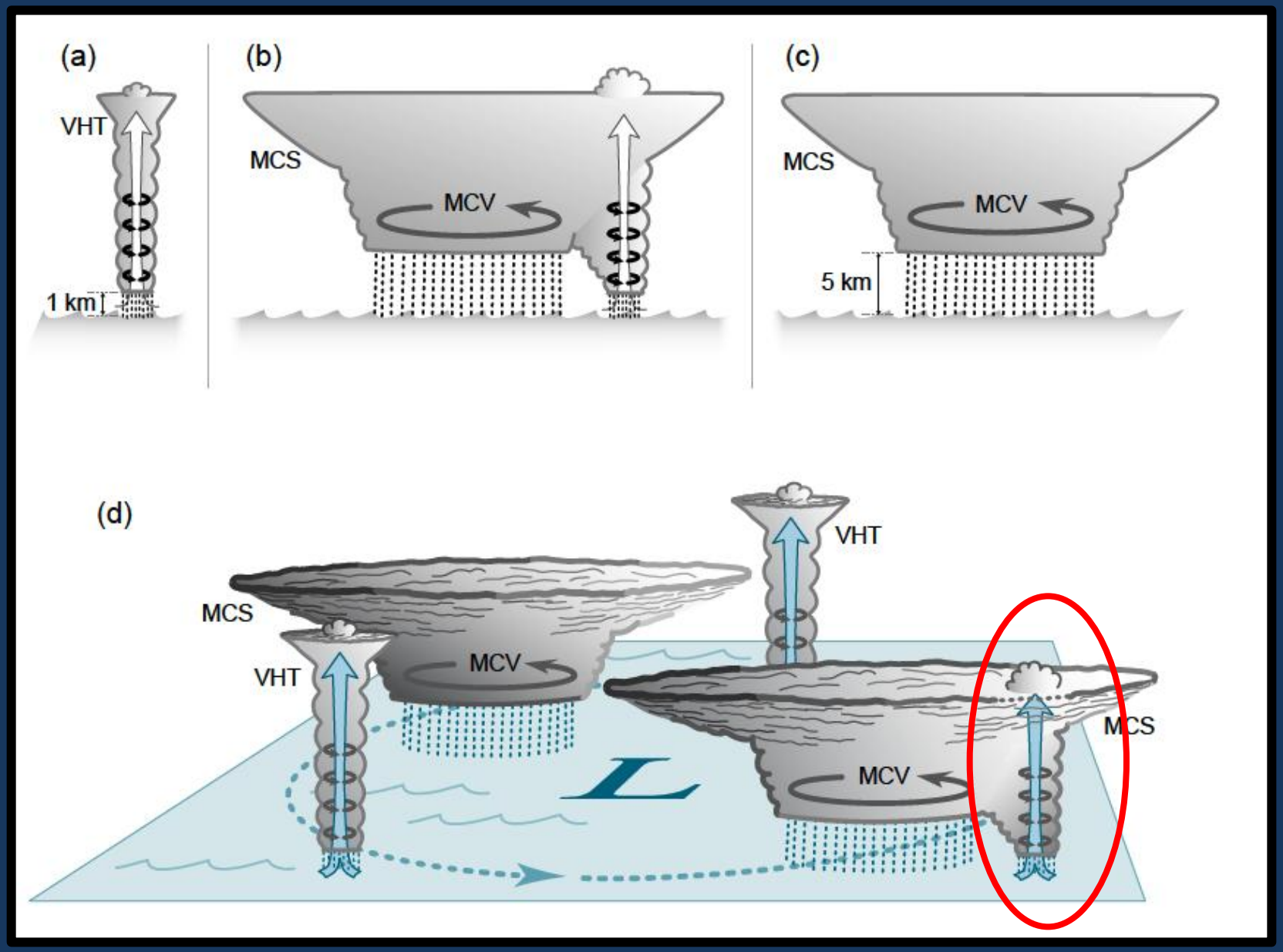
Convective Cell Shown by ELDORA



Convective Cell Shown by ELDORA

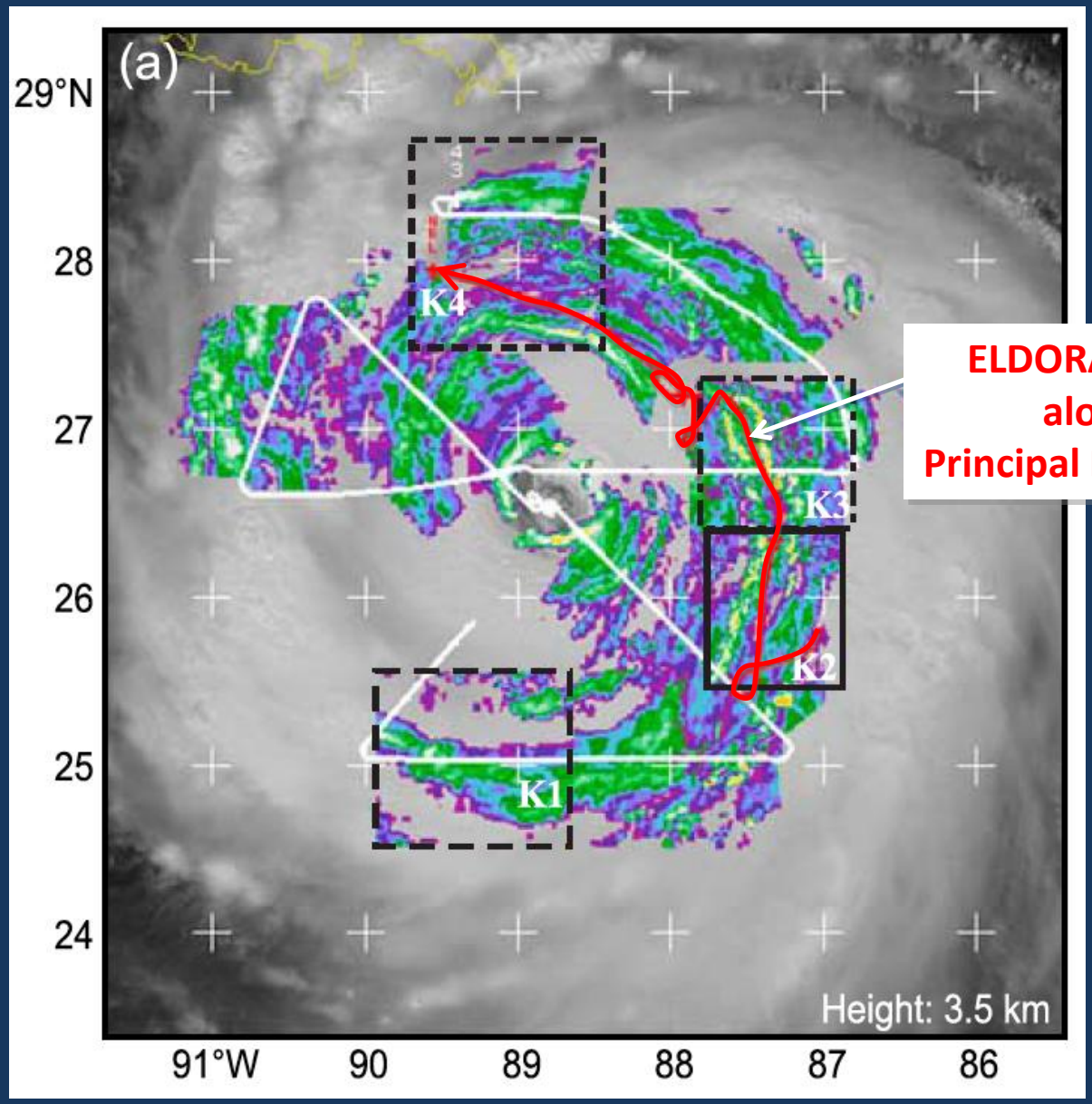


Convective contributions to genesis

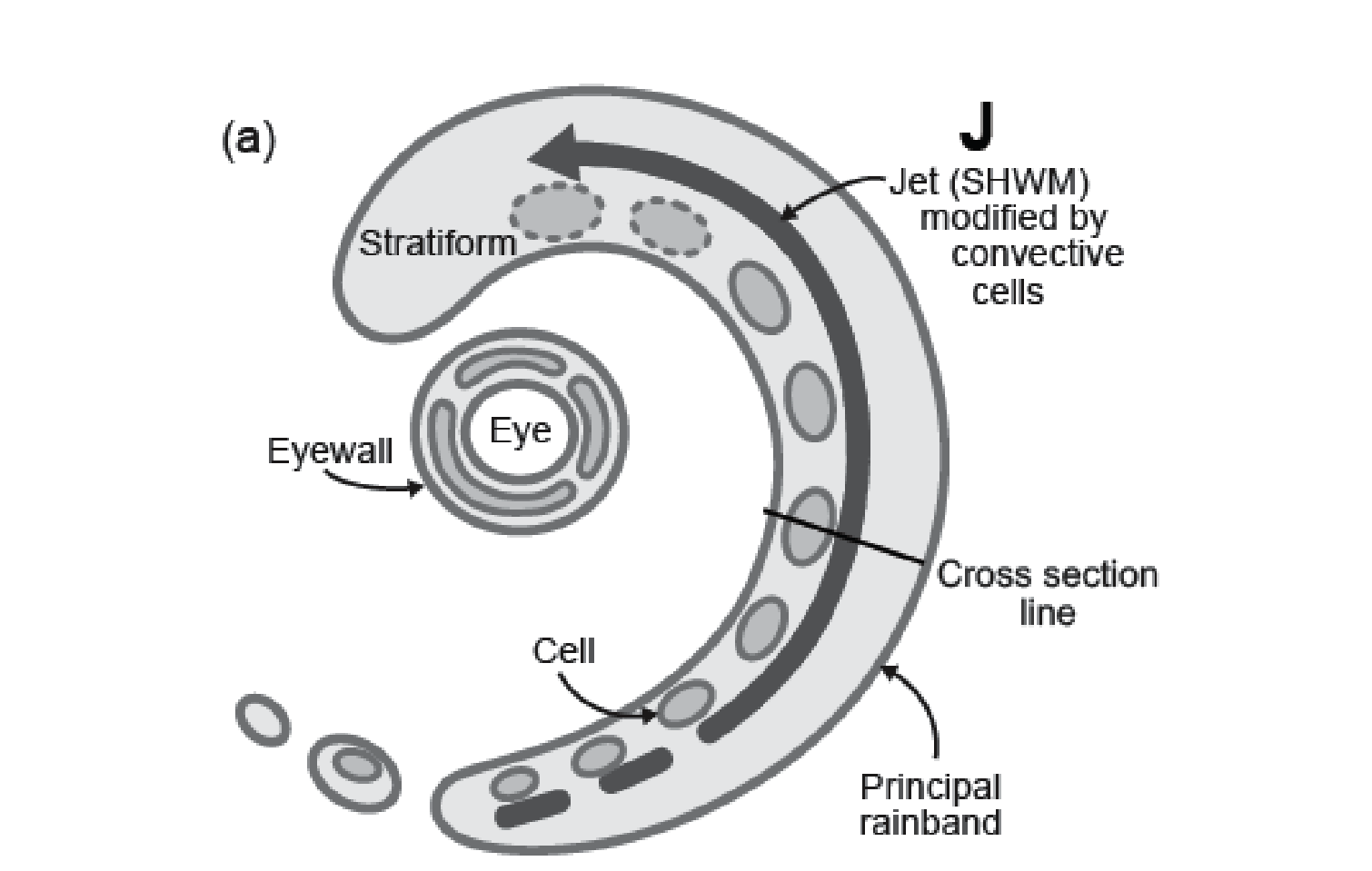


Katrina

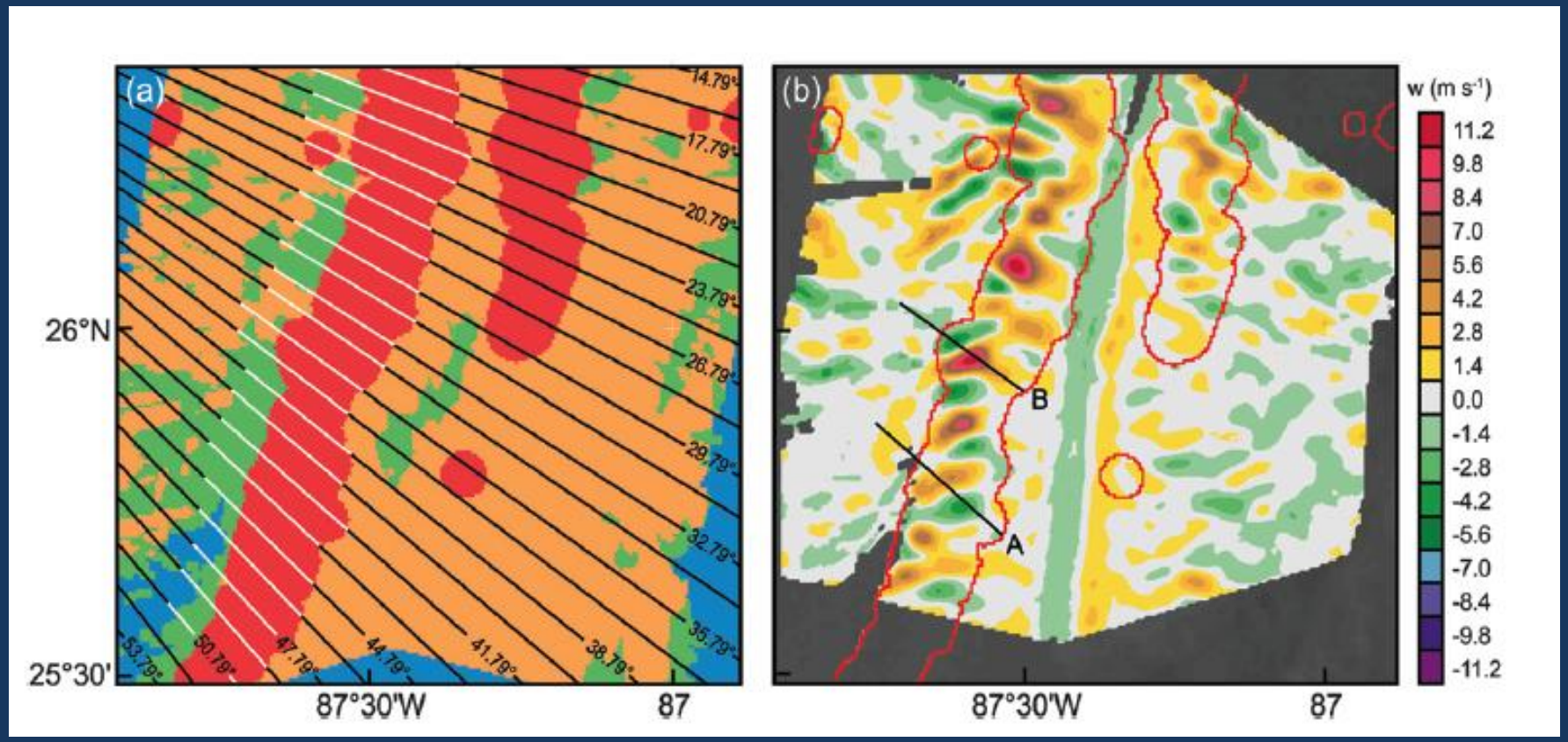
Katrina


(a)
29°N
28
27
26
25
24
91°W
90
89
88
87
86
K4
K3
K2
K1
Height: 3.5 km
ELDORA flight along Principal Rainband

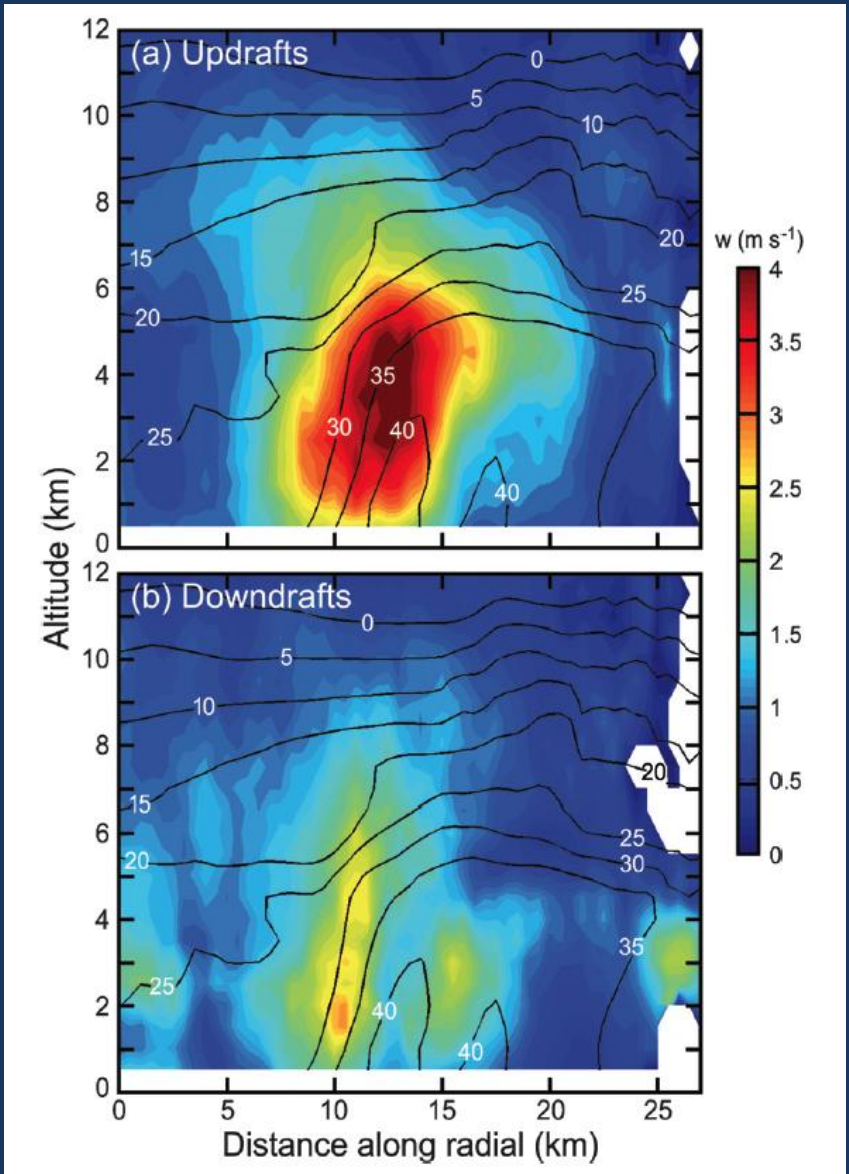
Principal Rainband



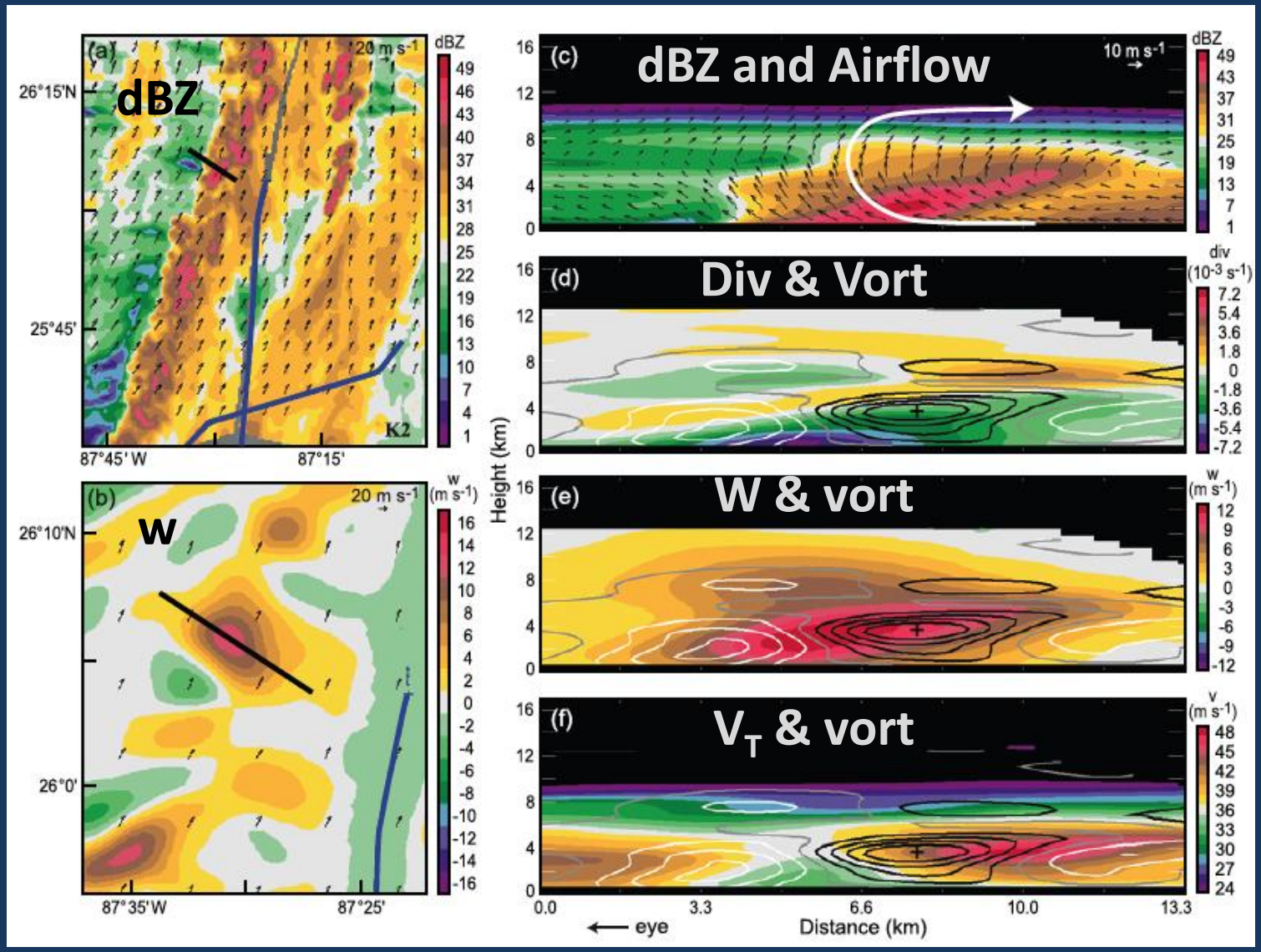
Obtained Statistics of the Cells in the Principal Rainband



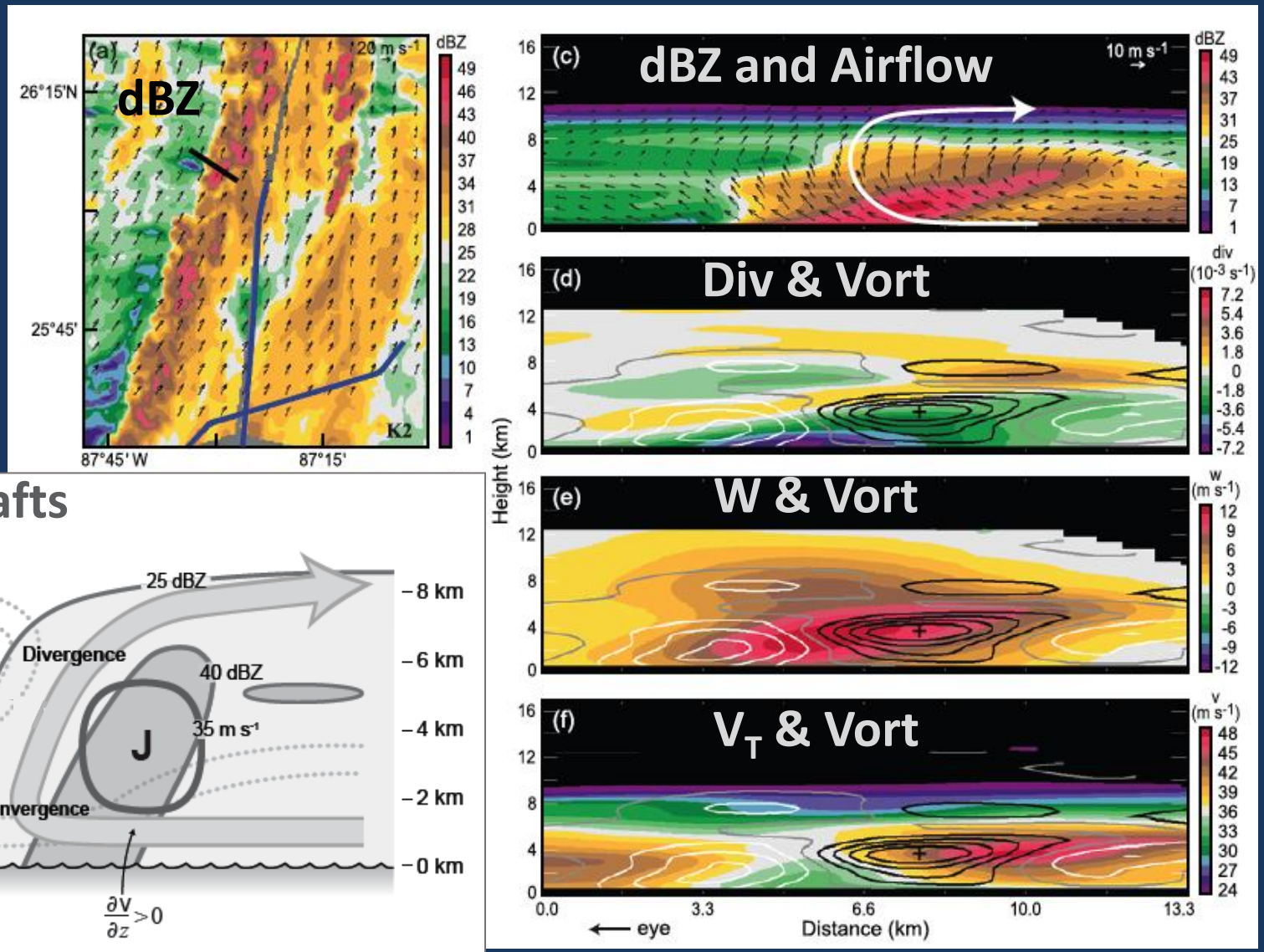
Mean w in the Principal Rainband

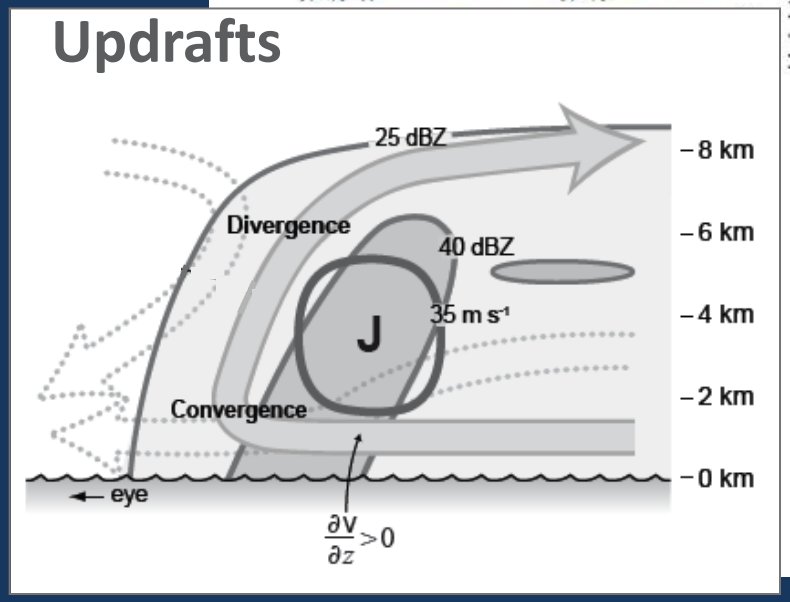


Detail of a Cell in the Principal Rainband

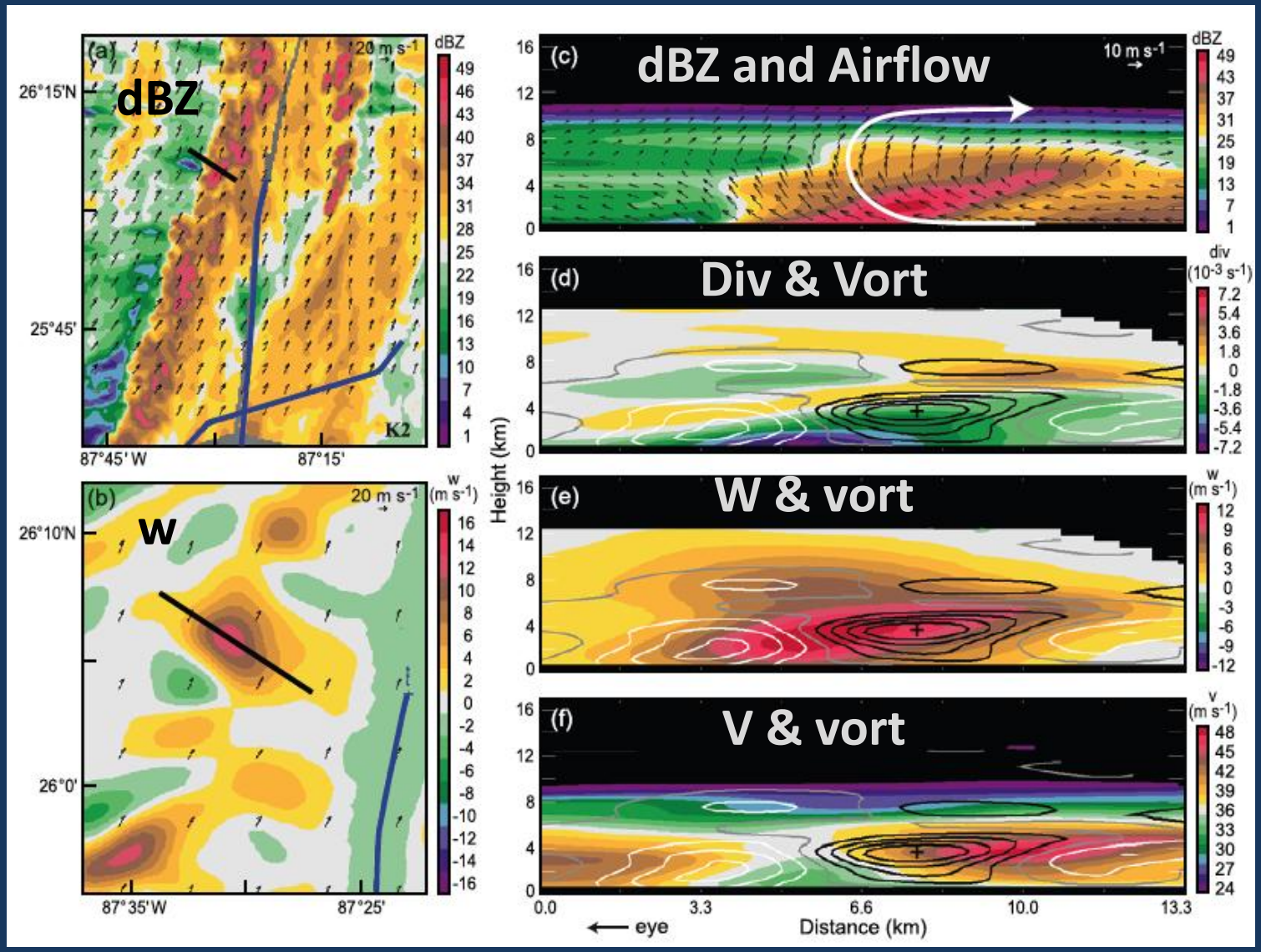


Consistent with the Idealization

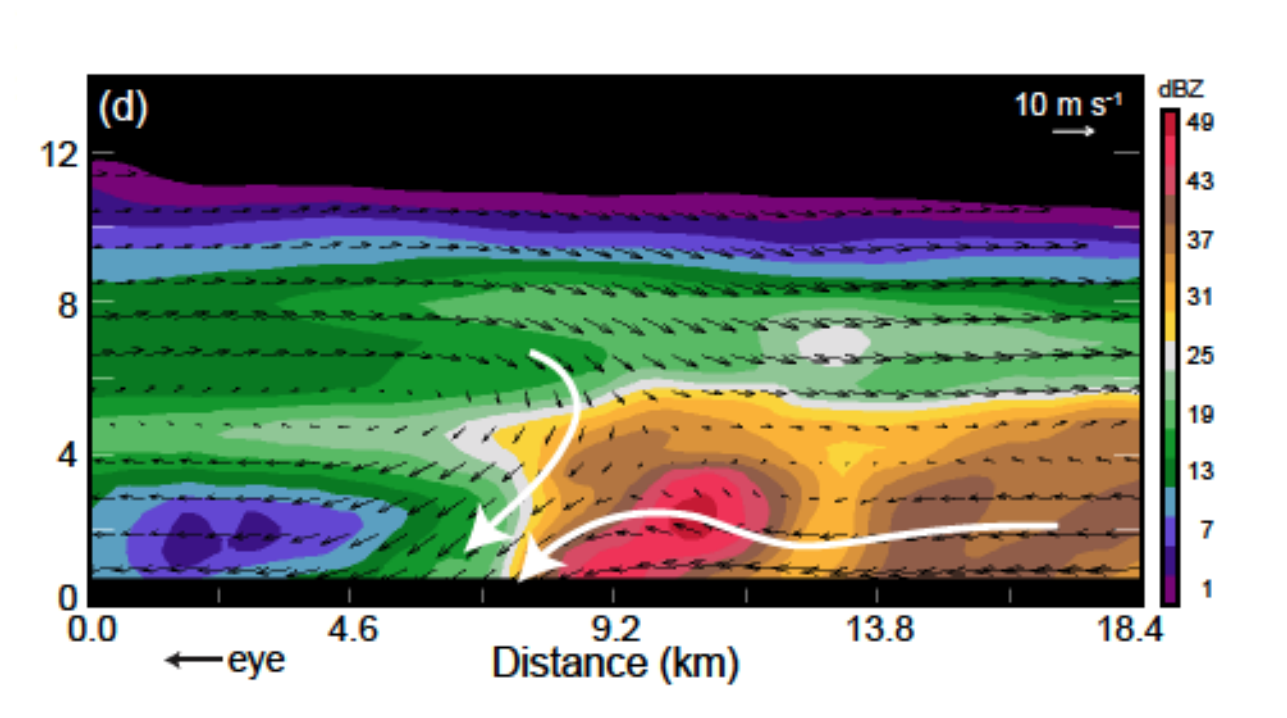


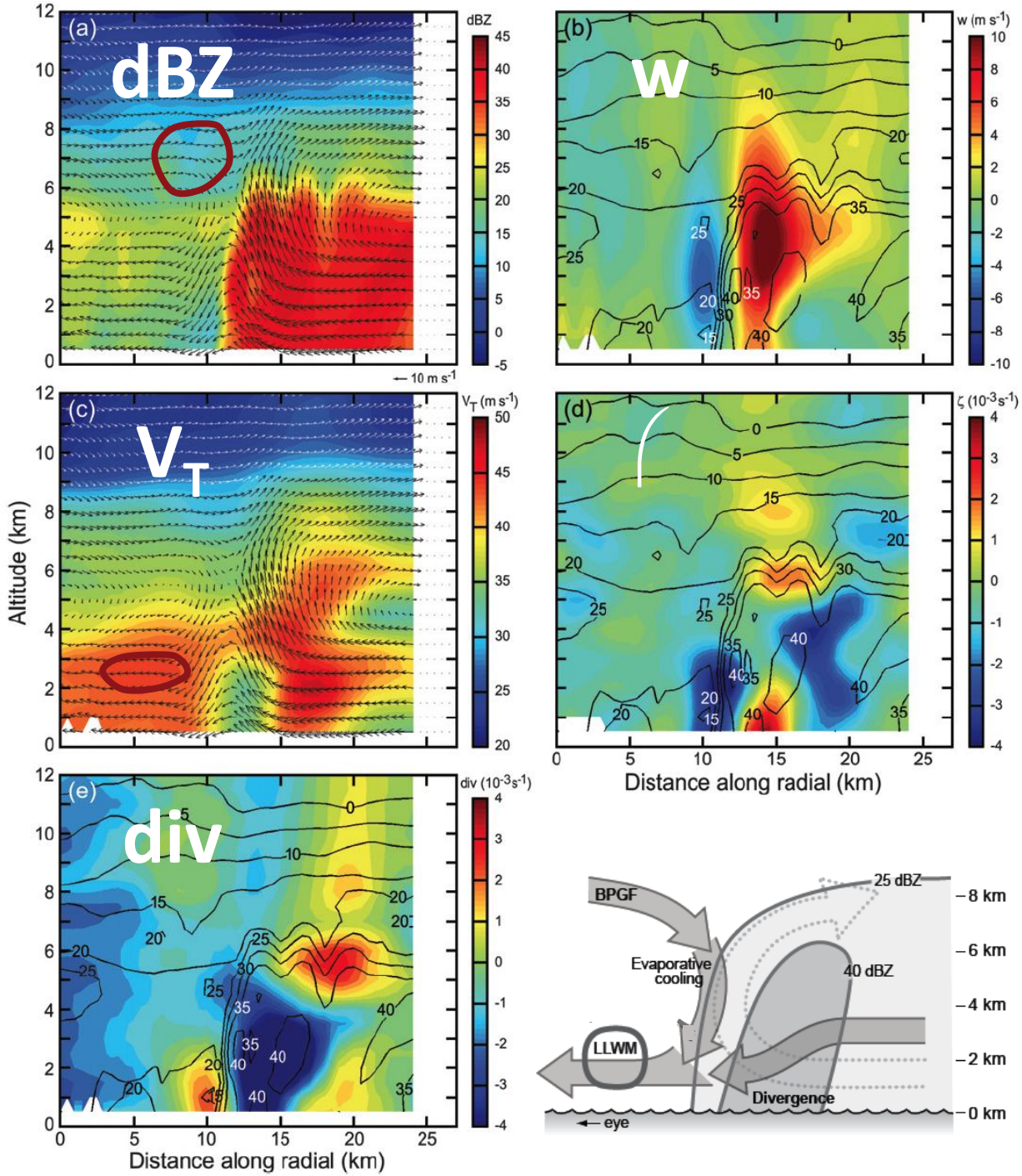


Detail of a Cell in the Principal Rainband



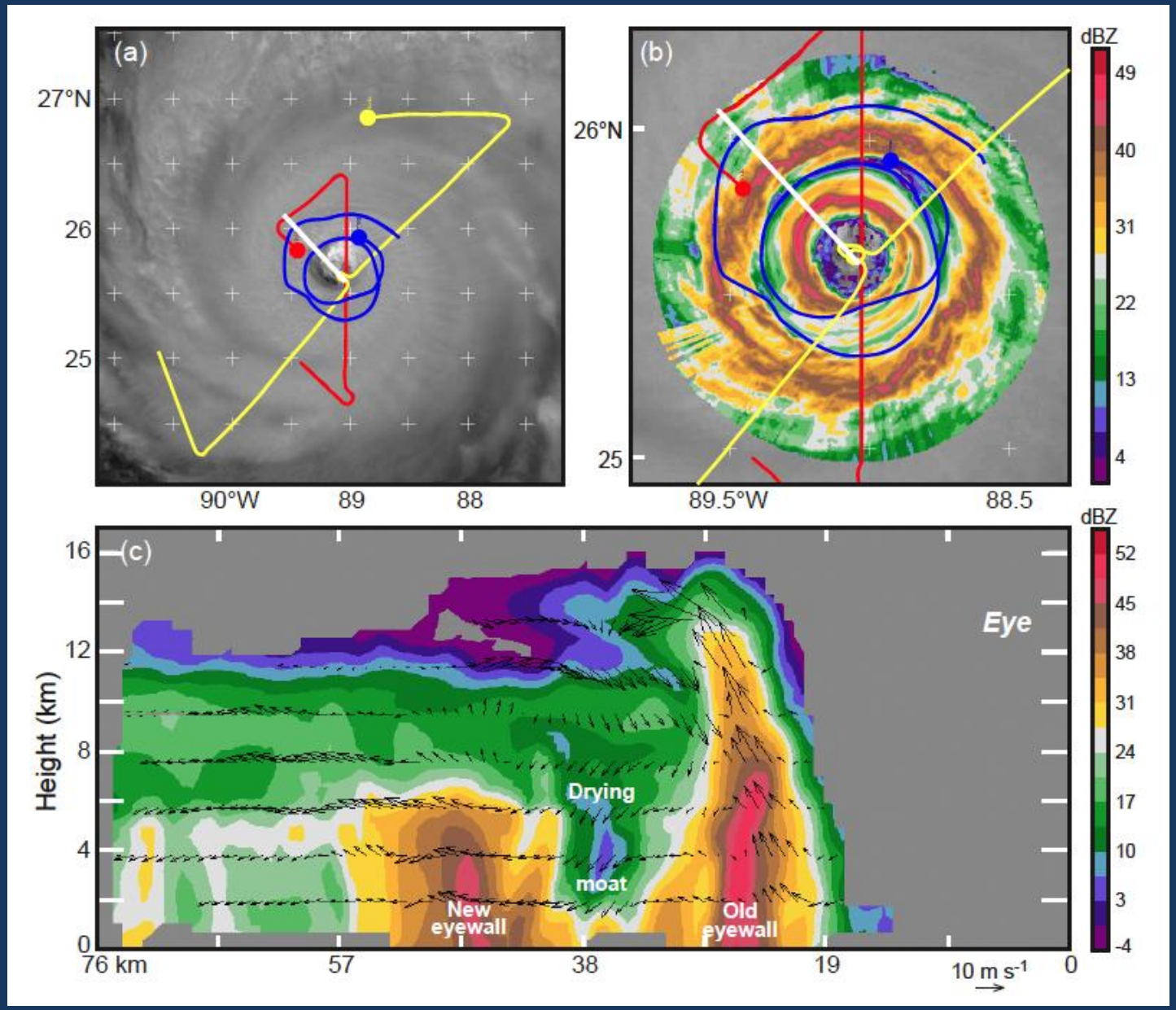
Detail of Downdrafts in the Principal Rainband



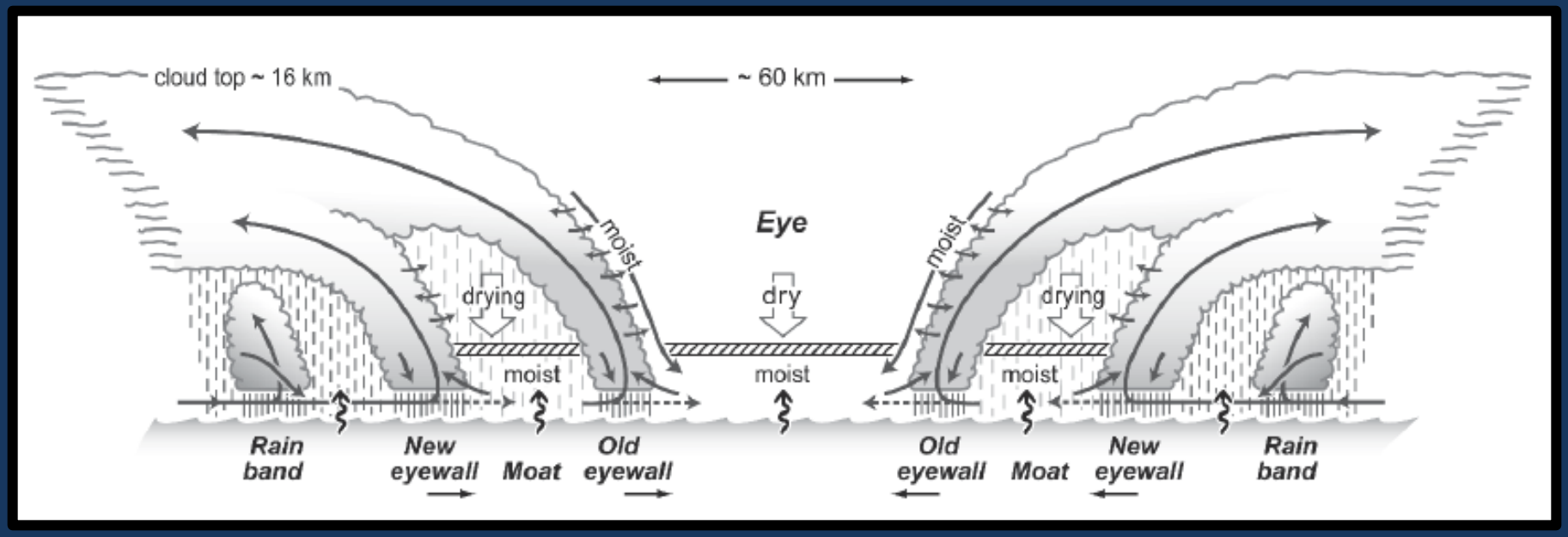

(a)
dBZ
(b)
w
w (m s-1)
(c)
VT
VT (m s-1)
(d)
ζ (10-3s-1)
(e)
div
div (10-3s-1)
Altitude (km)
Distance along radial (km)
10 m s-1
BPGF
25 dBZ
Evaporative cooling
40 dBZ
LLWM
Divergence
eye
8 km
6 km
4 km
2 km
0 km

Rita

Double Eyewall of Rita

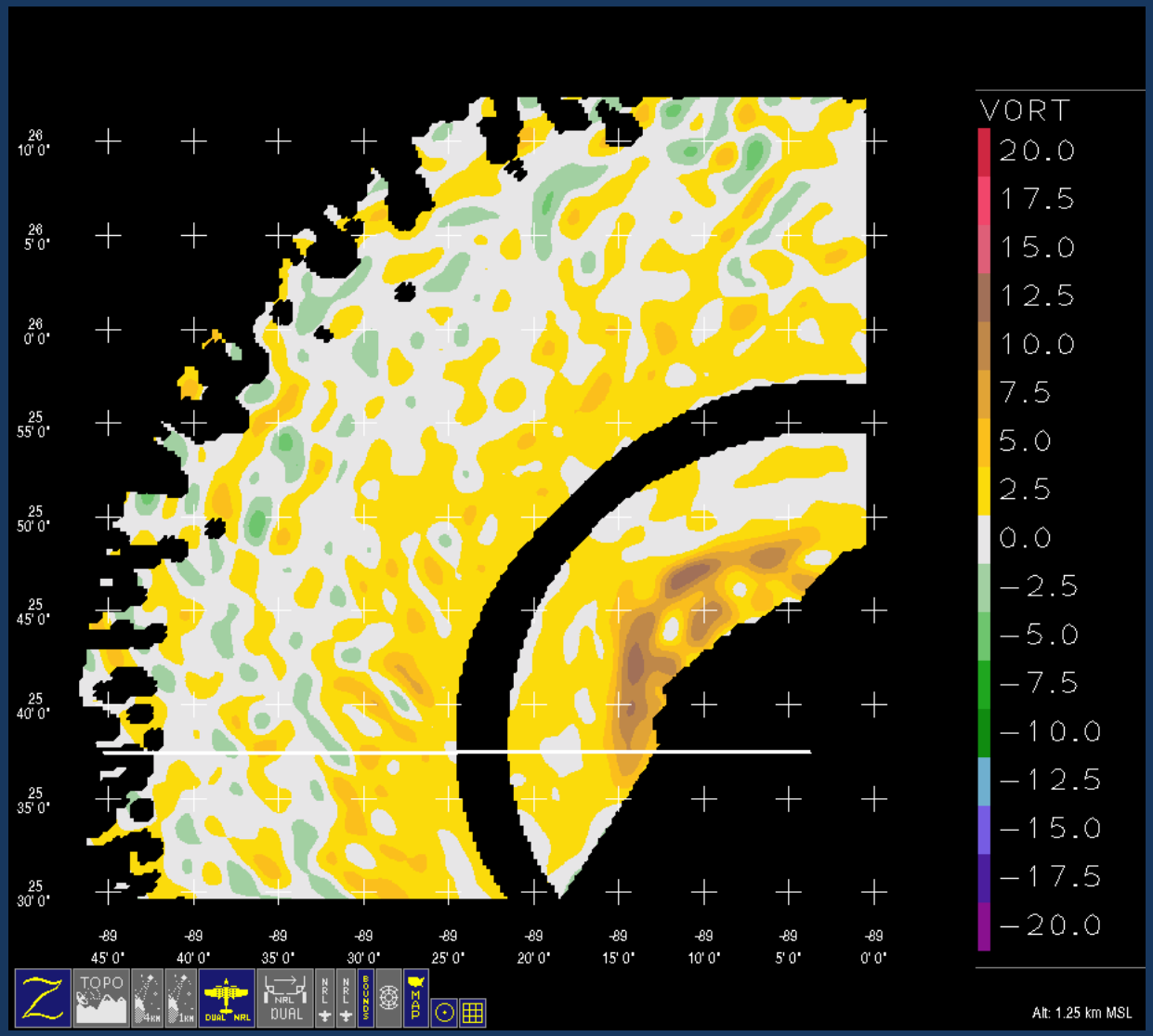


Better Understanding of the Moat



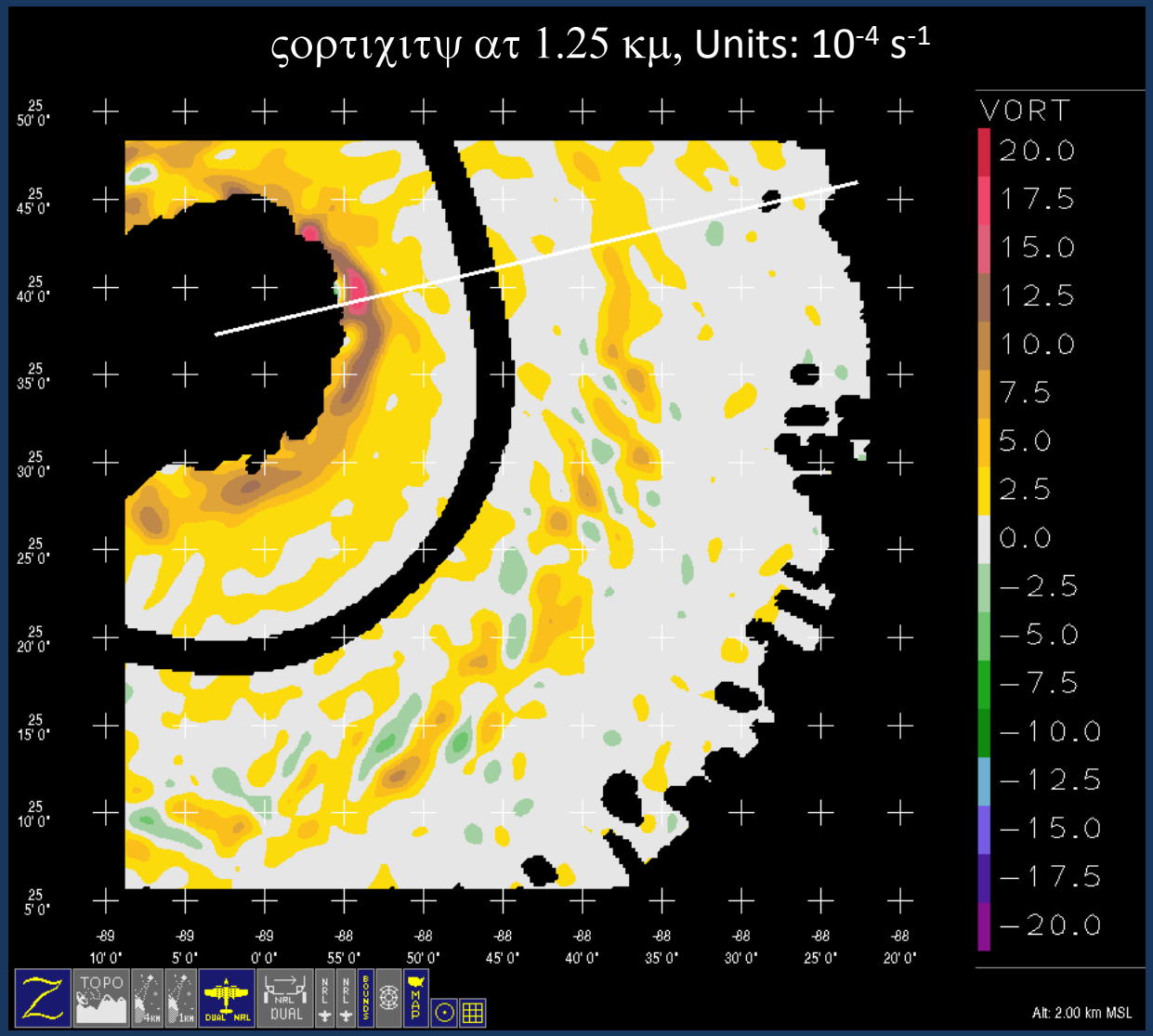
Vorticity Distribution the 2 Eyewalls

Secondary eyewall **exhibits** complex, high-wavenumber structure

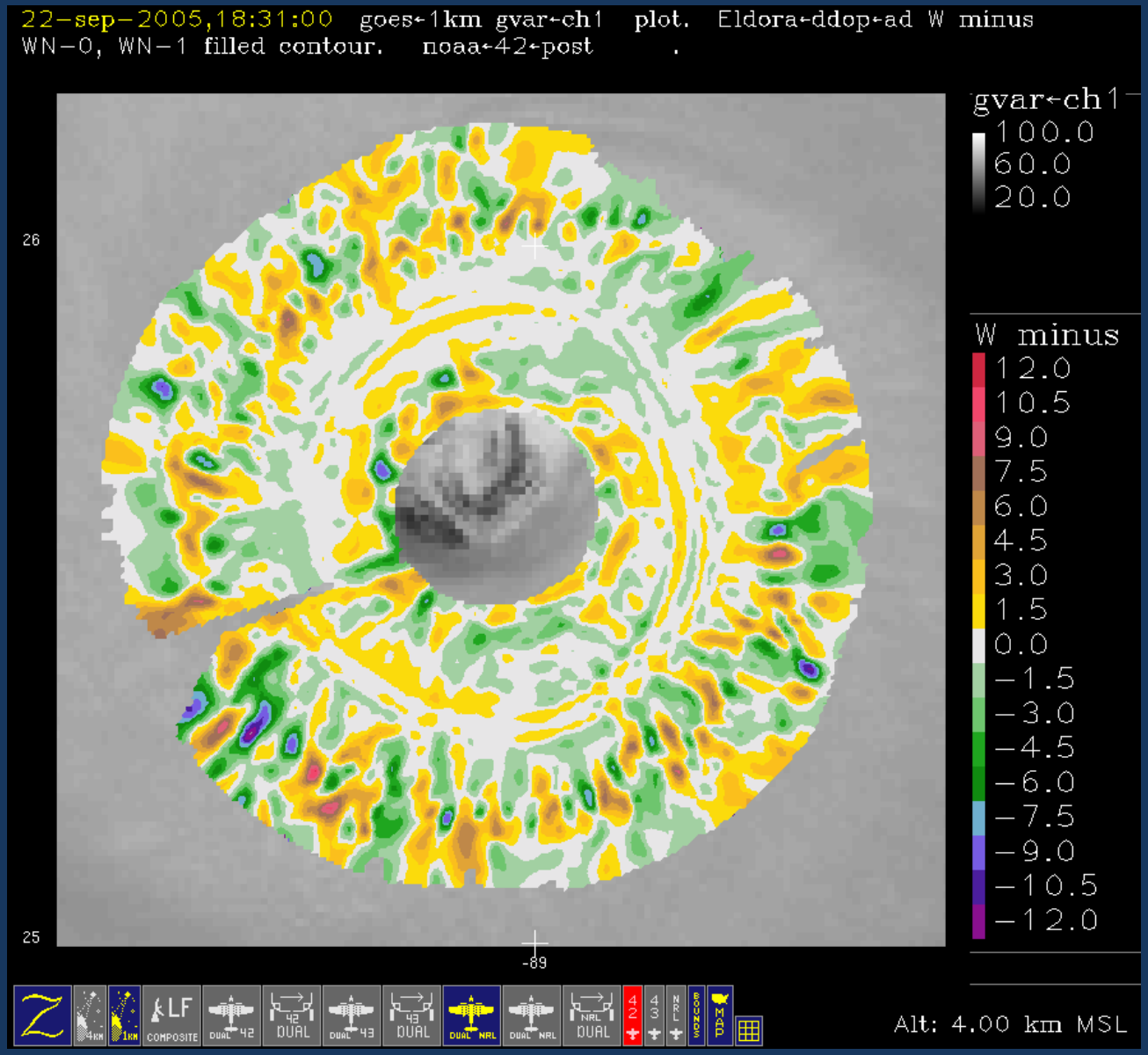


Vorticity Distribution the 2 Eyewalls

Secondary eyewall **exhibits** complex, high-wavenumber structure



Vertical Velocity in 2ndary Eyewall



RAINEX/ELDORA Findings About Convective Structures in Hurricanes

- Convection during Ophelia's genesis
  - Deep
  - Wide
  - Intense
  - Rotating
  - Very little downdraft

RAINEX/ELDORA Findings About Convective Structures in Hurricanes

- Principal rainband in Katrina
  - Alternating convective-scale elements
  - Updraft cells feed vorticity into jet at 4 km
  - Inner-edge downdrafts strengthen low-level tangential flow inward of band

RAINEX/ELDORA Findings About Convective Structures in Hurricanes

- Eyewall replacement in Rita
  - Moat was taking on structure of an eye
  - Outer eyewall had an alternating cellular structure but not like principal rainband

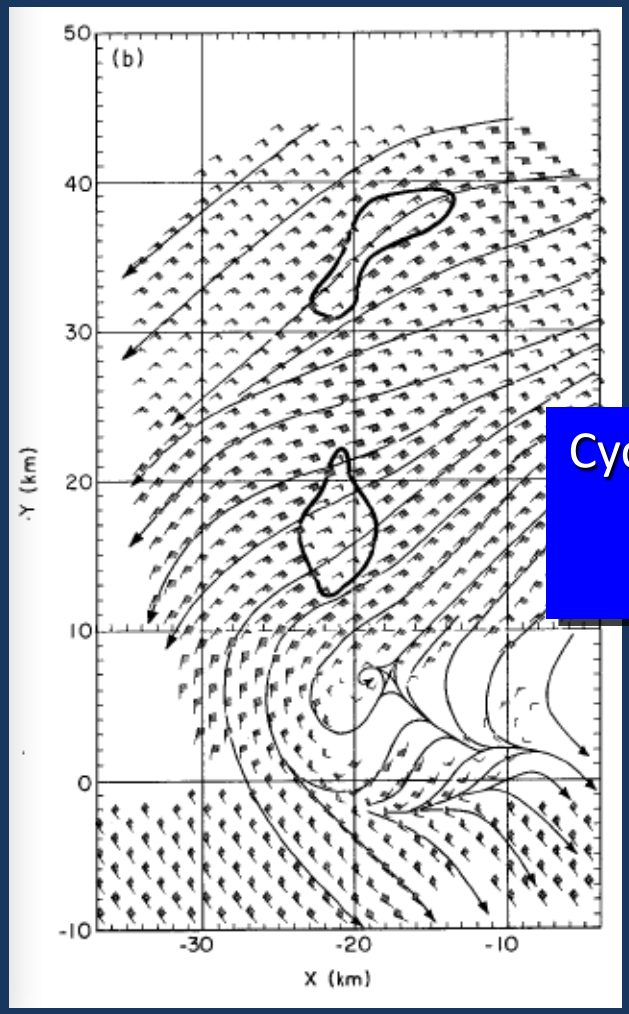
End

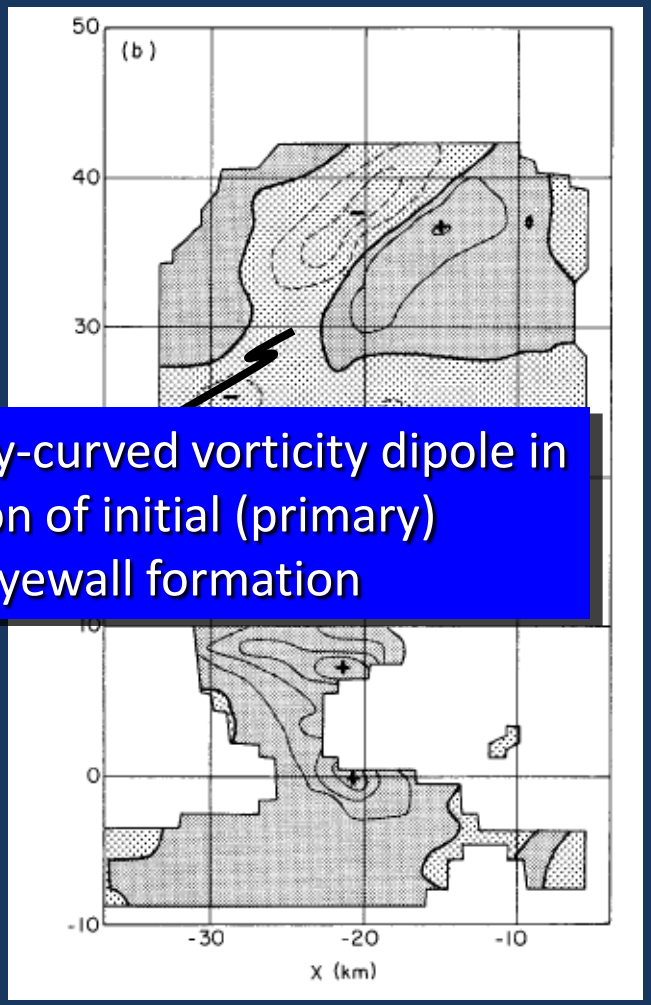
Acknowledgment

This research was supported by NSF grant ATM-0743180 and NASA grant NNX07AD59G

Extra Slides

Curvilinear ϖορτιχιτψ structures in formative stage of Hurricane Debby from Marks and Houze (1983)

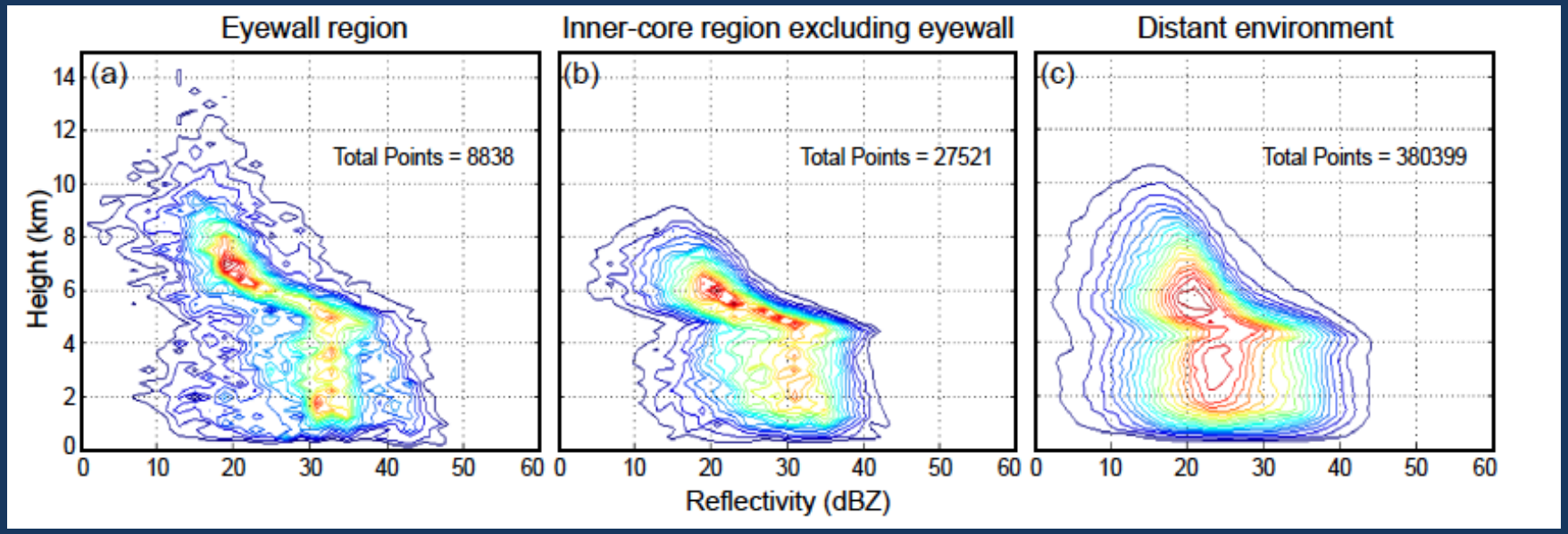




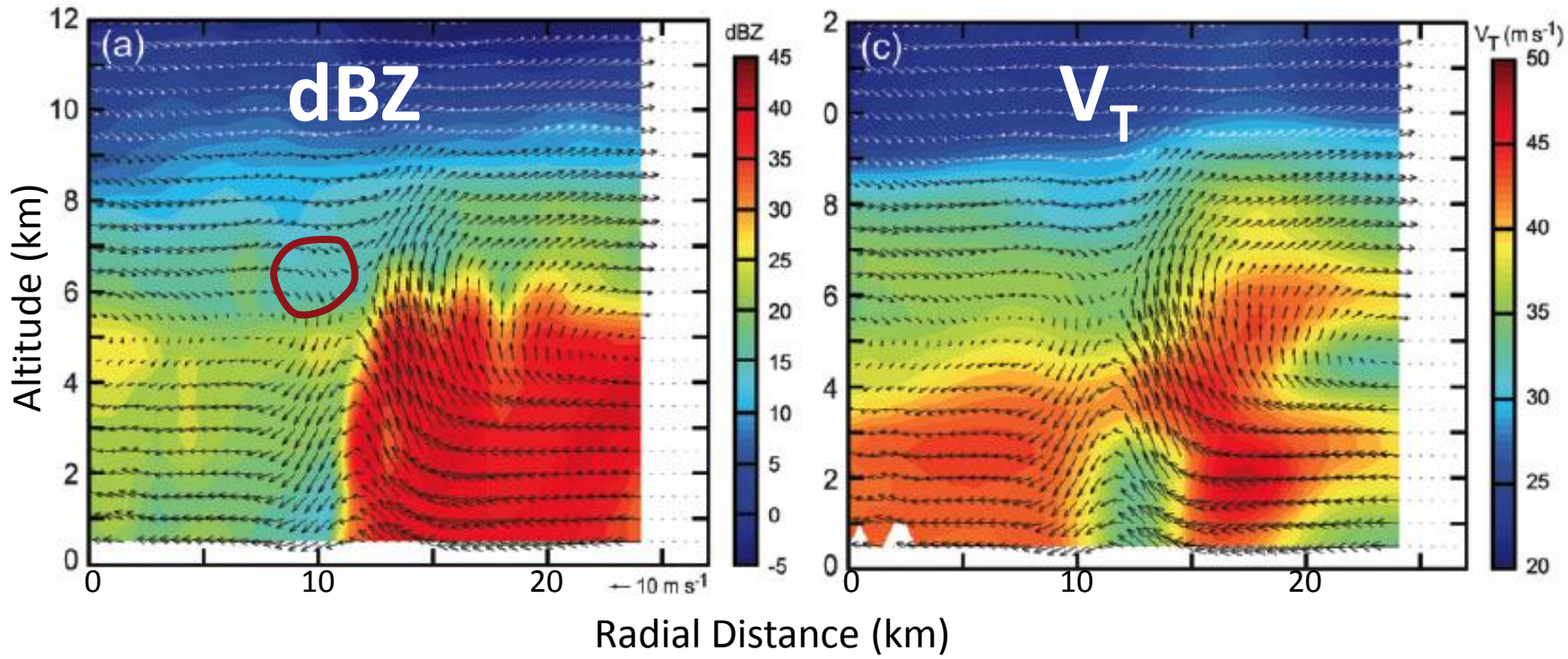
Cyclonically-curved vorticity dipole in region of initial (primary) eyewall formation

Winds/Streamlines & Vertical Vorticity (ζ) at 3 km MSL
(Contours @ -3, 0, 3, 4, 5, 6, 7 and 8 x 10^{-3} s^{-1})

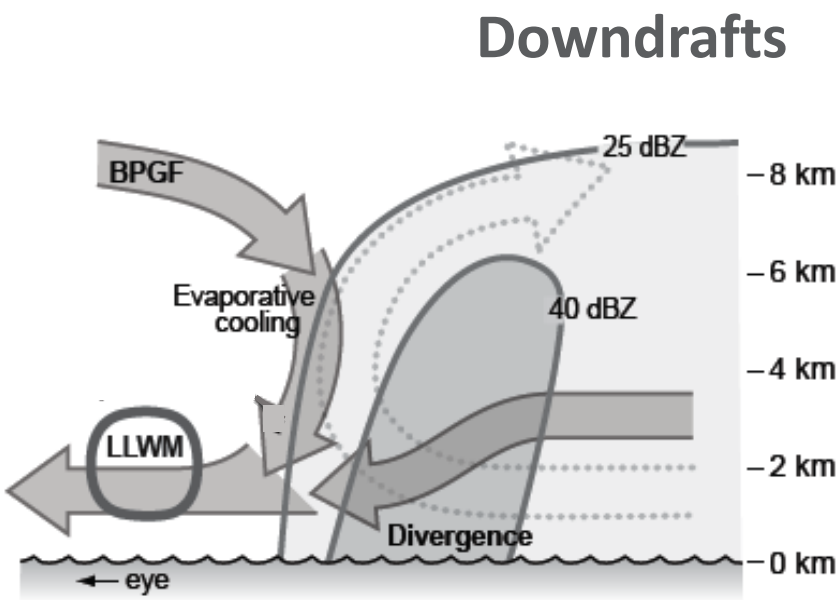
CFAD of eyewall, rainband, and outer band areas

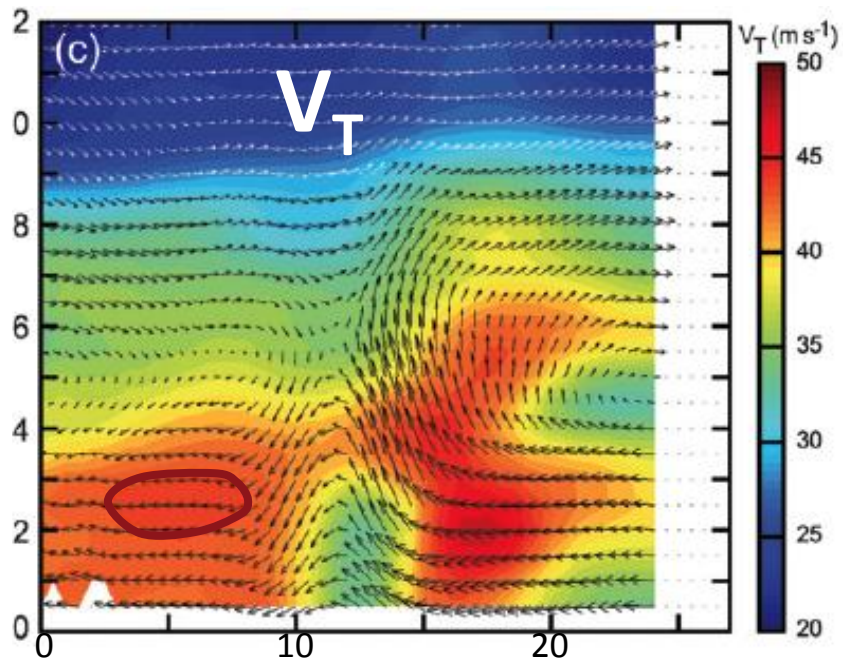


Inner edge downdraft strengthens low-level flow inward of rainband

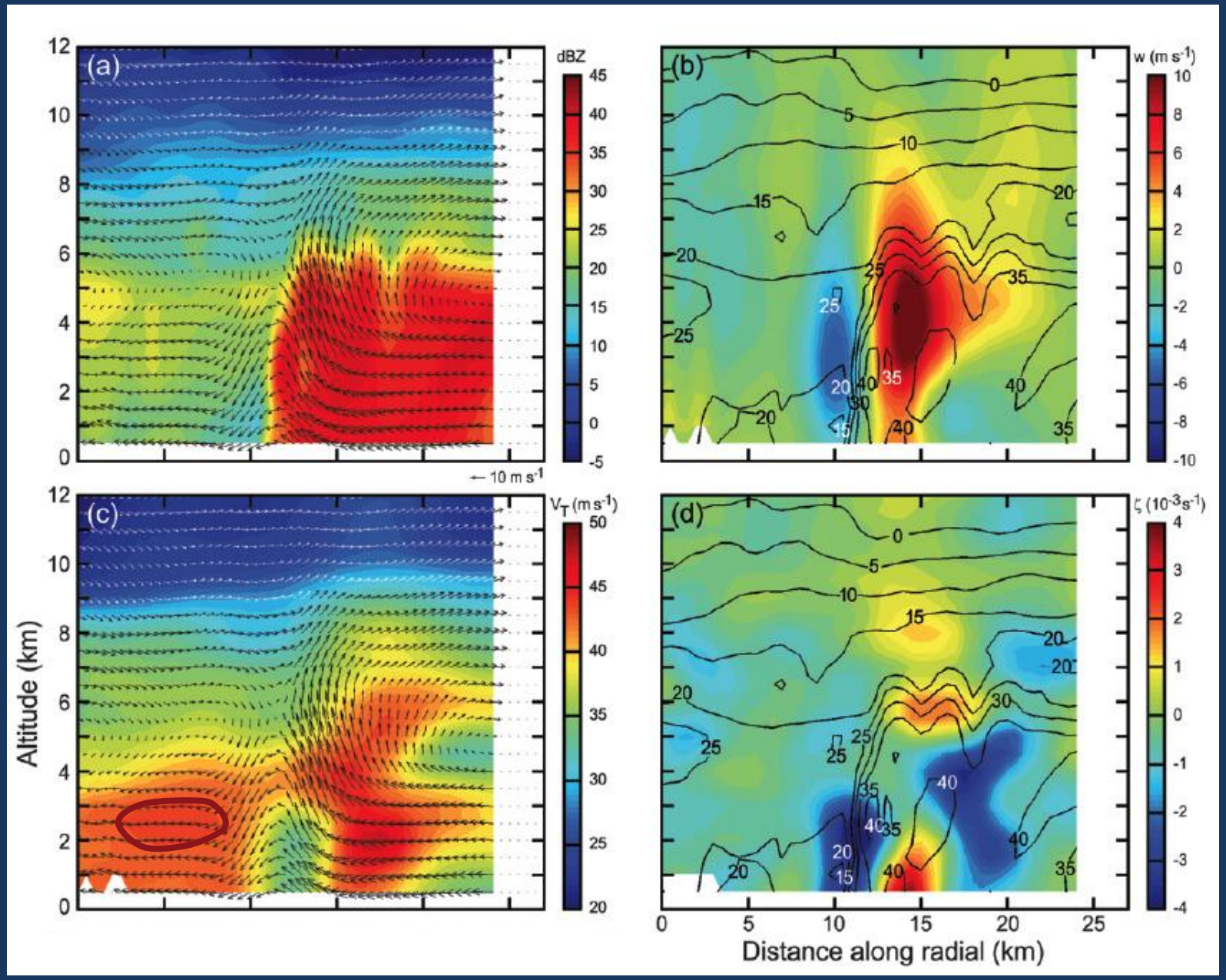


Inner edge downdraft strengthens low-level flow inward of rainband

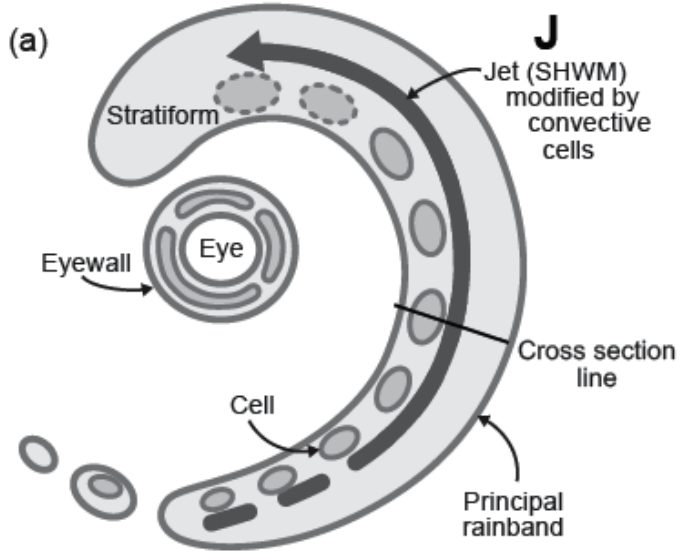




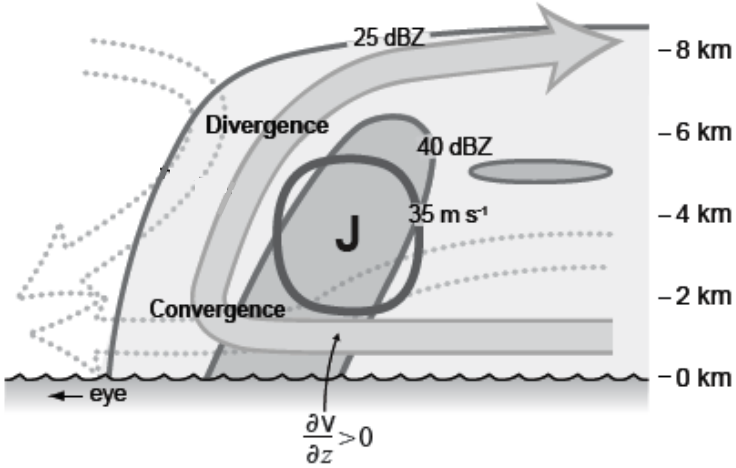
Radial Distance (km)


(a)
dBZ
← 10 m s-1
(b)
w (m s-1)
(c)
VT (m s-1)
(d)
ζ (10-3s-1)
Altitude (km)
Distance along radial (km)

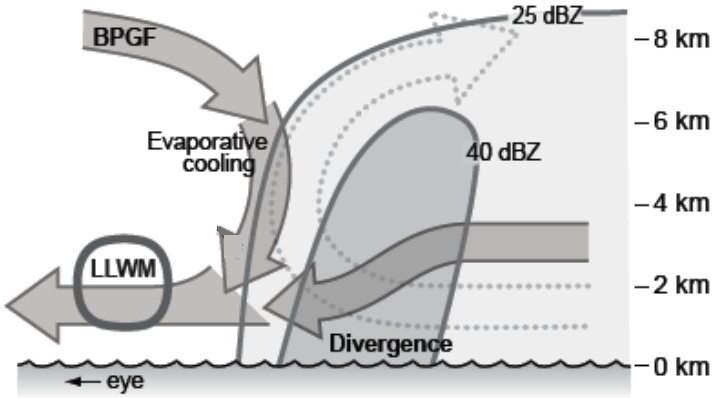
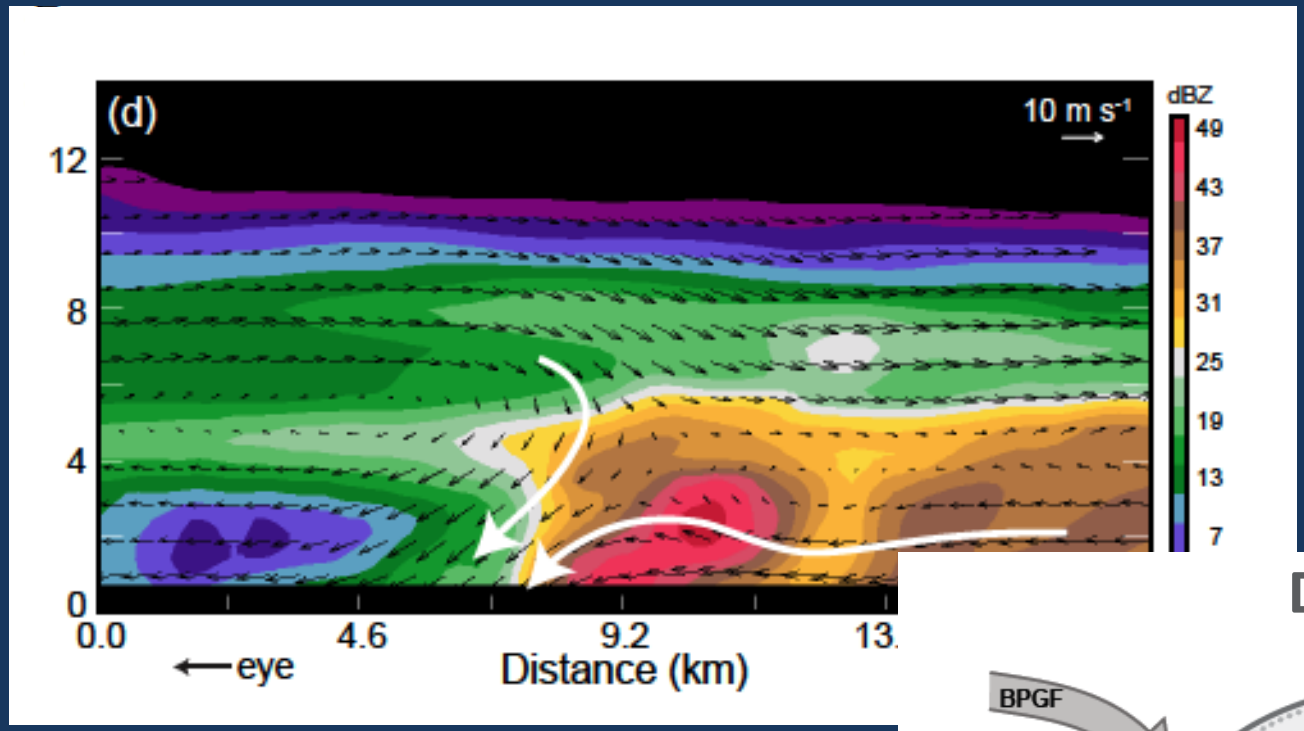
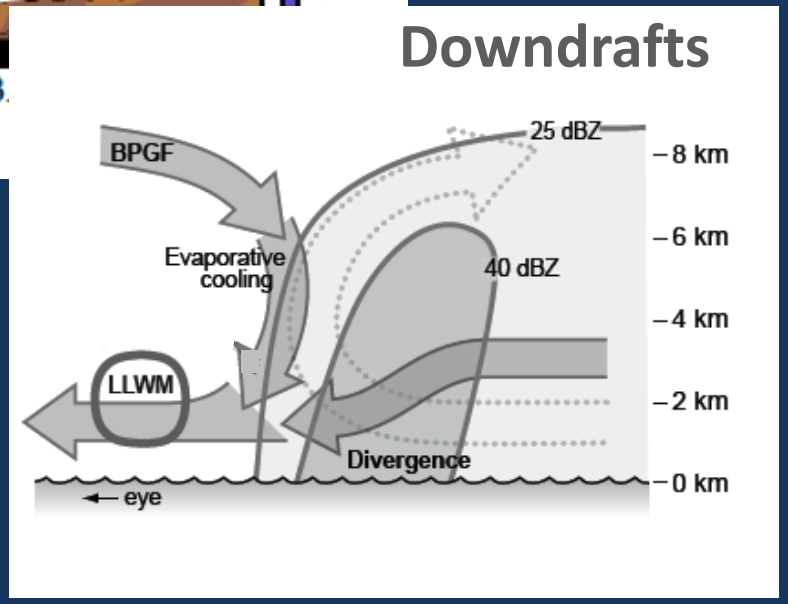
Principal Rainband



Updrafts



Downdrafts



Detail of Downdrafts in the Principal Rainband