VORTRAC – A Utility to Deduce Central Pressure and Radius of Maximum Wind of Landfalling Tropical Cyclones Using WSR-88D Data

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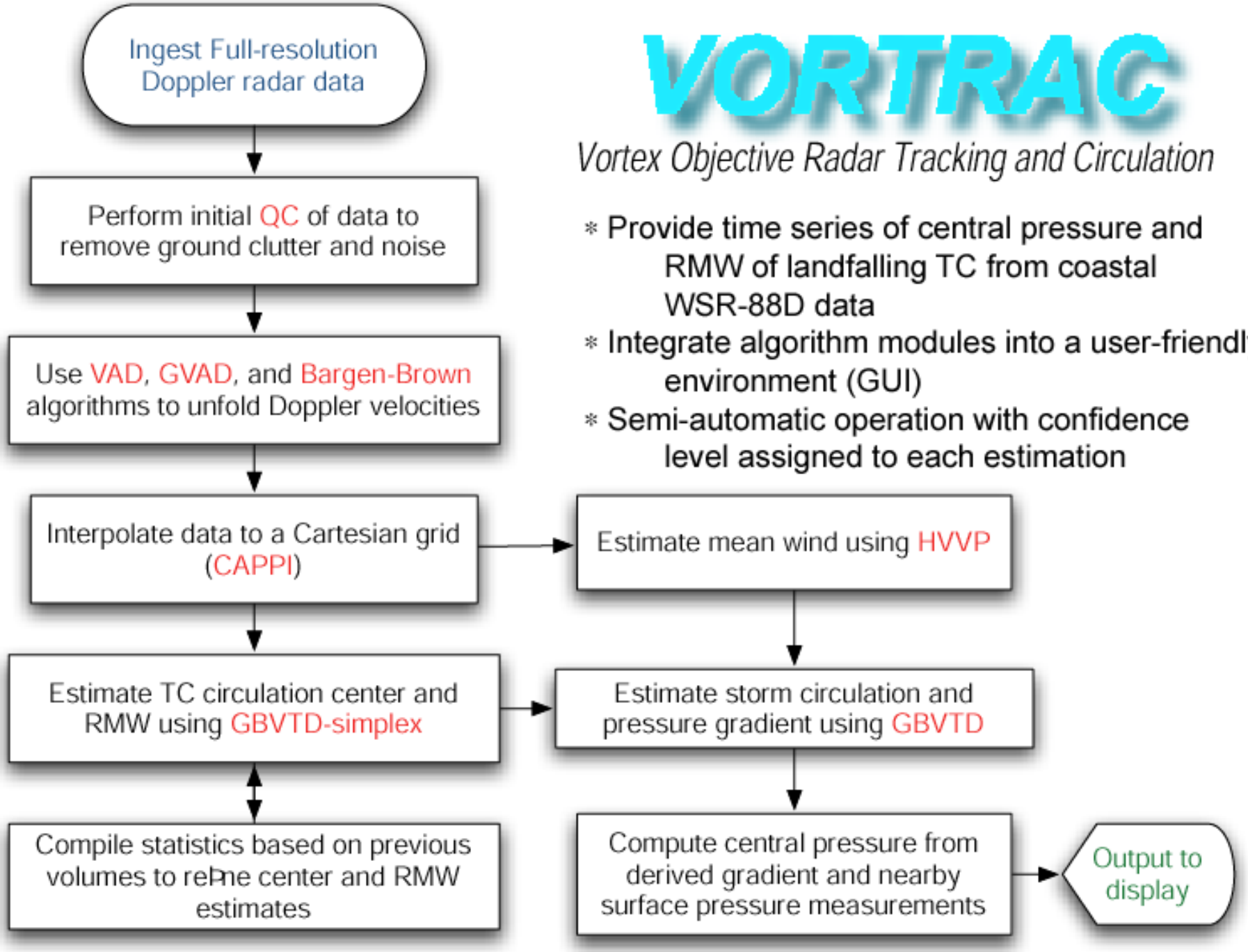
Michael Bell	NCAR/EOL

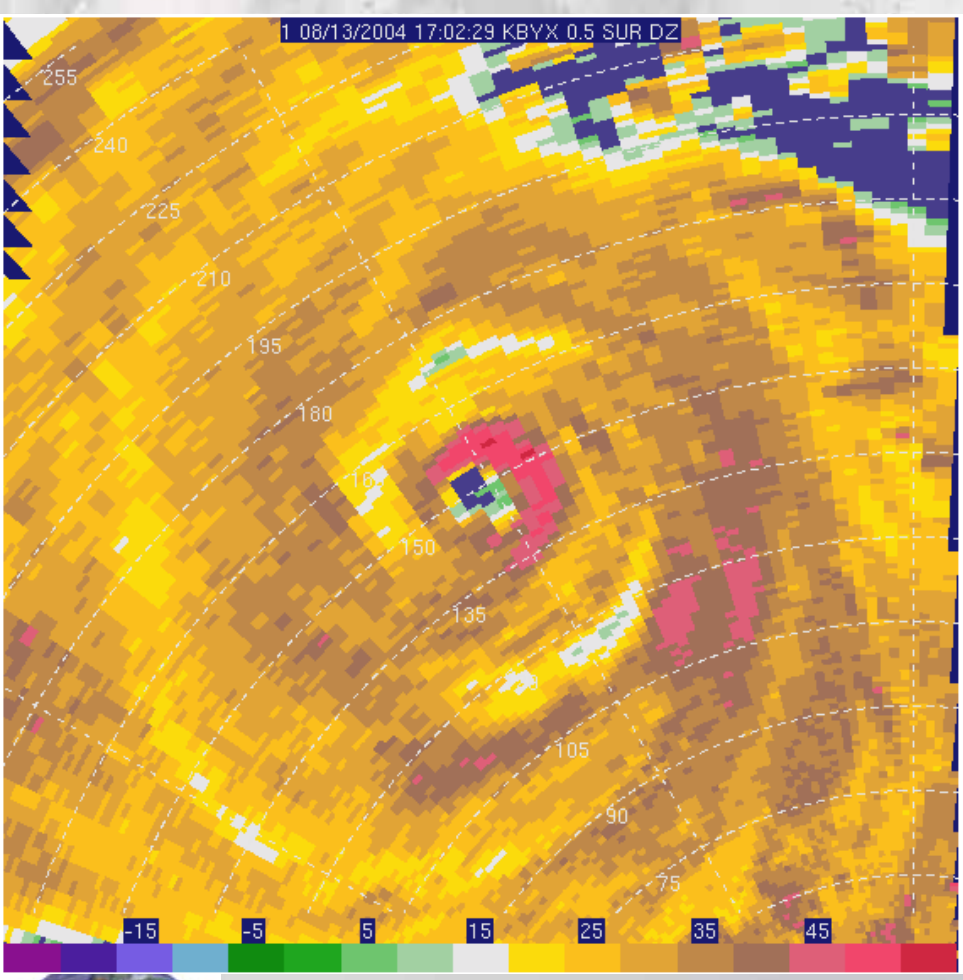


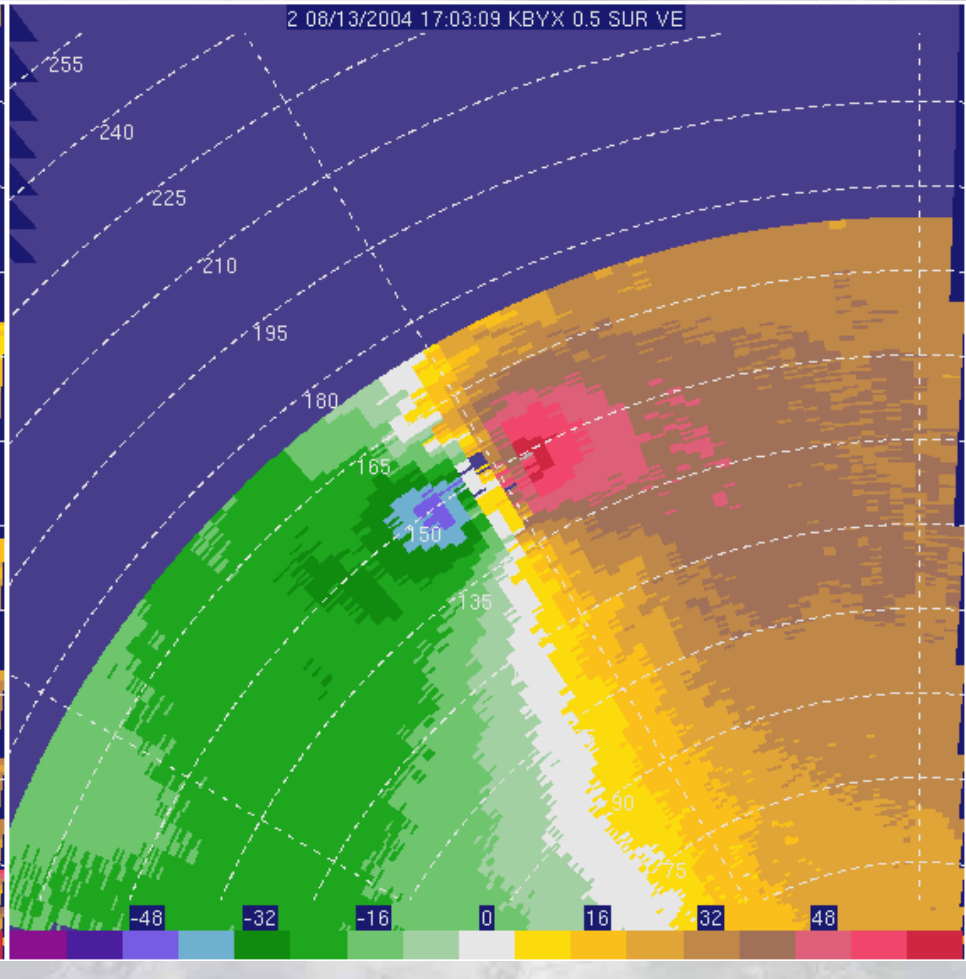
VORTRAC

Vortex Objective Radar Tracking and Circulation

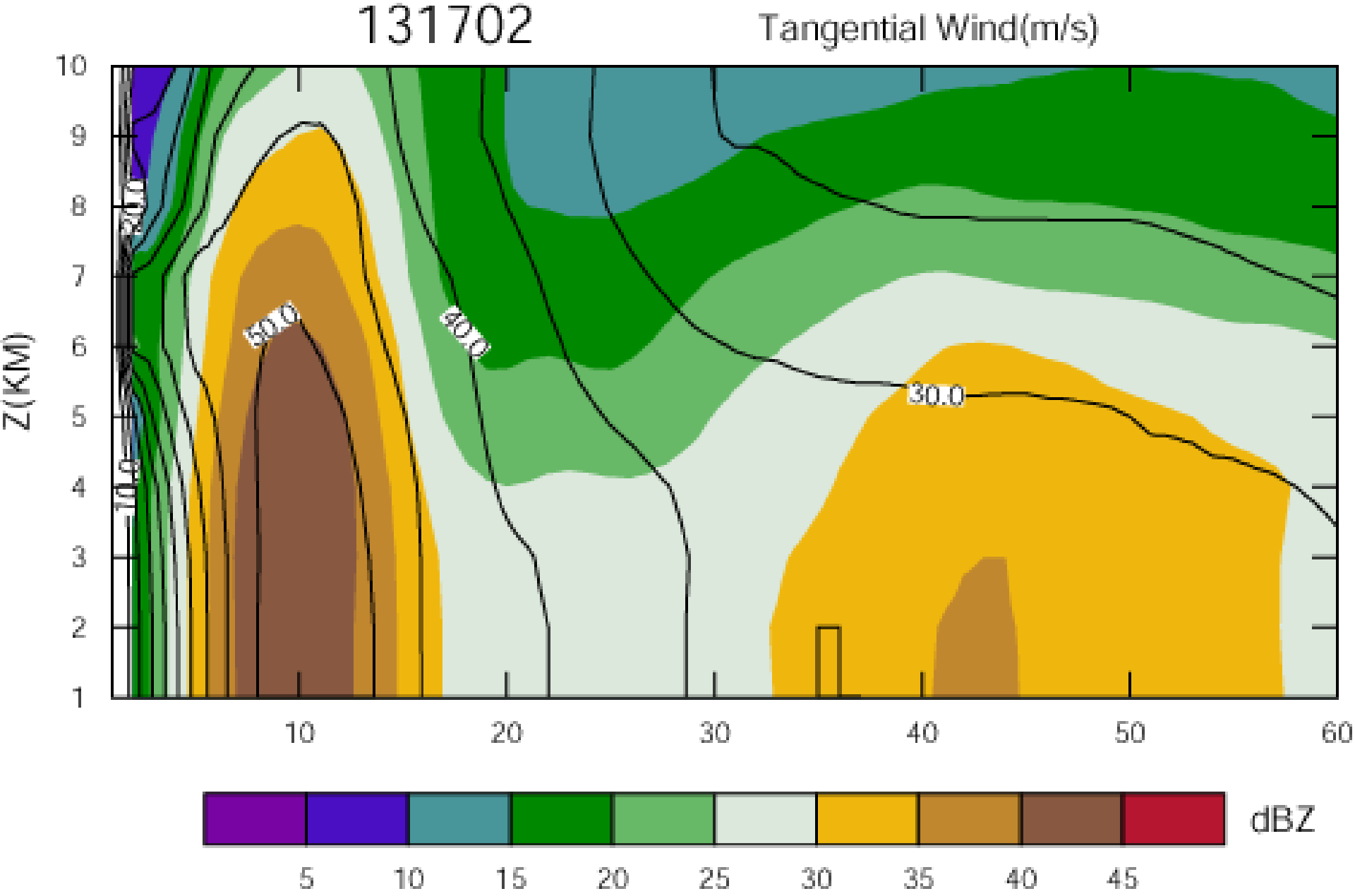
* Provide time series of central pressure and RMW of landfalling TC from coastal WSR-88D data
* Integrate algorithm modules into a user-friendly environment (GUI)
* Semi-automatic operation with confidence level assigned to each estimation

Hurricane Charlie Radar Images





EOL
Deployment
Development
Data Services



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VTD-derived Axisymmetric Quantities:

$$w = -\frac{1}{r}\int_{z=0}^{z=H} r\left(\frac{\partial V_R}{\partial R} + \frac{V_R}{R}\right) dz$$

Vertical Velocity

$$M = V_T R + \frac{1}{2} f R^2$$

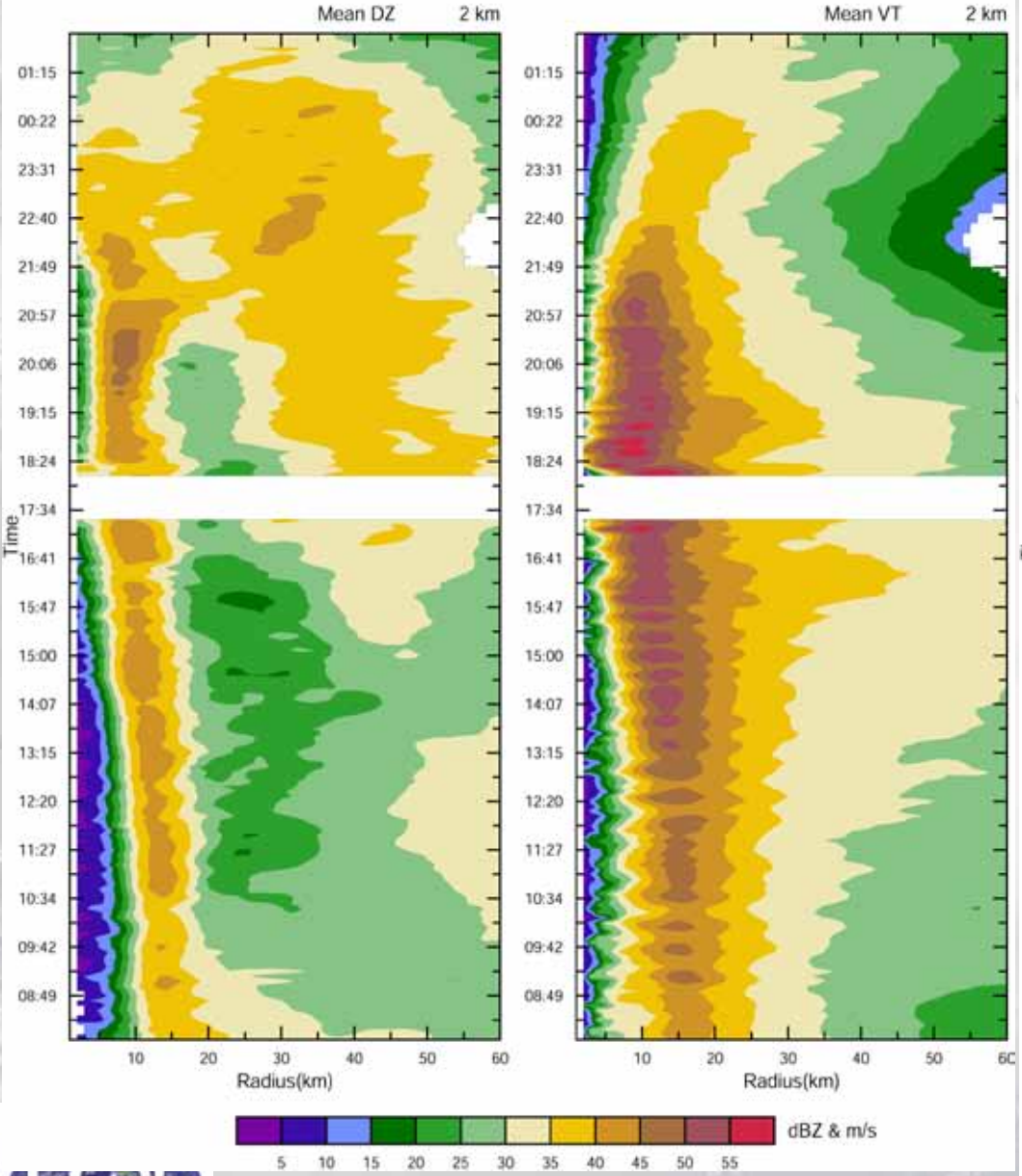
Angular Momentum

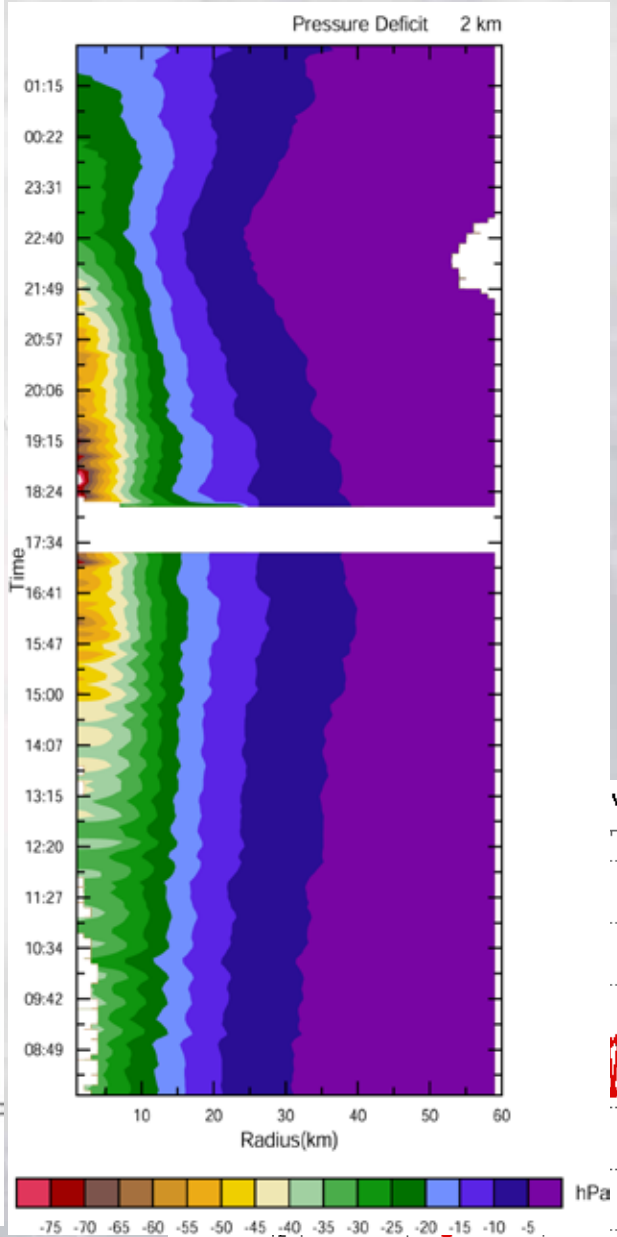
$$\frac{\partial P}{\partial r} = -r\left(V_R\frac{\partial V_R}{\partial R} + W\frac{\partial V_R}{\partial z} - \frac{V_T^2}{R} - fV_T\right)$$

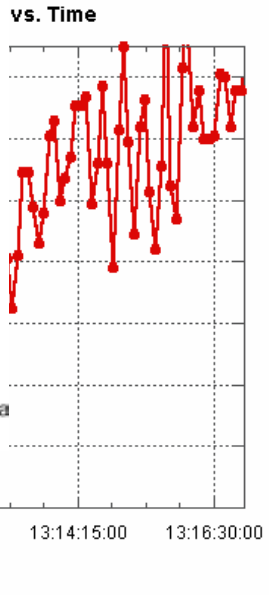
$$\left(-\frac{v_T^2}{R} + w\frac{\partial v_R}{\partial z} + v_R\frac{\partial v_R}{\partial R}\right)$$

Pressure Gradient

Hurricane Charley (2004) 13/08Z - 14/02Z







EOL
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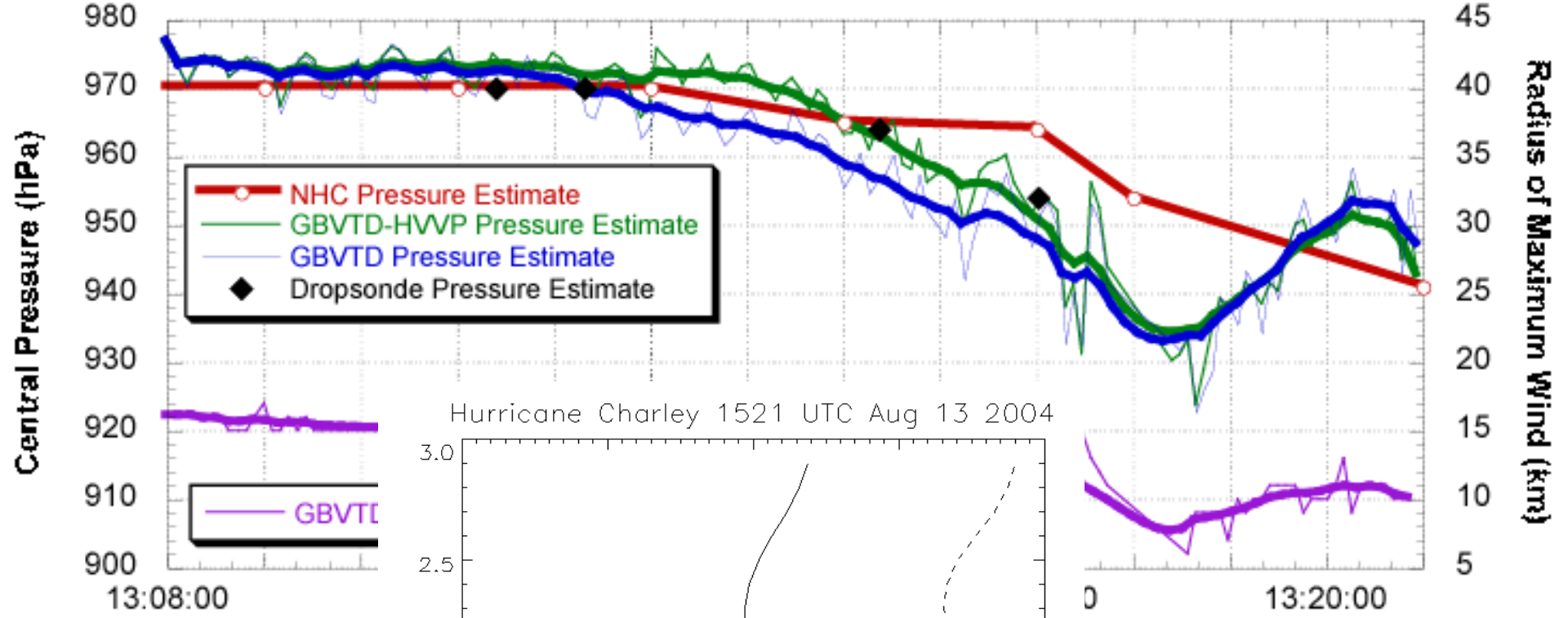
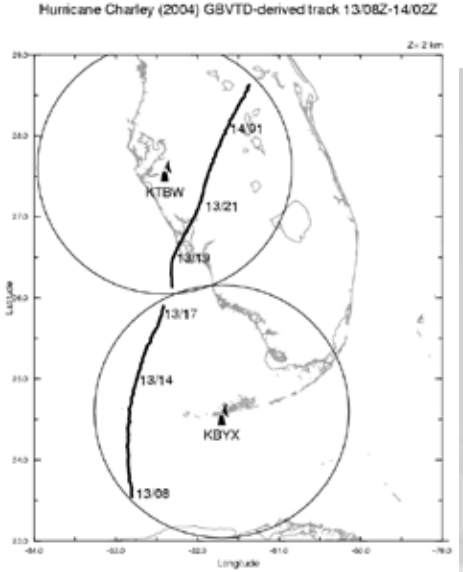
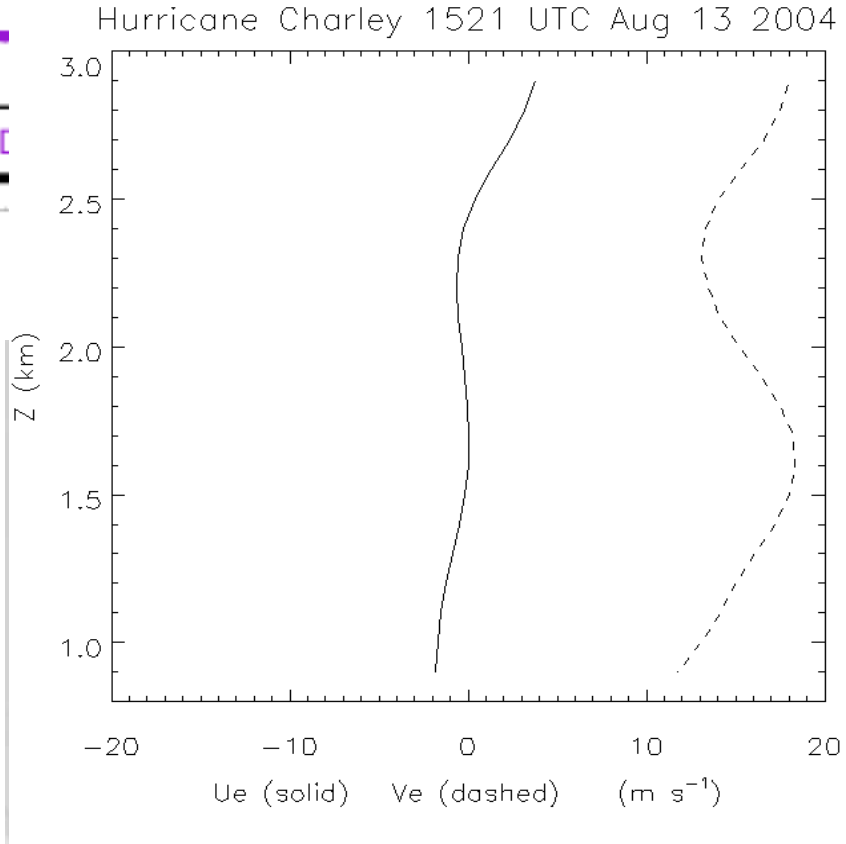
Hurricane Charley (2004)
Central Pressure and Radius of Maximum Wind Estimates







Cat.	Maximum Sustained Wind Speed m/s	Minimum Surface Pressure mb
1	33-42	>980
2	43-49	979-965
3	50-58	964-945
4	59-69	944-920
5	>70	<920

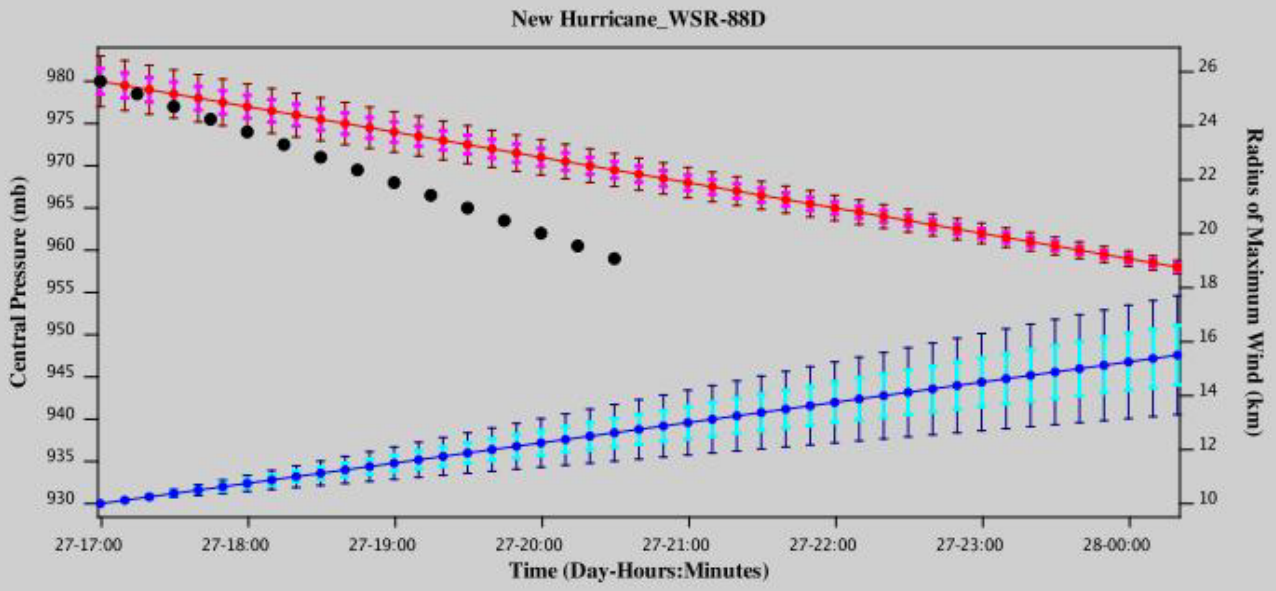
File Vortex

New Hurricane_WSR-88D

Category	Parameter
vortex	
radar	
cappi	
center	
vtd	
dir	/path/to/vtd/output
geometry	GBVTD
closure	original
reflectivity	DZ
velocity	VE
bottomlevel	1
toplevel	5
innerradius	1
outerradius	60
maxwavenumber	1
maxdatagap_0	180
maxdatagap_1	120
ringwidth	1.0
hvvp	
pressure	
graphics	
qc	

Current Pressure (mb):

Current RMW (km):



See Legend | Plot Example Points | Save Graph

VORTRAC Status Log for Mon Feb 27 21:59:12 2006 UTC

Run Abort

EOL Deployment Development Data Services

- Vortex Configuration
- Radar Configuration
- CAPPI Configuration
- Simplex Configuration
- **VTD Configuration**
- HVVP Configuration
- Pressure Configuration
- Graphics Configuration
- Quality Control Configuration

VTD Output Directory

/path/to/vtd/output | Browse..

Geometry: GBVTD | Reflectivity: DZ

Closure: Original | Velocity: VE

VTD Grid Region

Bottom Level	1	Inner Radius	1
Top Level	5	Outer Radius	60

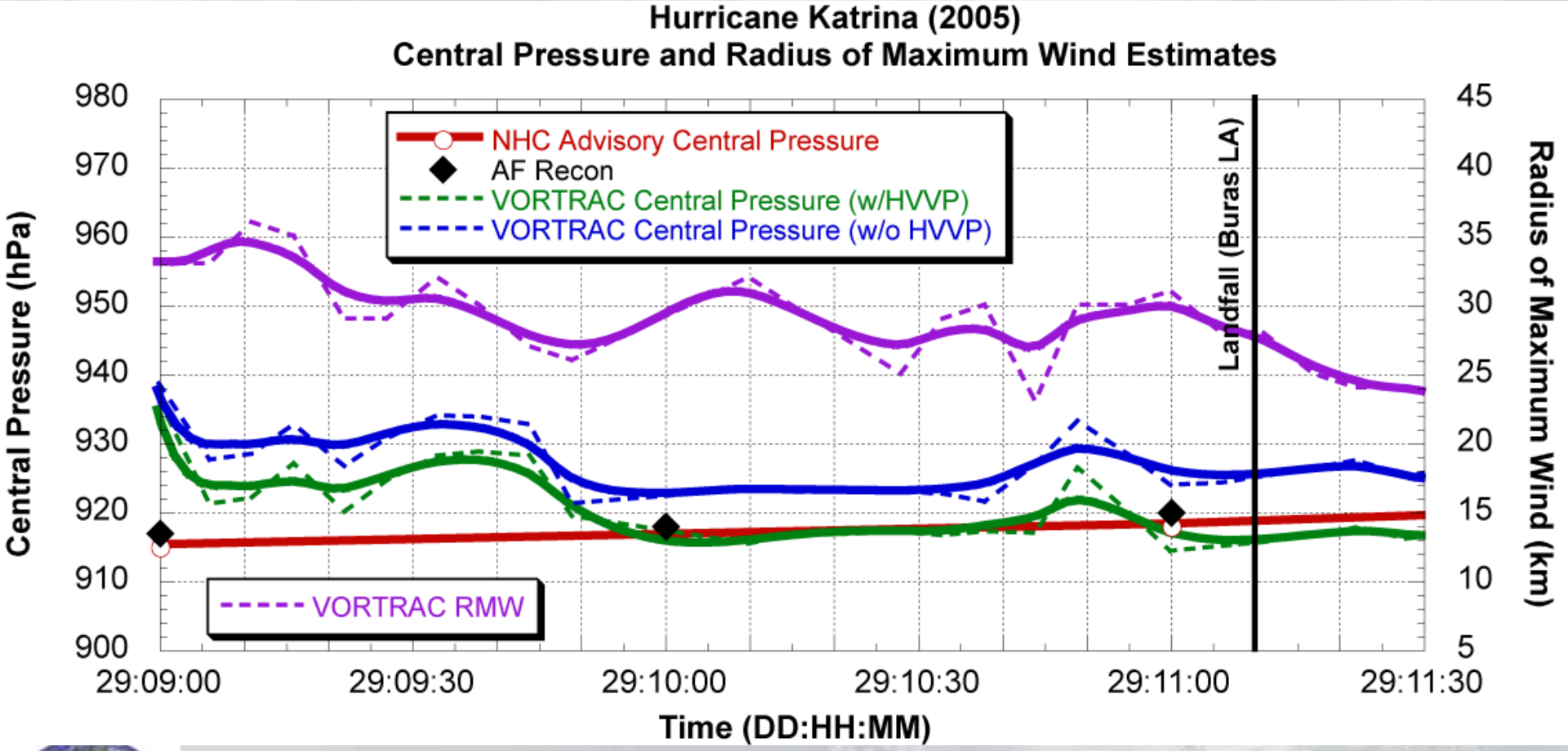
Maximum Wave Number: 1

Maximum Data Gaps

Wave 0	180.0	Wave 1	120.0

Width of Search Rings: 1.0

Apply | Cancel

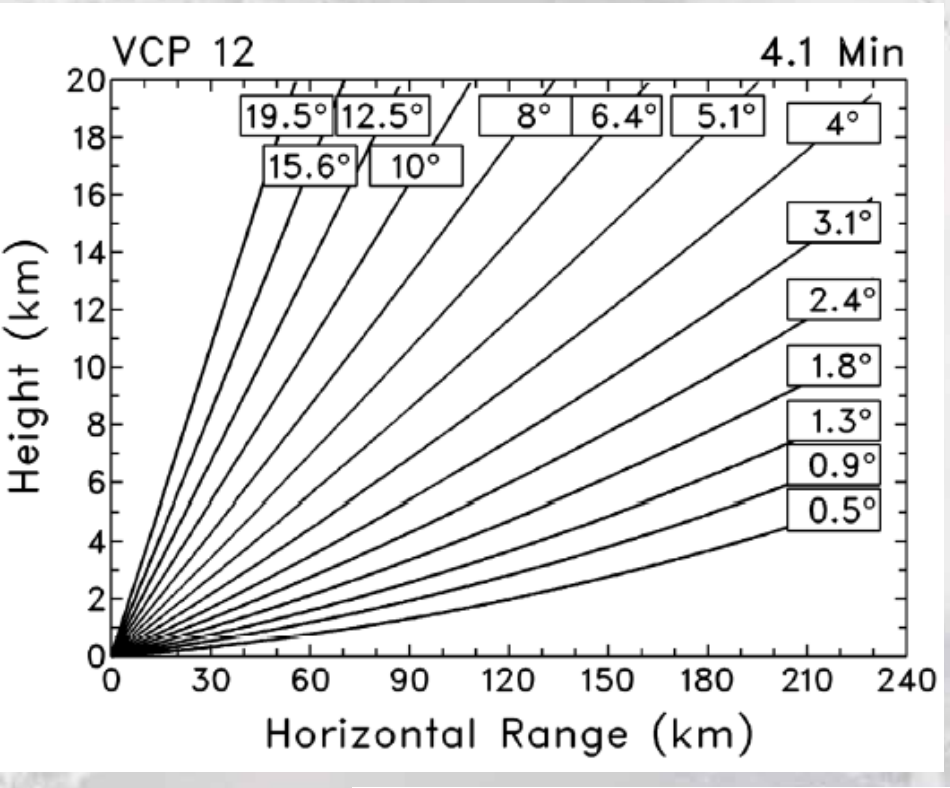

Hurricane Katrina (2005)
Central Pressure and Radius of Maximum Wind Estimates
Central Pressure (hPa)
Radius of Maximum Wind (km)
Time (DD:HH:MM)
980
970
960
950
940
930
920
910
900
45
40
35
30
25
20
15
10
5
29:09:00
29:09:30
29:10:00
29:10:30
29:11:00
29:11:30
Landfall (Buras LA)
NHC Advisory Central Pressure
AF Recon
VORTRAC Central Pressure (w/HVVP)
VORTRAC Central Pressure (w/o HVVP)
VORTRAC RMW

Confidence Level

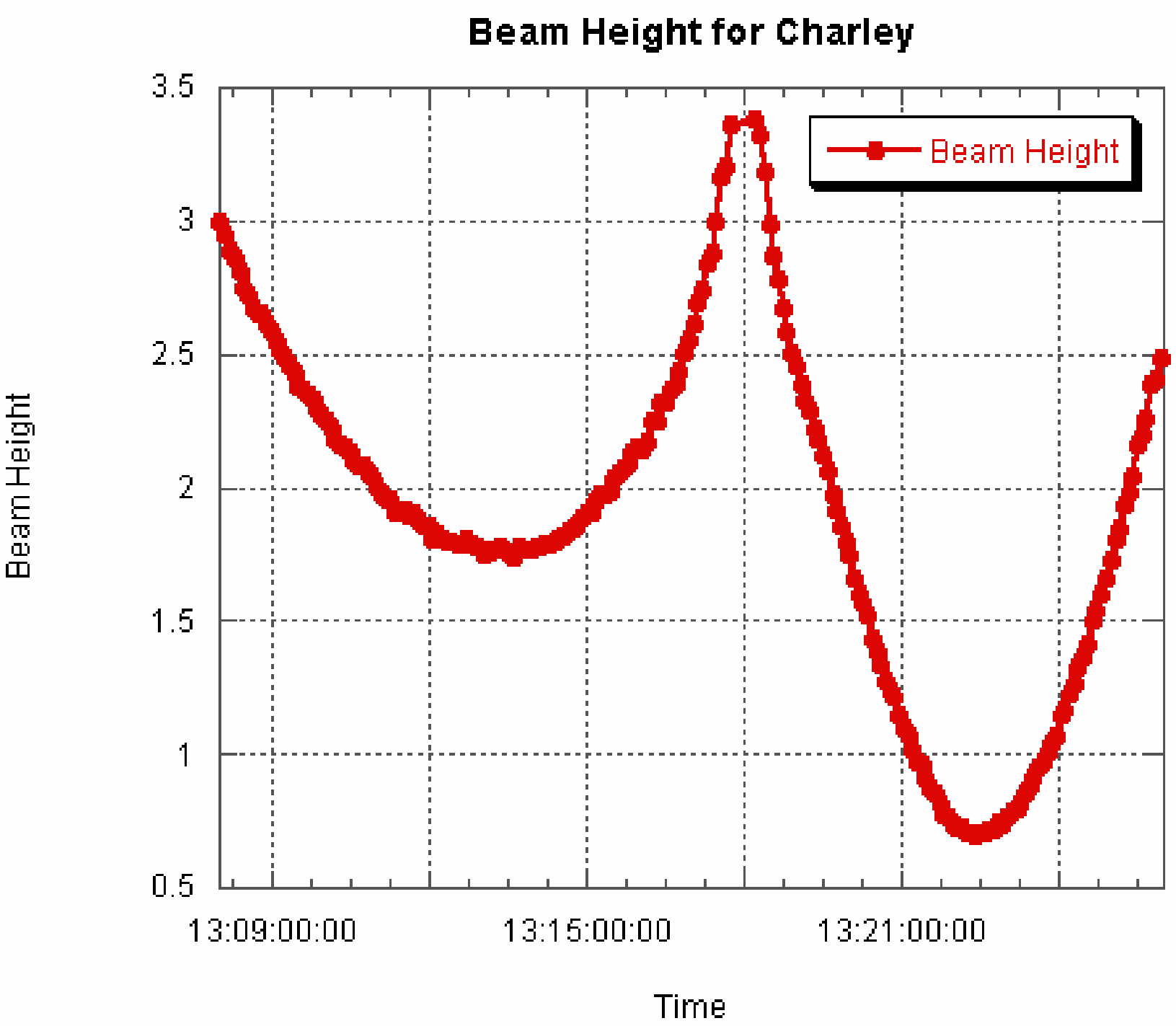
- Charlie
  - X: 0.56 km
  - Y: 0.70 km
  - RMW: 0.82 km
  - VT: 1.9 m/s
- Katrina
  - X: 0.86 km
  - Y: 2.58 km
  - RMW: 4.38 km
  - VT: 9.00 m/s

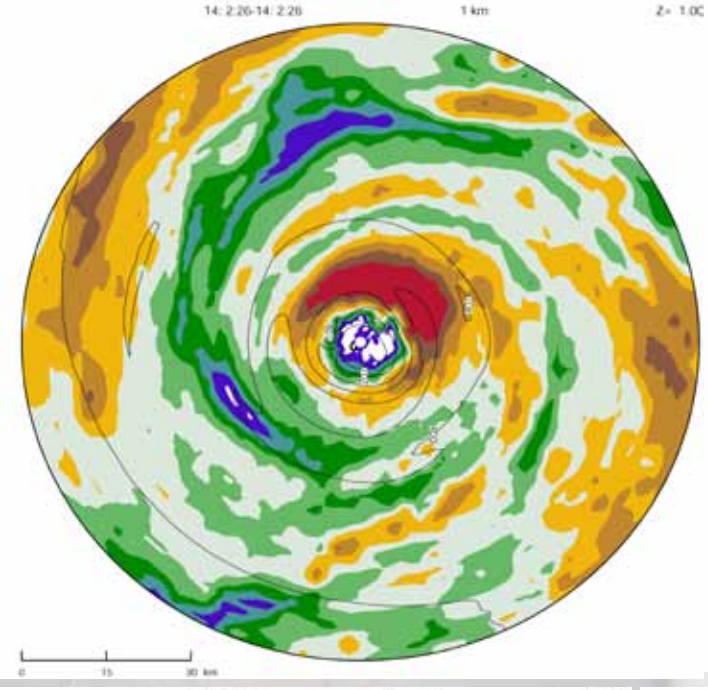
WSR-88D Scanning Sequence

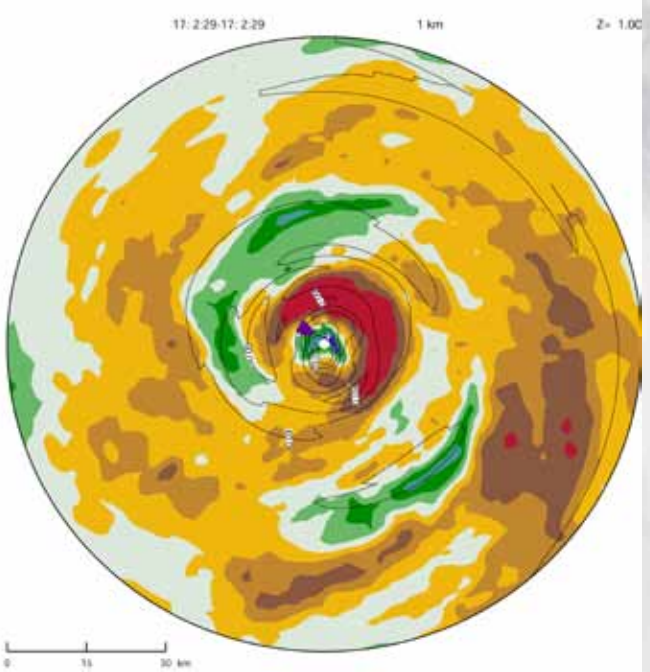
- VCP 12
- VCP 121

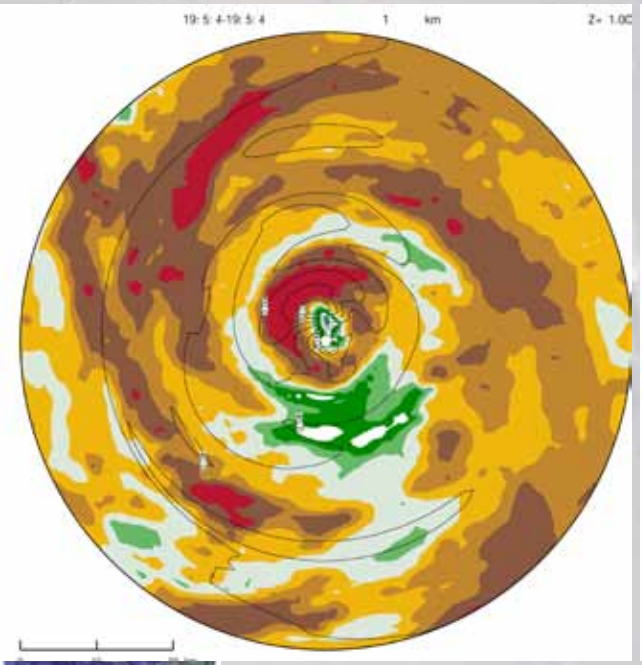


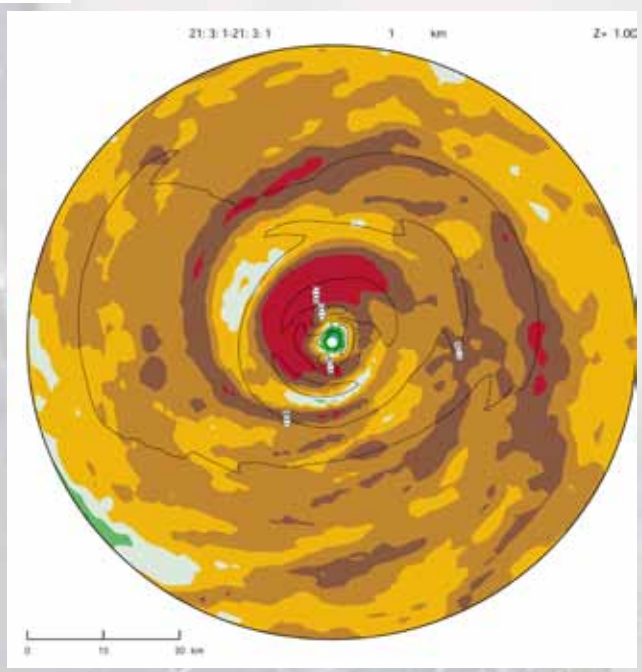
Tilt #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
VCP 11	0.5	1.45	2.4	3.35	4.3	5.2	6.2	7.5	8.7	10.0	12.0	14.0	16.7	19.5
VCP 21	0.5	1.45	2.4	3.35	4.3	6.0	9.9	14.6	19.5					
VCP 31	0.5	1.5	2.5	3.5	4.5									
VCP 32	0.5	1.5	2.5	3.5	4.5									
VCP 12	**0.5**	**0.9**	**1.3**	**1.8**	**2.4**	**3.1**	**4.0**	**5.1**	**6.4**	**8.0**	**10.0**	**12.5**	**15.6**	**19.5**
VCP121	**0.5**	**1.45**	**2.4**	**3.35**	**4.3**	**6.0**	**9.9**	**14.6**	**19.5**					

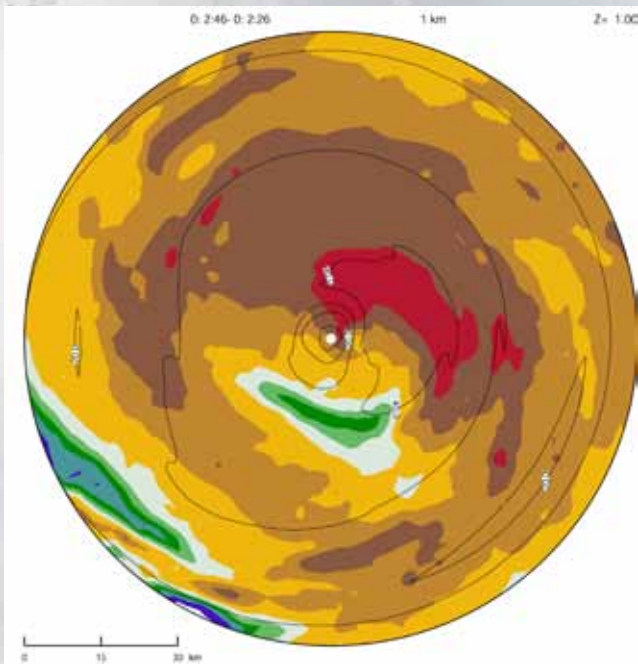

Beam Height for Charley
Beam Height
3.5
3
2.5
2
1.5
1
0.5
13:09:00:00
13:15:00:00
13:21:00:00
Time
Beam Height











Deployment
Development
Data Services

GBVTD Formulation:

$$V_d = V_M \cos(\theta - \theta_M)\cos\phi - V_T \sin\varphi \cos\phi + V_R \cos\varphi \cos\phi + (w - v_t)\sin\phi$$

$$\frac{\hat{V}_d}{\cos\phi} = V_M \cos(\theta - \theta_M) - V_T \sin\varphi + V_R \cos\varphi$$

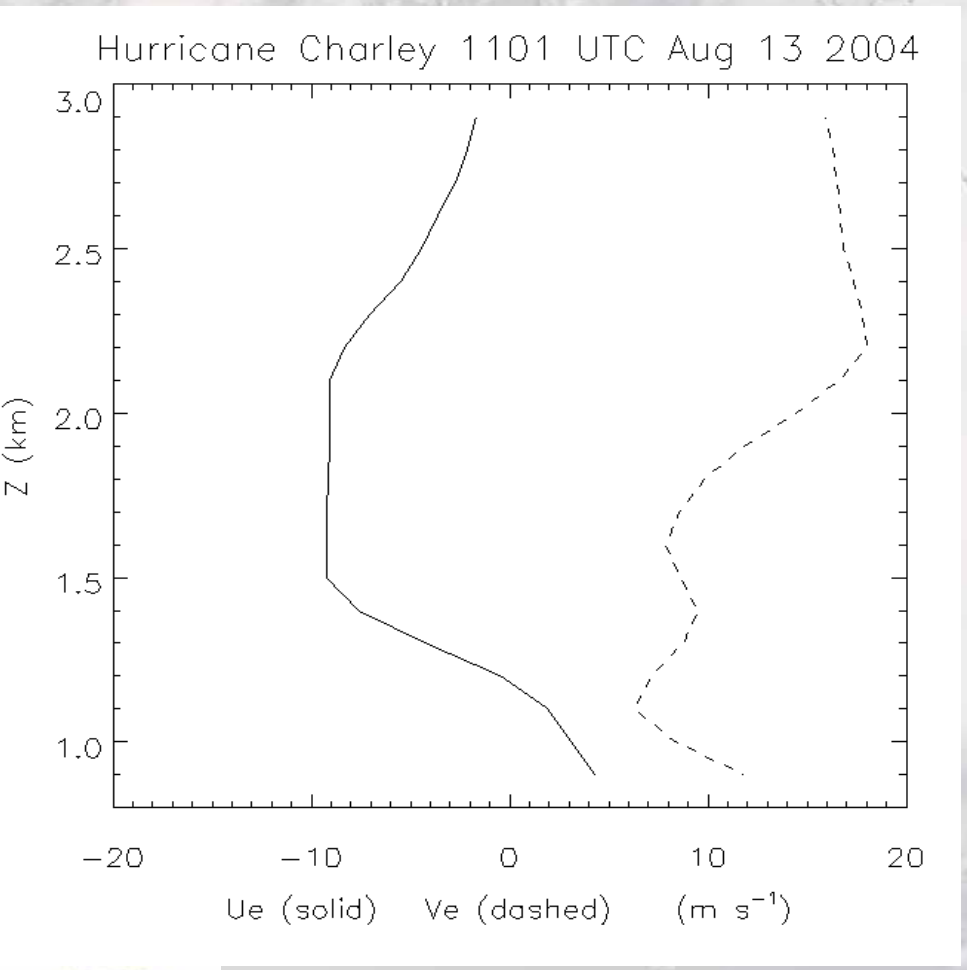
$$\frac{\grave{U}_d(\varphi)}{\cos\phi} = \sum_{n=0}^{L} (A_n \cos n\varphi + B_n \sin n\varphi)$$

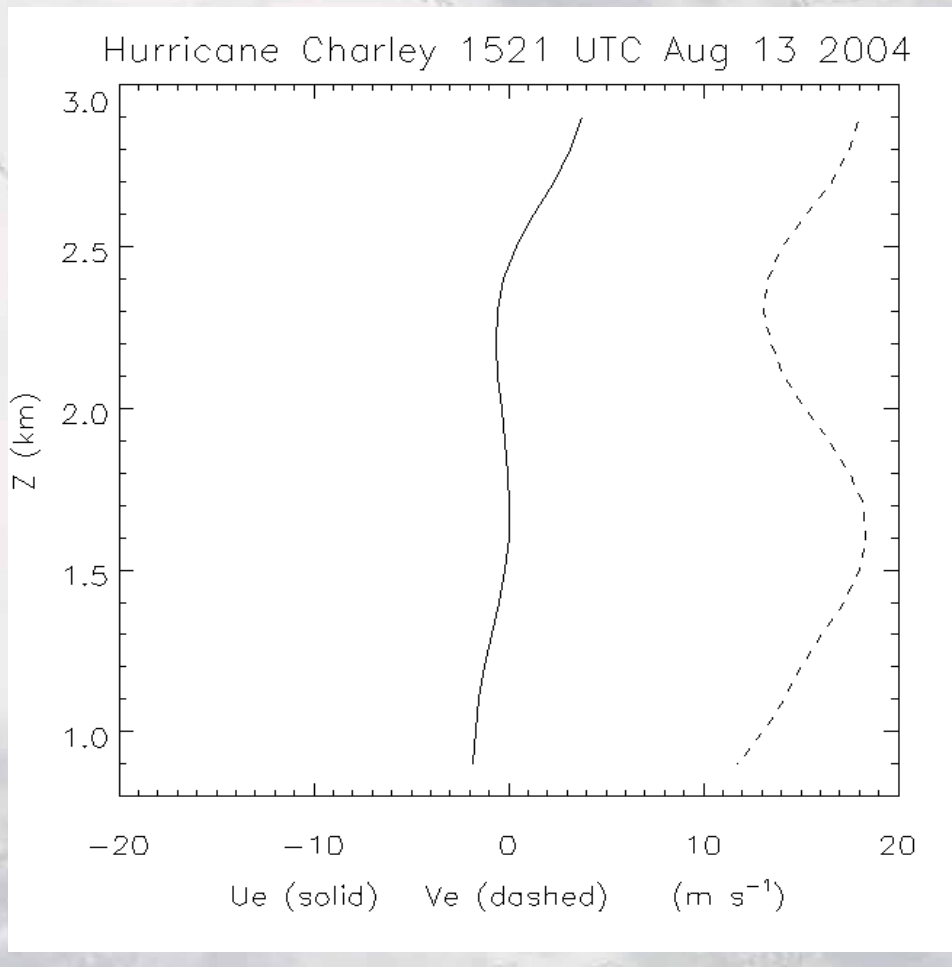
$$V_T(\varphi) = \sum_{n=0}^{M} (V_T C_n \cos n\varphi + V_T S_n \sin n\varphi)$$

$$V_R(\varphi) = \sum_{n=0}^{N} (V_R C_n \cos n\varphi + V_R S_n \sin n\varphi)$$

V_d: Doppler velocities
V_M: Mean flow
V_T: Tangential wind
V_R: Radial velocity
w: Vertical velocity
v_t: Terminal velocity
ϕ : Elevation angle
φ : Angle in GBVTD coordinate
θ: Azimuth angle
θ_M: Math angle of the mean flow
C_n: Amplitude of cosine wavenumber n
S_n: Amplitude of sine wavenumber n

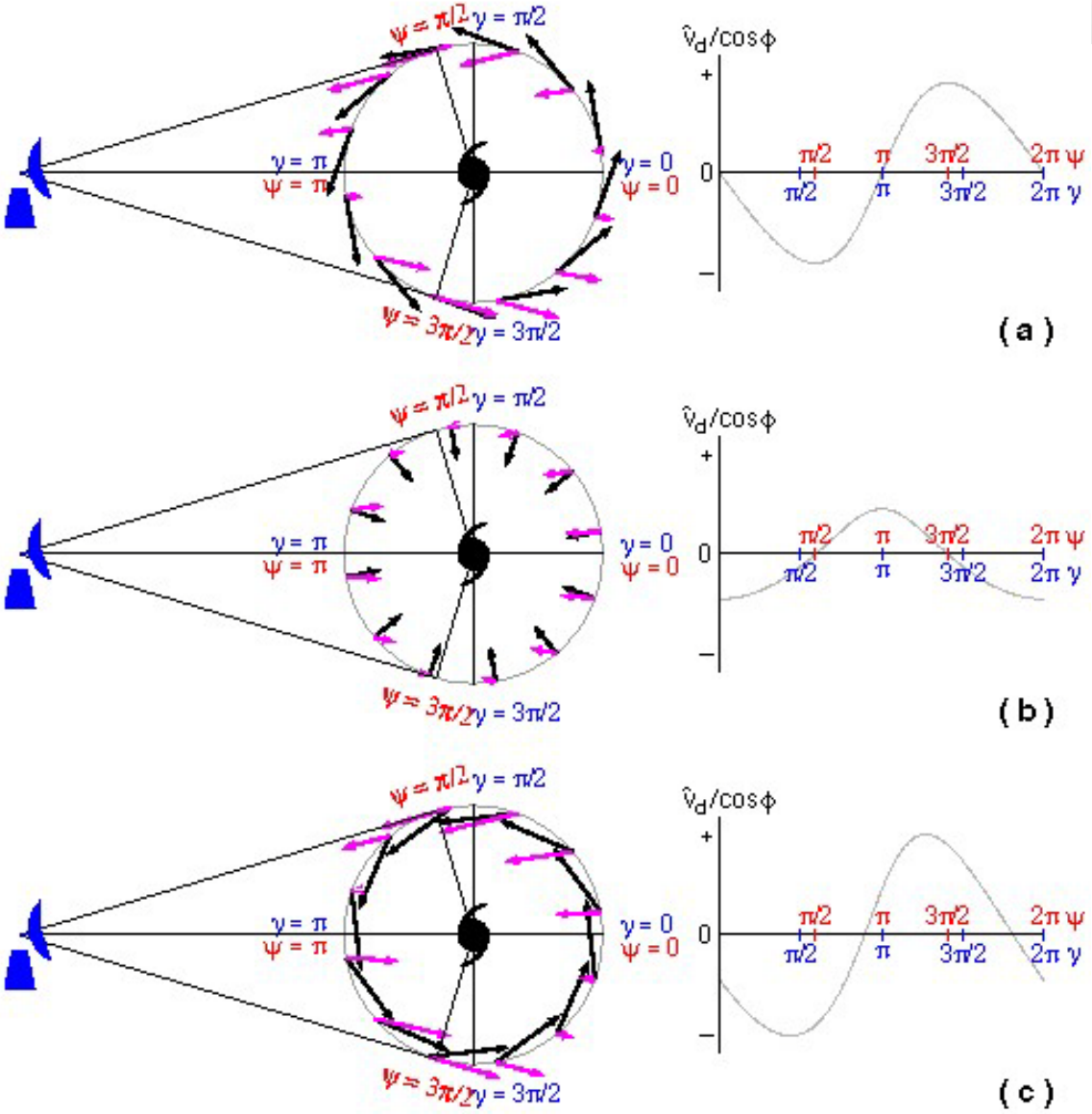
HVVP Mean Wind Profiles

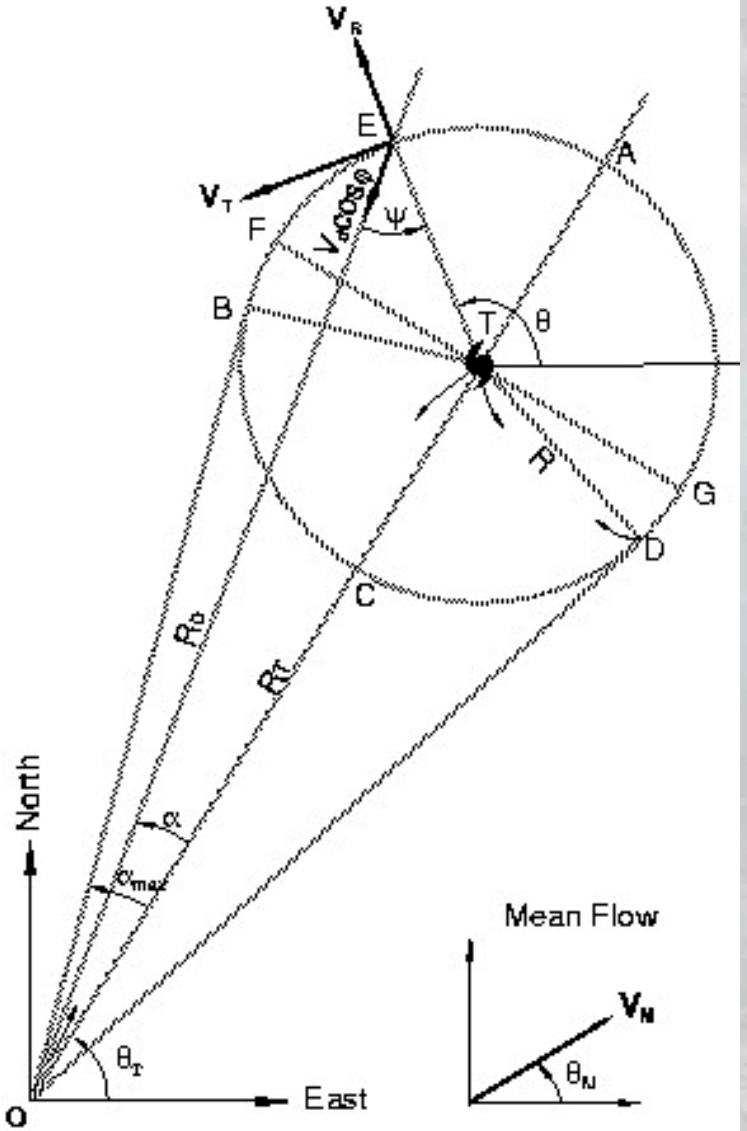




The GBVTD Technique

Lee, Jou, Chang, and Deng (1999)





VTD Formulation

For L=3, M=N=2:

$$V_M \cos(q_T - q_M) = (A_0 - A_2)/\cos a_{\max}$$

$$V_T C_0 = -B_1 - B_3 - V_M \sin(q_T - q_M)\sin a_{\max} - V_R S_2$$

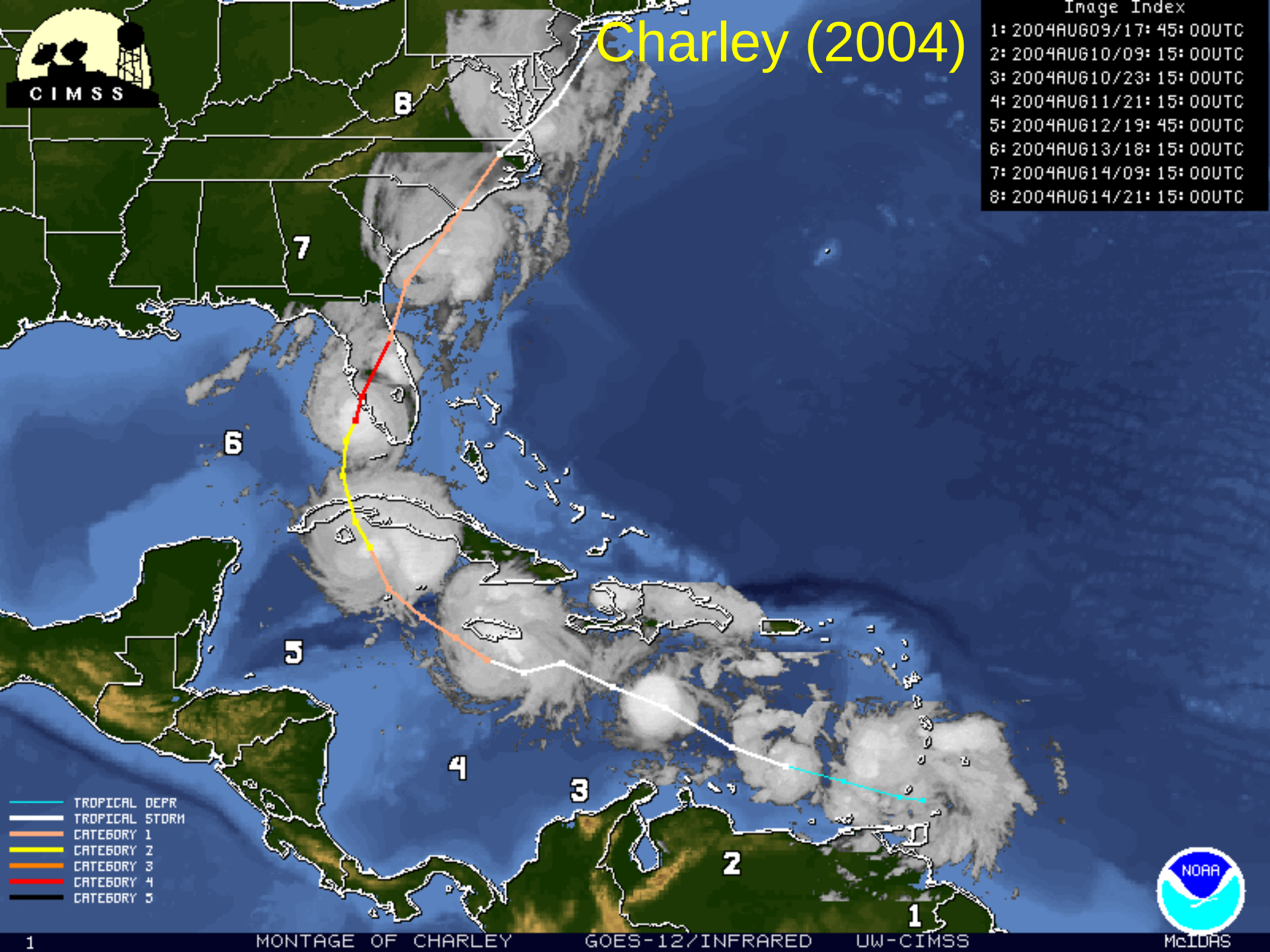
$$V_R C_0 = A_1 + A_3 - V_R C_2$$

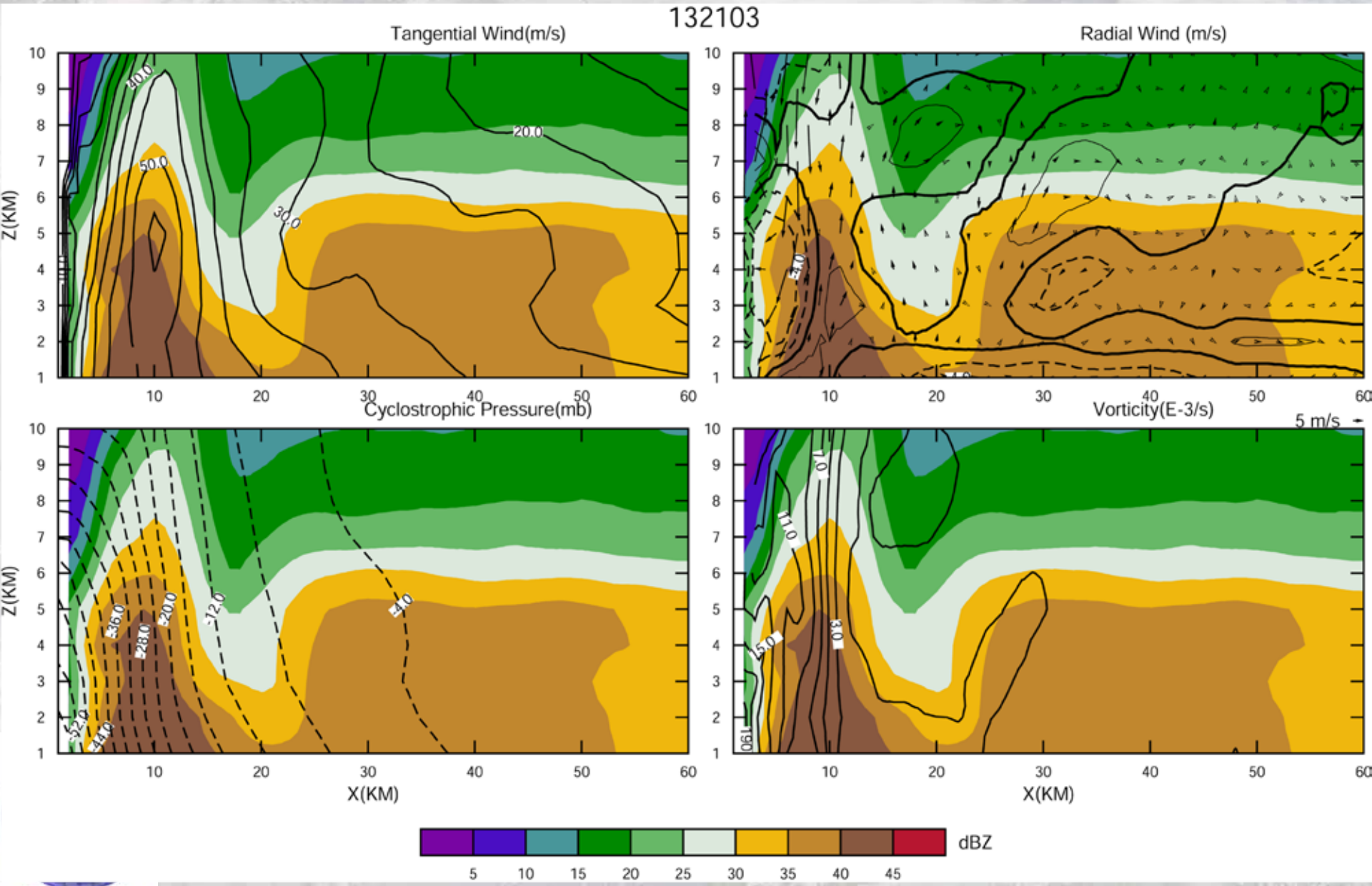
$$V_T S_1 = A_2 + A_0 - V_M \cos(q_T - q_M) - V_R C_1$$

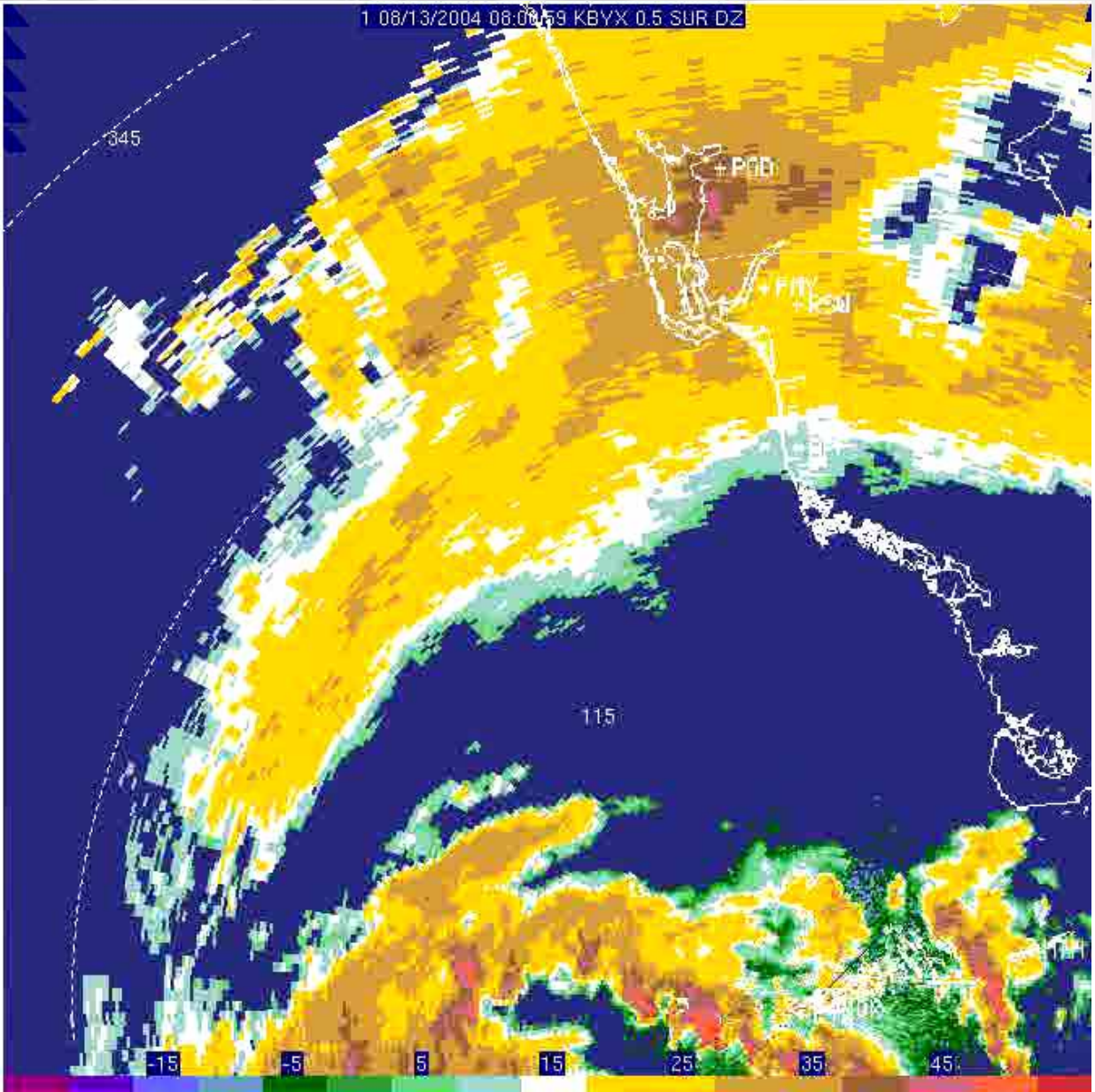
$$V_T C_1 = -2B_2 + V_R S_1$$

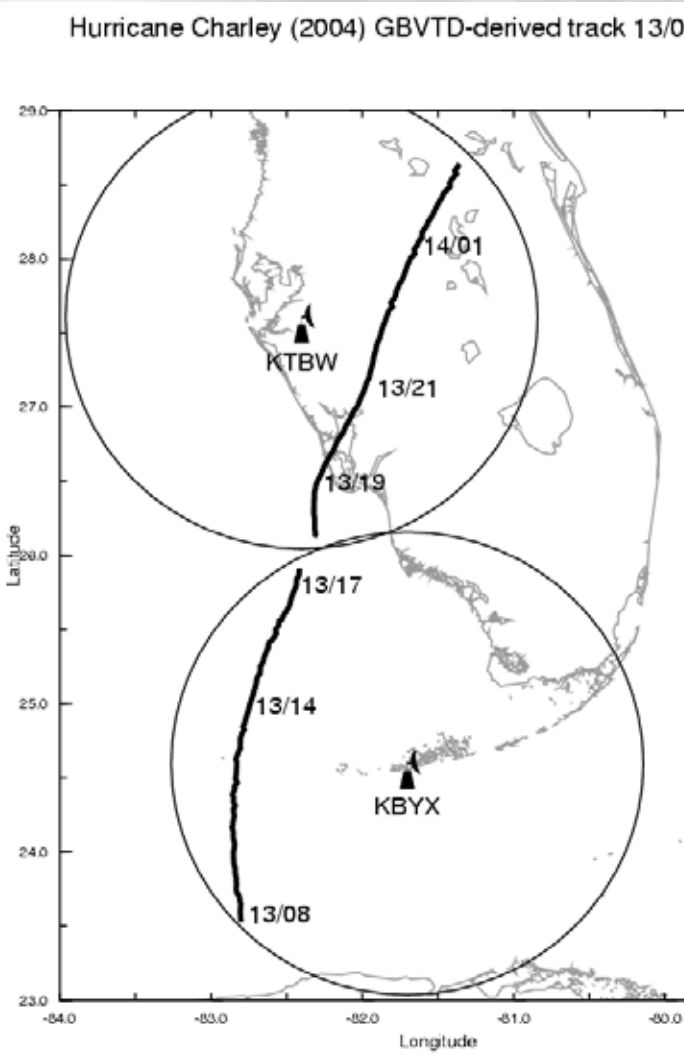
$$V_T S_2 = 2A_3 - V_R C_2$$

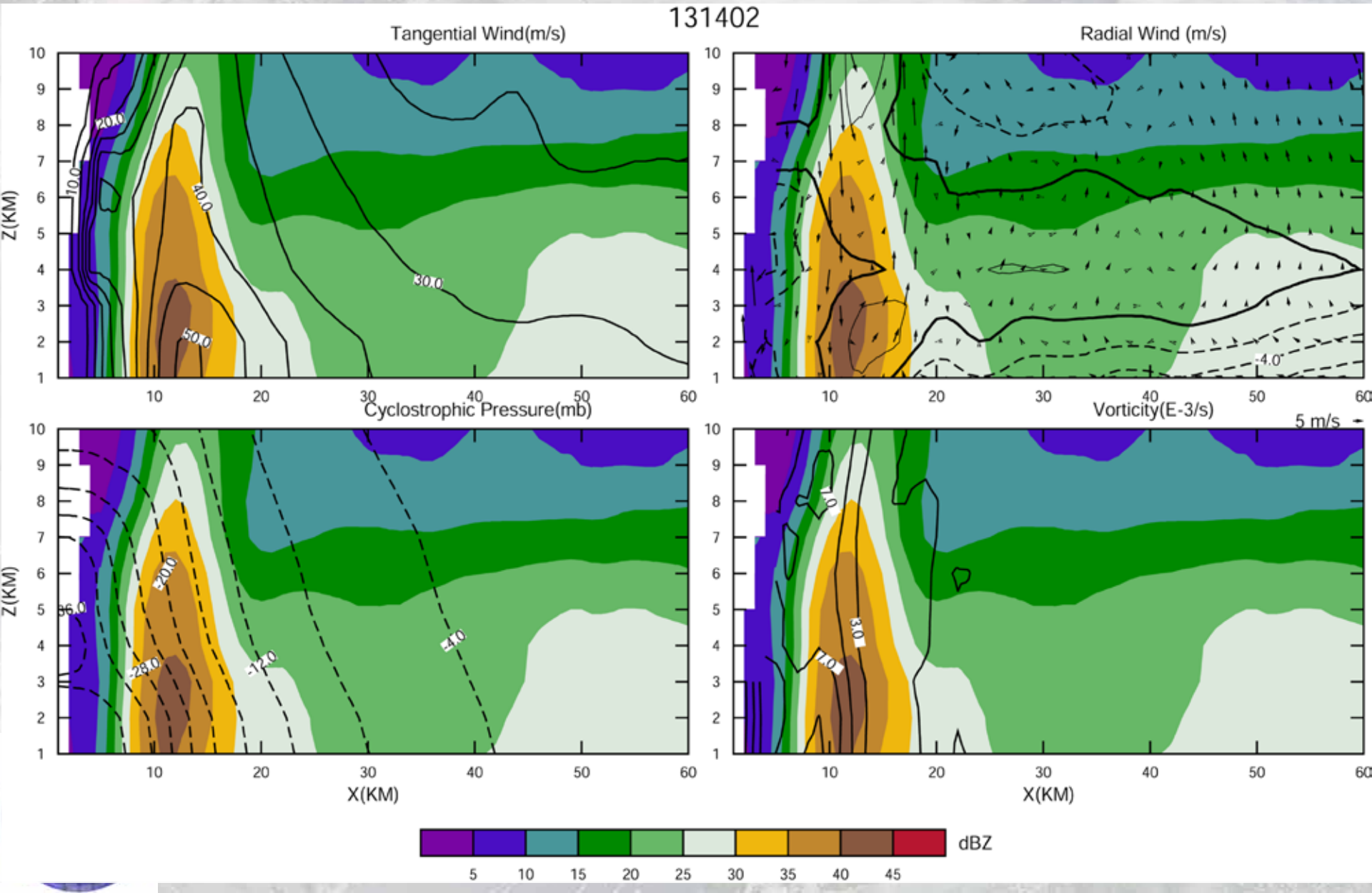
$$V_T C_2 = -2B_3 + V_R S_2$$

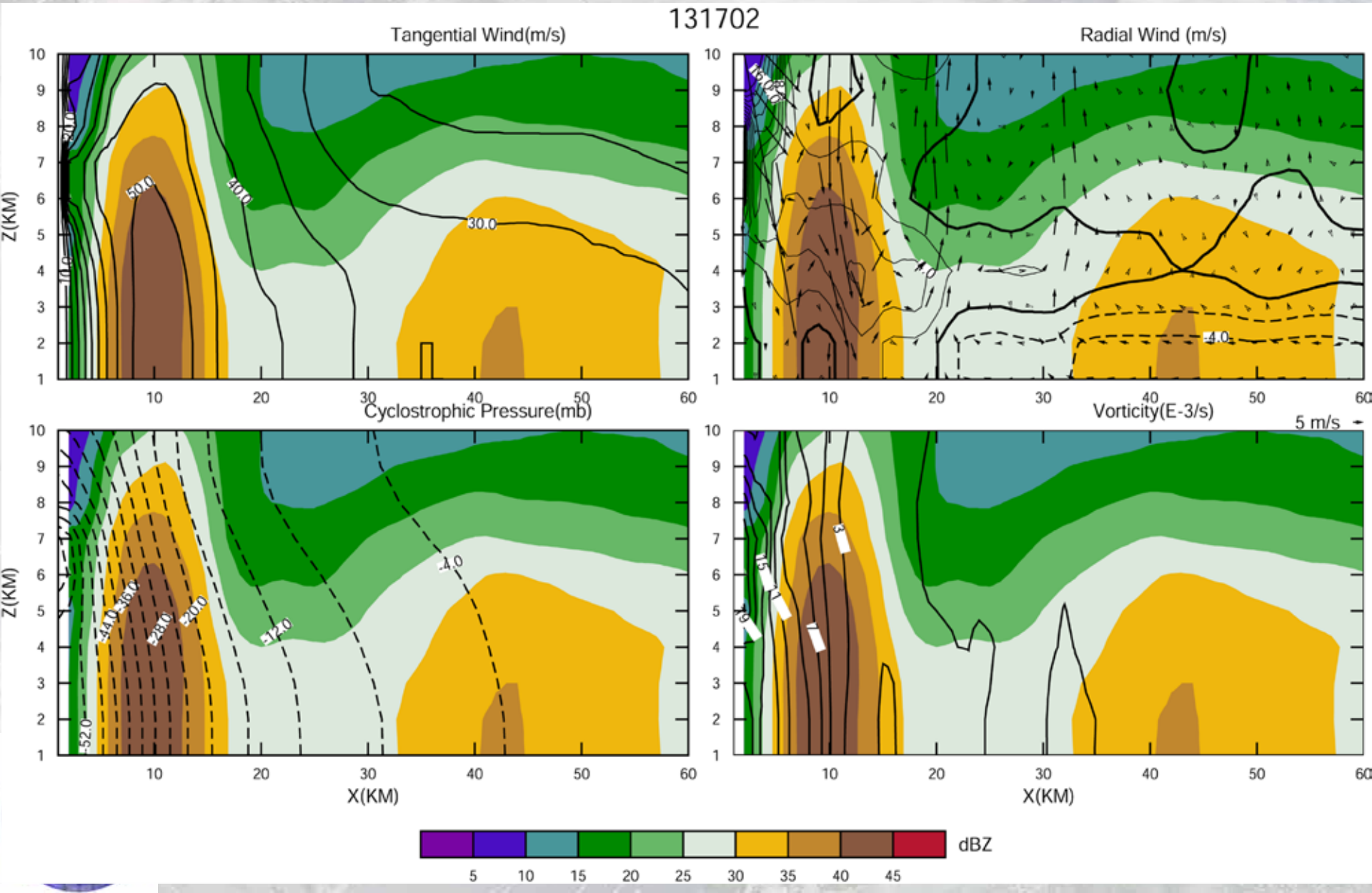

Charley (2004)
Image Index
1: 2004AUG09/17:45:00UTC
2: 2004AUG10/09:15:00UTC
3: 2004AUG10/23:15:00UTC
4: 2004AUG11/21:15:00UTC
5: 2004AUG12/19:45:00UTC
6: 2004AUG13/18:15:00UTC
7: 2004AUG14/09:15:00UTC
8: 2004AUG14/21:15:00UTC
CIMSS
TROPICAL DEPR
TROPICAL STORM
CATEGORY 1
CATEGORY 2
CATEGORY 3
CATEGORY 4
CATEGORY 5
NOAA
1 MONTAGE OF CHARLEY GOES-12/INFRARED UW-CIMSS McIDAS

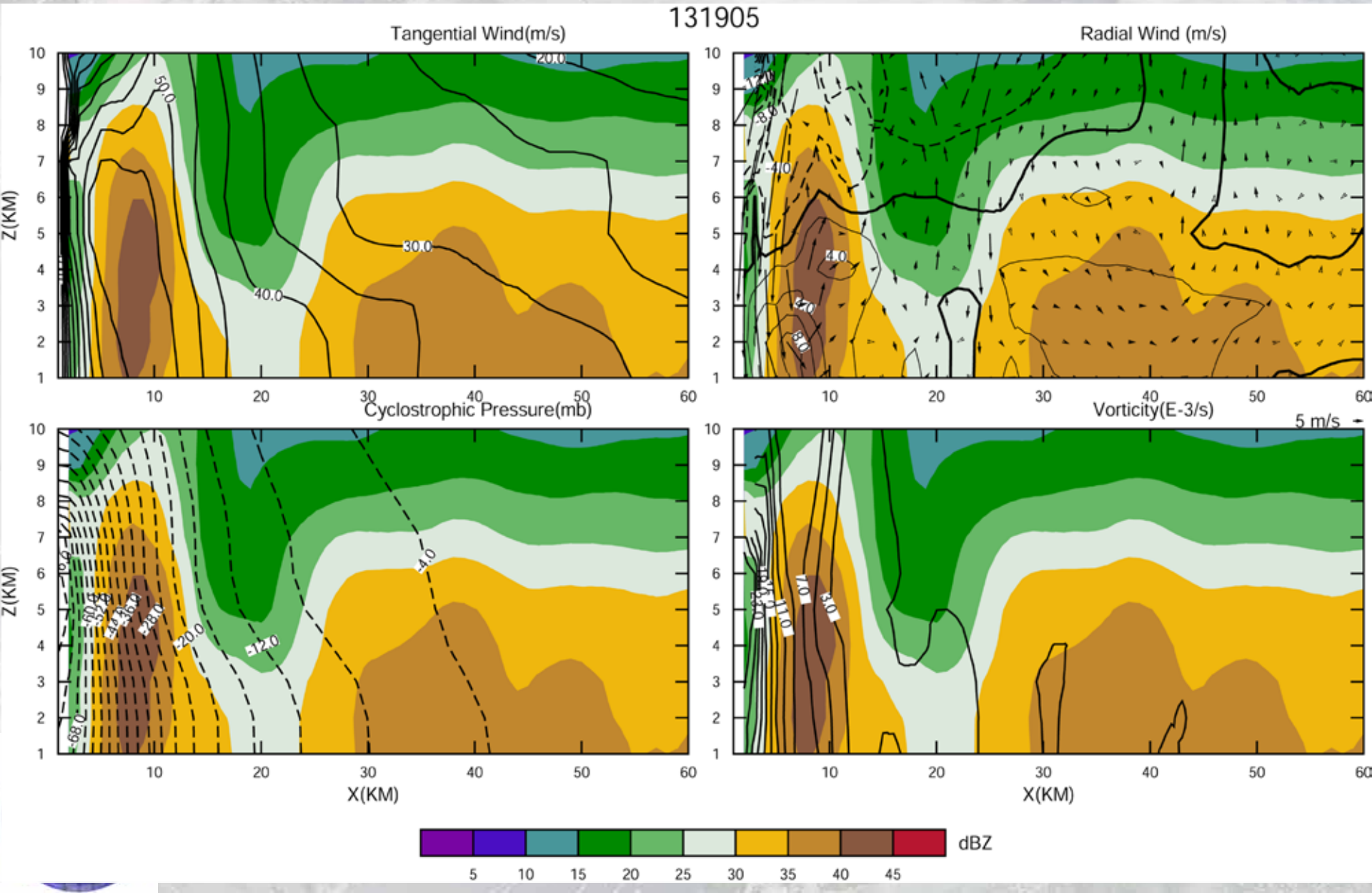

132103
Tangential Wind(m/s)
Radial Wind (m/s)
Cyclostrophic Pressure(mb)
Vorticity(E-3/s)
5 m/s
Z(KM)
X(KM)
dBZ
5
10
15
20
25
30
35
40
45

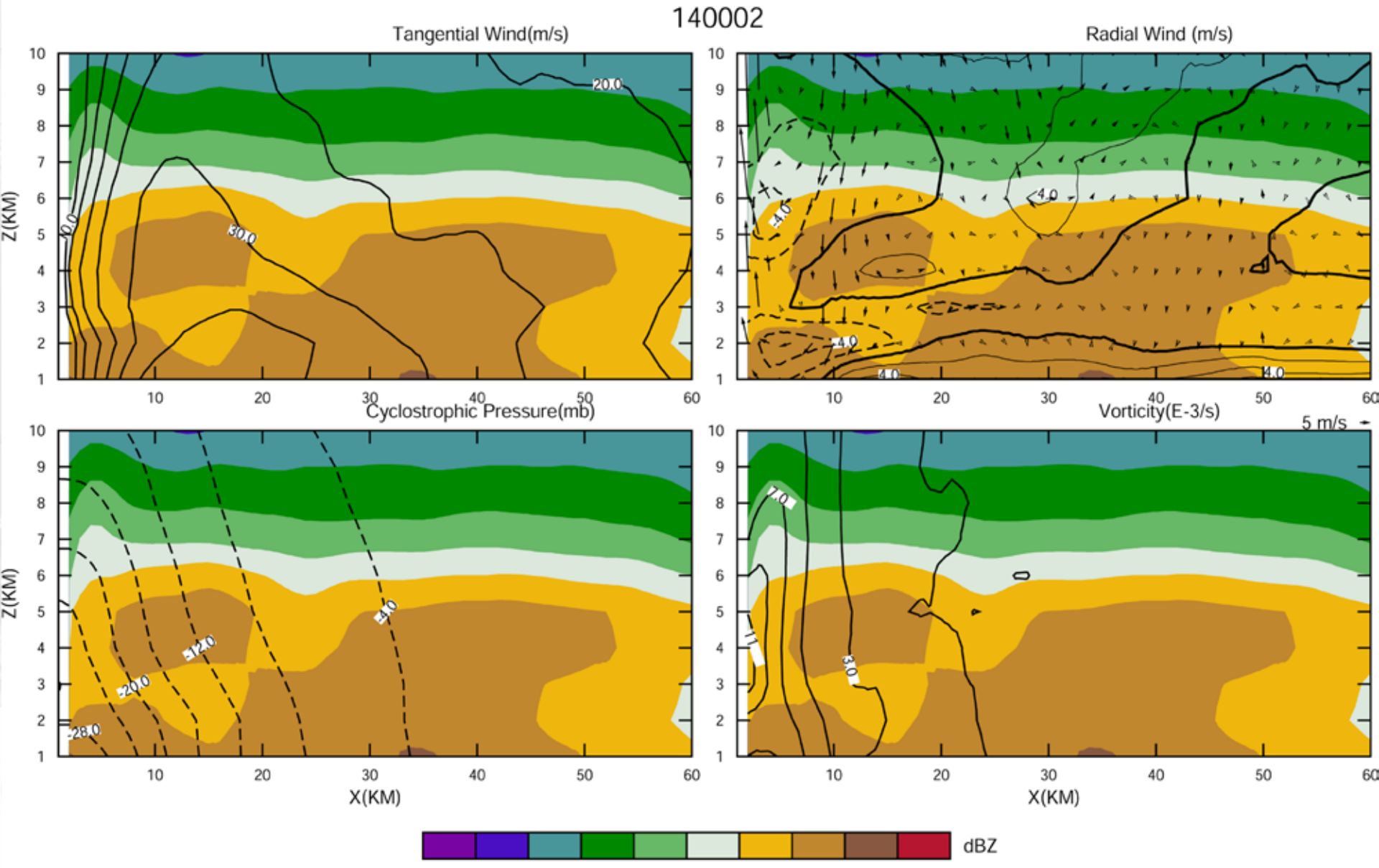

1 08/13/2004 08:00:59 KBYX 0.5 SUR DZ
345
115
-15
-5
5
15
25
35
45

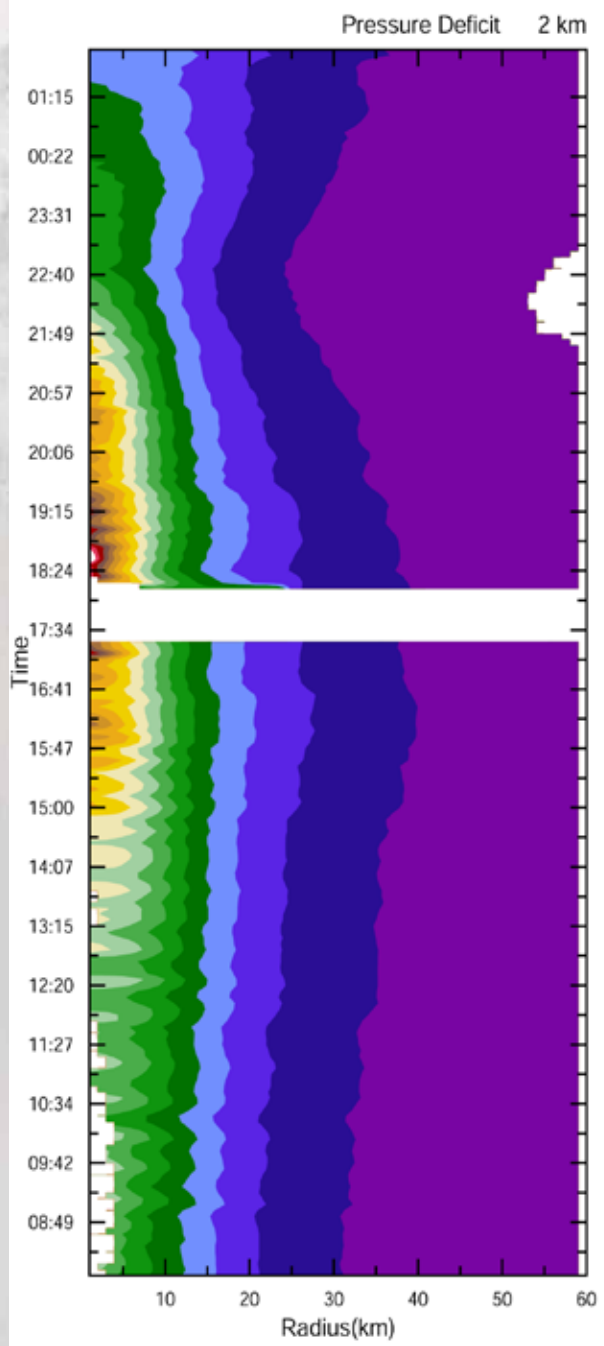

Hurricane Charley (2004) GBVTD-derived track 13/0
14/01
KTBW
13/21
13/19
13/17
13/14
KBYX
13/08
29.0
28.0
27.0
26.0
25.0
24.0
23.0
-84.0
-83.0
-82.0
-81.0
-80.0
Longitude

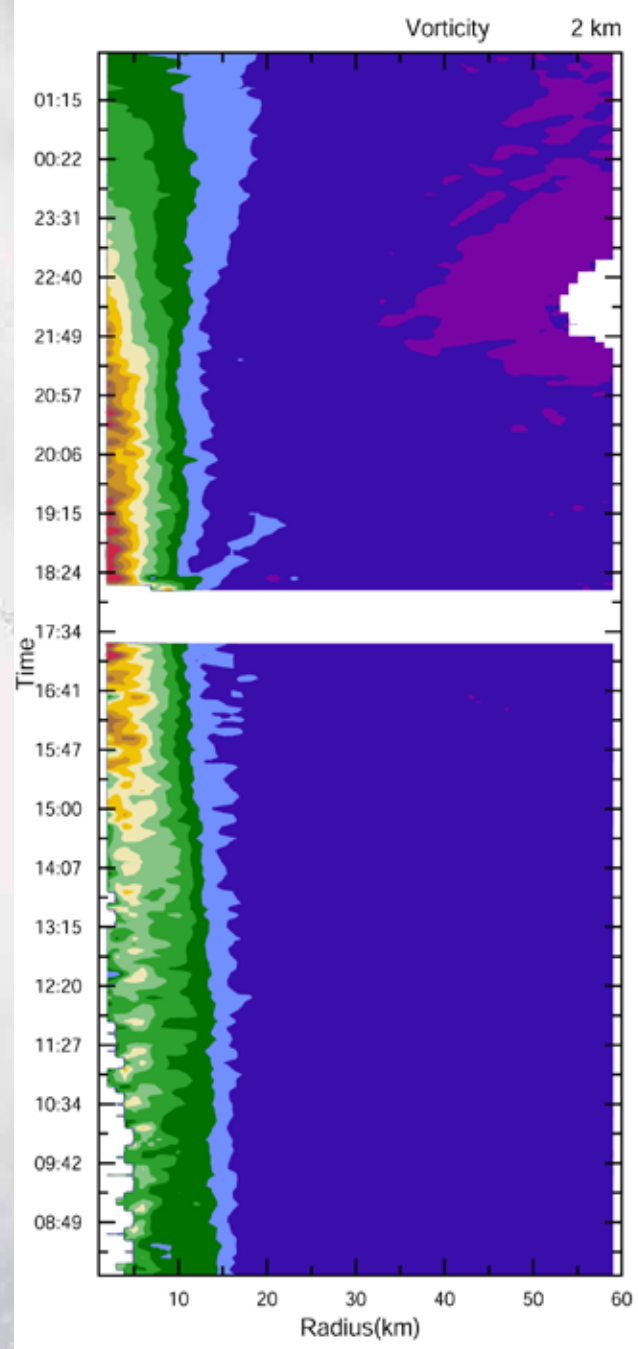

131402
Tangential Wind(m/s)
Radial Wind (m/s)
Cyclostrophic Pressure(mb)
Vorticity(E-3/s)
5 m/s
Z(KM)
X(KM)
dBZ
5 10 15 20 25 30 35 40 45


131702
Tangential Wind(m/s)
Radial Wind (m/s)
Cyclostrophic Pressure(mb)
Vorticity(E-3/s)
5 m/s
Z(KM)
X(KM)
dBZ
5
10
15
20
25
30
35
40
45


131905
Tangential Wind(m/s)
Radial Wind (m/s)
Cyclostrophic Pressure(mb)
Vorticity(E-3/s)
5 m/s
Z(KM)
X(KM)
dBZ
5 10 15 20 25 30 35 40 45


140002
Tangential Wind(m/s)
Radial Wind (m/s)
Cyclostrophic Pressure(mb)
Vorticity(E-3/s)
5 m/s
Z(KM)
X(KM)
dBZ





EOL
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Development
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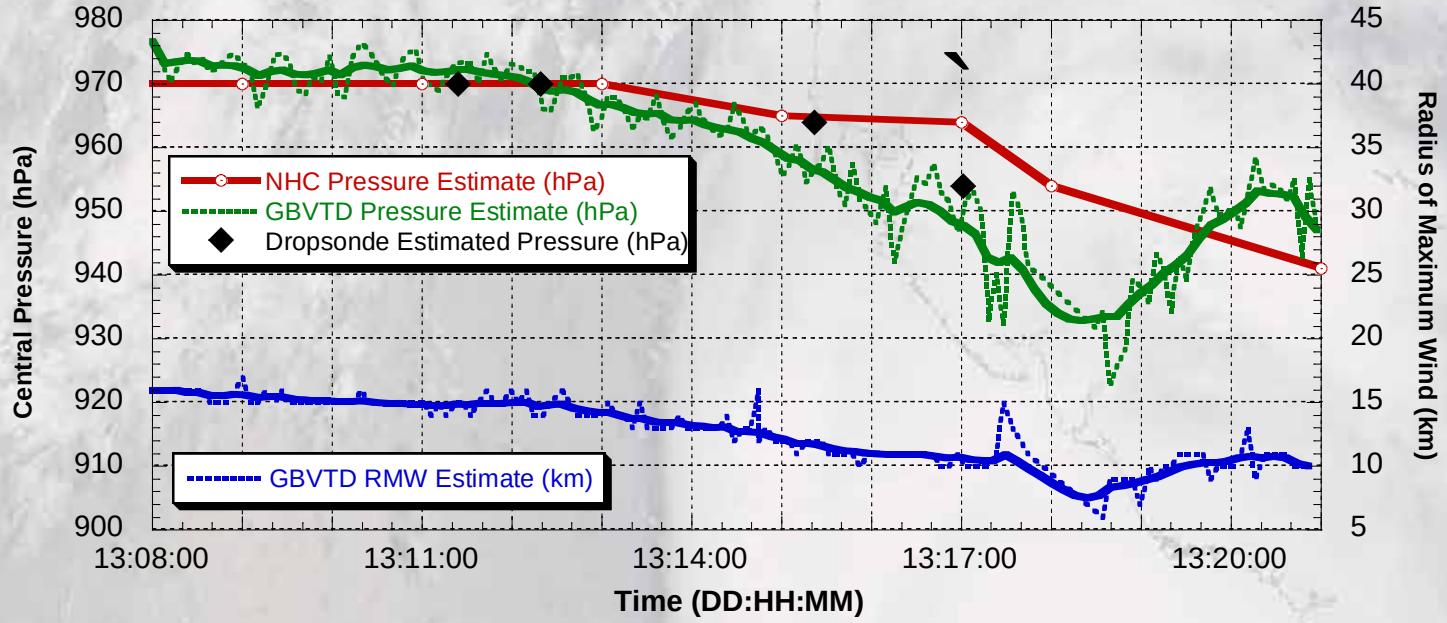
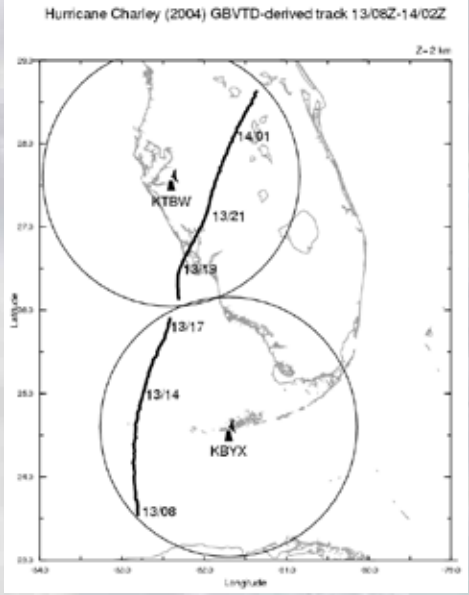
What have we learned from Charley?

- Rapid intensification can occur near landfall
- Coastal Doppler radar can effectively detect rapid intensification if they are operated properly
- Vertical structure of the eyewall can provide indications on intensity change (e.g., more scans at lower angles are needed)
- Most intense winds may occur in the eyewall but severe storms (e.g., tornado) may occur in the outer rainband precedes the arrival of the eye
- Longer range is preferred over higher Nyquist velocity when setting scanning parameters

Hurricane Charley (2004)
Central Pressure and Radius of Maximum Wind Estimates





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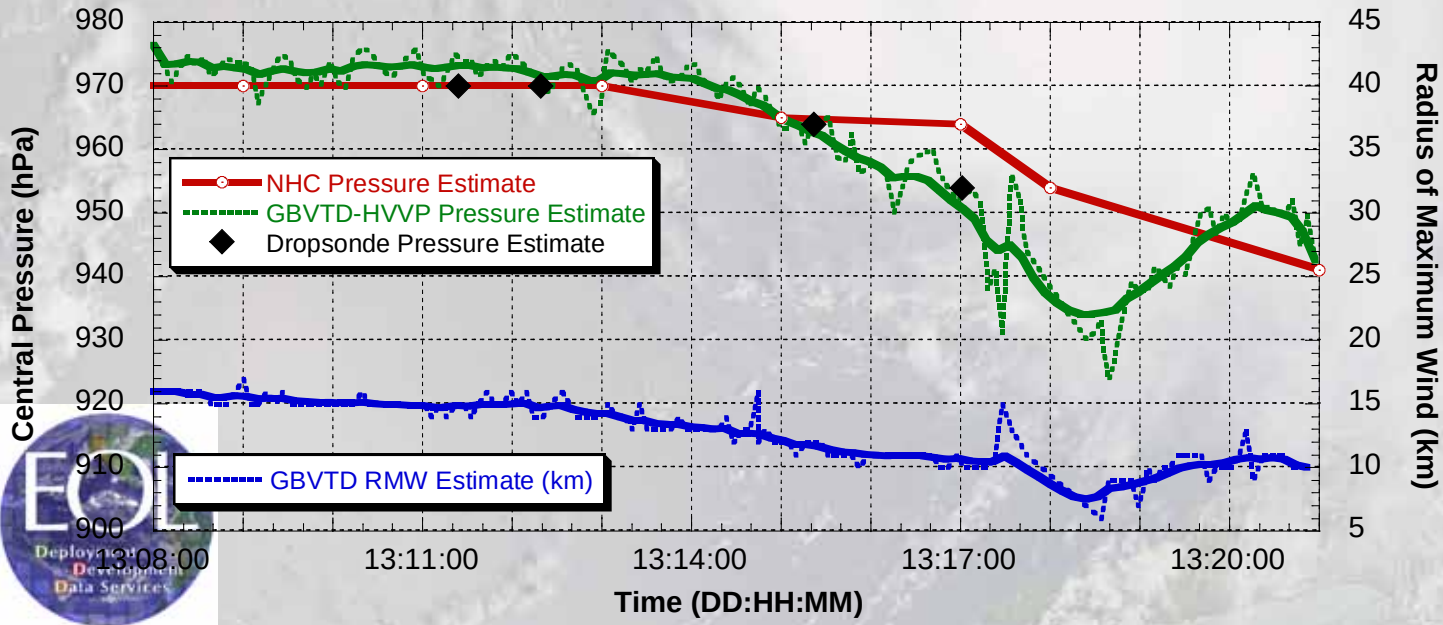
Central Pressure and Radius of Maximum Wind Estimates



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