

APR-2 Tropical Cyclone Observations

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Airborne 2nd Generation Precipitation Radar (APR-2)

- Dual-frequency operation with Ku-band (13.4 GHz) and Ka-band (35.6 GHz)
 - Geometry and frequencies chosen to simulate GPM radar
- Measures reflectivity at co- and cross-polarizations, and Doppler
- Range resolution is ~ 60 m
- Horizontal resolution at surface (DC-8 at 11 km altitude) is ~ 1 km

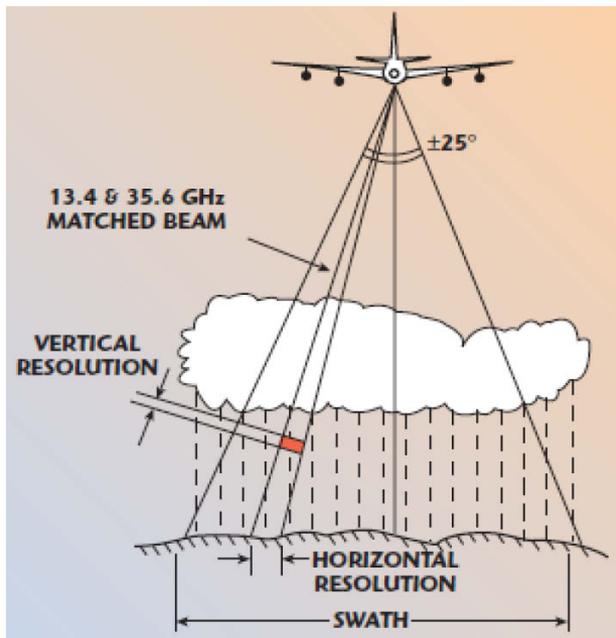
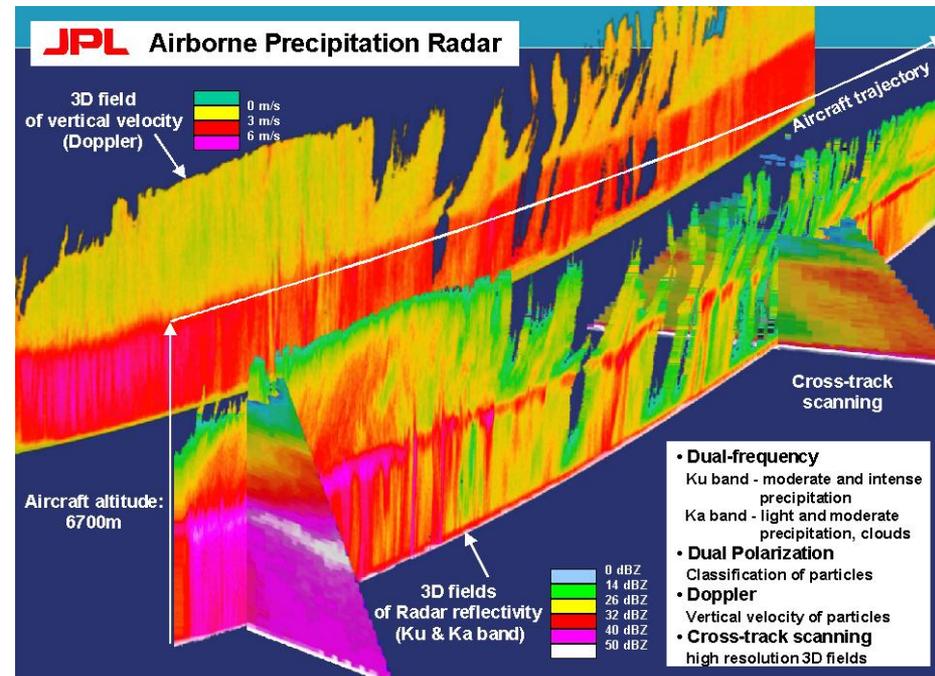


Image below shows 3D nature of APR-2 data; 50-degree data wedge underneath flight track



APR-2 Data Collected in Tropical Cyclones

Date	Name	Comments
8/20/01	Chantal	Tropical storm
9/15	Gabrielle	Tropical storm
9/22	Humberto	Tropical storm
9/23	Humberto	Cat 1
9/24	Humberto	Cat 1
8/23/06	Debby	Tropical storm
9/12	Helene	Tropical depression
8/29/10	Earl	Cat 1 – developing eye
8/30	Earl	Cat 3-4
9/1	Earl	Cat 4
9/2	Earl	Collapsing eyewall
9/14	Karl	Genesis
9/16	Karl	Emerged from Yucatan
9/17	Karl	Landfall – orographic rain

Post-Experiment Processing

- First step - align raw radar data with the aircraft navigation data
- Both nav data and our Doppler surface measurements are used to estimate aircraft orientation and correct APR-2 Doppler in precip
 - In standard product, the radar correction is used
- Calibration uses cal-loop data then surface reflectivity at Ku and light precipitation at Ka
- Products to be examined here:
 - 13 and 35 GHz reflectivity and their ratio (DWR)
 - Linear Depolarization Ratio (LDR)
 - Vertical motion – direct measurement is hydrometeor motion; v-Z relation can be used to estimate vertical air motion
 - Cross-track wind
 - estimated from using Doppler at each altitude over scan

Calculated Products from Cross-Wind

- We approximate the vortex azimuthal (tangential) wind v as the cross-track wind
 - a better estimate may be possible by correcting for scan angle versus hurricane radius vector
- Calculate the inertial frequency by

$$I^2 = \left(f + \frac{2v}{r} \right) \left(f + \frac{v}{r} + \frac{\partial v}{\partial r} \right)$$

- We can estimate
 - Boundary (Ekman) layer thickness $h = \sqrt{\frac{2K}{I}}$
 - Rossby length, where rotational effects become as important as buoyancy effects $L = NH/I$
 - Larger inertial stability \rightarrow smaller Rossby length \rightarrow “stiffer” vortex

Pressure/Density/Temperature from Wind Structure

- Use method from Smith, “Accurate determination of a balanced axisymmetric vortex in a compressible atmosphere,” *Tellus* 2006.
 - Assume axisymmetry, gradient and hydrostatic balance
 - Use anelastic approximation

$$\frac{\partial p}{\partial r} = \rho_o \left(\frac{v^2}{r} + f v \right) \quad \frac{\partial \rho}{\partial r} = -\frac{1}{g} \frac{\partial}{\partial z} \left[\rho_o \left(\frac{v^2}{r} + f v \right) \right]$$

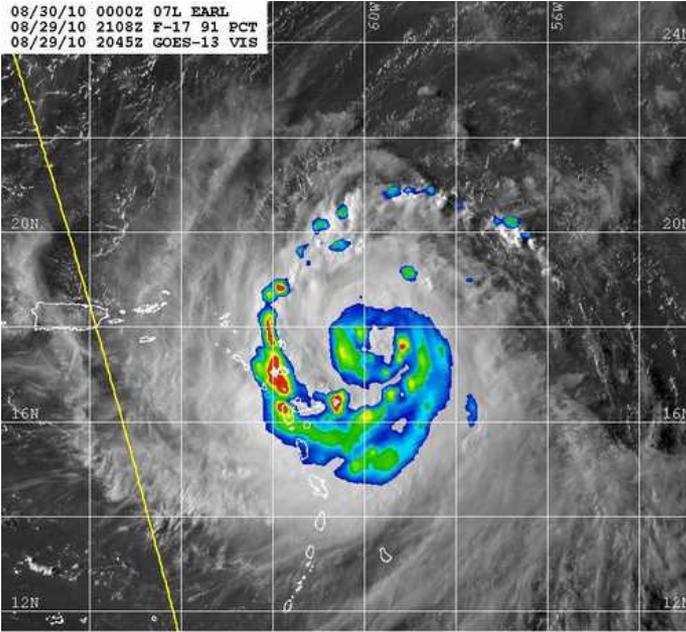
- ρ_o is environmental density; 1.2 kg/m³ at surface
- p is pressure
- Use finite difference approximation to compute right side of second eqn
- Integrate to get pressure/density versus radius at each altitude
- Can get temperature from pressure, density, and gas law

Microphysics from Dual-pol/Dual-frequency

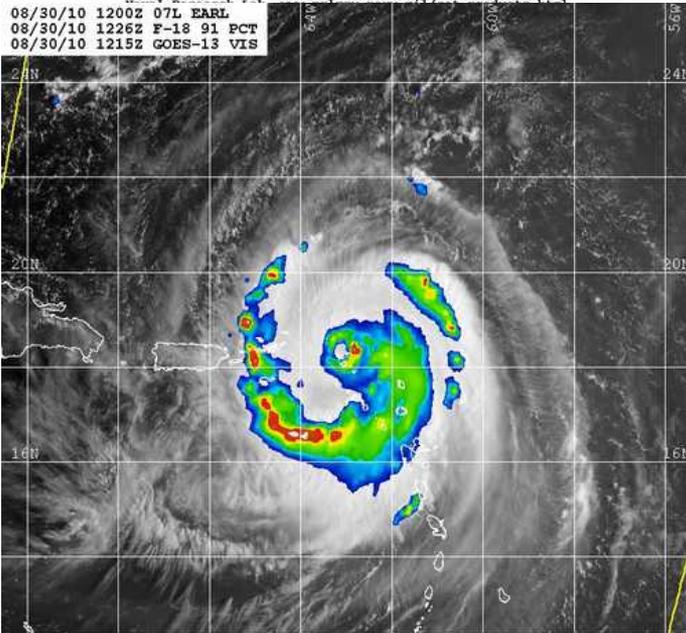
- LDR is generated by non-spherical particles
 - Mostly visible in mixed phase areas, even in convection
 - Primarily useful for qualitative applications, e.g., classification
- The dual-wavelength ratio (DWR) Ku/Ka is useful for identifying large ice particles
 - Larger particles tend to be in non-Rayleigh scattering regime at Ka-band but still in Rayleigh at Ku-band
 - Depressed Ka-band reflectivity results in non-zero DWR (in dB)
- In rain DWR is useful for identifying areas with heavy rainfall
 - Due to differential attenuation DWR becomes larger as rain rate increases
 - In very heavy rain DWR can potentially reach tens of dB

Passive Microwave Overview of Earl 8/29 & 8/30

08/30/10 0000Z 07L EARL
 08/29/10 2108Z F-17 91 PCT
 08/29/10 2045Z GOES-13 VIS



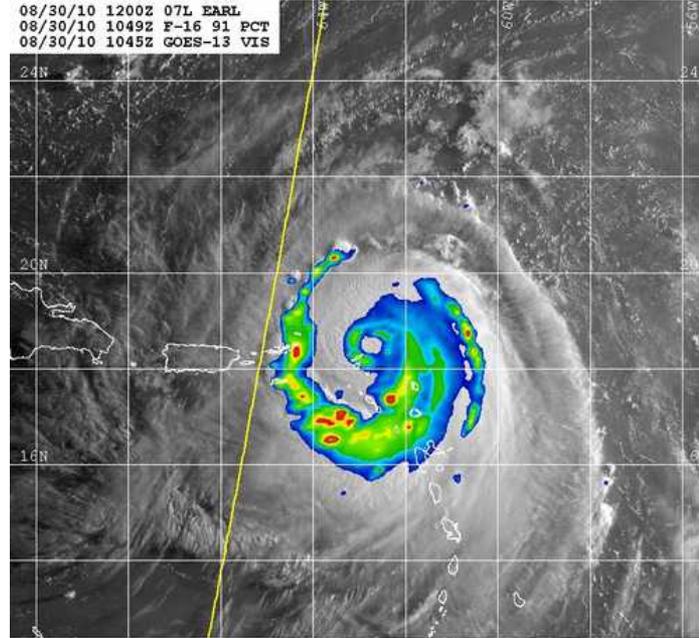
08/30/10 1200Z 07L EARL
 08/30/10 1226Z F-18 91 PCT
 08/30/10 1215Z GOES-13 VIS



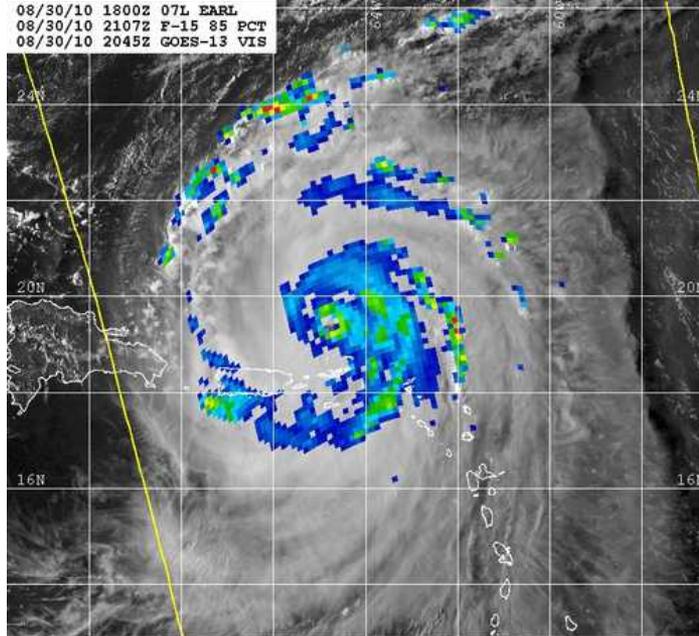
Naval Research Lab www.nrlmry.navy.mil/sat_products.html
 91 GHz PCT (Kelvin) -->



08/30/10 1200Z 07L EARL
 08/30/10 1049Z F-16 91 PCT
 08/30/10 1045Z GOES-13 VIS



08/30/10 1800Z 07L EARL
 08/30/10 2107Z F-15 85 PCT
 08/30/10 2045Z GOES-13 VIS

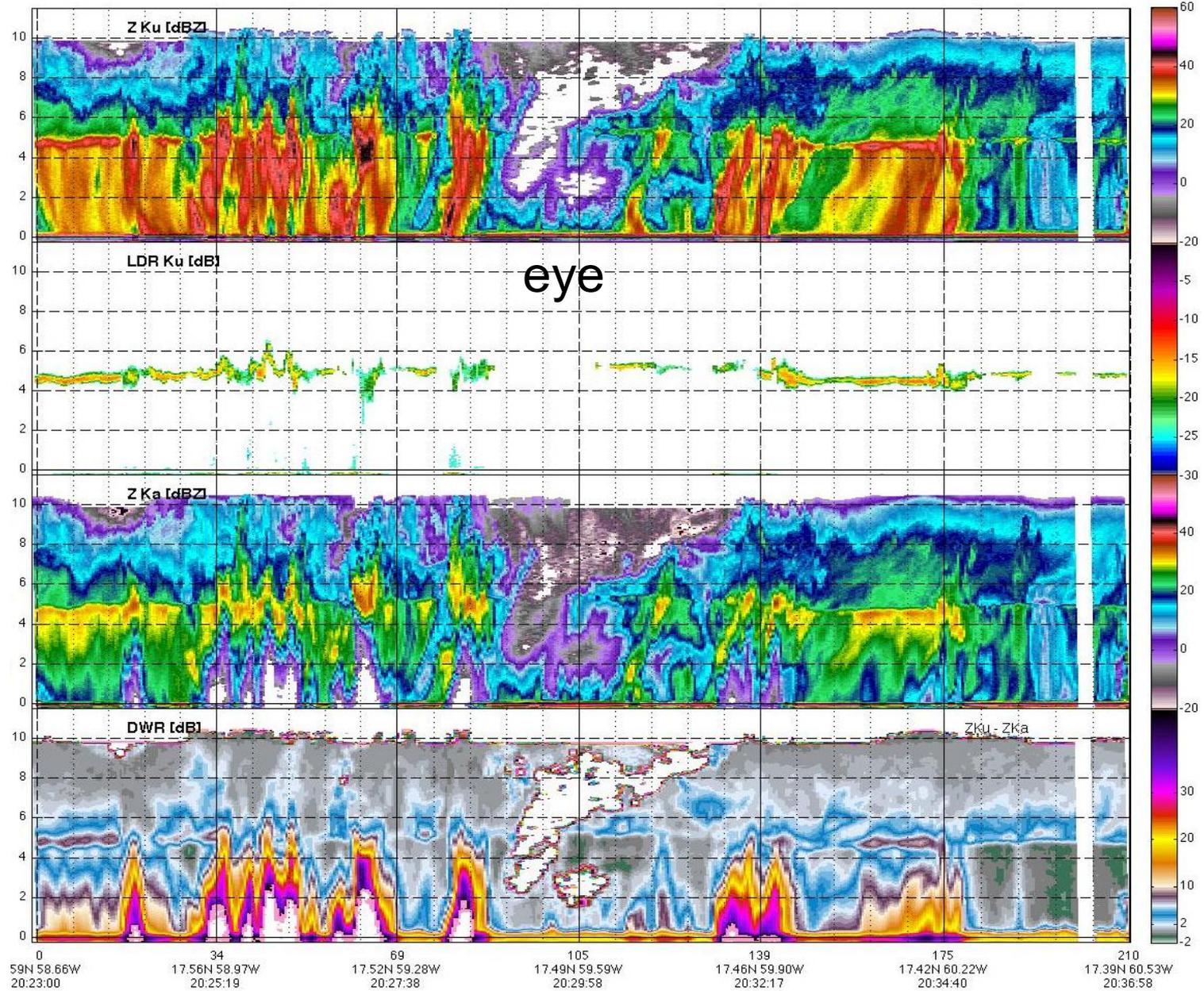


Naval Research Lab www.nrlmry.navy.mil/sat_products.html
 85 GHz PCT (Kelvin) -->

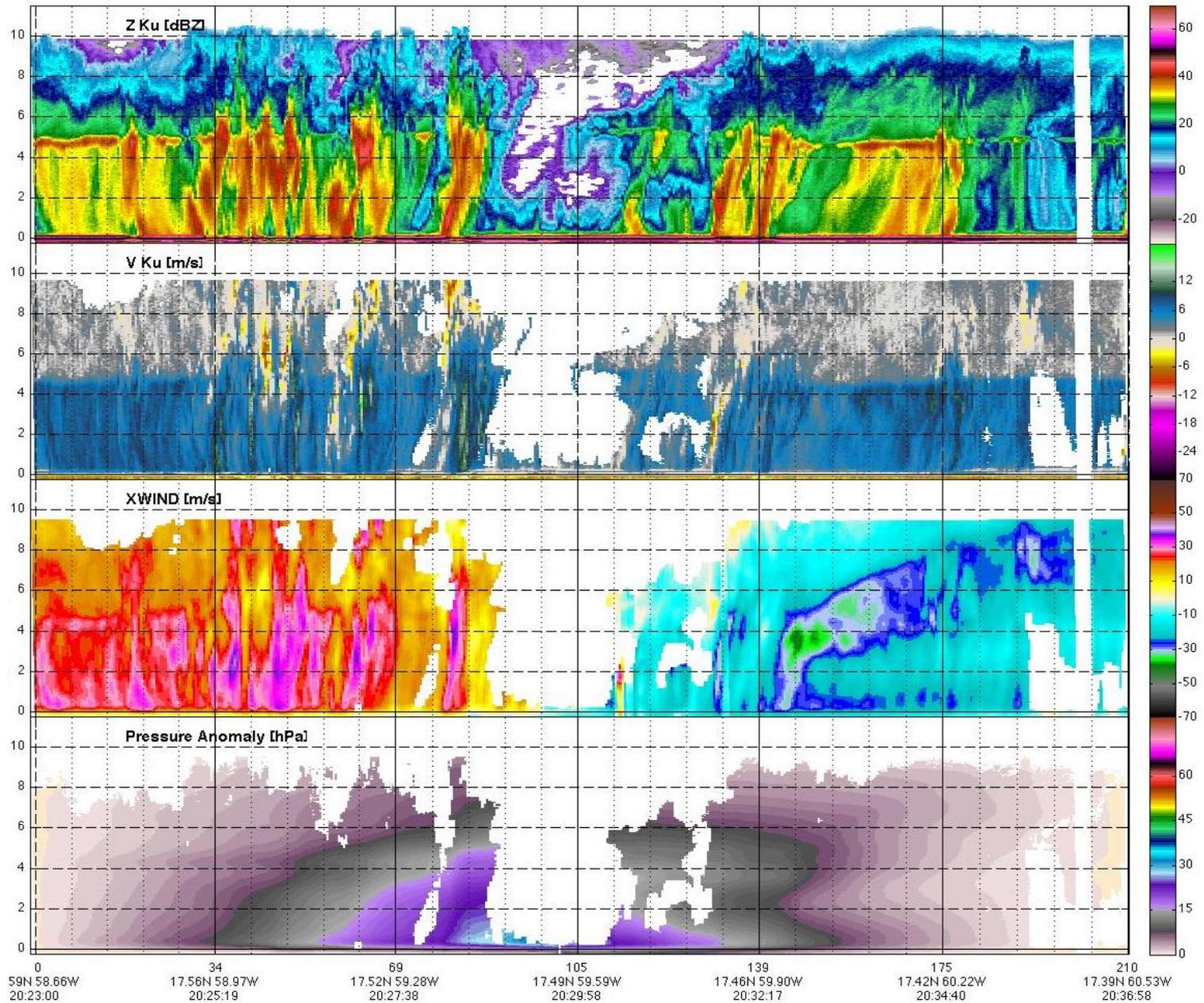


Imagery
 courtesy
 NRL

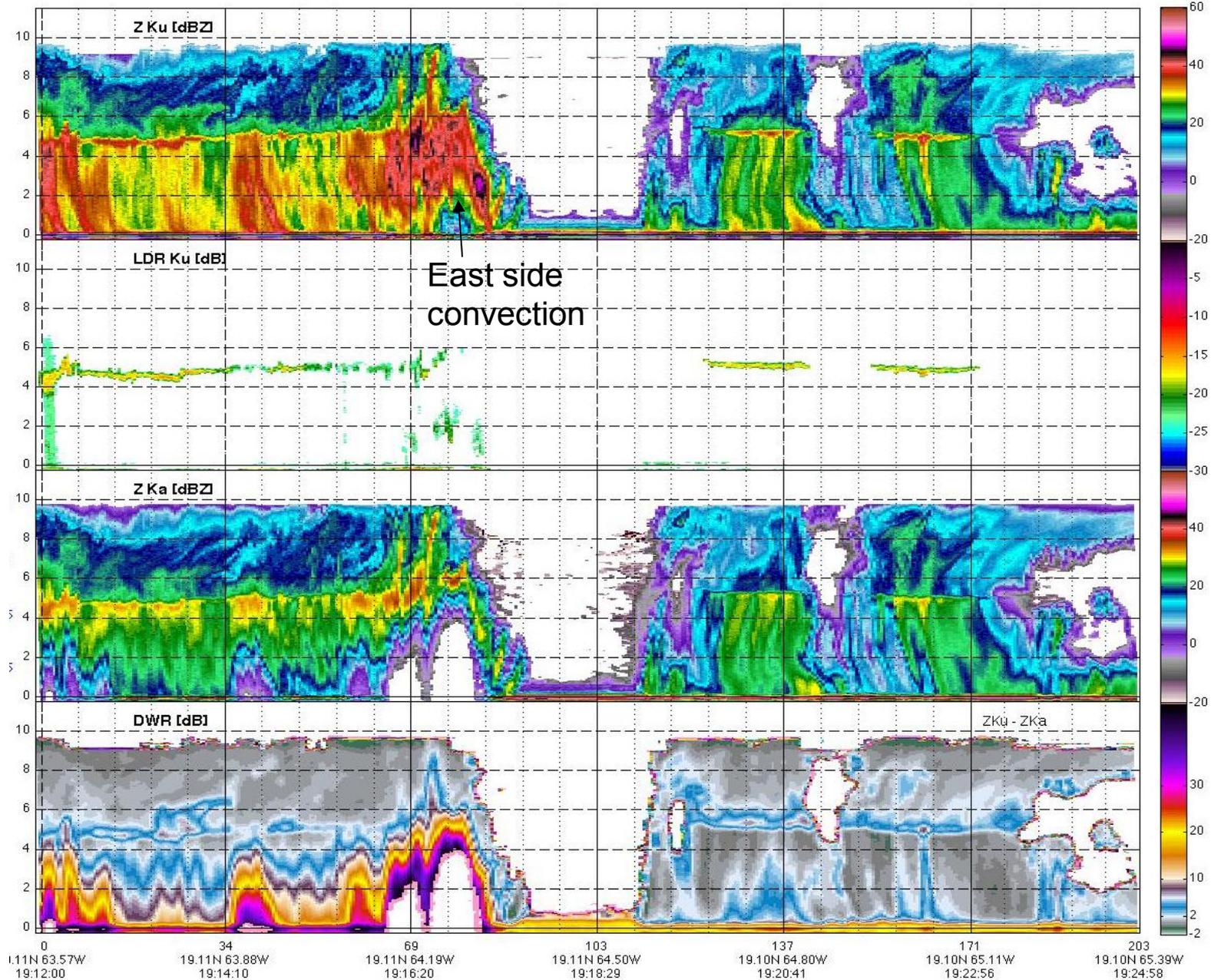
Hurricane Earl – August 29



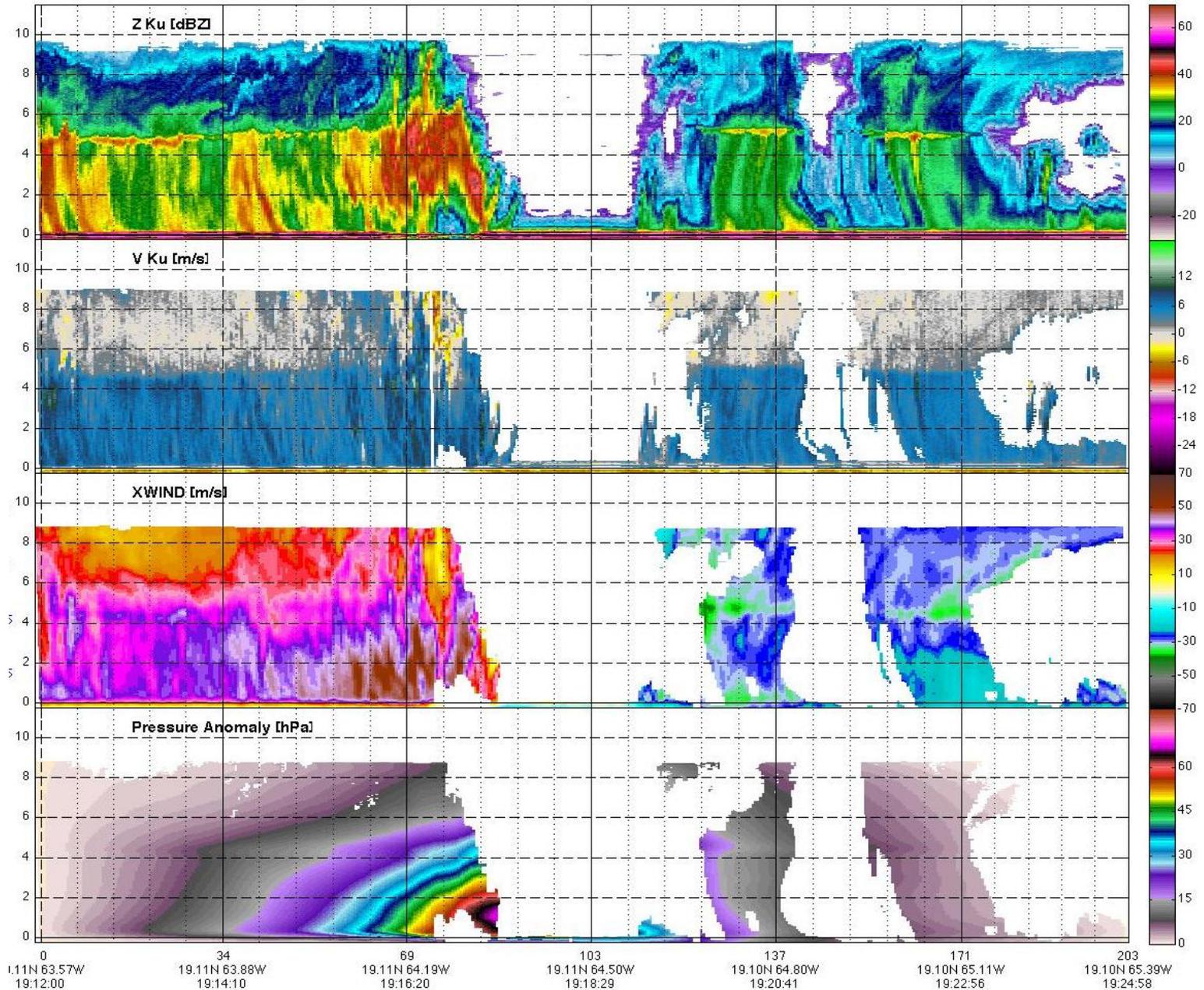
Hurricane Earl – August 29



Hurricane Earl – August 30

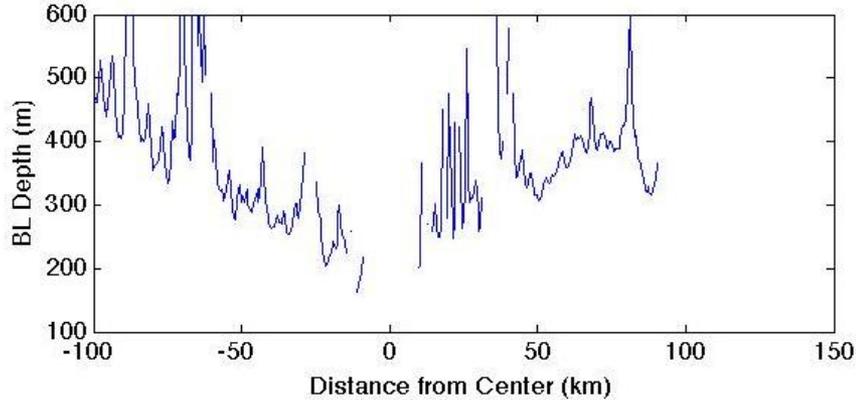


Hurricane Earl – August 30

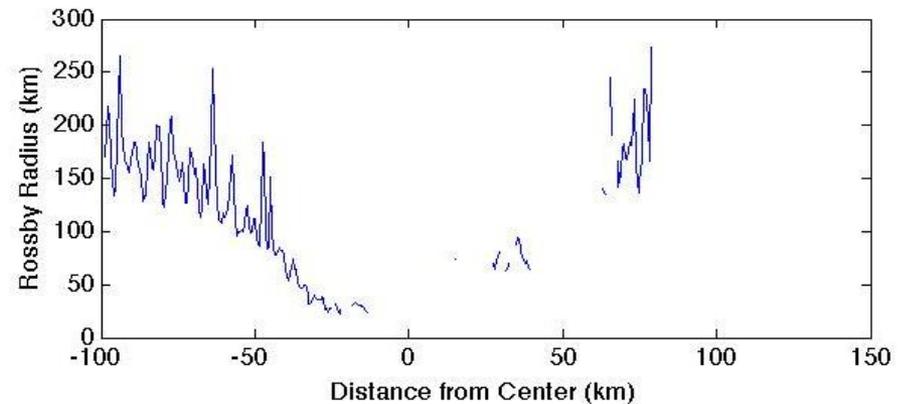
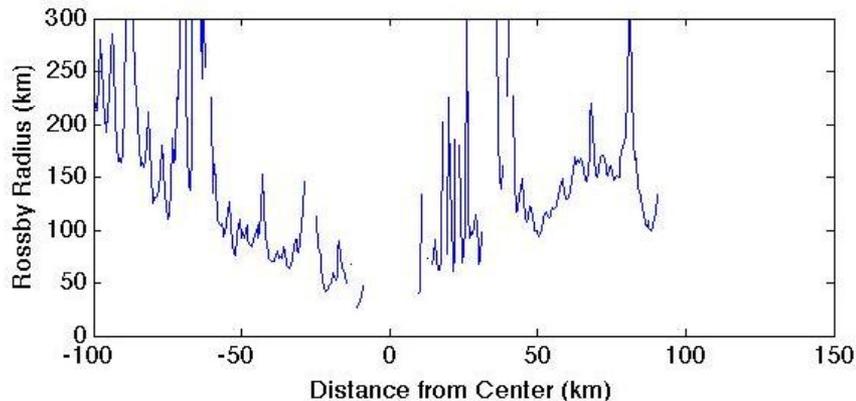
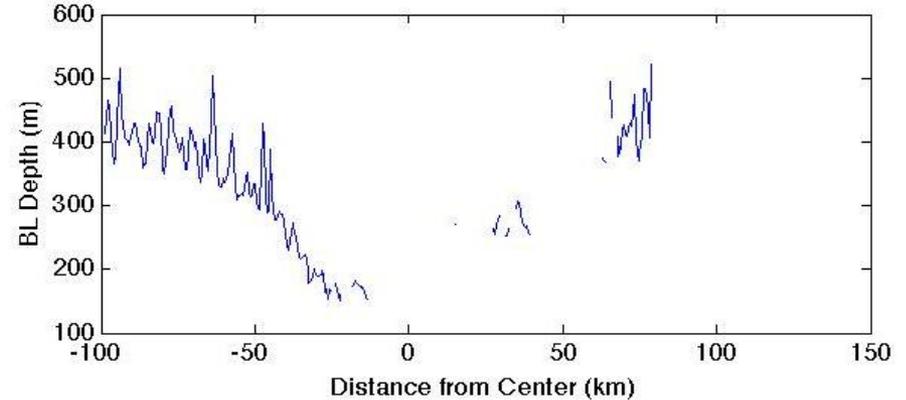


Earl – Rossby Length and BL Thickness

8/29/2010



8/30/2010

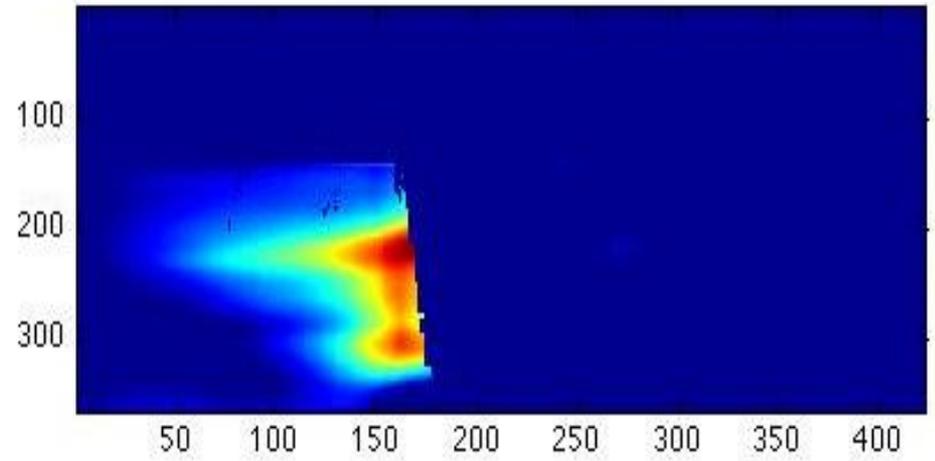
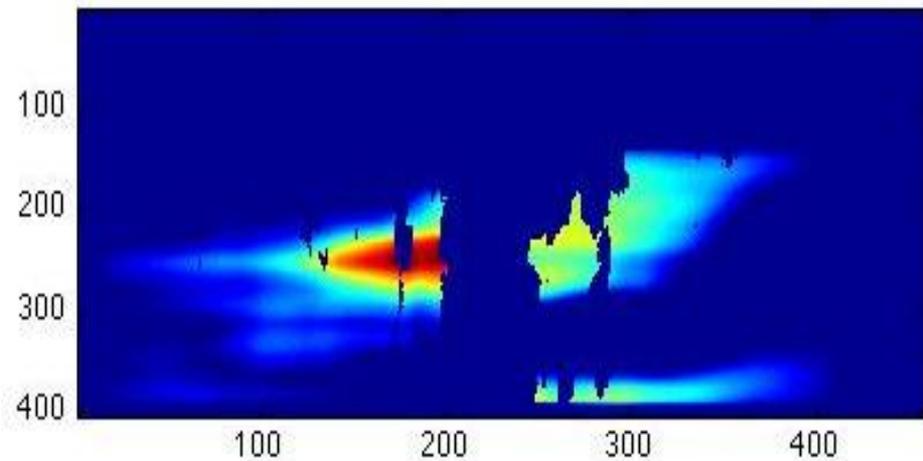
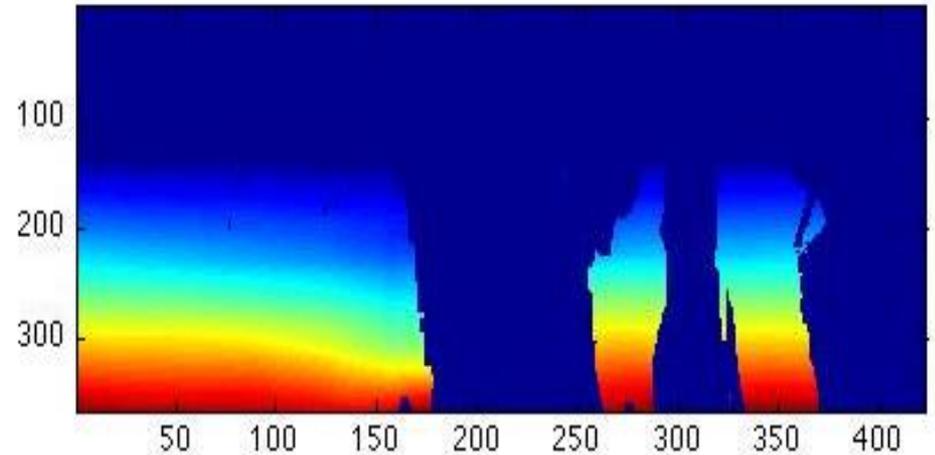
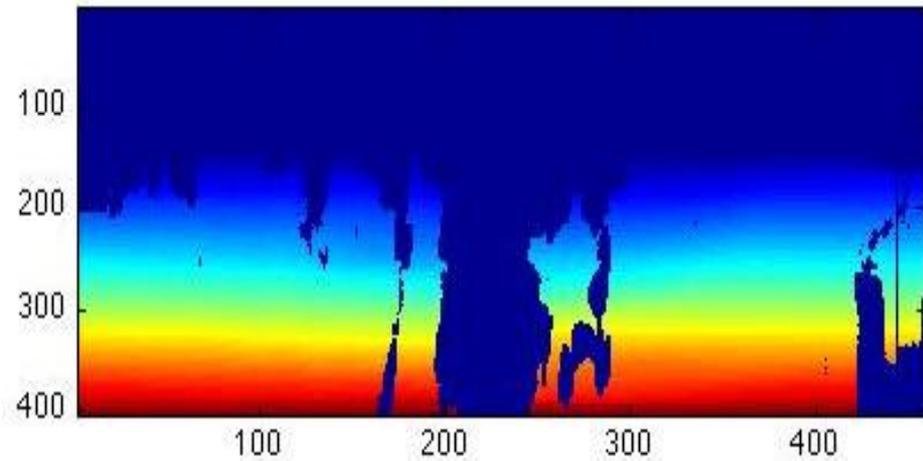


- Similar to values calculated from recon flight level
- Both decrease toward center; both smaller on 30th

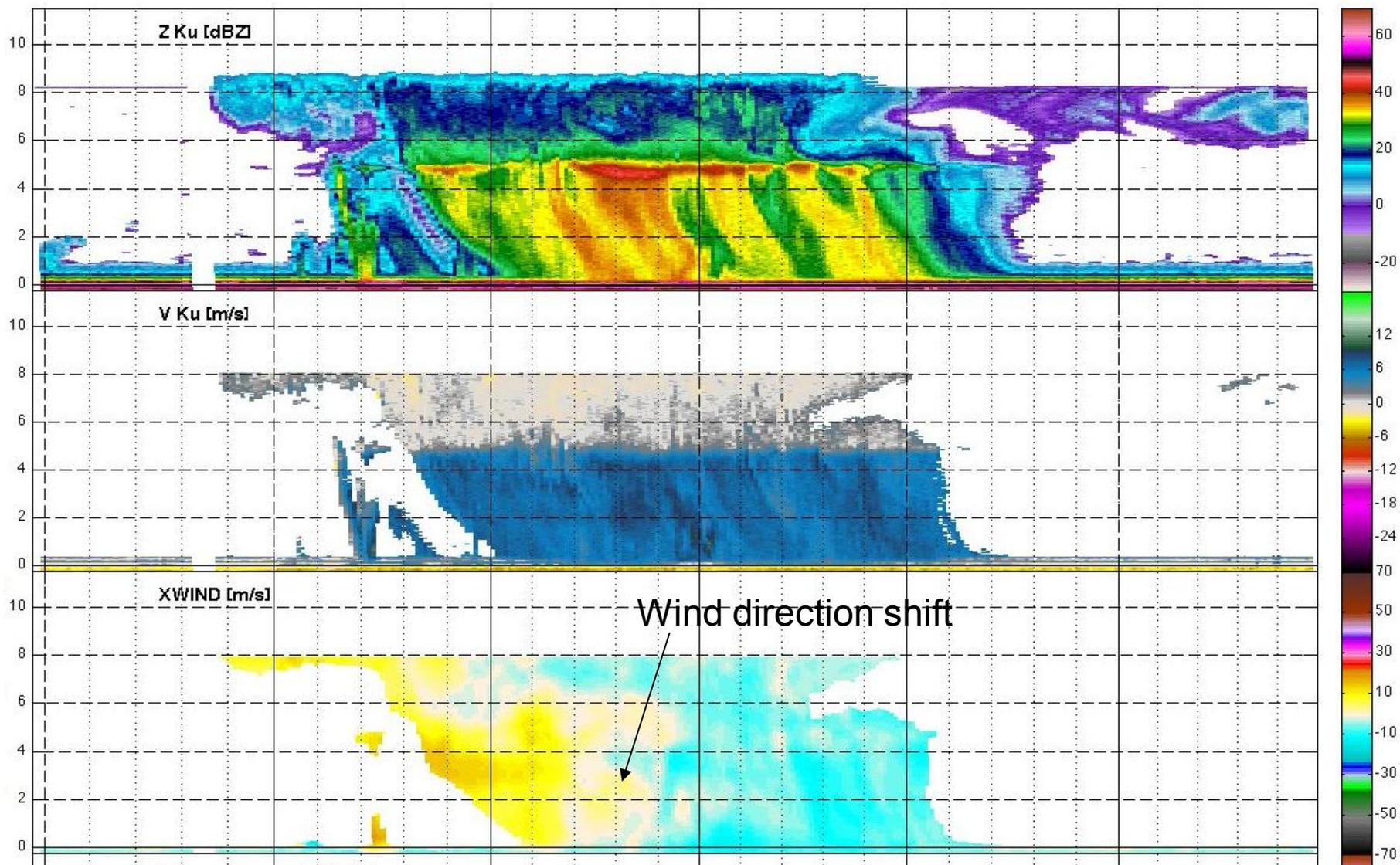
Earl – Density and Thermal Structure

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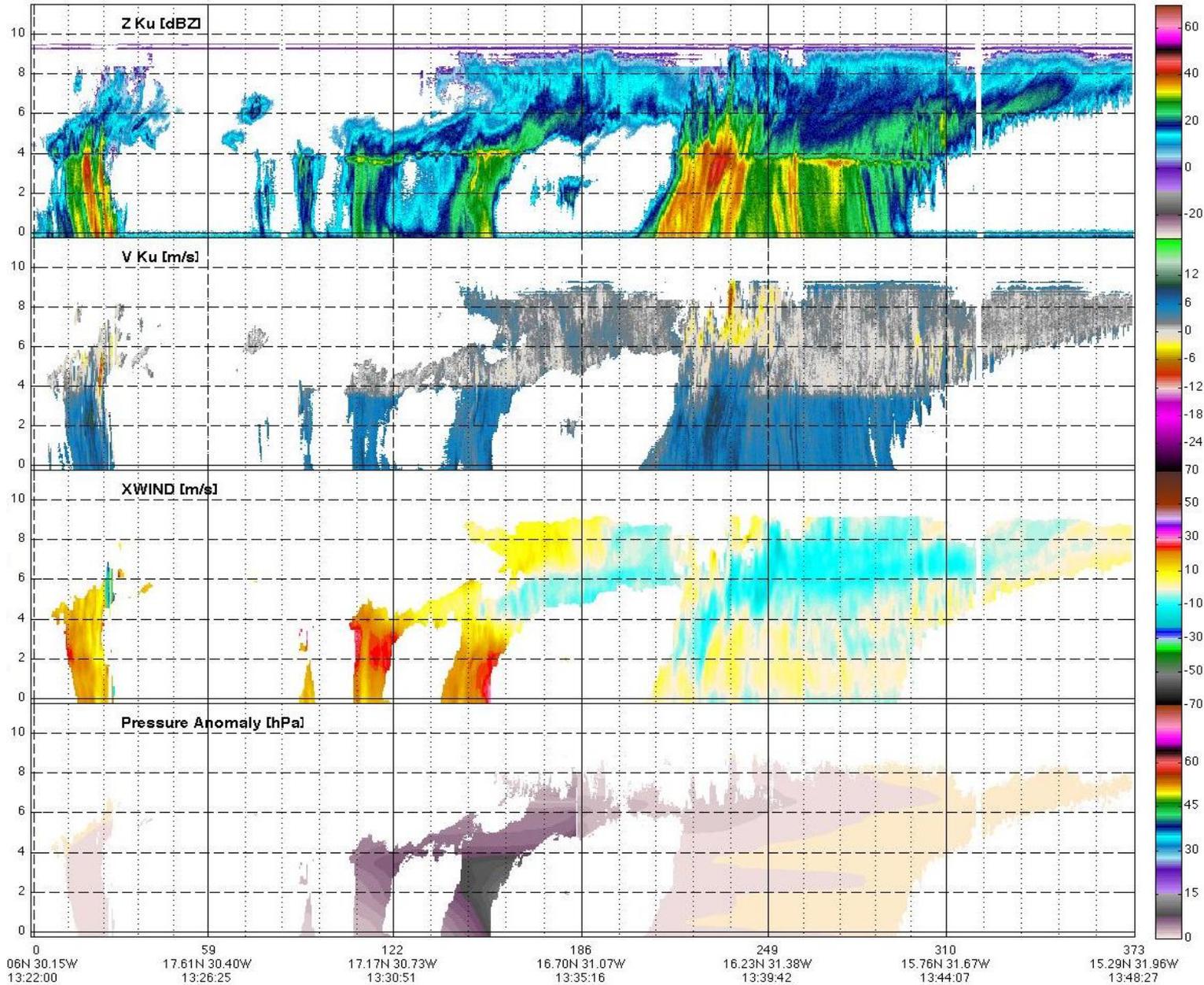
8/30/2010



Karl Genesis 9/14



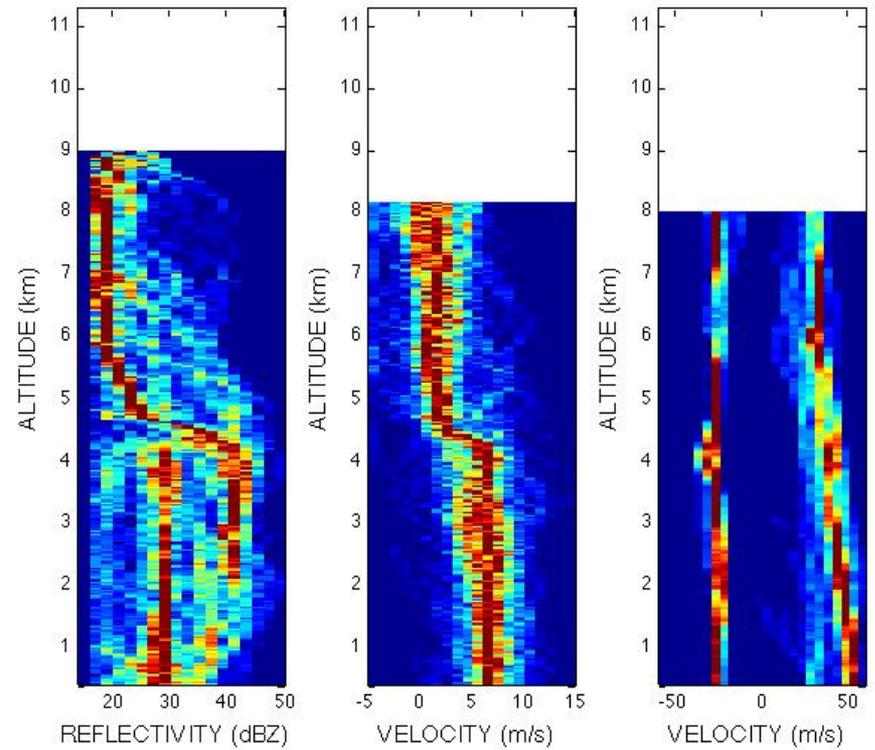
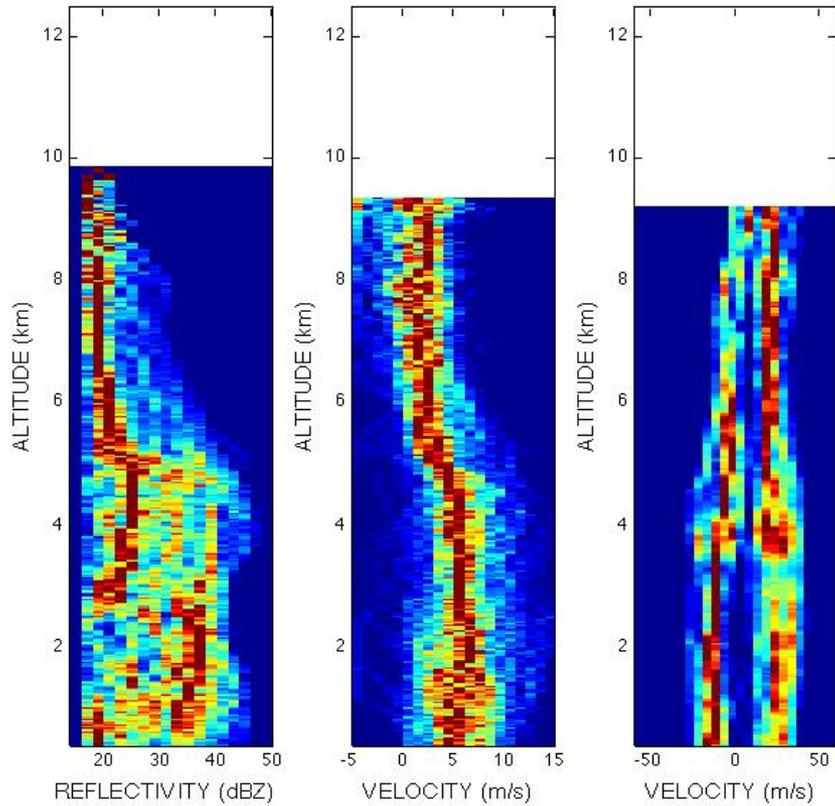
Tropical Storm Debby 2006



Earl – CFADs for Inner Core Reflectivity and Velocity

8/29/2010

8/30/2010



Tropical Storm Debby 2006

