Status of DAWN Data from NASA GRIP Campaign

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GRIP DC-8 and DAWN Wind Lidar: By the Numbers

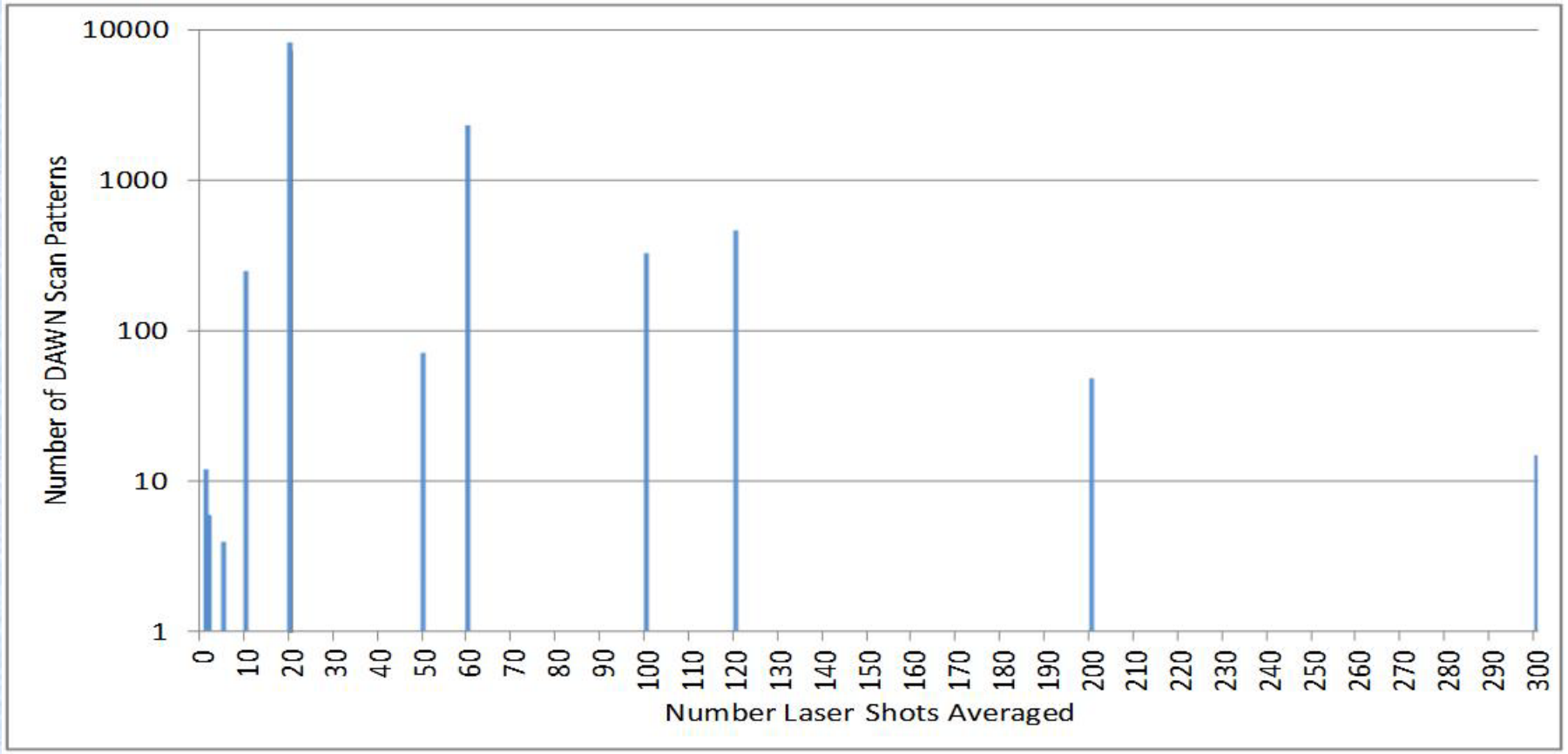
	All Flights	Science Flights
Dates	8/5 - 9/25/10	8/17 - 9/22/10
Flights	25	15
DAWN Scan Patterns*	13,062	11,685
DAWN Laser Shots	2,243,620	2,058,520
DAWN Emitted Photons**	$5.8\ 10^{24}$	$5.3\ 10^{24}$

	Total	Fraction
DC-8 Flight Minutes	6712	5987 (89%) DAWN Collecting Data
DAWN Data Minutes	5987	4634 (95%) Uploaded to GRIP Web Site

*scan pattern yields horizontal wind vertical profile; ~1 dropsonde
**assuming 250 mJ pulses

Lidar Scan Patterns vs. Number Laser Shots Averaged

Measurement Time & Horizontal Range Resolution



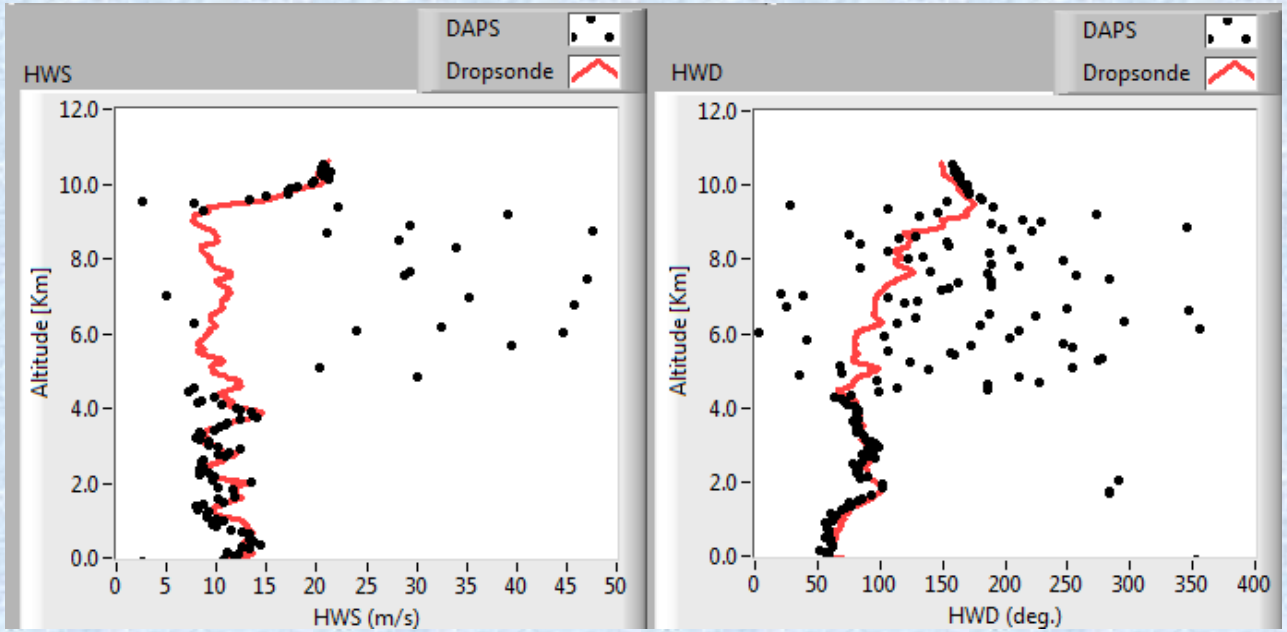
Shots Averaged	Scan Pattern Time	If V_{DC8} = 450 knots = 231.5 m/s
20	22 s	5.1 km
60	42 s	9.7 km
120	72 s	16.7 km

Example: Comparison DAWN to Dropsonde

9/1/10, data folder 161736, 20 shots averaged, 5.1 km resolution, Earl

Dropsonde Time		Time Since Last Dropsonde (min)	Dropsonde File Names				FOLDER NUMBER FIRST	FOLDER NUMBER SECOND	DROP TIME SCAN NUMBER	N
172015	12.6	12.6	D20100901_172015_PQC.eol				20100901	161736	120	20

12 km



N = number shots averaged

Agreement near the DC-8 and 0 – 4 km altitude

Example: Vertical Slice, ~ 75 Minutes Duration, 20 Shots Averaged, ~5.1 km Resolution, Taking off from Ft. Lauderdale, Earl

9/1/10, data folder 161736

10 km

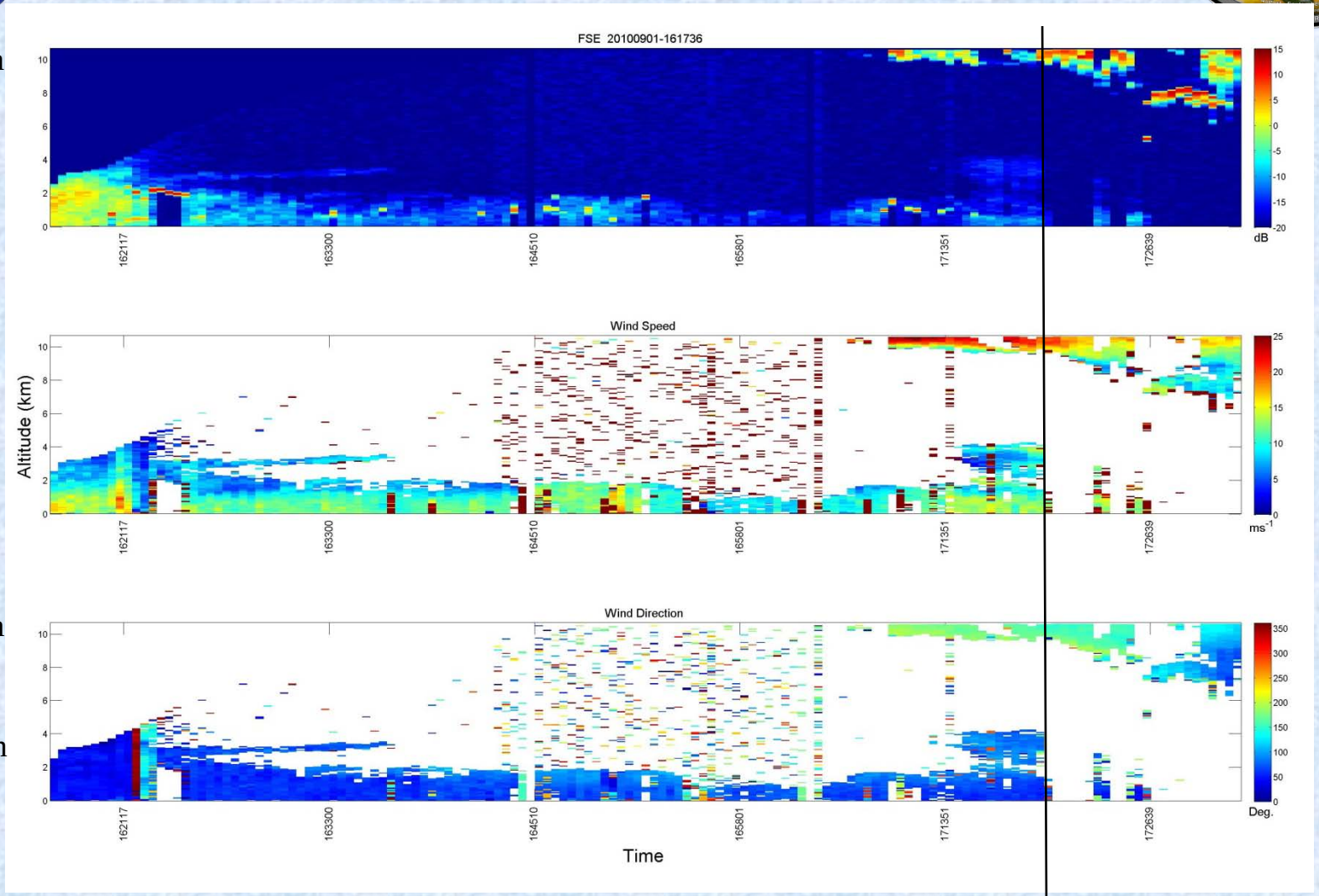
Energy

10 km

Speed

10 km

Direction



25 m/s

Region of relatively high aerosol backscatter

~ 17:20:15 dropsonde launch time of previous slide

This is the uploaded data type
FSE = Frequency-domain signal energy estimate

Example: Vertical Slice, ~ 163 Minutes Duration, 100 Shots Averaged, ~14.4 km Resolution, Karl, No Visible Eye

9/17/10, data folder 174448

12 km

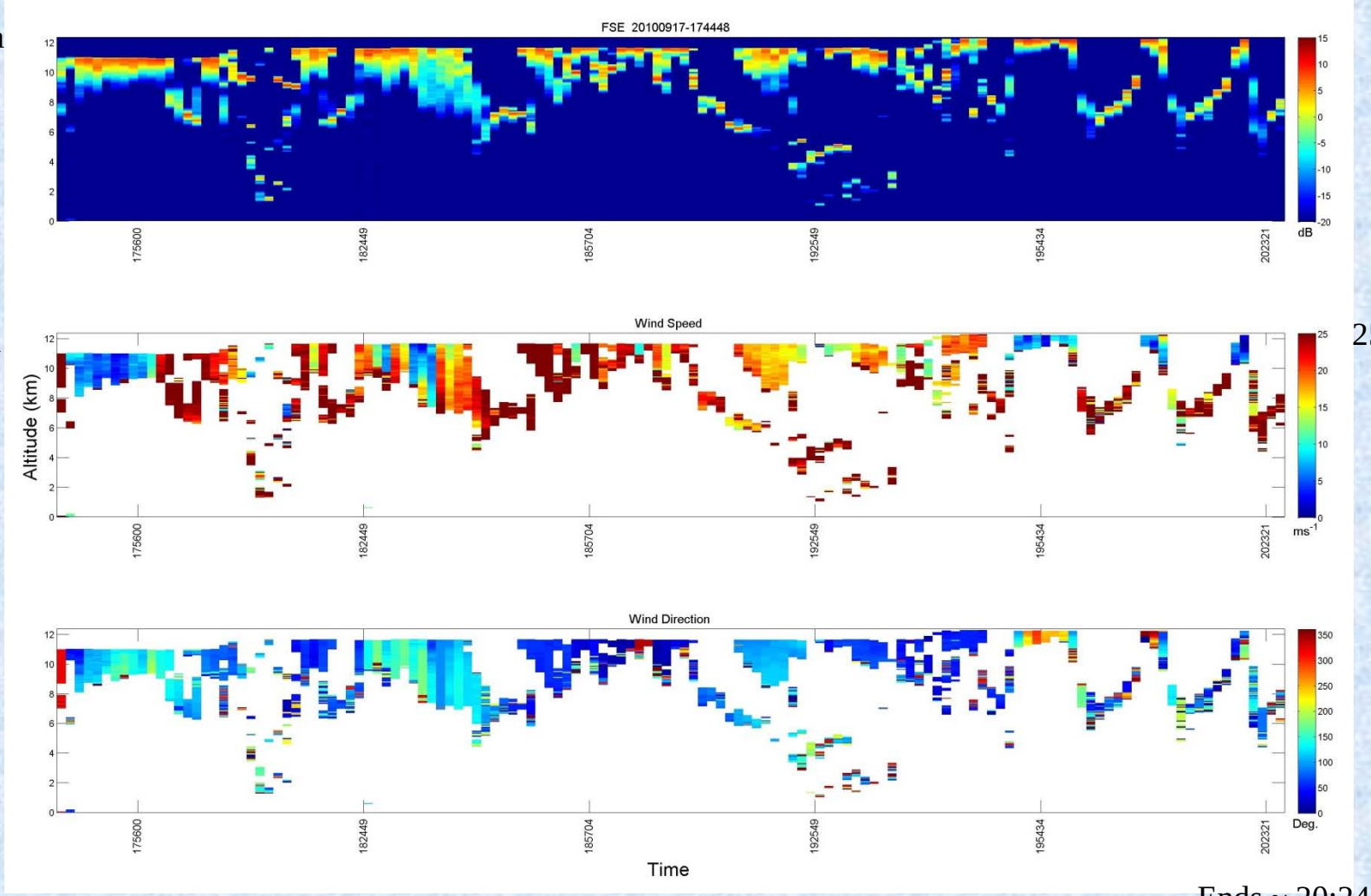
Energy

12 km

Speed

12 km

Direction



25 m/s

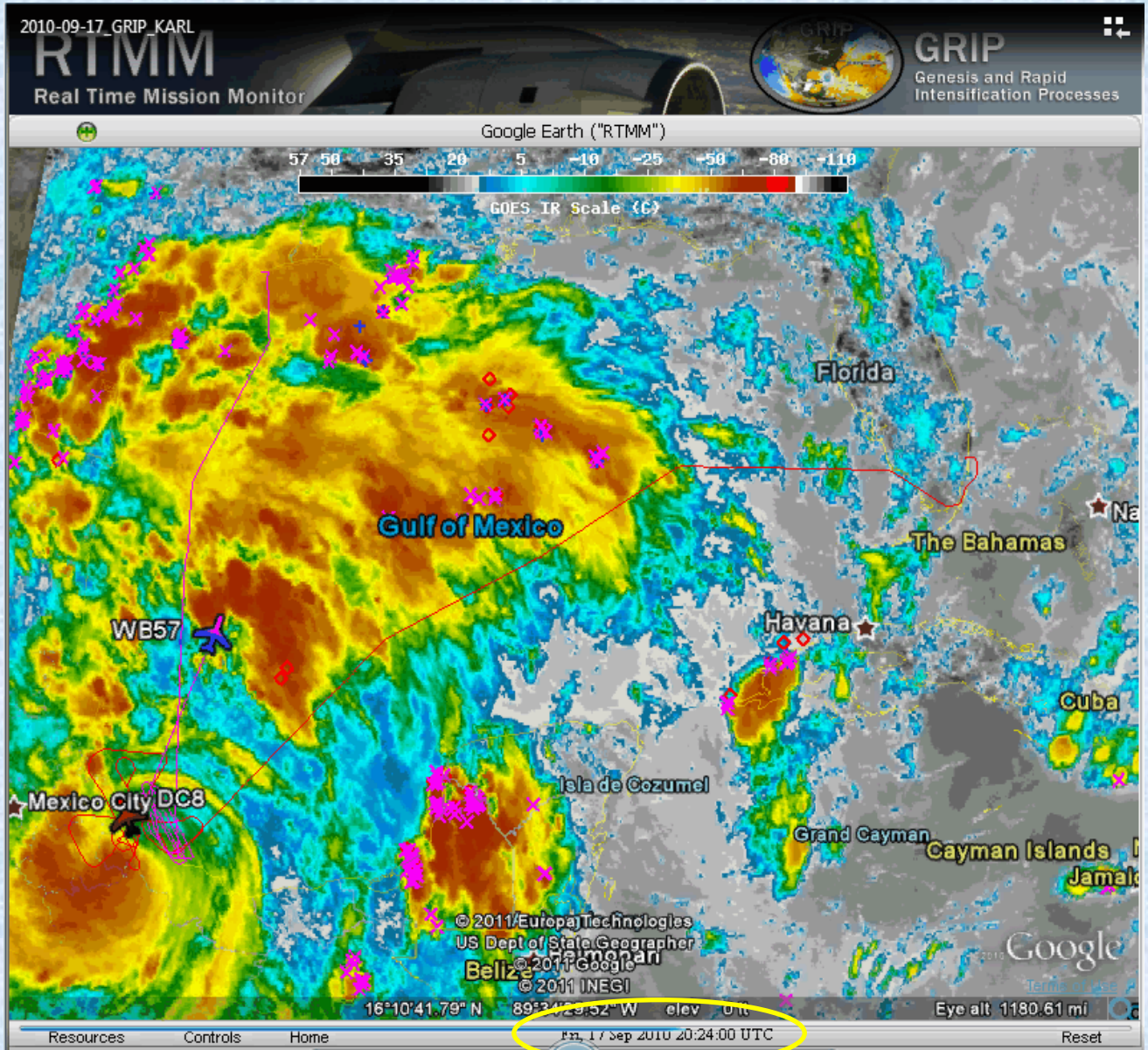
Ends ~ 20:24:00

Note: ascending and descending clouds; lots of repeated flight legs

Example: Vertical Slice, ~ 163 Minutes Duration, 100 Shots Averaged, ~14.4 km Resolution, Karl, No Visible Eye

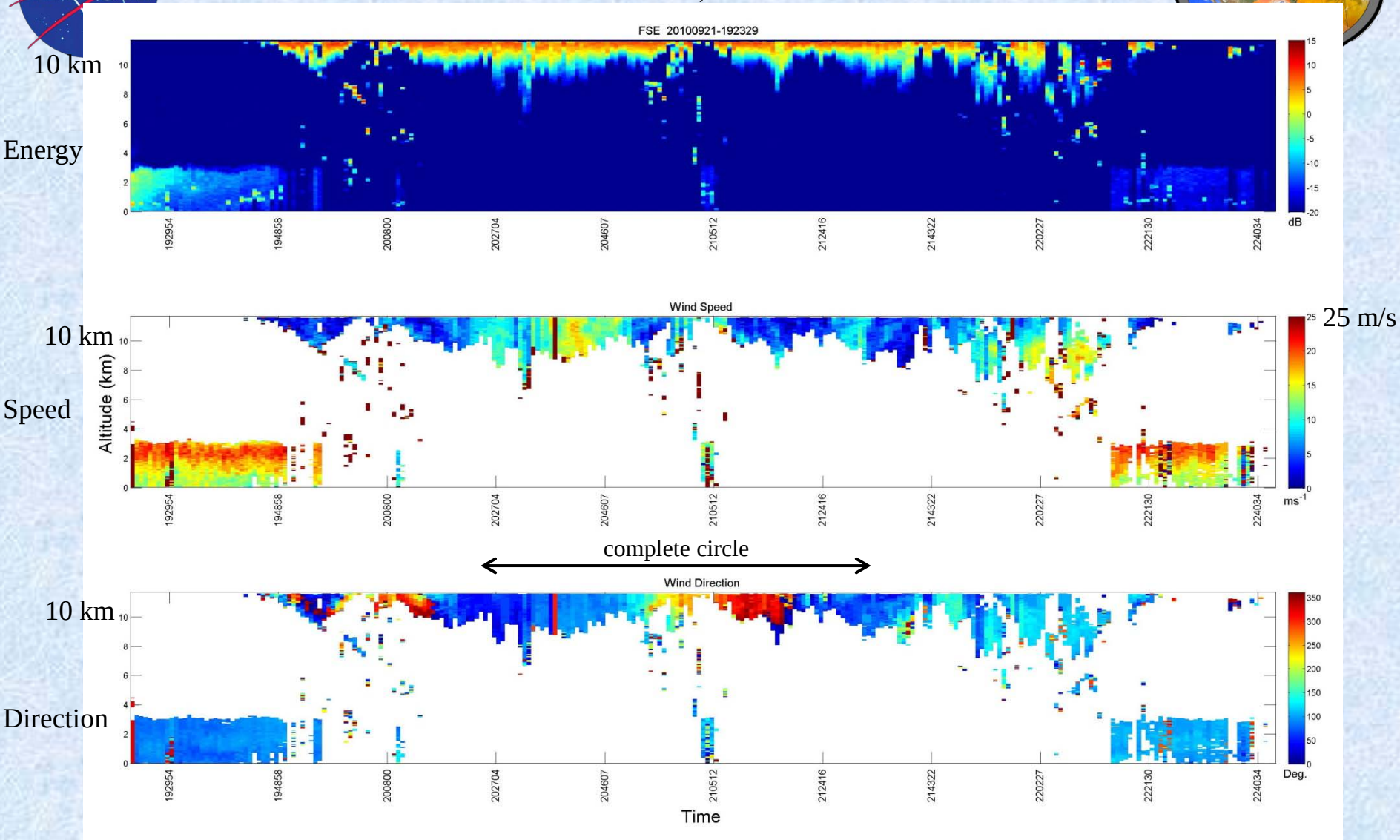
9/17/10, data folder 174448

End of previous slide data, repeated flight legs shown



Example: Vertical Slice, ~ 202 Minutes Duration, 60 Shots Averaged, ~9.7 km Resolution, PG146, AL95, No Visible Eye

9/21/10, data folder 192329

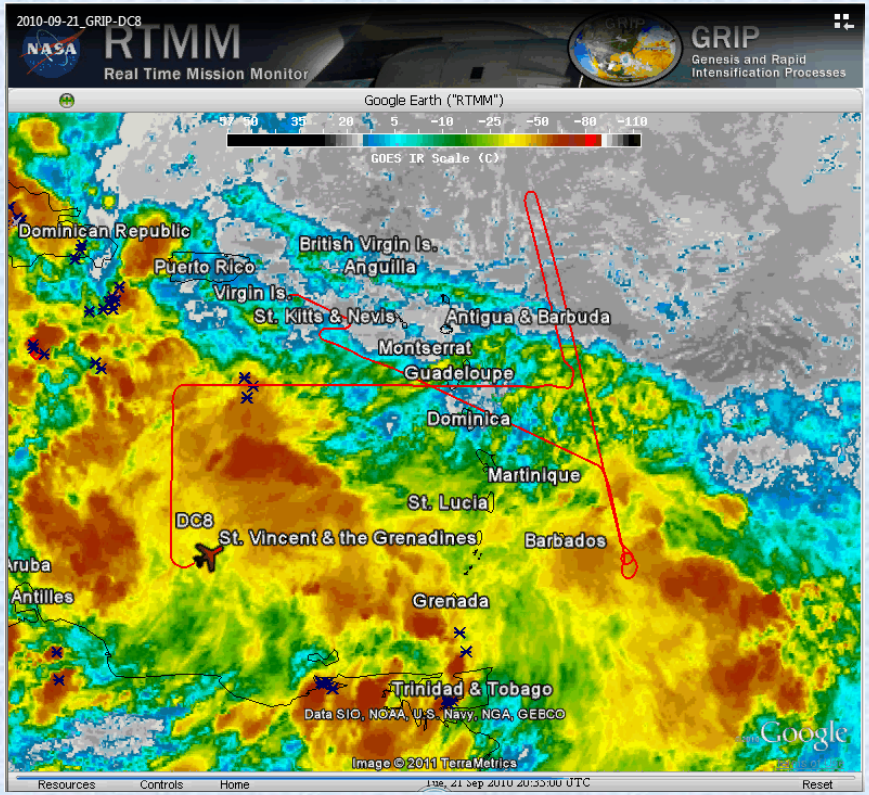


Note: complete direction sweep centered ~ 21:00:00; wind measurement extends below obvious FSE; BL to cloud deck transitions

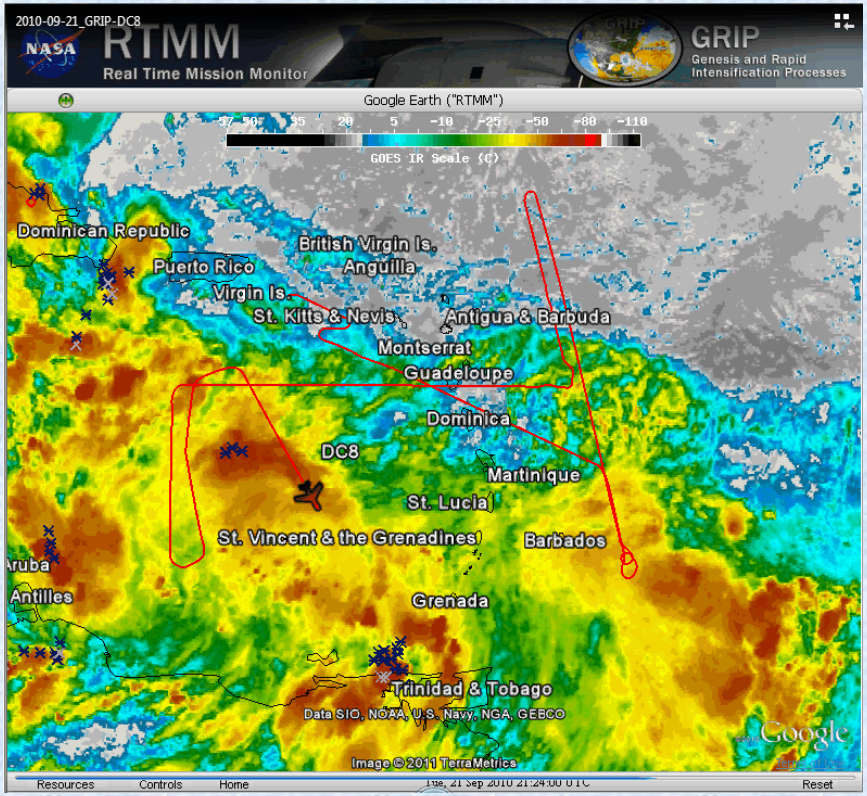
Example: Vertical Slice, ~ 202 Minutes Duration, 60 Shots Averaged, ~9.7 km Resolution, PG146, AL95, No Visible Eye

9/21/10, data folder 192329

Complete Circle of Wind Direction



20:35:00, ~Begin



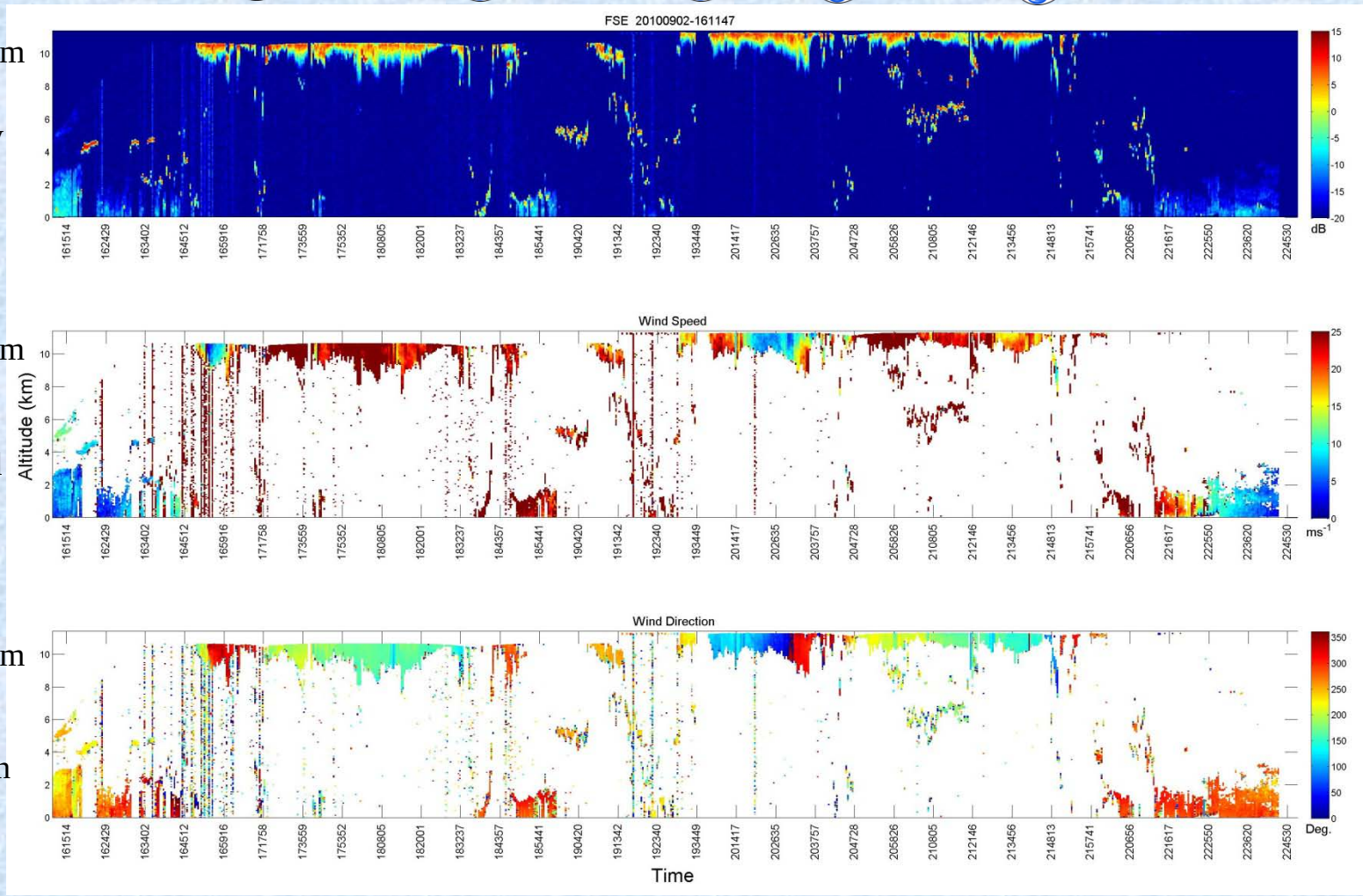
21:24:00, ~End

Example: Vertical Slice, ~ 396 Minutes Duration, 20 Shots Averaged, ~5.1 km Resolution, Earl, Visible Eye

9/2/10, data folder 161147

10 km

Energy



10 km

Speed

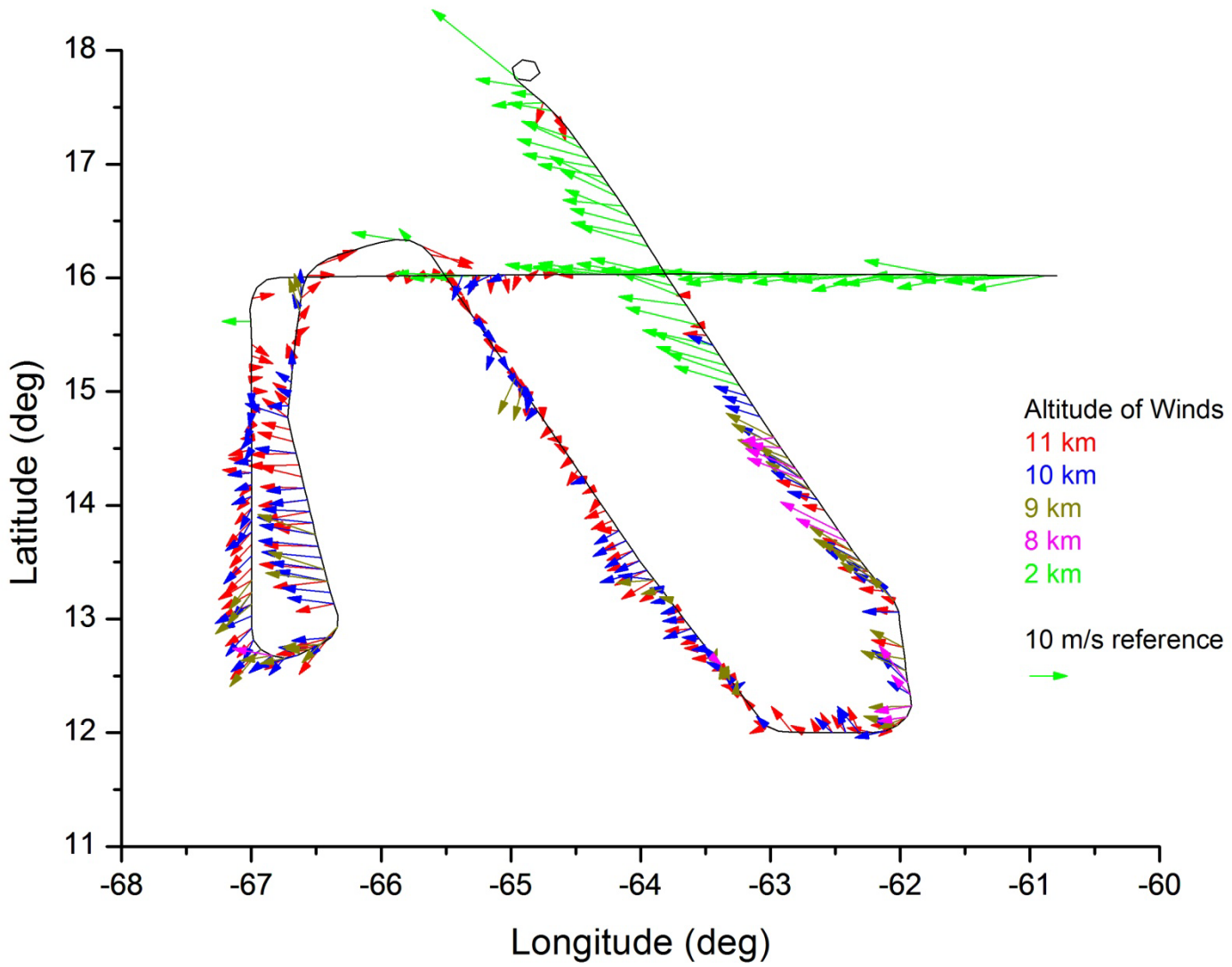
25 m/s

10 km

Direction

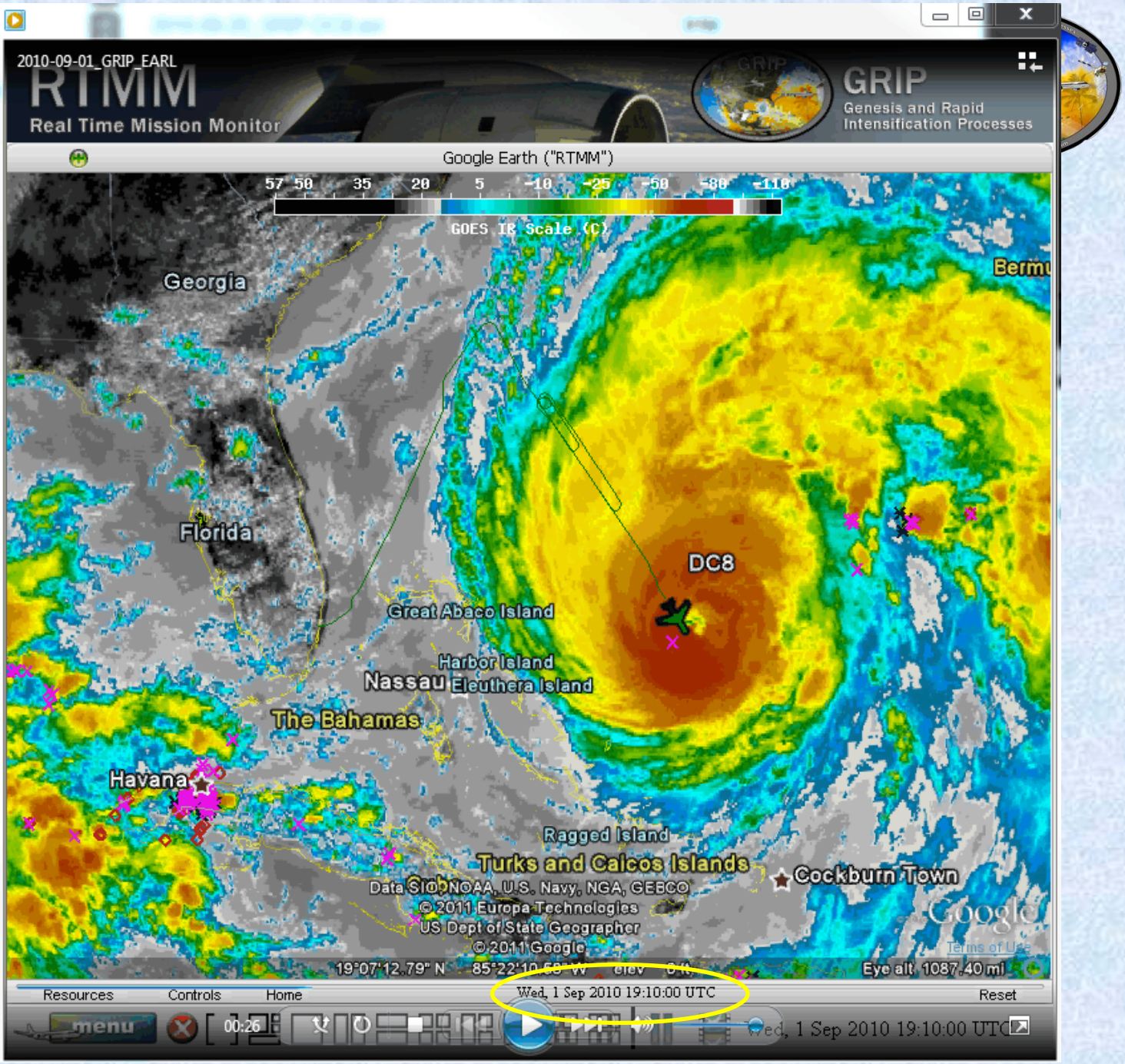
Note: eye clearly seen in lidar data; MBL & cloud layers at 5 km; 791 scan patterns

Example: Comparison of 5 Constant-Altitude Slices
9/21/10, data folder 192329, 60 shots averaged, ~202 minutes duration,
~ 285 horizontal wind profile attempts



Example:
Crossing Hurricane Earl Eye

9/1/10
Eye crossing of Earl at ~19:12:00 Zulu



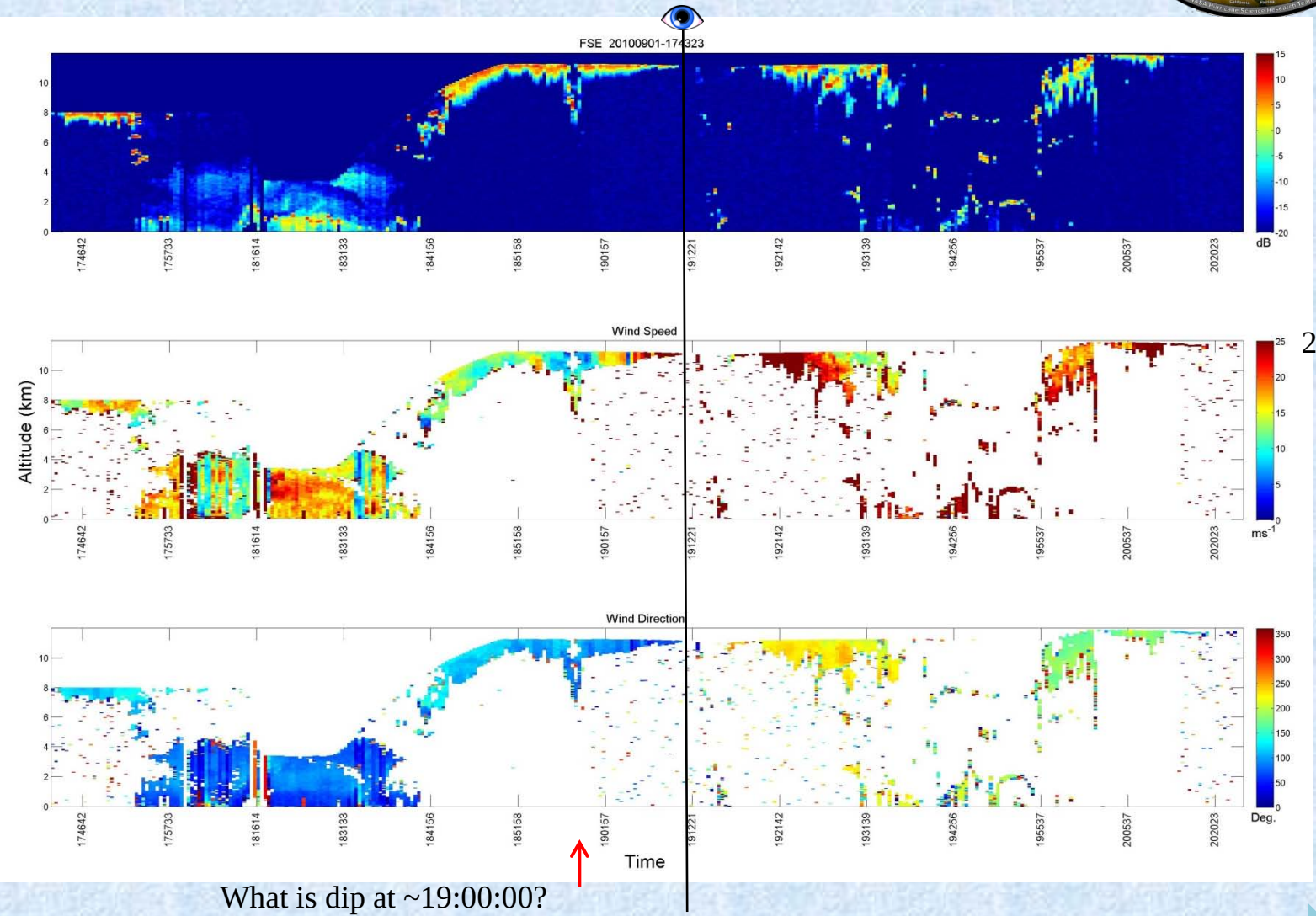
Example: Crossing Hurricane Earl Eye
9/1/10 Eye Crossing of Earl at ~19:12:00 Zulu

9/1/10, data folder 174323

Energy

Speed

Direction

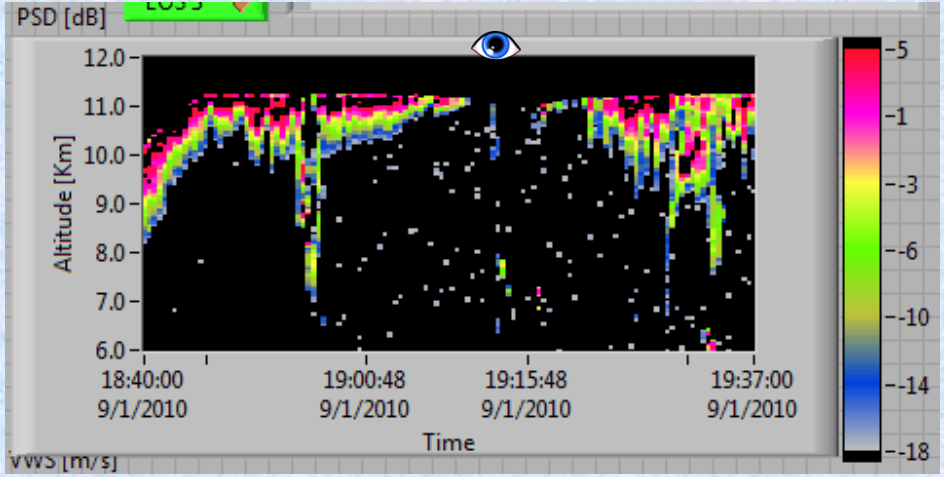


25 m/s

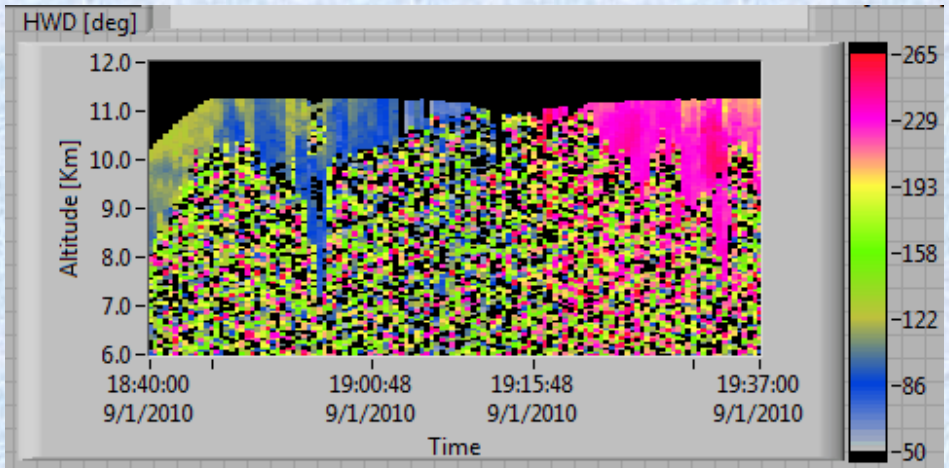
What is dip at ~19:00:00?

~19:12:00 Zulu

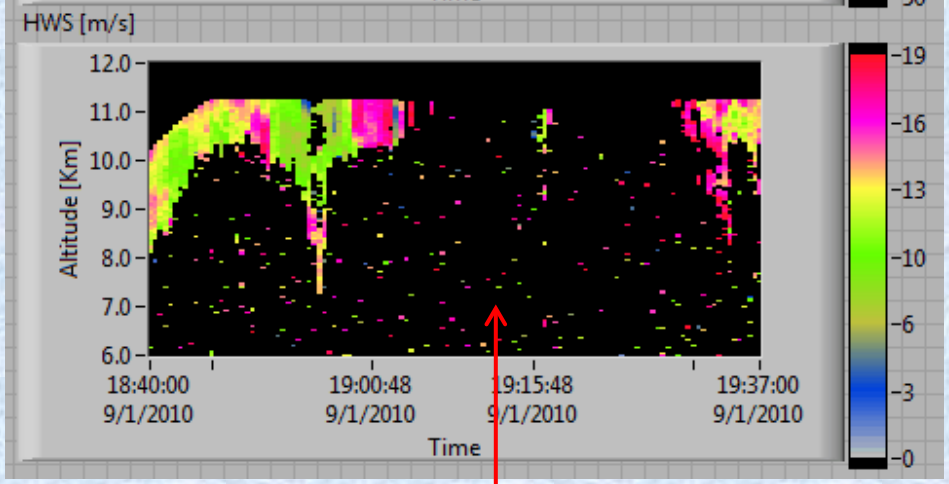
Energy



Direction



Speed



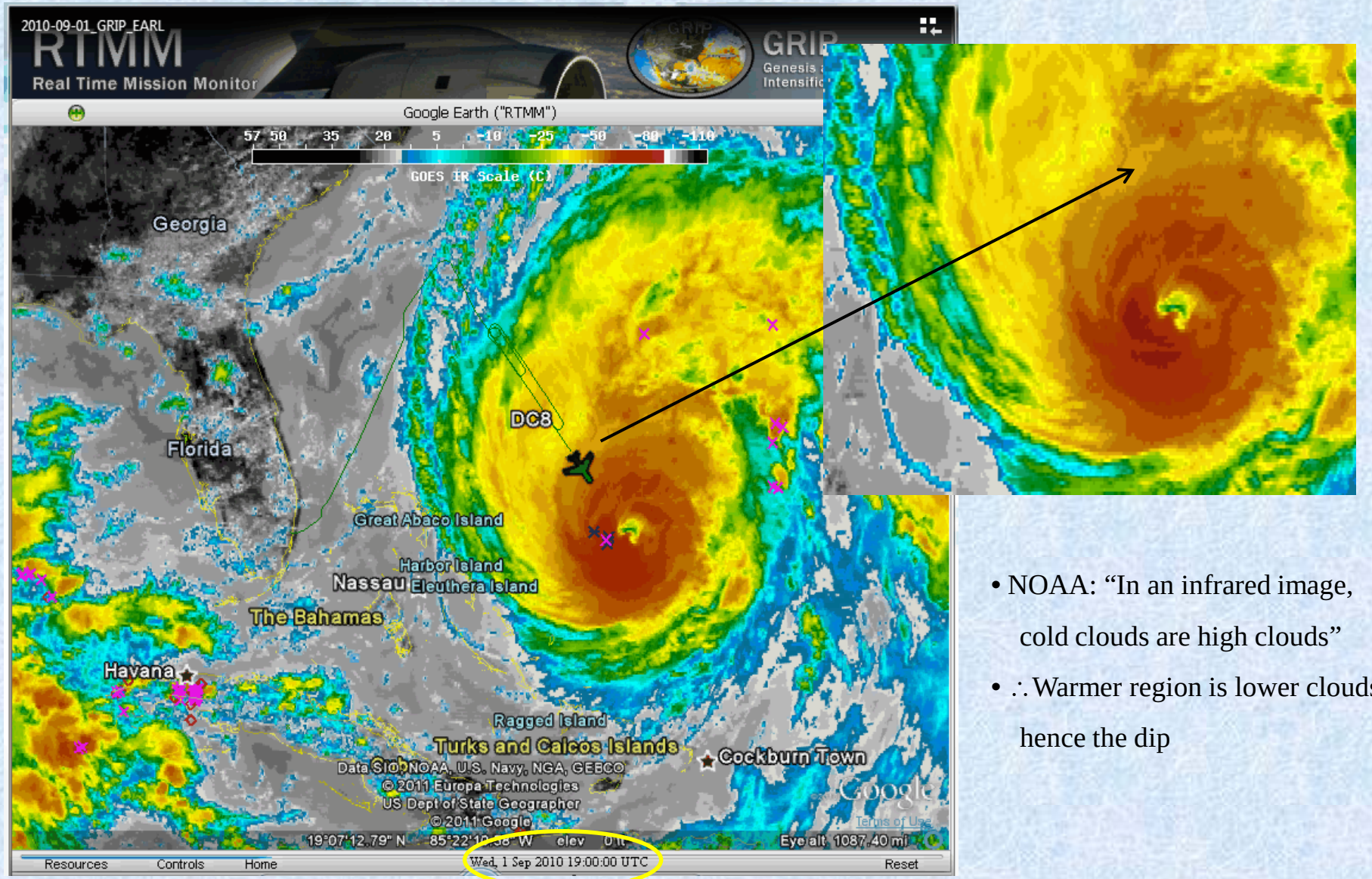
9/1/10 Eye Crossing

Zoom in Altitude,
Zoom in Color Bars

- ~ 150 deg wind direction change across eye
- Slower wind magnitude at dip
- Higher wind magnitude down low in dip

9/1/10 Eye Crossing

What is Dip at ~ 19:00:00?



- NOAA: "In an infrared image, cold clouds are high clouds"
- ∴ Warmer region is lower clouds, hence the dip

Summary

- Our group's first airborne science campaign
- First flights of new instrument DAWN (pulsed, 2-micron, coherent Doppler lidar)
- Hardware problems turned 250 mJ laser energy into effective 10 mJ
- Problems mostly fixed now

Processing to date is single scan pattern, using only -45° and + 45° azimuth angles. Plan to use all 5 azimuth angles for better wind accuracy and coverage. Plan to average consecutive scan patterns for better coverage at expense of horizontal resolution.

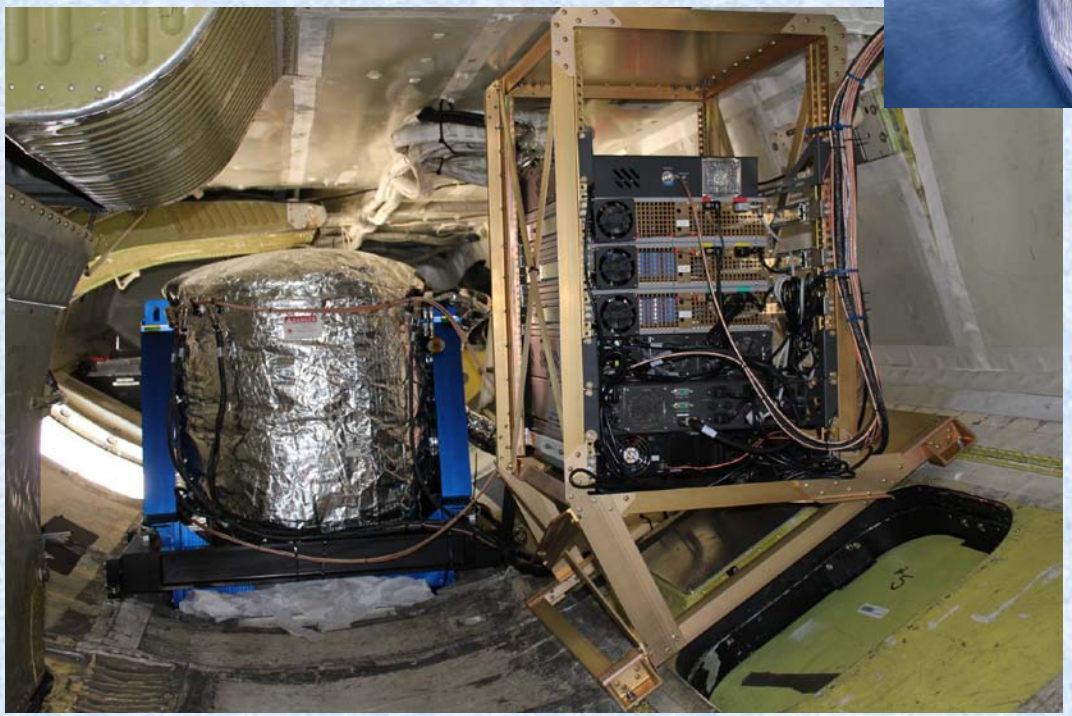
- Lots more information in data such as wind turbulence values and LOS wind profiles
- Integrating DAWN into LaRC UC-12B aircraft to have two choices of aircraft
- We sincerely hope the wind data will help GRIP investigators

BACK UP

DAWN in DC-8 for GRIP

Three laser chillers

Laser control (L), and data acquisition control (R)



Optics canister above nadir window & electronics

Nadir window, shutter open

Pulsed, Coherent-Detection, 2-Micron, Doppler Aerosol Horizontal WiNd (DAWN) Profiling Lidar during GRIP

Pulsed Laser

Ho:Tm:LuLF, 2.05 microns
3.1 m folded ring resonator, FSR = 967 MHz
~250 mJ pulse energy
10 Hz pulse rate
200-220 ns pulse duration
Master Oscillator Power Amplifier
Laser Diode Array side pumped, 792 nm, 1 ms
~Transform limited pulse spectrum
~Diffraction limited pulse spatial quality
Designed and built at LaRC

Lidar System

15-cm diameter off-axis telescope
Dual balanced heterodyne detection
InGaAs signal optical detectors (2)
InGaAs monitor optical detector (1)
Zero motion heterodyne frequency = 0 Hz
10-bit ADC
INS/GPS integrated to lidar

Lidar System in DC-8

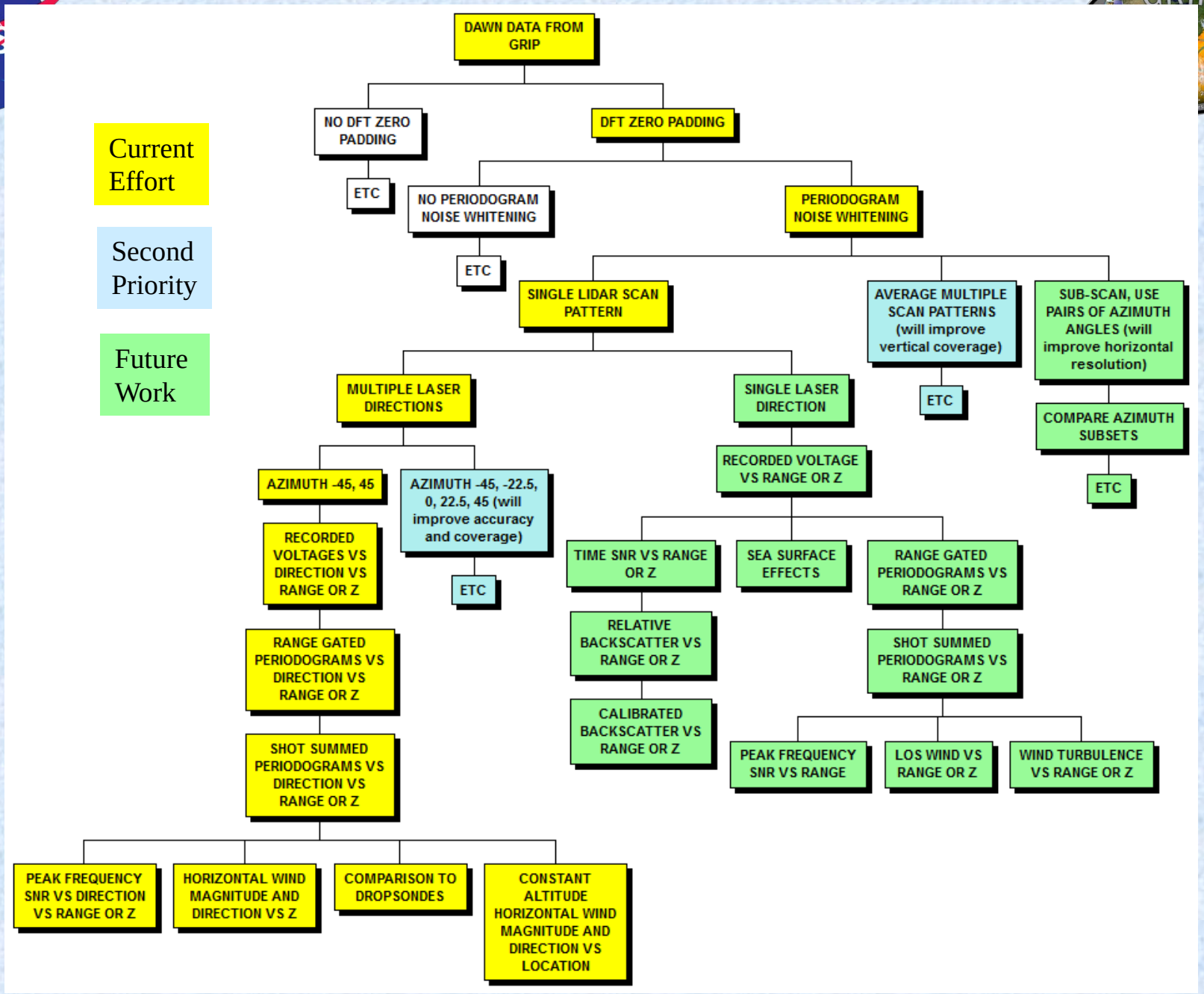
Optics can in cargo level
Centered nadir port 7
One electronics rack in cargo level
Two electronics racks in passenger level
Refractive optical wedge scanner, beam deflection 30.12° = nadir angle
Conical field of regard centered on nadir
All azimuth angles programmable

Data Acquisition & Processing

5 azimuth angles (-45°, -22.5°, 0°, 22.5°, 45°), all forward
500 Msamples/second ADC
Per sample 2 ns, 0.3 m, 0.26 m height
55,000 samples/shot, 512 samples pre-shot
Maximum 54,488 samples,109 microseconds, 16.335 km range
Nominal range gate 512 samples, 1 microsecond, 154 m, 133 m height
Range gate overlap 256 samples, 50%
N-shot, freq-aligned, averaged periodograms
Periodogram maximum 250 MHz
Periodogram maximum ±128 m/s LOS, ±256 m/s = ±572 mph horiz.
Periodogram information resolution 0.98 MHz, 1.0 m/s
Nominal range gate samples after zero padding 2048
Periodogram resolution for frequency alignment 0.24 MHz, 0.25 m/s

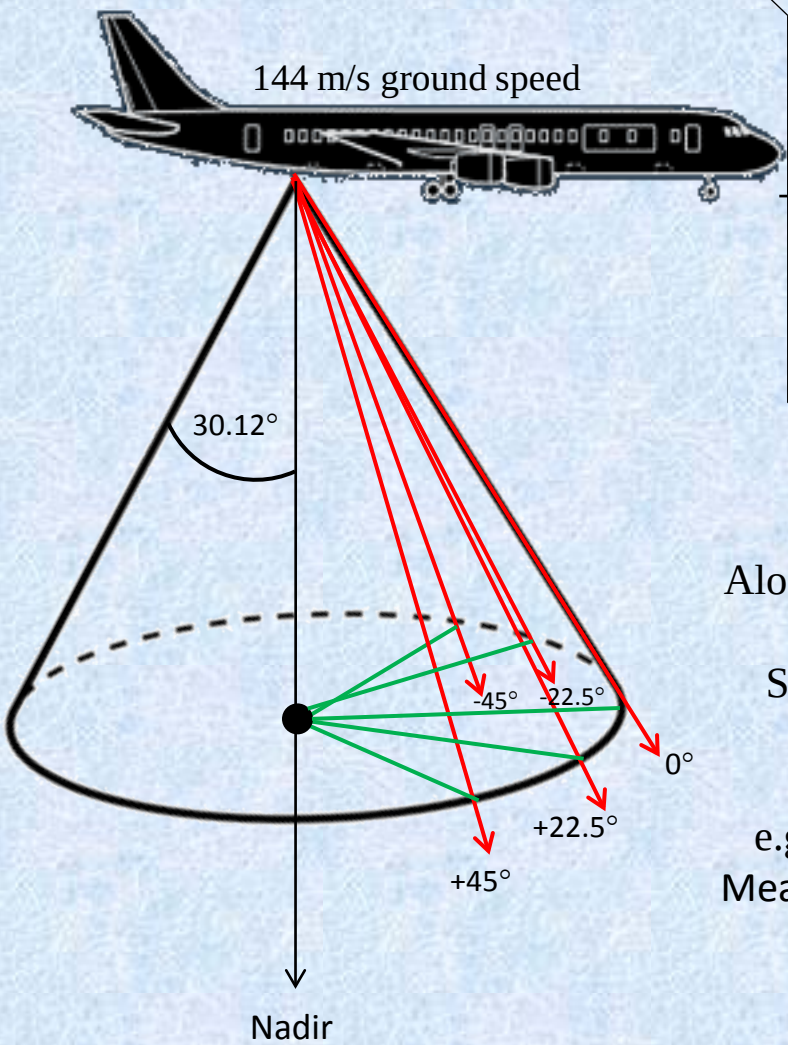
Pre Data Collection Selectable
Post Data Collection Selectable

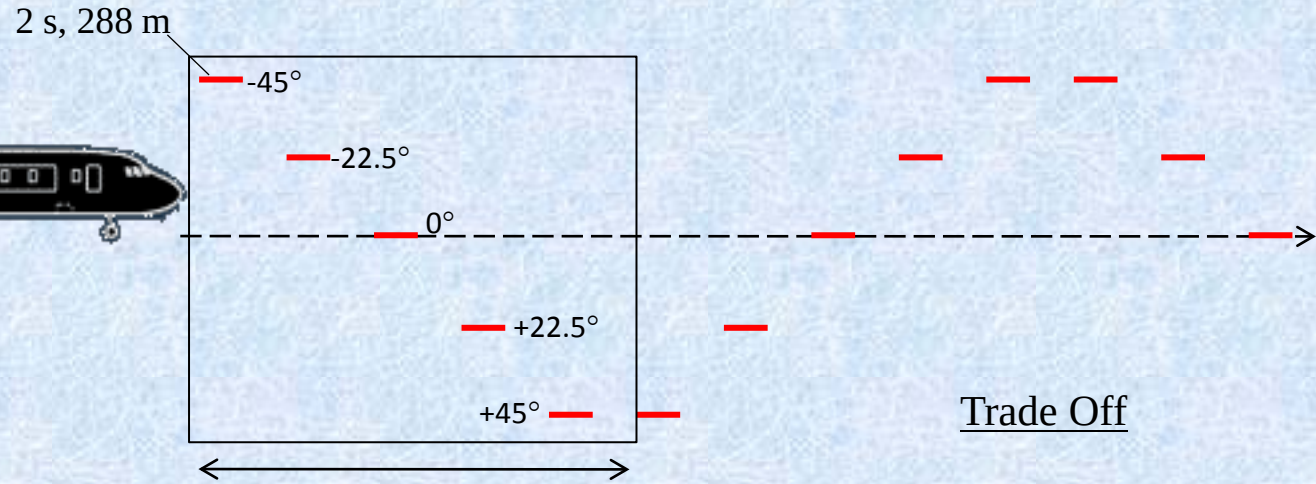
DAWN Data Processing Outline. All Data vs. Along-Track Dimension



Nominal Scan Pattern: DAWN During GRIP Campaign

5 different azimuth angles from -45 to + 45°
2 sec shot integration; 2 sec scanner turn time





Example:
1 pattern = 22 s = 3,168 m
Along-Track & Temporal Resolution

Swath Width Depends on Flight
And Measurement Altitudes

e.g., Flight Altitude = 10,586.4 m
Measurement Altitude = 0 m
Swath Width = 8,688 m

Trade Off

Fast revisit time to
less azimuth angles
vs.
Slower revisit time to
more azimuth angles
(less cloud blockage?,
wind variability
studies, measure w)

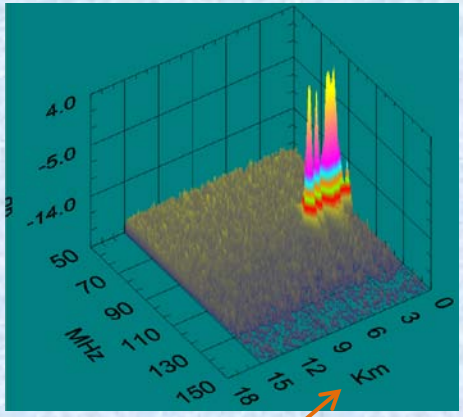
Note: weather models
assimilate LOS winds

Example: Spectra vs. Azimuth Angle

8/24/10; data folder 143213; scan pattern 1, 60 laser shots averaged

Periodograms shifted to remove laser jitter before averaging

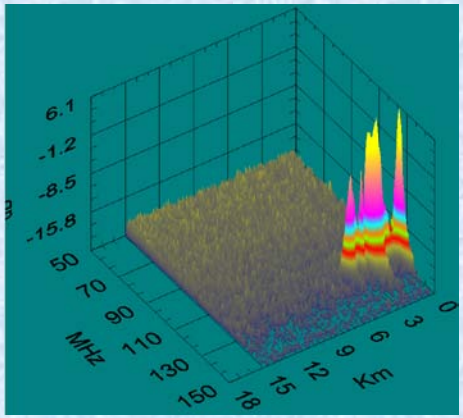
-45 Azimuth 1



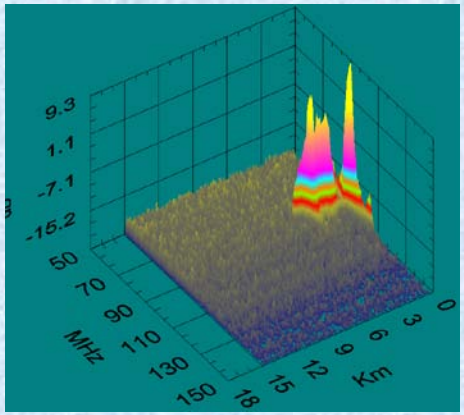
dB

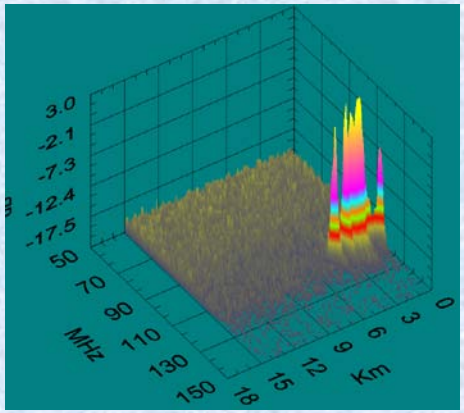
Slant range from DC-8

0 Azimuth 3

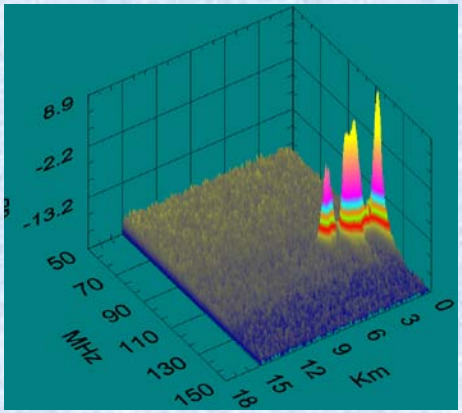


45 Azimuth 5





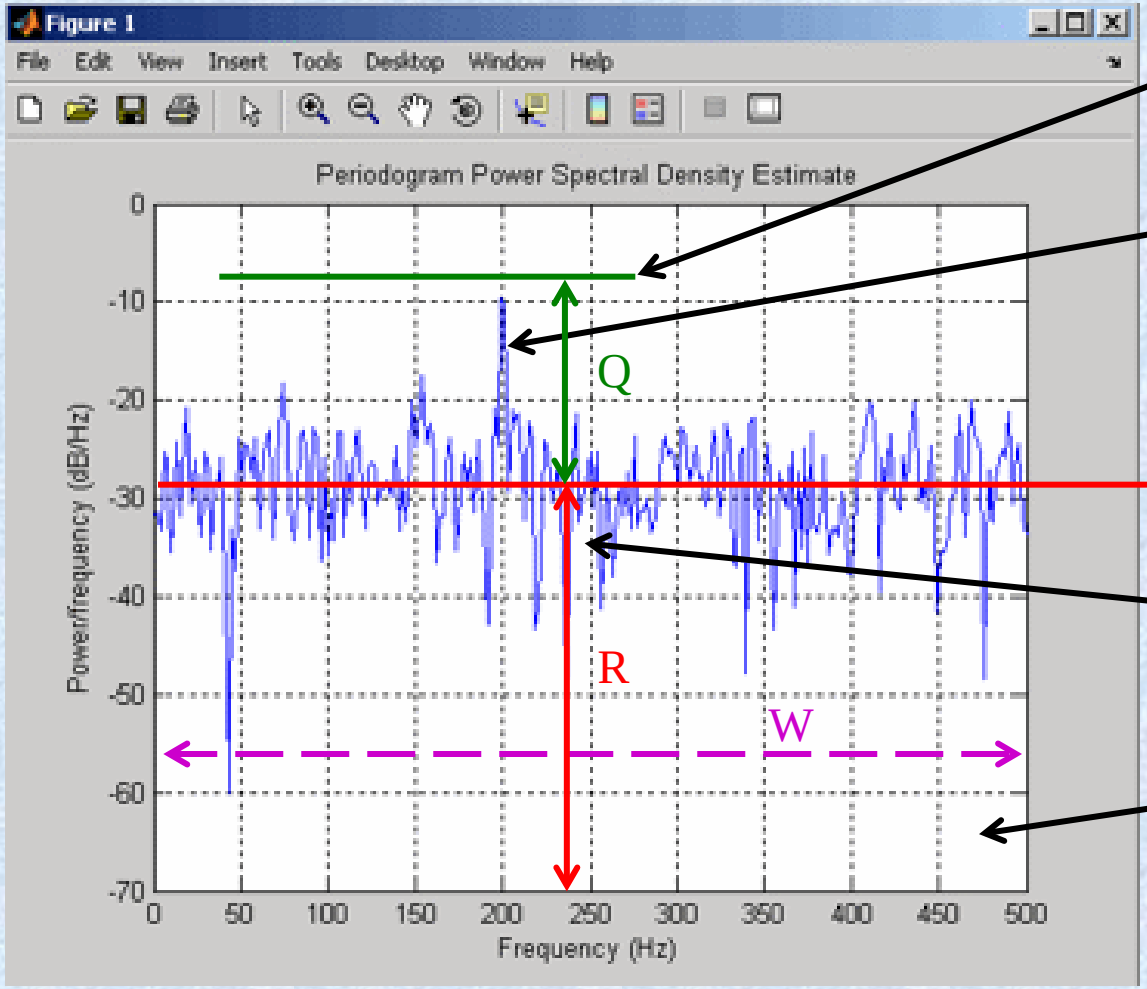
-22.5 Azimuth 2



22.5 Azimuth 4

In principle, zero, first, and second moments measured

Periodogram: Estimating Signal Frequency After N_P Shot Accumulation One Range Gate, One Realization



Mean Data Level = L_D
Data Fluctuations = $s_D = L_D/\sqrt{N_P}$

Mean Signal Power = area under mean signal bump but above mean noise level. $P_S = A_S = [(L_D - L_N) \cdot \Delta f \cdot 1]$ (if signal in one bin)

Mean Noise Level = L_N

Noise Fluctuations = $\sigma_N = L_N/\sqrt{N_P}$

Mean Noise Power = area under mean noise level = R x W

$$\Phi = \frac{L_D - L_N}{L_N} = \frac{Q}{R}$$ ☺

$$SNR = \frac{Q}{RW}$$ ☹

Data = Signal + Noise, D = S + N

$$\int_0^\infty (Mean\ Periodogram)\, df = Ave.\ (Signal + Noise)\ Power$$