Status of DAWN Data from NASA GRIP Campaign

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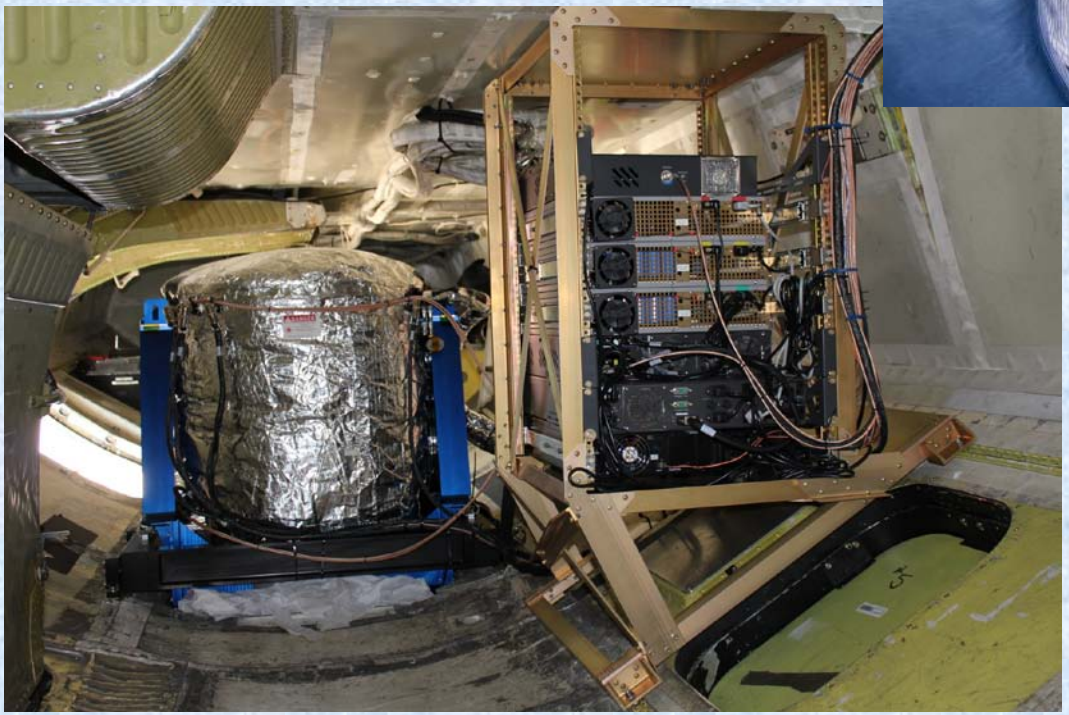
DAWN in DC-8 for GRIP

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

GRIP Campaign Facts

- 3 shakedown flights, 8/5-6/10
- 1 checkout flight, 8/10/10
- 6 ferry flights (2 for CA – FL and FL - CA)
- 25 science flights, 8/17 – 9/22/10
- Science flights based in Fort Lauderdale or St. Croix
- Target storms include hurricanes Earl, Gaston, Karl
- DC-8 flight time = 6712 minutes
    - DAWN recording data for 5787 (89%)
- 328 dropsondes
    - DAWN recording data for 314 (96%)

DAWN Nominal Scan Pattern

- Most frequent value of laser shot averaging was 20
  - 68% of scan patterns during science flights
- 2 s for 20 shots, 2 s to change azimuth, 2 s to conclude scan pattern $\Rightarrow$ 22 s
- 22 s x nominal DC-8 450 knots (231.5 m/s) = 5.1 km horizontal resolution

- For 60 shots averaged:
- 6 s for 20 shots, 2 s to change azimuth, 2 s to conclude scan pattern $\Rightarrow$ 42 s
- 9.7 km horizontal resolution

Data Processing Priority

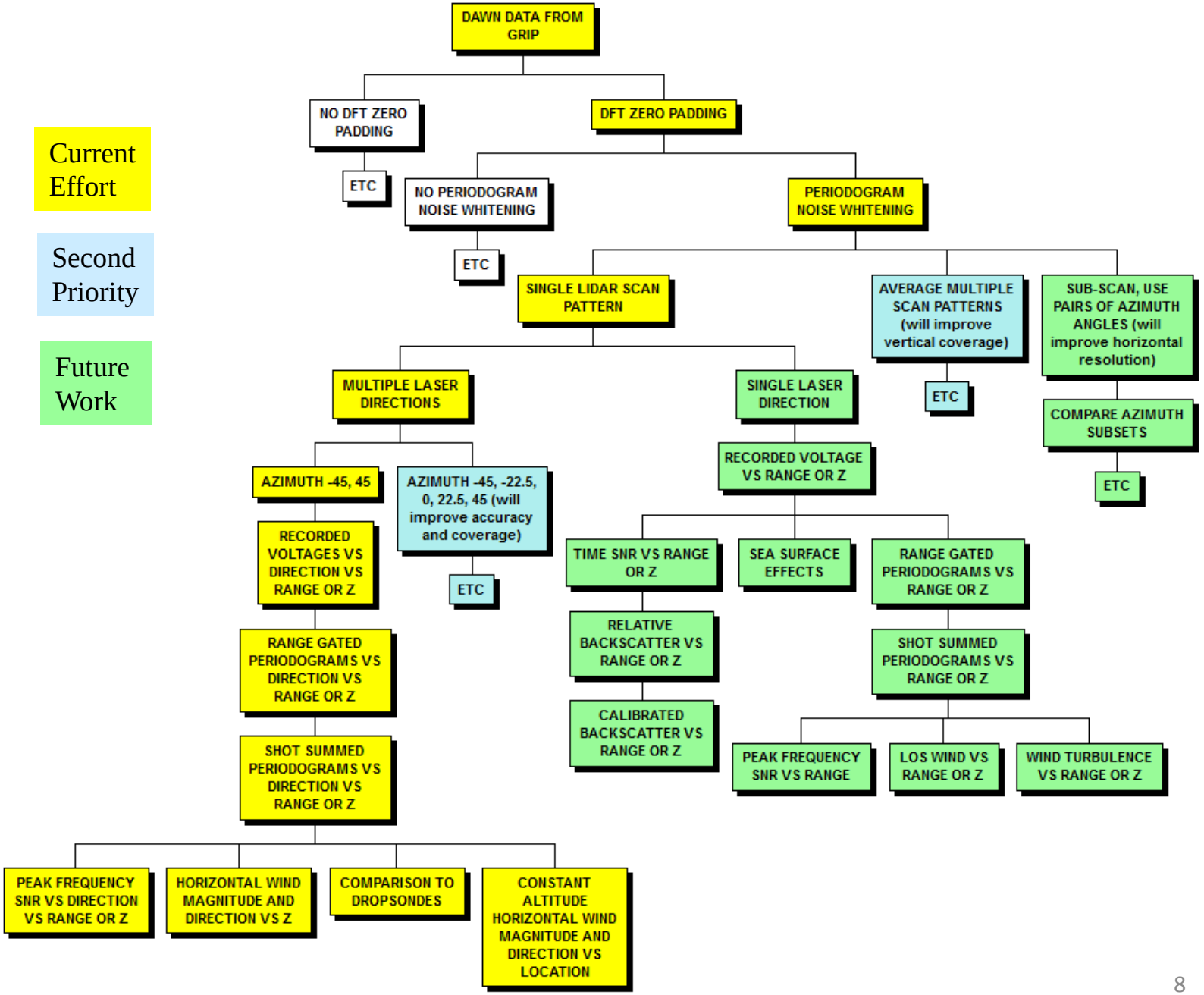
- Flight and processing software written in ANSI C
- Did not have lidar diagnostic, quality control, and ASCII file generation software at time of GRIP campaign
- Data acquisition & processing lead won ACT project as PI, and given other assignments since GRIP campaign ended
- Got 2-azimuth data processing to work before 5-azimuth data processing; 5-axis still in queue to date
- Since campaign we have worked on correct aircraft velocity removal, noise whitening, zero padding, data processing options, generation of text files, and quality control threshold by SNR
- Have recently processed, QC'ed, and uploaded majority of data to GRIP web site; should be publicly available before May 9 GRIP Science Team meeting
- Second tier priority is 5-azimuth angle processing, and scan pattern averaging for better vertical coverage at expense of nominal 5.1-km horizontal resolution

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

Current Effort

Second Priority

Future Work



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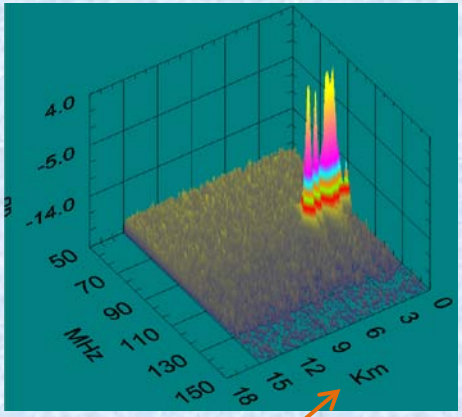
Example: Spectra vs. Azimuth Angle

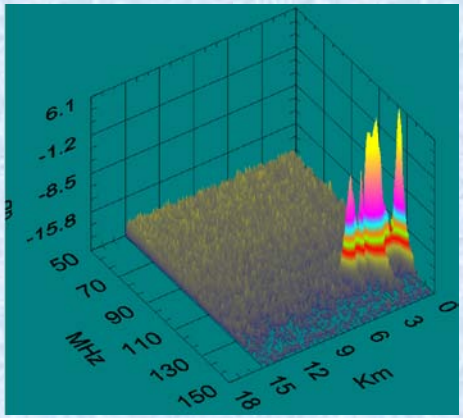
8/24/10; data folder 143213; scan pattern 1, 60 laser shots averaged

Periodograms shifted to remove laser jitter before averaging

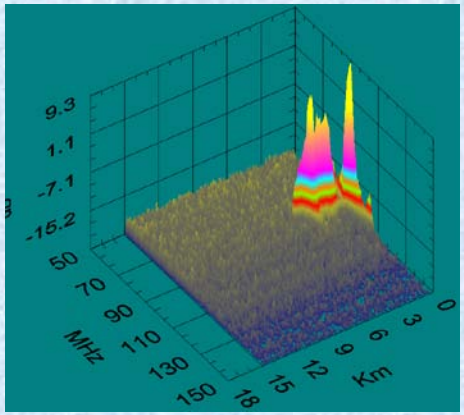
-45 Azimuth 1



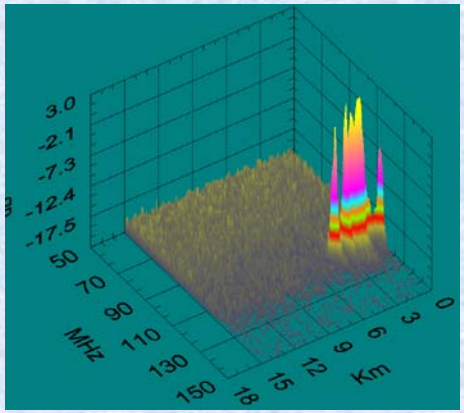
0 Azimuth 3



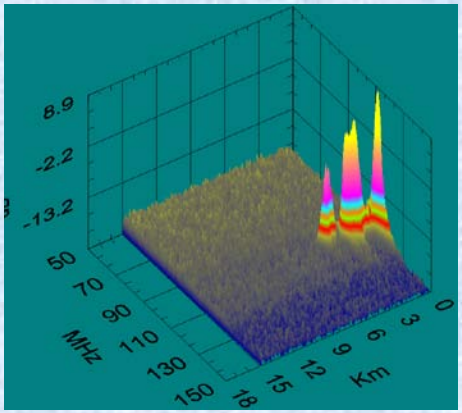
45 Azimuth 5



Range from DC-8



-22.5 Azimuth 2



22.5 Azimuth 4

$$f_{SIGDET} = \left| \left[\left(f_{SEED} + f_{JITTER} \right) + f_{AIRCRAFTLOS} + f_{WINDLOS} \right] - f_{SEED} \right|$$

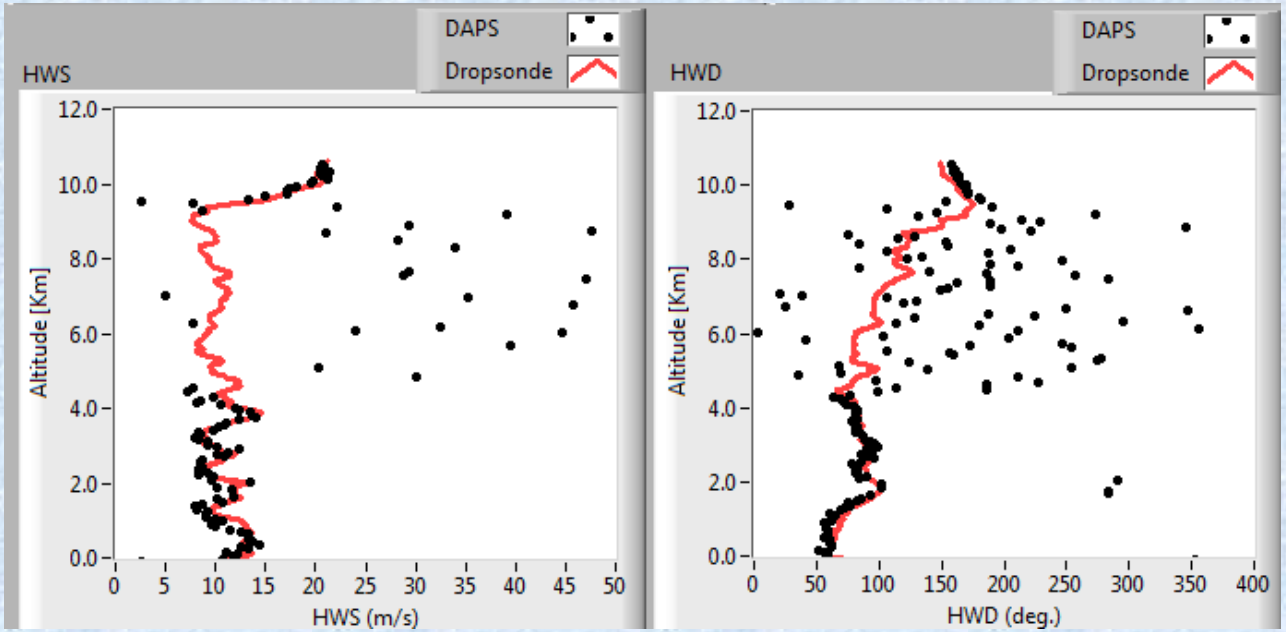
$$= \left| f_{JITTER} + f_{AIRCRAFTLOS} + f_{WINDLOS} \right| = f_{JITTER} + f_{AIRCRAFTLOS} + f_{WINDLOS} \approx f_{AIRCRAFTLOS} + f_{WINDLOS} \approx f_{AIRCRAFTLOS}$$

Assumption of zero DC-8 drift angle predicts $f_{AIRCRAFTLOS}$ for 231.5 m/s are: 80, 105, 113, 105, 80 MHz

Example: Comparison DAWN to Dropsonde

9/1/10, data folder 172015, 20 shots averaged

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

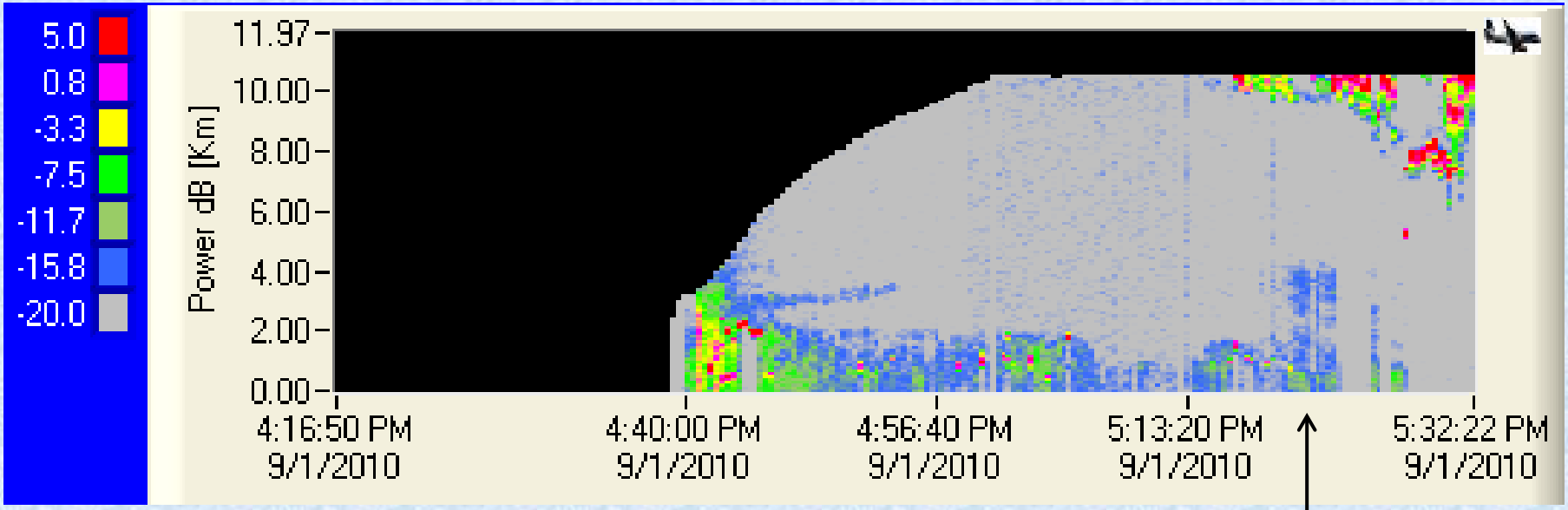


N = number shots averaged

Example: Signal Energy vs. Altitude During Takeoff

9/1/10, data folder 172015, 20 shots averaged

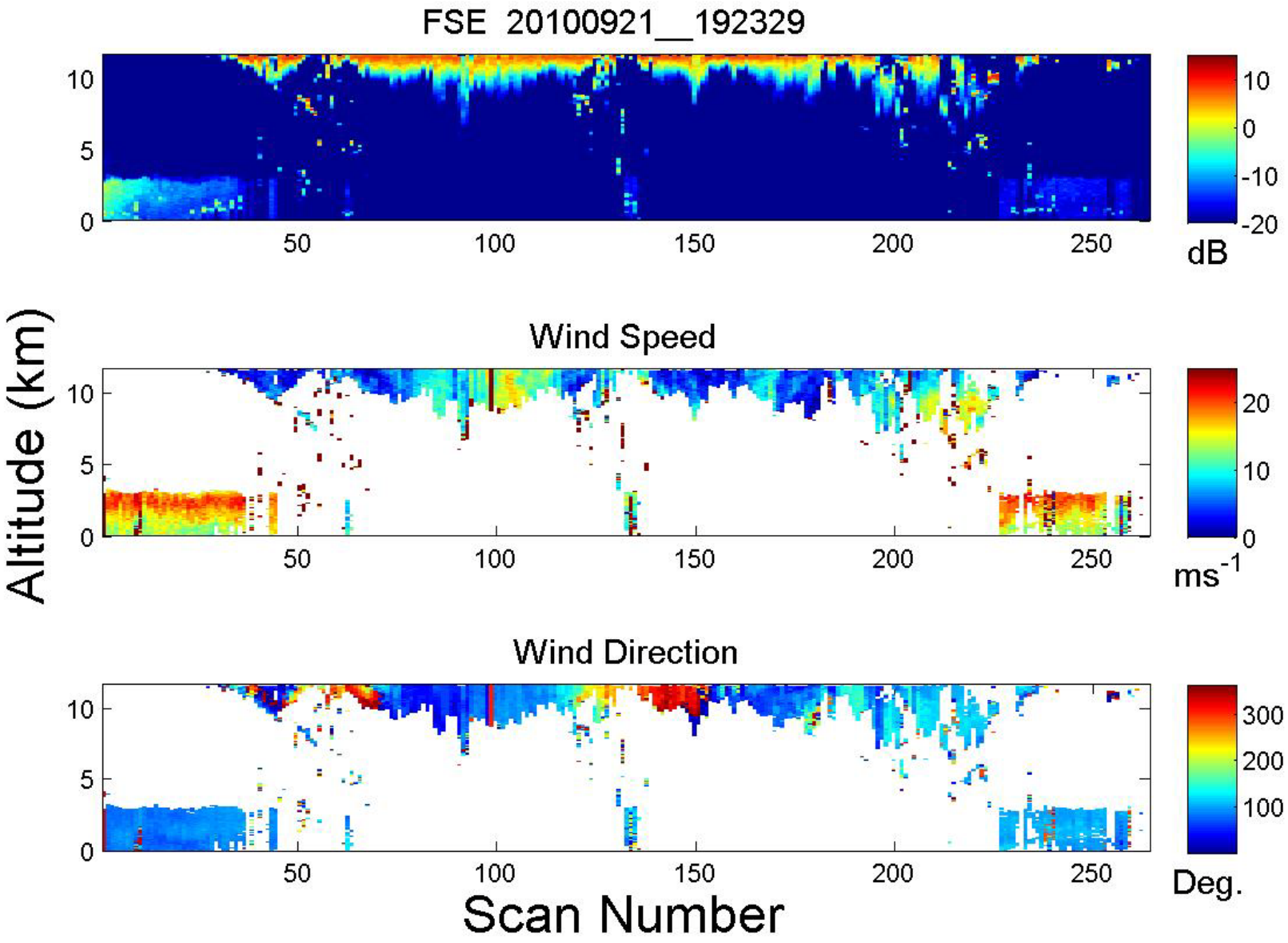
Taking off from Fort Lauderdale to fly into Earl



~ dropsonde launch

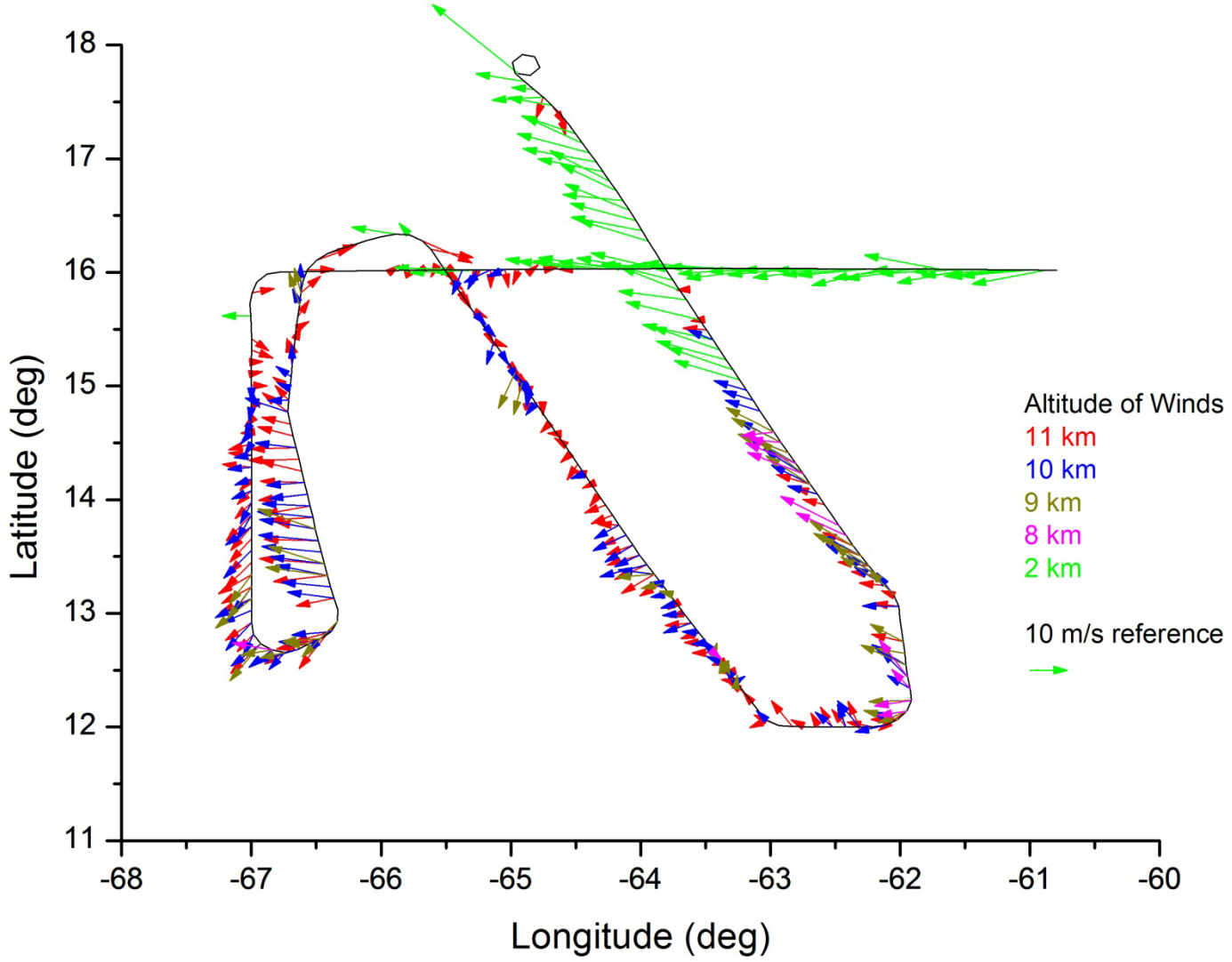
time for previous slide

Example: Vertical Slice, ~ 202 Minutes Duration, 60 Shots Averaged, ~9.7 km Resolution



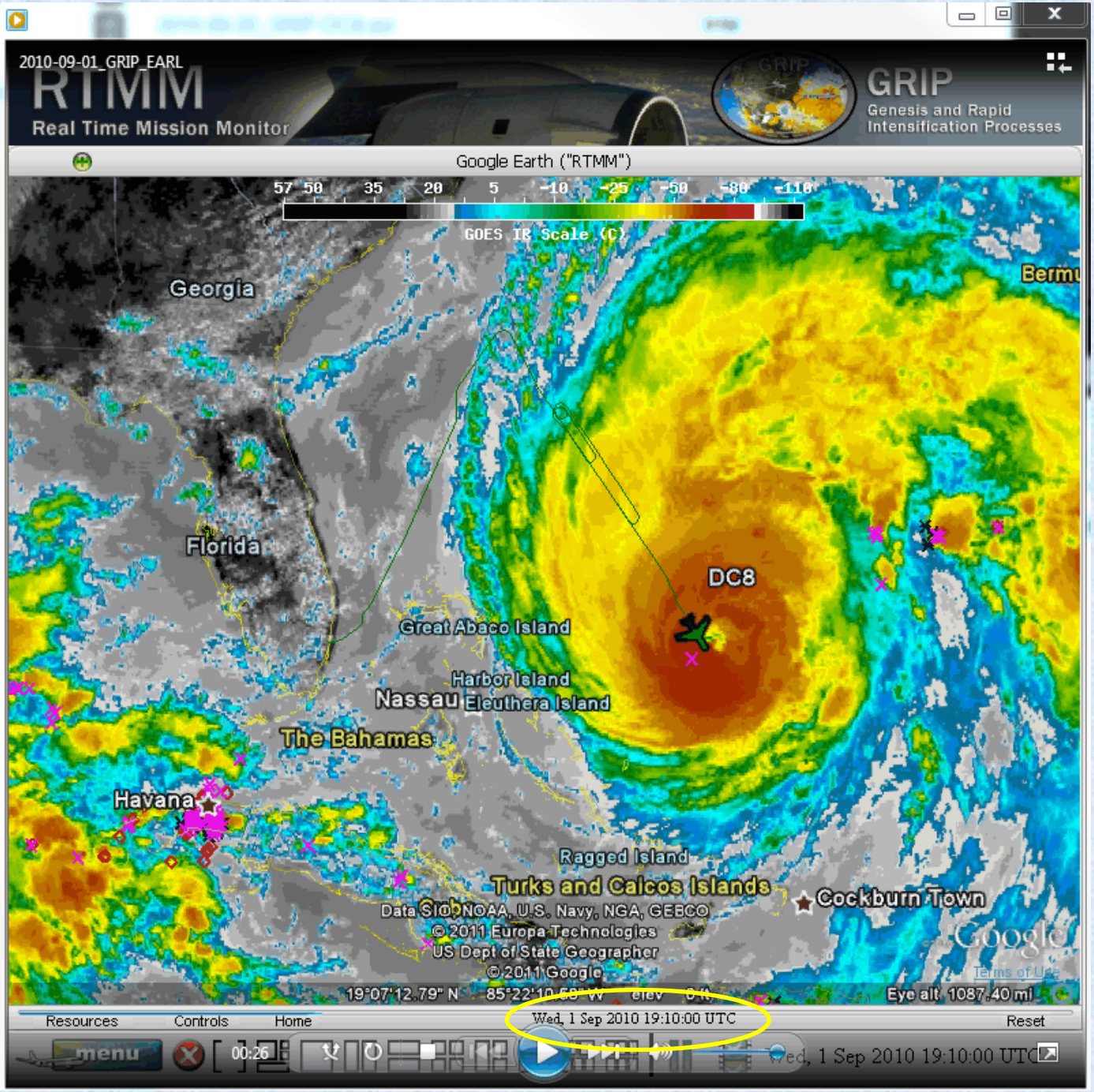
~ 285 independent wind profile attempts, FSE = Frequency-domain signal energy estimate

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



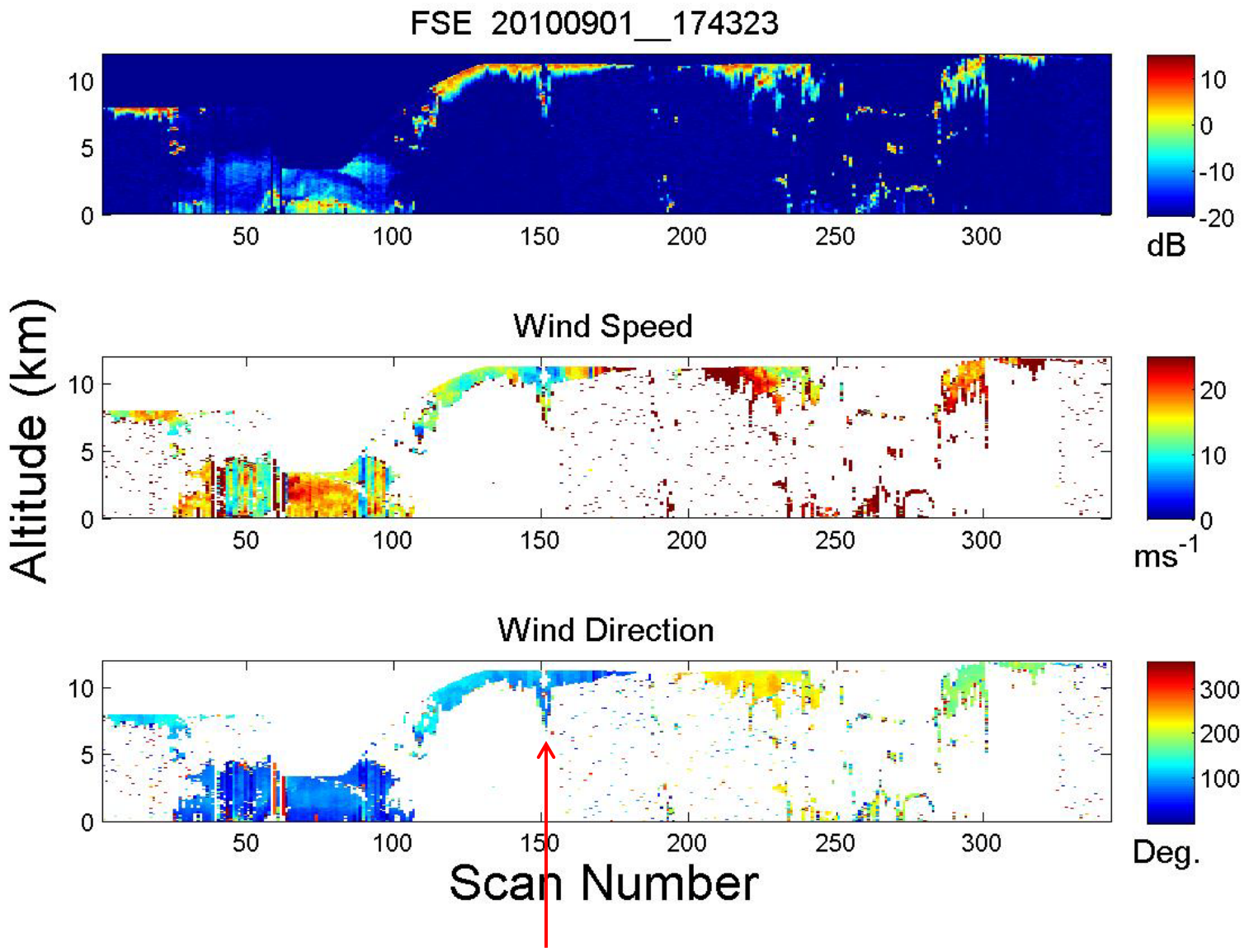
Example:
Crossing Hurricane Earl Eye

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



Example: Crossing Hurricane Earl Eye
19:00:00 is DAWN scan 154

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



Lessons Learned

- DAWN-AIR projects were funded about $500K below requested levels
- Unexpected money and time spent helping LaRC investigate project risk even though funder was comfortable with proposed risk
- Several last minute calamities combined with inadequate schedule reserve led to ~14 dB loss in signal level for all flights; 250 mJ pulse energy was effectively 10 mJ !
- PI overly optimistic in proposing to participate in science campaign without adequate checkout flights
- NASA's rare and focused funding opportunities do not permit low risk and steady technology advancement at same time; no core directed funding to bridge project duration gaps
- PI did not request adequate software capabilities for problems encountered in GRIP
- Very difficult to measure pulsed, 2-micron, coherent-detection lidar sensitivity gap below theoretical; inadequate instrumentation for pulsed 2-micron light exists or is very expensive; lack of long test range without atmospheric uncertainties
- Hurricane research in clouds over water was wrong venue to debug 2-micron lidar

The Good News

- Thanks to NASA SMD ESD, ESTO, and LaRC funding:
- We are fixing the hardware and software problems
- We are almost done with the repairs
- We are gaining more understanding of proper lidar integration steps
- We are integrating DAWN onto LaRC UC-12B aircraft to validate the repaired lidar system, and to perform research for offshore wind power
- We will soon be ready for UC-12B science opportunities
- We are ready today for DC-8 science opportunities