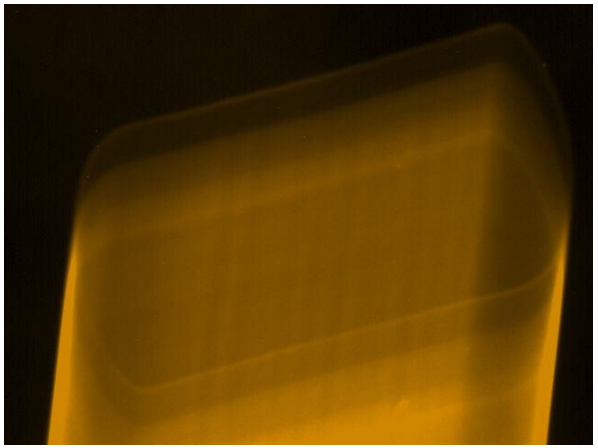

Science Report
DEEPWAVE Lidars

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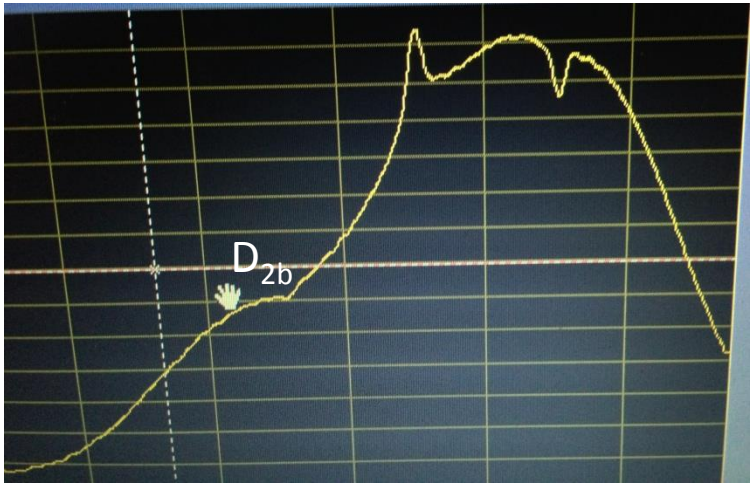
Na lidar

Crossover D_{2a}

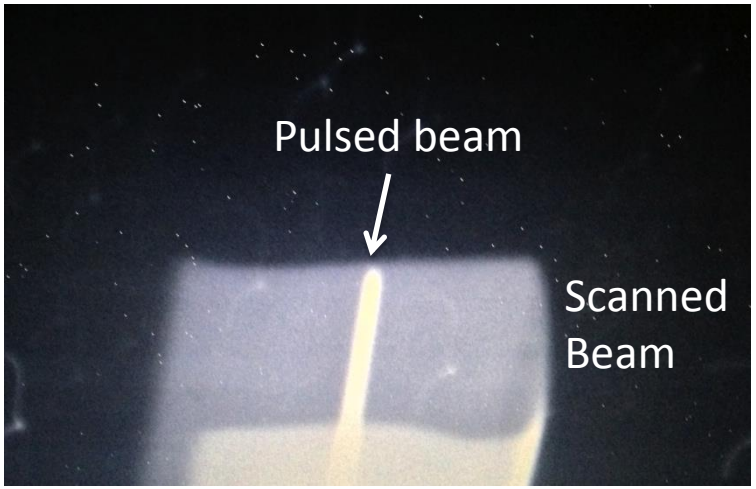


Na Doppler-Free spectrum in flight
1 sec laser frequency scan

- The sodium laser (Toptica DL-RFA-SHG) produces 10W CW power at the Na D_2 line at 589nm using a standard IR seeder, a new Raman fiber amplifier, and a standard doubling cavity
- Doppler-Free spectroscopy uses a Na vapor cell to obtain two frequency lock points with an absolute frequency calibration of 1-2 MHz
- Ratio of atmospheric Na scattering at two frequencies (D_{2a} and crossover) is proportional to temperature – Joe She's original two-frequency method
- Third lock point produced with acousto-optic frequency shifter (same as current systems) to obtain the radial wind along the beam direction
- Laser can scan 10GHz/sec with no mode hops, very good frequency agility, 10x narrower line width than current Na lidars
- Output beam is locked to Na spectrum, so no frequency offset (chirp) between the seeder and amplifier like other Na lidars
- Laser only needs optical adjustment every ~3-6 months with little or no adjustment needed after shipping or between test flights
- Can be operated by a technician, no laser skills necessary, much easier to operate than current Na systems

Na lidar (cont)

- Uses two innovative techniques to obtain range-resolution with a CW laser: acousto-optic modulation and angle modulation
- 14W beam is divided in parallel into two beams:
  - Acousto-optic modulator makes a 100mW pulsed beam for vertical wind and temperature measurements from 15-30 km ASL and Na density profiles
  - 7W beam scanned in 1.5^0 rectangle for high time resolution temperatures and vertical winds from 80-100km altitude
- We are moving the AOM and scanner into series configuration to double the output power of both beams
- Pulsed beam uses exact same fiber coupled receiver (40% PMT, filter) and analysis procedure as some of the current Na lidars -> safe design
- Scanned beam shape is produced with a 70,000 point-per-second galvo scanner and the linear edge is aligned with a new 32 channel PMT with an integrated 32 channel counter board
- Each of the 32 channels sees a pulsed 100mW profile staggered in time, these can be shifted and co-added to get very high signal strengths and good time resolution
- The beam guiding camera and motorized beam steering mirrors worked and allowed quick beam alignment and monitoring during flights



View from beam guiding camera
2.5 degree field-of-view

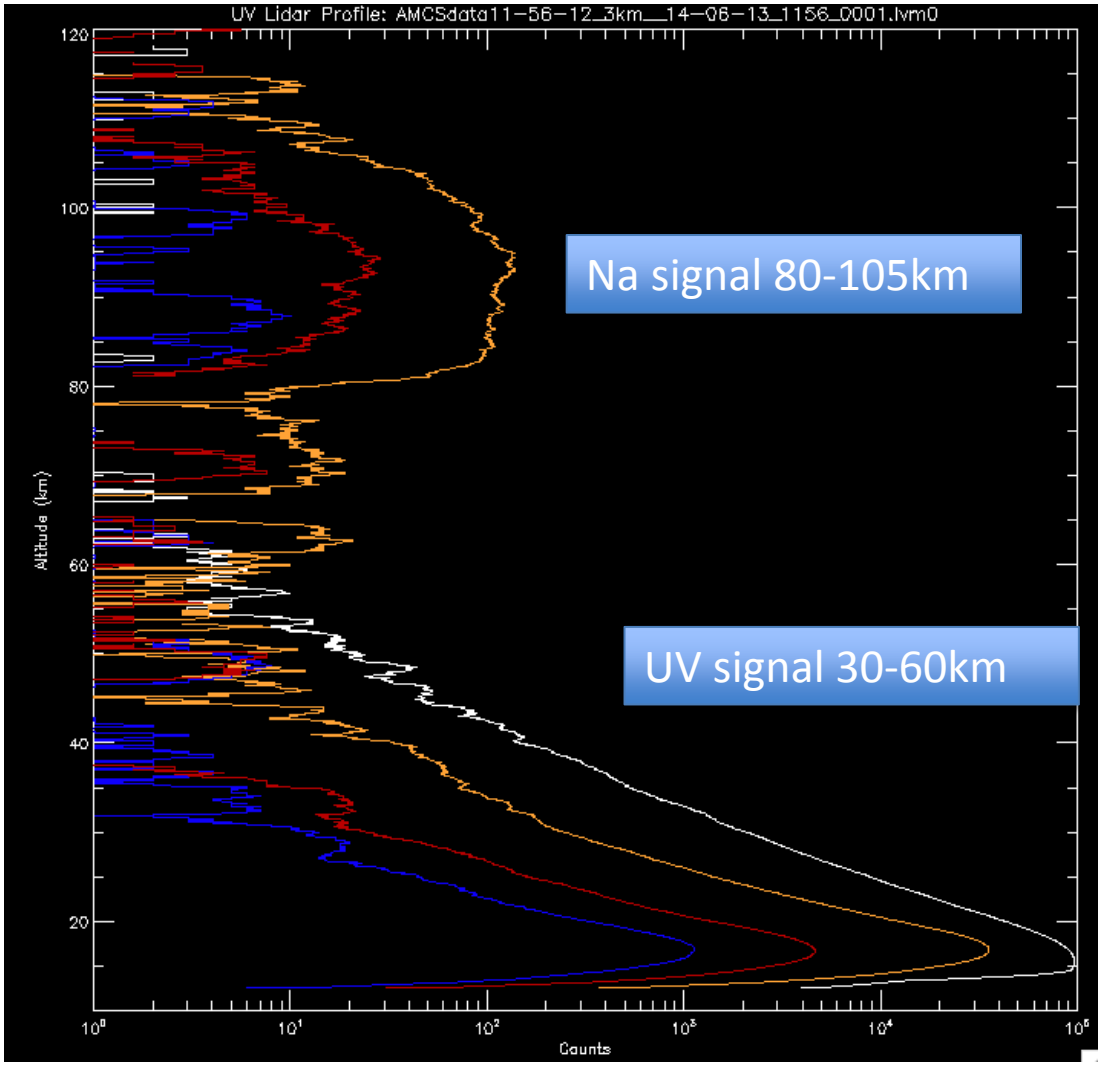
Rayleigh (UV) lidar

- The stock Photonics Nd:YLF laser produces 5W of power at 351nm at 1kHz pulse repetition rate
- Beam is eye safe for overflying aircraft
- Measures the molecular Rayleigh scatter which is proportional to atmospheric density
- Density profile integrated from top down, assuming hydrostatic equilibrium, => temperature profile
- Model used for the start temperature at the top altitude (~60-70km), so top scale height is not independent
- Altitudes below 30km are not used due to possible aerosol contamination
- No issues currently, except for lower signal from 12” backup telescope

Photonics DM20-351 laser

UV, Na, and Double-Edge Profiles

120km

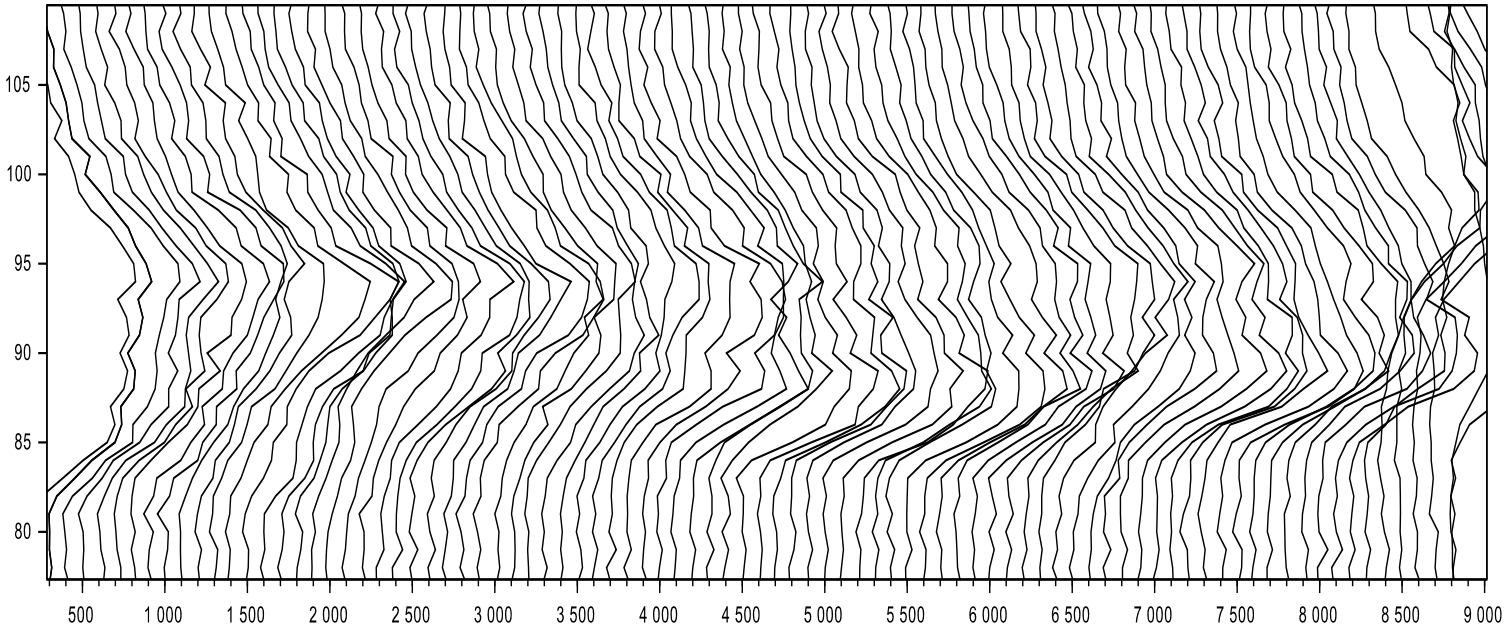


Double-Edge
15-25km

10km

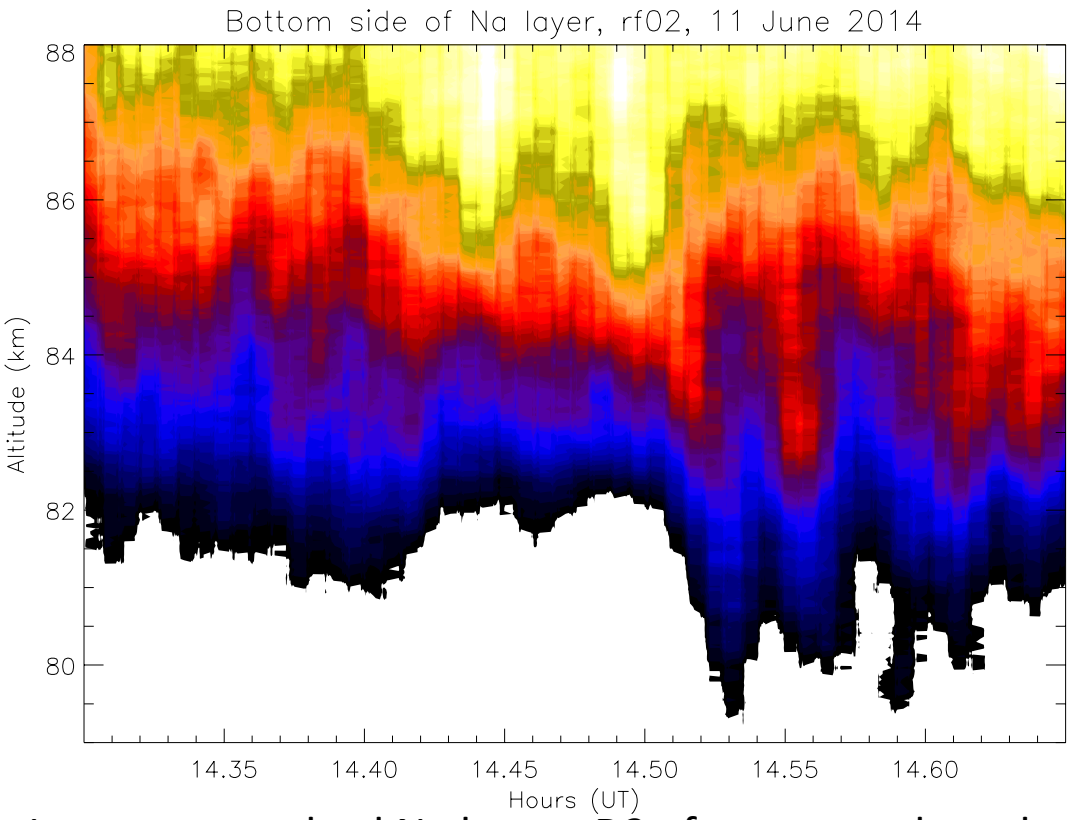
Log scale

Waves in Na Density: rf06



- Low power pulsed Na beam, D2a frequency plotted
- Altitude vs distance/time plot
- 30 sec profile cadence, 45 min total during WP6 to WP2
- Both ascending and descending wave fronts

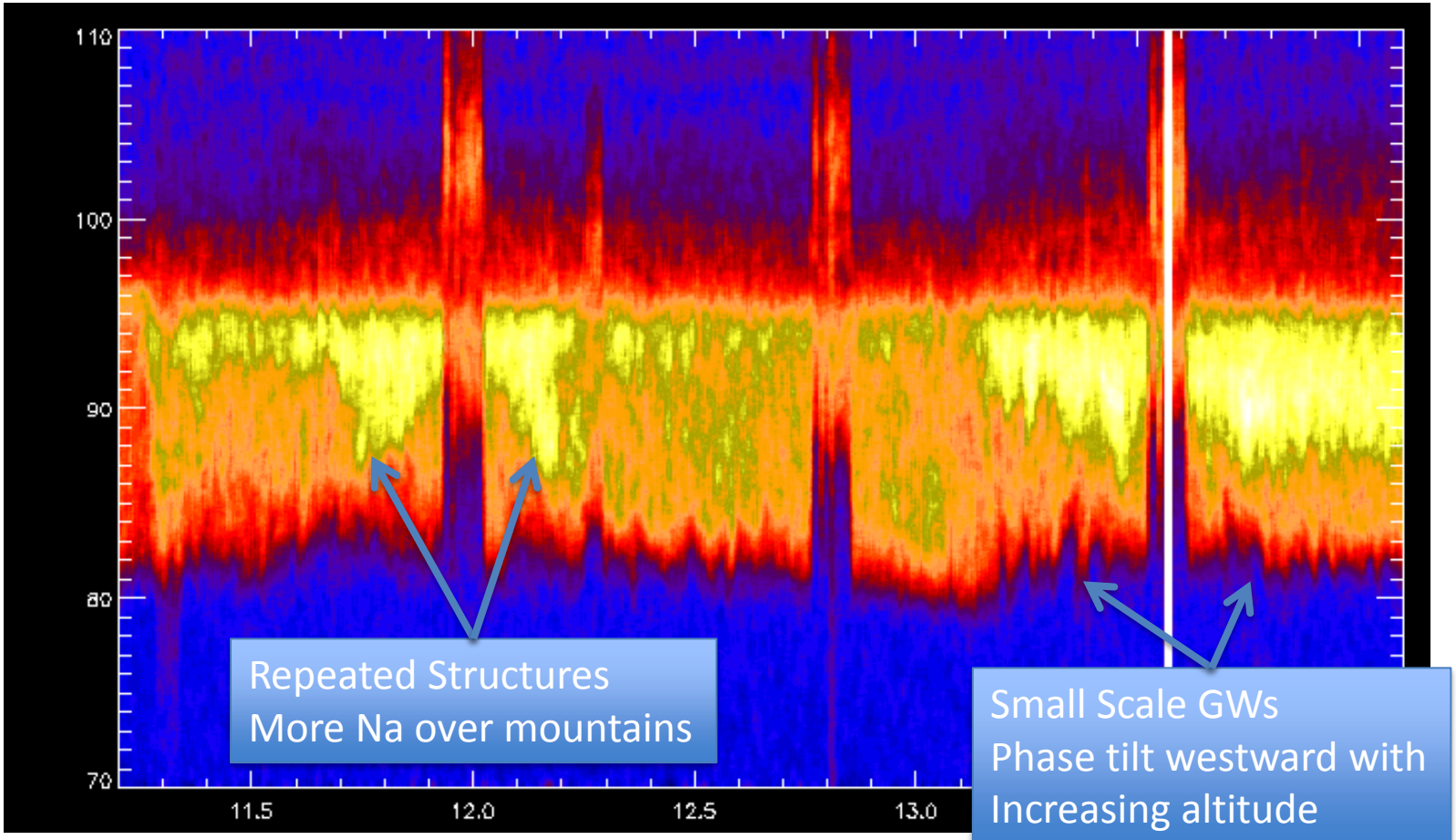
Waves in Na Density: rf02



- Low power pulsed Na beam, D2a frequency plotted
- Altitude vs distance/time plot
- 30 sec profiles cadence, 14.3 to 14.7 UT
- Waves perturb bottom edge of Na layer 1-2 km vertically

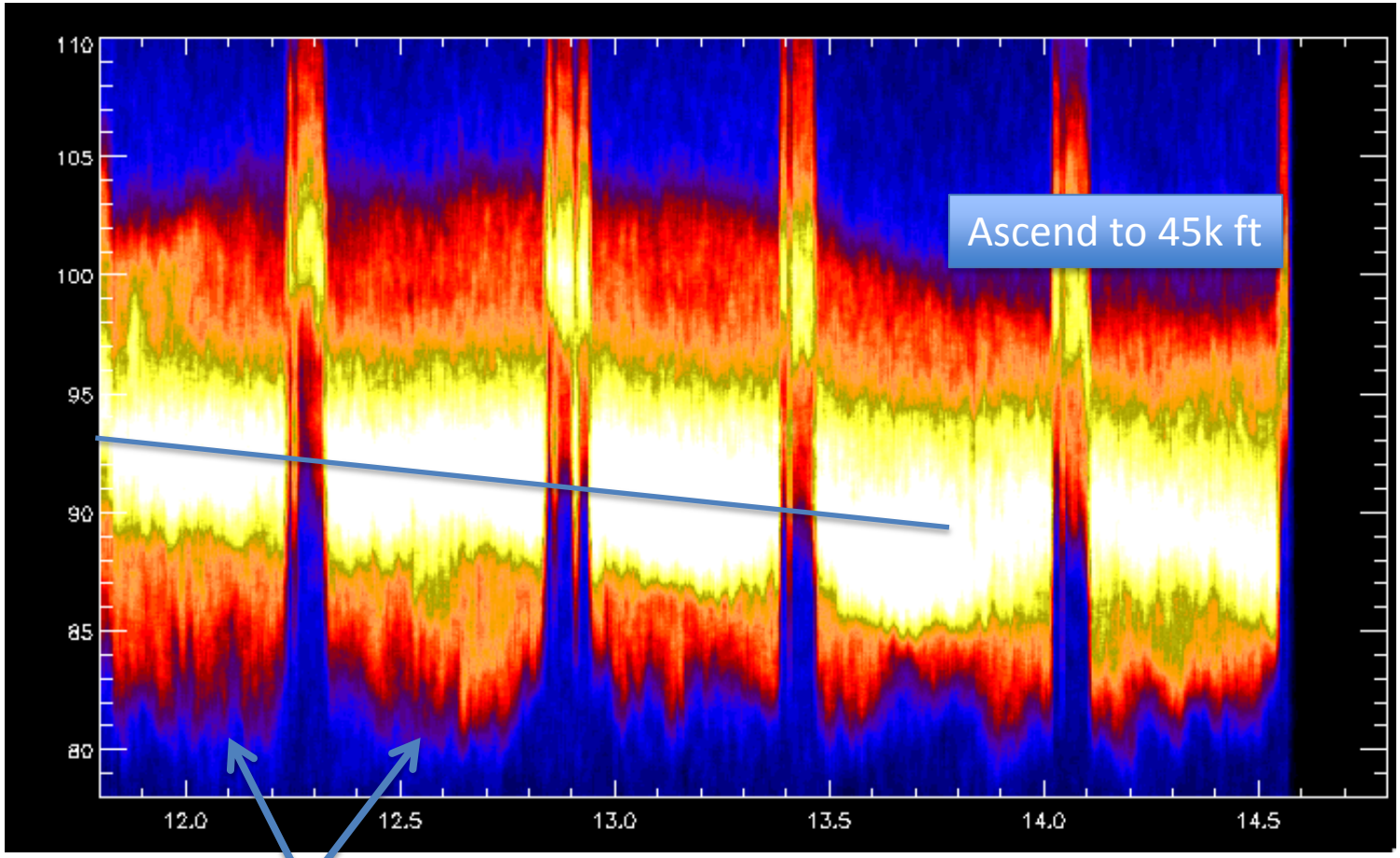
Waves in Na Density: rf04

Turn on W side Turn on E side Turn on W side



Waves in Na Density: rf05

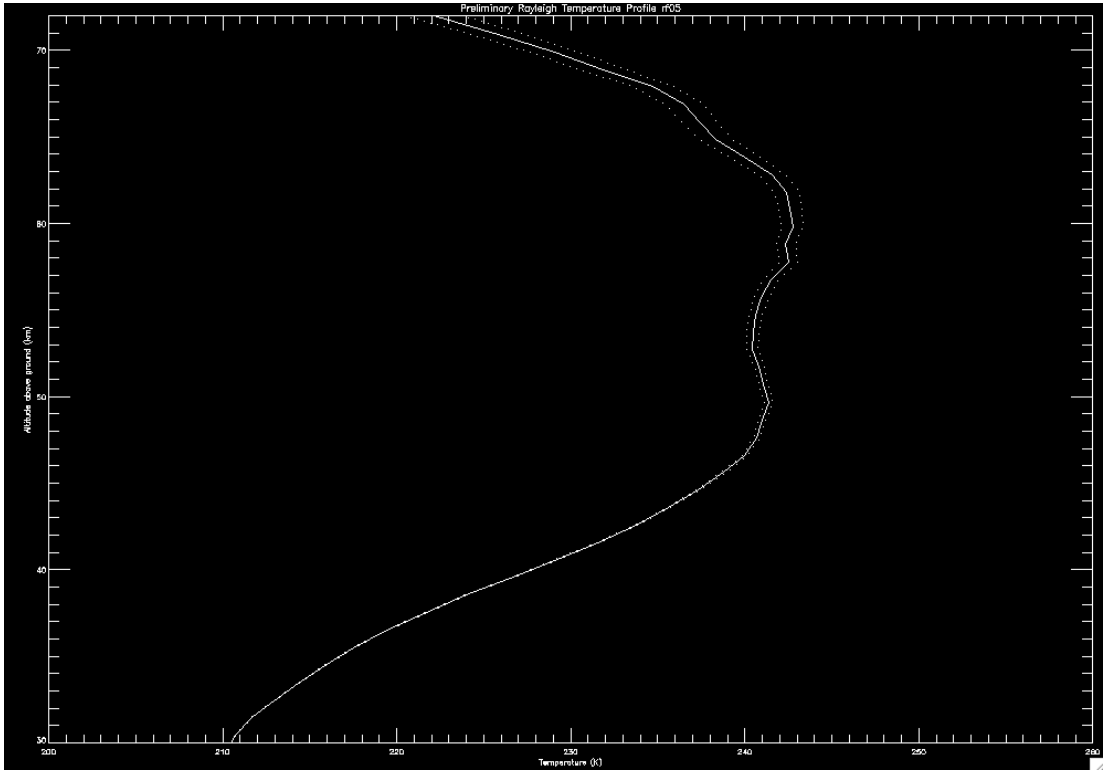
W side E side W side E side W side E side



Small Scale GWs

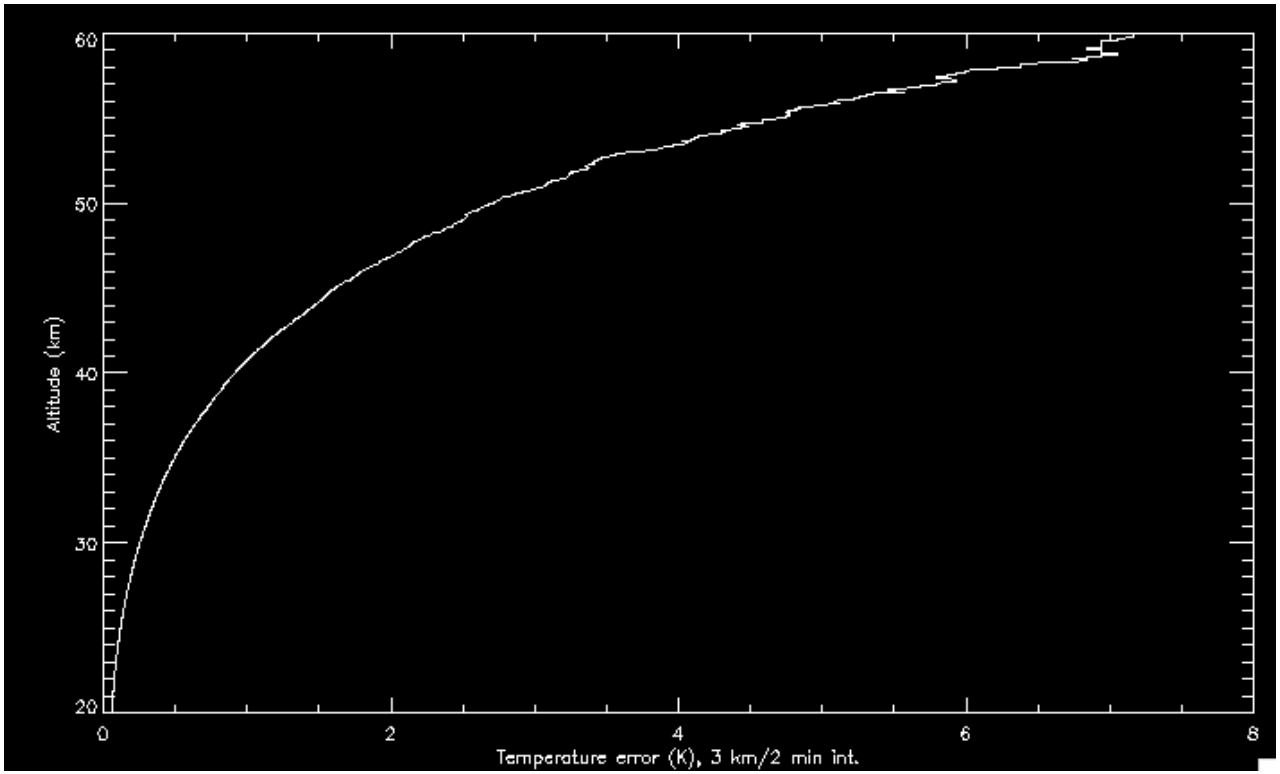
Large scale variation in top of Na layer and centroid
Likely due to long-period GW or tide

Rayleigh Temperature Profile



- Example plot, used old start point on top end.

Rayleigh Temperature Errors



- Based on current signal levels, consistent with 2013 flight test
- 0.5K error at 30 km in 2min, 3km integration
- 1K error at 40 km in 2min, 3km integration
- 2.5K error at 50 km in 2min, 3km integration
- Can go higher in altitude with longer integrations

Conclusions

- Sodium and Rayleigh lidars are working and measuring density and temperature variations with the Rayleigh and low-power Na beam
- Observe many GW's in the upper mesosphere in the Na density
- Still working on high power (scanned) Na beam alignment and timing
- Working on Doppler spectral analysis for the DEMOF stratospheric measurements
- Na laser frequency locking slightly worse in flight, need to adjust analysis code