Airborne Lidars to Measure Stratospheric Winds and Temperatures over Deep Convection during the CGWaveS Campaign

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Poster 12

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References:

Dörnbrack, A., Eckermann, S. D., Williams, B. P., and Haggerty, J. (2022). Stratospheric Gravity Waves Excited by a Propagating Rossby Wave Train—A DEEPWAVE Case Study, Journal of the Atmospheric Sciences, 79(2), 567-591.

Huang, W., X. Chu, B. P. Williams, S. D. Harrell, J. Wiig, and C.-Y. She, Na Double-Edge Magneto-Optic Filter for Na Lidar Profiling of Wind and Temperature in the Lower Atmosphere, Optics Letters, 34, 199-201, 2009.

Williams, B. P. and S. Tomczyk, Magneto-optic Doppler analyzer: A new instrument to measure mesopause winds, Applied Optics, 35, 6494--6503, 1996.

CGWaveS Campaign

- **CGWaveS:** Convective Gravity Waves in the Stratosphere, June/July 2023 in midwestern USA
- Thunderstorms and other convective systems produce convective gravity waves (CGWs) which have major influences on stratospheric circulation, structure, variability, and predictability

- Goal: Measure CGW generation, propagation, and variability in the stratosphere
- Method: Fly NCAR HIAPER Gulfstream V aircraft over large thunderstorms at night
- Instruments: Two lidars, aircraft in situ, OH imagers, and ground-based instruments.
- WRF, MAGIC, and CGCAM models will provide forecasts and context (Figure at right)
- Airborne lidars were developed at GATS for the DEEPWAVE campaign in 2014 over New Zealand

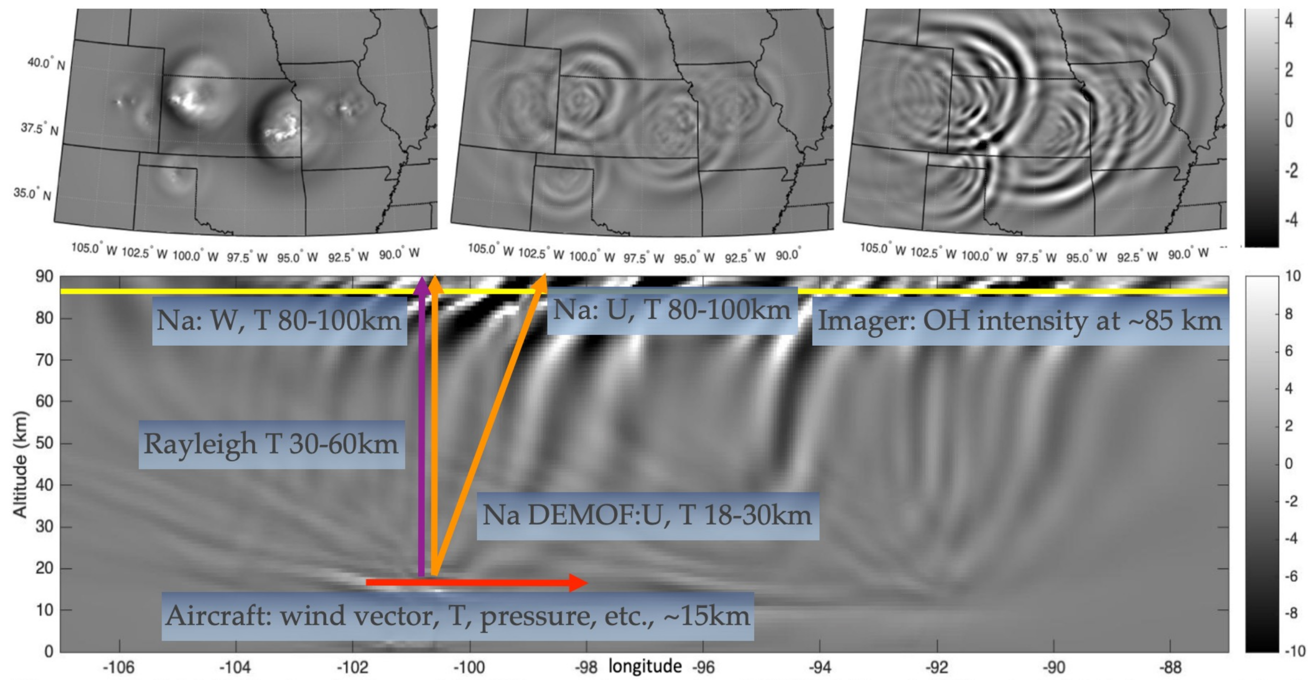


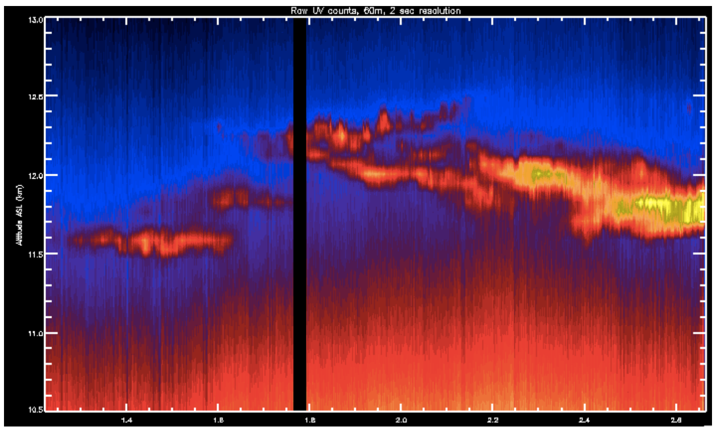
Figure 13. MAGIC simulation of CGWs employing the NEXRAD rainfall rate SA15 forcing at 2- km resolution over the CGWaveS RAO on 8 July 2016 at 15, 30, and 60 km, and in the x-z plane.

Airborne Rayleigh Lidar

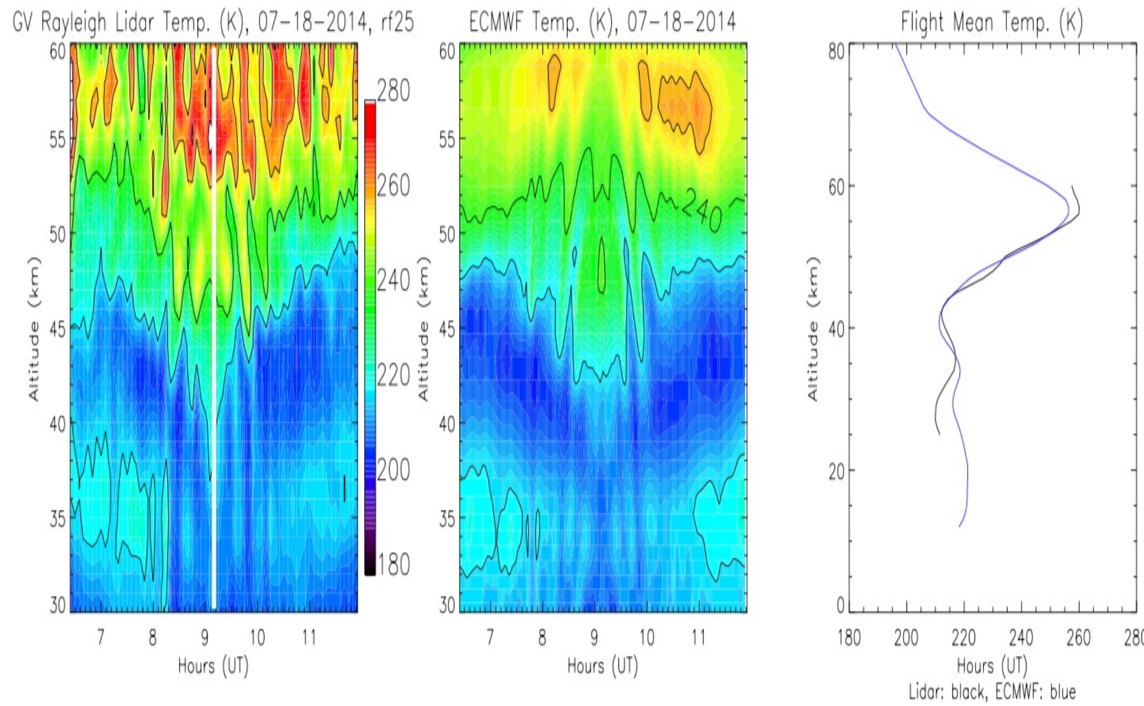
- Both lidars fit in two standard NCAR Gulfstream V instrument racks (right)
- Transmitter: diode-pumped Nd:YLF Photonics DS20-351, 5W, 1kHz, 351nm wavelength (bottom)
- Reason for UV instead of higher power green:
  - Eye safe at aircraft exit for overflying aircraft
  - Stronger Rayleigh scatter in UV
  - Less atmospheric absorption flying at ~14km
- Receiver: 0.4m Newtonian fiber coupled receiver
  - upgraded from 0.3 m -> 75% more signal than DEEPWAVE

Airborne Rayleigh Lidar Example Data

Aerosol layers: 15-25km altitude at 200m horizontal and 37.5m altitude resolution

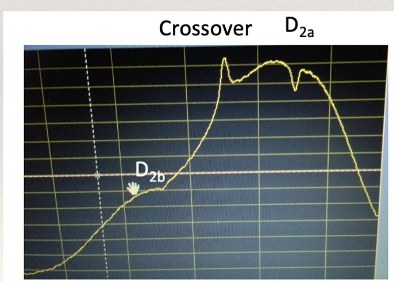


Density and temperature: 30-70km altitude, 3-12km horizontal and 1-2km vertical resolution, example below showing waves in temperature over the ocean near Antarctica on 18 July 2014 (see Dörnbrack et al., 2022).

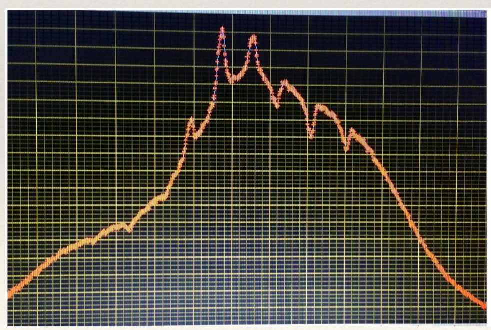


Airborne sodium wind-temperature lidar

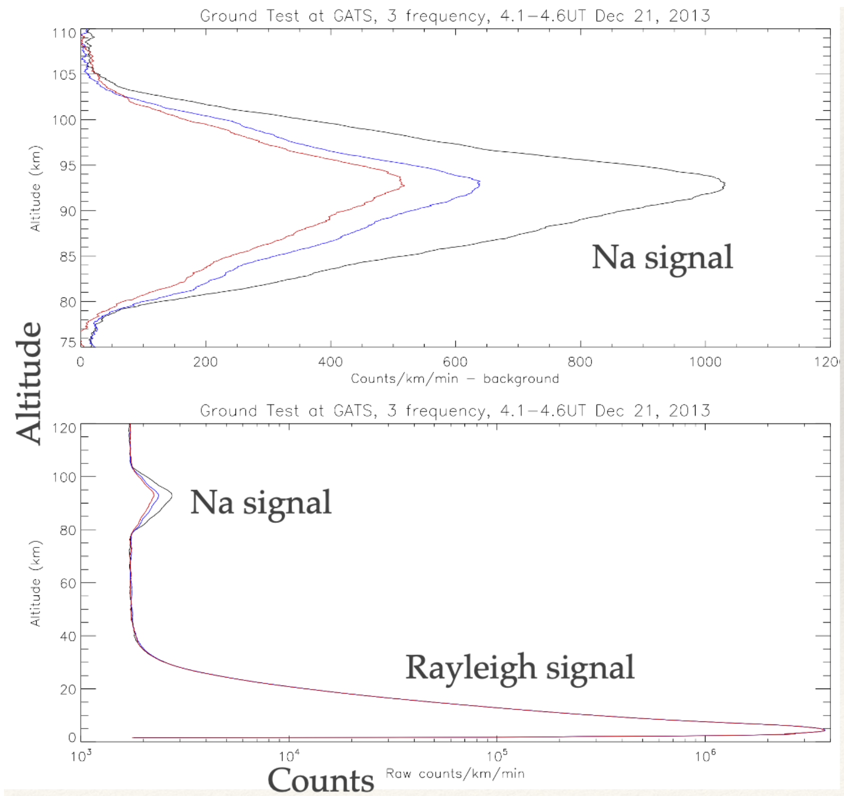
- 10W Toptica DL-RFA-SHG CW laser externally pulsed into two 150mW beams
- 589nm, 10 MHz linewidth, 2MHz absolute frequency accuracy, 1kHz pulse repetition rate
- Laser scanned and locked to 3 frequencies using acousto-optic saturation vapor spectroscopy
- Zenith beam shares 0.4m Rayleigh telescope -> temperatures and vertical winds from 80-100km altitude
- Second 0.4m telescope points 20deg off zenith to get winds, temperatures and BSR ahead of aircraft from 18-30km and 80-100km



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



Acousto-optic frequency shift added



Stratospheric winds from sodium vapor double-edge magneto-optic filter (DEMOF)

- Measures radial wind, temperature, and aerosol backscatter ratio from the Rayleigh/Mie scatter from the inclined Na beam from ~18-30km altitude
- The DEMOF was first developed at NCAR (Williams and Tomczyk, 1996) and at CU (Huang et al., 2009).
- The Wisconsin HSRL is a similar airborne lidar that uses an iodine absorption line to study aerosol backscatter.
- Uses a longitudinal magnetic field in a sodium vapor cell to Zeeman split the Na absorption line into two absorption lines coded by polarization
- The edge of the two absorption lines act as the “double-edge” to measure the Doppler shift of the returned light
- We switch the laser to two other frequencies to measure temperature and BSR with lower sensitivity
- DEMOF is less sensitive to vibrations than etalon-based systems