DEEPWAVE meeting, May 2015

GV Rayleigh Lidar Data Quality Report

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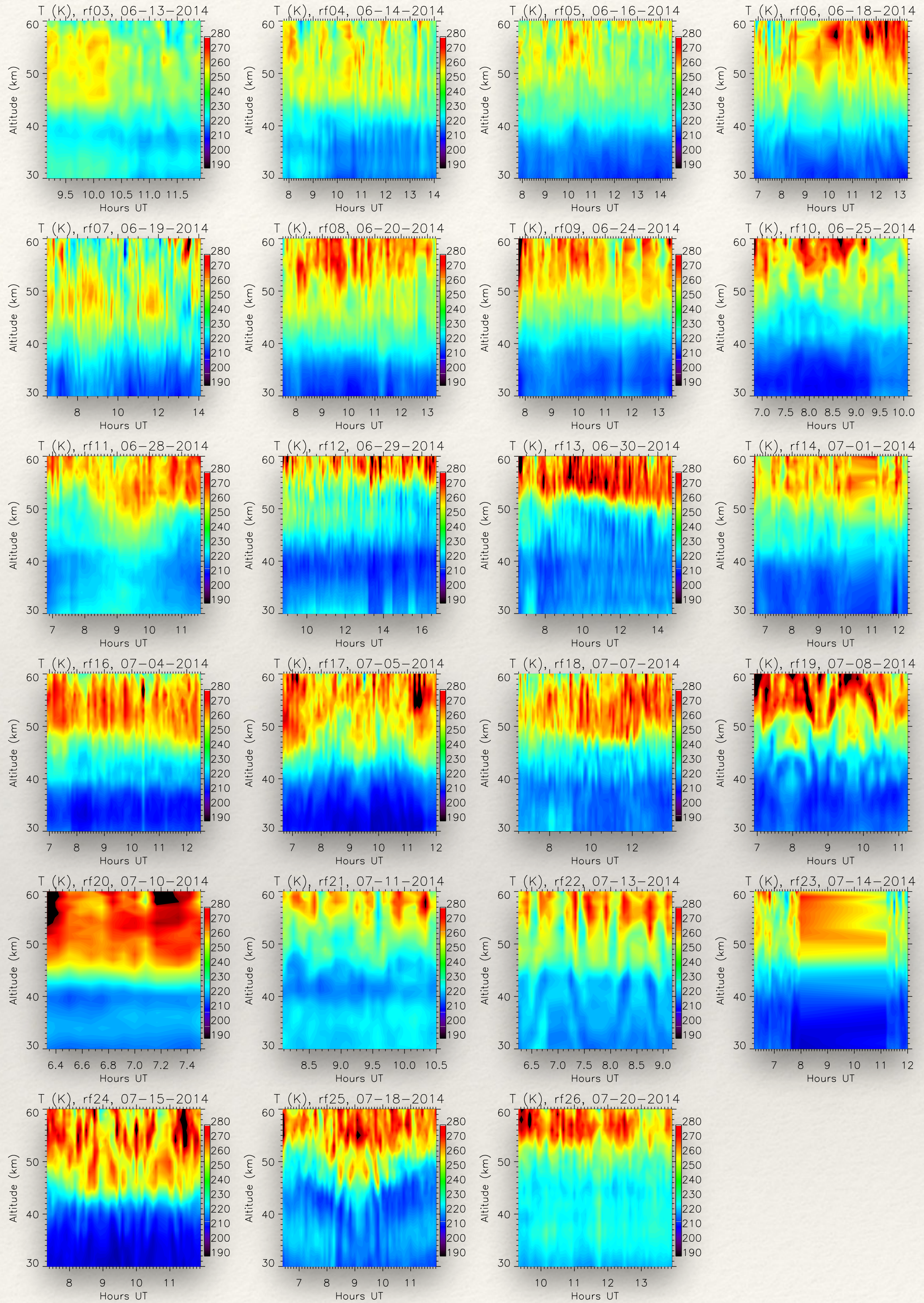
Rayleigh Lidar Data Set Overview

- Uses Rayleigh scatter from molecules (N_2, O_2, etc.) to calculate the change in density with height and infer temperature
- The Rayleigh lidar operated on 23 flights
  - rf01: large viewport not installed
  - rf02: loose connection in receiver
  - rf03 - f14: good data
  - rf15 daytime flight, no lidar data
  - rf16 to rf26: good data
- Coverage: 32° in latitude, 40° in longitude
  - Latitude: 31.2S to 63.4S
  - Longitude: 144.4E to 184.2
- 130 hours of lidar operation
  - lower signal data to be uploaded later



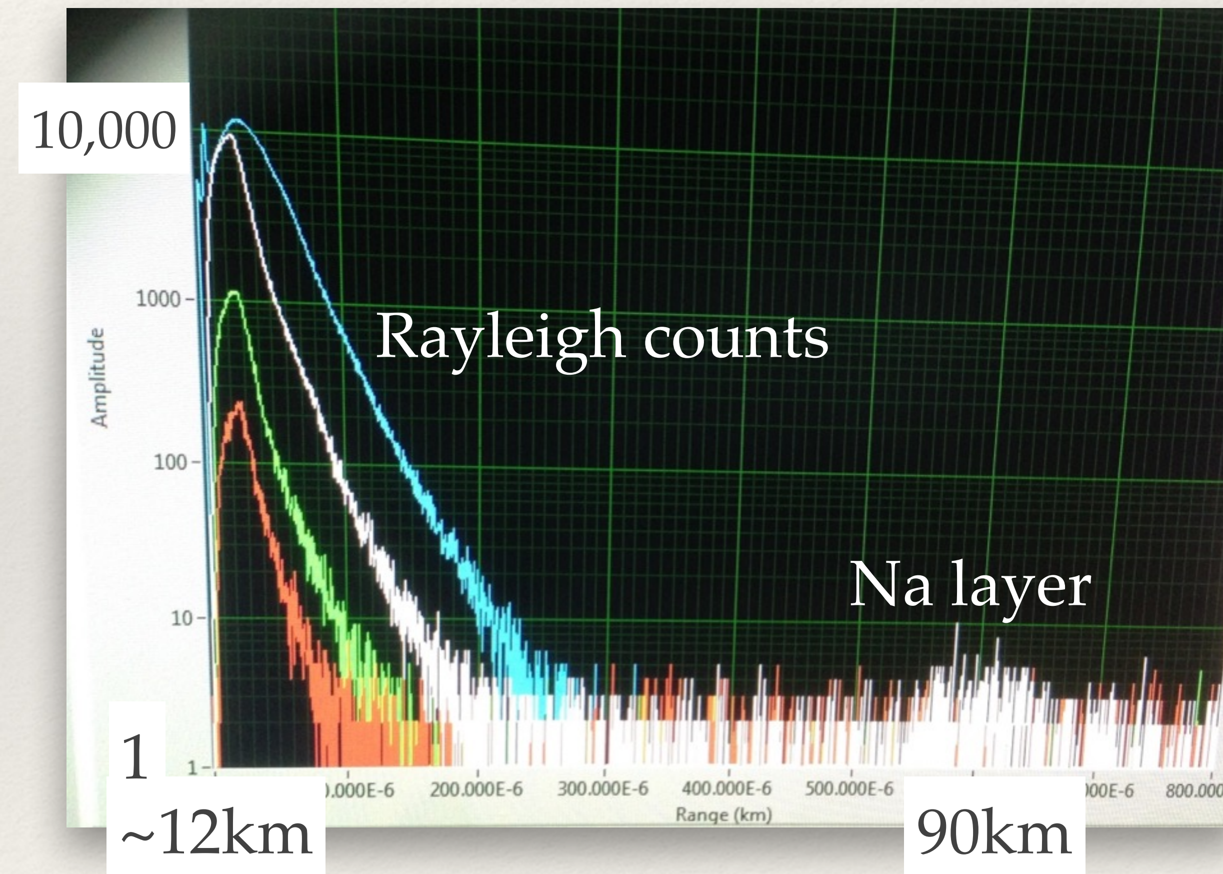
Rayleigh Lidar Instrument Description

- New facility instrument built at GATS, Inc. for the GV
- **Racks:** two standard GV instrument racks in the L1 and L2 position (along with Na lidar)
- **Laser:** diode-pumped Nd:YLF Photonics DS20-351
  - 5W at a 351nm wavelength, strong Rayleigh scatter in UV
  - 1 kHz pulse repetition rate
  - Small, robust and power efficient
  - No issues throughout the 6-week campaign.
- **Transmitted beam:** expanded to 20mm diameter, 0.4mrad
  - eye-safe at the aircraft exit for overflying aircraft
- **Telescope:** 305mm diameter f/4 Newtonian
- **Fiber-coupled receiver:**
  - 50% efficiency, low noise photomultiplier tube
  - 0.5nm FWHM interference filter
- **Returned signal profiles:**
  - **Raw:** 1 sec time and 37.5m altitude resolution
  - **Temperature:** Bin to 1min, 3km typ.

Data Collection and Processing

- Discriminate data:
  - Turns, maneuvers (> 1.5° zenith angle)
  - Low signal (<50% nominal)
  - Variable signal (>30% profile-to-profile changes)
- Calculate relative atmospheric density profile from lidar backscatter profile
  - correct for airplane altitude, attitude, sky and detector background noise, and $1/r^2$
  - Assume no aerosol scatter -> lower bound 20-30km
- Integrate the density profile down from an assumed top starting temperature to obtain a temperature profile
- Start temperature: ECMWF model temperature at 71km interpolated to the aircraft time and position.
- Affect of errors in assumed start temperature:
  - fall off as 1/density, ~ 2x every 5km
  - 10K error at 71km - > ~1K error at 50km
- Random error from photon statistics (5 min, 3km integration)
  - 60km: temperature error is ~5K.
  - 40km: temperature error is ~1K

Raw photon count profiles: 1 sec, 37.5m resolution



Validation: Comparison with Lauder Rayleigh Lidar

rf18 rf23 rf16

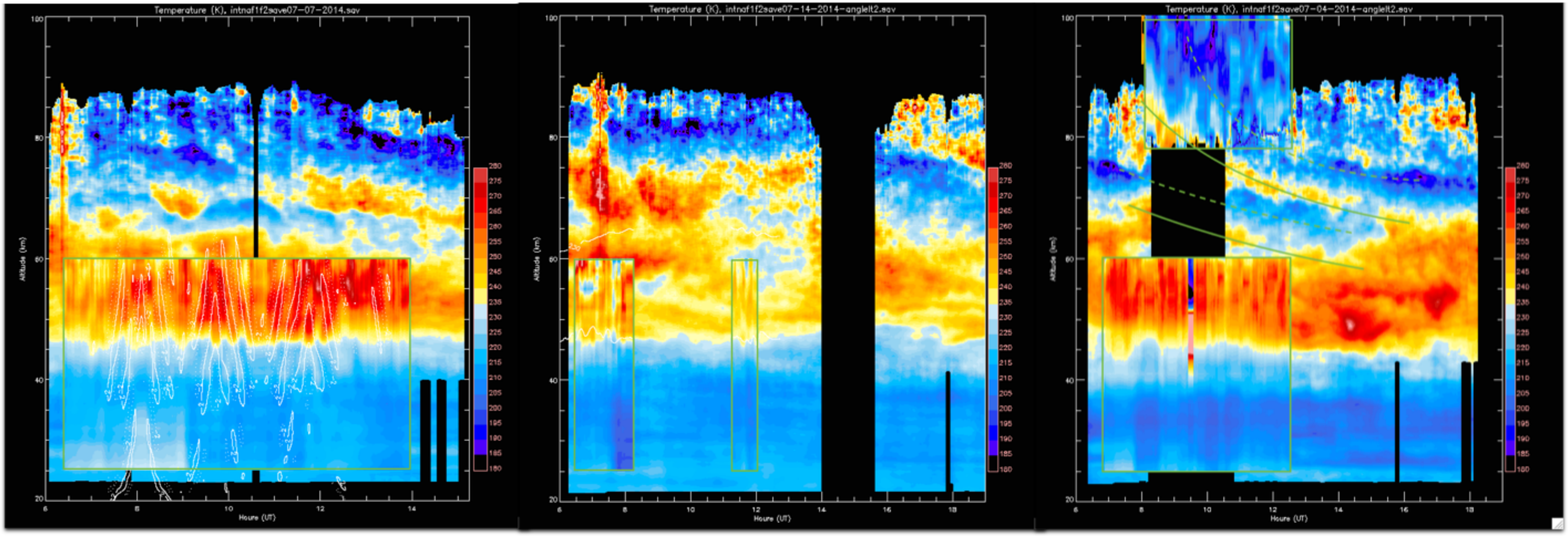
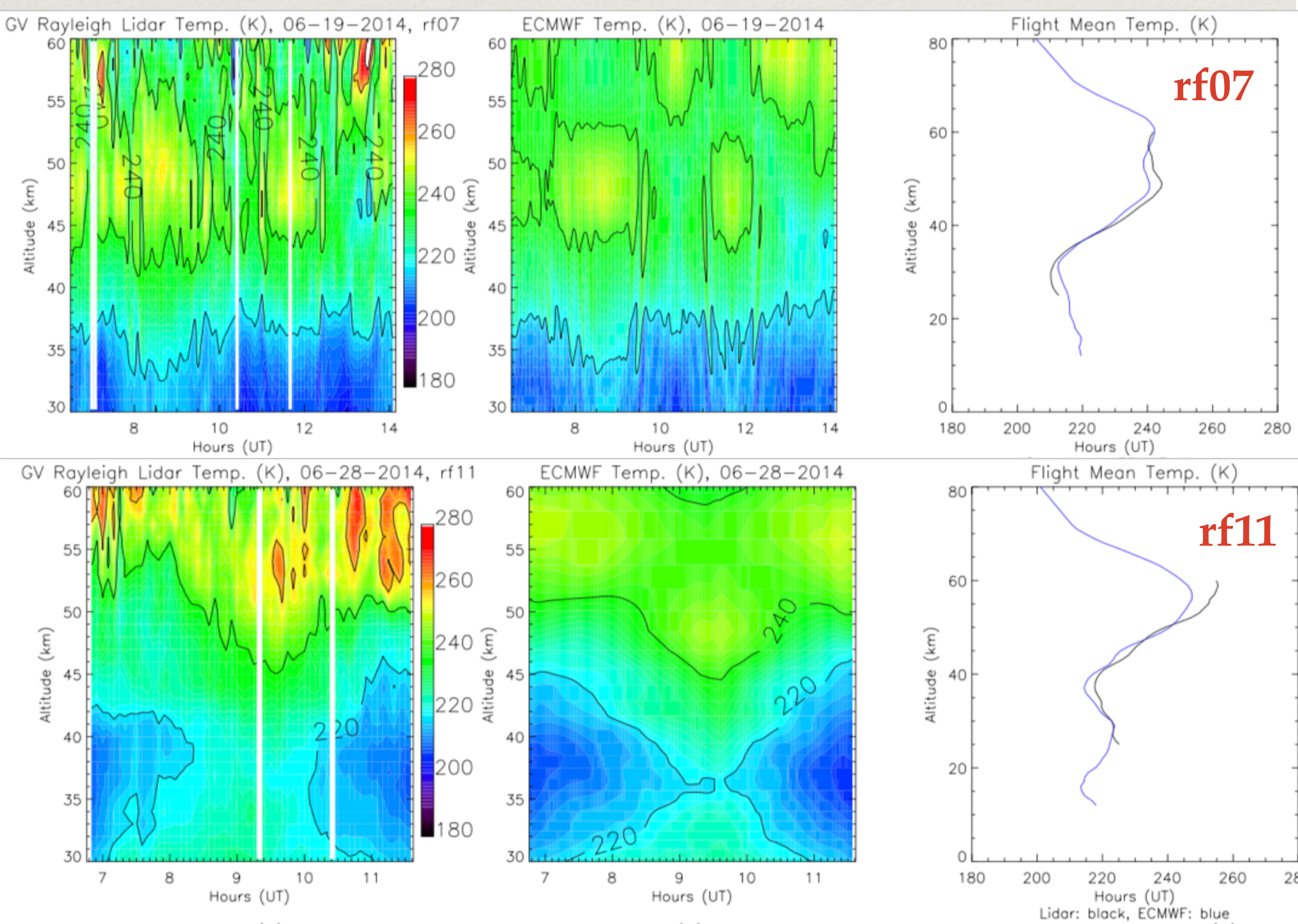


Figure 2: Rayleigh lidar comparison: GV (inside green boxes) vs ground-based (Lauder): left: rf18, middle: rf23, right: rf16.

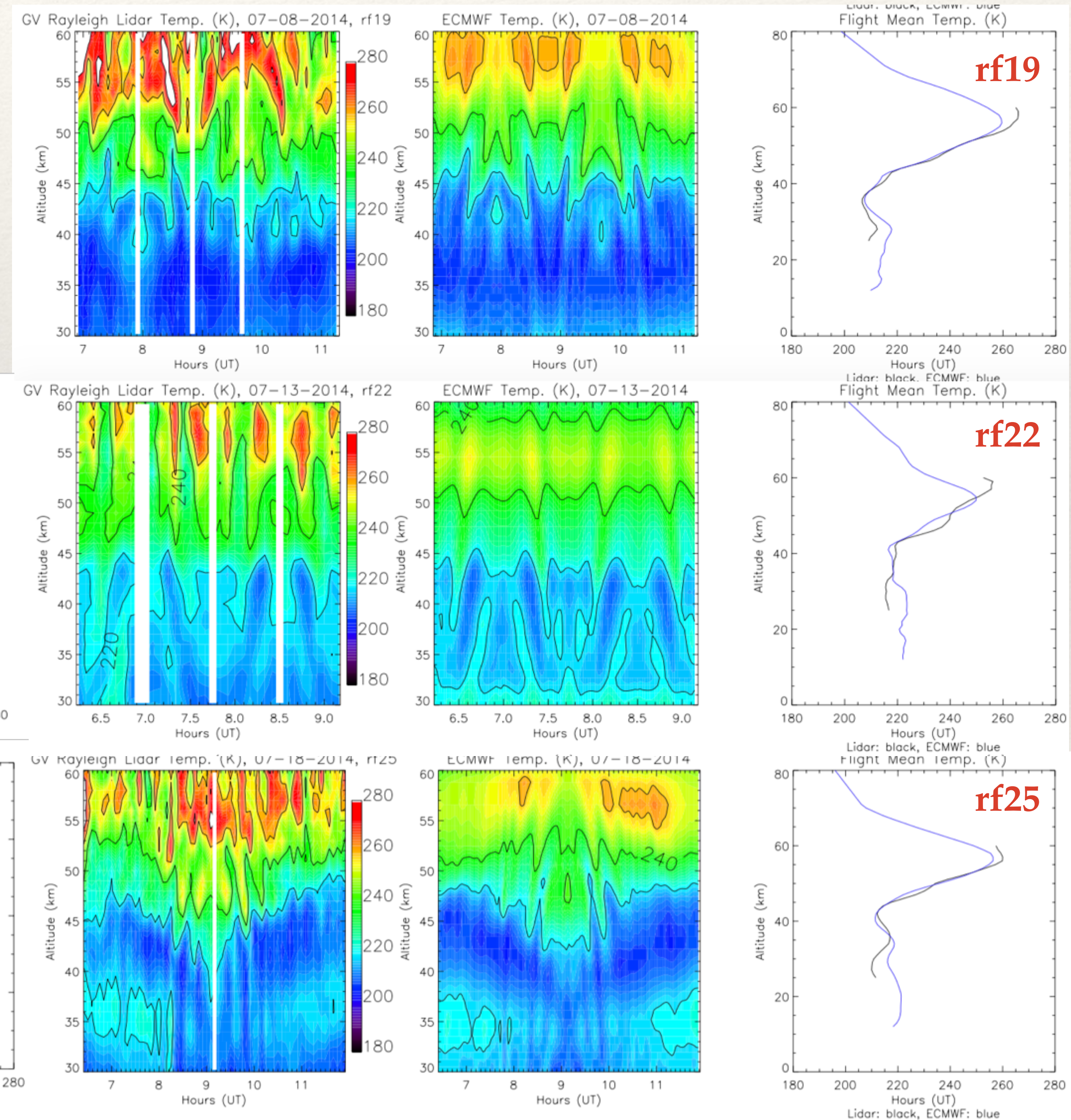
Validation: Comparison with ECMWF

- ECMWF temperatures interpolated to GV time, latitude, longitude
- Mean temperatures very similar from 35-55km
- ECMWF sometimes warmer at 30km and cooler at 60km
- Medium scale waves (HWL > 50km) predicted well, both over the mountain and southern ocean
- Horizontal temperature changes also well predicted

Lidar **ECMWF** **Mean**

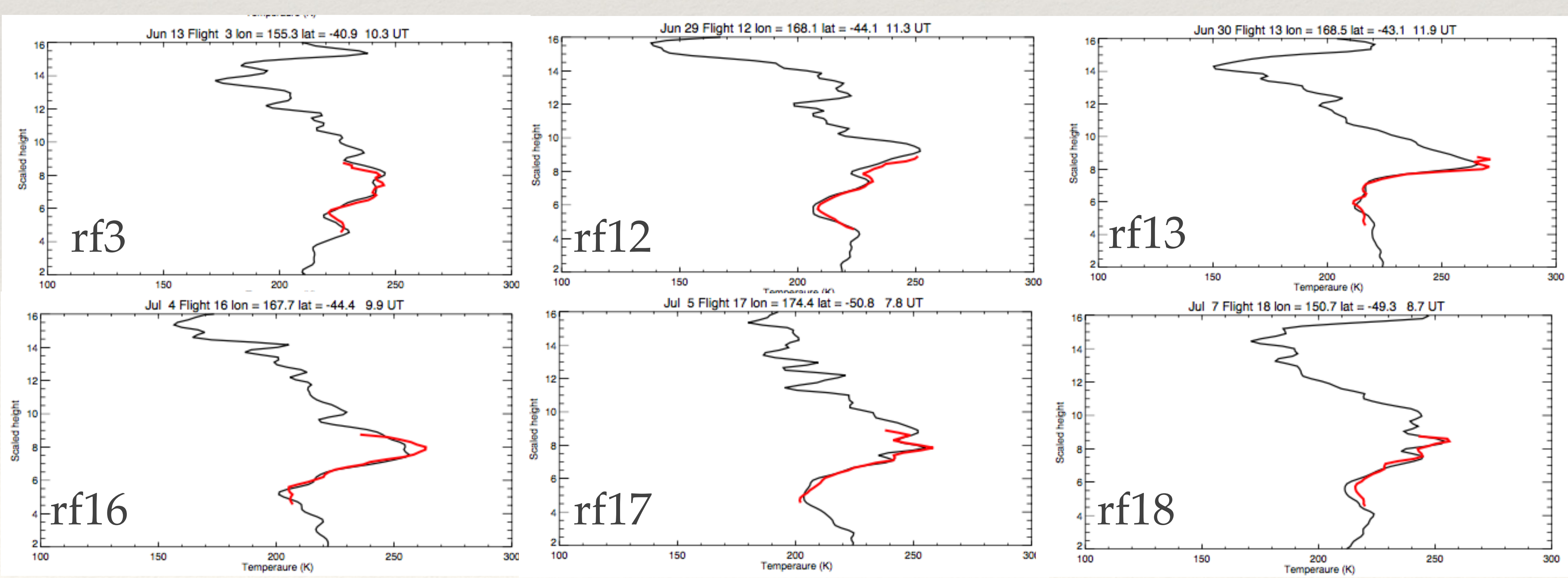


Lidar **ECMWF** **Mean**



Validation: Comparison with SABER

- The TIMED satelllite yawed on 08 July 2014
- 6-7 swaths/day rf3-rf19, 3-4 swaths/day rf20-rf26
- Flights with SABER overpasses within 1 hour and 200km horizontal
    - rf3-rf19, rf23, rf25
- Comparison quite good except lidar sometimes hotter at 60km
    - Assumed start temperature too high or noise too high at top edge? Will seed with SABER temperatures to check
- SABER picks up the persistent layered structures and large vertical gradients seen in the aircraft and Lauder lidar



Data Format

- **filename:** netCDF file for each flight
  - aircraft.NSF_NCAR_GV_Rayleigh_Lidar.YYYMMDDHHmm.Temperature_rf[FlightNumber]_[VerticalResolution]_[TimeResolution].nc
  - example: aircraft.NSF_NCAR_GV_Rayleigh_Lidar.201406130910.Temperature_rf03_3km_5min.nc
- netCDF Global Attributes:
  - "**Title**" (string), "**Month**" (int), "**DayOfMonth**" (int), "**Year**" (int), "**NumTimes**" (int), "**NumAlt**" (int)
- netCDF Variables:
  - **Hour** [Hours UT] 1D float array (NumTimes): Mean time for each measurement
  - **Altitude** [km ASL] 1D float array (NumAlt): Altitudes for temperature profile typically at 30-60km at 1km separation. See filename for actual vertical resolution (typically 1 or 3km) of measurement.
  - **Latitude** [Degrees North] 1D float array (NumTimes): Mean aircraft latitude for each measurement
  - **Longitude** [Degrees East] 1D float array (NumTimes): Mean aircraft longitude for each measurement
  - **GValt** [km ASL] 1D float array (NumTimes): Mean aircraft altitude for each measurement
  - **Temperature**, [Degrees (K)] 2D float array (NumTimes x NumAlt)
  - **TempErr** [Degrees (K)] 2D float array (NumTimes x NumAlt): Random error in temperature (photon noise)
- Variable Attributes: Each variable has two attributes: "**long_name"** (string) and "**units" (string)**.
- example IDL procedure provided: **readRayleighLidarNetcdf.pro**
  - **Pro readRayleighLidarNetcdf, file, title, numt, numz, month, day, year, hour, z, gvlat, gvlon, gvalt, temperature, temperr**
  - **inputs:** file= path + filename, **outputs:** the rest

Data Notes and Conclusions

- Wave structures and temperature mean profile and gradients corroborated by multiple measurements:
  - Consistent in multiple passes over same area by aircraft
  - Large-scale temperature gradients present in SABER, ECMWF, and Lauder lidar
  - Most medium scale waves predicted by ECMWF, , especially their location and phase structure
- Most of the missing data is due to aircraft turns or descents to lower altitudes, rather than instrument issues
- Temperatures from ~22km to 30km can be produced on request
- Temperature calibration and error levels very good in middle of profiles (35-50km)
- Lidar sometimes hotter than SABER and ECMWF 50-60km
  - Effect of assumed start temperature
  - Random error from lower signal and higher relative background
- Below 30km (sometimes 35km), possible issues with:
  - Aerosols (NZ stratosphere should be cleaner than normal)
  - Beam/telescope alignment errors, especially during after aircraft motion (turns/turbulence)
- rf12 (29 June 2014) may have aerosol contamination 30-35km from 13-17UT
- rf20 (10 July 2014) needs work. 2nd half of dataset (not shown) has low signal
- Need to add in other temperature datasets: radiosondes, MTP, dropsondes, etc.