The Upgraded Rayleigh Lidar at USU's Atmospheric Lidar Observatory

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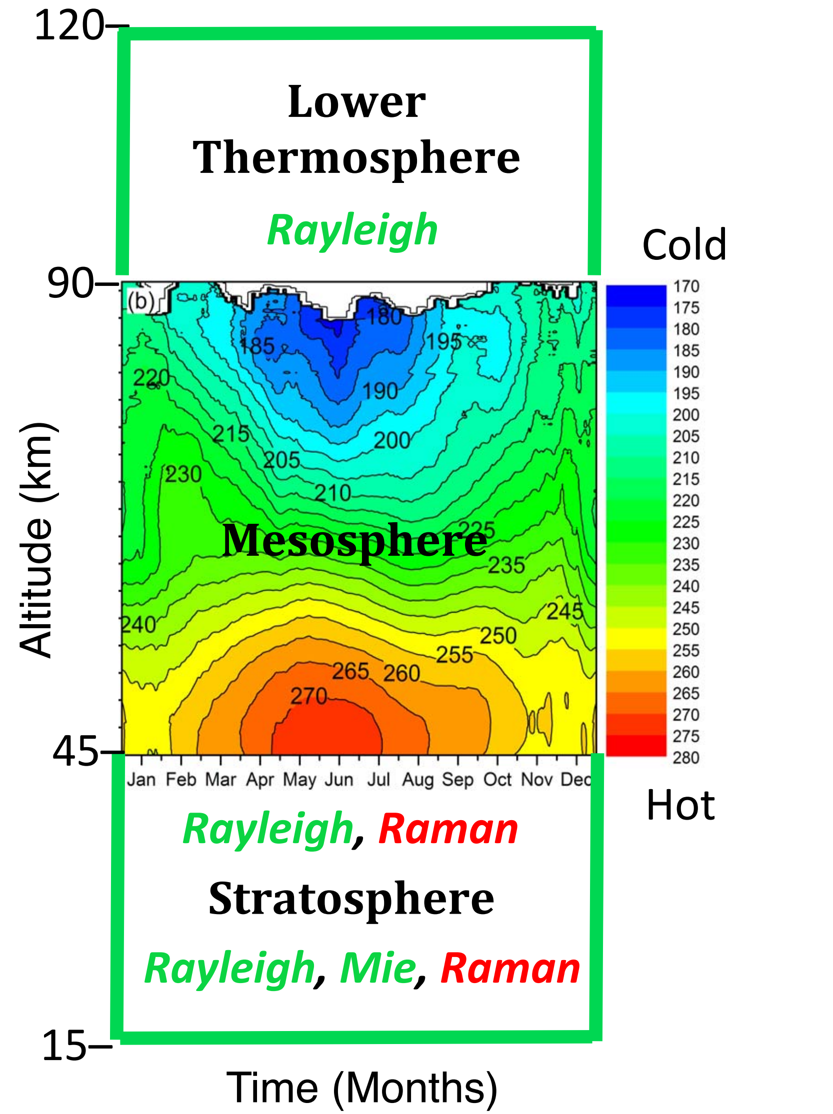
Original ALO Rayleigh Lidar

- **Description**
  - Build by Vincent Wickwar, John Meriwether, and Tom Wilkerson
  - ~21 W at 532 nm & 0.44 m mirror — PAP = ~3.1 Wm^2
  - Good data from 45 to ~90 km for 1993 – 2004

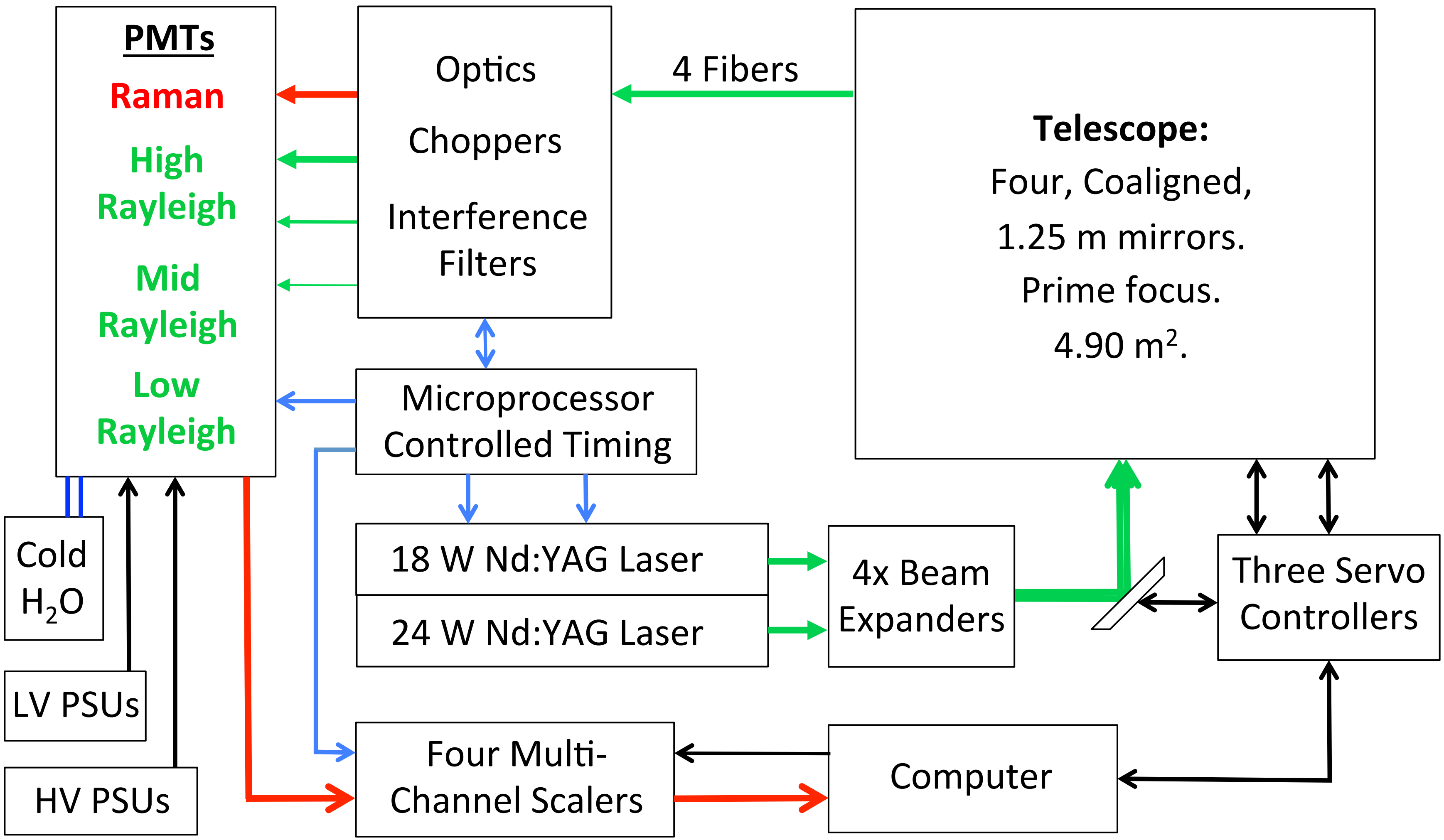
- **Science**
  - Temperature Climatology
  - Noctilucent Clouds
  - Thin Aerosol Layer
  - Mesospheric Inversion Layers
  - Brunt-Väisälä Frequency Climatology
  - Characterization of Mesospheric Gravity Waves
  - Upward Propagation of Gravity Waves — Growth and Energy Loss
  - Secular Trends in Temperatures from 11 years of data
  - Solar Cycle Effects on Temperatures
  - Sudden Stratosphere Warmings
  - Cold Island in October near 80-87 km
  - Extremely Cold Januarys

Upgrade Overview — 207 Wm^2

- Greater sensitivity to open the 90 –120 km region for neutral density and temperature observations from the ground.
- Greater precision and accuracy below 90 km.
- Extend the observations down to nearly the tropopause. Add a Raman scatter capability from N_2 at 607 nm to account for Mie scatter and extinction from aerosols.
- Can follow structures, disturbances, and waves as they emerge from the troposphere and propagate, on occasion, all the way into the thermosphere, or dissipate, or reflect.
- Obtain absolute density calibration at the lowest altitudes. This gives absolute densities between 90 and 120 km where all the thermospheric neutral models begin.

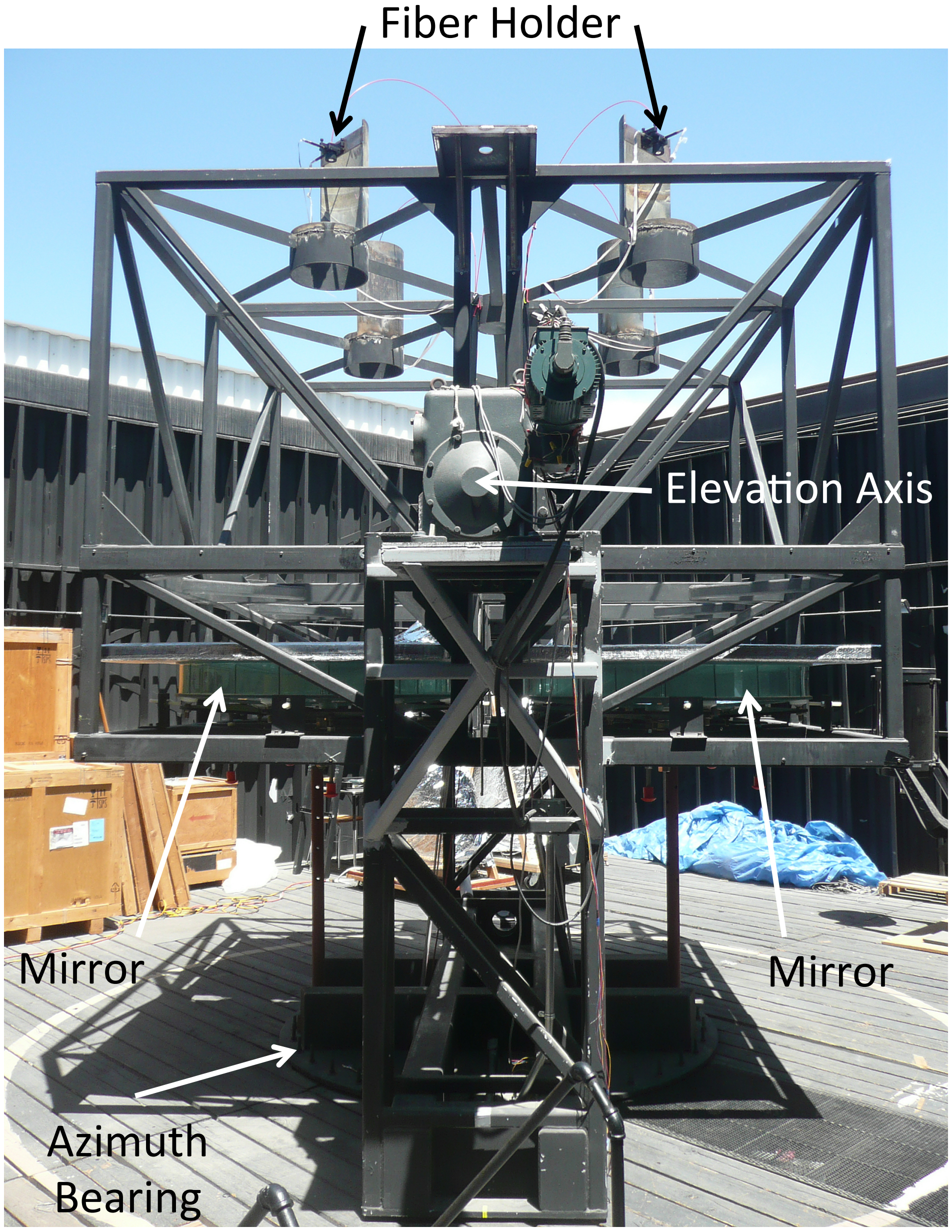


Block Diagram of Rayleigh Lidar

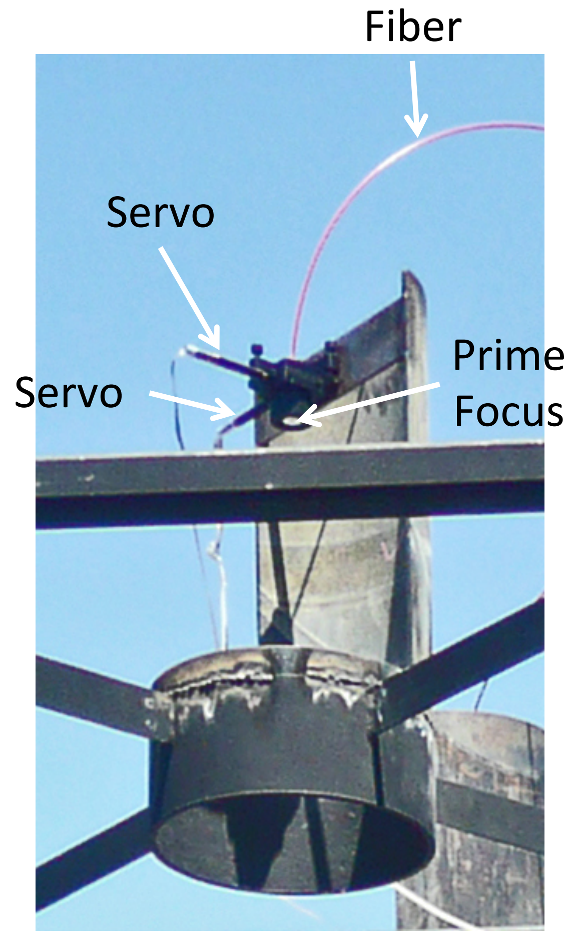


ALO Observatory

Rayleigh Lidar Telescope

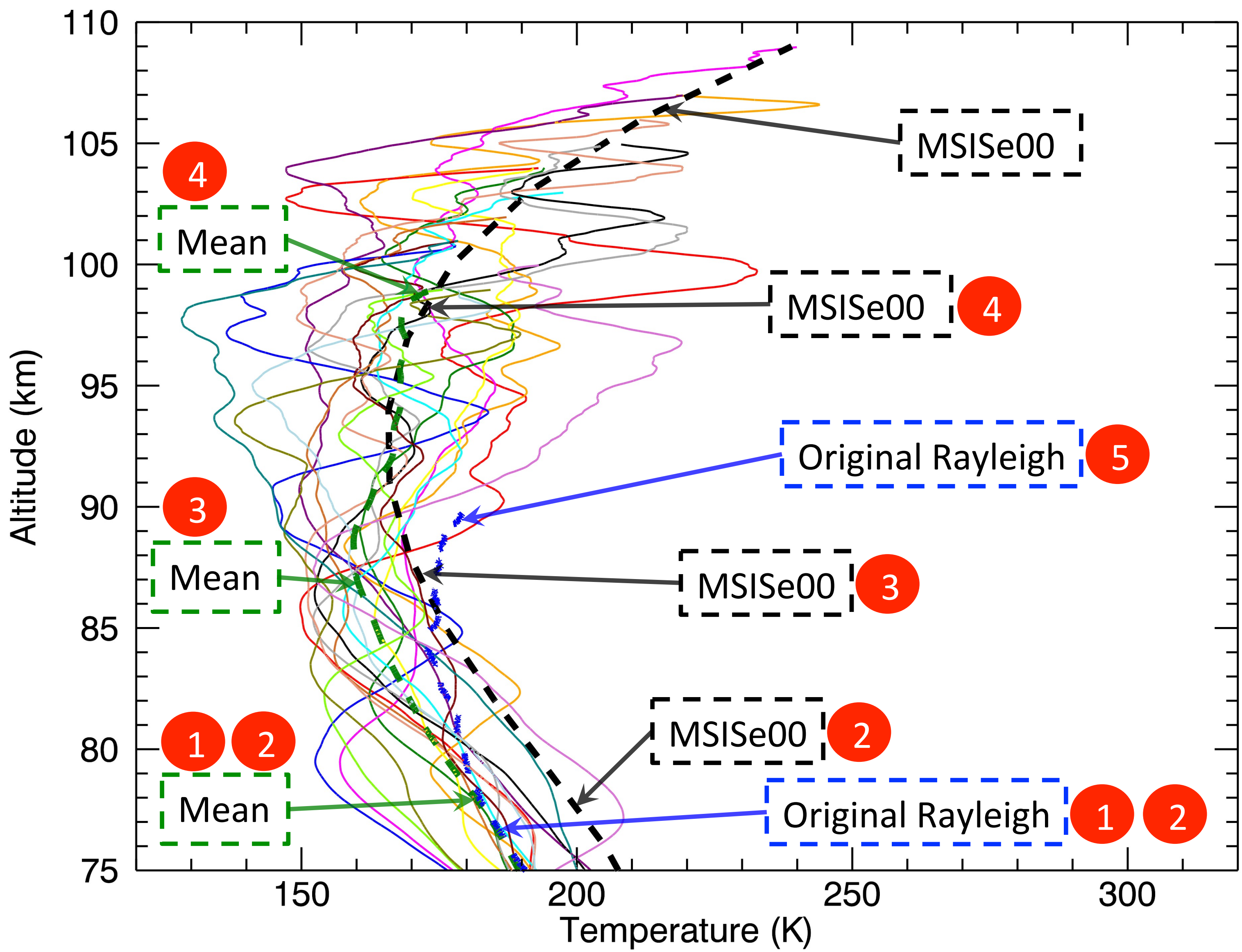


Cage: 3-m Square x 2.5-m High
Laser Beam Through the Middle



Fiber Assembly
(Not yet Finished)

18-Day Solstice Campaign — June/July '12



Discussion of Temperature Structure

- **Huge day-to-day variability — greatly exceeding uncertainties**
- **Temperatures often low enough for noctilucent clouds — however, no NLCs**
- **Because of this variability, the "mesopause" has to be a statistical concept**

① **New & Original Rayleigh temperatures agree between 75 & 79 km.**
Proof that data acquisition and analysis of New Rayleigh are working properly.

② **New & Original Rayleigh ~18 K cooler than MSISe00.**
Suggests a systematic offset in MSISe00 at mid latitude near solstice.

③ **New Rayleigh still ~12 K cooler than MSISe00 at 87 km.**
The possible systematic offset in MSISe00 continues upward.

④ **New Rayleigh and MSISe00 agree from 92 to 99 km.**
Artifact because MSISe00 provides the initial temperatures for the New Rayleigh data reduction. (Effects 10 to 15 km for a temperature error of 15 K.)

⑤ **Old Rayleigh greater than MSISe00 and New Rayleigh by 10 and 20 K at 90 km.**
Artifact because initial temperatures for the Original Rayleigh came from CSU Na lidar climatology. But, it suggests that that Na climatology was too warm.

- The last two items indicate the importance of
  - *New Lidar data going all the way to 120 km or higher*
  - *The new analysis technique advanced by Khanna et al. [2012] of UWO*

System —What Next?

- Last summer reached 109 km (all night integration).
- So far this summer reached 114 km (2 hours). Would mean 120 km for all night integration.

- Optimize the subsystems. (The new goal is 130 km.)
- Implement Khanna et al. [2012] forward method to obtain good Rayleigh temperatures as high as possible. (Eliminate problem in Notes 4 and 5.)
- Finish adding two more Rayleigh detector channels for to go down to ~15 km.
- Add a Raman detector channel for N_2 at 607 nm for the lowest altitudes.
- Implement Klett algorithm for the lowest altitude temperatures.
- Add "shoes" to mirrors to prevent them from moving when cage is tilted.
- Move and scan telescope in azimuth and zenith angle to observe structures and waves.

Science — What Next?

- Special campaigns to verify good temperatures at highest and lowest altitudes, and to establish and verify good absolute densities.
- Campaigns (Structure of the region above 90 km, Conditions conducive to NLCs, Seasonal mesopause transitions, Cold island, Sudden Stratospheric Warmings).
- Regular Observations (Climatologies, Coupling between regions, Waves, Disturbances, Special events, Climate change, Solar cycle changes).
- Campaigns with other mesospheric instruments at Logan & Bear Lake Observatory (BLO).
    - Na lidar (Temperatures, winds, sporadic thin Na layers, Na mixing ratio).
    - Airglow imaging of OH, $O(^1S)$, and O_2 Atmospheric (Temperatures, waves, and structures).
    - Meteor wind radar (Sudden Stratospheric Warmings).
    - Ionosonde observations (Sporadic E and SIDs).
- Compare with lidar, airglow, and radar observations from other geographical locations, and compare / combine with satellite observations.
- Compare with model calculations.

Summary & Conclusions

- Pushed the state-of-the art to obtain high altitude data with the Big Rayleigh Lidar
  - Used two lasers to maximize the power, ~42 W
  - Used four big coaligned mirrors to obtain a huge collecting area, 4.90 m^2
  - Combined the light from four fibers into one beam for detection
- Results on MLT temperature structure from last year's Solstice campaign
  - MSISe00 appears to over estimate the temperature by 10 – 20 K
  - CSU's Na temperatures at 90 km are greater than ALO's Rayleigh temperatures
- Next major upgrade steps
  - Implement the Khanna et al. [2012] temperature reduction procedure
  - Finish three lower altitude channels
  - Implement Klett stratospheric temperature reduction procedure
  - Move and scan the telescope in azimuth & zenith angle
- Next major science steps
  - Campaigns to verify lidar data analysis and to examine special situations
  - Coordinated campaigns with middle atmosphere cluster at Logan & BLO
  - Regular Observations
  - Compare with middle atmosphere measurements from elsewhere and with model calculations

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