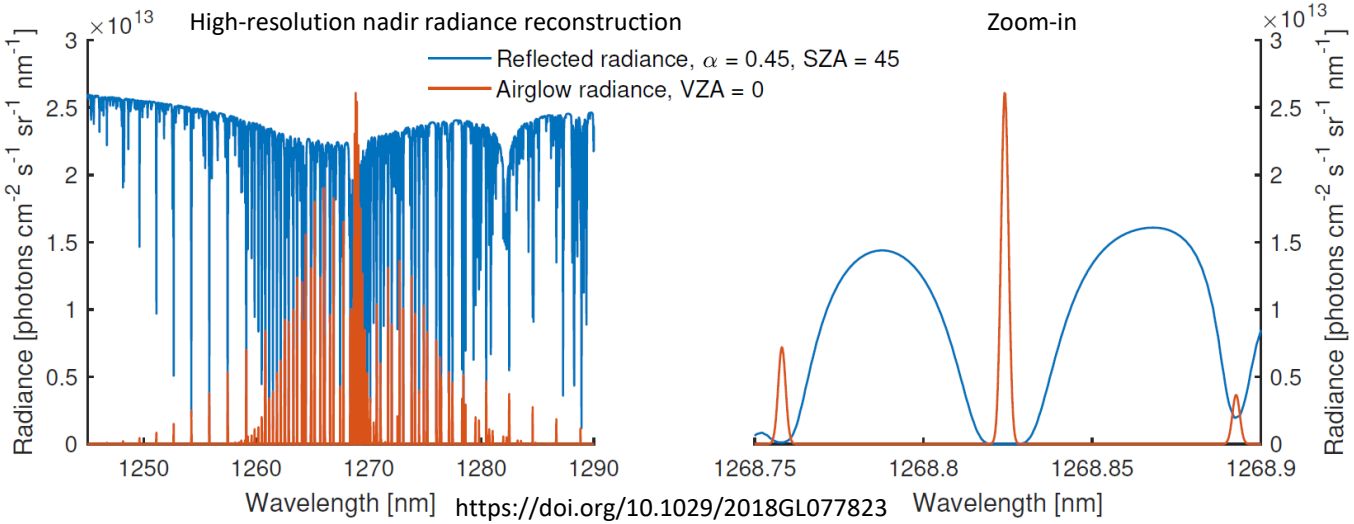
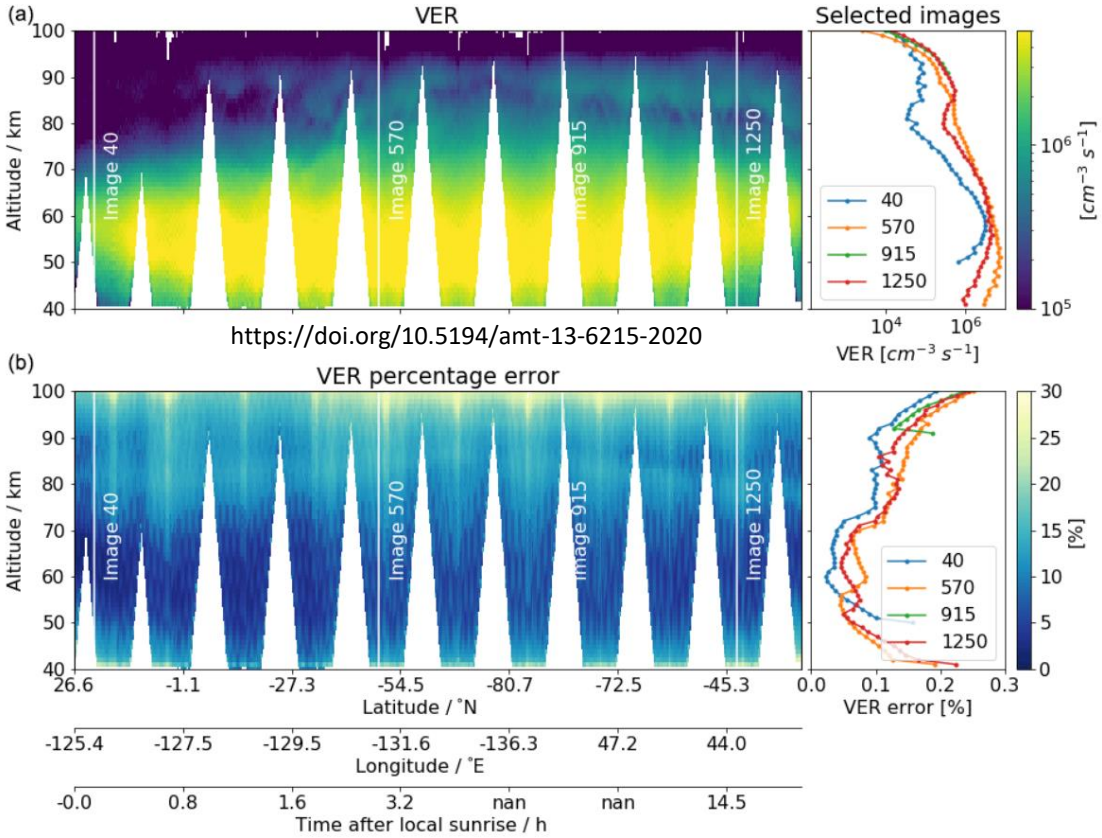
The O_2 airglow retrievals: implications to mesospheric temperature and greenhouse gas remote sensing from space

- The singlet Delta O_2 band at 1.27 μm facilitates greenhouse gas remote sensing but is infested by airglow emissions
- The spectral distribution of airglow emissions is reproducible using HITRAN (Sun et al., 2018, bottom figure)
- Airglow spatial distribution from OSIRIS IR imager (Li et al., 2020, right figure), although spectrally unresolved
- Objective: retrieve both 4D airglow and air temperature distributions from SCIAMACHY limb observations
- Got singlet Sigma band (i.e., *A* band) for free





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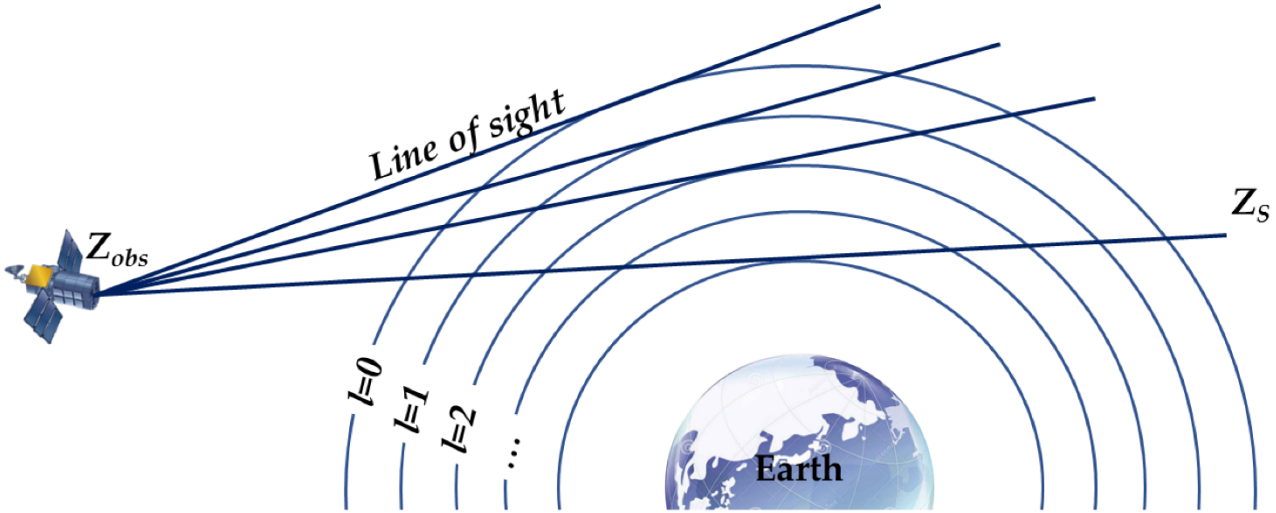
O_2 infrared bands observed by SCIAMACHY

- O_2 $b^1\Sigma_g^+ - X^3\Sigma_g^-$ band (singlet Sigma, or *A* band) at 0.76 μm is the standard way used by all major greenhouse gas missions so far
  - Airglow exists but too weak to interfere nadir absorption
- O_2 $a^1\Delta_g - X^3\Sigma_g^-$ band (singlet Delta band) at 1.27 μm might be a better choice
  - Less saturated lines – less systematic errors
  - Closer to CH_4/CO_2 bands – less variations in aerosol/cloud optical property
  - Used by ground-based greenhouse gas column measurements (e.g., TCCON, CLARS-FTS)
  - Strong airglow that may lead to a negative bias of ~10% to O_2 column, if not considered
- The spatial, temporal, and spectral distributions of airglow in both bands can be obtained from SCIAMACHY limb observations from 2002 to 2012
- Normal limb scans from surface to 90 km
- Special MLT (mesosphere-lower thermosphere) mode scans 50-150 km two days per month from 2007 to 2011



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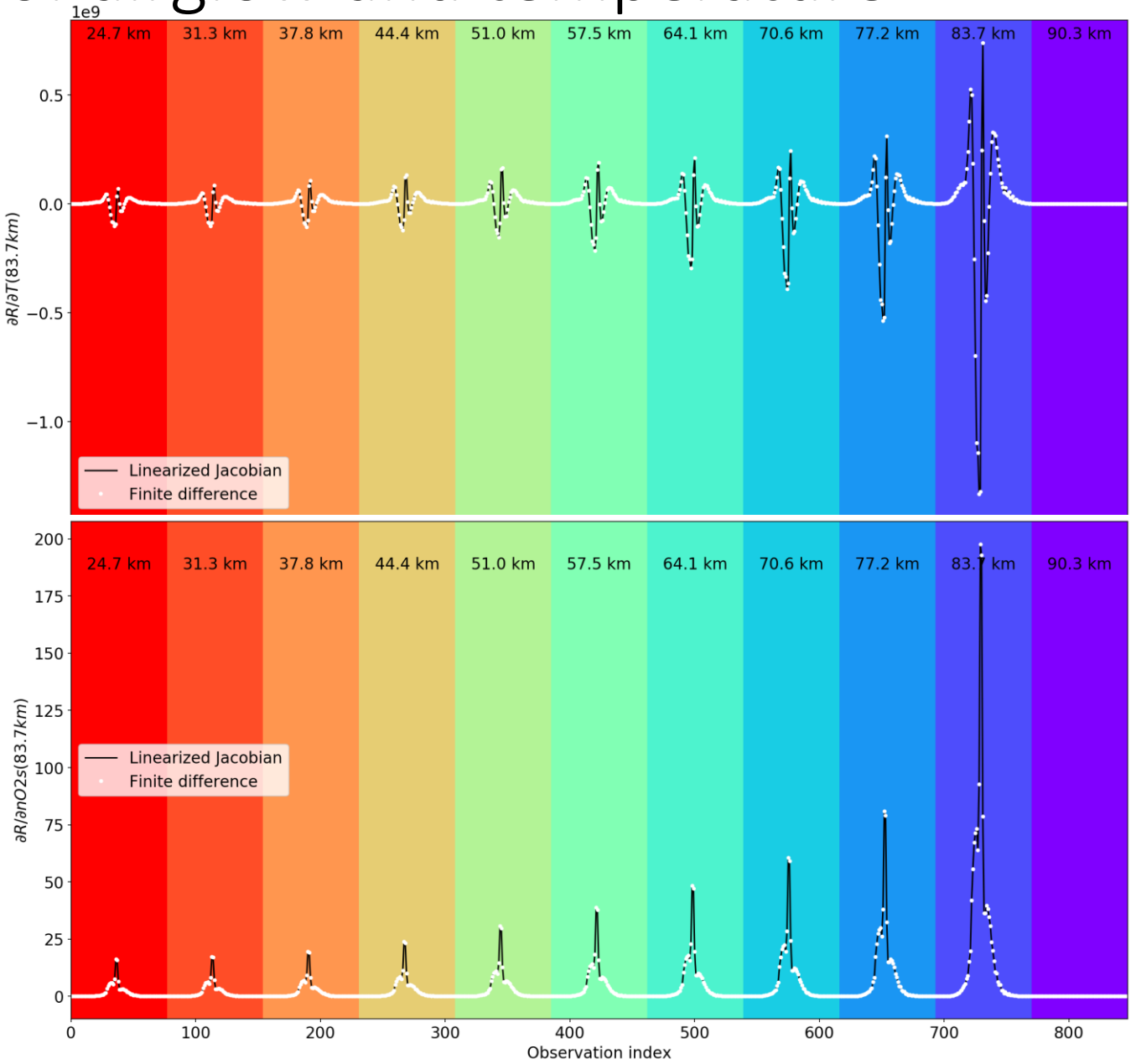
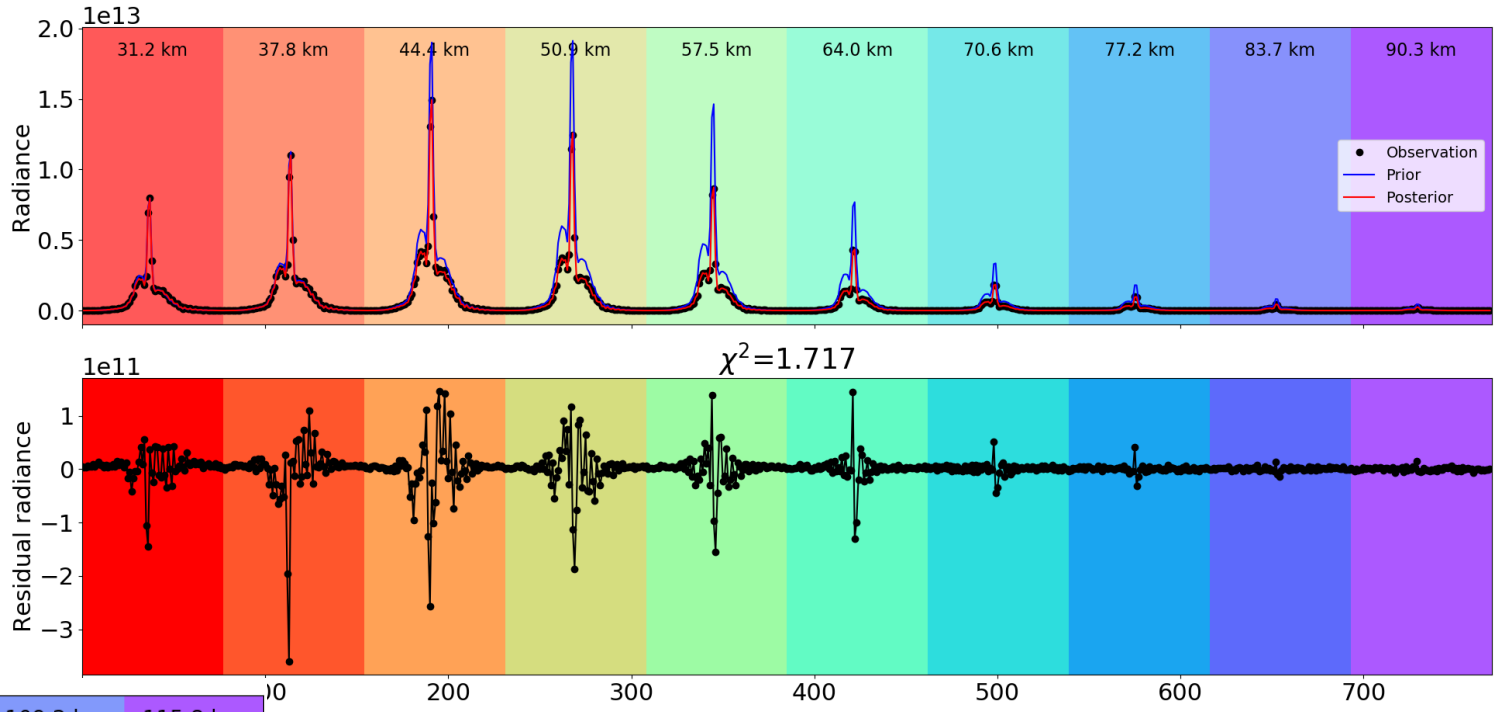
Optimal estimation retrieval of airglow and temperature

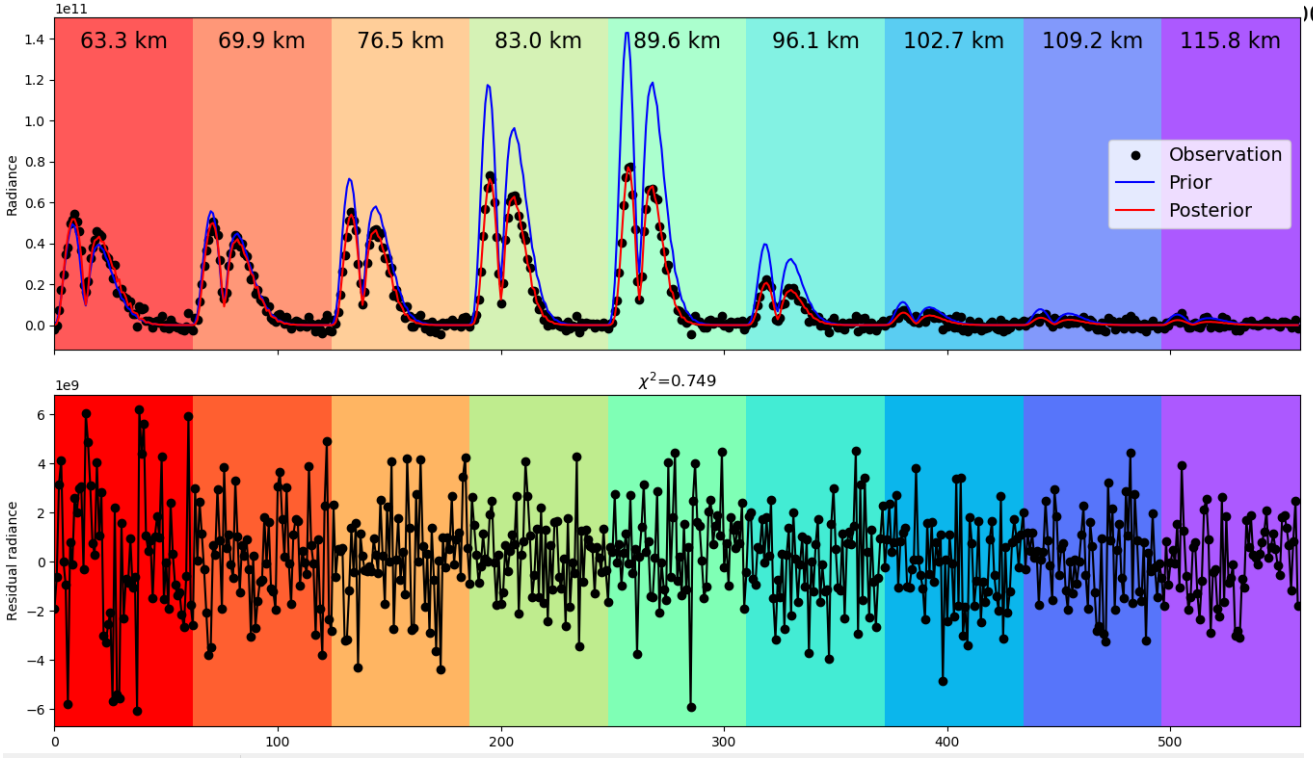
- Observation vector
  - Concatenated limb radiance from all tangent heights
- Observation noise
  - Parameterized from estimated readout noise and detector gain
- State vector
  - Temperature/O_2* density profiles
  - ISRF squeeze, spectral shift
  - O_2 density scaling (optional)
- Jacobians
  - Analytically linearized when possible and validated using numerical finite difference
- Prior
  - Temperature/pressure from the MSIS model
  - O_2* density from linear inversion (no absorb)
  - Error correlation scale of one scale height



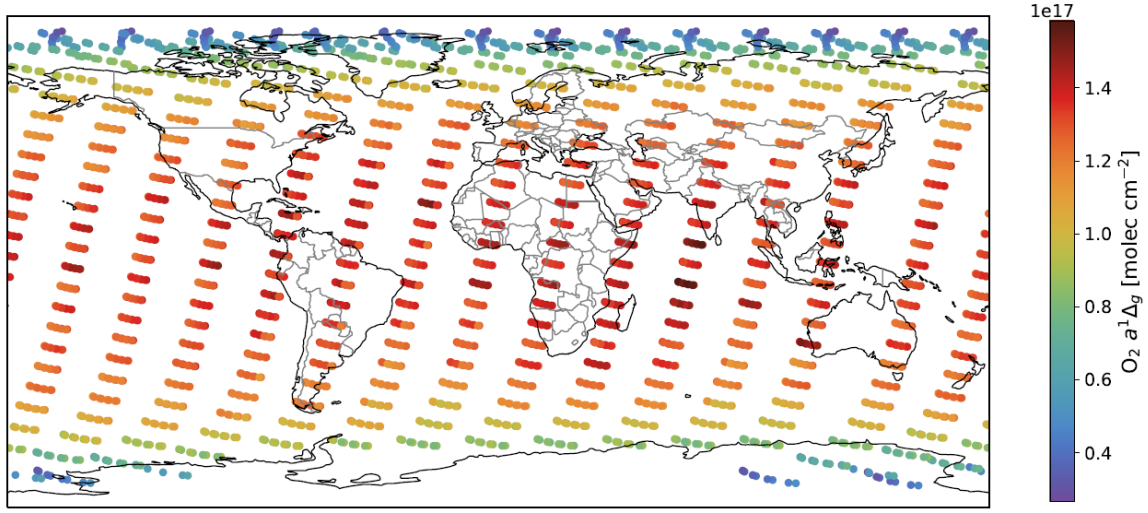
Spectral fitting

- Gauss-Newton method
- HITRAN 2016 line lists
- Example singlet Delta normal limb scans (right) and singlet Sigma MLT scans (bottom)



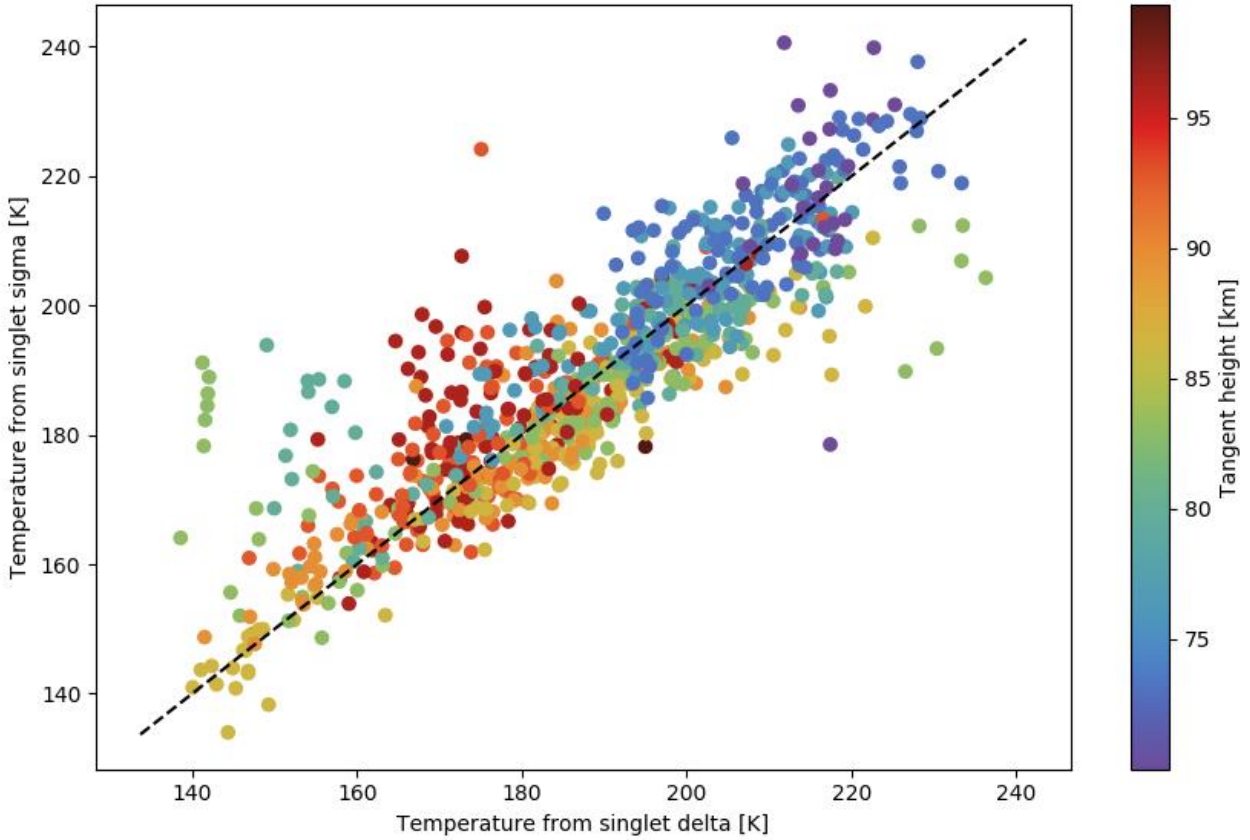


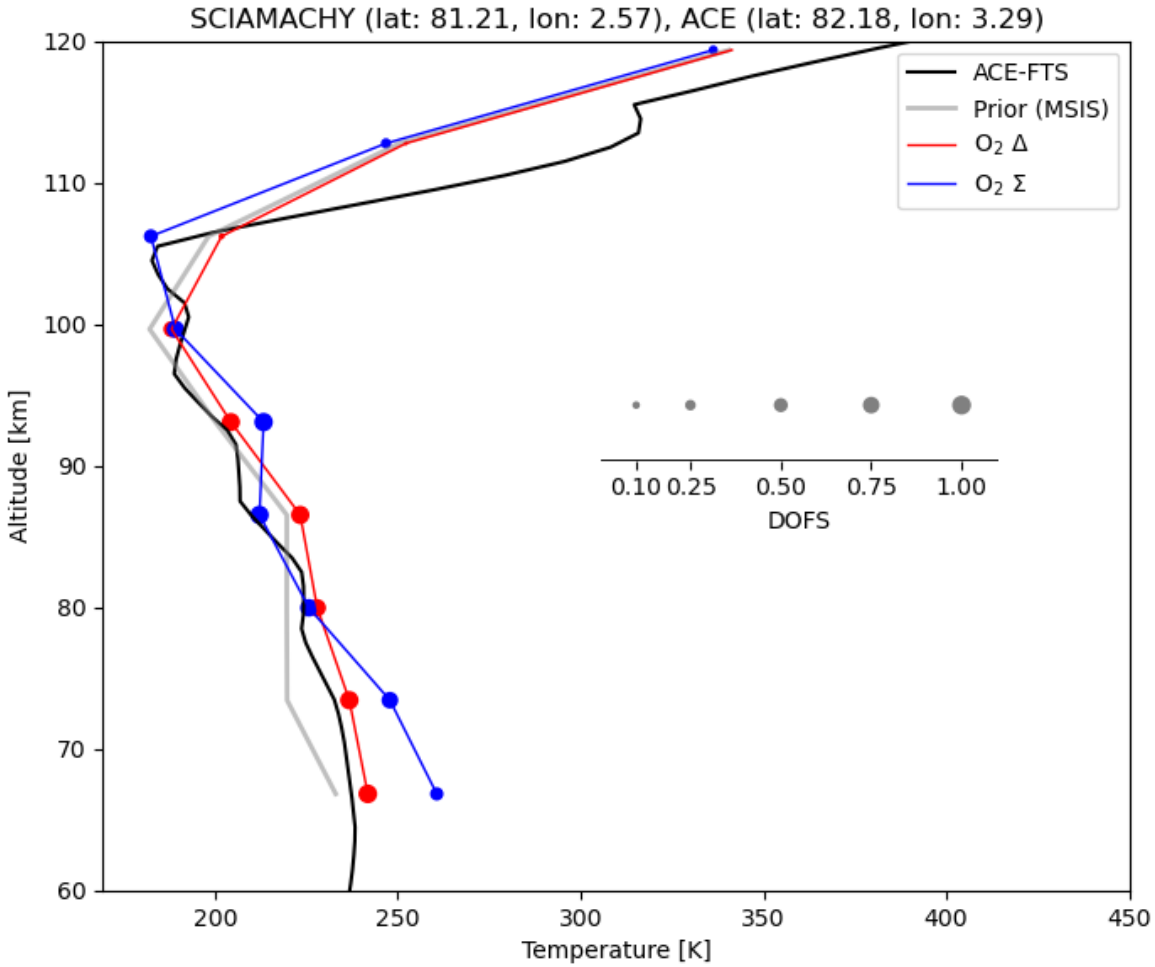
- Level 2 products include O_2* density profiles and temperature profiles



Intercomparison of temperature retrievals

- Upper mesosphere temperature retrieved from Delta and Sigma bands
- Temperature profile validation with collocated ACE-FTS sounding





Mesopause temperature (Level 3 data in 2010 from MLT)