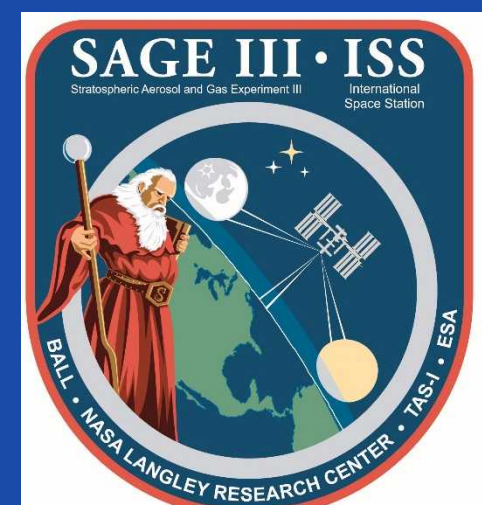




An Initial Assessment of SAGE III/ISS Temperature and Pressure Retrievals

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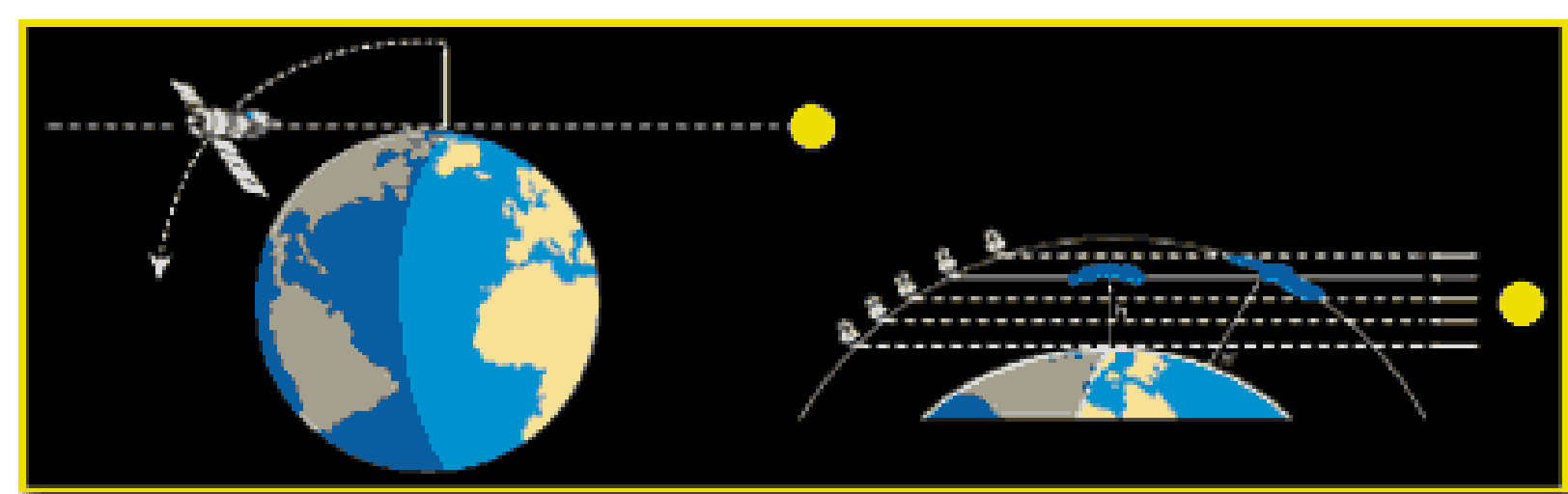
Abstract

The Stratospheric Aerosol and Gas Experiment (SAGE) III instrument was deployed to the International Space Station (ISS) in February 2017. SAGE III/ISS is the latest in the NASA lineage of solar occultation satellite instruments designed to monitor the vertical distribution of aerosol, ozone and other trace gases in the upper atmosphere. Originally built in the early 2000s, the SAGE III/ISS instrument required extensive testing and refurbishment prior to deliver to ISS, including the replacement of the neutral density filter that has been associated with some instrument response issues during the METEOR/3M mission. In particular, METEOR/3M measurements of the oxygen A-band absorption feature near 762 nm that were to be utilized to retrieve profiles of temperature and pressure were adversely affected by this instrument issue. Preliminary examination of the SAGE III/ISS oxygen A-band spectra indicate that the measurements are of higher fidelity than from the METEOR/3M instrument, which may permit successful retrieval of science quality temperature and pressure products. In this paper, we will provide an overview of the temperature and pressure retrieval algorithm, present preliminary analyses of the SAGE III/ISS oxygen A-band measurements, and an initial assessment of the quality of the temperature and pressure retrievals.

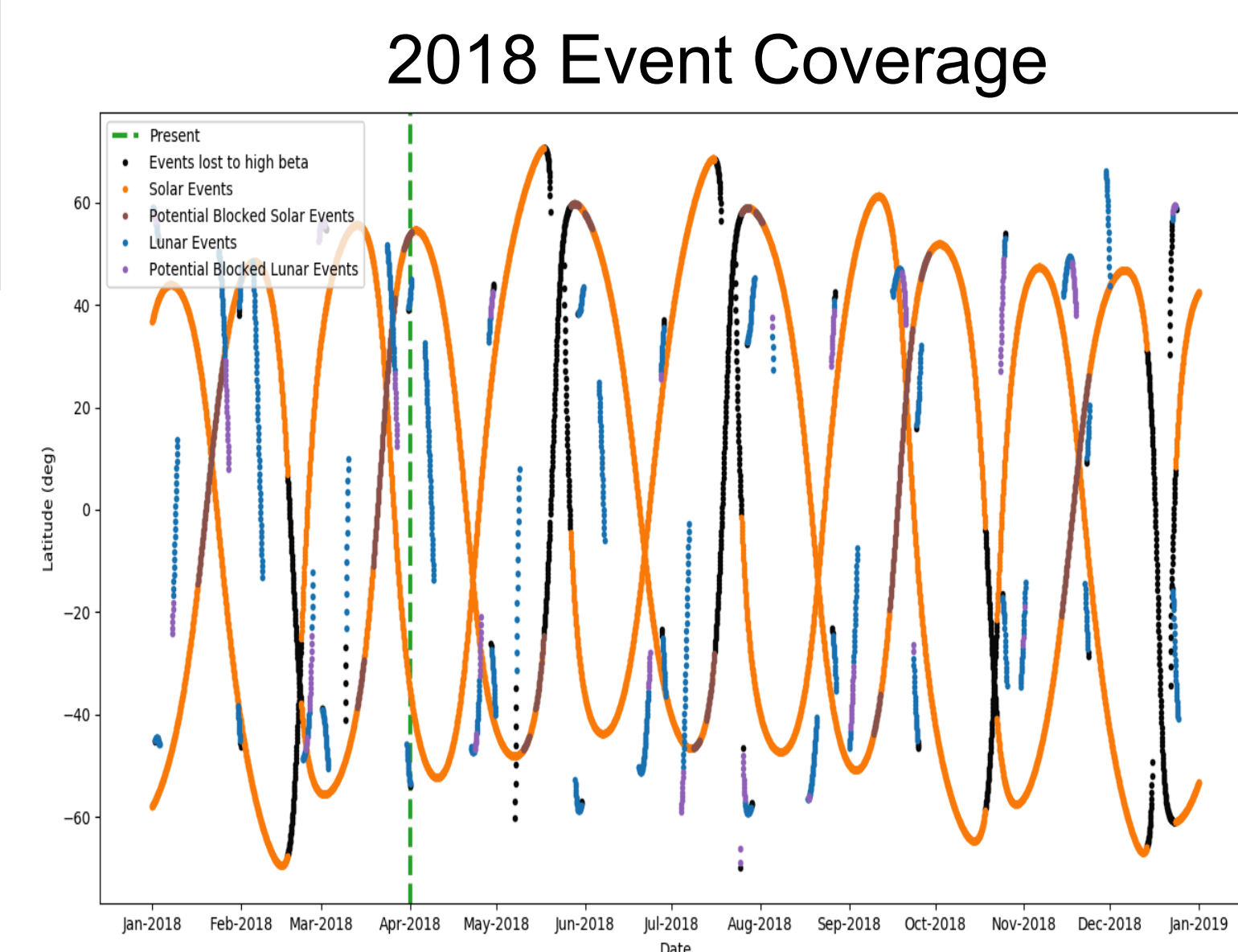
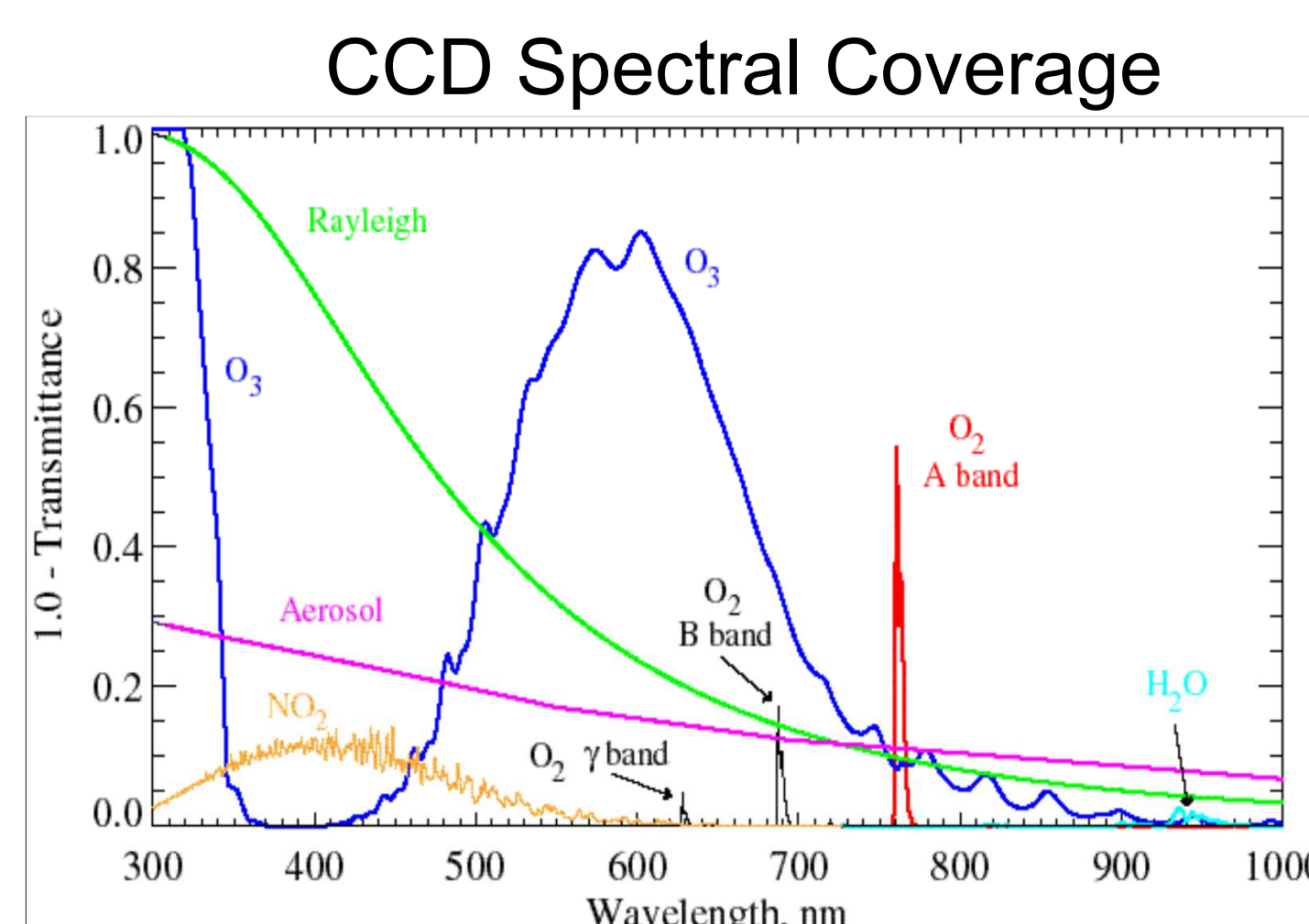
SAGE III on ISS

- Fifth in the SAM/SAGE series of solar occultation satellite instruments designed by NASA to measure vertical profiles of aerosol, ozone, and other trace gases
- SAGE III/ISS deployed to ISS in February 2017 and began routine measurements in June 2017
- CCD linear array of detectors allows continuous wavelength coverage between 280 and 1030 nm
- Provides multi-spectral measurements of O₂ A-band for temperature/pressure retrievals

Solar Occultation Measurement Approach

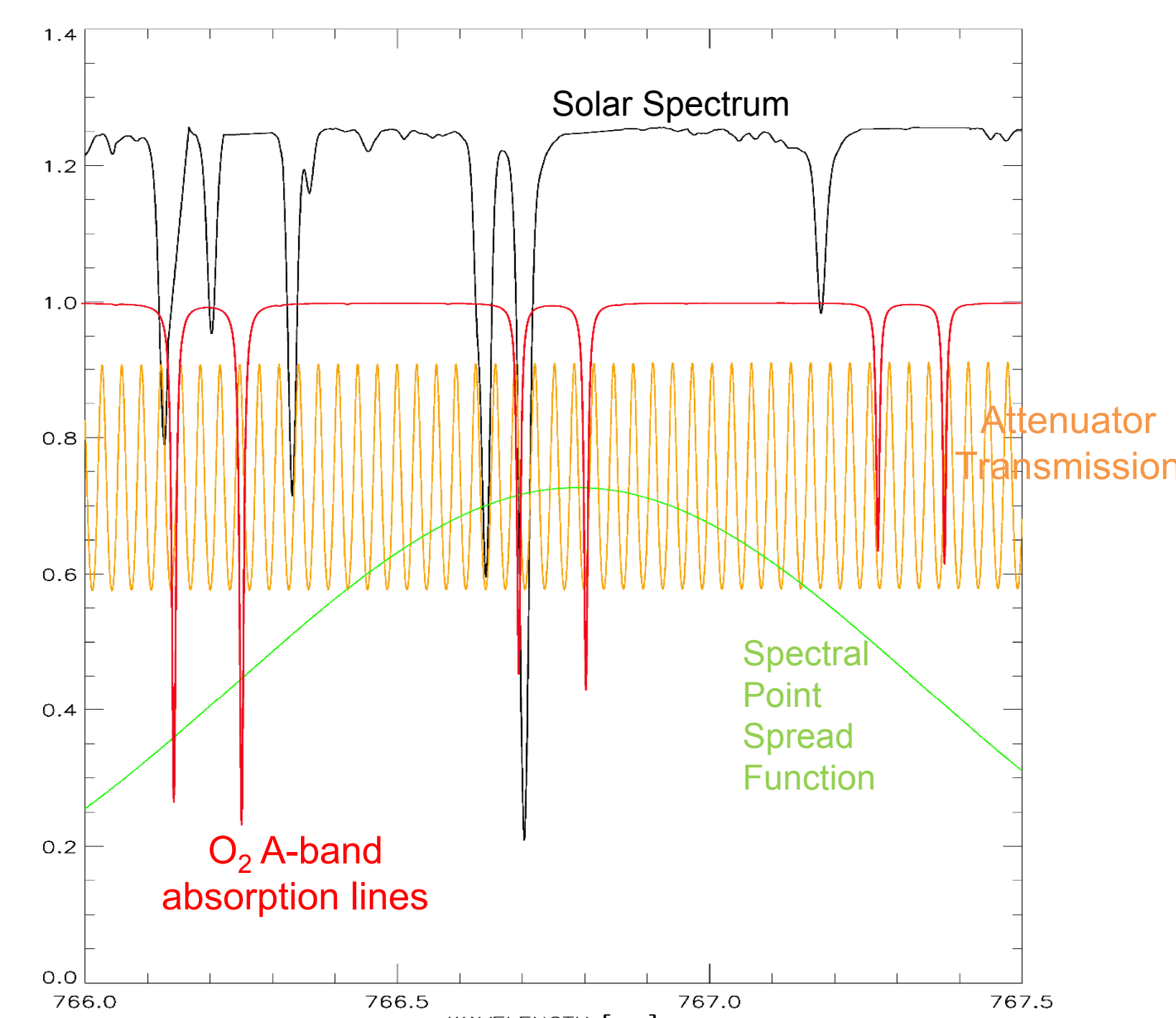


- During each sunrise and sunset encountered by the orbiting spacecraft, the SAGE III instrument measures the attenuated solar radiation through the Earth's limb, $I(z, \lambda)$, as a function of altitude and wavelength
- The exo-atmospheric solar radiation, $I_0(z, \lambda)$, is also measured during each event
- Atmospheric transmission is calculated as I/I_0
- Transmission data is then used to infer vertical profiles of O₃, NO₂, H₂O, multi-wavelength aerosol extinction, and temperature/pressure (O₂ A-band)



Impact of SAGE III/Meteor-3M Attenuator 'Etalon' on T/p Retrievals

- Solar attenuator on SAGE III/Meteor 3-M instrument was nearly plane-parallel and unexpectedly acted like an etalon with moderate reflectivity on one side
- Glass substrate of 'etalon' had temperature dependent index of refraction
- Transmission characteristics of 'etalon' changed during occultation events due to solar heating of the attenuator
- High frequency 'etalon' transmission pattern modulated the O₂ A-band and solar spectra in unpredictable manner
- Post-launch attempts to characterize and model 'etalon' had limited success and T/p products were not science quality



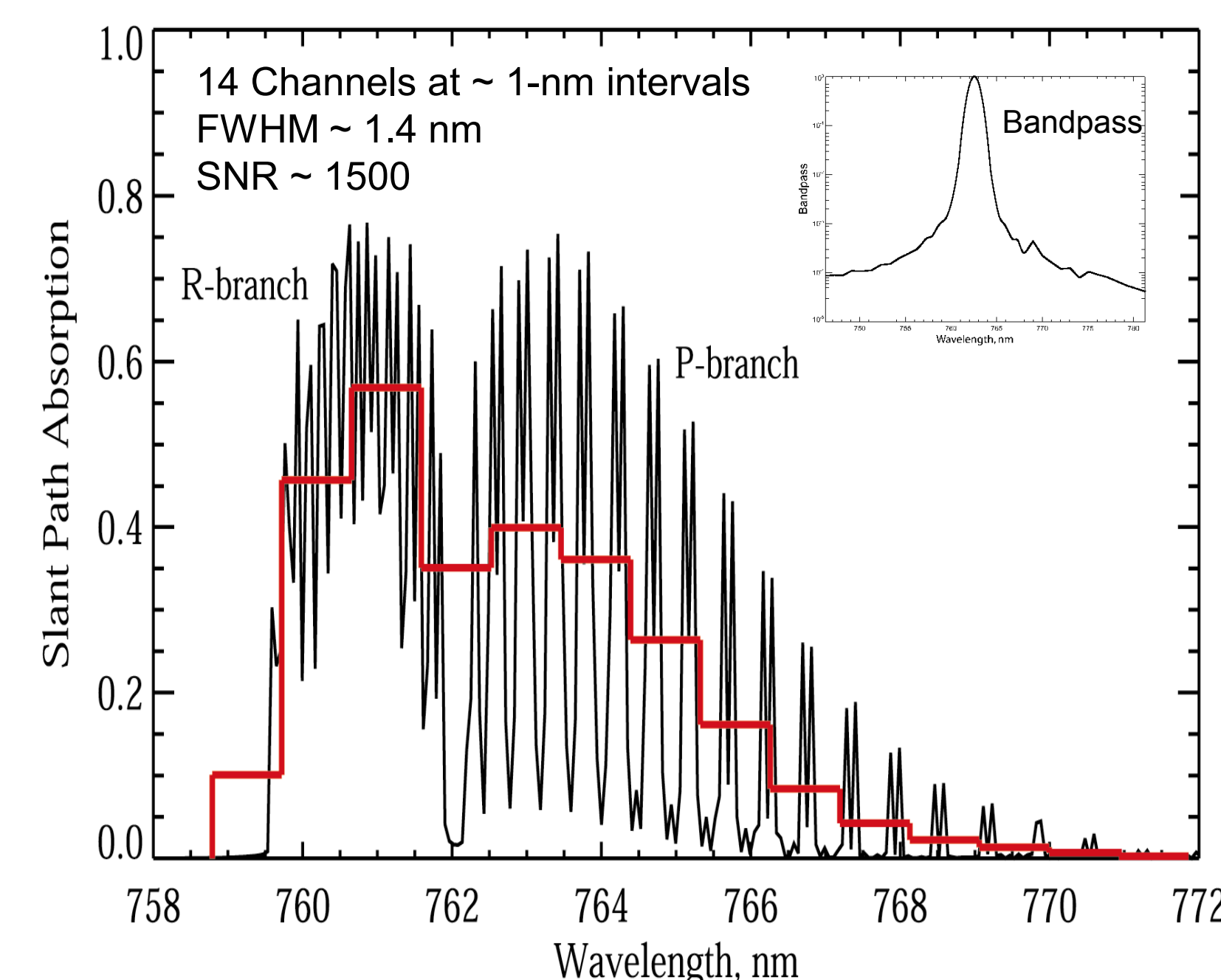
Strategy for Temperature/Pressure Retrievals

- Iterative approach required due to non-linear nature of problem
- Uses non-linear least squares fitting routine (Levenberg-Marquardt)
 - Simultaneously fits measured O₂ absorption spectra from all 14 channels and 90 tangent altitudes
 - Solves for successive adjustments to trial T,p profiles by minimizing residuals between measured and modeled absorption

$$\chi^2 = \sum_{i=1}^M \left[\frac{A_i^m - A_i^c(\mathbf{a})}{\sigma_i} \right]^2$$

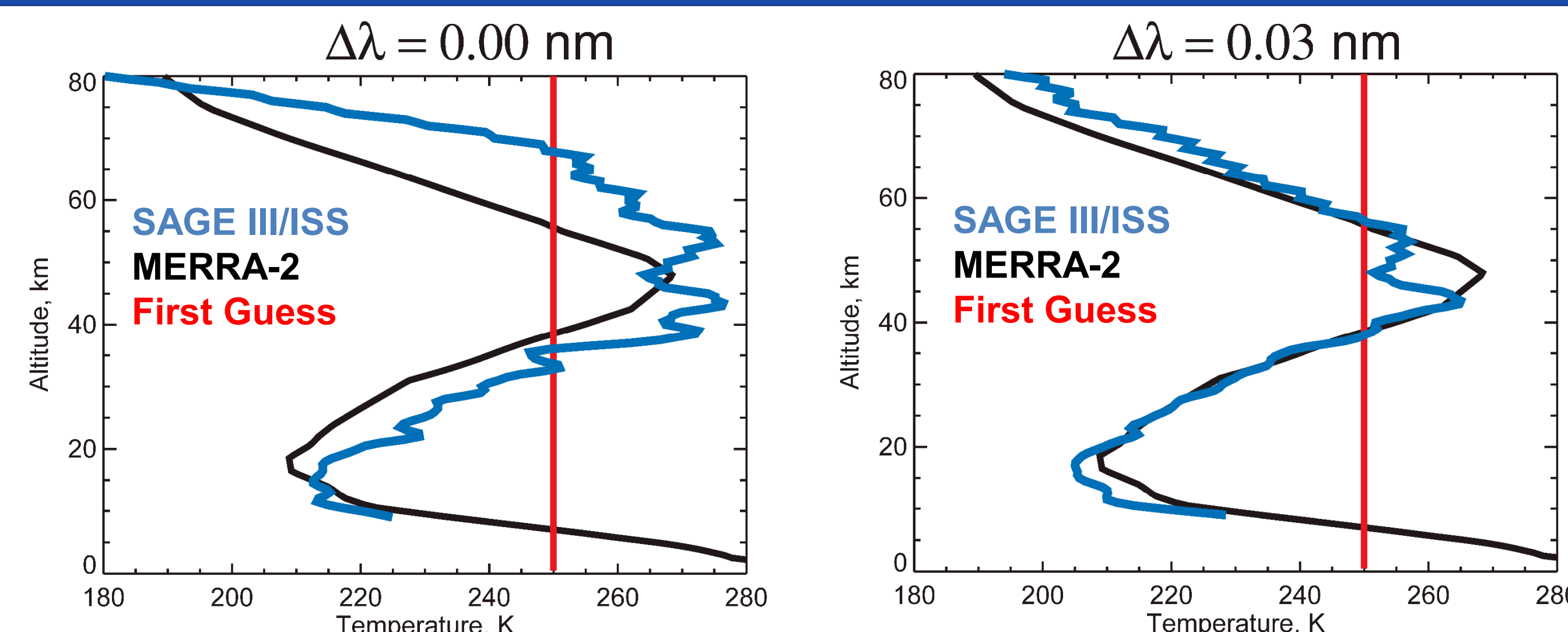
- Includes non-rigid hydrostatic constraint

- Uses GPU accelerated version of line-by-line radiative transfer code (~8x faster than CPU only)

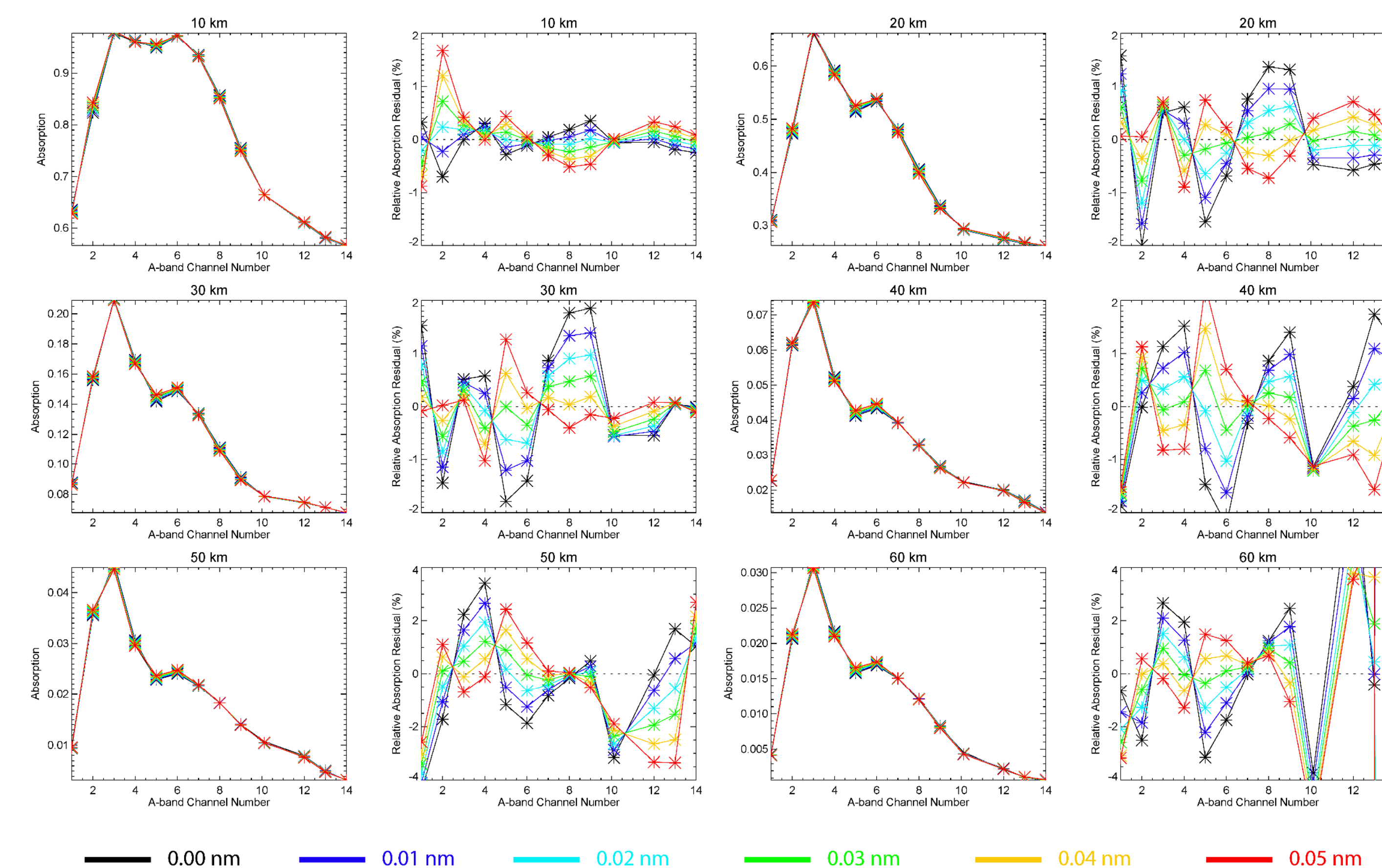


A-band contains ~290 individual absorption lines with the distinctive R-branch and P-branch structure. Broad features are still visible at SAGE III resolution (red line)

Sensitivity to Wavelength Registration



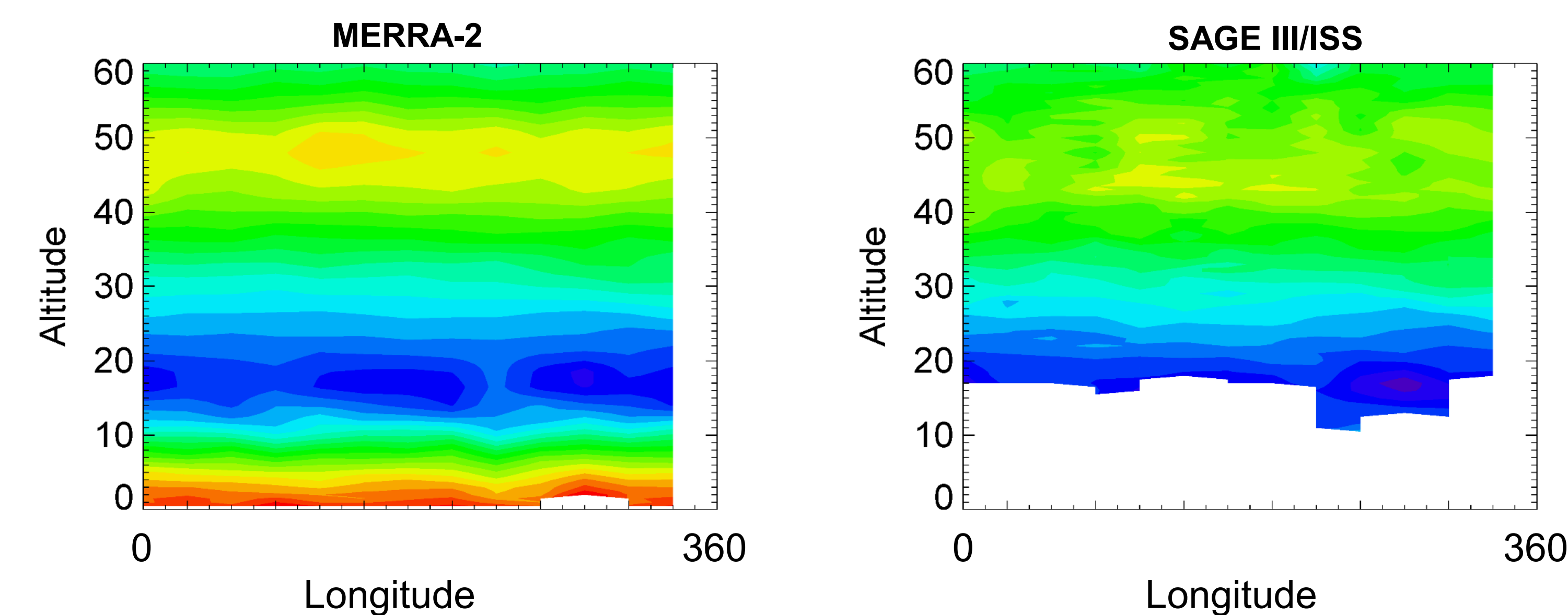
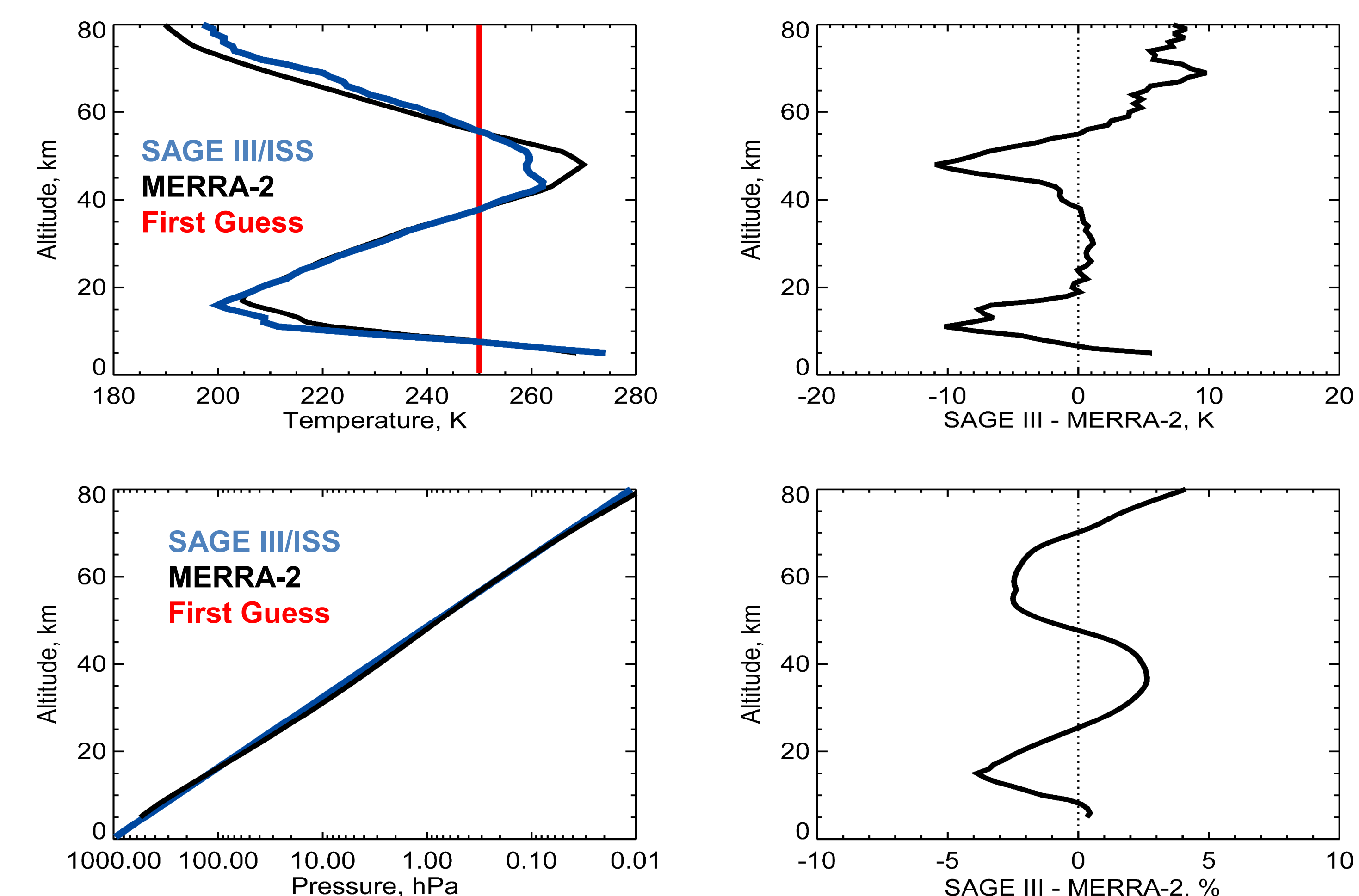
Mean SAGE III/ISS retrieved temperature profiles from 15 sunset events on 2017-11-14 using the nominal wavelength registration (left) and a wavelength map adjusted by 0.03 nm (right).



Measured versus modeled spectra and residuals at selected tangent altitudes for five test cases where the wavelength map was adjusted by intervals of 0.01 nm. Best fits for these 15 sunset events generally occur at for wavelength shifts of ~0.03-0.04 nm.

Preliminary Results

Composite of 15 Sunset Events on 2017-11-14 (~27.5° S)



- Retrieved temperature profiles agree reasonably well with MERRA-2, but appear too cold near tropopause and stratopause
- Retrieved pressure agrees with MERRA-2 within 5%

Summary and Future Direction

- Preliminary Assessment:**
 - SAGE III/ISS O₂ A-band measurements are of higher fidelity than SAGE III/Meteor 3-M with no apparent instrument issues
 - Sensitivity tests indicate small wavelength shift (~0.03-0.04 nm) in A-band channels relative to nominal registration
 - Preliminary retrievals are promising with near science quality products
- Future Work:**
 - Examine sensitivity to forward model parameters
 - Bandpass (width, wings, etc.)
 - Spectroscopy (line intensities, line shape)
 - Solar spectrum
 - Exclude weaker channels and/or solar feature near 766.7 nm
 - More detailed comparisons with correlative measurements (e.g., radiosondes, lidar, MLS, and global analyses)