National Aeronautics and Space Administration

SAGE III/ISS

Stratospheric Aerosol and Gas Experiment

An Earth Science Mission on the Internatinal Space Station

An assessment of the SAGE III/ISS temperature and pressure research products

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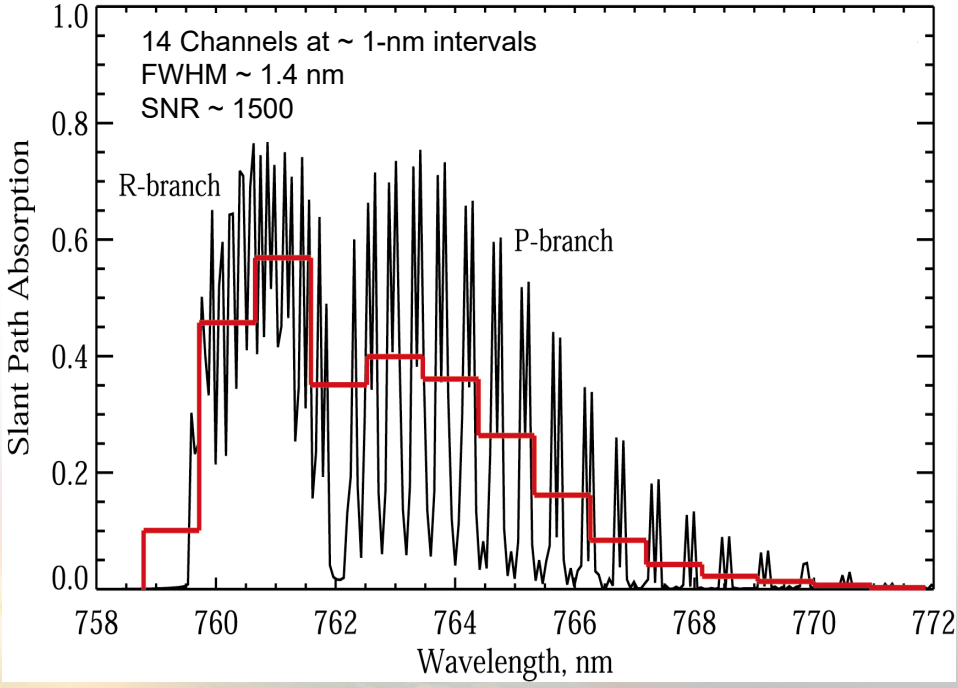
Strategy for Temperature/Pressure Retrievals

- **Iterative approach required due to non-linear nature of problem**
- **Uses non-linear least squares fitting routine (Levenberg-Marquardt)**
  - Simultaneously fits measured A-band spectra from all 14 channels and 90 tangent altitudes
    - Includes O_2 absorption, Rayleigh scattering, aerosol extinction, and O_3 absorption components
  - Solves for successive adjustments to trial T,p profiles by minimizing residuals between measured and modeled absorption

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

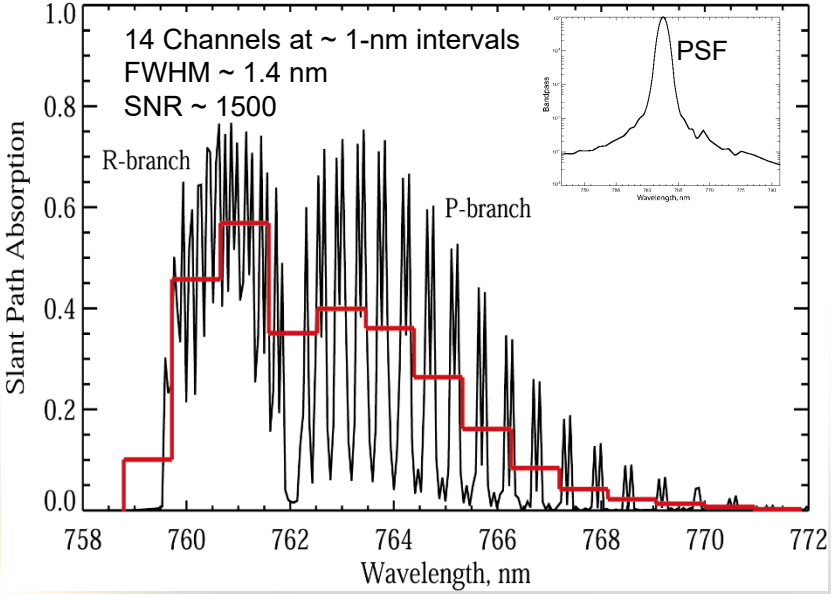
  - Includes non-rigid hydrostatic constraint



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)

Forward Model Elements

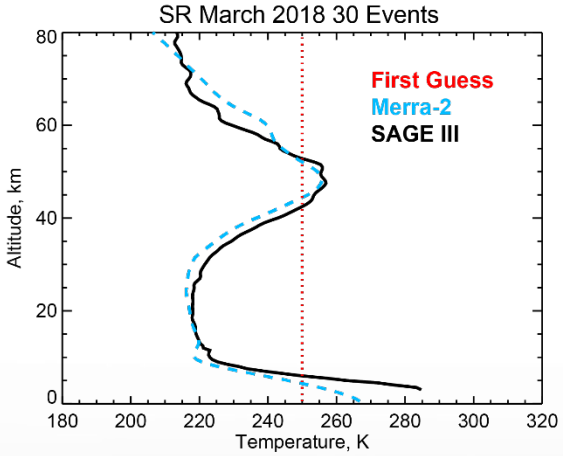
- **Forward model simulates SAGE III/ISS LOS transmission measurements in 14 O_2 A-band channels using LBL radiative transfer calculations**
- **Inputs:**
  - Initial guess T/p profiles
  - Pathlength matrix
  - O_2 Spectroscopic parameters (HITRAN 2016)
  - Initial guess aerosol (linear fit: slope + intercept)
  - Initial guess ozone (cross sections + ozone number density)
  - Channel wavelength map
  - Channel point spread function (PSF)
- **Outputs**
  - LOS transmission (O_2 + Rayleigh + aerosol + O_3)

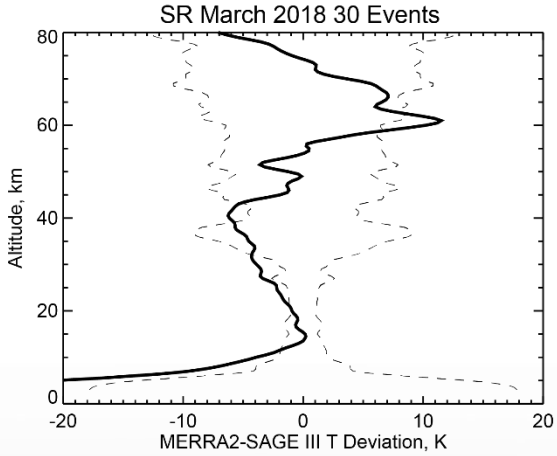


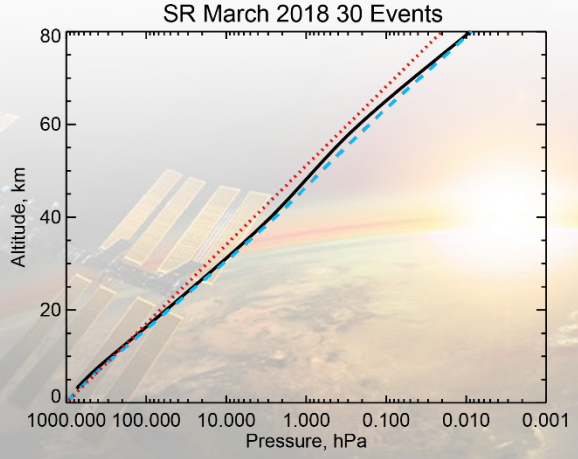
A-band contains ~290 individual absorption lines with the distinctive R-branch and P-branch structure. Broad features are still visible at SAGE III resolution (red line)

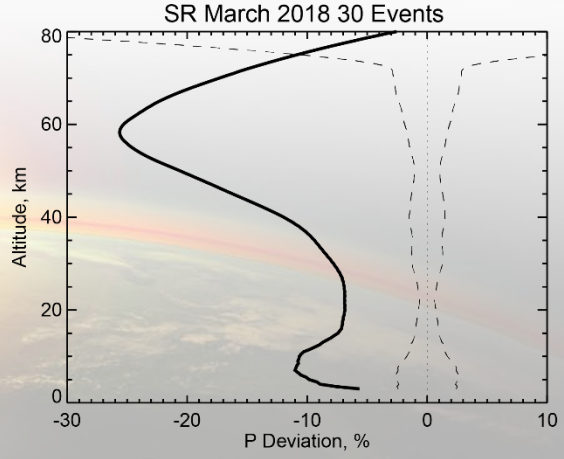
Baseline Retrievals (Sunrise Events)

Mean SAGE III/ISS retrieved temperature and pressure profiles from 30 sunrise events during March 2018 with baseline wavelength map and PSF factor



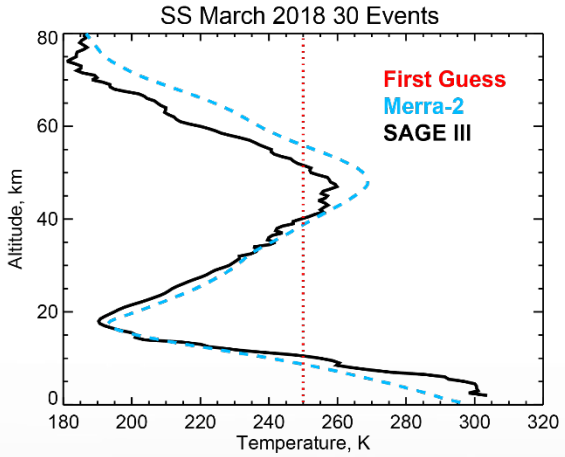


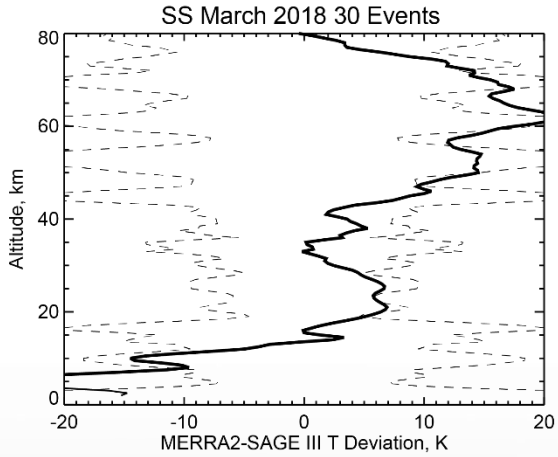


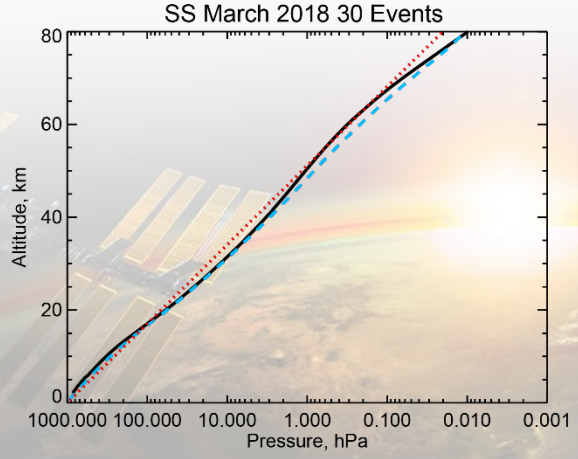


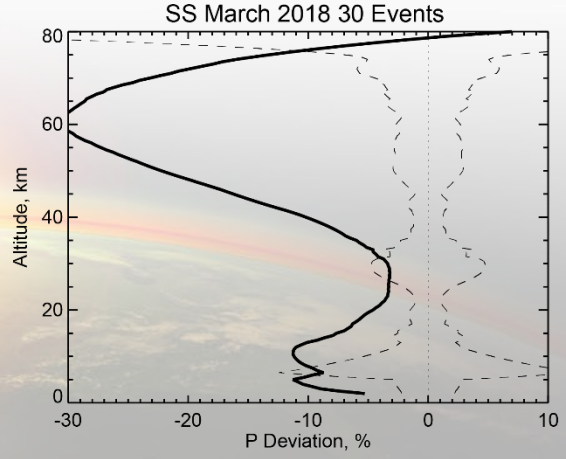
Baseline Retrievals (Sunset Events)

Mean SAGE III/ISS retrieved temperature and pressure profiles from 30 sunset events during March 2018 with baseline wavelength map and PSF factor



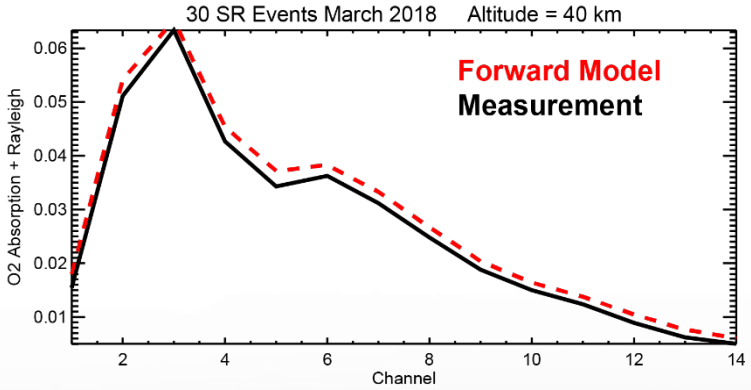


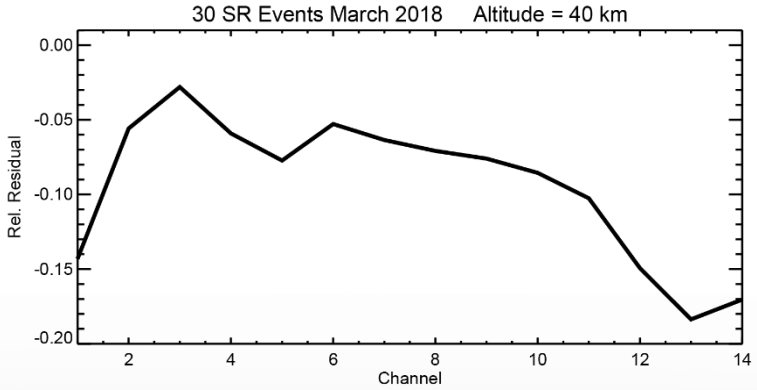


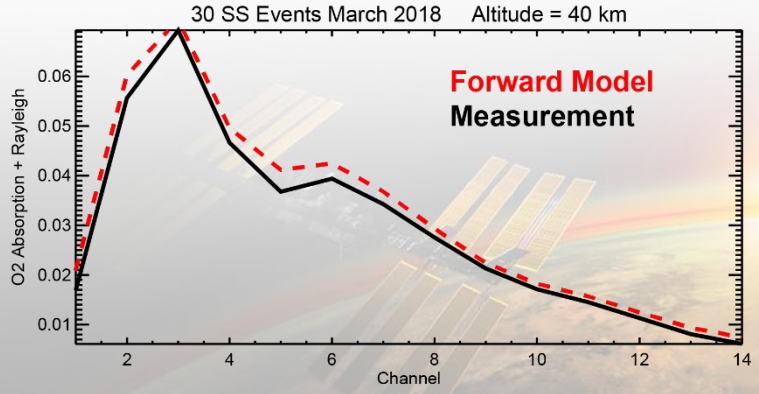


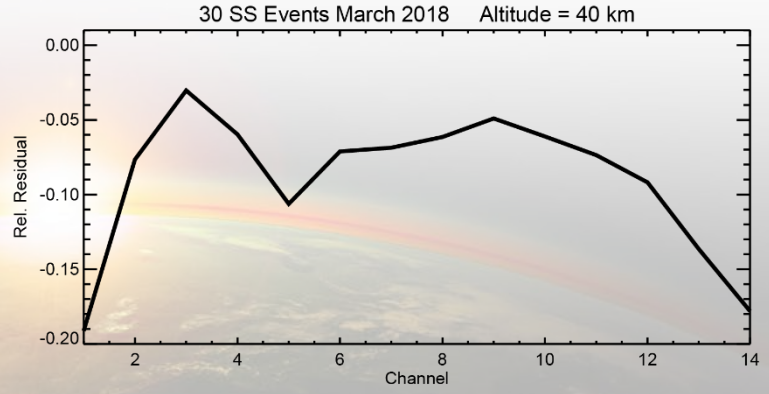
Measured vs. Modeled O_2 + Rayleigh Components

Baseline wavelength registration and instrument response functions



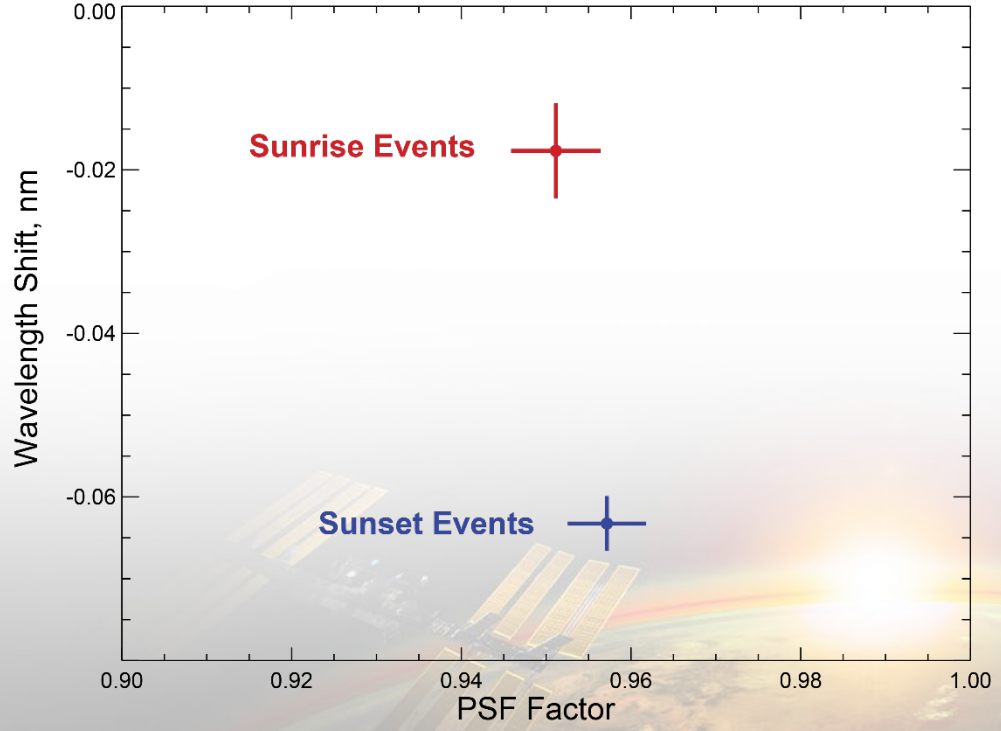






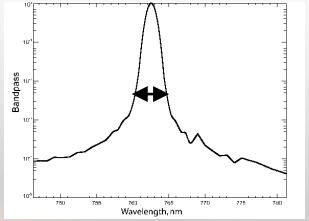
- Modeled spectra too broad and misregistered in wavelength

Wavelength and PSF Factor Adjustments



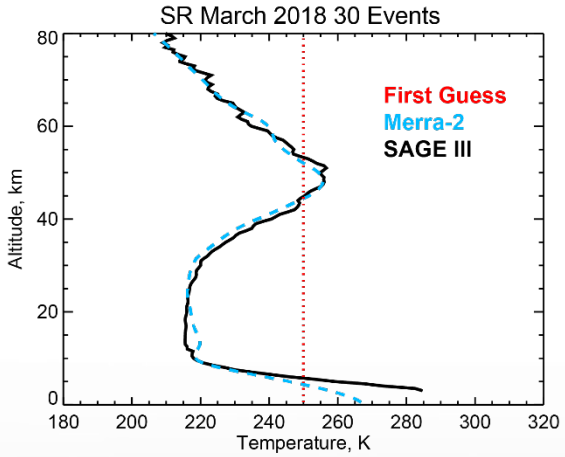
- **Assume Merra-2 T/p profiles are truth**
- **Retrieved adjustments to baseline wavelength map and PSF widths (mean ± 1 σ) required to best fit measured spectra**

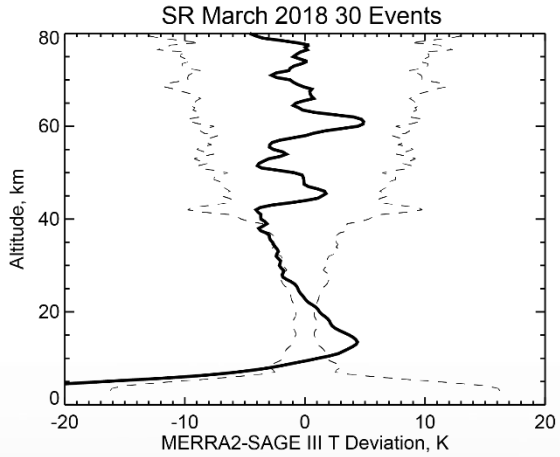
Channel PSF

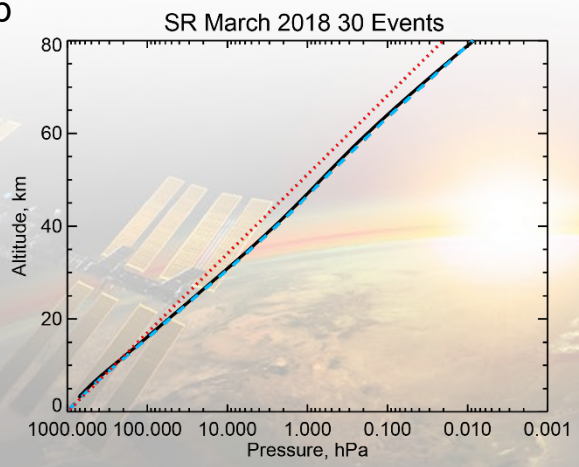


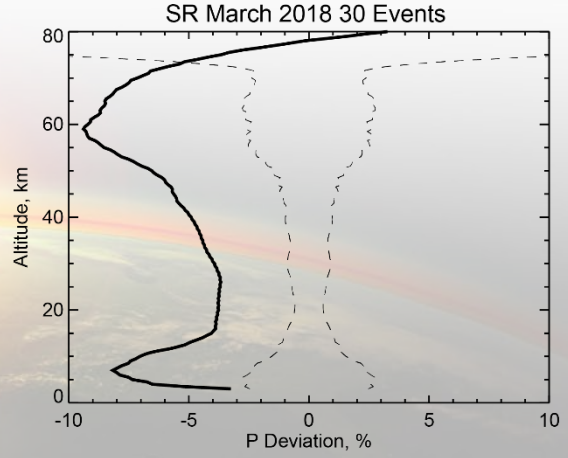
Retrievals Using Adjusted Wavelength & PSF

Mean SAGE III/ISS retrieved temperature and pressure profiles from 30 sunrise events during March 2018 with adjusted wavelength map (-0.018 nm) and PSF factor (0.95)



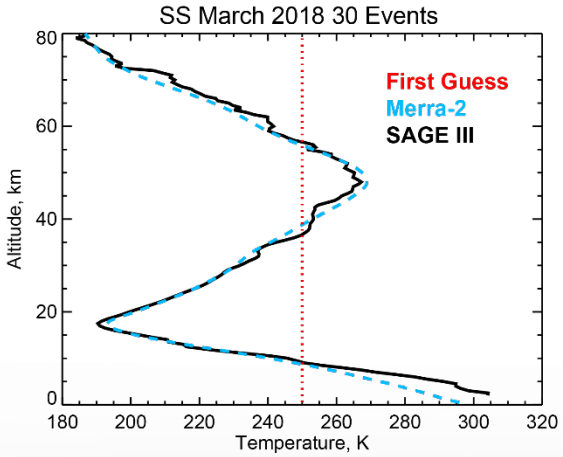


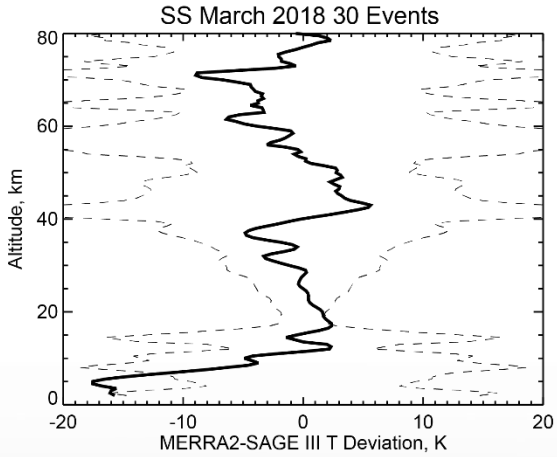


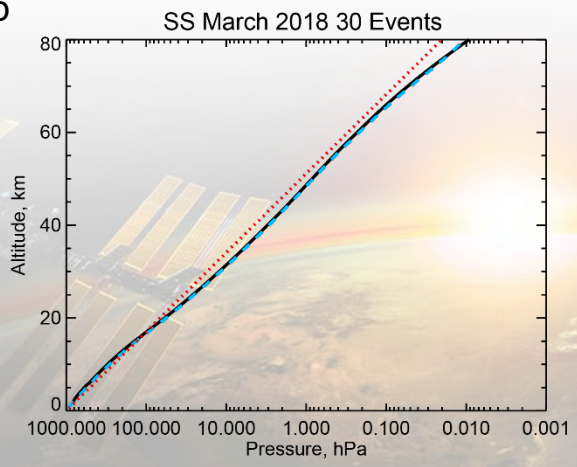


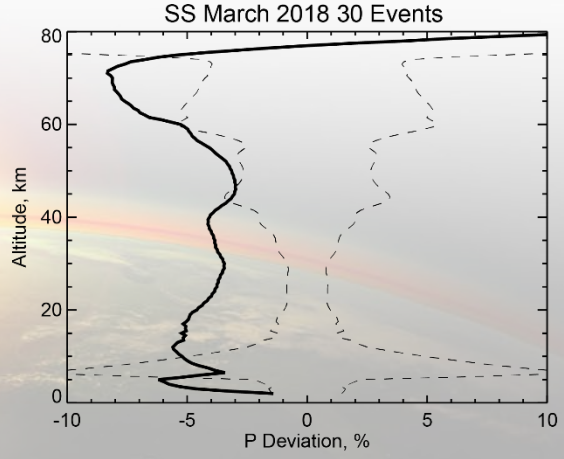
Retrievals Using Adjusted Wavelength & PSF

Mean SAGE III/ISS retrieved temperature and pressure profiles from 30 sunset events during March 2018 with adjusted wavelength map (-0.063 nm) and PSF factor (0.95)

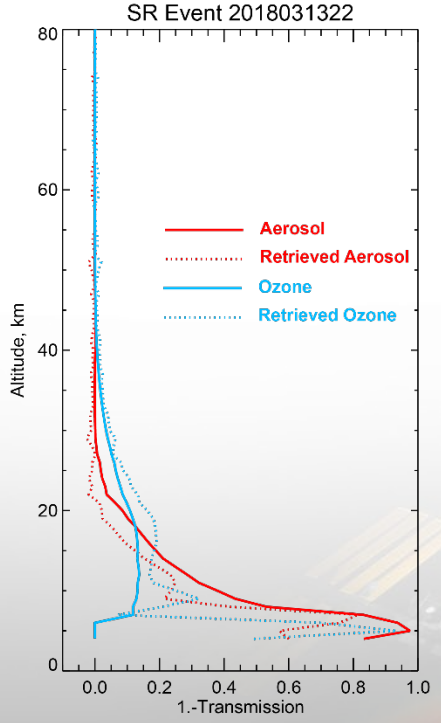


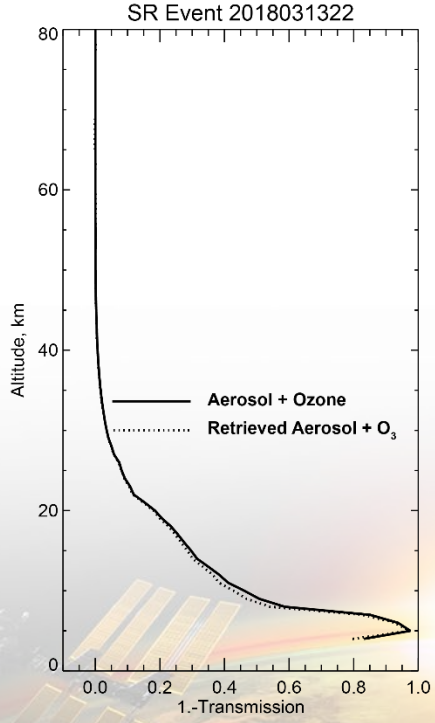


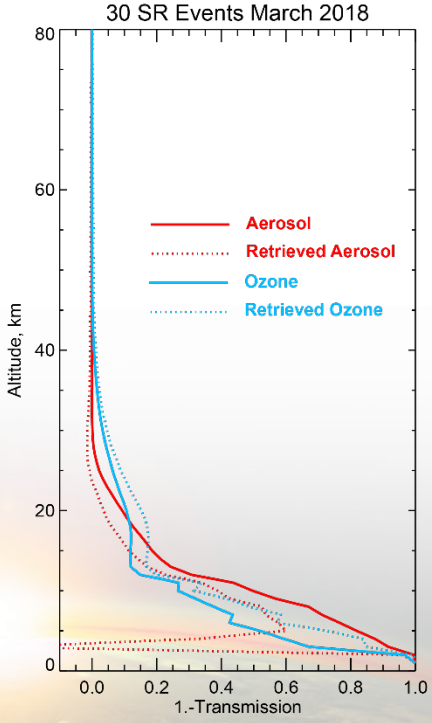


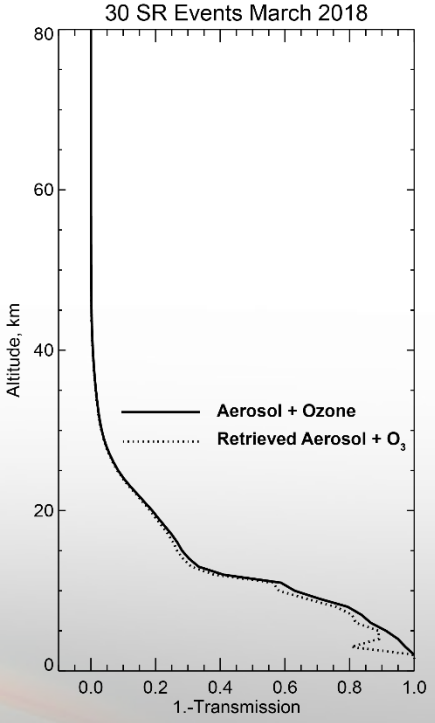


Aerosol and Ozone Fitting









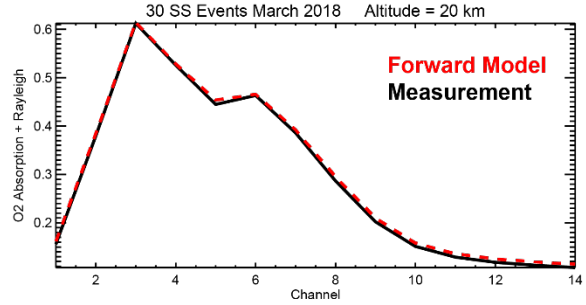
Retrieved aerosol and ozone components compared with measurements (aerosol interpolated from aerosol channels and AO3 ozone product)

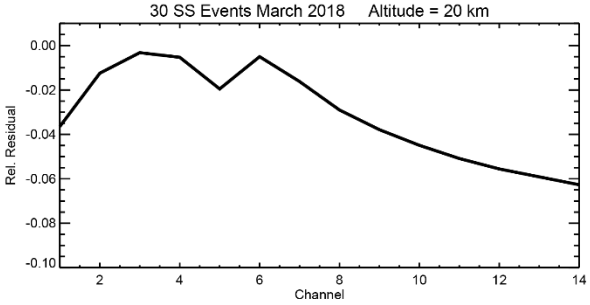
O_2 + Rayleigh Fitting

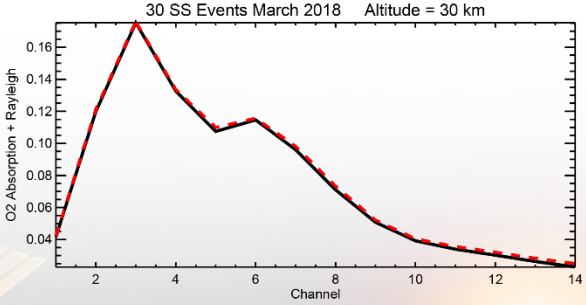
- Mean measured vs. modeled O_2 absorption + Rayleigh scattering for 30 SS events

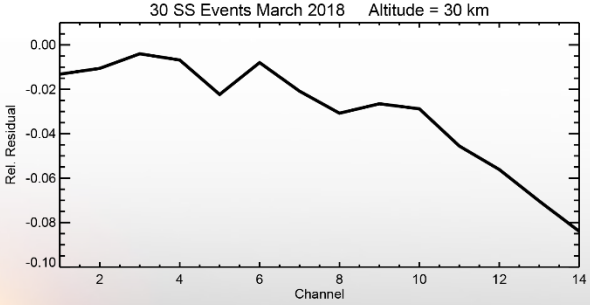
- Forward model parameters:
- $\Delta\lambda$ = -0.063
- PSF Factor = 0.95

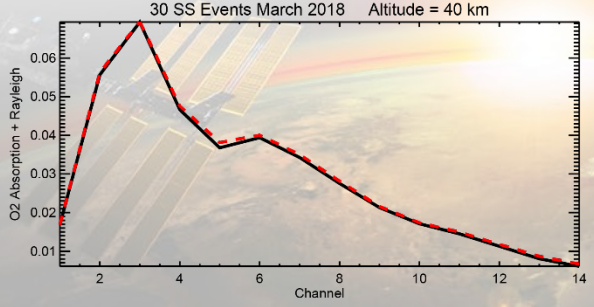
- Systematic shape of residuals may indicate that some component is not being properly fitted

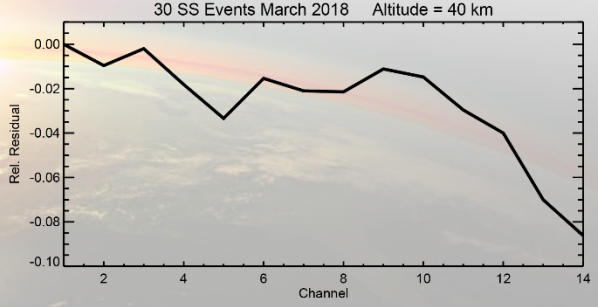




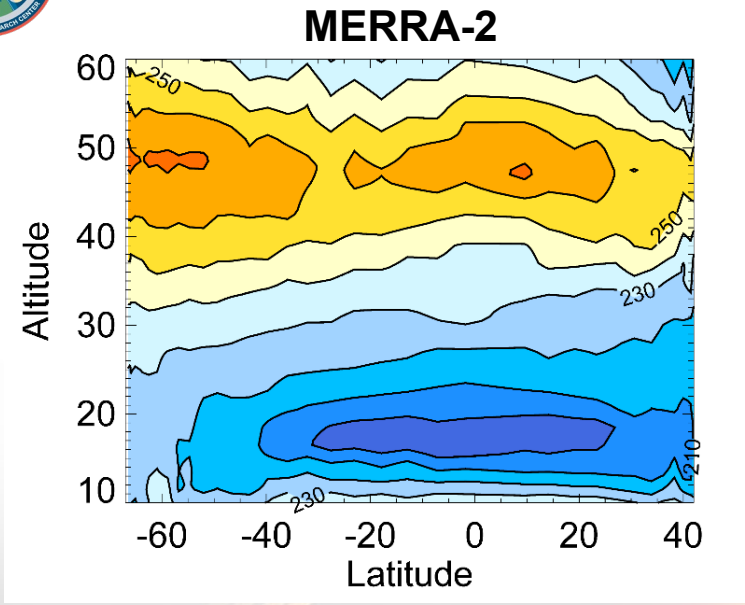


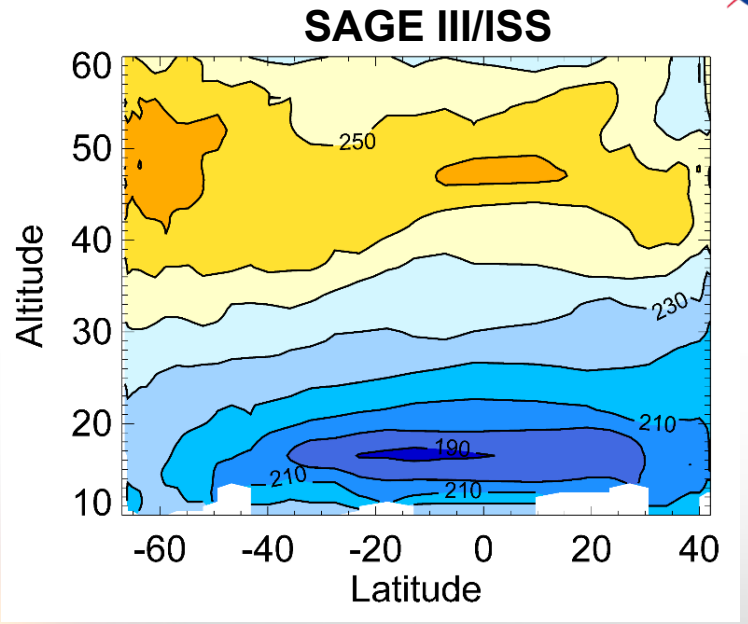






SAGE III/ISS vs. Merra-2 zonal cross sections





MERRA-2 (left) and SAGE III/ISS (right) meridional temperature distributions compiled from sunrise events over the period 1 January -15 February 2018. The SAGE III/ISS temperature distribution captures the general temperature structure seen in MERRA-2, but is colder at the tropopause and stratopause, and somewhat noisier at higher altitudes.

Summary and Future Work

- **Forward Model Assessment:**
  - Small wavelength shifts are apparent in A-band spectra relative to baseline registration (approximately -0.018 nm for sunset and -0.063 nm for sunrise events)
  - Baseline PSFs too broad- fits are improved using narrower (0.95 x baseline) widths
- **Retrievals with adjusted forward model parameters look encouraging with *near science quality* temperature products, but some issues remain, especially in pressure product**
- **Future Work:**
  - Continue examining sensitivity to forward model parameters
    - Bandpass (width, wings, etc.)
    - Spectroscopy (line intensities, line shape)
    - Potential altitude offset
    - Aerosol + O_3 components
  - Exclude weaker channels
  - Explore alternative retrieval approaches to L-M (e.g., Newton-Raphson)
  - Perform more detailed comparisons with correlative measurements (e.g.,radiosondes, lidar, MLS, and global analyses) to quantify precision and accuracy of T/p products