



# SAGE III / ISS

## Stratospheric Aerosol and Gas Experiment

An Earth Science Mission on the International Space Station

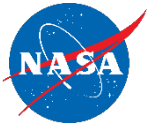
Update on SAGE III/ISS temperature and pressure research products

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13 September 2023





# Outline

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- **Brief overview of T/p retrieval algorithm**
- **Assessment of forward model**
- **Example retrieval results**
- **Devil is in the details**
- **Summary and future work**





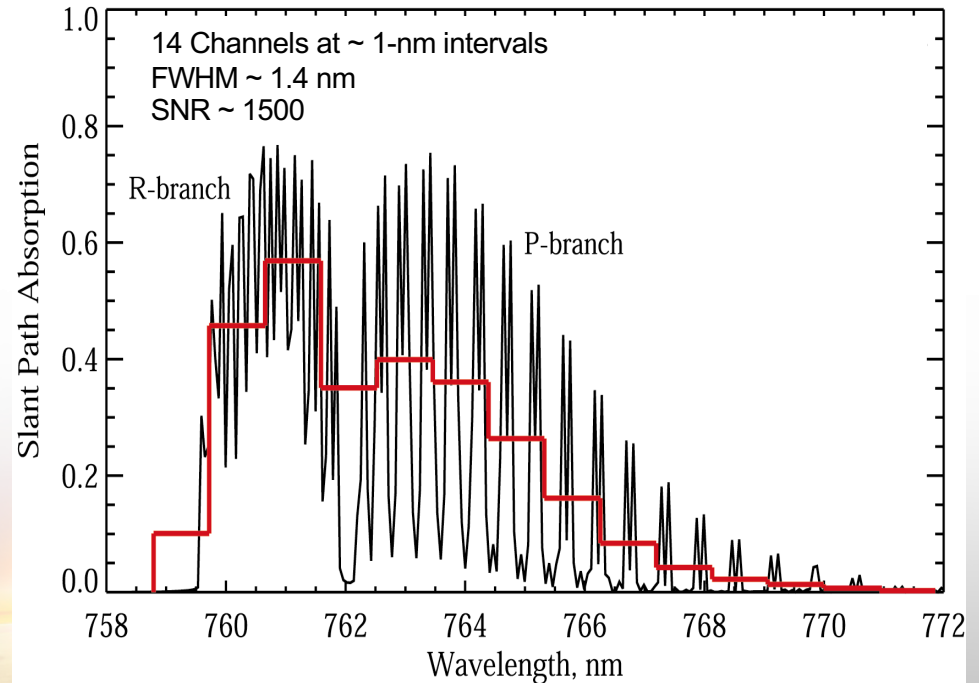
# Strategy for Temperature/Pressure Retrievals



- 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<sub>2</sub> absorption, Rayleigh scattering, aerosol extinction, and O<sub>3</sub> 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



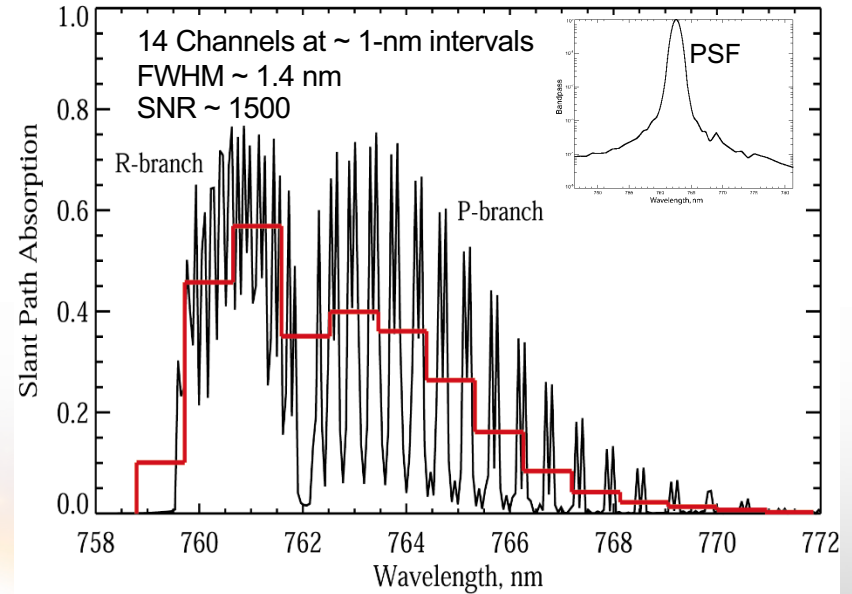
➤ **Forward model simulates SAGE III/ISS LOS transmission measurements in 14 O<sub>2</sub> A-band channels using LBL radiative transfer calculations**

➤ **Inputs:**

- Initial guess T/p profiles
- Pathlength matrix
- O<sub>2</sub> Spectroscopic parameters (HITRAN 2020)
- Initial guess aerosol (linear fit: slope + intercept)
- Initial guess ozone (cross sections + ozone number density)
- Channel wavelength map
- Channel point spread function (PSF)

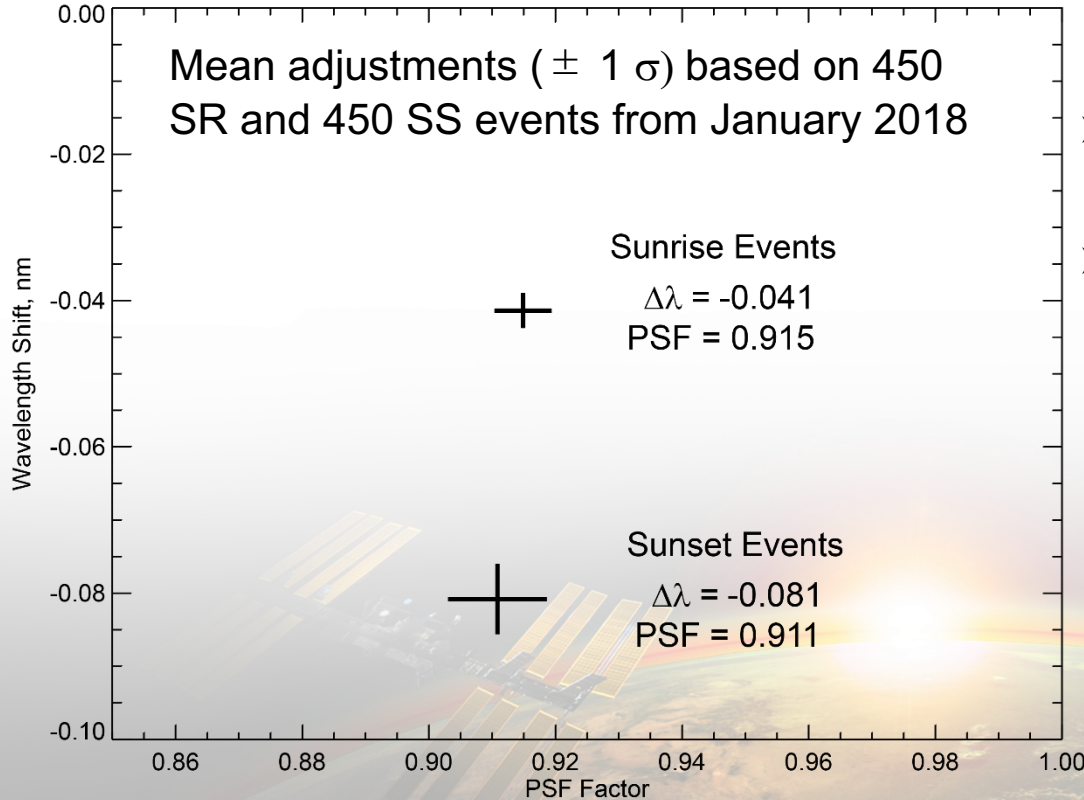
➤ **Outputs**

- LOS transmission (O<sub>2</sub> + Rayleigh + aerosol + O<sub>3</sub>)

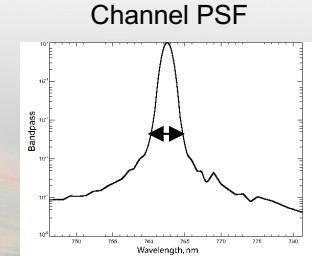


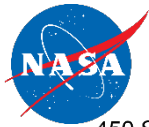
A-band contains ~290 individual absorption lines with the distinctive R-branch and P-branch structure. Broad features are still visible at SAGE III resolution (red line)

# V5.3 Wavelength and PSF Factor Adjustments



- Modeled spectra too broad and misregistered in wavelength relative to baseline measurements
- Retrieved adjustments to baseline wavelength map and PSF widths required to best fit measured spectra
  - Assume Merra-2 T/p profiles are truth
  - Solve for best-fit  $\Delta\lambda$  and PSF factors



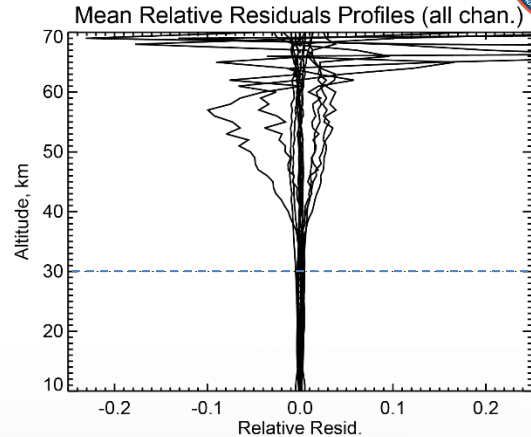
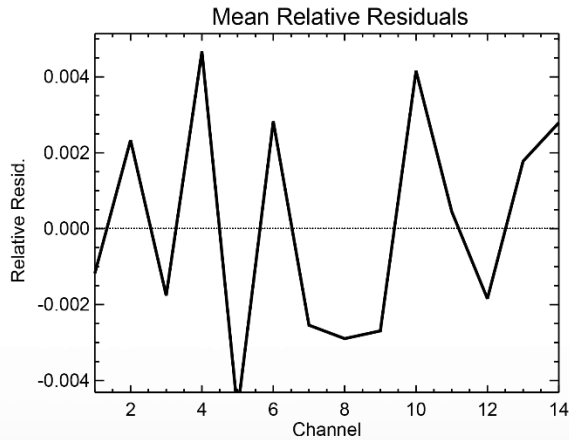
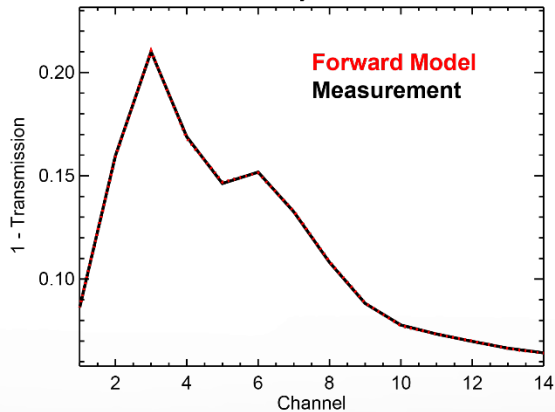


# Forward Model Fitting

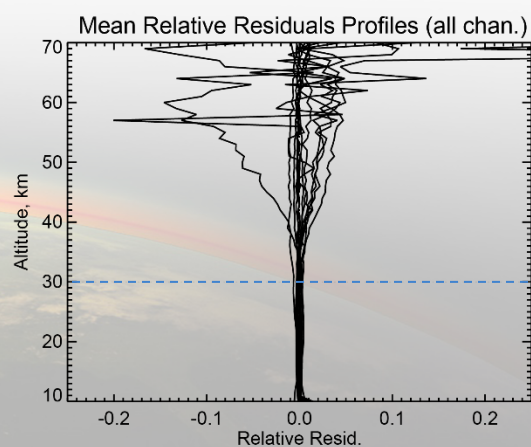
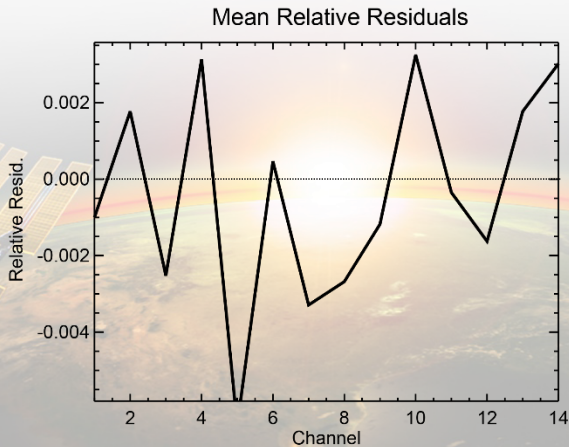
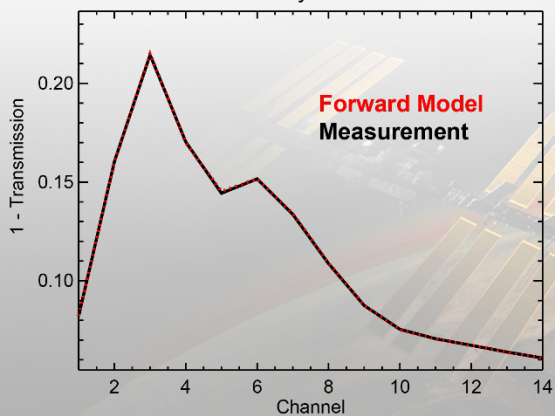
## Adjusted wavelength registration and instrument response functions

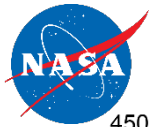


450 SR Events January 2018 Altitude = 30 km



450 SS Events January 2018 Altitude = 30 km



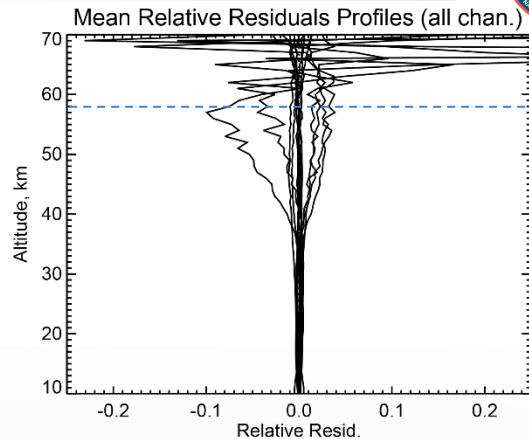
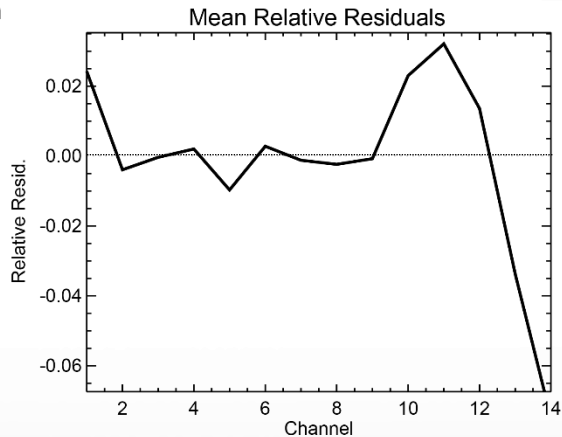
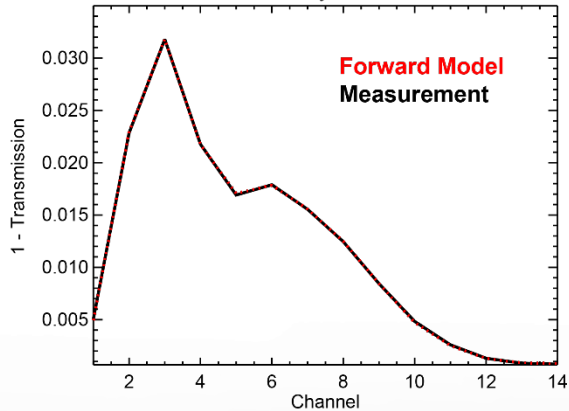


# Forward Model Fitting

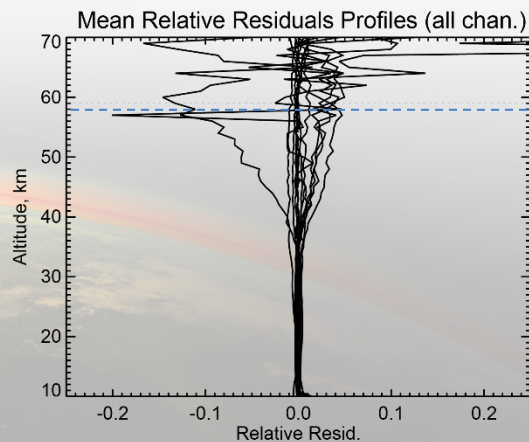
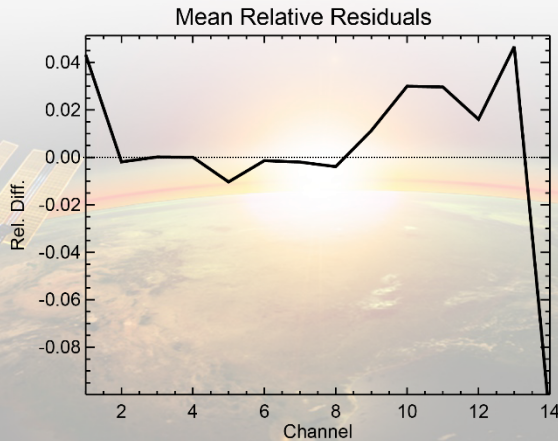
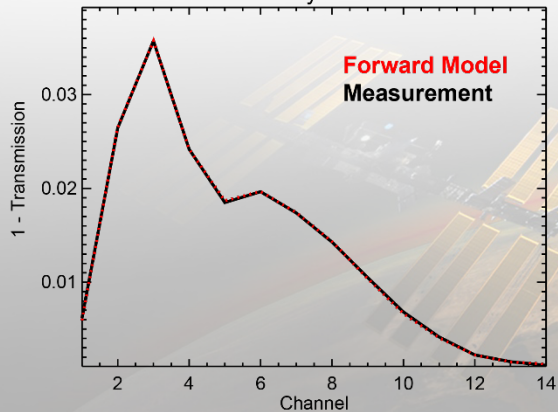
## Adjusted wavelength registration and instrument response functions



450 SR Events January 2018 Altitude = 58 km



450 SS Events January 2018 Altitude = 58 km



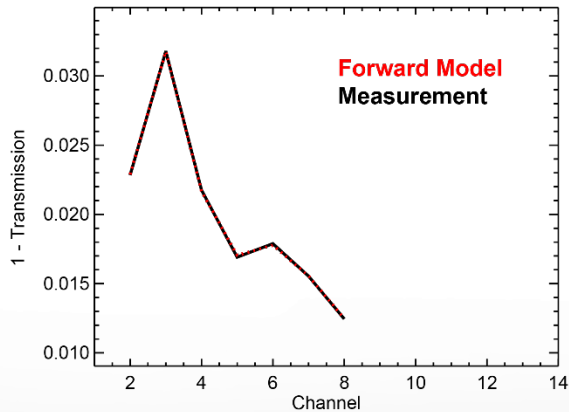


# Forward Model Fitting

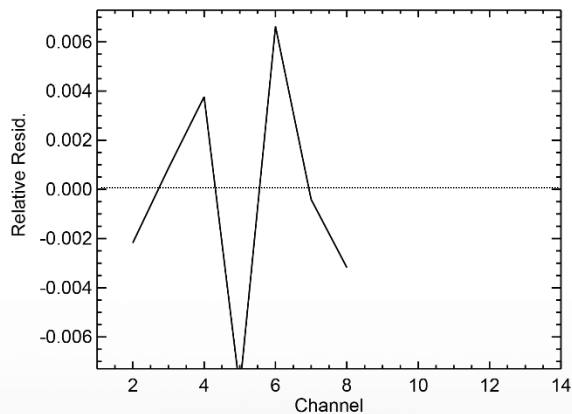
## Weak channel (transmission > 0.99) filtering



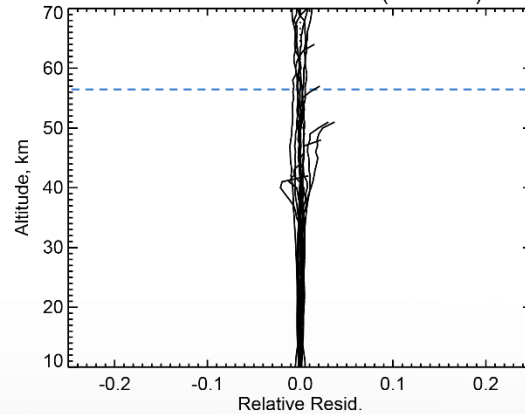
450 SR Events January 2018 Altitude = 58 km



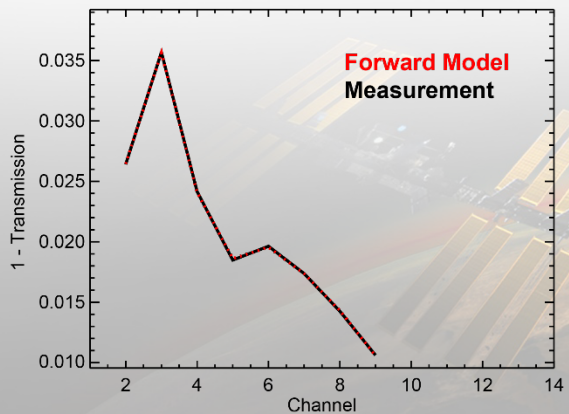
Mean Relative Residuals



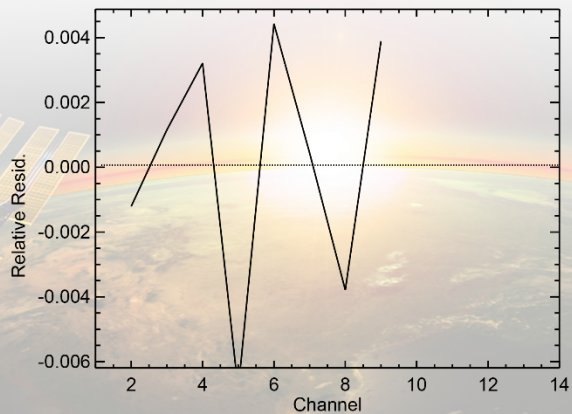
Mean Relative Residuals (all chan.)



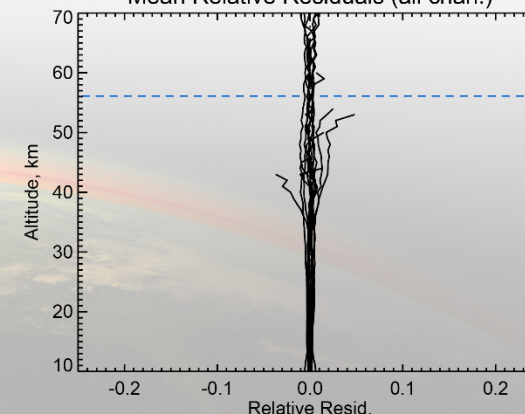
450 SS Events January 2018 Altitude = 58 km



Mean Relative Residuals



Mean Relative Residuals (all chan.)







# Example Retrievals

## Sunrise Events January 2018



Mean SAGE III/ISS  
retrieved T/p profiles  
with adjusted wave-  
length map (-0.041 nm)  
and PSF factor (0.915)

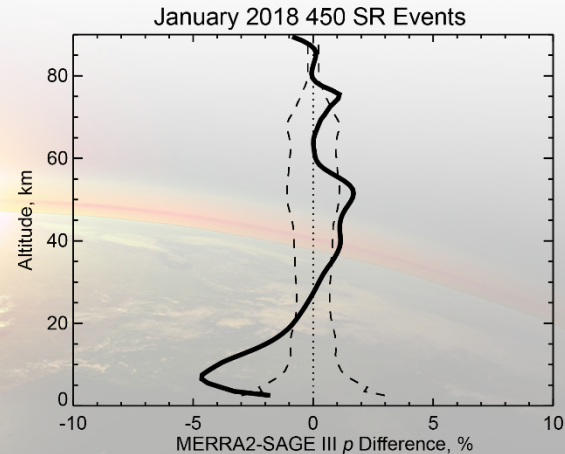
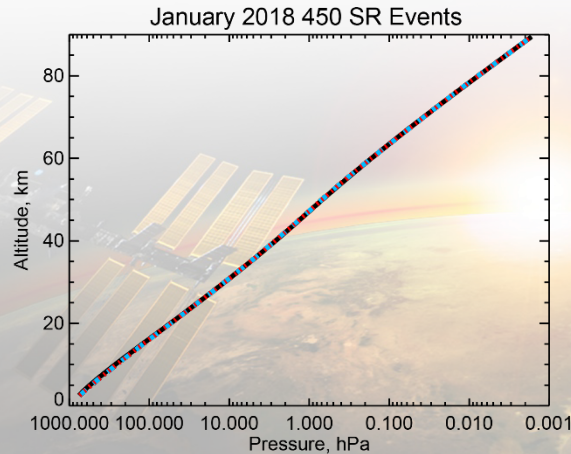
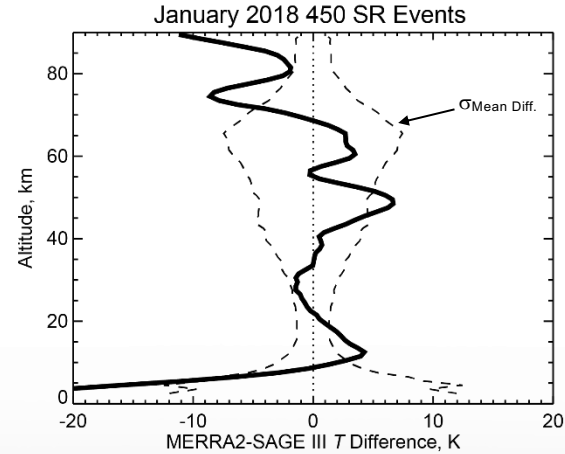
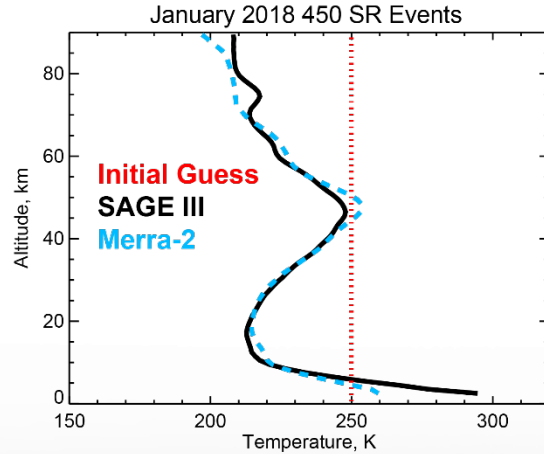
+

Weak channel filtering  
(Transmission > 0.99)

Initial guesses

$$T = 250 \text{ K}$$

$$\rho = \rho_{\text{Merra-2}}$$





# Example Retrievals

## Sunset Events January 2018



Mean SAGE III/ISS  
retrieved T/p profiles  
with adjusted wave-  
length map (-0.081 nm)  
and PSF factor (0.911)

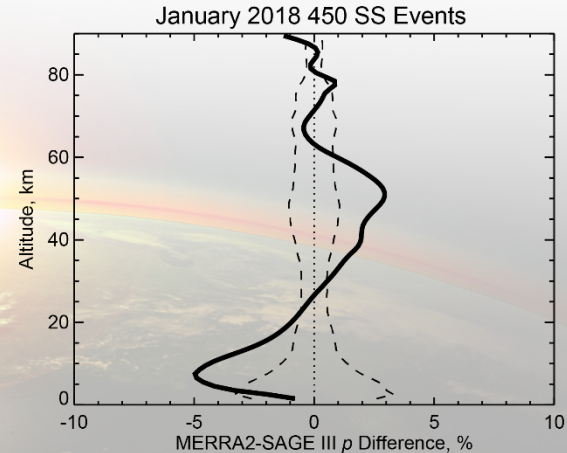
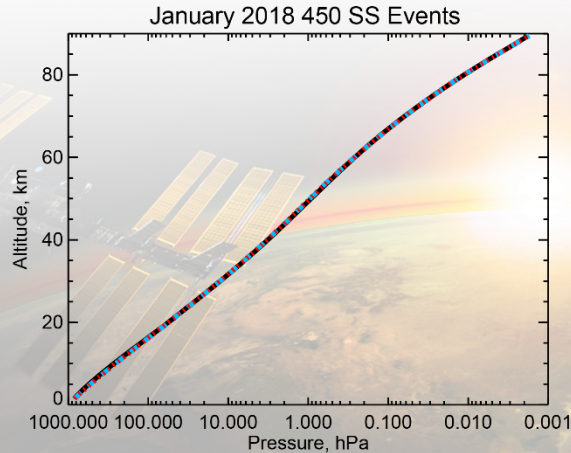
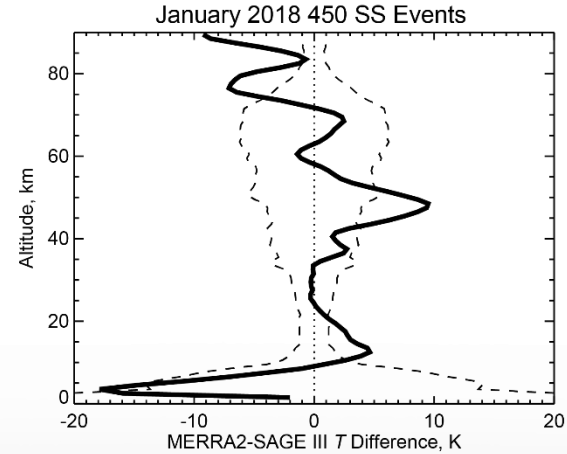
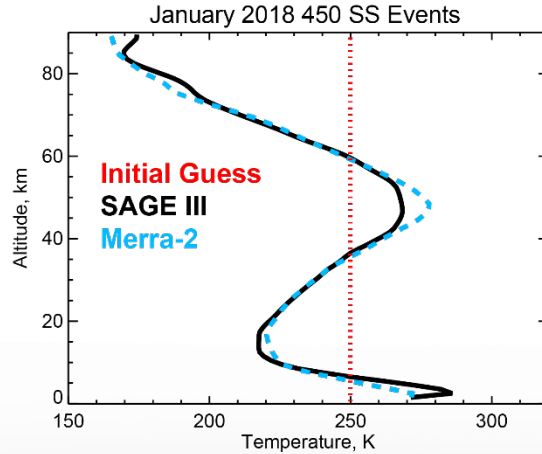
+

Weak channel filtering  
(Transmission > 0.99)

Initial guesses

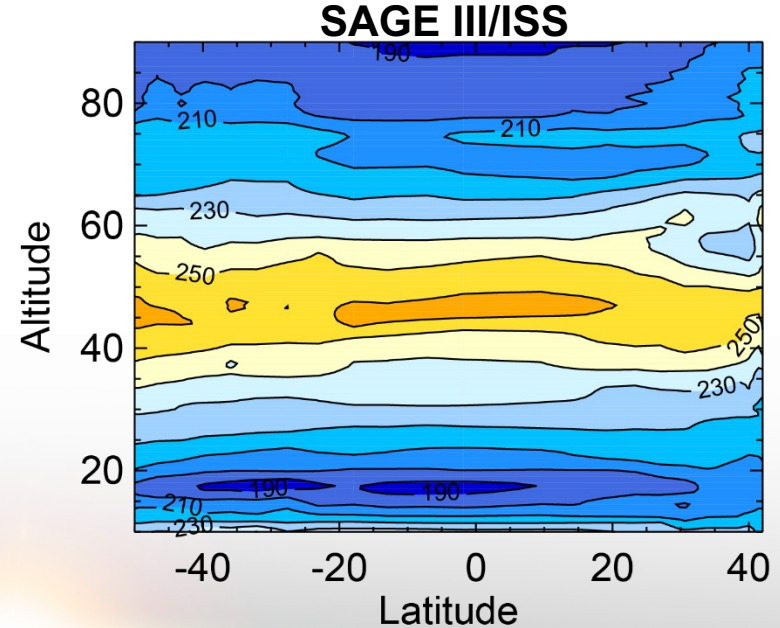
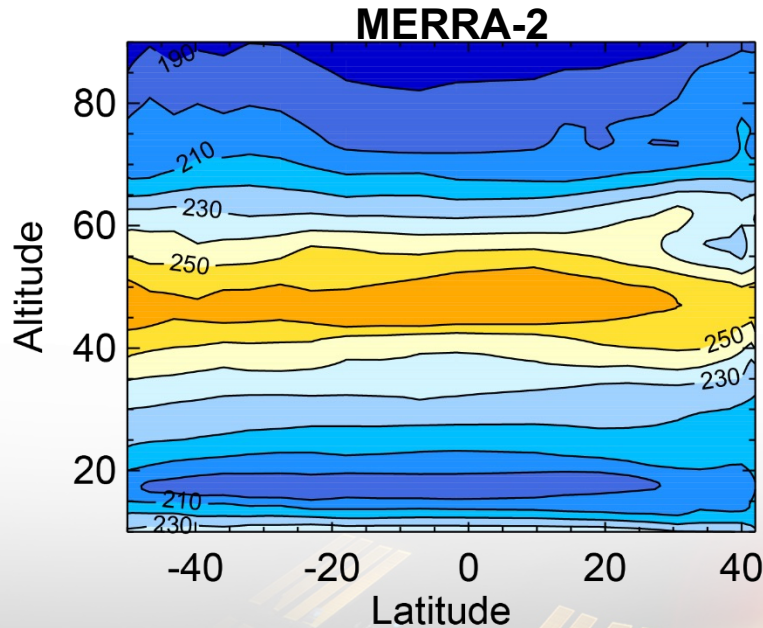
$$T = 250 \text{ K}$$

$$p = p_{\text{Merra-2}}$$





# SAGE III/ISS vs. Merra-2 meridional cross sections



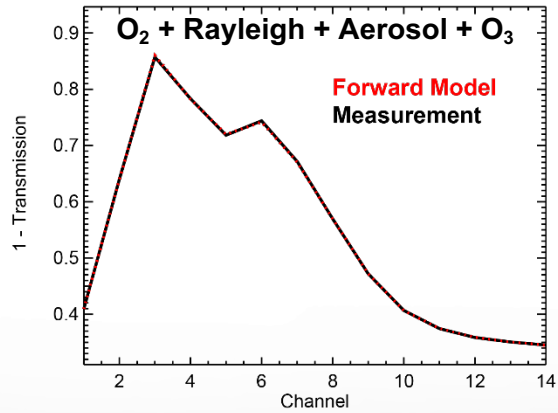
MERRA-2 (left) and SAGE III/ISS (right) meridional temperature distributions compiled from sunrise events over the period 1 January -1 February 2018. The SAGE III/ISS temperature distribution captures the general temperature structure seen in MERRA-2, but is colder at the tropopause and stratopause.



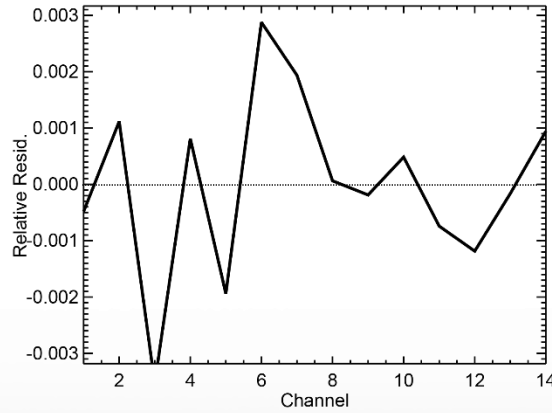
# Individual Component Fitting- the Devil's in the details



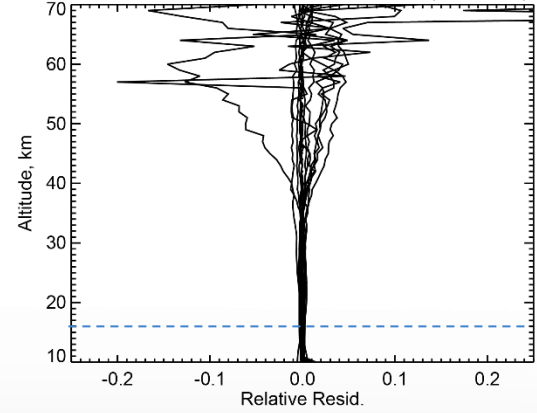
Total Transmission at 16 km



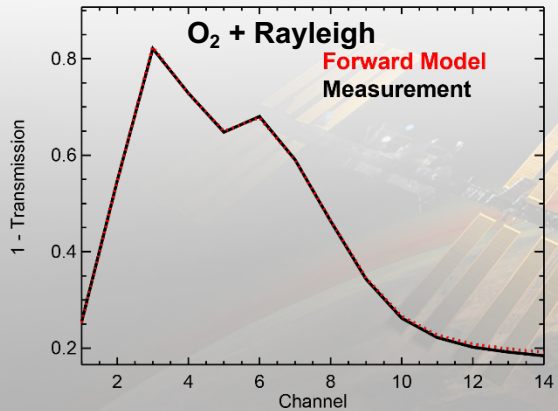
Mean Relative Residuals



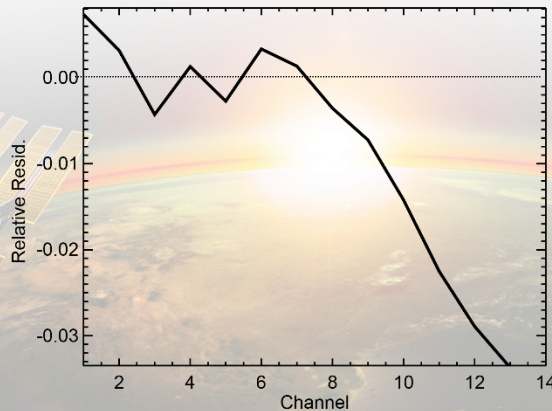
Mean Relative Residuals Profiles (all chan.)



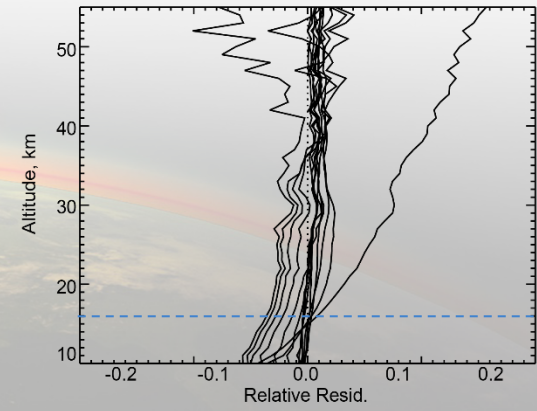
O<sub>2</sub> + Rayleigh components at 16 km



Mean Relative Residuals



Mean Relative Residuals Profiles (all chan.)

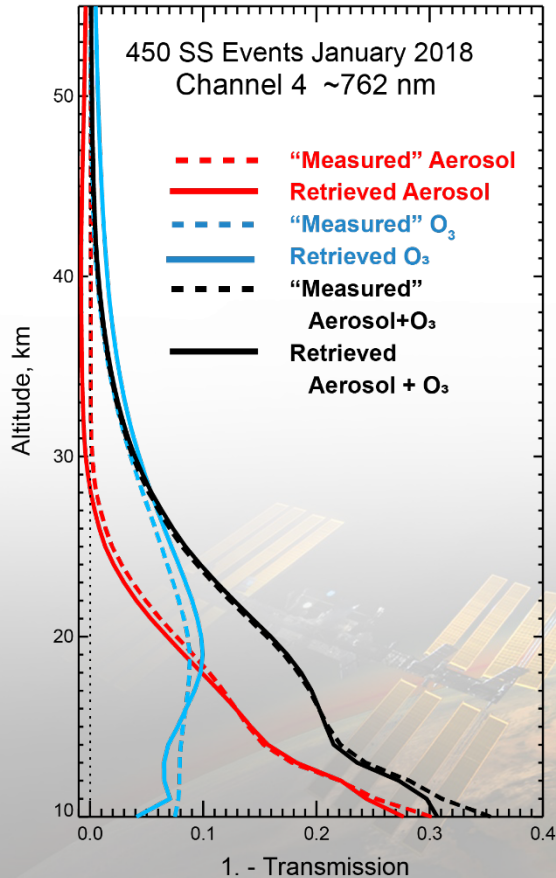




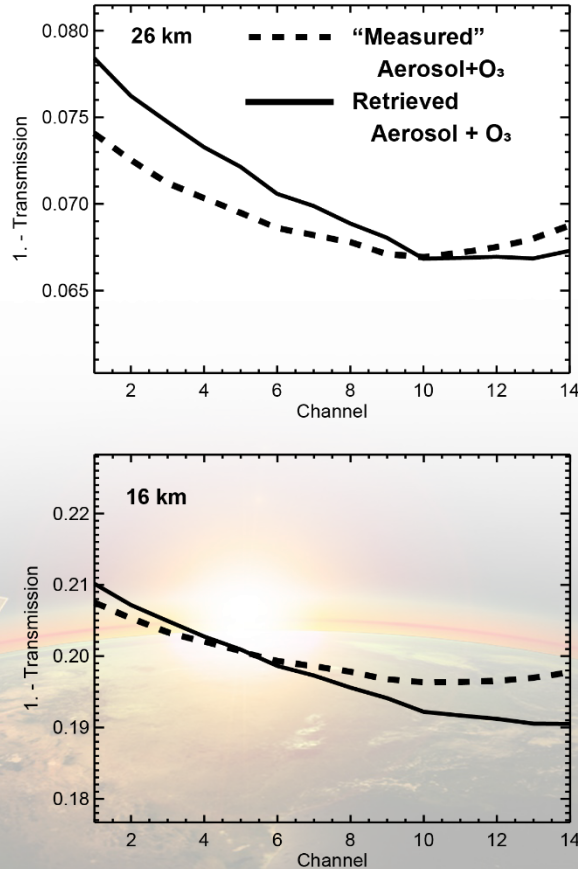
# Individual Component Fitting- the Devil's in the details



### Aerosol/O<sub>3</sub> Component Profiles



### Combined Aerosol+O<sub>3</sub> Component Spectra



- "Measured" aerosol and O<sub>3</sub> components interpolated from aerosol channels and AO3 ozone product
- "Measured" vs. retrieved aerosol+O<sub>3</sub> components have different slopes across the band
- Possible cross talk between aerosol/O<sub>3</sub> fitting and O<sub>2</sub>-Rayleigh fitting



# Summary and Future Work



- **Forward Model Assessment**

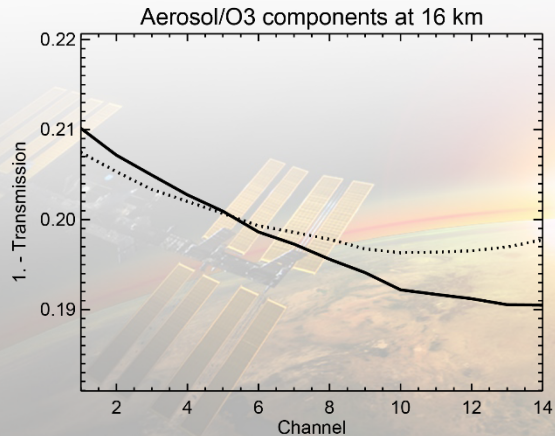
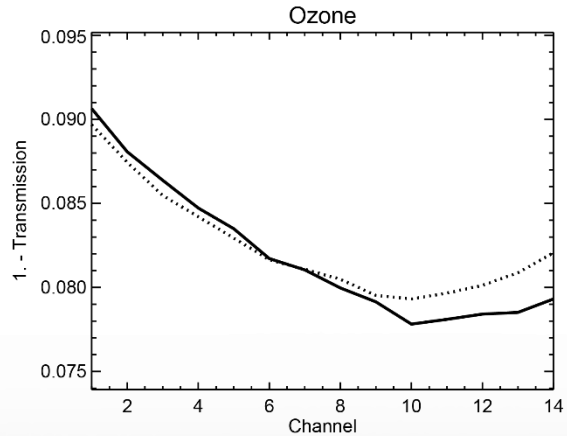
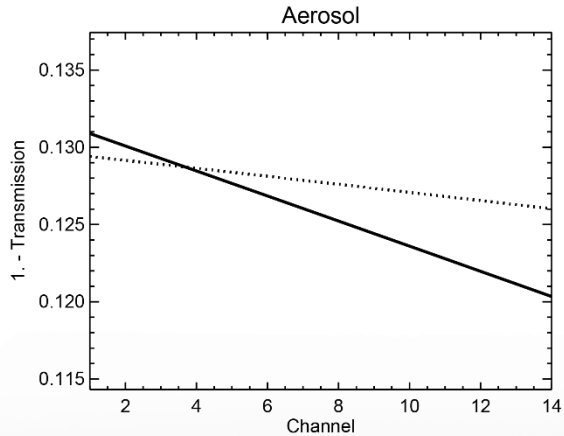
- Derived adjustments to wavelength and PSF widths required to accurately model A-band spectra
  - Wavelength shifts of -0.041 nm for SS and -0.081 nm for SR events relative to baseline registration
  - PSF factor of 0.91 x baseline widths
- Incorporating these adjustments produces accurate simulations of measured A-band LOS transmission spectra, but still some issues with individual component fits

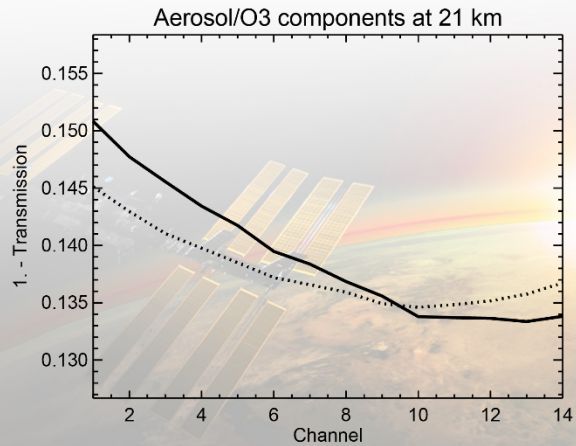
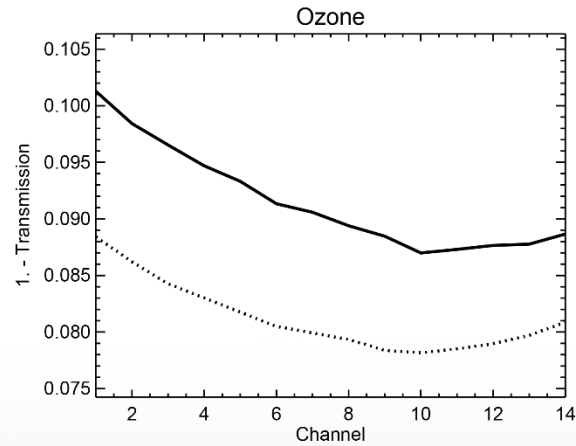
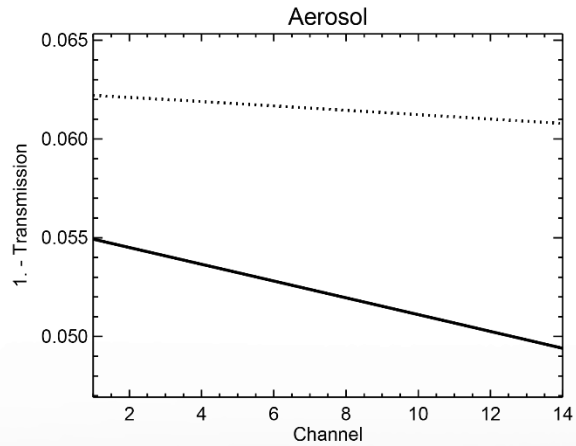
- **Retrievals with adjusted forward model parameters are encouraging**

- Retrieved temperature shows good agreement with Merra-2, but systematically colder at tropopause and stratopause
- Retrieved pressure better than previous versions, but still short of target accuracy
- Additional refinements (e.g., T retrieval only; including aerosol/O<sub>3</sub> only below 40-50 km) are being evaluated

- **Future Work:**

- Continue examining forward model parameters (e.g., bandpass spectroscopy, aerosol + O<sub>3</sub> components)
- Perform more detailed comparisons with correlative measurements (e.g., radiosondes, lidar, MLS, and global analyses) to better quantify precision and accuracy of T/p products





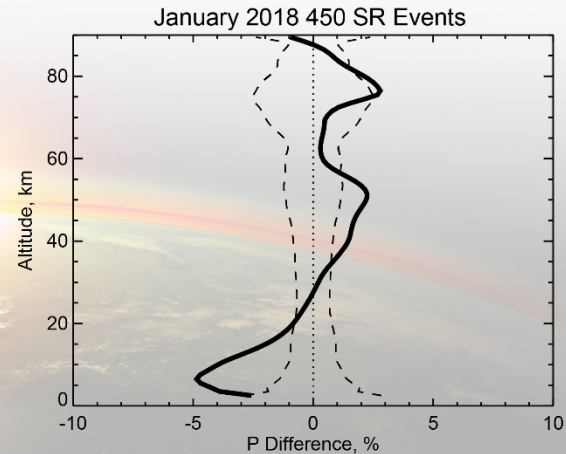
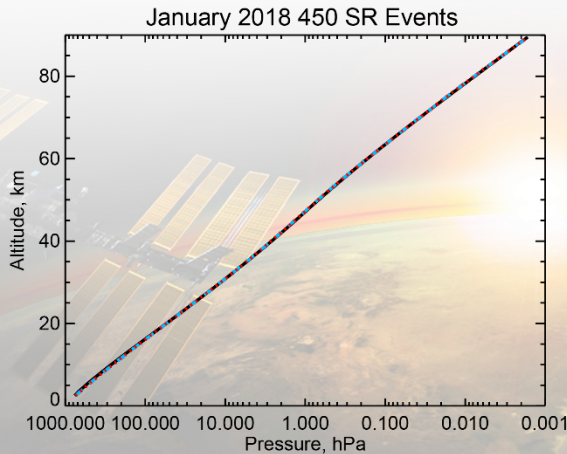
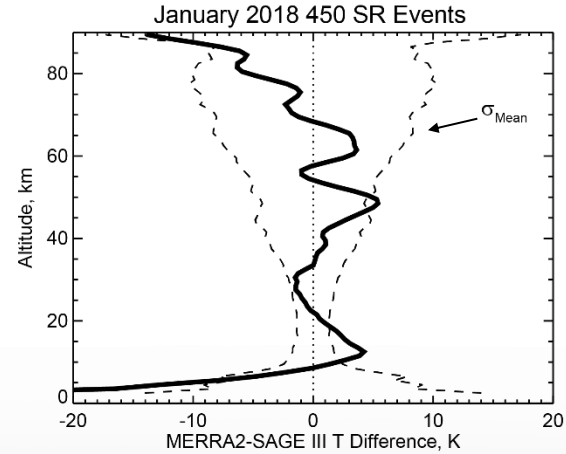
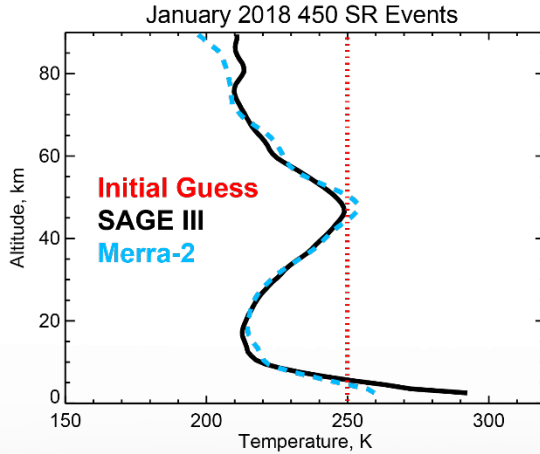


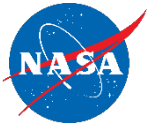


# Baseline Retrievals with Adjusted Wavelength & PSF Sunrise Events January 2018



Mean SAGE III/ISS  
retrieved T/p profiles  
with adjusted wave-  
length map (-0.041 nm)  
and PSF factor (0.915)

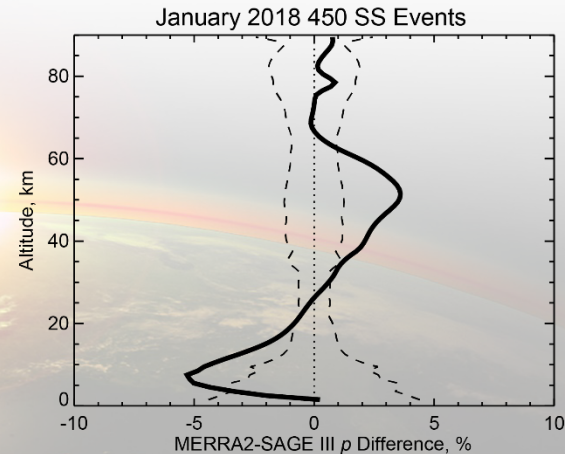
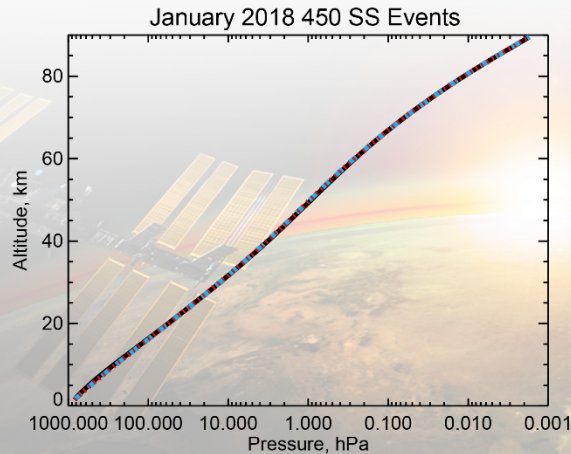
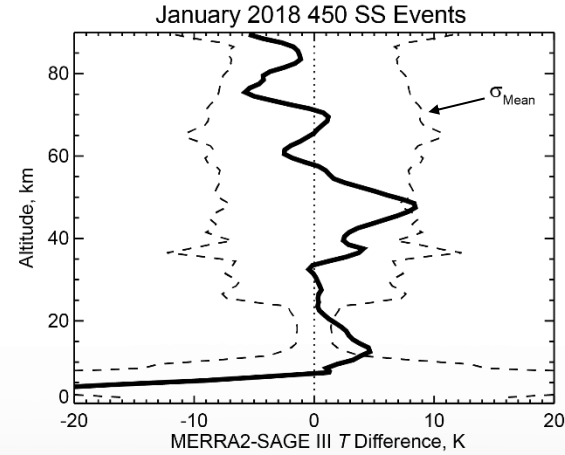
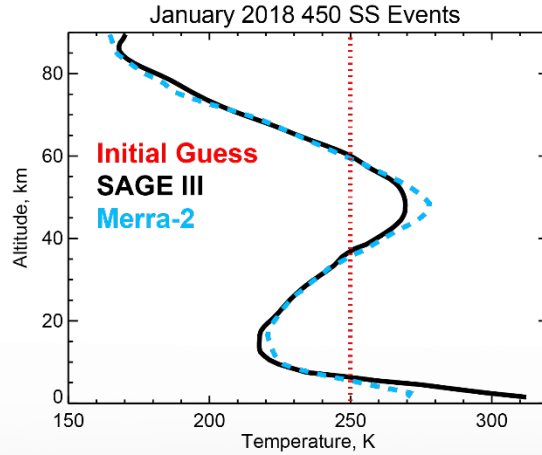




# Baseline Retrievals with Adjusted Wavelength & PSF Sunset Events January 2018



Mean SAGE III/ISS  
retrieved T/p profiles  
with adjusted wave-  
length map (-0.081 nm)  
and PSF factor (0.911)





# Temperature Retrieval Only with Fixed Pressure January 2018



Mean SAGE III/ISS  
retrieved T profiles with  
adjusted wave-length  
map (-0.041 nm) and  
PSF factor (0.915)

+

Weak channel filtering  
(Transmission > 0.99)

+

Fixed pressure  
(Merra-2)

