GEO-CAPE Workshop 2009

Sensitivity to Tropospheric Ozone from Backscattered UV, UV Polarization, and Visible Measurements

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1. Introduction

- One important question for GEO-CAPE pre-phase study to address is whether we can measure boundary layer ozone from Geostationary satellites.
- The GEO-CAPE retrieval sensitivity group has built a tool to conduct troposphere ozone/trace gases sensitivity studies by combining UV, UV polarization, visible, mid-infrared, and thermal infrared measurements.
- UV radiances (for ozone profile retrievals) vary by several orders of magnitude. Inclusion of shorter wavelengths will significantly complicate instrument design and increase mission cost.

2. Objectives of This Presentation

- What are the effects of adding polarization (UV) and visible measurements on tropospheric ozone sensitivity from UV retrievals (based on only one profile/viewing geometry).
- What are the effects of Signal to Noise Ratio (SNR) and spectral resolution on the tropospheric ozone sensitivity?
- How short should we measure in the UV to minimize mission cost while keeping tropospheric ozone information?

3. Ozone profile, radiances, and signal to noise ratio

- Ozone profile (Fig. 1) : 40°N, 74°W, July 2007, 318 DU total ozone
- SZA=55°, VZA=30°, AZA=0°, surface albedo ~5%
- 0.4 nm FWHM, sampled rate 0.1 nm, SNR based on OMI (Figs. 2-4)

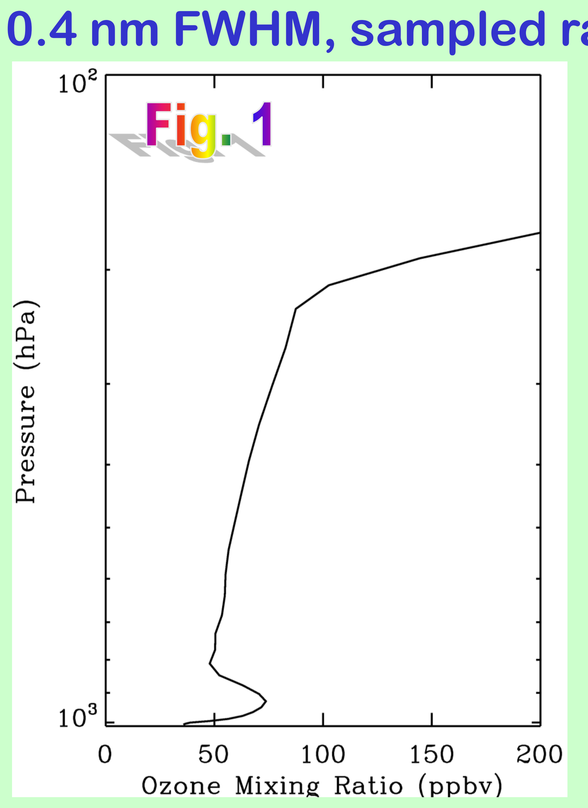


Fig. 1. Ozone profile in the troposphere.

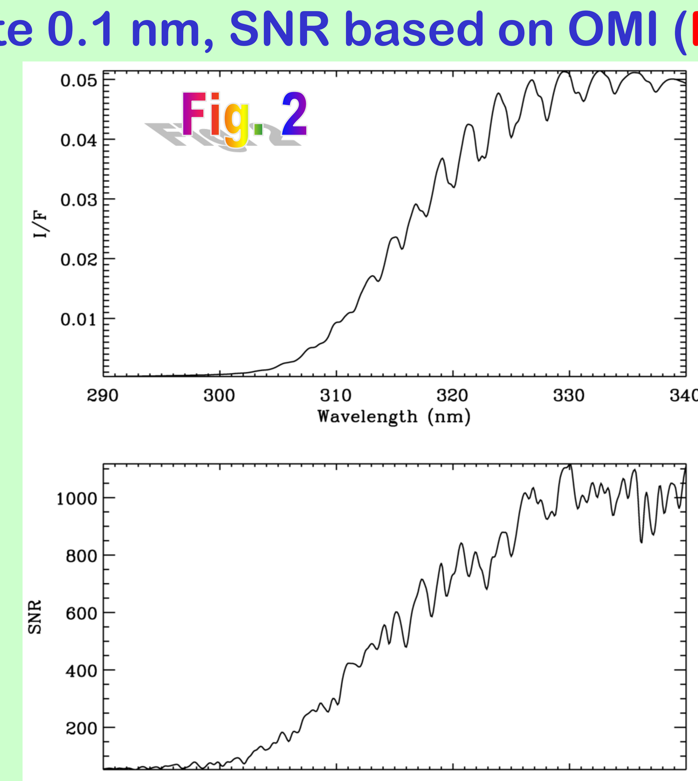


Fig. 2. UV radiances and corresponding SNR.

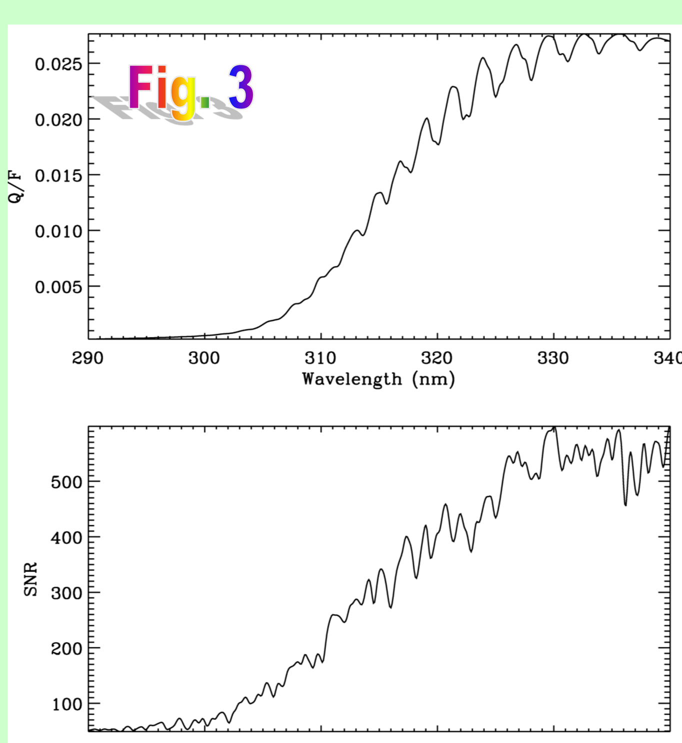


Fig. 3. UV Q component and corresponding SNR.

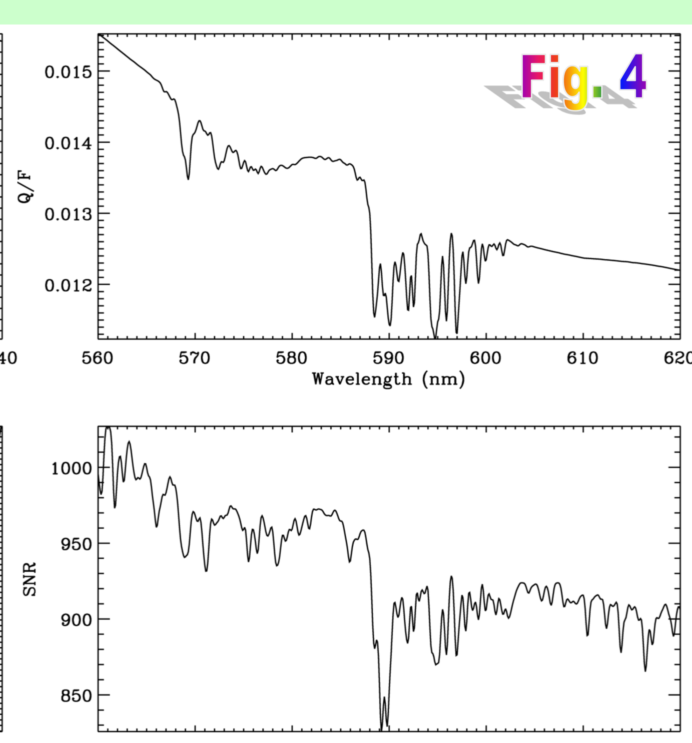


Fig. 4. Visible radiances (should be I/F instead of Q/F) and corresponding SNR.

4. Sensitivity Study

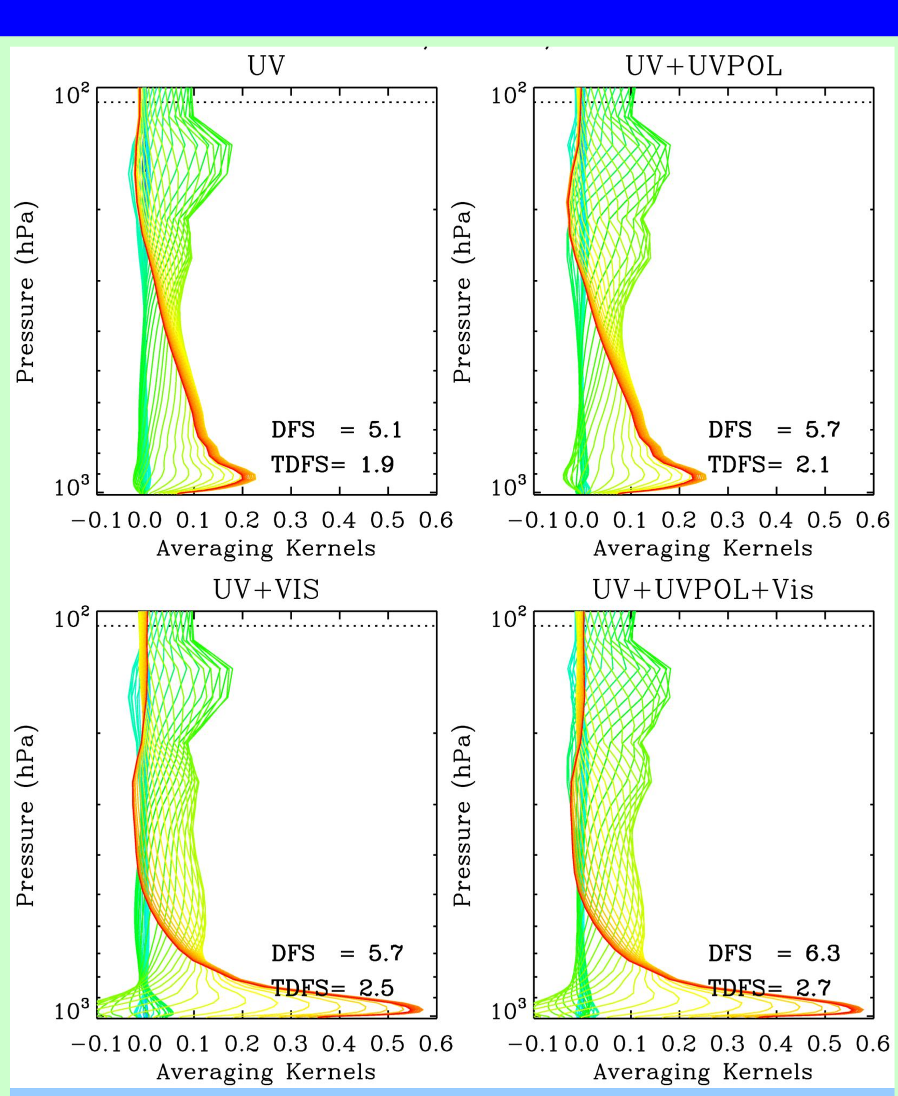


Fig. 5. Retrieval averaging kernels (normalized to 1 km and also by a priori error) from UV radiances, UV radiances and polarization (Q), UV and visible radiances, UV radiances, polarizations and visible radiances, respectively (Only O_3 is considered in the sensitivity analysis).

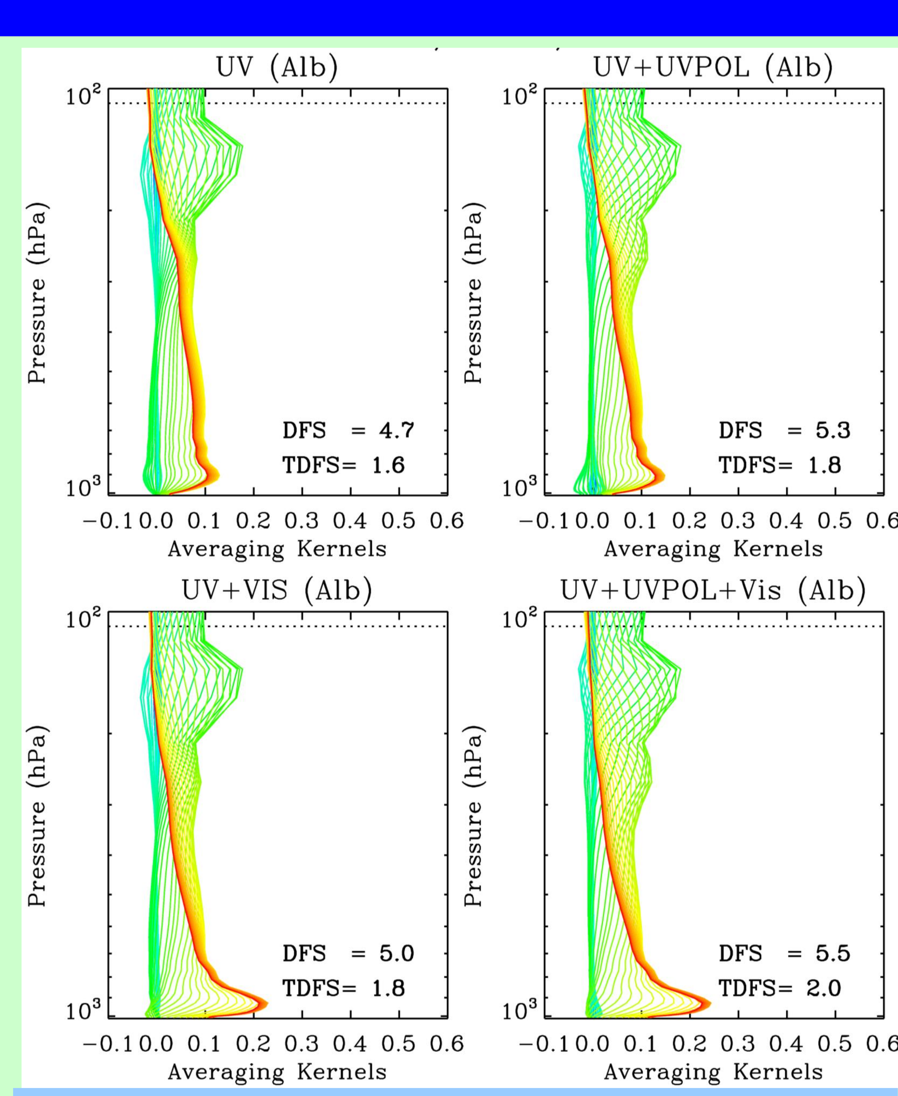


Fig. 6. Similar to Fig. 5 except for first-order polynomials of wavelength-dependent surface albedo are included in both UV and visible, respectively, to account for the retrieval interferences from surface albedo, aerosols, and radiometric calibration.

4. Sensitivity study (continue)

Table 1. The Effects of Combination on DFS.

	Total DFS	DFS(>108 mb)	DFS(>891 mb)
SZA=55°,VZA=30°,AZA=0°, Clear, log(O_3),40°N,74°W,0.4 nm FWHM, OMI SNR			
UV	5.10	1.89	0.19
UV+UVPOL	5.74	2.15	0.22
UV+Vis	5.66	2.48	0.55
UV+UVPOL+Vis.	6.26	2.68	0.56
UV (Alb*)	4.74	1.56	0.10
UV+UVPOL (Alb)	5.33	1.79	0.12
UV+Vis (Alb)	4.97	1.80	0.22
UV+UVPOL+Vis. (Alb)	5.54	1.99	0.23

* (Alb): wavelength-dependent surface albedo (first-order polynomial) is included to account for aerosol/surface albedo/calibration effects.

Table 2. The Effects of SNR and Spectral Resolution on DFS.

	Total DFS	DFS(>108 mb)	DFS(>891 mb)
Standard Case: UV+Vis (Alb*), 0.4 nm FWHM, OMI SNR			
Standard	4.97	1.80	0.22
2 OMI SNR	5.89	2.27	0.35
0.2 nm FWHM	5.47	2.06	0.28
2 OMI SNR, 0.2 nm FWHM	6.37	2.51	0.42
0.6 nm FWHM	4.66	1.65	0.19
0.8 nm FWHM	4.44	1.53	0.17
1.0 nm FWHM	4.26	1.44	0.15
1.6 nm FWHM	3.90	1.27	0.12

- State vector: log. of O_3 partial column at each layer
- Constrained by McPeters climatology (Fig. 7, corr. length: 6 km) and measurement errors (Figs. 2-4)
- Averaging Kernels (AKs) for O_3 variables only (ideal conditions) are shown in Fig. 4 and retrieval errors are shown in Fig. 7. DFS are summarized in Table 1:
  - Vis. mainly increases sensitivity to boundary O_3 (DFS> 891mb increases from 0.19 to 0.55 when adding Vis. to UV)
  - Polarization (Q) increases sensitivity throughout the atmosphere (more tests needed due to the large Q dependence on viewing geometry).
- Retrievals from UV/Vis. depend on knowledge of aerosols, surface albedo, and calibration. λ-dependent surface albedo is fitted to partly account for these effects at the cost of sensitivity. See Figs. 6 & 8, and Table 1:
  - Sensitivity in the boundary layer and free troposphere is greatly reduced.
- Larger SNR and spectral res. increases O_3 sensitivity (e.g., DFS>891 mb for UV/vis. Increases from 0.22 to 0.35 when doubling SNR). The effects of doubling spectral resolution is ~ equal to the increase of SNR by SQRT(2).

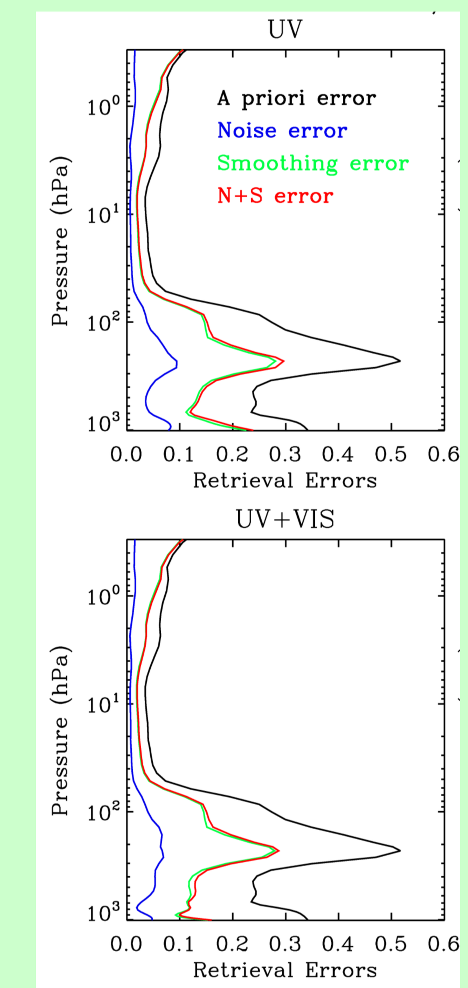


Fig. 7. A priori, noise, smoothing, and solution errors for UV & UV+Vis. (only O_3 variables).

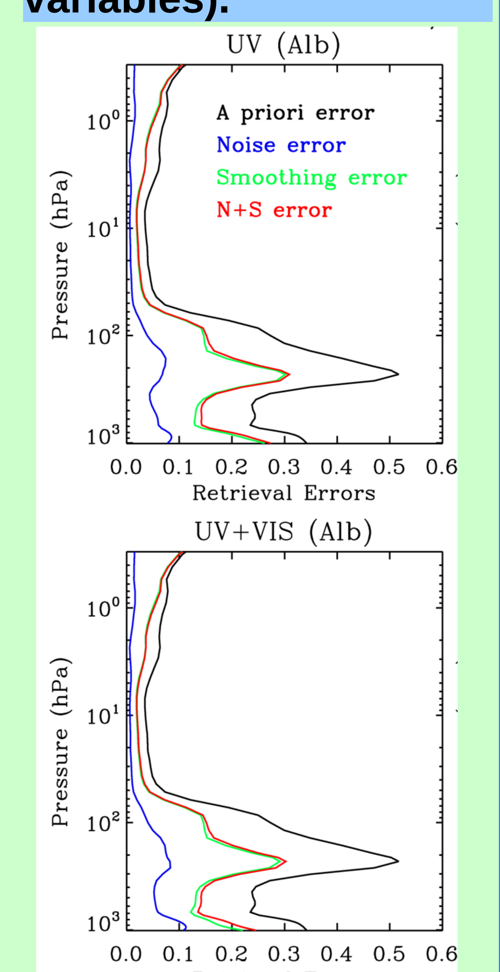
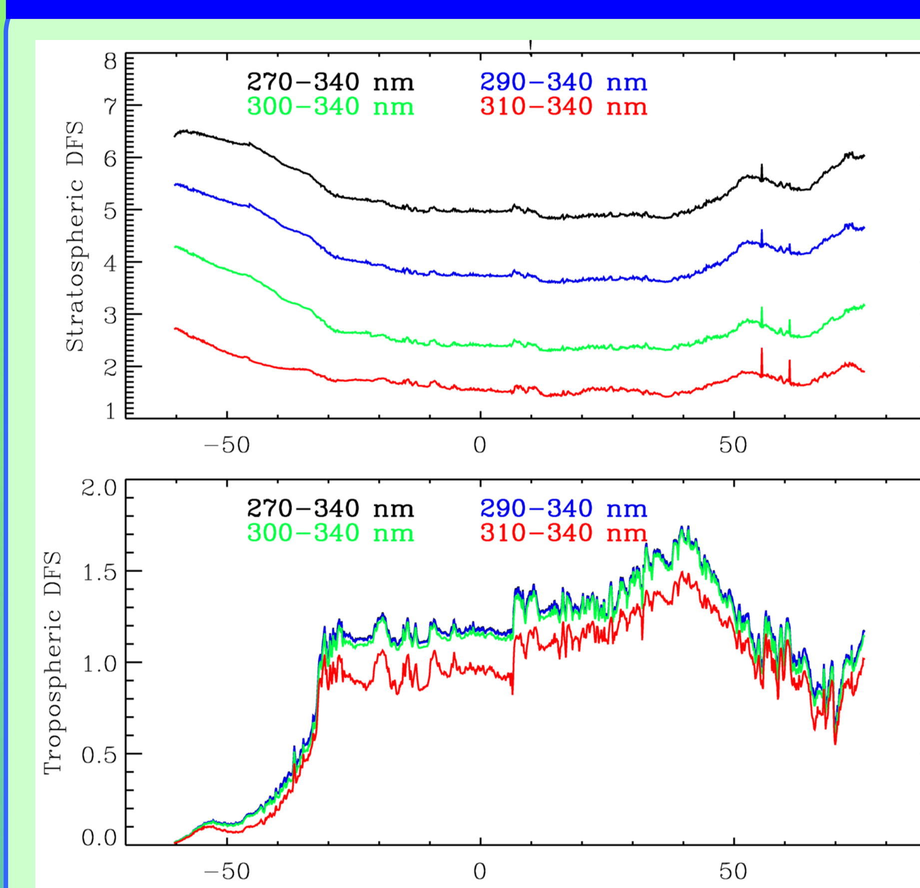


Fig. 8. Same as Fig. 7 except that surface albedo interference is considered.

4. How short should we measure in the UV?



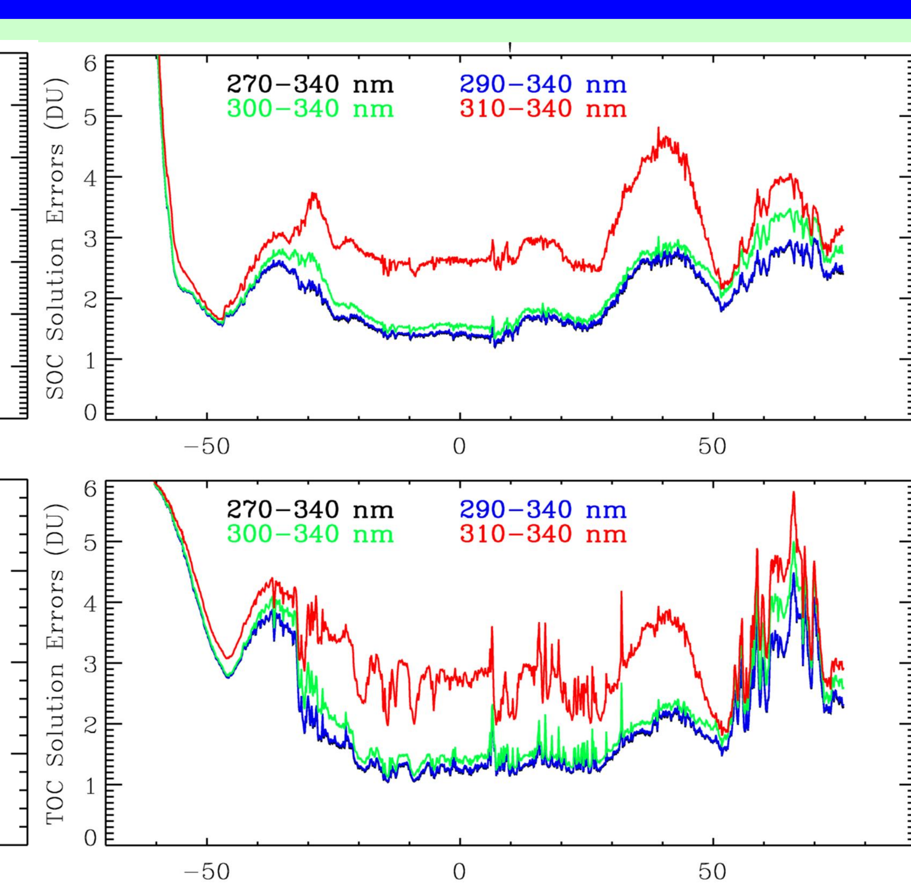


Fig. 9. Stratospheric and tropospheric DFS vs. different start wavelengths for an orbit of OMI retrievals. NCEP tropopause is used. Clouds are included.

Fig. 10. Retrieval errors (sum of random-noise and smoothing errors) in Stratospheric and tropospheric ozone column vs. different start wavelengths.

- Starting at 310 nm only loses 0.1-0.2 tropospheric DFS, but significantly increases errors.
- Starting at 300 nm keeps almost all tropospheric ozone information.
- UV meas. should be in 1 channel. No need to enhance SNR for 300-310 nm.

Summary and future outlook

- Visible measurements enhance sensitivity to boundary layer ozone and are worthy of further exploring.
- We can & should measure UV down to 300 nm to keep trop. O_3 information
- The retrieval group will continue to investigate of the effects of combining UV, Vis., MIR, and TIR on tropospheric O_3 sensitivity for a variety of conditions.