Aerosol Correction for Improving OMPS/LP Ozone Retrieval

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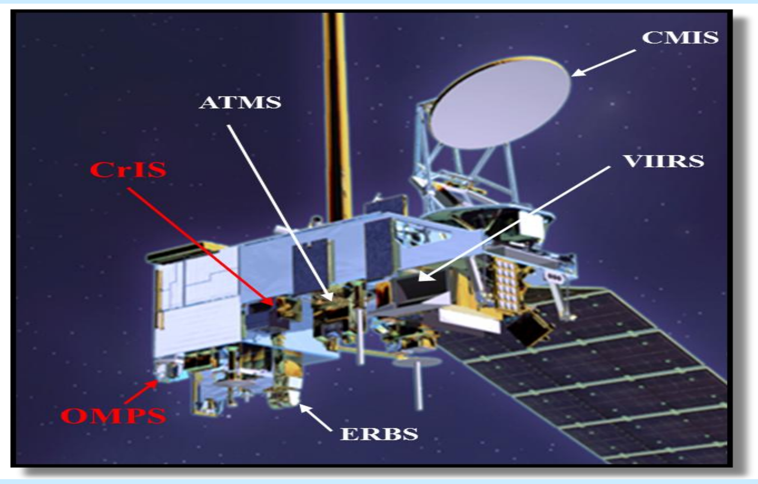
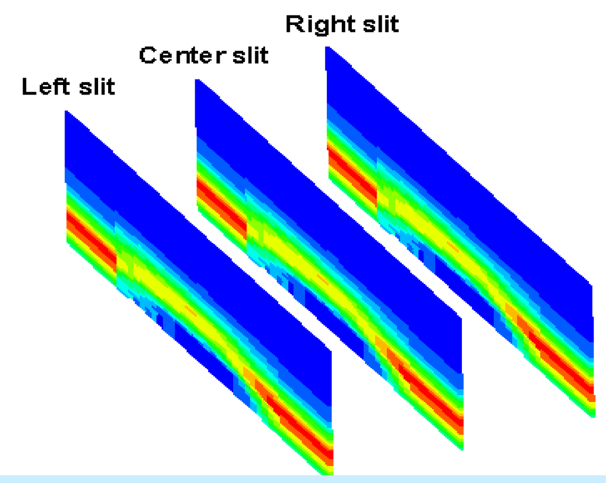
OMPS Limb Profiler

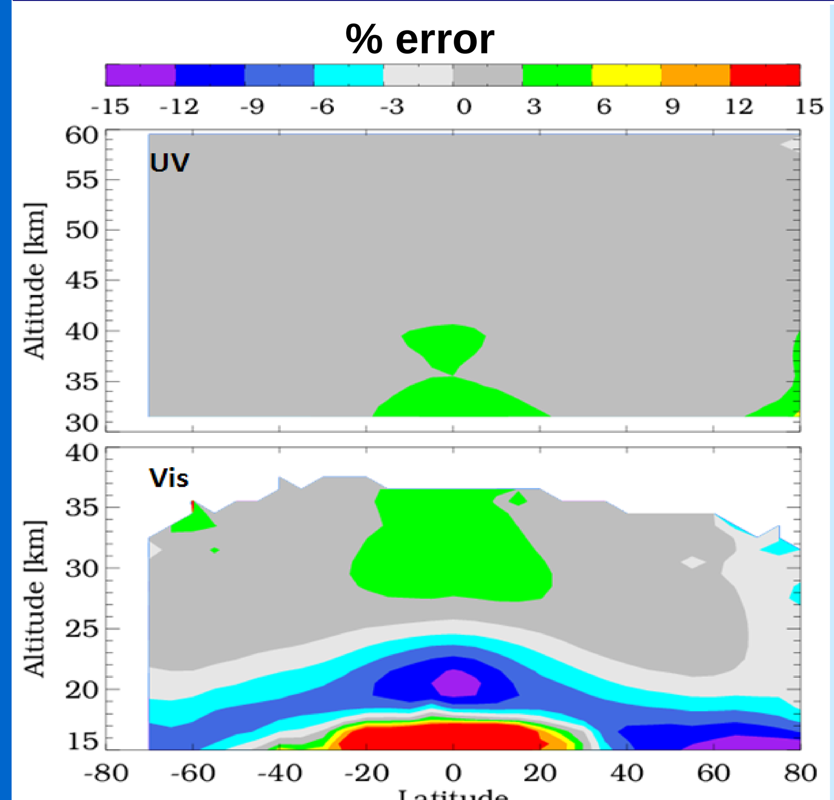
The Ozone Mapping and Profiler Suite Limb Profiler (OMPS/LP) on board the Suomi National Polar-orbiting Partnership (S-NPP) satellite (1:30 PM ascending node & 833 km altitude) was launched on October 28, 2011. Instruments include OMPS, VIIRS, ATMS, CrIS and CERES





The LP instrument measures the radiance scattered from the Earth's atmosphere in limb viewing mode and retrieves ozone profiles from the tropopause to 60 km. OMPS/LP views the Earth limb 0~110 km vertical range; 250 km horizontal separation between 3 slits every 18.7s (1° latitude sampling); 290 nm ~1000 nm @ 0.8 nm – 25 nm resolution

Aerosols are a problem for Ozone Retrievals



Ozone Retrieval Algorithm

Ozone retrieval algorithm is based on Rodgers' Optimal Estimation method [Rodgers, 2000], and uses the Pair/Triplet methodology. The measurement vector **y** used in the optimal estimation retrieval is defined as

UV: $y=\ln I(\lambda,z)-\ln I(\lambda_0,z)$

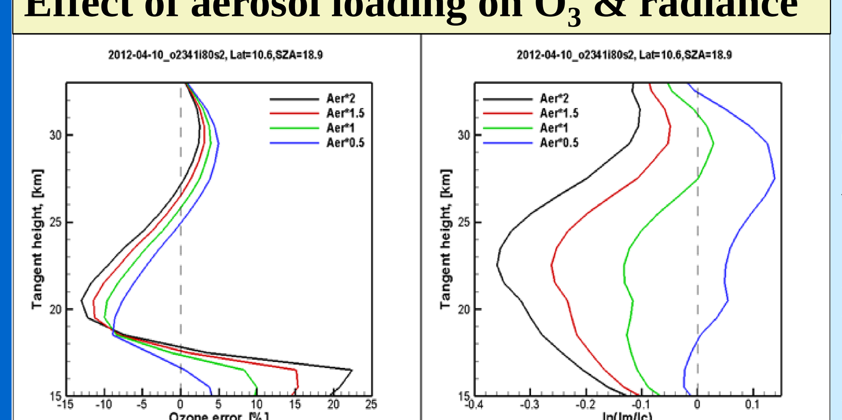
Vis: $y=\ln I(\lambda,z)-\omega_1\ln I(\lambda_1,z)-\omega_2\ln I(\lambda_2,z)$

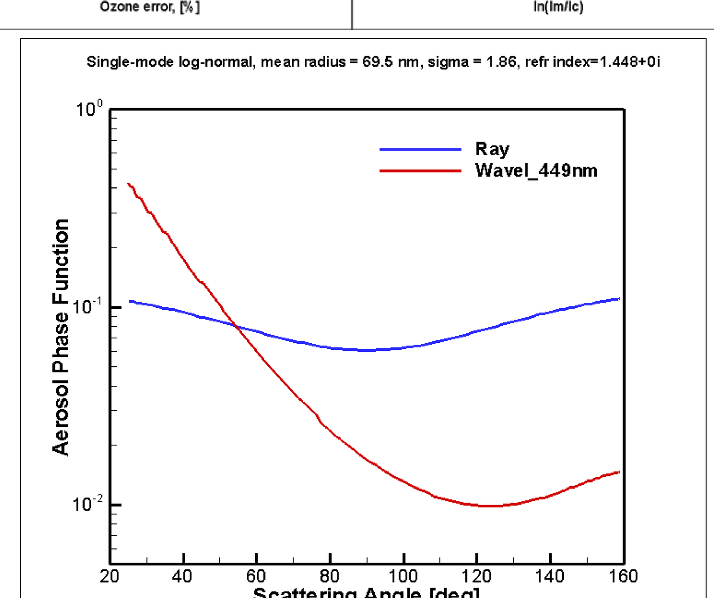
$I(\lambda,z)$ is the radiance at wavelength λ and tangent height z, and it is normalized @ the chosen tangent height z_0;

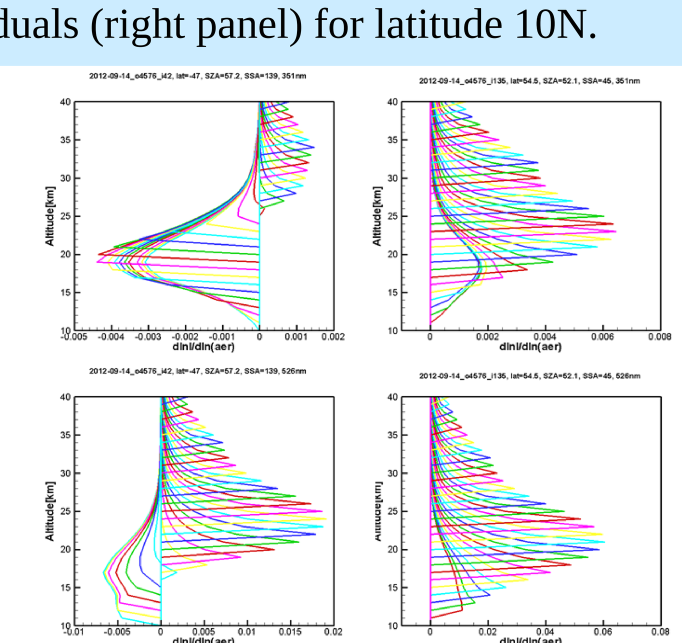
λ_0=350nm; λ_1=508nm; λ_2=674nm;
$\omega_1=(\lambda_2-\lambda)/(\lambda_2-\lambda_1)$; $\omega_2=1-\omega_1$

Ozone error from the no-aerosol algorithm assuming true aerosols = SAGE climatology. The LP ozone profile retrieval error can reach **15%** if aerosols are neglected in the ozone retrieval algorithm (see two maps left above). The influence of aerosol is much larger in the visible wavelengths. The ozone error depends on aerosol extinction coefficient profile. The left figures show the effect of aerosol loading on ozone error (left panel) and 674nm radiance residuals (right panel) for latitude 10N.

Effect of aerosol loading on O_3 & radiance



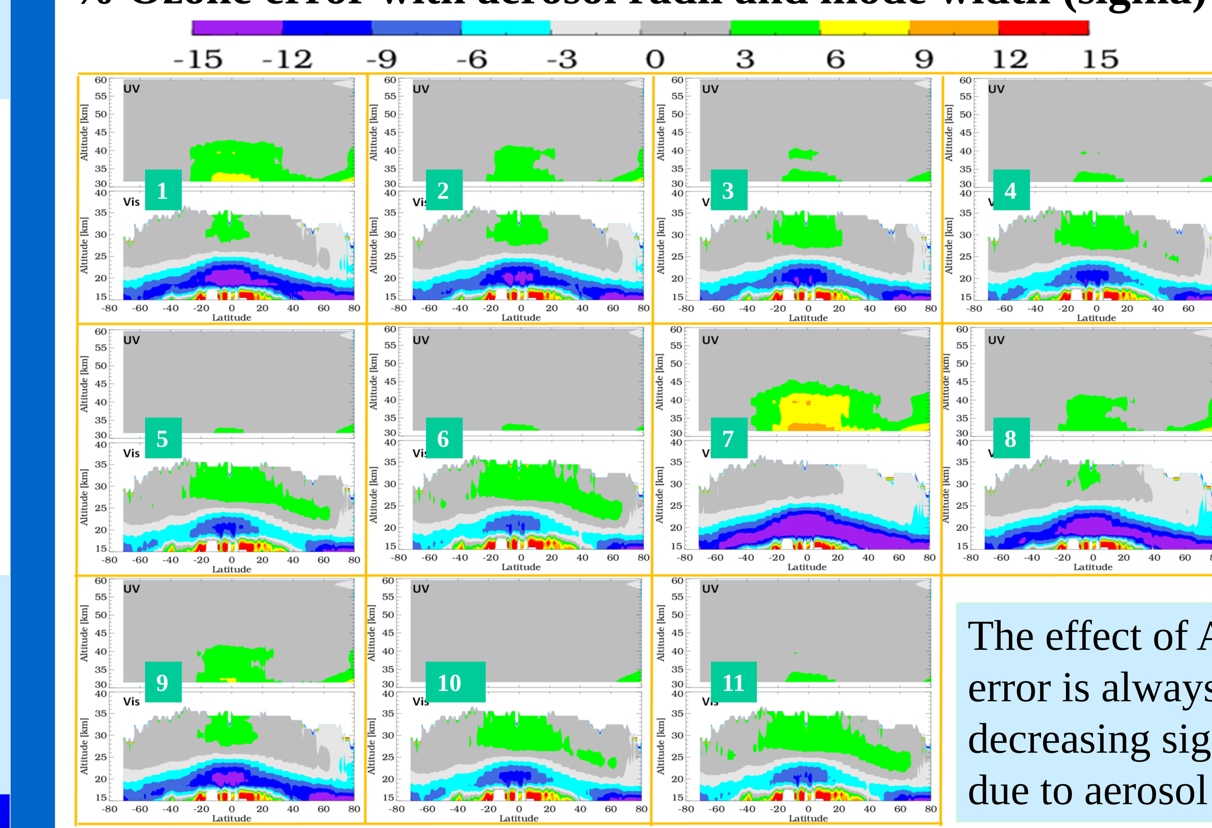




The ozone error also depends on scattering angle. The left figure above shows that aerosol scattering phase function varies with the scattering angle by about a factor of 40 as Rayleigh scattering weakens. The right figure above shows aerosol Jacobians at 351 (top panel) and 525 nm(bottom panel) for two SSAs of 45 (right panel) and 139(left panel). For the small SSA, the Jacobians are positive. For the larger SSA at a certain tangent altitude, the Jacobian becomes negative and reduces the sensitivity of the limb radiance to aerosols. This characteristic is problematic for the inversion algorithm.

Effect of ASD on Ozone Retrieval

% Ozone error with aerosol radii and mode width (sigma)



Single-model,log-normal
Refractivity=1.448+0*i*

Case #	radii,[nm]	sigma
1	40	1.8
2	50	1.8
3	60	1.8
4	70	1.8
5	80	1.8
6	90	1.8
7	60	1.5
8	60	1.6
9	60	1.7
10	60	1.9
11	60	2.0

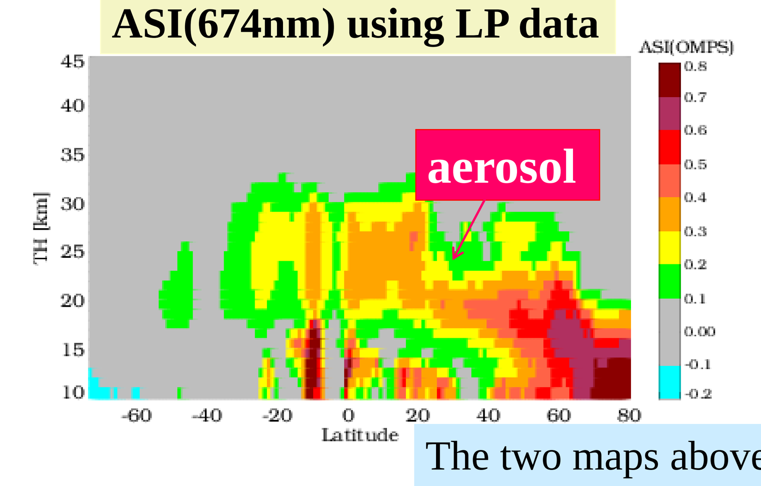
The effect of ASD is complicated. UV O_3 error is always positive, and increases with decreasing sigma or radii, while Vis O_3 error due to aerosol changes sign with height.

Aerosol Scattering Index (ASI)

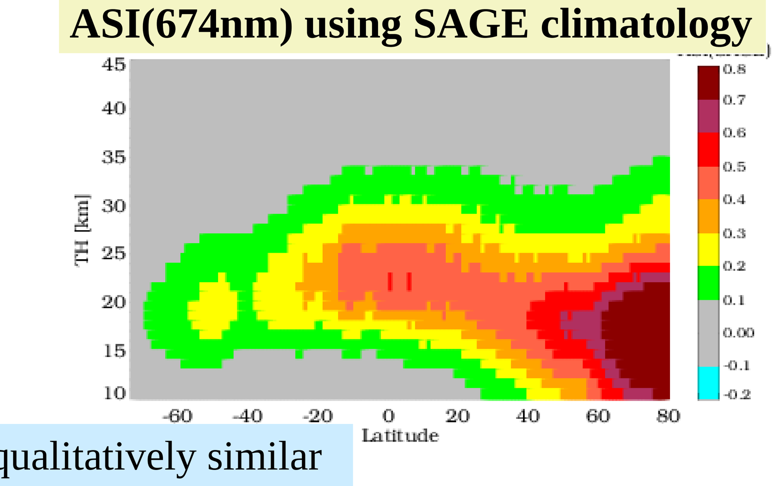
$$ASI(\lambda, SSA, z) = (I_m-I_{c0})/I_{c0}$$

- λ is the wavelength;
- SSA is the single scattering angle;
- z is the tangent height;
- Im is the measured limb radiances;
- Ic0 is the calculated limb radiances assuming no aerosols;
- Im & Ic0 are normalized at 40 km
- ASI @ 40 km=0;
- ASI =Aerosol/Rayleigh Scattering Ratio;
- ASI profile figures below show hemispherical asymmetry due to change in aerosol scattering phase function with SSA shown in previous column.
- ASI is sensitive to aerosol size distribution (ASD);
- ASI is also sensitive to PMC/PSC and volcano.

ASI(674nm) using LP data

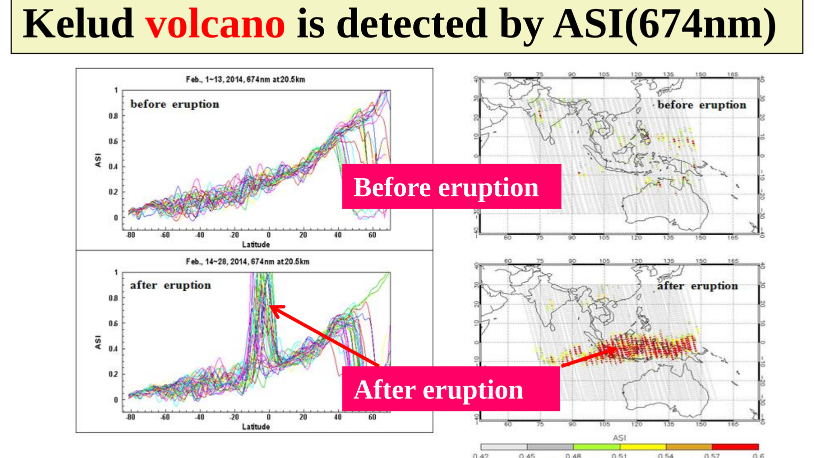


ASI(674nm) using SAGE climatology

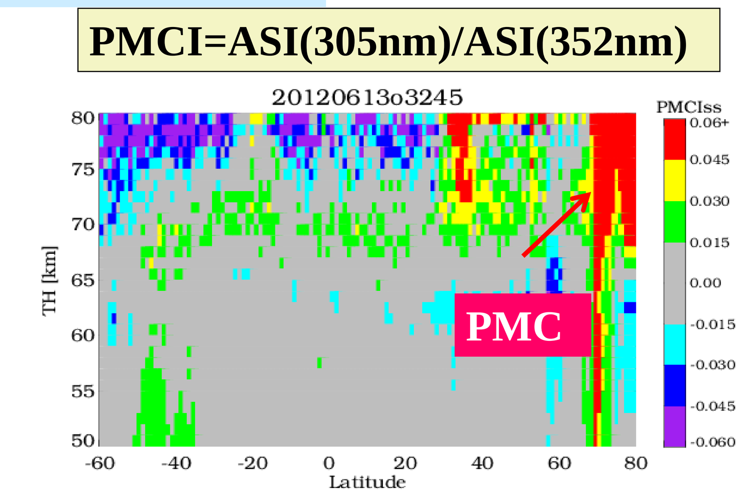


The two maps above are qualitatively similar

Kelud volcano is detected by ASI(674nm)



PMCI=ASI(305nm)/ASI(352nm)

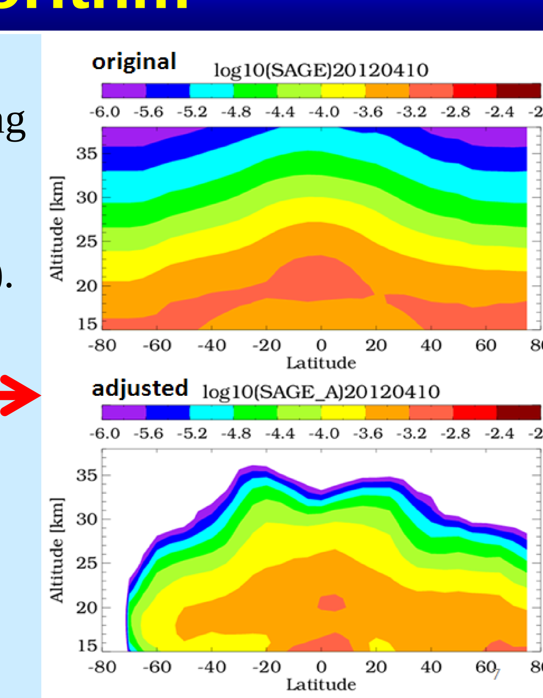


Aerosol Correction Algorithm

- Assume an aerosol size distribution (ASD).
- Compute aerosol cross-section and aerosol phase function using SAGE extinction profiles @ one wavelength.
- Calculate ASI @ 674nm using LP data, ASI(LP).
- Calculate ASI @ 674nm using SAGE climatology, ASI(SAGE).
- Adjust SAGE aerosol climatology:

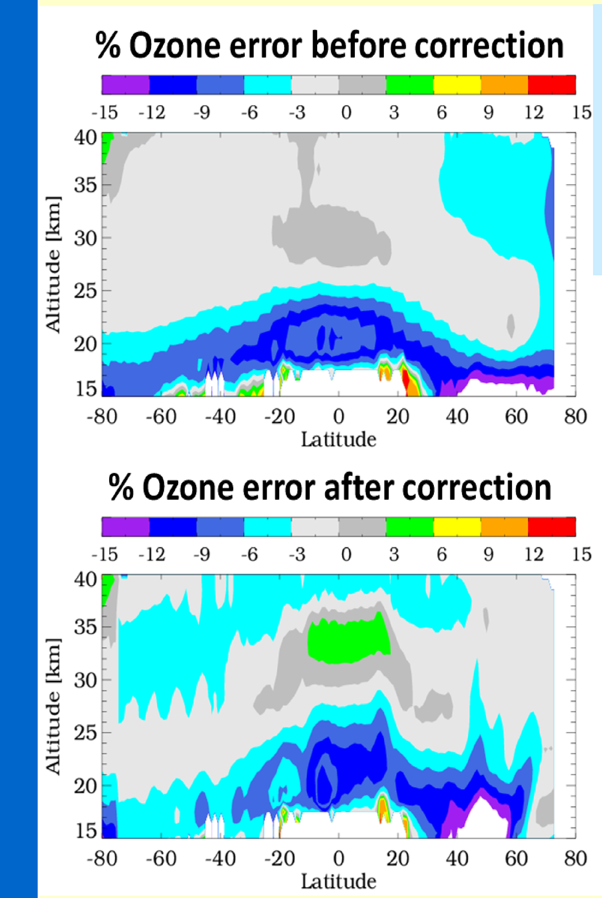
SAGE_a=SAGE*A(z)
A(z)=ASI(LP)/ASI(SAGE) when ASI(LP) >0
A(z)=0 when ASI(LP)<=0

- Update aerosol size distribution based on normalized radiance residuals (NRRS) @ 352,508 and 674nm.
- Retrieve ozone with the adjusted SAGE climatology.

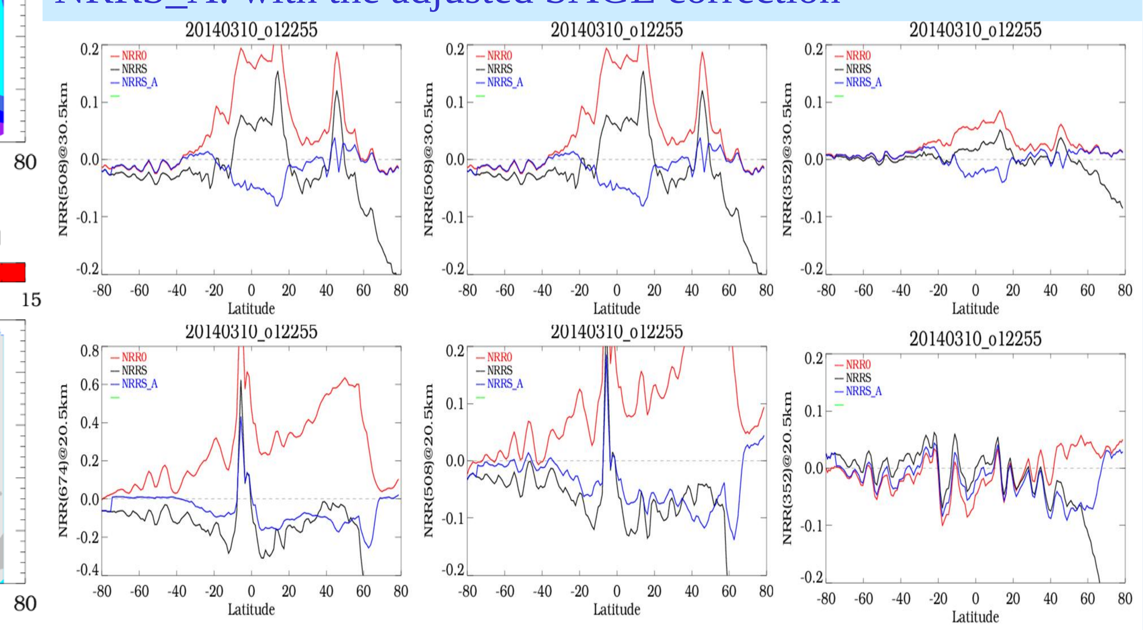


Evaluation of the Aerosol Correction

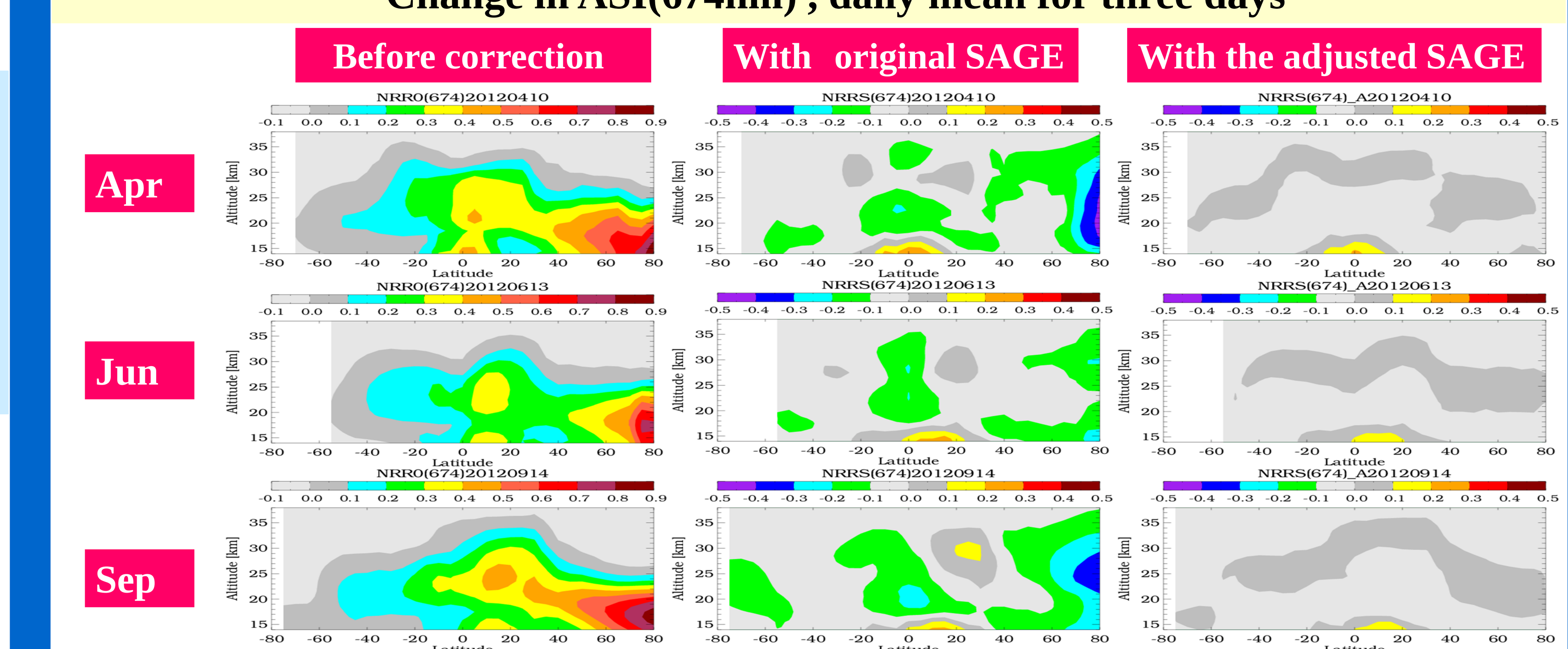
Aerosol correction on an orbital basis



Left figures show % ozone errors between with and without aerosol correction. Below figures show changes in 674nmASI:
NRR0: without aerosol correction;
NRRS: with original SAGE correction;
NRRS_A: with the adjusted SAGE correction



Change in ASI(674nm) , daily mean for three days

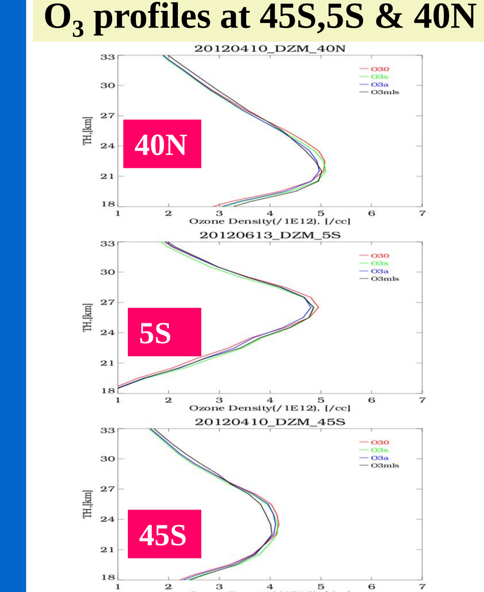


Significant improvements in reducing radiance residuals

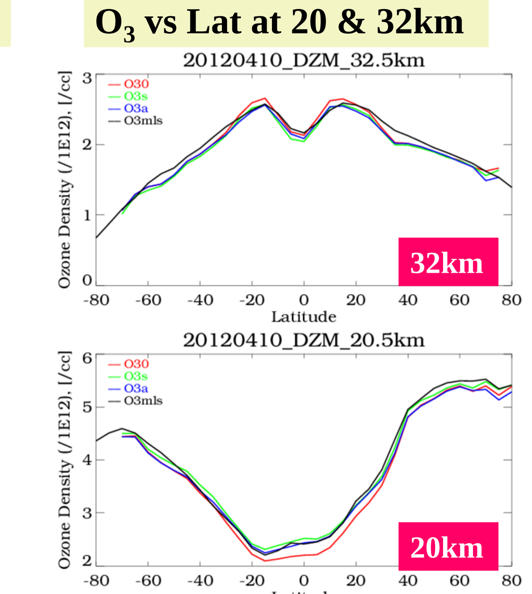
Comparison with MLS Ozone Profile (daily mean)

O_30: without corr.; O_3s: with SAGE; O_3a: with the scatted SAGE; O_3m: MLS

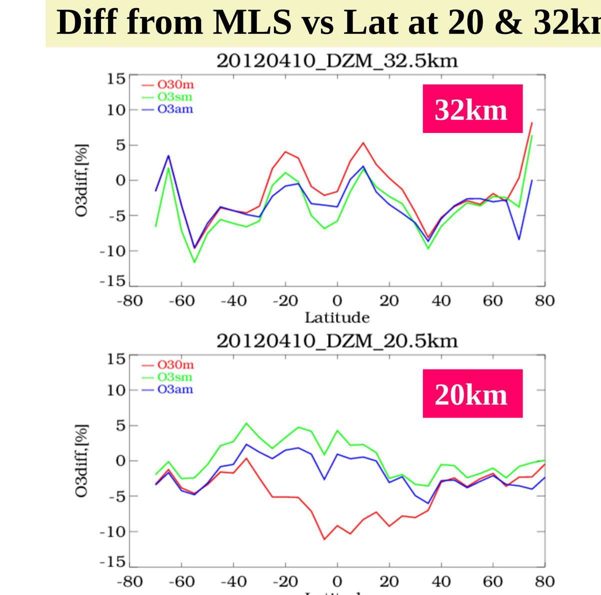
O_3 profiles at 45S,5S & 40N



O_3 vs Lat at 20 & 32km



Diff from MLS vs Lat at 20 & 32km



Improvement in O_3 retrieval as a result of more accurate calculation of LP radiances

Summary

Aerosols have a detectable effect on OMPS/LP data. Our analysis shows that ignoring the aerosol contribution can produce an ozone density bias of up to 15% in the region of maximum aerosol extinction. The Aerosol Scattering Index (ASI), as defined in the text, is used to evaluate the effect of aerosols on OMPS/limb radiances and to assess errors in ozone retrievals. An aerosol correction algorithm is then developed for ozone retrieval by scaling the SAGE climatology using the ratio ASI(LP)/ASI(SAGE). The algorithm improvement is verified by comparison to MLS ozone profile. This work suggests that using the proposed aerosol correction algorithm would significantly reduces the radiance residuals and improve the quality of the retrieved ozone concentration profile.