Angle dependency of UV Aerosol Index and sensitivity to SO2 – preparations for the TROPOMI mission

Marloes Penning de Vries, Steffen Beirle, Christoph Hörmann, Holger Sähler, and Thomas Wagner
Max Planck Institute for Chemistry, Mainz, Germany

Contact: marloes.penningdevries@mpic.de

UV AEROSOL INDEX (UV AI)

• UVAI is a measure of aerosols
• Most sensitive to elevated UV-absorbing aerosols (e.g., mineral dust and biomass burning smoke)
• Differentiation between UV-absorbing (UV AI>0) and non-absorbing aerosols (UV AI<0)
• Can be interpreted even in presence of clouds
• Dependent on solar and viewing geometry
• Sensitive to aerosol amount, absorption, altitude

Differentiation between UV-absorbing (UV AI>0) and non-absorbing aerosols (UV AI<0)

UV AI is a measure of aerosols

Increased SO2 column leads to increases in O3 and O4 absorption generally taken into account

Wavelengths used in UVAI calculations are indicated by colored pairs of vertical lines.

Clouds with small to moderate optical thickness

The magnitude of the viewing angle effect depends on scattering angle

Due to anisotropy of Rayleigh and Mie phase functions UVAI depends on scattering angle

The viewing angle effect was modeled in [de Graaf et al., JGR 2005], then observed and more extensively investigated in [Penning de Vries et al., ACP 2014]

Using Radiative Transfer Modeling (RTM) it was found that the effect is very pronounced at viewing angles > 40°, i.e., for OMI and TROPOMI, but barely for GOME-2 and not at all for SCIAMACHY

The magnitude of the viewing angle effect depends strongly on the altitude of the aerosol layer and scales with aerosol optical thickness (AOT), a variation of single-scattering albedo (SSA) causes a change in absolute values, but no difference in shape

Clouds with small to moderate optical thickness display a viewing-angle dependent UVAI, but the effect is less pronounced

The eruption of Nabro (Eritrea) in June 2011 caused the introduction of large quantities of SO2 into the atmosphere

Sulfate plume was seen from the East during orbit 36772 and from the West during orbit 36773

Difference in viewing direction causes change of UVAI sign from negative to positive

To remove signals from clouds and desert dust, only pixels with SO2 columns >1.5 DU are selected for panels E and F

Not all plume pixels show a clear aerosol signal, yet viewing angle effect can be very well seen

RTM simulations using sulfate aerosol parameters (plume at 18-19 km) are shown in panels G-H

Agreement between measurement and model results not perfect, but viewing angle effect is very well reproduced.

SUMMARY

• UVAI has long heritage – unique opportunity to obtain 4 decades of aerosol information
• Viewing angle dependence of UVAI allows independent identification of high-altitude plumes and gives an indication of aerosol type (absorption)
• SO2 dependence of TOMS UVAI wavelength pair (331/360 nm) needs to be taken into account for large volcanic eruptions (SO2 slant columns > 100 DU, e.g., Pinatubo 1991, Nabro 2011)

VIEWING ANGLE DEPENDENCE – THEORY

• Due to anisotropy of Rayleigh and Mie phase functions UVAI depends on scattering angle
• The viewing angle effect was modeled in [de Graaf et al., JGR 2005], then observed and more extensively investigated in [Penning de Vries et al., ACP 2014]
• Using Radiative Transfer Modeling (RTM) it was found that the effect is very pronounced at viewing angles > 40°, i.e., for OMI and TROPOMI, but barely for GOME-2 and not at all for SCIAMACHY
• The magnitude of the viewing angle effect depends strongly on the altitude of the aerosol layer and scales with aerosol optical thickness (AOT), a variation of single-scattering albedo (SSA) causes a change in absolute values, but no difference in shape
• Clouds with small to moderate optical thickness display a viewing-angle dependent UVAI, but the effect is less pronounced

SENSITIVITY TO SO2 – THEORY

• Wavelengths used in UV AI calculations selected for least interference due to Fraunhofer lines or trace gas absorption
• O3 and O4 absorption generally taken into account
• For SO2 columns higher than 100 DU (due to volcanic eruptions) radiances at 331 nm are affected by SO2 absorption
• Increased SO2 column leads to increases in 331/360 UVAI of 1.5 (nadir) to 2.5 units
• Linear dependence of UVAI change on logSO2 slant column density allows correction by simple subtraction of a UVAI offset

The eruption of Nabro (Eritrea) in June 2011 caused the introduction of large quantities of SO2 into the atmosphere

Highest SO2 slant column density measured by OMI: ~1x1019 molec/cm2 (~400 DU) on June 13

OMT3 UVAI most sensitive to ice/sulfate plume, but also shows linear dependence on SO2 column density

For OMT3 product (operational NASA OMI product), UVAI decreases with increasing SO2 column due to different UVAI definition

REFERENCES


Figure 1. Examples of extended UVAI plumes from different instruments.

Figure 2. Modeled line-of-sight dependence of UVAI using the RTM McArtim; solar zenith angle = 20°; surface albedo (AOD given at 380 nm). A, AOD 0.4, and SSA=1.0; B, SSA = 1.0 at 18-19 km; C, AOT=0.4 at 18-19 km; and D, clouds with g=0.87 and SSA=1 at 10-11 km.

Figures from supplementary information to Penning de Vries et al., ACP 2014.

Figure 3. OMI SO2 vertical column density (A-B), UVAI from OMI (C-F) and from RTM (G-H) for the plume on June 14, 2011. Right: data from orbit 36772; left: data from orbit 36773. Data in panels E-H are filtered by SO2 column (> 1.5 DU) to more clearly show the volcanic plume. The UVAI in G and H were modeled using the RTM McArtim.

Figure 4. A. Absorption cross section of SO2 (black); note the logarithmic y-axis. Wavelength pairs used for UVAI calculations are indicated by colored pairs of vertical lines. B. And C. Effect of SO2 absorption on UVAI for the wavelength pairs 331/360 nm (blue), 340/380 nm (green), and 354/388 nm (red); note the logarithmic x-axis.

Figure 5. OMI UVAI from three different algorithms for the volcanic plume detected on June 13, 2011: A: OMAERUV (340/380 nm); B: OMAERO (354/388 nm); C: OMT3 (360/391 nm). MLER algorithm D: Dependence of the three UVAI products on OMI SO2 vertical column density (NASA). Coefficients of a linear fit of SO2 vertical column (in DU) to the OMAERUV data (red) and the correlation coefficient are given in the plot.