TOMS Ozone Anomalies and Ozone Retrieval Errors Over Cloudy Areas

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Abstract: This study characterizes TOMS Ozone Retrieval Errors (ORe) associated with clouds, investigates the effects of ORe on tropospheric ozone derivation, and analyzes Ozone Anomalies (OAs) in TOMS data. Large errors occur in TOMS assumed Cloud-Top Pressure (CTP) and CTP-caused ORe are mostly from inappropriately added ozone below clouds. Assuming Lambertian cloud top surface in good when Cloud Optical Depth (COD) ≥ 20, relevant ORe are usually within the TOMS retrieval precision. The assumption of opaque clouds can introduce large positive ORe even for optically thick clouds because of Intra-Cloud Ozone Absorption Enhancement (ICOAEN). The ICOAEN effect depends strongly on viewing geometry and intra-cloud ozone amount and distribution. Using TOMS Partial Cloud Model (PCM) corrects ozone retrieval because its negative ORe partly compensate other positive errors. The ICOAEN effect is typically 5-13 DU over the Atlantic and 1-7 DU over the Pacific for tropical high-reflectivity clouds and it is insensitive to the TOMS assumed cloud-dielectric functions. Ozone anomalies OAs) with high correlation (i.e., 0.5 or < 0.5) between ozone and reflectivity frequently occur in TOMS data with an average fraction of 31.8% in Nimbus-7 TOMS data. Some OAs are caused by ORe and some are caused by actual geophysical phenomena.

4 Intra-Cloud Ozone Absorption Enhancement (ICOAEN) Effect

Phenomena, patterns, and magnitudes of errors enhancing ozone absorption. Assuming opaque clouds overestimates ozone above clouds. The ICOAEN effect depends greatly on viewing geometry. Linearly dependent on intra-cloud ozone amount and cosθ.α > 0 for view zenith angle < 30°. (Figure 4) Still significant for a 500 km cloud with optical depth 400 and reflectivity 0.5.

Figure 4 Example of positive (left) and negative (right) ICOAEN effects.

4 Cloud-Top-Height (CTP) induced Errors

Large errors occur in TOMS CTP compared to collocated TOA/CTP on board Nimbus-7. -50 mb -150 mb. CTP errors increase for non-obscured clouds. (Figure 5) 

Figure 5 CTP-induced errors for different profiles in (a) as a function of solar zenith angle for view zenith angle 30°.

4 Causes for OAs?

Convection, thin cloud top pressure, gross tropospheric ozone, and marine stratus clouds. Marine Stratus: COD 15; 2-12 km depth of 20 DU. (b) ICOAEN effect for different profiles in (a) as a function of solar zenith angle for view zenith angle 30°. (Figure 6)

Figure 6 ICOAEN effect vs. cloud optical depth for 2-12 km clouds.

4 How Frequent do Ozone Anomalies (OAs) Occur?

Average fraction of 31.8% in Nimbus-7 TOMS data during 1979-1992. (Figure 7)

Figure 7 High correlation between ozone and reflectivity (a) OA occurrence in TOMS data during 1979-1992.

4 Conclusions

Ozone retrieval errors (ORe) caused by incorrect cloud top pressure are mostly from improperly added ozone below clouds. Assuming Lambertian cloud top surface is good when COD ≥ 20 ORe usually within 5%. Large negative errors when COD become smaller because cloud fraction is underestimated so the added ozone below clouds decreases.

Figure 8 Errors due to assumption of Lambertian cloud top and use of PCM.

4 Overall Errors: Opaque Lambertian Clouds and TOMS PCM (Figure 9)

Large cloud pressure errors by TOMS assume Lambertian clouds and using TOMS PCM. CTP: Cloud Top Pressure. COD: Cloud Optical Depth.

Figure 9 Errors due to assumption of opaque Lambertian clouds and using TOMS PCM.

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