HIGH FREQUENCY RETRIEVAL OF TOTAL OZONE FROM A GROUND-BASED NILU-UV RADIOMETER USING A NEURAL NETWORK MODEL: VALIDATION OF THE MODEL AND EVALUATION OF SATELLITE OBSERVATIONS


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Abstract

The present study presents a new approach to retrieve total ozone at high temporal frequency from surface irradiance measurements performed with a NILU-UV multi-filter radiometer. Time series of 1-minute NILU-UV irradiances at central wavelengths of 302, 312, 320, 340 and 380 nm are used as inputs to a neural network model together with collocated solar zenith angles calculated at Thessaloniki, Greece (40.63E, 22.96N), and the day of the year and as well as sinusoidal components as temporal variables. A decade of coincident Brewer total ozone measurements (TOCs) are used as the target (ground truth) values. A key feature of this Neural Network Model is the use of Singular Spectrum Analysis to denoise all time-series variables. The model is then fed with unseen real (in situ) inputs to estimate TOCs for the decade 2005-2014. Satellite total ozone from the GOME/ERS-2, SCIAMACHY/Envisat, OMI/Aura, and GOME-2/MetOp GOSAT ozone-CCI ESA algorithm at each overpass time are used to provide a comparison for instantaneous TOC estimates produced by the neural network model from NILU-UV irradiances. Furthermore, a collocated CCD spectrometer system provides TOCs values since late 2013 to evaluate the DOAS technique to the day-to-day measurements performed in the UV spectral region of 315-337 nm. Time series analysis and correlation of agreement in absolute differences as well as algorithm-related and technical factors responsible for sources of discrepancy among the TOC retrievals.

Ground-Based Measurements

The calculation of the total ozone column over Thessaloniki, Greece, are based on measurements of three different types of instruments. A single monochromator Brewer with serial number 8005 (B005) has been providing total ozone column measurements since 1982. B005 has been calibrated in the past a number of times against the reference Brewer (Brewer#137). Its latest calibration showed an agreement with the reference Brewer#137 of ±0.5%. A calibrated Brewer MKIII spectrophotometer with serial number 8008 (B008) measures the UV solar spectrum (286.5 – 363 nm) at 1° sampling intervals. In this UV multi-wavelength product is limited to wavelengths higher than 305 nm and solar zenith angles, smaller than 80°. A high-resolution single-channel radiometer with serial number 8011 (NILU1) provides one-minute measurements in 5 UV channels with nominal central wavelength at 302, 312, 320, 340 and 380, while its sixth channel that measures the Photosynthetically Active Radiation (PAR) is used to determine cloud-free cases. The NILU dataset was subjected to intercomparisons with the BrewerB008 UV irradiance data for the whole period under investigation and its measurements uncertainty was found to be 6.4% for the 305 nm channel and less than 5.4% for the remaining UV channels.

A feed-forward function-approximating neural network (NN) model was trained to calculate the TOC results from B005 retrieved TOCs as outputs from the denoised NILU1013 ozone measurements, using as inputs the daily solar zenith angle (ZDA) and temporal variables as the day of the year, DOY, and its sinusoidal components Coz(DOY) and Sin(DOY). The denoised NILU1013 ozone data resulted from the NN model of a standard deviation of 0.5% of the differences between the NN estimates and the coincident target Brewer data fall within ±13 D.U.

Satellite Measurements

Total ozone column records from GOME/ERS-2, SCIAMACHY/Envisat, OMI/Aura and GOME-2/MetOp have been retrieved with the European Space Agency’s Climate Change Initiative GOSAT (GOME-type Direct FITting) version 3 algorithm. Inter-sensor comparisons and ground-based validation of this dataset indicate that these ozone data sets are of unprecedented quality with stability better than 1% per decade, a precision of 1.7%, and systematic uncertainties less than 3.6% over a wide range of atmospheric states.

Results: NILU-UV & SATELLITE GODFIT-3 Ozone-CCI ESA

Scatter plots of all 4 satellite sensor TOC retrievals against the NILU-UV estimated TOCs are presented in the left panel of Figure 1, while the percentage relative differences are provided in the right panel of the same figure. For the comparisons mean values of the ground retrieved TOCs of ±30 min around overpass time of each satellite platform were used. No filter was applied to limit these comparisons.

All 4 satellite instruments provide a unique agreement with the NILU-UV ground-based TOCs, with the satellite estimations found to overestimate by less than 2%, while the standard deviation of the comparisons doesn’t exceed 0.7% for all cases, as seen in Figure 1. The relative differences of the scatter plots between the satellite TOC retrievals and the NILU-UV TOCs are less than ±3.6 D.U., for most of the cases. The high R² values reveal the good agreement between satellite and NILU-UV TOC estimates.

Results II: NILU-UV & CDD

The scatter plot between the CDD TOC retrievals and the NILU-UV estimated TOCs are presented in the upper panel of Figure 2, while the histogram of the relative differences is provided in the lower panel of the same figure. The coincidences of the two datasets were found within a time window of 5 minutes.

As seen in Figure 2 the ground-based retrieved TOC datasets agree within 3.5% for all skies cases, while this percentage is reduced to 3.18% when the NILU-UV cloud screening algorithm based on its sixth measurements, detected cloud free. The standard deviation of the relative percentage differences is of the order of 3% for both the cloudiness cases. According to the scatter plots, retrievals under cloudless conditions, end to end overestimation, though the R² value is higher than that of all the skies circumstances.

Conclusions

In this work ground-based measurements, model estimates, and satellite-retrievals of the total ozone column (TOC) have been produced, compiled and compared to see thoroughly discuss their accuracy and limitations at the mid-latitude UV and Ozone monitoring station in the Laboratory of Atmospheric Physics of the Aristotle University of Thessaloniki, Greece.

We show how a NN can be trained on NILU-UV multi-filter radiometer irradiances at 5 different wavelengths together with TOCs from a Brewer spectrophotometer to produce 1-minute time series of TOC values. While the accuracy of the NILU-UV estimated TOCs are assessed by internal processes, retrievals of TOC from 4 different satellite sensors are evaluated through the NILU-UV TOC data. Furthermore, an additional source of ozone data stemming from DOAS techniques applied to CDD measured spectra is also evaluated revealing promising results.

References