Ozone Estimation with the ABI

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Realtime GOES ozone on the web: http://cimss.ssec.wisc.edu/goes/rt/viewdata.php?product=o3_us

GEOSTATIONARY OZONE WITH GOES: NOW AND IN THE FUTURE

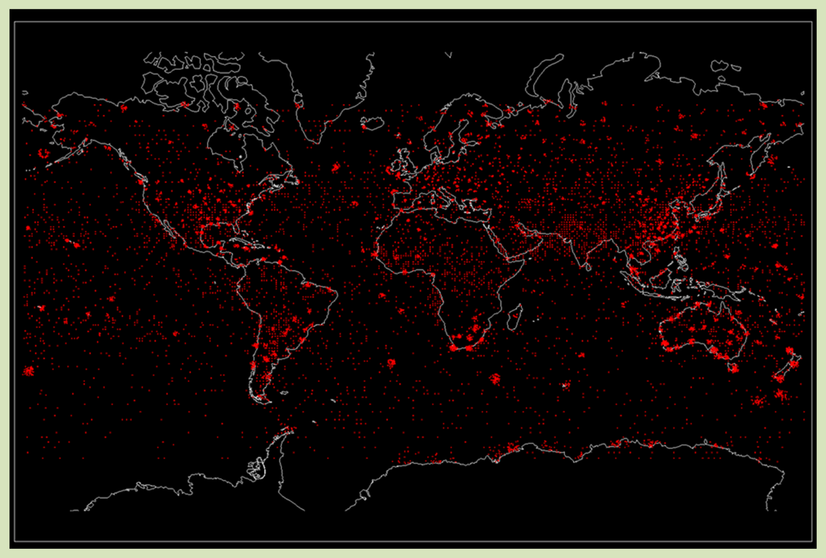
Ozone is primarily viewed as a climate variable, and as a result the focus for ozone detection has been polar orbiting satellites and ground stations. However, total column ozone is correlated to potential vorticity and thus to the height of the tropopause and the sensible weather at the surface; ozone can vary as rapidly as the weather. Ozone features highlight jet streams and tropopause folds and may assist in the detection of clear air turbulence. Tropopause folds can impact air quality at the surface and thus the air quality community has an interest in monitoring ozone.

The GOES-R Air Quality Algorithm Working Group is funding work to produce an Advanced Baseline Imager (ABI) total column ozone (TCO) algorithm and to determine the best way to apply ABI ozone data to air quality issues. Instruments such as the current GOES Sounder and GOES-R ABI are unable to resolve ozone to any useful accuracy in the lower atmosphere (below roughly 300 hPa). Obtaining the tropospheric residual would require ancillary data, though total column ozone data is also useful for model assimilation, specifically as a source function for tropopause folds. Ancillary ozone data could include data from satellites with ultra-violet sensors such as TOMS and OMI, allowing greater total column accuracy and some ability to resolve atmospheric layers of ozone. To improve accuracy the ABI ozone algorithm utilizes model temperature profiles to make up for the lack of upper atmospheric temperature bands on ABI.

CREATING THE REGRESSION COEFFICIENTS

The ABI TCO algorithm utilizes a regression based on that currently used for the GOES Sounder. To generate the regression coefficients for the TCO algorithm, >10,000 atmospheric temperature, moisture, and ozone profiles (with associated total column ozone, location, fraction of land at the location, and other information) located between 70° N and 70° S were selected from a training dataset consisting of NOAA88b profiles, radiosondes, ozonesondes, ECMWF+SBUV data, and TIGR data. A forward model (PFAAST) is used to generate brightness temperatures from selected bands, including the 9.6 μm, aka the ozone band. Scattering by aerosols is neglected. Satellite zenith angle is varied for each profile in 0.5° steps from 0° to 80°. The result is 161 sets of coefficients to use to solve for ozone in the regression equation shown below:

$$\begin{vmatrix} O_1 \\ \cdots \\ \cdots \\ O_{NS} \end{vmatrix} = \begin{vmatrix} C_1 & \cdots & \cdots & C_{NP} \end{vmatrix} \bullet \begin{vmatrix} P_{1,1} & P_{1,2} & \cdots & P_{1,NS} \\ P_{2,1} & P_{2,2} & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ P_{NP,1} & \cdots & \cdots & P_{NP,NS} \end{vmatrix}$$



Locations of profiles used to generate regression coefficients

Regression Terms	
C_{NP}	Regression coefficients for NP predictors
O_{NS}	Total column ozone for NS sets of predictors from training dataset
$P_{NP,NS}$	The training dataset, each location with its data is a column, NS/number of rows is the number of members of the training dataset
NS	Number of members of the training dataset
NP	Number of pieces of information for each member of the training dataset

CALCULATING TCO

Calculating the TCO is a simple vector multiplication of the vector predictors and the vector of predictands. In this particular algorithm, the result is the natural logarithm of the TCO:

$$\ln(TCO) = C_0 + \sum_{j=1}^{n} C_j Tb_j + \sum_{k=1}^{n} C_k Tb_k^2 + \sum_{l=1}^{101} C_l Ta_l + C_{2n+102} p_s + C_{2n+103} L_p + C_{2n+104} \cos\left(\frac{M-6}{12}\pi\right) + C_{2n+105} \cos(LAT)$$

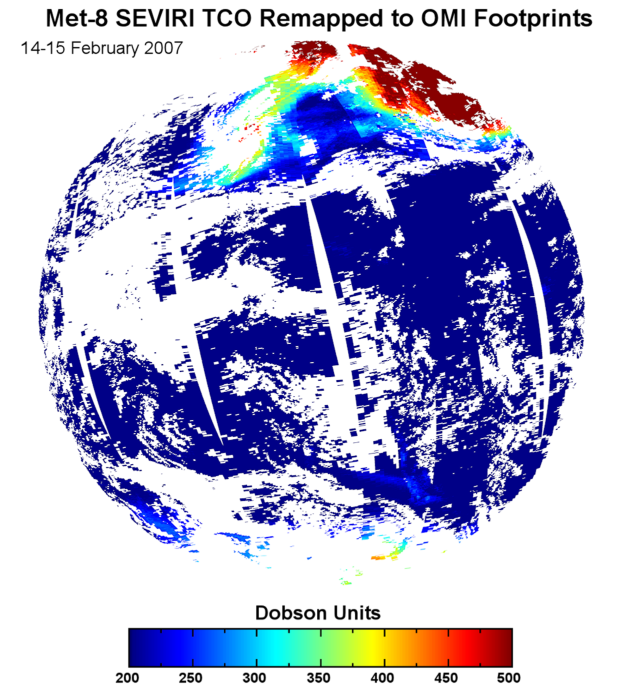
Regression Terms	
C_x	Regression coefficients (C_0 is an offset)
n	Number of bands used
Tb	Brightness temperature
Ta	Atmospheric temperature profile
p_s	Surface Pressure
L_p	Fraction of land within pixel
M	Month of year
LAT	Latitude of pixel

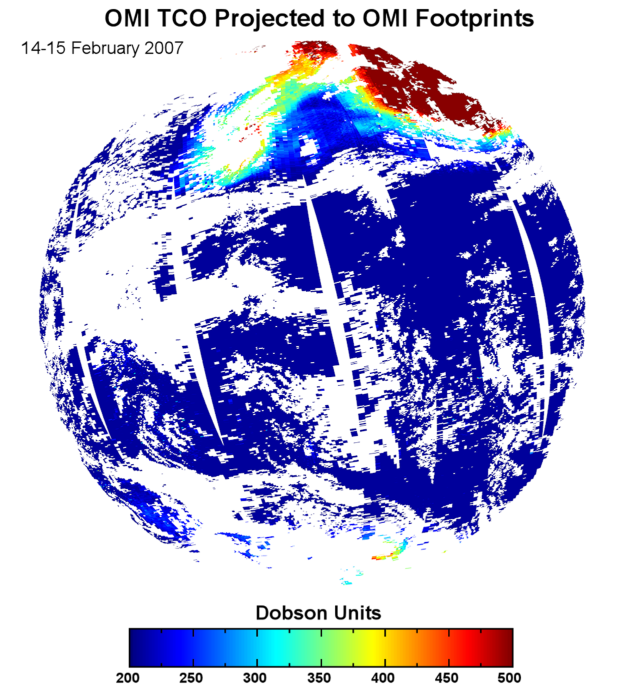
VALIDATION AGAINST THE OZONE MAPPING INSTRUMENT (OMI) ON AURA

Validaton of SEVIRI TCO using OMI TCO as truth is accomplished by remapping the clear-sky SEVIRI TCO to the OMI footprints and generating statistics, including accuracy, precision, and root mean squared error. The definitions of accuracy and precision are those adopted for GOES-R algorithm work. Accuracy is the absolute value of the bias, and precision is equivalent to one standard deviation.

Under most scenarios and surface types the algorithm meets its requirements, with the exception of over desert surfaces. Deserts and other surfaces with very high emissivities are a challenge for the regression and are a subject of further research.

A comparison of TCO from SEVIRI and OMI is presented below. The images were remapped to the OMI footprints and a cloud mask was applied.

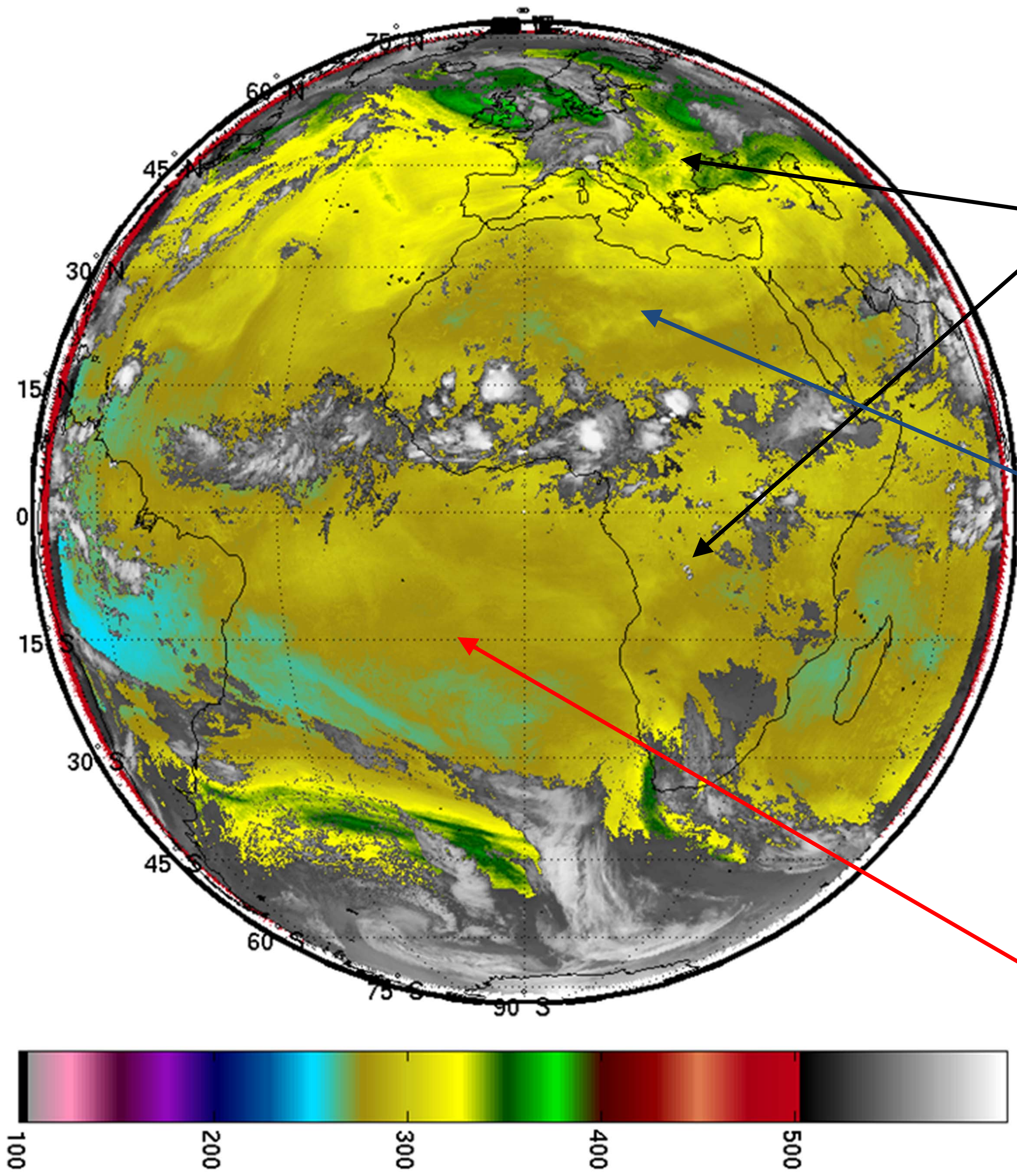




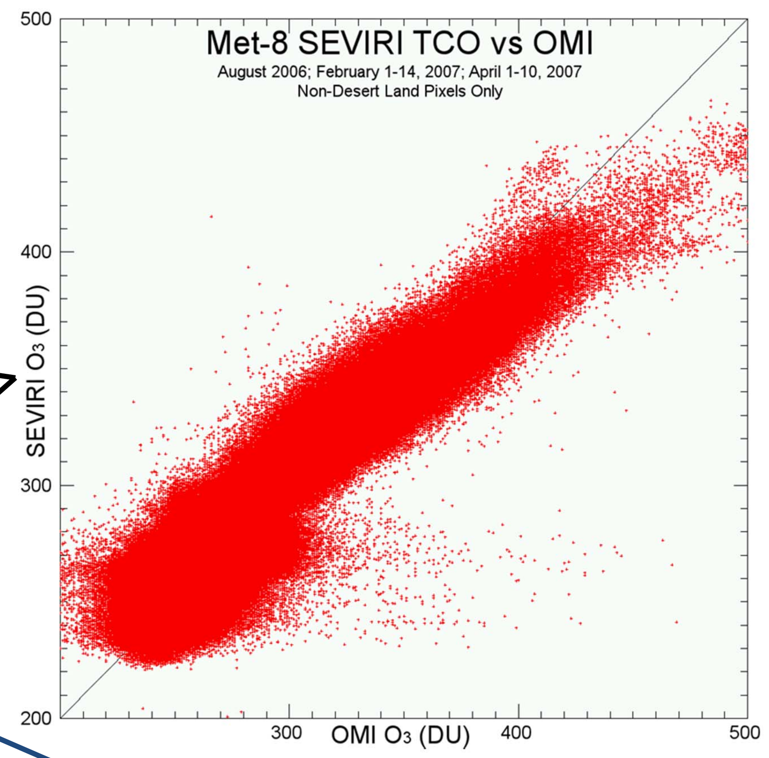
	Number of co-locations	Accuracy (DU) (req: 15 DU)	Precision (DU) (req: 25 DU)	RMSE (DU)
August 2006; February 1-14 and April 1-10, 2007 (all clear-sky pixels)	5,796,726	3.3	14.8	15.1
August 2006; February 1-14 and April 1-10, 2007 (non-desert land)	1,862,589	3.3	14.4	14.7
August 2006; February 1-14 and April 1-10, 2007 (desert)	1,177,329	14.8	12.9	19.6
August 2006; February 1-14 and April 1-10, 2007 (water)	2,756,808	1.5	13.1	13.1
August 2006 (all clear-sky pixels)	3,408,432	6.5	13.3	15.8
August 2006 (desert only)	681,994	18.3	11.9	17.4
August 2006 (non-desert land)	1,124,385	6.5	12.5	14.1
August 2006 (water only)	1,602,053	1.4	11.1	11.2
April 2007 (all clear-sky pixels)	1,052,090	1.2	15.4	15.4

The table above lists the accuracy and precision values for various dates and surface types for Met-8 SEVIRI TCO as compared to OMI. Deserts provide the greatest challenge for the regression, whereas water pixels provide some of the best results. Water does not have a strong diurnal heating signature like deserts do, causing the TCO results to be more stable there. Green highlights the results that show the algorithm meets its specifications.

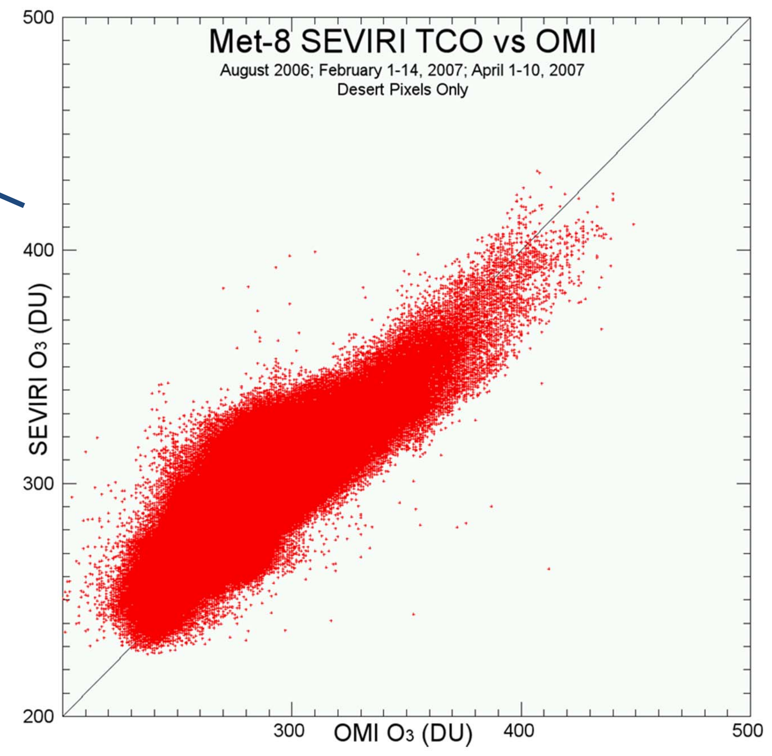
SEVIRI Total Column Ozone on 1 August 2006 at 0 UTC

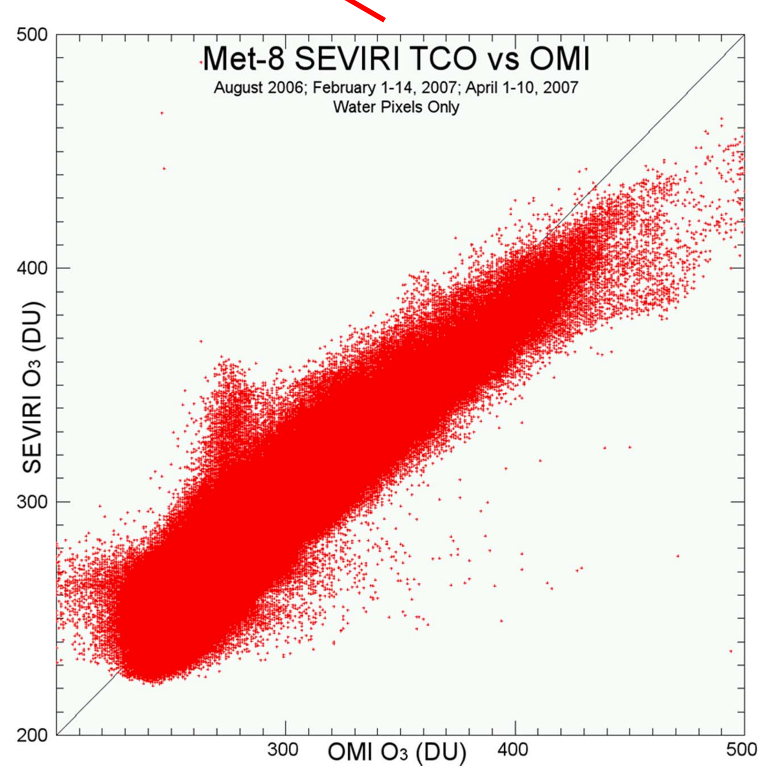


Total column ozone (DU)

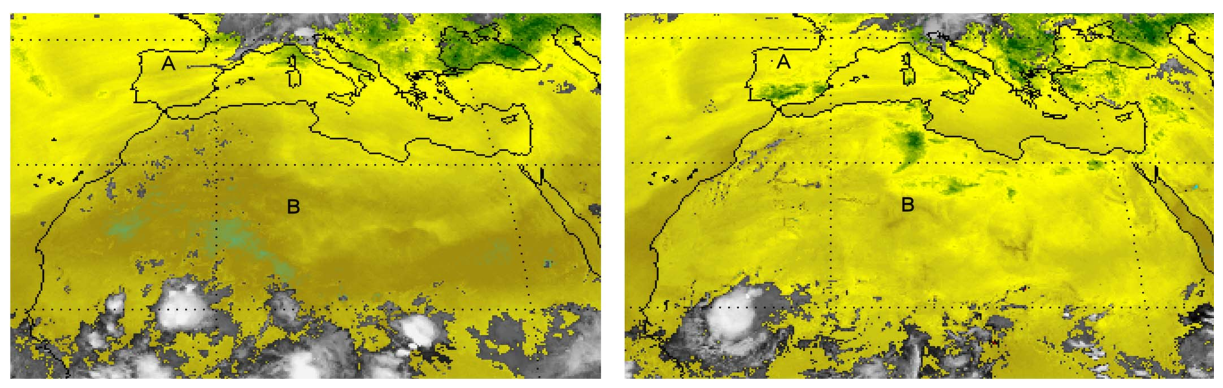


These scatterplots are divided up by ecosystem and illustrate the general similarities and differences in TCO performance over the various surface regimes. The scatterplot for deserts shows the tendency for SEVIRI to over-estimate TCO, for example.





SURFACE EMISSIVITY IMPACTS ON TCO



Left: 1 UTC 1 August 2006, Right: 12 UTC 1 August 2006

The GOES Sounder TCO experimental product often shows a diurnal variation over hot surfaces, and as expected this behavior is observed in SEVIRI TCO data as well. Label A shows how the hot, reflective surface of southern Spain effectively enhances a pre-existing streamer. Similar behavior is seen over the Sahara at label B. Further research is necessary to isolate which band(s) may be responsible for this and how it may be corrected.

Realtime GOES ozone on the web: