Assessment of tropospheric ozone trends inferred from satellite observations: reconciliation of differences among different instruments and with in situ data

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Overview and Goals in support of TOAR-II

Satellites are a billion dollar investment that provide a global-scale view on tropospheric ozone and its precursors, with different types of sensors being sensitive to different parts of the atmosphere. They are used to help improve numerical weather prediction and more recently to improve predictions of air quality, e.g within the Copernicus Atmosphere Monitoring Service. Data from these sensors are complementary to more detailed and more precise in situ data that are spatially and temporally limited.

A wide variety of trends and variations in tropospheric ozone were reported by satellite sensors in TOAR-1 (Gaudel, et al, 2018). However, there was little attempt to reconcile differences between a) satellite-based estimates from sensors that view different parts of the atmosphere and b) the satellite-based data and values reported by the in situ data. TOAR-II is an opportunity to address these important issues and place the satellite data on an equal footing with the in situ data in terms of quantifying changes in tropospheric ozone with well-defined uncertainties.

In this activity, we intend to address these knowledge gaps. One or more global 3-D chemistry transport models will act as an intermediary or “transfer standard” between different satellite sensors (taking into account their averaging kernels) and between the satellite sensors and ground-based and aircraft in situ data (see Methods).

Plans for broader community involvement

The remote sensing community is central to the success of this activity. Preliminary discussion with groups who provided data to TOAR-I has identified renewed support for the TOAR process. In some cases, newer retrieval versions will be used to re-process older data and in other cases retrievals of data from newer sensors will be delivered. We will reach out to the groups listed in Table 1 and welcome participation from any other interested groups that contact us through email or at meetings when working group participation is solicited.

We have yet to determine a timeline of activities but we anticipate designing a data format that we will use to transform all incoming data from the individual research groups to a common standard. This approach will simplify our analysis code, will allow TOAR groups to access a uniformly described dataset, and eventually allow the wider community to access the satellite data.The model-based evaluation described in the Methods will commence once we have agreed on a study period for these datasets.

We also plan to provide the satellite groups with a common methodology for validating trends using the long-term ozonesonde record. We will select a set of ozonesonde sites and ask each group to use a common coincidence criteria and to calculate monthly or seasonally averaged differences against the sondes (using the averaging kernel for that particular instrument) for 5 broad latitude bands. The teams can provide these differences to the satellite working group along with the number of samples and the standard deviation of each average and so that we can assess whether the differences with respect to the sondes change with time across the entire length of the evaluation period.

Data and Methods

Data

Table 1. Satellite observations of tropospheric ozone (initial list)

Satellite - Instrument	Time period	Groups
Metop A,B,C - IASI	2008 - present	LATMOS (FORLI retrieval) LISA (KOPRAFIT retrieval) U.Toulouse/CNRS (SOFRID)
Metop A,B,C - GOME-2	2008 - present	U. Bremen
Metop - IASI/GOME-2	2008 - present	LISA (KOPRAFIT) STFC
Aura - OMI trop. column	2004 - present	NASA/GSFC KNMI
Aura - OMI/MLS	2004 - present	NASA/GSFC

Aura - OMI profile	2004 - present	SAO
Aqua - AIRS/ Aura - OMI	2004 - present	NASA/JPL
Aura - TES	2004 - 2010	NASA/JPL
Envisat - SCIAMACHY	2002 - 2012	U. Bremen

Methods

The model reanalysis(es) described below will be sampled at the time and location of each satellite data point and convolved with the scene-dependent averaging kernel so that we have an equivalent model representation for each satellite dataset. We will also perform the same analysis using a climatology from the model with seasonal but no interannual variability. The reanalysis results will be used to diagnose trend differences due to different instrument vertical sensitivities and the climatology results will be used to determine trend errors due to potential changes in sensitivity with time. We will then apply a series of statistical methods to understand the trend and variations of ozone, taking into consideration uncertainties and year to year variation that may preclude robust trend estimates. If the datasets are able to provide trend estimates above the noise level, we will determine annual growth rates and quantify non-linear trends, allowing for stepwise changes in emissions. If time and resources allow, we will also use the reanalysis output to determine whether the trends and variations observed by the satellites are consistent with in situ data by comparing the statistics of the differences between the reanalysis and the observed trends for both types of data.

Models

Model output with realistic long-term ozone changes is necessary for this analysis. We will use output from the Tropospheric Chemistry Reanalysis (TCR-2) [Miyazaki et al., 2020] and possibly also the European CAMS reanalysis system as our “truth” against which to diagnose differences in the satellite trends.

Tentative timeline of activities

Summer 2020: Solicit participation in working group and set up virtual meetings

Fall 2020: Generate the methodology for direct satellite-sonde comparisons to be distributed to the various groups

Winter 2020: Establish the evaluation period to be used as well as a common definition for the vertical extent of the measurements (e.g. tropospheric ozone column, partial column, individual pressure levels, etc).

Spring 2021: Request updated data from the satellite groups listed in Table 1 below.

Summer 2021: Begin analysis using the model output to reconcile difference among the satellite trends

Spring 2022: Complete analysis using the model and assess the consistency of the satellite trends with one another and with in situ data

Fall 2022-Winter 2023: Write up results of our analysis for publication

Spring 2024: submit for publication in TOAR II.

References

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