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Evaluating trends in tropospheric ozone observations from TES with sonde data for the period 2005-2010

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Tropospheric ozone is a global air pollutant and an important greenhouse gas. It is mainly produced by the photochemical reaction of short wave radiation with precursor molecules such as NO_x and VOC's originating from anthropogenic pollution and biogenic sources. Besides that, intrusions of stratospheric ozone into the higher troposphere contribute to the ozone abundance in the lower atmosphere.
Balloon soundings are one way of measuring ozone. These sondes provide in situ measurements of temperature, pressure, humidity and ozone from balloons launched from stations located all over the world.
As the distribution of ozone in the troposphere is not uniform both temporal as well as spatial variability in ozone concentrations must be considered. In contrast to the poor spatial sampling by sondes, spaceborne sensors provide a much better coverage and a fixed time retrieval of ozone enabling the understanding of patterns and origins of tropospheric ozone. These sensors, for instance TES (Tropospheric Emission Spectrometer onboard NASA's EOS-Aura satellite), however need to be evaluated with independent data, such as worldwide sonde ozone data (i.e. World Ozone and Ultraviolet Data Center, WOUDC).
The objective of this study is to investigate any tropospheric ozone trends when evaluating the TES v4 data record with the worldwide WOUDC sonde dataset for the period 2005-2010. A comparison between the TES and the WOUDC data provides a detailed consistency check of the ozone spatial distribution as well as the seasonal and multi-year patterns in TES and sonde ozone.
We used a maximum range of 300 km and a maximum time difference of $\pm$ 9 hours between the version 4 TES and sonde ozone data as coincidence criteria to increase the probability that the same air parcels are sampled. To ensure a valid comparison, the TES averaging kernel was applied on the sonde data. Validation of TES tropospheric ozone is conducted at the lower (surface - 500 hPa) and upper (> 500 hPa) troposphere (cfr. two degrees of freedom of TES in the tropospheric region), per season, year, station, latitudinal zone and for some specific regions.
First validation results for all seasons and all stations show better agreement between TES v4 and sonde ozone in the upper troposphere ($r = 0.9$) than in the lower troposphere ($r < 0.8$), consistent with the better sensitivity of the satellite instrument higher up in the troposphere. Generally, TES is biased high by 7-15 ppbv in the upper troposphere, in line with earlier reports on the validation of TES v2 retrievals with sondes. A first analysis of TES v4 time series indicate a increasing trend of tropospheric ozone at the 464 hPa level in eastern Asia, more specific in NE China. Further research will focus on an in-depth analysis of these trends and will explore the potential to map and correct for the observed bias between TES and sonde ozone data.