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Improvement of OMI ozone profile retrievals in the troposphere and lower troposphere by the use of the tropopause-based ozone profile climatology

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Introduction

❖Liu et al. (2005) developed an advance algorithm based on the optimal estimation tech. [Rodgers, 2000] to derive ozone profile from GOME UV radiances and have adapted it to OMI UV radiances [Liu et al. 2010].

❖ OMI vertical resolution : 7-11 km in the troposphere and 10-14 km in the stratosphere.

❖ Satellite ultraviolet measurements (GOME, OMI) contain little vertical information for the small scale of ozone, especially in the upper troposphere (UT) and lower stratosphere (LS) where the sharp O3 gradient across the tropopause and large ozone variability are observed. Therefore, retrievals depend greatly on the a-priori knowledge in the UTLS

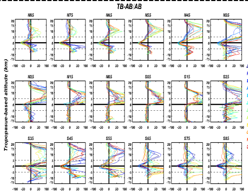
Tropopause-based (TB) climatology

❖ The use of TB coordinate is an established method in analyzing the UTLS ozone field, with the advantages; better preserves the sharp gradient across the tropopause and significantly reduces ozone variance due to daily meteorological variability

❖ Wei et al. (2010) developed the TB climatology based on the ozonesonde profiles from 1983-2008 and existing climatology.

ozone profile 2004 to 2008, aircraft measurements during the START08 were used to validate the ozone retrievals based on the TB climatology.

♣ FIG. 1 ♣ Effectiveness of using TB coordinate in reducing ozone variability due to daily tropopause height variability.
Note : TB coordinate = Altitude-based (AB) coordinate – tropopause height

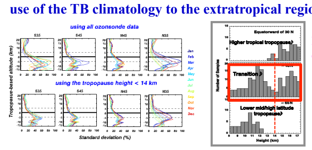


Using TB coordinate reduces the ozone variability by more than 50 % around the tropopause for the extratropical latitudinal bands

Using TB is not useful where the atmospheric dynamics is expected to be low ; tropics, altitudes without ± 5 km

❖ We improve the way to derive the TB climatology.

1. Filtering ozonesonde profiles with the tropopause height > 14 km, in order to confine the use of the TB climatology to the extratropical region



Histogram of tropopause height sampled by ER-2 during STRAT & POLARIS [Pan et al., 2004]

▪ Two different groups of tropopause heights is observed in ~ 40 N. The two peaks happen where the double tropopause often observed.

▪ The 14 km tropopause height : separates samples into tropical and extra-tropical groups.

➔ Reducing O3 variability induced by mixing air-masses between troposphere and stratosphere, especially in the vicinity of the subtropical(♣ FIG. 2 ♣)

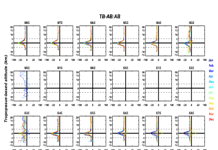
2. Using the TB coordinate the variable shifting offset is applied, in order to confine the use of them to the UTLS region

▪ offset is dependent on the distance away from the tropopause at altitude within ±5km, and then fixed with the mean tropopause

$$Z_{tb}(i) = Z_{ab}(i) - Z_{offset}(i)$$

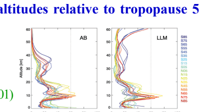
$$Z_{offset}(i) = \begin{cases} (Z_{tp} - \bar{Z}_{tp}) \times \left(1 - \frac{|Z_{ab}(i) - Z_{tp}|}{5}\right) + \bar{Z}_{tp} & (|Z_{ab}(i) - Z_{tp}| > 5\text{km}) \\ \bar{Z}_{tp} & (|Z_{ab}(i) - Z_{tp}| < 5\text{km}) \end{cases}$$

♣ FIG. 3 ♣ Effectiveness of using TB coordinate in reducing ozone variability due to daily tropopause height variability.
Note : TB coordinate = Altitude-based (AB) coordinate – variable shifting offset; TB climatology is derived when the number of ozonesonde profiles with the tropopause height < 14 km is greater than 20.



3. TB/AB climatology is merged to LLM climatology at altitudes relative to tropopause 5 km

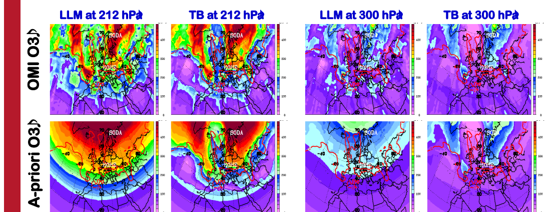
♣ FIG. 4 ♣ AB climatology shows the highly smoothed ozone variability above ~ 40 km, compared to LLM, due to the different composition for the stratosphere.
AB/TB = existing stratospheric ozone climatological profiles.
LLM = Stratospheric Aerosol and Gas Experiment II (SAGE II; 1988-2001) at low/mid latitudes or Microwave Limb Sounder (MLS; 1991-1999)



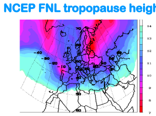
Validation using the meteorological data

The horizontal and vertical distribution of OMI retrievals on 30 April 2007 with two different ozone climatologies; LLM climatology from McPeters et al. (2007) and our TB climatology, which are evaluated using meteorological data from NCEP FNL data.

♣ Fig 5 ♣ O3 horizontal map



NCEP FNL tropopause height



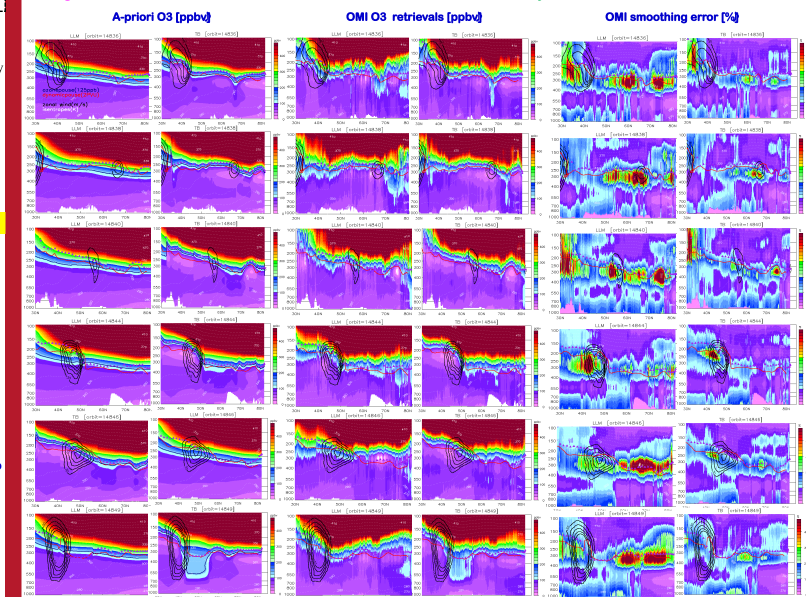
▪ The FNL 2 Potential Vorticity Unit surface derived at 250 hPa is contoured with the red line. This indicates the transition from the tropospheric air mass to the tropospheric air mass that is correlated with the O3 value of 100 to 300 ppbv.

▪ Large ozone values are closely collocated with the low tropopause height and large PVU values

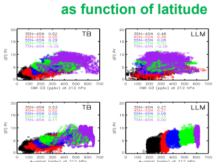
▪ when using the TB climatology, the O3 transition between tropospheric and stratosphere seems to be more distinct and be better consistent with the 2 PVU surface.

▪ TB a-priori O3 is highly correlated with the dynamical features, whereas no longitudinal dependence is founded in the LLM ozone field.

♣ Fig 6 ♣ Several orbits of OMI retrievals between 14836 and 14849, with dynamic variables.



♣ Fig 7♣ O3 versus PV at 212 hPa as function of latitude

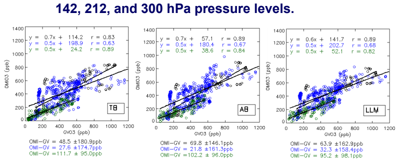


▪ Using TB climatology better Show the linear relationship between ozone and and PV values

Validation using the aircraft measurements

▪ We used in situ measurements obtained from the START08 experiment (Pan et al. 2010) as another validation reference.

▪ OMI retrievals are evaluated in three pressure layer, bounded by the 103, 142, 212, and 300 hPa pressure levels.



♣ Fig 7♣ OMI versus GV

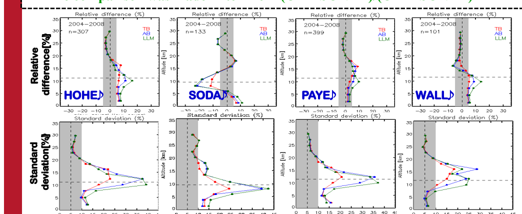
Validation using the ozonesonde data

▪ Ozonesonde measurements observed from 2004 to 2008 were used, from four stations in northern hemisphere; Wallop Island (37.9N, -75.5W) , Payerne (46.5 N, 6.6E), HohenpeiBenberg(47.9N, 11.0E) , and Sodankyla (67.4N, 26.7E).

▪ The criterion to select the collocated sonde data with OMI pixels is within 1 ° grids and within 8 hour of each other where the FNL tropopause height is less than 14 km. To reduce the cloud influence, we only use OMI retrievals with cloud fraction <0.8.

▪ NOTE: In order to eliminate systematic biases introduced by the OMI smoothing error, we degraded sonde profiles into the OMI vertical resolution by convolving them with the OMI averaging kernels, according to [Rodgers, 2000] except for Fig 11.

♣ FIG. 09 ♣ comparing ozone profiles between OMI and ozonesonde
The comparison was made in term of 2(OMI-SONDE)/(OMI+SONDE)

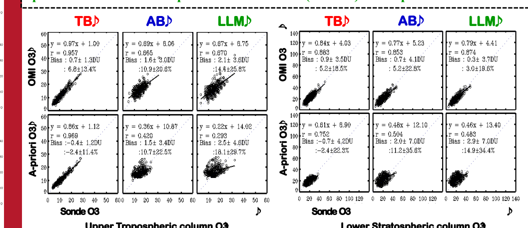


▪ Significant disagreement between OMI and ozonesonde are distributed over the UTLS .

▪ OMI retrievals based on TB climatology show the better agreement with sonde data than others, by up to a factor of ~ 2 at mean tropopause (~10 km)

▪ This improvement illustrates how well the combination of the TB climatology and the daily tropopause height data represents the daily behavior of ozone, coupled with the atmospheric dynamics in the UTLS region

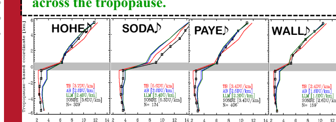
♣ FIG. 10 ♣ comparing Upper Tropospheric/Lower Stratospheric column O3 between OMI/A-priori and ozonesonde at HOHE
Also shown are the linear regression line (sold) and the 1:1 line (dashed). The slope, offset, correlation, mean bias, and 1 standard deviation are given. Right panel : the lower stratospheric column ozone (0~3 km) is compared.



▪ In TB case, OMI UTO3 and a-priori UTO3 are closely scattered with respect to ozonesonde UTO3 with excellent statistics, compared to others.

▪ In the US region, Using TB climatology slightly improves the OMI retrievals.

♣ FIG. 11 ♣ comparing the sharpness of the tropopause
Averages of ozonesonde/OMI ozone profiles at TB altitude during the period 2004-2008. A given value represent the vertical gradient of the mean ozone profile across the tropopause.



▪ the sharpest gradient of O3 profile at the tropopause observed in sonde data can be well reproduced in OMI retrievals based on TB clim.

Summary and discussion

■ Optimize the use of TB climatology in OMI O3 profile retrievals by combining with AB & LLM climatologies, because the benefit of TB clime. is limited to UT/LS at mid/high latitudes.

■ Using TB climatology significantly improves the spatial consistency in the UT/LS between O3 and PV gradients, and reduces the retrieval vertical smoothing across the UT/LS.

■ Comparisons with ozonesonde observations support that the TB climatology significantly improves the retrieval in the upper troposphere and the lowermost 2~3 km above the tropopause.