Ozone Retrieval from GEMS

Jae. H. Kim[1], Juseon Bak[1], Kanghyun Baek[1] and Xiong Liu[2]

[1] Pusan National University

[2] Smithsonian Astrophysics Lab

Outline

1. Current Ozone retrieval Algorithm for total ozone and ozone profile

2. Optimal Estimation Method for ozone profile and it's application to reduce retrieval error near the tropopause

3. Benefit of inclusion of Chappuis band to get improved tropospheric ozone signal

4. Future work

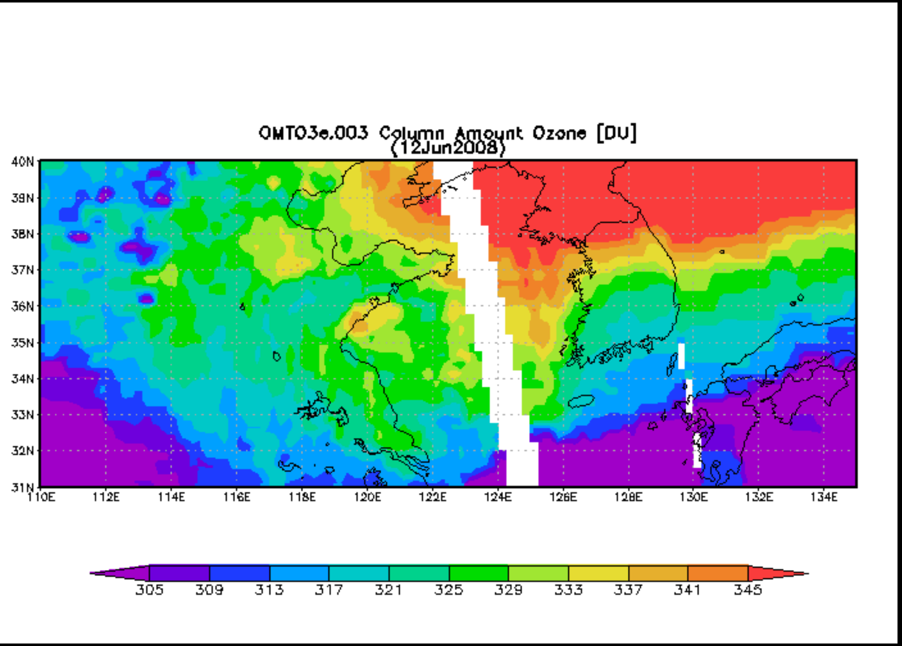
Total ozone retrieval algorithm

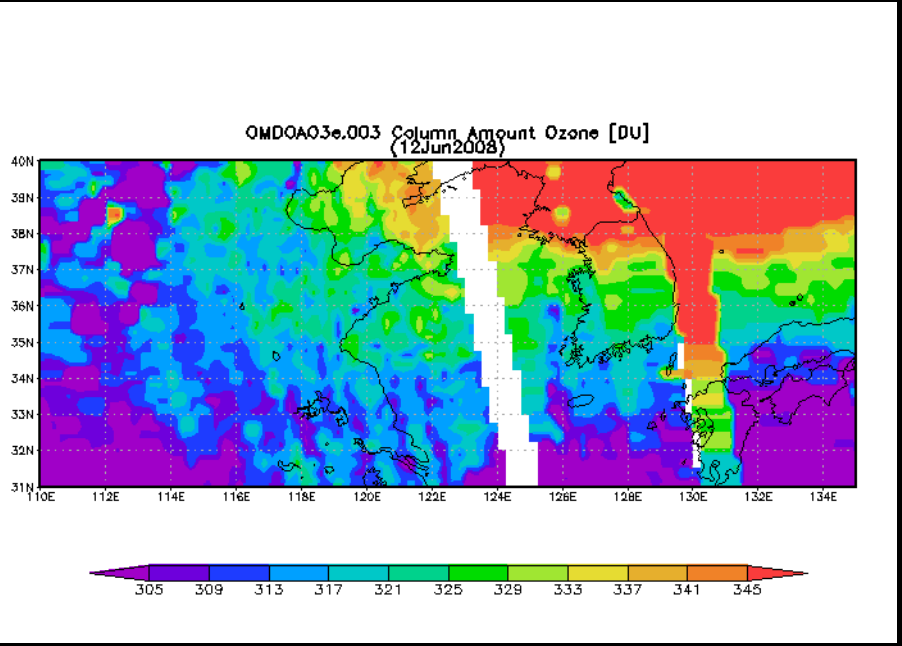
TOMS Alorithm

- Since 1979–present by NASA
- Used for TOMS and OMI
- RMS error ~ 2%

DOAS Algorithm

- Since 1996–present by ESA
- GOME, SCIA, and OMI
- RMS error ~ 2%





Ozone profile retrievals

- There has been no operational algorithm used for ozone profile
- The Optimal Estimation Method (OEM) is a widely used retrieval methodology that characterizes the solution by combining information from the measurements and the a priori.

Optimal Estimation [OE] Method [Rodgers et al., 2000]

$$x^2 = \left\| S_y^{-1/2} \{ K_i (X_{i+1} - X_i) - [Y - R(X_i)] \} \right\|_2^2 + \left\| S_a^{-1/2} (X_{i+1} - X_a) \right\|_2^2$$

$$X_{i+1} = X_i + \left(k_i^T S_y^{-1} K_i + S_a^{-1} \right)^{-1} \{ k_i^T S_y^{-1} [Y - R(X_i)] - S_a^{-1} (X_i - X_a) \}$$

Ozone Profile

- Retrieval error based on OEM [Liu et al, 2011]

	Mean Bias	STD (1σ)
GOME Tropospheric Column O3	15%	13-27%
GOME Stratospheric O3 profile	15%	15%
OMI Tropospheric Column O3	?	?
OMI Stratospheric O3 profile	10%	15%

Ozone profile retrievals from backscattered ultraviolet radiances have a relatively week vertical information in the lower stratosphere and troposphere where chemistry and dynamics is well coupled

➔ ***depend on the climatological a priori information.***

➔ Collaboration study with Liu for understanding and application of OEM to OMI

Collaboration with X. Liu

- **Main purpose is to learn how to use OEM and to get to the level where we can easily manipulate.**

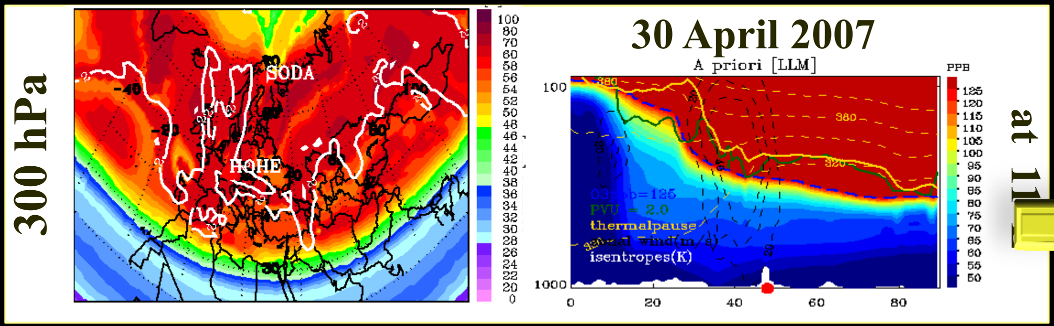
- **Research title (Juseon Bak)**

  "Improvement of OMI ozone profile retrievals in the troposphere and lower stratosphere by use of a tropopause-based (TB) ozone profile climatology"

The current a priori information

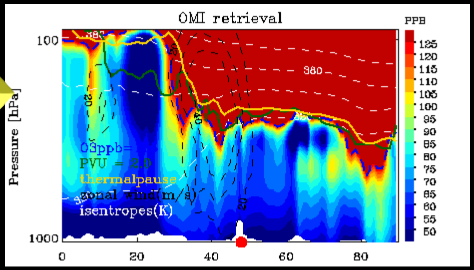
LLM Climatology [McPeters et al. 2007]

- ➔ Zonally and monthly averaged ozone climatology
- ➔ Ozoensondes (1998-2002) and *satellite measurements*
  - SAGE2, 1988-2001 and MLS, 1991 -99
- ➔ Climatological ozone *a-priori* profile varies with 10 degree latitude band in a given month



A priori O3 variance is Independent on dynamics related to 2-PVU and thermal tropopause height

OMI retrieval profiles fails to capture dynamics

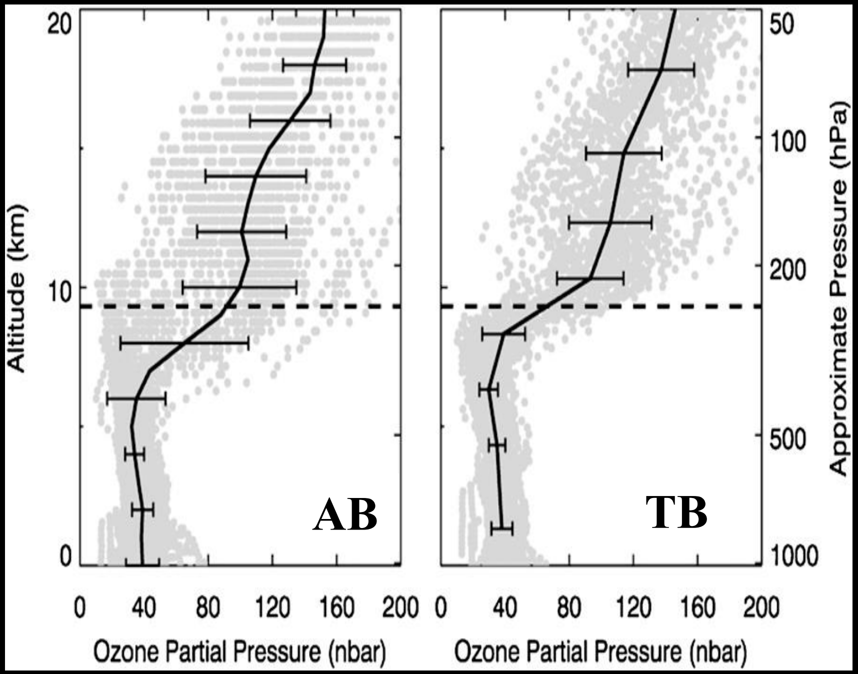


Constructing the ozone profile climatology by use of tropopause height as a proxy for atmospheric dynamics for resolving vertical structures across the tropopause

The benefit of the TB coordinate

TB coordinate(T_i) = AB coordinate(Z_i) – offset

The use of tropopause-based coordinate is an established method in UTLS ozone analyses, and has been used for AIRS O3 retrievals [Wei et al., 2010]



➔ better preserving the sharp gradient across the tropopause

➔ significantly reducing o3 variance due to variability of daily tropopause height

Monthly mean ozone profiles and 1-sigma standard deviation in the latiudinal bin between 60 N and 70N for May in Regular altitude and TB altitude.Origianl ozone profiles (dot), mean tropopause height (dash line) **[Wei et al., 2010]**

Development of TB Climatology

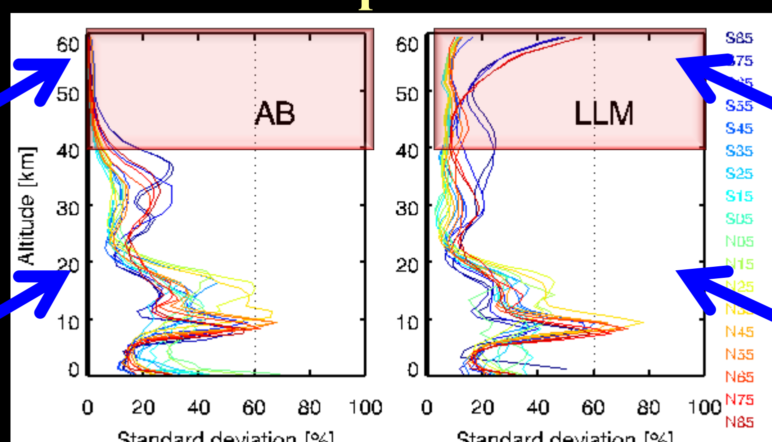
Ozonesonde profiles from 1983 to 2008 [**Wei et al., 2010**]

- ➔ Each individual profile is extended from the *climatological stratospheric ozone profile* depending on the month and latitude bin above the balloon bursting altitude, and then interpolated to the 100 RTA layers.
- ➔ These profiles are averaged in 10-latitude bin for every month from -20 to 60 km (TB clima) or from 0 to 60 km (AB clima) with 1 km vertical resolution.

April

Climatological profile
STD is close to zero

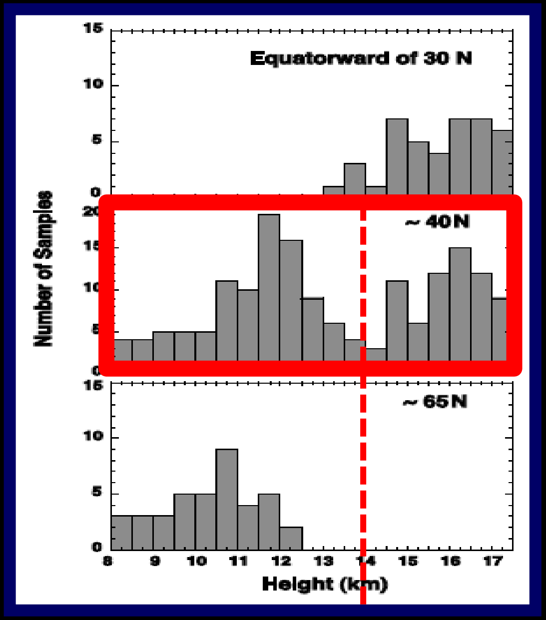
Ozonesonde from
1982-2008



Satellite measurements
STD is around 20%

Ozonesonde from 1982-2002

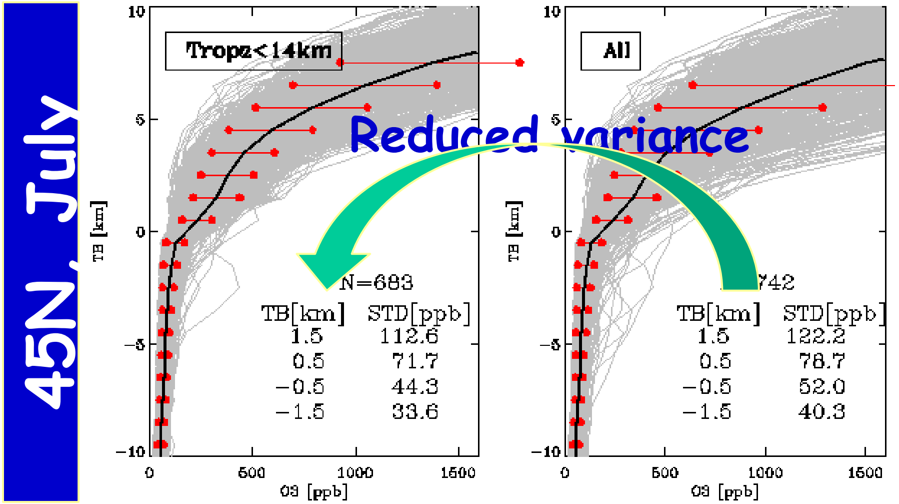
Both AB and TB climatologies are merged with the LLM climatology between 5-10 km above the tropopause and are replaced by the latter 10 km above the tropopause



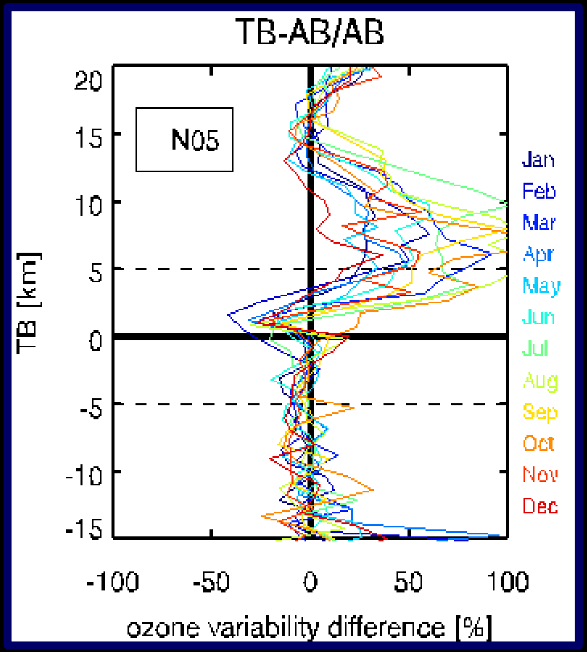
Histogram of the tropopause height sampled by ER-2 during STRAT and POLARIS *[Pan et al., 2004]*

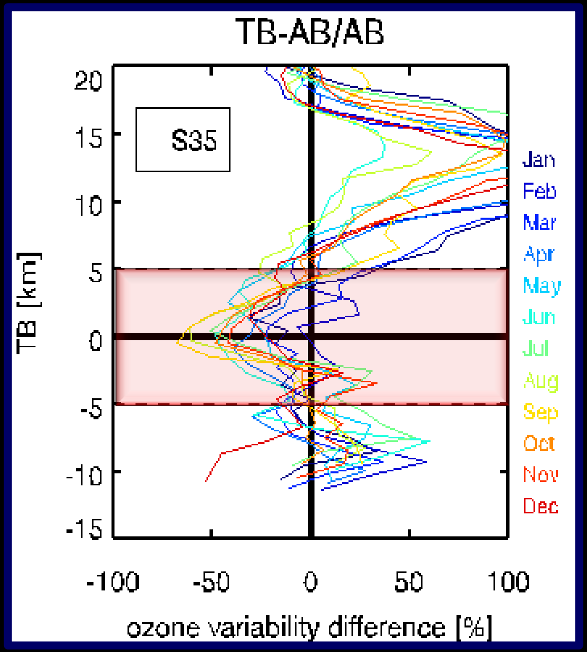
Two different groups of tropopause heights significantly contribute variability of ozone profiles relative to tropopause

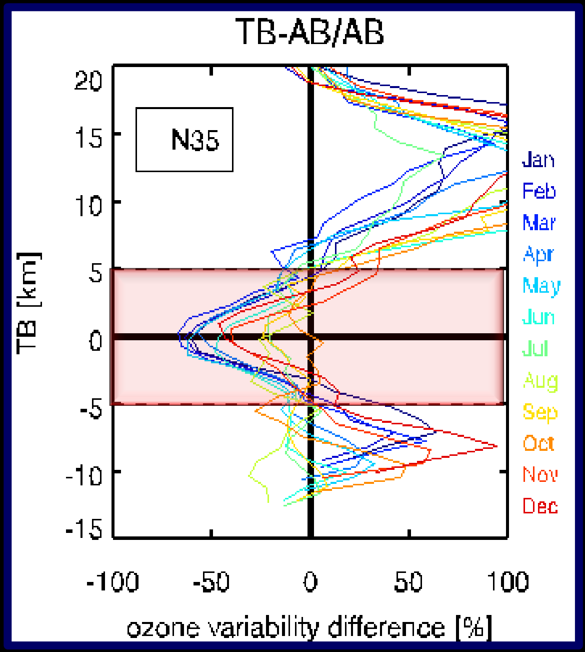
Ozone variabilities for source profiles with tropopause height < 14 km (left) VS all source profile (right) relative to the tropopause



Relative difference in 1-sigma standard deviation between Tropopause-based climatology, and Altitude-based climatology







Tropics

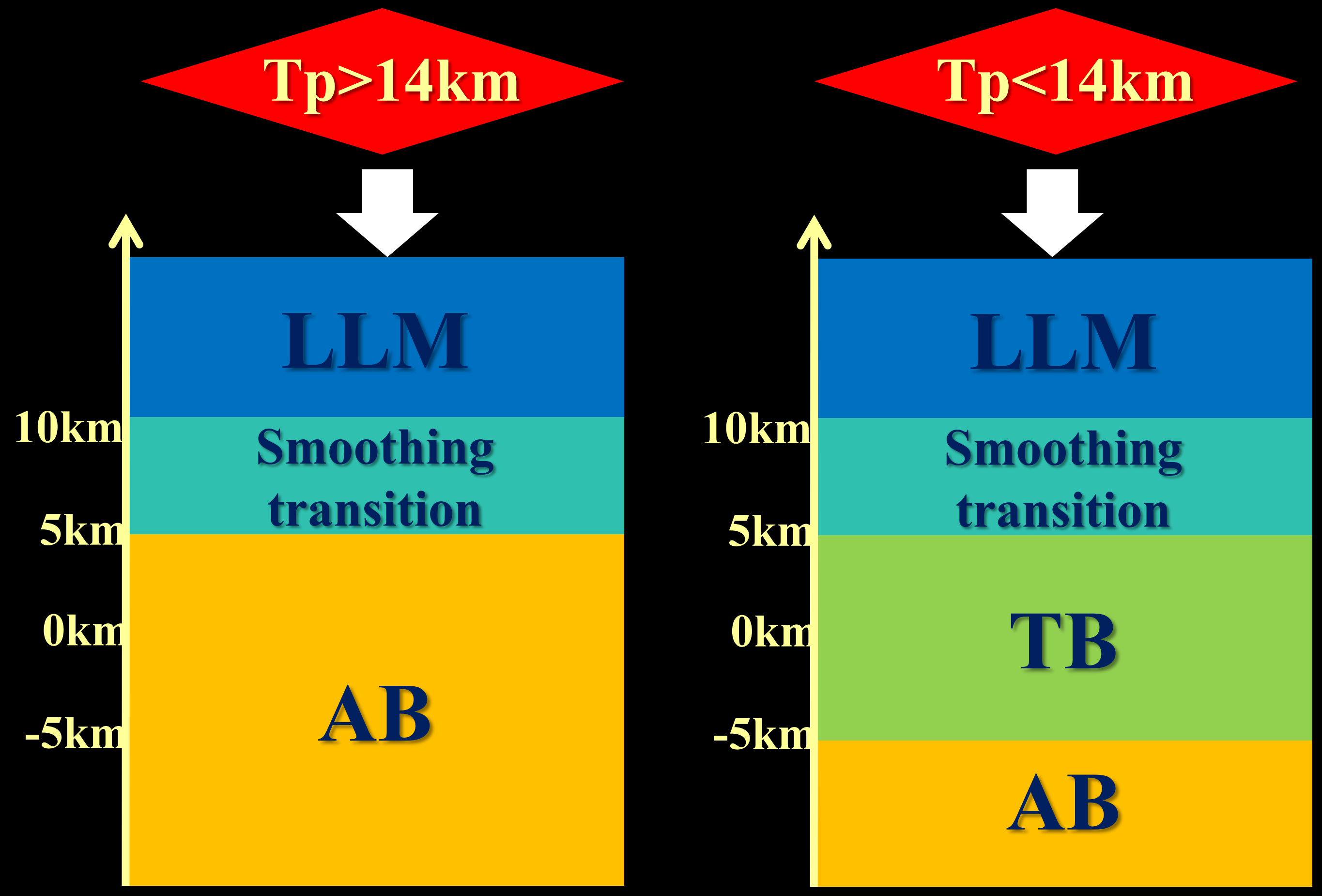
- note: 14-km tropopause height
- based filtering is not applied

Southern mid/high latitude band

Northern mid/high latitude band

➔The use of the TB climatology should be limited to ±5km around tropopause when the tropopause height is less than 14 km (mostly mid and high latitudes).

Optimizing the use of the Tropopause-based (TB) ozone climatology



Evaluation of OMI ozone profile retrievals using TB, AB and LLM

- dynamic variables derived from NCEP FNL (final operational global analysis) data

  ** The FNL tropopause is used in the retrievals*

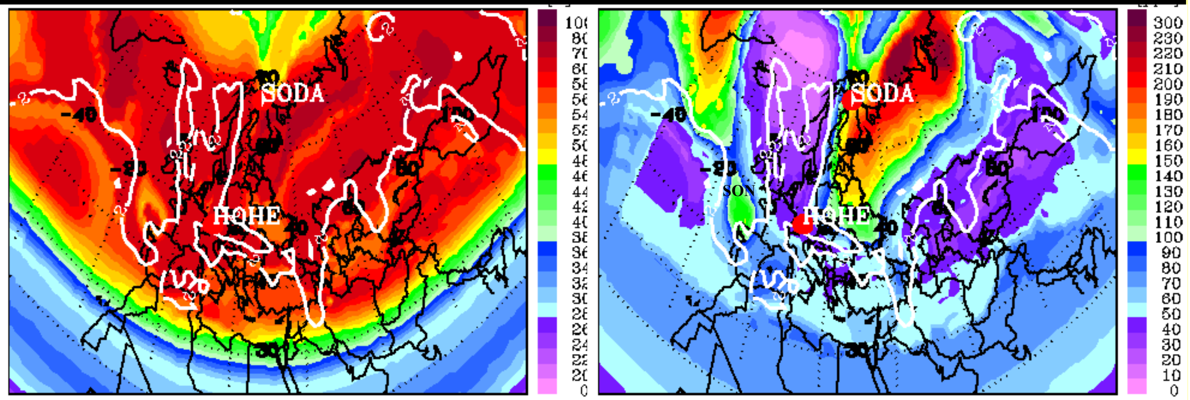
- ozonesonde observations at Hohenpeissenberg (47.9^{o}N,11.0^{o}E) during the period 2004-2008

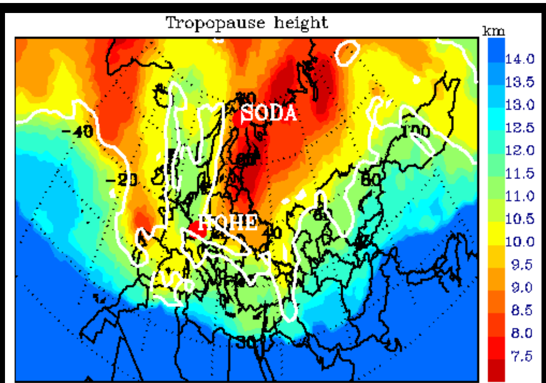
  ** Ozonesonde profiles are downgraded to the OMI vertical resolution by convolving with the OMI AKs*

LLM TB

A priori ozone distribution at 300 hPa

300 hPa

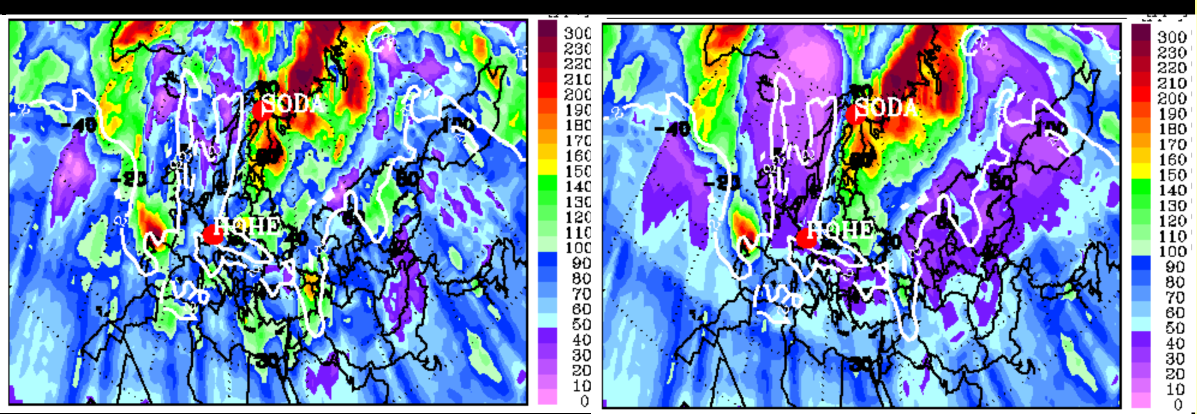




Tropopause height

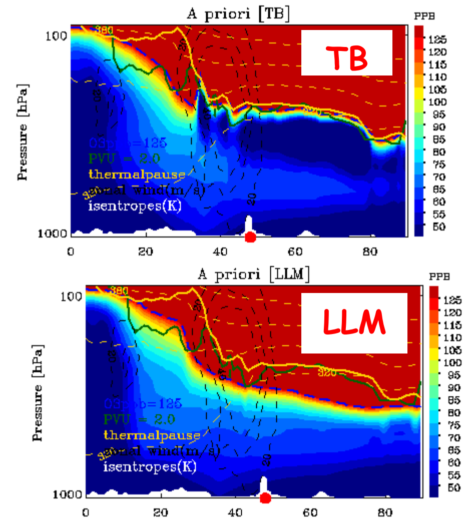
Retrieved OMI ozone

300 hPa



Vertical profile

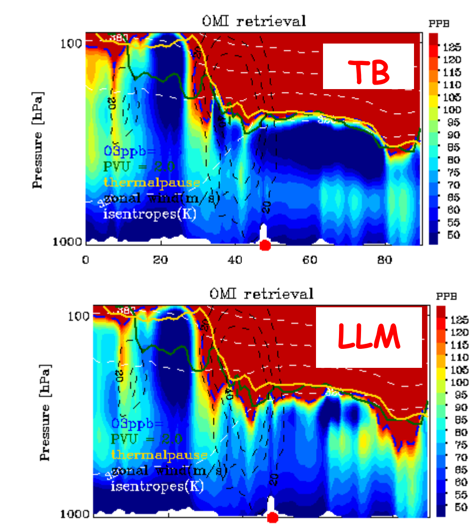
At 11.0°E



Green : dynamicpause(2PVU)

Yellow : thermalpause

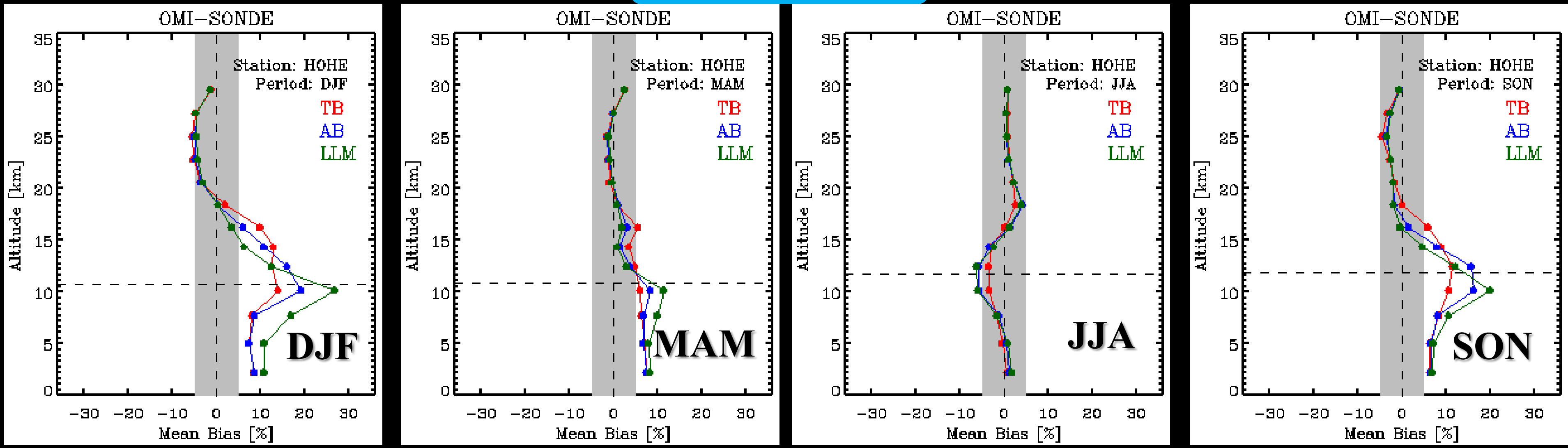
Blue : ozonepause(125ppb)



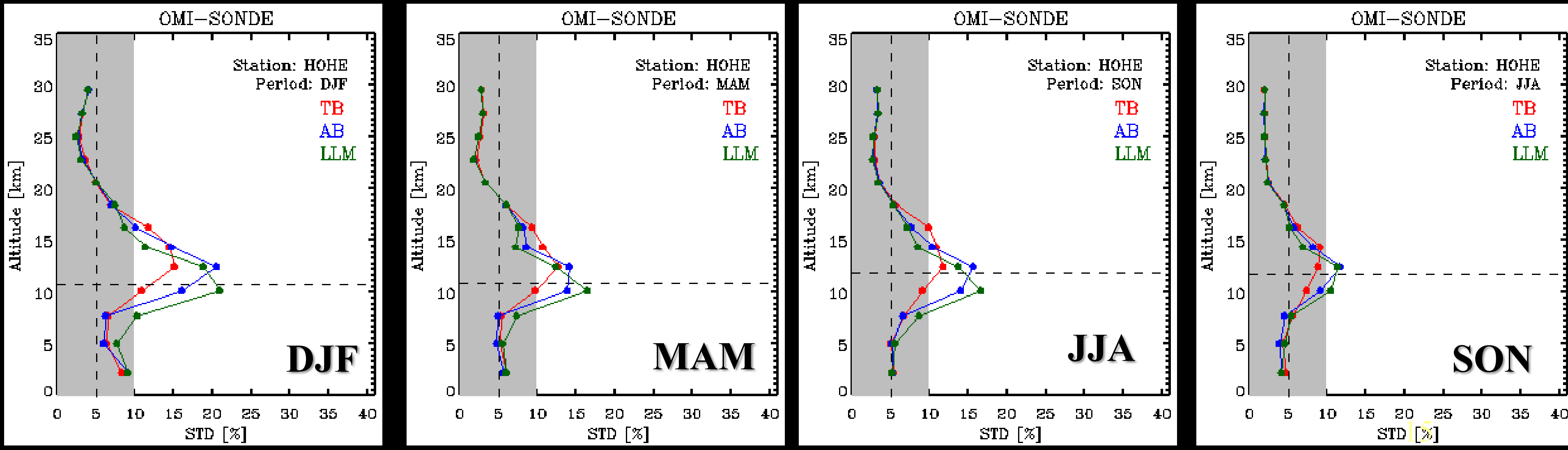
OMI - SON for four seasons

HOHE

mean bias



Standard deviation



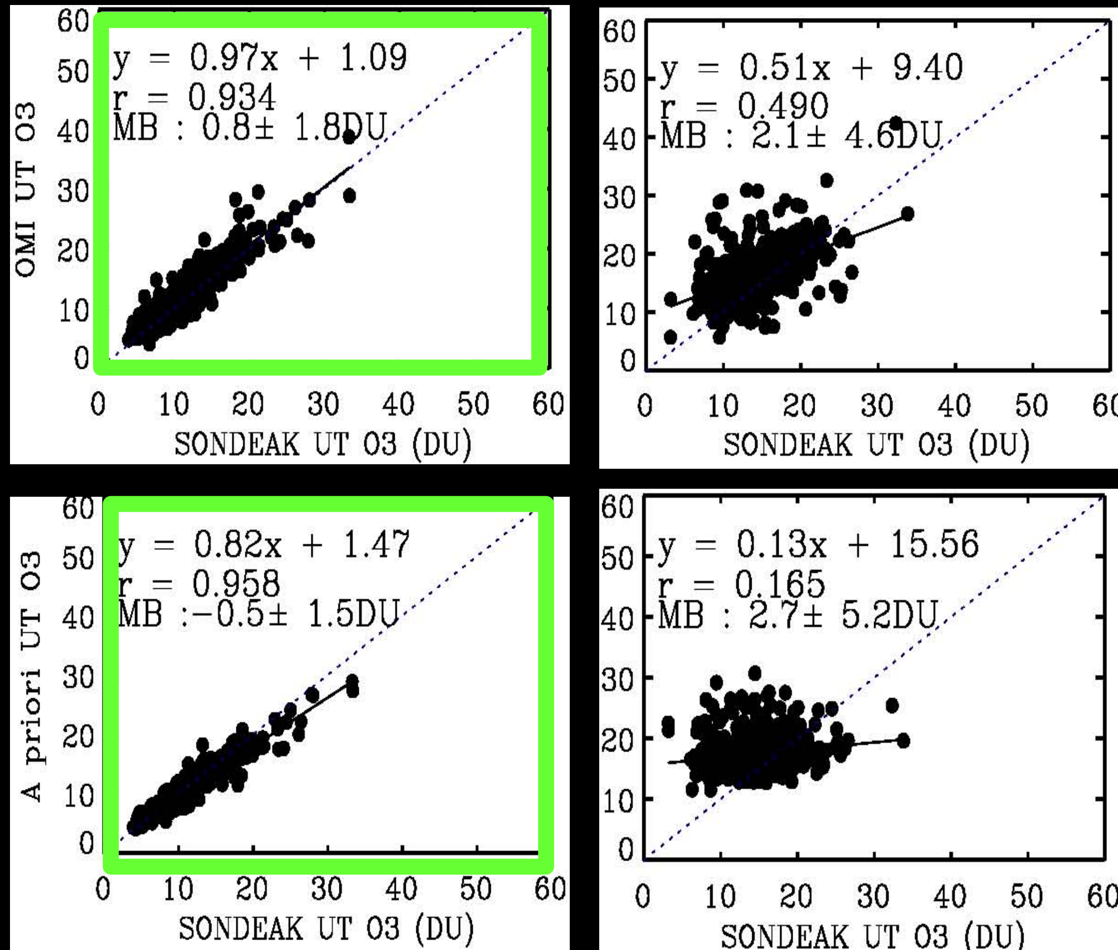
OMI VS SONDE

Scatter plot for the upper tropospheric column O3 at HOHE from the 2004-2008 years

TB LLM

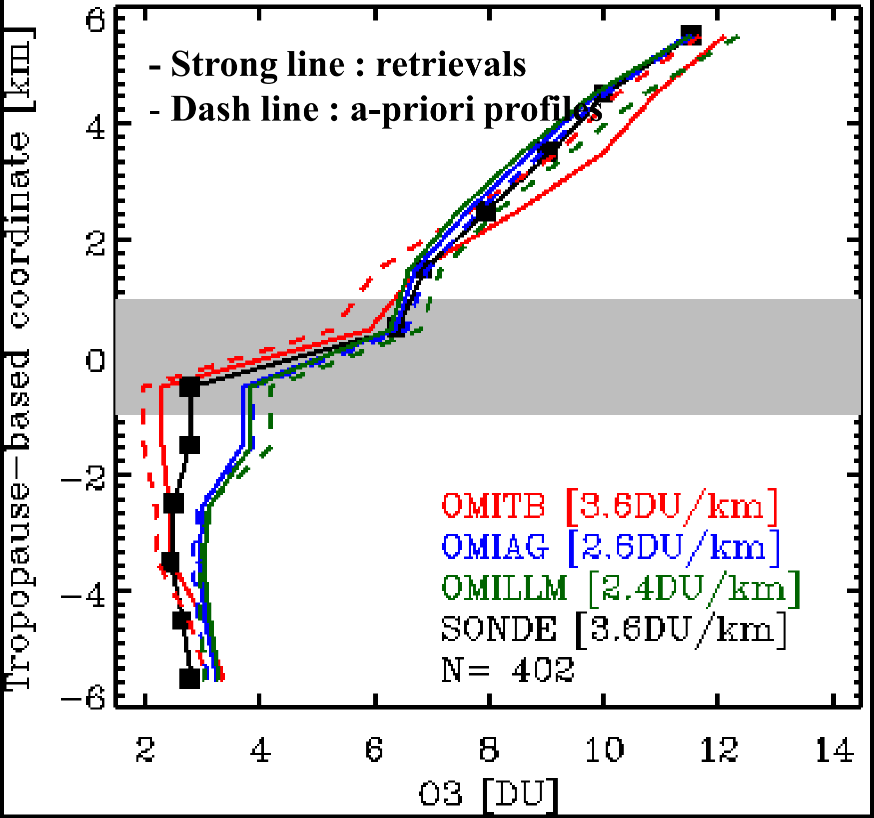
OMI retrievals

A Priori



Ozonesonde column ozone for the highest 5km of the troposphere

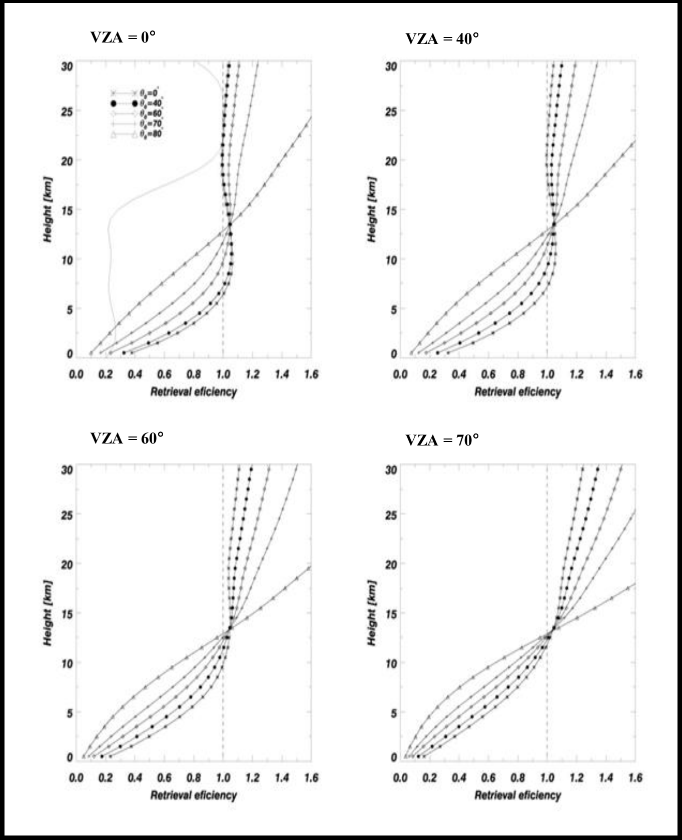
O3 gradient across tropopause
from the 2004-2008 years at HOHE



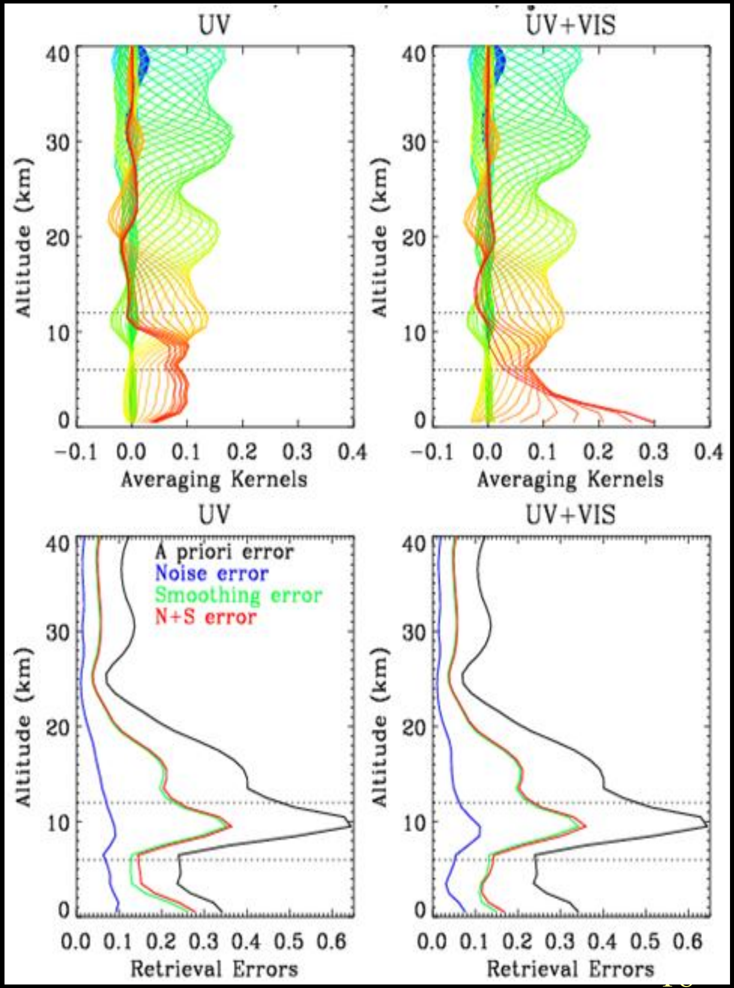
Using TB climatology provides better O3 structure near the tropopause than LLM and AB climatologies

Chappuis band

Ozone retrieval efficiency



Averaging Kernels



Spectral dependence of DFS

UV only measurement

DFS	Total	0-10 km	0-5 km
0.4 nm FWHM	5.10	1.38	0.88
0.6 nm FWHM	5.06	1.36	0.88
0.8 nm FWHM	5.02	1.33	0.87

UV +VIS measurement

DFS	Total	0-10 km	0-5 km
0.4 nm FWHM	5.49	1.73	1.17
0.6 nm FWHM	5.44	1.70	1.15
0.8 nm FWHM	5.39	1.66	1.13

Summary

- We optimized the use of the TB climatology in OMI ozone profile retrieval algorithm by combining with altitude-based climatologies derived from same dataset, because the benefit of TB climatology is limited to the UTLS region at mid/high latitudes.

- Validation of the outcomes w.r.t ozonesonde and dynamic variables supports that the TB climatology is best constraint in the lower stratosphere and upper troposphere.

- From the collaboration with Dr. Liu, we are able to learn how to use OEM and get to the level where we easily manipulate OEM

Future work

- There is an intrinsic problem of low retrieval efficiency for tropopsheric ozone under clear-sky condition. The only way to overcome this problem is measurements over clouds that provide high retrieval efficiency. We will further investigate how to improve tropospheric retrievals for this case.
- By applying the OEM over northeast Asia, we will get more experienced for OEM.