GEMS Workshop

"Evaluation of ozone profile and tropospheric ozone retrievals from GEMS and OMI spectra"

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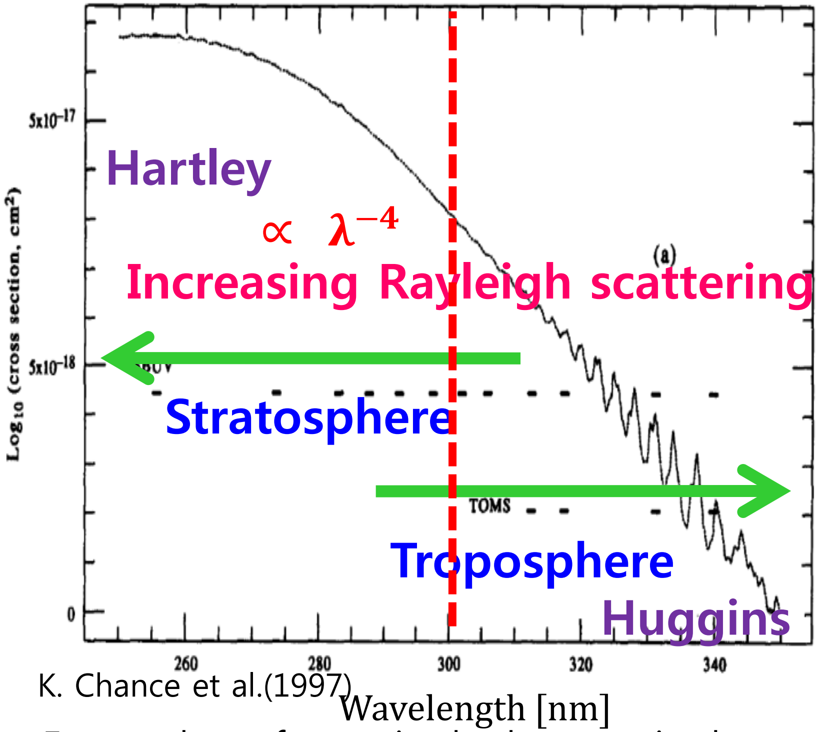
GEMS style vs. OMI style

Objective

Ozone absorption for UV



K. Chance et al.(1997)

- Four orders of magnitude decrease in the O_3 absorption cross section from 270 to 330 nm.

Comparison OMI VS GEMS

Instrument	Spectral Coverage	Spectral Resolution
OMI (2004-now)	270-500 nm	0.42-0.63 nm
GEMS	300-500 nm	0.6 nm

Fitting window for ozone
270 -330 nm
300- 330 nm

"Issues"

1) Is it possible for GEMS to obtain **tropospheric ozone information** comparable to OMI ?
2) What is possible **stratospheric ozone information contents** from the reduced GEMS spectral coverage ?

Ozone Profile algorithm

- **Main developer**: Xiong Liu (Harvard)
- **Principal theory:** optimal estimation tech. (Rodgers, 2000)
- **Heritage** : GOME, SCIAMARCY, OMI, GOME-2

Cost Function

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

Measured radiance

Current state vector

$$\mathrm{X}_{i+1} = \mathrm{X}_i + (K_i^T S_y^{-1} K_i + S_a^{-1})\{K_i^T S_y^{-1}[Y - F(x_i)] - S_a^{-1}(\mathrm{X}_i - \mathrm{X}_a)\}$$

Simulate radiances

A priori vector from LLM clima. (McPeters et al., 2007)

Measurement error A priori error

Ozone profiles by minimizing difference between measured and simulated radiances and difference between retrieved and a priori state vector with constraints of measurement and a priori errors.

Forward model : VLIDROT (Spurr, 2007)
A priori data : Monthly and latitude mean ozone profile climatology (McPeters et al. 2007)
Measurement errors : OMI level1 b random-noise error

Question 1

❖ Is the proposed GEMS ozone fitting window of the 300 - 330 nm enough to keep all tropospheric ozone information obtained by OMI ?

❖ Can we obtain any useful information on column amount and vertical distribution in the stratosphere ?

How to find the answers

❖ compare the retrieval performance of OMI (270-330 nm) to GEMS (300-330 nm).

Retrieval characteristics

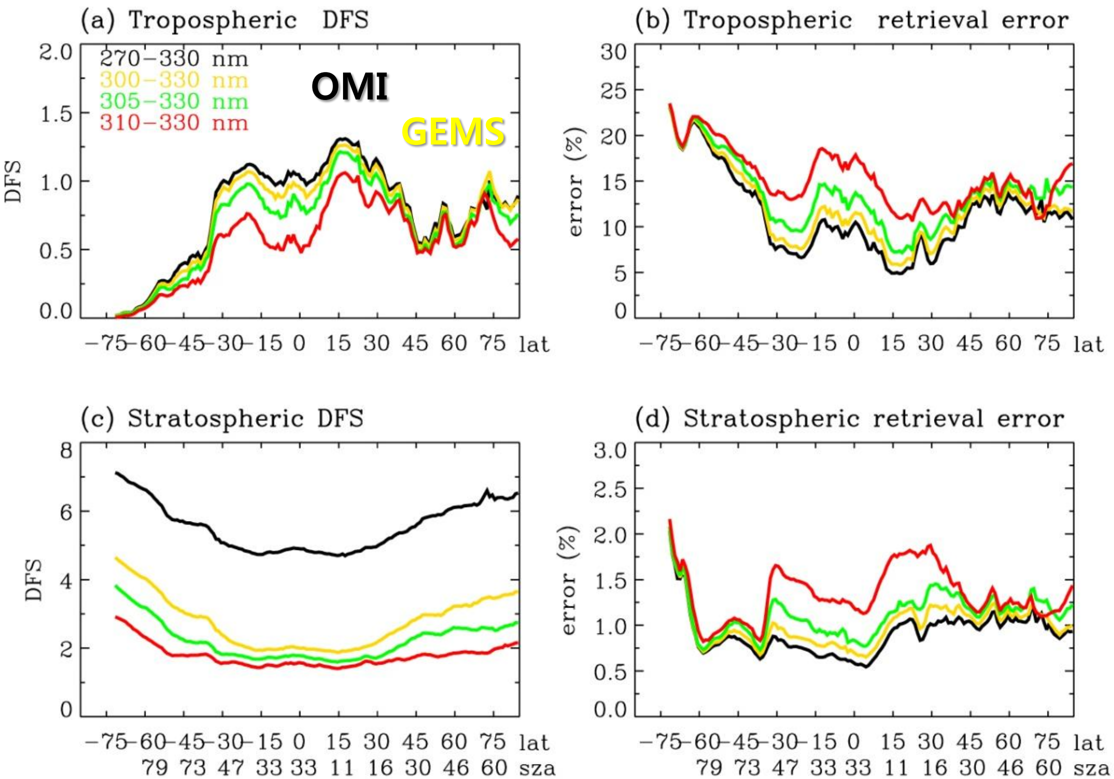
Averaging kernels (AK) : the sensitivity of the retrieved ozone at each layer to the perturbation of ozone at all layers

Degrees of freedom for signal (DFS) : the number of independent pieces of information available at that layer from measurements (Diagonal element of the AK matrix)

Solution errors : the root-sum-square of the random noise and the smoothing error

Column ozone information

Retrieval characteristics at the four spectral ranges between 270nm and 330 nm, calculated from OMI level 1b data on 30 April 2006.



♧ **Tropospheric ozone column retrievals**
- **comparable DFS** of 300-330 nm relative to 270-330 nm
- **comparable retrieval errors** of GEMS w.r.t GEMS

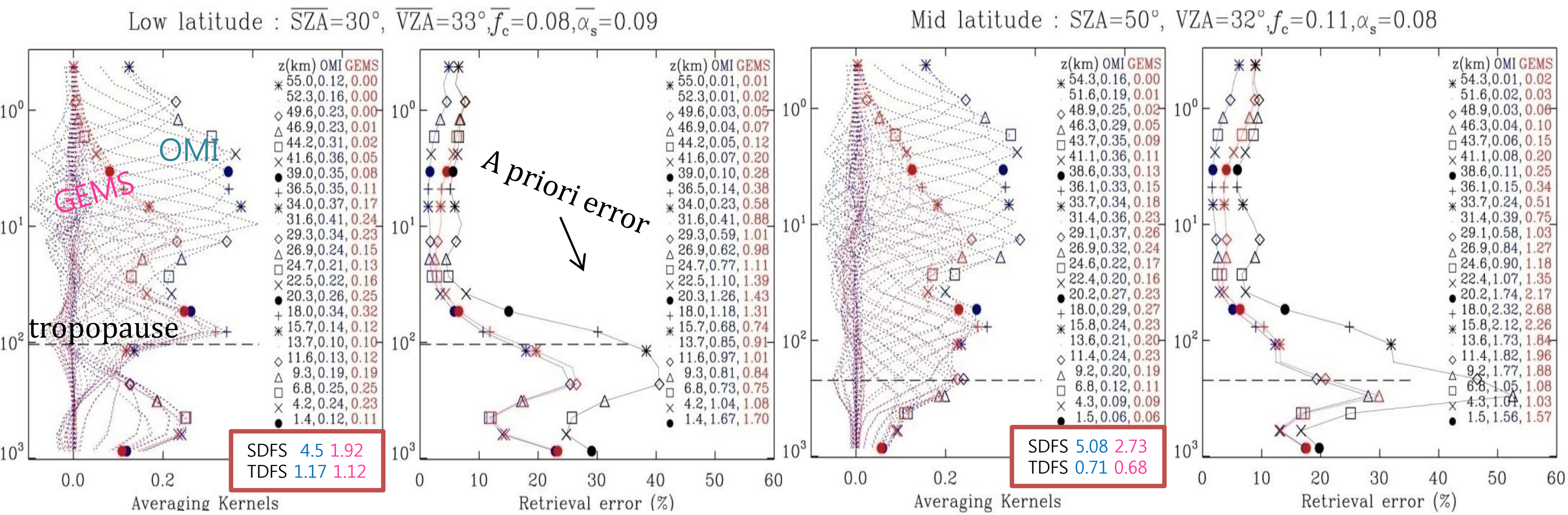
♧ **Stratospheric ozone column retrievals**
- **significant loss in the DFS** of 300-330 nm relative to that from 270-330 nm.
- The average DFS values decrease to **~3 for GEMS relative to ~ 6 for OMI.**
- GEMS **retrieval error for stratospheric column** is **similar to OMI.**

➢ **The proposed GEMS spectral coverage is nearly optimal for maximizing the tropospheric ozone information available from UV and for simplifying instrument design.**

➢ **The exclusion of spectral information below 300 nm substantially reduces stratospheric DFS.**

Ozone profile information

Which altitude of ozone retrievals will be influenced by excluding below 300 nm ?



- **AKs** for both instruments show **similar distribution below ~ 20 km**.
- GEMS obtains most of the tropospheric vertical ozone information comparable to OMI, and has a capability to separate tropospheric ozone from stratospheric ozone.
  - GEMS AKs show very **broad features above 30 km**, with rapid reduction in their DFS values.
- GEMS **retrieval errors** increase by 1-2 % for most of the stratosphere and by **3-4 % above ~ 40 km**, relative to OMI.
- The magnitude of GEMS retrieval errors becomes **close to a priori error above ~ 40 km**, indicating the weak retrieval sensitivity resulting in the strong influence of a priori on the retrievals.

Question 2

❖ **Is information obtained from GEMS spectra enough to resolve the true variability of the stratospheric ozone profiles ?**

❖ **What is the quality of GEMS stratospheric ozone product with respect to OMI ?**

How to find the answers

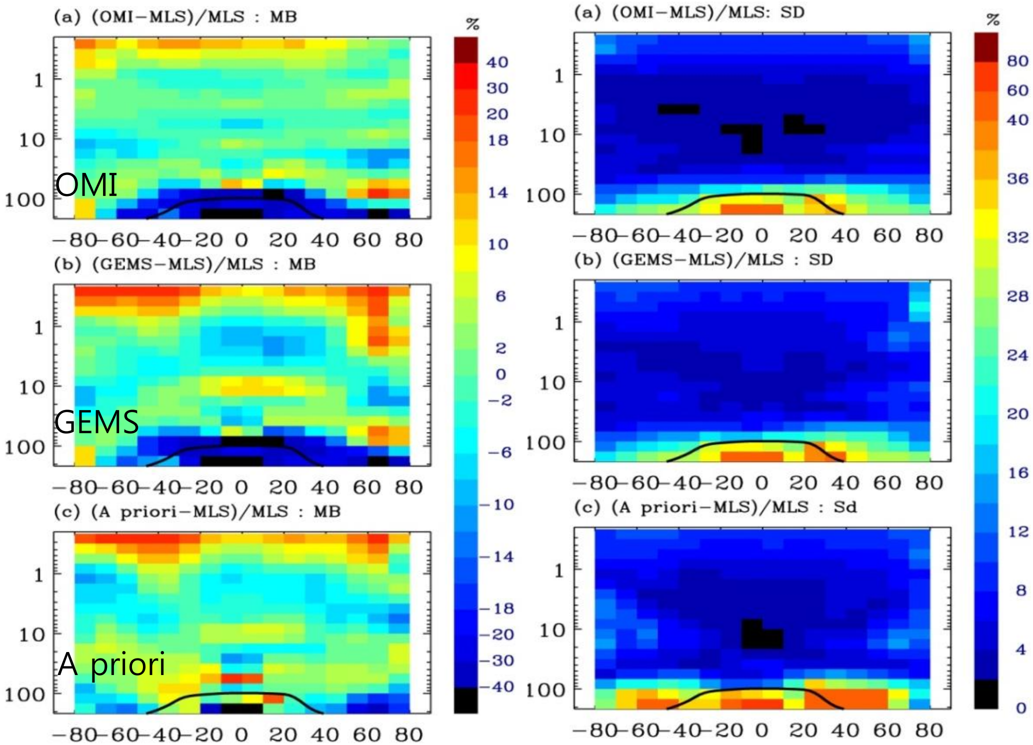
❖ **Compare the GEMS/OMI ozone profile retrievals with MLS ozone product for the altitude of 215 - 0.2 hPa for April 2006.**

MLS data

- **MLS is on board the Aura platform with OMI**, the effect of the spatiotemporal variability on comparisons with OMI is relatively small [Liu et al., 2010b].
- Collocate MLS and OMI pixels within ±0.5° in both lat and lon and 500 s in time, giving ~30, 000 pixels.
- MLS is **limb-viewing and thus has higher vertical resolution (~ 3km),** but much sparser horizontal coverage than OMI.
- The **precision** of ozone profile is ~ 5 % for much of stratosphere, ~ 10 % at the lowest stratospheric altitudes, and stratospheric column ozone down to 215 hPa is about 2 %.

Profile comparison

mean bias vs. 10° latitudinal bins at each MLS layer for 0.22-215 hPa and thier 1σ standard deviations



♧ **Tropopause (black line)**

- Both OMI and GEMS retrievals have a negative biases w.r.t MLS near the tropopause.

- Negative biases whitin -20 % to -40 % below 68 hPa at low/mid latitude and standard deviations 20% - 50%
  ➔ These large differences occur due to insufficient vertical resolution of nadir viewing measurements relative to high vertical resolution MLS data as well as systematic biases between OMI/GEMS and MLS from the comparison with a priori biases (positive).

♧ **The largest impact of the exclusion below 300 nm is mainly found for altitude above ~ 40 km**

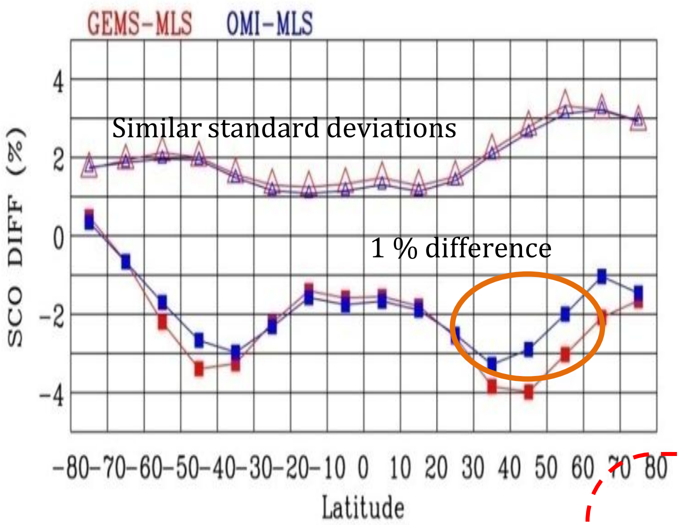
➔ corresponse to altitude where no peak in GEMS Aks is found and the retrieval error is close to a priori.

➔ the large GEMS biases of ~ 20 % above ~40 km comes from the a priori

- GEMS retrievals have more vertical oscillation in the biases between 1-50 hPa especially in tropical region
- However, because the SD is small in the middle to upper stratospheric ozone, better a priori could reduce GEMS error in these altitude ranges due to small degree of freedom.

Stratospheric column ozone comparison

Comparison of stratospheric column ozone (SCO) from 0.2 to 215 hPa as function of latitude



The GEMS show <u>negative biases of less than 4%</u> for stratospheric column ozone, with <u>standard deviations of 1-3%,</u> while **OMI** show similar tendency except for <u>1% smaller biases at mid and high northen latitudes</u>

The SCO nagative biases might be largely contributed by the retrievals in the UTLS region.

Positive biases above 68 hPa and negative biases below it for sub-layer column O3

Weak sensitivity of GEMS

Lat.	GEMS – MLS Bias±1σ[a]	R[b]	OMI – MLS Bias±1σ	R	A priori – MLS Bias±1σ	R
Upper column O_3 [0.2 hPa - 1 hPa]						
0ºN-30ºN	0.02±0.07 (1.7±5.3)	0.04	0.04±0.07 (3.2±5.5)	0.19	0.04±0.07 (3.0±5.5)	0.02
30ºN-60ºN	0.09±0.10 (7.7±8.1)	–0.06	0.02±0.07 (1.9±6.1)	0.64	0.07±0.08 (6.1±7.0)	0.28
60ºN-90ºN	0.10±0.18 (9.8±15.5)	–0.21	-0.01±0.08 (–0.9±7.2)	0.64	0.04±0.12 (3.9±10.7)	0.04
Middle column O_3 [1 hPa - 68 hPa]						
0ºN-30ºN	2.23±3.65 (1.0±1.6)	0.83	1.42±2.86 (0.6±1.2)	0.89	2.76± 5.54 (1.3±2.4)	0.44
30ºN-60ºN	4.00±7.10 (1.7±3.0)	0.88	0.44±5.65 (0.2±2.4)	0.92	1.22±12.52 (0.7±5.4)	0.04
60ºN-90ºN	4.85±8.28 (2.2±3.7)	0.92	1.75±7.05 (0.8±3.2)	0.93	2.98±14.49 (1.7±6.6)	0.54
Lower column O_3 [68 hPa – 215 hPa]						
0ºN-30ºN	–7.09± 3.72 (–40.7±15.7)	0.91	–6.53± 3.62 (–37.3±16.3)	0.92	0.17± 5.58 (4.1±26.8)	0.75
30ºN-60ºN	–15.48±11.96 (–20.8±16.0)	0.94	–9.09±11.18 (–13.0±15.3)	0.96	–5.45±25.32 (1.6±30.6)	0.70
60ºN-90ºN	–12.19±15.27 (–8.4±10.7)	0.81	–7.88±14.67 (–5.3±10.2)	0.83	–17.03±21.00 (–10.4±13.9)	0.43

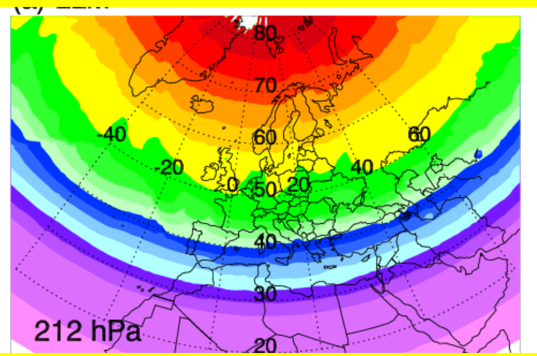
Significant information from OMI and GEMS

Future Study

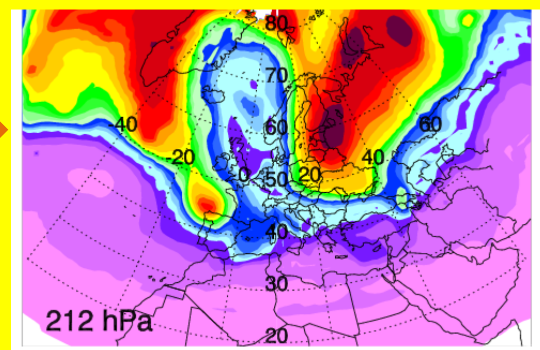
- **Need an algorithm improvement for ozone retrieval in UTLS region**
- **Optimize the *a priori information* for GEMS ozone profile retrievals.**

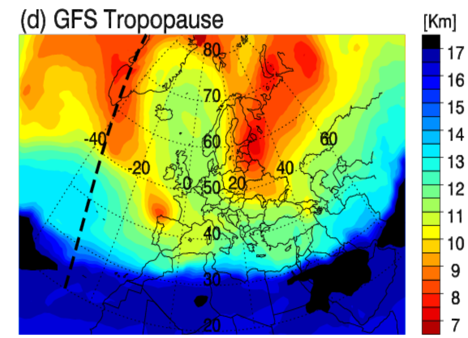
J. Bak et al., (2012) : Improvement of OMI ozone profile retrievals in the upper troposphere and lower stratosphere by the use of the **tropopause-based ozone profile climatology,** in preparation

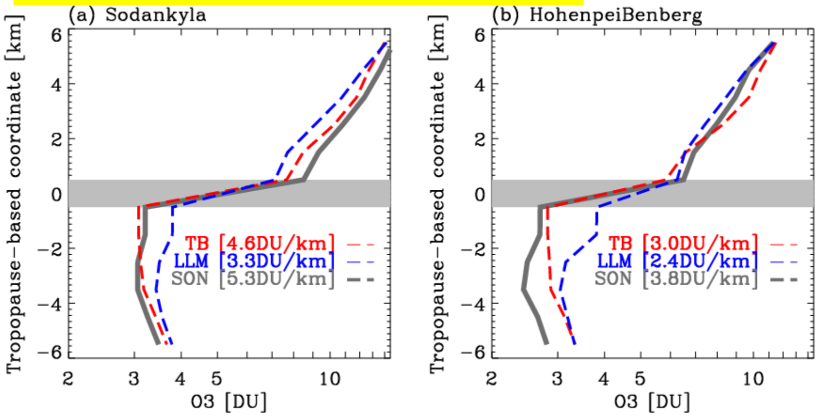
LLM Clima. (2007)



TB Clima. (2012)







- **The use of TB climatoloy** provide substantial improvements in retrievals for the extratropical lowermost stratosphere and UT
- The combination with hourly based tropopause information could be the best a priori constraints for future GEMS retrievals.

Averages of ozonesonde profiles (gray lines) as a function of altitude relative to the tropopause during the period 2004-2008 at four stations, and avreages of collocated OMI profiles retrieved based on TB (red lines), and LLM(bluelines) climatologies, respectively. The given values in the unit of DU/km represent the vertical gradient of the ozone profiles across the tropopause

Future Study

Optimize the *a priori information* for GEMS ozone profile retrievals.

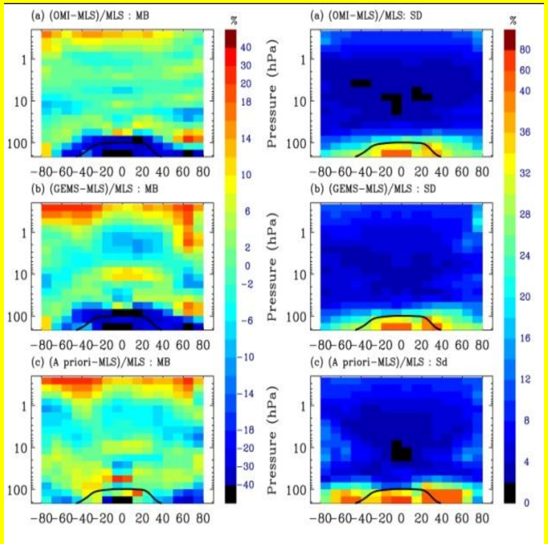
♧ The GEMS ozone profile retrievals above ~ 40 km can be improved by better a priori information

- Use of the ML climatology greatly improves the GEMS/OMI retrievals above ~40 km.
- Even for below ~40 hPa, some improvements are found outside of the UTLS region.

- However, <u>the use of ML cli matology in the retrievals te nds to make worse near the UTLS compared to the LLM climatology.</u>

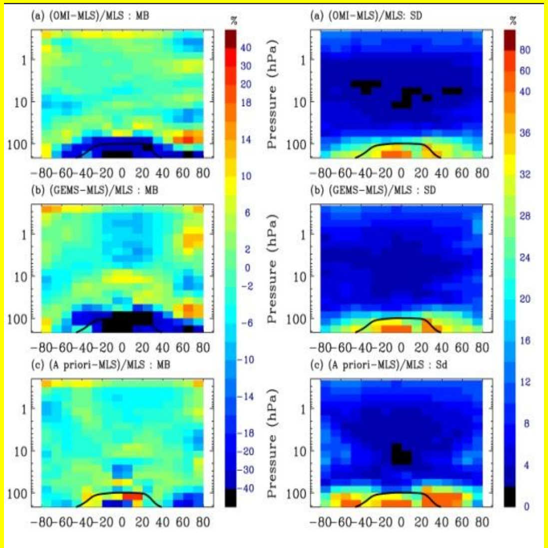
➔ Need further analysis for the best use of ML climatology for GEMS/OMI retrievals.

LLM Clima. (2007)



ozonesondes (1988–2002), SAGE II (1988–2001), and Upper Atmosphere Research Satellite (UARS) MLS (1991–99)

ML Clima. (2012)



Aura MLS V3.3 data (2004-2010) and ozonesonde data (1988-2010).

Summary

- Proposed GEMS spectral coverage is nearly optimal for maximizing the tropospheric ozone information available from UV measurements.

- Exclusion of spectral information below 300 nm leads to loss of stratospheric ozone information mostly above ~20 km and no information above ~40 km.

- Comparison with MLS data exhibits
  1) the simialr ability to retrieve the stratospheric column ozone and profiles below ~ 40 km relative to OMI.
  2) the severe weakness of GEMS for retrieving ozone profiles above ~ 40 km.

  ➡ Because upper stratospheric region has small dynamic variability, improvement of a priori could reduce the error occuring due to small DFS of GEMS.

- Found large negative biases in both OMI and GEMS w.r.t MLS data near tropopause. ➔ This bias can be rduced the GEMS retrievals by using better a priori profile associated with dynamic variability such as TB climatology.

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