
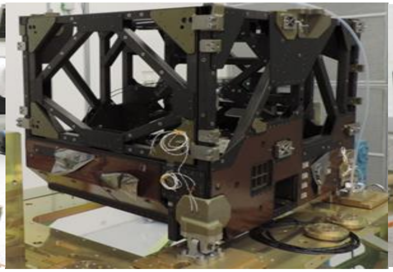
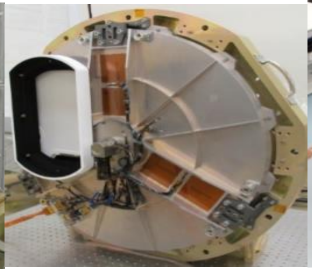

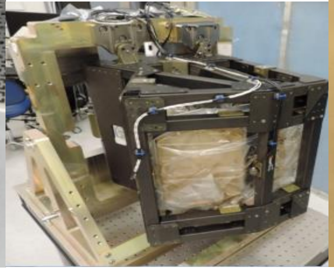
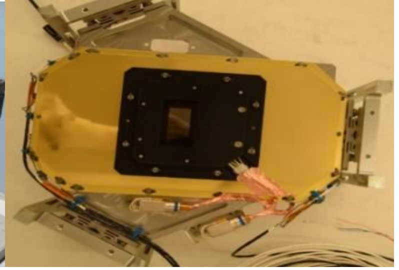
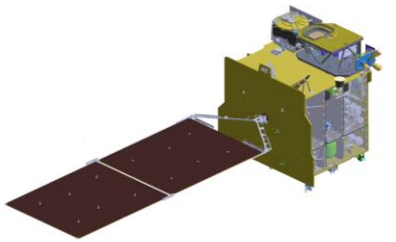

The current status of GEMS ozone measurement

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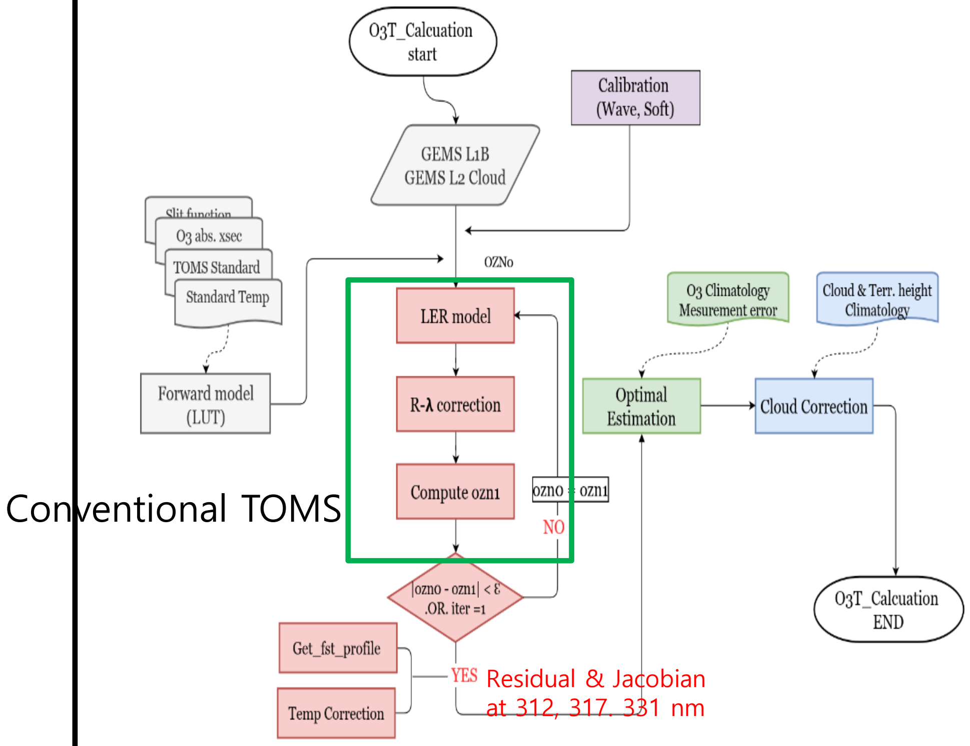
GEMS

환경부

Contents of this presentation

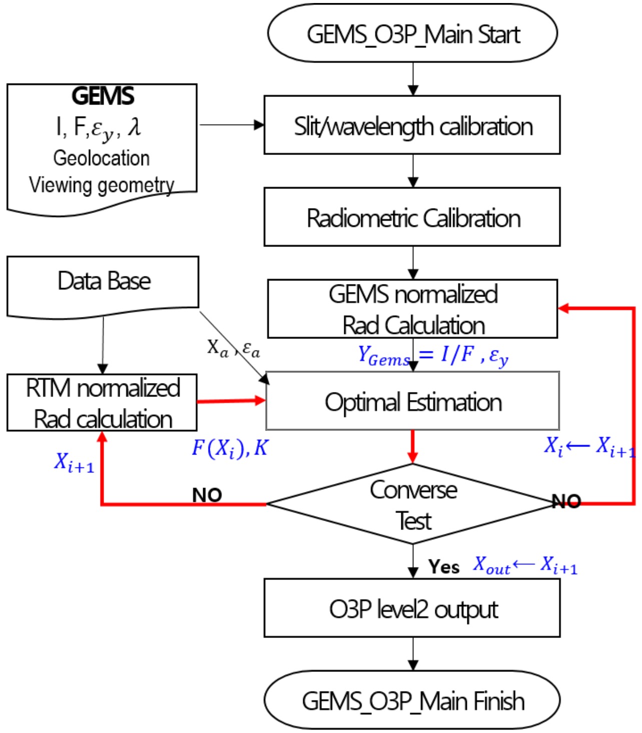
Flowchart of GEMS O_3 algorithm

GEMS Total Ozone Algorithm



- Used New NASA/TOMS V9 algorithm
- retrieved total ozone with (312.5, 317.5 331nm) and then optimized them to get final total ozone

GEMS Ozone Profile Algorithm



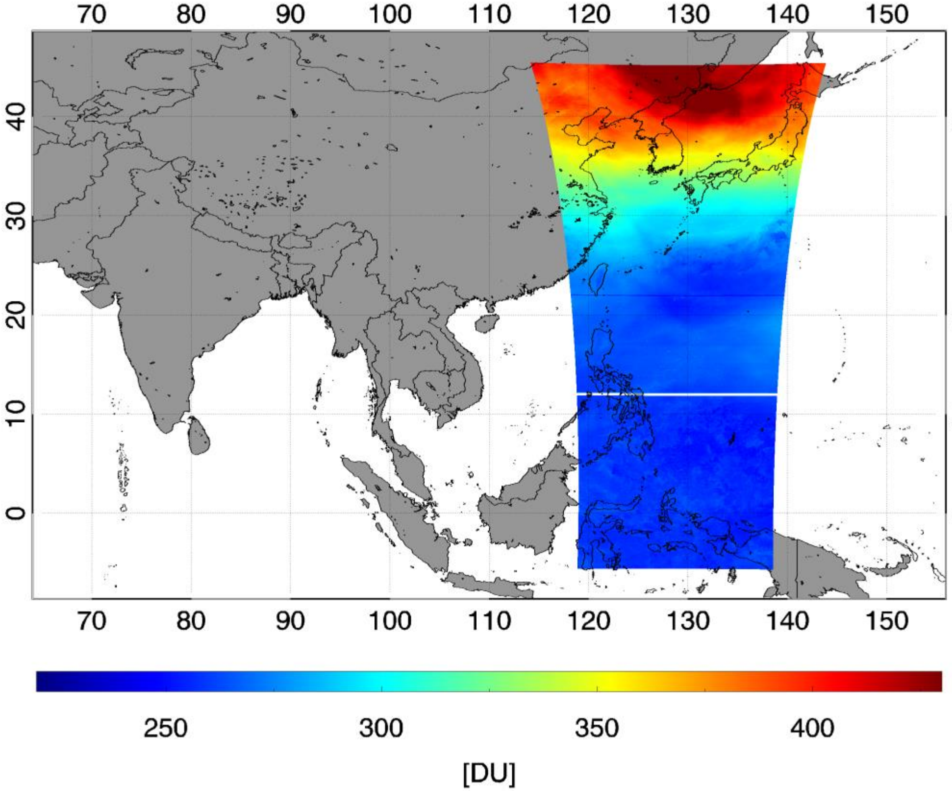
- Used SAO Optimal Estimation Method
- Ozone fitting window of 300-340 nm

ML climatology (Mcpeter 2011) for a-proiori ozone profile
VLIDORT 2.6 for RTM with BDM ozone cross-section

GEMS hourly total column ozone distribution

- **GEMS diurnal observation [29 March, 2021]**

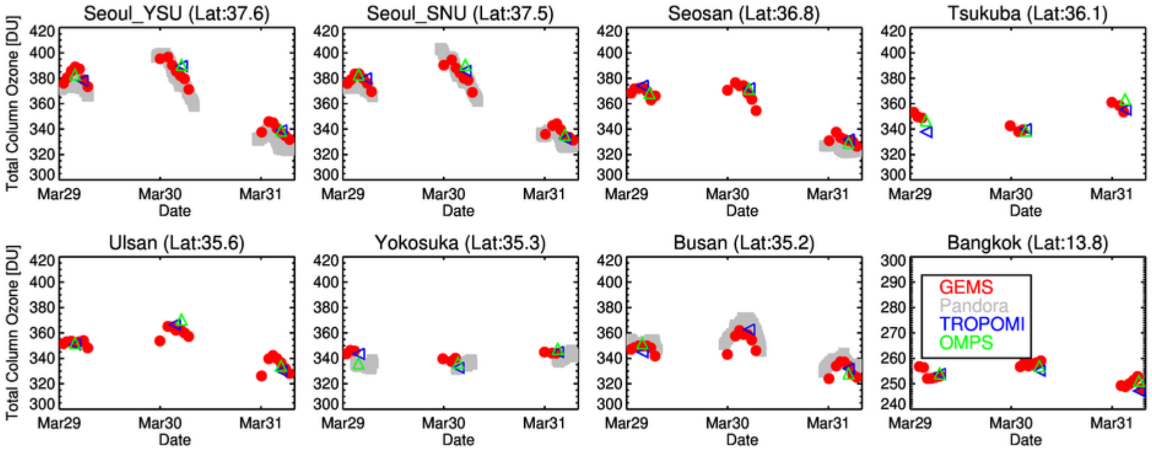
Total Column Ozone
2021/03/29 00:45 UTC



- GEMS observes diurnal variations in total column ozone for the first time.

- A typical ozone distribution in March: Values are highest at high latitudes; decreasing towards the equator

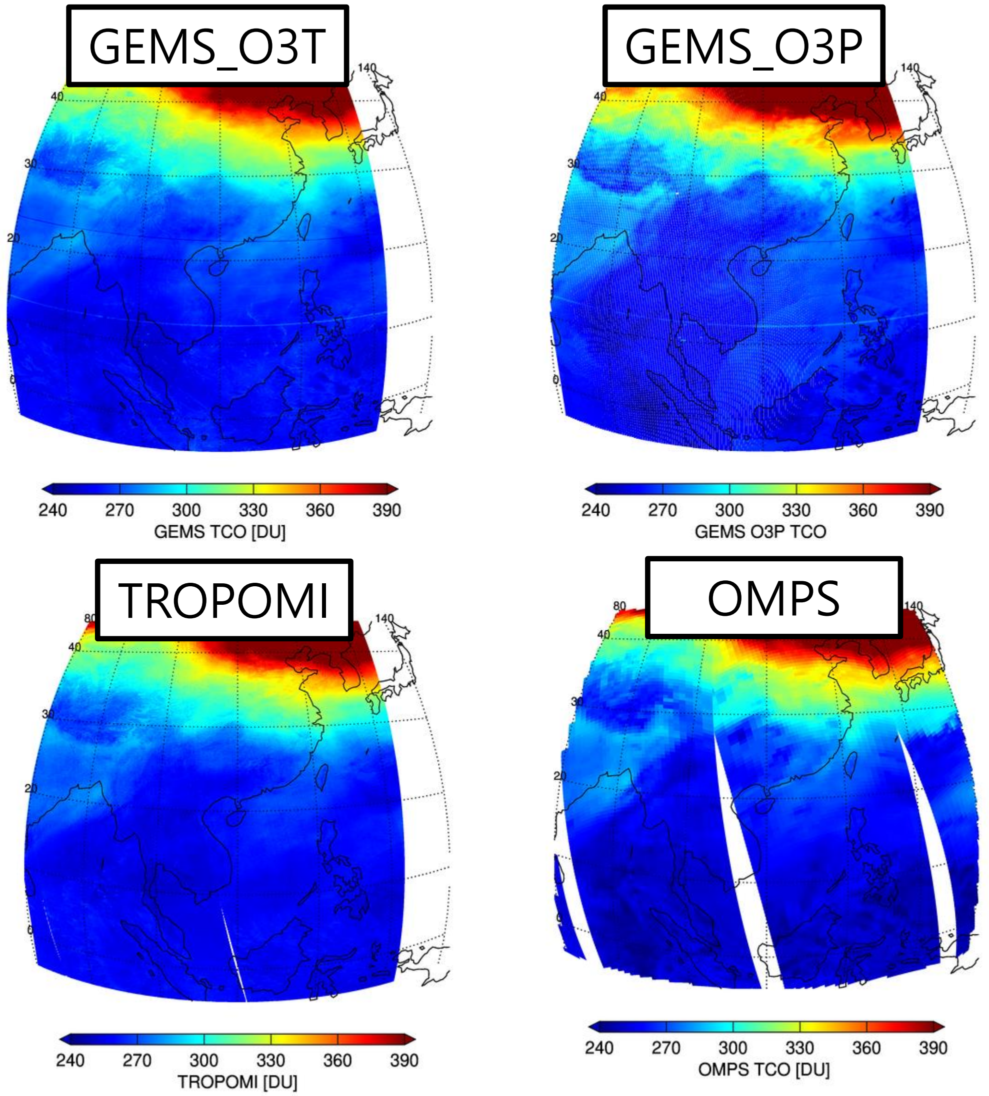
29 March, 2021 to 31 March 2021



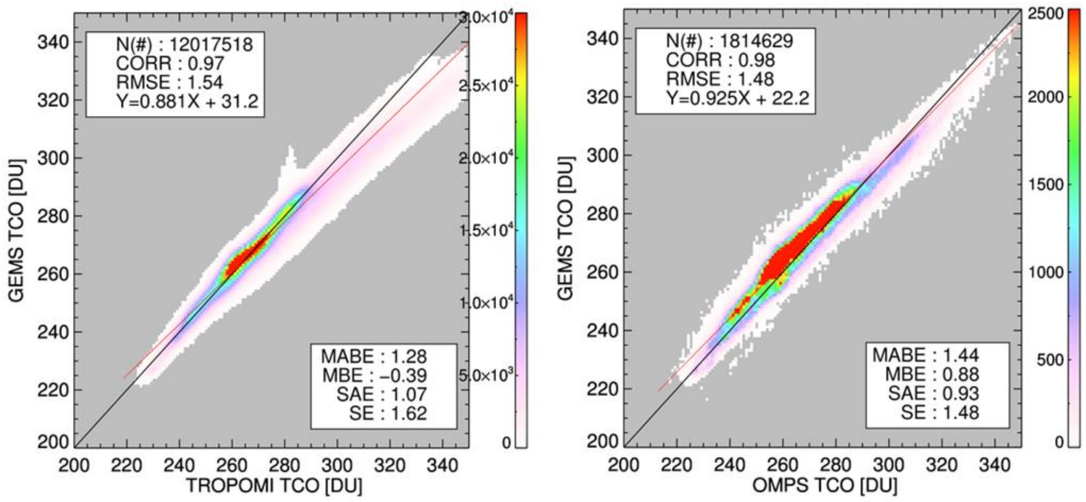
This is the comparison of GEMS hourly ozone with Pandora observed for three consecutive days. It shows that GEMS captures ozone diurnal variation well.

GEMS TCO validation w.r.t. TROPOMI and OMPS TCO

GEMS TCO at 13:45 KST in 29 March 2021



- Clear case (reflectivity < 10 %)

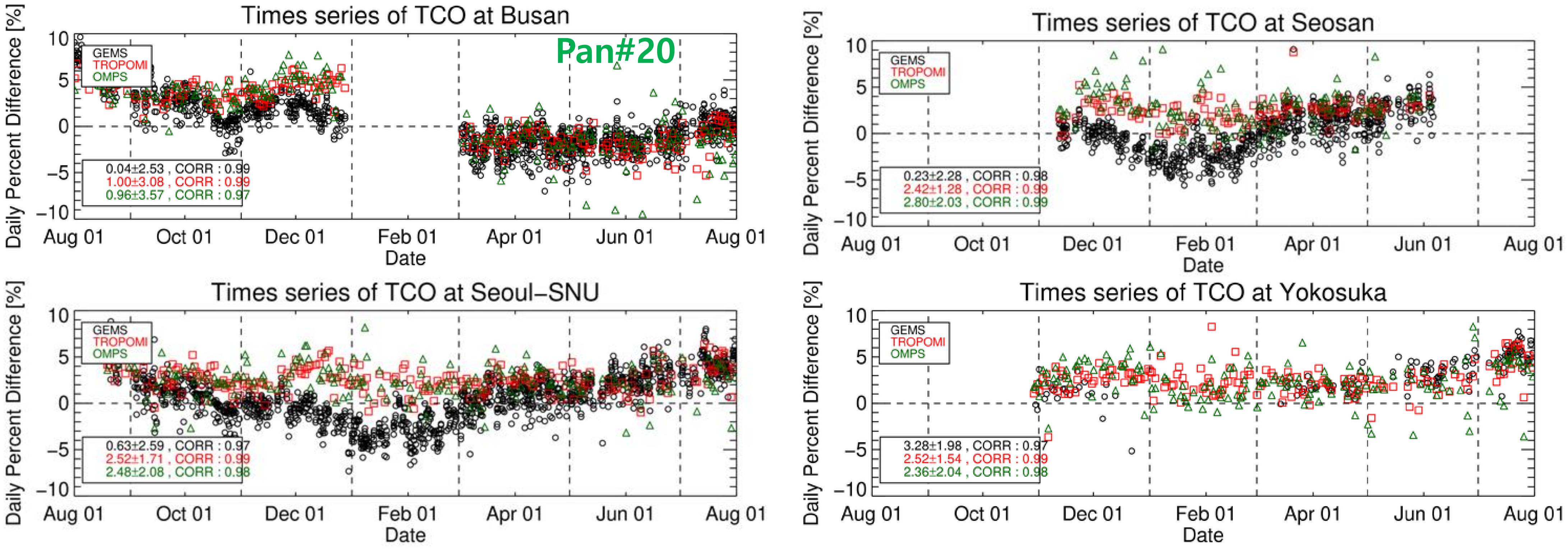


- A good Correlation coefficient of 0.97, RMSE of 1.5 DU and MB of ~ < 1 % for clear sky condition.
- GEMS TCO underestimates by - 0.4 % (1.2 DU) relative to TROPOMI and overestimates by +0.9 % (2.8 DU) relative to OMPS.
- Three satellite total ozone measurements show a good agreement in spatial and temporal distribution.
- GEMS agree with OMPS total ozone better than TROPOMI, probably because the two algorithms are similar.

Comparison of GEMS, TROPOMI, and OMPS total ozone w.r.t. ground Pandora total ozone

PD = (SAT-PAN)/Pan * 100

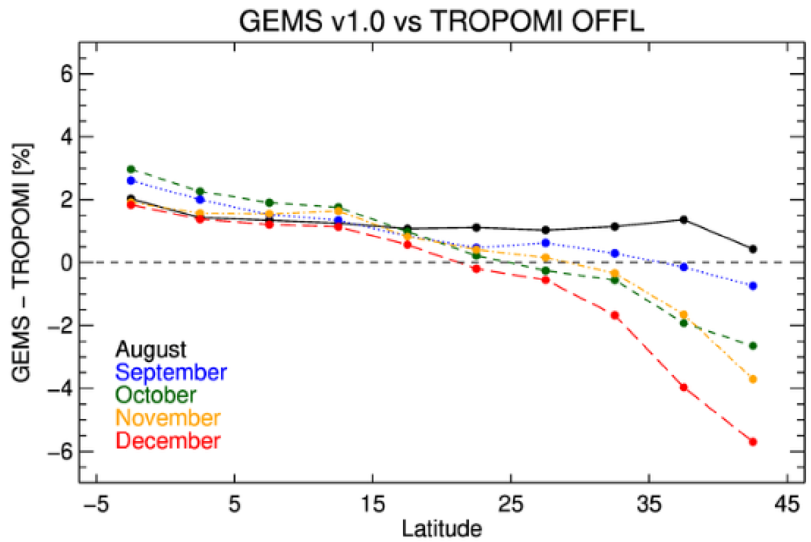
2020.08 ~ 2021. 08 (operational PGN sites)

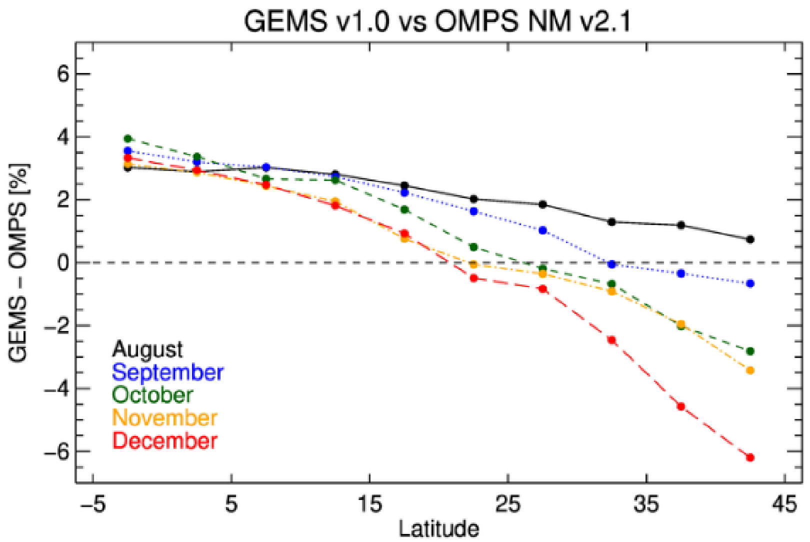


- Time series of GEMS TCO agree well with that of Pandora TCO (R > 0.98, RMSE < 2 DU, MB < 1 %).
- Compared with other satellite measurements, GEMS total ozone shows the time dependence

Spatial and temporal dependence of GEMS TCO

GEMS- SAT [%] with latitude for each given month.

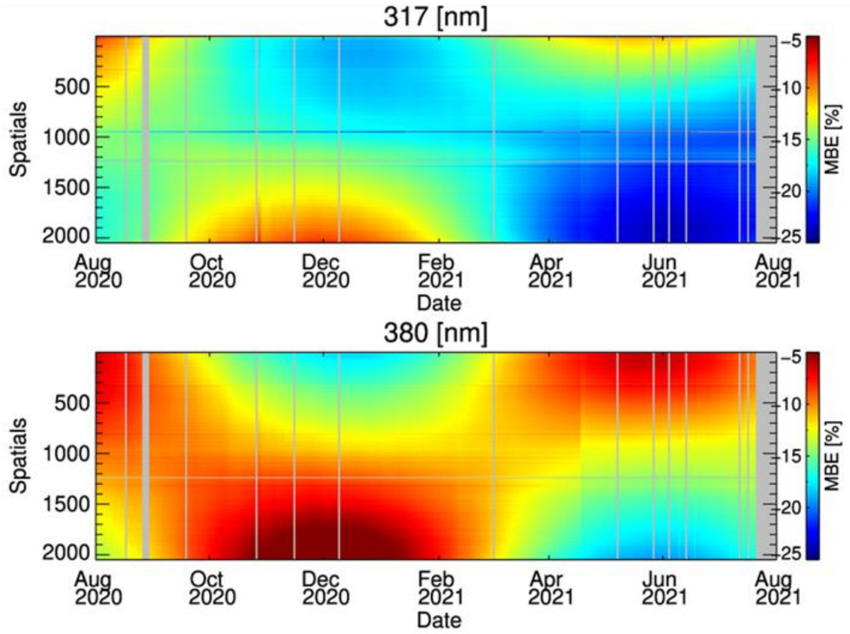




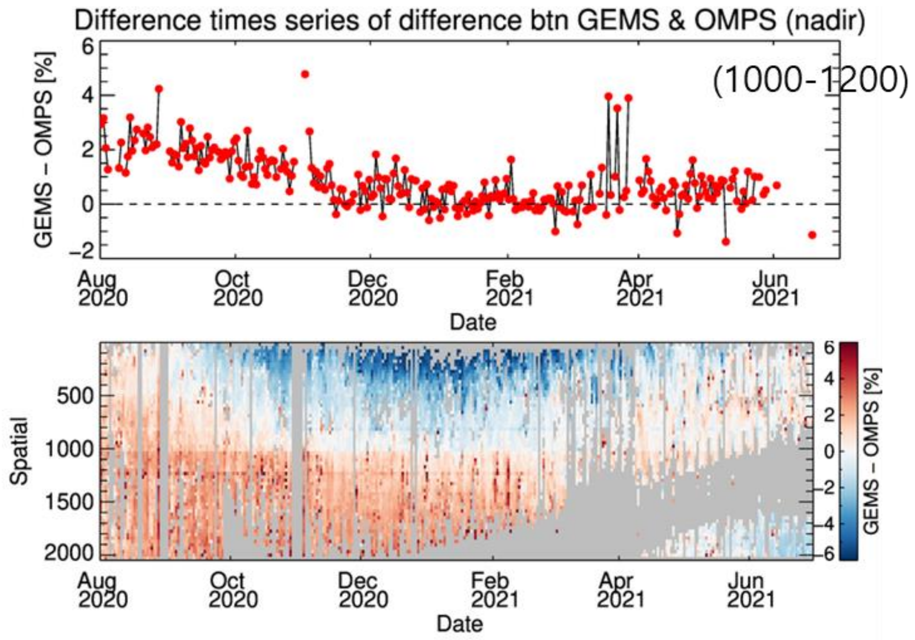
- This shows the variation of the difference between GEMS and two satellites with latitude in a given month..
- A clear trend is observed from low latitudes to high latitudes and from August to December.

Spatial, temporal, and spectral dependence of GEMS solar irradiance measurement

Normalized solar irradiance difference
(GEMS each_day – TSIS-1)/TSIS-1*100



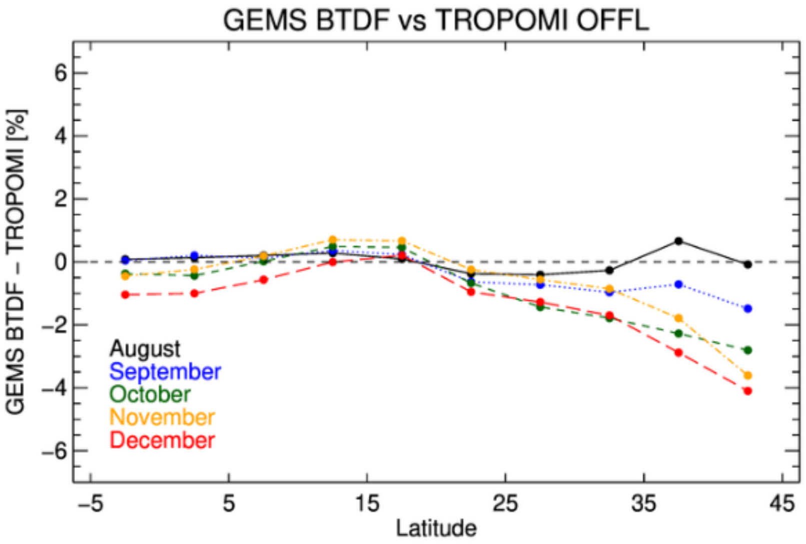
Normalized total ozone difference
$(GEMS_{each\_day}$ - OMPS)/OMPS*100

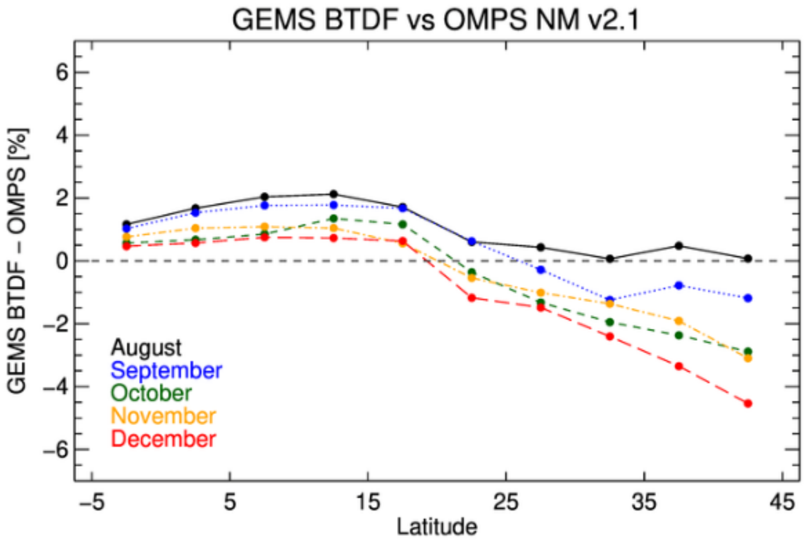


- The GEMS irradiance was 20% smaller than that of the reference spectrum and showed distinct spatial and seasonal variability
- It shows that the difference between GEMS and OMPS varies with spatial and temporal distribution
- This total ozone difference is strongly correlated with solar irradiance difference in spatial and temporal distribution

The effect of the BTDF correction on GEMS O3T

Kang et al., (2022)





- After applying the BTDF correction, the spatial and temporal trend decreased, but still remained.
- It is still necessary to calibrate the GEMS solar irradiance measurements

Overview of GEMS O3P Algorithm

- Optimal Estimation Method by X. Liu (SAO)
- GEMS L1B fitting window: 300-340 nm.
- Input data: normalized radiance

$$\frac{Radiance}{Solar\ Irradiance}$$

- Radiative Transfer Model: VLIDORT v2.6

➔ BDM O3 cross-section

➔ Slit Function : pre-flight measurements slit function

➔ OMI Raman cloud product, OMI surface albedo climatology

➔ KMA UM temperature profile, surface pressure,
surface temperature (1x1 deg, 26 levels)

- A priori: ozone climatology (Bak et al., 2013)

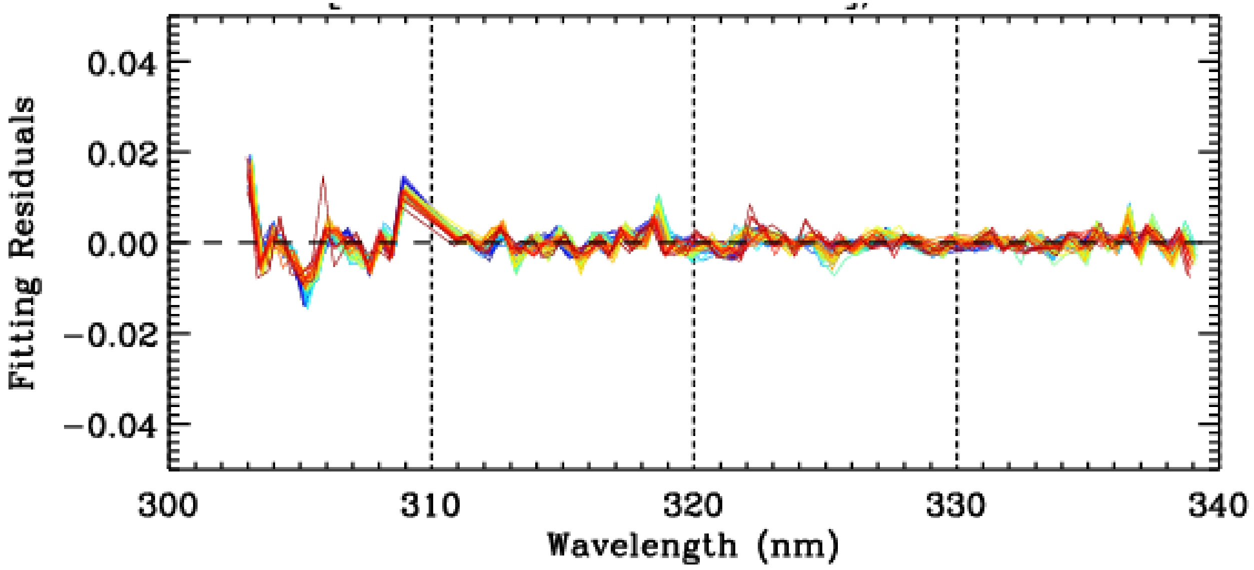
OEM: Minimize the cost function

$$\chi^2 = \left\| \mathbf{S}_y^{-\frac{1}{2}} \{ \mathbf{K}_i (\mathbf{X}_{i+1} - \mathbf{X}_i) - [\mathbf{Y} - \mathbf{R}(\mathbf{X}_i)] \} \right\|_2^2 + \left\| \mathbf{S}_a^{-\frac{1}{2}} (\mathbf{X}_{i+1} - \mathbf{X}_a) \right\|_2^2$$

$$\mathbf{X}_{i+1} = \mathbf{X}_i + (\mathbf{K}_i^T \mathbf{S}_y^{-1} \mathbf{K}_i + \mathbf{S}_a^{-1})^{-1} \{ \mathbf{K}_i^T \mathbf{S}_y^{-1} [\mathbf{Y} - \mathbf{R}(\mathbf{X}_i)] - \mathbf{S}_a^{-1} (\mathbf{X}_i - \mathbf{X}_a) \}$$

$$\text{nomalized radiance} = \frac{Radiance}{Solar\ Irradiance}$$

$$\text{Fitting residual} = \frac{(GEMS\ N.R - VLIDORT\ N.R.)}{VLIDORT\ N.R.}$$



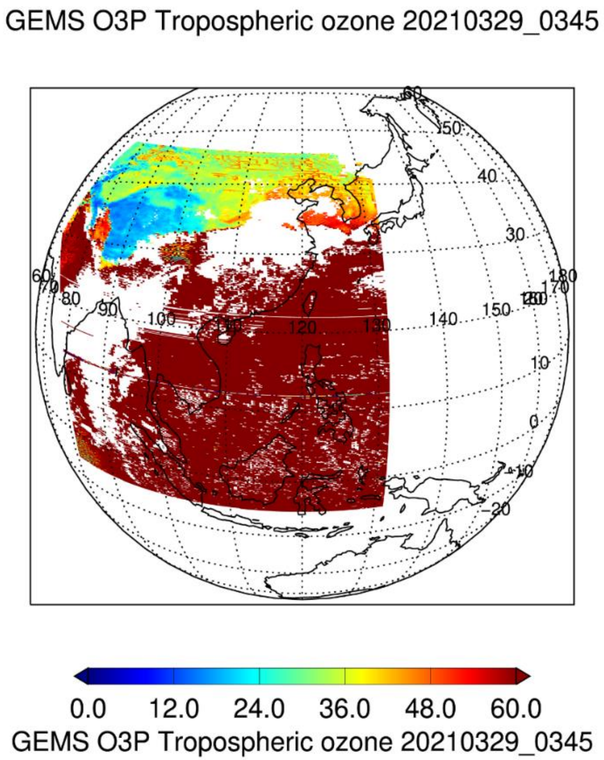
We want the fitting residual to converge close to zero over a given ozone fitting window range.

The following three cases may occur during the optimization process due to GEMS measurement errors

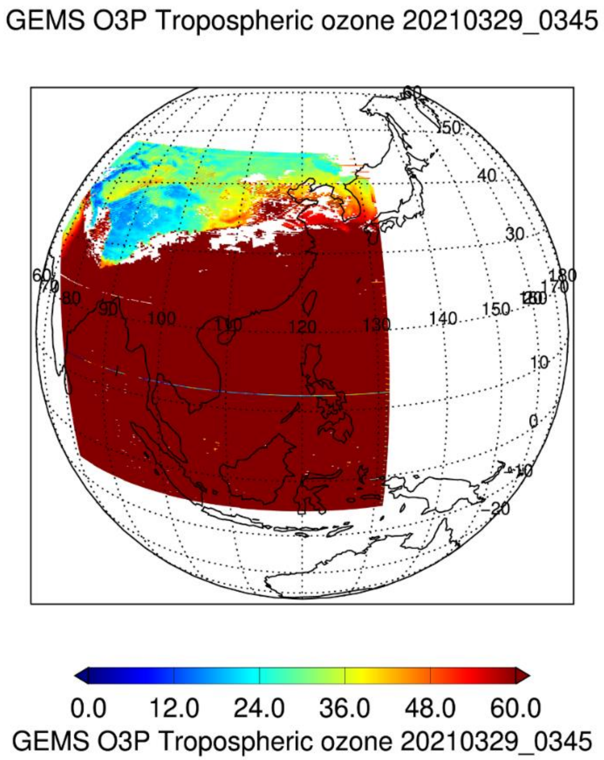
1. The retrieval process ends when the fitting residual successfully converges to near zero over the ozone fitting window of 300-340 nm.
2. If it fails to reach convergence after a few iterations, the retrieval will be stopped
3. If the fitting residual becomes large, the retrieved value leads to a large error.

GEMS tropospheric ozone retrieval with ozone-fitting windows

300-340 nm ozone fitting window



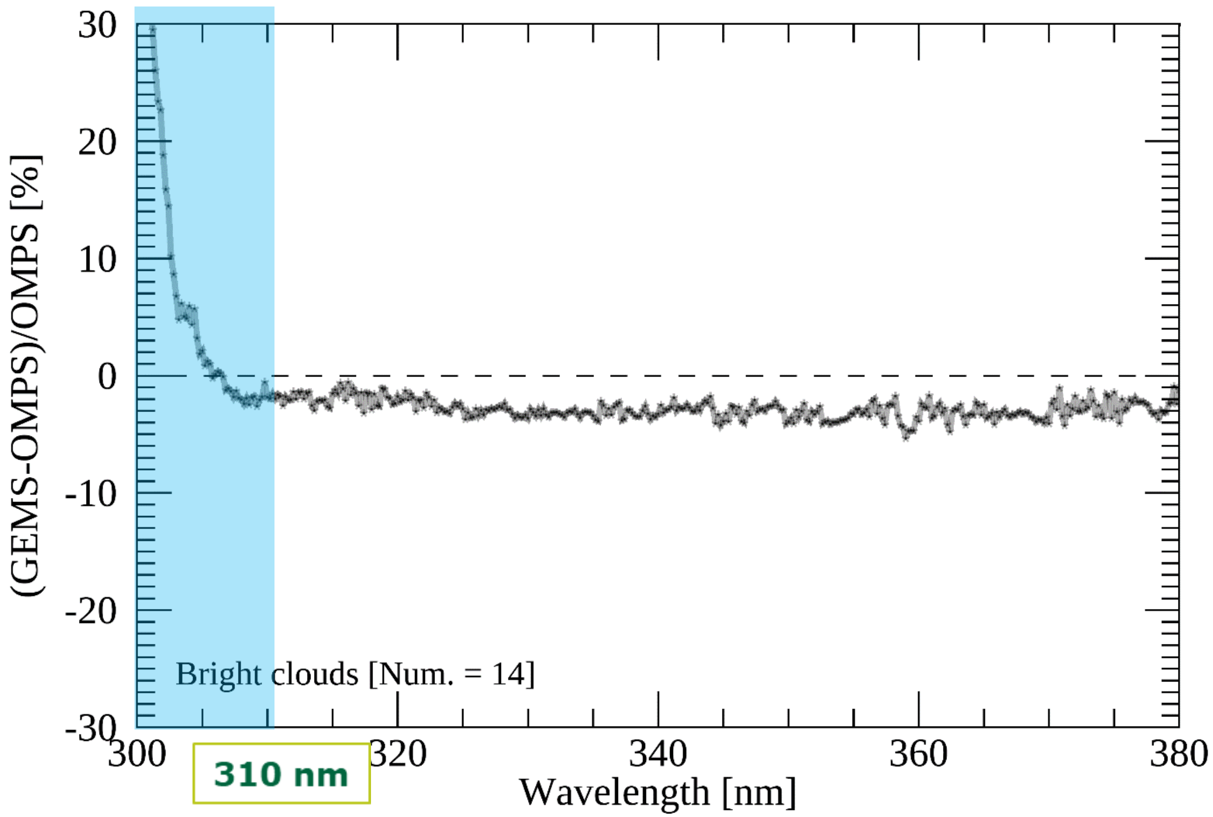
305-340 nm window



- Missing pixels are where the OEM process dis not converge
- Extremely high values in tropical areas are where the fitting residual was relatively large.
- With 305-340, the missing pixels have been disappeared, but the values are still abnormally high

Straylight impact on GEMS radiance and solar irradiance

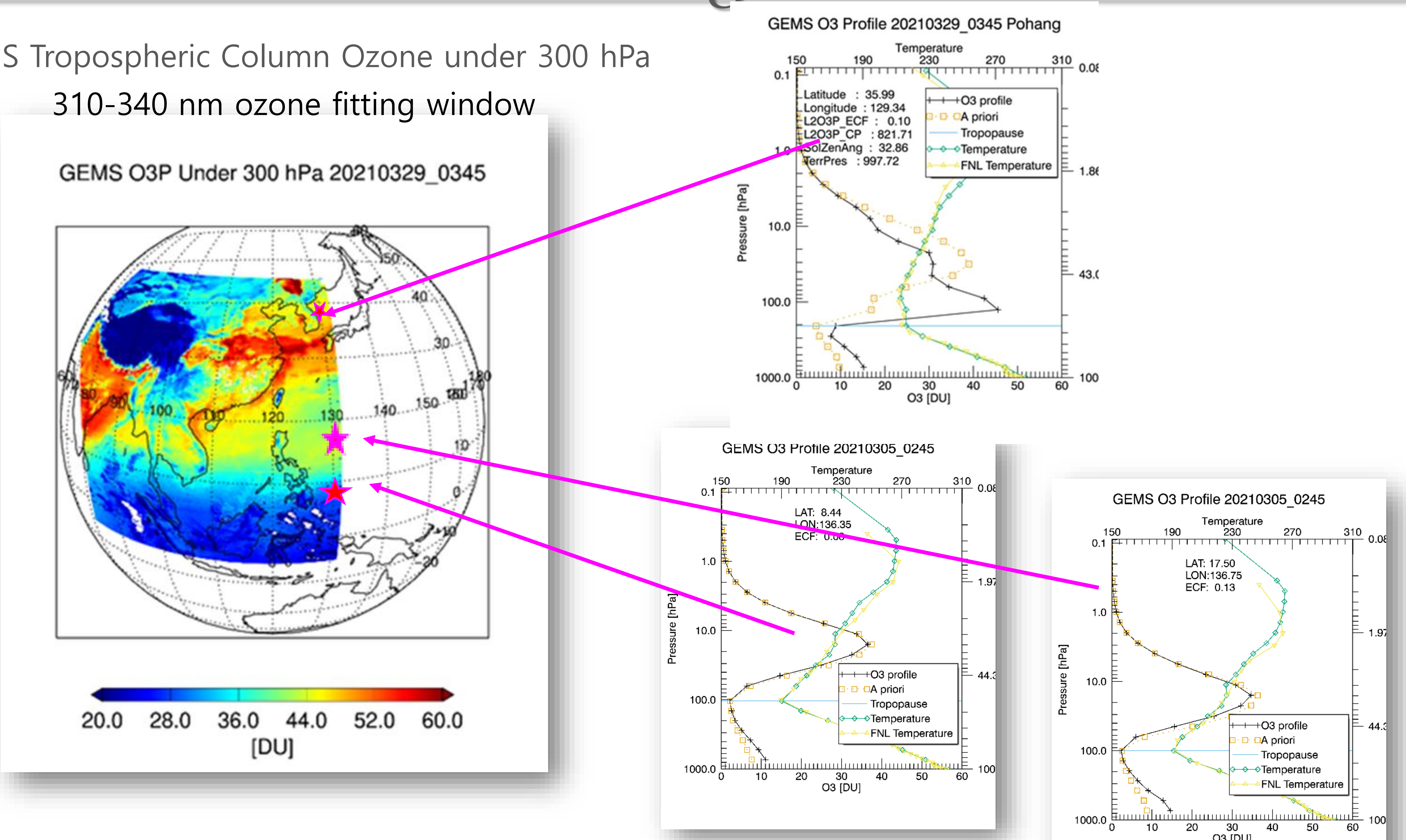
- **Solar irradiance difference between GEMS and OMPS with wavelengths**
  - The effect of straylight is very significant in the wavelengths shorter than 310 nm.
  - Because of this error, the ozone profile algorithm is having difficulty in converging with ozone fitting window of 300-340 nm



O3P Retrieval Algorithm Result

❖GEMS Tropospheric Column Ozone under 300 hPa

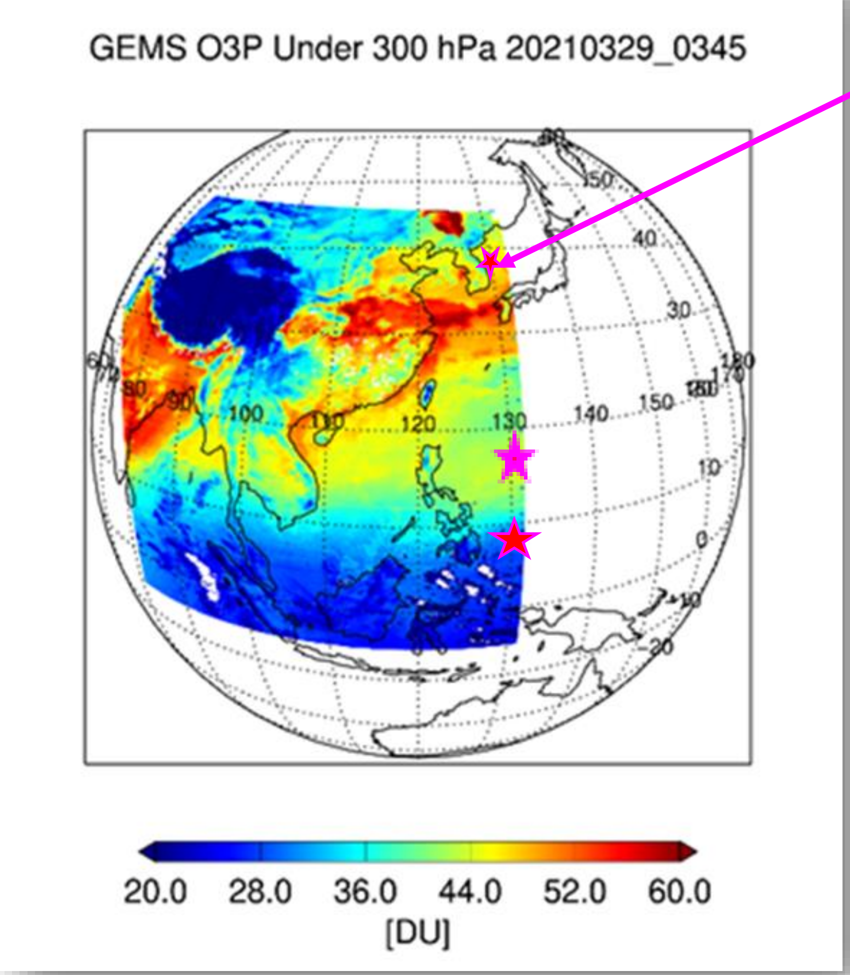
310-340 nm ozone fitting window

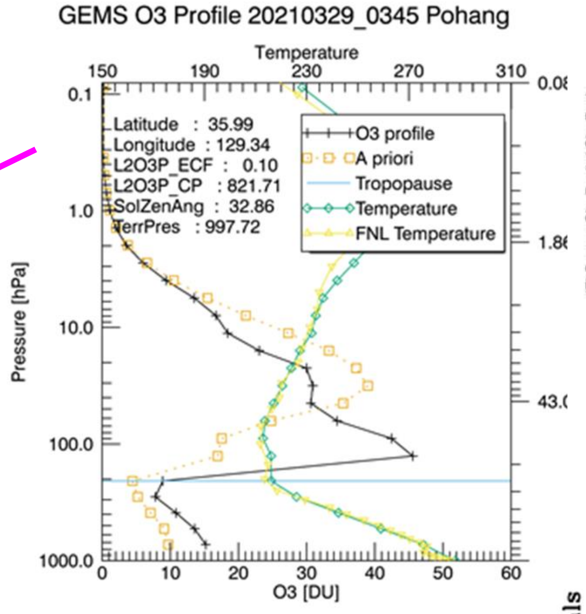


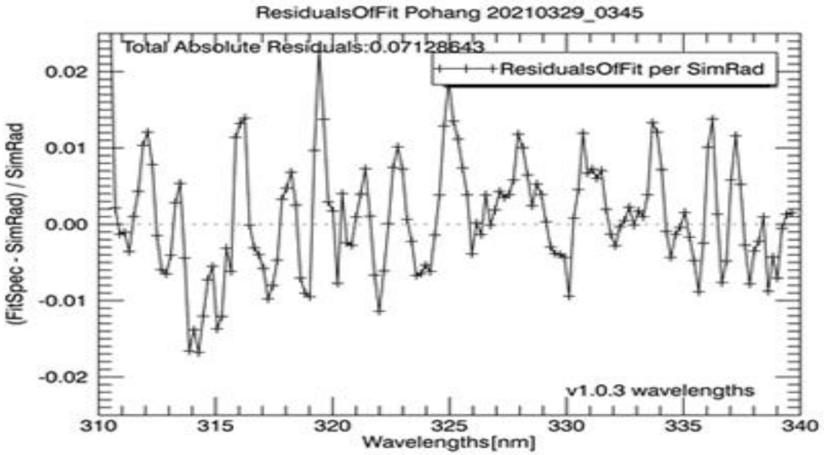
O3P Retrieval Algorithm Result

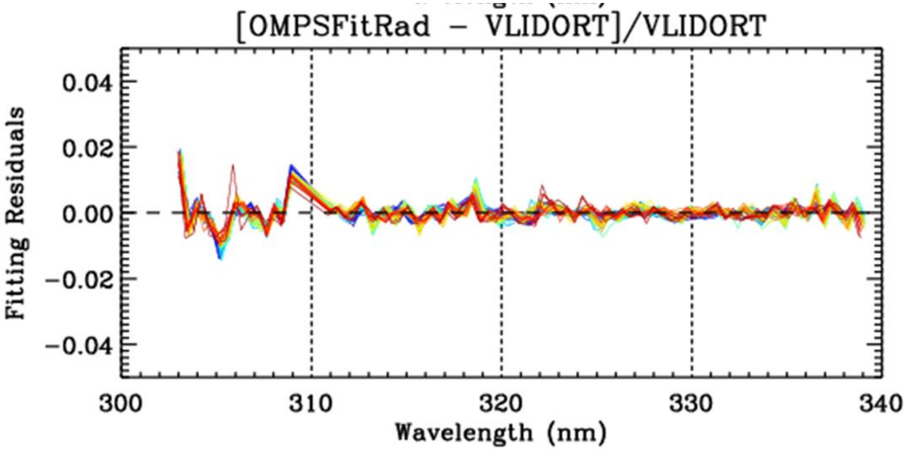
❖GEMS Tropospheric Column Ozone under 300 hPa

310-340 nm Fitting





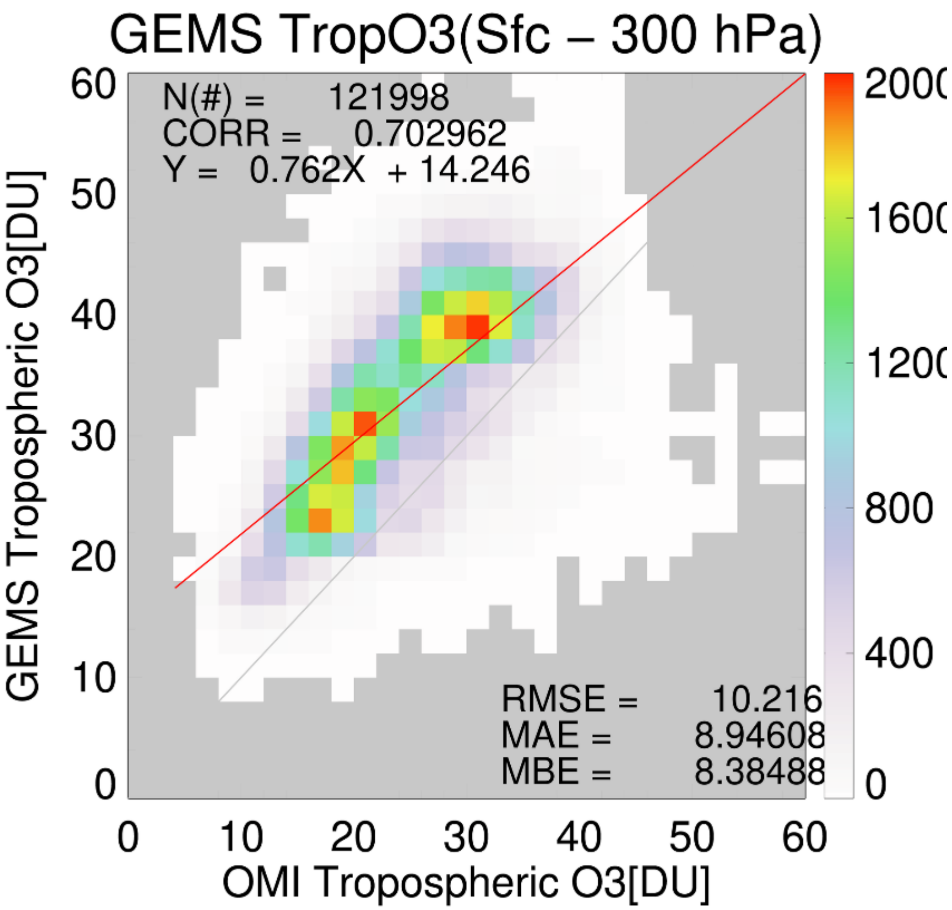




The algorithm is having trouble in converging to a minimum, because the fitting residual is relatively large.

Losing wavelengths shorter than 310 is equivalent to losing some tropospheric ozone information.

Tropospheric ozone validation w.r.t. OMI PROFOZ for March 2021



GEMS ozone fitting window of 310-340 nm

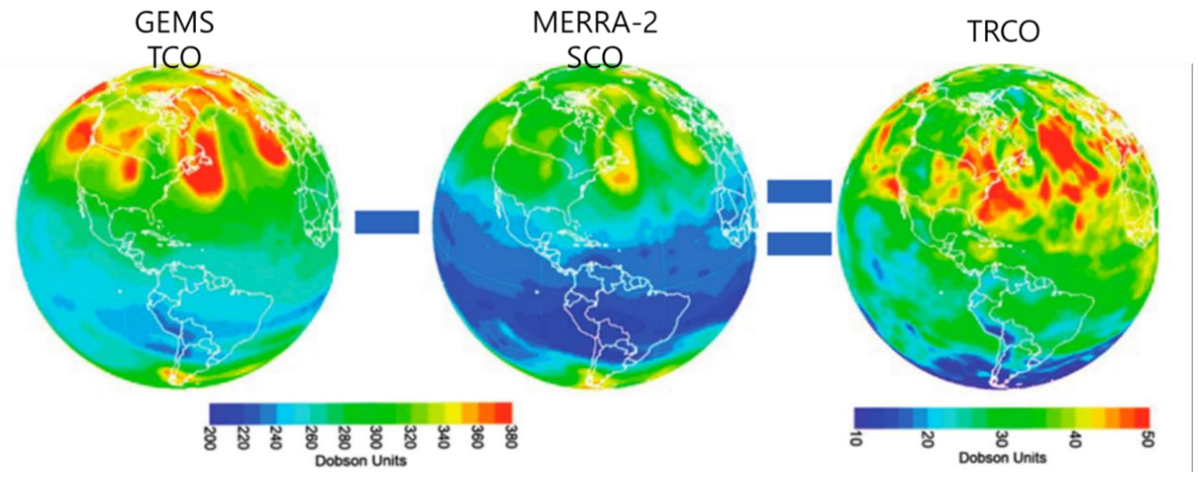
with OMI	Score
N(#)	121998
CORR	0.702962
SLOPE	0.762
INTERCEPT	14.246
RMSE	10.216

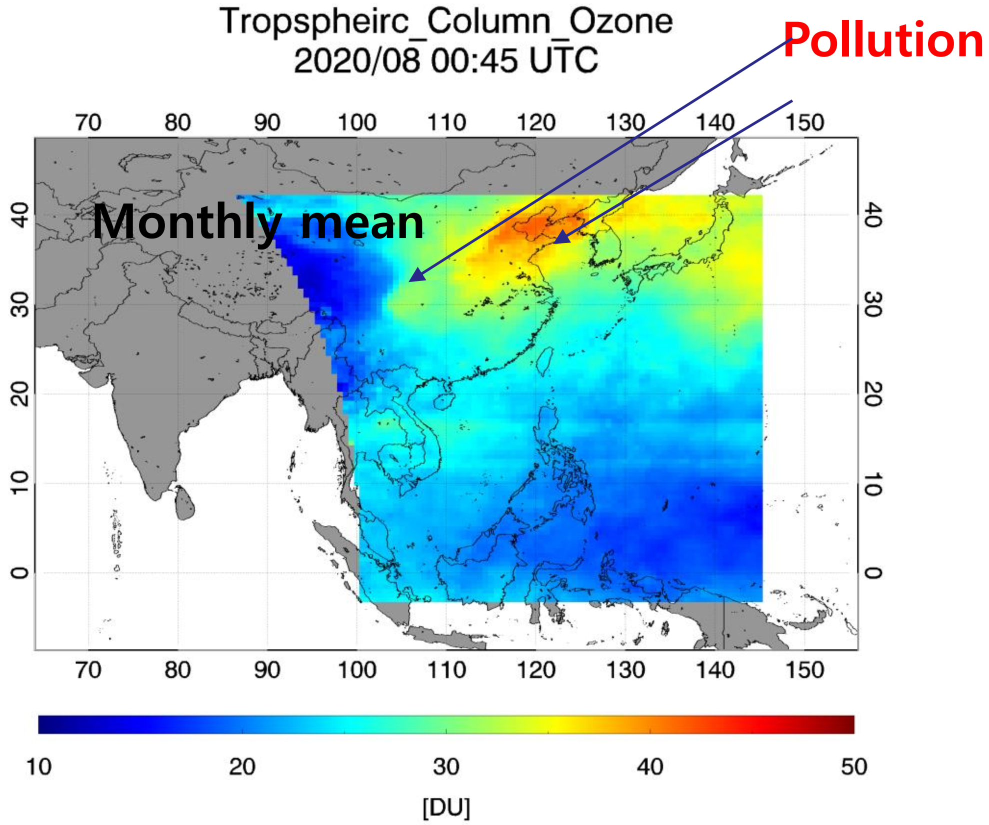
- GEMS tropospheric column ozone is about 10 DU higher than OMI
- If GEMS radiance/solar irradiance measurement error is improved, GEMS tropospheric ozone retrieval will be improved.

GEMS Tropospheric Column Ozone (TRCO) based on Residual Method

GEMS TRCO is retrieved based on TOR method.

- GEMS Total Column Ozone (TCO) (cf < 0.2)
- MERRA-2 Stratospheric Column Ozone (SCO)
- Tropopause pressure is derived from MERRA-2 potential vorticity (2.5 PVU) and potential temperature (380 K)
- **GEMS TRCO = GEMS TCO - MERRA-2 SCO**

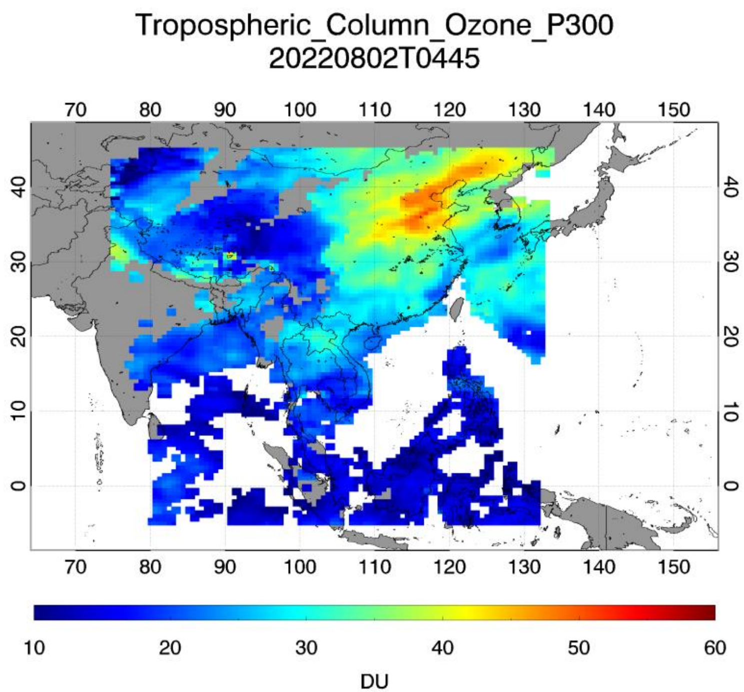




Comparision of tropospheric column ozone

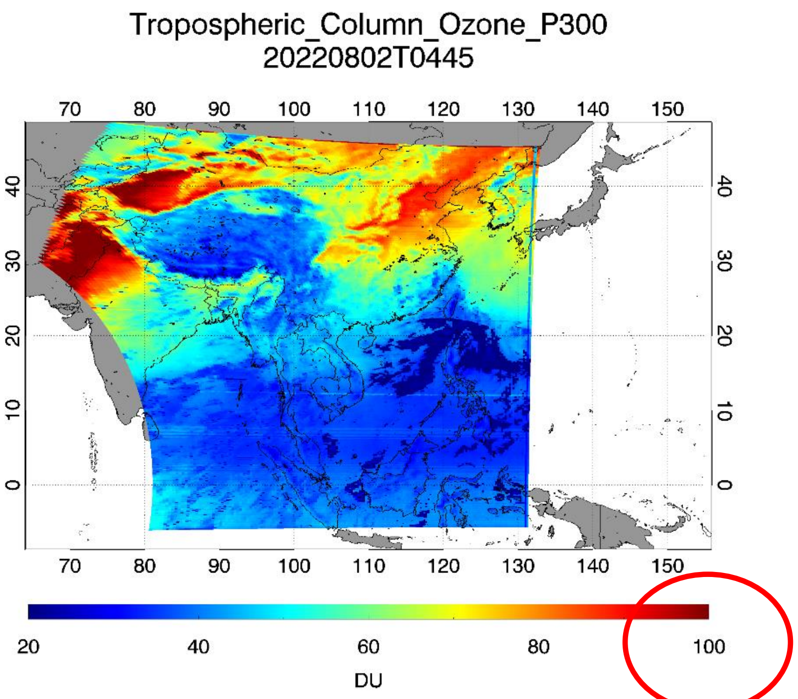
GEMS Residual algorithm (CF <0.2)

TOR method



GEMS ozone profile algorithm

OEM method

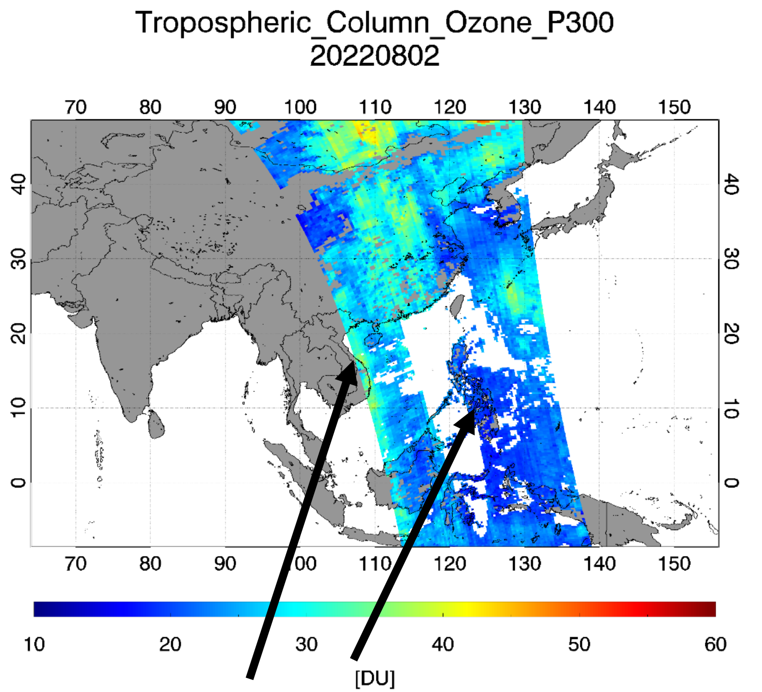


Similar to ozone distribution but too much O3

Tropospheric ozone > 100 DU (error)

TROPOMI algorithm (CF <0.2)

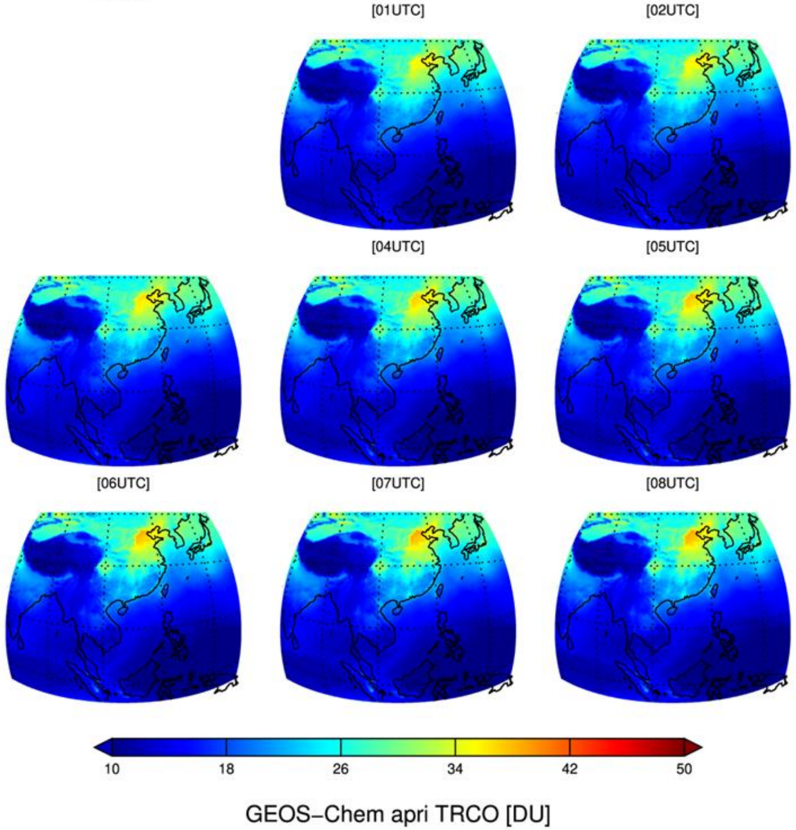
OEM method



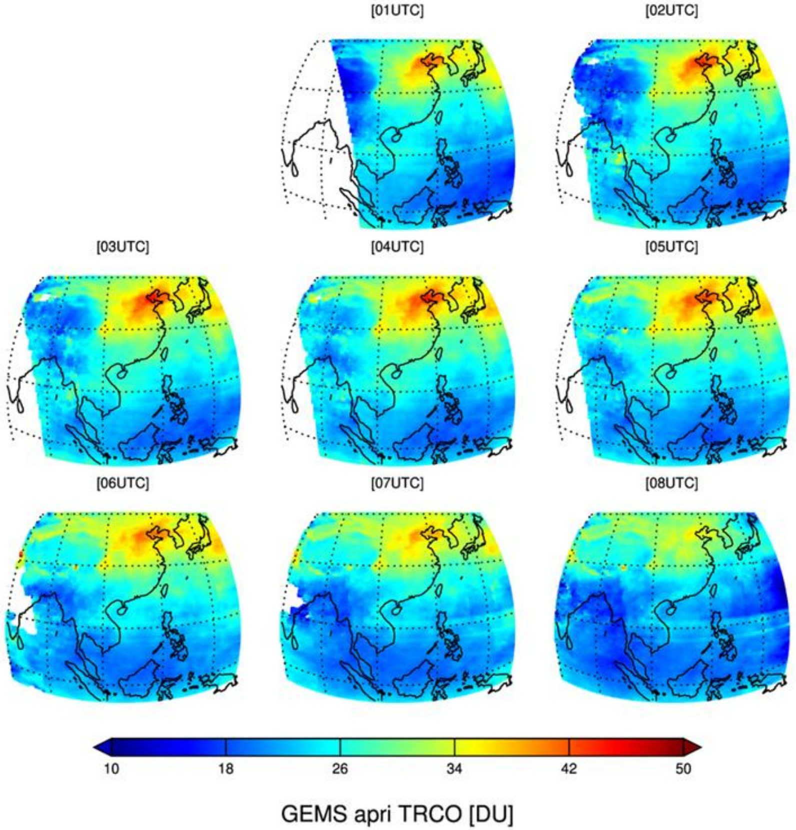
Dependence on cross-track

Comparison between GEMS Residual and GEOS-Chem tropospheric ozone

GEOS-Chem Tropospheric Ozone



GEMS Tropospheric Column Ozone



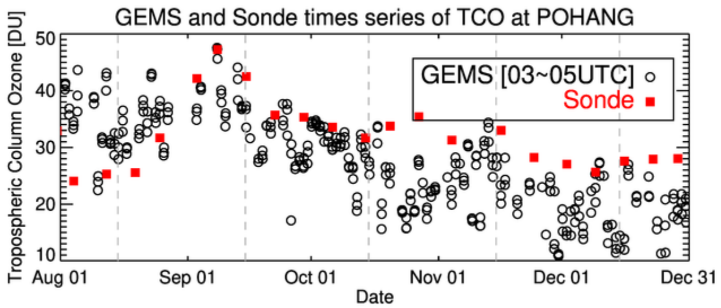
- GEMS tropospheric column is higher than GEOS-chem especially over Eastern China and South Asia region.
- According to photochemical theories, afternoon GEOS-Chem tropospheric ozone is higher than morning ozone. However, GEMS shows the opposite pattern, so we suspect that the temporal dependence in GEMS solar irradiance measurements caused this pattern.

Comparison between GEMS TOR and Ozonesounding measurements

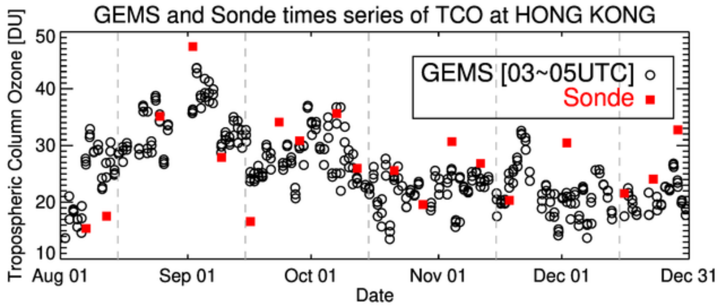
❖ WODUC sonde (2020. 08 - 2020. 12)

Significant decrease on winter

Pohang

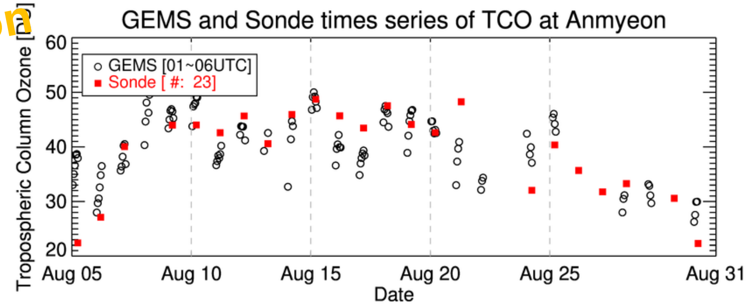


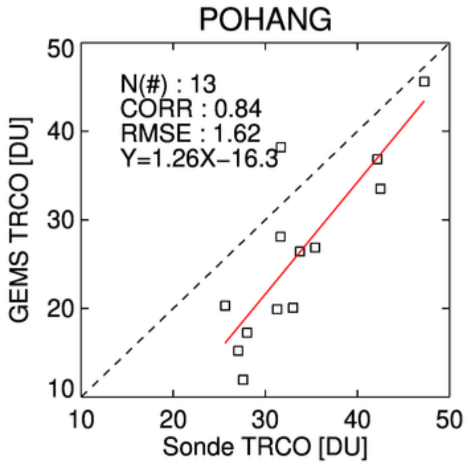
Naha

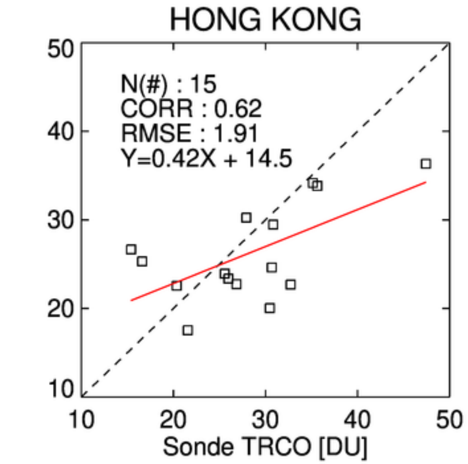


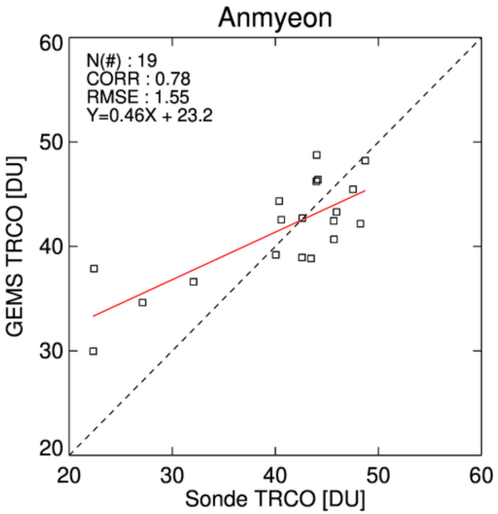
❖ SIJAQ 2021 campaign (2021. 08)

Anmyeon









- Hongkong, 0.84, RMSE 1.62 DU
- Pohang, 0.62, RMSE 1.92 DU
- Anmyeon, 0.78, RMSE 1.55 DU

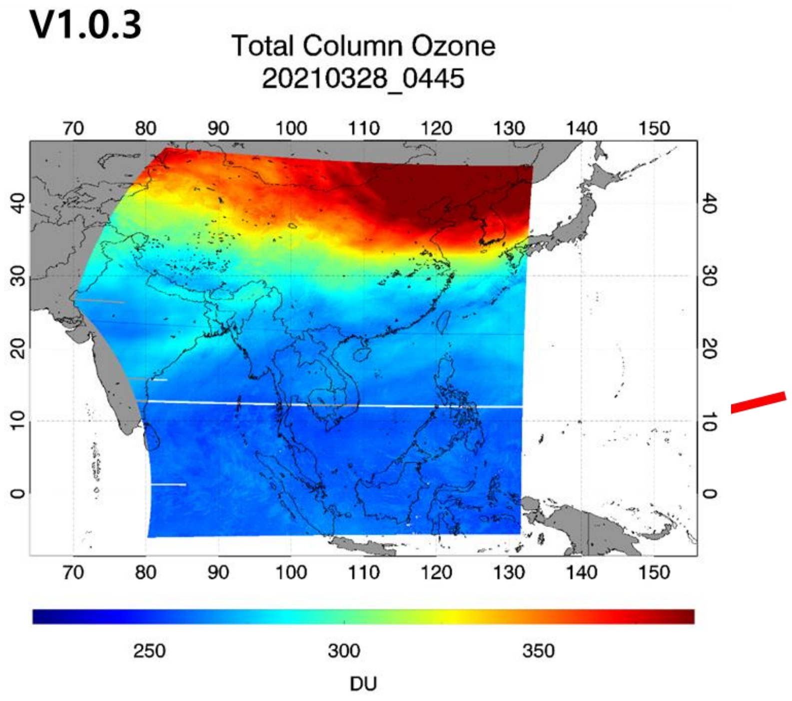
Keep track of the latest version of GEMS data.

GEMS V0.1

- Distributed version to GEMS-AO Team (IOT)

GEMS V1.0 (V1.0.x)

- Updated LUT (use measured GEMS slit function)
- Problem in QF sea-glint and VZA > 75 (V1.0)
- Updated GEMS L2 Cloud products (2021. 09).
- Update information of quality flag



GEMS V2.0

- Use of KMA GDAPS (UM) temperature profiles (instead of temperature climatology).
- Add quality flag for Elevated SO2 case due to volcanic eruption.
- Update subroutine related to ozone *a-priori*
- 2022. 11. will be distributed.

Summary

- Even though there is an issue with GEMS solar irradiance calibration, GEMS total ozone measurements show excellent agreement with Pandora and other satellite measurements
- Because the fitting residual has a large value due to the GEMS radiance and irradiance measurement error, the ozone profile algorithm has difficulty in converging. As a result, improving GEMS measurement errors still requires a lot of work.
- In the meantime, the tropospheric residual method will be an alternative to tropospheric ozone derivation