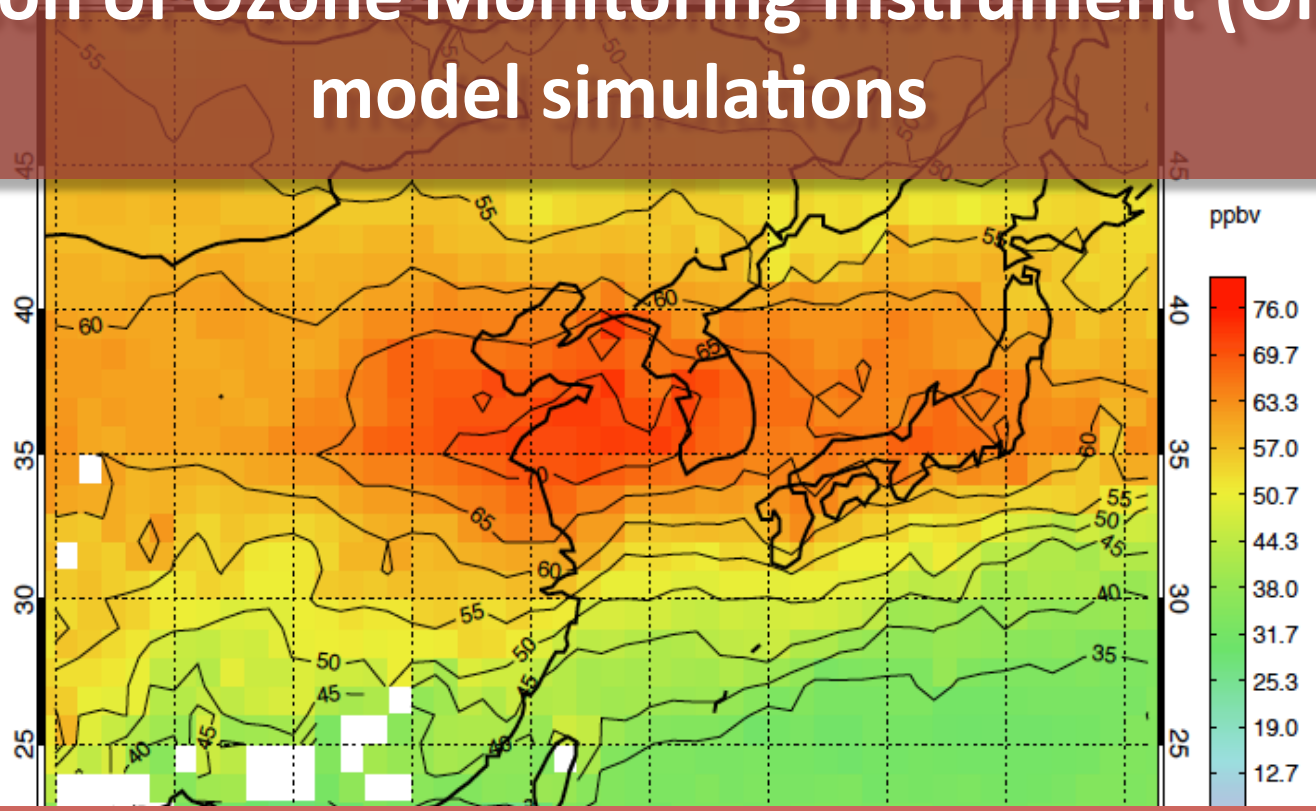
The 3rd ACAM workshop, June. 5-9, 2017

Enhancement of the lower tropospheric ozone over China: Comparison of Ozone Monitoring Instrument (OMI) and model simulations



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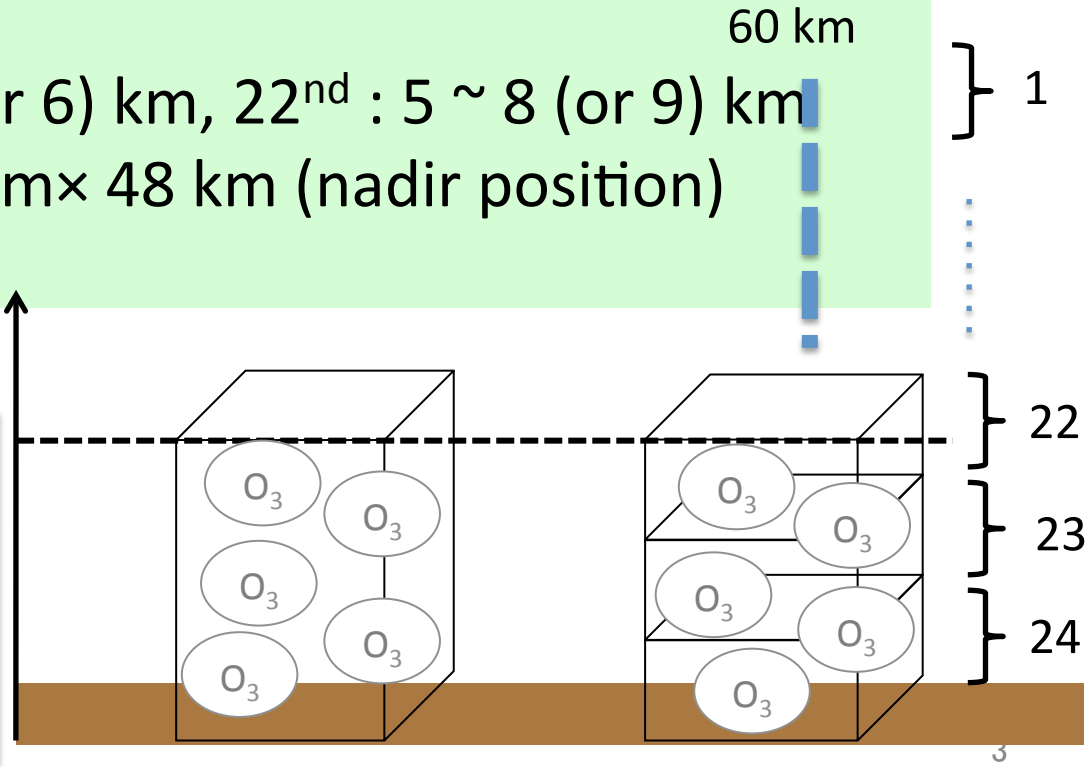
Introduction

- Satellite measurements have the advantage of making observations over wide areas.
- Almost 90 % of O_3 is in the stratosphere, 10 % in the troposphere: the amount of O_3 in the boundary layer is usually only a small percentage of the total amount.
- Ozone profiling is a big challenge of satellite missions.
- From OMI (Ozone Monitoring Instrument) UV spectra, O_3 profiles have been derived (Liu et al., ACP, 2010)
- The lower tropospheric O_3 distribution maps were obtained from the OMI UV measurements (Hayashida et al., ACP, 2015).

Satellite data: OMI O_3 profile

Liu et al., ACP, 2010: Xiong Liu and Kelly Chance successfully retrieved ozone profiles for 24 layers from OMI spectra, in 270-330 nm (270-309 nm in UV1, 312-330 nm in UV2), with 3-7 layers in the troposphere.

- Optimal estimation with climatology by McPeters et al. (2007) for a priori
- 24th : 0 ~ 3 km, 23rd : 3~5 (or 6) km, 22nd : 5 ~ 8 (or 9) km
- Horizontal resolution of 13 km× 48 km (nadir position)



Our Analysis

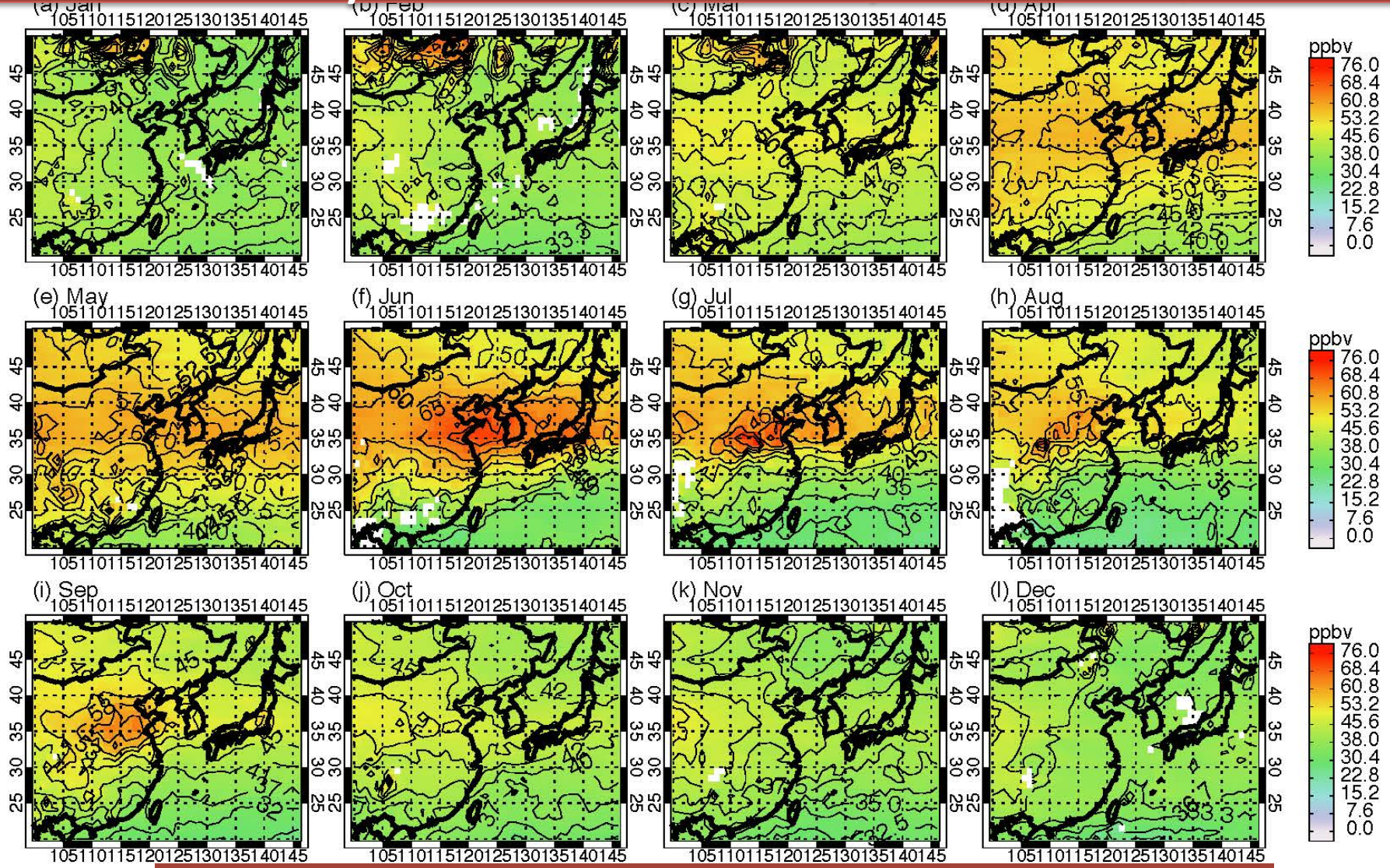
Level 3: archived 1 x 1 deg.
Pre- screening
Cloud fraction < 0.2
RMS (UV2) < 2.4

OMI ozone profiles

- In Hayashida et al., ACP, 2015:
- we compared the OMI-derived O_3 profiles over Beijing with airborne measurements (MOZAIC) and demonstrated the reliability of OMI O_3 retrievals in the lower troposphere under enhanced ozone conditions.
- we showed significant enhancement of O_3 in the lower troposphere observed by OMI over central and eastern China (CEC) with Shandong as its center.
- The O_3 enhancement is most notable in June every year.

- *S. Hayashida, X. Liu, et al.: Observation of ozone enhancement in the lower troposphere over East Asia from a space-borne ultraviolet spectrometer, Atmos. Chem. Phys., 15, 9865–9881, 2015*

OMI retrieval (the 24th layer:0-3km) Monthly mean in 2005 *Hayashida et al.ACP, 2015*



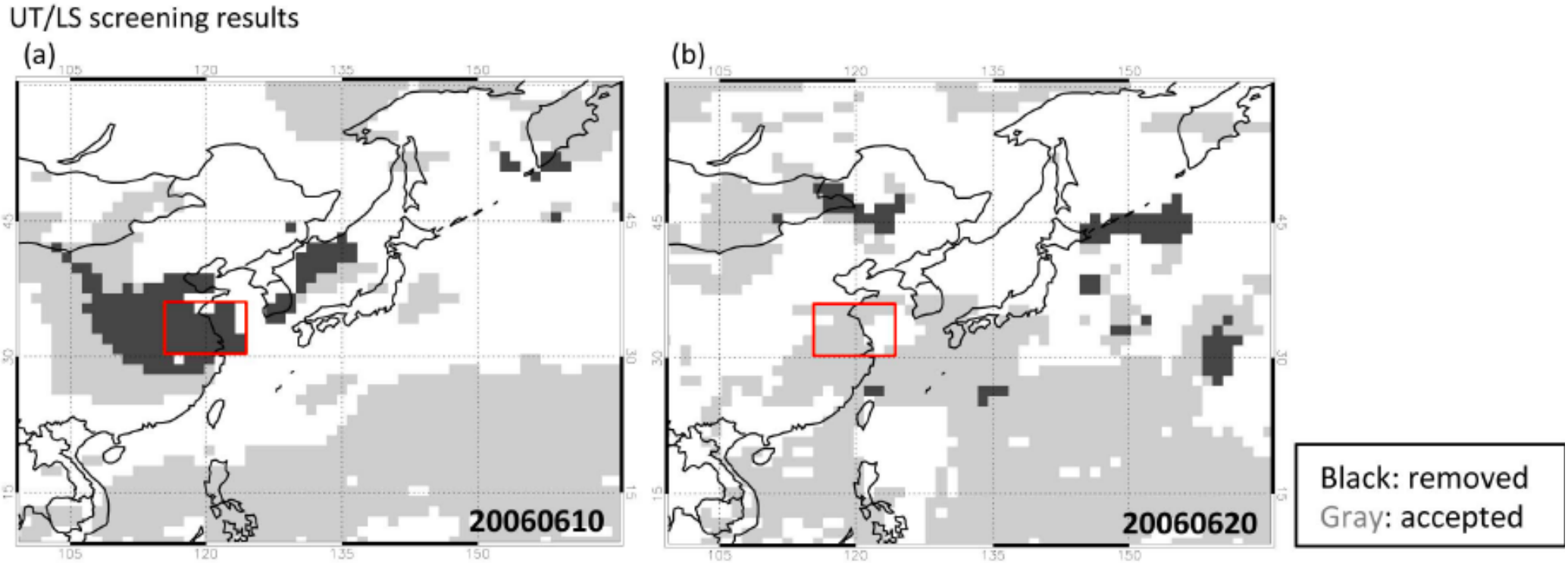
June is most outstanding in ozone enhancement

UT/LS screening for 24th layer ozone

Hayashida et al. Springer, in press

- However, O_3 variability in the upper-troposphere/lower-stratosphere (UT/LS) region may lead a significant artificial effect on lower tropospheric O_3 due to large smoothing errors.
- *Hayashida et al. (Springer, 2017)* clarified the concept of screening out the artificial effect and developed a UT/LS screening scheme.
- They were able to find a clear enhancement in lower tropospheric O_3 over CEC in June 2006 even after the UT/LS screening, and confirmed the conclusion described in *Hayashida et al. (2015)*.
- In this study, we applied the screening for all OMI retrievals during the period from October, 2004 through December, 2013 to remove any suspect data that might be affected by the UT/LS ozone variability.

Grid Selection:
Remove the grids in which the effect of the UT/LS O_3 variability on the 24th-layer O_3 is larger than the threshold



"Doubtful grids" were determined based on a model simulation, and those grids were removed from OMI dataset

"Study of lower tropospheric ozone over central and eastern China: Comparison of satellite observation with model simulation" was accepted to Land-Atmospheric Interactions in Asia, Springer (to be published soon).

Springer

springer.com

Land-Atmospheric Interactions in Asia

Book Series: Springer Remote Sensing/Photogrammetry

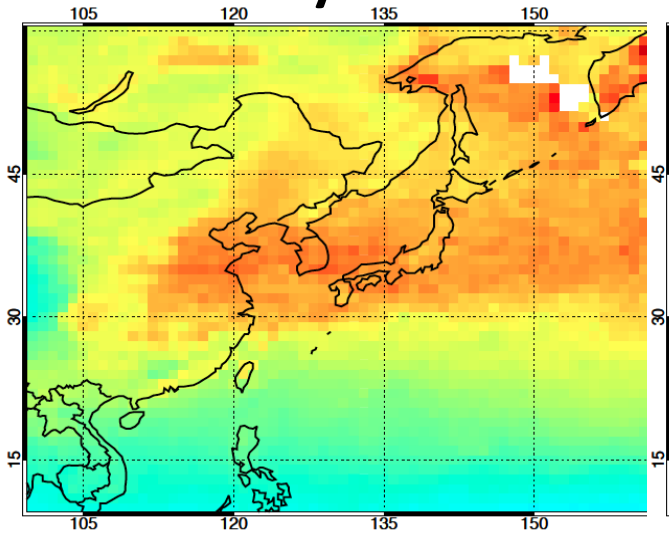
Editors: Krishna Prasad Vadrevu, Toshimasa Ohara, Chris Justice

Forthcoming, Summer 2016

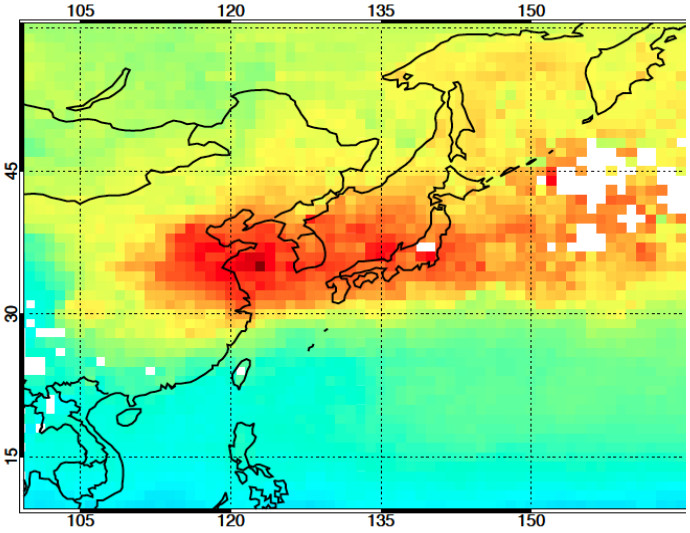
▸Maximizes reader insights into the quantification of land cover/land use changes (LCLUC) and greenhouse gas emissions in Asia.

After the UT/LS screening
Monthly mean in 2006

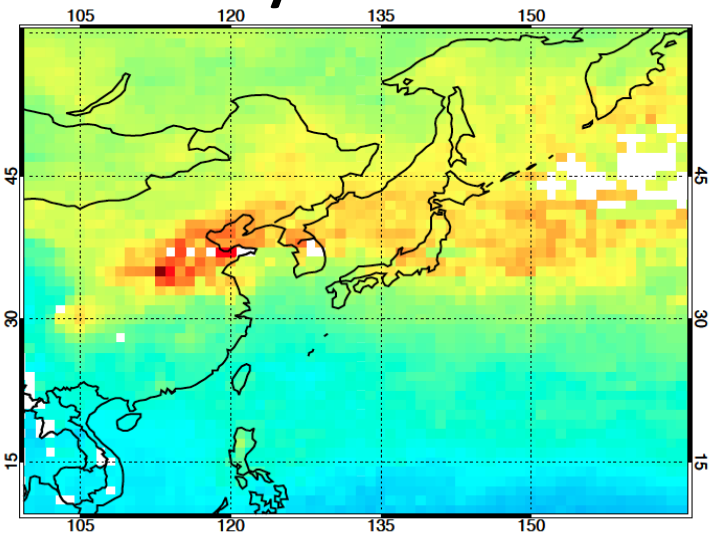
May



June



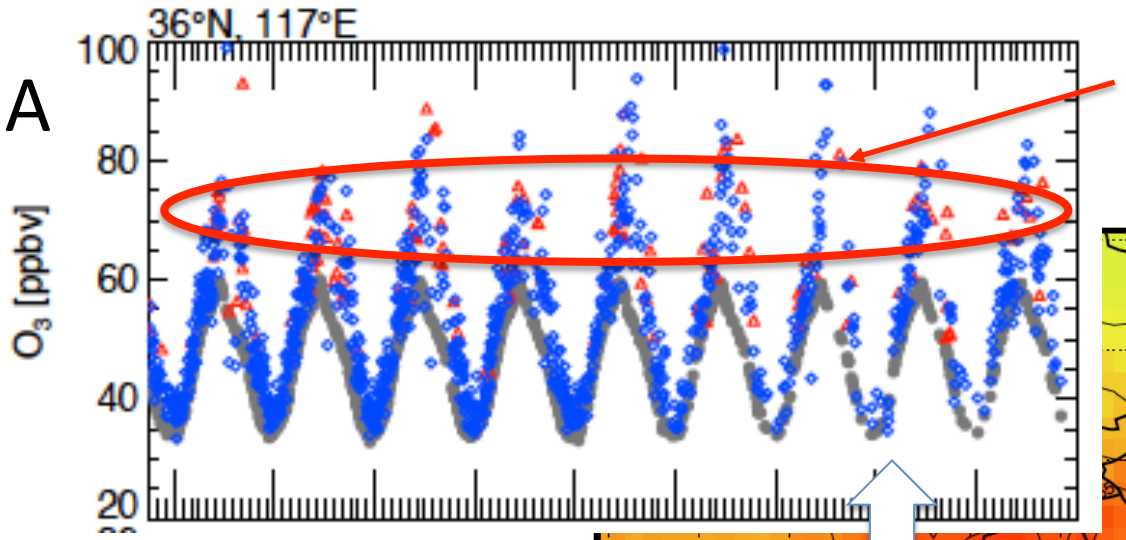
July



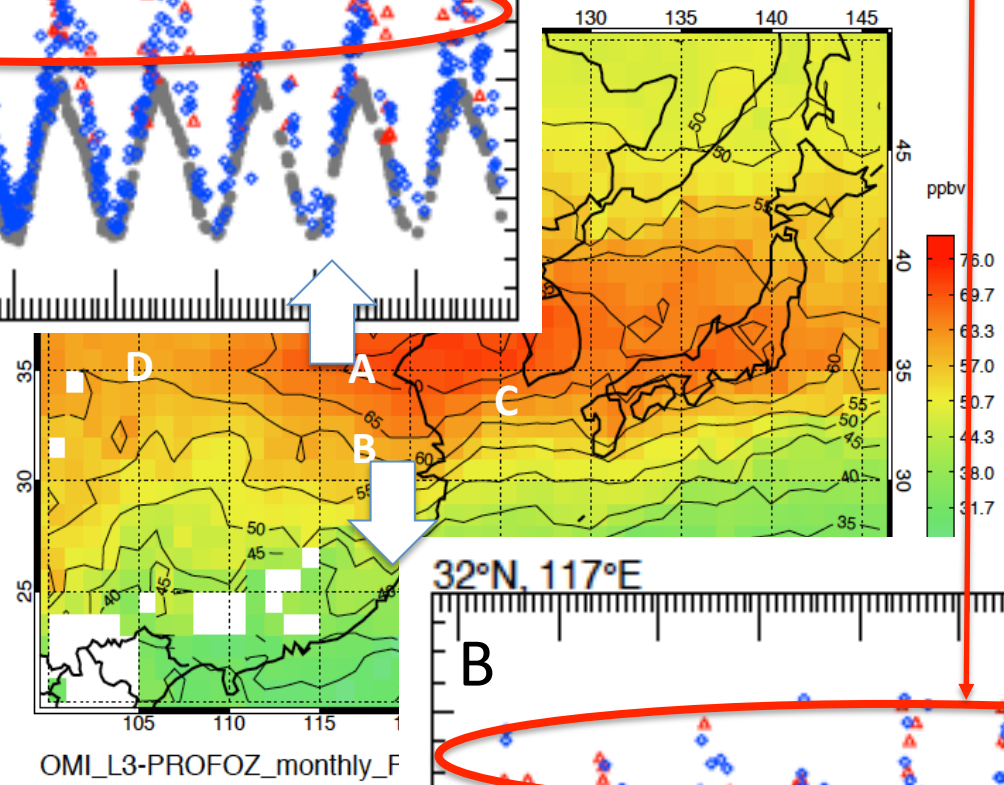
Even after the UT/LS screening, we were able to find a clear enhancement of lower tropospheric O_3 over CEC in summer of 2006.

This signal comes really from tropospheric ozone change!

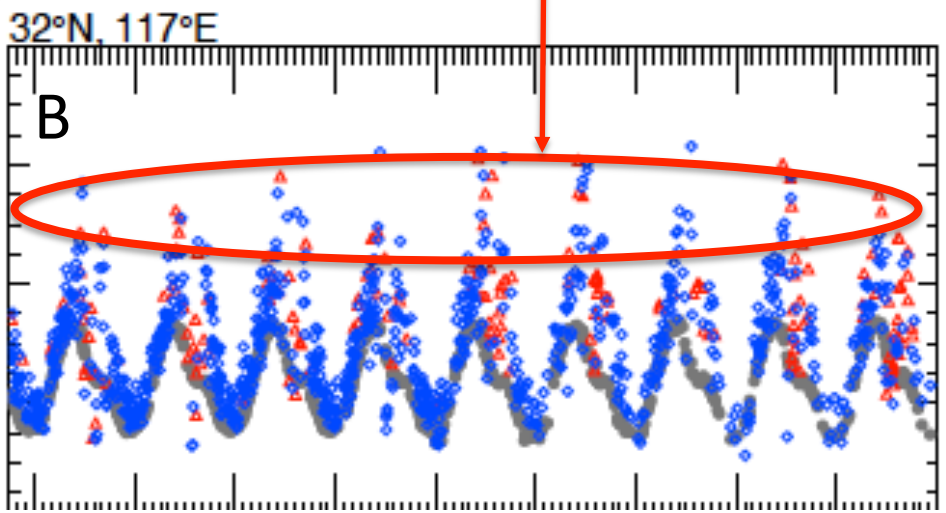
Map of the 24th layer O_3 in June 2005



In summer: significant enhancement of O_3 (larger than a priori)

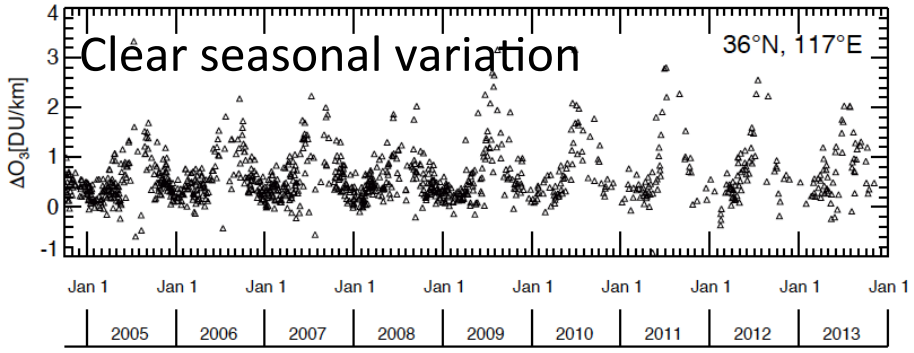


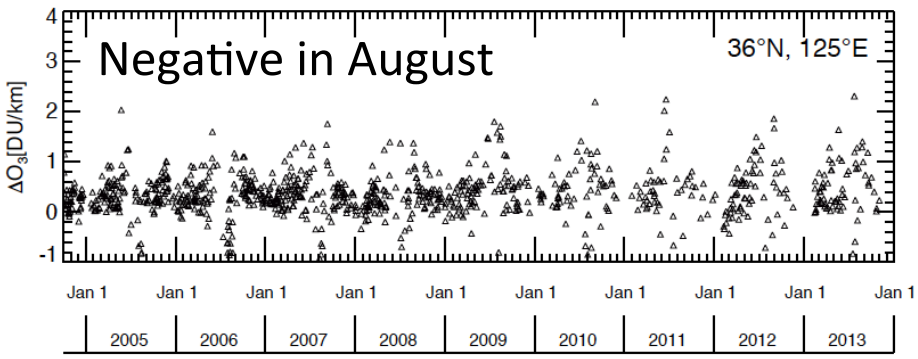
Gray: a priori
Blue: O_3 retrieval
Red: screened out
(not used in analysis)

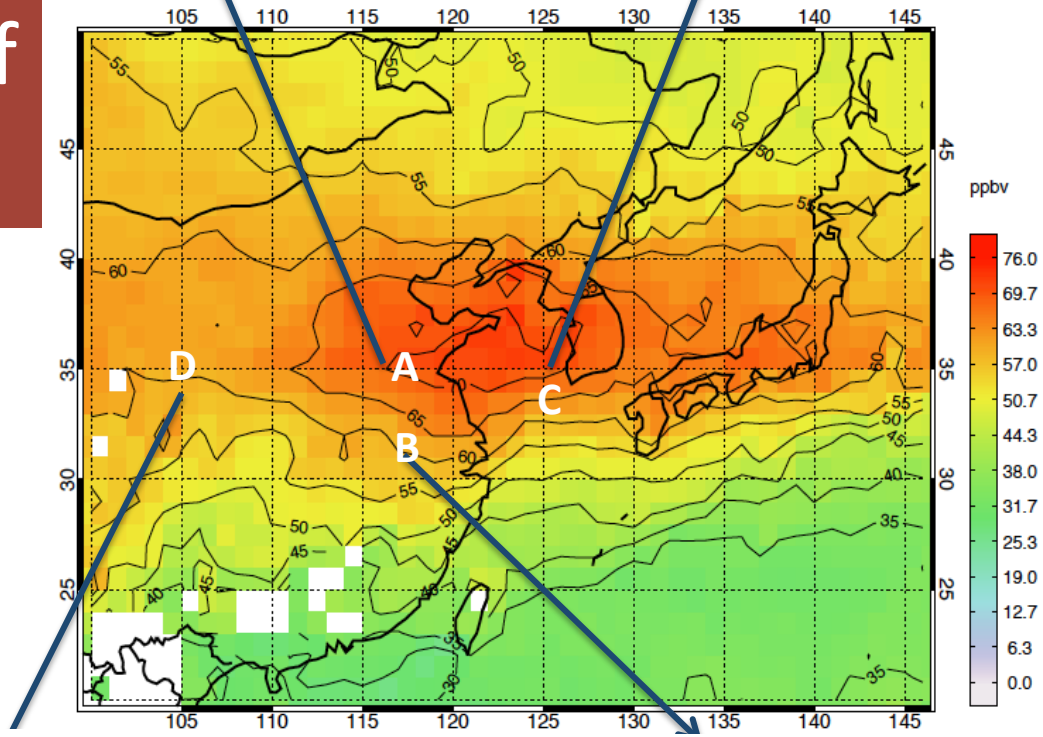


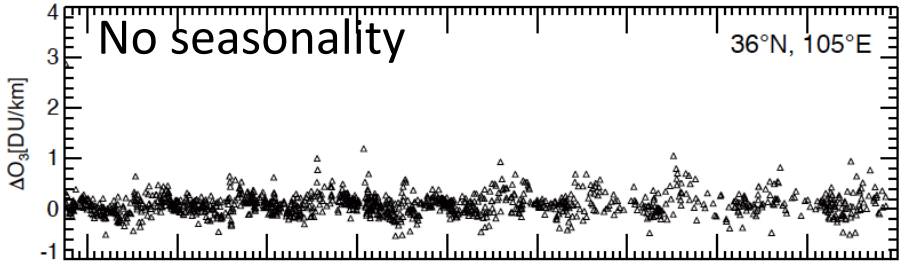
We focus on
$\Delta O_3 = O_3$[retrieval] – O_3[*a priori*]
to track O_3 enhancement.

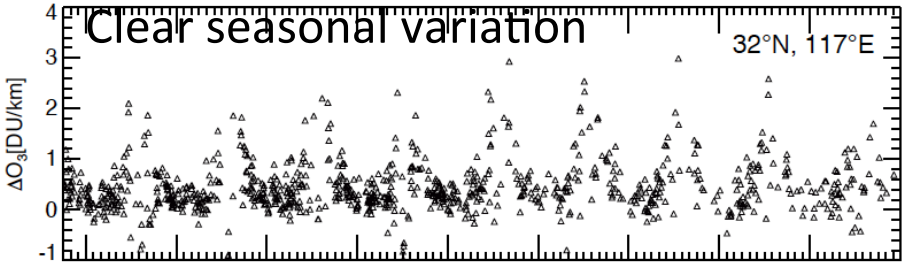
Time series of ΔO_3







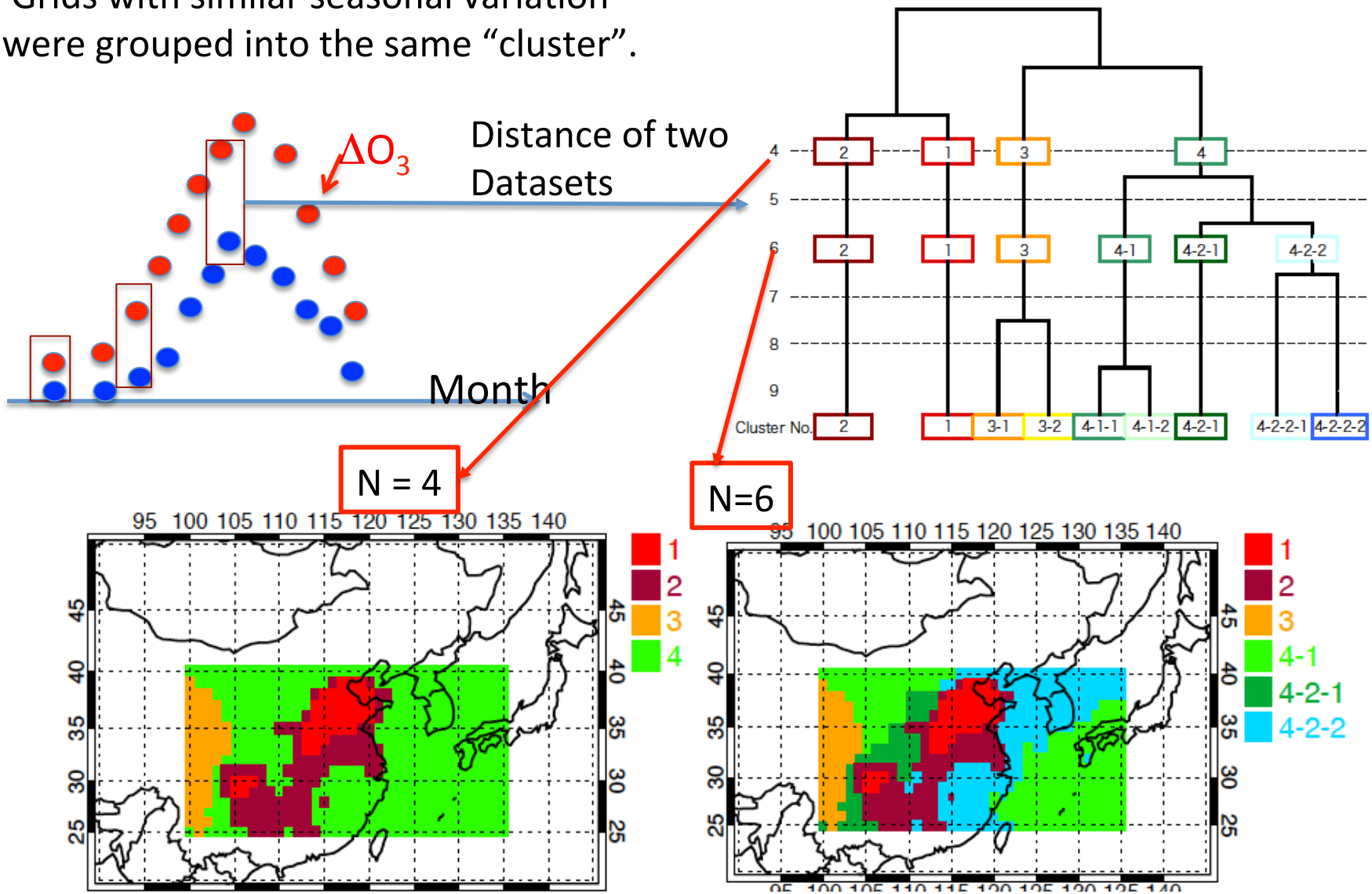




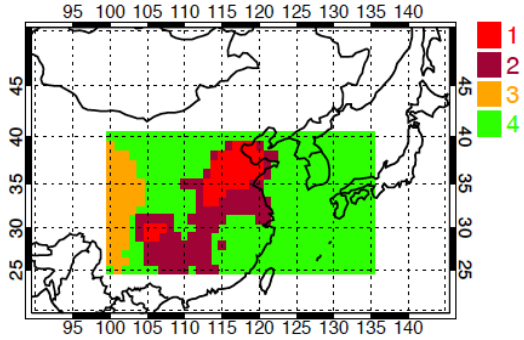
Cluster analysis of the time series of ΔO_3

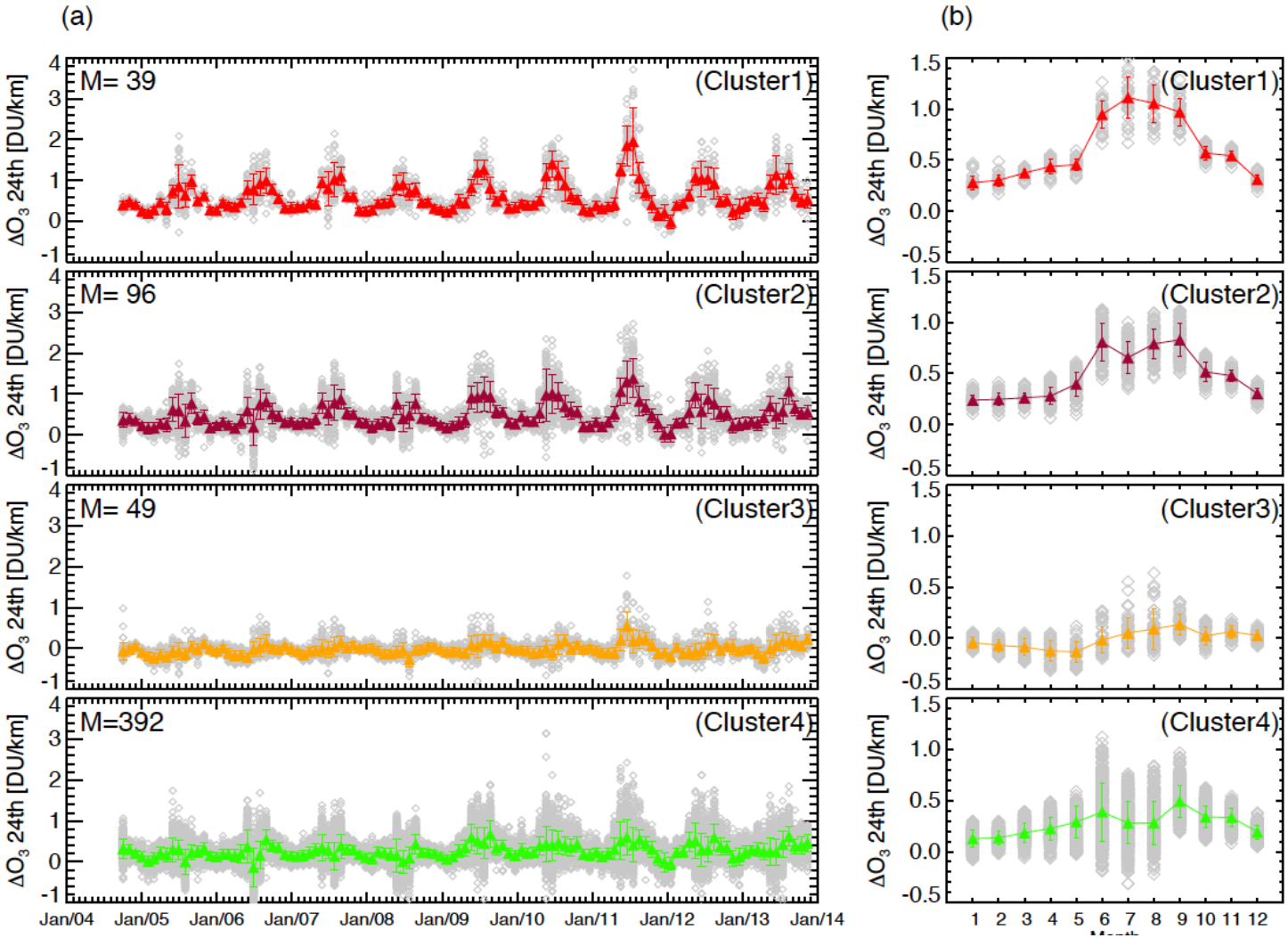
the complete linkage method for hierarchical clustering

Grids with similar seasonal variation were grouped into the same "cluster".

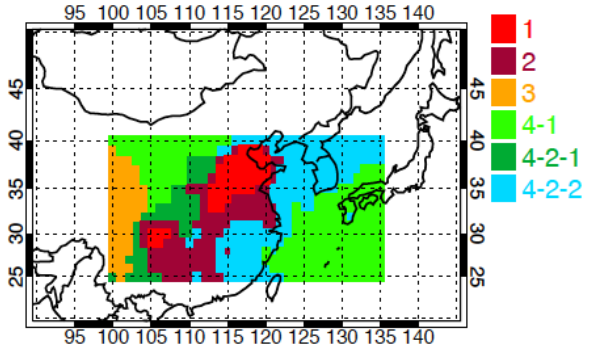


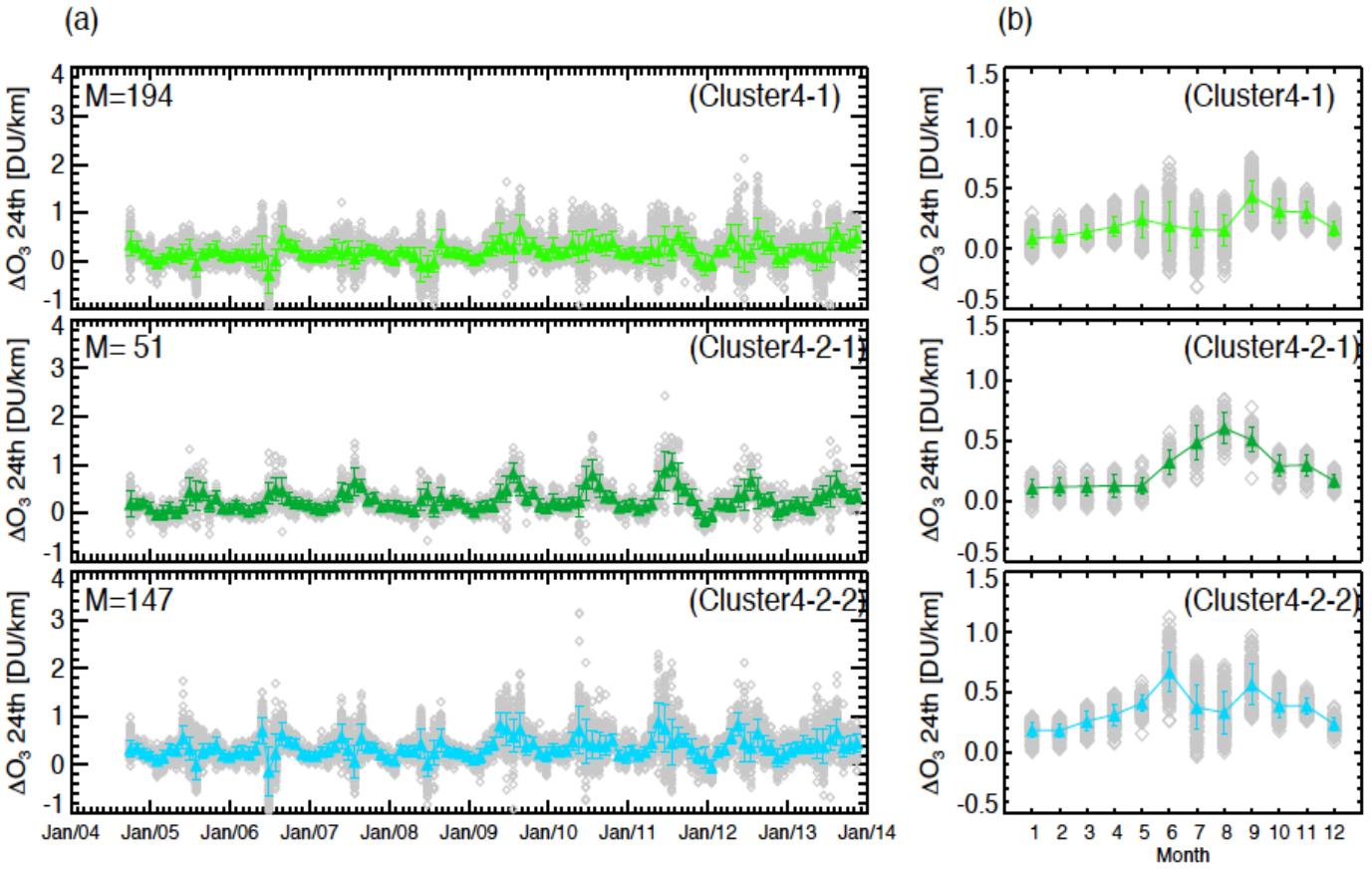
Time series of the monthly mean values of the ΔO_3 at 24th layer in the four clusters 1-4



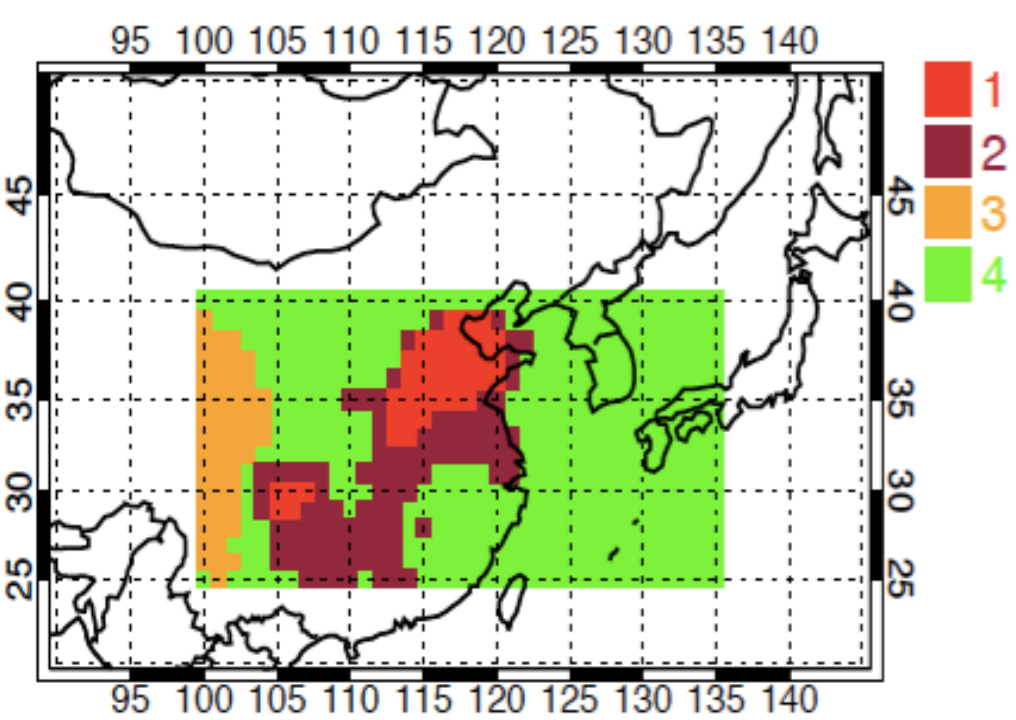


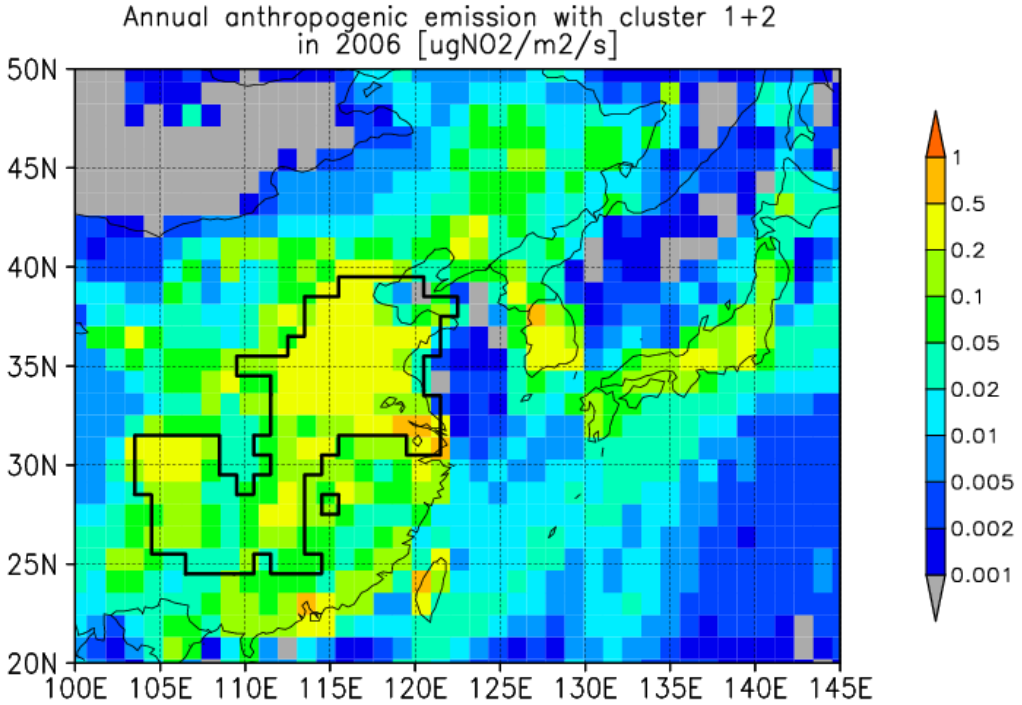
Time series of the monthly mean values of the ΔO_3 at 24th layer in the clusters 4-1, 4-2-1, 4-2-2 (N=6)





Annual anthropogenic NO_2 emission in 2006 [$\mu gNO_2/m^2/s$] (MaCCity)



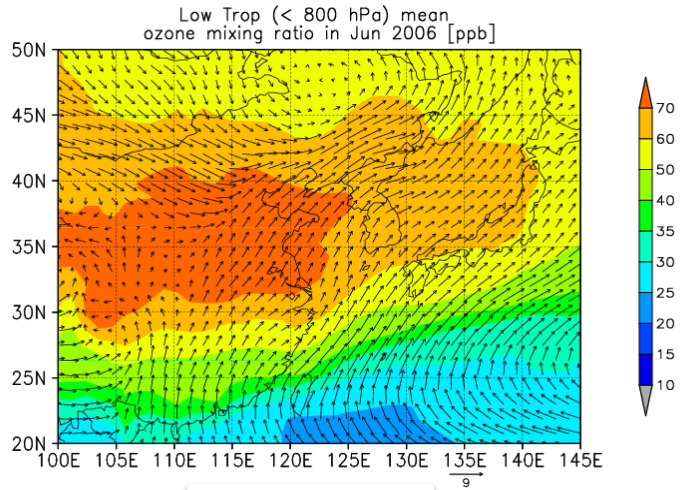


The high NO_2 emission area very clearly corresponds to the areas of Clusters 1 and 2 as shown with a thick line.

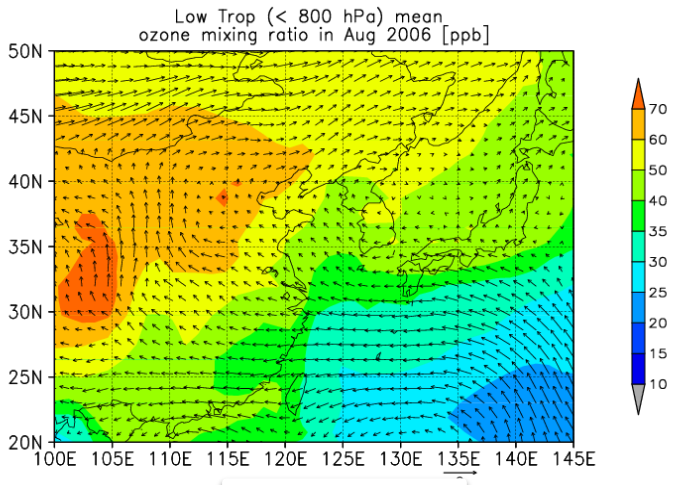
Ozone mixing ratio in the lower troposphere (below 800hPa) simulated by MRI-CCM2: June & Aug. 2006

Meteorological Research Institute-Chemistry Climate Model

O_3 concentration with wind vectors at 925 hPa

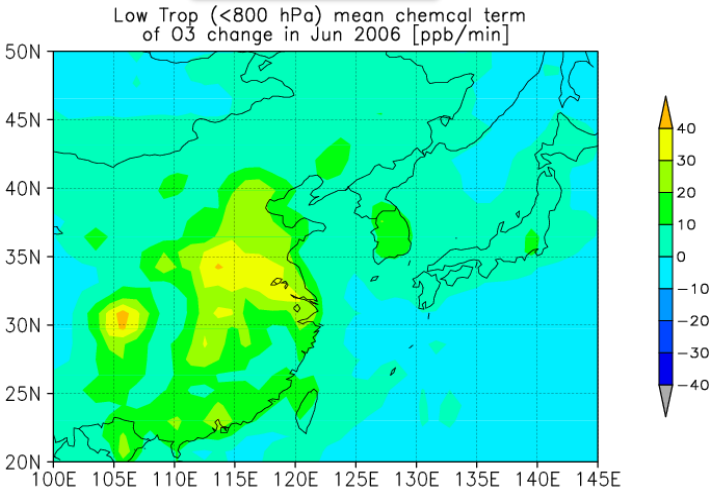


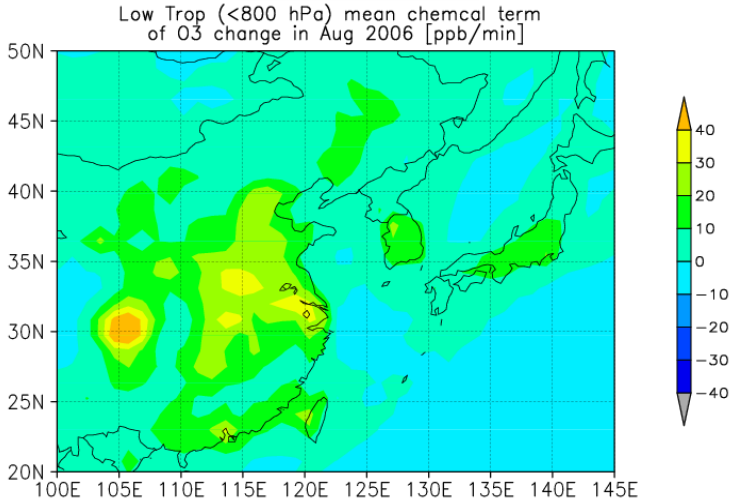
June 2006



Aug. 2006

Chemical Terms (ppb/min)





Summary

- The OMI O_3 profile products (by Liu et al.. 2010) over China
  - We focused on the O_3 anomaly, which is defined as
  - $\Delta O_3 = O_3[\text{retrieval}] - O_3[\textit{a priori}]$
  - This analysis is effective in tracking O_3 enhancement under polluted conditions, because our focus is the temporally high O_3 compared to background levels.
- Cluster analysis to the ΔO_3 data at the 24^{th} layer
  - Over the North China Plain and Sichuan basin, O_3 has outstanding seasonality with high values in summer (June, in particular) and low values in winter.
  - These anomalous O_3 value areas correspond to areas that is known as high NO_2 emissions.
- Comparison with ACTM simulations
  - Cluster 1 corresponds to areas of high chemical production rates in June.
  - Along the coastal area in August, O_3 tends to drop to negative values, which can be interpreted as due to the inland inflow of clean oceanic air.