An integrated analysis for ozone and carbon monoxide over the western Pacific using satellite and aircraft during the ACCLIP summer campaign 2022

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Contents

- Western pacific region exhibited a complex interplay of Monsoonal dynamics and meteorological transport in 2022 summer
- Carried out an observational study of trace-gas measurements of ozone and carbon monoxide during the ACCLIP campaign.
- Ozone is a stratospheric tracer, CO as a tracer for tropospheric pollutant air.

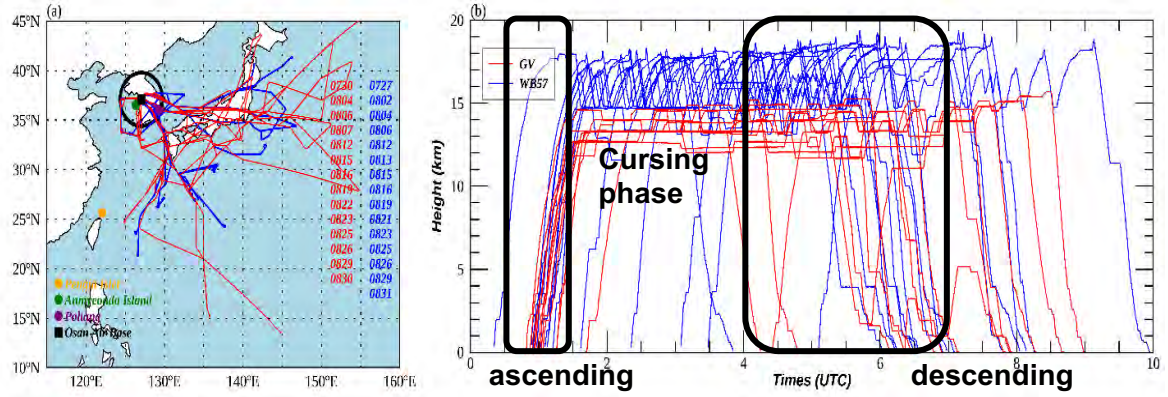
- The focus is on the transport processes that lead to the observed trace gas signatures, including the ASM transport in the UTLS region as well as transient mixing between upper troposphere and lower stratosphere and the transboundary transport in the lower troposphere.

- To diagnose the transport pathways influencing the chemical tracers, space-based TROPOMI and MLS Observations are applied to supplement the airborne data.

Data description

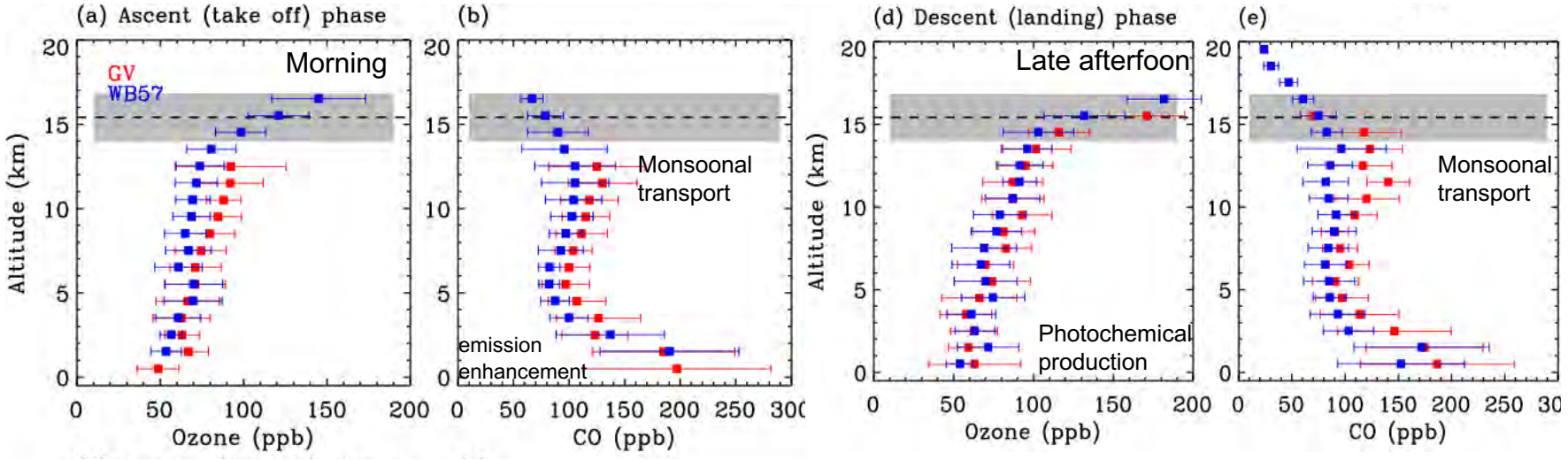
1. ACCLIP flight data

- Flight spatial and vertical domain (2022 July 27- August 31)



- GV flights (14)
  - Fast O3 instrument
  - Aerodyne-CO measurements
- WB-57 flights (15)
  - UAS Ozone Photometer
  - COMA (Carbon mOnoxide Measurement from Ames)
- **Ozonesonde**
  Anymendo (daily launch), Pohang (8), Pengjia (8)

- Comparison between GV and WB57 for O_3 and CO averaged through August



- Comparison is made between GV and WB57 platform and between Ascending (morning) and descending (late afternoon).
- Confirm the good agreement below 5 km, due to their spatiotemporal coherence.
- O3 with gradually increasing Reaching 120 ppb near tropopause
- CO with two distinct peak

Data description

2. Satellite measurements

- TROPOMI/S5P nadir-view instrument

wide field of view (FOV), daily global coverage, 3.5 x 7 km^2

- **TROPOMI Level 2 CO total column product**

have sensitivity to boundary layer below 5 km ➔ 3 day-composite

- **Ozone Profiles (this work)**

Optimal estimation to Backscattered ultraviolet spectrum (310-335 nm)

coarse vertical resolution (a few 10 km)

➔ integrated lower and upper tropospheric column ozone

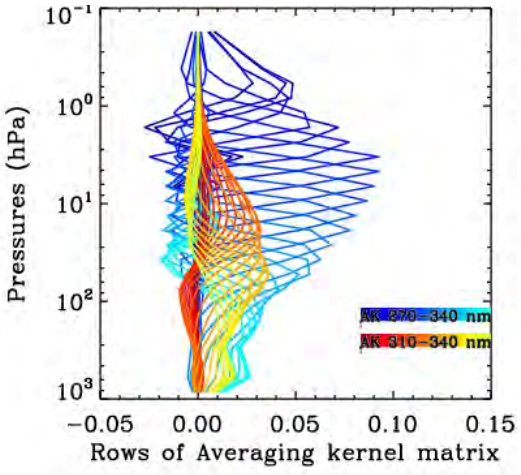
- MLS/Aura limb-view instrument

High vertical resolution (4 km) in stratosphere, Narrow filed of view, 5 km cross-track x 500 km along-track

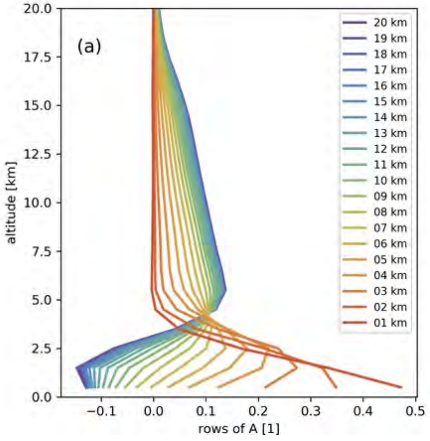
- MLS/Aura Near-Real-Time L2 CO V005

➔ 5 day-composite

<TROPOMI O3P AK>

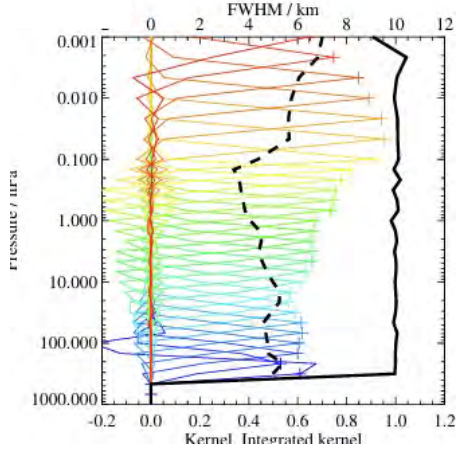


<TROPOMI CO AK>

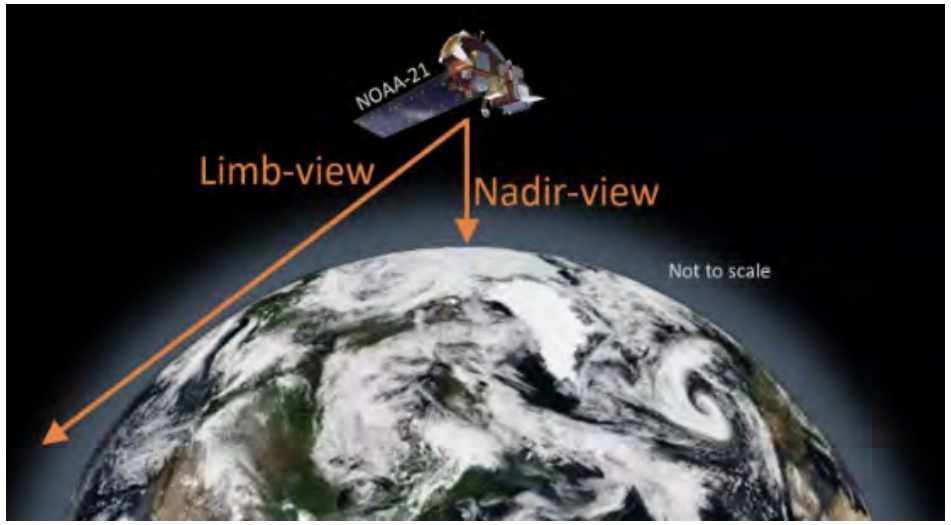


Borsdorff et al. (2022)

<MLS CO AK>

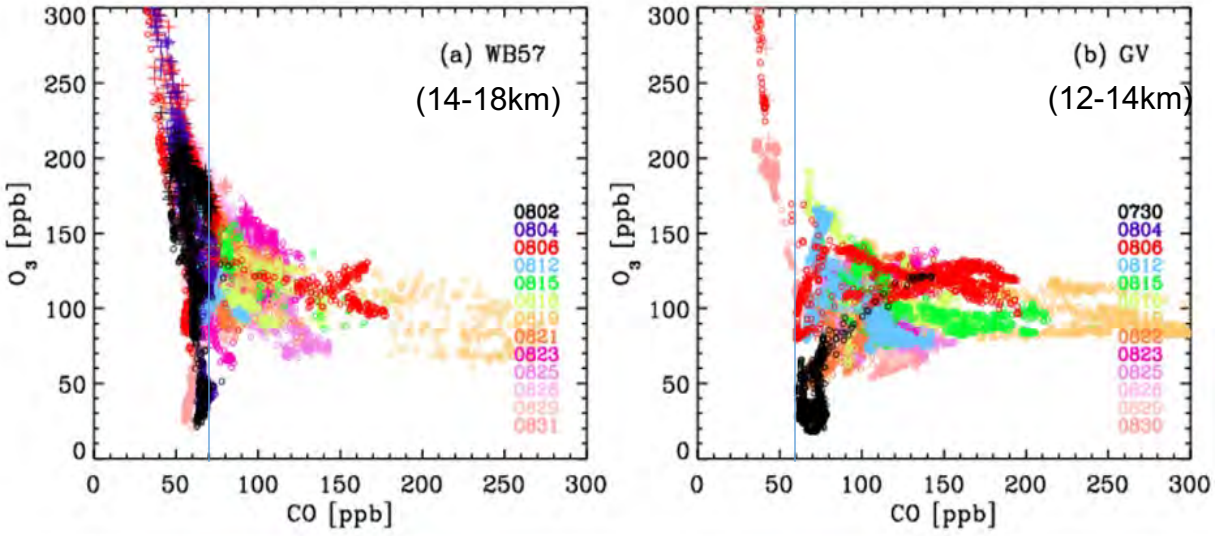


Livesey et al. (2020)



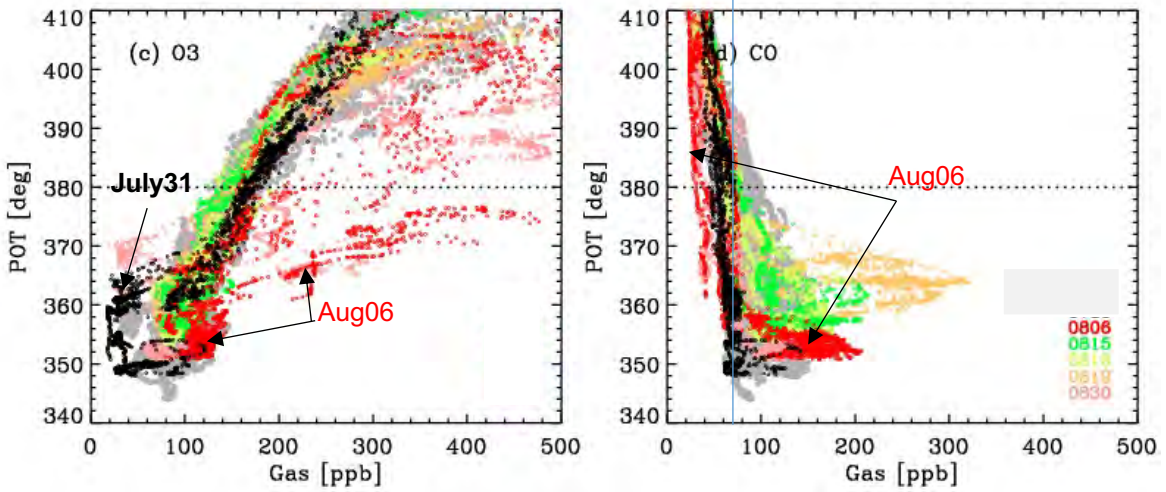
Individual flights in tracer-tracer space

- **Scatter plots btw O3 and CO at cruise altitudes**



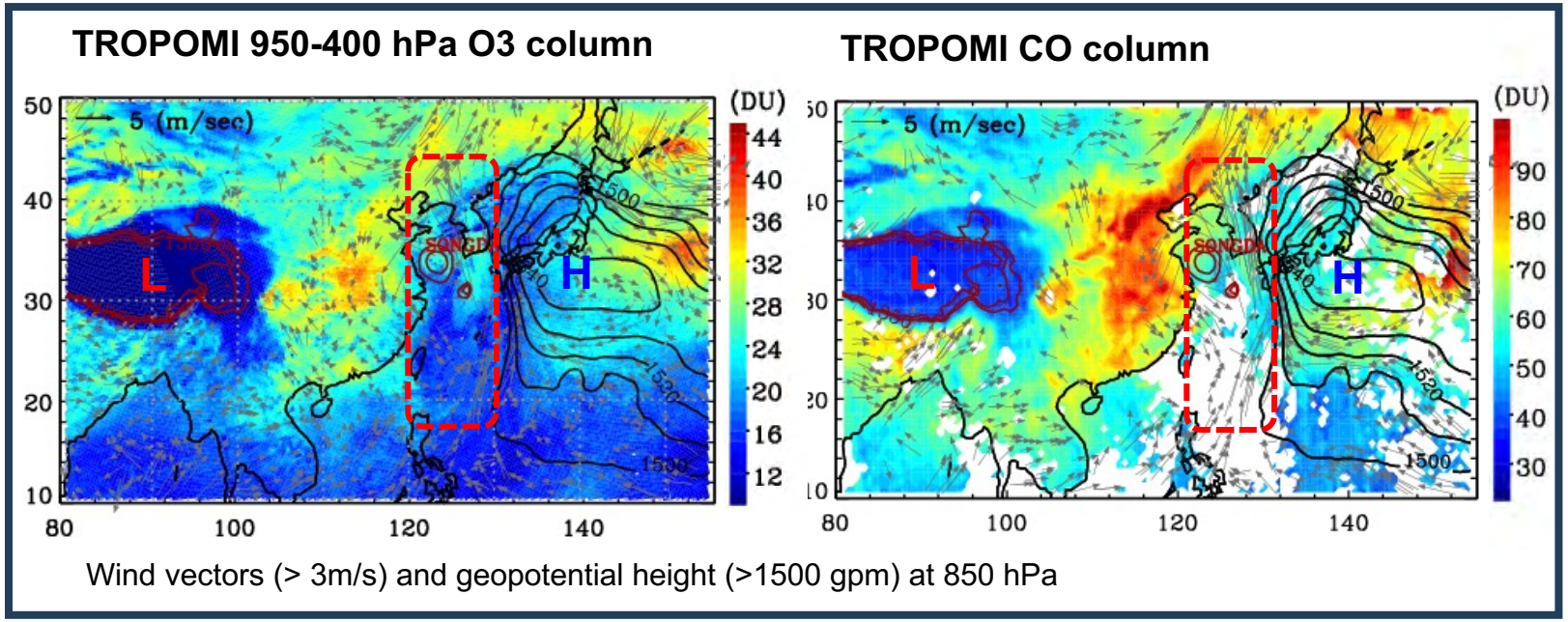
- the cruise elements provide the UTLS composition over the western pacific (20-40ºN, 135-145ºE).
- thirteen flight pairs assigned generate a well-known "L" shaped curve with a transition region of mixed air masses in the corner space
-vertical lines represent the strongly increasing O_3 at stratospheric CO equilibrium (~ 50 ppb)
-horizontal lines of "L") is generated with anomalous CO concentrations peaking up to 300 ppb in the UT region

- **O3 and CO in the tracer-potential temperature space**



- In the free troposphere ($\theta < 370^o$), abnormally high CO levels (> 150 ppb) were observed from flights on 6, 15, 16, and 19Aug.
- the coherent ozone levels remained unperturbed except for on **August 6** (30-ppb increase below 360^O)
- Abnormally high O3 due to the stratospheric intrusion **July 31** and August 30.
- Abnormally low O3 due to the typhoon induced uplifting

Comparative analysis in the lower troposphere : July 31

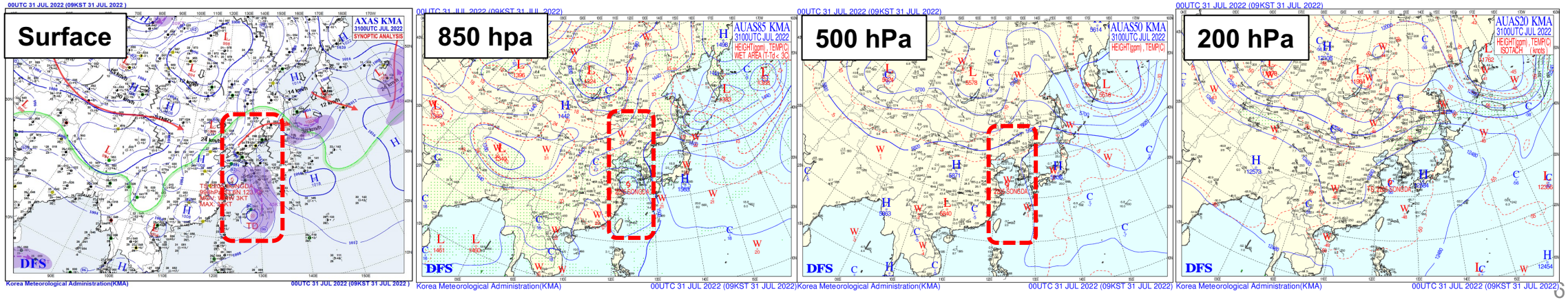


Wind vectors (> 3m/s) and geopotential height (>1500 gpm) at 850 hPa

GPH – the location of WPSH.
Wind – fast-moving air mass originating from remote tropics, by southerly winds Along the western edge of the WPSH, Coinciding with the path of the typhoon.

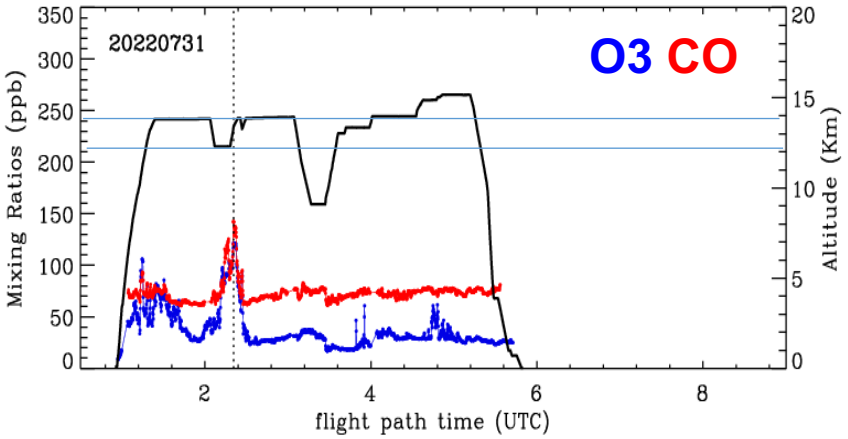
TROPOMI-the relatively low amount of Both CO and O3. Peaked over the North China Plain extending between 25 and 45 latitudes where the winds are very weak.

- Synoptic map from Korean Meteorological Agency (KMA)

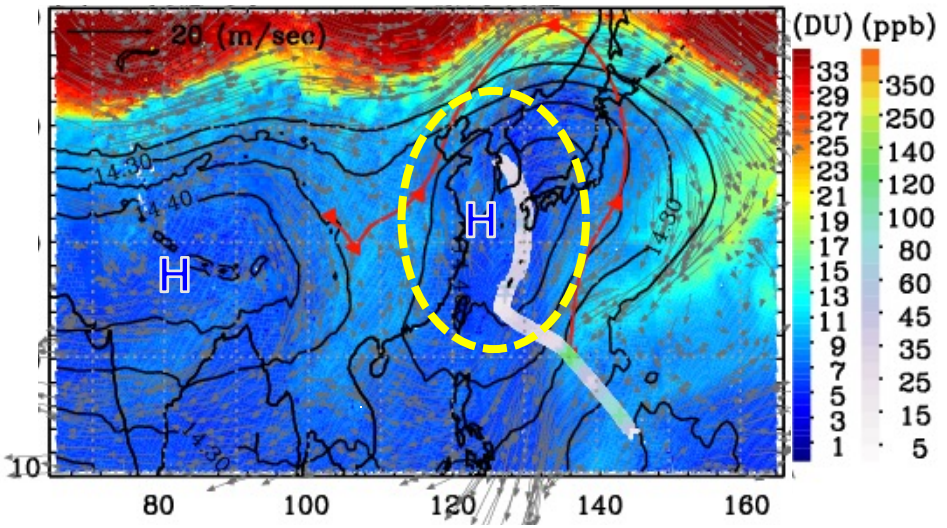


GV flight : July 31

1. GV flight observations

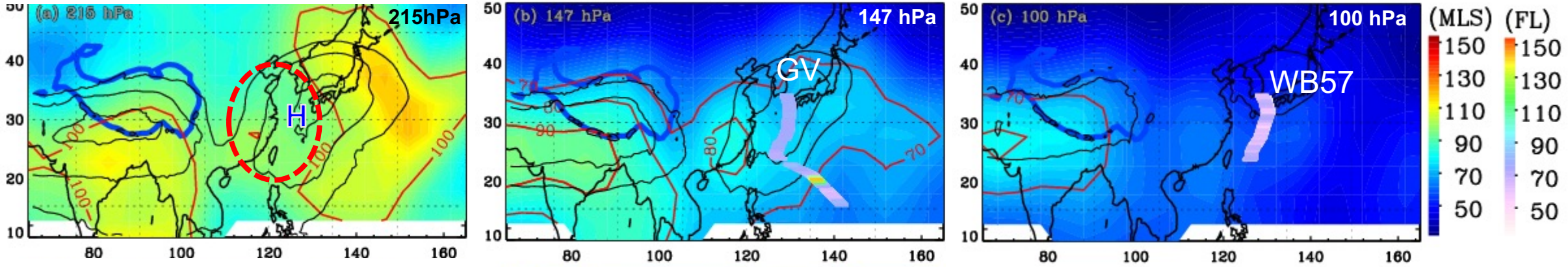


2. TROPOMI O_3 colum 215-100 hPa



Filled contour (red-blue) O3
Colored line path : GV
Black contour : GPH
Red line : 4day-backtrajectory

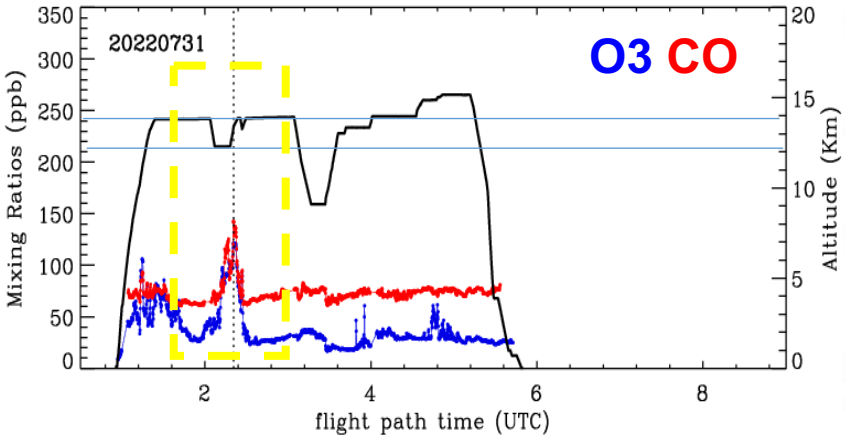
2. MLS CO ppb



- Western Pacific High (WPH) is clearly identified as a western mode of ASM anticyclone.
- Convectively lifted clean air mass is trapped within WPA, with GV = 25 ppb, CO = 70 ppb

GV flight date : July 31

1. GV flight observations



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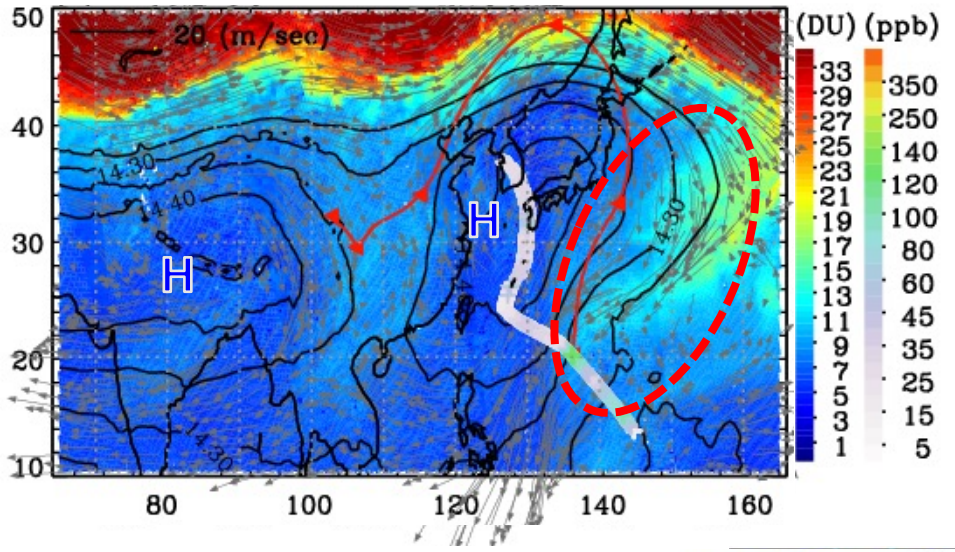
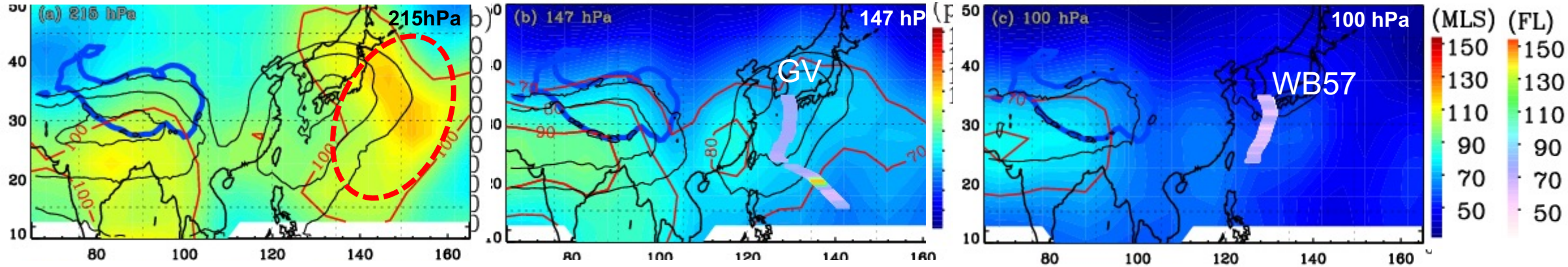


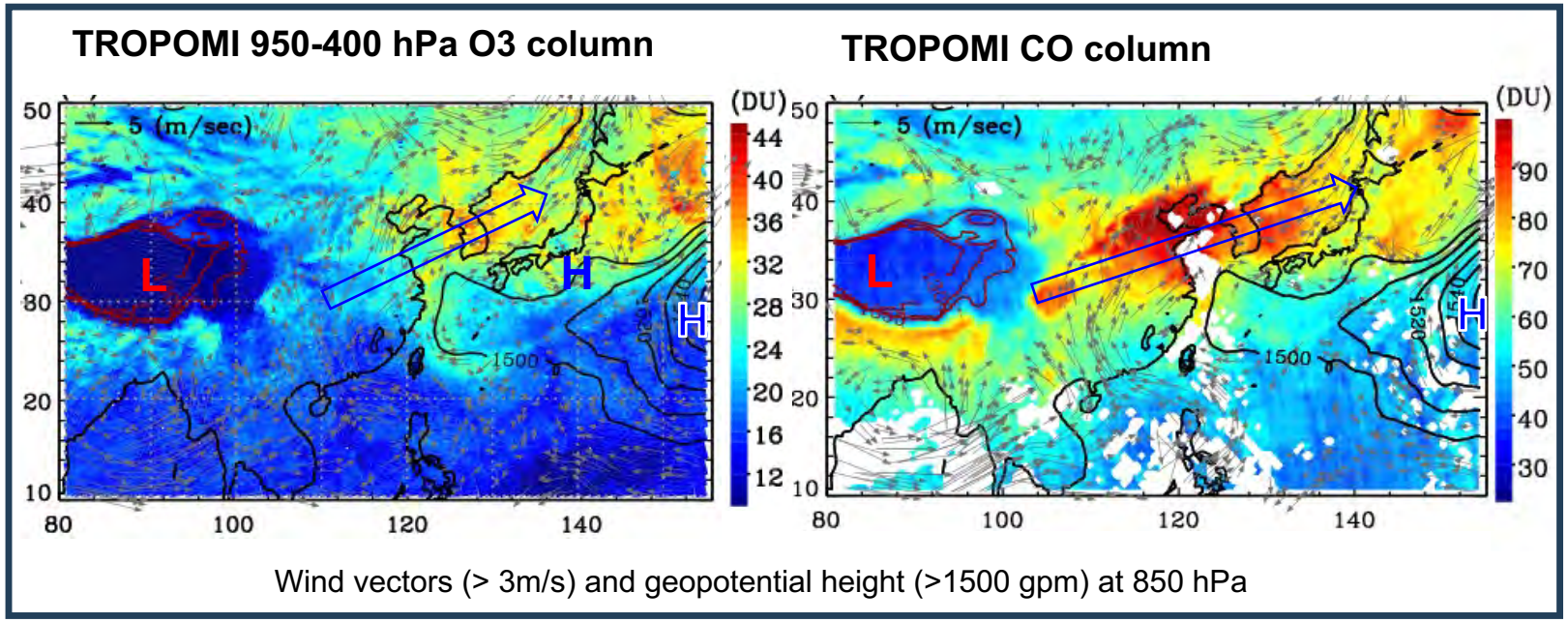
Filled contour (red-blue) O3
Colored line path : GV
Black contour : GPH
Red line : 4day-backtrajectory

2. MLS CO ppb (July 29-August02)



- Anticyclone eddies with its elongated shape in north-south direction, over the western edge of the WP anticyclone
- Carrying air with high CO (140 ppb) and ozone (120 ppb) toward tropics (135E,20N).
- Back trajectory results (red line) also suggest the origin of the eddies to the Asian continent.

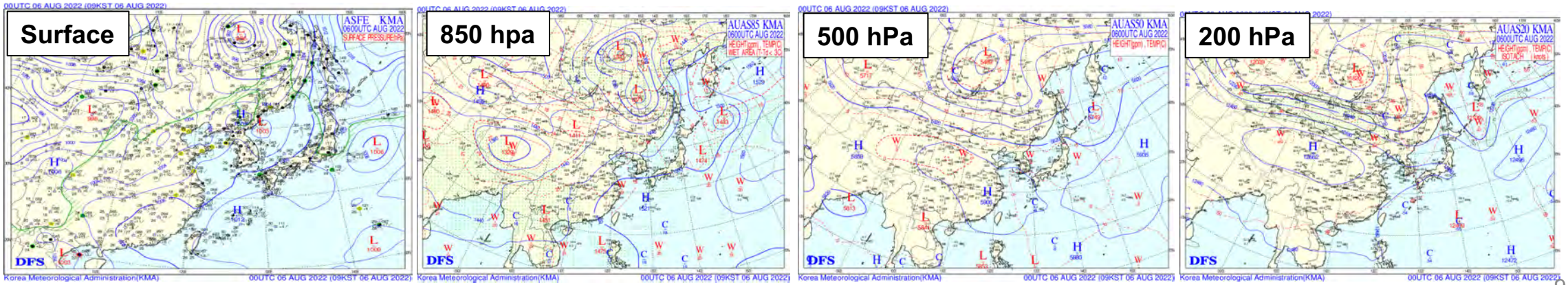
Comparative analysis in the lower troposphere : Aug 06



Wind vectors (> 3m/s) and geopotential height (>1500 gpm) at 850 hPa

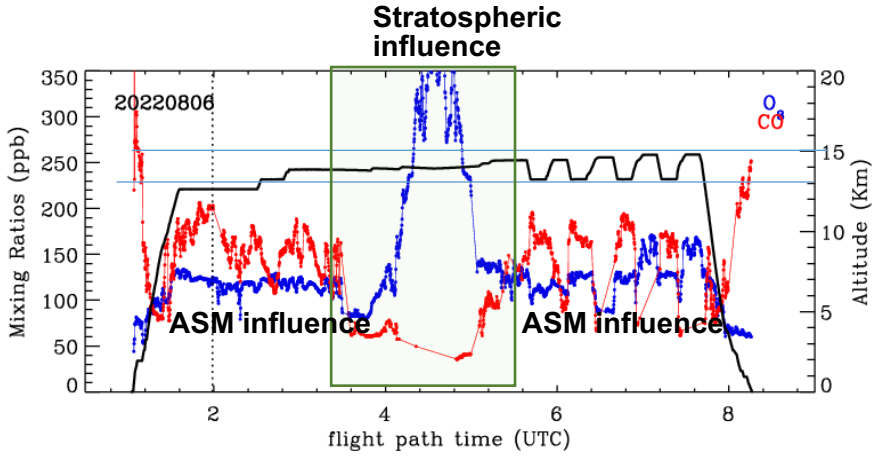
GPH – the WPSH is moved toward south.
(Low O3 and Low CO)
Wind – transboundary of pollutants From China to Korea and Japan.
TROPOMI - air pollutants are spread out from the coast of China to the western pacific with intensified westerlies.

- Synoptic map from Korean Meteorological Agency (KMA)

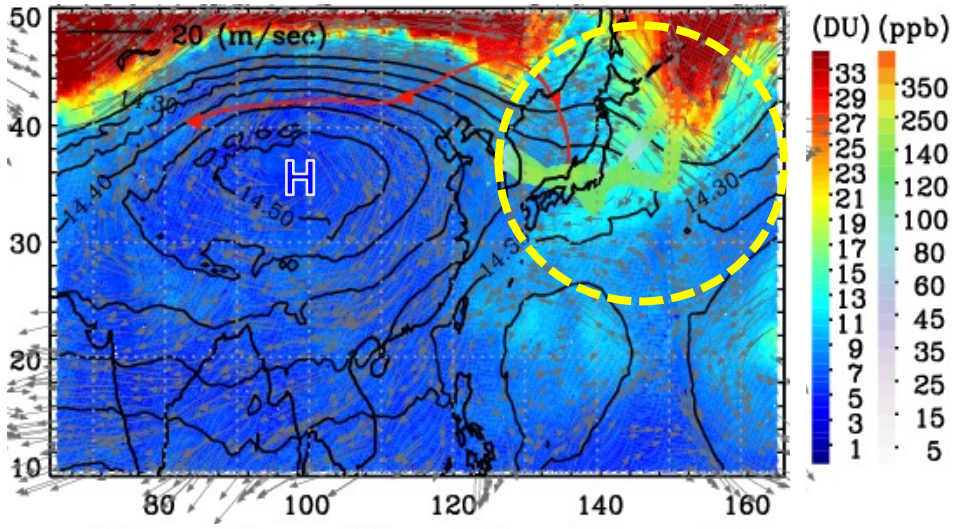


GV flight date : August 06

1. GV flight observations

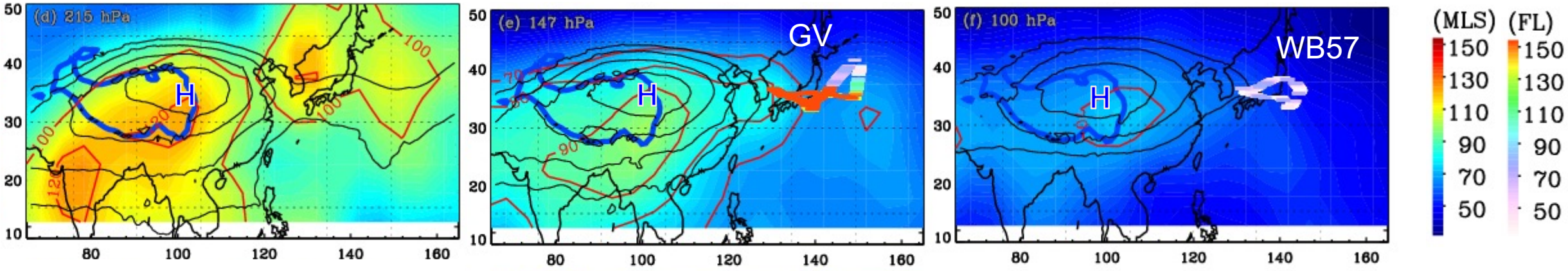


2. TROPOMI O_3 colum 215-100 hPa at the 150 hPa GPH/wind



- ASM centering Tibet. (Low O3 and High CO), without WPA
- ASM airmass is captured during GV observations over the eastern edge of ASM circulation (High CO >150 ppb)
- Transient mixing (low CO and High O3)

2. MLS CO ppb (August 04-August08)

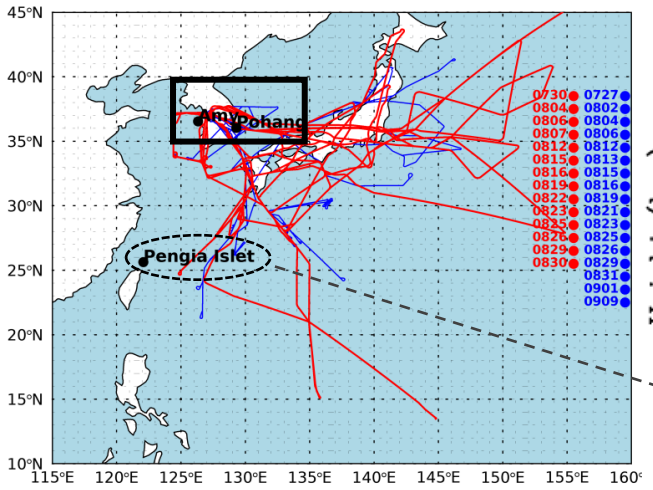


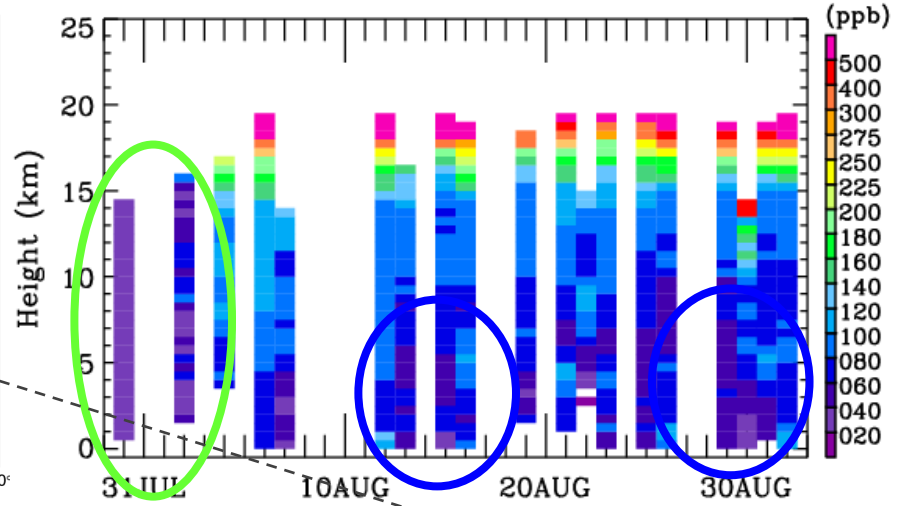
Summary

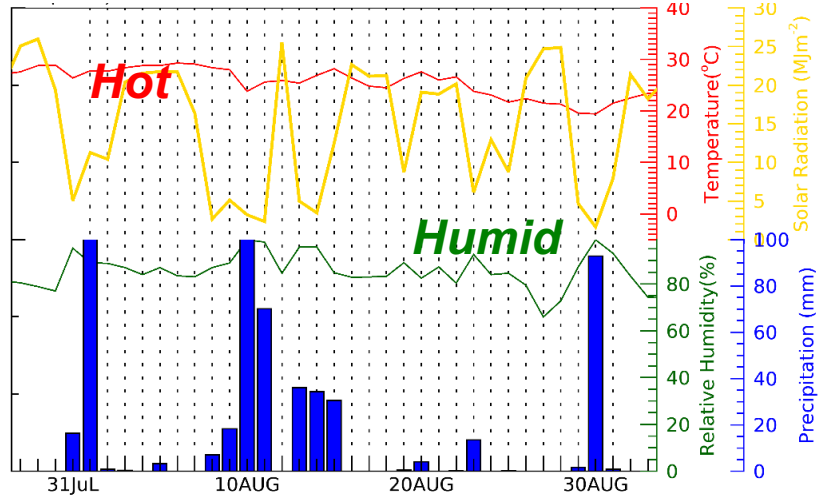
- Ozone concentrations were observed to be a few ten ppb higher in the free troposphere than the boundary layer ozone of ~ 50 ppb on average.
- CO concentrations exhibits an isolated peak of ~ 150 ppb on average around 13 km, distinct from the maximum in the boundary layer.
- The flight measurements taken through the UTLS western pacific reveal anomalous correlations between ozone and CO tracers, diverging from the typical ‘L’ tracer-tracer correlation.
- Case of July 31 when the combination of the tropical cyclone and the WPSH mainly modulates the tracer distribution and the eastward eddy-shedding is observed.
- Case of August 06, with tracer anomalies caused by the strong ASM anticyclone, meteorological transport, and the transient mixing across the tropopause

Comparison of O3 profiles near Korean peninsular

- Daily profiles from GV+WB57 measurements in afternoon







- Comparison with ozonesonde measurements