A54D-01: Atmospheric trace gas (NO2 and ozone) dynamics over coastal waters near polluted urban regions

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At the interface between the land, oceans, and atmosphere, coastal regions are highly dynamic environments, characterized by strong variability in both water and air quality. Variability in atmospheric composition is associated with highly variable anthropogenic emissions, as well as complex meteorological processes that influence the circulation and accumulation of atmospheric pollutants at the land-ocean interface. Assessing the spatial and temporal dynamics of atmospheric pollutants, aerosols, and absorbing trace gases in coastal areas is critical for improving modeling of coastal tropospheric air quality, developing accurate satellite retrievals of coastal ocean color and biological processes, determining impacts of atmospheric pollution on human health, and assessing the ecological implications of atmospheric pollutant deposition for coastal terrestrial and aquatic ecosystems.

Here, we present new measurements of atmospheric trace gas (NO2, and ozone) dynamics across a range of estuarine and coastal waters near urban regions. Measurements were conducted from research vessels using NASA's shipboard Pandora spectrometers, as part of recent multidisciplinary, multiplatform field campaigns, including the 2016 KORUS OC/AQ field campaign in the Yellow Sea and East Sea/Sea of Japan, the 2017/2018 OLWETS field campaign in the Chesapeake Bay estuary, and the 2018 LISTOS field campaign in the Long Island Sound. Shipboard measurements over these coastal waters were integrated with measurements from a ground-based Pandora network to examine differences in air quality over the land and over the ocean. Measurements were combined with air-parcel back-trajectory simulations to determine the origin of air masses over the coastal ocean. Comparisons with satellite retrievals of atmospheric composition reveal the benefits and limitations of polar-orbit satellite observations in capturing variability in atmospheric pollution gradients over land-water boundaries.

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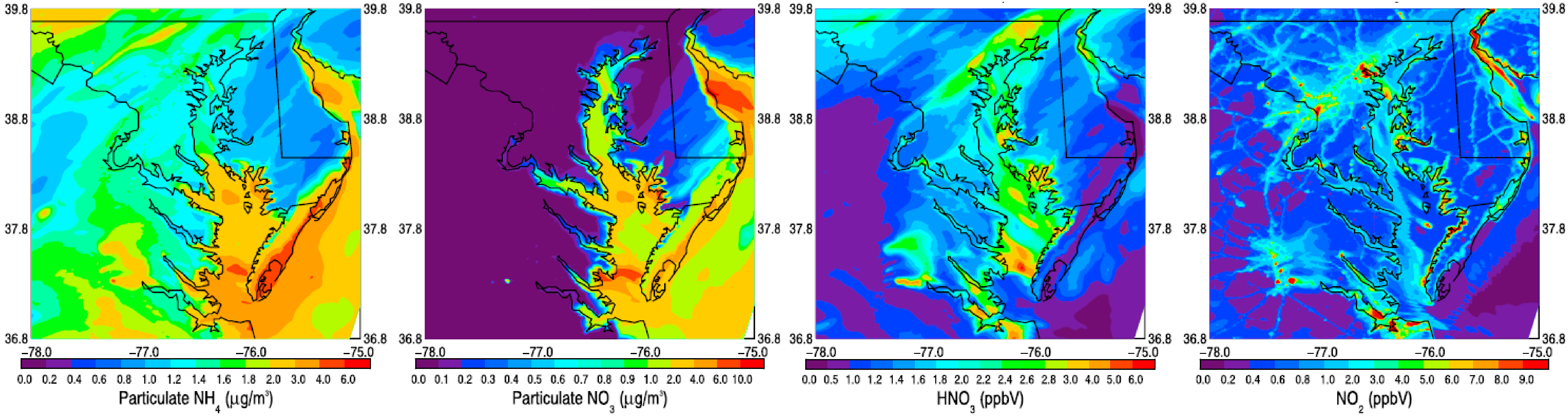
DISCOVER-AQ/CBODAQ campaign in the Chesapeake Bay

DISCOVER-AQ/CBODAQ campaign in the Chesapeake Bay

Coastal and estuarine waters are characterized by particularly high concentrations of atmospheric pollutants, higher than inland areas …

CMAQ Model run at 1.3 km resolution (July 2, 2011)



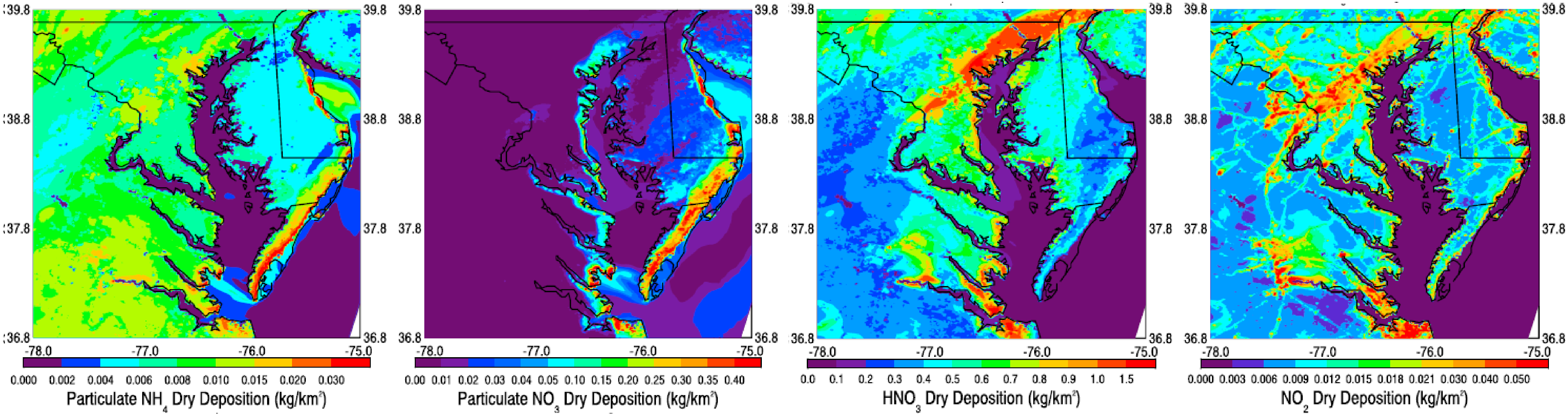
Loughner, Tzortziou et al 2016, J. Geophys. Res. Atmos.,121, 14,221–14,238, doi:10.1002/2016JD025571

DISCOVER-AQ/CBODAQ campaign in the Chesapeake Bay

Coastal and estuarine waters are characterized by <u>particularly high concentrations</u> of atmospheric pollutants, <u>higher than inland areas …</u>

… resulting in <u>elevated deposition of N</u> along shorelines, with major implications for coastal ecological processes

CMAQ Model run at 1.3 km resolution (July 2, 2011)



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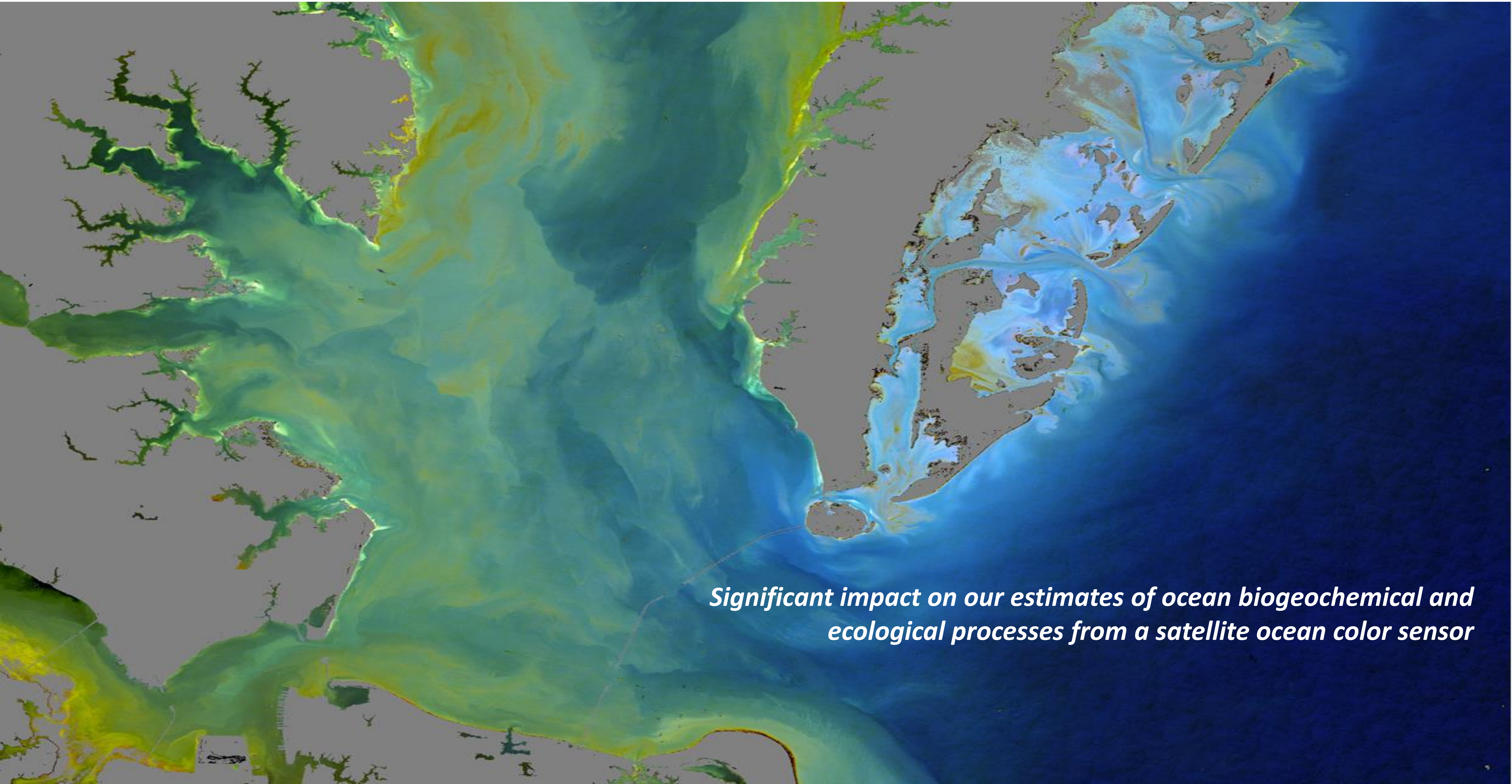
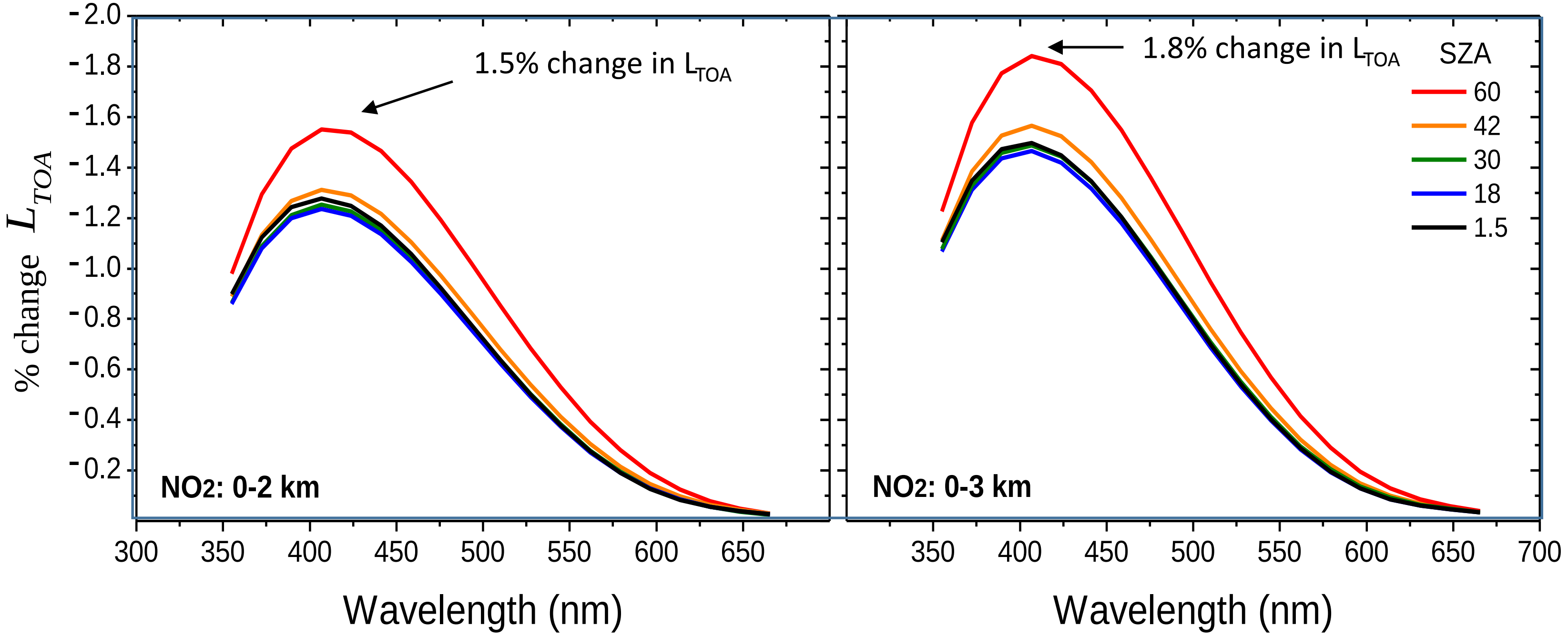


Significant impact on our estimates of ocean biogeochemical and ecological processes from a satellite ocean color sensor

Percent change in TOA signal, per 1 DU change in atmospheric NO_2

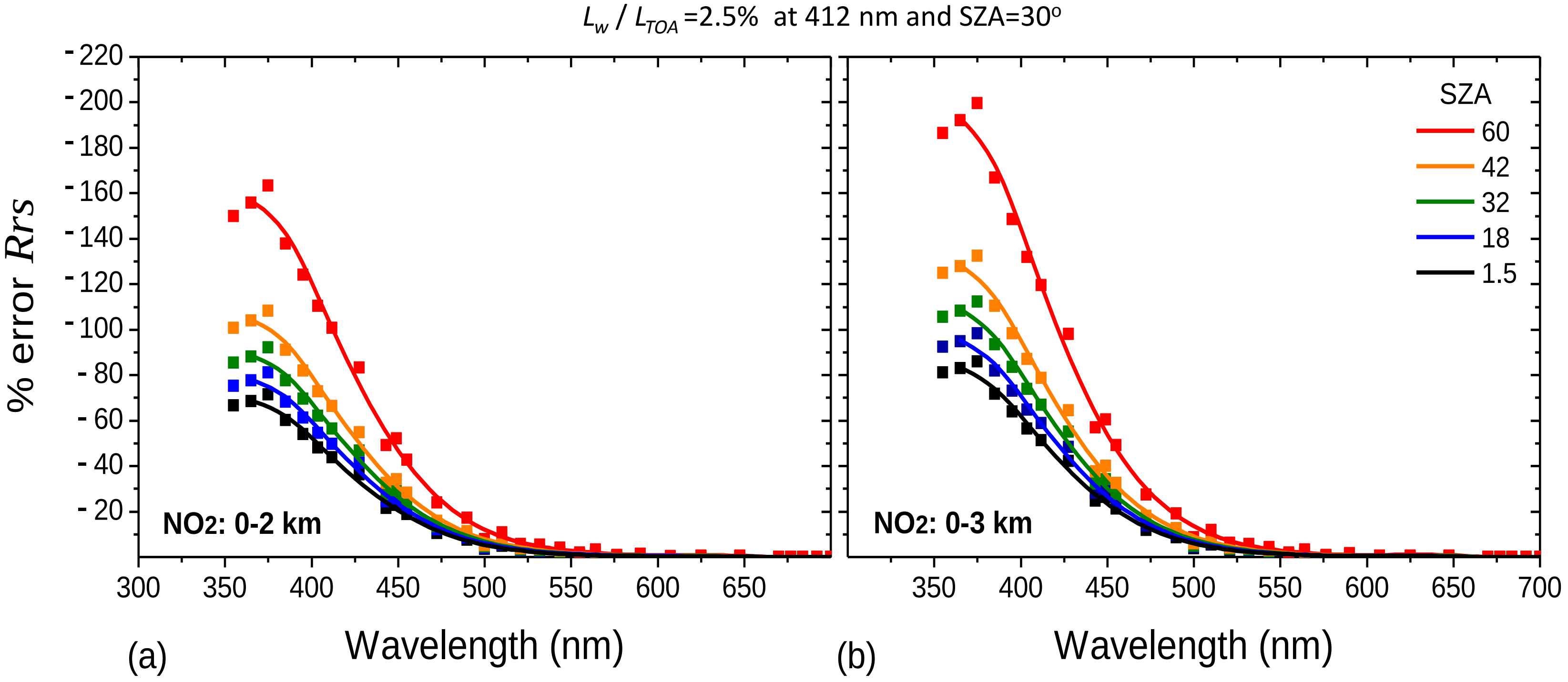


The impact on *L_{TOA}*

- has a strong spectral dependence: **max in 400-420 nm**, due to spectral shape in NO_2 abs. cross sections
- has a SZA dependence: because of the larger slant path with increasing SZA
- depends on NO_2 vertical distribution, and becomes larger as the NO_2 is distributed at higher altitudes

Tzortziou et al. 2014, Geophys. Res. Oceans, 119, 3834–3854, doi:10.1002/2014JC009803

Percent error in R_{rs} caused by not accounting for 1 DU of atmospheric NO_2



The impact on R_{rs}

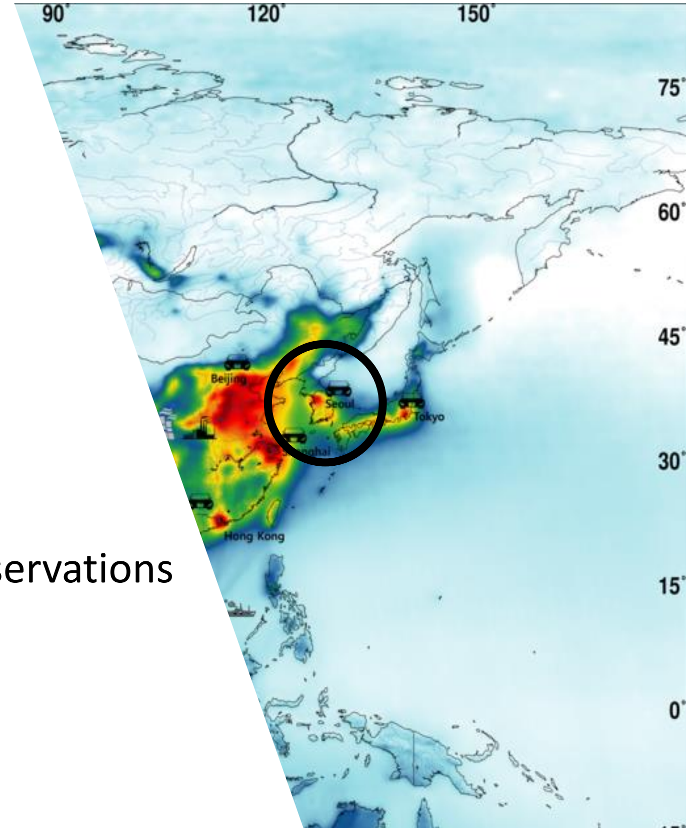
- has a strong spectral dependence: **max in 350-400 nm**, due to spectral dependence of Lw/L_{TOA}
- has a SZA dependence: because of the larger slant path with increasing SZA
- depends on NO_2 vertical distribution, and becomes larger as the NO_2 is distributed at higher altitudes

Tzortziou et al. 2014, Geophys. Res. Oceans, 119, 3834–3854, doi:10.1002/2014JC009803

KORUS-AQ

May-June 2016

3 aircraft, 2 research vessels
> 350 scientists and other personnel in the field



Objectives:

- Capture **spatial dynamics and diurnal variability** in NO_2 and O_3 using shipboard and satellite observations
- Examine **differences in air quality across the land-ocean interface**
- **Assess source contributions** to atmospheric pollution over these coastal waters

RV Onnuri

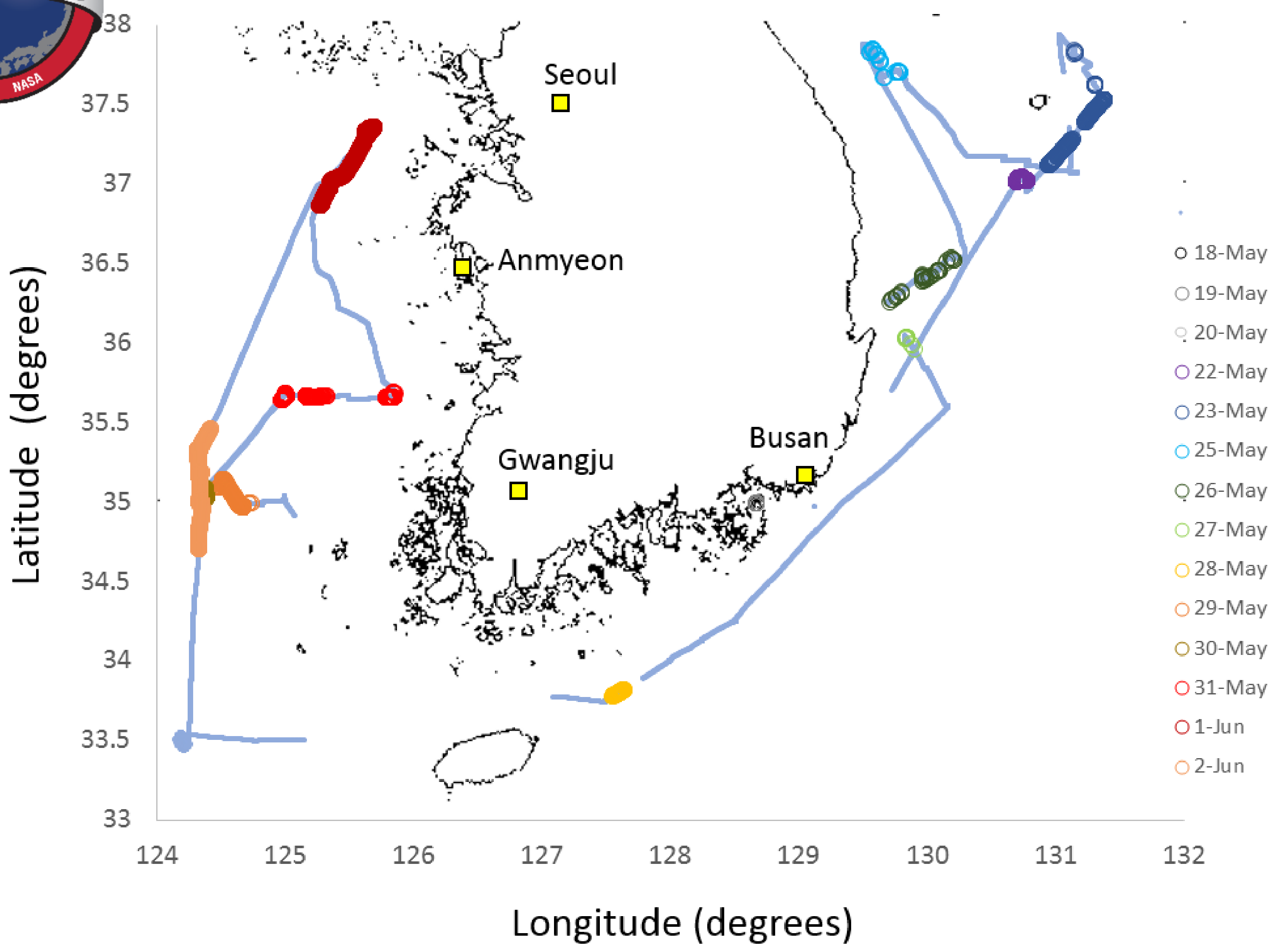
RV Jangmok

3 airplanes with 37 different instruments onboard (MOS+P, GeoTASO)

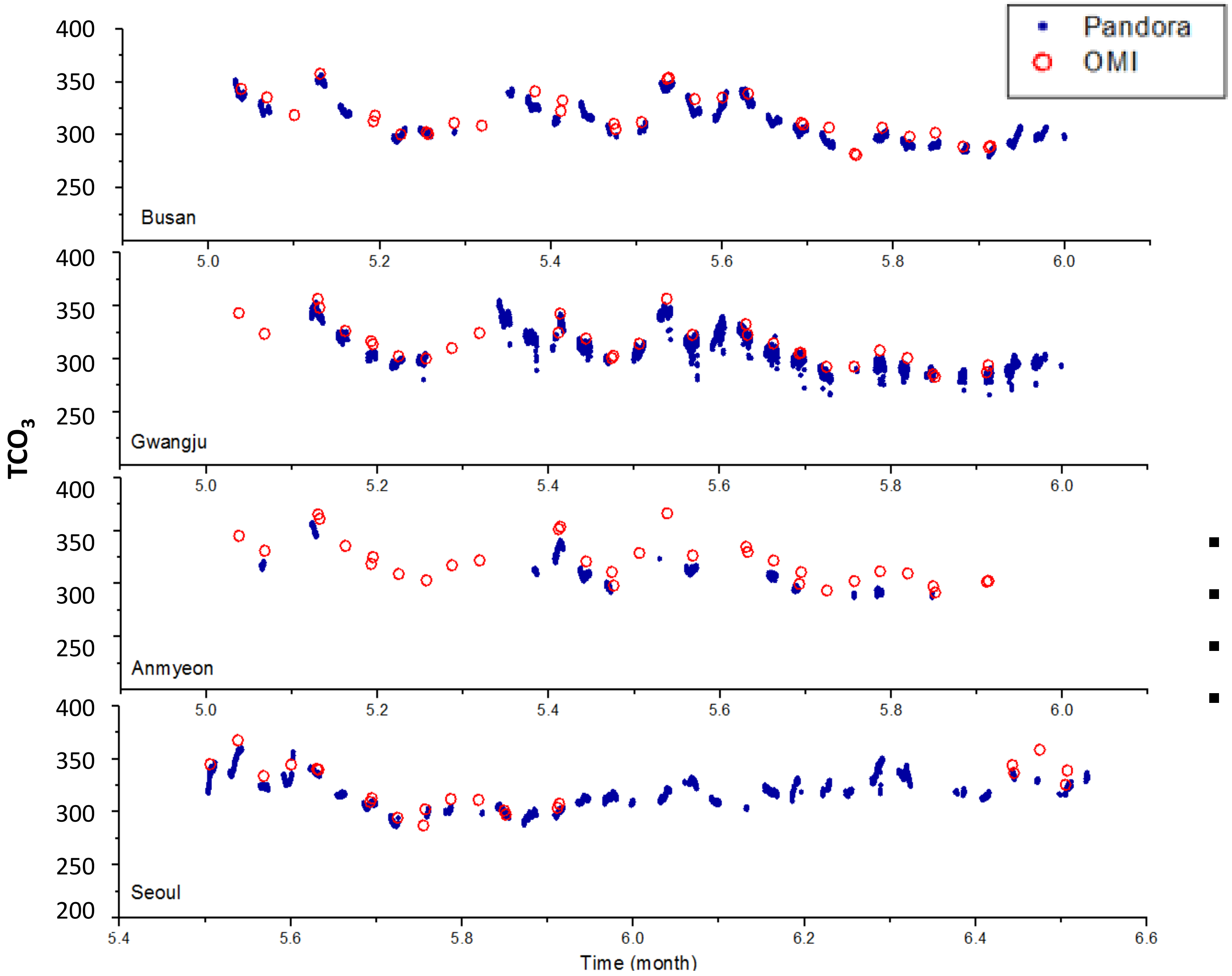
KORUS-AQ KORUS-OC

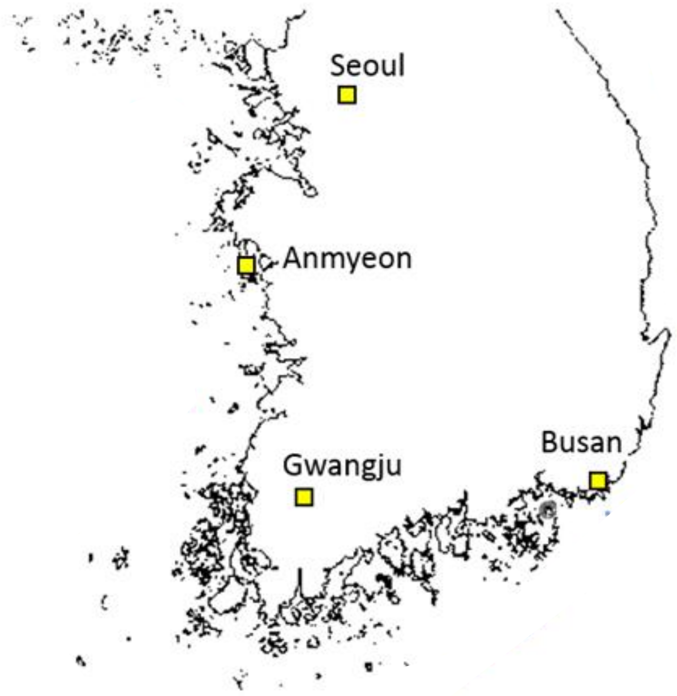
Continuous measurements of **$TCNO_2$ and TCO_3 over coastal land sites and over the coastal ocean** from the Pandora network

During KORUS OC, the RV *Onnuri* covered an area along the Eastern, Southern and Western South Korean coasts



Total Column Ozone (TCO_3) from Pandora and OMI

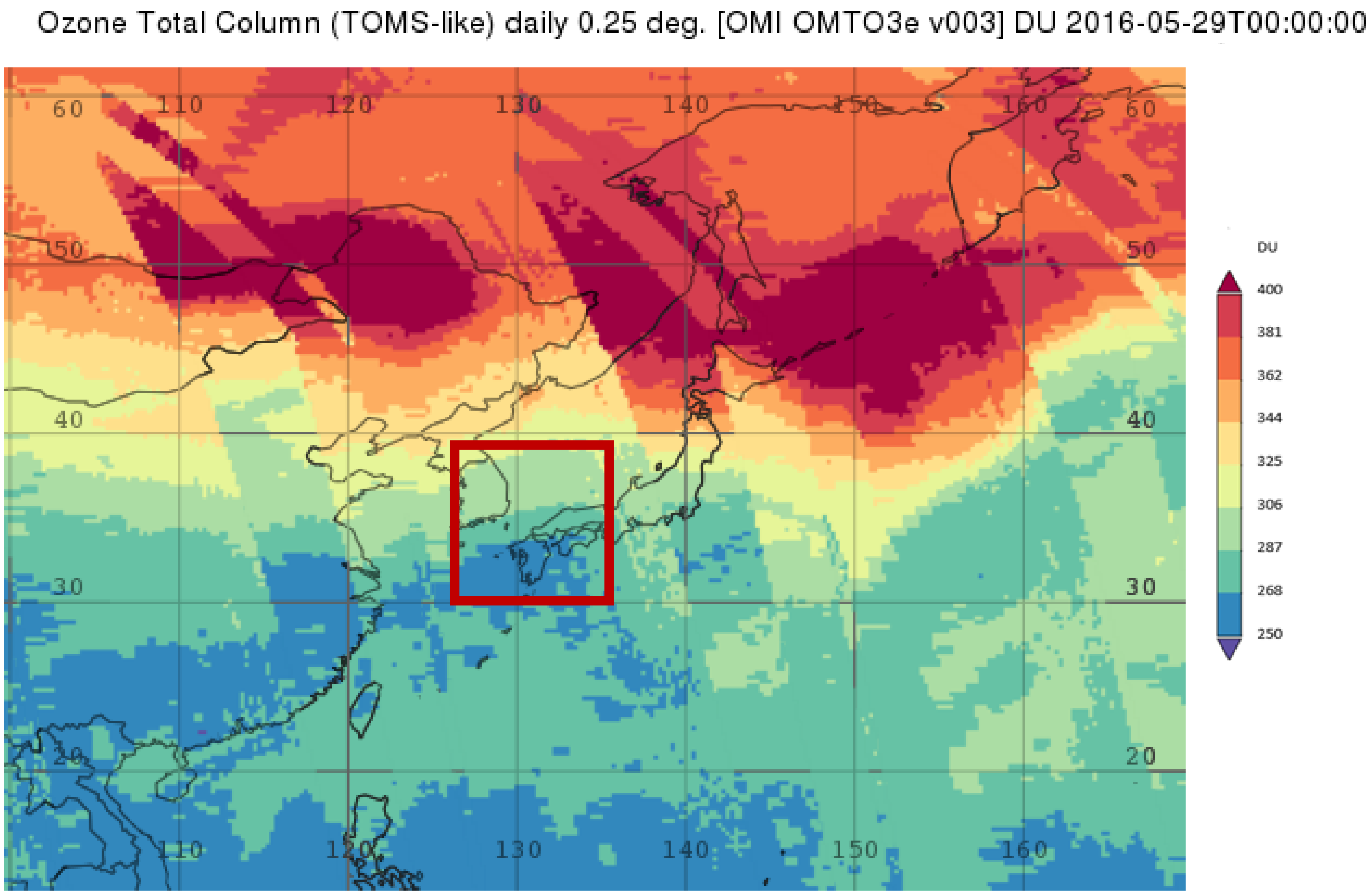




- Similar TC ozone range & dynamics across coastal land sites
- TCO_3 changed by <25% at each site
- Clear quasi bi-weekly oscillation
- Excellent agreement between OMI-PSI (< 2.2% difference)

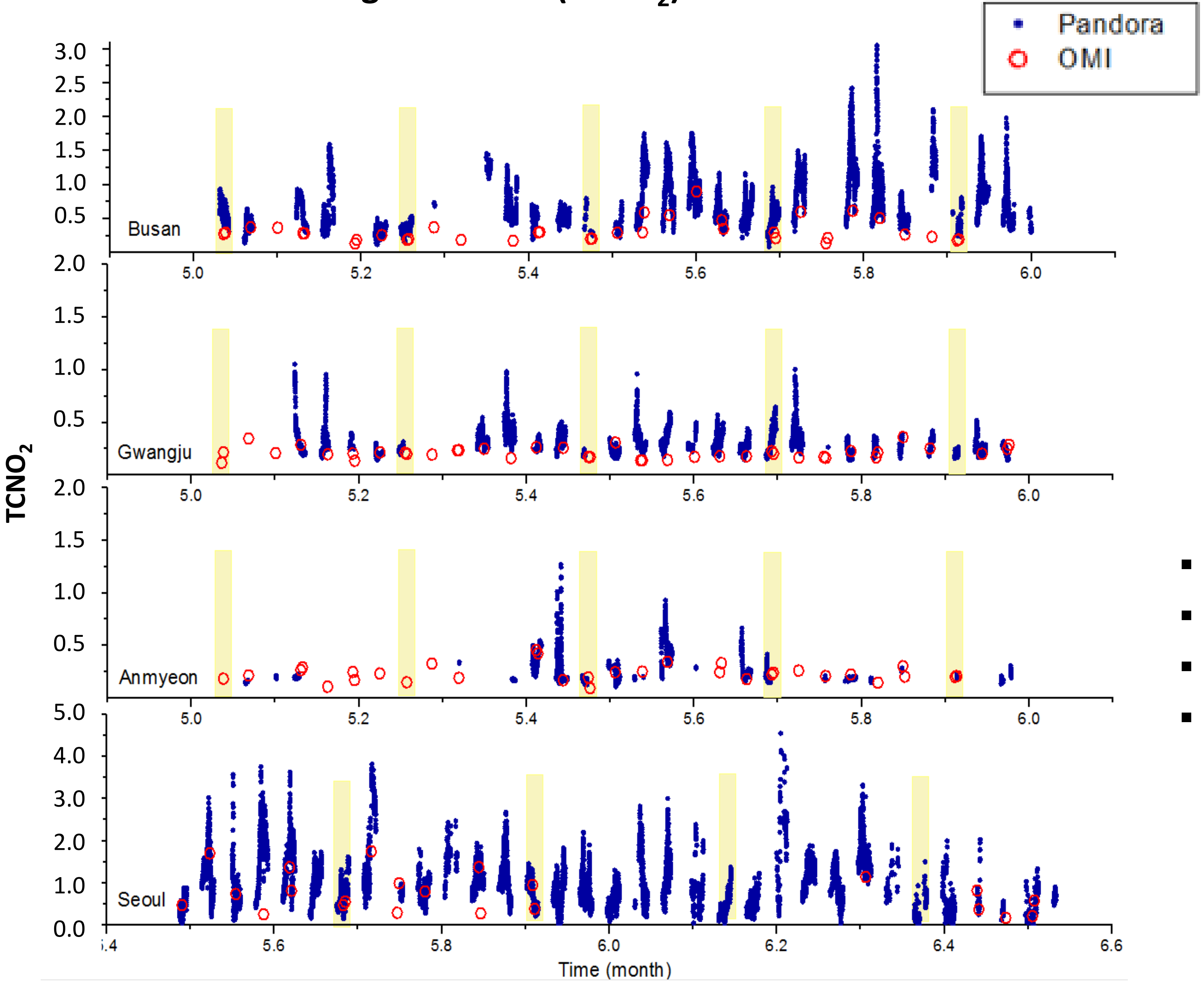
	OMI TCO_3	PSI TCO_3	$\%DTCO_3$
Busan	316 (± 21)	314 (±19)	0.38%
Gwangju	315 (± 20)	311 (± 19)	1.17%
Anmyeon	322 (± 21)	315 (± 17)	2.15%
Seoul	323 (± 22)	320 (± 15)	1.15%

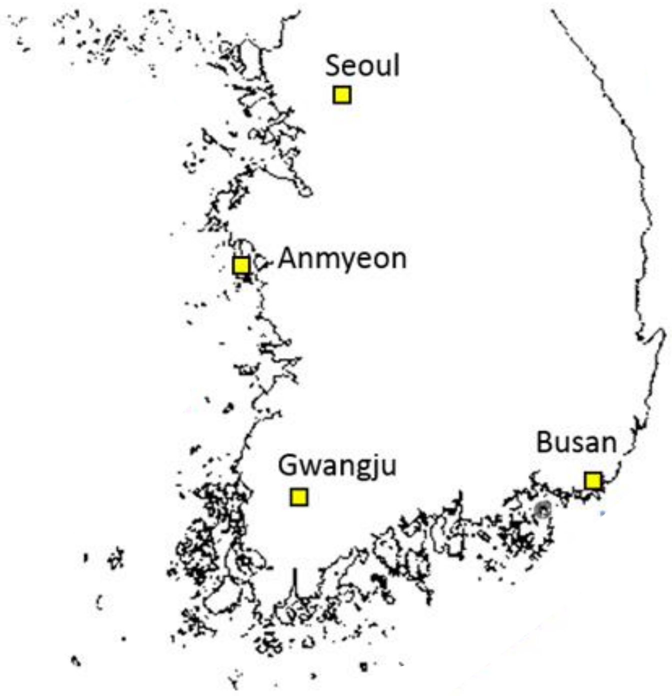
OMI synoptic observations highlighted the influence of large scale, eastward moving air masses on TCO_3 distributions



Aura OMI data not available during May 30 -June 10 due to satellite communication failure

Total Column Nitrogen Dioxide ($TCNO_2$) from Pandora and OMI

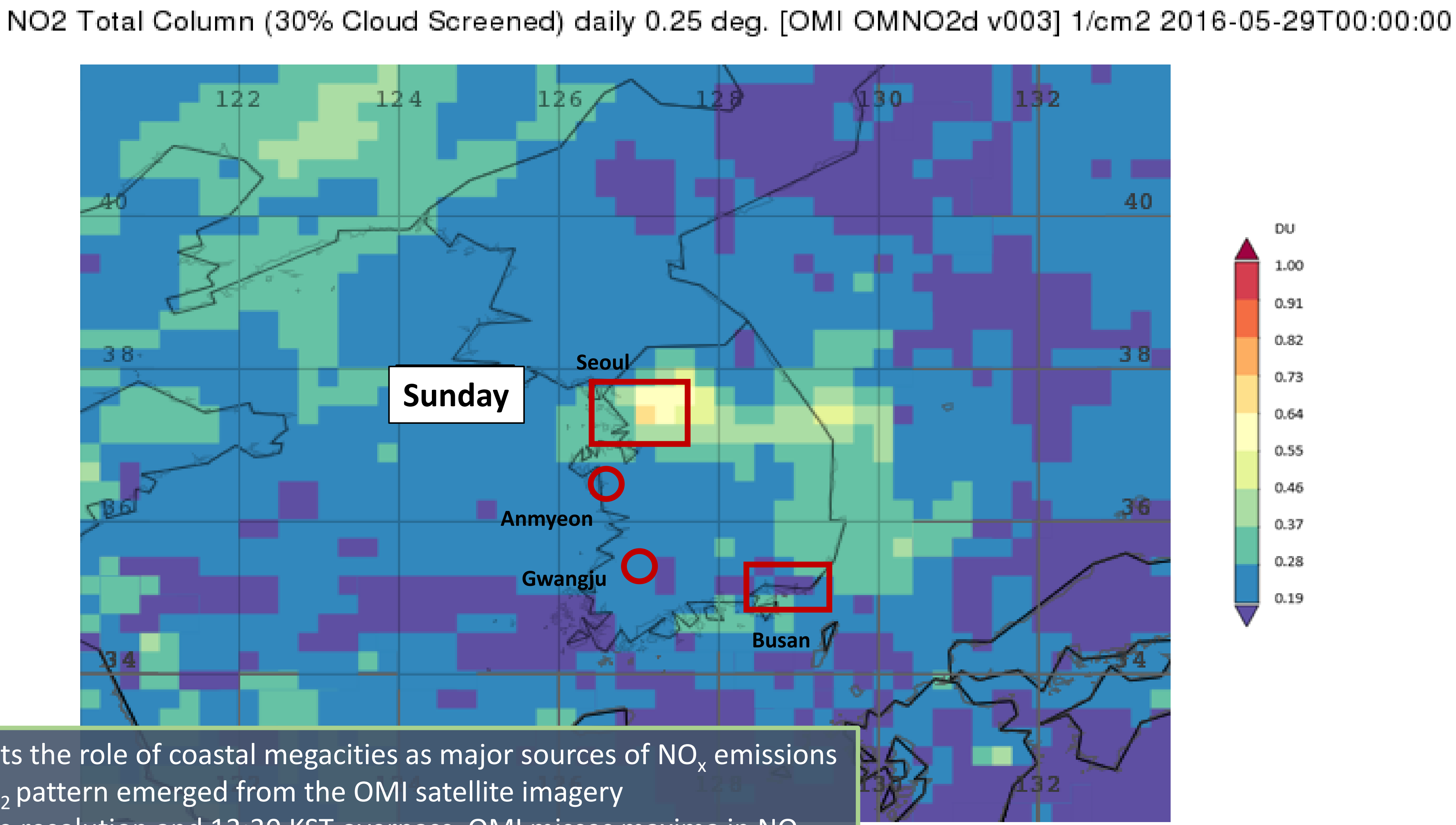




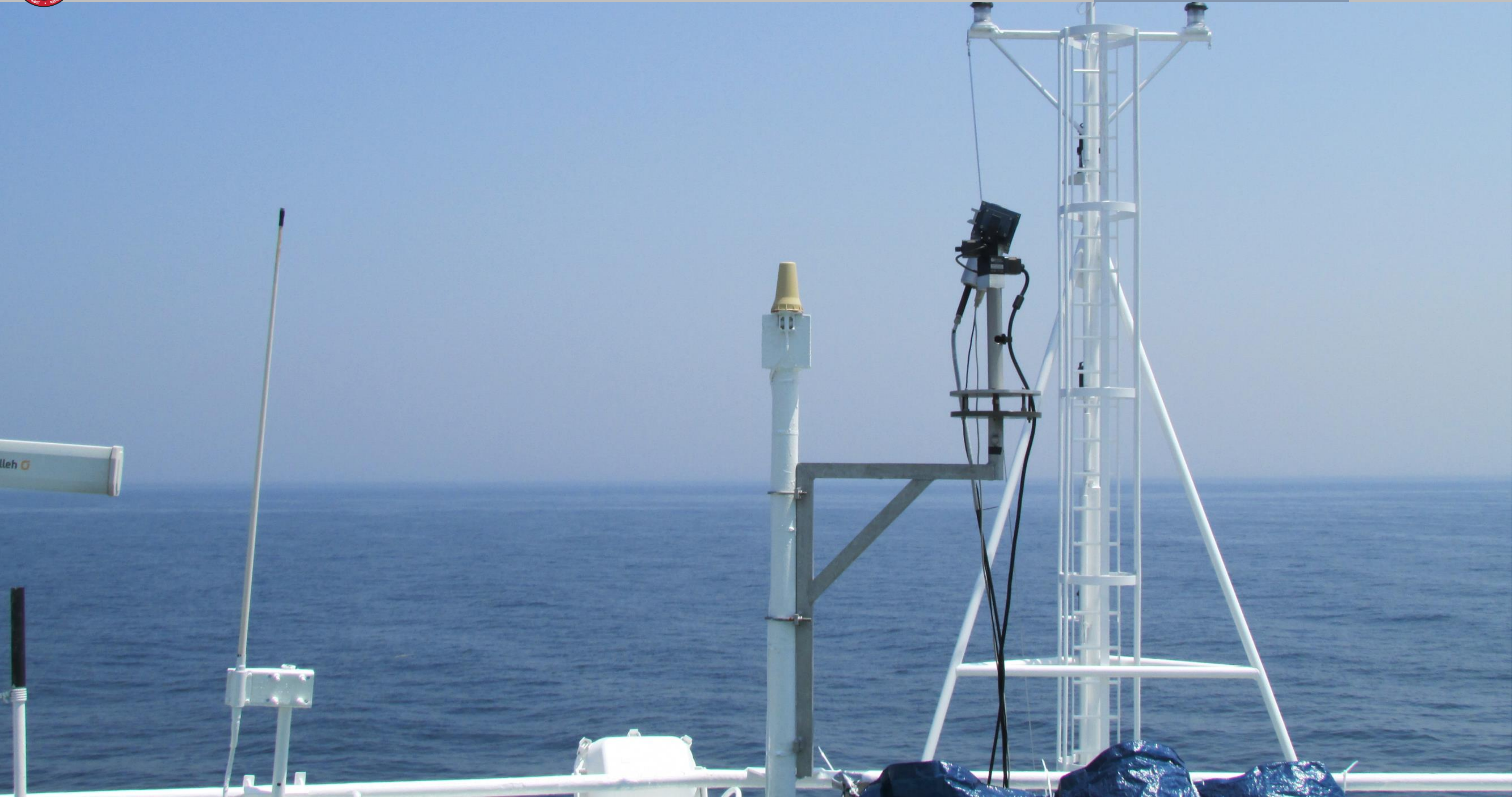
- Clear differences in TC NO_2 across coastal land sites
- Strong diurnal variability (change by 2-3 DU within 3-4 hrs)
- Clear weekly cycle at urban sites (minima on Sundays)
- Disagreement between OMI-PSI (> 50% difference)

	OMI $TCNO_2$	PSI $TCNO_2$	$\%DTCNO_2$
Busan	0.32 (± 0.17)	0.71 (± 0.39)	-55.00%
Gwangju	0.20 (± 0.05)	0.31 (± 0.13)	-37.01%
Anmyeon	0.24 (± 0.08)	0.27 (± 0.14)	-11.37%
Seoul	0.75 (± 0.48)	1.01 (± 0.64)	-25.45%

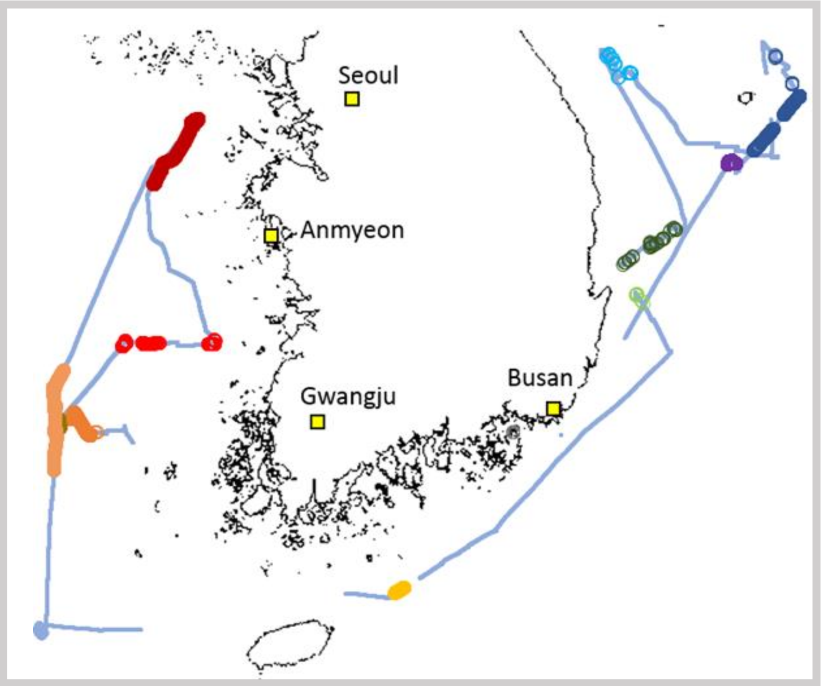
TCNO$_2$ dynamics driven primarily by local processes and local emissions

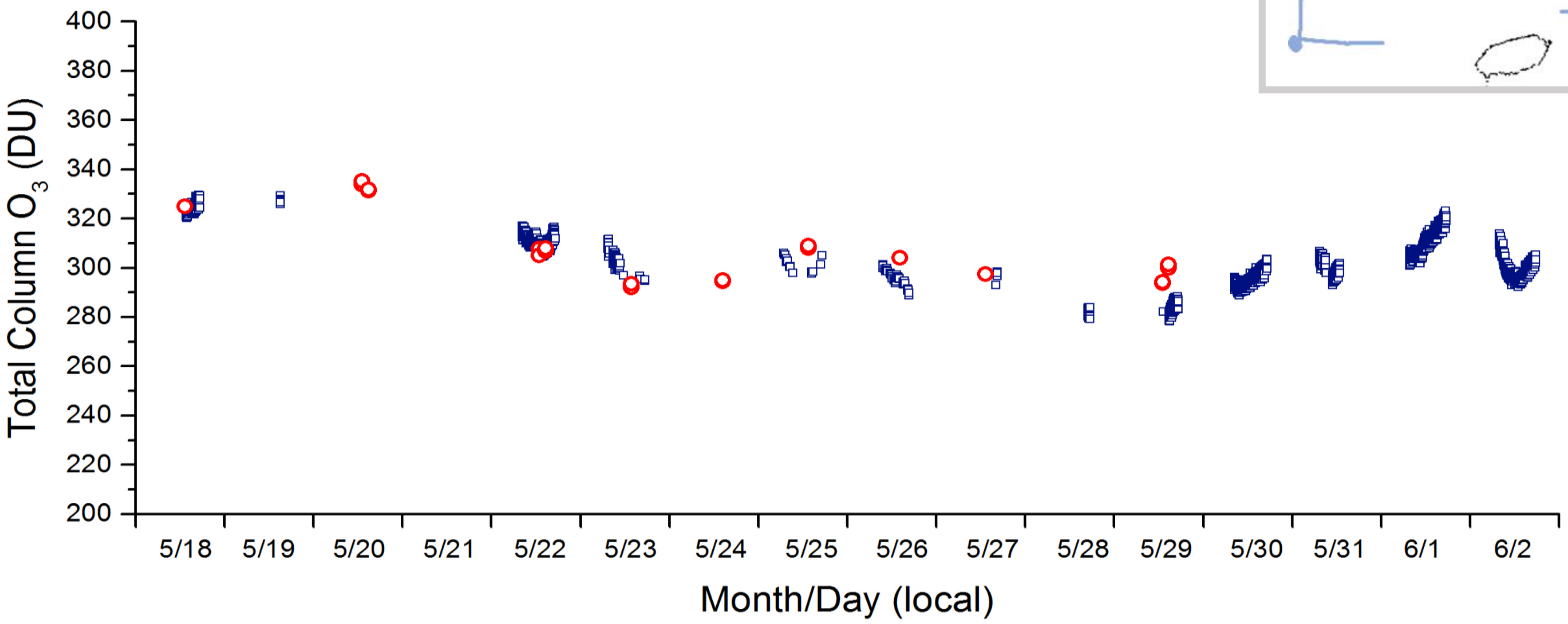


- OMI highlights the role of coastal megacities as major sources of NO_x emissions
- A weekly NO_2 pattern emerged from the OMI satellite imagery
- Due to coarse resolution and 13:30 KST overpass, OMI misses maxima in NO_2

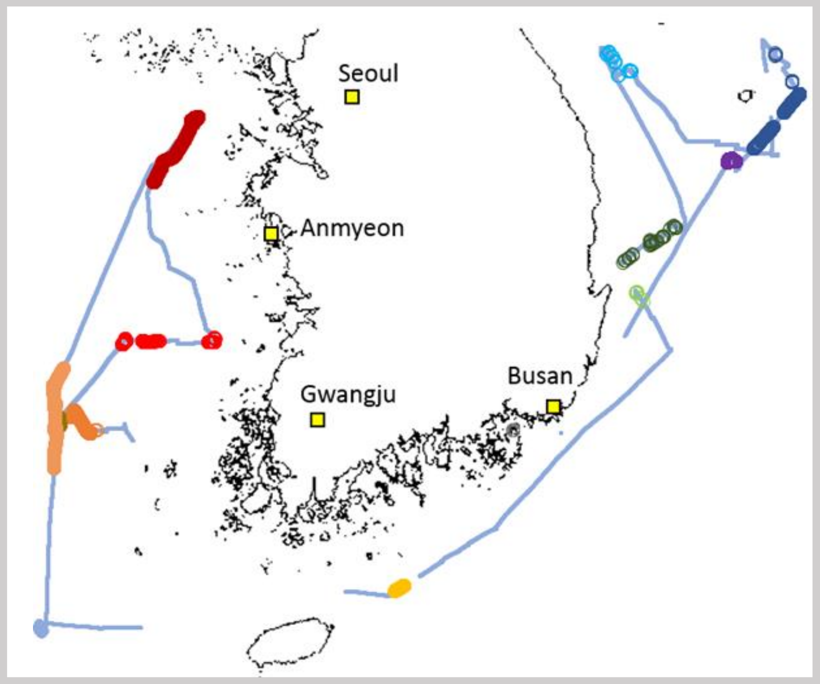


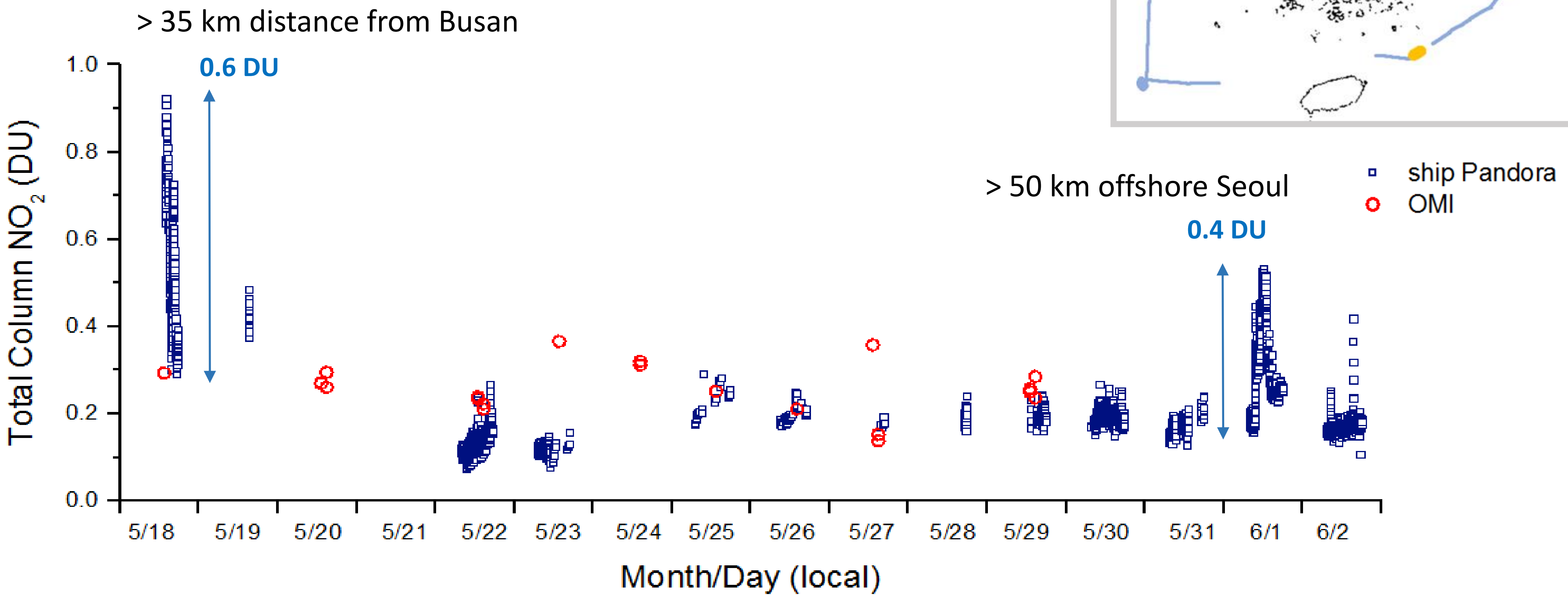
- Range in TCO_3 over the ocean very similar to that over land
- TC O_3 varied by ~20% over the ocean (~25% over land)
- Clear quasi bi-weekly oscillation
- Change by < 7% (~22 DU) during any single day
- Excellent agreement between OMI-PSI(mean APD =3%)

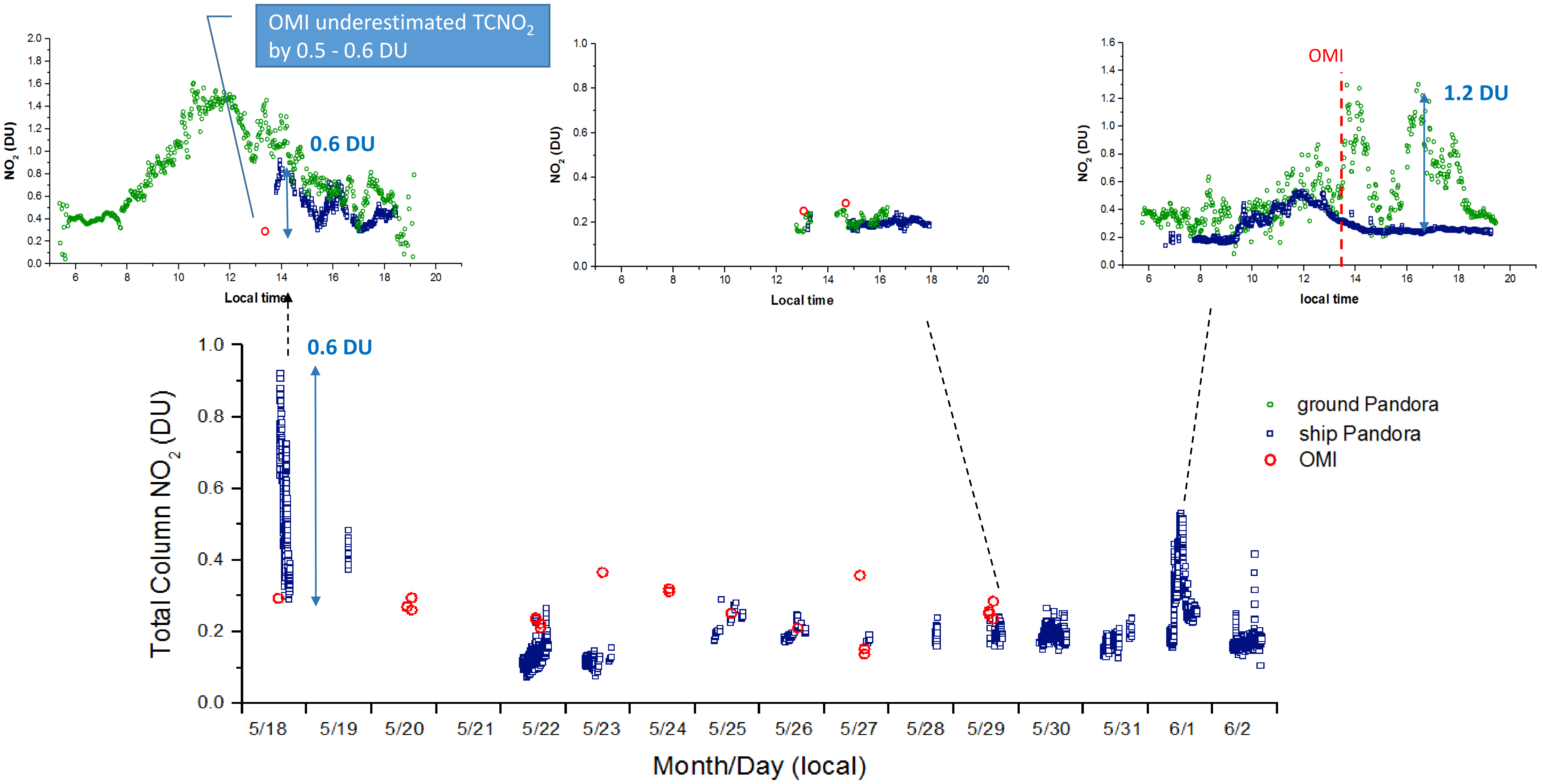




- TC NO_2 varied from 0.07 DU to 0.92 DU during KORUS OC
- OMI underestimated $TCNO_2$ in areas of high NO_2 pollution, and overestimated NO_2 over the ocean under relatively clean-air conditions
- Change as large as 0.6 DU within 3 hours

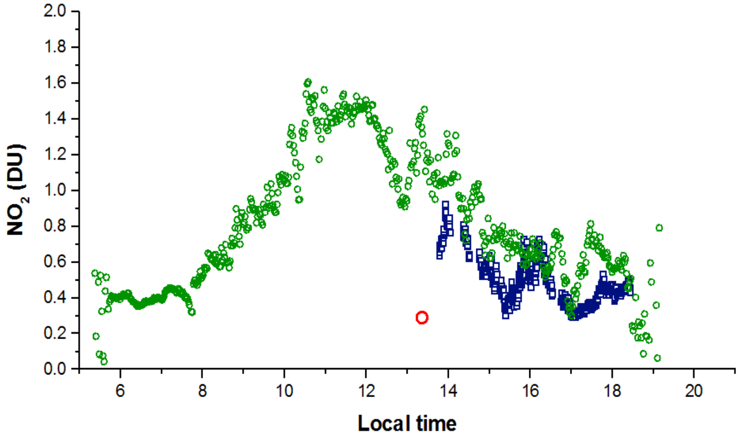


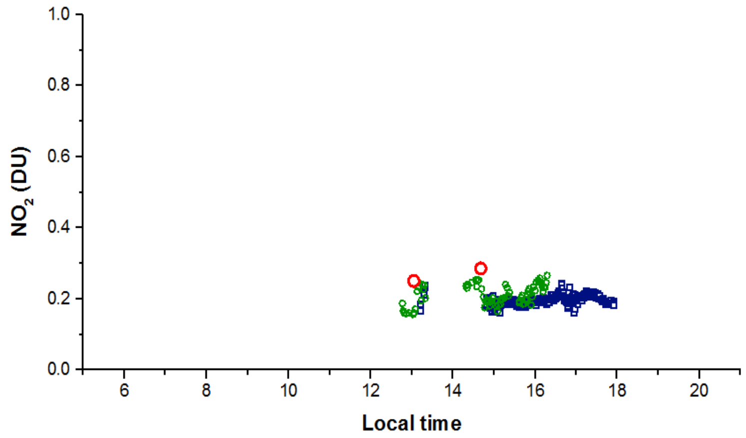


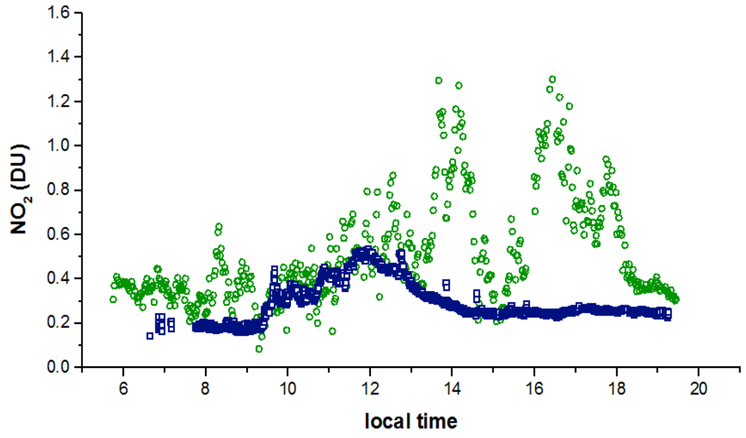

OMI underestimated TCNO2 by 0.5 - 0.6 DU
0.6 DU
NO2 (DU)
Local time
OMI
1.2 DU
local time
0.6 DU
Total Column NO2 (DU)
Month/Day (local)
5/18
5/19
5/20
5/21
5/22
5/23
5/24
5/25
5/26
5/27
5/28
5/29
5/30
5/31
6/1
6/2
ground Pandora
ship Pandora
OMI

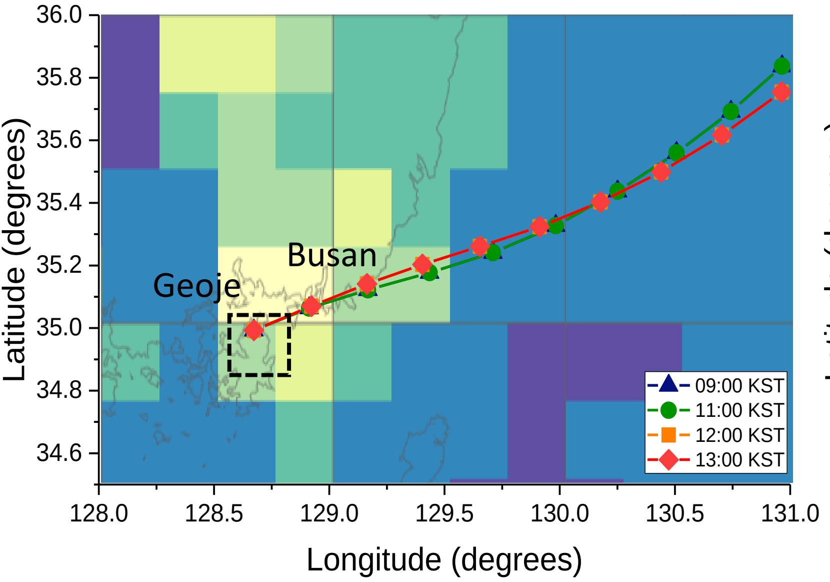
Backward air parcel trajectories simulated using HYSPLIT4 to determine the origin of air masses over *RV Onnuri*

Air mass trajectories and Aura OMI NO_2 imagery

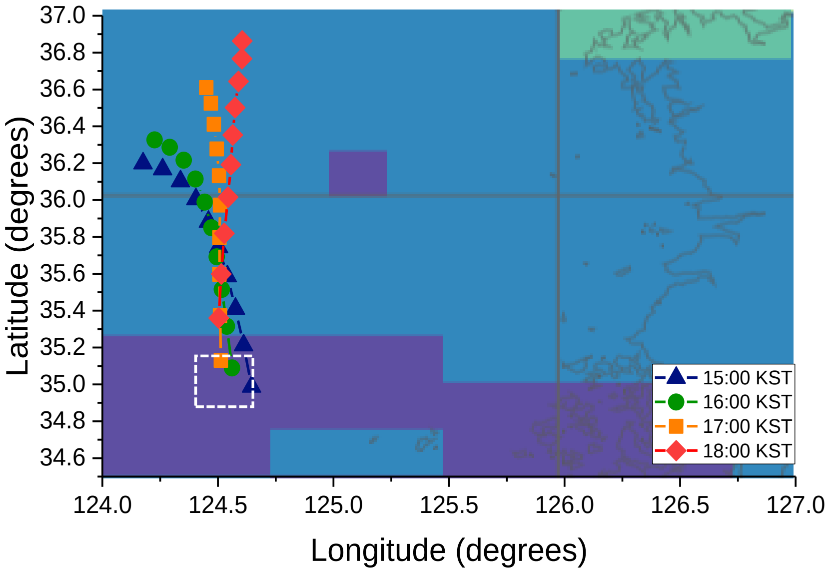




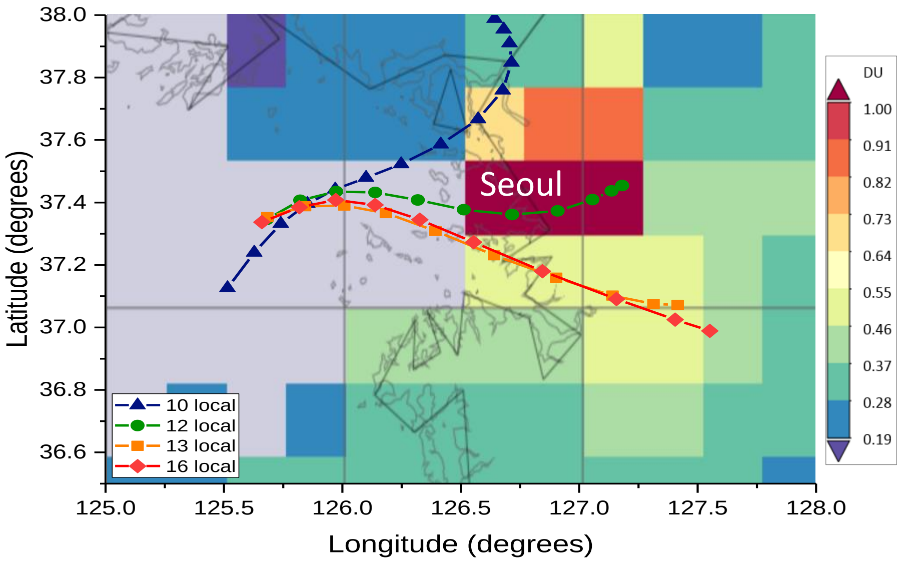




Consistent transport of pollution from Busan throughout the day



Transport of marine air masses from relatively low pollutions areas



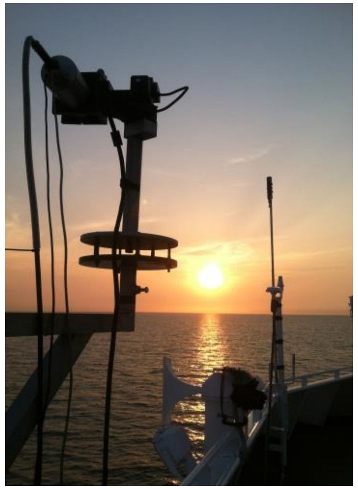
Transport of air masses from areas characterized by different levels of NO_2 pollution drove diurnal variability over the ocean

Summary

- Temporal changes in TCO_3 were driven primarily by larger scale meteorological processes and synoptic weather fronts that were captured successfully in OMI imagery.
- Variability in $TCNO_2$, in contrast, was mostly affected by local anthropogenic emissions and highly dynamic air mass transport pathways. OMI **significantly** underestimated NO_2 near hotspots, and overestimate NO_2 in 'rural'/clean areas
- NO_2 emissions over the land considerably affected $TCNO_2$ dynamics over the ocean but in complex ways, often resulting in very different temporal patterns between coastal land sites and offshore coastal waters.
- **NO_2 over the ocean can be highly variable**; During KORUS-OC, $TCNO_2$ reached 0.9 DU at > 35 km from Busan, and >0.5 DU offshore Seoul at >50 km distance from shoreline. This has major implications for **atmospheric correction of coastal ocean color retrievals**. Dry deposition of this N-pollution over coastal ecosystems, such as tidal wetlands, can have **major ecological implications**.








Thank you for your attention – Questions?

- ***Need for geostationary missions (TEMPO, Sentinel-4, GEMS, GOCI)***
- ***Need for more field observations over the ocean***
- ***Need for improved models***

Remote Sens. **2018**, *10*(10), 1587; https://doi.org/10.3390/rs10101587 Open Access Article

Atmospheric Trace Gas (NO_2 and O_3) Variability in South Korean Coastal Waters, and Implications for Remote Sensing of Coastal Ocean Color Dynamics

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Full-Text | PDF [6262 KB, uploaded 3 October 2018] | Figures

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