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Spatial distribution and diurnal variation of NO₂ over Asia from GEMS observation: Comparison with TROPOMI

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² National Institute of Environmental Research

³ Royal Belgian Institute for Space Aeronomy (BIRA-IASB)

⁴ Pusan National University

GEMS instrument



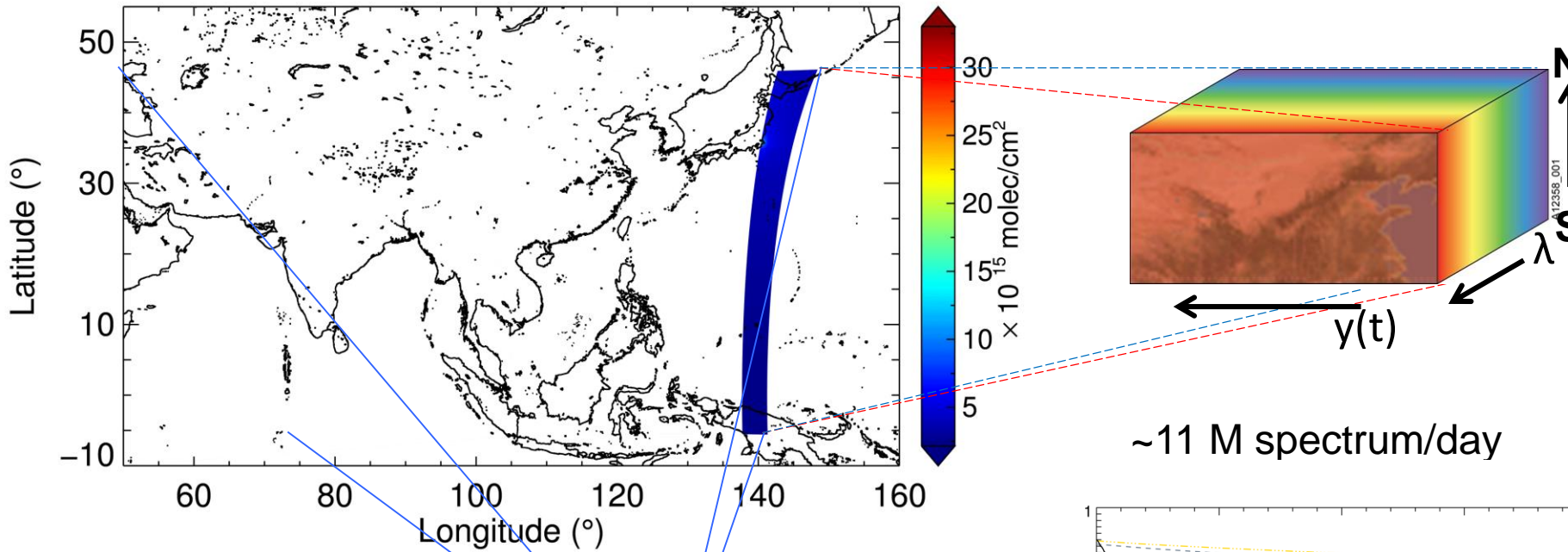
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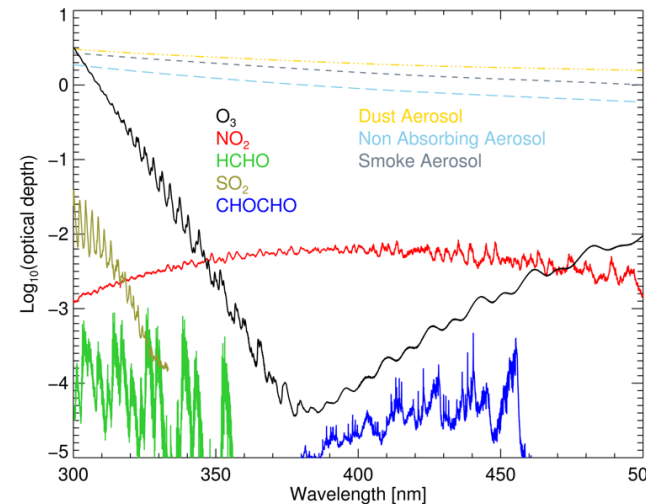
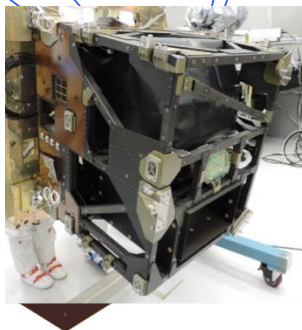
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OMI mean NO₂ (from 2005 to 2014) over GEMS FOR



~11 M spectrum/day



	GEMS(GK2B)
Products	O ₃ , NO ₂ , SO ₂ , HCHO, AOD, AI, AEH, CHOCHO, UVI
Orbit	Geostationary
Domain	5°S - 45°N, 75°E - 145°E / Asia-Pacific
Spatial Resolution	3.5km N/S x 8km E/W @38°N
Spectral Resolution	0.6 nm
Spectral Range	UV-VIS 300 - 500 nm

Schedule of the GEMS observation



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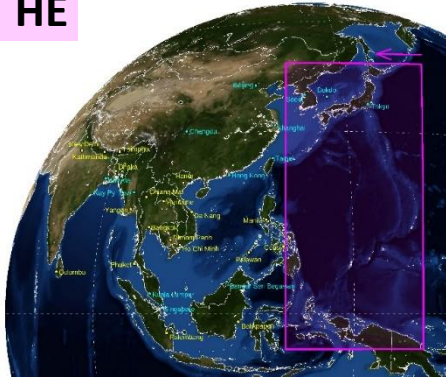


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Provided by NIER

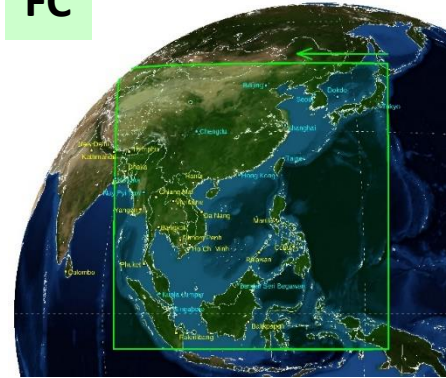
HE



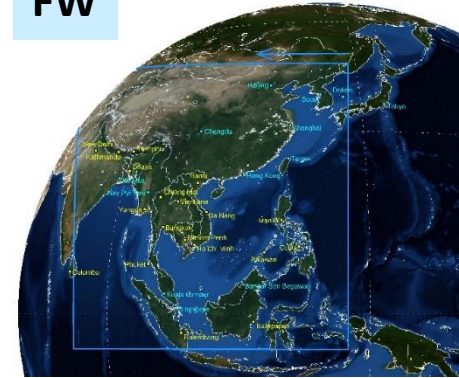
HK



FC



FW



No.	1	2	3	4	5	6	7	8	9	10	11	Total Obs.
UTC	23:00	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	
KST	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	
JAN	X	X	HE	HK	FC	FW	FW	FW	X	X	X	6
FEB	X	X	HE	HK	FC	FW	FW	FW	FW	X	X	7
MAR	X	HE	HK	FC	FC	FW	FW	FW	FW	X	X	8
APR	HE	HK	FC	FC	FC	FW	FW	FW	FW	FW	X	10
MAY	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
JUN	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
JUL	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
AUG	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
SEP	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
OCT	X	HE	HK	FC	FC	FW	FW	FW	FW	X	X	8
NOV	X	X	HE	HK	FC	FW	FW	FW	X	X	X	6
DEC	X	X	HE	HK	FC	FW	FW	FW	X	X	X	6

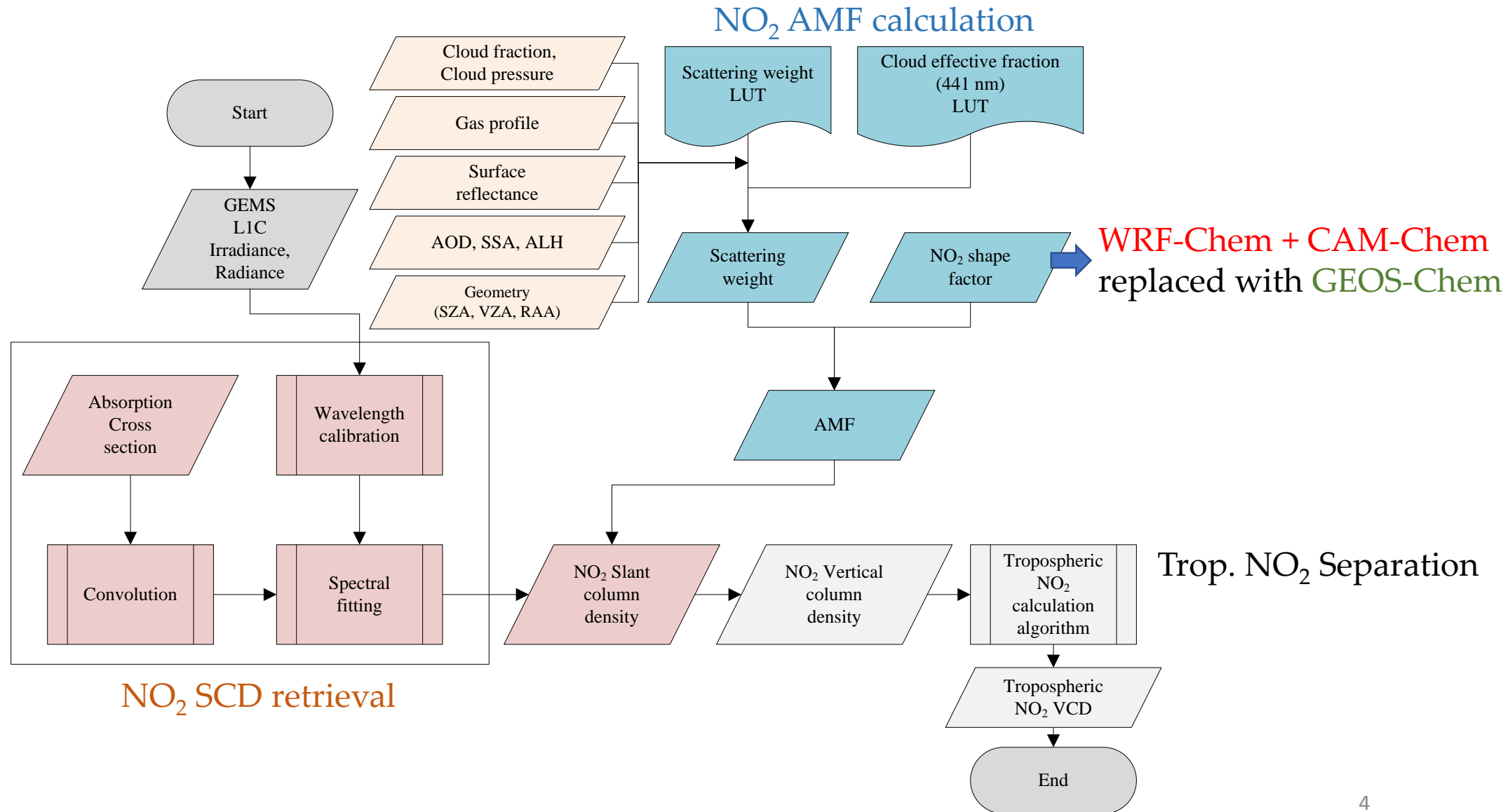
GEMS NO₂ retrieval algorithm



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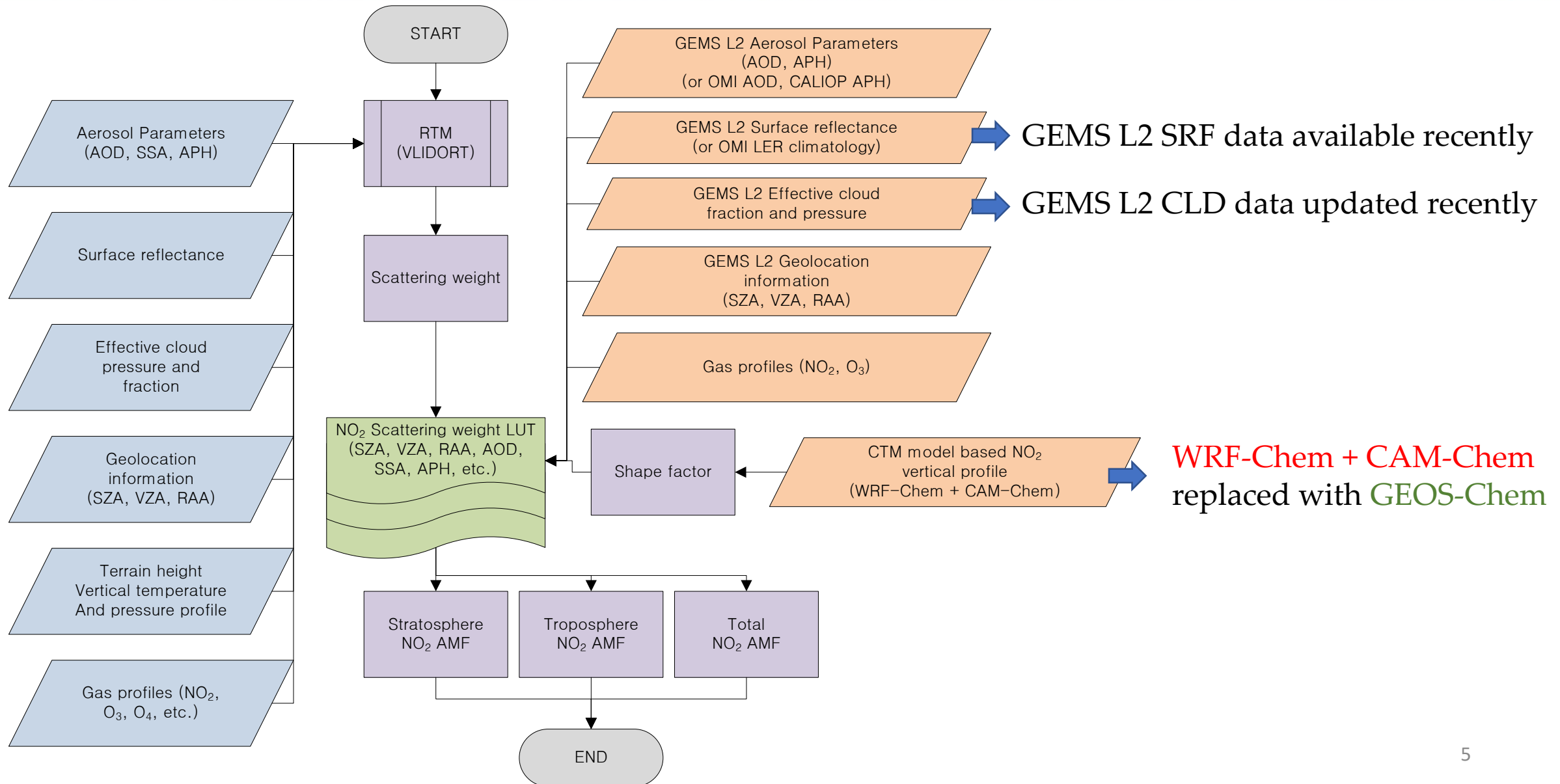
NO₂ AMF calculation



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Stratosphere-Troposphere Separation



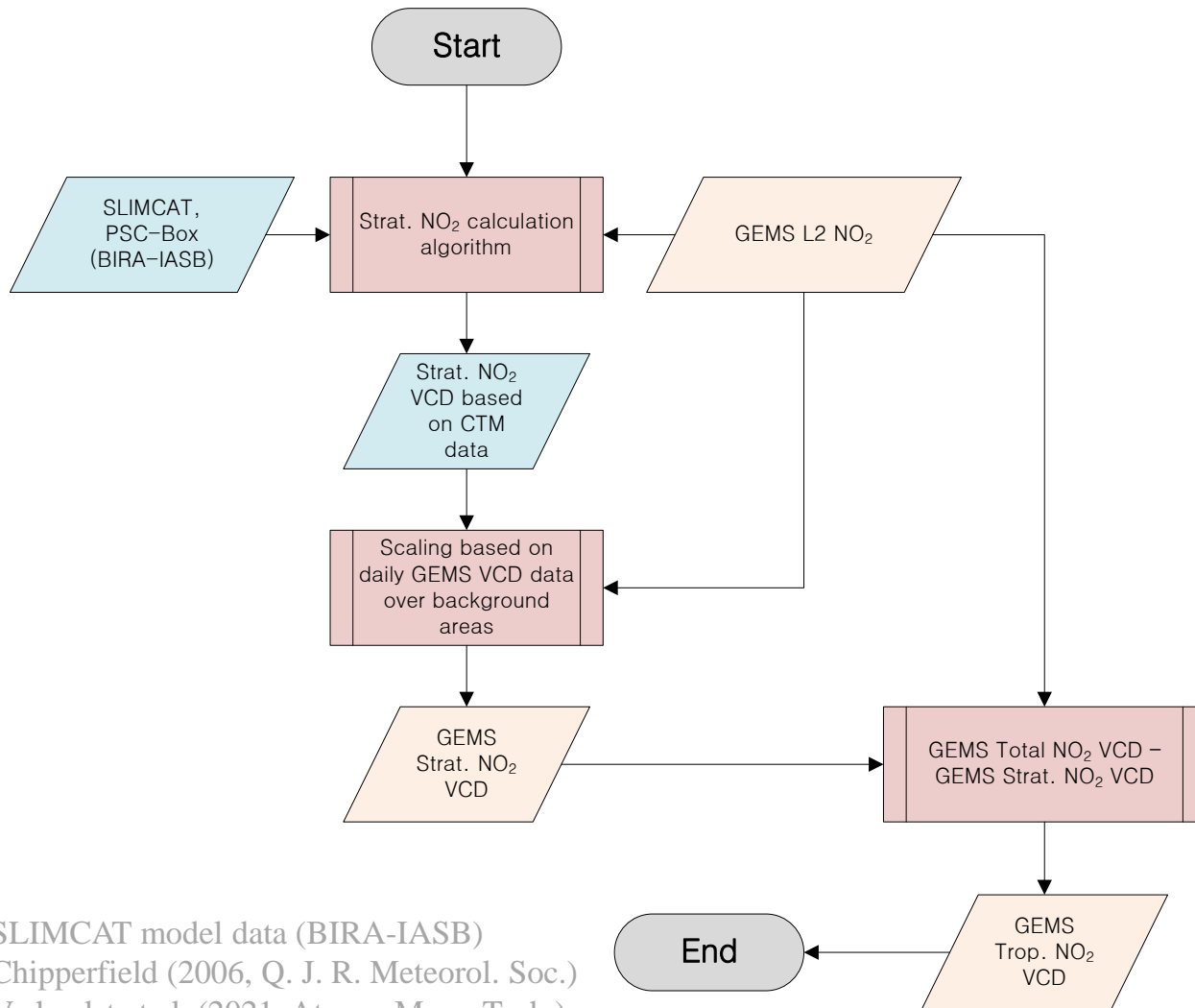
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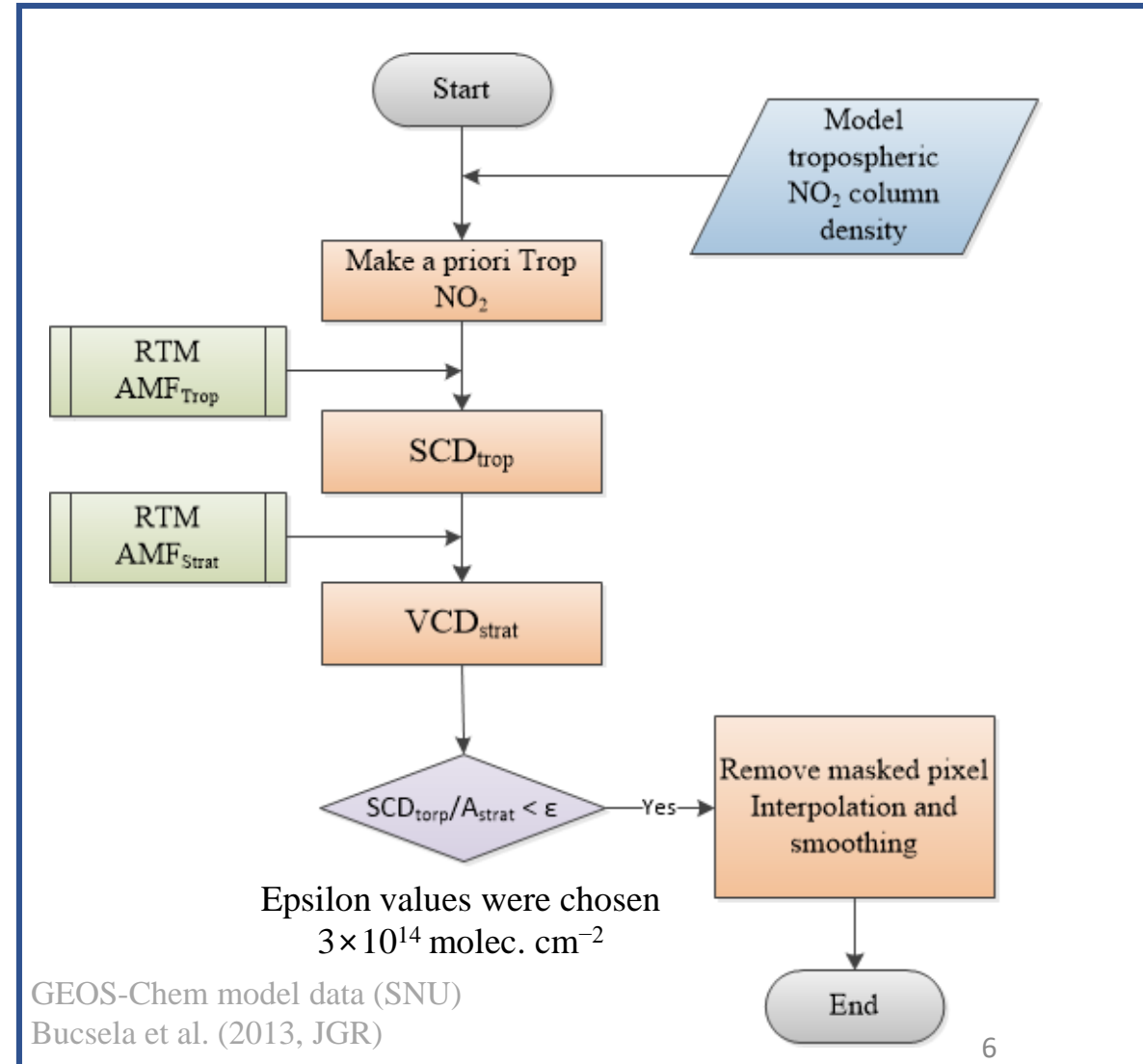


STS method used for this presentation



SLIMCAT model data (BIRA-IASB)
 Chipperfield (2006, Q. J. R. Meteorol. Soc.)
 Verhoelst et al. (2021, Atmos. Meas. Tech.)

STS method used for operational GEMS NO₂ retrieval algorithm



Epsilon values were chosen
 $3 \times 10^{14} \text{ molec. cm}^{-2}$

GEOS-Chem model data (SNU)
 Bucselá et al. (2013, JGR)



V1.0

- Early version of GEMS L2 NO₂ product

V1.3

- GEMS L2 CLD product updated

V1.4

- GEMS L2 CLD product updated
- GEMS L2 AOD product updated

V2.0

- GEMS L2 SRF product applied
- WRF-Chem + CAM-Chem CTM model data replaced with GEOS-Chem CTM model

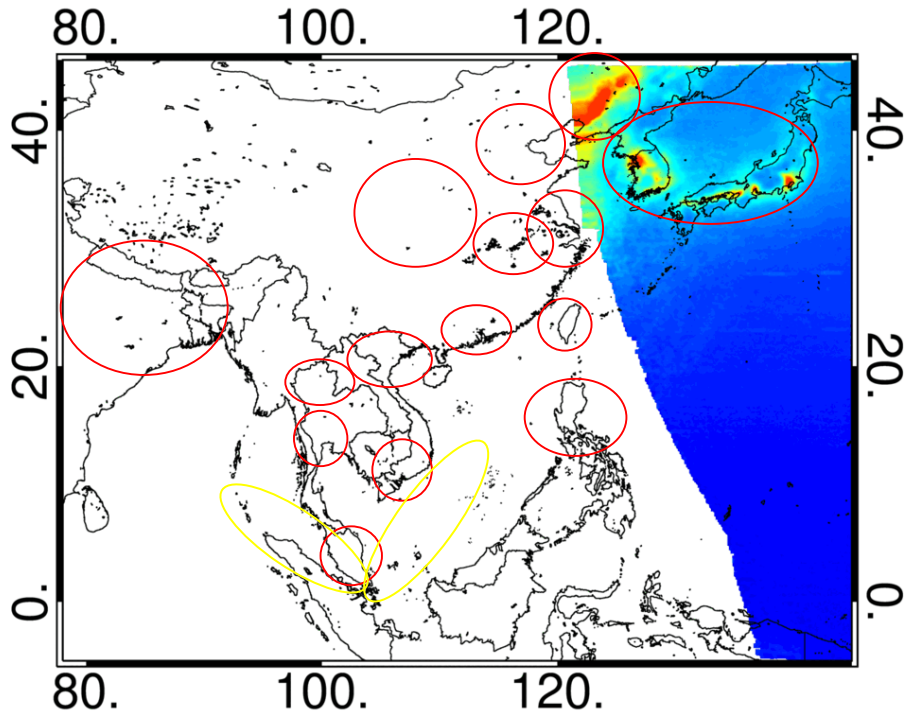
Total and Trop. NO₂ VCD in the GEMS domain



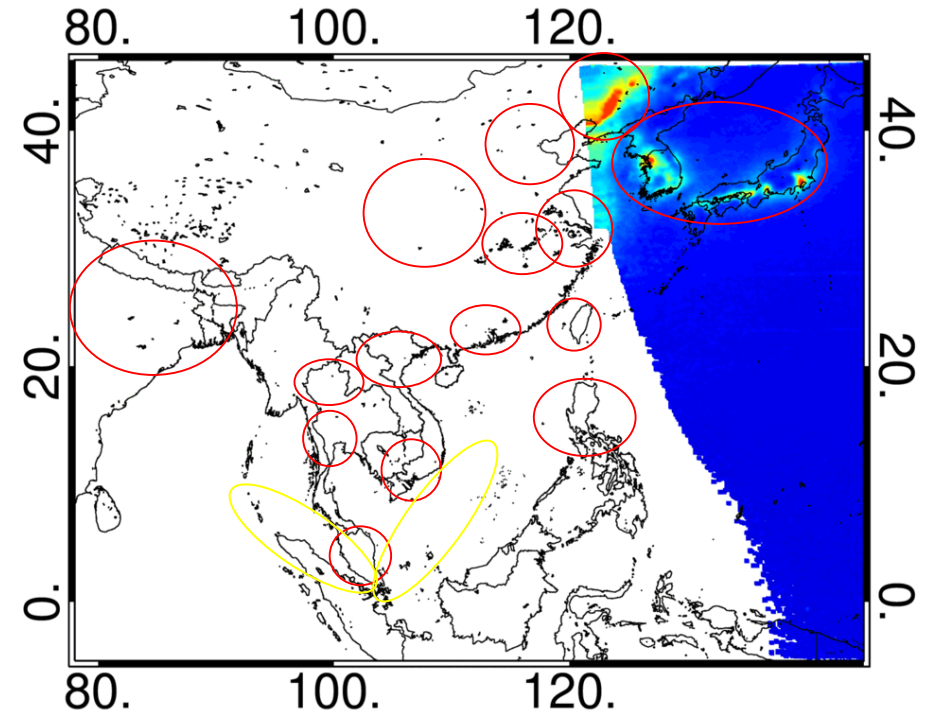
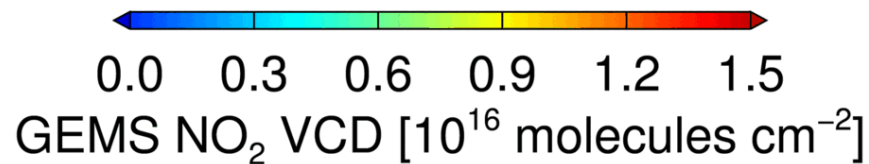
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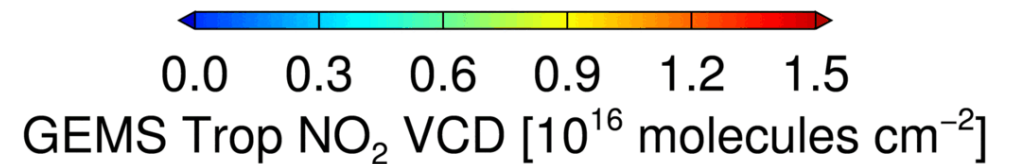
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22:45 UTC



22:45 UTC



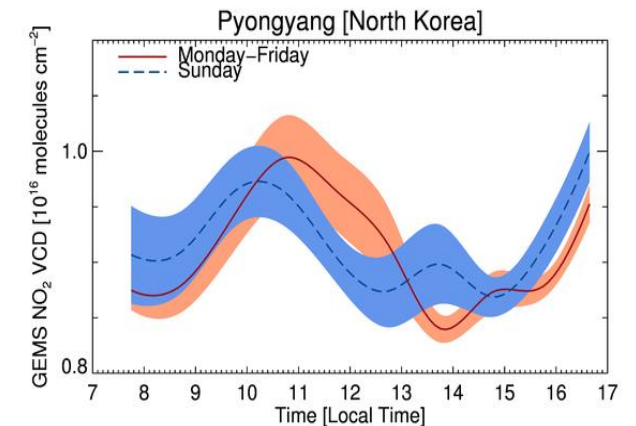
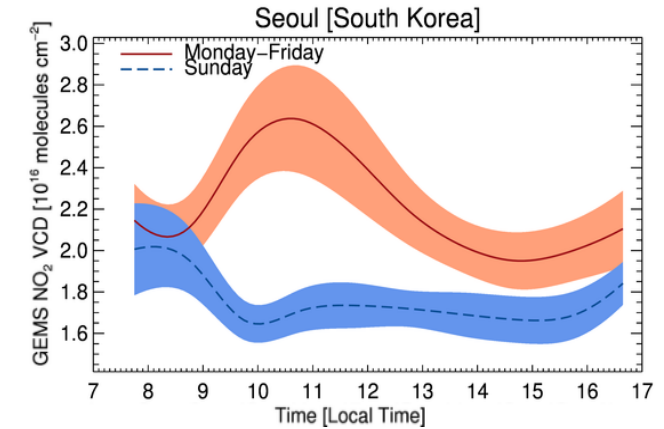
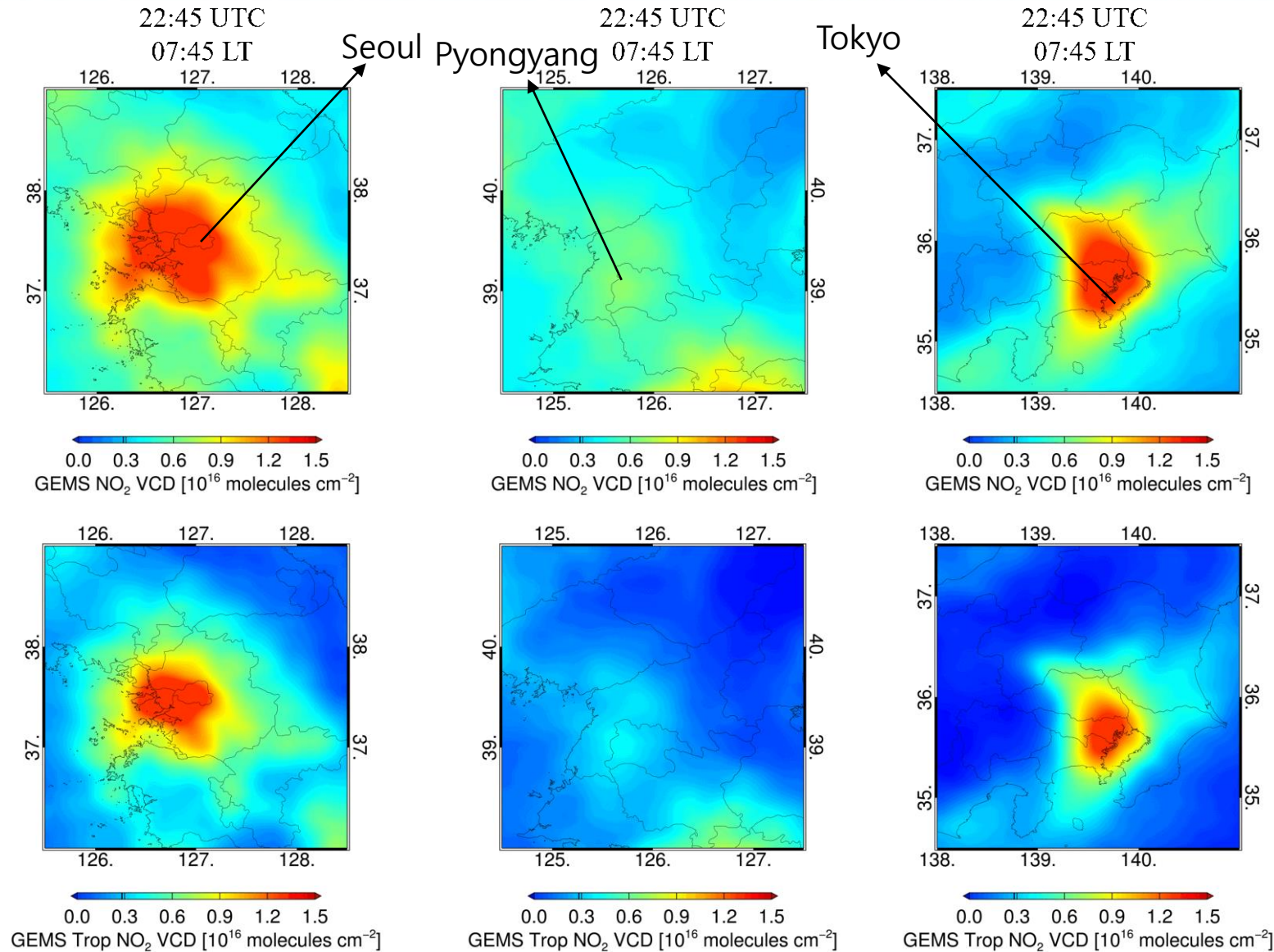
Total and Trop. NO₂ VCD at Major cities



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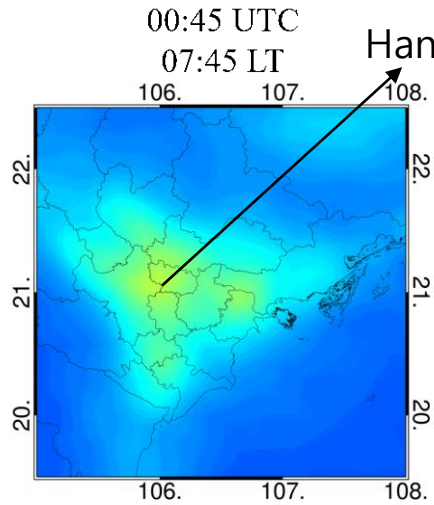
Total and Trop. NO₂ VCD at Major cities



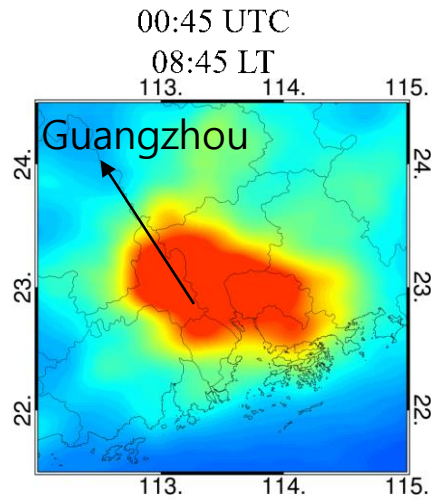
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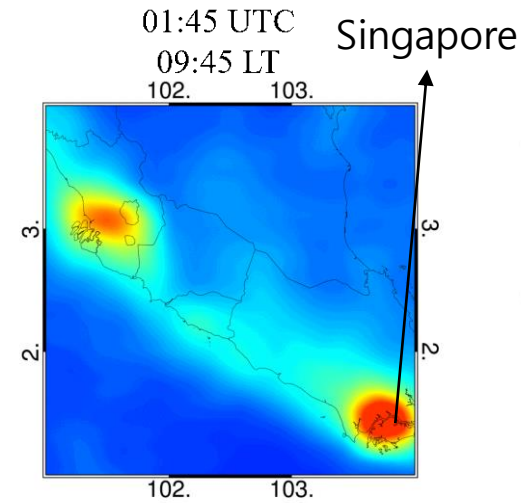
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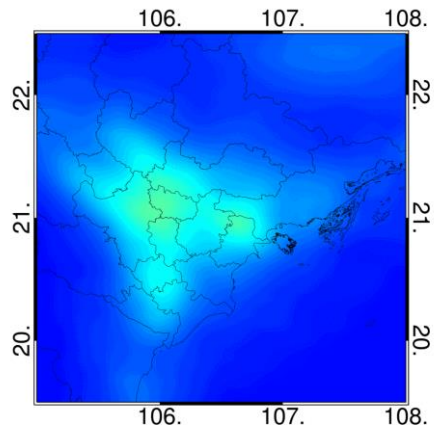
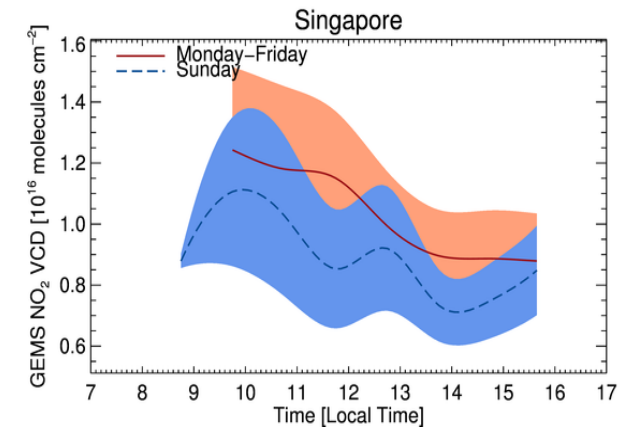
0.0 0.3 0.6 0.9 1.2 1.5
GEMS NO₂ VCD [10¹⁶ molecules cm⁻²]



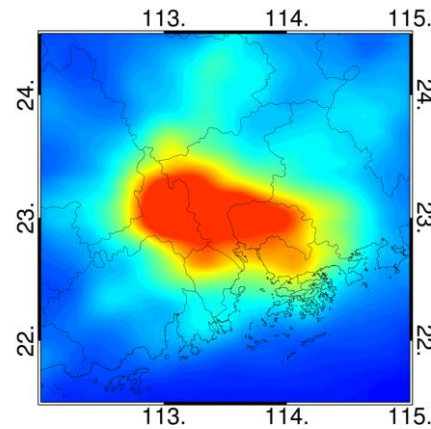
0.0 0.3 0.6 0.9 1.2 1.5
GEMS NO₂ VCD [10¹⁶ molecules cm⁻²]



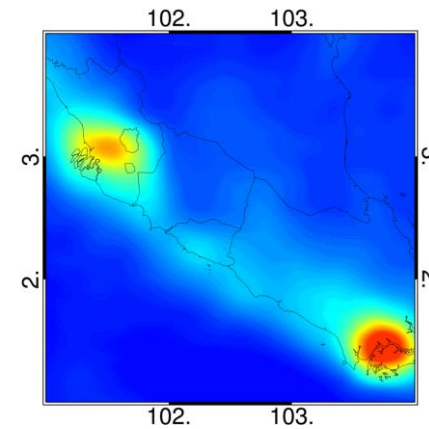
0.0 0.3 0.6 0.9 1.2 1.5
GEMS NO₂ VCD [10¹⁶ molecules cm⁻²]



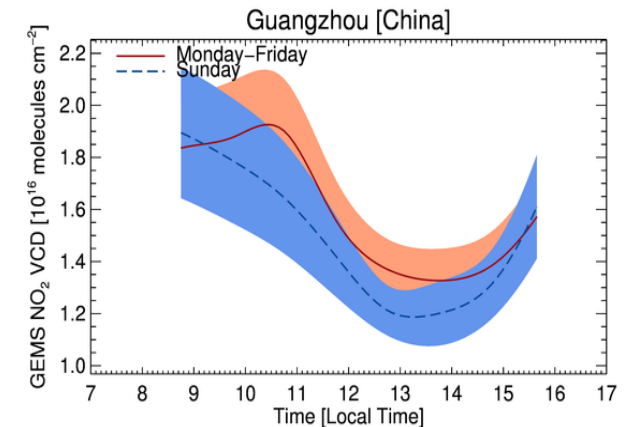
0.0 0.3 0.6 0.9 1.2 1.5
GEMS Trop NO₂ VCD [10¹⁶ molecules cm⁻²]



0.0 0.3 0.6 0.9 1.2 1.5
GEMS Trop NO₂ VCD [10¹⁶ molecules cm⁻²]



0.0 0.3 0.6 0.9 1.2 1.5
GEMS Trop NO₂ VCD [10¹⁶ molecules cm⁻²]



Total and Trop. NO₂ VCD at Major cities



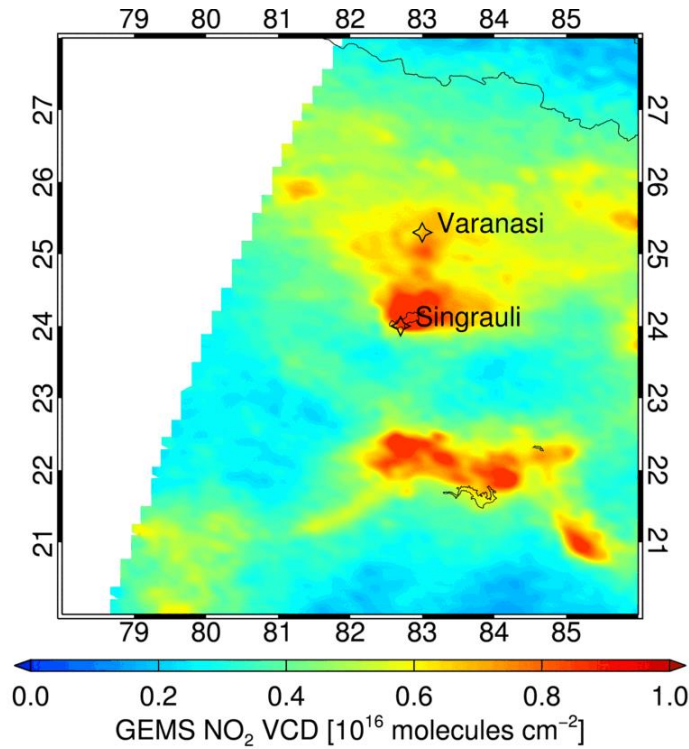
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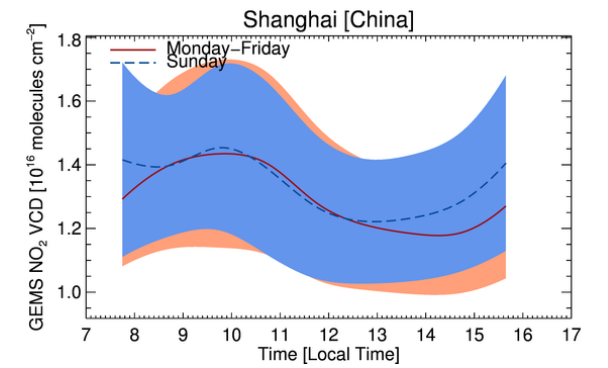
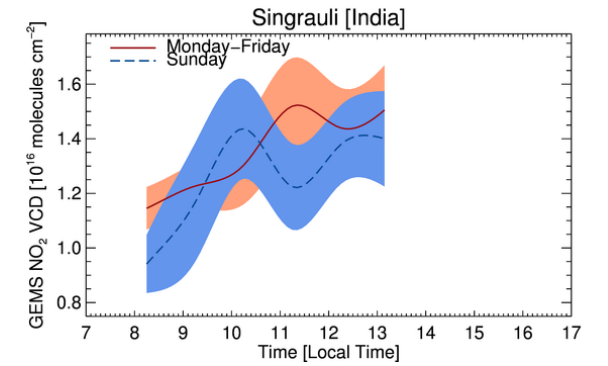
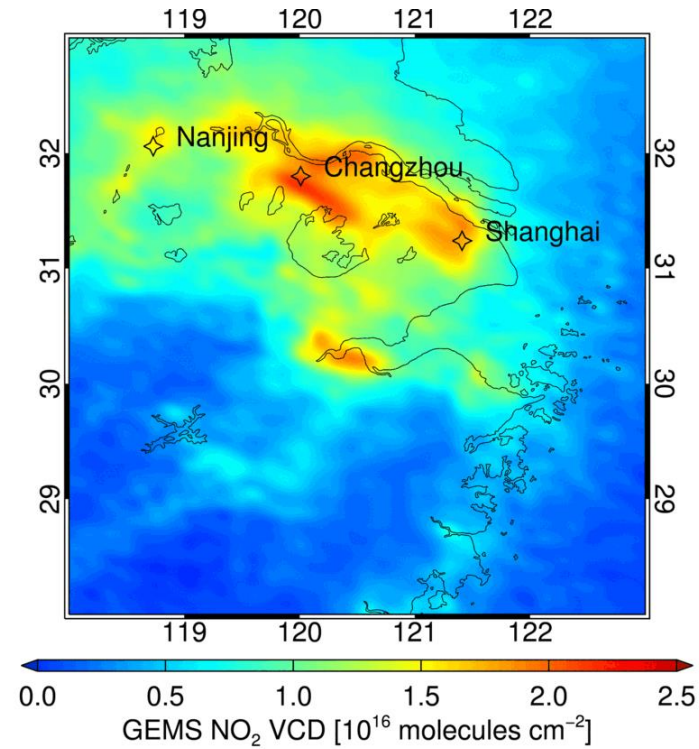
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02:45 UTC
08:15 LT



23:45 UTC
07:45 LT



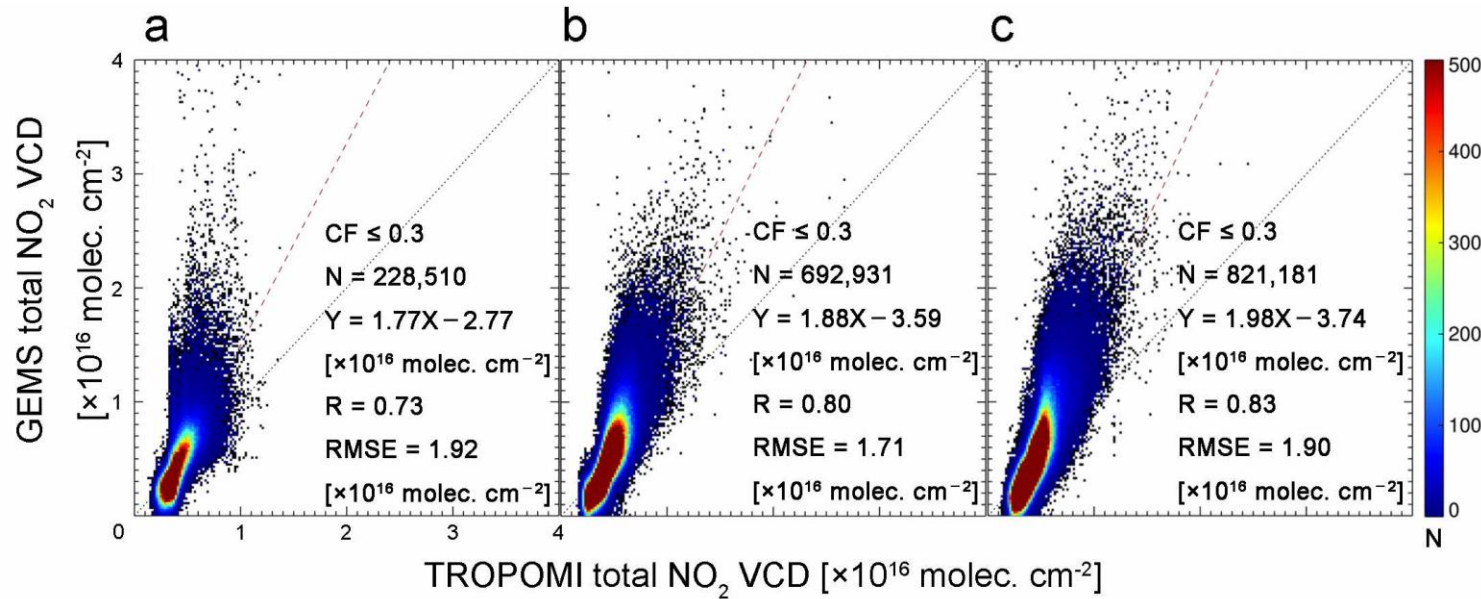
Total and Trop. NO₂ VCD at Major cities



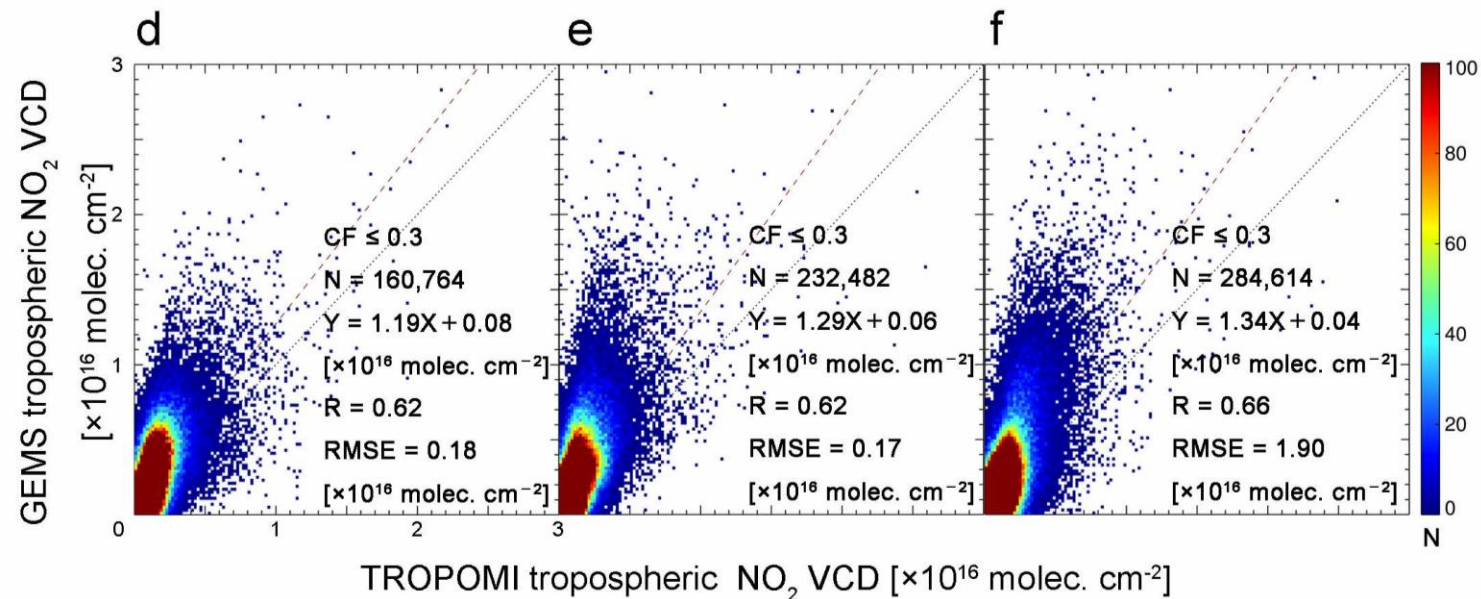
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Total NO₂ VCD
R = 0.73-0.83
Slope = 1.77-1.98



Trop. NO₂ VCD
R = 0.62-0.66
Slope = 1.19-1.34

Major updates of GEMS NO₂ retrieval algorithm



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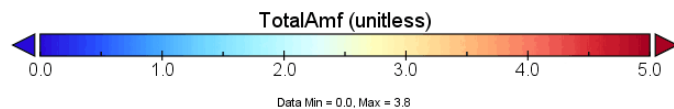
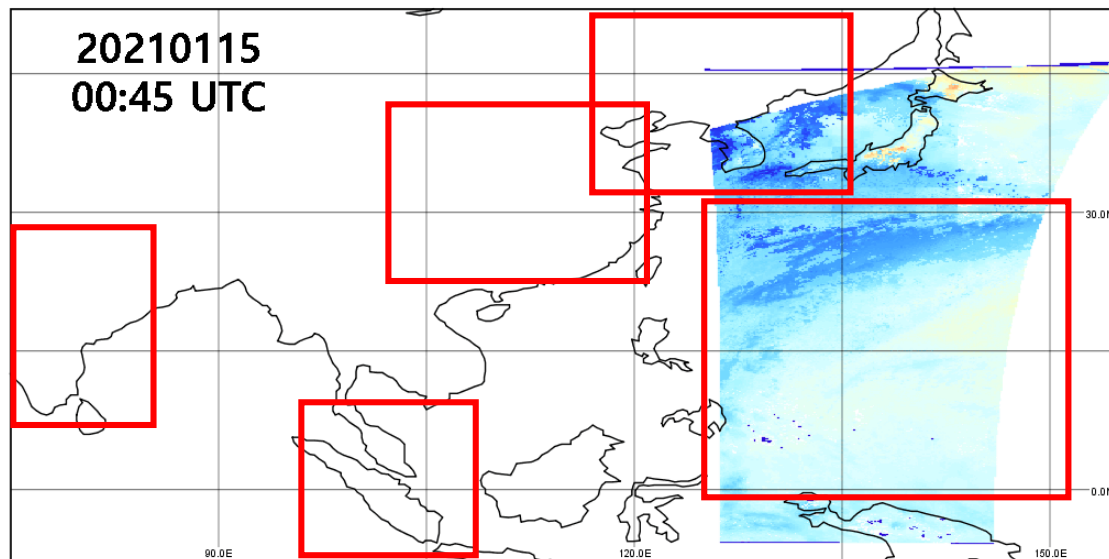
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- ❖ WRF-Chem+CAM-Chem data replaced with GEOS-Chem data
 - ✓ Total NO₂ AMF (20210115 00-05 UTC)
 - ✓ AMF is increased over the Pacific Ocean

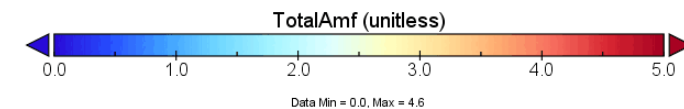
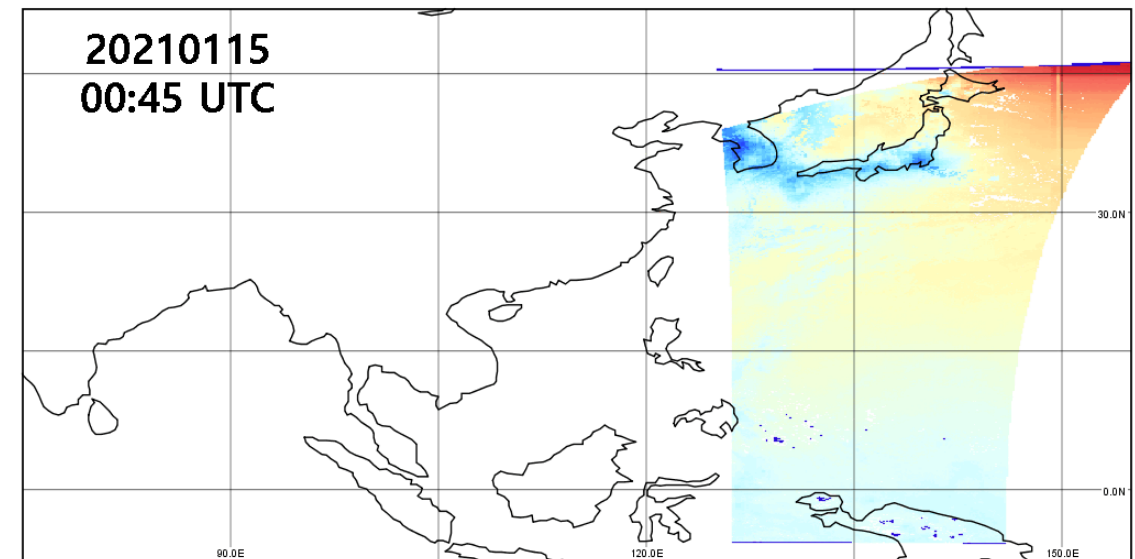
WRF-Chem + CAM-Chem

TotalAmf



GEOS-Chem

TotalAmf



Major updates of GEMS NO₂ retrieval algorithm



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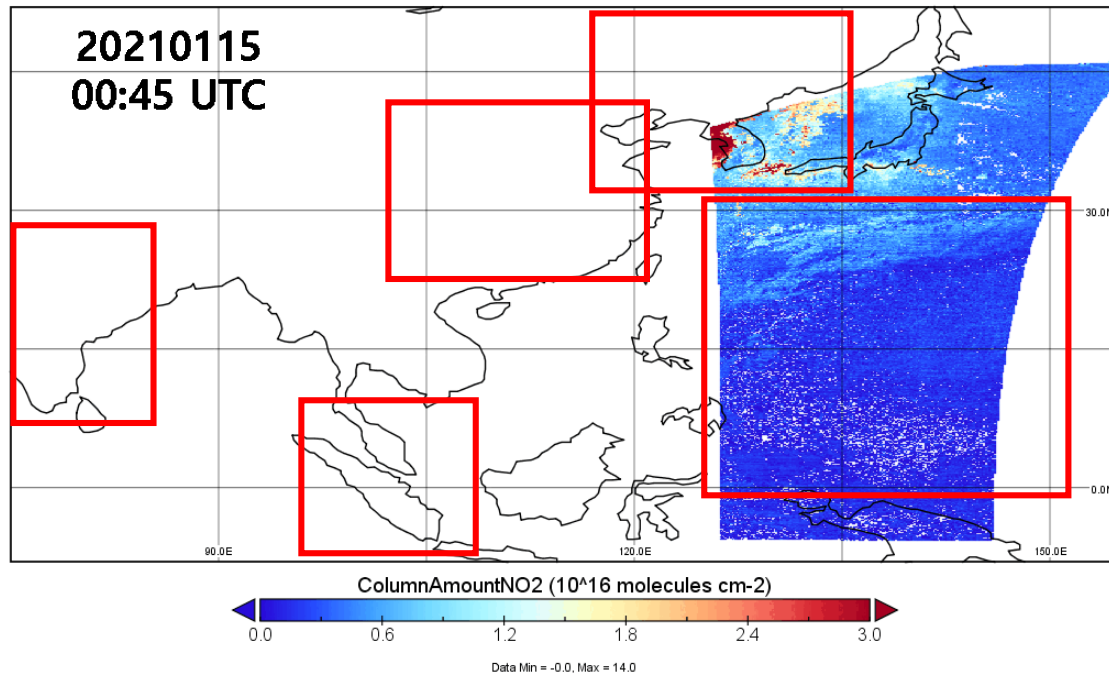
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- ❖ WRF-Chem+CAM-Chem data replaced with GEOS-Chem data
 - ✓ Total NO₂ Column (20210115 00-05 UTC)
 - ✓ NO₂ total column are decreased over the background regions

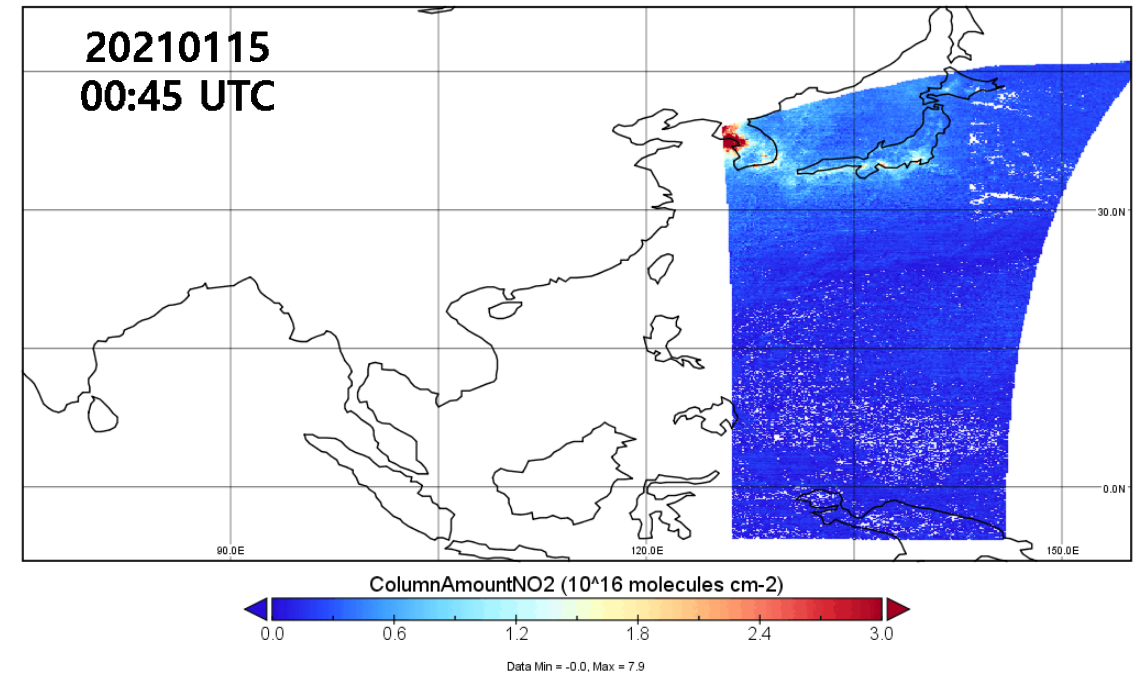
WRF-Chem + CAM-Chem

ColumnAmountNO2



GEOS-Chem

ColumnAmountNO2



Major updates of GEMS NO₂ retrieval algorithm



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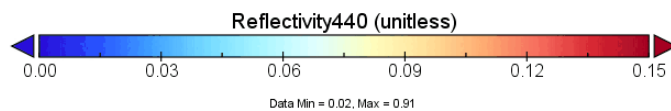
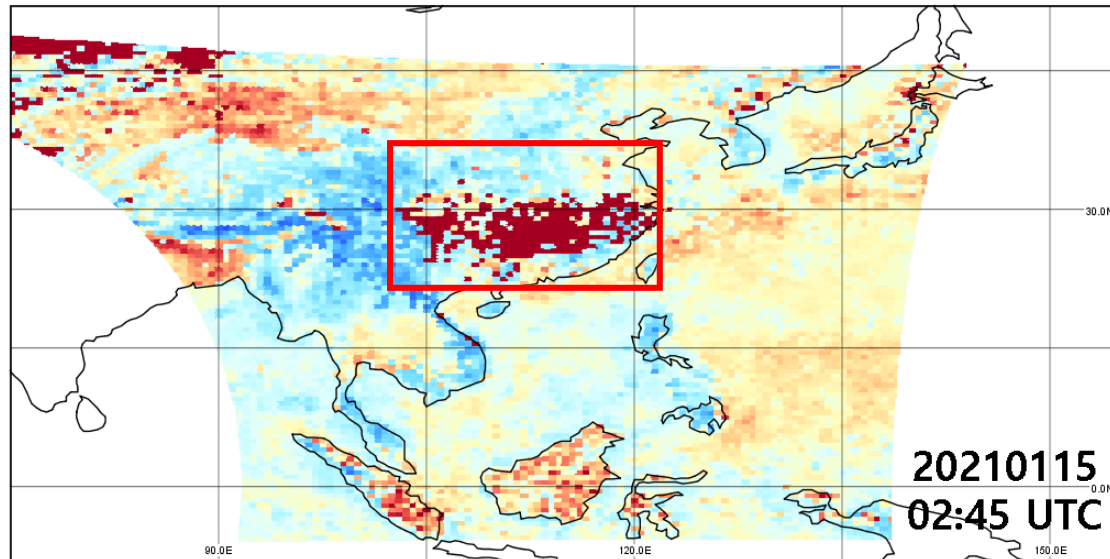


- SRF variable from GEMS L2 NO₂ product
 - (Before updated) OMI LER Climatology VS (After updated) GEMS L2 SFC

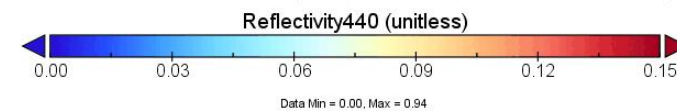
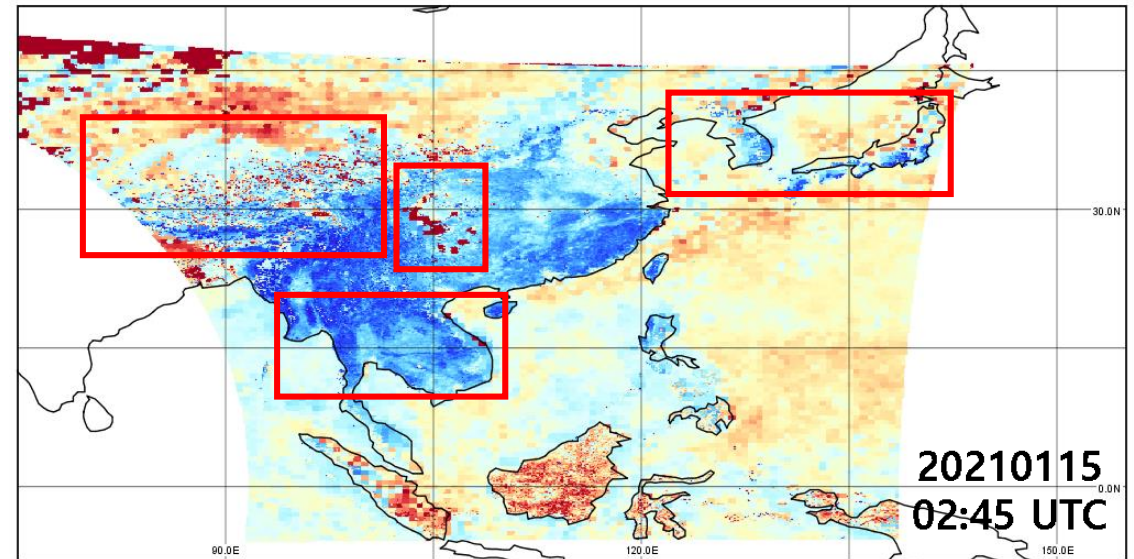
OMI LER Climatology

GEMS L2 SFC

Reflectivity440



Reflectivity440



Major updates of GEMS NO₂ retrieval algorithm



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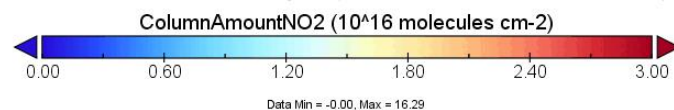
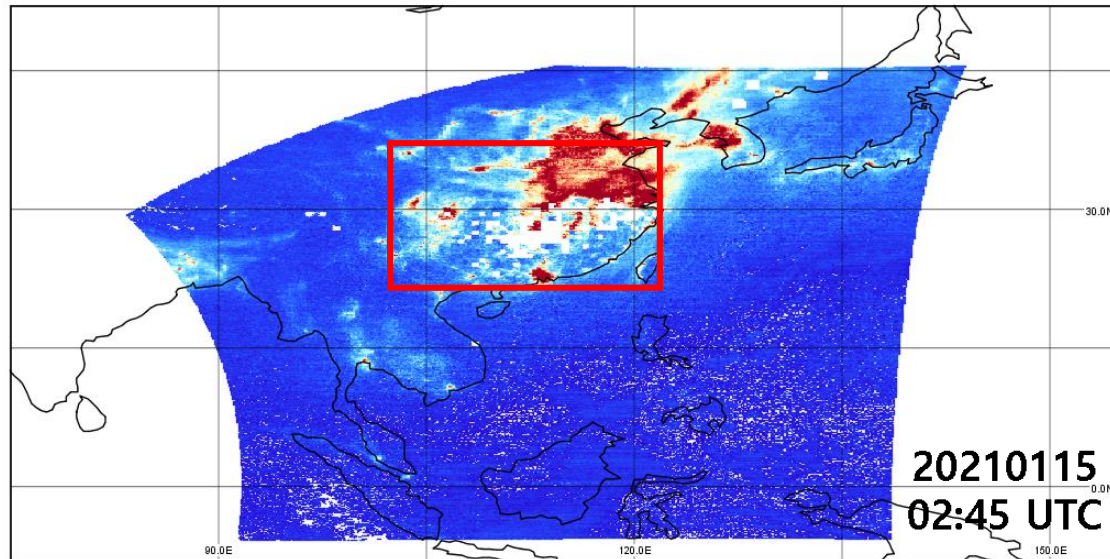
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- GEMS NO₂ total column from the GEMS L2 NO₂ product
 - (Before updated) **OMI LER Climatology** VS (After updated) **GEMS L2 SFC**

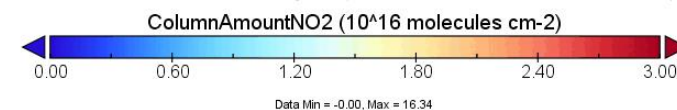
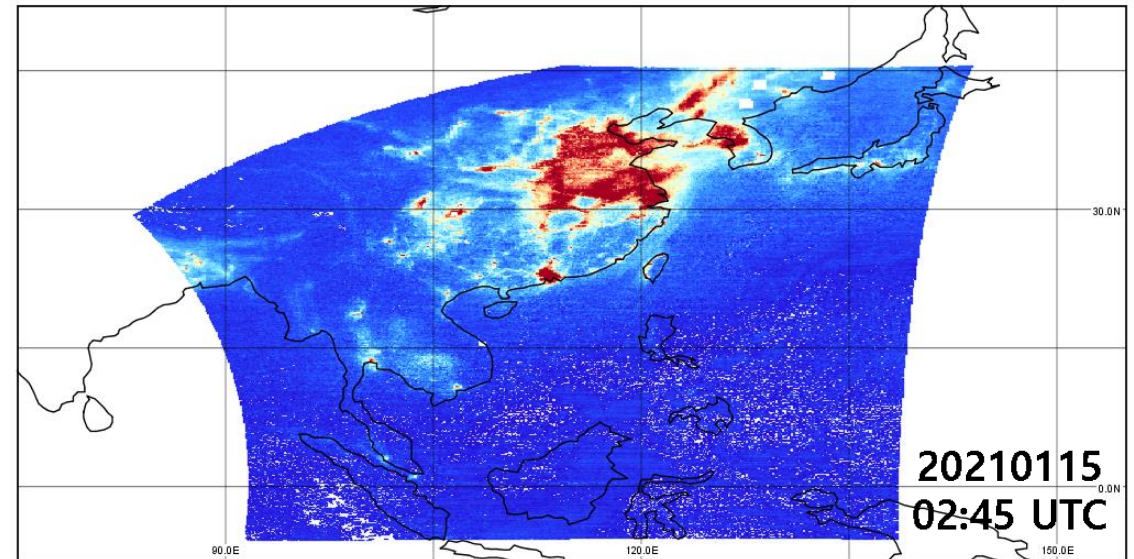
**GEOS-Chem
OMI LER Climatology**

ColumnAmountNO2



**GEOS-Chem
GEMS L2 SFC**

ColumnAmountNO2



- **Spatial distributions and diurnal variation**
 - Difference in spatial distributions and diurnal variations in each cities. It need to be compare with NO₂ VCDs measured by other instruments.
- **Total and Trop. NO₂ VCD (all of values are June-August 2021 averaged)**
 - VS. TROPOMI: [Total: R of 0.78, Slope of 1.87], [Trop.: R of 0.63, Slope of 1.27]
 - VS. OMI: [Total: R of 0.58, Slope of 0.53], [Trop.: R of 0.76, Slope of 0.83]
 - VS. Pandora: [Total: R of 0.66, Slope of 0.57], VS. MAX_DOAS: [Trop.: R of 0.51, Slope of 0.13]
 - These validation results will be more upgraded when using updated currently version of GEMS NO₂.
- **Future study**
 - Validate GEMS total and trop. NO₂ VCDs during the ground campaign (SIJAQ).
 - Conduct multiple schedules to improve GEMS NO₂ retrieval accuracy.



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Grazie!

QnA

