NO_2 diurnal and seasonal variation from GEMS and TEMPO

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Thanks to the GEMS and TEMPO Teams

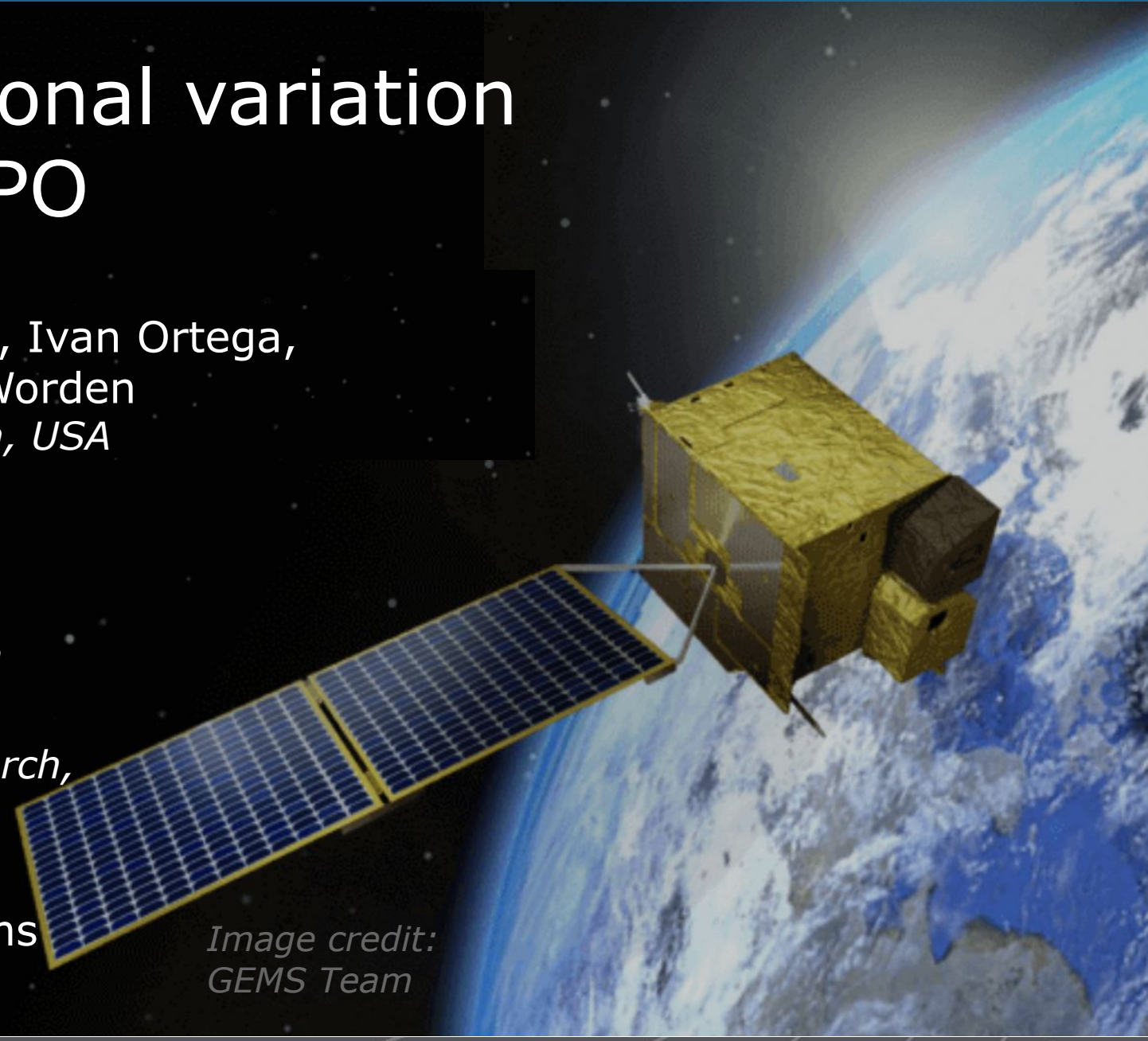
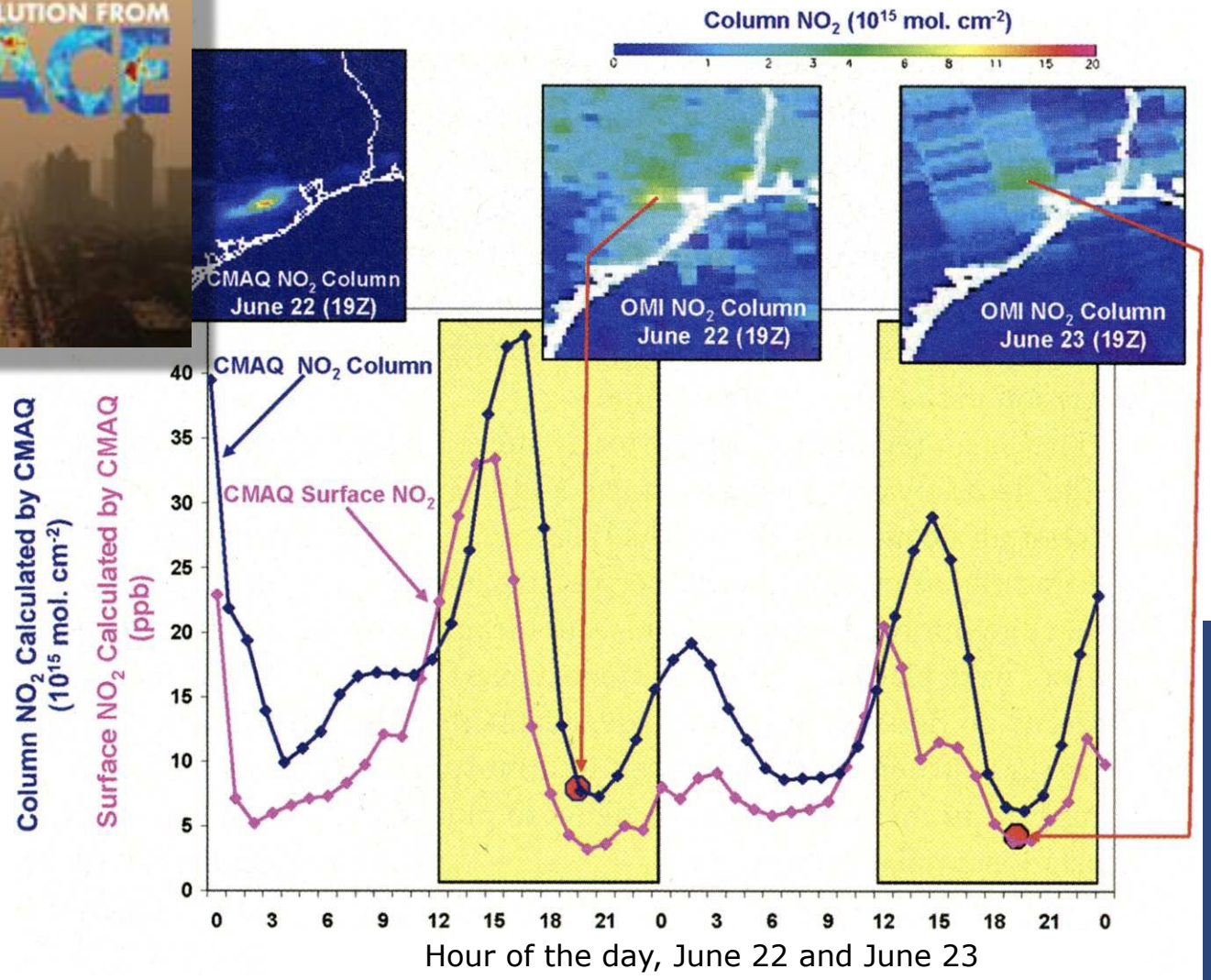


Image credit: GEMS Team

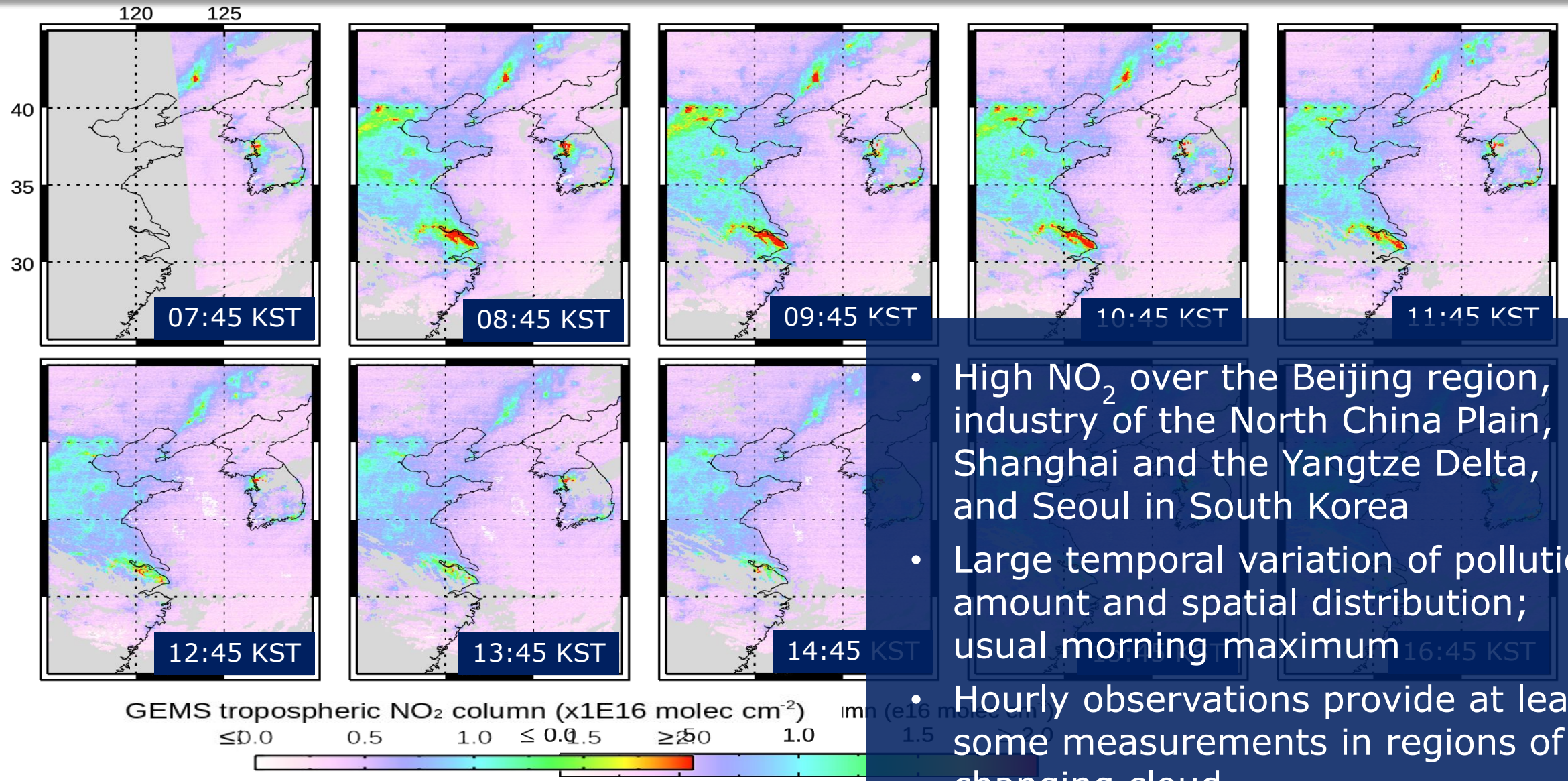
Studies to prepare for going to GEO



- NASA initiated the GEOCAPE project following the recommendation of the 2007 Decadal Survey to quantify the added value of GEO observations of atmospheric composition
- Motivational modeling studies highlighted the rapid diurnal variability in reactive pollutants that a GEO satellite might capture

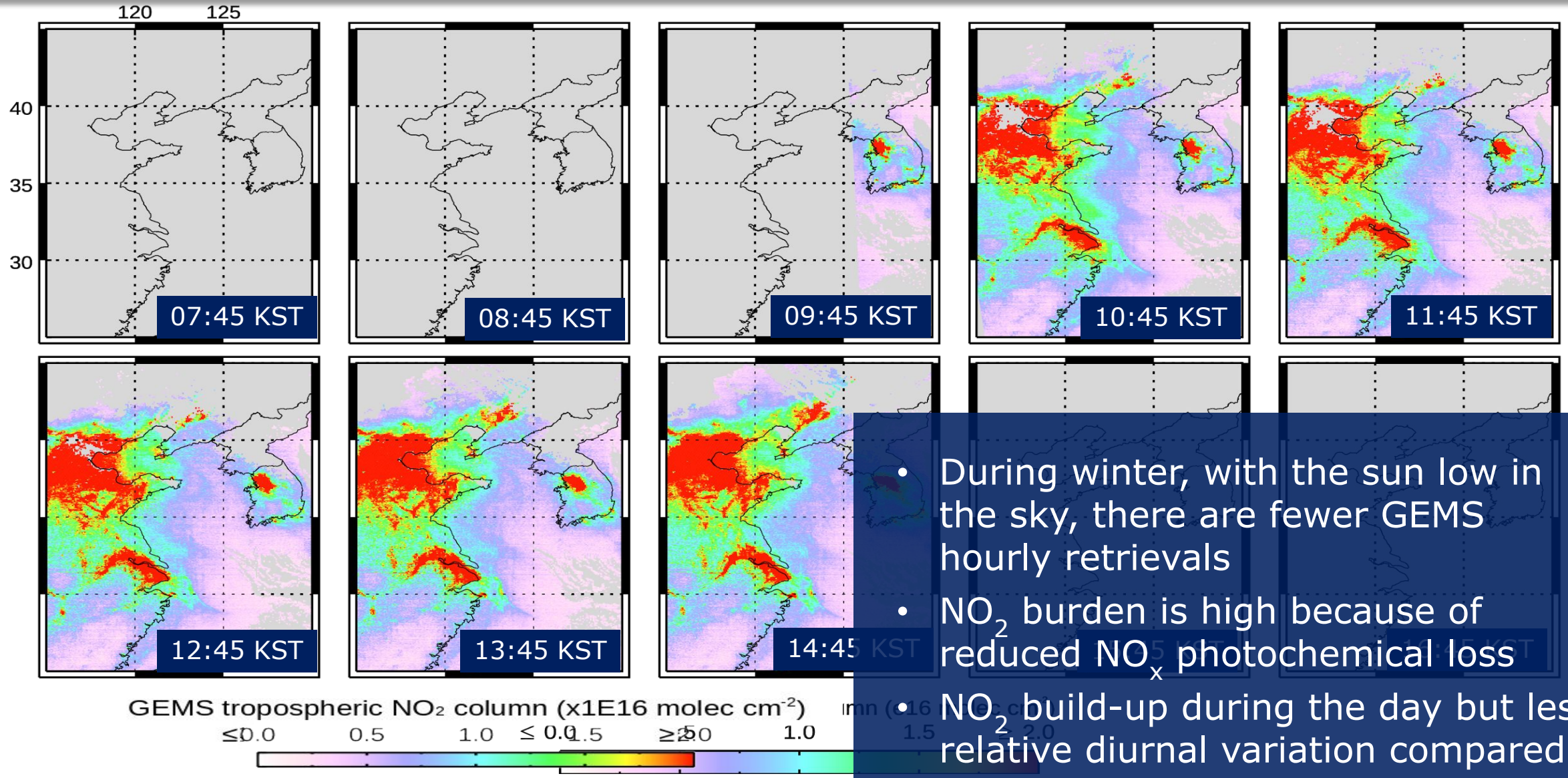
CMAQ modeling of the NO_2 column and surface values over Houston are shown with the 1:30 local time OMI observation for June 22-23, 2005 from *Fishman et al., BAMS, 2012*

GEMS V2 NO_2 diurnal variation maps, June 15 2023



- High NO_2 over the Beijing region, industry of the North China Plain, Shanghai and the Yangtze Delta, and Seoul in South Korea
- Large temporal variation of pollution amount and spatial distribution; usual morning maximum
- Hourly observations provide at least some measurements in regions of changing cloud

GEMS V2 NO_2 diurnal variation maps, Jan 30 2023

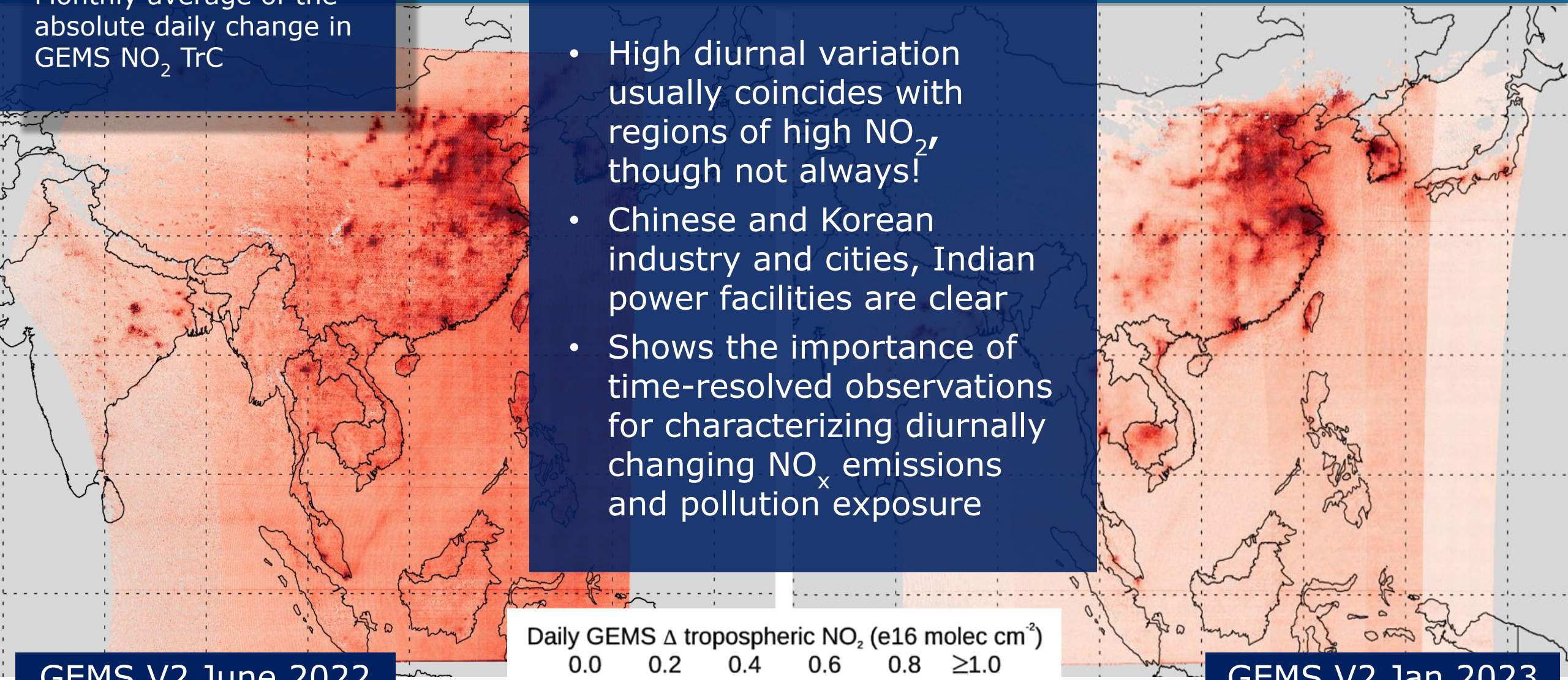


- During winter, with the sun low in the sky, there are fewer GEMS hourly retrievals
- NO_2 burden is high because of reduced NO_x photochemical loss
- NO_2 build-up during the day but less relative diurnal variation compared to summer

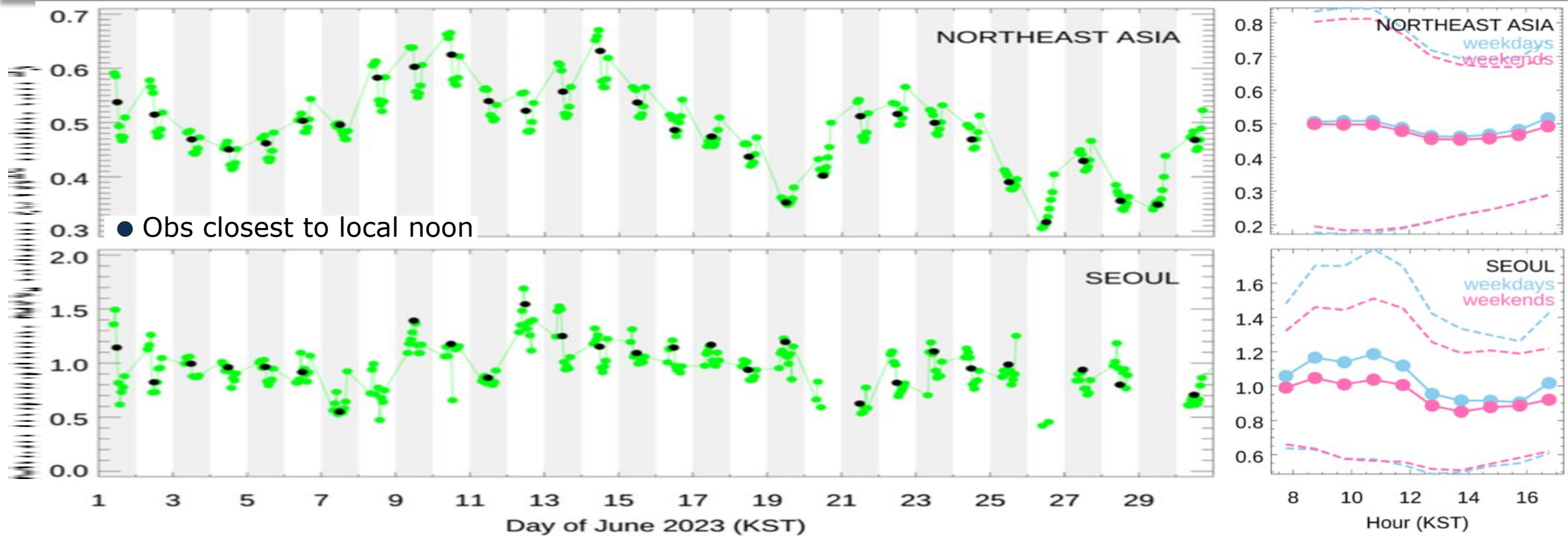
Seasonal change in diurnal variation

Monthly average of the absolute daily change in GEMS NO_2 TrC

- High diurnal variation usually coincides with regions of high NO_2, though not always!
- Chinese and Korean industry and cities, Indian power facilities are clear
- Shows the importance of time-resolved observations for characterizing diurnally changing NO_x emissions and pollution exposure

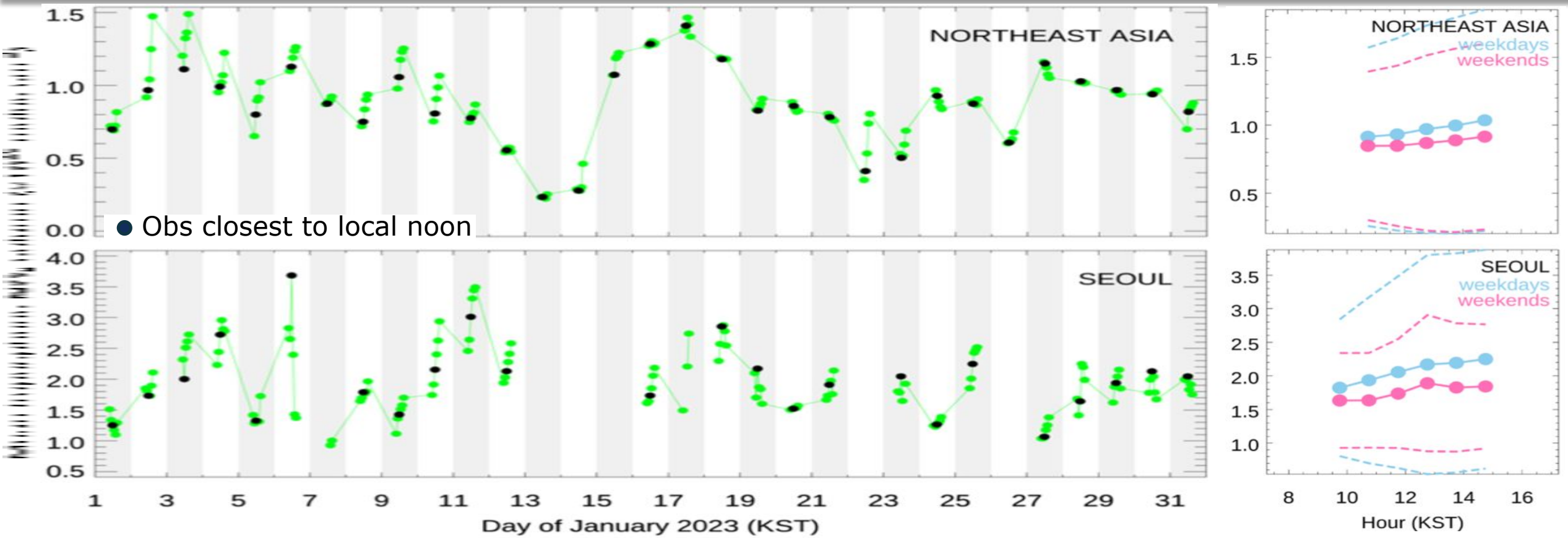


Comparing GEMS V2 NO_2 over NE Asia & Seoul Jun 2023



- NE Asia NO_2 timeseries shows a consistent diurnal variation with an afternoon minimum driven by photochemistry
- Seoul diurnal cycle is less consistent - more affected by local emissions and meteorology – providing examples of both morning and afternoon peaks in NO_2

Comparing GEMS V2 NO_2 over NE Asia & Seoul Jan 2023



- Less sun in winter, reduced photochemical loss and usually higher NO_2 values
- Relative diurnal variability is not as large as in summertime
- Usually a build-up of NO_2 column during the day

Tropospheric column NO_x budget analysis

4. After 10:00, NO loss with the build-up of O_3 pushes the NO_x ratio toward NO_2 at the same time that NO_x is lost to nitrogen reservoirs HNO_3, and to a lesser extent, PAN

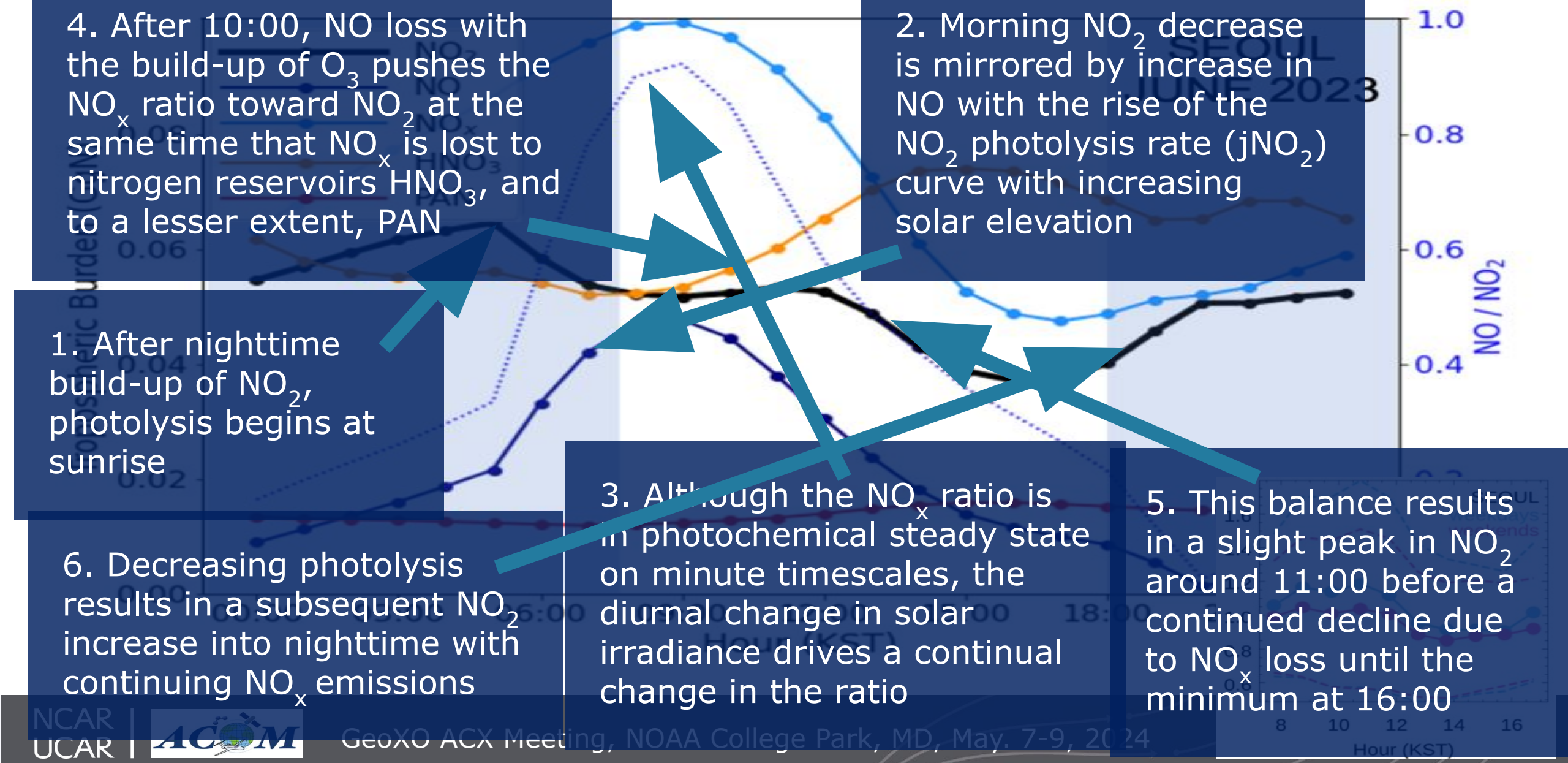
2. Morning NO_2 decrease is mirrored by increase in NO with the rise of the NO_2 photolysis rate (jNO_2) curve with increasing solar elevation

1. After nighttime build-up of NO_2, photolysis begins at sunrise

3. Although the NO_x ratio is in photochemical steady state on minute timescales, the diurnal change in solar irradiance drives a continual change in the ratio

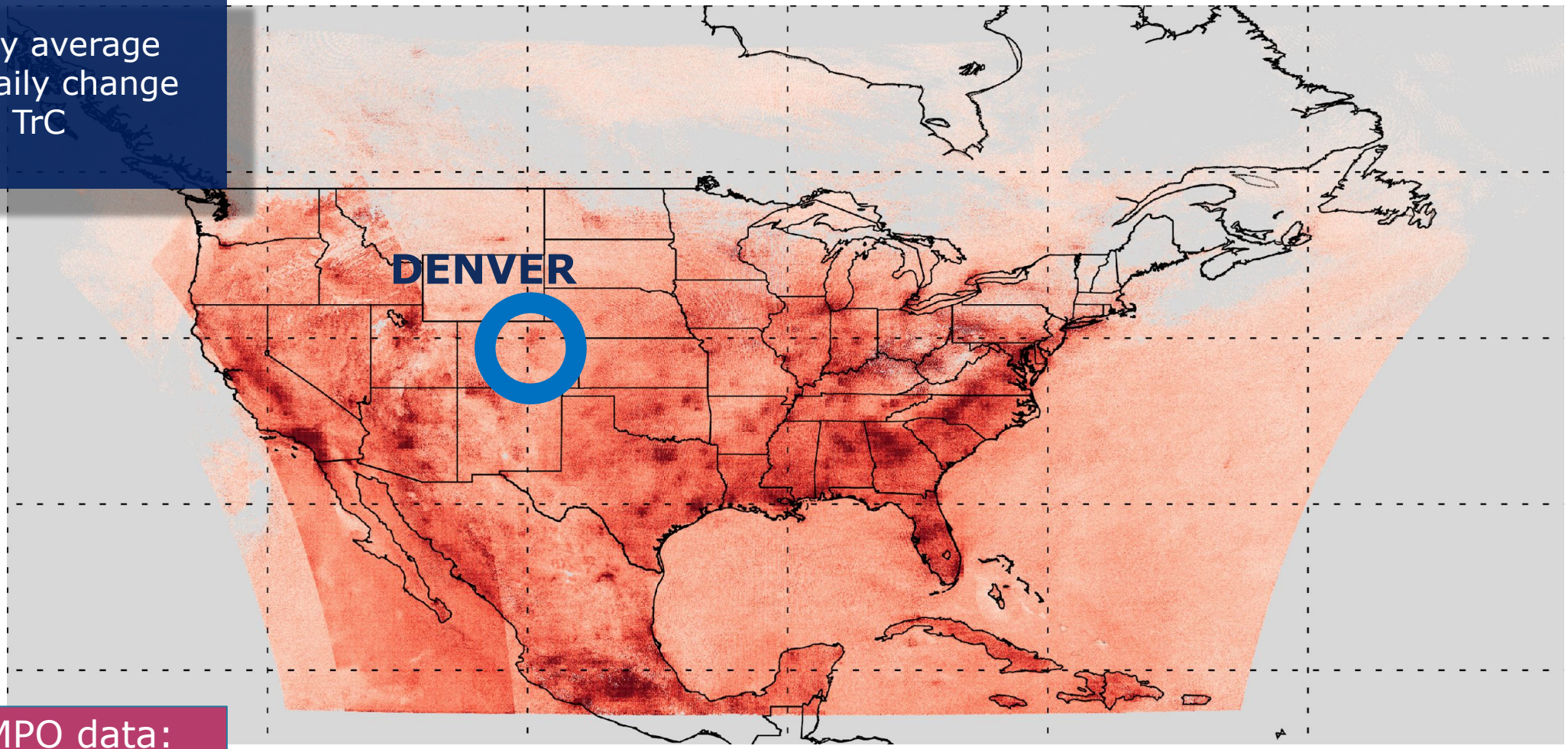
5. This balance results in a slight peak in NO_2 around 11:00 before a continued decline due to NO_x loss until the minimum at 16:00

6. Decreasing photolysis results in a subsequent NO_2 increase into nighttime with continuing NO_x emissions



TEMPO diurnal variability

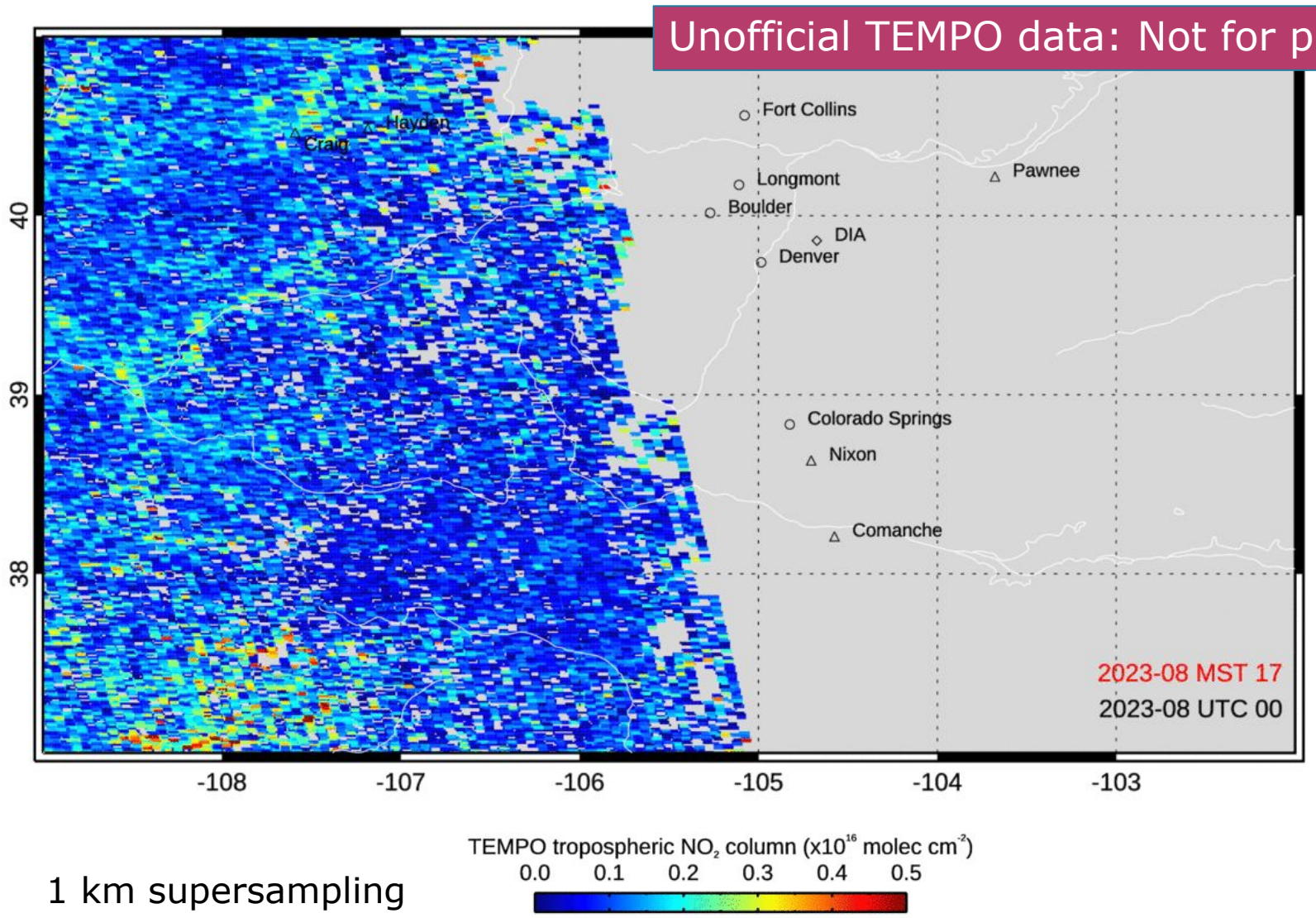
Aug 2023 monthly average of the absolute daily change in TEMPO V1 NO_2 TrC



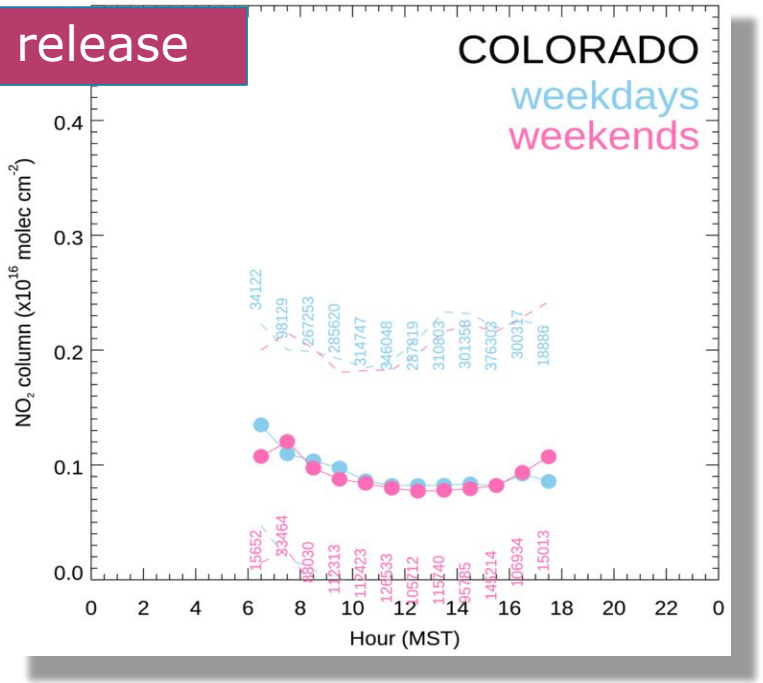
Unofficial TEMPO data:
Not for public release

August 2023 mean hourly TEMPO NO_2 TrC over CO

Unofficial TEMPO data: Not for public release



1 km supersampling

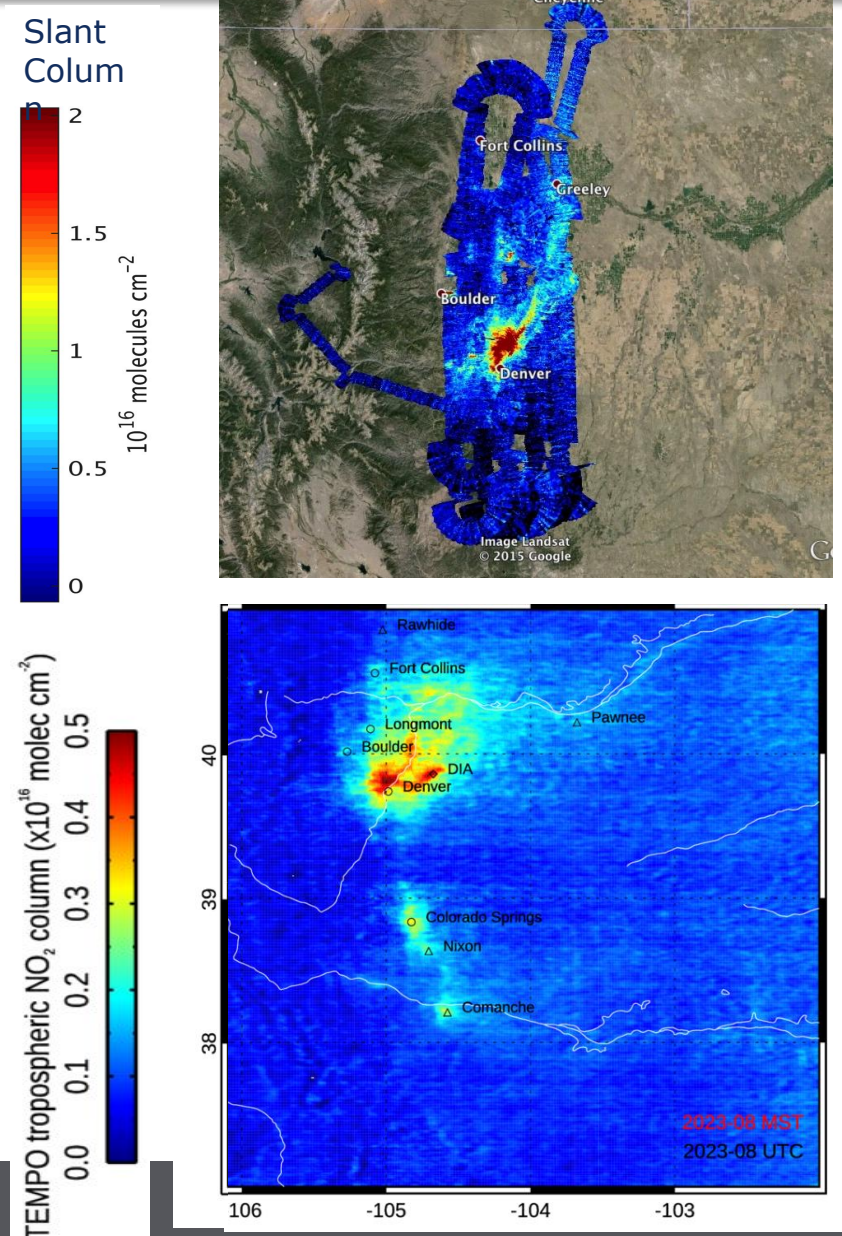


- Average over all of CO shows a morning max and an afternoon photochemistry decline followed by a small evening increase
- Similar to what we see for large area average in GEMS

Pattern over Denver

08:00–11:30 LT

14:00–16:00 LT



DISCOVER-AQ GeoTASO NO_2 over Denver, raster scans 2 August 2014

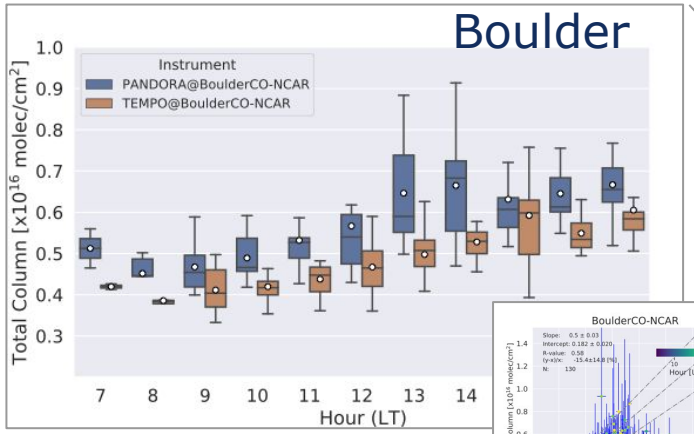
- GeoTASO shows clear indication of PM NO_2 transport to the West
- Not as evident in the TEMPO average, but PM NO_2 column values are higher over Boulder
- In agreement with Boulder Pandora observation
- Also high NO_2 over O&G region to the North of Denver

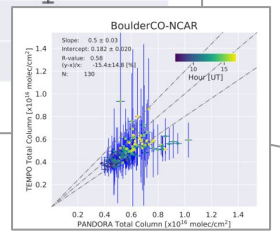
TEMPO NO_2 L2 average with 1 km supersampling over Colorado August

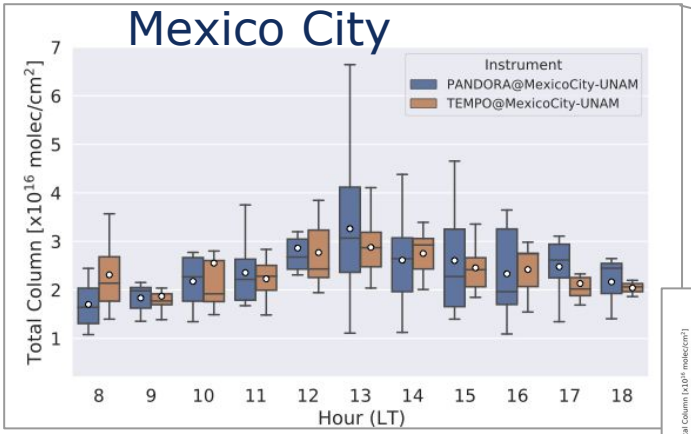
Unofficial TEMPO data: Not for public release

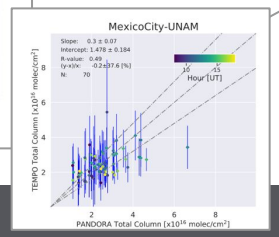
Diurnal variability of TEMPO and Pandora NO_2 tot column

Quality assured data for Aug 2023: TEMPO L2 V02 NO_2 and Pandora Total Columns (direct sun)
TEMPO data within 10km of the Pandora sites (Mean values).

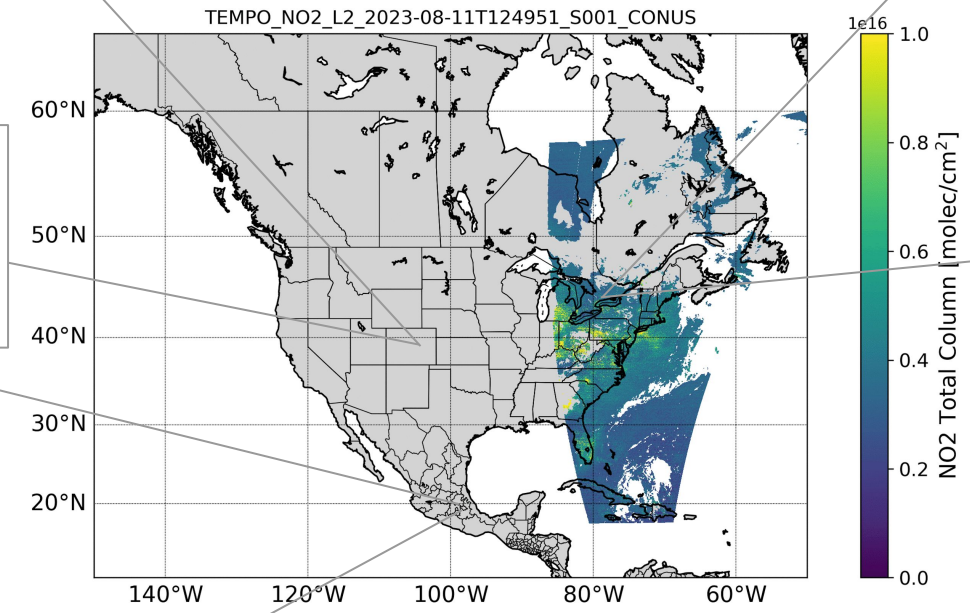


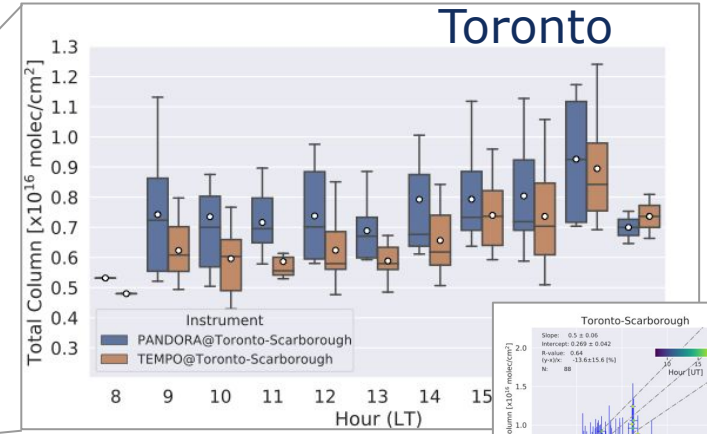


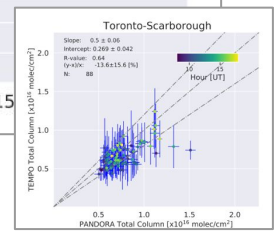




Example of TEMPO NO_2 on Aug 11 2023



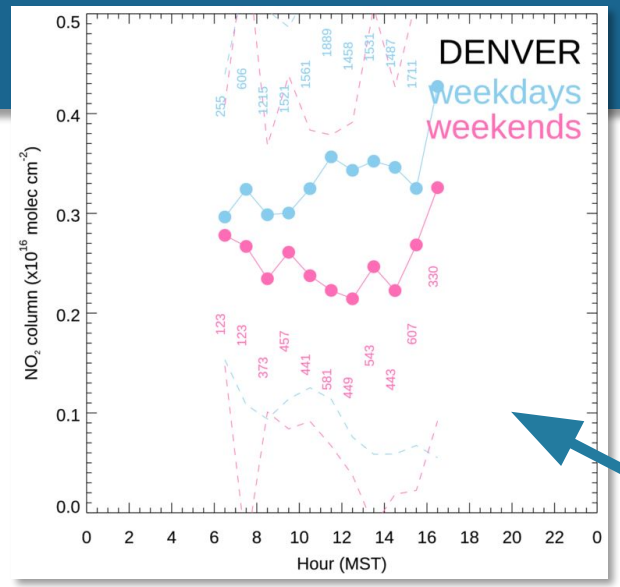


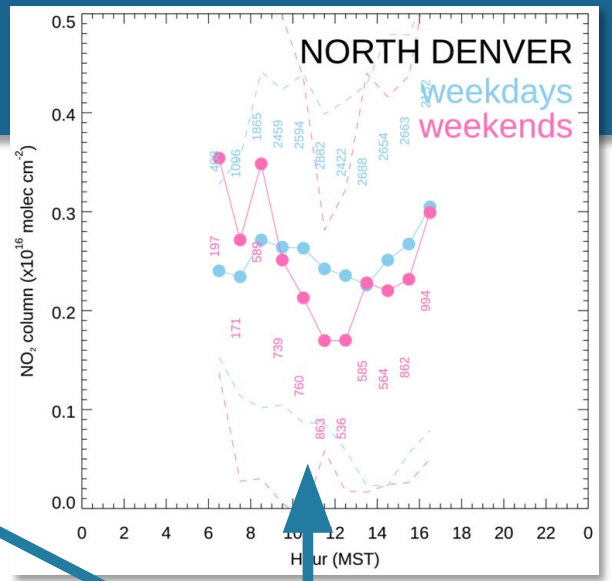


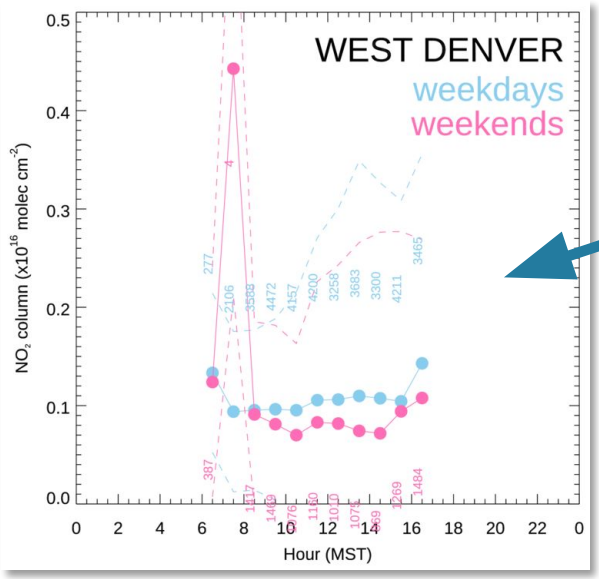
Unofficial TEMPO data:
Not for public release

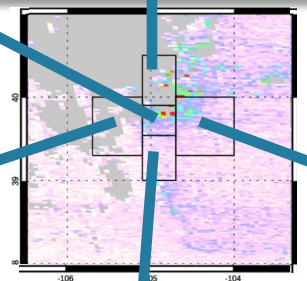
- Diurnal variability is captured by TEMPO among different latitudes.
- Bias is defined as the median of (TEMPO - Pandora/Pandora) obtained from all coincident times/dates.
- Mexico City shows the best comparison with a median bias of -0.2 +/- 37 % while Boulder and Toronto have a bias of around -15 %.

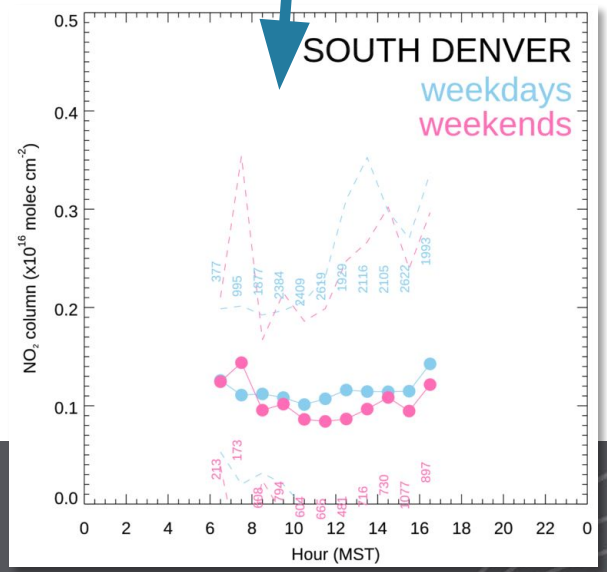
Denver regions

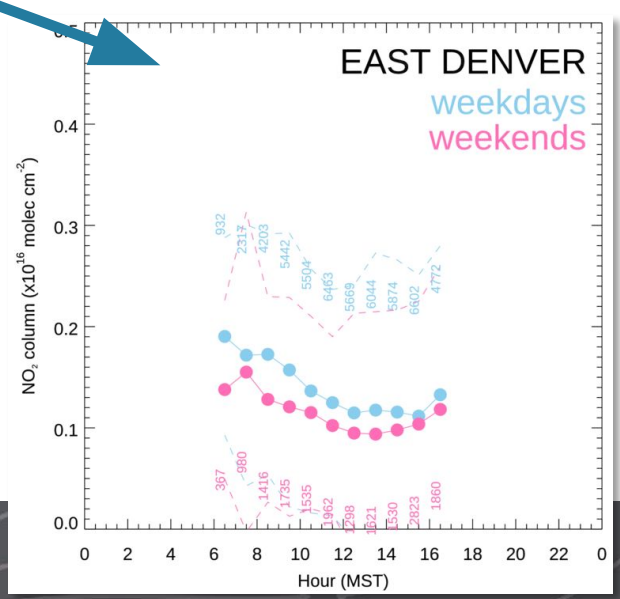












- Over smaller Denver regions, diurnal cycle is affected more by local emissions and transport
- Some data points with few samples are suspect
- NO_2 higher over Denver and to the North where O&G is located
- Also largest weekend difference in these areas
- Lower values to West and South

Unofficial TEMPO data:
Not for public release

Summary

- GEO shows that diurnal NO_2 spatial and temporal variability is large, and that compared with once-a-day LEO observations, the new data will advance understanding of pollutant distributions, emissions and human exposure
- In summer, NO_2 photochemistry is an important driver of diurnal variability, especially at the regional scale
- At local scale, NO_2 magnitude and diurnal variability patterns change day-to-day, showing the impact of emissions and meteorology
- In winter, NO_2 columns are higher and diurnal variability is lower as a result of reduced photochemistry
- Validation is going to be be very important to avoid uncertainties in diurnally varying retrieval algorithm parameters aliasing onto the retrieved products