Coupled modeling studies over East Asia during the KORUS-AQ field campaign

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vEGU21-9002 in AS 5.3
(also see live talk:
16:13 CEST, 30 April)



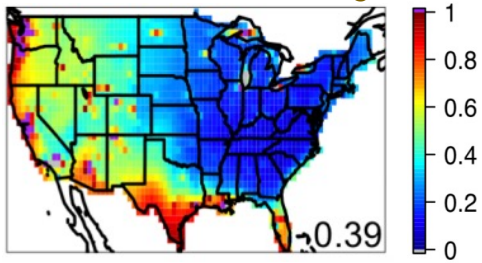
Figure Source: S. Hall/NASA ESPO

KORUS-AQ

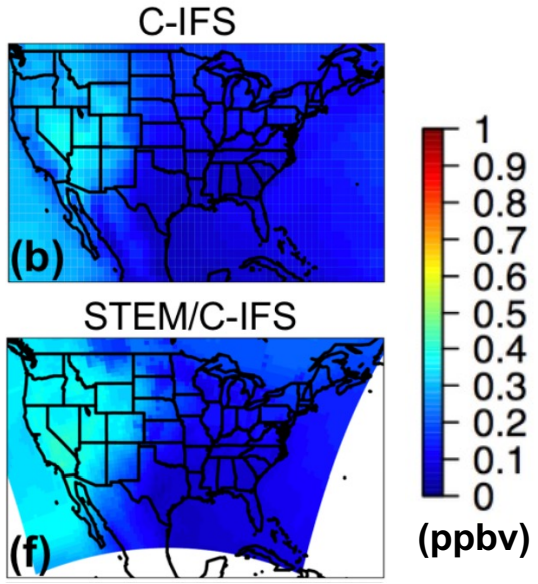
Previous multi-scale modeling studies over the US: Policy-relevancy and recommendations

- **HTAP2 (2012-2017): STEM simulations (offline regional model, ~half degree) with chemical boundary conditions downscaled from C-IFS (CAMS forecast model) and other global systems, based on which policy-relevant metrics were calculated**
- **Stressed the importance of event-scale analyses based on regional modeling systems to studying US and other regions including East Asia**
- **Strongly recommended the utilization of observation-constrained boundary condition models as well as rich, high-accuracy observations from various platforms to support the analysis**

RERER (C-IFS): indicating importance of non-local sources to NA O_3



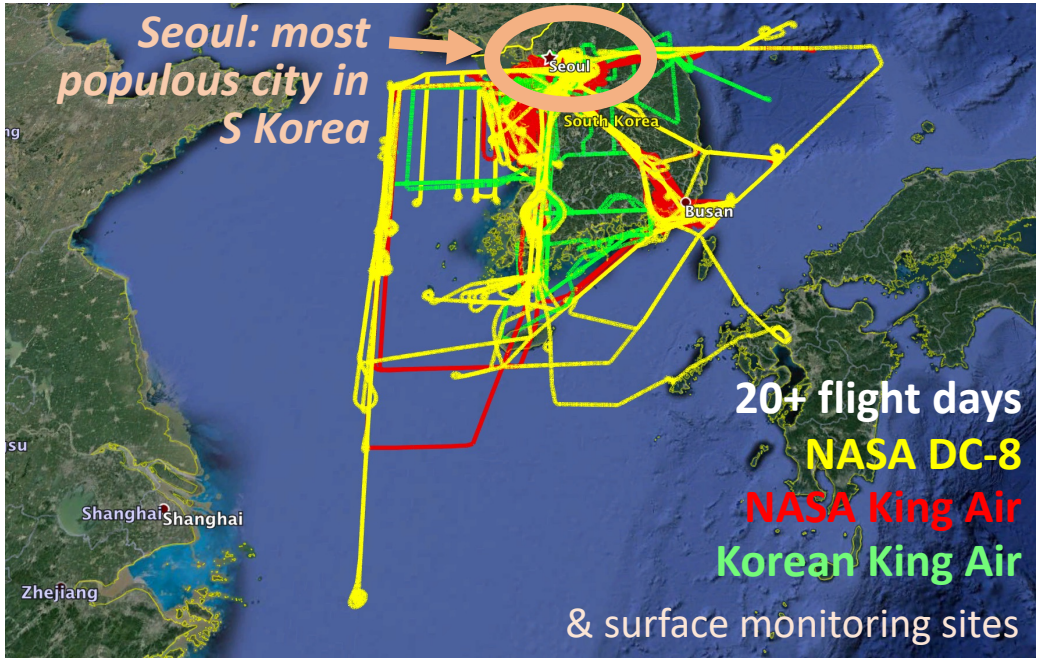
ΔSurface O_3 due to 20% E Asia anthro. emission changes

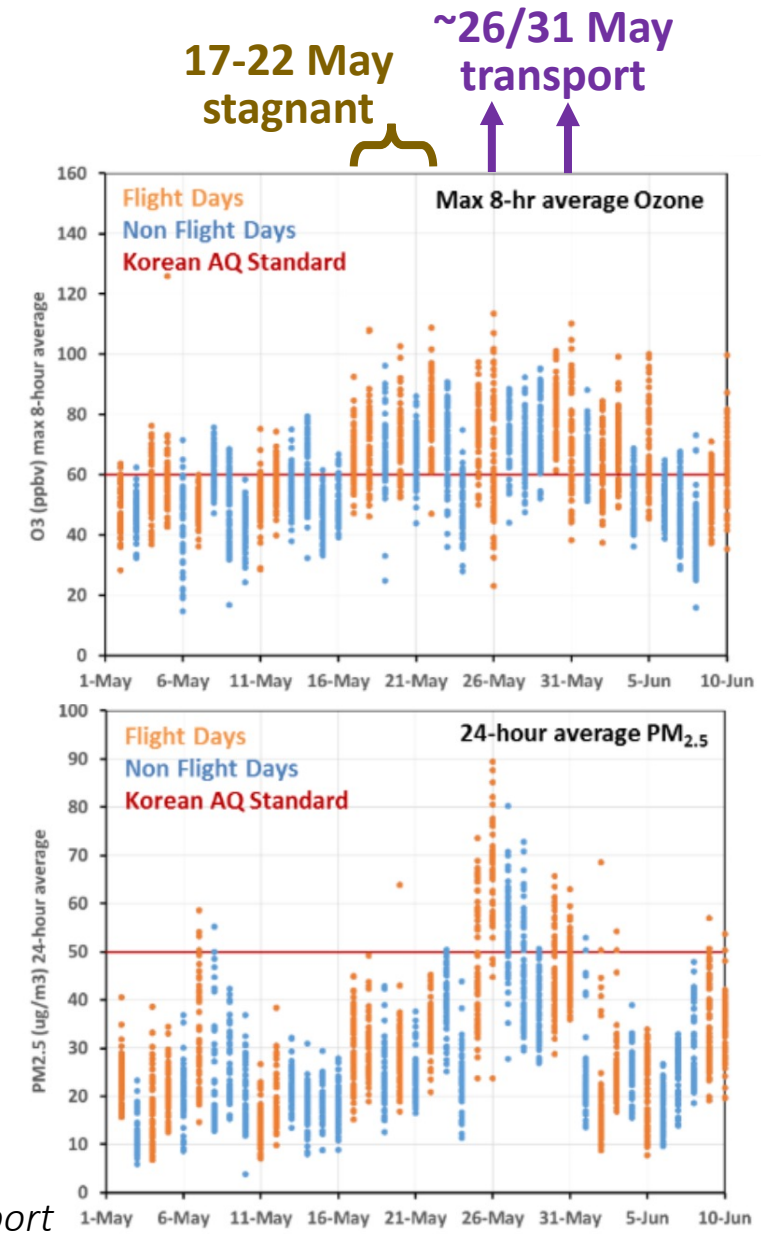


Huang et al., 2017

KORUS-AQ campaign overview (May-June 2016)

- **To improve the understanding of factors controlling air quality across urban, rural, and coastal interfaces in/around South Korea during its polluted seasons**
- **To determine opportunities and challenges related to Earth system models and future geostationary pollution monitoring satellites (e.g., GEMS)**

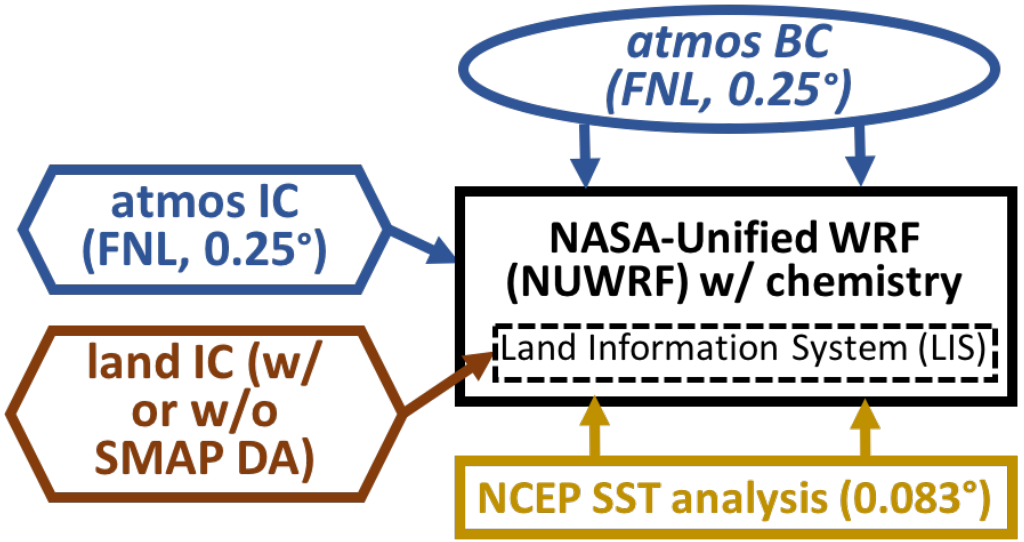




KORUS-AQ report

Our tool: WRF-Chem with aerosol feedbacks & improved representation of land-atmosphere interactions

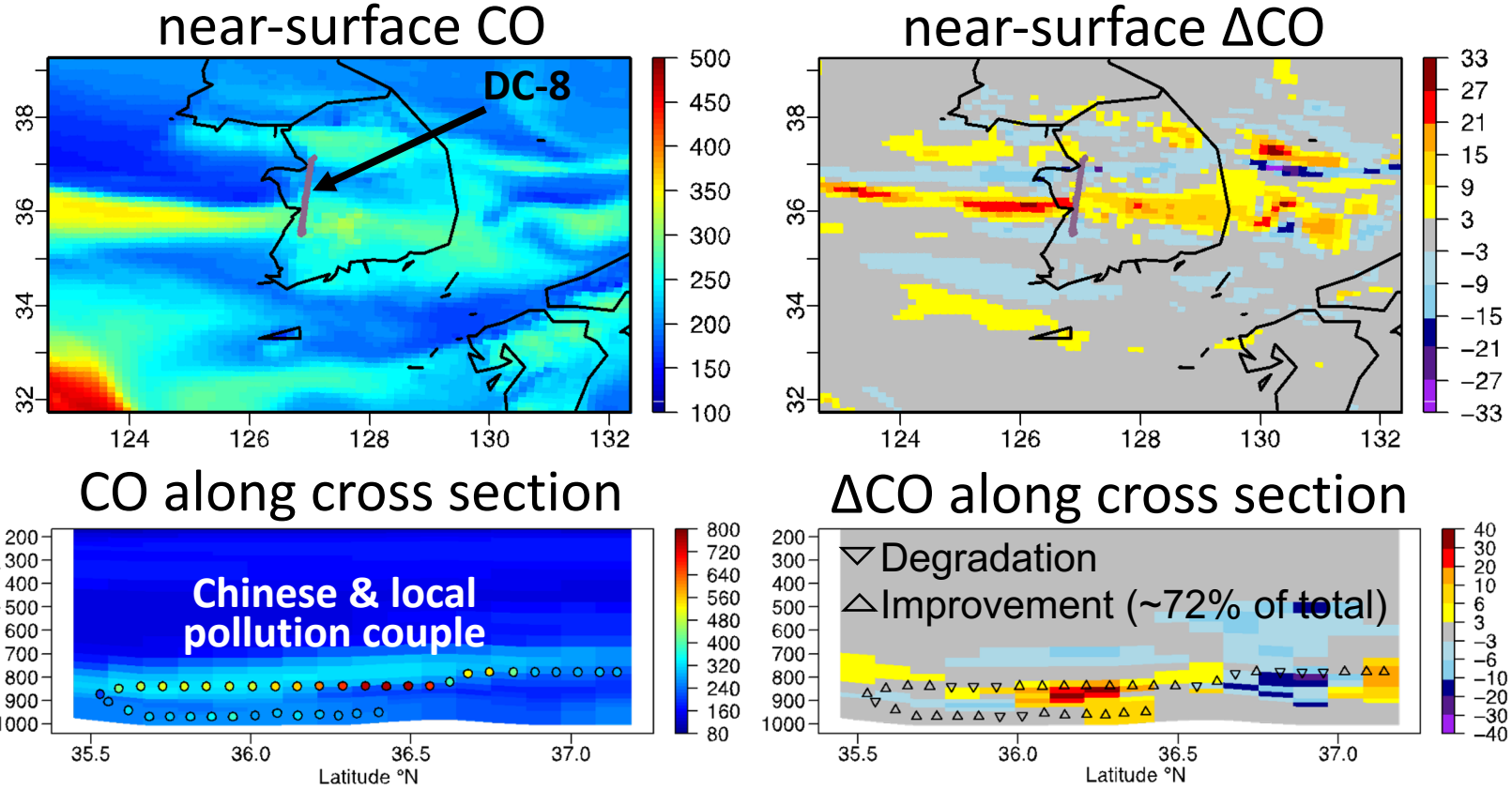
- **WRF-Chem w/ aerosol feedbacks as well as an alternative land component (NASA's Land Information System) which facilitates studies on land-atmosphere interactions based on various land surface models**
- **Evaluating benefits of Earth observations (atmosphere, land) and chemical/land data assimilation (DA)**

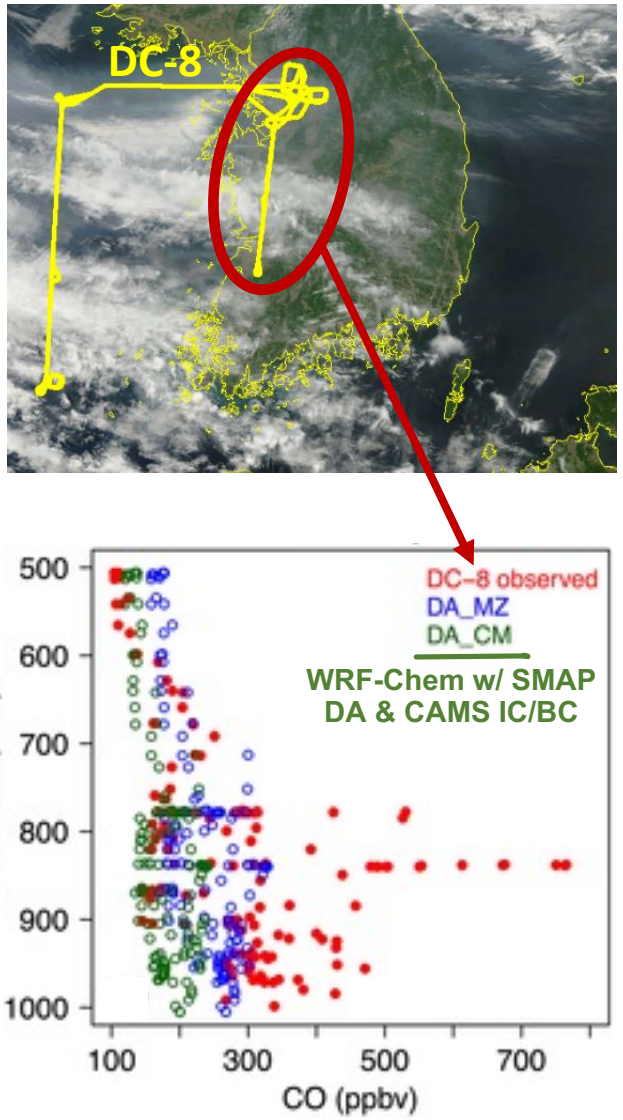


- **Focusing on carbon and nitrogen cycles which are specified in "WMO GAW Implementation Plan: 2016-2023"**
- **Case studies, particularly for the 31 May 2016 event, will be shown today**

CO transport case study: impact of land and chemical DA

SMAP soil moisture DA (into Noah land model, EnKF) impacts on WRF-Chem CO (ppbv) on 31 May 2016

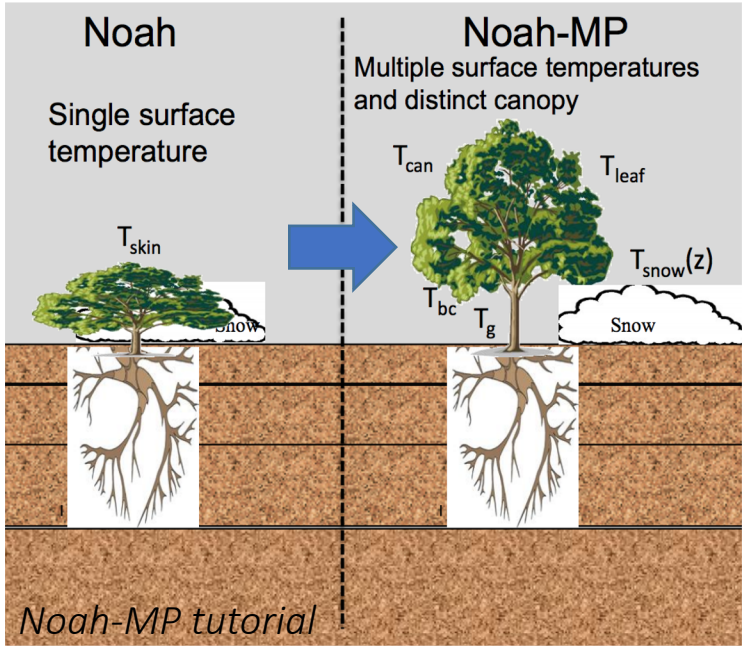




- SMAP DA improved WRF-Chem (weather &) CO in places
- Chemical IC/BC downscaled from high-res CAMS w/ chemical DA improved CO performance <600 hPa and is advantageous for determining the high uncertainty in emission inputs (e.g., HTAP2, QFED)

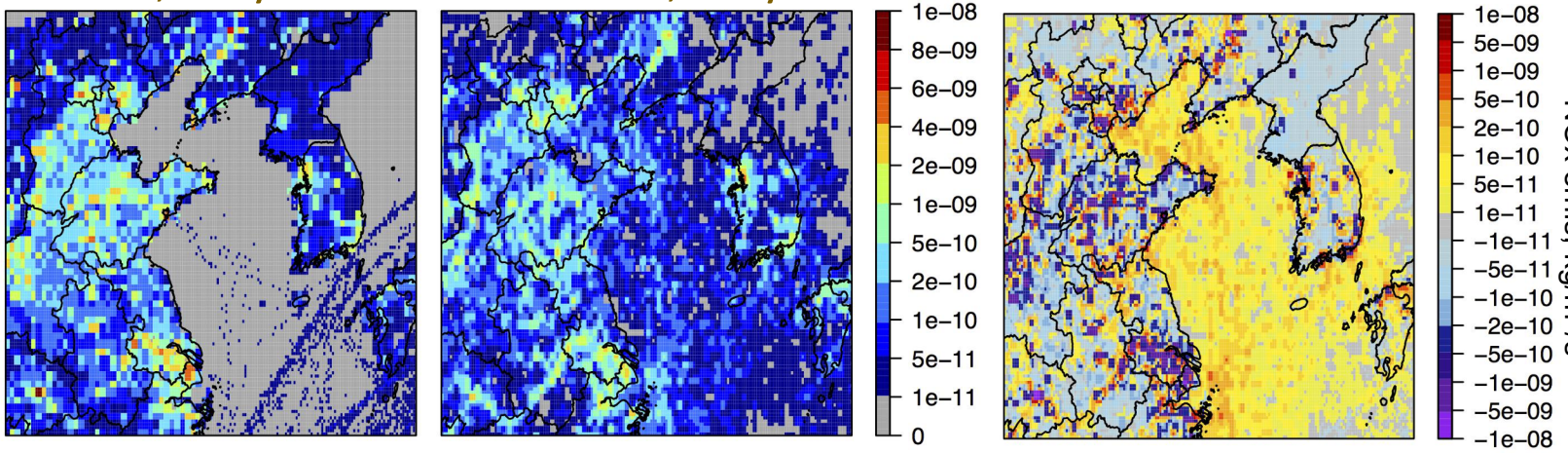
Huang et al., 2018

Emission impacts on atmosphere-biosphere interactions



Noah-MP land model

- **Separate vegetation canopy**
- **Dynamic vegetation w/ Ball-Berry stomatal resistance**
- Multi-layer snowpack + other improvements from Noah
- We updated key land model inputs (soil type, land cover)



WRF-Chem experiments

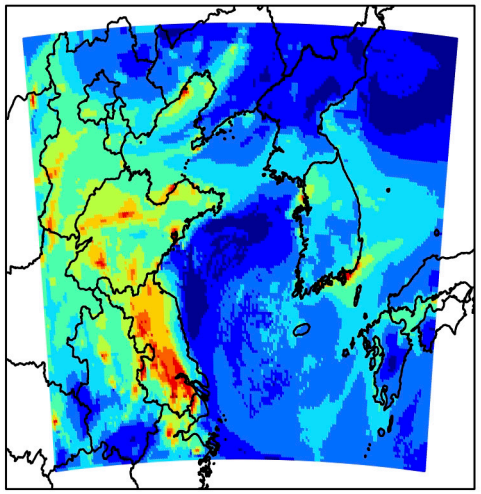
Base: **largely based on HTAP2 for 2010**

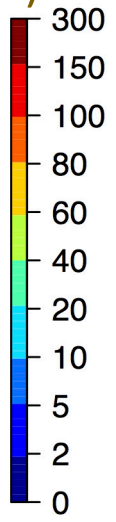
Sensitivity: **NOx emissions replaced with OMI-constrained DECSO in urban & non-terrestrial areas (based on CCI land cover): total anthro. emissions ~10% lower than base case, w/ urban & shipping contributed to >60 % of the total**

Both cases: **WRF-Chem chemical fields compared with AERONET, GOCI, aircraft, ship obs; modeled GPP/ET compared with SMAP L4C/COMS ET**

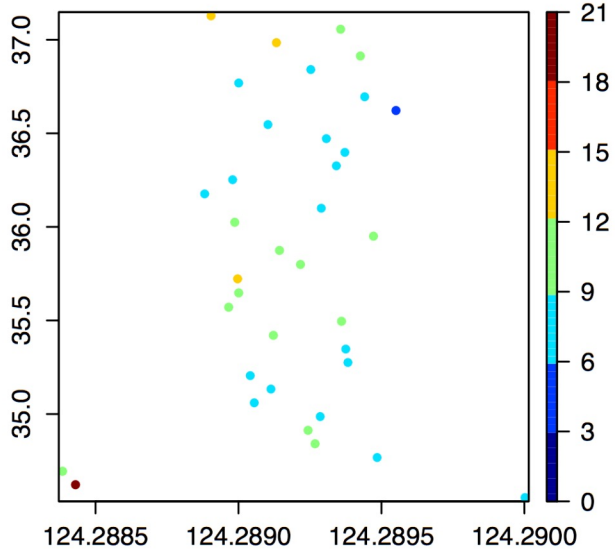
WRF-Chem ΔNOy due to NOx emission adjustments

Base, surface (9-16 KST)

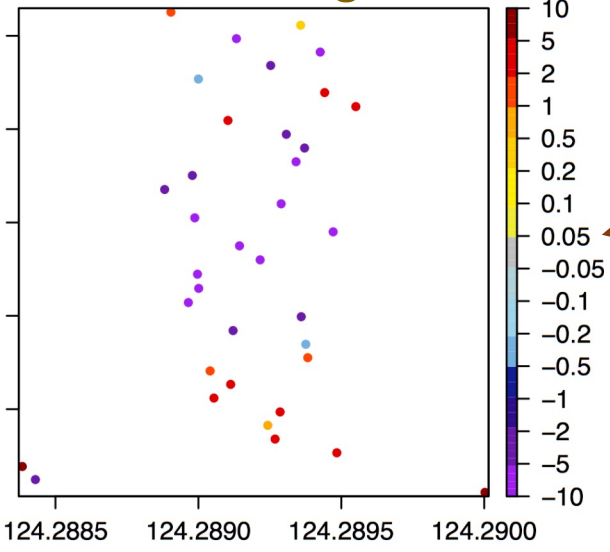


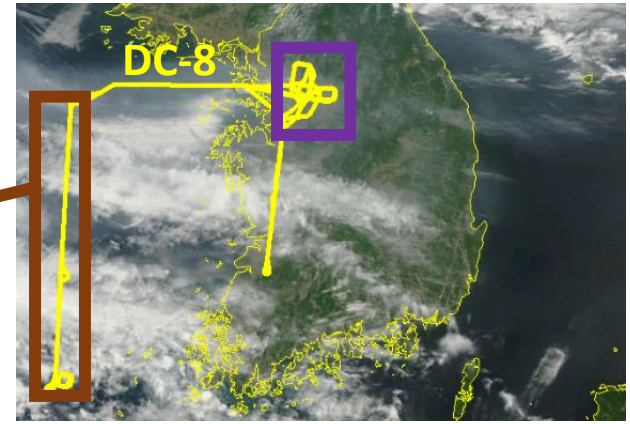


Observed



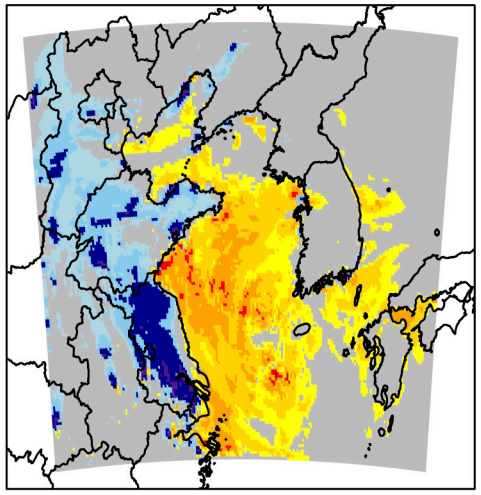
Error changes

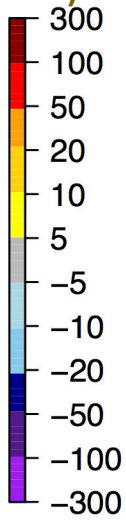


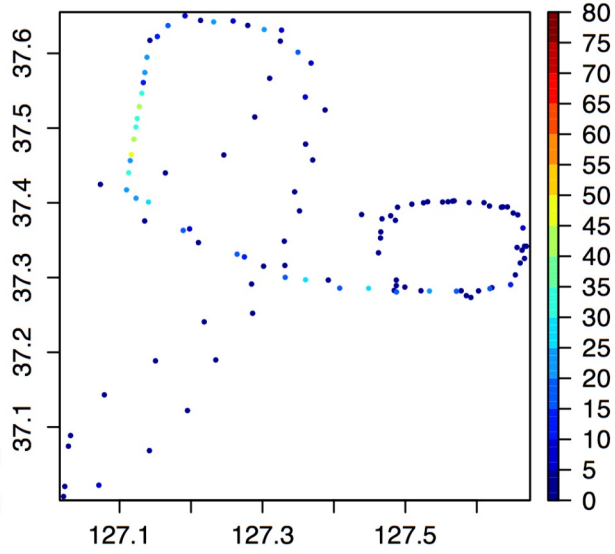


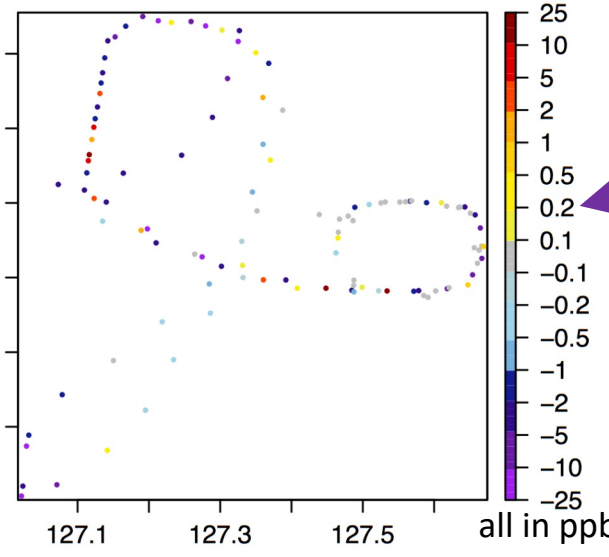
Near-surface, ~10 am

Sensitivity-base (9-16 KST)

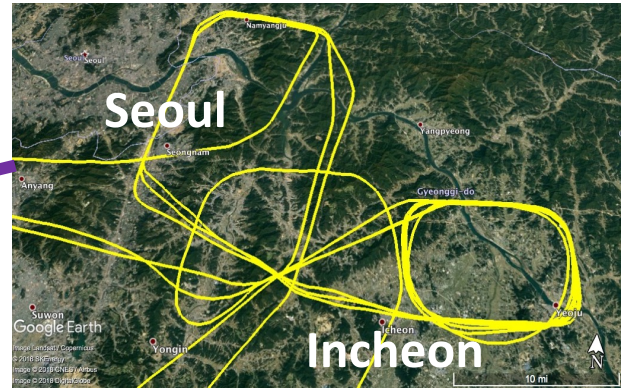








all in ppbv

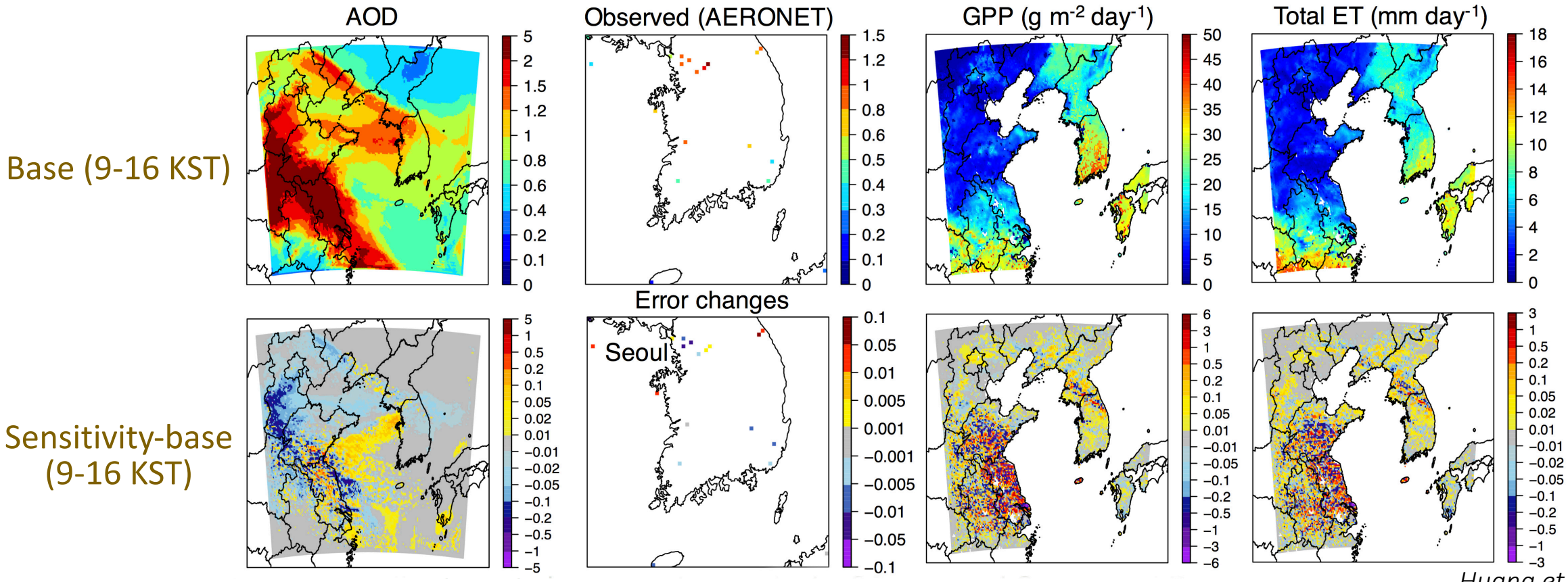


All altitudes, 3 times, daytime

Huang et al., 2020

For the entire flight, offshore, or around Seoul, RMSEs reduced by 1-3 ppbv

WRF-Chem ΔAOD, GPP, ET due to NOx emission changes

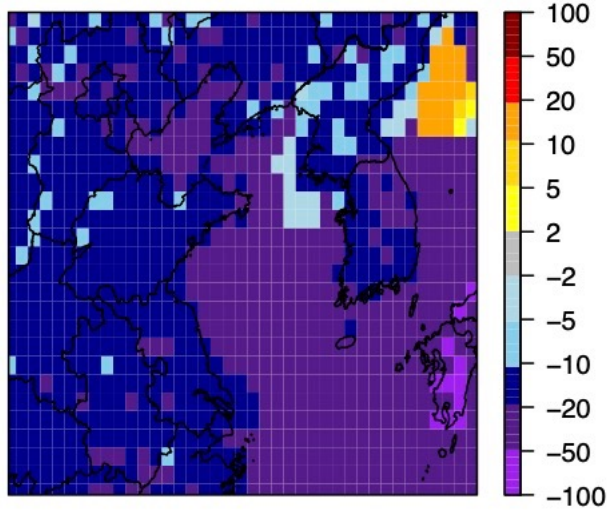


Huang et al., 2020

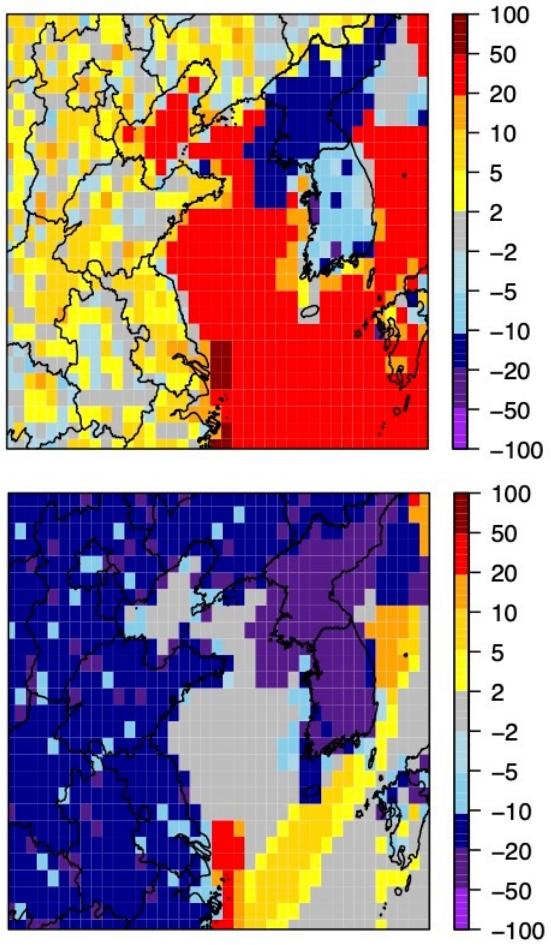
- **Emission-induced aerosol changes interact with radiation & temperature, affecting GPP & ET which together indicate plants' resilience to environmental changes**
- **Selected as a NASA HECC highlight, for the scientific value and computation complexity of this study based on this coupled modeling system**

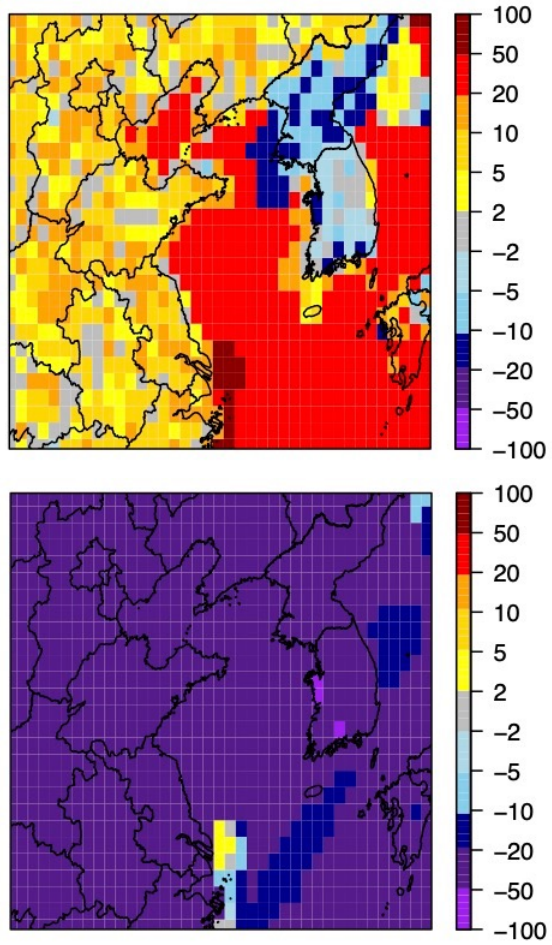
Relevancy to COVID and post-COVID conditions

-15.2%, May 2020 relative to May 2015



Emissions source: Forster et al., 2020





Recovered with similar and enhanced fossil fuel consumptions: +2.8% and +6.6%, May 2030 relative to May 2020

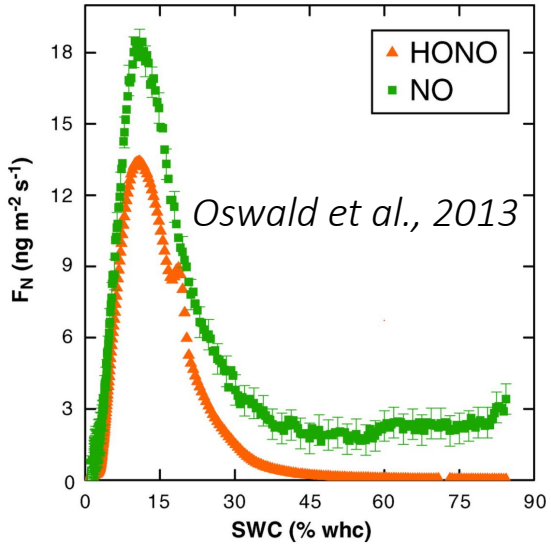
Moderate and strong green scenarios: -15.2%, -35.6%, May 2030 relative to May 2020

- **Magnitude of emission changes (including strong NOx emission reductions) due to COVID similar to that of the sensitivity test shown earlier**
- **Now using multi-scale coupled modeling systems to assess the climate impacts of COVID and post-COVID emission changes including event-scale analysis**

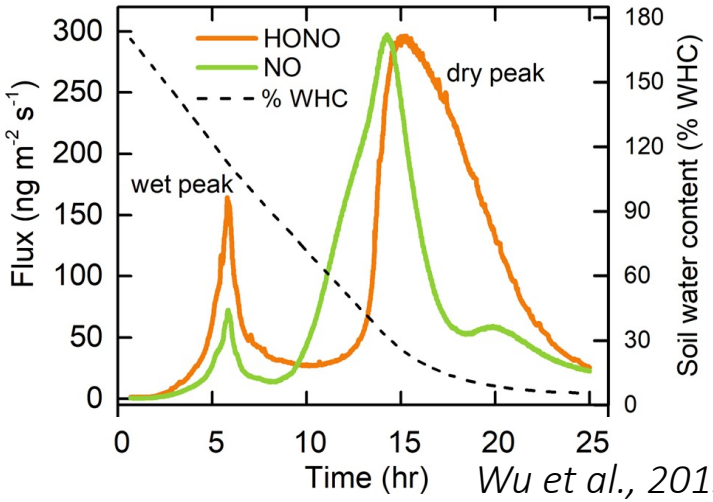
Improving model representation of soil NO and HONO emissions: role of soil moisture

Soil emissions are important in some regions but poorly represented in emission/air quality models:

- **Soil NO and HONO emissions show soil moisture dependency: dry peak at ~15% SWC, and wet peak at >70% SWC (affected by microbial activities)**
- **Soil NO emissions for various surface types largely sensitive to temperature in the widely-used MEGAN scheme; only the "dry peak" is reflected in some other schemes (Berkeley-Dalhousie, CAMS)**
- **Soil HONO emissions are often missing, which can be in comparable magnitude and correlated with soil NO emissions**



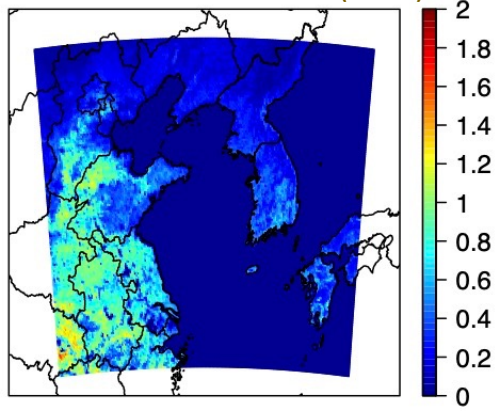
Oswald et al., 2013



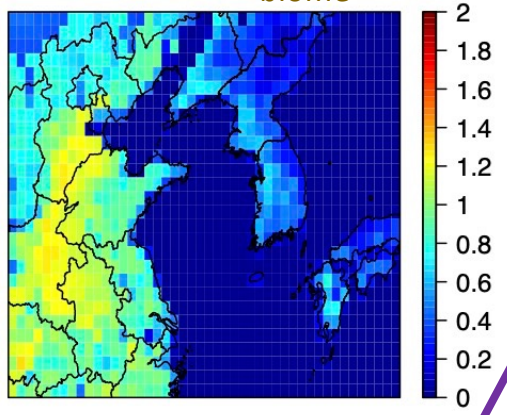
Wu et al., 2019

WRF-Chem and CAMS soil NO emissions: Spatiotemporal variability and soil moisture influences

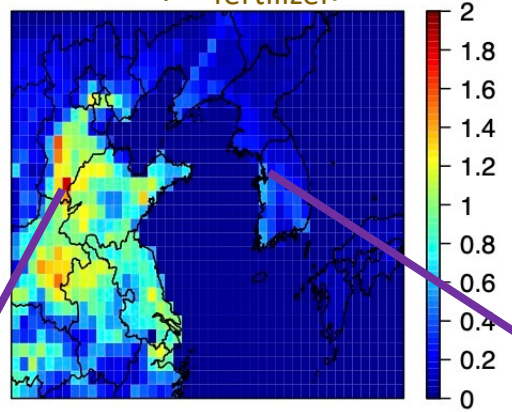
WRF-Chem $F_{soil\ (total)}$



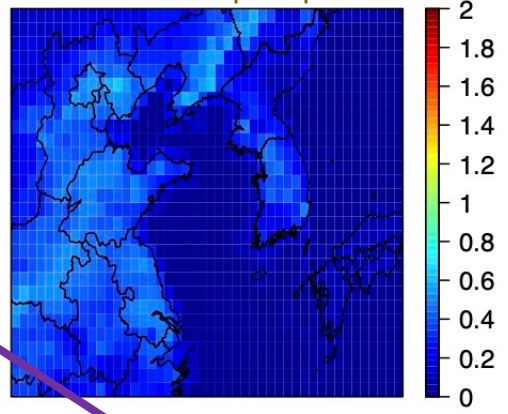
CAMS, F_{biome}



CAMS, $F_{fertilizer}/2$

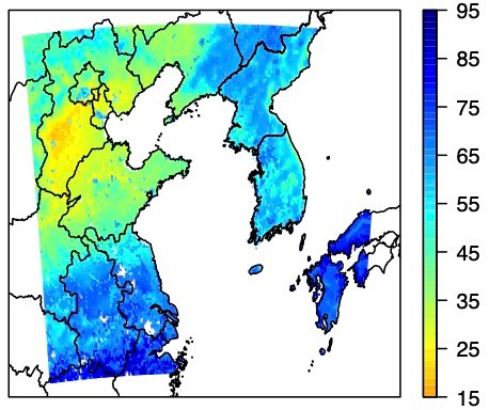


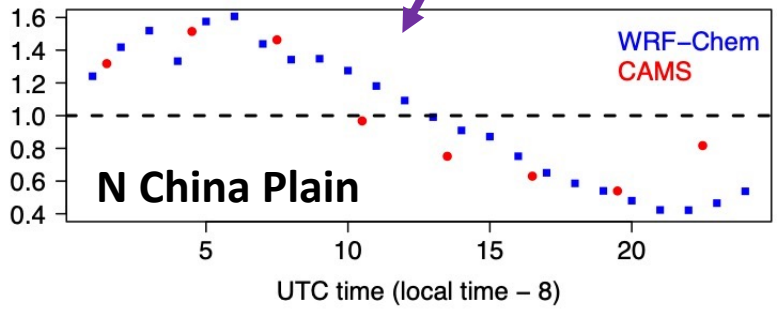
CAMS, $F_{dep}+F_{pulse}$

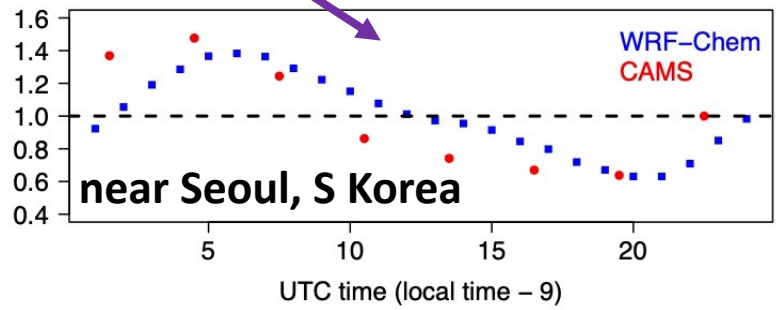


(mol/km^2/hr)

WRF-Chem SM/porosity (%)







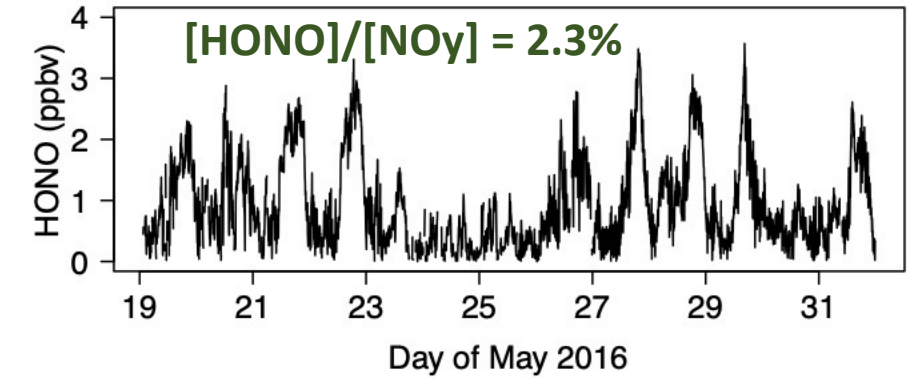
(normalized)

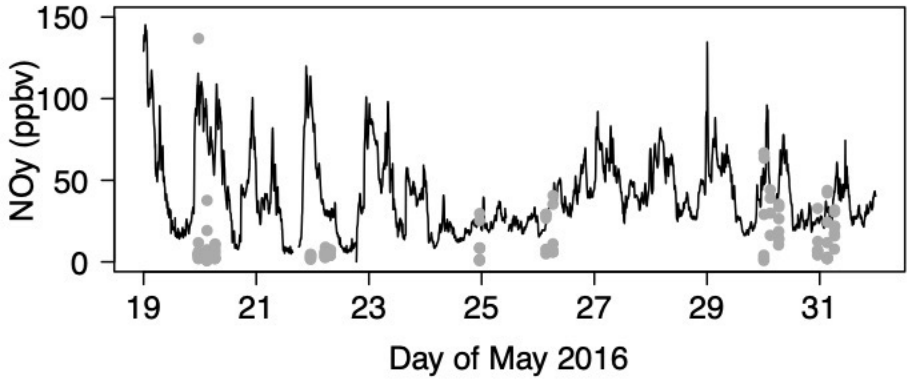
- **Soil NO emissions peak in the early afternoon, particularly high over dry, warm regions (e.g., N China Plain)**
- **Comparing our WRF-Chem and CAMS emissions indicates largest uncertainty related to (lack of) fertilizer information**

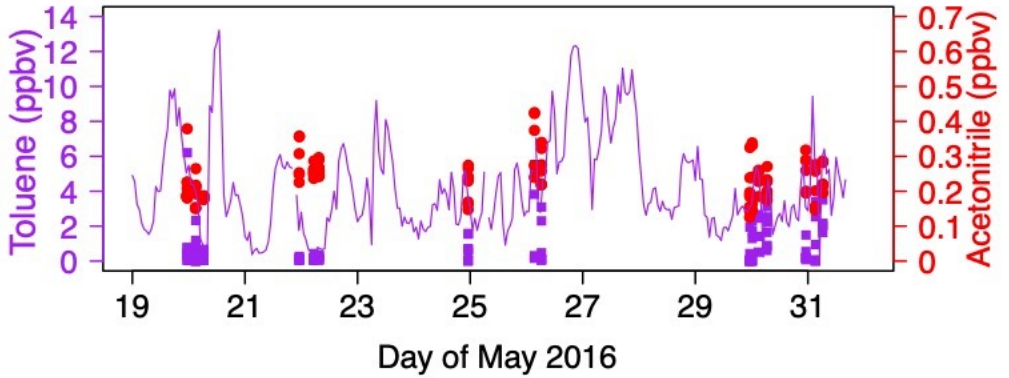
Understanding HONO sources and model uncertainty



WRF-Chem far from satisfactory







(dots: DC-8, >800 hPa; lines: Olympic Park site)

- **HONO correlated well with NOy & toluene: HONO co-emitted with other NOy species from traffic sources (emissions of HONO/NOx: 0.8-1.6% in literature)**
- **Biomass burning impacts persistent, as indicated by acetonitrile, via direct emissions and surface chemistry on aerosols**
- **Soil emission related: strongly variable land cover and wet soil (SM/porosity >70%)**

Key messages, acknowledgements, references

- **Various observations, coupled LIS/WRF-Chem system and CAMS products are utilized to study sources and processes related to carbon and nitrogen cycles in East Asia (case studies shown in this presentation)**
- **Improved soil emissions and deposition schemes have been/are being tested in WRF-Chem, constrained by observations (future publications expected)**
- **Subdaily GEMS(-like) Earth observations would be beneficial for more accurately studying diurnal cycles of air pollutants/emissions and their links to quickly-evolving situations: e.g., transport (outlook)**

Thanks to:

- KORUS-AQ aircraft, ship and ground measurement teams (PIs: Diskin, Weinheimer, Thompson, Wisthaler, Lee, Kim, Cho)
- Satellite teams (SMAP, Aura, GOCI, COMS)
- Modeling communities (WRF-Chem, STEM, LIS, NUWRF)
- CAMS (Flemming, Parrington, Simpson)

References:

- Huang et al. (2017), doi: 10.5194/acp-17-5721-2017
- Huang et al. (2018), doi: 10.1029/2018JD028554
- Huang et al. (2020), doi: 10.1029/2019JD030818
- Forster et al. (2020), doi: 10.1038/s41558-020-0883-0
- Oswald et al. (2013), doi: 10.1126/science.1242266
- Wu et al. (2019), doi: 10.1038/s41396-019-0379-y
- CAMS emission report (2019), doi:10.24380/d0bn-kx16

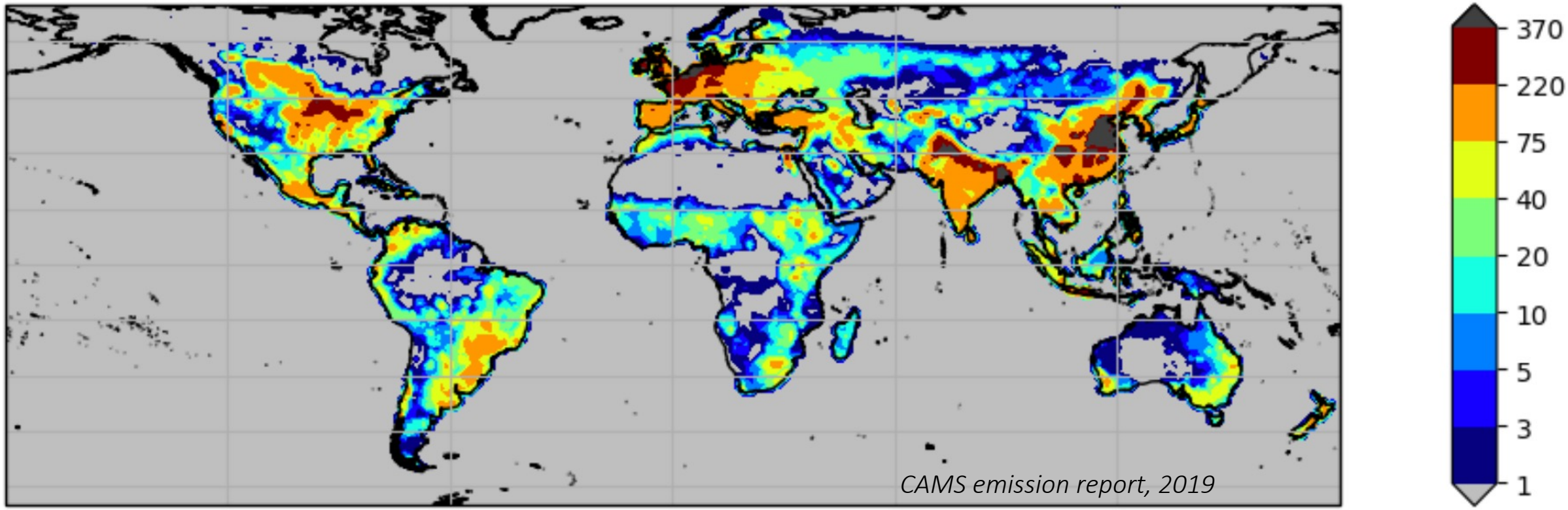
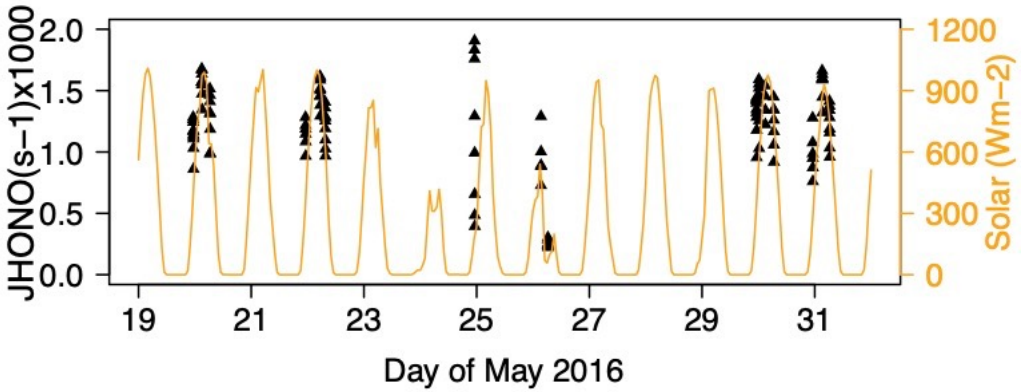
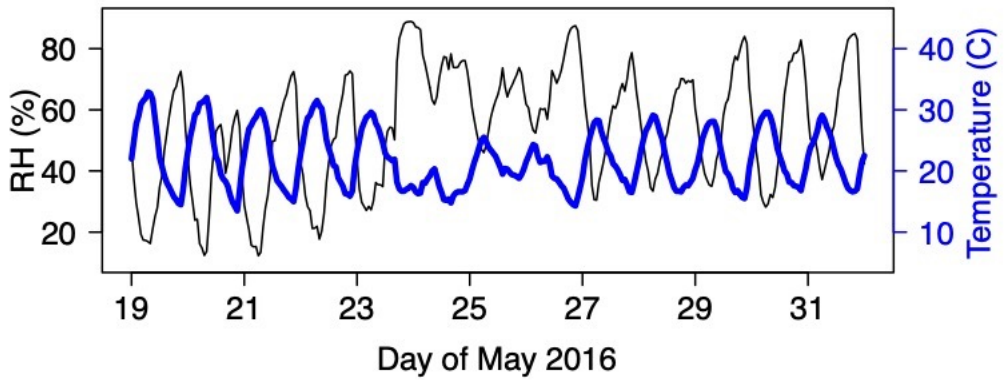


Figure 9.1: Inputs of fertilizer and manure (kgN/ha), from Potter et al. (2010), via HEMCO database.

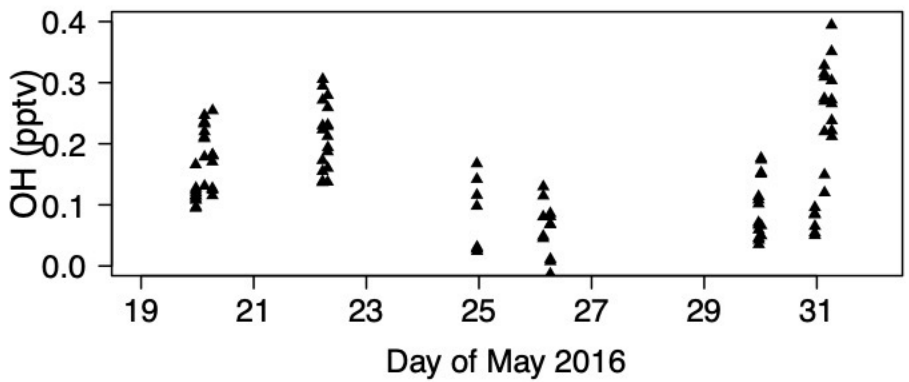
Extremely high fertilizer N over N China Plain; moderately high across S Korea (2000s data, still broadly used)

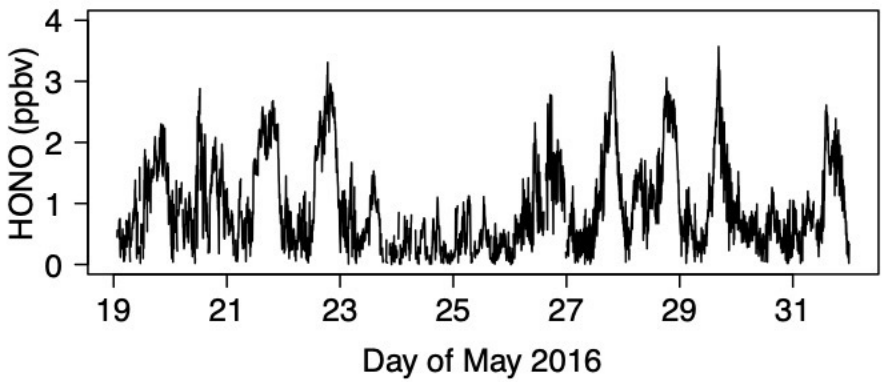


J [HONO -> NO + OH]
J coupling with soil moisture is minor



2NO2 + H2O -> HONO + HNO3
Reaction rate RH dependent, which is weakly coupled to soil moisture for this region





(dots: DC-8, >800 hPa; lines: Olympic Park site)