Simulating Air Quality with Regionally Refined Grids over Three Continents

Louisa Emmons

Atmospheric Chemistry Observations and Modeling (ACOM) Lab
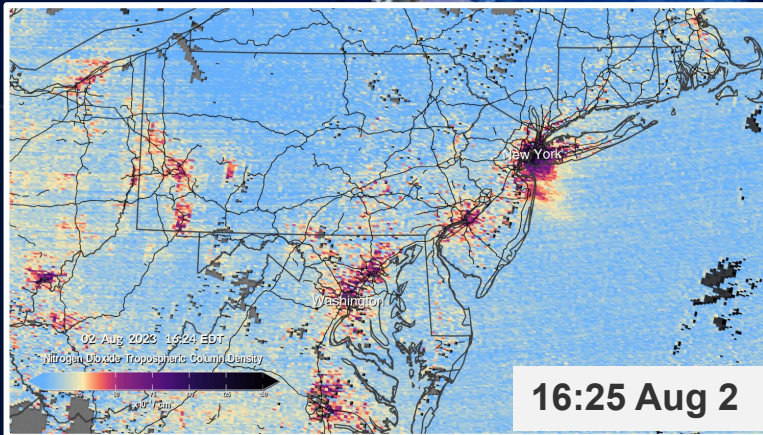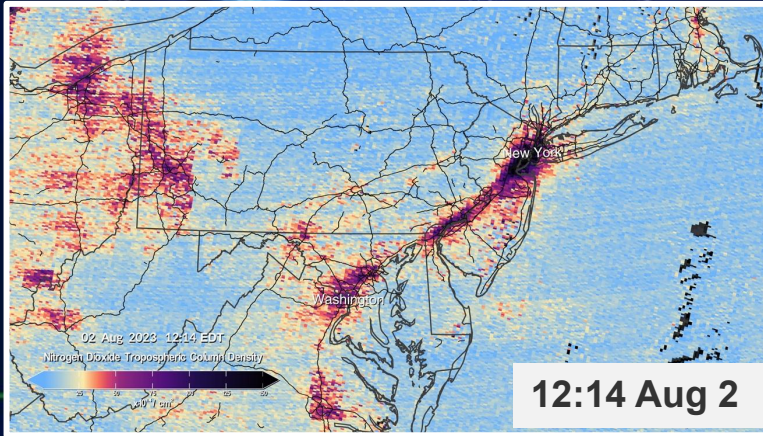
NSF NCAR

CESM Workshop - 12 June 2024

MUSICA
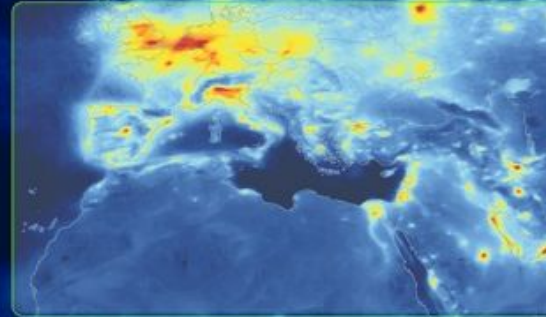Multiscale Infrastructure for
Chemistry and Aerosols

Geostatsionary Satellites: GEMS and TEMPO now providing diurnal observations
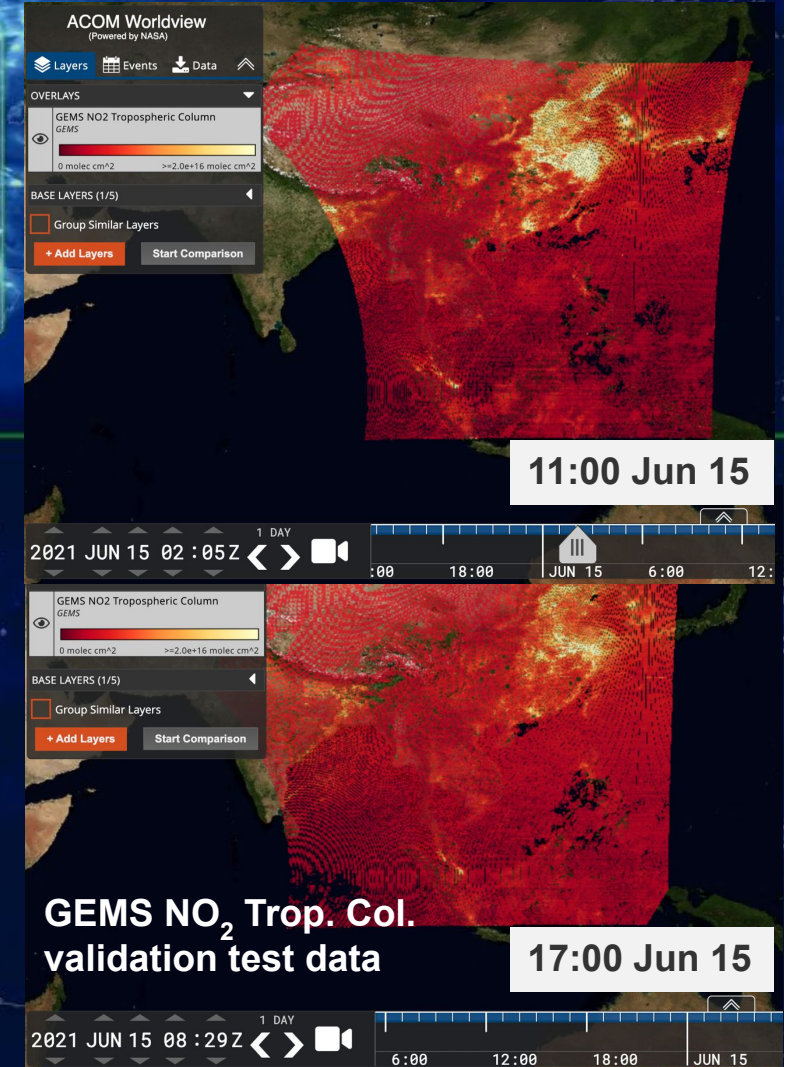

TEMPO (hourly)

12:14 Aug 2

16:25 Aug 2

TEMPO NO$_2$ Trop. Column (NASA/SAO press release)

Sentinel-4 (hourly)

GEMS (hourly)

Observations of the diurnal cycle of pollutants will lead to improved air quality predictions

11:00 Jun 15

**GEMS NO$_2$ Trop. Col. validation test data**

17:00 Jun 15

MUSICAv0 – CAM-chem with variable resolution

MUSICAv0 = CAM-chem (Community Atmosphere Model with Chemistry) with
   Spectral Element (SE) dynamical core, allowing for regional refinement
   Configuration of the Community Earth System Model (CESM v2.2 and later)

Custom variable resolution grids can be created

Nudged to reanalysis meteorology (GEOS/MERRA2) or free-running climate

MUSICAv0 12-km resolution regions, 100-km rest of globe
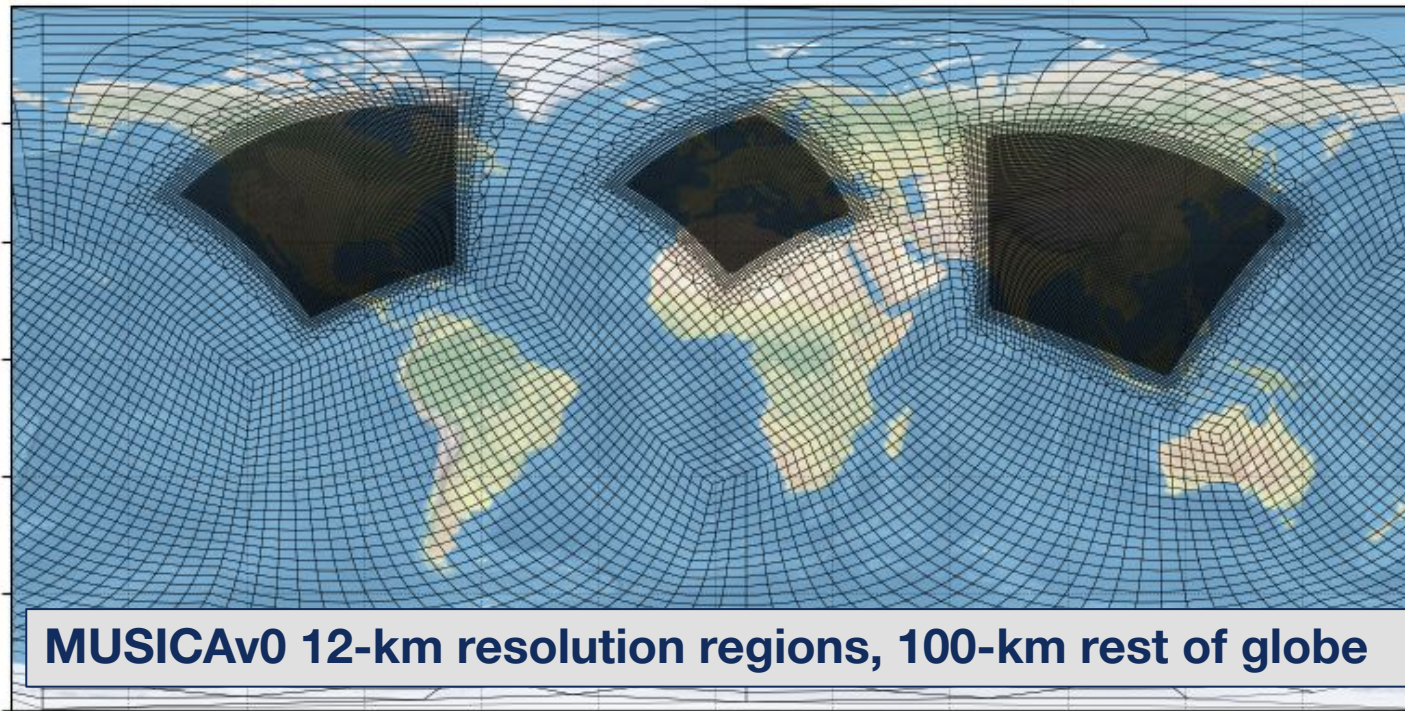
Grid created to replicate Geostationary
   Constellation, matching resolution of
   observations

458,000 grid points
250 transported tracers
~2M core-hrs/sim-year

Also have version with 25-km resolution
   regions

MUSICA
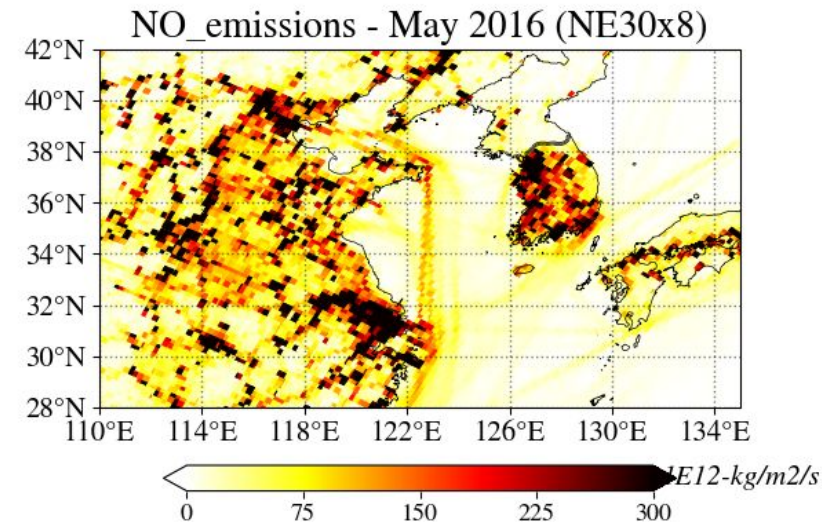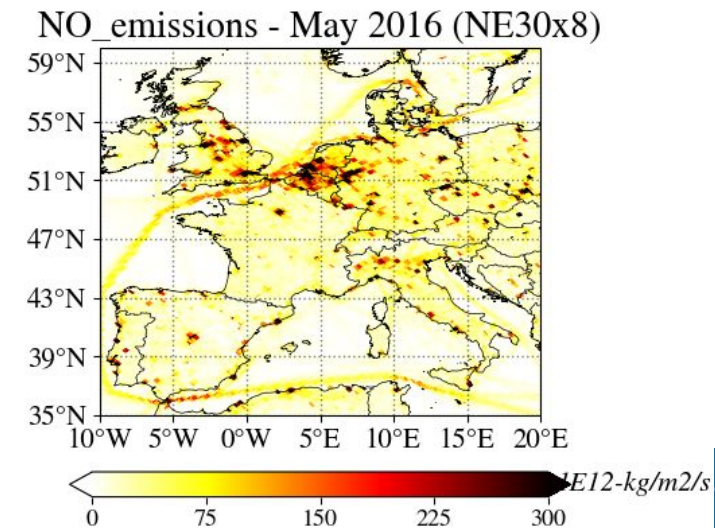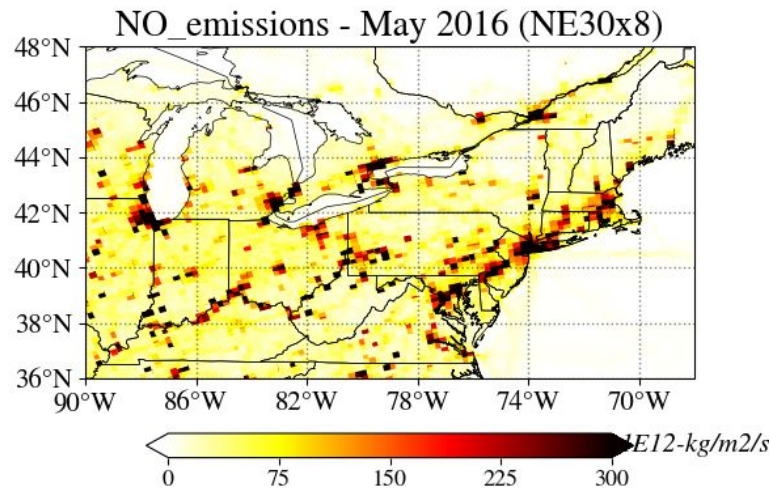Multiscale Infrastructure for
Chemistry and Aerosols

~100km vs ~12 km horizontal resolution

Emissions at higher resolution in source regions
More realistic chemical regimes (NOx / VOCs)
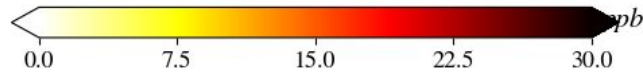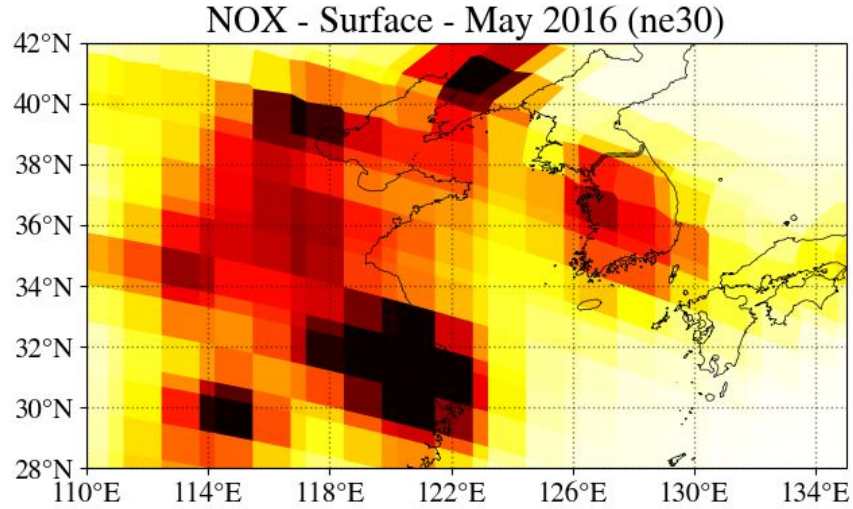Impact on background composition and intercontinental transport
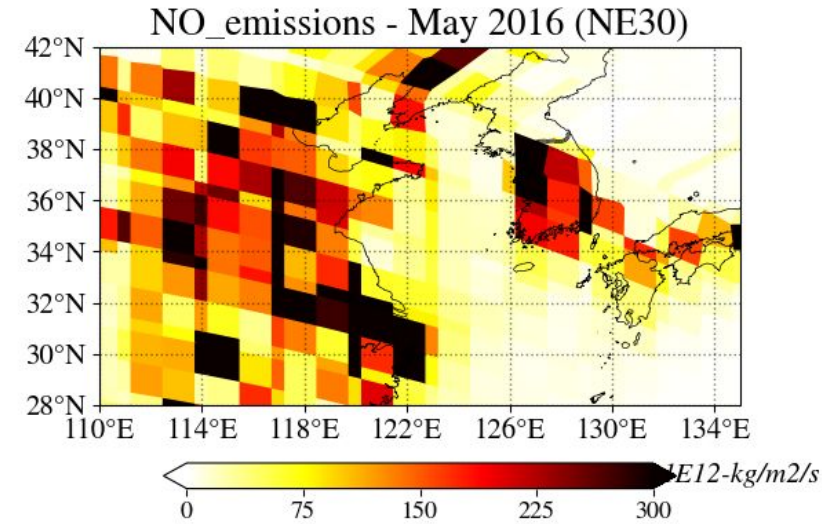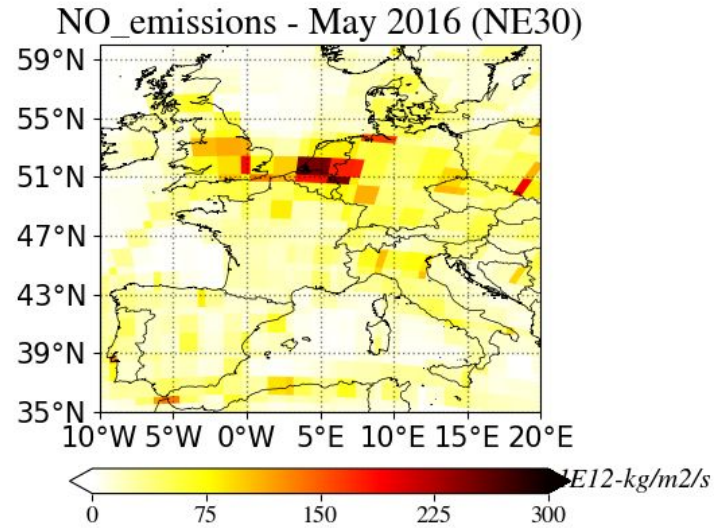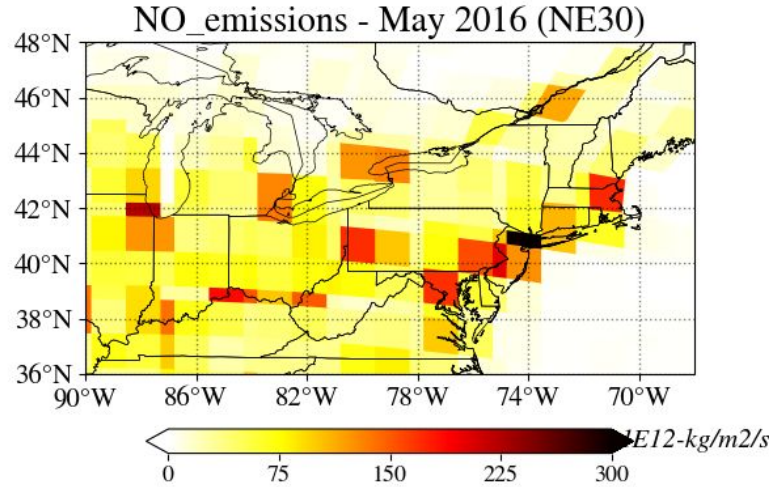
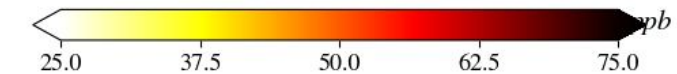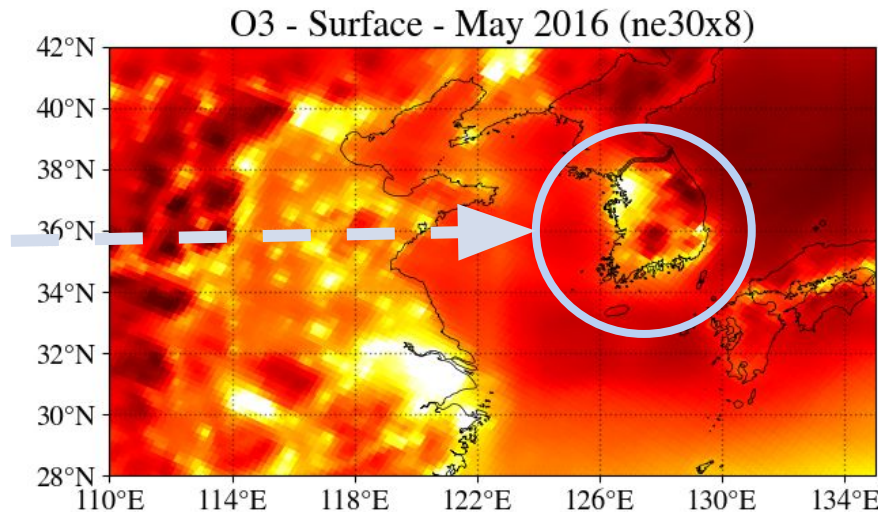# East Asia

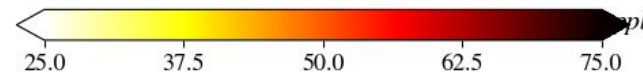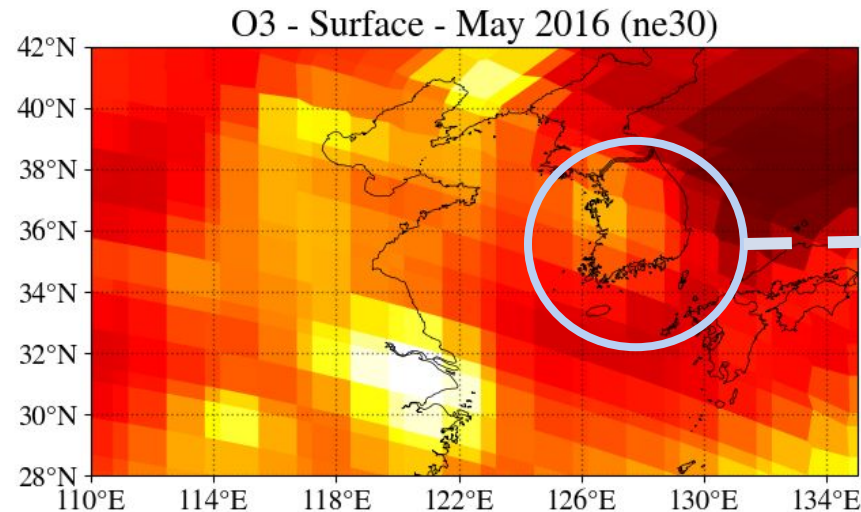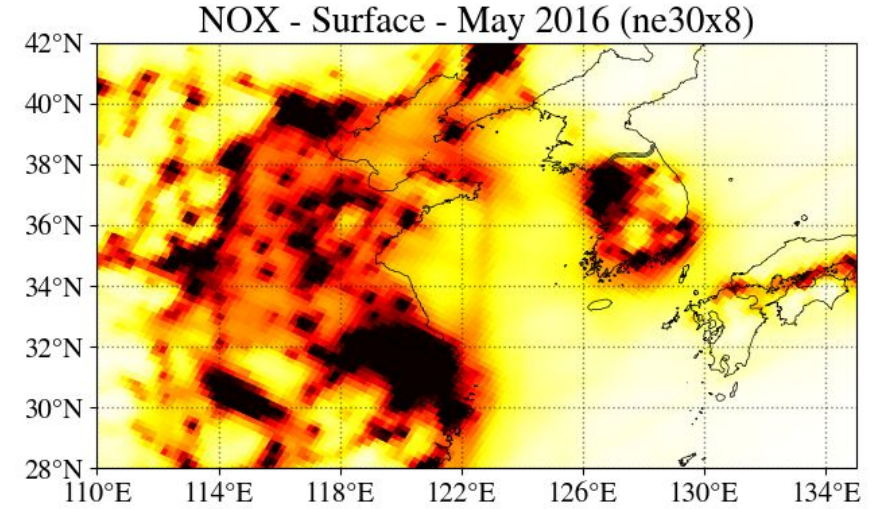12-km horizontal resolution closer to urban scale

NOx concentrated at finer resolution, resulting in decreased ozone in cities
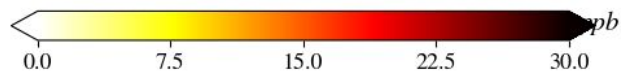e.g., Seoul and South coast of Korea

100 km resol.

12 km resol.

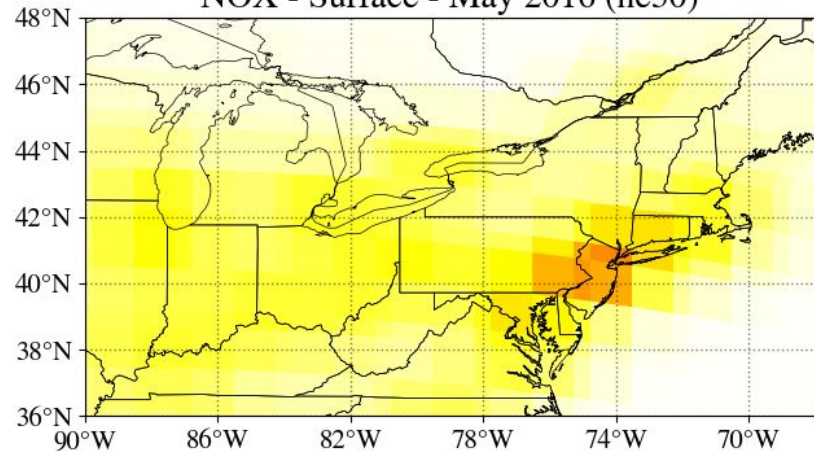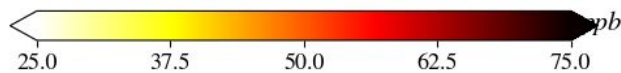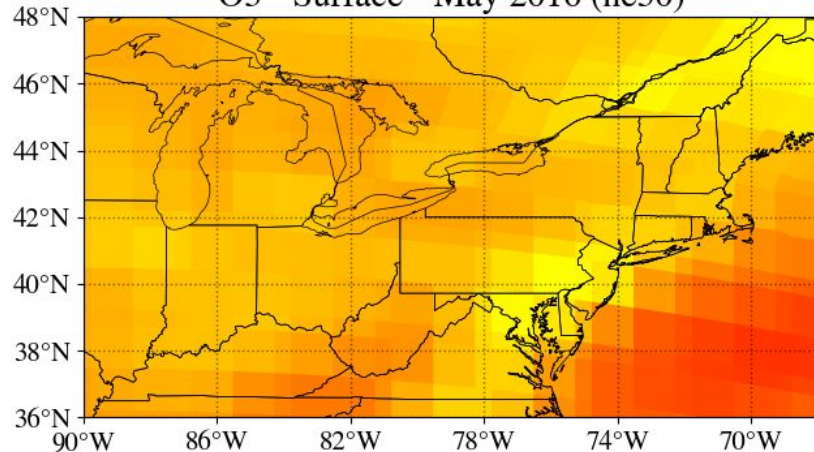100 km

12 km

NE U.S.

Some cities not apparent at 100km resol.:
Chicago, Detroit, Boston

Europe

12-km horizontal resolution closer to urban scale

NOx more concentrated in finer resolution, resulting in decreased ozone in cities

NOX - Surface - May 2016 (ne30)

NOX - Surface - May 2016 (ne30x8)

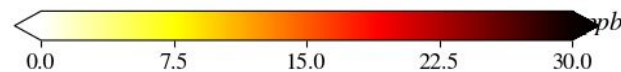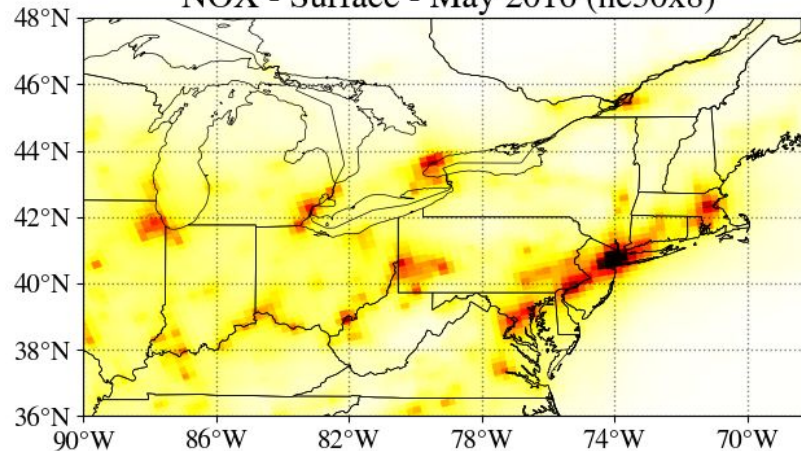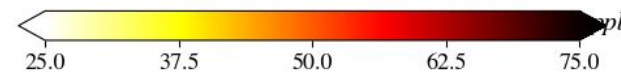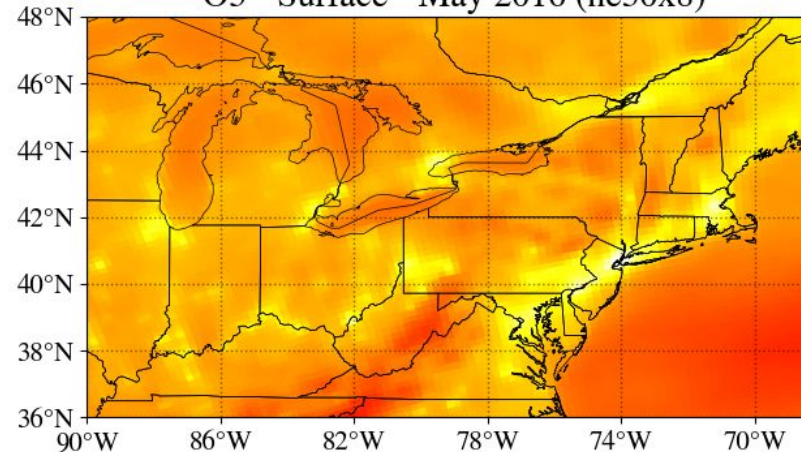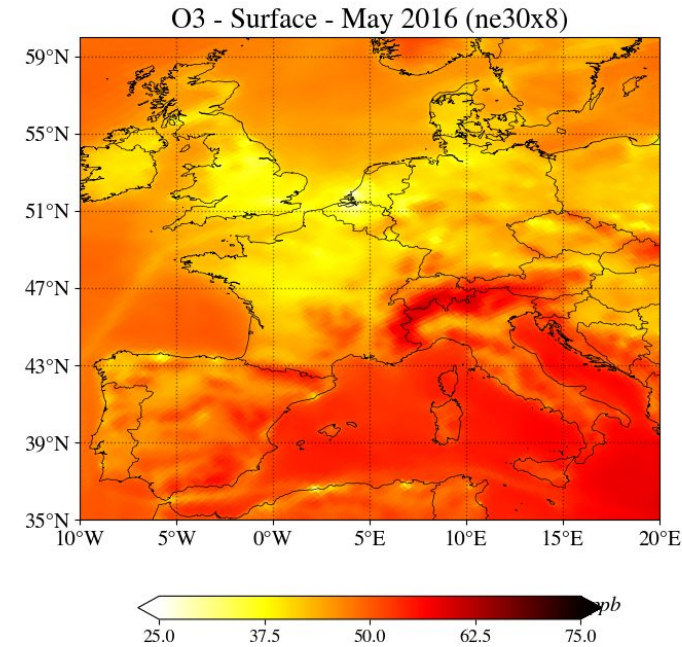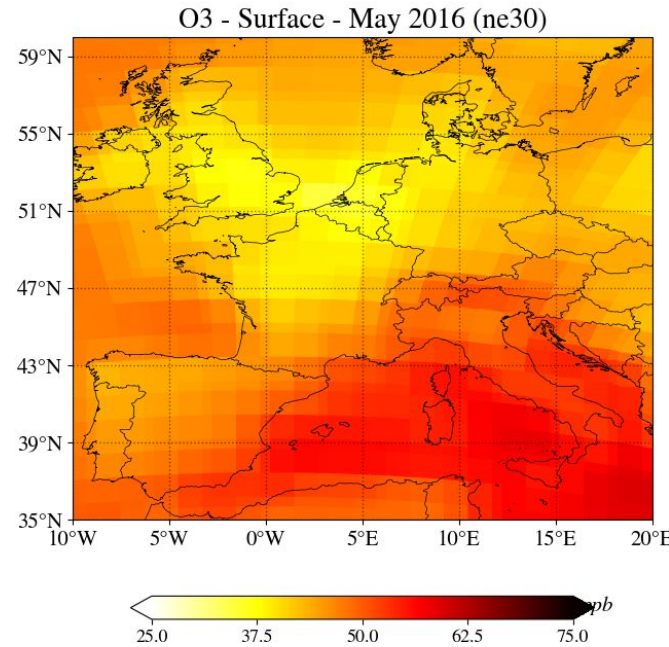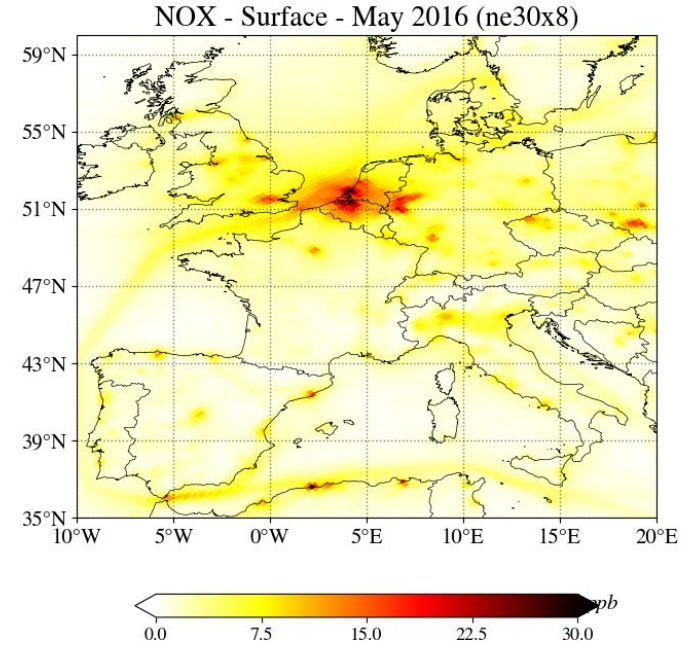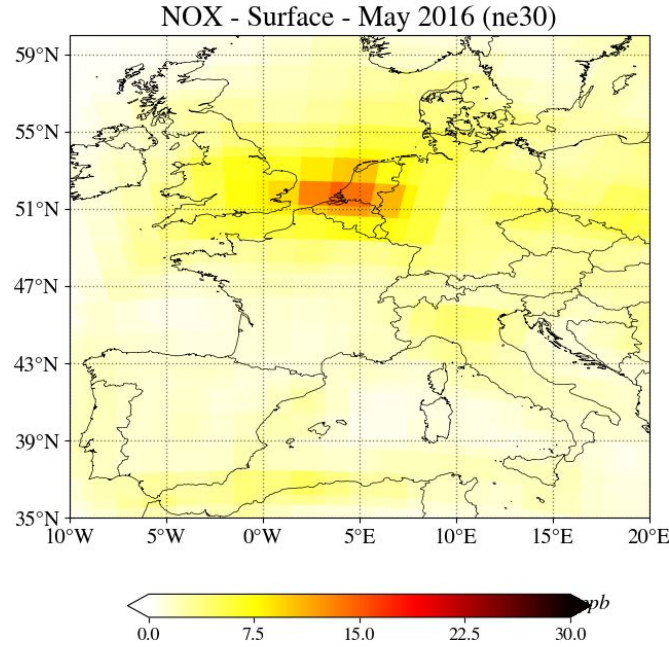
O3 - Surface - May 2016 (ne30)

O3 - Surface - May 2016 (ne30x8)

ASIA-AQ
Feb-Mar 2024

- Aircraft measurements on same track multiple days
- Pandora column NO_2, CH_2O
- Aeronet, etc.
- AQ monitors

Goal: understand AQ influence from local and transported pollution

GEMS NO_2 Mar 1 3Z

https://worldview.acom.ucar.edu/

Seoul

Taiwan

Manila

Bangkok
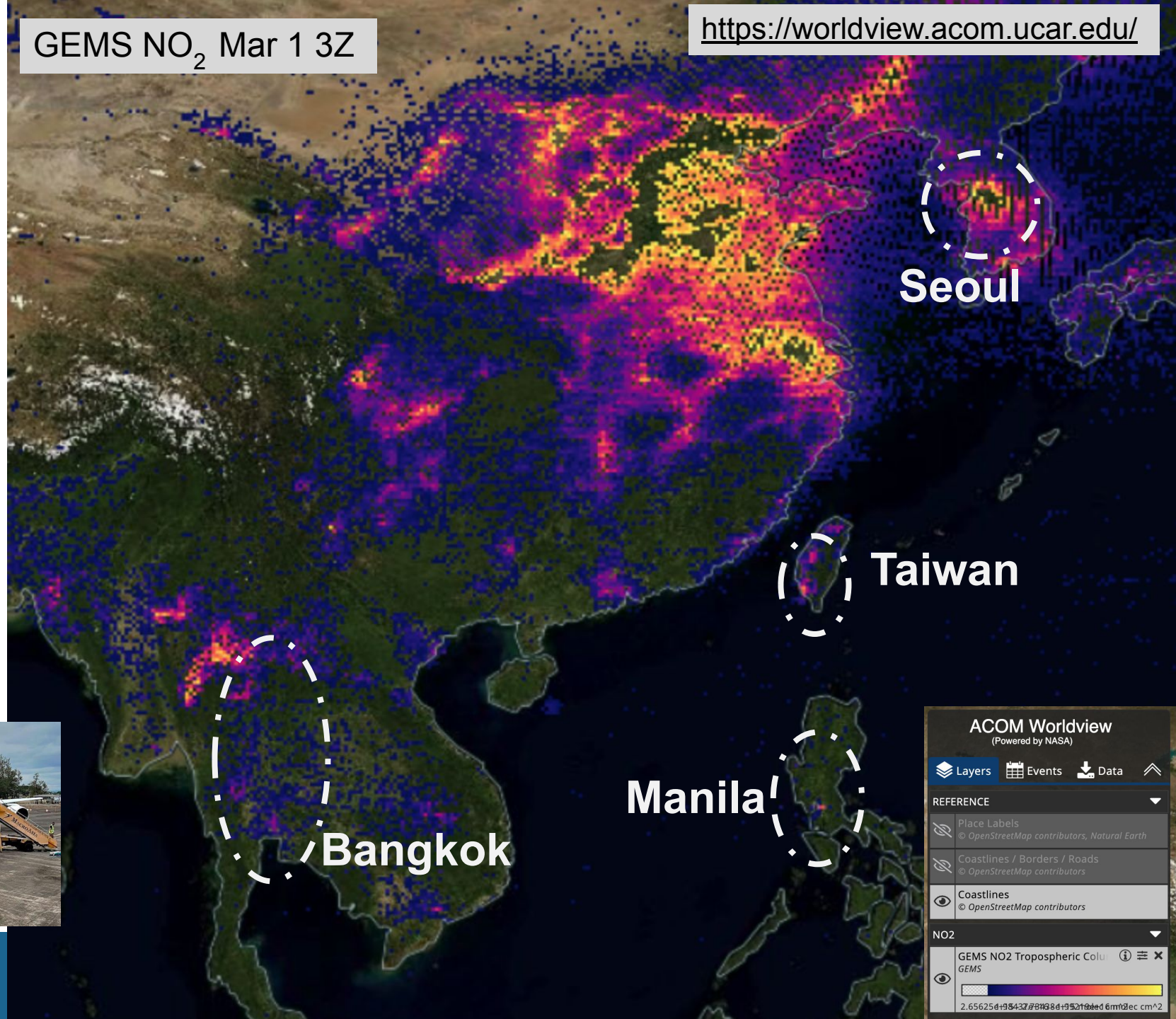
ACOM Worldview
(Powered by NASA)

Layers | Events | Data

REFERENCE

Place Labels
© OpenStreetMap contributors, Natural Earth

Coastlines / Borders / Roads
© OpenStreetMap contributors

Coastlines
© OpenStreetMap contributors

NO2

GEMS NO2 Tropospheric Colu
GEMS

Platforms and instruments:
- NASA DC-8 (161 hours): 26 instruments measuring in situ parameters relevant to gas phase and aerosol composition
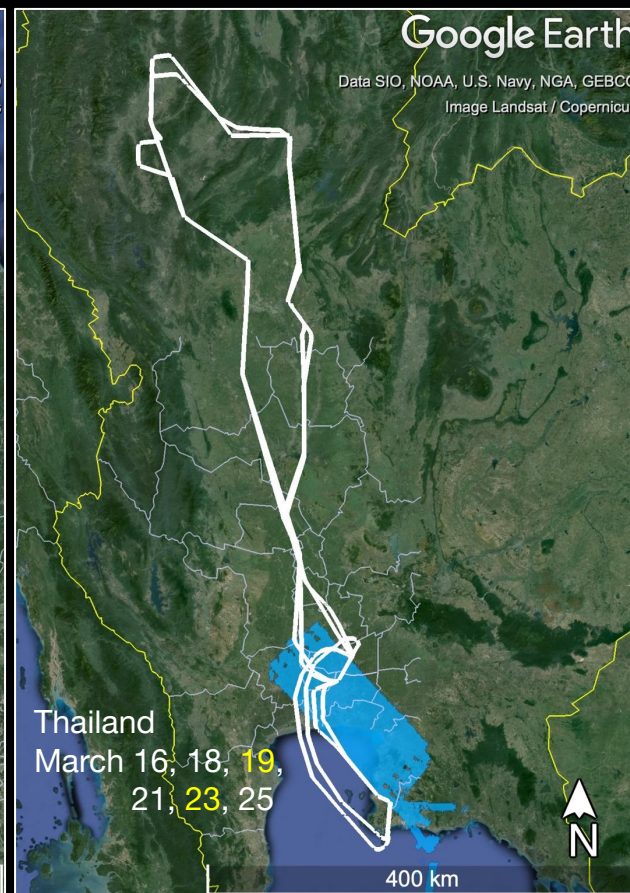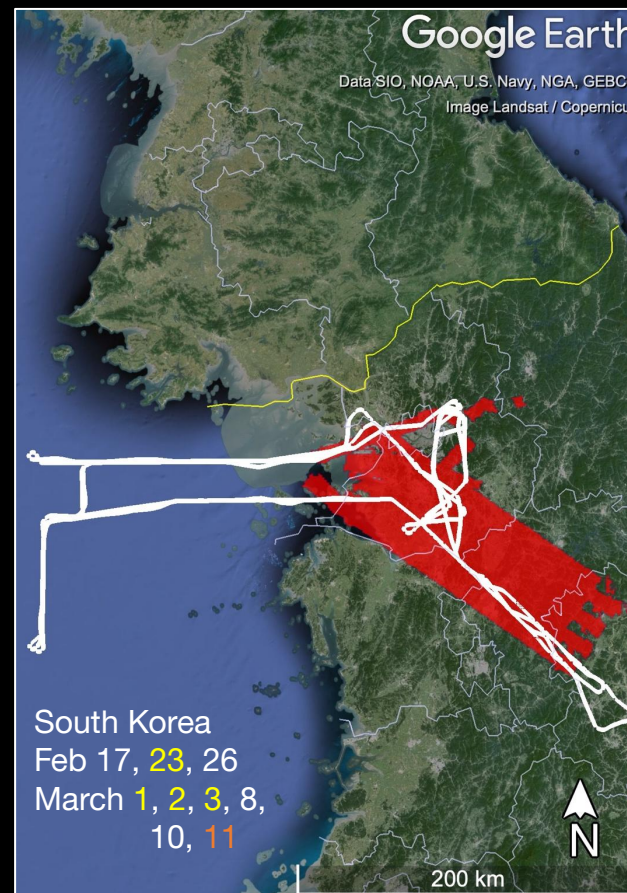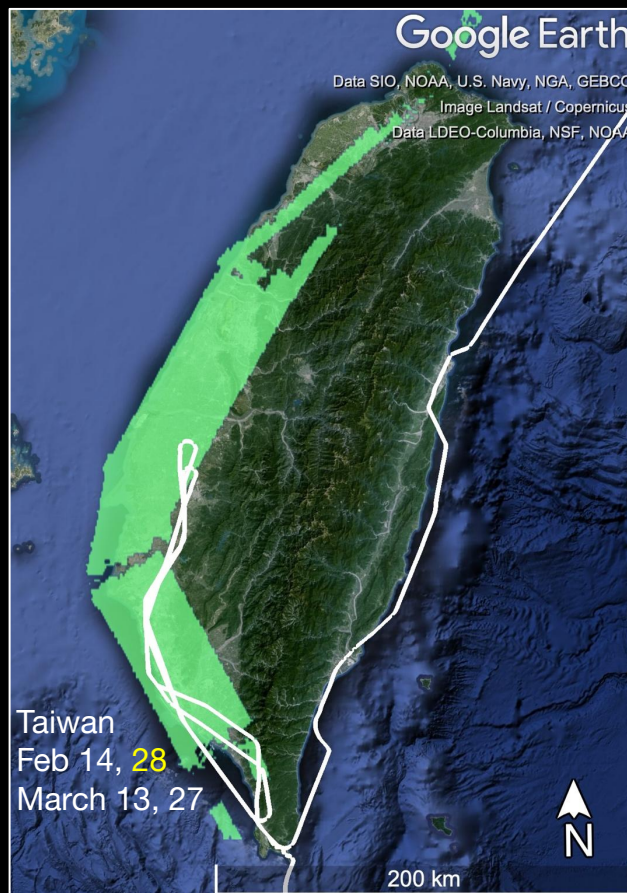- LaRC GIII (209 hours): GCAS + HSRL2 measuring column densities of NO_2 and HCHO and profiles of aerosol characteristics and ozone.

Primary collaborators include:
→ DENR, PhilSA, and Manila Observatory in the Philippines,
→ NIER and KMA in South Korea,
→ GISTDA and PCD in Thailand,
→ Ministry of Environment, NCU and Academia Sinica in Taiwan with numerous other agencies and research institutions
https://espo.nasa.gov/asia-aq/content/ASIA-AQ_Participants

Philippines
Feb 6, 7, 10,
11, 13

Taiwan
Feb 14, 28
March 13, 27

South Korea
Feb 17, 23, 26
March 1, 2, 3, 8,
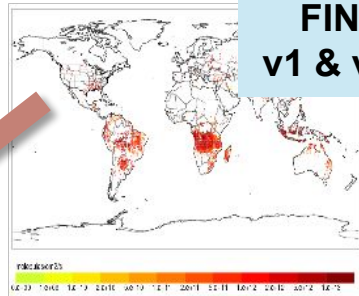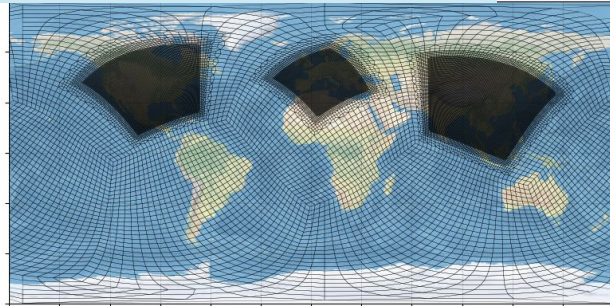10, 11

Thailand
March 16, 18, 19,
21, 23, 25

Maps of the geographical regions sampled in February-March 2024 during ASIA-AQ. Colored areas are those mapped by the GIII and the white lines represent one flight from the DC8.

Data will be released before Oct 2024
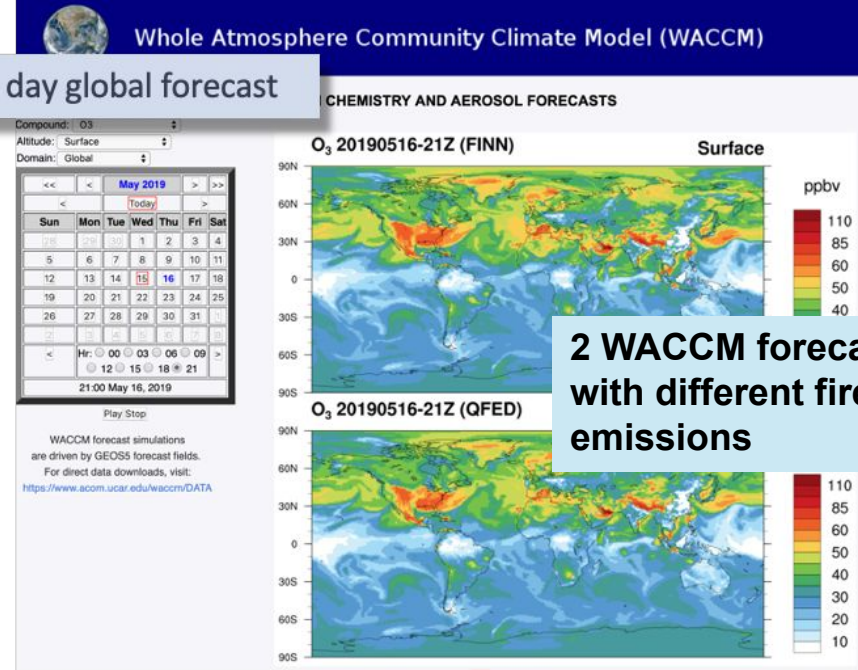
NCAR's Experimental Air Quality Prediction System

FINN v1 & v2.5

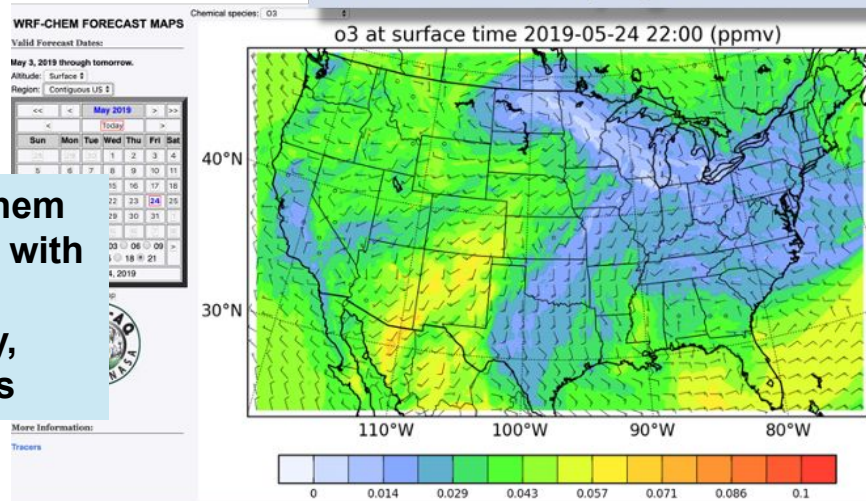**MUSICAv0(NA-Eu-As) CAM with CO tags**

Near-real-time FINN fire emissions

WACCM – 10 day global forecast

2 WACCM forecasts with different fire emissions

WRF-Chem – 2 day regional forecast

2 WRF-Chem forecasts with different chemistry, emissions

- Early identification of model errors and biases
- Field campaign planning and support
- Boundary conditions for real-time applications
- Information for policy makers - complement NOAA's operational forecast
- Forecasting for NASA TOLNET network

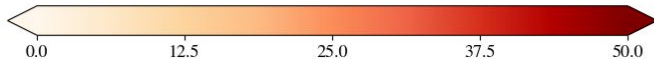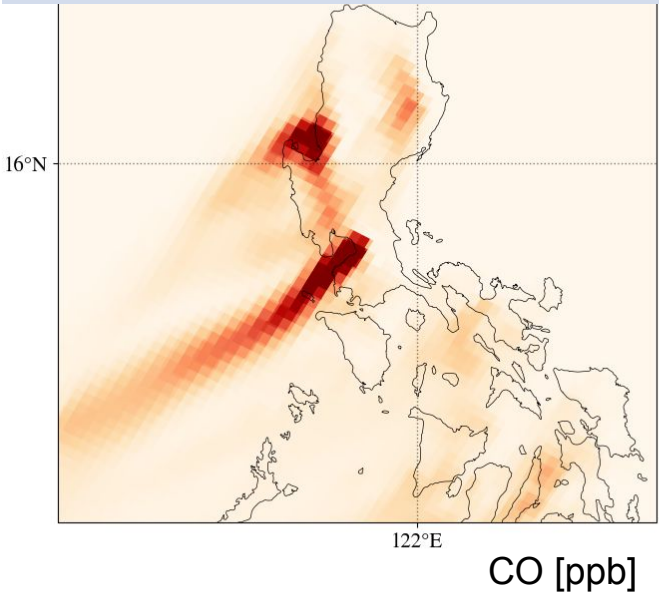https://www.acom.ucar.edu/firex-aq/forecast.shtml

MUSICAv0 forecasts for Philippines

CO_PHL at surface
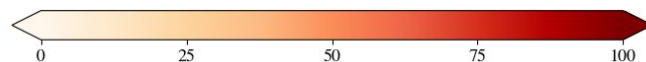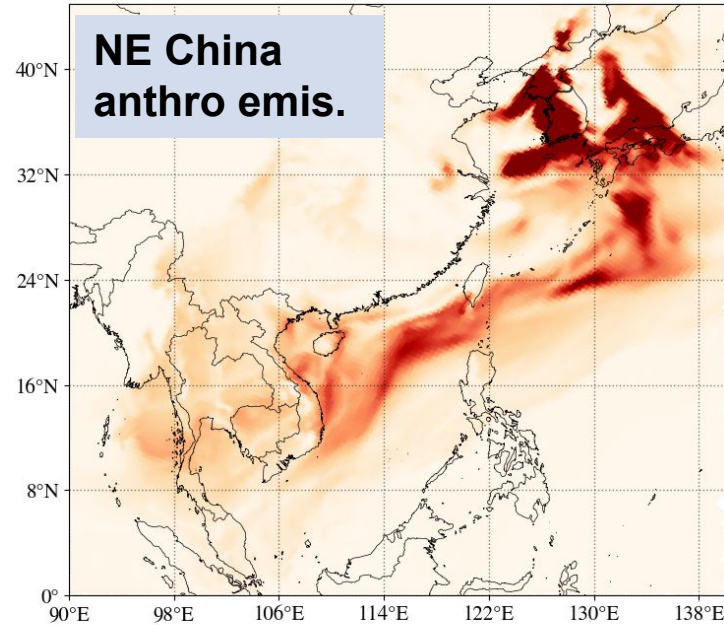Time: 2024-02-11 03:00:00

Tag of Philippines anthro emis.

CO [ppb]

Local urban and
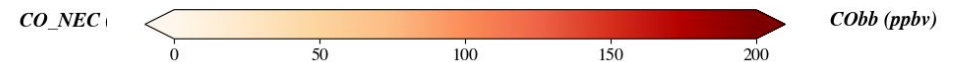industry emissions

CO_NEC at 1.5km
Time: 2024-02-11 03:00:00
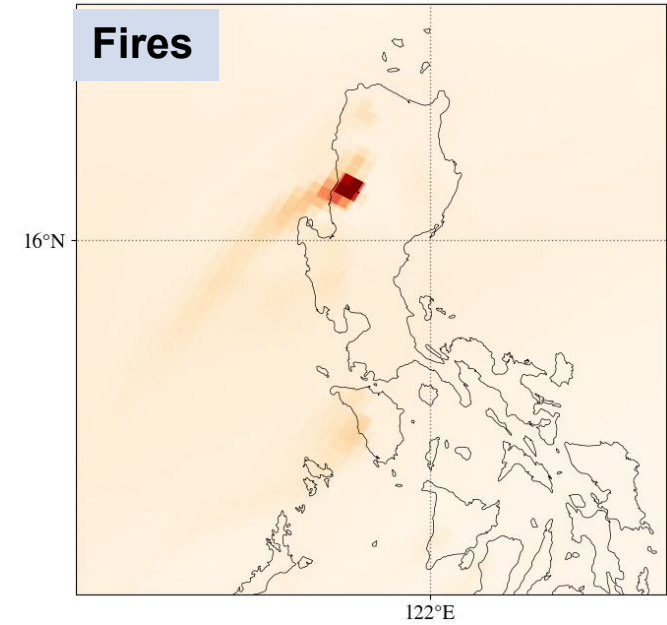
**NE China
anthro emis.**

CO_NEC

Long-range transport
from continent
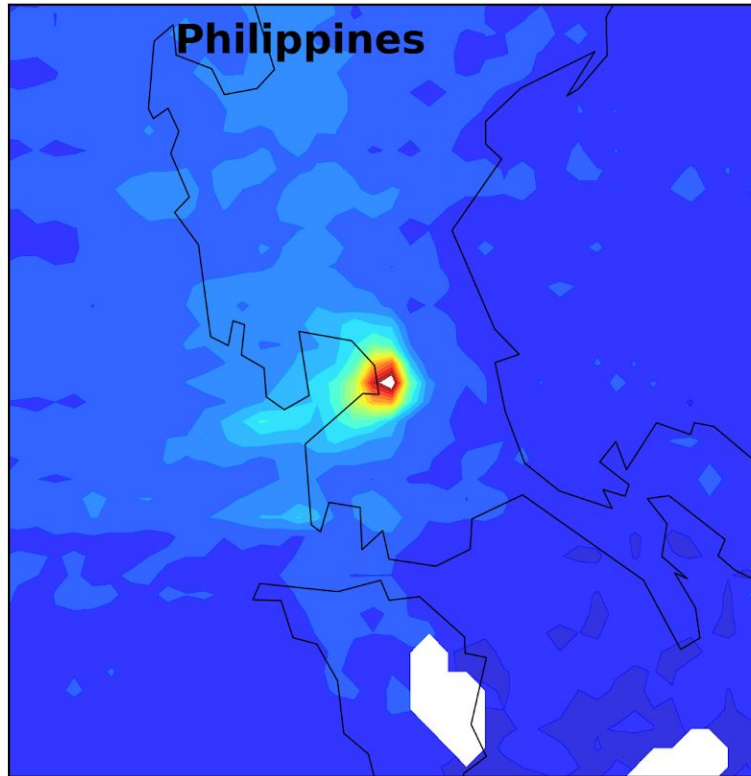

CObb at surface
Time: 2024-02-11 03:00:00

Fires

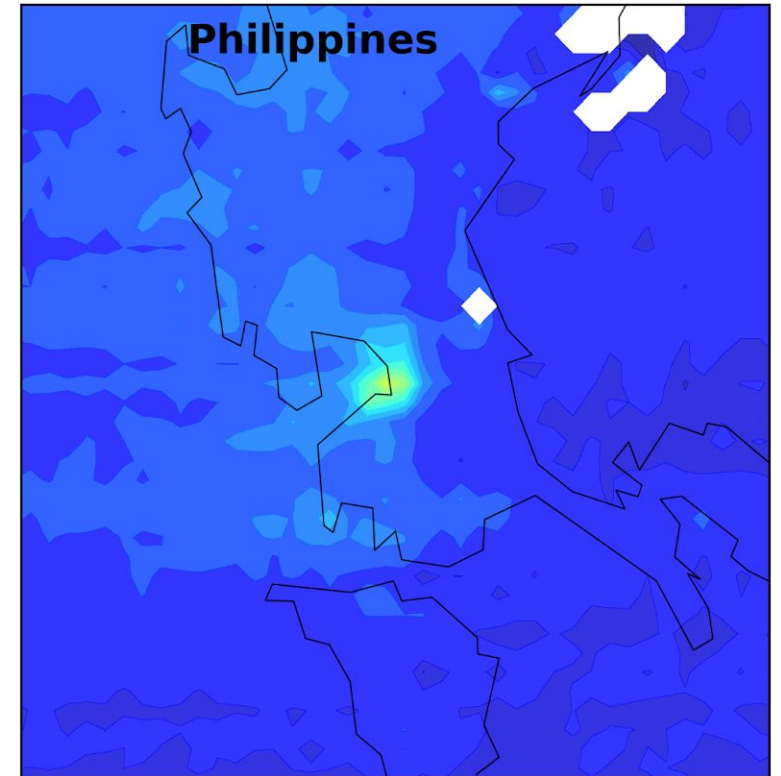CObb (ppbv)

Local and regional
fires

Manila: GEMS Daily NO$_2$

20240206
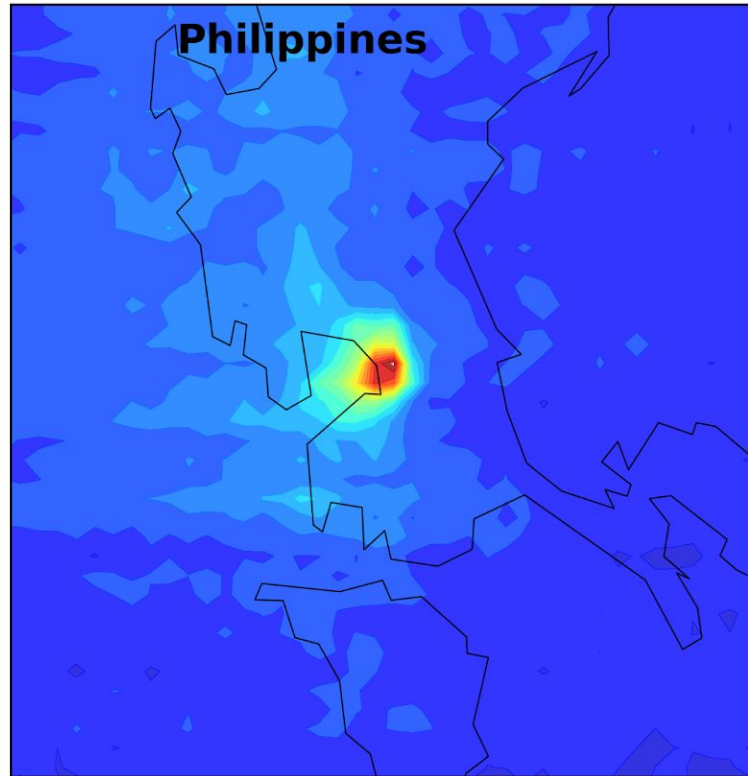
20240207

20240211

Plots from Katie Travis, NASA Langley

MUSICAv0 with full chemistry

CO

Feb 6 — CO - Surface - 06 Feb 20...

Feb 7 — CO - Surface - 07 Feb ...

Feb 11 — CO - Surface - 11 Fe...

O₃

O3 - Surface - 06 Feb 2024 (ne30x8)

O3 - Surface - 07 Feb 2024 (ne30x8)

O3 - Surface - 11 Feb 2024 (ne30x8)

Philippines
Feb 6, 7, 10, 11, 13

Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Data LDEO-Columbia, NSF, NOAA
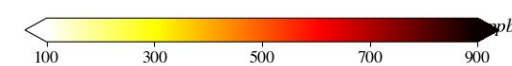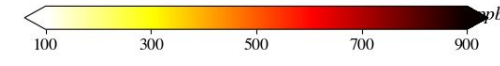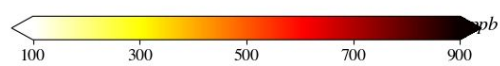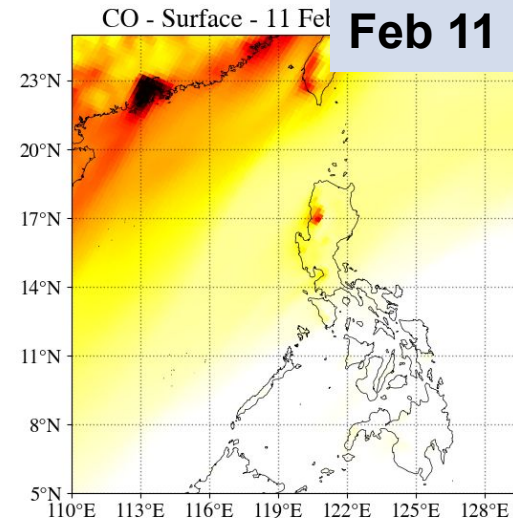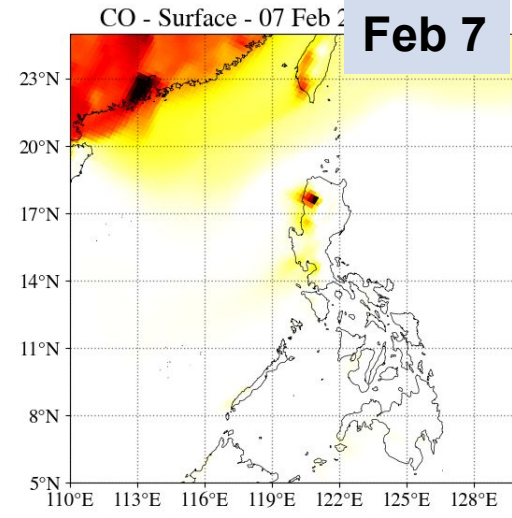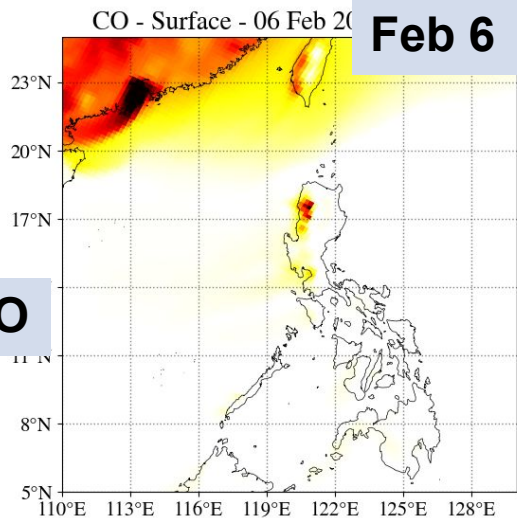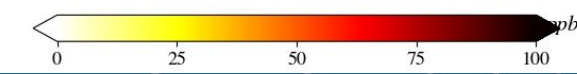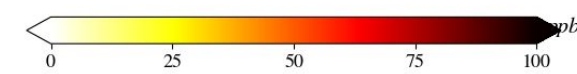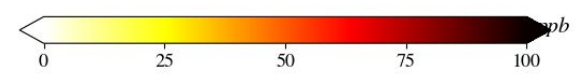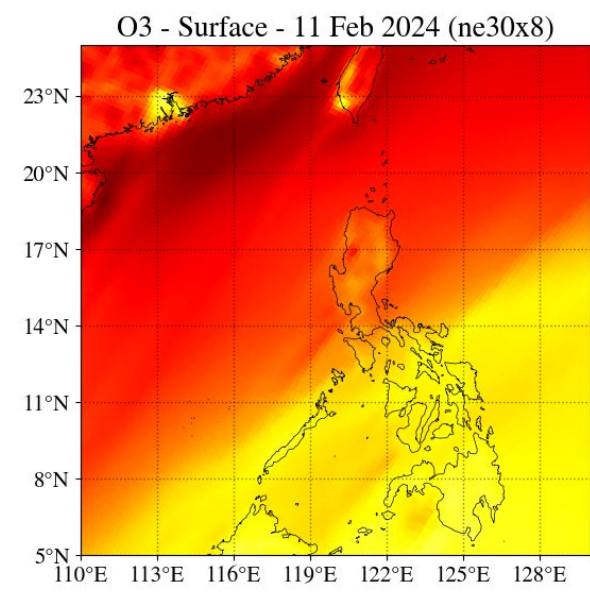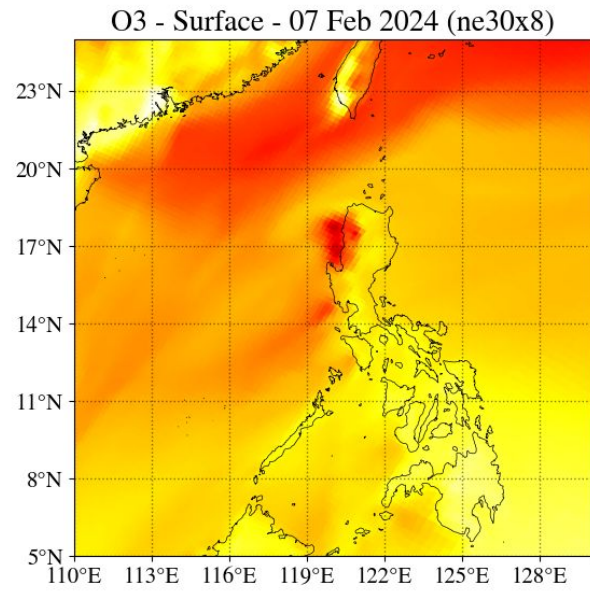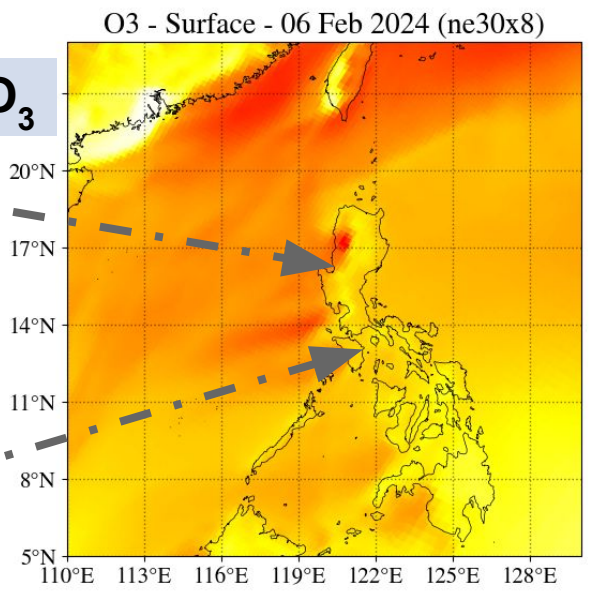
Korea

CO from China & N.Korea
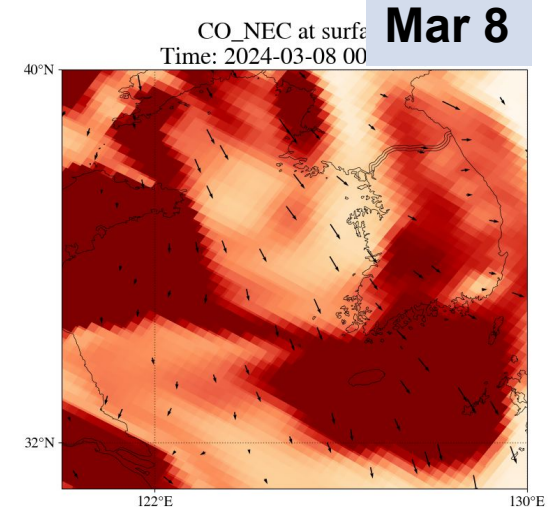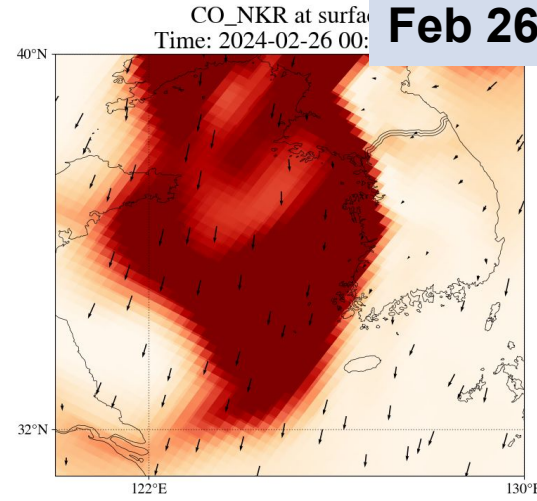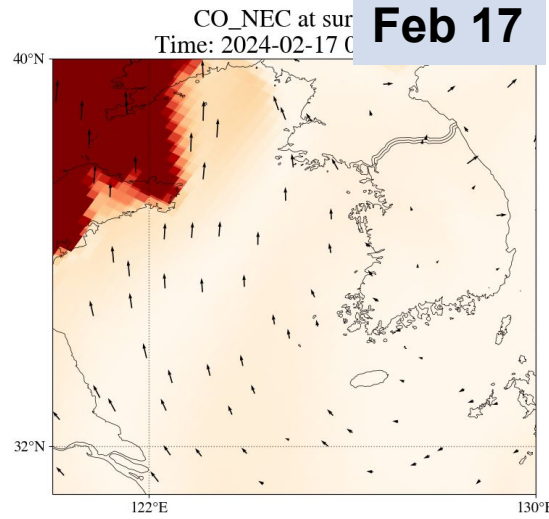
PM2.5
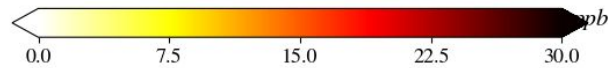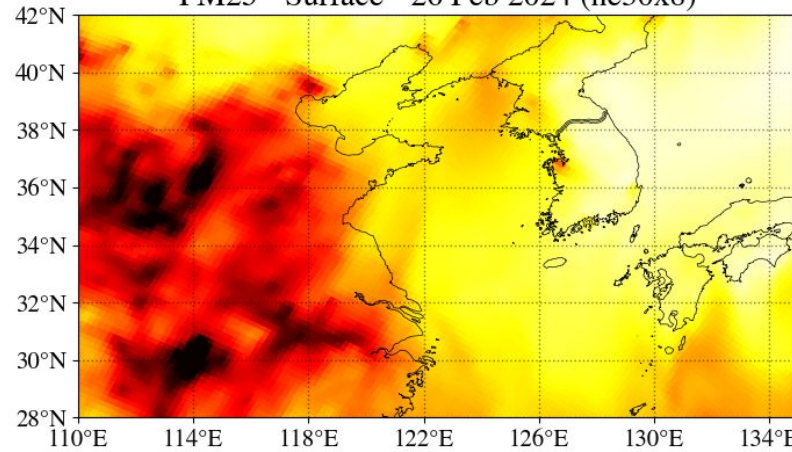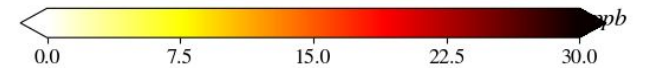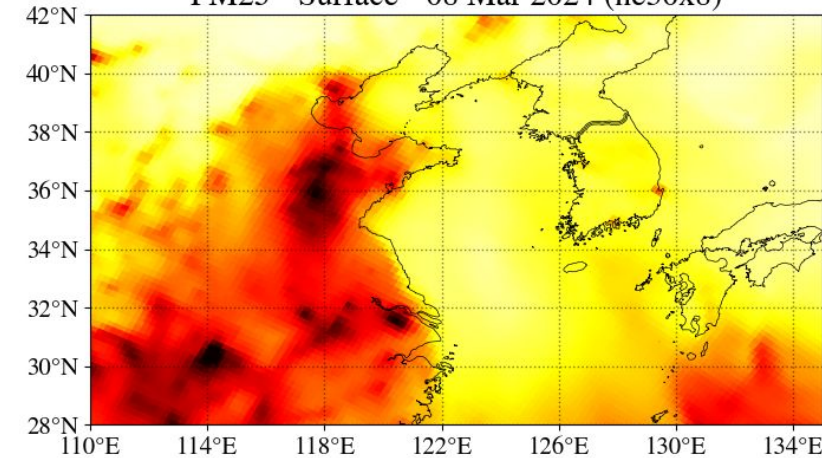
Thailand

CO_SEA at surface
Time: 2024-03-18 06:00:00

CO_SEC at surface
Time: 2024-03-18 06:00:00

CO_SEA at surface
Time: 2024-03-21 06:00:00
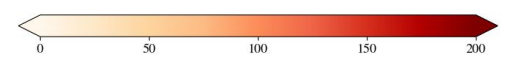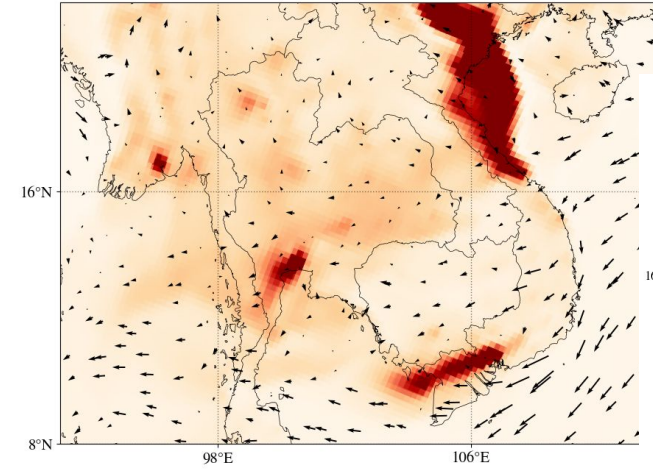
CO_SEC at surface
Time: 2024-03-21 06:00:00

CObb at surface
Time: 2024-03-18 06:00:00
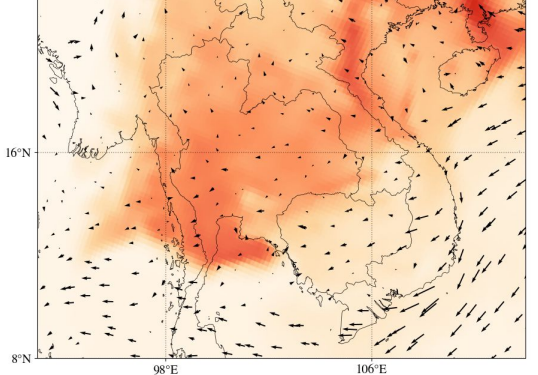
CObb at surface
Time: 2024-03-21 06:00:00

Task Force on Hemispheric Transport of Air Pollution (HTAP)
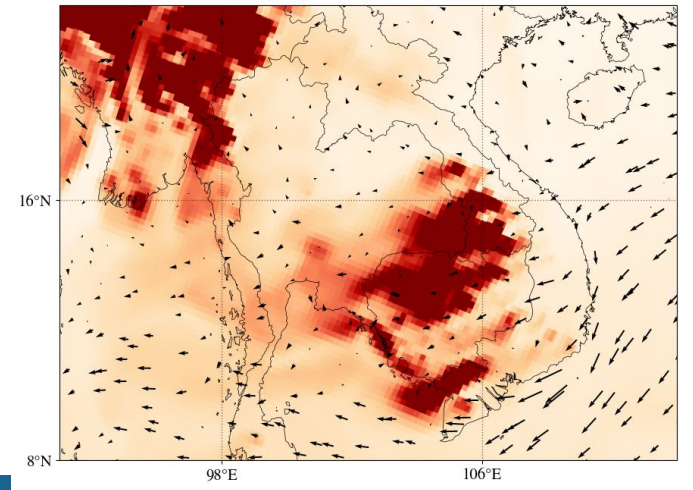
UNECE
Convention on Long-range
Transboundary Air Pollution

HTAP organized under UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP)
- Mandate to **quantify the long-range (hemispheric to global) influence of remote sources of air pollution** (including methane) in the UNECE region
- Current legislation is not sufficient to meet the long-term clean air objectives of CLRTAP

New round of multi-model experiments (HTAP3-OPNS: Ozone, PM, Nitrogen and Sulphur Deposition) to address:
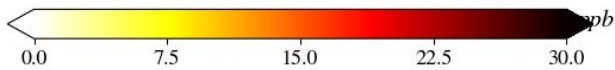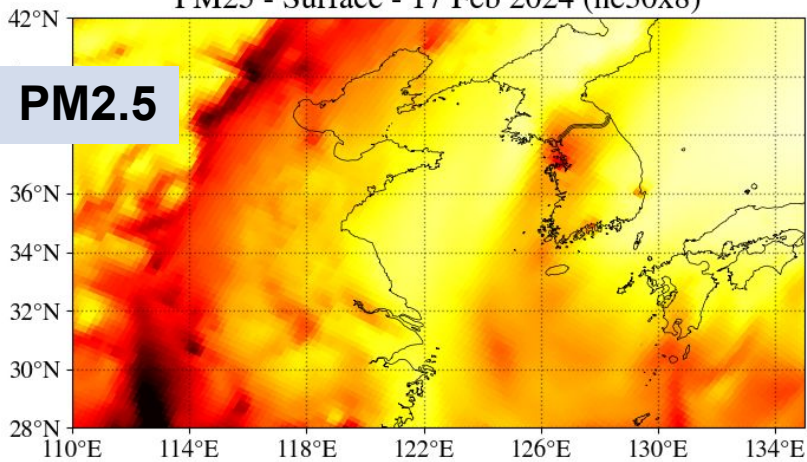
- Relative contributions of intra-regional and extra-**regional sources** to air pollution

- Contributions under **future** emission scenarios and under future climate change

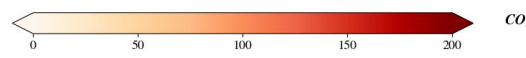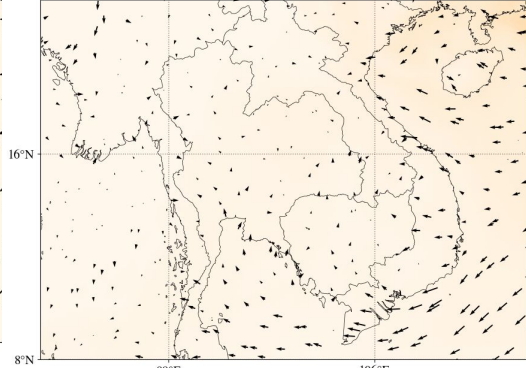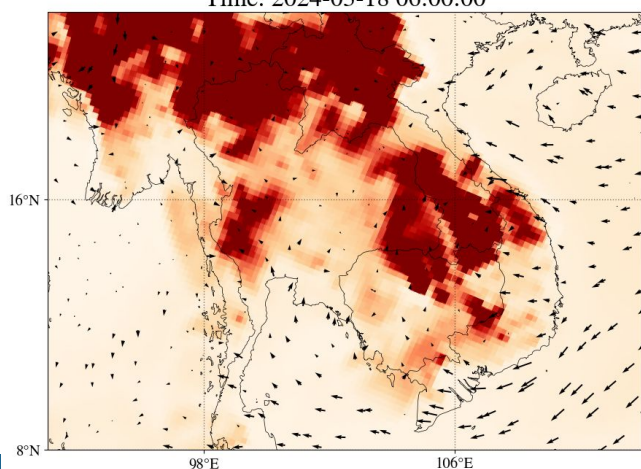- Impacts of ground-level **ozone**, especially damage to vegetation; effects of **methane** on ground-level ozone; effects of **wildfires** on long-range air pollution; total atmospheric **deposition**

- Free-running future simulations with chemistry-climate models

Spring 2025: Completed simulations – Future scenarios, source/receptor simulations, historical simulations

**Please contact Louisa Emmons (emmons@ucar.edu)
if you want to contribute to CAM-chem/MUSICA simulations**

NSF | NCAR
Operated by UCAR

LRTAP
Long-range Transboundary Air Pollution
**Task Force on Hemispheric
Transport of Air Pollution**

A modular framework to compare model results and observations of atmospheric chemistry

MELODIES: Model EvaLuation using Observations, DIagnostics and Experiments Software
MONET: Model and ObservatioN Evaluation Toolkit

MELODIES MONET

EarthCube

https://github.com/NOAA-CSL/MELODIES-MONET
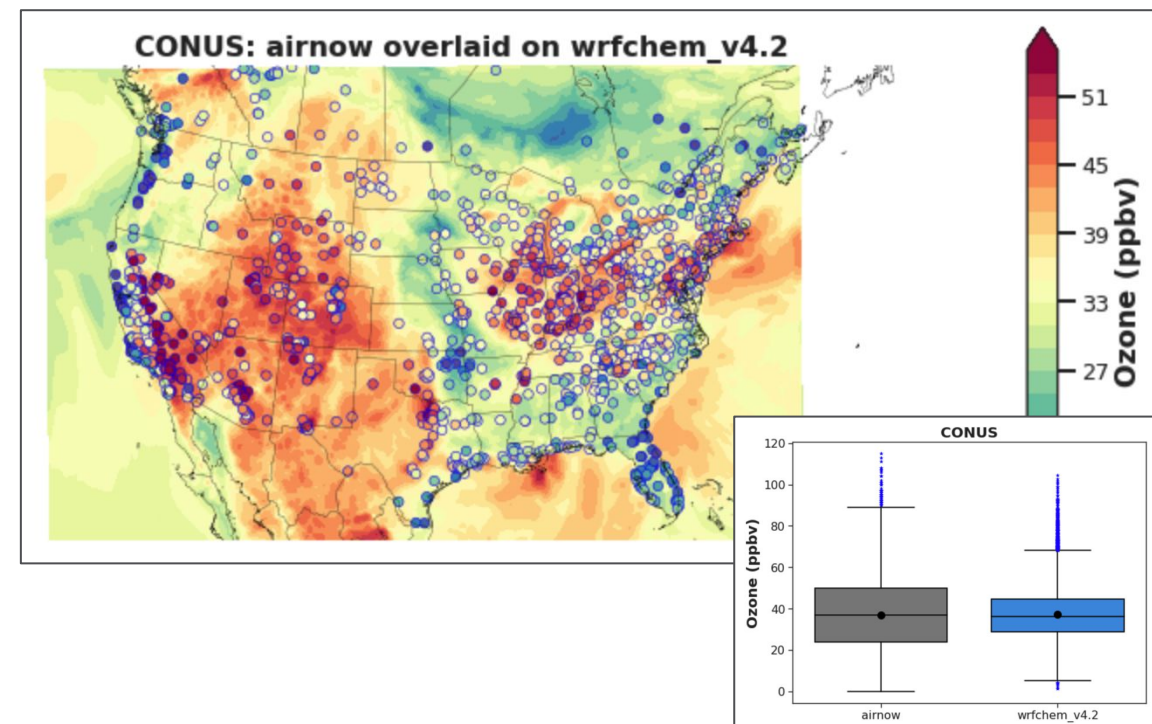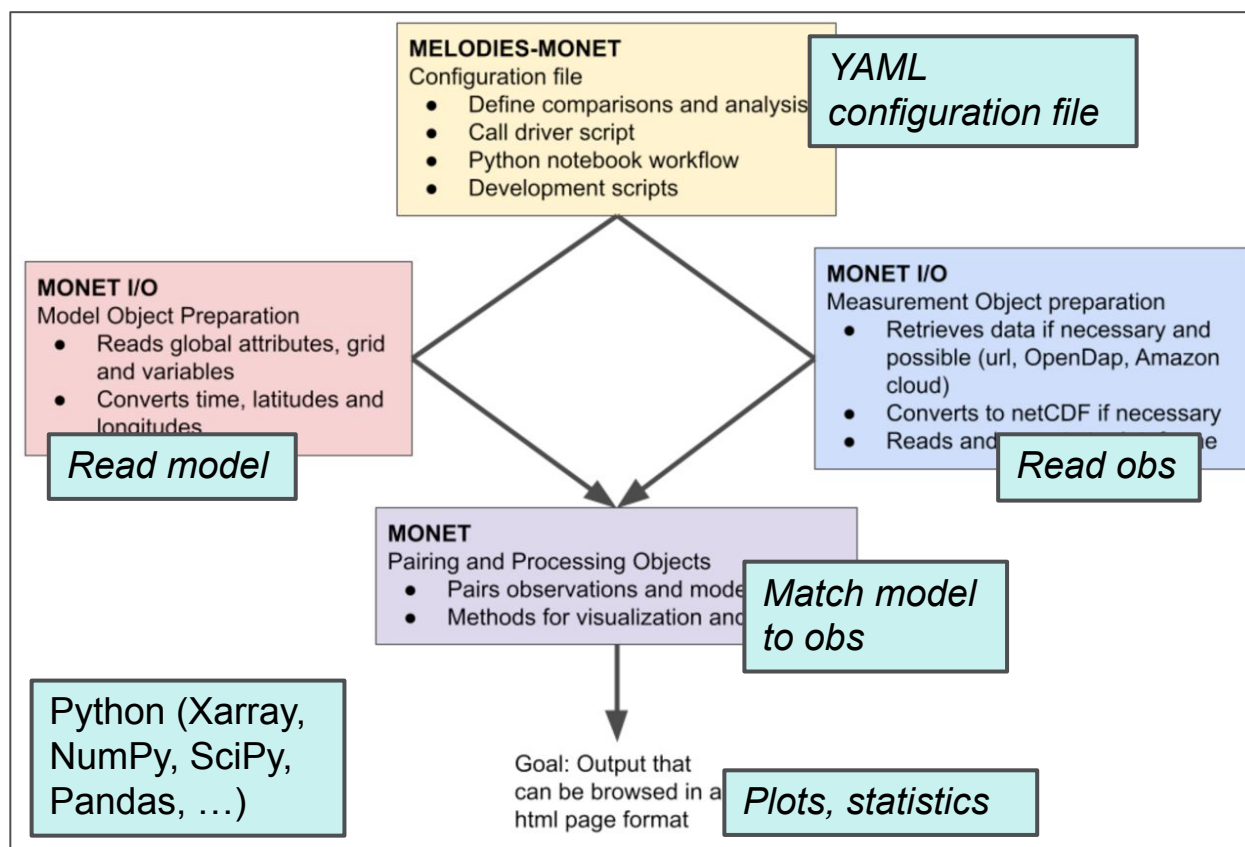

MELODIES-MONET
Configuration file
- Define comparisons and analysis
- Call driver script
- Python notebook workflow
- Development scripts

YAML configuration file

MONET I/O
Model Object Preparation
- Reads global attributes, grid and variables
- Converts time, latitudes and longitudes

Read model

MONET I/O
Measurement Object preparation
- Retrieves data if necessary and possible (url, OpenDap, Amazon cloud)
- Converts to netCDF if necessary
- Reads and...

Read obs

MONET
Pairing and Processing Objects
- Pairs observations and mode...
- Methods for visualization and...

Match model to obs

Python (Xarray, NumPy, SciPy, Pandas, …)

Goal: Output that can be browsed in a html page format

Plots, statistics

CONUS: airnow overlaid on wrfchem_v4.2

Tutorial: Oct 1-3 at NCAR

Thank You!

Questions?

emmons@ucar.edu