

MUSICAv0 for ASIA-AQ

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MUSICA: Mary Barth, Gabriele Pfister, Simone Tilmes, Rebecca Buchholz, Matt Dawson, ...

ASIA-AQ: Jun Zhang, Wenfu Tang, Ben Gaubert

Atmospheric Chemistry Observations and Modeling (ACOM) Lab, NSF NCAR

CESM Winter Working Groups Meeting – 5 Feb 2025



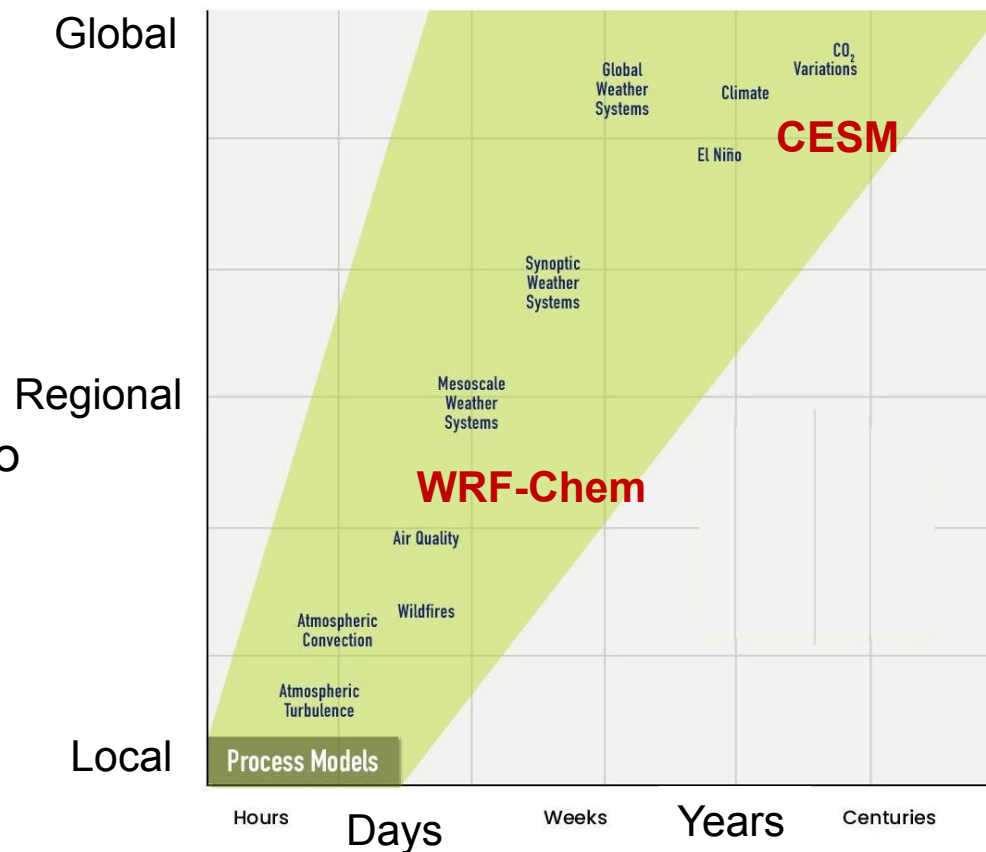
MUSICA: Multi-Scale Infrastructure for Chemistry & Aerosols

- A new **model-independent infrastructure**, which will enable chemistry and aerosols to be simulated at different resolutions in a coherent fashion
- Will facilitate use of a **variety** of chemistry schemes, physics parameterizations and atmospheric models
- **Coupled** to other earth system component models (land, ocean, sea ice, etc.)
- **Whole atmosphere** framework: troposphere to thermosphere

MUSICA

Multiscale Infrastructure for
Chemistry and Aerosols

Future
Chemistry and aerosols simulated at
different scales in a coherent fashion

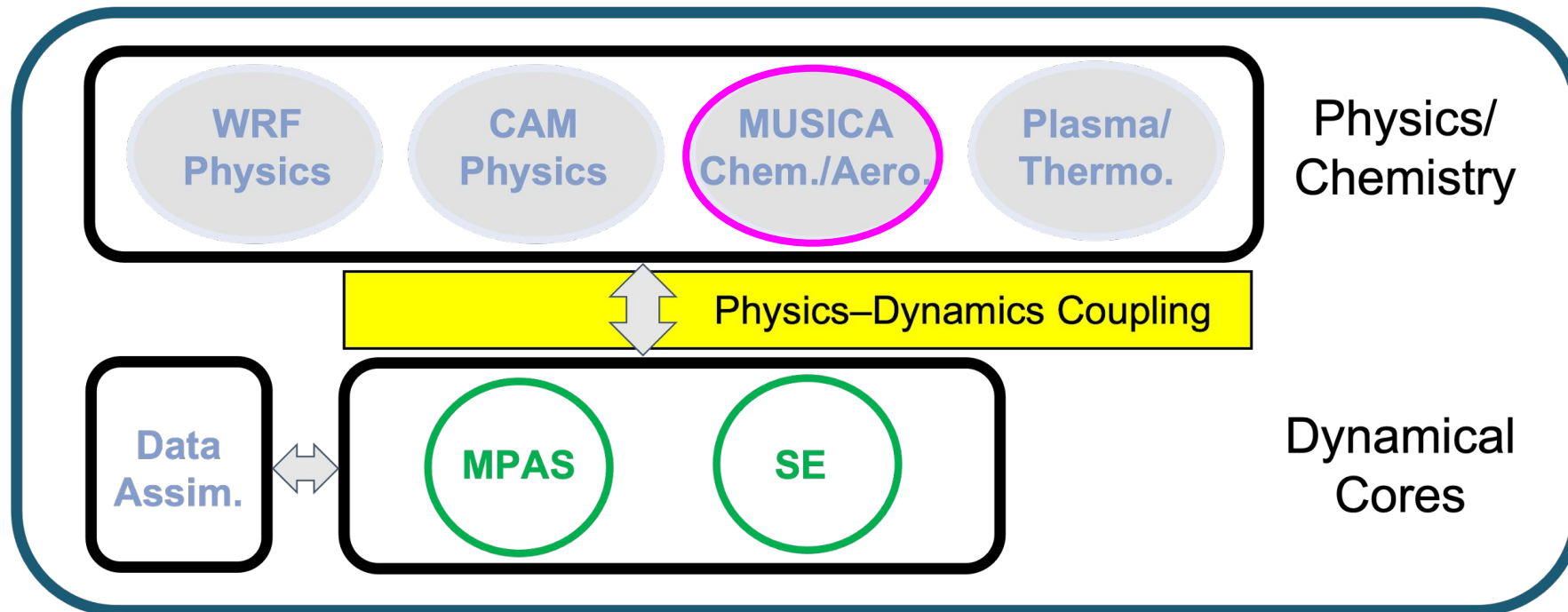


MUSICA website



CAM-SIMA structure

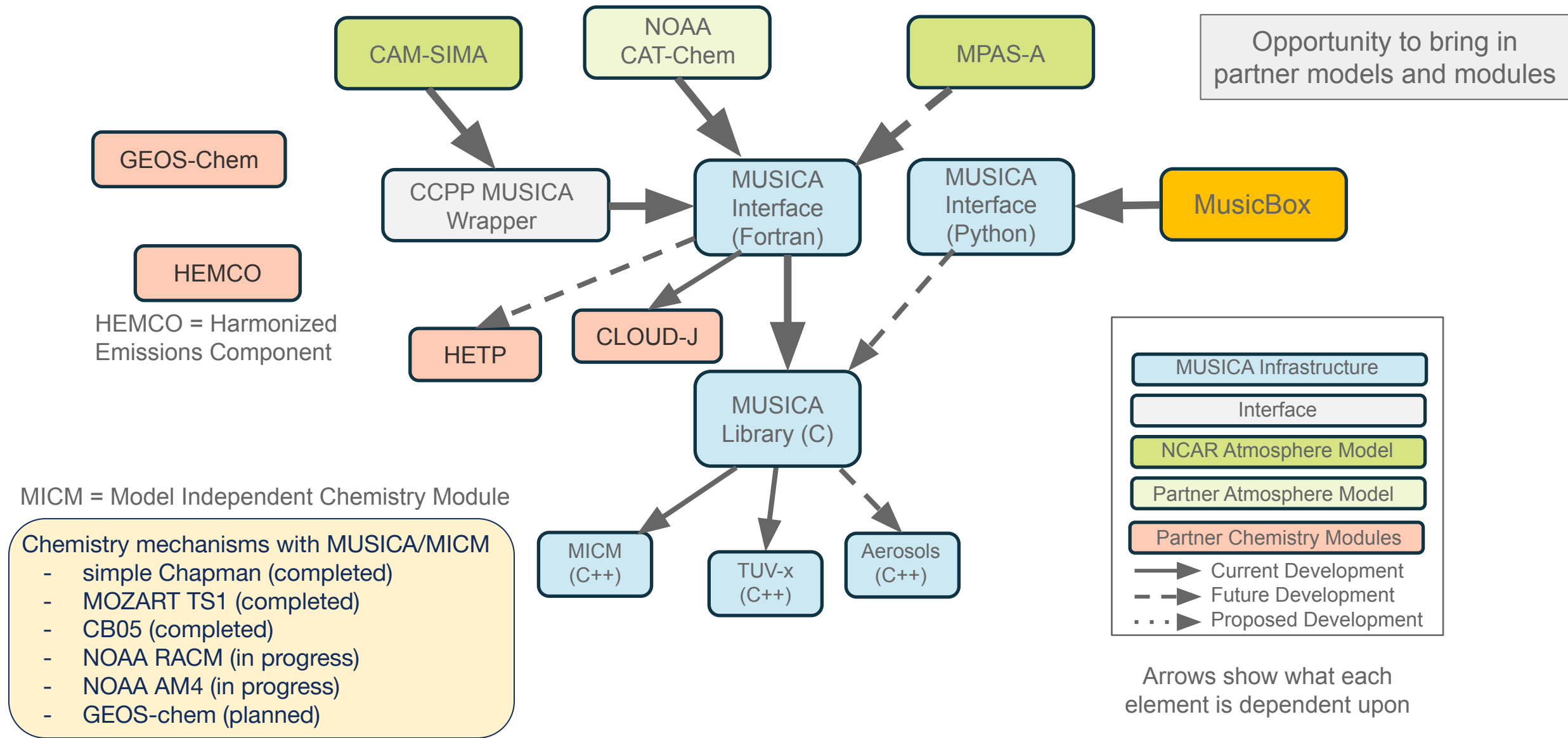
System for Integrated Modeling of the Atmosphere



CAM-SIMA schematic showing interoperability among dynamical cores, physics, chemistry, and geospace parameterizations.

SE = Spectral Element
MPAS = Model for Prediction Across Scales

MUSICA Software Development Plan

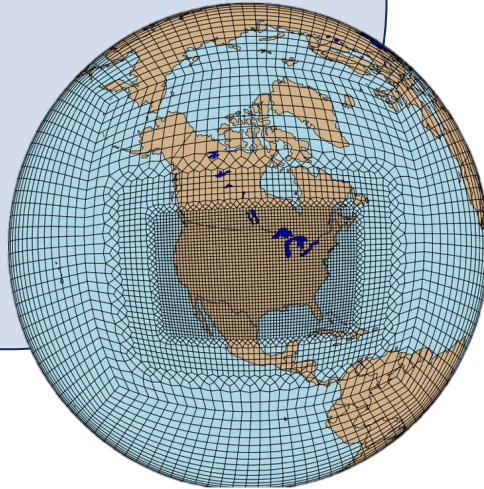


MUSICAv0 and MUSICAv1: Configurations of CESM CAM-chem

MUSICAv0

CESM/CAM

Hydrostatic Spectral Element DyCore

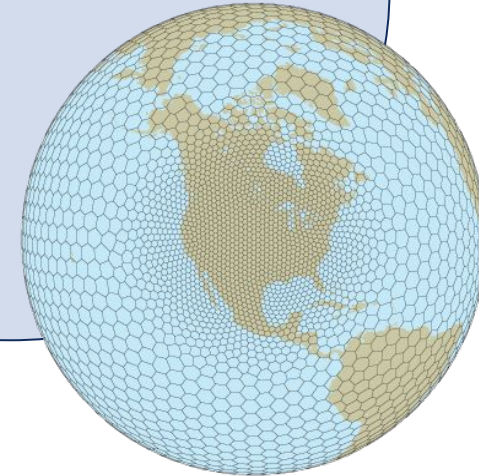


Available in CESM2.2 CAM-chem and WACCM

MUSICAv1

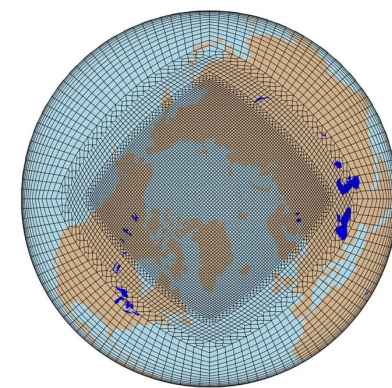
CESM/CAM

Non-Hydrostatic MPAS DyCore



CAM-MPAS-chem currently being tested

Using MUSICA



Documentation, Tutorials, etc: <https://wiki.ucar.edu/display/MUSICA/MUSICA+Home>

Grids available in CESM: CONUS, Arctic, Greenland Ice Sheet

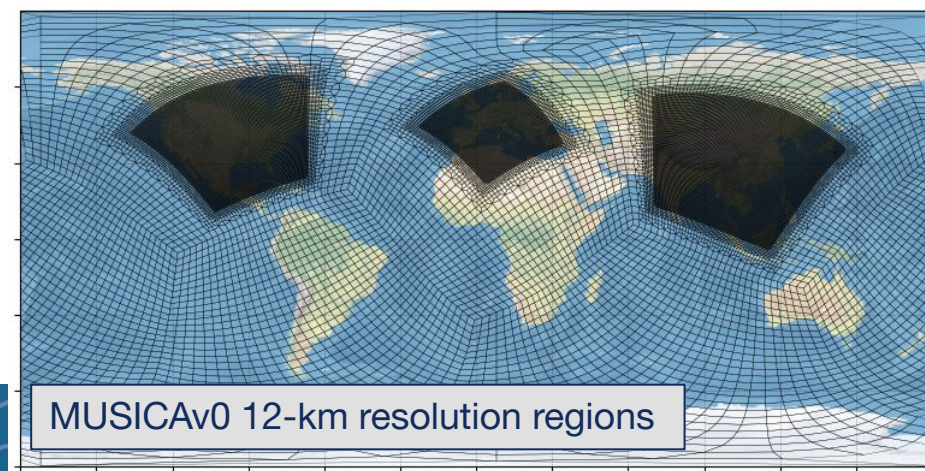
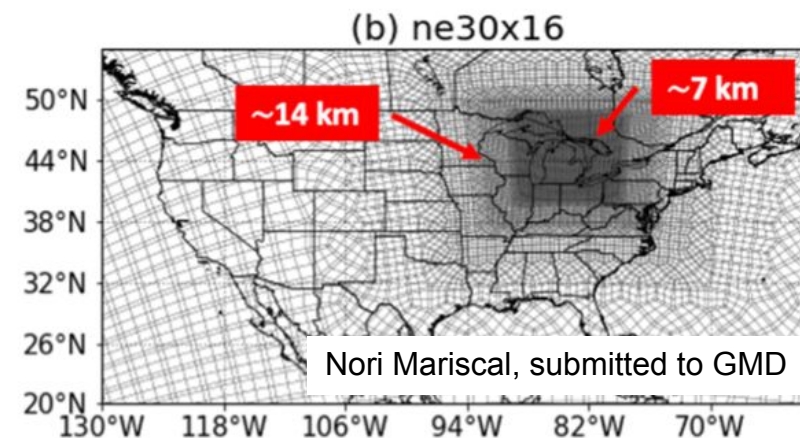
Can create custom grids for MUSICA_{v0} (CAM-SE) – instructions on wiki

MUSICA_{v1} (CAM-MPAS-chem) is being tested and evaluated

- Existing variable resolution grids can be rotated to region of interest

Community Users and Projects:

<https://wiki.ucar.edu/display/camchem/Users+and+Projects>

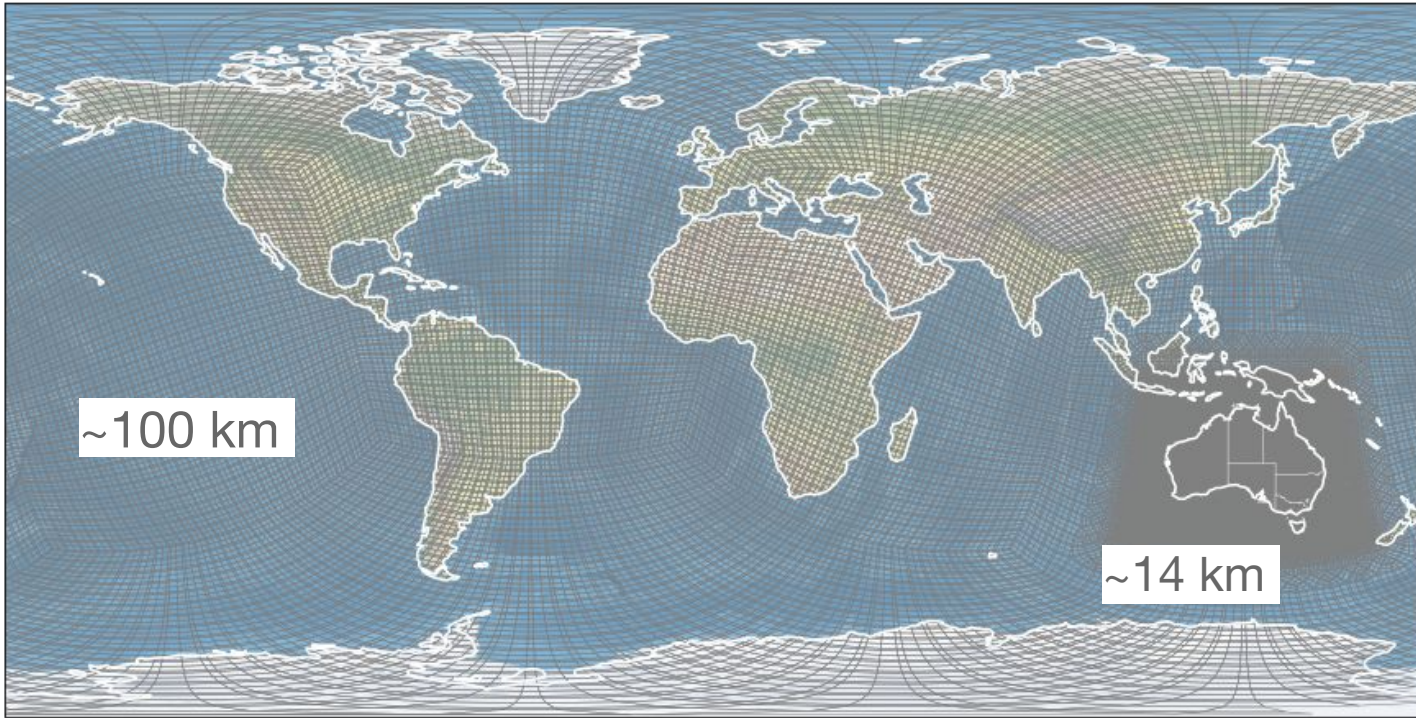


MUSICA Regional refinement: CO during the Australian 2019/2020 Wildfires

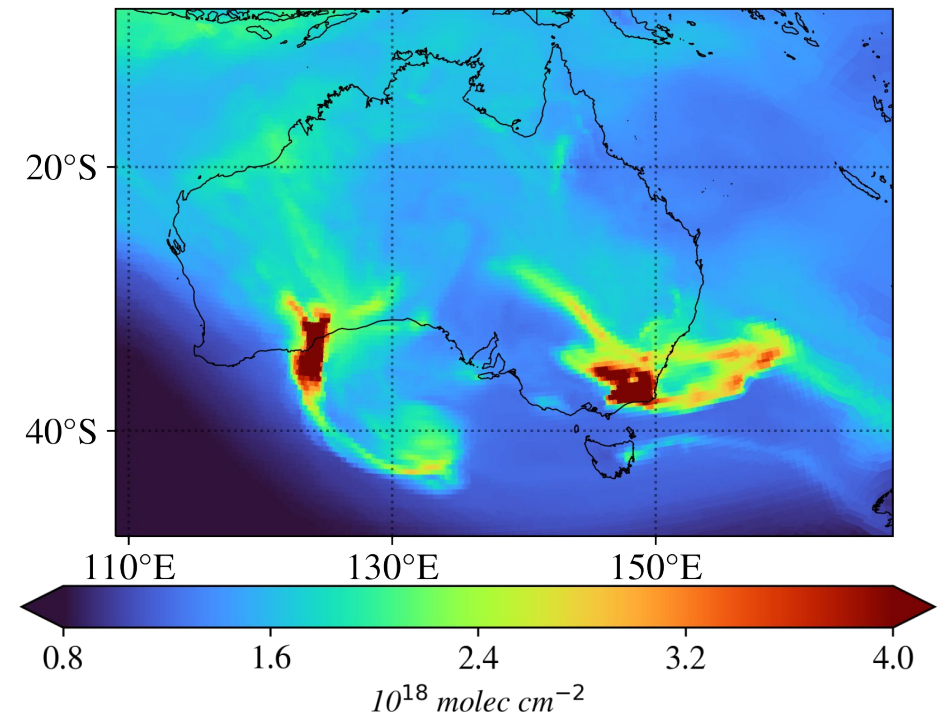
The event created a large atmospheric perturbation

- MOPITT shows over 40% increase in CO to 2002-2019 average
- MODIS shows over 120% increase in AOD to 2002-2019 average
- Developing MUSICAv0 RR for Australia to look at both local and transported impacts

Australia regional refined grid at ne30x8 (~14 km)



Regionally refined (CO)
CO total column, ne30x8 2020-01-02T06





ASIA-AQ

Feb-Mar 2024

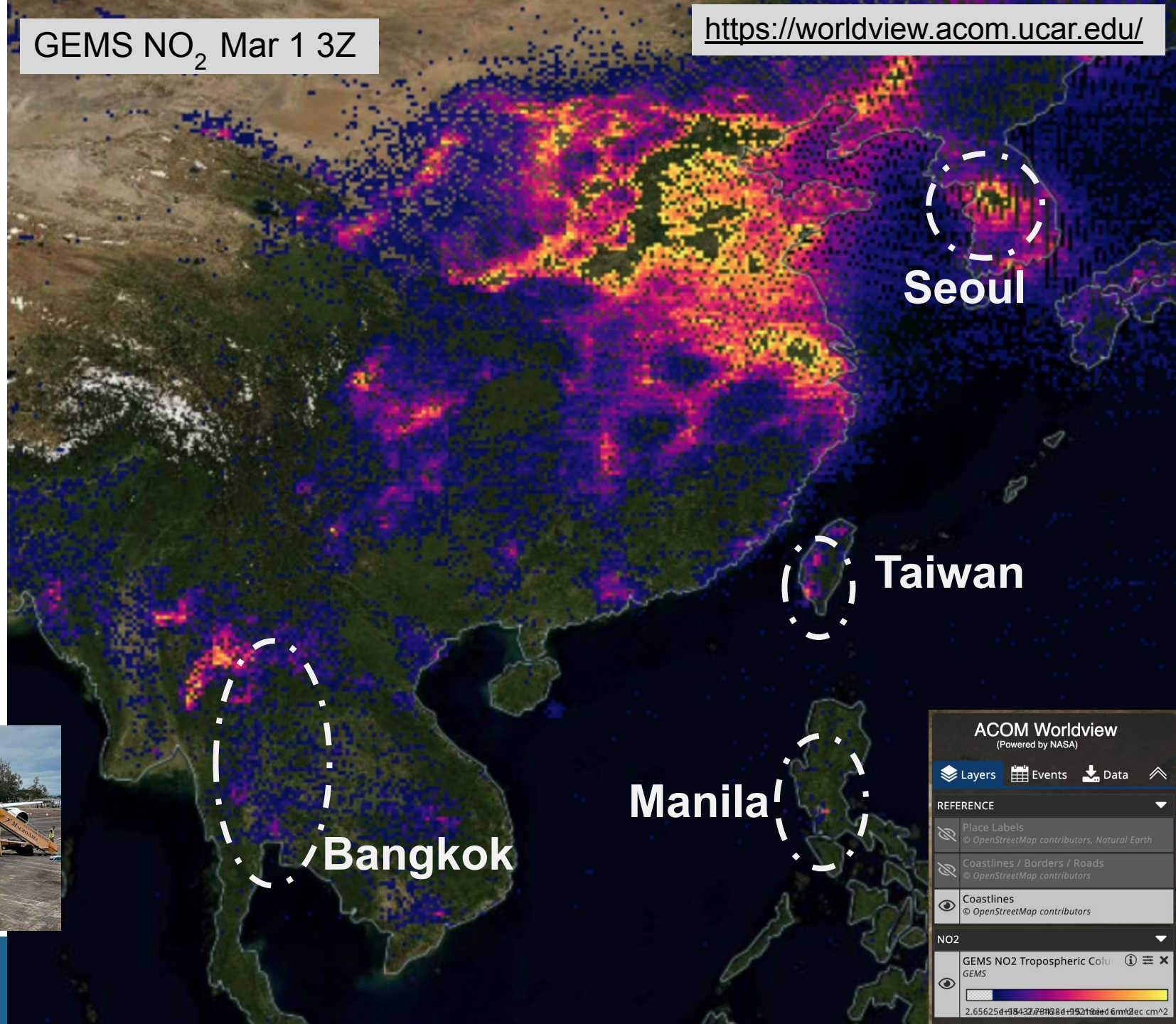
- Aircraft measurements on same track multiple days
- Pandora column NO_2 , CH_2O
- Aeronet, etc.
- AQ monitors

Goal: understand AQ influence from local and transported pollution



GEMS NO_2 Mar 1 3Z

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



ACOM Worldview
(Powered by NASA)

Layers Events Data

REFERENCE

- Place Labels
- Coastlines / Borders / Roads
- Coastlines

NO2

GEMS NO2 Tropospheric Colu

GEMS

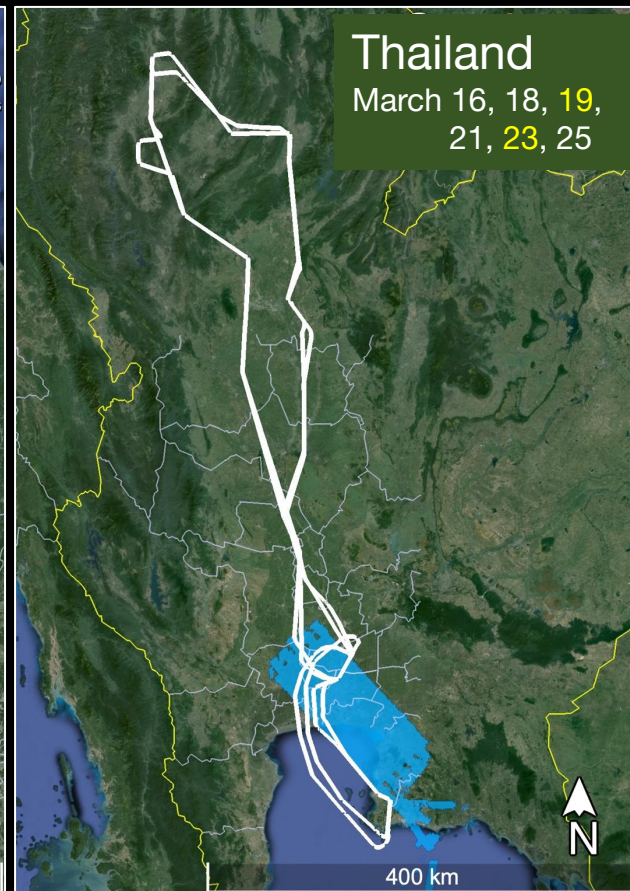
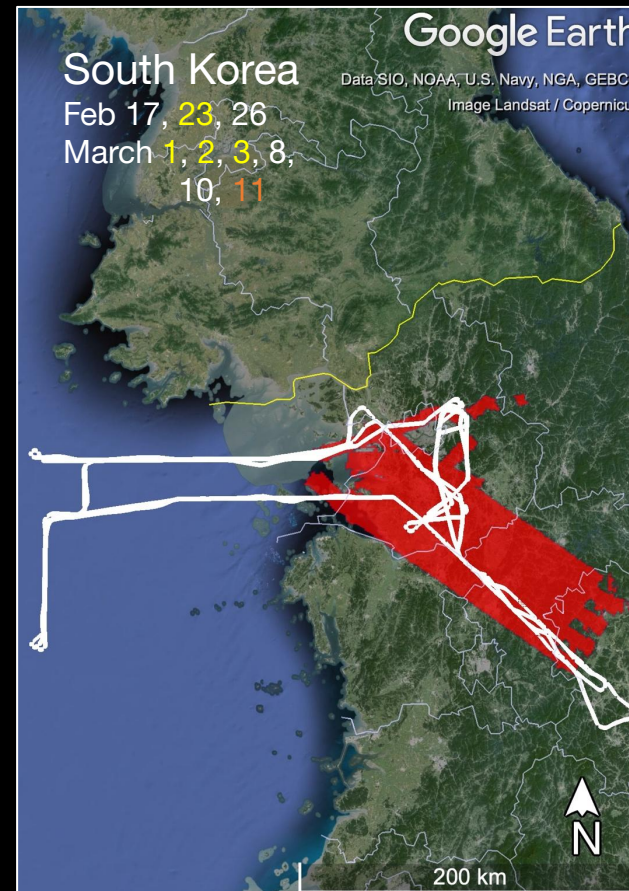
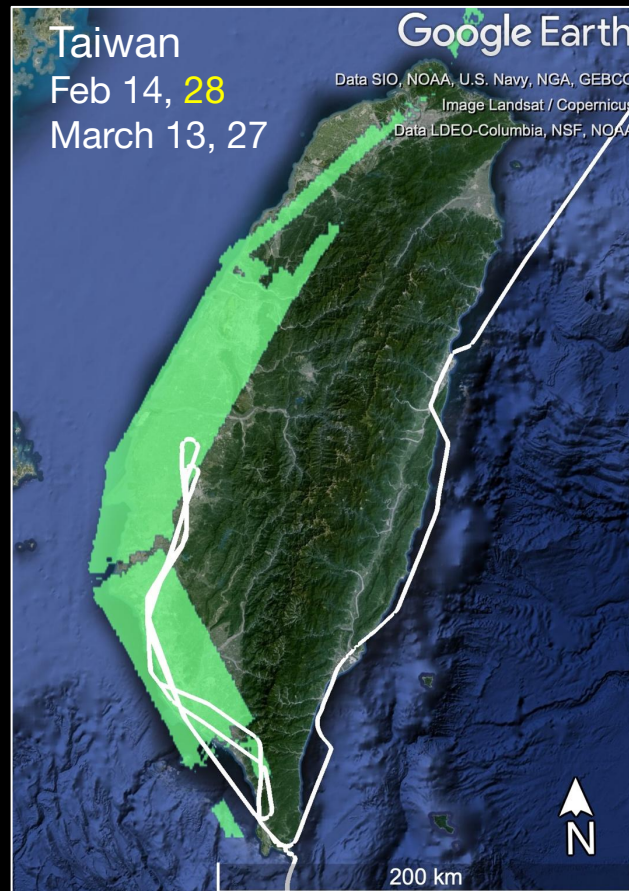


Platforms and instruments:

- 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 NO₂ 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



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

MUSICA simulations for ASIA-AQ

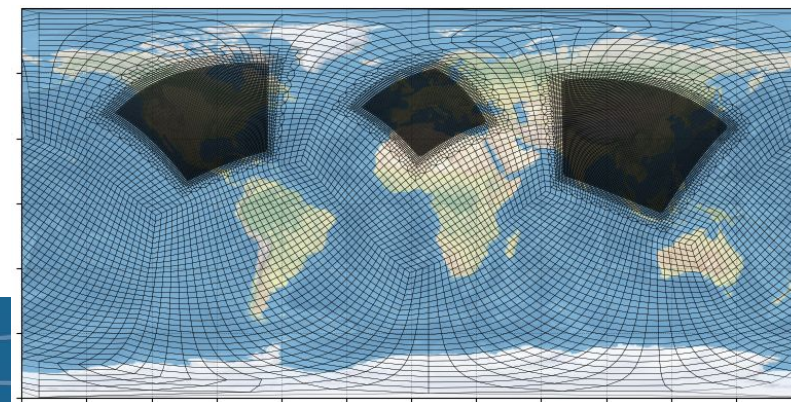
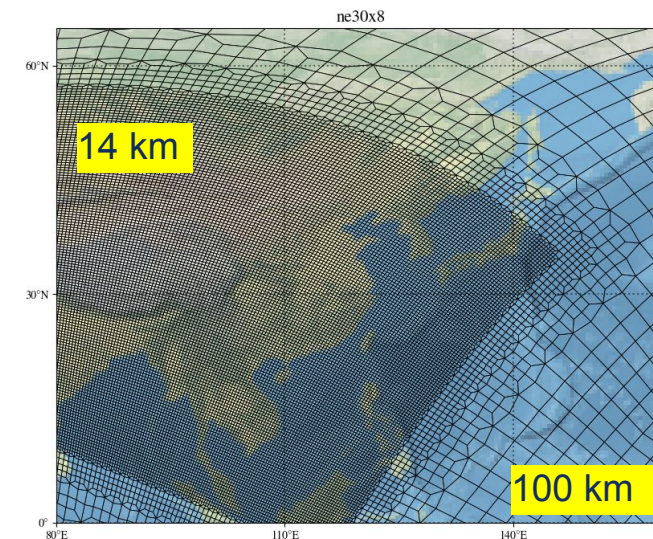
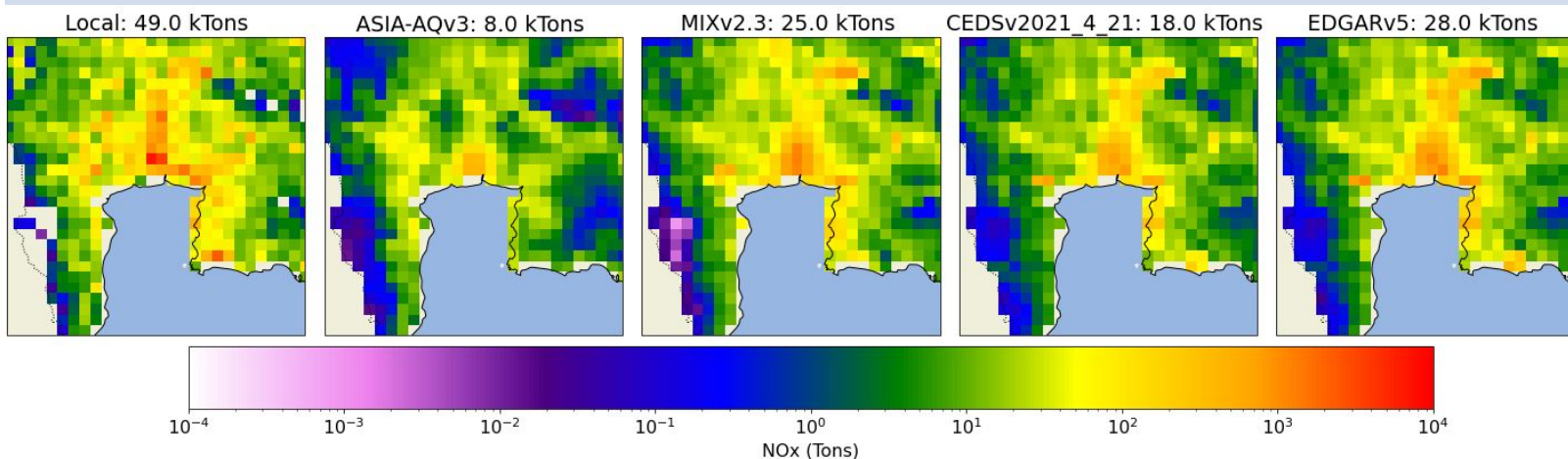
We provided forecasts with MUSICA_{v0} (CAM with Tagged CO tracers), as well as WRF with tracers (G. Pfister, R. Kumar) and several other NASA-funded and international teams

Model evaluation ongoing using surface, aircraft and satellite observations

Comparing different emissions inventories (Anthro and Fire)

MUSICA_{v0} with TROPOMI NO₂ and CO assimilation,
comparison of existing emissions inventory and trends
(how is 2024 different from previous years) [B.Gaubert]

Local inventory for Thailand 2-5 times greater than other inventories over Bangkok

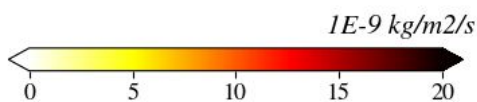
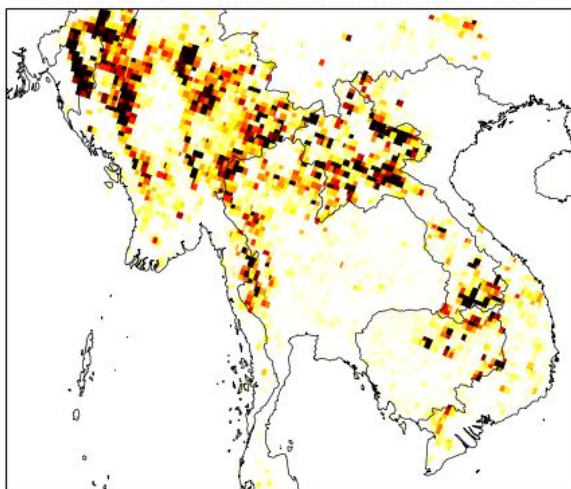


Fire emissions differ greatly – models with FINN are closer to obs

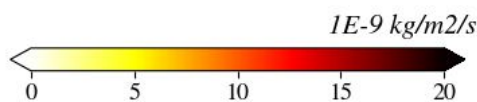
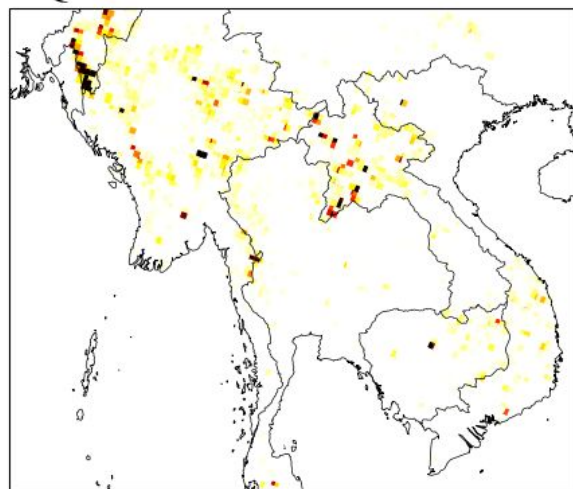
Will be challenging to evaluate: sampled air mixed with Anthro from China, etc.

CO data assimilation (MOPITT/TROPOMI) for estimating posterior emissions and track CO transport

FINN CO emissions 2024-03-16

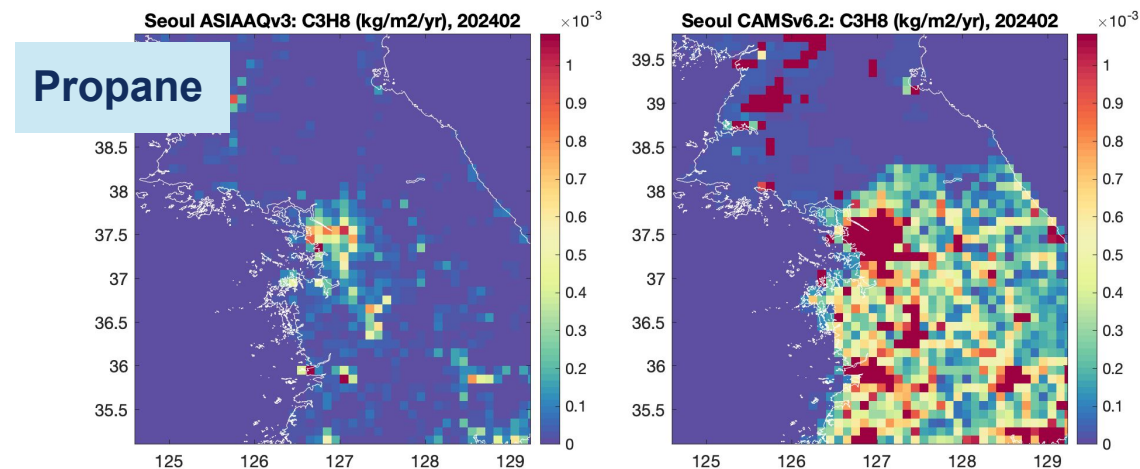


QFED CO Emissions 2024-03-16

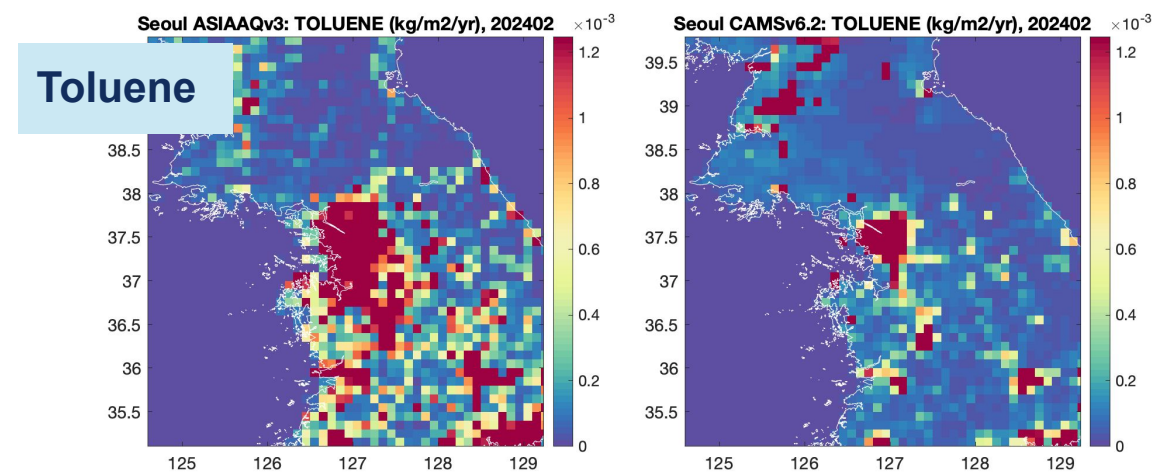


VOC speciation varies greatly between inventories
Always challenging to get accurate local speciation

Propane

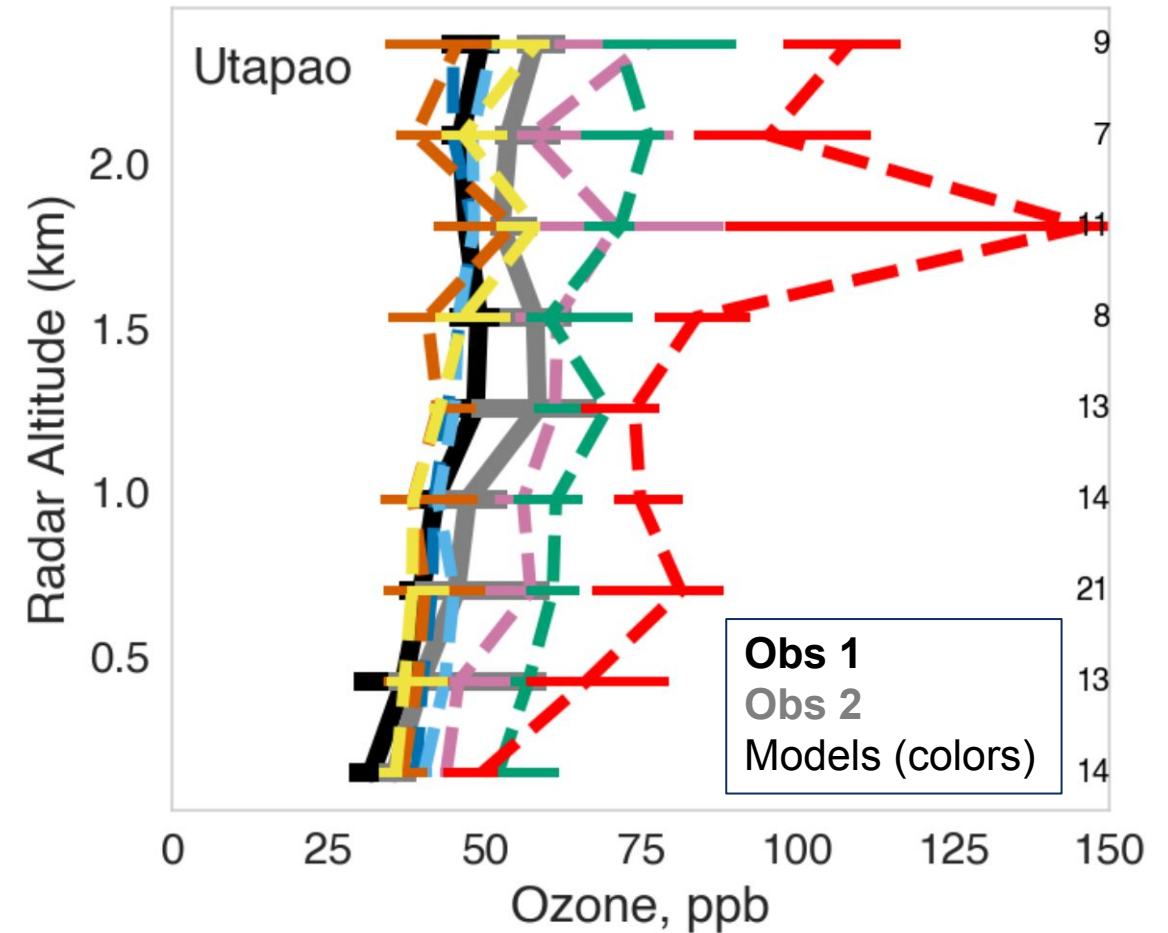


Toluene



ASIA-AQ Multi-model comparison

- Models supporting ASIA-AQ for forecasting and analysis – global and regional
- Goal is to select a common inventory for all models to use
- Model differences provide ensemble of model-obs differences



Surface Ozone Attribution

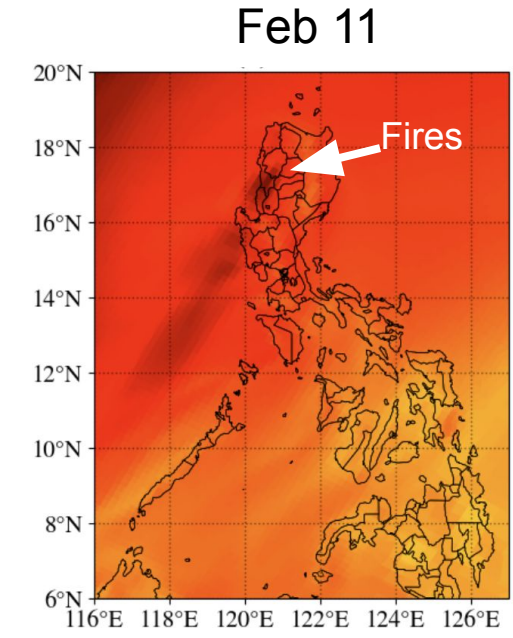
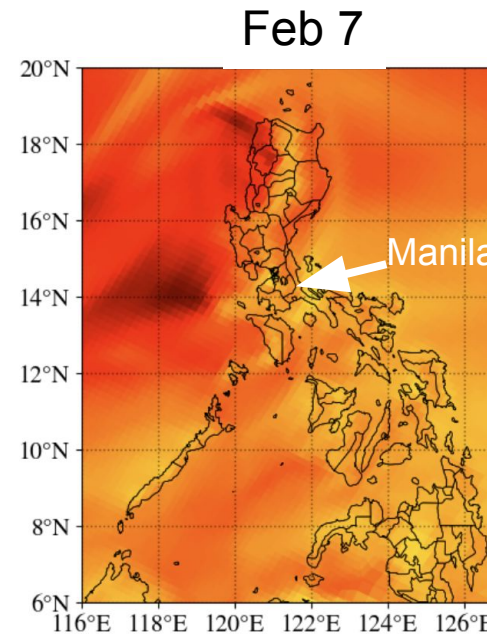
Sensitivity runs turning off local NO_x and VOC emissions

Goal: to inform local air quality managers in each region what are the contributions of local and transported pollutants

Also preparing tagged-NO_x mechanism based on T4S (cheaper and simpler than T1)

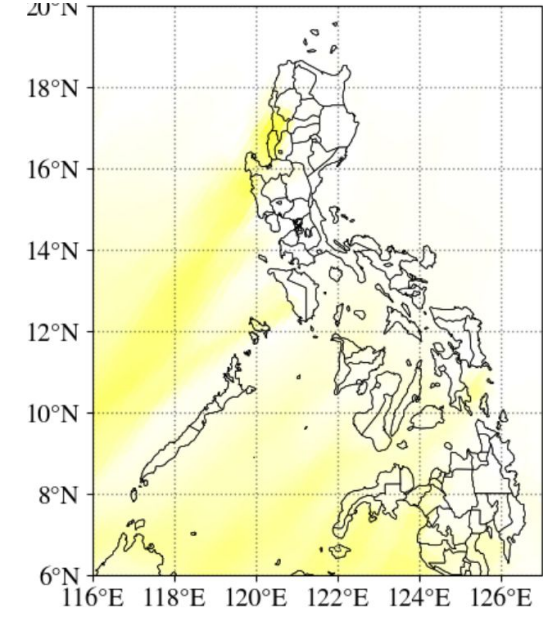
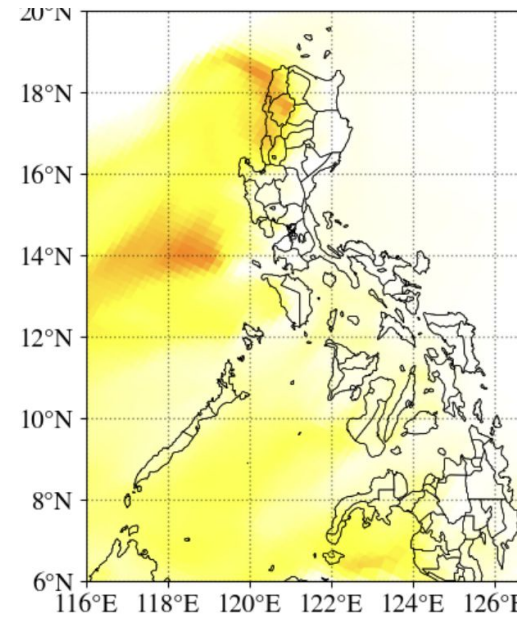
$xNO \rightarrow XNO_2 \rightarrow xNO_y(i) \rightarrow xO_3$

Ozone base case



Δ Ozone

Base case minus local NO_x emis. off



0.0 25.0 50.0 75.0 100.0

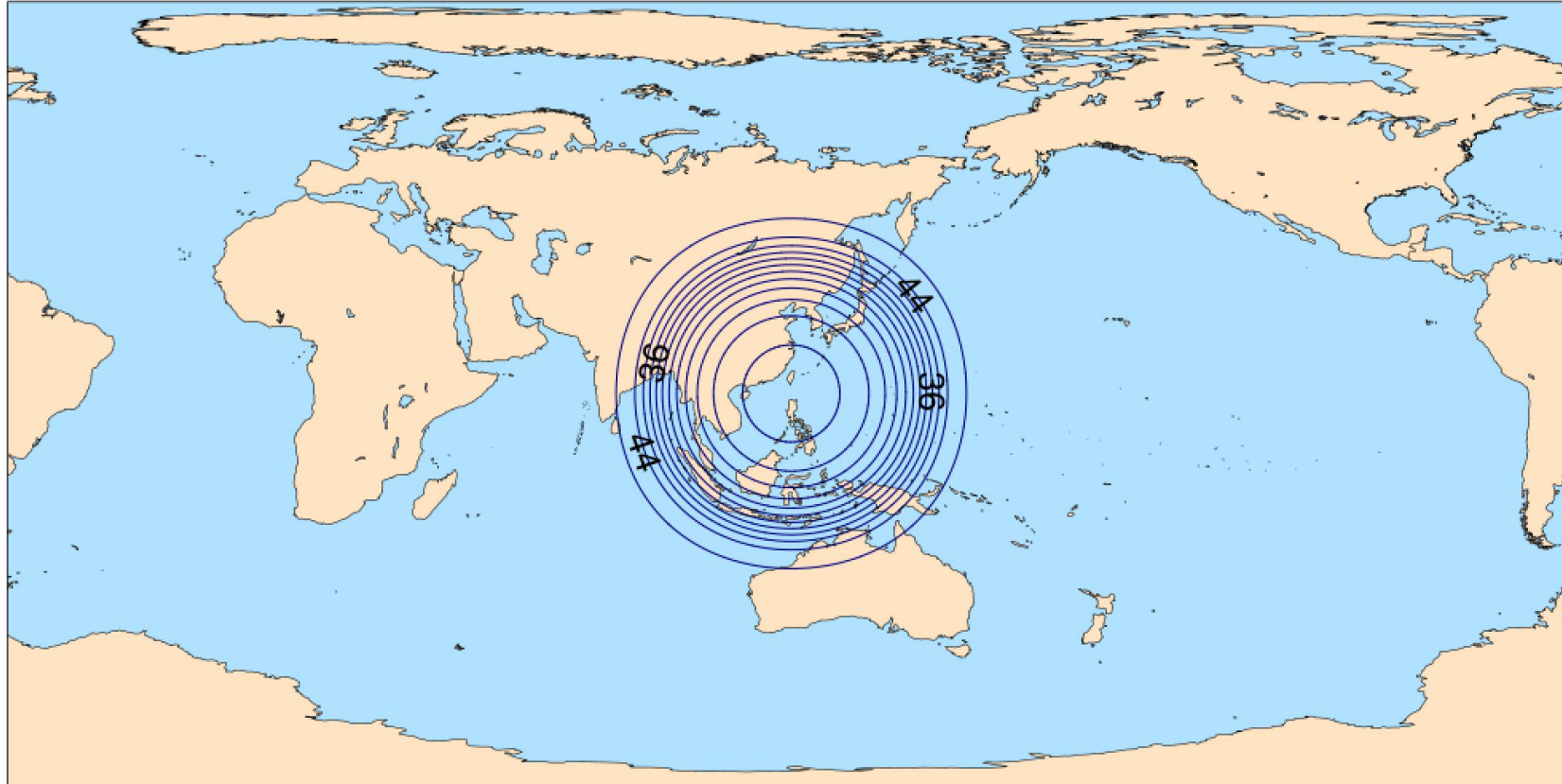
Mixing Ratio (ppbv)



Jun Zhang (NCAR/ACOM)

MUSICAv1 (MUSICA-MPAS) for ASIA-AQ

Grid Centered at 20N, 121E



We are testing MUSICA-MPAS for ASIA-AQ

60km-3km mesh is used

We are currently testing the domain for Manila, Philippines and Taiwan

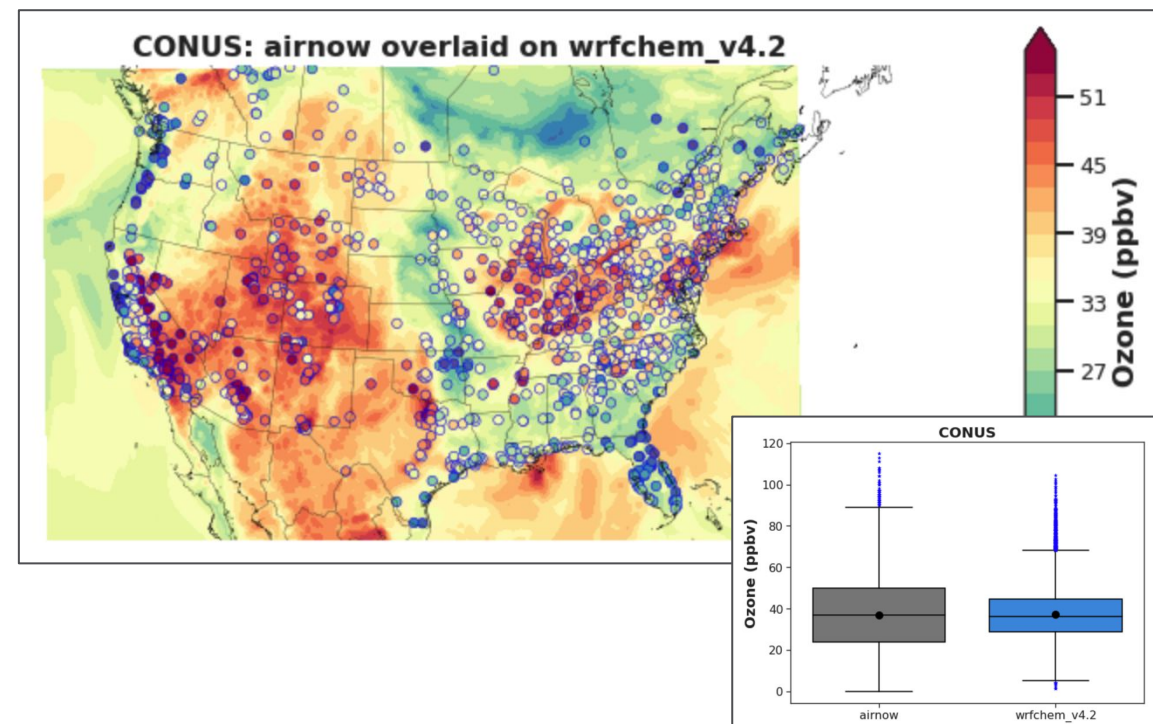
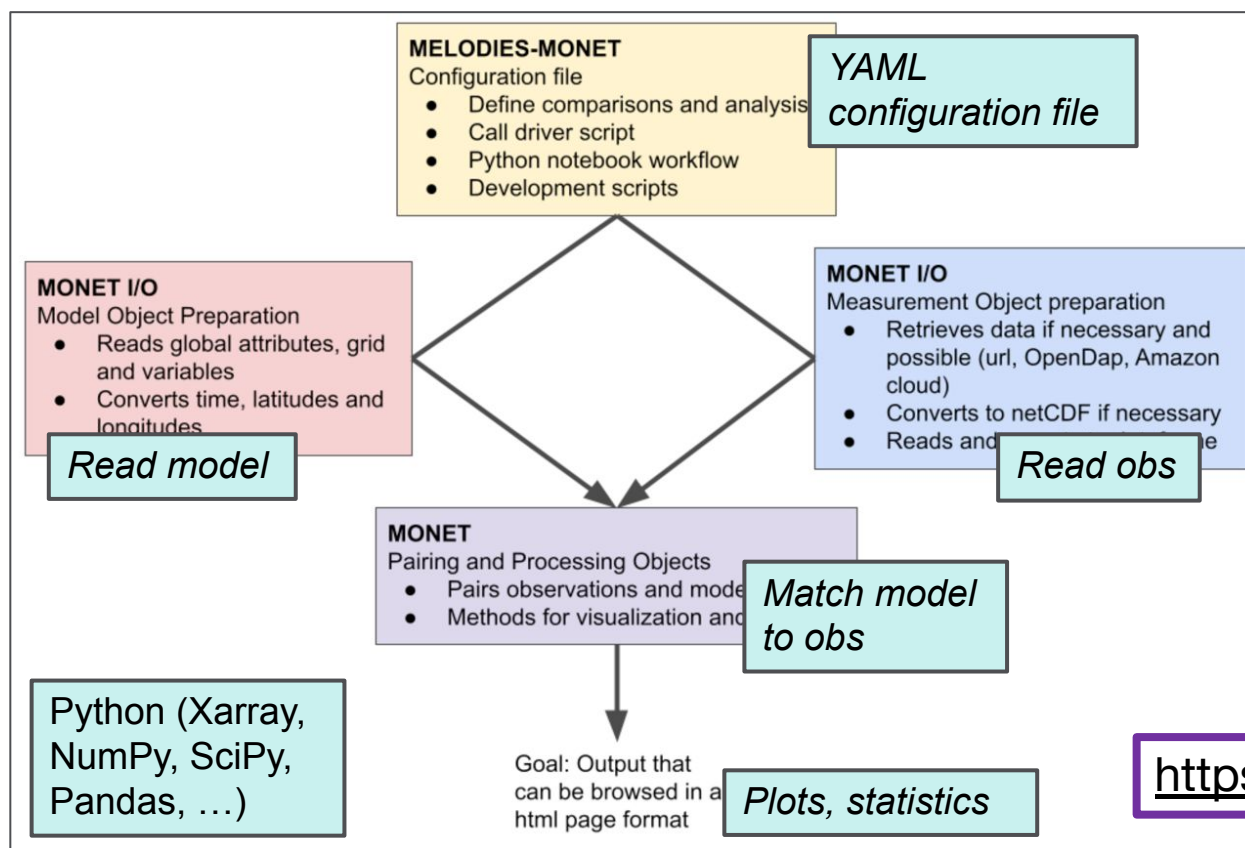
Grids and simulations for Thailand and Korea will also be tested

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

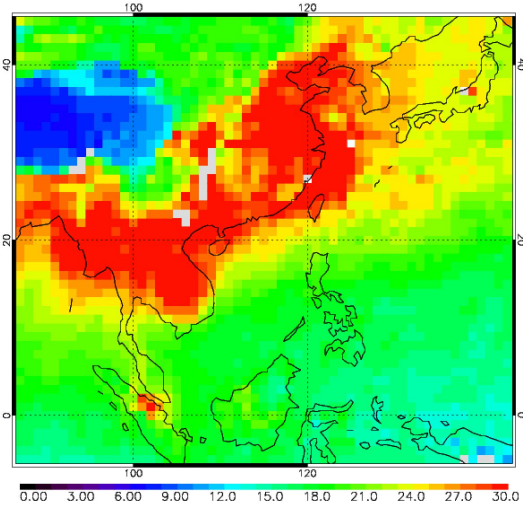
<https://github.com/NOAA-CSL/MELODIES-MONET>



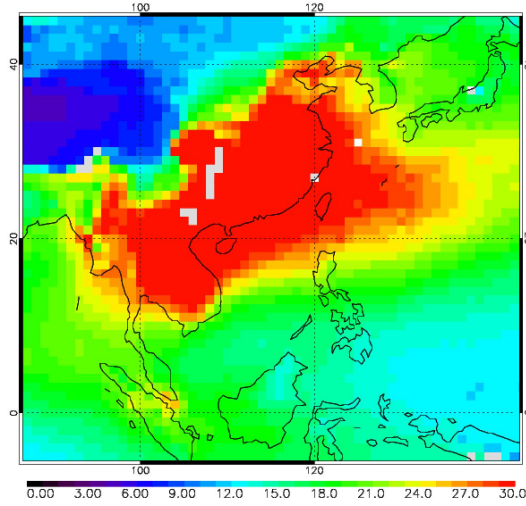
<https://www2.acom.ucar.edu/events/melodies-tutorial-2024>

Model evaluation with MELODIES MONET

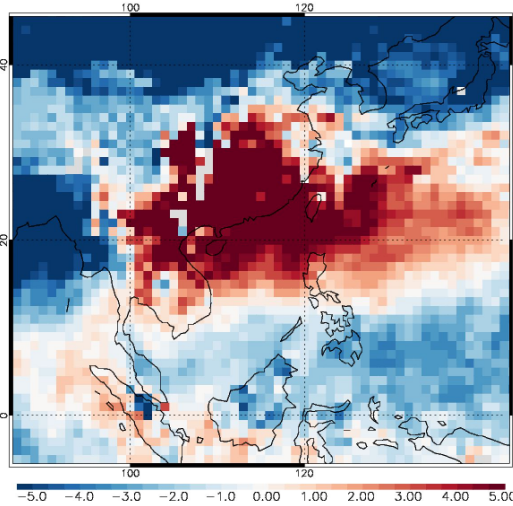
MOPITT CO



WRF-Chem

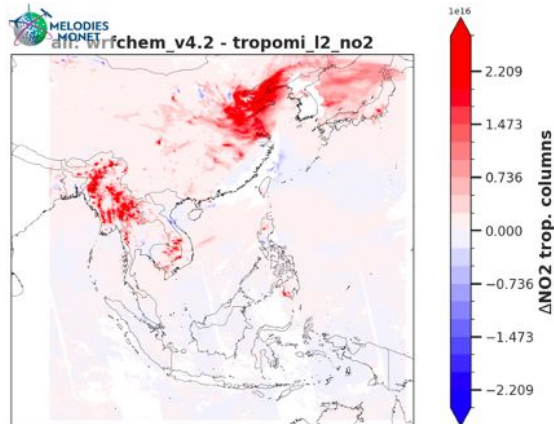


WRF-Chem - MOPITT

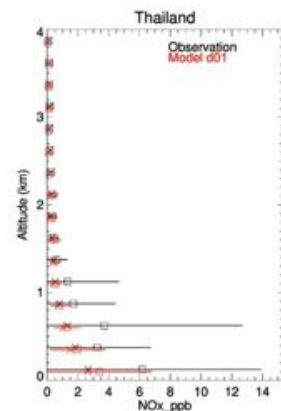


- MELODIES MONET pairs model and obs, produces plots
- March monthly avg
 - Model too high over China, but too low over India, Siberia, Tropical Pacific

model minus TROPOMI NO2



Model & aircraft obs



Model evaluation with satellite, aircraft and surface observations provides complementary information on emissions accuracy and model chemistry, etc.

Task Force on Hemispheric Transport of Air Pollution (HTAP)

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

Still waiting for emissions

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

Welcome to the **CESM with Chemistry Wiki**

CAM-chem (Low and Mid-Top): The **Community Atmosphere Model with Chemistry** (CAM-chem) is a component of the NCAR Community Earth System Model (CESM) and is used for simulations of global tropospheric and stratospheric atmospheric composition. Chemistry in CAM-chem is based on the MOZART family of chemical mechanisms, with various choices of complexity for tropospheric and stratospheric chemistry. The first version of CAM-chem is described in [Lamarque et al. \(2012\)](#). An overview of CESM2, which is based on CAM6, is provided by [Danabasoglu et al. \(2020\)](#), with details of the chemistry described in [Emmons et al. \(2020\)](#) and the secondary organic aerosols in [Tilmes et al. \(2019\)](#). CAM6-chem uses the MAM4 modal aerosol model ([Liu et al., 2016](#)).

WACCM (High-Top): The **Whole Atmosphere Community Climate Model** (WACCM) is a comprehensive numerical model, spanning the range of altitude from the Earth's surface to the thermosphere.

Wiki page:

<https://wiki.ucar.edu/display/camchem/Home>

Please help us fill in:
Current Projects
Development Plans

Run	<ul style="list-style-type: none">• Get an NCAR HPC Account• Quick Start - Run CAM-chem on Derecho (the new NCAR HPC)• Home Machine (fully coupled version in CESM)• Glossary for **new users'• Release Versions and Cor• Troubleshooting	User Community	<ul style="list-style-type: none">• Current Users/Projects• Development Plans• Contributions to Model Intercomparisons (MIPs)• CAM-chem Forum• Chemistry-Climate Working Group Publications• CAM-chem Publications from NCAR• CESM Publications
Tutorials	<ul style="list-style-type: none">• CESM Tutorials• CESM 2022 Tutorial videx• CESM Chemistry 2023 Tu• MUSICA Tutorial Series		