



July 28, 2026



NCAR
OPERATED BY UCAR

A Generalized framework for the evaluation and comparison of atmospheric chemistry models with observations

Liam Thomson, Ben Gaubert, Orhan Eroglu, & MELODIES
MONET Development Team

NSF NCAR

This material is based upon work supported by the NSF National Center for Atmospheric Research, which is a major facility sponsored by the **U.S. National Science Foundation under Cooperative Agreement No. 1852977**.

We acknowledge funding support from the **Summer Internships in Parallel Computational Science (SiParCS) Program**

Measurement of Pollution

minutes

Credit: NASA

Air Quality and atmospheric chemistry datasets



1. Surface Networks

2. Airborne Field Campaigns

3. Satellite data

1. Surface Networks



- ❖ Inconsistent spatial coverage
- ❖ Great temporal resolution
- ❖ Limited chemical detail
- ❖ Limited vertical detail

2. Airborne Field Campaigns

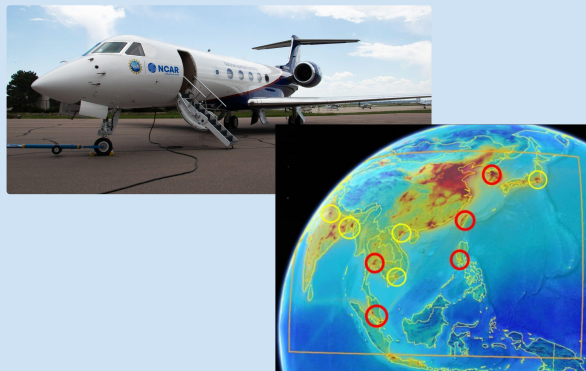
3. Satellite data

1. Surface Networks



- ❖ Inconsistent spatial coverage
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2. Airborne Field Campaigns



- ❖ Limited spatial & temporal coverage (snapshots only)
- ❖ Great chemical detail
- ❖ Great vertical detail

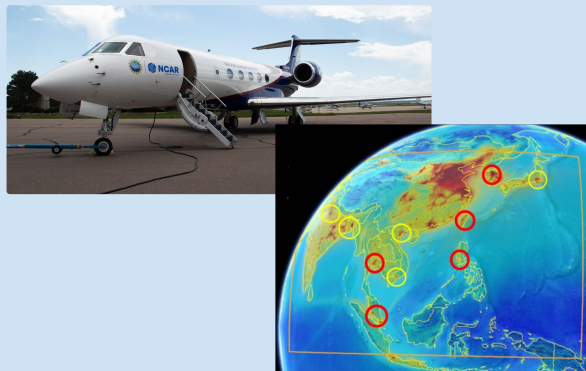
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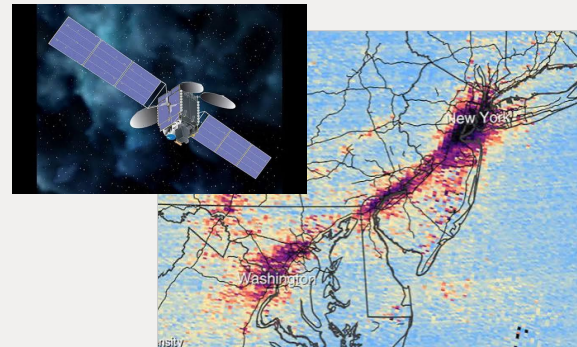
- ❖ Inconsistent spatial coverage
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- ❖ Limited chemical detail
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2. Airborne Field Campaigns



- ❖ Limited spatial & temporal coverage (snapshots only)
- ❖ Great chemical detail
- ❖ Great vertical detail

3. Satellite data



- ❖ Best spatial coverage and great temporal detail (via geostationary)
- ❖ Limited vertical and surface detail
- ❖ Limited chemical detail

- ❖ How do you unify ***different sources of observations*** for the ***comparison and evaluation*** of atmospheric chemistry and air pollution models?

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- ❖ What happens when your models increasingly exist on ***unstructured model grids***?

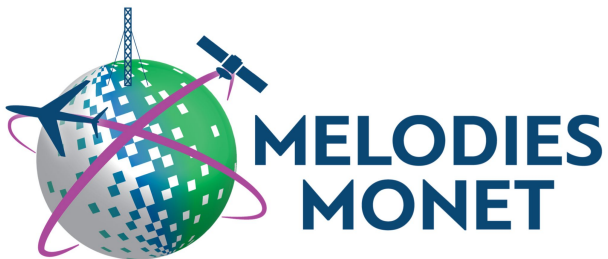
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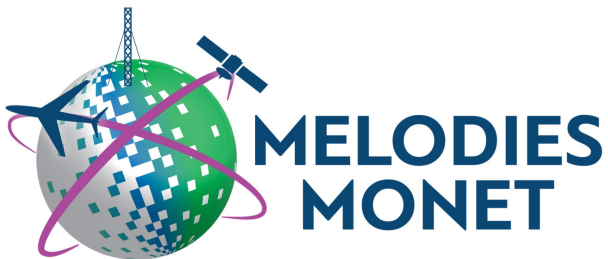
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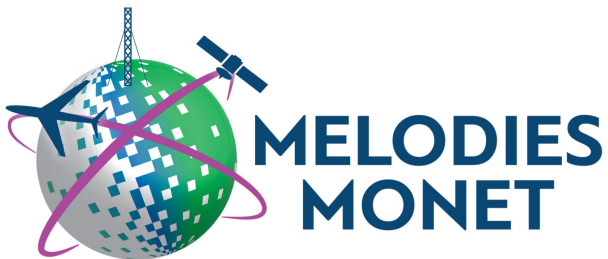
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Model

Observations

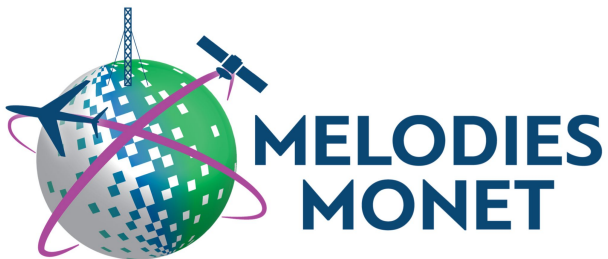
Pairing

Plotting

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Save the paired dataframe
as a netcdf for additional
analyses

Model

Observations

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Plotting



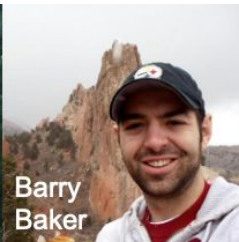
Zach Moon



David Fillmore



Becky Schwantes



Barry Baker



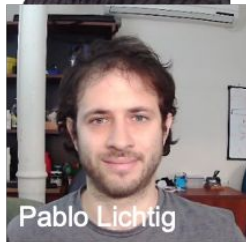
Colin Harkins



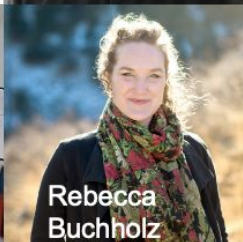
Quazi Rasool



Beiming Tang



Pablo Lichtig



Rebecca
Buchholz



Jian He



Meng Li



Jordan Schnell



Maggie Bruckner



Louisa Emmons



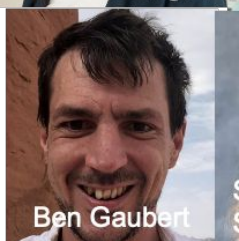
Duseong Jo



Sarah Lu



Shih-Wei Wei



Ben Gaubert



Shima
Shams



Liam Thompson



MELODIES-MONET

Core Functionality

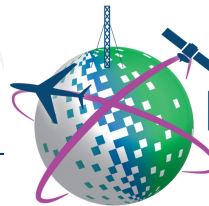
A diagnostic, Python-based tool that does *data ingestion, pairing, & plotting*.

Operational Impact

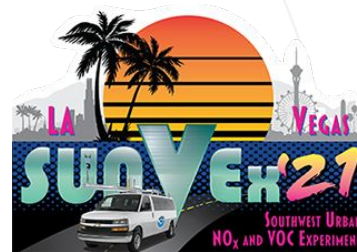
Unified evaluation of atmospheric chemistry and air quality models against **NOAA, NSF NCAR, & NASA field campaigns, surface observations, TEMPO & TROPOMI satellites**, & more.

Source Code: github.com/NCAR/MELODIES-MONET

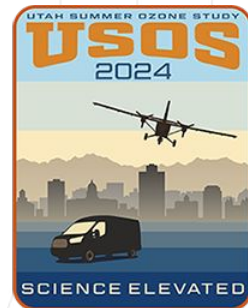
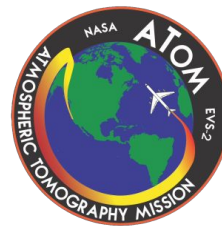
User Guide: melodies-monet.readthedocs.io



MELODIES
MONET



ReadTheDocs



MELODIES-MONET

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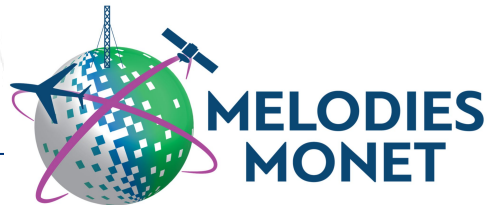
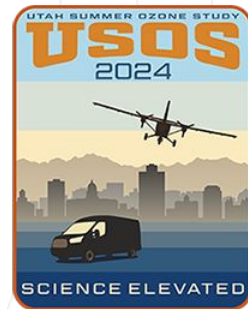
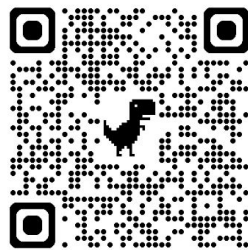
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Ongoing through
September 2027



ReadTheDocs



Core Functionality

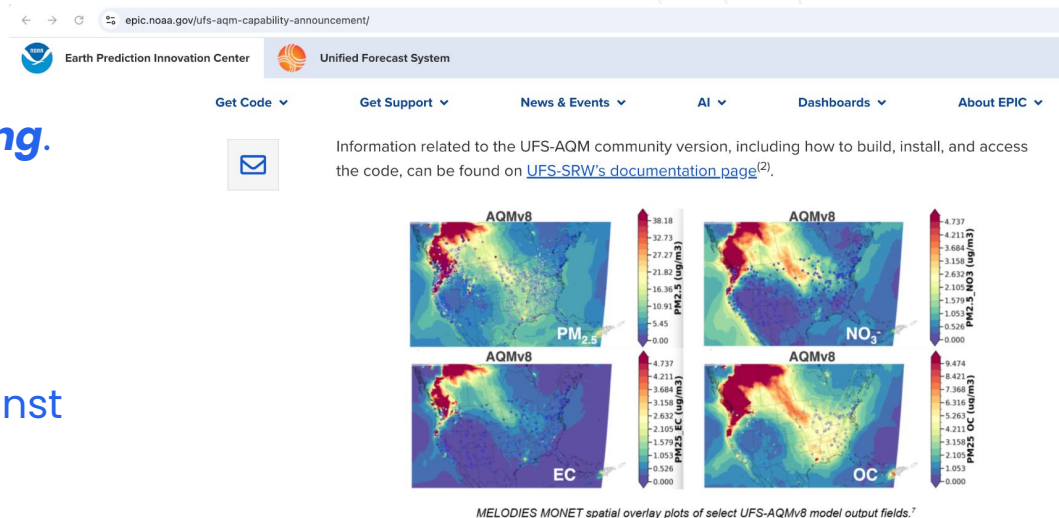
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Highlighted below are features included in the community version which will also be included in the next UFS-AQM operational implementation:

- CMAQ upgraded from v5.2.1 to v5.4. This upgrade includes major code and science changes primarily related to gas and aerosol chemistry, dry deposition, and structural software upgrades (e.g., improved IO performance and configurability)⁽⁸⁾.

Community Earth System Model (CESM)

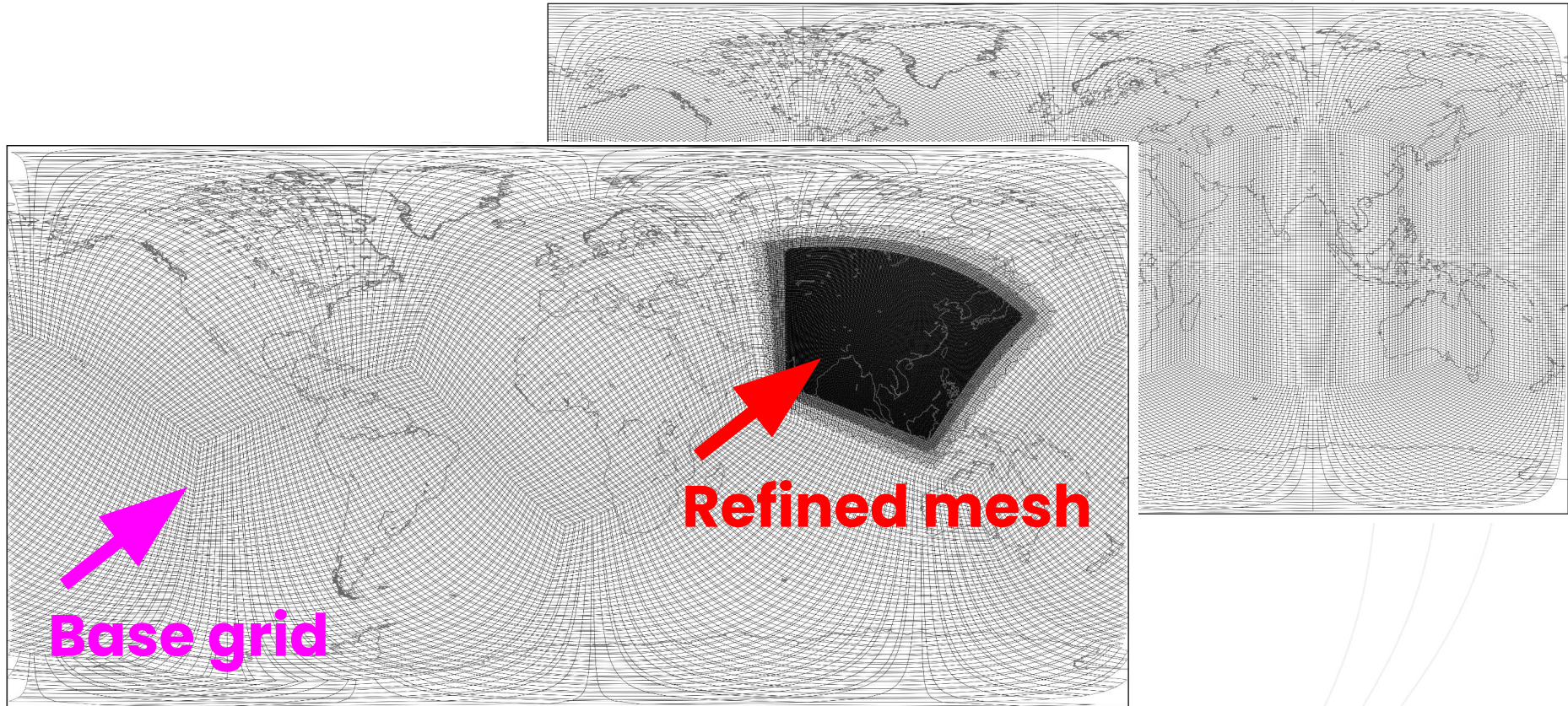


CESM-FV

CESM-SE

CESM-MPAS

Community Earth System Model (CESM)



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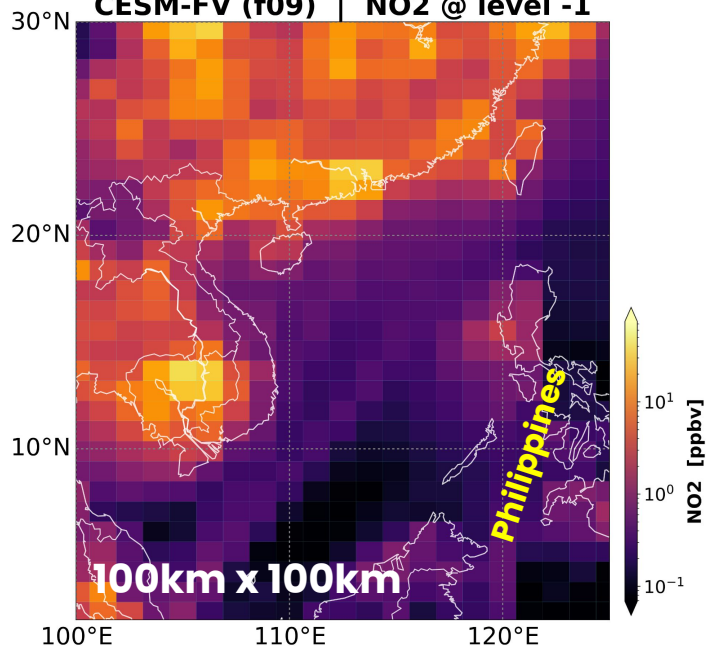


CESM-FV

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CESM-MPAS

CESM-FV (f09) | NO₂ @ level -1



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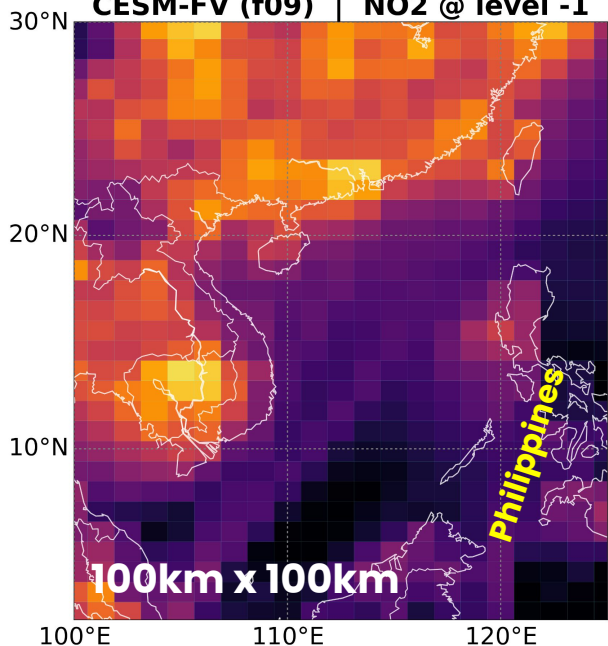


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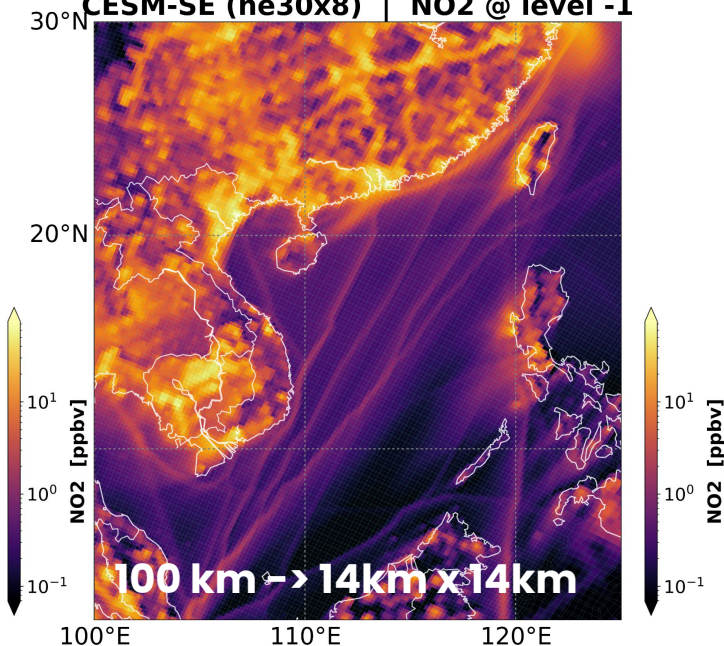
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CESM-SE (ne30x8) | NO₂ @ level -1

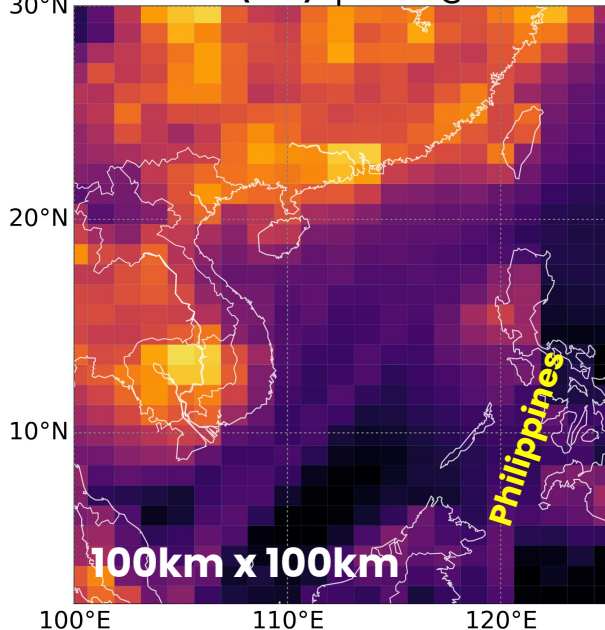


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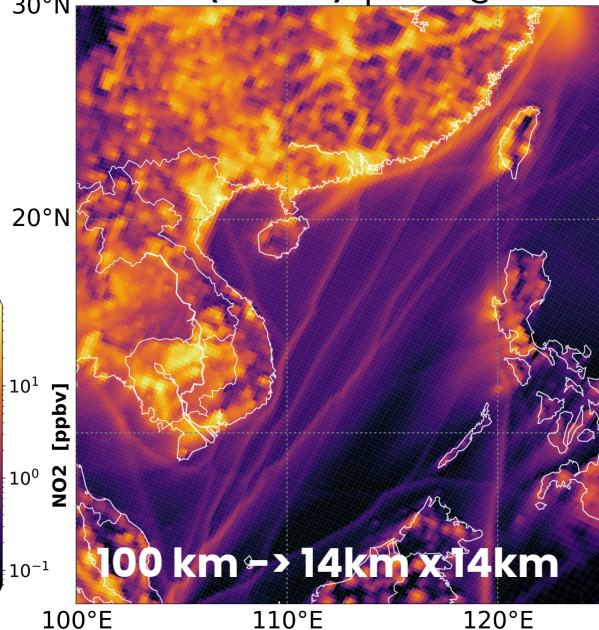
CESM-FV

CESM-FV (f09) | NO₂ @ level -1



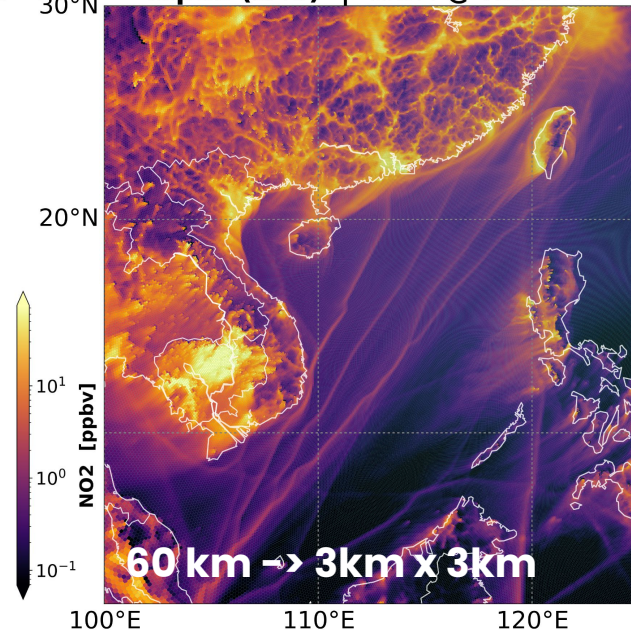
CESM-SE

CESM-SE (ne30x8) | NO₂ @ level -1



CESM-MPAS

mpas (x20) | NO₂ @ level -1



How are unstructured grids supported in MELODIES MONET?



How are unstructured grids supported in MELODIES MONET?



❖ UXarray

zenodo

Search records...



Communities

My dashboard

Published July 21, 2026 | Version v2026.07.0



EarthCube



U.S. DEPARTMENT OF
ENERGY

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PANGEO

uxarray

Chen, Hongyu ; Chmielowiec, Philip ; Clyne, John ; Eroglu, Orhan ; Jacob, Robert ; Jain, Rajeev ; Medeiros, Brian ; Ullrich, Paul ; Zarzycki, Colin



Xarray extension for unstructured climate and global weather data analysis and visualization.

How are unstructured grids supported in MELODIES MONET?



- ❖ UXarray
- ❖ Update MELODIES MONET to accept a SCRIP / MESH file

zenodo

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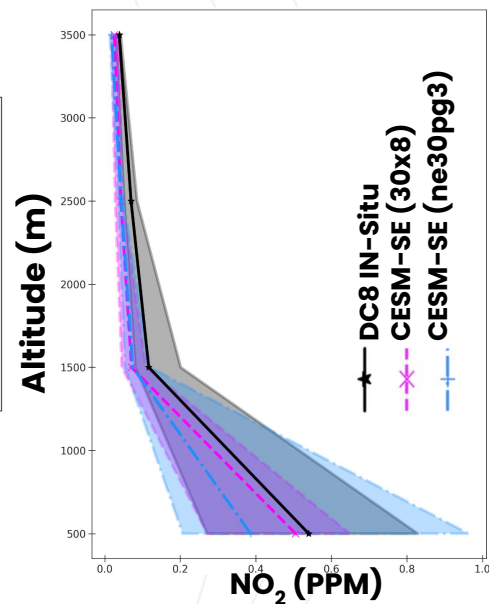
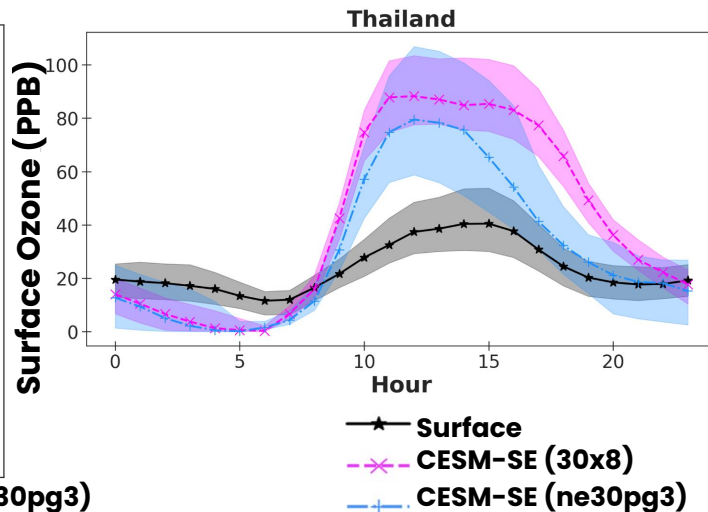
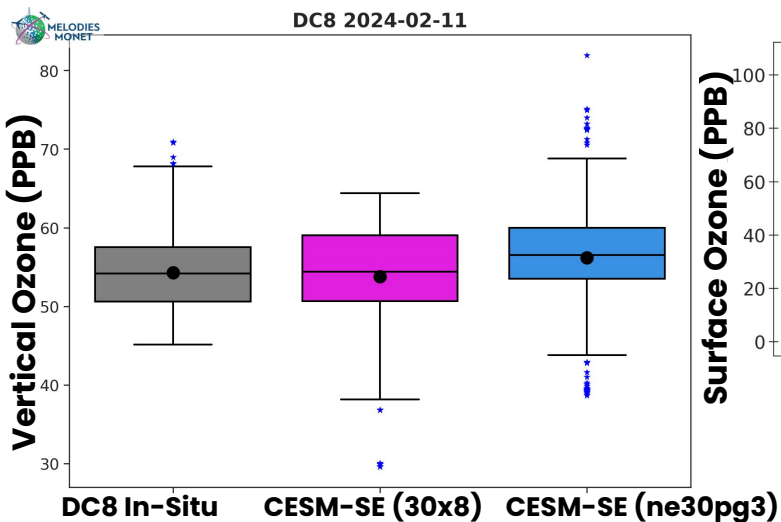


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- ❖ Satellite data?

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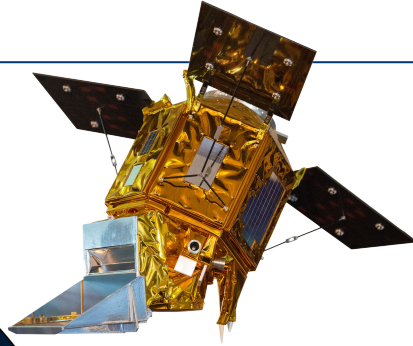
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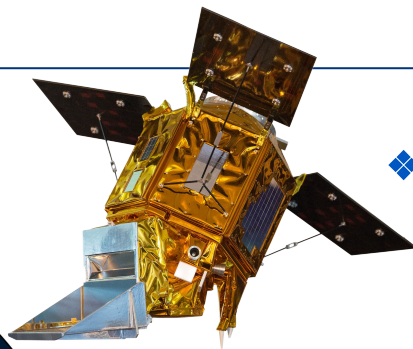


Satellites



Satellites





Geostationary Satellite

- **Fixed** point above Earth's atmosphere
- NASA TEMPO launched in 2023
 - Hourly, daytime measurements of key pollutants (NO_2 , O_3) over the CONUS



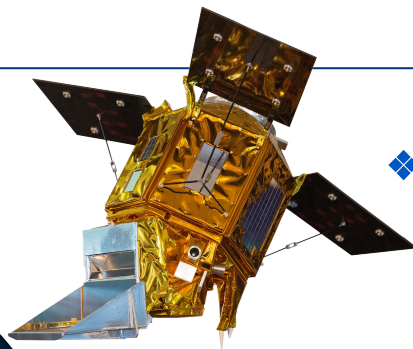
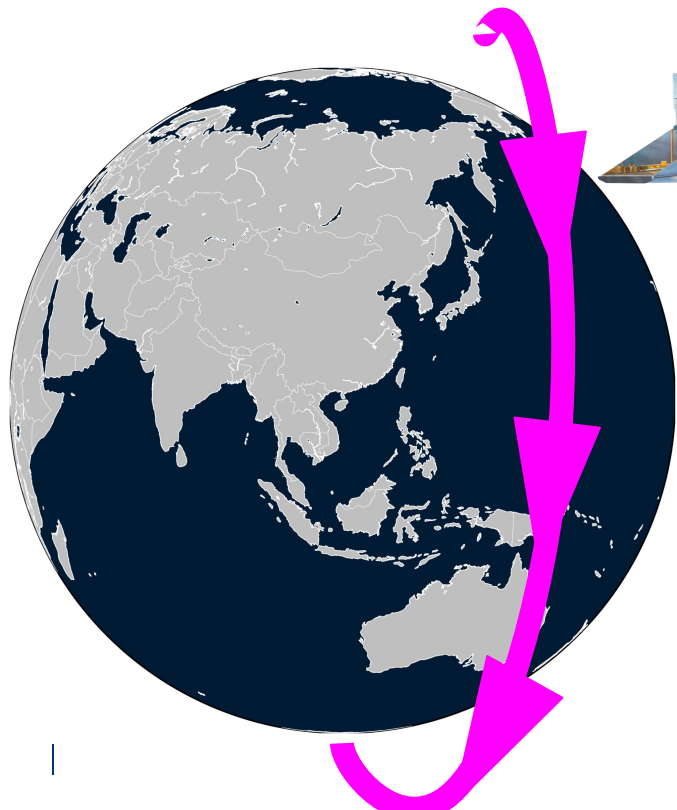
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Polar Orbiting Satellite

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 - 1x daily, daytime measurements of key pollutants (NO_2 , O_3) globally



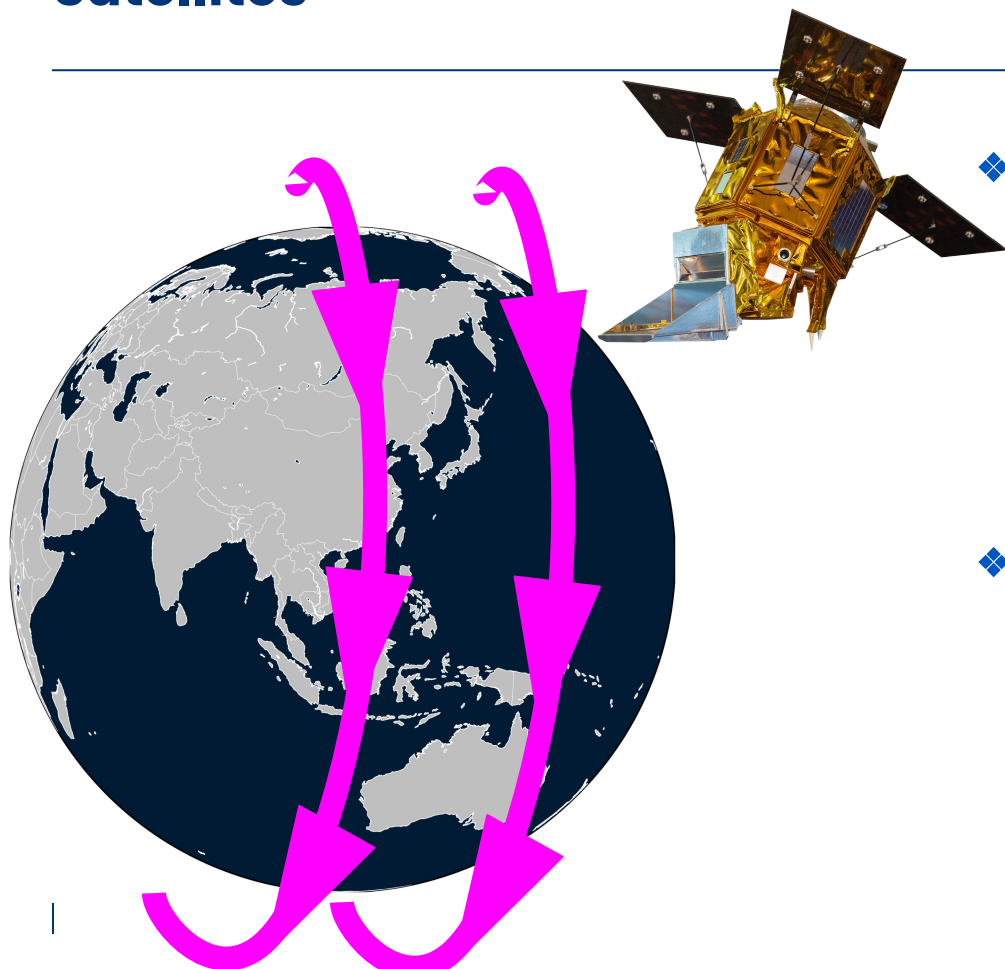
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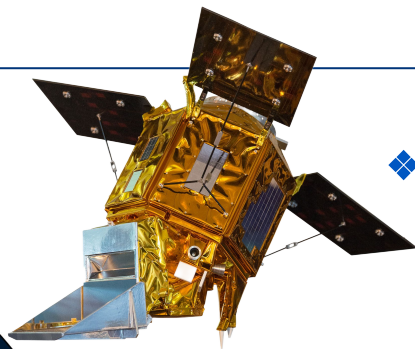
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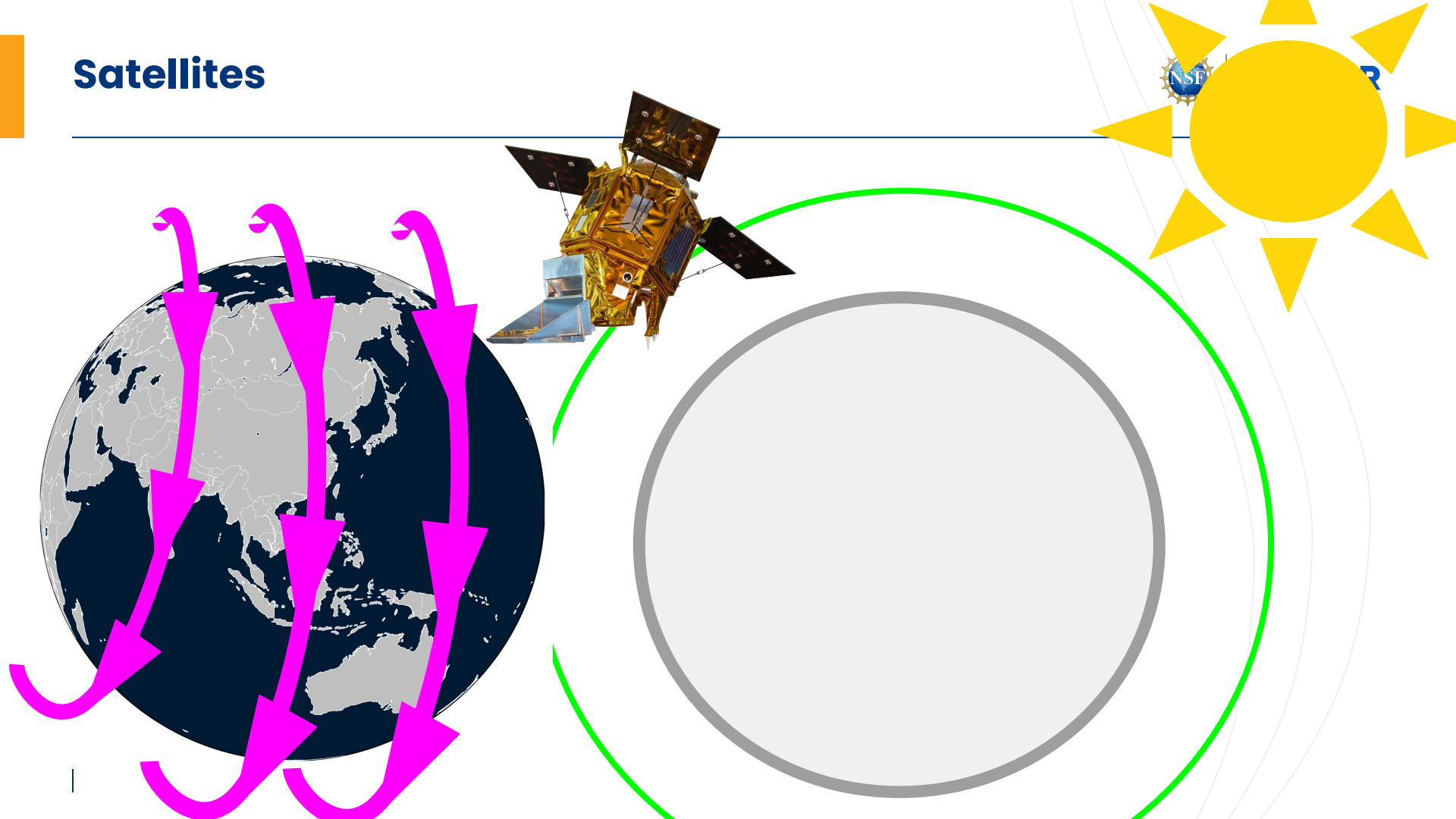


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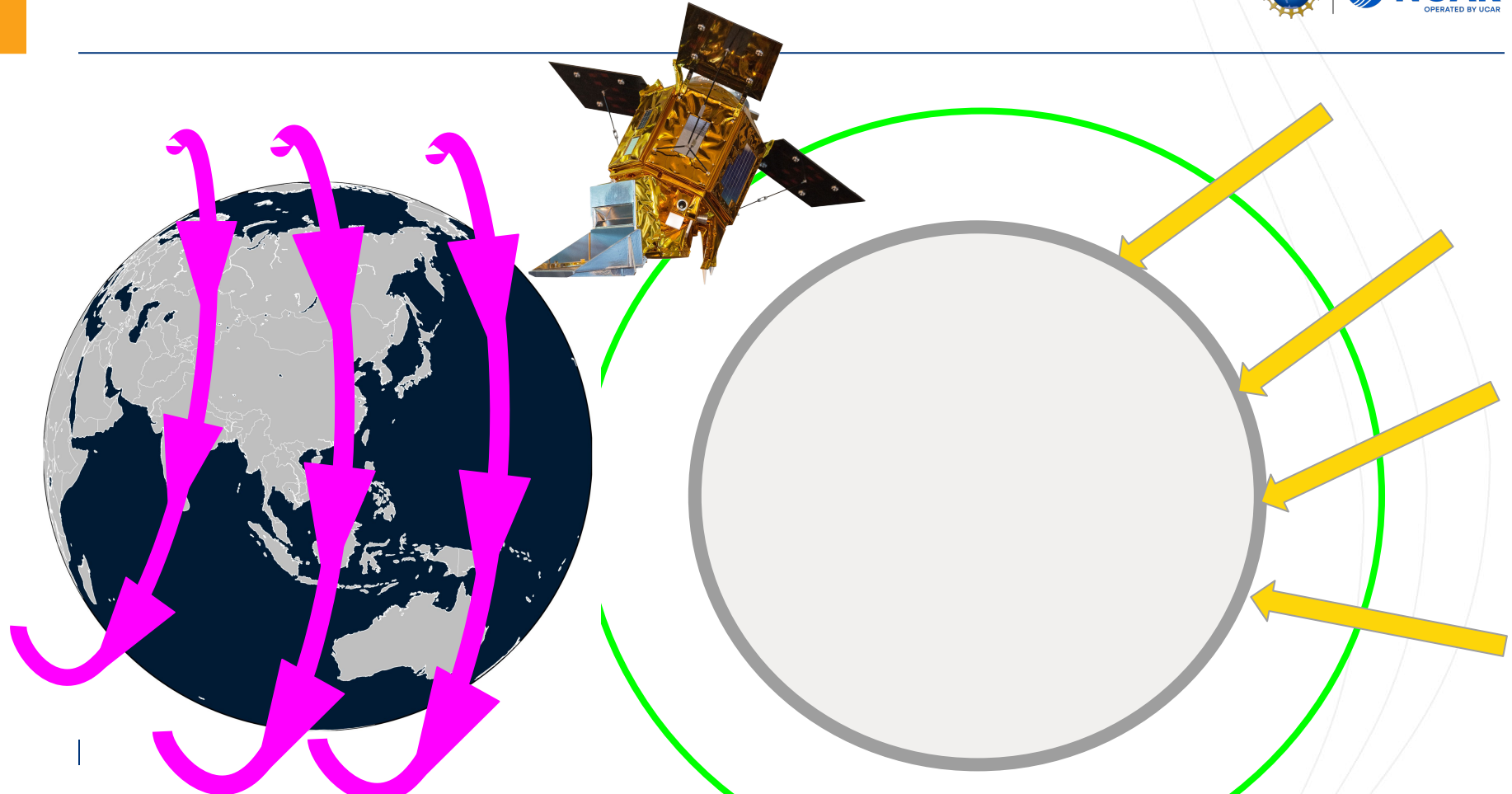
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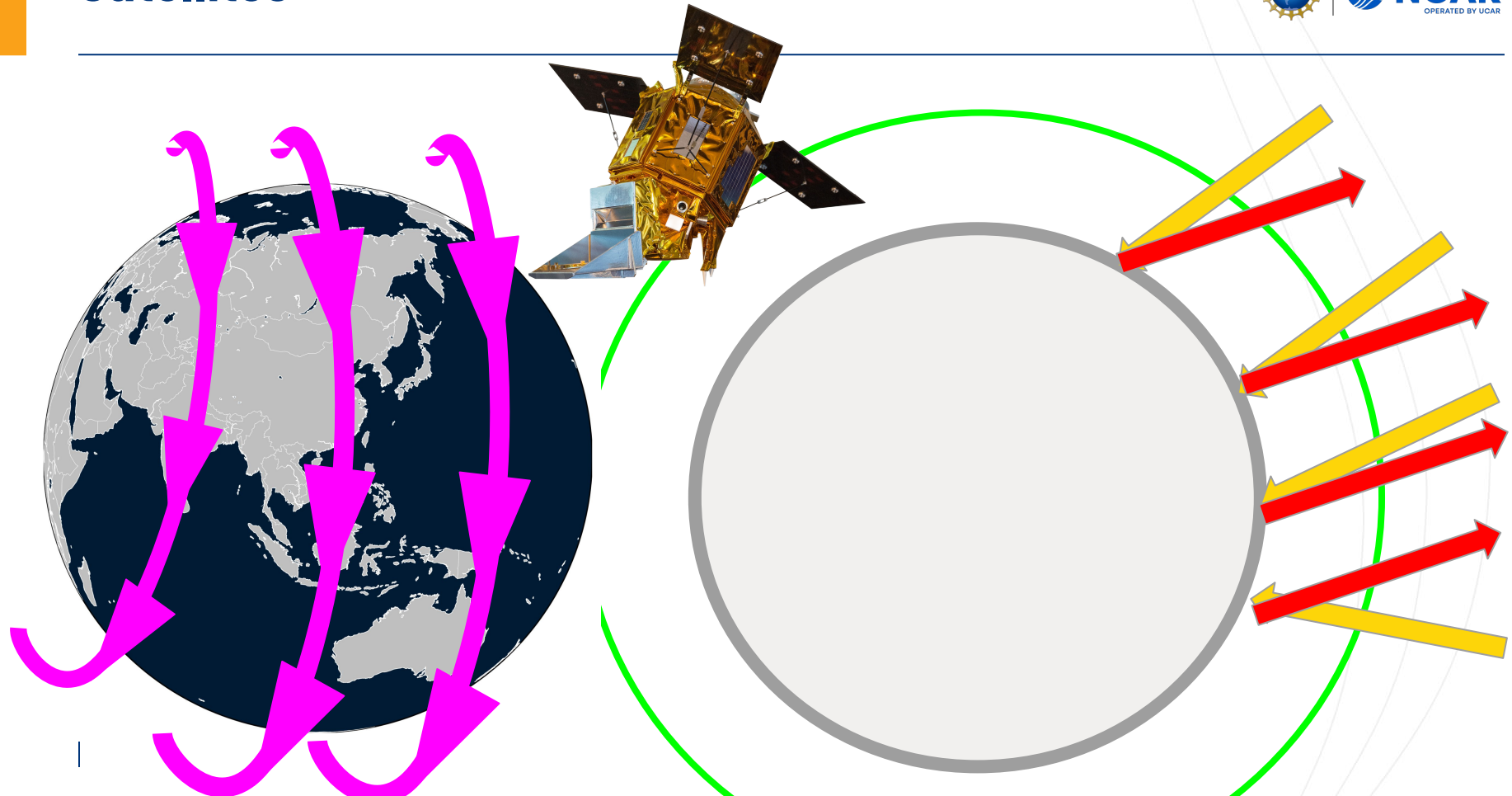
Satellites



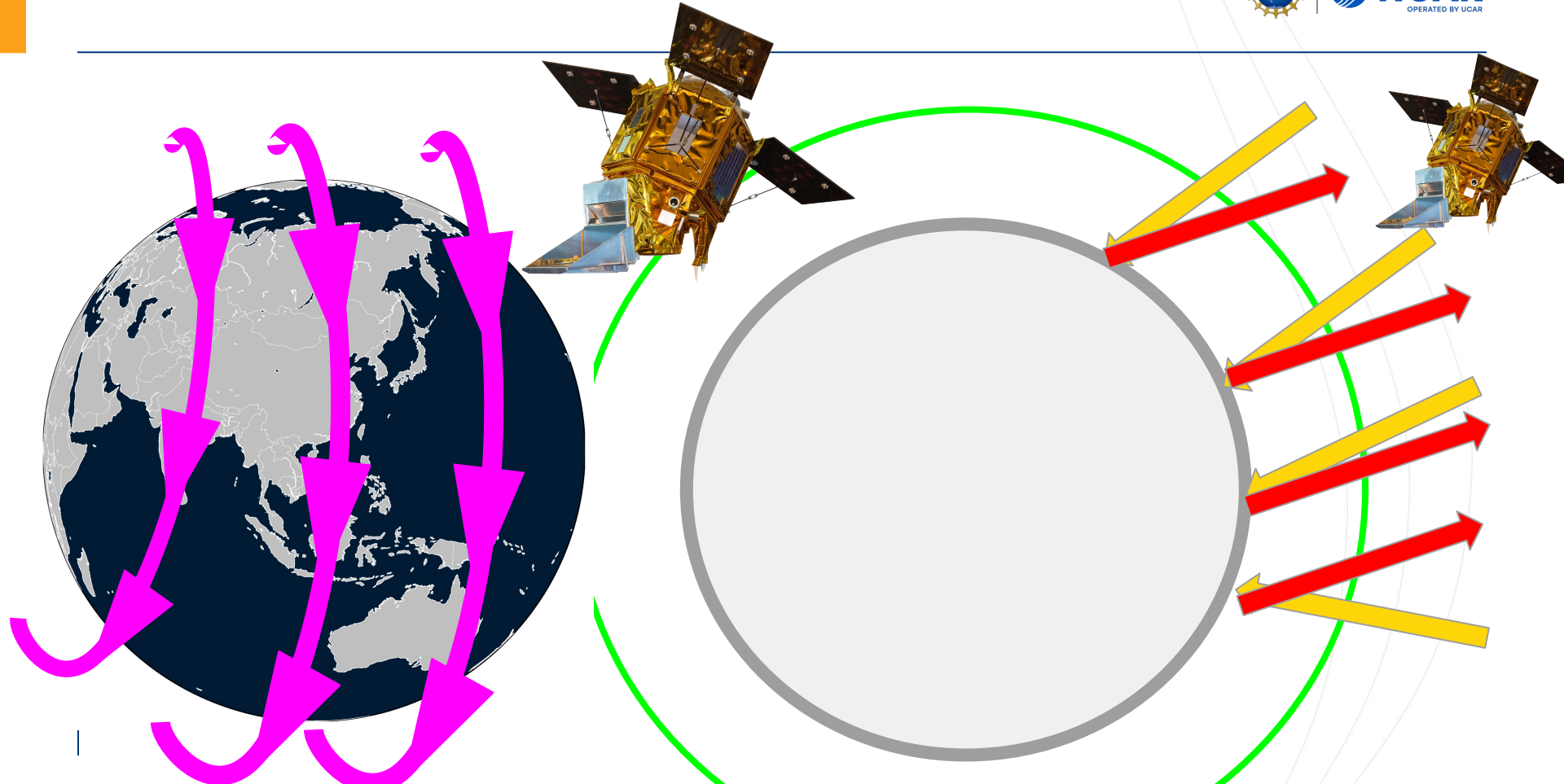
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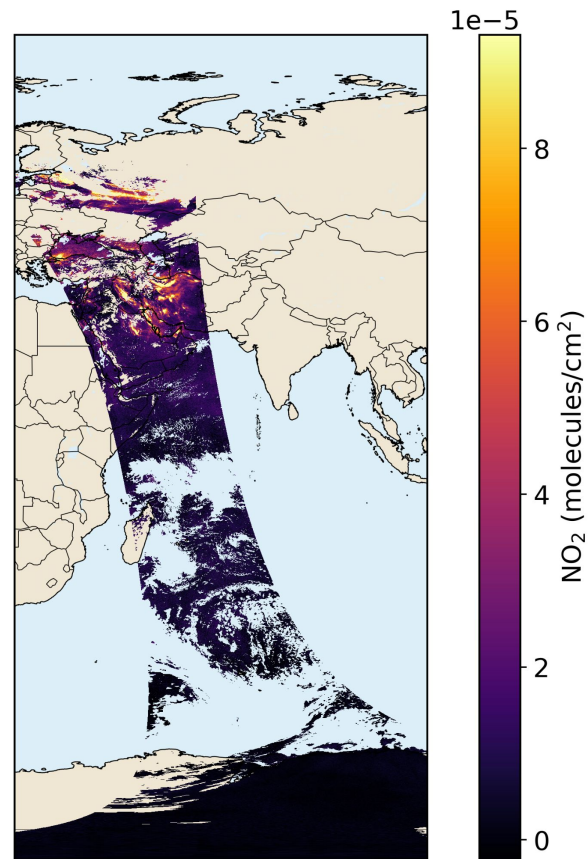
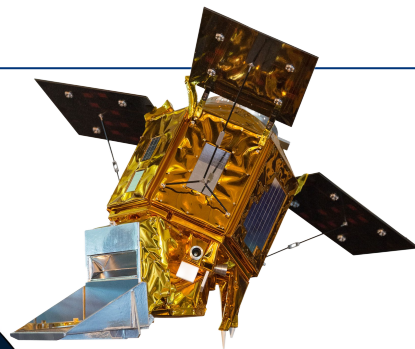
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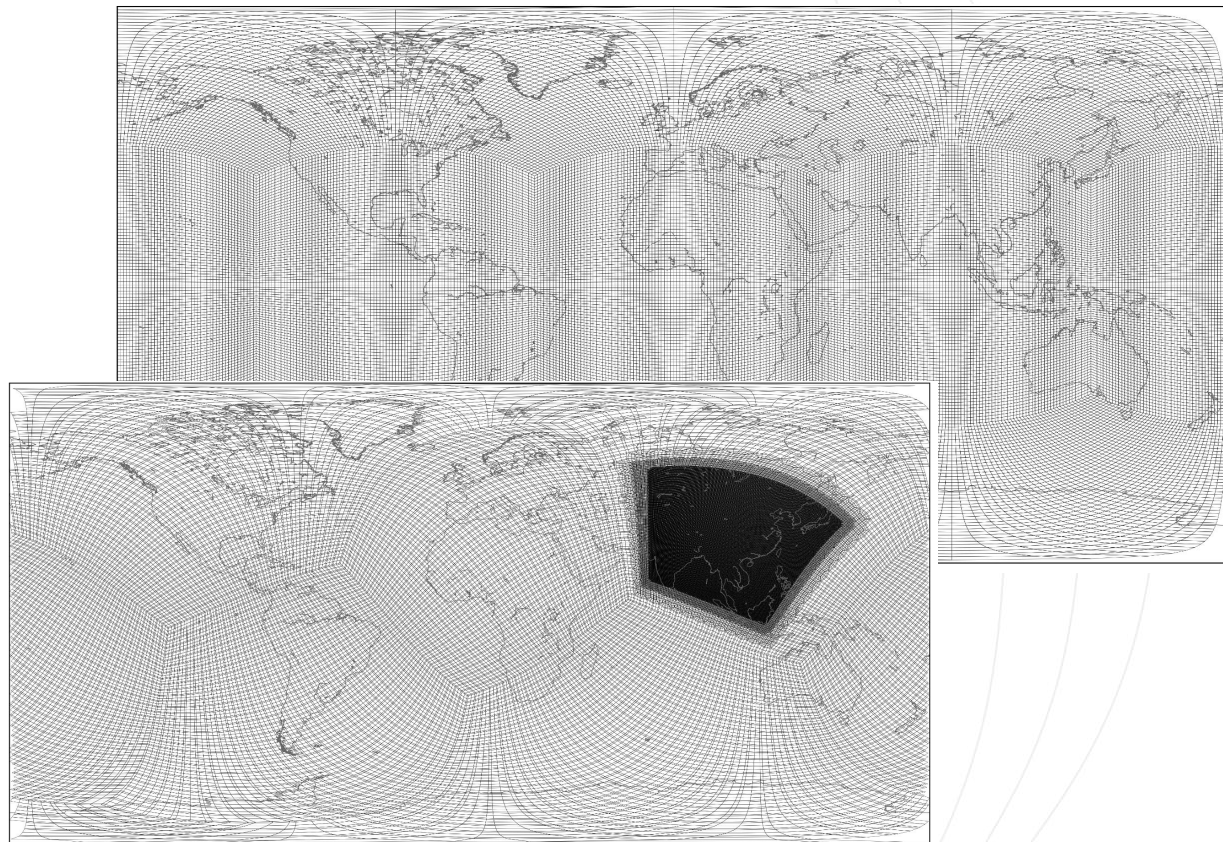
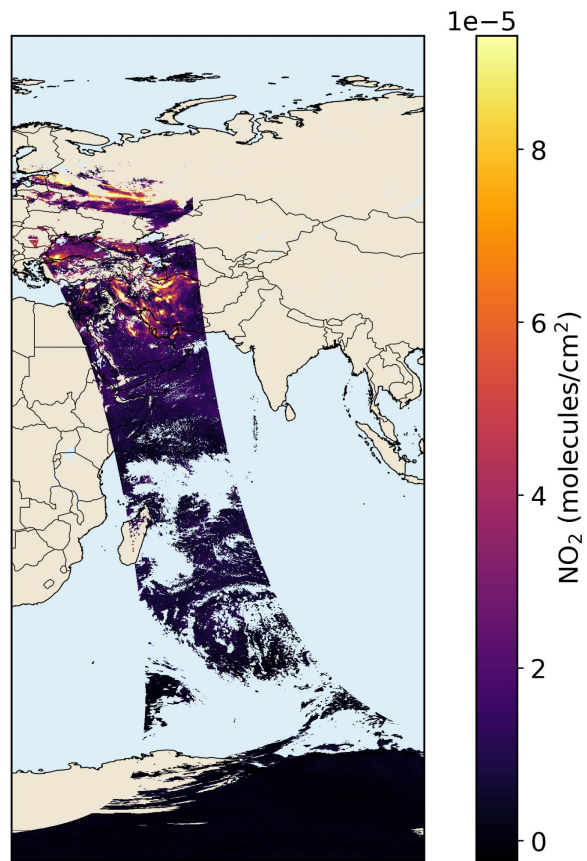
Satellites



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Satellites



MONETIO

Model specific
grid geometry





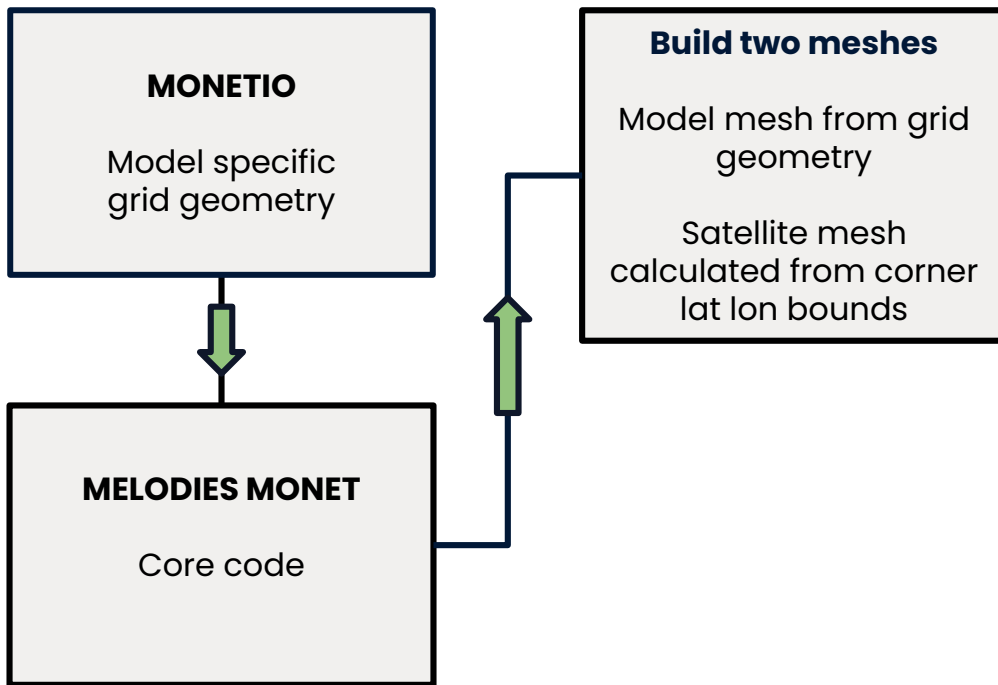
MONETIO

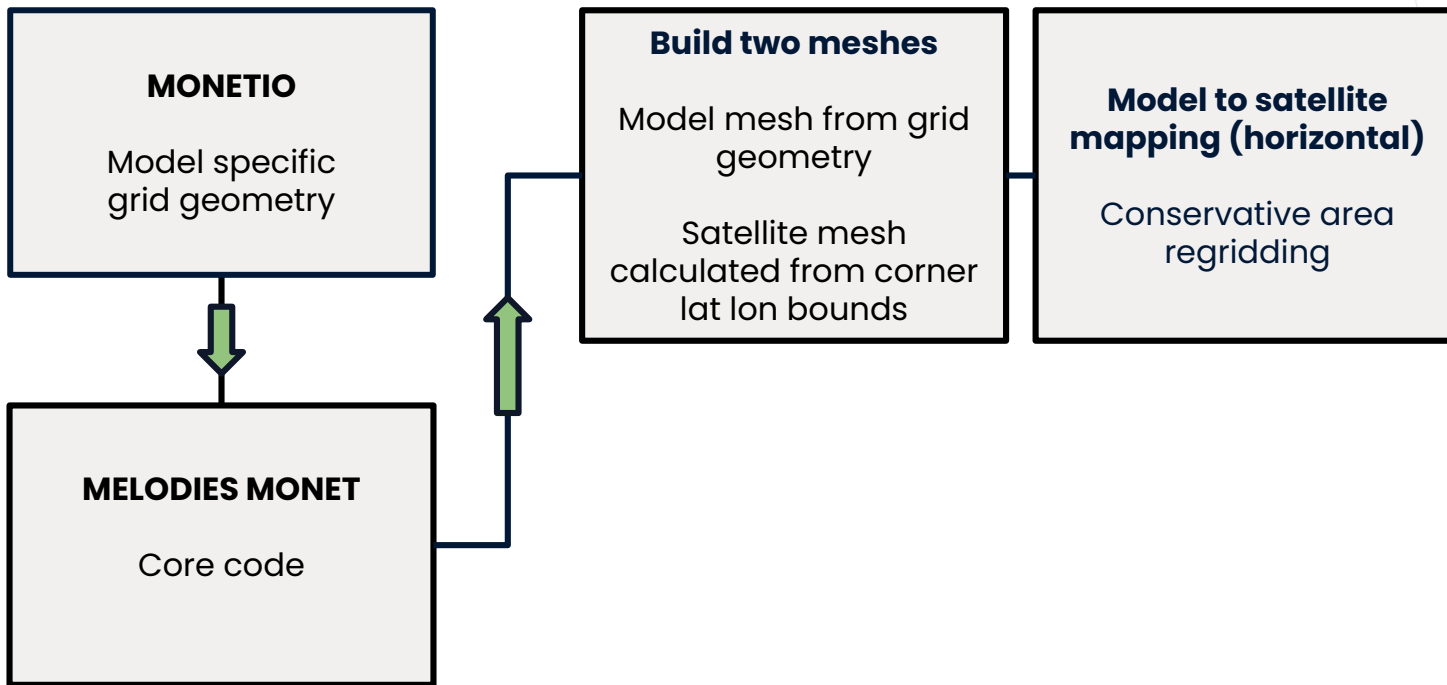
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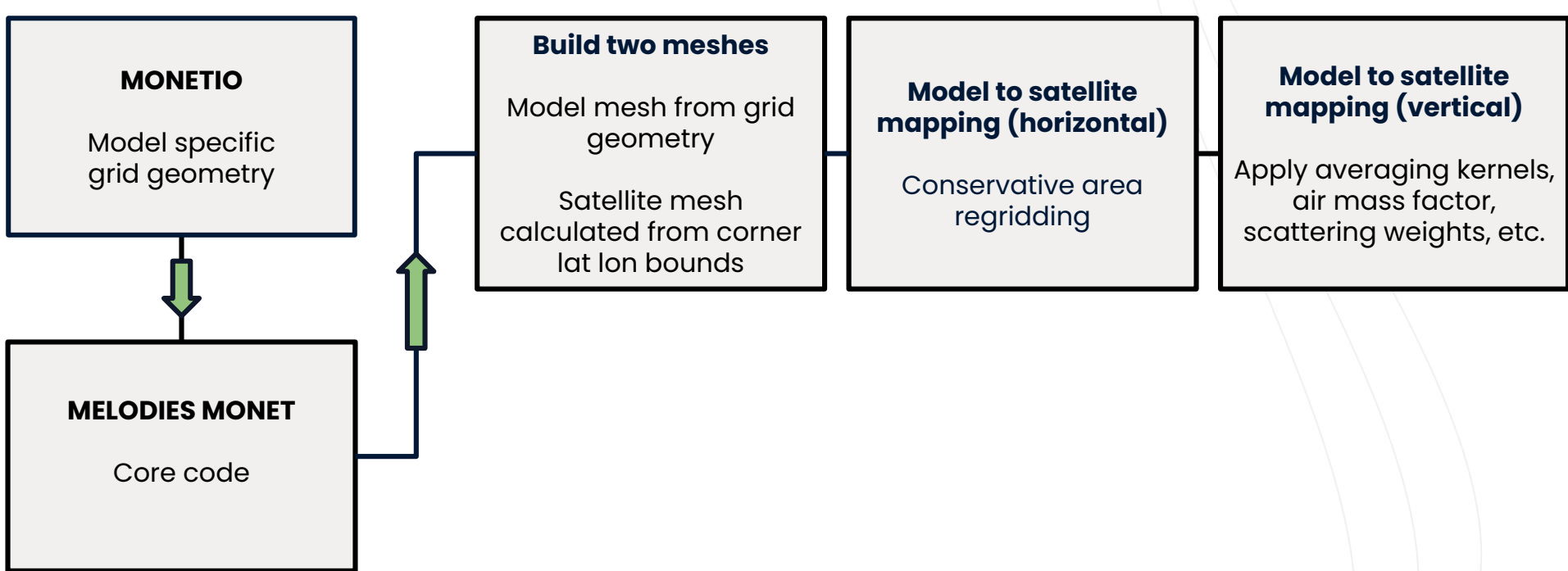


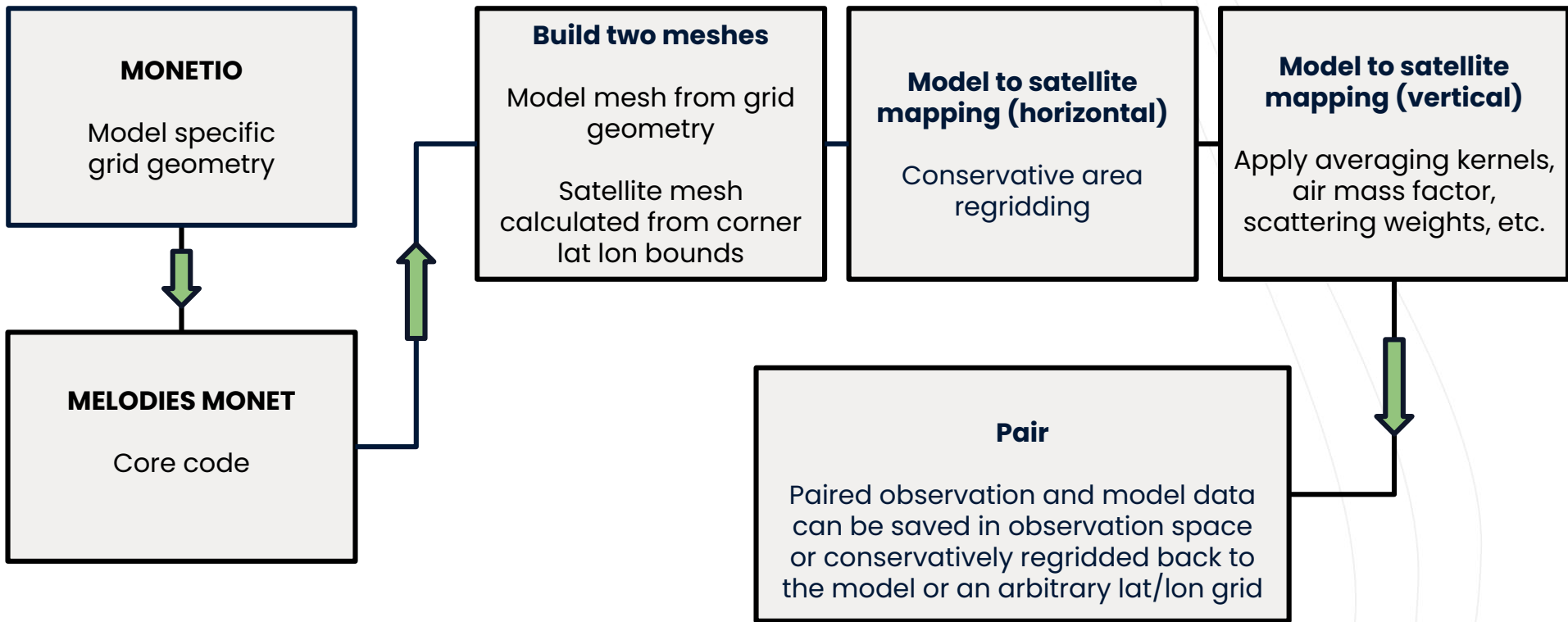
MELODIES MONET

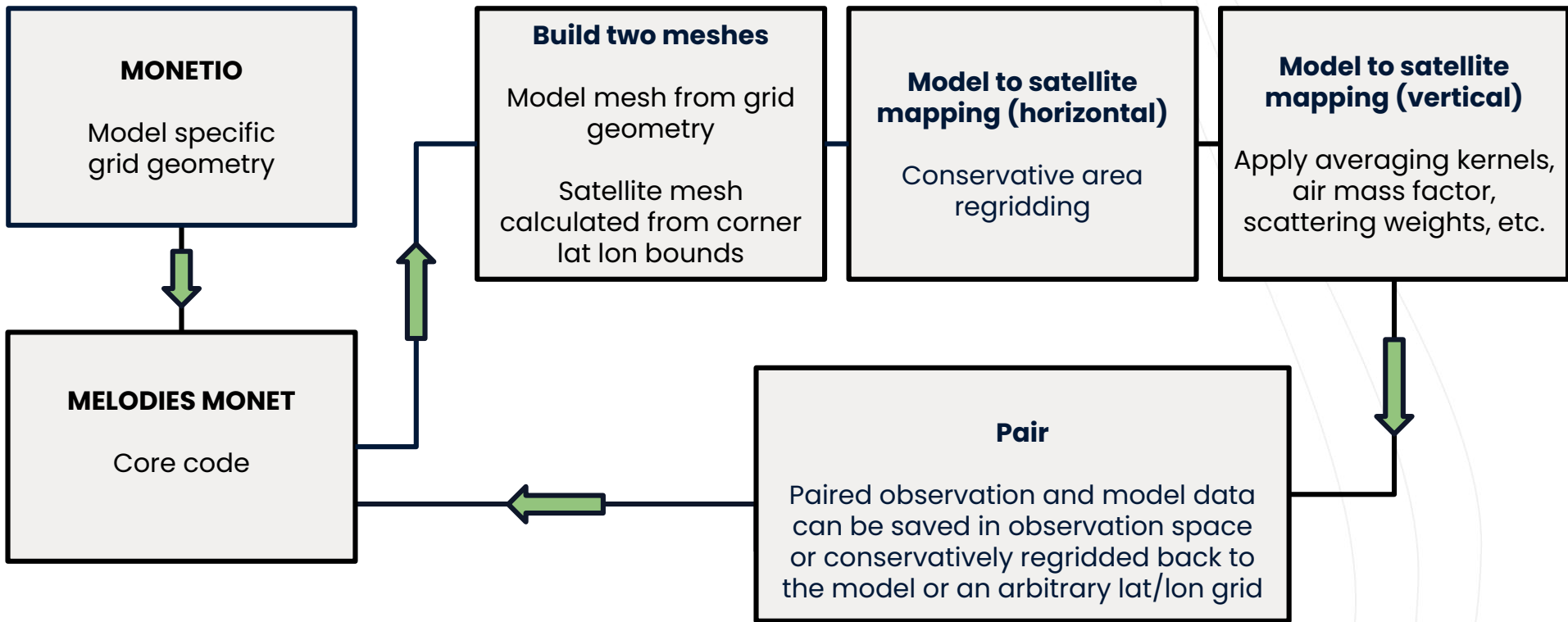
Core code

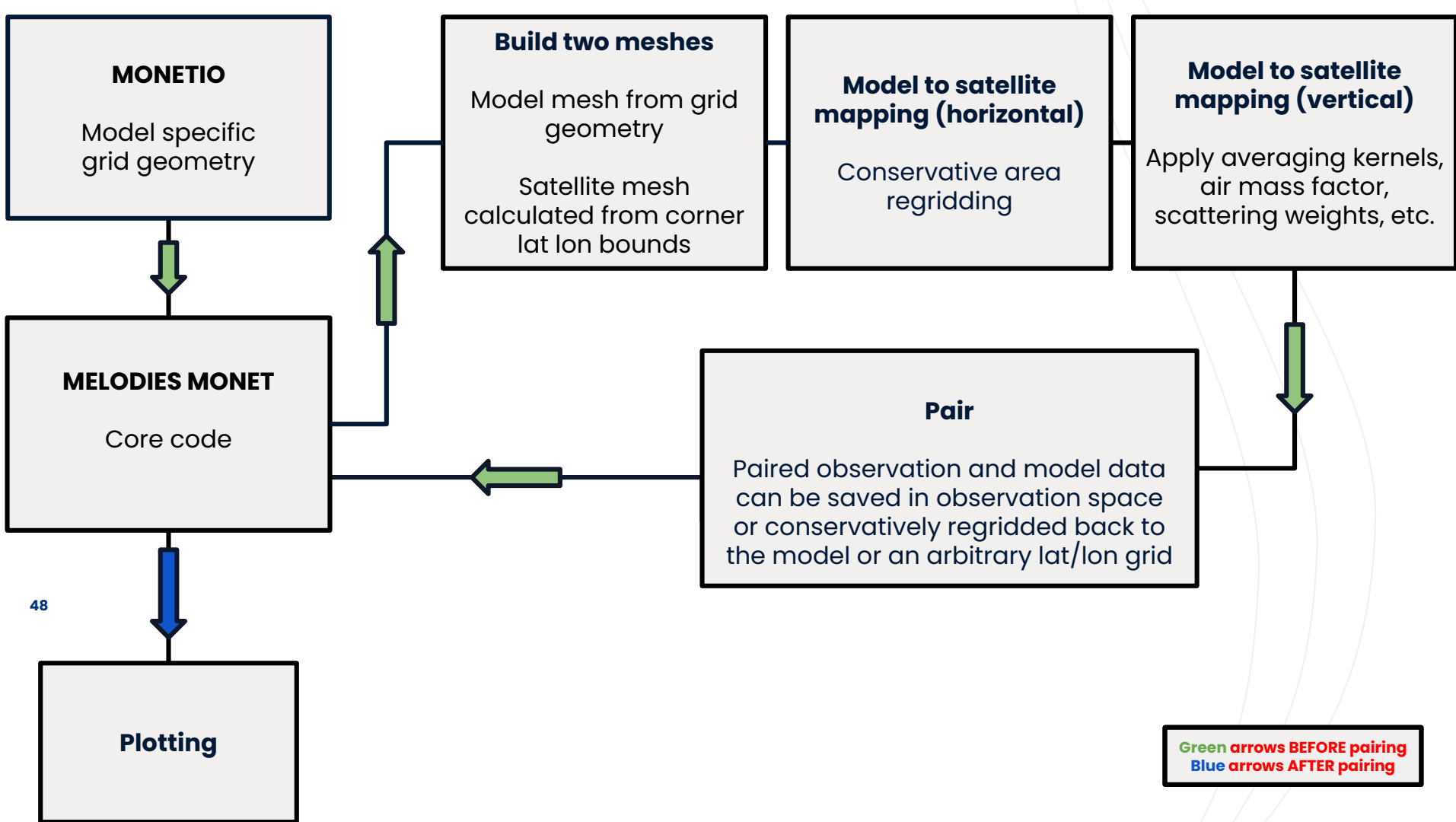


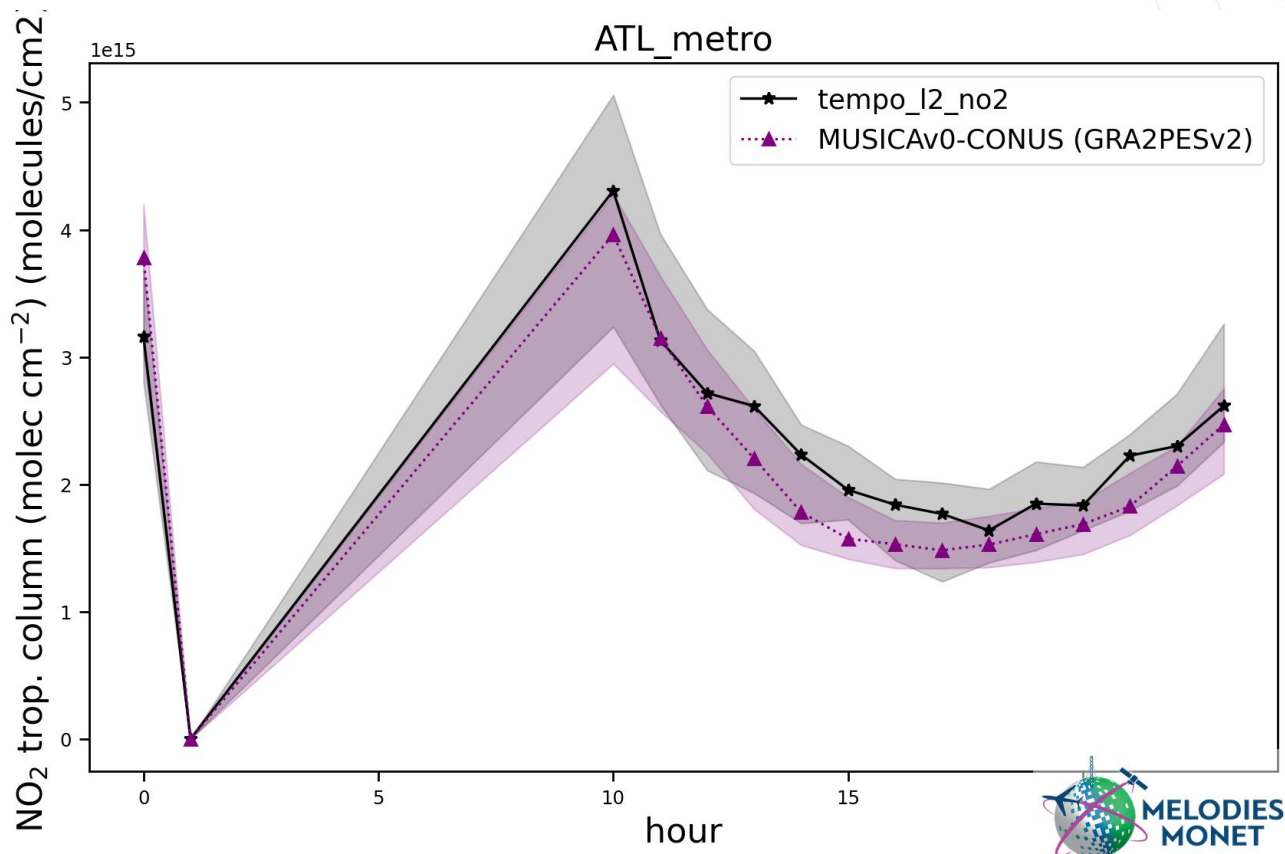




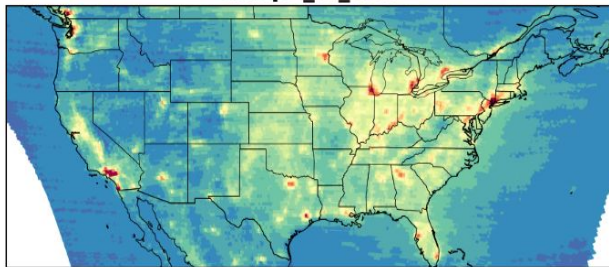




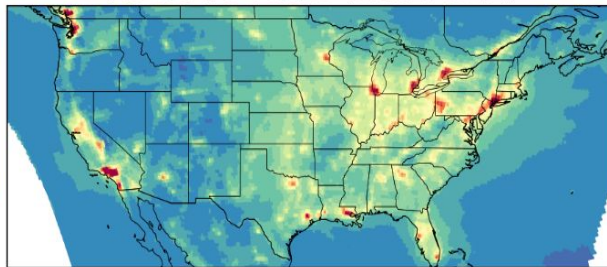




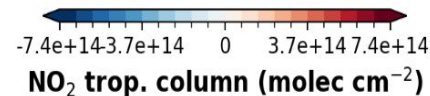
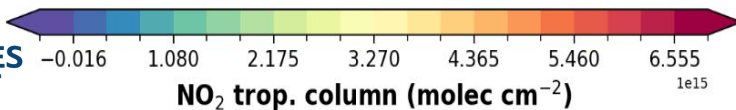
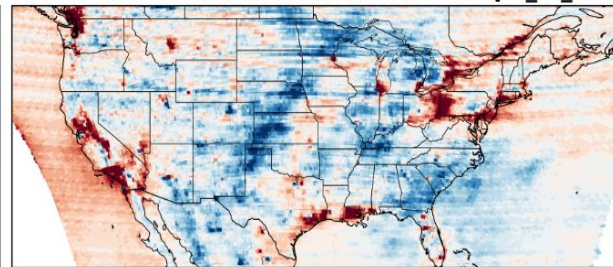
tempo_l2_no2



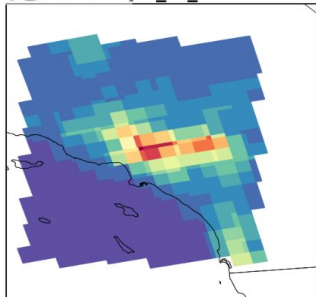
MUSICAv0-CONUS (GRA2PESv2)



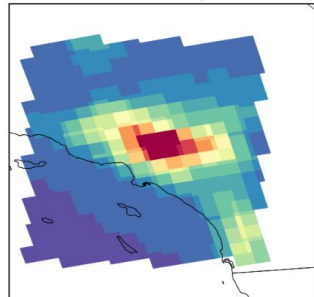
MUSICAv0-CONUS (GRA2PESv2) - tempo_l2_no2



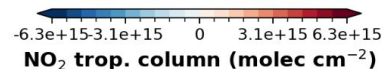
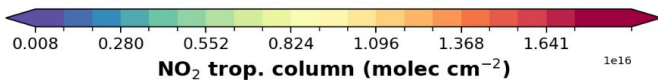
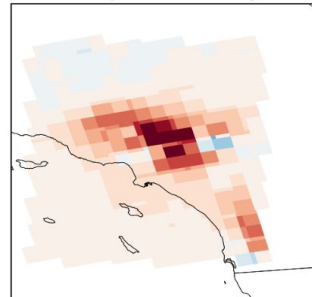
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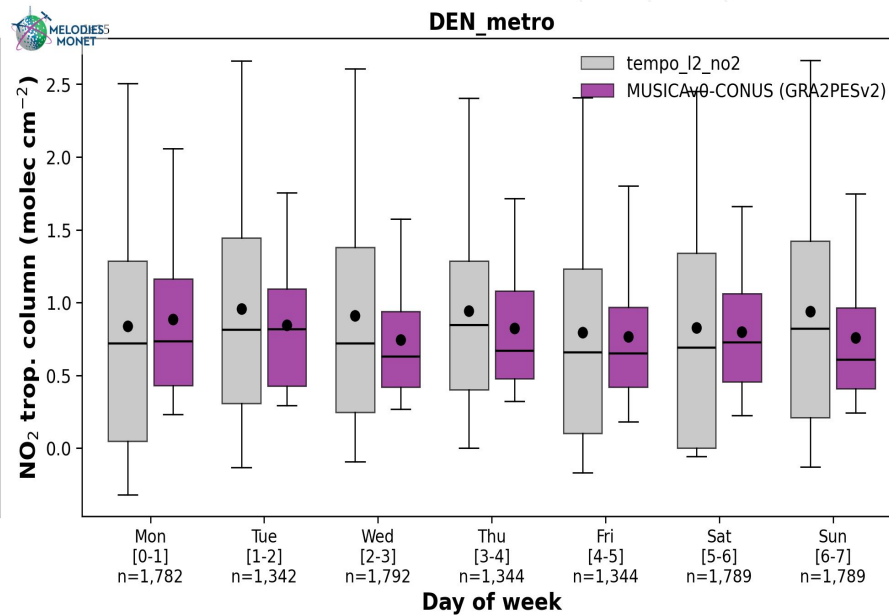
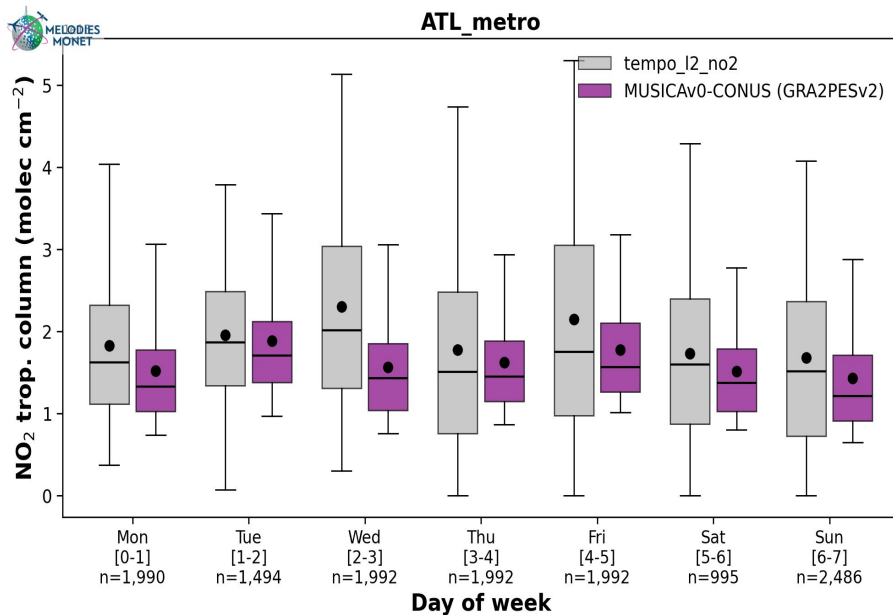


LA_metro
MUSICAv0-CONUS (GRA2PESv2)



MUSICAv0-CONUS (GRA2PESv2) - tempo_l2_no2





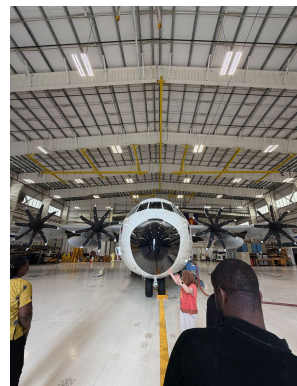
NSF SCENICS & NASA HAMAQ

Stereoscopy of Multi-scale Chemical Exchanges and Interactions between a City and its Surroundings

NASA Hemispheric Airborne Measurements of Air Quality

Objectives include:

- ❖ Improving connections between satellites and surface networks through chemically detailed, vertically- and diurnally-resolved in-situ measurements
- ❖ Investigating and further developing satellite proxies for air quality
- ❖ Investigating the complex factors controlling air quality across urban areas





MELODIES-MONET can now

***natively read, pair, & plot unstructured
model grids* for surface, aircraft, & satellite
observations**





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Thank you to Ben Gaubert, Orhan Eroglu, Virginia Do, the SIPARCS
interns, SIPARCS Program, CISL, & ACOM

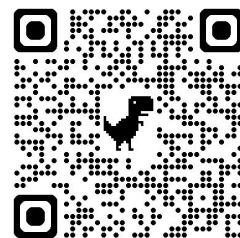


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Questions?