MUSICA
Multiscale Infrastructure for Chemistry and Aerosols

What is MUSICA?
How does MUSICA compare to WRF-Chem?
And going to higher resolution

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

What is MUSICA?

MUSICA

Multiscale Infrastructure for Chemistry and Aerosols

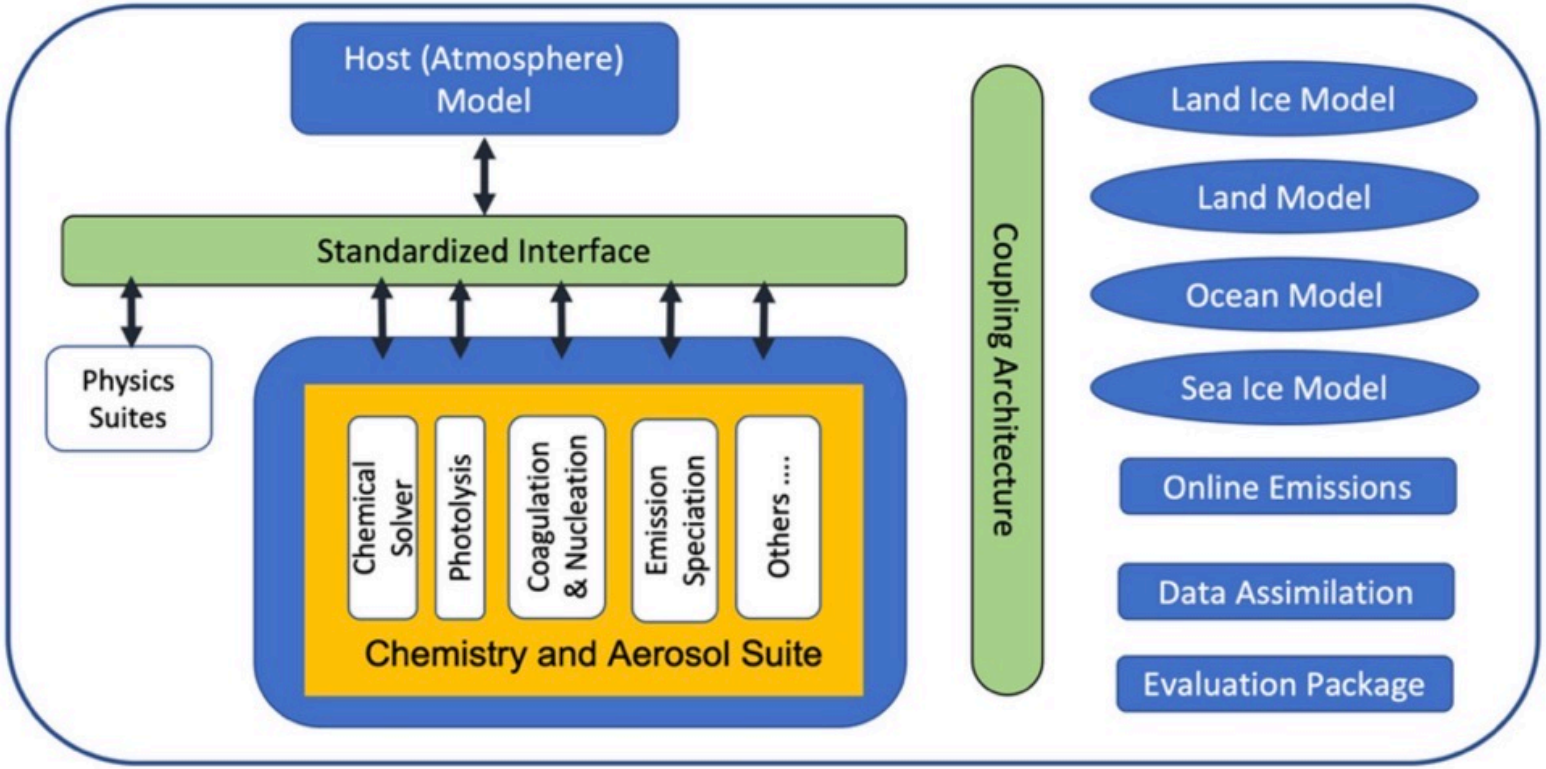
A new model-independent infrastructure, which will enable chemistry and aerosols to be simulated at different resolutions in a coherent fashion

To be developed collaboratively with university and government researchers

Vision of MUSICA

MUSICA
Multiscale Infrastructure for Chemistry and Aerosols

1. **Modularized** for flexibility
2. **Coupled** to other **Earth system** component models
3. **Whole atmosphere** framework: troposphere to thermosphere



Vision of MUSICA

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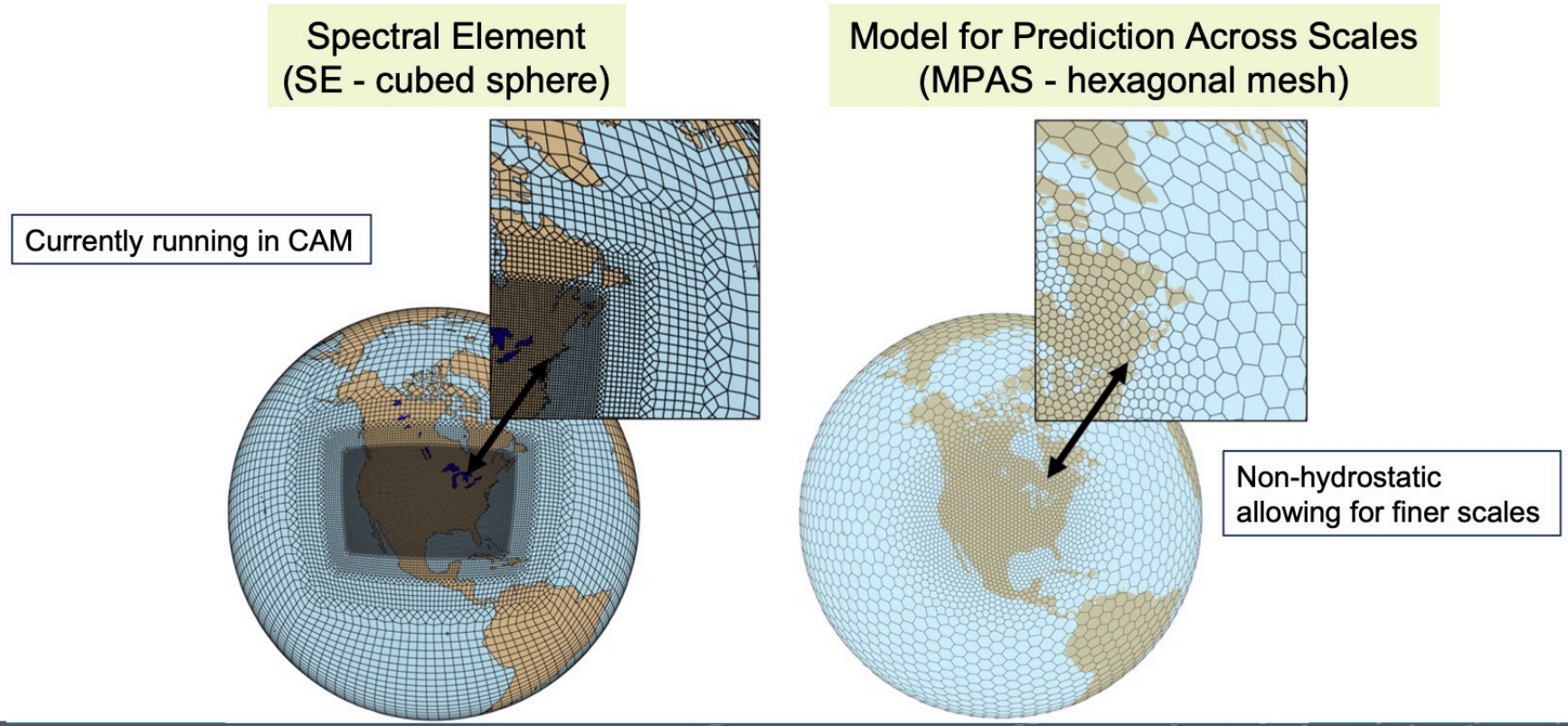
Multiscale Infrastructure for Chemistry and Aerosols

4 Choices for variable resolution atmosphere models

5 Allows for the simulation of large-scale atmospheric phenomena, while still resolving chemistry at emission and exposure relevant scales



Vision of MUSICA

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6 No need to deal with boundary conditions!

7 Simulating **global impacts and interactions** (long-range transport, inflow, outflow, etc) in a consistent and coherent way

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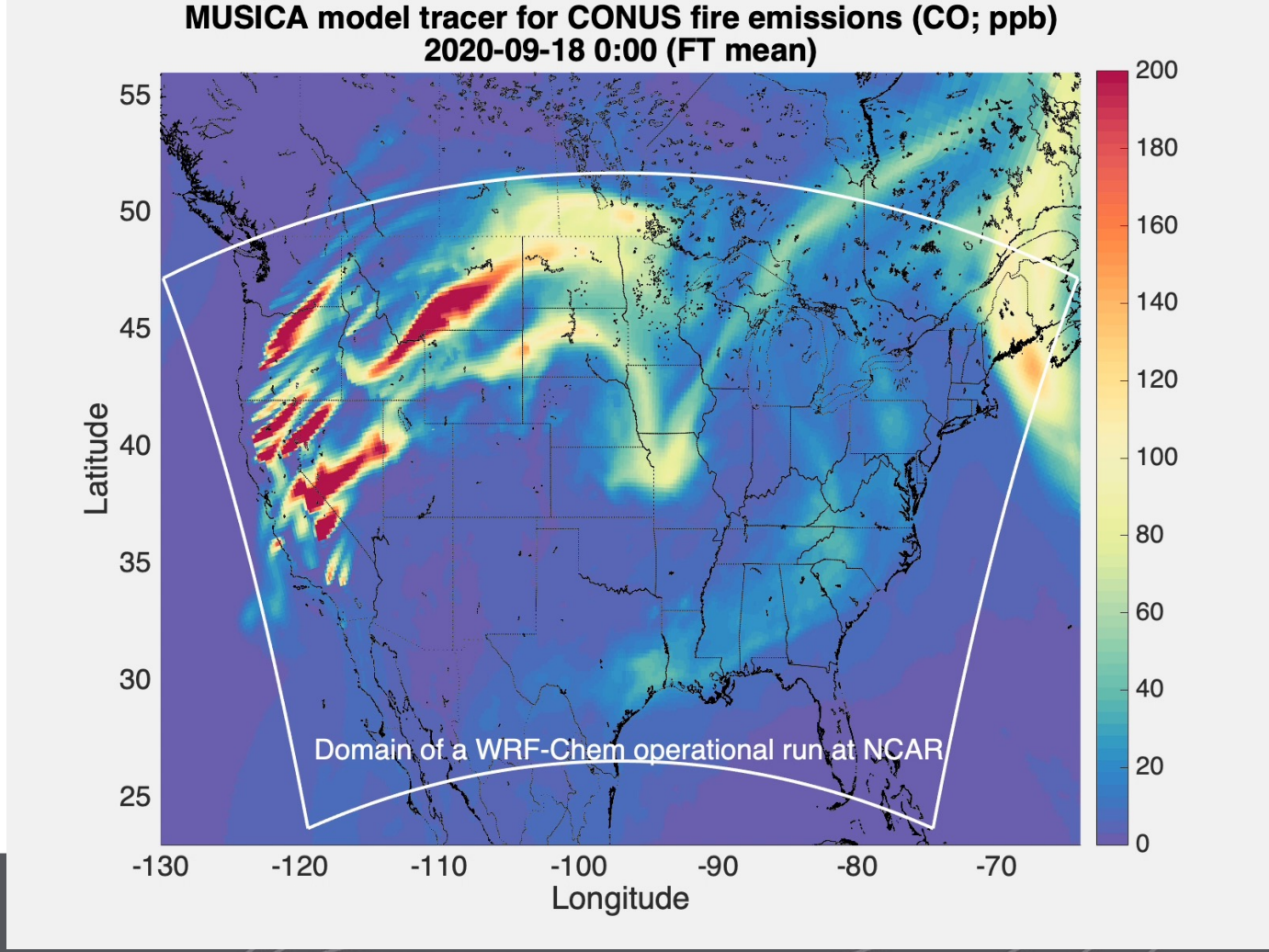
Example:
Accounting for interactions outside the domain:

6 No need to deal with boundary conditions!

7 Simulating **global impacts and interactions** (long-range transport, inflow, outflow, etc) in a consistent and coherent way



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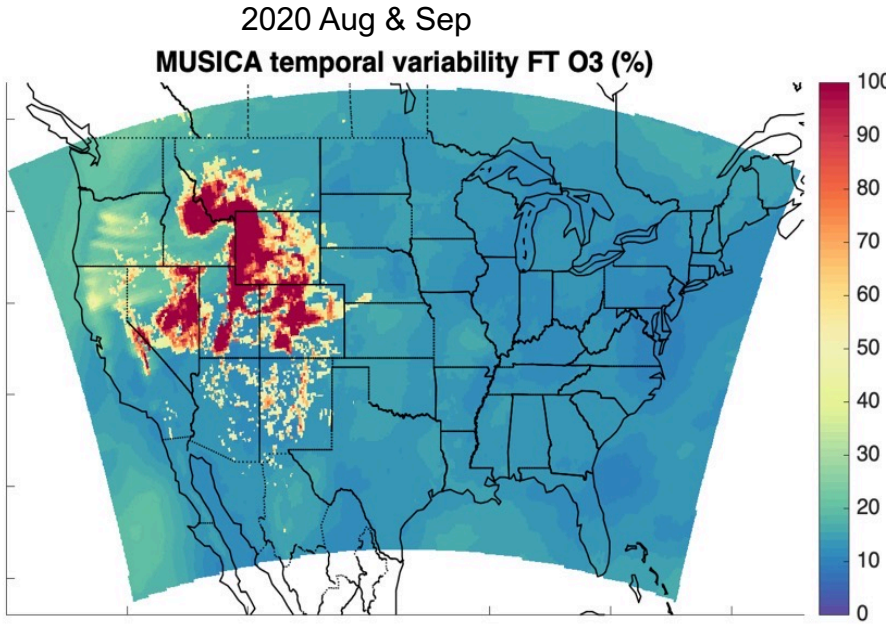
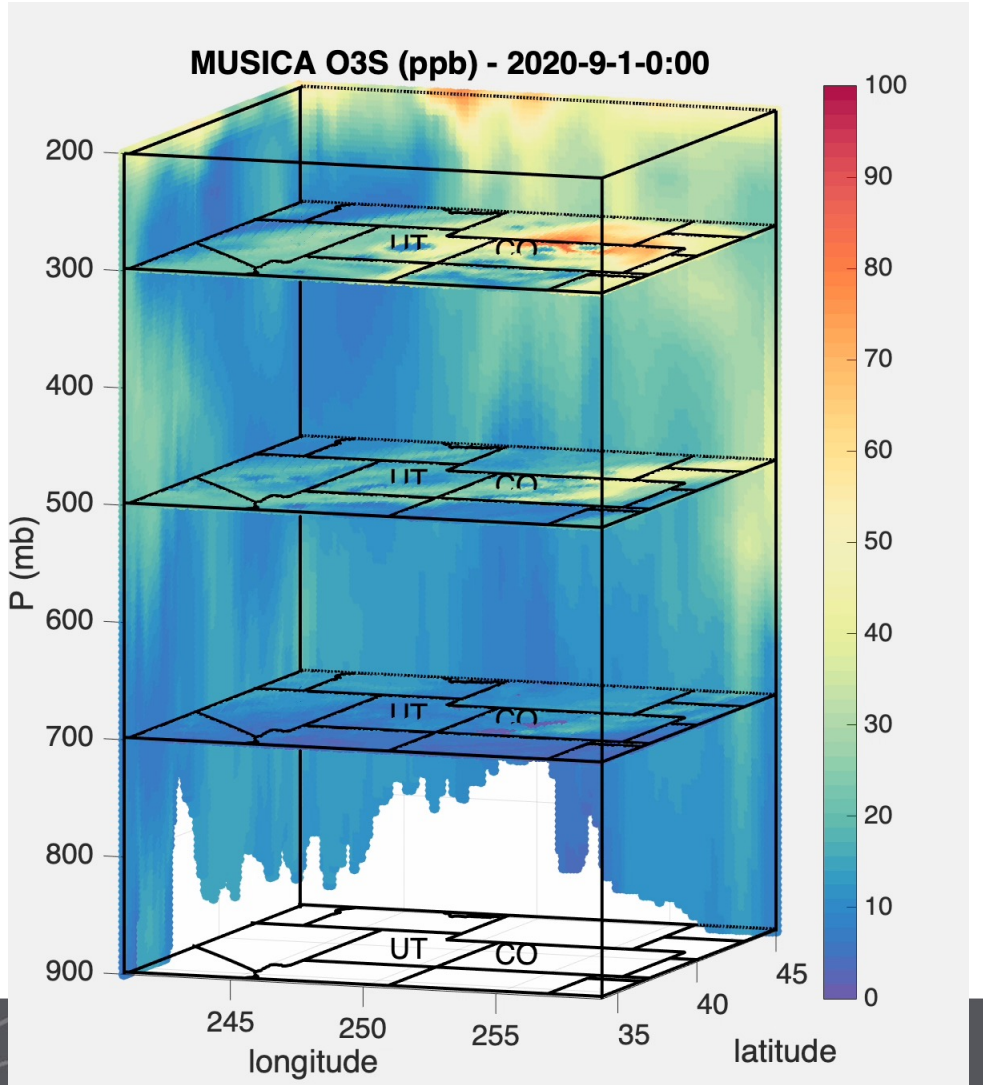
6 No need to deal with boundary conditions!

7 Simulating **global impacts and interactions** (long-range transport, inflow, outflow, etc) in a consistent and coherent way



Example:
Accounts for full stratospheric chemistry which is important for STE



NCAR | UCAR

Vision of MUSICA

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6 No need to deal with boundary conditions!

7 Simulating **global impacts and interactions** (inflow, outflow, etc) in a consistent and coherent way

8 For the shown simulations computational cost of MUSICA is similar to WRF-Chem

9 Fairly straightforward to run

10 User resources online

MUSICAv0 – released in CESM2.2

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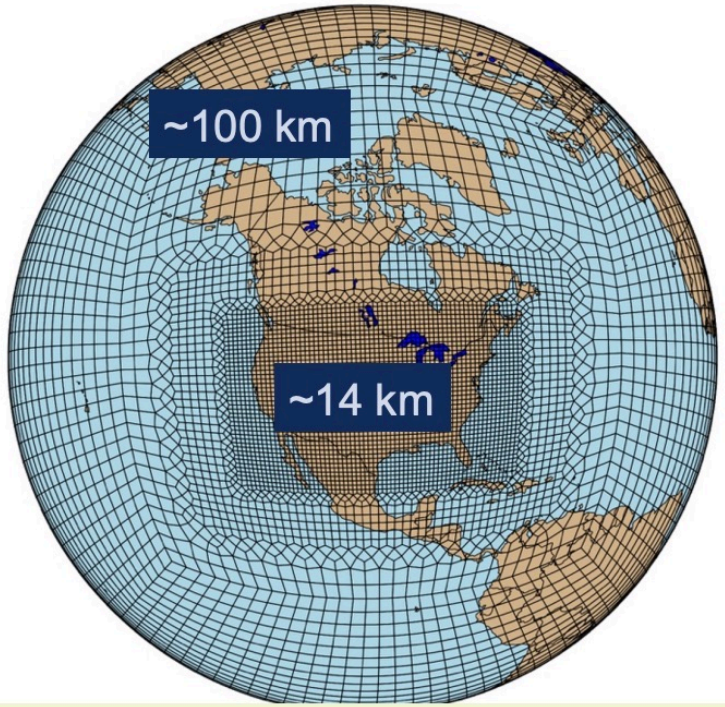

Users can create their own grids

MUSICAv0 is a configuration of the Community Earth System Model (**CESM**):

CAM-chem (Community Atmosphere Model with Chemistry) With Spectral Element (SE) dynamical core and Regional Refinement (RR) [CAM-chem-SE-RR]

How does MUSICA compare to WRF-Chem?

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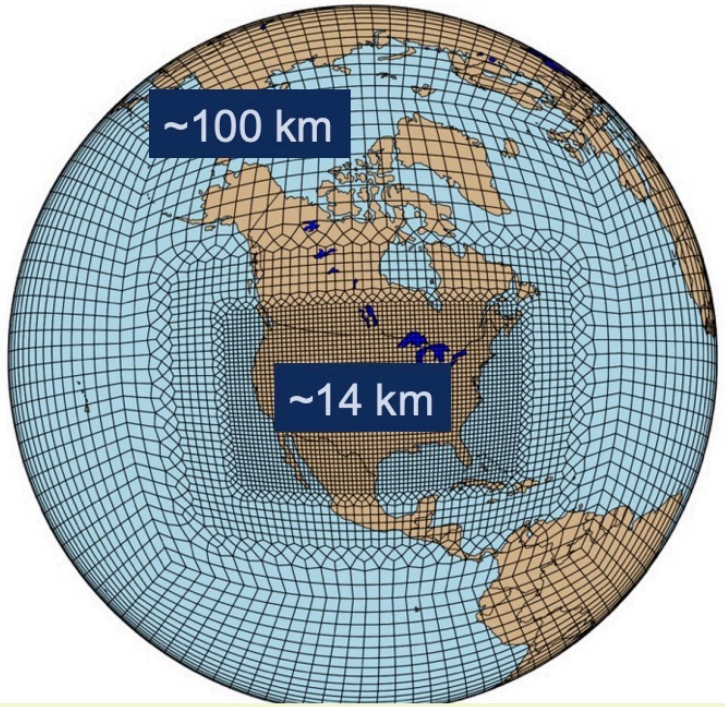


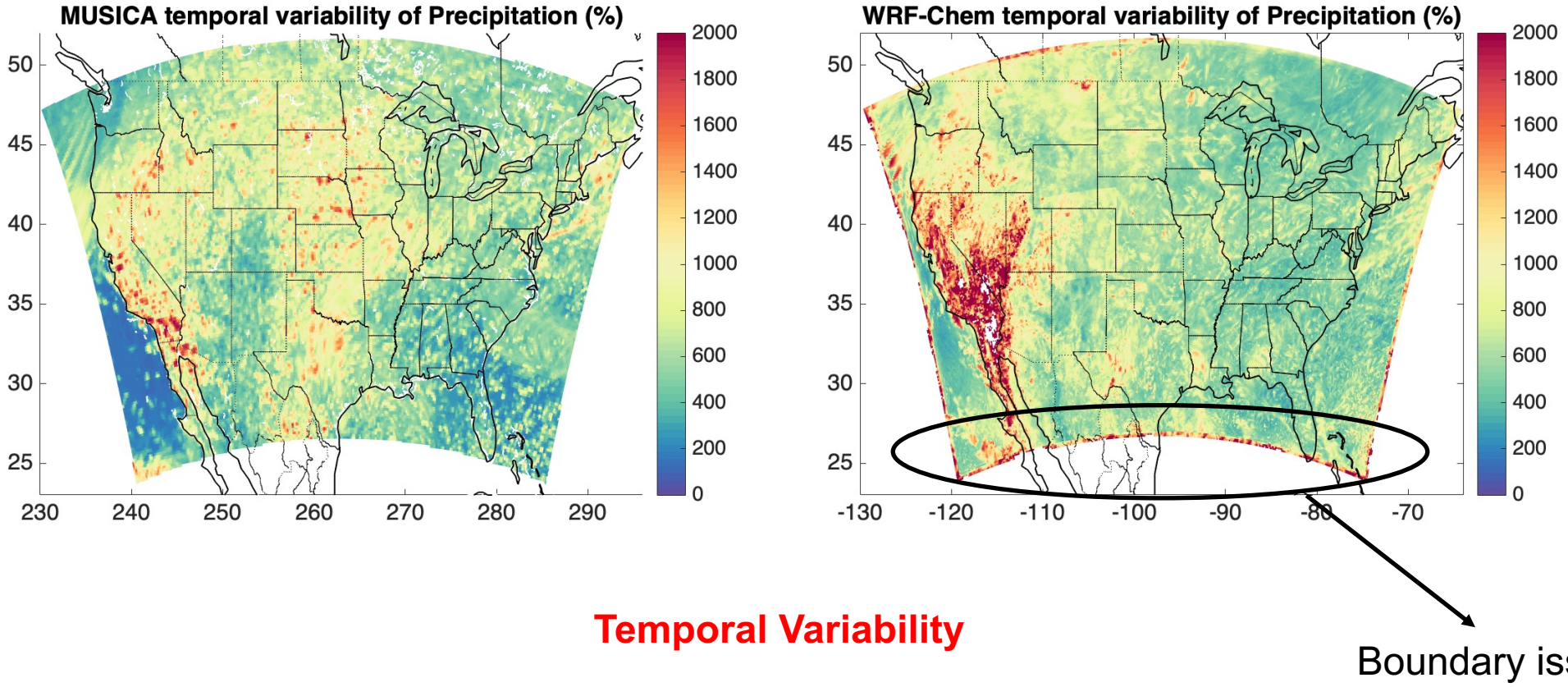
Users can create their own grids

To demonstrate the value of MUSICAv0 at the regional scale, we show that **the MUSICAv0's capability of representing regional-scale features is comparable to that of regional models.**

Here we compare MUSICAv0 with 2 WRF-Chem simulations (with resolution of ~12km).

How does MUSICA compare to WRF-Chem?

Precipitation Variability Aug and Sep 2020



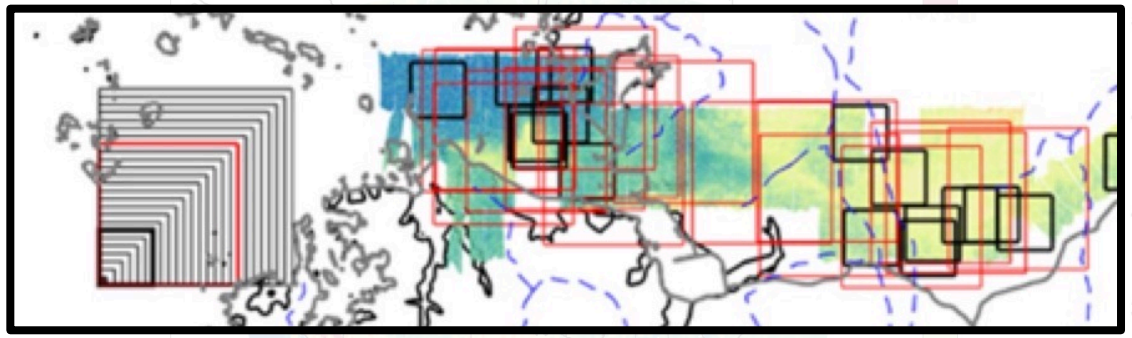
Temporal Variability

Boundary issue

Temporal variability at a model grid is represented by standard deviation of 3-hourly data in Aug and Sep 2020 (data at 00:00 UTC are excluded for precipitation)

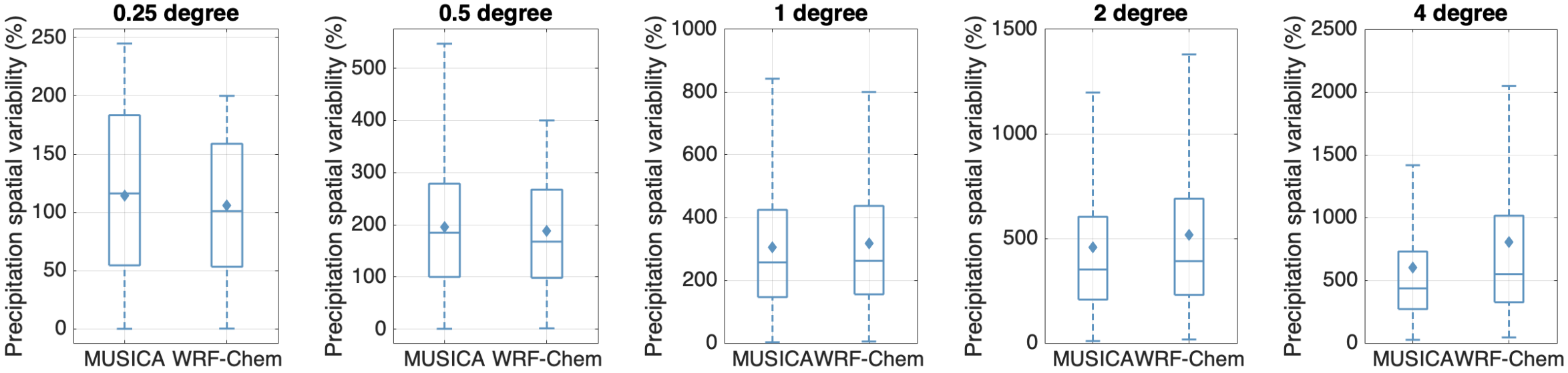
How does MUSICA compare to WRF-Chem?

Precipitation Variability Aug and Sep 2020



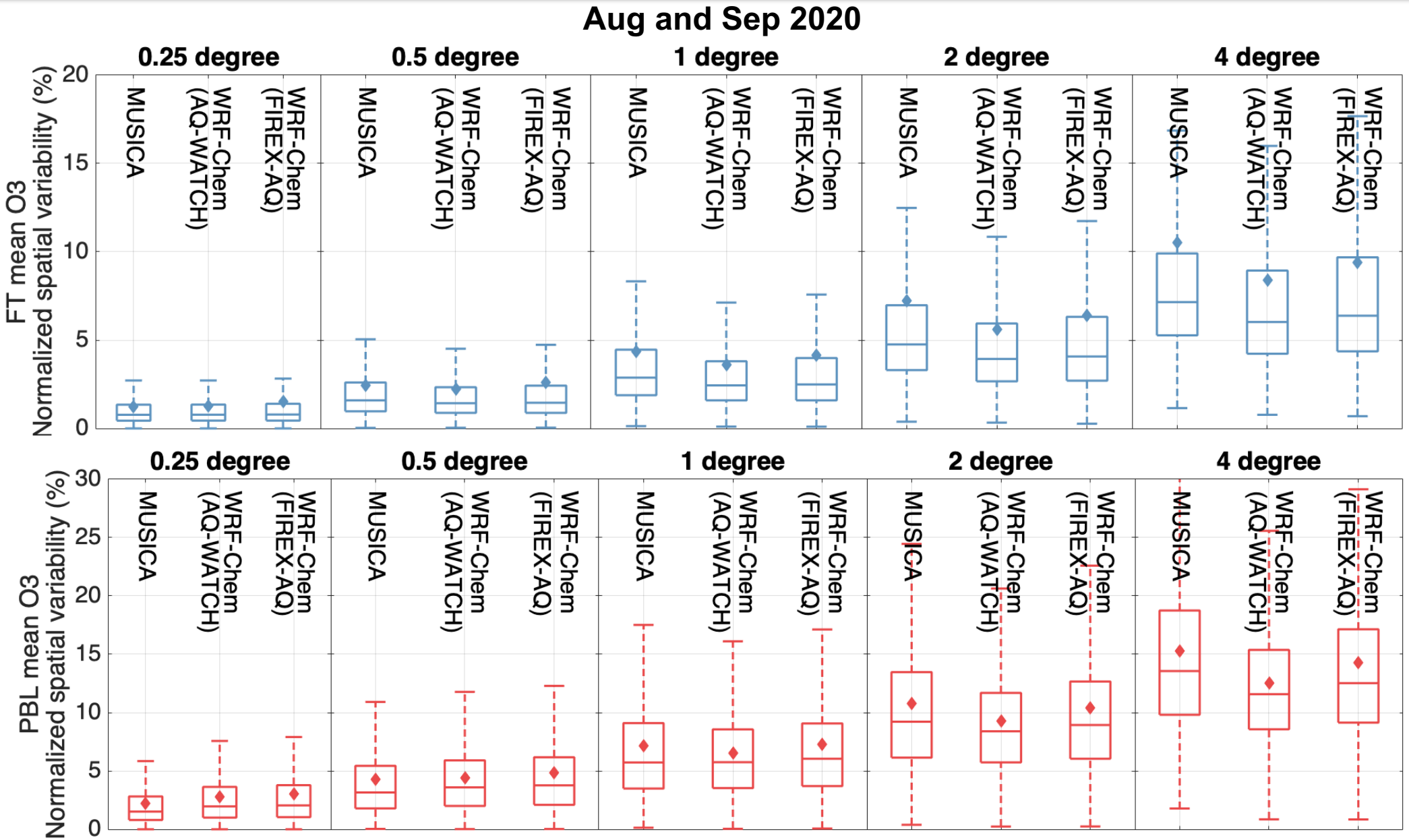
Spatial variability at a given spatial scale is represented by the variability of model grids within the randomly drawn boxes at that scale.

Spatial Variability



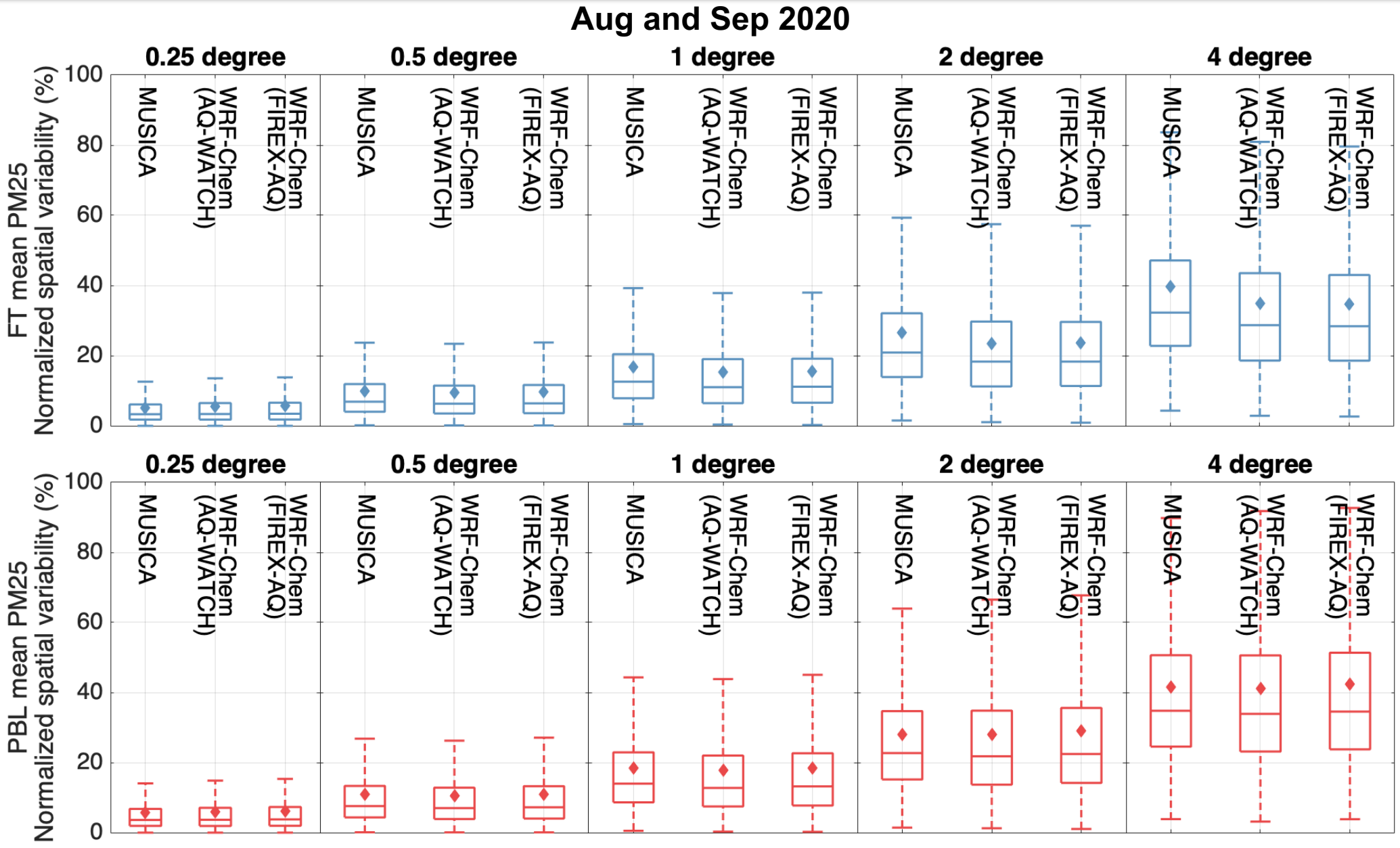
How does MUSICA compare to WRF-Chem?

O_3 spatial variability at different scales



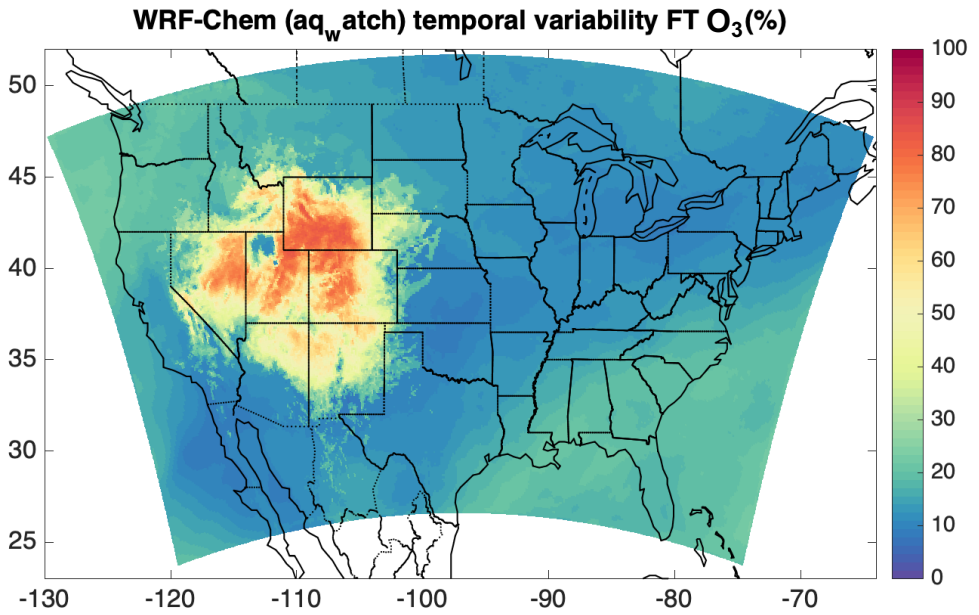
How does MUSICA compare to WRF-Chem?

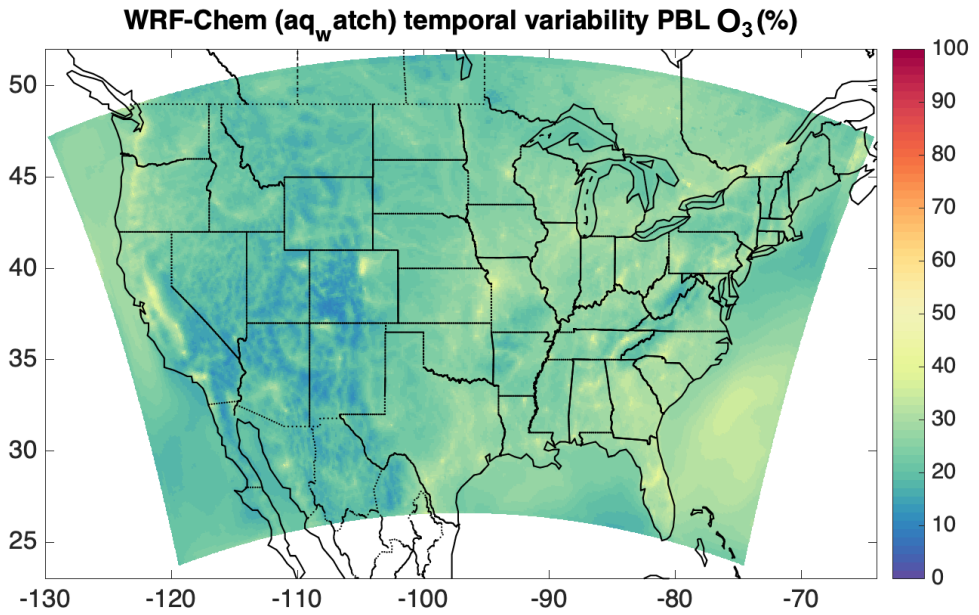
$PM_{2.5}$ spatial variability at different scales

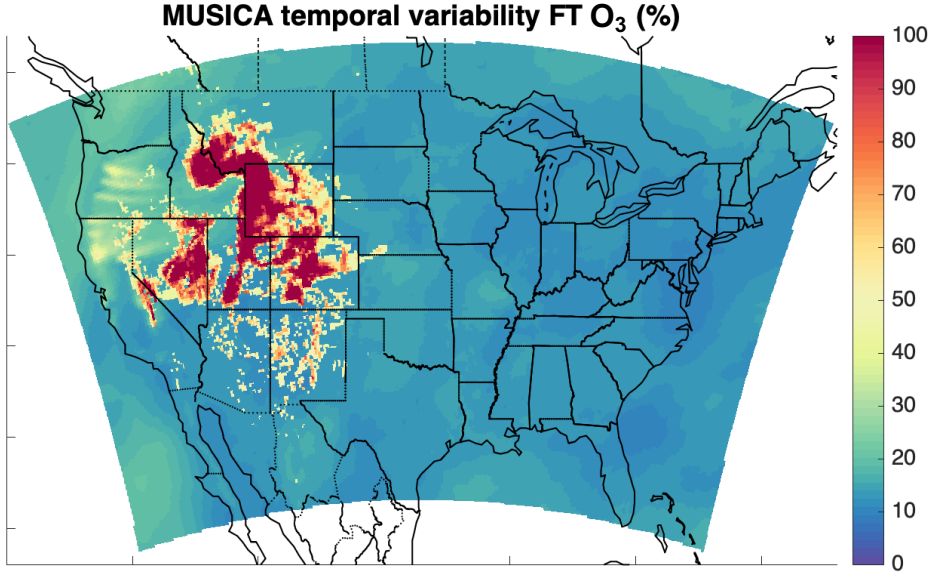


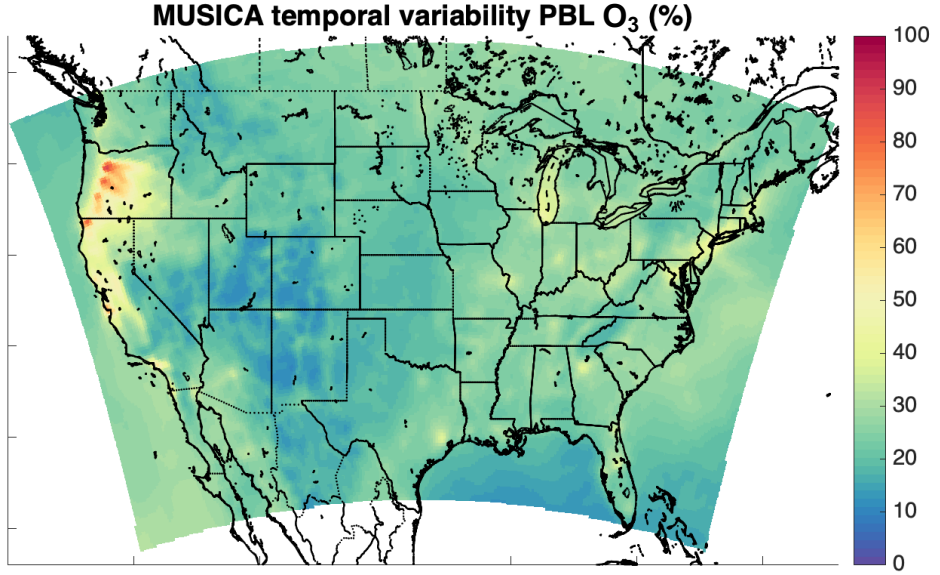
How does MUSICA compare to WRF-Chem?

O_3 Temporal Variability





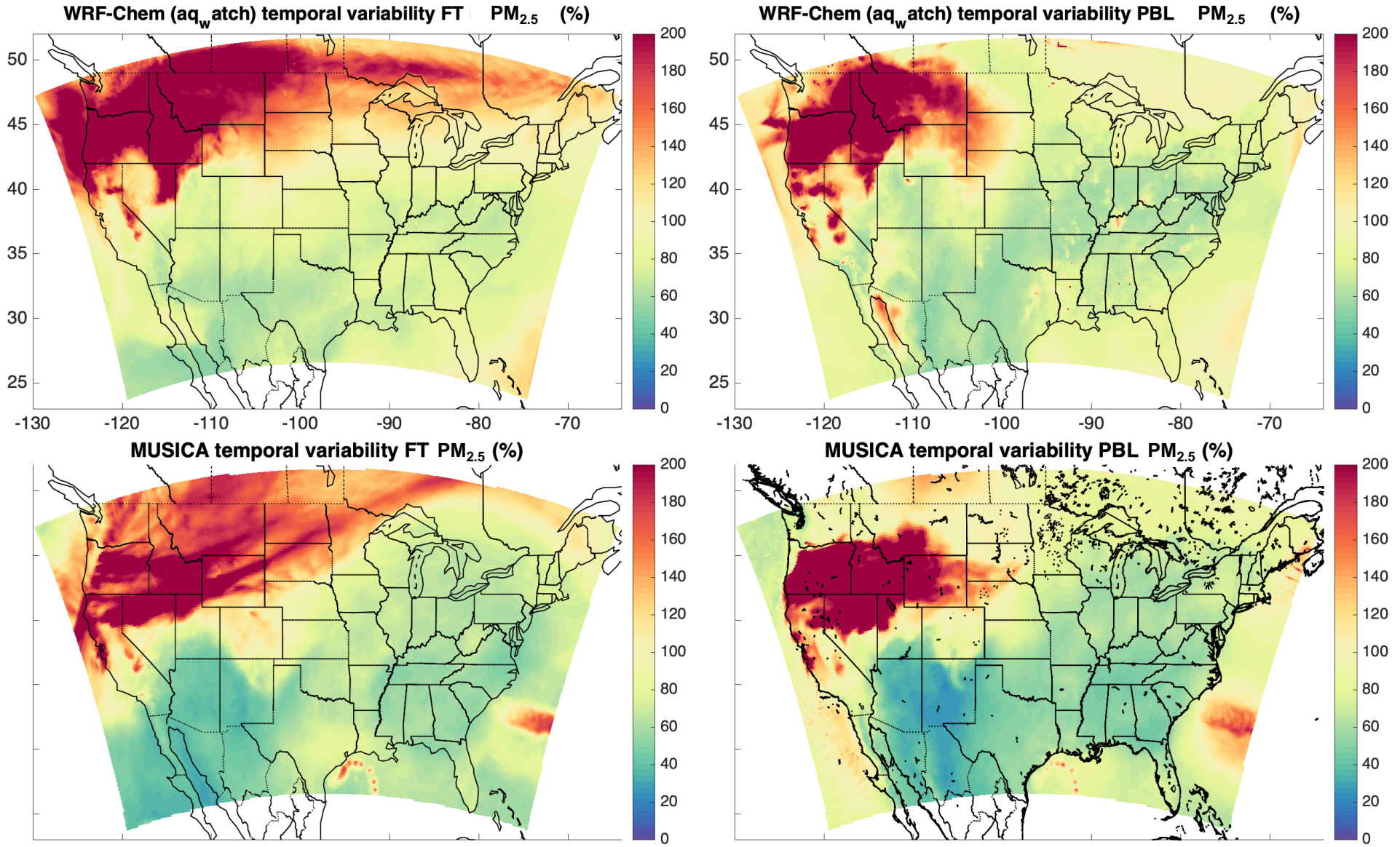




Aug and Sep 2020

How does MUSICA compare to WRF-Chem?

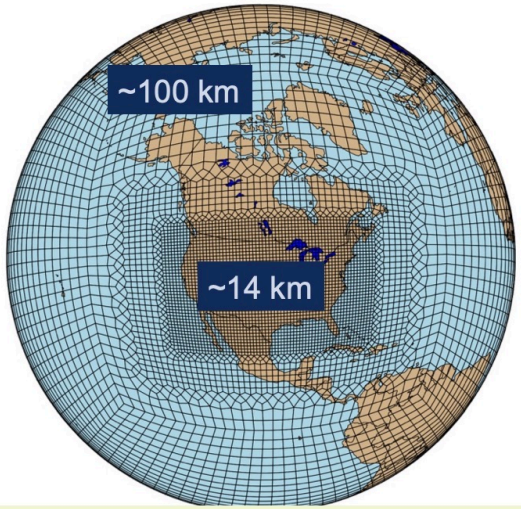
$PM_{2.5}$ Temporal Variability



Aug and Sep 2020

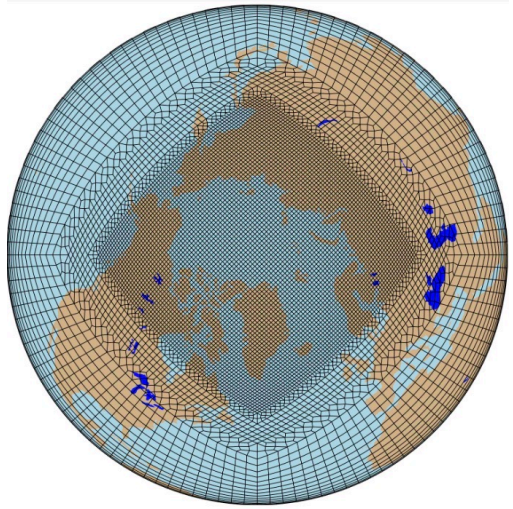
Current applications of MUSICAvo

CONUS

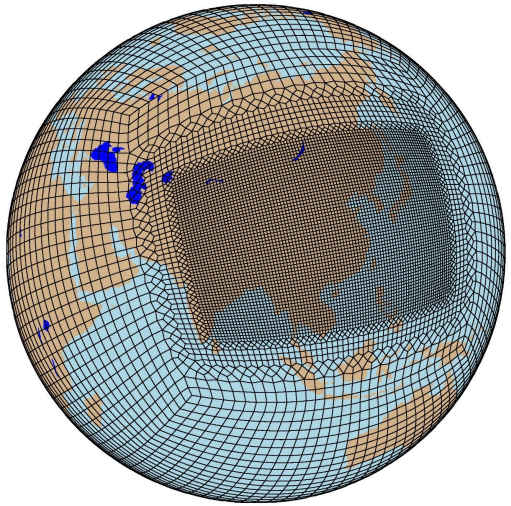


Users can create their own grids

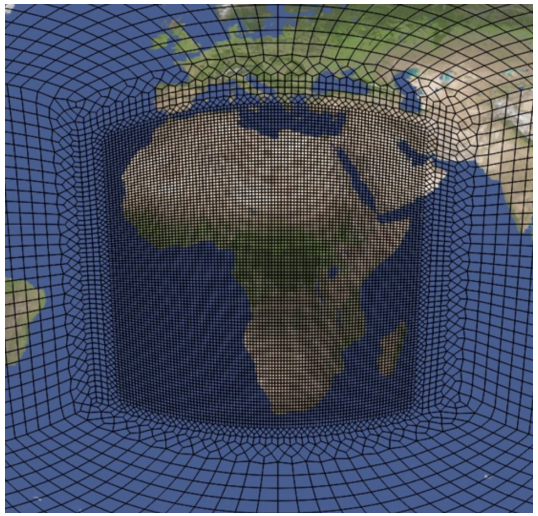
Arctic

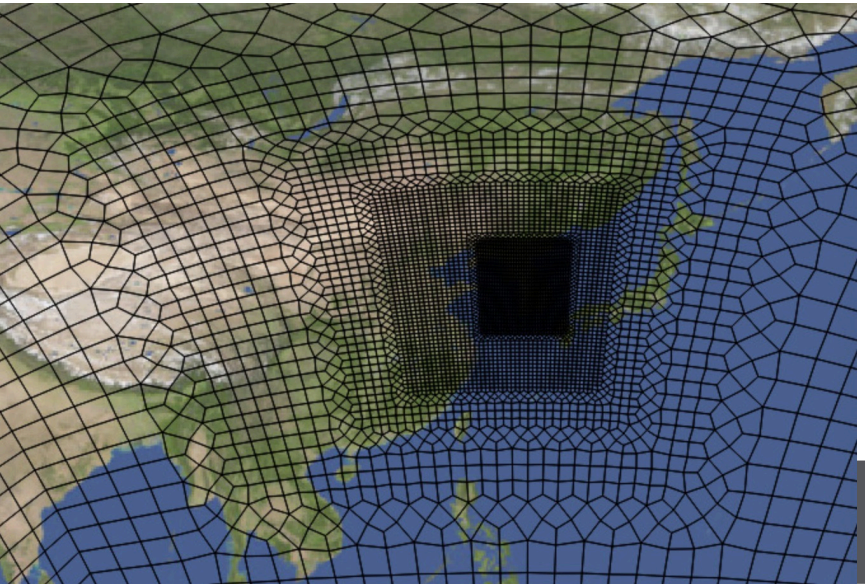


Asia



Africa





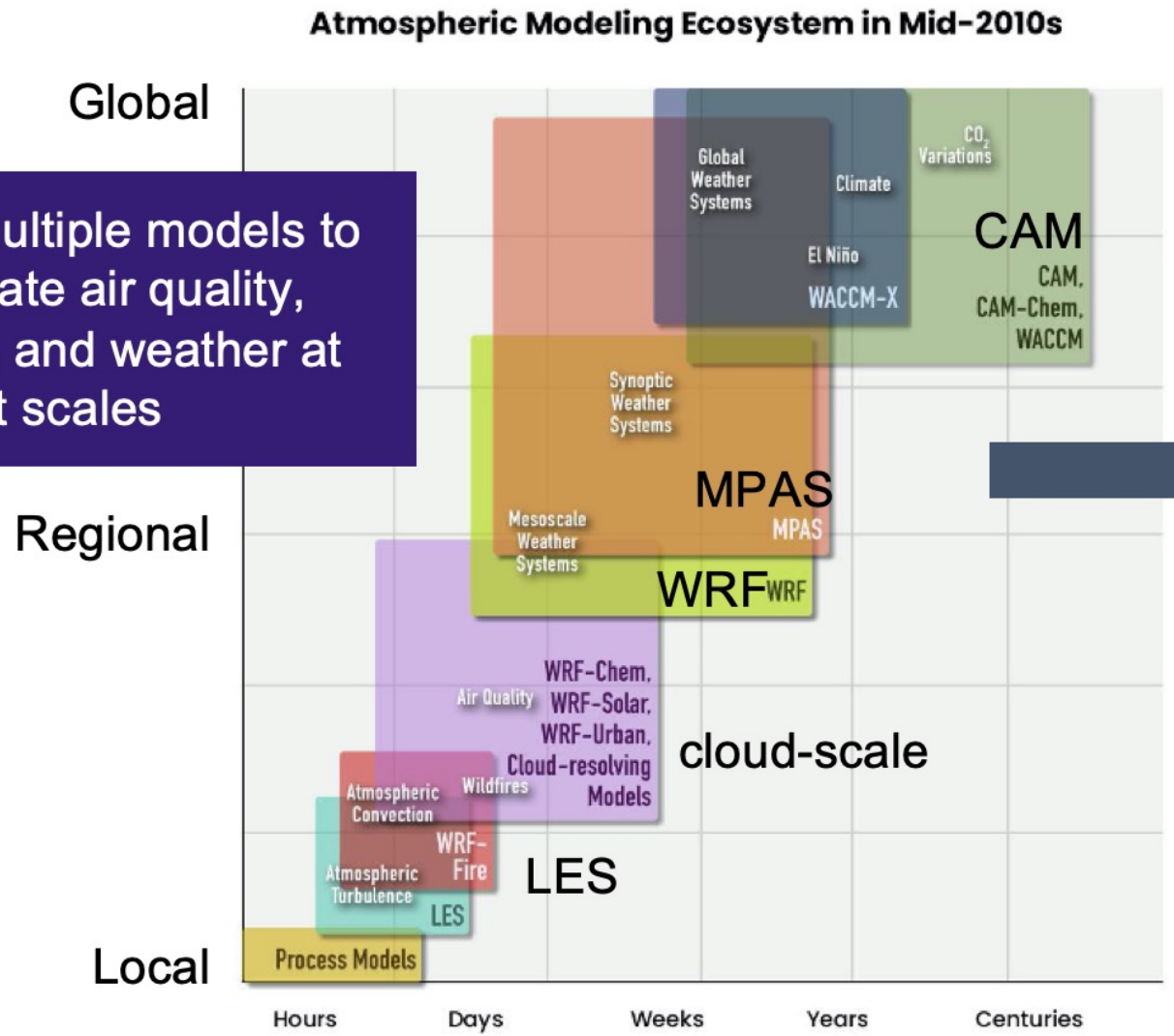
Korea (6 km)

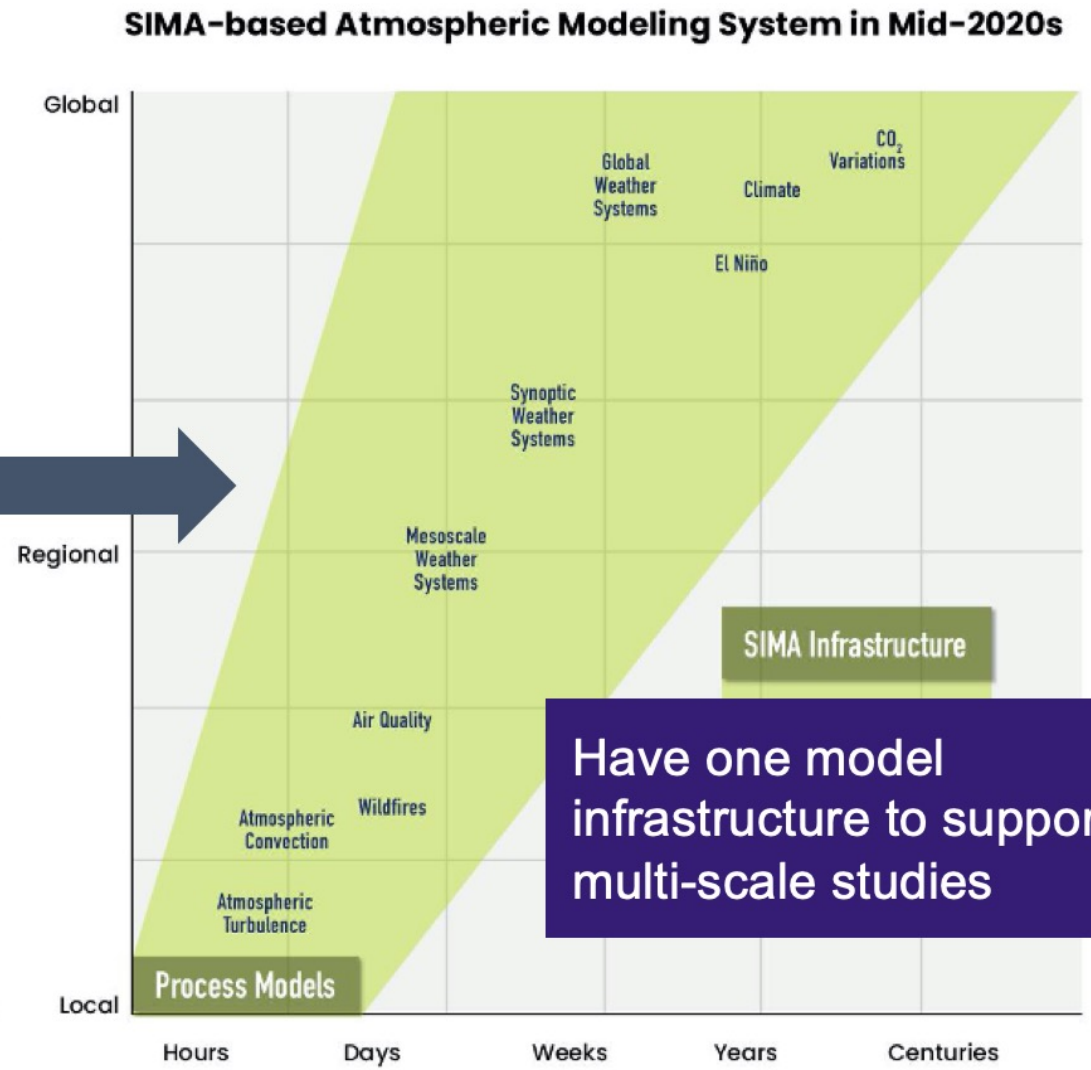
https://wiki.ucar.edu/display/MUSICA/Available+Grids

And going to higher resolution …

https://sima.ucar.edu/

Need multiple models to investigate air quality, climate, and weather at different scales

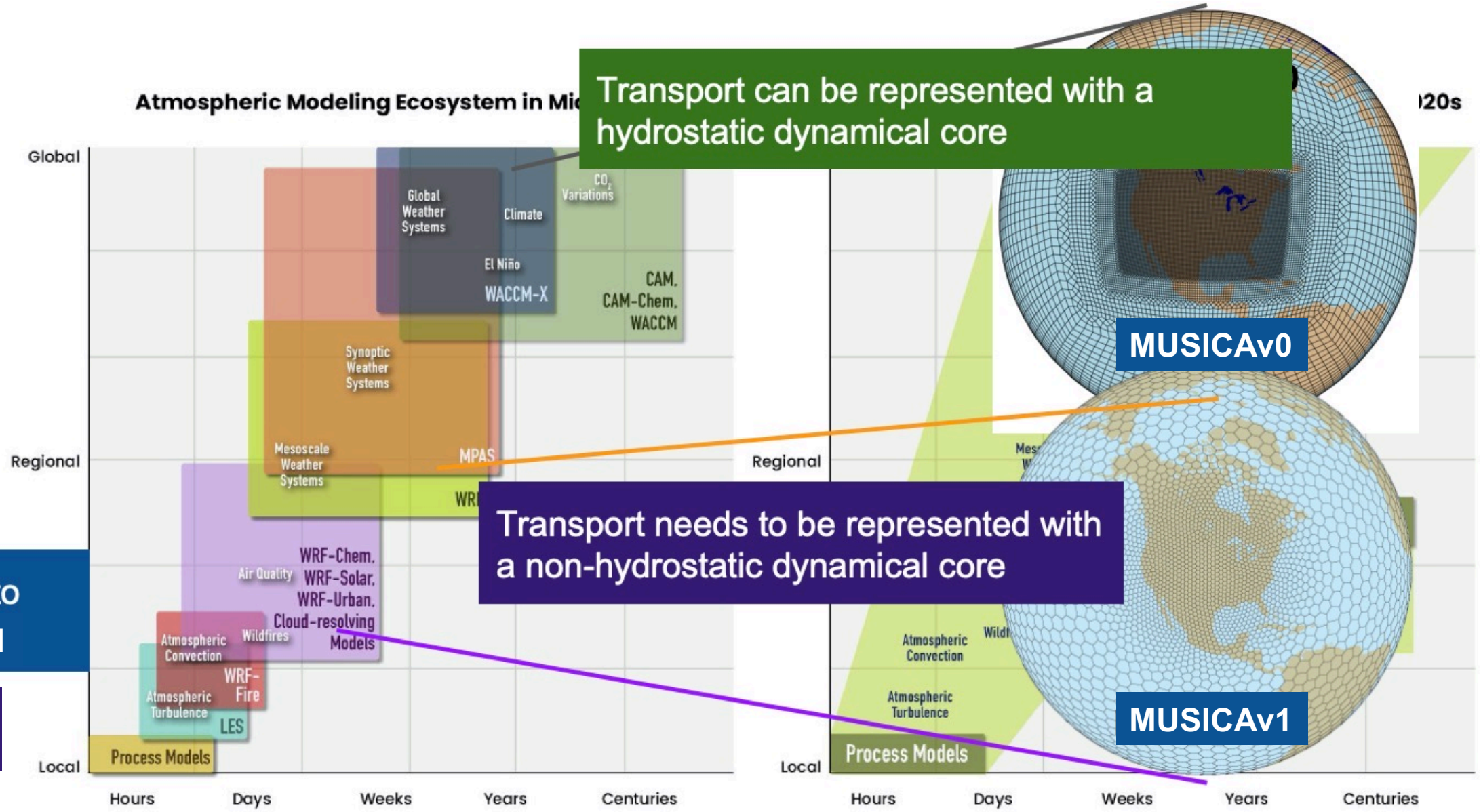




Have one model infrastructure to support multi-scale studies

And going to higher resolution …

System for Integrated Modeling of the Atmosphere:



➢ Progress to **MUSICAv1**

MPAS

Take home messages

1. **MUSICA is a new model-independent infrastructure, which will enable chemistry and aerosols to be simulated at different resolutions in a coherent fashion.**
2. **The MUSICAv0's capability of representing regional-scale features is comparable to that of WRF-Chem.**
3. **MUSICA is to be developed collaboratively with university researchers and the community (Your contribution is welcomed!).**

- MUSICA tutorial (very useful and easy to follow):
  https://www2.acom.ucar.edu/workshop/musica-tutorial-2021
- For more information:
  https://www2.acom.ucar.edu/sections/multi-scale-chemistry-modeling-musica
- MUSICA Vision paper published in BAMS
  (Pfister et al., 2020: https://doi.org/10.1175/BAMS-D-19-0331.1)
- MUSICA evaluation against airborne data paper published in JAMES
  (Schwantes et al., 2022: https://doi.org/10.1029/2021MS002889)

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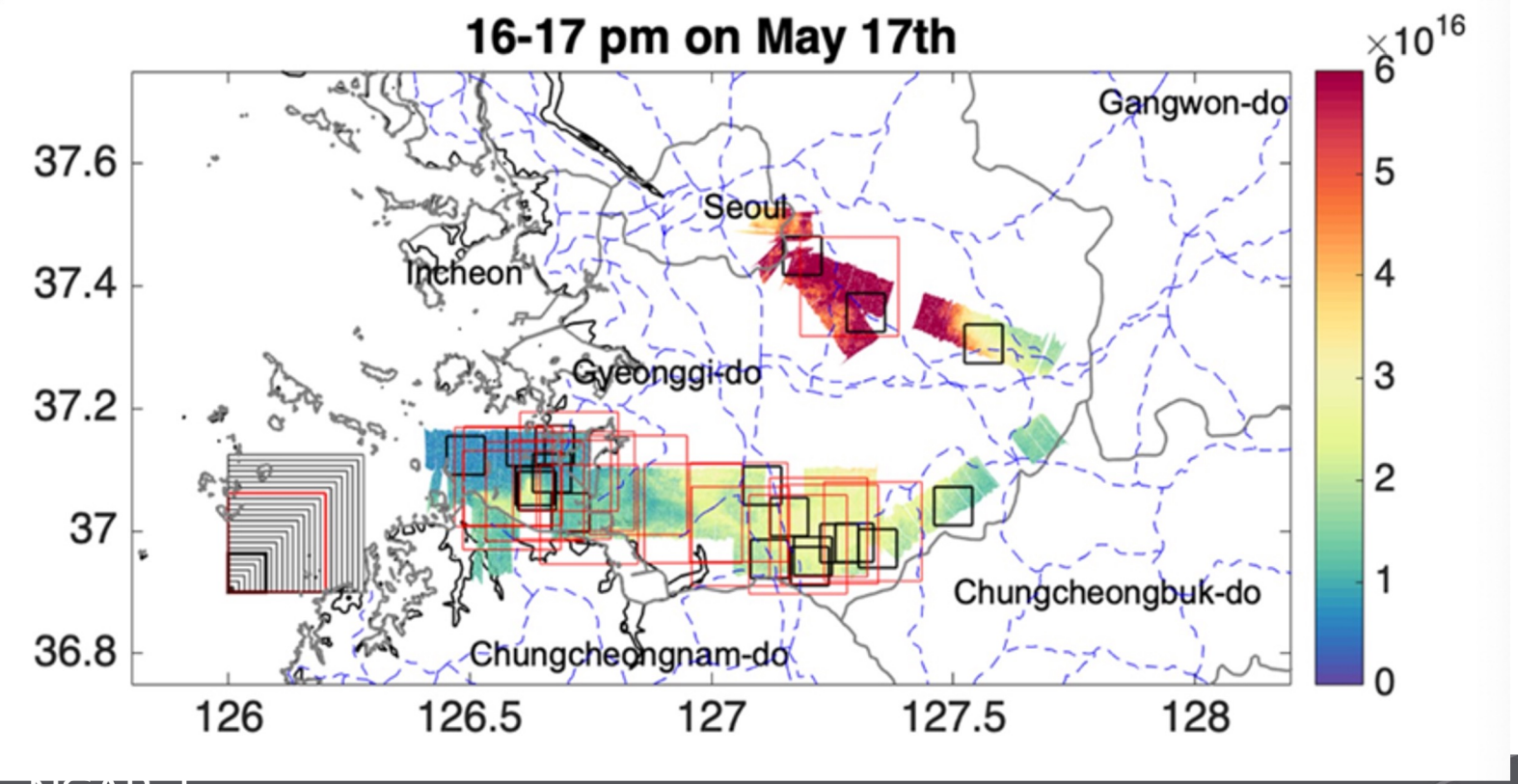
Spatial variability

Method to calculate spatial variability at different scale:



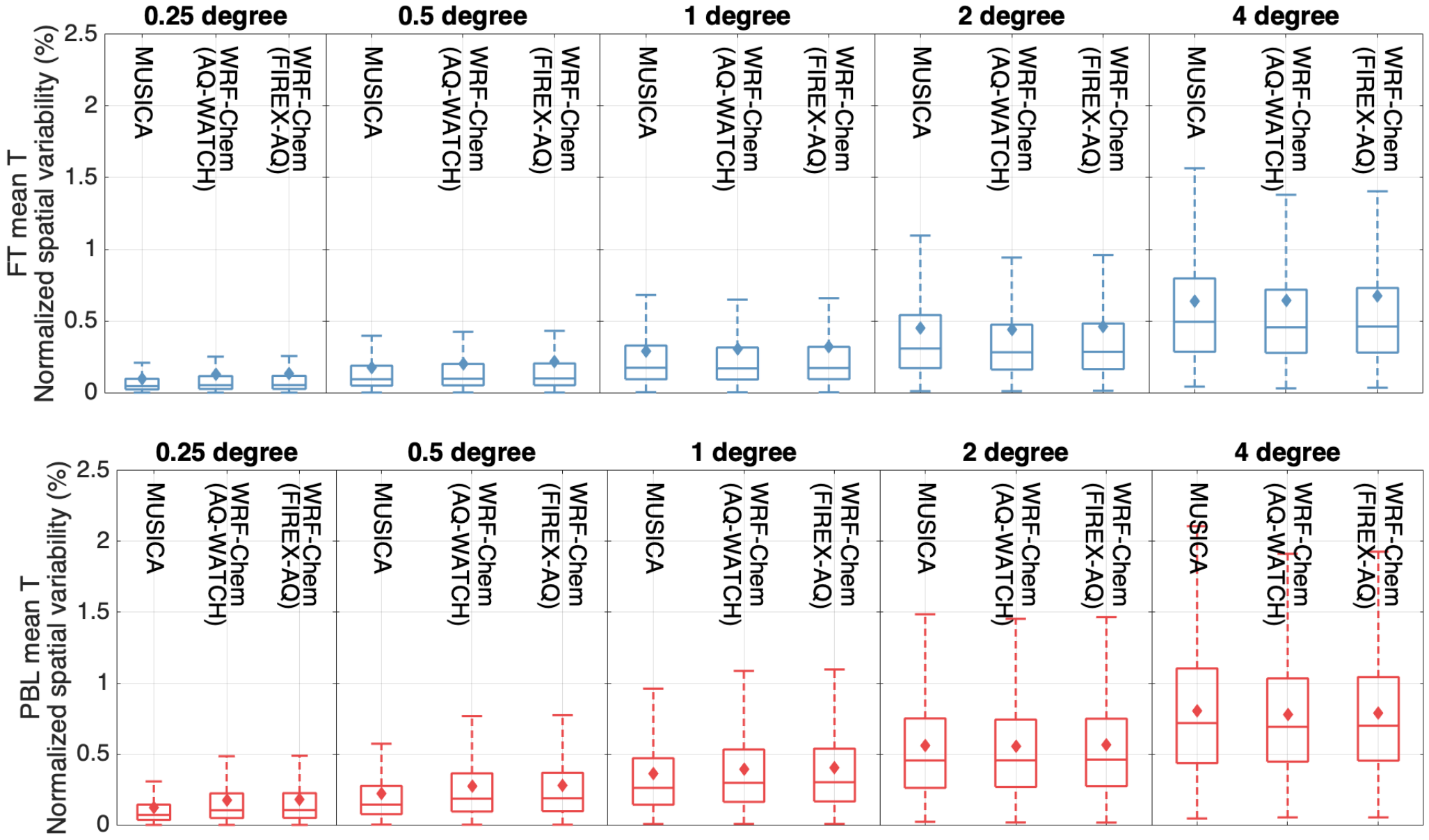
Randomly draw boxes of interested scale over model data;
And calculate variability of the model grids with in the boxes

When the amount of the boxes is large, the statistics of the variability within boxes can represent the model spatial variability at the scale of interest.

(Tang et al., 2021)

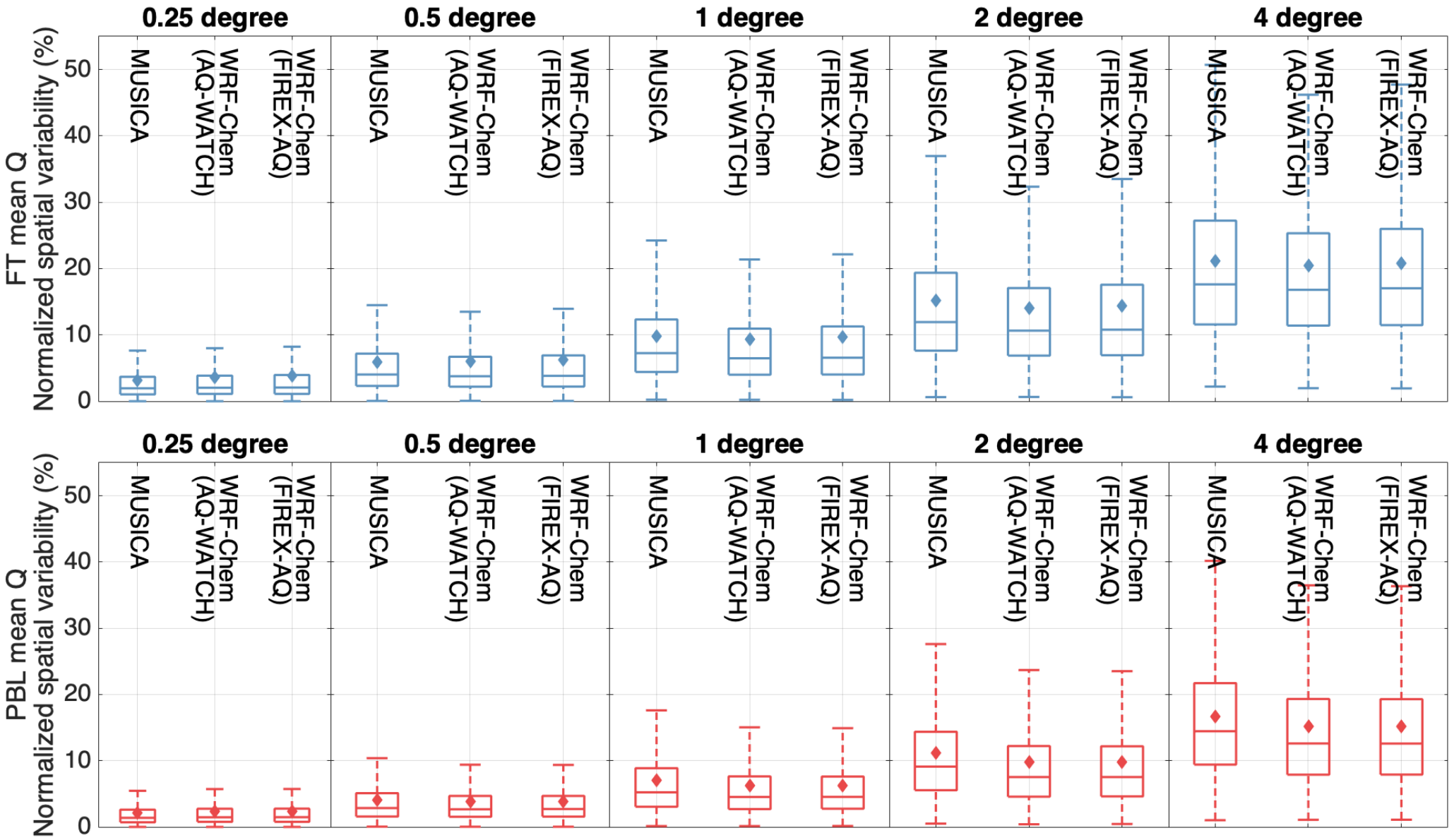
Spatial variability: calculated using random sampling over 3-hour data

T

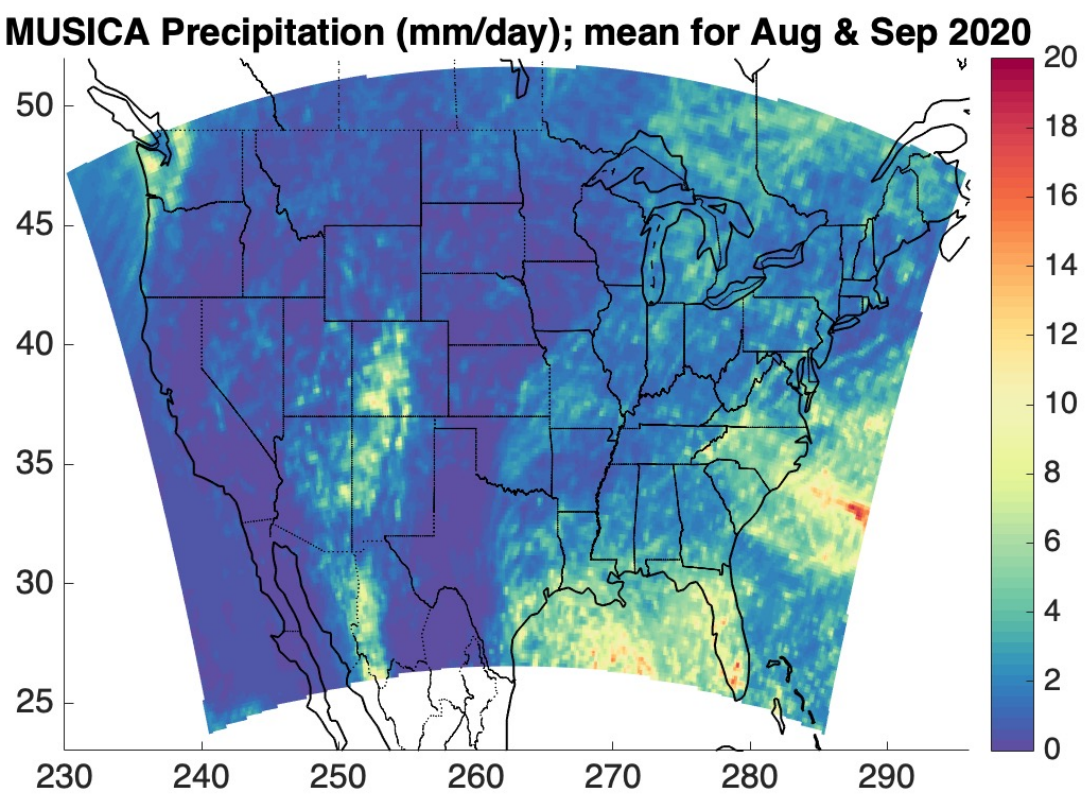


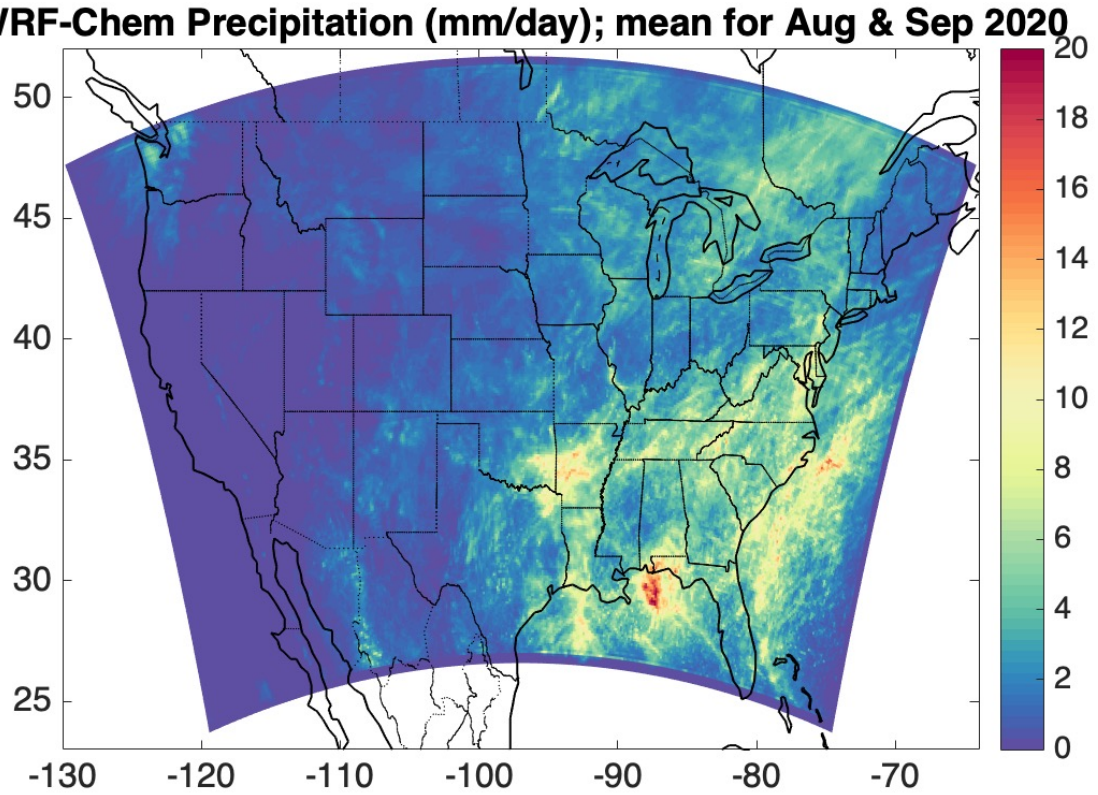
Spatial variability: calculated using random sampling over 3-hour data

Q



Precipitation from the two models:





1. Introduction to MUSICA (Mention tutorial)
2. **Advantages of MUSICA** (boundary conditions, global impact, inflow etc, connections to other earth component)
Similarly expensive to run
Not hard to run compare to WRF-Chem

3. Case study to demonstration the value
4. **Comparisons with WRF-Chem over CONUS**
5. Current applications (other grids) websites
6. Future plan (MPAS here?) going to higher resolution