MUSICActivities

Newsletter

Issue No. 15
February 2026

of the Multiscale Infrastructure for Chemistry and Aerosols - MUSICA

MUSICA is a computationally feasible global modeling framework currently in development that allows for the simulation of large-scale atmospheric phenomena, while still resolving chemistry at emission and exposure relevant scales (down to 4 km). MUSICA will replace and extend the current community chemistry modeling efforts at NSF NCAR (e.g., WACCM, CAM-Chem, WRF-Chem) paralleling other activities to streamline and unify model developments.
MUSICAv0 is an initial configuration based on the CESM Community Atmosphere Model with chemistry using the Spectral Element with Regional Refinement dynamical core.
MusicBox is a box model using a model independent chemistry module.
MELODIES is a modular framework to compare model results with observations.
MUSICA is part of SIMA (System for Integrated Modeling of the Atmosphere).

Summary of this issue

MUSICA Library Release Version is available at https://github.com/NCAR/musica

Mark your calendar:

- CESM workshop (June 15-17)
- MPAS/WRF workshop (June 23-26) – *abstract deadline 15 April 2026*
- **iCACGP-IGAC 2026 Joint Conference**
  7–11 September 2026
  Cultural & Conference Center of Heraklion, Crete, Greece
  https://icacgp-igac2026.org/
  Abstract deadline is 27 February 2026

We want to hear what you are doing with MUSICA! Please send us contributions to the newsletter (please email gaubert@ucar.edu)

MUSICA updates

❖ MUSICA v0.13.0 Release Notes

MICM

- ✓ Fixing various broken links in the documentation
- ✓ Minor updates to prepare for mixed-phase solving
- ✓ Performance improvements for the CUDA solver
- ✓ Choosing more strict tolerances for unit and integration tests

Music box interactive

- ✓ Documentation and tutorials for the Python interface
- ✓ Added support for the GPU version of MUSICA
- ✓ Fixed bug to support heterogenous reactions
- ✓ Combining the frontend and backend repositories in MusicBox Interactive

TUV-x

- ✓ Updates to the cmake packaging
- ✓ Using some newer cross section datasets
- ✓ Exposing more internal data for use in the MUSICA Python interface for TUVx

MUSICA

- ✓ Include a Python wrapper for some parts of TUVX
- ✓ Include a Python wrapper for CARMA
- ✓ Include the beginnings of a Javascript wrapper around MUSICA
- ✓ Documentation and tutorials for the Python interface

❖ MELODIES-MONET

- ✓ The GitHub v1 release is here: https://github.com/NCAR/MELODIES-MONET/releases/tag/v1.0
- ✓ Zenodo record is here: https://zenodo.org/records/15776660
- ✓ The v1.0 also has a readthedocs snapshot: https://melodies-monet.readthedocs.io/en/v1.0/

MUSICA updates

❖ MusicBox Interactive

- ✓ Chemistry box model using prescribed atmospheric conditions. It currently runs gas-phase chemistry only. Current chemical mechanisms available are Chapman, simple wall loss example for flow tube reactors, CB05, and MOZART-TS1. See MusicBox interactive
- ✓ Used to test chemical schemes, for classroom teaching or summer schools, or research focused on chemical sources and sinks.
- ✓ *MusicBox tutorial available at its github page using the launch binder option. https://github.com/NCAR/music-box*
- ✓ *Beginning testing phase of scripts that can extract output from WACCM and WRF-Chem to produce MusicBox input files.*
- ✓ *Currently testing MusicBox-CARMA, which is available in the python package.*

❖ MUSICA Library

- ✓ MICM is gaining the capacity to solve together gas, cloud, and aerosol chemistry by implementing a differential algebraic equations (DAE) solver that allows constraints (e.g., pH of the aqueous phase from the charge balance) to be placed on the chemistry system. Documentation of how to install and use MICM can be found at the MICM github page.
- ✓ *MUSICA Python package tutorial is available at its github page using the launch binder option. https://github.com/NCAR/musica*

❖ MPAS-A

- ✓ MPAS-A is a standalone atmosphere model used for numerical weather prediction. MPAS-A can be run as a global or regional model, used with the JEDI and DART DA systems, and offline meteorology. Its LES capability is in development.
- ✓ *The NSF NCAR MPAS-A with GOCART-2G aerosols development testing continues. It is on schedule to be released to the community in late spring 2026.*
- ✓ *The MPAS-A model has been connected to MICM in the MUSICA library with the successful testing of a 2-reaction toy model. Connecting MPAS-A with the TUV-x calculator is underway.*

❖ MELODIES-MONET

- ✓ NSF NCAR ACOM and RAL are in the process of wrapping up a project on the evaluation of the Colorado State Implementation Plan, funded by the Colorado Air Quality Enterprise (CAQE). This project has supported parts of the development of MELODIES MONET including the integration of comparison to TEMPO, TROPOMI and PANDORA measurements. As part of the project, ACOM and RAL held a MELODIES MONET tutorial for Colorado stakeholders on 28 January 2026. The training focused on the evaluation of WRF-Chem using TEMPO and all the materials, including an updated Installation Guide for MELODIES MONET are available from this link.

Demonstrating MUSICA in 3d Modeling

For the past several years, the MUSICA software engineering team has been creating a software library that represents atmospheric chemistry processes in a model independent and runtime configurable fashion so that MUSICA can interface with any atmosphere model. In the January 2024 newsletter, we showed this vision for MUSICA software development; a simplified version of the schematic is repeated in Figure 1.

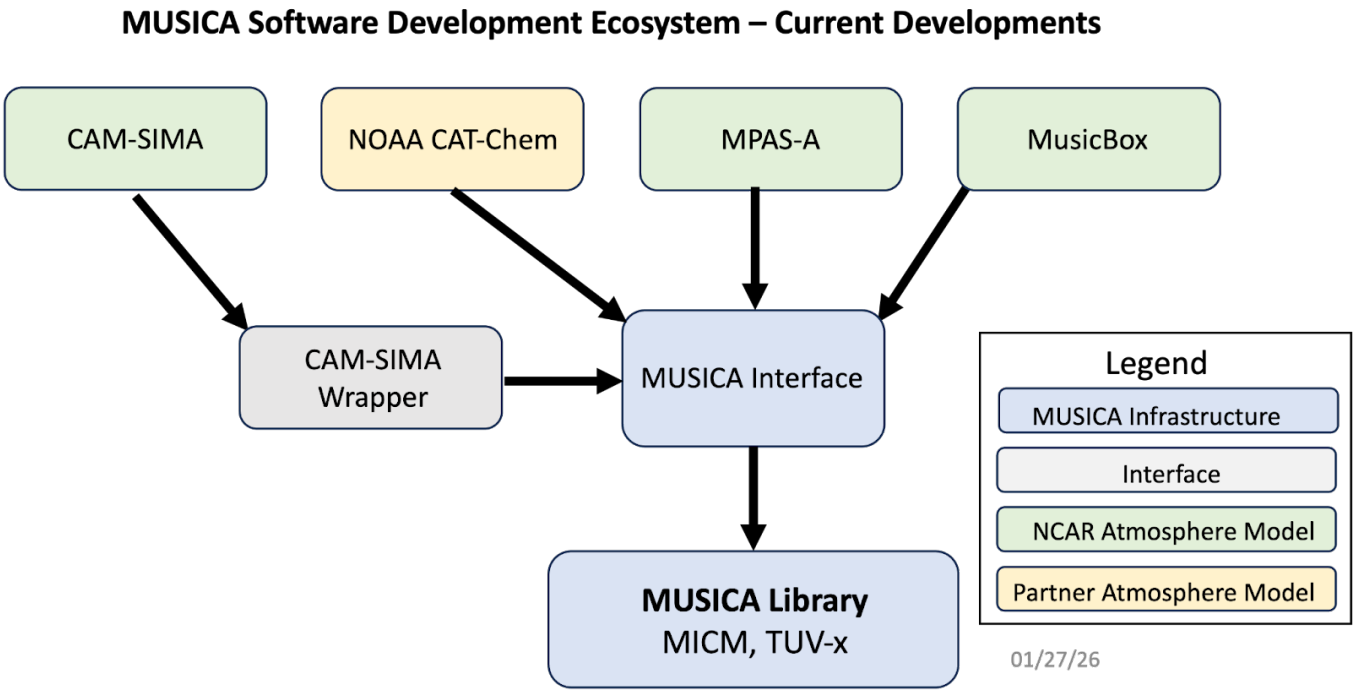


Figure 1. MUSICA software development ecosystem depicting the current developments. Arrows show what each element is dependent upon.

The MUSICA Library contains the Model Independent Chemistry Module (MICM) that solves gas-phase chemistry with an ODE solver and the Tropospheric Ultraviolet and Visible radiation code eXtended (TUV-x) to the whole atmosphere that calculates photolysis rates. In 2025 the CAM-SIMA wrapper was completed allowing MICM and TUV-x (and any future module that will be introduced into the MUSICA Library) to be connected to CESM's next generation Community Atmosphere Model (CAM), called CAM-SIMA. A demonstration of Terminator chemistry was then performed.

Terminator Chemistry

$Cl_2 \rightarrow 2\ Cl$ j1 = photolysis rate from TUV-x

$Cl + Cl \rightarrow Cl_2$ k1 = reaction rate

Demonstrating MUSICA in 3d Modeling

The top row of Figure 2 shows the Cl mixing ratios and the change in Cl_2 mixing ratios for hour 16 of a 24-hour simulation. The photochemistry produces high Cl in the daylit regions, when Cl_2 experiences some depletion. The summation of Cl and Cl_2 is conserved. To further demonstrate MUSICA capabilities, the species Foo is introduced via a JSON file. The demonstration has Foo produced by Cl_2 photolysis and destroyed through reaction with Cl and reaction with itself. Thus, a species and its reactions are shown to be added to a 3-dimensional chemistry transport model without the need to recompile the code base. To see movies of these two simulations, please visit the MUSICA news article.

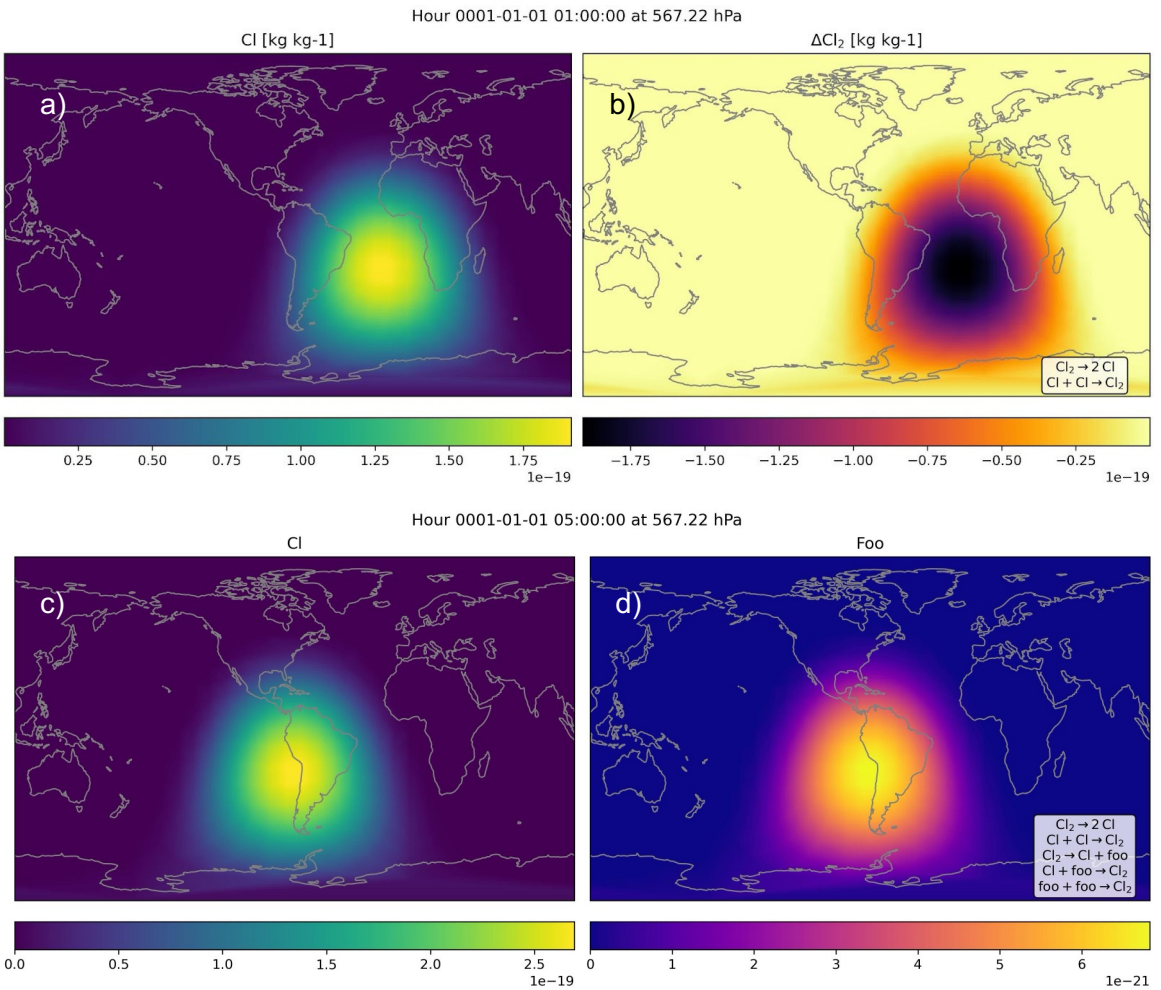


Figure 2. Latitude-Longitude cross section at 567 hPa of Terminator chemistry running in CAM-SIMA at hour 1 (top row) and hour 5 (bottom row) of a 24-hour simulation. Panels a) and b) display Cl mixing ratios and the change in Cl_2 mixing ratios from its initial mixing ratio, respectively. Panels c) and d) display Cl and the new species Foo, respectively. The chemistry with Foo is listed in the bottom right of panel d).

MUSICA Science

Evaluating CAM-chem modeled atmospheric wet deposition with observed long-term records

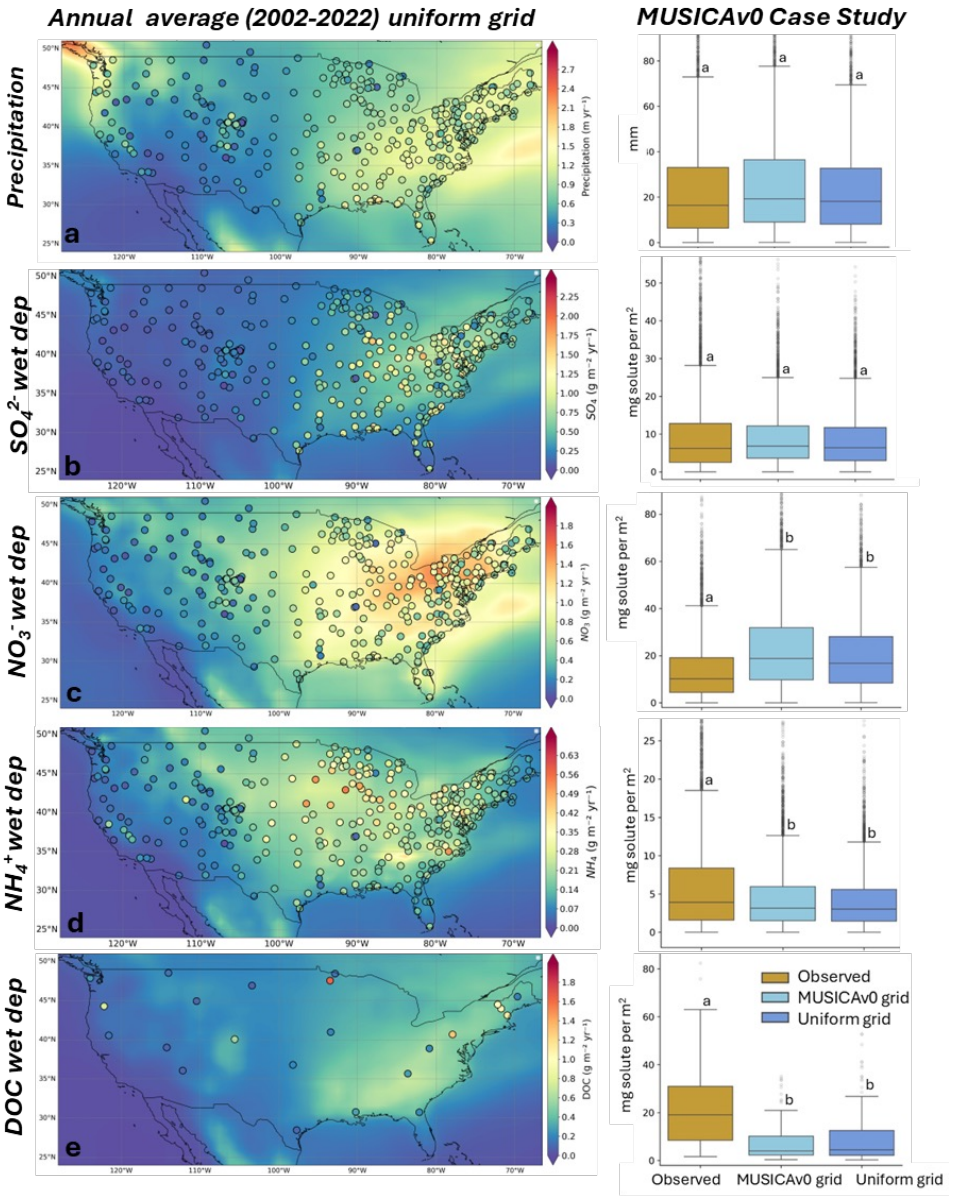
Contributed by Dr. Desneiges (Deni) Murray (dmurray1@bu.edu), Boston University

Dr. Desneiges (Deni) Murray participated in the NSF NCAR ASP Graduate Visiting Program under the guidance of ACOM's Dr. Rebecca Buchholz to explore the use of CAM-chem for understanding emission controls of wet deposition chemistry. She is currently an NSF Earth Sciences Postdoctoral Fellow at Boston University researching landscape drivers and ecological consequences of wet deposition chemistry.

Accurate modeling of carbon, nitrogen, and sulfur wet deposition flux is important for characterizing and quantifying the role of deposition in global biogeochemical cycles. In this work, wet deposition from CAM-chem and MUSICAv0 was evaluated over the contiguous U.S. (CONUS) with the weekly composite National Atmospheric Deposition Program data for 2002-2022. The panels on the left in the figure show where CAM-chem performs well for precipitation and sulfate, nitrate, ammonium, and dissolved organic carbon wet deposition. CAM-chem also reproduced the long-term and seasonal patterns of wet deposition. To examine the effect of horizontal resolution, a case study from 2017-2018 evaluated modeled wet deposition outputs from MUSICAv0 (with regional refinement from ~100 km to ~14 over CONUS), finding that wet deposition fluxes are consistent between the model resolution versions, although some regional advantages of MUSICAv0 persist potentially due to MUSICA's ability to capture mesoscale precipitation.

Murray, D. S., Buchholz, R. R., Emmons, L. K., Honomichl, S., Tang, W., Tilmes, S., Barth, M., and Wymore, A. S. (2026). Evaluating CAM-chem modeled atmospheric wet deposition with observed long-term records. Journal of Geophysical Research: Atmospheres, 131(2), e2025JD044196. https://doi.org/10.1029/2025JD044196

MUSICA Science



The **left** column of shows maps of modeled (uniform grid) annual average from 2002-2022 for **a)** precipitation, and wet deposition of **b)** sulfate (SO_4^{2-}), **c)** nitrate (NO_3^-), **d)** ammonium (with modeled estimates expressed as NH_4^+ + NH_3), and **e)** dissolved organic carbon (with modeled estimates expressed as SOA + POM + BC). Points on the map also reflect annual average of variables from 2002-2022 for observed data from sites operated by the National Atmospheric Deposition Program (and other data sources for panel e). Colors indicate magnitude of a given value in the modeled and observed data sources. The **right** column shows boxplots of each variable from the MUSICAv0 model outputs (light blue), and uniform grid model outputs (dark blue), and observed data (yellow) for the case study period of 2017-2018. Statistical significance between groups is noted by letters.

Presentations and Publications

Publications

1. Murray, D. S., Buchholz, R. R., Emmons, L. K., Honomichl, S., Tang, W., Tilmes, S., ... & Wymore, A. S. (2026). **Evaluating CAM-chem modeled atmospheric wet deposition with observed long-term records**. *Journal of Geophysical Research: Atmospheres*, *131*(2), e2025JD044196. https://doi.org/10.1029/2025JD044196
2. Ibarra-Espinosa, S., Dias de Freitas, E., Gaubert, B., Lichtig, P. et al. (2026), **A Century of Vehicular Emissions in Brazil: Unveiling the Impacts of Unique Fuel Mix on Air Quality**, Environmental Science & Technology, https://doi.org/10.1021/acs.est.5c08400
3. Tao, M., Fiore, A. M., Emmons, L. K., Scott, J. R., Pfister, G. G., Jo, D. S., and Tang, W.: **Contrasting Air Pollution Responses to Hourly Varying Anthropogenic NOx Emissions in the Contiguous United States**, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-4304, 2025.
4. Visaga, S. M., Pierce, R., et al.: **Air Quality Impacts of Biomass Burning Transport during 2019 CAMP2Ex using MUSICAv0 with Regional Refinement over Southeast Asia**, ESS open archive, 10.22541/essoar.177046371.19686183/v1, 2026.

Presentations

- ✓ I. Ortega, Evaluation of TEMPO Formaldehyde Retrievals Using Co-Located Ground-Based FTIR and Pandora Observations and Comparisons with NCAR MUSICA Simulations, 106th AMS annual conference, January 2026, Houston, TX.
- ✓ Z. Song, Meteorological Drivers and Health Impacts of O3 and PM2.5 During the 2018 Saddleworth Moor Fires, 106th AMS annual conference, January 2026, Houston, TX.
- ✓ W, Tang, Global Expansion of Wildland-Urban Interface (WUI) and WUI Fires and the Impact of WUI Fires on Global Air Quality, 106th AMS annual conference, January 2026, Houston, TX.
- ✓ R. Buchholz, Investigating the Atmospheric Response to the Extreme Australian 2019/2020 Wildfire Season, 106th AMS annual conference, January 2026, Houston, TX.
- ✓ W. Wang, Effects of plume rise on long-range transport of wildfire aerosols and Arctic clouds using the Multi-Scale Infrastructure for Chemistry and Aerosols (MUSICAv0) model, AGU25, New Orleans, LA.
- ✓ Y. Cheng, Urban-resolving air quality modeling during the ASIA-AQ campaign using Multi-Scale Infrastructure for Chemistry Modeling (MUSICA) Version 0, AGU25, New Orleans, LA.
- ✓ A. Aboagye-Okyere, Quantifying the Changing Role of Natural Aerosols in Brazil's Air Quality and Health Impacts, AGU25, New Orleans, LA.
- ✓ S. Ibarra-Espinosa, A Century of Vehicular Emissions in Brazil: Unveiling the Impacts of Unique Fuel Mix on Air Quality, AGU25, New Orleans, LA.