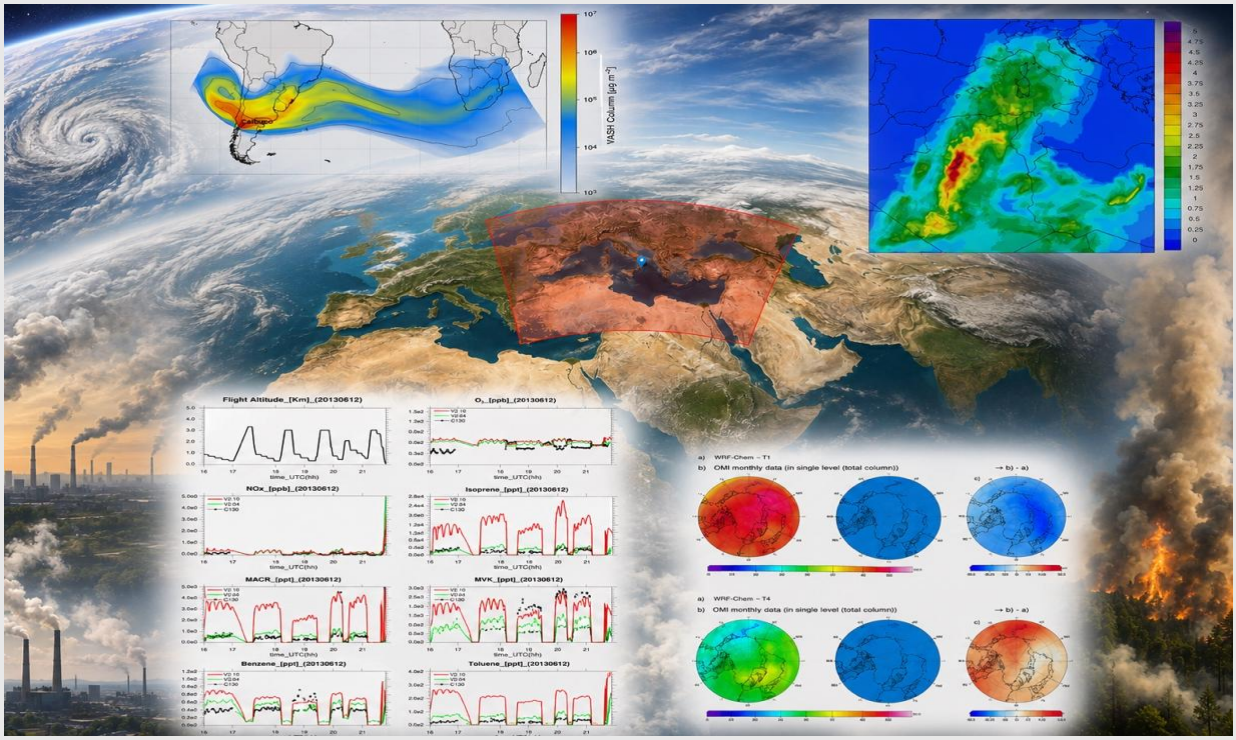
Rijeka, Croatia

12-14 May 2026

Book of Abstracts

EUROPEAN WRF-CHEM WORKSHOP 2026



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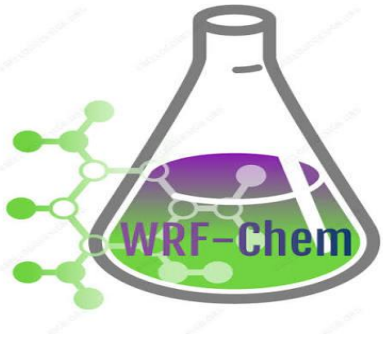

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The European WRF-Chem Workshop 2026 brings together researchers, model developers, and users working on atmospheric chemistry, aerosol processes, air quality, regional climate modelling, and atmosphere-biosphere feedback.

The workshop aims to promote scientific exchange on the development and application of coupled atmospheric models.

This volume contains the abstracts presented during the workshop and reflects the broad range of ongoing research activities across Europe and international institutions.

Hosted by

Faculty of Physics, University of Rijeka, Rijeka

Venue

InnovaLab, Sveučilište u Rijeci Trg braće Mažuranića 10, 51000 Rijeka

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Workshop Agenda

Online presentation*
Seminars
Volcanic Emissions & Eruption Modeling
Tools, Frameworks & Model Development

Chemistry–Meteorology Interactions & Extreme Events
Biosphere–Atmosphere & Land Interactions
Air Quality, Emissions & Urban Environment
Aerosols, Dust & Biomass Burning

Time	Name	Surname	Title Abstract
Day 1 - May 12			
09:00	Introduction and presentation of the workshop		
09:30	Georg	Grell	History, state of the art, and overview of WRF-Chem
10:30	Coffee Break & Poster Session		
11:00	Alexander	Ukhov	Recent advances in modeling regional simulations and in Extending WRF-Chem volcanic capabilities
11:15	Umberto	Rizza	Evaluating the Radiative Forcing impacts of the 2015 Calbuco eruption using WRF-Chem v4.8 and the PrepEmissSource Preprocessor
11:30	Silvia	Di Nisio	Coupling WRF-Chem v4.8 with Near-Source L-Band Radar Observations for High-Resolution Simulation of Volcanic Emissions at Mt. Etna
11:45	Ólafur	Rögnvaldsson	Simulating gases from volcanic eruptions in SW-Iceland
12:00	Georg	Grell	The new version of the GFL convective parameterization (former GF) in WRF and MPAS, including aerosol–convection interactions
12:15	Maja	Bubalo	Modeling with LOTOS-EUROS: Comparison of two simulations with different time profiles with measured data
12:30	Amirhossein	Nikfal	A Modular Toolchain for Reproducible WRF and WRF-Chem Workflows

Time	Name	Surname	Title Abstract
12:45	**Lunch**		
14:45	Pablo*	Licthig	MELODIES-MONET: A User-Friendly Tool for Model Evaluation
14:30	William*	Hatheway	WRF-MOSIT: a modular and cross-platform tool for configuring and installing the WRF model
15:00	Huanxin*	Zhang	Development of UI-WRF-Chem Modeling Framework for the MAIA Satellite Mission
15:15	Anahí	Villalba Pradas	Evaluation of High-Resolution WRF-Chem Simulations During the East Asian Summer Monsoon
15:30	**Coffee Break & Poster Session**		
16:00	Mary*	Barth	NSF NCAR's Transition from WRF-Chem to MPAS-A with Chemistry and Aerosols
17:00	Jordan*	Schnell	NOAA GSL experimental aerosol forecasting in MPAS-A
WRAP UP - Day 1			

Time	Name	Surname	Title Abstract
Day 2 - May 13			
09:00	Jan	Karlický	Impact of boundary conditions, model type and chemistry on ambient meteorology and air-quality

Time	Name	Surname	Title Abstract
09:15	Sompoke*	Kingkaew	Analytical Forecasting of a Destructive Summer Storm Event Driven by Aerosol-Induced Convective Intensification in Northern Thailand
09:30	Antonio	Ricchi	Implementation of a fully coupled atmosphere-aerosols-waves-ocean model based on the COAWST package and the WRF-Chem model: Application for the Medicane IANOS
	Umberto	**Rizza**	
10:30	**Coffee Break & Poster Session**		
11:00	Giorgos*	Papadopoulos	High-resolution Assessment of the Impact of Climate Change on Air Quality in Thessaloniki, Greece with WRF-Chem: Model Configuration, Performance Evaluation and Future Projections
11:15	Andrea	Mazzeo	How Heatwaves Reshape Ozone Budgets over the UK: Transport and Chemistry Interactions within the PBL
11:30	Cansu*	Düzgün	Simulating Parameterized Vertical Transport by Mesoscale Storms Using Lightning Data Assimilation in WRF-Chem
11:45	Andrea	Miranda-Corzo	Spatiotemporal variability of black carbon in high mountain environments: an observational and modeling approach in the huaytapallana mountain range
12:00	Leandro C.	Segado-Moreno	Tropospheric ozone sensitivity in response to changes in soil moisture and vegetation over the Iberian Peninsula
12:15	Luka	Ilić	Toward a Globally Transferable Numerical Pollen Forecasting System: Advancing DREAM-POLL for Multi-Region Pollen Prediction

Time	Name	Surname	Title Abstract
12:30	Boris	Mifka	Fungal Spore Parameterization in WRF-Chem: Implementation and Finland Case Study
12:45	Qing*	Luo	Assessing the Contribution of Urban Green Spaces to Atmospheric CO_2 Dynamics Using WRF-Chem in a Metropolitan Area
13:00	**Lunch**		
14:30	Mauro	Morichetti	Climate-driven loss of resilience in Italian forests under ISIMIP3 scenarios: insights from 3D-CMCC-FEM v5.7
14:45	Rami*	Yagni	High-Resolution Urban Emission Mapping and WRF-Chem Simulations to Evaluate Clean-Air Pathways for Ahmedabad, India
15:00	Antoine	Pasternak	WRF-Chem analysis of ammonia emissions over the Benelux and neighboring regions: seasonal insights from IASI
15:15	Rene*	Parra	Modeling PM2.5 Levels Due to Combustion Activities and Fireworks at the Beginning of the Year in Quito (Ecuador) Using WRF-Chem
15:30	**Coffee Break & Poster Session**		
16:00	Jordan*	Schnell	Using WRF-Chem and MPAS-A for experimental pollen forecasting in RAP-Chem and cheMPAS-Fire
WRAP UP - Day 2			

Time	Name	Surname	Title Abstract

Day 3 - May 14			
09:00	Goran	Gašparac	Evaluation of WRF-Chem performance in simulating background particulate matter in Europe during stable atmospheric conditions
09:15	Zorica*	Podrascanin	Possible use of the WRF-Chem model for air quality prediction in Serbia
09:30	Alessandra	Chiappini	Sub-seasonal WRF-Chem reanalysis of extreme Saharan dust outbreaks in spring-summer 2024: balancing phase consistency and aerosol realism
09:45	Luka	Ilić	Sensitivity of Dust Absorption to Regionally and Size-Resolved Mineralogy in MONARCH
10:00	Douglas	Lima de Bem	Investigating Aerosol-Driven Atmospheric Perturbations from Extreme Biomass Burning over South America with WRF-Chem
10:15	Stergios*	Kartsios	The impact of aerosols on a severe weather event in Greece
10:30	Anas Ibnu*	Basheer	Impact of LULC modifications on Aerosol-induced changes in surface temperature and energy partitioning
10:45	Vagner	Anabor	Aerosol-Induced Shifts in Mesoscale Convective Trajectories
11:00	**Coffee Break**		
11:30	Mauro	Morichetti	WRF-Chem hands-on: how to use, set up and run
WRAP UP - Day 3			

Table of Abstracts

WRF-Chem: History, Current Status, and Future Plans *1*

Recent advances in modeling regional simulations and in Extending WRF-Chem volcanic capabilities *2*

Evaluating the Radiative Forcing impacts of the 2015 Calbuco eruption using WRF-Chem v4.8 and the PrepEmissSource Preprocessor *3*

Coupling WRF-Chem v4.8 with Near-Source L-Band Radar Observations for High-Resolution Simulation of Volcanic Emissions at Mt. Etna *5*

Simulating gases from volcanic eruptions in SW-Iceland *7*

The new (old) GFL convective parameterization *8*

Modeling with LOTOS-EUROS: Comparison of two simulations with different time profiles with measured data *9*

A Modular Toolchain for Reproducible WRF and WRF-Chem Workflows *10*

MELODIES-MONET: A User-Friendly Tool for Model Evaluation *12*

WRF-MOSIT: a modular and cross-platform tool for configuring and installing the WRF model *14*

Development of UI-WRF-Chem Modeling Framework for the MAIA Satellite Mission *15*

Evaluation of High-Resolution WRF-Chem Simulations During the East Asian Summer Monsoon *17*

NSF NCAR's Transition from WRF-Chem to MPAS-A with Chemistry and Aerosols *18*

NOAA GSL experimental aerosol forecasting in MPAS-A *20*

Impact of boundary conditions, model type and chemistry on ambient meteorology and air-quality *21*

Analytical Forecasting of a Destructive Summer Storm Event Driven by Aerosol-Induced Convective Intensification in Northern Thailand *22*

Implementation of a fully coupled atmosphere-aerosols-waves-ocean model based on the COAWST package and the WRF-Chem model: Application for the Medicane IANOS *23*

High-resolution Assessment of the Impact of Climate Change on Air Quality in Thessaloniki, Greece with WRF-Chem: Model Configuration, Performance Evaluation and Future Projections *25*

How Heatwaves Reshape Ozone Budgets over the UK: Transport and Chemistry Interactions within the PBL *26*

Simulating Parameterized Vertical Transport by Mesoscale Storms Using Lightning Data Assimilation in WRF-Chem *28*

Spatiotemporal Variability of Black Carbon in High Mountain Environments: An Observational and Modeling Approach in the Huaytapallana Mountain Range *29*

Tropospheric ozone sensitivity in response to changes in soil moisture and vegetation over the Iberian Peninsula *31*

Toward a Globally Transferable Numerical Pollen Forecasting System: Advancing DREAM-POLL for Multi-Region Pollen Prediction *32*

Fungal Spore Parameterization in WRF-Chem: Implementation and Finland Case Study *34*

Assessing the Contribution of Urban Green Spaces to Atmospheric CO_2 Dynamics Using WRF-Chem in a Metropolitan Area *36*

Climate-driven loss of resilience in Italian forests under ISIMIP3 scenarios: insights from 3D-CMCC-FEM v5.7 ..... *37*

High-Resolution Urban Emission Mapping and WRF-Chem Simulations to Evaluate Clean-Air Pathways for Ahmedabad, India *39*

WRF-Chem analysis of ammonia emissions over the Benelux and neighboring regions: seasonal insights from IASI *42*

Modeling $PM_{2.5}$ Levels Due to Combustion Activities and Fireworks at the Beginning of the Year in Quito (Ecuador) Using WRF-Chem *43*

Using WRF-Chem and MPAS-A for experimental pollen forecasting in RAP-Chem and cheMPAS-Fire *45*

Evaluation of WRF-Chem performance in simulating background particulate matter in Europe during stable atmospheric conditions *46*

Possible use of the WRF-Chem model for air quality prediction in Serbia *48*

Sub-seasonal WRF-Chem reanalysis of extreme Saharan dust outbreaks in spring-summer 2024: balancing phase consistency and aerosol realism *50*

Sensitivity of Dust Absorption to Regionally and Size-Resolved Mineralogy in MONARCH *51*

Investigating Aerosol-Driven Atmospheric Perturbations from Extreme Biomass Burning over South America with WRF-Chem *53*

The impact of aerosols on a severe weather event in Greece *55*

Impact of LULC modifications on Aerosol-induced changes in surface temperature and energy partitioning *56*

Aerosol-Induced Shifts in Mesoscale Convective Trajectories *57*

WRF-Chem hands-on: how to use, set up and run *59*

Meso- to micro- scale impacts of alternative fuels for aviation on air composition around airports *61*

WRF-Chem: History, Current Status, and Future Plans

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Keywords: *WRF-Chem development; WRF-Chem applications*

WRF-Chem has evolved over the past two decades from an experimental online chemistry extension of the Weather Research and Forecasting (WRF) model into one of the most widely used coupled meteorology–chemistry modeling systems in the atmospheric sciences community. This presentation reviews the historical development of WRF-Chem, highlights major scientific and operational milestones, and discusses ongoing efforts that will shape future coupled atmospheric modeling capabilities.

The talk begins with an overview of the major development phases of WRF-Chem, including the establishment of the fully coupled online framework, the introduction of aerosol–radiation and aerosol–cloud feedback, the integration of advanced chemistry mechanisms, and the expansion toward coupled fire, smoke, dust, and forecasting applications. Bibliometric analyses demonstrate the rapid global growth of WRF-Chem usage across atmospheric chemistry, air quality, numerical weather prediction, and climate research communities.

Current WRF-Chem capabilities are reviewed, including gas-phase chemistry, aerosol processes, dust and fire emissions, greenhouse gas transport, online chemistry–meteorology interactions, and passive tracer applications. Particular emphasis is placed on the advantages of online coupling, where chemistry and meteorology share identical transport, physics, and grid structures, enabling physically consistent treatment of feedback processes important for weather, air quality, and climate prediction.

Examples are presented from a wide range of research and operational applications, including dust transport over the Middle East, urban air quality forecasting, wildfire smoke prediction within NOAA's operational HRRR-Smoke system, aerosol impacts on clouds and precipitation, and large-eddy simulations of urban pollutant dispersion. Recent developments involving aerosol-awareness in a convective parameterization and simplified prognostic aerosol approaches are also discussed. Finally, the presentation addresses ongoing transition efforts toward MPAS- and UFS-based coupled chemistry systems (CheMPAS).

Acknowledgements

Web of Science was used to help derive historic facts. Some figures, bibliometric analyses, slide organization, and text editing assistance were supported with the help of OpenAI's ChatGPT.

Recent advances in modeling regional simulations and in Extending WRF-Chem volcanic capabilities

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Keywords: *SO_2, ash, Lagrangian trajectories, TROPOMI, AERONET*

As regional atmospheric chemistry applications expand, there is a growing need for flexible tools for emissions processing, initial and boundary condition preparation, and trajectory analysis. This work presents three Python-based tools developed for WRF-Chem workflows and structured for future extension to MPAS-Chem. (i) *WRF-Chem_Emissions* converts EDGAR inventories into hourly, model-ready emissions using conservative regridding, temporal allocation, local-time adjustment, and mechanism-aware species mapping. (ii) *Merra2BC* constructs MERRA-2 chemical initial and lateral boundary conditions through horizontal and vertical interpolation. (iii) *Plume-traj* enables backward/forward in time Lagrangian analysis, including three-dimensional parcel advection, optional aerosol settling, and diagnostics such as trajectory maps, deposition timing, and source-height reconstruction.

The second component of the talk focuses on an improved WRF-Chem v4.8 [1] volcanic capability for simulating ash and SO_2 clouds. The update improves ash, SO_2, and sulfate mass conservation; corrects ash gravitational settling; adds wet and dry deposition for ash and sulfate; improves SO_2 to sulfate oxidation; and enables direct radiative effects for interactive aerosol–meteorology coupling. It is supported by an emission-preprocessing workflow for time- and height-varying volcanic source terms in rapid-response simulations. The improved capabilities of the WRF-Chem v4.8 code are demonstrated for the Hayli Gubbi eruption in Afar, Ethiopia, on 23 November 2025. Emissions are reconstructed using backward trajectories and constrained with AERONET and TROPOMI SO_2 retrievals. The simulation reproduces the observed plume timing and structure, yielding approximately 1.0 Mt of fine ash and 0.3 Mt of SO_2. Ash is injected mainly at 7–11 km, with a brief pulse up to 14 km, while SO_2 is emitted at 8–16 km and remains mostly tropospheric during the first day. Simulated ash deposition reaches the southern Red Sea and Gulf of Aden within 28 hours, consistent with observed chlorophyll anomalies and demonstrating the value for near-real-time plume forecasting and impact assessment.

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Evaluating the Radiative Forcing impacts of the 2015 Calbuco eruption using WRF-Chem v4.8 and the PrepEmissSource Preprocessor

Umberto Rizza[1, *], Fabio Grasso[1], Alexander Ukhov[2], Ibrahim Hoteit[2], Douglas Lima do Bem[3] and Vagner Anabor[3]

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After 54 years of dormancy following its last major eruption in 1961, Calbuco Volcano (Ensenada, southern Chile) reawakened with only a few hours' warning on 22 April 2015 at 18:05 local time. The main explosive phase comprised two eruptive pulses lasting approximately 1.5 and 6 hours, respectively, on 22 and 23 April, generating eruption columns that reached stratospheric heights (>15 km). The erupted products were porphyritic basaltic andesite (~55 wt.% SiO_2). Tephra falls primarily affected areas northeast of the volcano, while fine ash was dispersed across southern Chile and Patagonia, Argentina.

We used the Weather Research and Forecasting–Chemistry (WRF-Chem) model version 4.8 to simulate ash transport from the 22–23 April 2015 eruptions of Calbuco Volcano in southern Chile. The numerical simulations were conducted from 22 to 27 April 2015, encompassing both the eruptive phases and the subsequent ash dispersion across South America and the Austral regions. The improvements introduced in WRF-Chem v4.8 include the addition of wet and dry deposition of ash and sulfate, SO_2 chemical transformation mechanisms, corrections to the gravitational deposition of ash, and the inclusion of the direct radiative effects of ash and sulfate aerosols. An open-source emission preprocessor written in Python, developed by Ukhov and Hoteit (2025), called PrepEmisSources, has been introduced to facilitate and streamline the preparation of volcanic emission inputs. Accordingly, the WRF-Chem model was updated to version 4.8, enabling the simulation of complex volcanic emission scenarios using emission files generated by the PrepEmisSources tool. The results obtained by the authors indicate that the enhanced WRF-Chem v4.8 accurately represents the dispersion and deposition of volcanic ash, SO_2, sulfate, and water vapor, as well as the chemical transformation of SO_2. The model is designed to be used starting from version 4.8 with the following namelist options: chem_opt = 402 and emiss_opt_vol = 3.

In this study, we use the PrepEmisSources tool and the WRF-Chem model v4.8 to describe the two eruptions of Calbuco Volcano that occurred on 22 and 23 April 2015. From a meteorological perspective, we analyze the transport of tropospheric volcanic ash and sulfate in the Southern Hemisphere (Figure 1 - left) and their associated radiative forcing. Analysis of the simulated data indicates an average surface temperature change (ΔT) of approximately −0.5 K, with a corresponding negative radiative forcing in the range of 10 – 20 W m^{-2} (Figure 1 – right).

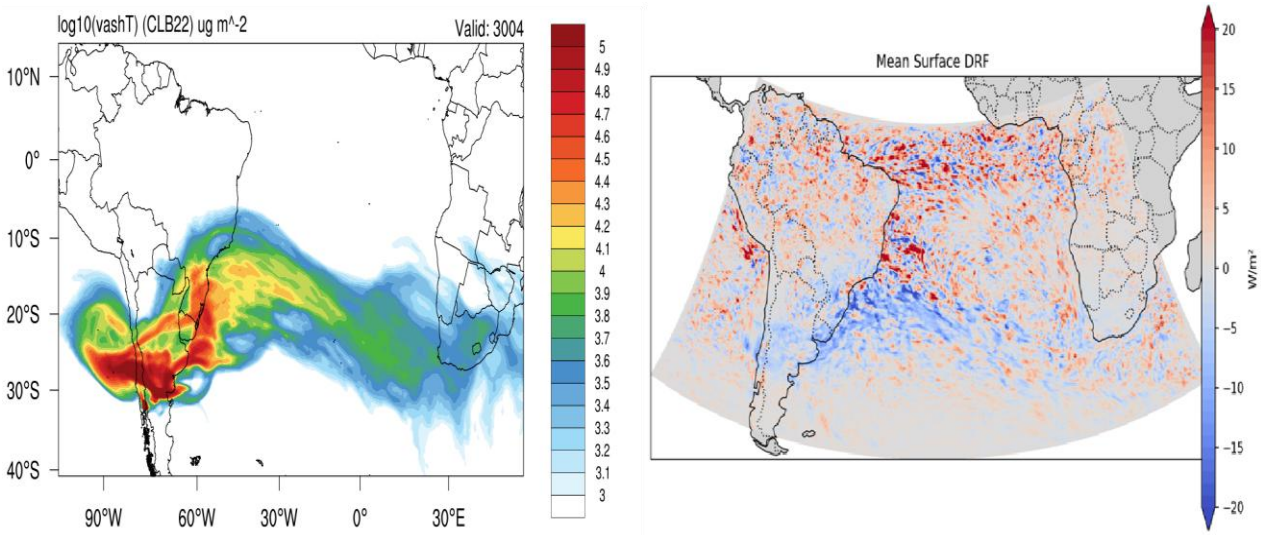

Figure 1: (left) Average (April 22-30) Vash total columnar density, units are log10 (µgm-2); (right) average (April 22-30) surface DRF, units are Wm-2.

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Ukhov, A. and Hoteit, I.: PrepEmisSources a framework for preparing volcanic emissions, Zenodo [code], https://doi.org/10.5281/zenodo.16856541, 2025.

Coupling WRF-Chem v4.8 with Near-Source L-Band Radar Observations for High-Resolution Simulation of Volcanic Emissions at Mt. Etna

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Keywords: *WRF-Chem model, volcanic eruption, Mount Etna, VOLDORAD-2B Doppler radar*

The purpose of this work is to assess the performance of the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) version 4.8 in simulating the atmospheric dispersion of volcanic emissions generated during recent eruptions at Mt. Etna. This is done by coupling the new model pre-processing python-tool for volcanic emission (PrepEmissSource) with eruption source parameters (ESPs) derived from L-band VOLDORAD-2B (V2B) Doppler radar observations. In this context, the study investigates the impact of the latest improvements introduced in WRF-Chem, including wet and dry deposition processes for ash, the refinement of SO_2 chemical transformation pathways, the correction of ash gravitational settling, and the incorporation of the direct radiative effect of ash and sulfate aerosols.

The analysis is conducted through three case studies corresponding to short-duration paroxysmal events at Mt. Etna on 3 December 2015, 23 October 2021, and 21 February 2022, for which high- temporal resolution ESPs are available. These include mass eruption rates (MER) and plume height estimates derived from V2B radar measurements, which are elaborated through the open-source emission preprocessor PrepEmissSource into vertically distributed injection umbrella profiles, which are provided to the model at 6-minute intervals, enabling a realistic representation of the temporal variability of eruptive activity.

The proposed framework evaluates the influence of assimilating radar-derived, time-resolved emissions, together with the updated physical and chemical schemes of WRF-Chem, on the simulation of plume evolution, and ash and SO_2 dispersion patterns at regional scales. Model outputs are compared with satellite observations to validate the computed spatial distribution and temporal evolution of volcanic clouds, allowing an assessment of improvements in overall model accuracy and predictive capability in simulating the transport of volcanic products and their interaction with radiation.

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Remote Sensing, *13*(20), 4037.

Simulating gases from volcanic eruptions in SW-Iceland

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Keywords: *High-resolution volcanic dispersion simulations*

During the Fagradalsfjall volcanic eruption in Iceland in 2021, the atmospheric flow was simulated at high-spatial and temporal resolutions with the WRF-Chem model as part of the WOD framework [1]. The output of the real-time simulations of SO2 was compared to ground-based observations, showing that on timescales of 12-24 hours, the numerical system had considerable skill, but moving to temporal scales shorter than 6 hours lead to substantial drop in the model performance. The data and the model output suggest that there may be strong long-lasting horizontal gradients in the trace gases and limited horizontal mixing at times, calling for a denser network of monitoring of gases from the volcano. Wind variability on the time scale of minutes up to few hours remains a challenge.

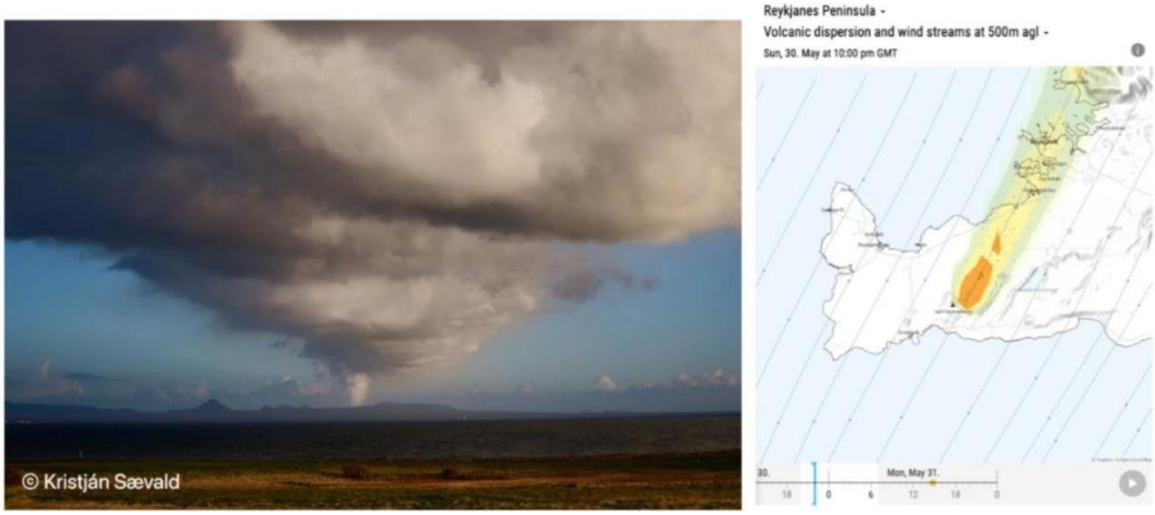

Figure 1: Visual comparison from 22UTC 30 May 2021.

Substantial improvements have been made to the dispersion simulation capabilities of the WOD framework in recent years. Among these is the potential of running a multi-domain dispersion forecast of volcanic ash and gases. On-going developments focuses on the use of in-situ UAV profiles and radar data as input to the WOD data assimilation system.

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The new (old) GFL convective parameterization

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Keywords: *convective parameterization; scale-awareness; aerosol interactions*

This presentation reviews the development and current status of the Grell-Freitas-Li (GFL) convective parameterization and its role within coupled meteorology–chemistry modeling systems such as WRF-Chem and emerging MPAS-based frameworks. Particular emphasis is placed on new developments compared to the previous version of the Grell-Freitas (GF) convection parameterization in WRF and MPAS.

The GFL scheme was designed to provide a scale-aware treatment of convection applicable across a broad range of horizontal resolutions, from mesoscale forecasting to convection-permitting applications. Recent developments extend the framework to include interactions between aerosols and convective processes through modifications to precipitation efficiency and conversion of cloud water to rain and ice. Initial experiments demonstrate systematic sensitivities of convective behavior to aerosol loading, including reductions in precipitation efficiency under polluted conditions and corresponding impacts on cloud structure, radiation, and precipitation distributions.

Examples are presented from both idealized and full-model simulations, including single-column experiments and global FV3 applications. The talk also discusses how aerosol-aware convection interfaces with operational smoke and aerosol forecasting systems, including NOAA's HRRR-Smoke and emerging CheMPAS/MPAS aerosol capabilities. These developments highlight the growing importance of unified physics–chemistry coupling strategies for next-generation forecasting systems.

Finally, future directions for GFL development are outlined, including improved treatment of aerosol–cloud interactions, coupling with prognostic aerosol fields, and implementation within MPAS-based operational and research frameworks. Options in MPAS include a new way to treat scale-awareness that is physically more realistic.

Modeling with LOTOS-EUROS: Comparison of two simulations with different time profiles with measured data

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Keywords: *air quality; LOTOS-EUROS; modeling; time profiles.*

The LOTOS-EUROS is a 3D chemistry transport model which simulates air pollution concentrations in the lower troposphere on a regular Eulerian grid with variable resolution over Europe, whereas the vertical grid can be adjusted according to the applied meteorological input data [Schaap et al 2008, Manders et al 2017]. LOTOS-EUROS version 3.0.002 with a total number of 12 vertical layers and the gas-chemistry scheme Carbon Bond Mechanism (CBM)-IV is applied. The meteorological input is retrieved from the 00:00 and 12:00 GMT runs of the ECMWF Integrated Forecast System at hourly (surface fields) or 3-hourly (model layer fields) temporal resolution, with spatial resolution of roughly 10 x 10 km. Chemical emission input data available (CAMS-REG-AP v8.1) on an annual basis has been disaggregated into hourly, daily and monthly values by using two versions of time profiles, a standard static time profile for the Gridded Nomenclature for Reporting (GNFR) C-sector and a dynamic version of the time profile, which has been modified by using 2 m air temperature data to create a temporally and spatially varying profile that accommodates for different amounts of heating (and, thus, emission of pollutants) depending on how cold or warm the day is. We present an overview of the validation of the model with measurements of the SO_2, NO_2, CO, PM_{10}, $PM_{2.5}$ and O_3 obtained in 2024 at Croatian measuring stations. The dynamic time profile is found to provide overall better agreement with the measured data.

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A Modular Toolchain for Reproducible WRF and WRF-Chem Workflows

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Keywords: *WRF-Chem, Reproducible workflows, Input tailoring, Satellite radiance simulation, Model evaluation*

The Weather Research and Forecasting (WRF) model and its chemistry extension (WRF-Chem) are widely used for meteorological and air-quality applications. However, the full modelling workflow—ranging from input data modification and chemistry boundary preparation to post-processing and satellite-based evaluation—often relies on fragmented scripts and manually configured utilities. This fragmentation can hinder reproducibility, introduce configuration errors, and complicate sensitivity experiments and model validation studies. There remains a practical need for an integrated and structured toolchain that connects these stages within a consistent configuration philosophy familiar to WRF users.

We present a modular, namelist-driven ecosystem designed to streamline WRF and WRF-Chem experiments across preprocessing, chemistry setup, diagnostics, and radiative applications. The framework consists of four complementary components. WRFtailor [1] enables controlled modification of WPS geographical data and WRF-Chem emissions within user-defined areas of interest using shapefiles, bounding boxes, coordinate pairs, nested domains, or GeoTIFF raster replacement with optional mass conservation. Auxiliary WRF-Chem utilities automate the configuration of commonly used preprocessing tools (e.g., mozbc and prep_chem_sources), reducing setup errors in chemistry boundary and emission workflows. PostWRF [2] provides structured post-processing and diagnostic capabilities through a unified namelist interface, supporting horizontal and vertical visualisation, statistical evaluation (including Taylor diagrams), GIS export, and extraction of model variables at observation sites. Finally, rttovpy, a Python-based interface, automates the execution of the RTTOV radiative transfer model using WRF outputs or ERA5 data, generating satellite-consistent brightness temperatures in NetCDF format for further analysis and visualisation.

A demonstration case involving a regional WRF-Chem simulation illustrates how emission modifications, automated chemistry boundary configuration, diagnostic evaluation, and satellite radiance simulation can be executed within a coherent workflow. The integrated design facilitates reproducible sensitivity experiments and supports comparison of model outputs in both physical and radiance space.

By bridging preprocessing, model evaluation, and forward radiative modelling within a unified configuration paradigm, this ecosystem enhances transparency, reproducibility, and efficiency in WRF-Chem research and satellite-aware model validation studies.

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MELODIES-MONET: A User-Friendly Tool for Model Evaluation

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Keywords: *Model evaluation, Python, open access*

Evaluating model simulations with observations is an integral part of any modeling effort. MELODIES-MONET (https://melodies-monet.readthedocs.io) is a Python package developed for atmospheric chemistry applications, that systematically compares model output from different models, including WRF-Chem, with observations, providing the community with a tool to reproducibly evaluate atmospheric chemistry simulations. The framework is developed by NOAA and NSF NCAR, aiming to have a unified, modular, cross-platform, open source and user-friendly framework. Users can automatically download observational datasets, and directly compare model output with in-situ, aircraft and satellite observations. It is designed to make it easy to extend to new observational datasets or models. MELODIES-MONET builds on the capabilities of already well established Python libraries as well as the NOAA MONET and MONETIO projects, to do analysis, pairing and plotting. It is able to handle multiple types of model grids, including unstructured ones. The MELODIES-MONET code is on GitHub (https://github.com/NCAR/MELODIES-MONET) and user contributions are encouraged. As part of a grant from the Colorado Air Quality Enterprise, we have adapted the framework for the evaluation of regulatory modeling, which traditionally has relied on comparison to surface observations only. In this work, we present the framework, as well as show examples of the added benefit of including the remote sensing such as retrievals from the TROPOspheric

Monitoring Instrument (TROPOMI) and the Tropospheric Emissions: Monitoring of Pollution (TEMPO) in assessing model performance.

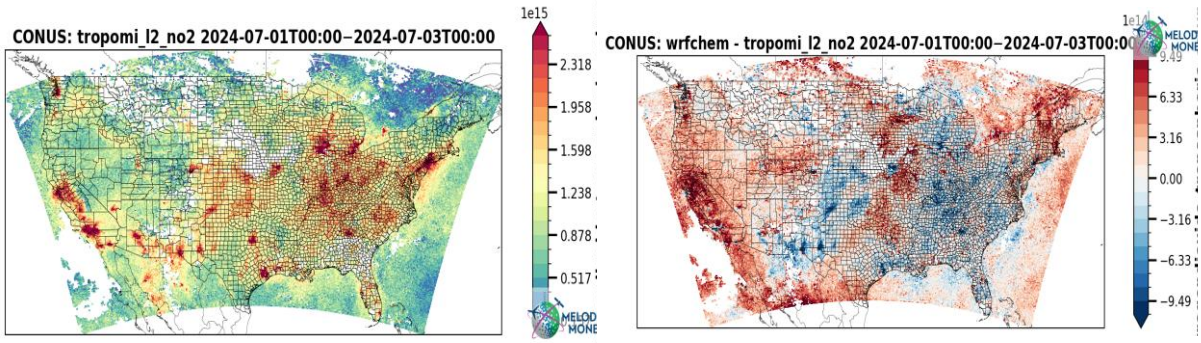

Figure 1: WRF-Chem compared to TROPOMI tropospheric NO_2 column retrievals over the US for 07/01-07/03 2024 using MELODIES MONET .

WRF-MOSIT: a modular and cross-platform tool for configuring and installing the WRF model

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Keywords: *WRF, WRF-Chem, installation, automation, cross-platform*

The Weather Research and Forecasting-Multi Operating System Installation Toolkit (WRF-MOSIT) streamlines the otherwise error-prone setup of the WRF modeling system, including WRF-Chem, by automating compiler, library, pre- and post-processing, and geography-data installation across major platforms. The toolkit detects system architecture and operating system, including Debian-family Linux, Fedora and CentOS-family Linux, macOS, and Windows Subsystem for Linux, configures environment variables, verifies storage and permissions, and performs guided or one-click installations via native package managers. Users may select GNU or Intel oneAPI Fortran compilers where supported, alongside core dependencies and widely used analysis and visualization tools. WRF-MOSIT supports installation of the broader WRF suite, with particular relevance for WRF-Chem applications requiring complex dependencies. The toolkit substantially reduces installation time and lowers barriers for education, research, and operational workflows. Global adoption, with thousands of downloads across more than 140 countries, highlights the demand for a reproducible and cross-platform pathway toward WRF-Chem readiness. Ongoing development includes support for additional coupled systems such as WRF-CMAQ, compiler parity across platforms, and a graphical user interface.

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Development of UI-WRF-Chem Modeling Framework for the MAIA Satellite Mission

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Keywords: *MAIA, UI-WRF-Chem, total $PM_{2.5}$, speciated $PM_{2.5}$*

The Multi-Angle Imager for Aerosols (MAIA) satellite mission, to be jointly implemented by NASA and the Italian Space Agency, aims to study how different types of particulate matter (PM) pollution affect human health. The investigation will primarily focus on 12 globally distributed Primary Target Areas (PTAs) containing major metropolitan cities (https://maia.jpl.nasa.gov/mission/#target_areas). For each PTA, it will employ a Geostatistical Regression Model (GRM) to generate maps of near-surface $PM_{2.5}$, PM_{10} and speciated $PM_{2.5}$ including sulfate, nitrate, dust, organic carbon (OC), and elemental carbon (EC) at a 1-km spatial resolution. The GRMs use satellite-retrieved aerosol parameters, CTM outputs (meteorological variables and total and speciated PM mass concentrations), and other ancillary information as predictors, with surface observations of total and speciated PM serving as target variables.

To support the mission, we have developed a Unified Inputs (of initial and boundary conditions) for WRF-Chem (UI-WRF-Chem) modeling framework, building upon the standard WRF-Chem model. Major updates include:

(1) application of NASA GEOS-FP and MERRA-2 data to provide both meteorological and chemical initial and boundary conditions for performing WRF-Chem simulations at a fine (4 km) spatial resolution;

(2) application of GLDAS and NLDAS data to constrain surface soil properties;

(3) application of recently available MODIS land data to improve land surface properties such as land cover type;

(4) development of a new soil NOx emission scheme – the Berkeley Dalhousie Iowa Soil NO Parameterization (BDISNP);

(5) development of a stand-alone emission preprocessor that ingests both global and regional anthropogenic emission inventories as well as fire emissions.

All UI-WRF-Chem model simulations for MAIA PTAs are configured using 2 nested domains: an outer domain (D1) and inner domain (D2) with a 12 km and 4 km spatial resolution, respectively. To support the upcoming MAIA launch, we have generated one year of UI-WRF-Chem outputs (October 2022 to September 2023) over 11 of the 12 PTAs, excluding Santiago, Chile (which will use a later simulation period due to more recent deployment of its surface monitors). These data will be used to train separate GRMs for each PM component and derive pre-launch coefficients within each PTA. The MAIA project leverages existing PM monitoring networks where available and has deployed additional PM speciation monitors in PTAs where such data were otherwise unavailable. In this presentation, we first describe the development and configuration of UI-WRF-Chem for MAIA applications, followed by an evaluation of simulated PM concentrations over three PTAs: Barcelona, Spain; Rome, Italy; and Tel Aviv, Israel.

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Evaluation of High-Resolution WRF-Chem Simulations During the East Asian Summer Monsoon

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Keywords: *high resolution, Eastern Asia, chemistry, ozone, observations*

Deep convection in the Asian summer monsoon acts as an efficient vertical transport pathway, influencing the chemical composition of the upper troposphere and lower stratosphere. Most studies on this topic have focused on the South Asian summer monsoon; however, recent studies and an observational campaign have shifted attention toward the impact of the East Asian summer monsoon in atmospheric composition near the tropopause. In this study, we conducted high-resolution simulations using the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) over East Asia during the Asian Summer Monsoon Chemical and CLimate Impact Project (ACCLIP) campaign. Model results are evaluated against observational data collected during the campaign. We examine key meteorological variables, such as temperature, as well as chemical species, including ozone, to assess the model's ability to reproduce observed spatial and temporal variability during episodes of reported high pollution. These results contribute to ongoing efforts to improve regional chemical transport modeling.

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NSF NCAR's Transition from WRF-Chem to MPAS-A with Chemistry and Aerosols

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Keywords: *Model Development, Chemistry, Aerosols, MPAS-A*

In an effort to gain new capabilities, NSF NCAR is transitioning from the WRF-Chem model to the Chemistry and aerosols with the Model for Prediction Across Scales – Atmosphere (CheMPAS-A) model. It is planned for CheMPAS-A to have many of the same capabilities as WRF-Chem, including limited area modeling, an LES configuration, and data assimilation, as well as expanded capabilities, such as global uniform and regionally-refined grid meshes that allow representation of local processes in the context of the global environment. As a first step along this development pathway, the GOCART-2G aerosol scheme has been implemented in MPAS-A. In this presentation, we will describe MPAS-GOCART2G and present results and their evaluation from a few example case studies as well as demonstrate the capability of assimilating PACE AOD satellite retrievals via the MPAS-GOCART2G-JEDI system. The addition of full chemistry in CheMPAS-A has also begun. In this development, MPAS-A is interfacing with the Multiscale Infrastructure for Chemistry and Aerosols (MUSICA) software library. The MUSICA library currently contains a model independent chemistry module that determines reaction rates and solves the gas-phase chemical system as well as the TUV-x photolysis rate calculator. It will soon have the capability to solve multiphase chemistry. By the end of summer 2026, a minimum viable CheMPAS-A that reads in emissions and calculates gas-phase chemistry will be available. This presentation will show early results from this CheMPAS-A initial configuration. Subsequent developments will include connecting to the GOCART-2G module, adding deposition processes, and improving other representations. In parallel, a software framework will be created to allow for quick and easy ingestion of science parameterizations. This presentation will conclude with a description of planning this new framework.

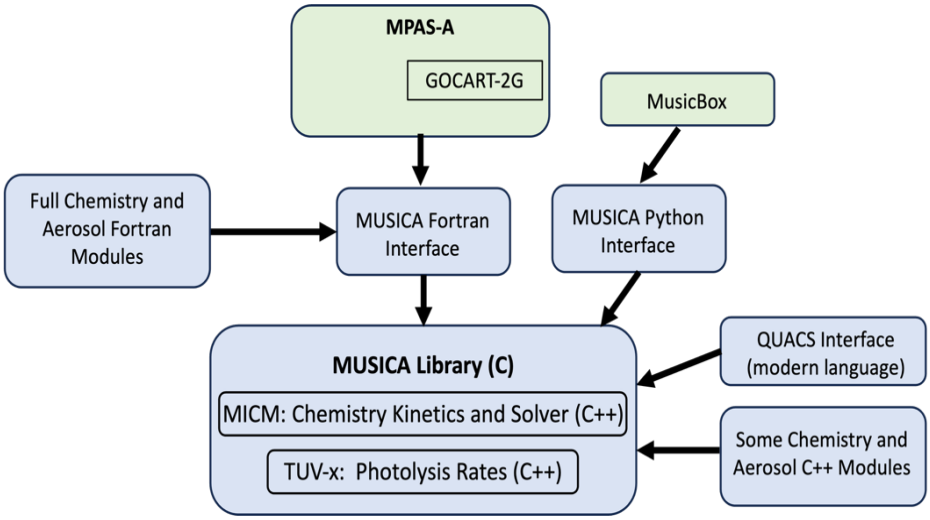

Figure 1: Schematic of the CheMPAS-A ecosystem illustrating the GOCART-2G module as part of MPAS-A, while CheMPAS-A is interfacing with the MUSICA library. QUACS (Quick Updates for Aerosol and Chemistry Systems) is the planned software infrastructure for bringing in new chemistry and aerosol parameterizations. MusicBox is a box model for solving chemistry systems.

NOAA GSL experimental aerosol forecasting in MPAS-A

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Air pollution is implicated in 1 in 8 global deaths and seasonal allergies due to wind-blown pollen affect ~20% of the global population. Climate-change induced warming is lengthening and intensifying the pollen season and increasing the intensity and frequency of wildfires in North America, amplifying air pollution impacts in some regions despite reductions in anthropogenic emissions. Smoke, pollen, and other anthropogenic and natural aerosols modify the radiation budget and serve as cloud and/or ice condensation nuclei, thus impacting temperature, clouds, and precipitation. The NOAA Global Systems Laboratory (GSL) in collaboration with other laboratories has been developing an experimental pollen forecast and aerosol numerical weather prediction model as a follow on to the High-Resolution Rapid Refresh with Smoke (HRRR-Smoke), Rapid-Refresh Forecasting System with Smoke and Dust (RRFS-SD), and Rapid-Refresh with Chemistry (RAP-CHem) models. The new model is a standalone version of MPAS-A, and has been configured with improved versions of the RAP-Chem pollen module (tree, grass, weed, and ruptured pollen) and RRFS-SDv1 smoke and dust modules. Online emissions of anthropogenic residential wood combustion and high-resolution (1 km) anthropogenic emissions from other sources, and point sources with inline plume rise emissions have also been added. Further, we have made additional developments for full physics coupling (e.g., aerosol optical properties calculation with Mie theory, simplified aerosol indirect effect). The experimental modelling system is running in real-time on the Ursa supercomputer, over a 3.75 km resolution domain covering most of North and Central America (https://rapidrefresh.noaa.gov/MPAS-Aerosols/) and is compared with observations in near-real time (https://rapidrefresh.noaa.gov/monet_rrfs_verif/). Here we will present the aerosol modeling developments in MPAS-A and verification of our initial experimental forecasts against novel pollen measurements and other particulate matter observations.

Impact of boundary conditions, model type and chemistry on ambient meteorology and air-quality

Jan Karlický[1,*], Peter Huszár[1], Natália Machada Crespo[1], Anahí Villaba Pradas[1], Michal Belda[1]

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Keywords: *WRF-Chem model, RegCM5-Chem*

As part of the FOCI project ("Non-CO_2 Forcers and their Climate, Weather, Air Quality and Health Impacts"), regional climate simulations are conducted using two chemistry-coupled models: RegCM5-Chem and WRF-Chem. These models are applied over Europe to assess the influence of atmospheric chemistry, emission inventories and boundary conditions on both air quality and meteorological conditions. The simulations are driven by reanalysis and by the global climate model EC-Earth3-AerChem for historic period of years 2004–2019. Preliminary results suggest that both models tend to underestimate particulate matter and ozone concentrations, with varying biases in nitrogen dioxide. Additionally, the inclusion of chemistry affects surface meteorological variables such as temperature, radiation, and wind speed. Also boundary conditions and model type have a significant impact on results. Our findings are supporting future regional chemistry-climate model inter-comparisons and ensemble strategy for projection simulations.

Analytical Forecasting of a Destructive Summer Storm Event Driven by Aerosol-Induced Convective Intensification in Northern Thailand

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Keywords: *Aerosol-Radiation Feedback, Convective Intensification, Summer Storm Forecast, Transboundary Haze, WRF-Chem and MPAS*

Forecasting summer storms in Northern Thailand remains a significant challenge due to their rapid development and the complex influences of topography and atmospheric pollutants. During the peak haze season, these convective events can become exceptionally violent; in a recent case, extreme $PM_{2.5}$ loading preceded a destructive thunderstorm characterized by large-scale hail and high-velocity downbursts. This study provides an analytical forecasting evaluation using the WRF-Chem model at a convection-permitting resolution to investigate how the interplay between local biomass burning and transboundary aerosol transport modulates the lifecycle and intensity of such severe events.

By integrating a developed FRP-based (Fire Radiative Power) biomass open burning emission inventory, the research evaluates the predictive accuracy of four numerical scenarios: two standard meteorology-only configurations of WRF and MPAS, a local-only aerosol feedback run, and a full-feedback simulation accounting for the total regional aerosol burden. The results indicate a dual-phase aerosol impact where initial radiative cooling stabilizes the boundary layer, effectively capping the atmosphere and delaying storm initiation in the forecast. However, once the convective temperature is reached, the high aerosol loading alters the microphysical pathway by suppressing warm-rain processes and promoting the vertical transport of supercooled water in the cloud tower.

Atmospheric stability indices were analyzed alongside forecasting performance, which was evaluated against surface observations of wind, rain, and temperature, as well as radar reflectivity, satellite cloud imagery, and localized damage records. This microphysical shift leads to enhanced graupel formation and increased latent heat release aloft, ultimately intensifying the updraft and resulting in the severe downdrafts observed. Overall, the study demonstrates that accounting for transboundary aerosol feedback is crucial for improving the accuracy of severe weather warnings in Southeast Asia.

Implementation of a fully coupled atmosphere-aerosols-waves-ocean model based on the COAWST package and the WRF-Chem model: Application for the Medicane IANOS

Umberto Rizza[1], Fabio Grasso[1], Alessandro Coluccelli[2], Antonio Ricchi[3], Piero Serafini[3], Elisa Canepa[4] and Giorgio Passerini[5]

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Keywords: *WRF-Chem; COAWST; Marine aerosols; sea-spray; Medicanes*

Accurate atmospheric simulations increasingly require a comprehensive representation of the Earth system, as atmospheric dynamics are strongly influenced by interactions with the ocean, waves, aerosols, and surface processes. Stand-alone atmospheric models often fail to capture these feedbacks, particularly in coastal and hotspot regions where air–sea exchanges and aerosol–meteorology interactions are critical. Earth system models address these limitations by enabling consistent, two-way coupling among components, allowing atmospheric circulation, radiation, and chemistry to respond dynamically to evolving marine and surface conditions.

In this framework, the proposed modelling system uses the Model Coupling Toolkit (MCT) to exchange data among key components: the ocean model ROMS, the atmosphere–chemistry model WRF-Chem, the wave model SWAN, and the sediment module of the Community Sediment Transport Model within COAWST. A key innovative feature is the integration of WRF-Chem, which allows online feedbacks between meteorology and aerosols, essential for realistically simulating high-impact regions.

COAWST is an open-source coupled modelling system developed to investigate coastal and storm-driven processes through interacting Earth system components. It combines ocean circulation via ROMS, atmospheric processes through WRF, hydrology using WRF- Hydro, wave dynamics with SWAN, WAVEWATCH III, and InWave, sediment transport through the USGS Community Sediment Models, and sea-ice processes. Since its initial formulation (Warner et al., 2008), COAWST has been enhanced to support one-way grid refinement in ocean and wave models, atmosphere–ocean–wave coupling, refined-grid field exchanges, and interpolation across different spatial resolutions (Warner et al., 2010).

The COAWST-Chem configuration integrates ROMS for ocean circulation, SWAN for wave modelling, and WRF-Chem for atmospheric and aerosol processes, enabling consistent interactions between marine and atmospheric systems. It is a widely used, open-source model for simulating atmospheric chemistry, aerosols, and air quality, with online coupling to the WRF-ARW dynamical core. Aerosol processes are represented using the GOCART module, which simulates major tropospheric aerosol species and includes emission, transport,

deposition, and settling mechanisms. Aerosol–radiation and aerosol–cloud interactions are treated using the Goddard radiation and microphysics schemes.

This modelling framework is applied to the simulation of Medicane Ianos, a Mediterranean tropical-like cyclone that developed in September 2020 and caused severe impacts over Greece and surrounding regions. Its intense winds, heavy rainfall, and strong air– sea coupling make Ianos a suitable case to assess the role of fully coupled atmosphere–ocean–wave–aerosol interactions in extreme Mediterranean events.

High-resolution Assessment of the Impact of Climate Change on Air Quality in Thessaloniki, Greece with WRF-Chem: Model Configuration, Performance Evaluation and Future Projections

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Keywords: *urban air quality, climate change, regional modelling, model evaluation, future projections*

High-resolution air quality modelling in complex urban environments remains a critical challenge for regional chemistry–climate simulations, while the combined effects of climate change and shifting emission regimes further obscure our understanding of how urban air quality will respond in the future. In this study, the Weather Research and Forecasting model coupled with chemistry (WRF-Chem) is implemented at high spatial resolution (2 km) over the metropolitan area of Thessaloniki, Greece. The simulations are conducted for three five-year periods, representative of the present, near future and end of the century climate and air quality regimes. Outputs of models that participated in the Coupled Model Intercomparison Project 6 (CMIP6) of the Intergovernmental Panel on Climate Change (IPCC) were used as meteorological and chemical boundary conditions. Anthropogenic emissions were derived from the Shared Socioeconomic Pathway SSP3–7.0 emission scenario and were downscaled to 2 km horizontal resolution to ensure consistency with the urban-scale modelling configuration. Model performance for key meteorological variables and major air pollutants (O_3, NO_2, PM_{10}, and $PM_{2.5}$) is evaluated against in situ observations from monitoring stations operated by the Greek Ministry of Environment and Energy and the Municipality of Thessaloniki. The model configuration, together with preliminary results for model evaluation and future projections are presented and discussed.

How Heatwaves Reshape Ozone Budgets over the UK: Transport and Chemistry Interactions within the PBL

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Keywords: *Heatwaves, Ozone, Air quality, emissions, pollution transport*

Heatwaves (HWs), prolonged periods of excessively hot weather, are increasingly recognised as a public health threat due to their significant impact on air quality, particularly surface ozone (O_3) levels [1,2]. While many studies have observed a positive correlation between extreme temperature and extreme O_3 concentrations [3], the underpinning chemical and physical factors involved, and their interconnections are not well quantified and may vary across regions and individual HW events.

The O_3 pollution in the United Kingdom is strongly influenced by regional-scale transport from north-western Europe, particularly in summer [4]. Despite decades of national mitigation policies reducing domestic emissions of its precursors [5], surface O_3 remains high, indicating that local controls alone are insufficient when imported pollution is significant. While transboundary transport is known to shape UK air quality, it remains unclear how extreme meteorological events, such as HWs, modify this contribution and how much enhanced O_3 during heatwaves originates from domestic versus external sources.

The UK summer of 2019 offers a compelling case study as three distinct HWs occurred, characterised by record-breaking temperatures, including a peak of 38.7°C, and widespread O_3 exceedances above health-relevant thresholds across both urban and rural areas. We use the chemistry-transport model WRF-Chem [6] to quantify daily maximum 8-hour average (MDA8) O_3 and daily maximum temperature, highlighting the HW impacts over the summer period. We use diagnostic variables to calculate O_3 budget within the planetary boundary layer (PBL), quantifying the resulting PBL-integrated O_3 burden. Finally, we run scenarios with suppressed biogenic Isoprene emissions or boundary conditions from non-UK areas to quantify the impact of these parameters on the HW Air Quality periods.

Our results show that a mixture of changes in temperature, isoprene emissions, and stagnant air masses drove elevated O_3 levels during the HWs. Budget analysis revealed that during the HWs, enhanced concentrations of O_3 are predominantly obtained by an increase in photochemical activity and their accumulation below the PBL is favoured by poor vertical mixing and weak air circulation. Removal of boundary conditions from non-UK areas, though, shows the highest impact on the final O_3 reduction during the whole period, confirming that the UK Air Quality has a strong regional dependence and cannot rely exclusively on national mitigation policies. Furthermore, in the context of adaptation to a changing climate, the combined impact of meteorological extreme events and their link with Air Quality should be carefully considered in future mitigation policies.

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Simulating Parameterized Vertical Transport by Mesoscale Storms Using Lightning Data Assimilation in WRF-Chem

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Keywords: *Mesoscale models; Data assimilation; Parameterization; Subgrid-scale processes; Entrainment; Atmospheric chemistry*

Deep convective clouds play a critical role in regulating upper-tropospheric and lower-stratospheric (UTLS) composition by rapidly transporting trace gases and aerosols from the planetary boundary layer (PBL). The magnitude and vertical extent of this transport strongly influence atmospheric chemistry, air quality, and climate, yet remain challenging to represent in regional and climate models due to limited resolution and uncertainties in convective parameterizations. In this study, we investigate convective transport to the UTLS using Weather Research and Forecasting model simulations coupled with Chemistry (WRF-Chem) for two cases of observed deep convection during the Deep Convective Clouds and Chemistry (DC3) campaign: an Oklahoma supercell on 29 May 2012 and a mesoscale convective system (MCS) on 11 June 2012.

WRF-Chem simulations are conducted using nested domains with 36 and 12 km horizontal resolution and 70 vertical levels extending to 50 hPa. To reduce errors in the timing, location, and vertical development of convection, a lightning data assimilation (LDA) technique is applied that activates or suppresses the Kain-Fritsch cumulus parameterization based on observed lightning. Simulations with and without LDA are evaluated against STAGE-IV and IMERG Final Run precipitation products and GOES-13 brightness temperatures, using both grid-based and object-based verification methods.

Results show that LDA substantially improves the representation of convective evolution, including storm timing, spatial placement, and cloud-top heights, for both storm types. Improved convective structure leads to better agreement between simulated and aircraft-observed trace gas profiles in the UTLS such as carbon monoxide (CO). Analysis of vertical transport reveals distinct differences between storm modes. The supercell exhibits stronger localized mass flux densities and more efficient vertical transport per unit area, while the MCS shows greater UTLS transport due to larger spatial coverage despite weaker mass flux densities that are influenced by storm-scale dynamics including a rear-inflow jet. The subgrid contribution of supercell convective transport to the UTLS is found to be greater than that of the MCS, with supercell contributions ranging from 60% to 80%, but being 40% for the MCS. A mean fractional entrainment rate exceeding 0.1 km^{-1} at higher altitudes results in less subgrid-scale CO transport to the lower stratosphere for both cases.

Spatiotemporal Variability of Black Carbon in High Mountain Environments: An Observational and Modeling Approach in the Huaytapallana Mountain Range

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Keywords: *Black carbon, glacial albedo, Andes-Amazon transition, Huaytapallana*

Glaciers act as receptors of various atmospheric pollutants, which modify their optical properties and accelerate melting. Among these pollutants, black carbon (BC) contributes to the darkening of snow and ice surfaces, reducing their albedo and enhancing melt rates, while also affecting air quality and human health. However, there is currently limited understanding of the sources, transport pathways, and temporal variability of BC in valley and mountain environments in Peru.

To address this issue, this study combined BC observations collected during 2022–2023 with WRF-Chem model simulations and HYSPLIT back-trajectory analyses to examine transport processes and identify areas of stronger BC source influence. The results show that high BC concentrations are associated with seasonal variability, the valley–mountain wind system occurring on both sides of the Huaytapallana mountain range, and synoptic-scale circulations. The Andes–Amazon transition valleys, which connect to the inter-Andean valleys, were identified as effective transport channels for BC. During the dry and transition seasons, the northern valley stands out as the main BC transport pathway, contributing approximately 80% of the BC reaching the Huaytapallana region.

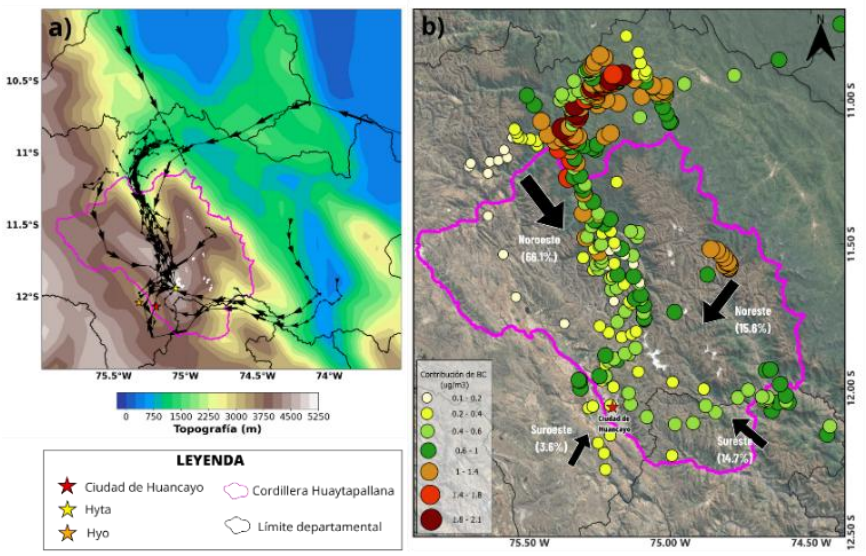

Figure 1: Potential contribution to BC concentrations reaching Hyta: (a) daily air mass back-trajectories arriving at Hyta and (b) spatial average of high surface BC concentrations estimated at each trajectory point, for the period 4–13 September 2022.

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Tropospheric ozone sensitivity in response to changes in soil moisture and vegetation over the Iberian Peninsula

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Keywords: *Tropospheric ozone, Biogenic emissions, Air quality modeling, Volatile organic compounds,*

Extreme weather events, such as stagnation conditions and heatwaves, exacerbate hazardous air quality situations by promoting the accumulation and persistence of pollutants like ozone (O3) in the near-surface environment. In particular, during the summer over the Iberian Peninsula (IP), extreme O3 values often exceed the 120 µg/m3 threshold, significantly impacting air quality and public health. While meteorological factors like high temperatures and radiation are important drivers of these events, classifying them based solely on synoptic weather patterns fails to capture the full scope of the risks involved. Even when events are classified under the same synoptic category, O3 concentration can vary greatly. This implies that variability is not only due to direct meteorological influences, but also other factors related to transport, previous concentrations, or processes linked to surface conditions can modify emissions of compounds that affect O3 formation. In this regard, biogenic volatile organic compounds (BVOCs) emissions from vegetation can significantly influence O3 formation in a complex and non-linear way. The amount and type of vegetation, as well as the available soil moisture, modulate these emissions.

In this study, we conducted sensitivity experiments using the Weather Research and Forecasting model coupled with chemistry (WRF-Chem, version 4.6.0) to explore how factors like soil moisture and vegetation amount influence extreme O3 events over the IP. We first performed simulations varying leaf area index (LAI) and soil moisture (SM) by multiplying the original fields of SM (all layers) and LAI by a factor ranging from 0.25 to 2. The results indicate that decreasing the available soil water (-50%) increases BVOCs emission rates (20% spatial and temporal average), which is reflected in an increase in daily maximum O3 concentrations (10%). On the other hand, increasing the vegetation (50%) leads to an increase in BVOCs emission rates (10%), as well as in O3 concentrations (up to 10%). The combined experiments exacerbated the changes, although most of the time, they are smaller than the sum of the isolated experiments.

Regional Climate Models (RCMs) often use climatological variables to characterize vegetation. Some stxudies show that differences in vegetation fraction concerning climatological values can reach up to 40% over the IP. Preliminary results indicate that such

differences in vegetation moderately modify final O3 concentrations, in most cases obtaining better agreement with observations.

Toward a Globally Transferable Numerical Pollen Forecasting System: Advancing DREAM-POLL for Multi-Region Pollen Prediction

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Keywords: *pollen, numerical simulation, forecasting*

Extreme pollen episodes associated with convective storms represent one of the most severe bio-meteorological hazards. The 21 November 2016 Melbourne epidemic thunderstorm asthma (TA) event demonstrated how mesoscale dynamics coupled with pollen rupture processes can produce high concentrations of respirable allergenic particles within hours. While most operational pollen warning systems consider only the intact pollen grains, evidence shows that within convective clouds pollen rupture can be triggered, releasing large numbers of sub-pollen particles (SPPs) capable of penetrating deep into the lungs.

We present DREAM-POLL, a physically based Eulerian pollen transport system derived from the DREAM dust aerosol framework and coupled online with the WRF-NMM nonhydrostatic mesoscale model. In addition to intact pollen transport, the model explicitly simulates pollen rupture and the subsequent formation, transport, and deposition of allergenic SPPs. SPPs originate within moist convective regions and can be advected independently from heavier intact grains. This enables representation of the observed temporal lag between intact pollen arrival and peak respirable particle concentrations during thunderstorm outflows.

Convection-permitting simulations of the Melbourne 2016 event reproduced the pre-frontal intact pollen enhancement, the frontal-passage triggering of fragmentation, and a delayed near-surface maximum of SPP concentrations consistent with observed hospital presentation timing. These results confirm the importance of explicitly resolving moist convection and humidity fields for TA prediction.

Future development focuses on extending the system into a globally transferable early-warning framework. Planned advancements include region-specific phenology modules and species-dependent rupture parameterizations.

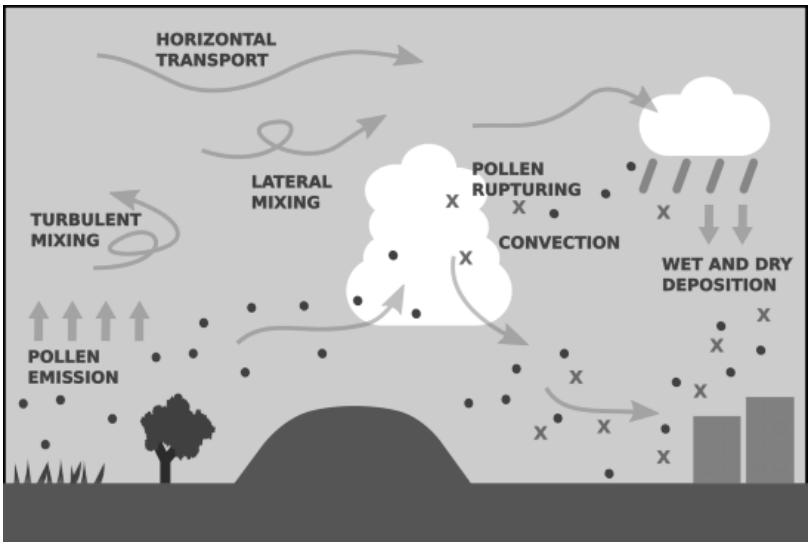

Figure 1: A schematic of atmospheric and pollen processes in DREAM-POLL.

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Fungal Spore Parameterization in WRF-Chem: Implementation and Finland Case Study

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Keywords: *Fungal spores, emission parameterization, HFAPs, WRF-Chem, Finland*

Fungal spores are a type of organic aerosol that is not widely represented in numerical models. Recent studies suggest that fungal spores contribute significantly to particulate matter (PM10) concentrations and can influence cloud microphysical processes by acting as high-temperature ice-nucleating particles (INPs). This is particularly important in the Arctic and sub-Arctic regions, where temperatures are increasing 1.5–4 times faster than the global average due to Arctic amplification [2]. In these regions, radiative cloud feedback associated with INP concentrations introduce major uncertainties in numerical models. Measurements of fungal spore concentrations and properties remain scarce. Recently, an extensive measurement campaign [3] was conducted at the Sammaltunturi station in Finland's Pallas–Yllästunturi National Park. eDNA analysis [2] showed that the highly fluorescent aerosol particles (HFAPs) observed at this site were predominantly of fungal spore origin. These measurements are used here as reference data to evaluate two fungal spore emission parameterizations implemented in the WRF-Chem model [4]. The first parameterization is the Heald and Spracklen (HS) scheme [5], in which the emission flux depends linearly on the specific humidity at the lowest model level and the leaf area index (LAI). The second scheme is based on the statistical approach presented by Janssen [8]. First, the fungal spore emission flux is estimated from measured HFAP concentrations and ERA5 [6] planetary boundary layer (PBL) height using the tracer conservation equation. Subsequently, a statistical emission function is derived by assuming a linear dependence of fungal spore flux on ERA-5 [6,7] specific humidity, friction velocity, and MERRA-2 LAI [1] using multivariate linear regression. Preliminary tests include five-day simulations during a period with no recorded precipitation near the measurement site in August. At this stage, the Janssen-based parameterization remains under development, while the HS scheme shows good agreement with the observed HFAP concentrations.

Acknowledgement

The HPAFs concentrations were obtained from the TU Wien Research Data under https://doi.org/10.48436/0xmsb-eps20 [3]. Meteorological precipitation data are available at https://en.ilmatieteenlaitos.fi/download-observations (last access: 8 May 2026). WRC-Chem v4.7.1 is taken from https://github.com/wrf-model/WRF. Copernicus Climate Change Service, Climate Data Store, (https://cds.climate.copernicus.eu/datasets) was a source of ERA5 hourly data on single and pressure levels. LAI data were taken from MERRA2 reanalysis at https://gmao.gsfc.nasa.gov/gmao-products/merra-2/. Text editing assistance was supported with the help of OpenAI's ChatGPT.

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Assessing the Contribution of Urban Green Spaces to Atmospheric CO_2 Dynamics Using WRF-Chem in a Metropolitan Area

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Keywords: *Biogenic Fluxes, WRF-Chem Modeling, Carbon Sinks and Sources, Urban Carbon Dioxide*

The role of urban green spaces in regulating atmospheric CO_2 has gained increasing attention as cities promote nature-based solutions to advance sustainability and achieve climate neutrality. However, accurately quantifying their contribution remains challenging due to high spatial heterogeneity of urban land cover and the mixing of biogenic and anthropogenic CO_2 sources within densely populated areas.

In this study, the Weather Research and Forecasting model with chemistry (WRF-Chem) is applied to simulate atmospheric CO_2 concentrations over the Metropolitan Area of Barcelona (AMB) for April and December 2023 at 1 km spatial resolution. Biogenic CO_2 fluxes are calculated using the Vegetation Photosynthesis and Respiration Model (VPRM), driven by high-resolution vegetation indices derived from Sentinel-2 (S2) satellite imagery. Anthropogenic emissions are from a state-of-the-art local fossil fuel inventory. Model performance is evaluated against 4 stations from the AMB atmospheric monitoring network. To constrain the modelled biogenic CO_2 emissions and determine their uncertainties, two sensitivity experiments are conducted: (1) VPRM driven by MODIS satellite data, and (2) a modified VPRM which accounts for soil moisture effects driven by S2 satellite data. Results show that WRF-Chem generally underestimates CO_2 concentrations but well captures the observed diurnal variability of atmospheric CO_2. The biospheric concentrations from different VPRM configurations show major difference between the default and the modified VPRMs instead of with different satellite inputs, highlighting the importance of careful model configuration to ensure reliable simulations. These findings improve understanding of urban CO_2 dynamics and support more robust quantification of the climate mitigation potential of urban green spaces, thereby informing urban planning and the development of effective nature-based climate strategies.

Climate-driven loss of resilience in Italian forests under ISIMIP3 scenarios: insights from 3D-CMCC-FEM v5.7

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Keywords: *Mediterranean region; Climate change; ISIMIP; 3D-CMCC-FEM; Carbon dynamics*

Mediterranean bioclimatic regions are recognized as climate change hotspots, experiencing warming rates higher than the global average. Increasing frequency and intensity of droughts and heat waves are already affecting the functionality, productivity, and stability of forest ecosystems, particularly for species located at the edge of their ecological distribution. Within the framework of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP3b), which provides a coordinated framework for assessing climate change impacts across sectors using harmonized climate forcing datasets and scenarios, this study investigates the future resilience of Italian forest ecosystems under changing climatic conditions.

Forest plots were selected from the second Italian National Forest Inventory (INFC 2005)[1], focusing on the main Italian ecoregions (Alpine, Apennine, Tyrrhenian, Adriatic, and Po Plain) where detailed structural and ecological information was available. Only pure stands were considered, selecting 3,698 plots in which a single species represented more than 70% of the total basal area, in order to reduce structural heterogeneity and better isolate species-specific climate responses. In addition, two FLUXNET sites were selected for model evaluation against ecosystem carbon flux observations. Simulations were performed using the process-based forest ecosystem model 3D-CMCC-FEM [2], [3], [4] over the 2005–2100 period.

Future projections were driven by bias-corrected CMIP6 climate simulations following the SSP1-RCP2.6, SSP3-RCP7.0, and SSP5-RCP8.5 scenarios from 2015 onward, using two Earth System Models (ESM): GFDL-ESM4 and UKESM1. For the historical period (2005–2015), corresponding historical simulations from the same ESM were adopted. Climate forcing data were complemented with the high-resolution (0.1°) ERA5-Land reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) [5].

The study aims to quantify the (i) extent to which ecosystem services and carbon sequestration capacity provided by Italian forests may lose resilience and stability under future climate conditions. Particular attention is devoted (ii) to assessing how climate change alone affects long-term trajectories of forest productivity, carbon fluxes, and carbon stocks. Furthermore, (iii) the analysis identifies the key specie-related factors that may enhance the adaptive capacity of Mediterranean forests and support the protection of these natural carbon sinks under increasing climate stress.

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High-Resolution Urban Emission Mapping and WRF-Chem Simulations to Evaluate Clean-Air Pathways for Ahmedabad, India

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Keywords: *WRF-Chem; Emission Inventory; Particulate Matter; Urban Air Quality; Mitigation Scenarios*

Urban air pollution remains one of the most severe environmental and public-health challenges in South Asia, driven largely by rapid urbanization and concentrated emission sources (WHO, 2018). High-resolution emission inventories coupled with chemical transport models such as WRF- Chem have become essential tools for diagnosing pollution sources and evaluating sector-specific mitigation strategies (Grell et al., 2005). This study develops an integrated WRF-Chem framework to assess particulate matter (PM_{10} and $PM_{2.5}$) dynamics across Ahmedabad, India—one of the non- attainment cities under the National Clean Air Programme (NCAP) (MoEFCC, 2019).

A bottom-up, gridded emission inventory was constructed for the year 2018 at 2 × 2 km resolution using detailed multisectoral activity data, following recommended bottom-up emission inventory practices (Guttikunda & Calori, 2013). Total PM emissions were estimated at 802 tons/day, dominated by industrial point sources (94%), followed by vehicular (4.3%) and area sources (2.1%). These emissions were integrated into WRF-Chem (v3.9.2) and compared against simulations using the global EDGAR-HTAP dataset (Janssens-Maenhout et al., 2015) for representative summer (May) and winter (December) episodes.

Model evaluation against in-situ observations from the SAFAR network (Beig et al., 2015) showed substantially improved performance using the local inventory, achieving $R^2 \approx 0.93$ for $PM_{2.5}$ and PM_{10}. This demonstrates the importance of localized emissions for capturing intra-urban variability, meteorological influences, and episodic pollution events—limitations often observed in global inventories (Kurokawa & Ohara, 2020). Seasonal differences were pronounced, with winter simulations showing stronger accumulation driven by low planetary boundary layer height and weak ventilation, consistent with established meteorological controls on PM (Seinfeld & Pandis, 2016).

Three mitigation scenarios aligned with India's clean-energy transition were simulated: 30% electric-vehicle adoption, 30% substitution of industrial fuel with natural gas, and 30% natural-gas- based power generation. Combined, these resulted in 145 tons/day of PM reduction (≈18%), yielding winter PM_{10} decreases up to 33 $\mu g/m^3$. Industrial clusters such as Naroda, Odhav, and Vatva showed the highest improvements, though benefits were uneven across residential zones.

Overall, this study highlights that city-specific, high-resolution emissions significantly enhance WRF-Chem predictability, and that targeted interventions offer meaningful, though still insufficient, reductions relative to NAAQS and WHO thresholds. The framework provides a transferable model for urban air-quality planning and supports evidence-based implementation of NCAP objectives.

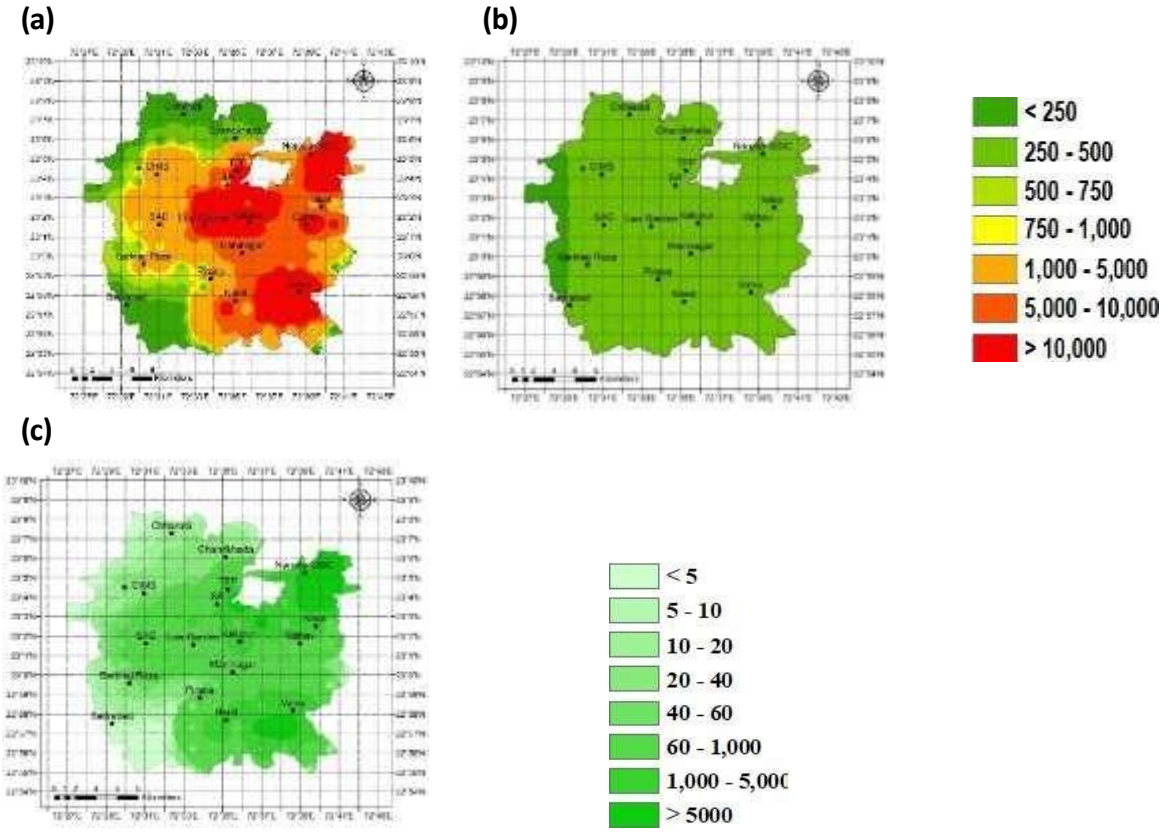

Figure 1: Spatial Distribution of PM Emissions (Kg/Day) (a) Local, b) EDGAR PM Emission Inventory (Kg/Day) and (c) Mitigative PM Reduction (Kg/Day)

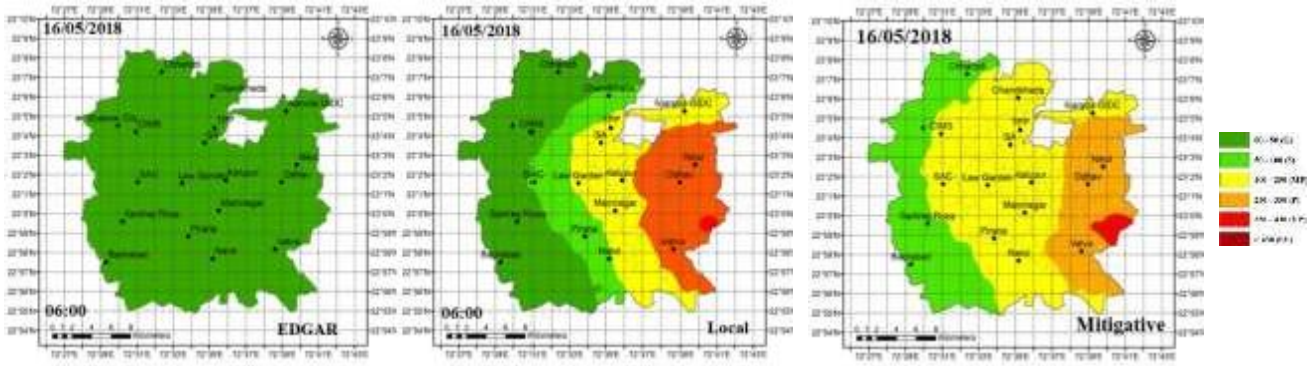

Figure 2: Spatial Distribution of Daily Average PM_{10} Concentrations ($\mu g/m^3$) using EDGAR, Local, and Mitigative Inventories

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WRF-Chem analysis of ammonia emissions over the Benelux and neighboring regions: seasonal insights from IASI

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Keywords: *Ammonia, inverse modeling, emissions, satellite.*

Ammonia (NH_3) plays a key role in air quality and ecosystem impacts through its contribution to particulate matter formation and nitrogen deposition. We investigate the spatial heterogeneity and seasonality of NH_3 over Western Europe, with a focus on Benelux and neighboring regions, by combining regional chemical transport modeling, high-resolution anthropogenic emission inventories, and in situ and satellite observations.

We use the WRF-Chem model at 15 km horizontal resolution over Western Europe, with a 5 km nested domain over Belgium, to simulate two periods in 2022 representative of high agricultural activity, in spring and in summer. Anthropogenic NH_3 emissions are prescribed using high-resolution (1 km) inventories, including TNO for Europe and VMM for Flanders.

Model results are evaluated against surface measurements and satellite retrievals from the Infrared Atmospheric Sounding Interferometer (IASI), with a focus on the complex chemistry of NH_3 and related species across both seasons. An iterative mass-balance approach is implemented to adjust NH_3 emissions where discrepancies between modeled and observed NH_3 column concentrations are identified. We highlight and discuss the resulting changes in emission magnitude and the spatial distribution of NH_3 hotspots.

Modeling $PM_{2.5}$ Levels Due to Combustion Activities and Fireworks at the Beginning of the Year in Quito (Ecuador) Using WRF-Chem

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Keywords: *Air pollution, fireworks, PBLH, Andean region, Forecasting*

PM2.5 levels increase in cities during the first hours of the year due to combustion activities and the use of fireworks. In Quito (2800 masl), the capital of Ecuador, air quality records at the beginning of 2020 to 2025 (6 years) ranged between 13.4 and 217.8 µg m-3 (maximum mean levels for 24 hours), most of them being higher than 15.0 µg m-3, the current recommended concentration by the World Health Organization (WHO). The highest records at the beginning of these years were measured in the city's south, with levels ranging from 34.7 to 217.8 µg m-3. The lowest and highest concentrations were recorded for 2025 and 2024, respectively. Hourly temperature records indicated that the city's south is colder than the center and the north, suggesting a lower volume of air to disperse pollutants. The meteorological conditions were simulated at the beginning of these years using the Weather Research and Forecasting (WRF) model. According to our assessment, the temperature and wind speed were captured by modeling in 6 stations of the air quality network. The modeled planetary boundary layer height (PBLH) was generally lower in the city's south compared to the center and the north. In addition, using a population density map and a reference emission factor (2.7 g PM2.5 person-1), the spatiotemporal distribution of PM2.5 emissions for the first hours of 2024 and 2025 was inferred through numerical simulations with the Weather Research and Forecasting with Chemistry (WRF-Chem) model. The results of our numerical experiments indicated that in the south, higher PM2.5 levels were driven by higher emissions and lower PBLH values than in the center and north, highlighting the importance of reducing PM2.5 emissions. The final emission maps used for modeling the dispersion at the beginning of 2024 and 2025 are proposed as inputs for future forecasting of the PM2.5 levels at the start of the year, considering very high and high PM2.5 levels scenarios, as preventive information to the public, to discourage in advance both the combustion activities and the use of fireworks.

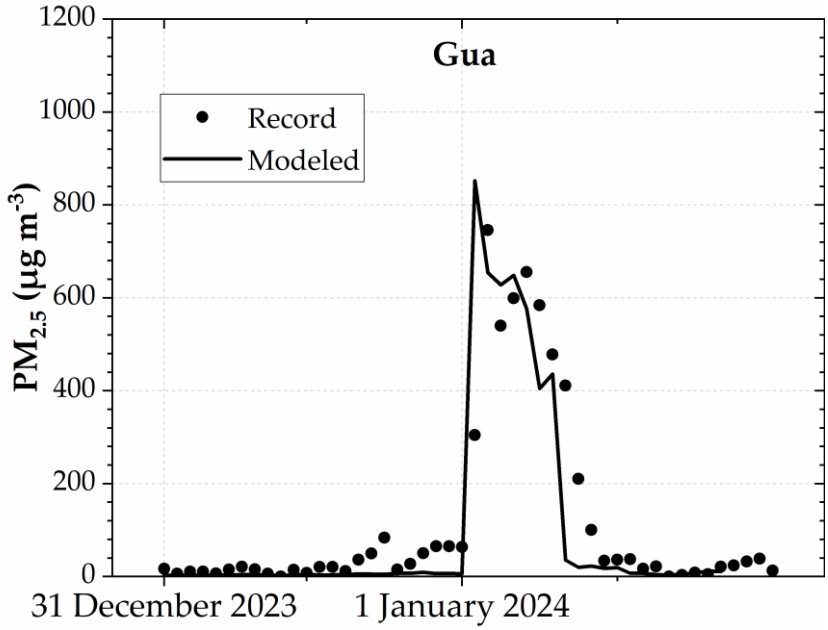

Figure 1: Observed and modeled hourly $PM_{2.5}$ levels in the South of Quito (Guamaní station) during 31 Dec 2023 and 1 Jan 2024.

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Using WRF-Chem and MPAS-A for experimental pollen forecasting in RAP-Chem and cheMPAS-Fire

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Seasonal allergies due to wind-blown pollen affect ~20% of the global population. Climate-change induced warming is lengthening and intensifying the pollen season in many locations, leading to amplified and extended impacts. Pollen, like other aerosols, modify the radiation budget and can serve as cloud and/or ice condensation nuclei, impacting temperature, clouds, and precipitation. Yet, the United States neither operates an operational pollen forecast nor a federal monitoring network. SInce 2022, the NOAA Global Systems Laboratory (GSL) has been operating a once daily, 06Z initialized, 48 h, 13 km resolution experimental pollen forecast over North America as part of a broader air quality forecast in the Rapid-Refresh model coupled to chemistry (RAP-Chem; https://rapidrefresh.noaa.gov/RAPchem/). The model includes separate tracers for tree, grass, and weed pollen, with an additional tracer representing ruptured pollen, each coupled to multiple physics parameterizations. Recently, NOAA GSL has been developing a new modelling system based on the Model for Prediction Across Scales (MPAS) and has included the initial pollen capabilities from RAP-Chem. The first version of the experimental MPAS-A modelling system (MPAS-Aerosols: https://rapidrefresh.noaa.gov/MPAS-Aerosols/) began real-time forecasting in April 2025, and currently produces a 00Z initialized, 48 h forecast each day over a 3 km resolution CONUS domain. Here we will present the pollen modeling developments in the RAP-Chem and the MPAS-Aerosols and demonstrate the first forecasts from the new modeling system. We will also evaluate the forecasts against novel pollen observations and compare with other publicly available forecasts produced by the private sector.

Evaluation of WRF-Chem performance in simulating background particulate matter in Europe during stable atmospheric conditions

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Keywords: *WRF-Chem, particulate matter, rural background stations, stable boundary conditions, transboundary pollution*

Regional-scale air quality models are essential scientific and regulatory tools for air quality assessment and management, making a thorough understanding of their performance crucial, particularly under complex meteorological conditions. This study investigates the spatial and temporal variability of background particulate matter (PM) concentrations across Europe in 2011 and evaluates the performance of the online-coupled Weather Research and Forecasting model with Chemistry (WRF-Chem) in simulating PM levels during statically stable atmospheric conditions. The focus is on Eastern and Central Europe, with particular emphasis on the Republic of Croatia. The research domain covered almost the entire European continent to account for regional and transboundary pollution transport influencing Croatia. Observed PM concentrations from 310 rural background stations were analysed to assess large-scale spatial patterns and seasonal variability. Special attention was given to two high-pollution episodes in November 2011, characterized by persistent stable atmospheric conditions that promoted pollutant accumulation and limited vertical mixing.

WRF-Chem was applied to simulate pollutant transport, chemical transformations, and interactions between meteorology and atmospheric composition [1]. The model was further used to investigate processes contributing to regionally elevated PM concentrations during the identified episodes. Model performance was evaluated using background PM measurements and meteorological data (wind speed, surface pressure, and ambient temperature) from 920 meteorological stations across Europe. Stations were classified according to elevation to assess model skill under different topographic and atmospheric regimes.

The best modelling performance, in terms of both meteorology and PM concentrations, was achieved at sea-level stations (up to 200 m above ground). Overall, WRF-Chem showed satisfactory performance; however, PM concentrations were frequently underestimated during statically stable conditions, indicating limitations in representing boundary layer processes, vertical mixing, and regional pollutant transport under weak dispersion scenarios [1]. These findings highlight the importance of accurately representing atmospheric stability and land–atmosphere interactions in regional air quality modelling. Continuous and systematic model evaluation remains essential for improving predictive capability. The results contribute to a better understanding of WRF-Chem performance in simulating background aerosol distributions and high-pollution episodes, providing valuable insights for air quality assessment and management in Croatia and the broader Eastern and Central European region [1].

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Possible use of the WRF-Chem model for air quality prediction in Serbia

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Keywords: *WRF-Chem model, grid resolution and emission*

The development of a reliable Real-Time Air Quality Forecasting system is crucial for every country to mitigate the impact of pollutants and protect public health. This study presents the first effort to implement and evaluate an online-coupled WRF-Chem (v3.6.1) system for Serbia. The research focuses on identifying the optimal model configuration by investigating the sensitivity of the system to different horizontal grid resolutions (20 km, 10 km, and 5 km) and anthropogenic emission inventories (global RETRO vs. regional EMEP) [1].

Simulations were performed for August 2016 using the Global Forecast System (GFS) analysis as meteorological initial and boundary conditions. The chemical part of the model utilized the RADM2 gas-phase chemistry mechanism and the GOCART aerosol model. The model's performance was validated against hourly measurements of O_3, NO_2, and PM_{10} from the Serbian Environmental Protection Agency (SEPA) monitoring network. Results demonstrate that while O_3 concentrations follow a realistic diurnal cycle the model tends to overestimate nighttime minimums. NO_2 levels showed significant sensitivity to the emission inventory, with EMEP data providing a much better representation of urban-rural gradients. For PM_{10}, the model consistently underestimated concentrations, indicating a need for improved primary emission data or secondary aerosol schemes. The 5 km resolution coupled with EMEP emissions proved to be the most effective configuration for this region [1]. This study provides a foundational framework for operational chemical weather forecasting in Serbia and highlights the importance of high-resolution modeling in establishing a reliable national air quality warning system.

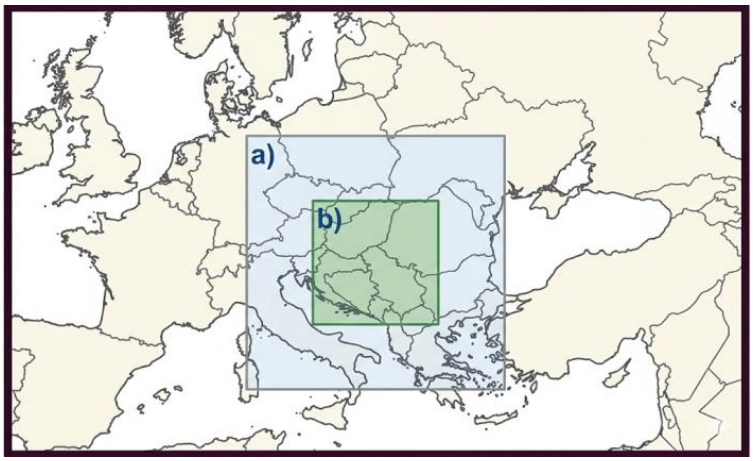

Figure 1: The WRF-Chem model domain: (a) for 20 × 20 and 10 × 10 km simulations and (b) for 5 × 5 km

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Sub-seasonal WRF-Chem reanalysis of extreme Saharan dust outbreaks in spring-summer 2024: balancing phase consistency and aerosol realism

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Keywords: *WRF-Chem; extreme Saharan dust; spectral nuding; sub-seasonal reanalisys; dust impact*

Saharan dust outbreaks intermittently exert strong radiative, air quality and depositional impacts across the Euro-Mediterranean, due to the intrinsic characteristics of this phenomenon, yet their numerical reproduction remains challenging. Here we investigate modelling strategies that preserve spatio-temporal consistency in sub seasonal integrations with WRF-Chem, focusing on three major dust intrusions affecting Italy in 2024: 25 March to 1 April, 18 to 21 June, and 8 to 14 July. We perform a set of reanalysis driven experiments over a single 5 km grid domain spanning North Africa and the Mediterranean into continental Europe, forced by ECMWF IFS analyses at 6 hourly frequencies. Model performance is assessed against complementary observing systems ver the Euro-Mediterranean with emphasis on Italy. Our core objective is to quantify how spectral nudging can mitigate large scale phase errors and long run drift, while avoiding an overly constrained mesoscale circulation that may distort dust emission, uplift and transport. In addition, using a sequence of sensitivity runs initialized at increasing lead times, we estimate event dependent spin-up thresholds that stabilize domain integrated dust mass and optical depth, while maintaining realistic emission timing, intensity and extension, to suggest a transferable good practice workflow for episodic dust reanalysis and for longer sub seasonal experiments. Overall, this study frames spectral nudging not as an arbitrary choice but as a tunable constraint whose optimal setting depends on the intended balance between large scale fidelity and internally generated aerosol meteorology feedback, with clear implications for WRF-Chem based dust assessments over Italy and the central western Mediterranean. The focus is on the fact that, despite an approximate 40% increase in computational time, the use of spectral nudging emerges as an optimized approach, both in terms of physical consistency and final computational cost savings. This technique proves particularly advantageous in reducing the overall number of simulations required within the context of sub-seasonal reanalysis.

Sensitivity of Dust Absorption to Regionally and Size-Resolved Mineralogy in MONARCH

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Keywords: *Mineral dust, Mineralogy. Single Scattering Albedo (SSA), Direct Radiative Effect (DRE), MONARCH*

Mineral dust is the dominant natural aerosol by mass and has a significant role in the Earth's radiation budget through scattering and absorption of solar radiation. However, large uncertainties persist in the estimates of dust direct radiative effect (DRE). These uncertainties can be linked to the representation of dust optical properties. In particular, the single scattering albedo (SSA) is highly sensitive to mineralogical composition, yet most regional and global models assume spatially homogeneous and size-independent mineralogy at emission. Dust mineral composition varies substantially across source regions. Furthermore, mineral fractions exhibit size-dependent partitioning. Iron oxide–bearing minerals are the main factor in modulating the shortwave absorption by dust.

We investigate the sensitivity of dust absorption to mineralogical assumptions using the Multiscale Online Non-hydrostatic AtmospheRe CHemistry (MONARCH) model coupled with the Rapid Radiative Transfer Model for GCMs (RRTMG). A suite of one-year global simulations is performed to assess different representations of dust mineralogy: (i) globally uniform composition, (ii) globally uniform composition varying by size, and (iii) regionally and size-resolved individual mineral tracers. Furthermore, the sensitivity experiments explore alternative soil datasets, and sets of mineral complex refractive indices.

By constraining the variability in particle mineralogy, we quantify how regional heterogeneity and size partitioning affect SSA and DRE. Results show that increasing the number of factors that contribute to the variability in mineralogical composition enhances

spatial and seasonal variability in SSA, leading to regional differences in shortwave DRE. These findings provide guidance for implementing mineralogy-aware dust schemes in models.

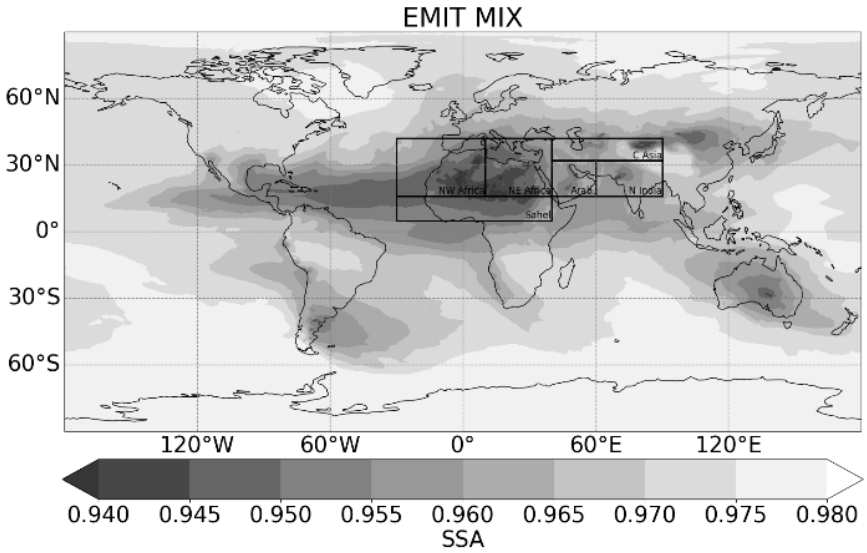

Figure 1: Annual mean SSA based on dynamic mineral mixing, EMIT soil atlas with Di Biagio optical properties

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Investigating Aerosol-Driven Atmospheric Perturbations from Extreme Biomass Burning over South America with WRF-Chem

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Keywords: *Biomass Burning, Aerosols, Radiation, Microphysics*

Large-scale biomass burning (BB) episodes across South America constitute a major source of atmospheric aerosols, substantially perturbing the regional radiation balance, cloud microphysics, and precipitation regimes. Despite robust observational evidence documenting these impacts, most operational and regional numerical weather prediction systems still neglect fully interactive atmospheric chemistry. This limitation constrains their ability to represent aerosol–radiation interactions (ARI) and aerosol–cloud interactions (ACI), and thus to realistically simulate the coupled aerosol–meteorology feedbacks that emerge during extreme BB events.

In this study, we investigate the atmospheric response to a prolonged and intense BB episode over South America during September 2022 using the Weather Research and Forecasting model with Chemistry (WRF-Chem). Fire activity was characterized using active fire detections from FIRMS, corroborated by enhanced Aerosol Optical Depth (AOD) from MODIS and elevated carbon monoxide (CO) column concentrations from IASI. Numerical experiments were conducted from 25 August to 12 September 2022, employing the MOZART–MOSAIC chemical and aerosol module, the Morrison double-moment microphysics scheme, and the RRTMG radiative transfer parameterization.

To isolate aerosol-induced effects from the background synoptic forcing, two simulations were performed a control experiment (CTRL; chem_opt = 0), in which chemistry and aerosol feedbacks were disabled, and a fully coupled experiment (FULL), in which interactive chemistry was enabled, allowing explicit representation of ARI and ACI processes. The contrast between CTRL and FULL provides a quantitative estimate of aerosol-driven perturbations in thermodynamic structure, cloud microphysical properties, and precipitation patterns across four subregions encompassing the most severely affected areas. Model performance was evaluated against multiple observational datasets.

Simulated AOD and CO fields were compared with MODIS and IASI retrievals to assess the representation of aerosol loading and transport. Meteorological variables, including near-

surface temperature, wind speed, and relative humidity, were validated against ground-based observations using standard statistical metrics. The results highlight the central role of coupled ARI and ACI processes in modulating atmospheric stability, cloud development, and rainfall during extreme BB conditions. By explicitly contrasting simulations with and without interactive chemistry, this study demonstrates the added value of fully coupled chemistry–meteorology frameworks for improving the representation of biomass burning impacts in regional weather and climate modeling over South America.

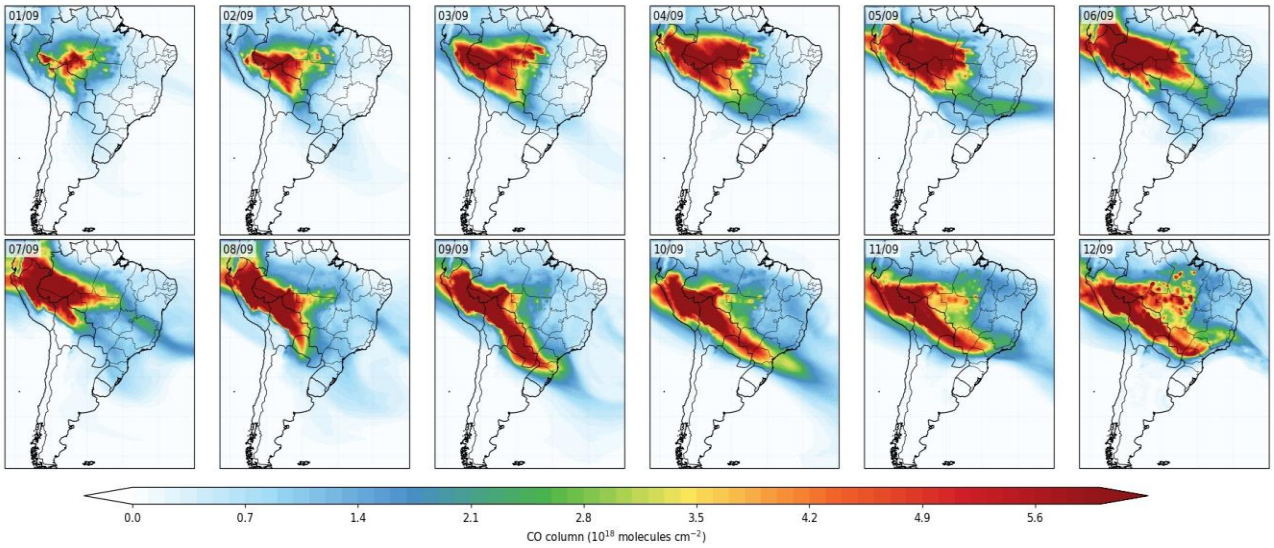

Figure 1: Daily time Averaged Map of CO Total Column, [WRF-Chem] 10^{18} molecules cm^{-2}.

The impact of aerosols on a severe weather event in Greece

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Keywords: *WRF-Chem, Aerosols, Daniel Storm, PANORAMA*

This study investigates the impact of aerosols during a severe weather event that affected Greece and Libya in early September 2023. Storm Daniel, originally a low-pressure system, evolved into a Tropical-Like-Cyclone and produced excessive amounts of precipitation in Central Greece (Thessaly) and Libya, causing flashfloods, damages in infrastructure and casualties. Although a number of studies indicate that the Mediterranean's unusually high sea surface temperatures contributed to the cyclone's intensity and extreme rainfall, the role of aerosols in cyclone's dynamics has not been investigated to such extent. For this reason, we utilize the WRF-Chem modelling system into a very high-resolution configuration to assess the cloud-aerosol interactions over the wider area of Thessaly region in Greece and to evaluate the model performance in terms of simulated precipitation. This work is part of PANORAMA project (European Union program under Grant Agreement No. 101182795), which is actively contributing to the EO uptake of new satellite retrievals regarding aerosol properties by developing innovative products and applications for Earth System predictions.

Impact of LULC modifications on Aerosol-induced changes in surface temperature and energy partitioning

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Keywords: LULC, Aerosols, Surface temperature, Energy decomposition, Non-radiative fluxes.

Rapid and massive urbanisation and developments during the 20th century, through diverse human activities, have had profound impacts on Land Use Land Cover (LULC), especially over the South Asian region, significantly affecting surface fluxes, overlying atmospheric processes, and thereby the local and regional climate (Gogoi et al., 2019; Mukherjee & Singh, 2020). Correspondingly, the aerosol loading also shows an increasing trend over the region.

In this study, we investigate the impact of aerosols on surface temperature and associated changes in latent heat flux (LHF) and sensible heat flux (SHF) using a decomposition technique (Vanden Broucke et al., 2015) across different LULC categories during the winter period, using the chemistry-coupled Weather Research and Forecasting model (WRF-Chem). We have found an approximately 50% difference in aerosol-induced perturbations to surface temperature, exclusively due to the LULC change alone from 2004 to 2018, over the Indian region.

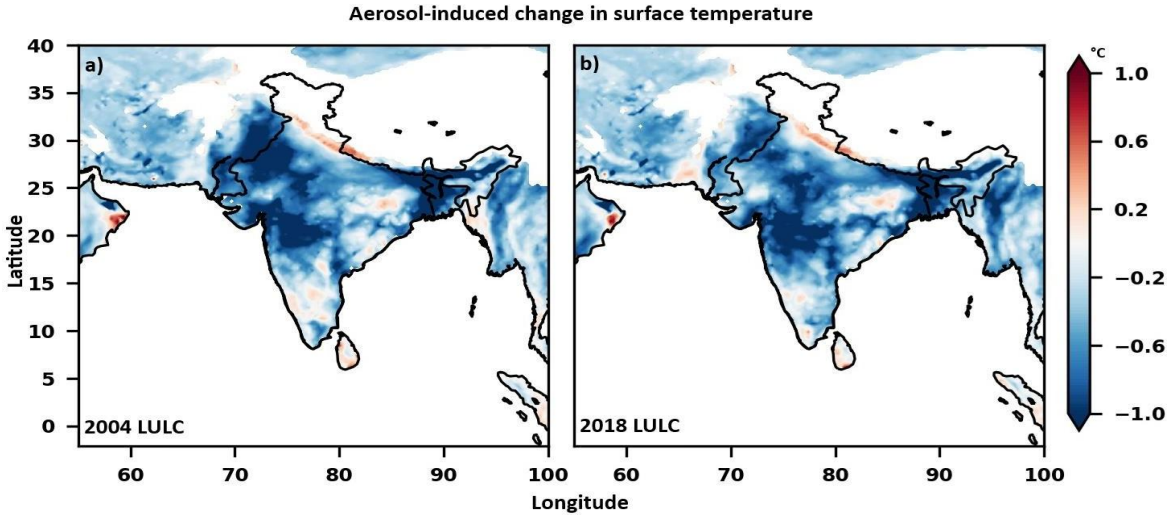

Figure 1: Spatial variation of aerosol-induced perturbations in surface temperature with a) 2004 LULC and b) 2018 LULC over the South Asian region.

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Aerosol-Induced Shifts in Mesoscale Convective Trajectories

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Keywords: *Biomass Burning, Aerosols, Mesoscale Storms*

Biomass burning aerosols alter mesoscale convection not only by modulating intensity but by actively rerouting storm tracks. Two competing mechanisms govern this spatial reorganization: radiative stabilization and microphysical invigoration (Fan et al., 2016).

The semi-direct effect occurs when elevated aerosol layers absorb solar radiation, warming the mid-troposphere while cooling the surface. This inversion stabilizes the boundary layer within the plume core, suppressing convective initiation. Consequently, developing storms avoid the stabilized region, preferentially triggering along the plume periphery or in adjacent clear-air zones. This effectively deflects convective trajectories away from heavy aerosol loading.

Conversely, when convection initiates within moist, aerosol-laden air, microphysical pathways dominate. High cloud condensation nuclei concentrations suppress warm-rain coalescence, delaying precipitation onset (Rosenfeld et al., 2008). Condensate is instead lofted above the freezing level, where glaciation releases latent heat, invigorating updrafts and elevating cloud tops. This altered vertical heating profile modifies the mesoscale pressure field, inducing low-level convergence spatially offset from the original heat source. The resulting dynamic feedback shifts the convective system's propagation path.

Additionally, delayed precipitation and enhanced evaporation of small droplets generate stronger cold pools. These intensified density currents interact with ambient wind shear to trigger new cells in locations distinct from those expected under clean conditions. Over the Amazon, the non-linear interplay between aerosol-radiation and aerosol-cloud interactions has been shown to dominate convective responses under heavy aerosol loading (Liu et al., 2020).

Thus, heavy aerosol loading does not merely enhance or suppress storms; it fundamentally reorganizes their spatial distribution by rerouting initiation and propagation pathways. The net trajectory shift depends critically on the competition between radiative stabilization and microphysical invigoration.

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WRF-Chem hands-on: how to use, set up and run

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Keywords: *WRF-Chem; MOZART; GOCART; MOSAIC; Emission databases.*

This work provides an overview of the implementation and application of the online coupled atmospheric chemistry model WRF-Chem (Weather Research and Forecasting with Chemistry) [1], with a specific focus on the MOZART [2] gas-phase chemistry mechanism combined with the aerosol modules GOCART [3] and MOSAIC [4]. WRF-Chem enables the simultaneous simulation of meteorological processes, trace gases, and aerosols within the same numerical framework, ensuring consistency in transport, physics, and chemistry interactions. The seminar introduces the advantages of online coupling for investigating chemistry–meteorology feedback, air quality, aerosol–radiation-clouds interactions, and climate-related processes from regional to continental scales.

The workflow required to configure and run WPS (WRF Preprocessor System), and WRF-Chem simulations is described, including the domain setup, the preparation of emission data: anthropogenic (i.e., EDGAR-HTAP - [5]), biogenic (i.e., MEGAN - [6], [7]), and fire emissions (i.e., FINN data - [8], [9], [10]) preprocessing, as well as the implementation of chemical initial and boundary conditions (e.g. MOZART, CAM-Chem, WACCM). Special emphasis is given to the MOZART chemical mechanism and to the differences between the GOCART and MOSAIC aerosol schemes, highlighting their suitability for long-term atmospheric chemistry studies and detailed aerosol–climate analyses, respectively.

Several practical applications and case studies are presented, including Arctic simulations focused on short-lived climate forcers such as ozone and black carbon, Mediterranean aerosol studies, and simulations involving biogenic emissions from vegetation and wildfire emissions using MEGAN and FINN inventories, respectively. The presentation also discusses computational requirements, domain nesting strategies, and challenges related to high-resolution simulations and large atmospheric chemistry datasets.

Overall, the presentation aims to provide both theoretical background and practical guidance for researchers approaching WRF-Chem simulations, with emphasis on the integration of chemistry, aerosols, emissions, and meteorology for advanced atmospheric and climate studies.

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Meso- to micro- scale impacts of alternative fuels for aviation on air composition around airports.

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Keywords: *hydrogen, leakage, ozone,*

As alternative fuels are proposed with the intention to lower the radiative forcing impact of aviation, the impact on local air composition from such changes in fuels at a mesoscale around airports remains underexplored. For example, hydrogen is known to leak through a range of processes such as purging/venting/boil off, slip and fugitive emissions due to the physical properties of hydrogen. Hydrogen is known to interfere reduce the oxidizing capacity of the atmosphere, thereby perturbing ozone cycles and carbon cycles. We employ the WRF-Chem model (4.7.1) to investigate the impact as a function of leakage rates for hydrogen based on scaled fuel consumption for the case at London Heathrow Airport (LHR). We distinguish internal combustion engine and fuel cell hydrogen aircraft scenarios, we also look at other fuels such as 8 varieties of so called sustainable aviation fuels and ammonia. We investigate this through a base case with no aircraft or tanks, with fuel tanks and with aircraft and fuel tanks as well with various changes in background composition. With scope for airports with unique geography and meteorological aspects, such as Longyearbyen (LYR) representing an arctic/cold temperature airport. As well as further studies employing other models. We report on the impacts on ozone, carbon monoxide, formaldehyde and other relevant species through aspects such as concentration, lifetime and more.

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