Barcelona Supercomputing Center
Centro Nacional de Supercomputación

RED ESPAÑOLA DE SUPERCOMPUTACIÓN

TEMP-2019-3-0013 Air Quality modeling with the NMMB-MONARCHv1.0 model: research and developments to fulfill the Copernicus Atmosphere Monitoring Service requirements on air quality and emission modeling

1. General Information

Activity Id

TEMP-2019-3-0013

a) Activity Title

Air Quality modeling with the NMMB-MONARCHv1.0 model: research and developments to fulfill the Copernicus Atmosphere Monitoring Service requirements on air quality and emission modeling

b) Area

Astronomy, Space and Earth Sciences

c) Type of application

Standard Activity for the next 4 months

2. Research Project Description

a) Is this a Test Activity?

No

b) Is this a Long Term Activity that will extend over two application periods?

Yes

c) Brief description of the Project

Air pollution is associated with adverse effects on human health through population exposure to particulate matter (PM), nitrogen oxides (NOx) and ozone (O3), loss of biodiversity through acidification and eutrophication, decreased crop yields as well as climate change through interactions of short-lived climate forcers with the earth's radiation balance and carbon and nitrogen cycles. Furthermore, atmospheric composition may affect solar power generation, transport safety and UV exposure. The Copernicus Atmosphere Monitoring Service (CAMS, atmosphere.copernicus.eu/) is establishing the core global and regional atmospheric environmental service delivered as a component of Europe's Copernicus Programme, and aims to support policymakers, business and citizens with robust atmospheric environmental information to address the different impacts of air pollution.

The regional forecasting service (CAMS_50) currently provides daily 4-day forecasts of the main air quality species over Europe and analyses of the day before, as well as posteriori re-analyses using the latest validated observation dataset available for assimilation. The main product of CAMS_50 is the median ensemble, which has higher performance than individual air quality models. The CAMS ensemble is calculated from raw individual atmospheric chemistry models, which represent the state-of-the-art air quality models in-house developed in Europe. Recently, the new CAMS_50 contract has been expanded to include 2 new partners (BSC and ENEA) in view of further increasing the number of models contributing to the regional ensemble at the end of the contract (mid 2021). The new teams will develop their models to fit the CAMS technical requirements along the contract with the aim at demonstrating their capability to increase the robustness of the ensemble prediction. The NMMB-MONARCH v1.0 model, developed by the Atmospheric Composition Group of the Earth Sciences Department at BSC, is one of the candidate models. During the CAMS_50 project, the NMMB-MONARCH v1.0 will be evaluated to prove the benefit of adding it to the regional forecasting service. For that, the Atmospheric Composition Group will refine the photochemistry, aerosol formation, and emissions of the NMMB-MONARCH v1.0 model.

The development of reliable anthropogenic emission inventories is of great importance for both air quality modelling research and forecasting applications. The Copernicus global and regional emission service (CAMS_81), in which the BSC coordinates the work package on service evolution, has the objective to provide updated gridded and temporal distributions of anthropogenic (global and Europe) and natural emissions (global only) in direct support of CAMS_50 production chains. The emissions developed by CAMS_81 are used as input to the NMMB-MONARCH v1.0 model. For that, the BSC uses the in-house High-Elective Resolution Modelling Emission System version 3 (HERMESv3), an open source, parallel and stand-alone multiscale atmospheric emission modelling framework that computes gaseous and aerosol emissions for use in atmospheric chemistry models (Guevara et al., 2019 GMD).

The development of accurate treatments for gas-aerosol chemistry and physics for use in large-scale regional atmospheric chemistry models like NMMB-MONARCH v1.0 is critical to efforts to predict air quality and climate, and to evaluate the potential impact of proposed emissions scenarios. The oxidation of volatile organic species to form low-volatility products is an important source of aerosol mass in the global atmosphere. Because of the climate, health and visibility effects of particulate matter, inclusion of this so-called secondary organic aerosol (SOA) into chemistry models is the focus of on-going research. Complicating these efforts are the large number of species and oxidation pathways involved, their seasonally, spatially, and diurnally varying importance, and the complex physical processes controlling their phase partitioning. Models generally under-predict SOA mass in the atmosphere compared with field measurements, suggesting the presence of as-yet unidentified sources or unaccounted-for physical processes (Volkamer et al., 2006). Novel chemistry mechanisms of SOA will be implemented and tested in NMMB-MONARCHv1.0 to improve the skills of the model predicting the total PM.

The present project aims at developing and expanding the NMMB-MONARCHv1.0 model to fulfill the Copernicus Atmosphere Monitoring Service requirements on air quality and emission modeling. The results of this project will contribute to increase the robustness of the CAMS_50 service on providing air quality forecast over Europe through the incorporation of the NMMB-MONARCHv1.0 model as part of the ensemble, and therefore potentially allow Spain to be in the forefront of the European air quality modelling for the next years. This will be possible thanks to the combination of state-of-the-art atmospheric chemistry techniques and the use of cutting-edge computational resources.

d) Grants and funded projects related to this activity

Reference code	Project title		
CGL2016-75725-R	Modelización fotoquímica para atribuir fuentes y áreas de emision a altas concentraciones de material particulado en zonas urbanas de España (PAISA)		
Starting date	Ending date	Total financing (in EUR)	Financing source
2016-12-30	2019-12-29	118.580,00	National

Reference code	Project title		
2018/CAMS_50/SC1	Copernicus Project: CAMS_50 Regional Production		
Starting date	Ending date	Total financing (in EUR)	Financing source
2018-10-01	2021-06-30	91.466,00	European

Reference code	Project title		
2017/CAMS_81/SC1	Copernicus Project: CAMS_81 Global and regional Emissions		
Starting date	Ending date	Total financing (in EUR)	Financing source
2017-09-01	2020-09-01	109.687,50	European

e) Brief description of the Project (if this Activity takes place in the context of a Technology or Industrial Project)

The activity does not take place in the context of a Technology or Industrial Project.

f) Specific Activity proposed

As computational ability has improved, atmospheric chemistry models have begun incorporating more complex treatments of atmospheric chemistry that until recently had only been accessible to smaller- scale models. These include, e.g., a better characterization of volatile organic compounds, detailed chemical pathways for secondary formation of oxidants and particles, refined methodologies for emission estimates, the re-evaporation of semi-volatile species (equilibrium partitioning), aqueous-phase SOA production, and variations of the Volatility Basis Set (VBS) model to account for SOA aging (Tsigaridis et al., 2014 ACP).

The Multiscale Online Nonhydrostatic Atmosphere Chemistry model (NMMB-MONARCHv1.0) is a chemical weather prediction system maintained by the Atmospheric Composition Group of the Earth Sciences Department of BSC and includes modules for dust, sea salt, sulphate, and primary organic aerosol, along with a 2-product SOA module. The NMMB-MONARCHv1.0 is based on the Nonhydrostatic Multiscale Model on the B Grid (NMMB) from the National Center for Environmental Prediction (NCEP) and is a fully coupled, online chemical/meteorological model. It uses the recently developed emission model HERMESv3 and it is aimed to replace the CALIOPE modeling system as the primary weather and air quality model at BSC. Currently, the model is a candidate to be included in the Regional forecasting service (CAMS_50) of the European Center for Medium-Range Weather Forecast (ECMWF). For that, research and improvements are required in the NMMB-MONARCHv1.0 that needs HPC resources:

• Emissions: Emission inputs of trace gases and aerosols play a key role in the performance of atmospheric chemistry models for air quality research and forecasting applications. Currently the temporal release of anthropogenic emissions is described by European average diurnal, weekly and seasonal time profiles per sector. These default time profiles largely neglect the variation of emission strength with activity patterns, region, species, emission process and meteorology. In this Activity period the sensitivity of the model performance of NMMB-MONARCHv1.0 to the description of the temporal variability of emissions will be investigated. For that, the new temporal profiles developed under the framework of CAMS_81 will be tested combining the HERMESv3 emission model with NMMB-MONARCHv1.0. Several annual simulations will be conducted applying different versions of the developed temporal profiles, with the aim of improving the skills and performance that are present in current atmospheric chemistry models.
• Source apprortionment: The identification of the main sources contributing to air pollution episodes is a valuable information for policymaker to effectively designing plans that mitigate air pollution episodes. Furthermore, the source attribution studies increases our scientific knowledge on the formation of gas and aerosol pollutants, they support enhanced model evaluation and therefore potential model improvements by identifying problems in emission estimates (sectors or regions) or chemical boundary conditions. Source attribution of surface air pollutants remains a challenge, because the concentration at each location and time results not only from local biogenic

and anthropogenic precursors, but also from the transport of pollutants from neighbouring regions. During this Activity period, we will apply source apportionment techniques in deterministic air quality models to increase our understanding on the O3 and PM processes responsible of air pollution episodes in Europe, which contribute to guide the improvements of the NMMB-MONARCHv1.0 model to forecast air quality for the CAMS_50 service. First, we will estimate how much O3 is country-made produced relative to the contribution of imported O3 in Europe (Pay et al., 2019 ACP). Second, the research will quantify the contribution of the large variety of natural and anthropogenic sources and source regions to the PM concentrations at high resolution over EU using highly resolution emission from the HERMESv3 model. This task will be crucial to determining to what extent the urban PM concentrations in Europe are controlled by specific local anthropogenic sources and/or regional or transboundary contributions.

• Novel chemistry: The formation of SOA is one of the most uncertain processes when predicting the mass of particulate matter in the atmosphere. During this Activity period, different methodologies will be tested to improve the predictability of SOA formation and the burden of particles. A range of complexity in SOA formation will be tested. Most advanced treatments of SOA intend to accurately predict SOA formation over a wide range of conditions (both urban and remote) utilizing a fully coupled mixed-phase aqueous/organic aerosol mechanistic scheme with variable volatility products (e.g., Dawson et al. 2016 GMD, Griffin et al., 2018 AST). Other approaches opt to parameterize SOA formation with non-volatile assumptions based on field campaign observations and providing an efficient methodology for forecast applications (e.g., Pai et al., 2019 ACPD). Several annual simulations with the NMMB-MOARCHv1.0 will be conducted applying a variety of complexity in the formation of SOA to provide an efficient and skillful solution to reduce the systematic biases seen in current atmospheric chemistry models. The selected scheme will be used then for the CAMS_50 simulations that will be evaluated to prove the benefit of NMMB-MONARCHv1.0 in improving the CAMS Regional ensemble forecast.

Thus, NMMB-MONARCHv1.0 with the full chemistry option will be configured with two different resolutions (0.1º and 0.2º with 48 vertical layers) over a European domain using emissions calculated using the HERMESv3 model, and following the general procedure used for regional simulations in the CAMS_50 service. The NMMB-MONARCHv1.0 model in various configurations has been extensively tested and run in MareNostrum 4 as part of previous and ongoing projects.

For this Research Project we plan to do several calculations testing different temporal profiles for emissions, conducting O3 and PM source apportionment studies, and assess different SOA schemes with different complexity. The complete list of planned experiments with the estimated kcpu.hours is the following:

• Temporal variability of emissions scenario 1- 0.2º resolution - year 2016: 50 kcpu.hours
• Temporal variability of emissions scenario 2- 0.2º resolution - year 2016: 50 kcpu.hours
• Temporal variability of emissions scenario 3- 0.2º resolution - year 2016: 50 kcpu.hours
• Temporal variability of emissions scenario 4- 0.2º resolution - year 2016: 50 kcpu.hours
• Temporal variability of emissions scenario 5- 0.2º resolution - year 2016: 50 kcpu.hours
• Temporal variability of emissions final scenario - 0.1º resolution - year 2016: 400 kcpu.hours

• PM Source Apportionment PAISA sectors winter summer 2015: 290 kcpu.hours
• PM Source Apportionment PAISA regions winter summer 2015: 290 kcpu.hours
• O3 Source Apportionment EU28 (8 regions set 1) O3 season 2016: 290 kcpu.hours
• O3 Source Apportionment EU28 (8 regions set 2) O3 season 2016: 290 kcpu.hours
• O3 Source Apportionment EU28 (8 regions set 3) O3 season 2016: 290 kcpu.hours
• O3 Source Apportionment EU28 (6 regions set 4) O3 season 2016: 290 kcpu.hours
• O3 Source Apportionment EU28 (8 regions set 1) O3 season 2017: 290 kcpu.hours
• O3 Source Apportionment EU28 (8 regions set 2) O3 season 2017: 290 kcpu.hours
• O3 Source Apportionment EU28 (8 regions set 3) O3 season 2017: 290 kcpu.hours
• O3 Source Apportionment EU28 (6 regions set 4) O3 season 2017: 290 kcpu.hours
• SOA complex scheme scenario 1 - 0.2º resolution- year 2016: 200 kcpu.hours
• SOA complex scheme scenario 2 - 0.2º resolution- year 2016: 200 kcpu.hours
• SOA complex scheme scenario 3 - 0.2º resolution- year 2016: 200 kcpu.hours
• SOA intermediate scheme scenario 1 - 0.2º resolution- year 2016: 200 kcpu.hours
• SOA intermediate scheme scenario 2- 0.2º resolution- year 2016: 100 kcpu.hours
• SOA intermediate scheme scenario 3 - 0.2º resolution- year 2016: 100 kcpu.hours
• SOA simple scheme scenario 1 - 0.2º resolution- year 2016: 50 kcpu.hours
• SOA simple scheme scenario 2 - 0.2º resolution- year 2016: 50 kcpu.hours
• SOA simple scheme scenario 3 - 0.2º resolution- year 2016: 50 kcpu.hours
• SOA final scheme - 0.1º resolution- year 2016: 400 kcpu.hours
Total cpu.hours 5000 kcpu.hours

As can be seen, the most demanding runs are the ones for the Source Apportionment analysis, which requires extended chemical mechanisms and tracers depending the number of sectors/regions to analyze. The calculation requirements for the different temporal variability of emissions and different chemical mechanisms of SOA strongly depend on the model resolution (0.1 or 0.2 degrees), and for the SOA chemistry, on the complexity of the scheme (adding between 10 to 200 chemical reactions more to the default chemical mechanism of NMMB-MONARCHv1.0).

As this Research Project is a Long Term Activity, we plan to conduct the following subset of experiments during the first period:

• Temporal variability of emissions scenario 1- 0.2º resolution - year 2016: 50 kcpu.hours
• Temporal variability of emissions scenario 2- 0.2º resolution - year 2016: 50 kcpu.hours
• Temporal variability of emissions scenario 3- 0.2º resolution - year 2016: 50 kcpu.hours
• PM Source Apportionment PAISA sectors winter summer 2015: 290 kcpu.hours
• PM Source Apportionment PAISA regions winter summer 2015: 290 kcpu.hours
• O3 Source Apportionment EU28 (8 regions set 1) O3 season 2016: 290 kcpu.hours
• O3 Source Apportionment EU28 (8 regions set 2) O3 season 2016: 290 kcpu.hours
• O3 Source Apportionment EU28 (8 regions set 3) O3 season 2016: 290 kcpu.hours
• O3 Source Apportionment EU28 (6 regions set 4) O3 season 2016: 290 kcpu.hours
• SOA complex scheme scenario 1 - 0.2º resolution- year 2016: 200 kcpu.hours
• SOA complex scheme scenario 2 - 0.2º resolution- year 2016: 200 kcpu.hours
• SOA intermediate scheme scenario 1 - 0.2º resolution- year 2016: 100 kcpu.hours

• SOA simple scheme scenario 1 - 0.2º resolution- year 2016: 50 kcpu.hours
• SOA simple scheme scenario 2 - 0.2º resolution- year 2016: 50 kcpu.hours
Total cpu.hours 2490 kcpu.hours

The remaining experiments will be conducted during the following periods.

g) Computational algorithms and codes outline

The NMMB-MONARCHv1.0 is a parallel MPI application designed to run with both regional and global domains. The operational domain is divided into horizontal sub-sections, which are assigned to individual computational units. Thus, parallelization is accomplished using a sub-domain-based approach. The NMMB-MONARCHv1.0 is a fully coupled model constructed on the ESMF coupling framework, wherein between the execution of each module (e.g., dynamics, physics, chemistry, aerosol) the model performs a coupling step to exchange information. The numerical methods employed within the model are: the Adams–Bashforth Scheme for horizontal advection, the Crank–Nicholson scheme to compute vertical advection, the forward–backward scheme for horizontally propagating fast waves, and an implicit scheme for vertically propagating sound waves. The original chemistry module (CB-5; Yarwood et al., 2005) applies an Euler-Backward-Iterative scheme to solve the stiff set of ordinary differential equations associated with gas-phase chemistry. New updates in the chemistry are being built on the framework of the Part-MC model (Riemer et al., 2009), to provide flexibility in the gas- and aerosol-phase chemistry and partitioning mechanism, and employs the SUNDIALS Backward-Differentiation Formulas (BDF) solver.

The HERMESv3 is an open source, parallel and stand-alone multiscale atmospheric emission modelling framework that computes gaseous and aerosol emissions for use in atmospheric chemistry models. HERMESv3 is coded using Python 2.7.X and its emission core module is parallelized using a domain decomposition strategy. The HERMESv3 code package, sample configuration and ancillary input files (vertical, temporal and speciation profiles) and a test case data are available at the following gitlab repository: https://earth.bsc.es/gitlab/es/hermesv3_gr.

3. Software and Numerical Libraries

Software components that the project team requires for the activity.

a) Applications + Libraries

BLAS, GSL, HDF5, LAPACK, NETCDF, R, OPENMPI, NCO, OPENBLAS, INTELMPI

b) Compilers and Development Tools

GCC, TOTALVIEW, INTEL

c) Utilities + Parallel Debuggers and Performance Analysis Tools

CMAKE, PERL, PYTHON, GNUPLOT, IMAGEMAGICK, NCVIEW, GREASY, COMPSs

d) Other requested software

DDT, ESMF, CDO, SUNDIALS, SuiteSparse

e) Proprietary software

NMMB-MONARCHv1.0, multiscale online atmospheric chemistry model, private webpage
HERMESv3, emission model, https://earth.bsc.es/gitlab/es/hermesv3_gr

4. Research Team Description

a) Personal Data

Name of Team Leader	Oriol Jorba Casellas
Gender	Male
Institution	Barcelona Supercomputing Center
e-mail	oriol.jorba@bsc.es
Phone	+34 93 413 40 50
Nationality	Spain

b) The employment contract of the activity leader with the research organisation is valid at least 3 months after the end of the allocation period.

Yes

c) Curriculum Vitae of the Team Leader

Dr. Oriol Jorba recived the Industrial Engineer degree from the Technical University of Catalonia (UPC, Barcelona, Spain, 1999) and a PhD in Environmental Engineering from the Technical University of Catalonia (UPC-, Barcelona, Spain, 2005). In 2005, he was enrolled as researcher at the Earth Sciences Department of the Barcelona Supercomputing Center, and in 2008 moved to the Atmospheric Modelling Group Manager position at BSC. Since 2016, he was senior researcher of the Atmospheric Composition (AC) Group, and in 2018 moved to the Co-Group Manager position of AC at BSC. He has participated in projects funded by the European Commission on air quality, specifically in aerosols (APPRAISAL, EARLINET, FIELD-AC, ACTRIS1, ACTRIS2, FORCES, CAMS), and in the application of atmospheric modeling in HPC (IS-ENES, IS-ENES2, RETHINK big). He has lead the research project on the development of the multiscale chemical weather forecasting system NMMB-MONARCH which is the official model used by the Barcelona Dust Forecast Center (BDFC), the World Meteorological Organization (WMO) Regional Meteorological Center specializing in Atmospheric Sand and Dust. He has been a Spanish representative member of the management committee of COST Actions ES1002 and ES1004, and is part of the International Technical Meeting on Air Pollution Modelling and its Application (ITM) scientific committee since 2012. He is an active member of the International Cooperative for Aerosol Prediction (ICAP). A scientific reviewer of the Scientific Commission of the Spanish National Research Program, his research expertise includes high resolution multi-scale (global to local) atmospheric chemistry and air quality modeling, development of online meteorology-chemistry models, atmospheric chemistry processes and environmental impact assessment. He has co-authored more than 50 papers in international scientific journals, over 100 communications in international conferences and directed 7 PhD theses. Additionally, he has been the mentor of two national FPI PhD fellowships, has been part of the research group in charge of one Marie Curie Intra-European Fellowship in the call FP7-PEOPLE-2013-IEF, and acts as supervisor for two Marie Skłodowska-Curie Individual Fellowship in the call H2020-MSCA-IF-2015 and H2020-MSCA-IF-2016. Currently, he is the Principal Investigator at BSC of the project CAMS50_PhaseII of the Copernicus program of the European Commission.

d) Names of other researchers involved in this activity

Marc Guevara, Barcelona Supercomputing Center, marc.guevara@bsc.es
María Teresa Pay, Barcelona Supercomputing Center, maria.pay@bsc.es
Dene Bowdalo, Barcelona Supercomputing Center, dene.bowdalo@bsc.es
Hervé Petetin, Barcelona Supercomputing Center, herve.petetin@bsc.es
Gilbert Montané, Barcelona SupercomputingCenter, gilbert.montane@bsc.es

e) Relevant publications

Guevara, M., Tena, C., Porquet, M., Jorba, O., and Pérez García-Pando, C.: HERMESv3, a stand-alone multi-scale atmospheric emission modelling framework – Part 1: global and regional module, Geosci. Model Dev., 12, 1885-1907 (2019).

Pay, M. T., Gangoiti, G., Guevara, M., Napelenok, S., Querol, X., Jorba, O., and Pérez García-Pando, C.: Ozone source apportionment during peak summer events over southwestern Europe, Atmos. Chem. Phys., 19, 5467–5494, https://doi.org/10.5194/acp-19-5467-2019, 2019.

Benavides, J., Snyder, M., Guevara, M., Soret, A., Pérez García-Pando, C., Amato, F., Querol, X., and Jorba, O.: CALIOPE-Urban v1.0: coupling R-LINE with a mesoscale air quality modelling system for urban air quality forecasts over Barcelona city (Spain), Geosci. Model Dev., 12, 2811–2835, https://doi.org/10.5194/gmd-12-2811-2019, 2019.

Obiso, V., and Jorba, O.: Aerosol-radiation interaction in atmospheric models: Idealized sensitivity study of simulated short-wave direct radiative effects to particle microphysical properties. Journal of Aerosol Science, 115, 46-61, 2018.

Badia, A., O. Jorba, A. Voulgarakis, D. Dabdub, C. Pérez García-Pando, A. Hilboll, M. Gonçalves and Z. Janjic. Description and evaluation of the Multiscale Online Nonhydrostatic AtmospheRe CHemistry model (NMMB-MONARCH) version 1.0: Gas-phase chemistry at global scale. Geosci. Model Dev. 10, 609–638 (2017).

5. Resources

a) Estimated resources required for the Activity for the current Application Period

Requested machine	MareNostrum 4 ((Intel(R) Xeon(R) Platinum 8160, 2.10GHz with Intel(R) Omni-Path / 165888 cores)
Interprocess communication	Tightly Coupled

Typical Job Run				
Number of processors needed for each job		136.00		
Estimated number of jobs to submit		2555.00		
Average job durations (hours) per job		1.00		
Total memory used by the job (GBytes)		200.00		
Largest Job Run				
Number of processors needed for each job		1032.00		
Estimated number of jobs to submit		2555.00		
Average job durations (hours) per job		1.00		
Total memory used by the job (GBytes)		1000.00		
Total disk space (Gigabytes)	**Minimum**	60000.00	**Desirable**	110000.00
Total scratch space (Gigabytes)	**Minimum**	50000.00	**Desirable**	100000.00
Total tape space (Gigabytes) (*)	**Minimum**	0.00	**Desirable**	0.00
Total Requested time (Thousands of hours)		2500.00		

If this activity is asking for more than 10Million CPU hours, you need to justify the amount of resources requested for the activity. (max 1000 characters)

INFORMATION: The estimated cost of the requested hours, considering only the electricity cost, is 2675 euros.

The required resources have to be executed in the selected machines, the other architectures do not fit the requirements to execute the proposal.
** this option implies that if no hours in this machine/these machines are available, the acces committee will reject the full application.

b) Estimate of the total resources that the Activity will require until it is completed (including the present and all the following Application Periods), This information is only an estimation, if the proposal is accepted, it will be granted only for the current period, an the hours for the 2nd period will need to be requested in a "continuation activity" that needs to be submitted in the following period for evaluation.

Number of application periods expected to complete this Activity

2

Total Requested Time (thousands of hours) expected to complete this Activity (sum of both periods)

5000.00

6. Abstract for publication

Air pollution is associated with adverse effects on human health, loss of biodiversity, decreased crop yields as well as climate change. The Copernicus Atmosphere Monitoring Service (CAMS, atmosphere.copernicus.eu) is establishing the core global and regional atmospheric environmental service delivered as a component of Europe's Copernicus Programme. The regional forecasting service (CAMS_50) currently provides daily 4-day forecasts of the main air quality species over Europe by a multi-model ensemble approach. The NMMB-MONARCHv1.0 model, developed at BSC, is one of the new CAMS_50 candidate models that will be evaluated to prove the benefit of adding it to the regional forecasting service. During this RES Activity period, refinements in the photochemistry, aerosol formation, and emission estimates will be introduced in NMMB-MONARCHv1.0.

7. Contact with CURES during last year

Information about the RES Users Committee (CURES).

a) User has contacted the CURES during last year

No

b) If not, indicate why you have not contacted the CURES

Because I have not needed it.

Usage Terms & Conditions

- The Usage Terms & Conditions have been already accepted.