EVALUATION OF ALADIN-CAM$_X$ AND WRF/CHEM OPERATIONAL AIR QUALITY FORECASTS: FIRST RESULTS

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Abstract: Two modelling approaches, with ALADIN-CAMx modelling system and with WRF/Chem model, have been set-up for operational air quality forecast over Slovenia and the neighbouring countries. Both modelling systems started to run operationally in year 2013. ALADIN-CAMx and WRF/Chem models use data from the same anthropogenic emission databases, but differ in most other aspects. In the present contribution both modelling systems are described and the first preliminary results of model evaluation are presented. An extensive validation and verification will be performed in the coming months.

Key words: *air quality, dispersion modelling, ALADIN-CAMx, WRF/Chem, operational systems, atmospheric models.*

INTRODUCTION

Two operational air quality forecasting systems for Slovenia and the neighbouring areas have been set-up with the purpose to assure the accomplishment of legislation, to give an information about the expected level of air pollution, and as the basis for further scientific research. ALADIN/CAMx modelling system, running operationally at Slovenian Environmental agency since March 2013, consists of an offline coupled meteorological ALADIN (Aladin community) and photochemical dispersion CAMx (Comprehensive Air Quality Model with Extensions; ENVIRON, 2011) model. WRF/Chem (Grell et al., 2005) is an example of a fully coupled model. Namely, in WRF/Chem chemistry is online coupled within the Weather Research and Forecast (WRF; Skamarock et al., 2008) model. Operational WRF/Chem forecast is running experimentally since January 2013, and is one of the joined Center of excellence SPACE-SI and Faculty of mathematics and physics, University of Ljubljana, activities. Both modelling approaches use data from the same anthropogenic emission inventory, but differ in description of biogenic emissions, use different sources of chemical boundary conditions, and different domain setup and resolution. Differences in forecasted air quality are related also to differences in meteorological representation of the atmosphere, which is a consequence of two different meteorological models used.

Present contribution describes both modelling approaches and presents the first preliminary results of the two models validation and verification. Although both models have previously been evaluated for selected air pollution episodes, in the present contribution we analyse only results collected during a rather short time period in year 2013, when forecasts just started to run operationally. An extensive model validation will be performed in the coming months. It will consist mostly of the sensitivity study of the model results on input data (meteorology, emission, boundary conditions) and will be performed for a longer time period for different weather regimes, such as winter temperature inversions, summer stable conditions, strong southwesterly flow etc. Objective verification will also be performed for several kinds of pollutants (particulate matter, ozone, sulphur dioxide …) by comparing the model output concentrations with measurements collected from all available Slovenian and also some abroad air quality monitoring sites. These verification results will be further analysed taking into account different meteorological conditions.

MODELLING SYSTEMS

ALADIN-CAMx

The ALADIN/CAMx (the CAMx version 5.40) modelling system is currently running with double nesting (Fig. 2). The coarse horizontal grid with spatial resolution is covering approximately the same area as an operational ALADIN-SI domain. The finer grid surrounds Slovenia covering also important heavy industrial regions in neighbouring countries, such as for example industrial area in Po Valley. The vertical grid consists of 34 levels up to the 14 km in the troposphere. Initial chemical conditions are obtained from the previous model run, while the chemical boundary conditions are taken from global 3h MOZART forecast in the frame of MACC-II project. Biogenic emissions are prepared separately with emission model SMOKE (Sparse Matrix Operator Kernel Emissions) as shown in Fig. 1. The list of currently used CAMx chemical and physical schemes is shown in Tab. 1.

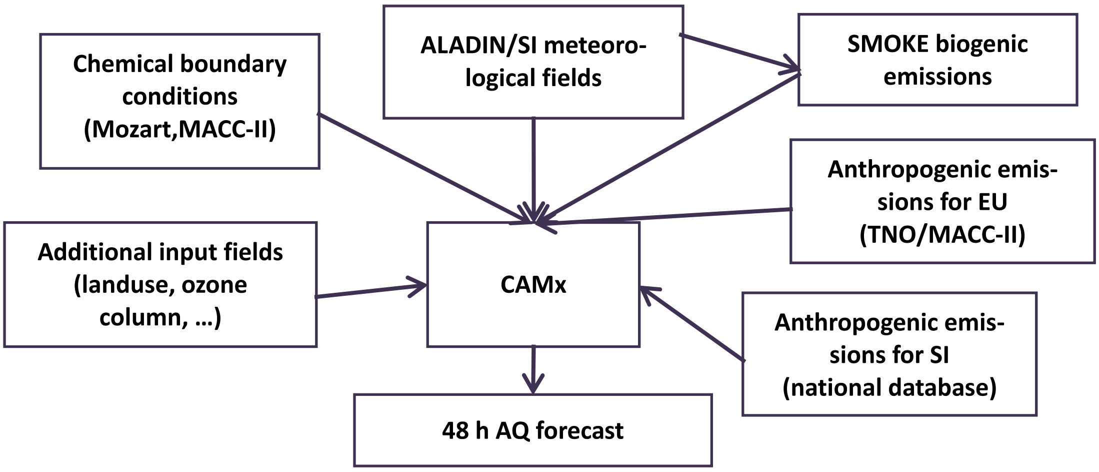

Figure 1. Shematic diagram of ALADIN/CAMx modelling system.

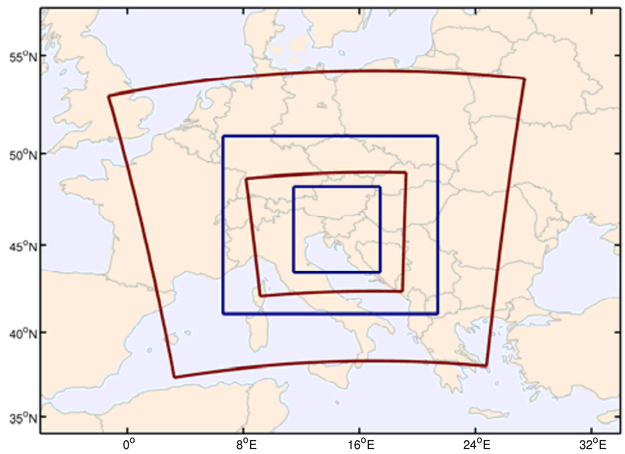

Figure 2. Modelling domains used in operational ALADIN-CAMx (red) and WRF/Chem (blue) model configurations. ALADIN-CAMx coarse domain with resolution of 13.2 km contains145x135 points, while fine domain with resolution of 4.4 km contains 185x167 points. WRF/Chem outside domain has resolution 11.1 km and 150×100 grid points, while inner domain has resolution 3.7 km and 181×145 grid points.

Table 1. Overview of the CAMx model parameterization schemes.

Item	Selection
Chemical kinetics solver options	EBI
Horizontal advection solver	PPM
Vertical diffusion (mixing) option	K-theory
Dry deposition options	ZHANG03
Advanced photolysis model	RADM
Chemistry option for gas phase chemistry	SAPRC99
Chemistry option for aerosol mechanism	CF

WRF/Chem

WRF/Chem model version 3.4.1 is configured with two domains (Fig. 2). Vertical structure of the atmosphere is resolved with 42 vertical levels. The meteorological boundary conditions are taken from Global Forecast System (GFS). In the WRF/Chem model, several choices for parameterizations of physical and chemical processes are available. Currently we are testing configurations with different parameterization schemes, but results presented in this contribution were obtained by schemes listed in Tab. 2. Initial chemical conditions are estimated from the previous model run, while chemical boundary conditions are taken from archived global 6h MOZART-4/NCEP (Emmons et al., 2010) fields. Biogenic emissions are estimated using MEGAN (Model of Emissions of Gases and Aerosols from Nature; Guenther et al., 2006) online calculations.

Table 2. Overview of the WRF/Chem model parameterization schemes.

Item	Selection
Cumulus physics option	Grell 3D scheme
Long wave radiation option	RRTM scheme
Short wave radiation option	Goddart scheme
Planetary boundary layer option	YSU scheme
Surface physics option	Noah land surface model
Microphysics option	Lin scheme
Chemistry option for gas phase chemistry	RADM2
Chemistry option for aerosol mechanism	MADE/SORGAM
Photolysis option	Fast-J

Anthropogenic emissions database

Both modelling system use the same inventory for anthropogenic emissions. Detailed anthropogenic inventory for Slovenia for pollutants CO, NH_3, NO_x, SO_2, CH_4 and nmVOC has been constructed for year 2009, while for the areas outside Slovenia TNO/MACC-II anthropogenic emissions for the year 2007 are being used (example in Fig. 3).

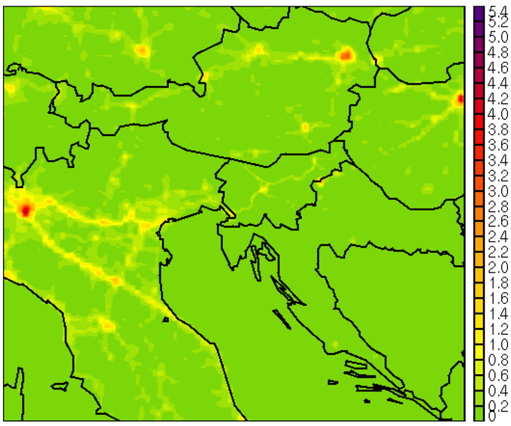

Figure 3. Hourly NO2 emission (in kmol/h) in the inner domain for January 24, 2013, between 7 and 8 UTC.

RESULTS

Model comparison and verification was performed for the time period from January 14 to January 31, 2013, for different pollutants. Only examples of first results for PM10 are presented and discussed in this contribution. Figure 4 shows examples of PM10 daily average concentrations as simulated by ALADIN-CAMx for selected days within the studied time period. Highest PM10 concentrations were (as expected) simulated over urban areas in the complex terrain of the interior of Slovenia. These high concentrations can be explained by stable atmospheric conditions with frequent temperature inversions and consequently suppressed vertical mixing in valleys and basins, where and when at the same time the need for heating during the wintertime increases.

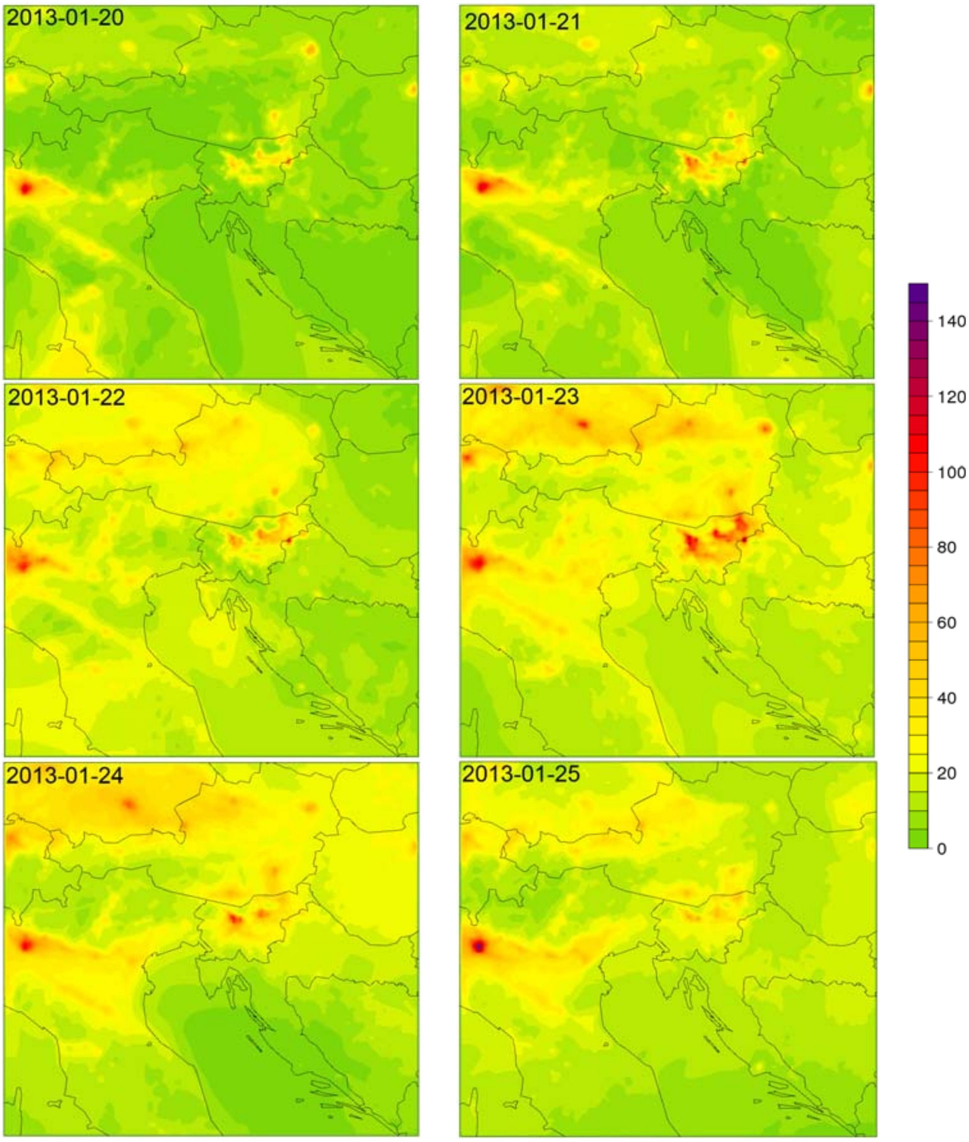

Figure 4. Average PM10 concentrations (in μgm^{-3}) at lowest model level as simulated by ALADIN-CAMx modelling system for days January 20 to 25, 2013. Shown are concentrations in the inner domain.

Figure 5 shows an example of comparison of results obtained with two different models. Although the main characteristics of the simulated near ground fields are similar, some notable differences can also be observed. These are related to many differences in both modelling approaches and will be in future studied and discussed also in the light of meteorological conditions.

Comparison of simulated and measured PM10 concentrations was performed for all available monitoring sites in Slovenia. Figure 6 shows examples of model verification for average daily PM10 concentrations for Ljubljana and Maribor city. In these examples ALADIN-CAMx somewhat better qualitatively reproduced the measured time course of PM10 concentrations. Nevertheless, further analyses are needed to improve the understanding of obtained discrepancies between results of both modelling approaches.

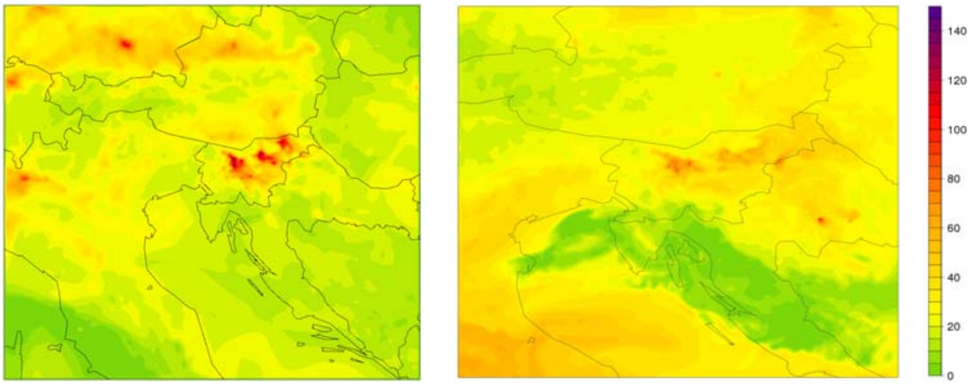

Figure 5. Hourly PM10 concentrations (in μgm^{-3}) at lowest model level as simulated by ALADIn-CAMx (left) and WRF/Chem (right) model. Shown are concentrations in the inner domain for January 23, 2013 at 12 UTC.

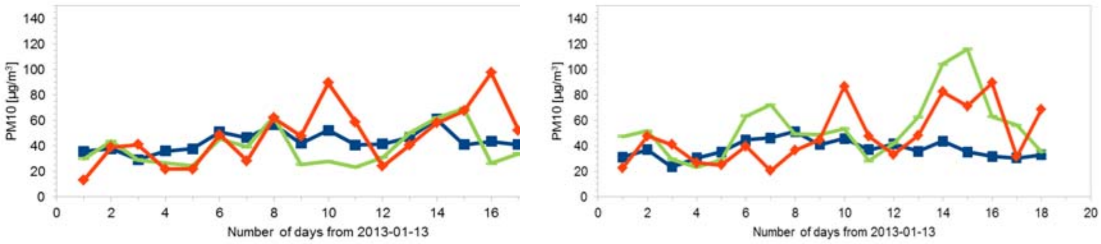

Figure 6. Verification of average daily PM10 concentrations (in μgm^{-3}) for Ljubljana (left) and Maribor (right) during the studied time period (January 14 to 31, 2013). Shown are results simulated by ALADIN-CAMx (red), WRF/Chem (blue) and measured values (green).

CONCLUSIONS

ALADIN/CAMx modelling system and WRF/Chem model were successfully set-up for operational air quality forecast in Slovenia. Although the first analyses showed some reasonable results, both modelling systems need to be further extensively tested and validated.

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