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COMBINING METEOROLOGICAL MODELS AND DISPERSION MODELS ON LARGESCALE AND MESOSCALE, IMPLEMENTED AS AN AIR QUALITY FORECAST MODEL SYSTEM IN IRAN

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Abstract: In many regions of the world air pollution and dust concentrations are so high, that local administrations need forecast systems to warn people or impose short term mitigation measures. In Iran such an Air Quality Forecast System (AQFoS) has been implemented for the entire country and in a higher resolution for the city of Tehran. The requirements for the implemented models comply with different scales and their vertical and horizontal resolutions, the possibilities of the model to describe emissions sources in different detail levels and furthermore interface methods between the models. In Iran the AQFoS has been implemented with special emphasis on dust generation and large range transport using the EURAD Air Quality Prediction System which was developed by the Rhenish Institute for Environmental Research at the University of Cologne (RIU) in a modified version. EURAD consists of three major components: The PennState/NCAR mesoscale model WRF, which predicts the needed meteorological variables, the EURAD Emission Module (EURAD-EEM), which calculates the temporal and spatial distribution of the emissions of the major pollutants and the EURAD Chemistry Transport Model (EURAD-CTM) which predicts the concentrations and deposition of the main atmospheric pollutants. The global emission data base EDGAR (Emissions Database for Global Atmospheric Research) is used as input. Furthermore a dust activation parameterization was implemented within the EURAD system in order to simulate dust emission from arid land areas. The area of Tehran is focused in a higher spatial resolution. For the Tehran area, AQFoS combines the models PROWIMO and LASAT with WRF/EURAD. The AQFoS runs on servers of the Iran National Meteorological Organization (IRIMO) and predicts concentrations of dust, NO_2, SO_2, PM10, NMVOC, CO and Ozone for 84 hours.

Key words: *largescale, mesoscale, Air Quality Forecast System, AQFoS, Iran, dust storm, WRF, EURAD, PROWIMO, LASAT.*

INTRODUCTION

In many regions of the world air pollution and dust concentrations are so high, that local administrations need forecast systems to warn people or impose short term mitigation measures. Such an Air Quality Forecast System (AQFoS) with emphasis on dust storms has been implemented by the Rhenish Institute for Environmental Research at the University of Cologne (RIU) and Ingenieurbüro Lohmeyer GmbH & Co. KG (LOH) as contract work for the Iran Atmospheric Science & Metrological Research Centre (ASMERC). The forecast system was implemented for the entire country of Iran and in a higher model resolution for the city of Tehran. The requirements for the implemented models comply with different scales and their vertical and horizontal resolutions, the possibilities of the model to describe emissions sources in different detail levels and furthermore interface methods between the models. AQFoS is a part of the Air Quality Forecast service for the Iran and is running operationally on servers of Iran Meteorological Organization (IRIMO). AQFoS predicts concentrations of dust, NO_2, SO_2, PM10, NMVOC, CO and Ozone for 84 hours.

MODEL COMPONENTS OF THE AIR QUALITY FORECAST SYSTEM AQFOS

The Air Quality forecast System (AQFoS) comprises of the following meteorological, dispersion and emission models:

- Meteorological model WRF (Weather Research & Forecasting Model, http://www.wrf-model.org), which provides the needed meteorological variables within EURAD.
- EURAD (European Air Quality Prediction System, http://www.eurad.uni-koeln.de), which is the prediction system at RIU.
- Prognostic mesoscale wind and climate model PROWIMO (www.lohmeyer.de/en/prowimo), developed by LOH.
- Lagrangian dispersion model LASAT (Lagrange-Simulation Aerosol-Transport, http://www.janicke.de/en/lasat.html).

Domain Configuration of WRF/EURAD and PROWIMO/LASAT

The Air Quality forecast System (AQFoS) of Iran consists of a nesting cascade starting with an initial horizontal domain size of 5 000 x 5 000 km² with a 50 km horizontal grid size, which covers major parts of the South West Asian. Within this domain a nested domain with 10 km horizontal grid size is embedded covering Iran (see **Figure 1**). In a further refinement step, a nested domain with a 1 km horizontal grid size has been implemented for urban region of Tehran. For this nested domain, the models PROWIMO/LASAT are applied. The specification of the domain and the nested grid are given in **Table 1**. Further nested domains with a 1 km horizontal grid size for other urban regions are possible and are subject to future work in the project.

Table 1: Domain and nested grid specifications

Domain	Region	Hor. grid size	Hor. grid points	Wind/Dispersion model
D01	South West Asia	50 km	100 x 100	WRF/EURAD
D02	Iran	10 km	201 x 201	WRF/EURAD
D02.1	Tehran	1 km	50 x 50	PROWIMO/LASAT

This configuration assures that the necessary computing time for the forecast is in an appropriate and acceptable time for the decision makers. A higher horizontal resolution will highly increase the computing time und thus delay the update of the daily forecast.

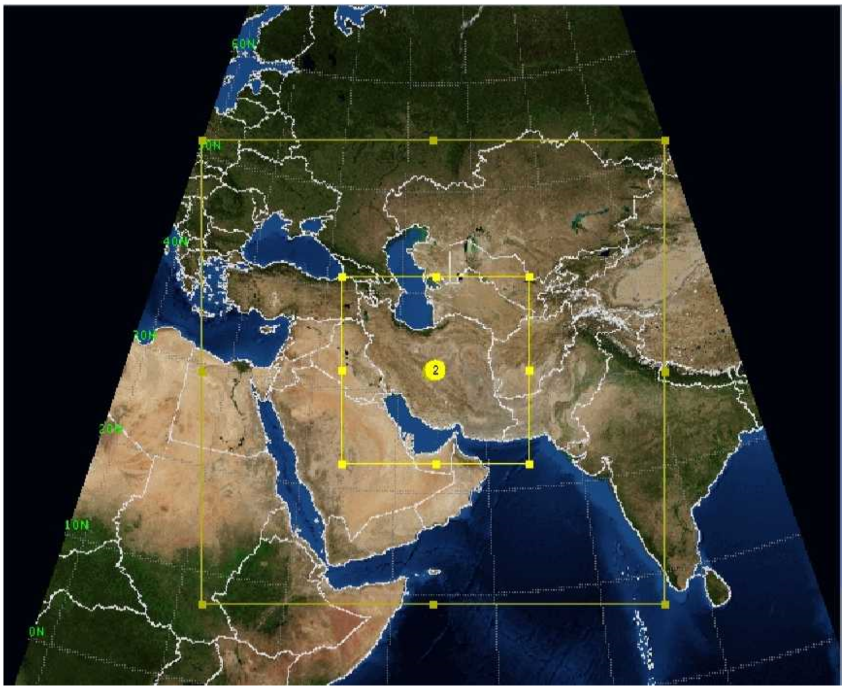

Figure 1: Model domain South West Asia and Iran

Modelling process
Each daily repeated AQFoS modelling process is started by running WRF. The meteorological results of WRF are passed to EURAD-CTM, which calculates the dispersion of emissions of the global emission data base EDGAR and of dust emissions estimated by the dust storm module.

The following steps are managed by the control software FAQIR. On domain D02.1, PROWIMO is started, which calculates meteorological parameters adopting the results of WRF from the larger D02 domain and provides wind and turbulence fields for LASAT. After that, LASAT is started, which calculates on the D02.1 domain the dispersion of emissions provided by the Tehran municipality. Mainly road traffic emissions are implemented yet. In the next process step, the background concentration calculated by EURAD-CTM and the additional load calculated by LASAT are superimposed.

The superimposed ground level concentration fields are visualized in a WebViewer which is a java based application and can be run with contemporary browsers. The time sequence of the schedule of the different AQFoS modules is shown in **Figure 3**.

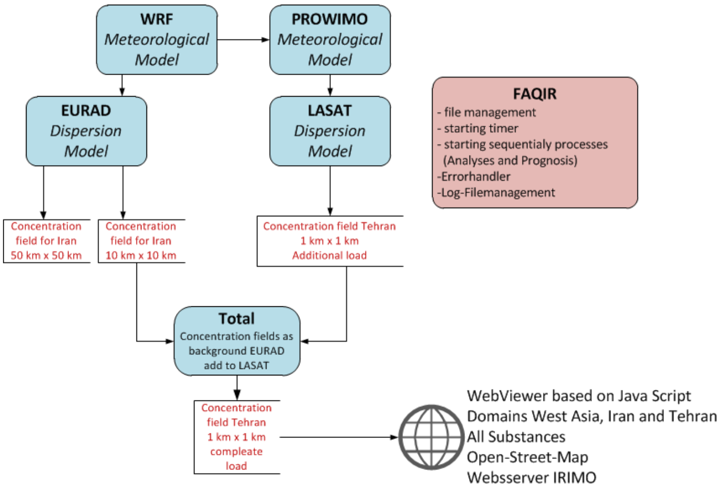

Figure 2: Modelling processes controlled by FAQIR

	Procedure	*Computing Time*	1	2	3	4	5	6
1	WRF	1.5h						
2	EURAD	2h						
3	PROWIMO	2.5h						
4	LASAT	.5h						
5	Superposition	.2h						
6	Preparing graphics for WebViewer domain D01 and D02	1.5h						
7	Preparing graphics for WebViewer domain D02.1	.5h						

Figure 3: *Model Schedule*

AQFoS starts every day at 20:00 UTC and calculates forecast concentration fields for 84 hours (three and a half days). All results are saved as netcdf-files and image files.

EURAD
The EURAD Model System is a high sophisticated Chemistry Transport System in order to predict the concentrations of pollutants in the atmosphere. It calculates the transport, chemical transformation and deposition of atmospheric trace gases. The EURAD Model System is used for case studies and especially for the daily operational forecast of air quality over Europe (http://eurad.uni-koeln.de). The EURAD

Model System is part of many national and international projects. The EURAD model is well described in numerous case studies (e.g. Hass, 1991, Ackermann et al., 1998, Memmesheimer et al., 2004). It contains also a data assimilation algorithm for analyzing observational data (Strunk, 2006 and Elbern et al., 2007). The system is running on LINUX operational system.
EURAD Model System includes the following submodules:

- Emission Module (EURAD-EEM) with the global emission data base EDGAR (http://edgar.jrc.ec.europa.eu) as input.
- Chemistry Transport Model (EURAD-CTM) which predicts the concentrations and deposition of the main atmospheric pollutants.
- A dust activation parameterization module (Chervenkov, Jakobs, 2011), which simulates dust emission from arid land areas due to soil moisture and type of ground substrate.

THE PROGNOSTIC MESOSCALE MODEL PROWIMO

The model PROWIMO is based on Flassak (1990) and was lately completely recoded and extended at LOH e.g. by the Predicted Mean Vote (PMV) or the "perceived temperature" according to VDI 3787 page 2 (2008) in order to be capable to provide climatological assessments. PROWIMO is suited to simulate the local wind and temperature distribution. The model can be adapted individually to site-specific conditions.

The model PROWIMO is based on the conservation equations for momentum, mass and energy, which are solved numerically in 3D in the flux formulation in terrain following co-ordinates. Prognostic variables are the 3 velocity components u, v and w, the potential temperature, the humidity, the surface temperature and the surface humidity. The non-hydrostatic pressure is computed by solving an elliptic differential equation. The elliptic solver is based on a Fast Fourier Transformation algorithm in conjunction with a generalized Conjugate Gradient Method. The model applies the anelastic approximation as well as the Boussines approximation. The sub-grid-scaled turbulent fluxes are parametrised with a first order closure. The complete documentation of the model PROWIMO (physical background, approximations, numerical methods, boundary and initial conditions, parametrisations) are given in Flassak (1990).

For the urban regions of Tehran, the PROWIMO simulation domain has a horizontal extent of 90 x 90 km². The horizontal grid size within an inner domain of 50 x 50 km² (Domain D02.1) is 1 km. Outside of that inner domain the horizontal grid size increases with a factor of 1.2. A vertical grid size of 20 m has been chosen from surface up to a height of 120m, above the vertical grid size increases with a factor of 1.2.

An example of the calculated wind and potential temperature distribution at ground level is shown in **Figure 4**.

THE LAGRANGIAN DISPERSION MODEL LASAT

The dispersion model LASAT (Lagrangian Simulation of Aerosol-Transport) computes the transport of trace substances in the atmosphere. It simulates the dispersion and the transport of a representative sample of tracer particles utilizing a random walk process (Lagrangian simulation). LASAT conforms to guideline VDI 3945 Part 3. LASAT is able to simulate accidental releases, screening, bio-aerosols, odorants, moving sources. Furthermore LASAT is able to simulate special emitter circumstances like the plum rise of stacks and cooling towers and well traffic induced turbulence. LASAT is able to calculate single meteorological situations and time series as well.

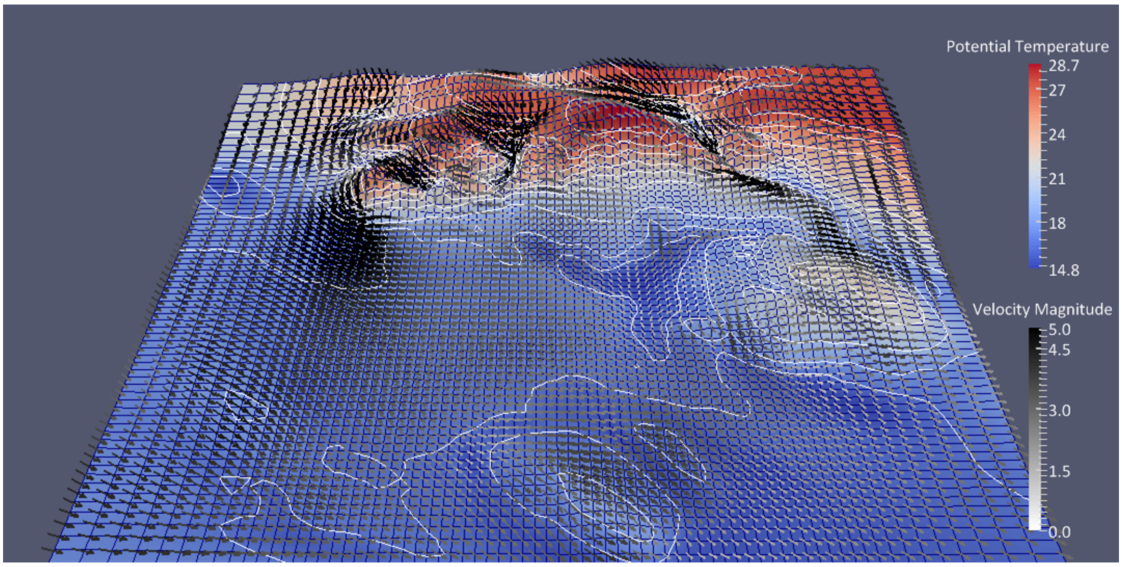

Figure 4: PROWIMO simulation results for Tehran on the D02.1 domain: Ground level wind and potential temperature distribution.

THE WEBVIEWER ONLINE PRESENTATION

The WebViewer is a java based application and can be run with contemporary browsers. The WebViewer visualises the ground level concentration fields for each domain as an animation on a Open-Street-Map layer (see **Figure 5**). The WebViewer is able to show concentrations fields for each, domain, substance and forecast hour.

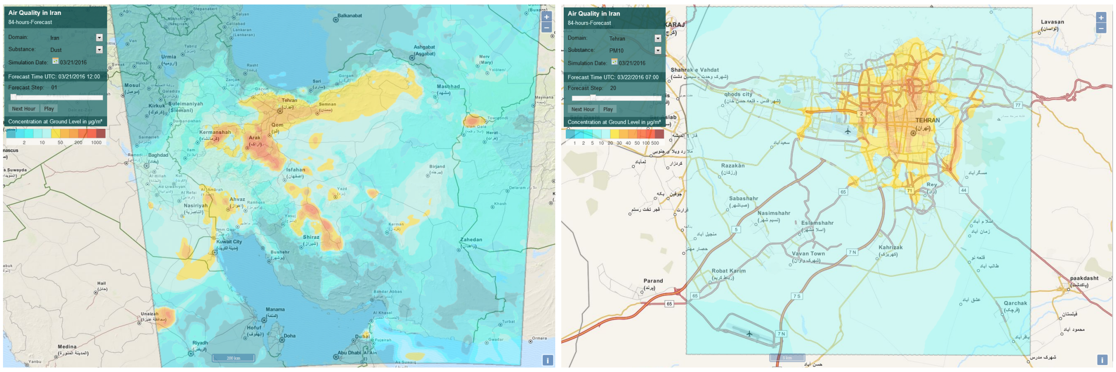

Figure 5: WebViewer sceenshot of the PM10 ground level concentration field in Iran and Tehran at forecast hour 70

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