

Satellite & in-situ Information for Advanced Air Quality Forecast Services – SiAiR

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Test Data Run

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Advances in Atmospheric Science and Applications (ATMOS) Conference

Heraklion, Crete, Greece, 08 - 12 June 2015

INTRODUCTION

Air Quality is not only an indicator of the pollution degree but has become a metric of life quality and well-being for the european citizen. Particulate matter, nitrogen dioxide and ground-level ozone are recognized as the three pollutants that most significantly affect human health.

Atmospheric models constitute an important tool for simulations of transport and transformation of aerosols and gases and thus to improve our knowledge about aerosol particles primary and secondary sources of aerosol particles.

Therefore it is of particular interest to investigate and understand how satellite measurements can be used to improve our characterization of the atmosphere. One of the key advantages of assimilating satellite products in the air quality models is the availability of data aloft.

In the frame of the project SiAiR (funded by ESA), satellite measurements of the Aerosol Optical Thickness (AOT) and ground-based PM10-measurements are combined to highly-resolved initial fields using assimilation techniques. It is expected that the assimilation of satellite measurements will significantly improve the quality of Air Quality model retrievals.

Motivation and goals

Evaluation of data assimilation impact

The AQ model output when no observational PM10 data have been ingested will be compared with PM10 retrievals of the same AQ model when measured (in-situ) data and satellite estimations of PM10 have been assimilated. Data from the AQ ground network will be used as a reference and the impact of assimilation on the forecast accuracy will be assessed. Pm10 in-situ measurements from all Romanian AQ stations (NEPA) for the months of January and June 2013 will be used as ground truth reference.





A recent project (AQA-PM Project, 2013) demonstrated improvements in air quality forecast when PM10 in-situ measurements and satellite based PM10 data estimates provided by the MODIS instrument was assimilated in the WRF/Chem model. At the National Meteorological Administration – NMA(the Romanian Weather Service), several numerical models are run operationally for weather (ALADIN, ALARO, COSMO, WRF), pollutant dispersion (INPUF) and air quality forecasting (CHIMERE). Together with an increasing preoccupation of the central and local administration, health authorities, NGO's and the population for more accurate information on air quality, defining the assimilation of observations (satellite and ground measurements) into the numerical modeling of NMA has been deemed a natural step towards future better air quality information.

Main project tasks

Selection of the AQ model

The on-line coupled model WRF/Chem has been selected as the Air Quality model for the observational data assimilation experiments and it will be operated at a resolution of 10 km in the core. The WRF model is already used operationally at NMA with boundary and initial conditions from the COSMO model at 7km.

Observational data assimilation methodology

Ground measurements are used in two ways: 1) in the ground site domain to perform several evaluations (e.g. to evaluate temporal signature (yearly, seasonal, monthly), to evaluate atellite data benefit, to evaluate key parameters for PM10 retrieval) and 2) both at the site and in the model domain to validate the forecast.

Information from ground measurements are not introduced in the satellite based PM10 map at this stage of this work. Preliminary investigations in this direction are recently performed with geostatistical techniques to evaluate PM10 estimation from space and ground data by Campalani et al. (2011, 2012). As the PM10-ground measurements are currently not included in the PM10 maps generation using the SVR process these data are assimilated separately into the model. To determine the initial condition of the PM10 distribution from ground measurements and simulated model distributions, optimal interpolation (OI) analysis (Daley, 1991) is used. The OI is an algebraic simplification of the computation of the weight K in the analysis equations:

On the 25 June 2013, using PM10 data from all the 58 available stations and forecasted WRF-Chem (no assimilation) values for the R² coefficient (0.1047), demonstrates a very low correlation, indicating significant under-/overestimation of the in-situ data.



X_a analysis values ; X_bbackground values K optimal weight matrix; Y observations H transforms from Model- to observation-space B background error covariance R observation error covariance

$$x_a = x_b + K(y - H_{[x_b]})$$

 $K = BH^T (BH^T + R)^{-1}$

Design & implement the prototype data assimilation system

The prototype assimilation system consist of 2 main modules: Calibration and PM10 Assimilation. Each module is made up of several input/output and processing elements.

Satellite PM10 Maps Provision

Machine learning methods are used to predict PM concentrations values from satellite based Aerosol Optical Thickness (AOT) and meteorological data (in-situ and model data). The Support Vector Machine method analyzes data and recognizes patterns for classification purposes. The SVR application in PM retrieval consist of data collection, match-up (space & time collocation of data), SVR training and SVR prediction.

Data used

Data covering the national territory of Romania for a 3 years period (2008-2010) have been collected in order to build SVR data models (fine tuning) for the prediction phase:

-Model data o Meteorological fields from the ECMWF-WRF/Chem Impact of EO products assimilation into the numerical model: all Romanian Air Quality stations are used to calculate the daily correlation over Romania between ground measurements and forecasts of PM10 from WRF with (red lines) / without (blue lines) assimilation.

During January 2013 a limited effect of EO product assimilation is observed probably due to the cloud cover that affect satellite observations, while in June 2013 there is a strong positive effect.



NWPM: Numerical Weather Prediction Model **AQMC**: Air Quality Model with Chemistry Module **EMPP**: Emission Pre-processor **EDAB**: Emission Database **WEPP**: Weather Pre-processor **GDMR**: Global Data Model Retriever **AQMC**: Air Quality Model with Chemistry Module **NWPM**: Numerical Weather Prediction Model **ISDI:** In-situ & Satellite Data Assimilation **MOPP**: Model Output Post-Processing **IDPR**: In-situ Data Processing **AQFV**: Air Quality Model Forecast Validation **REDI:** Result Dissemination Infrastructure **EGDB**: External Global Model Output Database **SADB**: Satellite Database **IPDB**: In-situ PM10 database **IMDB**: In-situ meteorological database



-In-situ data

o Meteorological data from all NMA weather stations o PM10 measurements from all 114 Romanian AQ stations (NEPA) o TNO PM10 emissions

-Satellite data (accessed through the MEA platform https://mea.eo.esa.int) o MODIS L1B Calibrated Geolocation Data Set o MODIS Geolocation Data Set o Aerosol Optical Thickness (AOT) products

Additionally, for the prediction phase, satellite data (MODIS) from January and June 2013 will be used.

Prototype system testing

The testing phase purpose is twofold: (1) to confirm the proper operation of the processing chain and (2) to obtain the forecasted PM10 values for January and June 2013 from the AQ model with and without observational data assimilation.

At the time of the writing of this presentation, the integration of the AQ model without data assimilation has been completed. As a supplementary test, the model has also been run with only in-situ PM10 data assimilation. The integration of the AQ model with data assimilation is ongoing.

Next Steps

Integration of the AQ model using observational data assimilation

- Validation of results

Evaluation of data assimilation impact on PM10 forecast accuracy

REFERENCES

Edwards, D. P. Air quality remote sensing from space. Eos Trans. AGU 2006, 87, 327.

Hirtl, M., S. Mantovani, B. C. Krüger, G. Triebnig, C. Flandorfer, M. Bottoni, M. Cavicchi, 2014: Improvement of air quality forecasts with satellite and ground based particulate matter observations. Atmos. Environ., 84, 20-27.

Thompson, T. M. and Selin, N. E.: Influence of air quality model resolution on uncertainty associated with health impacts Atmos. Chem. Phys., 12, 9753–9762, 2012.

Tuccella, P., Curci, G., Visconti, G., Bessagnet, B., Menut, L., Park, R. J. (2012), Modelling of gas and aerosol with WRF/Chem over Europe: evaluation and sensitivity study, J. Geophys. Res., 117, D03303, doi:10.1029/2011JD016302

AKNOWLEDGEMENT

This work was supported by a grant of the European Space Agency (ESA), project No. 4000110941/14/I-LG, Satellite & in-situ Information for Advanced Air Quality Forecast Services -SiAiR, in the framework of the Romanian Incentive Scheme.

The authors thank West University of Timisoara for providing access to the BlueGene supercomputer.