Science-Education: Online Integrated Modelling of Aerosol-Chemistry-Meteorology Effects using Enviro-HIRLAM

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Abstract

To attract more perspective young scientists for advanced research and development of complex and modern modelling systems, a specific approach is required. Thus, a special event such as **Young Scientist Summer School (YSSS)** can be organized, where young researchers could have an opportunity to attend not only relevant lectures, but also participate in practical exercises allowing to solidify lecture materials. Here, the practical exercises are presented as independent small-scale (having duration of up to a week) research projects or studies oriented on specific topics of the school. Developed approach was tested and realized in several summer schools. The main focus of these YSSSs was on the integrated modelling of meteorological and chemical/aerosol transport processes and impact of chemical weather on numerical weather prediction and climate modelling. Outline and detailed description of the developed approach, key items of the research projects, etc. are presented.

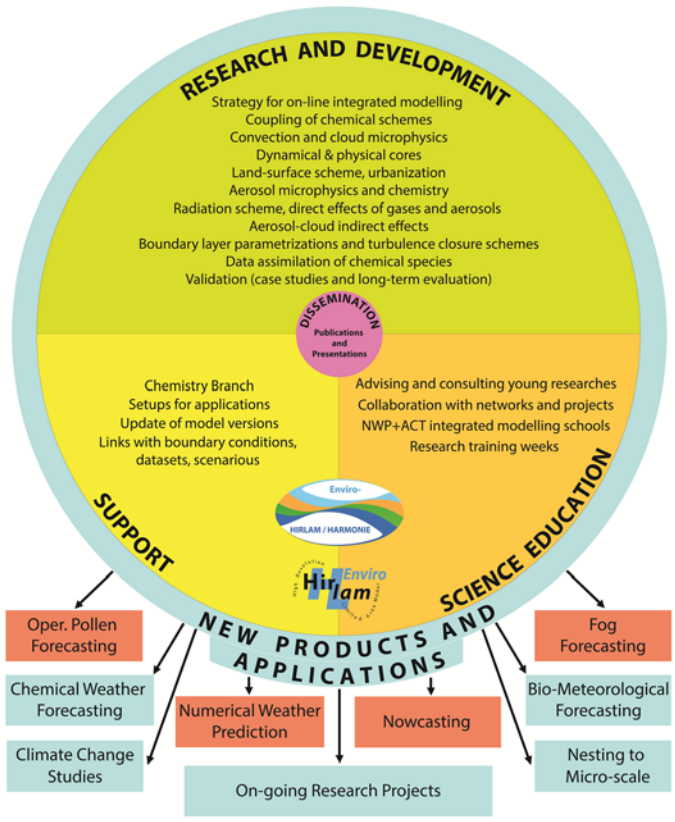

***Figure 1**: Enviro-HIRLAM / HARMONIE general scheme of research and development, support, products and applications, and science education components.*

YSSS-2008: 7-15 July 2008, Zelenogorsk, Russia

YSSS-2008 (*netfam.fmi.fi/YSSS08*) aim was to join young scientists and researches of the HIRLAM (HIgh Resolution Limited Area Model) community in order to elaborate, outline, discuss and make recommendations on the best strategy and practice for further developments and applications of the integrated modelling of both meteorological and chemical transport processes into the HIRLAM modelling system. The main emphasis was on fine-resolution models applied for chemical weather forecasting and feedback mechanisms between meteorological and atmospheric pollution processes. All exercises were based on 3D models Enviro-HIRLAM (on-line integrated meteorological-chemical-aerosol-cloud-transport model) and SILAM (off-line atmospheric chemical transport model).

YSSS-2011: 3-9 July 2011, Odessa, Ukraine

YSSS-2011 (*www.ysss.osenu.org.ua*) aim was to join young scientists and researches from the numerical weather prediction and air quality communities, University/Academia system in order to elaborate, outline, discuss and make recommendations on the best strategy and practice for further research, developments and applications of the integrated modelling of both meteorological and chemical transport processes into the numerical weather prediction modelling systems, and in particular, the Enviro-HIRLAM and HARMONIE/SURFEX modelling system. The main emphasis is on multi-scale models applied for chemical weather forecasting and feedback mechanisms between meteorological and atmospheric pollution processes.

YSSS-2014: 6-11 July 2014, Aveiro, Portugal

YSSS-2014 (*aveirosummerschool2014.web.ua.pt*) aim is to train students and researchers from the numerical weather prediction, air quality and climate communities, and to apply integrated modelling of both meteorological and chemical processes to understand the links between atmospheric composition, weather and climate. The main focus is on regional/urban scale models applied for chemical weather forecasting and feedback mechanisms between meteorological and atmospheric pollution processes.

The programme covers the following topics/ blocks:

- Fundamentals of atmospheric processes & modelling,
- Surface and atmospheric boundary layer physics and processes,
- Atmospheric chemical transport modelling,
- Aerosol physics-chemistry and modelling,
- Evaluation and application,

and will include training exercises with different models.

Several models were used in training exercises: HARMONIE (hirlam.org); BOLCHEM (bolchem.isac.cnr.it); Enviro-HIRLAM (www.hirlam.org); WRF-Chem (www.acd.ucar.edu/wrf-chem); COSMO-Art (www.imk-tro.kit.edu); METRAS (www.mi.uni-hamburg.de).

Motivation and Background

To attract more perspective young scientists (and especially, MSc and PhD students) for advanced research and development of complex and modern modelling systems, a specific approach is required. It should allow within a short period of time to evaluate personal background levels, skills, capabilities, etc. To learn more about new potential science-oriented developers of the models, it is often not enough to look into the personal resume. Thus, a special event such as Young Scientist Summer School (YSSS) can be organized, where young researchers could have an opportunity to attend not only relevant lectures, but also participate in practical exercises allowing to solidify lecture materials. Here, the practical exercises are presented as independent small-scale (having duration of up to a week) research projects or studies oriented on specific topics of YSSS.

Developed approach was tested and realized during 2008, 2011 and 2014 YSSS events held and organized in Zelenogorsk, Russia (by Nordic NetFAM et al.; http://netfam.fmi.fi/YSSS08); Odessa, Ukraine (by Odessa Sate Environmental University and Nordic MUSCATEN et al.; http://atmos.physic.ut.ee/muscaten/YSSS/1info.html), and Aveiro, Portugal (by the University of Aveiro, COST Action EuMetChem (eumetchem.info) et al., http://aveirosummerschool2014.web.ua.pt). The main focus of all these YSSSs was on the integrated modelling of meteorological and chemical transport processes and impact of chemical weather on numerical weather prediction and climate modelling.

Small-Scale Research Projects

During previous YSSSs some of such projects – "*URBAN: The Influence of Metropolitan Areas on Meteorology*" and "*AEROSOL: The Impact of Atmospheric Aerosols on Meteorology*" were focused on evaluation of influence of metropolitan areas on formation of meteorological and chemical fields above urban areas and surroundings. The **Environment – HIgh Resolution Limited Area Model (Enviro-HIRLAM)** model (aspects are shown in Figure 1) was used and modifications were made taking into account urban (anthropogenic heat flux, roughness, buildings and their characteristics), chemical species/ aerosol (feedback mechanisms) effects with further analysis of temporal and spatial variability of diurnal cycle for meteorological variables of key importance.

URBAN: Influence of Metropolitan Areas on Meteorology

Main Goal:
Study influence of the selected metropolitan area on a formation of meteorological fields above the urban area and surroundings due to modification of the land surface scheme of the numerical weather prediction (NWP) model by analysis of temporal and spatial variability of diurnal cycle for meteorological variables of key importance.

Specific Objectives:
1) Modify the land surface scheme of the Enviro-HIRLAM model: • by changing AHF - anthropogenic heat flux, R - roughness for urban grid cells; • by implementation the BEP (Building Effects Parameterization) module;
2) Perform simulations for selected specific cases/dates (meteorological conditions with dominating low and typical wind conditions over the metropolitan area and surroundings) in two modes - the control run and modified run (with changes: AHF+R vs. BEP);
3) Evaluate diurnal cycle variability for – air temperature, wind velocity, relative humidity, sensible heat flux, latent heat flux, and etc. – for two types of runs; estimate extension and direction of boundaries under influence of metropolitan areas, magnitude and signs of changes due to urban areas, etc. (see Figure 2).

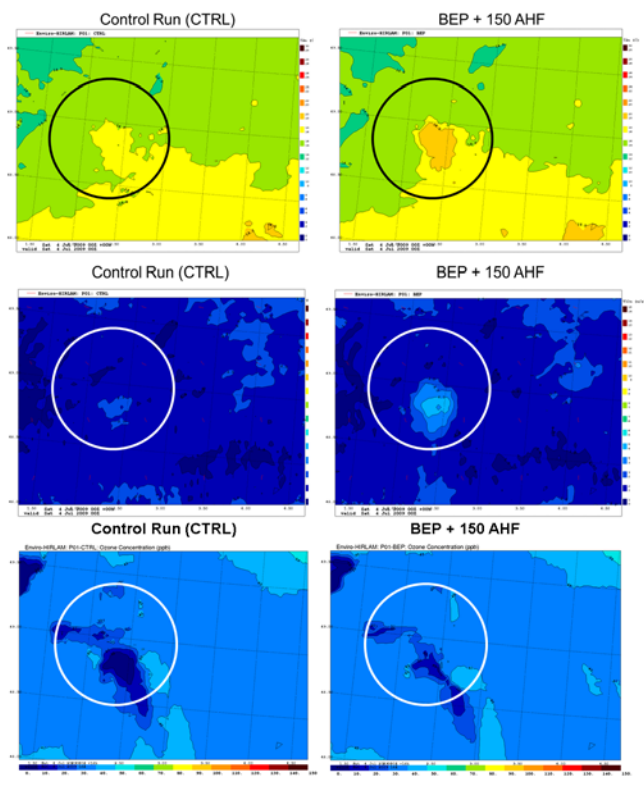

***Figure 2**: The Enviro-HIRLAM-P01 (runs: left — reference vs. right — BEP & AHF=150 W/m^2) high resolution modelling results for — (top) air temperature at 2 m in deg C, (middle) wind speed at 10 m in m/s, and (bottom) ozone concentration in ppb —for the Paris metropolitan area on 4 Jul 2009, at (top-middle) 00 UTC and (bottom) 18 UTCs.*

Projects' Summary and Outline

Main items of listed above YSSS small-scale research projects include the following:

- Introduction with background discussions (with brainstorming to outline research and technical tasks planned including main goal, specific objectives, etc.) in groups;
- Analysis of meteorological situations (selecting specific cases/ dates using surface maps, diagrams of vertical sounding, and surface meteorological measurements);
- Learning practical technical steps (in order to make necessary changes in the model and implementing urban and aerosol effects, compiling executables, making test runs);
- Performing model runs/simulations at different options (dates, control vs. modified urban and aerosol runs, forecast lengths, spatial and temporal resolutions, etc.);
- Visualization/ plotting of results obtained (in a form of graphs, tables, animations);
- Evaluation of possible impact on urban areas (estimating differences between the control and modified runs through temporal and spatial variability of simulated meteorological (air temperature, wind speed, relative humidity, sensible and latent heat fluxes, etc.) and chemical pollutants (concentration and deposition) fields/patterns;
- Team's oral presentation of the project about results and findings and following guidelines (including aim and specific objectives, methodology and approaches, results and discussions with examples, conclusions, acknowledgements, references).

AEROSOL: Impact of Atmospheric Aerosols on Meteorology

Main Goal:
Study influence of the anthropogenic emissions from selected metropolitan area on a formation of meteorological/ chemical fields in the urban area and surroundings due to inclusion of aerosols feedback mechanisms in the Enviro-HIRLAM model by analysis of temporal and spatial variability of diurnal cycle for meteorological/chemical variables of key importance.

Specific Objectives:
1) Modify the Savijärvi and STRACO schemes of Enviro-HIRLAM model by including the calculation of the activated anthropogenic aerosol number concentration, wet deposition in the condensation scheme, parameterization of the effect of the Cloud Condensation Precipitation Evaporation processes and dry deposition;
2) Perform simulations for selected specific cases/dates (meteorological conditions with convective regimes and typical wind conditions) in two modes - the control run and the modified run (with feedbacks included);
3) Evaluate diurnal cycle variability for – air temperature, sensible heat flux, latent heat flux, surface temperature, cloud reflectivity, and etc. – for two types of runs; estimate the impact of anthropogenic aerosols from metropolitan area, magnitude and signs of changes due to feedbacks, etc. (see Figure 3).

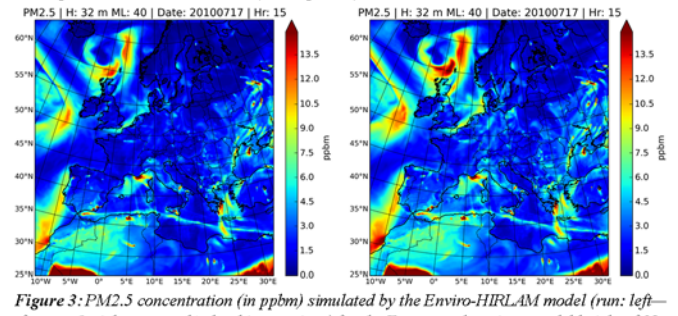

***Figure 3**: PM2.5 concentration (in ppbm) simulated by the Enviro-HIRLAM model (run: left—reference & right—aerosol+cloud interactions) for the European domain at model height of 32 m asl on 17 Jul 2010, 15 UTC.*

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