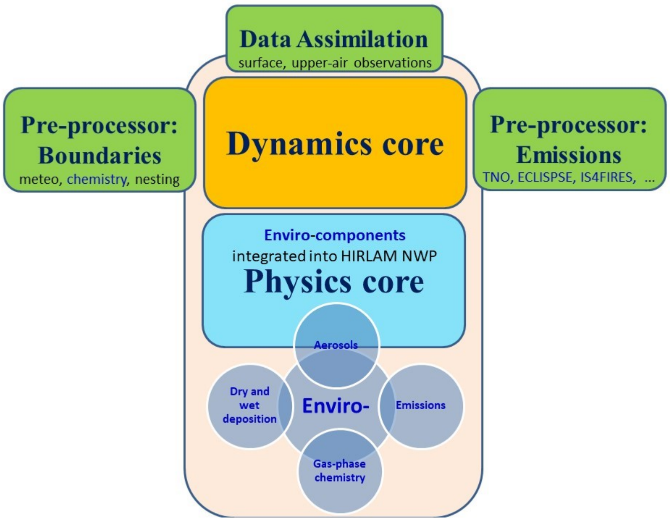

Enviro-HIRLAM

Environment – HIgh Resolution Limited Area Model

The Enviro-HIRLAM is a fully online-coupled ACT-NWP (Atmospheric Chemistry Transport – Numerical Weather Prediction) modeling system for regional-, subregional- and urban scale different environmental applications. The NWP part developed by HIRLAM consortium *(Unden et al., 2002)* is used for operational weather forecasting. The Enviro-components (see Figure) were developed by DMI and NBI/UoC with partners through collaboration (Denmark, Finland, Russia, Ukraine, Kazakhstan, Baltic States, Spain, Turkey, etc.). The overviews by *Korsholm et al. (2008), Baklanov et al. (2008)* and the latest by *Baklanov et al. (2017)* includes all corresponding references.

Enviro-HIRLAM consists of gas-phase chemistry CBMZ (*Zaveri & Peters, 1999*) and aerosol microphysics M7 (*Vignati et al., 2004*), which includes sulfate, mineral dust, sea-salt, black and organic carbon (*Nuterman et al., 2013*). There are modules of urbanization for land surface scheme, natural and anthropogenic emissions, nucleation, coagulation, condensation, dry and wet deposition, and sedimentation of aerosols. The Savijarvi radiation scheme (*Savijaervi, 1990*) has been improved to account explicitly for aerosol radiation interactions for 10 aerosol subtypes. The aerosol activation scheme (*Abdul-Razzak and Ghan, 2000*) was also implemented in STRACO condensation-convection scheme. The nucleation is dependent on aerosol properties and the ice-phase processes are reformulated in terms of classical nucleation theory.
Enviro-HIRLAM runs in a downscaling chain, for the outer model domain (run at low resolution) the initial and boundary conditions for meteorology and atmospheric conditions are taken from ECMWF; vertical levels vary between 40-60; finest horizontal resolution is about 1.5 km; model can be run in both research and operational modes. Emissions include anthropogenic, biogenic, and natural; and these are pre-processed. Different parts of the model were evaluated vs. ETEX-1 experiment, Chernobyl accident, Paris summer/winter campaigns, etc. The model was tested in FPs FUMAPEX, MEGAPOLI, TRANSPHORM, PEGASOS, MACC, MarcoPolo, etc. projects & currently is used within frameworks of the Pan-Eurasian EXperiment programme (PEEX; https://www.atm.helsinki.fi/peex).

Model Setup includes: period to be studied; boundaries of modeling domain; selected projection; horizontal & vertical resolutions; chemical & meteorological initial & boundary conditions; emissions (anthropogenic, biogenic, natural); chemical & aerosol modules.

Emission Inventories: used depend on research projects MEGAPOLI, TRANSPHORM, PEGASOS, MarcoPolo, EnsCLIM, CarboNord, etc. ***Anthropogenic***: TNO-MACC (species: SO_2, PM; Temporal profile: hour-of-day, day-of-week and day-of-year (depends on country time zone/shift); Vertical profile: according to TNO; PM emissions scaling following TNO). ***Biomass burning:*** IS4FIRES by FMI (species: SO_2 and TPM split into PM2.5 and PM10; vertical profile is as follows (approx. recommendation of emitting 50% in lowest 200 m and 50% between 200 and 1000 m). ***Natural:*** Interactive sea-salt (Zakey et al., 2008) and mineral dust (*Zakey et al., 2006*) emission modules.

Boundary (BC) and Initial (IC) Conditions Data: *Meteorological IC/BC*: taken from operational ECMWF IFS model at N-hr temporal & $N^{o}xN^{o}$ horizontal resolutions for domain specified in geographical coordinates and N-vertical levels; parameters need to be retrieved from ECMWF to force model are: 2D surface fields: soil moisture, snow depth, surface pressure & roughness, geopotential, land-cover/use classes, albedo, vegetation & soil types; and 3D fields: specific humidity, temperature, winds. ***Chemical IC/BC:*** taken from IFS-MOZART output. The two mineral dust size bins of IFS-MOZART are treated. The aerosol number concentration is computed from the aerosol masses according to the Hatch-Choate conversion equations. The following variables of IFS-MOZART are used: O_3, NO, NO_2, HNO_3, H_2O_2, SO_2, OH, SO_4, dust, black and organic carbon.

References

Abdul-Razzak, H., and S. J. Ghan (2000), A parameterization of aerosol activation: 2. Multiple aerosol types, J. Geophys. Res., 105(D5), 6837–6844.

Baklanov A., Korsholm U., Nuterman R., Mahura A., Nielsen K., Sass B., Rasmussen A., Zakey A., Kaas E., Kurganskiy A., Sørensen B., González-Aparicio I. (2017): Enviro-HIRLAM online integrated meteorology–chemistry modelling system: strategy, methodology, developments and applications (v7.2), Geosci. Model Dev., 10, 2971-2999.

Baklanov A., U. Korsholm, A. Mahura, C. Petersen, A. Gross (2008): ENVIRO-HIRLAM: on-line coupled modelling of urban meteorology and air pollution. Advances in Science and Research, 2, 41-46.

Korsholm U.S., A. Baklanov, A. Gross, A. Mahura, B.H. Sass, E. Kaas (2008): Online coupled chemical weather forecasting based on HIRLAM – overview and prospective of Enviro-HIRLAM. HIRLAM Newsletter, 54.

Nuterman, R., Korsholm, U., Zakey, A., Nielsen, K. P., Sørensen, B., Mahura, A., Rasmussen, A., Mažeikis, A., Gonzalez-Aparicio, I., Morozova, E., Sass, B. H., Kaas, E., Baklanov A. (2013): New developments in Enviro-HIRLAM online integrated modeling system. Geophysical Research Abstracts, Vol. 15, EGU2013-12520-1

Savijärvi H. (1990): Fast Radiation Parameterization Schemes for Mesoscale and Short-Range Forecast Models. J. Appl. Meteor., 29, 437–447.

Undén P. et al., (2002): Hirlam-5 scientific documentation. Tech. rep., SMHI.

Vignati E., Wilson J., Stier P. (2004): M7: An efficient size-resolved aerosol microphysics module for large-scale aerosol transport models. JGR 109(D22): D22202.

Zakey A.S., F. Giorgi, X. Bi (2008): Modeling of sea salt in a regional climate model: Fluxes and radiative forcing, J. Geophys. Res., 113, D14221.

Zakey, A. S., Solmon, F., Giorgi, F. (2006): Implementation and testing of a desert dust module in a regional climate model, Atmos. Chem. Phys., 6, 4687-4704.

Zaveri R.A., L.K. Peters (1999): A new lumped structure photochemical mechanism for large-scale applications. J. Geophys. Res., Vol. 104, D23, 30,387-30, 415.