INTEGRATION OF THE ENVIRO-HIRLAM ONLINE METEOROLOGY-CHEMISTRY-AEROSOL MODELLING SYSTEM INTO THE FLEXPART LAGRANGIAN PARTICLE DISPERSION MODEL

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INTRODUCTION

This project introduces an approach for integration of the Enviro-HIRLAM (Environment-High Resolution Limited Area Model) output into FLEXPART (FLEXible PARTicle dispersion model).

FLEXPART is a Lagrangian model to simulate dispersion of particles and air parcels, which can be run either in both forward and backward modes (Pisso et al., 2019). A FLEXPART simulation requires meteorological input from a numerical weather prediction (NWP) model. The out-of-the-box version of FLEXPART can utilize either ECMWF's (European Centre for Medium-Range Weather Forecasts) forecast or re-analysis data, or NCEP's (National Center for Environmental Prediction) Global Forecast System (GFS) forecasts or analysis data.

In this project, new functionality to FLEXPART was implemented so that it can utilize Enviro-HIRLAM model output. Enviro-HIRLAM is a seamless, online modelling system which includes simultaneous modelling of meteorology, atmospheric chemistry and aerosols (Baklanov et al., 2017). The benefit of using Enviro-HIRLAM over ECMWF or GFS is that it accounts for aerosol direct and indirect effects when simulating meteorology and atmospheric composition. Including effects of aerosols and chemistry can improve the quality of forecasts. Effects of aerosols are especially important during severe, widespread haze events where heavy aerosols have both direct and indirect effects on regional meteorology (Baklanov et al., 2016).

The novelty of this project is that, unlike the current out-of-the-box version of FLEXPART, aerosol effects will be accounted for when calculating trajectories when using FLEXPART with Enviro-HIRLAM as input. Additionally, Enviro-HIRLAM can be run at higher resolution than GFS or ECMWF, making use of nested domains. Nesting is an effective compromise between high-resolution modelling and efficient use of computing resources.

This project is part of the larger study of modelling air quality using the University of Helsinki's SOSAA (the model to Simulate the concentration of Organic vapors, Sulfuric Acid, and Aerosols) to better understand air chemistry, particle formation and growth, and pollution sinks during severe air pollution episodes in megacities.

METHODS

Modifications to FLEXPART: In this project, we modified FLEXPART so that it recognizes and accepts meteorology forecast output from Enviro-HIRLAM. Then it reads the forecast data to calculate either forward or backward dispersion.

Nesting: This project starts with 0.25º horizontal resolution for the greater Eurasia area, and then it uses nested domains (with 0.15º, 0.05º, and 0.02º in horizontal resolutions) covering the entire China, North China region, and finally the Beijing metropolitan area and sorroundings.

Coordinate system: Enviro-HIRLAM simulations are done in a rotated coordinate system. In this project, we used South Pole latitude of -80º and South Pole longitude of 0º. In our implementation, FLEXPART's calculations are done in the rotated coordinate space. Then the output is converted to geographic latitude/longitude coordinates.

Evaluation: The newly developed modelling system (Enviro-HIRLAM + FLEXPART) has been run for a severe air pollution episode in Beijing from 10-15 November 2015. Results of have been compared to FLEXPART results using ECMWF and GFS re-analysis data. Results have also been compared to the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT; Stein et al., 2015) model for cross-reference.

Additionally, results using Enviro-HIRLAM with aerosol effects enabled have been compared to the same Enviro-HIRLAM runs without aerosol effects (i.e. a control/reference run).

CONCLUSIONS AND FUTURE WORK

This project demonstrates the integration of an atmospheric model with aerosol and chemistry into FLEXPART, and it shows the differences when accounting for aerosol effects. This is the first such implementation for FLEXPART.

Applications of the combined model system include air quality analysis, tracking smoke and pollution, evaluation of atmospheric hazards, source apportionment of observed atmospheric chemical pollutants, and many other applications. These applications are invaluable to human health, safety, and scientific research. The FLEXPART + Enviro-HIRLAM integration approach will also be used in our applications of the SOSAA model, which aims to simulate chemical reactions and particle formation during air pollution and haze episodes. In addition to China, we plan to conduct similar studies in Finland, Turkey, Austria, and Greece (i.e. in different geographical regions with different meteorological/climatic and air quality conditions)

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REFERENCES

Baklanov et al. (2016). Atmos. Enviro. doi.org/10.1016/j.atmosenv.2015.11.059
Baklanov et al. (2017). Geosci. Model Dev. doi.org/10.5194/gmd-10-2971-2017, 2017
Pisso et al. (2019). Geosci. Model Dev. doi.org/10.5194/gmd-12-4955-2019
Stein et al. (2015). Bull. Amer. Meteor. Soc. doi.org/10.1175/BAMS-D-14-00110.1