Integration of the Enviro-HIRLAM online meteorology-chemistry-aerosol modelling system into the FLEXPART Lagrangian particle dispersion model

Enviro-HIRLAM → FLEXPART

A new trajectory and dispersion modelling system

New applications for atmospheric aerosol, chemistry and air quality modelling

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For more information about this project:

FLEXPART *FLEXible PARTicle dispersion model*

A Lagrangian trajectory and dispersion model for simulating particles and air parcels (Pisso et al., 2019).

- Can be run in forward or backward mode (i.e. trajectory after a release or a back-trajectory at a specific arrival point).
- Calculated based on a Numerical Weather Prediction (NWP) model as input.
    - Out-of-the-box FLEXPART can use either U.S. Global Forecast System (GFS), or ECMWF forecast or re-analysis datasets.

Enviro-HIRLAM *Environment-High Resolution Limited Area Model*

Enviro-HIRLAM is a seamless, online integrated modelling system which includes simultaneous simulation of meteorology and atmospheric composition (chemistry/aerosols Baklanov et al., 2017).

- Includes both direct and indirect aerosol effects when calculating weather forecasts.
    - Improves the quality of forecasts.
    - Especially important in areas of heavy aerosols, for example during haze episodes in northern China (Baklanov et al., 2016).
- Can be used with high-resolution nested domains.
    - Important for air quality forecasts, where emissions information is at higher resolution than GFS or ECMWF grids.
    - Nesting is an effective compromise between high-resolution modelling and efficient use of computing resources.

Methods

- We ran Enviro-HIRLAM with nested domains from 0.25° over Eurasia, down to 0.02° over the Beijing region. Enviro-HIRLAM was run with both aerosol effects enabled, and with aerosol effects disabled (for a reference run).
- We modified FLEXPART to accept Enviro-HIRLAM as meteorological input.
    - HIRLAM uses a system of rotated lat/lon coordinates. All of FLEXPART's calculations are done in the rotated space, and then the output is translated to cartesian lat/lon coordinates.
    - HIRLAM's hybrid vertical coordinates were transformed to FLEXPART's vertical system.
- Results of Enviro-HIRLAM+FLEXPART were evaluated alongside GFS+FLEXPART and ECMWF ERA5+FLEXPART before, during, and after the passage of a cold front in Beijing. Before the front there was a severe haze episode, and after the front the air was clean. Results were also compared to the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT; Stein et al., 2015)

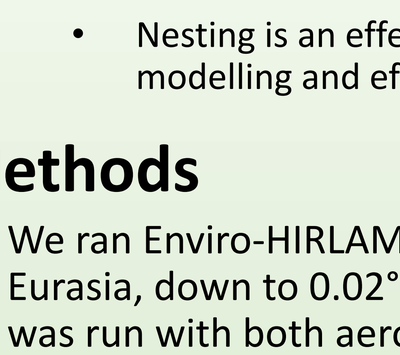

Figure 1: Map of the nested domains we used for Enviro-HIRLAM runs. From largest to smallest: 0.25°, 0.15°, 0.05° and 0.02°.

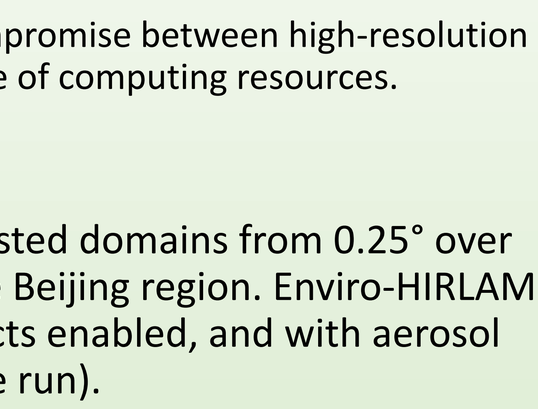

Figure 2: $PM_{2.5}$ during a severe air pollution episode. The aerosol effects are greatest before the passage of a front, around 8:00 local time on November 15.

Goal of this project

The combined modelling system will be used by SOSAA (the model to Simulate the concentration of Organic vapors, Sulfuric Acid, and Aerosols) to model air quality during a severe air pollution/haze episode in Beijing in November 2018. SOSAA will follow the trajectories simulated by FLEXPART, taking in emissions information and calculating aerosols and pollutant gases leading up to the episode and through the episode's lifecycle.

Our hypothesis is that using Enviro-HIRLAM will improve the quality of the SOSAA simulations because of its inclusion of chemistry and aerosols in when calculating meteorology forecasts, and because of its high-resolution domains.

Results and discussion

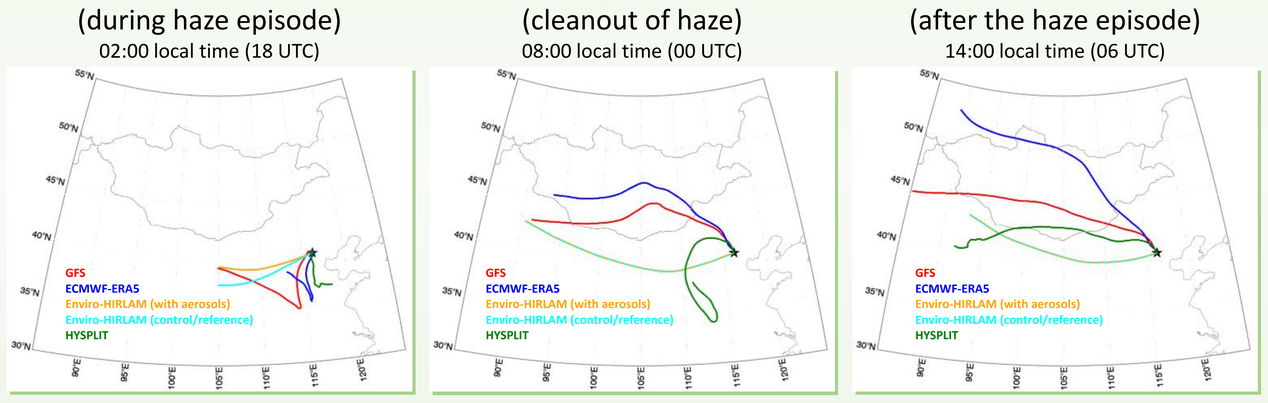

Figure 3: 96 hour back-trajectories arriving in Beijing on 15 November 2018. The trajectories were generated with FLEXPART using Enviro-HIRLAM (aerosol and reference runs) NWP input FLEXPART using GFS and ECMWF ERA5 input, and HYSPLIT.
Left: Before the cold front during low wind speeds and heavy aerosols. **Middle:** During the passage of the cold front. **Right:** After the cold front, when the aerosols are almost completely gone.

As expected, the Enviro-HIRLAM trajectory before the cold front which accounts for aerosol effects differed from the reference run, which is during the haze episode, when the aerosols were heaviest. During and after the cold front, there is very little distinction between Enviro-HIRLAM's aerosol and reference runs, and the plots appear on top of each other.

We also noticed that the different input NWP models resulted in different trajectories, and HYSPLIT also has different trajectories. Part of this difference may be that the different input models forecast the cold front passage at different times.

The **next steps** of this project will be to investigate how using different meteorological inputs (GFS, ECMWF, and Enviro-HIRLAM with and without aerosols effects enabled) and using different resolutions will affect results from SOSAA aerosol and chemistry runs during the pollution episode.

Code availability

Once ready, the modified FLEXPART code (based on FLEXPART v.10.4), which can use Enviro-HIRLAM in addition to the standard GFS and ECMWF NWP inputs, will be made available online (see QR above). For availability of Enviro-HIRLAM code, see Baklanov et al. (2017).

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