Enviro-HIRLAM Seamless Modelling: Research, Development, Application

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EGU-2023
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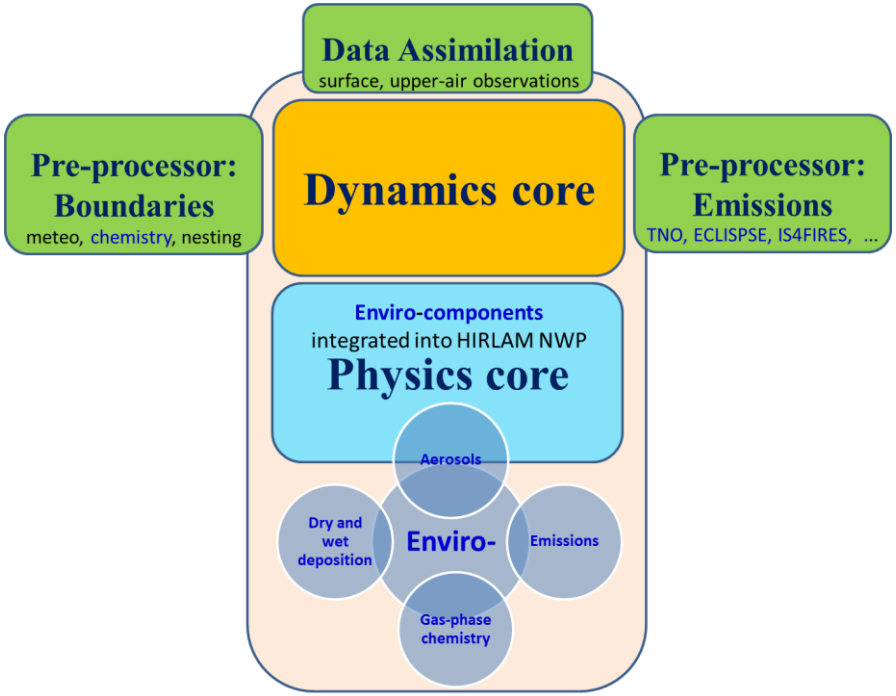
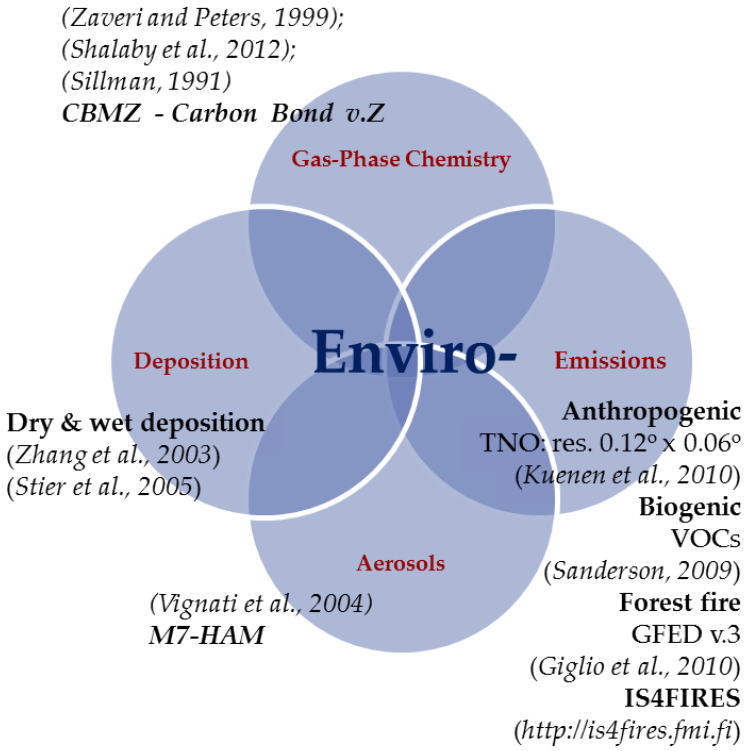
Enviro-HIRLAM (Environment – HIgh Resolution Limited Area Model)





- Seamless / online coupled integrated meteorology-chemistry-aerosols downscaling modelling system for predicting weather and atmospheric composition

(Baklanov et al., 2017; GMD) - last overview of the modelling system
Mahura et al. (2023+) – in preparation

Enviro-HIRLAM research and development team
contributions from many colleagues through collaboration Finland, Denmark, Russia, Ukraine, Kazakhstan, Baltic States, Spain, Turkey, etc.)

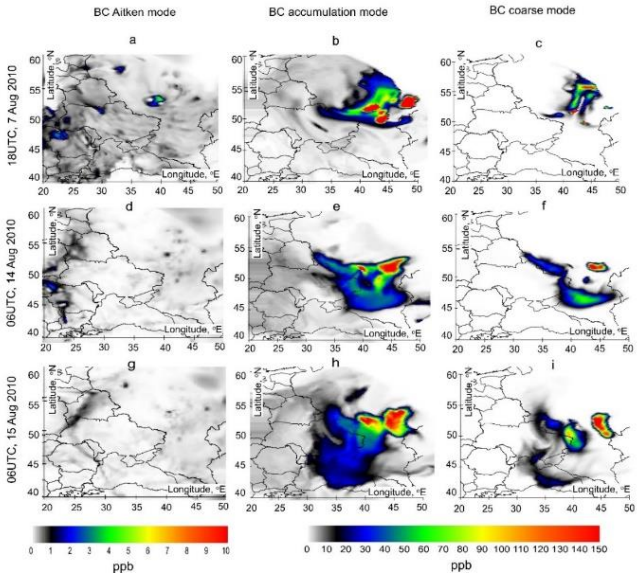
Research & Development through Collaboration with Partners

- **(2017-…) Enviro-HIRLAM on CSC –** "*Enviro-HIRLAM seamless modelling of meteorology-chemistry-aerosols interactions and feedbacks on multi-scales*"
  (linking to CSC's HPC projects using Enviro-HIRLAM model)

- **(2021-2023) Enviro-PEEX(Plus) on ECMWF (Plus)** - "*Research and development for integrated meteorology – atmospheric composition multi-scales and – processes modelling for the PEEX domain for weather, air quality and climate applications*" https://www.atm.helsinki.fi/peex/index.php/enviro-peex_plus
  (involving 15 Partners/ Organizations)

- **(2020-2022) PEEX-MP-Europa3** – "*PEEX Modelling Platform research and development through HPC-Europa3 Transnational Access Programme*"
  https://www.atm.helsinki.fi/peex/index.php/peex-mp-europa3
  (individual grants) **at CSC's HPCs, Finland**

Elevated Black Carbon Pollution over Ukraine Resulted from Forest Fires



Spatial distribution of the BC for the Aitken (a,d,g), accumulation (b,e,h) and coarse (c,f,i) modes in the days of air movement towards Ukraine with the highest BC content near the surface.

Savenets et al. 2022, ACP

Conclusions:

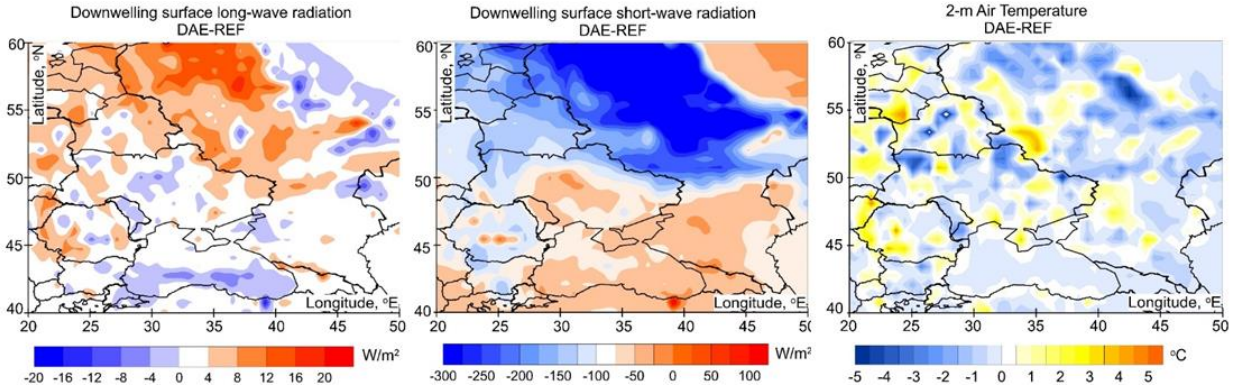
(*) BC emissions' influence from wildfires areas was identified: (i) up to 5 km height for the coarse and accumulation modes & (ii) at distances up to 2000 km.

(*) BC was mainly : (i) transported in the lowest 3 km layer & (ii) deposited at night- morning hours due to formation of strong surface temperature inversions.

(*) BC max increase in concentration: up to 73 % during wildfires vs. background.

(*) BC contribution in total aerosol mass: up to 20 % near the wildfires in the lowest 2 km layer.

(*) In areas with high BC content: (i) downwelling surface long-wave radiation increased up to 20 W m−2& (ii) 2 m air temperature increased by 1–4 ◦C during the midday hours.



Difference fields between the Enviro-HIRLAM DAE and REF model runs for downwelling surface long-wave, short-wave radiation and 2-m air temperature at 12UTC on 14th August 2010.

Integrated Modelling and Analysis of Influence of Land Cover Changes on Regional Weather Conditions/ Patterns

*with Larysa Pysarenko (**with UHMI, UA**)*

Aim: to investigate influence of land-cover changes (current vs. scenarios) and its consequences on meteorology for cases of extreme meteorological situations (heatwave, heavy rains and snowfall) & air quality/ atmospheric composition.

Pysarenko et al. (articles in preparation)

Methods:

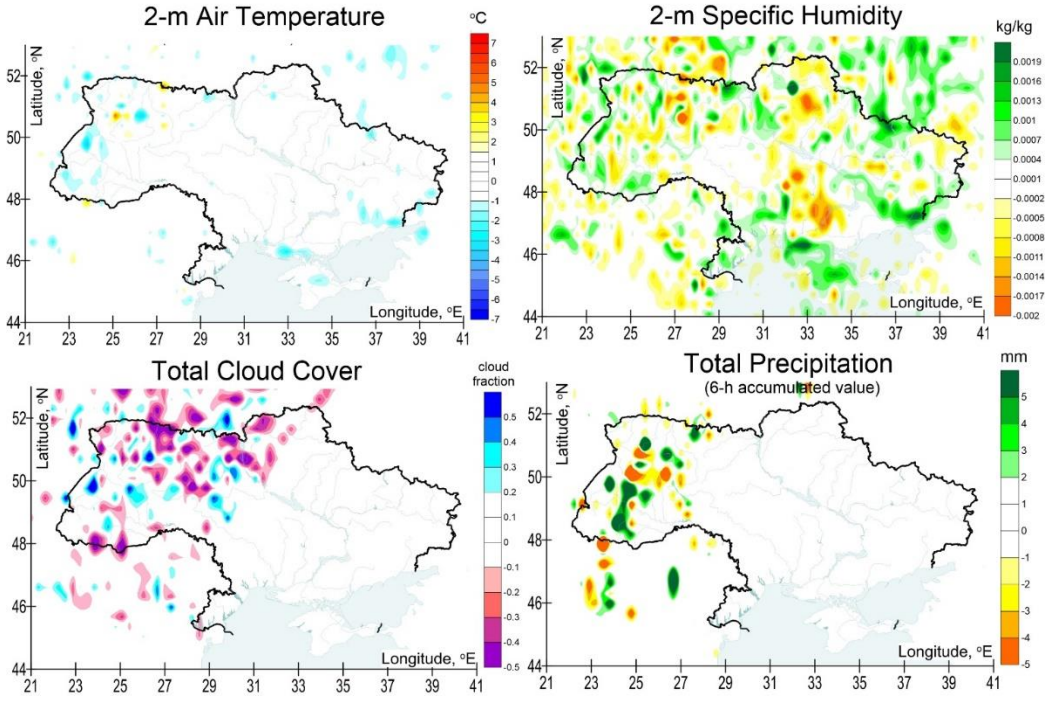
(1) **Seamless** multi-scale (15-5-2-1.5 km res.) Enviro-HIRLAM **modelling**; (2) **Study period**: Jul-Aug 2010; Mar-Apr 2013; (3) **Scenarios**: **deforestation** total (TOT_DEF) & half (HALF_DEF); **afforestation** total (TOT_AFF) & half (HALF_AFF); (4) **Model runs**: REF + DAE, IDAE, DAI+IDAE aerosol effects included.

Conclusions:

(*) **Land cover** changes significantly impact **regional weather** patterns through changes in radiation, moisture, temperature and wind regimes.

(*) **Land cover** changes can enhance the consequences of extreme meteorological conditions.

(*) **Outcomes** – showed **consequences of deforestation** and give solid ground for decision-makers in **planning adaptation** measures to **climate change** & developing possible **recommendations** for national **forestry** service.



Impact of total deforestation on selected meteorological parameters on 1 August 2010 (12UTC)
(for differences between runs: TOT_DEF – REF)

Integrated Modelling for Assessment of Potential Pollution Regional Atmospheric Transport as Result of Accidental Wildfires

*with Mykhailo Savenets (**with UHMI, UA**)*

Aim: to analyse regional influence of wildfires occurred in the Chernobyl exclusion zone & to identify affected territories in case of active wildfires near, within radioactive polluted hotspots, and in a close proximity to the nuclear power plant.

Savenets et al. (articles in preparation)

Methods:

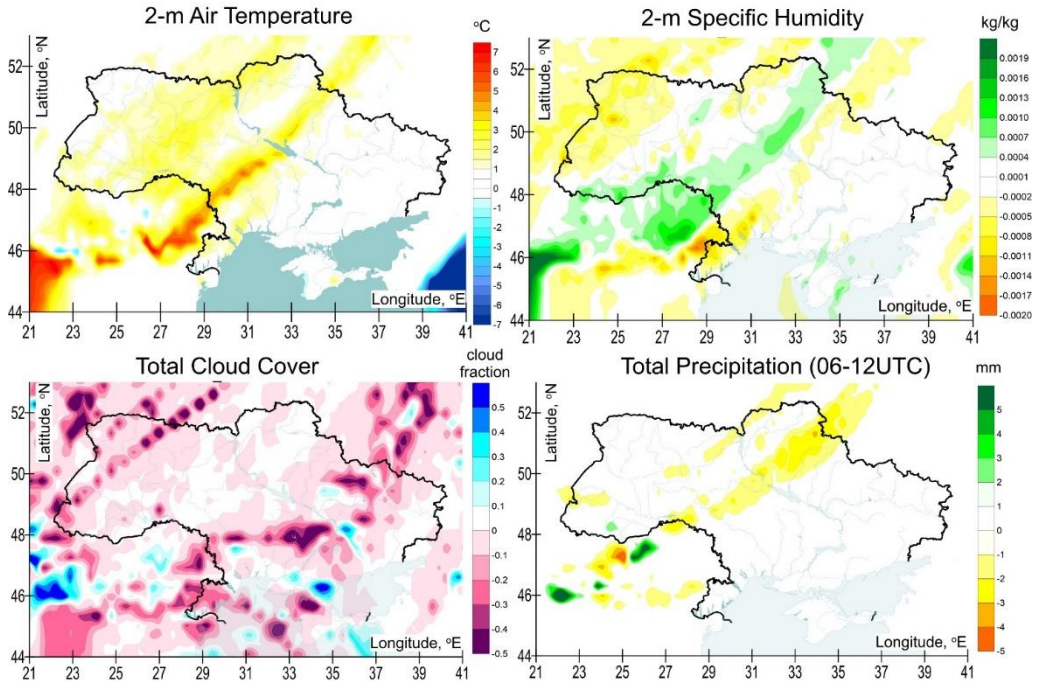
(1) **Seamless** multi-scale (15-5-2-1.5 km res.) Enviro-HIRLAM **modelling**; (2) **Study period**: 2-30 Apr 2020; (3) **Model runs**: REF + DAE, IDEA, DAI+IDAE aerosol effects included; (4) **Sensitivity tests**: time steps 300-240-180 sec (15 km), 150-120-90, 90-60-30 (2 & 1.5)

Conclusions:

(*) **Numerous feedbacks revealed** in the atmosphere enhanced by aerosol compounds (emitted from wildfires).

(*) **Aerosol effects** show spatial **non-homogeneity**, **dependence** on meteorological conditions, and **ratio** of species.

(*) **Outcomes** – crucial **for improving weather prediction** considering aerosols' influence & valuable **for impact assessment** on health and ecosystems in decision-making.



Difference between runs (DAE+IDAE – REF) selected meteorological parameters on 14 April 2020 (12UTC)

High-Resolution Integrated Urban Environmental Modeling

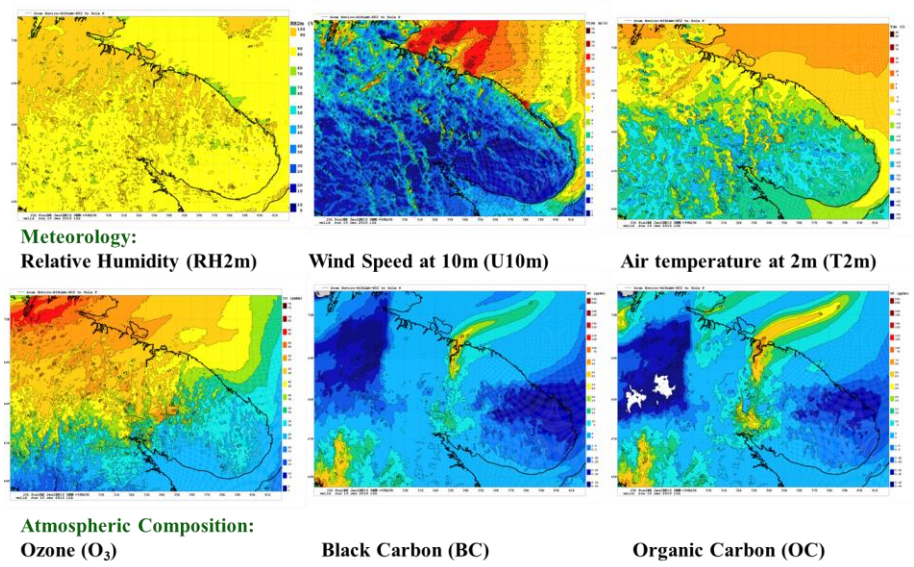
*with Igor Esau (**with UiT/ NERSC, NO**)*

Aim: to integrate turbulence–resolving urban large-eddy simulation, LES (meter-scale; PALM) and meteorological (km-scale; Enviro-HIRLAM) simulations into a seamless modeling chain & to study urban climate and air quality with high-resolution (from km to m) numerical modeling and urban observational data fusion.

Esau et al. (article in preparation)

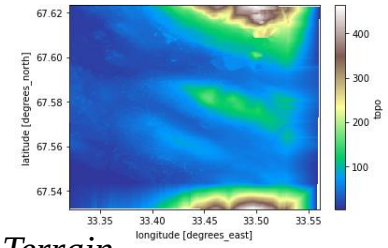
Methods:

(1) **Seamless** multi-scale (15-5-2 km res.) Enviro-HIRLAM **modelling**; (2) **Study period**: 1 Dec 2017 – 31 Jan 2018; (3) **Model runs**: REF + DAE, IDEA aerosol effects included; (4) **LES PALM modelling**: modelling for Apatity urban area.



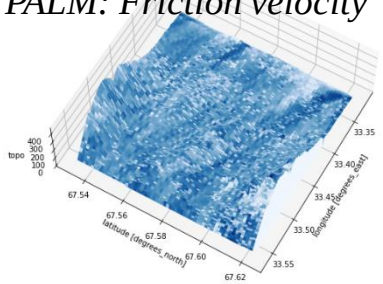
Enviro-HIRLAM: Downscaling (at 15, 5, 2 km resolutions)

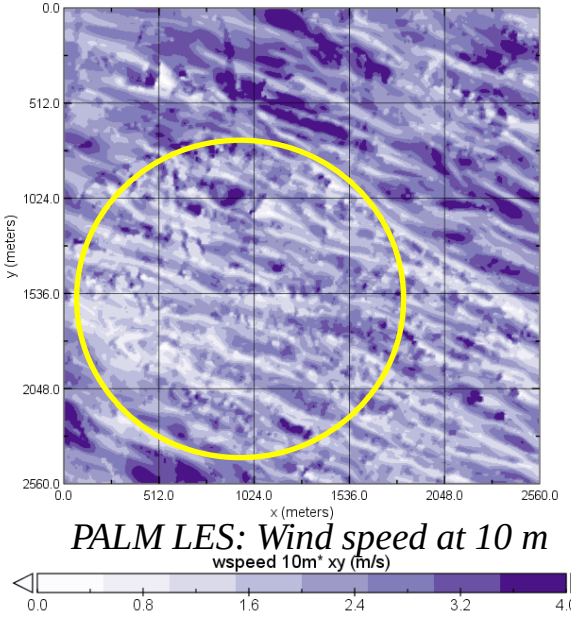
Work in Progress:



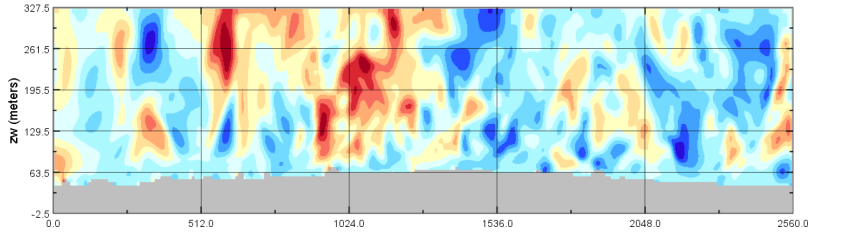
Terrain (over Apatity urban area)

PALM: Friction velocity





PALM LES: Wind speed at 10 m



PALM LES: Vertical wind velocity

Effects of Spring Air Pollution and Weather on Covid-19 Infection in Finland

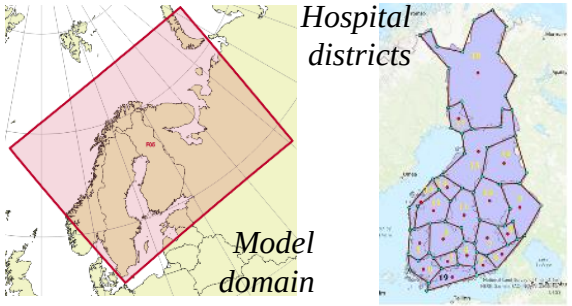
*with Behzad Heibati (**with UoOulu, FI**)*

Aim: to assess effects of meteorological (temperature, humidity and momentum regimes in the boundary layer) and air pollution (aerosol components) factors on covid19 cases in 20 hospital districts of Finland during spring 2020.

Heibati et al. (article in preparation)

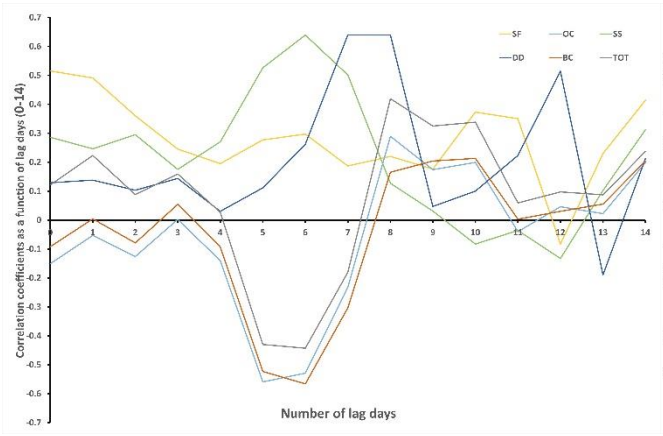
Methods:

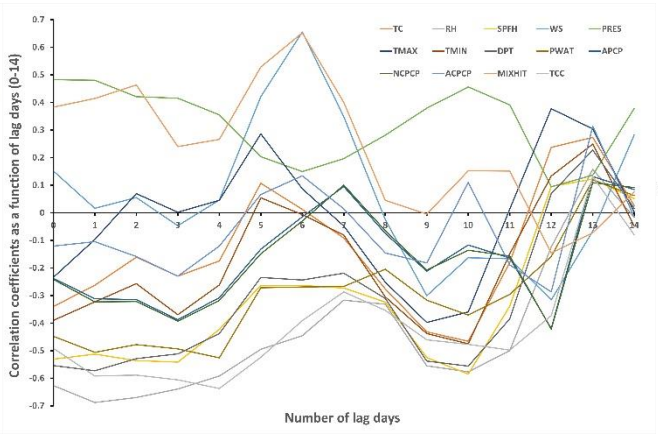
(1) **Seamless** subregional scale Enviro-HIRLAM **modelling**; (2) **Study period**: 1 March – 31 May 2020 with covid19 lockdowns; (3) **Model runs**: DAE+IDAE aerosol effects included; (4) **Covid19 data**: time-series of daily cases in 20 hospital districts of Finland in March-June 2020.

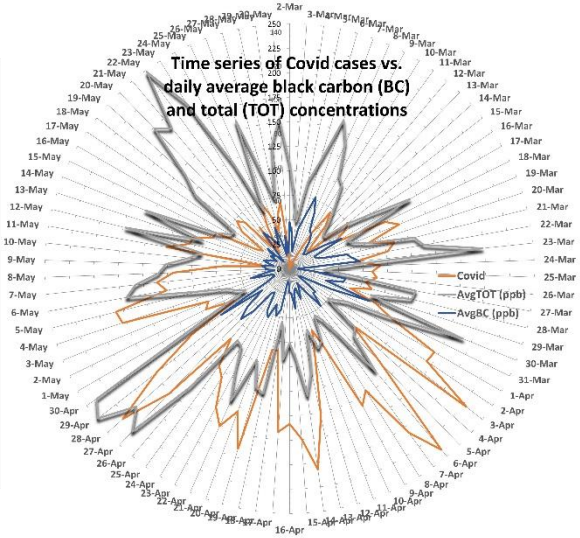


Work in Progress:

Example of correlation coefficients (for March 2020, with 0-14 lag days) for ***aerosol components*** *&* ***meteorological parameters*** *for the Helsinki Hospital District (Finland)*







Enviro-HIRLAM meteorology for FLEXPART atmospheric trajectory calculations

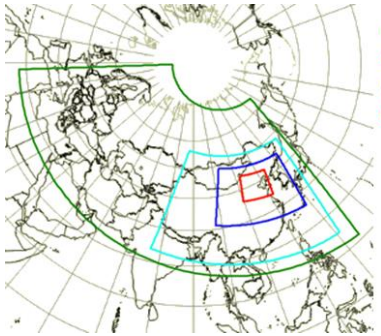
with Benjamin Foreback & Petri Clusius

Aim: to integrate (develop method) the Enviro-HIRLAM modelled meteorology as input for FLEXPART's calculations of trajectories and dispersion of particles & to evaluate impact of aerosol effects on meteorology and trajectories.

Foreback et al. (article in preparation)

Methods:

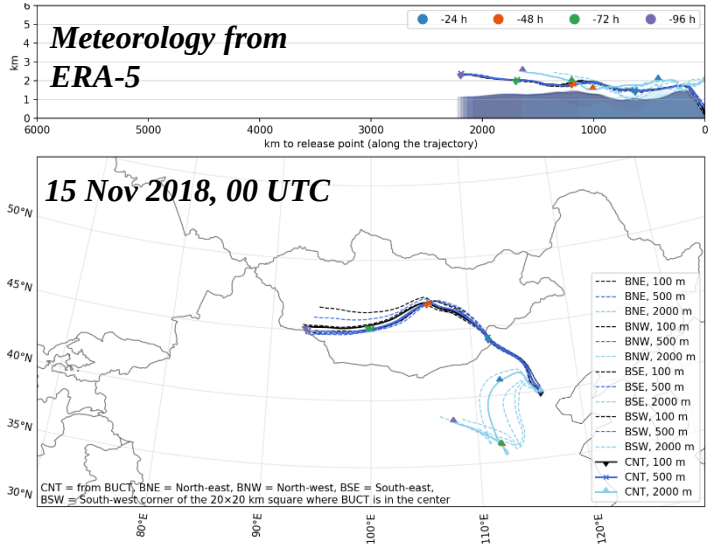
(1) **Seamless** downscaling (25-15-5-2+ km resol.) Enviro-HIRLAM **modelling**; (2) **Study period**: 1 Oct - 23 Nov 2018; (3) **Model runs**: REF, DAE, IDAE, DAE+IDAE aerosol effects included; (4) **FLEXPART**: atmospheric backward trajectory calculations for elevated pollution episode in Beijing, China.



Modeling domains

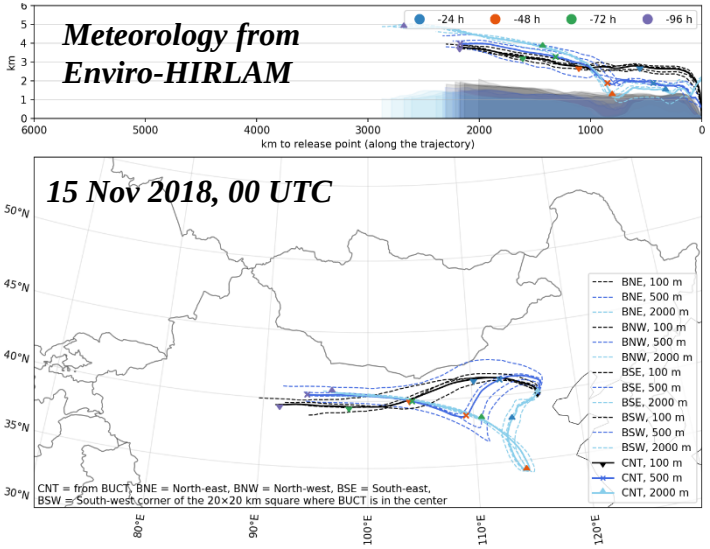
Work in Progress:

Atmospheric backward trajectories (96 hrs or 4 days) calculated by FLEX PART model



based on ERA-5 (0.25° resol.) and Enviro-HIRLAM (reference run at 0.25° resol.) meteorological input arriving at heights of 100, 500 and 2000 m at 5 locations (i.e., BUCT, Beijing & the corners of a 20×20 km box with BUCT in the centre).

Note, top panel shows altitude (ASL) and mean orography along the trajectories.



Enviro-HIRLAM in On-going Projects

H2020 CRiceS (coord. R. Makkonen & J. Thomas) - ***Climate relevant interactions and feedbacks: the key role of sea ice and snow in the polar and global climate system***

- To analyze effects of aerosols and their interactions with clouds & radiation; influence of sea ice and sea-spray aerosols on cloudiness and precipitation, sea ice and clouds albedo effects and feedbacks
- Downscaling modelling: regional - over the Artic domain, subregional - Nordic and Russian Arctic, and urban - Fennoscandia and Kola region with adjacent seas at urban scales
- Modelling results verification with Arctic datasets and up-scaling to EC-Earth climate scales

Horizon Europe FOCI (coord. T. Halenka & R. Sokhi) - ***Non-CO2 Forcers and their Climate, Weather, Air Quality and Health Impacts***

- Regional and urban multiscale climate impact: multi-scale modelling approach for Paris metropolitan area for episode in near and far future representative years to study the impact and co-benefits of future air quality and health at regional -urban scale.

H2020 RI-URBANS (coord. X. Querol & T. Petaja) - ***Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban and Industrial AreaS***

- Urban scale modelling of atmospheric composition and meteorology for the St.Petersburg metropolitan area with focus on elevated pollution episodes; study effects of aerosols on urban meteorology, pollution, health

https://www.helsinki.fi/en/inar-institute-for-atmospheric-and-earth-system-research

Thank you!

https://www.atm.helsinki.fi/peex

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- *Dr. Daniel Santos Munoz (UCM, Spain) - for providing and maintaining access to hirlam.org (Enviro-HIRLAM, HIRLAM, HARMONIE models repositories)*

- *Center for Science Computing (CSC, Finland) and ECMWF (UK, IT) - Computing Centers - technical staff for providing access, technical support and maintenance, computing and storage resources*