Seamless Modelling for Environmental Studies: Enviro-HIRLAM Recent Research and Development

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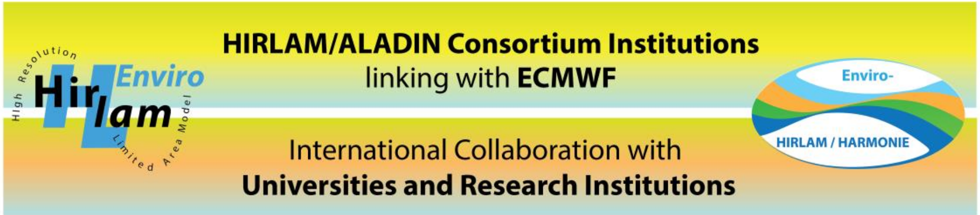
1 - UHEL – University of Helsinki, Finland
2 - UCPH – University of Copenhagen, Denmark
3 - WMO – World Meteorological Organization, Switzerland
4 - SPBU – St. Petersburg State University, Russia
5 - UHMI – Ukrainian Hydrometeorological Institute, Ukraine
6 - KSC – Kola Science Center, Russia
7 - RSHU – Russian State Hydrometeorological University, Russia

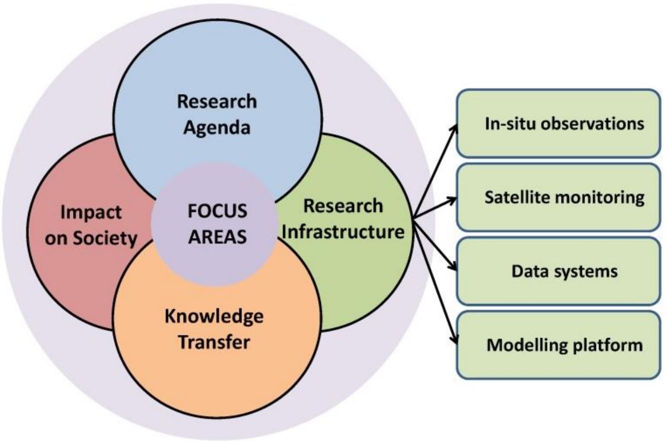
&

In linkage with multiple research projects and collaboration with many colleagues



Enviro-HIRLAM/ HARMONIE (EnviroHH)

(Collaboration, Research and Development, Science Education, Dissemination, New Products and Applications)

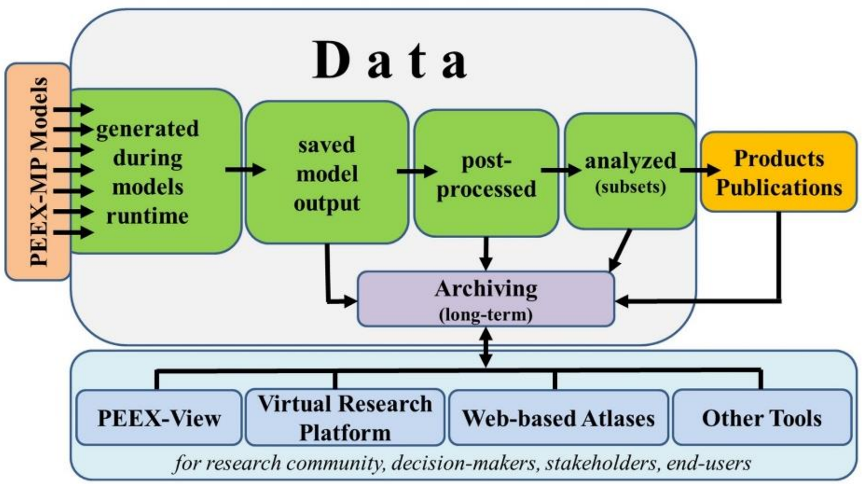


Enviro-HIRLAM linkage to the PEEX-Modelling Platform

PEEX-MP Models as Research Tools

https://www.atm.helsinki.fi/peex/index.php/infra

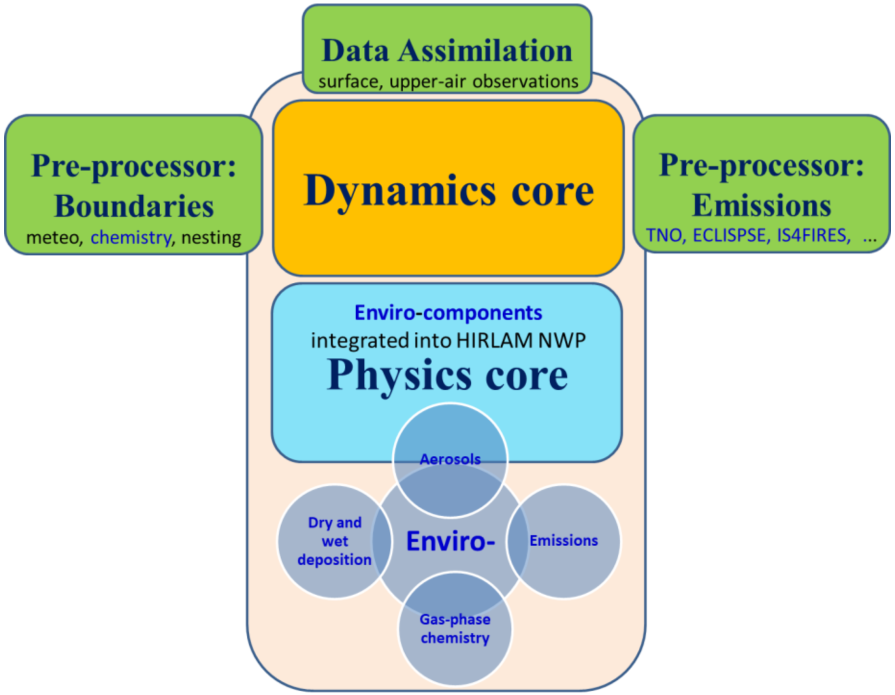
- **PEEX-Modelling-Platform (PEEX-MP) Overview with Modelling Tools & Demonstration**

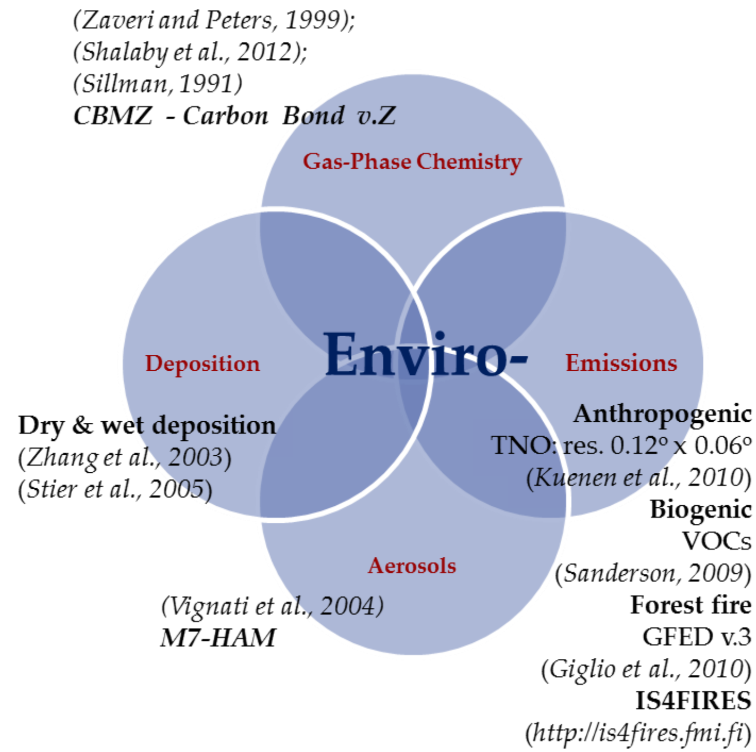


PEEX Modelling Platform for Seamless Environmental Prediction
Mahura et al. (60 co-authors)
MS in revision for ACPD (PEEX Vol-II), 2021+

ATMOSPHERE	HYDROSPHERE	PEDOSPHERE	BIOSPHERE		PHYSICAL	CHEMICAL	BIOLOGICAL	PEEX-MP Models
XXX					XXX	XXX		HadGEM2-ES
XXX	XXX	XXX			XXX	XXX		Enviro-HIRLAM
XXX	XXX		XXX		XXX	XXX	XXX	SILAM
XXX	XXX				XXX	XXX		FLEXPART
XXX					XXX	XXX		DERMA
XXX	XXX		XXX		XXX	XXX	XXX	SOSAA
	XXX				XXX			HYCOM-CICE
XXX			XXX		XXX	XXX	XXX	CH4MOD
	XXX				XXX			SWAN
XXX			XXX		XXX	XXX	XXX	Argo-C
XXX	XXX				XXX			GLOBO/BOLAM/MOLOCH
XXX		XXX	XXX		XXX		XXX	AVIM2
XXX	XXX	XXX	XXX		XXX	XXX	XXX	EC-Earth
XXX					XXX	XXX		UCLALES-SALSA
XXX					XXX	XXX		CTDAS
XXX			XXX		XXX	XXX	XXX	SIM-BIM
XXX					XXX	XXX		TOMCAT-GLOMAP
XXX					XXX	XXX		CAM-Chem
XXX	XXX				XXX	XXX		MPI-ESM
XXX	XXX	XXX	XXX		XXX	XXX	XXX	CESM
XXX	XXX				XXX			PALM
XXX					XXX			LESNIC
XXX			XXX		XXX	XXX	XXX	EmpBVOC
	XXX				XXX			HBM
XXX					XXX	XXX		WRF-Chem
XXX					XXX	XXX		DNDC-HONO
XXX					XXX	XXX		GEOS-Chem
XXX	XXX	XXX	XXX		XXX	XXX	XXX	CNMM-DNDC
XXX	XXX		XXX		XXX			SUEWS
XXX					XXX	XXX		ATMES
XXX					XXX			MMAD&IT
XXX					XXX	XXX		IMDAF
XXX					XXX	XXX		EurCTM

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





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

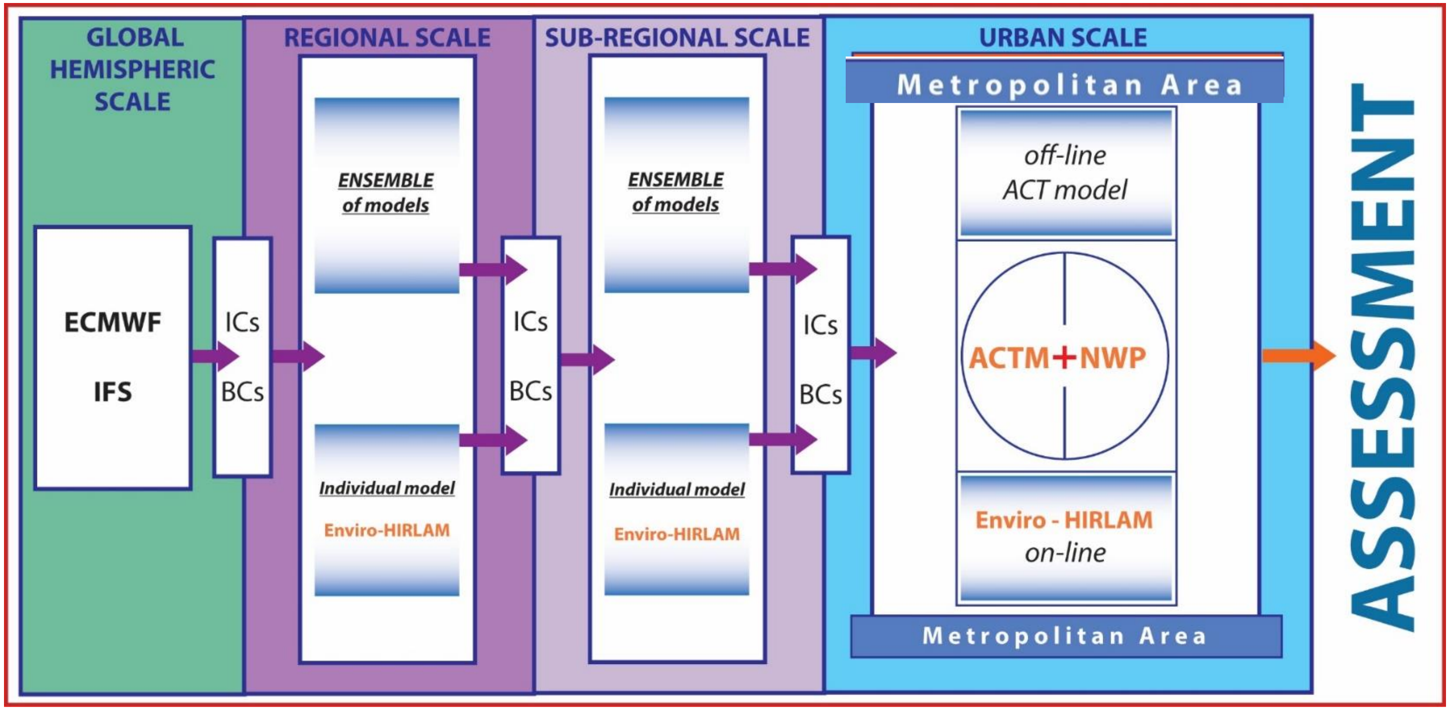
(Baklanov et al., 2017; GMD) - last overview of the modelling system
Mahura et al. (2022+) – in preparation

Enviro-HIRLAM research and development team

Baklanov et al., 2002-…; Mahura et al., 2004-…; Nuterman et al., 2007-…; Nerobelov et al., 2016-…

& many other colleagues contribution through collaboration (Denmark, Russia, Ukraine, Kazakhstan, Baltic States, Spain, Turkey, etc.)

Enviro-HIRLAM Downscaling for Regional-Subregional-Urban/City/Local scales

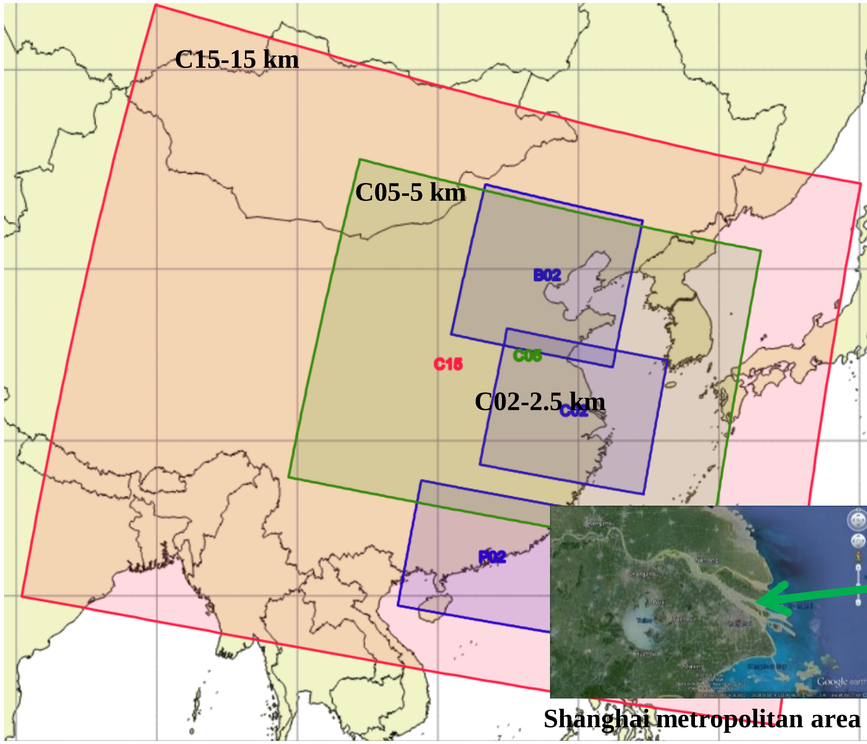


…- 2017 – 2018 – 2019 – 2020 – 2021 -…

DMI, DK: *CRAY-XT5 (hirdev) -> CRAY-XC30/XC40 (hirdev/disperse)*
ECMWF, UK/INT*: CRAY-XC30/40 -> (ecgate + cca)*
UHEL, FI: *CRAY-XC30/40 (taito/sisu) -> Atos BullSequana X400/XH2000 (puhti/mahti)*

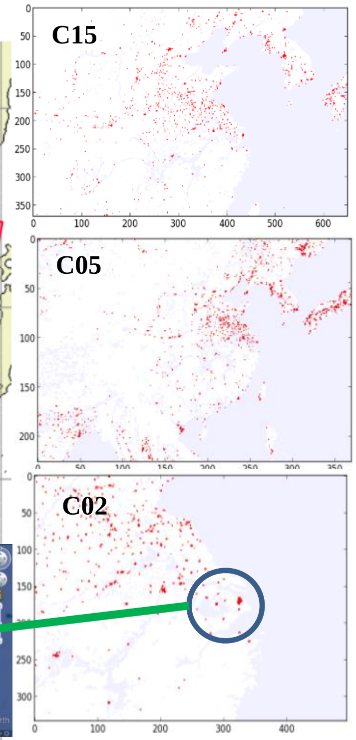
EU MarcoPolo/ Operational

Enviro-HIRLAM model downscaling domains (15 – 5 – 2.5 km resolutions)



Shanghai metropolitan area (MA)

Urban areas in domains



CPU time spent for 1 run:

C15: 1h2min
C05: 3h3min
C02: 3h6min

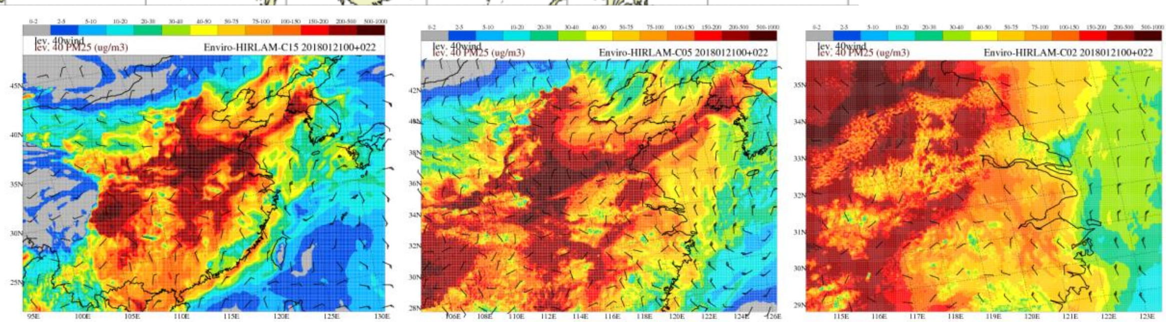
Surface level disc use for 1 run:

C15: 533M
C05: 1,5G
C02: 947M

Model level disc use for 1 run:

C15: 12G
C05: 33G
C02: 23G

The Silk Road agenda of the Pan-Eurasian Experiment (PEEX) Program
by Lappalainen, Kulmala, Kujansuu, Petäjä, Mahura, de Leeuw, Zilitinkevich, Juustila, Kerminen, Bornstein, Zhang, Yong, Yubao, Dong, Jie, Guo
MS: BED (2018)



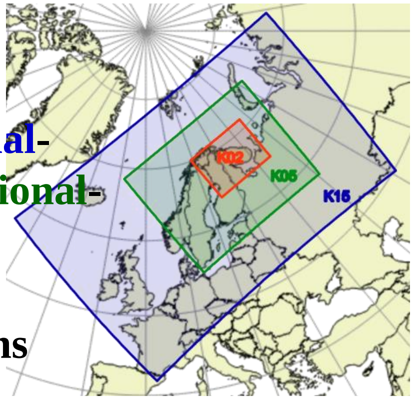
Enviro-HILRAM operational PM2.5 concentration forecasts for China in a downscaling chain (left-right: regional, sub-regional, urban - Shanghai metropolitan area) for 21 Jan 2018, 22 UTC
http://www.marcopolo-panda.eu/products/regional-air-quality-forecasts/enviro-hirlam

Nordic TRAKT

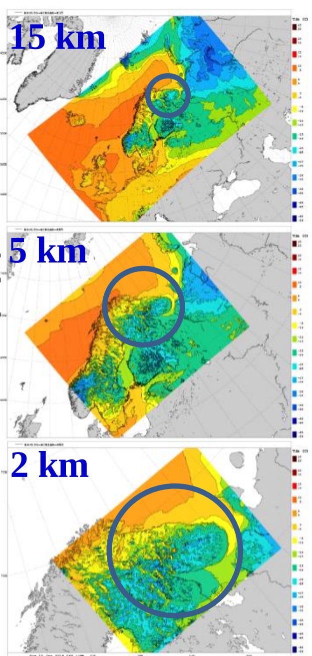
TRAnsferable Knowledge & Technologies for high-resolution environmental impact assessment & management (https://www.atm.helsinki.fi/peex/index.php/trakt-2018)

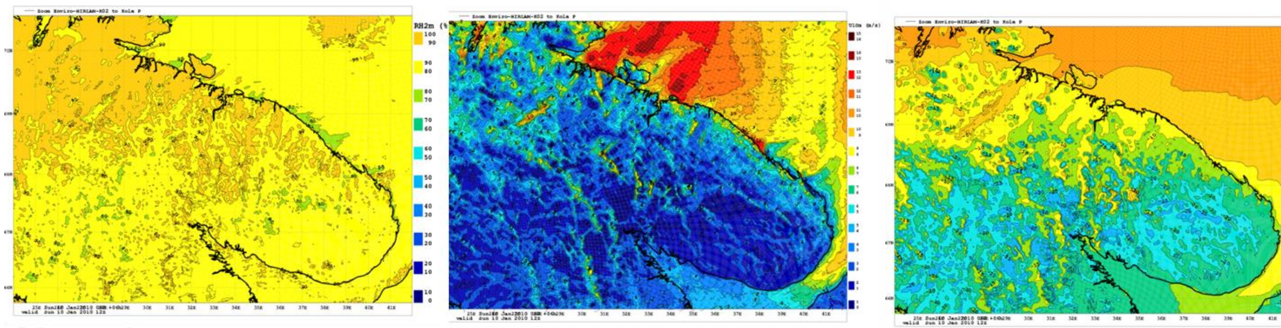
High resolution modelling (at 2 km) for meteorology and atmospheric composition

Regional-subregional-urban scale domains



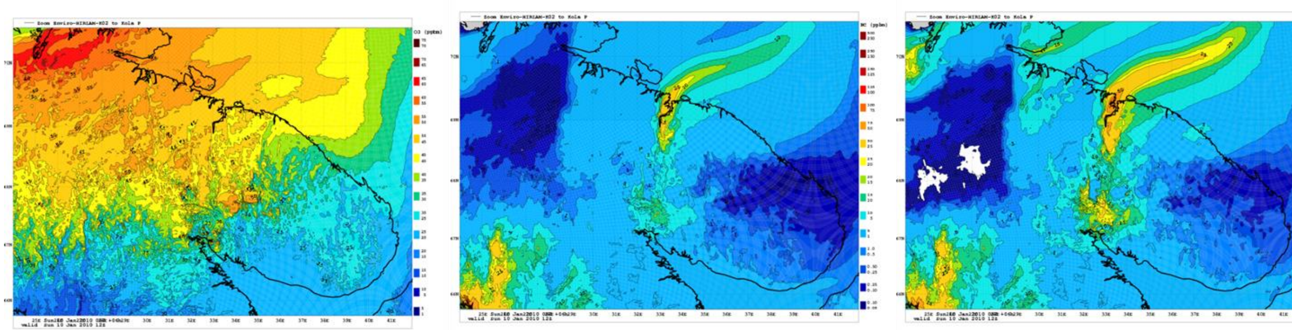
Seamless / online integrated meteorology-chemistry-aerosols modelling at multi-scales





Meteorology:

Relative Humidity (RH2m) | **Wind Speed at 10m (U10m)** | **Air temperature at 2m (T2m)**



Atmospheric Composition:

Ozone (O_3) | **Black Carbon (BC)** | **Organic Carbon (OC)**

Enhanced integrated approach to knowledgeable high-resolution environmental quality assessment

by Esau, Bobylev, Donchenko, Gnatiuk, Lappalainen, Konstantinov, Kulmala, Mahura, Makkonen, Manvelovac, Miles, Petäjä, Poutanen, Fedorov, Varentsov, Wolf, Zilitinkevich, Baklanovh

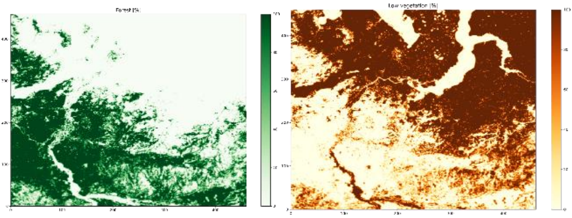
MS: ENVSCI 2877 (2021)

Numerical experiments on sensitivity of local meteorology vs. land-cover changes in Arctic

To study atmosphere-land-sea surfaces interactions, and in particular, heat-moisture exchange/ regime between these surfaces and for better understanding and forecasting of local meteorology in the *Arctic* ***(AoF ClimEco project)***

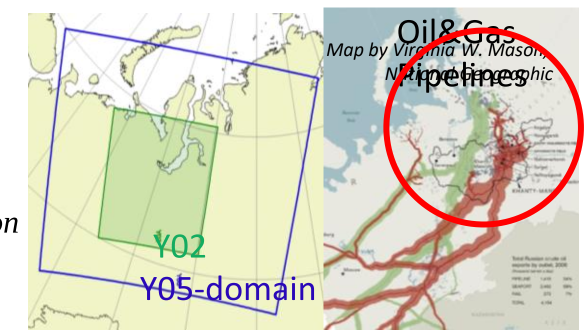
Mahura, Nuterman, Baklanov, Zilitinkevich, Kulmala

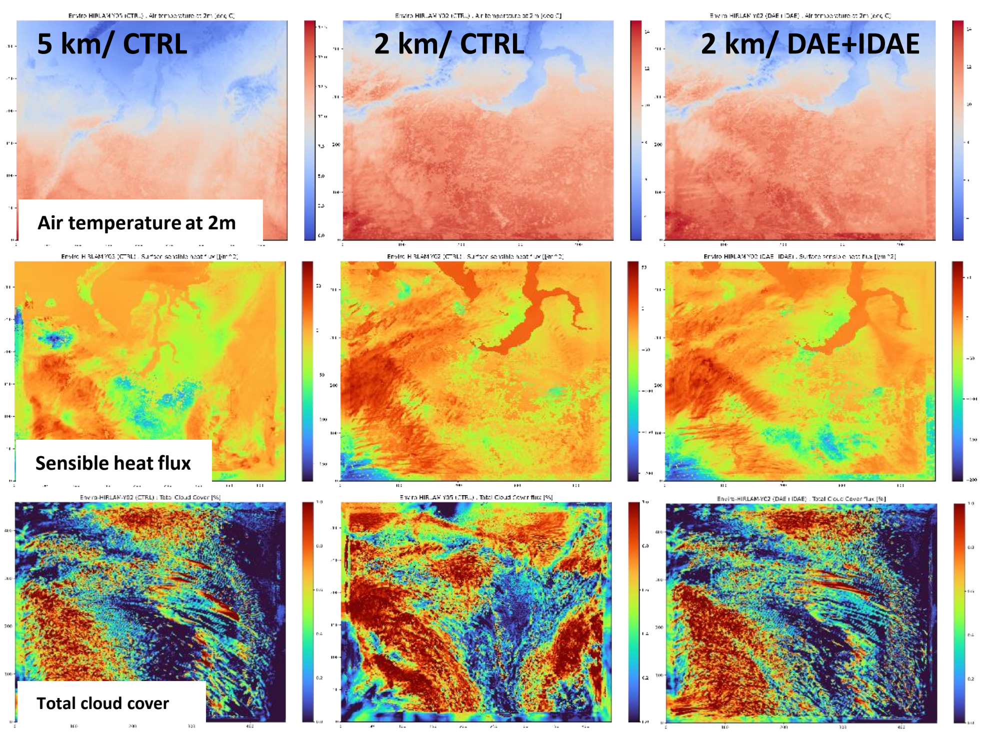
MS: in preparation for ACPD, 2021+

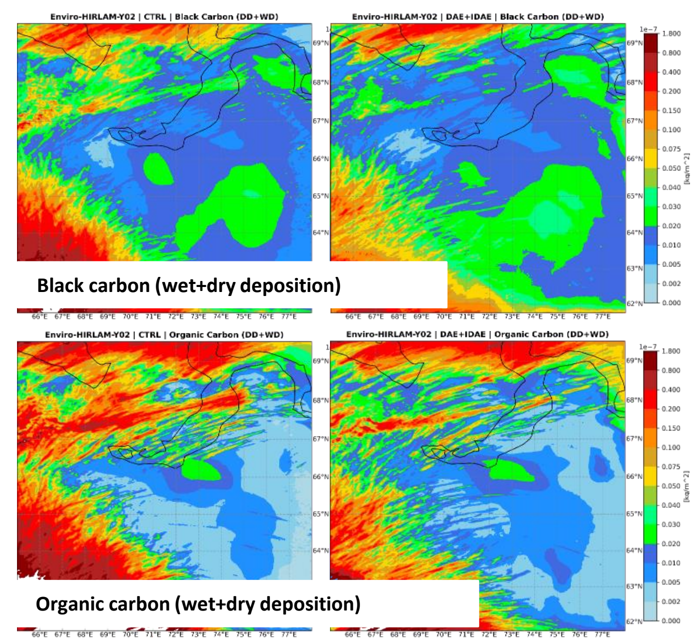


Forest **Low Vegetation**

Focus on Jul & Jan 2019 | ICs/BCs ERA-5 meteo & CAMS gases+aerosols, DA obs, SST | Emis.Inv – biogenic, anthropogenic | Runs - Reference/CTRL Direct/ DAE+Indirect/IDAE Aerosols Effects | Donwscaling 5km -> 2 km horiz.resol | Land cover changes – areas of pipelines & burned low vegetation

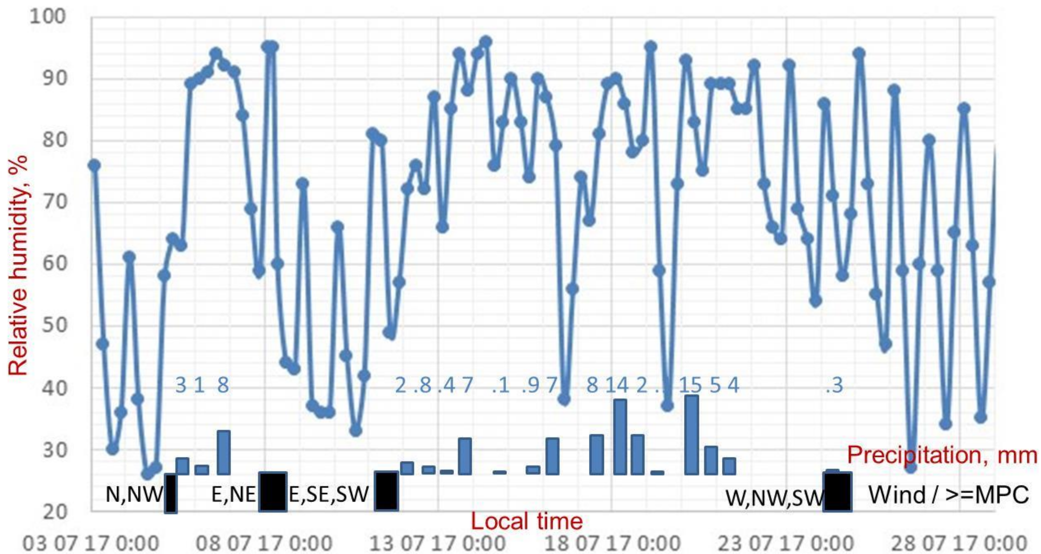


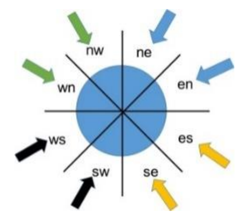


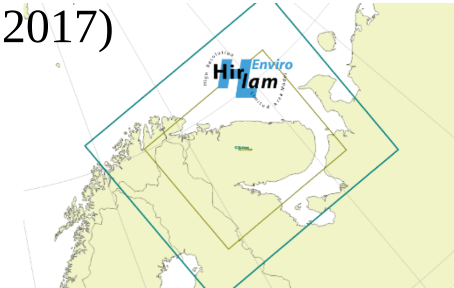


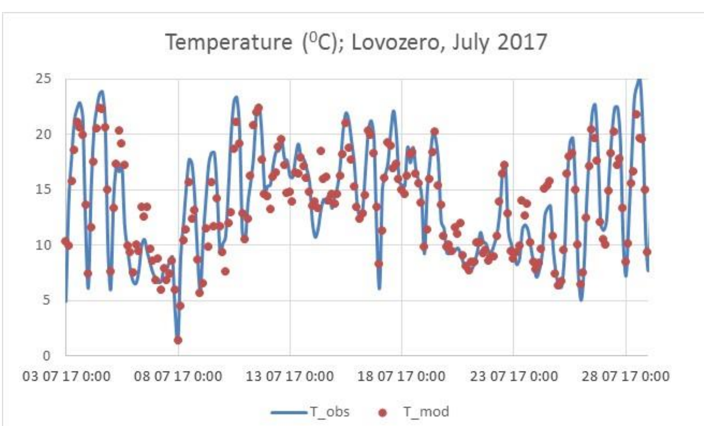
“Artificial Dust” Pollution

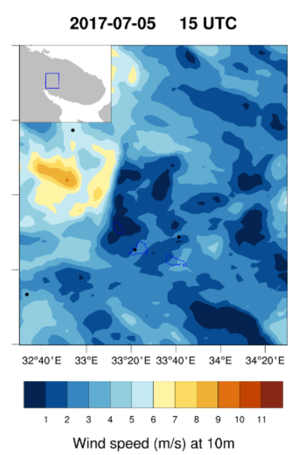
Focus on elevated dust pollution episodes (5, 7, 8, 11, 24 and 31 July 2017)

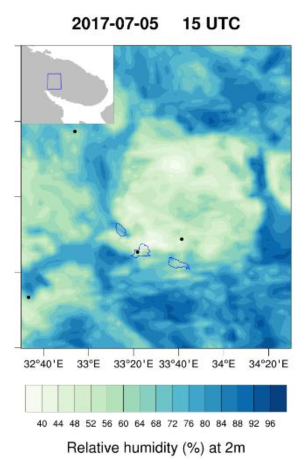


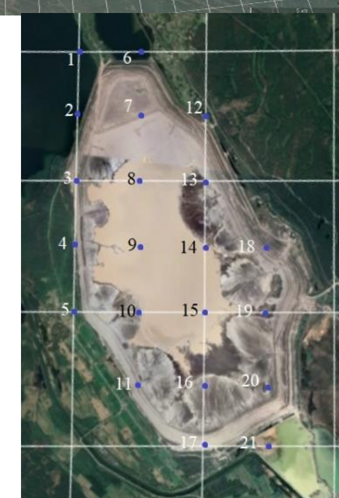












PEEX-MP Research & Development through HPC-Europa3

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

With Larysa Pysarenko,
Ukrainian Hydrometeorological Institute, Kyiv, Ukraine
(*) started in Dec 2020 /remote access to CSC HPC Puhti

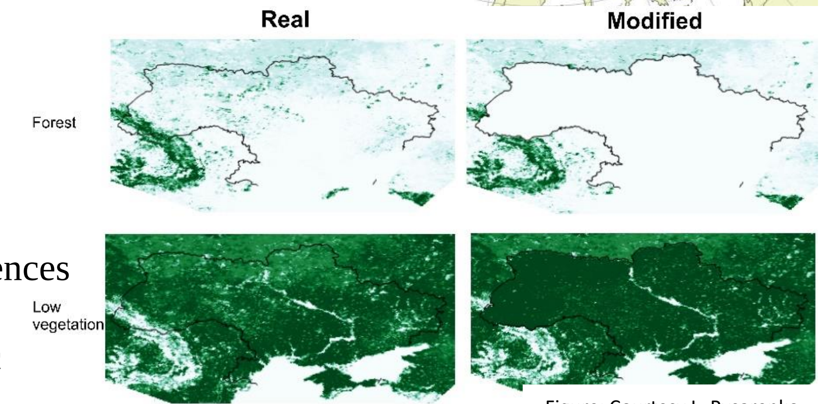


Figure: Courtesy L. Pysarenko

The study aims to investigate influence of land cover changes (current vs. scenarios, including hypothetical ones) and its consequences on meteorology for cases of extreme (with heatwave, heavy rains and snowfall) meteorological situations and air quality/ atmospheric composition. The main focus is analysis of regional scale weather, + influence on metropolitan areas.

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

With Mykhailo Savenets,
Ukrainian Hydrometeorological Institute, Kyiv, Ukraine
(*) started in Aug 2021 /remote access to CSC HPC Puhti

The study aims to analyze the regional influence of wildfire emissions occurred in the exclusion zone (abandon area) of the Chernobyl nuclear power plant (Ukraine) and to identify the affected territories in case of active fires near and within radioactive polluted spots and in a close proximity to the plant.

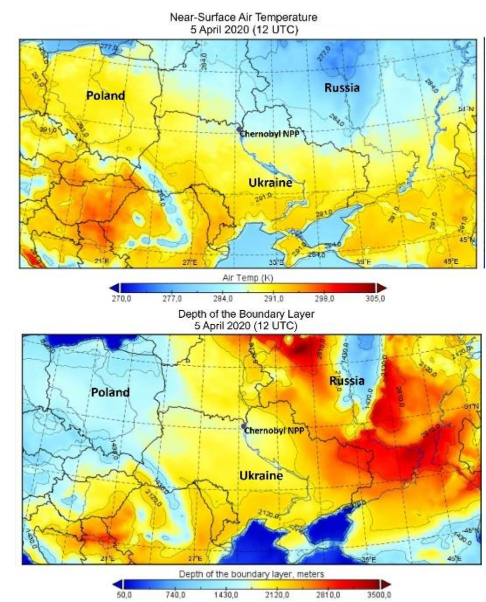


Figure: Courtesy M. Savenets

Enviro-HIRLAM – Science Education Component

short-term visits of young researchers, organization and carrying out research training weeks/ schools

The latest face-to-face trainings took place in Apr and Jun 2019 (Helsinki and Tyumen), and online in Nov-Dec 2021 (https://megapolis2021.ru)

- **Group Work on Small-Scale Research Projects (SSRP) with Enviro-HIRLAM**

Concluding Remarks

- **Enviro-HIRLAM model is seamless/ online integrated multi-scales and –processes modelling system capable to simulate simultaneously meteorology – atmospheric composition modelling on regional- subregional- urban scales**

- **Enviro-HIRLAM model research and development was demonstrated on several examples**

- **Enviro-HIRLAM science education component is realized as short/long-term visits/ research training weeks/ young scientist schools with group work on small-scale research projects**

ACKNOWLEDGEMENTS

- *Dr. Juha Lentho (UHEL- INAR & Center for Science Computing, CSC, Finland) – for CSC's HPC's hints and advises*

- *Dr. Carsten Maass (ECMWF, UK) - for providing support to ECMWF HPCs computing and storage resources, datasets and their usage*

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

- *Members of the current Enviro-PEEX(Plus) project team for active involvement into the PEEX-Modelling-Platform modelling activities and tasks (https://www.atm.helsinki.fi/peex/index.php/enviro-peex_plus)*

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

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

Thank you! Спасибо!

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

Research & Development through Collaboration with Partners

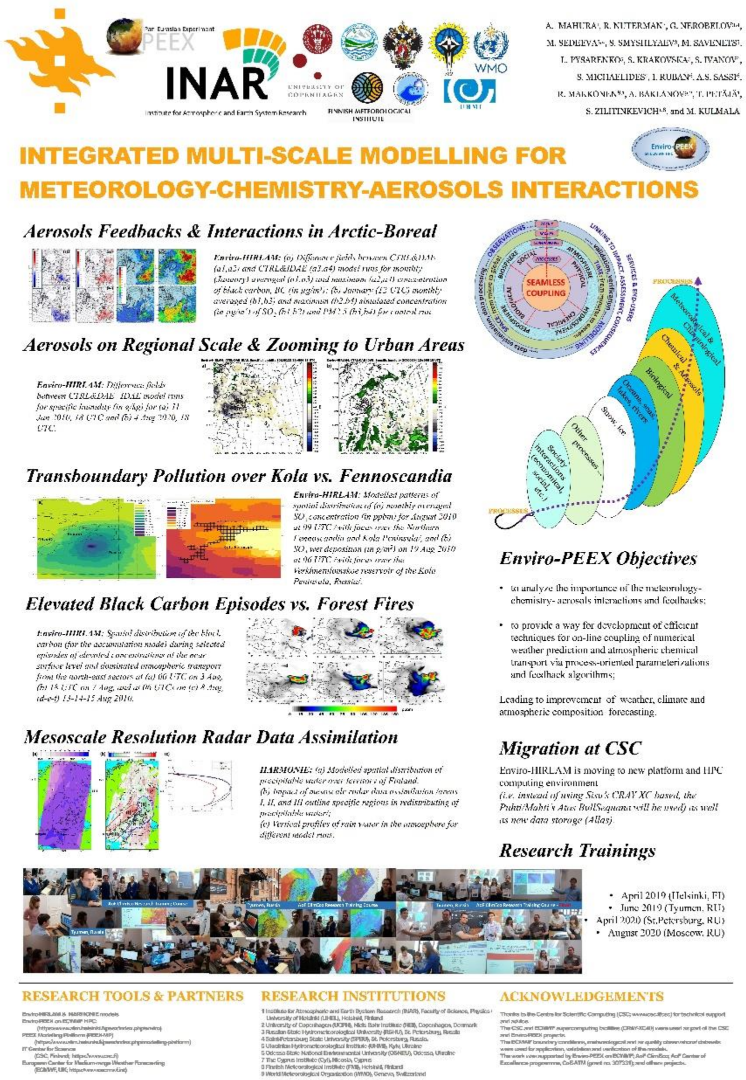
- **(2017-…) Enviro-HIRLAM on CSC –** "*Enviro-HIRLAM seamless modelling of meteorology-chemistry-aerosols interactions and feedbacks on multi-scales*"

- **(2018-2020) Enviro-PEEX on ECMWF** - "*PEEX-MP research and development for online coupled integrated meteorology-chemistry-aerosols feedbacks & interactions in weather, climate & atmospheric composition multi-scale modelling*" https://www.atm.helsinki.fi/peex/index.php/enviro-peex-2018-2020

- **(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

- **(2020-2022) PEEX-MP-Europa3** – "*PEEX Modelling Platform research and development through HPC-Europa3 Transnational Access Programme*" (individual grants)
  https://www.atm.helsinki.fi/peex/index.php/peex-mp-europa3
  - ✓ Project: *High-Resolution Integrated Urban Environmental Modeling*
  - ✓ Project: *Online Integrated Atmospheric Modelling: the Python Way*
  - ✓ Project: *Integrated Modelling for Assessment of Potential Pollution Regional Atmospheric Transport as Result of Accidental Wildfires*
  - ✓ Project: *Integrated Modelling and Analysis of Influence of Land Cover Changes on Regional Weather Conditions/ Patterns*

Collaboration with PEEX Partners



"PEEX-MP research and development for online coupled integrated meteorology-chemistry-aerosols feedbacks & interactions in weather, climate & atmospheric composition multi-scale modelling"

(2018-2020)

Online integrated modeling on regional scale in North-West Russia: Evaluation of aerosols influence on meteorological parameters.
by Nerobelov, Sedeeva, Mahura, Nuterman, Mostamandi, Smyshlyaev
MS: GES, 11(2), 2018

Estimation of elevated black carbon episodes over Ukraine using Enviro-HIRLAM
by Savenets, Pysarenko, Krakovska, Mahura, Petaja
MS: finalization for ACP (2021+)

Enviro-HIRLAM modeling and GIS evaluation of pollution in Northern Fennoscandia and North-West Russia
by Sedeeva, Mahura, Nuterman, Smyshlyaev, Petaja, Zilitinkevich, Kulmala
MS: in preparation (2021+)

Mesoscale resolution radar data assimilation experiments with the HARMONIE model
by Ivanov et al.
MS: RSJ, 10(9), 2018

Generated by Enviro-HIRLAM model output can be used for various assessment studies