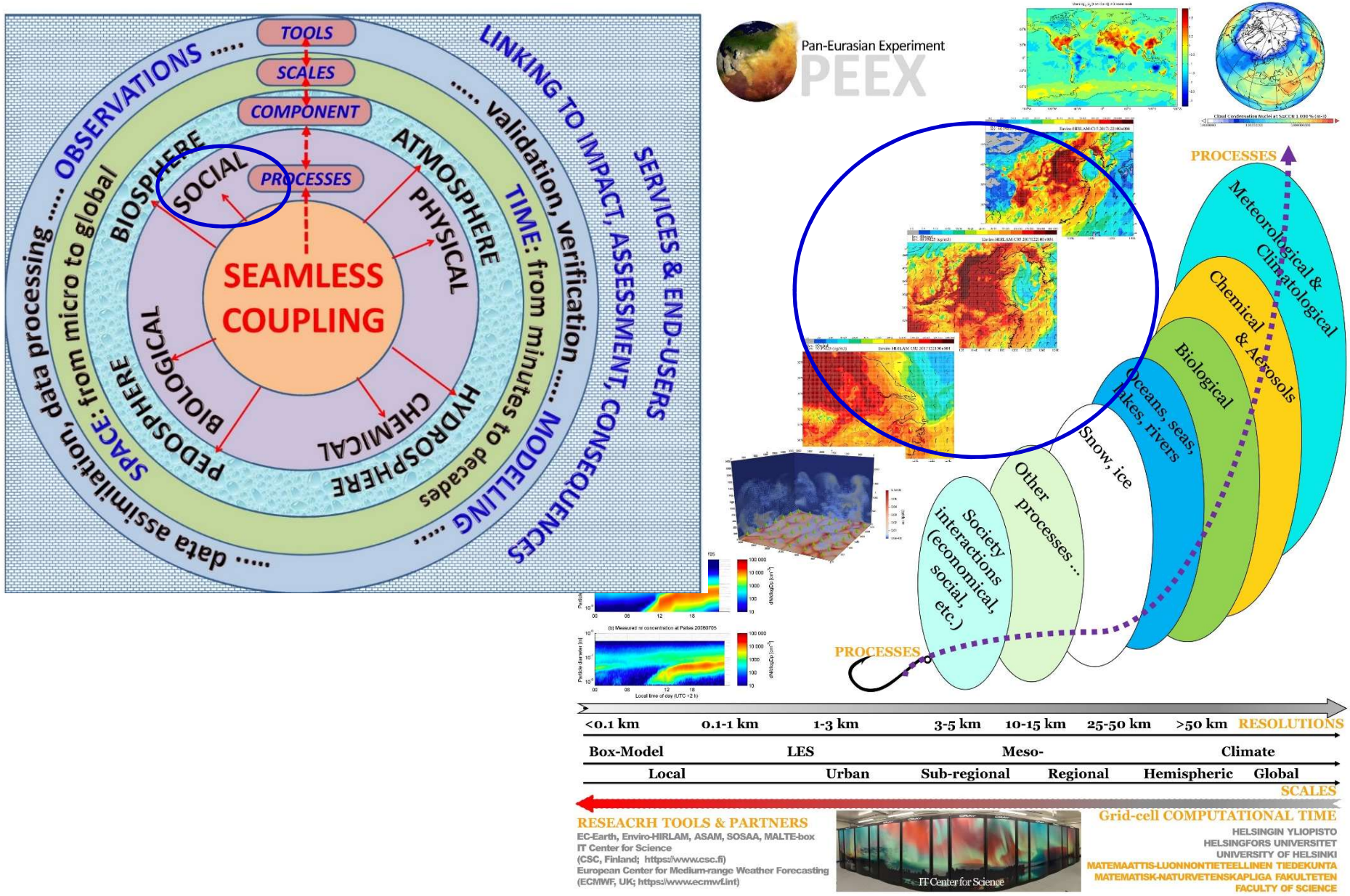
Regional-urban scales modelling - meteorology & atmospheric composition - in support socio-economical studies (SES)

by Alexander Mahura
& Enviro-HIRLAM developers & et al.

Institute for Atmospheric and Earth System Research (INAR) / Physics
Faculty of Science, University of Helsinki (UHEL), Finland
&
In linkage with various research projects and collaboration with many colleagues

Virtual-meeting/ workshop & discussions
"Holistic multi- and interdisciplinary approach in supporting the Arctic sustainable development"
19 February 2021

Multi-Scale & -Processes Modelling at INAR

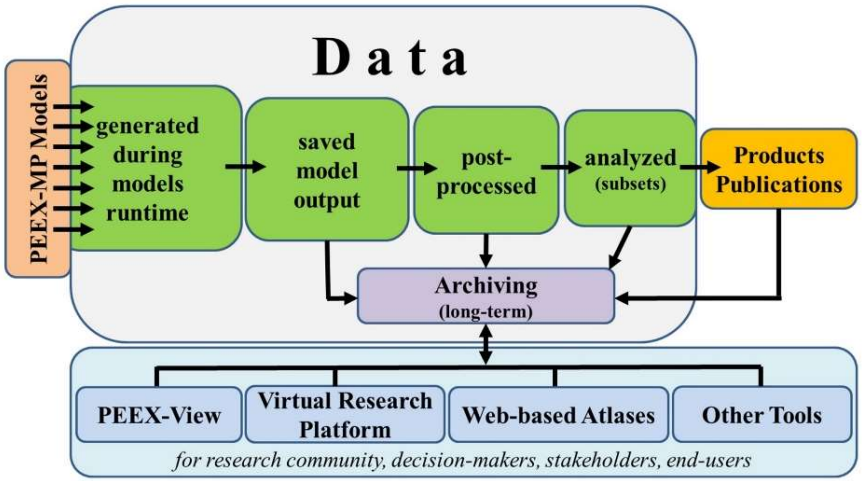


From the poster at the INAR kick-off-meeting (Helsinki, Finland), Jan 2018

PEEX-MP Models as Research Tools

https://www.atm.helsinki.fi/peex/index.php/modelling-platform

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



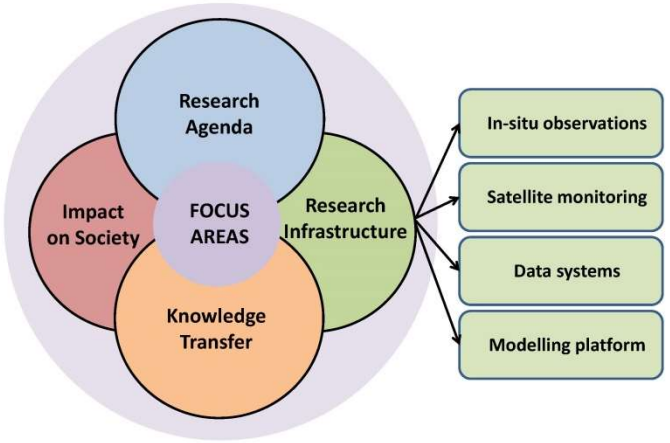
ATMOSPHERE	HYDROSPHERE	PEDOSPHERE	BIOSPHERE	PHYSICAL	CHEMICAL	BIOLOGICAL	PEEX-MP Models
XXX				XXX	XXX		HadGEM2-ES
XXX	XXX	XXX		XXX	XXX		Enviro-HIRLAM
XXX	XXX		XXX	XXX	XXX	XXX	SILAM
XXX	XXX			XXX	XXX		FLEXPART
XXX				XXX	XXX		DERMA
XXX	XXX		XXX	XXX	XXX	XXX	SOSAA
	XXX			XXX			HYCOM-CICE
XXX			XXX	XXX	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

INAR

Enviro-HIRLAM/ HARMONIE (EnviroHH)

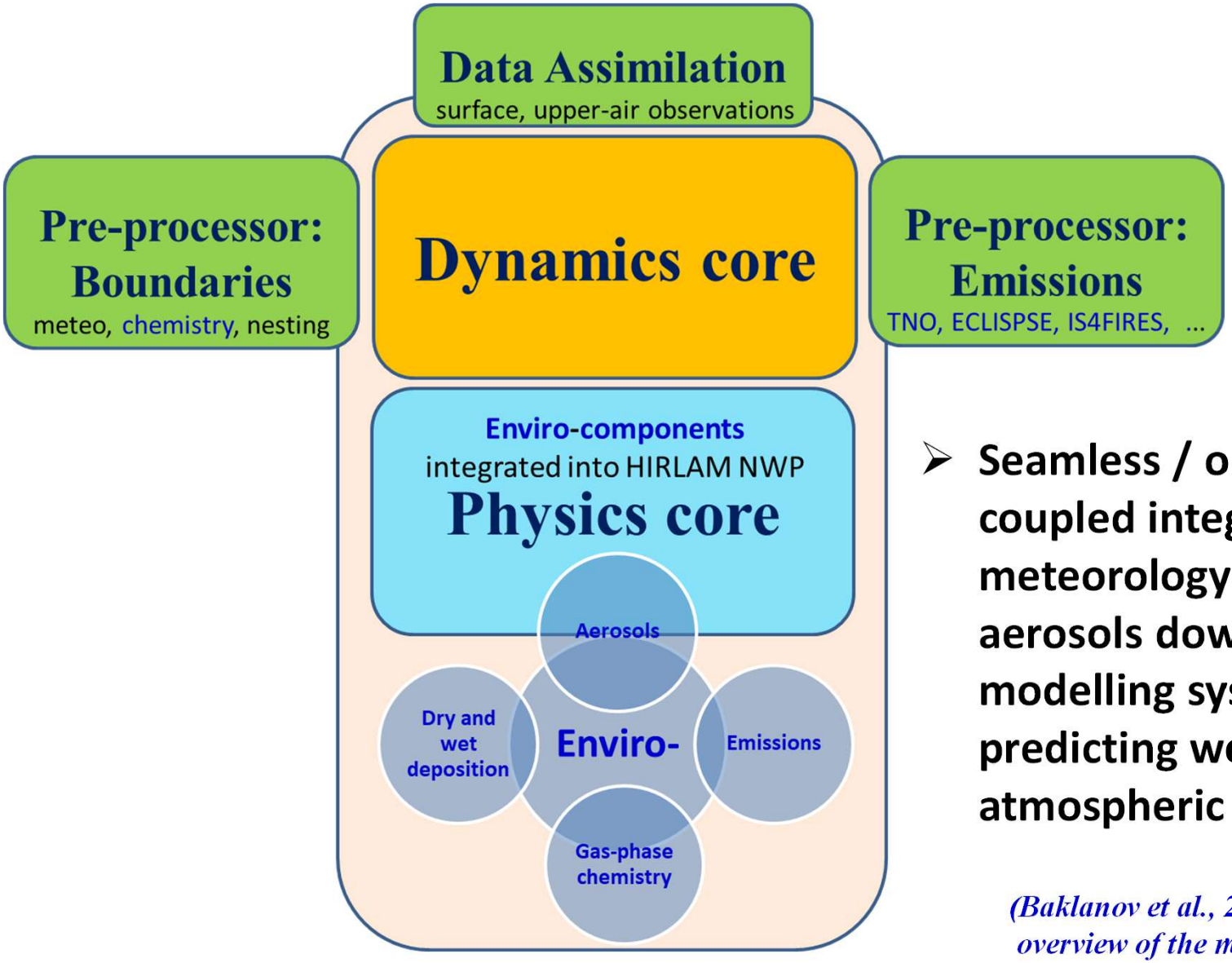
(Collaboration, Research and Development, Science Education, Dissemination, New Products and Applications)

Pan-Eurasian Experiment PEEX



Enviro-HIRLAM linkage to the PEEX-Modelling Platform

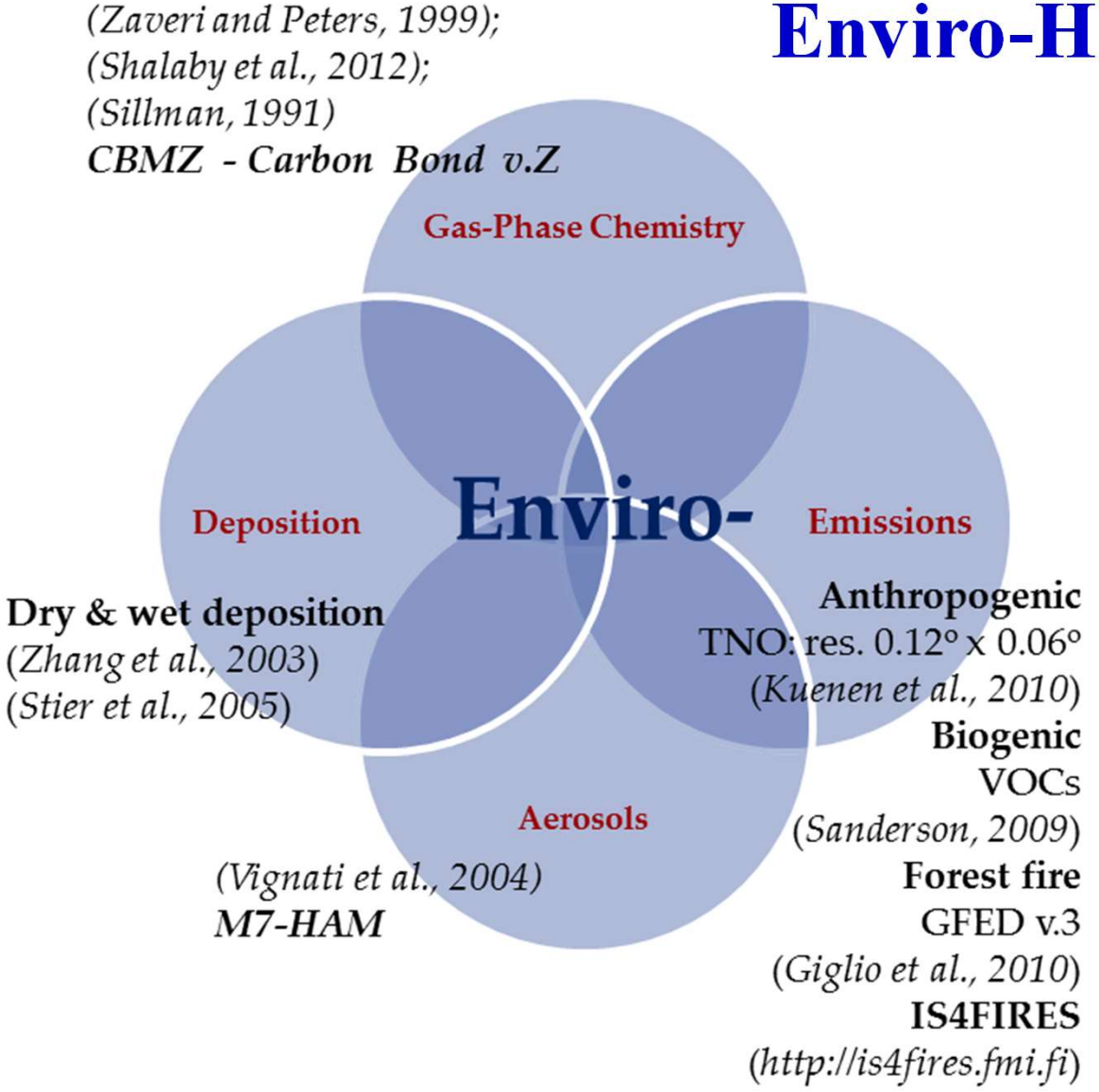
Enviro-HIRLAM (Environment – HIgh Resolution Limited Area Model)



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

(Baklanov et al., 2017) most recent overview of the modelling system

Components of Enviro-HIRLAM



Components of the Enviro-HIRLAM modelling system

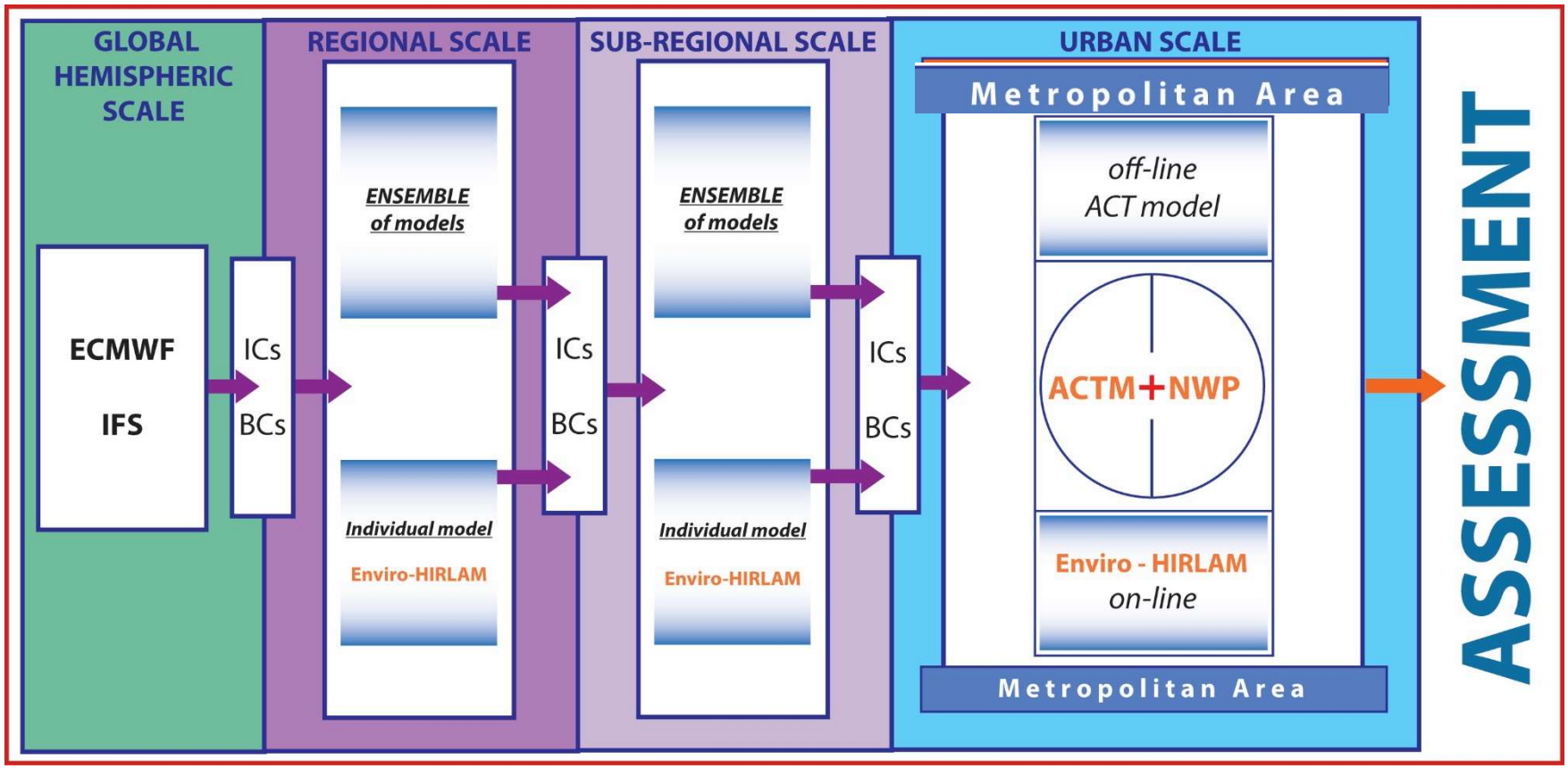
Enviro-HIRLAM research and development team

Baklanov et al., 2002-…;
Korsholm et al., 2006-2010;
Mahura et al., 2004-…;
Nuterman et al., 2007-…;

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

Note: emission datasets used depend on research projects:
MEGAPOLI, TRANSPHORM, PEGASOS, MarcoPolo, EnsCLIM, CarboNord, etc.

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



Generated modelling output (meteorological & atmospheric composition) can be used for various assessments and studies including socio-economical studies

Available Modelled Meteorology for SES studies

Basic ones:

Atmospheric pressure, air and soil and water temperatures, max & min temperatures and their anomalies, wind characteristics, specific/ relative humidity, visibility, precipitation, cloudiness, etc.

Additional ones:

Radiation (short-, long-wave, net), fluxes (latent, sensible, storage, etc.), snow (melt, depth, type), precipitation types, boundary layer height, cloud (total, low/medium/high, water, etc.

Extras/ specific ones:

Ice drift (direction, speed), thermocline (depth, anomaly), current (direction, speed), evaporation, thunderstorm probability, etc.

More elaborated list (i.e. modelled parameters) is at:

(up to 200+ meteorological variables and derived ones)

http://apps.ecmwf.int/codes/grib/param-db

& HIRLAM/HARMONIE website http://hirlam.org

Available Modelled Atmospheric Composition for SES studies

Basic ones:

Ozone, nitrogen dioxide and oxide, carbon monoxide, ammonia, sulfur dioxide, etc. + particular matter (PM2.5, PM10), sulphates, black and organic carbon, dimethyl sulphide, sea salt, dust, etc.

Additional chemical species:

Hydrogen peroxide, formaldehyde, ethane, toluene, isoprene, acetone, methanol, acetaldehyde, acids (nitric, sulfuric, …), etc.

Extras/ specific ones:

Deposition (wet, dry, total), concentration, time integrated air concentration, max/ min/ averaged/ summary concentrations and depositions over space and time intervals, etc.

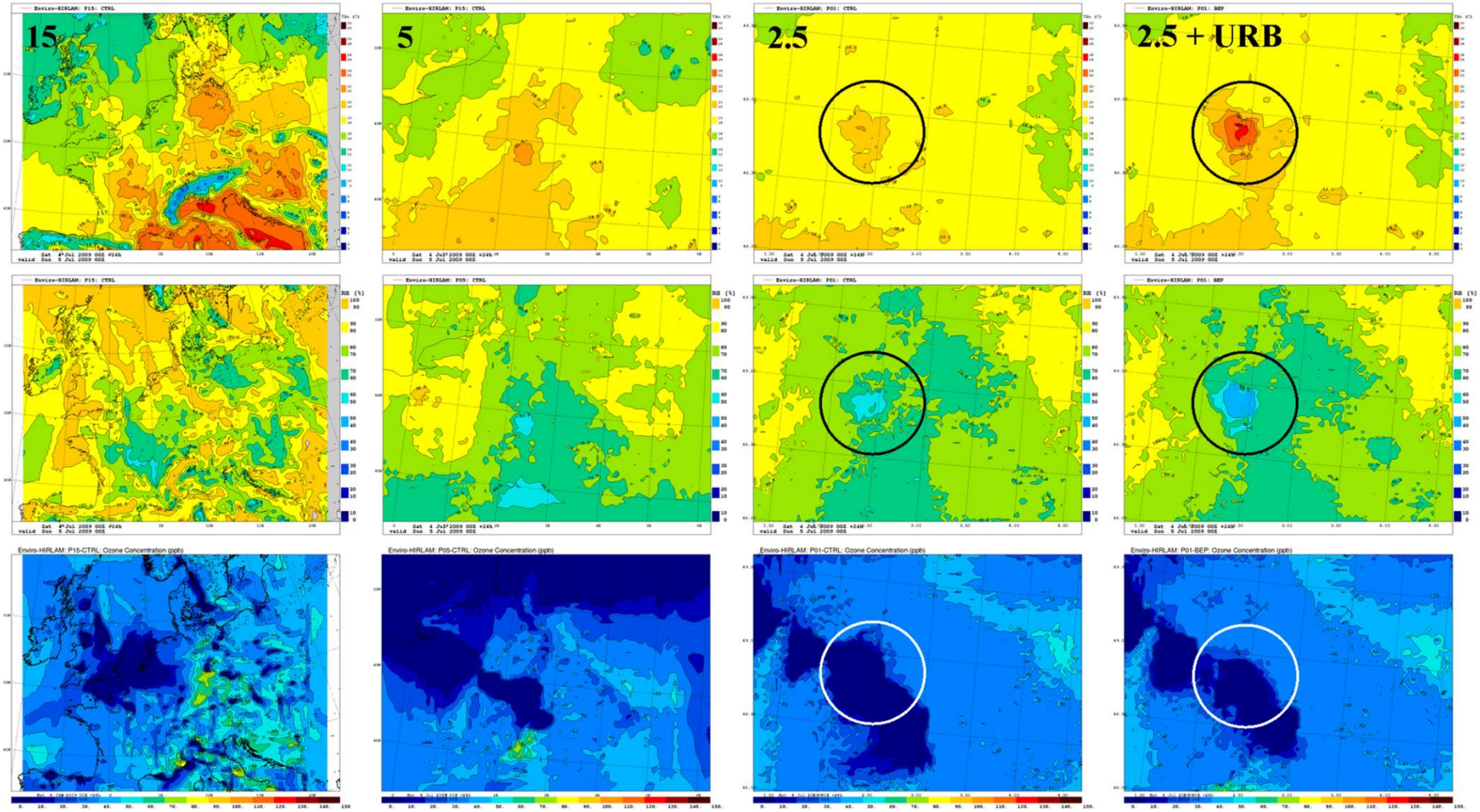
Number & mass concentration (for coarse, Aitken and accumulation modes/ soluble-insoluble), etc.

More elaborated list (i.e. modelled parameters) is at:

& Enviro-HIRLAM Chem Branch website http://hirlam.org

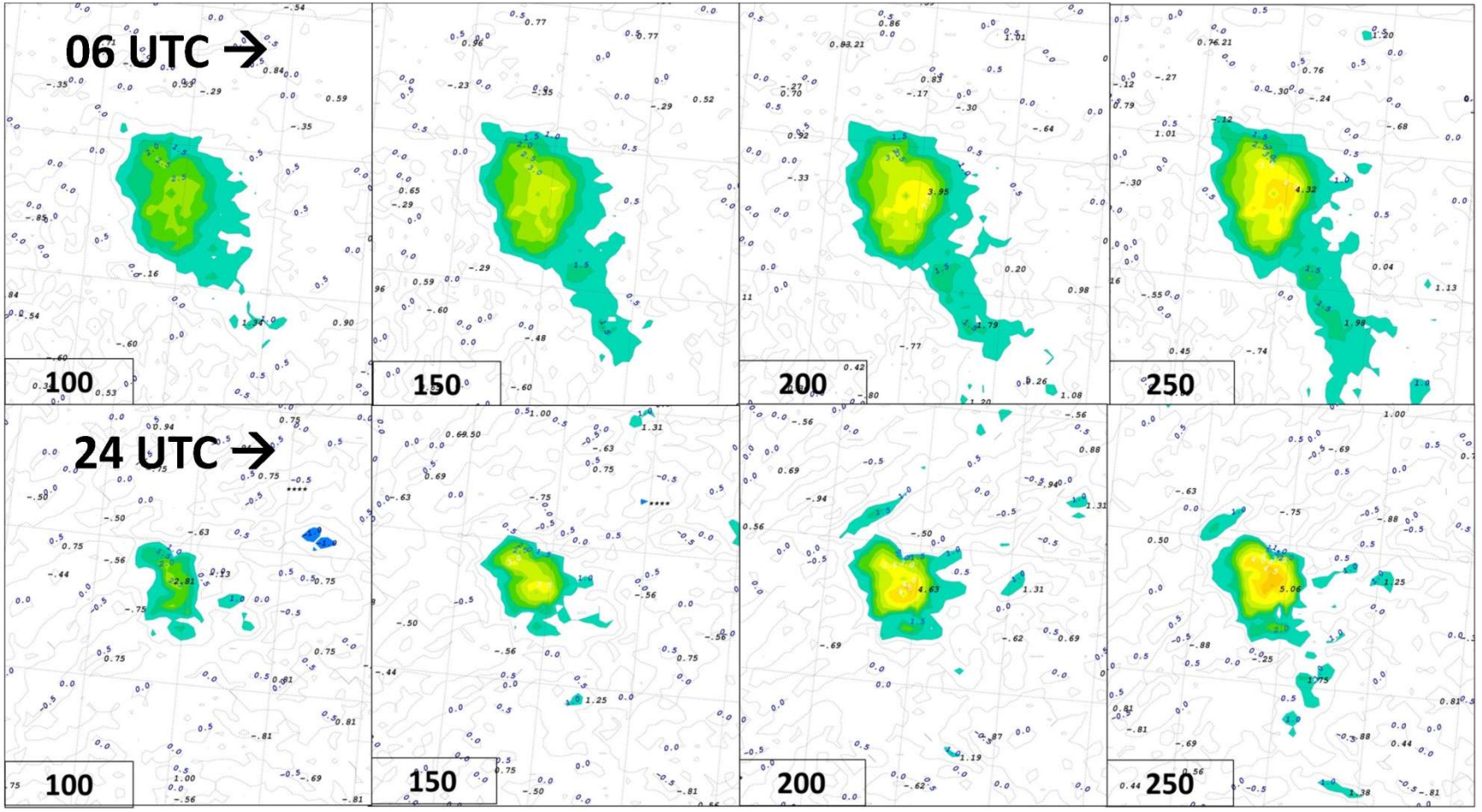

Paris Metropolitan Area
France

Downscaling for Paris Metropolitan Area (meteorology & chemistry)



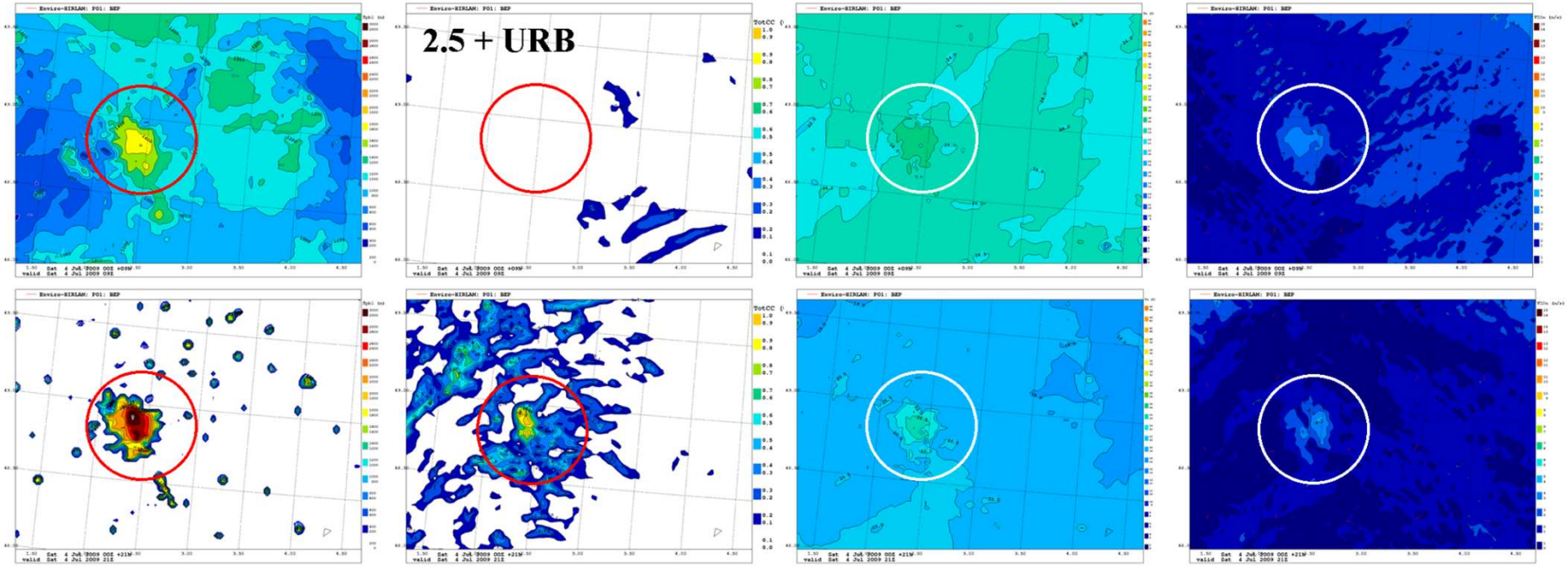
Enviro-HIRLAM downscaling (from left to right: CTRL 15—5—2.5 km & 2.5+URB) meteorological (top—air temperature, middle—humidity) and chemical (bottom—ozone) fields on 4 Jul 2009, 00+24 UTC.

Paris Metropolitan Area: T2m / AHF



Diurnal cycle variability of the difference fields (Enviro-HIRLAM-P01: urban vs. control runs) for air temperature at 2m with changing anthropogenic heat fluxes (100, 150, 200, and 250 W/m2) on 4 Jul 2009 at 06 and 24 UTCs

Paris Metropolitan Area: Temporal Variability of Meteo.Parameters

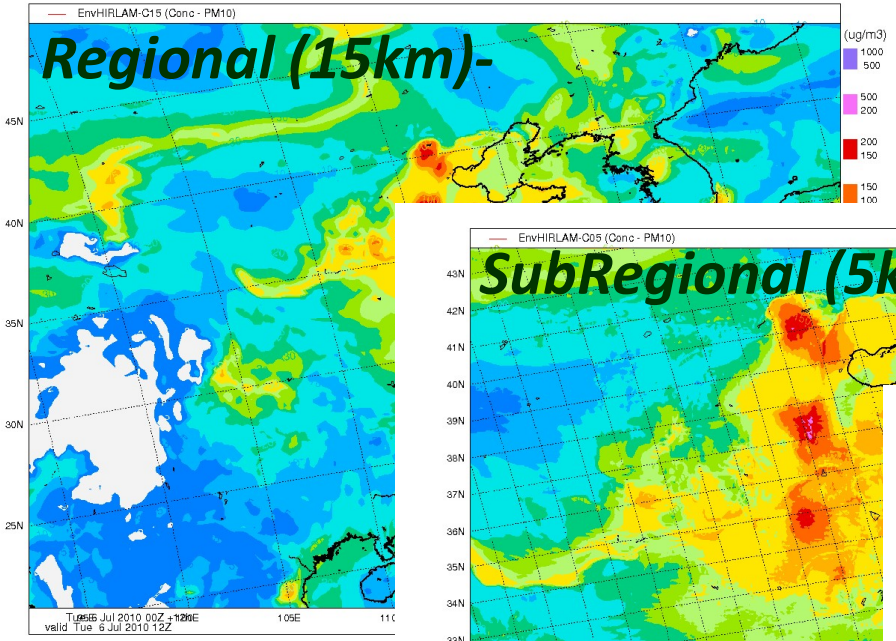


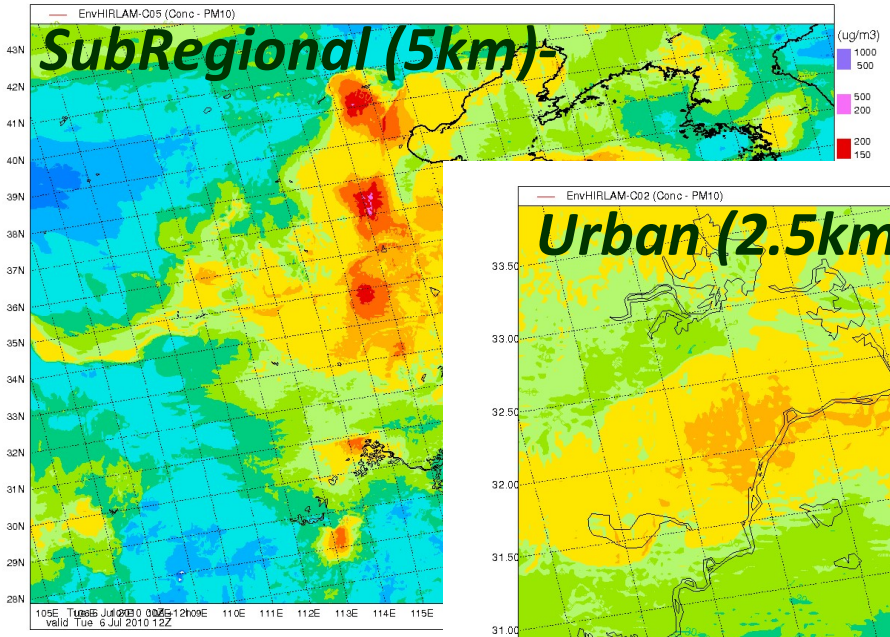
Variability of (from left-to-right) boundary layer height, total cloud cover, surface temperature, wind speed on 4 Jul 2009 at (top) 09 UTC and (bottom) 21 UTC based on Enviro-HIRLAM model run at 2.5 km resolution with URB=BEP+AHF included.

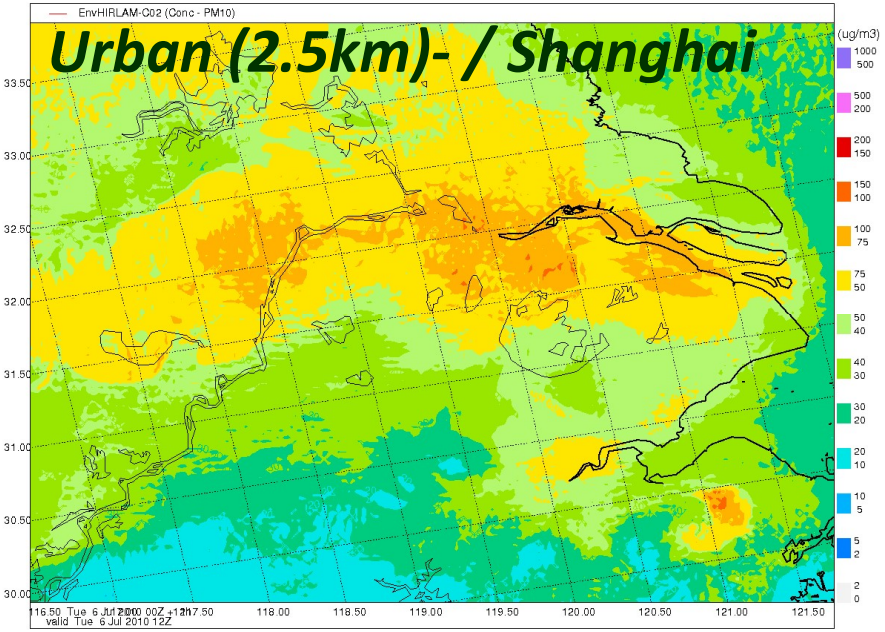

Shanghai Metropolitan Area
China
马可·波罗
MARCOPOLO
AURORA

Enviro-HIRLAM Downscaling: Aerosols

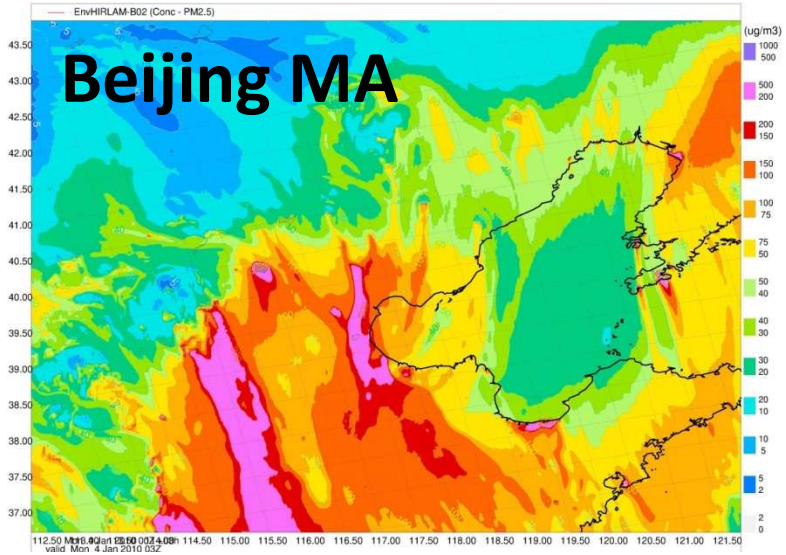
PM10 (ug/m3)

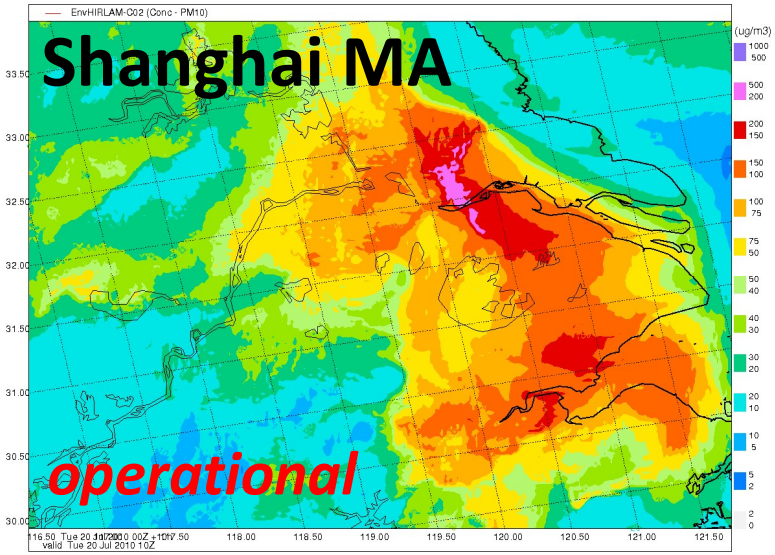


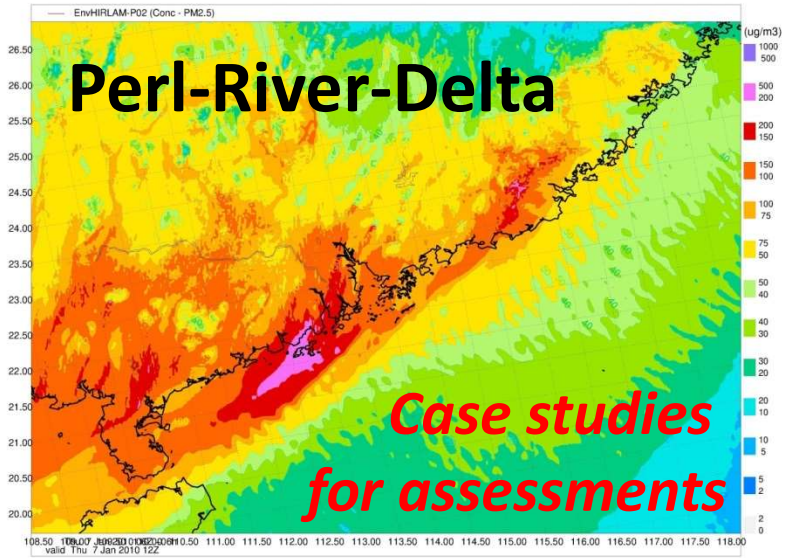




Downscaling to Metropolitan Areas (MA)







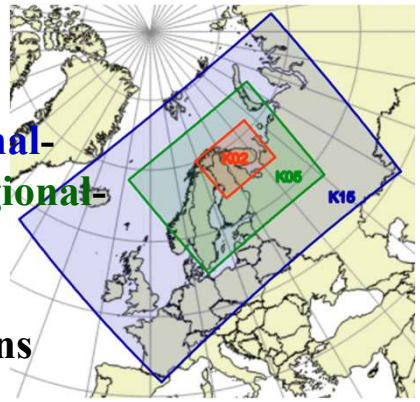
http://www.marcopolo-panda.eu/products/regional-air-quality-forecasts/enviro-hirlam


TRAKT-2018
Kola Peninsula
Alexandr Ermolitsky | www.ermolitsky.com

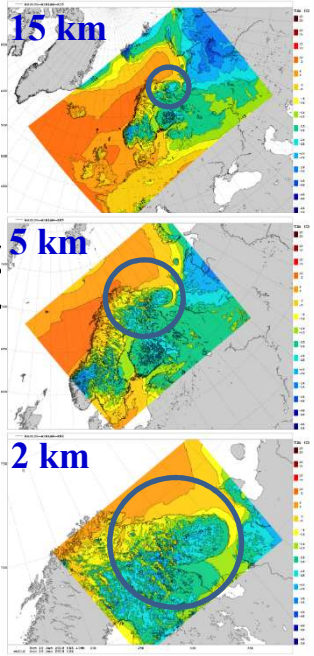
Seamless/ On-line Integrated Modelling

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

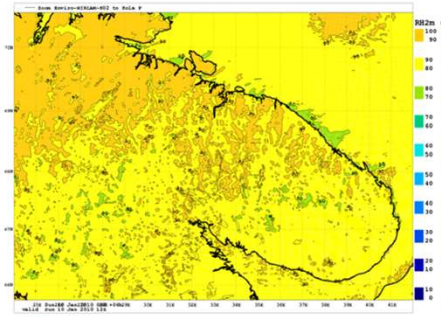
Regional-
subregional-
urban
scale
domains



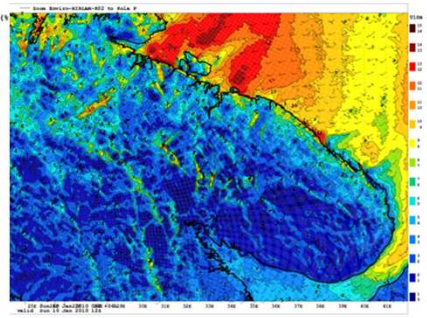
Seamless / online integrated meteorolog-chemistry-aerosols modelling at multi-scales



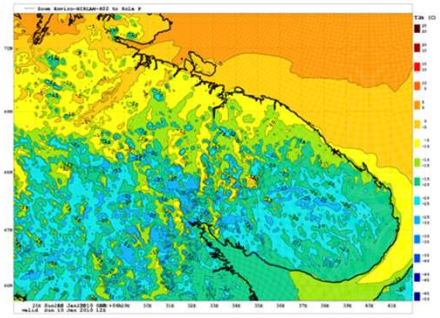
High resolution modelling (at 2 km)
for meteorology and atmospheric composition



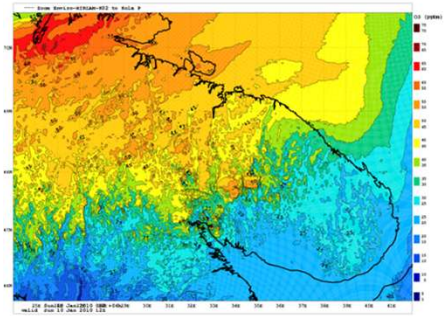
Meteorology:
Relative Humidity (RH2m)



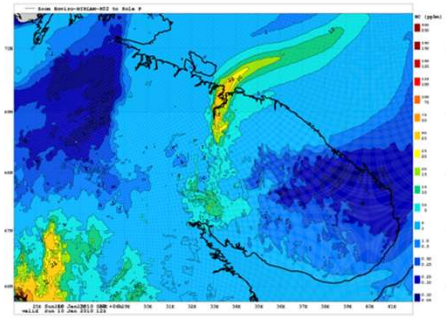
Wind Speed at 10m (U10m)



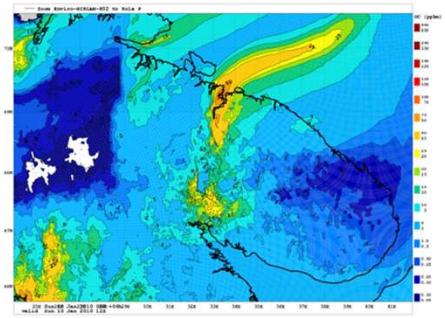
Air temperature at 2m (T2m)



Atmospheric Composition:
Ozone (O_3)



Black Carbon (BC)

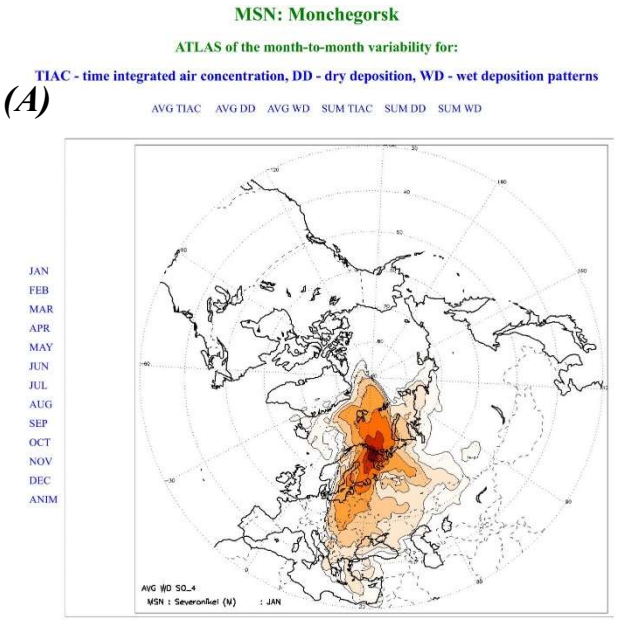


Organic Carbon (OC)

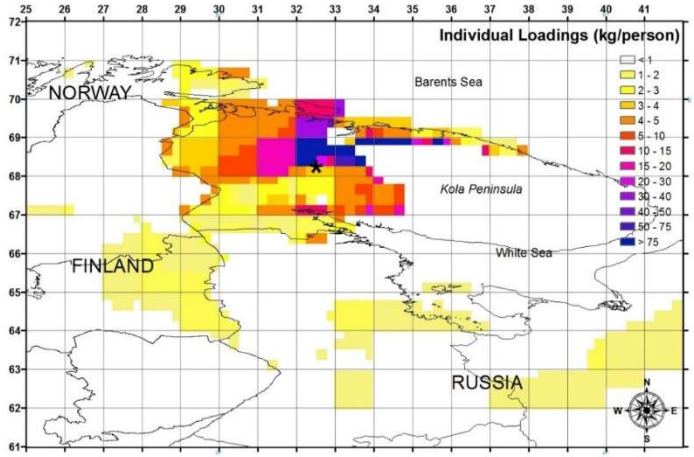
Web-Atlas for Transboundary Pollution & Loadings for Population

http://www.atm.helsinki.fi/peex/webatlas/WEBATLAS.html

(A)



(B)



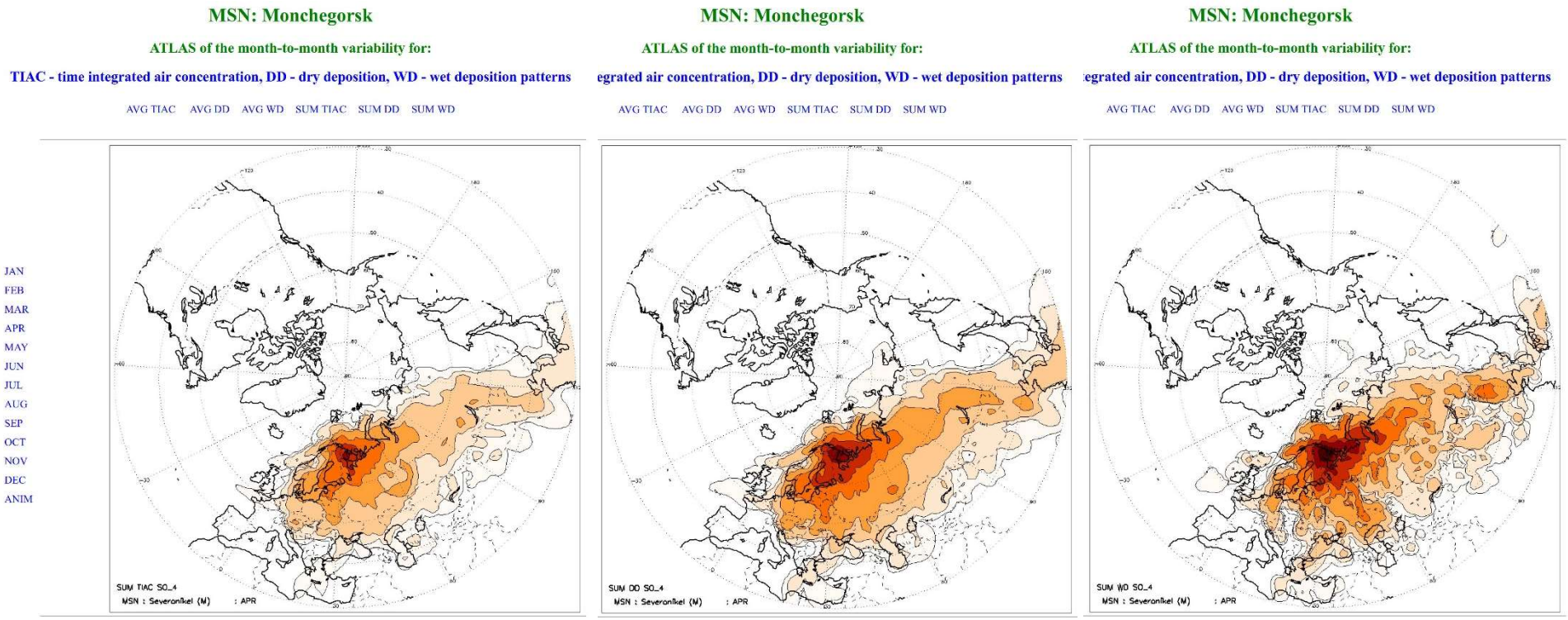
(A) Month-to-month variability of average (AVG) and summary (SUM) **time integrated air concentration** (TIAC), **dry** (DD) and **wet** (WD) **deposition patterns of sulphates** from smelters of the Mochegorsk Enterprize (Kola Peninsula, Mirmansk region, Russia);

&

(B) Individual yearly loadings for population (in kg/person) from deposited sulfates resulted from the Severonickel smelters continuous emissions (mild scenario, appx 32 thou. tonnes of SO_2).

Web-based Atlas

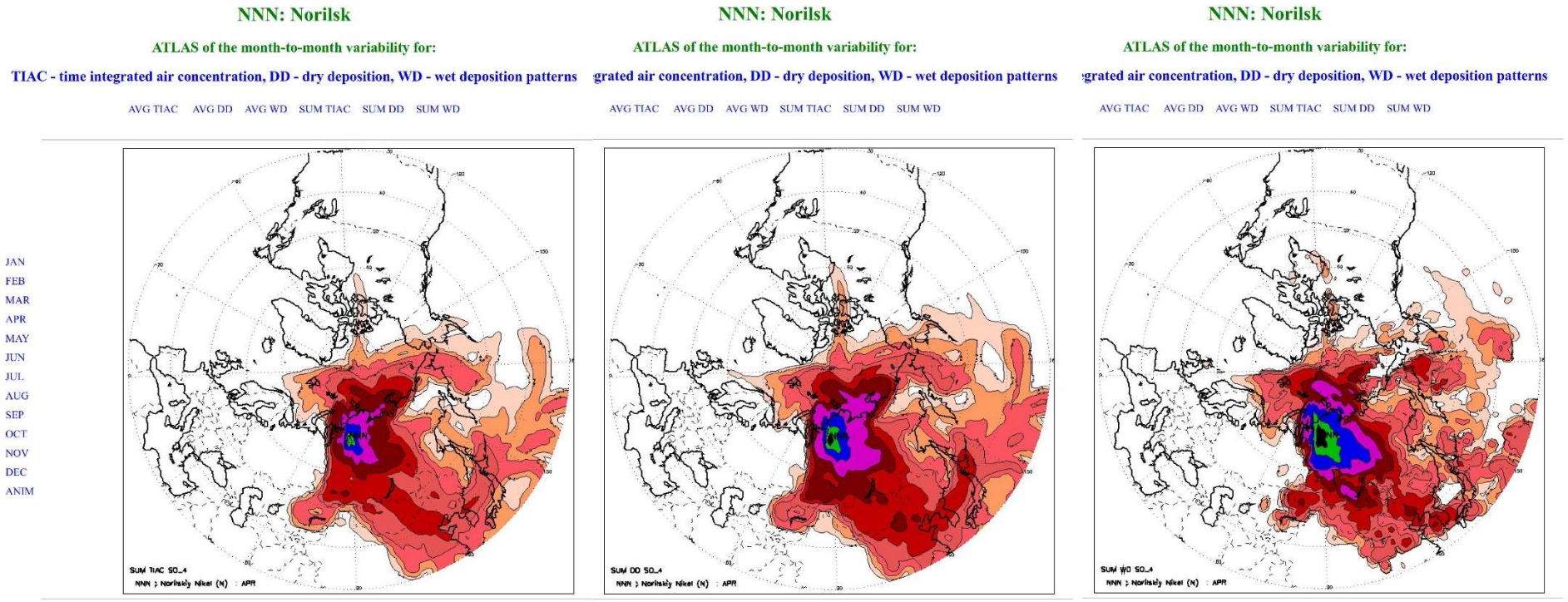
http://www.atm.helsinki.fi/peex/webatlas/WEBATLAS.html



Example of a month-to-month variability of summary (SUM) **time integrated air concentration** (TIAC), **dry** (DD) and **wet** (WD) **deposition patterns of sulphates** from smelters of the Mochegorsk Enterprize (Kola Peninsula, Mirmansk region, Russia)

Web-based Atlas

http://www.atm.helsinki.fi/peex/webatlas/WEBATLAS.html



Example of a month-to-month variability of summary (SUM) **time integrated air concentration** (TIAC), **dry** (DD) and **wet** (WD) **deposition patterns of sulphates** from smelters of the Norilsk Nickel Enterprize (Krasnoyask Krai, Russia)

Derived Indices for SES studies

Meteorology/ Climate / Pollution related:
wind chill index, heat wave, comfort temperature, exceedances of concentration thresholds, short-/long-term exposure, etc.

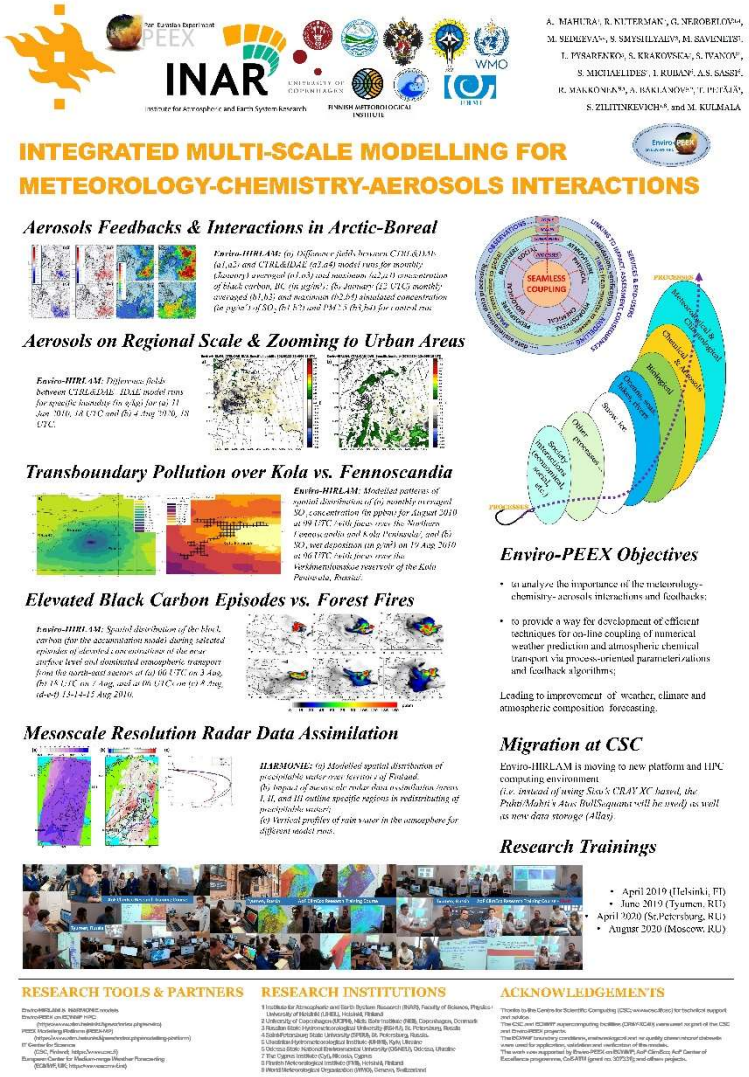
Which existing/ newly indicies might be applicable for SES studies & in particular, when we are focusing on cities/ urban areas:

for example: city of Apatity, Murmansk region, Russia

- urban air pollution index (all year around)
- urban inversion index (especially for winter period)
- dust urban impact index (especially for summer period)
- avalanche probability index (winter period)
- extreme precipitation index (all year around)
- fires pollution index (summer-autumn)
- others

and how these can contribute to socio-economical studies/ analysis

Collaboration with PEEX Russian 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)

www.atm.helsinki.fi/peex/index.php/enviro

+ MSU, RSHU, ICMMG , NIERSC

Objectives:

- to analyze importance of meteorology-chemistry-aerosols interactions & feedbacks;
- to provide a way for development of efficient techniques for on-line coupling of NWP and ACT via process-oriented parameterizations and feedback algorithms.

Generated by models output
can be used for various assessment studies

Collaboration with Russian Partners

- **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*" / **completed by Dec 2020**

  (2018-2020)

  www.atm.helsinki.fi/peex/index.php/enviro

- **Enviro-PEEX(Plus) on ECMWF** - "*Research and development for integrated meteorology – atmospheric composition multi-scales and – processes modelling for the PEEX domain for weather, air quality and climate applications*" / **started in Jan 2021**

  (2021-2023)

  www.atm.helsinki.fi/peex/index.php/projects/226-enviro-peex-plus-on-ecmwf

with RSHU, SRCES, SPBU, MSU, KSC, ICMMG, and others

Concluding Remarks

- **Multi-scale modelling approach** with Enviro-HIRLAM online integrated meteorology – atmospheric composition modelling system – demonstrated on examples with generated meteorology – atmospheric composition output and pollution atlas which can be utilized for SES studies

- **Results of modelling** are applicable in principle for evaluation of risks, vulnerability, and consequences due to atmospheric; impact assessments on population and environment; supporting decision-makers, adjustment of legislation at regional-city levels; planning measures, mitigation scenarios, etc.

- **Further:** continue development and improvement of online integrated approach with (i) consideration of socio-economical aspects/ processes and physio-geographical specifics of regions in focus, (ii) application of new IT technologies and digitalization approach for developing web-based services for public needs; and (iii) combination expertise and knowledge from collaborating partners and stakeholders.

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

Thank you! Спасибо!

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