Online integrated meteorology- chemistry- aerosols modelling: research and sci. education

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In linkage with multiple research projects and collaboration with many colleagues

FIRST⁺ PEEX-AC
Small-Scale
Research Projects (SSRP)
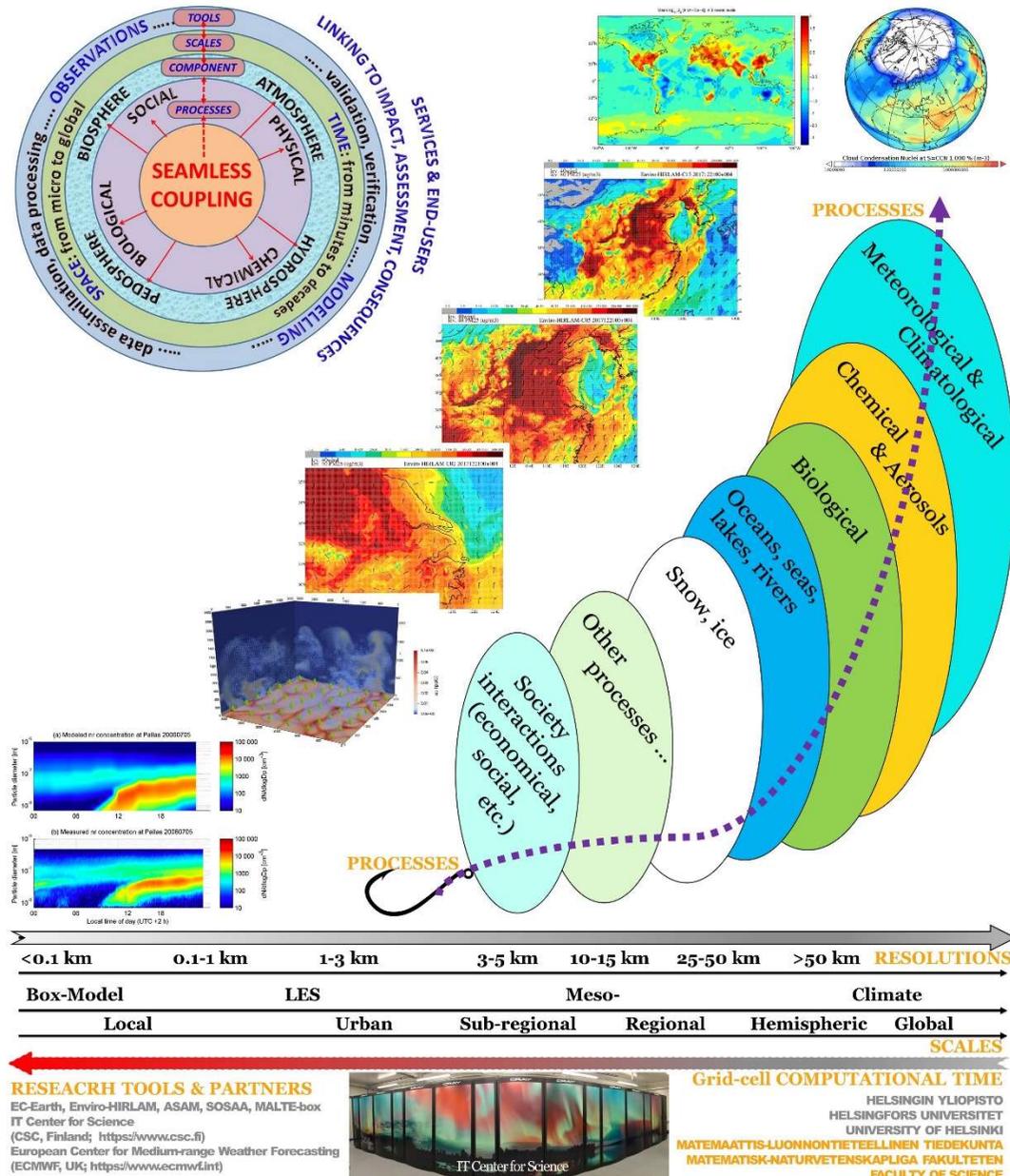
➢ **Based on Approaches for Multi-Scale and – Processes Modelling**

➢ **Research projects are designed by teachers of SSRPs with following selected models:**
   EC-Earth
   Enviro-HIRLAM
   MALTE-Box

➢ **More than 30 models are being a part of the PEEX-Modelling-Platform**

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

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

Enviro-HIRLAM/ HARMONIE (EnviroHH)

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

Left circular diagram

HIRLAM/ALADIN Consortium Institutions linking with ECMWF

International Collaboration with Universities and Research Institutions

RESEARCH AND DEVELOPMENT

Strategy for on-line integrated modelling
Coupling of chemical and aerosol schemes
Convection and cloud microphysics
Dynamical core
Land-surface scheme and urbanization
Aerosol chemistry and microphysics
Radiation schemes, direct effects of gases and aerosols
Aerosol cloud indirect effects
Boundary layer and turbulence closure schemes
Data assimilation of chemical species
Validation (case studies and long-term evaluation)

DISSEMINATION

HIRLAM Chemistry Branch
https://hirlam.org/trac/wiki/HirlamChemicalBranch/Introduction
Peer-reviewed publications
Presentations on conferences, seminars, workshops etc.

SCIENCE EDUCATION

Advising and consulting young researches
Networking NordForsk, TEMPUS, EU & national projects
Young Scientist Summer Schools (YSSS) on seamless integrated modelling for various applications
Research training weeks

NEW PRODUCTS AND APPLICATIONS

Enviro-HIRLAM linkage to the PEEX-Modelling Platform

Enviro-HIRLAM as part of PEEX-Modelling Platform
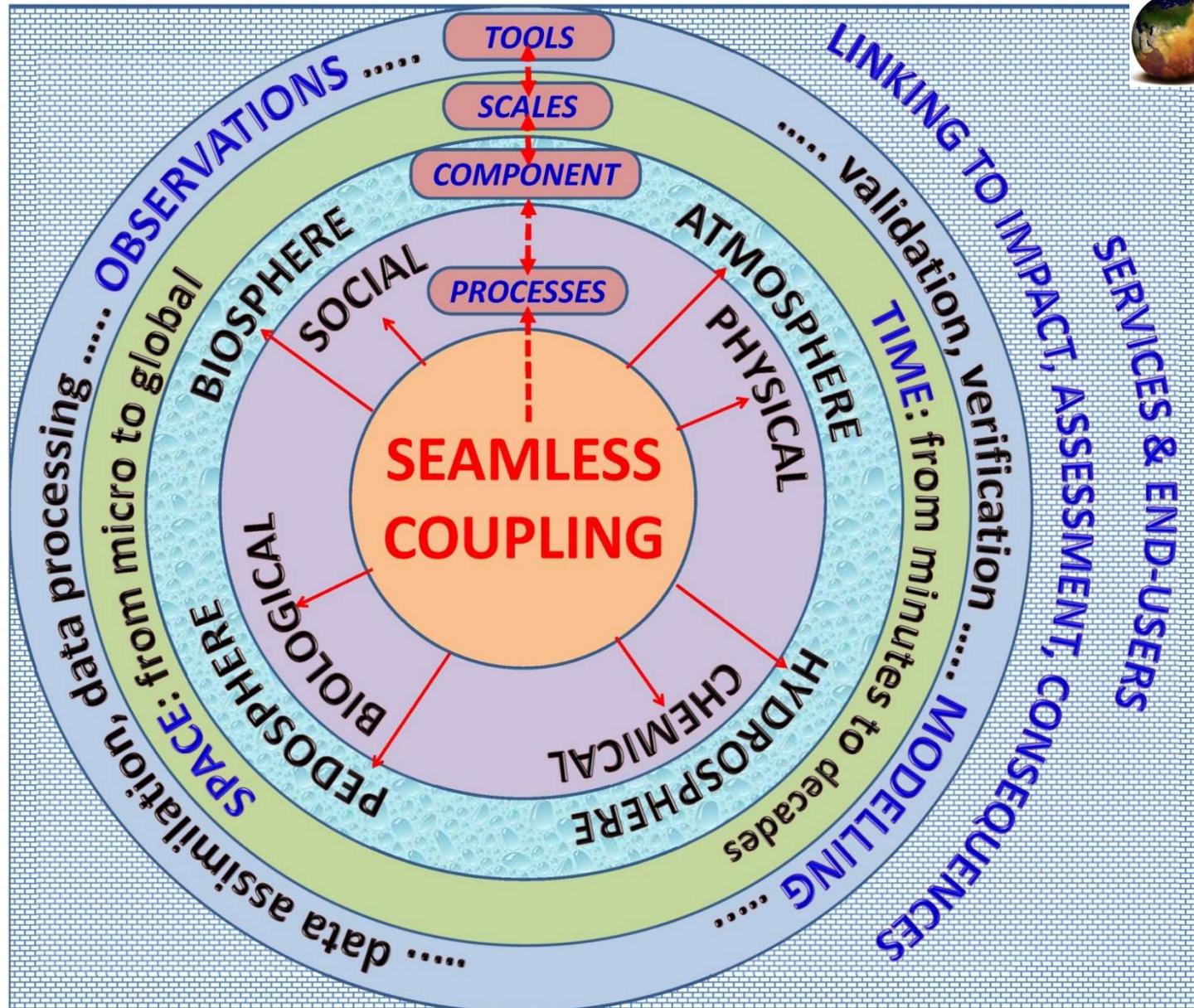
Downscaling for Enviro-HIRLAM
Regional-Subregional-Urban/City scales
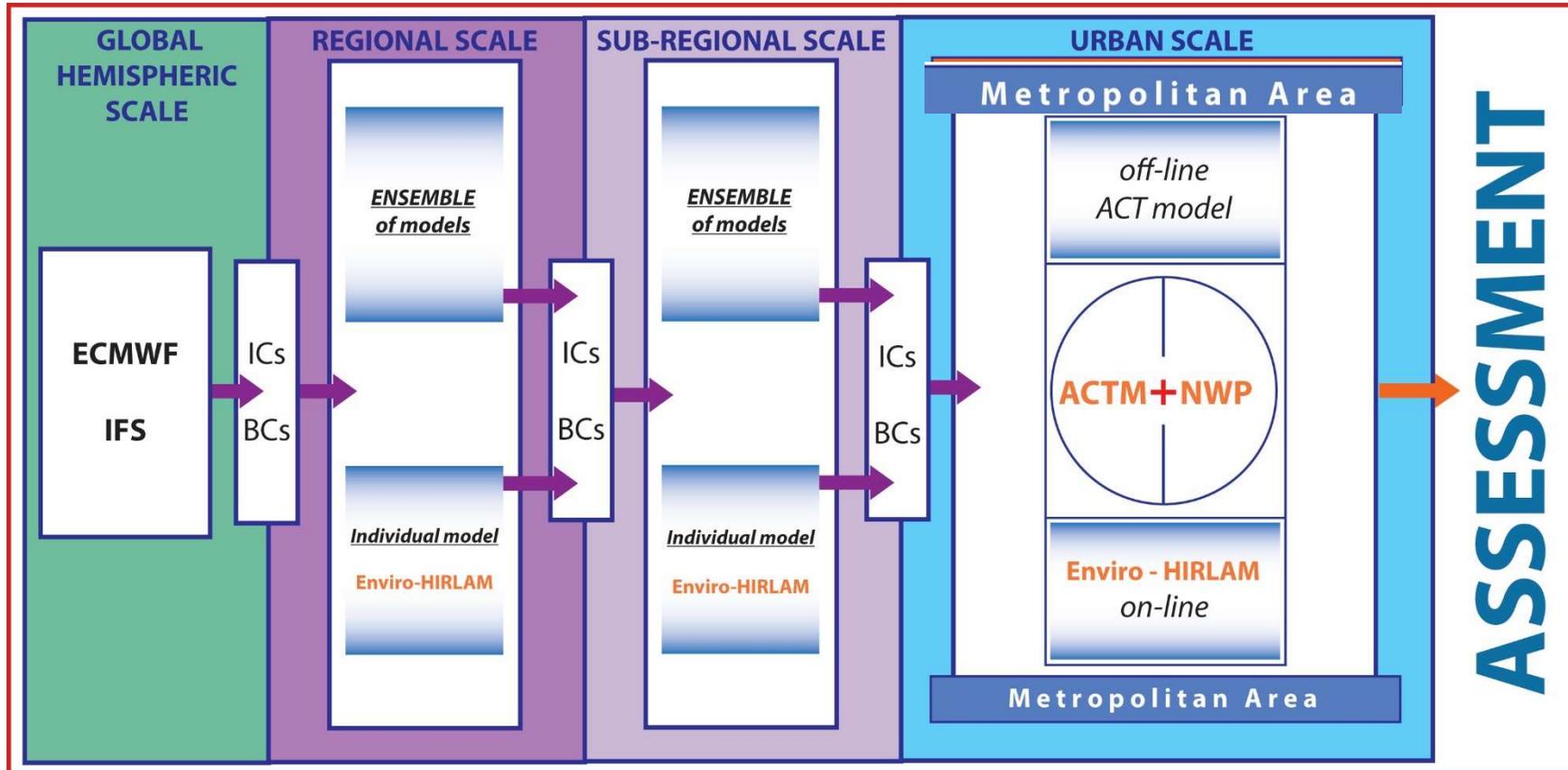
Components of Enviro-HIRLAM

(Zaveri and Peters, 1999);
(Shalaby et al., 2012);
(Sillman, 1991)
CBMZ - Carbon Bond v.Z

Gas-Phase Chemistry

Deposition

Emissions

Enviro-

Dry & wet deposition
(Zhang et al., 2003)
(Stier et al., 2005)

Anthropogenic
TNO: res. $0.12° \times 0.06°$
(Kuenen et al., 2010)
Biogenic
VOCs
(Sanderson, 2009)
Forest fire
GFED v.3
(Giglio et al., 2010)
IS4FIRES
(http://is4fires.fmi.fi)

Aerosols

(Vignati et al., 2004)
M7-HAM

Components of the Enviro-HIRLAM modelling system
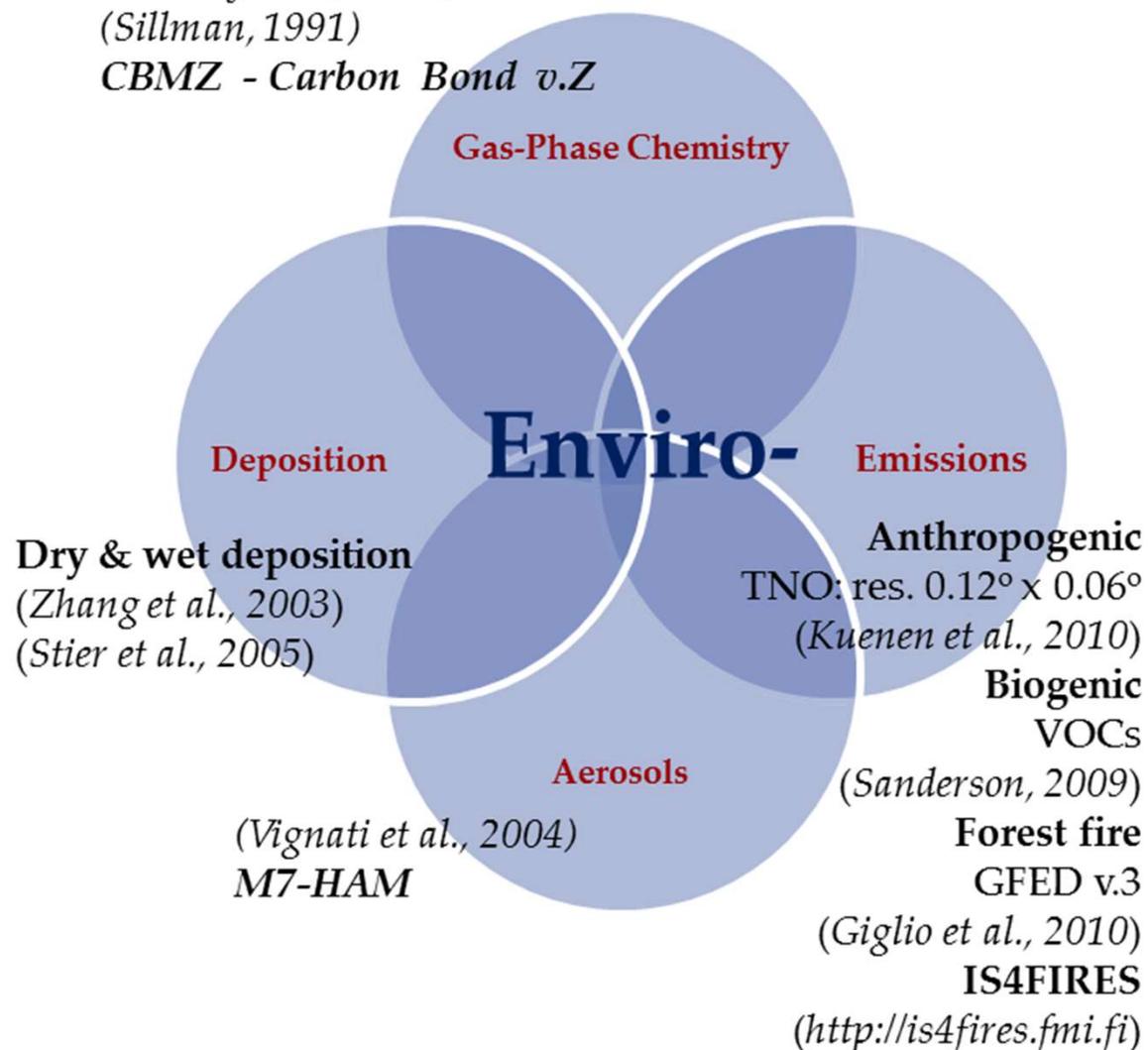
Enviro-HIRLAM research and development team

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.

(Baklanov et al., 2017) – most recent overview

Urbanization Modules Applied

Mahura et al. (2004-…) in FUMAPEX, HIRLAM, COST728, MEGAPOLI, MACC, TRANSPHORM, MarcoPolo, PEEX
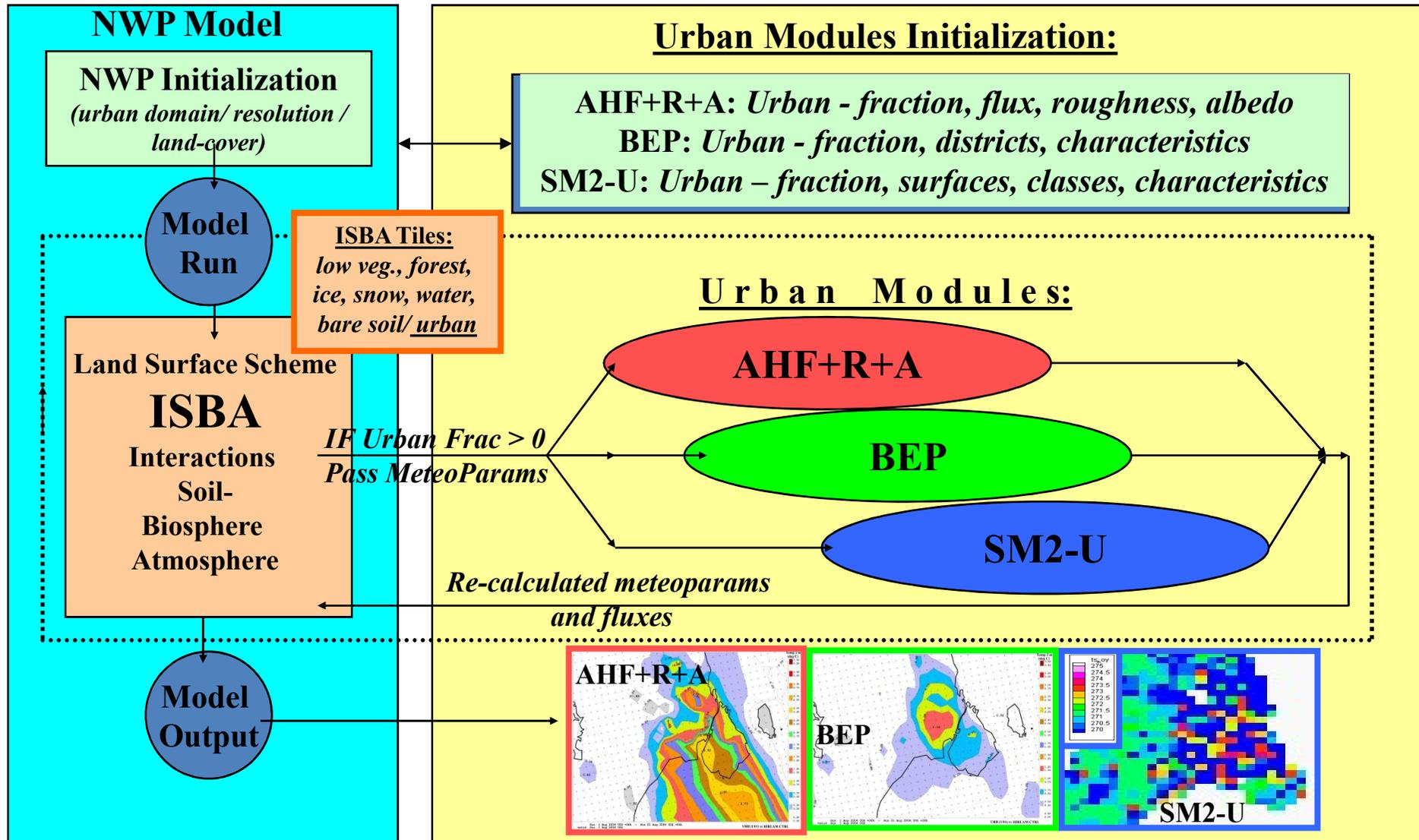
Urban Districts in Metropolitan Areas: Classification & Characteristics

Residential (RD)

City Center/High Buildings District (CC/HBD)

City Center
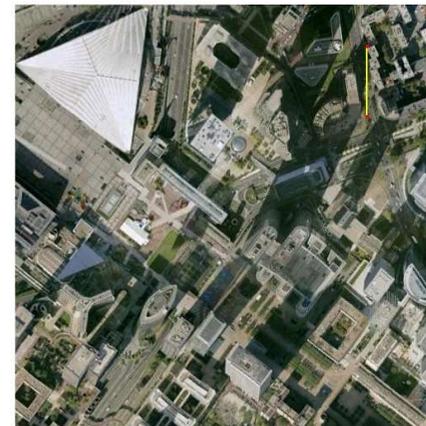
High Buildings District
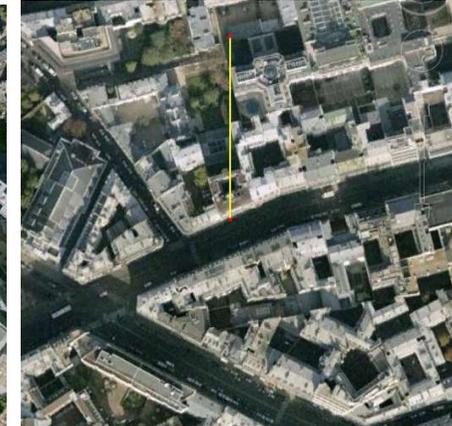
Industrial Commercial (ICD)

GIS - Extraction of districts related characteristics (statistics):

Residential District

Industrial Commercial District

- *Morphology parameters* (avg. height, volume, perimeter, compactness, space between buildings)
- *Cover modes* (surface density (SD) of buildings, of vegetation, hydrography, roads, N buildings)
- *Aerodynamic parameters* (roughness length, displacement height, frontal and lateral SD)

Urban Districts in Metropolitan Areas: Classification & Characteristics
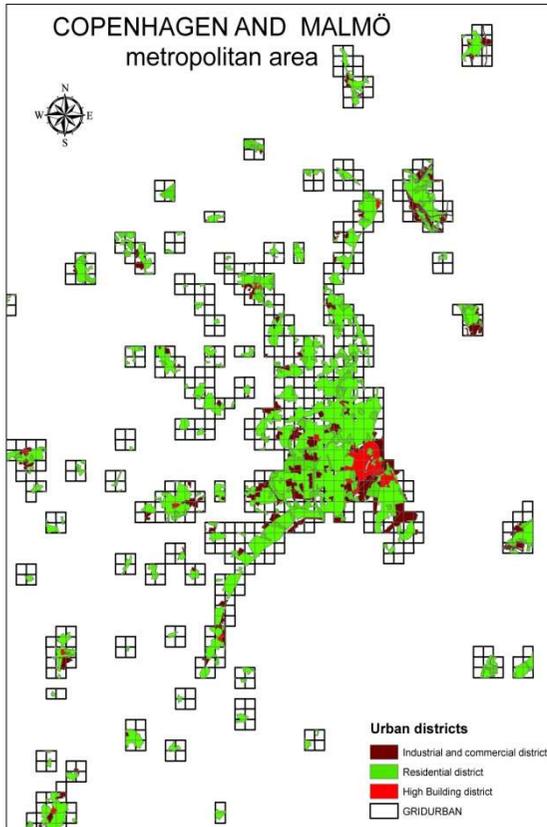
Copenhagen (Denmark)
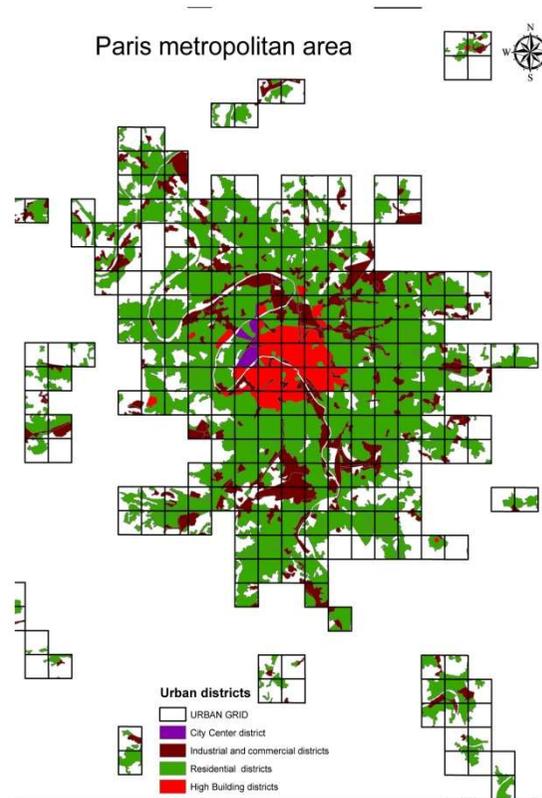
Paris (France) Metropolitan Areas
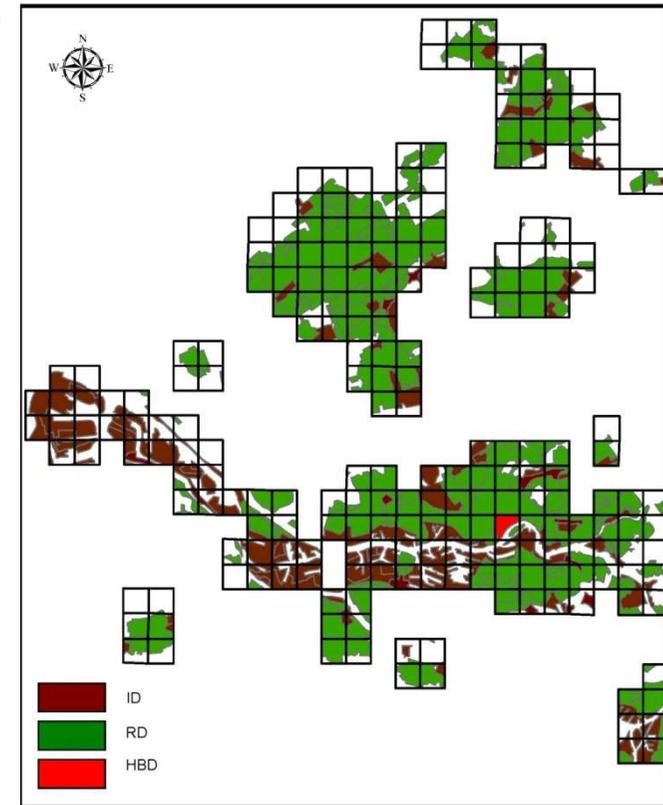
Rotterdam (The Netherlands)

EXAMPLES ON STUDIES FOR SCIENCE ORIENTED UNIVERSITY EDUCATION

Copenhagen Metropolitan Area
Denmark

24.05.2008

AHF+R: Copenhagen Urban Effects Modelling
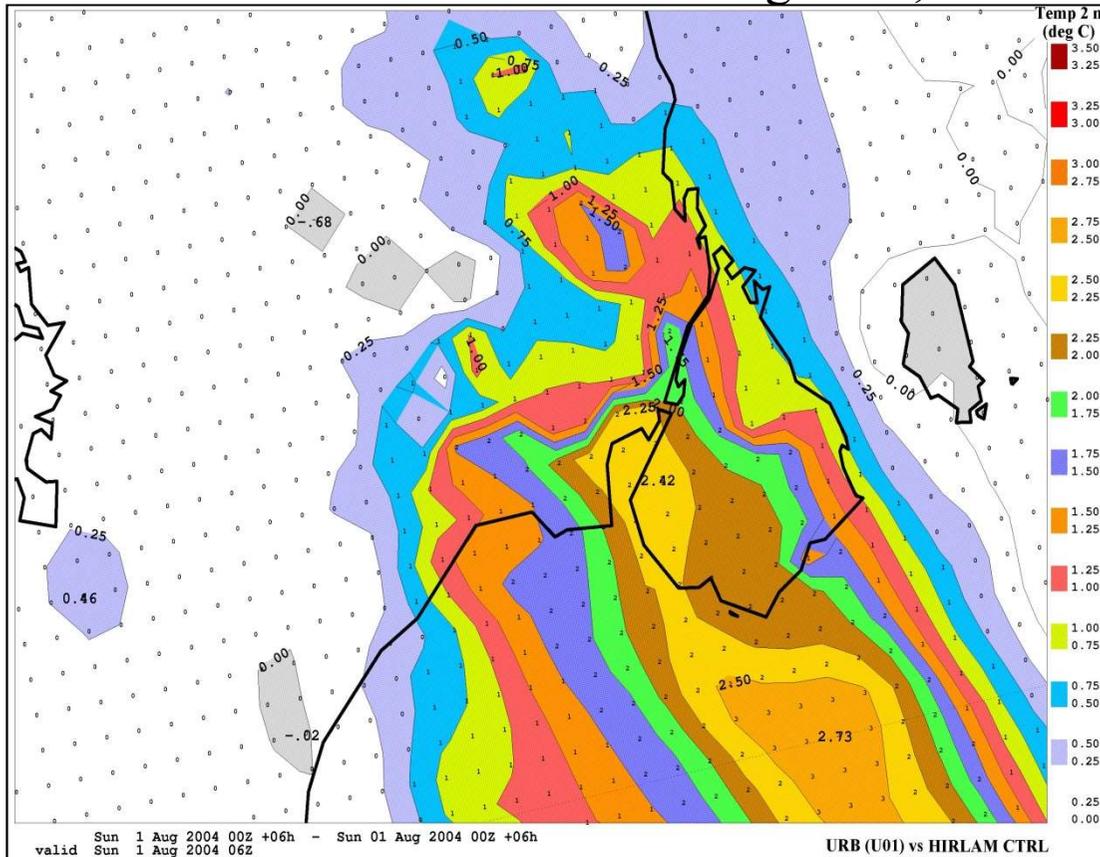
Difference between runs: 01 Aug 2004, 06 UTC

(control vs. urbanized run)
Difference field for wind at 10 m
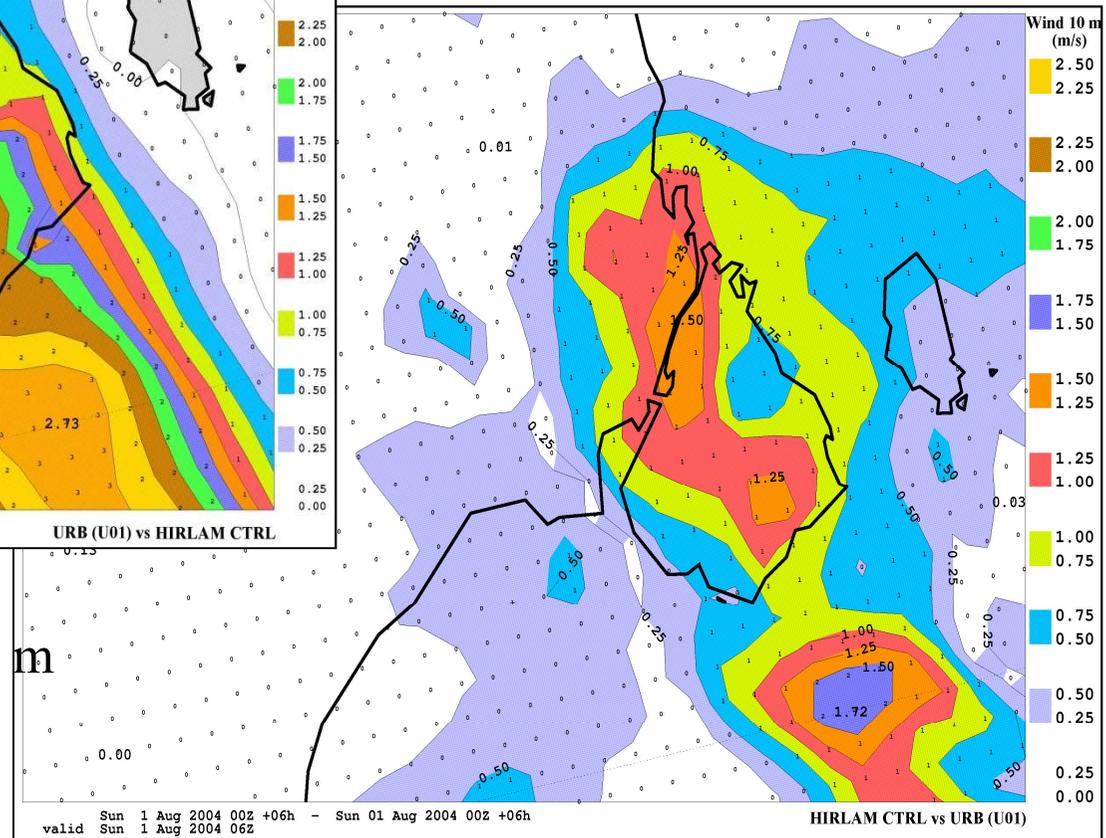
(control vs. urbanized run)
Difference field for temperature at 2 m

BEP: Copenhagen Urban Effects Modelling
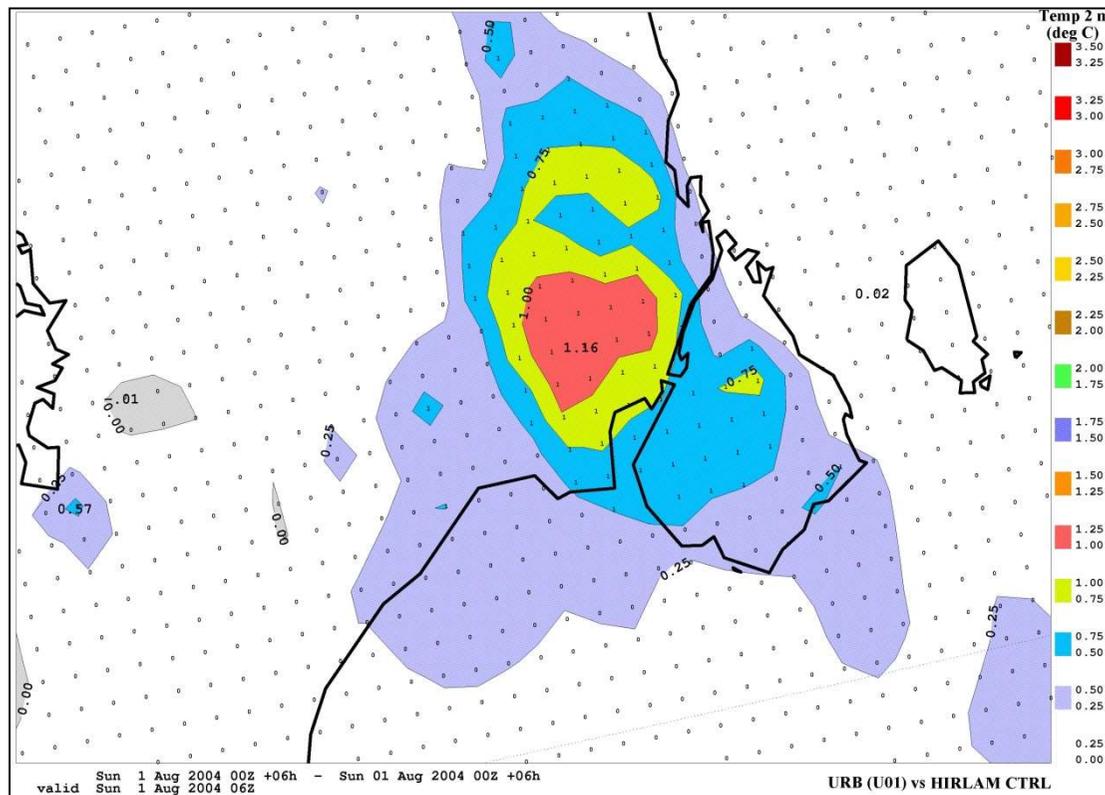
Difference between runs: 01 Aug 2004, 06 UTC

(control vs. urbanized run)
Difference field for wind at 10 m
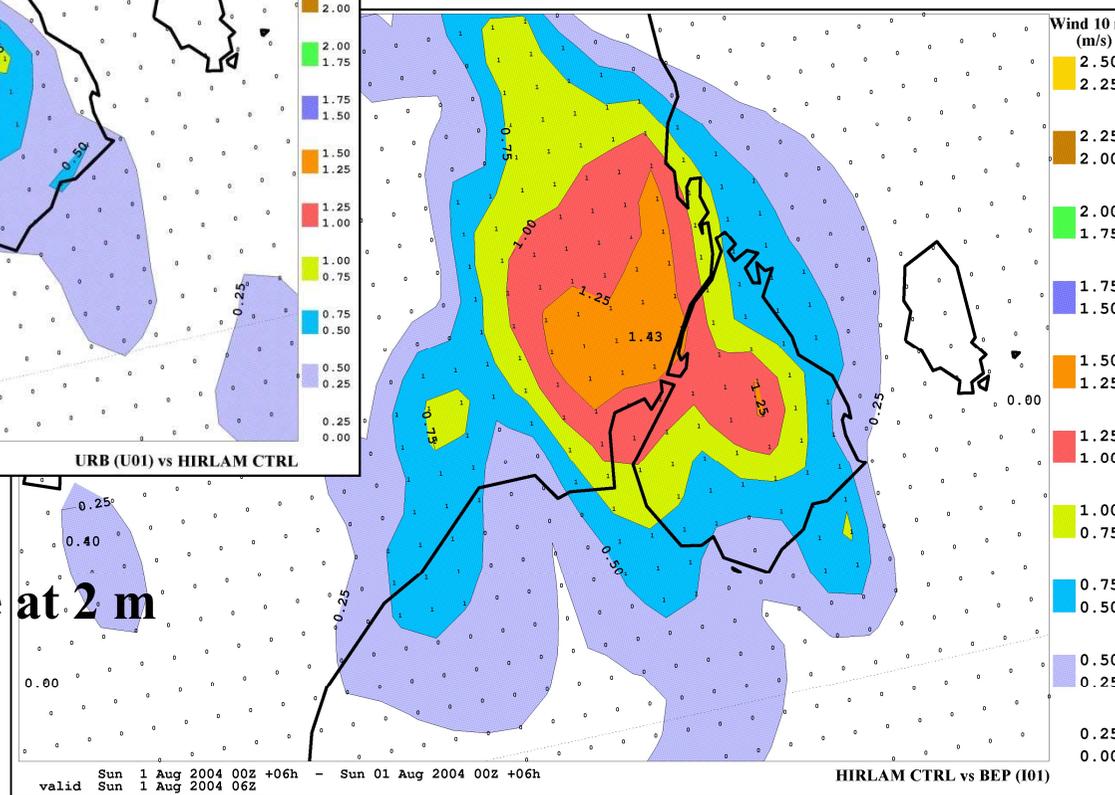
(control vs. urbanized run)
Difference field for temperature at 2 m

Paris Metropolitan Area France

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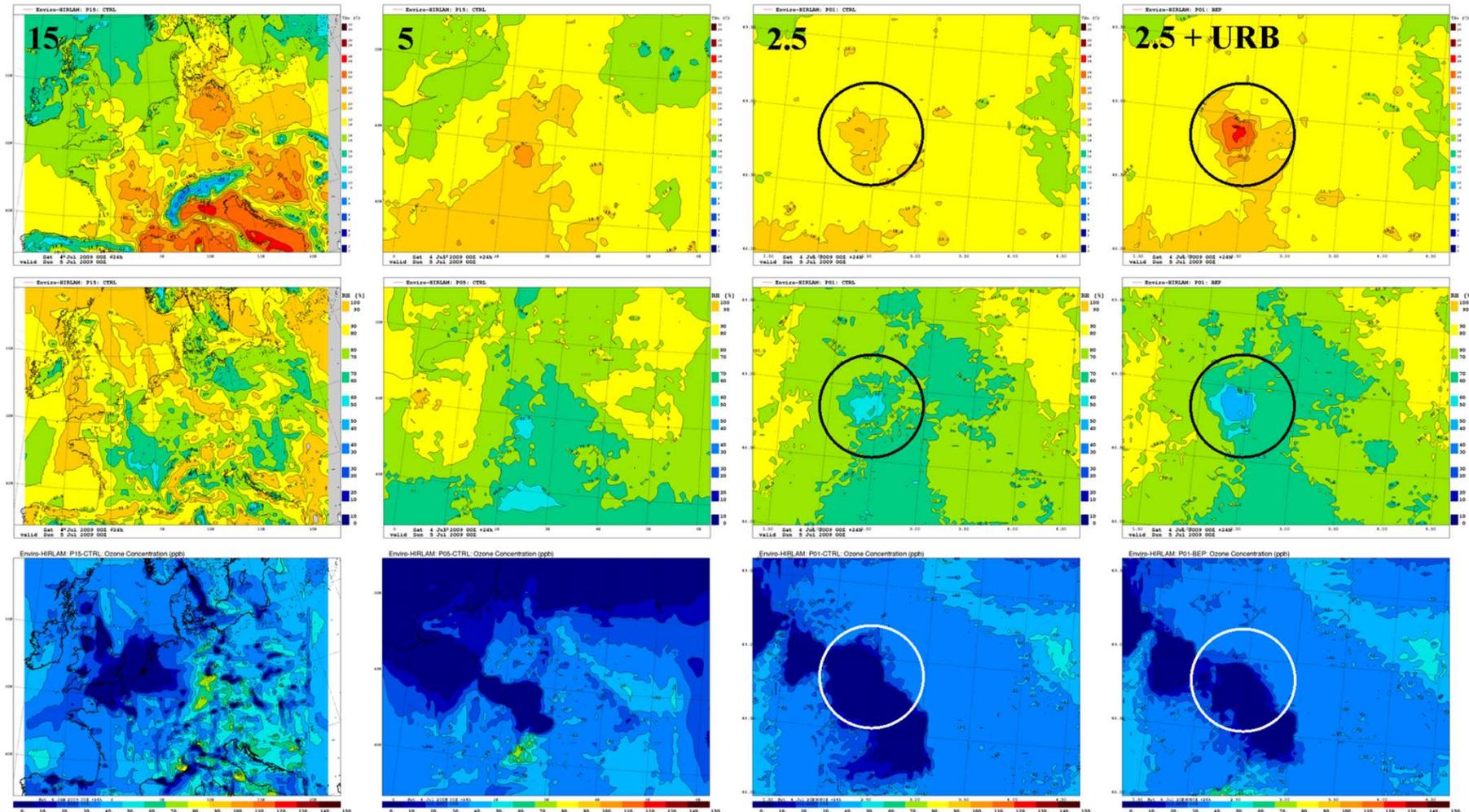
Enviro-HIRLAM downscaling (from left to right: CTRL 15—5—2.5 km & 2.5+URB) meteorological (top—air temperature, middle—humidity) and chemical (bottom—ozone) fields on 4 Jul 2009, 00+24 UTC.

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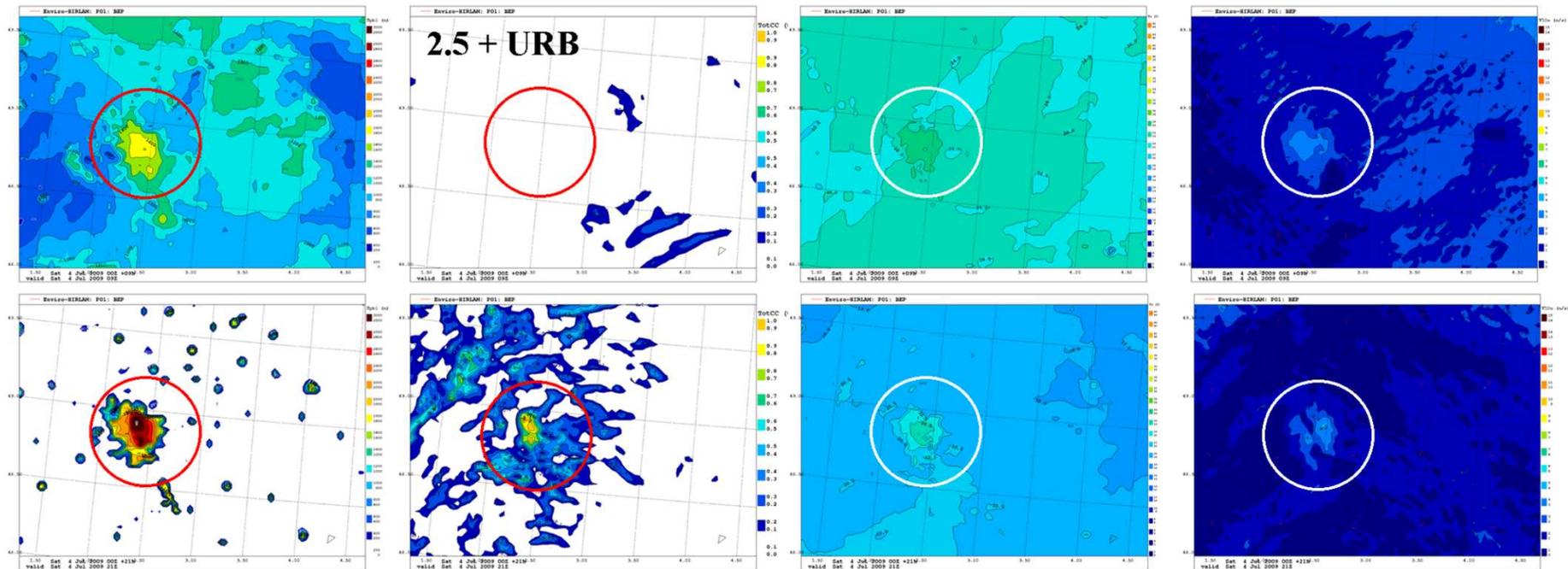
Variability of (from left-to-right) boundary layer height, total cloud cover, surface temperature, wind speed on 4 Jul 2009 at (top) 09 UTC and (bottom) 21 UTC based on Enviro-HIRLAM model run at 2.5 km resolution with URB=BEP+AHF included.

Downscaling to Metropolitan Areas (MA)

Mahura et al. (2014-2017)

Beijing MA

Shanghai MA

operational

Perl-River-Delta

Case studies for assessments

http://www.marcopolo-panda.eu/products/regional-air-quality-forecasts/enviro-hirlam
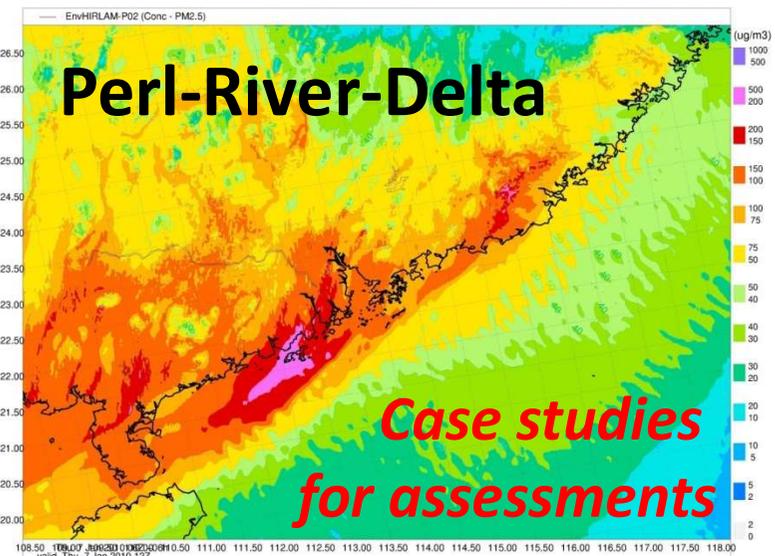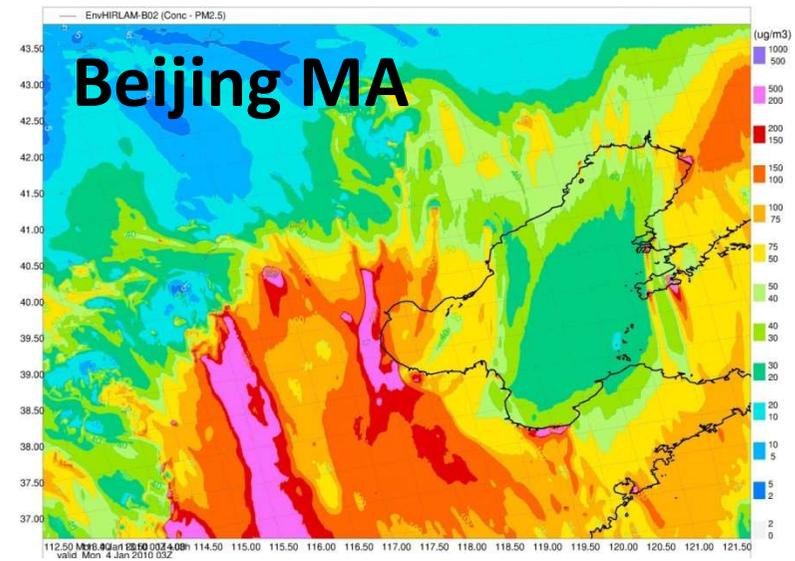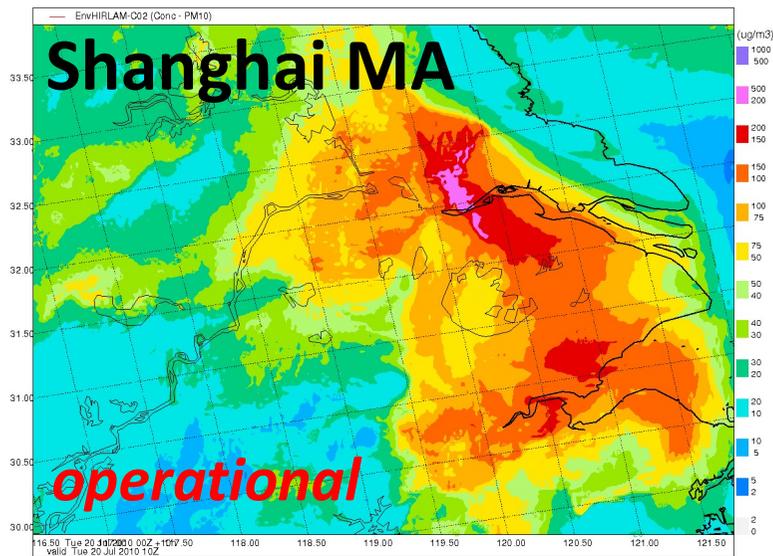
2.5km: Shanghai MA: PM10

Diurnal cycle: 20 Jul 2010
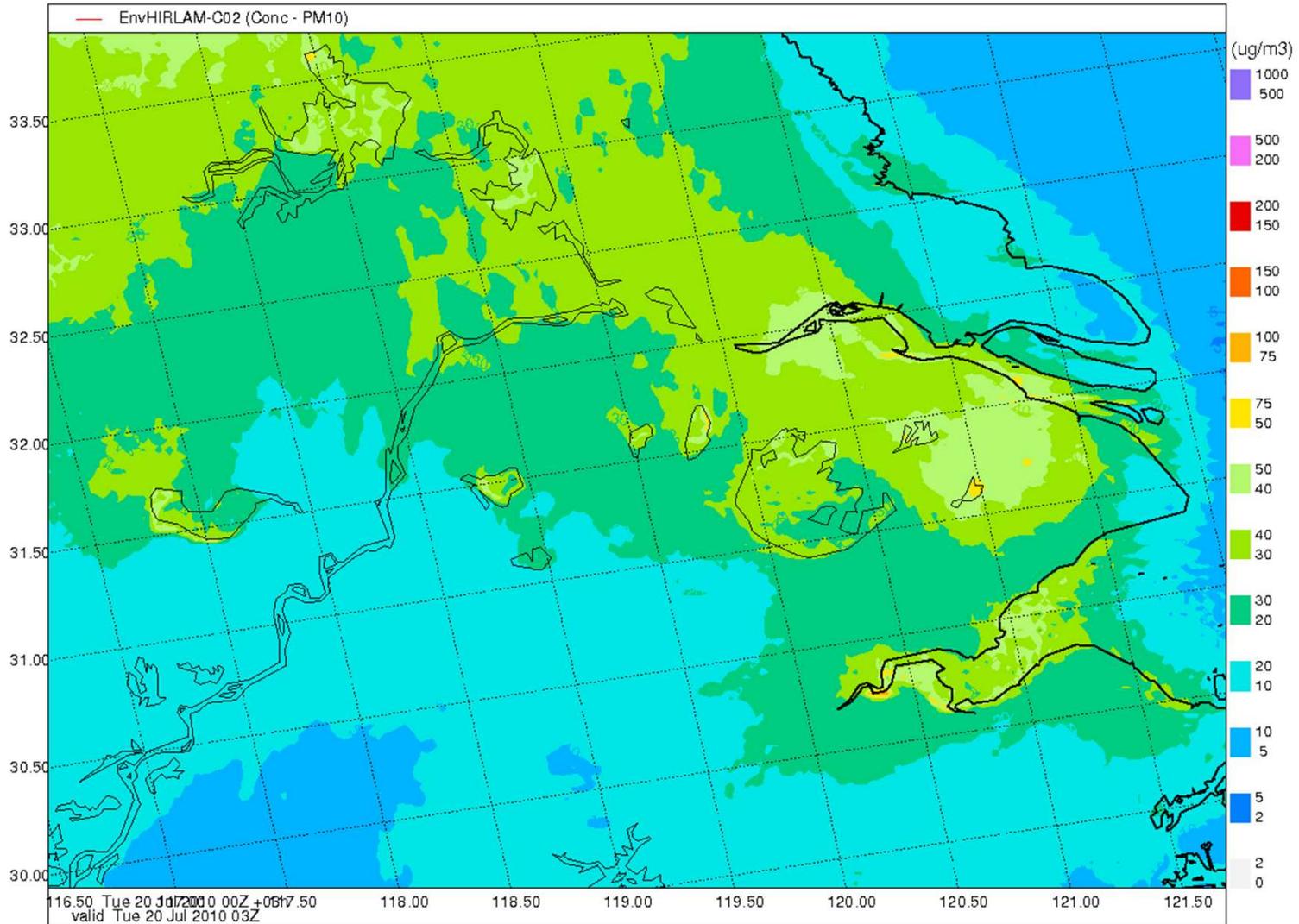
Enviro-HIRLAM:
science education and training

Enviro-HIRLAM/ HARMONIE (EnviroHH)
(Collaboration, Research & Development, Science Education, Dissemination, New Products & Applications)

Young Scientist Summer Schools (YSSS) on seamless/ online integrated modelling

Research Training Weeks:
2 per year in 2008 – 2011 (last Spr 2011)

YSSS Schools on Integrated Modelling:
Jul 2008 (St. Petersburg, Russia)
http://netfam.fmi.fi/YSSS08

Jul 2011 (Odessa, Ukraine)
http://www.ysss.osenu.org.ua

Jul 2014 (Aveiro, Portugal)
http://aveirosummerschool2014.web.ua.pt

Supported by funding to:
NordForsk NetFAM & MUSCATEN,
CRAICC-PEEX, CRAICC-CRUCIAL,
COST EuMetChem Action,
TEMPUS & Erasmus+ projects
FIRST+ PEEX-AC, H2020 NTAROS & iCUPE,
AoF ClimEco and other projects

Modelling - meteorological and chemical transport processes for weather, air quality, and climate applications.

Aim – to join young researchers from the numerical weather prediction, air quality and climate communities, & to apply integrated modelling of both meteorological and chemical processes to understand the links between atmospheric composition, weather and climate.

Focus - regional/ urban scale models applied for chemical weather forecasting and feedback mechanisms between meteorological and atmospheric pollution processes.

Lectures - fundamentals of atmospheric processes and modelling, surface and boundary layer processes, atmospheric chemical transport modelling, aerosol physics-chemistry, and modelling evaluation and application.

Science Education:
Small-Scale Research Projects (SSRPs)

1) Student workbooks on SSRPs
2) Supplementary materials
3) Introduction Into Exercises
(lecture by teacher)

The Enviro-HIRLAM research trainings at RSHU:

Enviro-HIRLAM Research Training Weeks: Jun 2015 & 2017 (St. Petersburg, RSHU)

During 22-26 June 2015 the research training course (for PostDoc, PhD, MSc and advanced BSc level students) on online integrated numerical weather prediction – atmospheric chemical transport modelling with Enviro-HIRLAM (Environment HIgh Resolution Limited Area Model) was organized and carried out at RSHU. This training is integral part of the Nordic–Russian Cooperation within Top-level Research Initiative "Joint CRAICC (Cryosphere-atmosphere interactions in a changing Arctic climate) - PEEX (Pan Eurasian EXperiment; https://www.atm.helsinki.fi/peex) research and educational activity", where DMI team is involved. It is performed to strengthen collaboration and build direct links between PEEX Nordic and Russian key investigators and involved institutes; to make design enabling longer-term top-level research activities within PEEX framework; and to establish student training and short-term exchange between institutes.

The event took place at Russian State Hydrometeorological University (RSHU). Drs. Alexander Mahura (DMI) and Suleiman Mostamandy (RSHU) carried out the training. In total 17 applicants successfully completed training (with certificates). Training was based on Young Scientist Summer Schools (YSSS, latest – Jul 2015; http://aveirosummerschool2014.web.ua.pt) experience with realization of small-scale research projects (SSRP) – in this case the Urban Exercise "Impact of Metropolitan Areas on Meteorology". Training format included lecturing, modelling, visualization and data analysis, discussions, work under supervision and independently, synergy of results, students' presentations. The course content included: lecturing on physiographic information: treatment of land-cover/use and urbanization of NWP models; introduction into exercise with background discussions; analysis of meteorological situations for selected dates; technical aspects of modelling and urban modules implementation; Enviro-HIRLAM model runs for selected dates/cases and different schemes of urbanization; visualization of model output/ results employing Metgraf/ Grads; analysis of urban area impact on meteorology (and chemistry); oral presentation of SSRP results (project defence). All necessary materials (lectures, workbook/booklet on SSRP, atlas with meteorological situations, etc.) were freely distributed among students. Training was done in dual English/Russian languages.

During 26 Jun – 1 Jul 2017 the research training course on seamless/ online integrated meteorology-chemistry-aerosols modelling with the Enviro-HIRLAM (Environment - High Resolution Limited Area Model) for numerical weather prediction and environmental applications was organized and carried out at the Russian State Hydrometeorological University (RSHU, St. Petersburg, Russia). This training is part of the Nordic–Russian cooperation within joint CRAICC (Cryosphere-atmosphere interactions in a changing Arctic climate) – CRUCIAL (Critical steps in understanding land surface – atmosphere interactions: from improved knowledge to socio-economic solutions) project as integral part of the PEEX Programme (Pan Eurasian EXperiment; https://www.atm.helsinki.fi/peex) research and educational activity. It is performed to strengthen collaboration and build direct links between PEEX Nordic and Russian key investigators and involved institutes; to make design enabling longer-term top-level research activities within PEEX framework; and to establish student training and short-term exchange between institutes.

Drs. Alexander Mahura (University of Helsinki, Finland), Roman Nuterman (University of Copenhagen, Denmark), Anders Persson (University of Uppsala, Sweden) and Eduard Podgaiskii (RSHU) have organized and carried out the training. Training was based on experience of the Young Scientist Summer Schools (YSSS, latest – Jul 2014; http://aveirosummerschool2014.web.ua.pt) and Enviro-HIRLAM Research Training weeks (latest at RSHU – Jun 2015) with realization of small-scale research projects (SSRP). In this case the advanced approach was taken and SSRP projects included 3 main blocks based on the Enviro-HIRLAM model simulations: 1) Impact of metropolitan areas at fine scale on meteorology (with focus on Paris, France), 2) Impact of aerosols at regional scale on meteorology (with focus on St. Petersburg, Russia), 3) Operational meteorology and atmospheric composition forecasting for environmental applications (with focus on Shanghai, China). Training format included lecturing, aspects of modelling, visualization and data analysis of model results, discussions, student's work under supervision and independently, synergy of results, students' presentations.

The course content included the lecturing on advantages of on-line/ seamless modelling; Enviro-HIRLAM model schematics, structure, components, downscaling, collaboration, research and development, science education, dissemination, new products and applications; urban areas and their characteristics, urban boundary layer, approaches and treatment of land-cover/use and urbanization of the models; urban lands, urban districts in metropolitan areas: classification and characteristics; global aerosol cycles, aerosols feedbacks, emissions, aerosol microphysics and implementation in the models; examples of Enviro-HIRLAM applications for Copenhagen, Paris, Shanghai and their metropolitan areas (from completed research projects), computational requirements and resources for operational runs. The lecturing also included a series of educational lectures on the monitoring of the ECMWF forecast system; group velocity thinking (in contrast to PV-thinking); statistical verification and validation of NWP systems; Kalman filtering of operational NWP; Bayesian statistics; Coriolis force and Coriolis effect; questions of concern and importance for dynamical meteorology. In addition, the seminar "Whole atmosphere model predictions with specified meteorology" was given by Dr. Valery Yudin (NCAR, Boulder, USA).

Practical realization of the SSRPs included introduction into exercises with background discussions; analysis of meteorological situations for selected dates; technical aspects of modelling and urban and aerosol modules implementation; analysis of Enviro-HIRLAM model runs for selected dates/cases and different modules; visualization of model output/ results; analysis of urban areas and aerosols impact on meteorology; oral presentation of SSRP results (project defence). All necessary materials (such as lectures notes, workbook on SSRP, supplementary materials, etc.) were freely distributed among the participants (http://rus.ums.rshu.ru/news/EnviroHIRLAM-HARMONIE2017). Training course was done in dual languages - English (lecturing) / Russian (practical exercises and discussions).

The students, whom have attended the lectures, realized all 3 main blocks of the research projects and successfully defended these projects with oral presentations, were awarded the research training certificates.

Especial thanks to the local RSHU organizers – Anastasia Kaptsova (International Relations Office) & Profs. Sergey Smyshlayev and Alexander Pogoreltsev (Department of Meteorological Forecasting)

& Planned 2020 trainings: *in St.Petersburg (RSHU) & Moscow (Moscow State University)*
FIRST+ & Erasmus+ Global Mobilities for FI+RU students and teachers

The recent Enviro-HIRLAM research trainings:

Enviro-HIRLAM Research Training Week: Jun 2019 (UTMN, Tyumen, Russia)

https://www.atm.helsinki.fi/peex/index.php/education/16-courses/188-june-2019-research-training-course-seamless-online-integrated-meteorology-chemistry-aerosols-multi-scale-and-processes-modelling

During 24-29 June 2019, the Academy of Finland ClimEco project ("*Mechanisms, pathways and patchiness of the Arctic ecosystem responses and adaptation to changing climate*"; www.atm.helsinki.fi/peex/index.php/climeco) research training course on "*Seamless / Online Integrated Meteorology-Chemistry-Aerosols Multi-Scale and –Processes Modelling*" took place in the city of Tyumen (Russia) situated on banks of the beautiful Tura River. The event was organized jointly by the University of Helsinki (UHEL), the Institute for Atmospheric and Earth System Research (INAR), the Finnish Meteorological Institute (FMI), and the University of Tyumen (UTMN); and arranged in premises of the Institute of the Earth Sciences. The training was organized in order to strengthen the collaboration between Finnish and Russian key investigators and corresponding institutes in the frameworks of the ClimEco project and PEEX (Pan-Eurasian EXperiment; www.atm.helsinki.fi/peex) programme; to make a detailed design enabling a longer-term, a top-level research activities in PEEX; and to build direct links and to establish student training and short-term exchange between the institutes. One of the PEEX-Modelling-Platform (PEEX-MP; www.atm.helsinki.fi/peex/index.php/modelling-tools-demonstration) models, the Enviro-HIRLAM (*Environment - HIgh Resolution Limited Area Model*) modelling system was demonstrated and used.

The training included: lecturing with respect to theoretical and practical aspects of the Enviro-HIRLAM modelling system (with focus on research and development). The *theoretical aspects* included: weather modelling in European community; advantages/ shortcomings of on-line vs. off-line approaches; model structure, downscaling, components, schematics; specific features of urban areas and modules/ parameterizations for urbanization; land-cover and land-use classification

Planned 2020 research trainings as PEEX-AC intensive courses & YSSSs vs. COVID-19

PEEX-Academic Challenge – FIRST+ Intensive Course

"Multi-Scales and -Processes Modelling and Assessment for Environmental Applications"
Location/ Host: Russian State Hydrometeorological University (RSHU, St.Petersburg, Russia)

Timeline: 20-25 April 2020

(arrivals: Sunday, 19 Apr 2020 & Course starts from Monday, 20 Apr until Saturday, 25 Apr & departures: Sat/Sun, 25-26 Apr)

	Day 1 - 20 Apr Monday	Day 2 – 21 Apr Tuesday	Day 3 - 22 Apr Wednesday	Day 4 – 23 Apr Thursday	Day 5 – 24 Apr Friday	Day 6 – 25 Apr Saturday
08:30 – 09:15	Registration, welcome & useful info	L4. Multi-model ensembles of climate change simulations (Jouni Räisänen, UH)	L8. Physiographical data for multi-scale modelling (Alexander Mahura & Risto Makkonen, UH)	L12. Atmospheric gas-phase chemistry (Sergey Smyshlayev, RSHU)	L16. Aerosol - cloud - radiation interactions (Tuukka Petäjä, Risto Makkonen, Alexander Mahura, UH)	Exercises
09:20 – 10:05	L1. Introduction to PEEX program (Markku Kulmala, Hanna Lappalainen, UH; with focus on science education component)	L5. Numerical schemes (Maxim Motsakov, RSHU)	L9. Process-based modelling for meteorology-chemistry-aerosol System (Michael Boy, UH)	L13. Atmospheric liquid-phase chemistry (Sergey Smyshlayev, RSHU)	L17. Chemical (& meteorological) data assimilation (Polina Blakitnaya, RSHU & Michel Boy, UH)	Students oral presentations
10:05 – 10:25	Coffee/ Tea Br.	Coffee/ Tea Br.	Coffee/ Tea Br.	Coffee/ Tea Br.	Coffee/ Tea Br.	Coffee/ Tea Br.
10:25 – 11:10	L2. Numerical weather prediction and specific challenges (Sergey Smyshlayev, RSHU)	L6. Atmospheric chemical transport modelling & emissions (Sergey Smyshlayev, RSHU)	L10. Atmospheric boundary layer and dispersion processes (Sergey Zilitinkevich, UH)	L14. Aerosol particles properties (Tuukka Petäjä, UH)	L18. Evaluation of models and verification (Part 1 - meteorology) (Sergey Smyshlayev, RSHU & Risto Makkonen, Alexander Mahura, UH)	Students oral presentations
11:15 – 12:00	L3. Earth system modelling and and specific challenges (Risto Makkonen, UH)	L7. Seamless/ online integrated modelling (Alexander Mahura, UH)	L11. Atmospheric boundary layer and removal processes (Sergey Zilitinkevich, UH)	L15. Aerosol chemistry and microphysics (Tuukka Petäjä, UH)	L19. Evaluation of models and verification (Part 2 – atmospheric composition) (Sergey Smyshlayev, RSHU & Risto Makkonen, Alexander Mahura, UH)	Students oral presentations
12:00 – 13:30	Lunch	Lunch	Lunch	Lunch	Lunch	Lunch
13:30 – 14:15	Exercises	Exercises	Exercises	Exercises	Exercises	Awarding diplomas ceremony & Official closure of the Intensive Course
14:20 – 15:05	Exercises	Exercises	Exercises	Exercises	Exercises	
15:10 – 15:55	Exercises	Exercises	Exercises	Exercises	Exercises	
15:55 – 16:15	Coffee/ Tea Br.	Coffee/ Tea Br.	Coffee/ Tea Br.	Coffee/ Tea Br.	Coffee/ Tea Br.	
16:20 – 17:05	Exercises	Exercises	Exercises	Exercises	Exercises	
17:10 – 17:55	Exercises	Exercises	Exercises	Exercises	Exercises	
18:00 – 18:45	Exercises	Exercises	Exercises	Exercises	Exercises	
19:00 –	Ice Breaking Party	St.Petersburg city Excursion	Official Dinner	RSHU Excursion (after lunch)	Free Time / CitySightseeing	Free Time / CitySightseeing

COVID19 /cancelled/ --- PEEX-AC research training intensive course (host - RSHU, St.Petersburg, Russia, 20-25 April 2020)

https://www.atm.helsinki.fi/peex/index.php/education/16-courses/184-april-2020-peex-ac-research-training-intensive-course

COVID19 /cancelled/ --- AoF ClimEco & RSF MegaCity Young Scientist Summer School (host - MSU, Moscow, Russia, 27 Jul – 7 Aug 2020)

https://www.atm.helsinki.fi/peex/index.php/education/16-courses/185-jul-aug-2020-young-scientist-summer-school-on-multi-scales-and-processes-integrated-modelling-observations-and-assessment-for-environmental-applications

	Practical exercises: as Small-Scale Research Projects (SSRP) on seamless/ online integrated meteorology-chemistry-aerosols multi-scale and – multi-processes Enviro-HIRLAM, EC-Earth, MALTE-Box modelling for environmental applications (4-5 students per project) led by teachers (whom designed and realized the exercise – Michael Boy, Alexander Mahura, Risto Makkonen, Univ Helsinki) from 1st day till official oral presentation/ defence of SSRP outcomes)
	Socializing events: for participants - 1) Ice-Breaking Party, 2) Official Dinner, 3) Excursion to the City of St.Petersburg, 4) Excursion to RSHU University (will be organized after the lunch (for appx. 1-2 h period) and then exercises will be continued), and 5) Free Time / City Sightseeing
	Lectures covering aspects of: Fundamentals of atmospheric processes and modelling, surface and atmospheric boundary layer processes, atmospheric chemical transport modelling, aerosol physics and chemistry and modelling, evaluation and application
	Finals: Oral presentations & defence of SSRP – with awarding diplomas (3 ETCS) ceremony for students successfully presented and defended their projects, and official closure of the intensive training