Student/ Group - First Name, Surname

Small-Scale Research Project (SSRP) – Exercise

Metropolitan Areas: Influence on Meteorology & Atmospheric Composition

Teacher: Alexander Mahura

Model: Enviro-HIRLAM

20-25 April 2020
St. Petersburg, Russia

Russian State Hydrometeorological University (RSHU)

Content

1. EXERCISE – Small-Scale Research Project (SSRP): General Information

Metropolitan Areas: Influence on Meteorology & Atmospheric Composition Patterns

Model used: **Enviro-HIRLAM**

Read, general description of the NWP-ACT Enviro-HIRLAM (Environment - HIgh Resolution Limited Area Model) modelling system at:
https://www.geosci-model-dev.net/10/2971/2017/
See for more details the scientific documentation on the NWP HIRLAM model at:
http://www.hirlam.org/index.php/hirlam-documentation/doc_download/270-hirlam-scientific-documentation-december-2002

Teacher: **Alexander Mahura**

Introduction Background:
Urbanization is considered as one of important steps for improvement of numerical weather forecasts in the metropolitan areas and surroundings. This has been also included into the Enviro-HIRLAM model developments, because due to rapidly extending urban areas, the impact of cities on the formation of meteorological fields became more evident. Since the urban areas change diurnal cycles of temperature, wind characteristics, humidity, etc., and hence, these influence the quality of forecasts from the numerical weather prediction (NWP) models. To improve forecasting, modifications of the land surface scheme of the model are required and for Enviro-HIRLAM these modifications include the following:

- Changes in anthropogenic heat flux, roughness, and albedo (AHF+R+A) characteristics in urban areas can be used for grid cells of modelling domain which are attributed to urban areas;
- Effects of buildings and street canyons can be implemented through the building effect parameterization (BEP) module;
- Re-classified land-use with respect to urban types of surfaces (such as buildings, artificial surfaces with/without vegetation, etc.) and urban districts with detailed morphological characteristics can be included through the soil model for sub-meso scales urban version (SM2-U) module.

These approaches (to study possible urban effects on meteorological patterns and atmospheric composition) have been tested & evaluated for the model for both specific case (related to low, typical, & high winds conditions) & long-term studies.

Main Goal:
Study influence of the selected metropolitan area on a formation of meteorological fields above the urban area and surroundings due to modification of the land surface scheme of the numerical weather prediction (NWP) model by analysis of temporal and spatial variability of diurnal cycle for meteorological variables of key importance.

Specific Objectives:
1. Modify the land surface scheme of the Enviro-HIRLAM model: (i) by changing the AHF+R+A - (a) anthropogenic heat flux, (b) roughness, and (c) albedo for urban grid cells; and (ii) by implementation the BEP (Building Effects Parameterization) module;

2. Perform simulations for selected specific cases/dates (meteorological conditions with dominating low and typical wind conditions over the metropolitan area and surroundings) in two modes - the control run and the modified run (with changes: AHF+R+A vs. BEP);
3. Evaluate diurnal cycle variability for – (a) air temperature, (b) wind velocity, (c) relative humidity, (d) sensible heat flux, (e) latent heat flux, and etc. – for two types of runs; estimate extension and direction of boundaries under influence of metropolitan areas, magnitude and signs of changes due to urban areas, etc.;
4. Summaries findings and results of the exercise in a form of an oral presentation (max 15 minutes).

Literature List:

Before the course, the students should read, at least, the required publications; the other papers are highly recommended to read to be useful for the discussions/talks; the additional readings might be useful too (but not obligatory).

REQUIRED READINGS

*Baklanov, A., Smith Korsholm, U., Nuterman, R., Mahura, A., Nielsen, K. P., Sass, B. H., Rasmussen, A., Zakey, A., Kaas, E., Kurganskiy, A., Sørensen, B., and González-Aparicio, I. (**2017**): Enviro-HIRLAM online integrated meteorology–chemistry modelling system: strategy, methodology, developments and applications (v7.2), Geosci. Model Dev., 10, 2971-2999, https://doi.org/10.5194/gmd-10-2971-2017, 2017. https://www.geosci-model-dev.net/10/2971/2017/*

RECOMMENDED READINGS

*Baklanov A., P. Mestayer, A. Clappier, S. Zilitinkevich, S. Joffre, A. Mahura, N.W. Nielsen, **2008**: Towards improving the simulation of meteorological fields in urban areas through updated/advanced surface fluxes description. Atmos. Chem. Phys., 8: 523-543.*

*Baklanov A., Mahura A., Nielsen N.W., C. Petersen, **2005**: Approaches for urbanization of DMI–HIRLAM NWP model. HIRLAM Newsletter **49**: 61-75.*

*Mahura A., Petersen C., Baklanov A., B. Amstrup, U.S. Korsholm, K. Sattler, **2008**: Verification of long-term DMI–HIRLAM NWP model runs using urbanization and building effect parameterization modules. HIRLAM Newsletter **53**: 50-60.*

*Martilli, A., Clappier, A., and Rotach, M. W., **2002**: An Urban Surface Exchange Parameterisation for Mesoscale Models, Boundary-Layer Meteorol. 104: 261-304.*

*Dupont S., P. Mestayer, **2006a**: Parameterization of the Urban Energy Budget with the Submesoscale Soil Model. J. of Appl. Meteor. and Climat., 45: 1744-1765.*

*Dupont S., P.G. Mestayer, E. Guilloteau, E. Berthier, H. Andrieu, **2006b**: Parameterization of the Urban Water Budget with the Submesoscale Soil Model. J. of Appl. Meteor. and Climat., 45: 624-648.*

ADDITIONAL READINGS:

*Mahura A., S. Leroyer, P. Mestayer, I. Calmet, S. Dupont, N. Long, A. Baklanov, C. Petersen, K. Sattler, N. W. Nielsen, **2005**: Large eddy simulation of urban features for Copenhagen metropolitan area. Atmos. Chem. Phys. Discuss., 5: 11183–11213.*

*Korsholm U.S., A. Baklanov, A. Gross, A. Mahura, B.H. Sass and E. Kaas, **2008**: Online coupled chemical weather forecasting based on HIRLAM – overview and prospective of Enviro-HIRLAM. HIRLAM Newsletter, **54**: 1-17.*

2. Schedule for the Research Training – Small-Scale Research Projects/ Exercises

Day	Period	Total time	Topics to be discussed	Runs	Comments	Assistance
(1) Monday	13:30-18:00+	4 h +	Enviro-HIRLAM introduction / Part 1 INTRODUCTION into exercise / SSRP SELECTION of specific dates/periods TECHNICAL PREPARATION for runs OUTLINE/PLAN of research project + ***INDEPENDENT WORK***	Remote / Local runs: HPC/ Cluster	Lecturing Select date/periods for runs Check implementation Test runs on computer Make presentation on project tasks	Teacher
(2) Tuesday	13:30-18:00+	4 h +	Enviro-HIRLAM introduction / Part 2 Research project OUTLINE/TASKS Demo MODEL RUNS at HPC/computer VISUALIZATION of modelling outputs ANALYSIS of modelling results + ***INDEPENDENT WORK***	Remote / Local runs: HPC/ Cluster	Lecturing Students present project outline/tasks Test & continue runs on computer Start visualization Start analysis	Teacher
(3) Wednesday	13:30-18:00+	4 h +	Enviro-HIRLAM introduction / Part 3 Demo MODEL RUNS at HPC/computer VISUALIZATION of modelling outputs ANALYSIS of modelling results + ***INDEPENDENT WORK***	Remote / Local runs: HPC/ Cluster	Lecturing Continue runs on computer Continue visualization Continue analysis	Teacher
(4) Thursday	13:30-18:00+	4 h +	Enviro-HIRLAM introduction / Part 4 Demo MODEL RUNS at computer VISUALIZATION of modelling outputs ANALYSIS of modelling results ORAL PRESENTATION preparation + ***INDEPENDENT WORK***	Remote / Local runs: HPC/ Cluster	Lecturing Finish runs on computer Continue visualization Continue analysis Draft presentation	Teacher
(5) Friday	13:30-18:00+	4 h +	+ ***INDEPENDENT WORK*** ANALYSIS of modelling results ORAL PRESENTATION preparation		Finalize analysis Finalize presentation Students practice pres. results	Teacher
(6) Saturday	08:30-09:15+ 09:20-12:00+	4 h +	Final practicing on presentation SSRP ORAL PRESENTATION	Defence of small-scale research project (SSRP) Awarding diploma/ certificates		

3. Items of the SSRP/ Exercise

Introduction into Exercise (Background Discussions)

Introduction into the urban exercise; main items of the exercise (selection of dates, technical aspects and implementations, runs, visualization and analysis of results, making presentation); brainstorming for both teams/groups to outline research and technical tasks required (including main goal, specific objectives, etc.) within groups, etc.

Make a link with consultants (lectors) asking theoretical questions and consider an exchange between teams of students – as research groups - during the exercise; additional talks/discussions on urbanization aspects including (*see Annexes A1-A7*):

- *A1. Enviro-HIRLAM: Numerical Weather Prediction (NWP) – Atmospheric Chemical Transport (ACT) Online Integrated Modeling System*
- *A2. Pan-Eurasian EXperiment Modelling-Platform (PEEX-MP) – seamless approach & models as research tools*
- *A3. Enviro-HIRLAM components (gas-phase chemistry, aerosols, dry/wet deposition, emissions, etc.) & downscaling (regional-subregional-urban scales)*
- *A4. Hierarchy of urbanization approaches/ modules*
- *A5. Anthropogenic heat fluxes*
- *A6. Urban/city scale modelling (modules: BEP - Building Effect Parameterization & SM2-U - soil Model for Sub-Meso scales Urbanized version)*
- *A7. Urban districts (on examples for selected metropolitan areas)*
- *A8. Characteristics of districts (on example of Paris)*

Meteorological situations for selected cases/ dates

Analyze meteorological conditions in the modelling domain over the urban area and surroundings for given dates/periods using available surface maps, diagrams of vertical sounding, and surface meteorological measurements (with data provided from the meteorological archives). Select the specific date/ period (to be used in runs) and make/write a general summary of meteorological conditions (to be used in final oral presentation by the team).

Searching and analyzing of supplementary material for the exercise (meteorological conditions for specific dates/periods):

- *http://weather.uwyo.edu/upperair/sounding.html - Vertical sounding (by stations/ regions) – since 1974*
- *http://weather.uwyo.edu/upperair/uamap.shtml - Upper air maps (Observations/ Analysis/ Levels/ Regions) – since 2012*

Technical aspects of modelling and urban implementation

Learn practical technical steps/ tasks / activities in order to make necessary changes in the Enviro-HIRLAM code, implementation of the urban effects (AHF, R, BEP) compile the executable, run the model at different options, save generated output, etc. (*see Annexes B1-B3*):

- *B1. Model – Preparations, Setups & Runs*
- *B2. Urban Implementation - AHF, R, BEP*
- *B3. Call-Tree for BEP Implementation*

Model runs

Perform simulations (note: use maximum forecast length as 24 hours) for the selected dates/periods for different options of urbanization (AHF, R, BEP), estimate computational times for different runs. Note, all simulations with the Enviro-HIRLAM model are with downscaling (regional-subregional-urban) to high horizontal grid resolution; as well as *see Annexes B1-B3*:

- *B1. Model – Preparations, Setups & Runs*
- *B2. Urban Implementation - AHF, R, BEP*
- *B3. Call-Tree for BEP Implementation*

Possible Enviro-HIRLAM runs for SSRPs/ exercises could be the following:

- Control (reference) run – without any modifications;
- Runs with different time steps (30, 60, 90, 120, 240, 360 sec) to select best suitable / optimal;
- Runs with different anthropogenic heat fluxes (AHF: 50, 100, 150, 200, 250 W/m^2) for urban areas (grid cells);
- Runs with extremely high AHF /unrealistic: 500 W/m^2/;
- Runs with modified roughness (R) for urban areas;
- Runs with both modified AHF and R (AHF+R) for urban areas;
- Runs with including building effects (building effects parameterization (BEP) module);
- Runs with other combinations.

Visualization of results

Learn on how to use the METGRAF software in order to plot results of simulations in different forms (see Annex C1-C2):

- *Parameter database (200+ meteorological variables and derived ones): http://apps.ecmwf.int/codes/grib/param-db http://hirlam.org (registration is required)*
- *C1. Visualization of results*
- *C2. Examples of visualizations*

Urban impact on meteorology and atmospheric composition: analysis

Analyze and evaluate possible impact of the urban areas on temporal and spatial variability of the simulated meteorological fields for selected meteorological parameters, for example: air temperature, wind speed, relative humidity, sensible heat flux, latent heat flux, and etc; evaluate diurnal cycle variability for analyzed parameters – for two types of runs – control vs. modified (urban); estimate extension and direction of boundaries under influence of metropolitan areas, magnitude and signs of changes due to urban areas, etc.;

- *C2 – Examples of visualization*

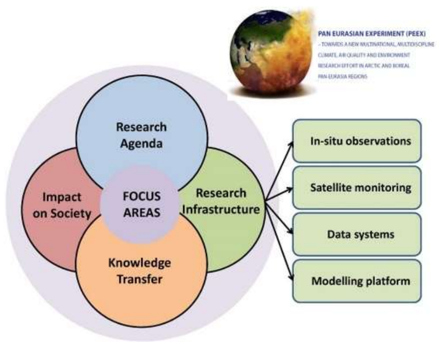
Team presentation

Make your team oral (using any application, preferably MS Power Point) presentation about findings and results obtained; follow guidelines of the presentation, which should, at least, include the title, main aim and specific objectives, methodology and approaches, results and discussions with examples, conclusions, acknowledgements, references, etc.

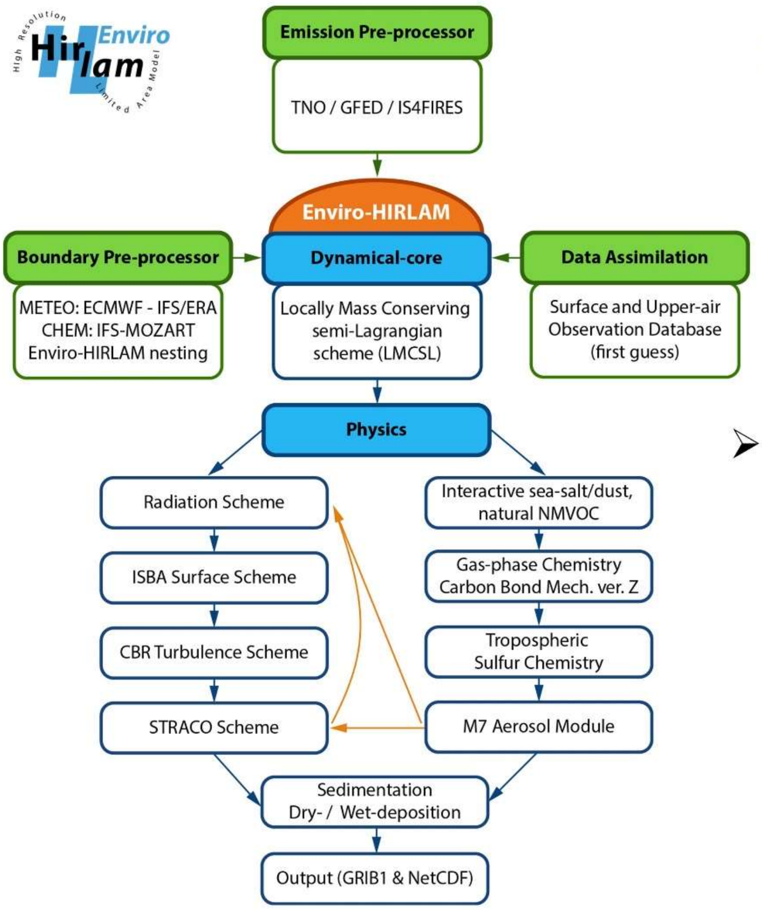
A1. Enviro-HIRLAM: NWP–ACT Modeling System

Enviro-HIRLAM/ HARMONIE (EnviroHH)

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



Enviro-HIRLAM linkage to the PEEX-Modelling Platform



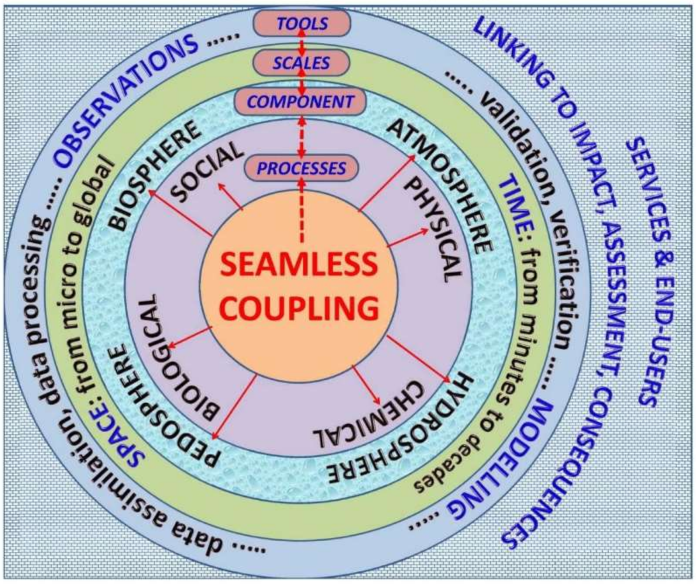
Enviro-HIRLAM (Environment – HIgh Resolution Limited Area Model)

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

(Baklanov et al., 2017)

A2. PEEX-Modelling-Platform (PEEX-MP)

Seamless approach considers several dimensions of the coupling



i) **Time scales** (from minutes and nowcasting till decades and climate time-scale);

ii) **Spatial scales** (from street till global scales with downscaling and upscaling methods);

iii) **Processes**: physical, chemical, biological, and social;

iv) **Earth system components**: atmosphere, hydrosphere, pedosphere, ecosystems/ biosphere;

v) Different types of **observations** and **modelling tools**: data processing and data assimilation, validation and verification of modelling results; and

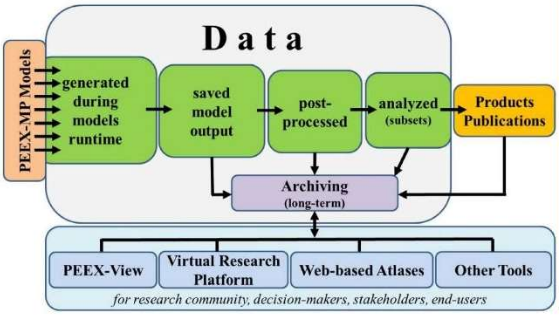
vi) **User-oriented** integrated systems and **impact based forecasts and services.**

=> New generation of seamless models integrated with observations

PEEX-MP Models as Research Tools

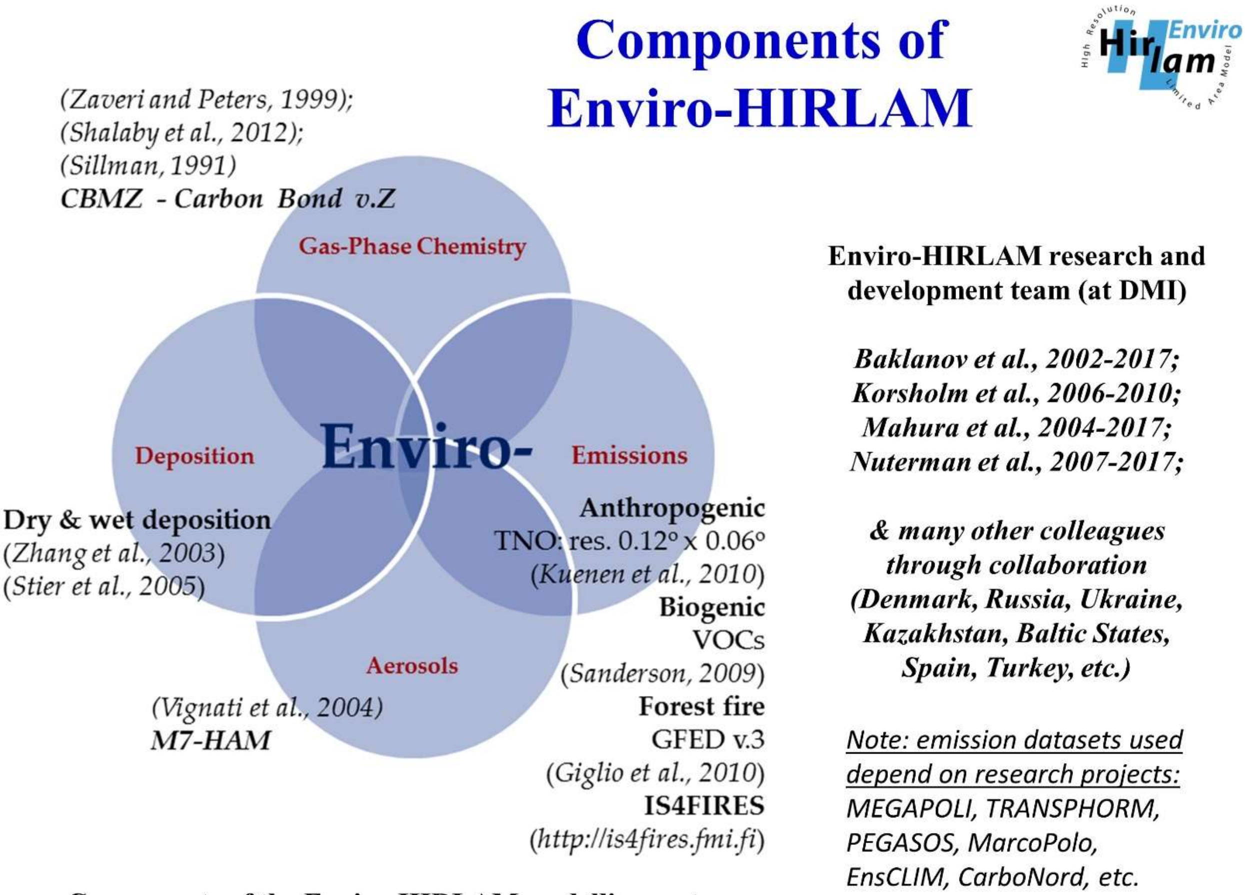
https://www.atm.helsinki.fi/peex/index.php/modelling-platform

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

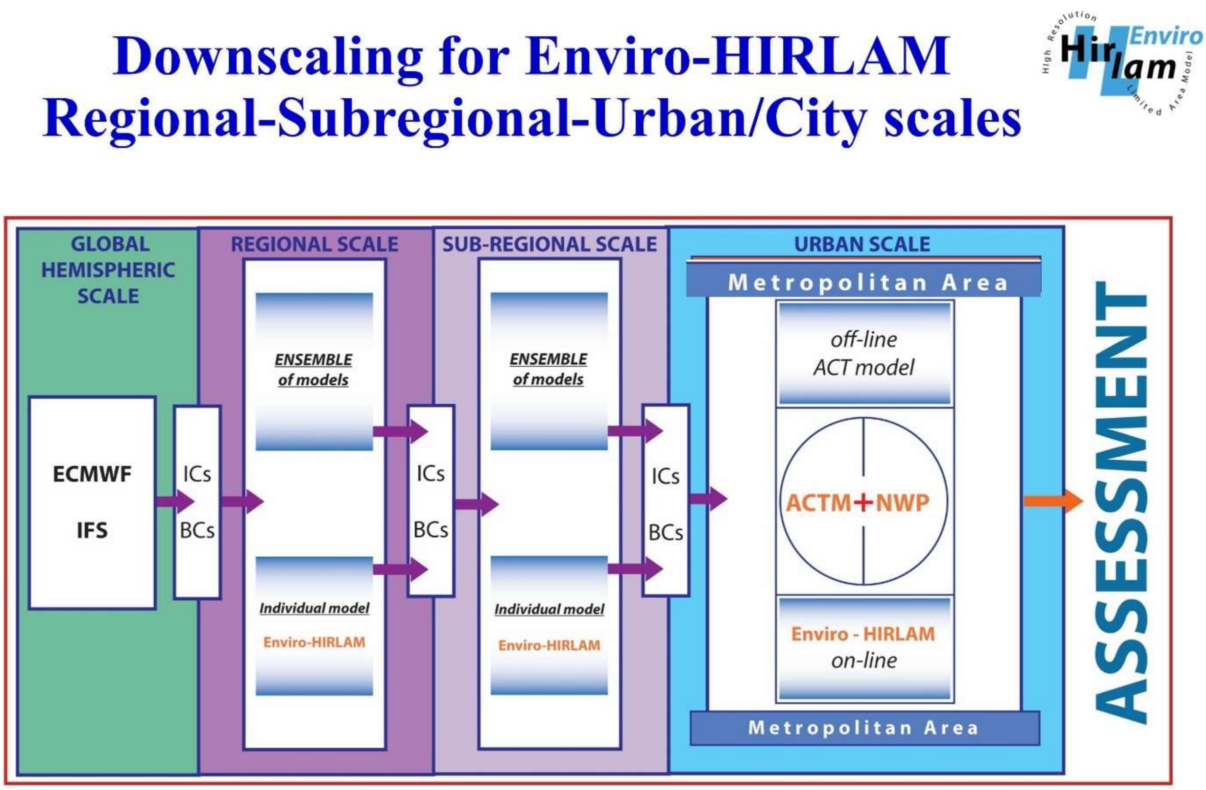


ATMOSPHERE	HYDROSPHERE	PEDOSPHERE	BIOSPHERE	PHYSICAL	CHEMICAL	BIOLOGICAL	PEEX-MP Models
XXX				XXX	XXX		HadGEM2-ES
XXX	XXX	XXX		XXX	XXX		Enviro-HIRLAM
XXX	XXX		XXX	XXX	XXX	XXX	SILAM
XXX	XXX			XXX	XXX		FLEXPART
XXX				XXX	XXX		DERMA
XXX	XXX		XXX	XXX	XXX	XXX	SOSAA
	XXX			XXX			HYCOM-CICE
XXX			XXX	XXX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

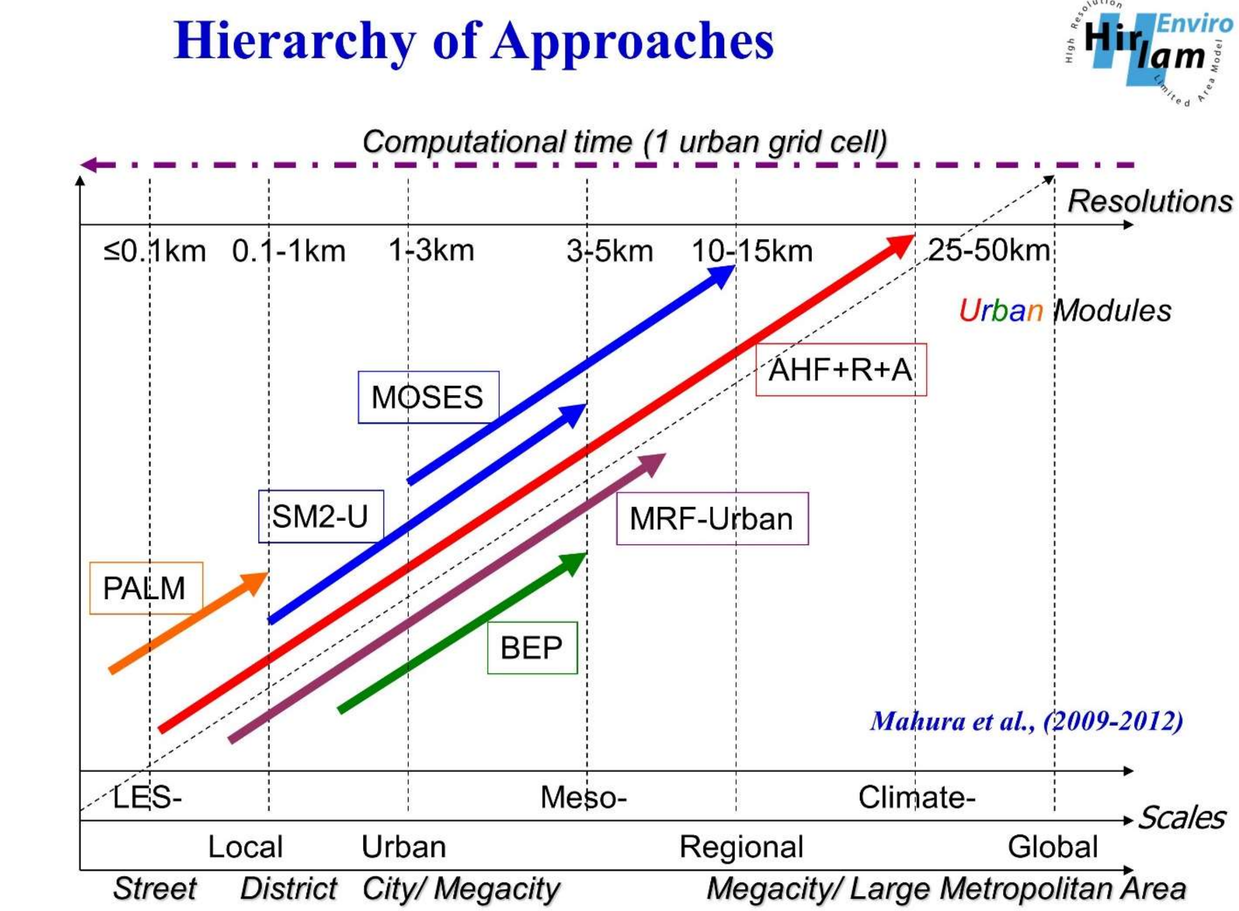
A3. Enviro-HIRLAM: Components & Downscaling

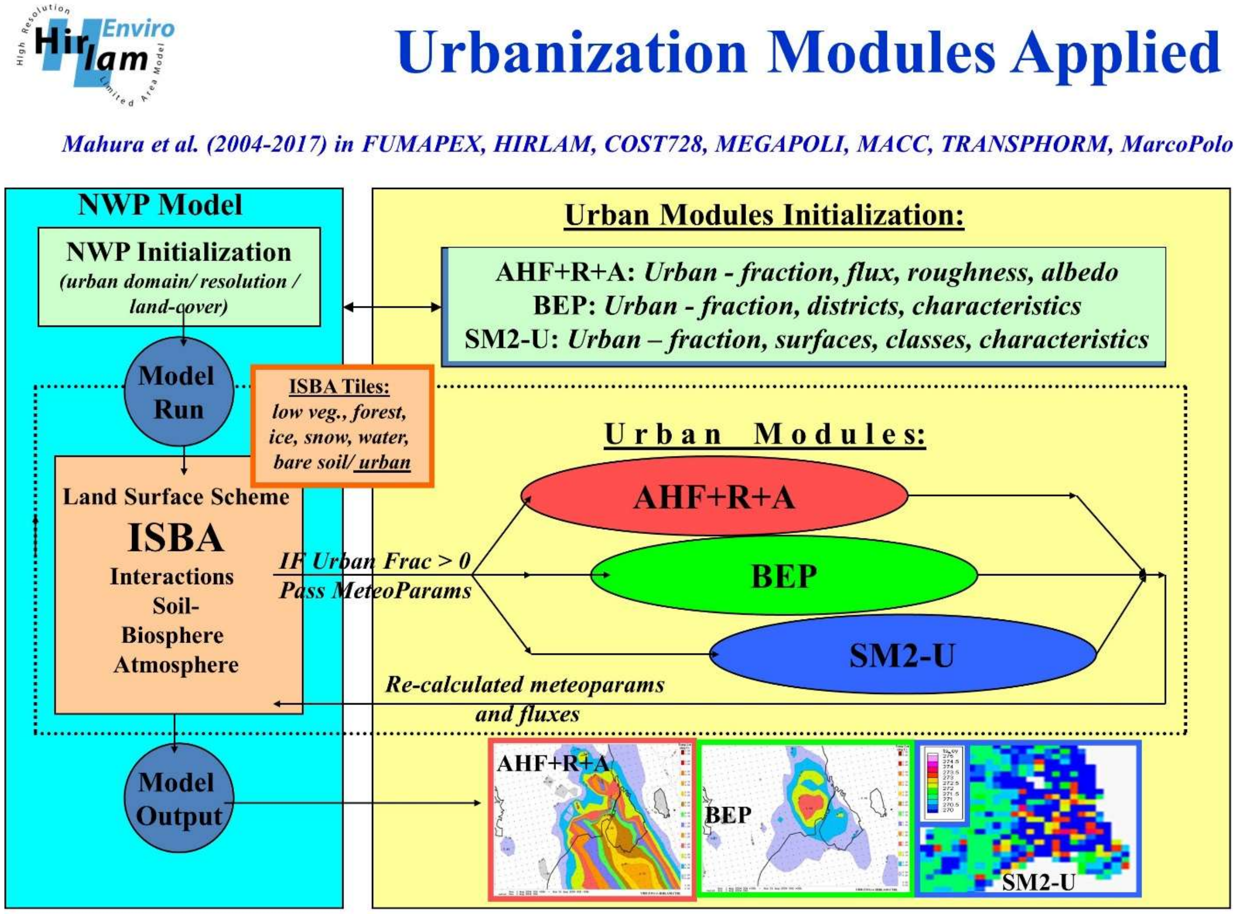


Components of the Enviro-HIRLAM modelling system



A4. Hierarchy of urbanization approaches/ modules



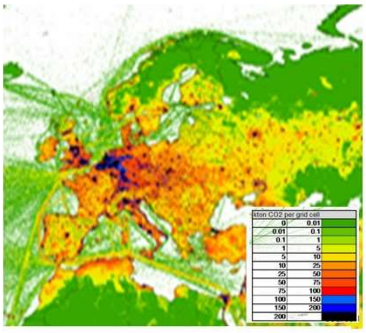


A5. Anthropogenic heat fluxes

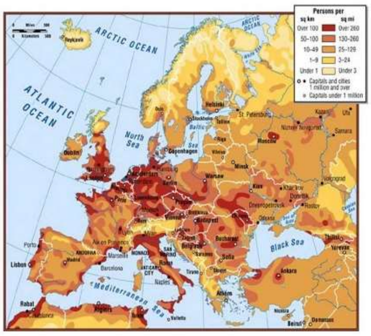
Anthropogenic Heat Flux in Urban Areas (AHF)

can be estimated based on assumption of dependency/ proportionality to other urban characteristics

- **Population density maps with a high resolution in urban areas;**
- **Satellite images of the night lightness over urban areas (but difficulties to use for industrial and developing countries, should be corrected);**
- **Land-use classification as a percentage of urban classes (central part, urban, sub-urban, industrial, etc.);**
- **Emission inventory for specific pollutants typical for urban areas (e.g., due to traffic emission, etc.);**
- **Monitoring or simulation of concentration fields for specific air pollutants typical for urban areas.**

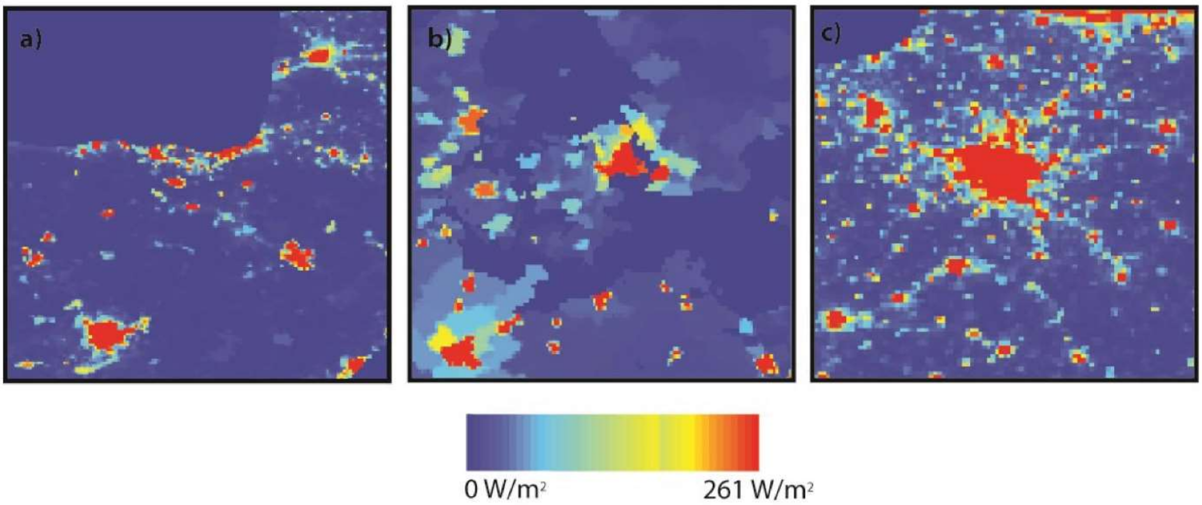


http://edgar.jrc.ec.ec.europa.eu



http://spworldstudiescp.wordpress.com

AHF - Anthropogenic Heat Fluxes

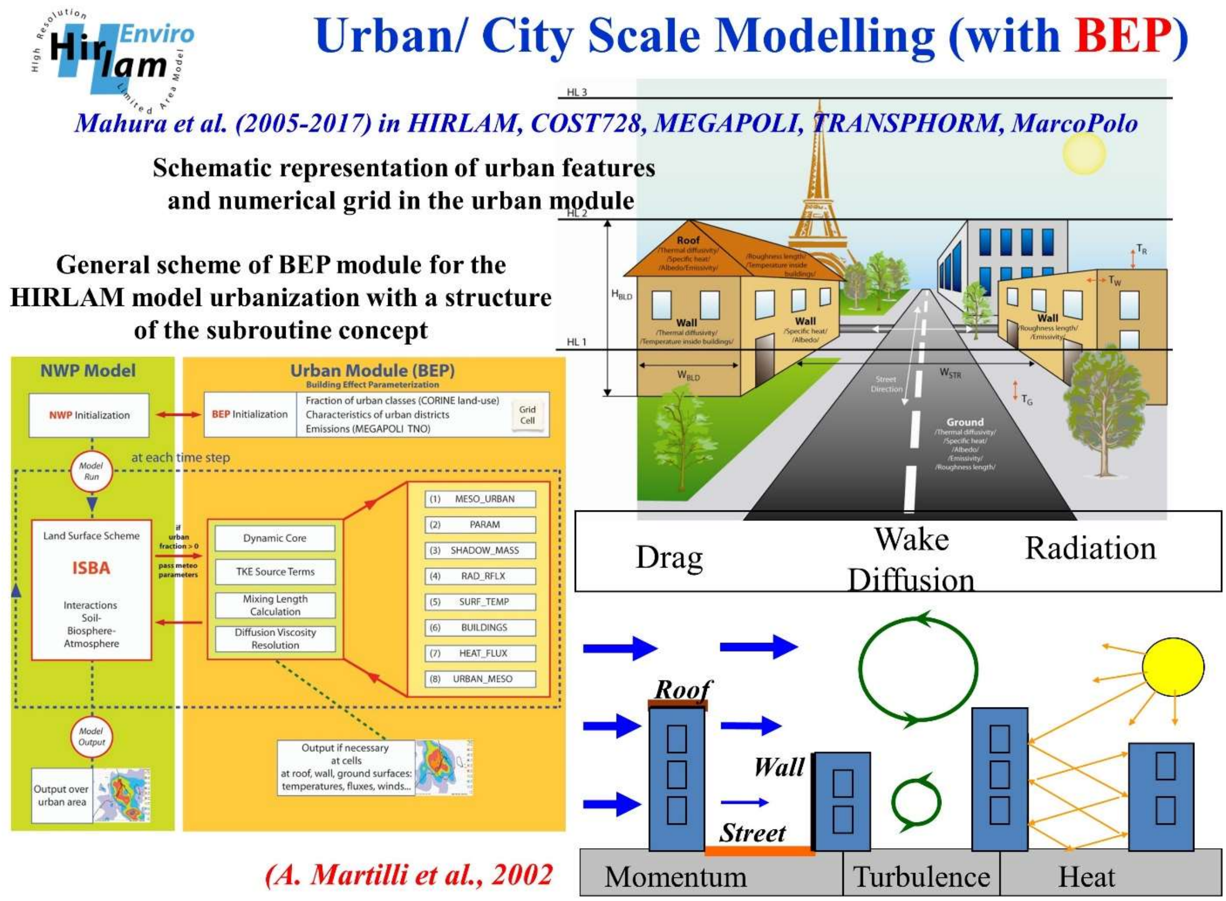


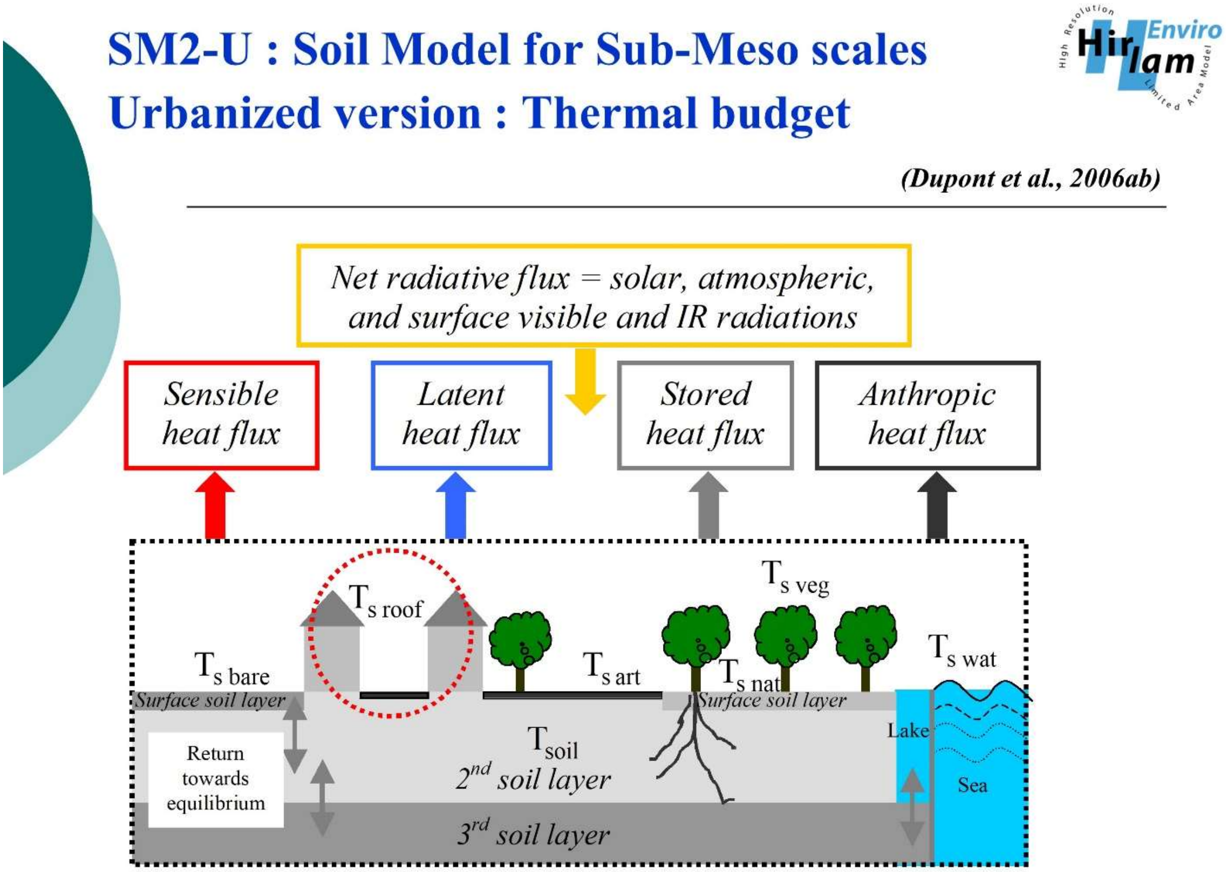
(a) (b) (c)

Figure: Athropogenic heat fluxes (in W/m^2) for 2005 based on extracted from the LUCY model for the: (a) Bilbao; (b) Copenhagen, and (c) Paris metropolitan areas.

*Allen L., S. Beevers, F. Lindberg, Mario Iamarino, N. Kitiwiroon, CSB Grimmond (**2010**): Global to City Scale Urban Anthropogenic Heat Flux: Model and Variability. Deliverable 1.4, MEGAPOLI Scientific Report 10-01, MEGAPOLI-04-REP-2010-03, 87p, ISBN: 978-87-992924-4-8;* http://megapoli.dmi.dk/publ/MEGAPOLI_sr10-01.pdf

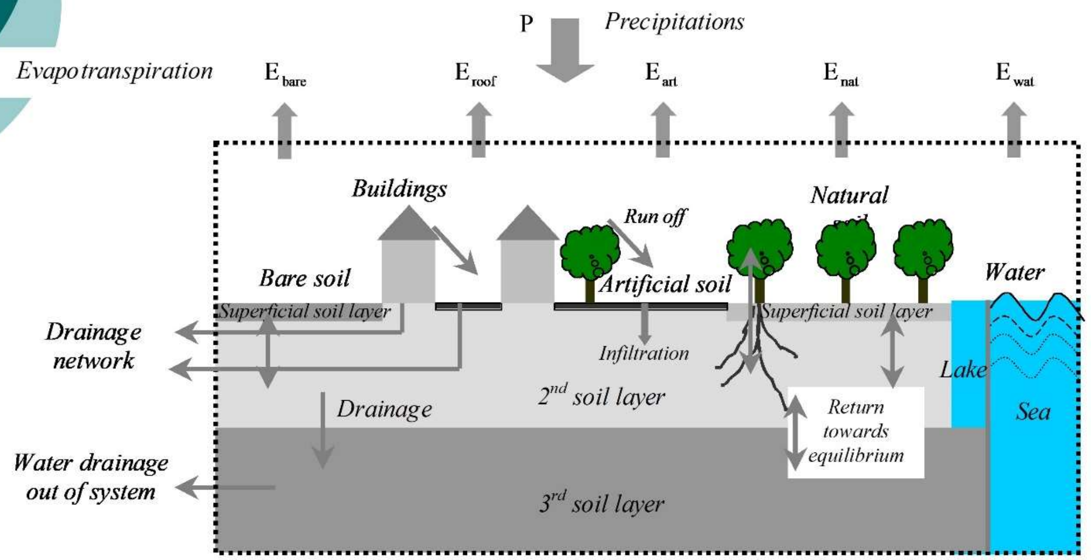
A6. Urban/city scale modelling (BEP & SM2-U)





SM2-U : Soil Model for Sub-Meso scales Urbanized version : Water budget

(Dupont et al., 2006ab)



A7. Urban districts

Urban Districts in Metropolitan Areas: Classification & Characteristics

Residential (RD)

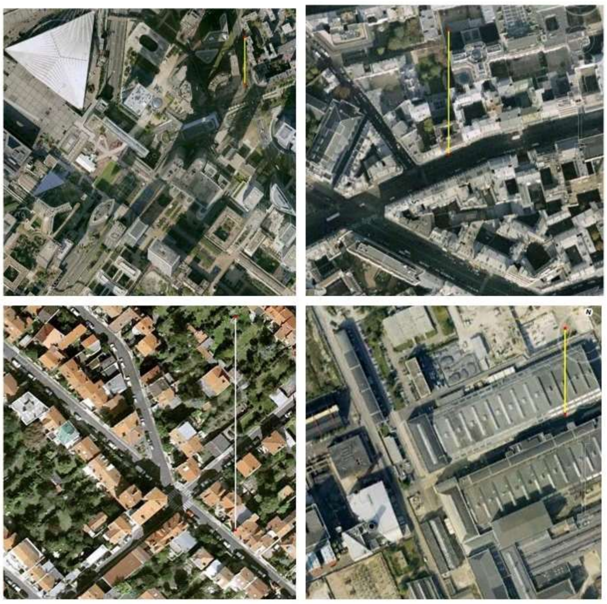
City Center/High Buildings District (CC/HBD)

Industrial Commercial (ICD)

GIS - Extraction of districts related characteristics (statistics):

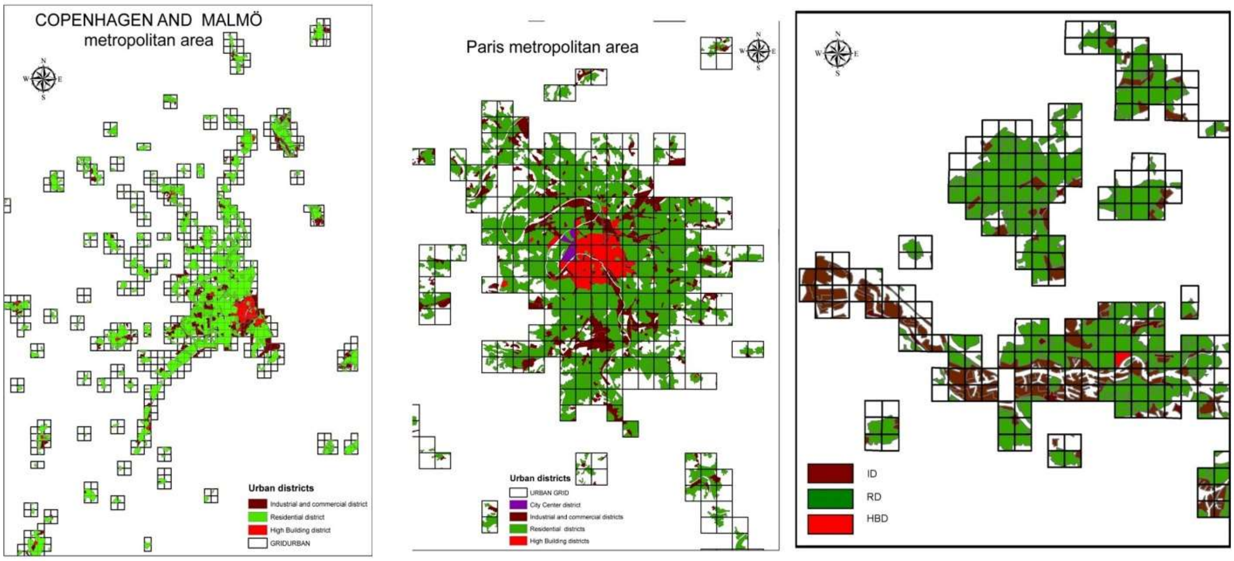
- ***Morphology parameters*** **(avg. height, volume, perimeter, compactness, space between buildings)**
- ***Cover modes*** **(surface density (SD) of buildings, of vegetation, hydrography, roads, N buildings)**
- ***Aerodynamic parameters*** **(roughness length, displacement height, frontal and lateral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

City Center | **High Buildings District**



Residential District | **Industrial Commercial District**

Urban Districts in Metropolitan Areas: Classification & Characteristics



Copenhagen (Denmark) **Paris (France)** **Rotterdam (The Netherlands)**

Metropolitan Areas

Revised Land-Use Classification for SM2-U (Types of Surfaces)

BARE	Bare soil without vegetation
NAT	Bare soil located between sparse vegetation elements
VEGN	Vegetation over bare soil
VEGA	Vegetation over paved surfaces
ART	Paved surfaces located between the sparse vegetation elements
BAT	Building/roofs
EAU	Water surfaces

Dominate type (a) **BAT type** (b) **VEGA type** (c) **ART type** (d)

Figure: (a) Distribution of dominated types of surfaces; and Distribution of fractions for surface types - (b) bat, (c) art and (d) vega - in grid cells of model domain.

A8. Characteristics of districts

Each of districts is described by a set of parameters which includes the thermal diffusivity, specific heat, temperature inside the buildings, albedo, emissivity; roughness length; streets' direction, length, and width; buildings' width and height as well as its probability distribution. Most of these parameters are defined for the ground, wall, and roof surfaces. Summary of districts' parameters (evaluated from different sources) is given in Table.

[*] *own rough estims*
[1] *http://de.wikipedia.org/wiki/Temperaturleitf%C3%A4higkeit* & *http://en.wikipedia.org/wiki/Thermal_diffusivity*
[2] *Derived form Table1, Albedo Concrete and Other Materials & Figure with albedo*
[3] *http://www.infrared-thermography.com/material.htm*
[4] *Ref. Tab. 15, p.38, EPA report 2009*
[5] *Table 5, EPA report, p. 15*
[6] *Ref. Tab. 10, p.23, EPA report 2009*

Table : Characteristics of urban districts for the Paris metropolitan area.

			Urban Districts					
Parameters	**Type**	**Units**	**RD**	**ICD**	**CC**	**HBD**	**RUR**	**Ref**
Thermal diffusivity	Ground	$m^2\ s^{-1}$	3,60E-07	3,60E-07	3,60E-07	3,60E-07	3,60E-07	1
	Wall	$m^2\ s^{-1}$	5,02E-07	3,32E-06	1,53E-06	1,06E-06	3,71E-07	1
	Roof	$m^2\ s^{-1}$	3,40E-07	5,40E-07	5,40E-07	5,40E-07	3,40E-07	1
Specific heat	Ground	$J\ m^3\ K^{-1}$	1,74E+06	1,74E+06	1,74E+06	1,74E+06	1,74E+06	
	Wall	$J\ m^3\ K^{-1}$	1,54E+06	1,54E+06	1,54E+06	1,54E+06	1,54E+06	
	Roof	$J\ m^3\ K^{-1}$	1,50E+06	1,50E+06	1,50E+06	1,50E+06	1,50E+06	
Temperature inside buildings	Wall	K	291	298	295	293	290	*
	Roof	K	293	300	297	295	292	*
Albedo	Ground		0,2	0,1	0,15	0,2	0,15	2
	Wall		0,2	0,25	0,175	0,2	0,15	2
	Roof		0,2	0,18	0,5	0,2	0,2	2
Emissivity	Ground		0,95	0,95	0,95	0,95	0.28	3
	Wall		0,72	0,9	0,9	0,91	0,72	3
	Roof		0,9	0,78	0,92	0,91	0,9	3
Roughness length	Ground		0.67/1.10	0.61/0.74	0.72/0.98	0.86/1.05	0.67/1.01	4
	Roof		0.67/1.10	0.61/0.74	0.72/0.98	0.86/1.05	0.67/1.01	4
Number of street direction (SD)			*2*	*2*	*2*	*2*	*2*	*
Street length	SD 1	m	100000	100000	100000	100000	100000	*
	SD 2	m	100000	100000	100000	100000	100000	*
Street direction	SD 1	radian	0,785	0,785	0,785	0,785	0,785	5
	SD 2	radian	2,355	2,355	2,355	2,355	2,355	5
Street width	SD 1	m	9	10	13	16	7	*
	SD 2	m	9	10	13	16	7	*
Building width	SD 1	m	15	112	30	20	10	*
	SD 2	m	15	112	30	20	10	*
Number of height levels (HL)			*2*	*2*	*2*	*2*	*2*	
Building height	HL1	m	5,7	6,09	105,9	21	5,02	6
	HL2	m	5,7	6,09	105,9	21	5,02	6
Probability of building height	HL1	m	100	75	50	60	100	*
	HL2	m	0	25	50	40	0	*

B1. Model – preparations, setups & runs

IMPORTANT START NOTE: all model runs are performed remotely at HPC facilities of the IT Center for Science Computing (CSC)

1. *COMPILE EXECUTABLE AND RUN MODEL --- **CTRL***
   - **A.** Make experiment directory **$HOME/hl_home/EXPNAME/**
   - **B. alias Hirlam ~username/hirlam_release/chemgas20100304/config-sh/Hirlam**
   - **C.** Go to the directory **$HOME/hl_home/EXPNAME/**
   - **D. Hirlam setup -r chemgas20100304 -d ~username/hirlam_release -h xtpgi**
   - **E.** Build/Recompile model executable and run the model using command:
     Hirlam start DTG=YYYYMMDDHH DTGEND=YYYYMMDDHH LL=FL
     DTG – starting date
     DTGEND - ending date
     (YYYY – year, MM – month, DD – day, HH – hour)
     LL – forecast length (select 06/24 hours)
     fx: *URBAN* -> **Hirlam start DTG=2009070300 DTGEND=2009070300 LL=24**
     fx: *AEROSOL* -> **Hirlam start DTG=2010071700 DTGEND=2010071718 LL=06**

     ... waiting for an executable to be compiled and steps of model run...
     ***tail –f /data/*$USER/hl_home/EXPNAME/hirlam.log**
     ... through steps of compilation, initialization, climate files generation, preparation of boundary conditions, and steps of forecasting ... until the run is completed

2. *COMPILE EXECUTABLE AND RUN MODEL --- **MODIFIED***
   - Repeat step **1(A,B,C,D)**
   - Modify scripts and source code accordingly (see call tree in appendix and teacher's explanation)
   - Follow step **1E**

3. *PRODUCED OUTPUT*
   - Go to the directory **/data/$USER/hl_arc/EXPNAME/YYYY/MM/DD/HH**
   - The generated output files to be analysed are the following:
     - **fcYYYYMMDD_HH+0LL** - 3D meteo. fields
     - **fcYYYYMMDD_HH+0LLmd** - surface meteo. fields

IMPORTANT NOTE:
*After each run finished - **ALWAYS** (!) change the name of the produced output directory:*
- Go to the directory called **/data/$USER/hl_arc/EXPNAME/**
- Rename the output directory called **EXPNAME** to **EXPNAME_run_YYYYMMDD**

B2. Urban implementation - AHF, R, BEP

MAKE CHANGES FOR THE URBANIZATION OF THE MODEL:

1) For inclusion URBAN effects – Anthropogenic heat flux (AHF) & Roughness (R)

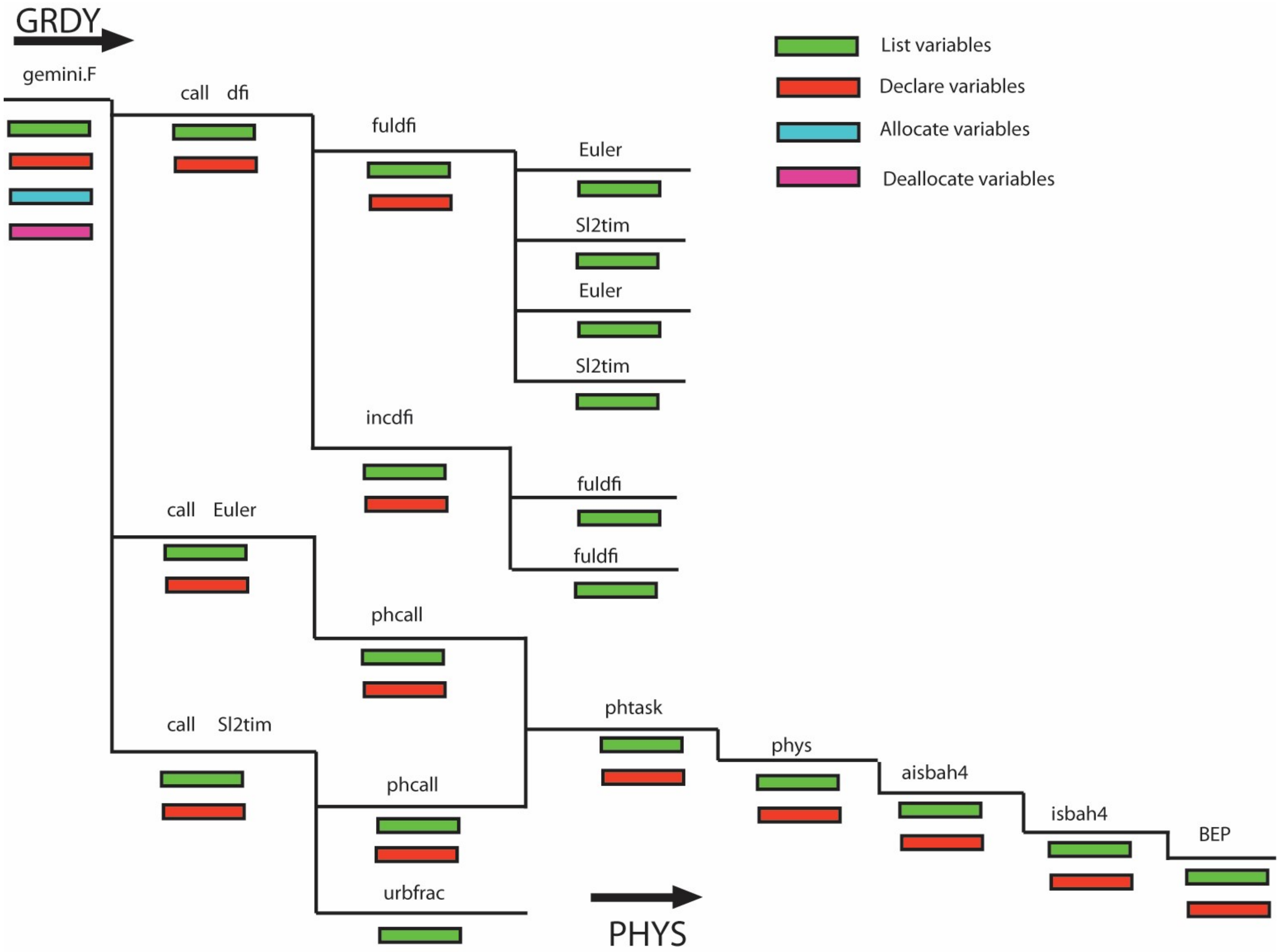
- Go to the directory called **$HOME/hl_home/EXPNAME/phys**
- Using any text-editor make necessary changes in the file called **isbah4.F**
  i.e. modify the anthropogenic heat flux from 10 to 200 (unrealistic 500) W/m^2
- Using any text-editor (vim, emacs, nano, mcedit) make necessary changes in file called **ini_veg.F**
  i.e. modify the roughness (from default value up to 1 and 2 meters or higher)

2) For inclusion URBAN effects – Building Effects Parameterization

- Go to the directory called **$HOME/hl_home/EXPNAME/src/grdy**
- Using any text-editor make necessary changes (*see Call-Tree; Annex B3*) in the files:
  gemini.F
  dfi.F
  euler.F
  sl2tim.F
  fildfi.F
  incdfi.F
  urbfrac.F

- Go to the directory called **$HOME/hl_home/EXPNAME/src/phys**
- Using any text-editor make necessary changes (*see Call-Tree; Annex B3*) in the files:
  phcall.F
  phtask.F
  phys.F
  aisbah4.F
  isbah4.F
  bep.F

B3. Call-tree for BEP implementation



C1. Visualization of results

METGRAF software
PRE-STEP:

- Go to the directory called **$HOME/metgrafenviro**
- Run the METGRAF application by typing: **source metgraf_cray** and then: **metgraf**

Step 1: ***See below examples of "Graphical illustrations for METGRAF"***
Select FIELDS / ADD NEW FIELD / SELECT FILE /
i.e. choose the name of the Enviro-HIRLAM output file to be plotted from directory
/data/$USER/hl_arc/EXPNAME_run_YYYYMMDDHH/YYYY/MM/DD/HH/
+ **fcYYYYMMDD_HH+0LLmd** - surface meteo.fields
+ **fcYYYYMMDD_HH+0LL** - 3d meteo.fields

(GRIB file 1: …path to the file …) – for plotting original field for 1 parameter
<u>*+ as time allowed also:*</u>
and by choosing also the second file
(GRIB file 2: …path to the file …) – for plotting difference between 2 fields (delta fields) of the same parameter

Step 2: Select parameter to be printed through GRIB parameters: Table/ Level Type/ Level/ Param
<u>**For original fields:**</u>

1. air temperature at 2 m (T2m, in K or subtract: 273.15 to get in C) - 1/ 105/ 2/ 11 (scale 1; contours: 0-30; step 2)
2. wind speed at 10 m (W10m, in m/s) - 1/ 105/ 10/ 33 (scale 1; contours: 0-25; step 1)

<u>*+ as time allowed also:*</u>

3. relative humidity at 2 m (%) - 1/105/2/52 (*md; scale 100; contours: 0-100; step 10)
4. total cloud cover (%) - 1/ 105/ 0/ 71 (*md; scale 1; contours: 0-1; step 0.1)
5. surface temperature (in K or subtract 273.15 to get in C) - 1/ 105/ 0/ 11 (*md; scale 1; contour: 0-50; step 2)
6. PBL height (Hpbl, in m) - 1/ 105/ 0/ 67 (*md; scale 1; contour: 0-3000; step 200)

<u>**For delta fields:**</u>

7. air temperature at 2 m (T2m, in K or Subtract: 273.15 to get in C) - 1/ 105/ 2/ 11 (scale 1; contours: -5/+5; step 0.5)
8. wind speed at 10 m (W10m, in m/s) - 1/ 105/ 10/ 33 (scale 1; contours: -5/+5; step 0.5)

<u>*+ as time allowed also:*</u>

9. relative humidity at 2 m (%) - 1/105/2/52 (*md; scale 100; contours: 0-100; step 10)
10. total cloud cover (%) - 1/ 105/ 0/ 71 (*md; scale 1; contours: 0-1; step 0.1)
11. surface temperature (in K or subtract 273 to get in C) - 1/ 105/ 0/ 11 (*md; scale 1; contours: -5/+5; step 0.5)
12. PBL height (Hpbl, in m) - 1/ 105/ 0/ 67 (*md; contour: -500/+500; step 50)

<u>*+ extras*</u>

13. max & min air temperature at 2 m, dew temperature at 2 m, latent and sensible heat fluxes at surface, etc.

Step 3: Select type of the field to be plotted: as an original field or as a difference field (Diffs)

Step 4: Select: Field options, Legend options, Wind Arrow options, Extreme values options, etc., Contours (use the user-defined contours/shades button) to play + choose the best visible and readable presentation of the results obtained

Step 5: Press button - DRAW – to draw/redraw the plot

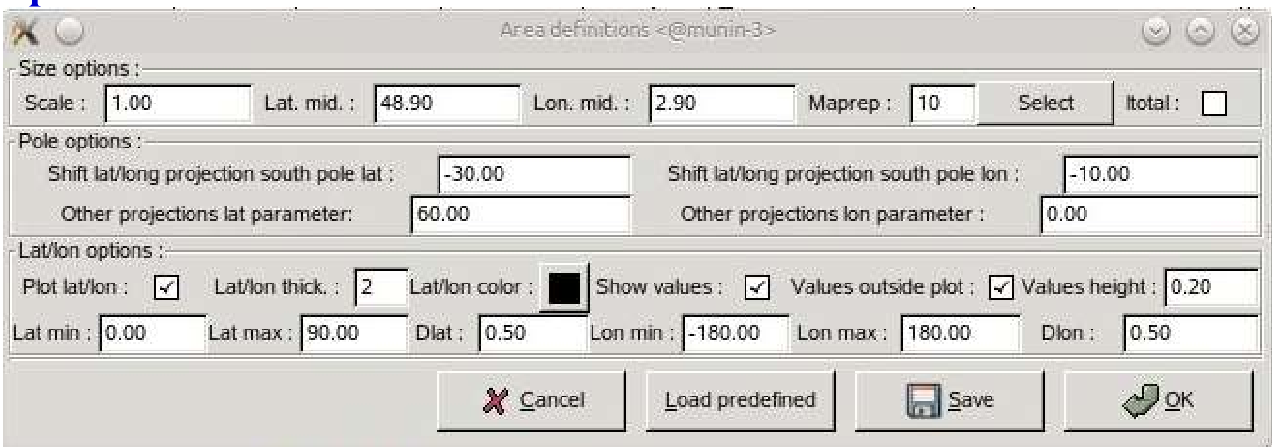
HINT: Always redraw plot after making changes by pressing button DRAW

NOTE: In order to select the area of domain to be plotted choose from the METGARF menu through the OPTIONS/ AREA *the setting options such as* SCALE/ LAT.MID/ LONG.MID/ etc.

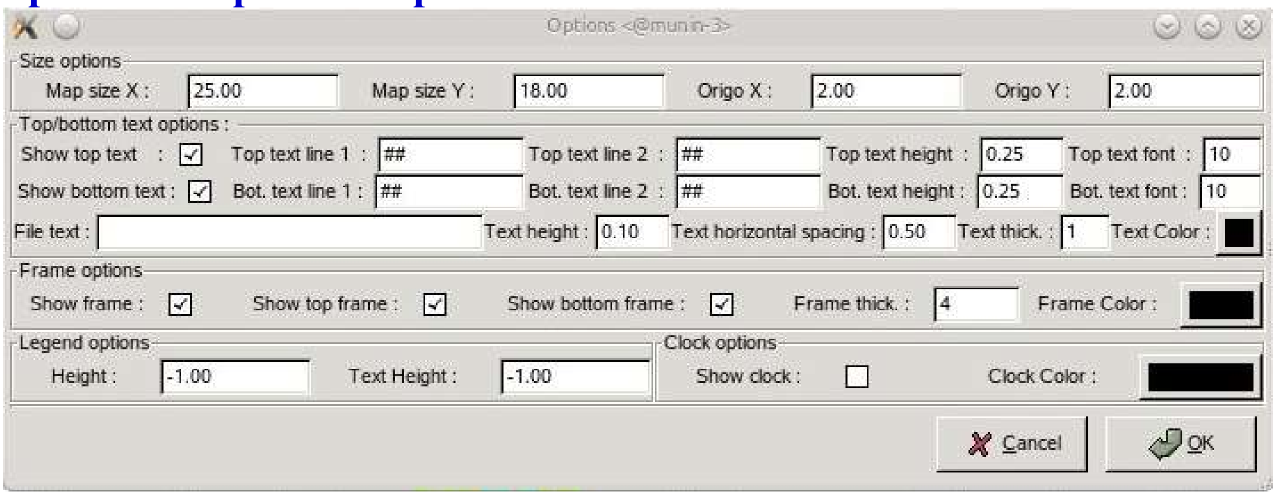
NOTE: To save the newly defined domain: FILE/ SAVE – select path to the directory called **$HOME/metgrafenviro/RESULTS/namelist_EXPNAME_run**
At the end, use this **namelist_EXPNAME_run** *as a template to draw the similar plots*
Do the similar for the OPTIONS/ OPTIONS *and* OPTIONS/ COASTLINES *as needed*

Graphical illustrations for METGRAF

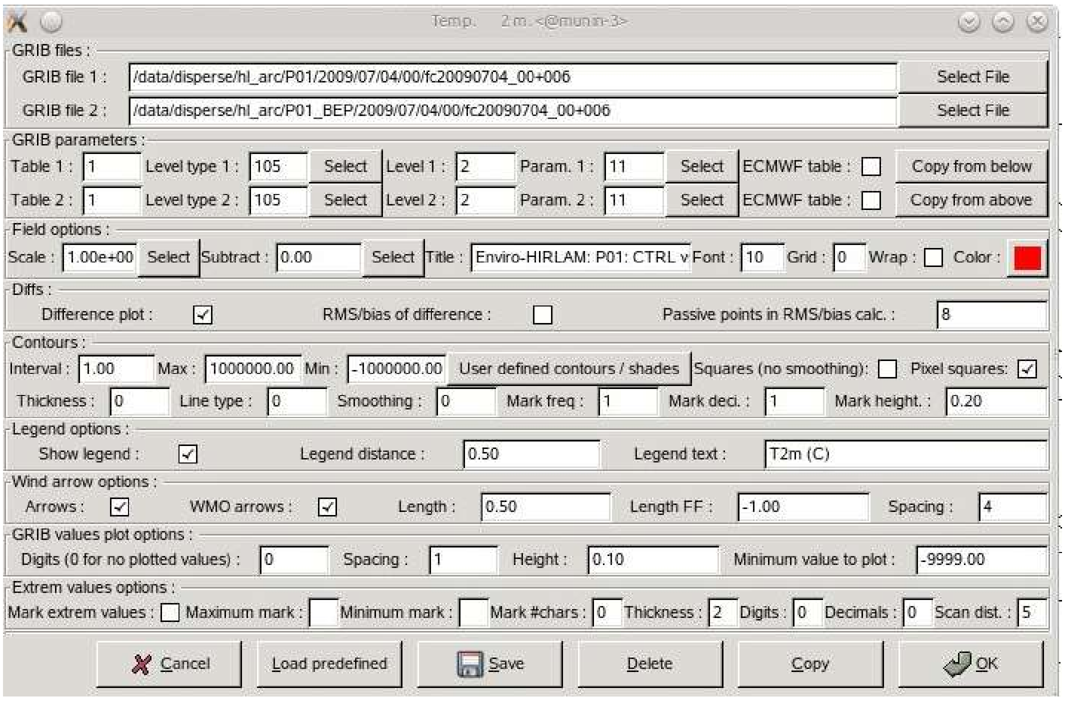
Options -> Area : AREA DEFINITIONS



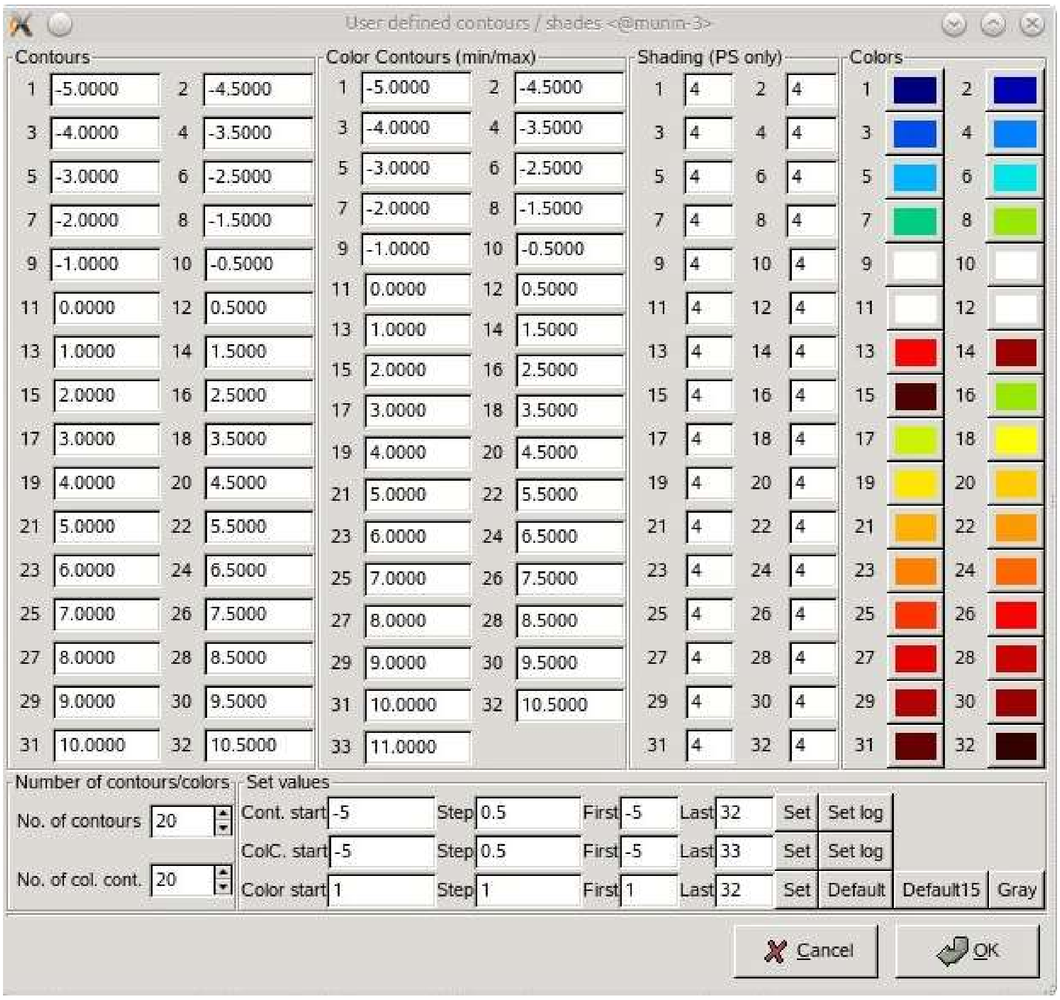
Options -> Options : Options



Fields -> Add new field



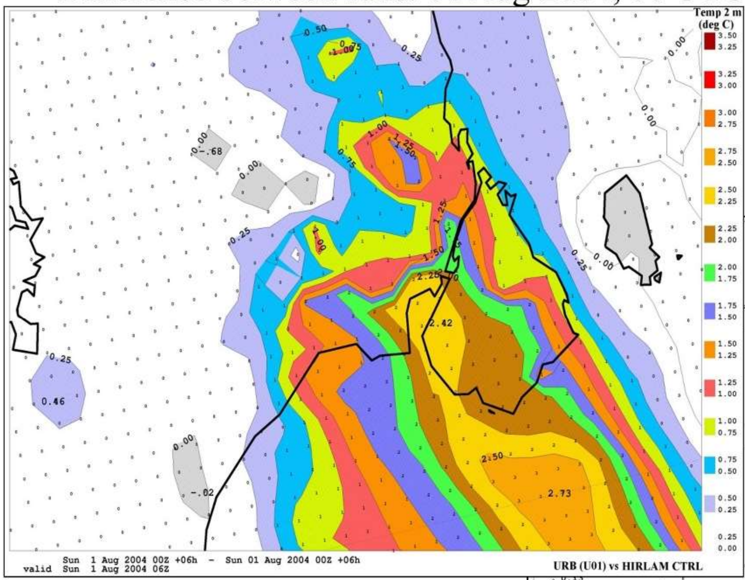
-> User defined contours / shades



C2. Examples of visualization

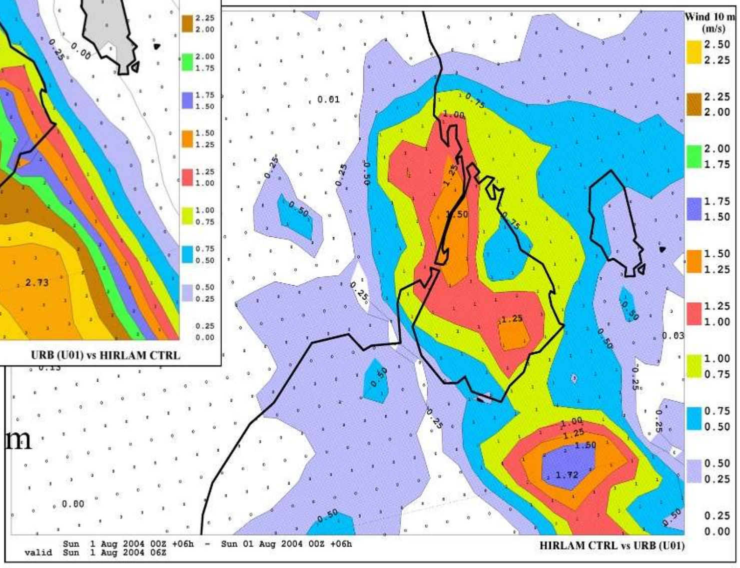
AHF+R: Copenhagen Urban Effects Modelling

Difference between runs: 01 Aug 2004, 06 UTC



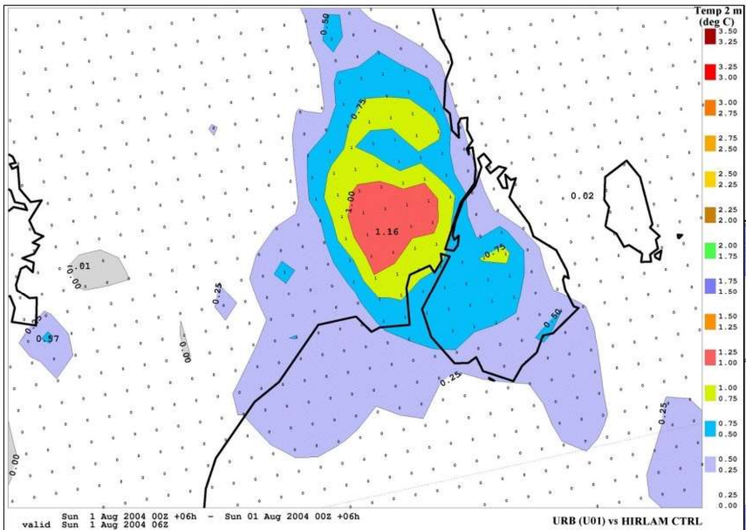
(control vs. urbanized run)
Difference field for temperature at 2 m

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



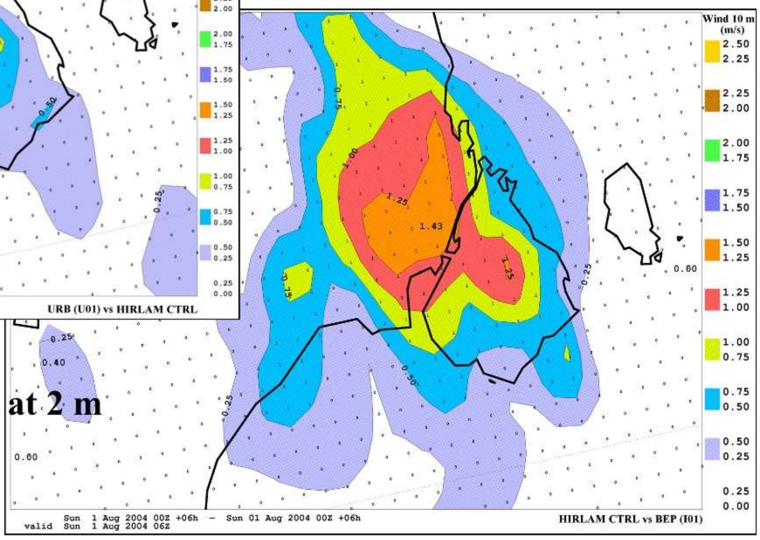
BEP: Copenhagen Urban Effects Modelling

Difference between runs: 01 Aug 2004, 06 UTC

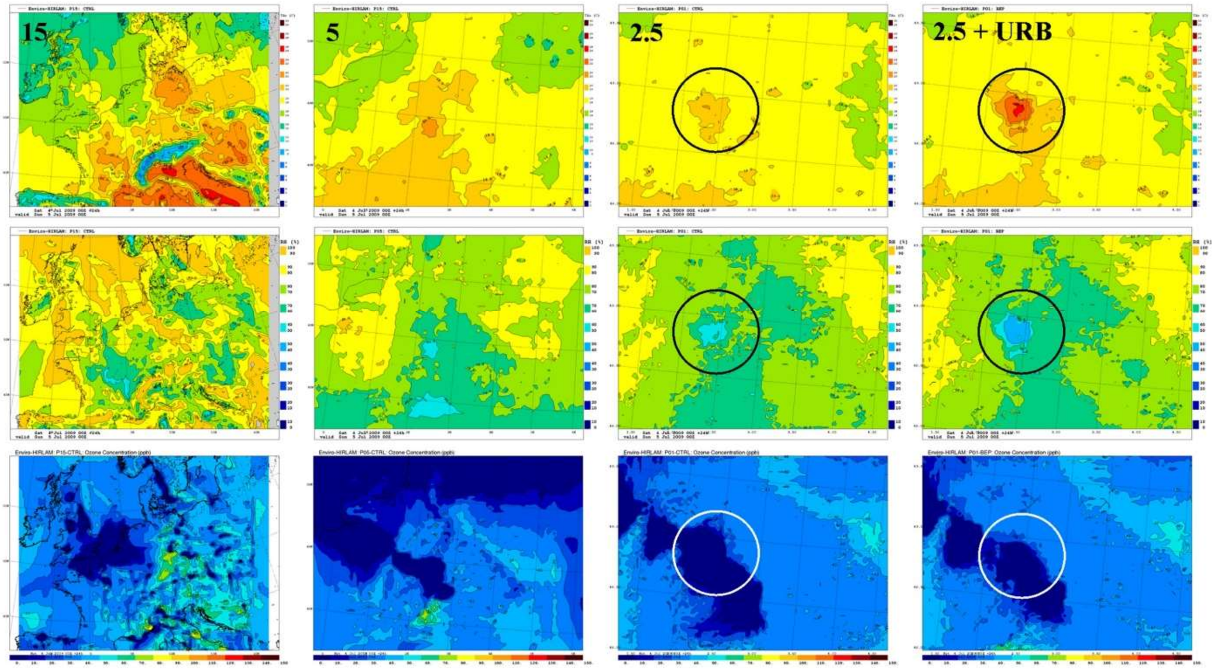


(control vs. urbanized run)
Difference field for temperature at 2 m

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

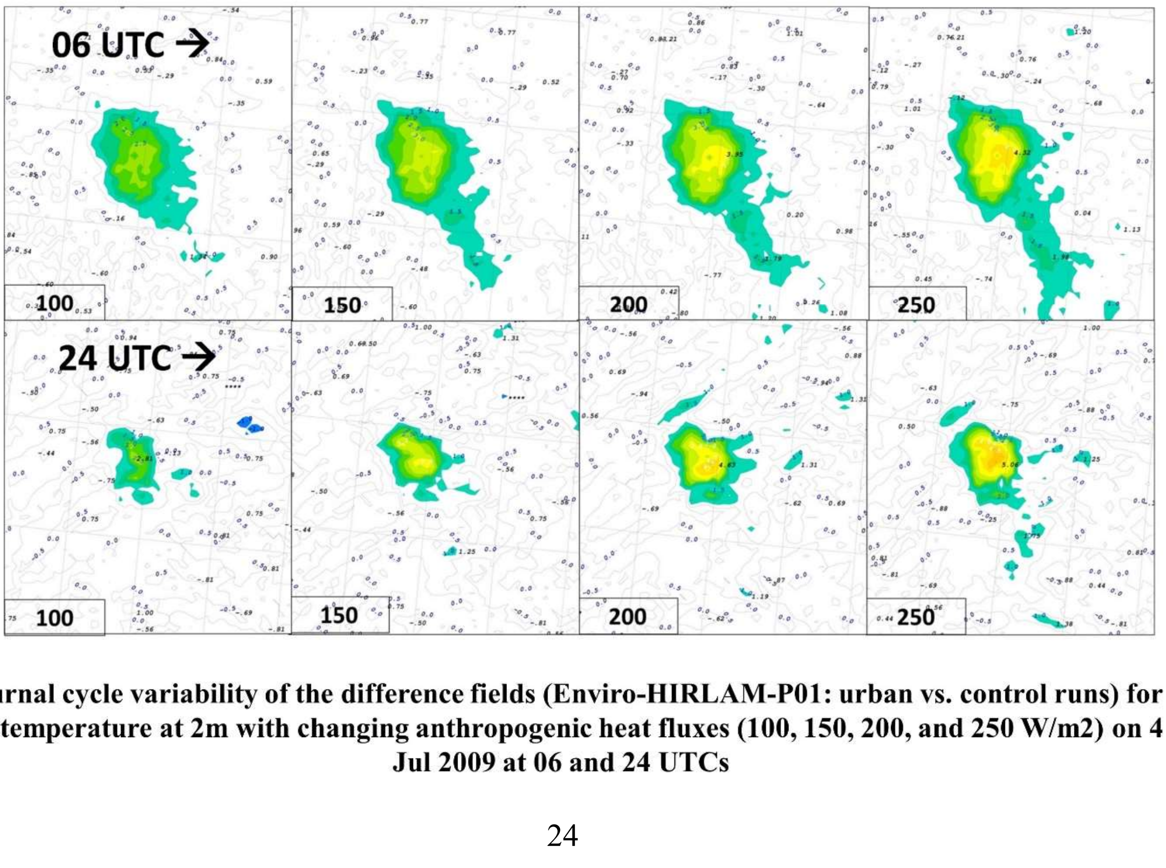


Downscaling for Paris Metropolitan Area (meteorology & chemistry)



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.

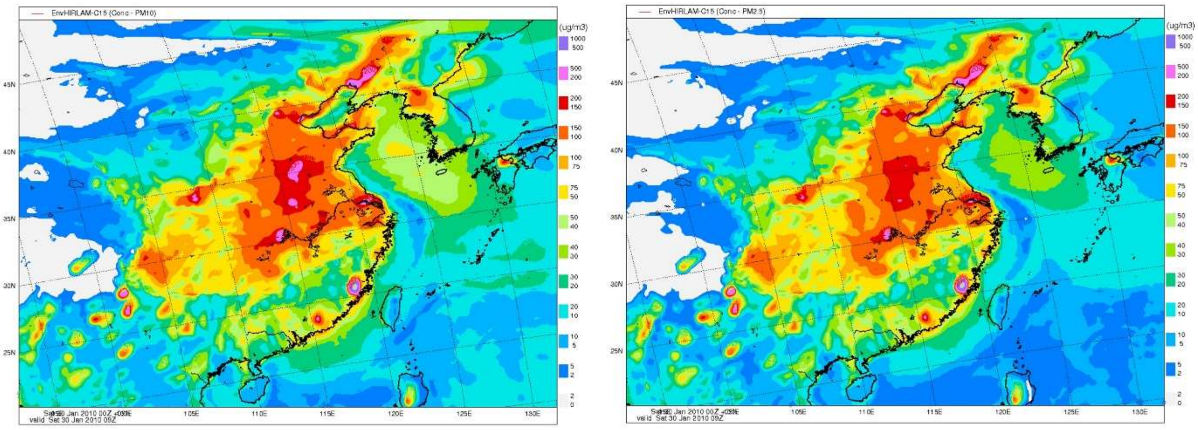
Paris Metropolitan Area: T2m / AHF



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

Air Quality Forecasts:
Enviro-HIRLAM: Jan & Jul 2010

PM10 **PM2.5**



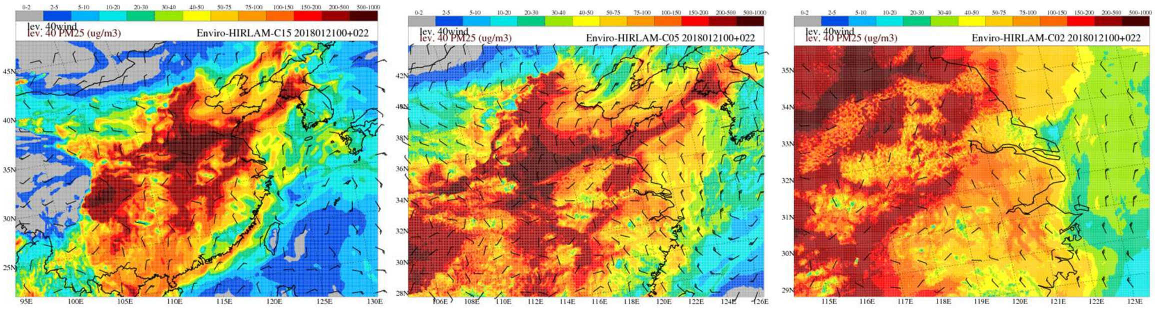
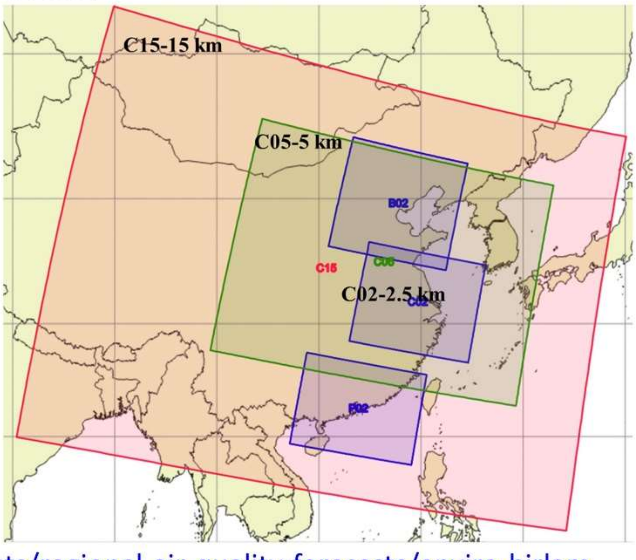


Figure: *Enviro-HILRAM operational PM2.5 concentration forecasts for China in a downscaling chain (left-right: regional, sub-regional, urban - Shanghai metropolitan area) for 21 Jan 2018, 22 UTC.*

Enviro-HIRLAM HPC Usage

EnvH models (C15, C05, C02) run twice per day at 00 & 12 UTCs (with intermediate runs at 06 & 18 UTCs for 9 h forecast length) & 48h forecasts for each EnvH run uploading at MarcoPolo-Panda website http://www.marcopolo-panda.eu from ftp.dmi.dk & verification based on NWP approach http://hirlam.org
(forecast part uses 208 mpi-tasks on 13 nodes)



CPU time spent for 1 run:

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

Surface level disc usage for 1 run:

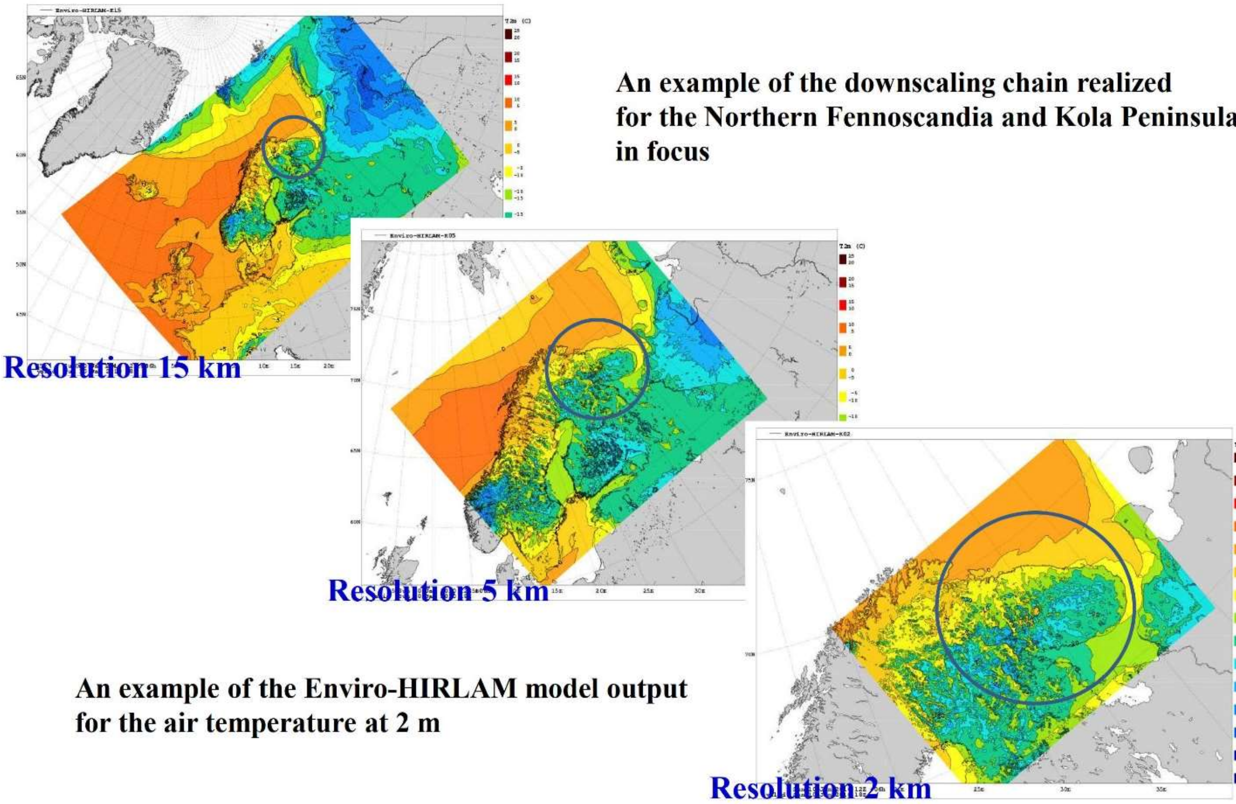
C15: 533M
C05: 1,5G
C02: 947M

Model level disc usage for 1 run:

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

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

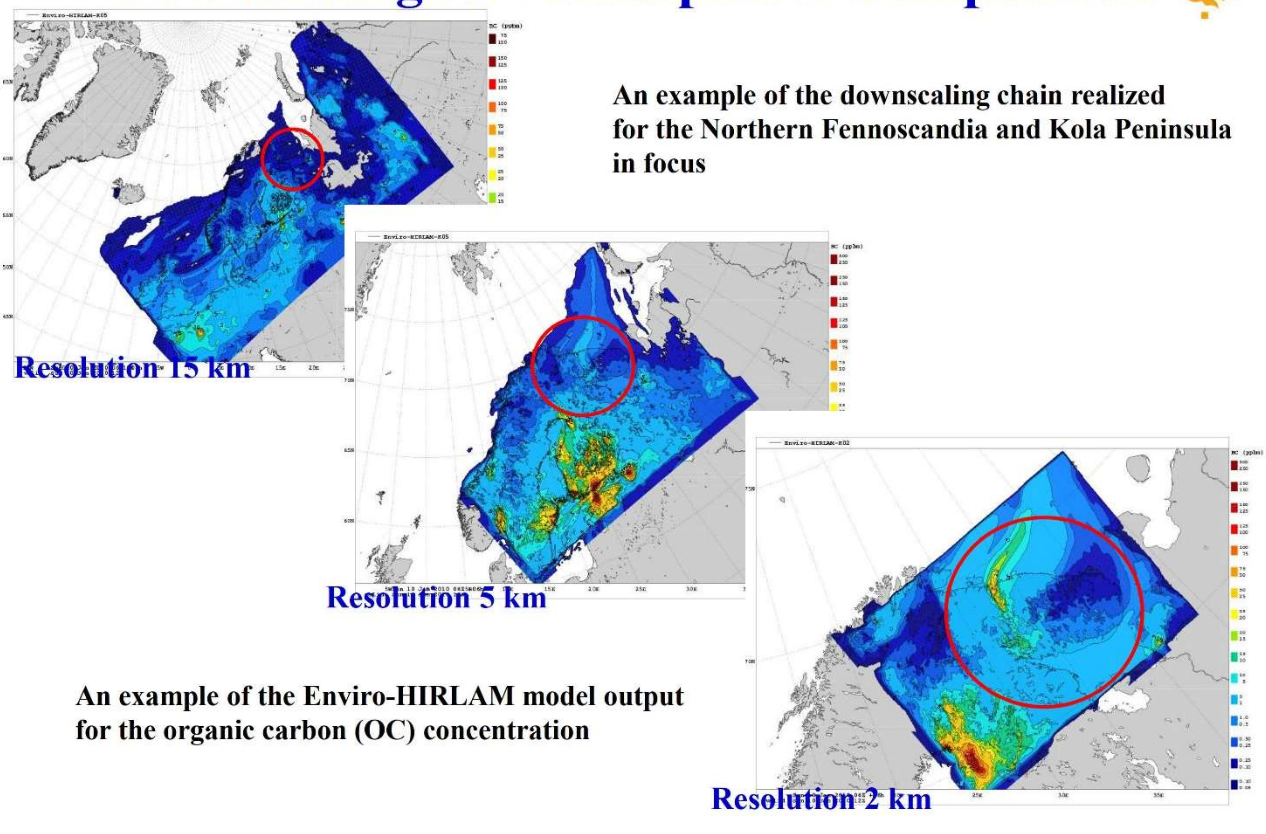
Downscaling for Meteorology



An example of the downscaling chain realized for the Northern Fennoscandia and Kola Peninsula in focus

An example of the Enviro-HIRLAM model output for the air temperature at 2 m

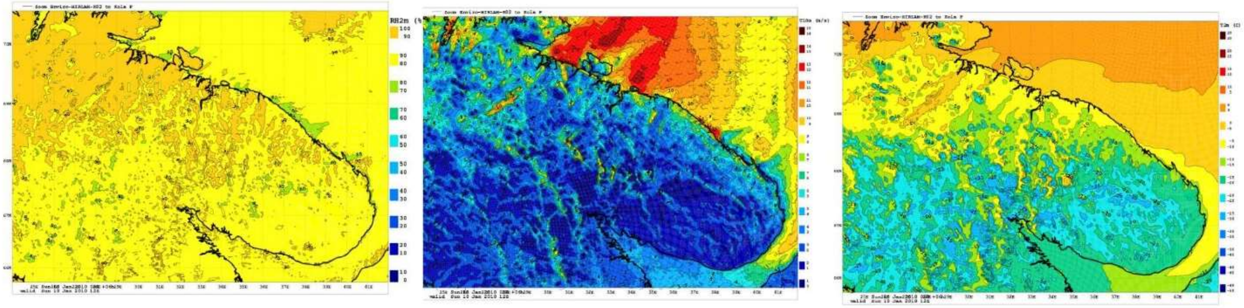
Downscaling for Atmospheric Composition



An example of the downscaling chain realized for the Northern Fennoscandia and Kola Peninsula in focus

An example of the Enviro-HIRLAM model output for the organic carbon (OC) concentration

***Figure:** examples of the Enviro-HIRLAM model high resolution (at 2 km) output for meteorology & atmospheric composition over the Kola Peninsula area*

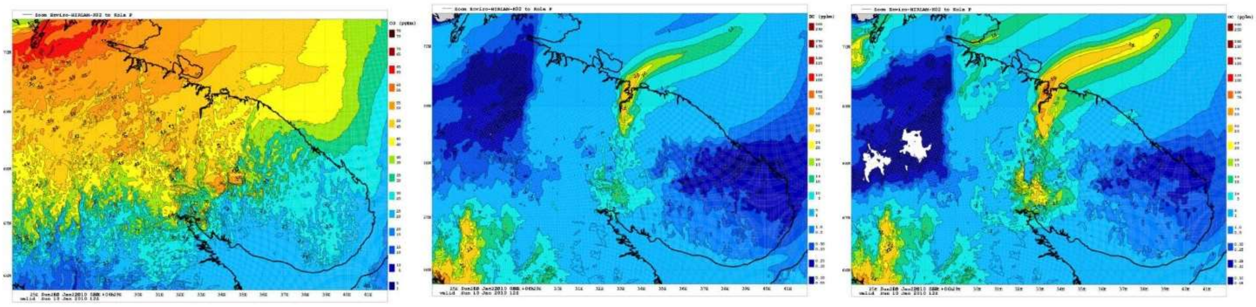


Meteorology:

Relative Humidity (RH2m),

Wind Speed at 10m (U10m) ,

Air temperature at 2m (T2m)



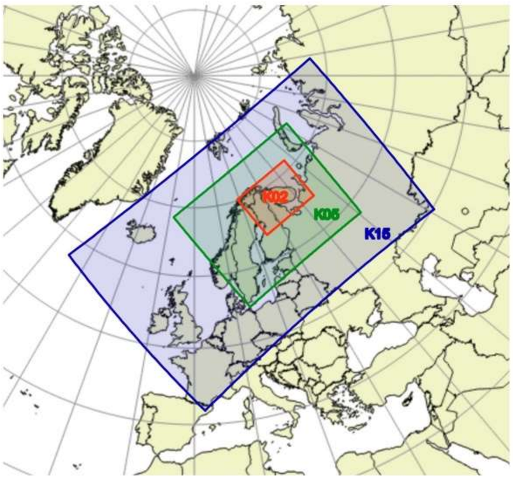
Atmospheric Composition:

Ozone (O_3)

Black Carbon (BC),

Organic Carbon (OC),

Enviro-HIRLAM Downscaling for Regional-Subregional-Urban scales



Regional-subregional-urban scale domains
K15 K05 K02

DOMAIN-NAME	K15	K05	K02	
RESOLUTION (deg)	0.15	0.05	0.02	
RESOLUTION (km)	15	5	2	appx.
# boundary points	10	10	10	
NLON (grid-points)	310	442	460	
NLAT (grid-points)	188	340	340	
SOUTH	-27.527	-21.527	-15.357	
WEST	-31.325	-16.025	-7.025	
NORTH	0.523	-4.577	-8.577	
EAST	15.025	6.025	2.155	
POLAT	-10.0	-10.0	-10.0	
POLON	40.0	40.0	40.0	
Time step (sec)	240	120	60	
# vertical levels	40	40	40	
N-W-S-E --- in rotated system of coordinates				

Setup of the Enviro-HILAM model domains in a downscaling chain
Run (DAI+IDEA both included)

D1. Useful readings afterwards

Allen L., S Beevers, F Lindberg, Mario Iamarino, N Kitiwiroon, CSB Grimmond (**2010**): Global to City Scale Urban Anthropogenic Heat Flux: Model and Variability. Deliverable 1.4, *MEGAPOLI Scientific Report 10-01, MEGAPOLI-04-REP-2010-03, 87p, ISBN: 978-87-992924-4-8;* http://megapoli.dmi.dk/publ/MEGAPOLI_sr10-01.pdf

Baklanov A., A. Mahura, R. Sokhi (Eds). (2010): Integrated Systems of Meso-Meteorological and Chemical Transport. Springer, 242 p., ISBN 978-3-642-13979-6, DOI 10.1007/978-3-642-13980-2

Baklanov A., Mahura A., Nielsen N.W., C. Petersen, (2005): Approaches for urbanization of DMI-HIRLAM NWP model. HIRLAM Newsletter 49, Dec 2005, pp. 61-75.

Baklanov A., S. Grimmond, A. Mahura, M. Athanassiadou (Eds) (2009): Urbanization of Meteorological and Air Quality Models. Springer Publishers, 169 p., ISBN 978-3-642-00297-7; DOI 10.1007/978-3-642-00298-4.

Baklanov, A., P. Mestayer, A. Clappier, S. Zilitinkevich, S. Joffre, A. Mahura, N.W. Nielsen, (2008): Towards improving the simulation of meteorological fields in urban areas through updated/advanced surface fluxes description. Atmospheric Chemistry and Physics, 8, 523-543.

Bringfelt, B., **1996**: Tests of a new land surface treatment in HIRLAM. Norrkøping, *HIRLAM Technical Report* 23.

CORINE, **2000**: The European Topic Centre on Terrestrial Environment: Corine land cover (CLC90) 100 m - version 12/2000. Web-site:

Gavrilova Yu., Mahura A., Smyshlayev S., Baklanov A. (**2010**): Urban effects in numerical weather prediction model at Saint-Petersburg metropolitan area for winter. *Abstracts of the European Geosciences Union (EGU) General Assembly, 2-7 May 2010, Vienna, Austria; Geophysical Research Abstracts, Vol. 12, EGU2010-314.*

González-Aparicio I., R. Nuterman, U.S. Korsholm, A. Mahura, J.Á. Acero, J. Hidalgo, A. Baklanov (**2010**): Land-use Database Processing Approach for Meso-Scale Urban NWP Model Initialization. *DMI Scientific Report 10-02; 32p., ISBN: 978-87-7478-593-4;* www.dmi.dk/dmi/sr10-02.pdf

Grimmond CSB., M. Blackett, M.J. Best, et al. (**2010**): Urban Energy Balance Models Comparison. Deliverable D2.3, *MEGAPOLI Scientific Report 10-07, MEGAPOLI-10-REP-2010-03, 72p, ISBN: 978-87-993898-0-3;* http://megapoli.dmi.dk/publ/MEGAPOLI_sr10-07.pdf

Grimmond, C. S. B. and Oke, T. R.: **2002**, Turbulent Heat Fluxes in Urban Areas: Observations and a Local-Scale Urban Meteorological Parameterization Scheme (LUMPS), *J. Appl. Meteor*., **41**, 792-810.

Grimmond, C. S. B., Cleugh, H. A., and Oke, T. R.: **1991**, 'An Objective Urban Heat Storage Model and its Comparison with other Schemes', *Atmos. Environ*. **25**B, 311-326.
http://dataservice.eea.eu.int/dataservice/metadetails.asp?id=309

Korsholm U.S., Mahura A., Baklanov A., (**2010**): Effects of Paris on regional meteorological and chemical weather in the context of the EC-project MEGAPOLI. *Abstracts of the European Geosciences Union (EGU) General Assembly, 2-7 May 2010, Vienna, Austria; Geophysical Research Abstracts, Vol. 12, EGU2010-10650.*

Mahura A., A. Baklanov, S. Hoe, J.H. Sørensen, C. Petersen, K. Sattler, (**2007**): Evaluation of land surface scheme modifications on atmospheric transport and deposition patterns in Copenhagen metropolitan area. Developments in Environmental Sciences, Eds. E. Renner, A. Ebel, Springer Elsevier Publishers, Vol 6, pp. 64-72, doi:10.1016/S1474-8177(07)06017-2

Mahura A., Baklanov A. (Eds.) (**2010**): Hierarchy of Urban Canopy Parameterisations for Different Scale Models. Deliverable D2.2, *MEGAPOLI Scientific Report 10-04, MEGAPOLI-07-REP-2010-03, 50p, ISBN: 978-87-992924-7-9;* http://megapoli.dmi.dk/publ/MEGAPOLI_sr10-04.pdf

Mahura A., Baklanov A., Petersen C., Sattler K., Amstrup B., N.W. Nielsen, (**2005**): ISBA Scheme Performance in High Resolution Modelling for Low Winds Conditions. HIRLAM Newsletter 49, Dec 2005, pp. 22-35.

Mahura A., Leroyer S., Baklanov A., Mestayer P., Korsholm U.S., Calmet I., (**2008**): Temporal and Spatial Variability of Fluxes in Urbanized Areas, pp-219-232; In "Urban Climate and Bioclimate", (Eds. Klysik K., Wibig J., Fortuniak K.), ISBN: 978-83-7525-243-9.

Mahura A., Petersen C., Baklanov A., Amstrup B., (**2008**): Evaluation of Building Effect Parameterization Module for Urbanized Numerical Weather Prediction Modelling, pp-371-380; In "Urban Climate and Bioclimate", (Eds. Klysik K., Wibig J., Fortuniak K.), ISBN: 978-83-7525-243-9.

Masson, V.: **2000**, 'A Physically-Based Scheme for the Urban Energy Budget in Atmospheric Models', *Boundary-Layer Meteorol.* **98**, 357-397.

Navascués B., Rodríguez E., J.J. Ayuso, S. Järvenoja, **2003**: Analysis of surface variables and parameterization of surface processes in HIRLAM. Part II: Seasonal assimilation experiment. Norrköping. *HIRLAM Technical Report* 59, 38 p.

Oke, T.R., **1978**: Boundary layer climates. London, Methuen & Co Ltd, J. Wiley & Sons, New York, 359 p.

Rodríguez E., B. Navascués, J.J. Ayuso, S. Järvenoja, **2003**: Analysis of surface variables and parameterization of surface processes in HIRLAM. Part I: Approach and verification by parallel runs. Norrköping. *HIRLAM Technical Report* 58, 52 p.

Sass B., N.W. Nielsen, J.U. Jørgensen, B. Amstrup, M. Kmit, K.S. Mogensen, **2002**: The operational DMI-HIRLAM system - 2002-version. *DMI Technical Report* 02-05, 60 p.

Sattler, K.: **2000**, New high resolution physiographic data and climate generation in the HIRLAM forecasting system at DMI, an overview, *HIRLAM Newsletter*, **33**, 96-100.

Unden, P., L. Rontu, H. Järvinen, P. Lynch, J. Calvo, G. Cats, J. Cuhart, K. Eerola, etc. **2002**: HIRLAM-5 Scientific Documentation. December 2002, *HIRLAM-5 Project Report,* SMHI.

Notes