On the Importance of Urbanization in Operational On-line Forecasting

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NetFAM School and Workshop on
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NetFAM/NordForsk
NetFAM:
Nordic Network on Fine-scale Atmospheric Modelling

Danish Meteorological Institute, DMI, Copenhagen, Denmark

NetFAM Workshop on Integrated Modelling …
14-15 July 2008, Zelenogorsk, Russia

Main Aim

Evaluate effects of urbanization of meteorological modelling on simulated meteorological operational and climatological patterns over the urbanized areas and surroundings

(on example of **Copenhagen metropolitan area**, Denmark)

Objectives

- Modify the existing meteorological models land surface scheme using:
  - 1) anthropogenic heat flux and roughness (**AHF+R**) module
  - 2) building effect parameterization (**BEP**) module
  - 3) soil model for sub-meso scales urban version (**SM2-U**) module

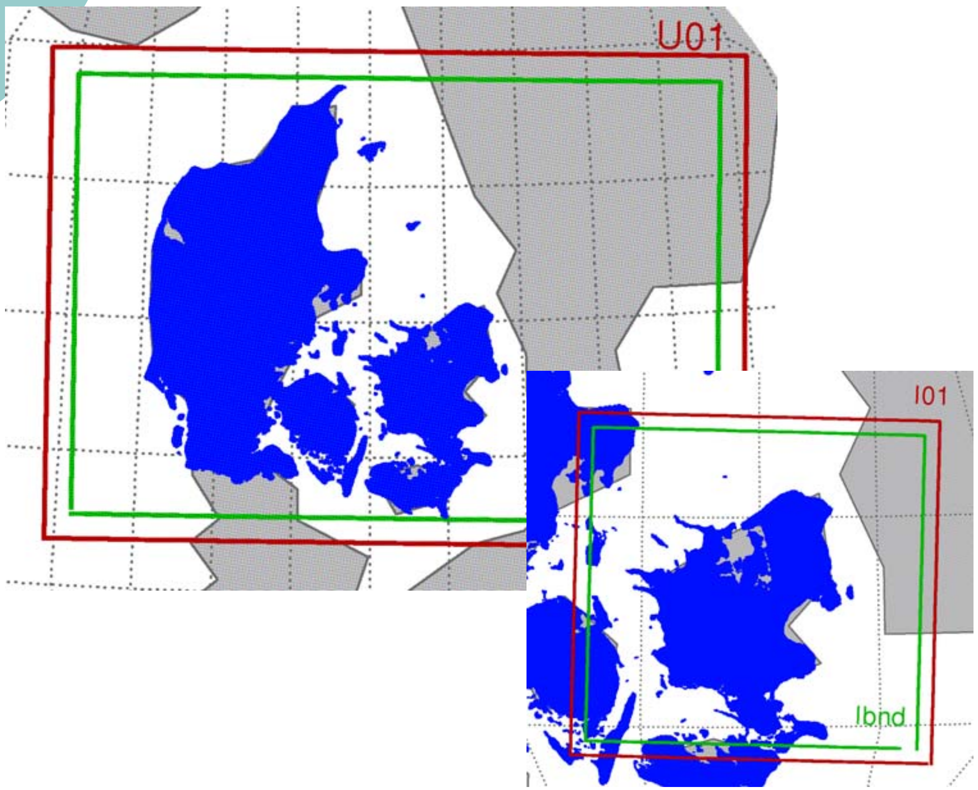
- Perform simulations of meteorological fields using DMI-HIRLAM (HIgh Resolution Limited Area Model) and SUBMESO (derived from the Advanced Regional Prediction System) models:
  - for two modes: 1) **Control** vs. 2) **Urban** runs,
  - for two types: 1) **Case Studies** and 2) **Long-Term Simulations**

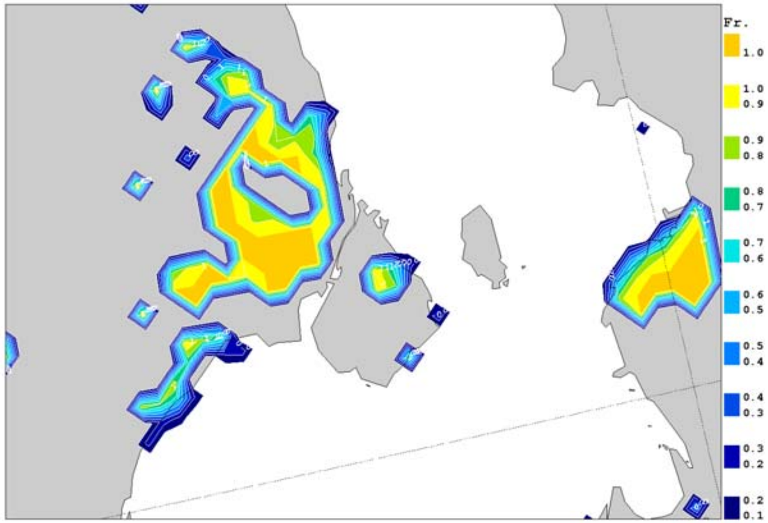
  for selected specific dates reflecting different atmospheric conditions such as **low, typical, high winds and high precipitation conditions**

- Evaluate effects of urbanization on temporal-spatial structure and variability of meteorological fields by estimation on a diurnal cycle the differences between control and urban runs for meteorological variables (**temperature, wind velocity, relative humidity**) as well as the net radiation, sensible and storage heat fluxes for different types of surfaces/covers and types of urbanized districts

Land-Use Classification, Domains, and Urban Features

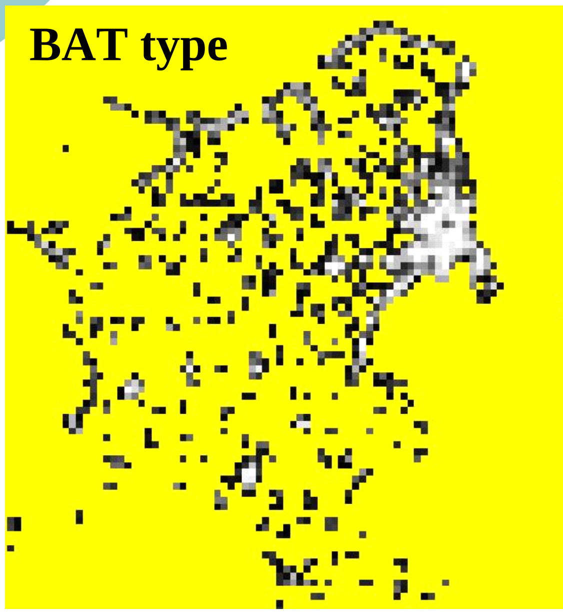
- **Land surface scheme** - Interaction Soil-Biosphere-Atmosphere (**ISBA**)
- **Tiles** (low vegetation, forest, ice, water, snow, bare soil) + **urban** fraction
- **High resolution domains -** HIRLAM-U01/-I01 (horiz resol of 1.4 km)
- **Focus -** Copenhagen metropolitan area (Island of Sjealland)

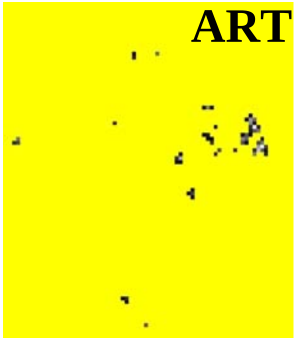


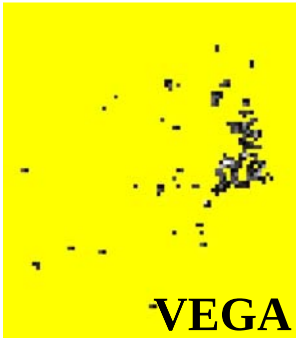


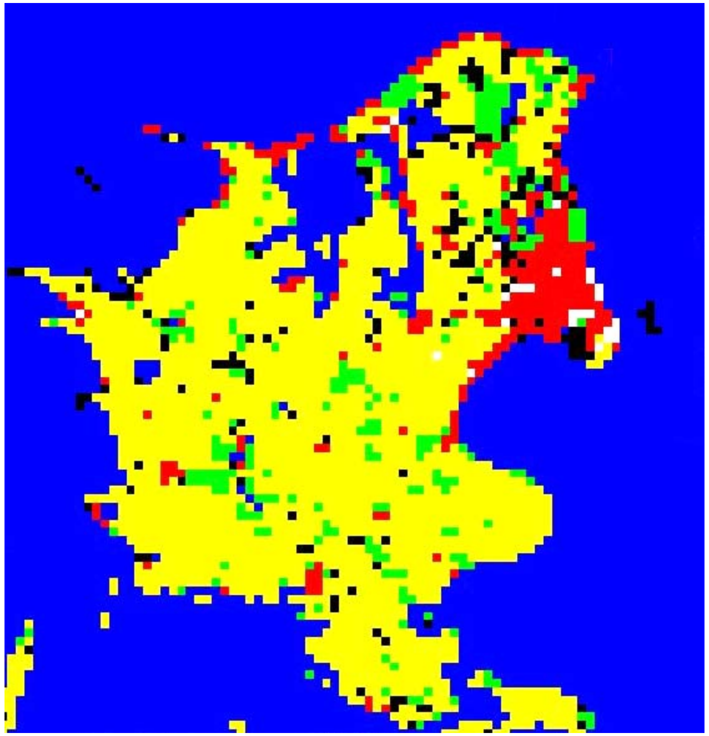
Revised Land Use Classification

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




ART type


VEGA type

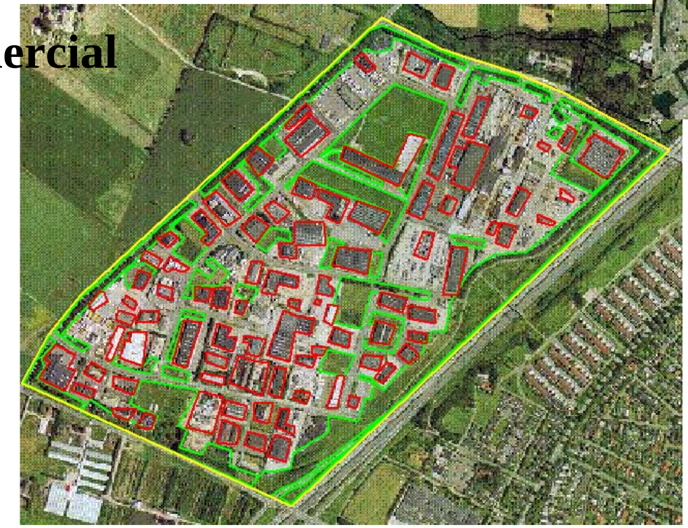

Dominated type

Urban Districts Classification

City Center/High Buildings District (CC/HBD)

Residential (RD)

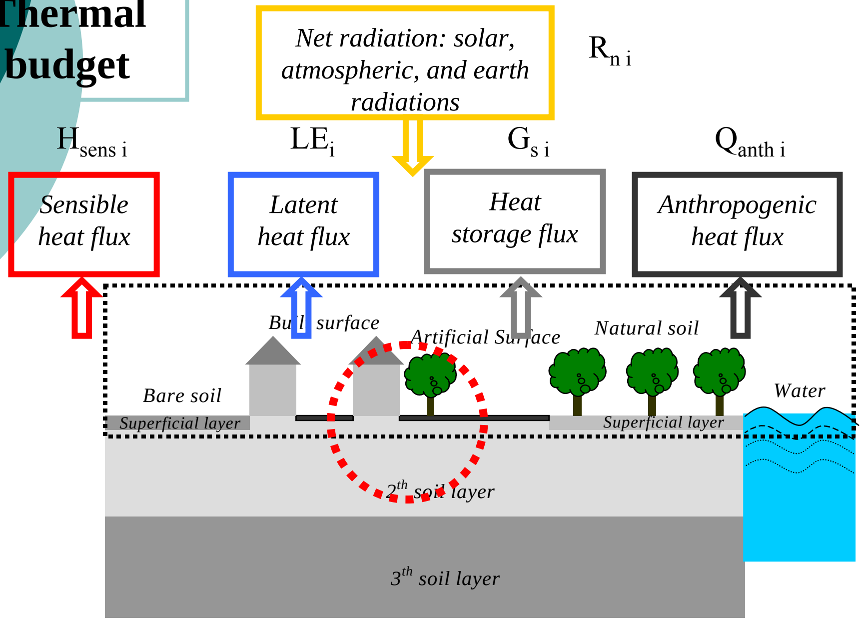
Industrial Commercial (ICD)



Extraction of districts related characteristics

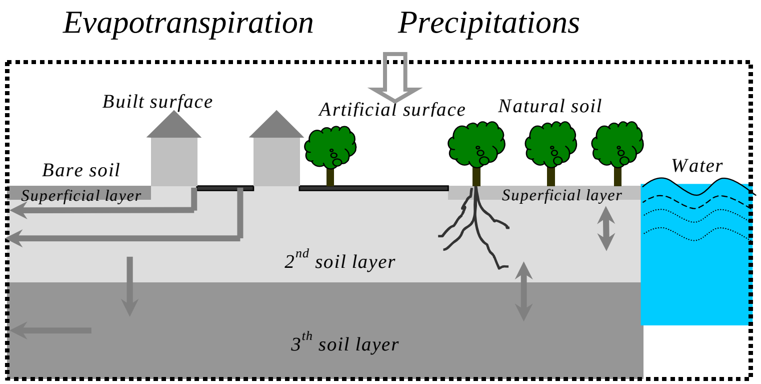
SM2-U : Soil Model for Sub-Meso scales Urbanized version

Thermal budget



+

Water budget



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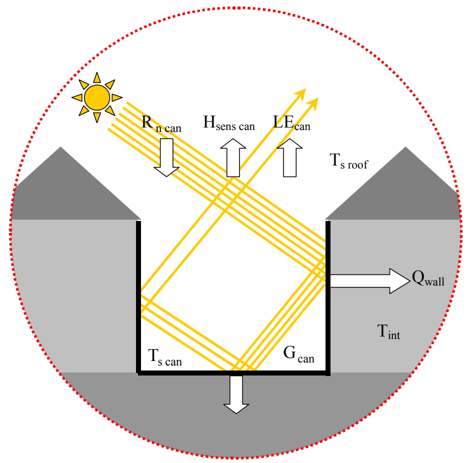
Canopy



(Dupont et al., 2006ab)

Input Meteorological and Surface Data
Model Setup

Original: climate generation files produced for DMI-HIRLAM model system; climatological data for Copenhagen and Danish sites of Island of Sjealland.

Surface related data: types of soil, vegetation above natural and artificial surfaces, water, buildings and artificial surfaces and its properties, and a set of water content related characteristics in soil layers, LAI, salinity, roughness, etc.

Meteorological related data: air temperature, direction and velocity components for wind, relative humidity, pressure, surface and sea surface temperatures, etc.

Meteorological Modelling

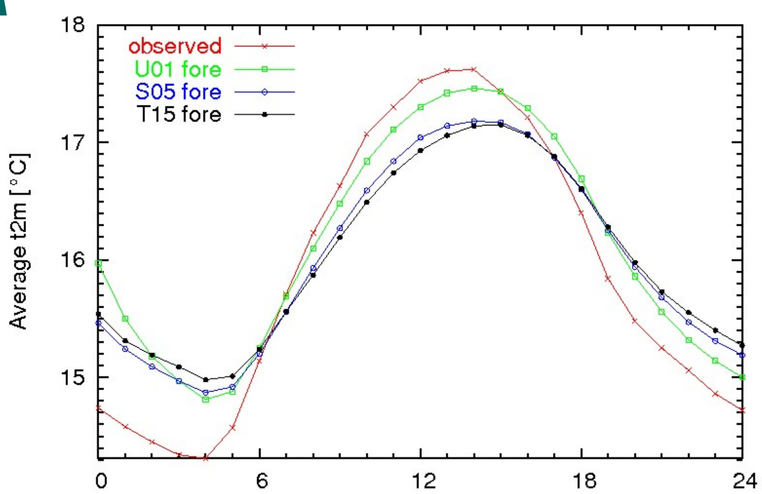
- **Approaches**
  - Specific case studies / meteorological situations
    (LWC, TWC, HWC, HPC)
  - Long-term simulations (summer months of 2004) and full climatological year
- **Boundary conditions**
  - ECMWF → DMI-HIRLAM-T15 → -S05 → -U01/I01
- **Runs**
  - control vs. urban (i.e. modify ISBA scheme)
- **Modification for urban grid cells**
  - anthropogenic heat flux and roughness (AHF+R)
  - building effects parameterization (BEP)
  - soil model for submeso-scales urban version (SM2-U)
- **Output**
  - 3D meteorological fields for 2 types of runs /control vs. urban/

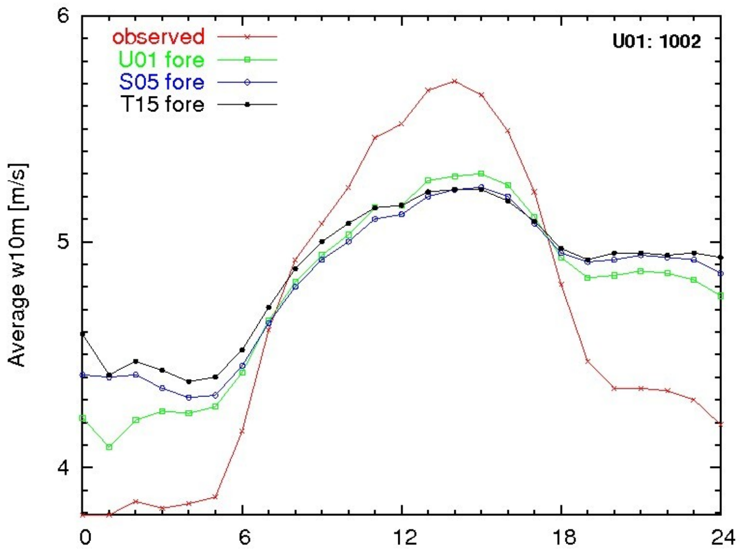
Evaluation of Results - 1

- Specific dates, summer months (July-August of 2004)
- Diurnal cycle
- Difference fields for control vs. urban runs
- Temperature and relative humidity at 2m, and wind at 10m
- Focus:
  impact of urban areas on simulated meteorological and pollution patterns

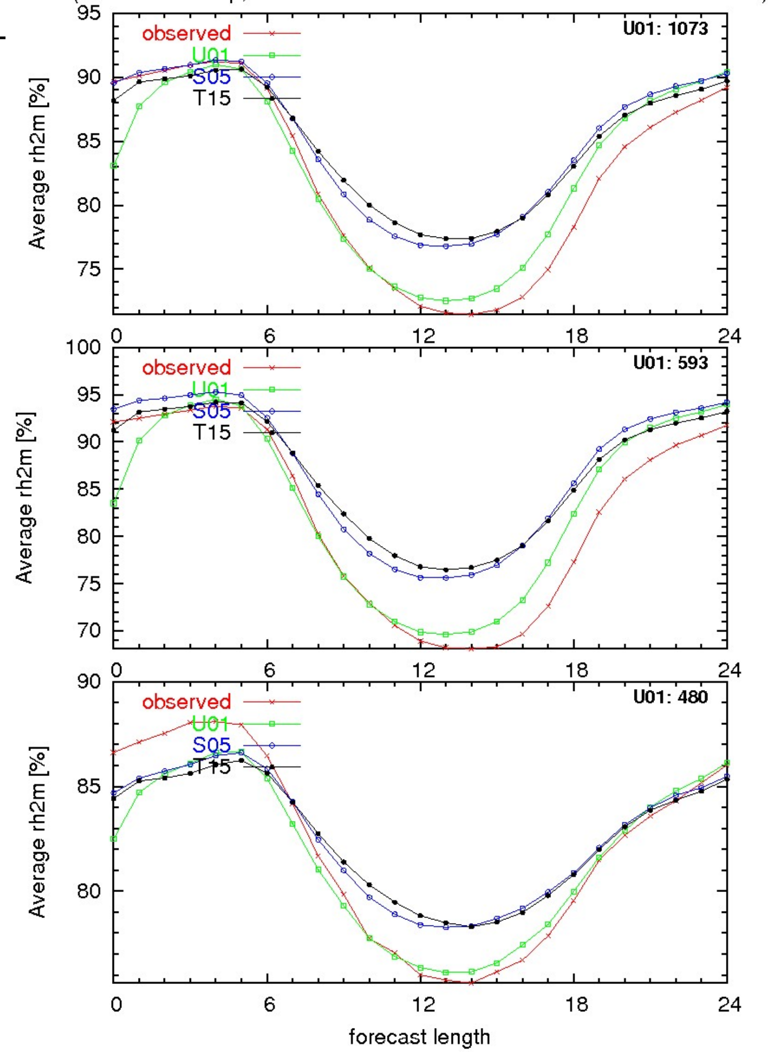
HIRLAM Modes Overall Performance

-------- all stations --------





diurnal variation for 00UTC forecasts for August :
(all stations at top, land stations in middle and coastal stations at bottom)

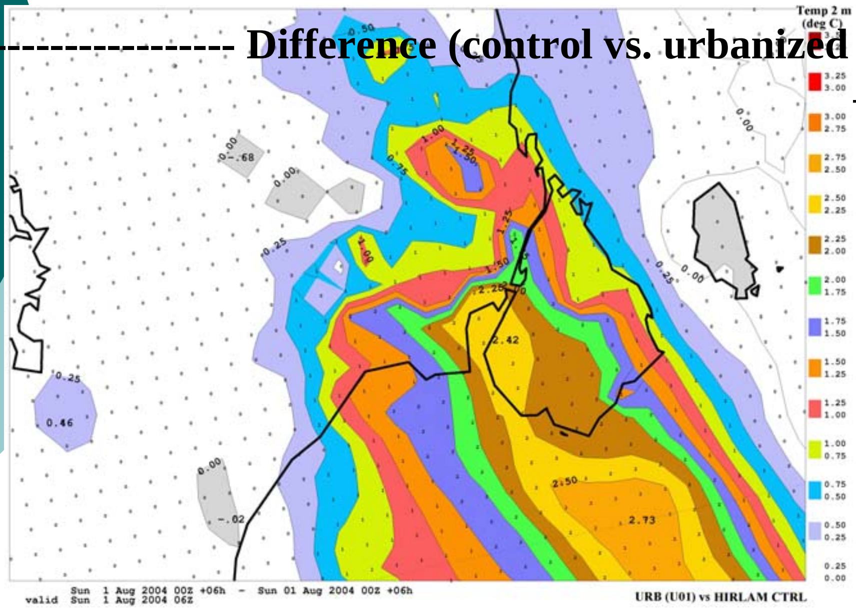


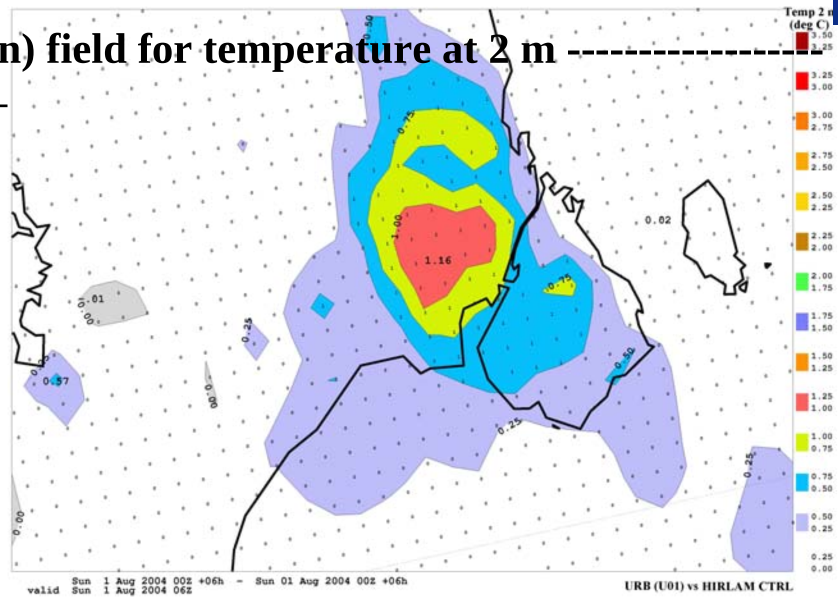
Example: Differences for AHF+R vs. BEP Modules

1 Aug 2004, 06 UTC

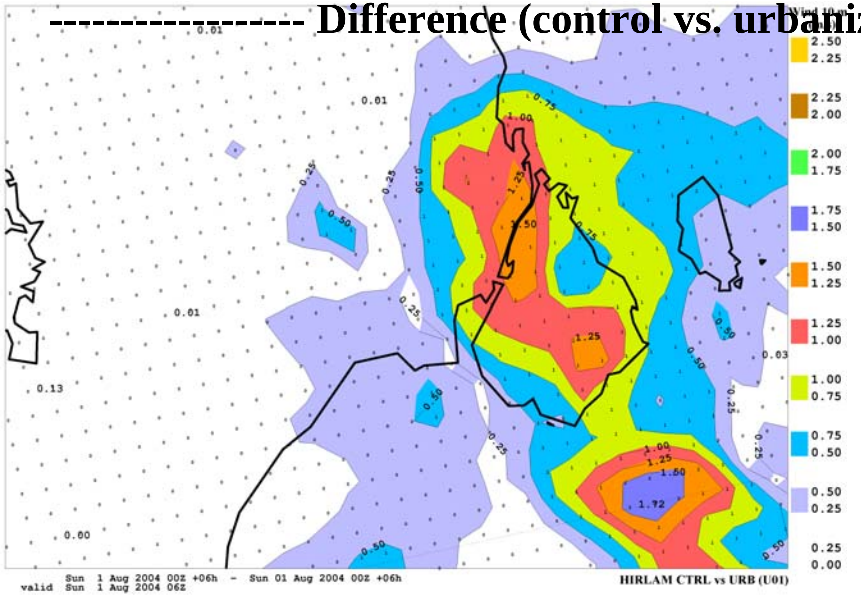
AHF+R **BEP**

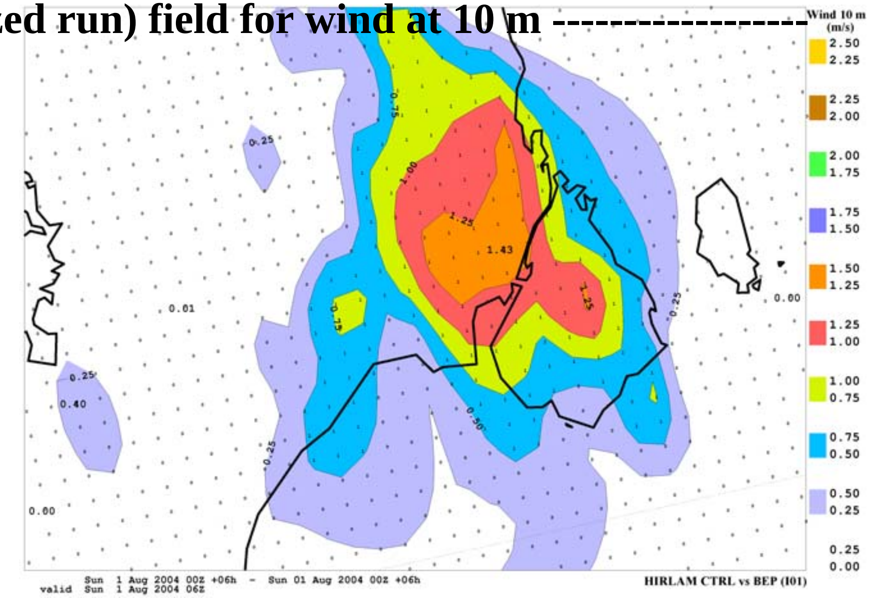
------------------ Difference (control vs. urbanized run) field for temperature at 2 m ------------------



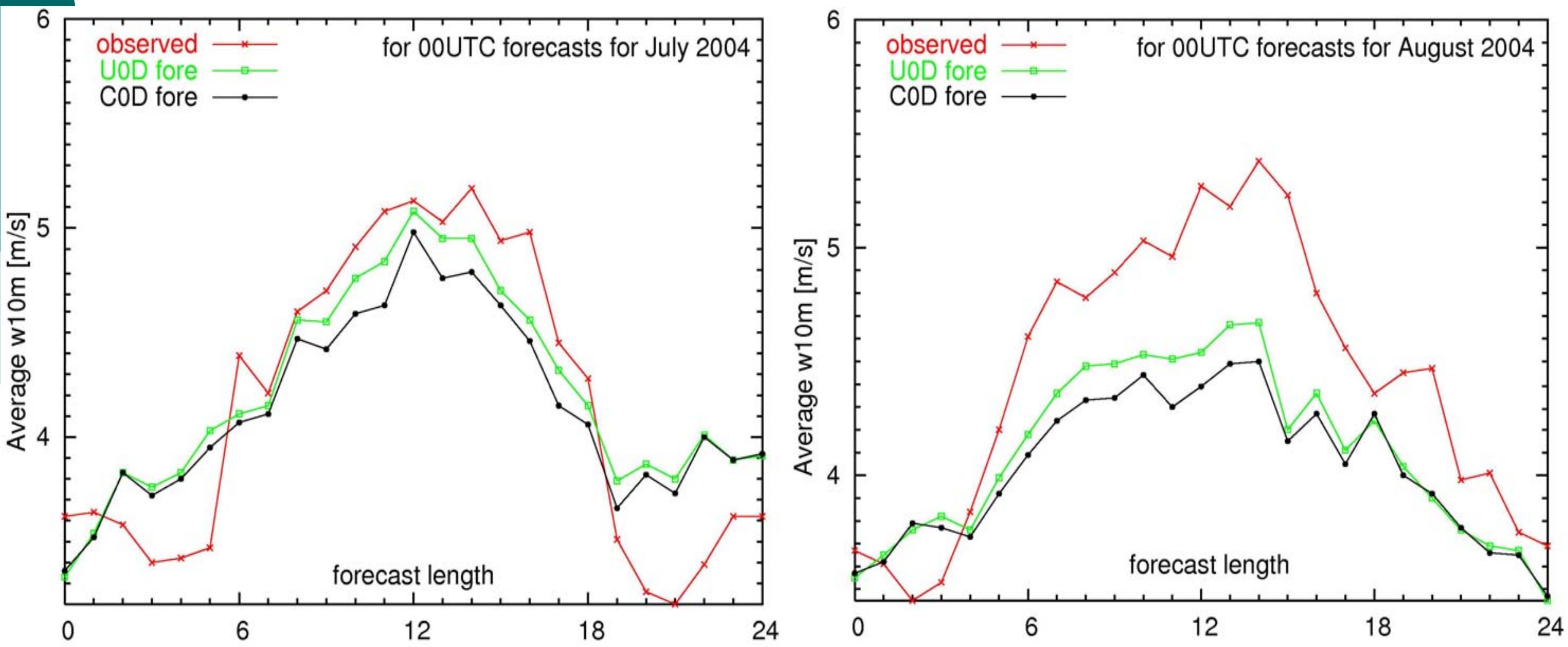


------------------ Difference (control vs. urbanized run) field for wind at 10 m ------------------





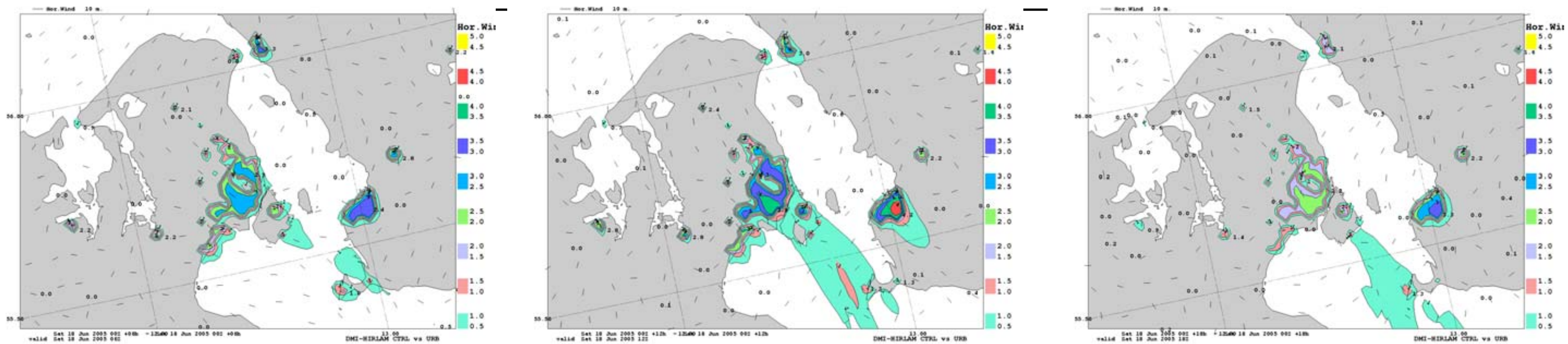
Example : Urban Station / Wind at 10 m



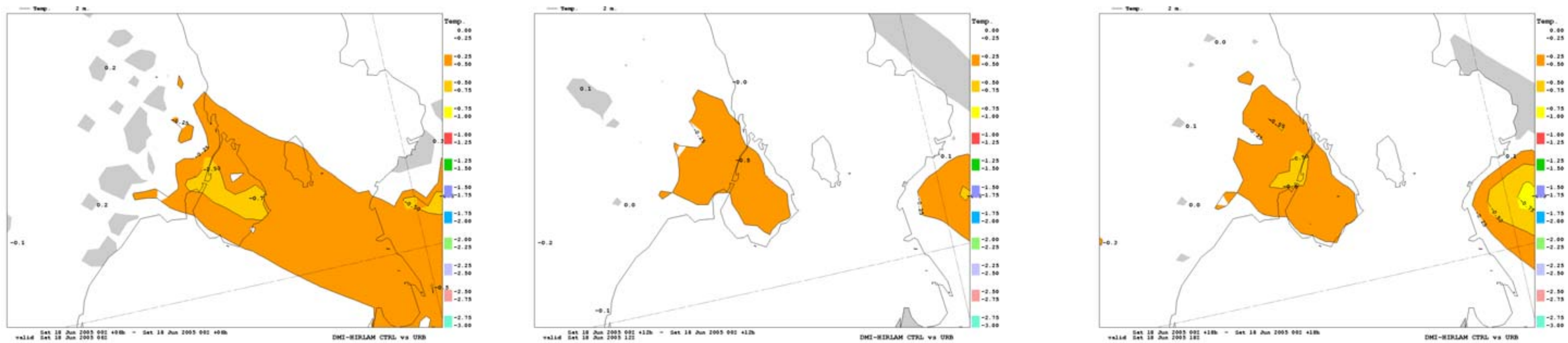
Diurnal variability for 00 UTC forecasts for the average wind velocity at 10 m for the urban station N–6180 in the Copenhagen metropolitan area during month of (a) July and (b) August of 2004 as function of the forecast length based on the DMI–HIRLAM–I01+BEP /U0D/ and –I01–CTRL /U0C/ model runs vs. observations

Typical Wind Conditions (TWC) date – 18 June 2005

---------------------- Difference (CTRL vs. URB run) field for wind at 10 m ----------------------



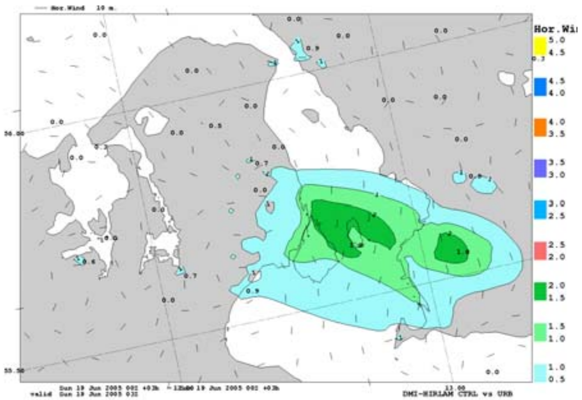
---------------------- Difference (CTRL vs. URB run) field for temperature at 2 m ----------------------

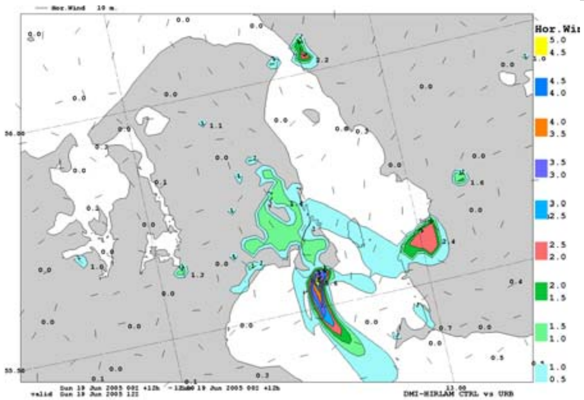


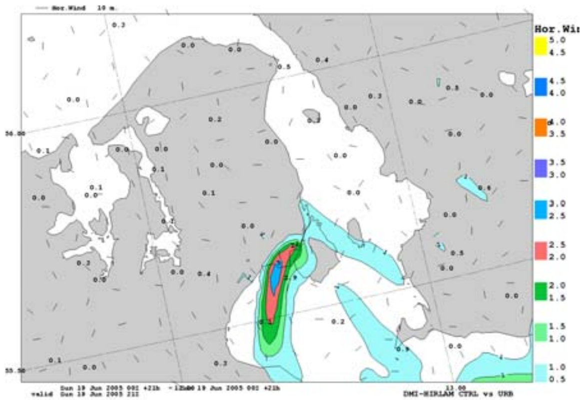
06 UTC **12 UTC** **18 UTC**

Low Wind Conditions (LWC) date – 19 June 2005

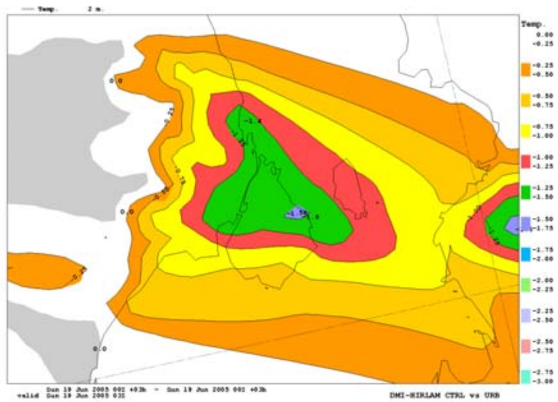
---------------------- Difference (CTRL vs. URB run) field for wind at 10 m ----------------------

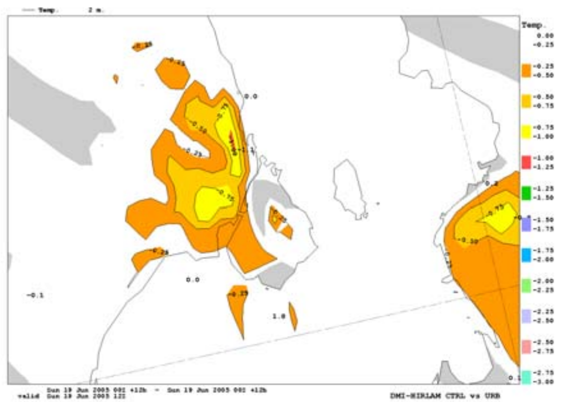


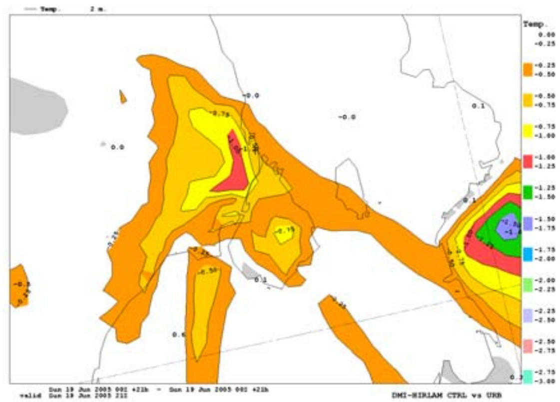




---------------------- Difference (CTRL vs. URB run) field for temperature at 2 m ----------------------



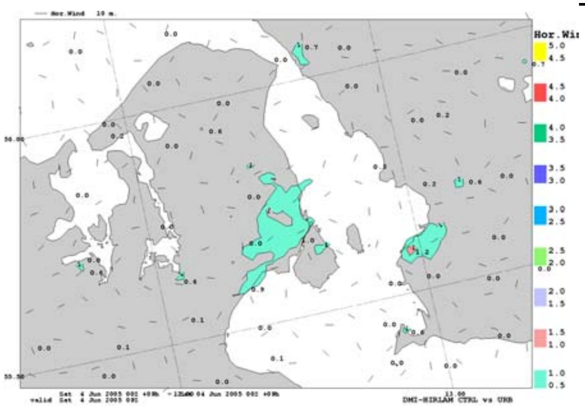


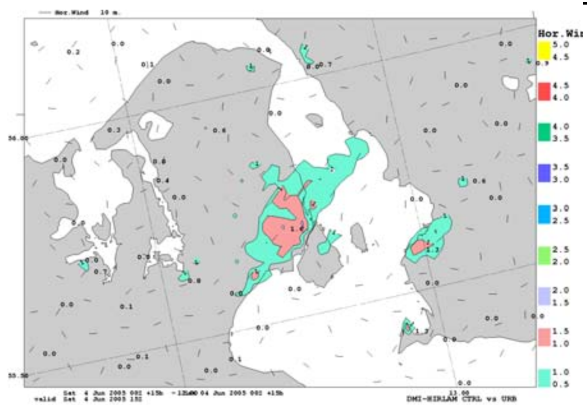


03 UTC **12 UTC** **21 UTC**

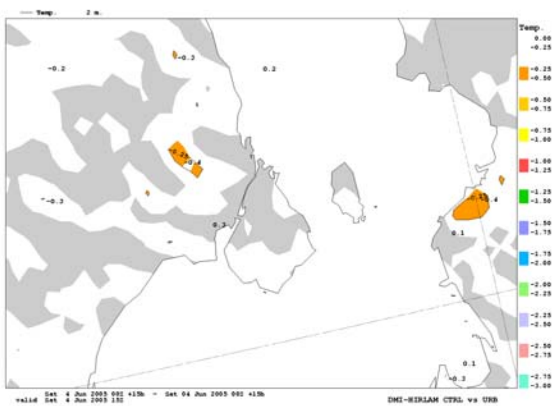
High Wind Conditions (HWC) date – 4 June 2005

---------------------- Difference (CTRL vs. URB run) field for wind at 10 m ----------------------





---------------------- Difference (CTRL vs. URB run) field for temperature at 2 m ----------------------



09 UTC

15 UTC

Evaluation of Results - 2

- Analysis of month-to-month variability

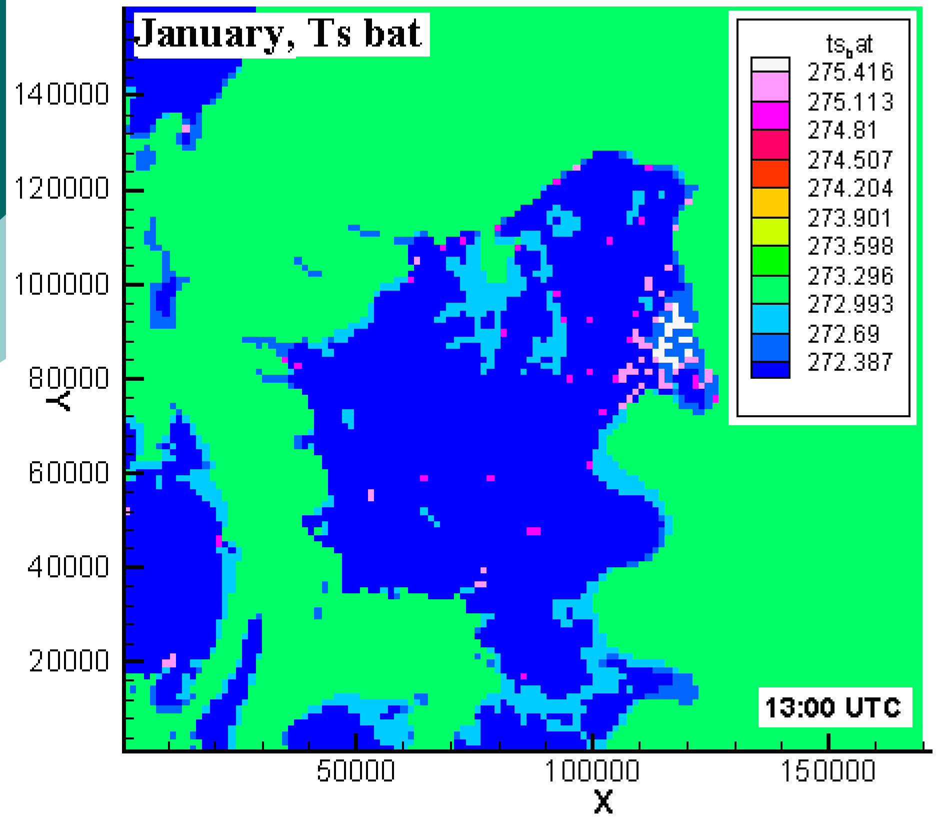
- Diurnal cycles on annual (entire dataset) and monthly basis
- For 7 types of selected covers/surfaces
- For different districts (urbanized vs. non urban areas)

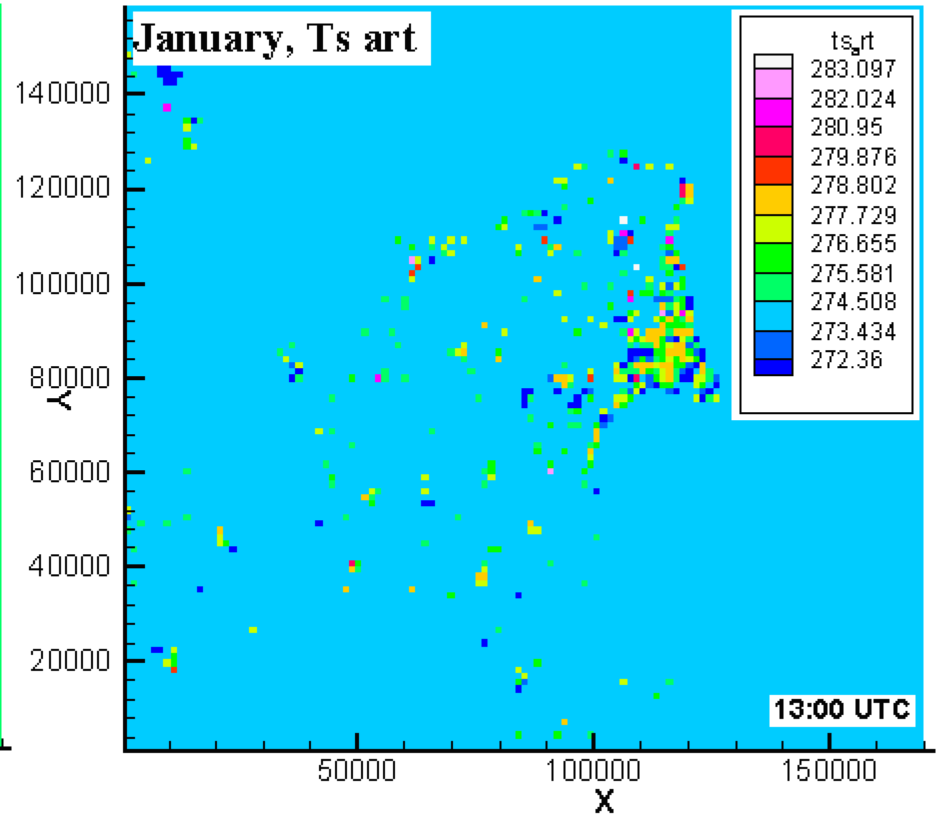
Districts:

City Center/High Buildings District	(CC/HBD)
Industrial Commercial District	(ICD)
Residential District	(RD)

- Diurnal cycle - on UTC scale
  (local standard time in DK - 1 hour of difference)

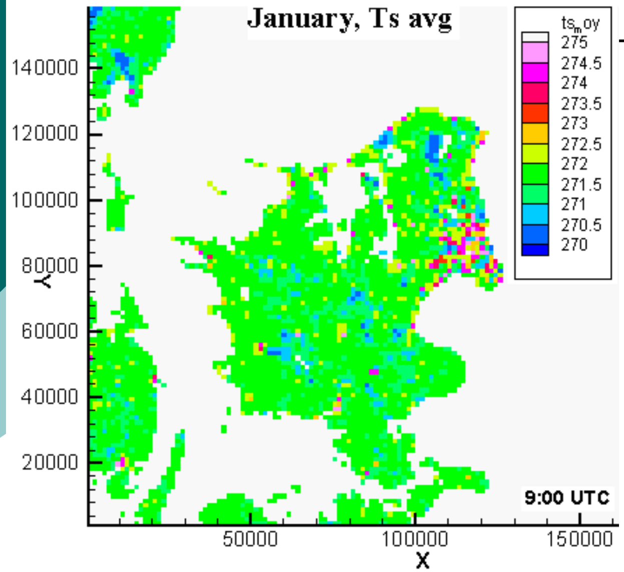
Example – SUBMESO+SM2-U Urban Climate Modelling: Temperature of Surface for Urban Types

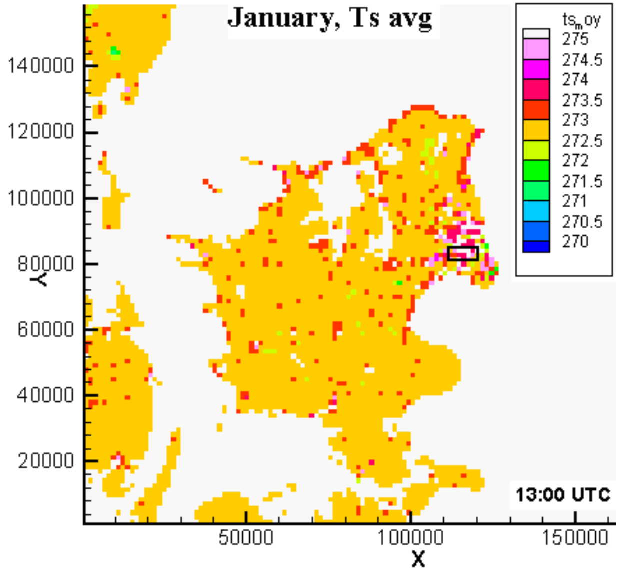


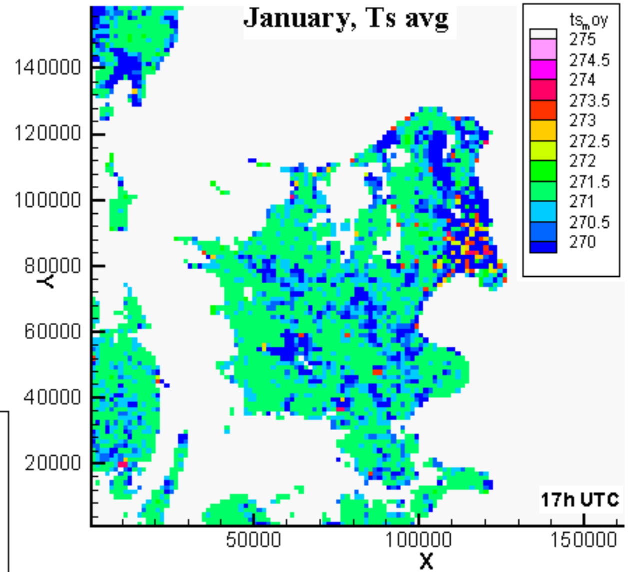


VEGA	Vegetation over paved surfaces
ART	Paved surfaces located between the sparse vegetation elements
BAT	Building/roofs
EAU	Water surfaces

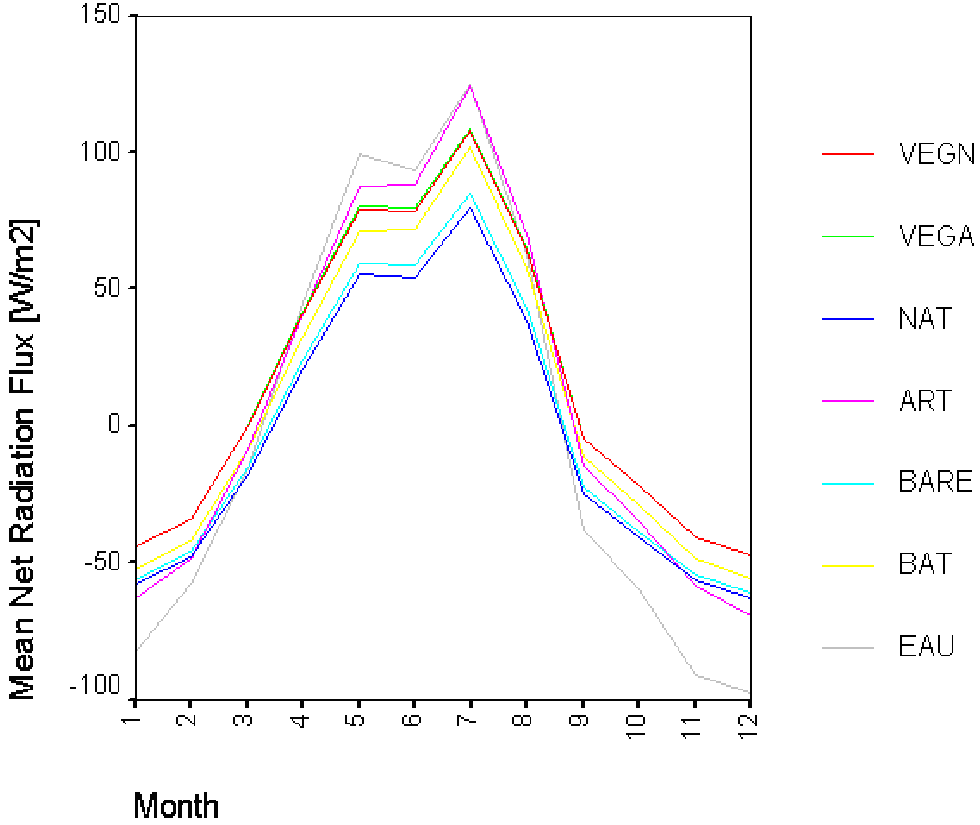
Example - SUBMESO+SM2-U Urban Climate Modelling: Average Temperature of Surface

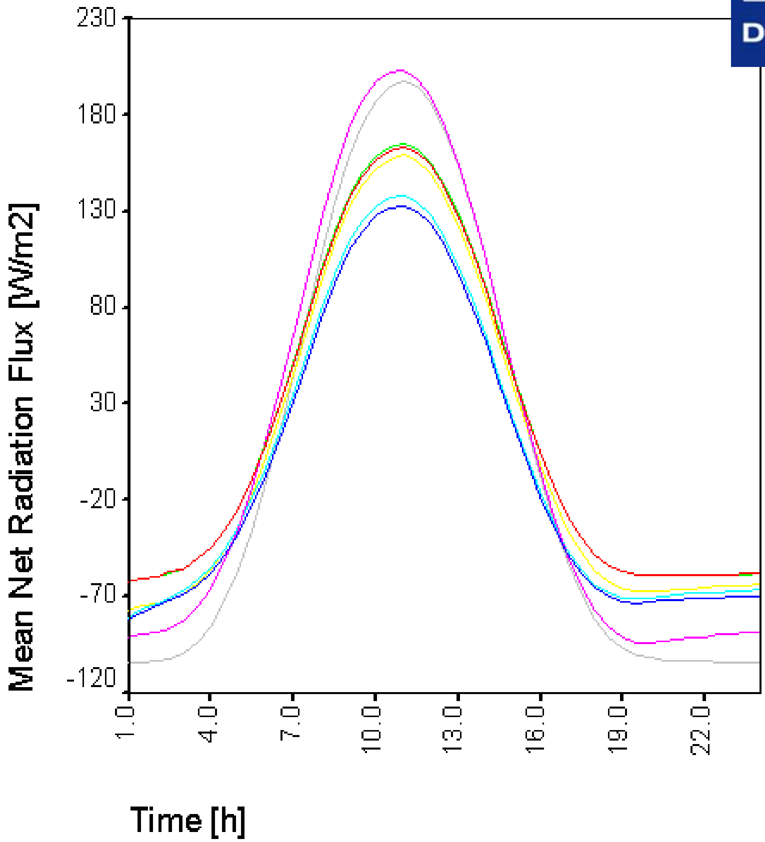






Net Radiative Fluxes : Types of Surfaces





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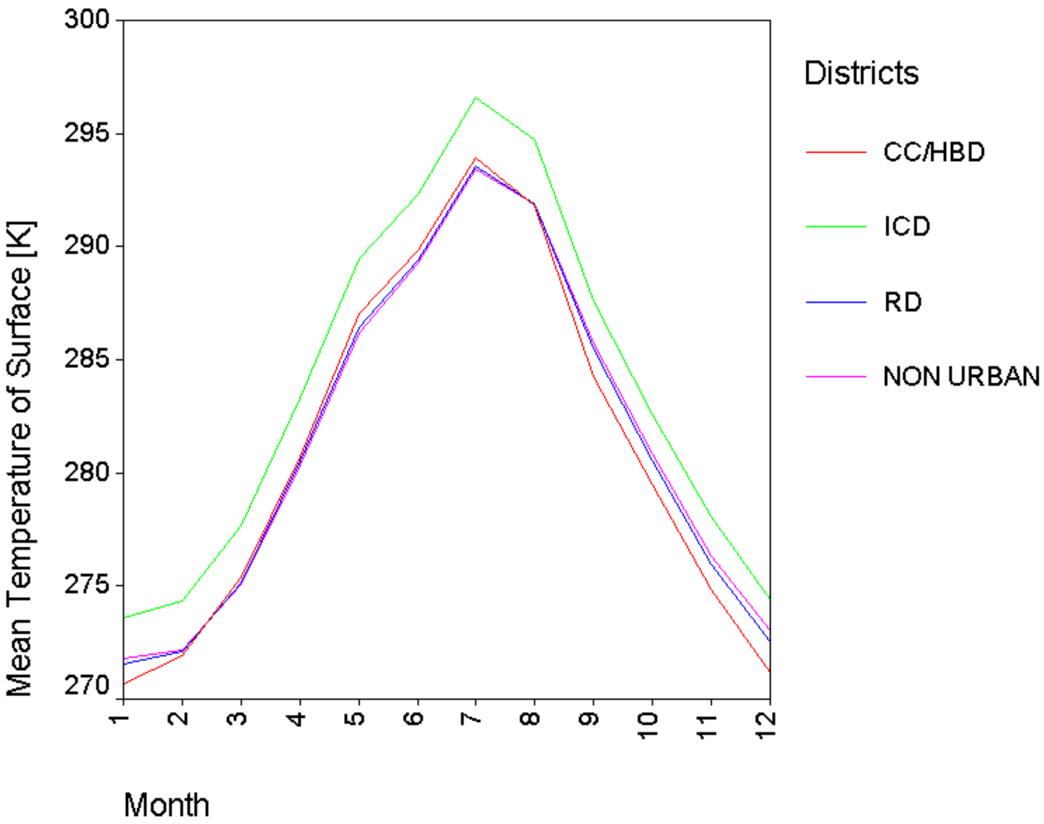
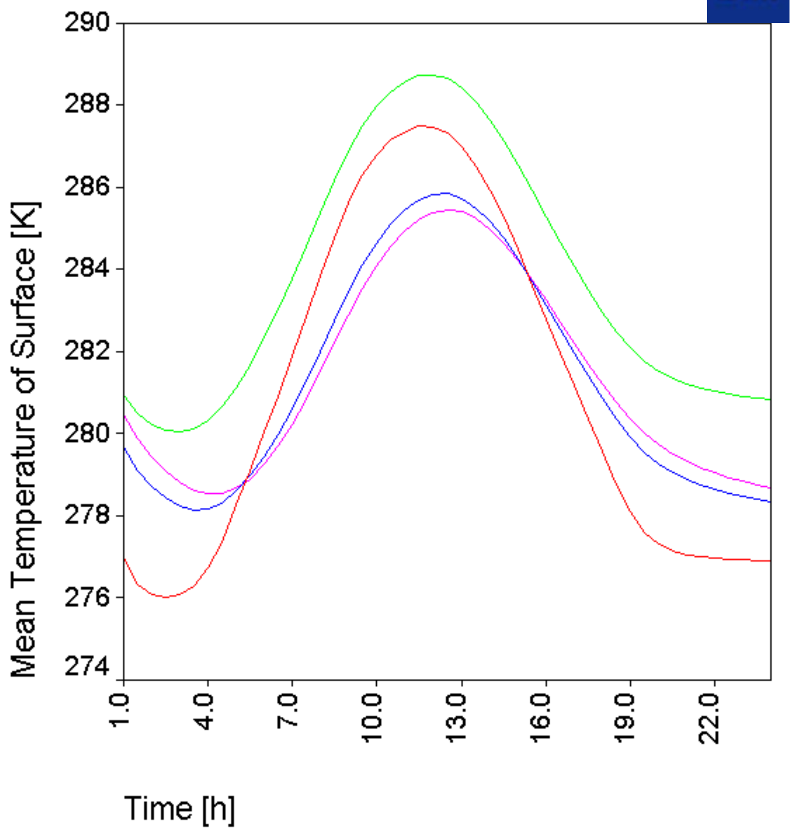
EAU	Water surfaces

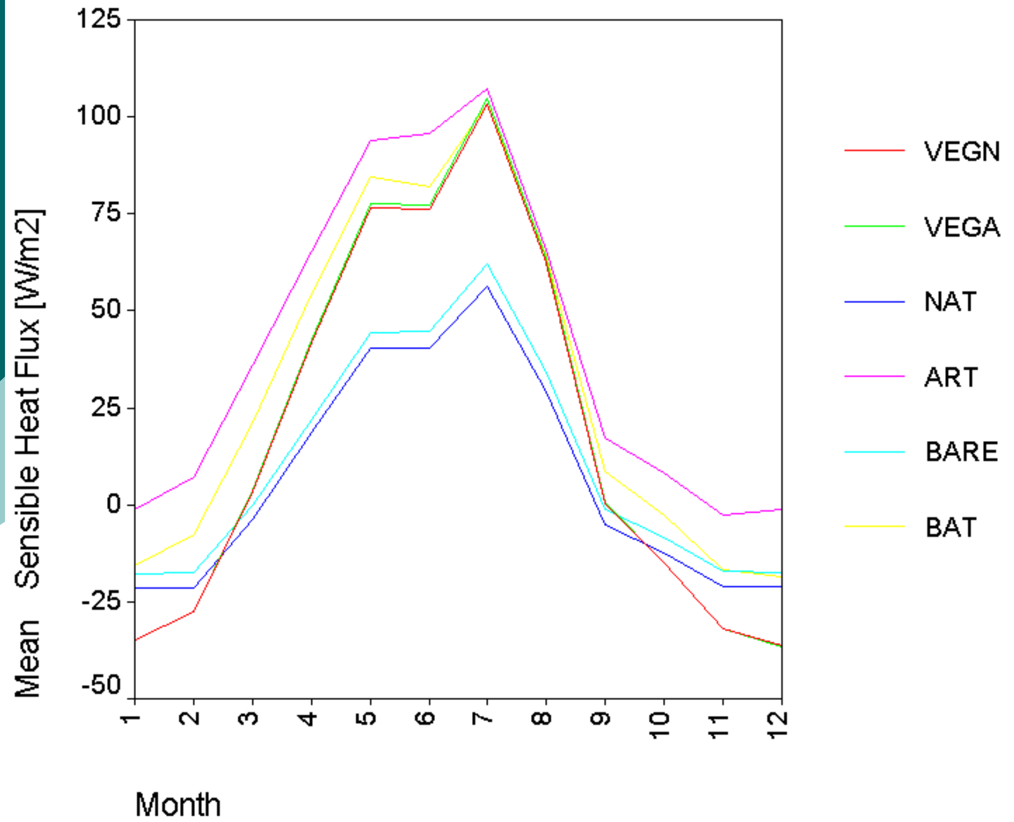
Surface Temperatures : Urban Districts

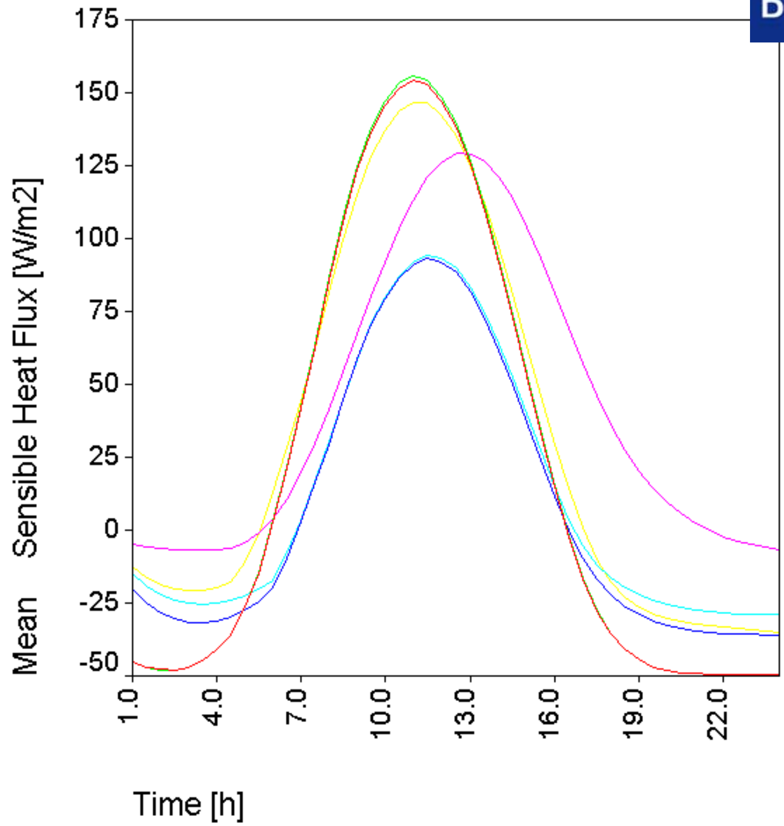




CC/HBD	City center / high buildings district
ICD	Industrial commercial district
RD	Residential district
Non-urban	Non-urban areas (no BAT type)

Sensible Heat Flux : Types of Surfaces





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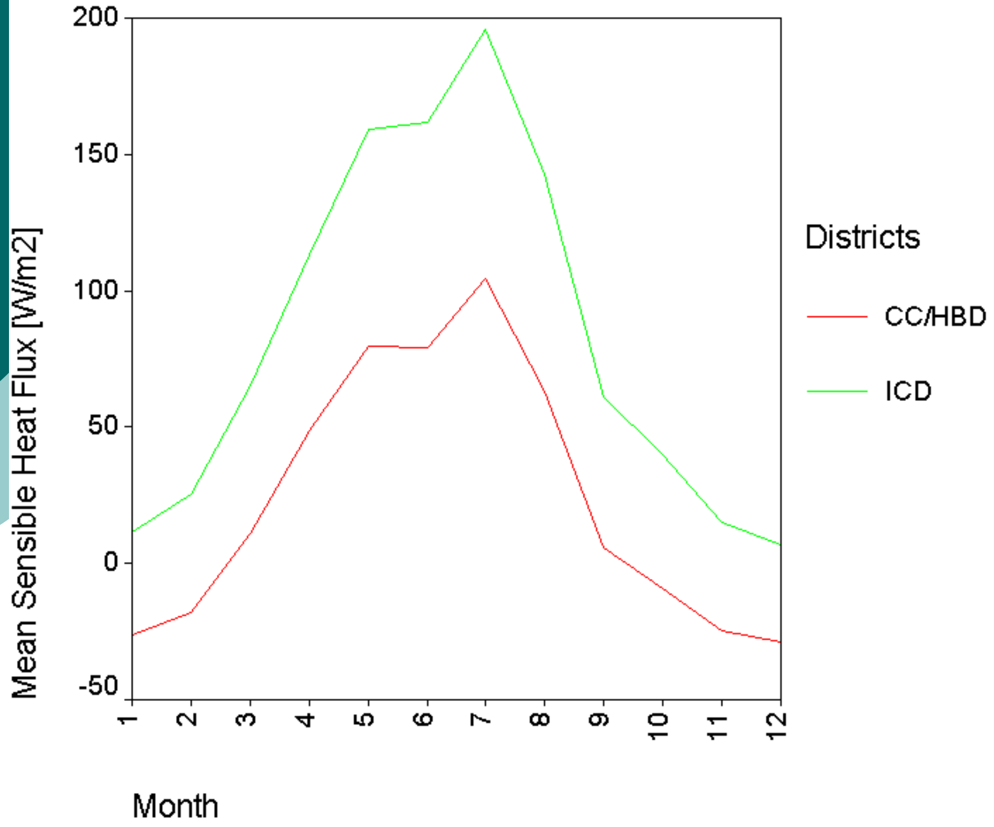
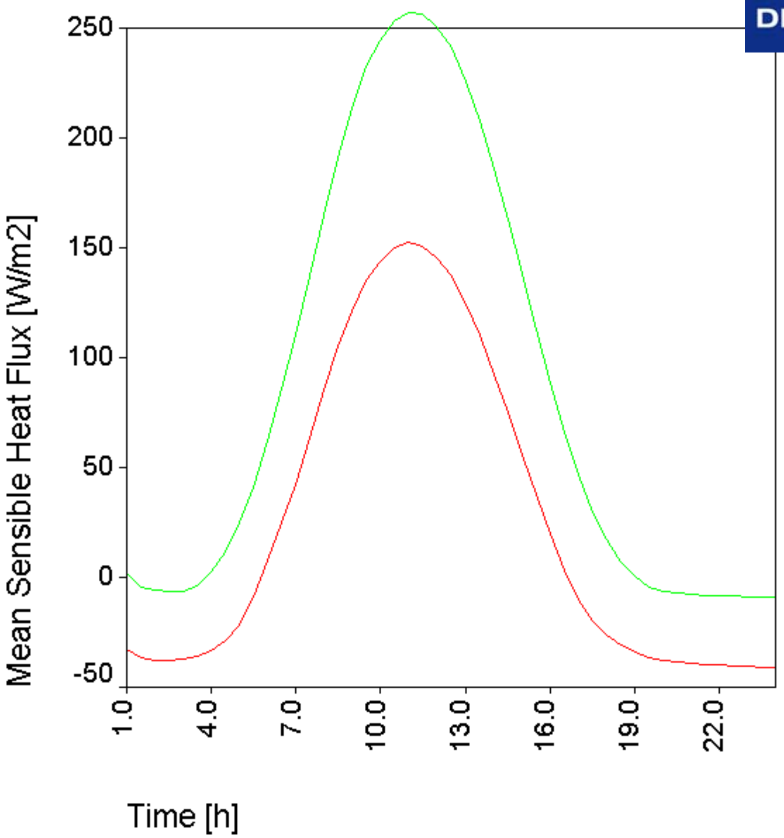
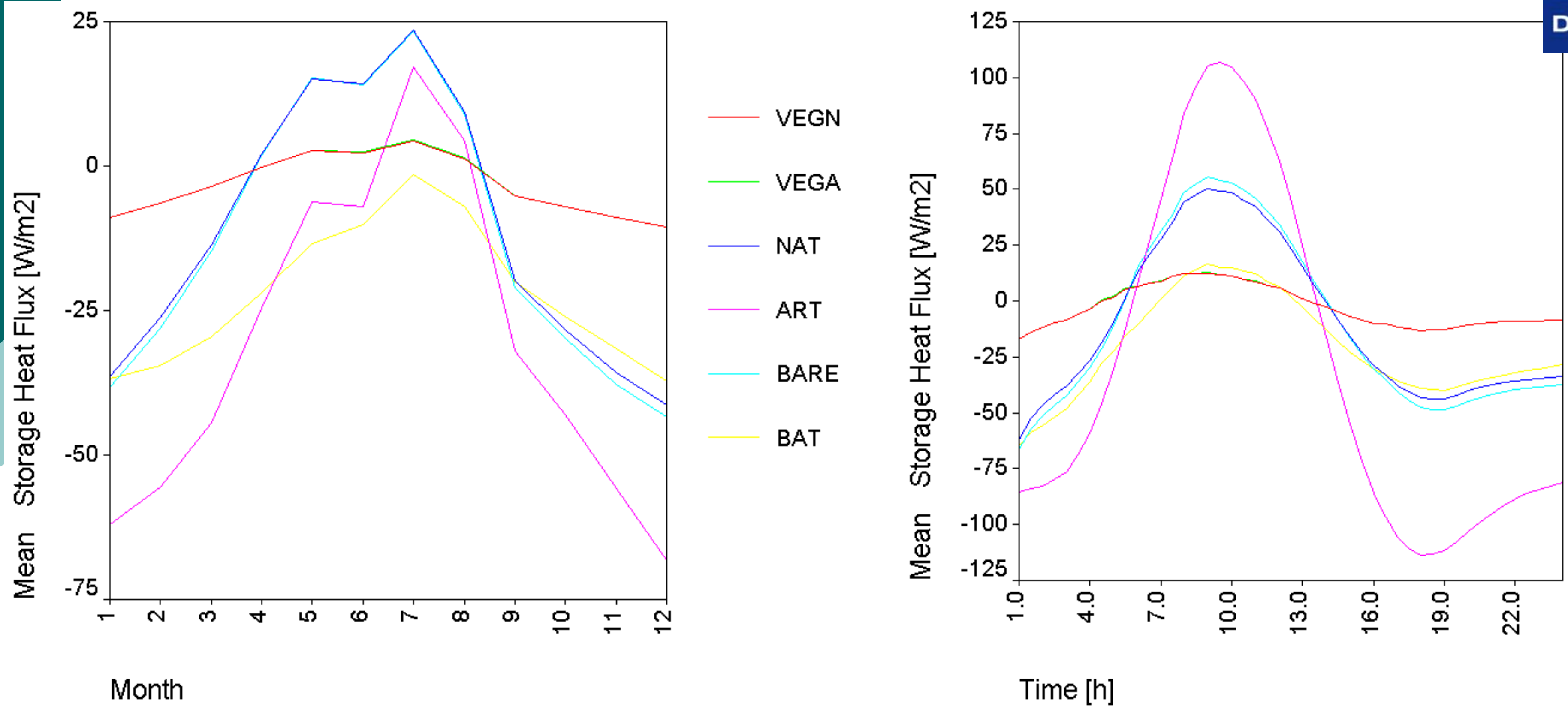
Sensible Heat Flux : Urban Districts





CC/HBD	City center / high buildings district
ICD	Industrial commercial district

Storage Heat Flux : Types of Surfaces



BARE	Bare soil without vegetation
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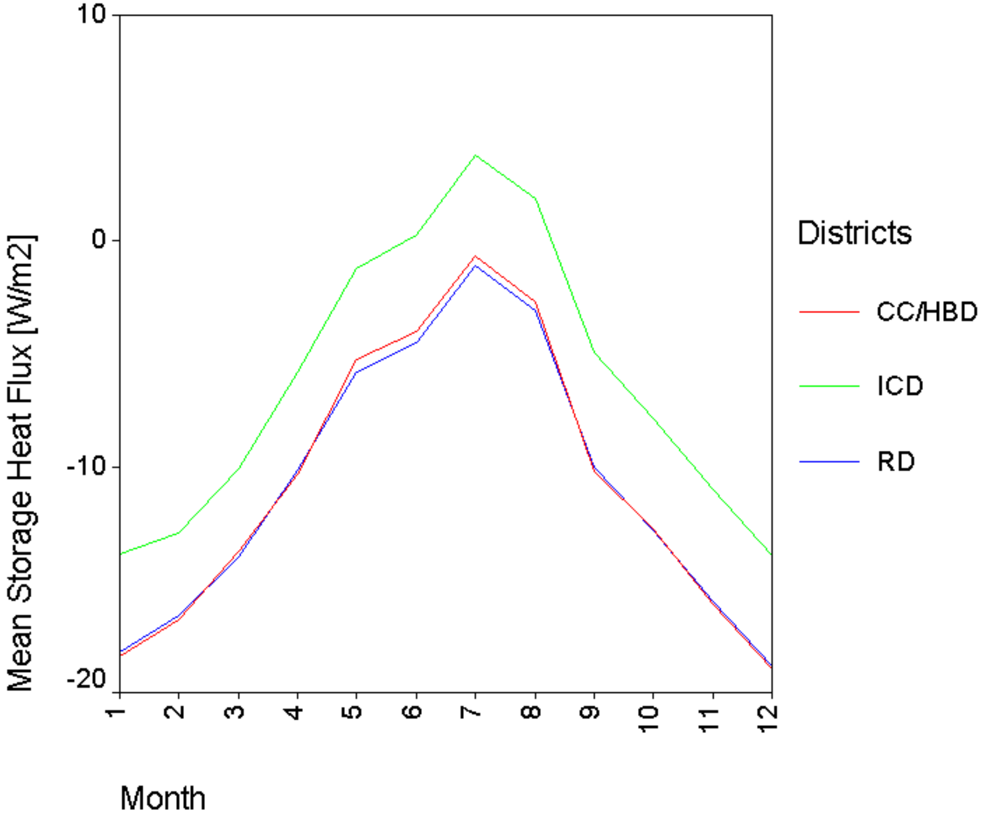
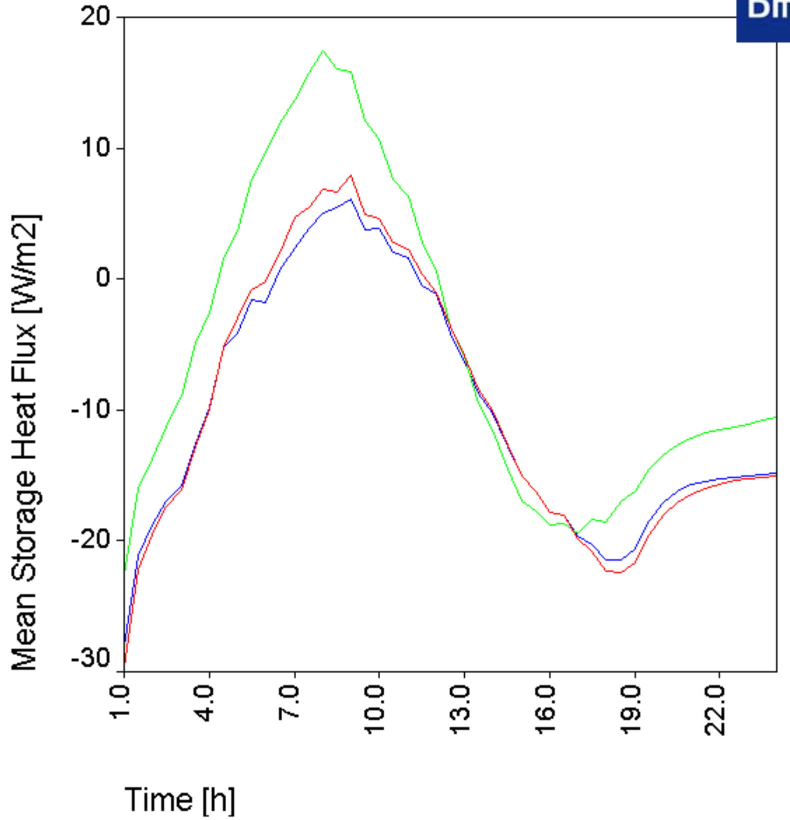
BAT	Building/roofs
EAU	Water surfaces

Storage Heat Flux : Urban Districts





CC/HBD	City center / high buildings district
ICD	Industrial commercial district
RD	Residential district

Conclusions

- Long-term operational (HIRLAM) and climatological (SUBMESO) runs with the high resolution urbanized models showed improvement for the overall models performances,
- &

this improvement is more visible over the urbanized areas such as Copenhagen

Differences between **control** vs. **urban** runs:

- For typical wind conditions (TWC):
  - wind at 10 m (m/s) <0.5 (max up to 1.5, at midday)
  - temperature at 2 m (ºC) <0.25 (max up to 0.5, at nighttime)
  - relative humidity (%) > 3 (max up to 5, at midday)
- For low wind conditions (LWC):
  - wind at 10 m (m/s) >1 (max up to 3 at nighttime)
  - temperature at 2 m (ºC) >0.5 (max up to 1.5, at nighttime)
  - relative humidity > 4 (max up to 7, at midday)

Results Applicability

- Testing and verification of numerical weather prediction and climatological models performance over high resolution model domains, and especially, over the urbanized areas;
- Investigation of temporal and spatial variability of various meteorological and derived variables over urbanized areas;
- Improvements in land use classification and climate generation properties;
- Distinguishing and selection of types of urban districts and their properties;
- Urbanization of climate regional and global models.

Thanks

- Ecole Centrale de Nantes, France – SM2-U
  (research group of Prof. Patrice Mestayer)
- University of Lousanne, Switzerland – BEP
  (research group of Prof. Allan Clappier)
- **Computing**: DMI supercomputer resources
  (NEC SX-6, from Sun 2008 – CRAY XT-5)
- **Collaboration, computer advice and assistance**: HIRLAM group, Data Processing Department, Danish Climate Center, EDB computer support