Deutscher Wetterdienst

Evaluation and comparison of operational NWP and mesoscale meteorological models for forecasting urban air pollution episodes - Helsinki case study -

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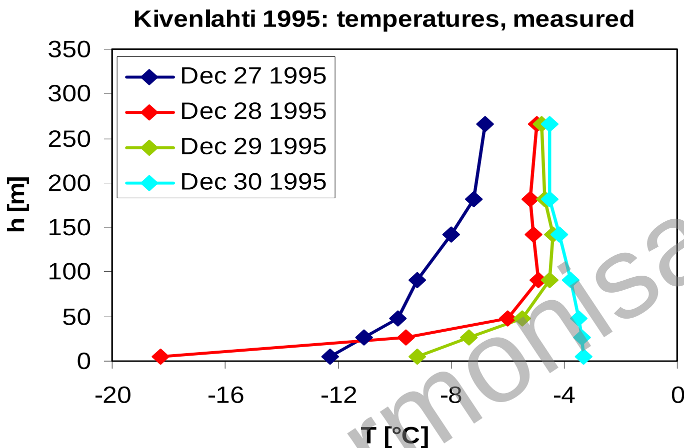
FUMAPEX: Integrated Systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure

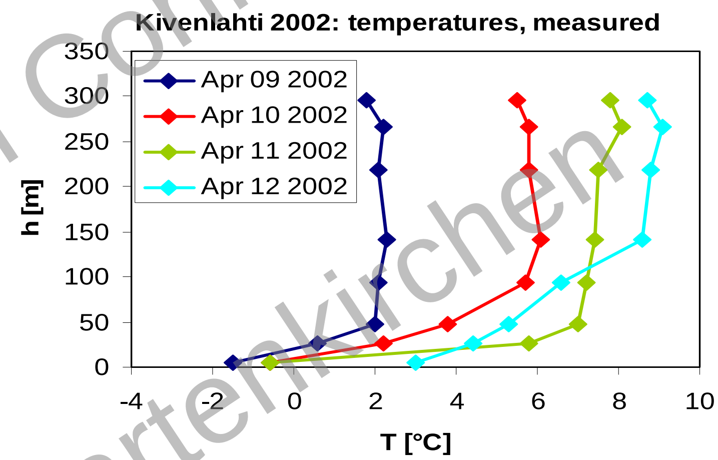
EU FP5 project, CLEAR cluster

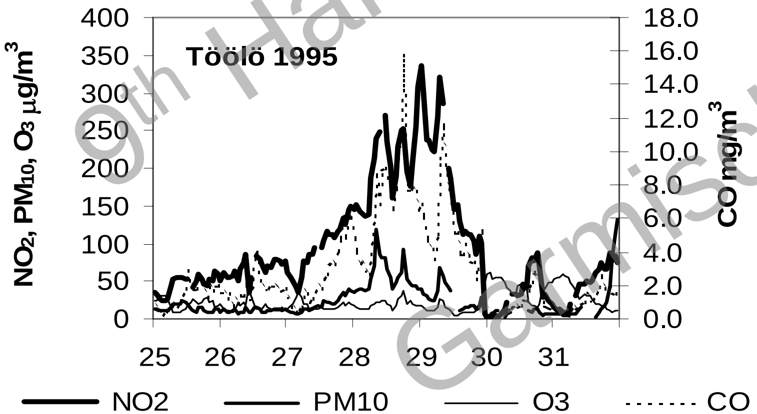
Outline

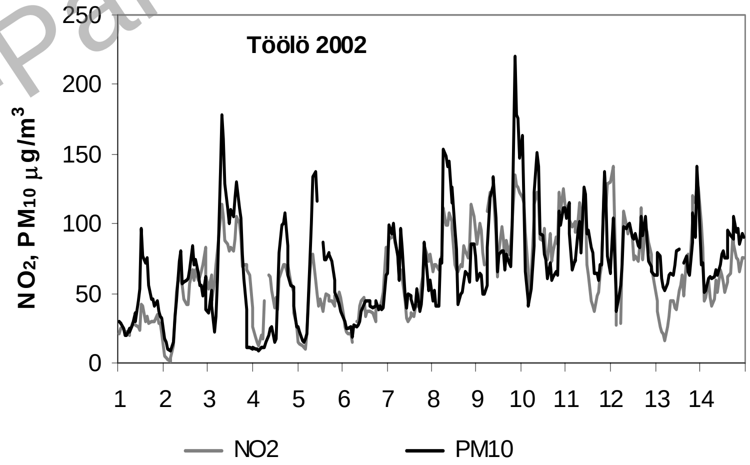
- **FUMAPEX: motivation, idea, realisation**
- **evaluation setup**
- **impact of NWP model grid resolution**
- **inter-comparison of NWP model results**
- **summary**
- **outlook**

Short-term pollution episodes in cities







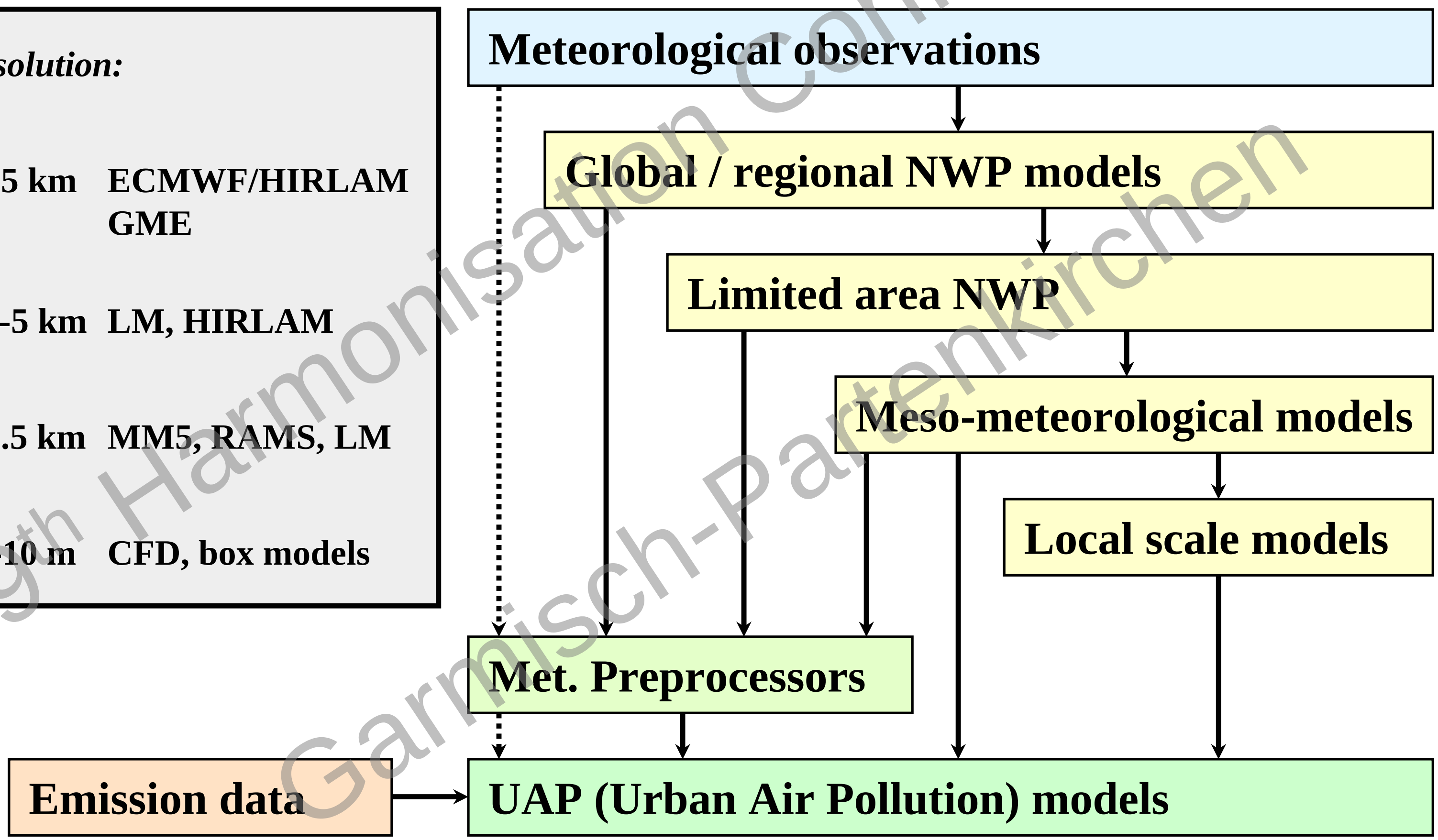


Data: FMI

Forecasting urban meteorology

Resolution:

> 15 km	ECMWF/HIRLAM GME
~ 1-5 km	LM, HIRLAM
> 0.5 km	MM5, RAMS, LM
~1-10 m	CFD, box models



FUMAPEX workflow scheme

WP 1 + WP 2: Episode analysis + data, existing UAP modelling approaches

WP 3: Testing different NWP-models using different resolutions

- DMI-/DNMI-/FMI-HIRLAM
- LM/LAMI
- MM5
- RAMS

WP 4: Urbanised parameterisations in meteorological models

- Urban heat flux
- Urban soil models
- Urban roughness
- Sat. surface info

WP 5: Improved interfaces to UAP models

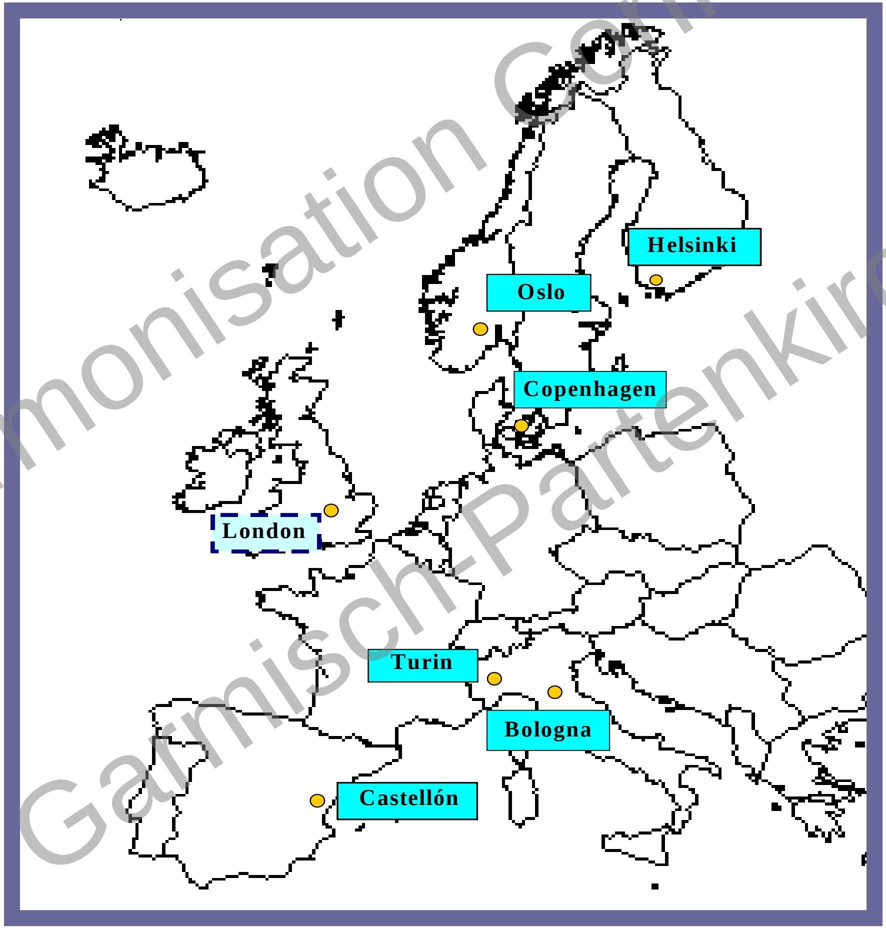
- Mixing height
- ABL param.
- met. param.
- NWP data

WP 6: Sensitivity of UAP models to NWP model designs

WP 7: Population Exposure models

**WP 8: Implementation and evaluation of improved UAQIFSs
(Urban Air Quality Information and Forecasting Systems)**

FUMAPEX main target cities

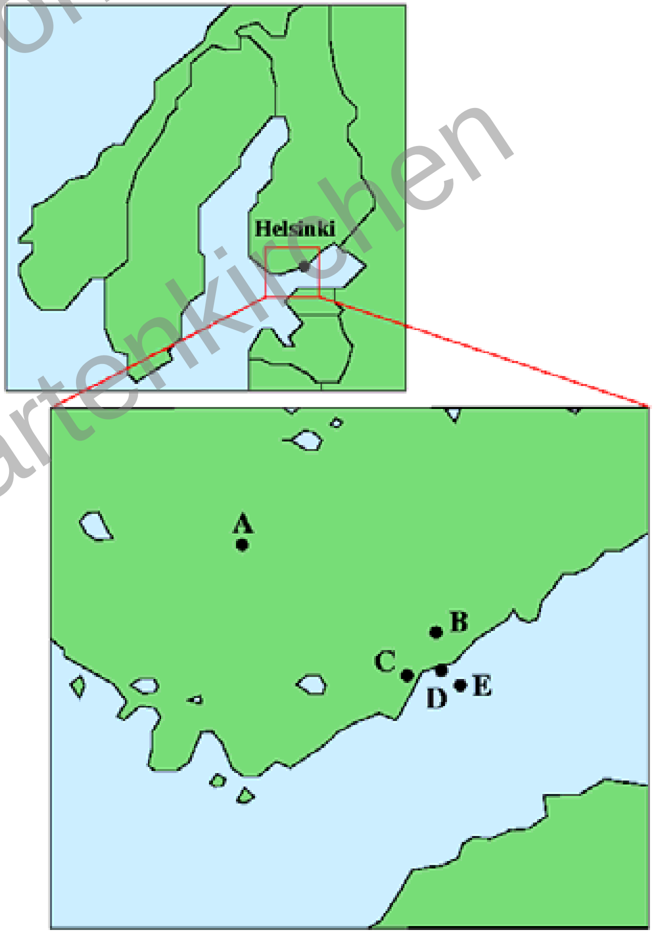


Meteorological conditions

Episode	Characterisation
27-29 Dec 1995	• local inversion induced episode (high NO_2, CO and PM_{10}) • high pressure, extremely strong ground inversion • low westerly winds, cold and dry • stable to very stable (nighttime) stratification • snow cover, no widespread ice cover over sea • warm front passage on Dec 29
22-24 Mar 1998	• local resuspended particle episode • high pressure, ground inversion • very low south(-westerly) winds, dry • moderately to extremely stable (nighttime) stratification
8-13 Apr 2002	• local resuspended particle episode • high pressure, ground inversion • very slight south-easterly winds, sunny and dry, cold nights • no snow or ice cover

Parameters of meteorological stations

code	name	h[m]	type
A	Jokioinen	103	rural
B	Vantaa	56	suburban
C	Kivenlahti	44	rural
D	Kaisaniemi	4	urban
E	Isosaari	5	rural/island



Simulation and evaluation methodology

key meteorological factors for episodes in northern/central Europe (Sokhi et al., 2003; Kukkonen et al., 2004):

the temporal evolution of

- **temperature inversion**
- **wind speed**
- **atmospheric stratification**
- **(topography)**

48h forecasting, starting at 00UTC, to be used for UAQIFSs

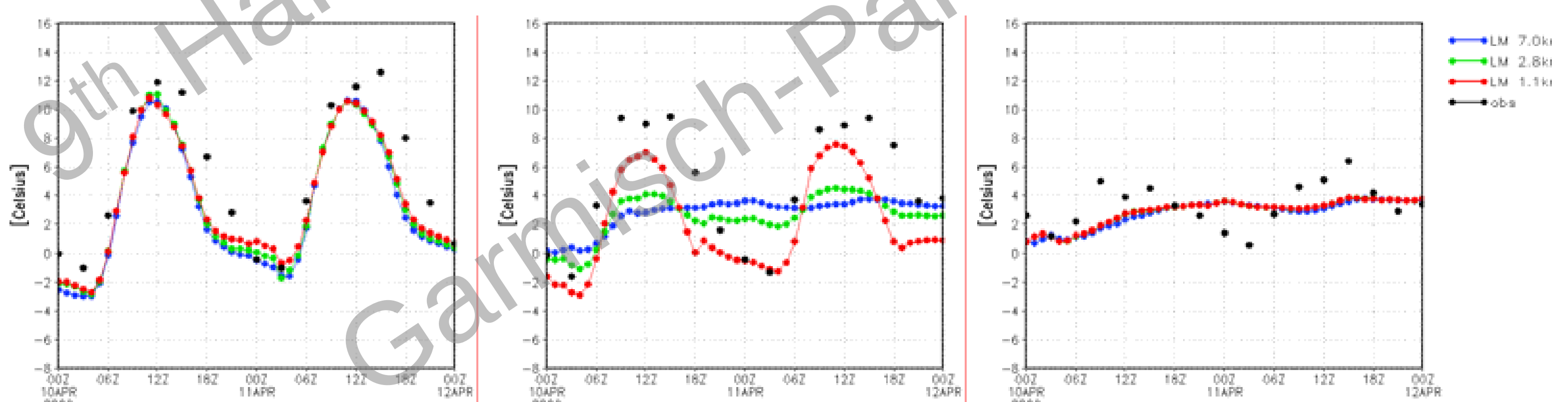
• **horizontal fields** • **vertical profiles at station locations** • **time series at station locations** • **vertical profiles as time series** • **vertical cross section**	**T, RH, WS, WD** **S_RAD, L_RAD** **SHF, LHF** **Tpot, TKE, MH**
• **standard statistical scores**	**T2m, RH2m, WS10m**

Influence of grid resolution

- **in general:** small influence, some improvement
- **for coastal cities:** distinct influence due to changes in physiographic parameters (land/sea mask, soil type)

Example: LM 7.0, 2.8, 1.1km, observations

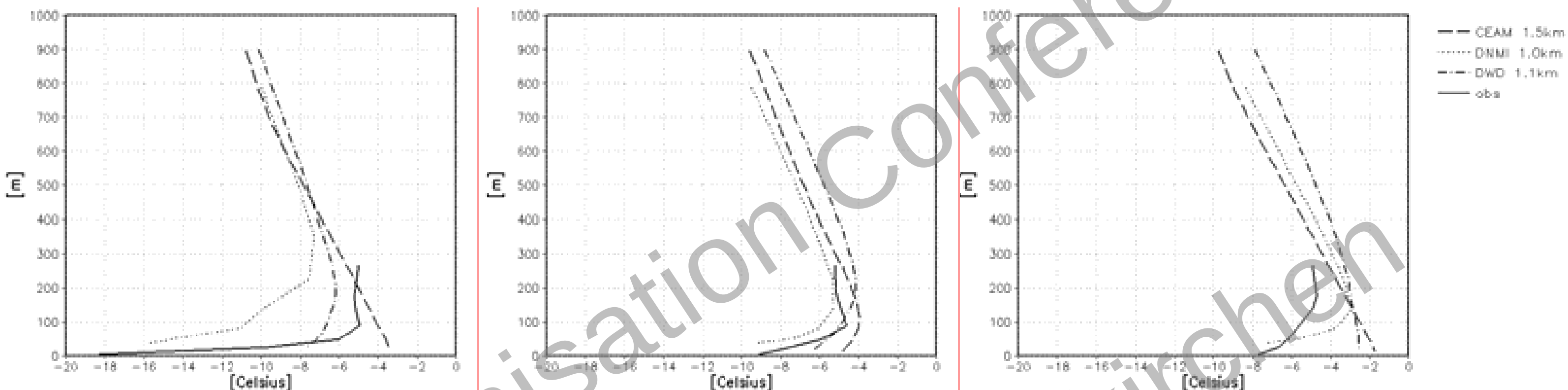
T_2m [°C] 48h time series starting 10 Apr 2002, 00UTC



Vantaa **Kaisaniemi** **Isosaari**

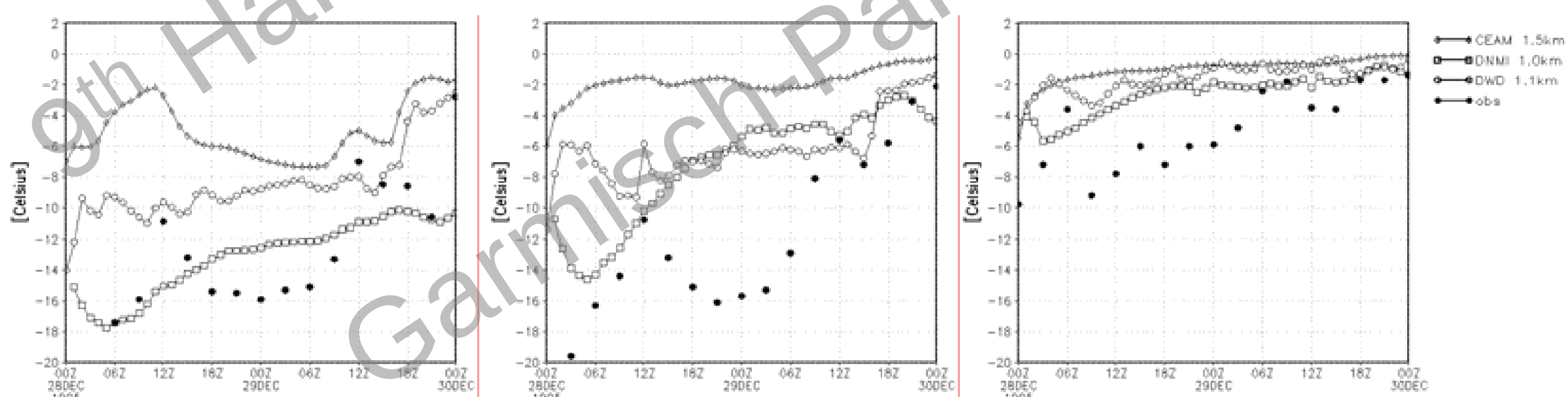
T [°C] for RAMS, MM5, LM, obs

Vertical profiles Kivenlahti 28 Dec 1995



00UTC + 6h 00UTC + 24h 00UTC + 42h

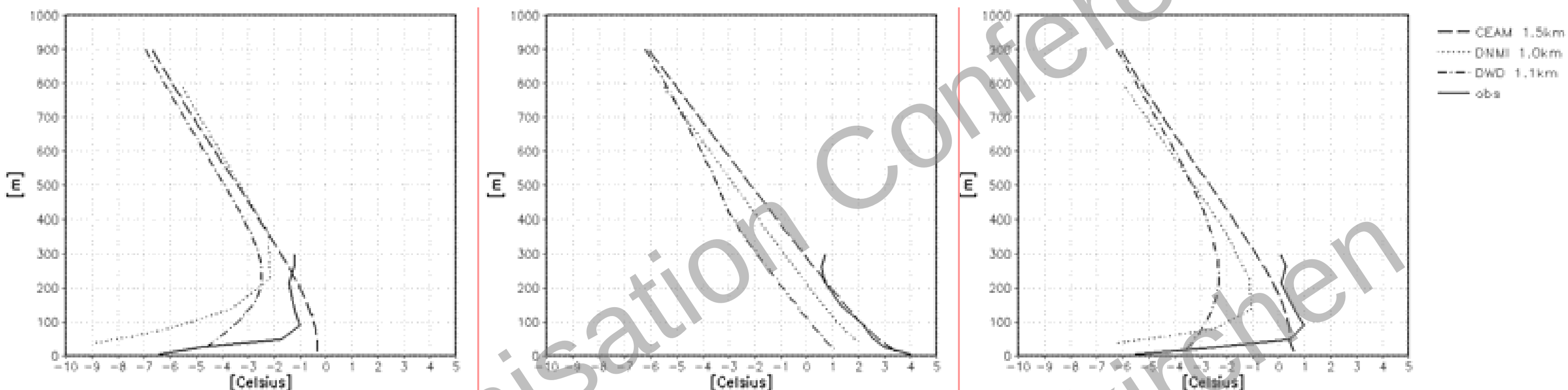
48h time series starting 28 Dec 1995, 00UTC



Vantaa Kaisaniemi Isosaari

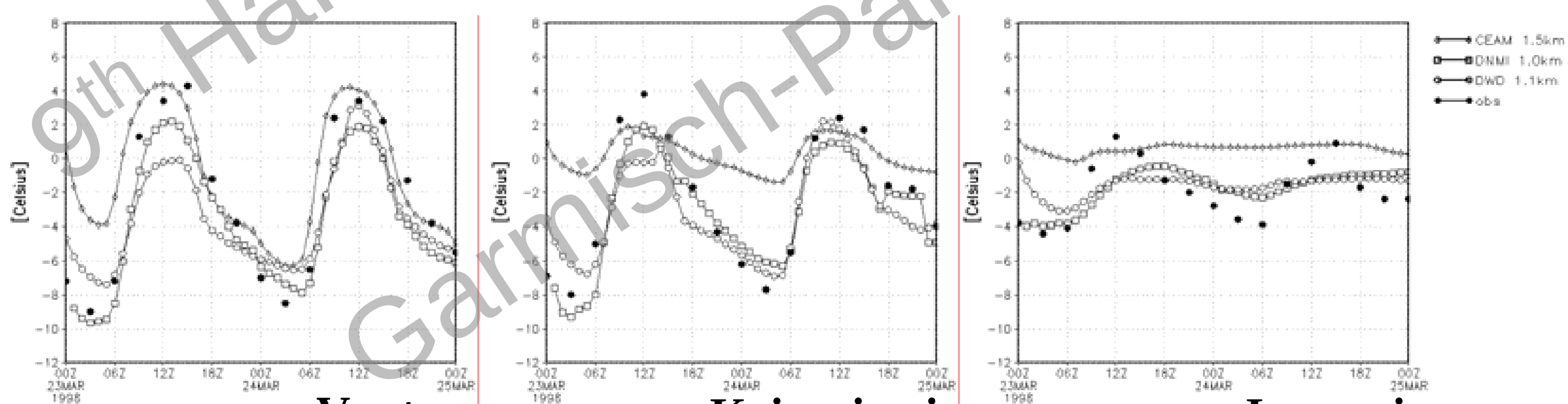
T [°C] for RAMS, MM5, LM, obs

Vertical profiles Kivenlahti 23 Mar 1998



00UTC + 6h | 00UTC + 12h | 00UTC + 24h

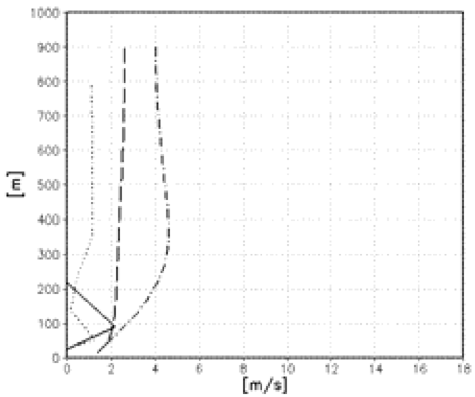
48h time series starting 23 Mar 1998, 00UTC



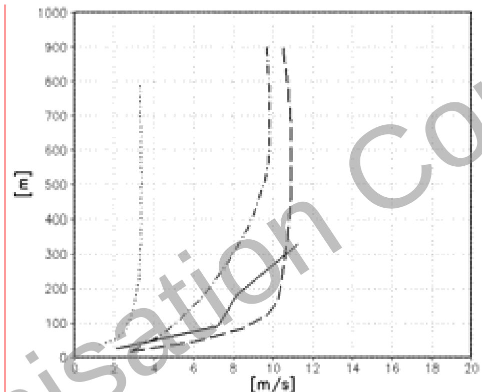
Vantaa | Kaisaniemi | Isosaari

Wind speed [m/s] for RAMS, MM5, LM, obs

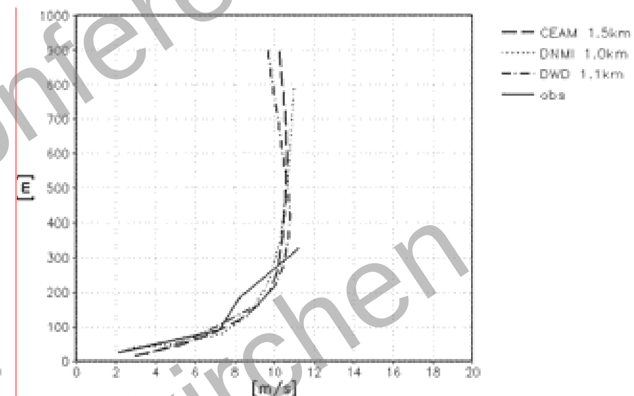
1998 | Vertical profiles Kivenlahti | 1995



23 Mar, 00UTC + 30h

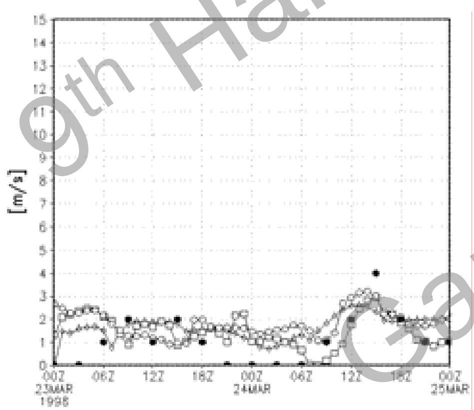


28 Dec, 00UTC + 30h

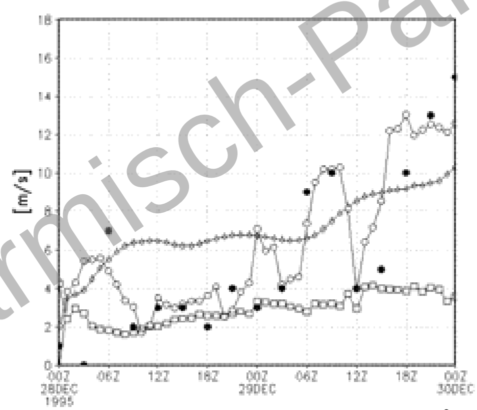


29 Dec, 00UTC + 6h

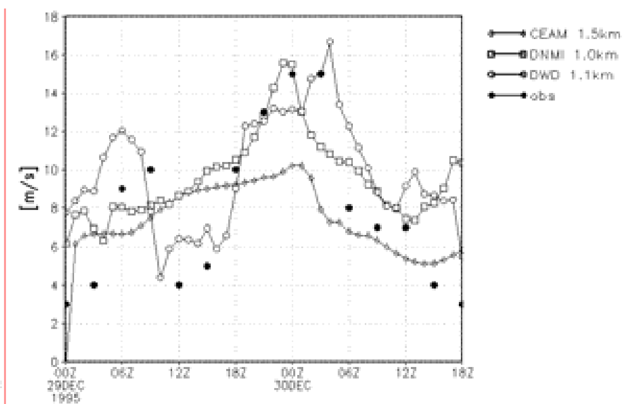
1998 | 48h time series, starting 00UTC | 1995



23 Mar, Vantaa



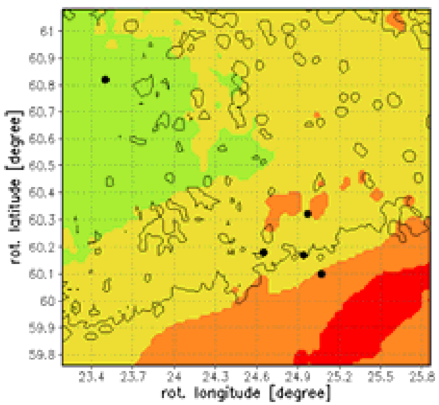
28 Dec, Isosaari



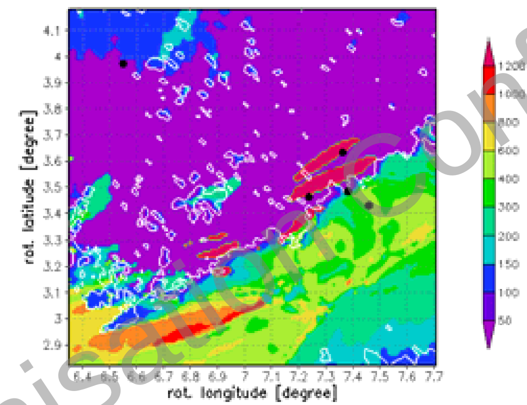
29 Dec, Isosaari

Planetary boundary layer heights

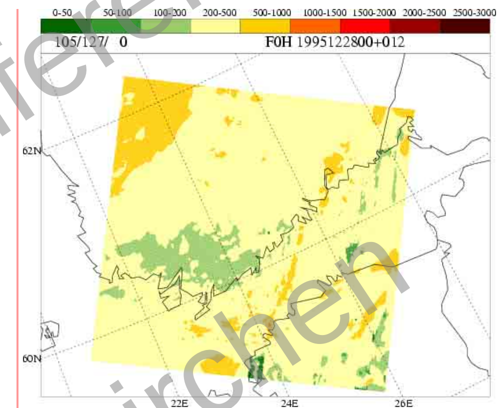
PBL [m], horizontal fields 28 Dec 1995, 00UTC + 12h



CEAM RAMS

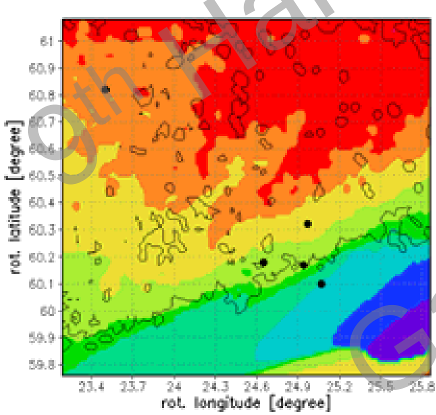


DWD LM

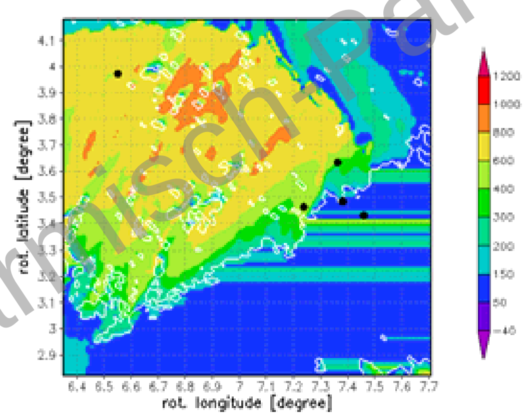


DMI-HIRLAM

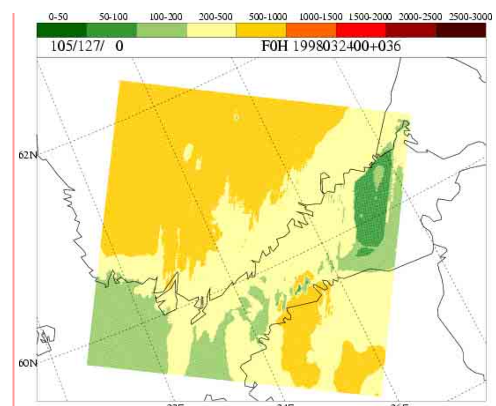
PBL [m], horizontal fields 24 Mar 1998, 00UTC + 36h



CEAM RAMS



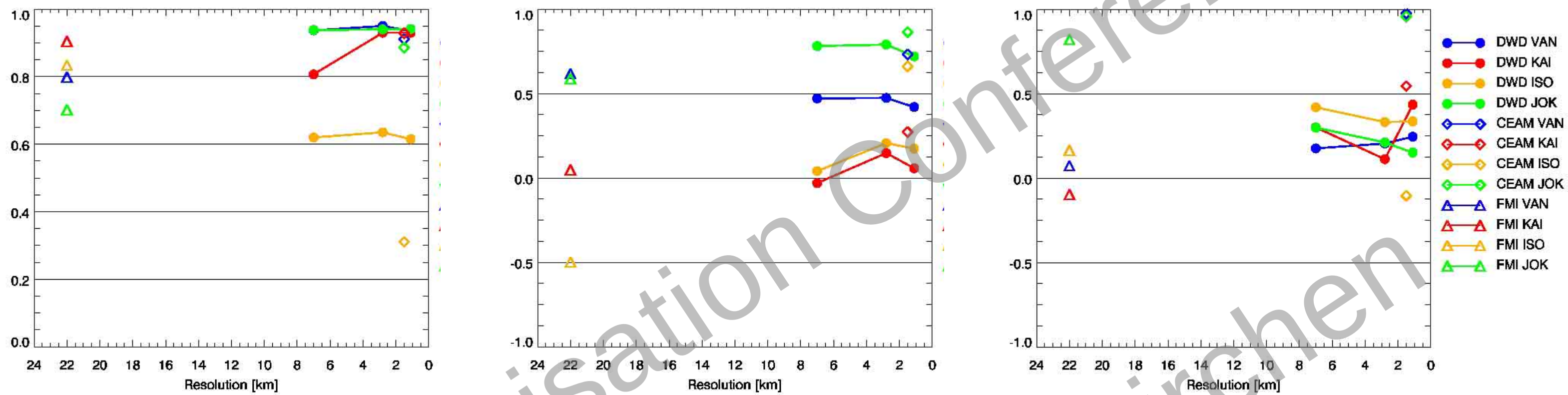
DWD LM



DMI-HIRLAM

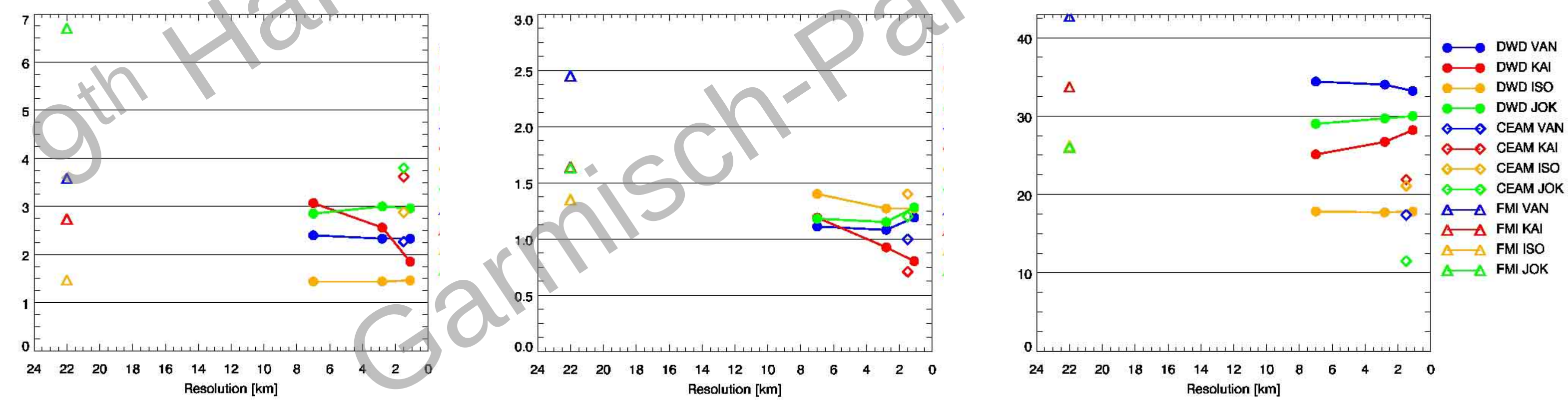
MMAS statistics of NWP model results

Correlation coefficients of 48h time series starting 23 Mar 1998



T_2m WS_10m RH_2m

RMSE of 48h time series starting 23 Mar 1998



T_2m WS_10m RH_2m

Summary I: NWP model inter-comparison

- **T2m and ground inversion**
  - **poorly modelled by all models for 1995, improved for 1998**
  - **DNMI MM5 lowest, CEAM RAMS highest, DWD LM mid**
  - **inversely correlated to modelling results of inversion strength**
- **WS**
  - **WS10m generally captured well, tendencially overestimated**
  - **larger WS10m variations on 29 Dec best captured by LM**
  - **boundary layer WS tendencially underestimated by DNMI MM5 / DWD LM and overestimated by CEAM RAMS**
- **Stability**
  - **stable atmosphere of episodes is portrayed by all models**
  - **u* of DNMI MM5 and FMI-MPP show acceptable agreement**
  - **Tpot results of DWD LM reveal much stronger stability compared to CEAM RAMS results**

Summary II: NWP model inter-comparison

- **PBL heights**
  - **spring: CEAM RAMS / DWD LM / DMI HIRLAM / FMI**
    provide similar results for ‘rural’ daytime mixing height
  - **winter: FMI best with 100m-default,**
    other models fail / simulate higher mixing height
- **Humidity**
  - **very variable, close inverse relationship with T**
- **Sensible heat flux**
  - **direct dependance on T and grid resolution (external parameters)**
- **Statistical scores**
  - **Correlation coefficients highest for T2m, lowest for RH2m**
  - **RMSE largest for RH2m**
  - **RMSE of T2m, WS10m smaller for spring time episode results**

Summary III: grid refinement

- **grid refinement leads to some improvement of model results**
  - **land/sea distribution and associated soil type distribution improve with increasing grid resolution**
  - **more improvement expected for mountainous areas (Bologna)**
- **model deviations remain due to deficiencies in**
  - **horizontal / vertical resolution (h: FMI HIRLAM, v: all)**
  - **using hydrostatic version (HIRLAM)**
  - **land/sea mask in coastal areas (DWD LM, HIRLAM)**
  - **description of snow cover (CEAM RAMS, DNMI MM5)**
  - **description of sea ice (most models)**
  - **urbanised and high-resolution soil and surface layer parameterisation (all)**

Outlook for FUMAPEX

model evaluation in WP3:

- **episode simulations for Oslo, Bologna, Turin and Castellón**
- **model inter-comparison for all target cities**
- **episode and long-term evaluation with standard statistical NWP-scores**

standard and guideline to improvements in following WPs:

- **WP 4: Improved parameterisations in meteorological models for urban areas**
- **WP 5: Interface to UAP models**
- **WP 6: Sensitivity of UAP models to NWP model designs**
- **WP 7: Population Exposure models**

Thank you for your attention!