SENSITIVITY ANALYSIS OF MM5 TO METEOROLOGICAL PARAMETERS DURING AN EPISODE PERIOD FOR LONDON

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MM5 PSU/NCAR mesoscale meteorological model v.3.6

LONDON

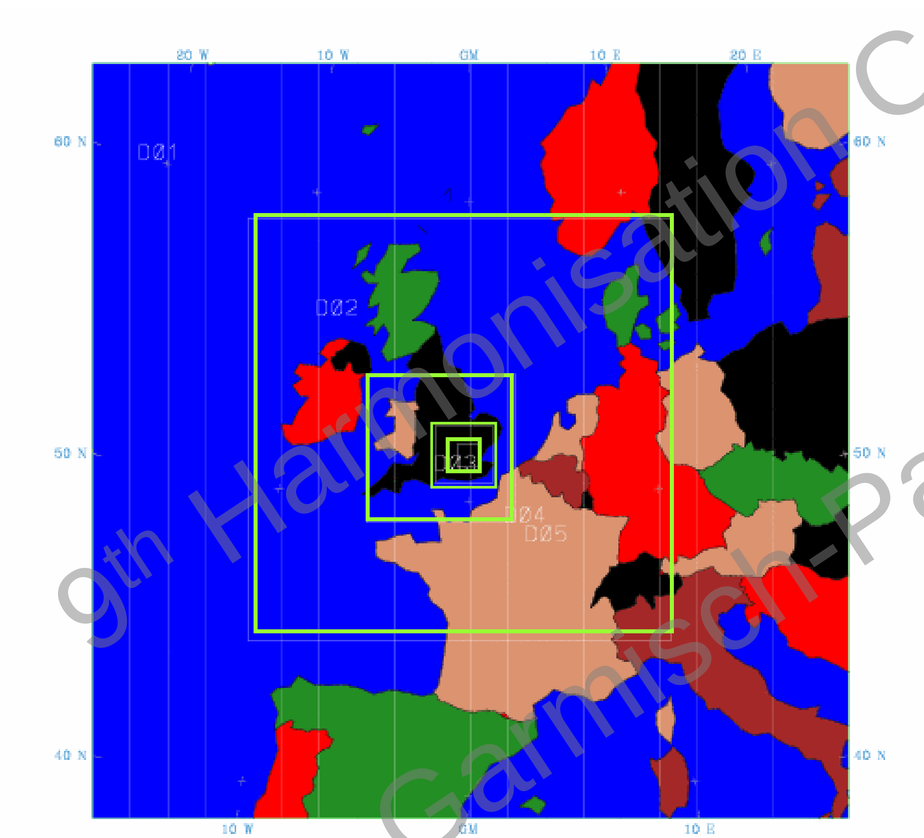
Summer

Ozone air pollution episodes

Winter

PM10 episodes

MM5 set up for London



1x1 km (82x82 gp)
start at 27,20

3x3 km (70x70 gp)
start at 29,17

9x9 km (61x61 gp)
start at 17,17

27x27 km (58x58 gp)
start at 8,9

81x81 km (35x35 gp)

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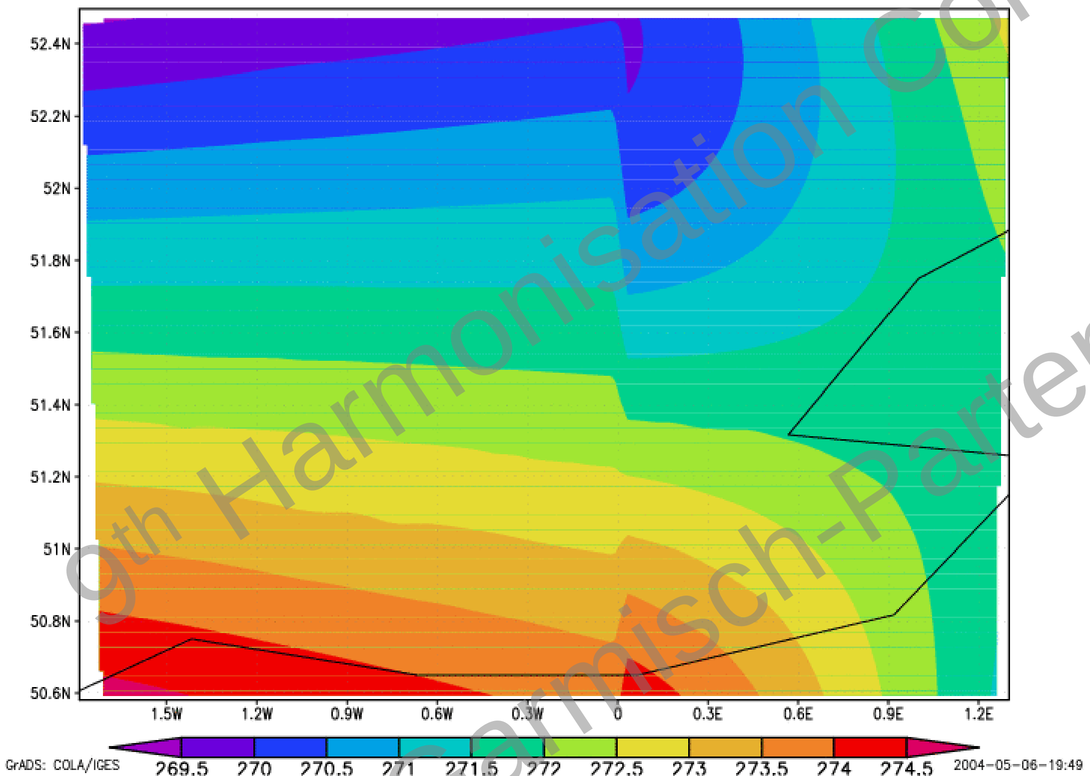
MM5 set up for London



AVN global data
  100 km resolution (NCEP/NOA)

Initial temperature field at 3x3 km grid

Calculations for 17-18 Feb 2003

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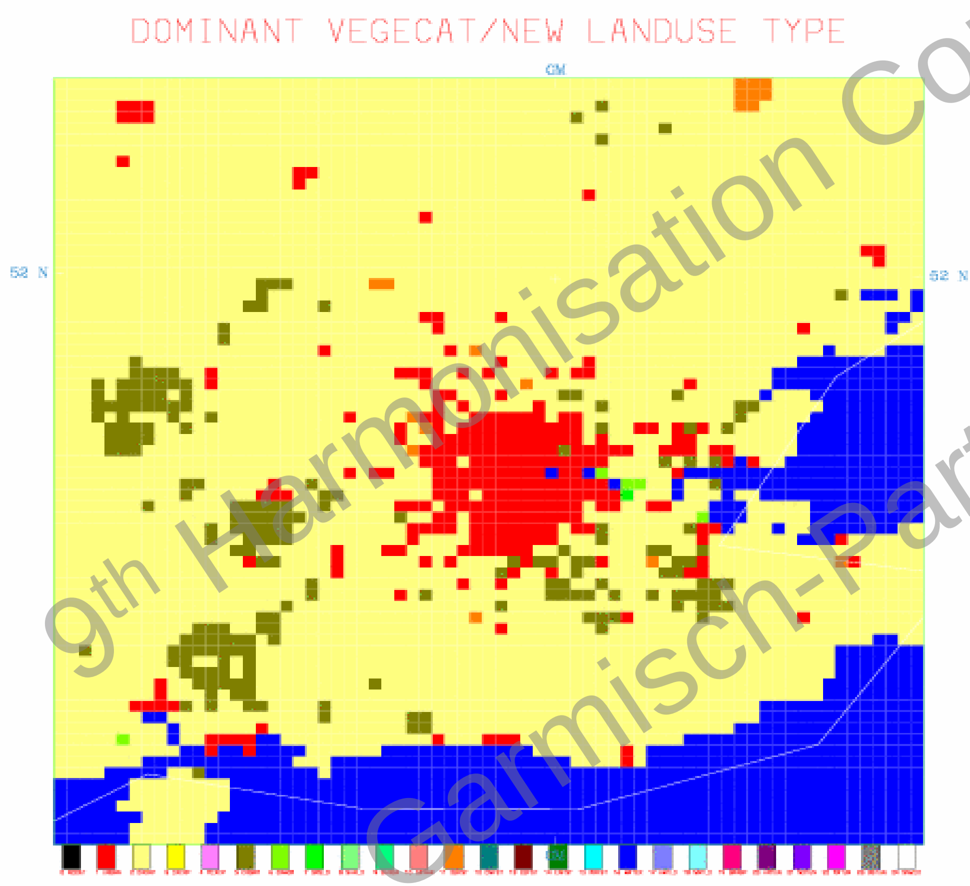
Land use



Global 25 category data

US Geological Survey data

3x3 km (3.7 km or 2 min)

PBL in MM5

- Bulk PBL
- High-Resolution (Blackadar) PBL
- MRF PBL
- Burk-Thompson PBL
- Eta PBL
- Gayno-Seaman PBL
- Pleim-Chang PBL

High-resolution (Blackadar) PBL

- Reference:Grell et. al. (1994): A description of the 5th generation Penn State/NCAR mesoscale model (MM5), NCAR Tech Note TN-398+STR
- 1st Order scheme
- Suitable for multi-layer PBL (e.g. 5 layers in lowest km ; surface layer < 100m)
- PBL depth determined from temperature profile
- Entrainment at PBL top due to overshooting thermals
- M-O similarity for surface exchange coefficients

High-resolution (Blackadar) PBL

- Four stability regimes
  - Nocturnal Regime
    - Stable case (R_{iB} ¤ 0.2)
    - Mechanically driven turbulence ($0 < R_{iB} < 0.2$)
    - Unstable (forced convection) ($R_{iB} \leq 0$; $|h/L| \leq 1.5$)
  - Free-Convective Regime (Mixed Layer)
    - Unstable (free convection) ($R_{iB} < 0$; $|h/L| > 1.5$)
- Free-Convective regime has ***nonlocal*** mixing between surface layer and all other layers in PBL

MRF PBL (or Hong and Pan PBL)

- Reference: Hong, S.-Y., and H.-L. Pan, 1996: Nonlocal boundary layer vertical diffusion in a medium-range forecast model. *Mon. Wea. Rev.*, 124, 2322-2339.
- 1st Order scheme
- Suitable for high-resolution in PBL
- $K_m = f(u_*, h)$
- PBL depth determined from critical (0.5) bulk Richardson number (shear and temp. profile)
- Similarity: Monin-Obhukov

MRF PBL (or Hong and Pan PBL)

- Four stability regimes
  - Nocturnal Regime
    - Stable case (R_{iB} ¤ 0.2)
    - Mechanically driven turbulence ($0 < R_{iB} < 0.2$)
    - Unstable (forced convection) ($R_{iB} = 0$)
  - Free-Convective Regime (Mixed Layer)
    - Unstable (free convection) ($R_{iB} < 0$)
- Free-Convective regime has ***nonlocal*** K

Pleim-Chang PBL

- Reference:
  - Pleim, J. E., and J.S. Chang, 1992: A non-local closure model for vertical mixing in the convective boundary layer. Atm. Env., 26A, 965-981.

- Currently can only be used with Pleim-Xiu LSM
- Based on Blackadar scheme, but differs in its treatment of downward transport
- Asymmetric Convective Model

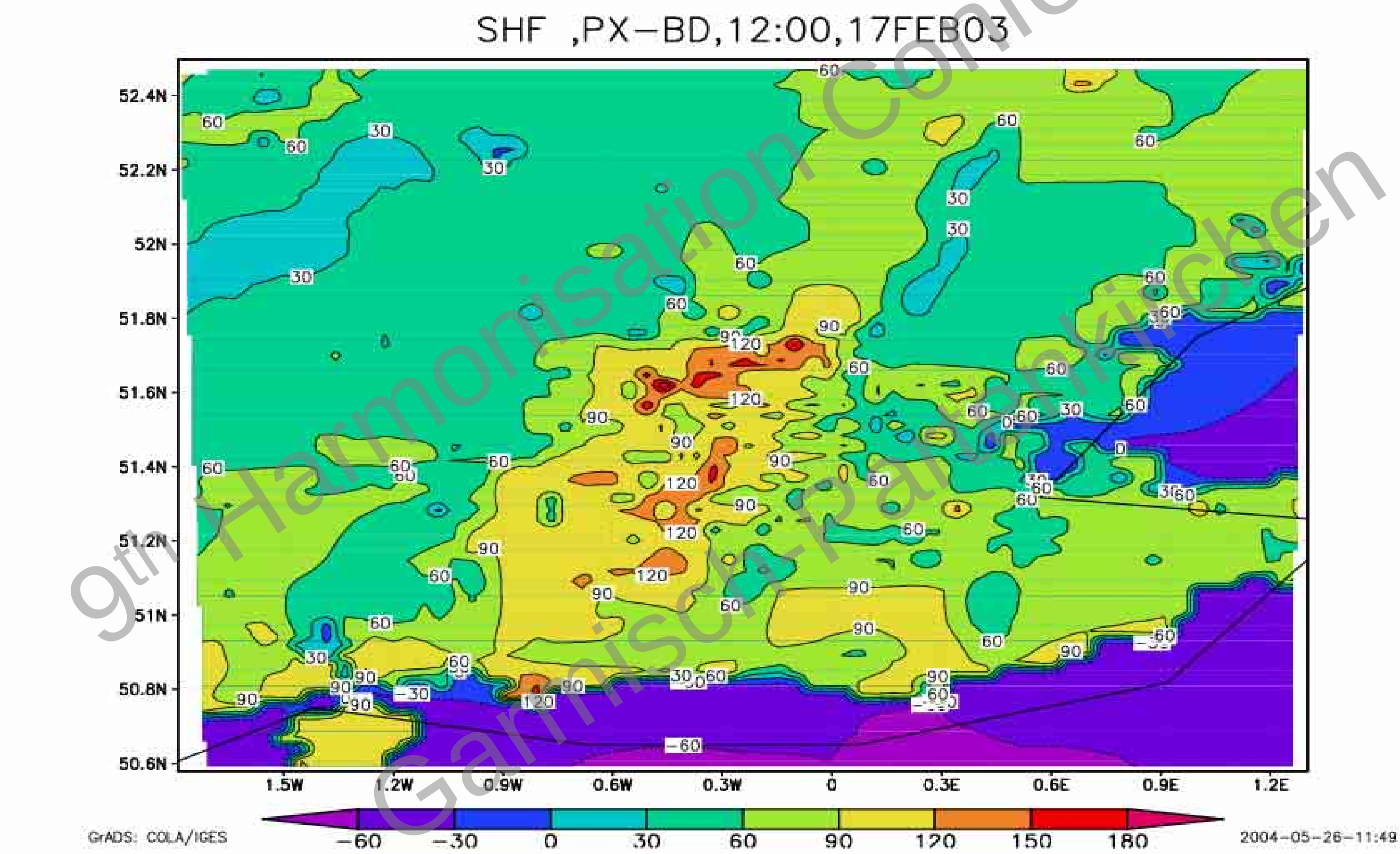
Pleim-Chang PBL

- Four stability regimes
  - Nocturnal Regime
    - Very stable ($z/L > 1$)
    - Stable ($1 > z/L > 0$)
    - Unstable (forced convection) ($z/L > 0$)
  - Free-Convective Regime (Mixed Layer)
    - Unstable (free convection) ($z/L > -3$)
- Free-Convective regime has ***nonlocal*** mixing between surface layer and all other layers in PBL

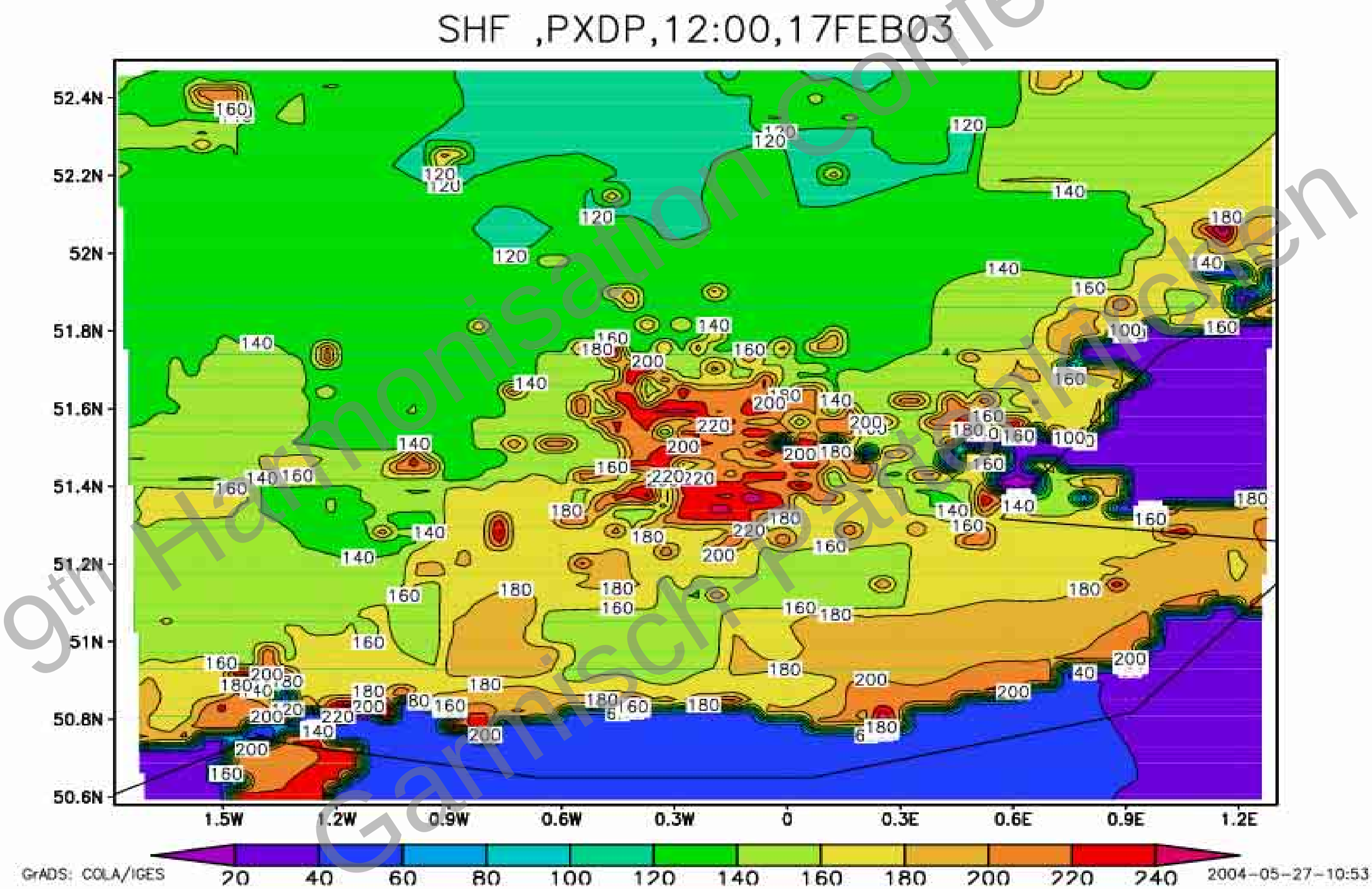
Summary – PBL schemes

Black.	K-theory 1^{st} order Nonloc.	PBL height T profile	MO	4 stability regimes	
MRF	K-theory 1^{st} order Nonloc.	PBL height Rib cr	MO	4 stability regimes	
PX	K-theory 1^{st} order Nonloc.	PBL height T profile	MO	4 stability regimes	Own soil Entrain-ment

Mid-day difference in SHF by 2 PBL schemes



Mid-day SHF PX PBL scheme



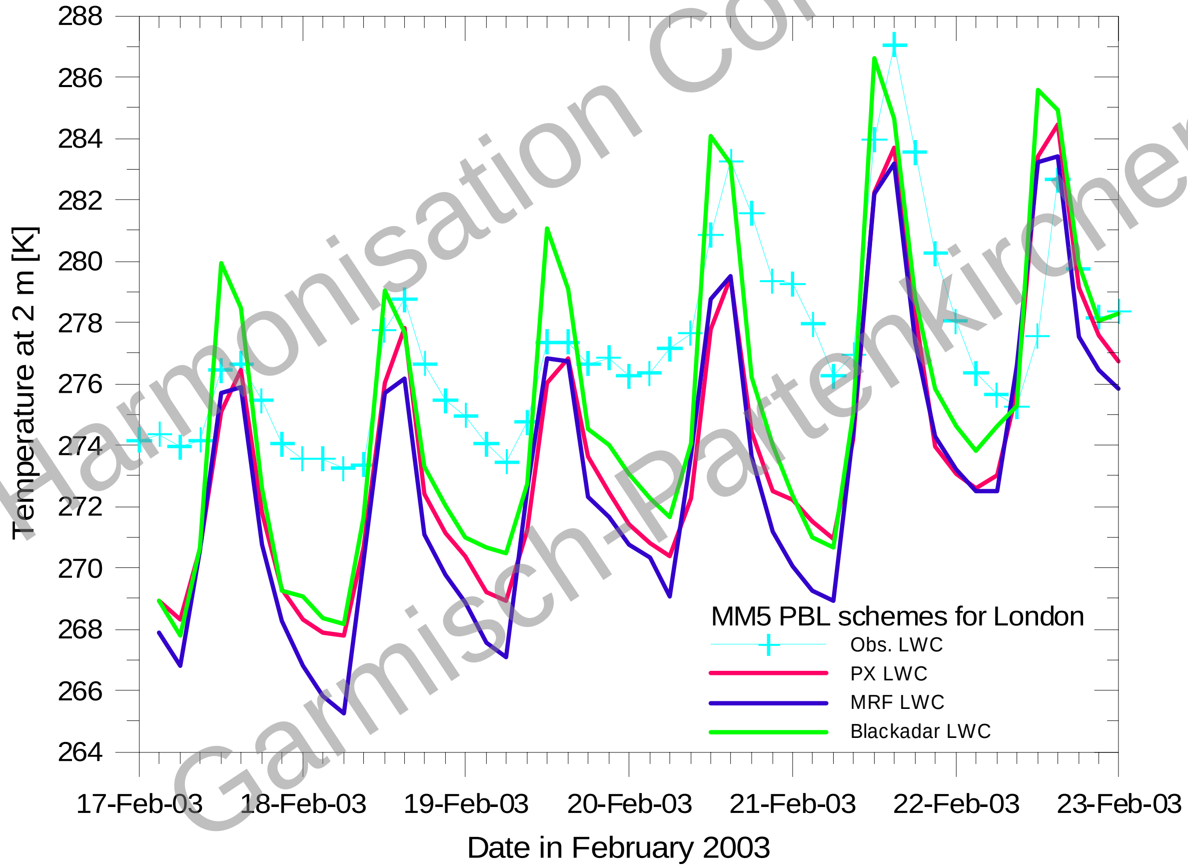
Sensitivity to PBL schemes

Parameters

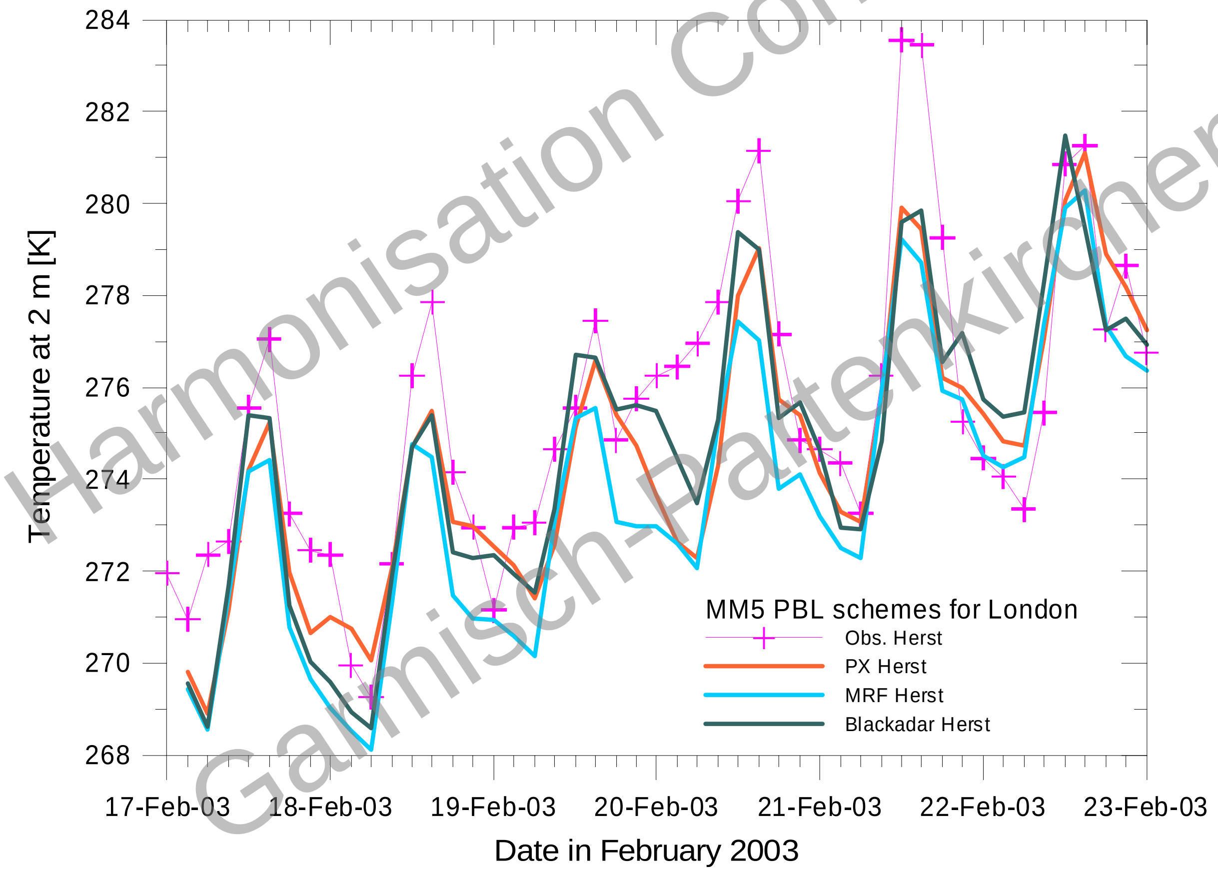
(for which observations are available)

- temperature
- relative humidity
- wind speed

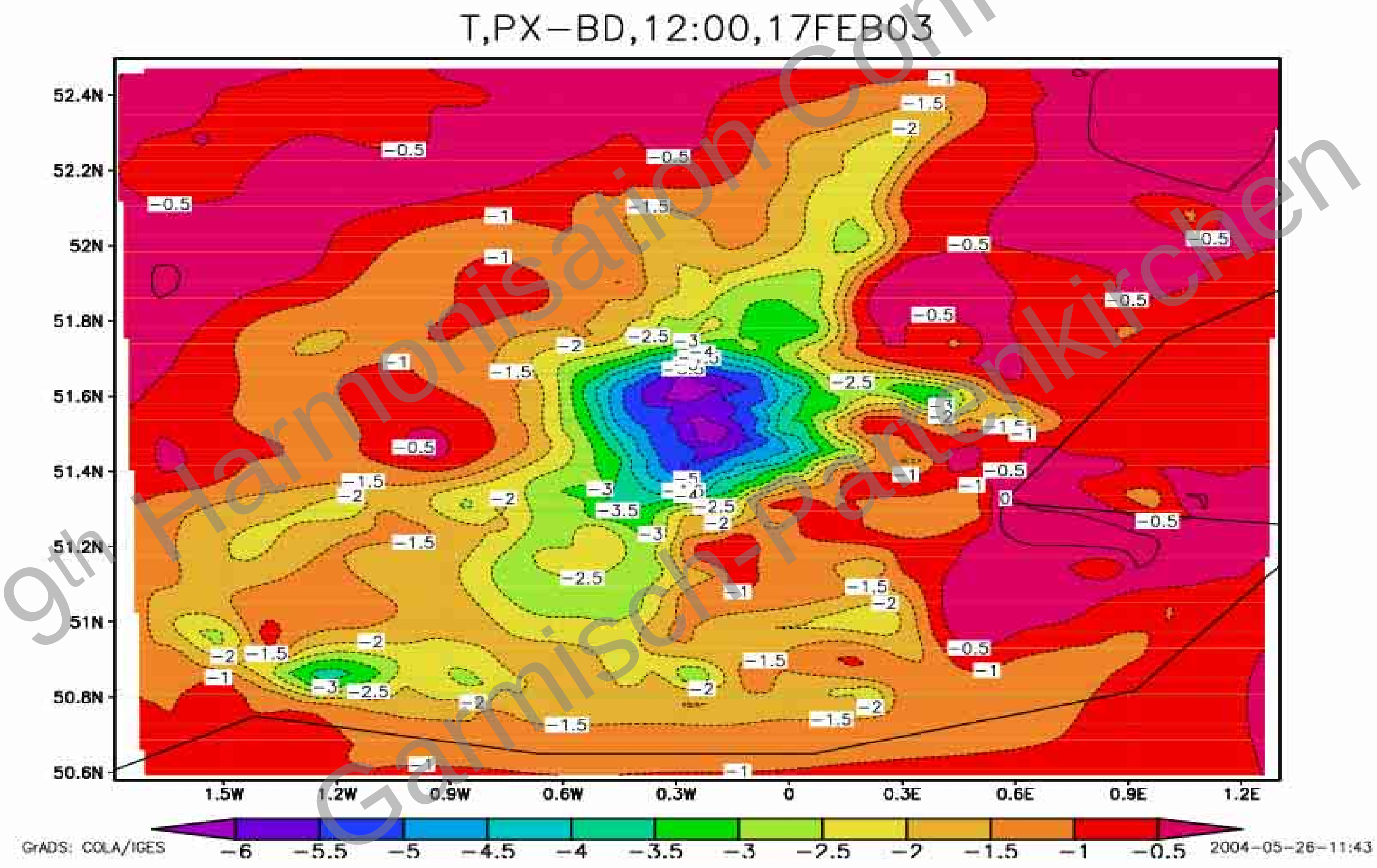
Temperature in Central London (LWC) – 3 PBL schemes and observations



Temperature SE of London (Herstmonceux) – 3 PBL sch.&obs.



Spatial variability – T 12 GMT



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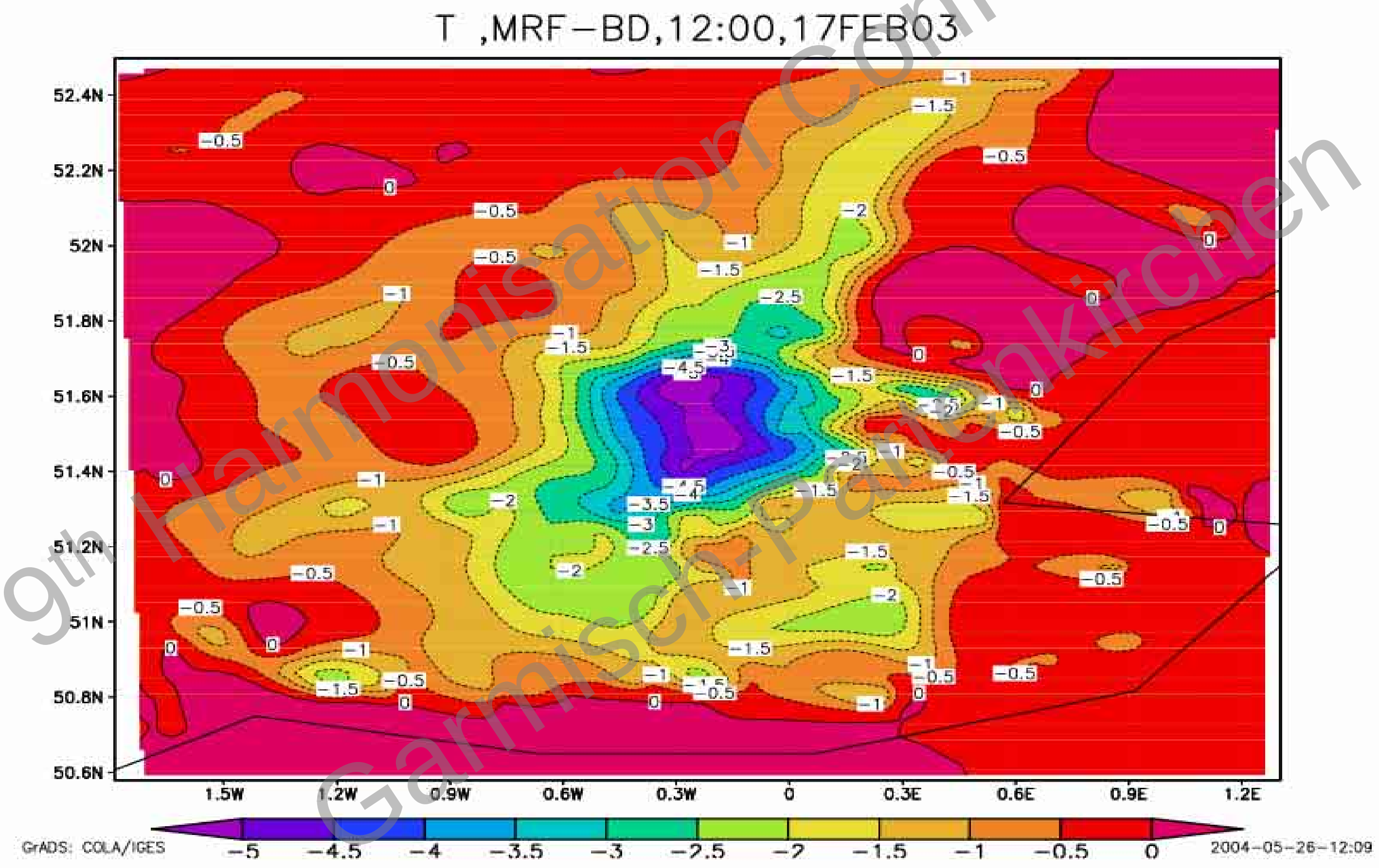
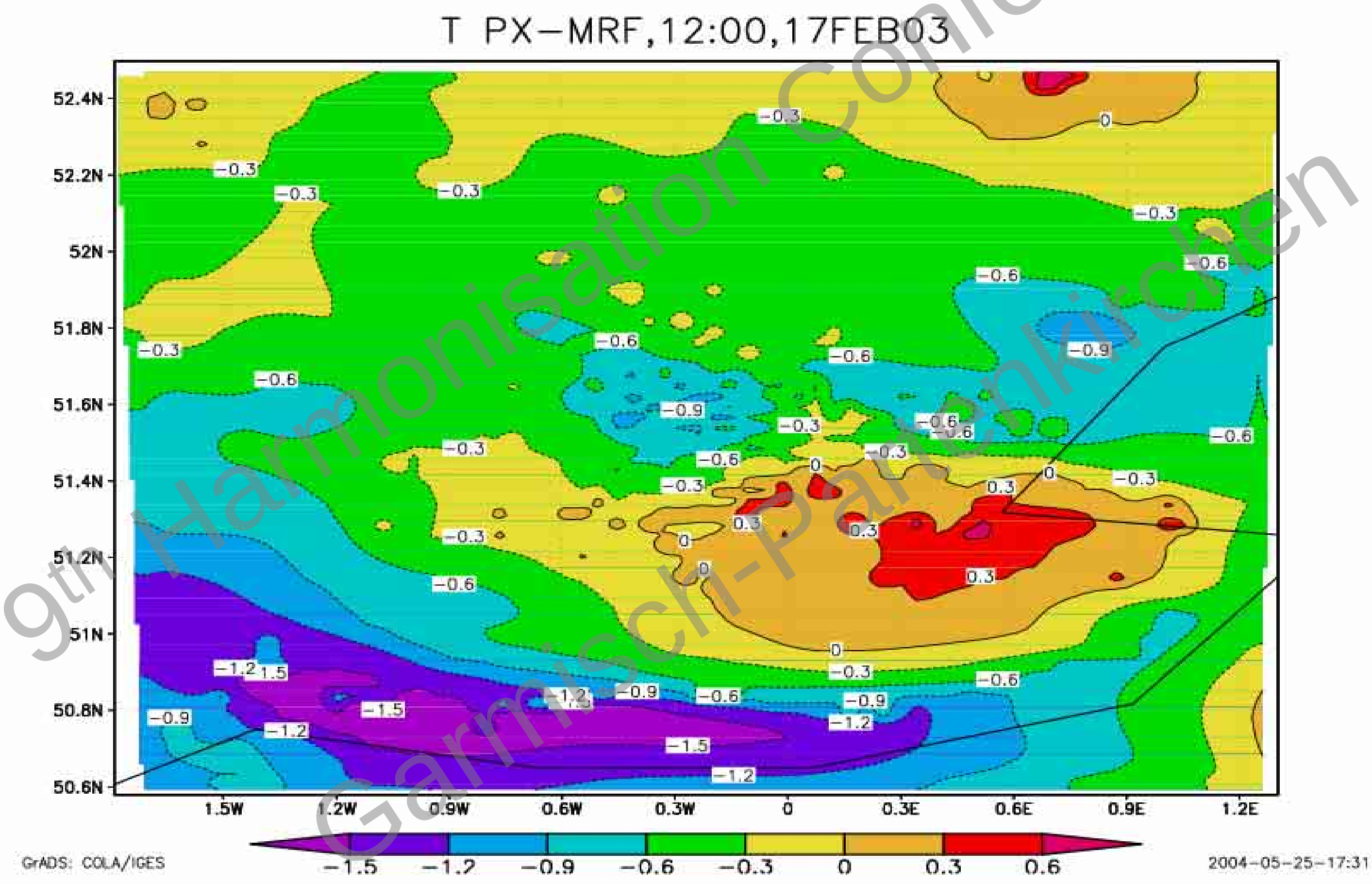
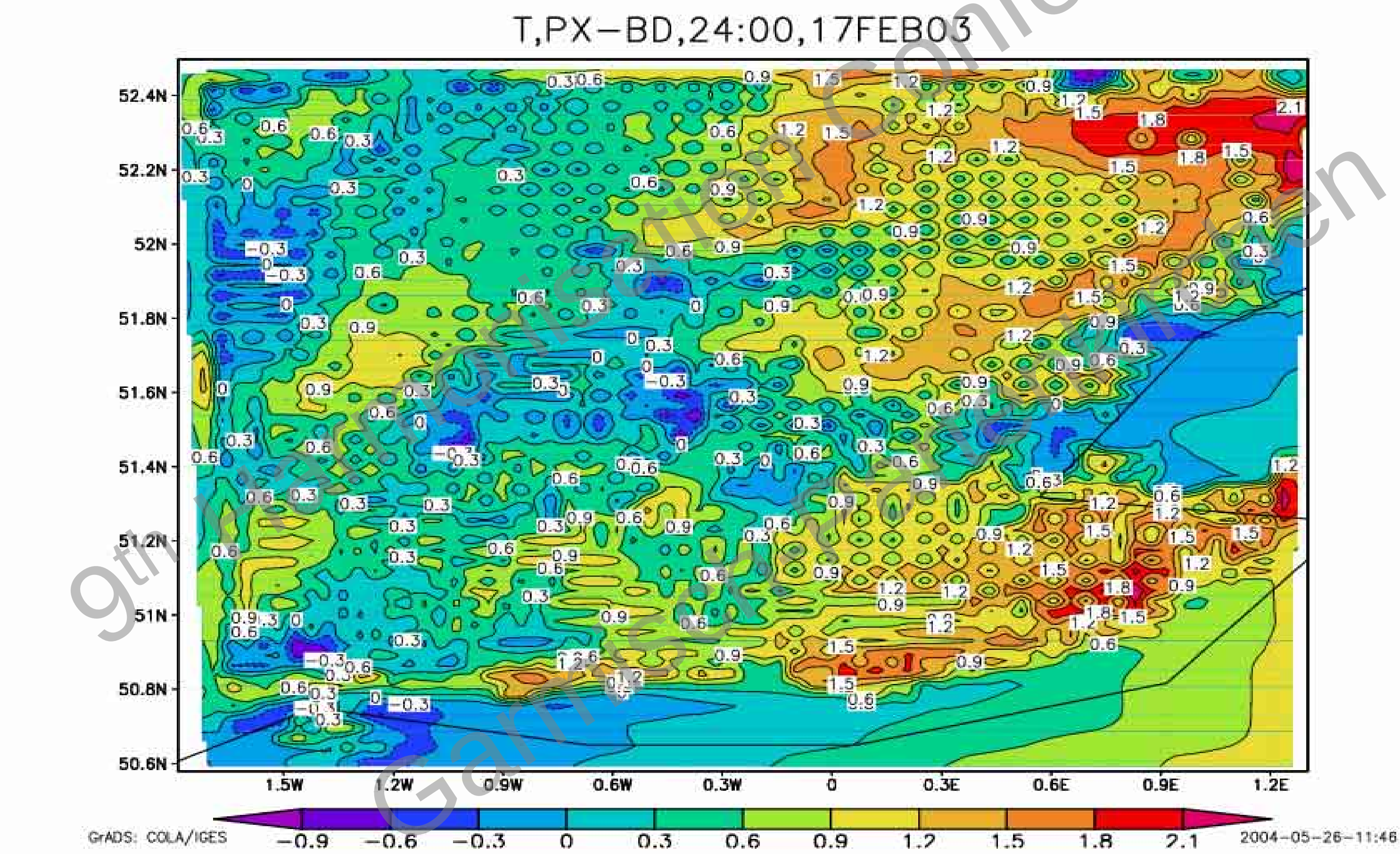
Spatial variability – T 12 GMT



Spatial variability – T 12 GMT



Spatial variability – T 00 GMT



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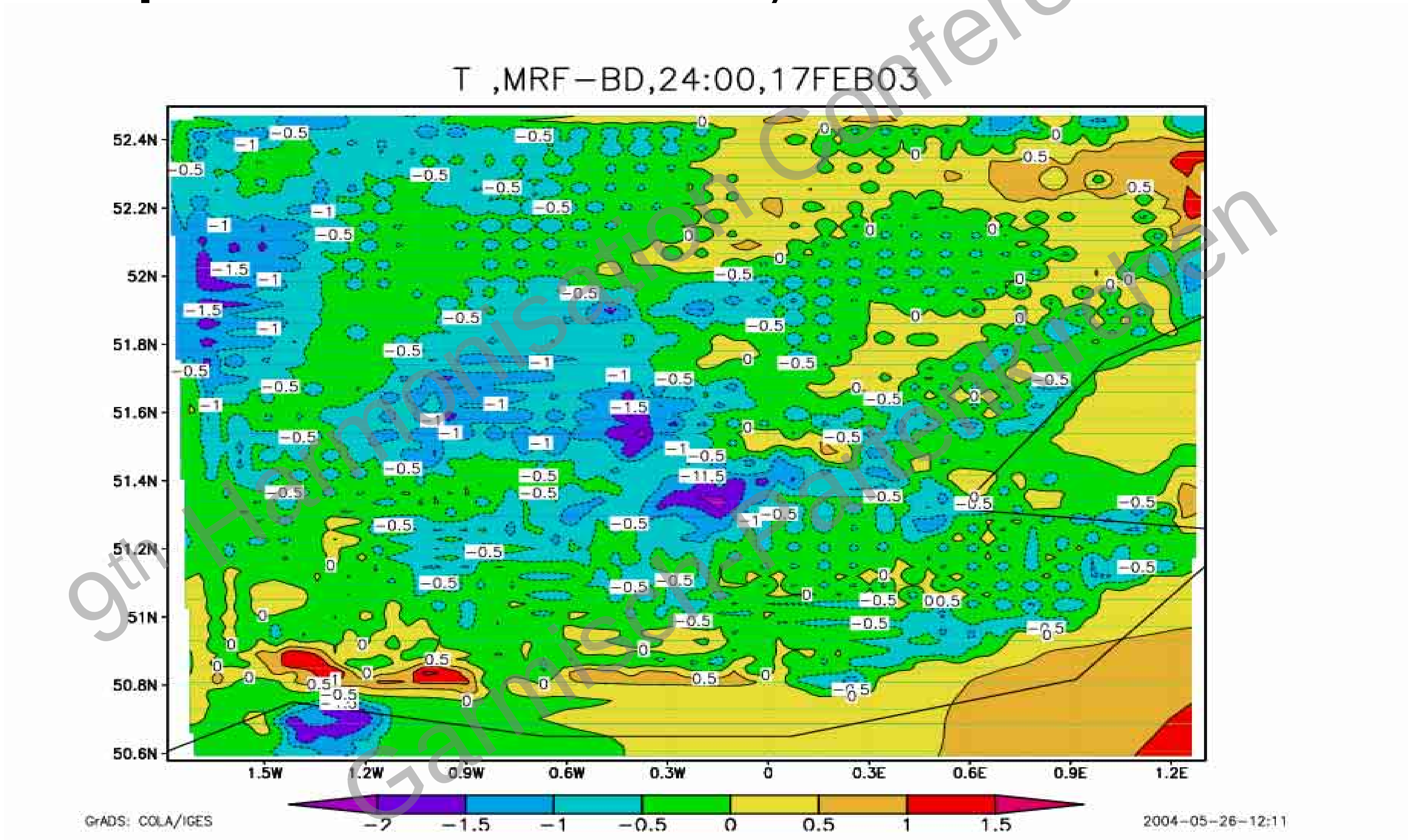
Spatial variability – T 00 GMT



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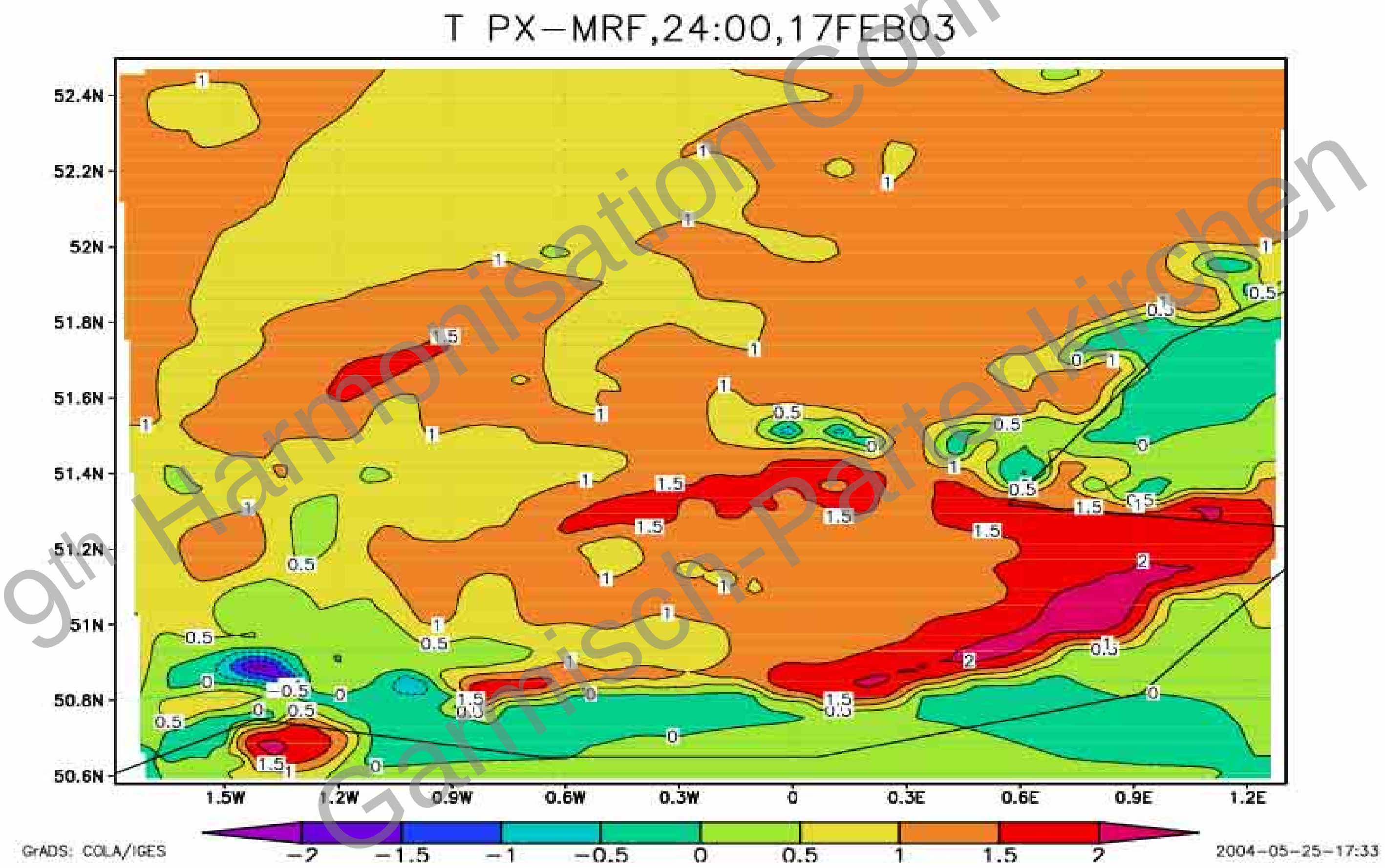
Spatial variability – T 00 GMT



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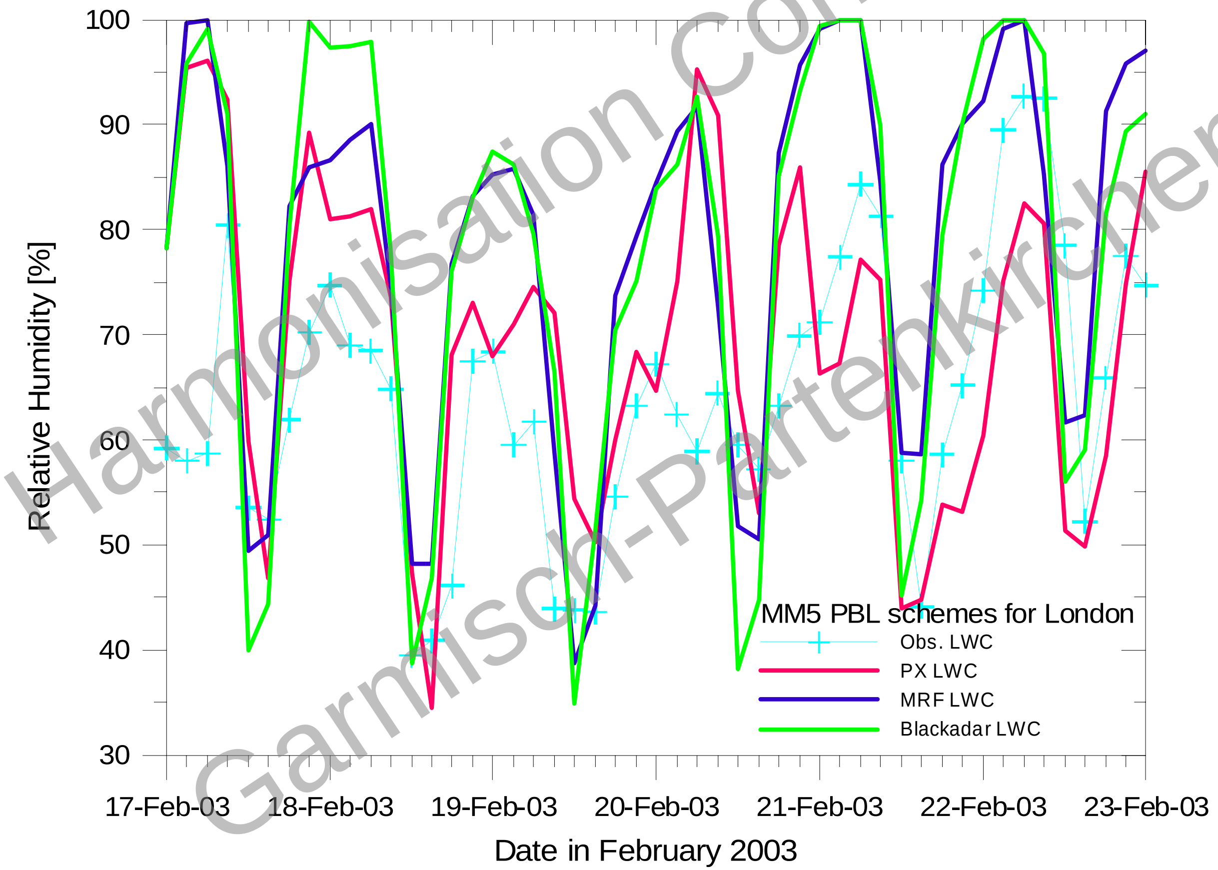
Results for temperature

- The model results follow the pattern of the measurements, with more notable under-predictions for the minimum temperatures in urban compared to rural areas
- The differences between PBL schemes are bigger during the day compared to night time
- PX and MRF are closer to each other. Blackadar is predicting higher maximums mainly in urban areas

Relative humidity in Central London (LWC) – 3 PBL sch. and obs.



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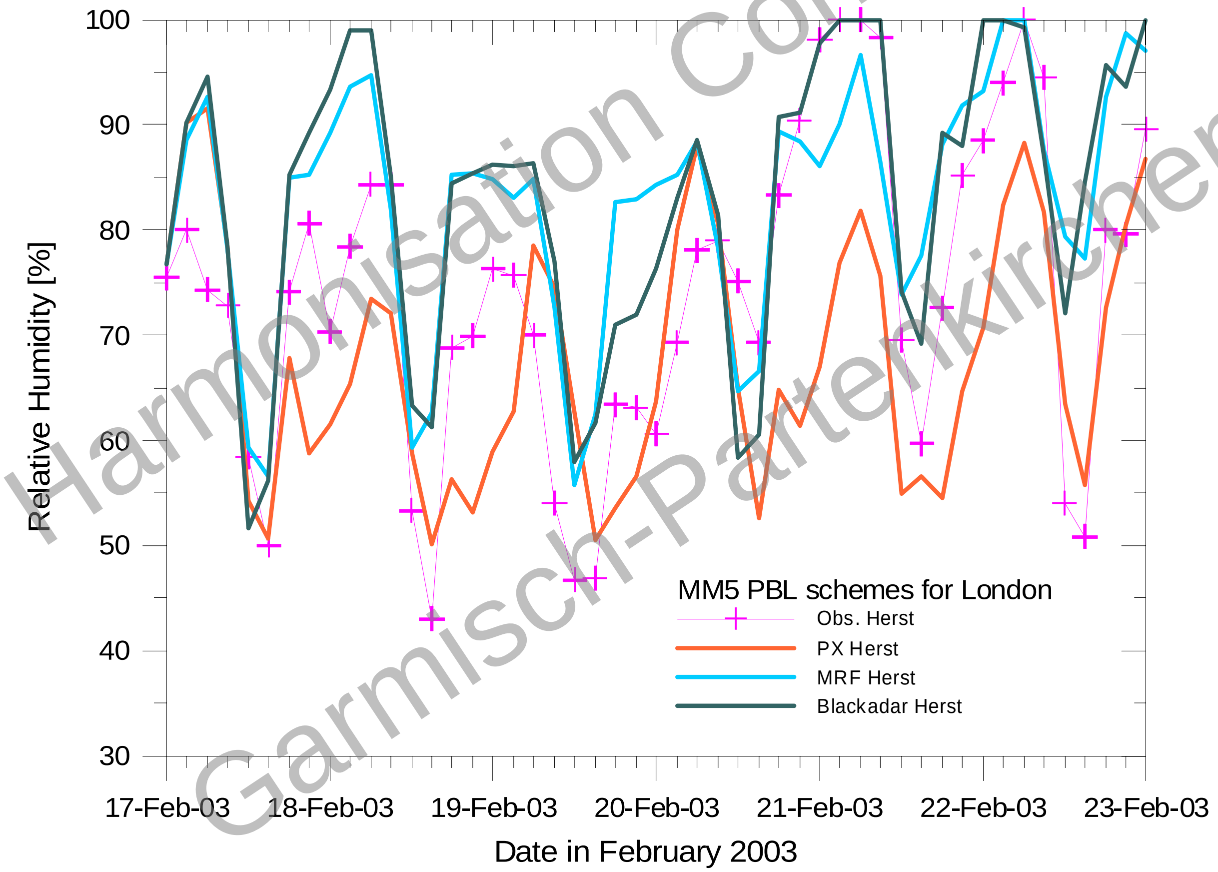
Relative humidity SE of London (Herstmonceux) – 3 PBL sch.&obs.



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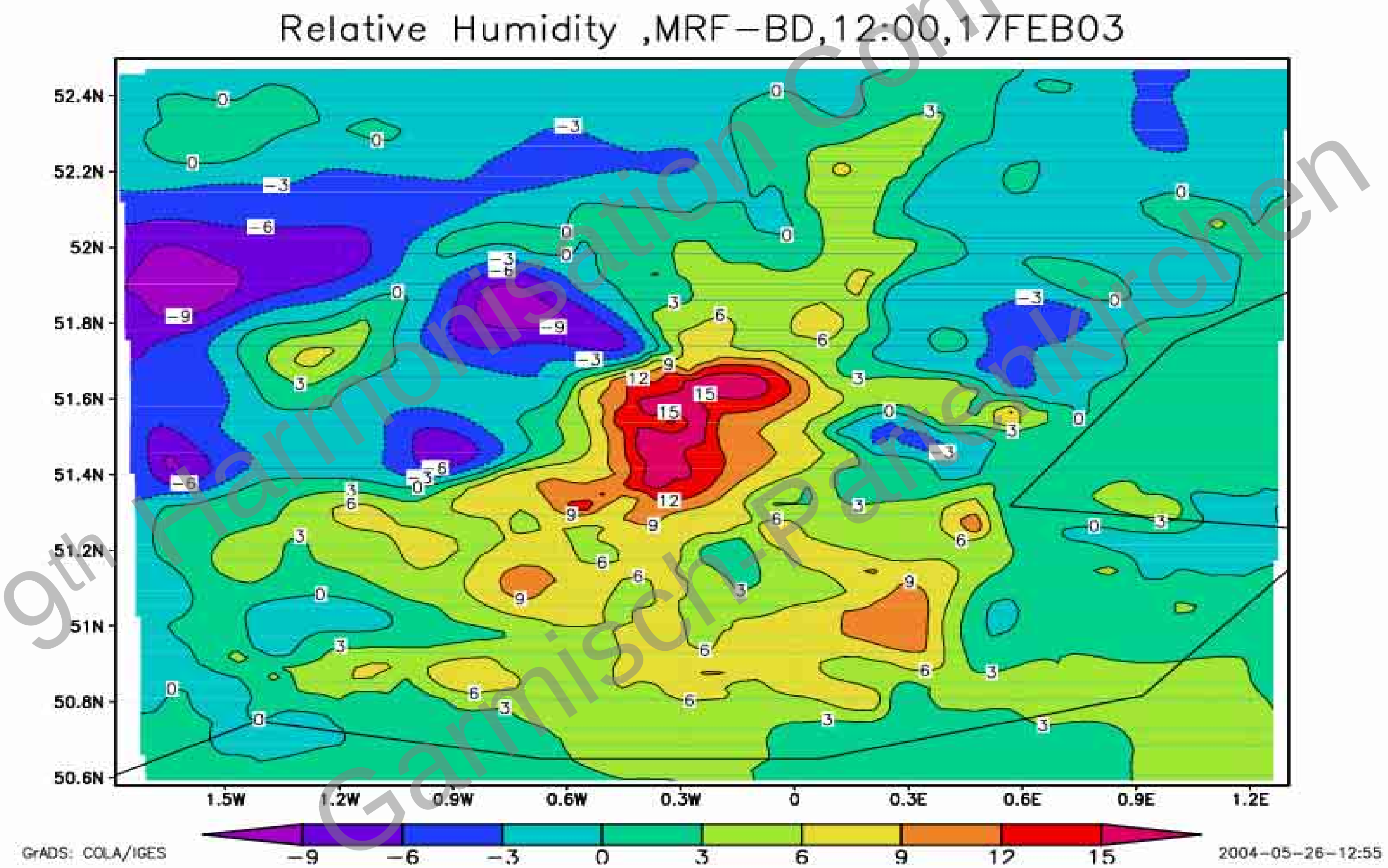
Spatial variability – rh 12 GMT



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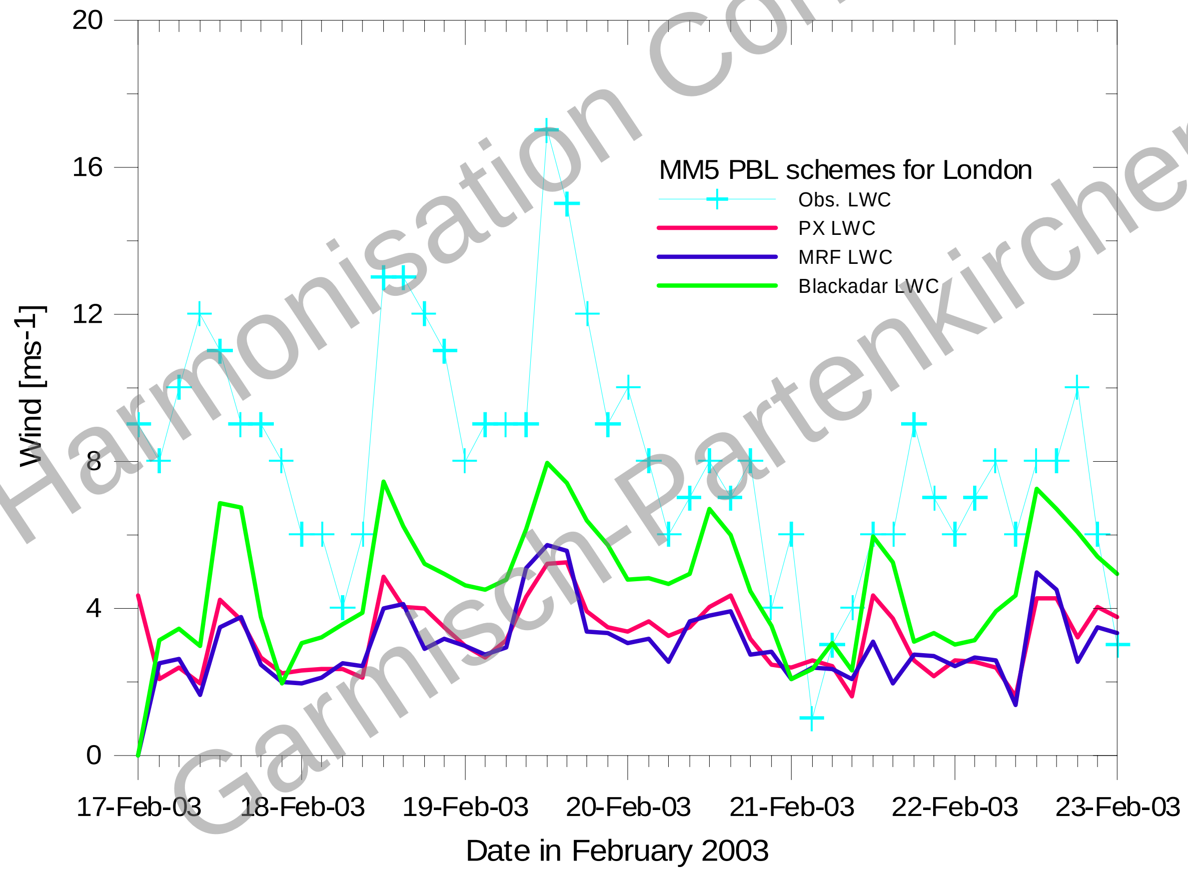
Results for relative humidity

The model results follow the pattern of the measurements, with more notable over-predictions for the maximum relative humidity in urban compared to rural areas

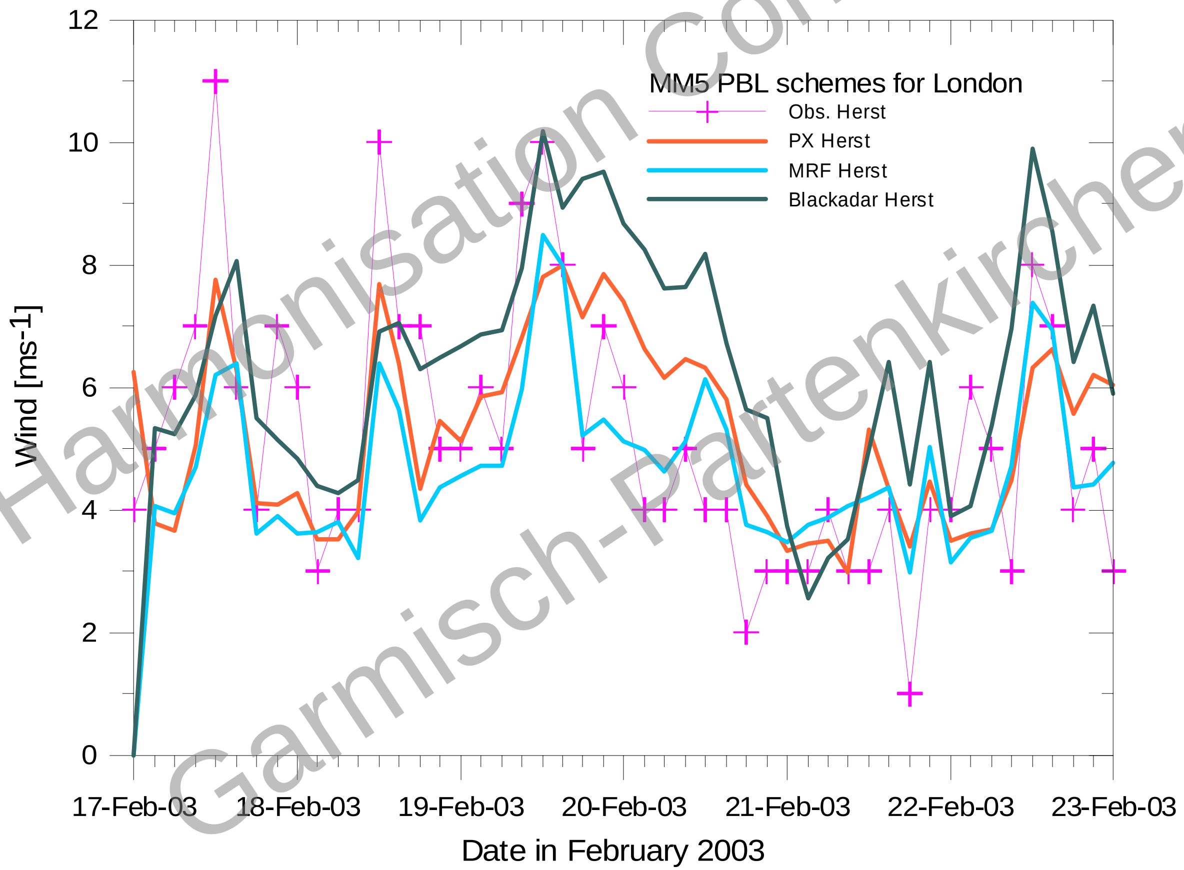
The differences between PBL schemes are bigger during the day compared to night time

PX and MRF are closer to each other.

Wind speed in Central London (LWC) – 3 PBL schemes and observations



Wind speed SE of London (Herstmonceux) – 3 PBL schemes and observations



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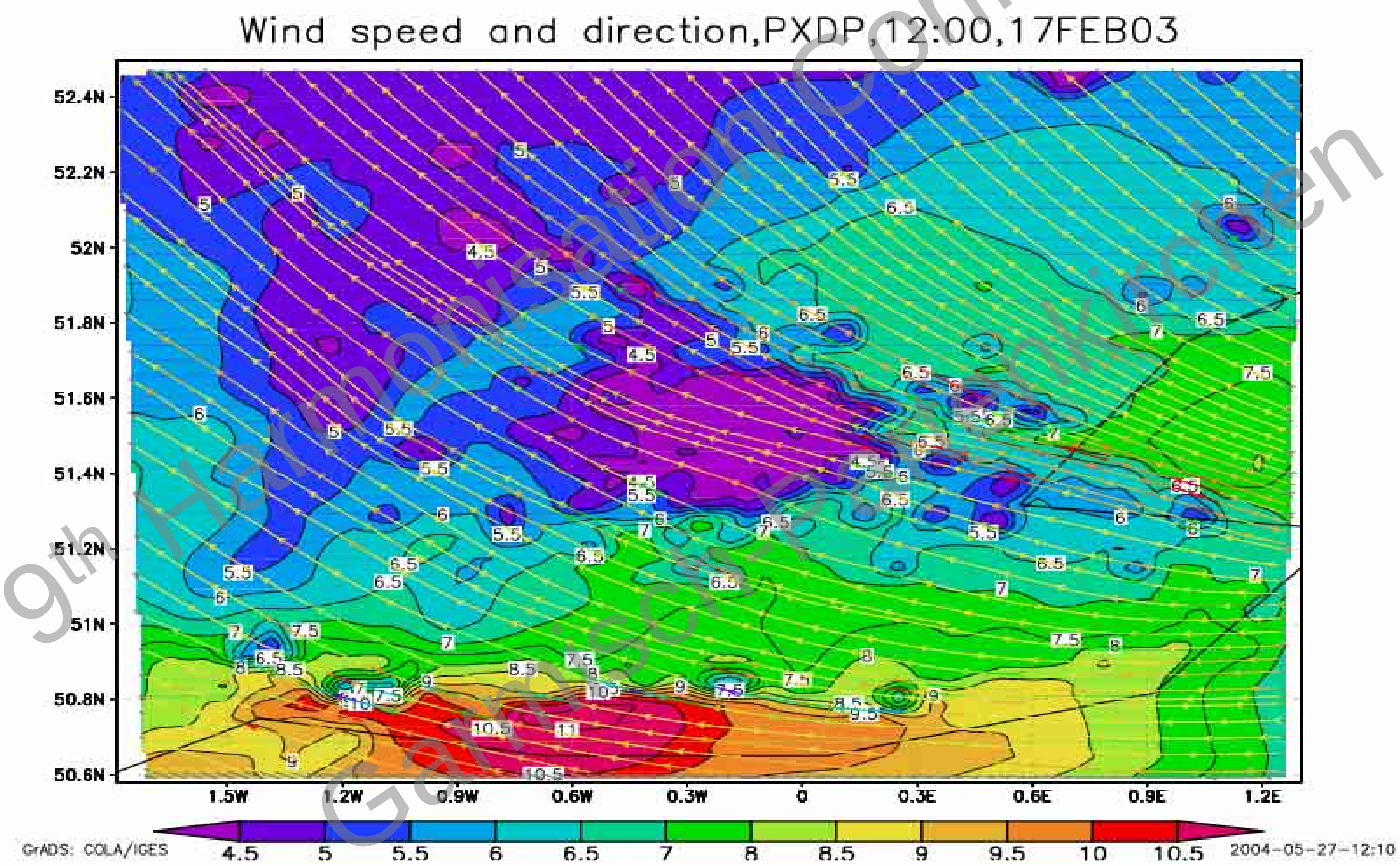
Wind field at 12:00 GMT 17 Feb 2003



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Results for wind speed

Model simulations in rural area are closer to observations

MRF and PX are giving closer predictions

Blackadar scheme is predicting higher wind speeds both in urban and rural sites

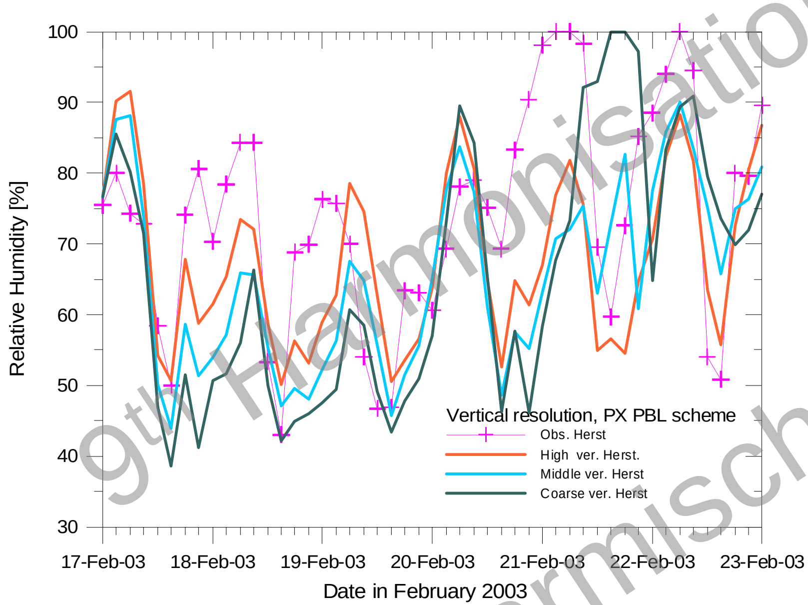
Vertical resolution in pressure levels (mb) – difference within the PBL, always 23 levels

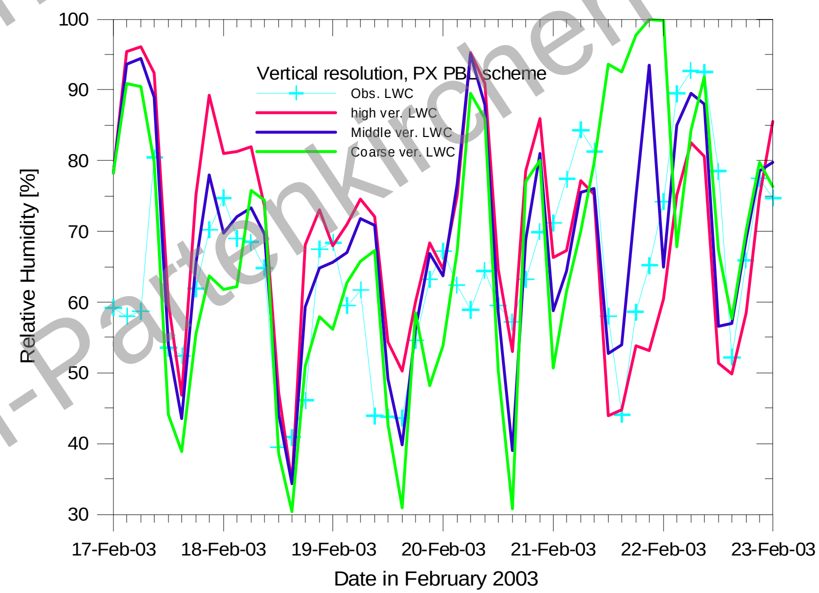
High – 1000, 998, 995, 991, 985, 980, 970, 960, 950, 940, 930, 910, 890, 870, 850, 800, 700, 600, 500, 400, 300, 200, 100

Middle – 1000, 995, 990, 985, 980, 970, 950, 930, 900, 890, 850, 700, 680, 650, 600, 550, 500, 450, 400, 350, 300, 200, 100

Coarse – 1000, 990, 980, 960, 890, 850, 800, 750, 700, 650, 600, 550, 500, 450, 400, 350, 300, 250, 200, 150, 100, 50

Vertical resolution – relative humidity, rural (left) urban (right)





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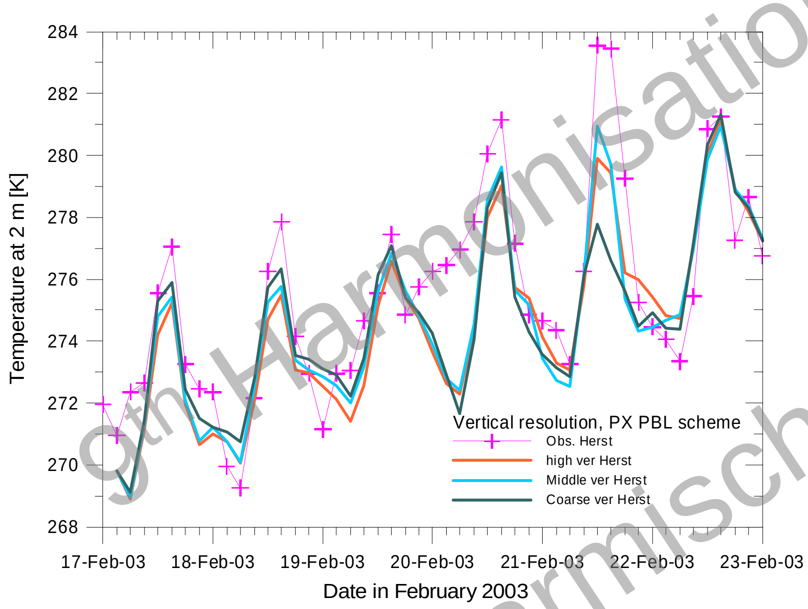
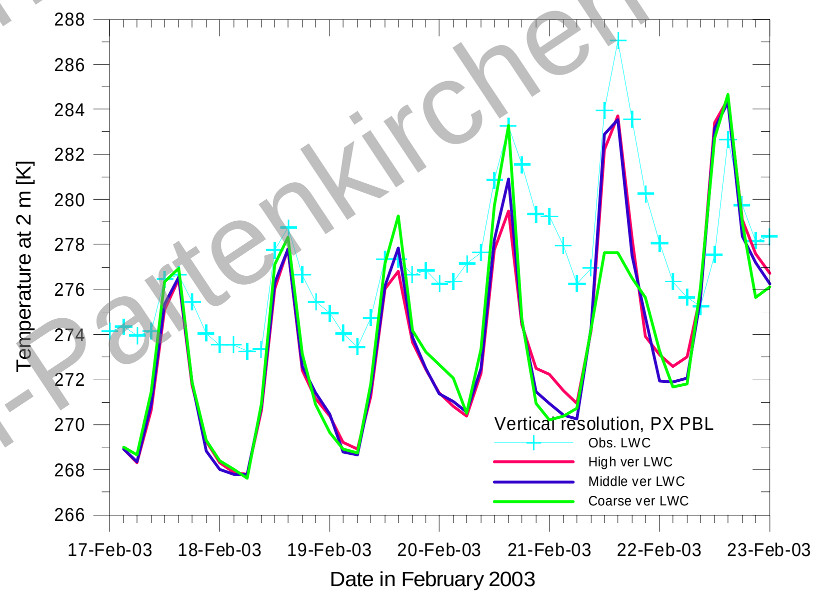
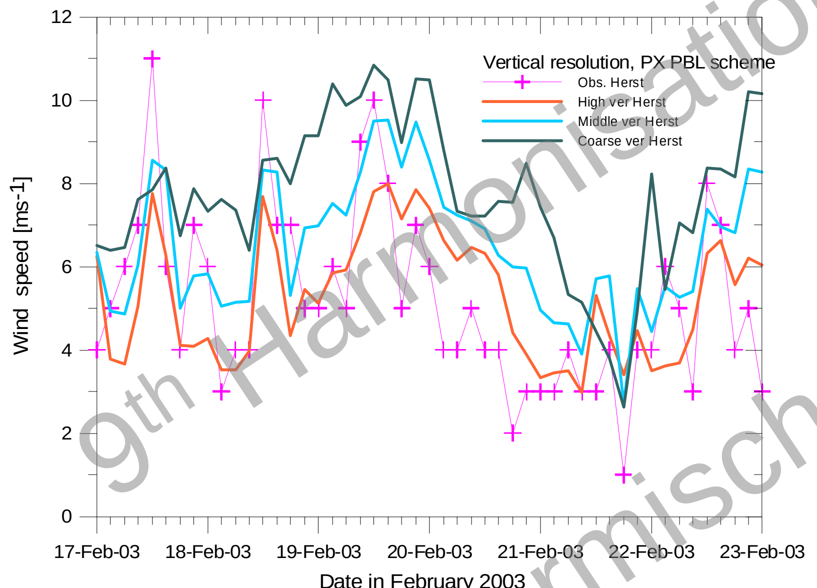
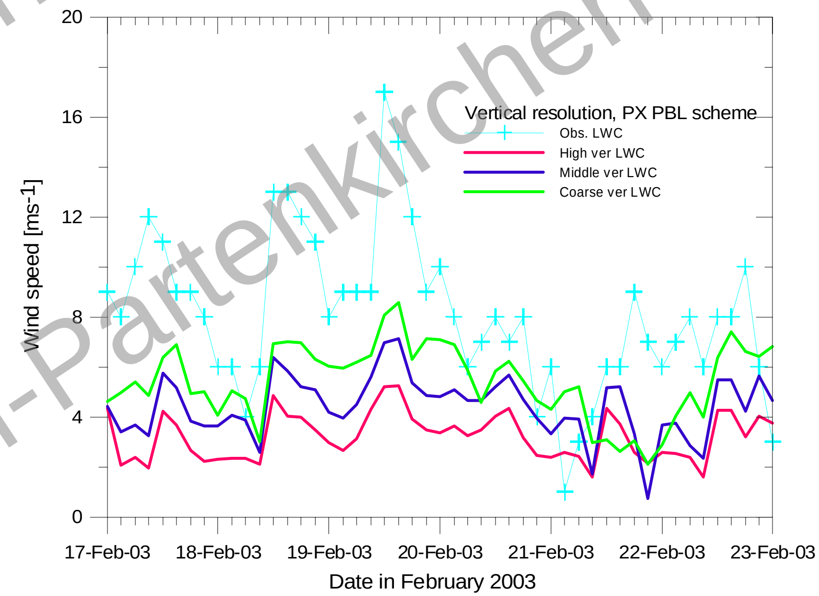
Vertical resolution – temperature, rural (left) urban (right)





Vertical resolution – wind speed, rural (left) urban (right)





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Vertical resolution

The vertical resolution within the PBL influences considerably the wind speed predictions and is not significant for temperature and relative humidity

Conclusions

- The choice of PBL scheme is important for simulations in urban areas during day time. During night time the schemes perform similarly.
- The observed T, rh and ws for London and Herst are successfully simulated.
- The agreement between observations and simulations is better for rural than for urban sites.
- The vertical resolution is more important for wind speed than for temperature and relative humidity.

Acknowledgement

FUMAPEX

AIE4EU

CLEAR