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)
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

Atmospheric Science Research Group (ASRG)
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


- 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 ($R_{iB} \geq 0.2$)
    • 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)

- 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 ($R_{iB} \approx 0.2$)
    • 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:

• 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

<table>
<thead>
<tr>
<th>Scheme</th>
<th>K-theory 1st order</th>
<th>PBL height</th>
<th>MO</th>
<th>Stability regimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>1st order Nonloc.</td>
<td>T profile</td>
<td>4</td>
<td>regimes</td>
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<tr>
<td>MRF</td>
<td>1st order Nonloc.</td>
<td>Rib cr</td>
<td>4</td>
<td>regimes</td>
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<tr>
<td>PX</td>
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<td>regimes</td>
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<td></td>
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<td>Own soil Entrainment</td>
</tr>
</tbody>
</table>

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Mid-day difference in SHF by 2 PBL schemes
Mid-day SHF PX PBL scheme

SHF, PXDP, 12:00, 17 FEB 03
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

Date in February 2003

MM5 PBL schemes for London
- Obs. LWC
- PX LWC
- MRF LWC
- Blackadar LWC

Temperature at 2 m [K]
Temperature SE of London (Herstmonceux) – 3 PBL sch. & obs.

MM5 PBL schemes for London
- Obs. Herst
- PX Herst
- MRF Herst
- Blackadar Herst

Date in February 2003

Temperature at 2 m [K]
Spatial variability – T 12 GMT
Spatial variability – T 12 GMT
Spatial variability – T 12 GMT
Spatial variability – T 00 GMT
Spatial variability – T 00 GMT

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Spatial variability – T 00 GMT
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.

Date in February 2003

Relative Humidity [%]

MM5 PBL schemes for London
- Obs. LWC
- PX LWC
- MRF LWC
- Blackadar LWC

Date in February 2003
Relative humidity SE of London (Herstmonceux) – 3 PBL sch.&obs.

Date in February 2003

Relative Humidity [%]

17-Feb-03 18-Feb-03 19-Feb-03 20-Feb-03 21-Feb-03 22-Feb-03 23-Feb-03

9th Harmonisation Conference
Garmisch-Partenkirchen
Spatial variability – rh 12 GMT
Results for relative humidity

The model results follow the pattern of the measurements, with more notable overpredictions 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

MM5 PBL schemes for London
- Obs. LWC
- PX LWC
- MRF LWC
- Blackadar LWC

Date in February 2003

Wind [ms⁻¹]

17-Feb-03 18-Feb-03 19-Feb-03 20-Feb-03 21-Feb-03 22-Feb-03 23-Feb-03
Wind speed SE of London (Herstmonceux) – 3 PBL schemes and observations
Wind field at 12:00 GMT 17 Feb 2003
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)
Vertical resolution – temperature, rural (left) urban (right)
Vertical resolution – wind speed, rural (left) urban (right)

Vertical resolution, FX PBL scheme
Obs. LWC
High var LWC
Middle var LWC
Coarse var LWC

Date in February 2003
Wind speed [ms⁻¹]
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
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CLEAR