Microscale modelling and validation

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CSIR

WASA 2 Mid-term Workshop
Cape Town, South Africa
Validation procedure in general

• Mesoscale modelling using WRF
  – Model setup
  – Reanalysis data
  – Elevation grid
  – Roughness grid
  – Predictions: mesoscale world

• Downscaling procedure
  – From mesoscale to generalised
    wind climate (PWC to GWC)
  – Wind potential over a flat,
    featureless, uniform world...

• Numerical wind atlas for SA
  – GWC presented as LIB files
  – Horizontal resolution 5 km

• Microscale modelling using WAsP
  – Model setup
  – Generalised wind climates
  – Elevation map
  – Roughness map
  – Predictions: microscale world

• Microscale modelling
  – From generalised to predicted
    wind climate (GWC to PWC)

• Measurements @ WASA sites
  – OWC @ several heights

• Validation procedure
  – Comparing OWC and PWC at
    all WASA mast sites
Meso- and microscale maps
WRF 5-km simulated winds
Wind Atlas for South Africa masts
Validation – WASA1 winds @ 62 m \((z_0 = 3 \text{ cm})\)

<table>
<thead>
<tr>
<th>WASA mast</th>
<th>Observed wind (U_0) [ms(^{-1})]</th>
<th>WASA1 wind (U_1) [ms(^{-1})]</th>
<th>(U_1 - U_0) [%]</th>
<th>WASA2 wind (U_2) [ms(^{-1})]</th>
<th>(U_2 - U_0) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM01</td>
<td>6.12</td>
<td>5.66</td>
<td>-8%</td>
<td>6.02</td>
<td>-2%</td>
</tr>
<tr>
<td>WM02</td>
<td>5.94</td>
<td>5.90</td>
<td>-1%</td>
<td>6.32</td>
<td>+6%</td>
</tr>
<tr>
<td>WM03</td>
<td>6.55</td>
<td>5.48</td>
<td>-16%</td>
<td>5.94</td>
<td>-9%</td>
</tr>
<tr>
<td>WM04</td>
<td>6.68</td>
<td>6.54</td>
<td>-2%</td>
<td>6.59</td>
<td>-1%</td>
</tr>
<tr>
<td>WM05</td>
<td>8.10</td>
<td>7.31</td>
<td>-10%</td>
<td>7.47</td>
<td>-8%</td>
</tr>
<tr>
<td>WM06</td>
<td>7.05</td>
<td>6.73</td>
<td>-5%</td>
<td>7.69</td>
<td>+9%</td>
</tr>
<tr>
<td>WM07</td>
<td>6.92</td>
<td>6.02</td>
<td>-13%</td>
<td>6.80</td>
<td>-2%</td>
</tr>
<tr>
<td>WM08</td>
<td>7.18</td>
<td>6.89</td>
<td>-4%</td>
<td>6.91</td>
<td>-4%</td>
</tr>
<tr>
<td>WM09</td>
<td>7.48</td>
<td>7.38</td>
<td>-1%</td>
<td>7.64</td>
<td>+2%</td>
</tr>
<tr>
<td>WM10</td>
<td>6.36</td>
<td>6.30</td>
<td>-1%</td>
<td>6.85</td>
<td>+8%</td>
</tr>
<tr>
<td>MAPE</td>
<td></td>
<td></td>
<td>6%</td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>All (signed)</td>
<td></td>
<td></td>
<td>-6%</td>
<td></td>
<td>0%</td>
</tr>
</tbody>
</table>
Validation procedure for WASA 2 masts

• Numerical wind atlas for SA
  – GWC from 5-km LIB files

• Microscale modelling @ each mast
  – WAsP 12 default setup
    • Adapted GWC heights
  – Generalised wind climates
    • Four for each site
  – Elevation map
    • Nine different tested
    • SRTM3+ used for all
  – Roughness map
    • Five different tested
    • No $z_0$ discretisation
Elevation data summary

Reference is the SUDEM data set

- The NGI ORT files (25-m DEM)
  - Small bias and spread
  - Adequate for flow modelling
  - Some issues comparing tiles

- SRTM3 & SRTM1 (3-/1-sec DSM)
  - Some bias, but small spread
  - Adequate for flow modelling

- CGIAR-CSI & SA20 (20-m contours)
  - Some bias and larger spread
  - Caution when flow modelling

- ASTER (1-sec DEM)
  - Large bias and large spread
  - Not adequate for flow modelling

| Data set      | $|\Delta z|$ | $\sigma_{\Delta z}$ |
|---------------|----------|---------------------|
| NGI ORT       | −0.32    | 1.65                |
| SRTM3 GL3     | +1.45    | 1.56                |
| SRTM3 v2.1    | +1.45    | 1.56                |
| SRTM1 GL3     | +1.46    | 1.92                |
| SRTM3 CSI     | +1.89    | 5.31                |
| SA20          | −1.65    | 3.59                |
| ASTER         | −2.86    | 8.55                |

- WASA site elevation maps
  - $40 \times 40$ km$^2$: 20-m contours
  - $20 \times 20$ km$^2$: 10-m contours
  - $10 \times 10$ km$^2$: 5-m contours
## Land cover and roughness length

<table>
<thead>
<tr>
<th>Class name (GlobCover)</th>
<th>Class number</th>
<th>RAM $z_0$</th>
<th>NGM $z_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Bodies</td>
<td>210</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Permanent Snow and ice</td>
<td>220</td>
<td>0.0004</td>
<td>0.0004</td>
</tr>
<tr>
<td>Bare areas</td>
<td>200</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>Grassland, savannahs, lichens/mosses</td>
<td>140</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Sparse vegetation</td>
<td>150</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Croplands</td>
<td>11, 14</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Shrubland</td>
<td>130</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Wetlands</td>
<td>180</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Mosaic natural vegetation / cropland</td>
<td>20, 30</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Flooded forest</td>
<td>160</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Mosaic grassland / forest</td>
<td>120</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Flooded forest or scrubland</td>
<td>170</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Urban Areas</td>
<td>190</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Forests</td>
<td>40, 50, 60, 70, 90, 100, 110</td>
<td>0.8</td>
<td>0.4</td>
</tr>
</tbody>
</table>
WM14 Memel input data
WM11 Rhodes (EC)

- Elevation = 2575 m
- Elevation range = 1280-2980 m
- Roughness range = 0-1.0 m
- Ruggedness index = 11%
WM11 Rhodes (EC)

- Elevation = 2575 m
- Elevation range = 1280-2980 m
- Roughness range = 0-1.0 m
- Ruggedness index = 11%
**WM12 Eston (NL)**

- Elevation = 770 m
- Elevation range = 220-1060 m
- Roughness range = 0-1.0 m
- Ruggedness index = 0%
WM13 Jozini (NL)

- Elevation = 80 m
- Elevation range = 40-720 m
- Roughness range = 0-1.0 m
- Ruggedness index = 0%
WM14 Memel (FS)

- Elevation = 2045 m
- Elevation range = 1270-2330 m
- Roughness range = 0.05-0.40 m
- Ruggedness index = 2%
WM15 Winburg (FS)

- Elevation = 1505 m
- Elevation range = 1340-1720 m
- Roughness range = 0-1.0 m
- Ruggedness index = 0%

![Land cover / roughness map](image)
# WASA 2 validation: nearest LIB file method

<table>
<thead>
<tr>
<th>WASA 2 mast</th>
<th>Observed wind $U_0$</th>
<th>GlobCover wind $U_1$</th>
<th>$U_1 - U_0$ [%]</th>
<th>ESACCI wind $U_2$</th>
<th>$U_2 - U_0$ [%]</th>
<th>ESACCI2 wind $U_3$</th>
<th>$U_3 - U_0$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM11</td>
<td>7.71 [ms$^{-1}$]</td>
<td>7.44 [ms$^{-1}$]</td>
<td>-4%</td>
<td>7.80 [ms$^{-1}$]</td>
<td>1%</td>
<td>8.32 [ms$^{-1}$]</td>
<td>8%</td>
</tr>
<tr>
<td>WM12</td>
<td>5.02 [ms$^{-1}$]</td>
<td>5.02 [ms$^{-1}$]</td>
<td>0%</td>
<td>5.22 [ms$^{-1}$]</td>
<td>4%</td>
<td>5.60 [ms$^{-1}$]</td>
<td>12%</td>
</tr>
<tr>
<td>WM13</td>
<td>5.19 [ms$^{-1}$]</td>
<td>4.89 [ms$^{-1}$]</td>
<td>-6%</td>
<td>4.56 [ms$^{-1}$]</td>
<td>-12%</td>
<td>4.87 [ms$^{-1}$]</td>
<td>-6%</td>
</tr>
<tr>
<td>WM14</td>
<td>7.51 [ms$^{-1}$]</td>
<td>6.80 [ms$^{-1}$]</td>
<td>-9%</td>
<td>7.11 [ms$^{-1}$]</td>
<td>-5%</td>
<td>7.50 [ms$^{-1}$]</td>
<td>0%</td>
</tr>
<tr>
<td>WM15</td>
<td>6.14 [ms$^{-1}$]</td>
<td>5.50 [ms$^{-1}$]</td>
<td>-10%</td>
<td>5.20 [ms$^{-1}$]</td>
<td>-15%</td>
<td>5.51 [ms$^{-1}$]</td>
<td>-10%</td>
</tr>
<tr>
<td>MAPE</td>
<td></td>
<td></td>
<td>6%</td>
<td></td>
<td>8%</td>
<td></td>
<td>7%</td>
</tr>
<tr>
<td>Mean bias</td>
<td></td>
<td></td>
<td>-6%</td>
<td></td>
<td>-6%</td>
<td></td>
<td>1%</td>
</tr>
</tbody>
</table>
WASA 2 validation: average of 4 LIB files method

<table>
<thead>
<tr>
<th>WASA 2 mast</th>
<th>Observed wind $U_0$ [ms$^{-1}$]</th>
<th>GlobCover wind $U_1$ [ms$^{-1}$]</th>
<th>$U_1 - U_0$ [%]</th>
<th>ESACCI wind $U_2$ [ms$^{-1}$]</th>
<th>$U_2 - U_0$ [%]</th>
<th>ESACCI2 wind $U_3$ [ms$^{-1}$]</th>
<th>$U_3 - U_0$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM11</td>
<td>7.71</td>
<td>8.29</td>
<td>7%</td>
<td>8.63</td>
<td>12%</td>
<td>9.24</td>
<td>20%</td>
</tr>
<tr>
<td>WM12</td>
<td>5.02</td>
<td>4.88</td>
<td>-3%</td>
<td>5.05</td>
<td>1%</td>
<td>5.42</td>
<td>8%</td>
</tr>
<tr>
<td>WM13</td>
<td>5.19</td>
<td>4.93</td>
<td>-5%</td>
<td>4.59</td>
<td>-12%</td>
<td>4.92</td>
<td>-5%</td>
</tr>
<tr>
<td>WM14</td>
<td>7.51</td>
<td>6.72</td>
<td>-11%</td>
<td>7.03</td>
<td>-6%</td>
<td>7.41</td>
<td>-1%</td>
</tr>
<tr>
<td>WM15</td>
<td>6.14</td>
<td>5.52</td>
<td>-10%</td>
<td>5.23</td>
<td>-15%</td>
<td>5.51</td>
<td>-10%</td>
</tr>
<tr>
<td>MAPE</td>
<td></td>
<td></td>
<td>7%</td>
<td></td>
<td>9%</td>
<td></td>
<td>9%</td>
</tr>
<tr>
<td>Mean bias</td>
<td></td>
<td></td>
<td>-4%</td>
<td></td>
<td>-4%</td>
<td></td>
<td>2%</td>
</tr>
</tbody>
</table>
WASA Phase 2 summary and conclusions

- Generalised wind climates (WASA 2 LIB files)
  - Four nearest LIB files give similar results, except in complex terrain
  - Nearest LIB method gives lowest spread, but slightly higher bias
  - Sum of 4 LIBs gives lowest bias, but slightly higher spread
  - LIB interpolation tool available in WAsP 12

- Elevation maps
  - SRTM3+ and 2.1 are excellent global data sets
  - NGI ORT files seem to work very well in South Africa
  - Caution: USGS GDEX, CGIAR-CSI, SA20, ASTER

- Roughness maps
  - GlobCover and ESACCi seem to work best in WASA 2
  - GlobCover gives lowest spread, but slightly higher bias
  - ESACCi gives lowest bias, but slightly higher spread
  - ESACCi is likely the data set we will employ for WASA 2 final runs
Conclusions and further work

- WASA 1 masts validation
  - Mean bias 0%
  - MAPE 5%

- WASA 2 masts validation
  - Mean bias –6% to 2%
  - MAPE 6% to 9%
  - Spread 4% to 11%

- WASA 2 and 3 focus areas
  - Land cover data
  - Land cover to roughness tables
  - Long-term extrapolation
  - Atmospheric stability
  - Adaptation of modelling
  - Uncertainty modelling
Acknowledgements

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WASA Project Steering Committee:

DoE (chair), DEA, DST, UNDP, Danish Embassy, SANEDI
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WASA download site
wasadata.csir.co.za/wasa1