Use of post processing techniques and satellite irradiance data to forecast short wave radiation

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## Model setup and MOS techniques

<table>
<thead>
<tr>
<th>Regional model</th>
<th>WRF ARW V3.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial and contour data</td>
<td>GFS 0.25°</td>
</tr>
<tr>
<td>Forecast interval analyzed</td>
<td>+12/+36h</td>
</tr>
<tr>
<td>Radiation scheme</td>
<td>RRTMG (short and long wave)</td>
</tr>
<tr>
<td>Model vertical resolution</td>
<td>26 levels exponentially spaced</td>
</tr>
<tr>
<td>Model horizontal resolution</td>
<td>12km</td>
</tr>
<tr>
<td>Period analyzed</td>
<td>2013-2014</td>
</tr>
</tbody>
</table>
Solar radiation forecast – known problems

- Tendency to overestimate radiation in cloudy situation
- Evidence of the “on/off switch”
- Difficulty in forecasting rapid changes in cloud cover
- Clear-sky radiation does not perfectly represent site-specific measurements

Model output statistics (MOS):

use of ground measurements
to remove bias and learnable errors from the NWP data
  - Physical based algorithm (MOSRH)
  - Pure Statistical based algorithm
  - Stochastic learning techniques (ANN)
MOSRH (*): two step post-processing

Pseudo cloud cover (PCC): integral of relative humidity of a vertical column of atmosphere

- Only levels with RH higher than a threshold value (60%) are considered
- Relative humidity is weighted accordingly to the humidity value itself
- Normalization to obtain a value between 0 and 1

$$\text{PCC} = \frac{\sum_{j} RH_j \cdot w_j}{\sum_{j} w_j}$$

Dampening effect of Pseudo cloud
- Clear sky radiation from the model (GHI cs) is dampened by a value proportional to the PCC
- The coefficients are obtained through a multilinear regression with the observation data

$$GHI^f = d \cdot GHI_{cs} \cdot (1 - a \cdot PCC^b) + c$$

Mean improvement values of MOSRH algorithm on raw model forecast: 15-25 %

MOSRH problems

1) Presence of a consistent radiation measurement series (at least 1-2 years)
2) Pre-processing of data measurements: every series must be treated independently
3) High quality measurements

Example: comparison between Rome and Bolzano coefficients

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolzano</td>
<td>PCC&lt;0.05</td>
<td>0</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>0.05&lt;PCC&lt;0.7</td>
<td>0.36</td>
<td>0.88</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>PCC&gt;0.7</td>
<td>0.68</td>
<td>2.33</td>
<td>0</td>
</tr>
<tr>
<td>Roma</td>
<td>PCC&lt;0.05</td>
<td>0</td>
<td>1</td>
<td>-12.5</td>
</tr>
<tr>
<td></td>
<td>0.05&lt;PCC&lt;0.7</td>
<td>0.69</td>
<td>1.32</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>PCC&gt;0.7</td>
<td>0.91</td>
<td>2.13</td>
<td>0</td>
</tr>
</tbody>
</table>

- **Use of satellite data**

1) Satellite data are available for several years for the entire area covered by Meteosat
2) A unique input data format for pre-processing
Meteosat GHI data

Known problems:

- Low accuracy compared to a high quality ground pyranometer
- Lower time resolution
- Data are represented as area integrated values and no as point values.
- Quality depends on weather, solar zenith angle and geographical area.

- Meteosat 9 (MSG2)
- Osi-Saf algorithm used to derive SSI (Surface Solar Irradiance) and DLI (Downward longwave Irradiance)
- A complete scan every 30 minutes (*)

Test sites

- Outdoor test facility of Airport Bolzano Dolomiti (position ca. 46.46N, 11.33E, alt 262m)
- Kipp&Zonen CMP11 secondary standard pyranometer

- Ester outdoor Laboratory at the University of Rome “Tor Vergata” (position ca. 41.85N, 12.62E, alt 30m)
- Kipp&Zonen CMP21 secondary standard pyranometer
The values are coherent with “Meteosat and Goes-R Radiative Fluxes validation report”
Satellite data: 2 different methodologies

1) **MOSRH SATPT**: MOSRH coefficients from a regression with the nearest point from the sat grid. Different set of coefficients for every point of the Italian domain.

2) **MOSRH SATMC**: MOSRH coefficients are calculated combining sat grid points in areas and altitudinal ranges. Points which behave similarly are treated with the same set of coefficient.

6 areas from the Italian energy market

4 different altitudinal ranges

24 different sets of coefficients

Courtesy of:
http://dataenergia.altervista.org/
Rome statistics

Hourly comparison: forecast vs ground based measurements

Solar radiation comparison - Rome

RMSE
- MOSRH_SATMC
- MOSRH_SATPT
- MOSRH
- RawModel

Mae
- MOSRH_SATMC
- MOSRH_SATPT
- MOSRH
- RawModel

Bias
- MOSRH_SATMC
- MOSRH_SATPT
- MOSRH
- RawModel

Error (W/m²)

 Improvement from raw forecast - Rome

CORR(%)
- MOSRH_SATMC 87.0
- MOSRH_SATPT 87.3
- MOSRH 87.3
Bolzano statistics

Hourly comparison: forecast vs ground based measurements

Solar radiation comparison - Bolzano

Error (W/m²)

MOSRH_SATMC
MOSRH_SATPT
MOSRH
RawModel

Bias

MSE

Mae

CORR(%)  
MOSRH_SATMC  88.1  
MOSRH_SATPT  88.3  
MOSRH  88.3

Improvement from raw forecast - Bolzano

Mae
Rmse

Improvement (%)
## Daily comparison

### Rome

<table>
<thead>
<tr>
<th></th>
<th>RAW MODEL</th>
<th>MOSRH</th>
<th>MOSRH_SATPT</th>
<th>MOSRH_SATMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAE (W/m^2)</td>
<td>103.8</td>
<td>57.9</td>
<td>57.7</td>
<td>61.4</td>
</tr>
<tr>
<td>NMAE (%)</td>
<td>21.3</td>
<td>11.9</td>
<td>11.8</td>
<td>12.2</td>
</tr>
<tr>
<td>CORR (%)</td>
<td>93.4</td>
<td>95.0</td>
<td>95.0</td>
<td>94.8</td>
</tr>
</tbody>
</table>

### Bolzano

<table>
<thead>
<tr>
<th></th>
<th>RAW MODEL</th>
<th>MOSRH</th>
<th>MOSRH_SATPT</th>
<th>MOSRH_SATMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAE (W/m^2)</td>
<td>126.4</td>
<td>68.3</td>
<td>68.4</td>
<td>80.5</td>
</tr>
<tr>
<td>NMAE (%)</td>
<td>29.3</td>
<td>15.8</td>
<td>15.8</td>
<td>18.7</td>
</tr>
<tr>
<td>CORR (%)</td>
<td>92.6</td>
<td>93.8</td>
<td>93.7</td>
<td>93.4</td>
</tr>
</tbody>
</table>
Conclusions

- MOSRH_SATPT and MOSRH_SATMC quality is comparable (or better) to MOSRH quality
- Lower quality of satellite data is balanced by a smoother data (preferable for regression)
- High number of regression data improves the coefficients quality (for MOSRH_SATMC)

Use of satellite data in finding regression coefficients can be a valid alternative to the use of ground measurement data.

Future work:
- Improvement of MOSRH_SATMC areas and altitudinal ranges
- Improvement of MOSRH algorithm
Thank you!