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

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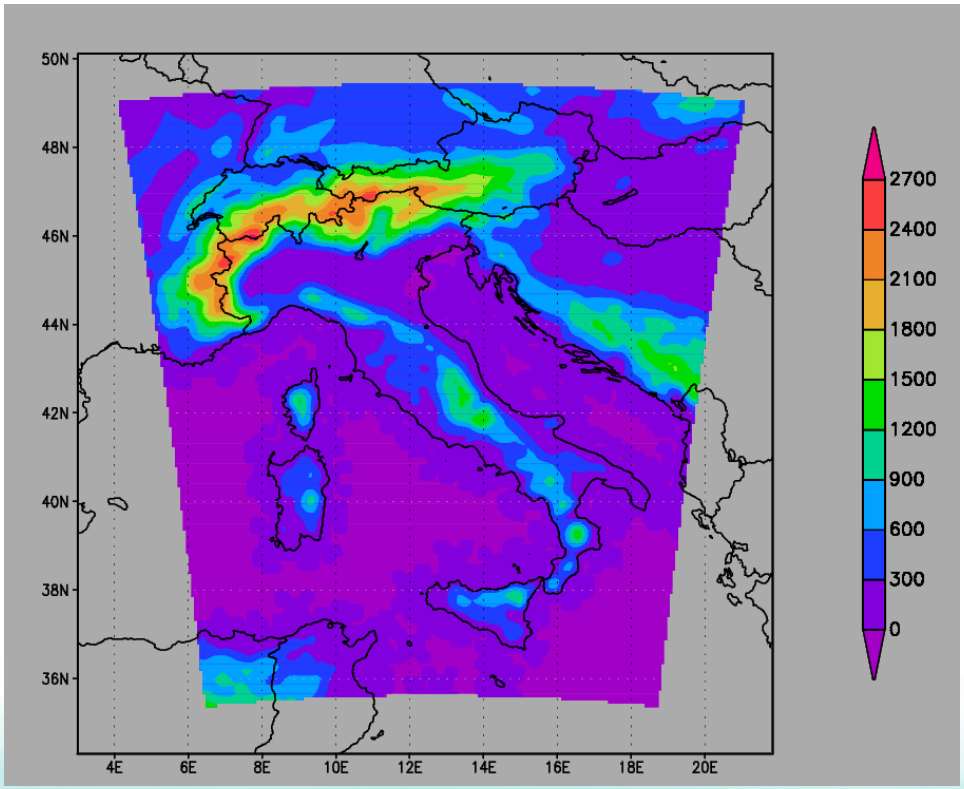
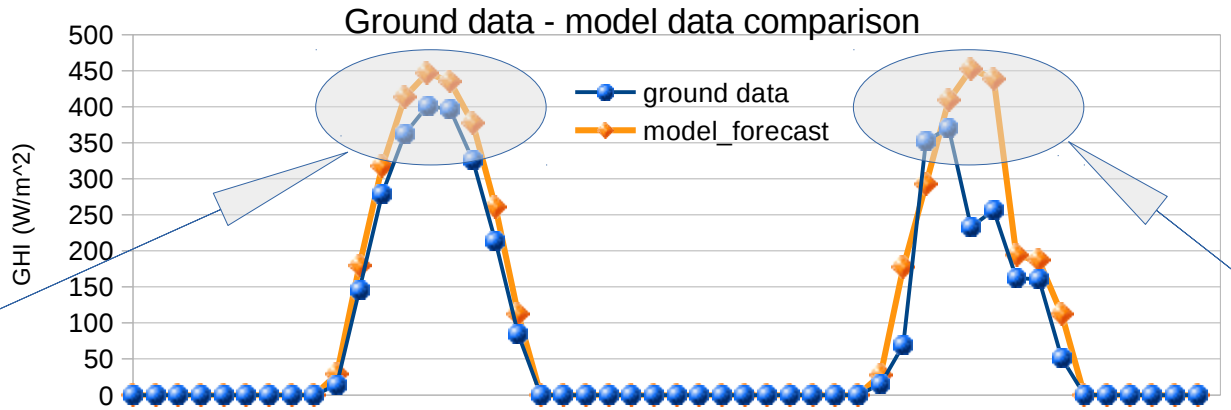
Model setup and MOS techniques

Regional model	WRF ARW V3.8
Initial and contour data	GFS 0.25°
Forecast interval analyzed	+12/+36h
Radiation scheme	RRTMG (short and long wave)
Model vertical resolution	26 levels exponentially spaced
Model horizontal resolution	12km
Period analyzed	2013-2014



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



Clear sky day bias

On/off switch in partly cloudy situation

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

$$PCC = \frac{\sum_j RH_j \cdot w_j}{\sum_j w_j}$$

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

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

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

(*) M. Pierro, F. Bucci, C. Cornaro, E. Maggioni, A. Perotto, M. Pravettoni, F. Spada, Model output statistics cascade to improve day ahead solar irradiance forecast, Solar Energy 117 (2015) 99–113

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

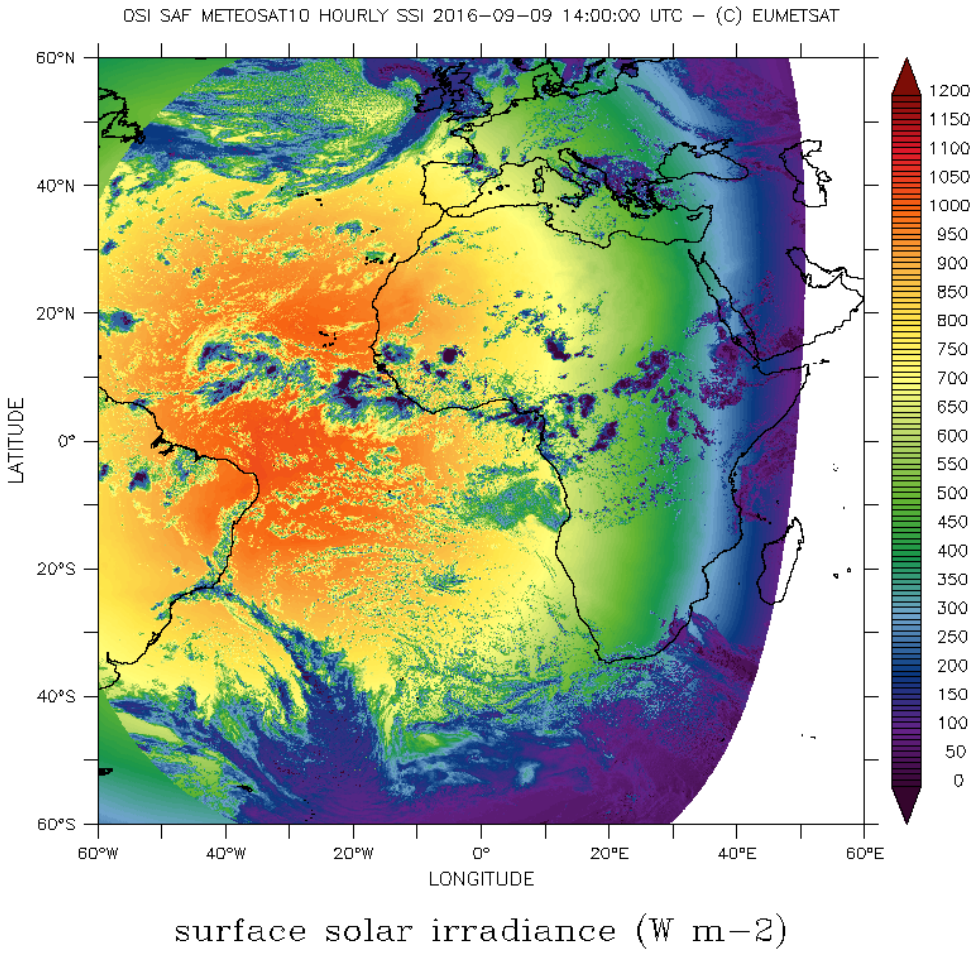
Example: comparison between Rome and Bolzano coefficients

		a	b	c	d
Bolzano					
	PCC<0.05	**0**	**1**	**22**	**0.96**
	0.05<PCC<0.7	**0.36**	**0.88**	**0**	**1**
	PCC>0.7	**0.68**	**2.33**	**0**	**1**
Roma					
	PCC<0.05	**0**	**1**	**-12.5**	**0.92**
	0.05<PCC<0.7	**0.69**	**1.32**	**0**	**1**
	PCC>0.7	**0.91**	**2.13**	**0**	**1**

- **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



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

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.

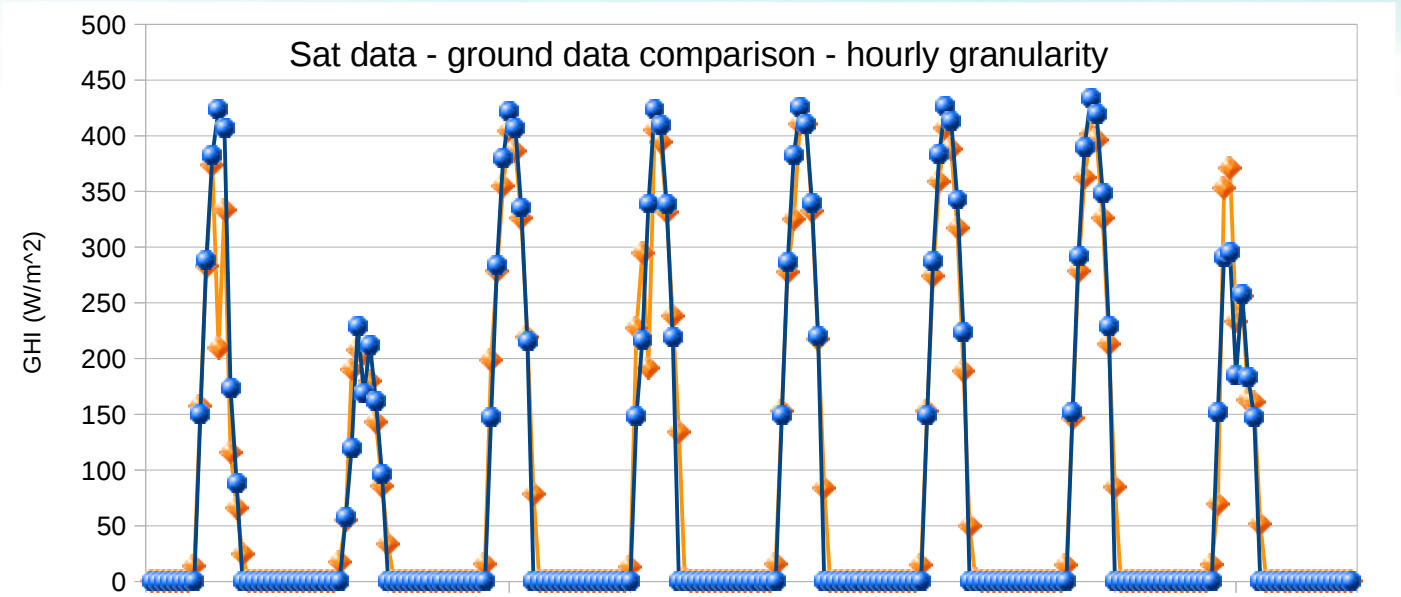
(*) Meteosat and Goes-R Radiative Fluxes validation report – P.Le Borgne, G. Legendre, A. Marsouin, S. Péré, S. Philippe – June 2011

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

Obs-sat comparison



Rome site

MAE (W/m2)	49.3
NMAE (%)	10.8
NRMSE (%)	18.8

Bolzano site

MAE (W/m2)	55.1
NMAE (%)	13.7
NRMSE (%)	21.2

The values are coherent with “Meteosat and Goes-R Radiative Fluxes validation report”

Satellite data: 2 different metodologies

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.

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

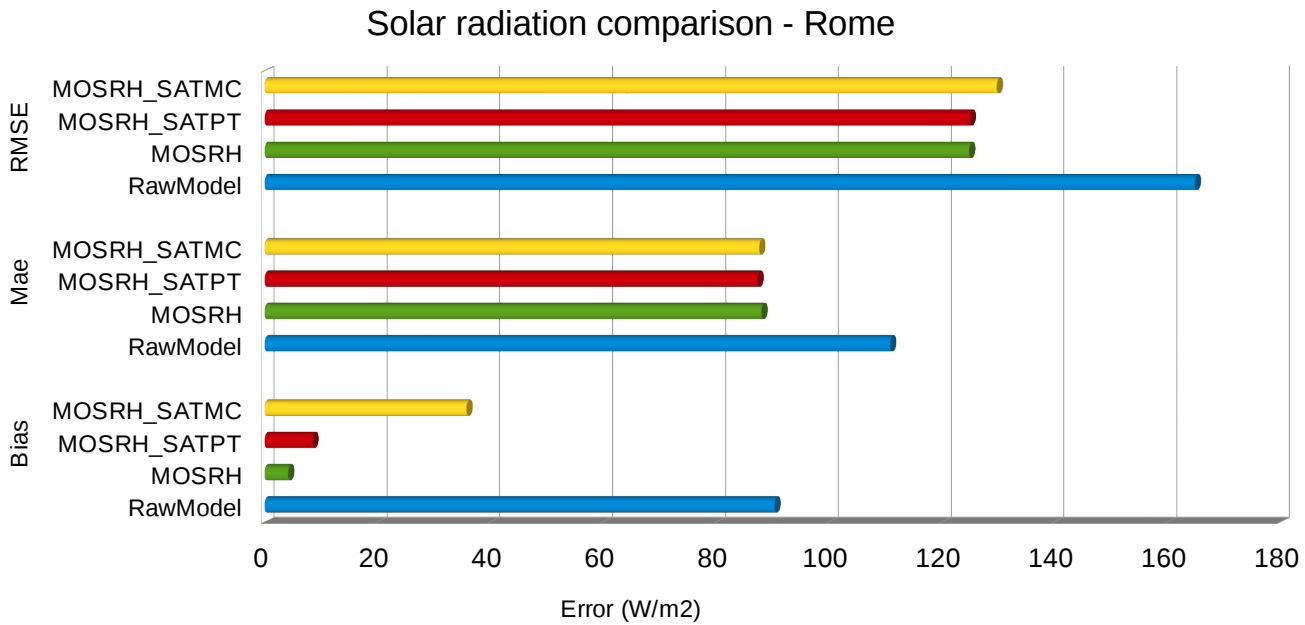
6 areas from the Italian energy market

4 different altitudinal ranges

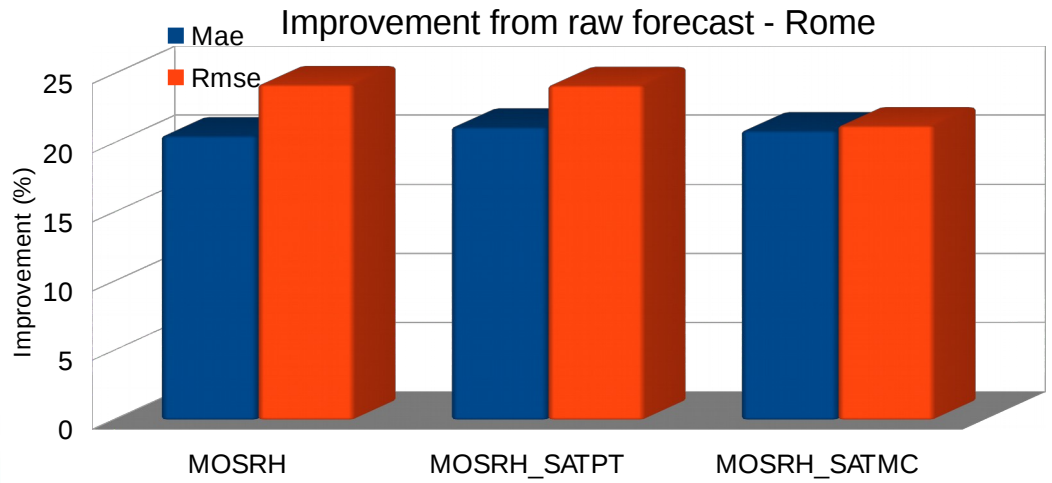
24 different sets of coefficients

Rome statistics

Hourly comparison: forecast vs ground based measurements

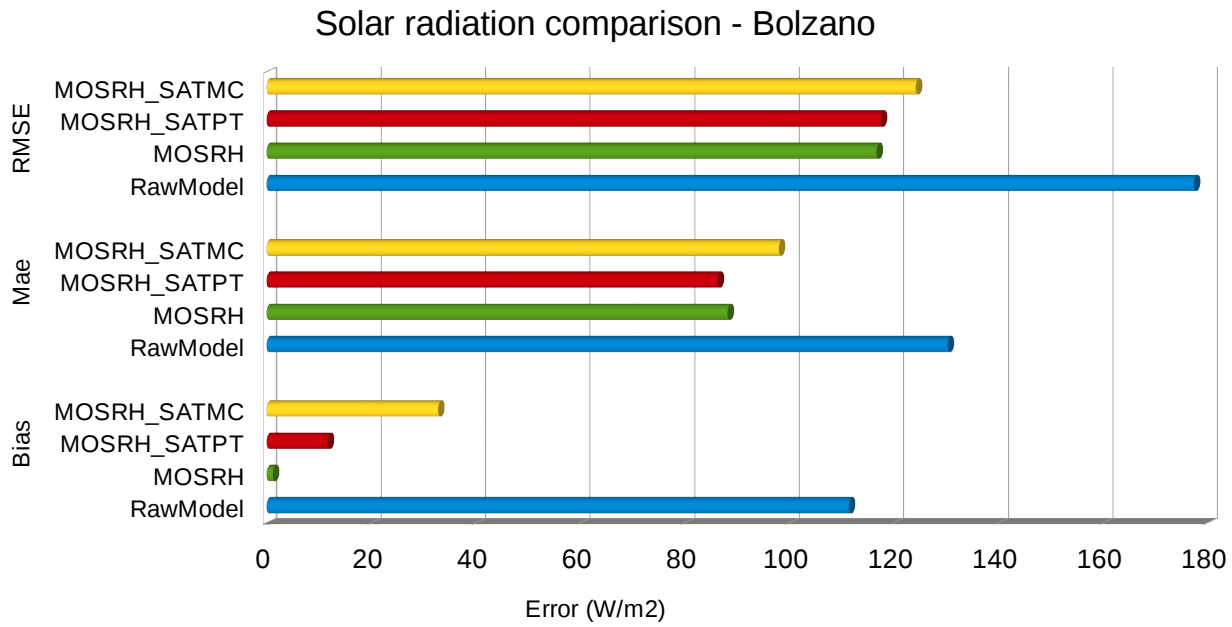


	CORR(%)
MOSRH_SATMC	87.0
MOSRH_SATPT	87.3
MOSRH	87.3

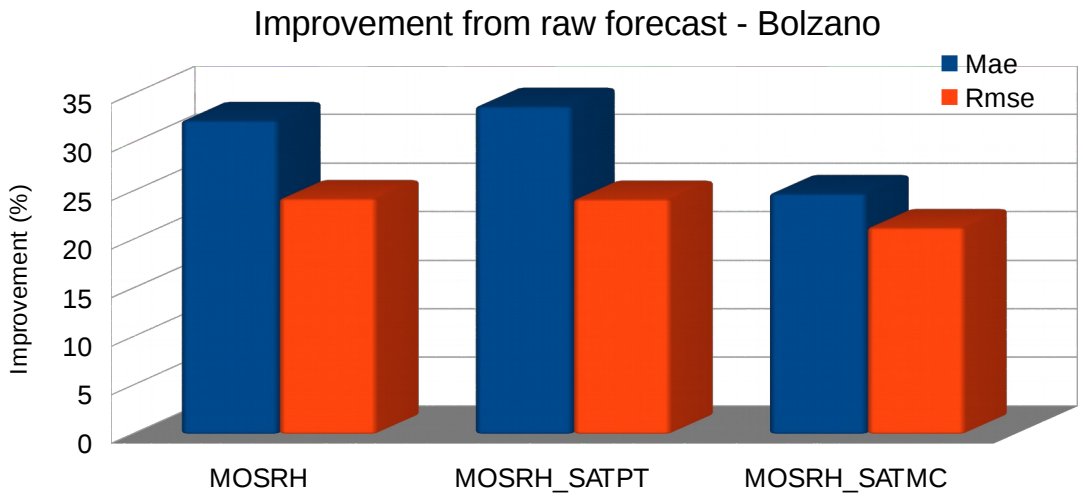


Bolzano statistics

Hourly comparison: forecast vs ground based measurements



	CORR(%)
MOSRH_SATMC	88.1
MOSRH_SATPT	88.3
MOSRH	88.3



Daily comparison

Rome

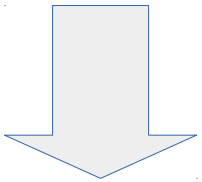
	RAW MODEL	MOSRH	MOSRH_SATPT	MOSRH_SATMC
MAE (W/m^2)	103.8	57.9	57.7	61.4
NMAE (%)	21.3	11.9	11.8	12.2
CORR (%)	93.4	95.0	95.0	94.8

Bolzano

	RAW MODEL	MOSRH	MOSRH_SATPT	MOSRH_SATMC
MAE (W/m^2)	126.4	68.3	68.4	80.5
NMAE (%)	29.3	15.8	15.8	18.7
CORR (%)	92.6	93.8	93.7	93.4

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!

Monthly Comparison – Rome