Monitoring and forecast of daytime fog for applications in solar PV systems

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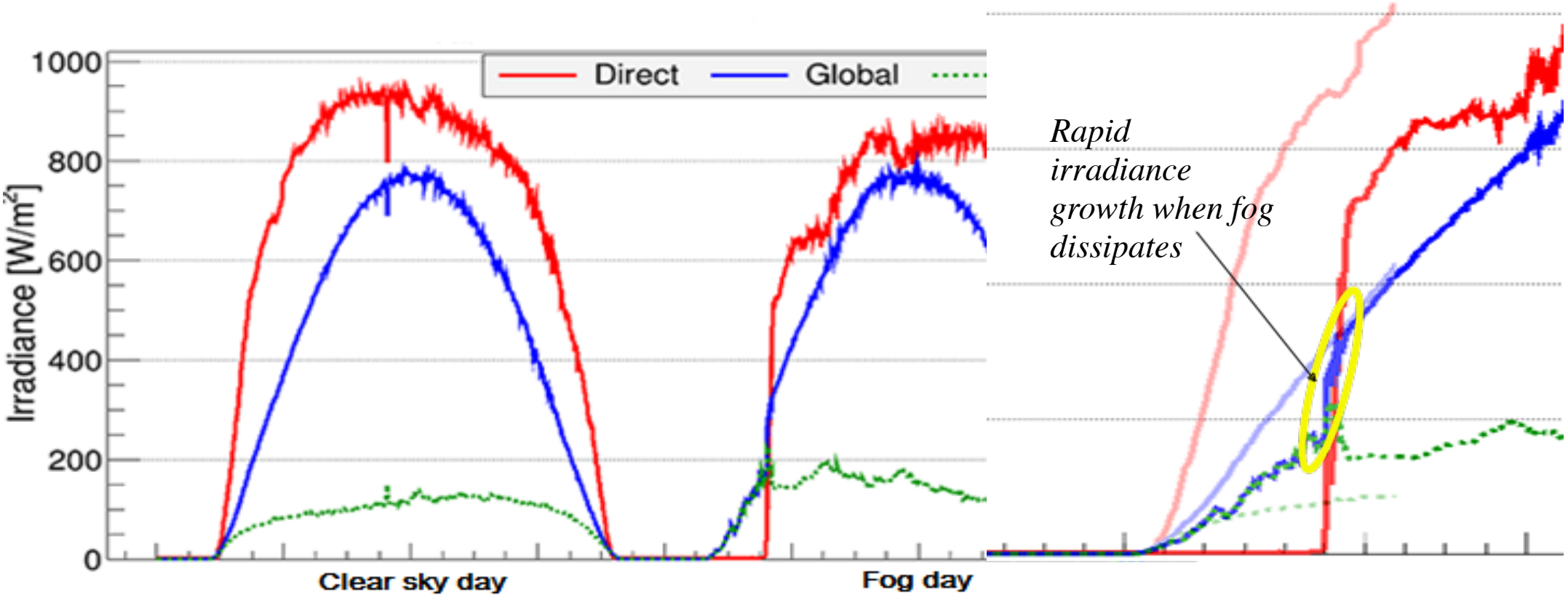
Factors affecting photovoltaic (PV) power production

- Global Solar Irradiance (~ 90%)
- Weather conditions
  (Cloud cover, Snow, **Fog**, Aerosols and Dust)

- Temperature (~ 10%)
- Wind (< 1%)
- PV plant specifics

Zack, J., Current status and challenges of solar power production forecasting, ETWG Solar Workshop

Fog and irradiance



Picture from Qatar Environment & Energy Research Institute

Fog monitoring using MSG Seviri

The proposed algorithm focuses on the monitoring of fog events that:

occur in clear sky conditions

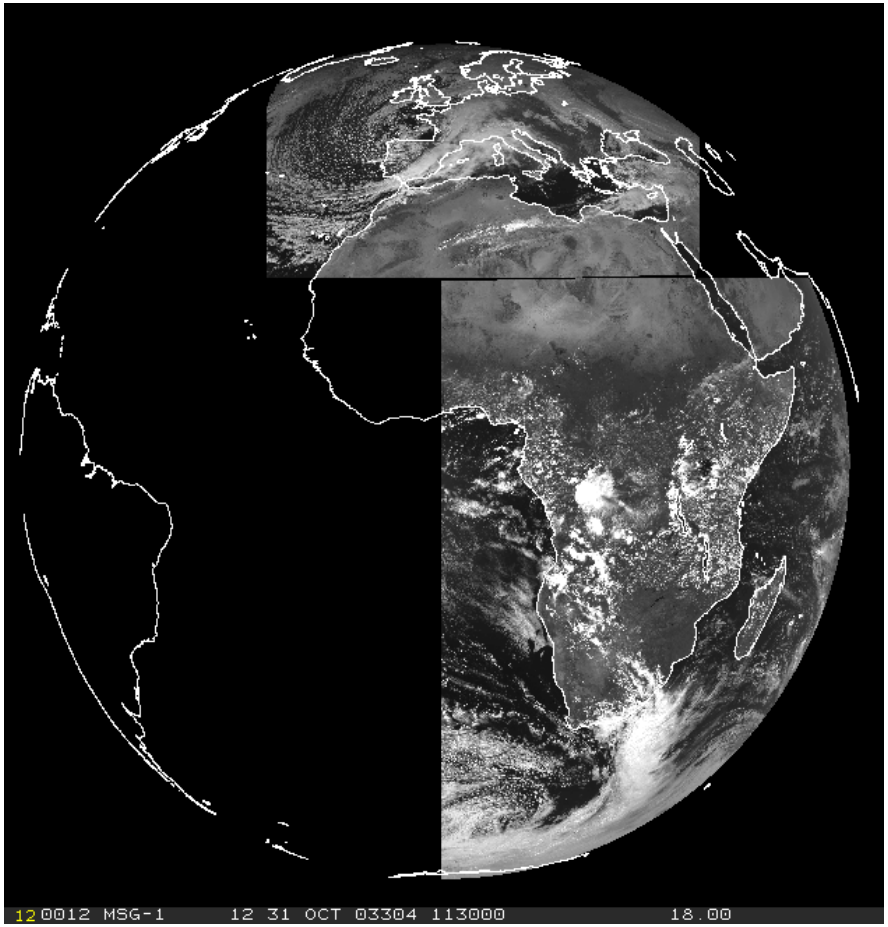
hence

have remarkable impact on PV power production.

Fog monitoring using MSG Seviri

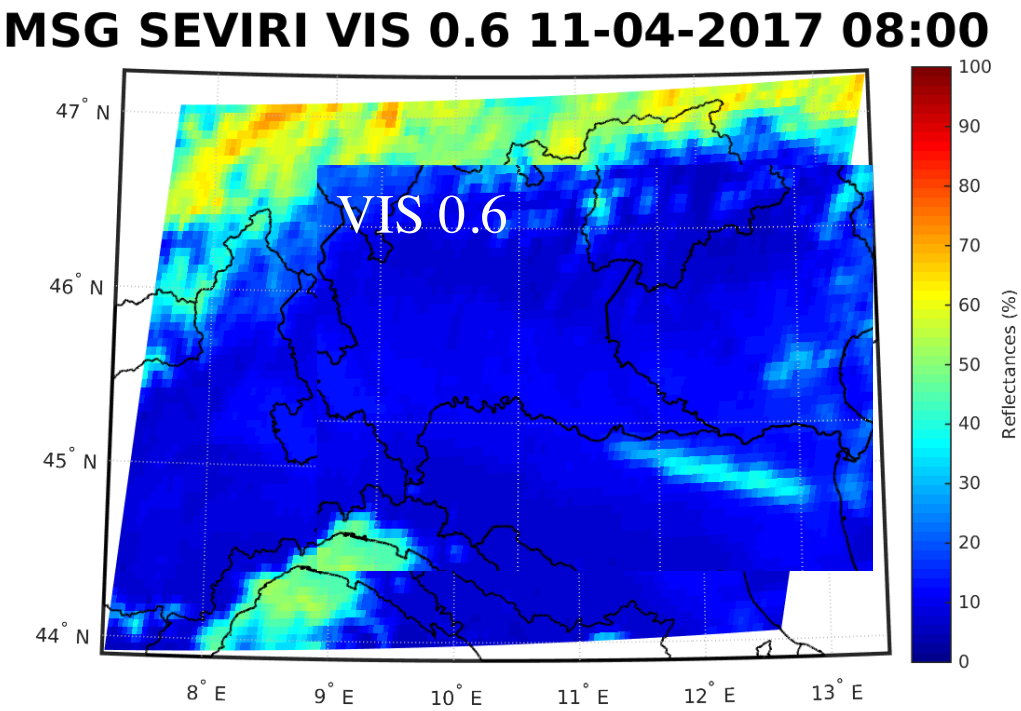
MSG SEVIRI Satellite data for Fog Monitoring:

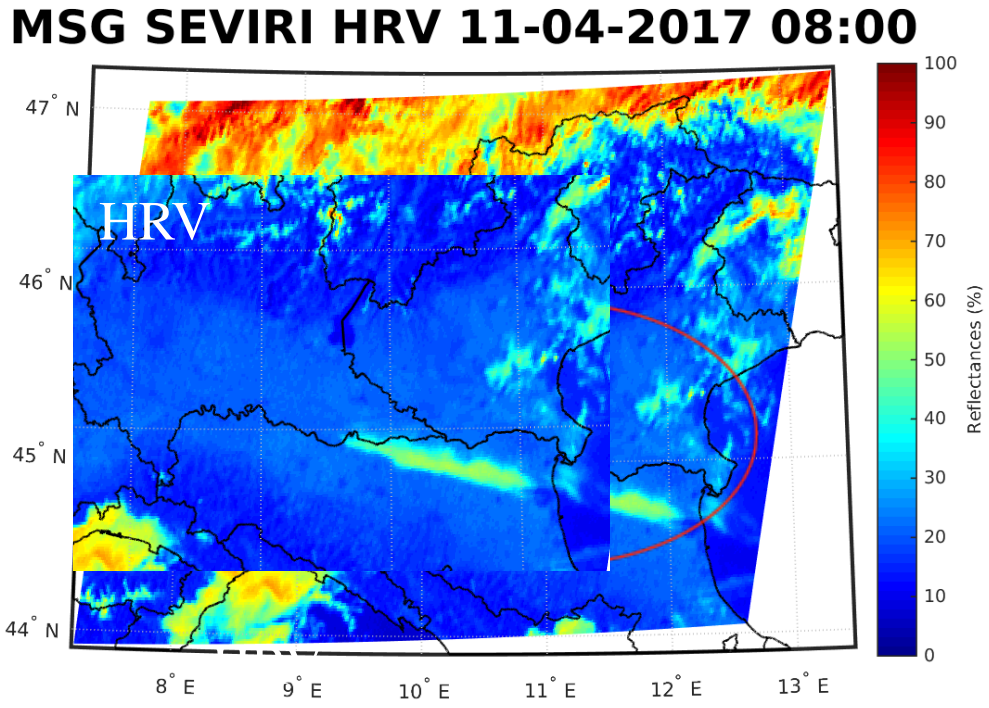
- 11 IR/VIS channels (3 km at ssp of spatial resolution)
- 1 High Resolution Visible broadband channel (1 km at ssp)
- High temporal resolution (15 min)
- Global Coverage



Fog monitoring - why using MSG HRV channel?

1 – Enhanced HRV spatial resolution compared to IR/VIS Seviri Channels





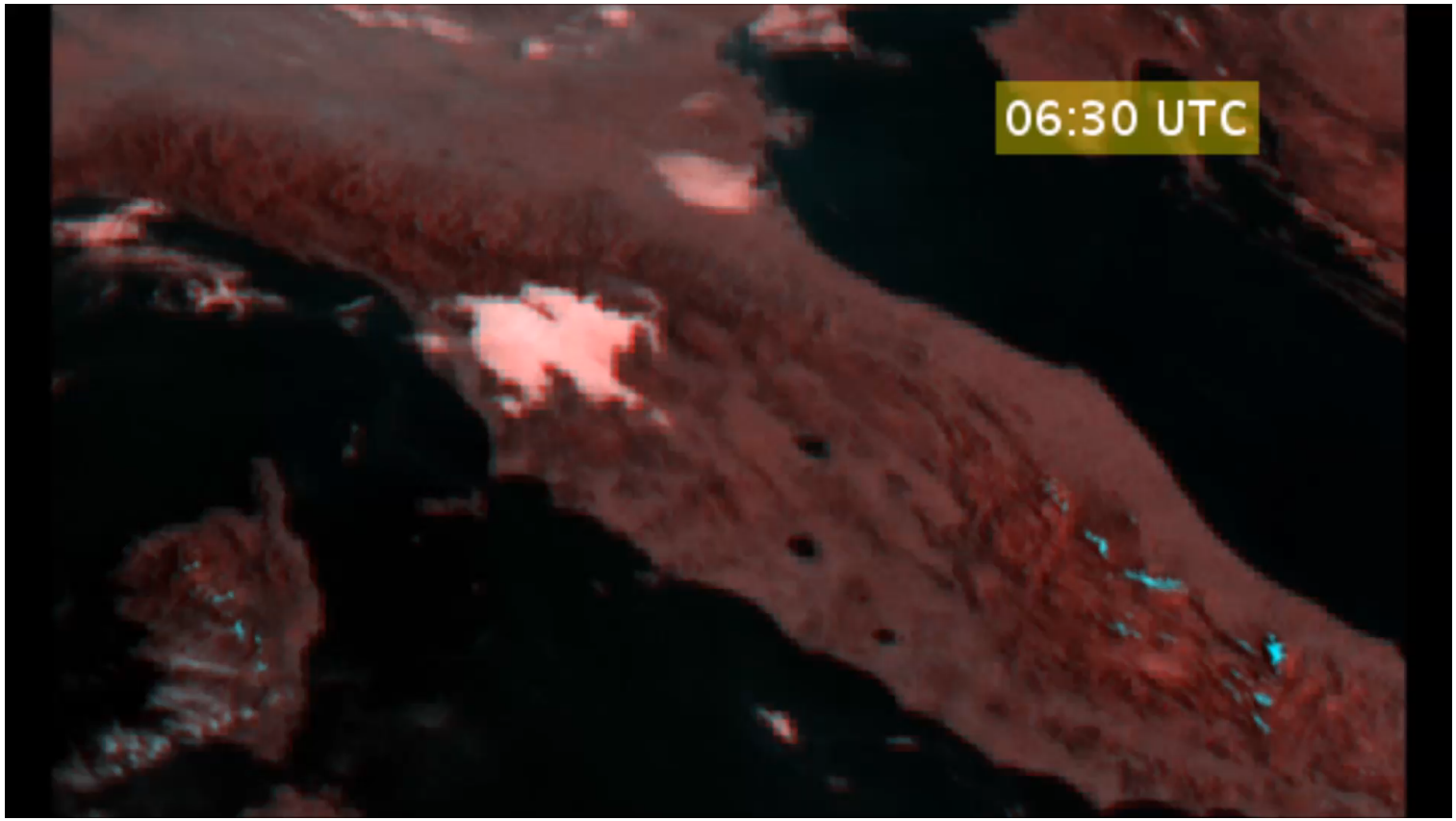
Fog monitoring - why using MSG HRV channel?

2 – Temporal resolution suitable for the monitoring of fog evolution

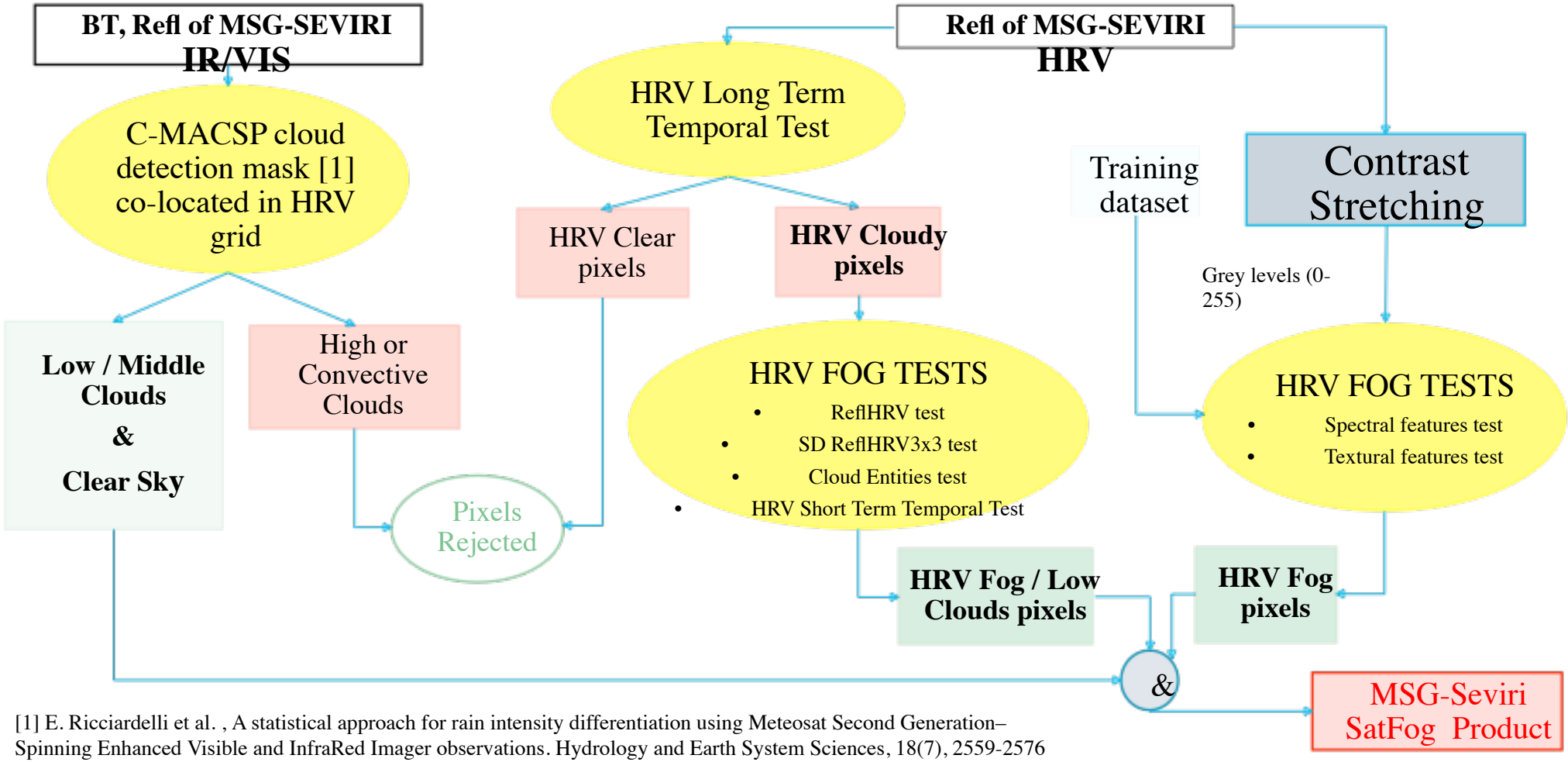
MSG HRV FOG RGB Product

R = NIR1.6
G = HRV
B= HRV

10 April 2017
06:30 – 10:30 UTC



MSG Seviri Satellite Fog (MSG-Seviri SatFog) monitoring algorithm



[1] E. Ricciardelli et al. , A statistical approach for rain intensity differentiation using Meteosat Second Generation–Spinning Enhanced Visible and InfraRed Imager observations. Hydrology and Earth System Sciences, 18(7), 2559-2576 (2014).

MSG-Seviri SatFog – C-MACSP

C-MACSP – Classification cloud MAsk Coupling of Statistical and Physical methods

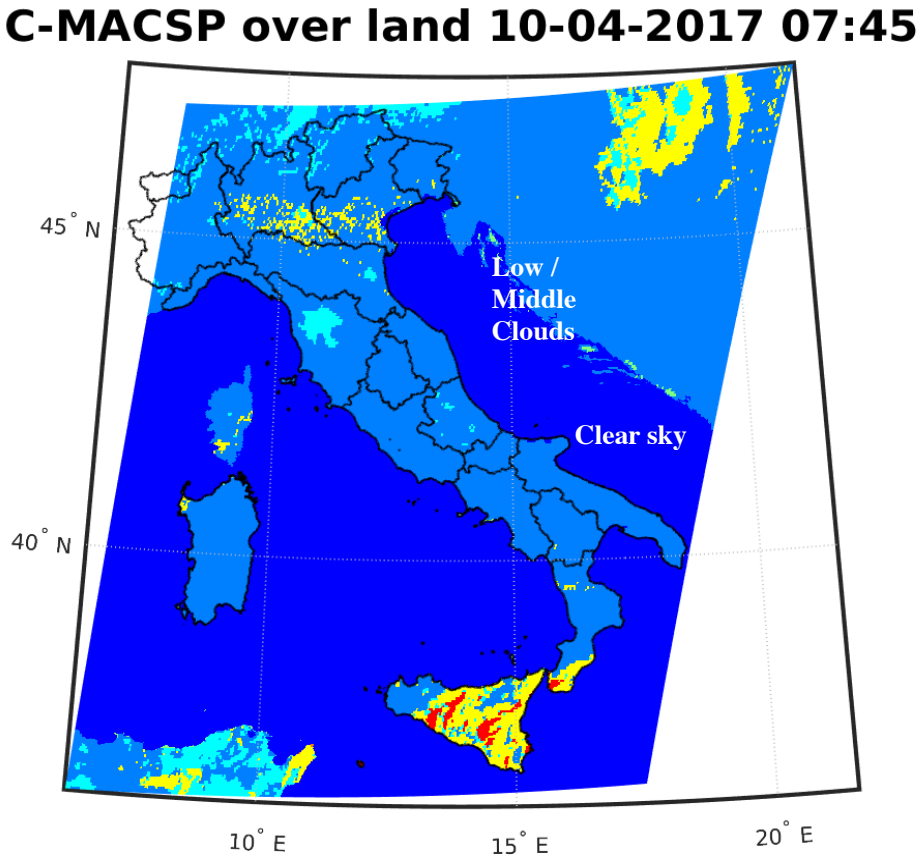
This is a cloud detection algorithm based on physical, statistical and statistical temporal tests.

C-MACSP INPUT :

- MSG-SEVIRI IR/VIS channels

C-MACSP OUTPUT classes:

- Clear
- Low and Middle Clouds
- High thin clouds
- High thick clouds
- Convective clouds

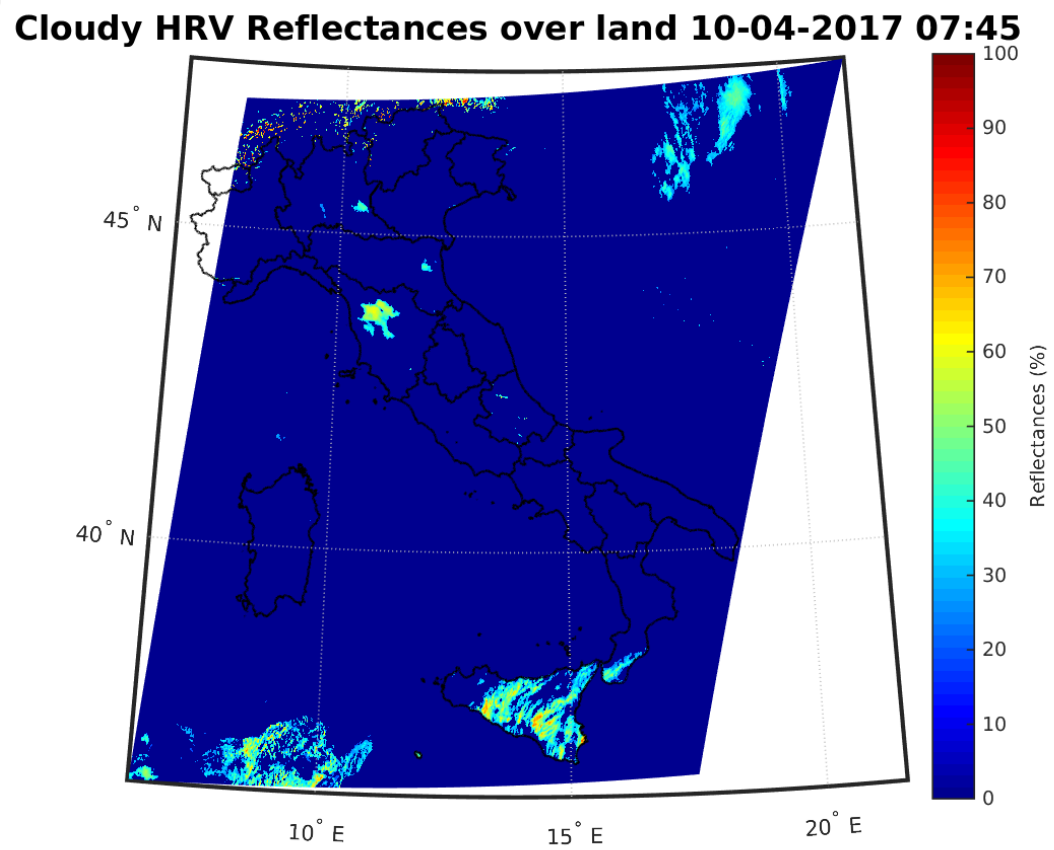


MSG-Seviri SatFog - HRV LTTT

HRV LTTT – HRV Long Term Temporal Test

- The thresholds have been estimated considering:
- the **minimum reflectance** during the previous 10 days,
- the simulated and measured clear sky datasets.

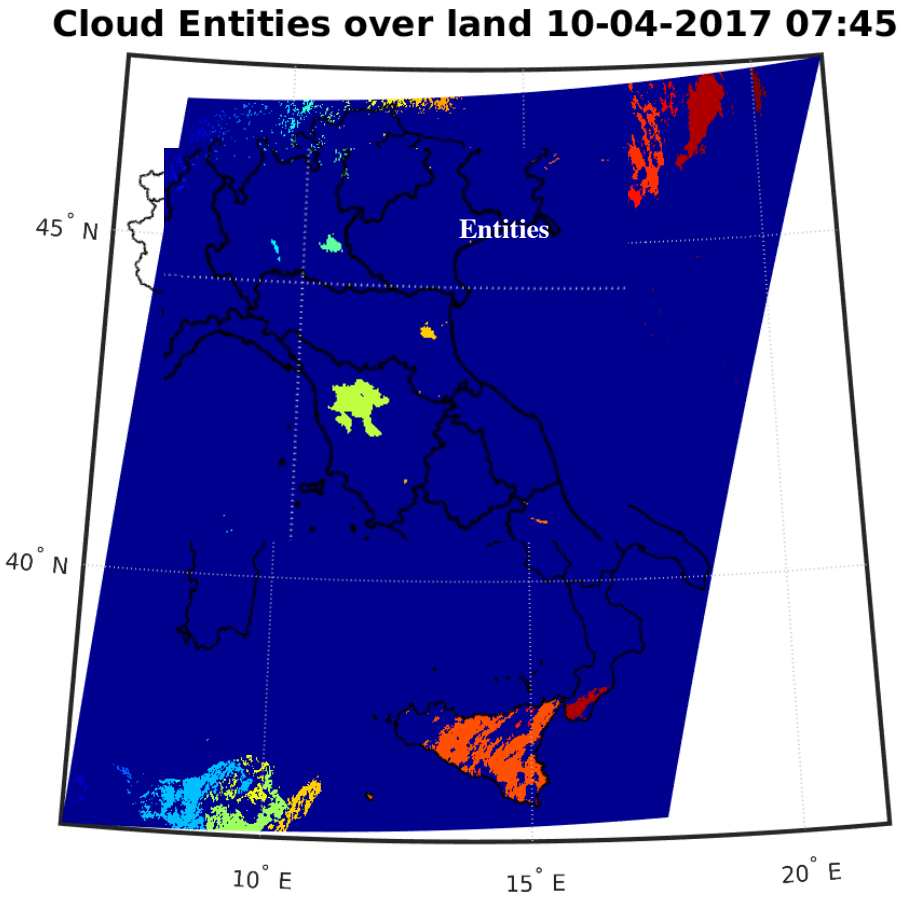
- HRV LTTT selects only the **cloud contaminated pixels**.



MSG-Seviri SatFog – HRV Fog Tests

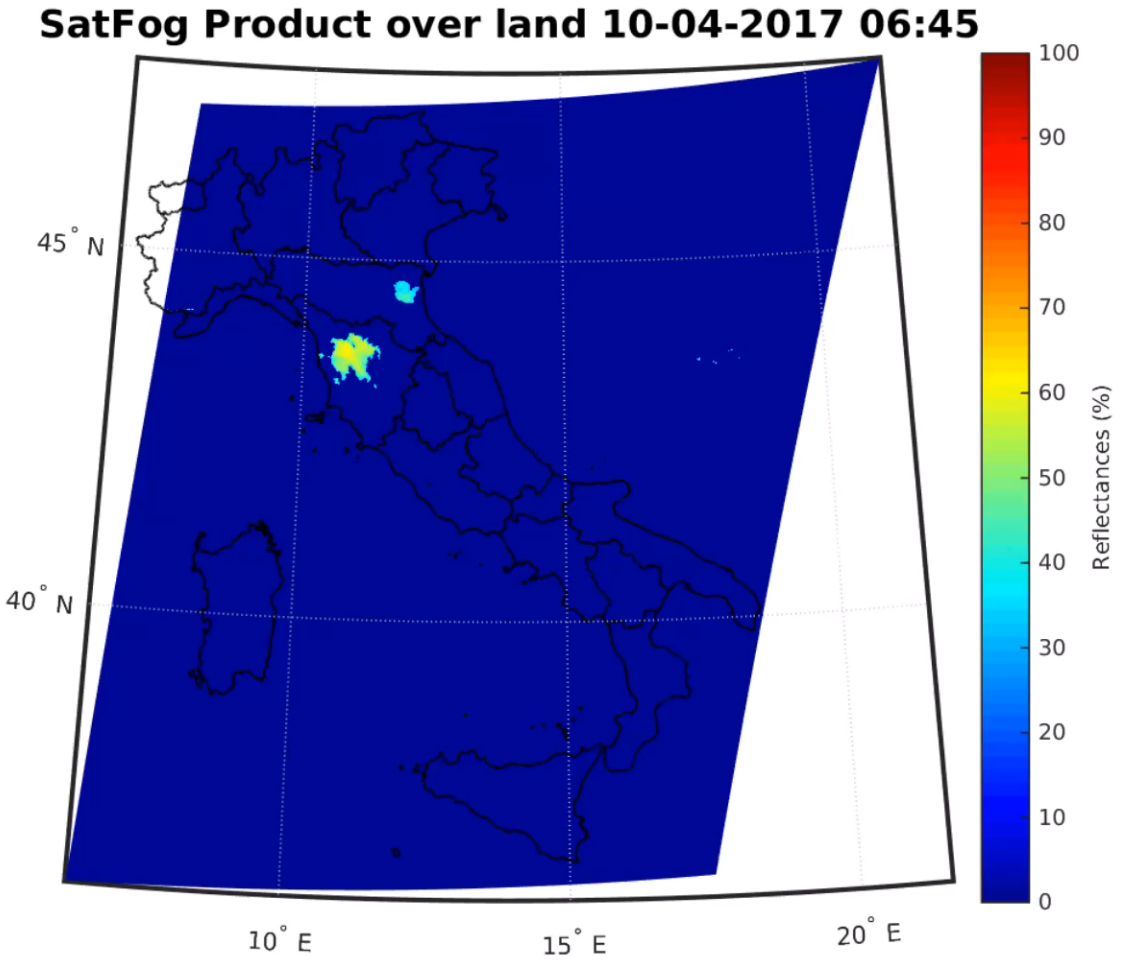
HRV FOG TESTS – ReflHRV , SD ReflHRV3x3 , Cloud Entities and STTT tests

- **ReflHRV test** and **SD ReflHRV3x3 test** are pixel-based threshold tests implemented to **identify fog or very low clouds**.
- Thresholds have been estimated using a database built with visual identified fog cases.
- **Cloud Entities test** computes the connected components according to the Haralick method [1] and returns cloud entities.
- **Short Term Temporal Test** uses two subsequent images at time t0 and t0-15min to monitor entities temporal evolution.



[1] Haralick, Robert M., and Linda G. Shapiro, *Computer and Robot Vision, Volume I*, Addison-Wesley, 1992, pp. 28-48.

MSG-Seviri SatFog Product



MSG-Seviri SatFog – METAR Validation

No adequate spatial data is available on fog, so METAR visibility data needs to be used as a reference to identify fog condition.

CONTINGENCY TABLE		HRV FOG MASK	
		True	False
METAR	True	tp	fn
	False	fp	tn

$$POD = \frac{tp}{tp + fn} \qquad POFD = \frac{fn}{fn + tn}$$

$$FAR = \frac{fp}{tp + fp} \qquad HKD = POD - POFD$$

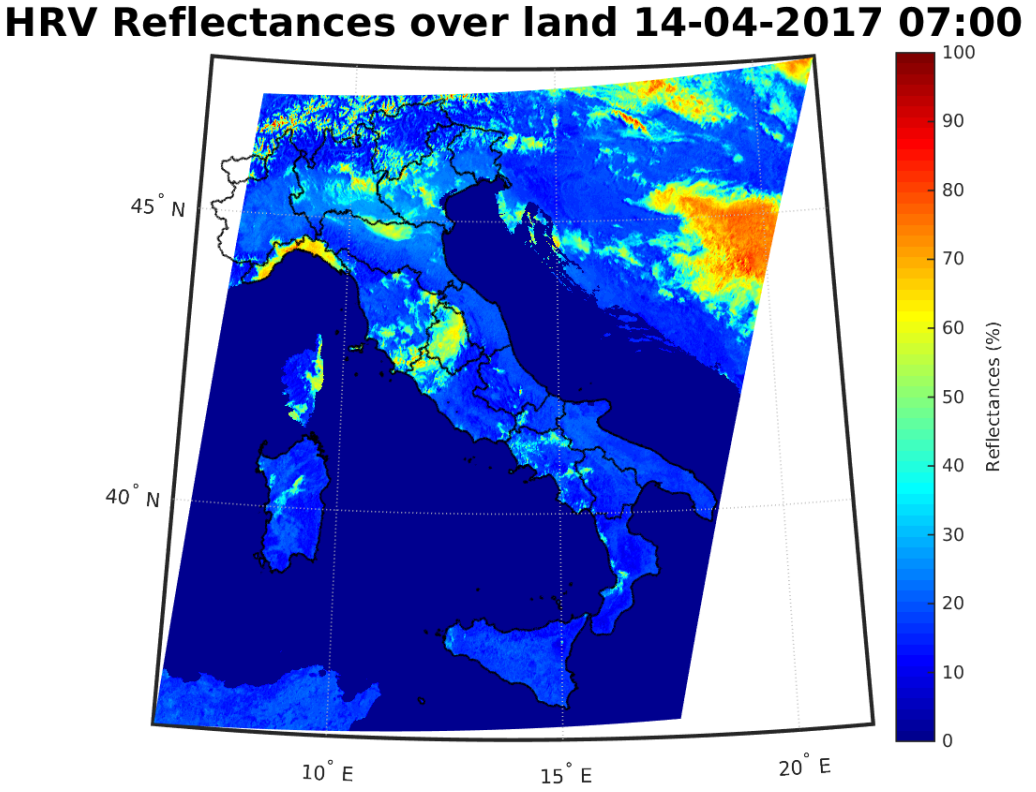
$$ACC = \frac{tp + tn}{tp + fp + tn + fn}$$

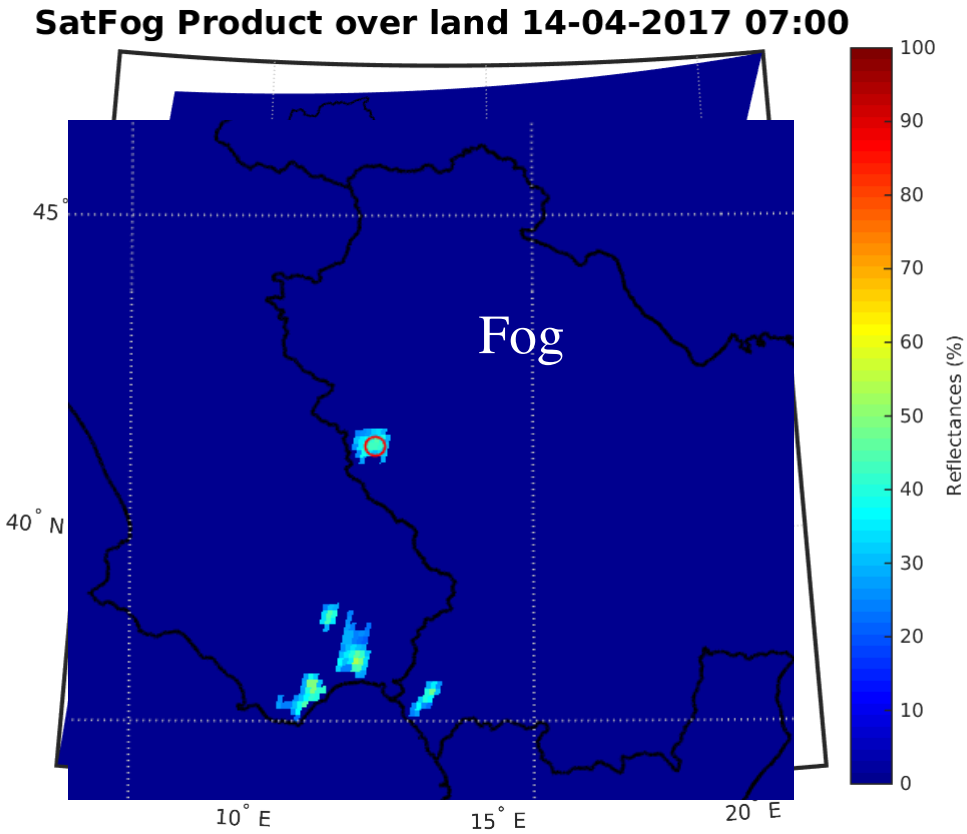
- 18 METAR sites in Italy
- 40 days between oct ‘16 and apr ‘17
- Early morning hours
- Fog condition = Visibility METAR < 1 km
- N = 4439

Scores:

ACC = 69.87 %
POD = 68.7 %
POFD = 30.01 %
FAR = 31.3 %
HKD = 38.69 %

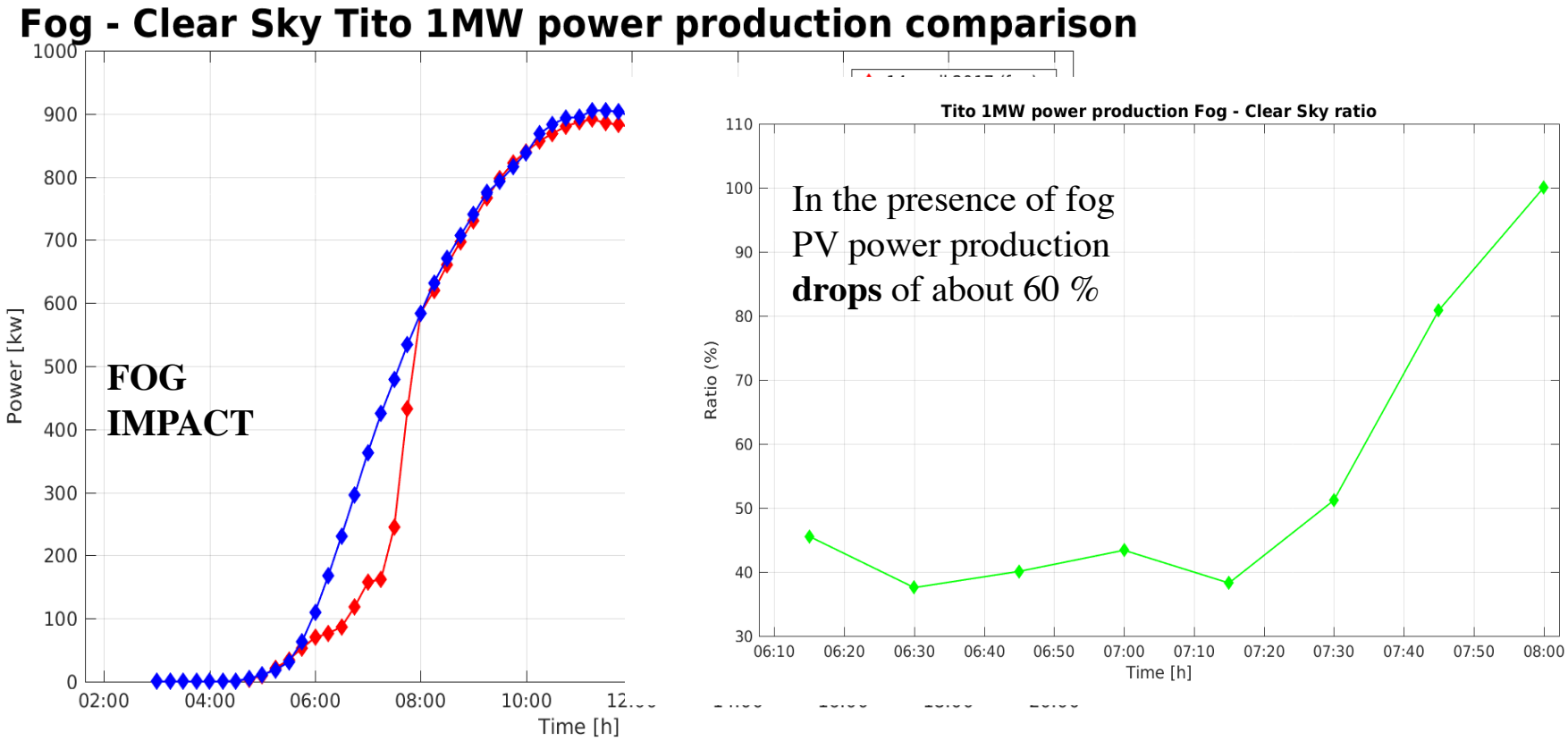
MSG-Seviri SatFog – case study 1



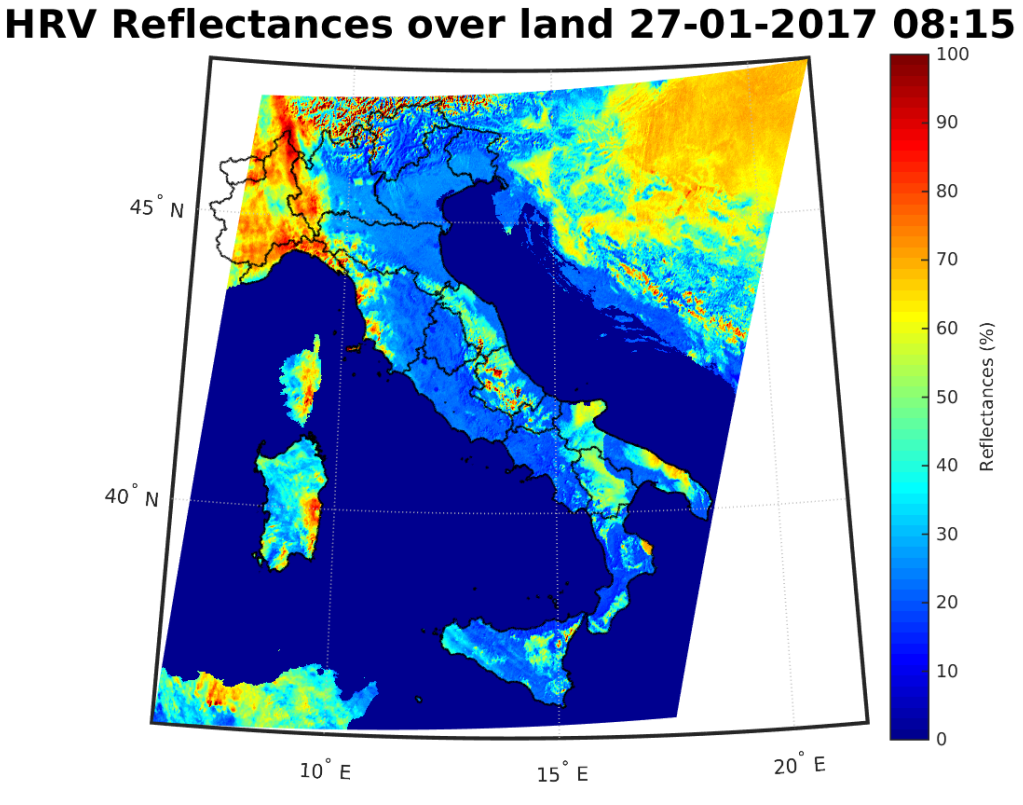


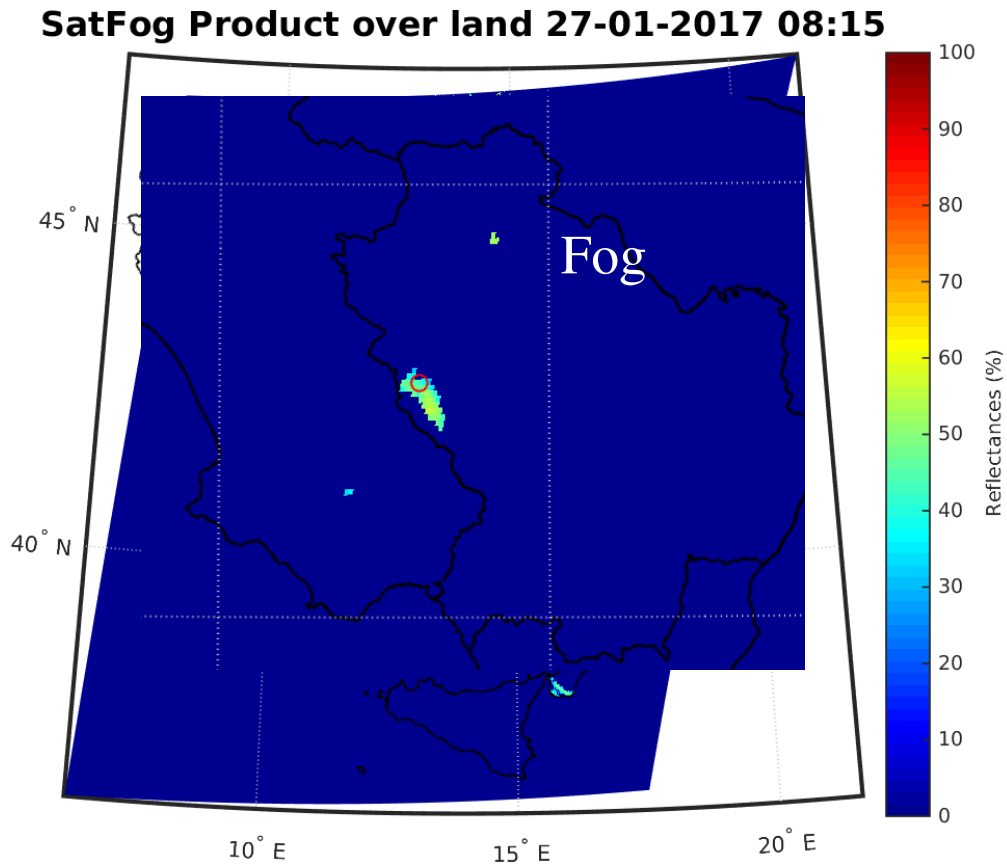
Fog detected between 6 and 7.30 UTC on the 1 MW PV power plant site located in Tito (PZ)

Fog impact on TITO 1MW PV power plant – case study 1



MSG-Seviri SatFog – case study 2

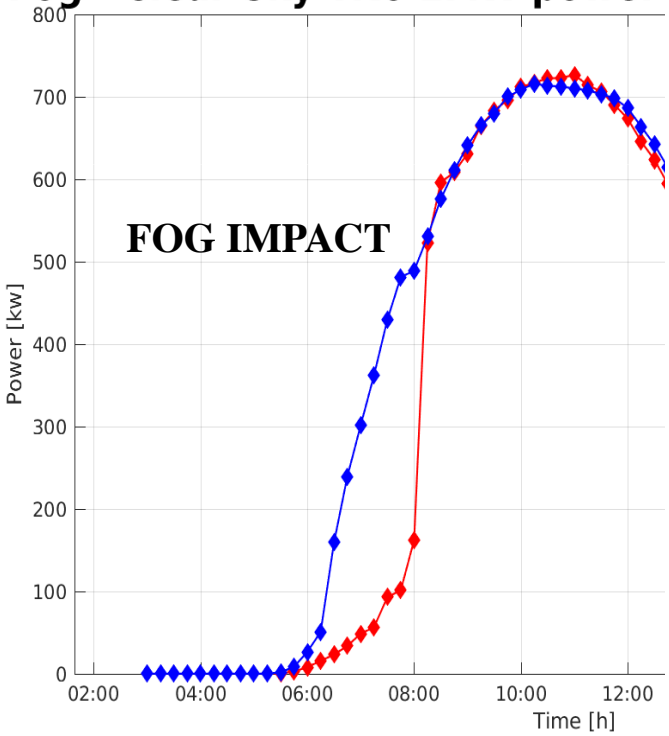


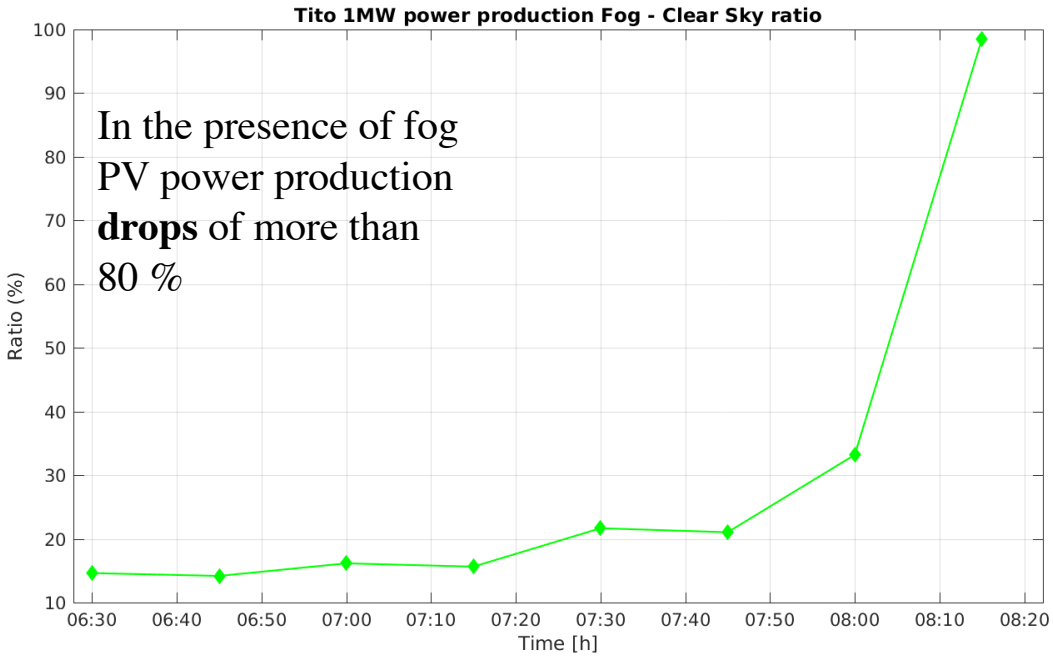


Fog detected between 6 and 9 UTC on the 1 MW PV power plant site located in Tito (PZ)

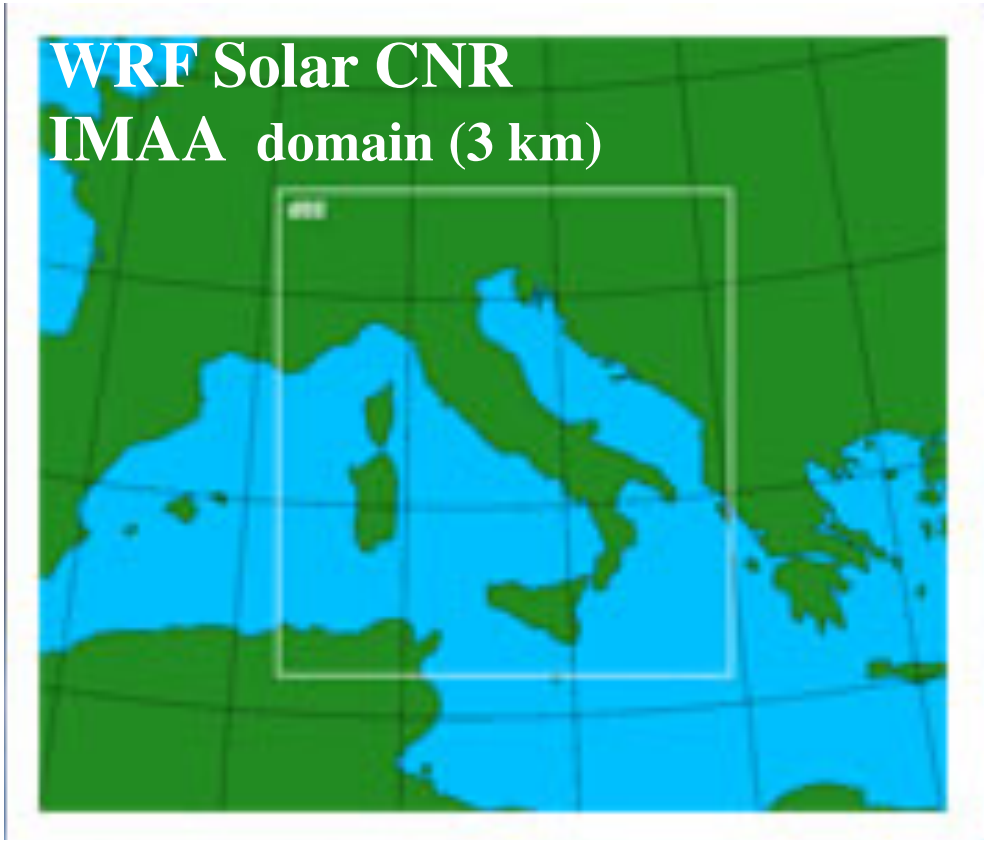
Fog impact on TITO 1MW PV power plant– case study 2

Fog - Clear Sky Tito 1MW power production comparison





Fog forecast – preliminary results



INPUTS:

Hourly WRF Output Variables:

- 2m temperature
- 850hp temperature
- 2m dew point temperature
- 850hp wind intensity

OUTPUTS:

Hourly Fog Probability

- 0 -> low probability
- 100 -> high probability

Fog forecast – preliminary results

METAR (Visibility) validation

- 4 sites
- 120 winter days
- Daytime hours
- N = 6776

MSG-Seviri images visual inspection validation

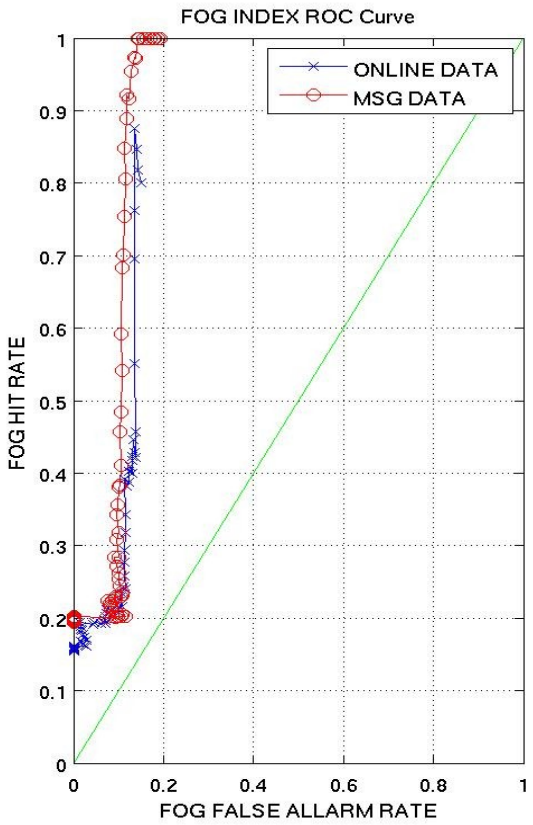
<u>Results:</u>

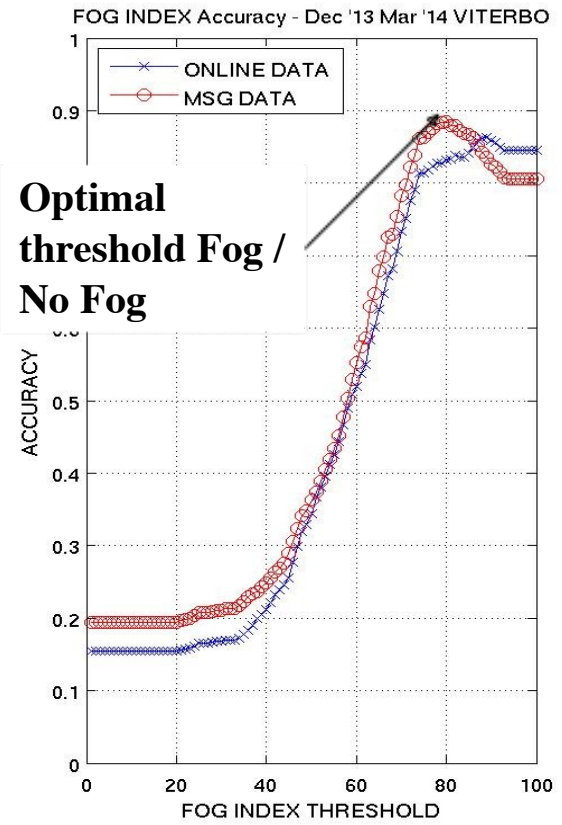
ACC = 83.07 %

POD = 78.05 %

FAR = 13.62 %

Area ROC = 72.26 %





Conclusions

- A fog satellite monitoring algorithm with high spatial and temporal resolution has been implemented using IR/VIS and HRV MSG Seviri data.
- MSG-Seviri SatFog product can be useful to evaluate the fog effect in solar PV power applications.
- Further work has to be done in fog forecasting to include site specific climate features.

THANKS FOR YOUR ATTENTION

Consiglio Nazionale delle Ricerche

imaa istituto di metodologie per l'analisi ambientale

ibam

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SolarCloud