Meteosat second Generation Surface Temperature assimilation for WRF model over Canary Islands domain

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METEOSAT SECOND GENERATION SURFACE TEMPERATURE ASSIMILATION FOR WRF MODEL OVER CANARY ISLANDS DOMAIN

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ABSTRACT

The use of weather forecasting models in energy applications has proven to be an effective tool in the management of renewable energy sources in power distribution networks which requires precise predictions and high-resolution of solar radiation and wind speed data. Therefore, the use of data from meteorological satellites such as Meteosat second Generation (MSG) can produce improvements in weather forecasting results. The integration of satellite data in weather prediction models is a developing field, because the assimilated data for these types of models mainly proceed from in-situ data at multiple stations, with low spatial resolution. The objective of this work has been the integration of data from the MSG satellite in the assimilation of meteorological model Weather Research and Forecasting (WRF-ARW), trying to improve results in meteorology predictions used in renewable power applications.

***Index Terms*—**Remote sensing, Meteosat, WRF, GFS, SST, Split-window.

1. INTRODUCTION

Nowadays, renewable energy sources are becoming a real alternative to the use of fossil energy. The threat of climate change has caused the governments of the countries encourage the installation of new power plants of solar and wind energy. The use of renewable energy sources are increasing over the years, so the development of new power plants of solar or wind energy is producing serious problems in the power distribution networks due to dependence on the weather conditions and the possibilities of integration of these energies. One of the problems introducing electricity generated by renewable-based generation units is that the amount of energy generated depends on the weather conditions. In order to balance the generation/demand and also guaranteeing the stability on the electrical system, the electrical network manager needs to know the clean generation forecast. The developmental tendency and primary method to account this problem goes trough predicting wind and/or solar radiation fields using numerical Weather Prediction Model (NWP). In this study Weather Research and Forecasting (WRF) model was used [1].

During decades the use of Meteosat satellites has allowed us to perform highly accurate weather forecasts. The Meteosat Second Generation and, specifically, the SEVIRI sensor have brought great improvements in radiometric, spatial and temporal resolution (12 channels, 1-3 km, 5 -15 minutes) that allows the use of these data for the numerical prediction by computer [2]. The instant access to data allows the development of new applications of prediction models by the use of meteorological MSG data. The inclusion of remote sensing images in the meteorological models aims to improve the resolution and quality of input data used in the model.

This study takes place over the Canary Islands area, where Alisios winds and Hadley's Cell produce a thermal inversion that generates stratocumulus. The insularity of the Canary Islands produces a strong correlation between Surface Temperature (ST) and Canary Islands weather [3].

The objective of this study is improve the initial ST conditions introducing values from TIR channels, calculated by MSG satellite, in order to obtain more accurate results using WRF model for solar shortwave flux at surface field.

2. METHODOLOGY

This paper proposes a software tool which predicts the amount of downward short wave flux at ground surface within WRF model, as shown in Fig.1, and explores their critical elements. Those elements include (see Fig. 1): Preprocessor module, satellite data assimilation and WRF model variation. Through the preprocessor module the first guess was built and used in the MSG assimilation step like input data. After the assimilation process, the initial conditions were ready to be used by the WRF.

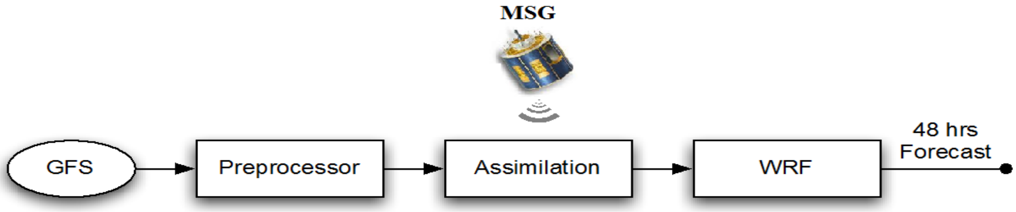

Figure 1. Proposed system data flow.

2.1. Weather research and forecasting configuration

WRF-ARW model, used in the present study, is a next-generation mesoscale modeling system. The advanced research WRF dynamical core is based on an Eulerian solver for fully compressible nonhydrostatic equations. It is considered by the National Center of Atmospheric Research (NCAR) as the successor of MM5 and, in contrast to this model, WRF uses η coordinates in accordance the domain terrain characteristics.

To initialize the NWP simulation, Global Forecast System (GFS) data, 0.5º spatial resolution, was used like first guess. The configuration of the WRF-ARW model was the following: 13.7 km horizontal grid resolution outer domain contained 92x100 points in the north-south and east-west direction respectively, as shown in Figure 2. On the other hand, the domain 2 had 4.566 km resolution and the inner domain 1.522 km resolution with 379x232 grid points. Model predictability was evaluated for 48 hours ahead. All domains used 28 vertical levels and Kessler cumulus parameters except the finer domain where cumulus was disable [5]. In order to reduce the computational cost, all the domains used the Rapid Radiative Transfer Model for GCMs like radiative scheme [4].

2.2. Meteosat Second Generation data assimilation for WRF model

The WRF model requires initial conditions of the state of the Earth's surface and atmosphere. These conditions are derived from data of global atmospheric models, such as the GFS. The GFS data are obtained in-situ in multiple stations and are interpolated by the model to provide comprehensive coverage, so it has a low spatial resolution. One of the most important input parameters is the surface temperature since it is correlated to many other parameters like wind, temperature and pressure at different atmospheric levels.

MSG data are widely used to obtain the accurate surface temperature with a 3 km resolution, and it can be used to substitute values from the GFS to improve results. The replacement is performed at the entrance of the WRF module, where data are inserted by domains, specifically in the finer domain since it has the highest resolution.

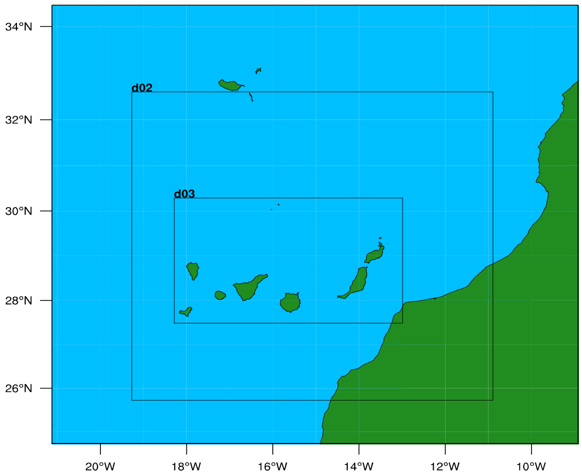

Figure 2. WRF model: Canary Islands domain.

For SST-LST generation TIR channels 10.8 and 12 µm, using the Planck equation, have been used. A split-window equation is used to correct the atmospheric effects [5] [6]. It is expressed by,

$$T_{SST} = T_{10.8} + a(T_{10.8} - T_{12}) + b(T_{10.8} - T_{12})^2 + c + B(\varepsilon)$$

where a, b, c are Split-window atmospheric coefficients. B(ε) corresponds to the Emissivity effects.

$$T_{LST} = T_{10.8} + a_1(T_{10.8} - T_{12}) + a_2(T_{10.8} - T_{12})^2 + a_3(1-\varepsilon) + a_4W(1-\varepsilon) + a_5\Delta\varepsilon + a_6W\Delta\varepsilon + a_0$$

where a_n are Split-window coefficients, ε mean Effective emissivity, Δε emissivity difference, W water vapor.

Once obtained, the surface temperature is projected and interpolated to match with the model format (Mercator projection), as shown in Figure 3. The clouds present in the area are removed by an interpolation of a series of images over two hours period and extrapolated with the model data in the persistent clouds areas.

3. RESULTS AND CONCLUSION

In this section, we provide some experimental results for SST assimilation within MSG satellite data. In Figure 4 a comparison between the forecasted shortwave flux and temperature at surface using MSG assimilation are presented. Can be observed that the forecasted solution without SST assimilation has underestimated the surface temperature and the variations over wind field (Figure 4 (a), (b)). When solar radiation is the aim of the forecast, SST assimilation is necessary because the wind variations produce fluctuations on the shortwave flux at surface as show on (Figure 4 (c), (d)). We can conclude that the first experimental data suggest the use of SST, obtained by processing MSG satellite data, produces some improvement in the WRF prediction results.

4. ACKNOWLEDGEMENTS

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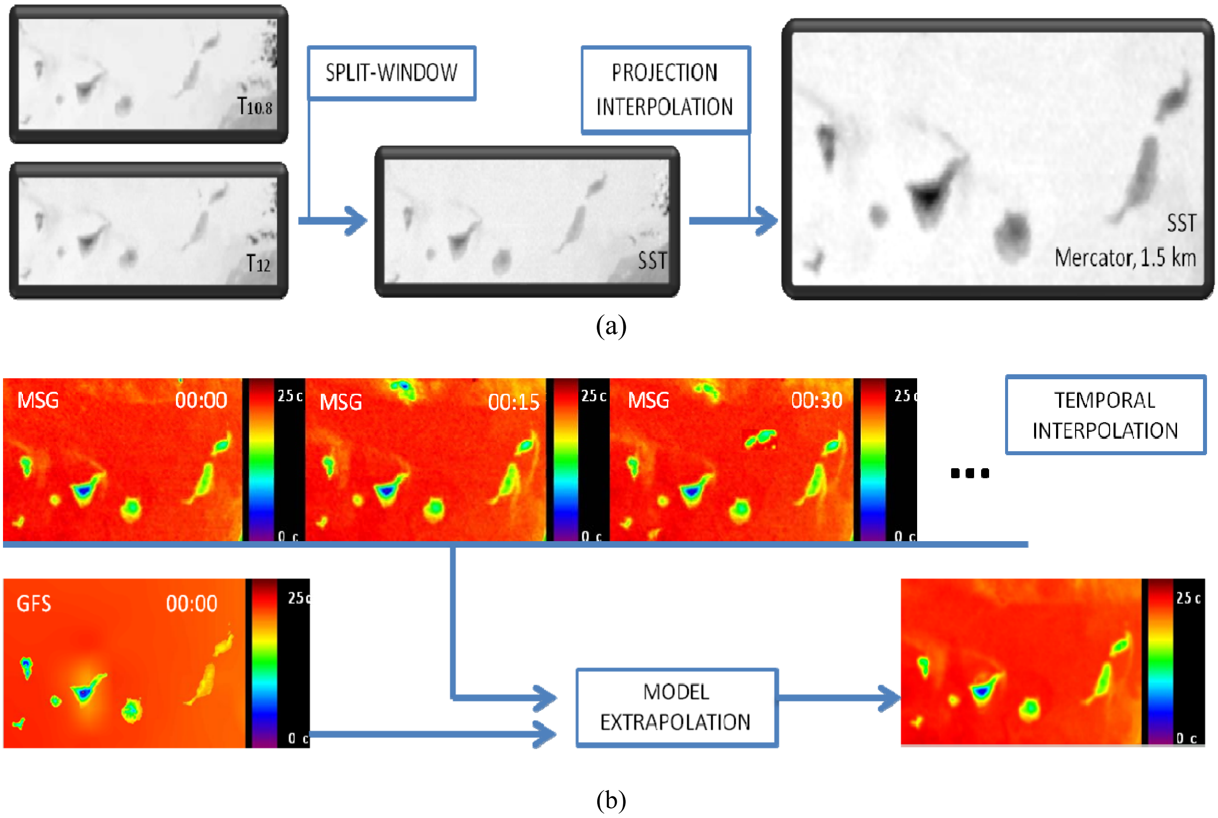
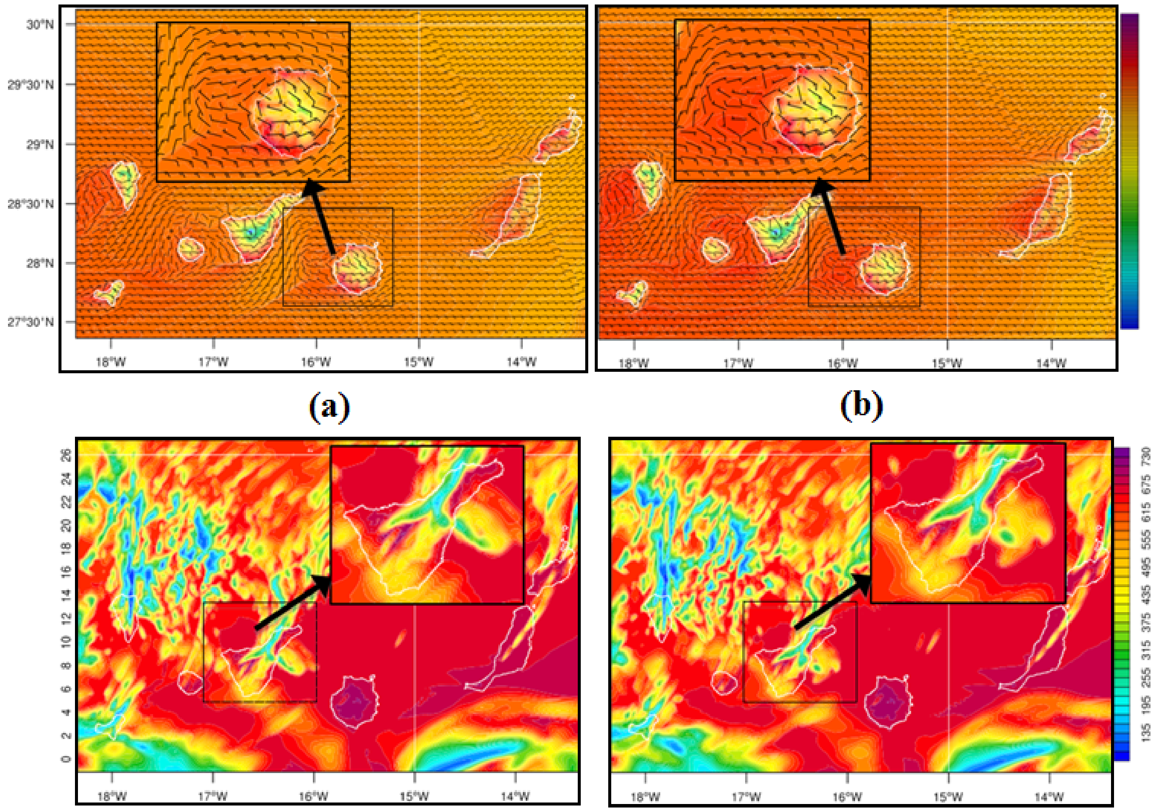


Figure 3. MSG data flow. (a) Split-window algorithm and, (b) Interpolation/extrapolation surface temperature algorithm.



(a) (b)

(c) (d)

Figure 4. Surface Temperature and Downward Shortwave Flux at Surface forecasted, respectively. (a), (c) without MSG assimilation and, (b), (d) with MSG assimilation.

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