Assimilation of satellite and lightning data in numerical simulations of tropical-like Mediterranean storms

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1 Introduction

Tropical-like storms are generated in the Mediterranean Sea and can affect islands and continental coastal lands. In situ observations in maritime areas are very scarce and, therefore, the detection and monitoring of these systems must be done through satellite observations. Previous studies show that numerical models are able to simulate the genesis of these features. However, numerical simulations of the phenomena have shown temporal and spatial shift with respect to satellite observations. Although known tropical-like storms did not achieve hurricane intensity, their potential for damage is extremely high due to the densely inhabitated Mediterranean countries. Thus, it would be of high interest to obtain successful forecasts of such systems. An attempt of improving the MM5 numerical simulations of these storms will be carried out through the adjustment of the humidity field in the driving ECMWF analyses using satellite and lightning data. Vertical humidity profiles at model grid points will be adjusted depending on the convective or stratiform precipitation type according to satellite and lightning information. This methodology will be applied in two different ways. In one case, the adjustment will be only done in the initial conditions of the simulations. In second case, MM5 observation nudging scheme is used to insert the satellite information during the model simulation. The work is in its initial phases and here it is shown the methodology that will be used and some preliminary results.

2 MM5 simulations

Spatial and temporal shifts between trajectories of the simulated and observed storms seem to be obtained as a consequence of the not well represented initial conditions of the fields. Simulated trajectory shows a sensitivity on the PBL scheme used. However, the initial position and trajectory of the storm is still poorly simulated (see figure 1). Changes of the humidity profile in the initial analyse generate an improvement of the simulation.

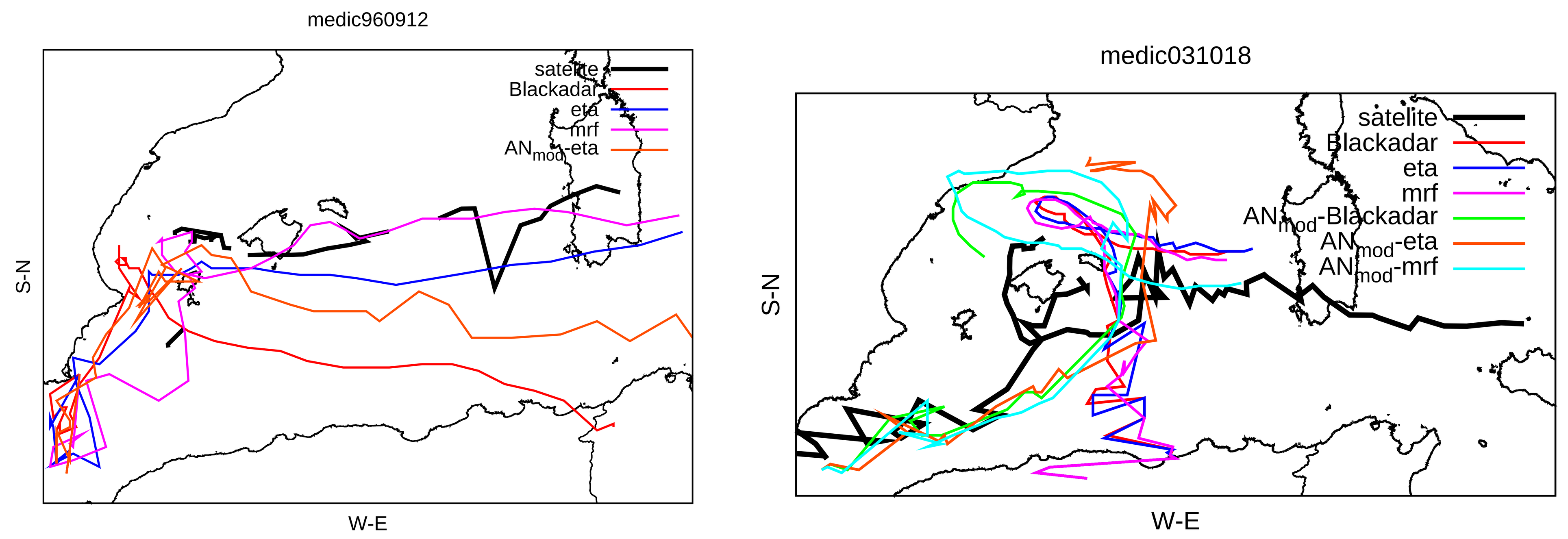

Figure 1: Satellite-based storm trajectory (black line) and MM5 simulated storm trajectory using different PBL schemes (High resolution Blackadar, red line; Mellor-Yamada (eta), blue; Hong-Pan (mrf) violet) for the September 1996 case (left) and the October 2003 case (right). Assimilating satellite information to modify humidity profile in the initial analyse ($AN_{mod} - Blackadar$, Blackadar (green); $AN_{mod} - eta$, eta (orange); $AN_{mod} - mrf$, mrf (light-blue)

3 MM5 FDDA observation nudging

The FDDA observation nudging implemented in the MM5 v3.7 model is used. Vertical humidity profile correction will be done through the satellite-based information.

The precipitation is obtained following the Histogram Matching Technique in which both Meteosat Infrared images and rain rate images from the SSMI and AMSR sensors are used to obtain a curve calibration of the Meteosat 11 μm band. Derived curve is adjusted using a particular developed calibration and it is also corrected of BIAS. Precipitation distinction will be made according to lightning activity (determined as a convective point), and an Infrared Dynamic Cloud Grow method (IRGR) from which the kind of precipitation is determined according to the Lagrangian thermal variations of the cloud-grid point. Convective precipitation will be introduced in the model as a saturation of the low levels of the grid point ($\sigma \geq 0.7$). Stratiform precipitation will be introduced as a saturation of the middle levels ($0.9 \leq \sigma \geq 0.7$).

In order to introduce correct values in the model, saturated vapour ratios are calculated as equivalent saturated vapour mixing ratios $\mathcal{Q}^*(i,j,k)$ are calculated according to the temperature and pressure values at the the model vertical grid point. Also, in order to avoid unstable vertical profiles, observation nudging of the satured value is done following a proportional curve ($\mathcal{R} \in [0,1]$, see figure 2) respect to the model value ($\mathcal{Q}(i,j,k)_{model}$). The proportional curve (see equation 1) establishes a gradual vertical relation between nudged satured values and the model ones.

$$\mathcal{Q}'(i,j,k) = \mathcal{Q}_{model}(i,j,k) + \mathcal{R}(\sigma)\left[\mathcal{Q}^*(i,j,k) - \mathcal{Q}_{model}(i,j,k)\right] \quad (1)$$

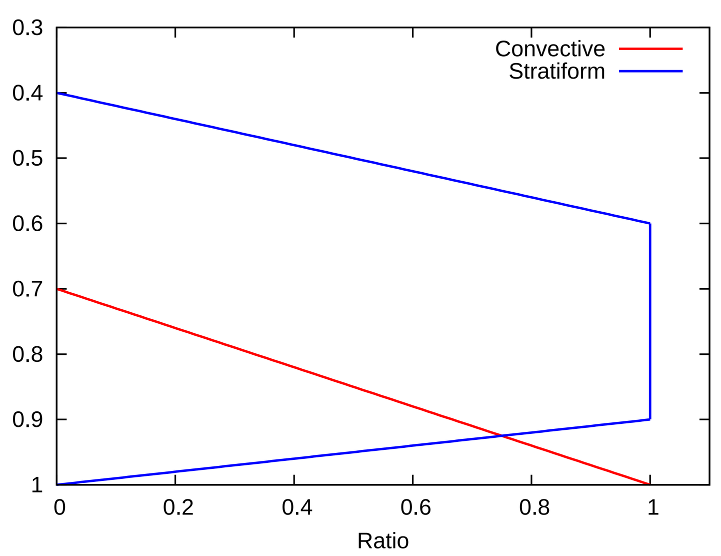

Figure 2: σ-level dependence of the ratio between satured mixing ratios of the observed nudging ($\mathcal{Q}^*$) and the model-simulated ($\mathcal{Q}_{model}$)

4 Satellite and lightning

Although tropical-like Mediterranean storms (*Medicanes*) exhibited deep convection, they do not show a significant lightning activity when they are on their mature state (see figure 3). Most of electrical discharges are detected during the initial stages of the systems.

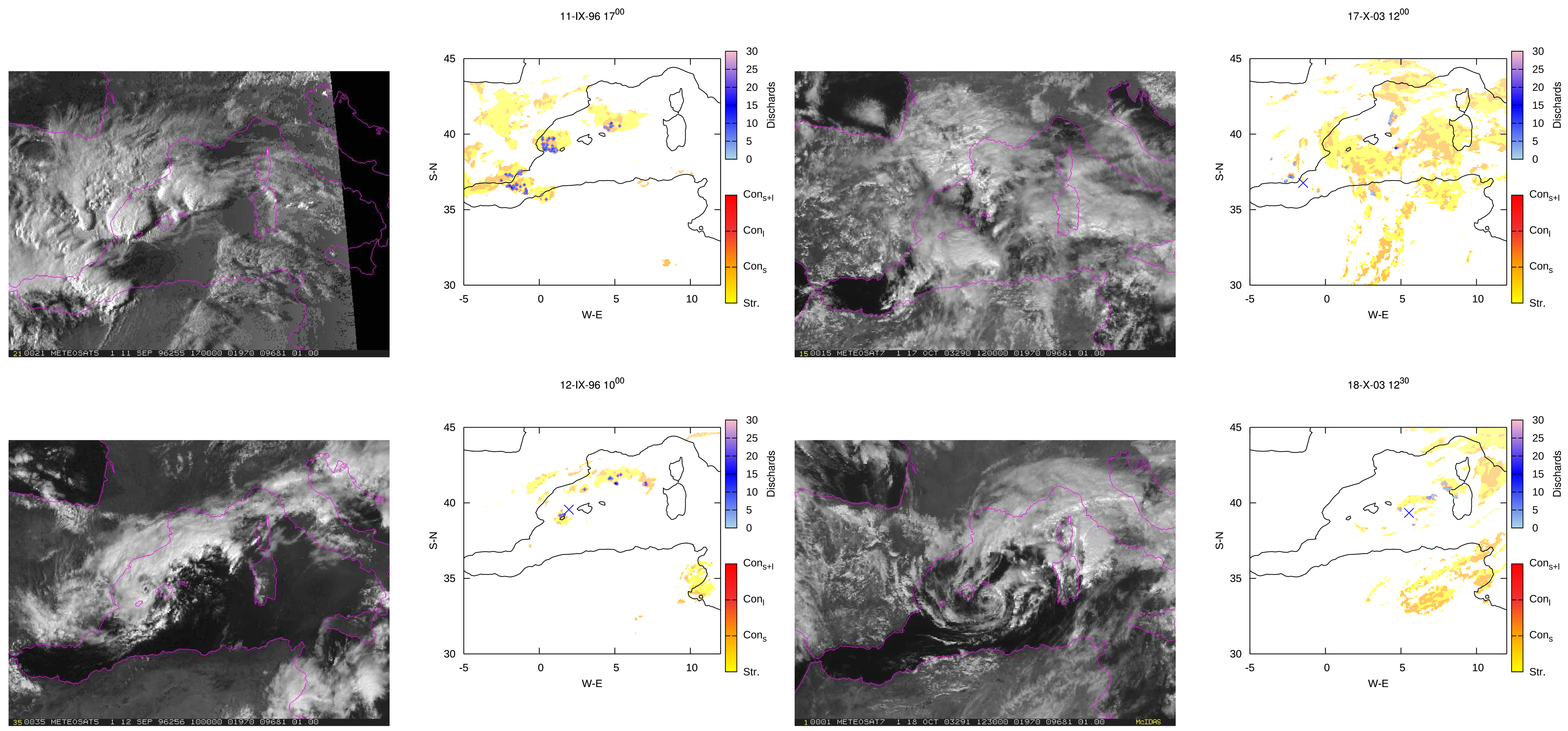

Figure 3: Satellite visible image and lightning activity plot of two medicanes at the formation phase (left) and on mature state (right). Blue cross denotes storm position. On lightning activity plot Red shadded values indicated kind of precipitation (Str.: Stratiform, and Convective: Con_s: satellite, Con_l: lightning, Con_{s+l}:satellite+lightning)

5 Further work

A sensitivity test of different aspects of the observation nudging is still in progress: horizontal radius of influence and temporal influence. Different moisture vertical profiles will be tested for each kind of precipitation. The technique will be also applied to other storm cases in order to obtain a deeper conclusions about the lightning activity of the Mediterranean tropical-like storms.

It will interesting to see whether the correction of the humidity profile in the initial conditions is efficiently enough to obtain more adequate simulations of the cases. Finally, it will be attempted to produce a low-cost operational method of nudging satellite-based information during the first period of the operational forecast done at the *Universitat de les Illes Balears* (`http://mm5forecasts.uib.es`).

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