Application of the Z-Coordinate Version vs. the Terrain Following Version of LM Nonhydrostatic Model over Greece

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1 Introduction

Local numerical weather prediction models using terrain following coordinates are sensitive to numerical errors induced by the singular behavior of the coordinate transformation Jacobian around steep orographic slopes (Sundqvist, 1976; Gallus and Klemp, 2000). This misfunction may produce artificial circulations that destroy clouds in the vicinity of the mountains leading to significant limitations regarding local weather forecasting.

In order for this pathology to be properly treated, a new version of the LM (subsequently denoted as "LM_Z") has been developed that explicitly uses the Z-coordinate representation in the model numerical scheme (Steppeler et.al., 2002; Bitzer and Steppeler, 2002; and others). The results for tests, mainly involving idealized cases, have been successful, leaving space towards its operational validation.

2 Test Case Justification and Results

The geographical domain of Greece may be considered an excellent candidate towards the relative evaluation of LM_Z against its terrain following coordinates operational version (LM_TF); since the area is characterized by the equipartitioned land-sea interchange combined with a complex orography as well as a large number of mountainous islands. In this particular test case, we investigated the weather development during the three day period of the 6^{th}, 7^{th}, and 8^{th} of March 2005. As it can be seen from the satellite pictures as well as the synoptic analysis (Fig. 1), on March 6, a deep low pressure system over East Balkans associated with frontal activity extended to East Aegean was moving East/Northeast. This activity was followed on March 7 and 8 by a moderate frontal development over South Italy moving East combined with a strong Southwestern wind field in the middle troposphere. The North to South orographic structure of mainland Greece was expected to effect cloud formation and precipitation in a way that might demonstrate differences between LM_TF and LM_Z. In Figs. 2, 3, 4, we show the relative forecasted low, medium and total cloud cover for LM_TF and LM_Z respectively. We used boundary conditions from the Global Model of the German Meteorological Service (DWD) with analysis of 00 UTC for every date under consideration. The cloud cover forecasted by LM_Z conforms more with the satellite pictures of Fig. 1. This looks consistent with Fig. 5 where the 12-hour forecasted accumulated precipitation in LM_Z is overall downgraded and less dispersed in reference to LM_TF, particularly over the sea surface. Regarding observation, the measured values of the 12-hour accumulated precipitation over the local meteorological stations were compared to the forecasted values of the nearest grid point. By summing these values, it was found that the total forecasted precipitation for LM_Z was closer to the total precipitation measured (Table 1). In Fig. 6, we depict with "R" the positions of the meteorological stations where the observed value for the precipitation was closer to LM_TF and with "Z" when this value was closer to LM_Z. The bullet sign corresponds to stations where precipitation was neither observed nor predicted by any version of LM. Within this context, it may be seen again that the forecasted values from LM_Z are relatively closer to observation.

	March 06	March 07	March 08
Observed: Total	10.52	152.00	78.01
Average	0.18	2.82	1.37
LM_TF: Total	145.99	304.56	266.06
Average	2.52	5.64	4.67
LM_Z: Total	36.87	167.82	155.57
Average	0.64	3.11	2.73

Table 1: Total and average observed and forecasted precipitation height (mm)

Conclusions

For the test case under consideration, LM_Z forecast shows relative preponderance over LM both for cloud coverage and 12-hour accumulated precipitation. However, more systematic investigation is necessary in the direction of further validating LM_Z for real weather situations in connection of further development of the code both in the direction of numerics as well as that of physics.

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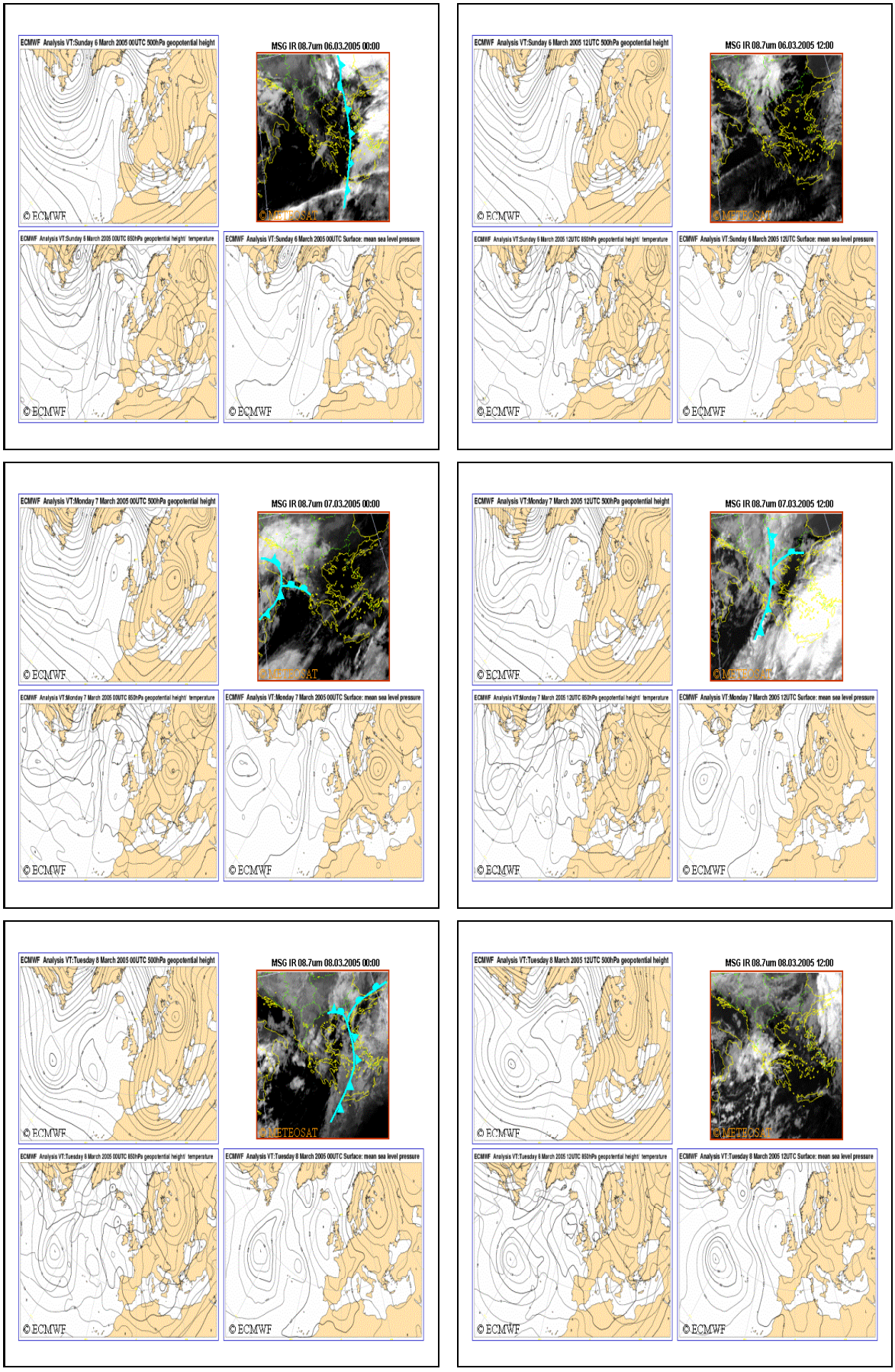

Figure 1: Satelite pictures and analysis charts for 6, 7 and 8 of March 2005.

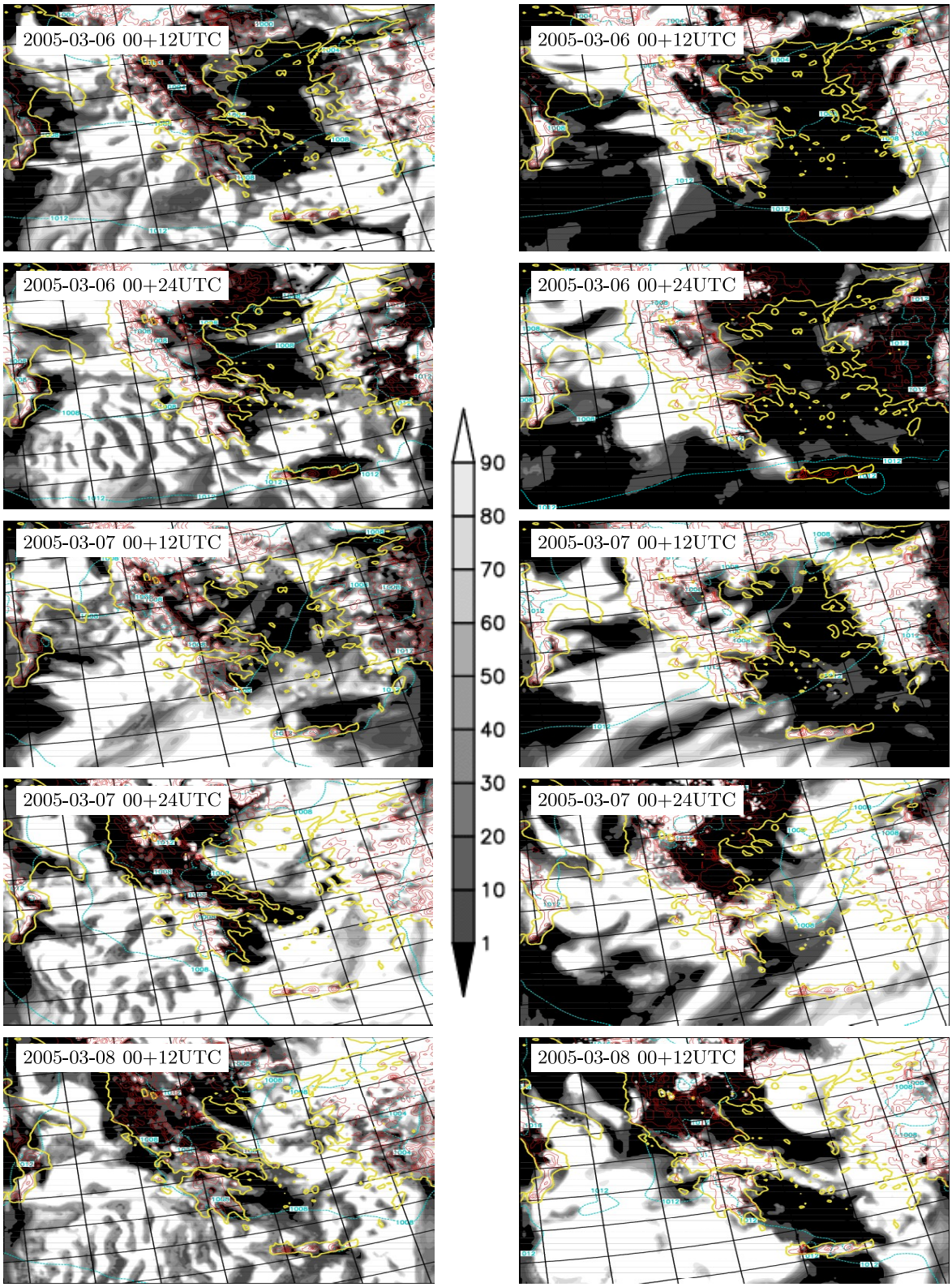

Figure 2: Low cloud cover forecast (%) and PMSL (HPa) from LM_TF (left column) and LM_Z (right column).

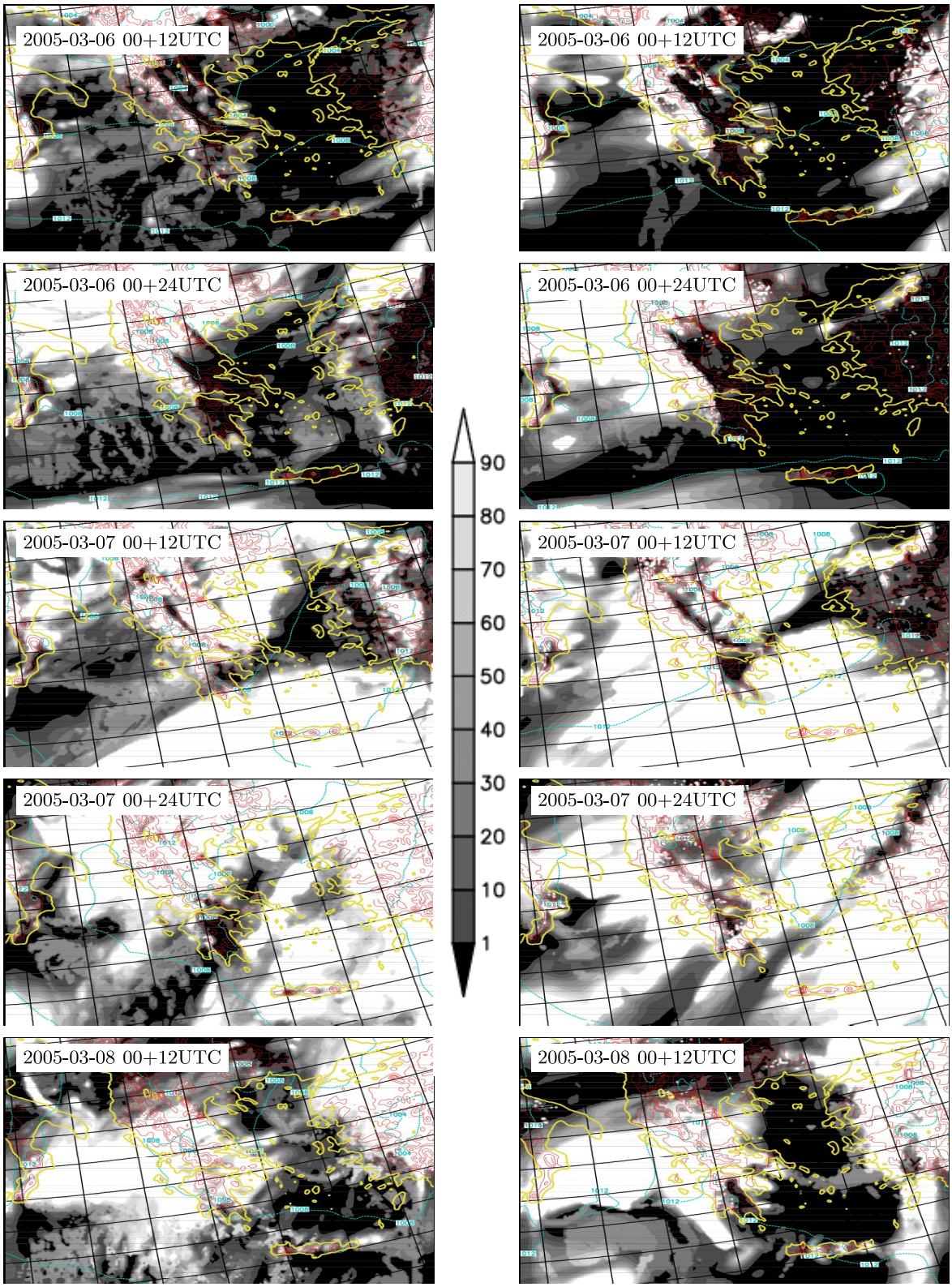

Figure 3: Medium cloud cover forecast (%) and PMSL (HPa) from LM_TF (left column) and LM_Z (right column).

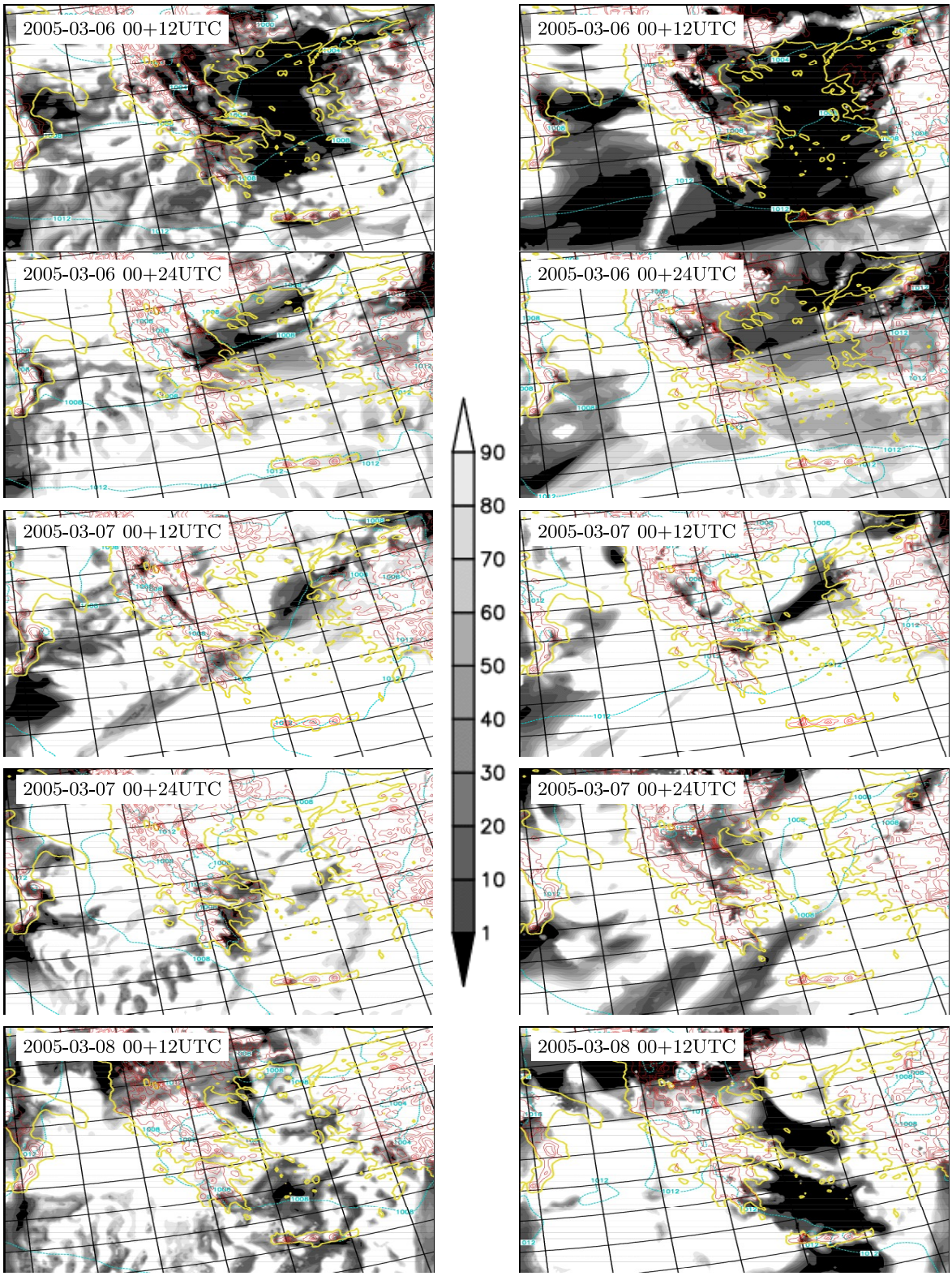

Figure 4: Total cloud cover forecast (%) and PMSL (HPa) from LM_TF (left column) and LM_Z (right column).

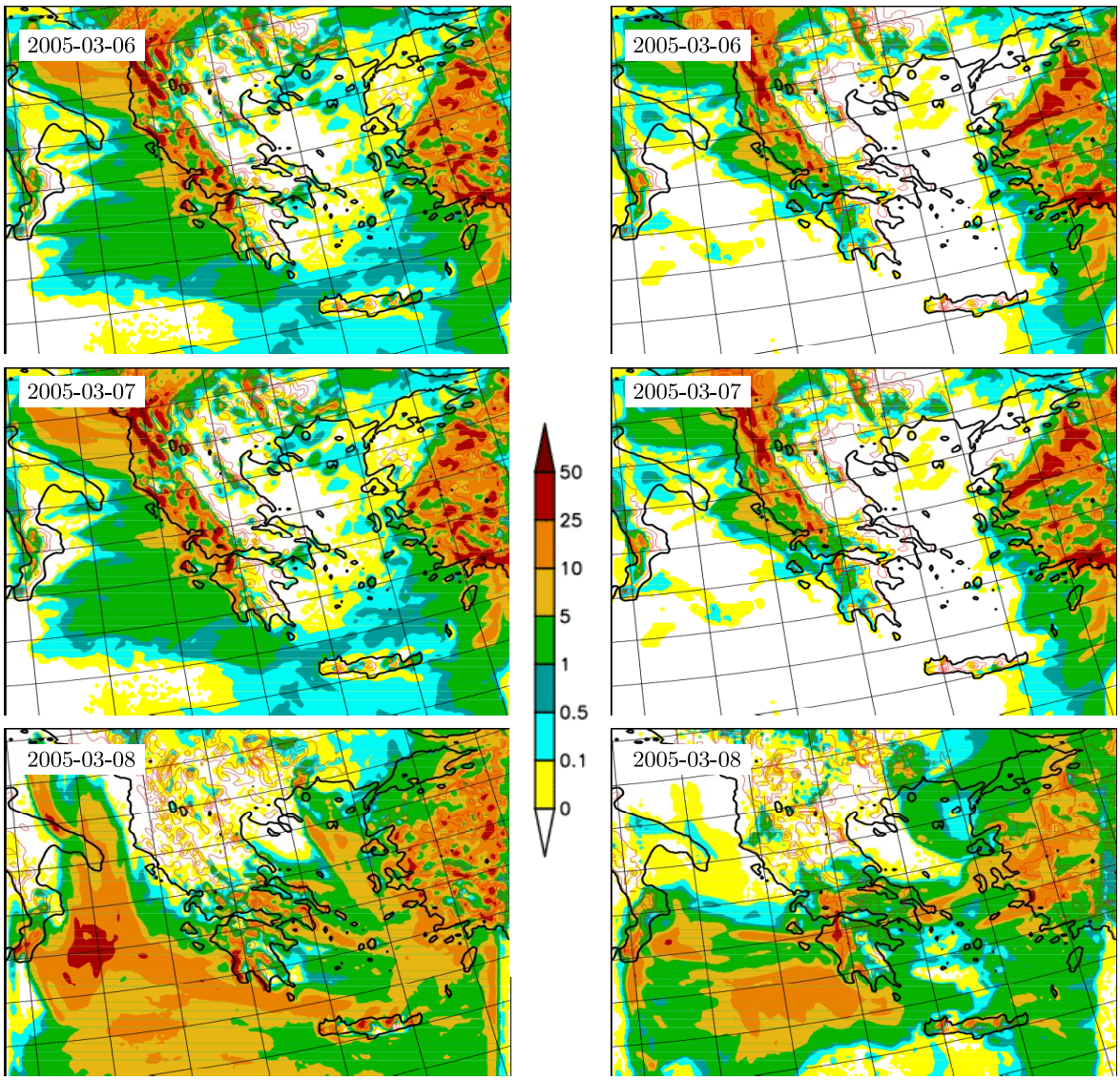

Figure 5: 12-hour accumulated precipitation (mm) from LM_TF (left column) and LM_Z (right column).

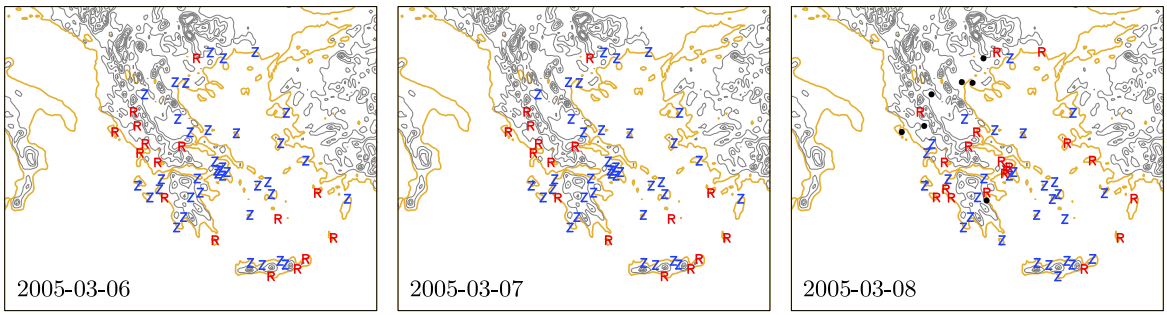

Figure 6: Represantation of the positions of the meteorological stations in reference to the relation of measured against the 12-hour accumulated precipitation; "R" and "Z" stand for stations where LM_TF and LM_Z forecast was closer to observation respectively. The "bullet" sign stands for stations where no precipitation was observed or forecasted by any version of LM.