On the Direct Comparison of COSMO Model Sub-Grid Stratiform Cloud Schemes with Satellite Images

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1 Introduction

In one of our previous works (Avgoustoglou E., 2012a), the possibility for direct comparison of the COSMO Model with remote sensing data was presented in reference to the wider geographical area around Greece. This possibility is based on the option of COSMO Model to create artificial satellite images and is enhanced by the fact that the Hellenic National Meteorological Service (HNMS) is using CineSat Software for the visualization of satellite data.

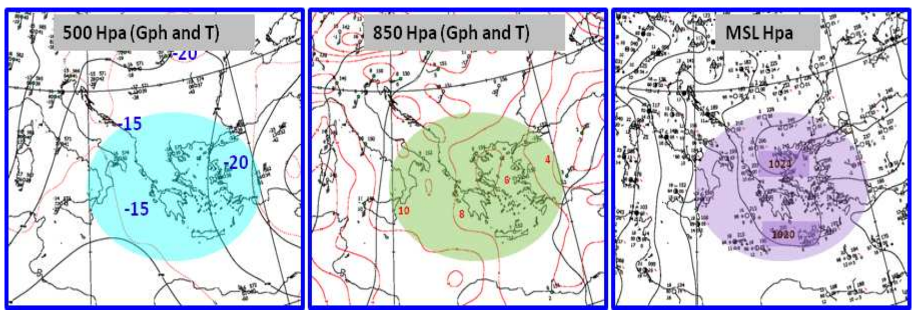

Figure 1: Analysis charts for 500 Hpa (left), 850 Hpa (medium), and Surface (right) at 00 UTC on the 5^{th} of November 2011 ©HNMS.

As a part of a systematic investigation under the UTCS project, a comparison of the implementation of two alternative sub-grid cloud schemes in the radiation scheme of COSMO model is presented over the wider geographical domain of the Balkans for a representative autumn case with extended areas of stratiform clouds developed over the Central-Eastern Mediterranean.

2 Highlights of the sub-grid stratiform cloud cover schemes in COSMO Model

The proper implementation of cloud cover in numerical weather prediction models stands as a challenging issue that goes beyond the straightforward assumption that all air inside the grid-box volume can be considered either saturated or unsaturated (Cotton, W. et al, 2011 and Mironov, D., 2009 and references there in). An obvious drawback of this hypothesis is that latent heat is released when condensation process occurs inside the grid box only after all its volume is saturated which might lead to an incorrect treatment to the initial cloud growth. Additionally, cloud cover might be affected by entrainment through grid box boundaries. In order to partially account for these processes in stratiform cloud-cover, a sub-grid statistical scheme, denoted as SGSL, is used in the moist turbulence module of COSMO model (Raschendorfer, M., 2005). This scheme is based on a bi-variate Gaussian distribution which is involving the quasi-conservative properties of saturation deficit and liquid water potential temperature (Sommeria, G. and Deardorff, J. W., 1977 and Mellor, G. L., 1977).

The resulting stratiform cloud cover from the implementation of SGSL in COSMO model is given by a two-parameter relation with respect to cloud cover at saturation and the critical value for over-saturation. The corresponding parameters and their default values used in this work are denoted as $clc\_diag = 0.5$ and $q\_crit = 4.0$ respectively.

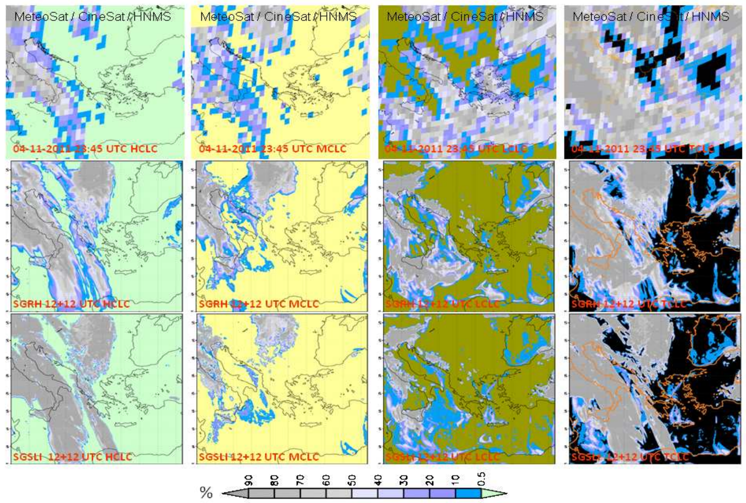

Figure 2: Cloud cover (%)on November 5 2011 at 00 UTC from the corresponding satellite (MPEF) figures (upper row ©HNMS/EUMETSAT), the SGRH Scheme (midle row) and the SGSLI scheme (lower row). The first, second, third and fourth columns refer to high, medium, low and total cloud cover respectivelly.

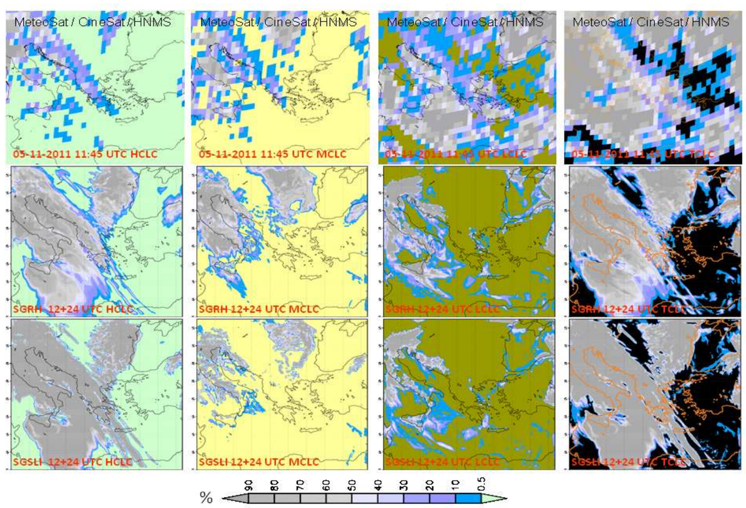

Figure 3: Cloud cover (%) on November 5 2011 at 12 UTC from the corresponding satellite (MPEF) figures (upper row ©HNMS/EUMETSAT), the SGRH Scheme (midle row) and the SGSLI scheme (lower row). The first, second, third and fourth columns refer to high, medium, low and total cloud cover respectivelly.

Within the context SGSL however, the cloud cover due to cloud ice content is treated by simply stating its value equal to 100% if *any* cloud ice is forecasted by the model. Additionally, the necessity for the effect of cloud-ice into the cloud cover (Deardorff, J. W., 1976 and Smith, S. A. and Del Genio, A. D., 2002) led to a modification of SGSL to a sub-grid statistical liquid-ice *mixed* scheme, denoted as SGSLI (Raschendorfer, M., 2008, 2011) through the introduction of a *mixed phase condensation* heat via an *icing factor* defined as the ratio of cloud ice over total cloud water content. In the radiation scheme of COSMO model, a semi-empirical sub-grid scheme, based on relative humidity and denoted as SGRH, is implemented by default to account for the stratiform cloud-cover (Seifert, A., 2011). The SGSL scheme is currently used operationally in the moist turbulence module of COSMO Model and the goal is to evaluate its use as a more general SGSLI scheme also in the radiation module within the scope of UTCS (Unified Turbulence Closure Scheme) priority project.

3 Case Study

A 36-hour period was considered, starting from 12 UTC of November 4 2011. The boundary conditions came from three-hour, forty-level analysis intervals based on GME and with horizontal grid of 0.5^0 ($\sim$ 50 Km). The horizontal grid size of COSMO model run is 0.0625^0 ($\sim$ 7 Km) and the integration time step was 30 secs. The domain under consideration is the wider Balkan Area with Greece at its center.

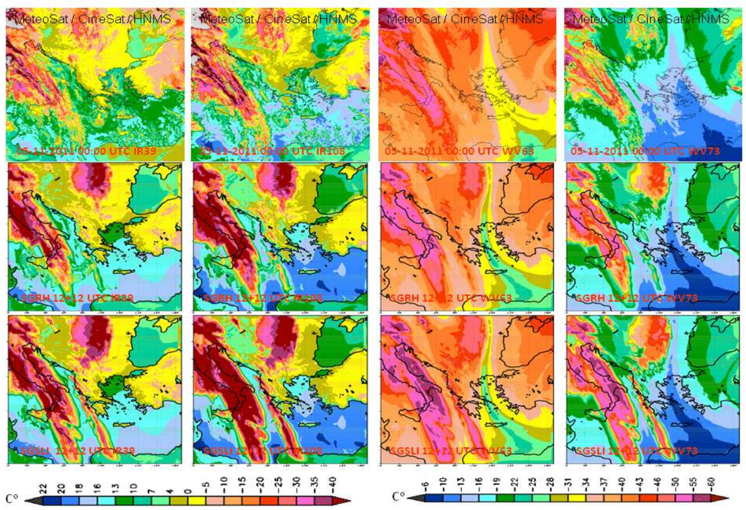

Figure 4: Cloud brightness temepratures (degs C) on November 5 2011 at 00 UTC from MSG satellite figures model (upper row) ©HNMS/EUMETSAT and the corresponding artficial satellite images from the SGRH scheme (midle row) and the SGSLI scheme (lower row). The first, second, third and fourth columns refer to 3.9 μm, 10.8 μm, 6.2 μm and 7.3 μm channels respectivelly.

From the synoptics standpoint (Fig. 1), the analysis charts show a relatively cold homogeneous filed in the center of the domain approximately between two barometric lows (eastern and western regions) and two highs (northern and southern regions) arranged alternately. This situation, resembling a barometric col, is characteristic of the area and favors low cloudiness practically over the Central-Eastern Mediterranean area. Some worm frontal activity over the western part of the domain should also be considered.

Regarding low cloud cover (third column of Fig. 2, and Fig. 3), it is overall underestimated by both SGRH and SGSLI schemes as shown in second and third rows of these figures respectively and with respect to the cloud analysis given in the first row. The cloud analysis figures have been produced by the Meteorological Products Extraction Facility Algorithms (MPEF) from METEOSAT (MSG) satellite data available locally at HNMS and were manipulated with CineSat software to match with the model figures. Both schemes miss most of low cloudiness over the eastern part of the domain while for the western part SGRH scheme performs relatively better.

The SGRH scheme performs also relatively better than the SGSLI scheme for high and medium cloudiness (first and second column of Fig. 2, and Fig. 3 respectively) that are practically confined over the western part of the domain and again in reference to the MPEF cloud analysis of the first row. An interesting feature regarding medium and high cloudiness is that the SGRH scheme provides a better tendency to resolve high cloud-cover, while the cloud structure of the SGSLI scheme has the tendency to remain more compact while for the medium cloud cover the situation is reversing. Both schemes agree with each other in reference to total cloud cover (fourth column of Fig. 2, and Fig. 3), however they both show a relatively poor performance over the eastern part of the domain which is essentially governed by low clouds. For the rest of the domain, the agreement with MPEF cloud analysis is excellent.

The above situation is highlighted in the comparison of cloud brightness temperatures between MSG and synthetic satellite images created by COSMO Model (Fig. 4 and Fig. 5) in the infrared channels of 3.9 μm, 10.8 μm (first and second column) and water-vapor channels of 6.2 μm, 7.3 μm (third and fourth column). The MSG images (first row these figures) show higher cloud brightness temperatures than the corresponding synthetic satellite images especially over the western region of the domain. However, the synthetic satellite images of the SGRH scheme (second row) provide an overall better signal than the ones of the SGSLI scheme.

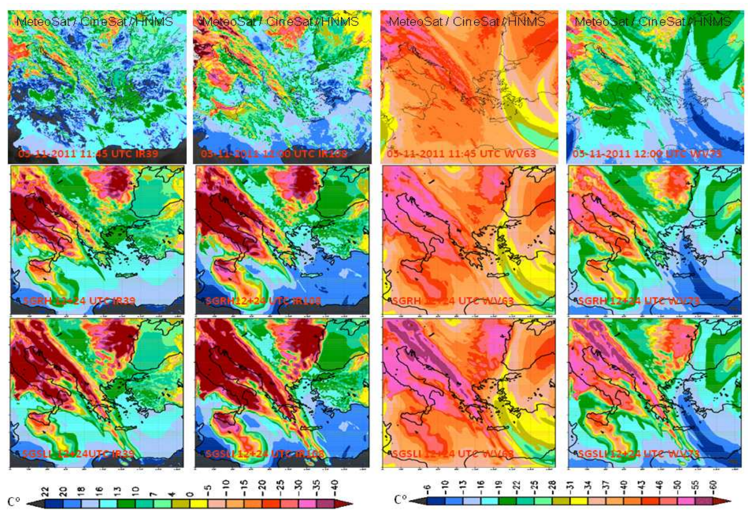

Figure 5: Cloud brightness temepratures (degs C) on November 5 2011 at 12 UTC from MSG satellite figures model (upper row) ©HNMS/EUMETSAT, and the corresponding artficial satellite images from the SGRH scheme (midle row) and the SGSLI scheme (lower row). The first, second, third and fourth columns refer to 3.9 μm, 10.8 μm, 6.2 μm and 7.3 μm channels respectivelly.

4 Summary and Outlook

The direct comparison of cloud cover and synthetic satellite images of COSMO model with the corresponding remote sensing products turns out to be a valuable feature towards the relative validation of the cloud schemes of the model. A more systematic evaluation of the different cloud schemes through the availability of these products (Avgoustoglou, E., 2011, 2012b) is currently under progress.

5 Acknowledgments

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