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Effect of undetected broken clouds on the MSG-SEVIRI clear sky radiances and the cloud radiative effect

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The role of clouds in the climate system is not yet fully understood. This is mainly due to the complex interaction of clouds and radiation and the large variability of their microphysical properties. Different cloud types such as water, ice, and mixed phase clouds have a diverse impact on the radiation balance through their varying optical properties. Depending on their water path, effective radius, and droplet number concentration the cloud radiative effect can vary strongly. Large cloud structures such as mesoscale convective systems are well resolved by satellite instruments because their size is bigger than the spatial resolution of the instrument. However problems occur for smaller clouds that are not so easy to observe. Especially the effect of sparse cumulus cloud fields at the top of the boundary layer induced by convection is not entirely clear. These cloud types occur behind the cold front of low pressure systems and over subtropical and tropical ocean surface.

Satellite imagers are limited in their spatial resolution for technical reasons. Clouds with sizes below this pixel scale are often not properly detected by cloud mask algorithms. Thus they contaminate the radiances of pixels detected as cloud free. Koren et al. (2008) showed a decrease of mean cloud reflectance with decreasing spatial resolution for broken cloud fields. This behavior is based on the fact that small clouds are not detected at coarse spatial resolution and therefore are not taken into account for cloud radiative budget calculations. However their reflected solar radiation is still part of the radiance measured by satellite. These problems lead to deviations in the computation of the cloud radiative effect by incorrectly attributing cloud affected radiances to clear sky radiances.

The aim of this study is to quantify the resulting uncertainty in the cloud radiative effect as derived from satellite data. Cloud mask algorithms on a pixel basis are confronted with a binary decision in differentiating between the cloudy and cloud free case. This does not match reality, however, which resembles a continuous system with a smooth transition from overcast to clear skies. If the free parameter of this continuous system – the cloud cover – were known, the uncertainty arising from the binary choice could be evaluated. Unfortunately, this information is not available directly from satellite images. We have instead chosen the ground-based radiation measurements from the Baseline Surface Radiation Network station at Cabauw, the Netherlands, as reference data for this purpose. Using the Long algorithms (Long et al., 2006 and 2000), small scale cloud fraction and downwelling clear sky radiation are estimated from downwelling shortwave direct and diffuse radiation, which are more sensitive to small-scale clouds than satellite imagers. Based on this dataset, the satellite radiances measured by the satellite were separated according to cloud fraction. Additionally the uncertainties in cloud radiative effect are evaluated for pixels masked as clear and cloudy, by knowing the amount of cloud affected radiances. Furthermore the cloud radiative effect at the surface is computed for different cloud.