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The short-wave radiation deficit over the Southern Ocean in the Met Office model: the role of midlatitude cyclone clouds

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We study the role of clouds in the persistent excess of surface downwelling shortwave radiation (SDSR) in the Southern Ocean in the atmosphere-only version of the Met Office model. When the atmosphere model is coupled to a dynamic ocean, a large sea-surface temperature (SST) bias develops. Part of this SST bias is directly caused by the excess of solar radiation reaching the ocean surface, and therefore the reduction of this bias in the atmosphere-only version is important to minimise the coupled sea-surface temperature biases. We use a range of passive (ISCCP, MODIS, ERBE) and active (CloudSat, CALIPSO) satellite data, satellite simulator model diagnostics, and clustering and compositing techniques to study the role of cloud 'regimes' in a mean composite cyclone. We apply this methodology to model outputs and observations and identify that the cloud regimes in the cold air of the cyclones are mainly responsible for the bias.

Based on this analysis, we develop and test a new diagnosis of shear-dominated boundary layers. The changes are also implemented in a multi-scale study, using the global model and nested models at 12, 4 and 1.5 km horizontal resolution. The results from a case study of a cold-air outbreak northwest of the British Isles suggest that the modified boundary layer parametrization provides a better cloud simulation. The global model results show that the frequency of occurrency of the cloud regimes in the cyclone composite are clearly improved, although the radiative properties of two regimes (mid-top and stratocumulus) are still biased, not being reflective enough. This change improves the simulation of the SDSR, although the results suggest that there is still a need to increase the optical depth of the low-level cloud with moderate optical depth and cloud with tops at mid-levels.

This work demonstrates the benefits of the use of process-based diagnostics as tools to understand the causes of model errors in the simulation of clouds and radiation, and how this can be used to steer the direction of new model developments. It also demonstrates the benefits of a multi-scale aproach by applying the same changes to models at very different resolutions.