Using visible satellite images for model evaluation and data assimilation

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Satellite provide high-resolution information on the state of the atmosphere and thus represent observations are well-suited for data assimilation and model evaluation. So far mainly the thermal infrared channels have been utilized for these purposes. However, there is a rising interest to use also the channels in the solar part of the spectrum, which contain additional, complementary information. Visible channels can provide better information on the water and ice content of clouds than thermal infrared channels, have no problems to detect low clouds and are sensitive to cloud microphysics and the cloud top structure. Moreover, visible reflectances are strongly correlated with the solar irradiation at the surface and thus their assimilation has a clear potential to improve also radiation forecasts.

So far visible satellite images have not been assimilated directly for operational purposes, as multiple scattering dominates in the visible spectral range and makes radiative transfer (RT) computations with standard methods complex and slow. Only recently, we developed a sufficiently fast and accurate forward operator that relies on a compressed reflectance look-up table (LUT) computed with slow standard RT methods. Here we report on using feed-forward neural networks as an alternative to the look-up table and demonstrate that it is possible to achieve higher speed and accuracy. Moreover, both the amount of training data and the memory required by the operator can be reduced by three orders of magnitude. A further advantage is that tangent-linear and adjoint versions can easily be derived for arbitrary network structures and do not have to be changed when the network is trained with different data.

We will also discuss two ways to use the forward operator to improve forecasts. First, we show that observed and synthetic visible Meteosat SEVIRI images can be used to detect systematic errors in the model clouds that can cause severe problems for data assimilation. Second, based on assimilation experiments using the ICON-D2 model and the local ensemble transformation Kalman filter implemented in DWDs data assimilation coding environment (DACE) we demonstrate for test periods of several weeks that errors in the cloud distribution and the surface radiation can be significantly reduced by assimilating visible SEVIRI images.