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Surrogate cloud fields with measured cloud properties

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It is (currently) not possible to measure the properties of a cloud field in all 3 dimensions at a sufficient spatial and temporal resolution. It is possible, however, to estimate the statistical properties of a cloud field from limited measurements. We have developed a cloud generator that can generate 3-dimensional fields from a 3D power spectrum and a height dependent PDF. This generator is ideally suited to generate cloud fields from measured data. In another abstract in this issue (S. Schmidt et al.) we report on a closure study made with these surrogate clouds on a stratocumulus and a cumulus field. The algorithm can be used as a flexible and user-friendly generator for fractal cloud fields for a variety of cloud water (or ice) distributions. More importantly, as we do not have to assume a fractal power spectrum, we can also use the algorithm to make cloud fields deviation in their structure from self-similarity. Beside the 3D Version, we also have versions for 2D fields and time series. In Garcia et al. (this issue) we compare radiative transport in 2D and 3D fields with the same statistics.

It is easy to include physical constraints in the iterative algorithm, like the conservation of the measured data. In this way, the algorithm becomes an interpolation tool that maintains the structure of the field. Our version can also implement a horizontal cloud mask from, e.g., a whole sky imager. For cumulus clouds the use of a cloud mask is needed, as the typically sparse measurements normally do not allow a good enough estimate of the power spectrum.

Another example of physical constraints is the inclusion of coarse grained means into the algorithm. Typical inputs to this algorithm could be a coarse satellite measurement or a field from an atmospheric model. The power spectrum is then calculated and extrapolated to smaller scales. After these preparations, the iterative algorithm generates a field with this power spectrum and the mean values at the original coarse resolution.

We calculated the structure functions of the Liquid Water Content of a cumulus field and the Liquid Water Path of a cumulus cloud and from their surrogates. As expected the second moments of the structure function were almost identical. Surprisingly, we found that also the other moments were very similar, except for the smallest scales. Thus, the inclusion of the distribution has a substantial influence on the structure of the generated time series.

The suitability of the surrogate clouds for radiative transfer is evaluated by comparing the radiative properties of model cloud fields of sparse cumulus (Cu) and stratocumulus (Sc) with their surrogate fields. The bias and root mean square error in the radiative budget of the surrogate Sc fields is better than 0.5 % of the incoming radiation. The average radiances of the Sc fields fit within 0.6 % and the actinic fluxes within 0.4 %. In case of the radiances and the irradiances, which were calculated with a Monte Carlo model, we can say that the differences found are not statistically significant.

Next to the normal Sc surrogates with the spectrum and the distribution of the model cloud fields, we have also made surrogate fields with either the spectrum or the distribution. In both cases we found that the radiances and the irradiances were much worse reproduced. For these simpler surrogates the differences were statistically significant.

The surrogate sparse Cu fields were surprisingly found to be identical to their model counterparts, except for translations and reflections.

This exemplifies that for many applications the cloud structure is described well from a radiative point of view, using only a power spectrum together with an amplitude distribution. These results suggest that radiative transfer problems may be easier as previously thought.