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3-Dimensional surrogate cloud fields with measured structures

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An iterative algorithm was developed that can generate 3-dimensional fields from a 3D power spectrum and a height dependent PDF. This algorithm can be used as a flexible and user-friendly generator for fractal cloud fields, but, actually, it was developed to create cloud fields that have the structure of a measured cloud fields for use in radiative closure studies. Therefore, the algorithm is flexible enough make cloud fields with the autocorrelations (power spectrum) and PDF of a measured Liquid Water Content (LWC) field. The algorithm can also make broken cloud fields.

Adding a dimension

By assuming that the cloud structure is horizontally isotropic, the method allows one to generate 3D Liquid Water Content (LWC) fields based on 2D LWC profile measurements. One can also generate 2D Liquid Water Path (LWP) fields from 1D LWP measurements assuming isotropy.

Structure preserving interpolation method

The newest version of the algorithm also utilizes the measured data points themselves. In this way, the algorithm becomes an interpolation tool that maintains the structure of the field, instead of generating a smooth field by estimating the means as well as possible. This version also has the option of using a horizontal cloud mask from an 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.

We will show results from simulated scanning measurements of LWP and a cloud mask and will apply the algorithm to generate surrogate clouds based on in situ airplane LWC measurements. The main limitation of such surrogates is the amount of

data available to estimate the PDF of the cloud field.

Furthermore, we are working on another version that simulates the inclusion of satellite data, by including coarse grained means into the algorithm. First results of both algorithms look good.

Liquid water content height distribution

Using other well-known algorithms such as the Fourier method and the Bounded Cascade method the generated fields have a specified Fourier (power) spectrum. However, the shape of the amplitude distribution (of the parameter of interest, like liquid water content or liquid water path) is fixed by the method. The amplitude distribution is especially important for radiative transfer problems, which can be seen in the success of the Independent Pixel Approximation (IPA). Thus these surrogate cloud fields are especially useful for empirical studies linking physical properties of (broken) cloud fields to their measured radiative properties.

Evaluation

The suitability of the surrogate clouds for radiative transfer is evaluated by comparing the radiative properties of model cloud fields of sparse cumulus and stratocumulus with their surrogate fields. The bias and root mean square error in the radiative budget of the surrogate fields is better than 0.5 % of the incoming radiation. The average radiances of the stratocumulus fields fit within 0.6 % and the actinic fluxes within 0.4 %. The standard deviations and the power spectra of radiative fields are captured well. The full distributions do show differences between the model clouds and the surrogates, but on average the full distribution of the radiative properties is almost identical. We will compare these results with optical properties of clouds that have either the correct PDF (but no spatial correlations) or the correct power spectrum (but a Gaussian PDF).

The surrogate sparse cumulus fields were 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.