Title

Data driven simulation of clouds using Markov Chain models with spatial dependence

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Abstract

Thanks to increasing computational resources, the grid sizes of global climate and weather prediction models are decreasing to scales at which subgrid processes, especially the evolution of clouds, can become spatially too variable for traditional deterministic parameterization approaches. We propose a stochastic parameterization in which clouds are represented by a Markov-Chain (MC) lattice model. The state of each lattice site is characterized by cloud top height (CTH) and cloud optical depth (COD). Based on these two parameters, clouds can be categorized into different cloud types (cumulus, stratus, cirrus, deep convection, etc.). In contrast to previous work, where the transition probabilities between different cloud types were calculated, we determine the transition probability densities in the continuous CTH-COD domain. We moreover explore the influence of neighbouring lattice sites on these transition densities to research whether it is possible to simulate cloud organization structures, without the use of extra external large scale variables or forcings. We estimate the parameters of the distributions using GOES-16 satellite images. Using these estimates, we perform simulations of the continuous state space Markov Chain over the lattice. This results in 2D spatial cloud evolutions, which spatial organization we compare to the original images.

The simulations did not show any spatial structures as were observed in the original images. All the simulations resulted in a granulated image of different cloud types after only a couple of hours.

A simulation from the MC model describing transitions from a finite number of cloud types converges to the observed occurrence frequencies, which is property of a MC. When describing the MC in a continuous state space the simulations still converged to the observed cloud state frequencies. However, introducing spatial dependence this property was not a given anymore.

Since we were unable to reproduce the organizational structure from previous work using the GOES-16 satellite images, we cannot conclude whether it is possible to simulate cloud organization using the MC lattice model. A better understanding of these type of models was achieved. Neighbouring sides could diverge too fast in the performed models. We believe adding a stronger coupling between the cloud state evolution of neighbouring cells can improve the spatial models. Therefore one method to simulate correlated variables was tried to implement on the CTH evolution. This showed promising early results for further research. Also a better correction for horizontal advection on the original images could be performed to observe a specific cloud over time, which could improve the observed data quality.