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# Non-local Second Order Closure Scheme for Boundary Layer Turbulence and Convection

Bettina Meyer (1) and Tapio Schneider (2)
(1) ETH Zurich, Switzerland (bettina.meyer@erdw.ethz.ch), (2) California Institute of Technology, Pasadena, USA

There has been scientific consensus that the uncertainty in the cloud feedback remains the largest source of uncertainty in the prediction of climate parameters like climate sensitivity. To narrow down this uncertainty, not only a better physical understanding of cloud and boundary layer processes is required, but specifically the representation of boundary layer processes in models has to be improved.

General climate models use separate parameterisation schemes to model the different boundary layer processes like small-scale turbulence, shallow and deep convection. Small scale turbulence is usually modelled by local diffusive parameterisation schemes, which truncate the hierarchy of moment equations at first order and use second-order equations only to estimate closure parameters. In contrast, the representation of convection requires higher order statistical moments to capture their more complex structure, such as narrow updrafts in a quasi-steady environment. Truncations of moment equations at second order may lead to more accurate parameterizations. At the same time, they offer an opportunity to take spatially correlated structures (e.g., plumes) into account, which are known to be important for convective dynamics.

In this project, we study the potential and limits of local and non-local second order closure schemes. A truncation of the momentum equations at second order represents the same dynamics as a quasi-linear version of the equations of motion. We study the three-dimensional quasi-linear dynamics in dry and moist convection by implementing it in a LES model (PyCLES) and compare it to a fully non-linear LES. In the quasi-linear LES, interactions among turbulent eddies are suppressed but nonlinear eddy—mean flow interactions are retained, as they are in the second order closure. In physical terms, suppressing eddy—eddy interactions amounts to suppressing, e.g., interactions among convective plumes, while retaining interactions between plumes and the environment (e.g., entrainment and detrainment).

In a second part, we employ the possibility to include non-local statistical correlations in a second-order closure scheme. Such non-local correlations allow to directly incorporate the spatially coherent structures that occur in the form of convective updrafts penetrating the boundary layer.
This allows us to extend the work that has been done using assumed-PDF schemes for parameterising boundary layer turbulence and shallow convection in a non-local sense.