Using the assumed PDF method to build a subgrid-scale parameterization

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1 Introduction

Traditionally, the role of parameterizations has been the prediction of physical properties such as subgrid-scale fluxes, cloud mass fluxes, and cloud properties. Models often rely on disparate parameterizations for the prediction of each one of these properties.

The assumed PDF method takes an alternate approach by focusing on the prediction of a more fundamental property: the joint probability density function (PDF) of subgrid-scale variations in vertical velocity, temperature and moisture variables. The joint PDF is more fundamental, because once known, turbulence fluxes, cloud mass flux and cloud properties can all be derived from it.

We present a PDF-based parameterization that we have developed for clouds and turbulence in the planetary boundary layer, Cloud Layers Unified By Binormals (CLUBB).

2 Methodology

CLUBB is based on the assumed probability density function (PDF) method (Golaz et al. 2002; Larson and Golaz 2005). From the viewpoint of the assumed PDF method, the task of a cloud parameterization is primarily the prediction of the subgrid joint PDF of vertical velocity (w), heat content (θ_l), and moisture content (q_t). The joint PDF is the probability that the triplet $[w, \theta_l, q_t]$ occurs at a particular location and time.

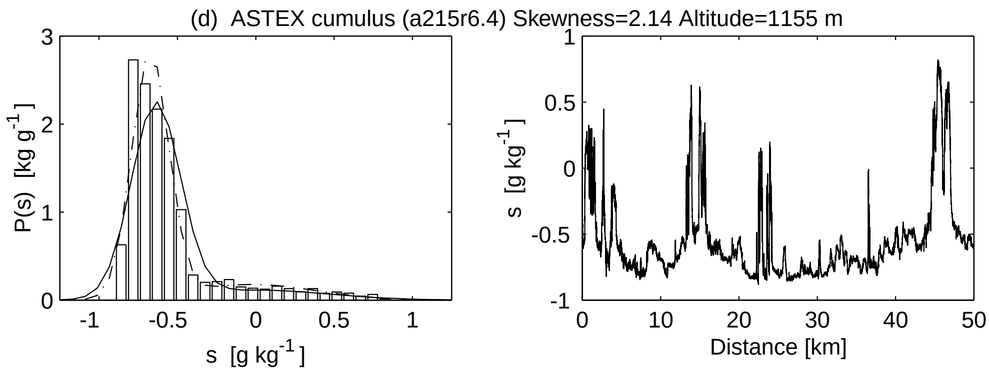

Figure 1: Cumulus layer observed during the field experiment ASTEX. s measures the departure from saturation with $s > 0$ for cloudy layers. Right panel shows data along aircraft transect, left panel shows observed PDF (bars) along with two fits based on double Gaussians. Note the presence of a long tail characteristic of cumulus layers. See Larson et al. (2001) for complete details.

Predicting the full subgrid PDF is computationally infeasible. Instead, we assume a functional form for the PDF, namely a mixture of Gaussians. A double Gaussian shape defines a functional form whose width, center, and skewness may vary. Such a form captures well the observed structures in the marine boundary layer (Figure 1; Larson et al. (2001)).

The steps in a parameterization based on the PDF method may be outlined as follows (Figure 2). We first write down standard higher-order moment equations (Reynolds averaged equations). This includes equations for turbulent fluxes and variances of heat and moisture. These equations contain unclosed, higher-order and buoyancy terms. Moments from the prognostic equations are used to select a particular PDF within the functional form for each grid box and time step. The PDF is thus allowed to vary in space and evolve in time. Once the subgrid PDF is determined, it is used to diagnose cloud properties as well as close higher-order moments in the prognostic equations.

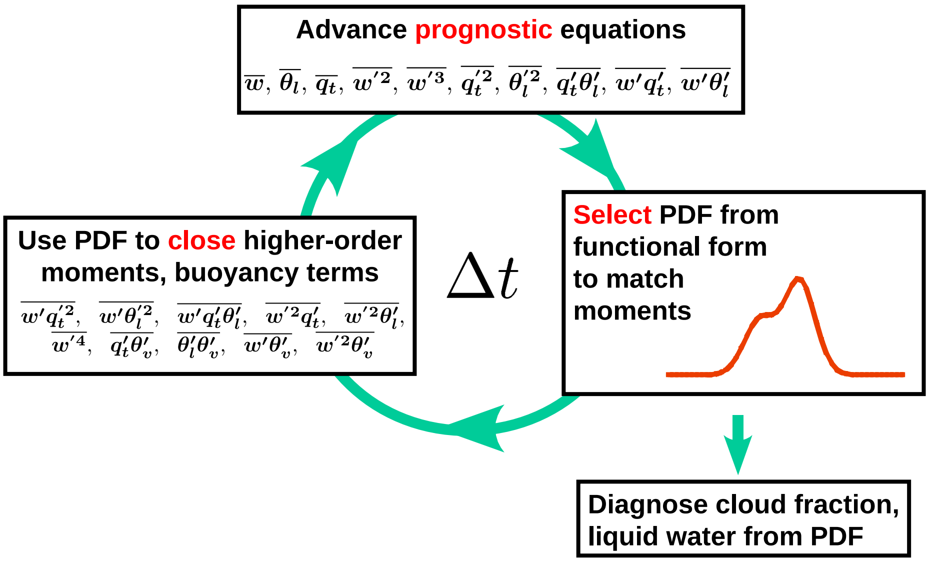

Figure 2: Major steps within a single time step of a parameterization based on the assumed PDF method. Moments are predicted using higher-order equations. Predicted moments are used to select a particular PDF from the functional form. Cloud properties and higher-order moments are diagnosed by integration over the PDF.

3 Additional information

CLUBB in single-column mode successfully simulates a variety of cloud regimes, including shallow cumulus clouds, stratocumulus clouds, and mixed regimes without any case specific adjustments. Additional information about the CLUBB parameterization is available at http://clubb.larson-group.com.

References

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