# Including a cold pool representation in a convection parameterization and simulating its impacts on the spatial and temporal variability of the precipitation in the NASA GEOS GCM.

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## Abstract

We developed and implemented a simple representation of a cold pool in the Grell-Freitas (GF) convection parameterization. The cold pool parameterization is based on the observation that convective-scale downdrafts produce a local 'deficit' of the moist static energy (MSE). This information is advected and becoming downwind available to trigger and intensify new convection. The cold pool is dissipated by a simple exponential decay using a lifetime of a few hours, or by interacting with the underneath surface by exchanging latent and sensible heat fluxes. Preliminary results show some improvement of the simulation of the diurnal cycle of the precipitation over the land, mainly during the nighttime.

### Brief Description of the GF Convection Parameterization

The GF scheme is based on the mass flux approach and the main features are:

- scale awareness through Arakawa et al. (2011) approach,
- aerosol dependence through auto-conversion and evaporation formulations depending on the environmental cloud concentration nuclei.
- A tri-modal formulation, which allows up to three plumes representing the main convective modes existing in a tropical environment (Johnson et al., 1999): shallow, congestus, and deep plumes.
- A set of closures to determine the mass flux at the cloud base to adequately account for the diverse regimes of convection in a given grid column.
- Transport of momentum, tracers, water, and moist static energy. Includes also wet removal of gases and aerosols particles.
- Application of probability density functions to emulate the vertical mass flux profiles, providing an effective method to set the vertical distribution of heat and mass, which is very useful for fine-tuning the model.
- A new closure for non-equilibrium convection adapted from Bechtold et al. (2014). Here this closure is called 'diurnal cycle' closure.

### The Cold Pool Parameterization

Definition of Buoyancy-Excess ($B_x$)

$$B_x = H_d - \tilde{H}, \text{ where } \begin{cases} H_d & \text{downdraft MSE} \\ \tilde{H} & \text{environment MSE} \end{cases}$$

Prognostic Equation

$$\frac{\partial B_x}{\partial t} = adv(B_x) + diff(B_x) + S + R$$

Source term $S = -\frac{g}{\Delta p}\delta_d B_x$, $\begin{cases} g \text{ is gravity, } p \text{ is pressure} \\ \delta_d \text{ is the downdraft detrainment mass flux} \end{cases}$

Sink term $R = -\frac{B_x}{\tau}$, $\tau$ is the cold pool lifetime ~ $10^3$ - $10^4$ seconds

adv and diff are the grid-scale advection and diffusion operators.

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### Preliminary Results

The GF scheme with the cold pool parameterization was tested using the NASA GEOS-5 GCM. The model was configured with c360 spatial resolution (~25km) for and ran re-forecasts for December 2017. Each forecast comprised 120 h time integration, with output every 1 h. Model configuration included the non-hydrostatic dynamical core FV3 and the single-moment version of the microphysics scheme. The cold pool lifetime used in this experiment was 6 hours.

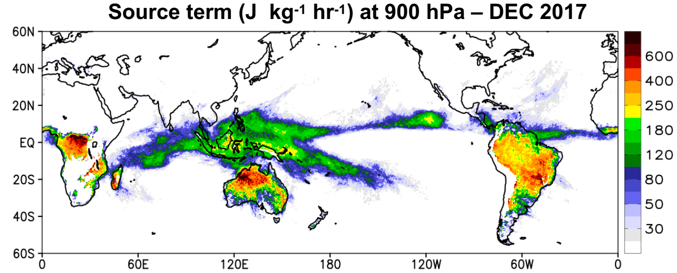


**Figure 1.** Monthly mean for DEC 2017 of the source term as defined before.

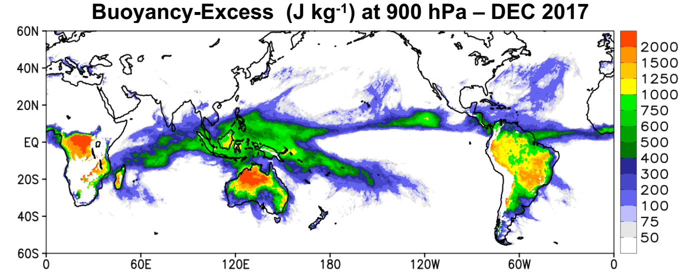


**Figure 2.** Monthly mean for DEC 2017 of the resultant buoyancy-excess at the vertical level of 900 hPa

### Preliminary Results (cont.)

In simulations presented here, the buoyancy-excess (see figure 2) is used in the boundary condition for the MSE of the updraft in the downwind direction, serving as an extra source for the convective air parcels.

The DEC 2017 diurnal cycle of the precipitation averaged over the global domain and land areas only are shown in Figure 3. The curves represent the TRMM precipitation, GEOS-GF without the diurnal cycle closure (DC, green), with the DC (red) and the DC with the cold pool parameterization (blue). With the cold pool scheme, the parameterized convection is kept more active ahead of the afternoon peak (see blue curves).

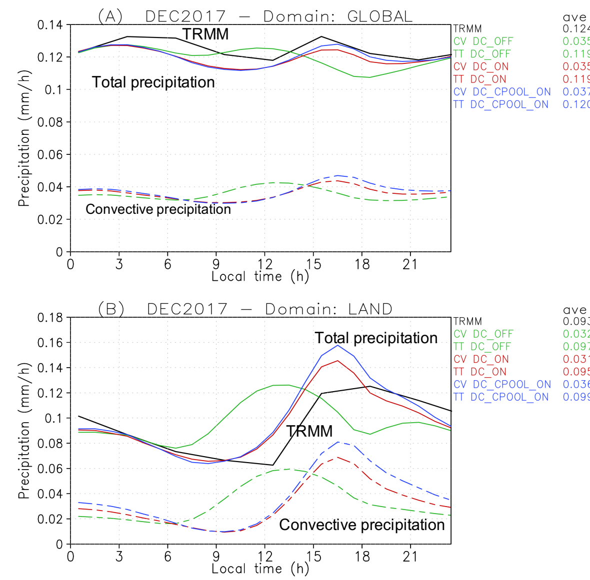


**Figure 3.** Diurnal cycle of precipitation from TRMM and NASA GEOS model with the GF scheme. Panel (A) shows results for global mean and (B) for land areas only. Model results are shown in terms of total precipitation (TT) and only from de GF convection parameterization (CV, dashed lines). Model results in green, red and blue colors correspond to simulations not including diurnal cycle closure (DC OFF), only with this closure (DC ON), and with DC and the cold pool parameterization, respectively.

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