DOE AWARD # DOE_DE-SC0008720

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Probing the transition from shallow to deep convection

1) how the research adds to the understanding of the area investigated;
In this funded project we highlighted the components necessary for the transition from shallow to deep convection. In particular we defined a prototype of shallow to deep convection, which is currently being implemented in the NASA GISS model. We also tried to highlight differences between land and oceanic convection.

2) the technical effectiveness and economic feasibility of the methods or techniques investigated or demonstrated
To assess the transition from shallow to deep convection we have used a combination of large-eddy simulations, observations (several of which at the ARM Southern Great Plains site) and convection prototype (in Matlab but to be implemented in Fortran in a single column model).

Provide a comparison of the actual accomplishments with the goals and objectives of the project.
We published 7 papers with PI Kuang (Harvard) so we believe we outpaced our expectations

Summarize project activities for the entire period of funding
(Just Gentine share – PI Kuang also submitted a report for both of us)

In 2016 (sent in 2015 for review) we published a manuscript in Geophysical Research Letters [*Gentine et al.*, 2016] on the role of surface heat fluxes on the life cycle and organization of convection with PI Kuang. The main objective of the study was to determine the effect of increased sensible and latent heat fluxes underneath cold pools, which could presumably kill the cold pool anomaly (see Figure 1). As can be seen in Figure 1, the cold surface temperature generates increased surface sensible heat flux, and is also typically accompanied by increased latent heat flux. Those two fluxes in turn reduce the buoyancy anomaly underneath cold pools and can then kill the cold pools, as its buoyancy becomes similar to the environment.

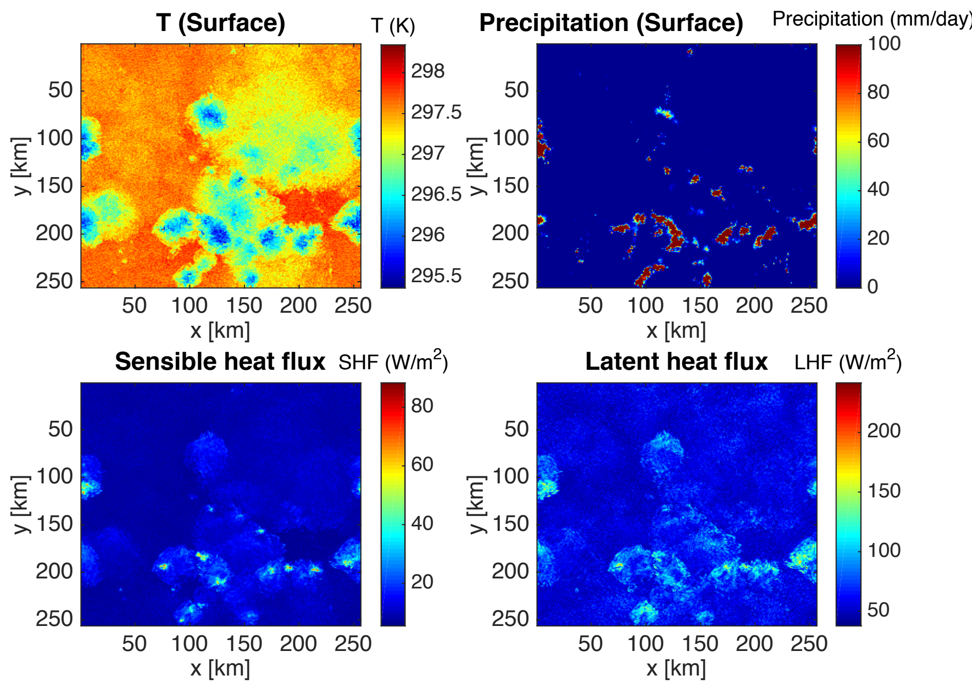

Figure 1: Surface air temperature cross-section (top left), precipitation (top right), sensible heat flux (bottom left), and latent heat flux (bottom right).

We ran a series of simulations using the SAM cloud-resolving model [*Khairoutdinov and Randall*, 2006] at 500m resolution over a 256km x 256km domain. We used 16 ensemble members to generate diverse surface conditions. In those simulations we had an original simulation (called HET), in which surface fluxes were naturally responding to the buoyancy anomaly in cold pools (Figure 2 left). We then performed the same simulation with homogenization of the surface fluxes (Figure 2 right). This was tested over an oceanic (prescribed sea surface temperature) and continental surface (without diurnal cycle).

We developed an algorithm that identify and tag each individual cold pools as seen in Figure 3. We could then analyze the size, gust front velocity, buoyancy and moisture anomaly of each individual cold pools with homogenization of the surface heat fluxes.

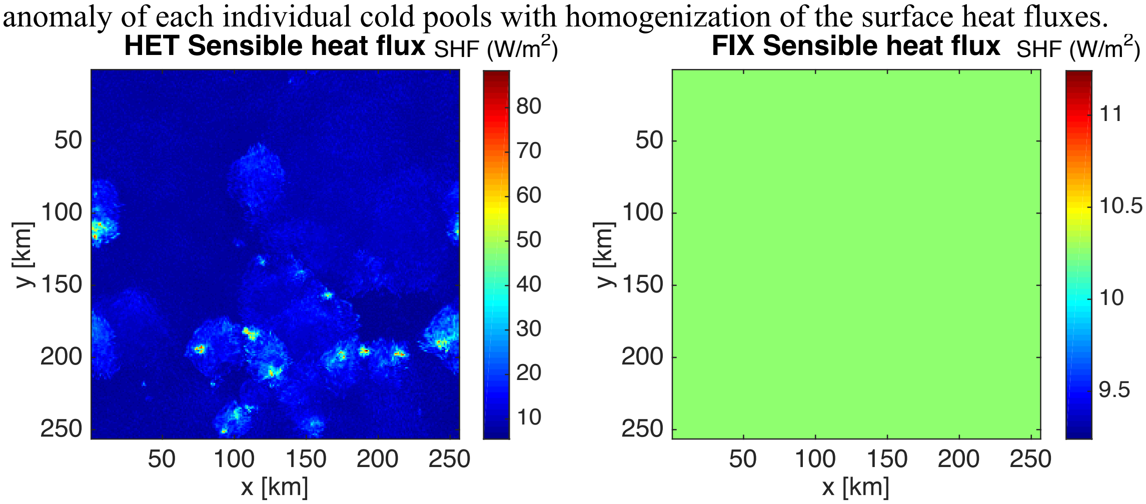

Figure 2: Experiment performed in SAM by homogenizing surface fluxes over the entire domain (rhs).

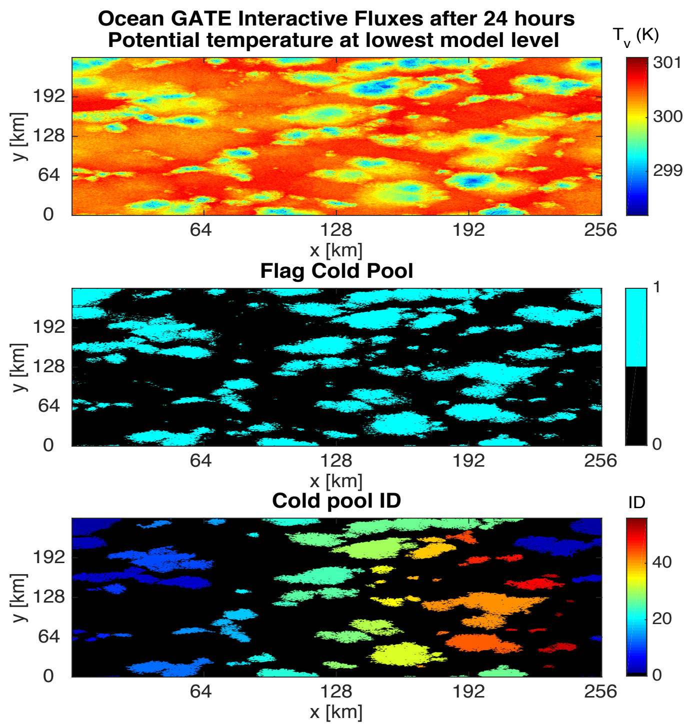

Figure 3: Cold pool identification based on a clustering algorithm (middle) and then breadth first search algorithm to tag individual cold pools (bottom).

Homogenizing the surface fluxes led to fewer but wider cold pools (FIX simulation – Figure 4). The gust front velocity and humidity distribution were about the same. Virtual potential temperature (buoyancy) was lower in FIX (no anomaly correction by fluxes) in the oceanic case. IN the continental case (Figure 5), there were fewer but wider cold pools in FIX i.e. convection was more organized. The gust front velocity was higher in FIX (no buoyancy reduction by surface fluxes) and the virtual potential temperature (buoyancy) was much lower in FIX. We also tested the impact on the entrainment rate and found that the entrainment rate was modified especially for the shallower convection.

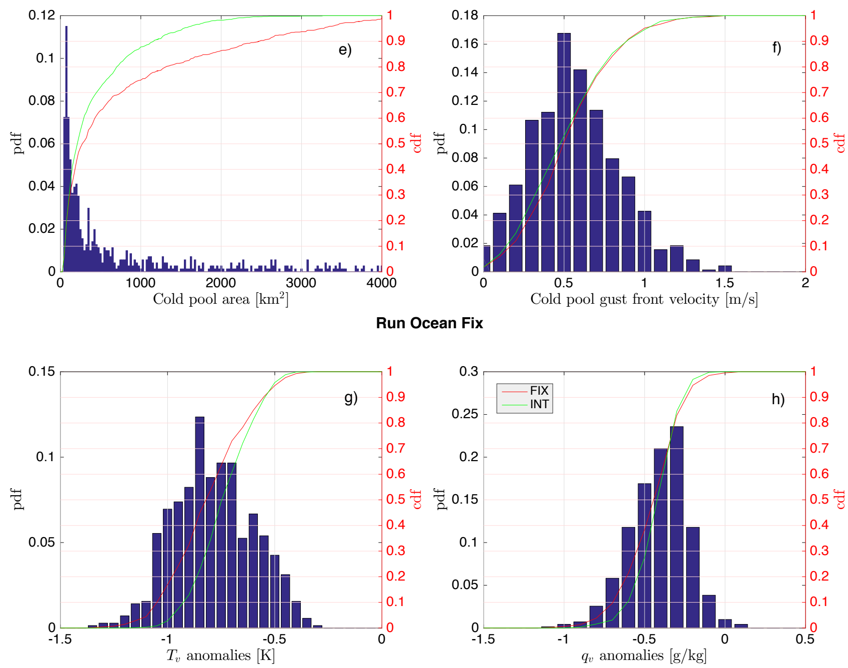

Figure 4: Changes in the pdf of the cold pool characteristics: area (top left), gust front velocity (top right), virtual temperature anomalies (bottom left) and specific humidity (bottom right). The thin continuous lines represent the cumulative density functions. FIX is the homogenous flux case and INT is the interactive surface flux case (OCEAN case).

In the FIX case, the wider cold pools tended to organize convection more and to generate lower entrainment rate, which reached higher levels.

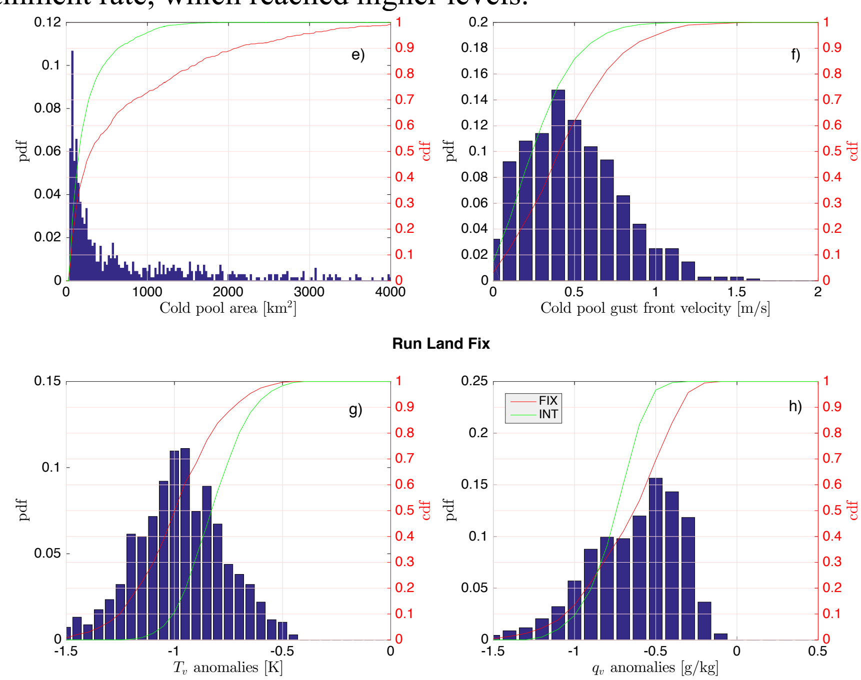

Figure 5: Same as Figure 4 but for a continental case.

Previously as part of this proposal we had published a paper on the effect of surface heat fluxes on the transition from dry to shallow and shallow to deep convection: [*Gentine et al.*, 2013]. The paper describes the mechanisms leading to shallow or deep convection over land and the fact that two types of mechanisms can be found: a dynamic and thermodynamic one. Convection can be triggered by either direct moistening of the boundary layer by surface evaporation (similarly to the ocean) or through condensation at the top of a deep boundary layer, because the temperature lapse rate induces condensation at the top of the PBL. The manuscript has been widely cited since its acceptance (~50 times).

In 2014 Gentine and colleague D'Andrea have developed a new parameterization of the transition from shallow to deep convection using a probabilistic plume approach. We demonstrated that the transition can be represented with a unified parameterization through the use of a simple cold pool modeling, which alter the entrainment rate [*D'Andrea et al.*, 2014]. This is now tested in a single column model at NASA GISS and we hope to develop this into full-blown parameterization in the future. In the meantime we have developed a prototype of cold pools that will be later included into the probabilistic parameterization.

References

D'Andrea, F., P. Gentine, A. K. Betts, and B. R. Lintner (2014), Triggering Deep Convection with a Probabilistic Plume Model, *J Atmos Sci*, 140527112639007, doi:10.1175/JAS-D-13-0340.1.

Gentine, P., A. A. M. Holtslag, F. D'Andrea, and M. Ek (2013), Surface and atmospheric controls on the onset of moist convection over land, *J Hydrometeorol*, 130211131121003, doi:10.1175/JHM-D-12-0137.1.

Gentine, P., A. Garelli, S.-B. Park, J. Nie, G. Torri, and Z. Kuang (2016), Role of surface heat fluxes underneath cold pools, *Geophys Res Lett*, n/a–n/a, doi:10.1002/2015GL067262.

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