Diagnosis of Convective Organization and Cold Pools using ARM Datasets and Evaluation of UNICON

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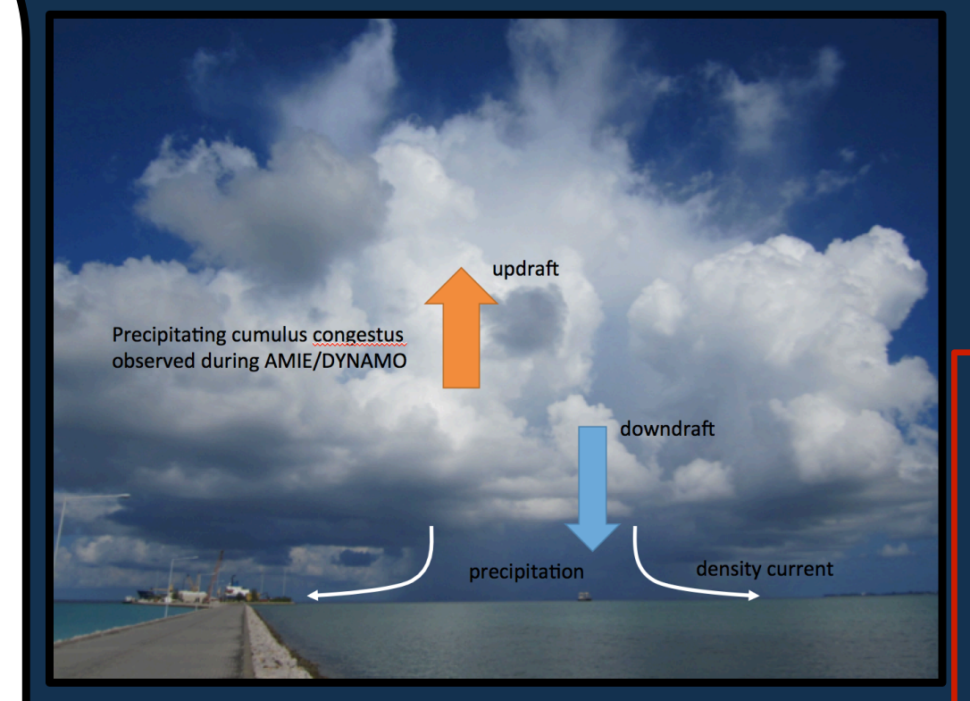
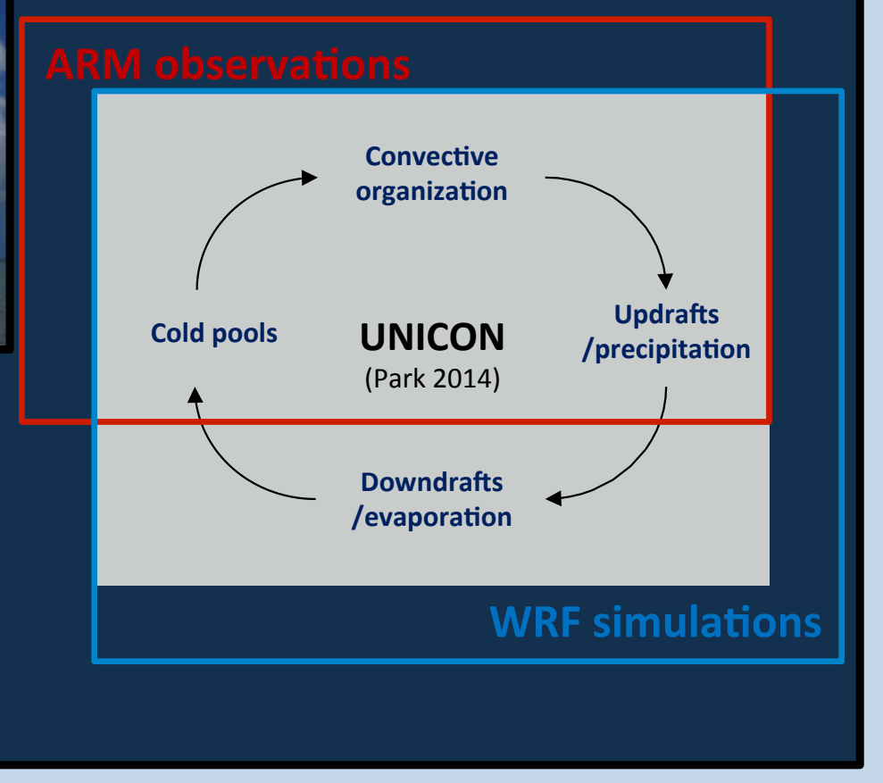
1. INTRODUCTION

The two-way feedback between convective updrafts and cold pools has been suggested as a critical mechanism for the shallow-to-deep convective transition and maintenance of deep convection. The unified convection scheme (*UNICON*) is an existing cumulus parameterization scheme that explicitly represents this interaction. This study uses ARM datasets to constrain the two-way feedback process between convection and cold pools simulated by UNICON.

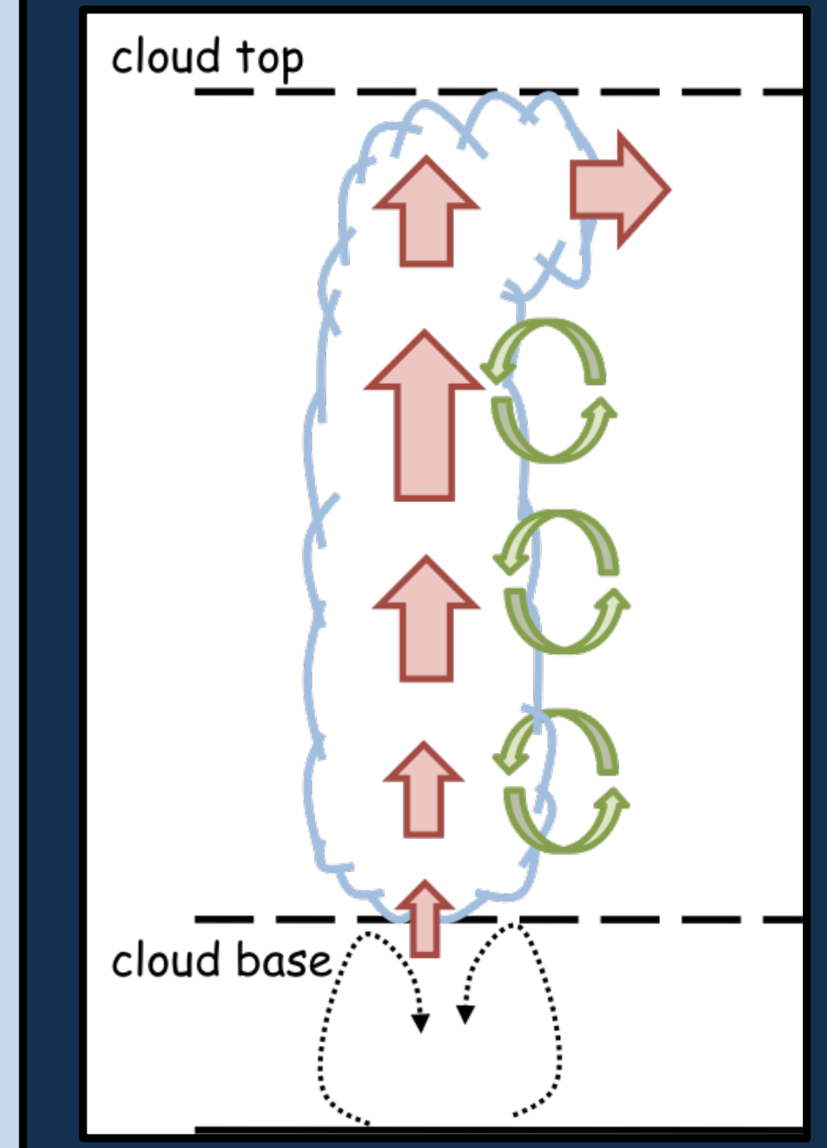
OBJECTIVES

- **Diagnose convective organization and cold pool processes <u>over the Indian Ocean (AMIE/DYNAMO)</u> and over SGP (MC3E) by combining field campaign datasets and high-resolution CRM simulations driven by ARM observations**
- **Evaluate processes related to convective organization and cold pools that are explicitly parameterized in UNICON**





2. UNICON



IMPACTS OF COLD POOL ON CONVECTION

Cold pools affect plume radius, temperature, specific humidity, and vertical velocity perturbation through a scalar that represents the degree of mesoscale convective organization

SOURCE OF COLD POOL ENERGY

Evaporatively driven convective downdraft penetrating down into boundary layer

Fractional mixing rate
: inversely proportional to plume radius

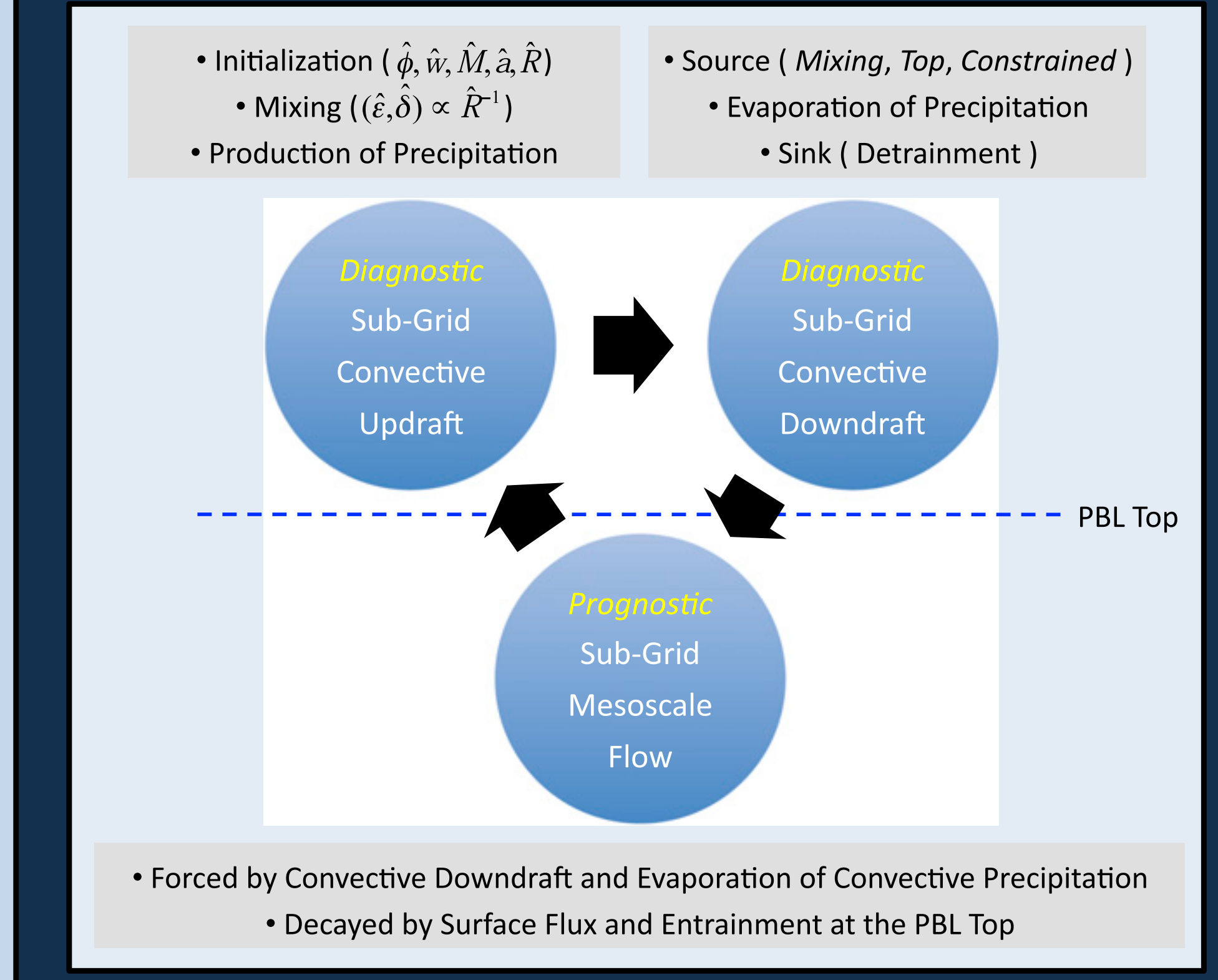
$$\hat{\epsilon}_o(z) = \left[\frac{a_1}{\rho g \hat{R}(z)}\right](1 + a_2 E)$$

The degree of convective organization (Ω)
: a linear function of cold pool fraction

$$\Omega \equiv \left(\frac{a_D^{\mathrm{adj}}}{1 - \hat{A}_{\max}}\right), \quad 0 \le \Omega \le 1$$

Plume radius at the surface
: a linear function of Ω

$$R_o(\Omega) = R_o|_{\Omega=0} + \Omega^{\gamma} \times (R_o|_{\Omega=1} - R_o|_{\Omega=0})$$



- Initialization ($\hat{\phi}, \hat{w}, \hat{M}, \hat{a}, \hat{R}$)
- Mixing ($(\hat{\varepsilon}, \hat{\delta}) \propto \hat{R}^{-1}$)
- Production of Precipitation

- Source (*Mixing, Top, Constrained*)
- Evaporation of Precipitation
- Sink (Detrainment)

Diagnostic Sub-Grid Convective Updraft

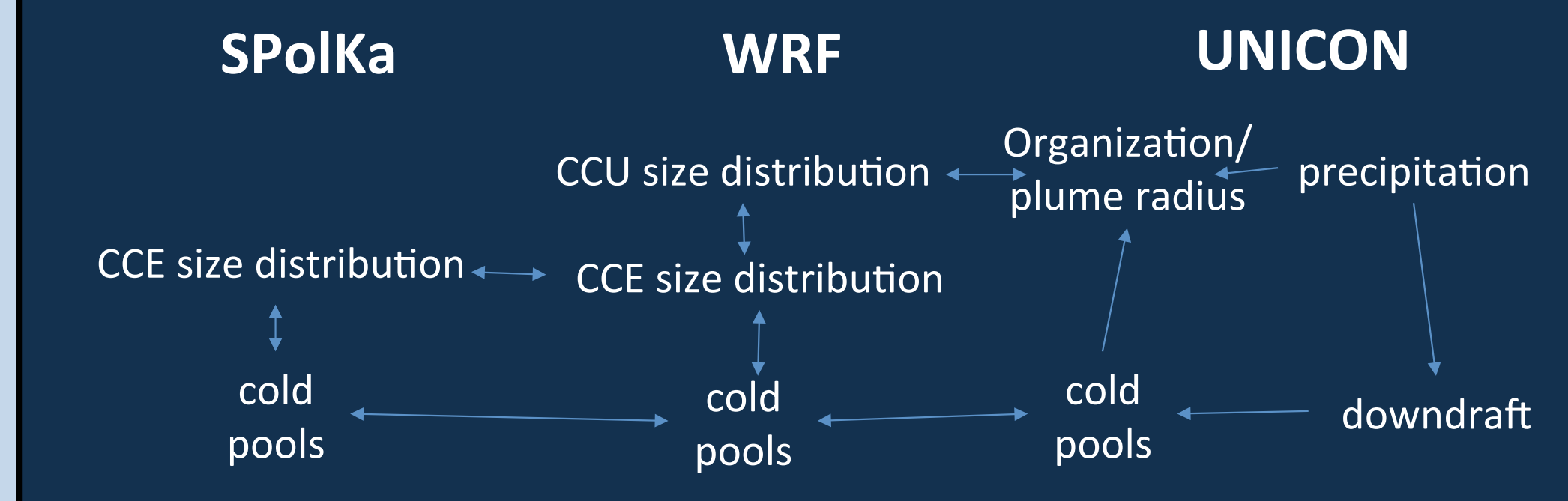
Diagnostic Sub-Grid Convective Downdraft

PBL Top

Prognostic Sub-Grid Mesoscale Flow

- Forced by Convective Downdraft and Evaporation of Convective Precipitation
- Decayed by Surface Flux and Entrainment at the PBL Top

When the degree of organization is high, convective plumes have lower entrainment rates and higher perturbation , temperature, specific humidity, and vertical velocity at the surface where the plumes initiate



SPolKa **WRF** **UNICON**

CCU size distribution
Organization/ plume radius
precipitation
CCE size distribution
CCE size distribution
cold pools
cold pools
cold pools
downdraft

<u>AMIE/DYNAMO</u>

- **Suppressed period (locally generated convection)**
  4-12 November 2011
- **Size distribution of contiguous convective echoes (CCEs) and contiguous convective updrafts (CCUs)**
- **Cold pool statistics**
- **WRF simulation, 500 m (Feng et al. 2015)**

<u>ARM AMIE Forcing Dataset</u>

Constrained variational objective analysis, ECMWF analysis, SMART-R adjusted precipitation, 2 October 2011 – 31 March 2012

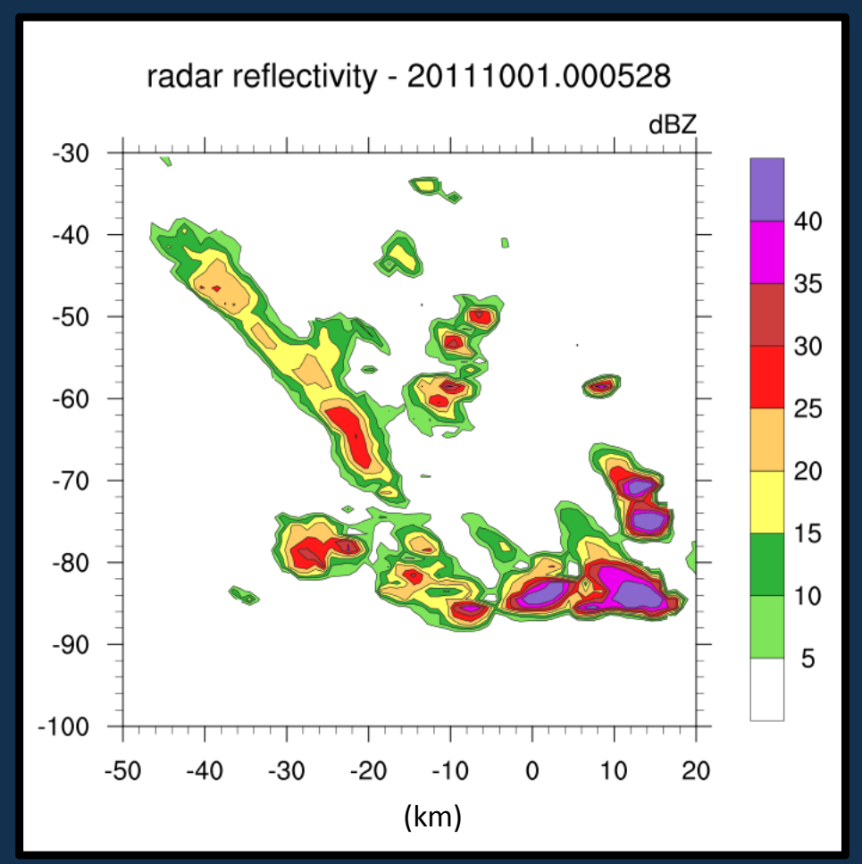
3. OBSERVATIONS AND WRF

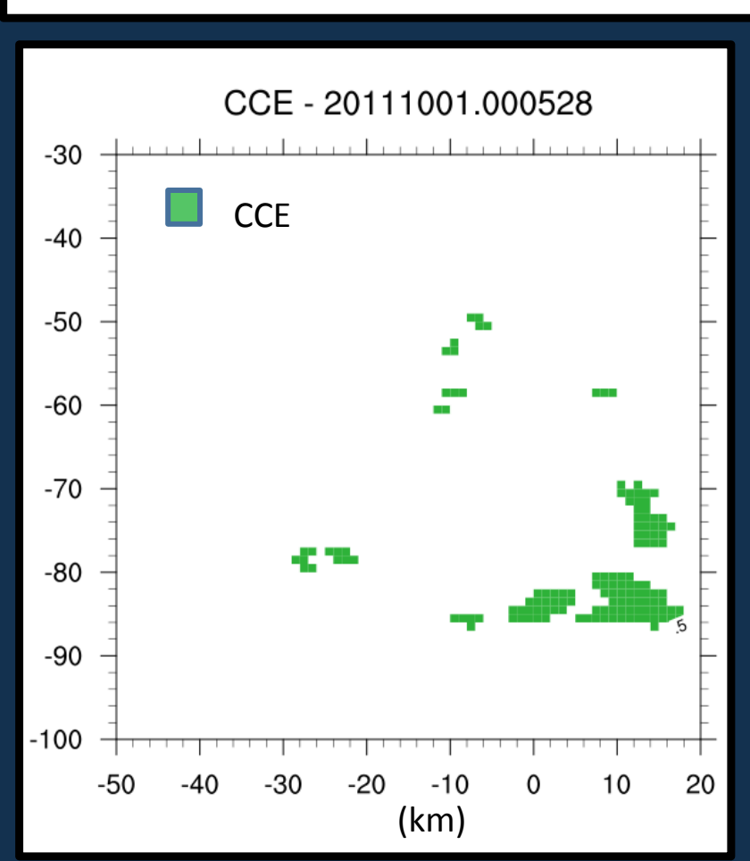
CONTIGUOUS CONVECTIVE ECHOES

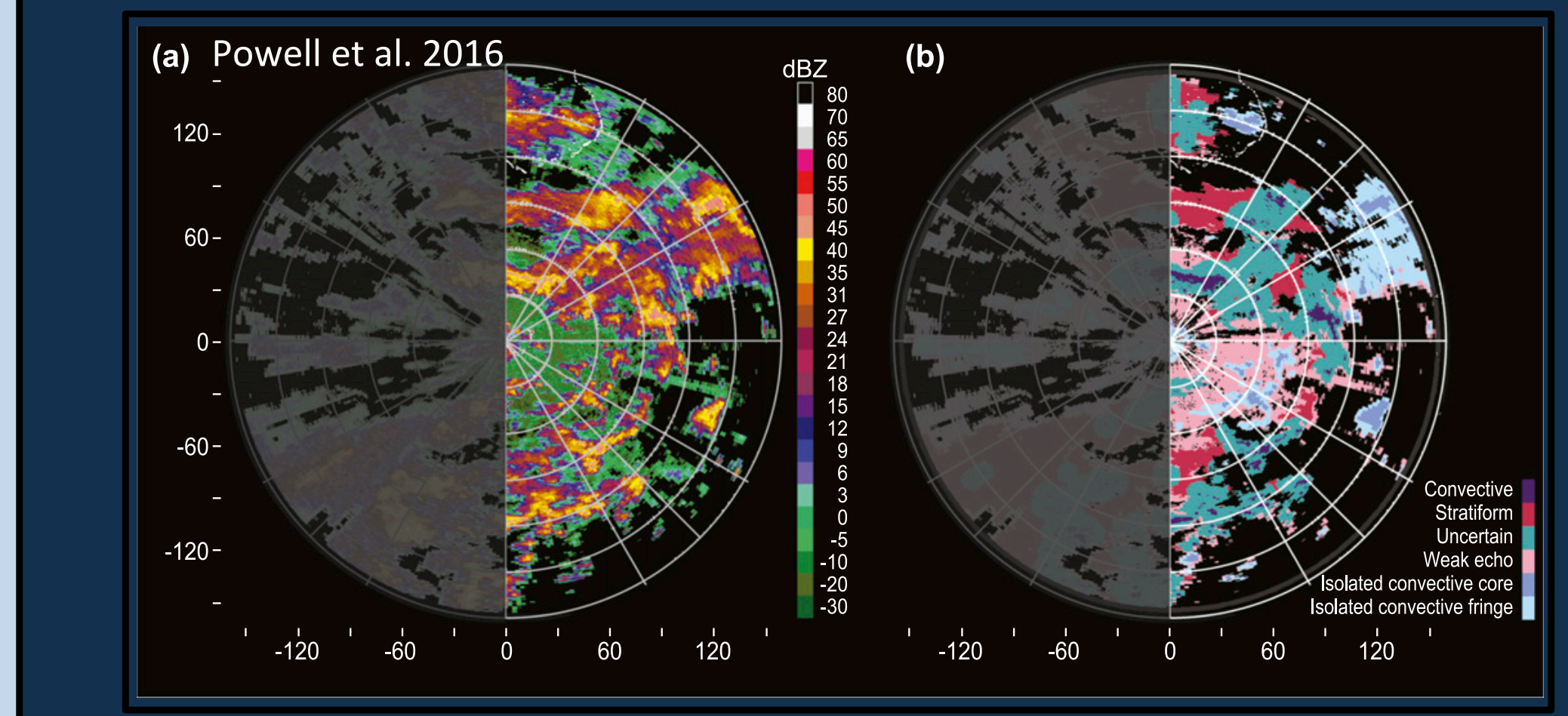
- Powell et al. (2016) algorithm (modified Steiner et al. 1995) applied to 1-km SPolKa and 500-m WRF reflectivity at 2.5 km height
- Group connected grid points of 'Convective' and 'Isolated convective core' echoes

CONTIGUOUS CONVECTIVE UPDRAFTS

- Grid points with updraft 5 m s^{-1} (> 1 km deep) above boundary layer

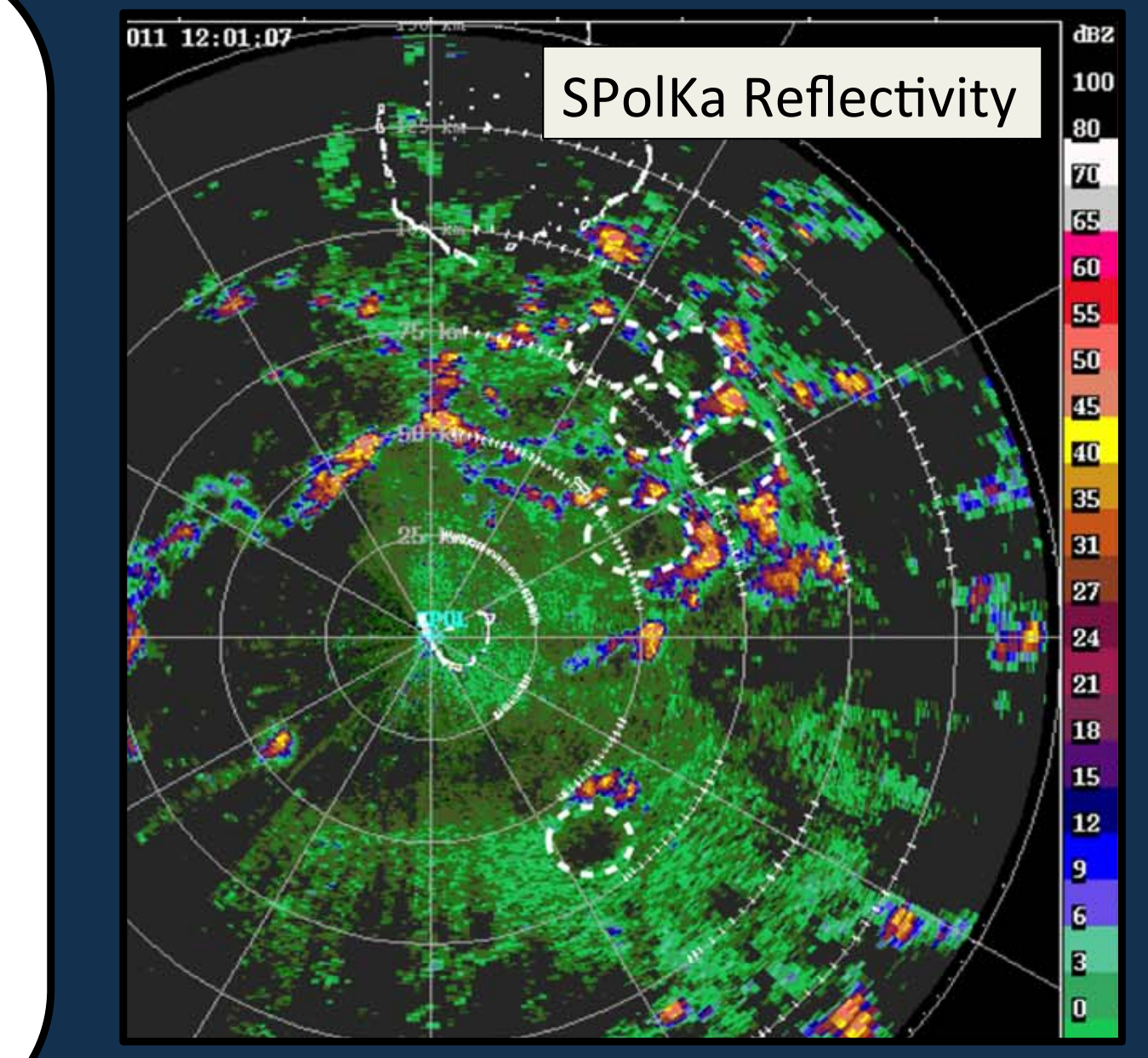


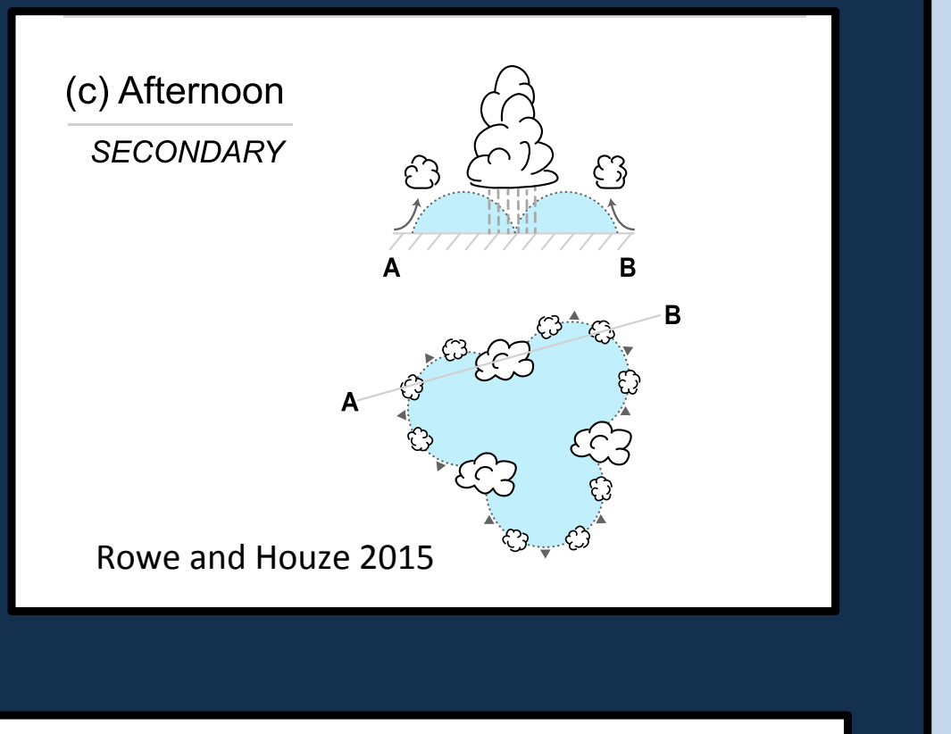




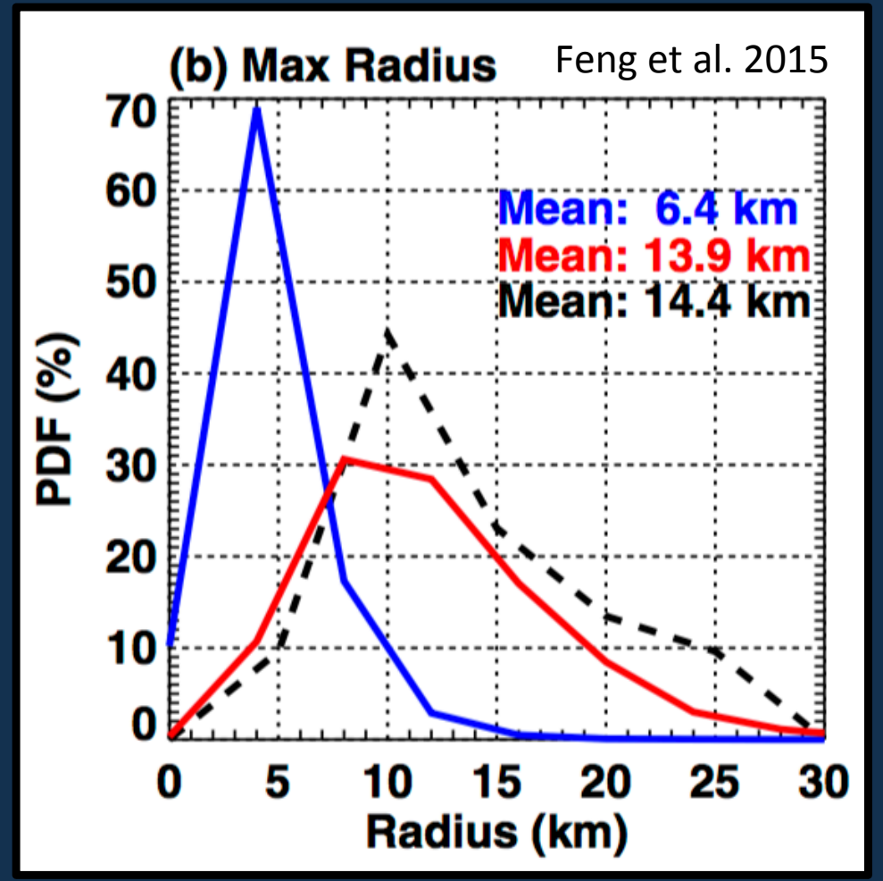
COLD POOLS: SPolKa

- **Manual tracking of cold pools from SPolKa (echo void bounded area in wake of convection)**
- **Estimates of maximum diameter, lifetime, fractional coverage**
- **Initiation and clustering of deep convection on intersecting cold pool boundaries (Rowe and Houze 2015; Feng et al. 2015)**

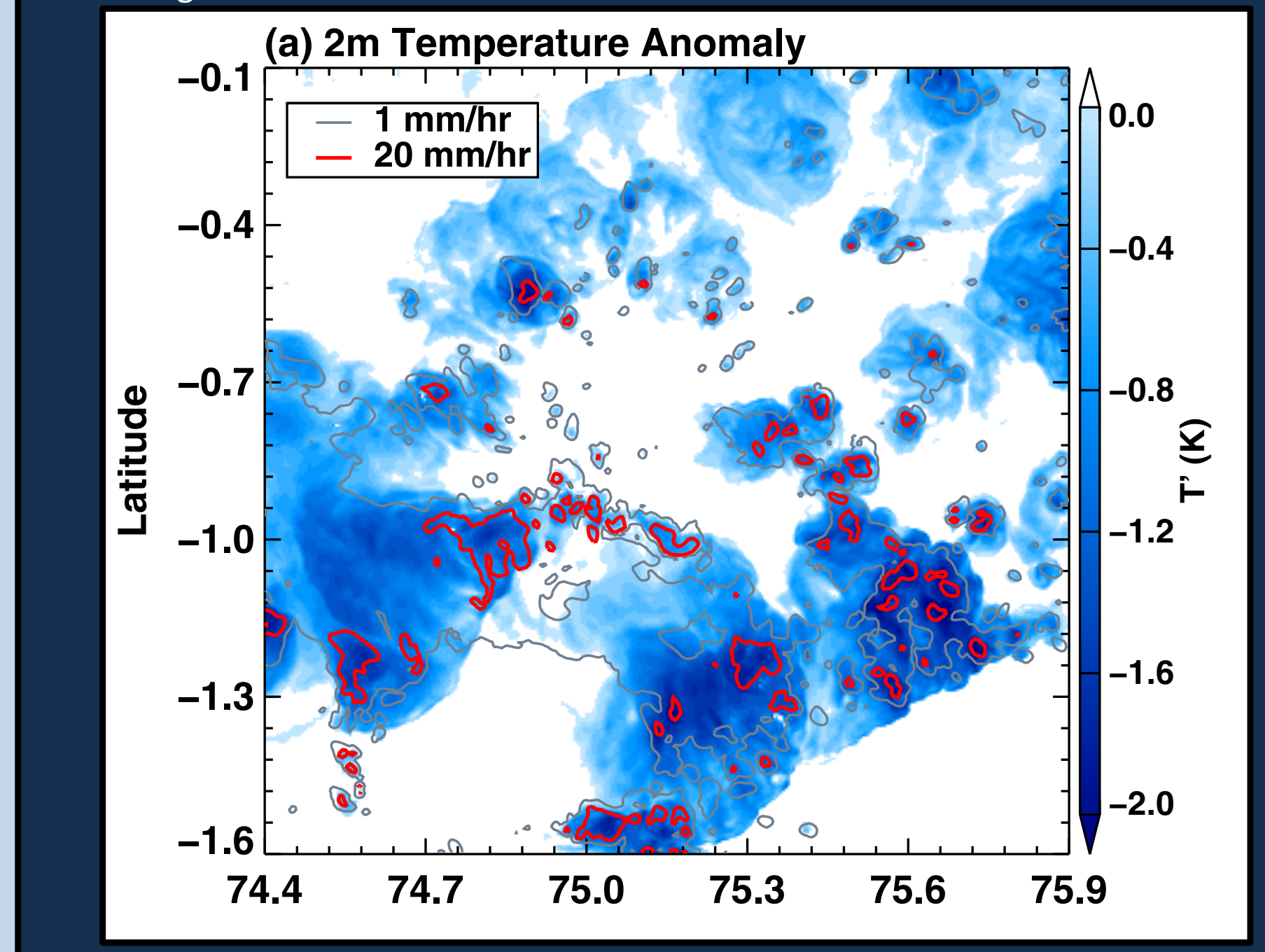




Rowe and Houze 2015



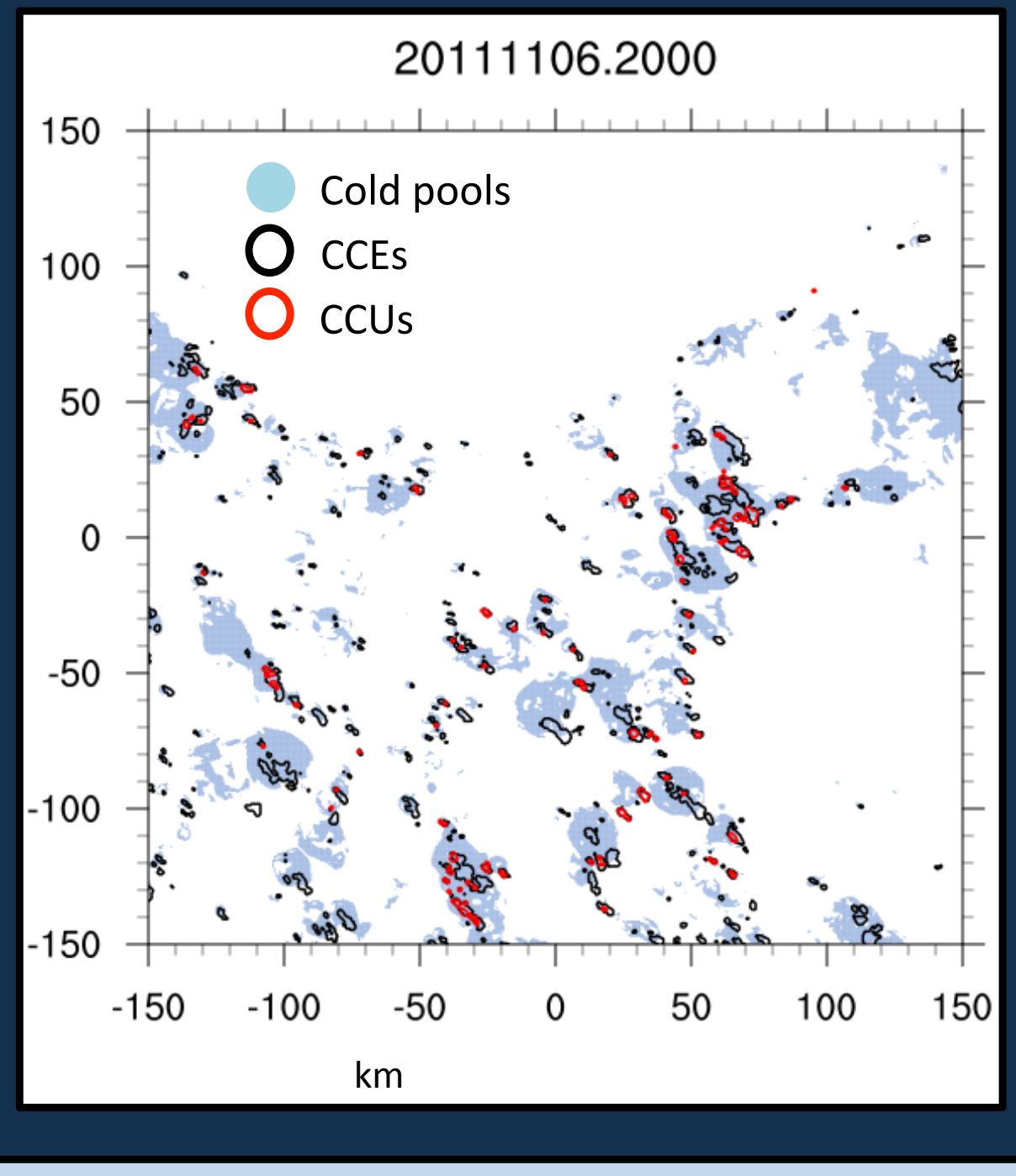
Feng et al. 2015



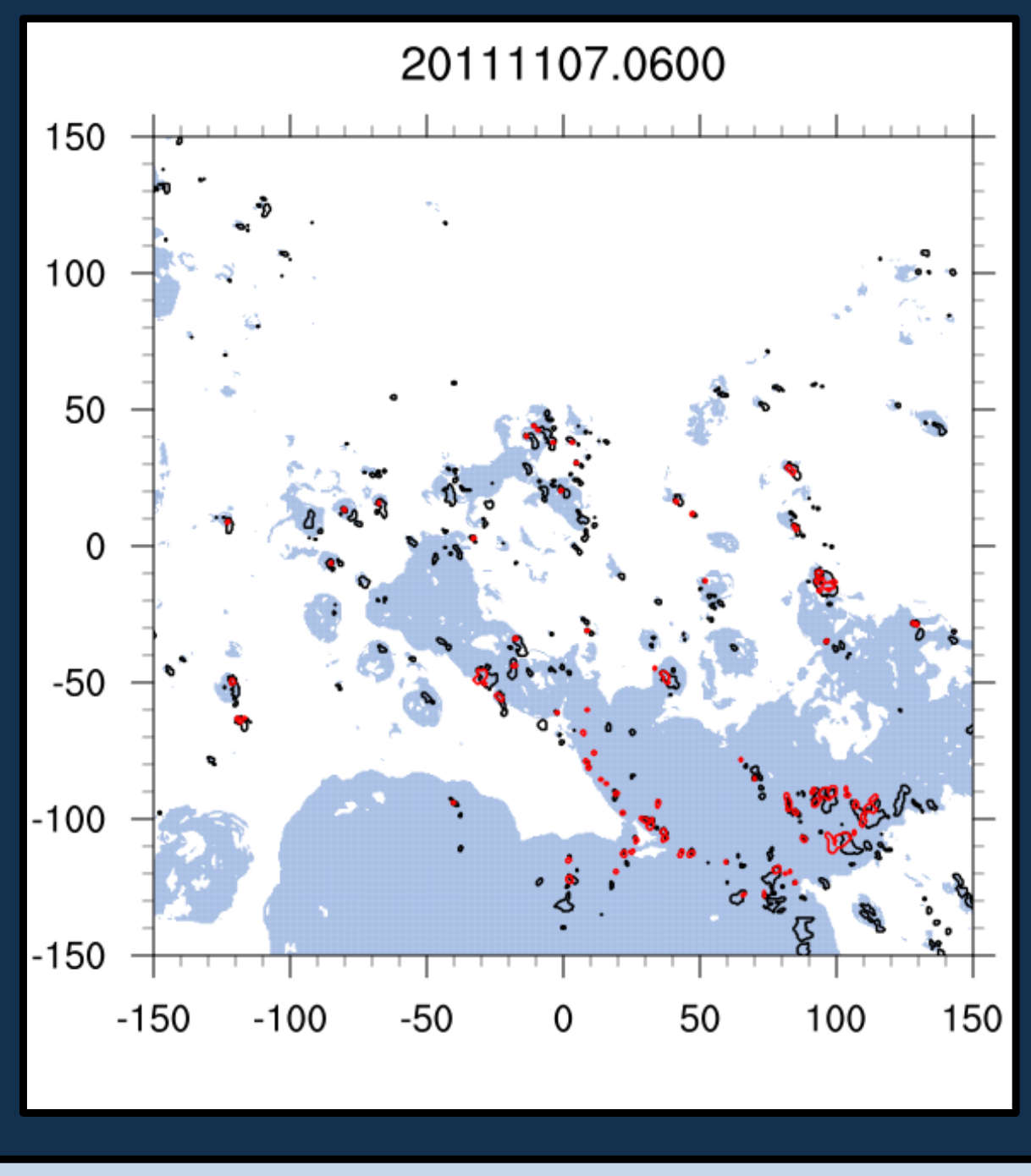
COLD POOLS: WRF

- **Potential Temperature < 0.5 K (virtual T in UNICON)**
- **Fractional area determined**
- **Can relate to thermodynamic (water vapor) and dynamic (vertical velocity) mechanisms for convection-cold pool interaction**
- **Relate cold pool properties to CCEs/CCUs**

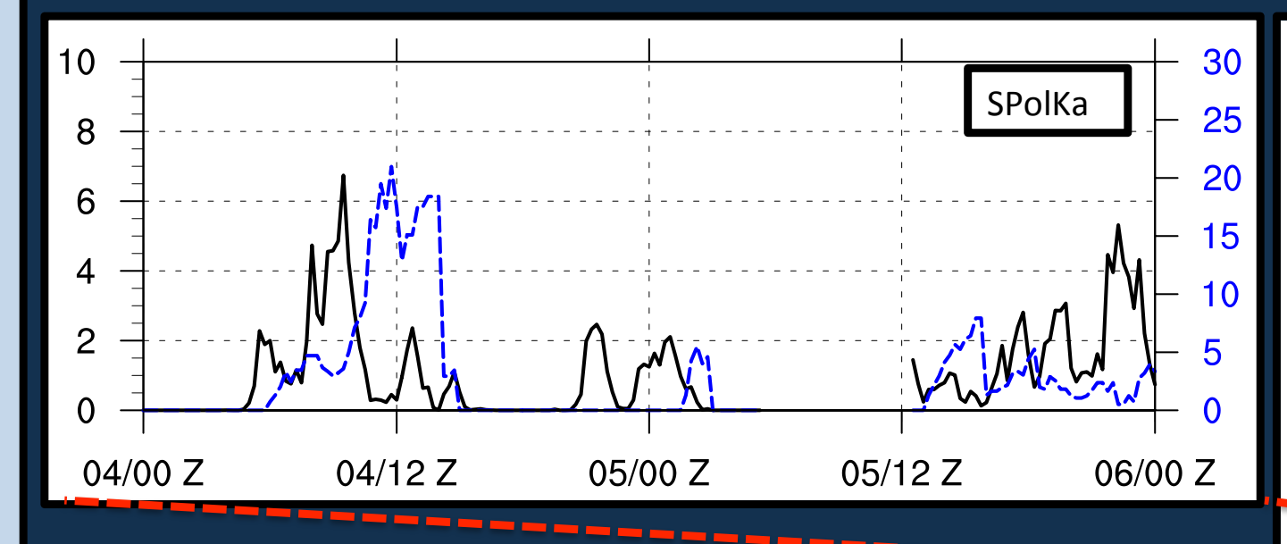
6 Nov 2011, 2000 UTC

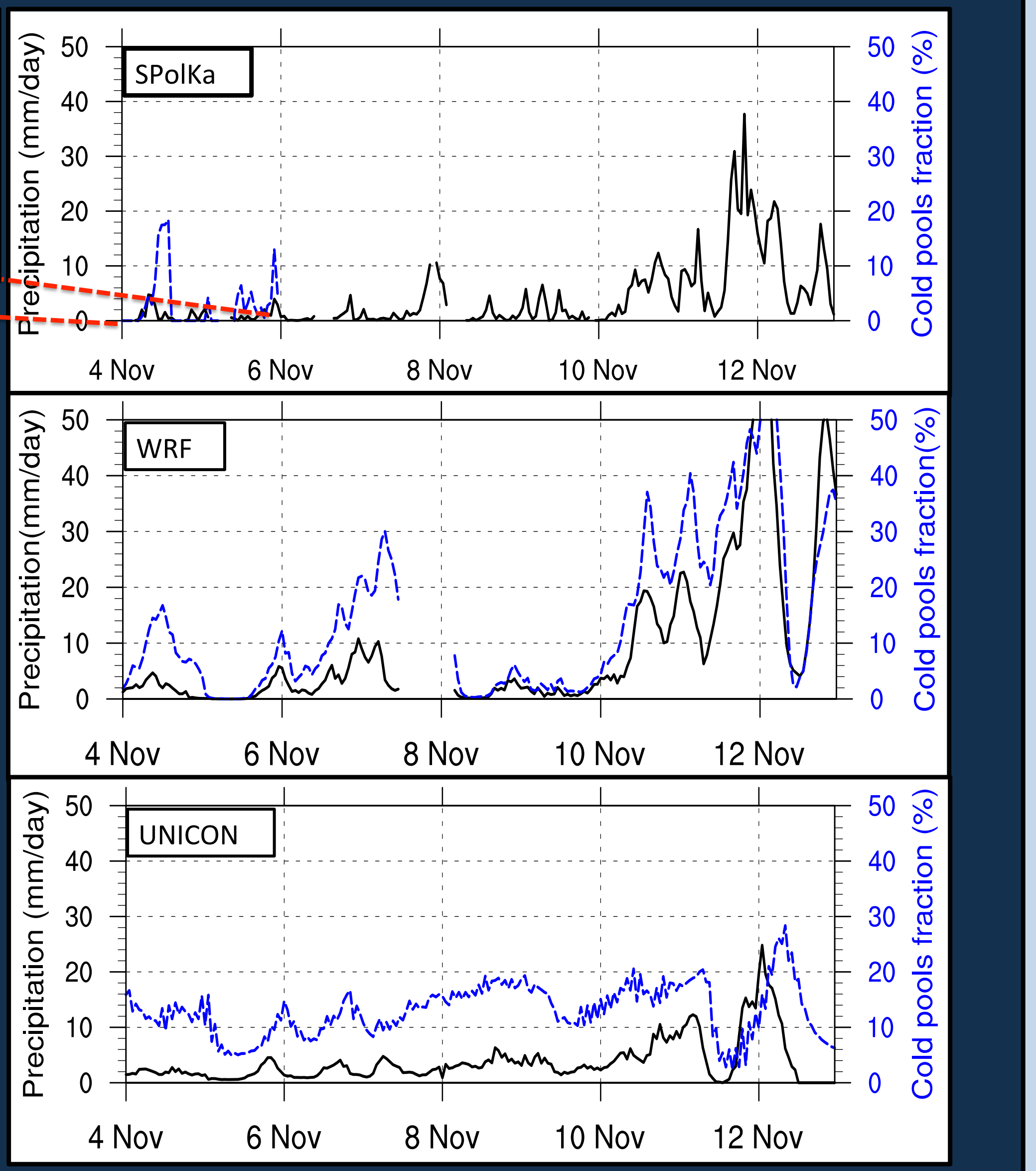


7 Nov 2011, 0600 UTC



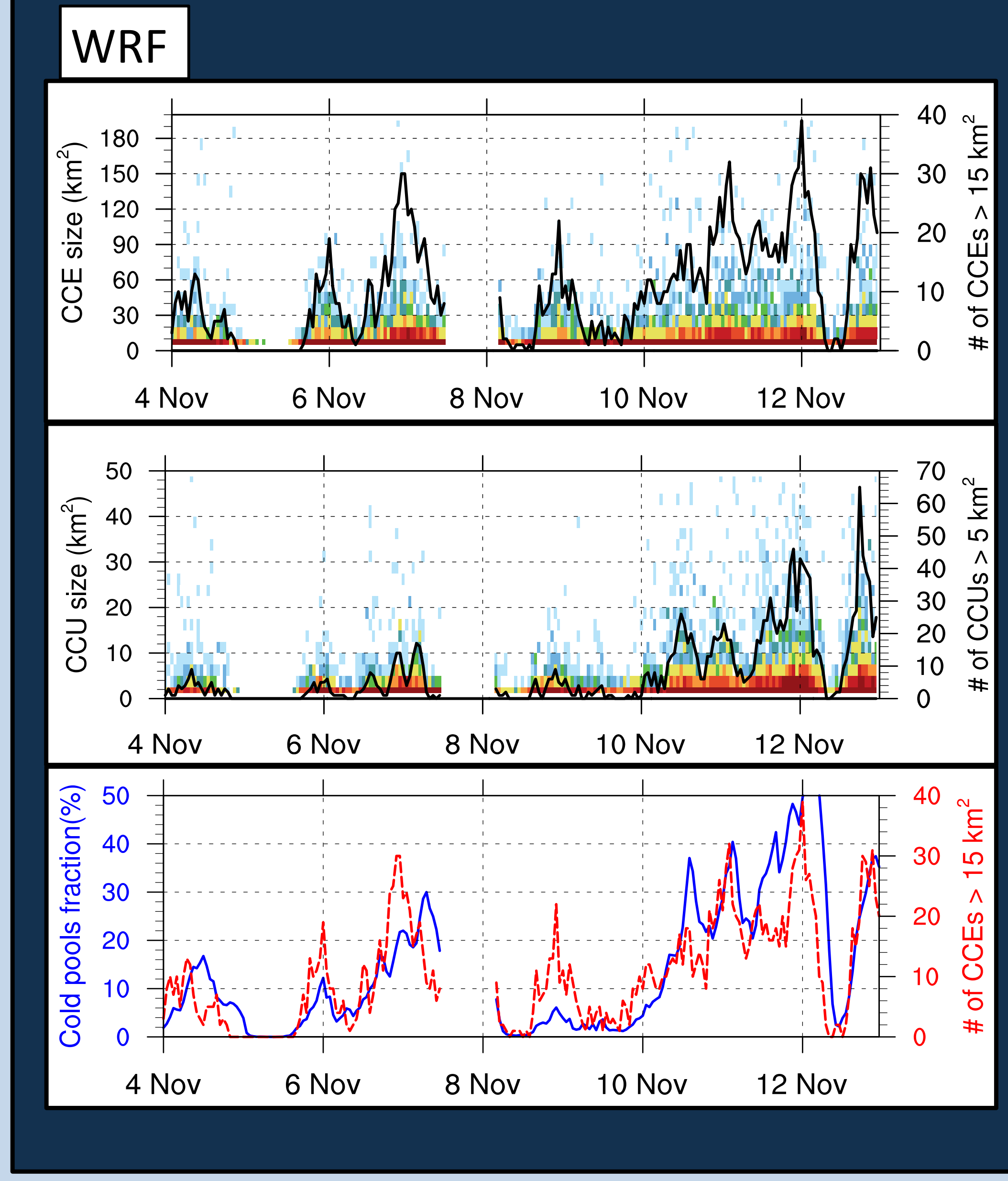
4. RESULTS





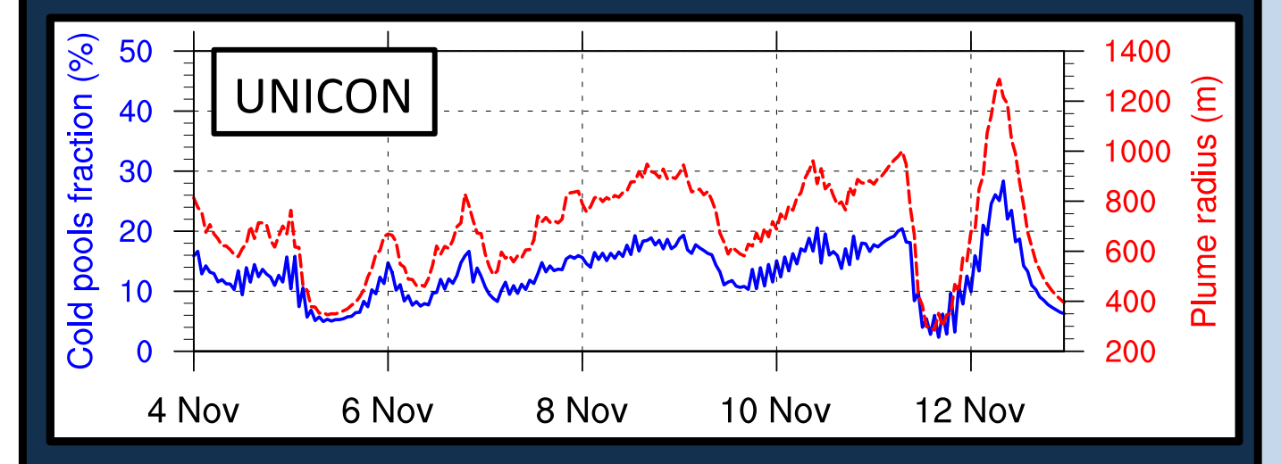
PRECIPITATION and COLD POOLS

- **WRF and UNICON capture observed increase in precipitation throughout suppressed period, with peak event on 11 Nov, but vary in terms of magnitude and timing of individual events**
- **Cold pool fraction timeseries follows precipitation with a few hours lag**
- **UNICON produces the lag, but cold pools tend to persist longer than observed and WRF**



CCEs and CCUs

- **CCE and CCU size distributions vary similarly in time**
- **Increase in large CCEs and CCUs indicative of organization convection**
- **CCE/CCU sizes increase with cold pool fraction in WRF, supporting UNICON's formulation of Ω (organization) and plume radius being linearly proportional to cold pool fraction**



5. CONCLUSIONS

- **SPolKa and WRF cold pool fractions lag precipitation by ~1-2 h; lagging reasonably represented in UNICON but cold pools tend to sustain longer (possibly due to lack of horizontal advection)**
- **SPolKa CCE size distributions vary similarly to WRF CCE sizes, which vary similarly to WRF CCU sizes → all increase with increasing cold pool fraction**
- **UNICON plume radius is linearly proportional to cold pool fraction; this relationship between organization and cold pools supported by radar and WRF results**
- **Future work will extend the analysis to entire AMIE/DYNAMO period, examine the sensitivity of UNICON results to varying evaporation parameters (for example), evaluate cold pool properties in UNICON, and extend this analysis to midlatitude continental cases (MC3E)**

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