Diagnosis of convective organization and cold pools using ARM datasets and evaluation of a unified convection parameterization (UNICON)

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March 15, 2017

Poster #19 in the afternoon

*Acknowledgements: Zhe Feng and Samson Hagos (PNNL)

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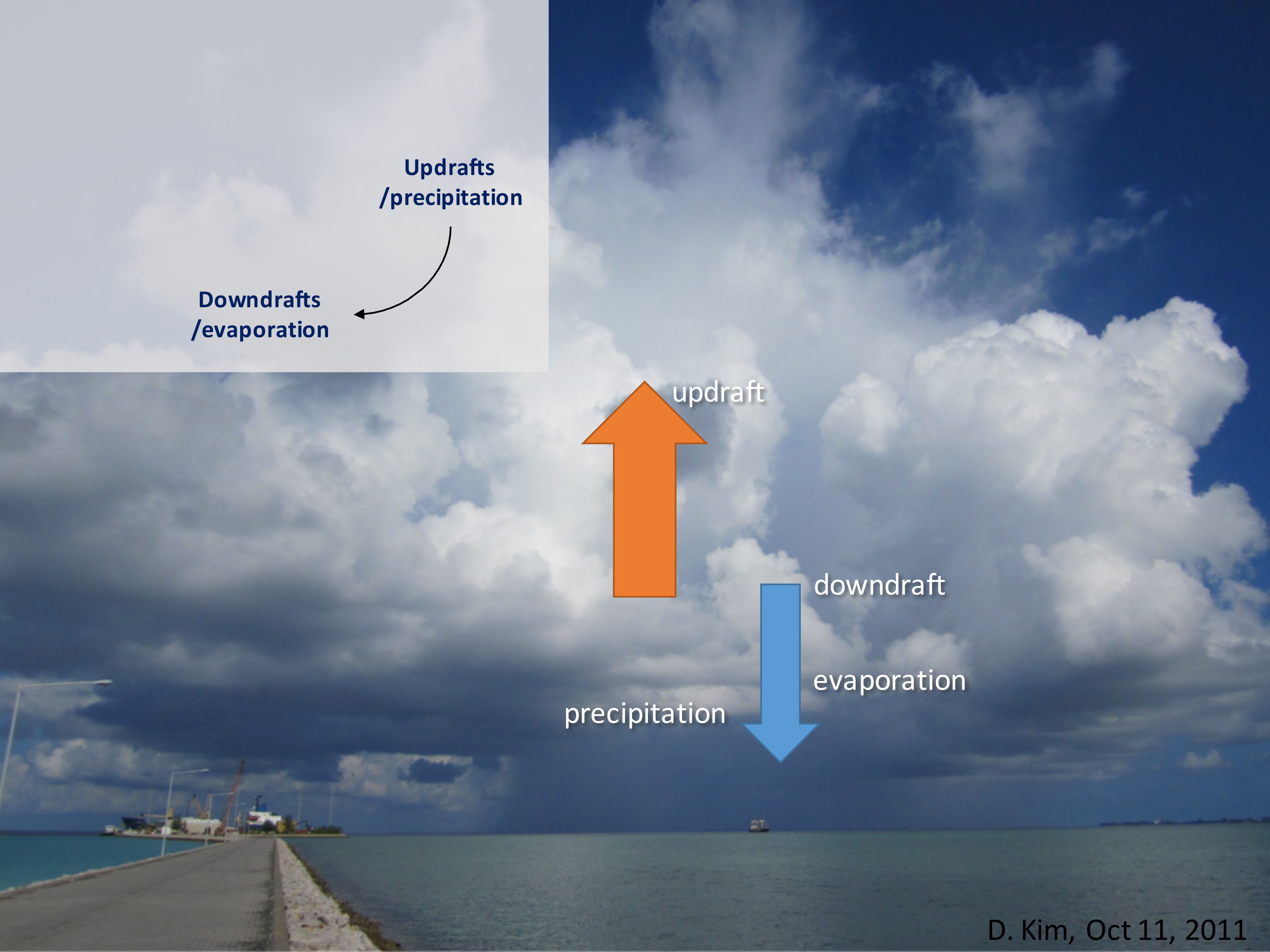
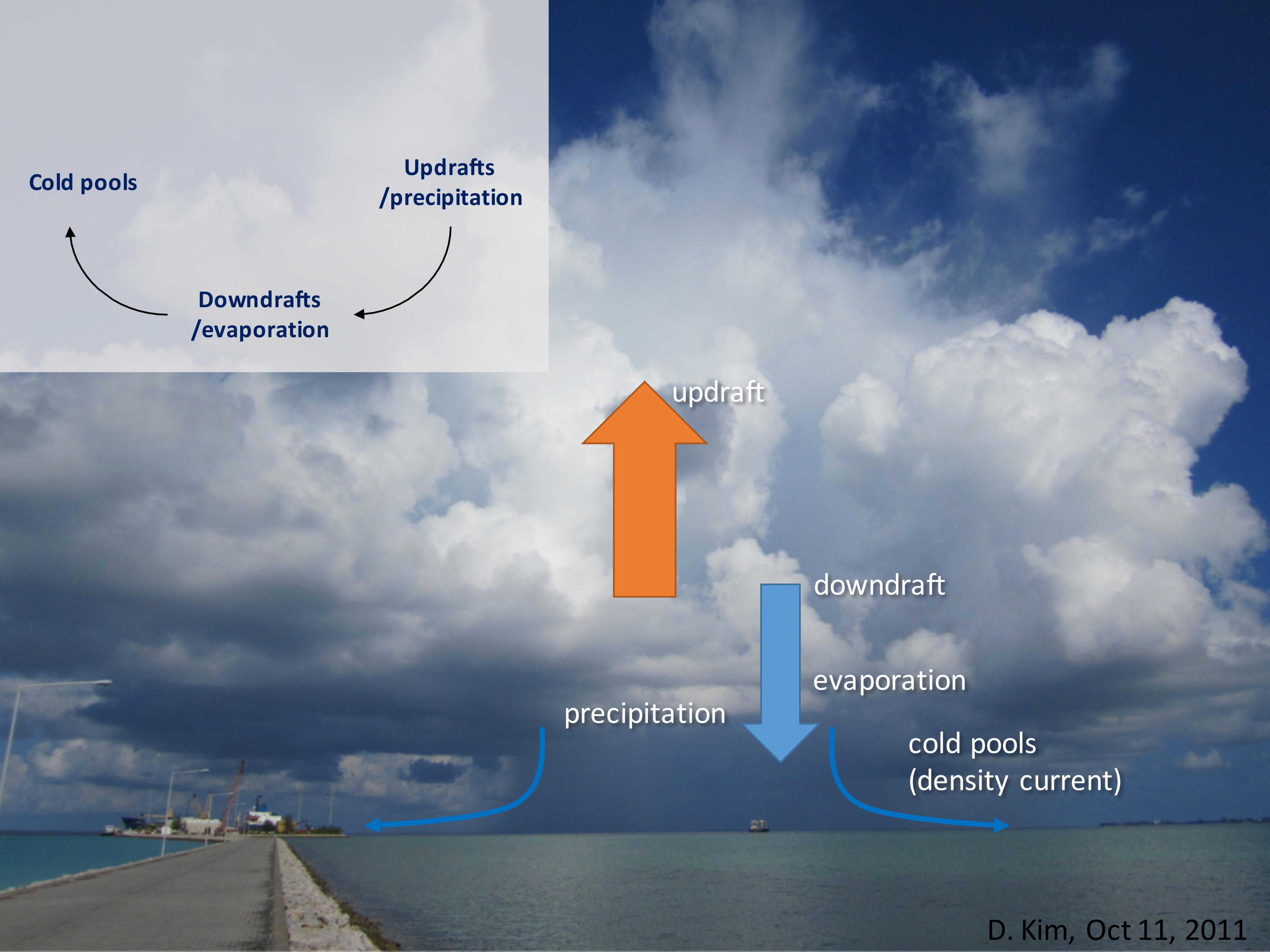
ASR Atmospheric System Research

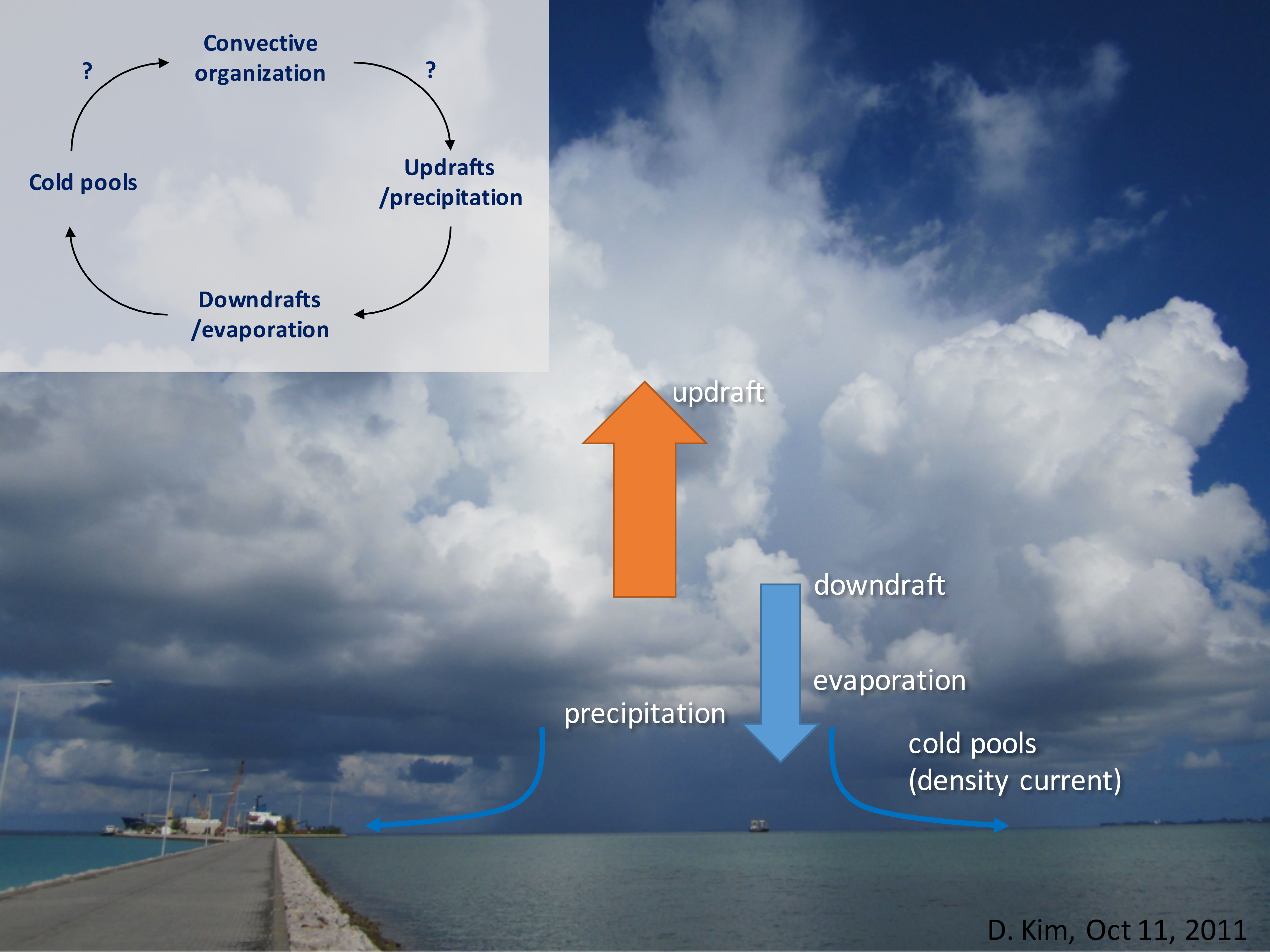
Award #: DE-SC0016223


D. Kim, Oct 11, 2011

Updrafts /precipitation


Updrafts
/precipitation
Downdrafts
/evaporation
updraft
downdraft
evaporation
precipitation
D. Kim, Oct 11, 2011


Cold pools
Updrafts
/precipitation
Downdrafts
/evaporation
updraft
downdraft
evaporation
precipitation
cold pools
(density current)
D. Kim, Oct 11, 2011


Convective organization
?
?
Cold pools
Updrafts /precipitation
Downdrafts /evaporation
updraft
downdraft
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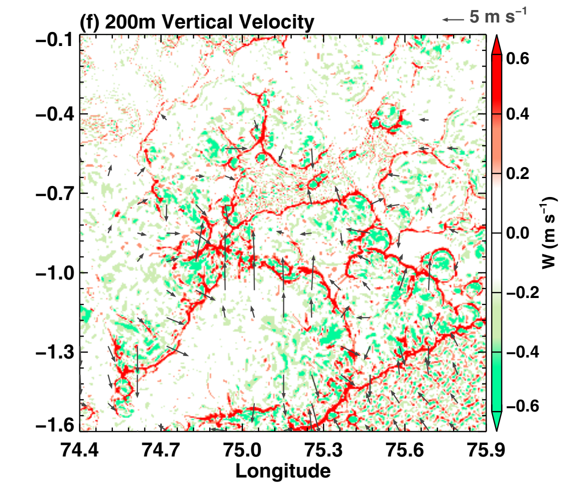
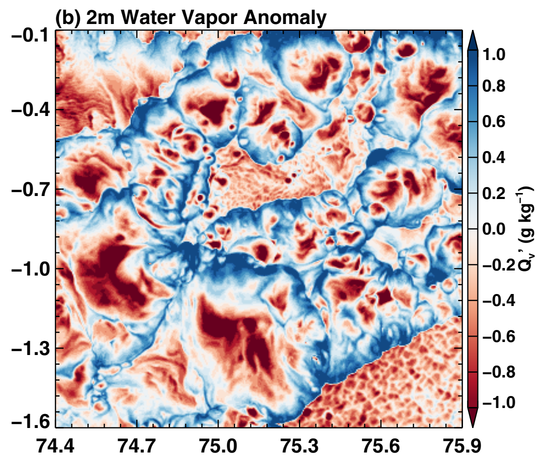
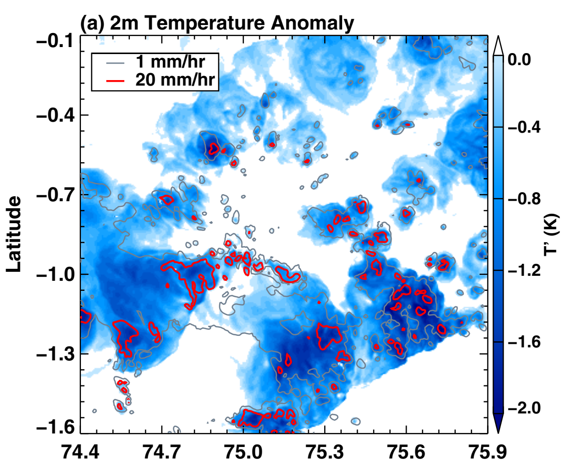
200 m vertical velocity

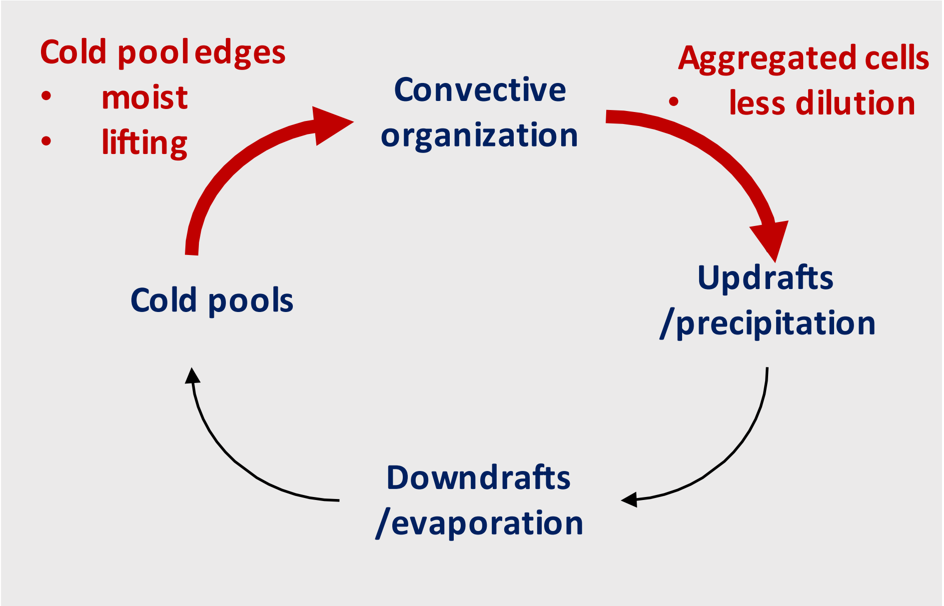


2m Water vapor anomaly



Cold pools

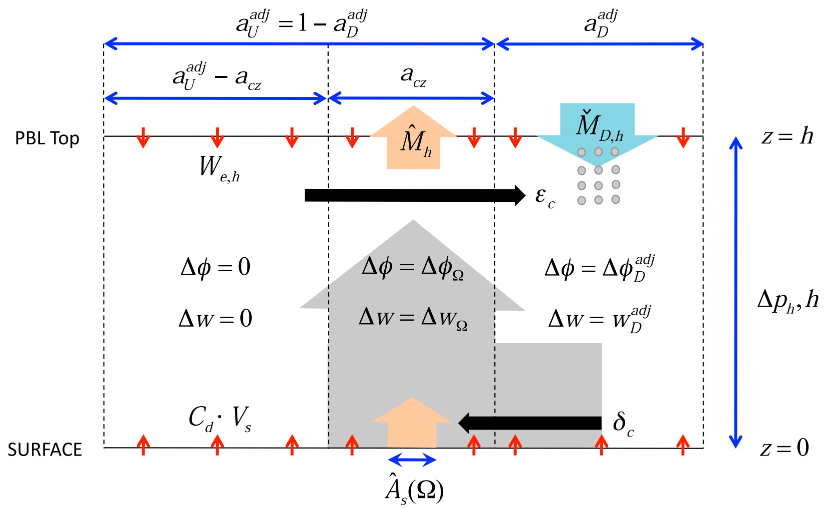


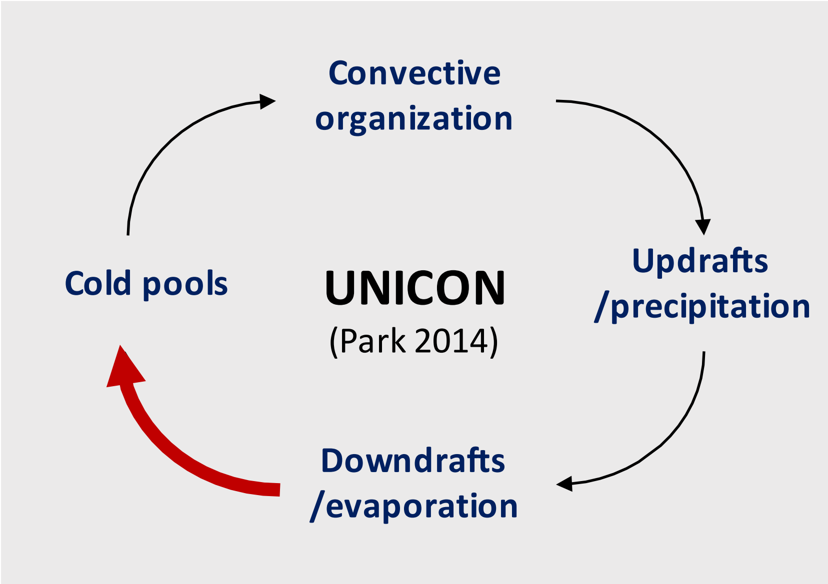


Feng et al. (2015)

Unified convection scheme (UNICON, Park 2014)

Cold pools fraction
: is driven by convective downdraft penetrating into boundary layer





Unified convection scheme (UNICON, Park 2014)

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

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

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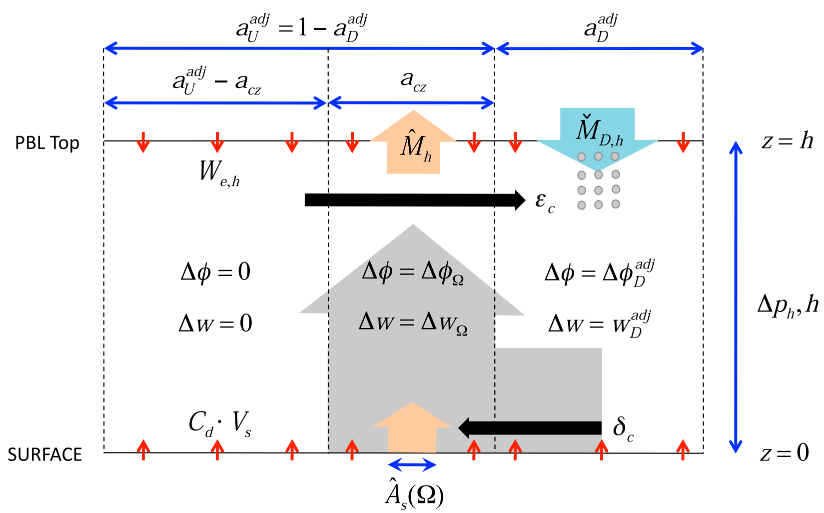

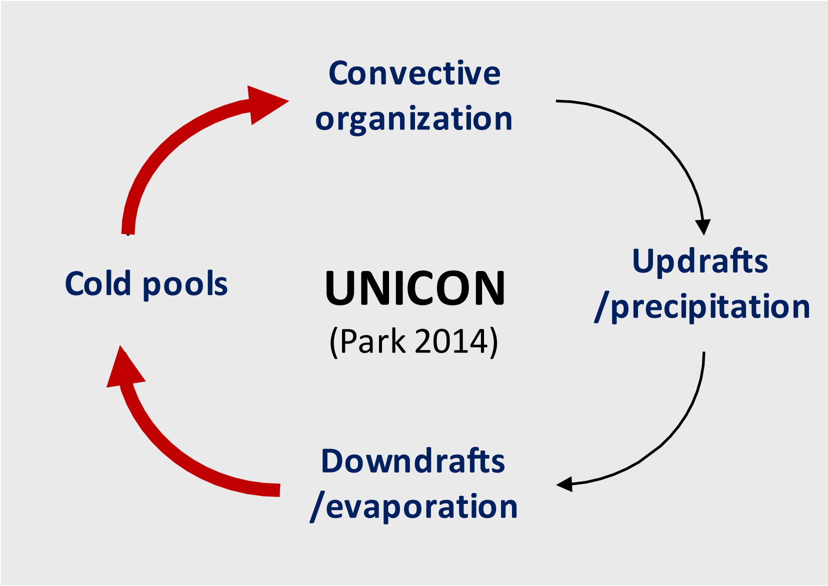

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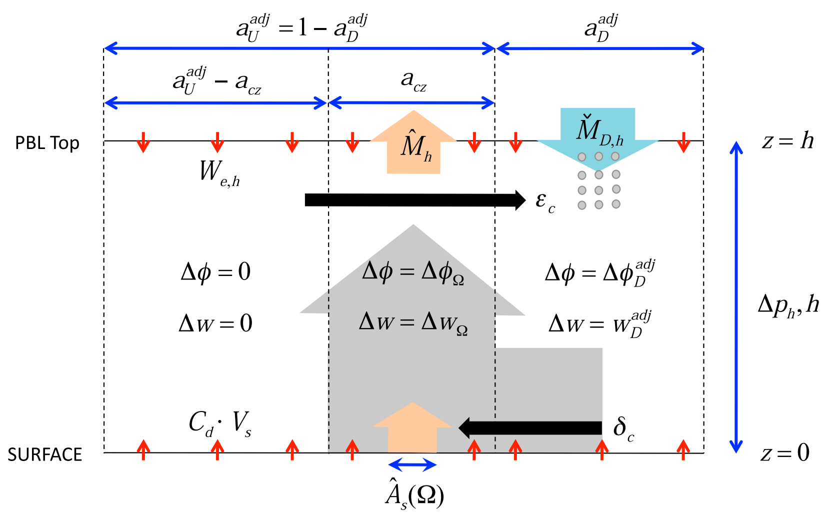
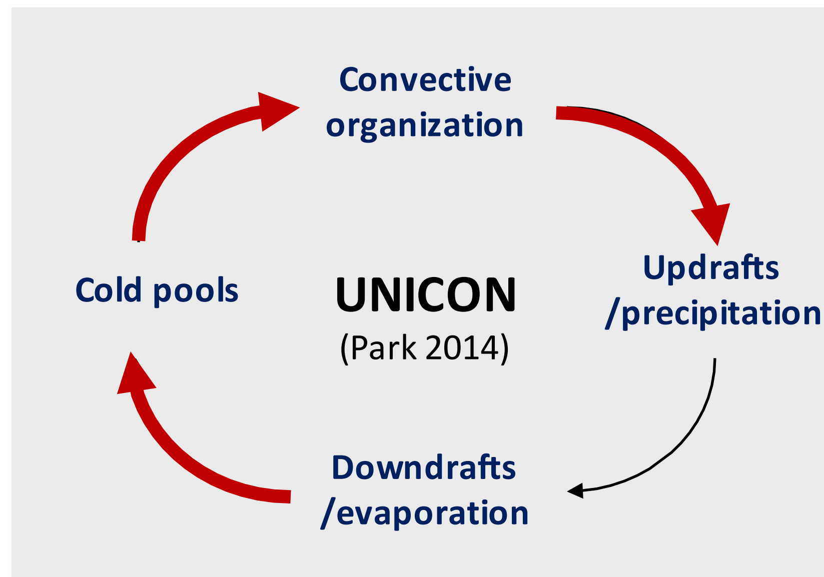


Plume and environmental properties
: affected by Ω

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

Fractional mixing rate
: inversely proportional to plume radius

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



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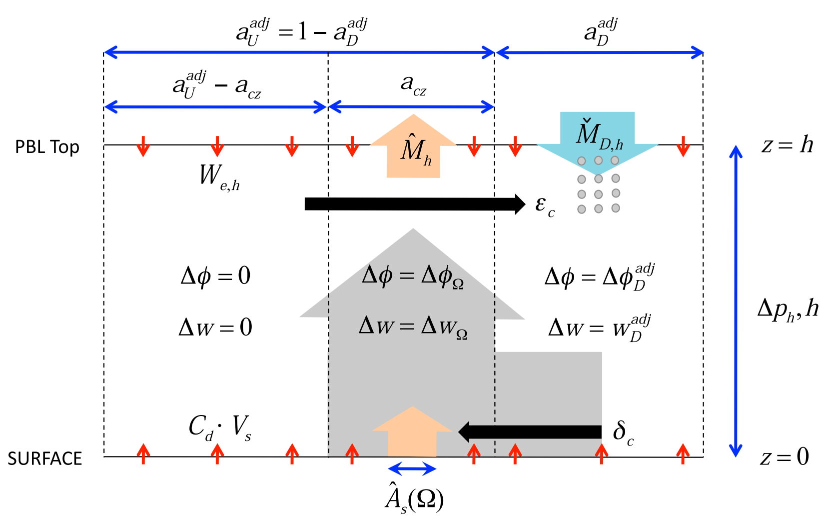

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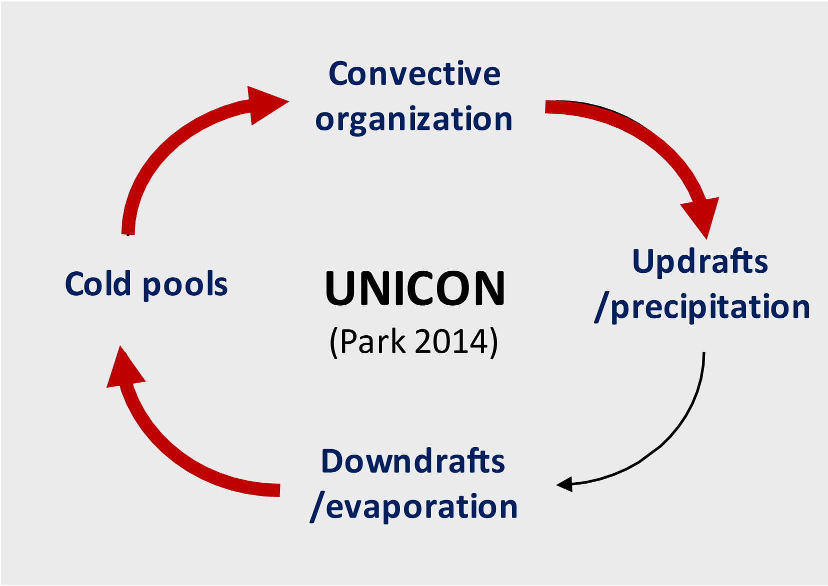
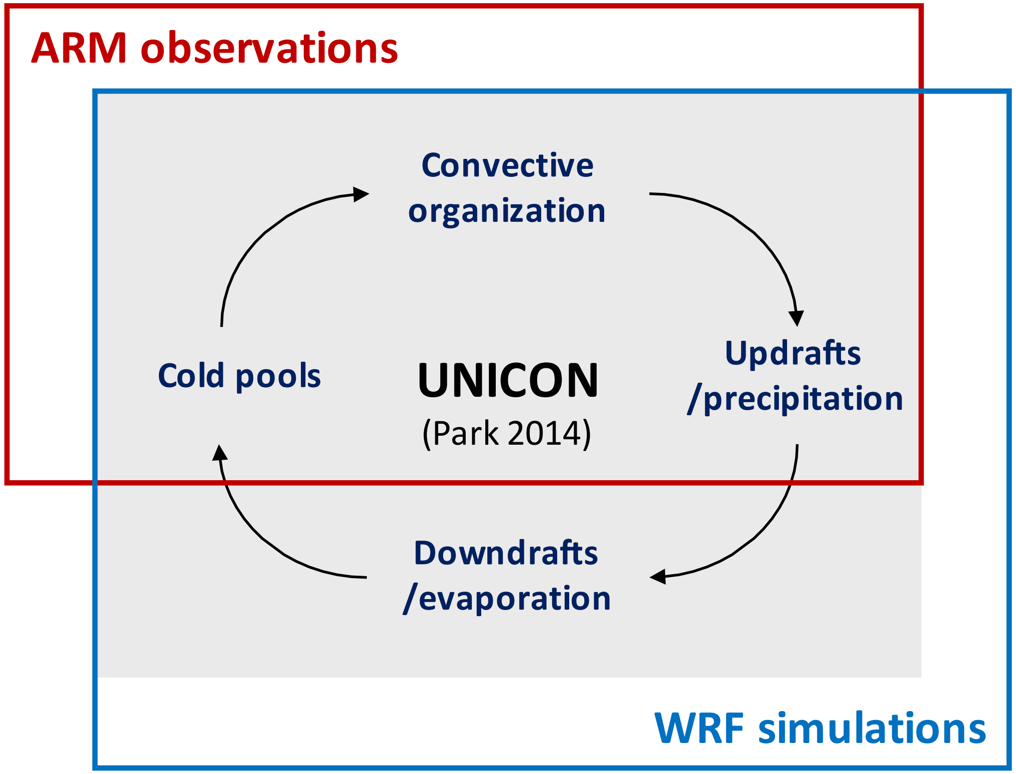


Project objectives



- Diagnose convective organization and cold pool processes over the SGP (MC3E) and central Indian Ocean (AMIE) using the ARM field campaign observations combined with related field campaign datasets (DYNAMO) and high-resolution CRM simulations driven by ARM observations.
- Evaluate processes related to convective organization and cold pools that are explicitly parameterized in a unified convection scheme (UNICON).

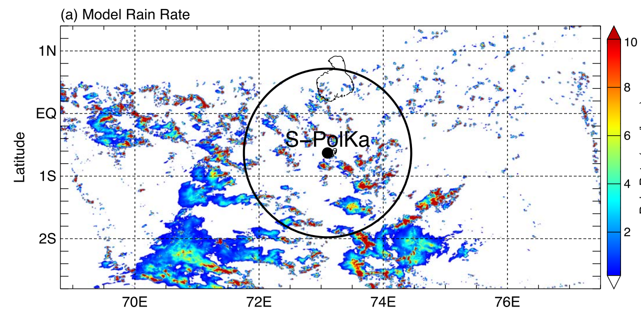
Data and period

SPolKa (AMIE/DYNAMO)

- dual-polarization S- and Ka-band radar
- Addu Atoll in Maldives
- reflectivity interpolated at 1-km resolution
- eastern half of the radar domain

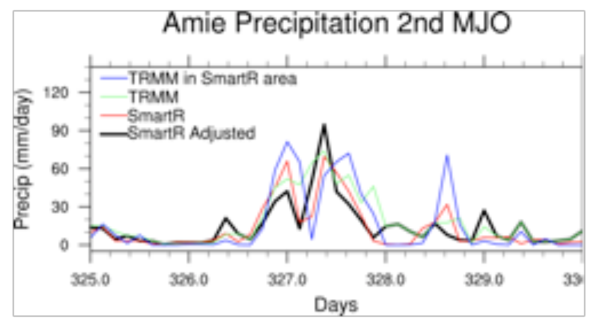
WRF simulation (Feng et al. 2015)

- limited-domain cloud-resolving (500-m) simulation over the central Indian Ocean
- surface rain rate, reflectivity, and temperature



ARM AMIE-Gan large-scale forcing data*

- constrained variational objective analysis
- ECMWF analysis/SMART-R adjusted precip
- omega, specific humidity
- SCM ran in a “semi off-line” mode

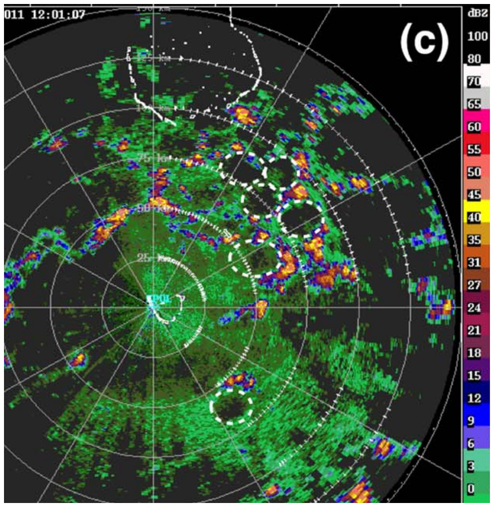


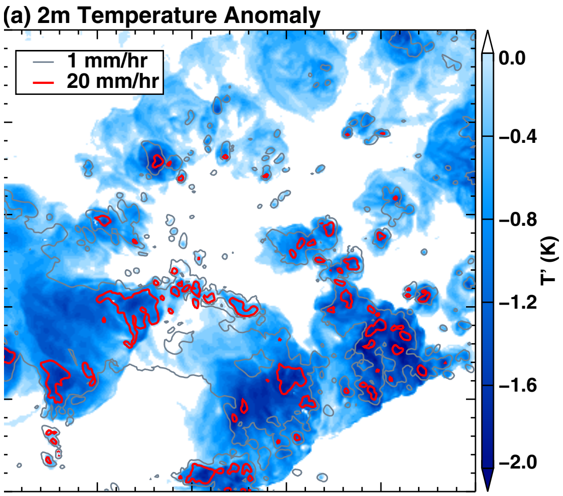
November 4-12: common availability, locally growing convection with negligible stratiform precipitation

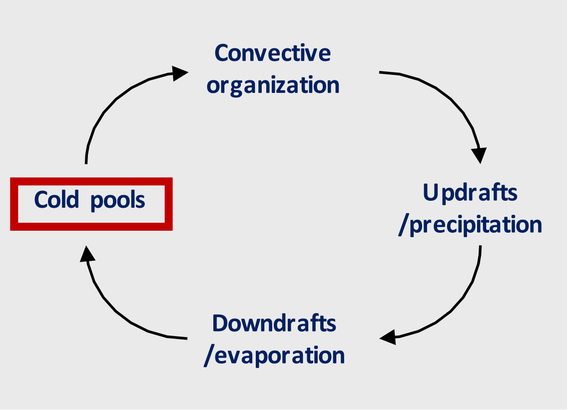
Cold pools identification

SPolKa
- manual tracking (Rowe and Houze 2015)
- fractional area (Nov 4-5)

WRF simulation
- potential temperature' < 0.5 K (virtual T in UNICON)
- fractional area (Nov 4-12)







Feng et al. (2015)

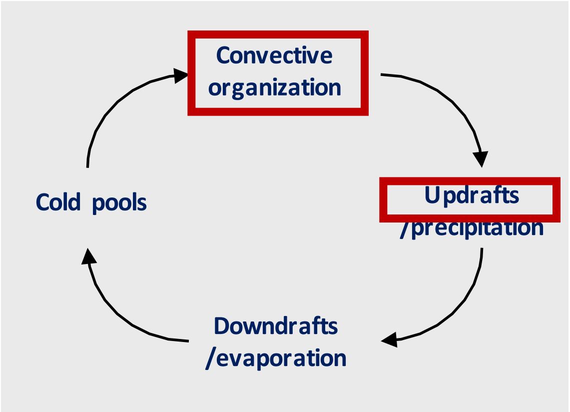
Convective elements: feature-based analysis

Contiguous convective echo (CCE)

- Convective-stratiform classification algorithm (Powell et al. 2016; Steiner et al. 1995)
- Applied to **SPolKa** and **WRF** reflectivity
- Group connected grids of convective echoes
- Minimum size: 2 km^2 (SPolKa), 0.5 km^2 (WRF)

Contiguous convective updraft (CCU)

- Identify grid points with strong enough updraft (>5 m/s, at least 1 km deep) above boundary layer (1 km)
- Group connected grids of 'convective updrafts'
- Applied to **WRF** 3-D vertical velocity fields
- Minimum size: 0.5 km^2



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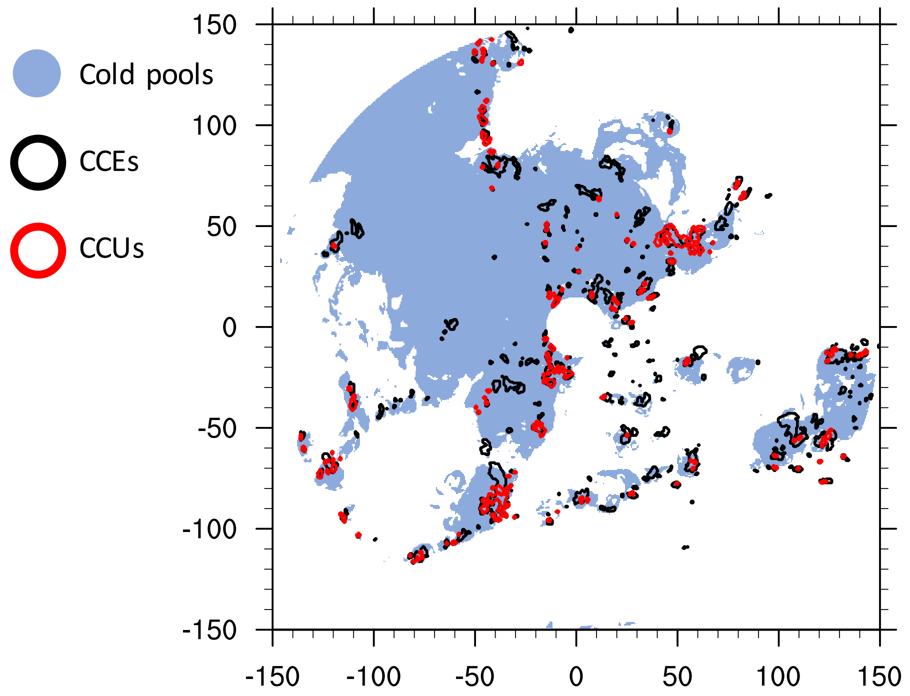
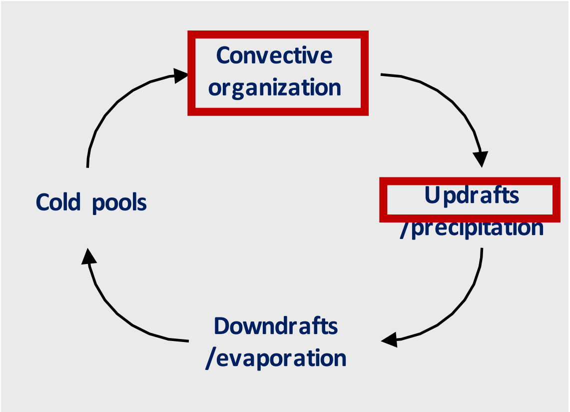
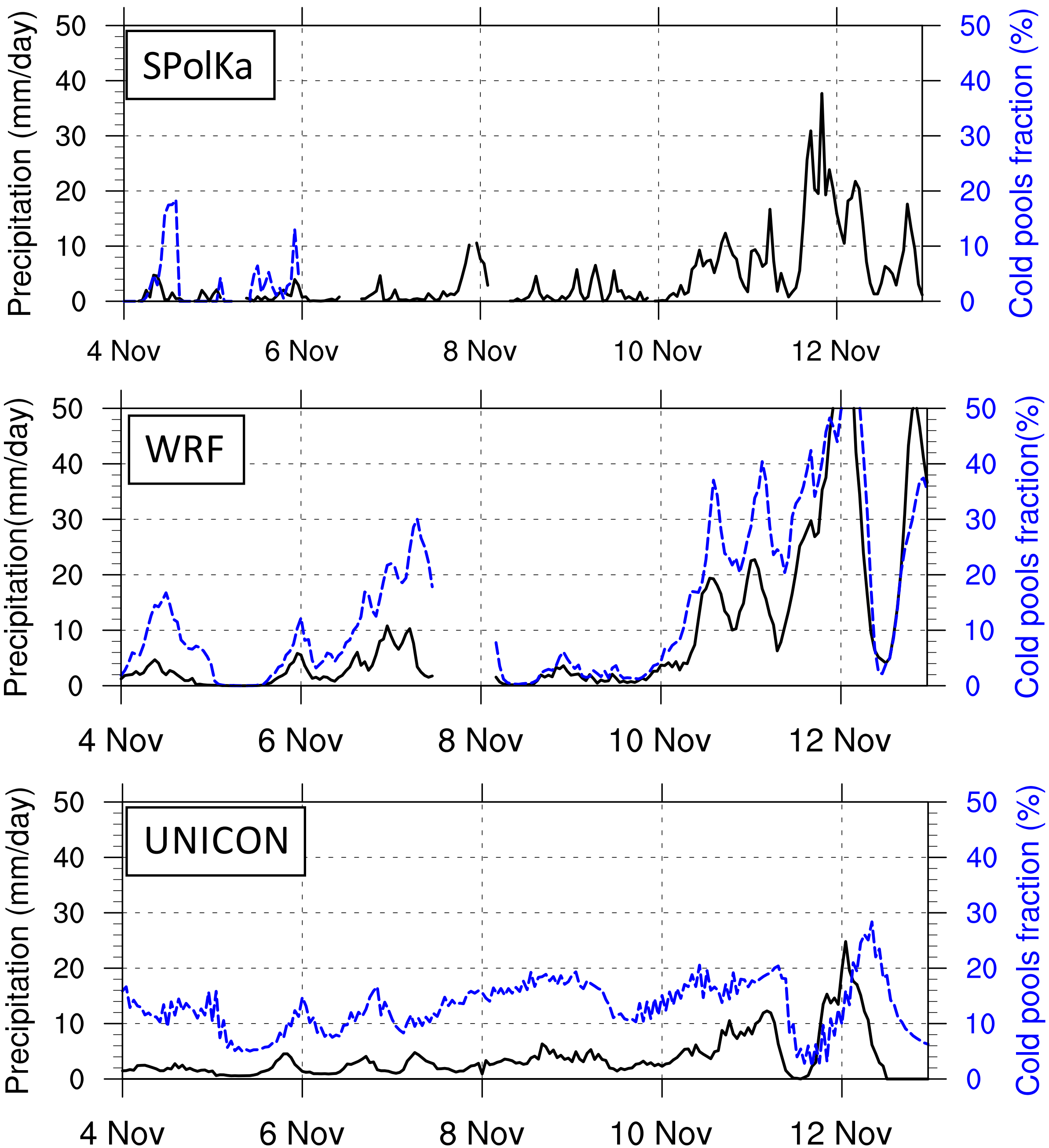
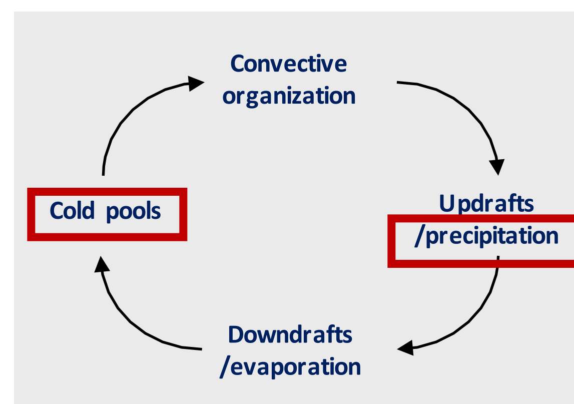


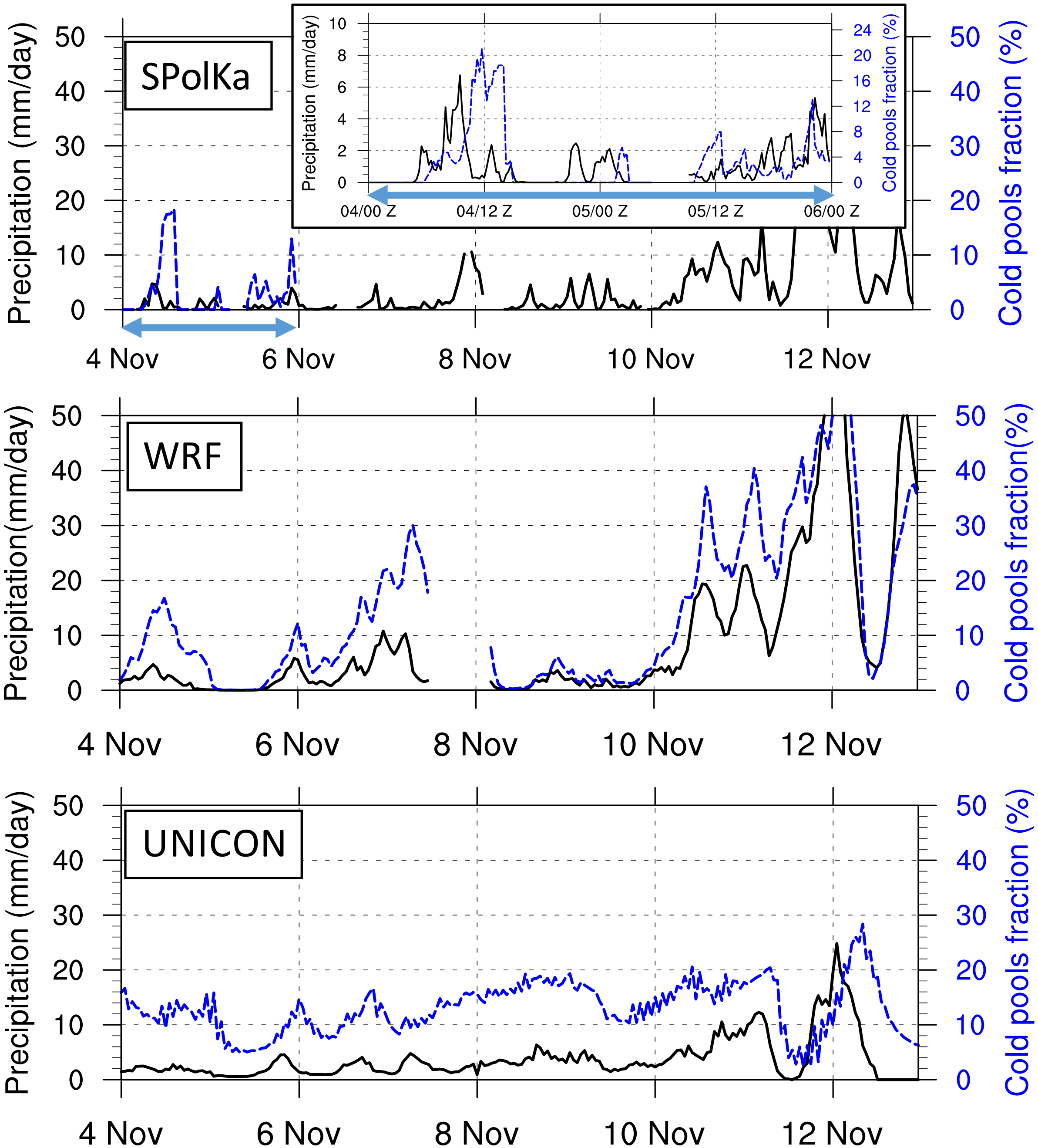




Cold pools fraction lags **precipitation** by a few hours

UNICON shows the lagging while the cold pools tend to persist longer than those in observations and in WRF





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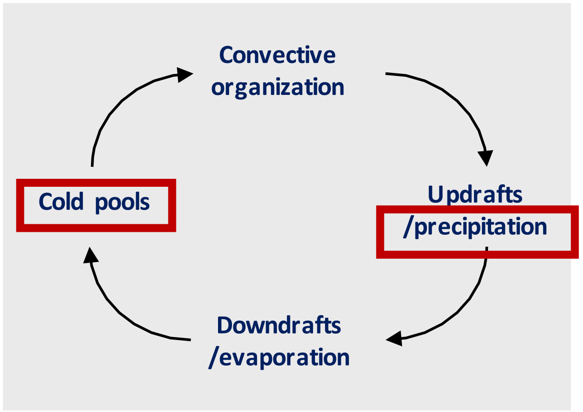
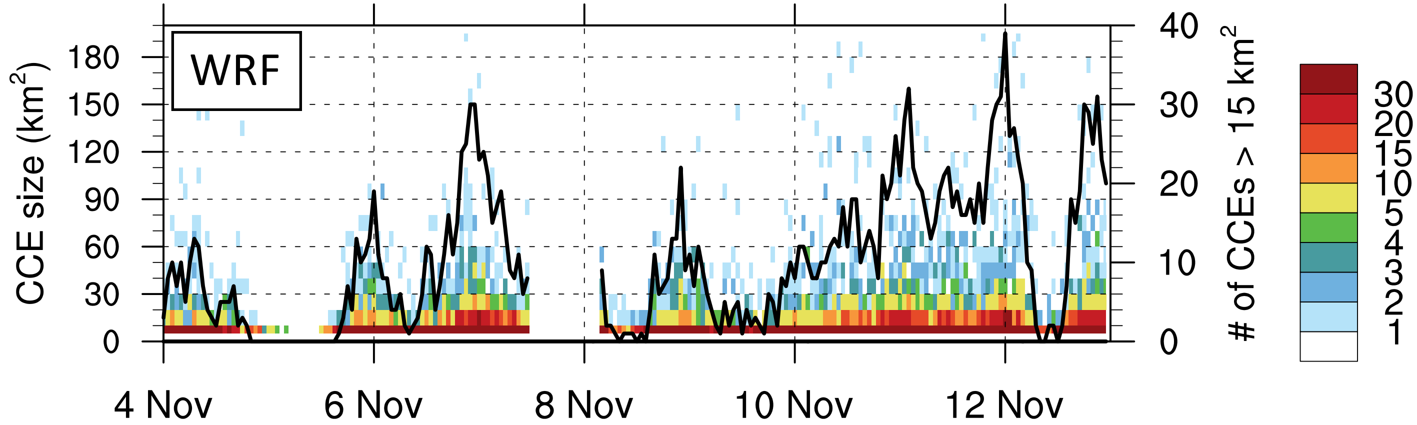
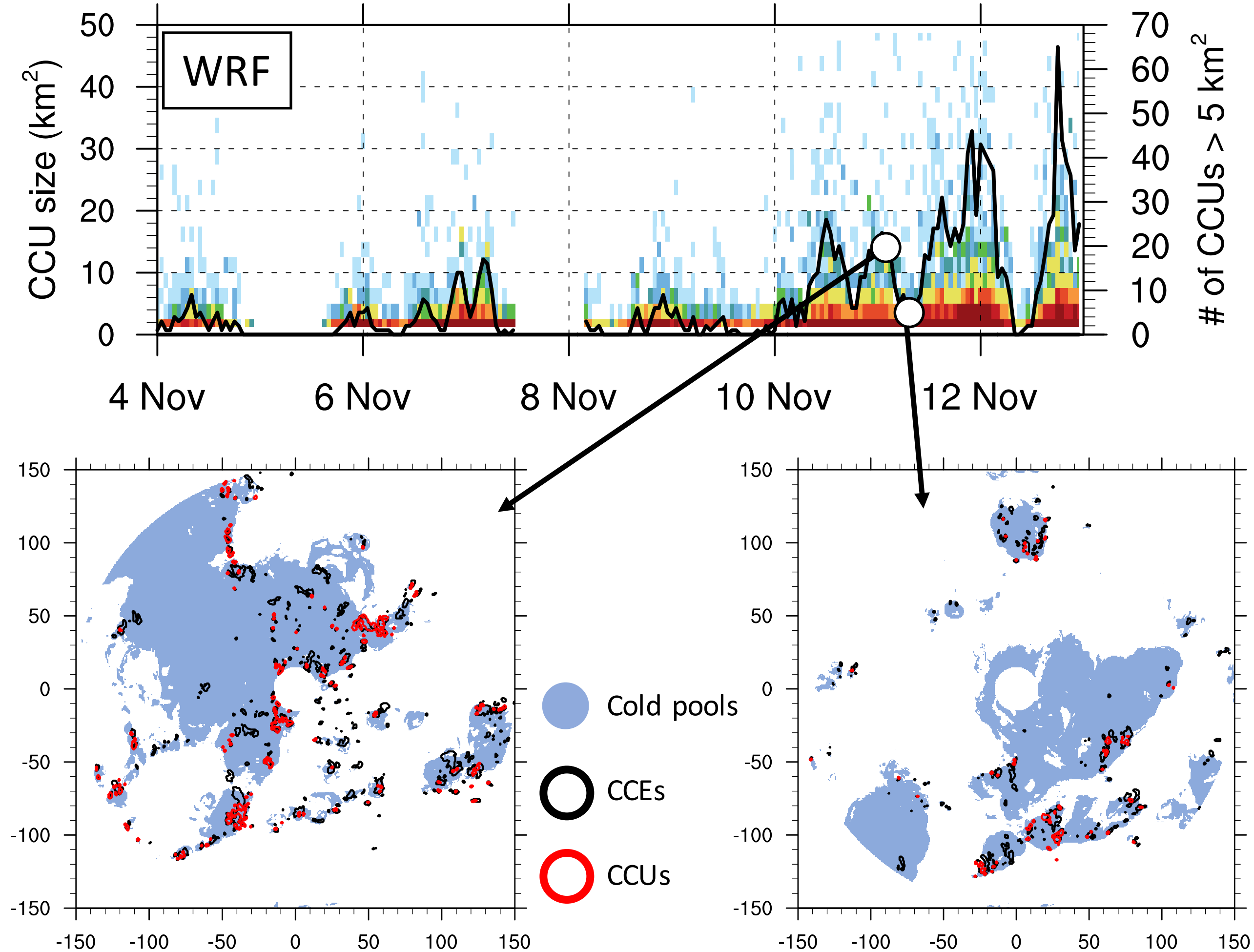
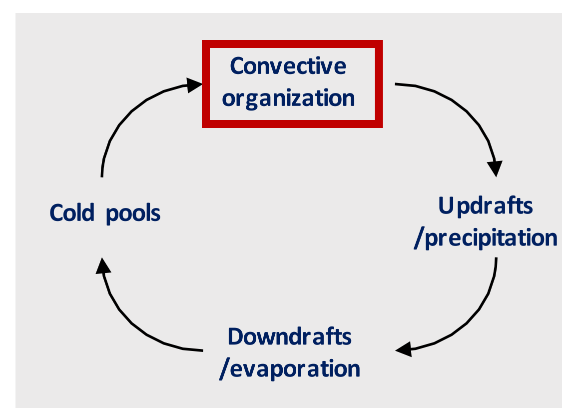


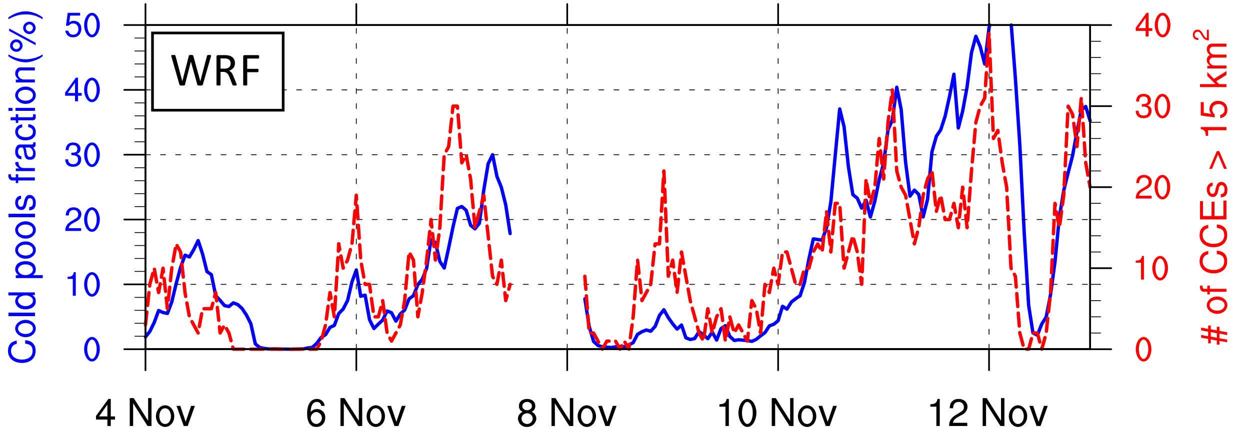




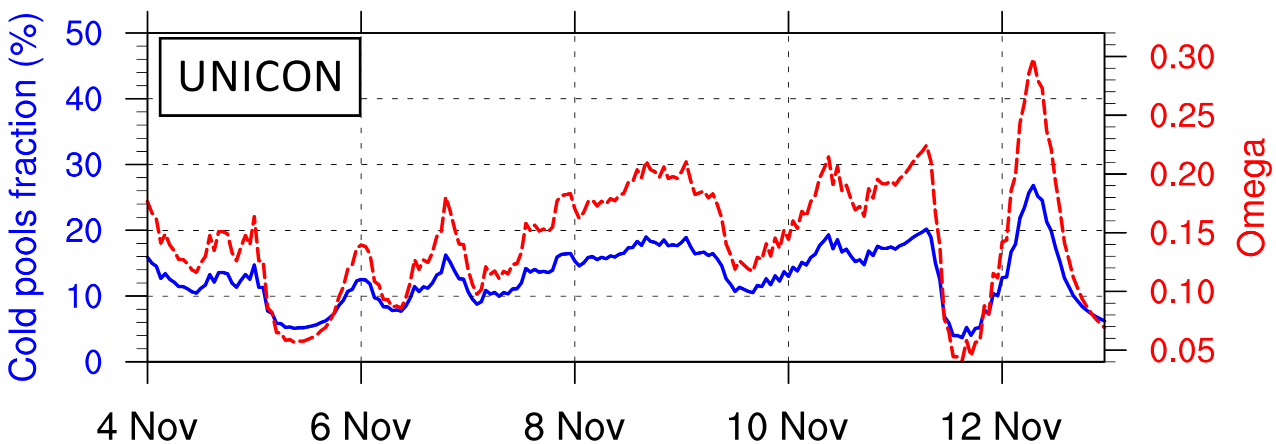
CCE and **CCU** size distributions evolve similarly in time

# of large CCE/CCU
: indicative of aggregated convective elements



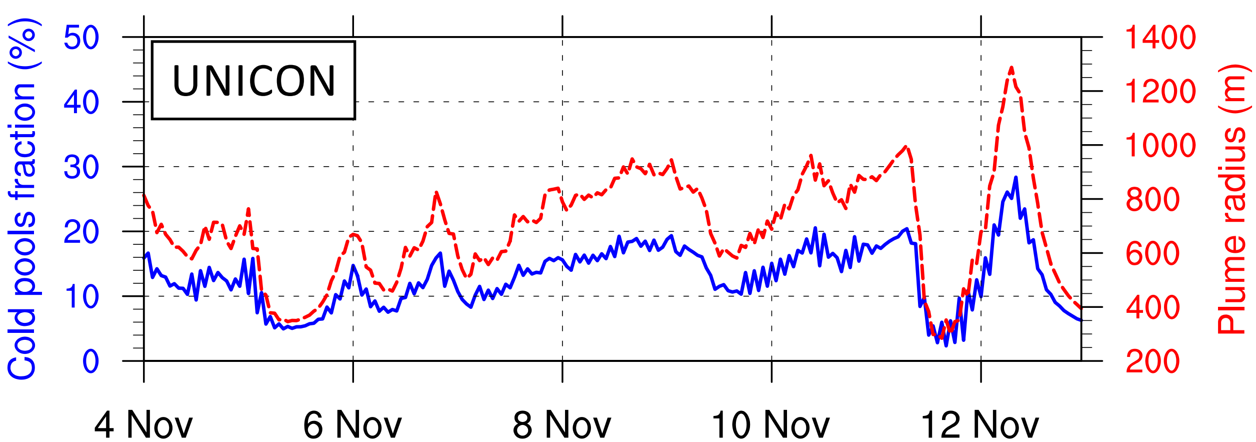


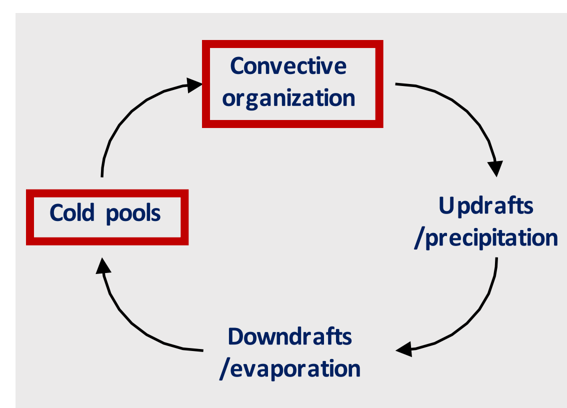
CCE/CCU size increases with cold pools fraction in the WRF simulation



In UNICON, formulation of Ω and plume radius are linearly proportional to cold pools fraction

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



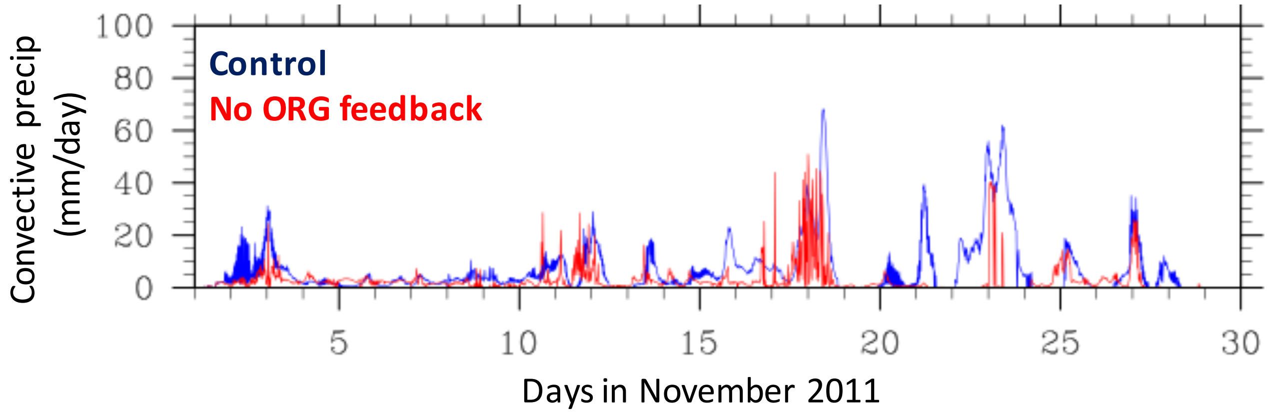


Summary

- Our project aims at evaluating the representation of the two-way feedbacks between convective updrafts and cold pools in UNICON
- Time evolution of precipitation, CCE/CCU size distribution, and cold pools fraction during AMIE/DYNAMO is examined using radar observations, a high-resolution WRF simulation, and a single-column model (UNICON) simulation forced with the ARM AMIE-Gan large-scale forcing
  *UNICON was not tuned for our study
- **Precipitation vs. cold pools fraction**
  - In SPolKa and WRF, cold pools fraction lags precipitation by a few hours
  - UNICON represents the lagging, while the cold pools tend to persist longer than that in observations and in the WRF simulation (possibly due to the lack of horizontal advection)
- **Cold pools fraction vs. CCE/CCU/plume size**
  - In WRF, CCEs and CCUs show similar time evolution in their size distributions and the number of large CCEs/CCUs (indicative of degrees of convective organization) increases with cold pools fraction
  - The WRF results support UNICON's formulation of the degrees of convective organization (Ω), which is linearly proportional to cold pools fraction

Future plan

- **AMIE/DYNAMO**
  - extend the analysis to the entire AMIE/DYNAMO period
  - high-resolution WRF simulations forced with the ARM AMIE forcing dataset
  - examine sensitivity of UNICON results to, for example, efficiency of rain re-evaporation in downdraft, and evaporation
  - evaluate cold pool properties in UNICON (e.g., temperature and specific humidity perturbation)

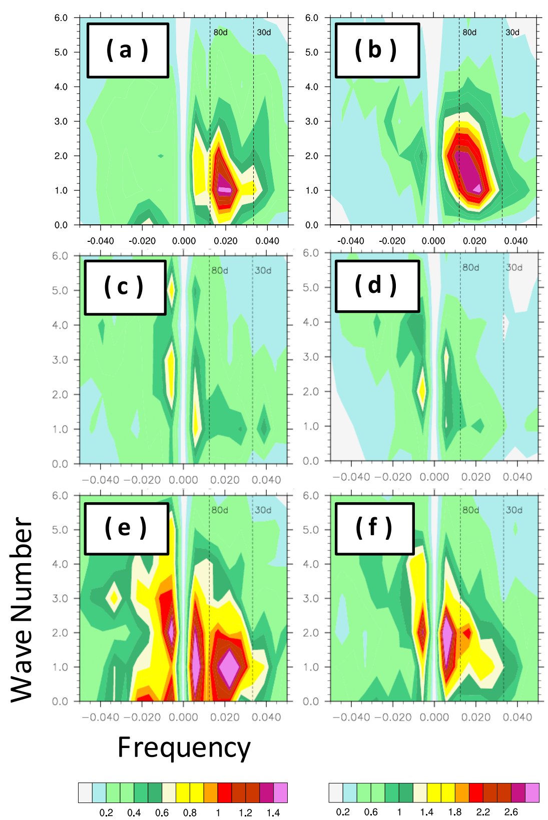


- **MC3E (Jensen et al. 2016)**
  - investigate the convection-cold pools interaction in a continental environment

UNICON global simulation results

Madden-Julian Oscillation

Summer Winter



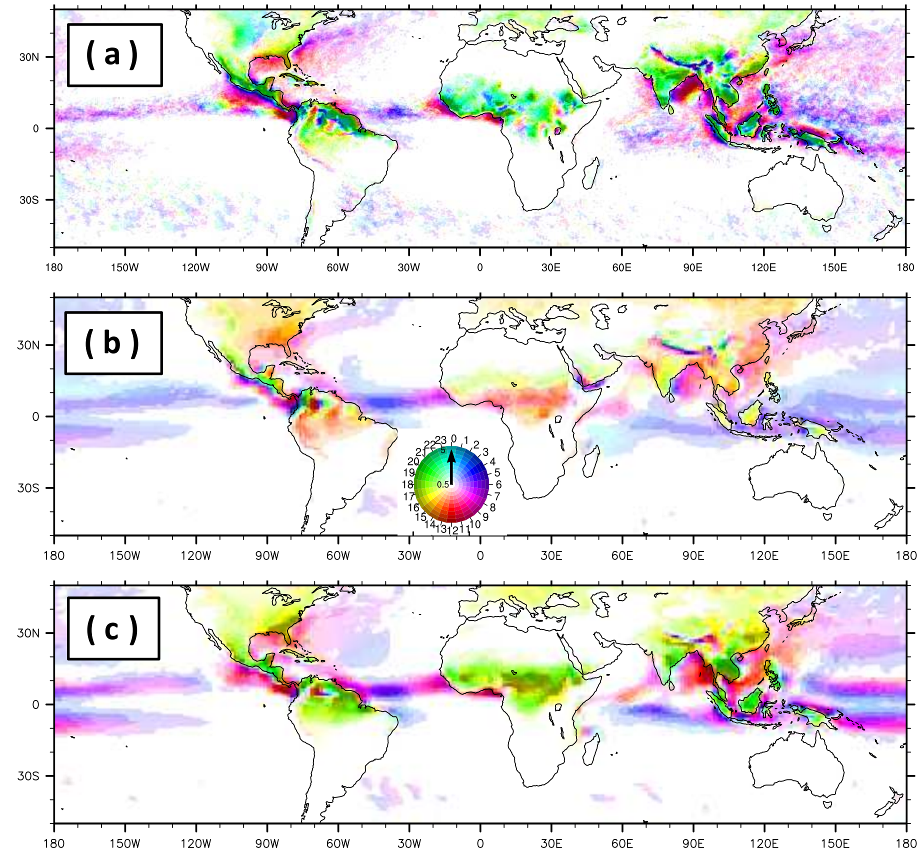
OBS

CAM5

UNICON

Diurnal Cyclone of Precipitation

JJA



Park 2017. Journal of Climate. In Preparation

The Impact of a revised fractional mixing rate on the climate simulated by the UNICON

Type A cold pools parameterizations where scalar variables are used to represent the two-way interaction between convection and cold pools without explicit representation of cold pool properties

Work	Source of cold pool energy	Variable used	Changes to plume properties as the value of the variable increases
Piriou et al. (2007)	Evaporation of convective precipitation	$\varsigma\,(z)$	Entrainment rate decreases
Mapes and Neale (2011)		org	Plume base temperature perturbation, base mass flux and radius increases

Type B cold pool parameterizations where cold pool properties are explicitly represented

Work	Source of cold pool energy	Impacts of cold pool on convection
Qian et al. (1998)	Evaporatively-driven convective downdraft penetrating down into boundary layer	Provides vertical velocity at the top of cold pool front to convection scheme
Grandpeix and Lafore (2010)		Convection occurs in 'unperturbed' sub-domain of a grid cell and cold pools provide additional lifting energy to boundary layer air parcel
Park (2014) UNICON		Cold pools affect plume radius, temperature, specific humidity, and vertical velocity perturbation through a scalar that represents the degree of mesoscale convective organization
Del Genio et al. (2015)		Scheme's less-entraining plume is triggered only when cold pools exist