Ensemble of Radiative-Convective Equilibrium Simulations near the Marginal Boundary between Aggregated and Scattered Regimes

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Abstract

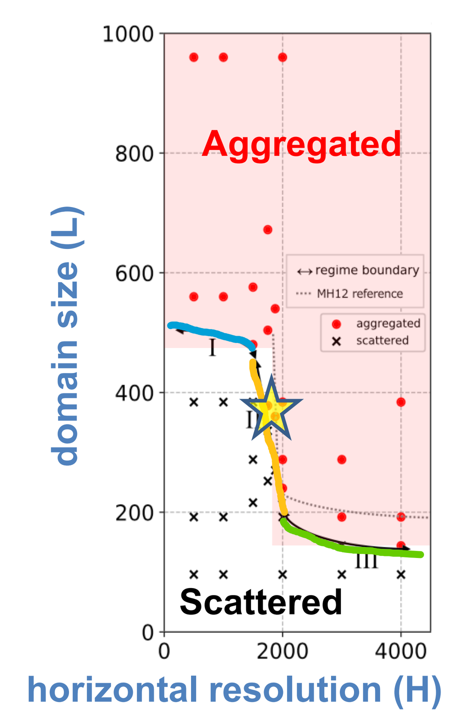
Ensemble of ten RCE simulations near the sharp transition zone between scattered and aggregated states are examined in SCALE-RM.

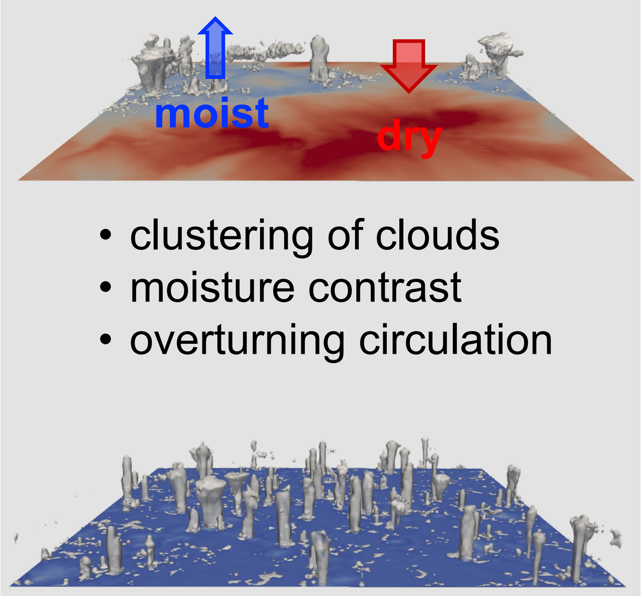
- Surprisingly, **occurrence of self-aggregation (SA) is not deterministic near the marginal boundary**: 6 aggregated & 4 scattered runs.
- Development of **moisture contrast in boundary layer (BL)** is the key indicator for SA. To reach aggregated state, a part of BL needs to be sufficiently dry and extensive to suppress convection triggered by cold pools.
- Marginal behavior of RCE near the transition boundary shows that **convective organization, moisture aggregation, & large-scale overturning circulation** each operate at different temporal and spatial scales.

Introduction

Dependence of SA on domain-size & resolution

RCE Regime Diagram Muller & Held (2012), Yanase et al. (2020)





- clustering of clouds
- moisture contrast
- overturning circulation

Line II & Line III : Muller and Held (2012)
- SA only occurs when L > 200 km & H > 2 km

Line I : Yanase et al. (2020)
- SA occurs regardless of H, if L > 500 km

How strict is the boundary line between aggregated & scattered regimes?

Model & Experiment Design

Model: SCALE-RM 5.3.6

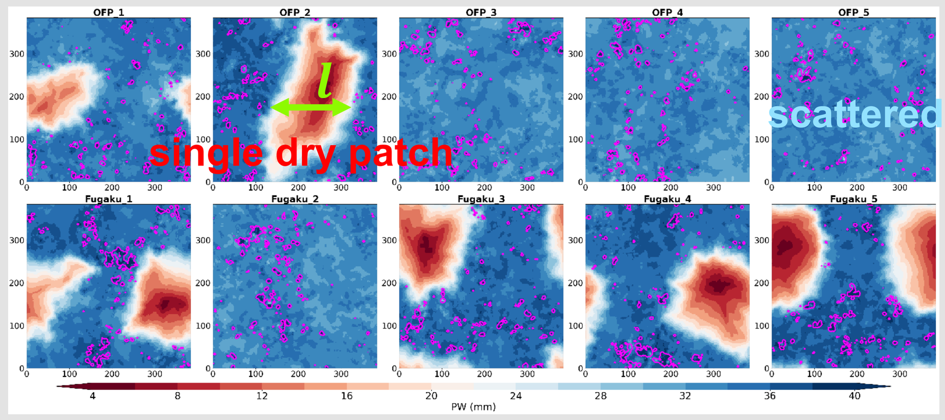
RCEMIP (RCE model intercomparison project)
- fixed SST = **300K**, uniform solar insolation
- uniform initial conditions + random noises
- zero wind

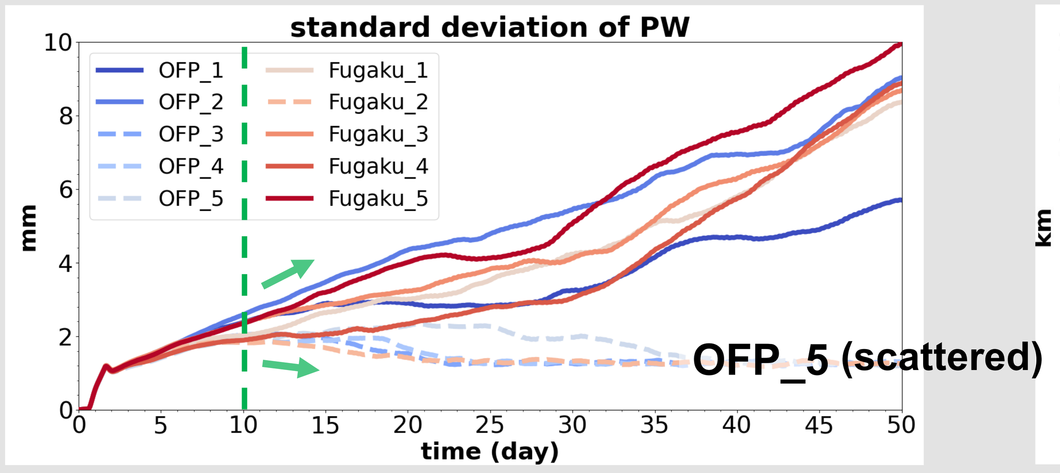
Ensemble Simulation
- 5 runs each in Oakforest-PACS (OFP) & Fugaku
- square domain: **L = 384 km , H = 2 km**

Results

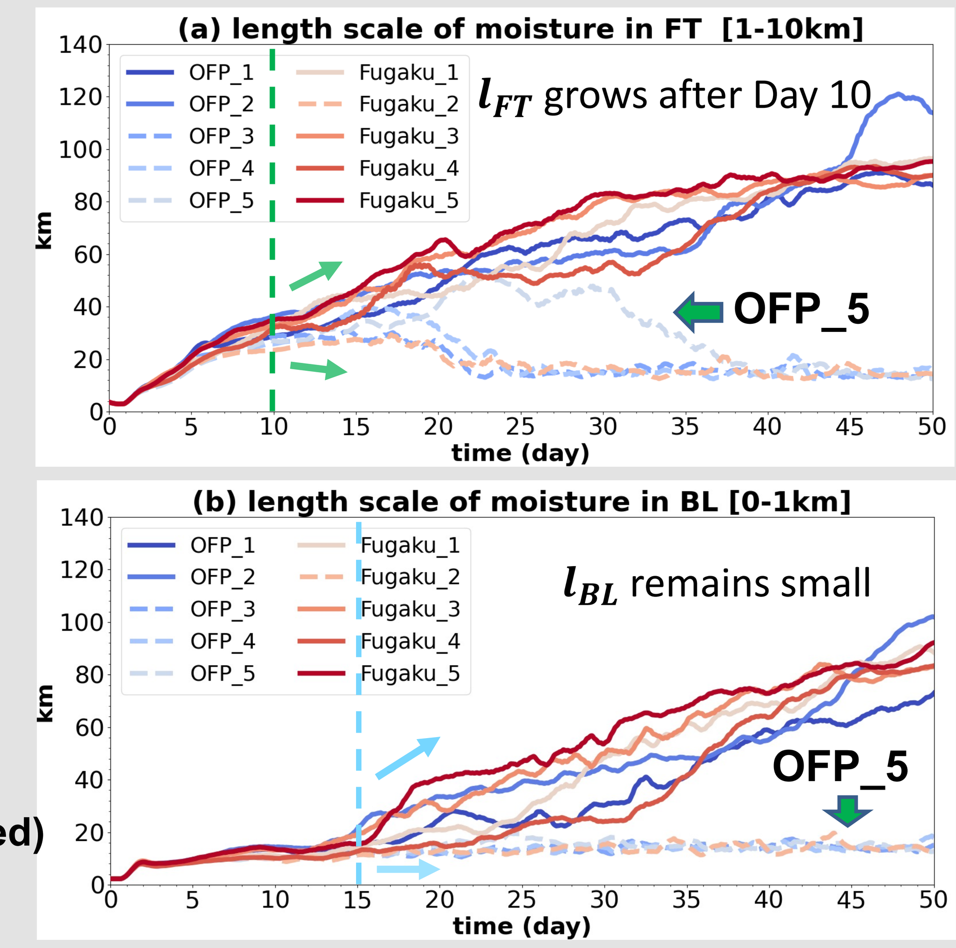
➢ **Evolution to distinct RCE states**

PW at Day 100 (pink ctr: precipitation, 10 mm/d)





➢ **Autocorrelation length of moisture: free troposphere (FT) vs. BL**



FT variation dominates spatial variance of column moisture, but the **development of BL moisture contrast is the key for the transition from scattered to aggregated state.**

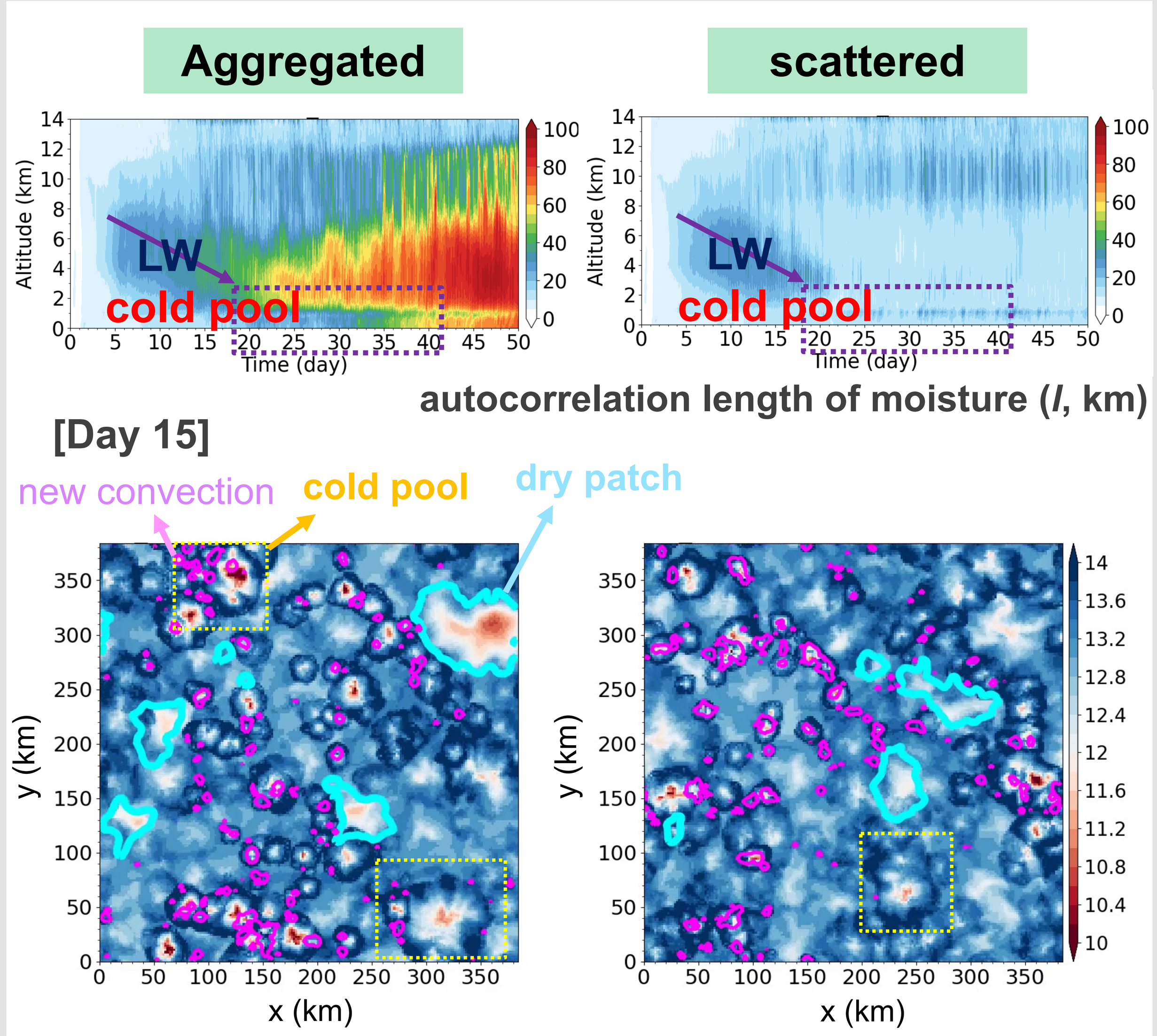
➢ **What controls the expansion of dry patch?**

Coppin & Bony (2015), Yanase et al. (2020)

two competing mechanisms
(+) **drying by radiative subsidence**
(−) **homogenization by cold pools**

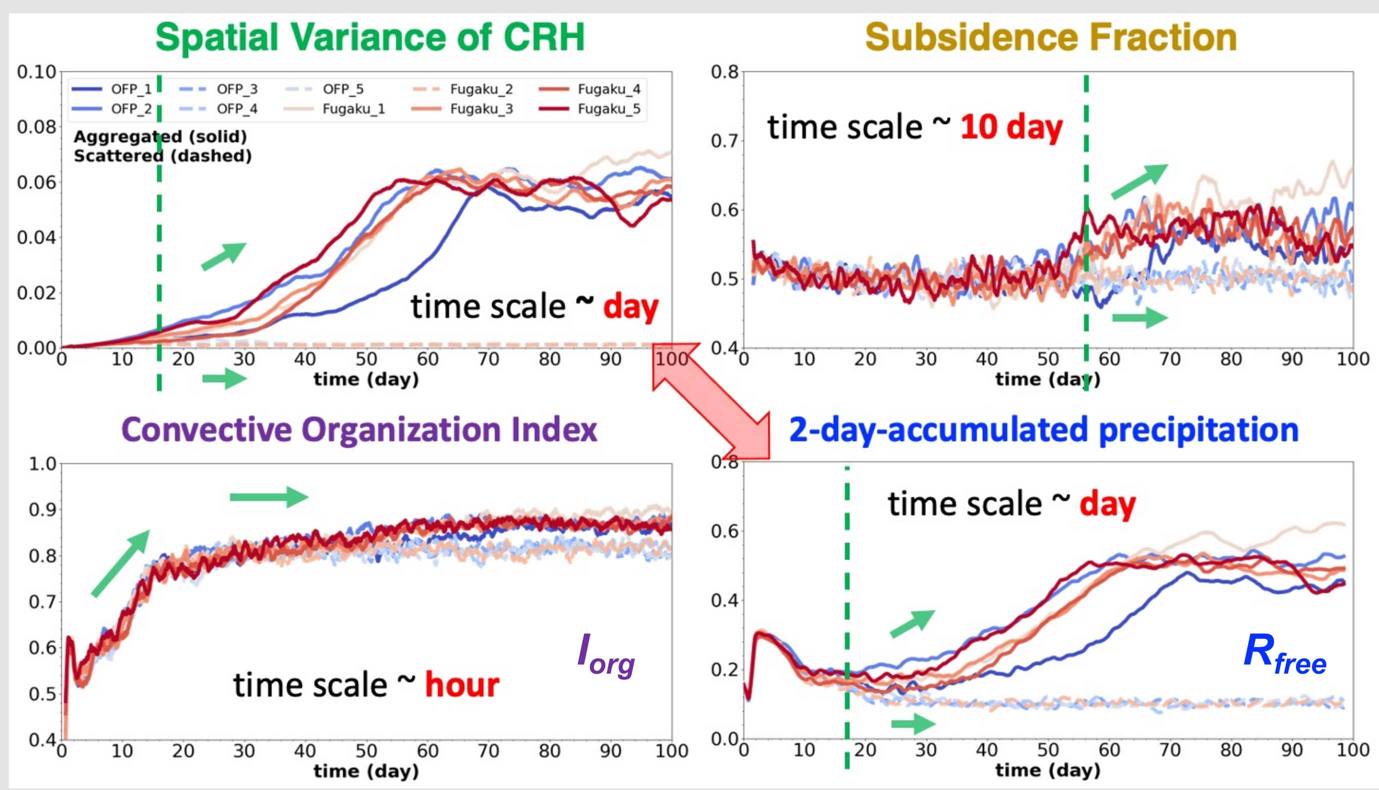
- **Aggregated**: extensive dry FT & BL suppress convective triggering by cold pools. Dry patch grows through positive moisture-LW radiative feedback.
- **Scattered**: BL isn't dry & extensive enough to suppress convection triggered by cold pools. Convection develops in dry patch & destroys dry anomalies in FT.

shading: BL moisture
blue ctr: FT moisture (18 mm)
pink ctr: precipitation (10 mm/d)



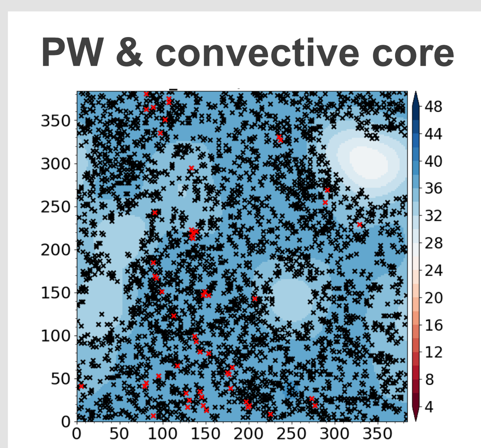
Discussion: comparison of SA indices

Time series of 4 SA indices (Wing et al., 2020) three essential scales



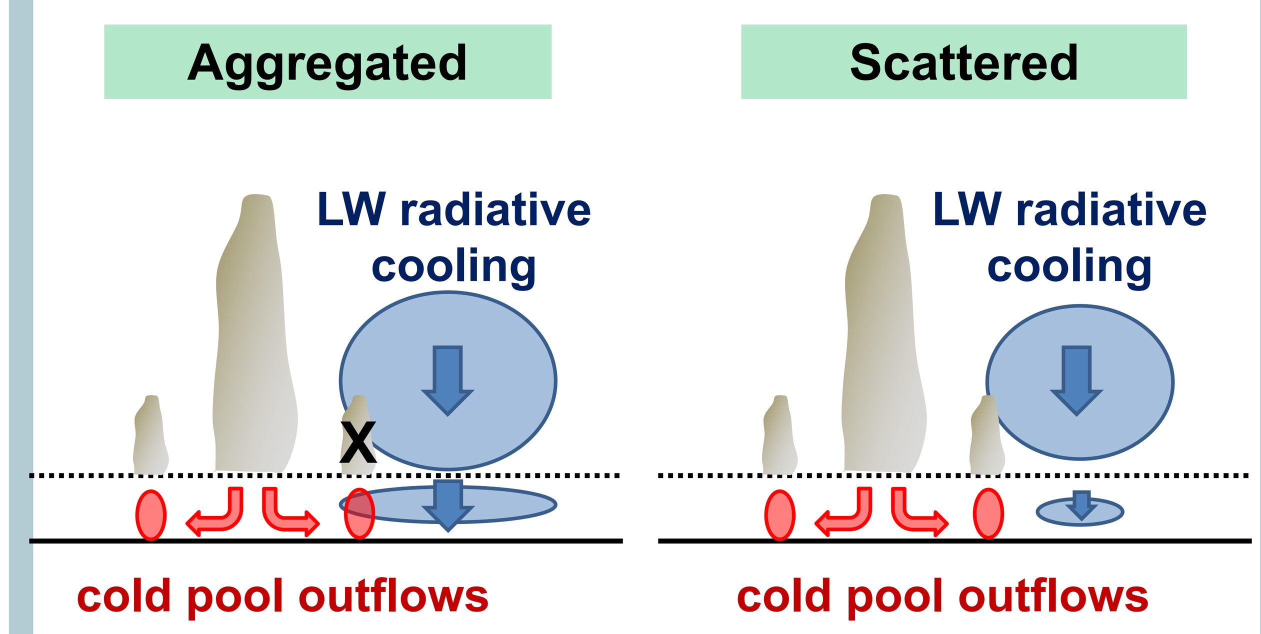
I_{org}: convective clustering related to clod pool dynamics [smaller, shorter time scale]

R_{free}: convective clustering related to moisture [larger, longer time scale]



x: hourly snapshot
x: 2-day-accumulated

Conclusion



1. **Deterministic of self-aggregation (SA)**
   - Occurrence of SA is not deterministic near the sharp transition zone between aggregated & scattered states: 6 aggregated & 4 scattered runs
2. **Key processes controlling SA**
   - Downward extension of dry patches from FT to BL is the key determining whether the system will reach aggregated state: competition between evaporation-driven cold pools & radiative cooling
3. **Multiscale structure of SA**
   - Convective organization, moisture aggregation, & large-scale overturning circulation each operate at different time & spatial scales: complicated interactions between convection, moisture, radiation, & atmospheric circulation
   - Index based on 2-day-accumulated convective statistics is proposed to measure convective clustering in longer time scale.

Selected References

- Hung, C.-S., & Miura, H. (2021). Ensemble of radiative-convective equilibrium simulations near the aggregated and scattered boundary. *GRL*
- Yanase, T., Nishizawa, S., Miura, H.,Takemi, T., & Tomita, H. (2020). New critical length for the onset of self-aggregation of moist convection. *GRL*
- Wing, A. A., et al. (2020). Clouds and convective self-aggregation in a multimodel ensemble of radiative-convective equilibrium simulations. *JAMES*
- Coppin, D., & Bony, S. (2015). Physical mechanisms controlling the initiation of convective self-aggregation in a General Circulation Model. *JAMES*

Animation for Simulation

https://www.youtube.com/playlist?list=PL7wzejGggNumal-15z199J5hBSs4YhlZx