Self-Aggregation of Convection in Radiative-Convective Equilibrium

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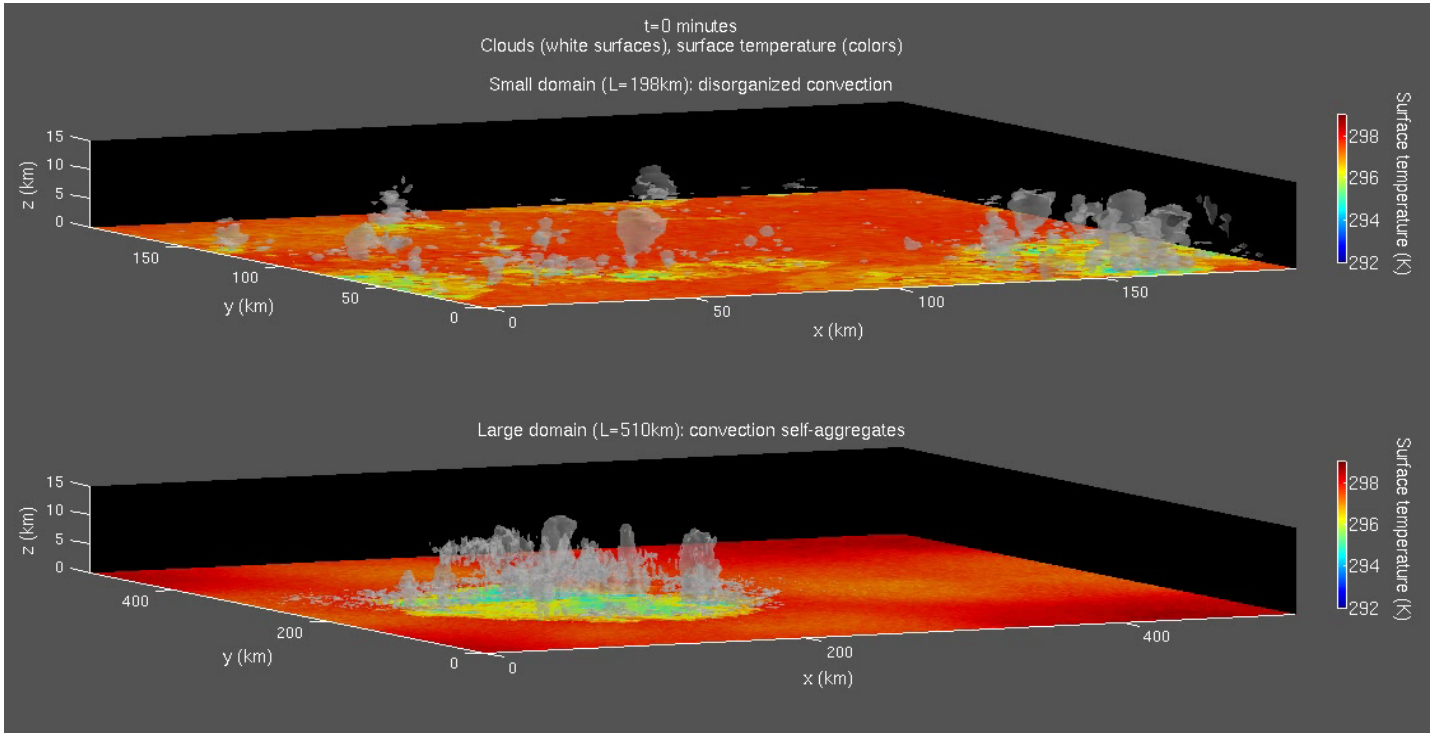
Self-Aggregation

- SAM *[Khairoutdinov, Randall, JAS 2003]*
- Interactive radiative cooling (LW&SW radiation scheme NCAR CAM3)
- Fixed SST, square doubly-periodic domain, no large scale forcing
- Run to RCE (Radiative-Convective Equilibrium)

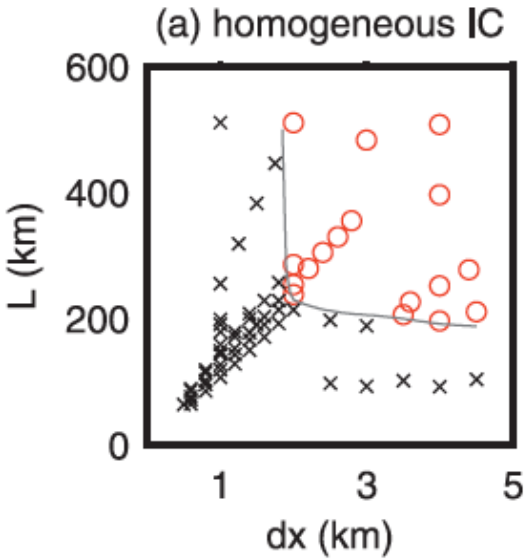
Self-aggregation = instability of disorganized RCE

[Raymond, Zeng QJRMS 2000; Bretherton, Blossey, Khairoutdinov, JAS 2005; Sobel, Bellon, Bacmeister GRL 2007; Emanuel, Wing, Vincent JAMES 2013]

Small domain (top) – large domain (bottom)



Background: domain size/resolution

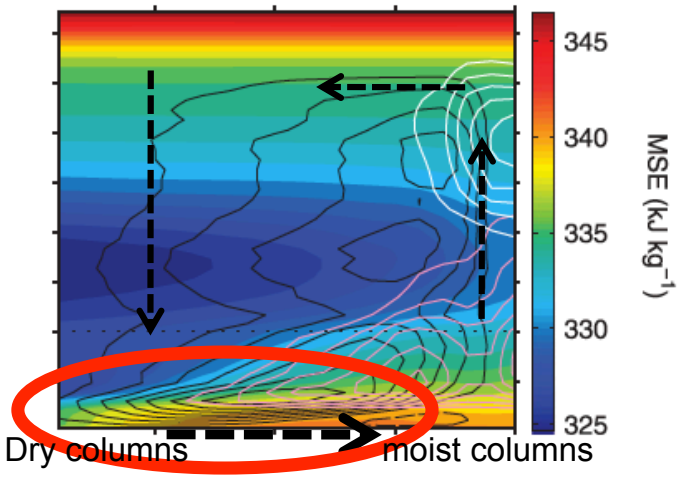


○ Self-aggregation
x Disorganized RCE

[Muller & Held JAS 2012]

Background: role of LW radiation

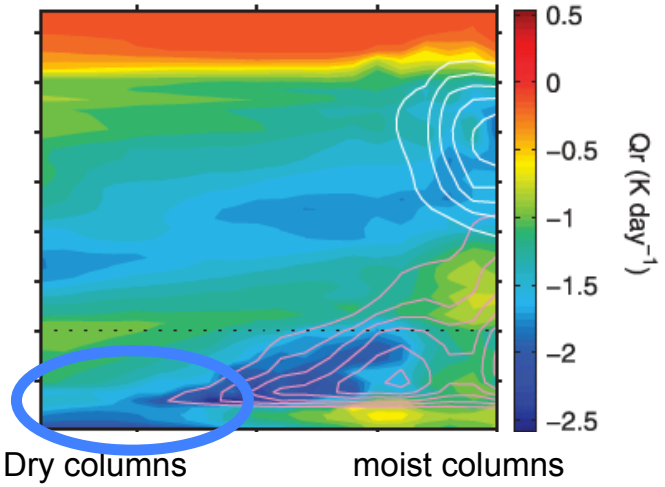
Circulation with aggregation
MSE (colors), streamfunction (dark lines)



Return flow is low
⇒ Energy transport from dry to moist region ie up gradient MSE transport

[Bretherton, Blossey, Khairoutdinov, JAS 2005]

Rad cooling (colors)



Due to rad cooling at low levels in dry region
⇒ low subsidence warming (w<0)
⇒ surface flow and up gradient MSE transport

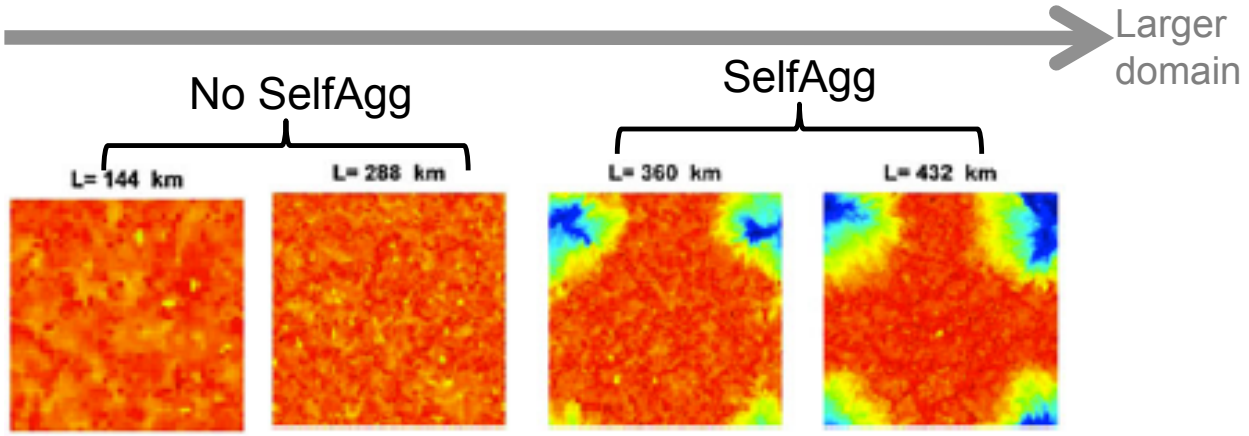
⇒NO spontaneous SELF AGGREGATION without low LW cooling

Why sensitivity to domain size/resolution?

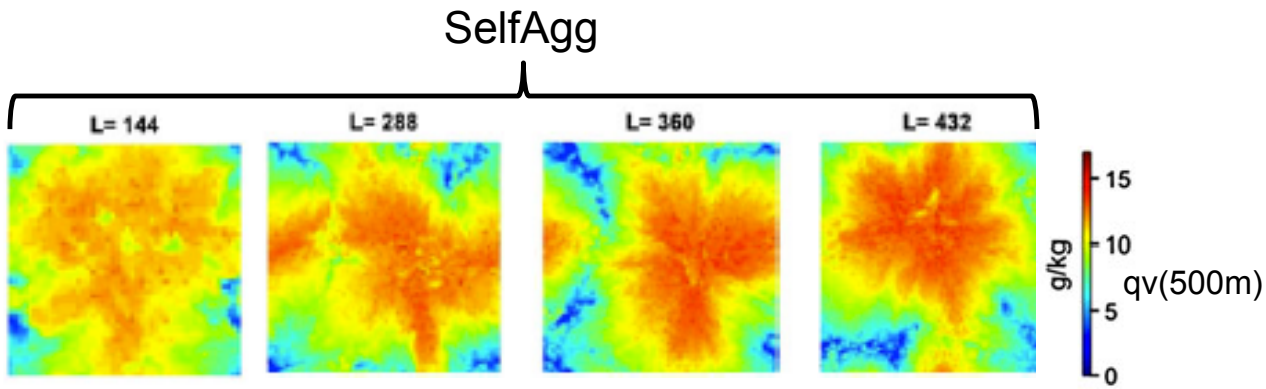
Why sensitive to domain size?

Domain size: role of cold pools? *[Jeevanjee&Romps 2013 GRL]*

With cold pools



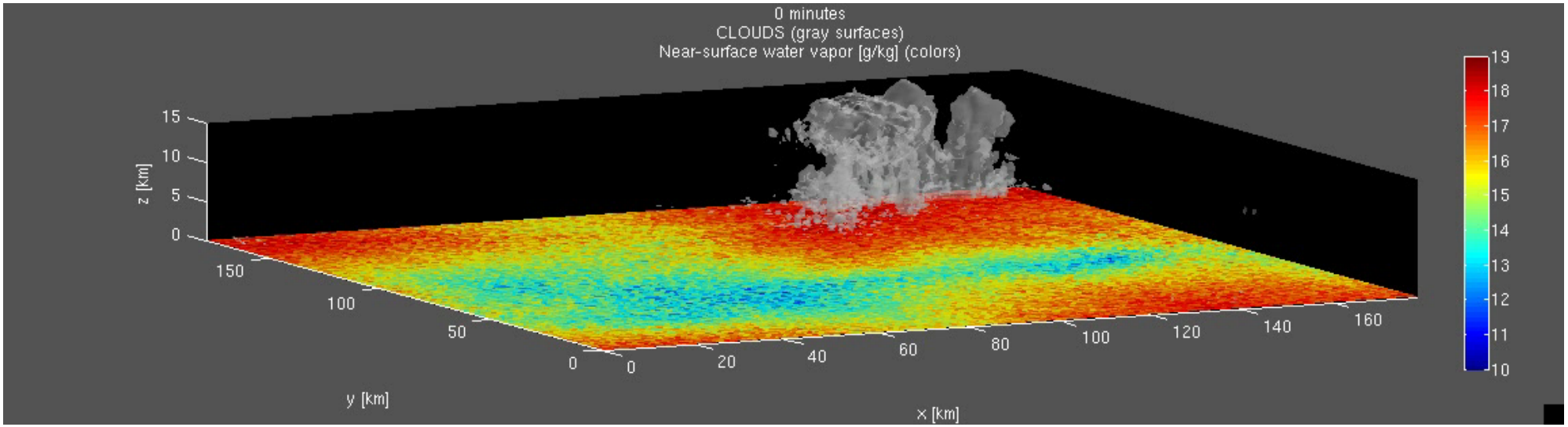
Without cold pools
(turn off reevaporation
of rain in lowest km)



⇒ No domain size dependence without cold pools

Why sensitive to domain size?

Simulation without cold pools BUT with fixed radiation aggregates



⇒ not same feedback

Water vapor feedback is responsible for aggregation here

[Tompkins JAS 2001, Craig&Mack JGR 2013]

In the absence of cold pools, no negative feedback on cloud which lives forever

Why sensitive to domain size?

=> It depends ?

No cold pools
Water-vapor feedback

No sensitivity to domain size

With cold pools
Radiative feedback

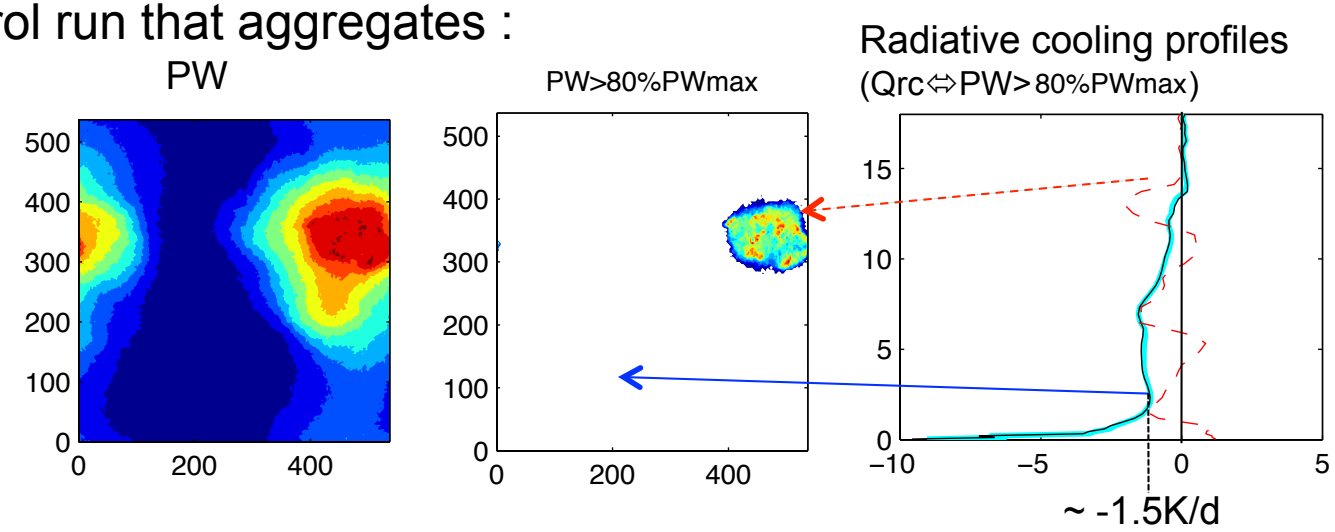
Is there another explanation for the domain size dependence?

Hyp:

- Due to difference in radiation between convecting region and dry environment
- Large difference => aggregation
- More variability on larger domains

Why sensitive to domain size?

Control run that aggregates :



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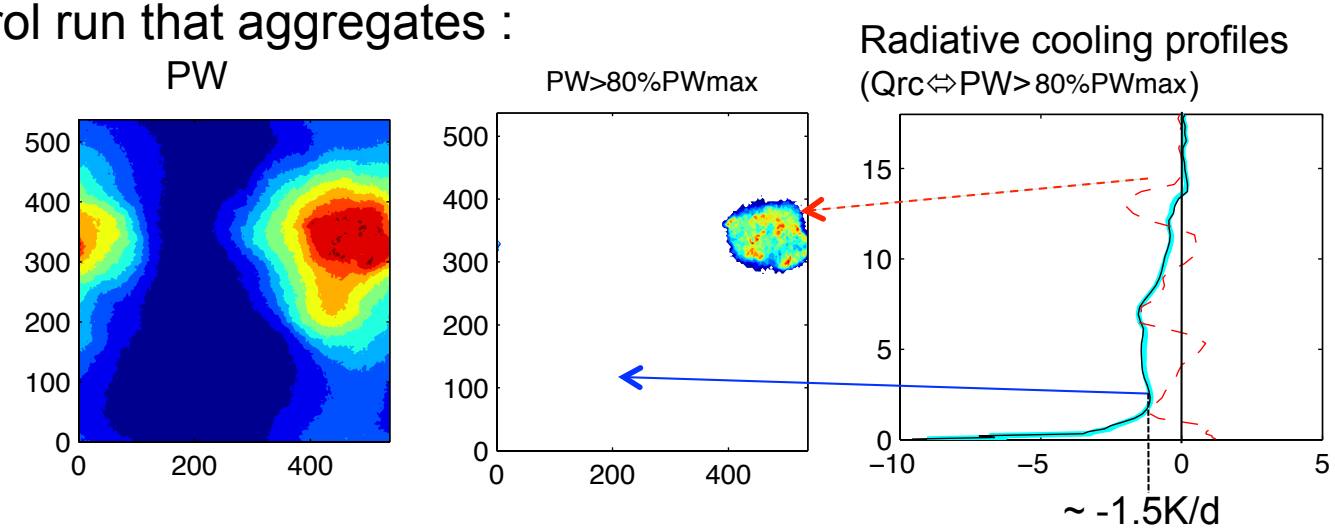
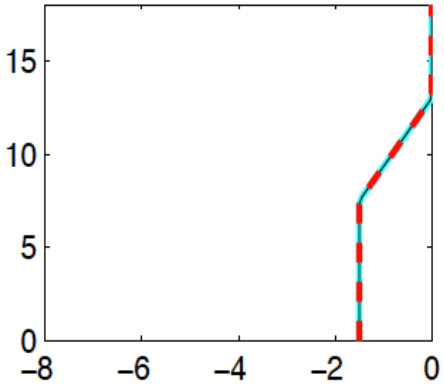


Fixed rad BUT 2 profiles (one imposed in the dry region, one imposed in the moist region) :



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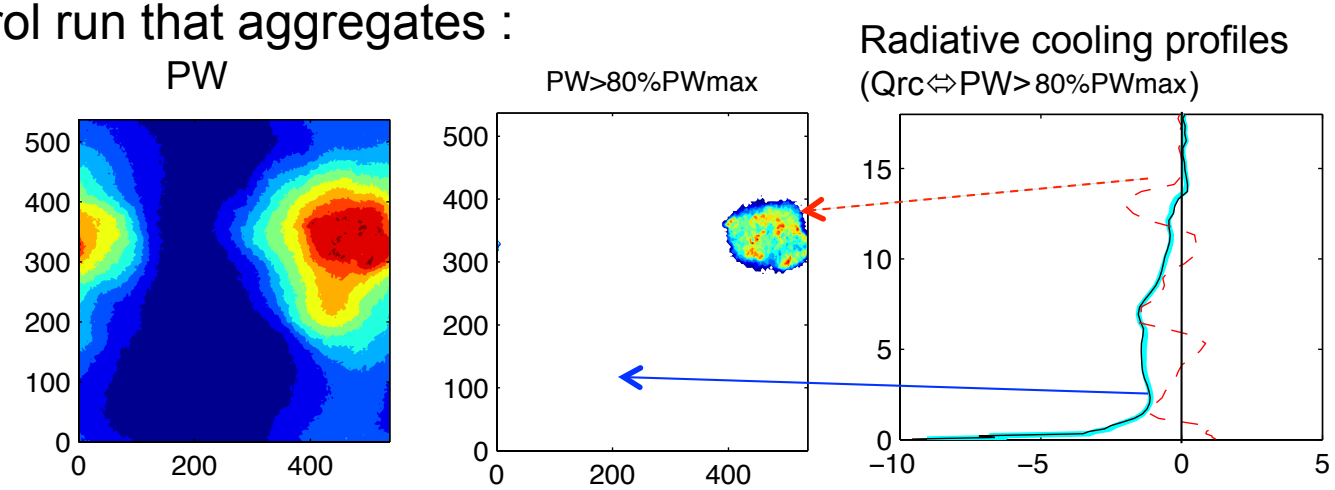

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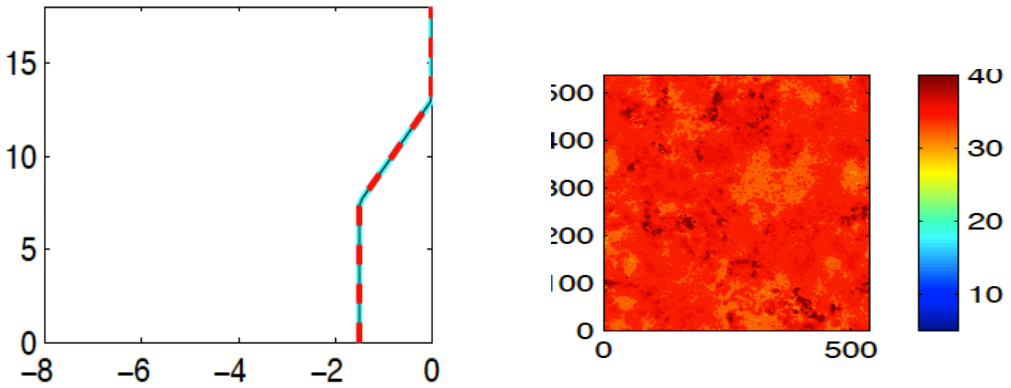

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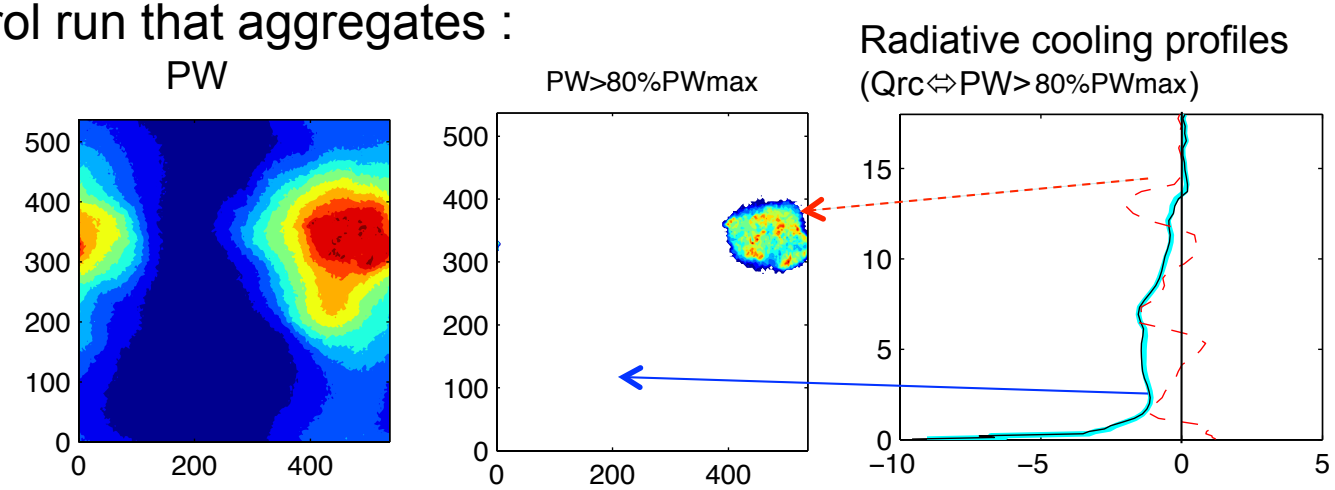

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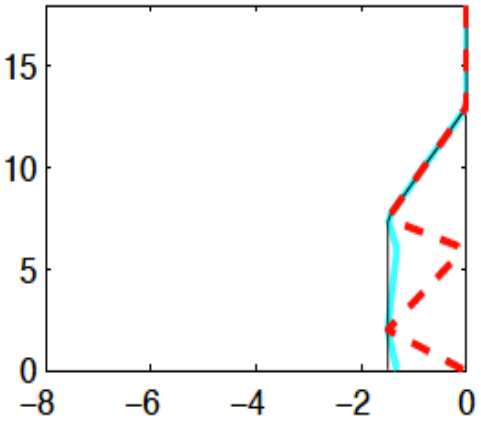

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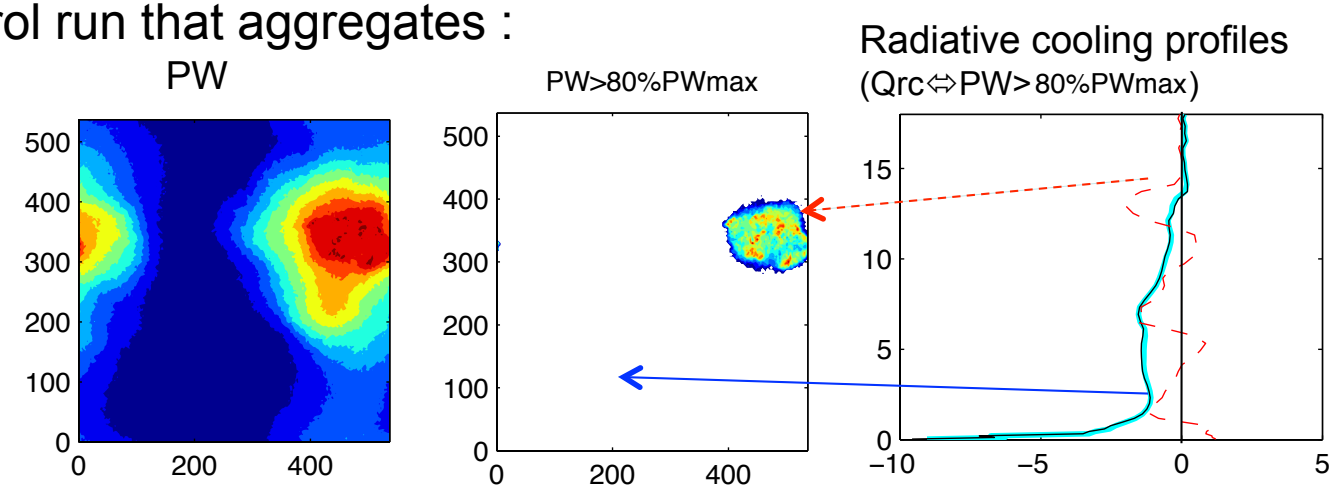

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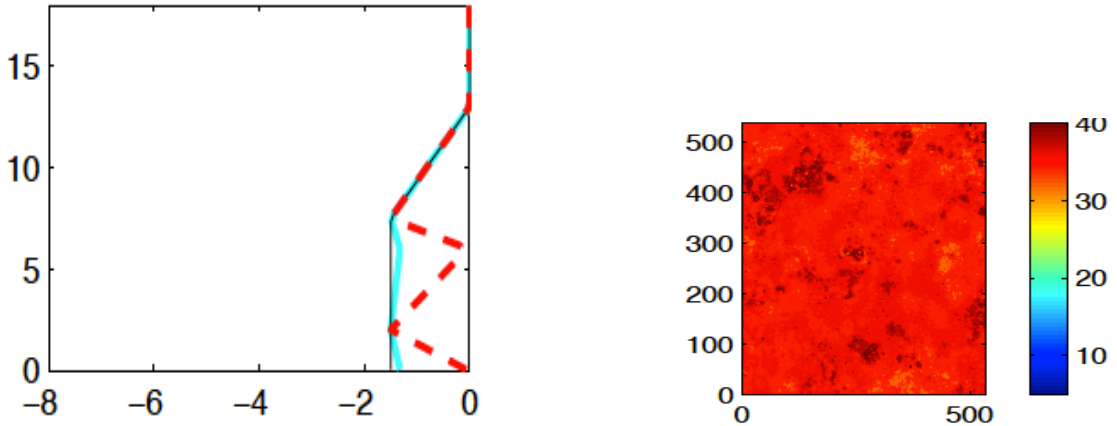

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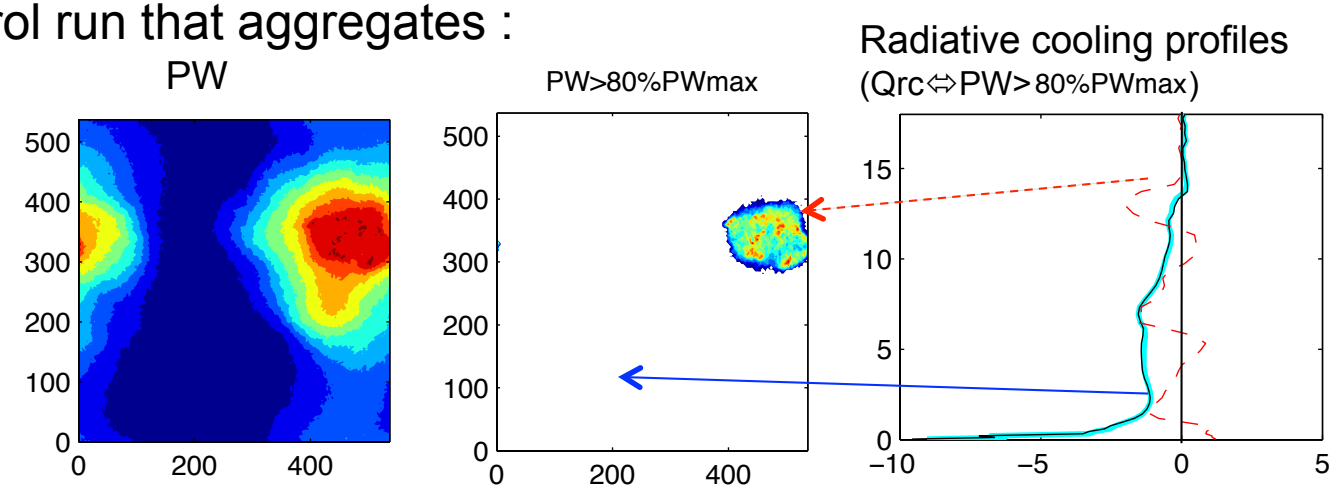

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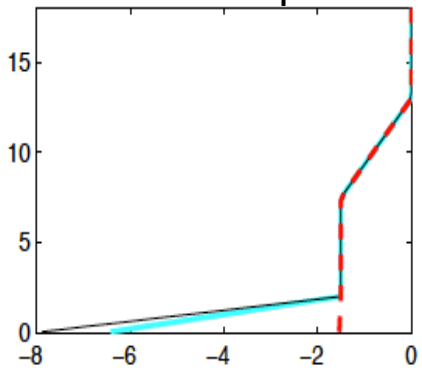

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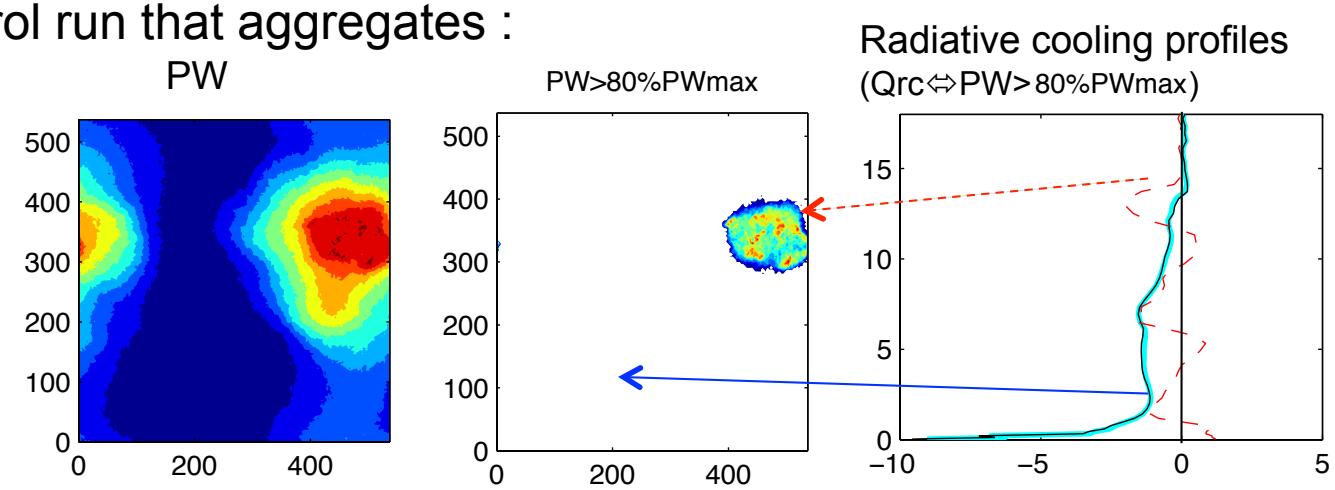

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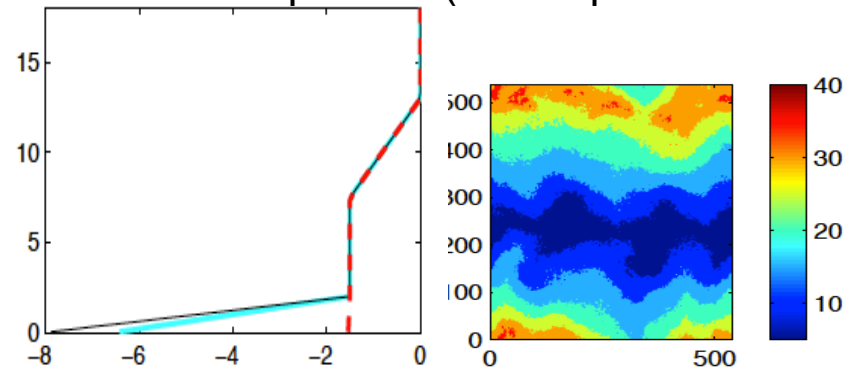
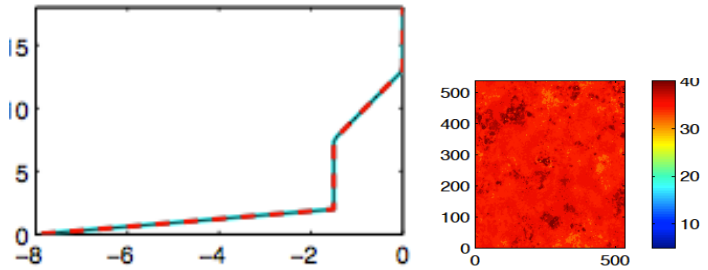


⇒ Low cooling in dry region causes aggregation

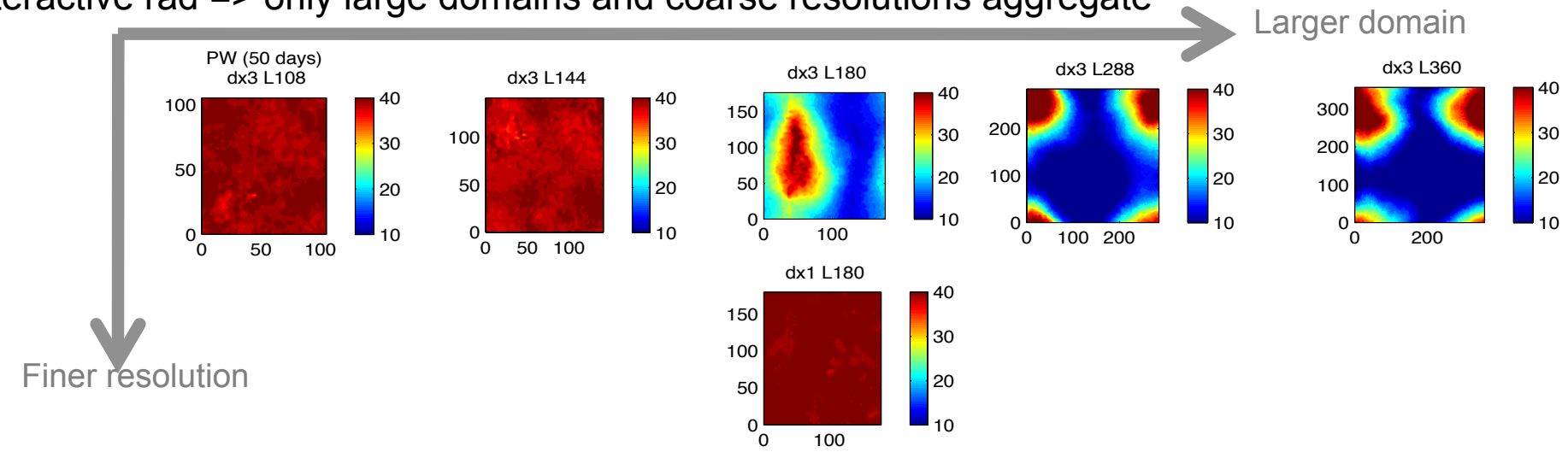


More precisely:

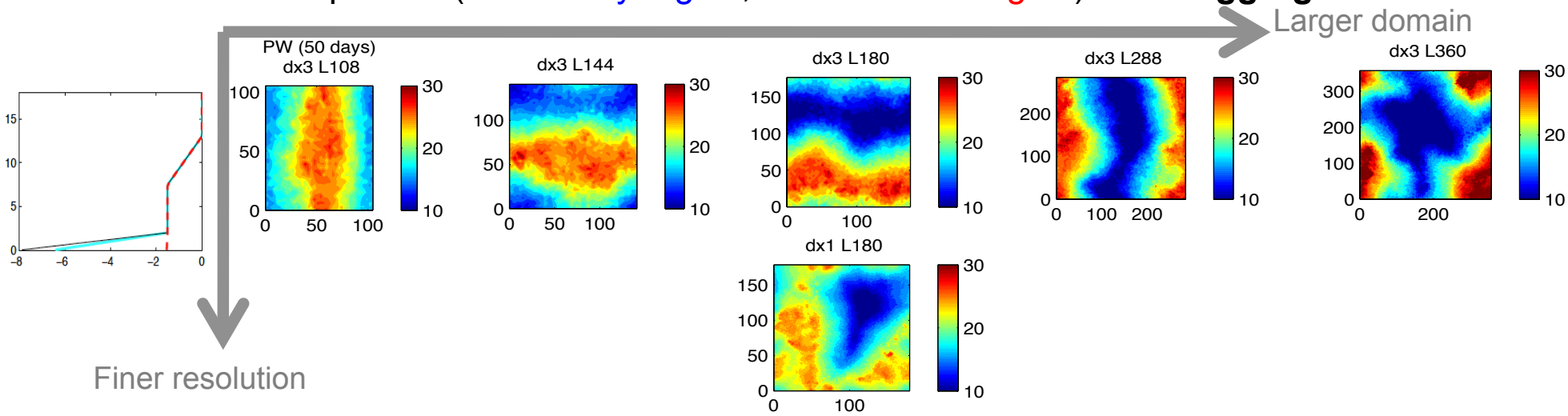
⇒ Variability in low level cooling causes spontaneous aggregation of convection

Why sensitive to domain size/resolution?

- Interactive rad => only large domains and coarse resolutions aggregate



- Fixed rad BUT 2 profiles (one for dry region, one for moist region) => **all aggregate**

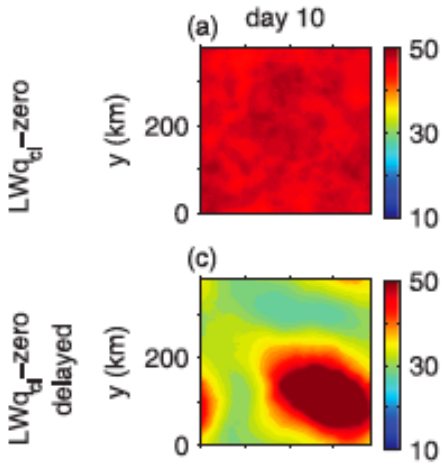


⇒ Domain size & resolution dependence due to variability in low level cooling between dry and moist regions

Why sensitive to domain size/resolution?

No low cloud LW

With low cloud LW



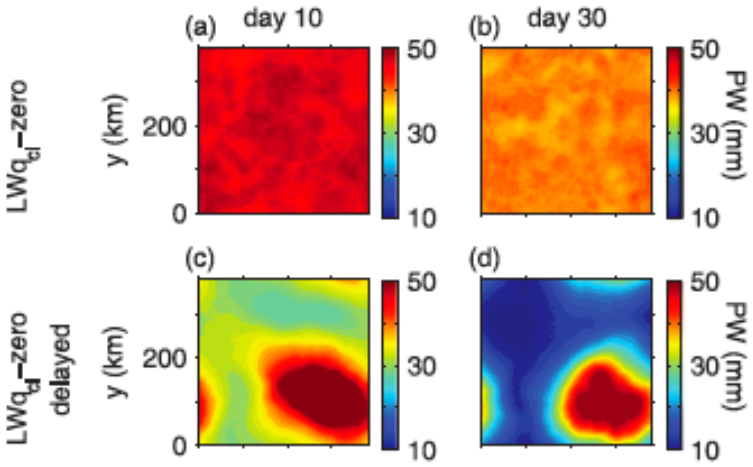
[Muller & Held JAS 2012]

⇒ **Variability in low cooling comes from variability in low clouds**

Why sensitive to domain size/resolution?

No low cloud LW

With low cloud LW until day 10



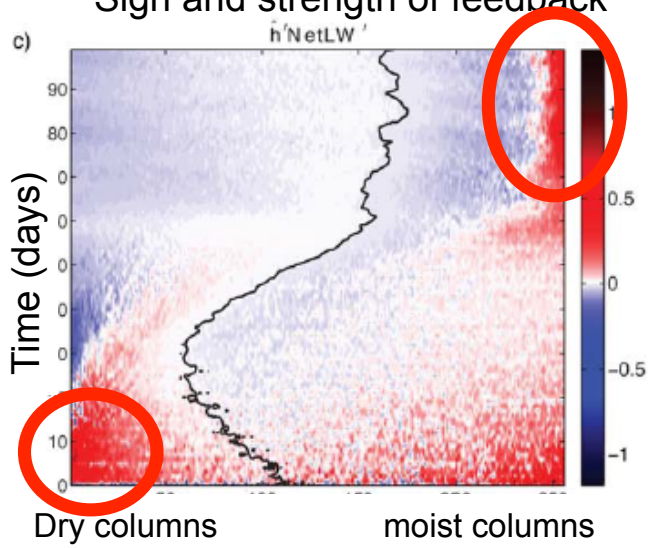
[Muller & Held JAS 2012]

⇒ Variability in low cooling comes from variability in low clouds

⇒ **Mechanism responsible for ONSET (low clouds LW)**
Different from mechanism responsible for MAINTENANCE (clear sky? high clouds?)

[Cf. A. Provenzale's talk]

Sign and strength of feedback



[Wing & Emanuel JAMES 2013]

Why sensitive to domain size/resolution? CONCLUSIONS

If water vapor feedback is responsible for aggregation (eg no cold pools or humid conditions with low reevaporation of rain), no domain size dependence

If radiative (LW) feedback is responsible for aggregation, domain size dependence due to larger variability in low level cooling between dry and moist regions

If we artificially impose a strong low level cooling in the dry region, aggregation occurs on small domains and at fine resolutions

The variability in low level cooling comes from variability in low clouds

Mechanism responsible for onset of aggregation may not the same as mechanism responsible for maintenance of aggregation

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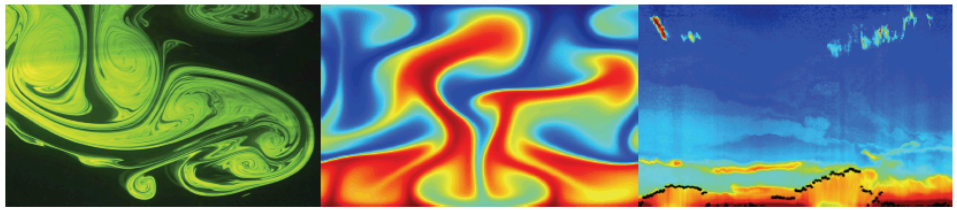

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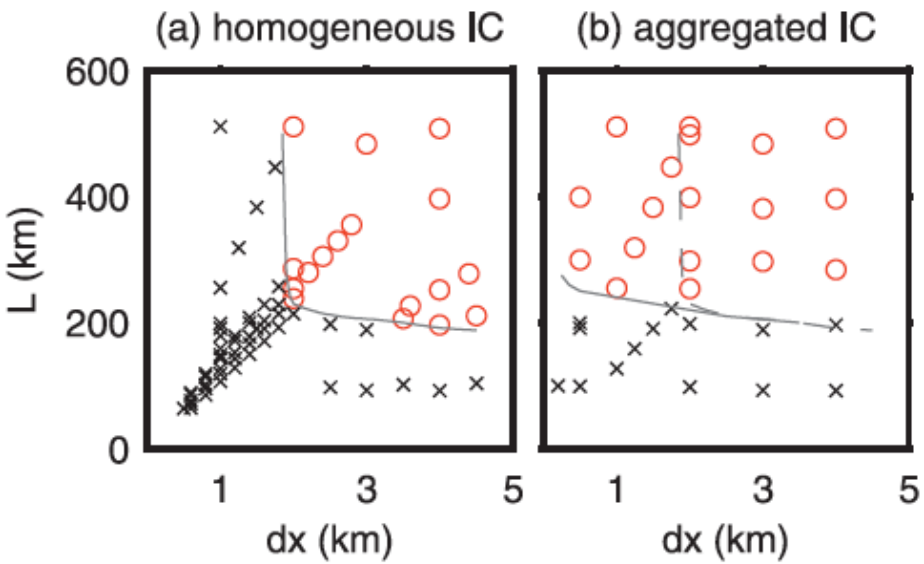
Self-Aggregation



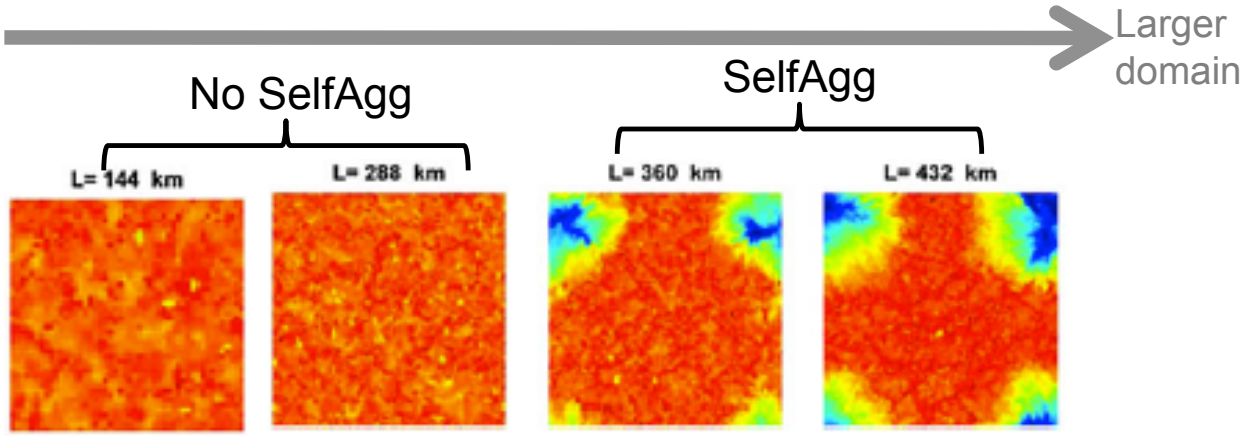
○ Self-aggregation
x Disorganized RCE

Why sensitivity to domain size/resolution?

Why sensitive to domain size?

Domain size: role of cold pools? *[Jeevanjee&Romps 2013 GRL]*

With cold pools



Without cold pools
(turn off reevaporation
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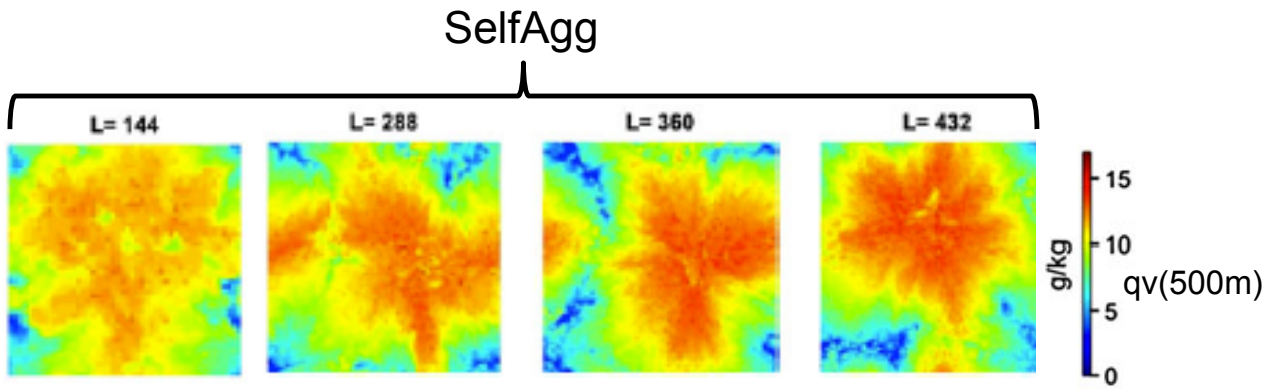

⇒ No domain size dependence without cold pools