Significant amplification of instantaneous extreme precipitation with convective self-aggregation

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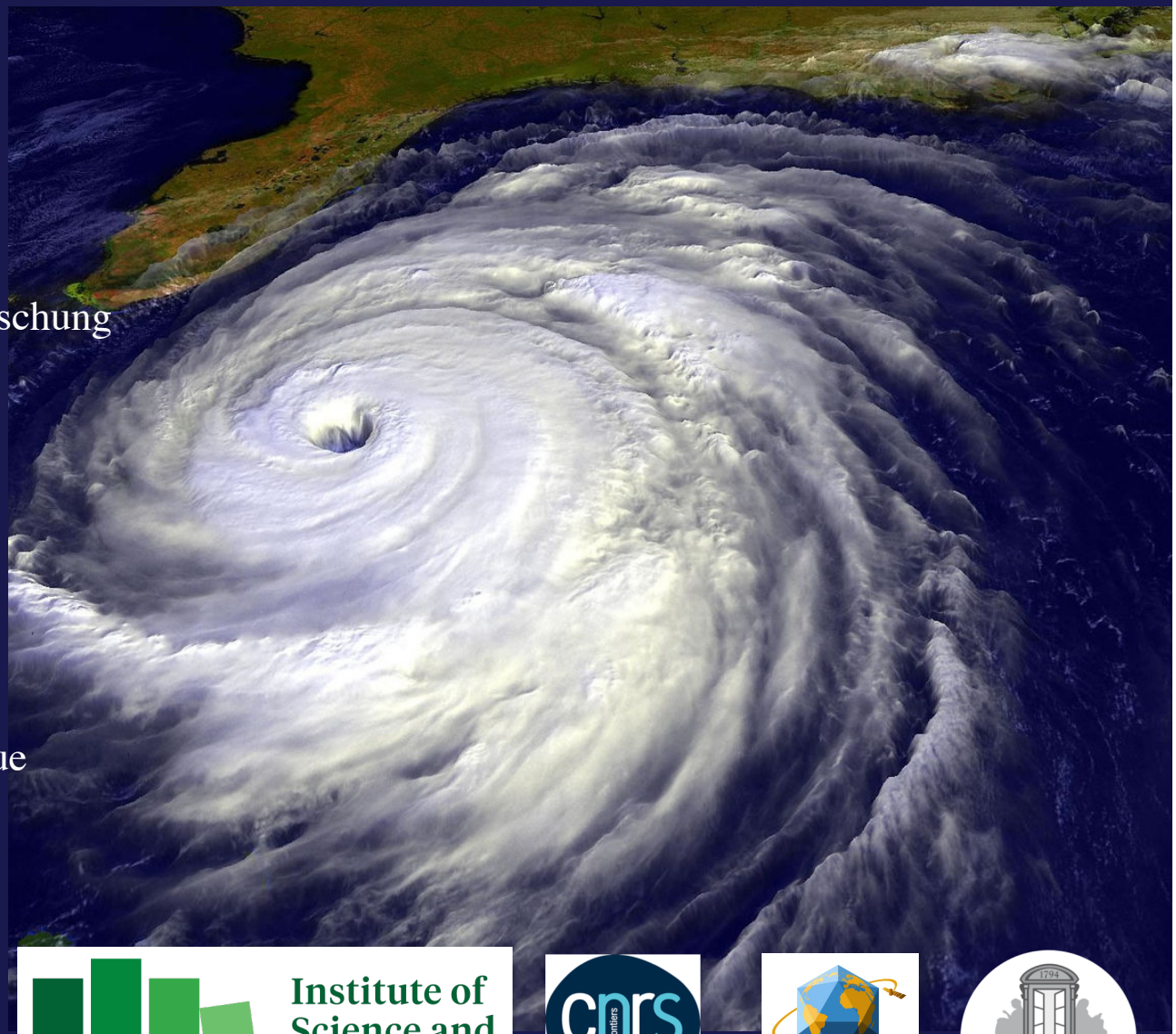

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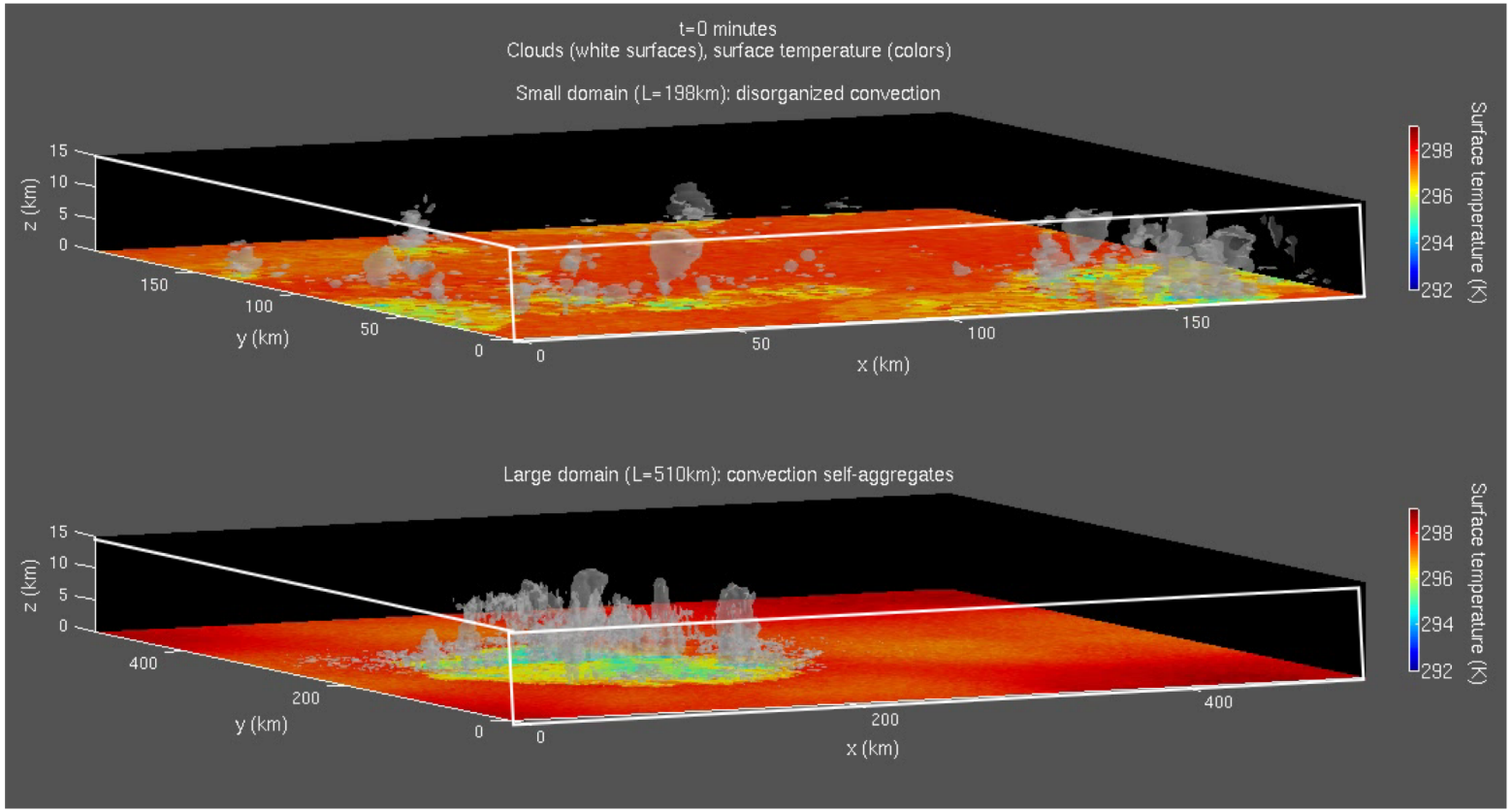
Self-aggregation

Clouds over near-surface temperature in cloud-resolving model SAM [Khairoutdinov & Randall, JAS 2003]



« pop corn »
convection

Larger domain

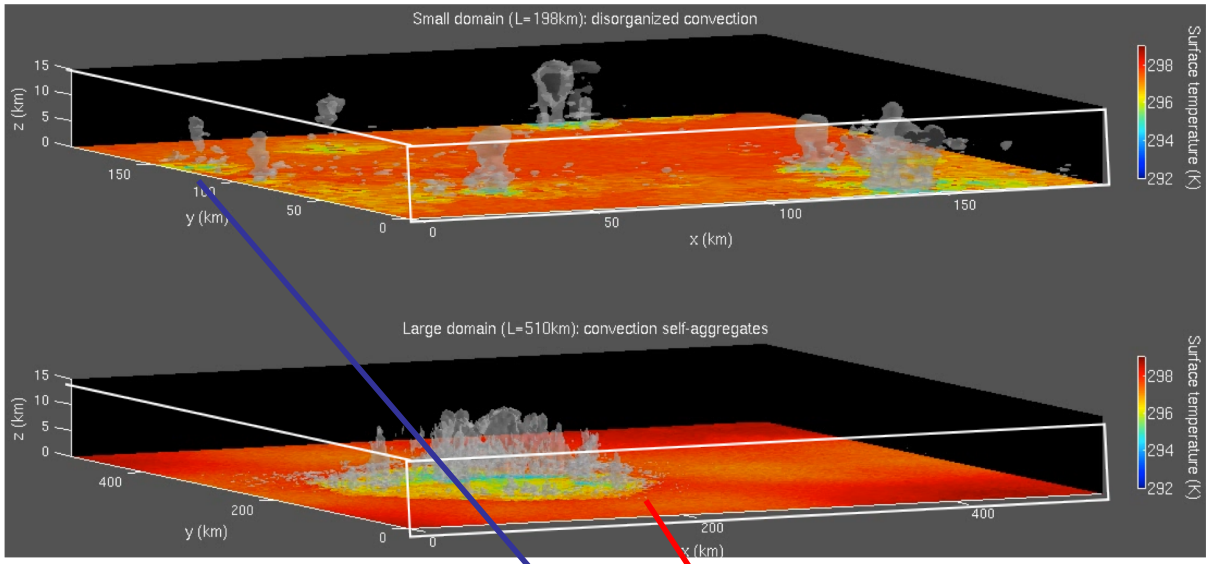
Self-aggregates

- SST=300K uniform
- Doubly periodic
- No Coriolis (f=0)
- No large-scale forcing

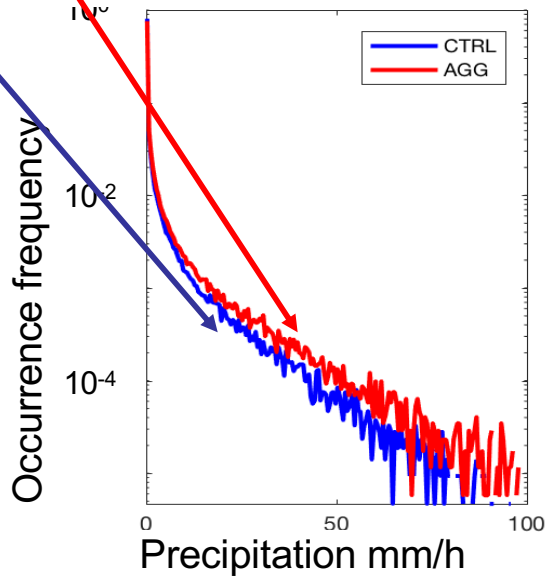
Self Aggregation = Instability of disorganized Radiative-Convective Equilibrium “pop corn” state

[Bretherton, Blossey, Khairoutdinov, 2005; Muller, Held 2012; Emanuel, Wing, Vincent 2013; Wing Emanuel 2013; Jeevanjee Romps 2013; Khairoutdinov Emanuel, 2013; Shi Bretherton 2014; Tobin, Bony, Roca, 2012; Tobin et al, 2013; Muller Bony 2015; Arnold Randall 2015; Coppin Bony 2015; Mapes 2016; Holloway Woolnough 2016; Tompkins Semie 2017; Wing Holloway Emanuel Muller 2017; Becker Bretherton Hohenegger Stevens 2018; Muller Romps 2018; Fildier et al 2021; Muller et al 2022 ARFM …]

Precipitation extremes with self-aggregation



Instantaneous precip extremes



Self-aggregation leads to larger rain accumulation => stronger 3-hourly precip

[Bao Sherwood 2019]

⇒ BUT increased instantaneous precipitation extremes as well +30%!

Precipitation extremes with self-aggregation

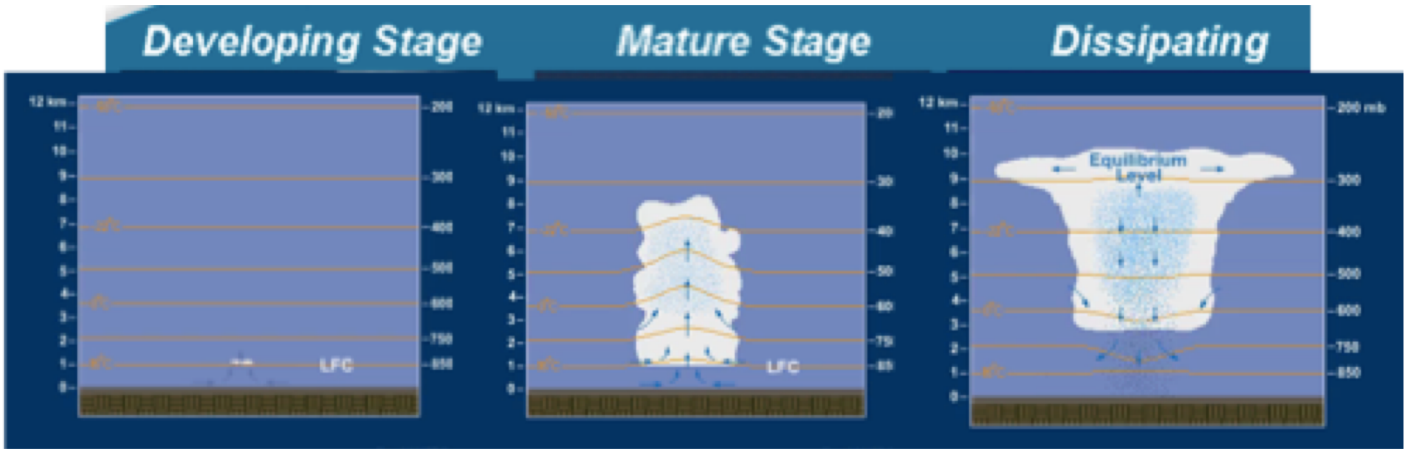
Main balance during precip extremes:

Precipitation efficiency *Condensation rate*

$$P \sim \varepsilon_p \int \rho w \left(-\frac{\partial q_{sat}}{\partial z}\right) dz$$

[Muller&Takayabu 2020]

Single cloud life cycle (from the COMET online material)



Precipitation extremes with self-aggregation

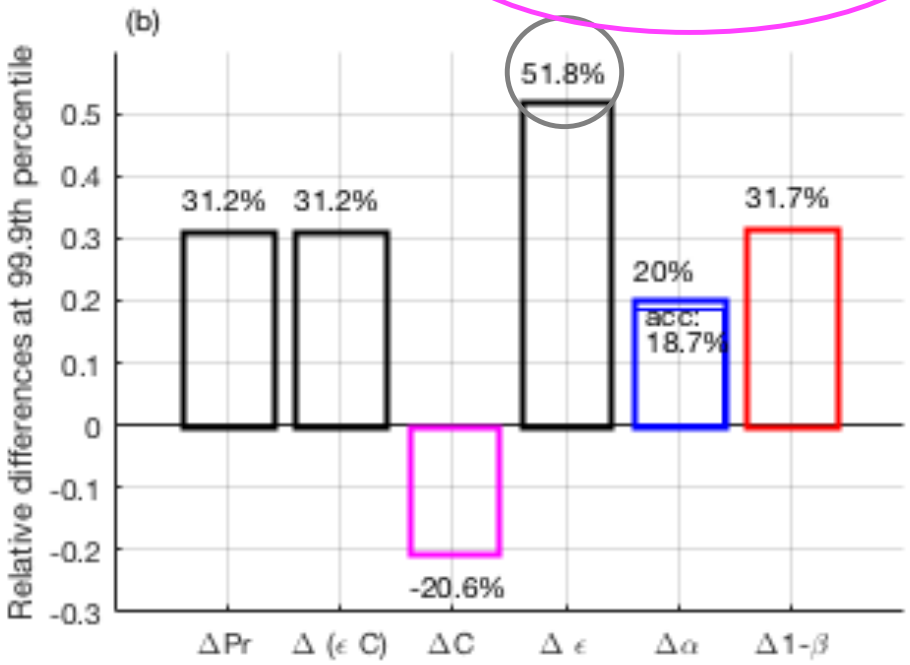
+30%

Precip efficiency +50%

Condensation rate C -20% = -25% + +5%

Dynamic *Thermodynamic*

$$\delta P \sim \delta\left[\varepsilon_p \int \rho w \left(-\frac{\partial q_{sat}}{\partial z}\right) dz\right]$$



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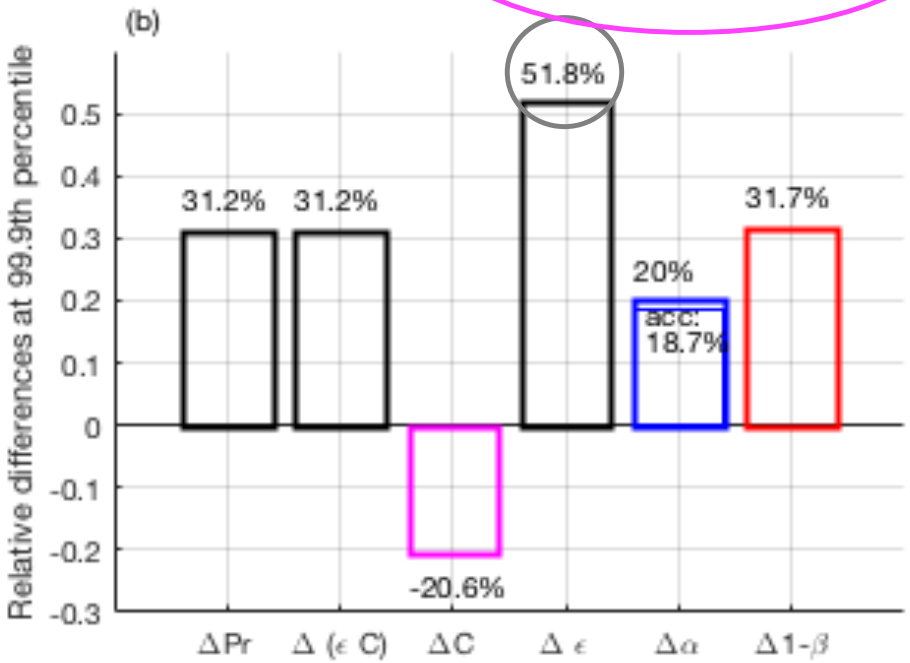
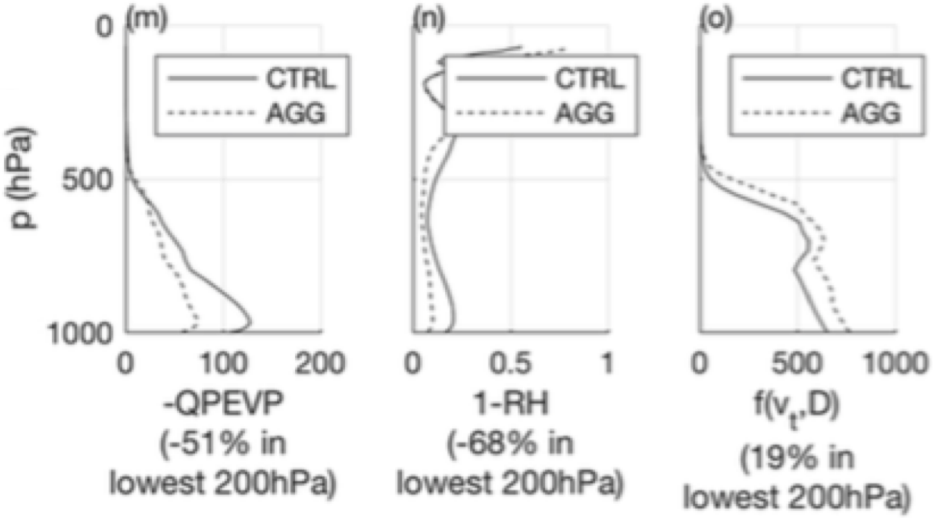


Profiles at extremes



accr (collection of cloud into precip) + (autoconversion) (cloud into precip)

evaporates (fraction β) or reaches surface

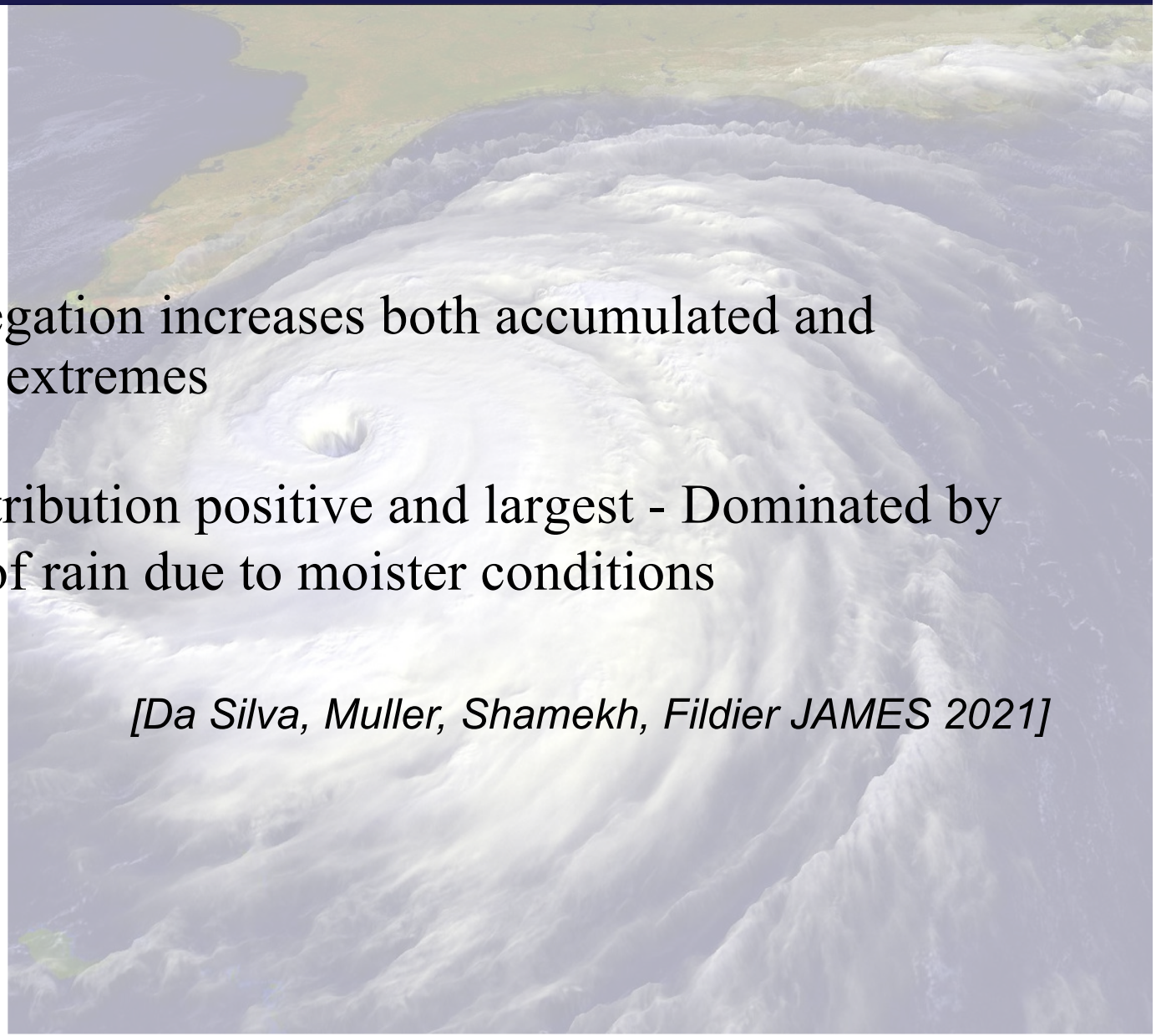
Cloud condensate → Precipitating condensate → Surface precip

Mainly reduced rain evaporation (due to moister conditions)

[Da Silva, Muller, Shamekh, Fildier 2021]

Rk: Different for squall lines ! See Sophie Abramian's presentation

CONCLUSIONS



Convective self-aggregation increases both accumulated and instantaneous rainfall extremes

Precip efficiency contribution positive and largest - Dominated by reduced evaporation of rain due to moister conditions

[Da Silva, Muller, Shamekh, Fildier JAMES 2021]