How does SST impact aggregation?

Our understanding might be better than we think

H0

Timothy Cronin

MIT, Department of Earth,
Atmospheric and Planetary Sciences

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Debate vs. Sandrine Bony

Look at the debates for Wednesday-Thursday

Raise your hand if the following statement is settled:

We know the primary causes of self-aggregation in idealized model settings

H0, the null hypothesis: Self-aggregation has little dependence on SST

If we cannot decisively refute this hypothesis across a range of models, then **it should be our starting point**, rather than our point of retreat

Failure to decisively refute H0 means that the current state of our understanding is H0

For this half of the debate…

Self-aggregation = spontaneous organization of convection over homogeneous SST, in the absence of heterogeneous boundary forcing

[observations tangent at end…]

I'll consider primarily three studies which look across a range of SSTs and find multiple moist regions:

Coppin & Bony (2015) – LMDZ (GCM)

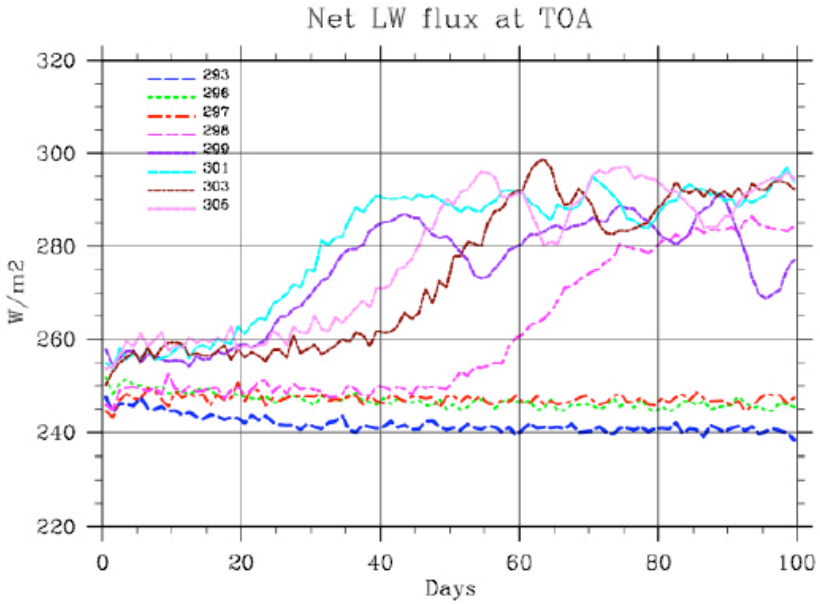
Cronin & Wing (2017) – SAM (CRM)

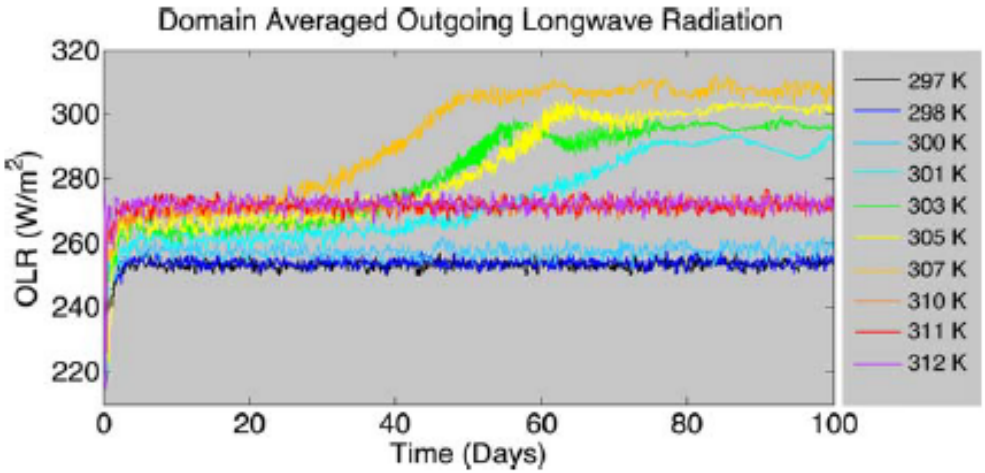
Becker et al (2017) – ECHAM (GCM)

The backdrop: SOC hypothesis + Wing & Emanuel (2014)

- Idea that aggregation might increase rapidly with warming past a certain SST threshold, stabilizing tropical climate
- Well-summarized by Marat yesterday and in Khairoutdonov and Emanuel (2010) [extended abstract]
- Would be great: a strong negative feedback that kicks in just near current tropical SSTs!

Khairoutdinov & Emanuel (2010); Wing & Emanuel (2014)





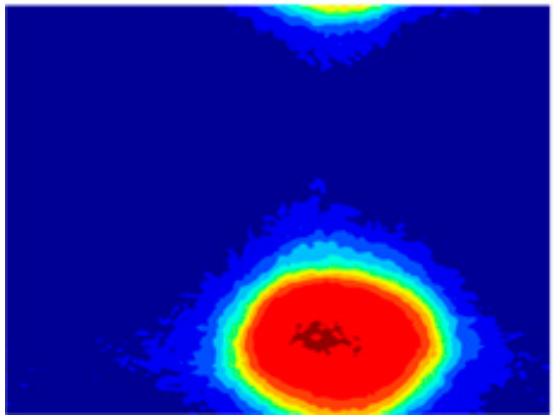
Both studies (using SAM in square domains) seem to show sharp SST-dependence

But what is the mechanism for SST-dependence?

Emanuel, Wing, Vincent (2014): convection - LW clear-sky feedbacks

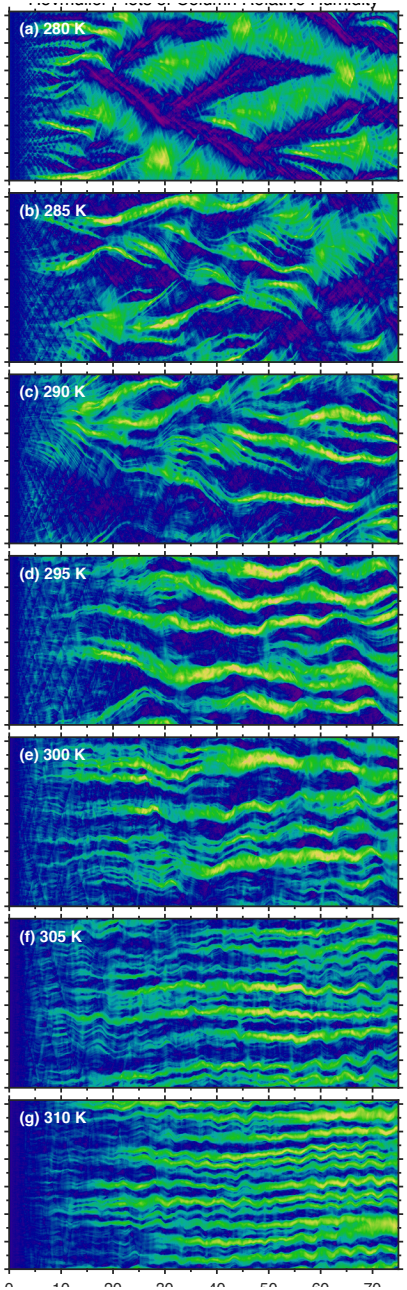
Beucler & Cronin (2016): clear-sky radiative feedbacks are very sensitive to vertical structure of humidity, can drive instability at much lower SSTs

Is that the full story?



Abbot (2014): Hey, guys, I found self-aggregation at snowball-earth temperatures!

Diagnosis of feedbacks: cloudy-sky longwave effects seem important



cold

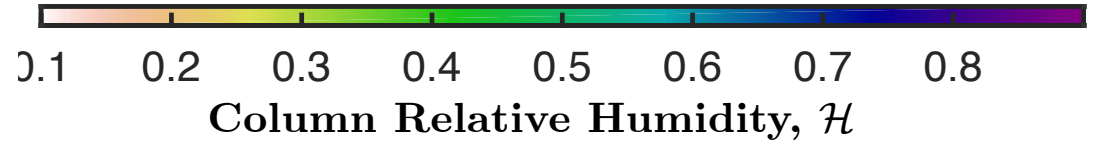
warm

Wing & Cronin (2015)

Long-channel (12288x192 km) simulations with SAM

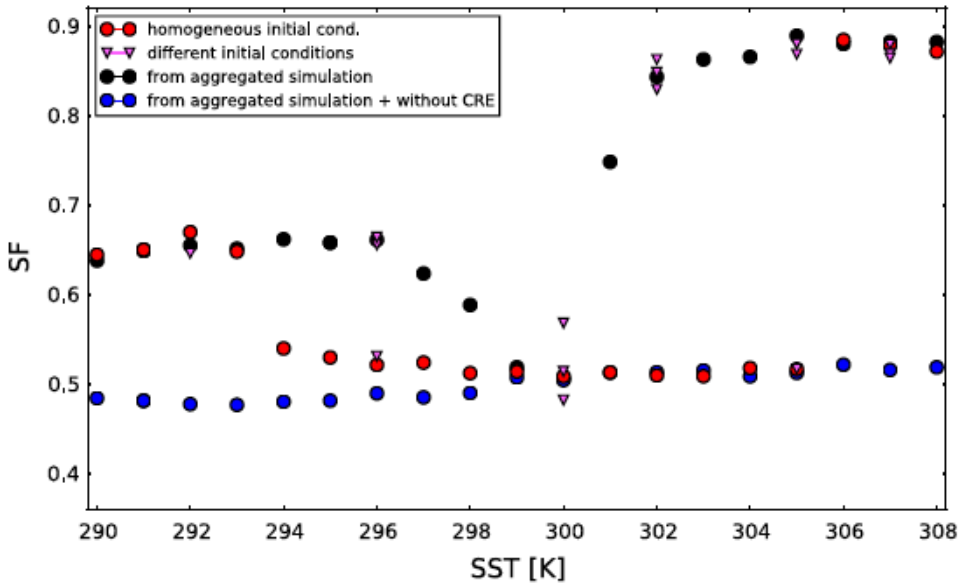
Self-aggregation across range of SSTs from 280-310 K

Cronin & Wing, 2017 show metrics of aggregation – subsidence fraction and organization index – have weak T-dependence

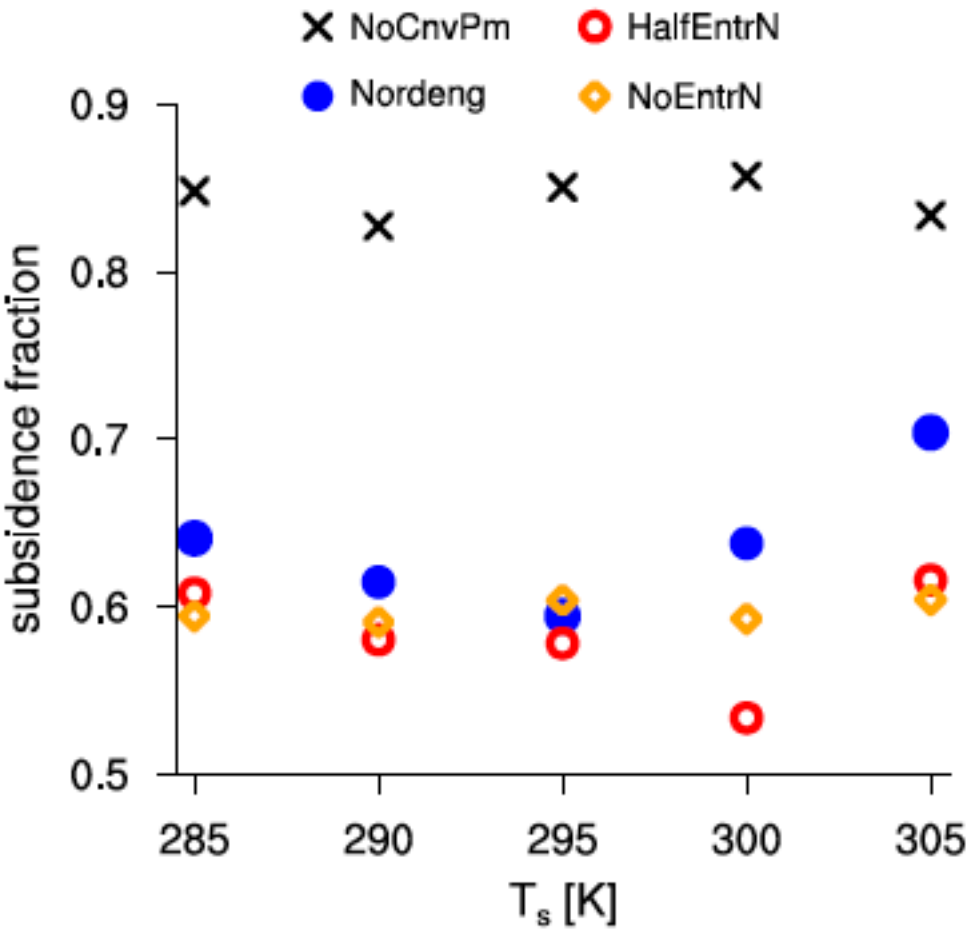


Coppin & Bony (2015)

Strong but non-monotonic dependence of aggregation on SST, with a lack of aggregation from 299-300 K or 294-305 K depending on initial conditions



Becker et al (2017)

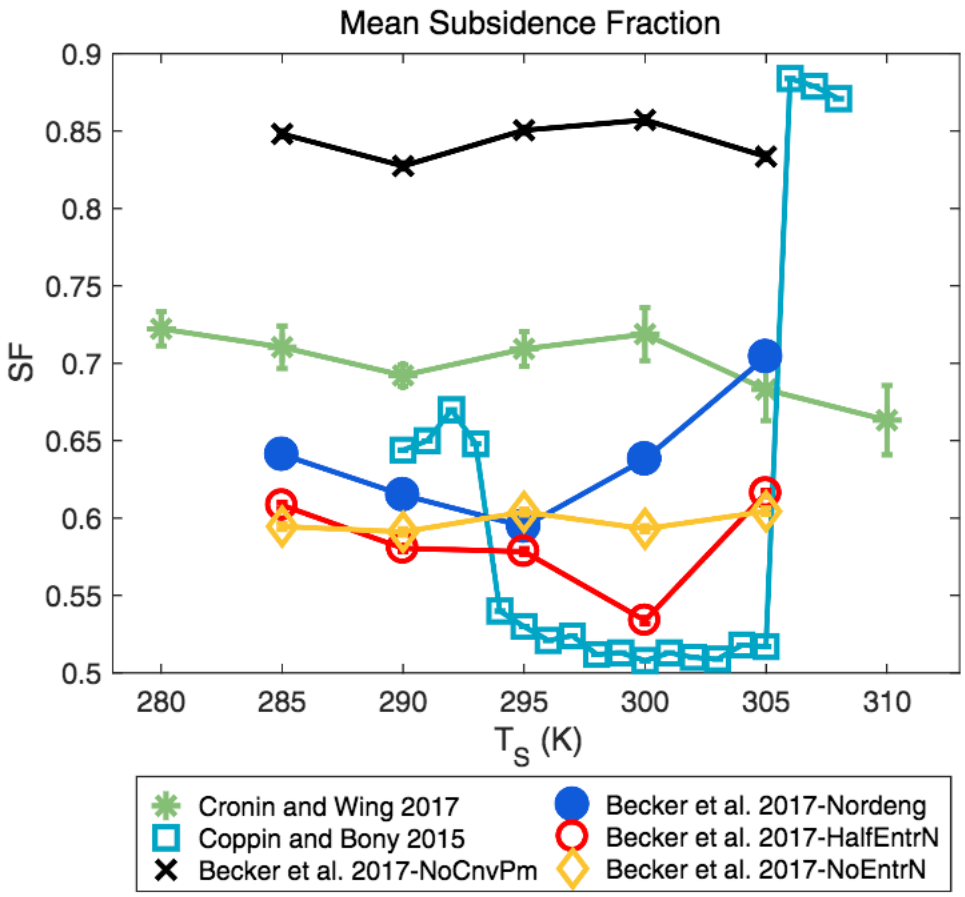


"the variations of convective self-aggregation with SST strongly depend on the representation of convection"

Holloway & Woolnaugh (2016)

CRM study, also find aggregation at "low" SSTs of 290-295 K

Putting these together



(Wing, 2019)

Only Coppin & Bony (2015) shows strong T-dependence, and it is sensitive to initial state

LW cloud and surface flux feedbacks diagnosed as most important

Theoretical basis for SST-dependence?

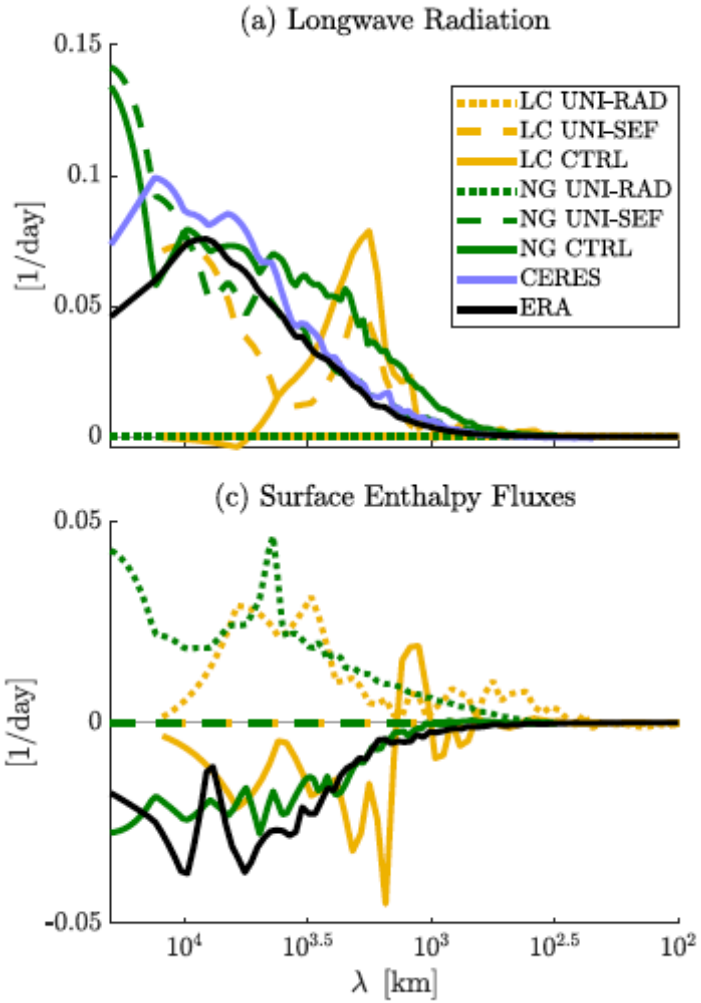
Of either longwave-cloud or surface latent heat flux feedbacks?

As far as I know, none exists, and models differ in their behavior

BUT: easy to generally reason that LW cloud feedback should be positive for developed aggregation (across wide range of SST)

Some reasons for skepticism about aggregation switching on/off…

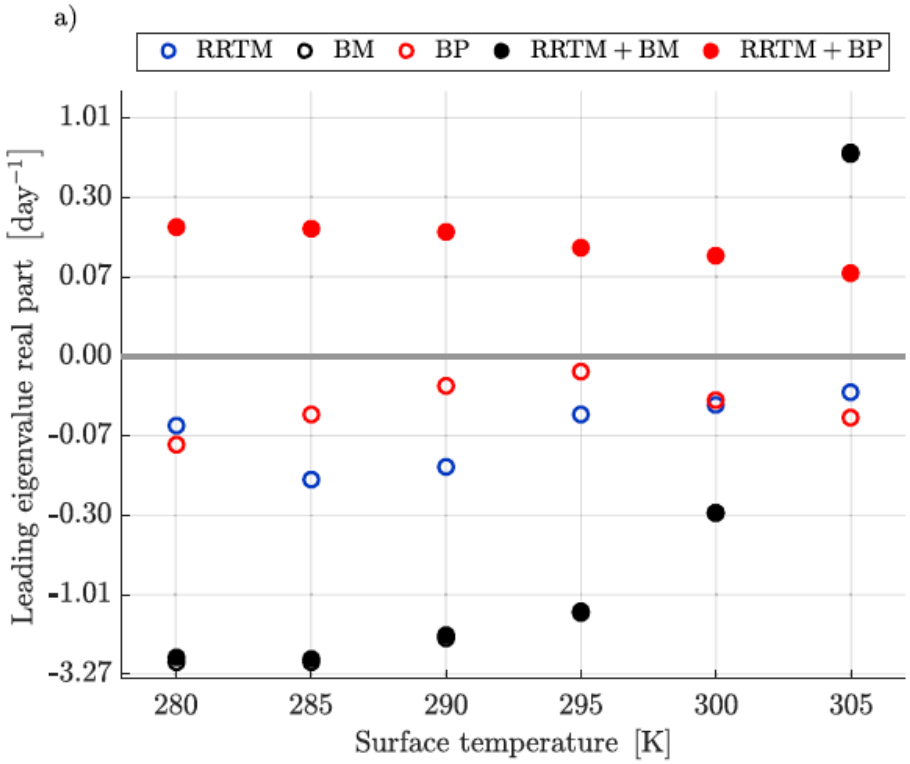
Strong surface flux feedbacks maybe not realistic



Khairoutdinov & Bretherton, 2015

Beucler et al, submitted (figure at left)

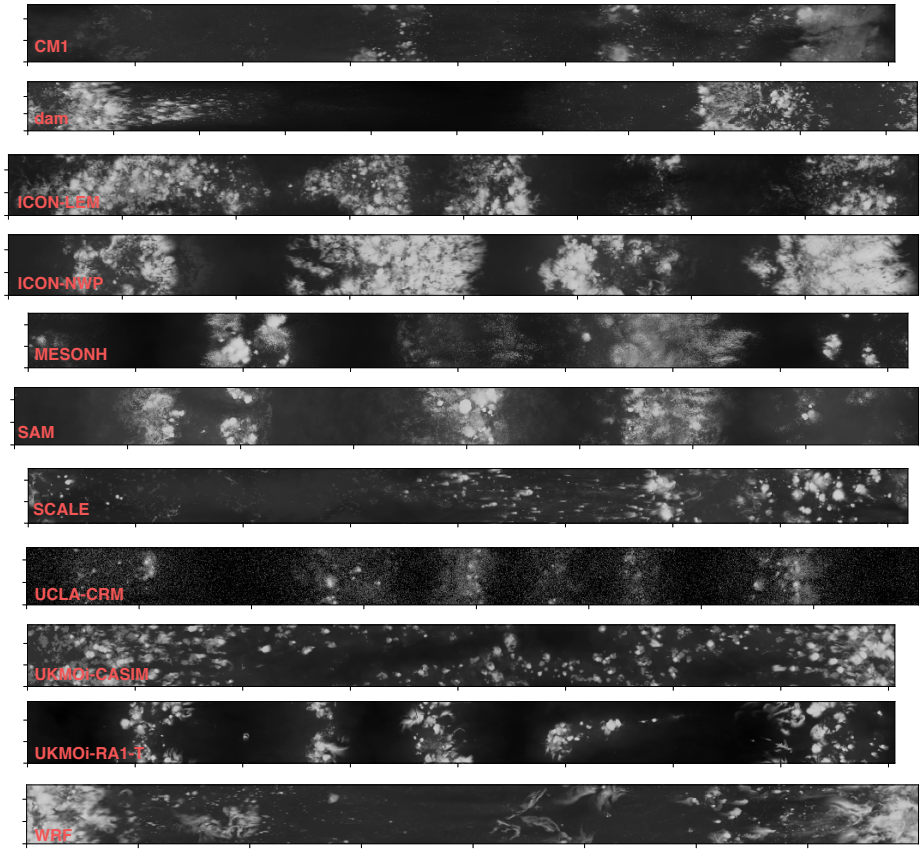
Linear instability of convective parameterization-radiation coupling



Beucler, Cronin, Emanuel (2018) –

Can get a range of responses depending on "convection scheme"!

Very strong aggregation reveals lack of noise from rest of domain?



Ahmed & Neelin, 2019

RCEMIP simulations with CRMs (left) – all show some degree of aggregation

A modest suggestion for H0

- Self-aggregation feedbacks are based on sound physics, and apply to the real atmosphere – especially the dominant cloud-longwave feedback
- In the real world, and some models, “self”-aggregation occurs alongside a sea of internal variability, and isn’t the only show in town
- We should be skeptical about strong temperature-dependence without strong mechanistic theory