On the influence of ice habit on Arctic cloud phase partitioning

with insight into ice particle parameterizations

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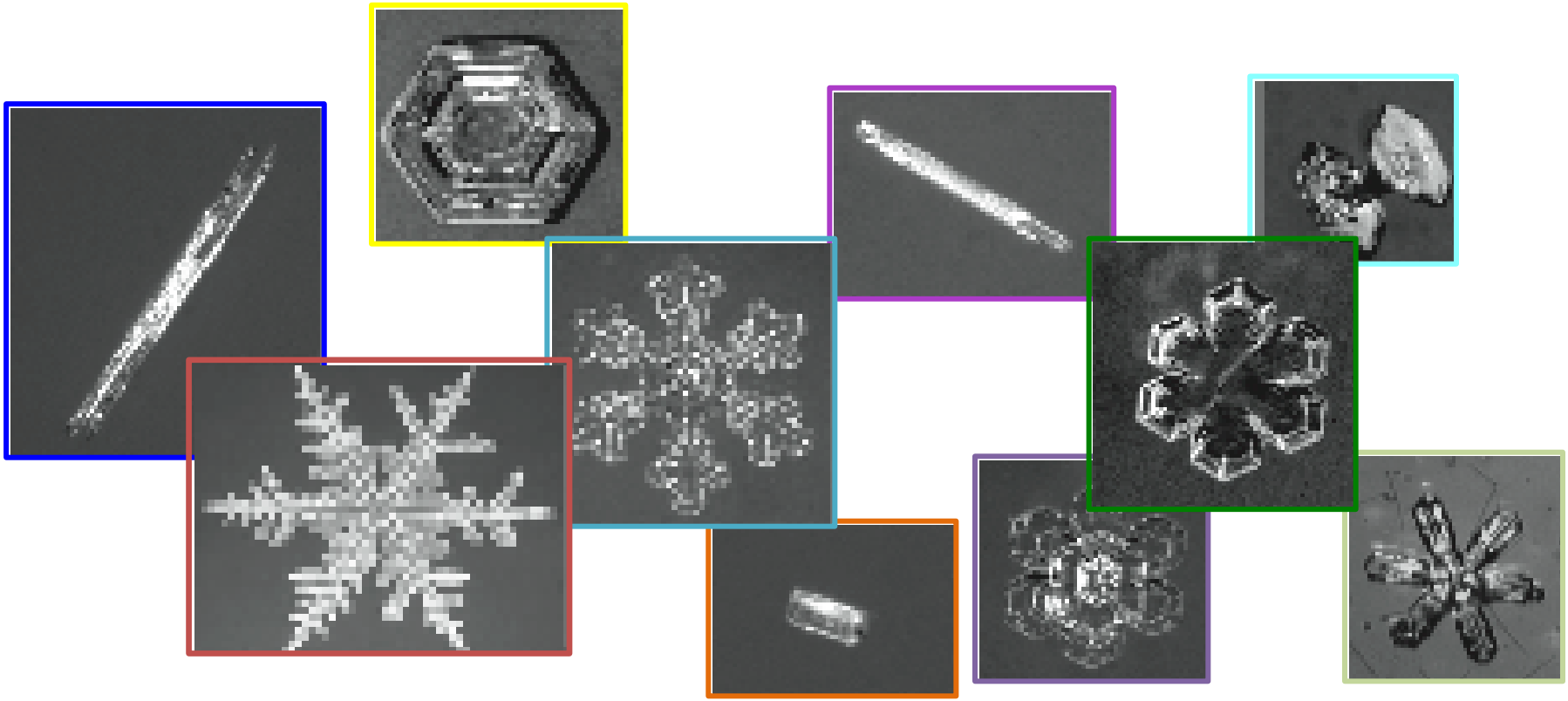
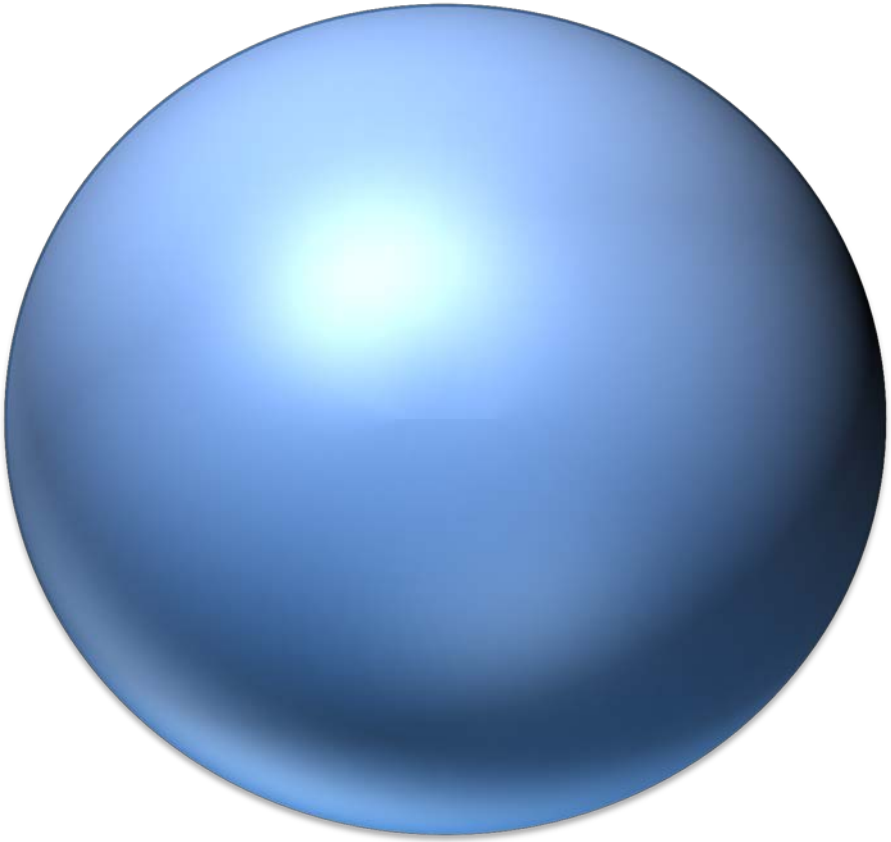
• Jerry Harrington, Penn State University
• Hugh Morrison, NCAR (MMM)
• Graham Feingold and Barbara Ervens, NOAA

Ice Has Multiple Personalities…



Vapor growth of ice is critical to mixed-phase lifetime!

As Modelers…

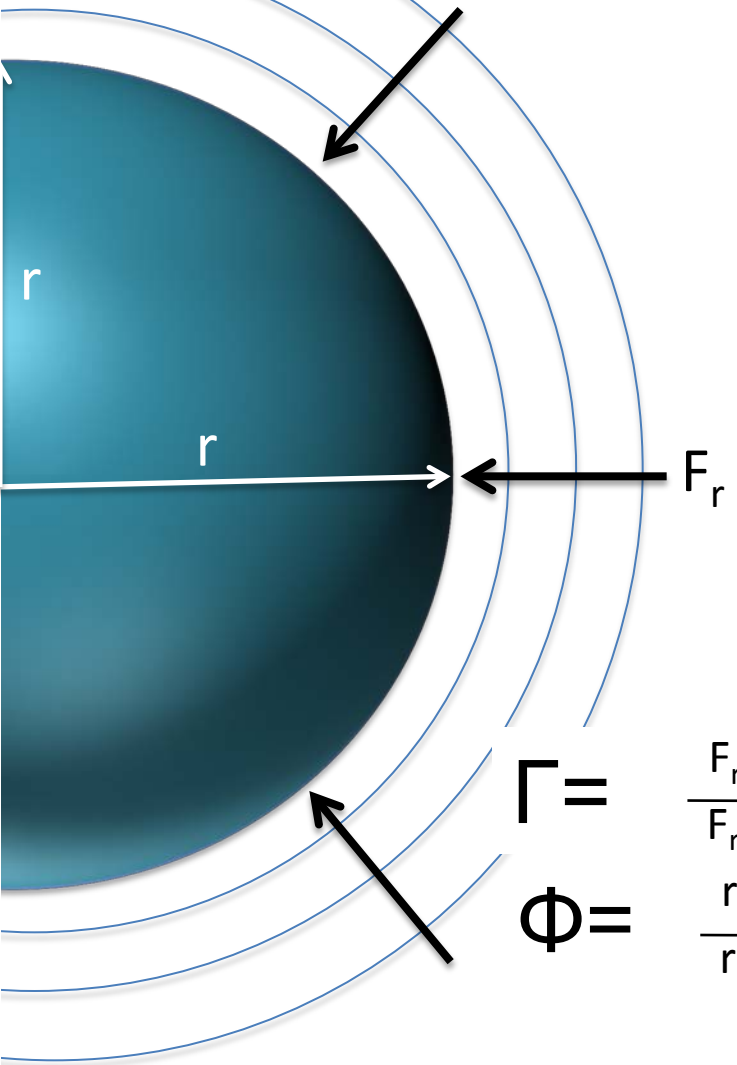


Why is this wrong?

Γ(T) = Inherent Growth Ratio
Φ = Aspect Ratio

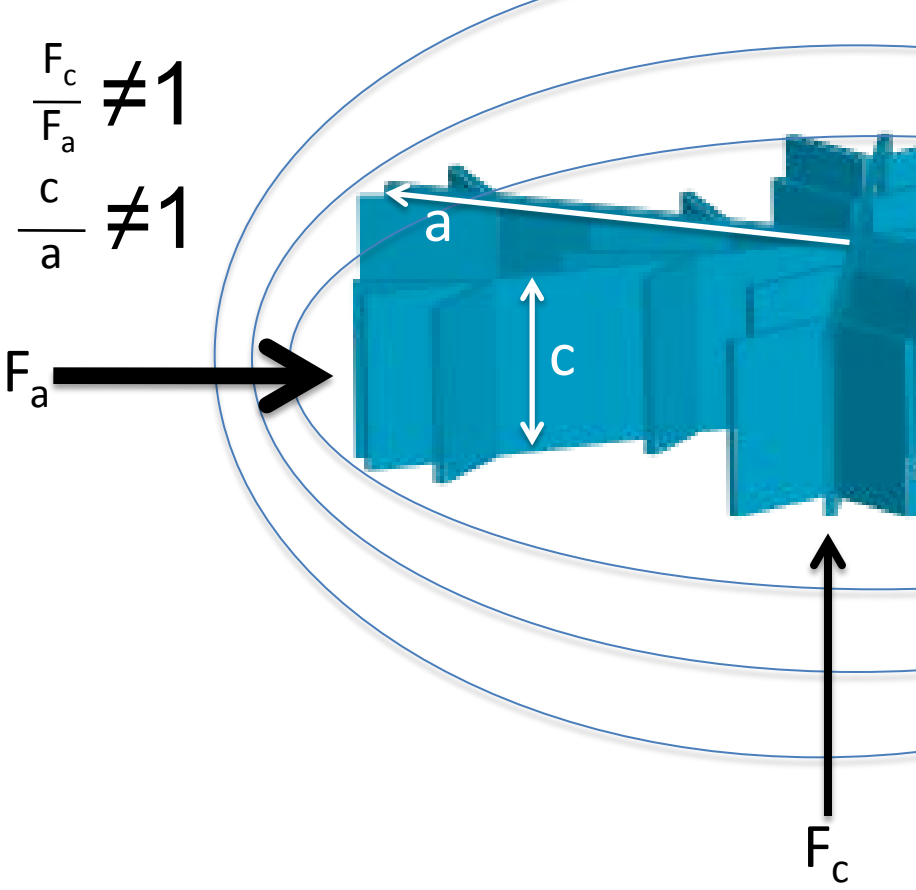
$$\Gamma = \frac{F_c}{F_a} \neq 1$$

$$\Phi = \frac{c}{a} \neq 1$$



$$\Gamma = \frac{F_r}{F_r} = 1$$

$$\Phi = \frac{r}{r} = 1$$



Spheres misinterpret the potential vapor uptake from the surrounding environment.

Remedy attempts with m-D Relationships

Allows:

$m = \alpha L^{2+\Gamma}$

$\Gamma \neq 1$

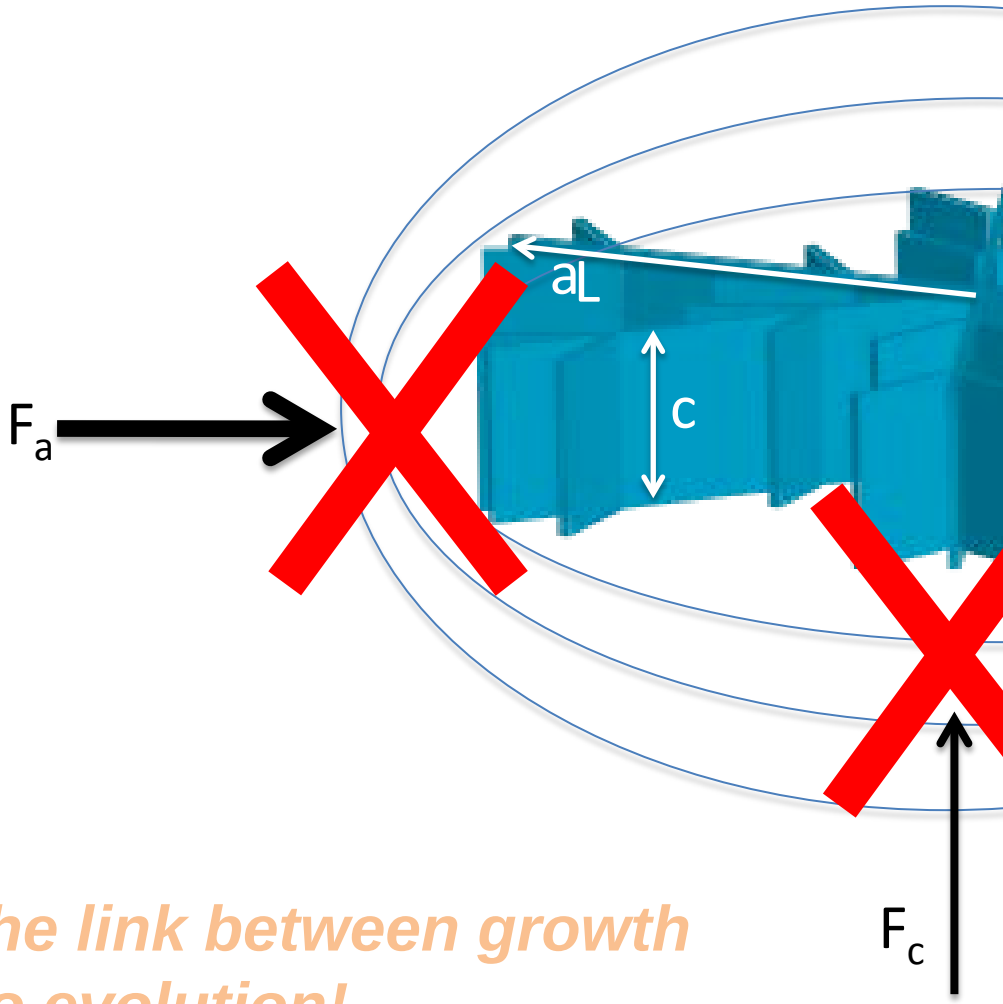
$\Phi \neq 1$

What's missing?

$\frac{dc}{da} \propto \frac{c}{a}$

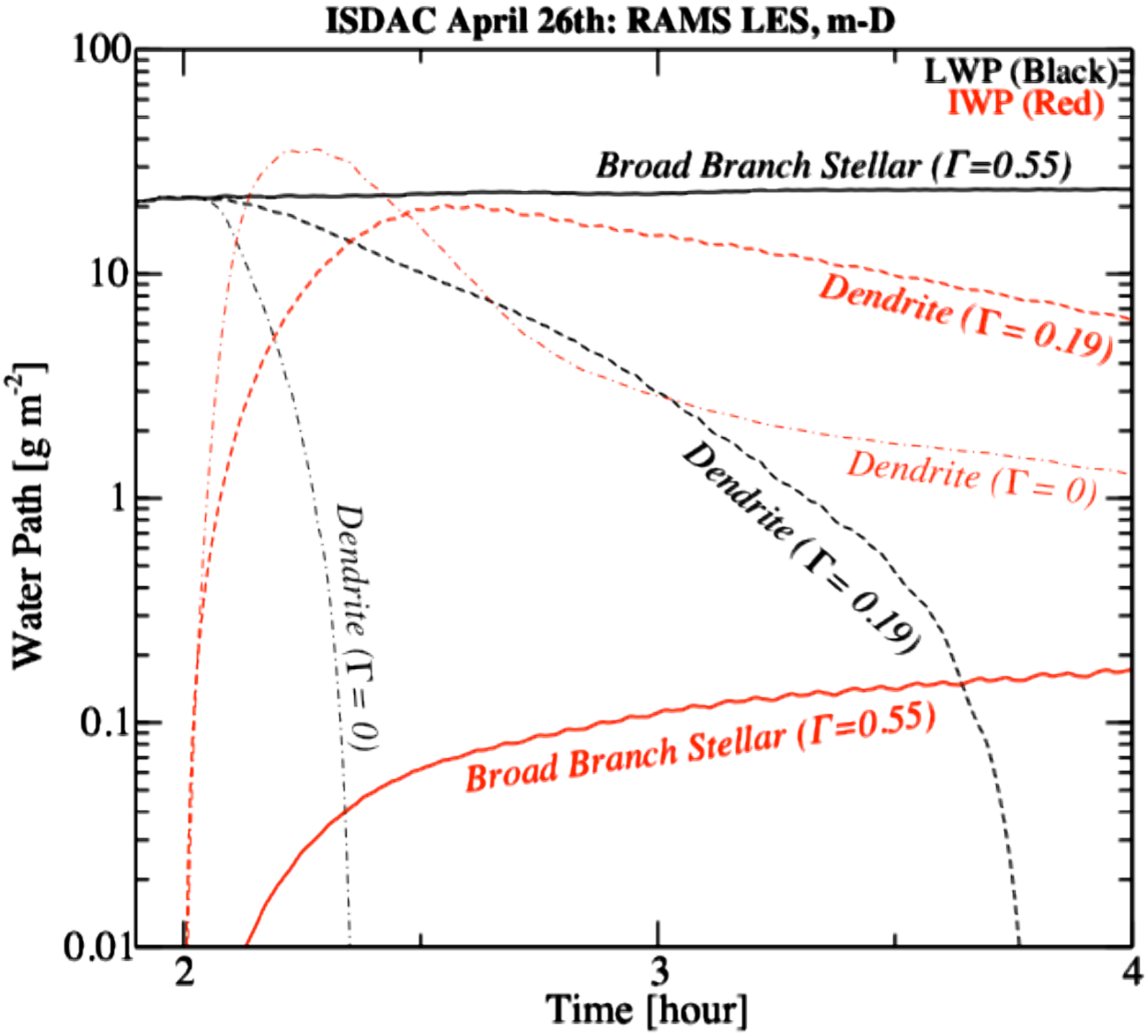
a = L

c = ??



m-D relationships ignore the link between growth and aspect ratio evolution!

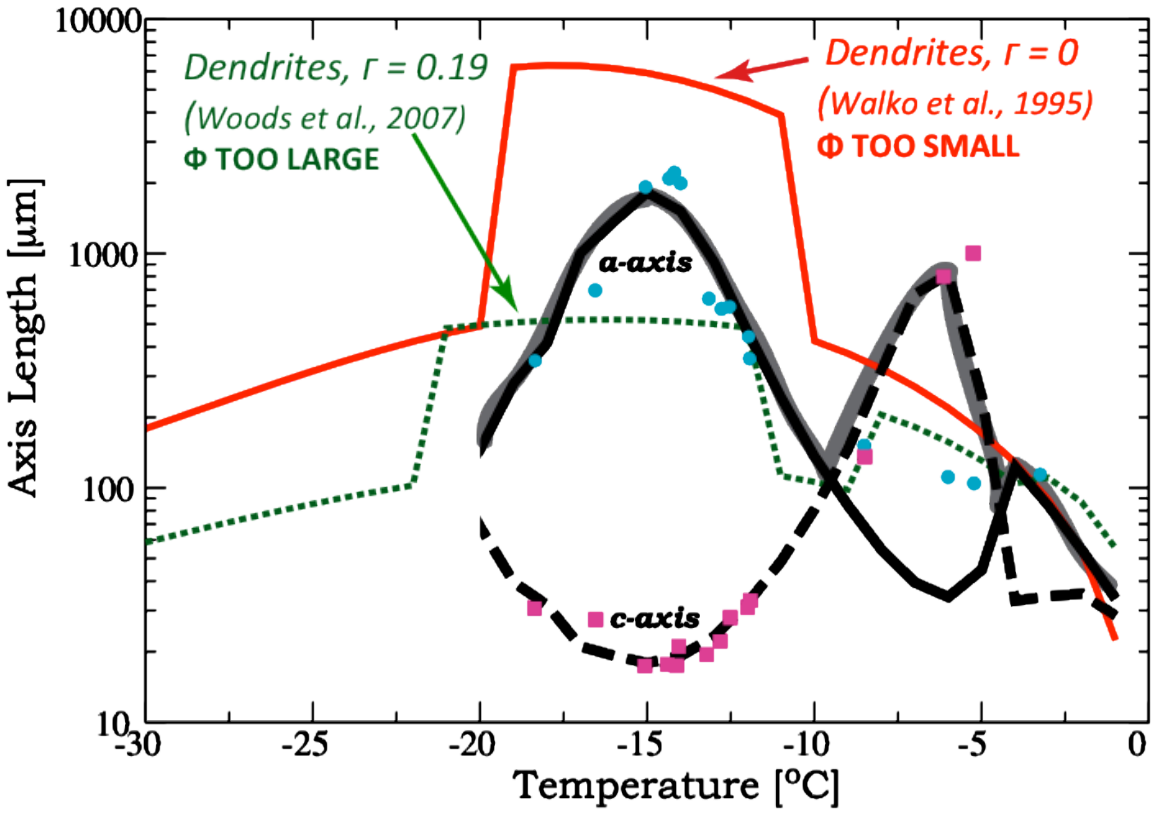
Some m-D Results…



…show a large **spread** in predicted water paths due to **inconsistent** mD parameterizations.

How do we fix this ice growth problem?

Step #1: Bin model with prognostic 'a' and 'c'



Bin results match wind-tunnel data (Fukuta and Takahashi, 1999).

Can this be captured in a Bulk model?

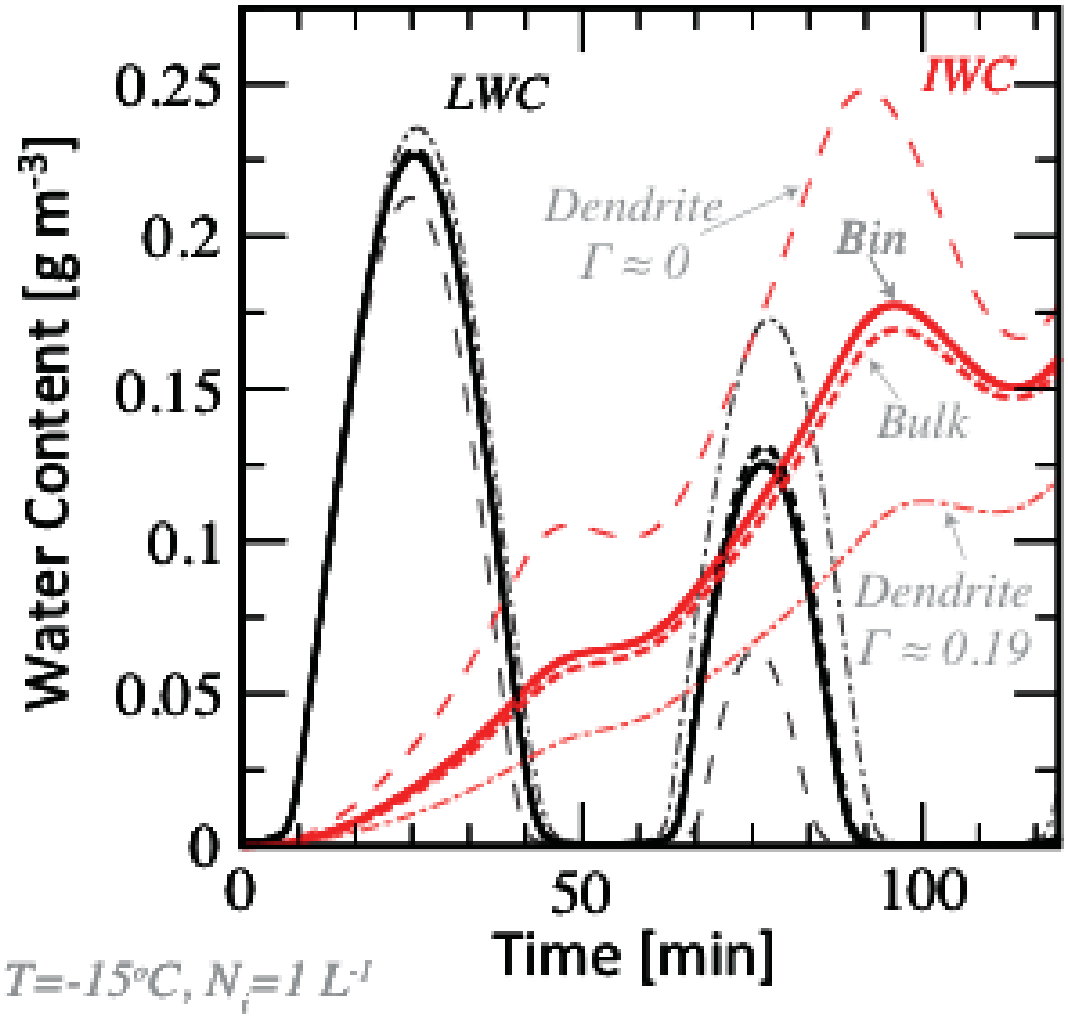
YES!...

Attempt #2: Bulk method predicting only ONE axis length!

1. One prognostic axis length, say ‘a’, assumed as Gamma distribution.

2. Diagnose second axis length, ‘c’, using ‘a’ and a predicted historical parameter, δ.
   - *relates ‘a’ and ‘c’ distributions over time.*
   - *determined by evolution of Γ.*

Does it work?



T=-15°C, N_t=1 L^{-1}

mD methods seem confused...

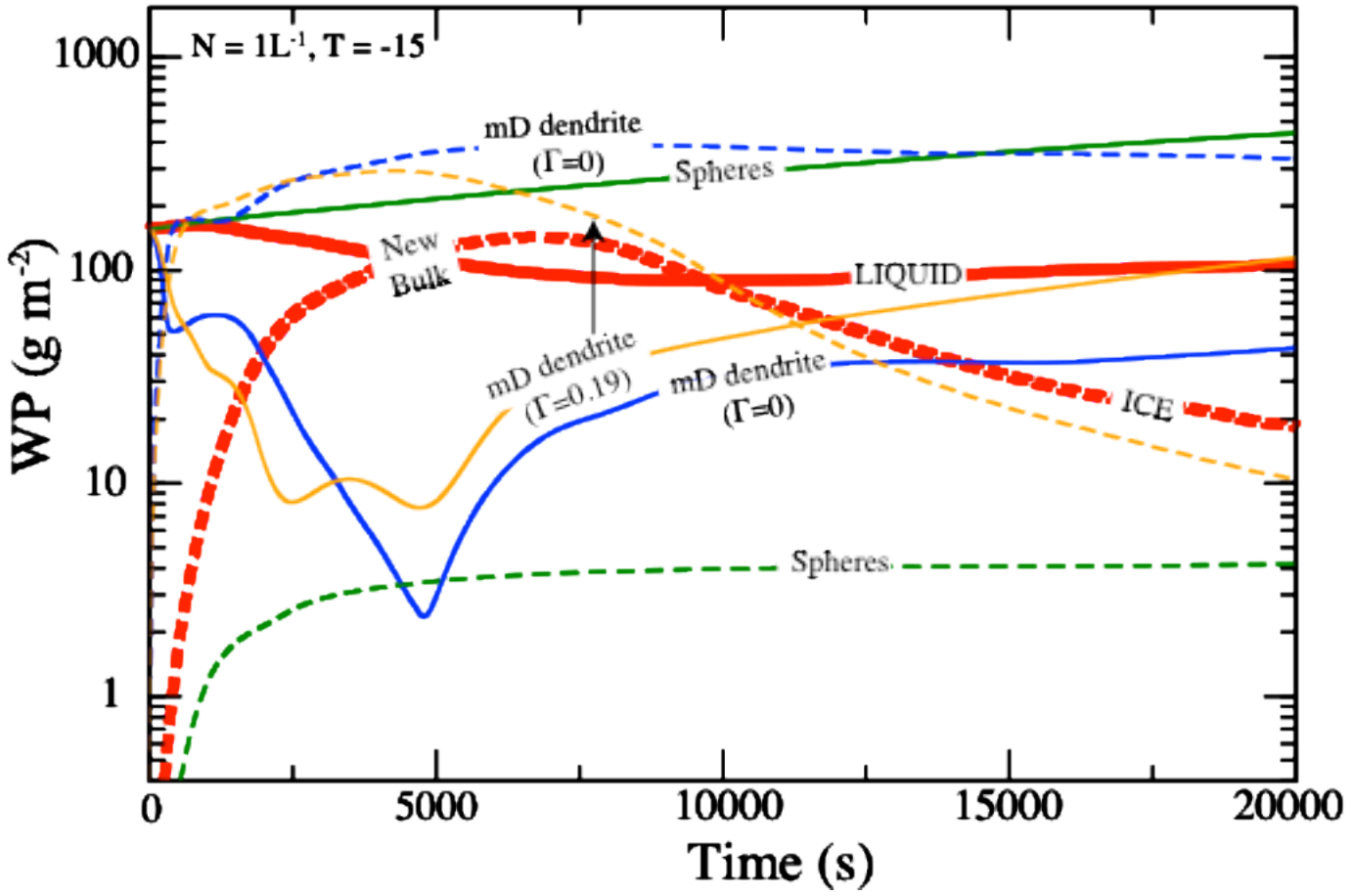
New bulk compares well to data-verified bin method (at liquid saturation).

It would seem so!

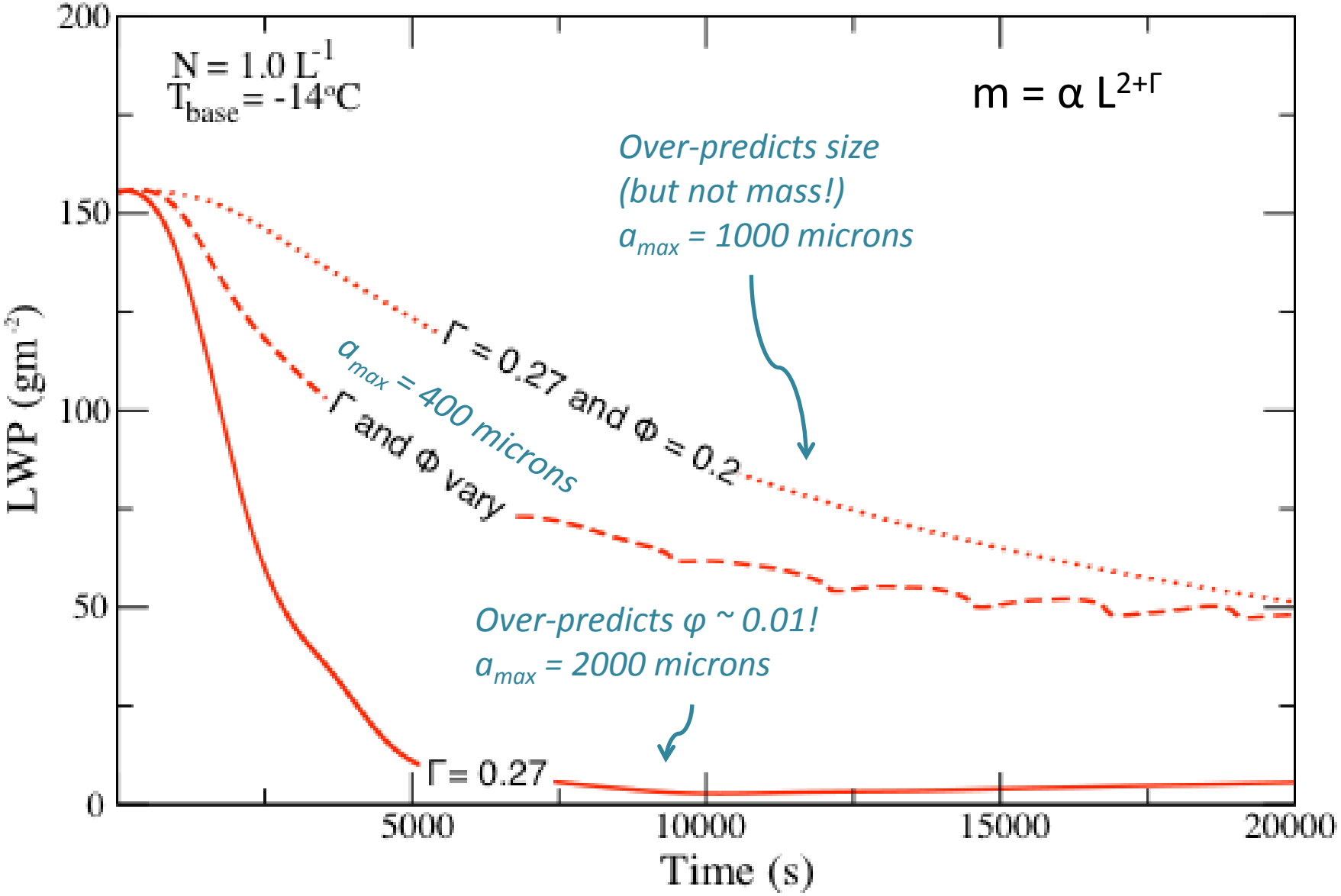
A more robust test.

2D Kinematic Model:

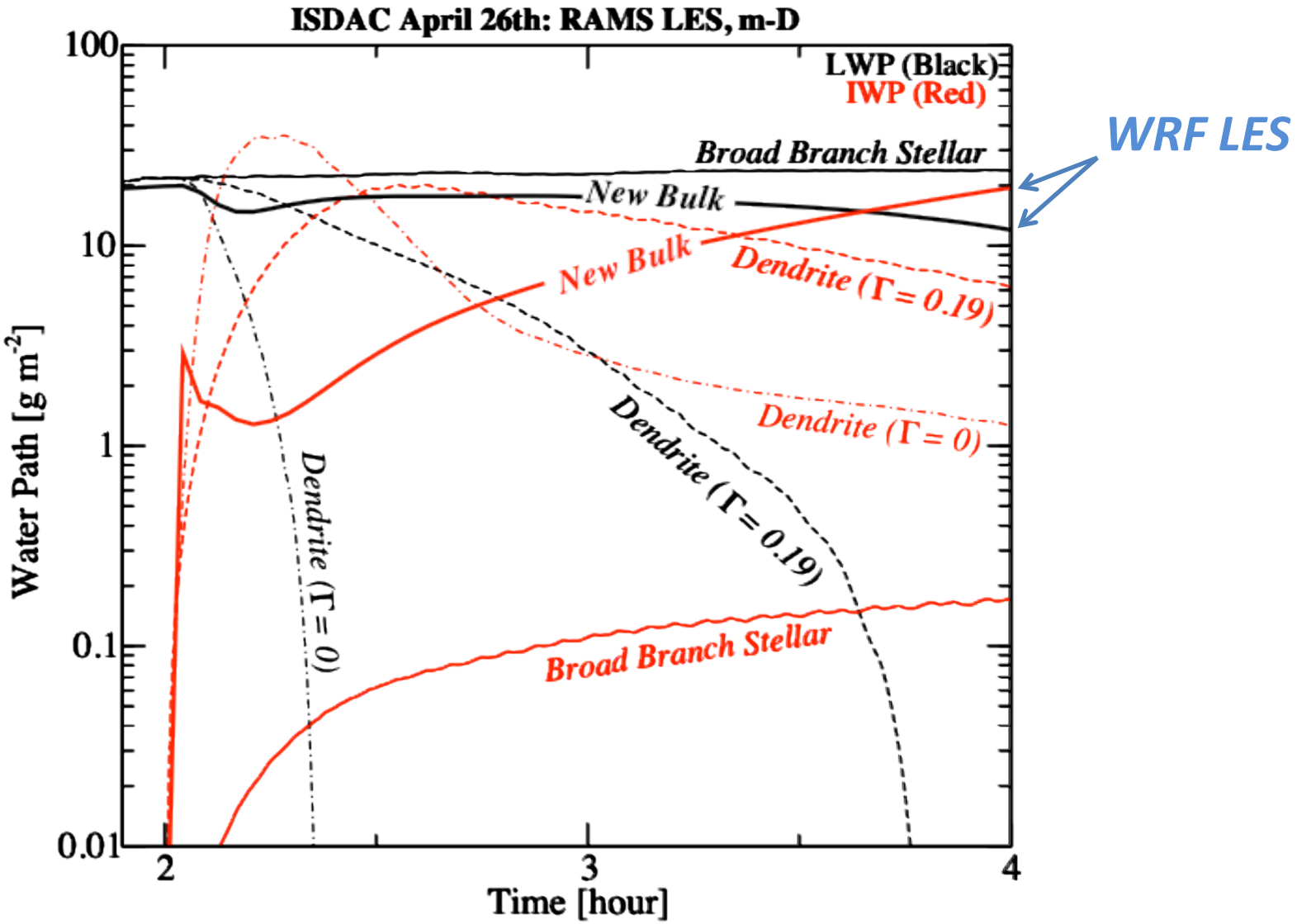
- *Fixed overturning eddie*
- *Sedimentation*
- *Cloud-top radiative coo*



Accurate habit prediction is a happy medium.



The Big Test: LES



The method passes the 'WRF Test!'

More ice and maintained liquid than with mD relationships!

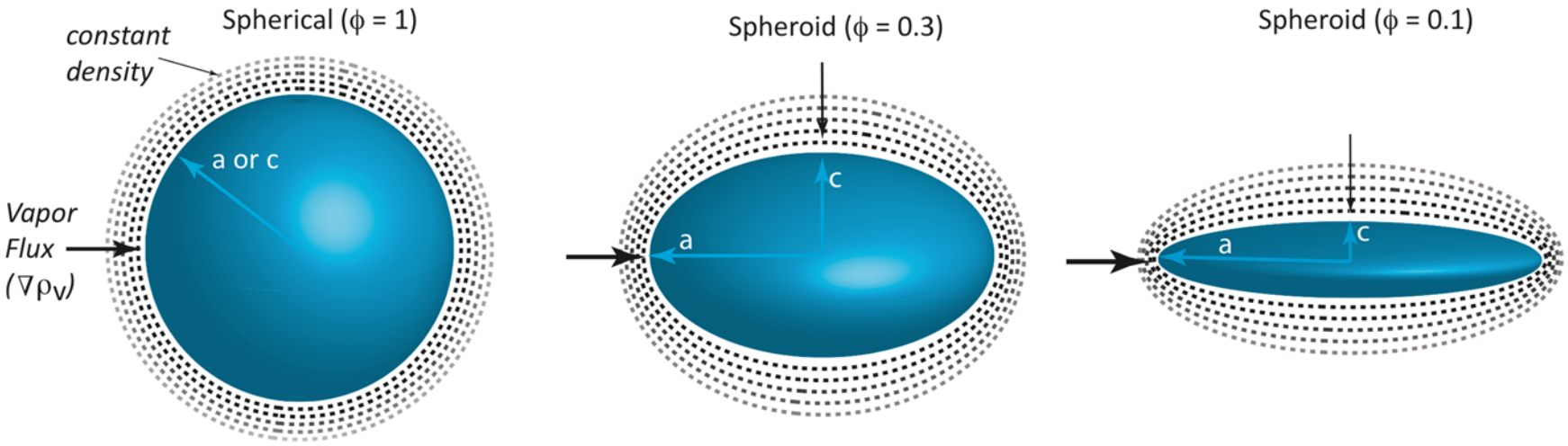
Conclusions

- Unadaptive ice habit (constant aspect ratio) severs the non-linear link between $d\Phi/dt$ and diffusional growth
  - *Thus, m-D relationships cannot simultaneously predict mass, size, and fall speeds!*
- New bulk method compares well to data-verified bin approach
- Future Work:
  - *Further simulations with WRF*
  - *influence of habit on the dynamics/structure of mixed-phase clouds*
  - *balance during cloud maintenance and how a glaciating state occurs dynamically.*

Thanks!

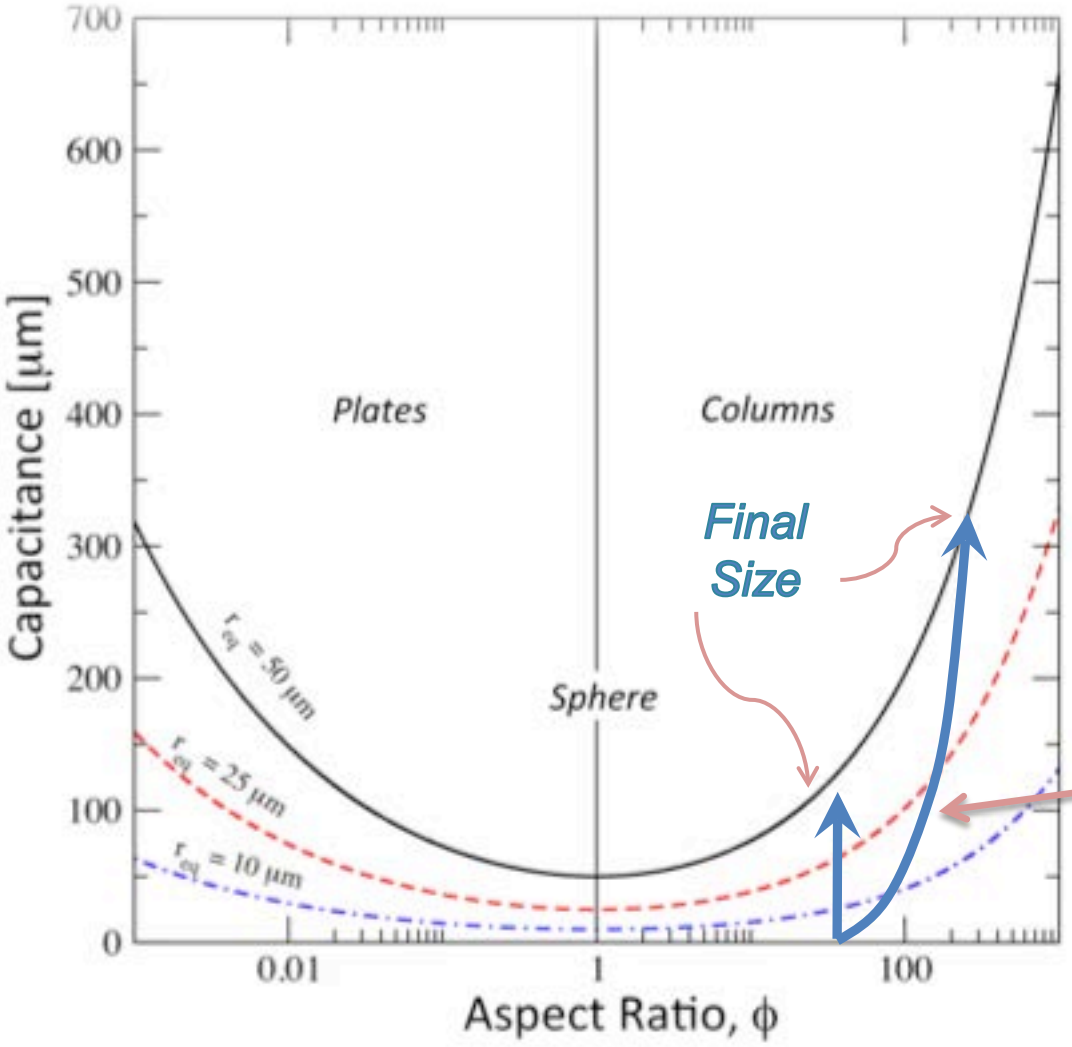
Remedy attempts with m-D Relationships

Unfortunately, this also ignores an important piece..



There exists a nonlinear relationship between vapor diffusional growth and aspect ratio evolution.

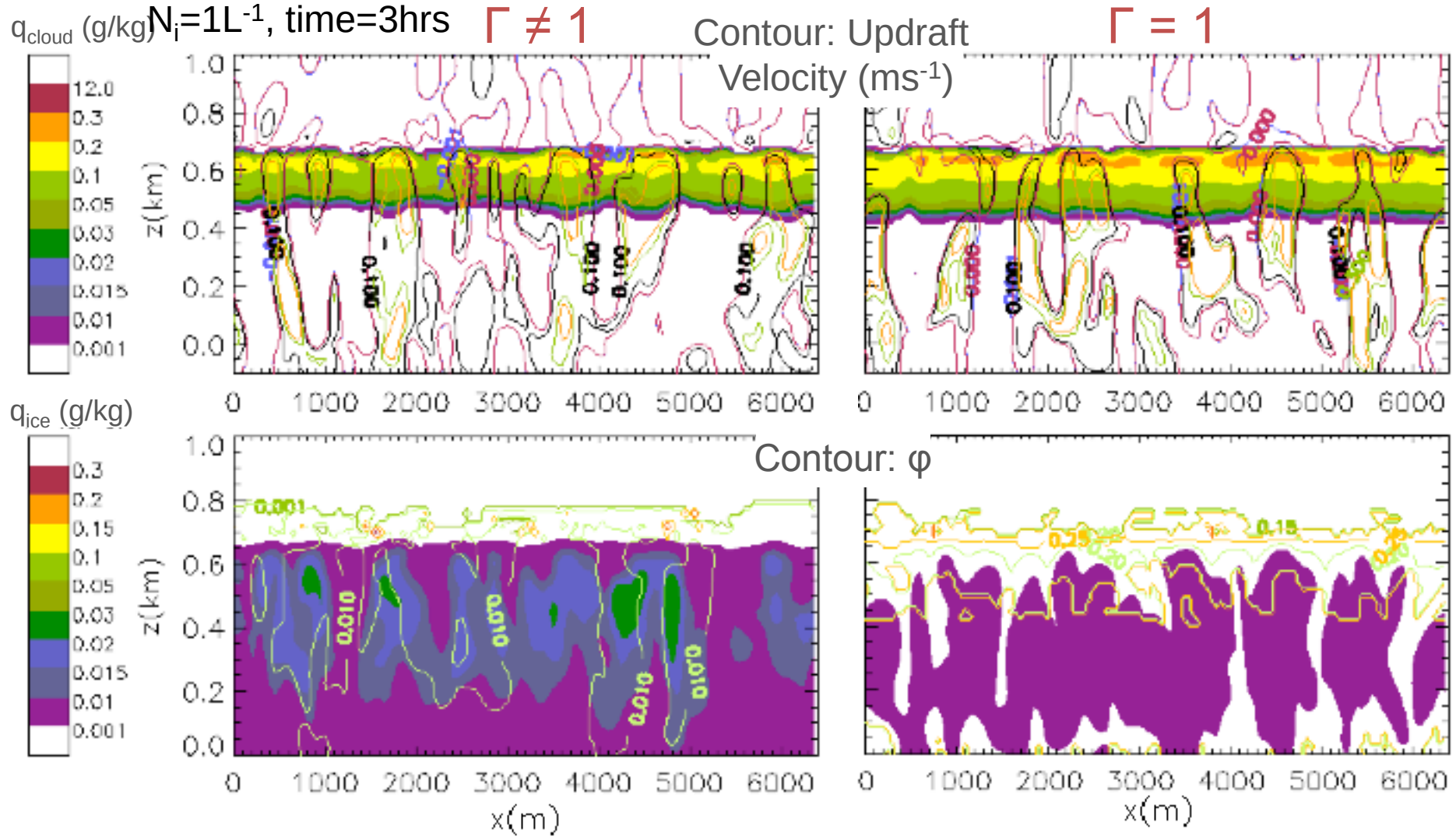
Ignoring the link: CONSEQUENCES!



Growth is underpredicted if φ is held constant in time

Aspect Ratio Evolution => Faster growth

Hit the method with a hammer: WRF



The method passes the 'WRF Test!'

More ice and less liquid than when the IGR is assumed unity.