Bridging The Divide Between Bin And Bulk Microphysics

What prognostic variables are best for simulating warm rain with bulk microphysics schemes?

Sean Patrick Santos[12], Marcus van Lier-Walqui[12], Hugh Morrison[3], and Adele Igel[4]

[1]CCSR, Columbia University [2]NASA Goddard Institute for Space Studies [3]National Center for Atmospheric Research [4]University of California, Davis

The BOSS Framework: Microphysics With No Assumed Drop Size Distribution

BOSS: The Bayesian Observationally constrained Statistical-physical Scheme

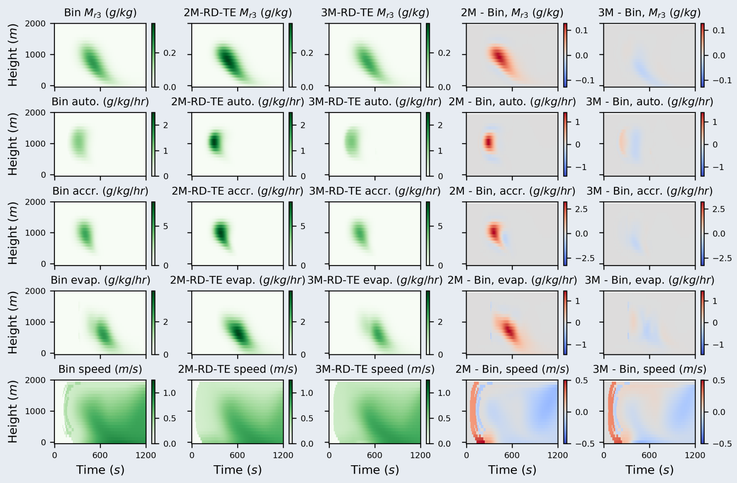

Figure 1:Rain-related quantities from kinematic driver using TAU bin scheme and BOSS schemes using two (2M-RD-TE) or three (3M-RD-TE) cloud moments. Rightmost two columns show deviation from the reference for two and three moment schemes, respectively.

- Bayesian inference is used to fit bulk microphysics to the TAU bin model in a 1-D kinematic driver.
- BOSS schemes with three cloud moments perform much better than those with two cloud moments (Fig. 1).
- Although rain moments are useful for diagnosing the autoconversion rate "offline", they do not benefit the model in a time-evolving context (Fig. 2).

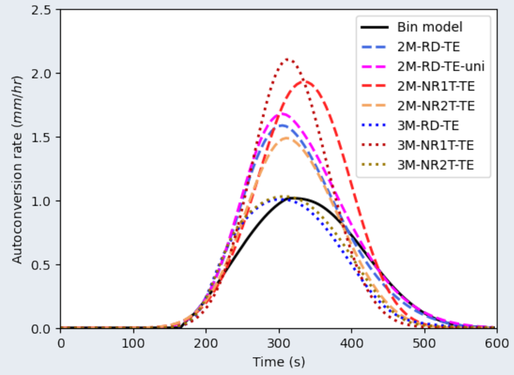

Figure 2:Autoconversion rates. Black=bin model, Red=power law, Yellow=sum of two power law terms, Blue=two terms with rain moments.

- We are developing a "single category" version of BOSS with no artificial rain/cloud distinction.

JEFE: Measuring Predictability

JEFE: Jacobian Evaluation of Functional Error

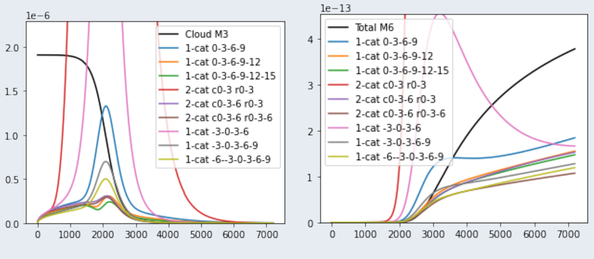

Figure 3:Adjoint-model-derived estimates of relative error of highly-accurate bulk schemes for cloud mass (left) and radar reflectivity (right).

Conclusions

- Two-moment schemes with separate rain and cloud categories are generally unable to emulate bin model precipitation.
- Box model studies (AMP and JEFE) show that four-moment single-category schemes are more accurate. We are working on corroborating this with BOSS.
- All studies agree that using three or more cloud moments substantially improves two-category autoconversion rates.
- Lowering the threshold size separating cloud from rain may also help based on AMP results.

AMP: A Bulk Scheme With Bin Physics

AMP: An Arbitrary Moment Predictor

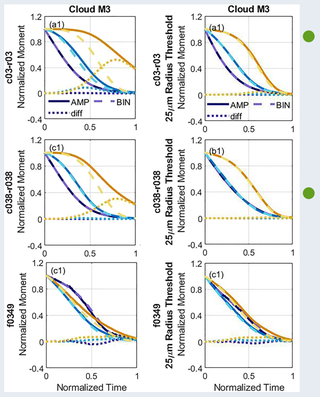

Figure 4:Comparison of cloud mass between bin and AMP schemes for different box model simulations. Different colors=different error terciles.

- The Hebrew University bin model was used to produce a bulk reconstruct-evolve-average collision-coalescence scheme.
- Using separate rain and cloud categories, defined by a 40 micron size cutoff, (schemes c03-r03 and c038-r038 in Fig. 4) is less accurate than using moments of the full hydrometeor size spectrum (scheme f0349).
- Two-category schemes perform much better with a 25 micron cutoff, though the two-moment scheme struggles with rain reflectivity (not shown).
- More details in Igel et al., 2022.

References

Igel, A. L., Morrison, H., Santos, S. P., & van Lier-Walqui, M. (2022). Limitations of separate cloud and rain categories in parameterizing collision-coalescence for bulk microphysics schemes. *Journal of Advances in Modeling Earth Systems, 14*(6), e2022MS003039. https://doi.org/https://doi.org/10.1029/2022MS003039

Acknowledgements

This work was supported by the U.S. Department of Energy under grant number DE-SC0021270.

Contact Information

- Email: SeanPatrickSantos@gmail.com