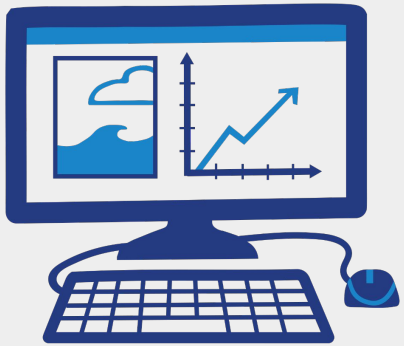


Upgrading cloud microphysical parameterization in GFDL GCMs

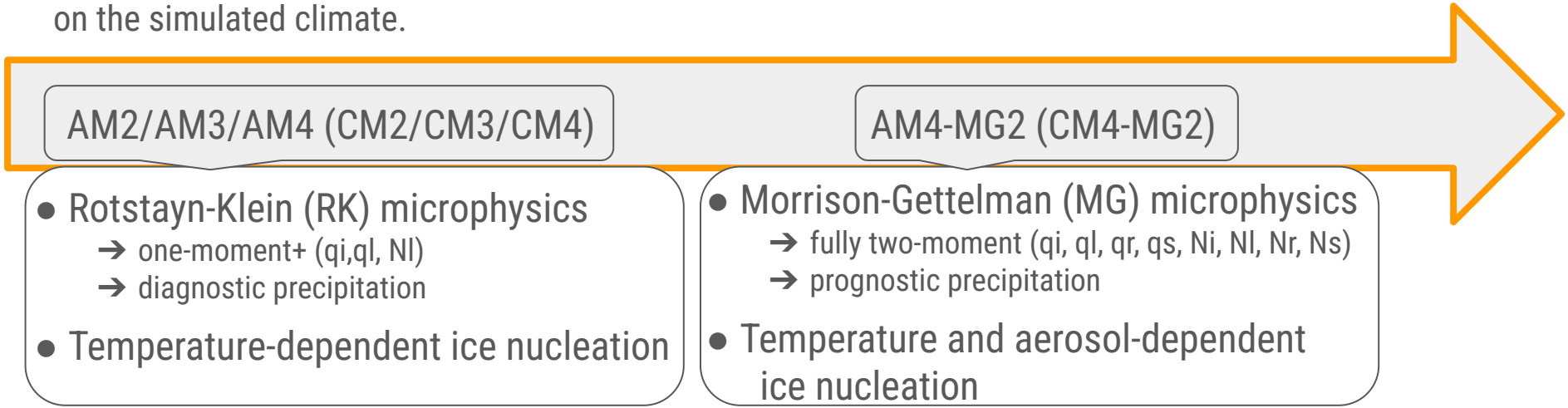
Huan Guo

Q1: Concerning GFDL's core strength of building and improving models of the weather, oceans, and climate for societal benefits, how can GFDL leverage advances in science and computational capabilities to improve its key models? What are the strengths, gaps, and new frontiers?

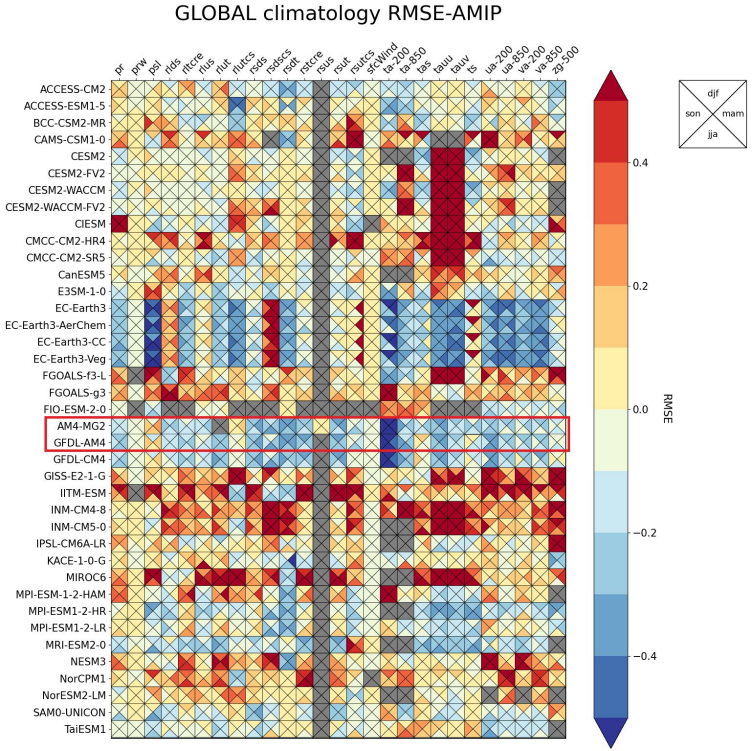
Updating cloud microphysics from RK to MG2 scheme

- There were limited microphysics updates going from AM2 to AM4.
- The existing RK scheme has issues: (a) diagnostic precipitation, (b) no ice number treatment, and (c) overestimate of ice nucleating particles.

To address these issues, we implemented the MG2 scheme in AM4/CM4 and assessed the influence on the simulated climate.



Comparable or better mean climate skill scores



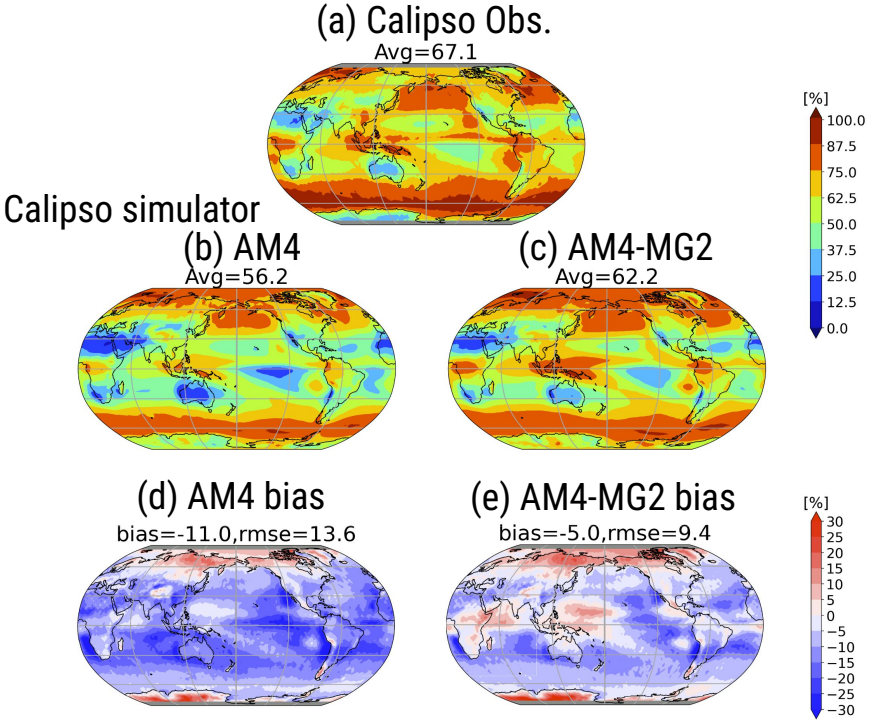
1. The left figure shows relative errors of AM4-MG2, AM4, and CMIP6 models for 27 global fields. More blueish means smaller errors, and more reddish means larger errors.

2. AM4-MG2 exhibits comparable (better) model skill scores with (than) AM4.

3. AM4-MG2 and AM4 perform better than most CMIP6 models.

Guo et al., 2021, *JAMES*

Better cloudiness simulations



1. The left figure shows total cloudiness from Calipso observation (top), Calipso simulators running online within AM4 and AM4-MG2 (middle), and model biases (bottom).
2. Both models are able to capture the spatial distribution of cloudiness.
3. AM4-MG2 enhances cloudiness with smaller bias and root mean square error (rmse) than AM4.

Guo et al., 2024, *submitted*

Weaker aerosol effective forcing & lower climate sensitivity

	CM4	CM4-MG2
TCR (k)	2.05	1.85 ↓
EffCS (K)	3.91	3.31 ↓
ECS (K)	4.89	4.52 ↓
Aerosol ERF(W/m^2)	-0.72	-0.62 ↓

TCR: transient climate response;
EffCS, ECS: effective, equilibrium climate sensitivity;
ERF: effective radiative forcing.

1. The magnitude of aerosol ERF is reduced with MG2, where prognostic precipitation enhances accretion for precipitation formation.
2. The climate sensitivity is also reduced when MG2 is active.

Guo et al., 2022, *JAMES*

Brief summary and future work

1. The mean climate skill scores with/without MG2 are comparable.
2. The prognostic precipitation treatment in MG2 promotes accretion and suppresses autoconverion, which is more realistic and reduces the magnitude of aerosol ERF.
3. The climate sensitivity is also reduced when MG2 is active.
4. MG2 enhances cloudiness, and reduces the bias of too-early and too-often precipitation initiation (not shown here).
5. Future work involves improving ice nucleation and microphysical parameterizations, and extreme weather/climate simulation and predictions, and investigating aerosol-cloud-precipitation interaction.