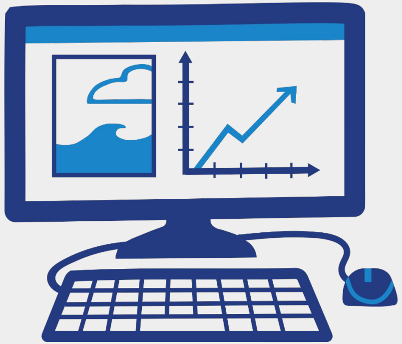
Overview of GFDL's next generation atmospheric model AM5



Presented by Pu Lin on behalf of the AM5 development team

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?

AM5 scope

- Advance NOAA's goals to increase the Nation's ability to prepare for, adapt to, and mitigate the negative impacts of weather and climate extremes associated with an evolving climate.
- Realistic representation of weather and climate phenomena that would improve predictions and projections from the sub-seasonal to centennial.

Priority goals:

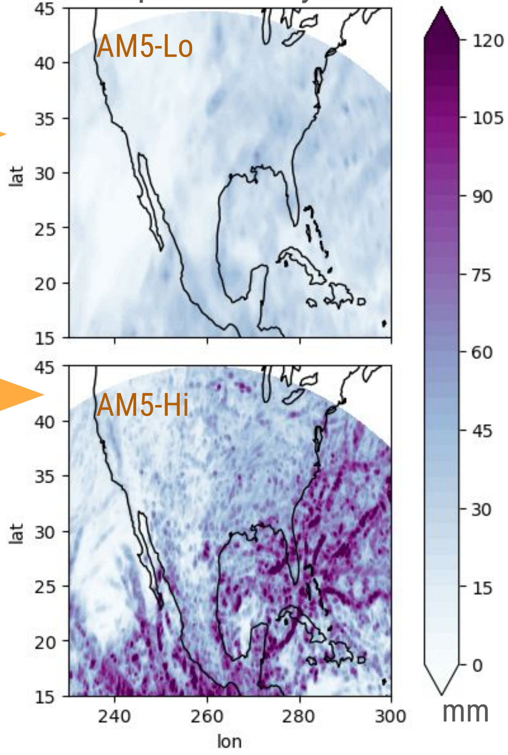
❖ Simulation of climate **extremes** with a focus on the US
❖ Prediction on **subseasonal to seasonal** timescales
❖ Characteristics of **regional surface climate** over the 20th century

Development began in 2022. Expected delivery in 2025

Higher resolution to better resolve extremes

	AM4.0	AM5
Horizontal resolution	100km	100km (AM5-Lo) 25km (AM5-Hi)
Vertical levels	33	65
Model top	1hPa/43km	0.01 hPa/75km

Max cumulative precip over a 3hr-period in a year



Challenges:

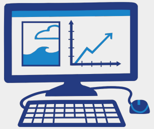
- Require systematic adjustment of all model settings
- Balance between performance and resources

More advanced representation of atmos/land processes:

Better predictions and projections across timescales

Model component	AM4.0	AM5	Impacts
Radiation	SEA/ESF (Schwarzkopf and Ramaswamy 1999, Freidenreich and Ramaswamy 1999)	RTE+RRTMGP (Pincus et al. 2019) + GFDL Cloud Optics	radiative forcing, cloud radiative effects
Convection	DPC (Zhao et al. 2018)	Non-equilibrium convection DPC (Zhang et al. 2024)	diurnal cycle of land precipitation
Boundary layer	Lock et al. (2000)	NCEP EDMF (Han and Bretherton 2019)	shallow clouds, tropical circulation
Cloud microphysics	Rotstayn-Klein (Rotstayn et al. 2000)	Morrison-Gettleman-2 (Guo et al. 2020, 2021)	stratocumulus, aerosol indirect effect
Aerosol-cloud interaction	Liquid only (Ming et al. 2006)	Dust and temperature-dependent ice nucleation (Fan et al. 2019)	cloud phase partitioning, climate sensitivity
Aerosol chemistry	Simplified	Updated aerosol emissions and deposition	decadal variations of surface temperature
Land	LM4	LM4+	regional climate characteristics
Air-sea flux algorithm	COARE3.5	HWRF version 2017	tropical cyclone intensity
Orographic gravity wave drag	Garner et al (2005)	Updated (Garner et al. 2005)	polar vortex climatology
Non-orographic gravity wave drag	Alexander and Dunkerton (1999)	Beres et al. (2004)	Quasi-Biennial Oscillation, polar vortex
Stratospheric ozone	Prescribed	Linear ozone (Lin and Ming 2021)	polar vortex variability
Dynamical core	FV3 v2017	FV3 v2023	tropical cyclone

SEA: Simplified Exchange Approximation
ESF: Exponential Sum Fit technique
RTE: Radiative Transfer for Energetics
RRTMGP: Rapid Radiative Transfer Model for General circulation model applications-Parallel
DPC: Double Plume Convection
EDMF: Eddy-Diffusivity Mass-Flux
COARE: Coupled Ocean-Atmosphere Response Experiment bulk algorithm
HWRF: Hurricane Weather Research and Forecasting model
FV3: Finite-Volume Cubed-sphere dynamical core



A new parameterization for non-orographic gravity waves

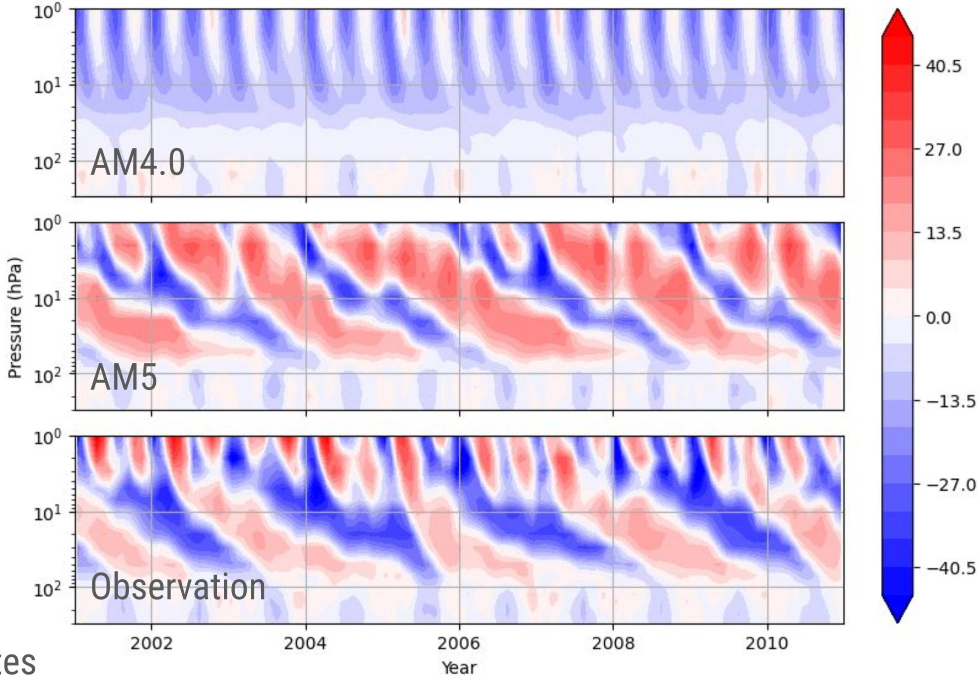
Why do we need it?

- A realistic representation of the stratosphere provides long-range predictability
- Reliable gravity wave parameterizations are crucial for simulating stratospheric circulation

What's new?

- Explicit expression of the wave source in terms of convection
- More realistic Quasi-Biennial Oscillation (QBO) climatology and variability

Simulated and observed QBO (equatorial zonal wind [m/s])



Fruitful collaboration with the NorthWest Research Associates

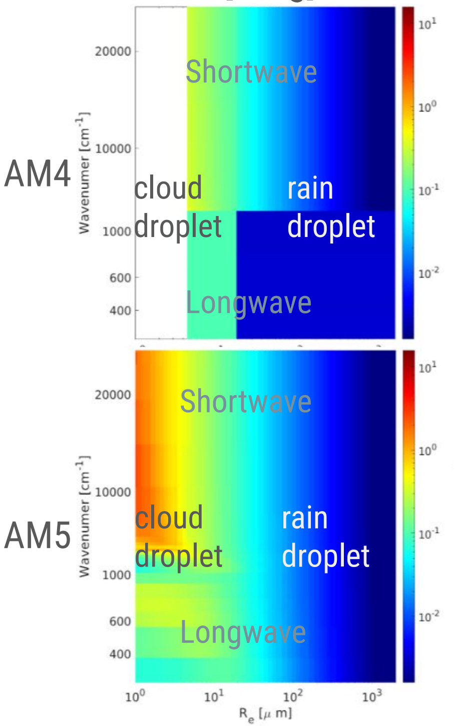
Updates in the radiative transfer calculations

Radiative transfer scheme sets the foundation for accurate and efficient climate projection and numerical weather prediction.

Benefits:

- Switching to the RTE+RRTMGP* framework takes advantage of the cumulative development over decades from the community.
- Modernized infrastructure allows flexibility to address user-tailored needs.
- A new unified parameterization developed at GFDL (Feng et al. submitted) yields more physical representation of clouds and precipitation.

Hydrometeor extinction coefficient [m^2/g]



*RTE+RRTMGP: Radiative Transfer for Energetics and Rapid Radiative Transfer Model for General circulation model applications-Parallel (Pincus et al. 2019)

AM5 Development Summary and Outlook

Leveraging advances in science and computational capabilities, GFDL is developing AM5 to better address NOAA's goals:

- Higher resolution to better simulate extremes
- More advanced physics (major updates in almost all components, see prerequisite slides) to improve regional climate simulations
- Seamless application from sub-seasonal to centennial

→ AM5 → CM5 & Others

Deliver in 2025

Next Generation Coupled Model & Prediction Systems

Joint efforts across divisions at GFDL and support/collaboration inside and outside NOAA (CPT projects, NOAA CVP/ERB/MAPP projects)

CPT: Climate Process Team
CVP: Climate Variability and Predictability
ERB: Earth's Radiation Budget
MAPP: Modeling, Analysis, Predictions and Projections