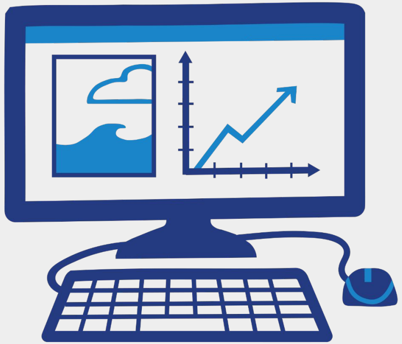


Atmospheric Aerosols and Chemistry

Fabien Paulot

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?

Precursor emissions
(anthropogenic, fire, natural, ships, aircraft, volcano)

Atmospheric chemistry

84 km

Stratosphere

O_3, HO_y, NO_y, Cl_y, Br_y, Polar clouds

Troposphere

Gases (O_3, CO, CH_4, NO_x, VOCs, SO_2, DMS, H_2)

Aerosols (SO_4, OM, BC, dust, nitrate, sea-salt, SOA)

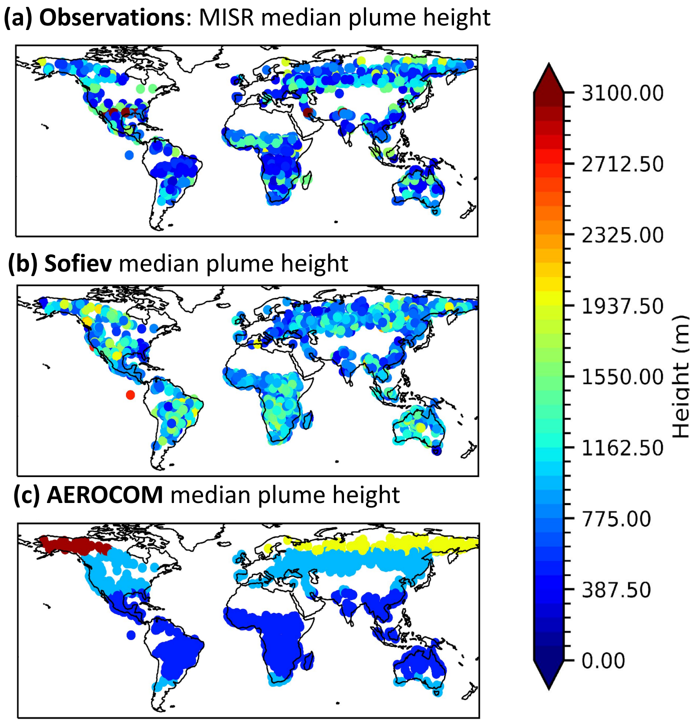
0 km

Radiation

Air quality
Deposition

Biomass Burning Injection Height

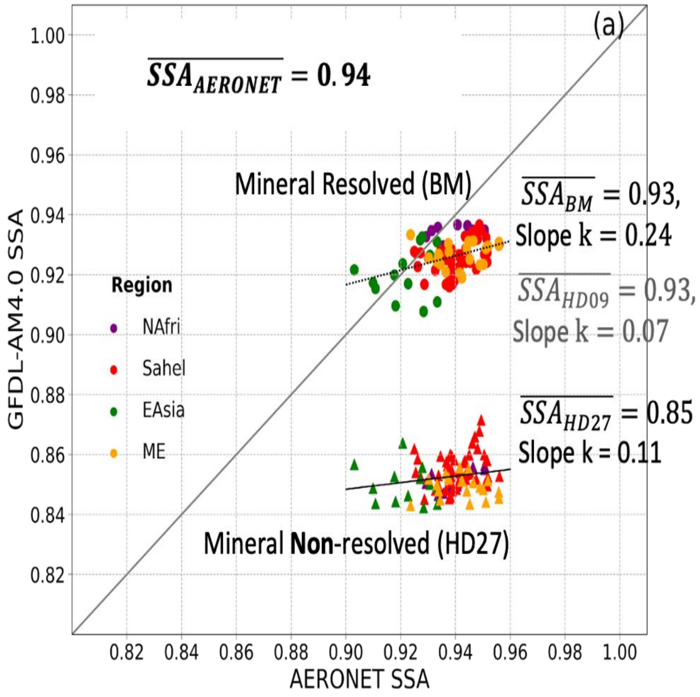
- Integrated Sofiev et al. (2010) parameterization for dynamic smoke plume height based on fire intensity, boundary layer height, and atmospheric stability.
- Achieved improved aerosol profiles (*Pouyaei et al., 2024, JAMES, in review*) and reduced bias in upper tropospheric ozone simulations (*Pouyaei et al., 2024, GRL, in prep*).
- Enables studying fire-vegetation-climate feedback with fully coupled fire emissions and atmospheric interactions.



Comparing observed plume heights with new mechanistic Sofiev scheme and previous AEROCOM scheme (*Pouyaei et al. 2024, JAMES, in review*)

Constraining Dust Absorption

- Uncertainty of Dust Radiative Effects is essentially related to mineralogy, in particular absorbing minerals such as iron oxides (Fe_2O_3), which percentage is fixed in atmospheric models (Li et al., 2021).
- GFDL AM4 used a fixed 2.7% Fe_2O_3 in dust (HD27), which is too absorptive (low SSA) compared to AERONET.
- Fixed 0.9% (HD09) Fe_2O_3 provides similar global absorption (or SSA) as simulated with 10 minerals (BM), which is expensive to run (Song et al., 2024)
- On regional scale, spatial distribution matters. The NASA space instrument EMIT is realizing the first global distribution of soil minerals (Thompson et al, 2024).

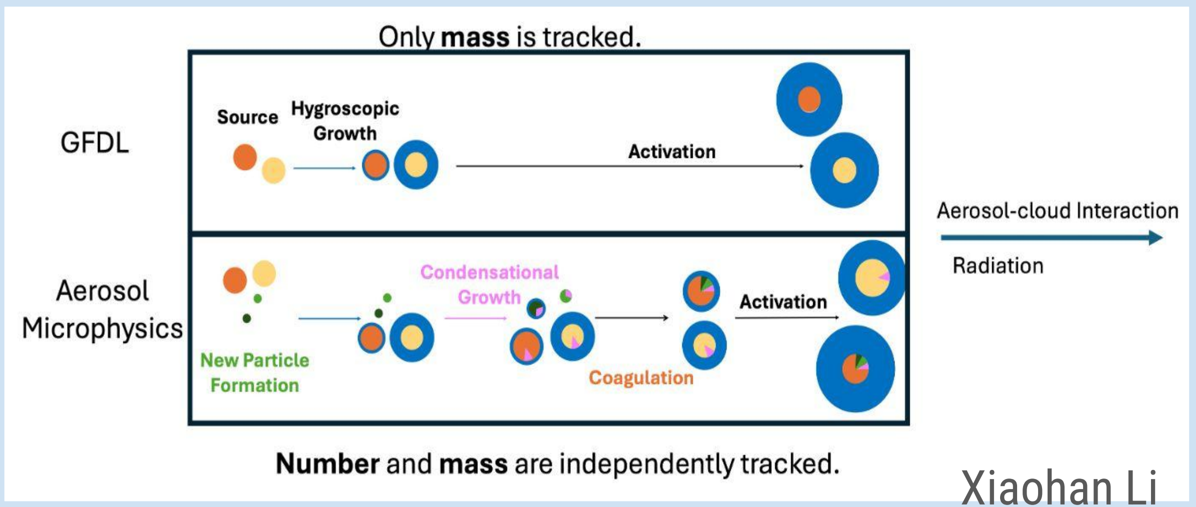


Implementation Of a New Aerosol Microphysics Model

The current GFDL aerosol scheme uses a bulk scheme tracking only aerosol mass.
New aerosol microphysics parameterization enables us to better tackle:

1. Aerosol-cloud interactions
    - New particle formation
    - Aerosol number
2. Aerosol radiative forcing
    - Mixing state
    - Coagulation
3. Response to:
    - Volcanic eruption
    - Climate intervention strategies

Schematics of aerosol processes in the model

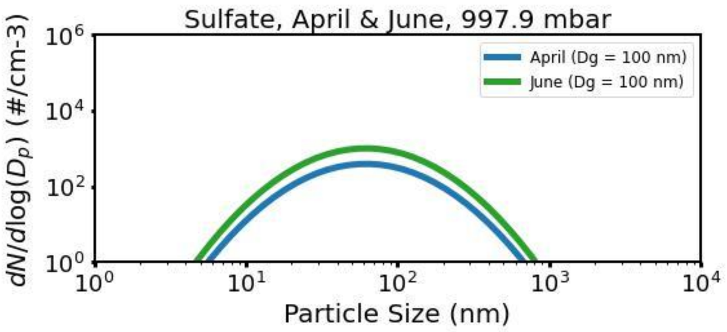


Xiaohan Li

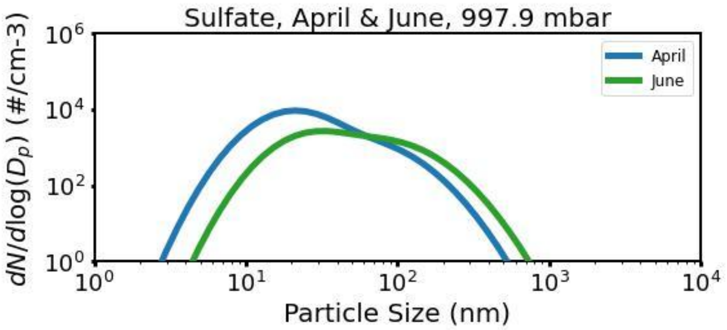
Examples of Aerosol Simulation Improvement

The new model development significantly improves the characterization of **seasonal variations** in aerosol particle **number** and **size** distribution.

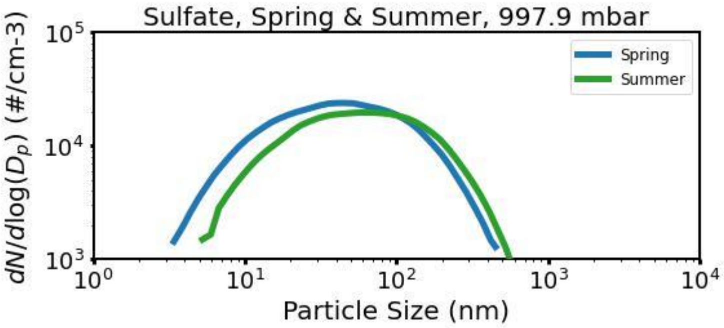
"Standard" GFDL



GFDL Aerosol Microphysics



Measurement

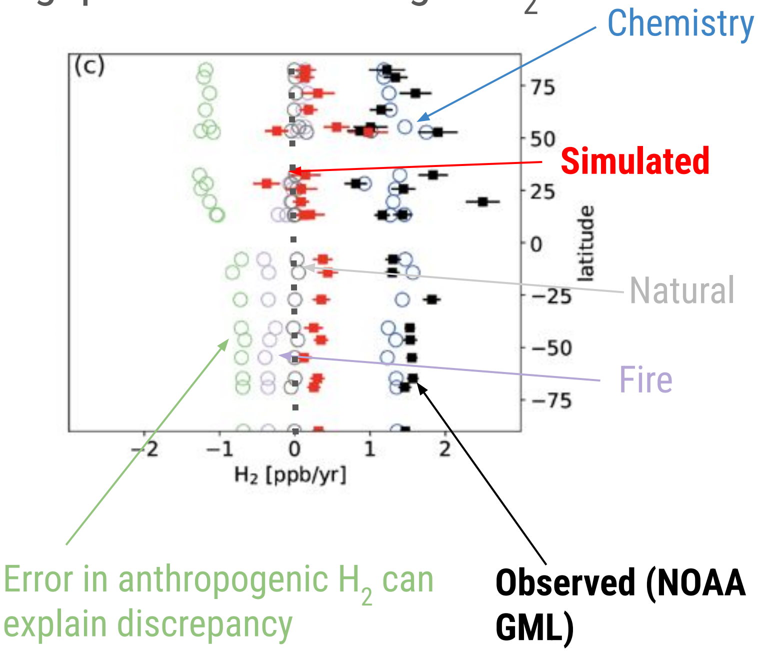


(Wu et al., Atmospheric Environment, 2008)

Representing H_2 in the GFDL Earth System Model

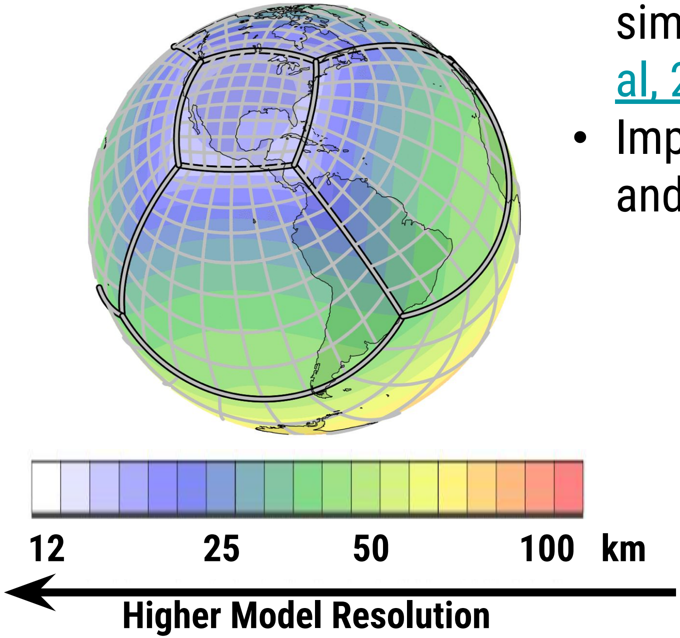
- Development of new inventories for H_2 sources (Paulot (2021,2024)) and new parameterization for soil removal (Bertagni, 2021)
- Novel evaluation strategies challenge our understanding of the H_2 atmospheric budget
  - NOAA GML background network (Paulot (2024))
  - UCI ice firn [1900-2000] (Patterson (in prep))
  - Princeton/UChicago soil uptake measurements (Reji (in preparation))
- Contribution to international research efforts (CICERO, HyVIS) ; policy-relevant output (DOE HFTO)

Increase in H_2 since 2010 highlights gap in understanding of H_2

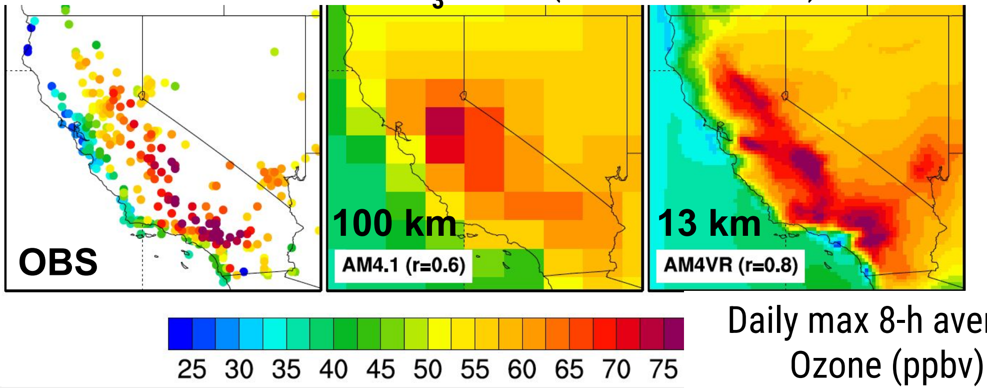


Variable-Resolution Global Chemistry-Climate Model (AM4VR) for Research at the Nexus of U.S. Climate and Air Quality Extremes

- 13 km spatial resolution over North America
- Reduced ozone uptake by water-stressed vegetation enables simulation of ozone pollution extremes during hot droughts (Lin et al, 2020)
- Improved representation of wildfire emissions, plume chemistry, and interaction with urban pollution (Lin et al., 2024)



Summer surface O_3 levels (2000-2020 climo)



Daily max 8-h average Ozone (ppbv)

Lin M. et al. [*JAMES*, 2024; AGU Editor's Highlights]