



Atmospheric Modeling II: Parameterizations

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NSF NCAR

CESM Tutorial: July 6, 2026

Learning Outcomes

By the end of this talk, you should have:

- An understanding of what a model “parameterization” is and why it’s necessary
- Familiarity with some of the main parameterizations in the Community Atmospheric Model version 7 (CAM7)
- The ability to find more information about any parameterization on your own

What is a parameterization?

The representation, in a dynamic model, of physical effects in terms of admittedly oversimplified parameters, rather than realistically requiring such effects to be consequences of the dynamics of the system.

-American Meteorological Society (AMS) Glossary

What is a parameterization?

The representation, in a dynamic model, of physical effects in terms of admittedly oversimplified parameters, rather than realistically requiring such effects to be explicitly resolved in the dynamics of the system.

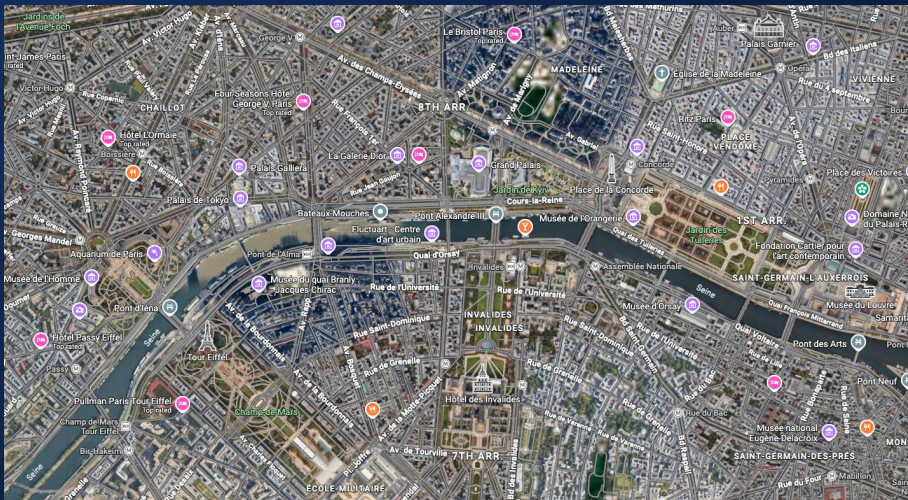
-American Meteorological Society

A method of replacing processes that are **too small-scale or complex** to be physically represented in the model by a **simplified process**.

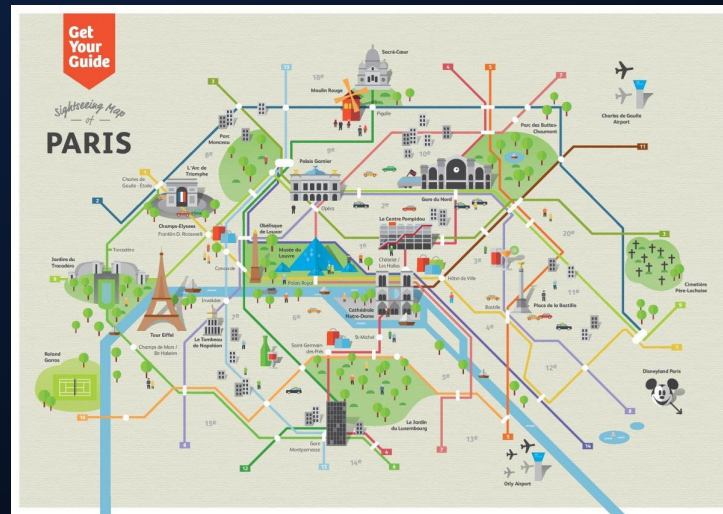
-Wikipedia

What is a parameterization?

- Imagine you're in Paris, but your phone broke and you can't zoom in on maps anymore! The map on the left has a *ton* of info, but the map on the right, with coarser resolution, has enough info to get around.



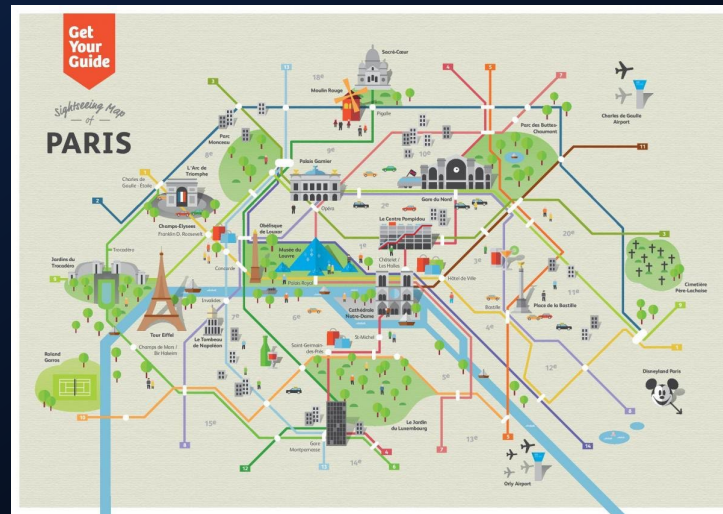
Google maps



<https://maps-paris.com/maps-paris-tourist/paris-places-to-visit-map>

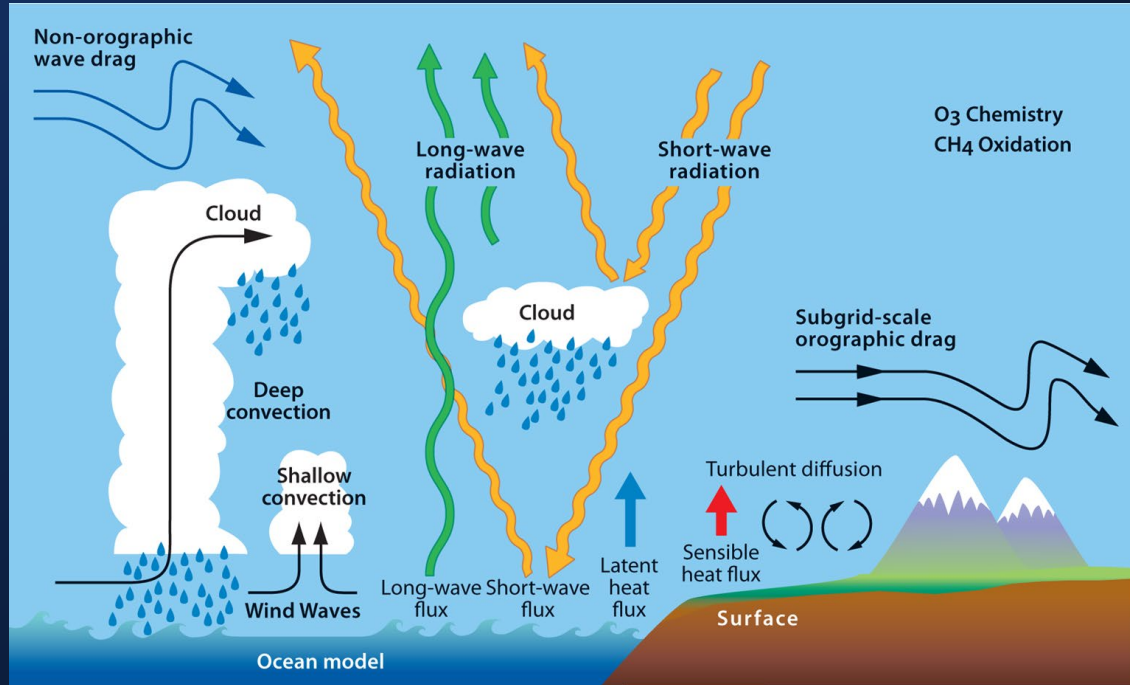
What is a parameterization?

- Imagine you're in Paris, but your phone broke and you can't zoom in on maps anymore! The map on the left has a *ton* of info, but the map on the right, with coarser resolution, has enough info to get around.
- This is similar to the idea of model parameterizations; they take complex, detailed information and turn them into simplified representations at larger scales.
- The goal is to capture the impact of those smaller (sub-grid) phenomena on the larger (resolved) scale.



<https://maps-paris.com/maps-paris-tourist/paris-places-to-visit-map>

What kinds of things would an atmospheric model need to parameterize?



Source: <https://www.ecmwf.int/en/research/modelling-and-prediction/atmospheric-physics>

Factors that go into choosing parameterizations

- Impact on the Earth system
 - E.g., shape of a leaf vs. land use
- Computational expense
 - Should be cheaper than explicitly representing the process in question
- Process uncertainty
 - What can be represented with limitations in process -level knowledge?

Learning Outcomes

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A parameterization is a way to represent unresolved (and potentially uncertain) sub-grid processes for their impact on the resolved scale.

Often stems from physics (conservation principles, etc.) and/or from observationally-derived constraints

Learning Outcomes

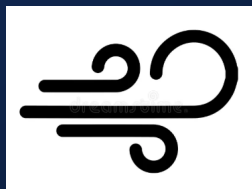
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Parameterizations in CAM7



Convection



Turbulence



Radiation



Aerosols

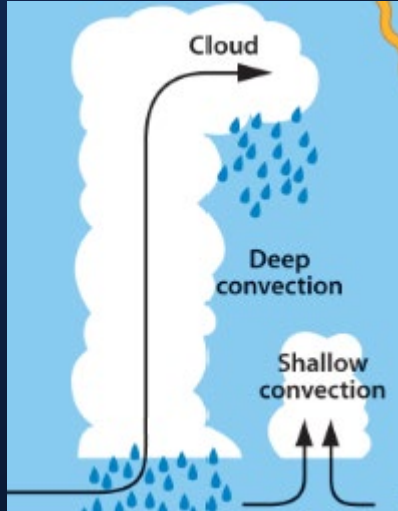


Microphysics

Convection in CAM7

Deep Convection

- Scale of convective plumes: up to tens of kilometers
- Instability through troposphere, allowing plumes to reach much higher
- Represented in CAM7 by Zhang McFarlane (ZM) scheme

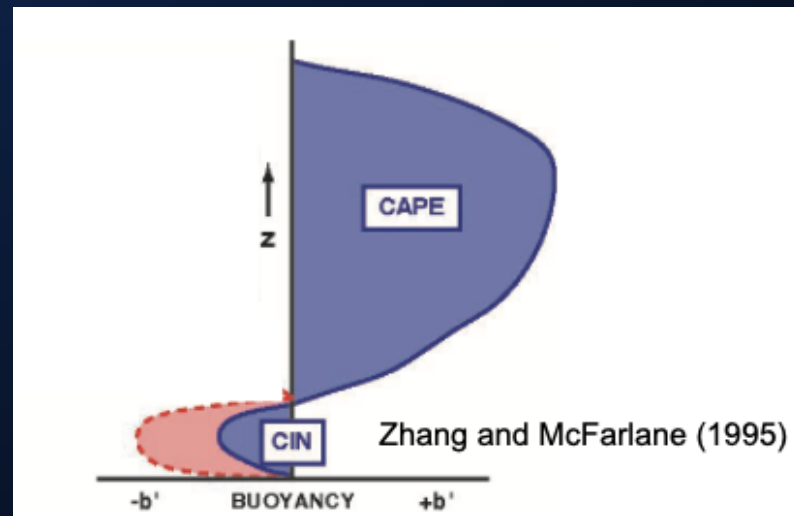


Shallow Convection

- Scale of convective plumes: 100s of meters to ~km
- Instability mainly within PBL, limiting vertical growth of plumes
- Represented in CAM7 by Cloud Layers Unified By Binormals (CLUBB)

Deep Convection (ZM)

- Originally based on Zhang & McFarlane 1995
 - Modifications made over time, see more detail in the CAM6 documentation
- Triggers based on Convective Available Potential Energy (CAPE)
- Convective intensity proportional to amount of CAPE
- Mass flux approach to calculate air motion within plumes
- Parameterized entrainment and detrainment
- Calculates convective heating and moistening at each level



Shallow convection & turbulence (CLUBB)

- Represents boundary layer turbulence and shallow convection
- Advances a system of equations to model heat, moisture, winds

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CLUBB prognoses 11 moments:

- Fluxes:
 - (2) Heat and moisture fluxes
 - (2) Momentum fluxes
- Variances:
 - (2) Heat and moisture variances
 - (1) Covariance of heat and moisture
 - (3) Momentum variances
- One third-order moment
 - (1) Third moment of vertical velocity

Shallow convection & turbulence (CLUBB)

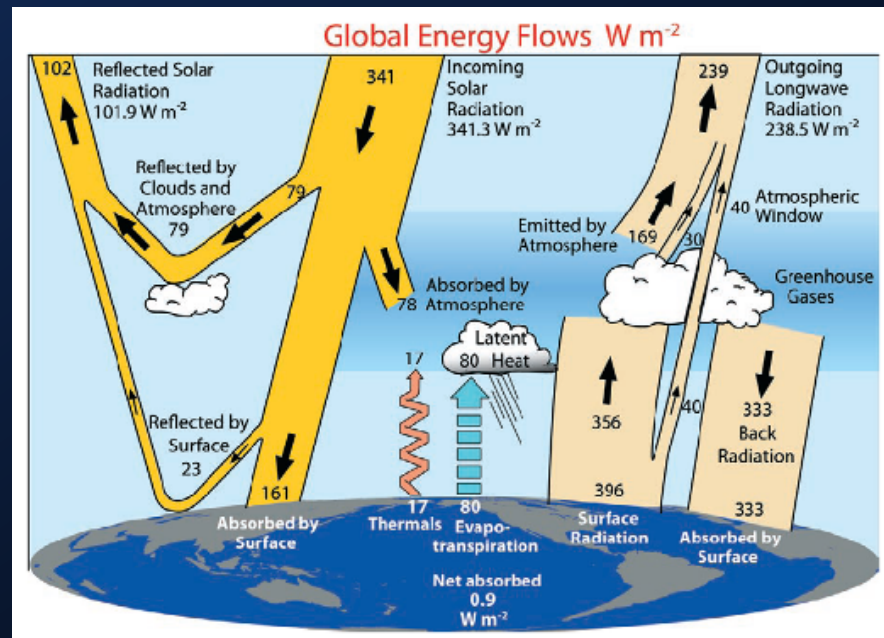
- Represents boundary layer turbulence and shallow convection
- Advances a system of equations to model heat, moisture, winds
- Some terms in eqs are unclosed
- To close some, CLUBB...
 - Predicts a joint PDF of vertical velocity (w), temperature (T), and moisture (q)
 - PDF is used to predict grid means, (co)variances, and other higher-order moments of all three variables (w , T , q)
- Other equations are closed with standard methods

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- One third-order moment
 - (1) Third moment of vertical velocity

Radiation in CAM7

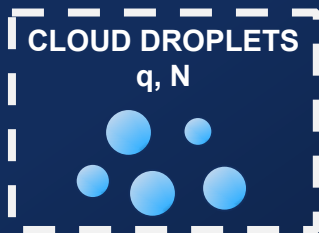
- The radiation code supplies:
 - the radiative fluxes between components of the Earth's system to estimate the surface energy balance
 - the radiative heating and cooling rates at each level of the atmosphere
- CAM7 uses the Rapid Radiative Transfer Model for GCMs–Parallel (RRTMGP), a correlated k-distribution band model
- The parameterization includes the combined effect of absorption and scattering by the radiatively active gases (H₂O, CO₂, O₃...), clouds and aerosols



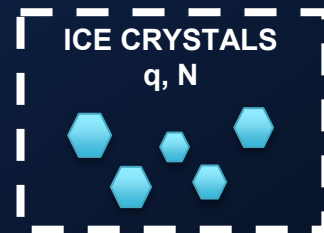
Trenberth and Fasullo (2008)

Cloud Microphysics in CAM7

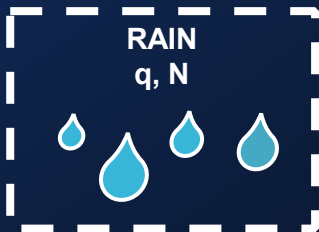
Parameterization of Unified Microphysics Across Scales (PUMAS)



Liquid phase



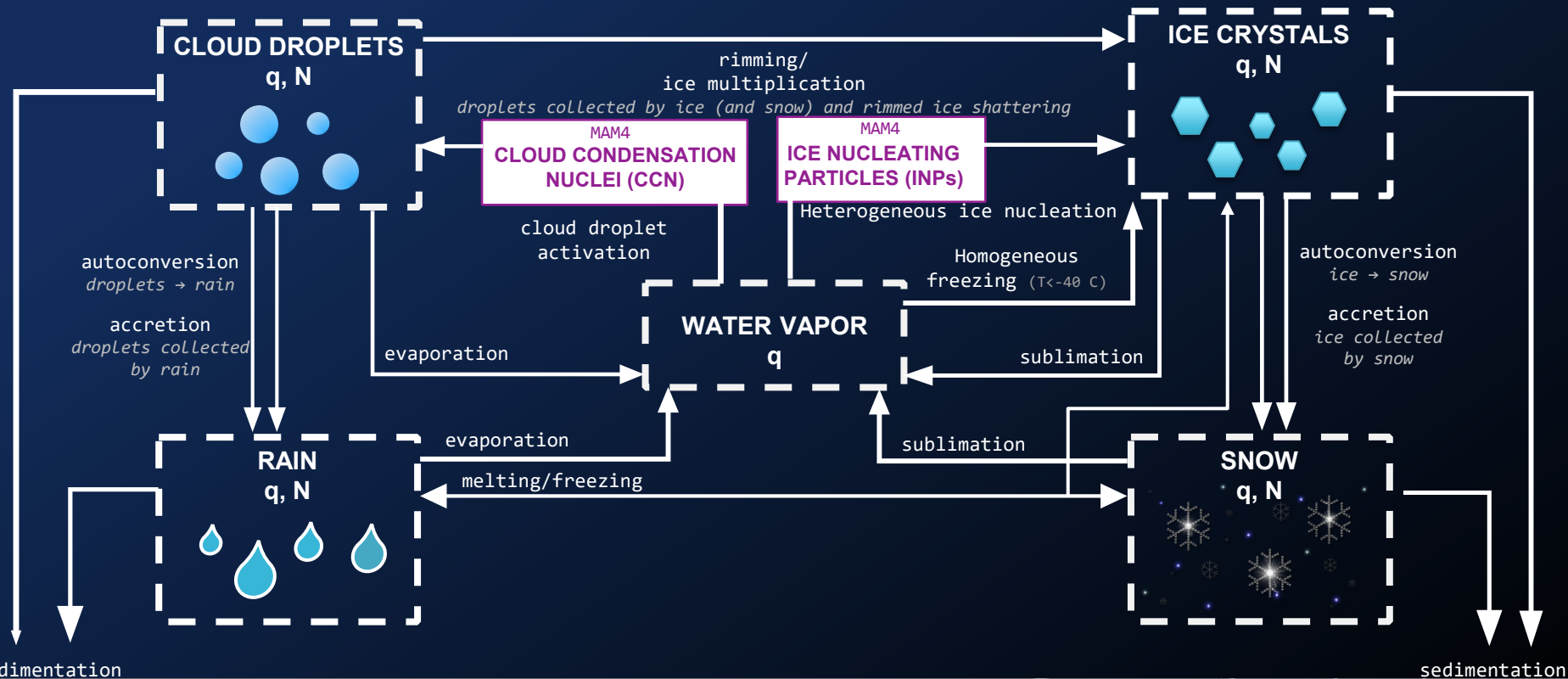
Ice phase



Note: all cloud hydrometeors are assumed to be spherical

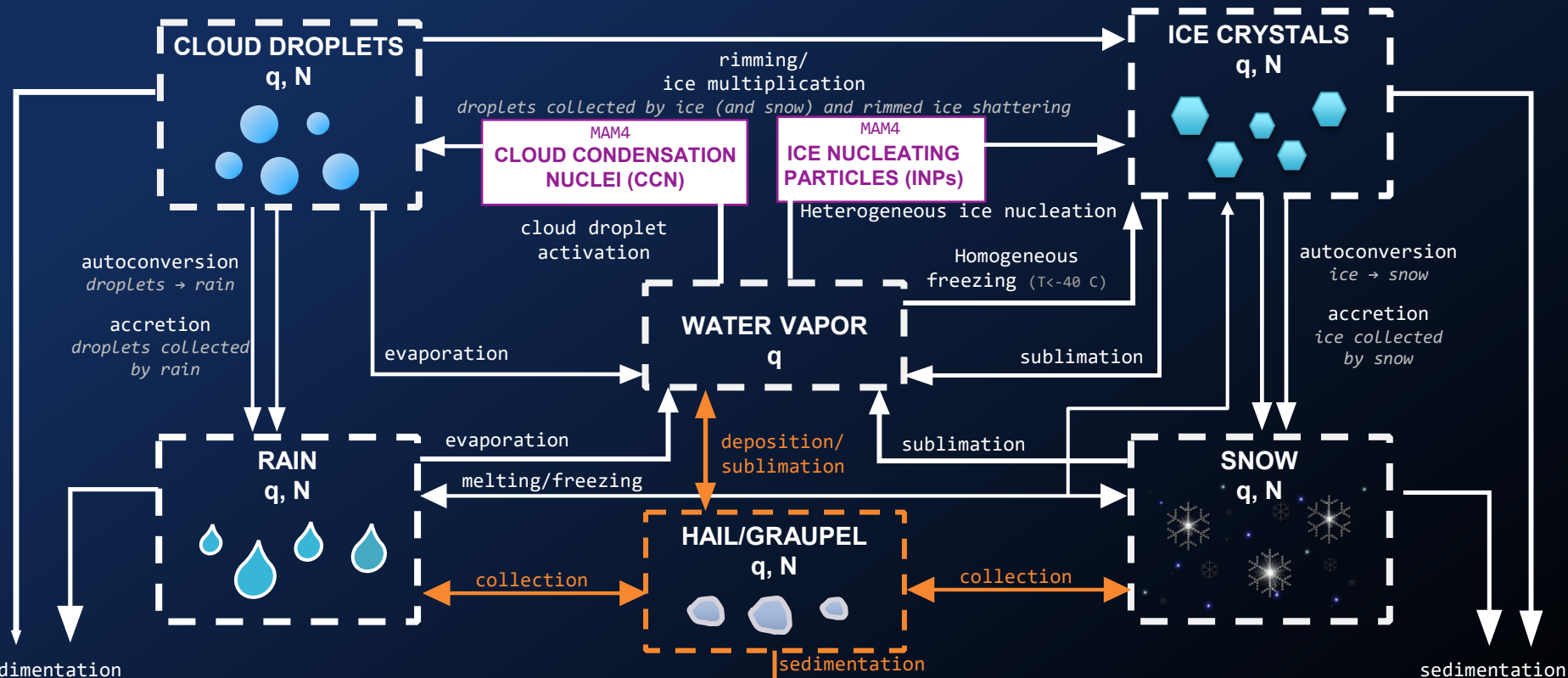
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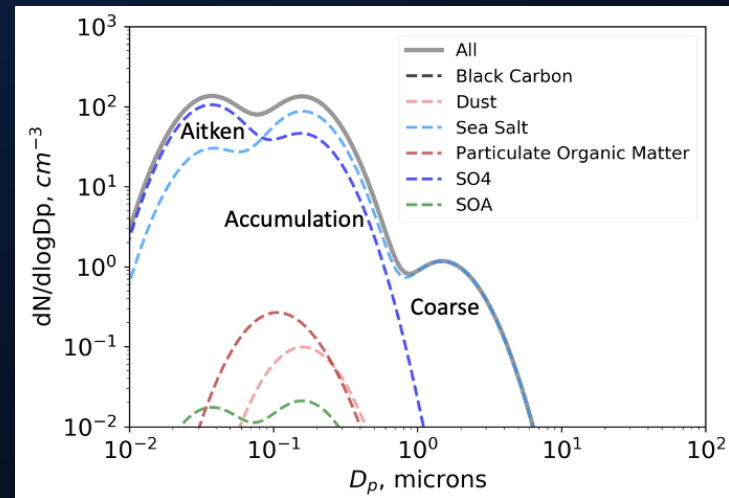
Aerosols in CAM7



1. Nucleation
2. Coagulation
3. Wet/dry deposition
4. Ageing

...

- Modal scheme (lognormal; MAM4):
 - Modal Aerosol Module
 - Number and modal diameter (D_g) prognostic
 - Constant modal width (sigma)



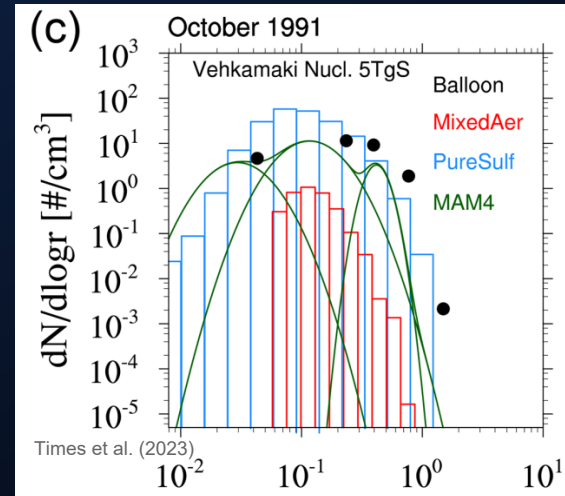
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 - Modal Aerosol Module
 - Number and modal diameter (D_g) prognostic
 - Constant modal width (sigma)
- Sectional scheme (bins; CARMA):
 - Community Aerosol and Radiation Model for Atmospheres
 - 2 groups - mixed and pure (sulfate)
 - Mixed - 0.05–8.7 μm
 - Pure - 0.2 nm to 1.3 μm



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Finding more detailed information on parameterizations in CAM7

- GitHub [CAM7](#) documentation
- Technical documents (e.g., [CLUBB-SILHS](#) arXiv document)
- Main parameterization papers
 - RRTMGP: [Pincus et al., 2019](#)
 - CLUBB: [Golaz et al., 2002](#)
 - ZM: [Zhang & McFarlane 1995](#)
 - PUMAS: [Gettelman et al., 2023](#) (doi:10.5194/gmd-16-1735-2023)
 - MAM4: [Liu et al., 2016](#) doi.org/10.5194/gmd -9-505-2016)
- Terminal (command line) scavenger hunt (e.g., `grep-rni 'CLDLIQ'`)
- CLUBB tutorial (ask Ben Stephens for access to online materials, stepheba@ucar.edu)



Questions?

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