Aerosol Effects on Liquid-Water Path of Thin Stratocumulus Clouds

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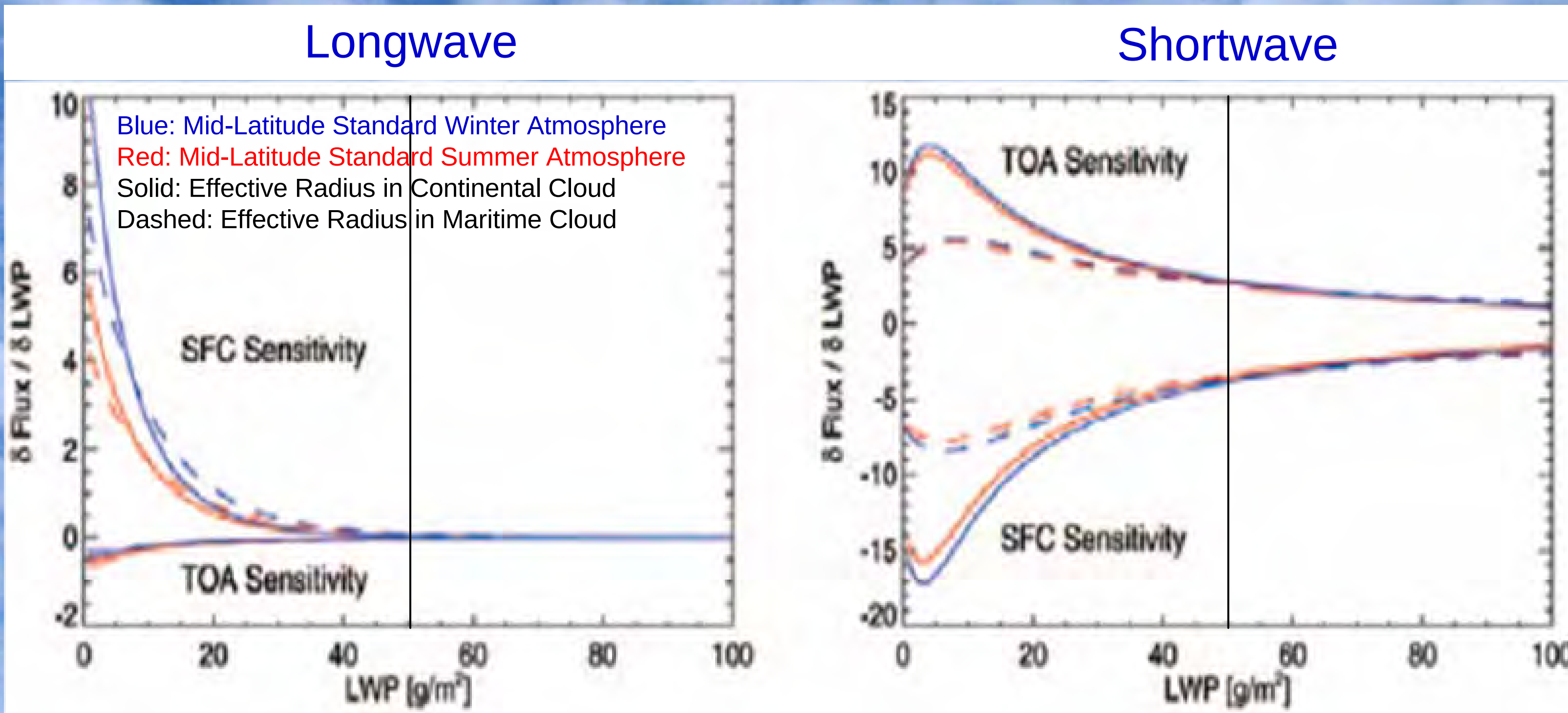
Motivation

- International Satellite Cloud Climatology Project (ISCCP) reports that thin clouds with liquid-water path (LWP) of ~ 50 g m^{-2} cover 28 % of the globe.

- Top of the atmosphere (TOA) and surface (SFC) radiative flux variations become very sensitive to the LWP variation for LWP smaller than ~ 50 g m^{-2} [Turner et al., 2007].

Sensitivity of the Radiation Variation to the LWP Variation



From Turner et al. (2007)

- **Aerosols modify the LWP and thus aerosol-cloud interactions in thin clouds can play an important role in global radiation budget.**

Goal

- **Gain the preliminary understanding of aerosol-cloud interactions in thin stratocumulus clouds**

- **To fulfill the goal, two cases of thin stratocumulus clouds, over the North Atlantic where significant aerosol increases have been observed since industrialization, are simulated**

Case Description

WET

PBL top RH: ~ 80 %

Location: 42° N 63° W

Period: 02 – 14 LST July 1st 2002

Average aerosol number in the PBL (cm^{-3})
- ◦High (present-day) aerosol : ~ 3100
- ◦Low (preindustrial) aerosol: ~ 1200

DRY

PBL top RH: ~ 40 %

Location: 42° N 53° W

Period: 02 – 14 LST July 1st 2002

Average aerosol number in the PBL (cm^{-3})
- ◦High (present-day) aerosol : ~ 2200
- ◦Low (preindustrial) aerosol: ~ 1100

Model Description

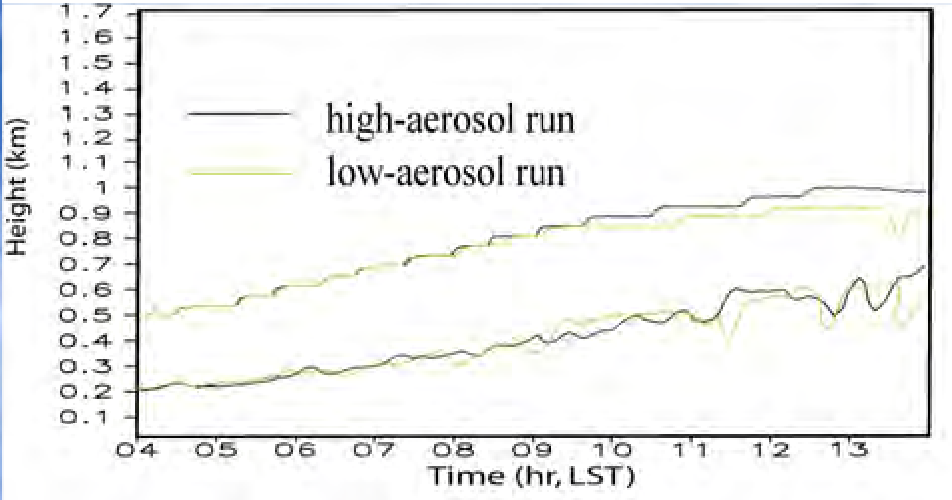
- Goddard Cumulus Ensemble (GCE) model coupled with Saleeby and Cotton's [2004] double-moment microphysics is used
- Full stochastic collection solutions with realistic collection kernels are employed
- Sedimentation of hydrometeors is simulated by emulating a full-bin model with 36 bins

Model Setup

- 2D framework (25 km x 20 km) is used
- Δx = 50 m and Δz = 40 m below 2 km and stretched to 240 m near the model top
- ECMWF reanalysis data provide initial sounding, large-scale forcings, and surface fluxes for simulations

Cloud-Top and Cloud-Base Height	LWP (g m^{-2})

WET



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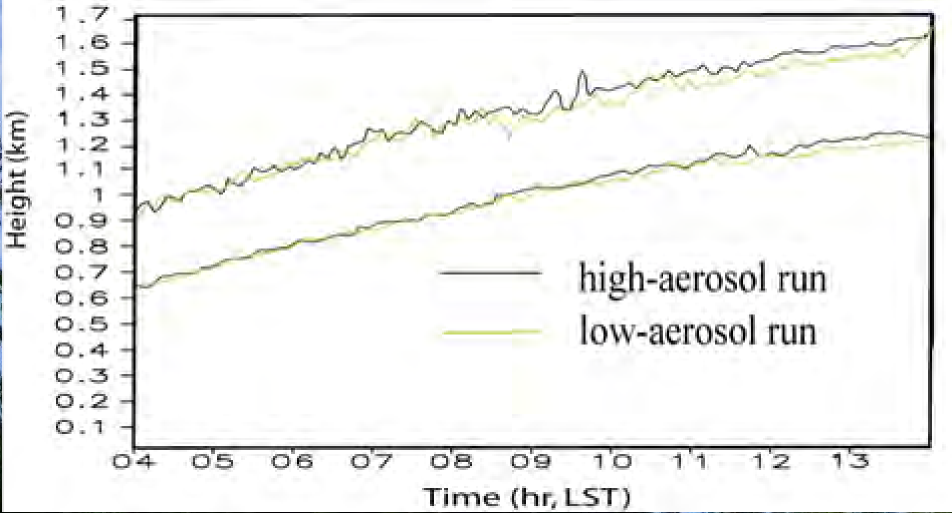

LWP (g m^{-2})

WET

High-Aerosol: 46.2

Low-Aerosol: 35.4

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High-Aerosol: 29.7

Low-Aerosol: 30.2

Surface Precipitation (mm day^{-1})

WET

High-Aerosol: 5.7×10^{-3}

Low-Aerosol: 1.5×10^{-2}

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No Surface Precipitation.

(Autoconversion+ Collection)/Condensation < 5 % !!

↓

Growth of Particles above 20- 40 Micron

$\propto$ Autoconversion+ Collection

↓

Sedimentation

$\propto$

Fall Velocity of Particles above the Critical Sizes

$\propto$

Particle size

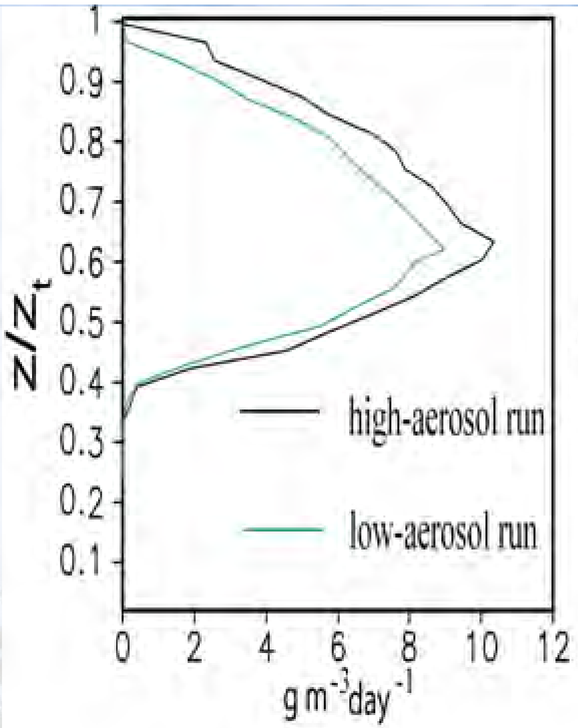
↓

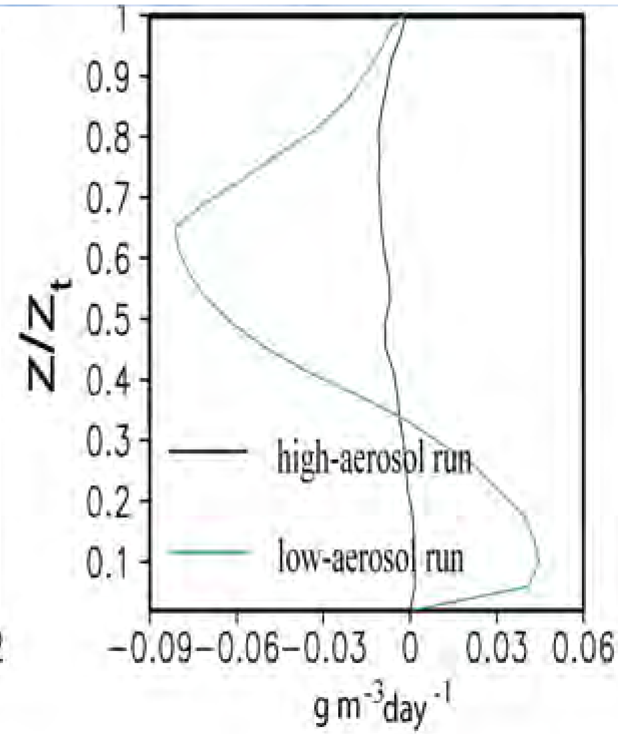
Inactive Sedimentation

WET

Condensation

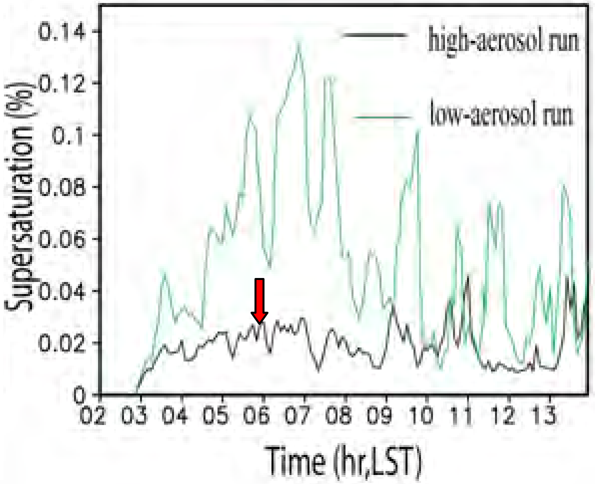
Sedimentation-Induced Cloud-Mass Change



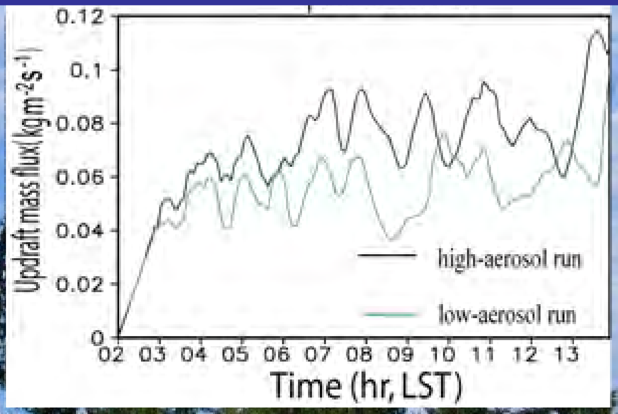


WET

Supersaturation



Updraft Mass Flux



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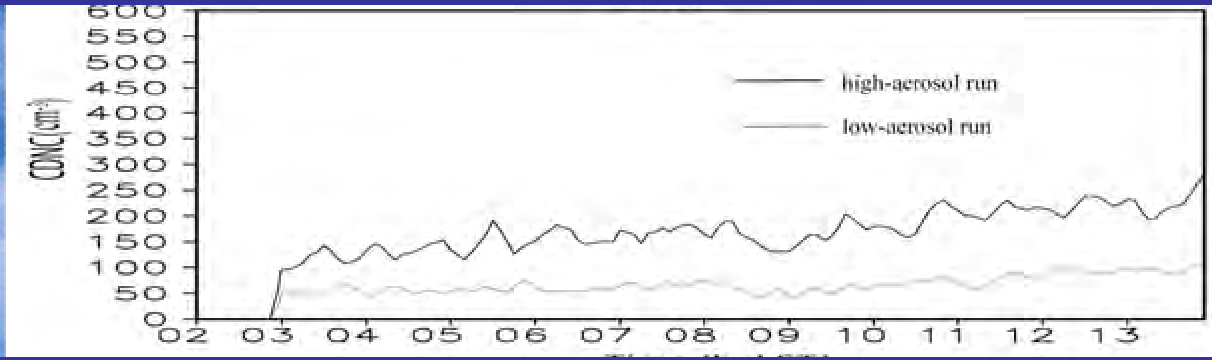
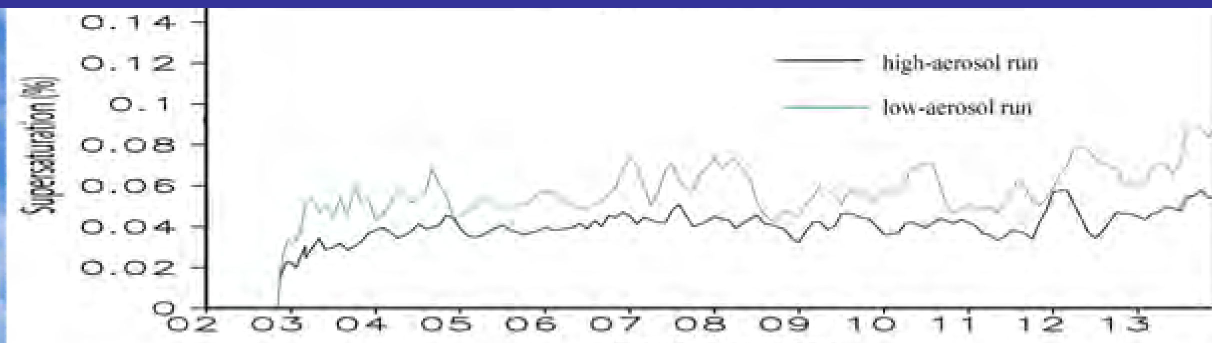
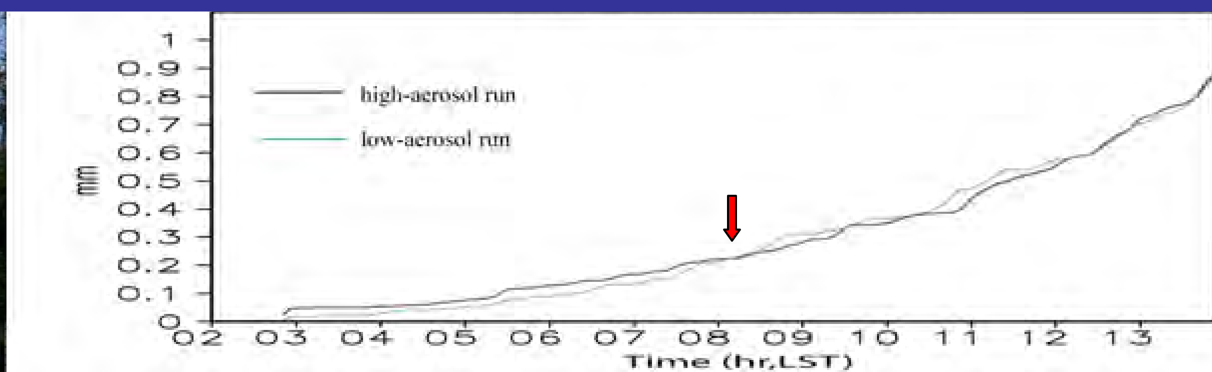
CDNC



Supersaturation



Cumulative Condensation



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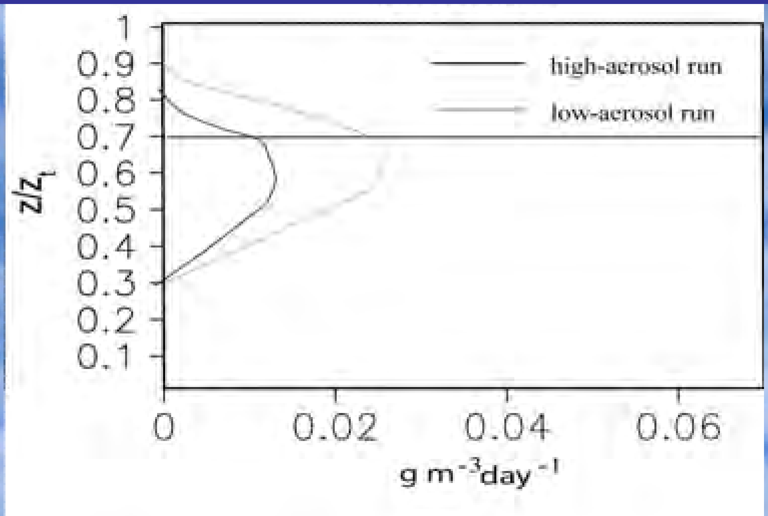
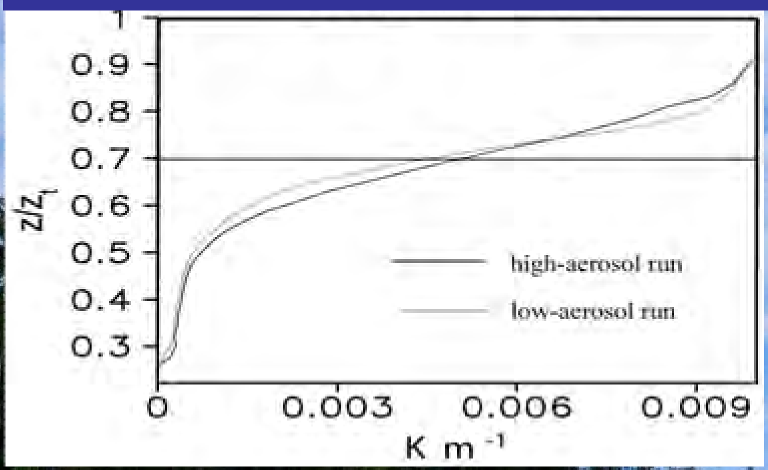
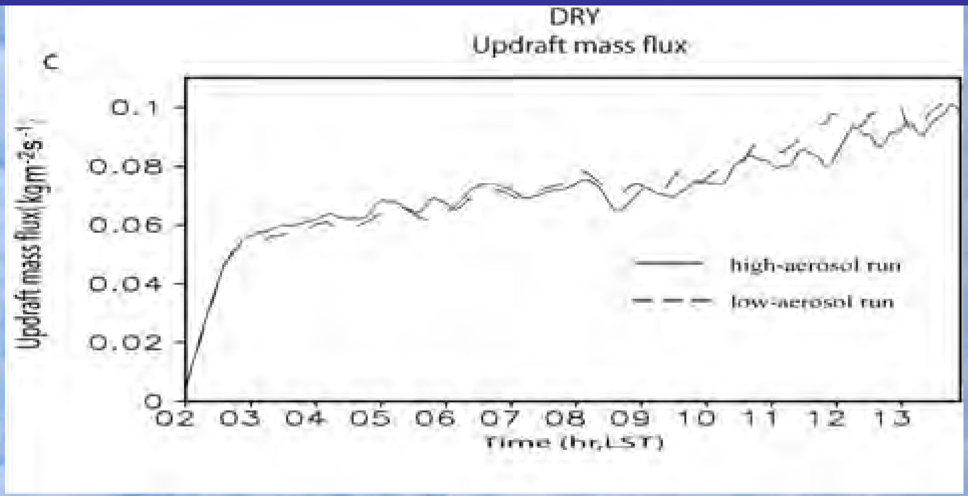
Rain Evaporation



dϴ/dz (03 - 07 LST)



Updraft Mass Flux



Summary and Conclusion

- Role of different autoconversion, collection, and sedimentation in responses of cloud mass to aerosols was negligible.
- Instead, feedbacks among CDNC, condensation, and dynamics led to increased LWP at high aerosol in the case with the surface precipitation.
- In the case with no surface precipitation, the effect of rain evaporation on the instability around cloud base played a crucial role in the response of LWP together with those feedbacks.
- Generally, parameterizations for the LWP variation with aerosols have simply relied on the aerosol-induced changes in the autoconversion and sedimentation in climate models.

- Also, coarse spatial resolutions and saturation adjustment schemes employed in climate models are not able to resolve interactions simulated here.

- This can contribute to a large uncertainty in the estimation of the radiative forcing associated with aerosol indirect effects.

Thank you !!

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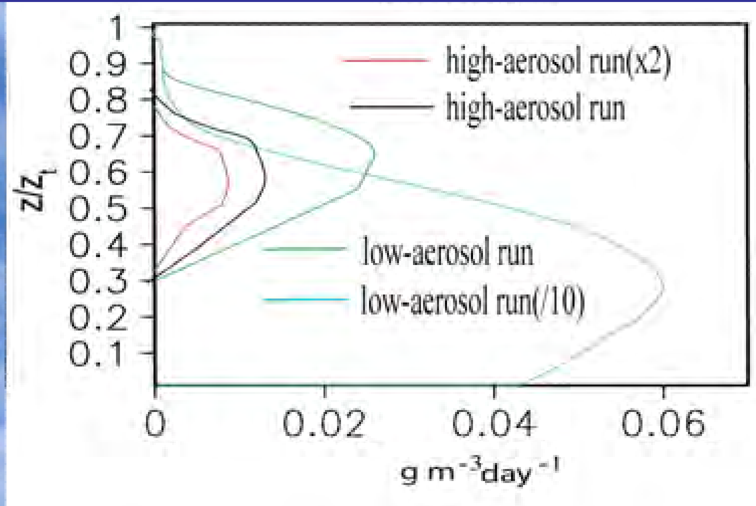
Rain Evaporation



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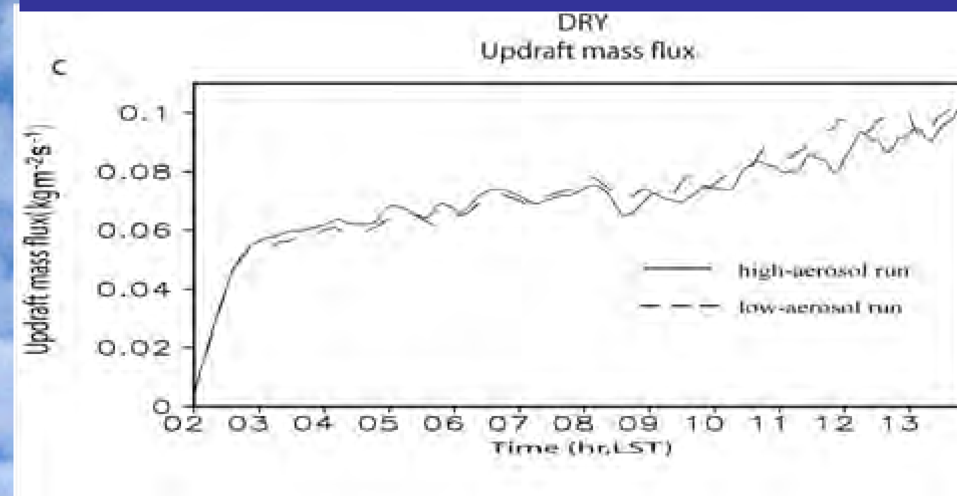

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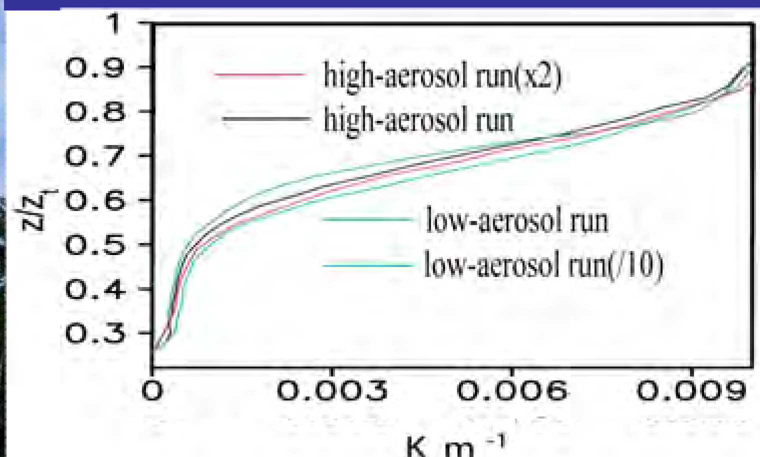

Cumulative Condensation