Indirect radiative forcing of aerosols via water vapor above non precipitating maritime cumulus clouds: a study using WRF-Chem at cloud-system resolving scale

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Aerosols and Radiation

A function of how each aerosol source changes:

- Aerosol particle number and size
- Cloud droplet number and size
- $H_2O_{(v)}$ concentration

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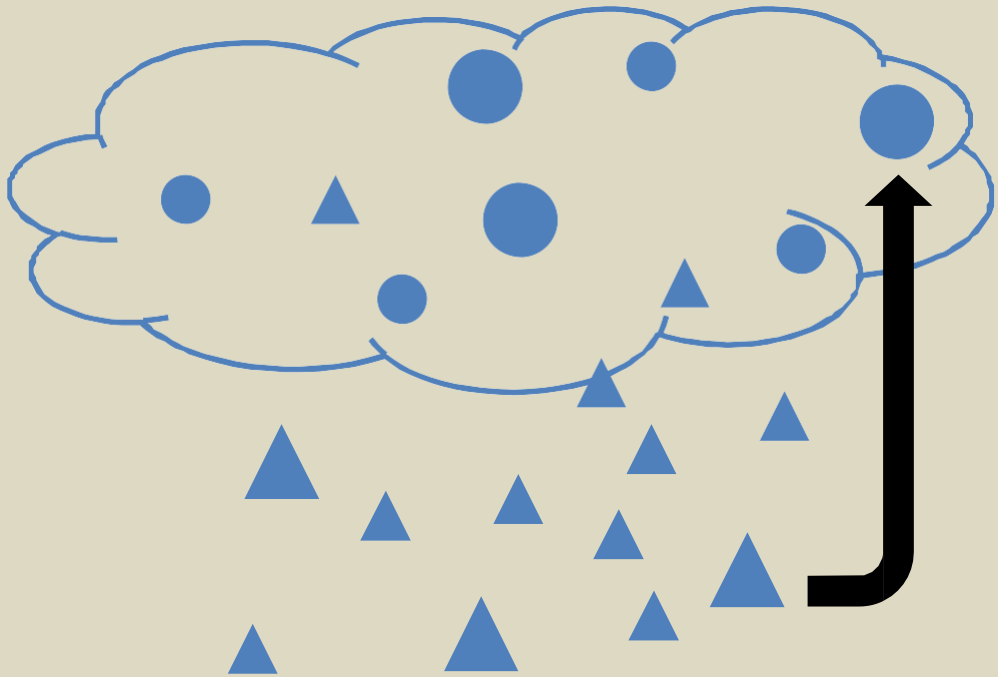
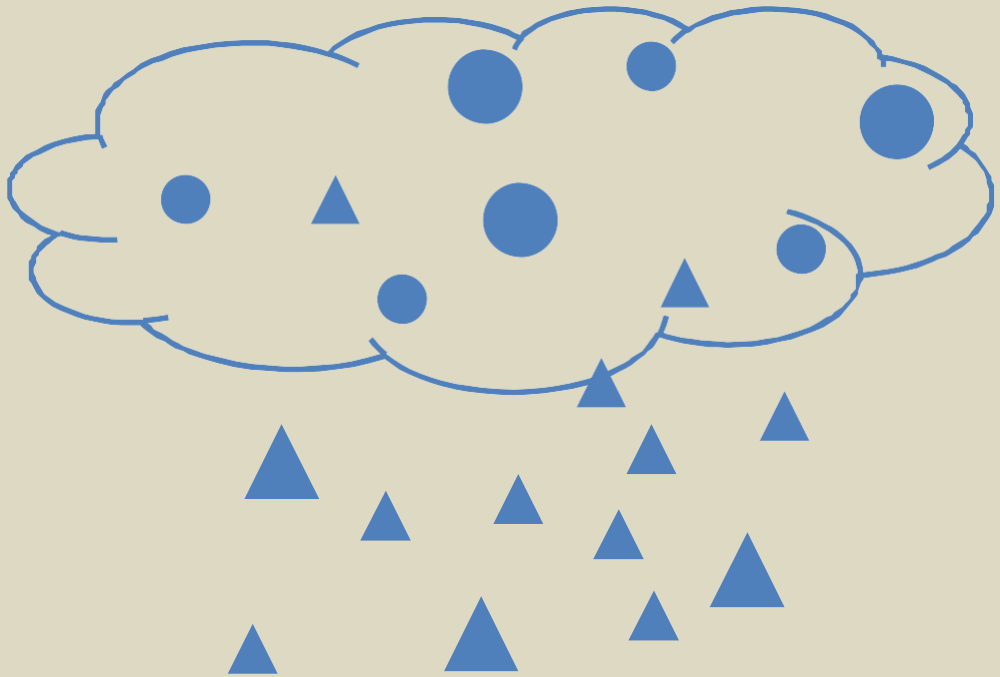
Aerosols – Clouds – Water vapor



Activation of aerosols determines cloud droplet number

warm cloud

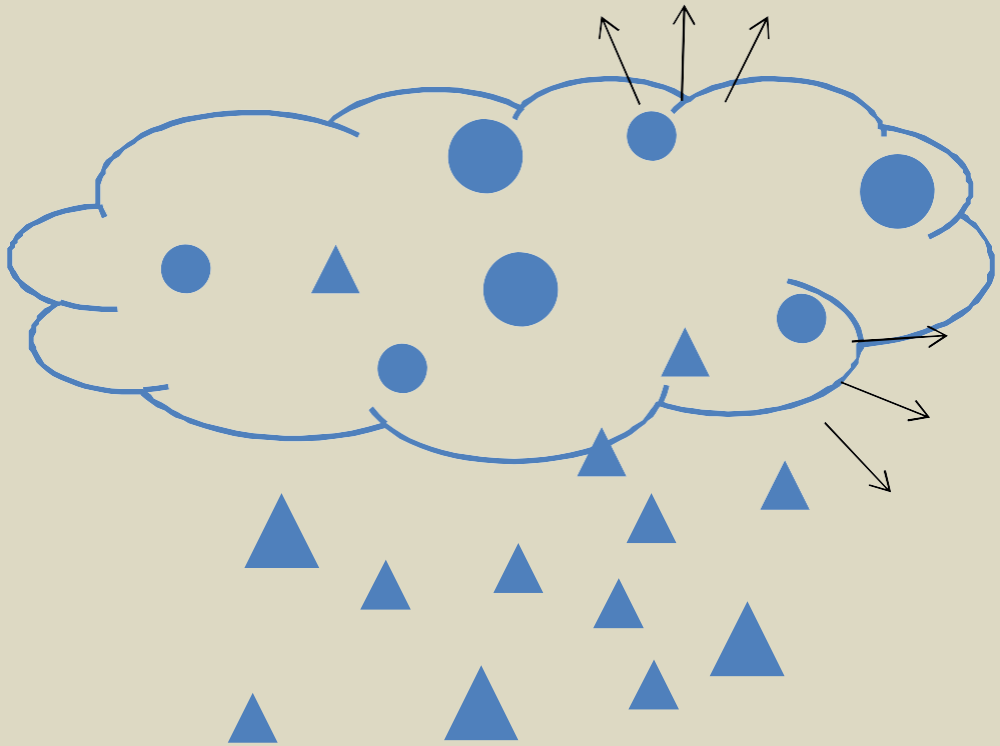
Aerosols – Clouds – Water vapor



More aerosol particles can lead to more, smaller droplets

warm cloud

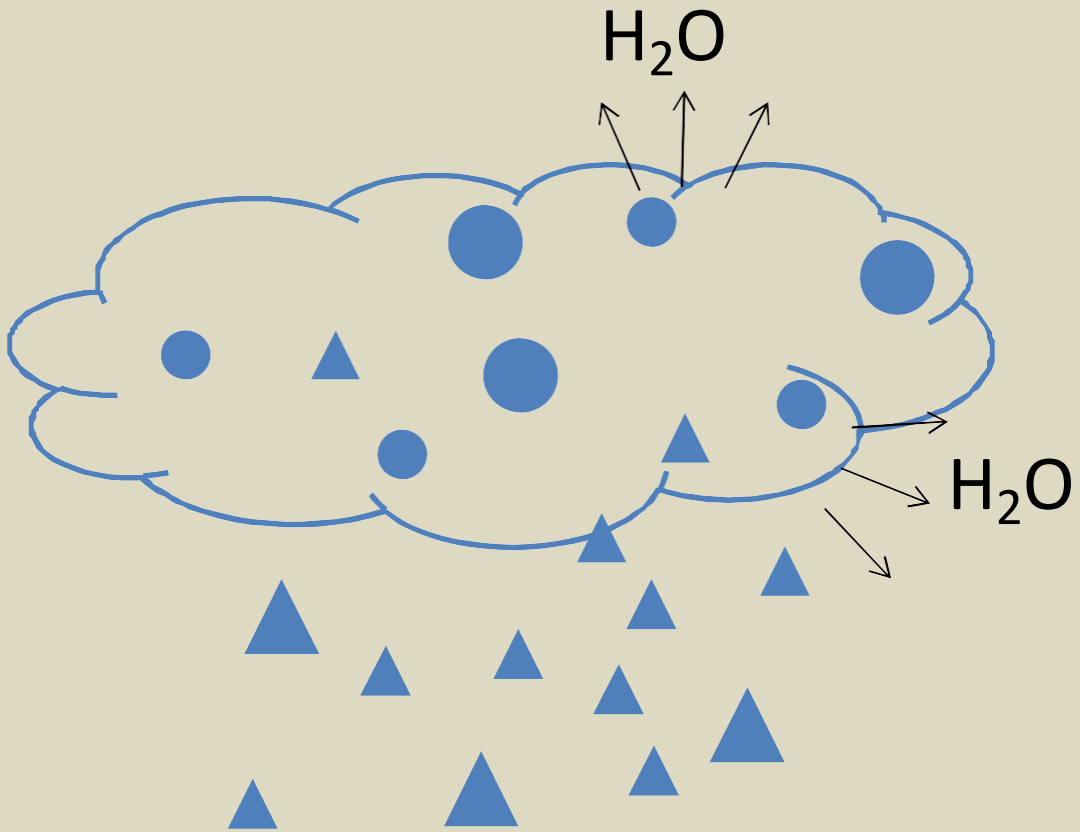
Aerosols – Clouds – Water vapor



Smaller cloud droplets may be more likely to evaporate at the edges of cloud

warm cloud

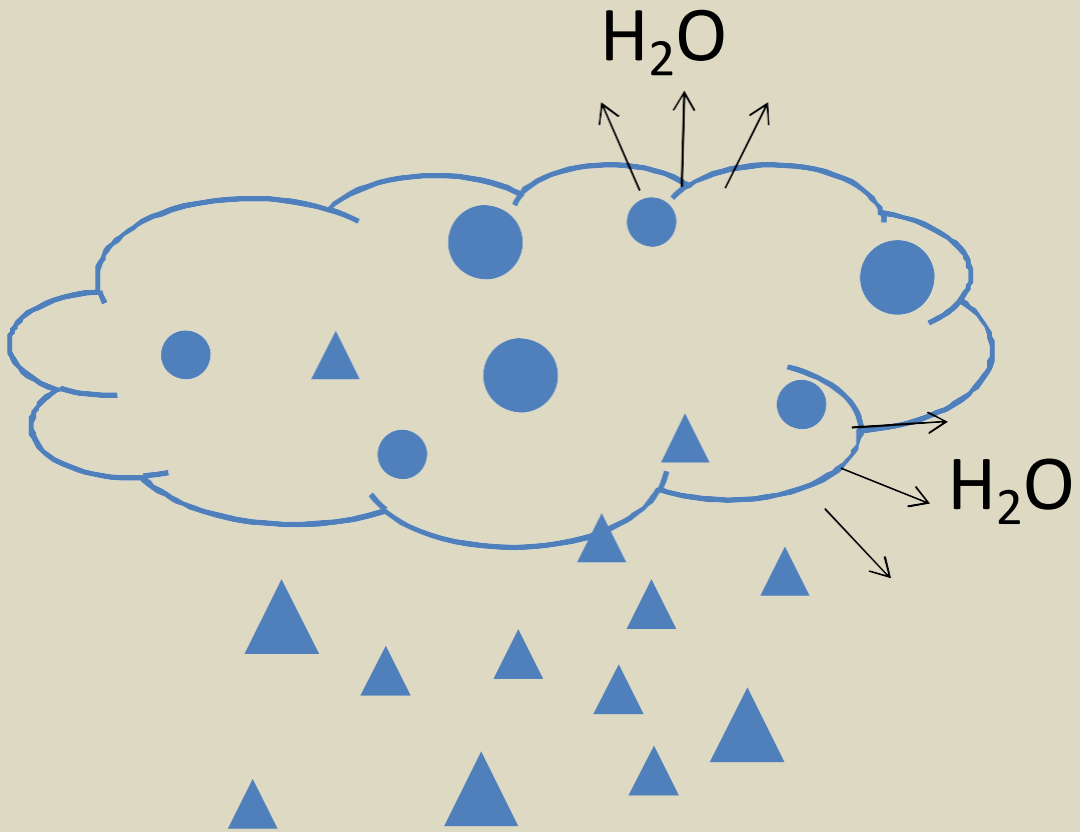
Aerosols – Clouds – Water vapor



This can increase atmospheric water vapor

warm cloud

Aerosols – Clouds – Water vapor



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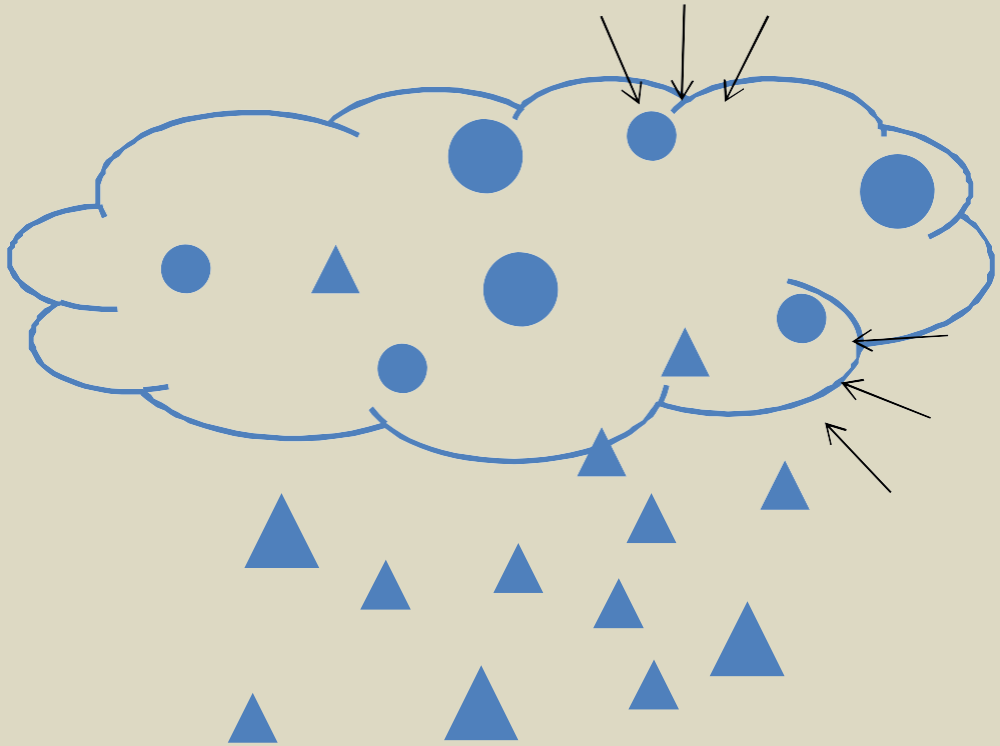
Evaporation effect

warm cloud

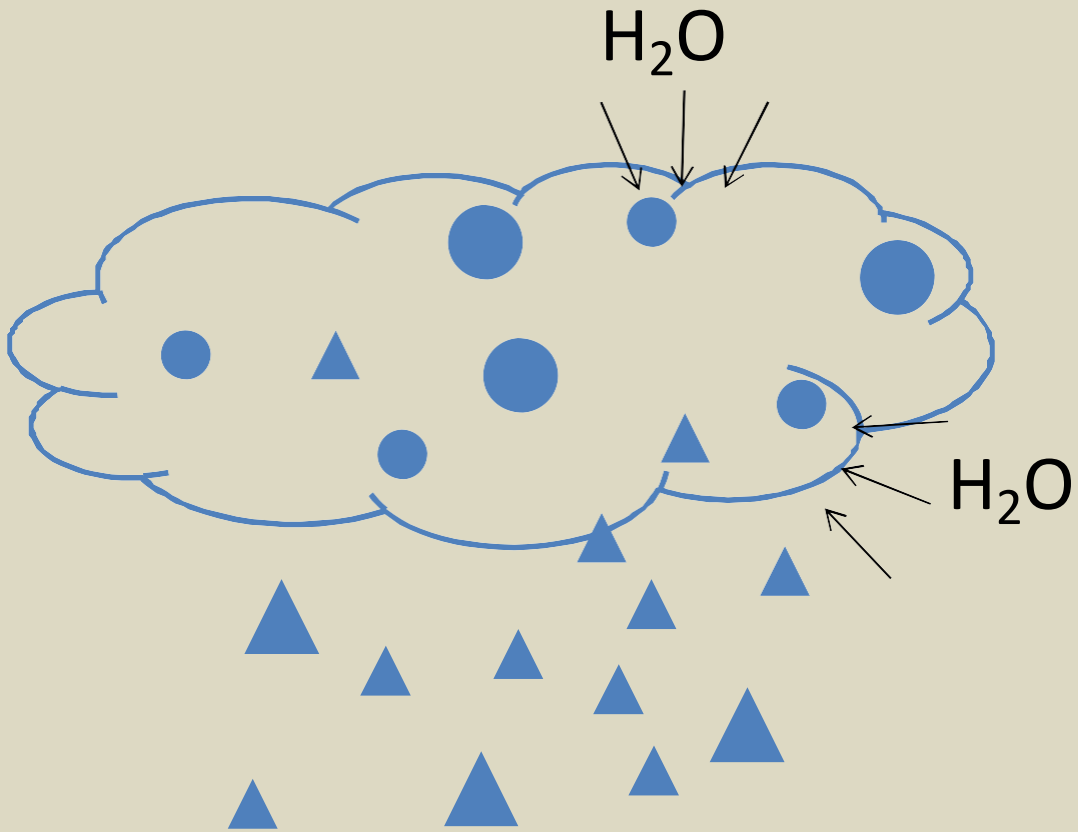
Aerosols – Clouds – Water vapor



Aerosol particles may allow more water vapor to condense

warm cloud

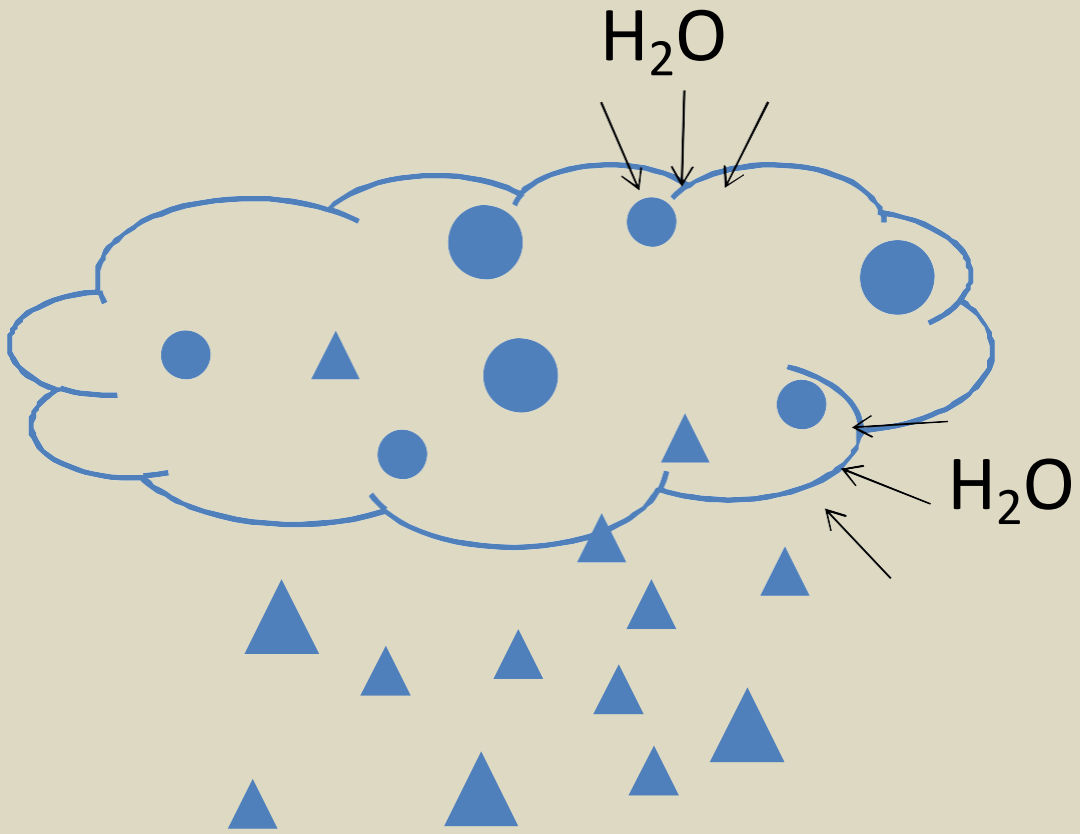
Aerosols – Clouds – Water vapor



This can decrease atmospheric water vapor

warm cloud

Aerosols – Clouds – Water vapor



This can decrease atmospheric water vapor

Condensation effect

warm cloud

Sensitivity Simulations

Reference Run →

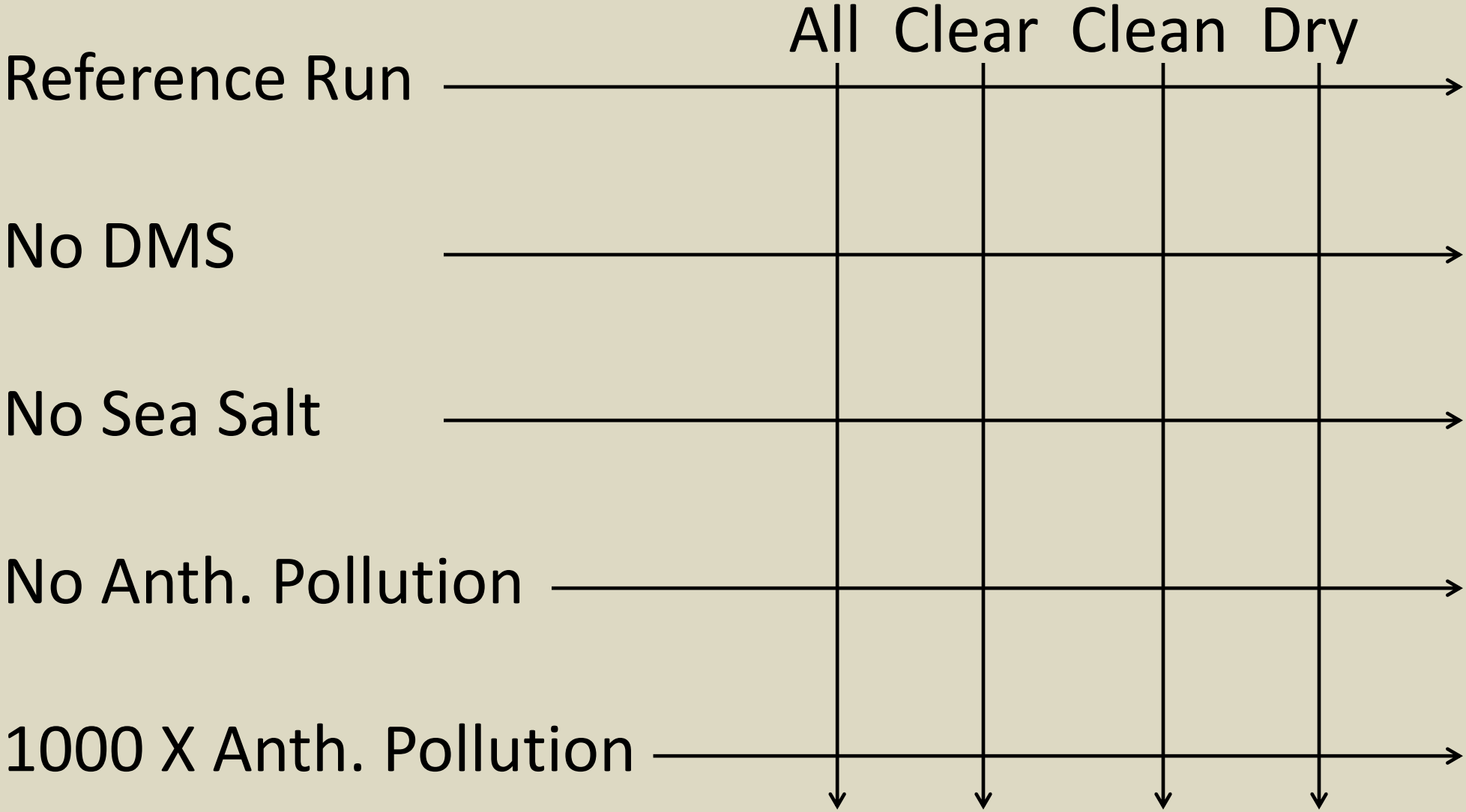
No DMS →

No Sea Salt →

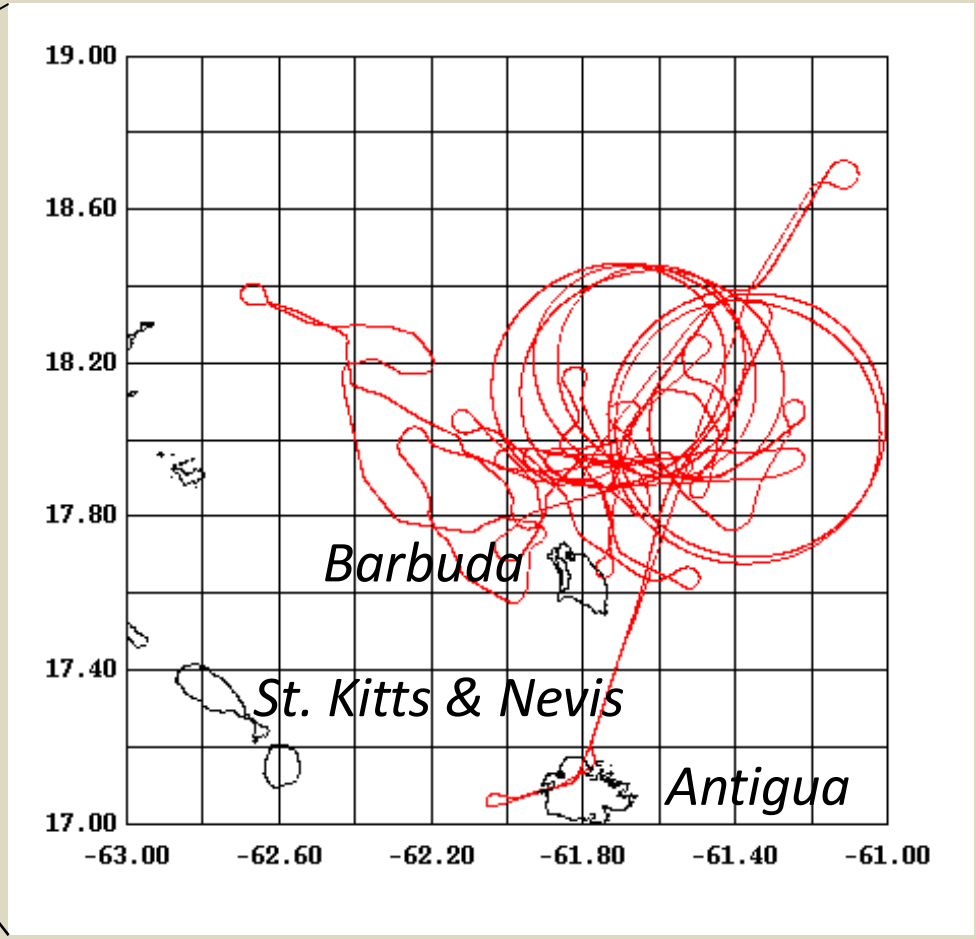
No Anth. Pollution →

1000 X Anth. Pollution →

Off-line radiative transfer calculations



RICO case study



11 Jan 2005

WRF-Chem set-up

- Modified two-moment Lin scheme with aerosol-cloud interactions
- CBMZ gas-phase chemistry
- MOSAIC 8 bin aerosols
- Updated vertical velocity distribution function

Run specifics

3 km horizontal resolution

- 175 X 130 grid boxes

49 vertical levels

- 42 in troposphere
- 5 from cloud base – cloud top

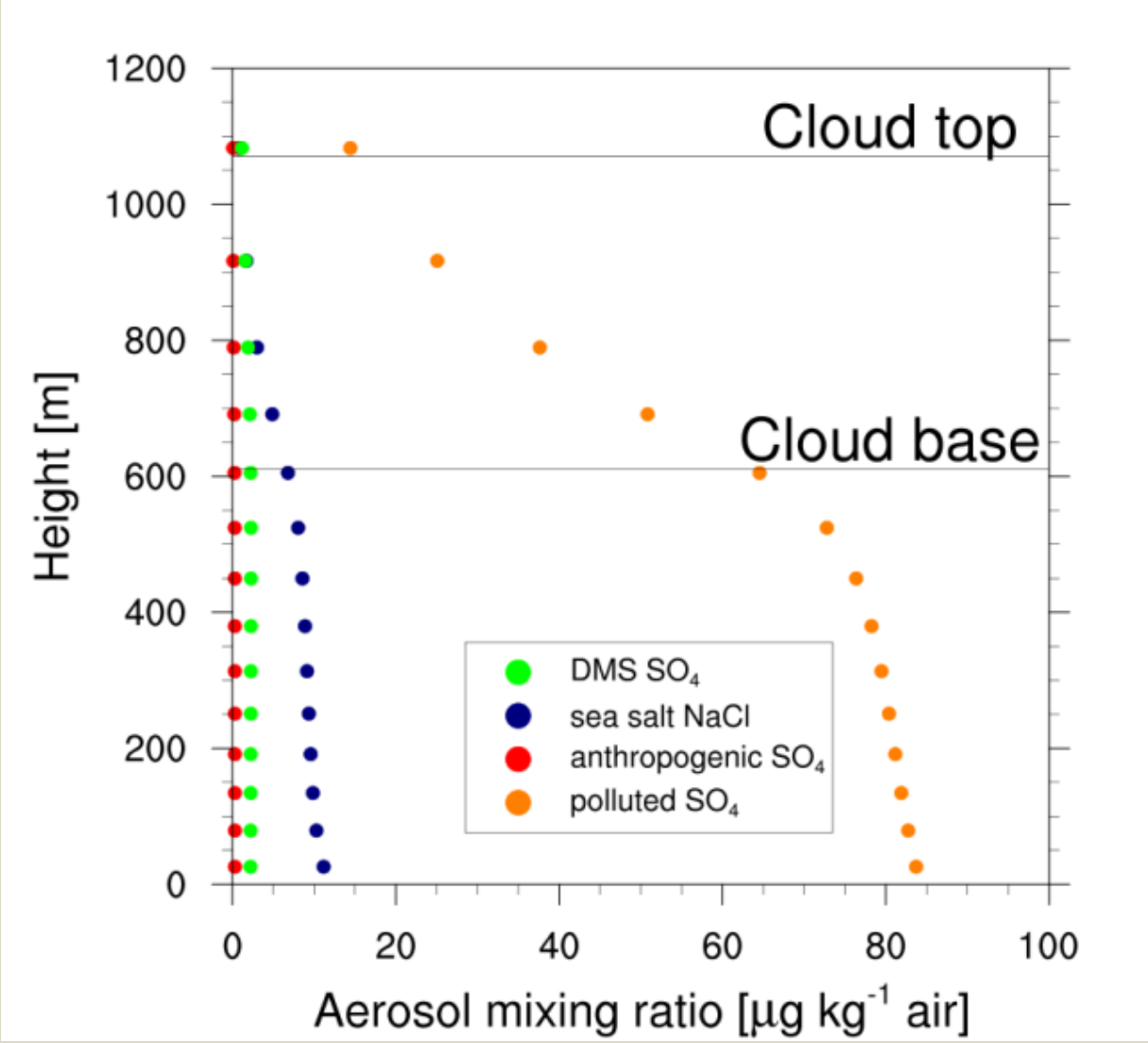
2 day runs

- 10 – 12 Jan 2005
- 36 hour spinup

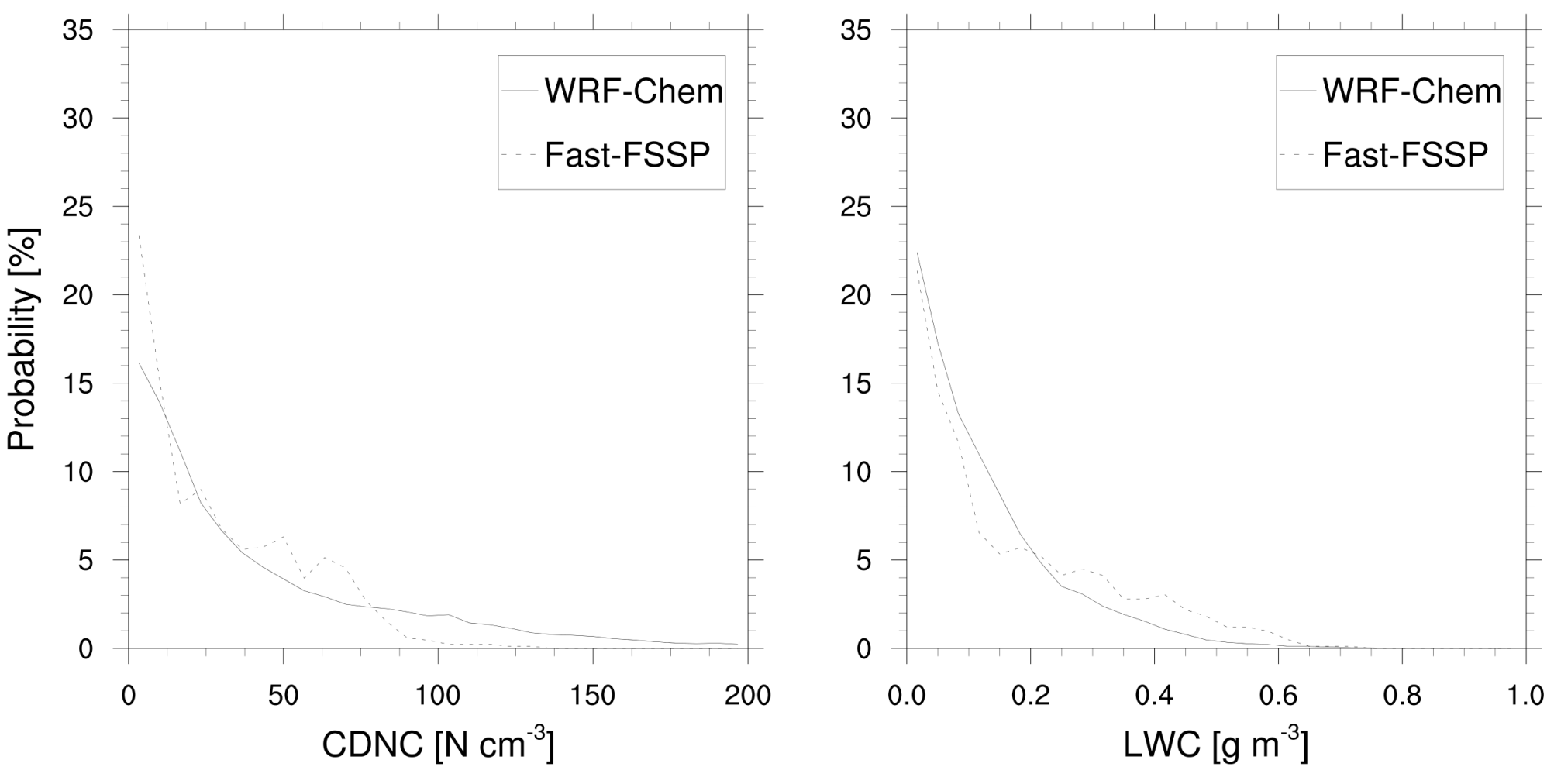
Emissions

- Online sea salt and dust
- Online DMS emissions from ocean surface concentrations
- Anthropogenic emissions from RETRO (monthly 0.5^o X 0.5^o) and Edgar (annual year 2000 SO_2)

Aerosol concentrations



Cloud droplet number concentration and liquid water content



Summary of main results

Forcing	Effect	Magnitude (approximate) Reference	Polluted	Explanation
clouds	decrease OLR	0.5 %		absorb and reemit radiation at a cooler temp.
$H_2O_{(v)}$	decrease OLR	27 %		absorb LW rad.
SO_4^{2-}	increase OLR	0.1 %		decrease $H_2O_{(v)}$
sea salt	increase/decrease OLR	0.1 %		decrease CDNC and increase $H_2O_{(v)}$
clouds	increase OSR	30 %	10 %	scatter SW rad.
direct effect	increase OSR	2 %	40 %	scatter SW rad.
$H_2O_{(v)}$	decrease OSR	17 %	12 %	absorb SW rad.
low concentration aerosol	decrease OSR	4 %		increase large cloud droplets thereby decreasing cloud reflect.
high concentration aerosol	increase OSR		60 %	increase forcing via direct effect

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