The important role of cloud microphysics in the multi-scale climate system

Lulin Xue

Saint Louis University, Saint Louis, MO

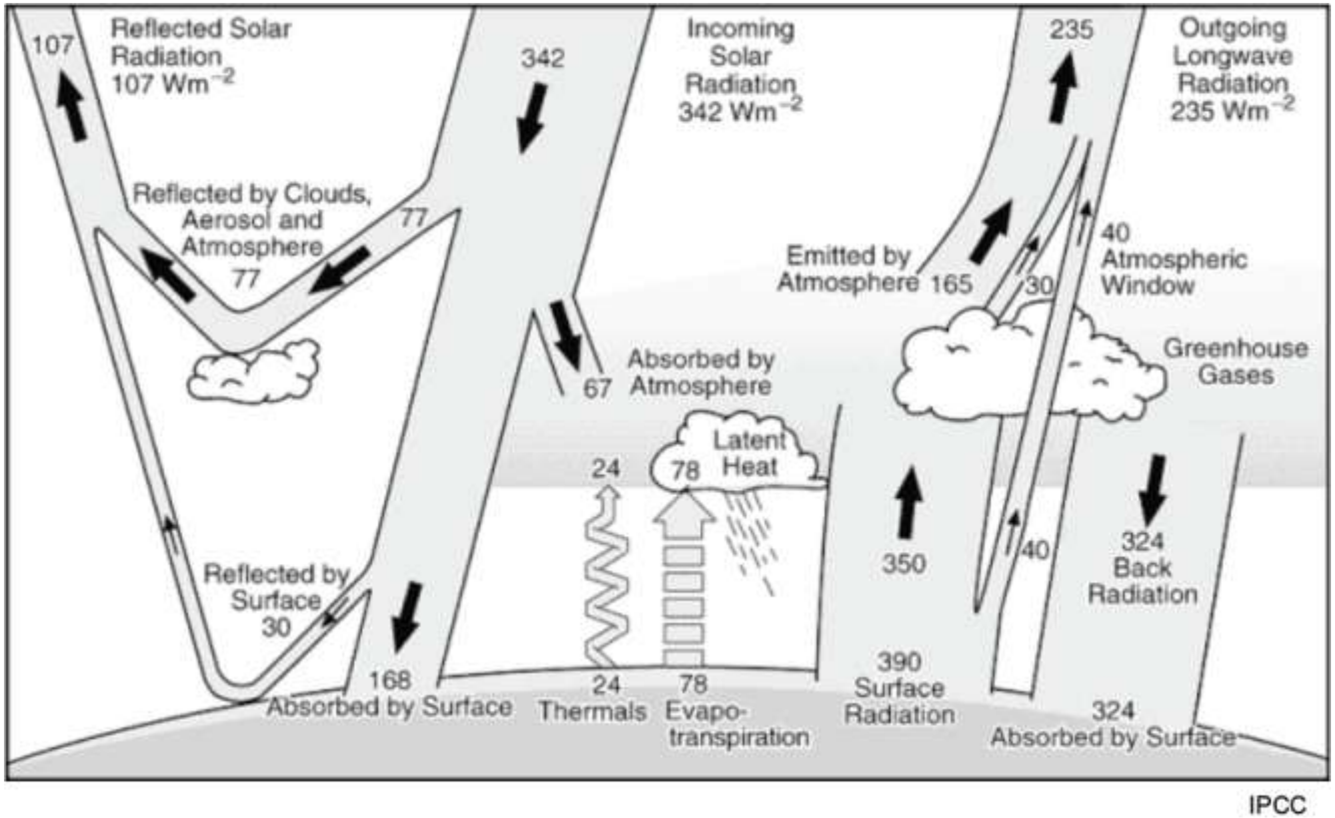
07/22/2008

$$\frac{1}{TA}\int_T\int_A WEATHER = CLIMATE$$

WEATHER

Water vapor: causes about 36–70% of the greenhouse effect on Earth

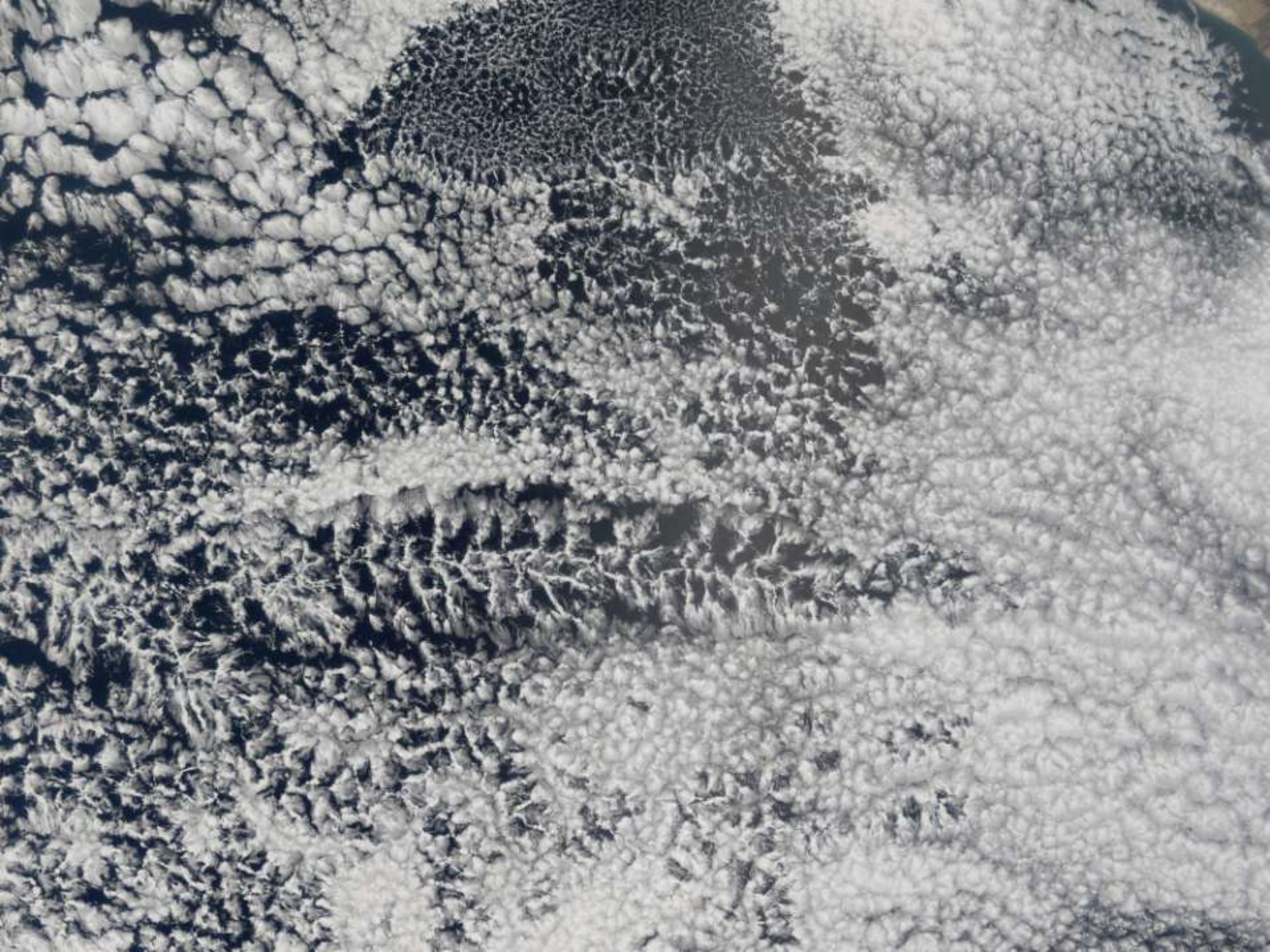
Cloud:

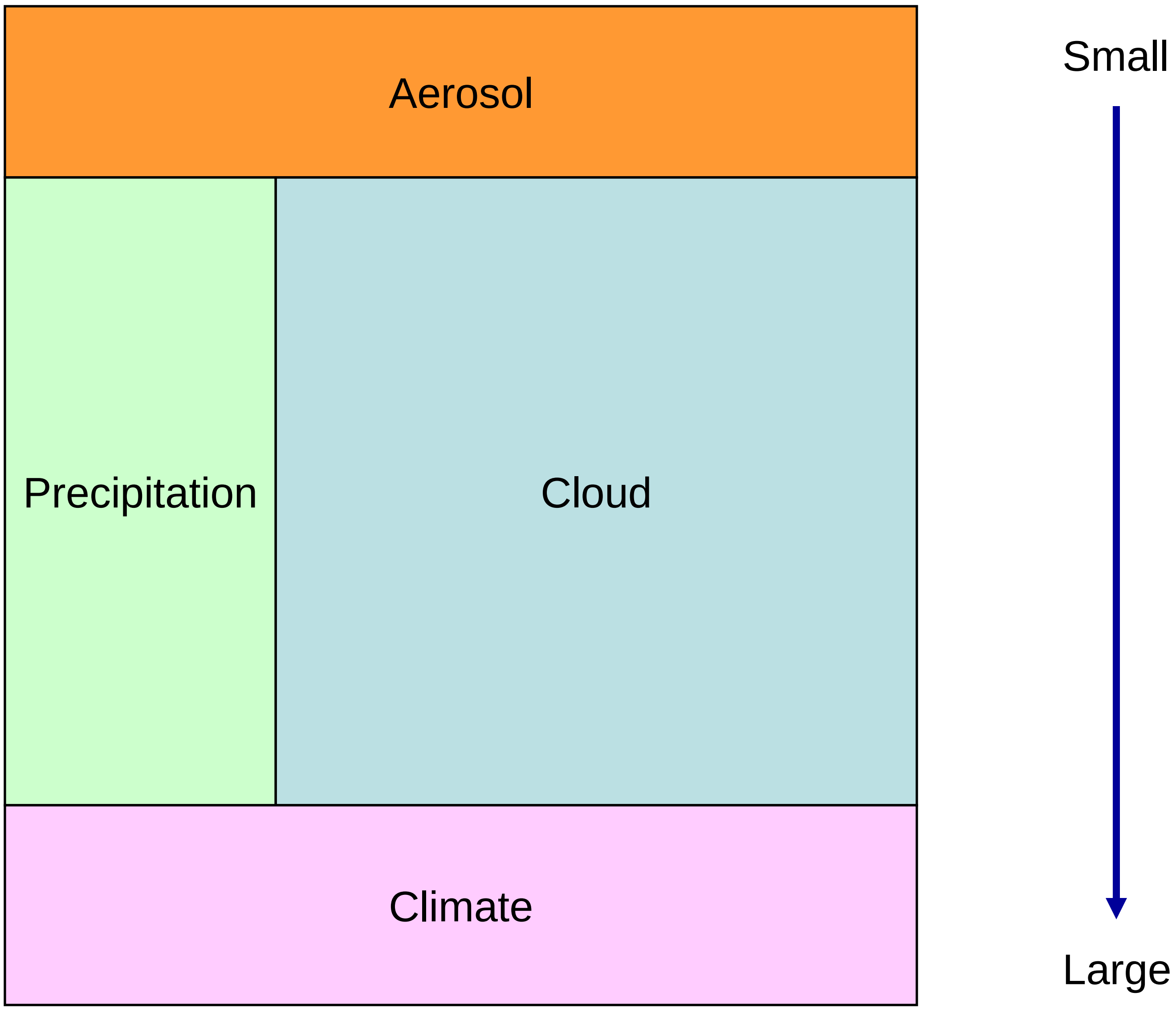


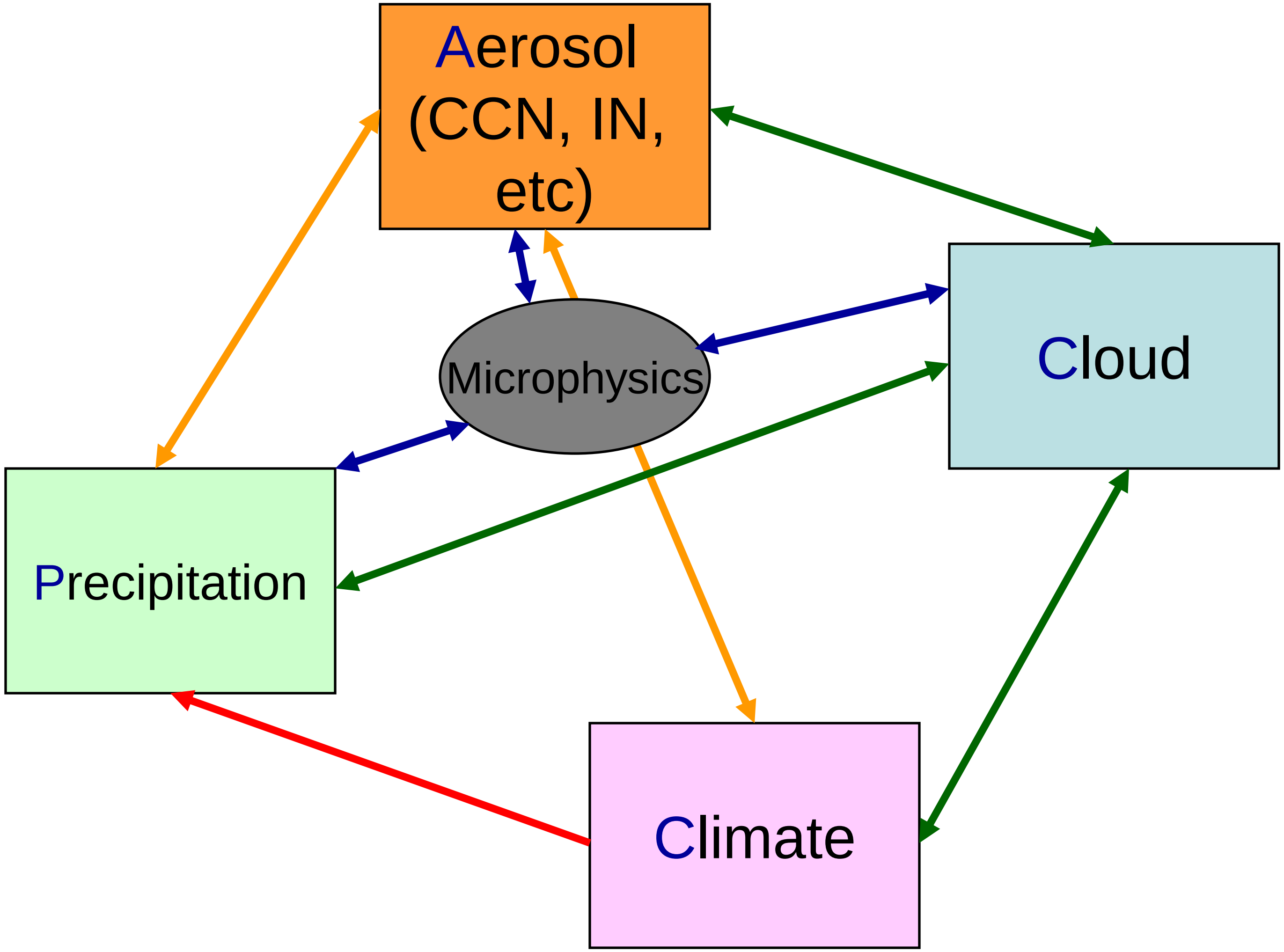
Precipitation: any product of the condensation of atmospheric water vapor that is deposited on the earth's surface.

Surface water and ground water, etc




Aerosol
Precipitation
Cloud
Climate
Small
Large



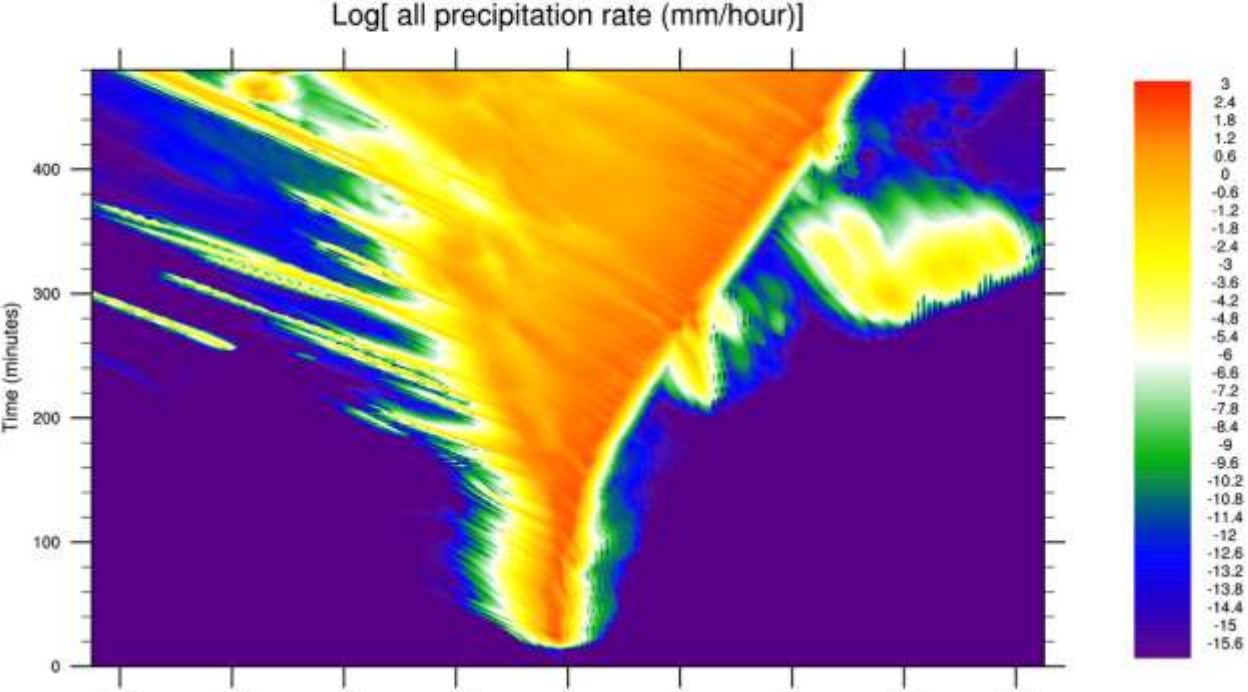
Cloud microphysics: the study of the physical processes that lead to the formation, growth and precipitation of cloud

Two bin (spectral) microphysics schemes have been coupled into the Weather Research Forecast (WRF) model. They are powerful and valuable tools for investigating microphysical processes inside clouds and dynamics feedbacks of clouds.

All kinds of cloud microphysical processes (condensation, collision-coalescence, breakup, deposition, sublimation, collisions between different species, etc) have been incorporated in mixed phase scheme. All warm rain processes and aerosol features have been implemented in aerosol warm rain scheme.

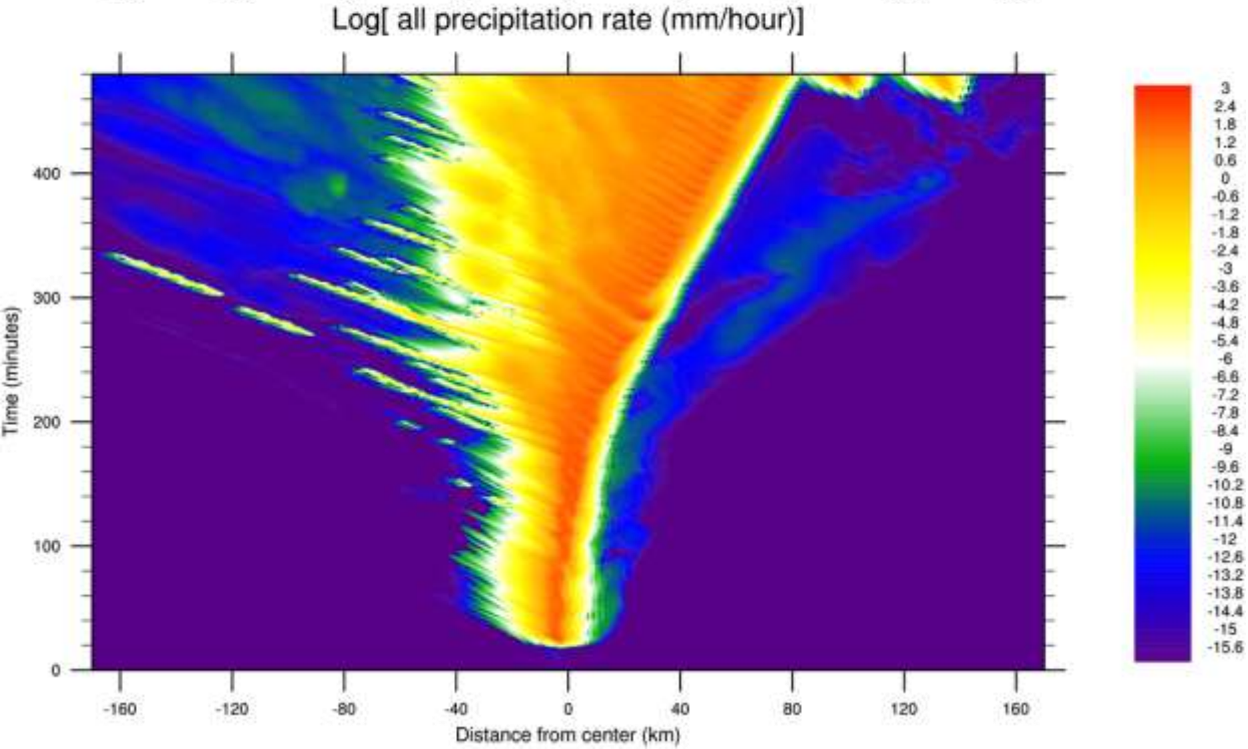
Multi-moments conservation method (Tzivion et al. 1987) is used to calculate the evolution of the size and mass spectrum of the different cloud particles for each time step.

Two ideal 2D-squall line cases using mixed phase scheme with clean and polluted CCN concentrations and one ideal LES case using aerosol warm rain scheme were simulated.



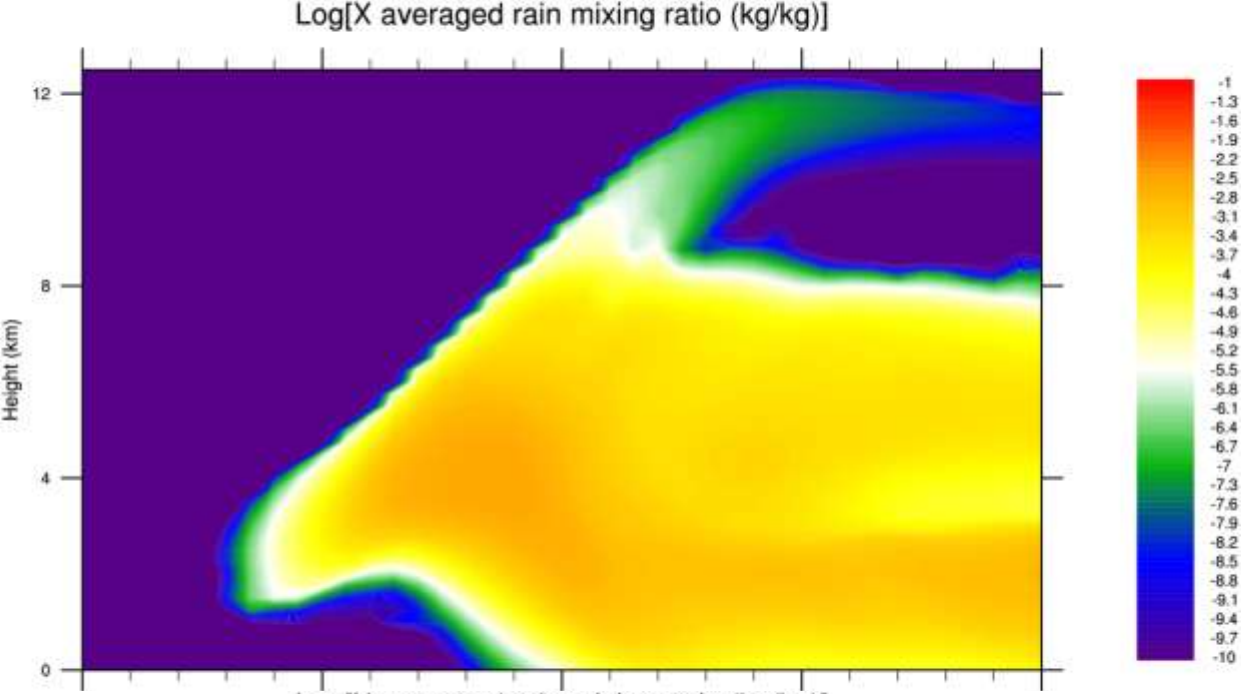
Clean case

- Squall line moves faster
- Broader stratiform precipitation



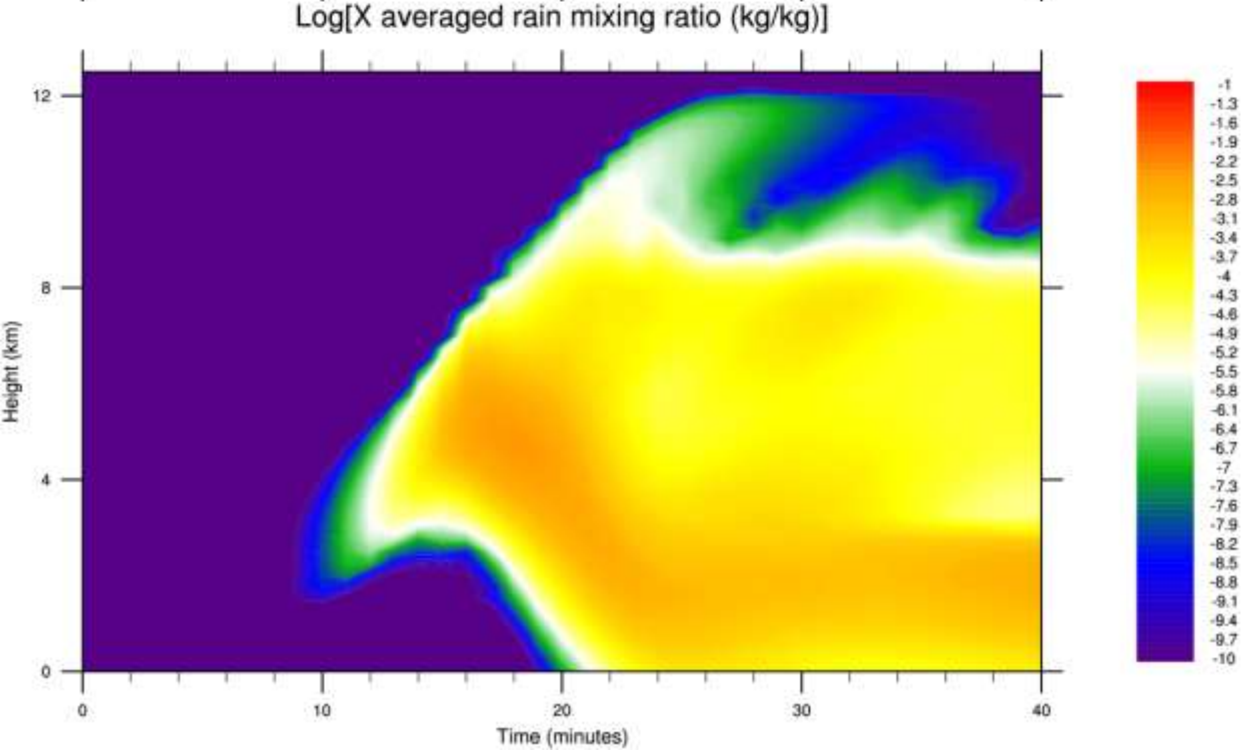
Polluted case

- Squall line moves slower
- Less stratiform precipitation



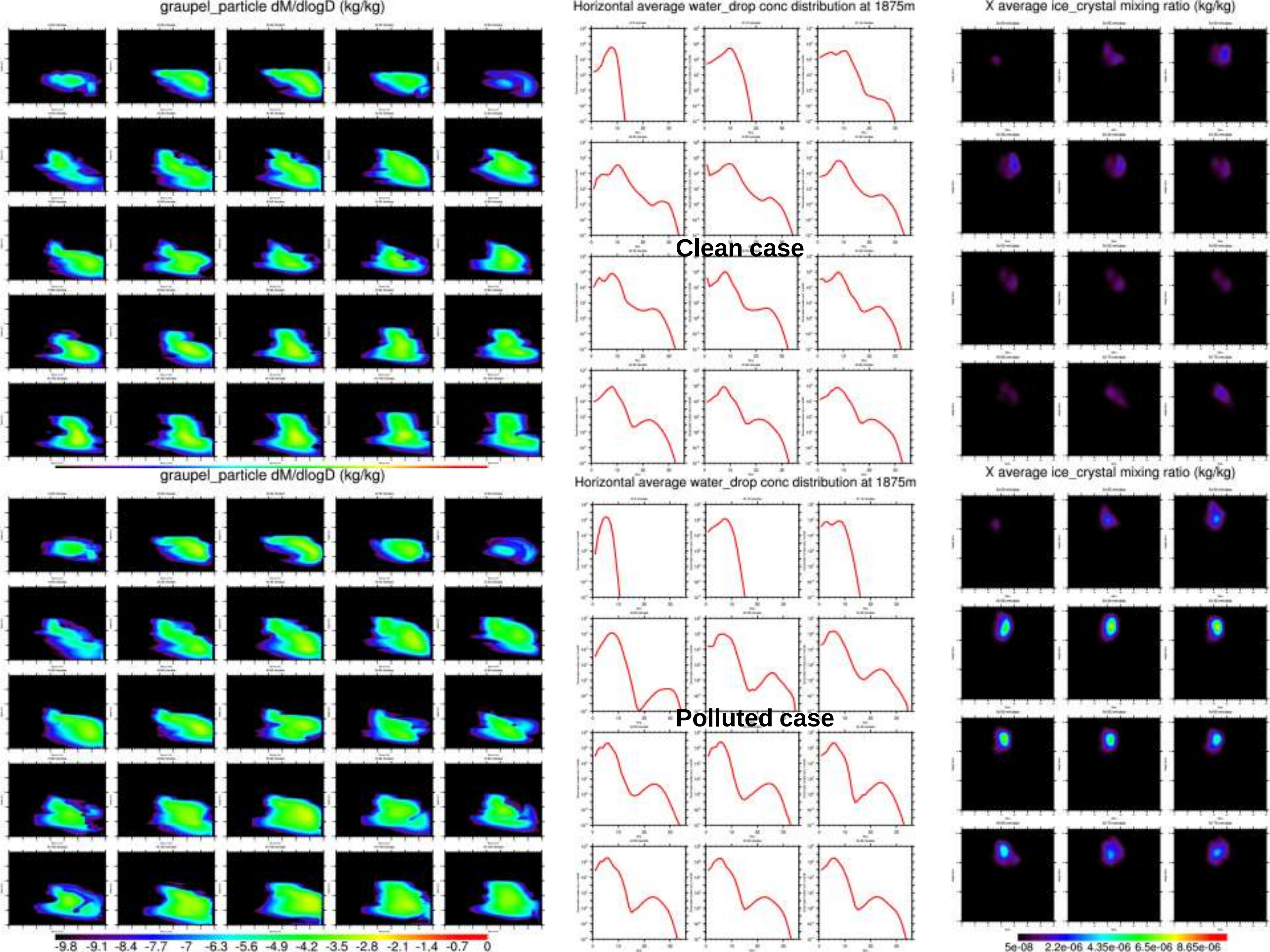
Clean case

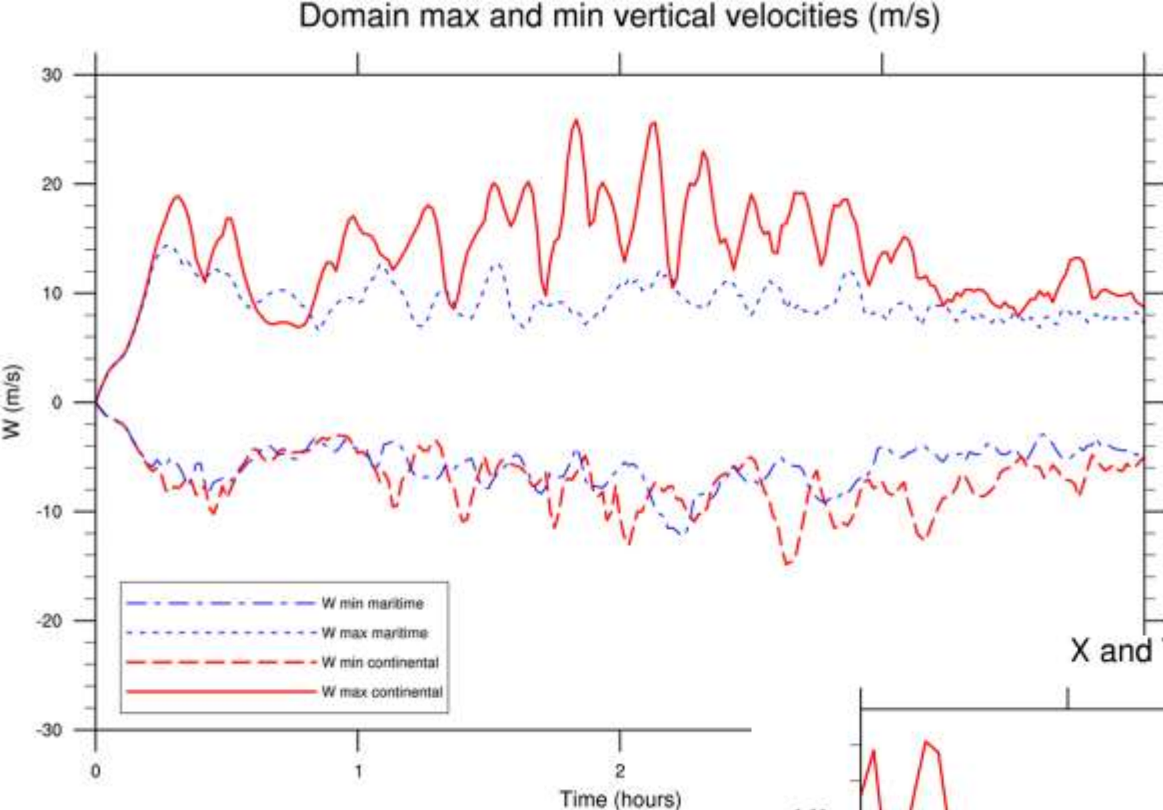
- Cloud and rain form earlier
- Cloud top is lower



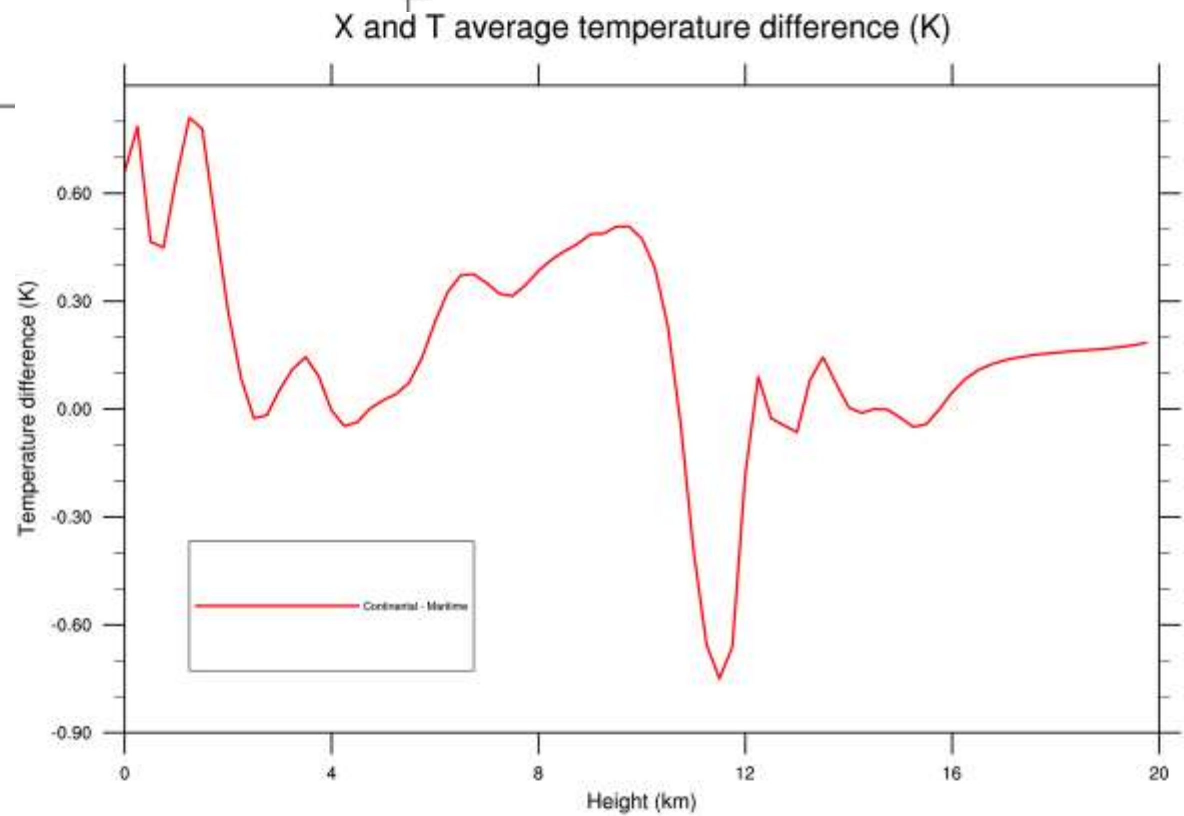
Polluted case

- Cloud and rain form later
- Cloud top is higher

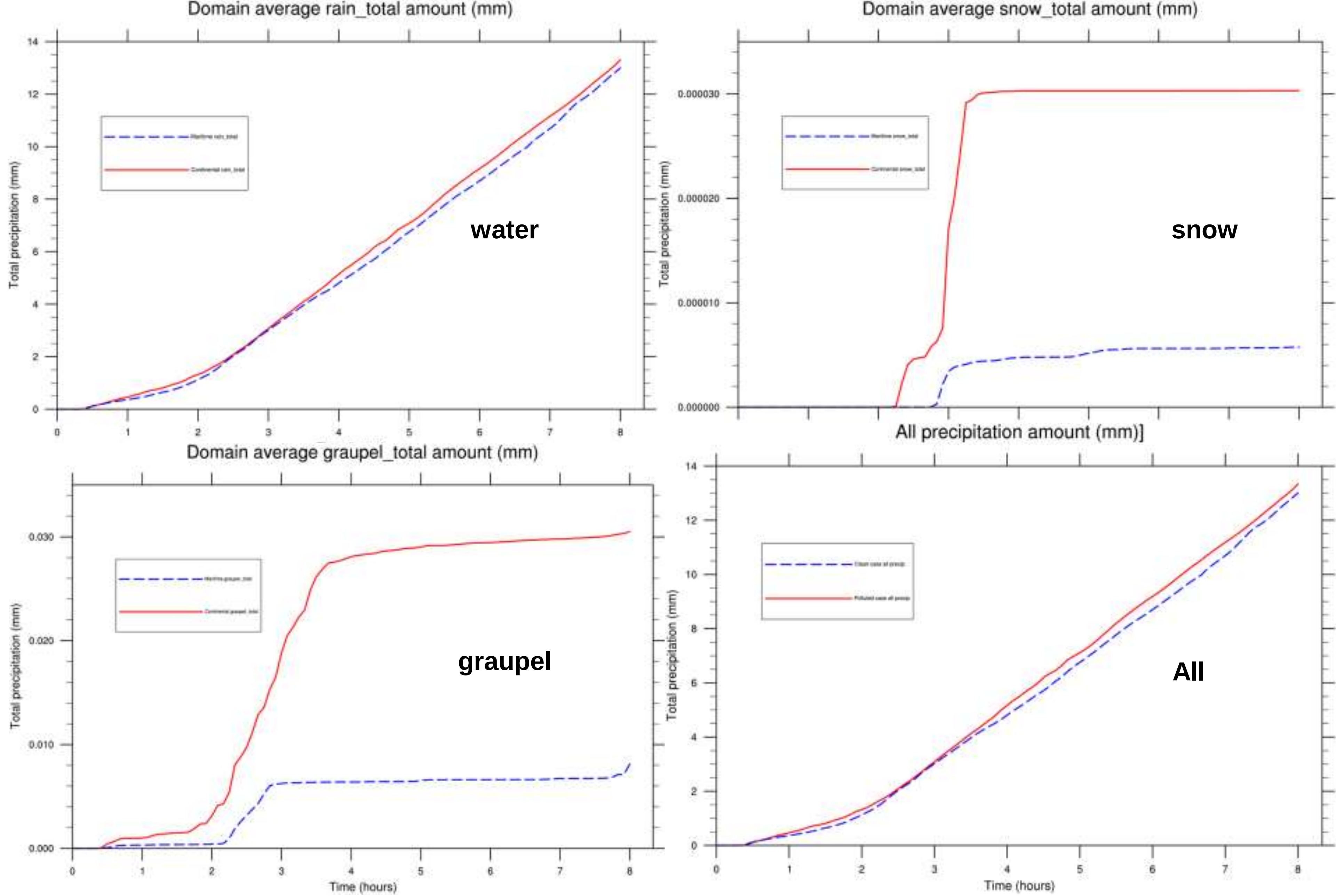

graupel_particle dM/dlogD (kg/kg)
Horizontal average water_drop conc distribution at 1875m
X average ice_crystal mixing ratio (kg/kg)
Clean case
graupel_particle dM/dlogD (kg/kg)
Horizontal average water_drop conc distribution at 1875m
X average ice_crystal mixing ratio (kg/kg)
Polluted case
-9.8 -9.1 -8.4 -7.7 -7 -6.3 -5.6 -4.9 -4.2 -3.5 -2.8 -2.1 -1.4 -0.7 0
5e-08 2.2e-06 4.35e-06 6.5e-06 8.65e-06



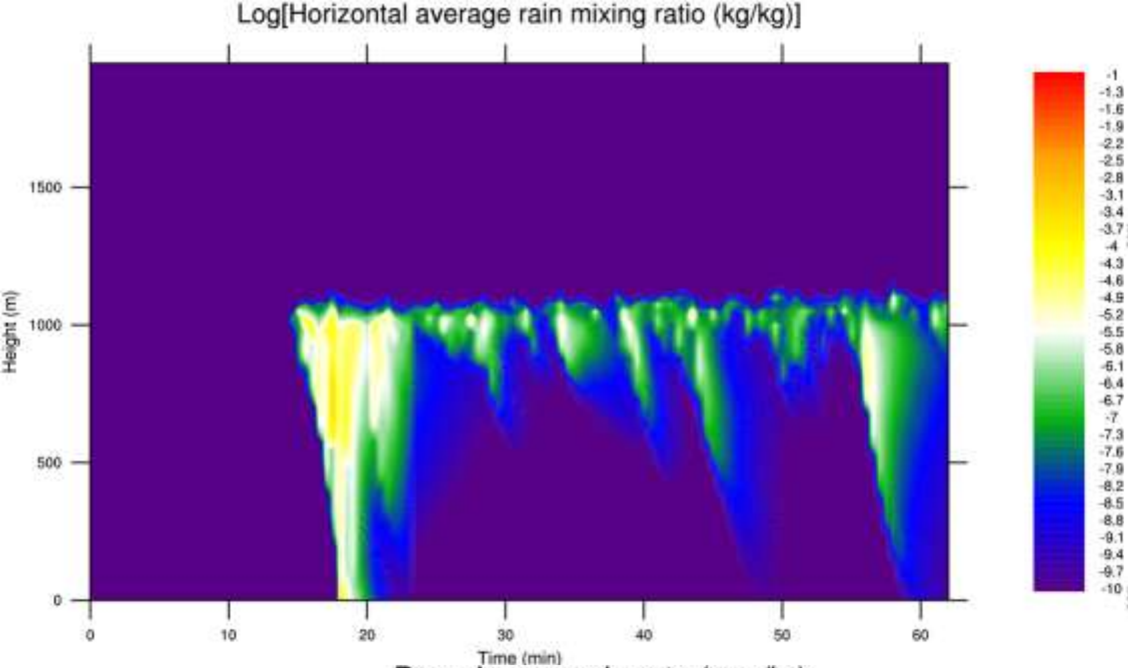
Polluted case has stronger updrafts and downdrafts than clean case

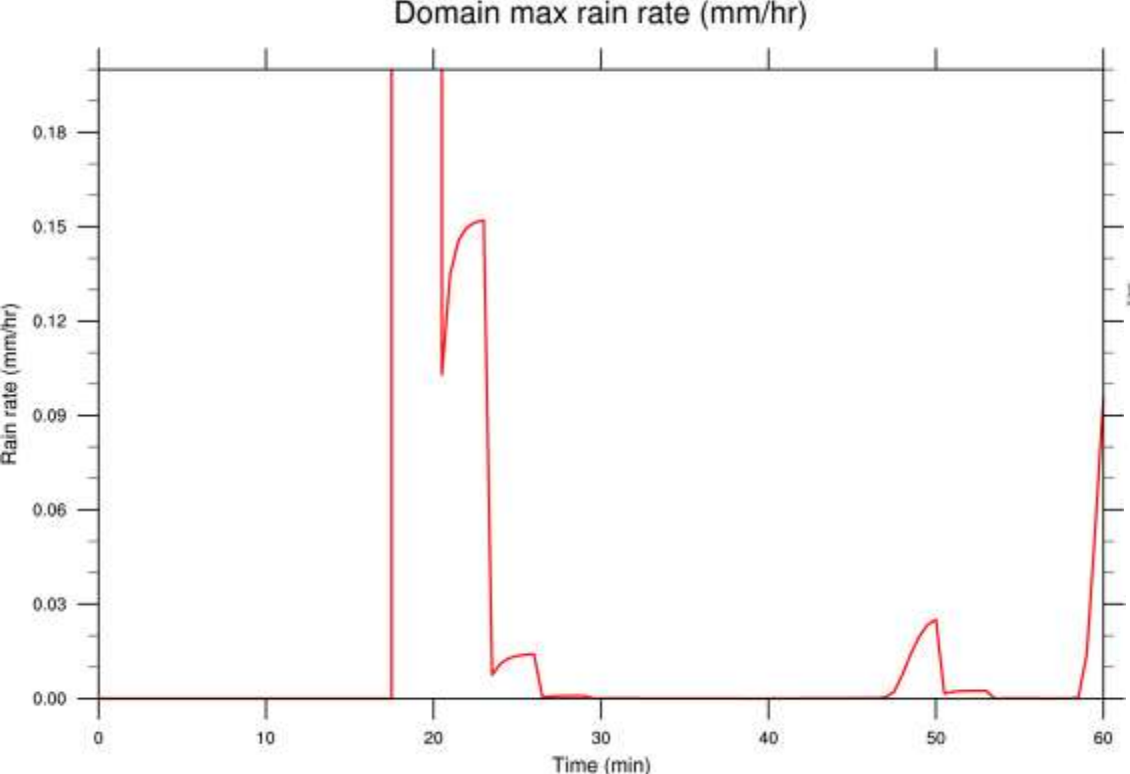


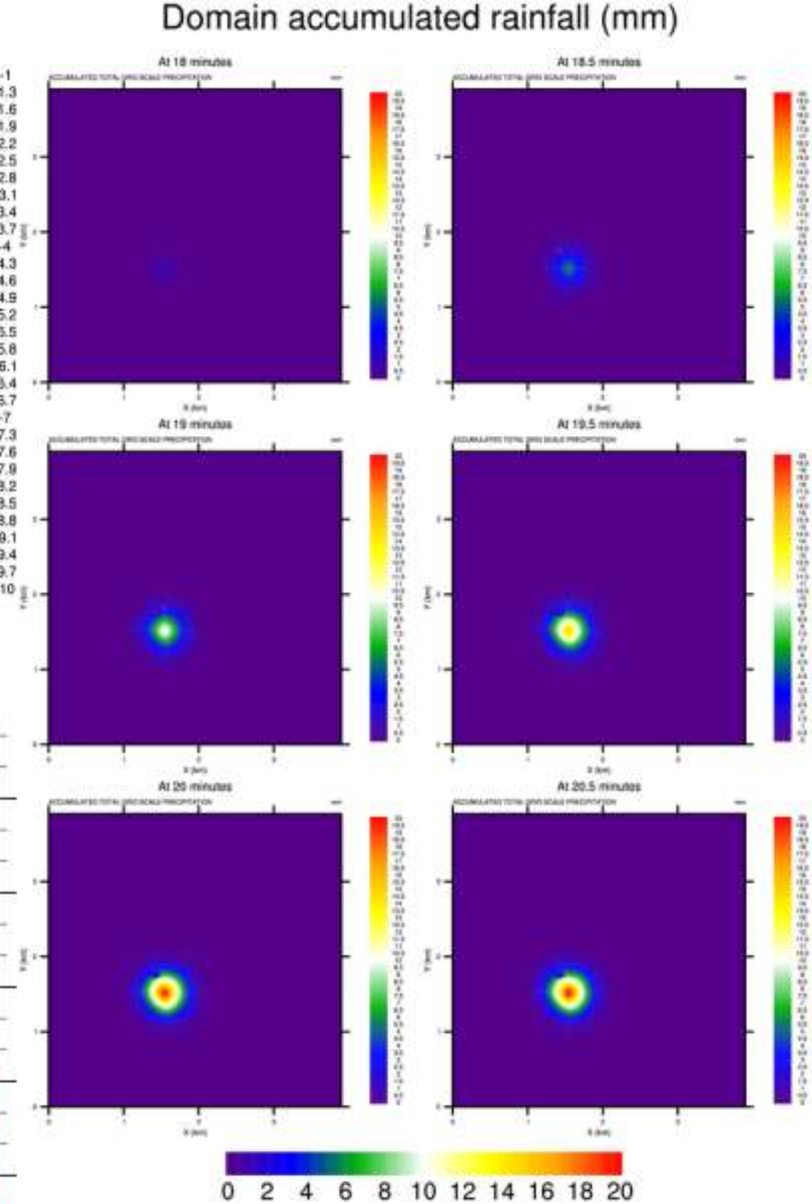
Polluted case is colder between 9km and 11km and warmer at surface than clean case



Polluted case generates more ice phase and total precipitation

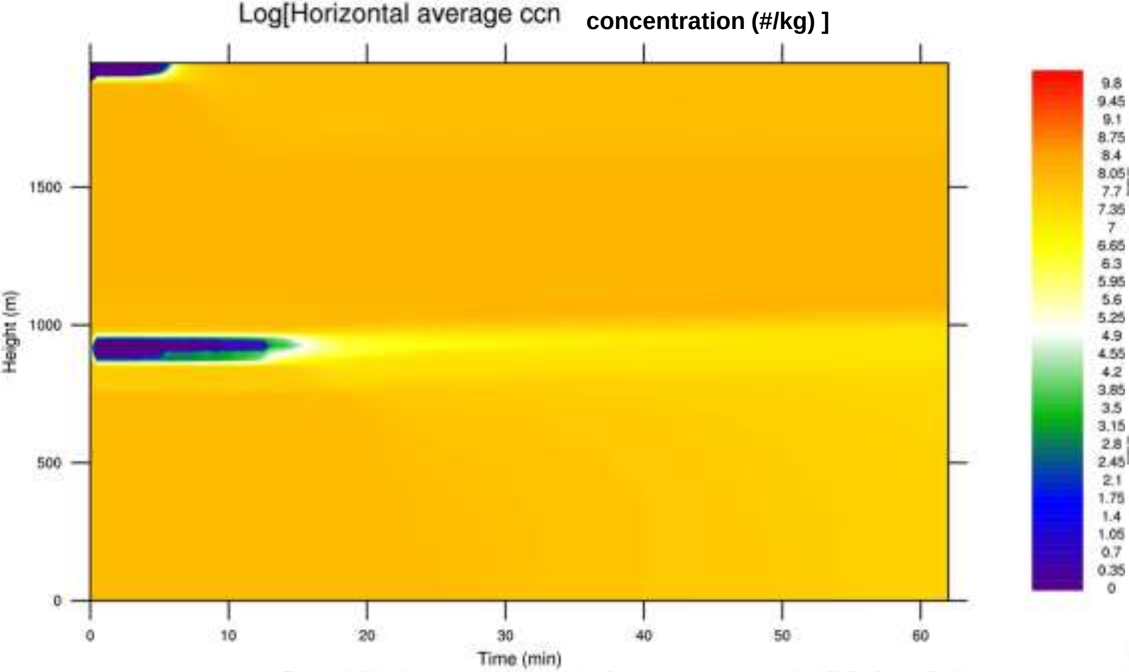


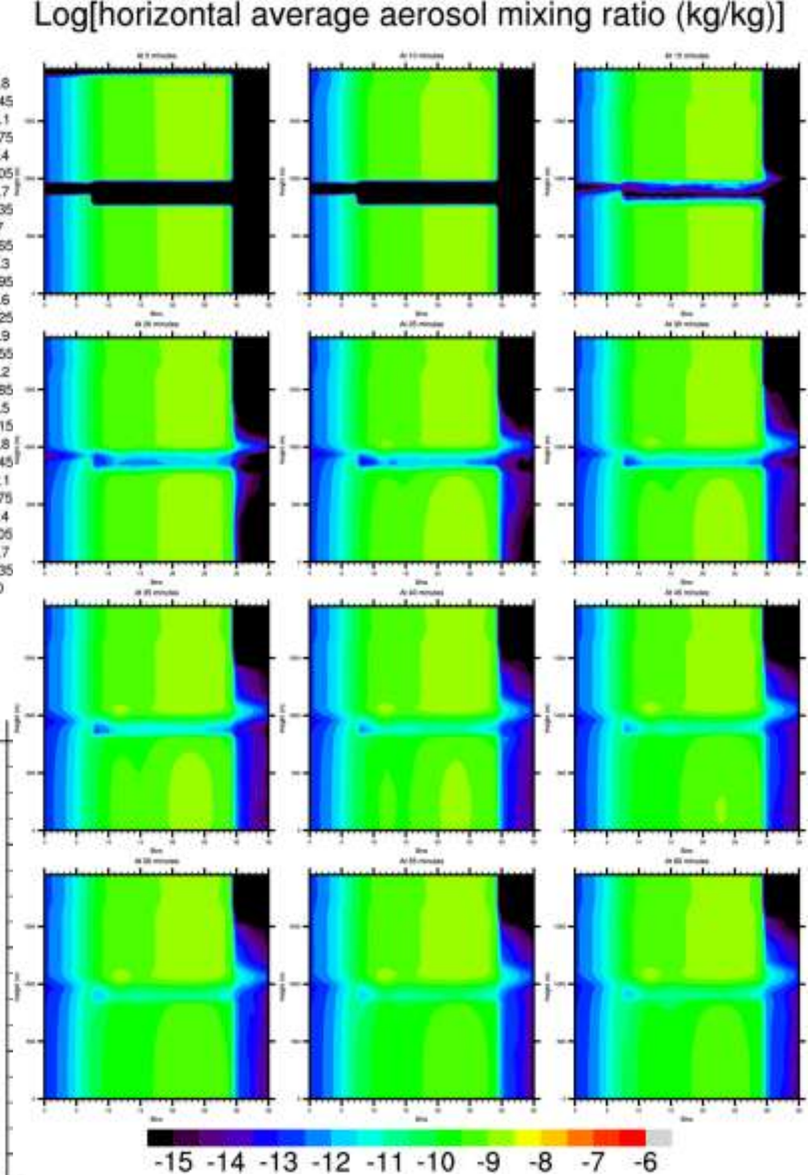


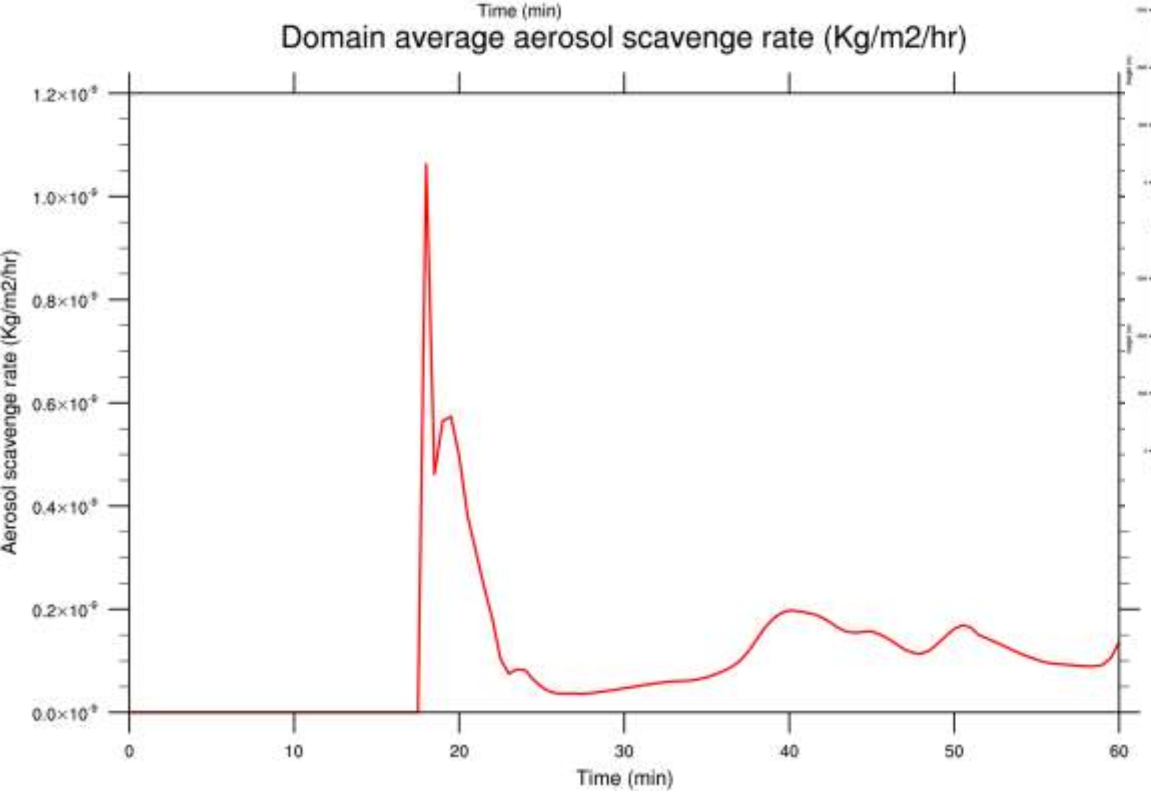


Precipitation information

LES cases -- results





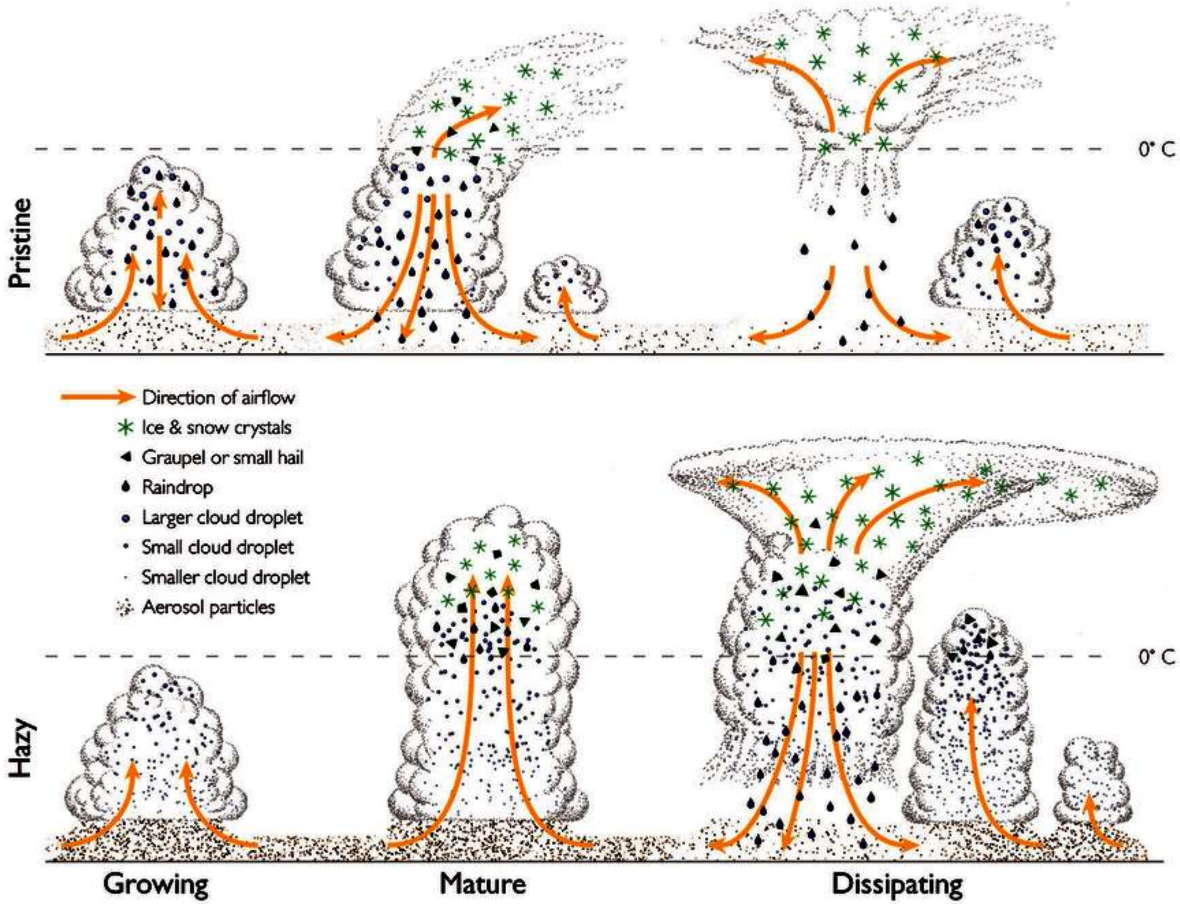


Dry aerosols and aerosol scavenging information

LES cases -- results

Mixed phase bin scheme works for strong convective system

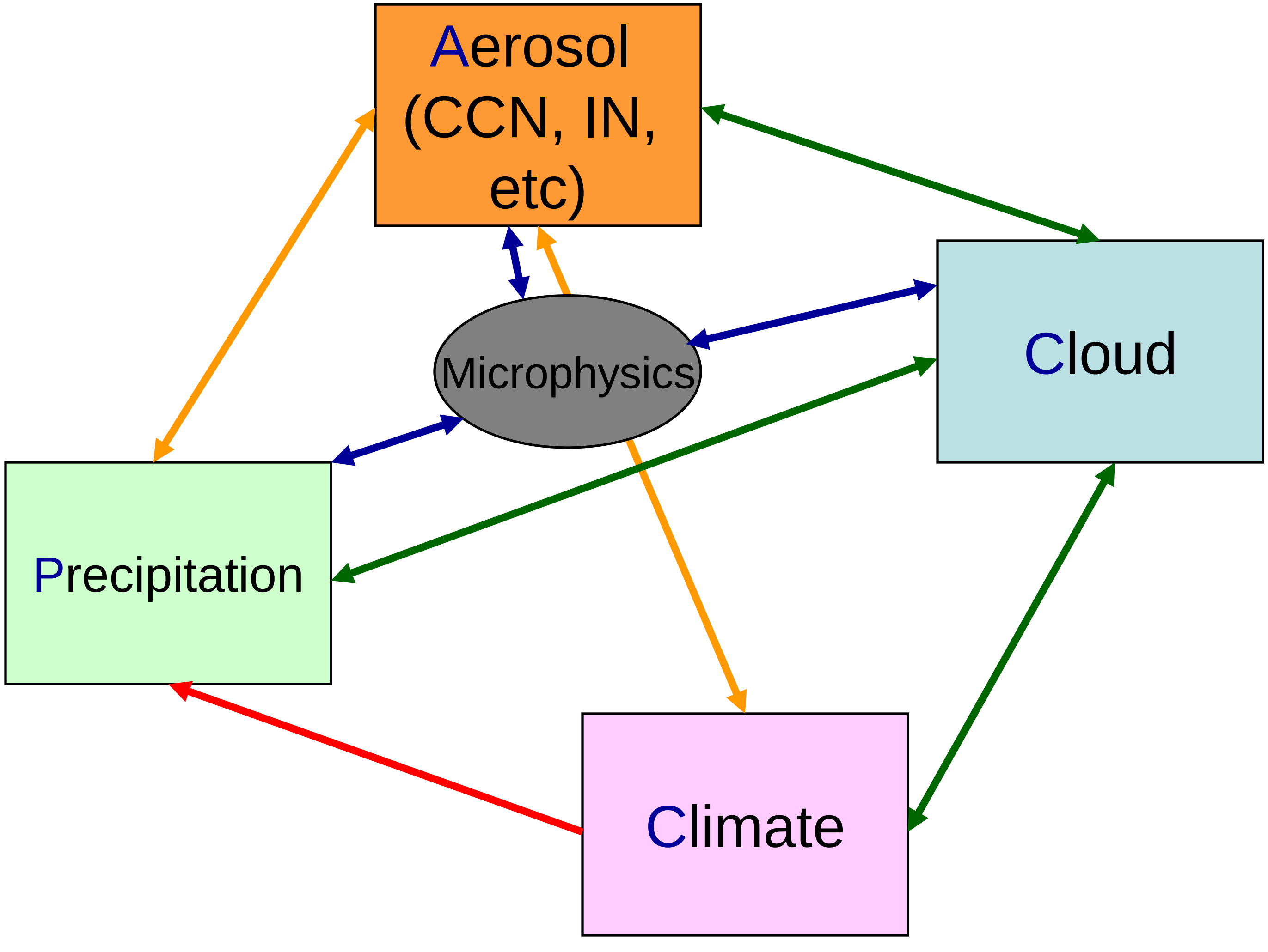
Results verify recently proposed hypothesis



Graphics by Robert Simmon, NASA (courtesy of Rosenfeld)

Aerosol scavenging can be investigated by the aerosol scheme

Changes of aerosol (CCN) affect the dynamics and thermodynamics


Aerosol
(CCN, IN,
etc)
Microphysics
Cloud
Precipitation
Climate