LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

FAKULTÄT FÜR PHYSIK
METEOROLOGIE

Evaluation of vertical mass flux in high-resolution simulations of convective clouds

Katrin Scheufele[1], George C. Craig[1,2]

[1] *Meteorologisches Institut, Ludwig-Maximilians Universität, München, Germany*
[2] *Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany*

Outline

1) Motivation

2) Simulation set-up

3) Results from control simulation

4) Outlook (Simulation & Evaluation)

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Motivation

Stochastic parameterization scheme for deep convection (Plant and Craig, 2008)

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- stochastic variability describes fluctuations about a large-scale equilibrium state

- plumes (cloud-base mass flux) are randomly drawn from a probability distribution function (PDF)

- model for equilibrium convective statistics by Craig and Cohen (2006) & Cohen and Craig (2006)

Motivation

Craig and Cohen (2006) & Cohen and Craig (2006)

- Elementary concepts from statistical mechanics

- Assume weakly interacting convective clouds

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$\rightarrow$ probability distribution function (PDF) of mass flux per cloud:

$\langle m \rangle$: Ensemble average mass flux per cloud

$$p(m)dm = \frac{1}{\langle m \rangle} \exp\left(\frac{-m}{\langle m \rangle}\right) dm,$$

Motivation

Craig and Cohen (2006) & Cohen and Craig (2006)

- exponential distribution robust over range of heights and forcings

- increasing the forcing:

  → increases the number of clouds in the domain
  NOT the shape of the distribution

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Reproduction of the
2 km-resolution results

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EUlerian/semi-LAGrangian fluid solver EULAG

- non-hydrostatic, anelastic three-dimensional fluid solver

- integrates the equations of motion with a second-order, semi-implicit, non-oscillatory, forward in time approach (MPDATA)

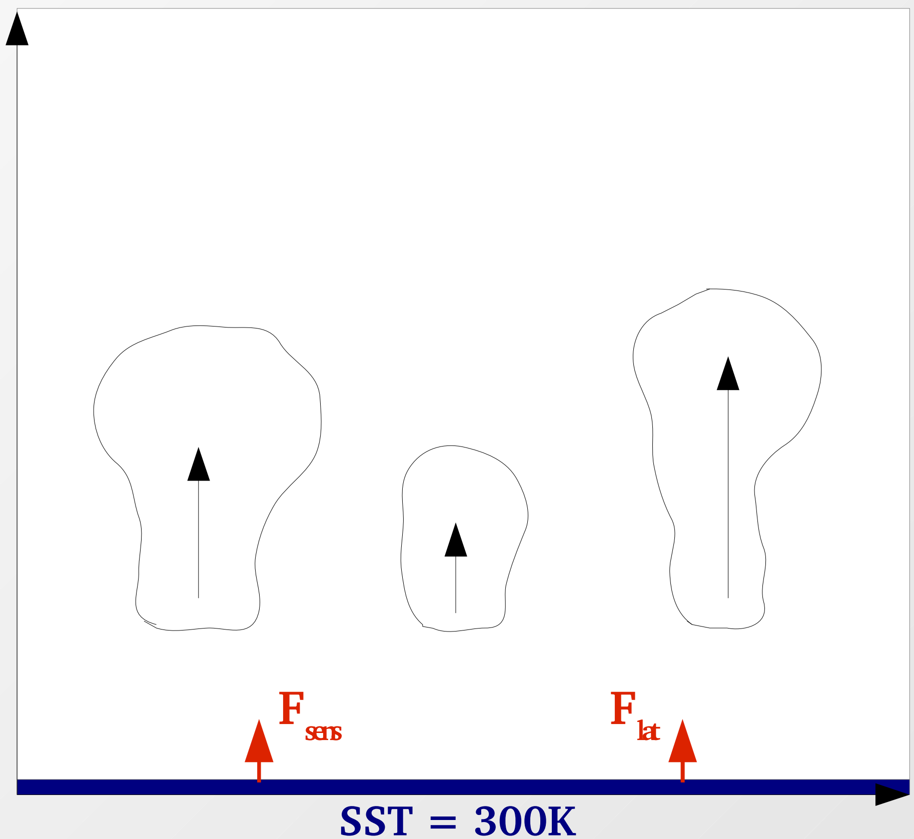
- simple warm rain scheme and ice microphysical scheme (Grabowski, 1998)

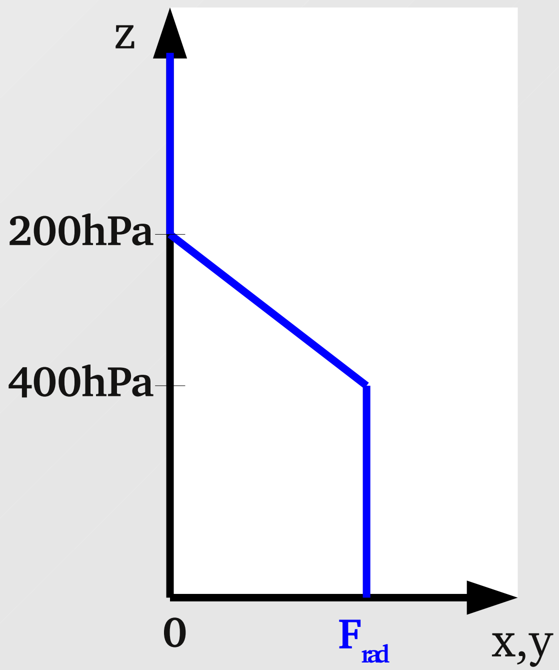
- bulk parameterization of surface fluxes of latent and sensible heat (Grabowski, 1998)

- Subgrid-scale model: Smagorinsky-type turbulence model (Margolin et al., 1999)

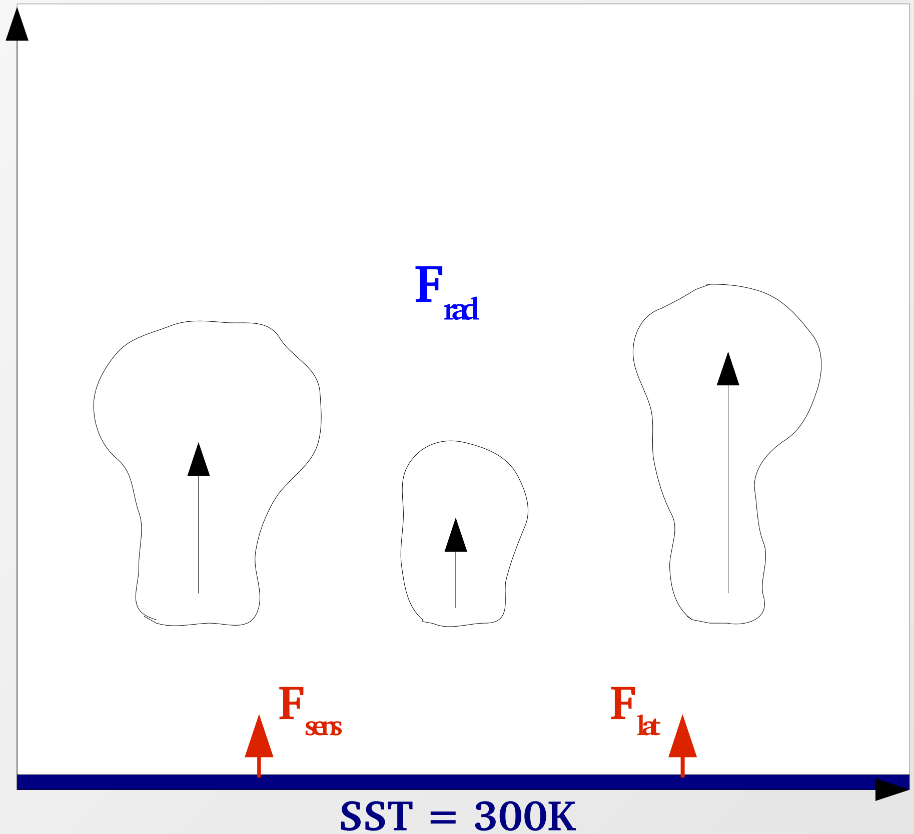
EULAG: set-up of the control simulation

Radiative Cooling and Surface Fluxes





EULAG: set-up of the control simulation



- domain: 128 km * 128 km * 20 km

- horizontal resolution: 2 km
- vertical resolution: 200 m

- periodic boundaries in the horizontal
- damping layer in the vertical

- neglecting coriolis effects

- initially at rest
- small perturbation of w-field

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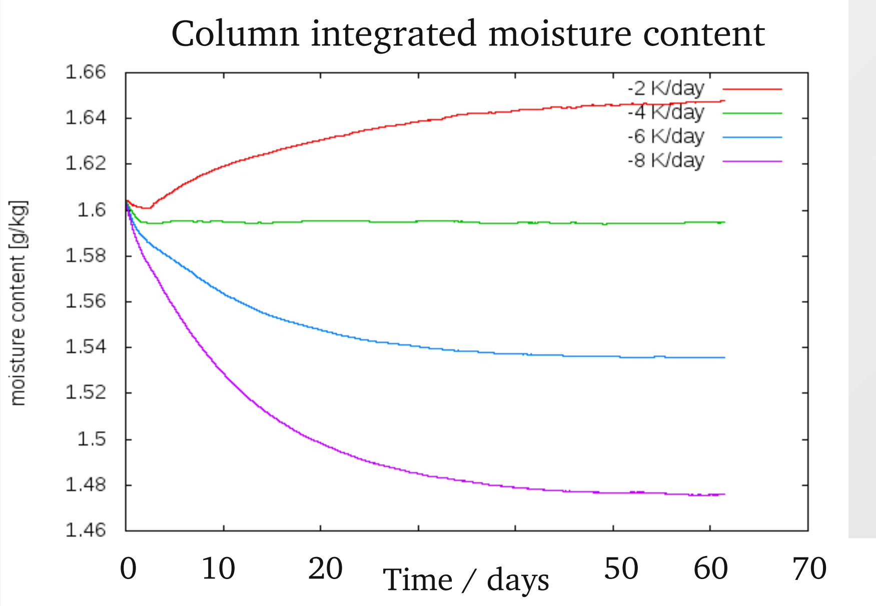
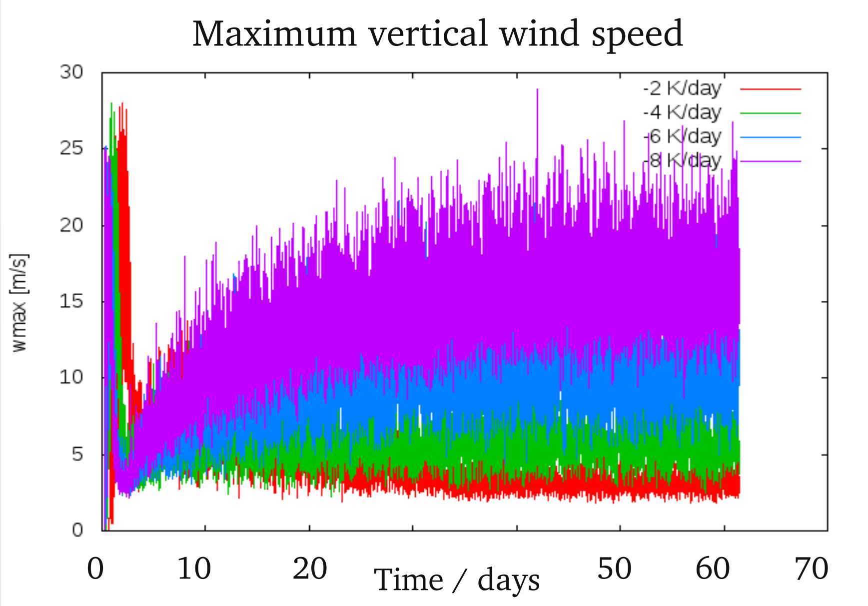
RESULTS of the control simulation

Timeseries: evolution of the simulation towards radiative-convective equilibrium



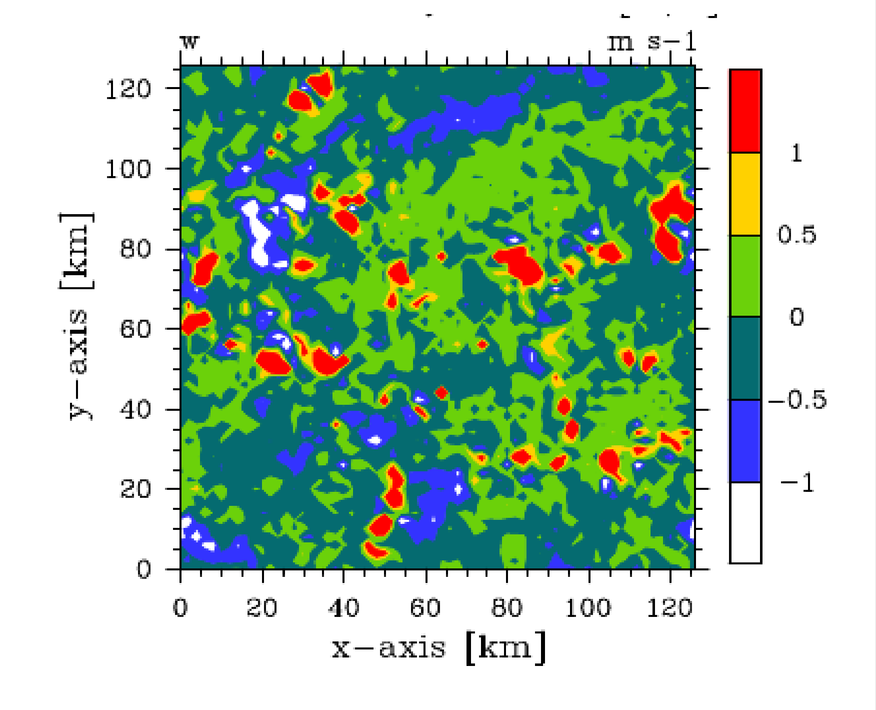


RESULTS of the control simulation

Computation of mass flux per cloud:

- x-y slice of vertical wind field at 2.4 km height

Vertical velocity [m/s]



RESULTS of the control simulation

Computation of mass flux per cloud:

- x-y slice of vertical wind field at 2.4 km height

- “cloudy grid point” where w > 1m/s

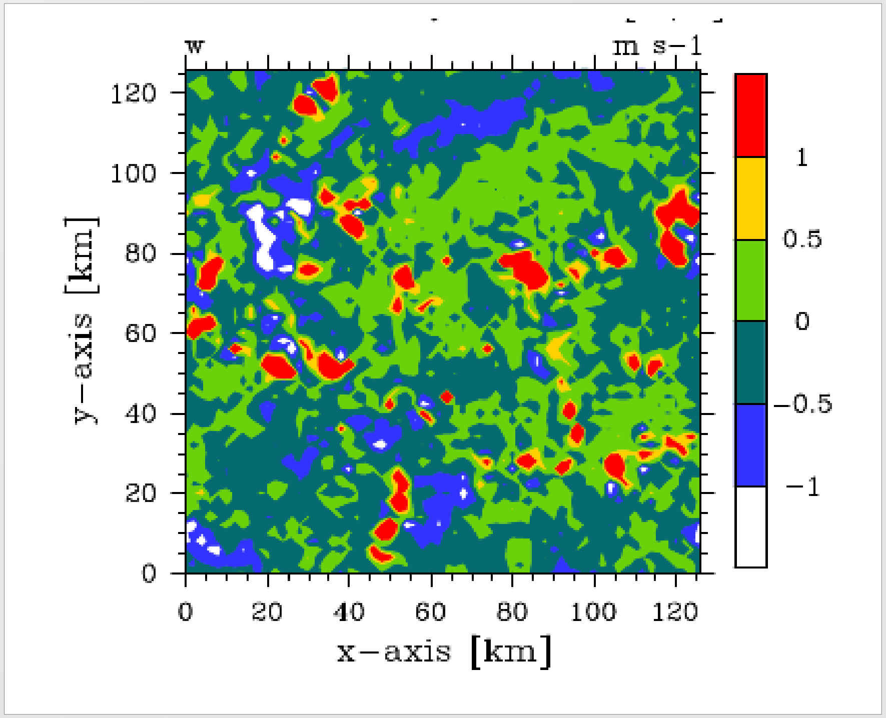
→ domain is searched for adjacent cloudy grid points

(Hoshen and Kopelman (1976), Dahl et al. (2011))

$$m_i = \rho * \sigma_i * \langle w_i \rangle$$

ρ : density of air
σ_i : size of the cloud
$\langle w_i \rangle$: average vertical velocity

Vertical velocity [m/s]

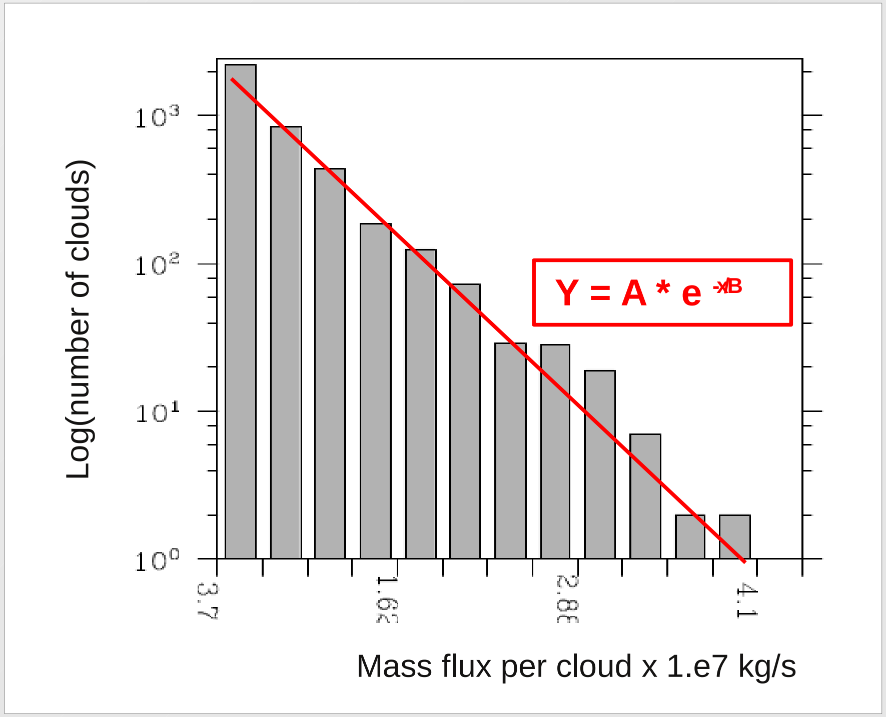


RESULTS of the control simulation

-2 K/day

Histogram: distribution of mass flux per cloud

→ distribution is exponential



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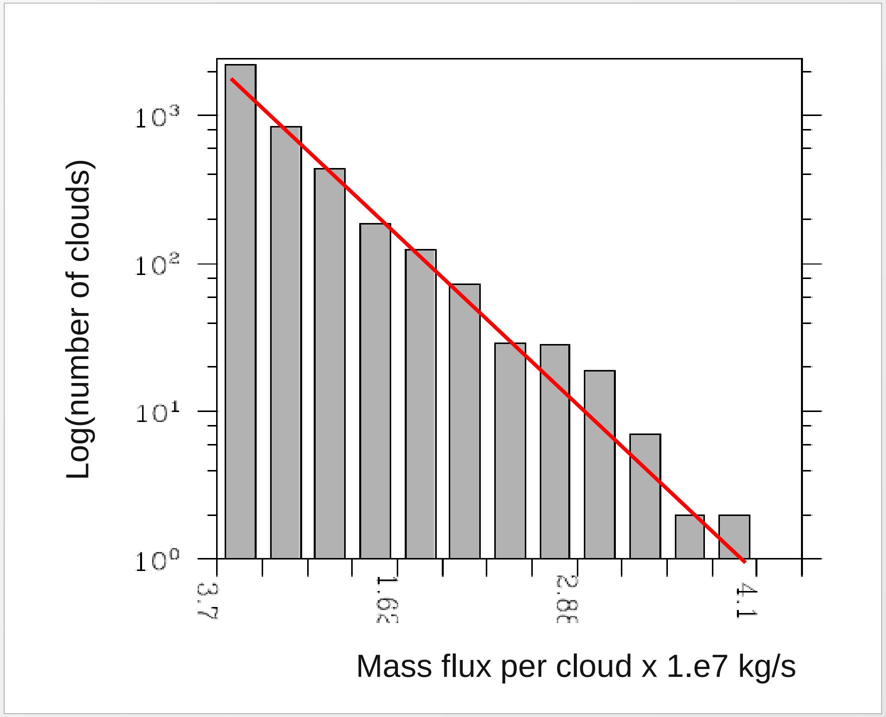
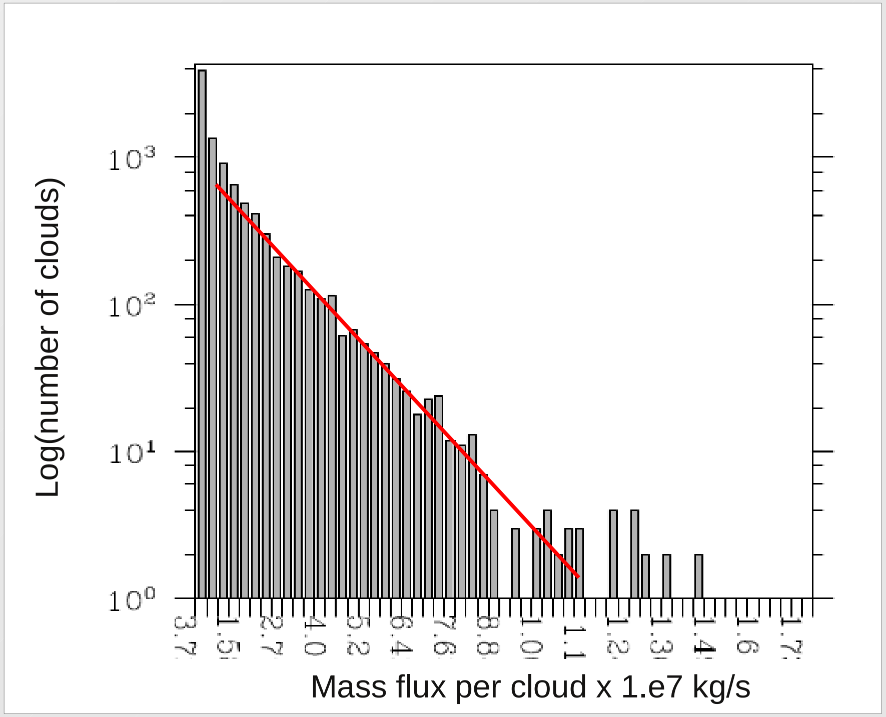


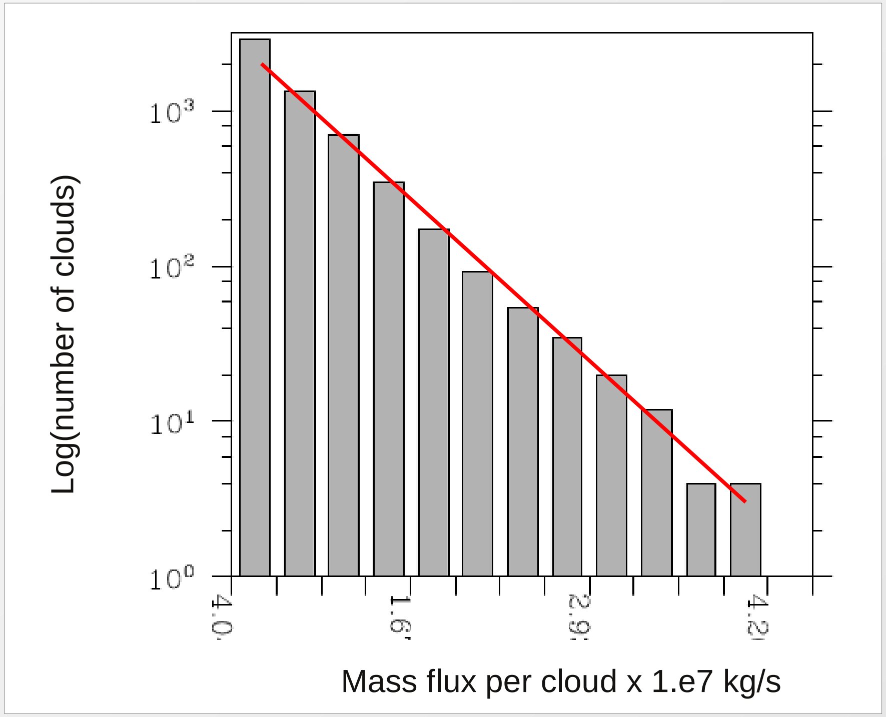
-4 K/day



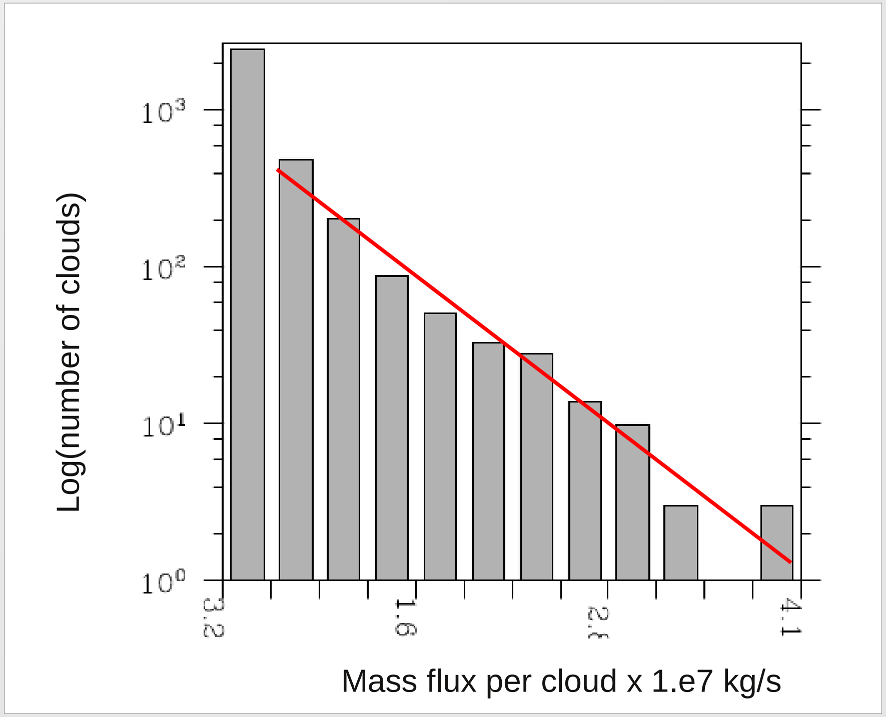
RESULTS of the control simulation

Different height levels with -2 K/day simulation

1.6 km



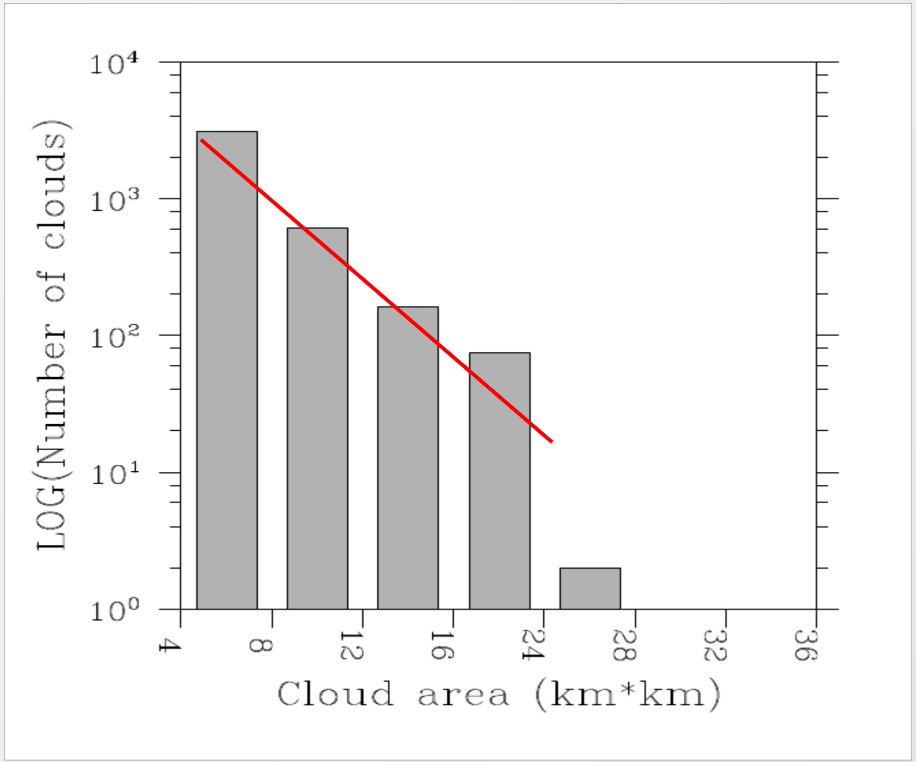
3.4 km



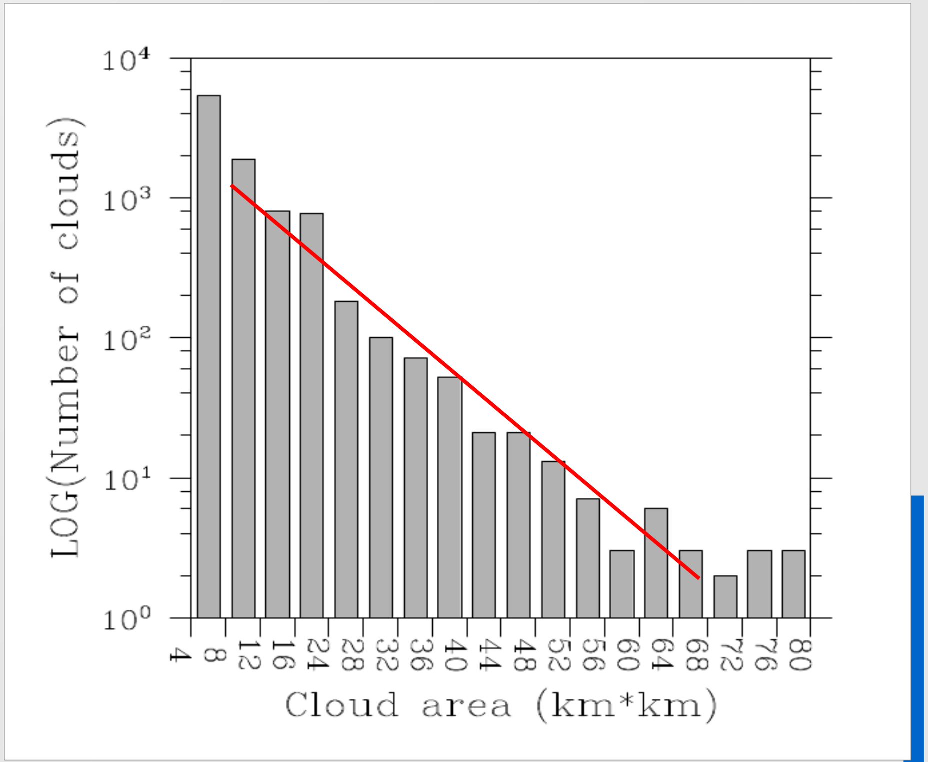
RESULTS of the control simulation

Distribution of cloud sizes

-2 K/day



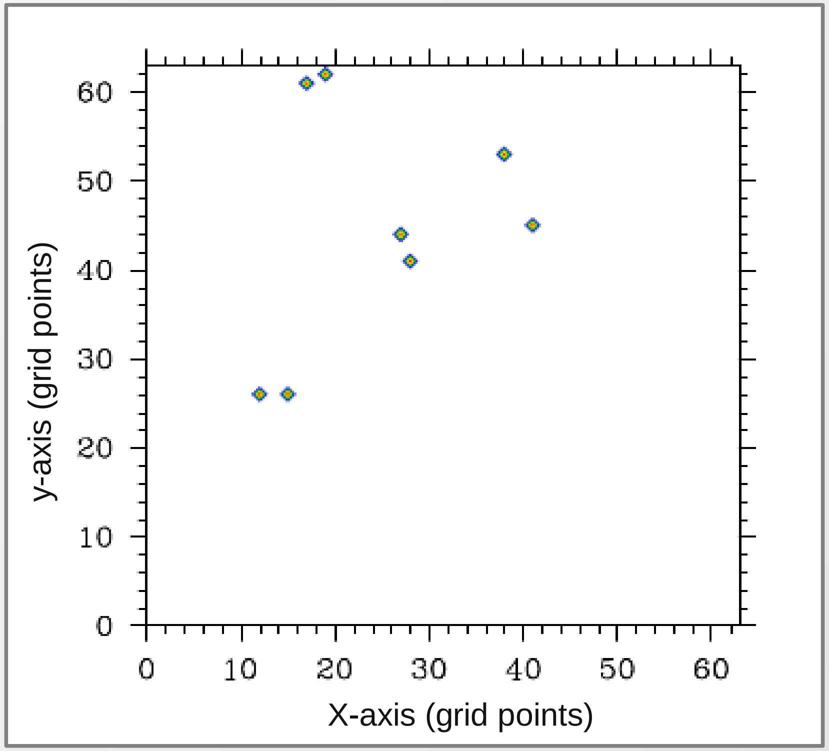
-4 K/day



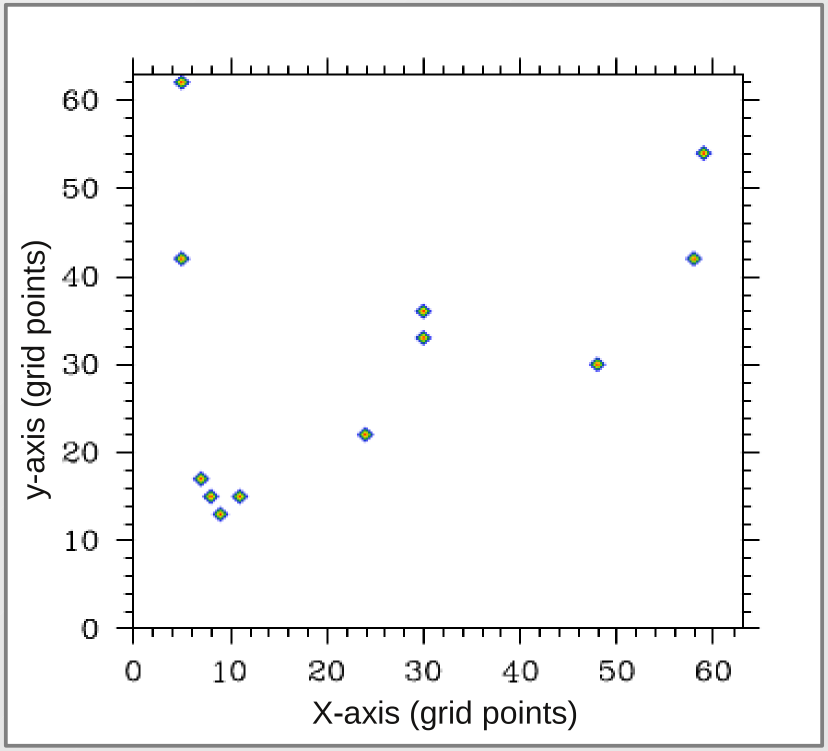
RESULTS of the control simulation

Number of clouds in the domain

-2 K/day

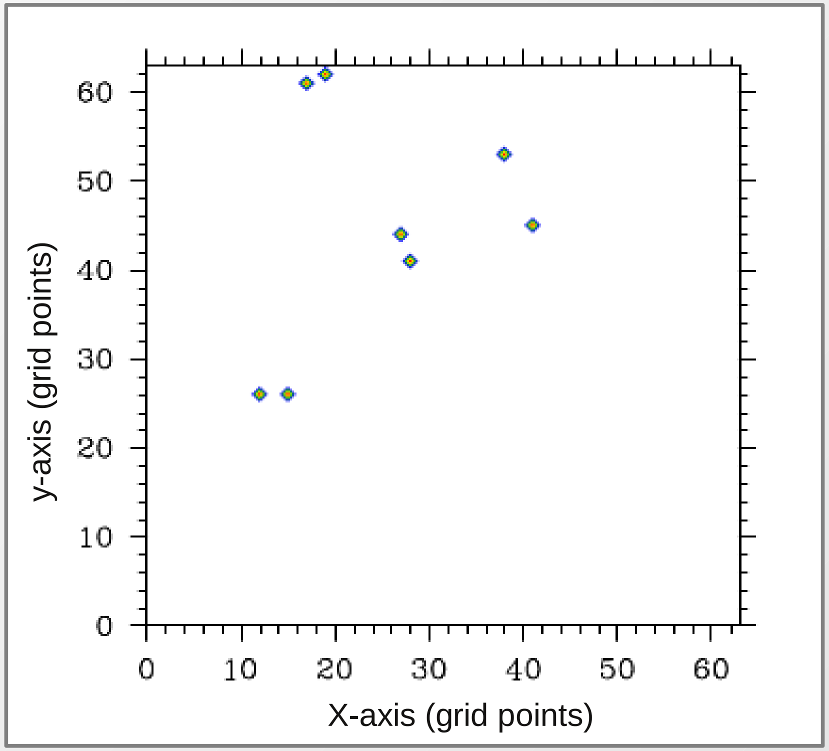


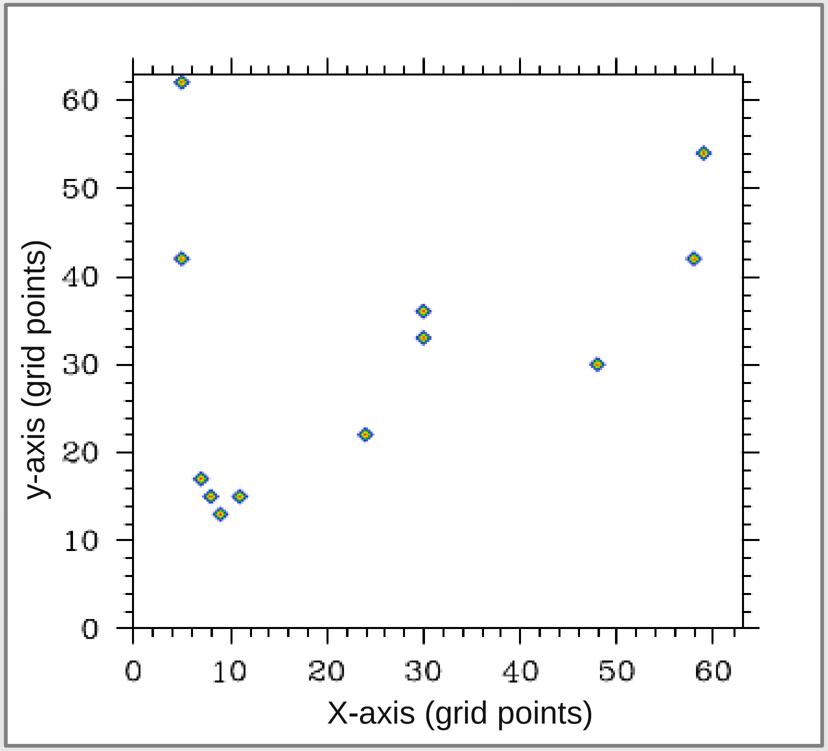
-4 K/day



RESULTS of the control simulation

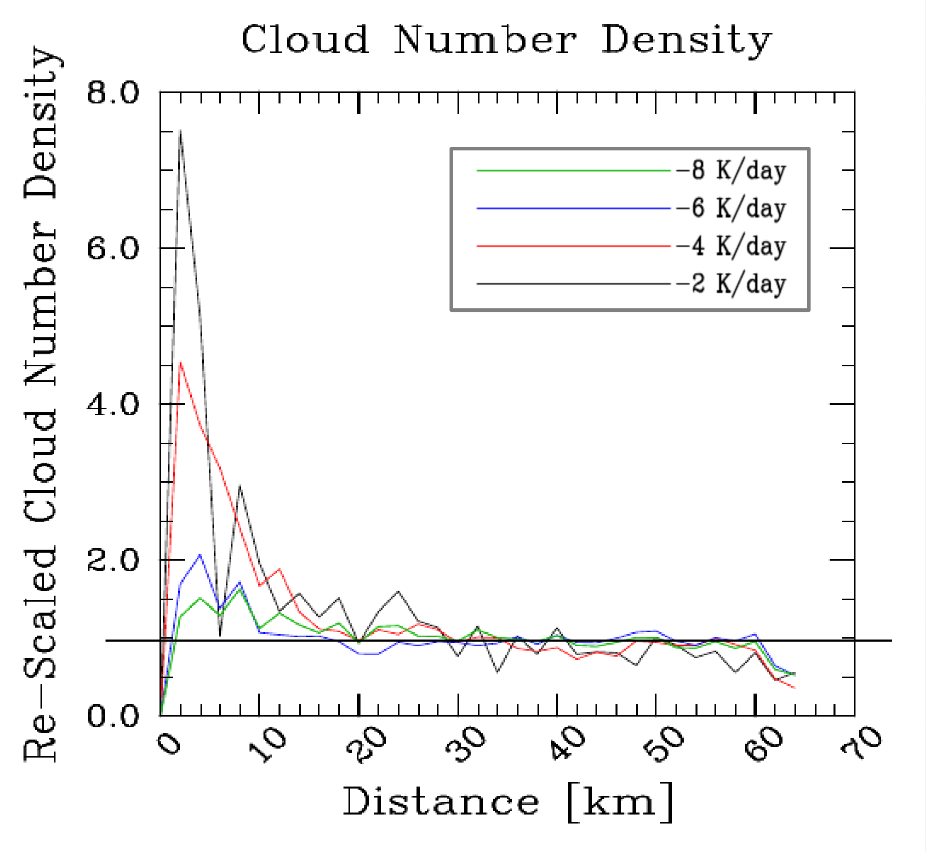
∼ 5 clouds per time step	∼ 10 clouds per time step
-2 K/day	**-4 K/day**

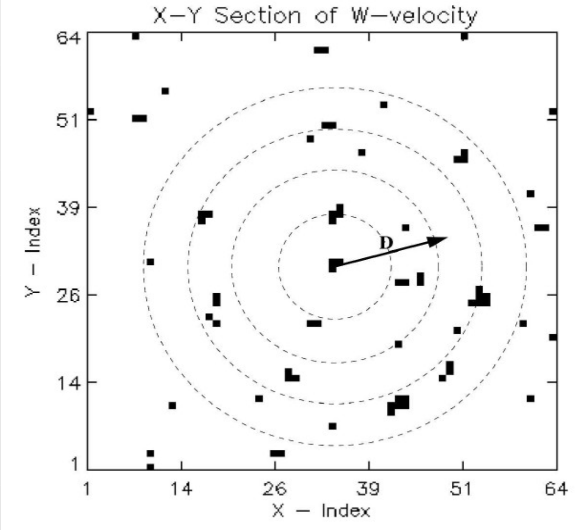




RESULTS of the control simulation

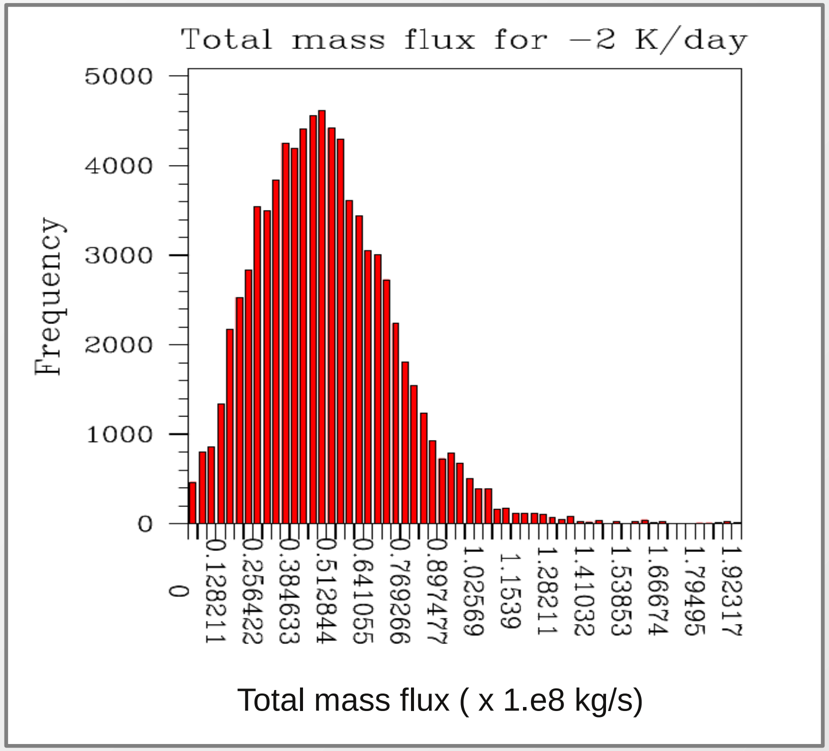
Cloud Number Density

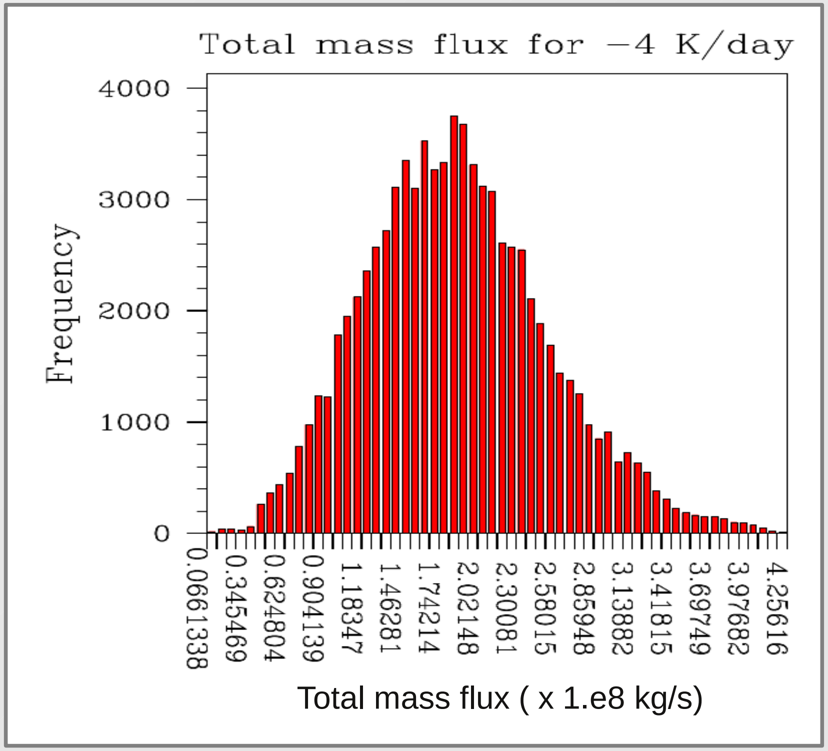




RESULTS of the control simulation

Total mass flux

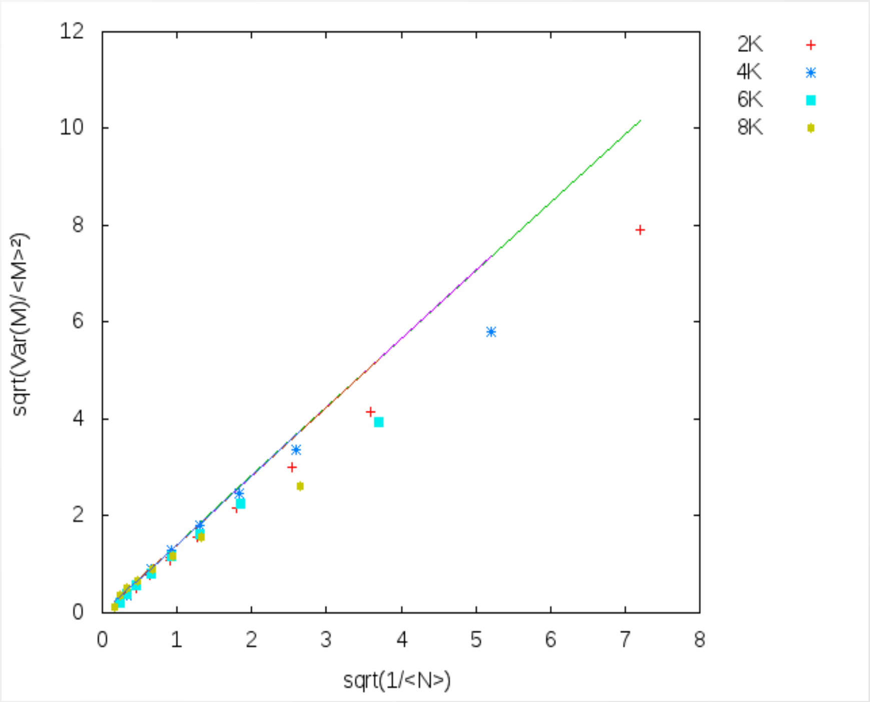




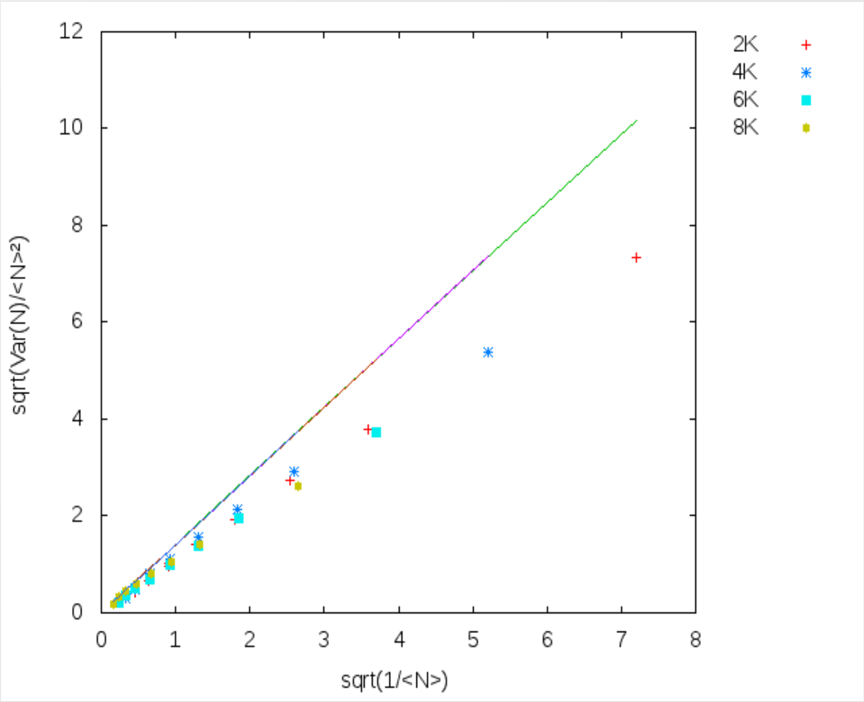
RESULTS of the control simulation

Variance of

total Mass flux



Cloud Number



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Outlook

Simulations to test the distribution of mass flux per cloud:

- horizontal resolutions: 1km, 500 m, 200 m, 100 m, 50 m
- different cooling rates (-2 K/day, -4 K/day, -6 K/day, -8 K/day, -12 K/day)

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→ does the distribution change when significantly increasing the resolution ?

→ do changes in the forcing continue to primarily effect the cloud number ?

Thank you very much
for your attention!