P1.38 INTEGRAL OF SATURATION RATIO VERSUS CUT OF SATURATION RATIO AT 100% AT THE END OF EACH TIME STEP IN CLOUD RESOLVING MODELS

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1.Introduction

Air super-saturation controls nucleation and growth of cloud particles and therefore determines the formation of rain. Models, which calculate cloud microphysics, have to correctly determine super-saturation.

This study analyzes the methods used to calculate the mean super-saturation and the time dependent super-saturation. The analytical method is the first method that has been studied and is hereby presented. The present work was motivated by the following questions: Is it correct to keep the super-saturation constant in simulations for an entire time step? How to find the equilibrium super-saturation? What is the temporal variability of super-saturation in the clouds? How to determine the super-saturation integral for a time step of the simulation?

2.The time evolution of the saturation with respect to water

In this study the saturation ratio is defined as the ratio between the vapor mixing ratio and the the saturation vapor mixing ratio.

In the absence of the ice, the time evolution of the saturation with respect to water is given by:

$dS/dt = A_1W - A_2(dy_L/dt)$;

$dy_L/dt = aS\text{-}b$

where W is vertical speed and y_l is the liquid water mixing ratio with respect to air,

$$a = F\sum_i r_j N_j$$

and

$$b = F\sum_i r_j S_j N_j$$

and A_1, A_2, F are thermodynamic functions. (Squires 1952; Pruppachet et Klett 1997).

The solution to the above equation with initial saturation ratio $\boldsymbol{S_0}$ at time t is given by:

$S_1=(S_0-S_{eq})\exp(-t/\tau)+S_{eq}$ where τ the saturation relaxation time as $\tau = 1/(A_2a)$.

3. The error in the condensation calculations introduced by the bulk model

Kogan and Martin (1994) studied the differences between the condensation treated with the bulk model and with the explicit microphysics model. The error in the condensation calculations introduced by the bulk model, based on the fact that there cannot be super-saturation at the end of a time step, can be explained using figure1.

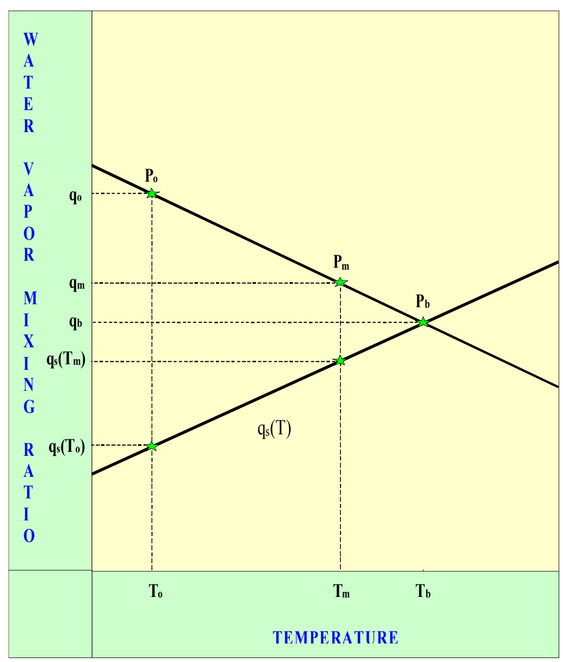


Figure 1. Conceptual model of the moist saturation adjustment process (after McDonald 1963).
Kogan and Martin 1993

This error is proportional to the ratio S_m/S_0 ,

where

$S_m=(q_m-q_s(T_m))/\ q_s(T_m)$

and

$S_0=(q_0-q_s(T_0))/q_s(T_0)$

The error is small in the case of intense convection or high vertical speeds when the difference $q_0-q_s\ (T_0)$ is large.

4. The integral of saturation ratio

If we are using a new variable $f = t/\Delta t$ (the number of time steps existing in the time interval t *)* the time dependence of the saturation becomes:

$$S(f) = (S_0-S_{eq})e^{-f\ \Delta t/\tau} + S_{eq}$$

where the time step interval Δt is known.

The geometrical interpretation of the integral of S = F(f) is represented on the graphs below. The graphs in figure 2 and figure 3 are of S versus f. The y-axis crosses the x-axis at x=0.0 and the separation between vertical grid line represents one time step.

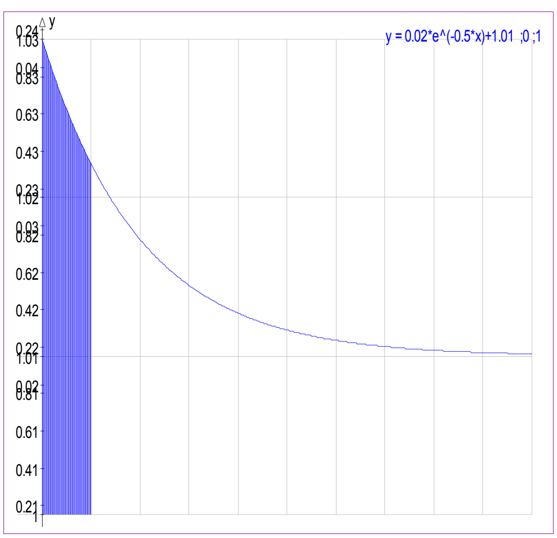


Figure 2 : Saturation ratio S versus number of time steps f for time step < relaxation time

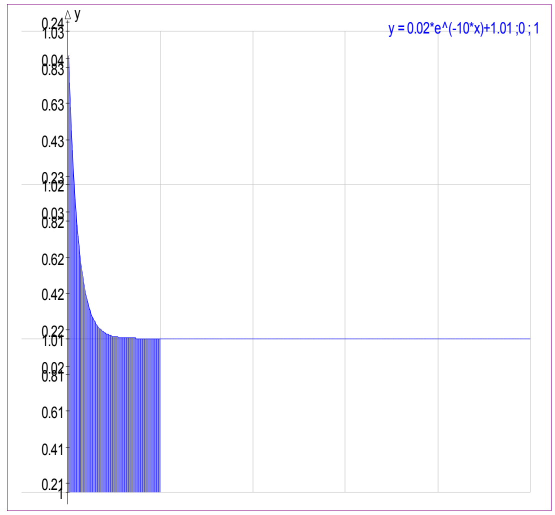


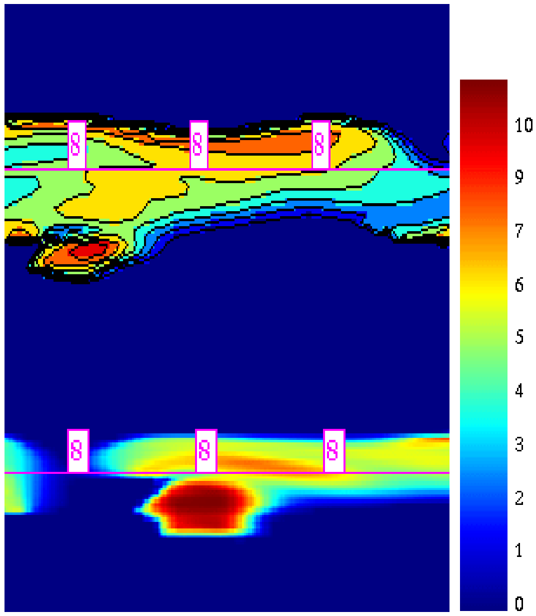
Figure 3 : Saturation ratio S versus number of time steps f for time step > relaxation time

Removal of excess water vapor so that there is no super-saturation at the end of each time step of the model usually gives an over-estimation of the latent heat exchanged with the system during phase changes. The energy balance is not the only one affected by saturation. The activation of condensation nuclei and ice nuclei is very sensitive to the value of super-saturation in clouds.

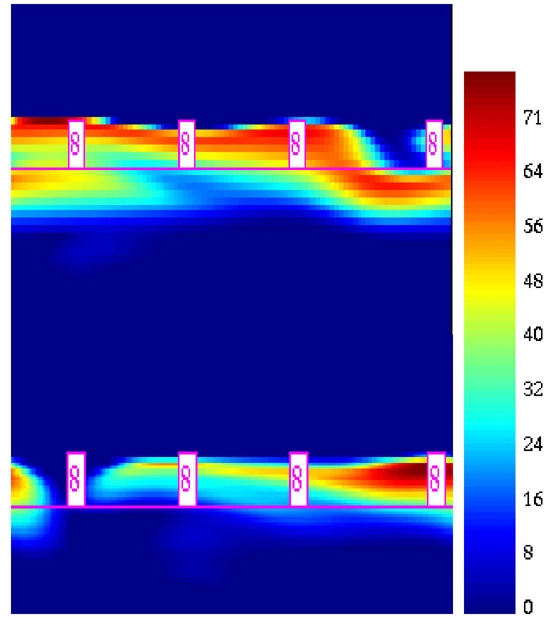
To introduce the temporal variation of saturation into the models is, therefore, necessary. In the work presented two different cases arise: the time step is smaller than the saturation relaxation time and the time step is larger than the saturation relaxation time.

The solution of the differential equations of saturation for warm and cold clouds should be calculated from the integral of saturation in the case where the time step is smaller than the saturation relaxation time. In the case where the time step is longer than the relaxation time, the model should calculate the equilibrium saturation.

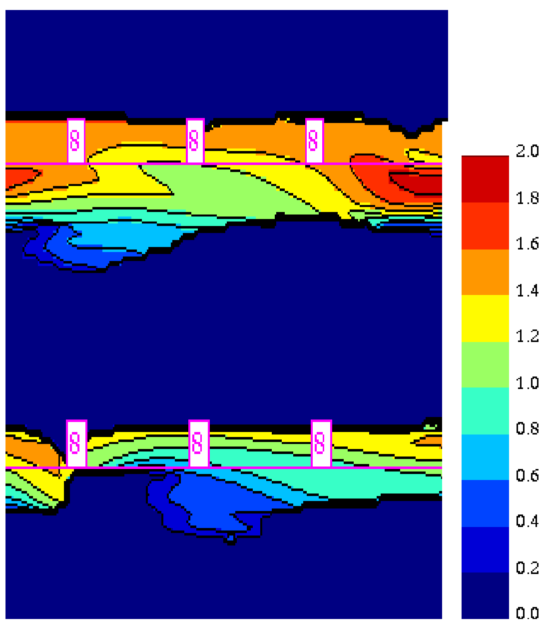
In order to confirm our assumption, we present in our poster some results obtained with the Cloud Resolving Model using the integral of the saturation ratio versus the results given by the same model which cuts the saturation at 100% at the end of each time step.



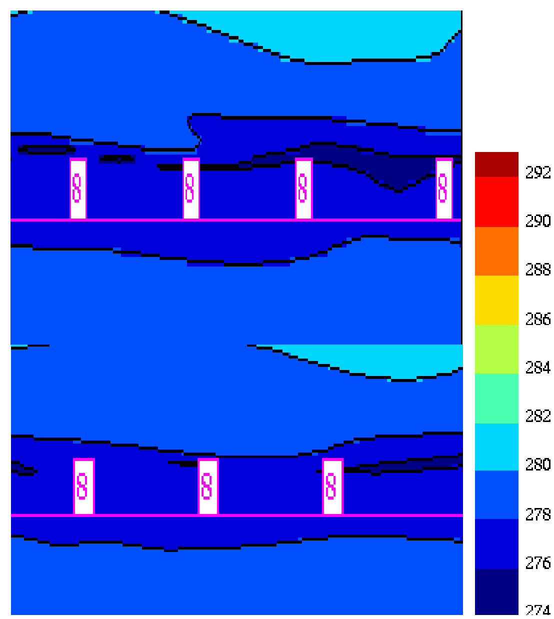
Drops concentration x10^{8} m^{-3}(upper), x10^{7} m^{-3} (lower)



Liquid water contents x10^{-2} (g/kg)



Mean radius µm (upper), x10 µm (lower)



Temperature (K)

Figure 4 : Drops concentration , liquid water contents, mean radius, temperature, for : initial no.aerosol 600 cm^{-3} (upper), initial no.aerosol 150 cm^{-3} (lower), time step 2s, resolution 25 m, and the magenta symbols : pressure x100(mb).

5. Brief description of the Cloud Resolving Model

The 2D/3D cloud resolving model includes the following, fully coupled, parts:

a) The dynamic module, a version of the Cooperative Center for Research (CCRM) mesoscale nonhydrostatic community model dynamics (Laprise et al. 1997; Caya and Laprise 1999) as well as of the Northern Aerosol Regional Climate Model (NARCM) adapted to utilization at fine scale.

b) The Smagorinsky-type subgrid turbulence scheme modified to include stability effects and calculations of turbulent mixing across cloud top (MacVean and Mason 1990).

c) The atmospheric radiation model for short-wave and long-wave radiative transfer through clear, cloudy or partly cloudy air parcels the same as in NARCM but adaped to fine-scale experiments and with cloud characteristics obtained from detailed microphysics scheme.

d) Different microphysical schemes: two-moments microphysics with three hydrometeor categories –cloud liquid water, pristine ice crystals and larger precipitation crystals.

- The conventional one-moment bulk microphysical package with five hydrometeor categories (cloud droplets and cloud ice crystals, raindrops, snowflakes and graupel particles).

- The new bulk parameterization scheme for melting layer (Szyrmer & Zawadzki 1999)

- The detailed microphysics module predicting the evolution of the cloud droplet spectra (Brenguier & Grabowski 1993) in link with the CCN concentration.

- The bulk scheme describing the drizzle category with prediction of two prognostic variables: concentration per unit mass (number mixing ratio) and mass mixing ratio (Khairoutdinov and Kogan 2000).

The model has been successfully tested with spatial resolutions of a few microns (study of air flow and cloud droplet trajectories around the airborne temperature sensor: Szyrmer 1998), of tens of meters (atmospheric melting layer: Papagheorghe 1996, Szyrmer and Zawadzki 1999; summertime Arctic stratus: Szyrmer et al. 1999), and hundred(s) meters (warm rain formation: Szyrmer 1998, supercooled clouds in the presence of snow: Zawadzki et al. 2000).

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