EGU 2011

Development of a detailed ice melting scheme for bin microphysics in a 3D cloud model

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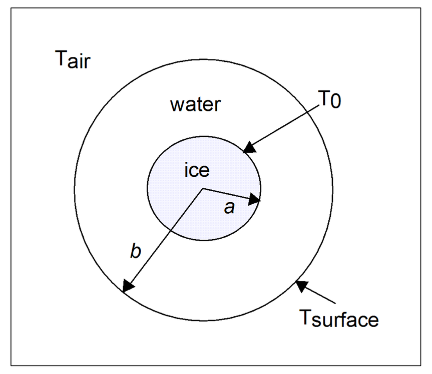
Objective: Improving the representation of ice particles for the interpretation of radar observations and to better describe the influence of the ice phase on rain formation.

Development of a melting parameterization based on the theory of Mason (1956) and the lab experiments of Rasmussen and Pruppacher (1982)



Assumptions:

1- the overall radius b of the melting particle remains constant

2- the melting ice particle is spherical and remains so at all times

3- the ice core remains spherical and concentric with the outer boundary of the melting particle at all times

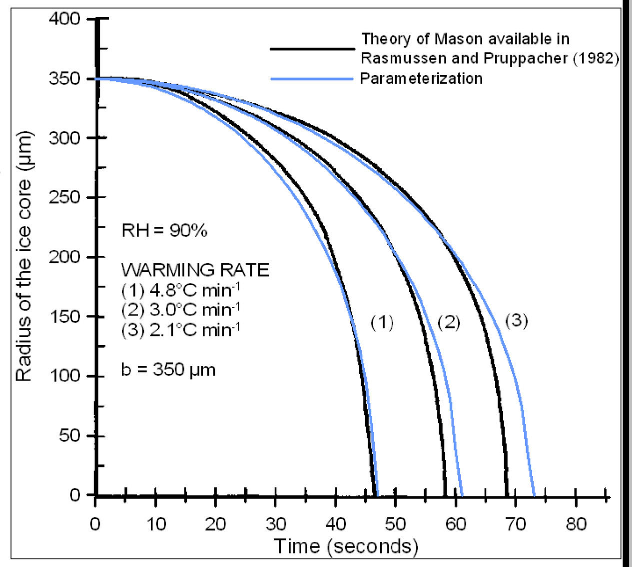
4- internal circulation in the thin melt water layer is neglected

Parameterization:

$$\frac{dm_i}{dt} = [a(T) \cdot RH + b(T)] \cdot e_{ice}^{1/3}$$

with:

- dm_i/dt: melting rate (g s^{-1})
- e_{ice} : ice mass in crystal (g)
- RH: relative humidity of the air
- a(T),b(T): polynomial functions depending on the temperature



1- The melting rate is a function of T and RH (Rasmussen and Heymsfield,1987)

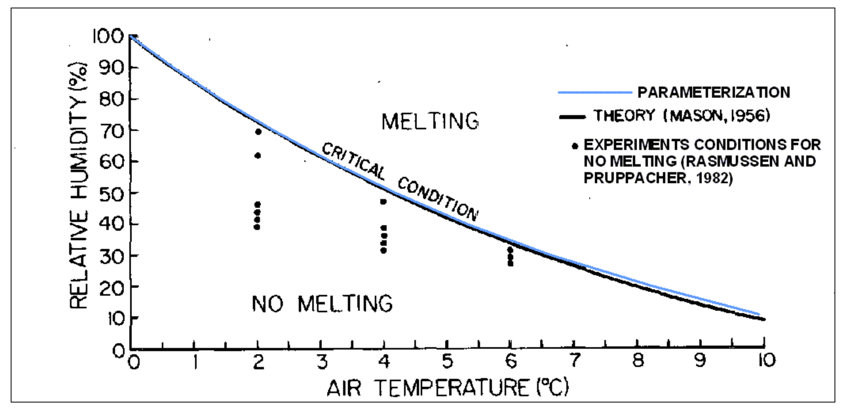
2- Various tests regarding the influence of T and RH have been performed and showed that the parameterized time rates of melting deviate less than 10% from those in Rasmussen and Pruppacher (1982).

Critical condition for the onset of melting

Parameterization:

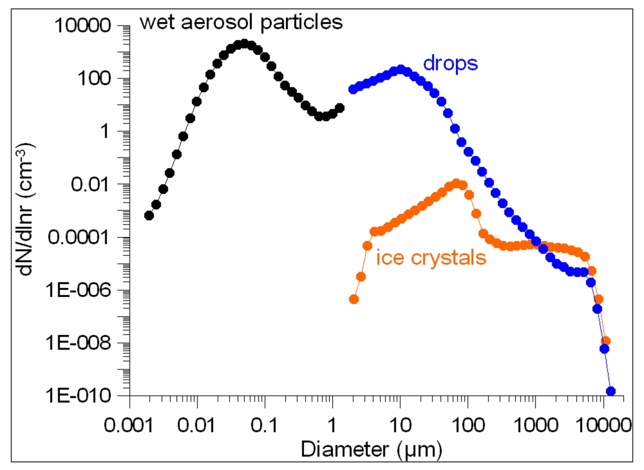
- Based on laboratory experiments of Rasmussen and Pruppacher (1982):

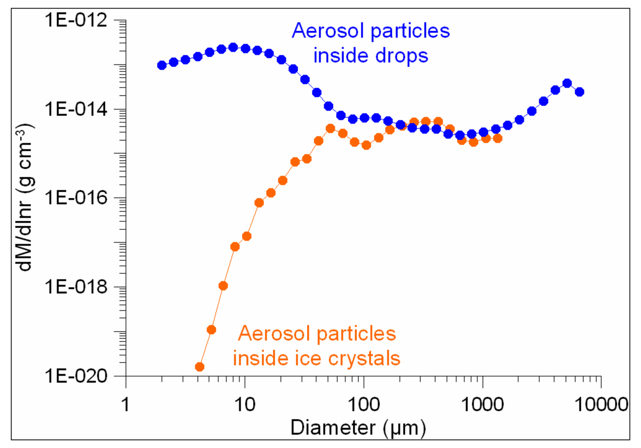
$$T_{critical} = 285.64 - 26.07RH + 27.23RH^2 - 19.86RH^3 + 6.23RH^4$$



The parameterized critical conditions are the same than the observations.

DESCAM (Detailed scavenging model, Flossmann and Wobrock, 2010) coupled with the 3D meso-scale dynamical model (Clark et al., 1996)





Warm microphysical processes :
aerosol particle growth and activation, droplet de-activation, growth of drops by condensation and collision-coalescence, break up.

Cold microphysical processes :
homogeneous and heterogeneous nucleation, growth by vapor deposition, riming.

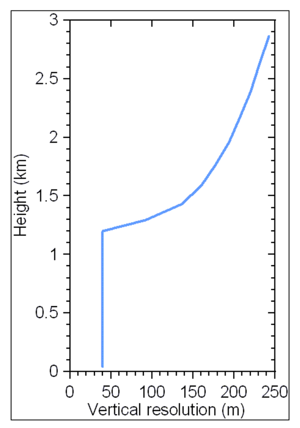
New microphysical processes :
aggregation, continuous melting and collision between droplets and melting hydrometeors.

f_d : drop number
f_i : ice crystal number
f_{AP} : wet aerosol particle number
$g_{AP,d}$: aerosol mass inside drops
$g_{AP,i}$: aerosol mass inside ice crystals
g_{wir} : water ice mass ratio of ice crystals

Set-up of the idealized case study

Domain :

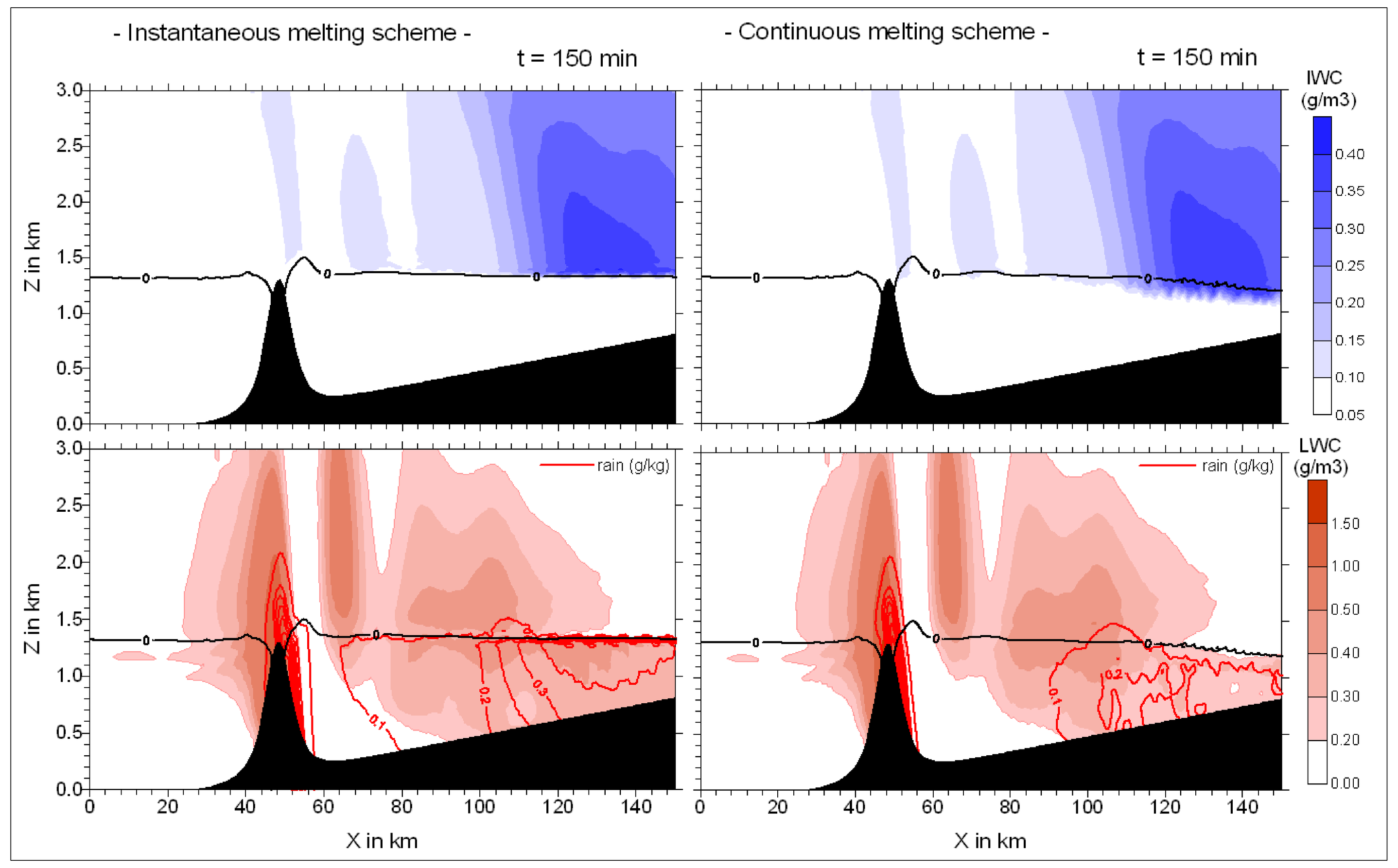
- 150 × 73 × 20 km^3
- dx = dy = 750 m
- variable grid in z



- winter sounding of Zängl et al. (2010)
- idealized topography : bell-shape mountain and continuous slope.

Objective :

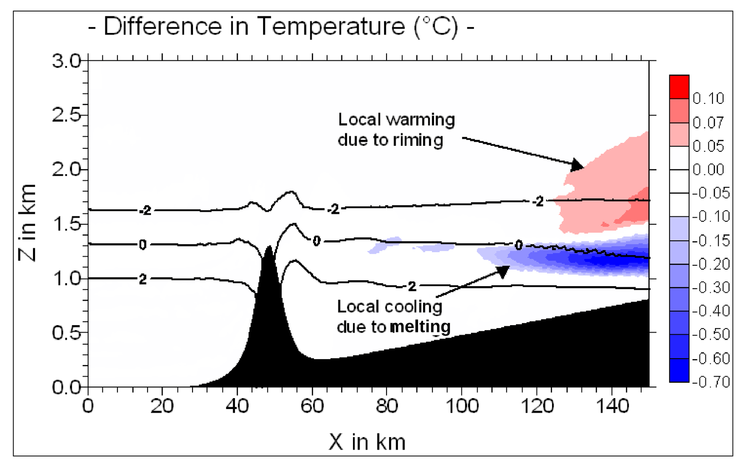
- simulating the ice phase in a stratiform situation to well observe the melting layer



Simulation results

- ice phase is present in areas with positive temperatures
- the melting layer has a depth of about 200 m
- the 0°C altitude level falls where the melting process is more effective
- in both cases, rain is caused mainly by melting, while the pattern of the rainwater content is quite different; melting occurs over a layer of finite depth below the freezing level in the detailed scheme as it does in the real atmosphere.

Local variation



- inclusion of the detailed melting scheme causes a stronger latent cooling; the local variation of the temperature causes the descent of the 0°C level
- warming by latent heat release caused by riming processes has a minor effect

→ latent warming and cooling slightly modify the vertical movements.

Conclusions

- a detailed melting scheme was introduced in the DESCAM 3D model
- the melting process influences the spatial distribution of the rainwater content
- the latent heat consumed during melting cools the local environment and slightly modifies the vertical motion
- the intensity of the rainwater will be examined in further studies because it seems lower in the detailed melting scheme than in the instantaneous one
- the study of the melting layer will enable to examine the evolution of radar bright band observations

Acknowledgement :

The calculations for this study have been done on computer facilities of IDRIS, CNRS at Orsay and CINES in Montpellier, under the project 940180. The authors acknowledge with gratitude the hours of computer time and the support provided.

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