THE ROLE AND IMPORTANCE OF ICE PHASE IN SEVERE STORMS

Franco Prodi 1,2

1 *Institute of Atmospheric Sciences and Climate, ISAC-CNR, Via Gobetti 101, 40129 Bologna, Italy*
f.prodi@isac.cnr.it
and
2 *Department of Physics, University of Ferrara, Ferrara, Italy*

I. INTRODUCTION

Among the microphysical processes of precipitation formation the accretion of supercooled droplets on an ice embryo to produce graupels and hailstones is of paramount importance in severe storms. Though the accretion process has a relevance in itself, it has also great consequences in the numerical modelling of severe storms since their dynamic characteristics (e.g. updraft intensity) are determined by the accretion parameters (e.g. density of the deposit, surface roughness). Therefore there is the need to review the results obtained in the microphysical investigation of ice accretion in order to verify that they are correctly introduced in numerical models of severe storms.

II. MICROPHYSICAL INVESTIGATIONS OF HAIL GROWTH

In hailstone growth, from the original ice crystal or large supercooled drop, various parts of physics are involved: fluid dynamics in aerodynamic capture of super-cooled droplets, thermodynamics in heat fluxes, nucleation theory and solid state physics in size and orientation of grains of the polycrystalline material (Levi and Prodi, 1978), in contaminant segregation along the grain boundaries (Prodi, 1975), in ageing of the accreted deposit (Prodi and Levi, 1980), in morphology of the deposit itself (air bubble internal structure, surface roughness).

The important specific characteristic of the hailstone is that, in contrast with liquid hydrometeors, it can keep a record of the growth conditions in their time evolution, with a certain correspondence with the radial features. So the stone itself can be considered as a natural sounding of the storm itself. All combined efforts in the cold room or cold wind tunnels to generate and study artificial hailstones are produced with the ultimate purpose of defining criteria to interpret the features found in natural hailstones in terms of the growth conditions.

One of the main variable property is density, which in turn has important effects on the physical behaviour of the accreted body, determining its mechanical strength, its ability to soak up super-cooled water, its terminal velocity and dynamics when the object is in free fall (in combination with the surface roughness). (Macklin, 1962, Prodi, 1970, Prodi et al 1986a)

A technique based on densitomectric analysis of contact x-ray micrographs of hailstone slices, developed by Prodi (1970) has been systematically used since (Prodi et al 1986a)

III. MICROPHYSICAL PARAMETERISATION IN MODELS OF SEVERE STORMS

.

A review of parameterisation of microphysical processes for atmospheric numerical models (Drofa, 2003) shows that the accretion processes for graupel and hail is rather roughly introduced.

Moreover one important evidence (Pflaum, 1980, 1984, Prodi et al, 1986b) is the possibility of two-stage growth for hailstone growth, which at least in part replaces the Browning's view of one stage only. Actually certain hailstone features (cuspidated lobes and radial lines of air bubbles) can be explained only by a two-stage growth. When the two-stage growth is effective, during the first stage a much less intense updraft is required, for the lower density of the deposit on one side, and for the higher drag coefficient (due to higher surface roughness) on the other. Current parameterisations in numerical models of severe storms do not consider such possibilities and this might be a reason of the poor performances of many of them.

IV. AKNOWLEDGMENTS

The author would like to thank Oxana Drofa, ISAC.CNR, for help in review of numerical models of deep convection and microphysical parameterisation in them.

V. REFERENCES

Drofa O. V., 2003: The parameterization of microphysical processes for atmospheric numerical models. *Il Nuovo Cimento, 26 C n.3* 233– 262

Levi L, Prodi F. 1978: Crystal size in ice grown by droplet accretion. *J.Atm.Sci.., 35* 2181– 2189

Macklin W.C., 1962: The density and structure of ice formed by accretion. *Quart.J.R.Met.Soc., 88* 30– 50

Pflaum J. C, 1980: Hail formation via microphysical recycling . J.Atmos.Sci, 37 160– 173

Pflaum J. C., 1984: New clues for decoding hailstone structure. *Bull.Am.Met.Soc., 65* 583– 593

Prodi F., 1970: Measurements of local density in artificial and natural hailstones *J.Appl.Met.*, 9 903-910.

Prodi F., 1975 Chlorides in natural and artificial hailstones. *J._Appl.Met., 9* 903– 910

Prodi F., Levi L.., 1980: Aging of accreted ice. J.Atmos.Sci., 37 1375– 1384

Prodi F., Levi L., Pederzoli, P.: 1986a: The density of accreted ice. *Qquart.J.Roy.Met.Soc, 112* 1081– 1090

Prodi F., Santachiara G., Franzini A., 1986b: Properties of ice accreted in two-stage growth. Quart.J.Roy.Met.Soc, 112 1057– 1080