Влияние на концентрацията на ледените кристали върху валежите от конвективни облаци – числено изследване

The impact of ice crystal concentration on the precipitation of convective clouds – numerical study

Савка Петрова и Румяна Мицева
СУ „Св. Климент Охридски“
Физически факултет
Катедра „Метеорология и геофизика“

* **AIM**: The study of the impact of ice crystal concentration on the precipitation amount

* **Used**: 1,5-dimensional numerical cloud model with parameterization of microphysical processes, created by R.Mitzeva et all.

* **Numerical simulations of three cloud cases**, using three different parameterizations for ice crystal formation (**Fletcher, Hallet-Mossop and Hobs**) were carried out.

* Analyses of the **impact of ice crystal** concentration (obtained at different processes of ice formation) on the **precipitation amount**.

Model description

Cloud structure
Convective clouds are composed of :
- active mass (successive ascending spherical thermals)
- non-active cloud region (thermals, that have previously risen and stopped at the level, where their velocity is zero).

Cloud microphysics - bulk microphysical parameterizations with 5 classes of water substance
(water vapor, cloud water - Sc, rain - Sp, cloud ice - Scf and graupel -Spf)

Parameterizations of ice crystal formation

Primary nucleation

Fletcher approximation

$$N_i(T) = A\exp[\beta\Delta T]$$

Secondary nucleation

Hallet-Mossop process

$$N_i(T) = A\exp[\beta\Delta T]N_{HM}$$

T= (-2.25°C to -11°C)

N_{HM} =1000

Hobs parameterization

$$N_i(T) = A\exp[\beta\Delta T]N_{HB}$$

N_{HB} at different in-cloud temperatures

Tepmerature	N_{HB}
-0.75	1.00E+04
-2.25	1.00E+04
-4	5.00E+03
-5.75	2.00E+03
-7.25	1.00E+03
-9	7.00E+02
-11	3.00E+02
-13	2.00E+02
-15	7.00E+01
-16.75	3.00E+01
-18.25	2.00E+01
-19.75	1.00E+01
-21.25	6.00E+00
-22.75	3.00E+00
-24.25	2.00E+00
-25.25	1.00E+00

Ni – the number of ice crystals per m^{-3} ,

ΔT = T-273.15 is the suppercooling,

parameters

A =0.01 m^{-3}

β =0.6 K^{-1}

Assume as in Katherine et al., (2001) that at temperatures lower than -25°C the number of ice crystals is constant based on some field measurements (e.g., Hobbs, 1969) .

Ni (T) – number of ice crystals per m^{-3}

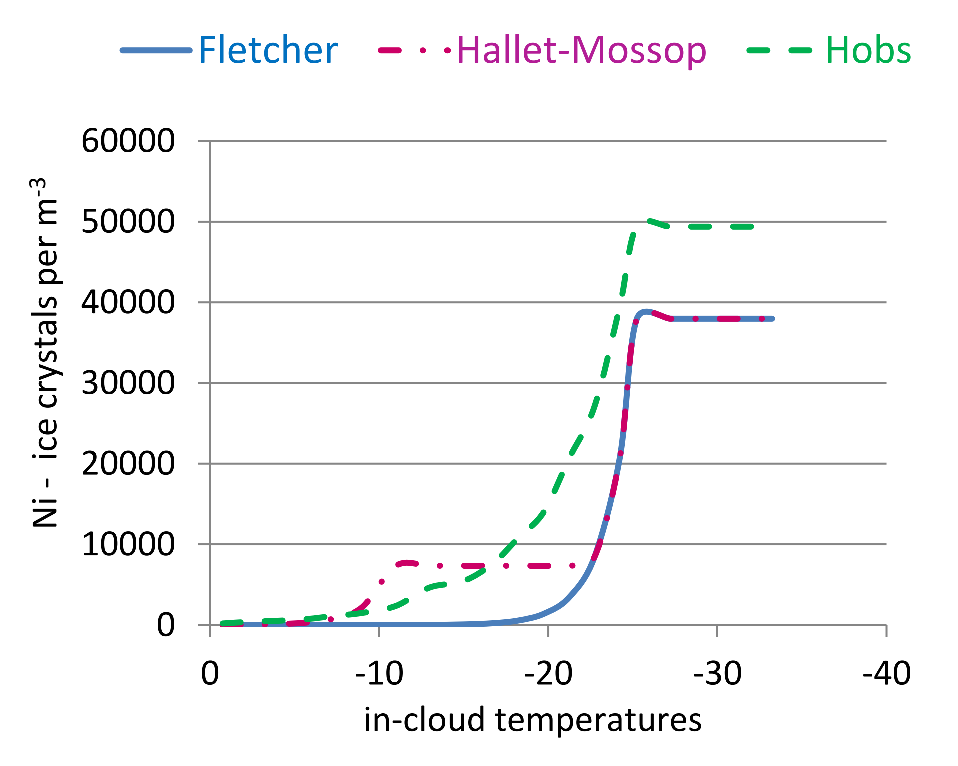
Primary nucleation

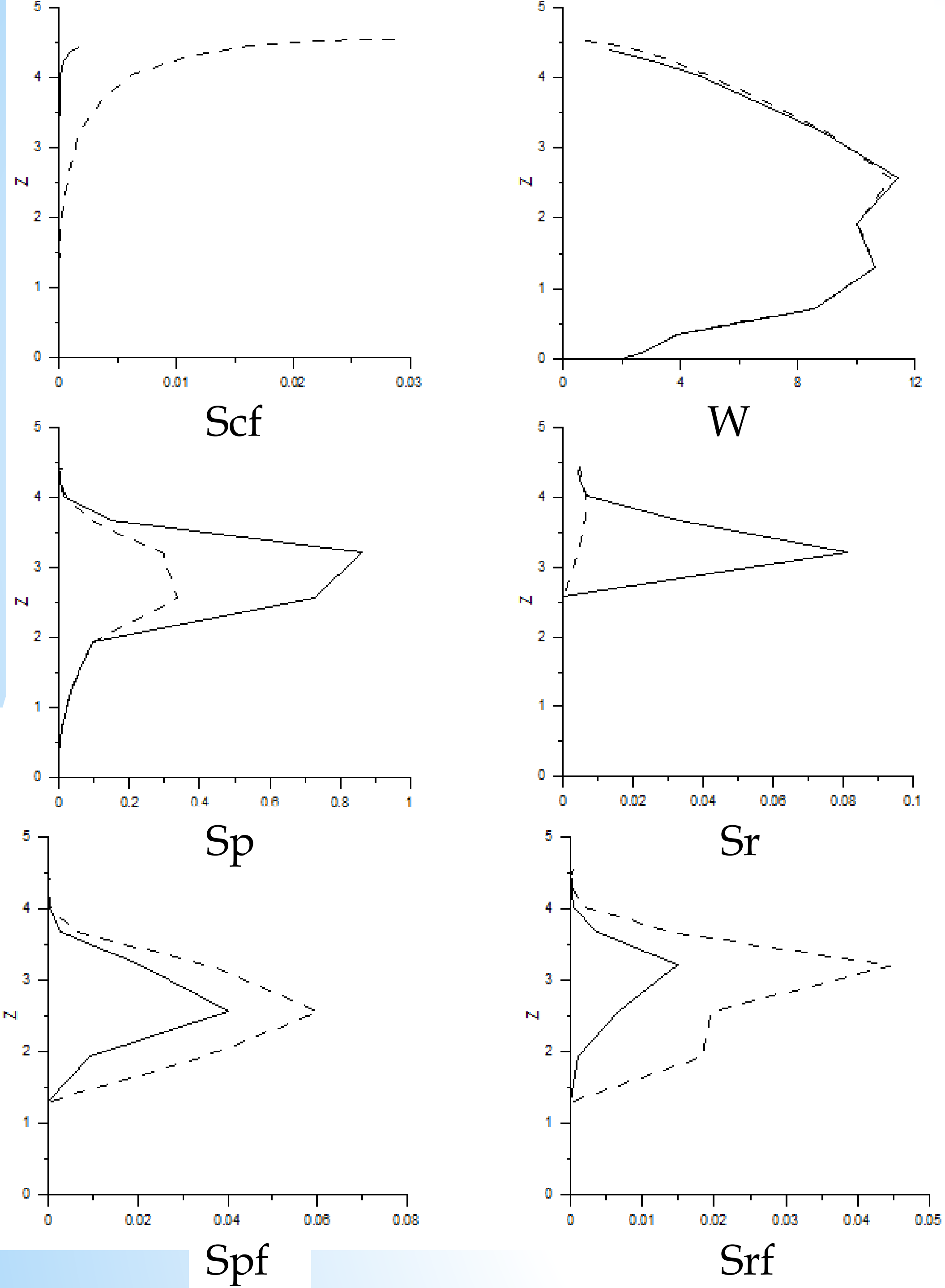
Fletcher approximation

Secondary nucleation

Hallet-Mossop process

Hobs parameterization





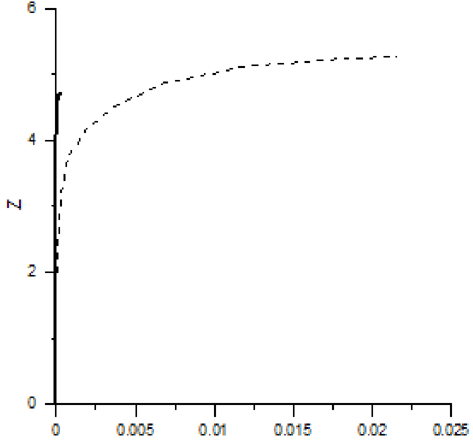
Cloud_1

3th thermal

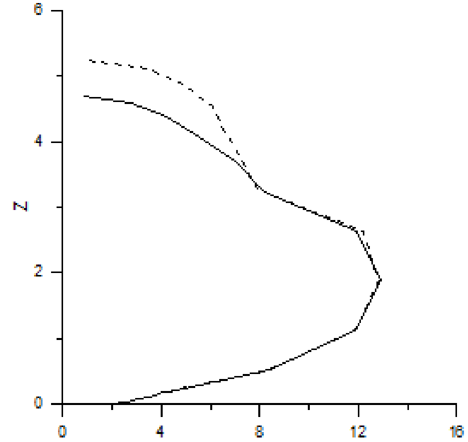
___Flether

- - - Hobs

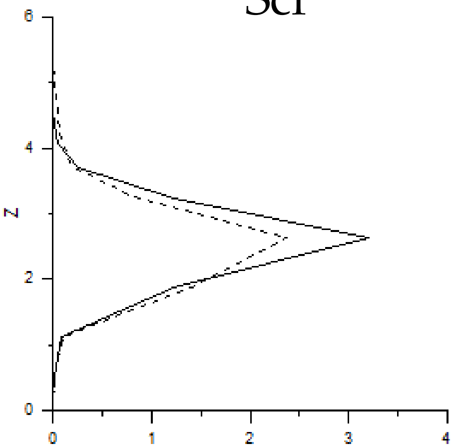
Spf (gm $^{-3}$) – ice crystals content
Sp (gm $^{-3}$) – precipitating drops content ,
Spf (gm $^{-3}$) – graupel content ,
Sr (gm $^{-3}$) – rain fallout ,
Srf (gm $^{-3}$) – graupel fallout ,
W (m/s) – updraft velocity
as a function of the height Z (km)



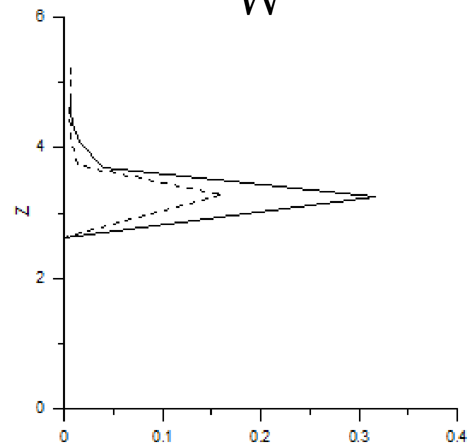
Scf



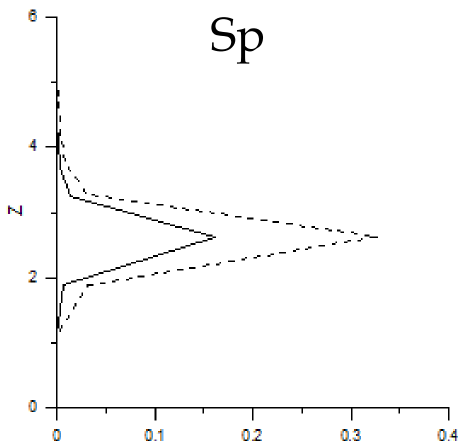
W



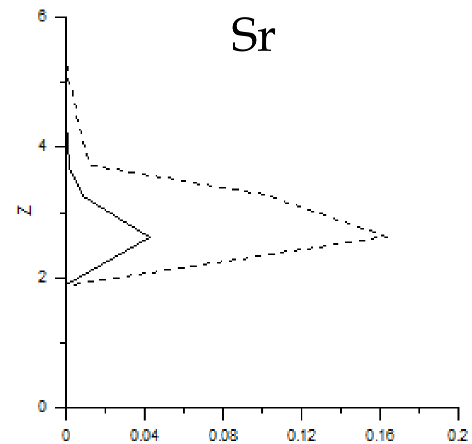
Sp



Sr



Spf



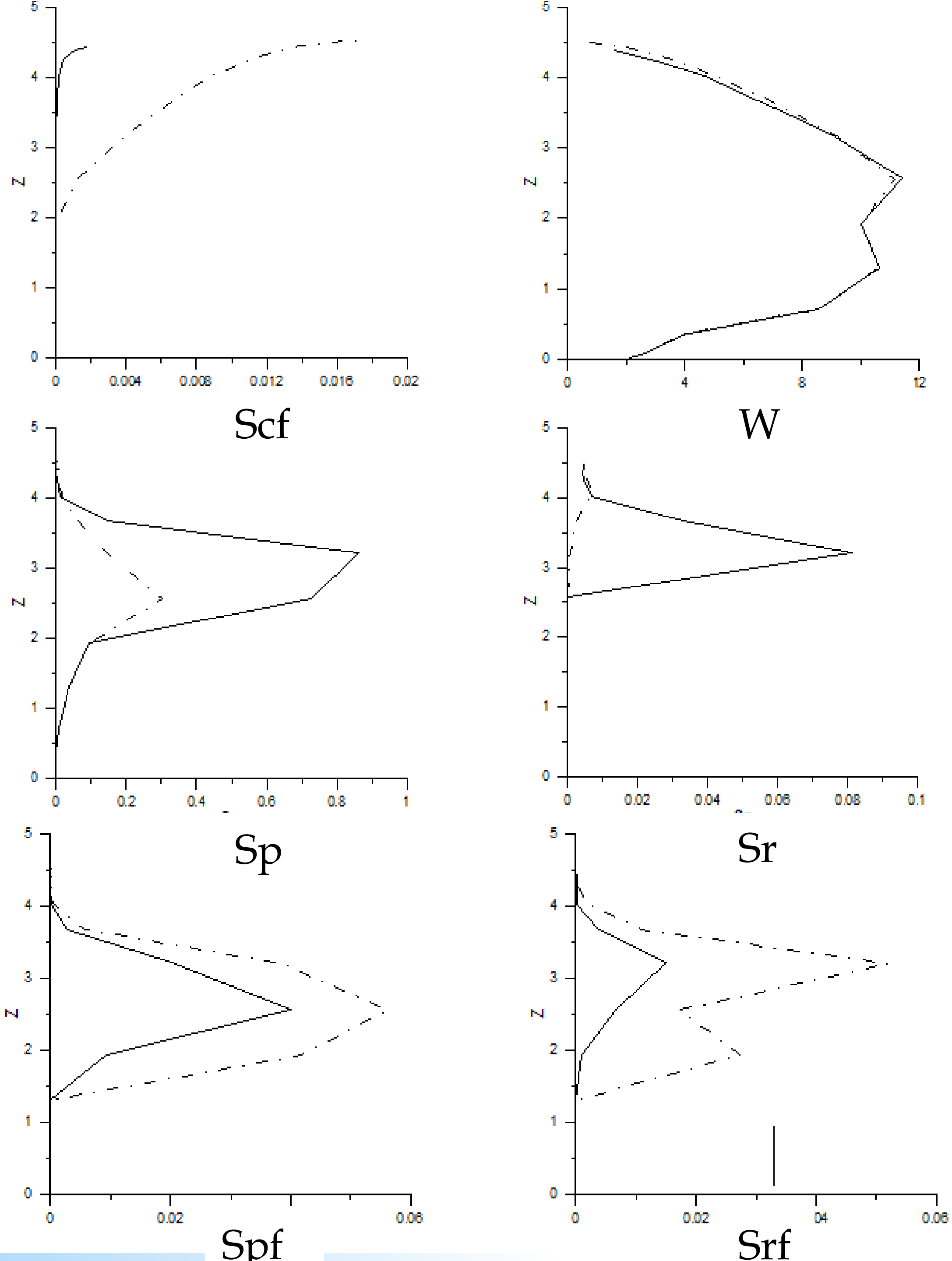
Srf

Cloud_2

5th thermal

___ Flether
- - - Hobs

Scf (gm $^{-3}$) – ice crystals content
Sp (gm $^{-3}$) – precipitating drops content ,
Spf (gm $^{-3}$) – graupel content ,
Sr (gm $^{-3}$) – rain fallout ,
Srf (gm $^{-3}$) – graupel fallout ,
W (m/s) – updraft velocity
as a function of the height Z (km)



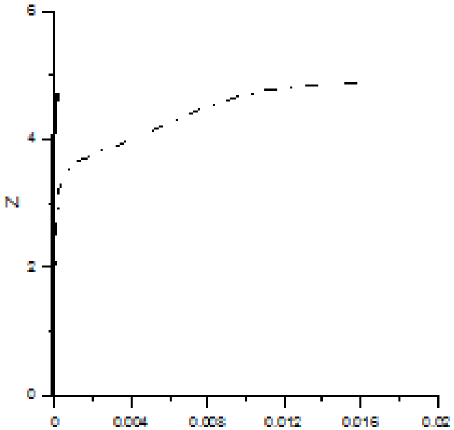
Cloud_1

3th thermal

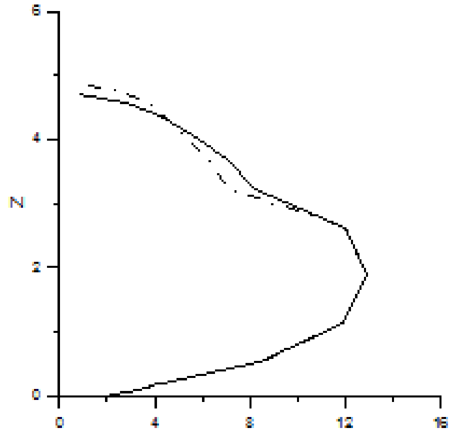
_____Flether

_ . _ . HM

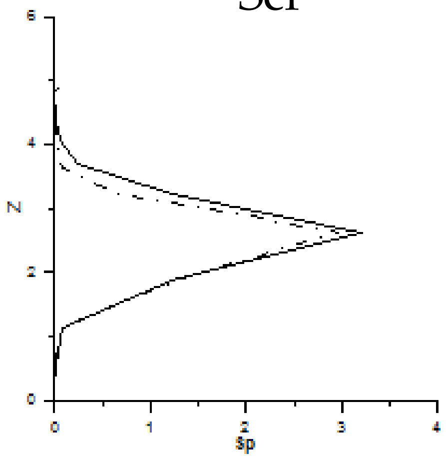
Scf (gm $^{-3}$) – ice crystals content
Sp (gm $^{-3}$) – precipitating drops content ,
Spf (gm $^{-3}$) – graupel content ,
Sr (gm $^{-3}$) – rain fallout ,
Srf (gm $^{-3}$) – graupel fallout ,
W (m/s) – updraft velocity
as a function of the height Z (km)



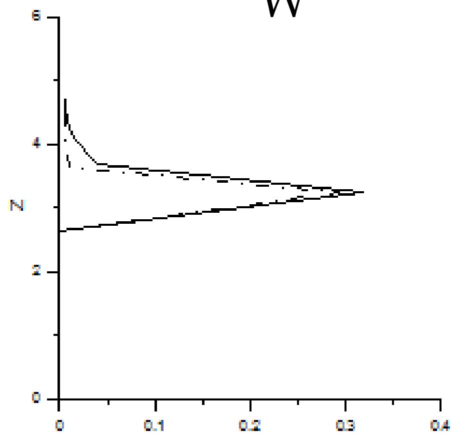
Scf



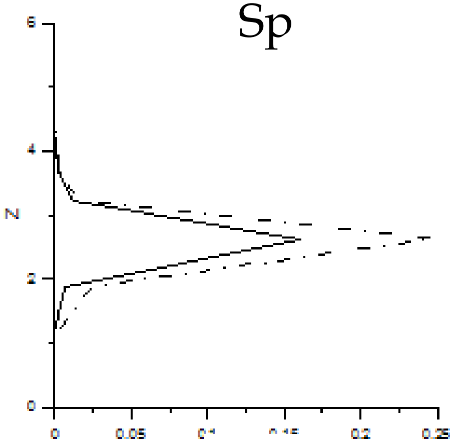
W



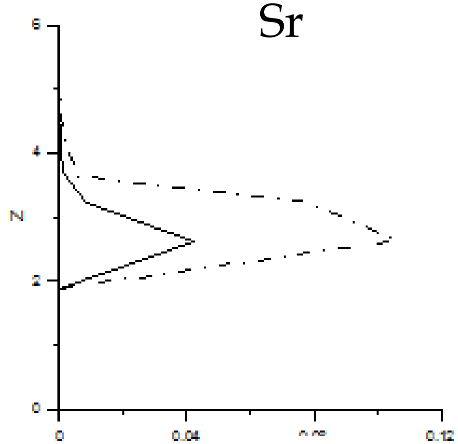
Sp



Sr



Spf



Srf

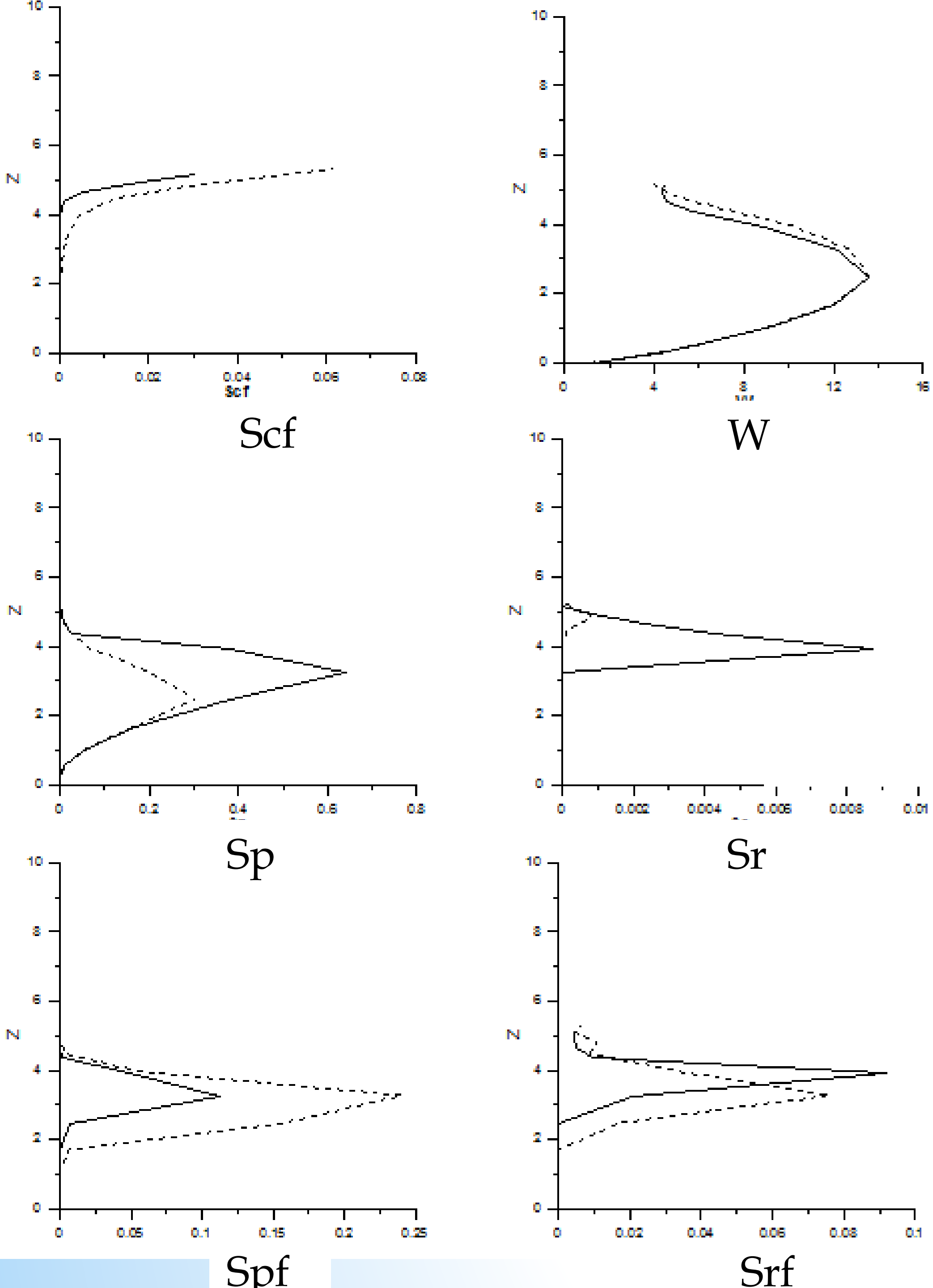
Cloud_2

5th thermal

____Flether

_ . _ . HM

Scf (gm $^{-3}$) – ice crystals content
Sp (gm $^{-3}$) – precipitating drops content ,
Spf (gm $^{-3}$) – graupel content ,
Sr (gm $^{-3}$) – rain fallout ,
Srf (gm $^{-3}$) – graupel fallout ,
W (m/s) – updraft velocity
as a function of the height Z (km)



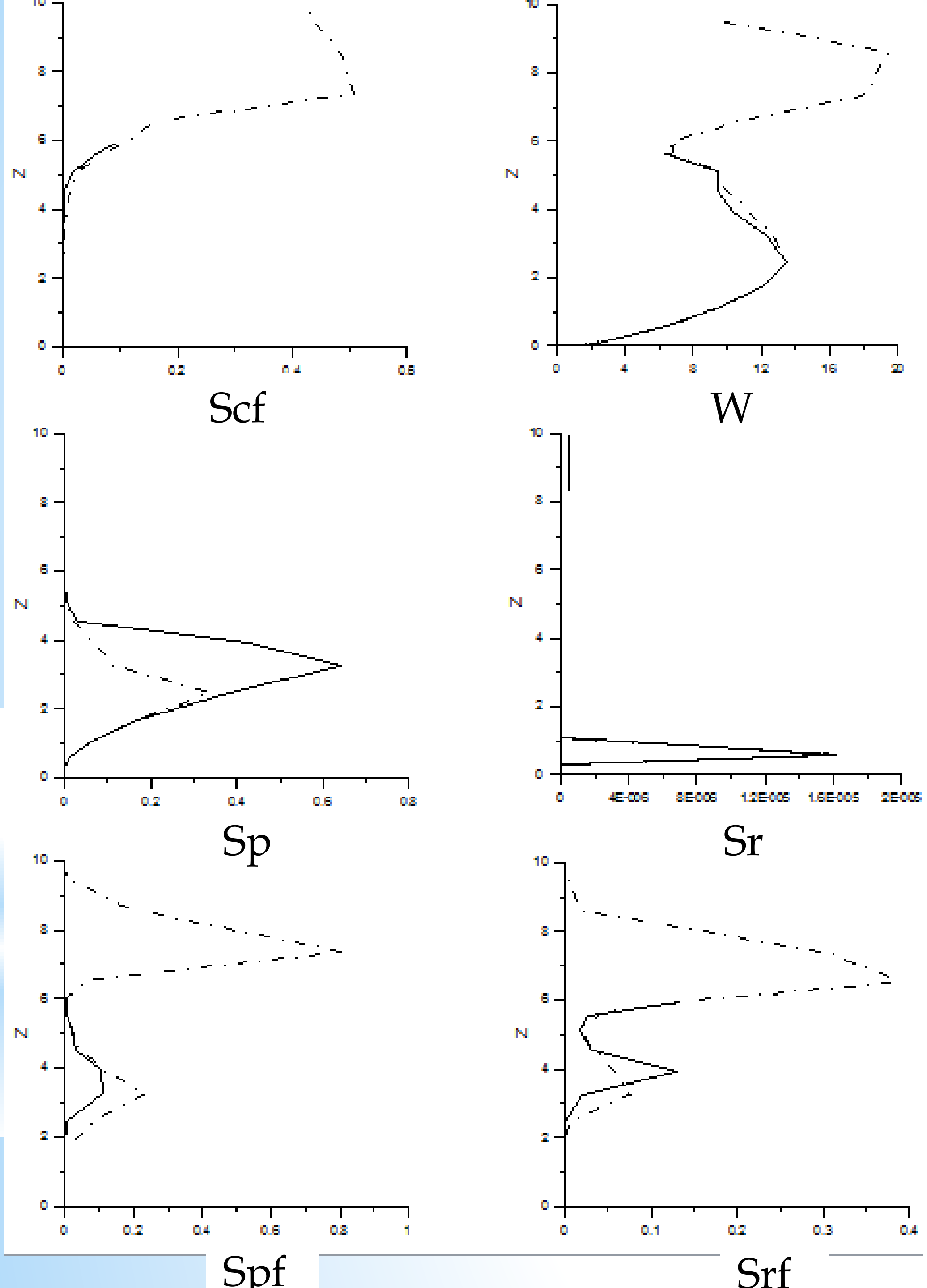
Cloud_3

2th thermal

___Flether

- - - Hobs

Spf (gm $^{-3}$) – ice crystals content
Sp (gm $^{-3}$) – precipitating drops content ,
Spf (gm $^{-3}$) – graupel content ,
Sr (gm $^{-3}$) – rain fallout ,
Srf (gm $^{-3}$) – graupel fallout ,
W (m/s) – updraft velocity
as a function of the height Z (km)



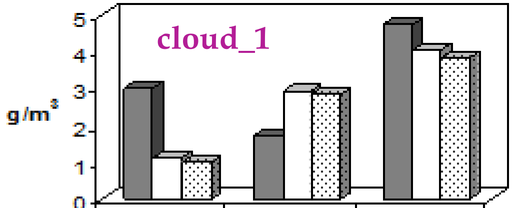
Cloud_3

3th thermal

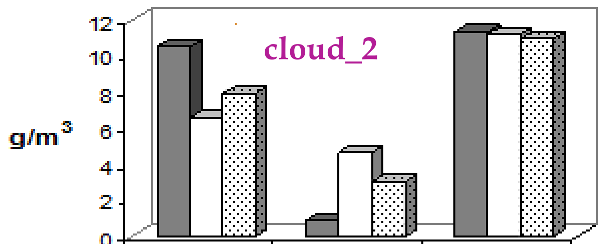
_____Flether

_ . _ . HM

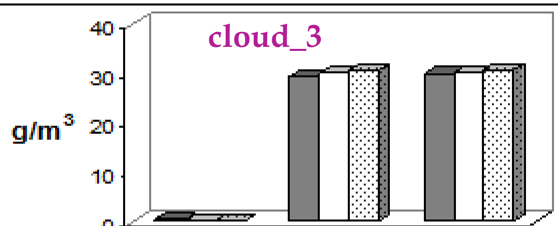
Scf (gm $^{-3}$) – ice crystals content
Sp (gm $^{-3}$) – precipitating drops content ,
Spf (gm $^{-3}$) – graupel content ,
Sr (gm $^{-3}$) – rain fallout ,
Srf (gm $^{-3}$) – graupel fallout ,
W (m/s) – updraft velocity
as a function of the height Z (km)



	sumSr	sumSrf	sumSr + sumSrf
Fletcher	3	1.73	4.73
Hobs	1.12	2.93	4.05
Hallet -Mossop	0.98	2.86	3.84



	sumSr	sumSrf	sumSr + sumSrf
Fletcher	10.5	0.81	11.31
Hobs	6.57	4.65	11.22
Hallet -Mossop	7.92	3.01	10.93



	sumSr	sumSrf	sumSr + sumSrf
Fletcher	0.38	29.4	29.78
Hobs	0.07	30	30.07
Hallet -Mossop	0.08	30.5	30.58

For the three simulated cases there is decrease in the liquid fallout and increase in the solid fallout when the secondary (Hallet- Mossop or Hobs parametrisation) nucleation is included in comparison with liquid/solid fallout using only primary (Fletcher) nucleation.

There is decrease in the precipitation fallout in two simulated clouds (cloud_1 and cloud_2) when the secondary nucleation is included, however in the simulated cloud_3 there is increase in the total fallout.

The model simulations are carried out from cloud base height to the height of zero updraft velocity, i.e. the model does not give information on precipitation at the ground. Part (probably all) of the solid fallout may melt during descent to the ground.

When the secondary nucleation is included, it influences the dynamics of the three simulated clouds in different ways

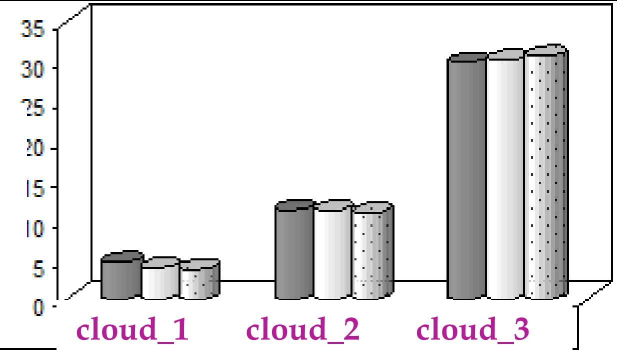
1. Increase of the updraft velocity (Wmax) and decrease of cloud top height (Ztop) for cloud_1
2. Decrease of the updraft velocity (Wmax) and increase of cloud top height (Ztop) for cloud_2
3. Increase of both updraft velocity (Wmax) and cloud top height (Ztop) on cloud_3

The analyses reveal that the change of cloud dynamics is a result of the latent heat of freezing by the formation of solid particles (ice and grapel).

Only in the simulated cloud_3 there is increase in the total fallout , where is observed so called positive dynamical effect (increase of the updraft velocity and cloud top height) when the secondary (Hallet- Mossop or Hobs parametrisation) nucleation is included

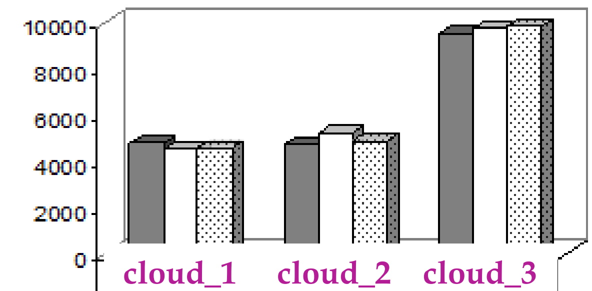
The impact of ice nucleation (primary and secondary) depends on the powerful of simulated cloud: there is increase in the precipitation of most powerful cloud (cloud_3) and decrease in the other two clouds (cloud_1 and cloud_2) when the secondary nucleation is also included in comparison with precipitation using only primary (Fletcher) nucleation .

Total fallout (gm^{-3})



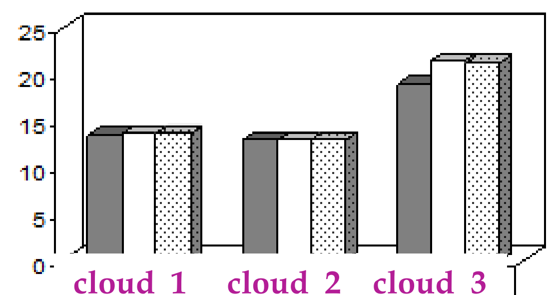
	cloud_1	cloud_2	cloud_3
Fletcher	4.73	11.31	29.78
Hobs	4.05	11.22	30.07
Hallet -Mossop	3.84	10.93	30.58

Ztop (m)



	cloud_1	cloud_2	cloud_3
Fletcher	4796	4715	9512
Hobs	4541	5260	9731
Hallet -Mossop	4576	4871	9829

Wmax (ms^{-1})



	cloud_1	cloud_2	cloud_3
Fletcher	13.53	12.92	18.83
Hobs	13.65	12.84	21.42
Hallet -Mossop	13.65	12.9	21.22

The main results:

1. The impact of ice nucleation (primary and secondary) depends on the powerful of simulated cloud: there is increase in the precipitation of most powerful cloud (cloud_3) and decrease in the other two clouds (cloud_1 and cloud_2) when the secondary (Hallet- Mossop or Hobs parameterization) nucleation is also included.

2. Precipitation starts earlier and at lower levels in the three simulated clouds when secondary (Hallet–Mossop or Hobs) nucleation is included in comparison with precipitation using only primary (Fletcher) nucleation.

3. The maximum updraught velocity and the cloud top height in the three simulated cloud cases by the three different parameterizations do not differ significantly. However only in the simulated cloud "cloud_3 " there is a huge increase in the updraft velocity and cloud top height in the early stage of cloud development when Hallet-Mossop parametrisation is included.

Thank you for your attention!

Funded by Sofia University Research Science Fund project 80-10-70/25.04.2023