Virtual Institute
Meeting 5-6 May 2008

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with: Amit Teller, Karin Ardon and Eli Ganor

WP M2 Cloud modelling

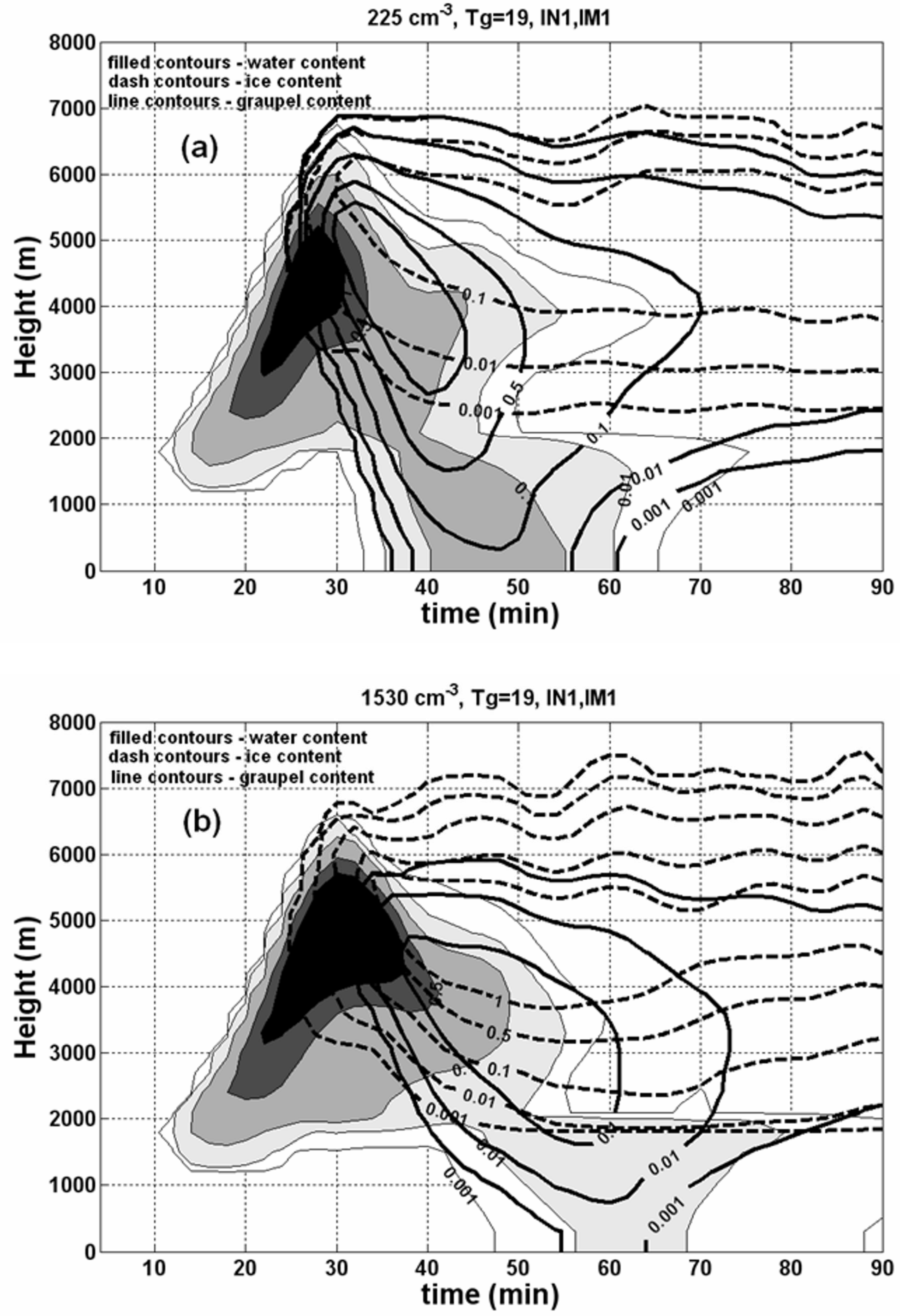
The WMO/IUGG
INTERNATIONAL AEROSOL PRECIPITATION SCIENCE
ASSESSMENT GROUP
(IAPSAG)

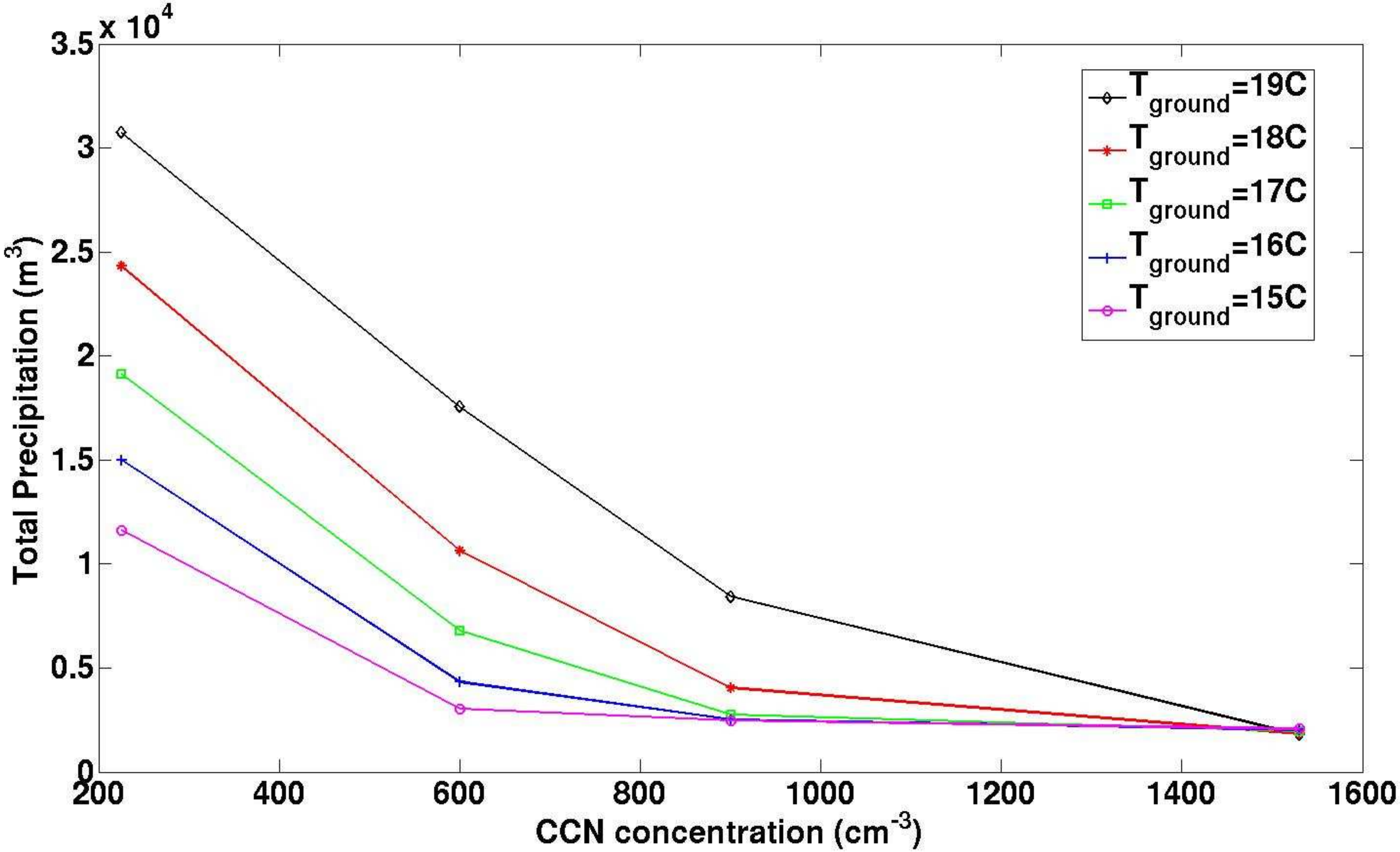
Aerosol Pollution Impact on Precipitation:
A Scientific Review

Zev Levin, Chairman
William Cotton, Vice Chairman

1. Factorial method-identifying the relative contribution to precipitation of CCN, IN and environmental conditions.

2. Ice nucleation measurements, contributing to data-bank for better parameterization of ice formation in clouds.

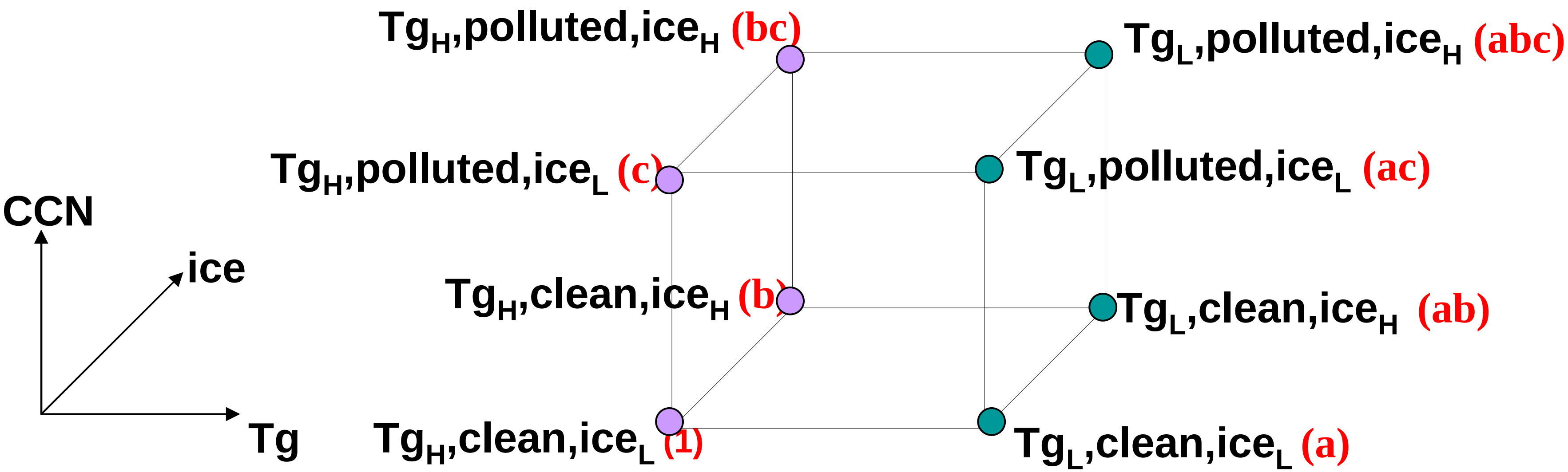

225 cm-3, Tg=19, IN1,IM1
filled contours - water content
dash contours - ice content
line contours - graupel content
(a)
Height (m)
time (min)
0.1
0.01
0.001
0.5
0.1
0.01
0.001
0.001
1530 cm-3, Tg=19, IN1,IM1
filled contours - water content
dash contours - ice content
line contours - graupel content
(b)
Height (m)
time (min)
1
0.5
0.1
0.01
0.001
0.01
0.001
0.01
0.001



x 10^4
3.5
3
2.5
2
1.5
1
0.5
0
Total Precipitation (m^3)
200
400
600
800
1000
1200
1400
1600
CCN concentration (cm^-3)
T_ground=19C
T_ground=18C
T_ground=17C
T_ground=16C
T_ground=15C

Experimental setup – The full factorial experiment

The contribution of each factor (Temp., IN, CCN)



$$\mathrm{Eff}_{Tg} = \frac{1}{4}\cdot(a + ab + ac + abc) - \frac{1}{4}\cdot(b + c + bc + (1))$$

Effect of changing temp.

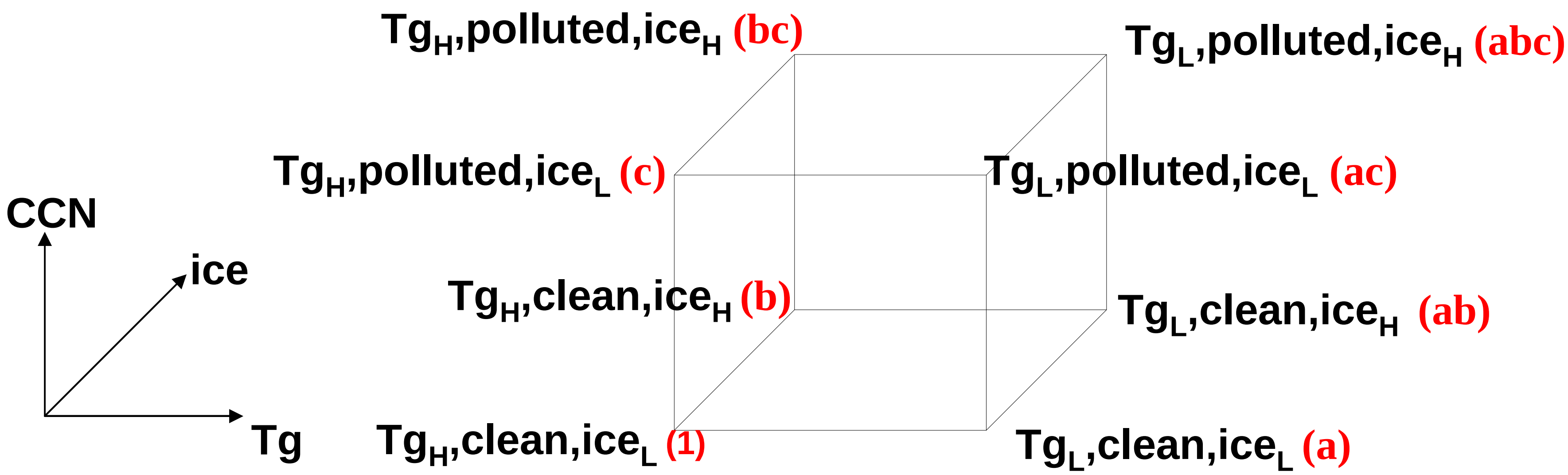
$$\mathrm{Eff}_{ice} = \frac{1}{4}\cdot(b + ab + bc + abc) - \frac{1}{4}\cdot(a + c + ac + (1))$$

Effect of changing IN

$$\mathrm{Eff}_{CCN} = \frac{1}{4}\cdot(c + ac + bc + abc) - \frac{1}{4}\cdot(a + b + ab + (1))$$

Effect of changing CCN

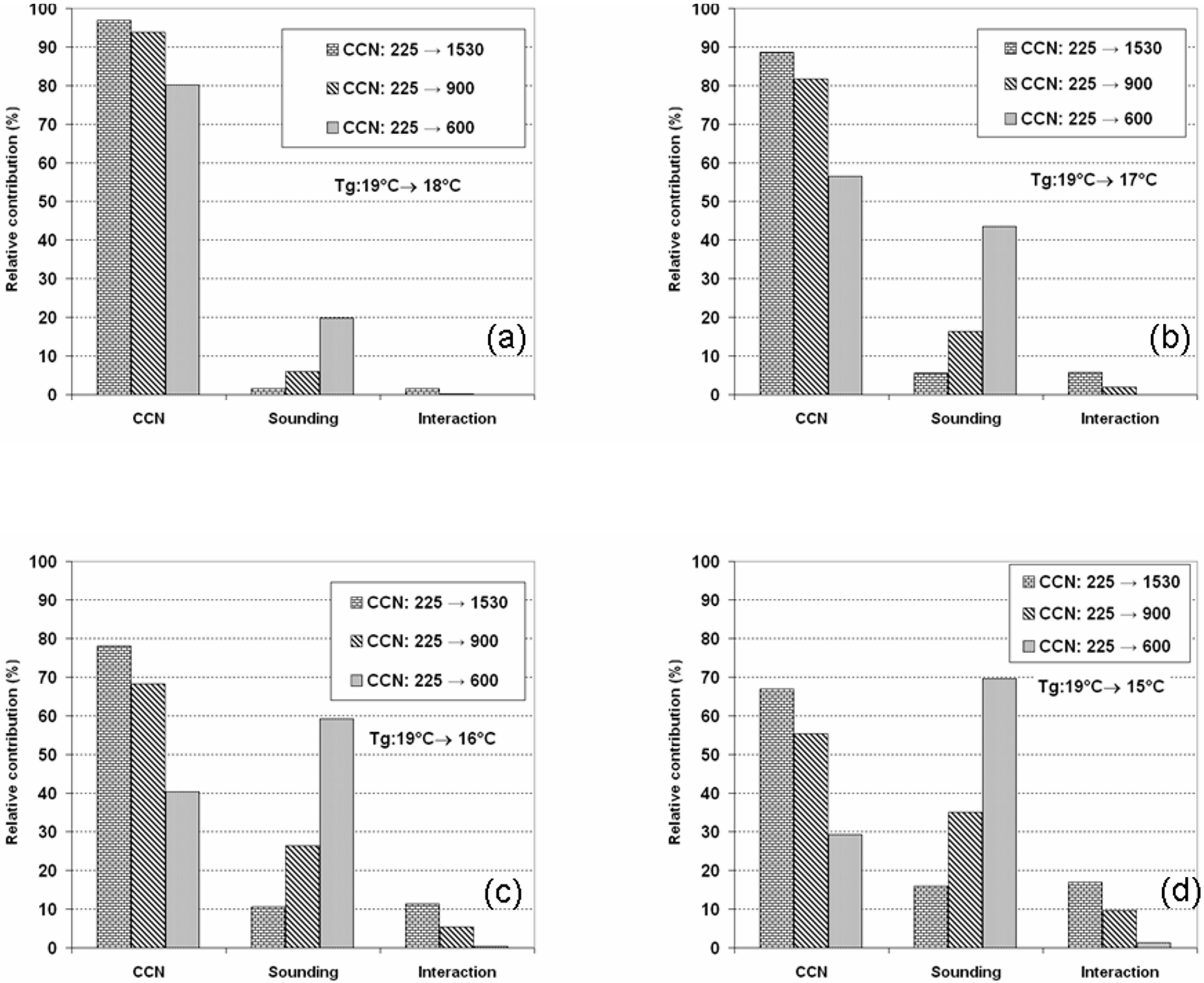
The contribution of the interaction effects



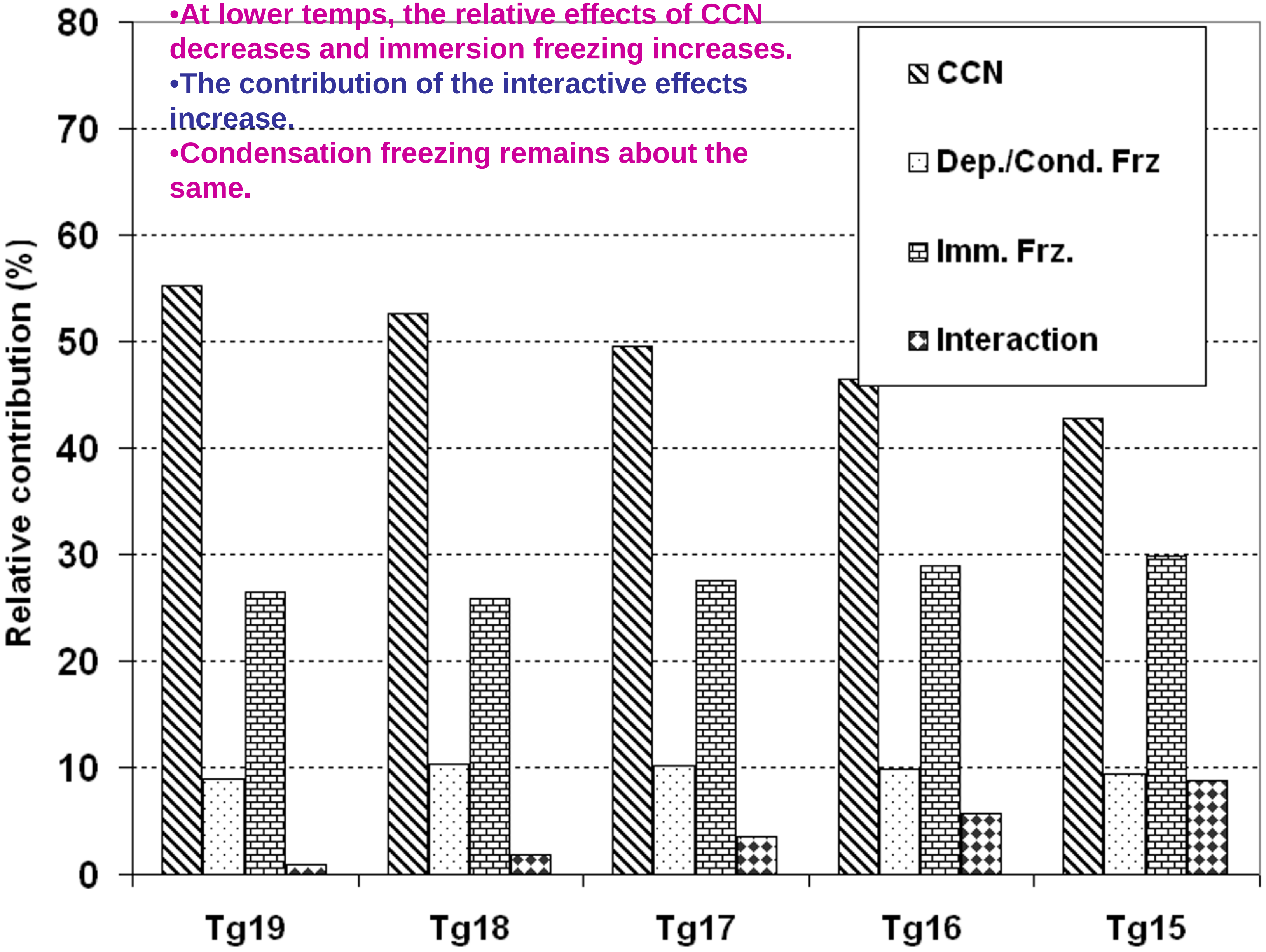
$$\mathrm{Eff}_{\mathrm{Tg\ (polluted)}} = \frac{1}{2}\cdot(\mathrm{abc}-\mathrm{bc}) - \frac{1}{2}\cdot(\mathrm{ab}-\mathrm{b})$$

$$\mathrm{Eff}_{\mathrm{Tg\ (clean)}} = \frac{1}{2}\cdot(\mathrm{ac}-\mathrm{c}) - \frac{1}{2}\cdot(\mathrm{a}-(1))$$

$$\mathrm{Eff}_{\mathrm{Tg\text{-}CCN}} = \frac{1}{2}\left(\mathrm{Eff}_{\mathrm{A\ (polluted)}} - \mathrm{Eff}_{\mathrm{A\ (clean)}}\right) = \frac{1}{4}(\mathrm{abc}+\mathrm{ab}+\mathrm{c}+(1)-\mathrm{bc}-\mathrm{b}-\mathrm{ac}-\mathrm{a})$$

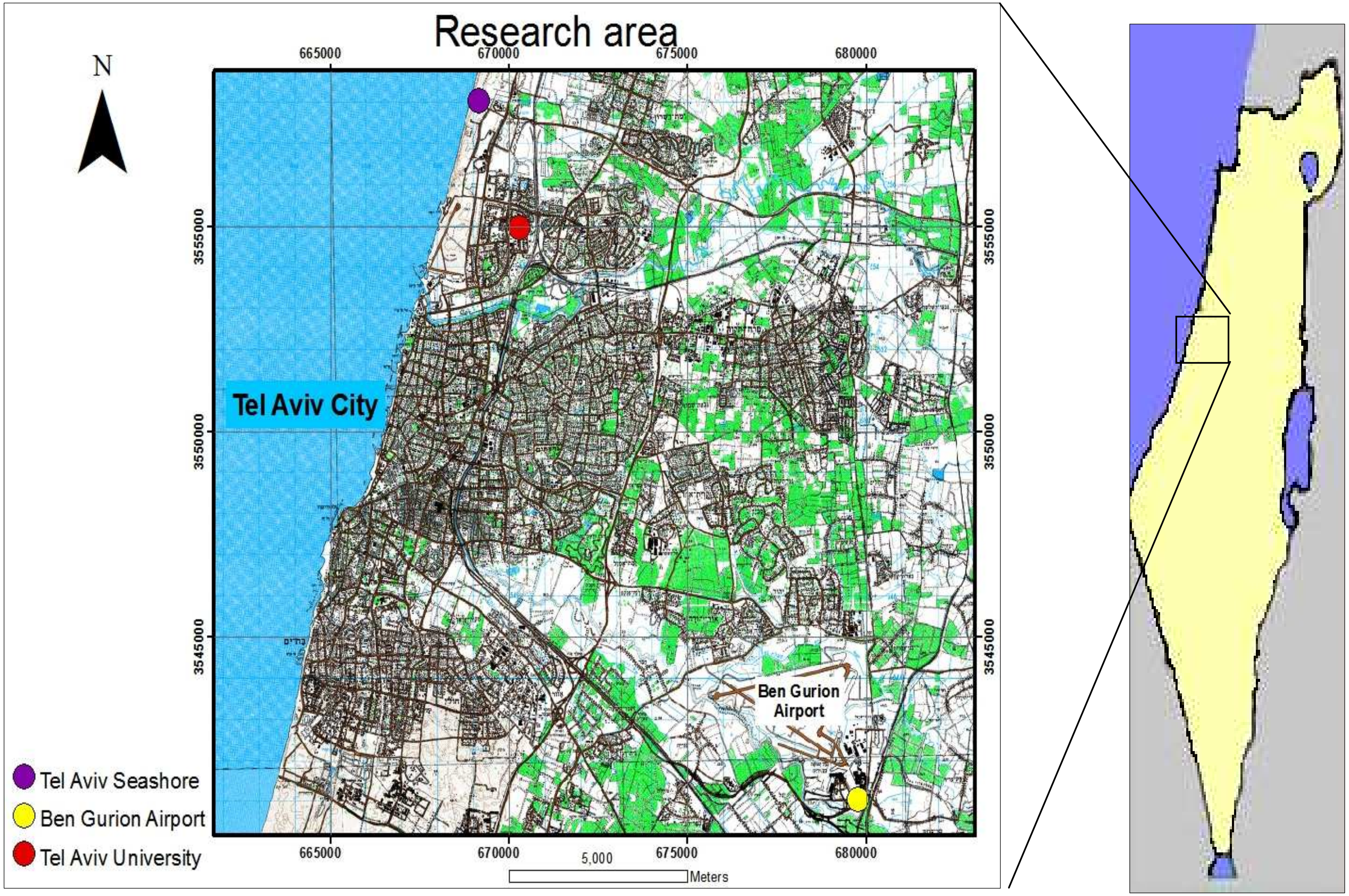

(a)
Tg:19°C→ 18°C
(b)
Tg:19°C→ 17°C
(c)
Tg:19°C→ 16°C
(d)
Tg:19°C→ 15°C
CCN: 225 → 1530
CCN: 225 → 900
CCN: 225 → 600
Relative contribution (%)
CCN
Sounding
Interaction
0
10
20
30
40
50
60
70
80
90
100

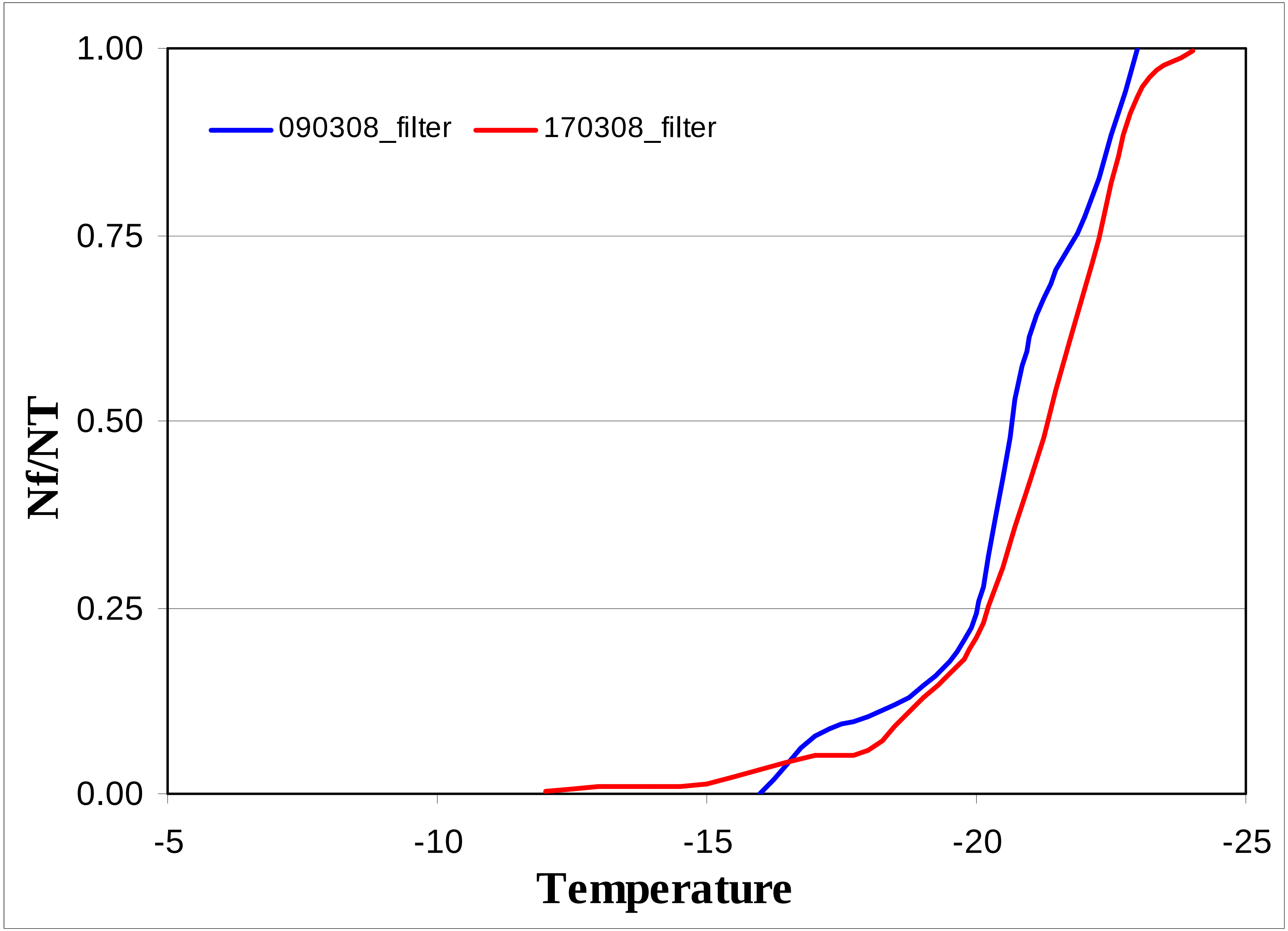
Relative contribution to precipitation suppression due to CCN and various ice nucleation modes at different temperatures.

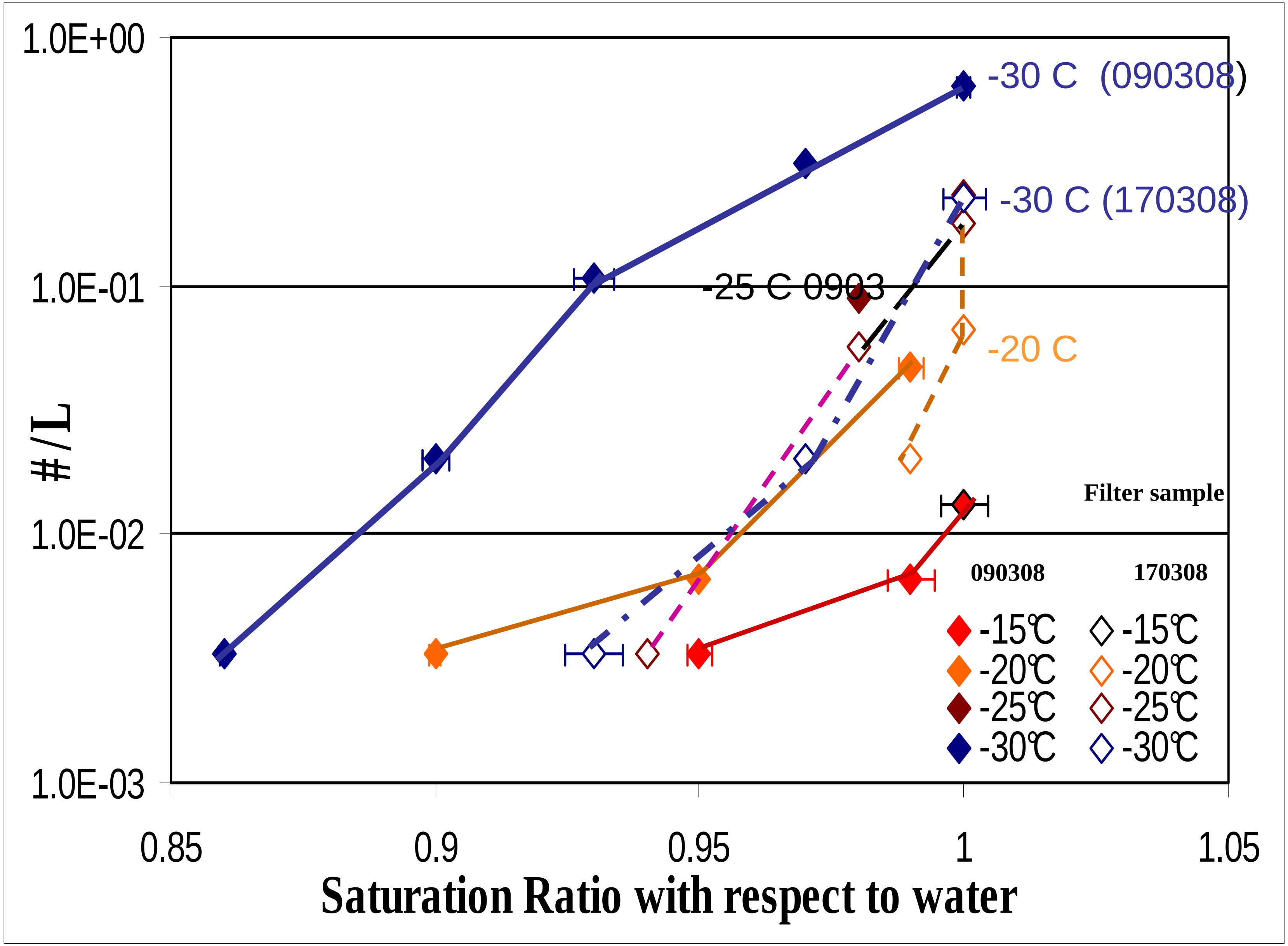


Ice Nucleation measurements with the FRIDGE

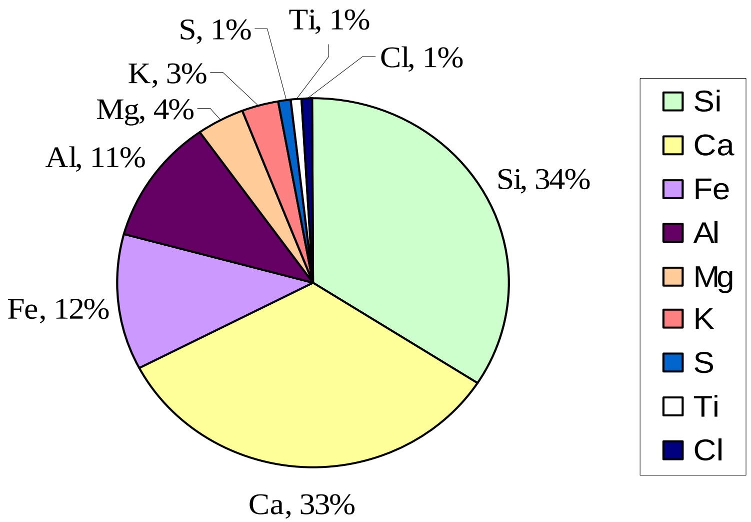
Ice nucleation experiments using drop freezing and the FRIDGE-TAU



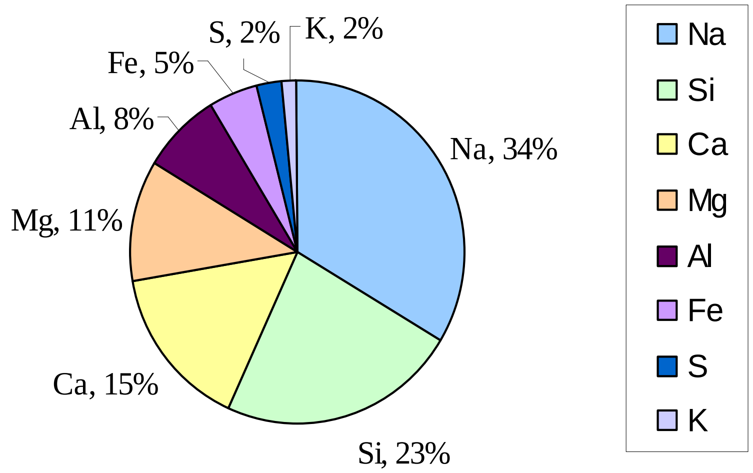

1.00
0.75
0.50
0.25
0.00
Nf/NT
090308_filter
170308_filter
-5
-10
-15
-20
-25
Temperature

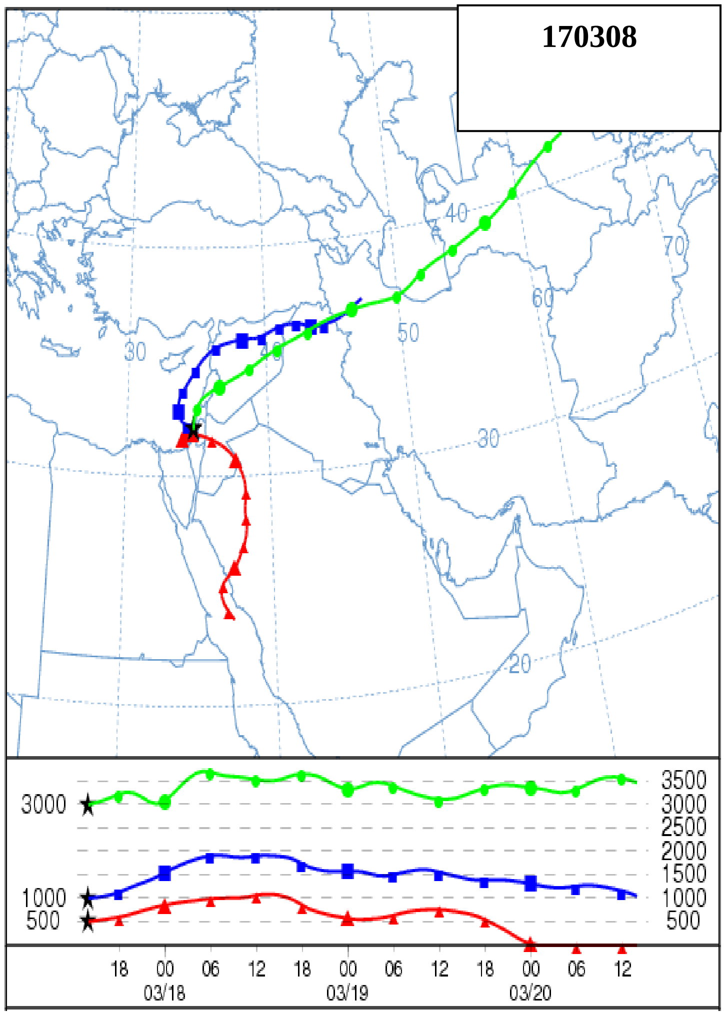

1.0E+00
1.0E-01
1.0E-02
1.0E-03
#/L
0.85
0.9
0.95
1
1.05
Saturation Ratio with respect to water
-30 C (090308)
-30 C (170308)
-25 C 0903
-20 C
Filter sample
090308
170308
-15℃
-20℃
-25℃
-30℃
-15℃
-20℃
-25℃
-30℃

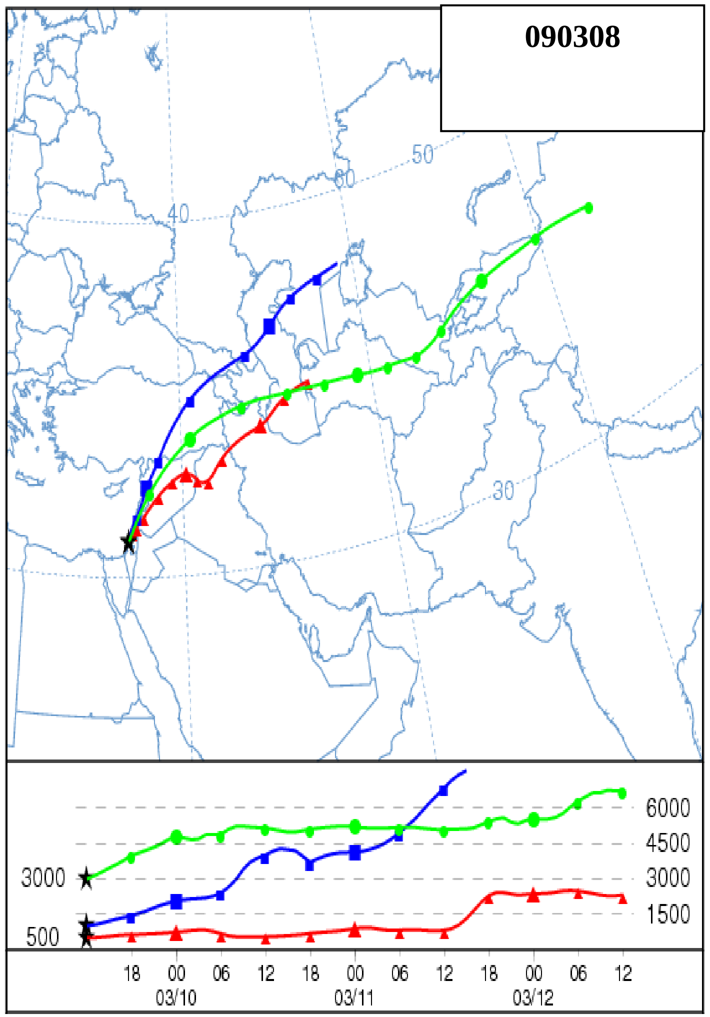
Chemical analysis of average suspended mineral dust (d<100 µm) measured during dust storms over TAU on 170308



Chemical analysis of average suspended mineral dust (d<100 µm) measured during dust storms over TAU on 090308




170308
3000
1000
500
3500
3000
2500
2000
1500
1000
500
18 00 06 12 18 00 06 12 18 00 06 12
03/18 03/19 03/20


090308
3000
500
6000
4500
3000
1500
18 00 06 12 18 00 06 12 18 00 06 12
03/10 03/11 03/12

Future plans:

- Include more simulations on the effects of ice concentrations on precipitation

- Center of Gravity studies in which ice is included (With Ilan Koren, Orit Altaraz, Tamir Reisin and Graham Feingold)

- Ice nucleation measurements: effects of pollution on ice nuclei

- Biological IN

Center of Gravity

- The center of gravity *R* of a system is the point in space at which the total mass can be considered to concentrate, and at which external forces may be applied. It can also be defined as the average position of the system elements *ri* weighted by their masses *mi*:
- (1)

$$R = \frac{\sum_i r_i m_i}{M} \qquad M = \sum_i m_i$$

- where the total mass *of condensate M* of the system is
- We will define the spread *S* of the cloud (in *x*, *y*, or *z*) as the distance from *R* weighted by mass, or the weighted standard deviation of the distances from the center of gravity:
- .

$$S = \sqrt{\frac{\sum_i m_i (r_i - R)^2}{M}}$$

we define in a similar manner a set of operators of any physical quantity *q*. To do so, we define the momentum-like product *MQ* of the mass and the variable *q* as

$$M_Q = \sum_i m_i q_i$$

and the weighted-by-mass averaging operator *Q* of the quantity *q* will be

$$Q = \frac{\sum_i q_i m_i}{M}$$

Analogously, the center of gravity operator *RQ* of the quantity *q* is defined as

$$R_Q = \frac{\sum_i r_i m_i q_i}{M_Q}$$

and the spread operator *SQ* as

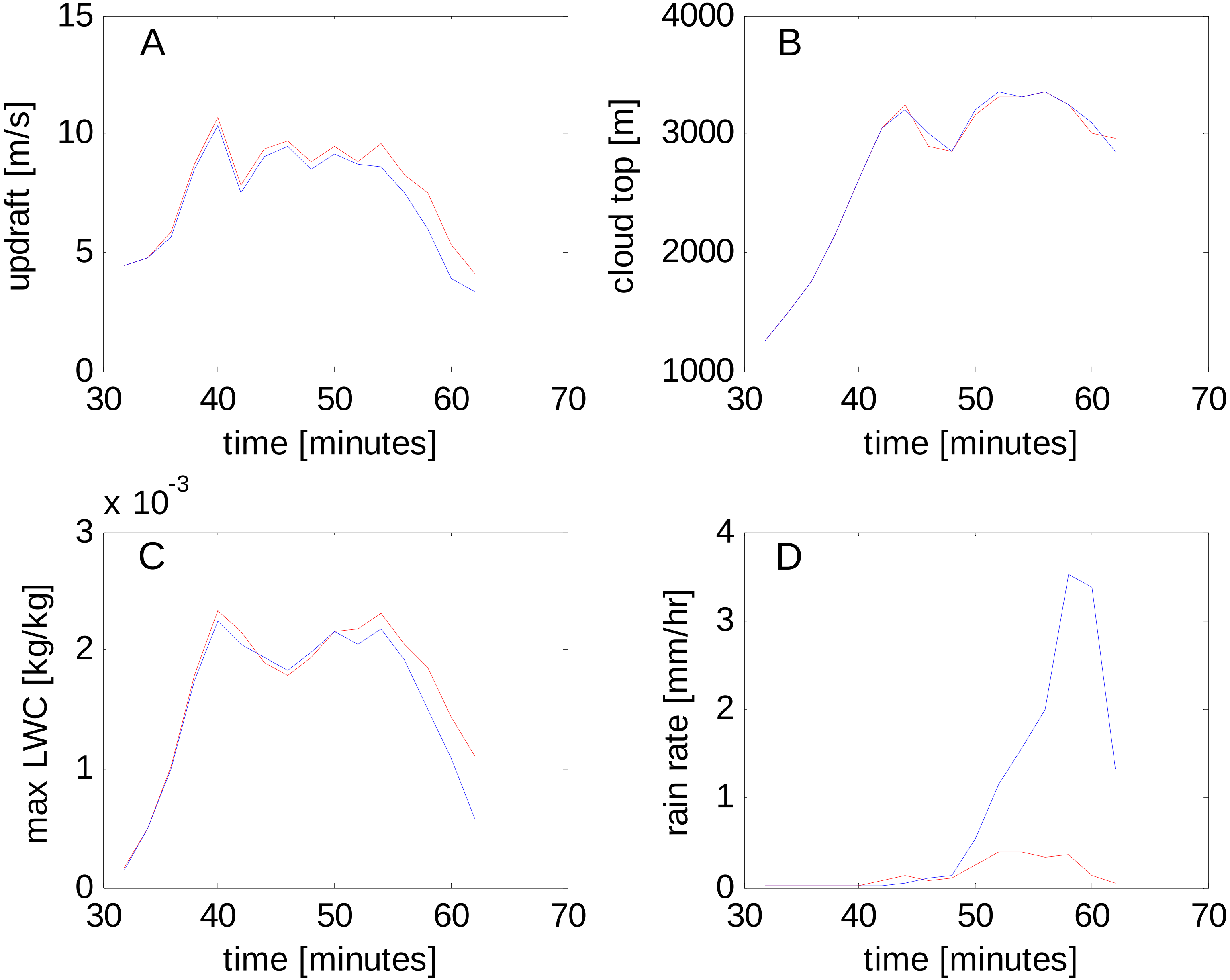
$$S_Q = \sqrt{\frac{\sum_i m_i q_i (r_i - R)^2}{M_Q}}$$

Advantages:

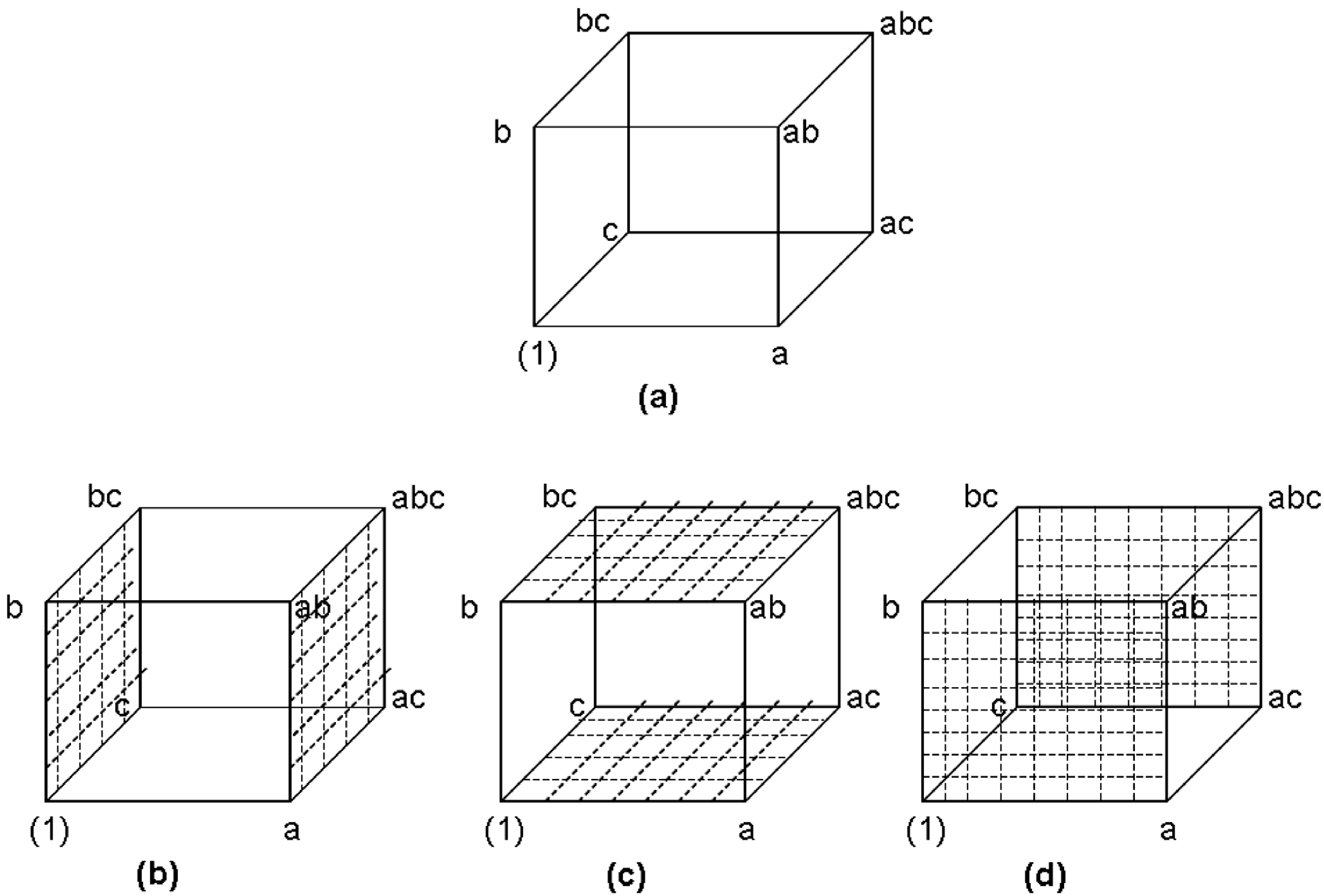
The set of the total mass *M*, the center of gravity *R(x,y,z)* and the spread *S(x,y,z)* (7 numbers in 3D cases) provides a multi-dimensional measure for the mass distribution inside the cloud.

Likewise, each of the dynamical and microphysical properties (updrafts, effective radius) is measured by 7 numbers per time step.

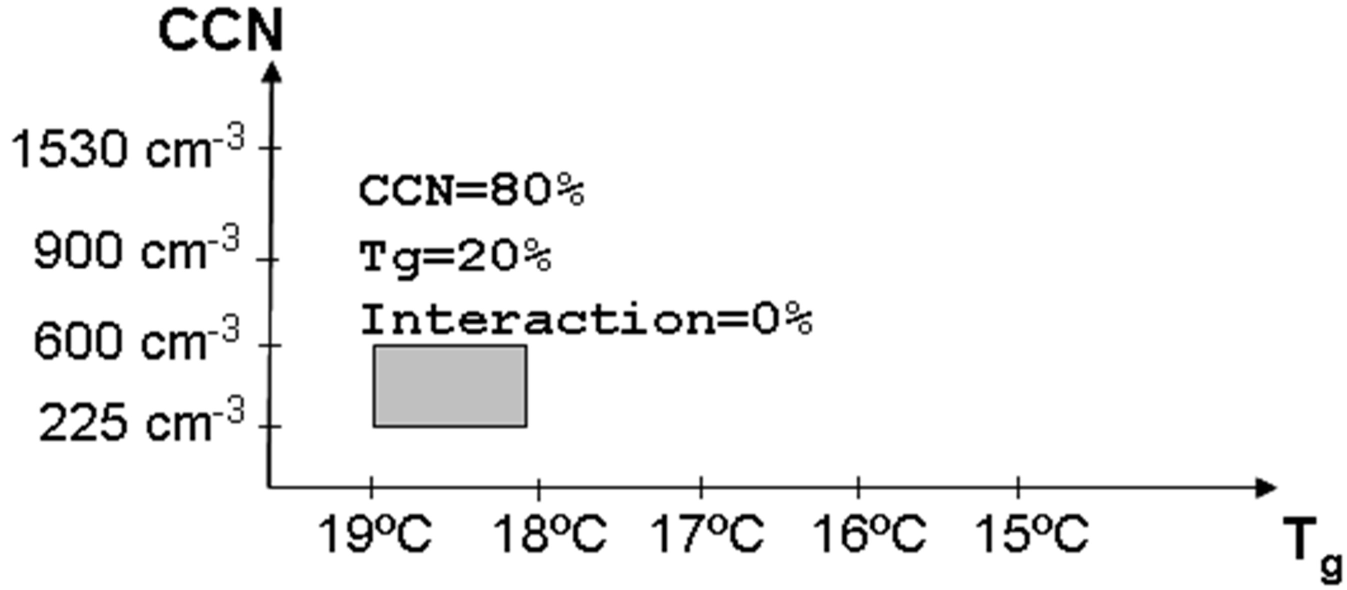
Therefore, a few numbers (7 for each variable) that give a compact measure of the evolution of the clouds replace much of the information in the complete 3D dataset.


A
B
C
D
updraft [m/s]
cloud top [m]
max LWC [kg/kg]
rain rate [mm/hr]
x 10^-3
time [minutes]
time [minutes]
time [minutes]
time [minutes]
0
5
10
15
1000
2000
3000
4000
0
1
2
3
0
1
2
3
4
30
40
50
60
70

Thank you

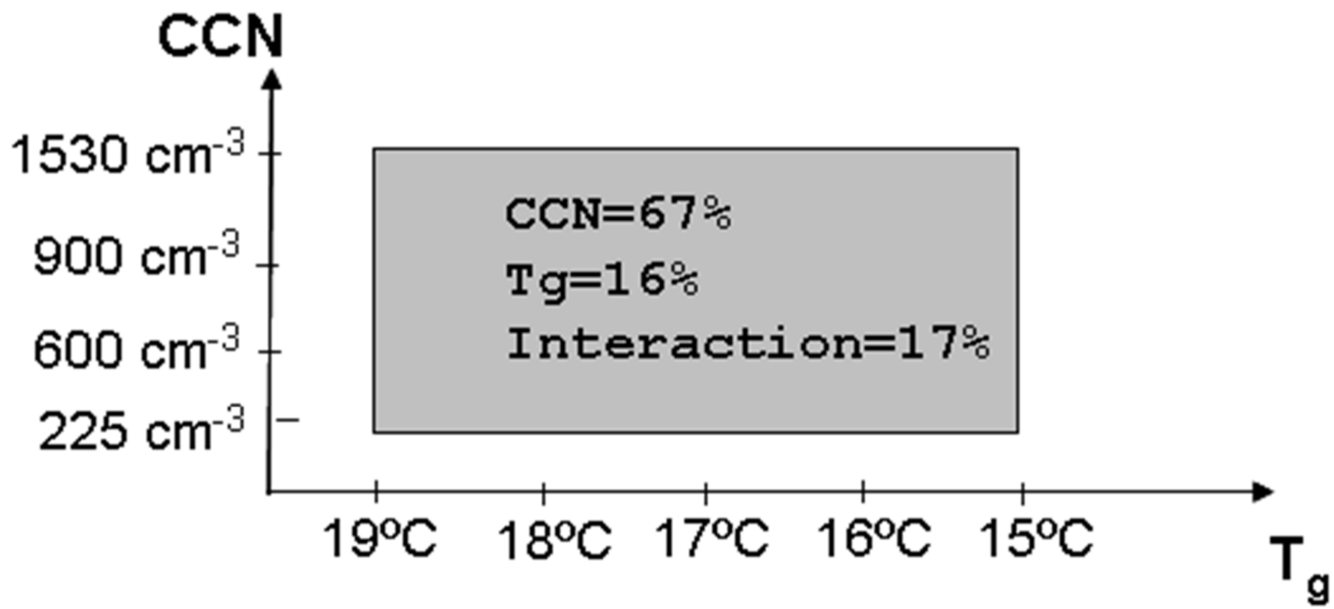


bc
abc
b
ab
c
ac
(1)
a
(a)
bc
abc
b
ab
c
ac
(1)
a
(b)
bc
abc
b
ab
c
ac
(1)
a
(c)
bc
abc
b
ab
c
ac
(1)
a
(d)



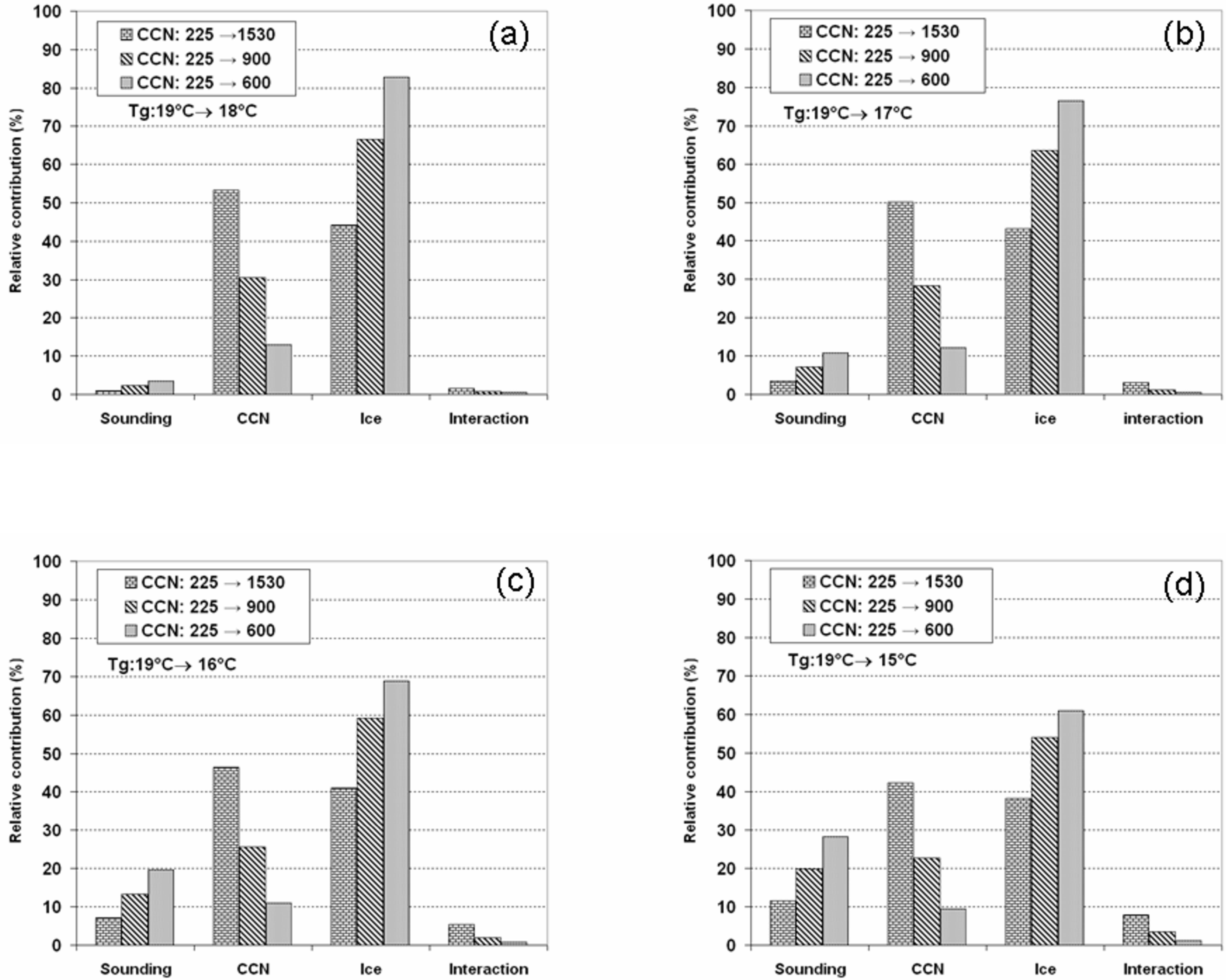
CCN
1530 cm-3
900 cm-3
600 cm-3
225 cm-3
CCN=80%
Tg=20%
Interaction=0%
19ºC
18ºC
17ºC
16ºC
15ºC
Tg

(a)



CCN
1530 cm-3
900 cm-3
600 cm-3
225 cm-3
CCN=67%
Tg=16%
Interaction=17%
19ºC
18ºC
17ºC
16ºC
15ºC
Tg

(b)



(a)
CCN: 225 →1530
CCN: 225 → 900
CCN: 225 → 600
Tg:19°C→ 18°C
Relative contribution (%)
Sounding
CCN
Ice
Interaction
(b)
CCN: 225 → 1530
CCN: 225 → 900
CCN: 225 → 600
Tg:19°C→ 17°C
Relative contribution (%)
Sounding
CCN
ice
interaction
(c)
CCN: 225 → 1530
CCN: 225 → 900
CCN: 225 → 600
Tg:19°C→ 16°C
Relative contribution (%)
Sounding
CCN
Ice
Interaction
(d)
CCN: 225 → 1530
CCN: 225 → 900
CCN: 225 → 600
Tg:19°C→ 15°C
Relative contribution (%)
Sounding
CCN
Ice
Interaction