



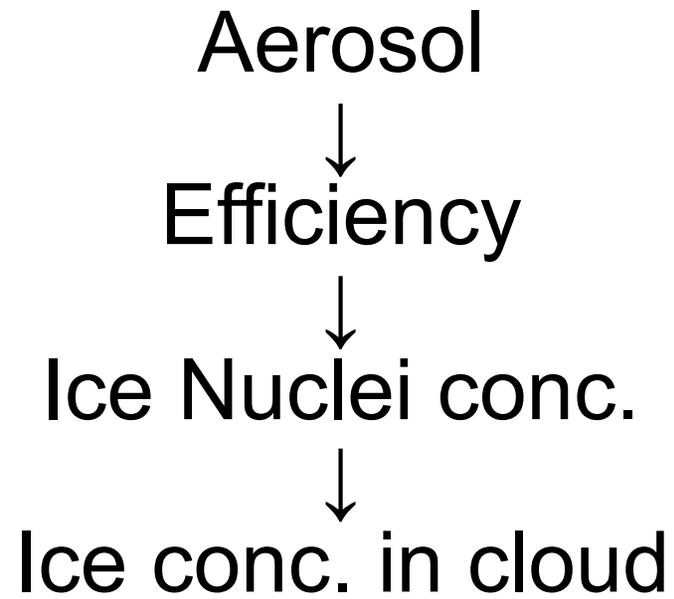
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Ice and aerosol – cause for optimism?

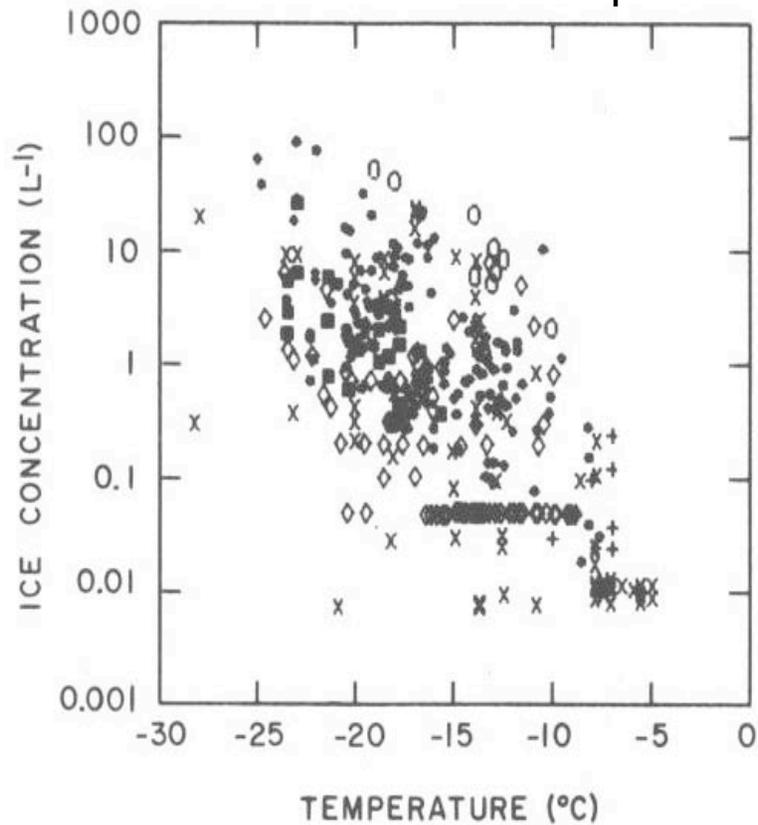
Paul Field, ARM/GCSS, Sept 2009

ICE-L science team including Heymsfield A., Rogers D., Stith J., DeMott P., Haimov S., Murphy S., Pratt K., Twohy C., K.A. Prather, Seinfeld J., Shipway B.J., Eidhammer T., A. Prenni +NCAR,RAF

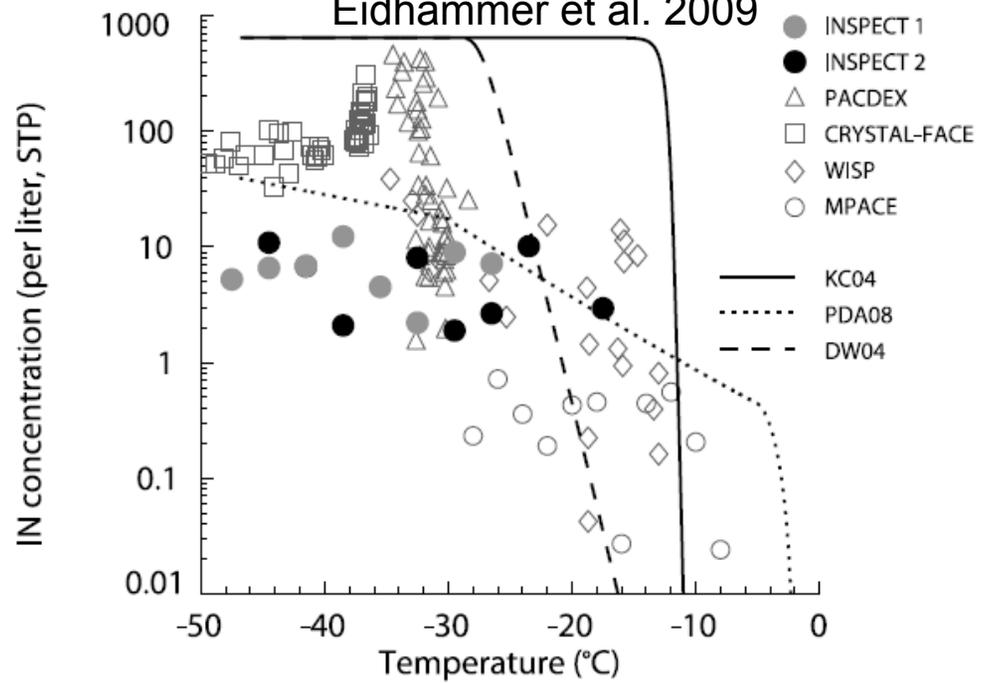
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Cooper 1986



Eidhammer et al. 2009

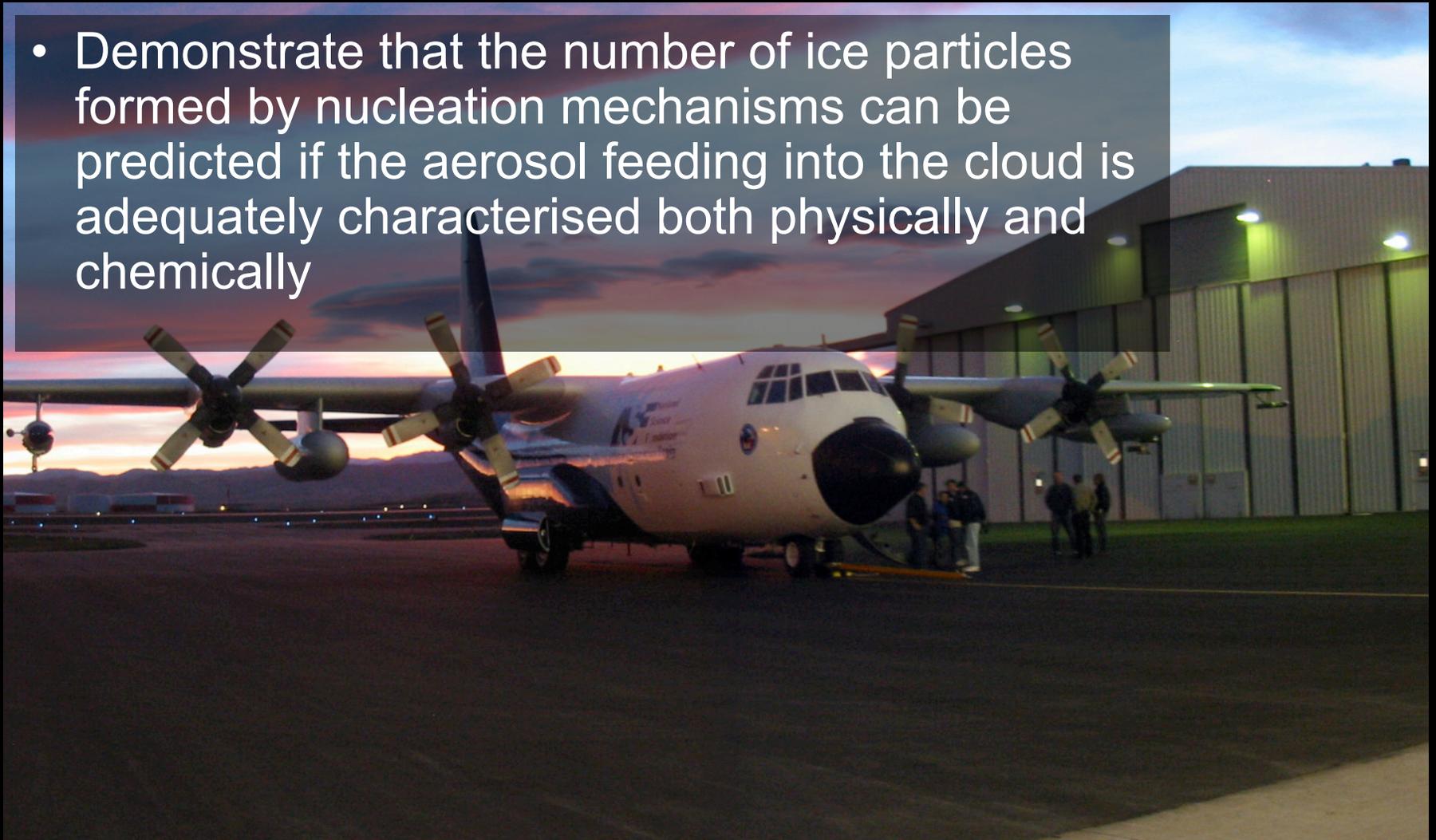




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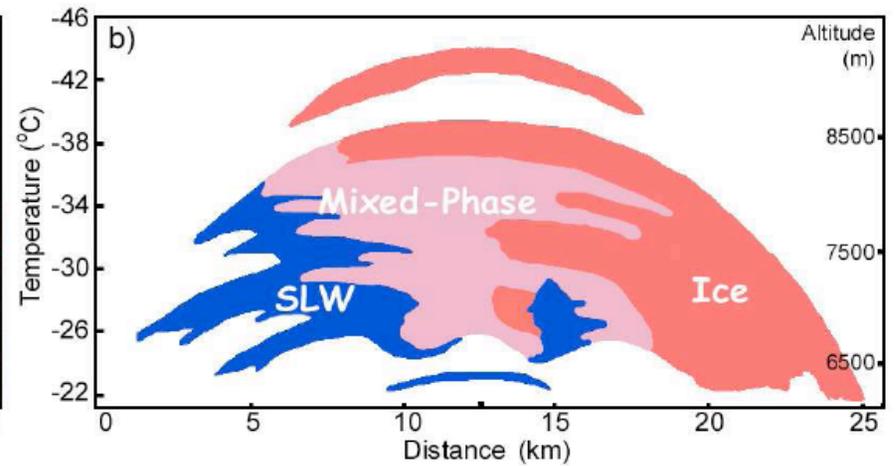
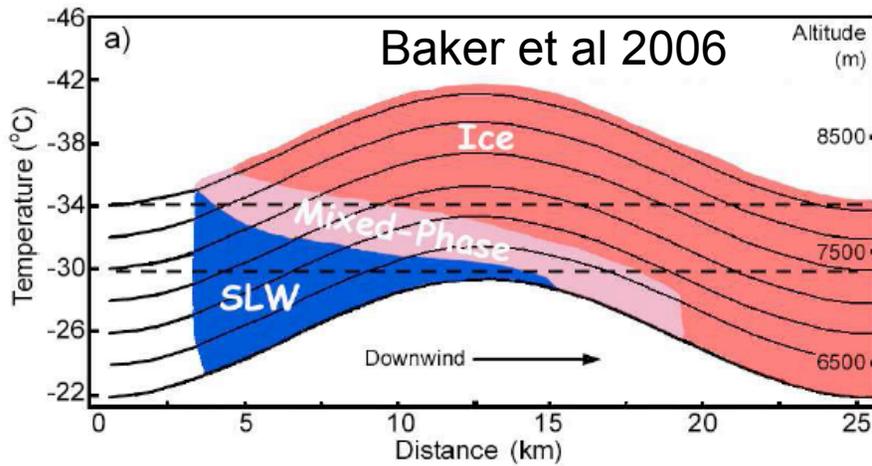
ICE-L

- Demonstrate that the number of ice particles formed by nucleation mechanisms can be predicted if the aerosol feeding into the cloud is adequately characterised both physically and chemically





Wave clouds – natural labs – giant IN counters?



RF03

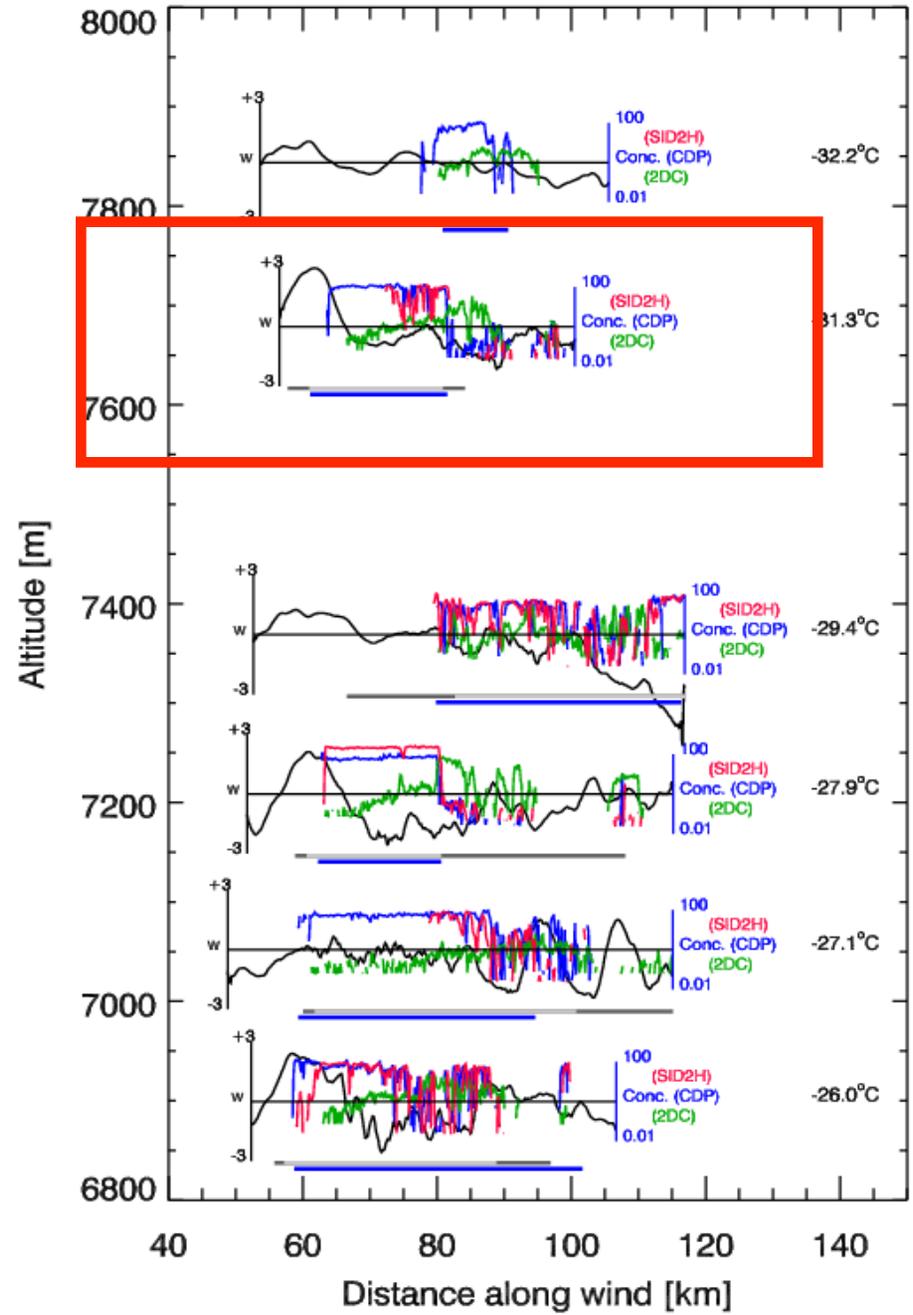
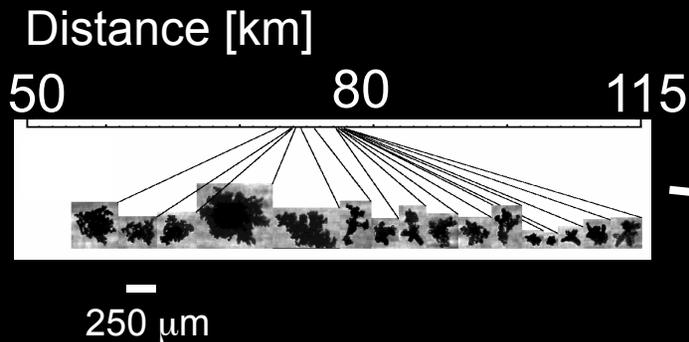


RF04

RF03

Vertical velocity, w [$m\ s^{-1}$]
 Cloud droplet probe, CDP [cm^{-3}]
 Small Ice Detector, SID2H [cm^{-3}]
 Fast 2D-C ($D > 100\mu m$), 2DC [L^{-1}]
 Supersaturation w.r.t. ice: — liquid: —
 1Hz change in Rosemount icing probe $> 0.01\ mV/s$ —

RF03:
 Droplet concs $\sim 100\ cm^{-3}$
 Ice concs ($D > 100\mu m$) up to $10-100\ L^{-1}$
 Ice concs (CDP, SID2H) up to $0.1-1\ cm^{-3}$



RF04

Vertical velocity, w [m s^{-1}]

Cloud droplet probe, CDP [cm^{-3}]

Small Ice Detector, SID2H [cm^{-3}]

Fast 2D-C ($D > 100\mu\text{m}$), 2DC [L^{-1}]

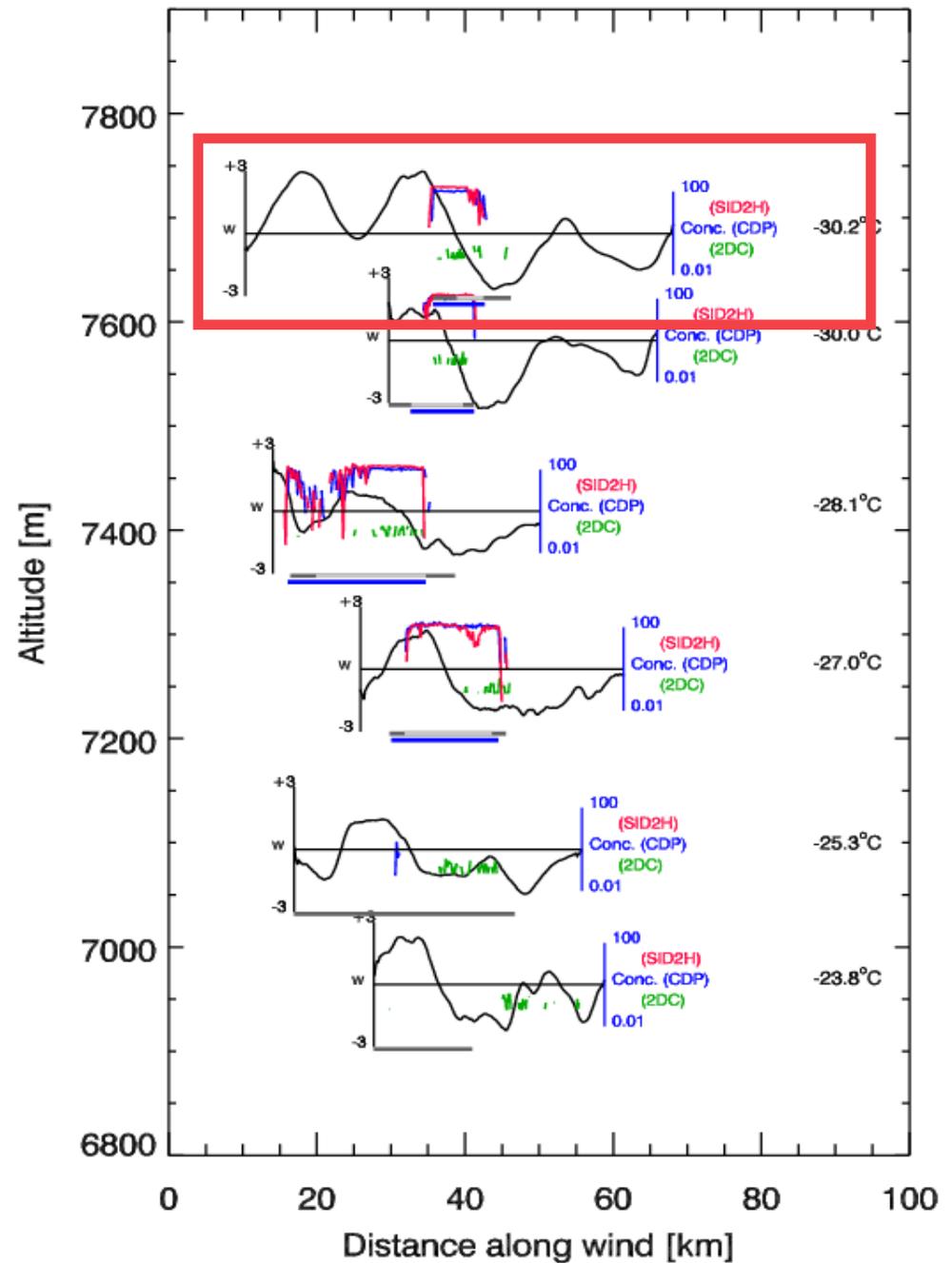
Supersaturation w.r.t. ice: \square liquid: \square

1Hz change in Rosemount icing probe $> 0.01\text{mV/s}$ \square

RF04:

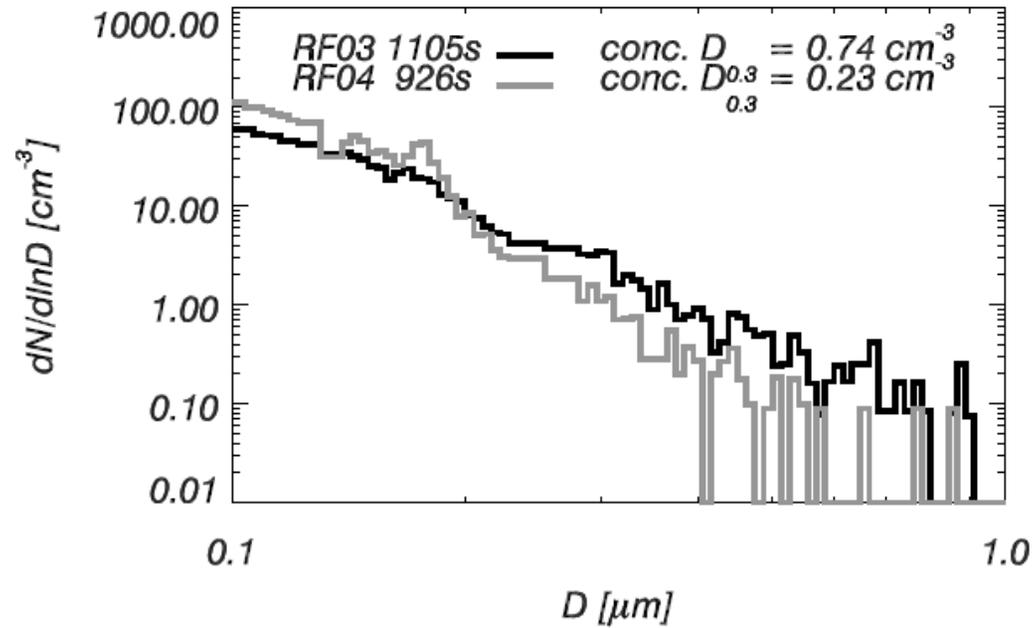
Droplet concs $\sim 100 \text{ cm}^{-3}$

Ice concs ($D > 100\mu\text{m}$) up to 1 L^{-1}

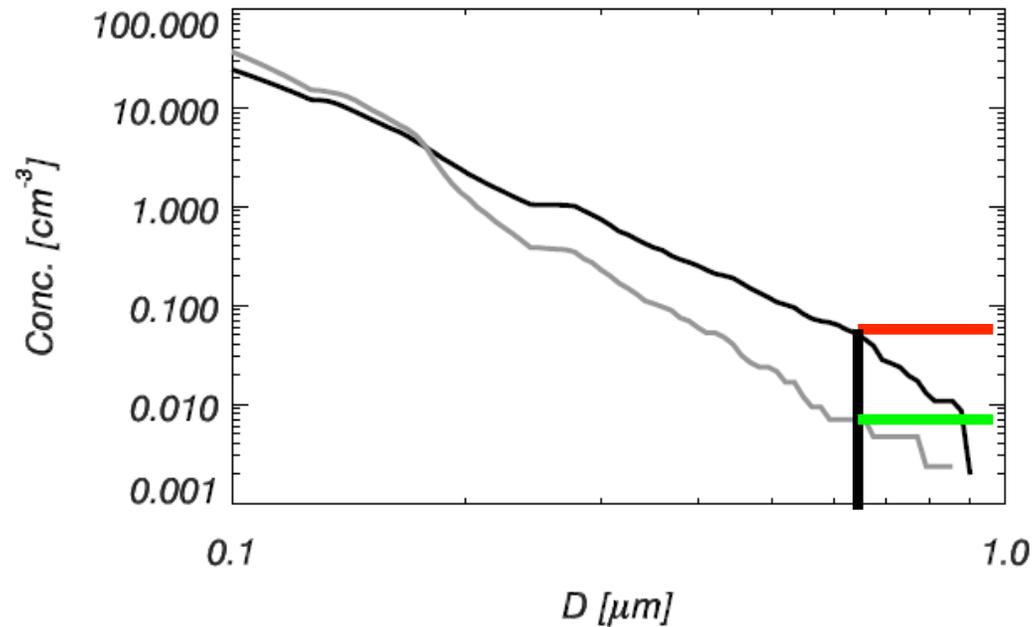




315 θ <math>< 320\text{K}</math> S+L, clear



Conc. for particles $> D$





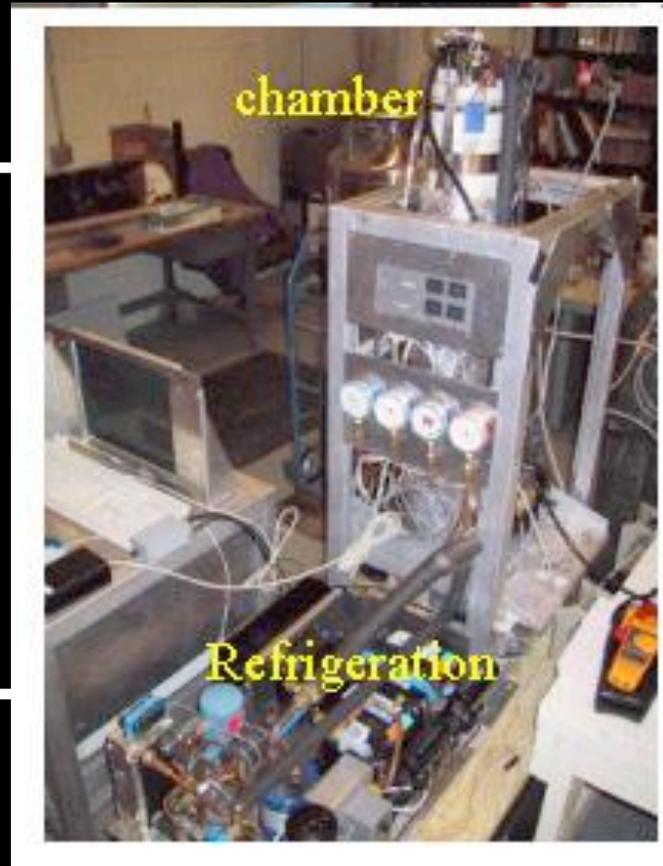
RF03



RF04



CFDC = IN counter



$\sim 5 \text{ L}^{-1}$

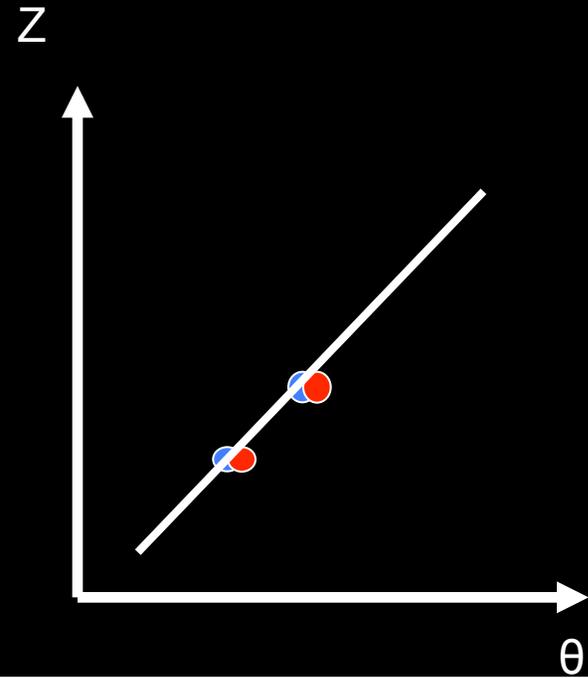
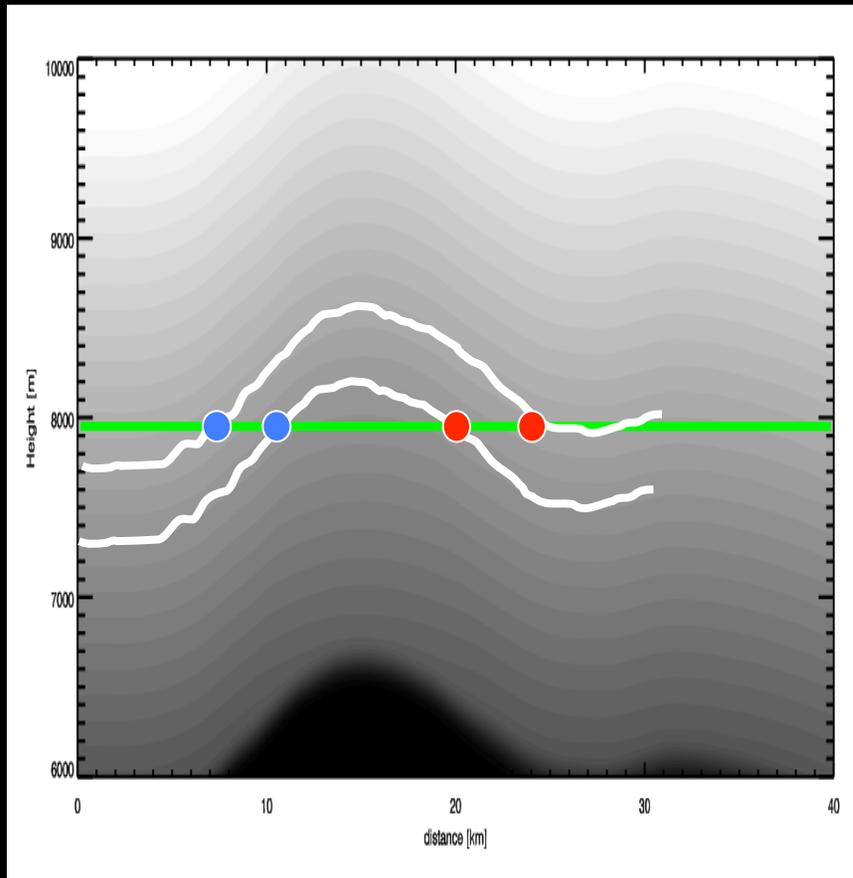
$\leq 1 \text{ L}^{-1}$



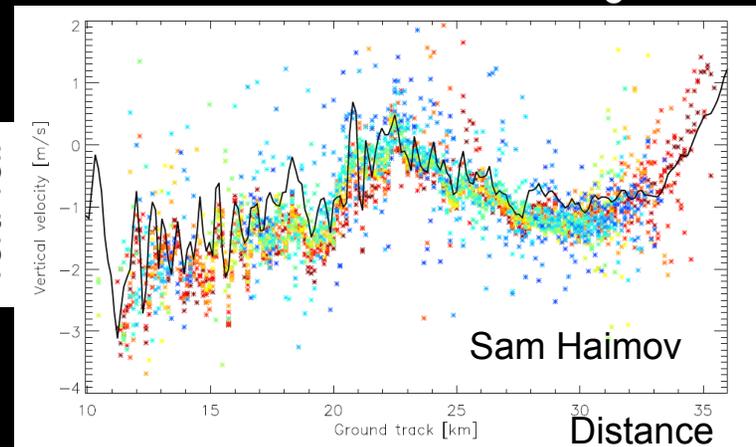
1D Kinematic model

- Use LEM in 1D – Ben Shipway (forerunner of his KiD framework)
- 1s timestep, $dz \sim 50\text{m}$ (5km – 15km)
- Cloud water, rain (mass, number), ice(mass, number), snow (mass number), graupel (mass, number)
- Sensitivities:
 - ice to snow autoconversion
 - Ventilation
 - Capacitance
 - Mass-dimension relation (density)
 - Fallspeed-dimension relation
 - Q_v profile
 - Theta profile
 - W offset
 - Het primary ice nucleation params (7)

Constructing initial profiles

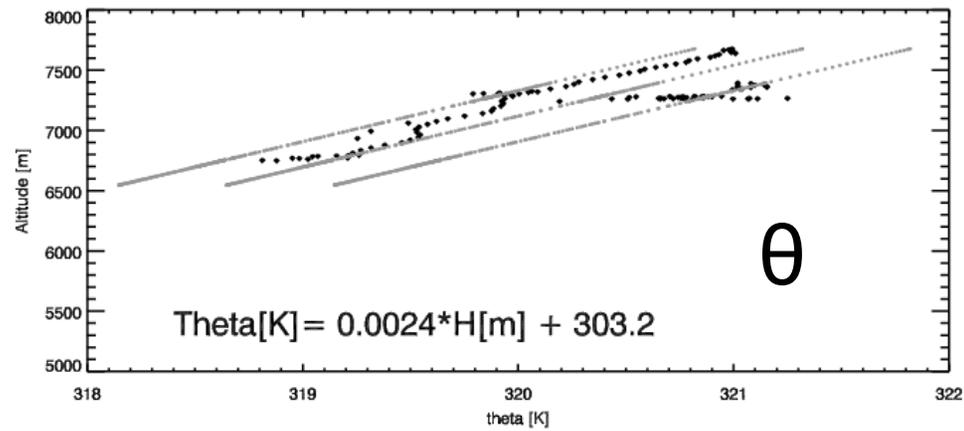
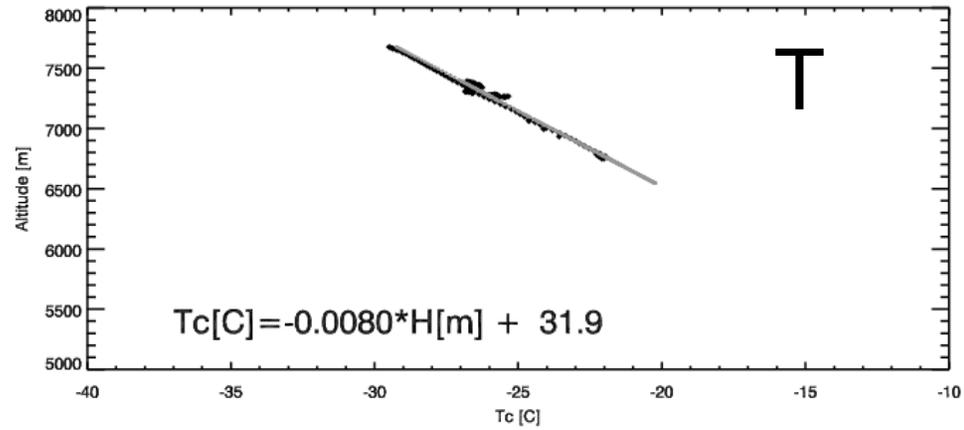
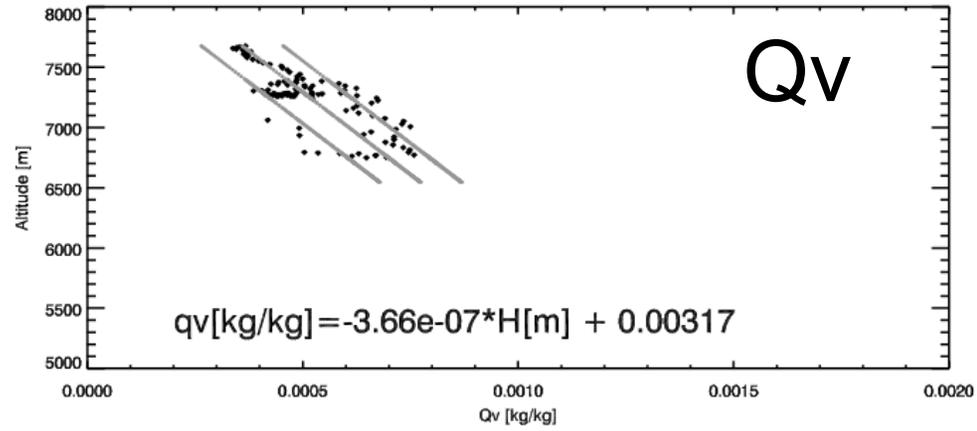


Vert. vel.





Altitude



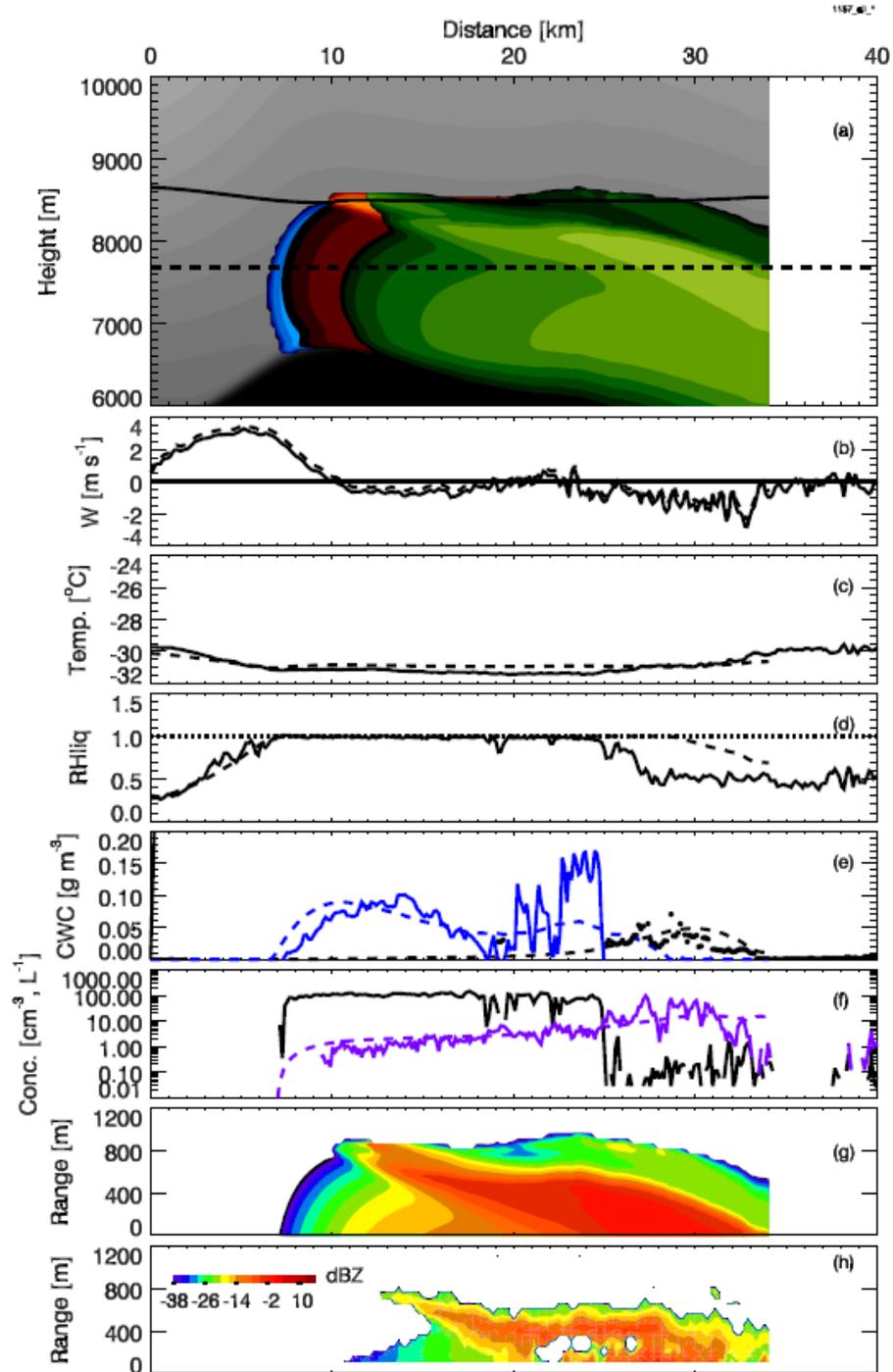


Wave clouds – Giant IN counters?

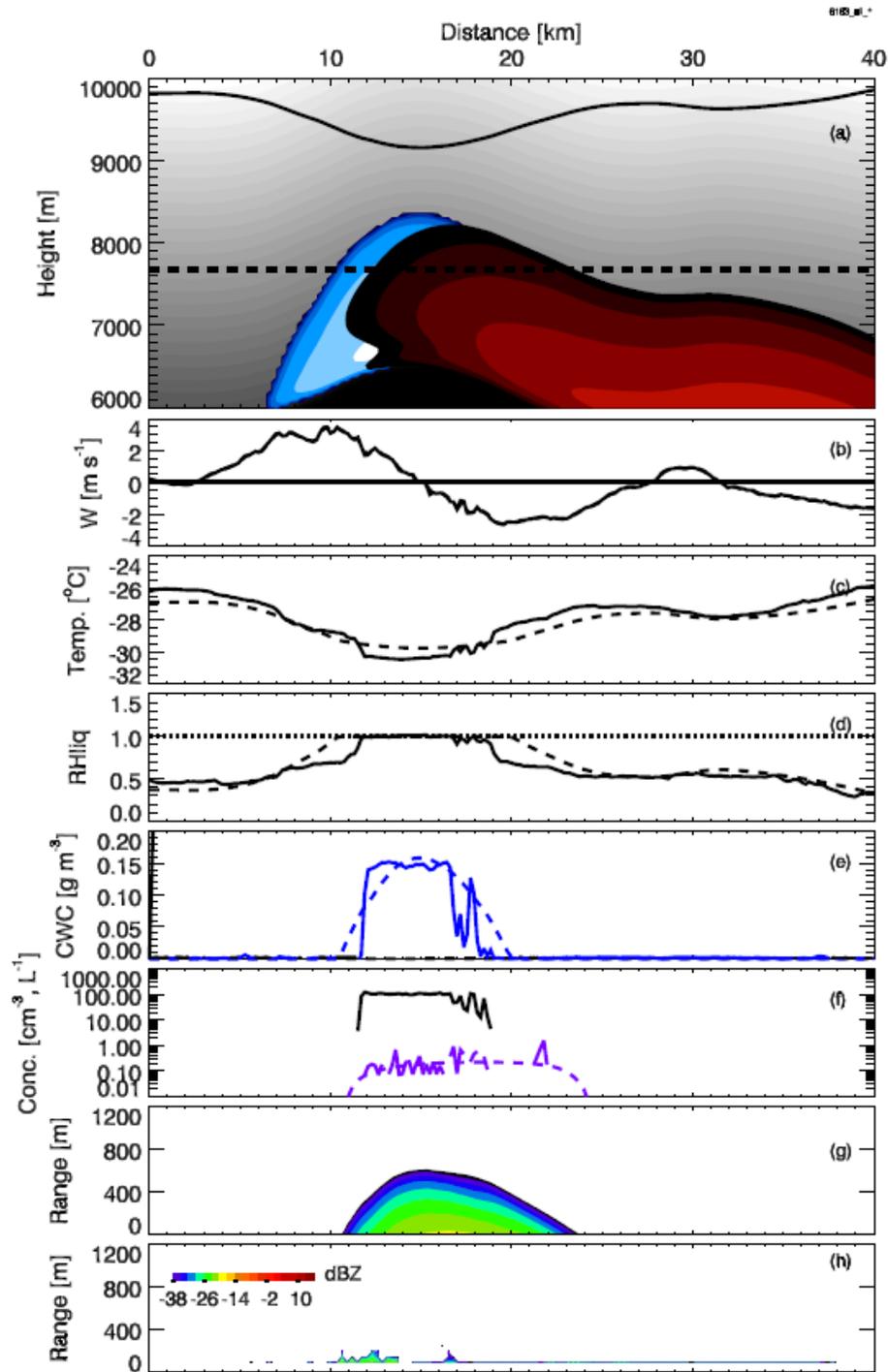
- Controlling the ice conc...
- Use Meyers et al (1992) and Connolly et al (2009) and Limit the max number of ice they can produce

	1	2	3	4	5	6	7
Nucleation	None	M92 x1	M92 x1e-2	C09 x1e-3	C09 x1e-4	C09 x1e-5	C09 x1e-6
Max ice conc. [L^{-1}]	0	50	0.5	60	6	0.6	0.06

RF03

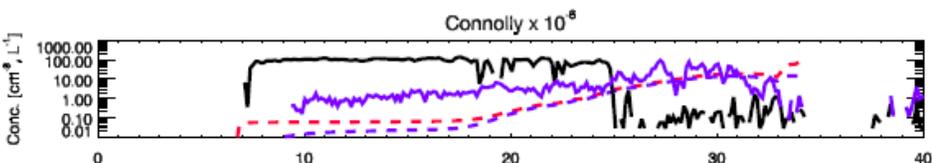
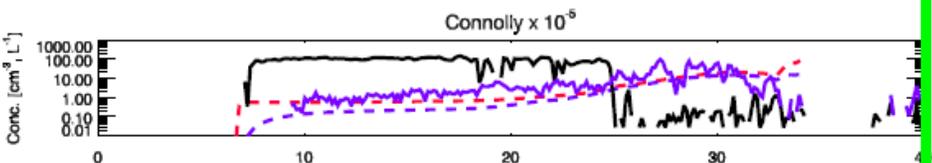
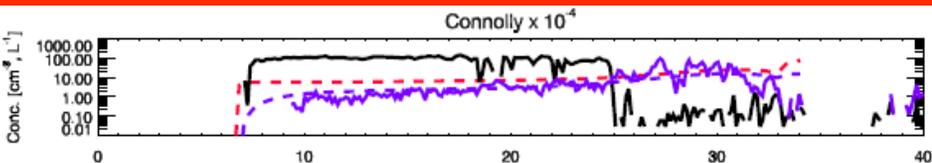
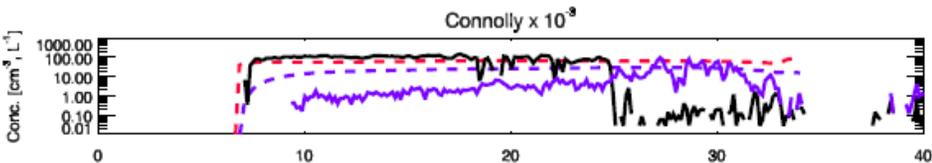
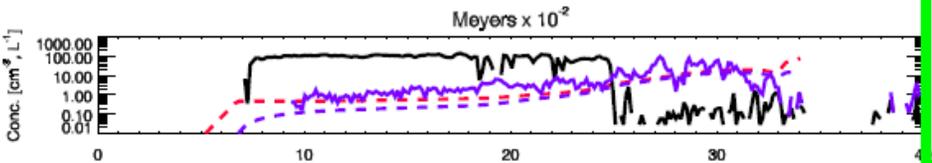
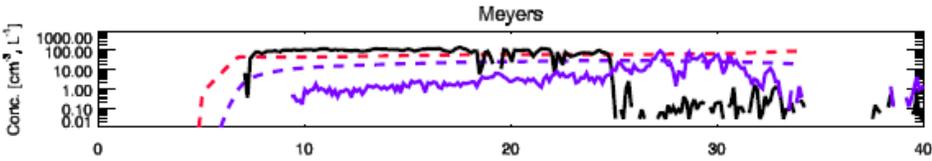
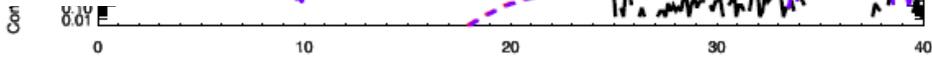


RF04



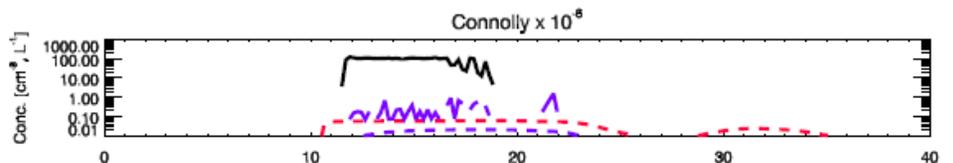
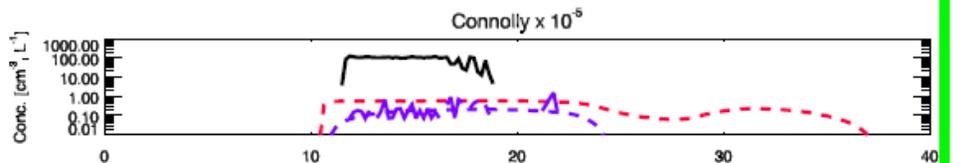
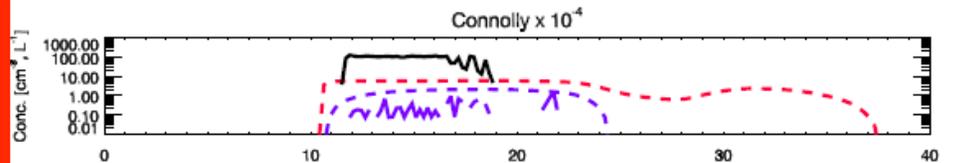
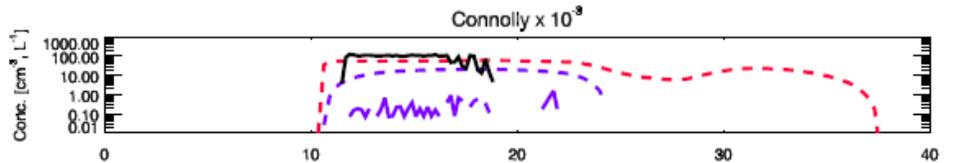
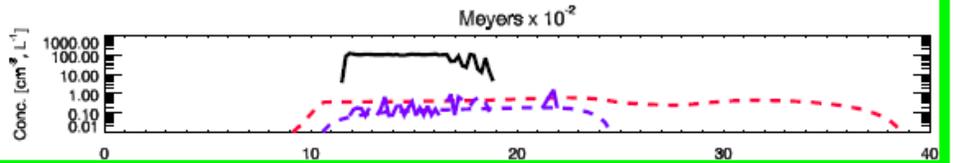
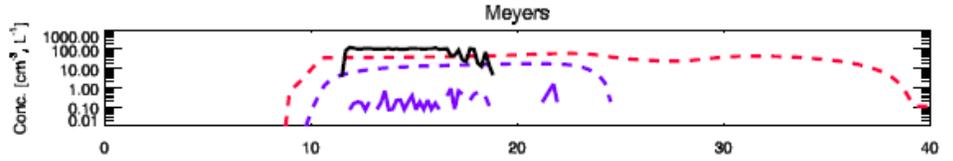
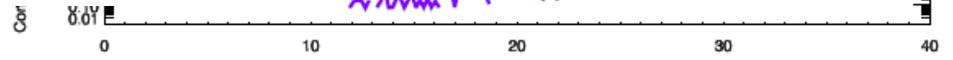
RF03

No Heterogeneous Nucleation



RF04

No Heterogeneous Nucleation





case		snow shape param.	snow auto	het. ice nuc.	Cap.	v-D	m-D
RF03	Conc.	Run ID					
		1157	1	1	5	2	1 2
		1129	1	1	5	1	1 2
		1045	1	1	5	2	1 1
		1158	2	1	5	2	1 2
		1213	1	1	5	2	2 2
		1130	2	1	5	1	1 2
		1046	2	1	5	2	1 1
		1131	1	2	5	1	1 2
		1132	2	2	5	1	1 2
	1159	1	2	5	2	1 2	
RF04	Conc.	Run ID					
		6163	1	2	6	2	1 2
		6164	2	2	6	2	1 2
		6219	1	2	6	2	2 2
		6220	2	2	6	2	2 2
		6161	1	1	6	2	1 2
		6151	1	2	3	2	1 2
		6152	2	2	3	2	1 2
		6162	2	1	6	2	1 2
		6217	1	1	6	2	2 2
	6218	2	1	6	2	2 2	

	1	2	3	4	5	6	7
Nucleation	None	M92 x1	M92 x1e-2	C09 x1e-3	C09 x1e-4	C09 x1e-5	C09 x1e-6
Max ice conc. [L ⁻¹]	0	50	0.5	60	6	0.6	0.06



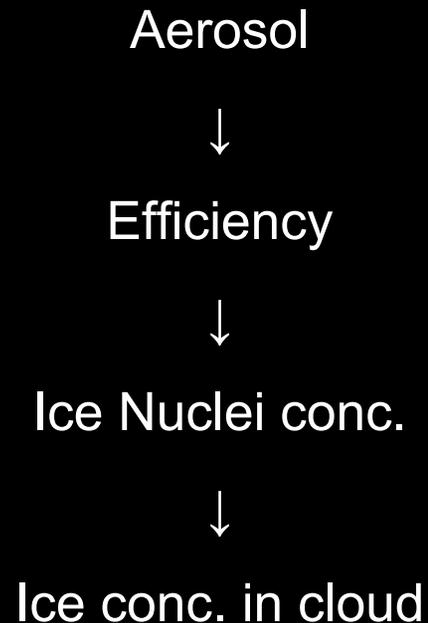
- Consistency between IN concs derived from the airborne IN counter and wave+1D modelling

IN conc. [L ⁻¹]	IN counter	Wave +Model
RF03	3-5	~6
RF04	~1	~0.5



Optimism?

- Demonstrated consistency between IN measured by IN counter (CDFC) and determined from combination of wave cloud obs+modelling





LEM convective bubble experiments with prognostic IN

- Thermodynamic profile based on Spring SW England small convection to ~4km (~-15C)
- 6x15x10km
- $dx=150m$, $dz=50m$
- Double moment rain, ice, snow, graupel
- Test sensitivity to IN conc with or without H-M.
- Caveats...

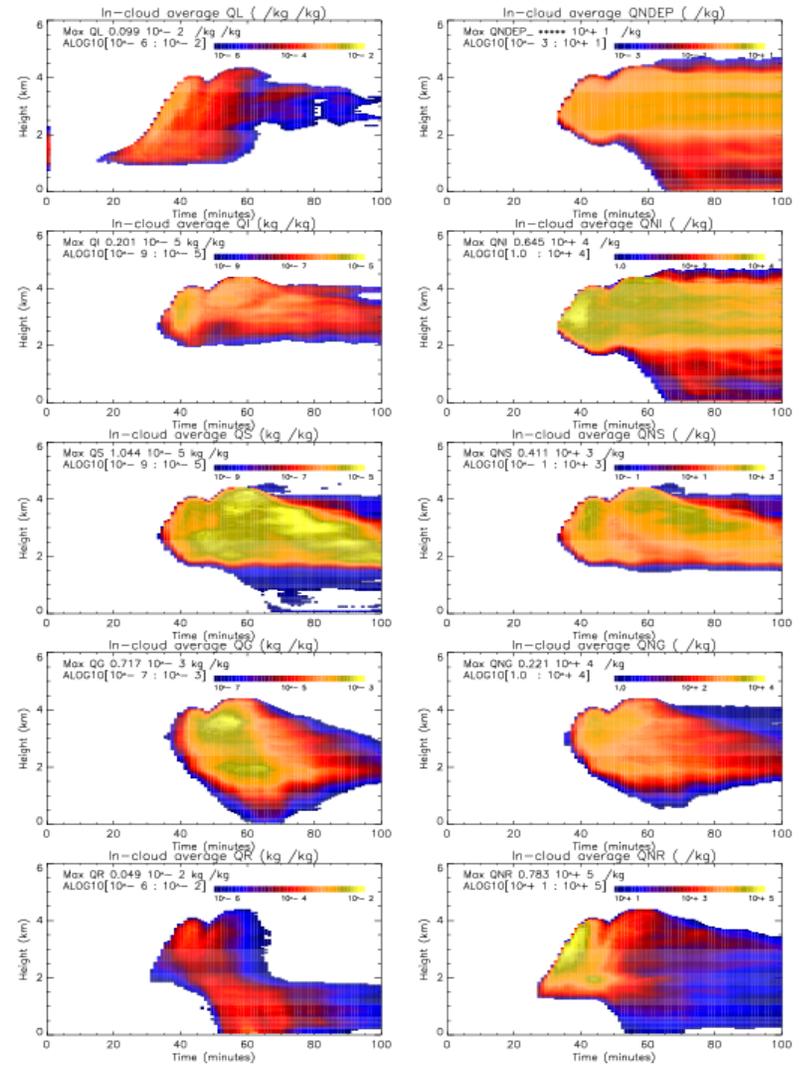
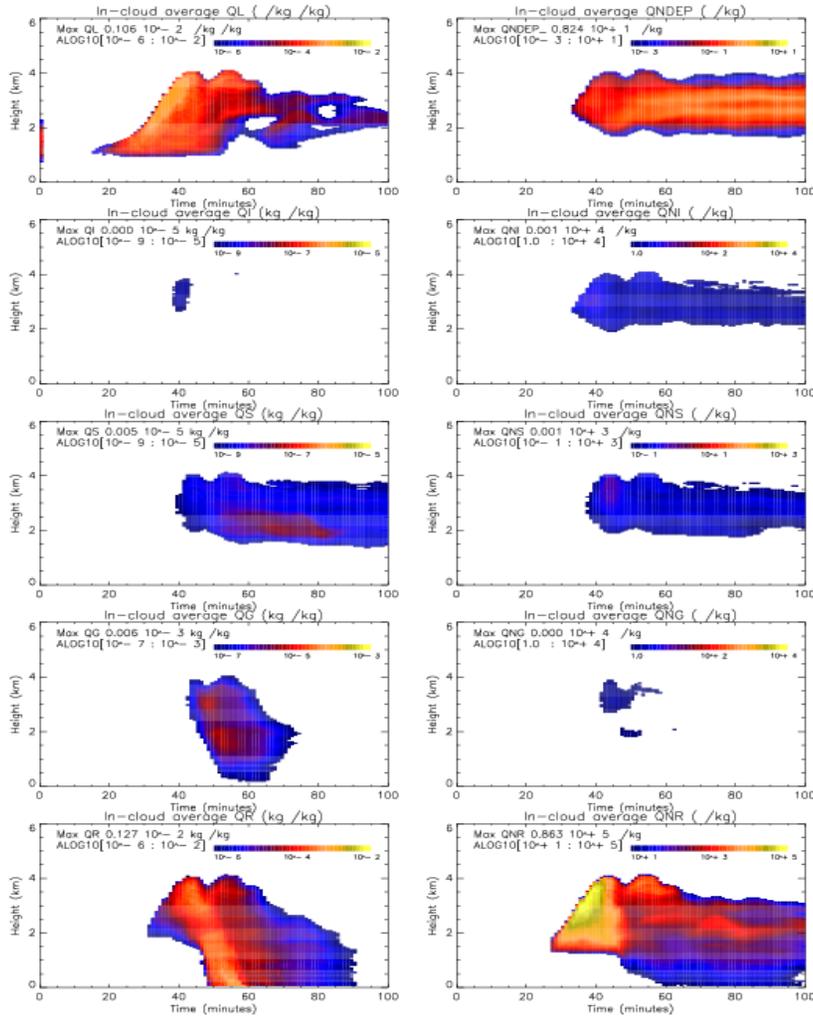
[thanks Richard Cotton]



Hallett-Mossop OFF

INconc=10 kg⁻¹

INconc=10⁴ kg⁻¹

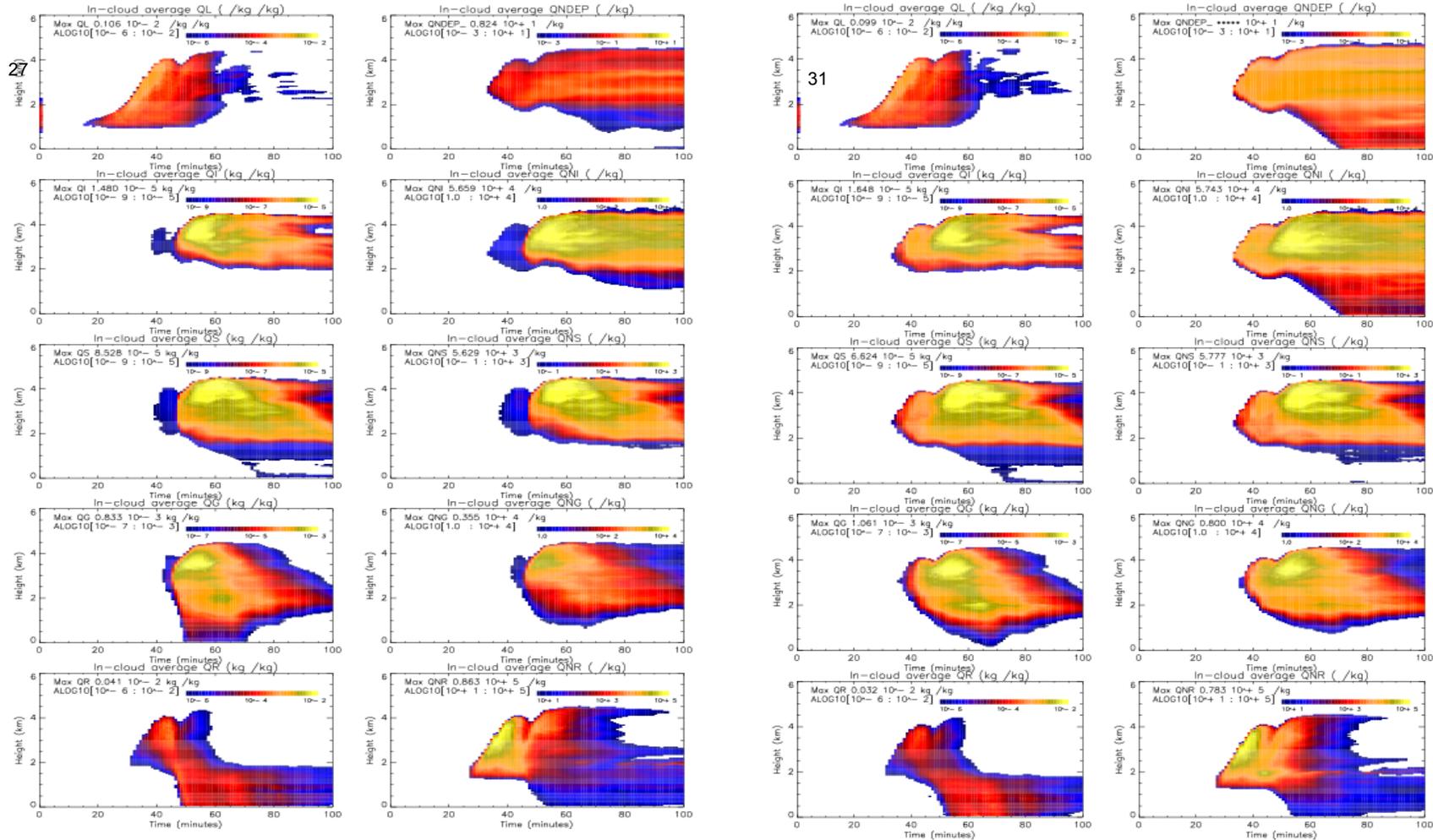


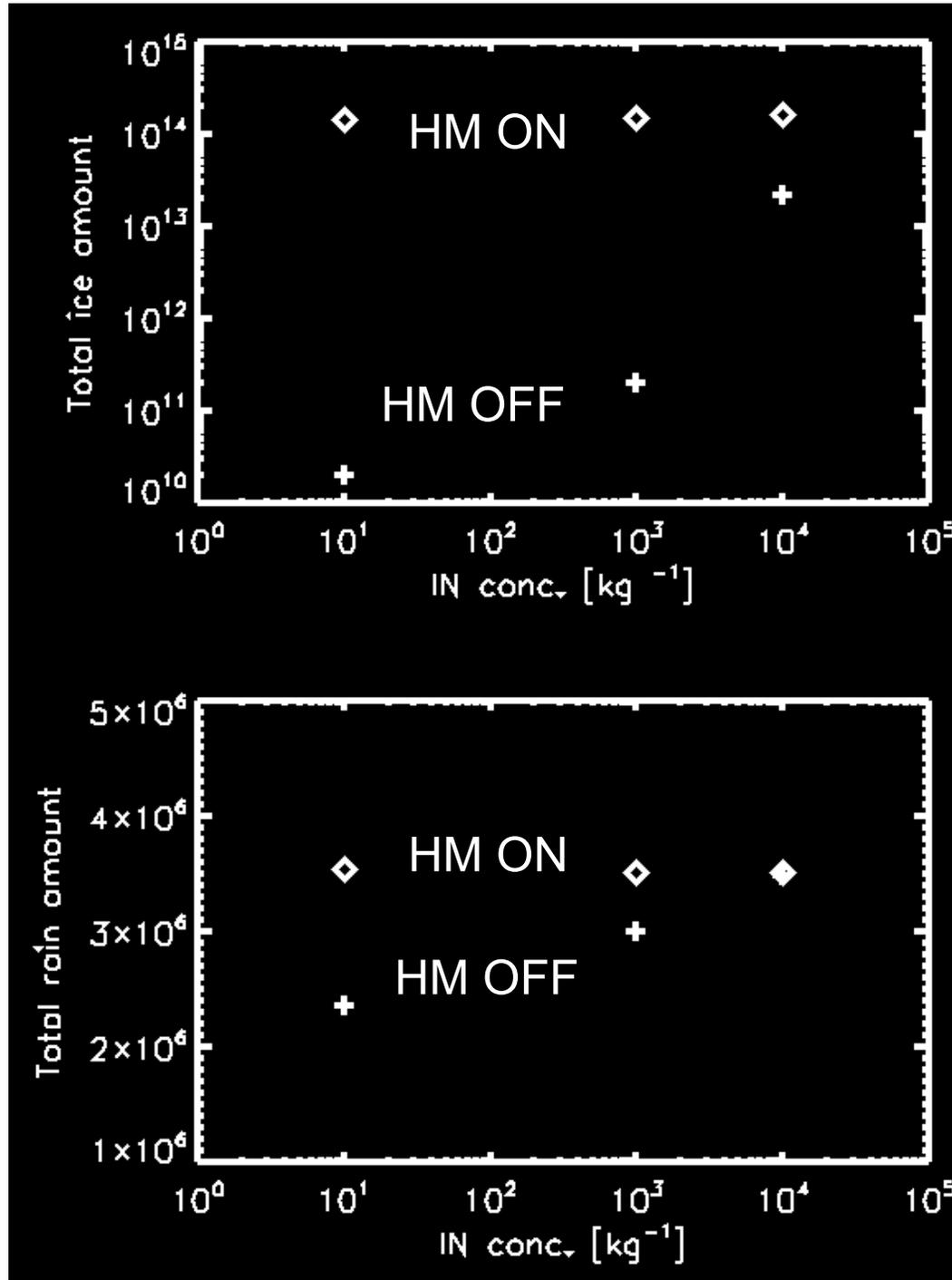


Hallett-Mossop ON

INconc=10 kg⁻¹

INconc=10⁴ kg⁻¹







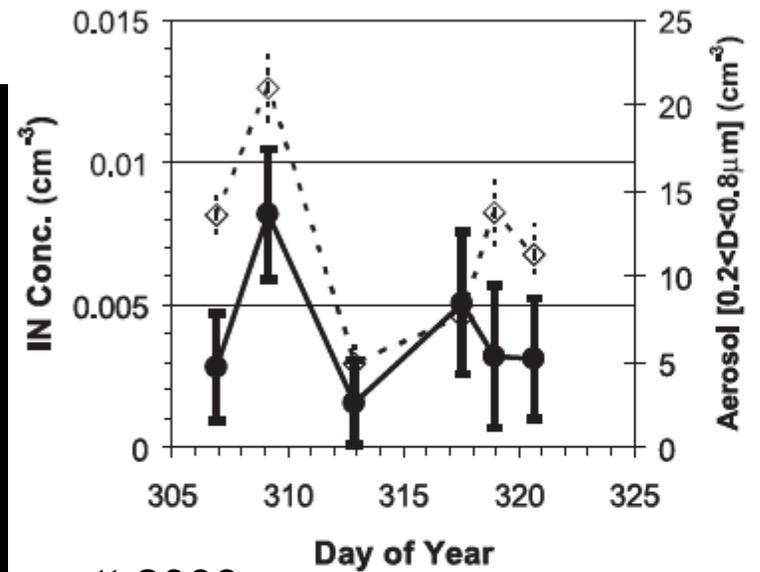
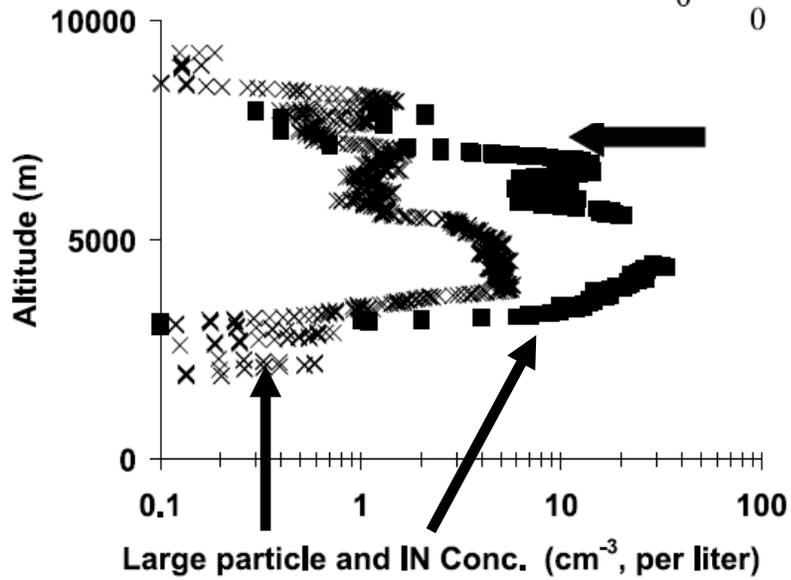
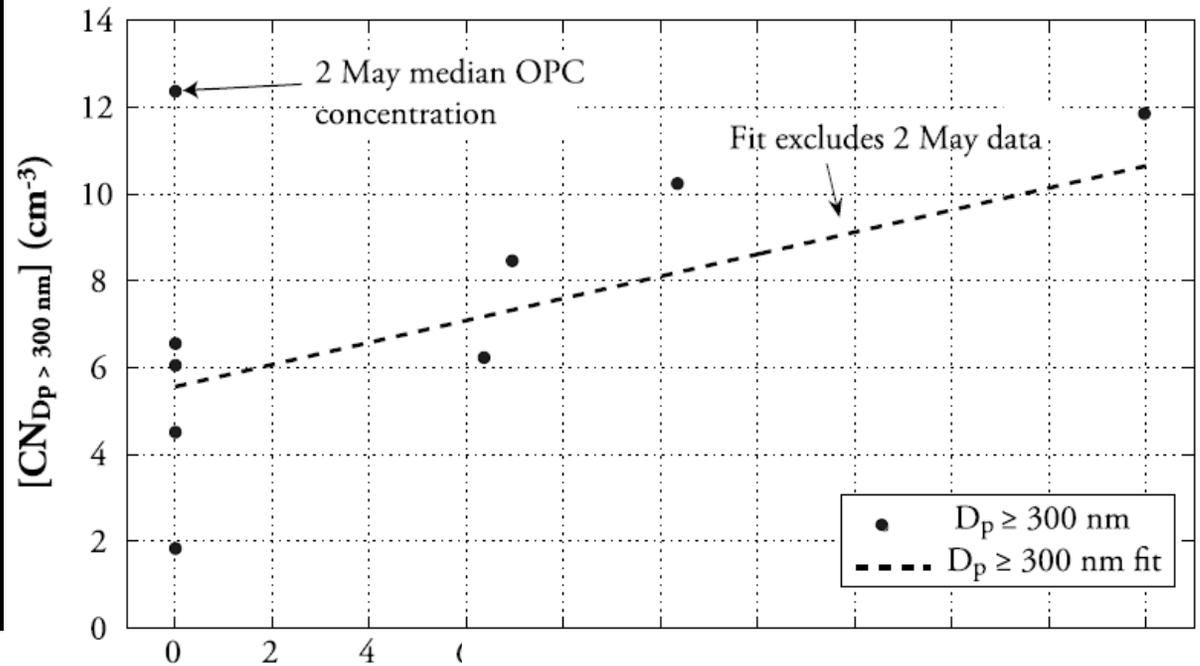
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Questions and answers

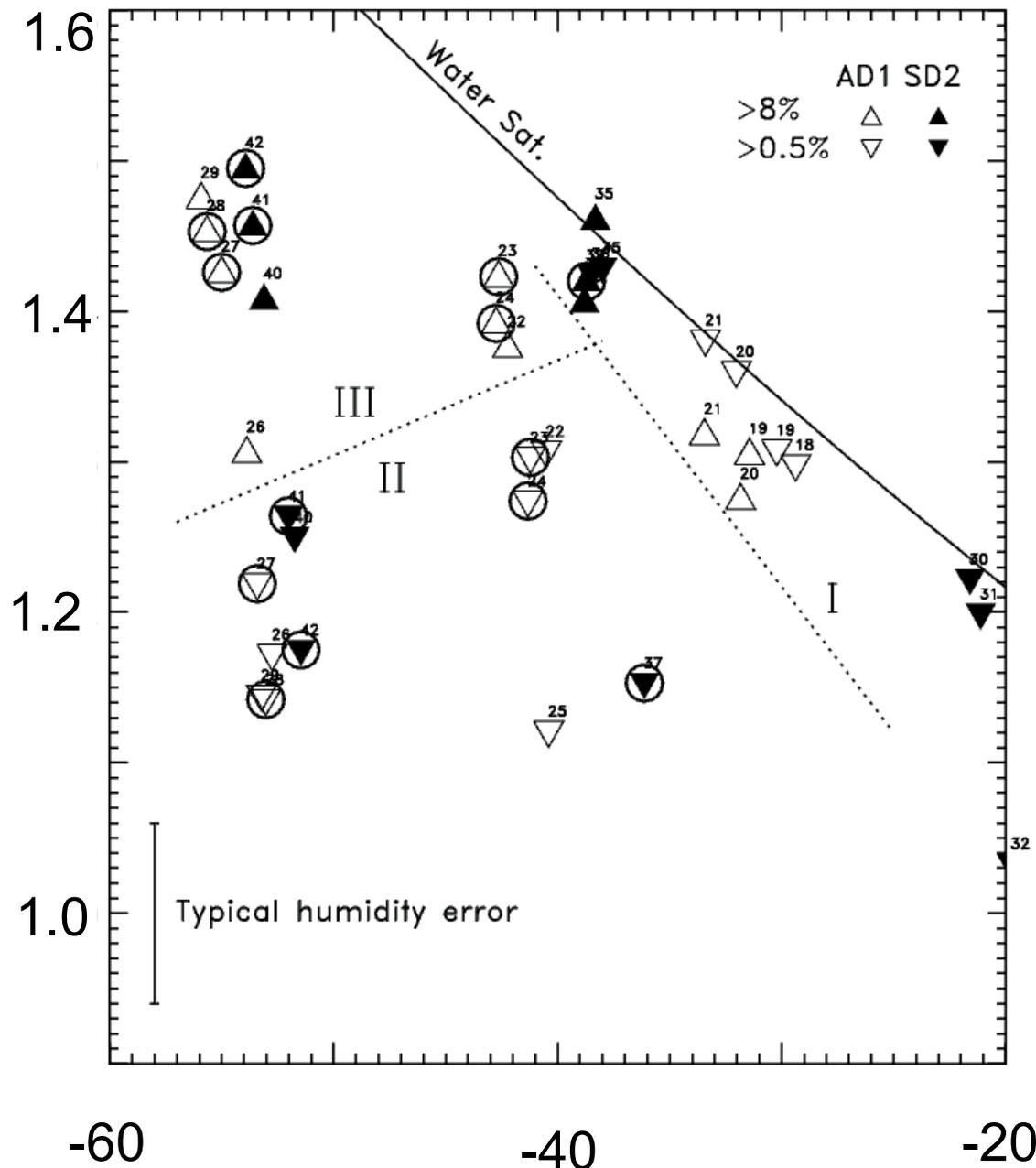


RICHARDSON ET AL.: INSPECT-II IN MEASUREMENTS





Critical ice saturation ratio

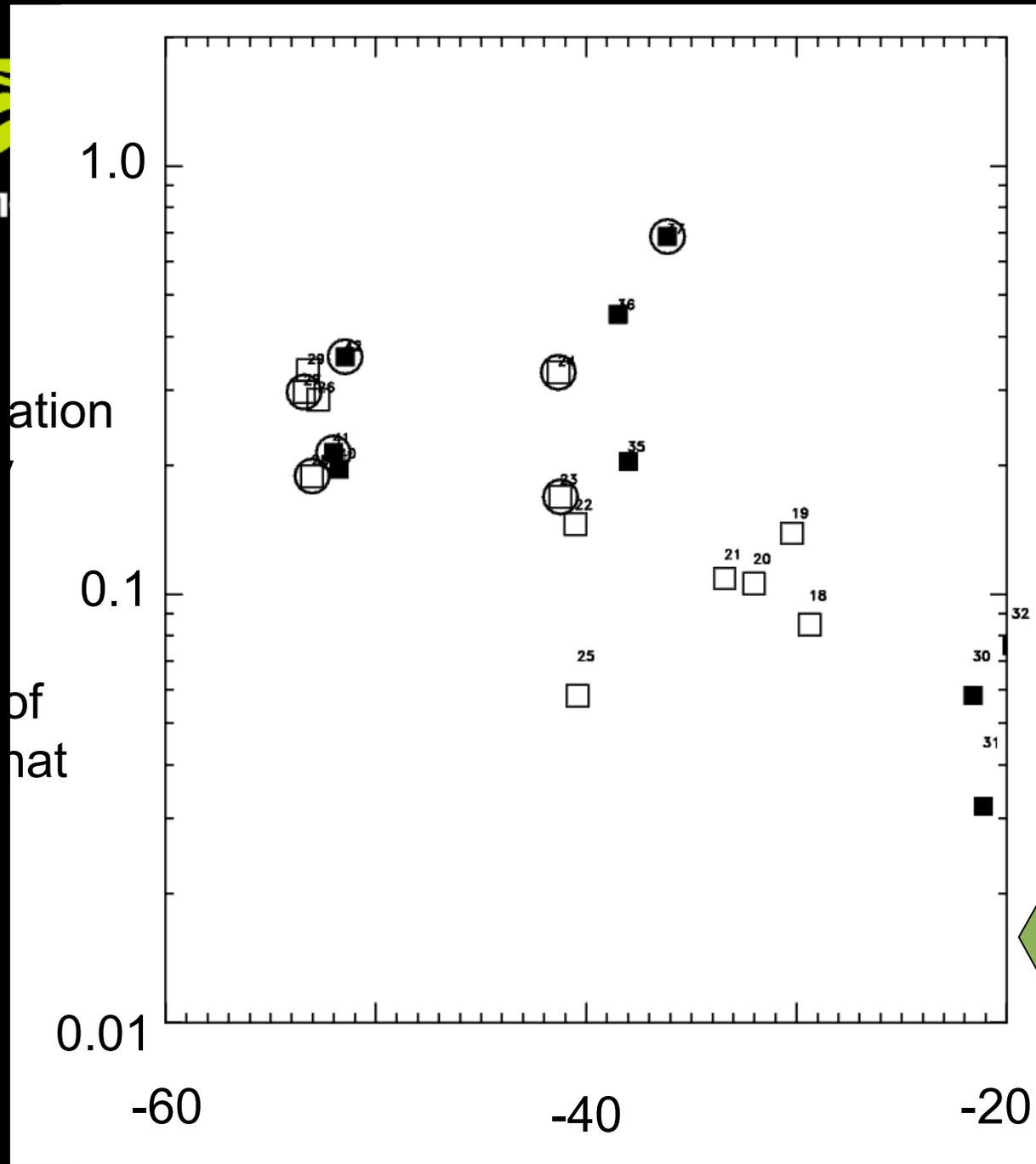


I – droplets form at the same time or before ice

II deposition

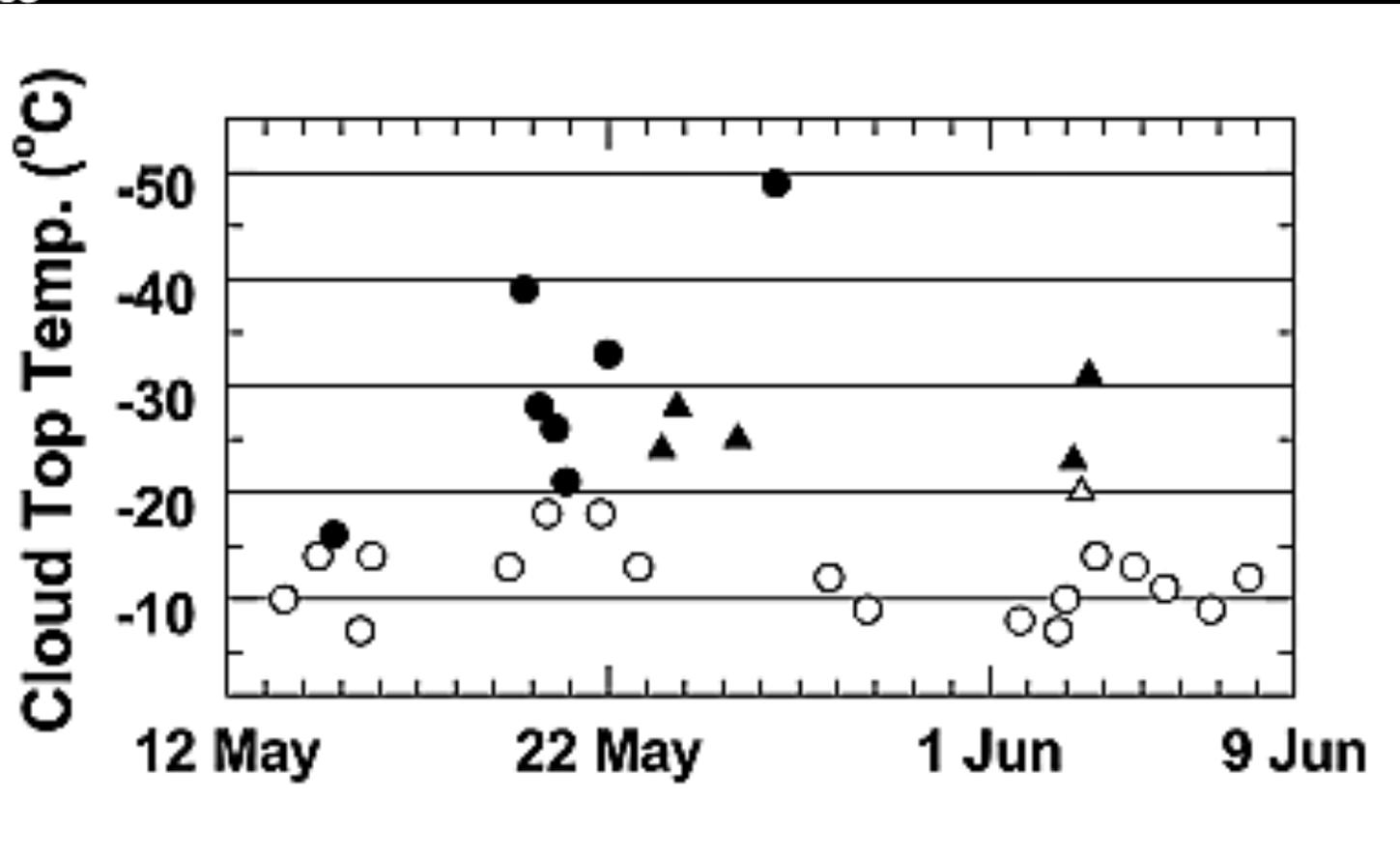
III – cond. fzg

Critical Temperature [°C]





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Recap

- IN concs. correlate with 'large' aerosol concs.
- Size proxy for aerosol type in these cases?
- $T > -38\text{C}$ condensation/immersion freezing is dominant for mineral dust
- $T > -20\text{C}$ not much freezing on mineral dust.