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Liquid vs. in-situ cirrus in Calipso/Cloudsat and ECHAM-HAM

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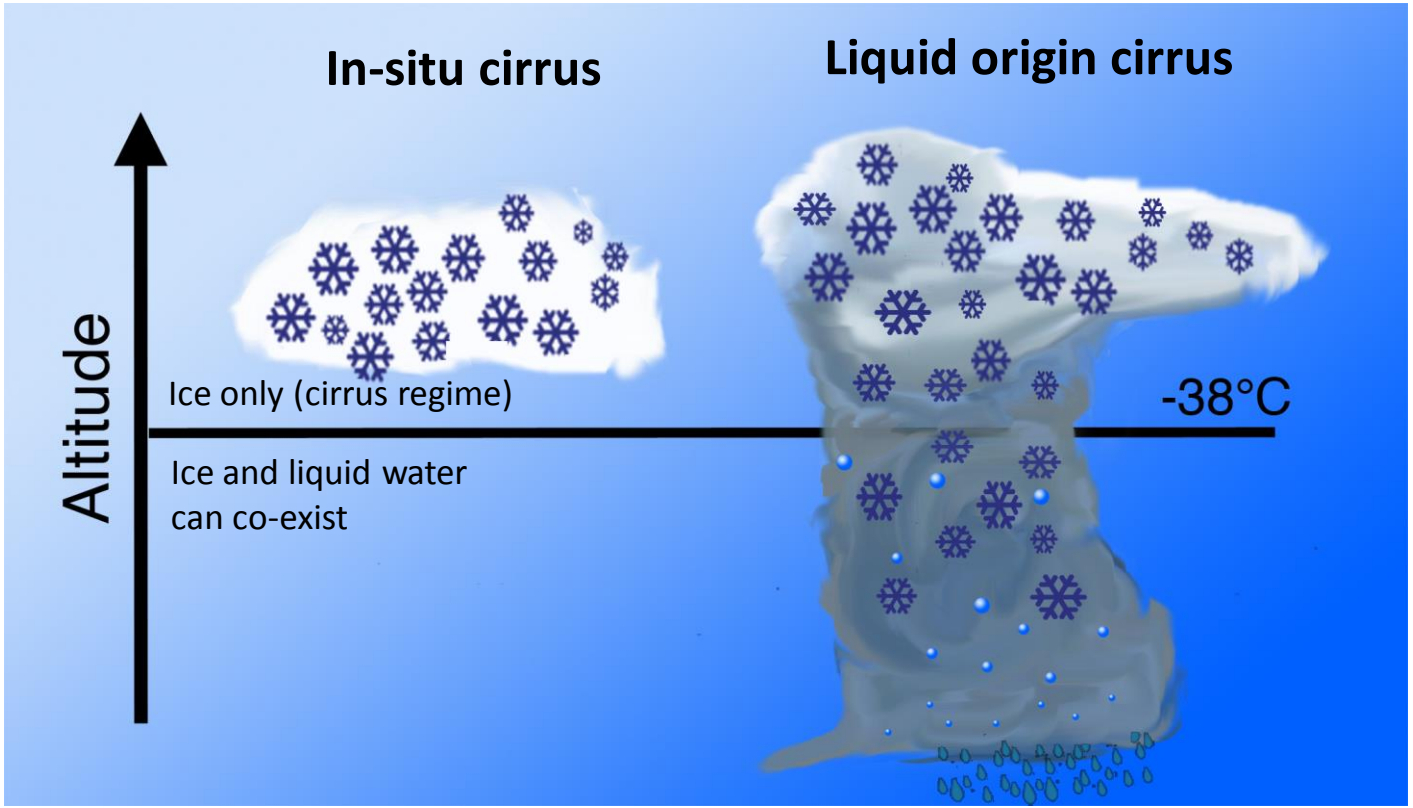
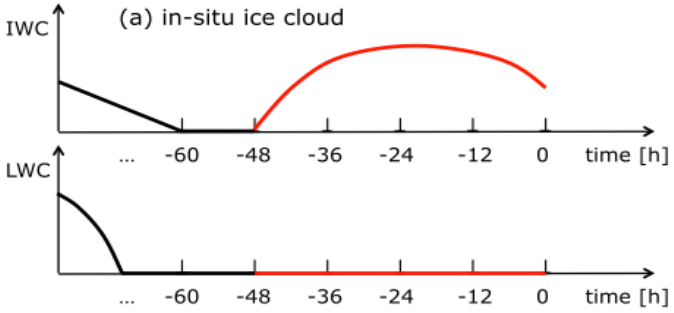
29th of Mar 2017

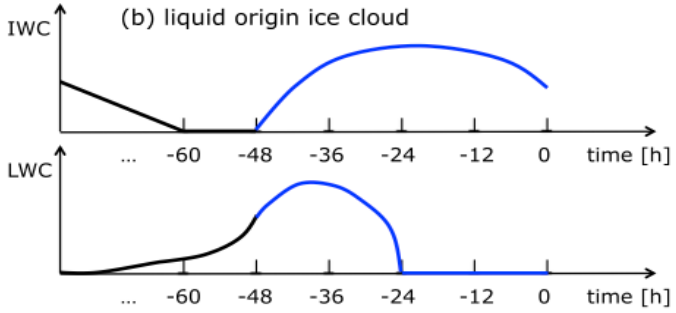
Liquid vs. in-situ origin cirrus

As defined by Krämer et al., 2016 and Luebke et al., 2016

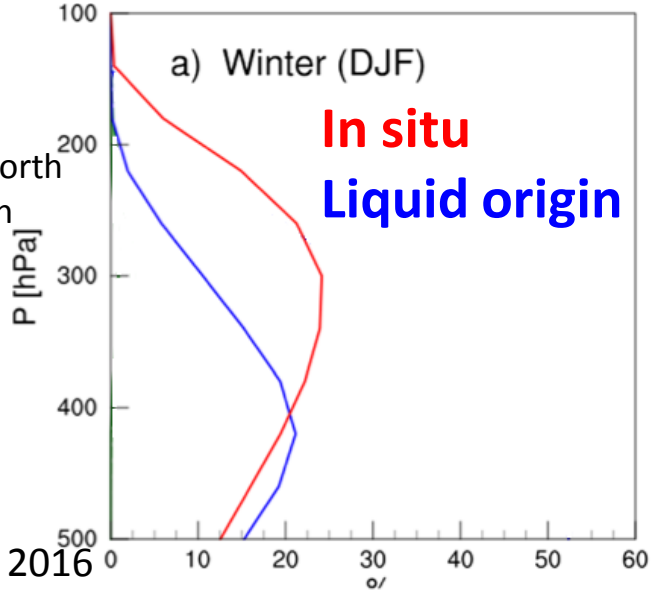


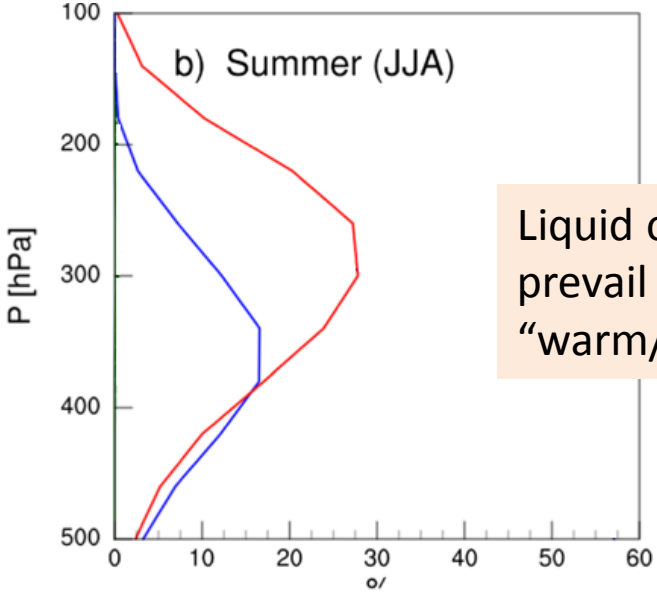
Midlatitudes





ERA-interim, trajectories, Europe and North Atlantic region

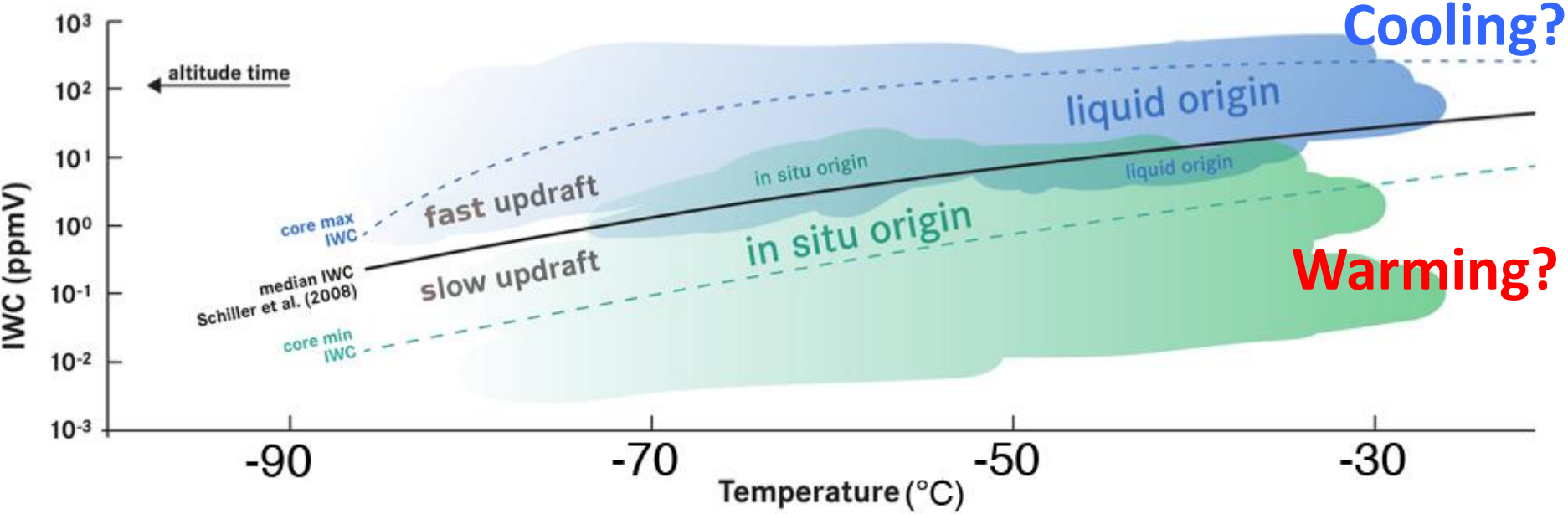




Liquid origin clouds prevail between "warm/low" cirrus

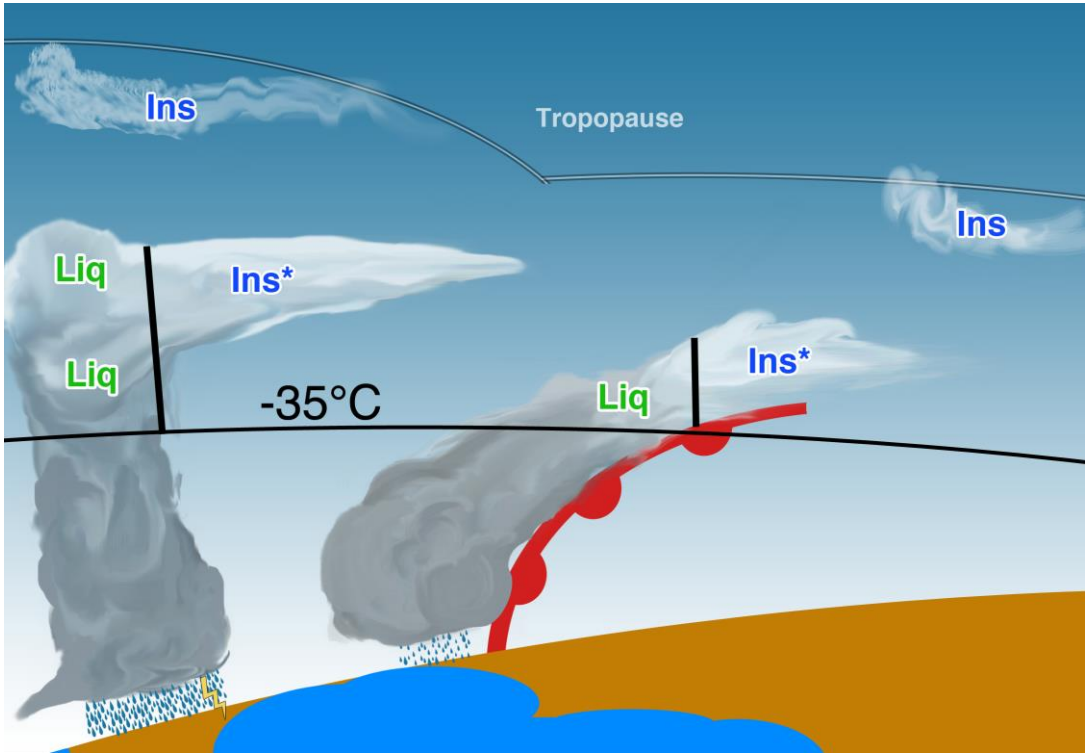
Wernli et al., 2016

They appear to be quite different as measured by aircraft observations

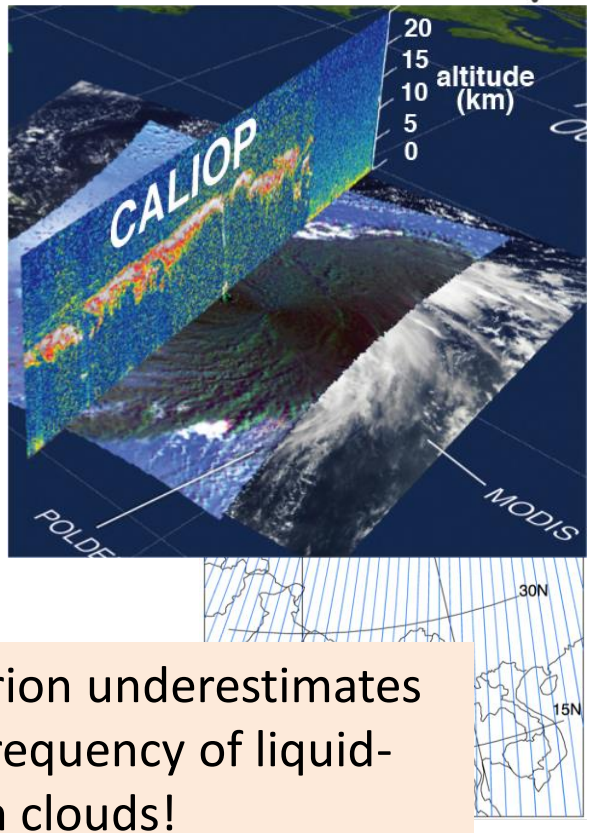


adapted from Luebke et al., 2016

Liquid vs. in-situ origin in Calipso satellite data



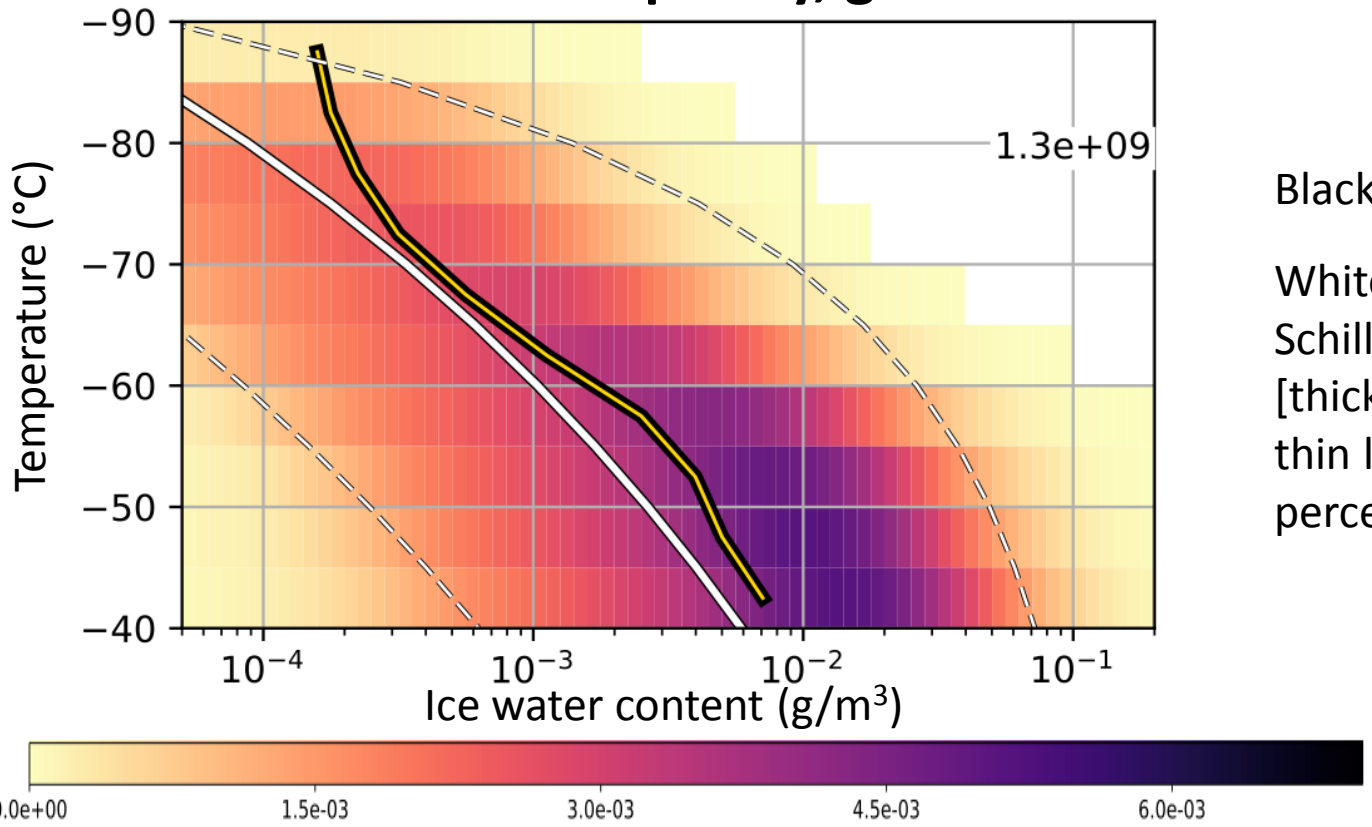
Defined cirrus as liquid origin when cloud base at T>-35°C



Criterion underestimates the frequency of liquid-origin clouds!

Liquid vs in-situ origin in Calipso satellite data

Gasparini et al., in review



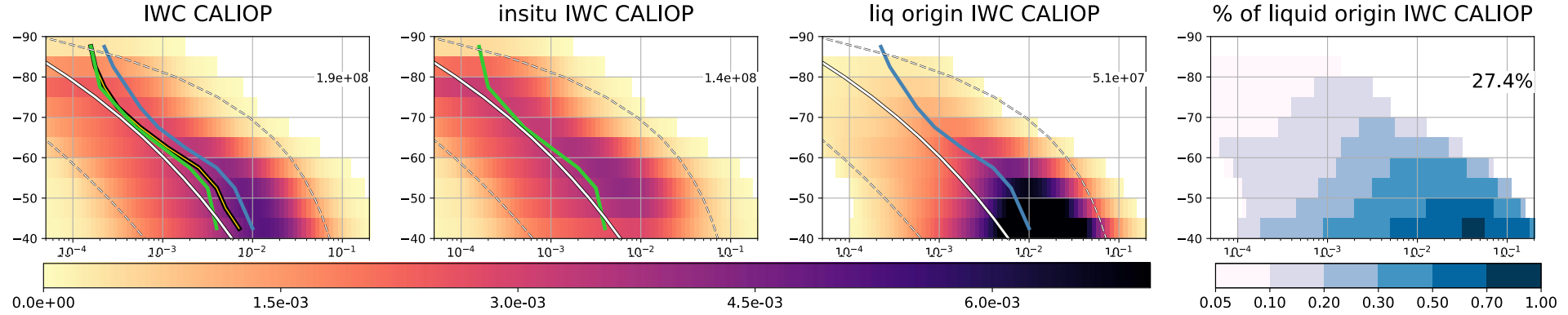
Black: median, CALIPSO data

White: aircraft observations, Schiller et al., 2008 [thick line = median, thin lines = 5 and 95 percentiles]

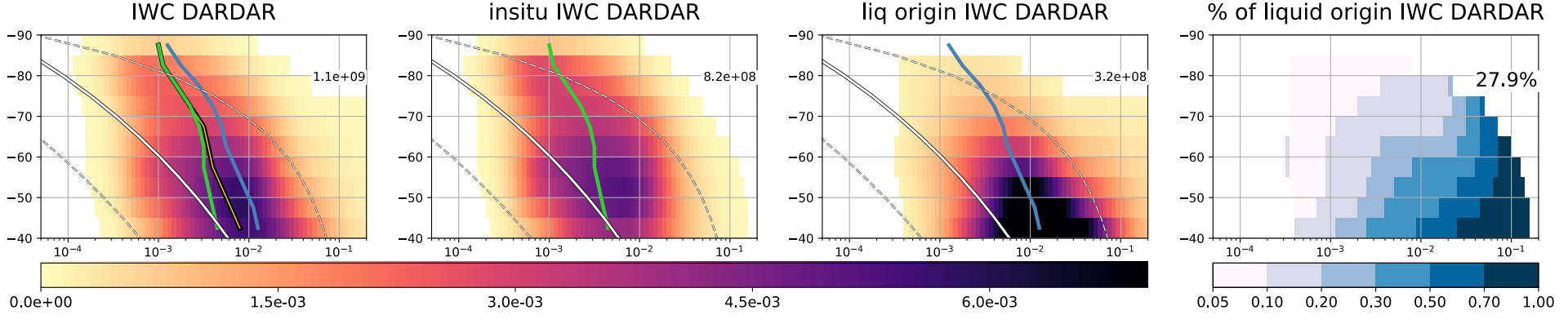
Liquid vs in-situ origin in Cloudsat satellite data

Gasparini et al., in review

1.) Calipso

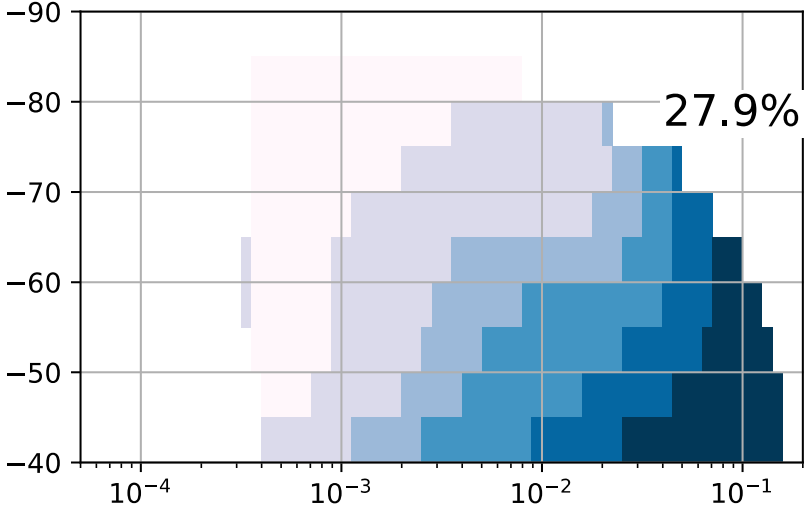


2.) DARDAR (calipso+cloudsat)

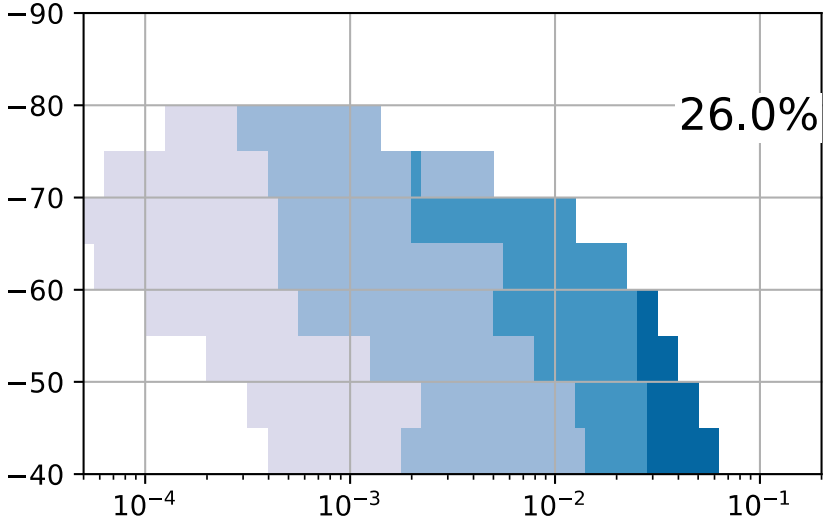


Liquid vs in-situ origin in CALIPSO and ECHAM-HAM

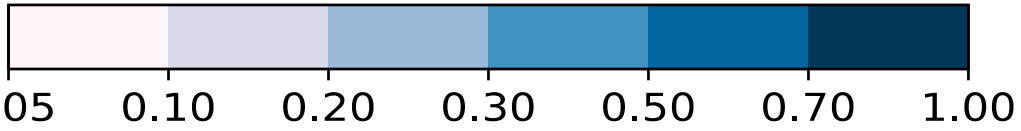
DARDAR



ECHAM-HAM

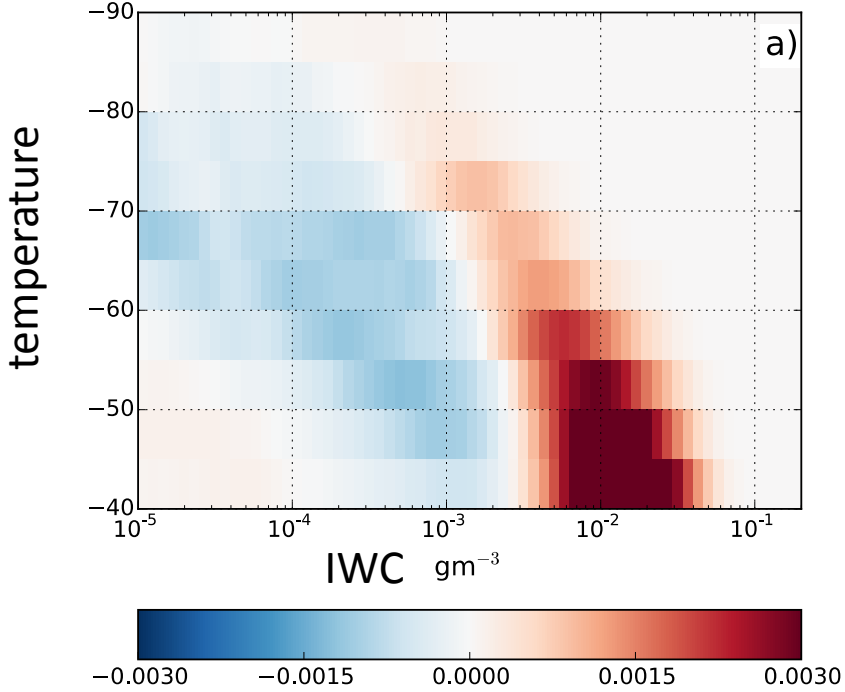


Gasparini et al., in review



Same message when we “turn off” liquid origin cirrus in the model

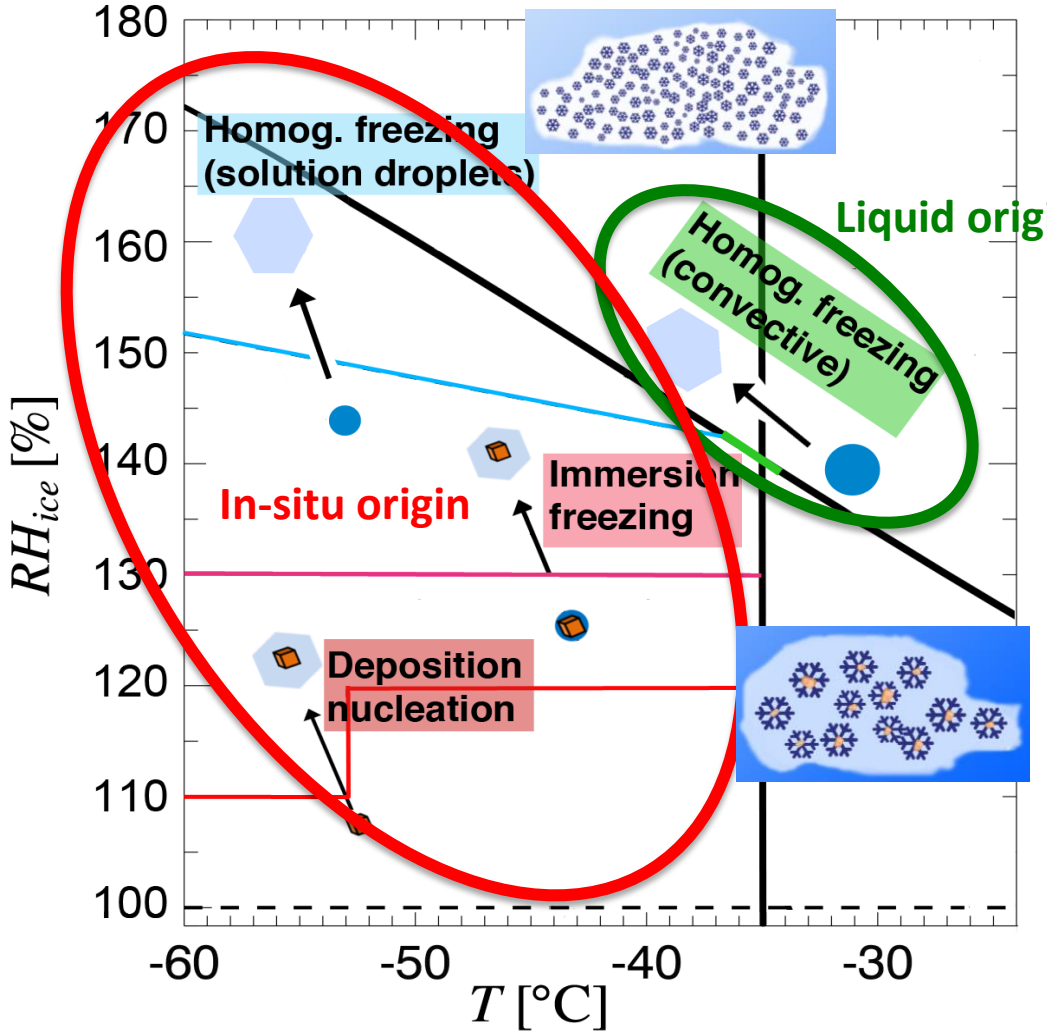
IWC frequency anomaly:
FULL model – NO liquid origin model



- Cirrus can form only by in-situ nucleation
- No detrained or advected cirrus from mixed-phase

Red => liq-origin dominated
Blue => in-situ origin dominated

Confirms the previous result and the usefulness of the liquid origin cloud criteria

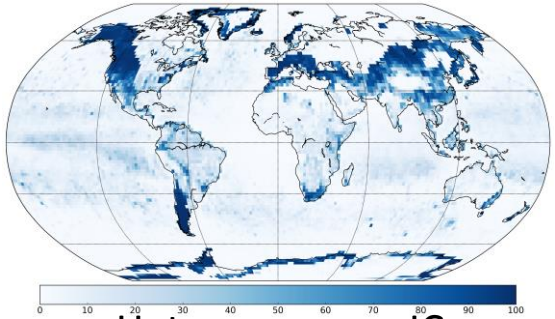


Cirrus cloud formation in ECHAM-HAM

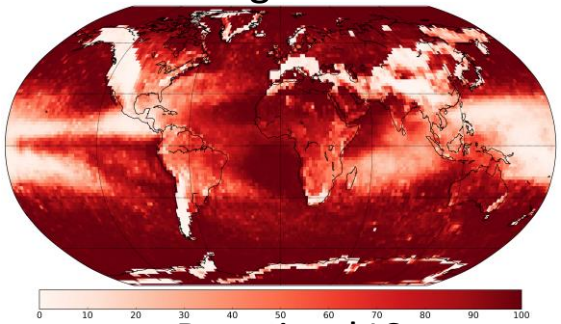
ECHAM-HAM

- General circulation model
- 1.875 x 1.875° resolution (200 km at equator)
- 31 vertical levels till 10 hPa (30 km)
- Vertical resolution at cirrus level 500-1000 m

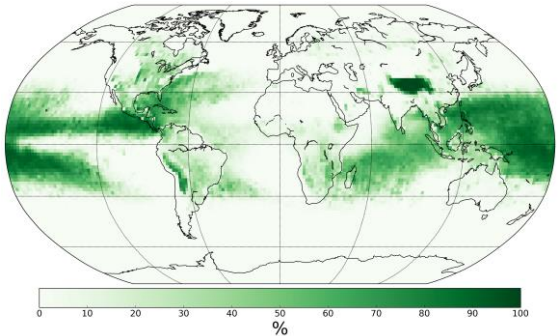
Homogeneous IC



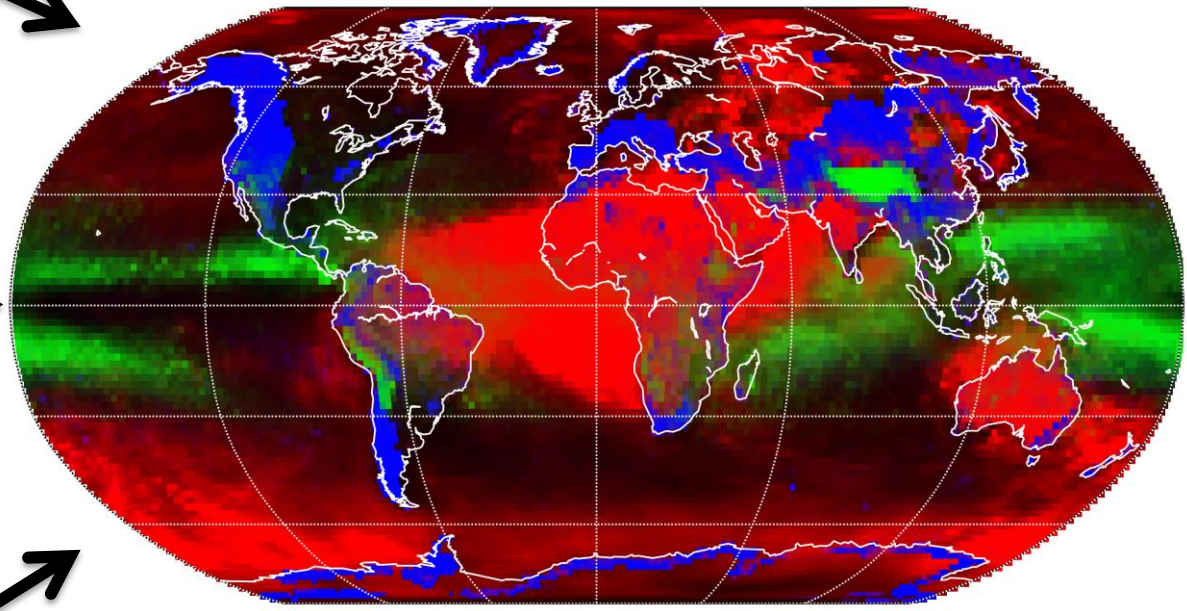
Heterogeneous IC



Detrained IC

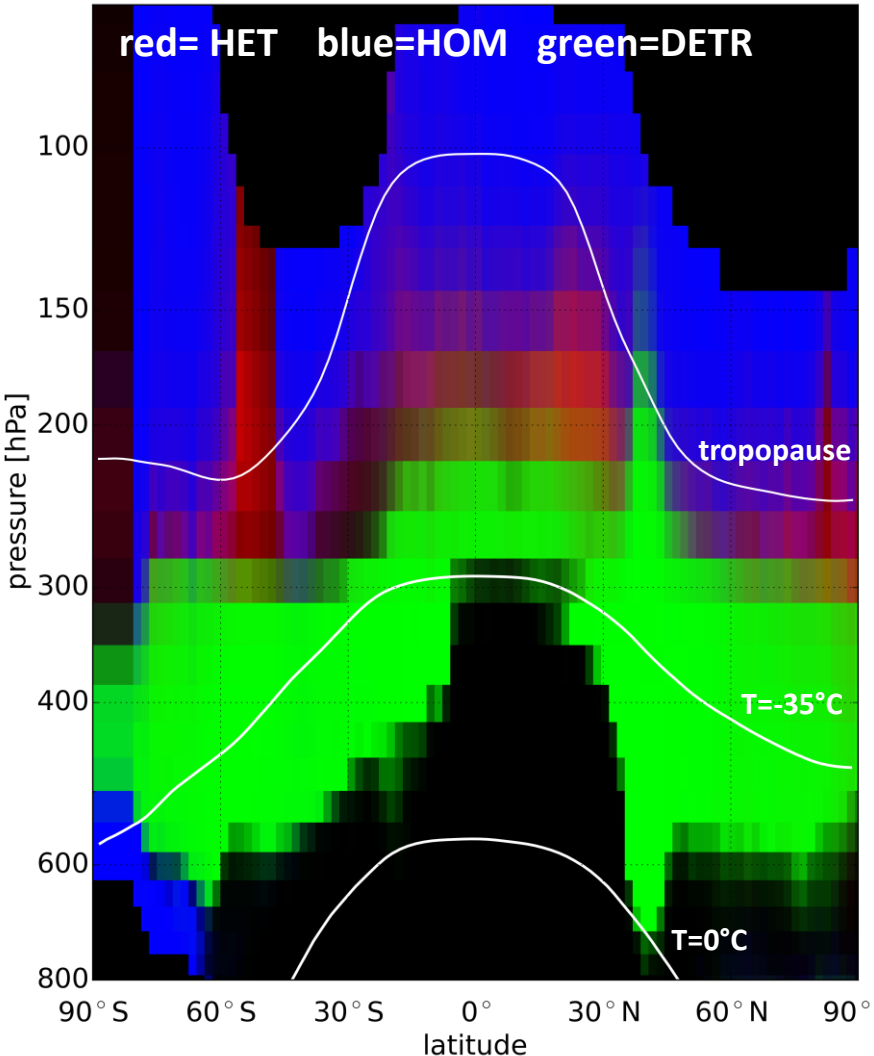


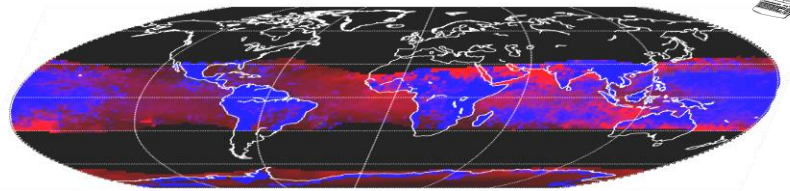
Source of ice crystals at 200 hPa

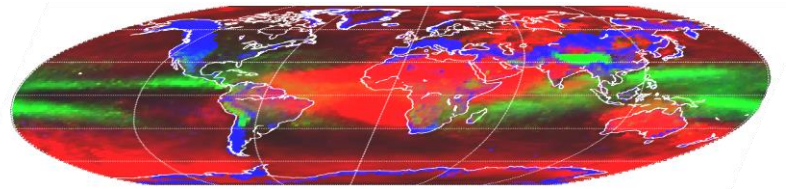


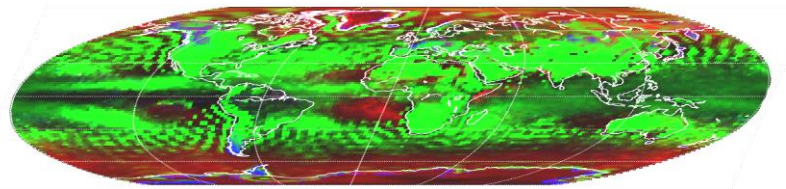
In-cloud values, shaded for areas with less than 8 IN/l

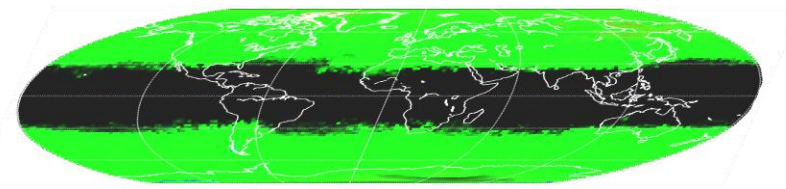
Gasparini and Lohmann, 2016



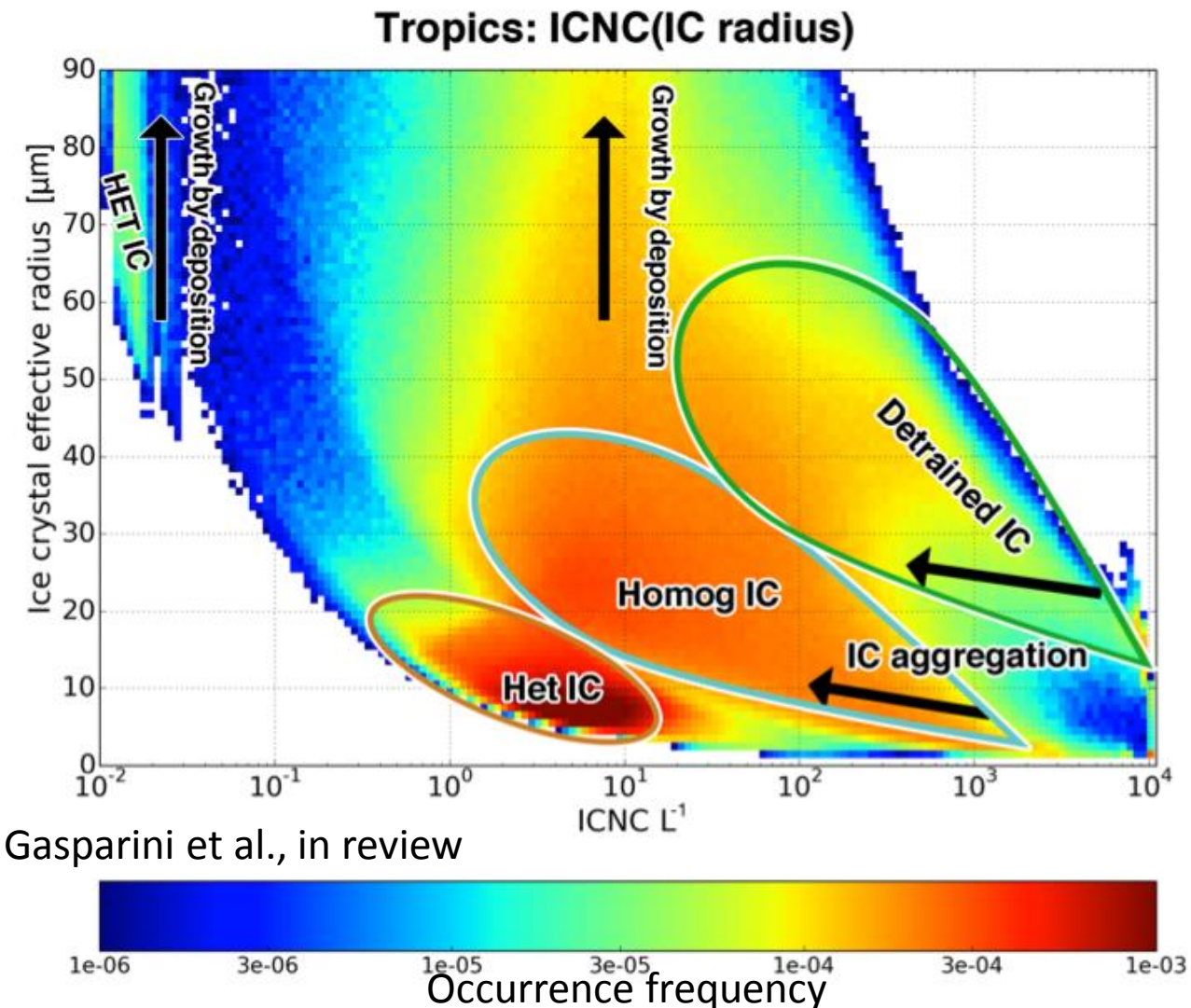








Homogeneous freezing is only important at higher altitudes and in mountainous regions



Gasparini et al., in review

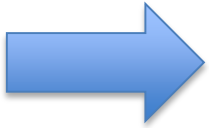
Cirrus (T<-40°C) ice crystal lifecycle?

- Detrained vs in-situ formed can be separated relatively well
- HOM vs HET – not that easy

Are liquid-origin cirrus really cooling the climate?

Temp [°C]	cCRE [W m^{-2}]	percentage [%]
-35	4.35	100
-40	3.42	79
-45	2.49	57
-50	1.73	40
-55	1.22	28
-60	0.83	19
-65	0.53	12
-70	0.34	8

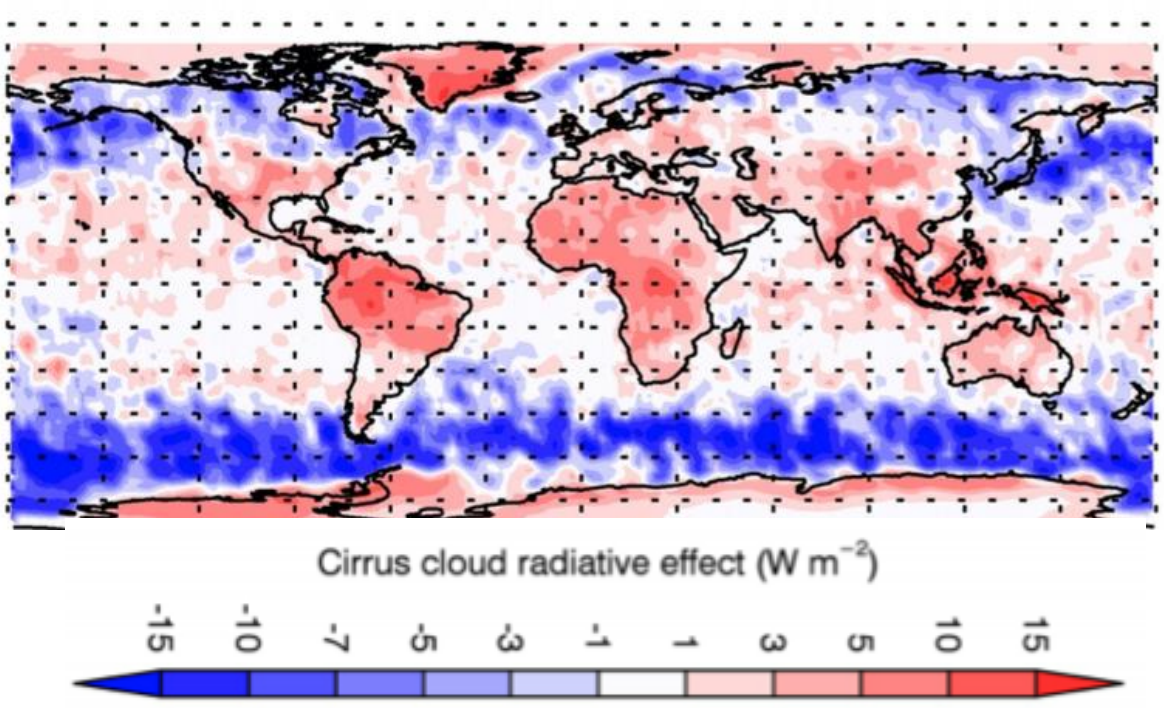
Gasparini et al., ACPD



Temp. [°C]	Approximate liq origin fraction	radiative effect [W/m^2]
-35 to -45	60%	1.9
-45 to -55	45%	1.3
-55 to -65	25%	0.7
Colder than -65	10%	0.5

Liquid origin cirrus warm the climate!

Radiative effects of clouds with top at T<-35°C and base at T>-35°C (2C-ICE)



Net full-sky CRE [W/m^2]	
DARDAR	2C-ICE
1.8	0.3

Courtesy **Yulan Hong**, Florida State University

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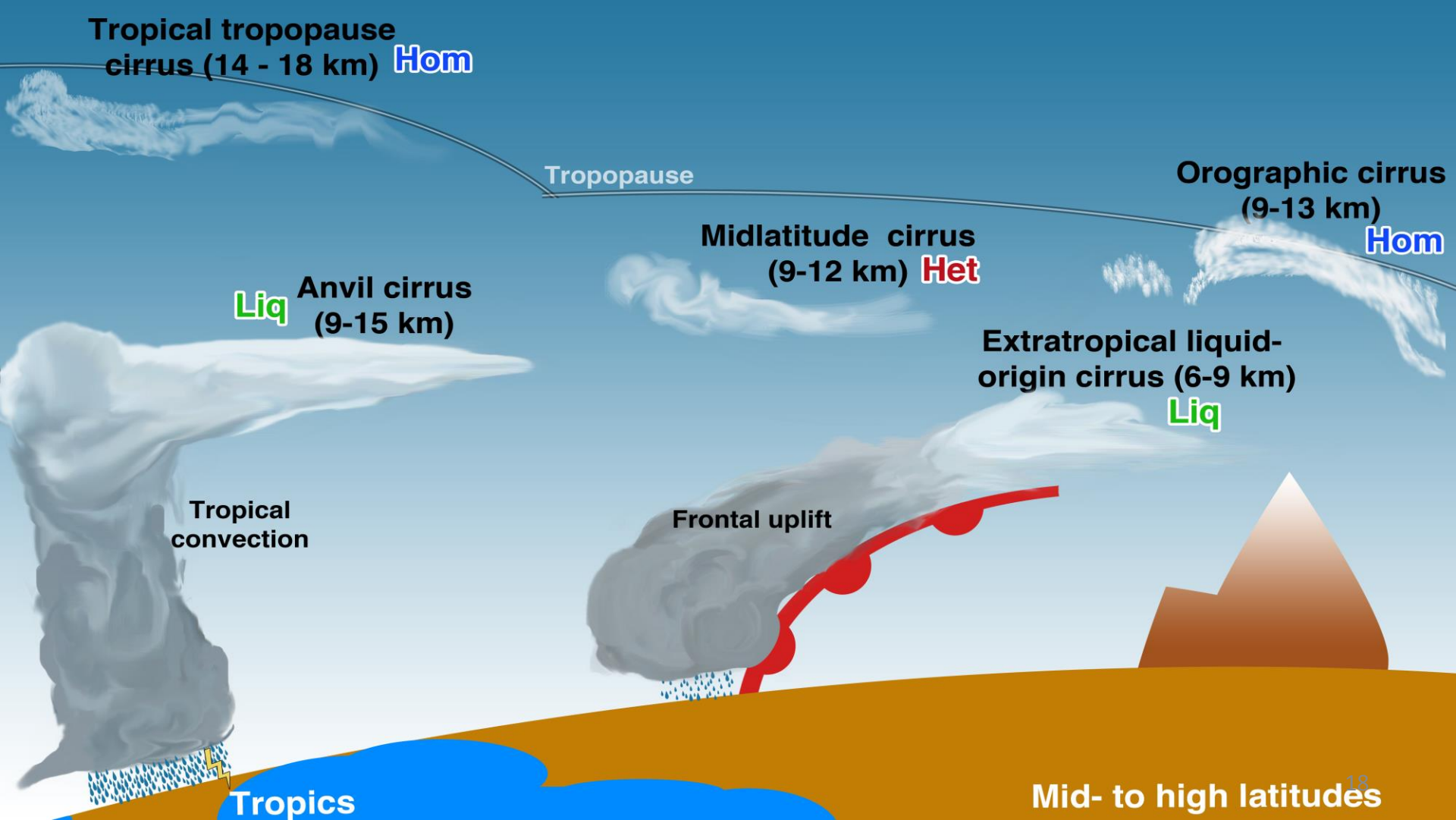
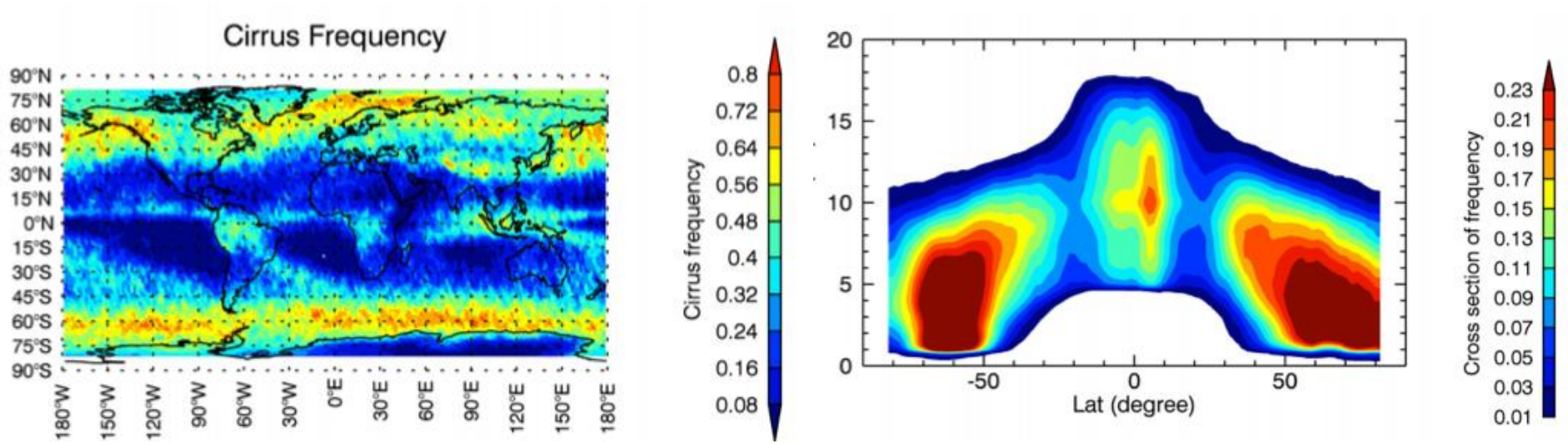
Conclusions

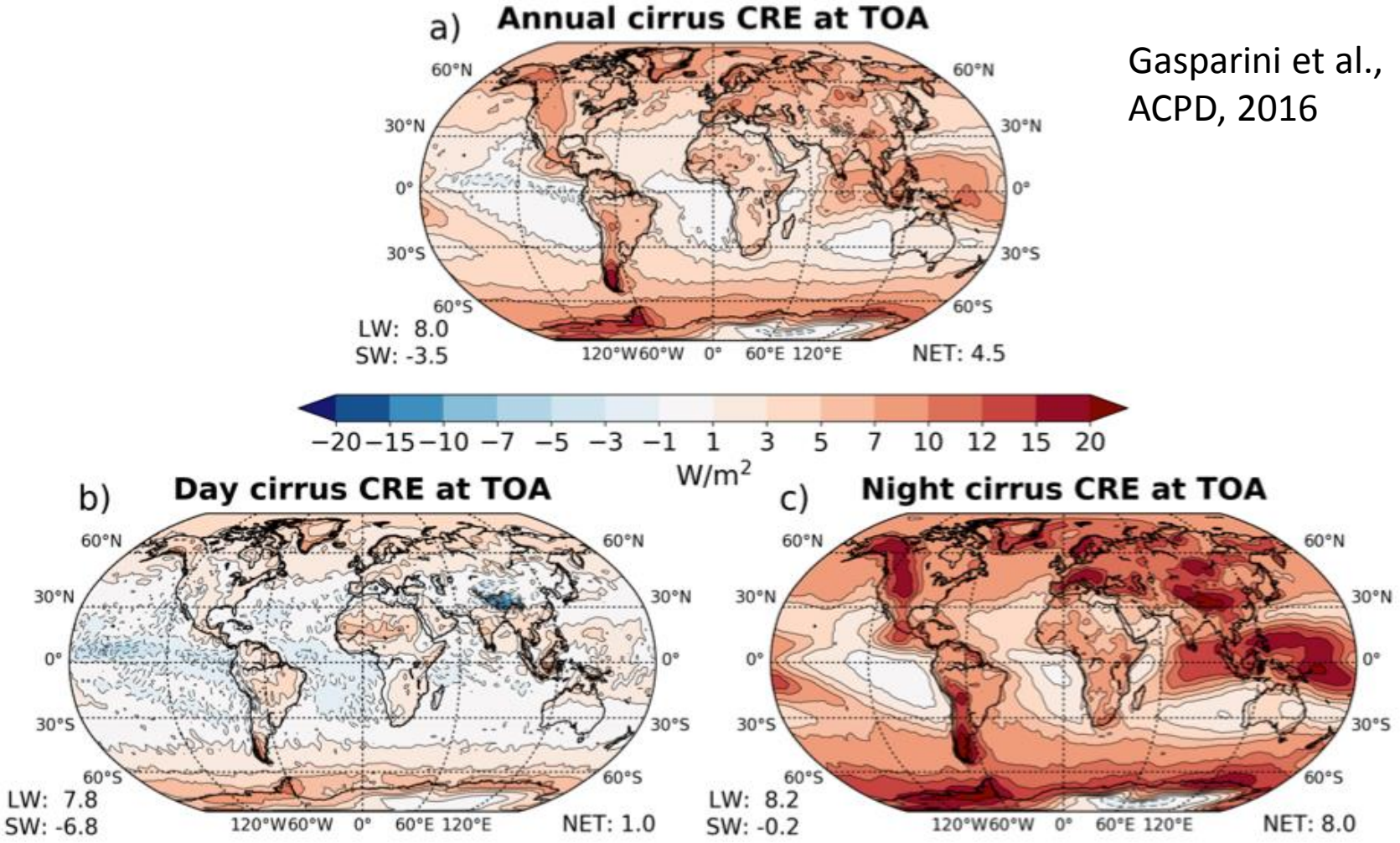
1. About 25-30% of cirrus clouds can be classified as liquid origin
2. They have a significantly higher IWC compared to in-situ origin cirrus
3. Liquid origin cirrus warm the climate based on ECHAM-HAM GCM and Calipso/Cloudsat data


Tropical tropopause cirrus (14 - 18 km)
Hom
Tropopause
Orographic cirrus (9-13 km)
Hom
Midlatitude cirrus (9-12 km)
Het
Liq
Anvil cirrus (9-15 km)
Extratropical liquid-origin cirrus (6-9 km)
Liq
Tropical convection
Frontal uplift
Tropics
Mid- to high latitudes

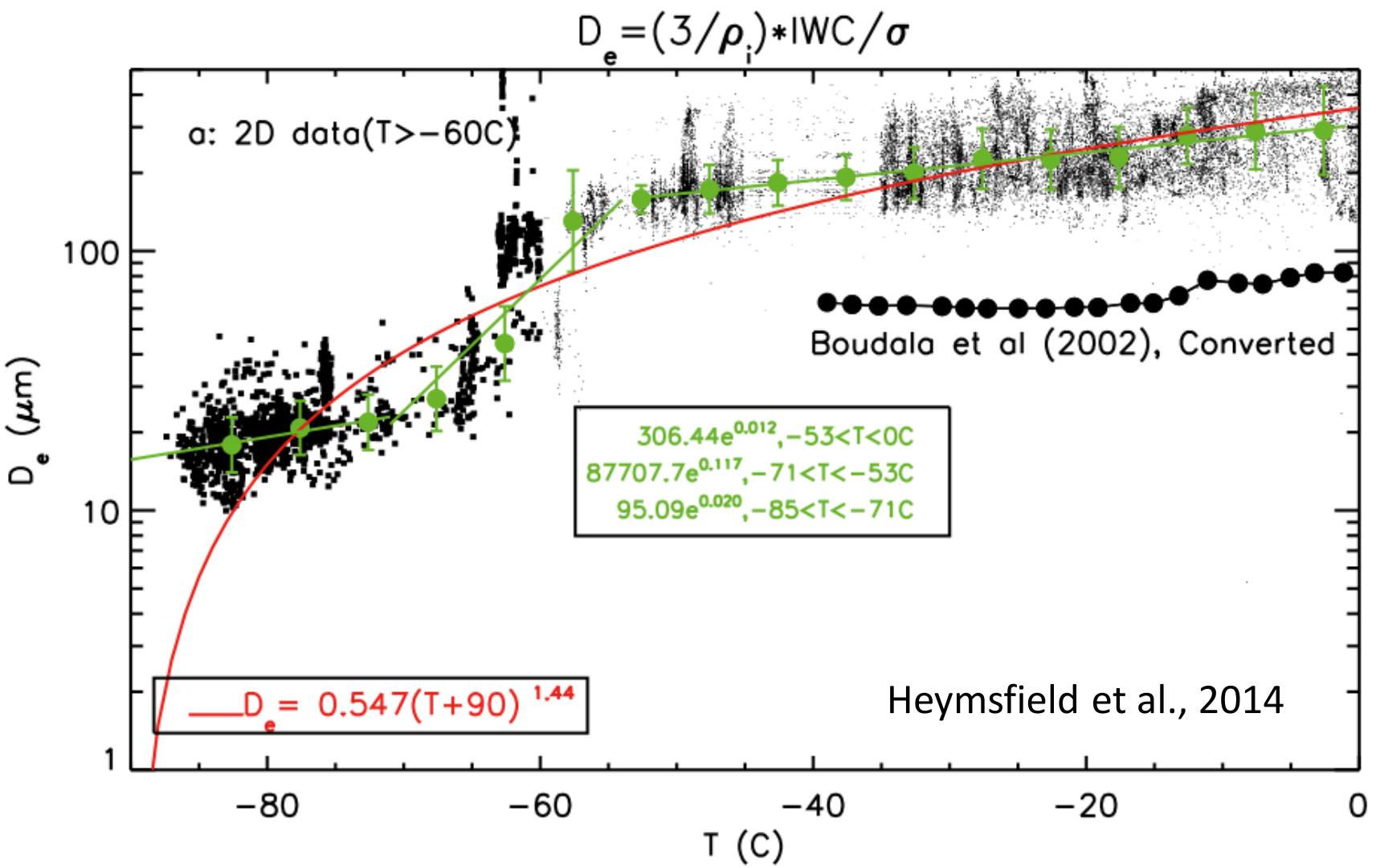
Radiative effects of clouds with top at T<-35°C and base at T>-35°C (2C-ICE)

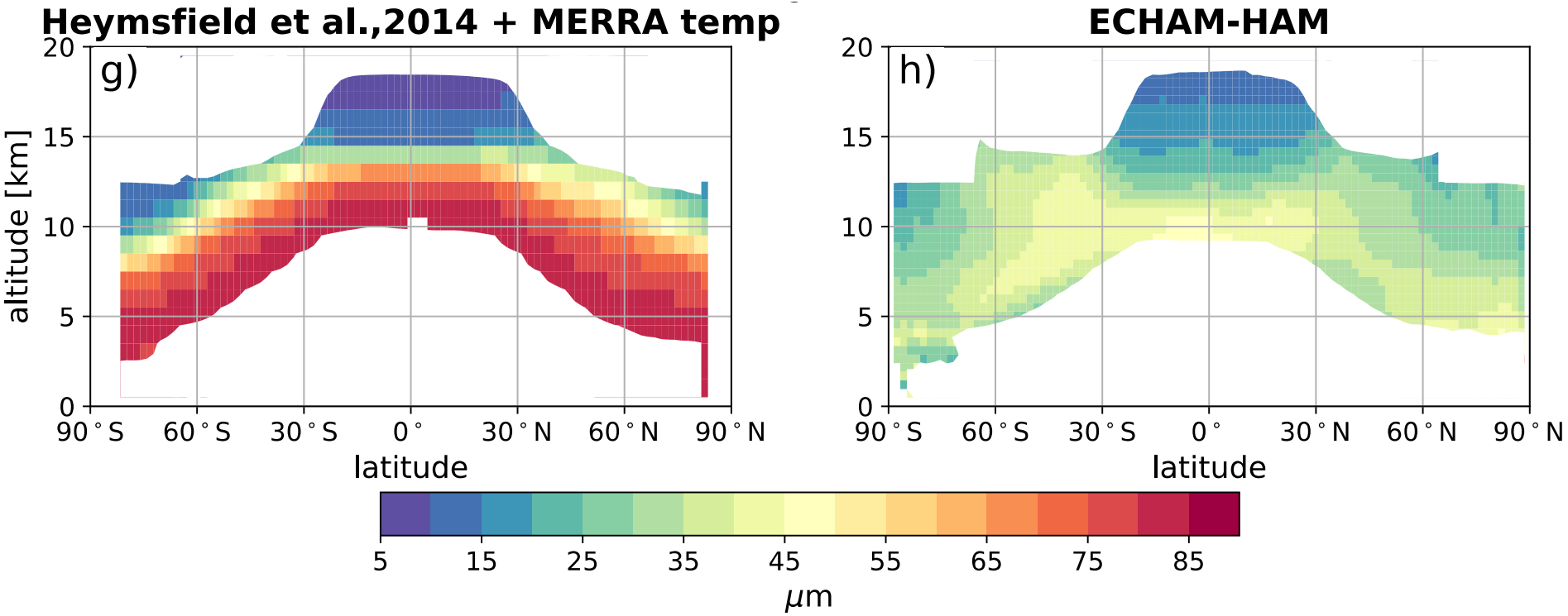


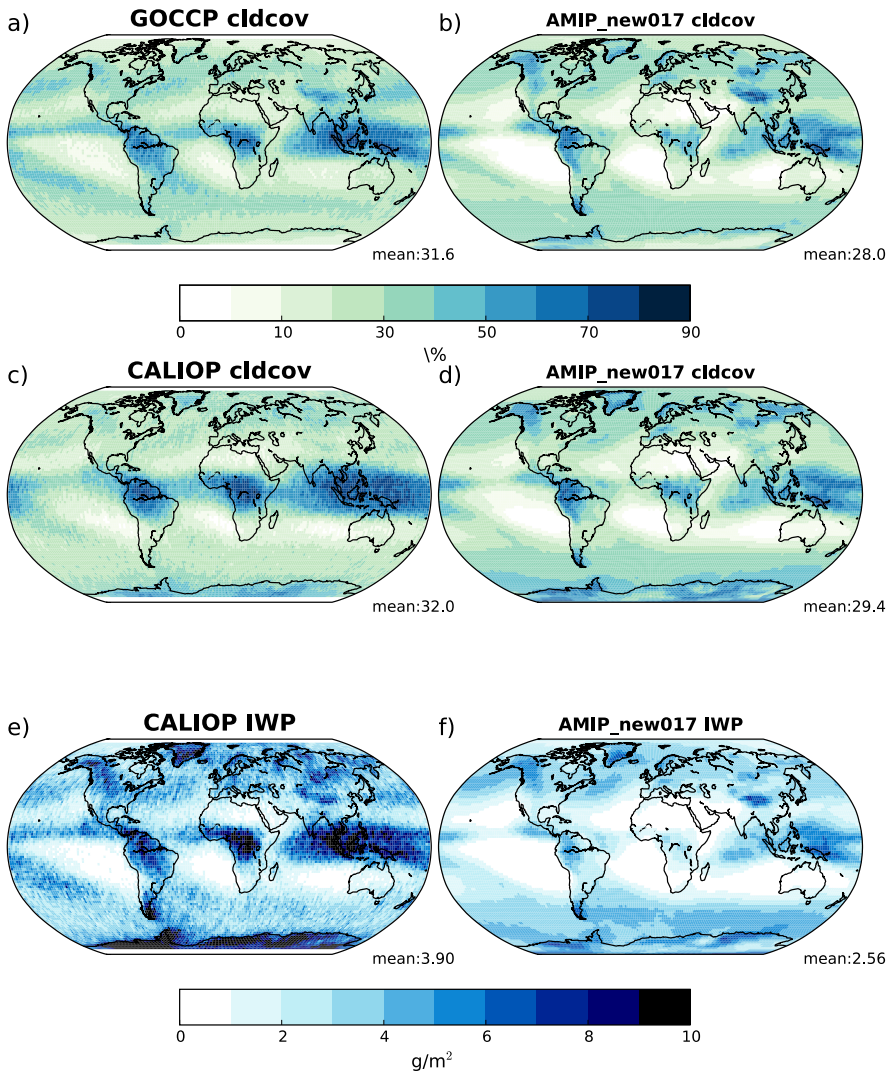
Courtesy **Yulan Hong**, Florida State University



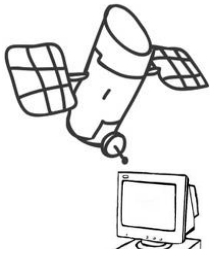
Gasparini et al., ACPD, 2016


$D_e = (3/\rho_i) * IWC/\sigma$
a: 2D data(T>−60C)
Boudala et al (2002), Converted
306.44e^0.012,−53<T<0C
87707.7e^0.117,−71<T<−53C
95.09e^0.020,−85<T<−71C
$D_e = 0.547(T+90)^{1.44}$
Heymsfield et al., 2014
D_e (μm)
100
10
1
−80
−60
−40
−20
0
T (C)


Heymsfield et al.,2014 + MERRA temp
ECHAM-HAM
g)
h)
altitude [km]
20
15
10
5
0
90 ° S
60 ° S
30 ° S
0 °
30 ° N
60 ° N
90 ° N
latitude
5
15
25
35
45
55
65
75
85
μm

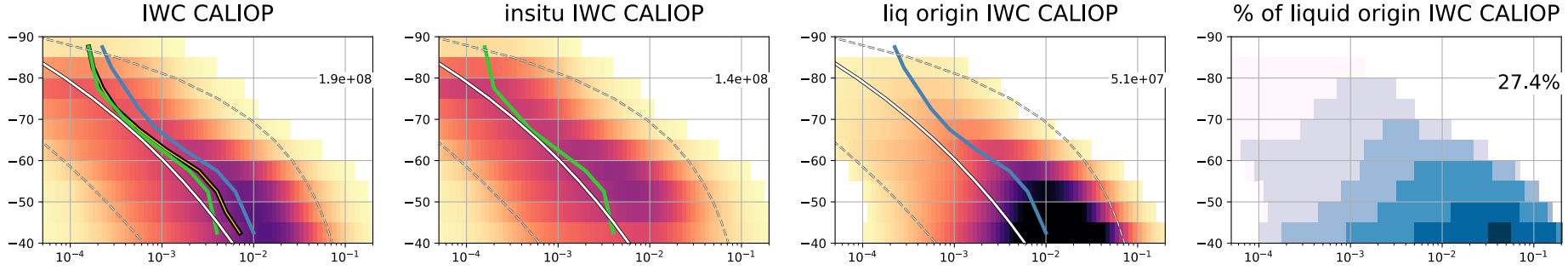

a)
GOCCP cldcov
b)
AMIP_new017 cldcov
mean:31.6
mean:28.0
0
10
30
50
70
90
\%
c)
CALIOP cldcov
d)
AMIP_new017 cldcov
mean:32.0
mean:29.4
e)
CALIOP IWP
f)
AMIP_new017 IWP
mean:3.90
mean:2.56
0
2
4
6
8
10
g/m^2

Liquid vs in-situ origin in Calipso and ECHAM-HAM

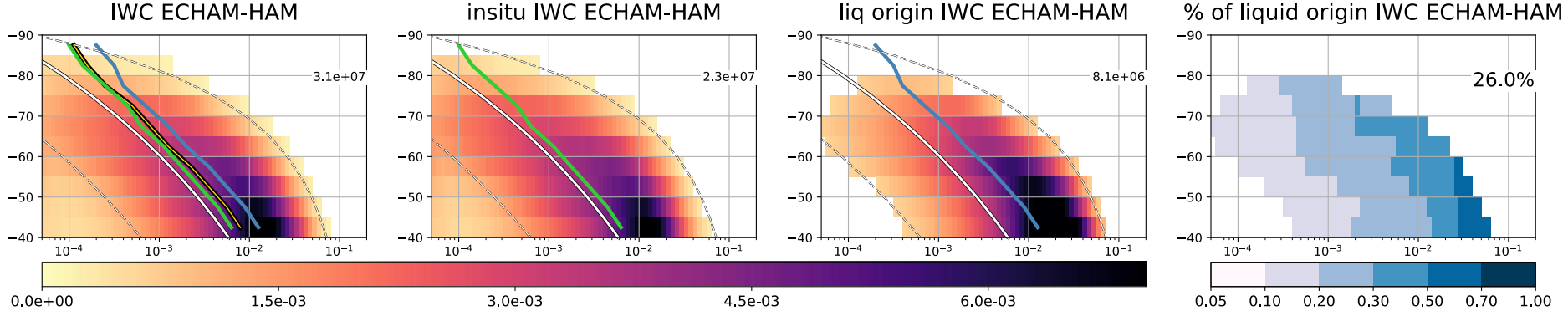


1.) Calipso only

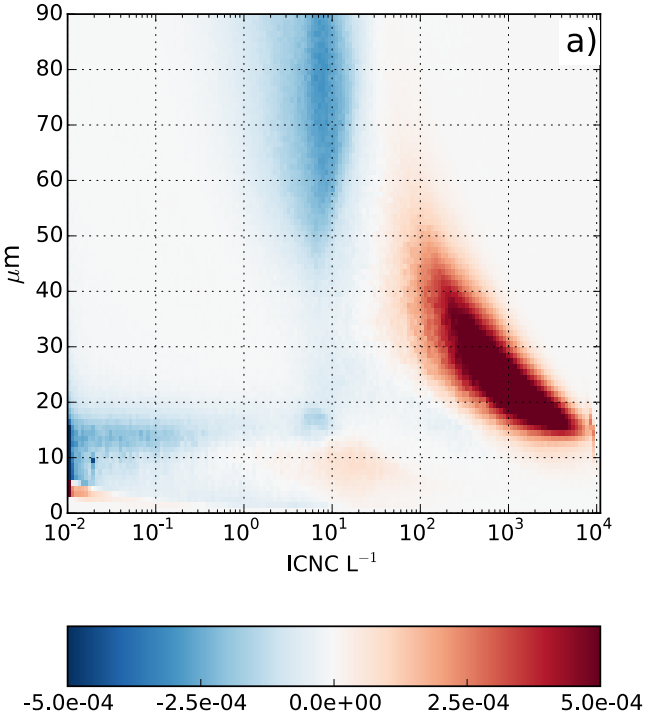
Gasparini et al., in review



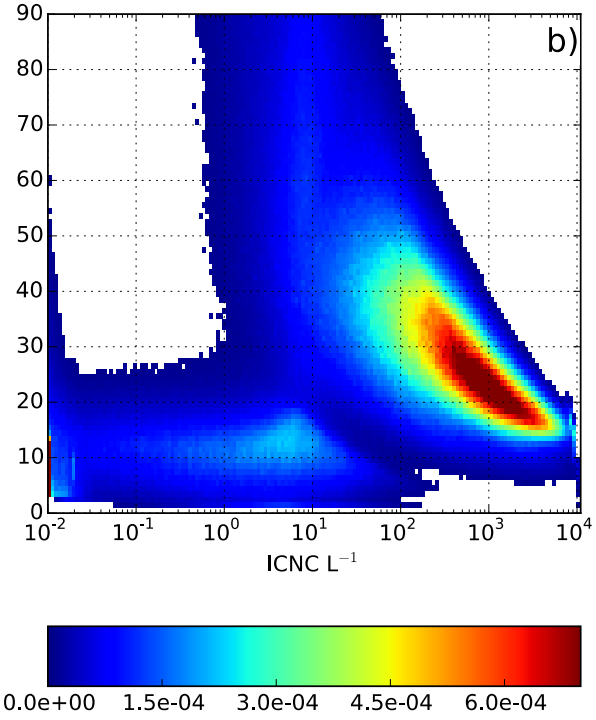
2.) ECHAM-HAM



ref017 FULL-NOLIQ Global ICNC(REFFI)



ref017 FULL Global ICNC(REFFI)



ref017 NOLIQ Global ICNC(REFFI)