Presented by

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Prepared by

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Important inputs from

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IWC from RASTA cloud radar observations

HIWC RASTA Objectives

1. Estimate all relevant convective cloud parameters using RASTA driven by the other measurements (PSD, IKP, Robust, in-situ winds) :

   - Convective cloud top height, vertical distribution
   - 3D dynamics on vertical cross-sections (including vertical air velocity W)
   - Ice microphysics : ice fall speed V_T, IWC, visible extinction, R_{eff}, N_T

2. Characterize the unique dynamical & microphysical ingredients of the HIWC regions

3. Investigate whether the RASTA MMD and IWC retrievals can be used to improve the statistical significance of the 99th percentile of IWC versus distance scale calculation (Appendix D/P)

RASTA: Fall speed estimates

RASTA measures almost directly $V_Z = V_T$ (fall speed) + W (vertical air velocity) but these need to be separated.

We use the convective index to screen out the convective profiles (graupel + assumptions)

We can use the Protat and Williams (2011) DOP-Z-H technique applied on the stratiform profiles
Assumption : <W> in each Z-H bin is zero (needs a lot of points + stratiform).
Error ~ 15 cms-1 estimated with dual-frequency wind profiler spectra observations.

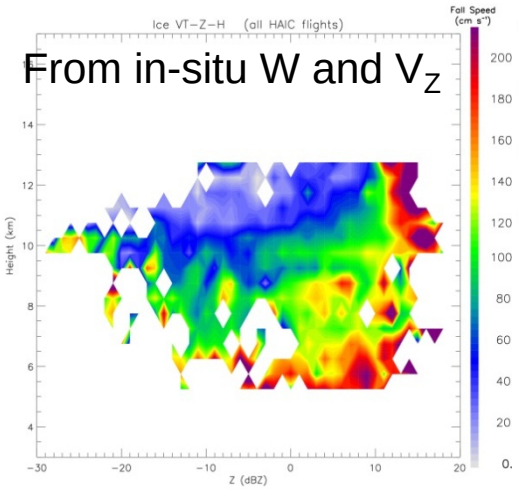
We can also use the Radonvar variational framework to get V_T and W (microphysical V_T model)

Problems for HIWC : when there is graupel /rimed particles in convective profiles V_T and W are underestimated by DOP-Z-H (under study).

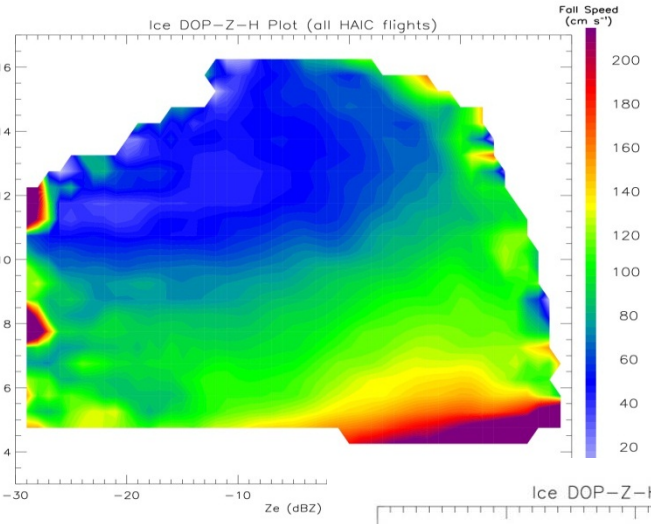
RASTA: Fall speed estimates

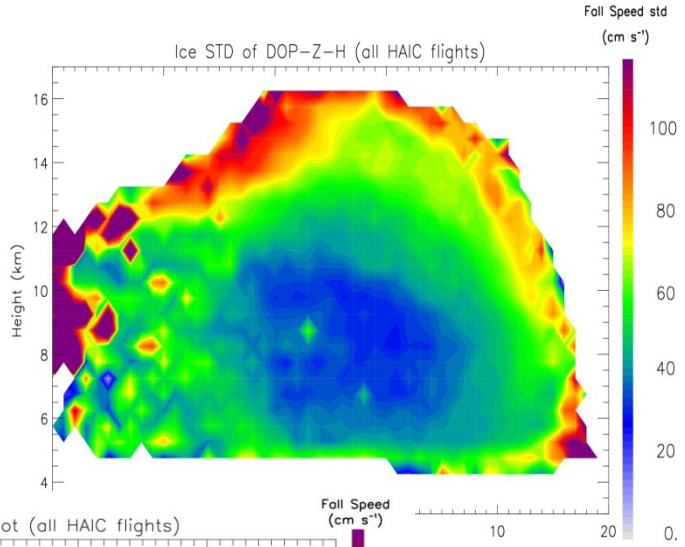
Concept OK :

From in-situ W and V_Z

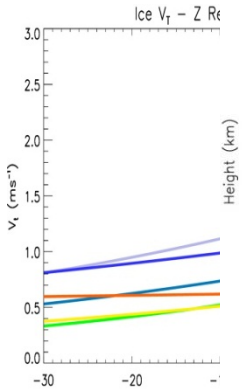


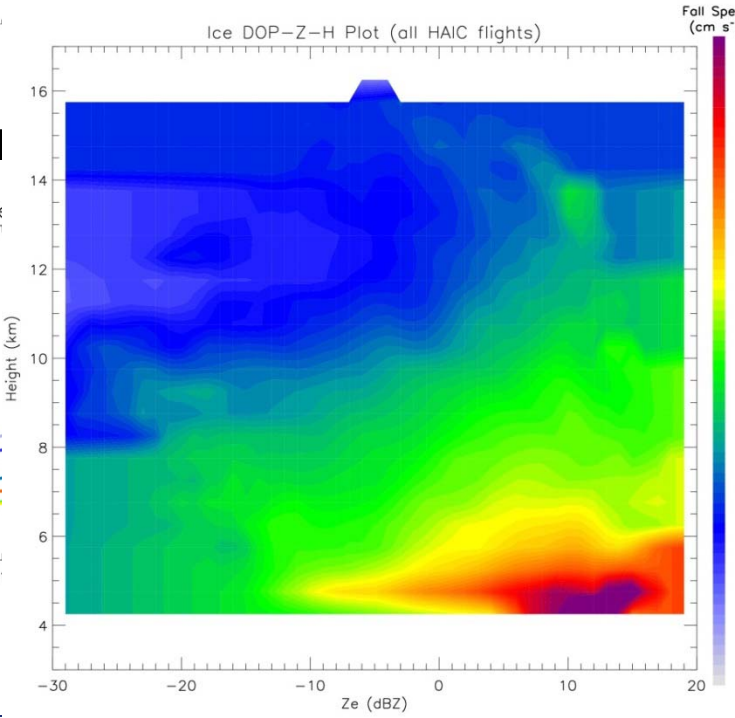
The ingredients :

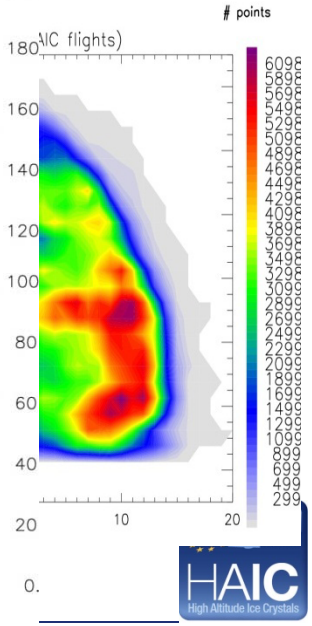




V_T - Z in 2 I







RASTA: IWC retrievals

Simple technique : use IWC from IKP (or Robust) and Z from RASTA to develop statistical relationships between these three parameters

Existing relationships **are not expected** to work for HIWC
(no reliable bulk measurements to constrain the relationships until now !)

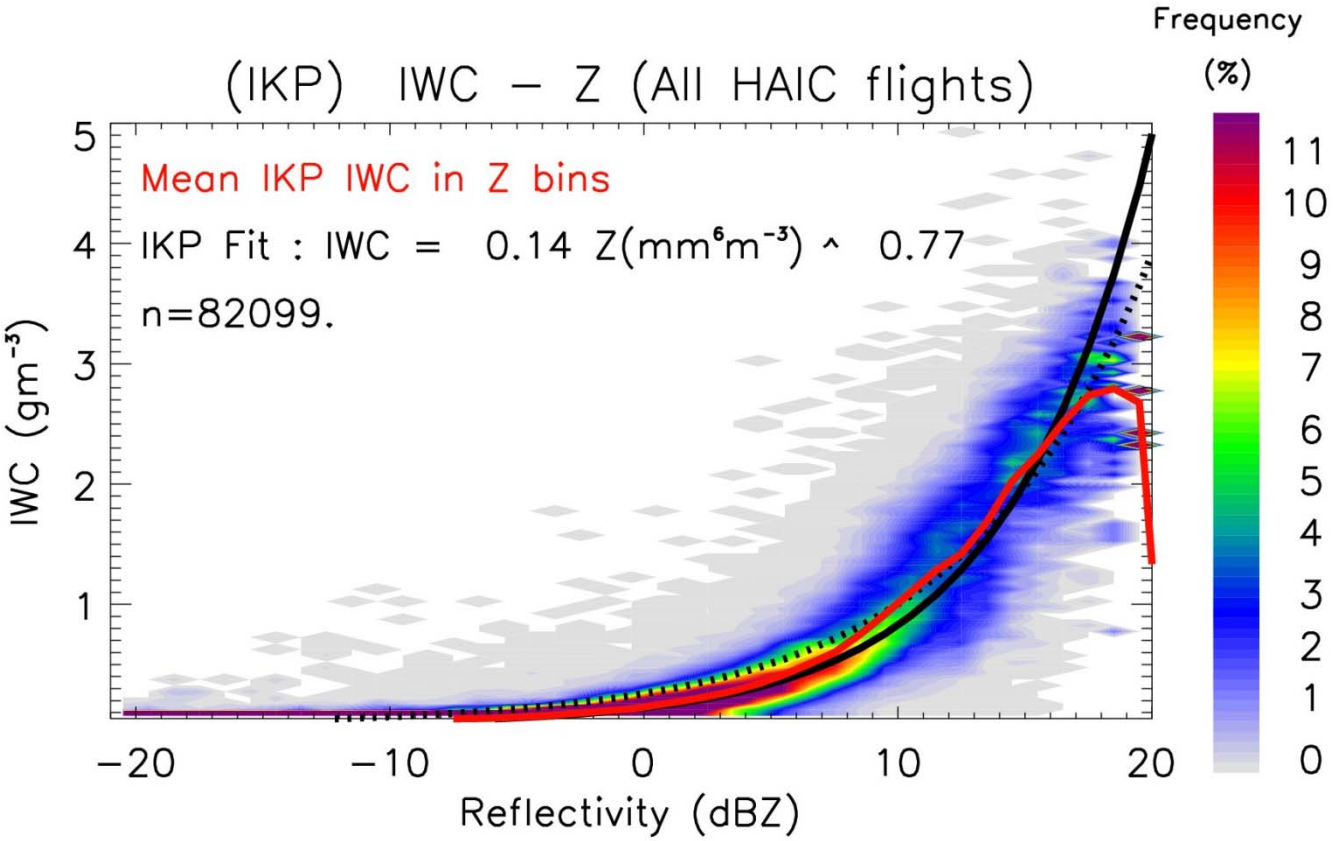
How accurately can we get IWC from Z ? From Z+T ? From Z+VT ?

More elaborated technique :
RadOnVar technique : variational version of the RadOn technique
(Delanoe et al., 2007, JAMC)

Uses Z and $V_z = (V_T + W)$ as inputs. V_T is related to particle size so it is a very valuable constraint for the specific HIWC environment.

We explore Temperature and Convective Index as additional constraints

Measured relationship between IWC and Z (95GHz)

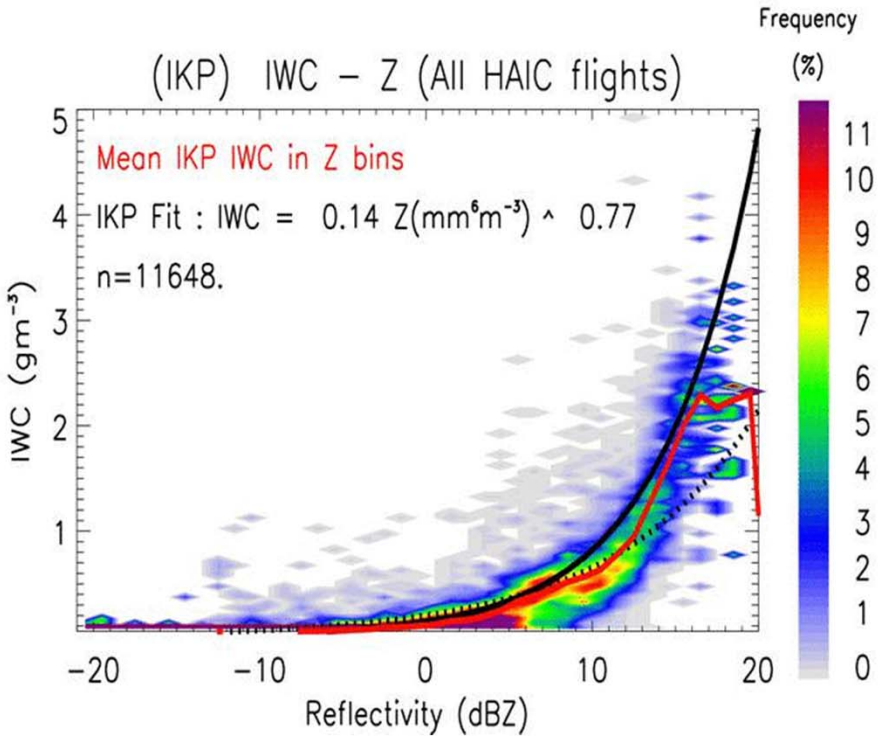


The normalization is done for each Z bin (2 dB size)

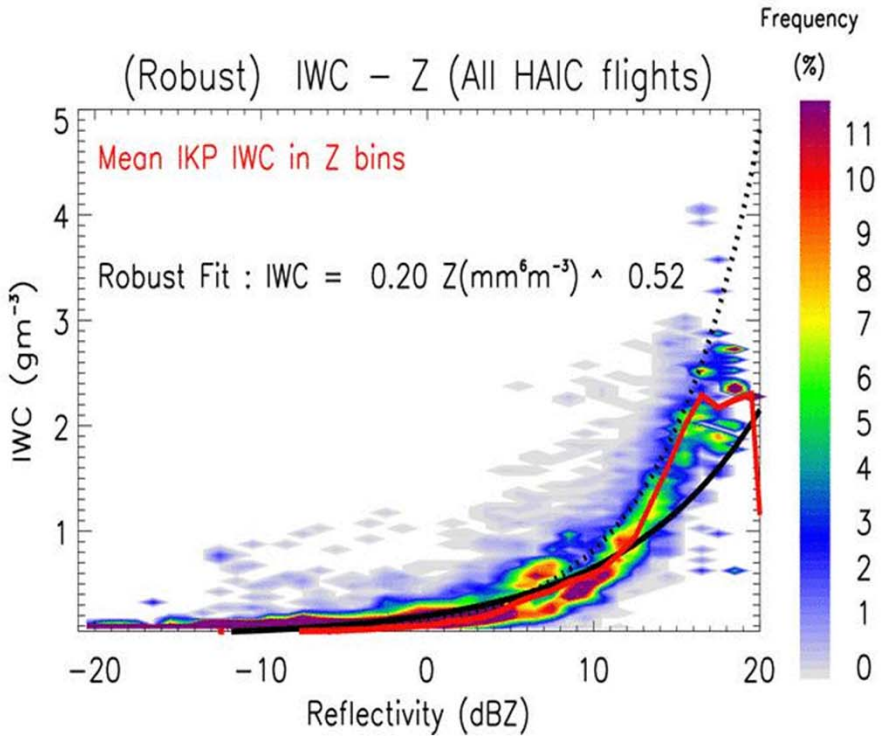
The width of the distribution increases with IWC
= more variability of IWC versus Z for larger IWCs

Variability of IWC-Z : Temperature ?

IKP

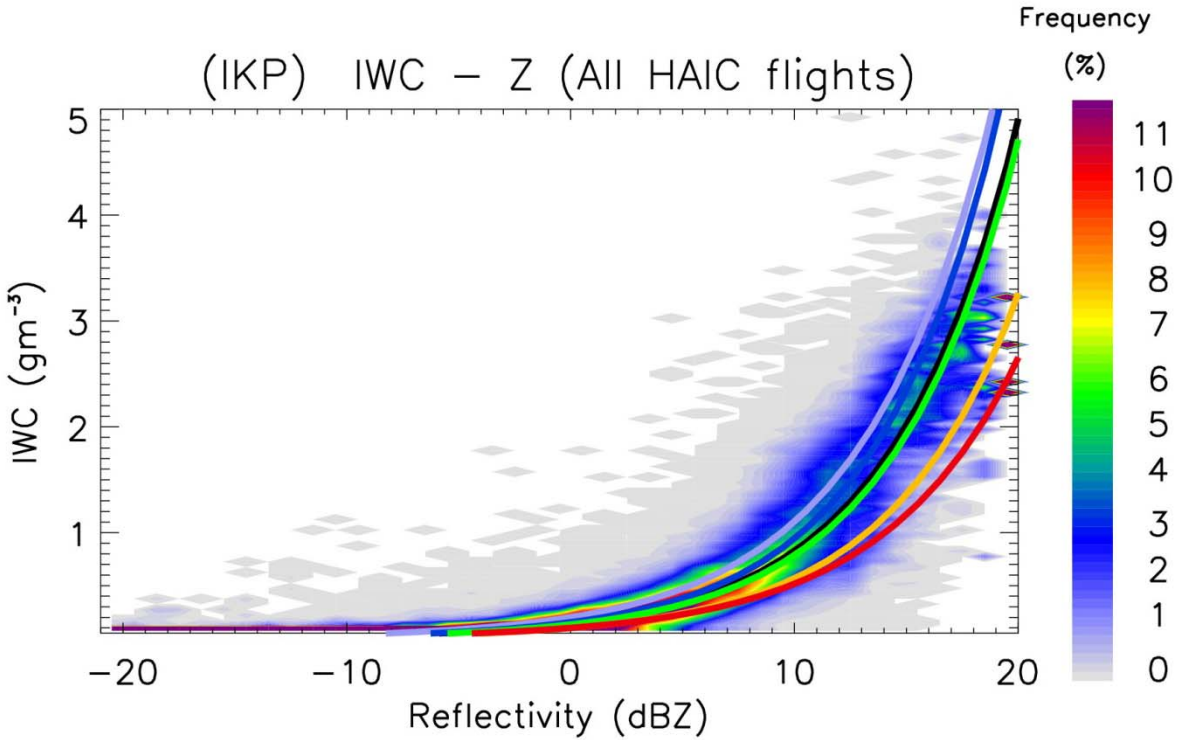


ROBUST



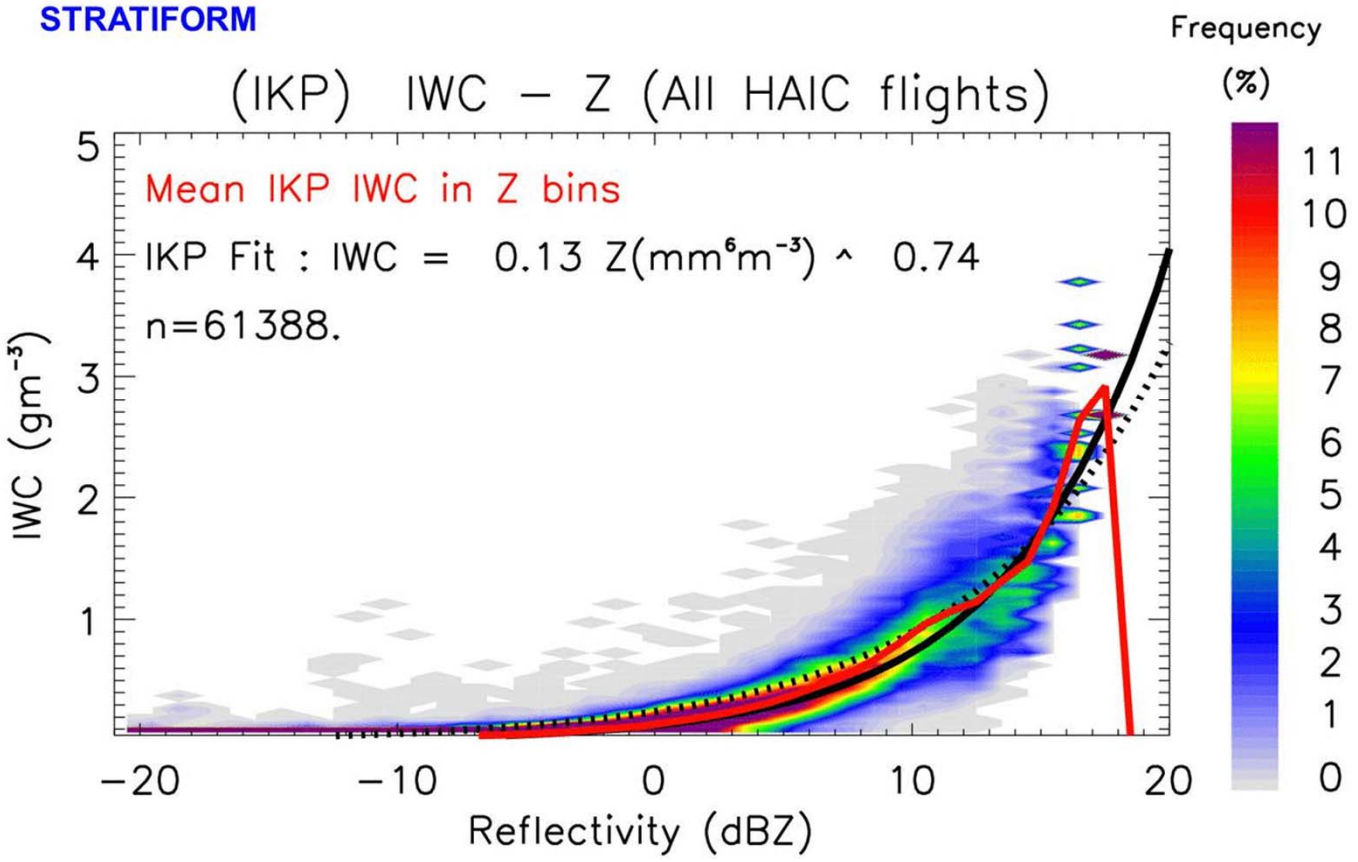
IWC for a given Z is larger for lower temperature

Variability of IWC-Z : Temperature



Temperature:	**-50.0000**	**#points:**	**4250.00**	**IWC =**	**0.201**	**Z ^**	**0.740**
Temperature:	**-40.0000**	**#points:**	**26489.0**	**IWC =**	**0.153**	**Z ^**	**0.790**
Temperature:	**-30.0000**	**#points:**	**18400.0**	**IWC =**	**0.132**	**Z ^**	**0.776**
Temperature:	**-20.0000**	**#points:**	**5273.00**	**IWC =**	**0.099**	**Z ^**	**0.758**
Temperature:	**-10.0000**	**#points:**	**3611.00**	**IWC =**	**0.101**	**Z ^**	**0.710**

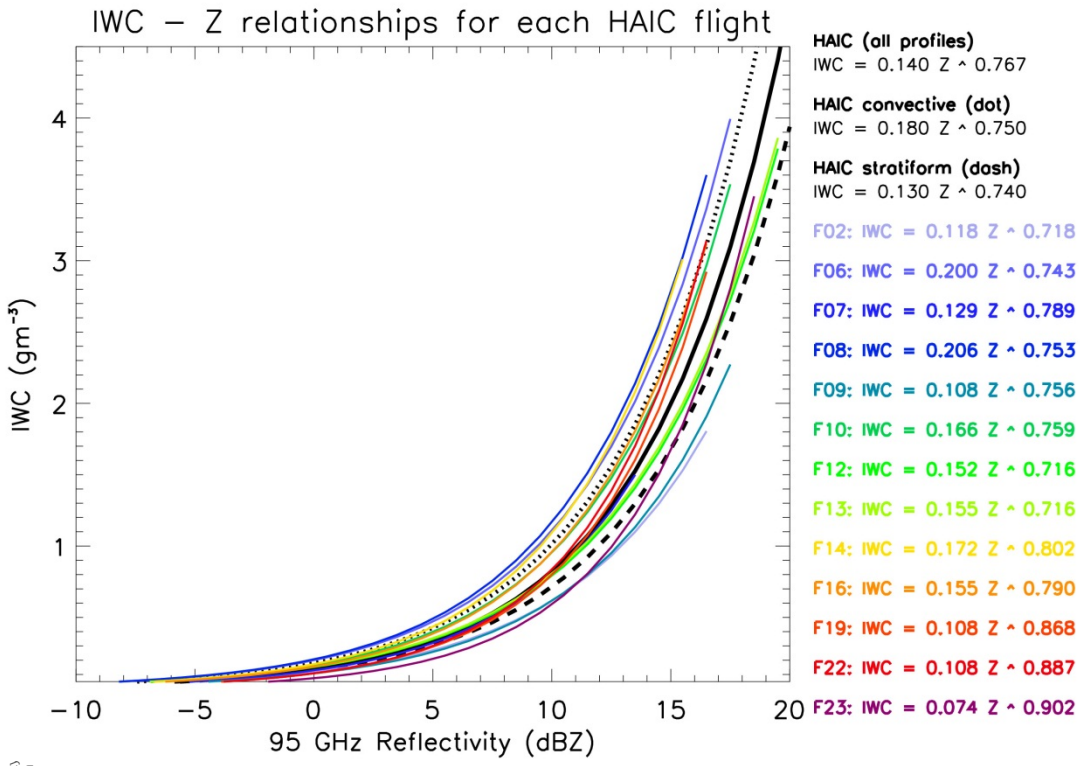
Variability of IWC-Z : Convective versus stratiform?

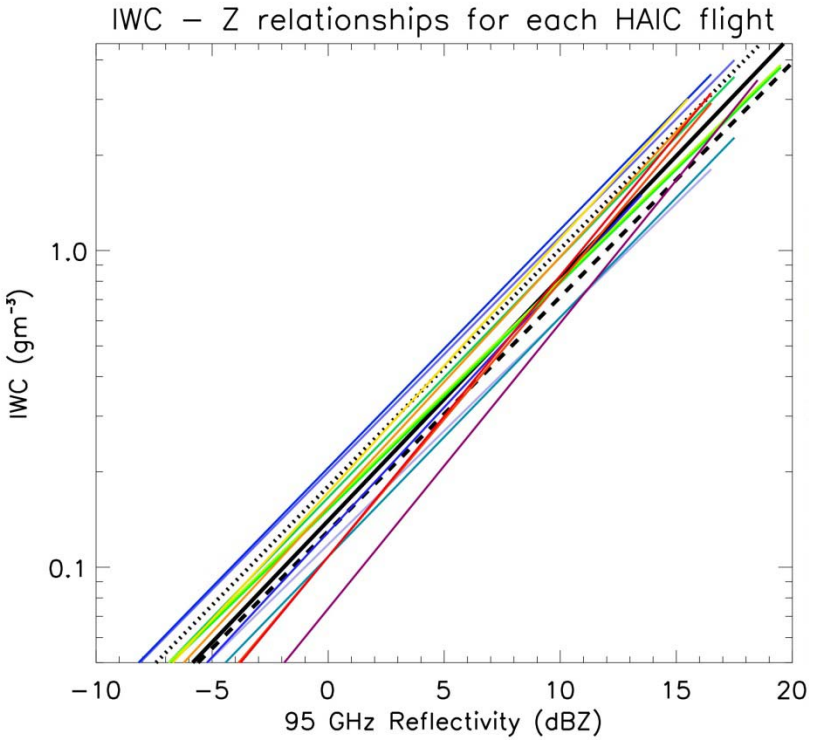


IWC for a given Z is larger in convective than in stratiform

e.g. For Z=15 dBZ IWC (convective) ~ 2.45 gm^{-3} while IWC (stratiform) = 2 gm^{-3}

Variability of IWC-Z : flight-by-flight ?

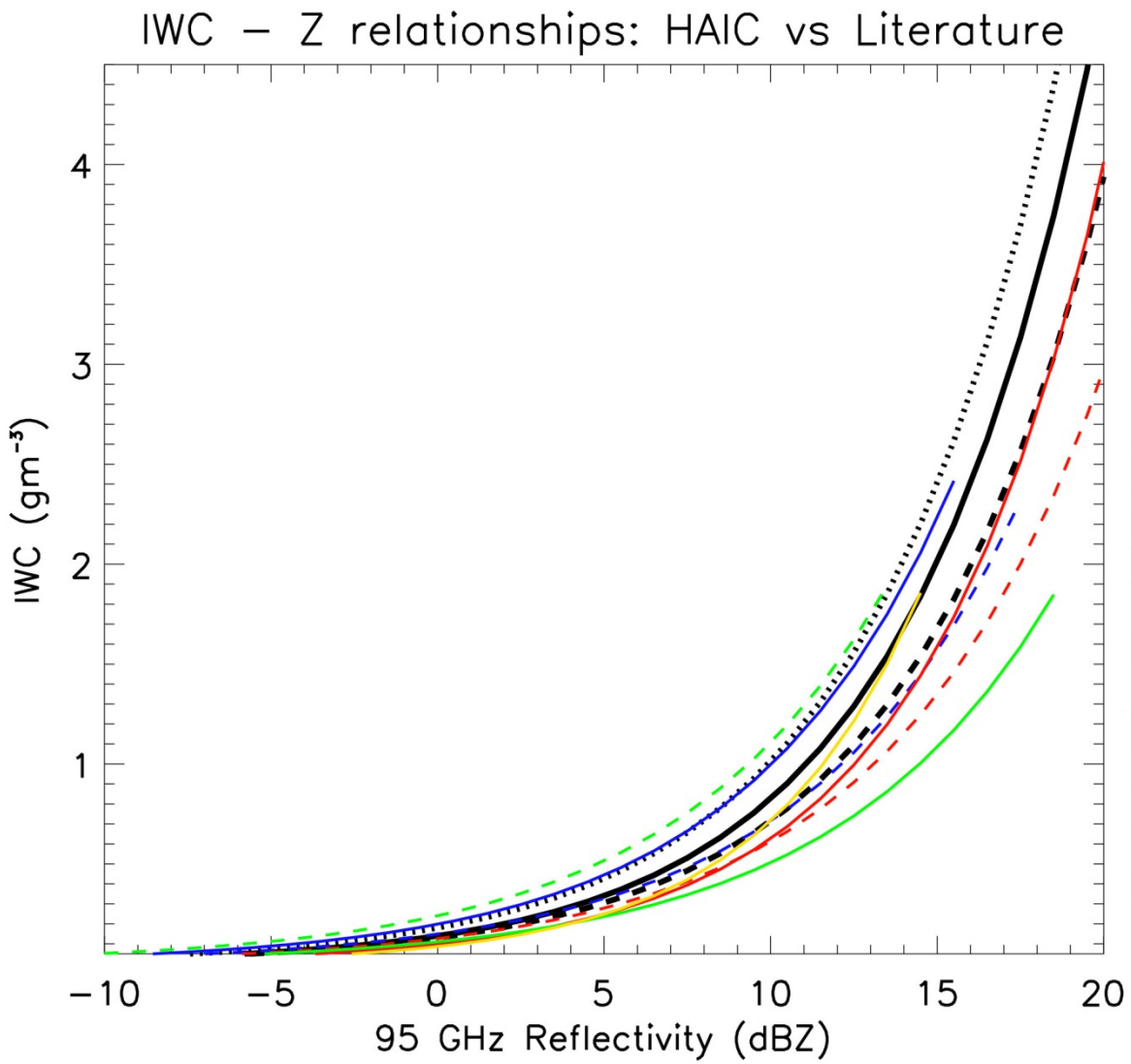




This flight-by-flight variability is largely due to temperature and convective vs stratiform dominated flight

e.g, flights 9, 23 have many samples at -10°C

IWC-Z_{95} in the literature vs HIWC measurements



HAIC (all profiles)
IWC = 0.140 Z ^ 0.767

HAIC convective (dot)
IWC = 0.180 Z ^ 0.750

HAIC stratiform (dash)
IWC = 0.130 Z ^ 0.740

Protat (2007) Tropics
IWC = 0.198 Z ^ 0.701

Protat (2007) Global (dash)
IWC = 0.149 Z ^ 0.681

Fontaine (2014) T-Matrix
IWC = 0.098 Z ^ 0.805

Fontaine (2014) T-param (dash)
IWC = 0.126 Z ^ 0.686

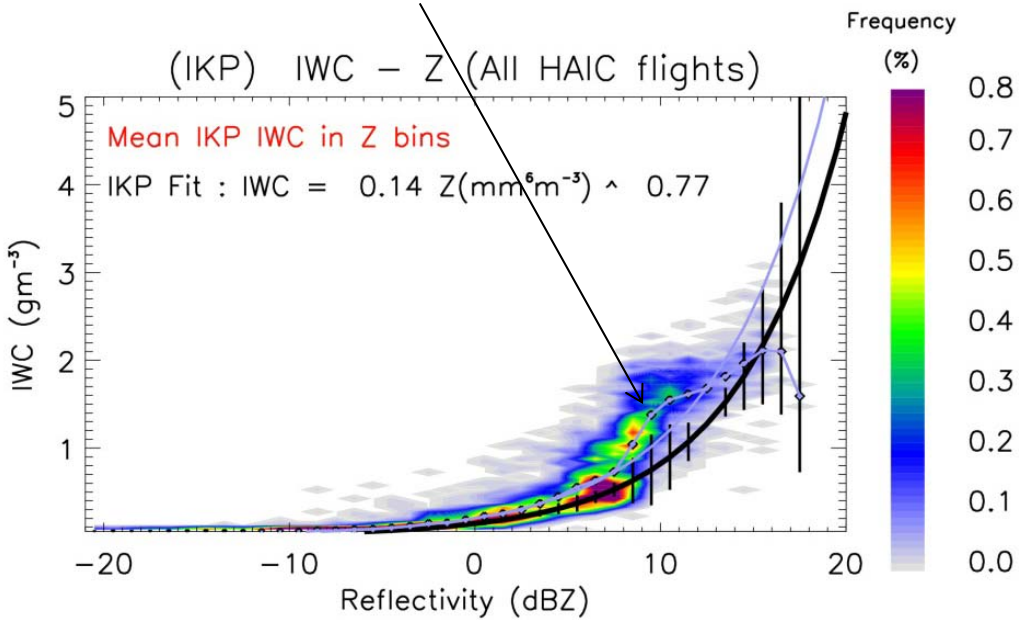
Heymsfield (2010) cg-param
IWC = 0.110 Z ^ 0.662

Heymsfield (2010) NAMMA (dash)
IWC = 0.240 Z ^ 0.664

Matrosov (2008) Z > 0 dBZ
IWC = 0.086 Z ^ 0.920

Look-up tables for IWC-Z-T

The relationship between IWC and Z departs from a power law for some T ranges.

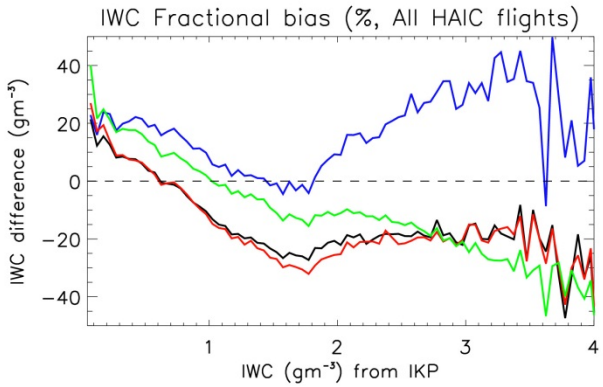


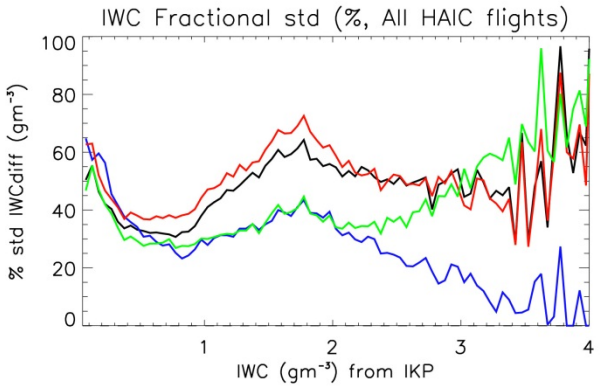
T=-55C
Blue line is IWC-Z fit for that T interval
Blue line with dots is mean values of IWC in 1 dBZ intervals (in the LUT)

So we have developed a look-up table that links IWC to each couple (Z,T)

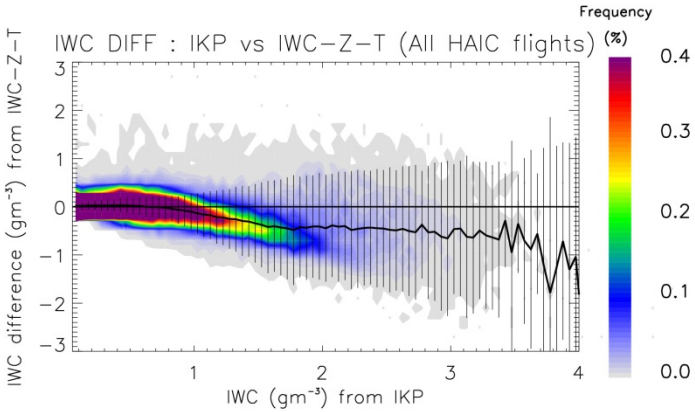
Implementation :
Develop look-up table with 1 dBZ and 10°C resolution,
then bi-linear interpolation using the actual (Z,T) measured using the look-up table.

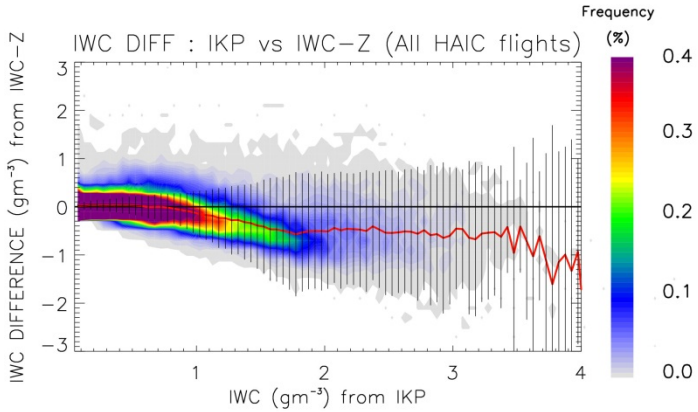
Error analysis (all flights)





IWC – Z – T
IWC – Z
LUT (Z,T)
Radonvar

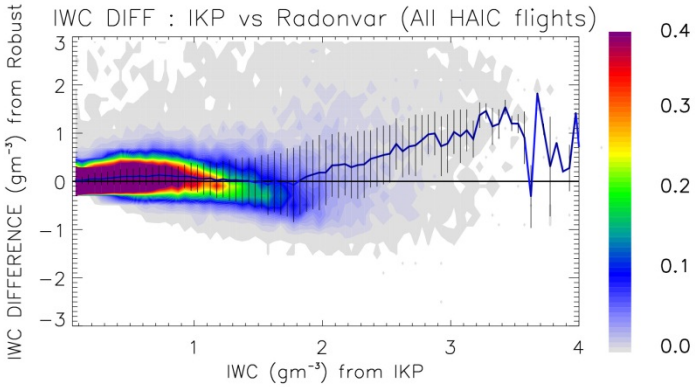


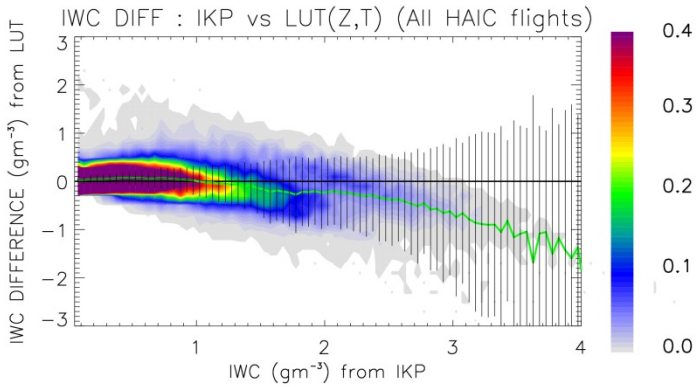


Errors (conv strat):
Bias ~ ± 20%
Std ~ 30-60%

Miss samples > 3 gm^{-3}

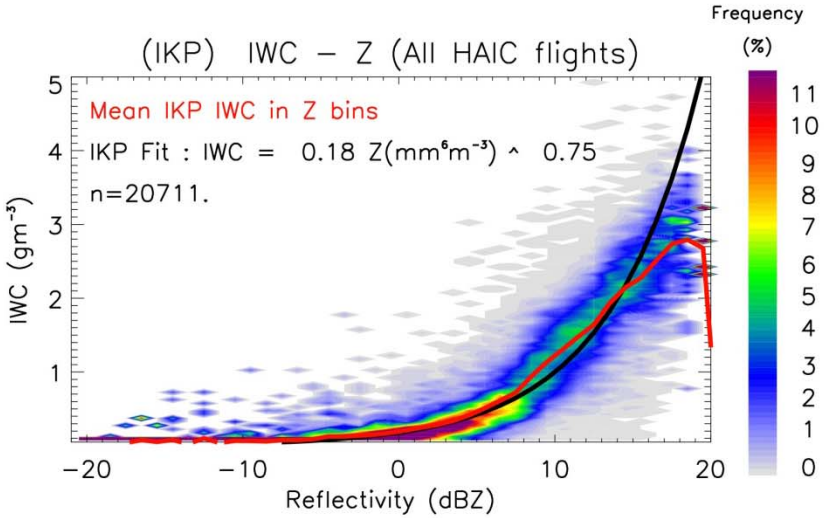
Radonvar and LUT(Z,T) better overall

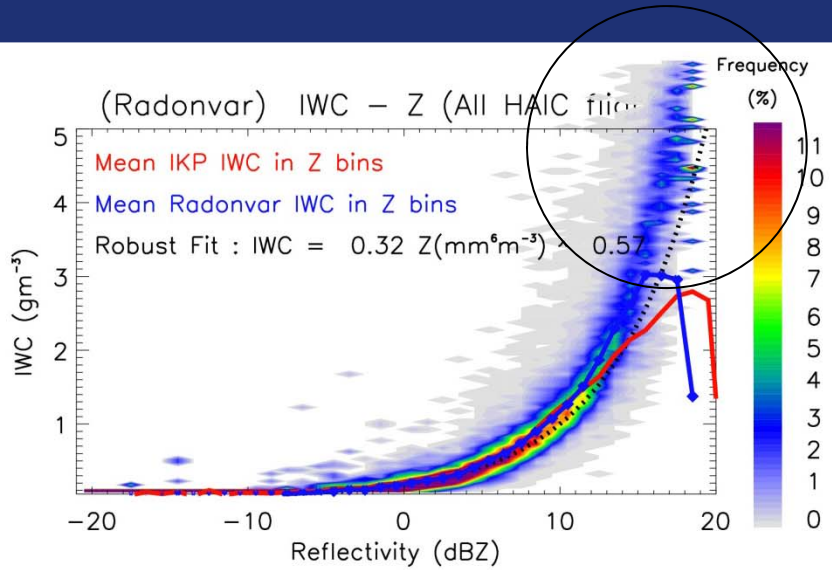


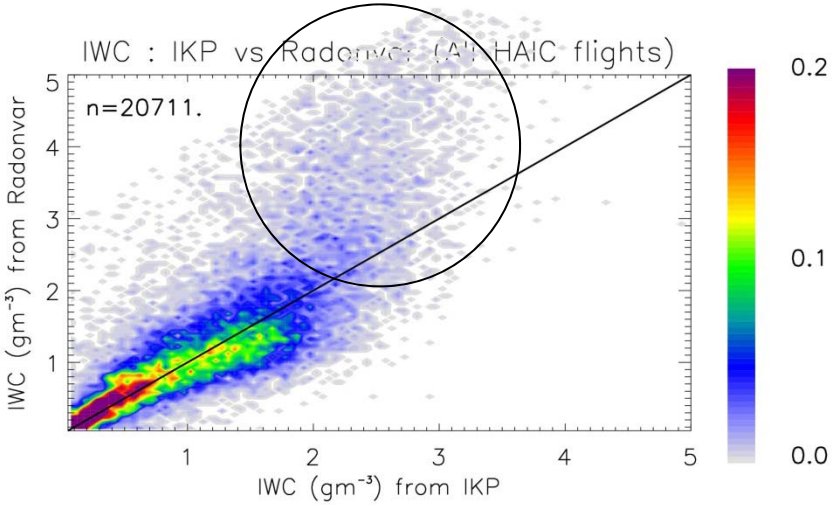


Radonvar produces large values of IWC
Where ? Why ?

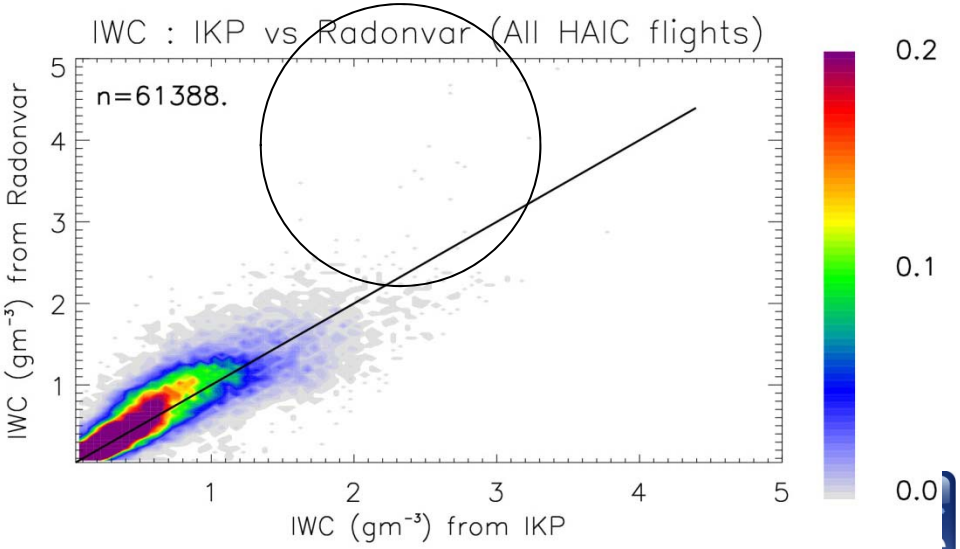
Radonvar : pb with convective profiles / large IWC



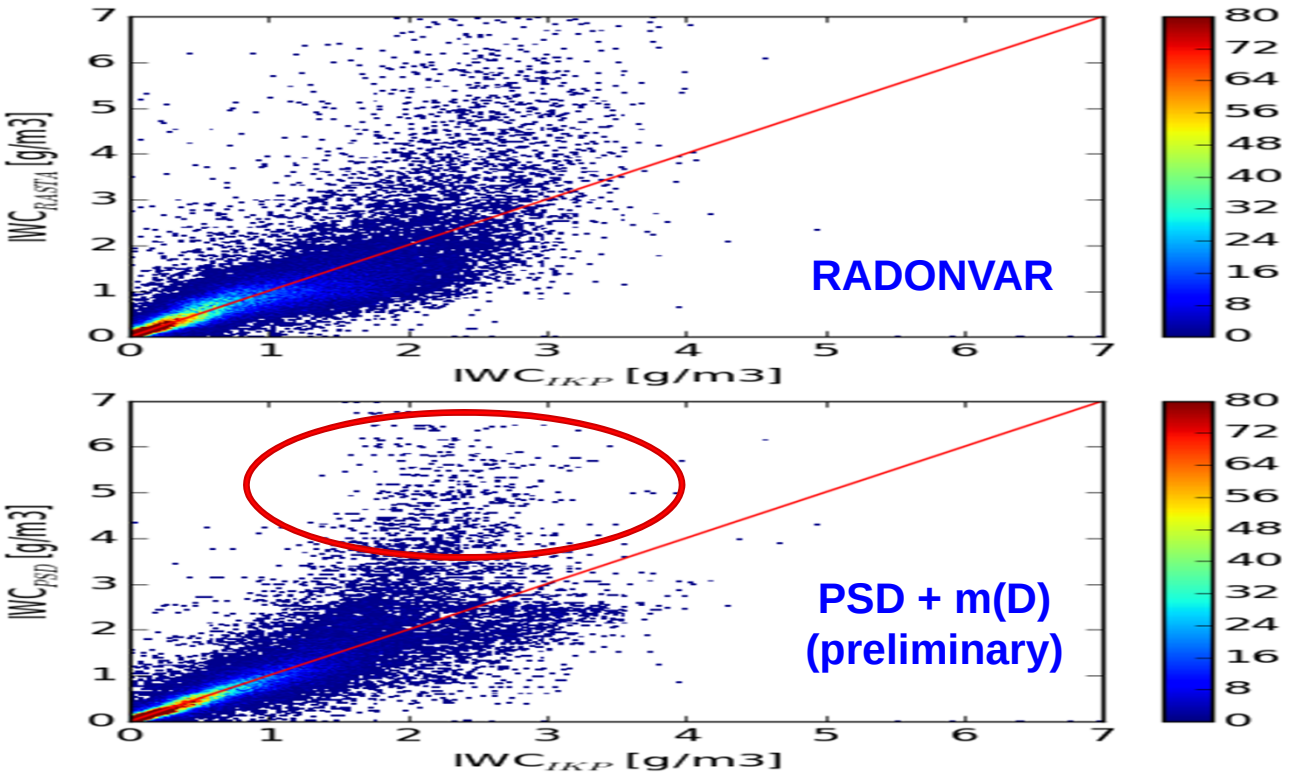




No problem with stratiform !



Same problem with PSD + m(D) using T-Matrix



Fontaine et al. 2014, ACP:

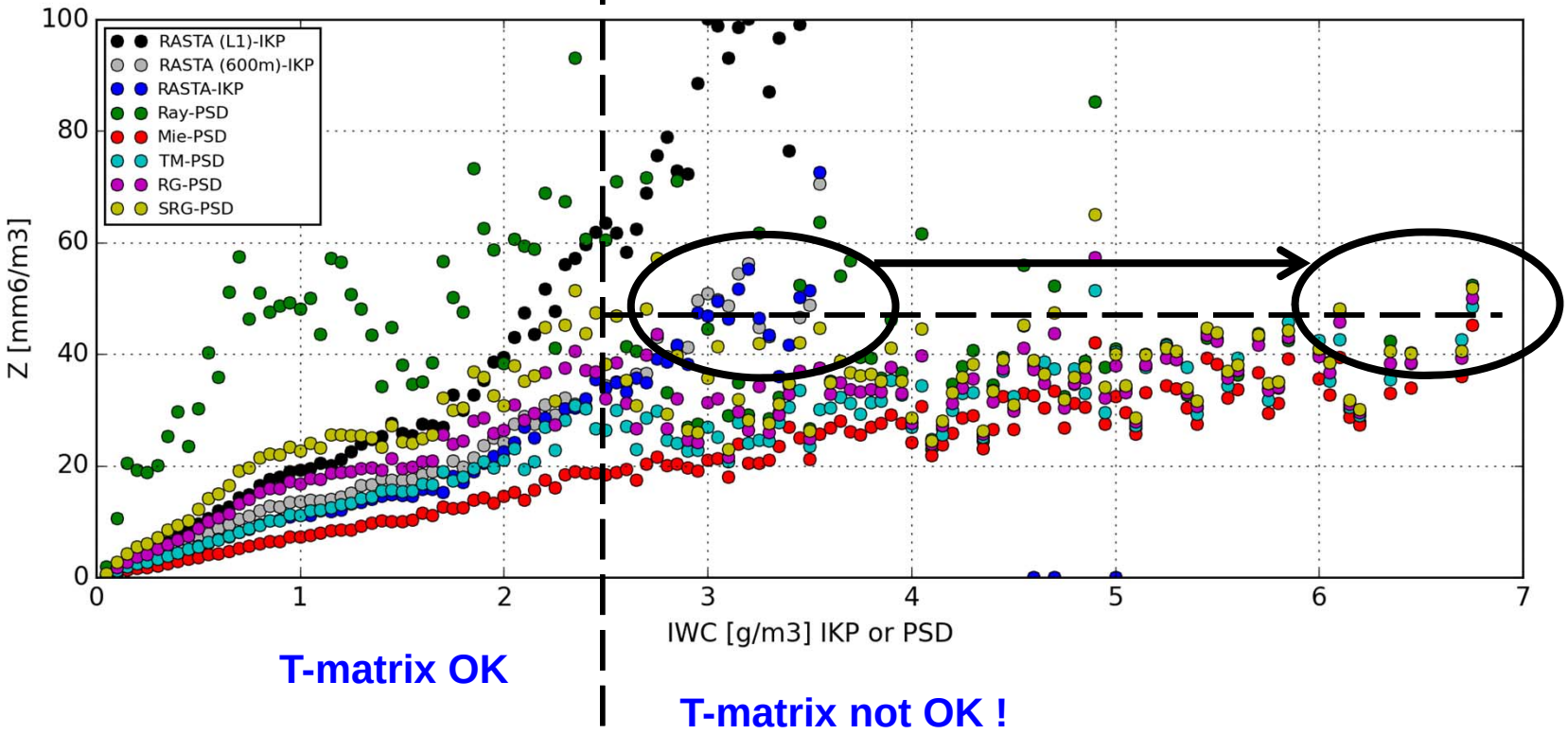
- Measured N(D)
- m(D) exponent constrained by measured A(D) exponent
- m(D) pre-factor constrained by measured RASTA Z
- T-matrix calculations of Z using N(D) and m(D)

Radar forward model issue or m(D) in HIWC ?

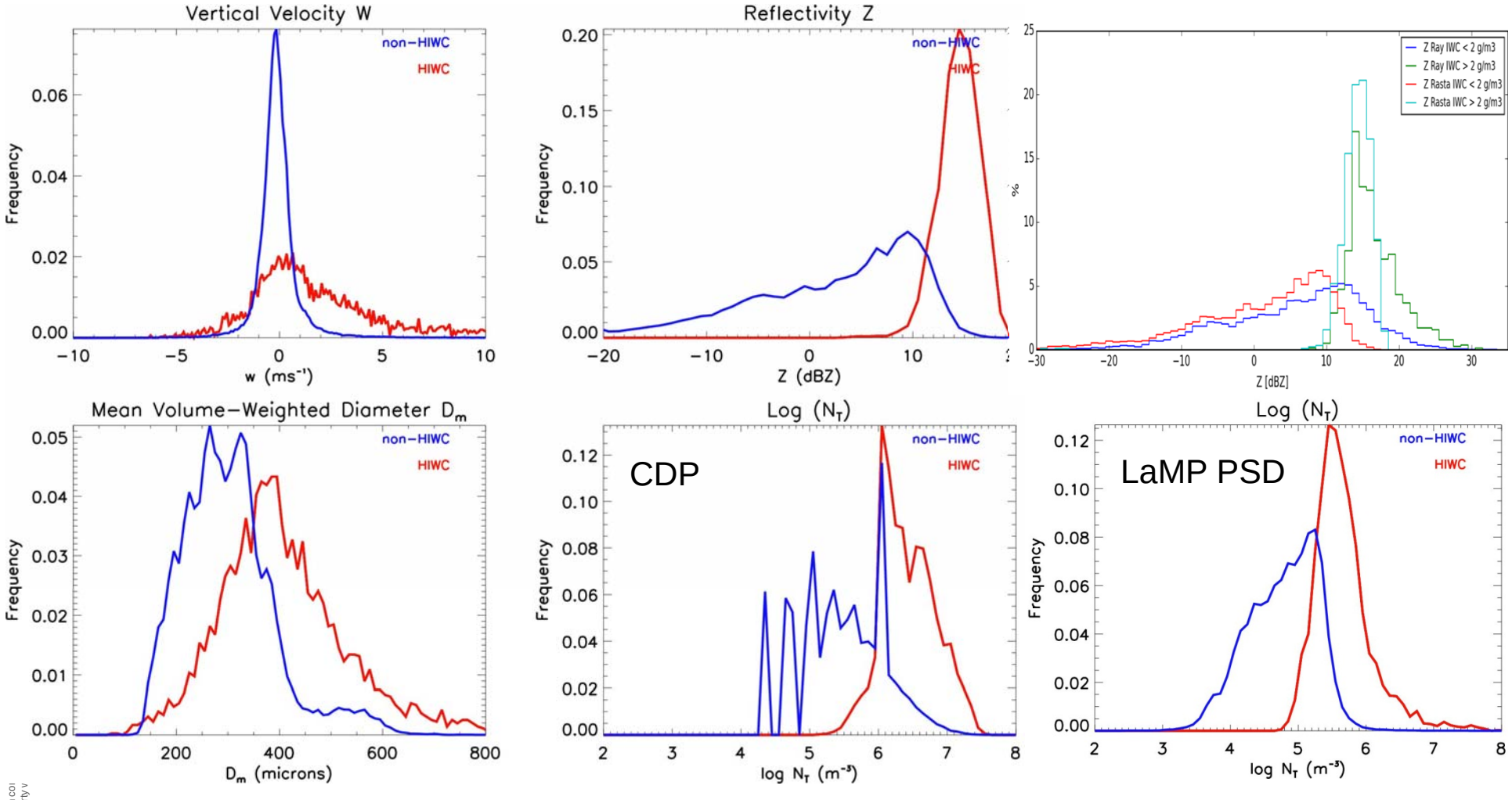
Radonvar is a variational technique, which uses a radar reflectivity forward model (T-matrix) with assumptions on the mean aspect ratio of ellipsoidal ice crystals.

How accurate are the reflectivity forward models ?

Review by J. Delanoe :



Unique aspect of HIWC regions



Wider PDF of W, larger Z (but less than 30 dBZ Rayleigh Z), larger D_m, larger N_T (CDP, PSD)
Higher concentration of small crystals, but also increase in D_m ???

Needs and collaboration ideas

We need the latest PSDs to refine the Radonvar Z forward model & microphysical model
Are the Robust and IKP data the final versions ?

We need more samples of high IWC to complement our statistics (few points above 3 gm^{-3})
Let's go to Cayenne !

Time is right to fully spin up collaborations discussed in earlier HAIC-HIWC STMs :

- Walter on the radar extension of Appendix D/P
- EC (Alexei) and LAMP to understand the HIWC formation and maintenance processes
- Satellite work from Pat (use of RASTA IWCs to train / evaluate passive technique)
- NCAR ALPHA development and validation work from Julie
- CRM modelling work using RASTA products (Adam, Ed, Ann, and Andy).
  Would be interesting to simulate RASTA Z and V_D from CRM outputs.
- Honeywell and NASA on upcoming X-band + W-band radar observations.

Publication plans

General problem : we need a reference in the literature for the IKP performance ! Who ?

Delanoe (lead): a general paper describing the RASTA cloud radar and applications.
This paper will make use of HAIC-HIWC Darwin RASTA + PSD + IKP data. Many co-authors expected from this group …

Delanoe (lead): a technical paper describing the reflectivity enhancement problem and how we fixed it. This paper will only use RASTA data from the Darwin campaign.

Protat (lead) : Description of the RASTA IWC retrieval work and results.
This paper will make use of HAIC-HIWC Darwin RASTA + PSD + IKP + ROBUST data.
Many co-authors expected from this group …

Protat (lead) : *Possibly* a paper on the terminal fall speed work, not sure yet.
This paper would only make use of HAIC-HIWC Darwin RASTA data.

We expect to contribute to the BAMS overview paper, Alexei's general "discovery" paper, and maybe to the J. Aircraft HIWC overview paper.

SAE conference abstracts: lost the count …