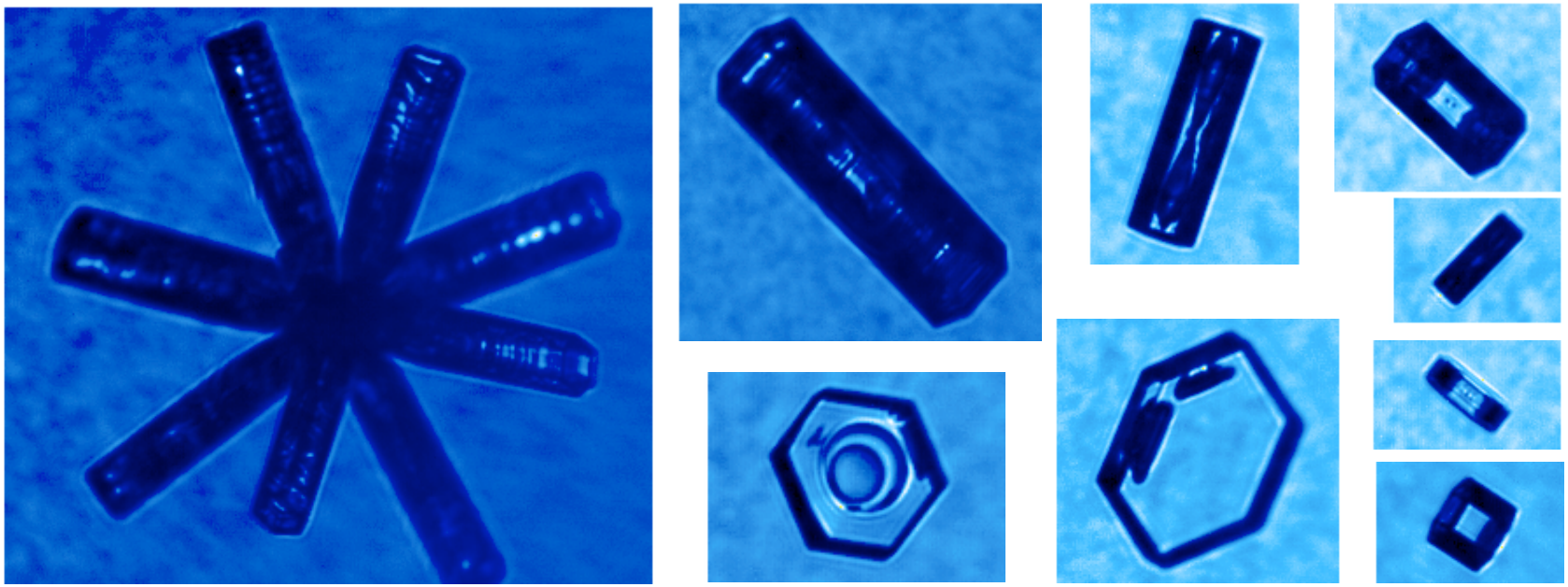
Aspect ratios of natural ice crystals from in-situ observations



Junshik Um and Greg M. McFarquhar
University of Illinois
03/10/2014

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Overview

- **Ice Crystal Ruler (IC-Ruler) measures dimensions of ice crystals was developed**

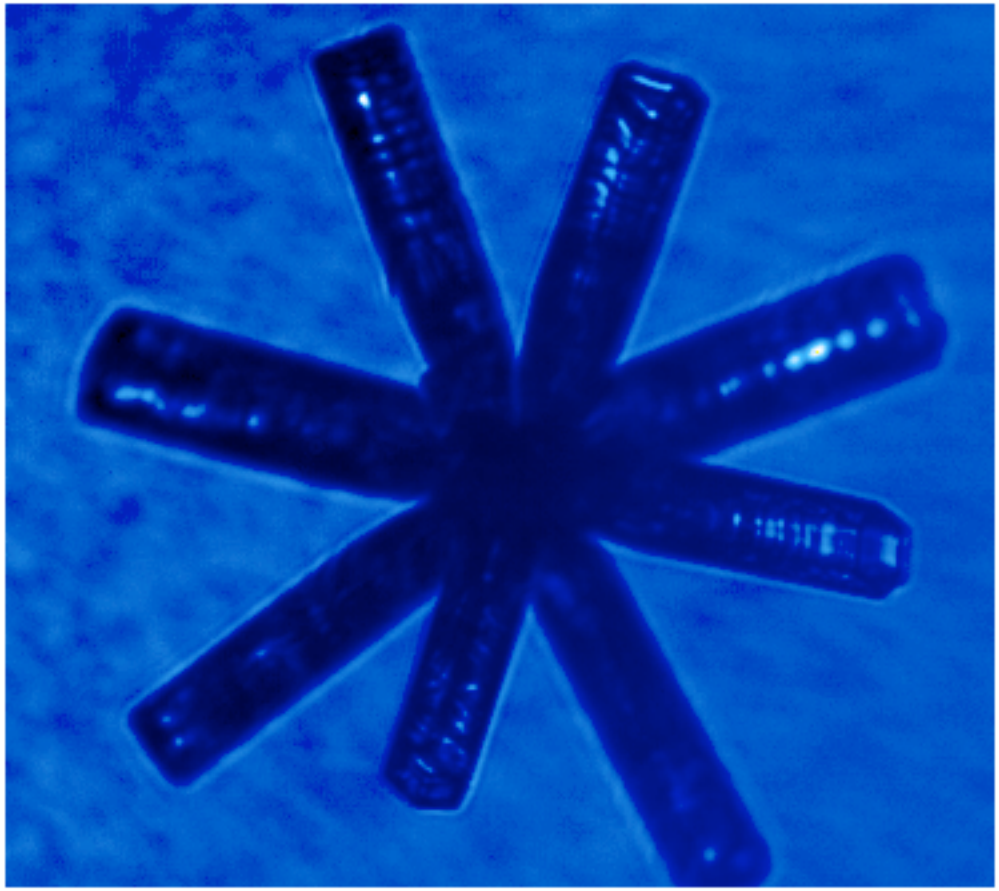
- **Dimensions of columns, plates, and individual branches of bullet rosettes from CPI images**

  - 2006 TWP-ICE, Tropics
  - 2008 ISDAC, Arctic
  - 2010 SPARTICUS, mid-latitudes

- **What controls aspect ratio of ice crystal?**
- **Systemic difference between geophysical locations?**

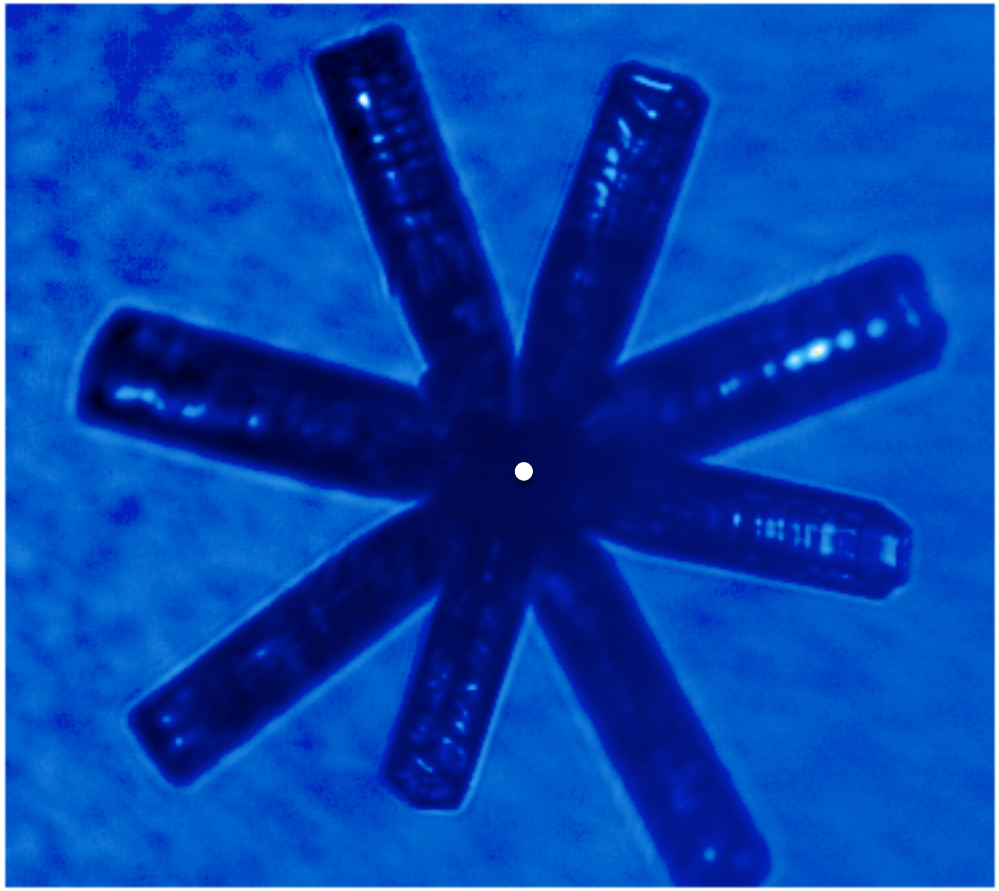
Ice Crystal Ruler (IC-Ruler)

BR



Ice Crystal Ruler (IC-Ruler)

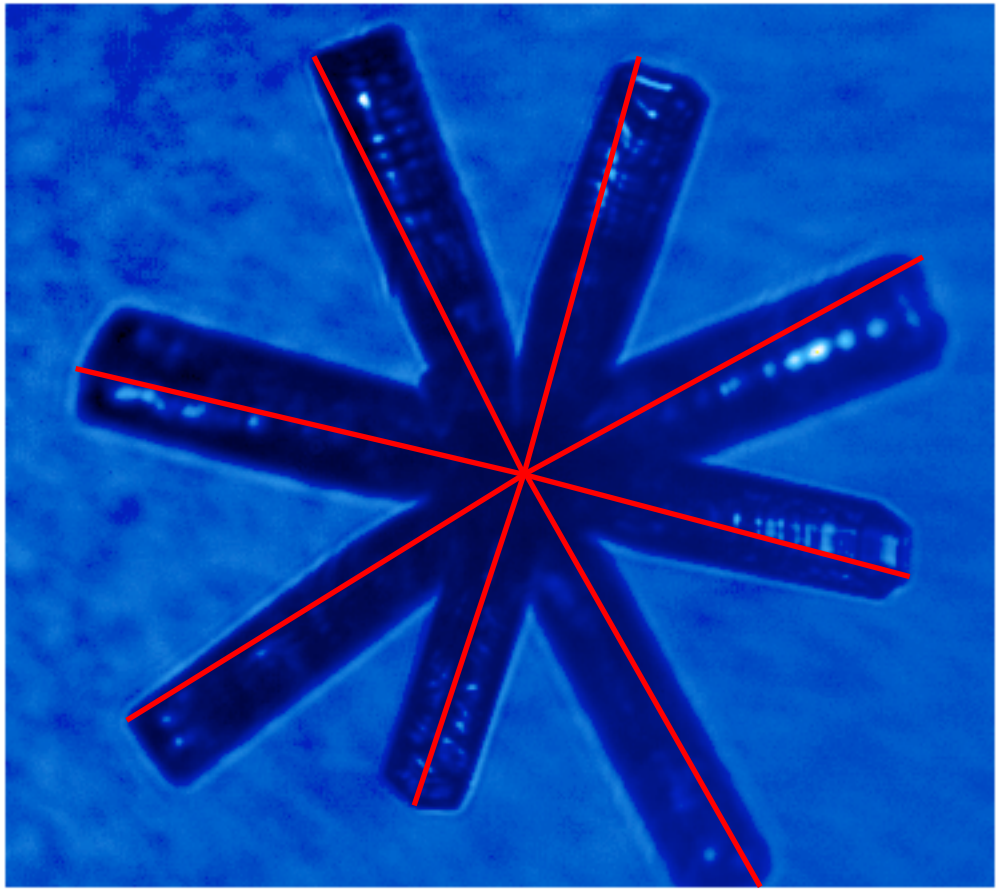
BR



Identifying center

Ice Crystal Ruler (IC-Ruler)

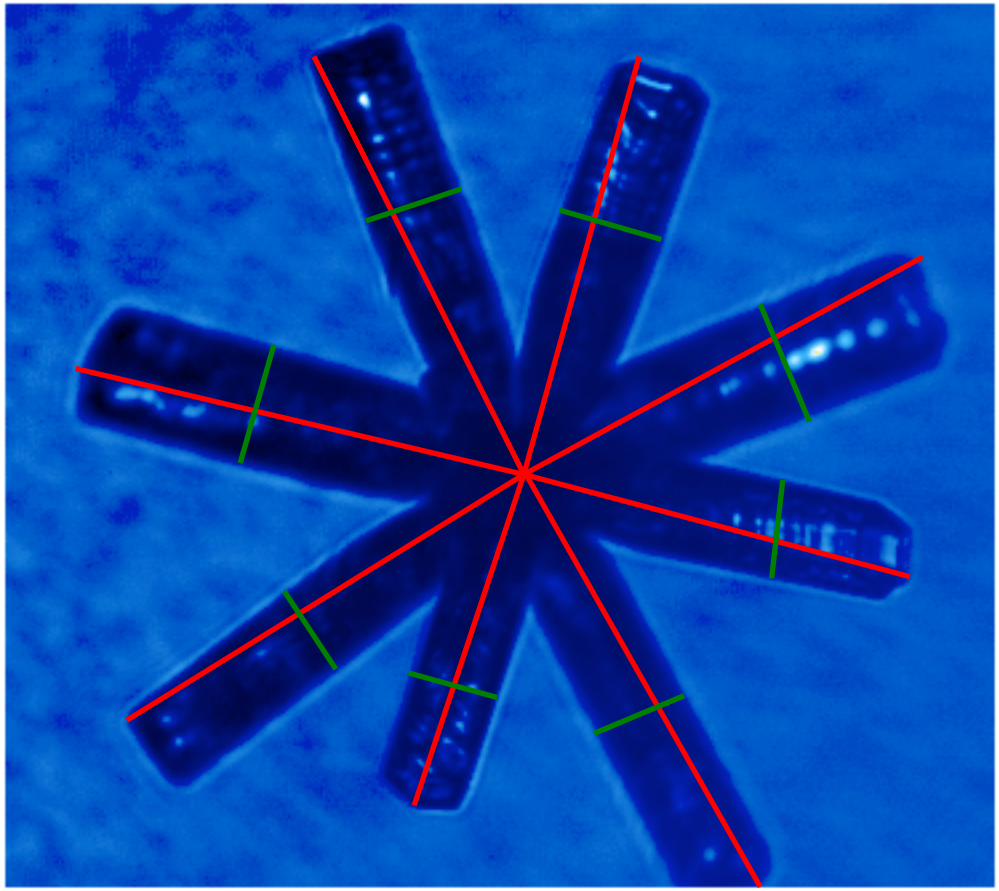
BR



- **Projected maximum dimension (*D'*)**

Ice Crystal Ruler (IC-Ruler)

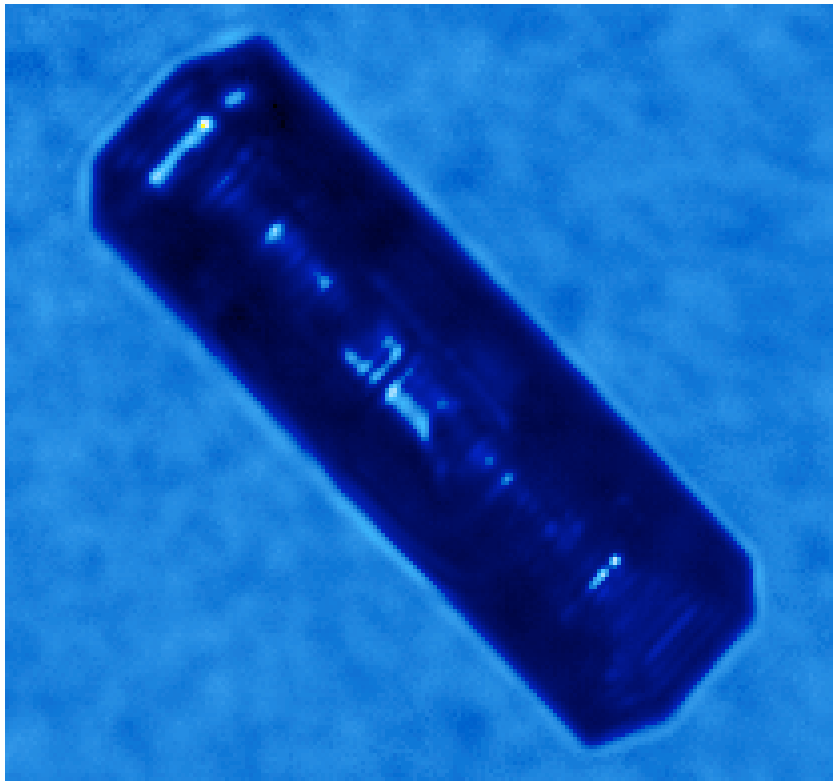
BR



- Projected maximum dimension (*D'*)
- Projected width (*W'*)

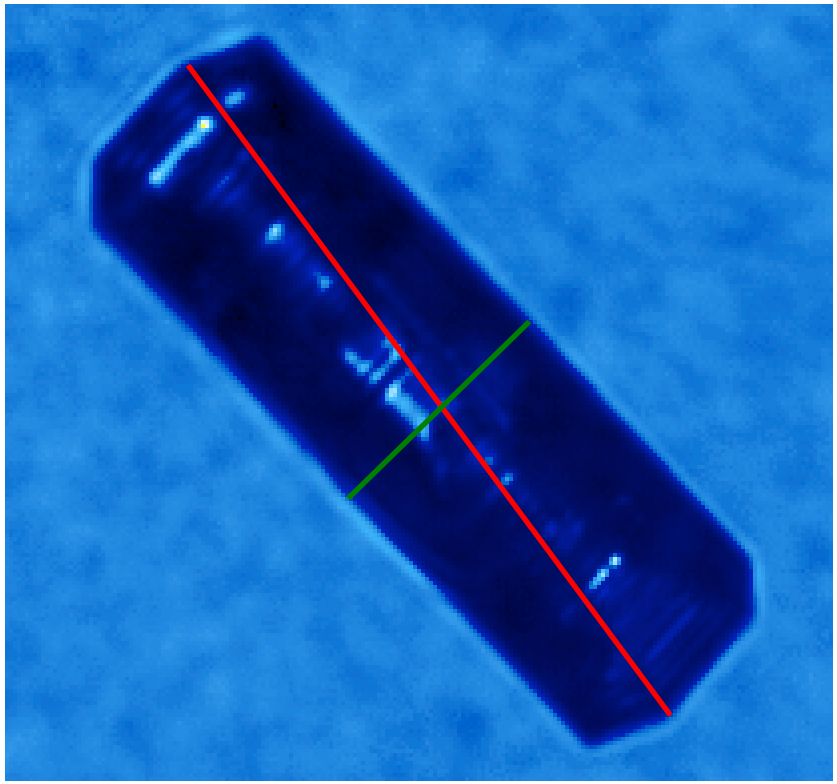
Ice Crystal Ruler (IC-Ruler)

Column



Ice Crystal Ruler (IC-Ruler)

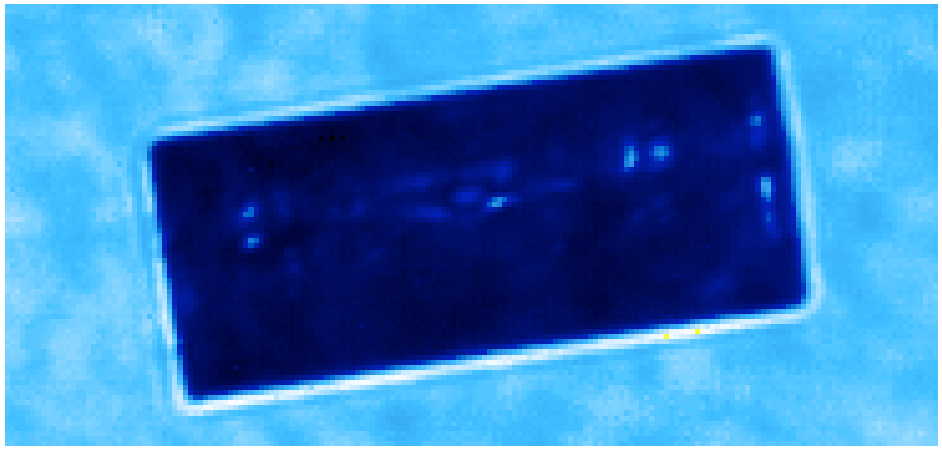
Column

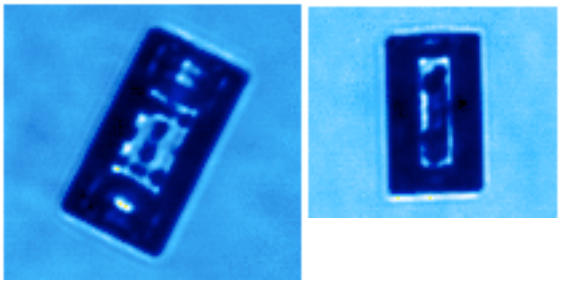


- **Projected maximum dimension (*D'*)**
- **Projected width (*W'*)**

Ice Crystal Ruler (IC-Ruler)

HCOL

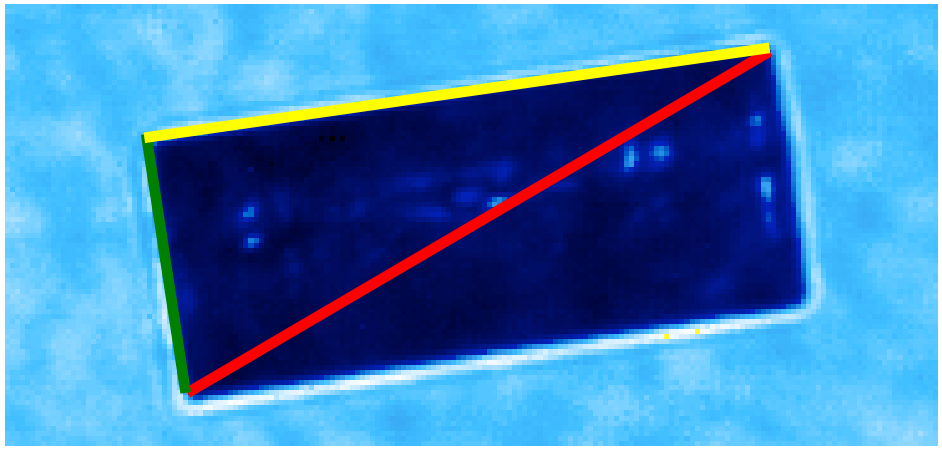


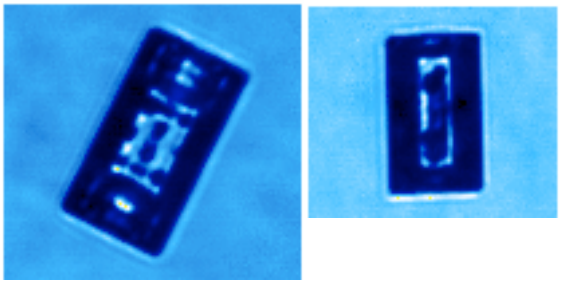


➢ **Horizontally oriented columns, *L* = *L'***

Ice Crystal Ruler (IC-Ruler)

HCOL

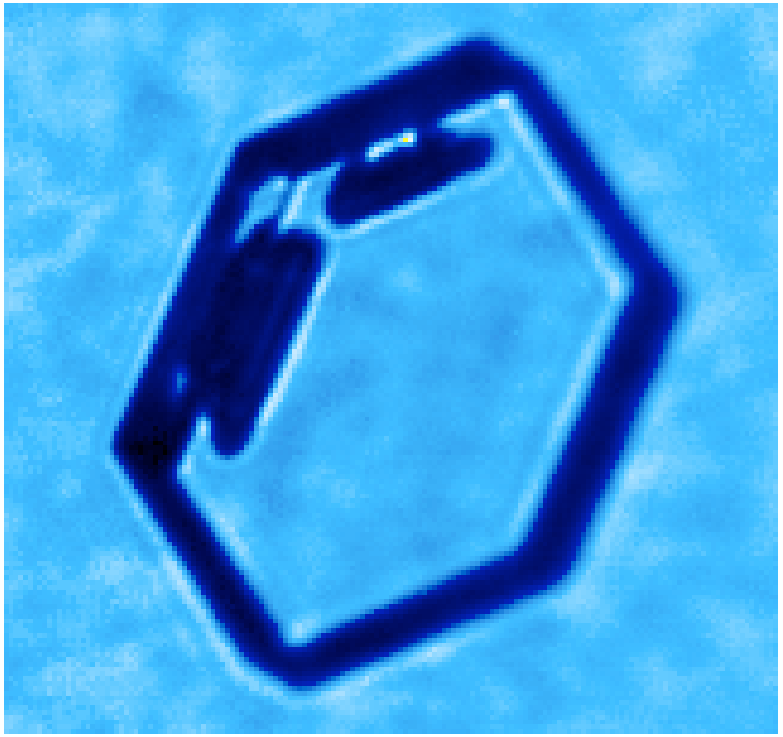




- Projected Maximum dimension (*D'*)
- Projected Width (*W'*)
- Projected Length (*L'*)

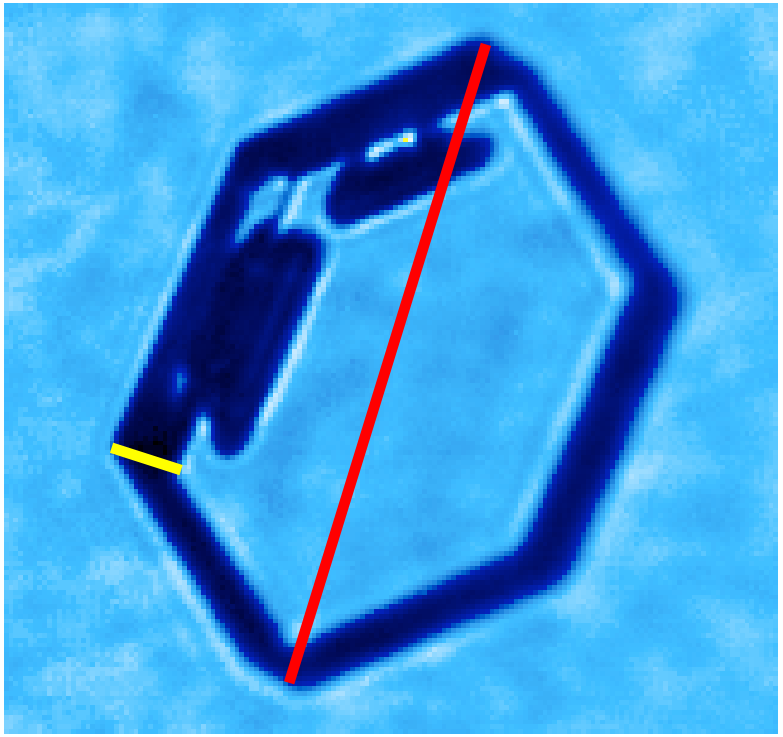
Ice Crystal Ruler (IC-Ruler)

Plate



Ice Crystal Ruler (IC-Ruler)

Plate



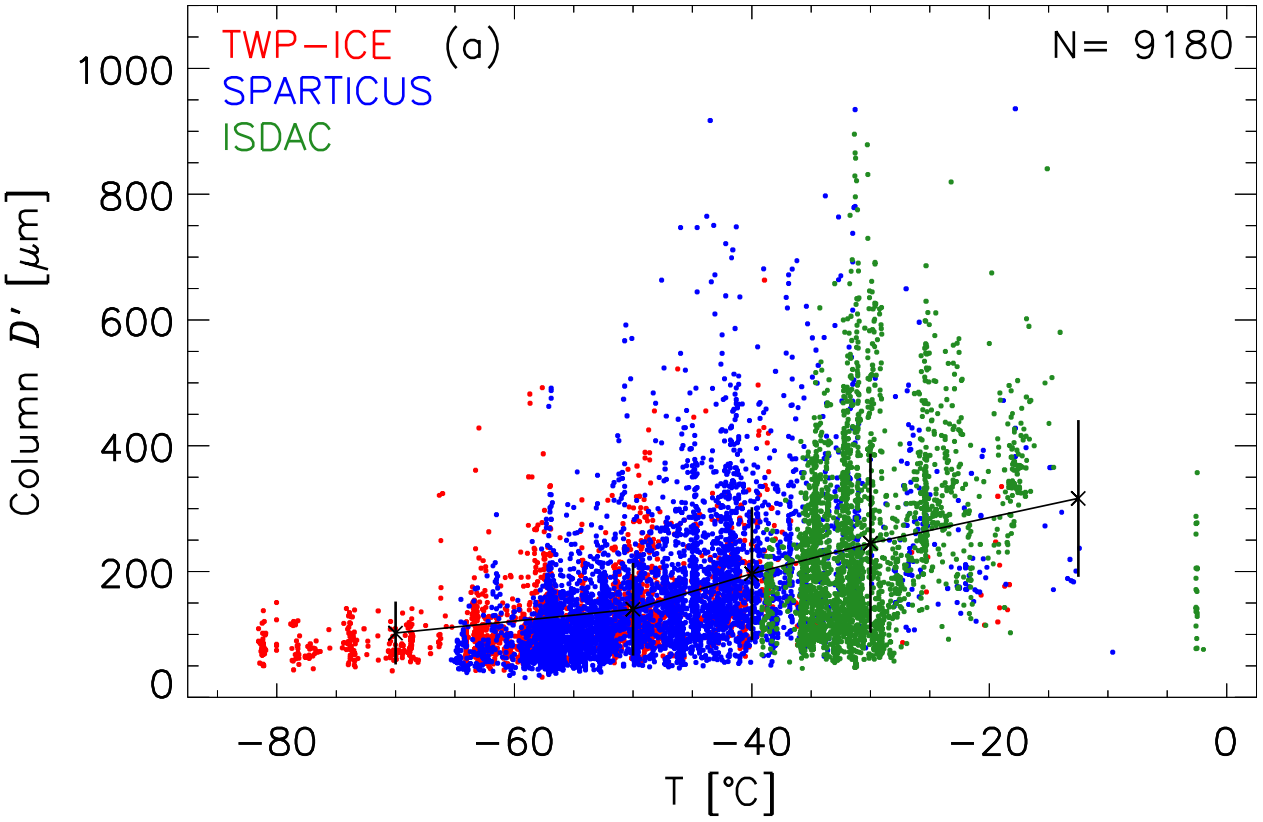
- Projected maximum dimension (*D'*)
- Projected length (*L'*)

IC-Ruler Measurements

Field Campaign	T (°C)	RHi (%)	Number of samples		
			Column (HCOL)	Plate	Bullet rosette (# of branch)
TWP-ICE	-81.5 – -18.3	NA	1977 (430)	2088	751 (4750, 6.3±1.3)
ISDAC	-39.4 – -1.0	37.6 – 137.5	2678 (827)	348	761 (3770, 5.0±1.0)
SPARTICUS	-66.9 – -9.6	8.1 – 199.7	4538 (1175)	1079	3377 (19807, 5.9±1.3)
Total			9193 (2432)	3515	4889 (28327, 5.8±1.3)

Column *D'* vs T

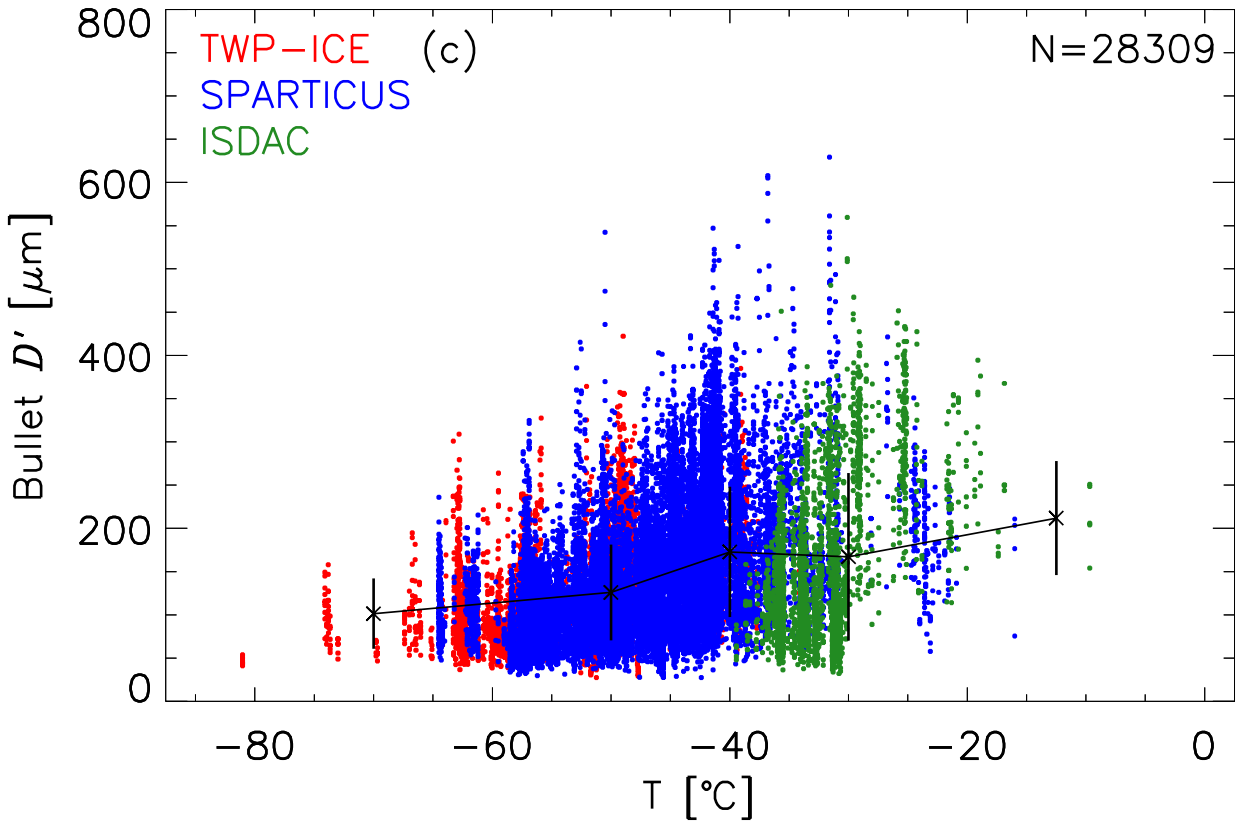
Column



- ***D'* increase with T**

Bullet *D'* vs T

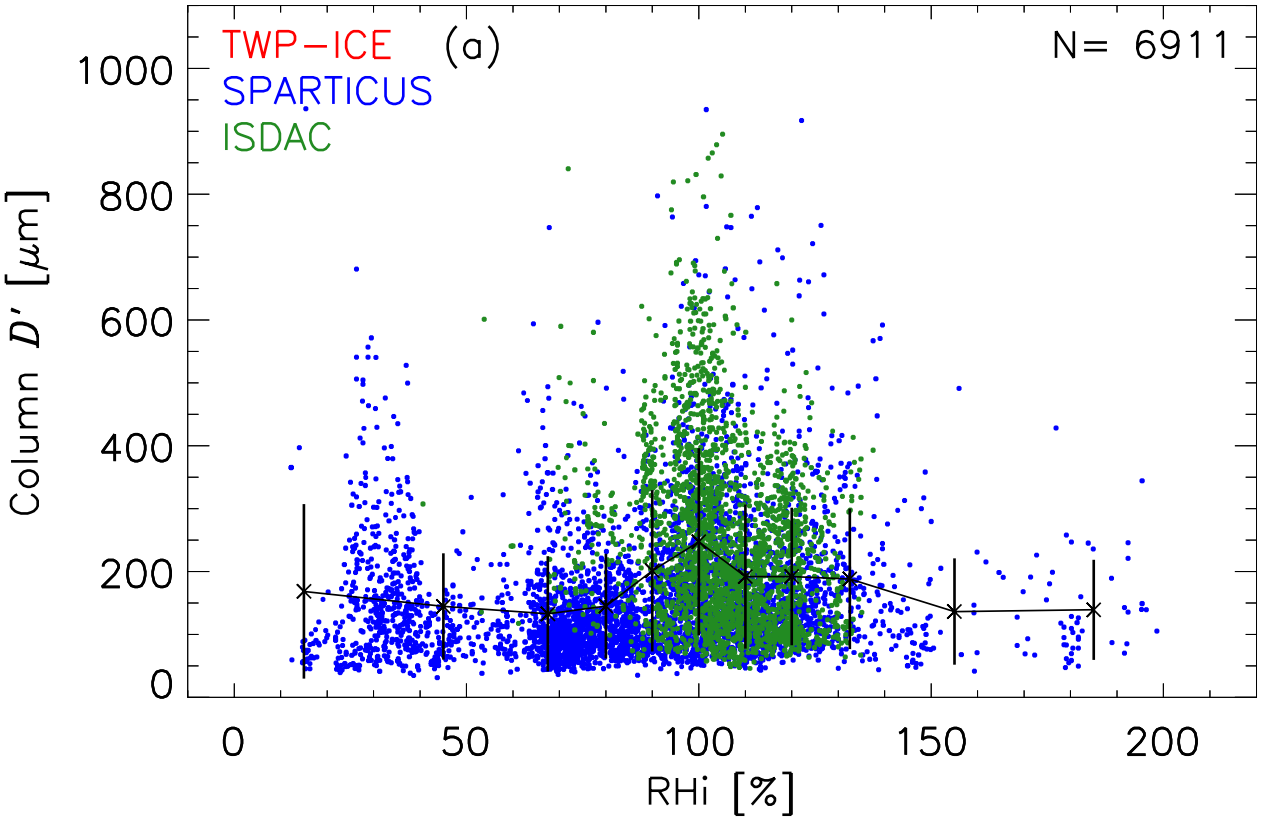
Bullet



- ***D'* increase with T**
- **Same trend for other dimensions and crystals**

Column *D'* vs RH_i

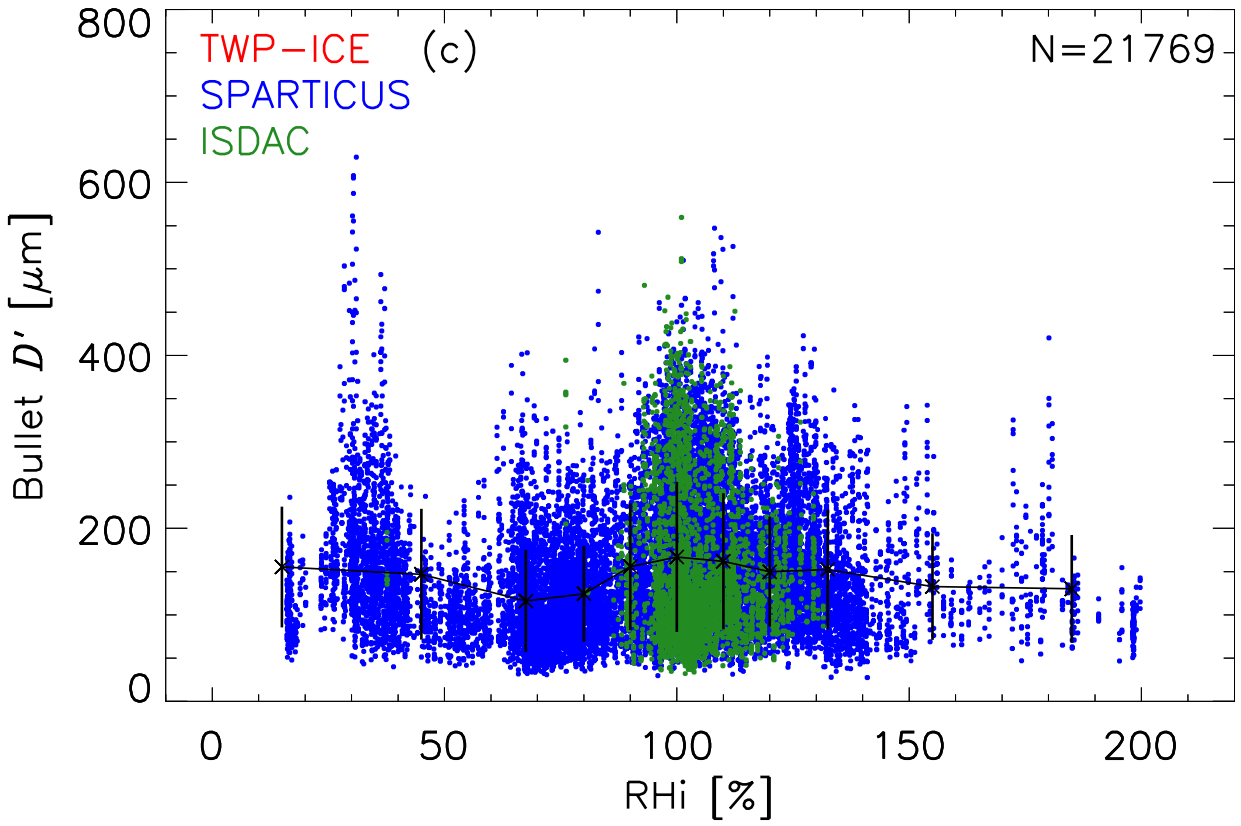
Column



- **No clear dependence on RHi**
- **Largest dimensions at ~ 100%**

Bullet *D'* vs. RH_i

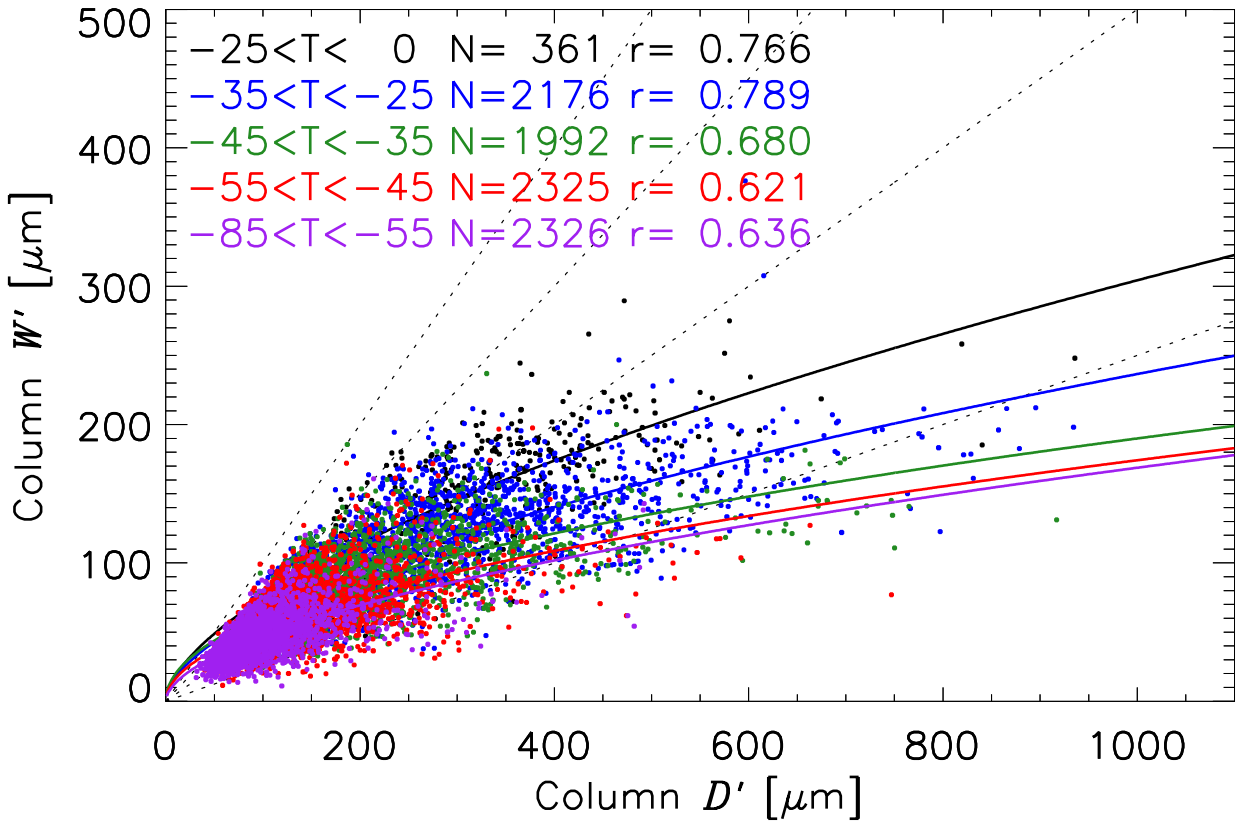
Bullet



- **No clear dependence on RHi**
- **Largest dimensions at ~ 100%**

Column *D'* vs *W'*

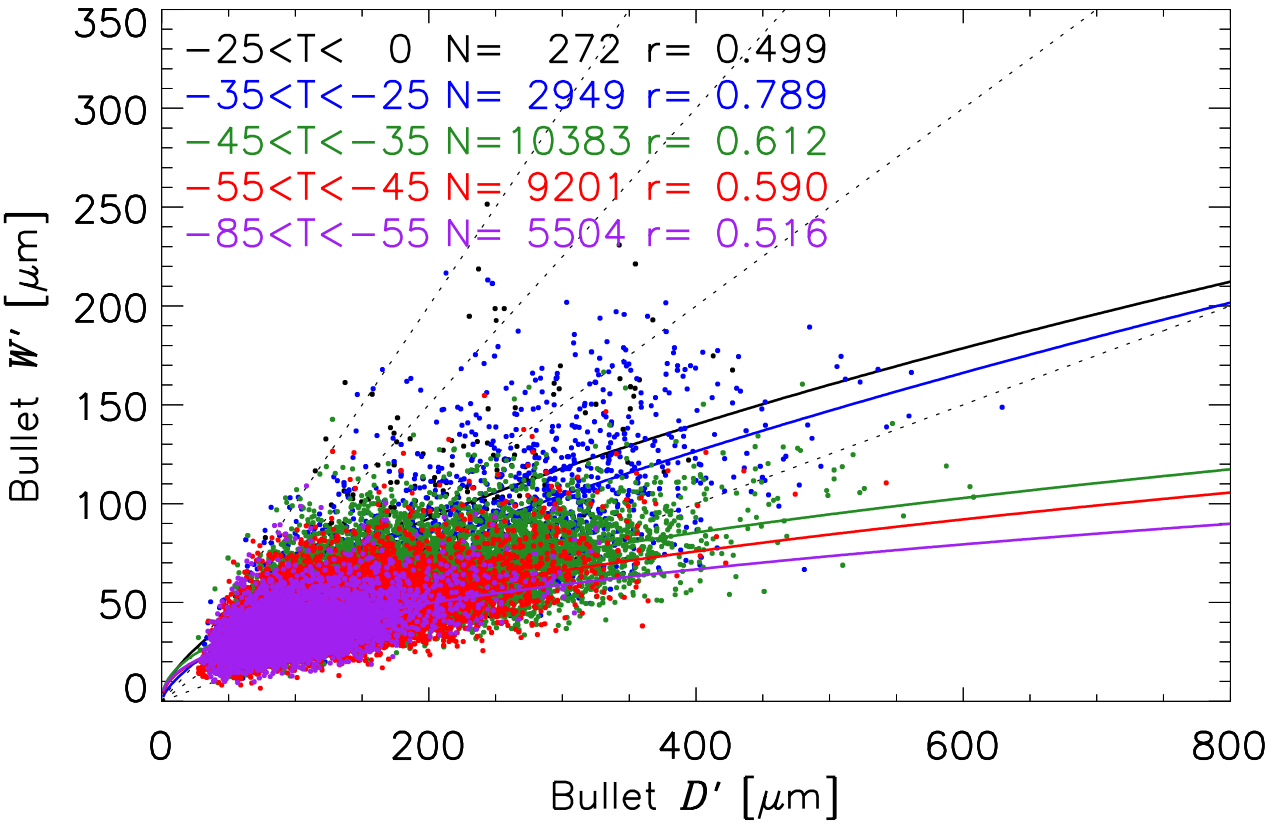
f of T



- **Relationship between *D'* and *W'*, i.e., area ratio depends on T**

Bullet *D'* vs *W'*

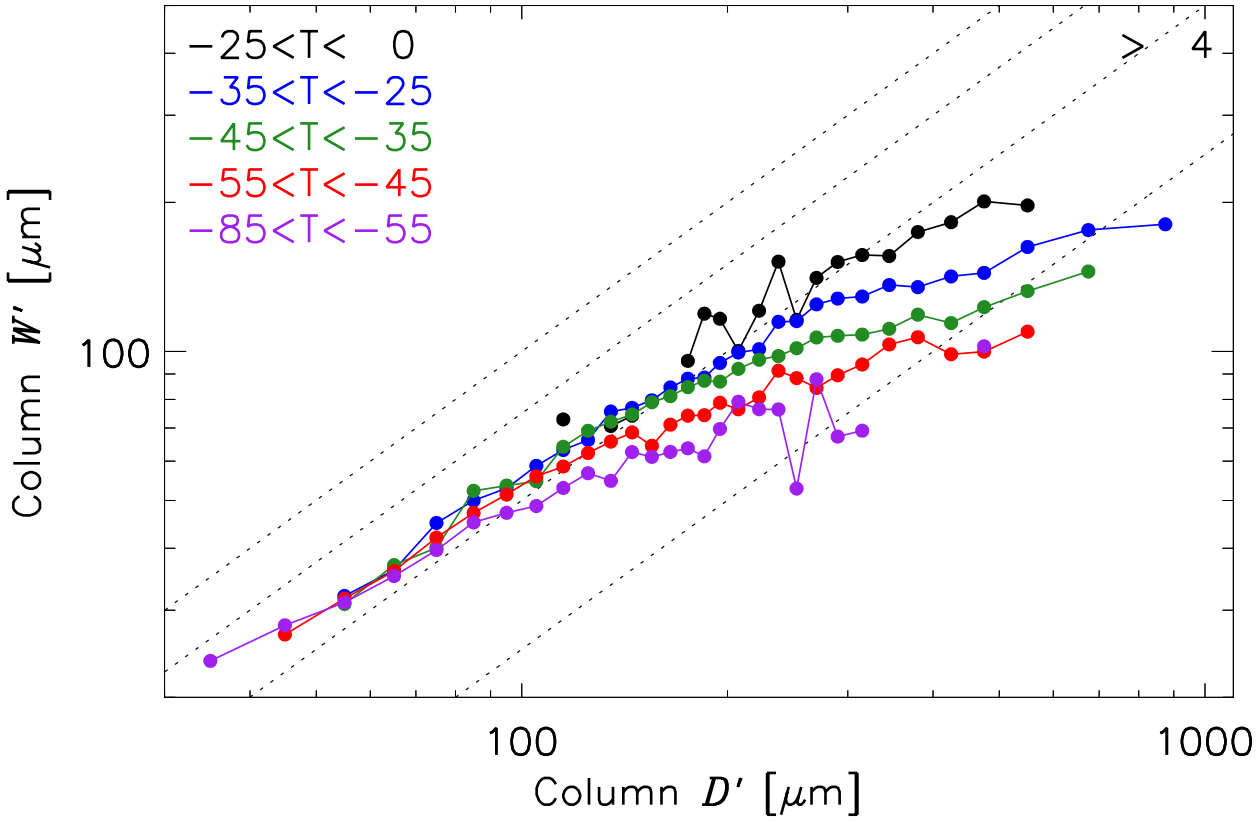
f of T



- **Relationship between *D'* and *W'*, i.e., area ratio depends on T**

Column *D'* vs *W'*

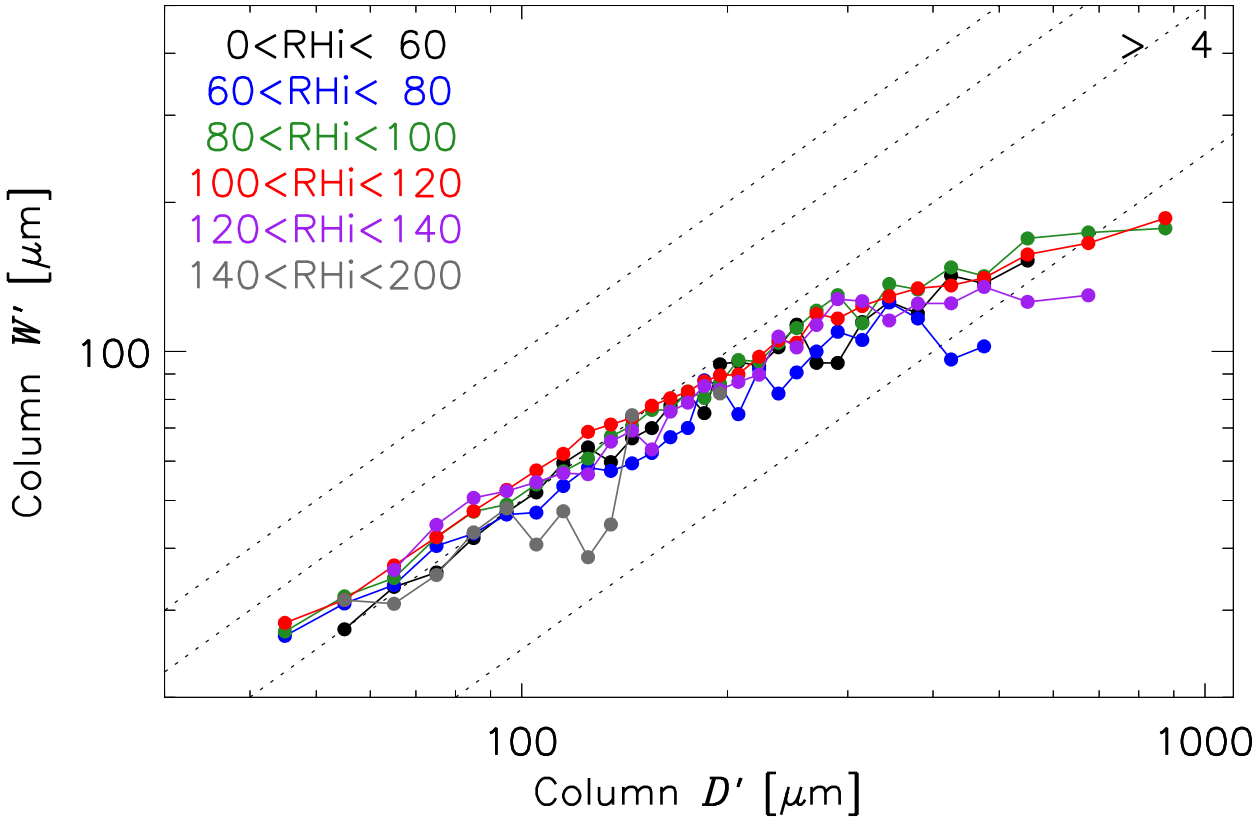
f of T



- **Given *D'* range, mean *W'* increases with T**

Column *D'* vs *W'*

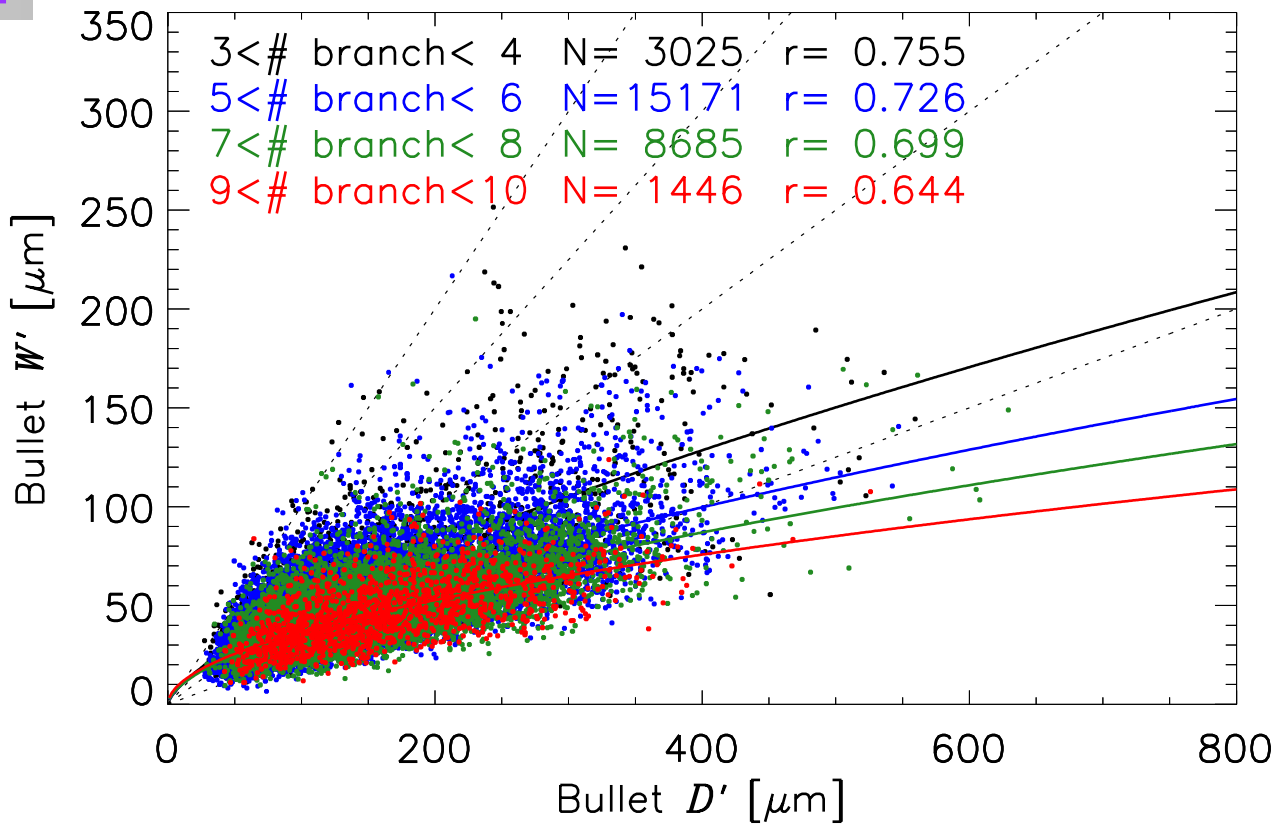
f of RH_i



- **Given *D'* range, no dependence of mean *W'* on RH_i**

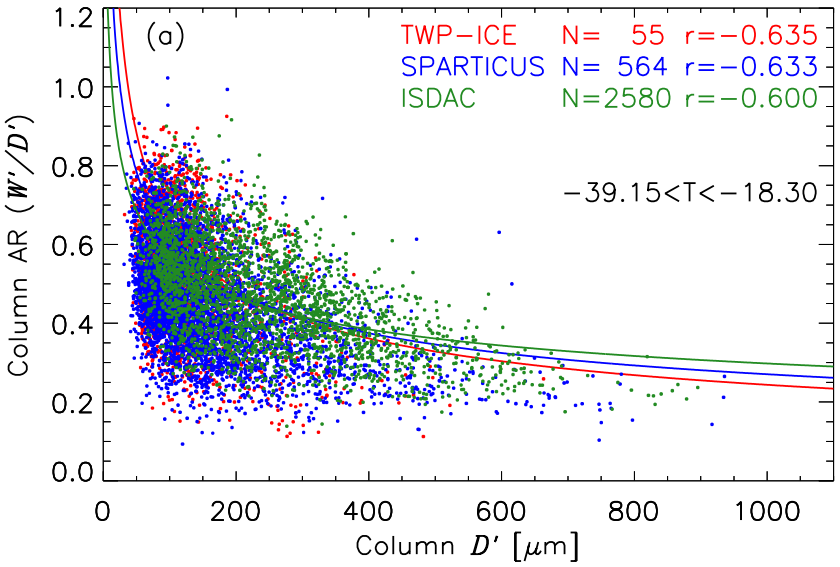
Bullet *D'* vs *W'*

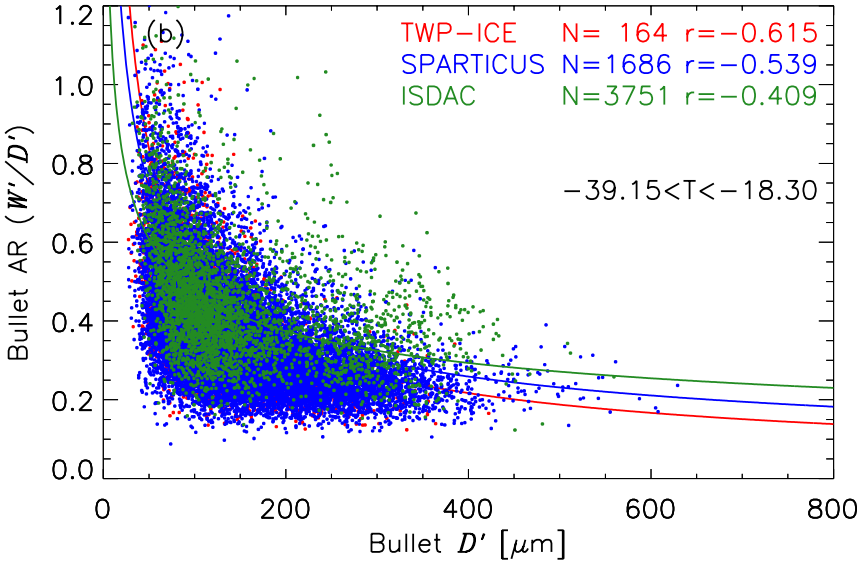
f of branch



- **Aspect ratio (*W'/D'*) increases as # of branch decreases**

Geophysical Location





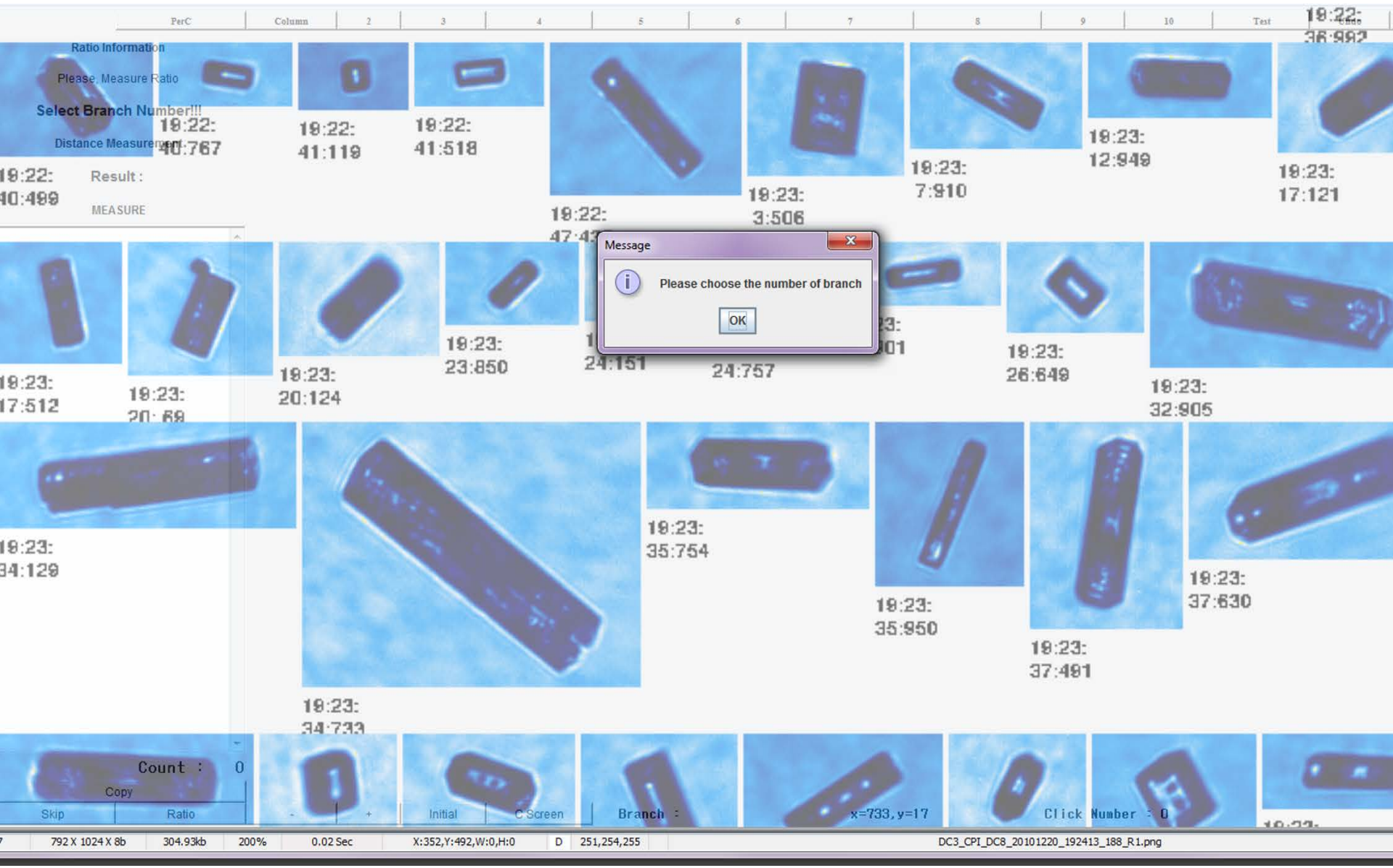
- **-39.15 < T < -18.30 °C measurements for all three campaigns**
- **No clear dependence**
- **Small samples in TWP-ICE**
- **Further analysis**

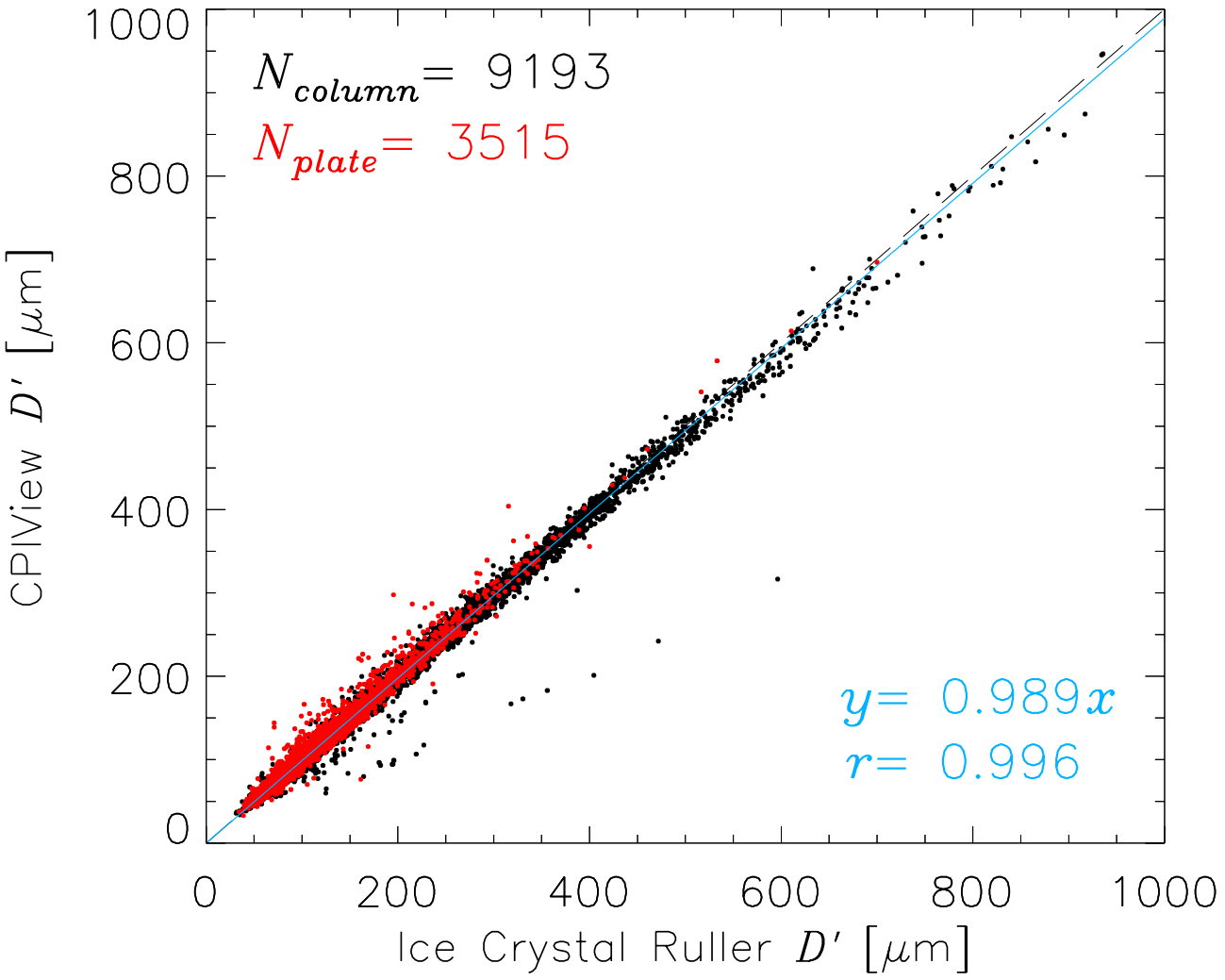
Summary & Future Work

- **Dimensions increase with T**
- **No clear dependence of RH_i**
- **Given *L'* or *D'*, aspect ratio (*W'/L'* or *W'/D'*) increases with T**
- **Aspect ratio of bullet increases as # branch decreases**
- **No clear dependence on geophysical location (further analysis required)**

- **Iterative approach to take into account impact of particle orientations on measured dimensions**
- **Particle habit classification database**

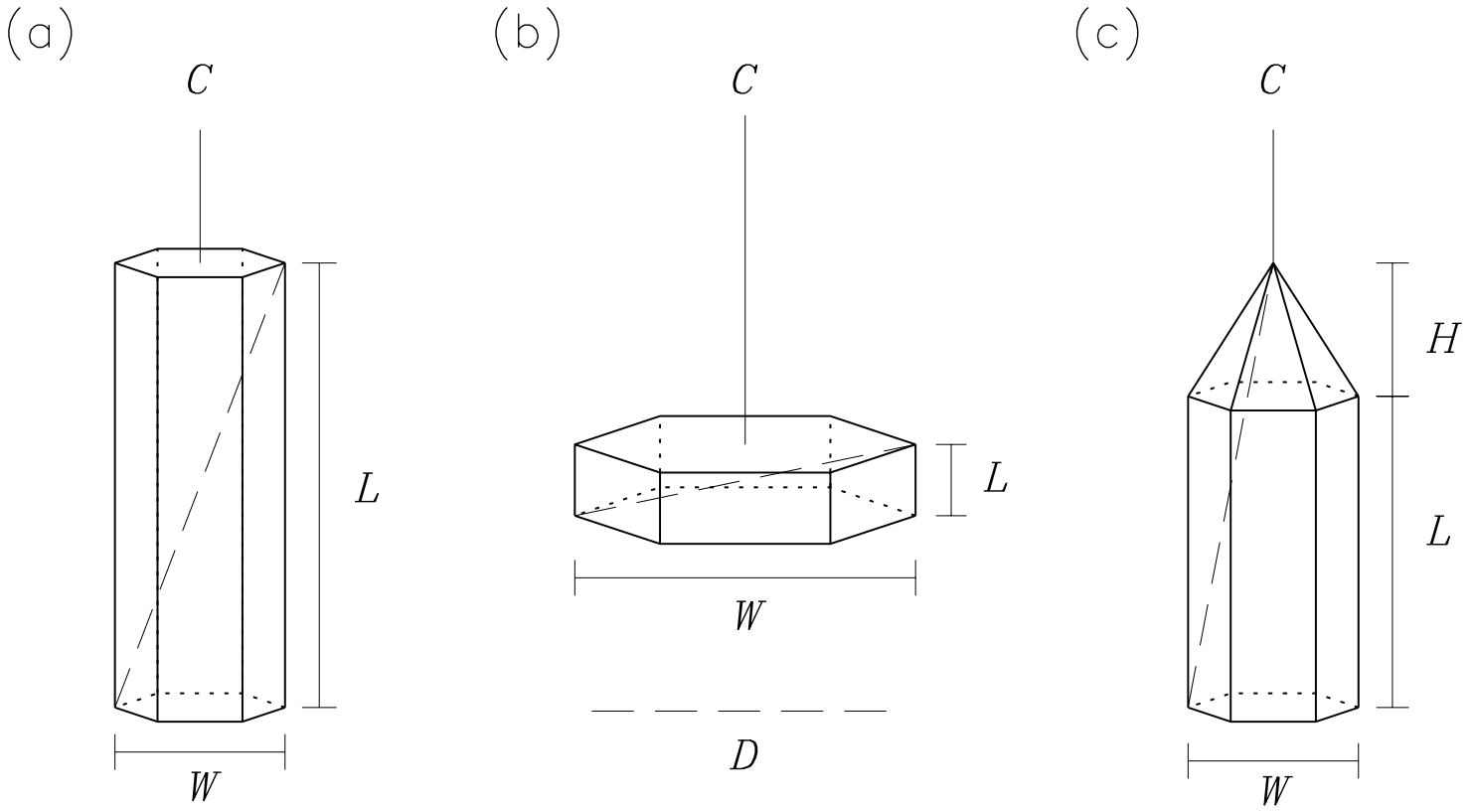
IC-Ruler


PerC
Column
2
3
4
5
6
7
8
9
10
Test
Ratio Information
Please, Measure Ratio
Select Branch Number!!!
Distance Measurement
Result :
MEASURE
Message
Please choose the number of branch
OK
Count : 0
Copy
Skip
Ratio
Initial
C Screen
Branch :
x=733,y=17
Click Number : 0
792 X 1024 X 8b
304.93kb
200%
0.02 Sec
X:352,Y:492,W:0,H:0
D
251,254,255
DC3_CPI_DC8_20101220_192413_188_R1.png



IC-Ruler *D'* / CPIView *D'* = 1.0042 ± 0.06915

Ice Crystal Structure



D **: Maximum dimension**
W **: Width**
L **: Length**

Horizontally Oriented Column *L'* vs T

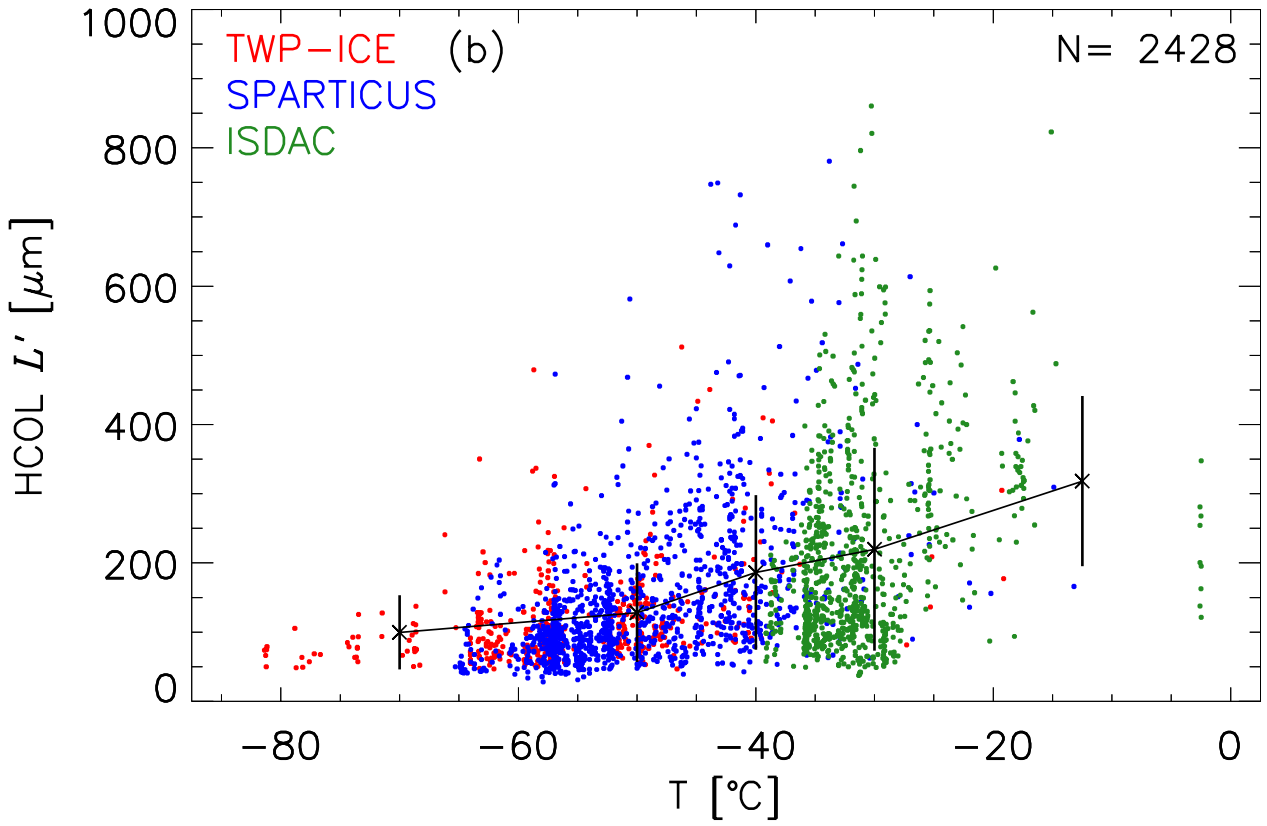
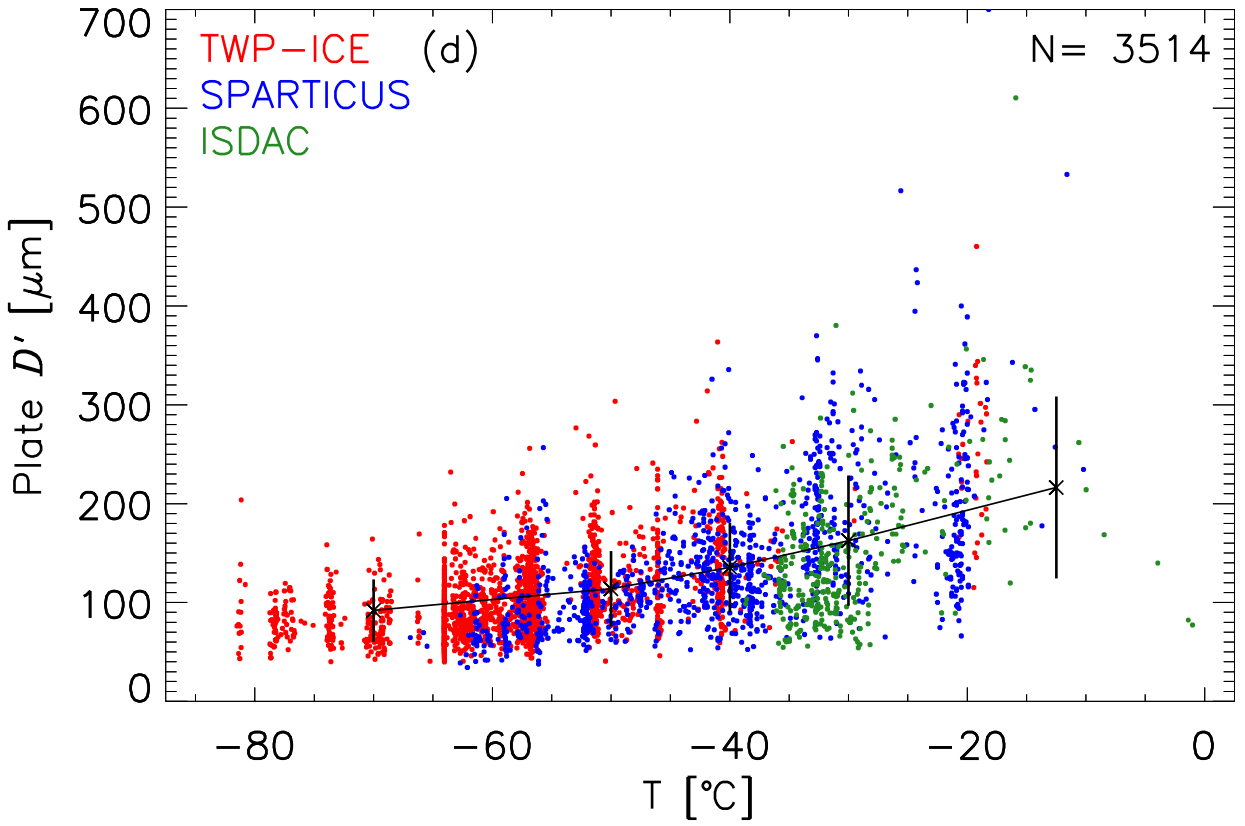


Plate *D'* vs T


TWP−ICE
SPARTICUS
ISDAC
(d)
N= 3514
Plate D' [μm]
700
600
500
400
300
200
100
0
−80
−60
−40
−20
0
T [℃]

Horizontally Oriented Column *L'* vs RH_i

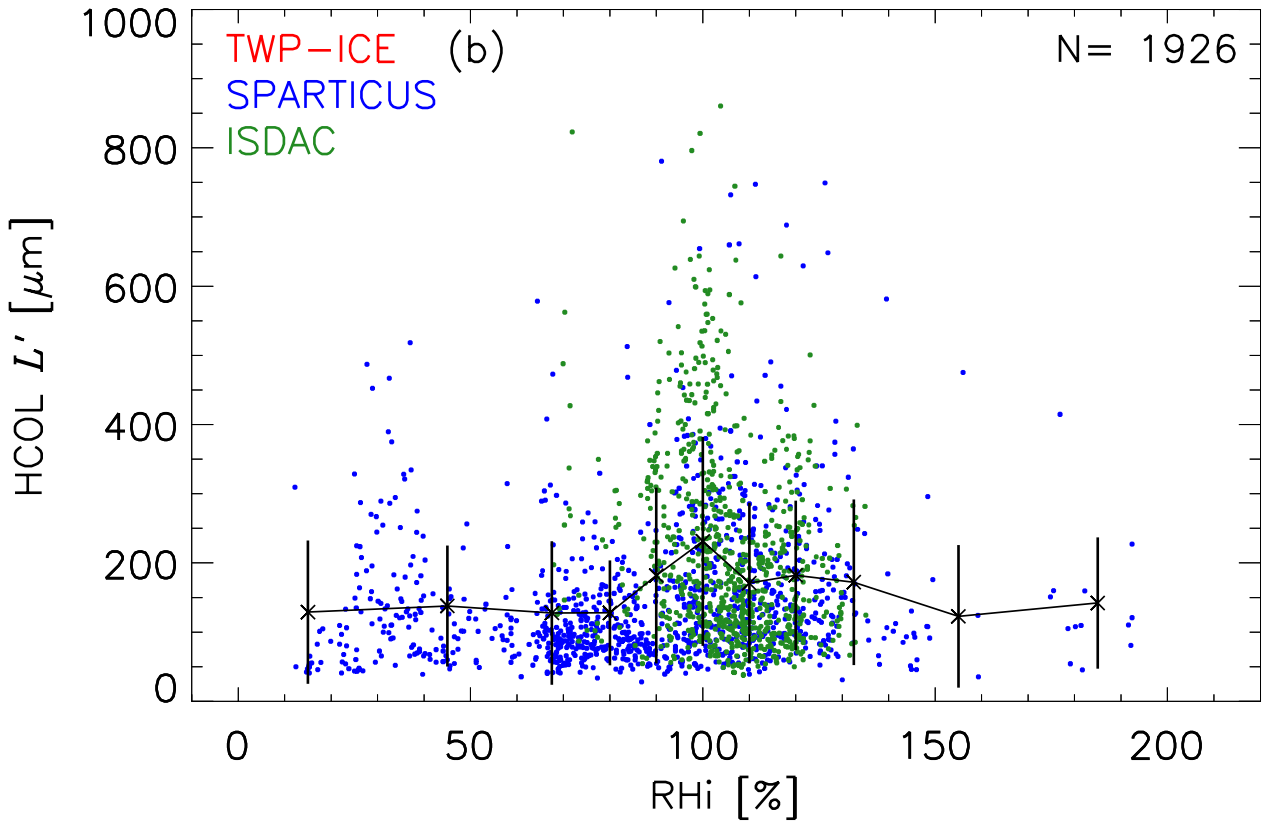
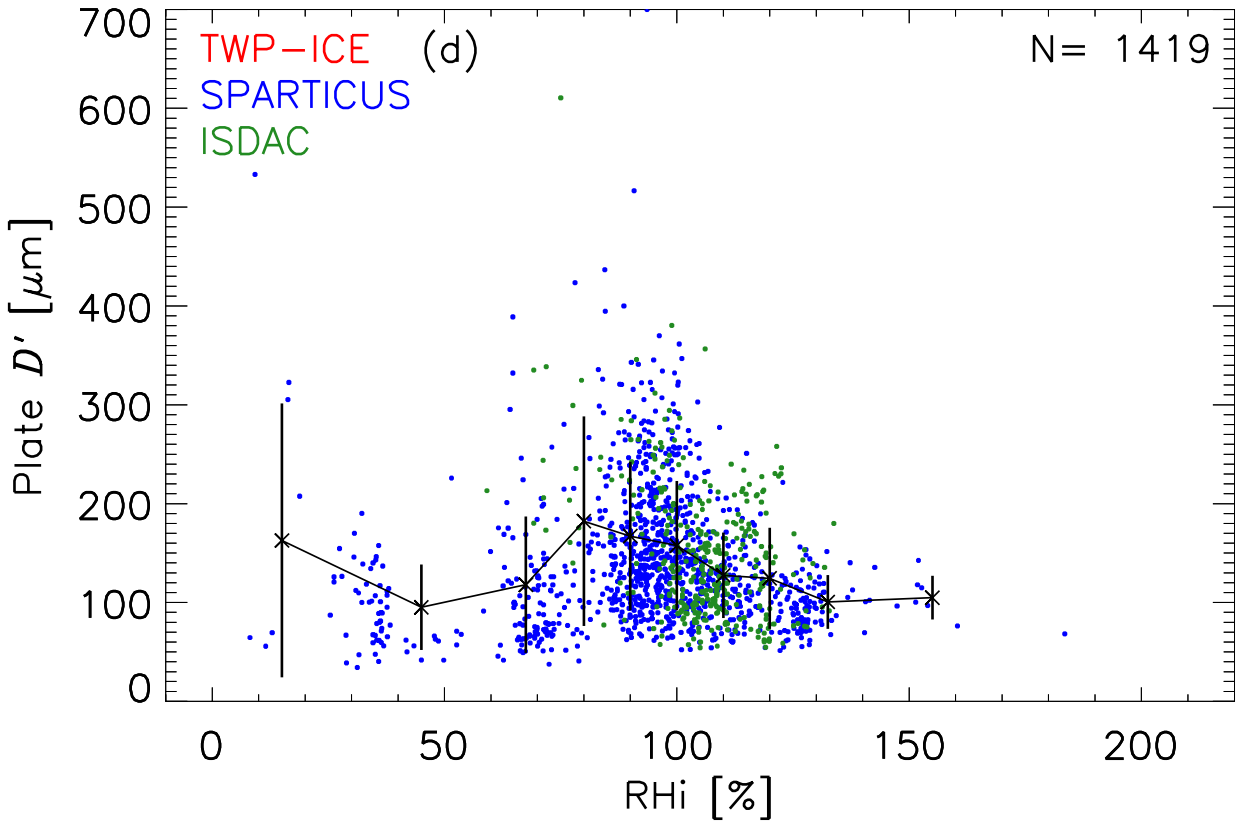
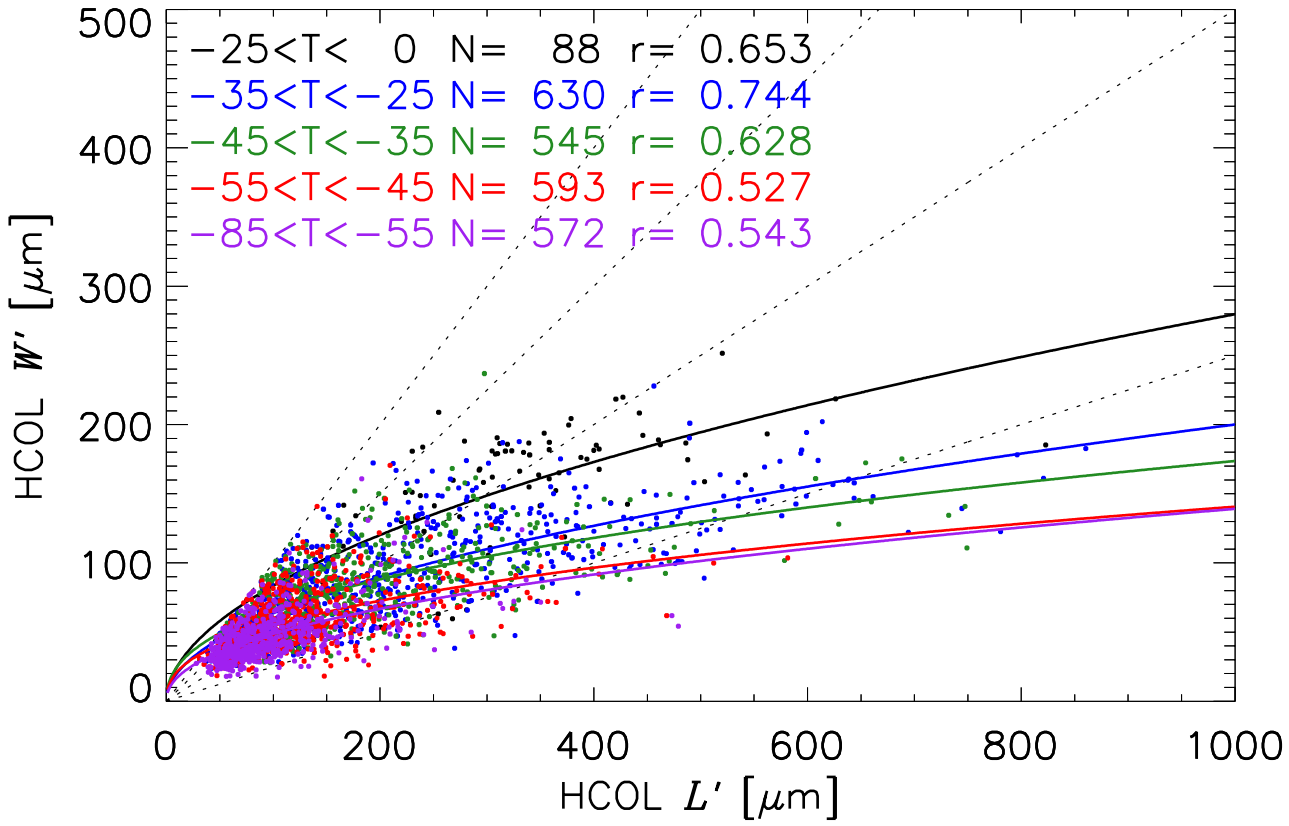


Plate *D'* vs RH_i



HCOL *D'* vs *W'*

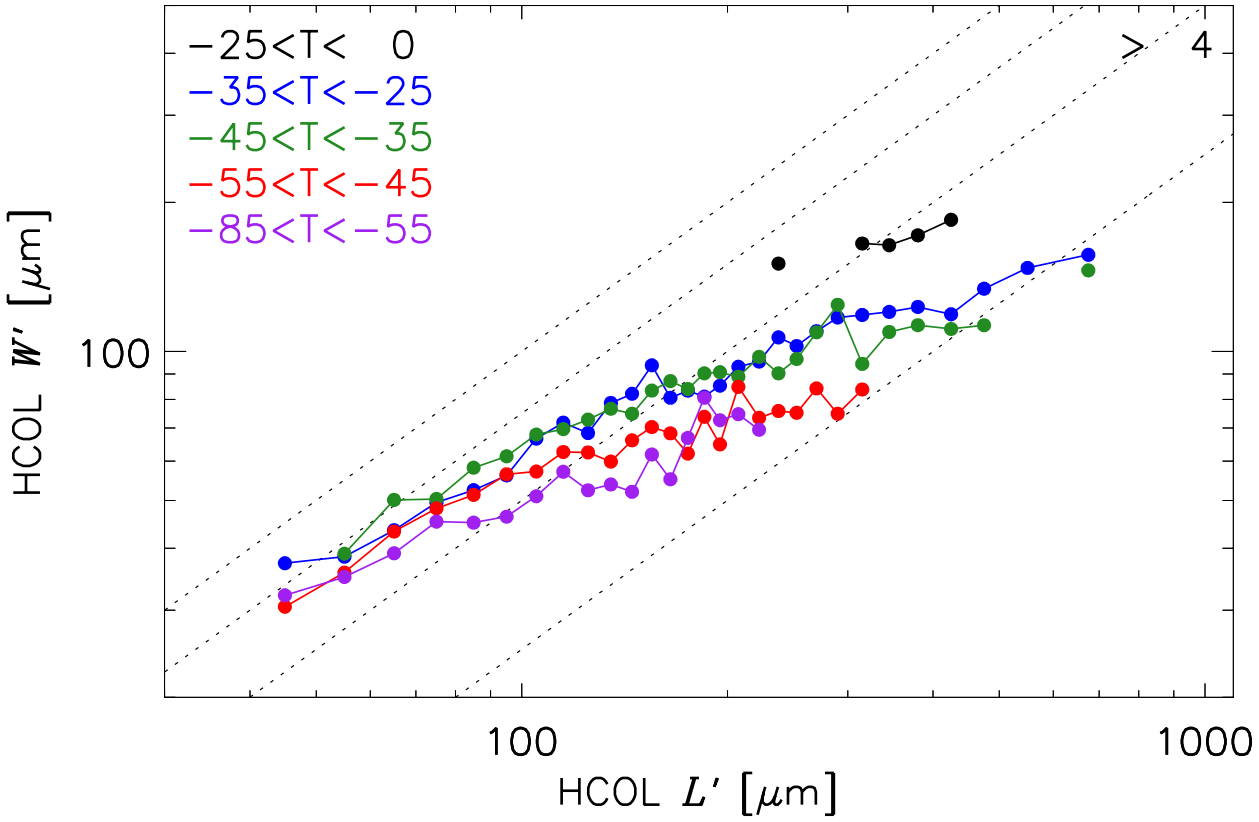
f of T



- **Relationship between *D'* and *W'*, i.e., area ratio depends on T**

HCOL *D'* vs *W'*

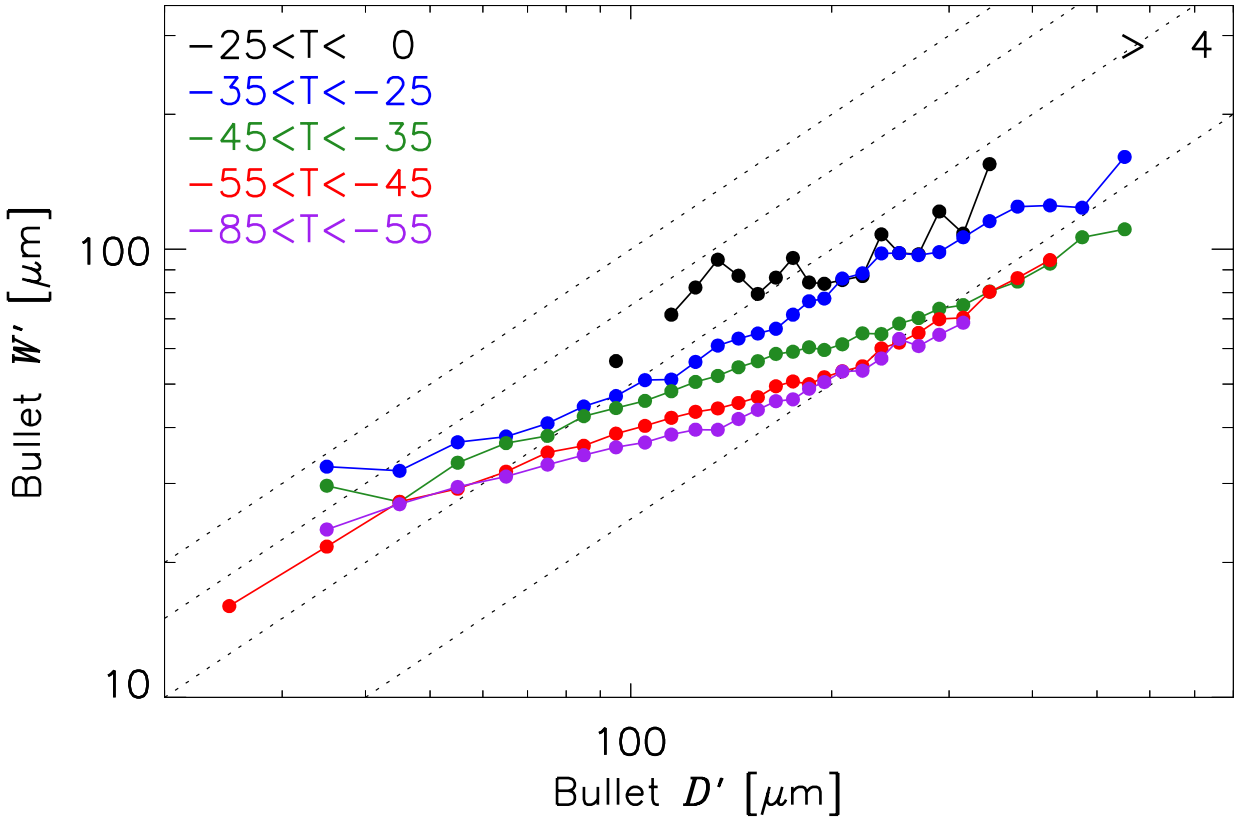
f of T



- **Given *D'* range, mean *W'* increases with T**

Bullet *D'* vs *W'*

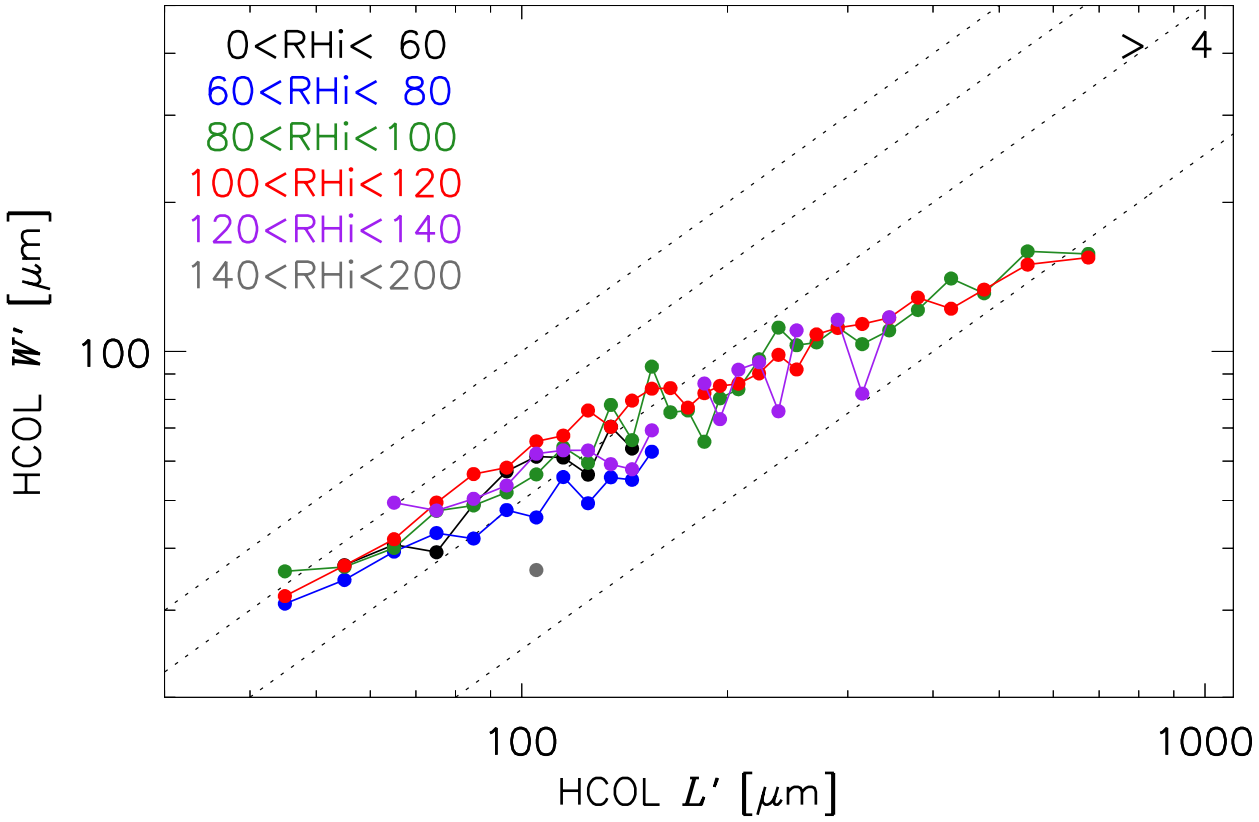
f of T



- **Given *D'* range, mean *W'* increases with T**

HCOL *D'* vs *W'*

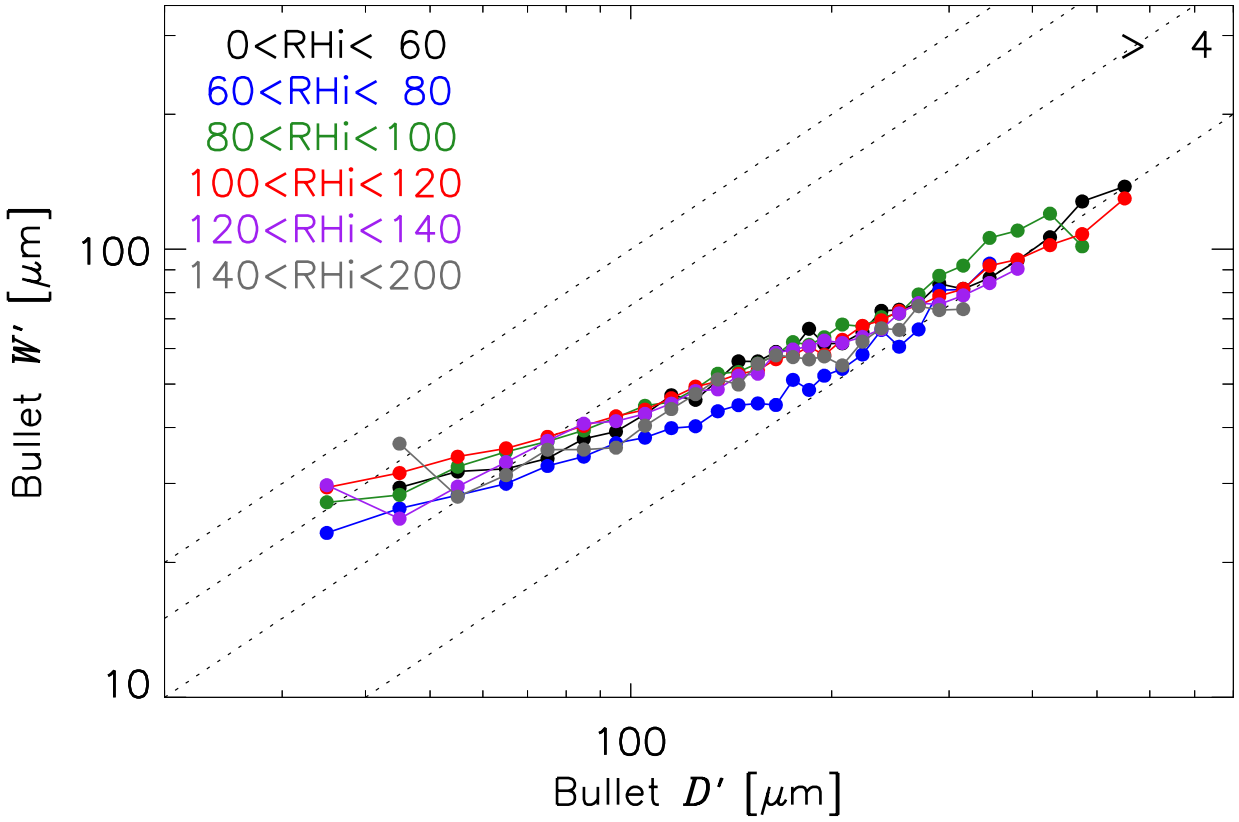
f of RH_i



- **Given *D'* range, no dependence of mean *W'* on RH_i**

Bullet *D'* vs *W'*

f of RH_i



- **Given *D'* range, no dependence of mean *W'* on RH_i**

SPARTICUS

Flight Date	T (°C)	RHi (%)	Number of samples		
			Column (HCOL)	Plate	Bullet rosette (# of branch)
0119A	-56.0 – -18.8	17.8 – 123.3	619 (168)	38	199 (1071, 5.4±1.1)
0120A	-59.3 – -43.3	42.4 – 148.4	648 (166)	48	592 (3489, 5.9±1.2)
0120B	-58.1 – -11.6	9.2 – 63.5	436 (96)	30	318 (1817, 5.7±1.3)
0211B	-47.8 – -31.5	85.1 – 127.6	214 (45)	14	576 (3495, 6.1±1.3)
0323A	-60.4 – -12.4	53.6 – 181.7	133 (39)	10	51 (314, 6.2±1.1)
0330A	-60.2 – -26.8	47.8 – 141.8	120 (38)	14	105 (696, 6.6±1.1)
0330B	-58.5 – -29.9	63.6 – 141.1	235 (56)	25	236 (1206, 5.1±1.1)
0401A	-54.2 – -38.0	19.9 – 199.7	374 (92)	6	482 (2825, 5.9±1.3)
0401B	-51.6 – -21.7	58.6 – 139.3	164 (31)	31	216 (1387, 6.4±1.4)
0402A	-59.3 – -18.6	65.9 – 146.8	209 (60)	11	41 (271, 6.6±1.0)
0414B	-52.5 – -30.6	63.4 – 166.3	193 (58)	76	109 (566, 5.2±1.3)
0422B	-62.7 – -10.2	28.9 – 133.4	110 (29)	131	7 (38, 5.4±1.1)
0424A	-48.3 – -14.3	59.9 – 141.0	190 (36)	210	136 (708, 5.2±1.2)
0428A	-66.9 – -50.7	8.1 – 117.1	180 (65)	3	4 (22, 5.5±1.0)
0428B	-65.8 – -31.3	12.9 – 137.8	295 (86)	12	104 (595, 5.7±1.2)
0429	-64.5 – -9.6	16.1 – 141.5	88 (21)	5	106 (719, 6.8±1.1)
0614	-52.3 – -20.0	80.5 – 154.0	138 (57)	185	12 (64, 5.3±1.1)
0615A	-51.1 – -19.7	56.8 – 123.4	54 (8)	215	5 (21, 4.2±0.8)
0624A	-50.6 – -28.9	81.9 – 145.4	138 (24)	15	78 (503, 6.4±1.2)
Total			4538 (1175)	1079	3377 (19807, 5.9±1.3)

TWP-ICE

Flight Date	T (°C)	RHi (%)	Number of samples		
			Column (HCOL)	Plate	Bullet rosette (# of branch)
0125	-70.2 – -51.4	NA	294 (80)	20	74 (432, 5.8±1.1)
0127	-81.5 – -45.5	NA	289 (64)	63	84 (551, 6.6±1.3)
0129	-74.5 – -37.7	NA	299 (54)	15	372 (2488, 6.7±1.3)
0202	-67.8 – -18.3	NA	282 (75)	143	90 (559, 6.2±1.3)
0206	-73.1 – -40.2	NA	271 (78)	439	0
0210	-78.7 – -40.5	NA	394 (46)	1049	0
0212	-72.7 – -34.1	NA	148 (33)	359	131 (720, 5.5±1.2)
Total			1977 (430)	2088	751 (4750, 6.3±1.3)

ISDAC

Flight Date	T (°C)	RHi (%)	Number of samples		
			Column (HCOL)	Plate	Bullet rosette (# of branch)
0404	-39.4 – -1.0	68.7 – 133.2	745 (272)	84	45 (260, 5.8±1.0)
0405	-38.3 – -14.0	69.2 – 135.1	325 (91)	50	21 (116, 5.5±0.8)
0413	-33.7 – -16.4	87.8 – 115.4	72 (13)	9	37 (227, 6.1±1.5)
0419	-33.5 – -8.5	53.8 – 110.8	409 (121)	19	304 (1455, 4.8±1.0)
0425	-36.0 – -4.0	67.8 – 137.5	634 (175)	126	279 (1361, 4.9±0.8)
0427	-36.3 – -16.5	37.6 – 133.0	493 (155)	60	75 (351, 4.7±0.9)
Total			2678 (827)	348	761 (3770, 5.0±1.0)

1. Today I will show measurements of ice crystals' dimensions.

2. Ice crystal ruler measuring dimensions of ice crystals was developed.
Dimensions of columns, plates, and individual branch of bullet rosette are measured from CPI images.
Three field campaigns data were used.
Ultimate questions to be answered are what controls aspect ratio of ice crystals?
Is there any systemic difference between geophysical locations?

3. Let me explain IC-Ruler
Here is 8 branches bullet rosette.

4. First we identifying center.

5. Here projected maximum dimension of individual branch is shown.
Ice crystals are 3 dimensional object, but dimensions shown in CPI images are 2 dimensional and they projected dimensions.

6. Next projected widths are shown.

7. Next one is a column.

8. Here projected maximum dimension and width are shown.

9. We distinguished horizontally oriented columns.
We a column has horizontal orientation respective to the image plane, its shape becomes rectangular.
In this case, the projected length and real length are same.

10. Projected maximum dimension, width, and length are measured for horizontally oriented columns.

11. Here is a plate.

12. For plates, projected maximum dimension and length are measured.

13. From three field campaigns, lots of ice crystals were measured.

14. Here are some results.
Projected maximum dimensions of column increase with T.

15. Same story for bullet and all dimensions we measured.

16. No clear dependence on RHi is shown.

17. Same story for bullets.

18. This figure shows column projected maximum dimension and width as function of temperature.
Temperature dependence is shown.

19. Same story for bullet.

20. This is more close look.
For given maximum dimension, width increases with Temperature.

21. But, no dependence on RHi.

22. This figure shows relationship between bullet maximum dimension and width.
Different colors indicate number of branch.
Aspect ratio increases as # of branch decreases.

23. At this temperature range, all three campaigns have crystal measurements.
Column and bullet aspect ratios as a function of maximum dimension are shown.
No clear dependence on geophysical location is shown, but more analysis will be made.

24. Here is summary and I will not gonna repeat.
We are working on an iterative approach.
It considers relationship between particle orientations and projected dimensions for real L and W relationship.
And we are also working on particle habit database.