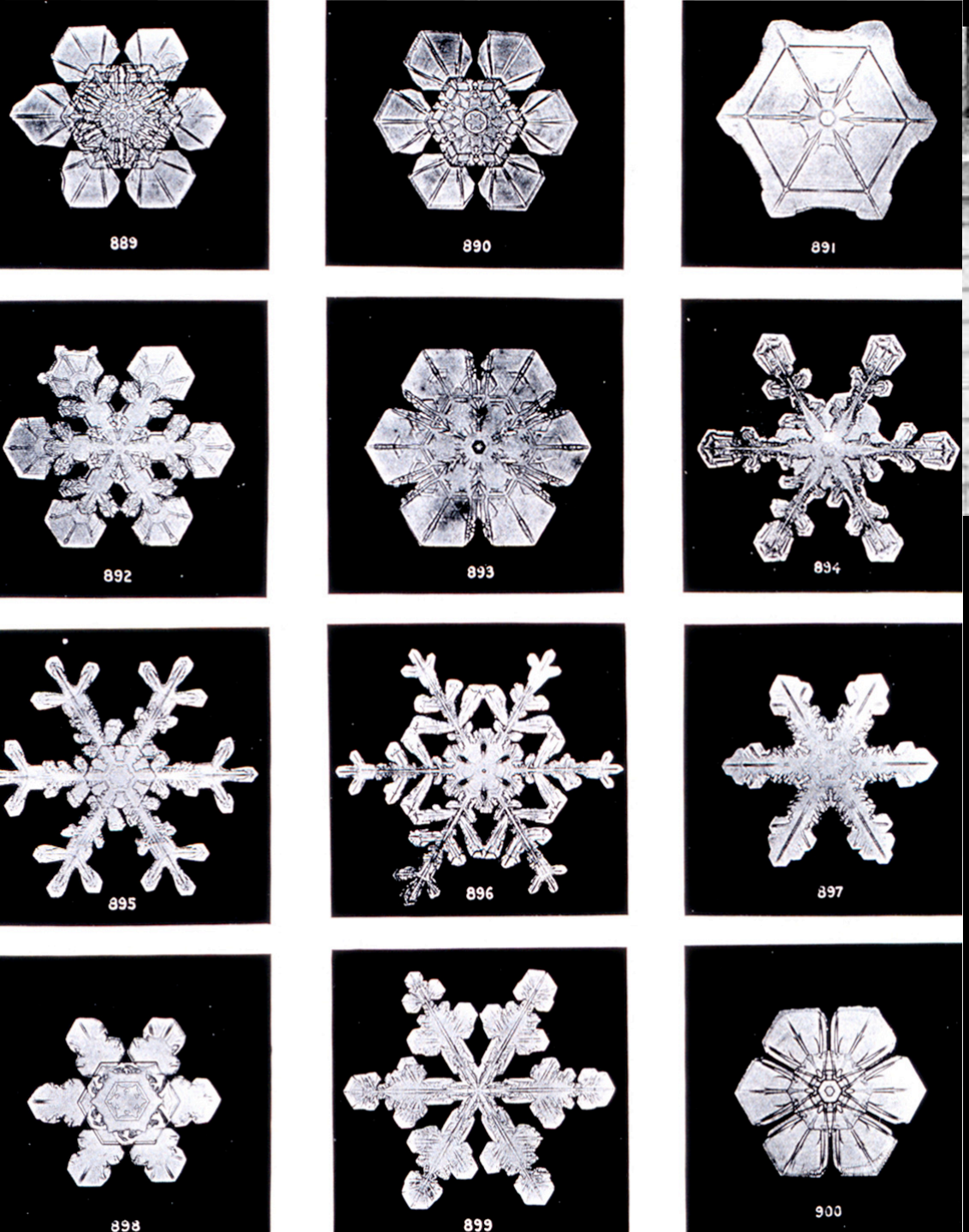
Photographing Snowflakes in Freefall at Alta

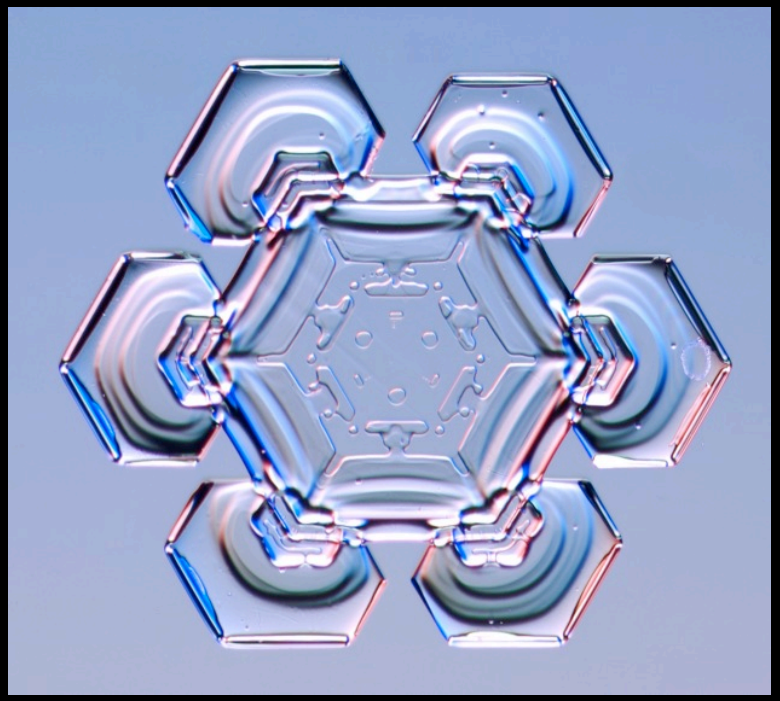
Tim Garrett U Utah
Cale Fallgatter U Utah

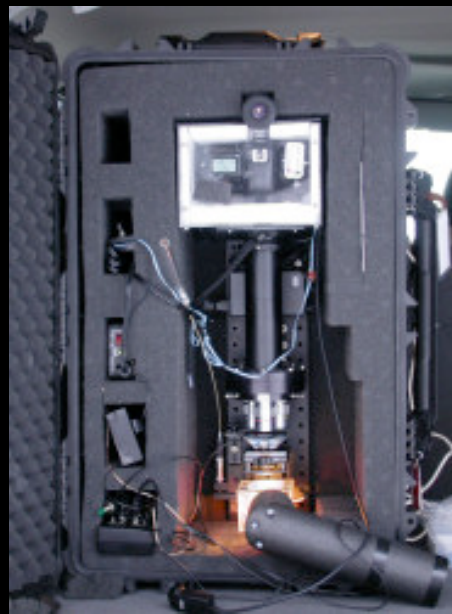
Collaborations with
Sandra Yuter (NC State)



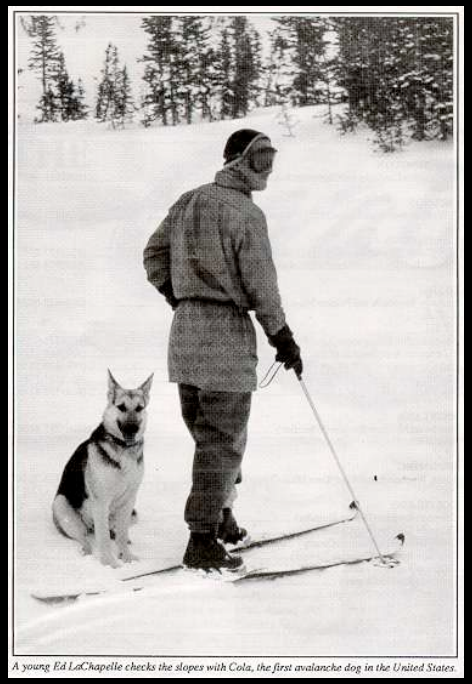
Wilson Bentley

Ken Libbrecht: Snowcrystals.com

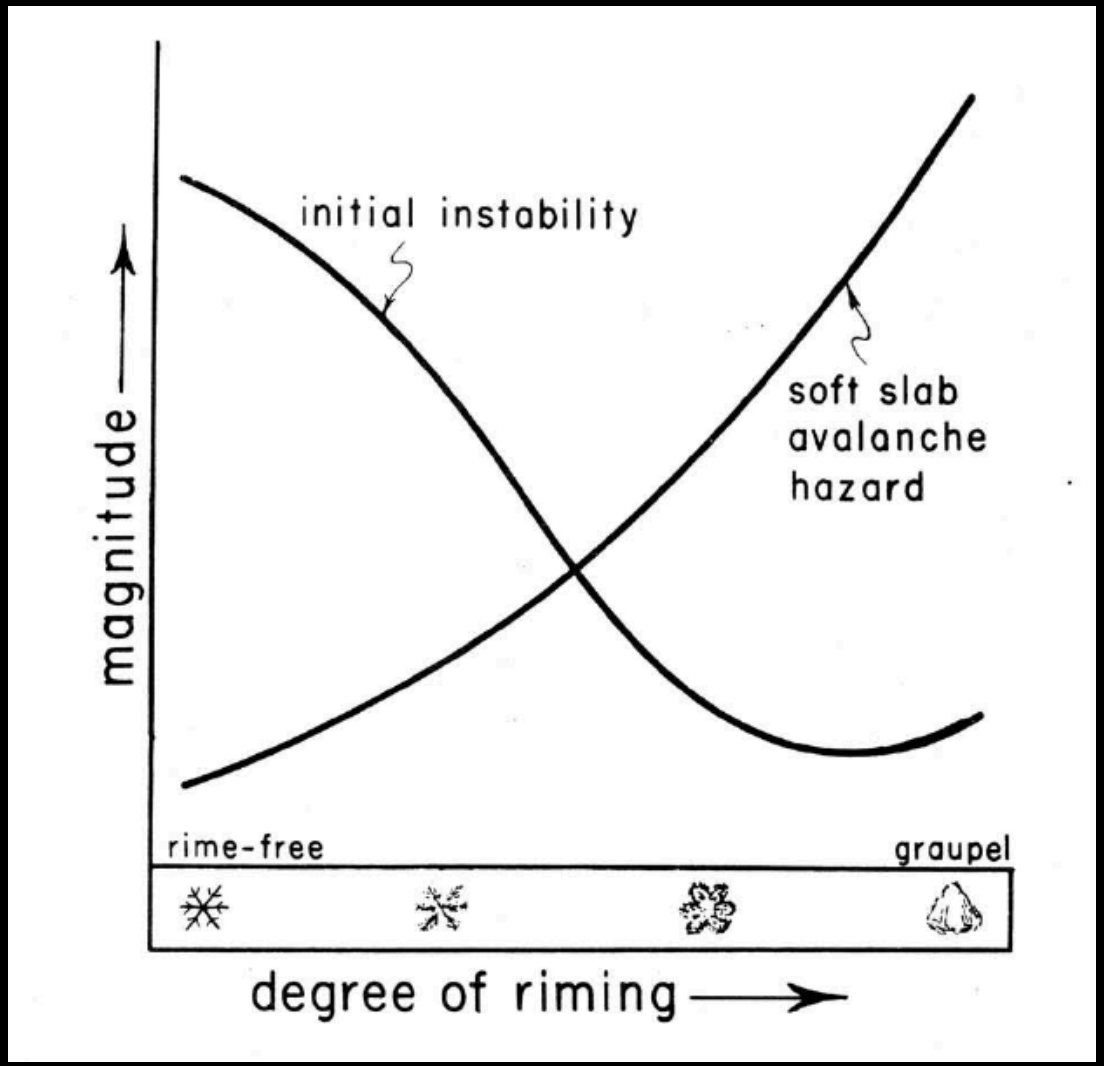




Edward LaChappelle, Alta, 1966

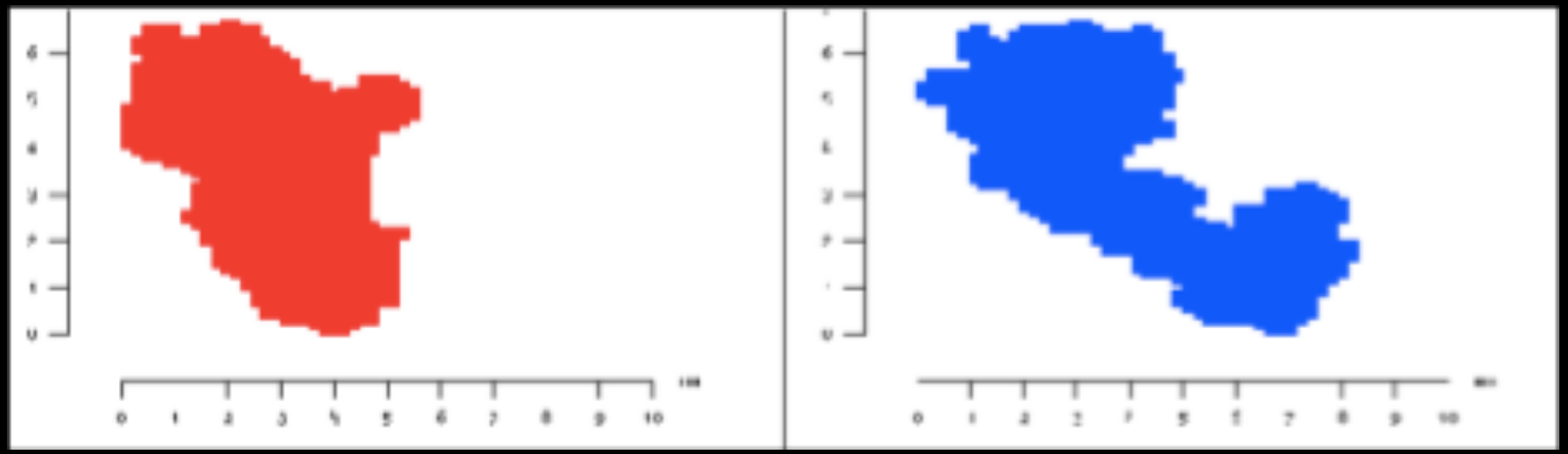


A young Ed LaChapelle checks the slopes with Cola, the first avalanche dog in the United States.




Field Guide to Snow Crystals
Edward R. LaChapelle

200 micron resolution silhouettes from two angles with fall speed

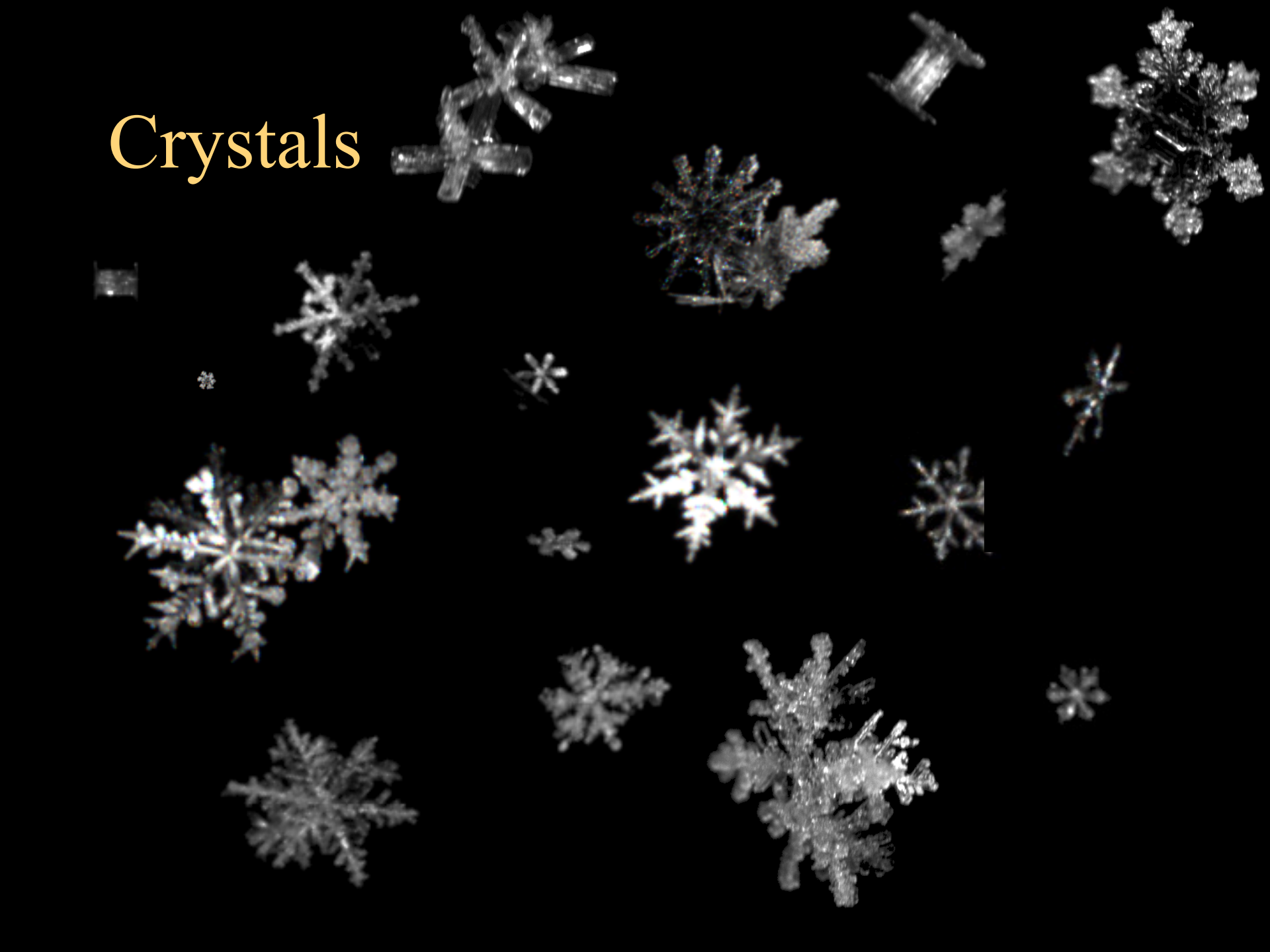


2D Video Distrometer from Joanneum Research in Austria

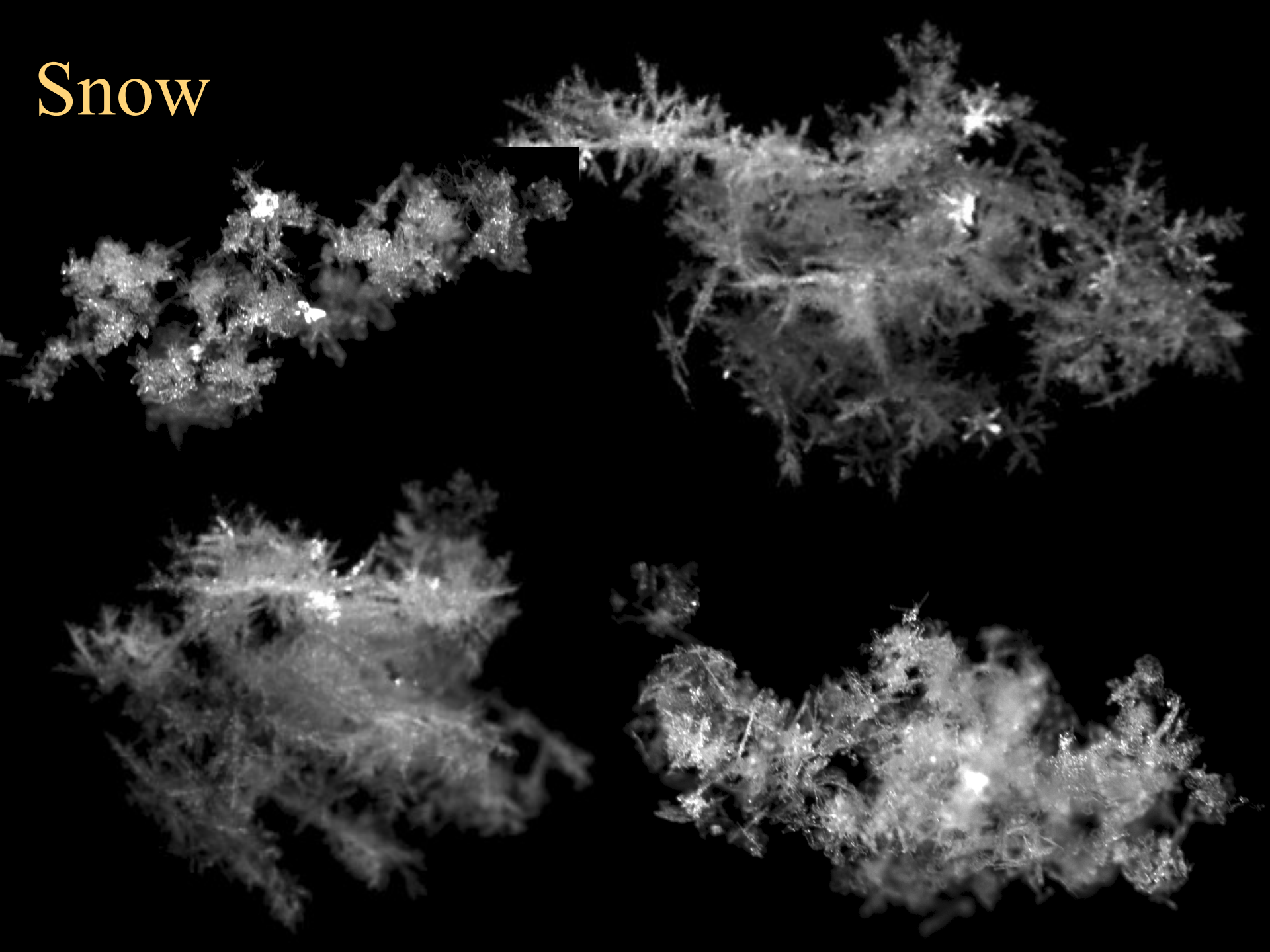
Multi Angle Snowflake Camera (MASC) at Alta Ski Area
Up to 10 micron resolution photographs of snowflakes in freefall with fallspeed


0.97 m/s fall speed

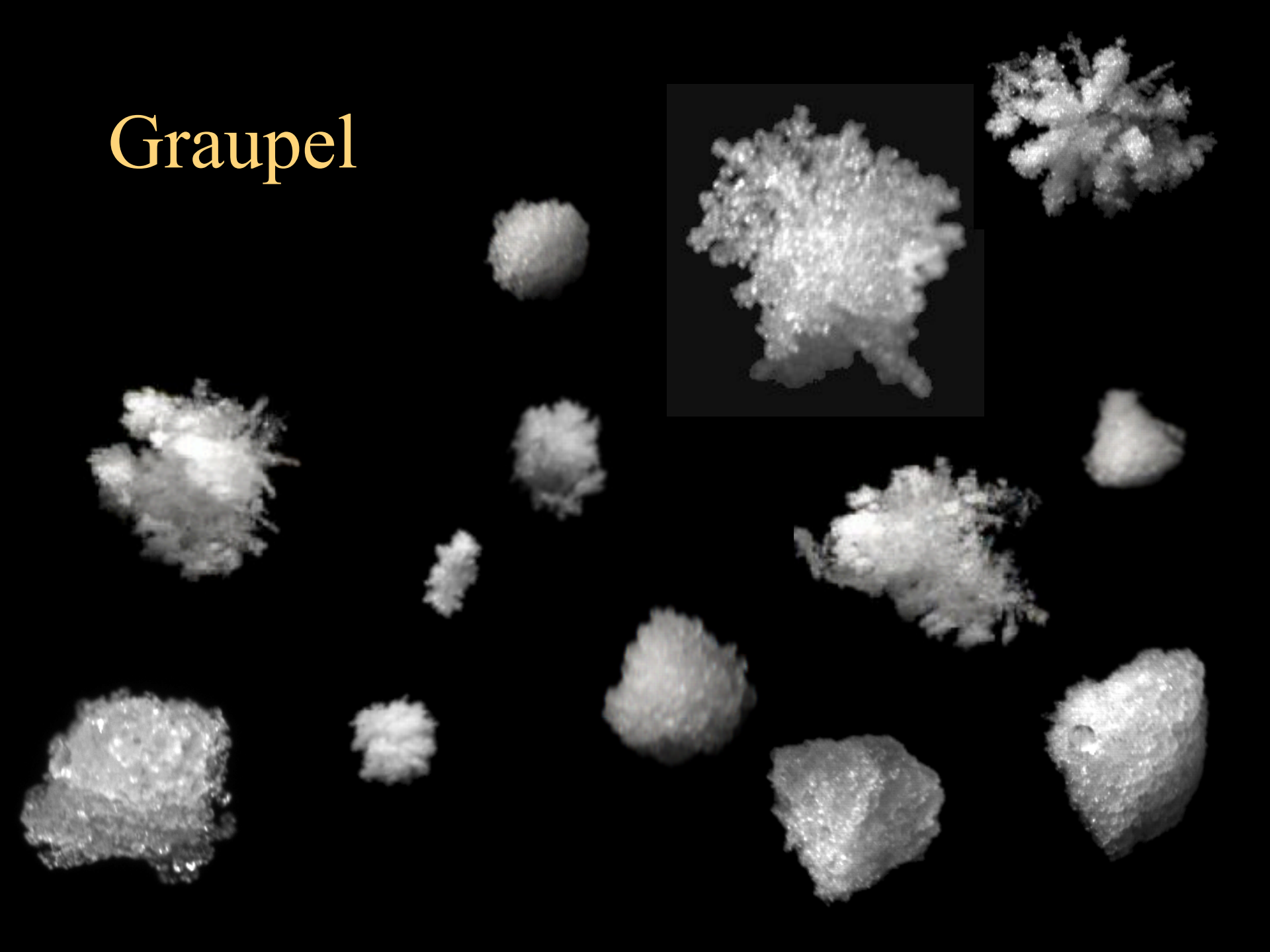
Crystals



Snow



Graupel



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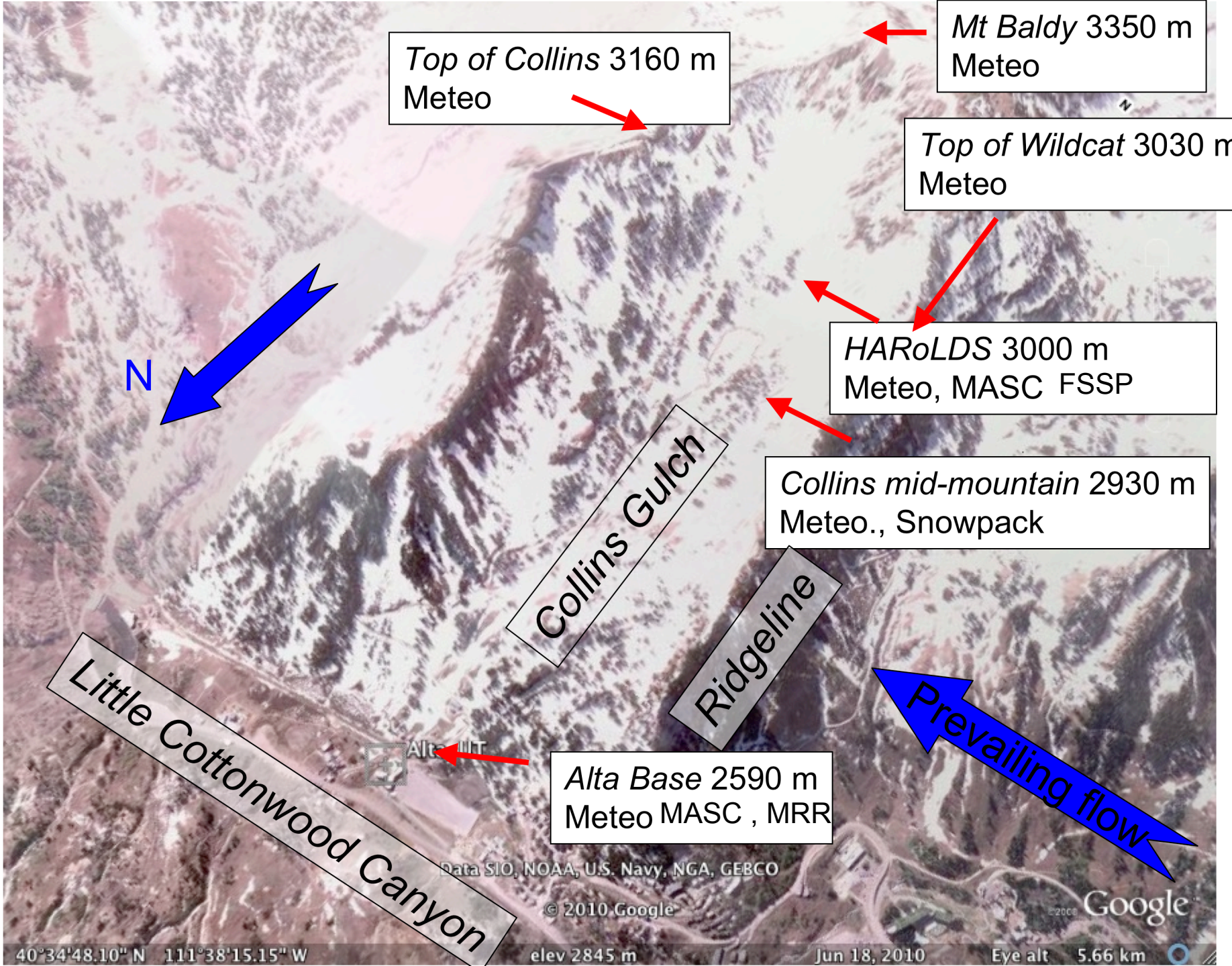
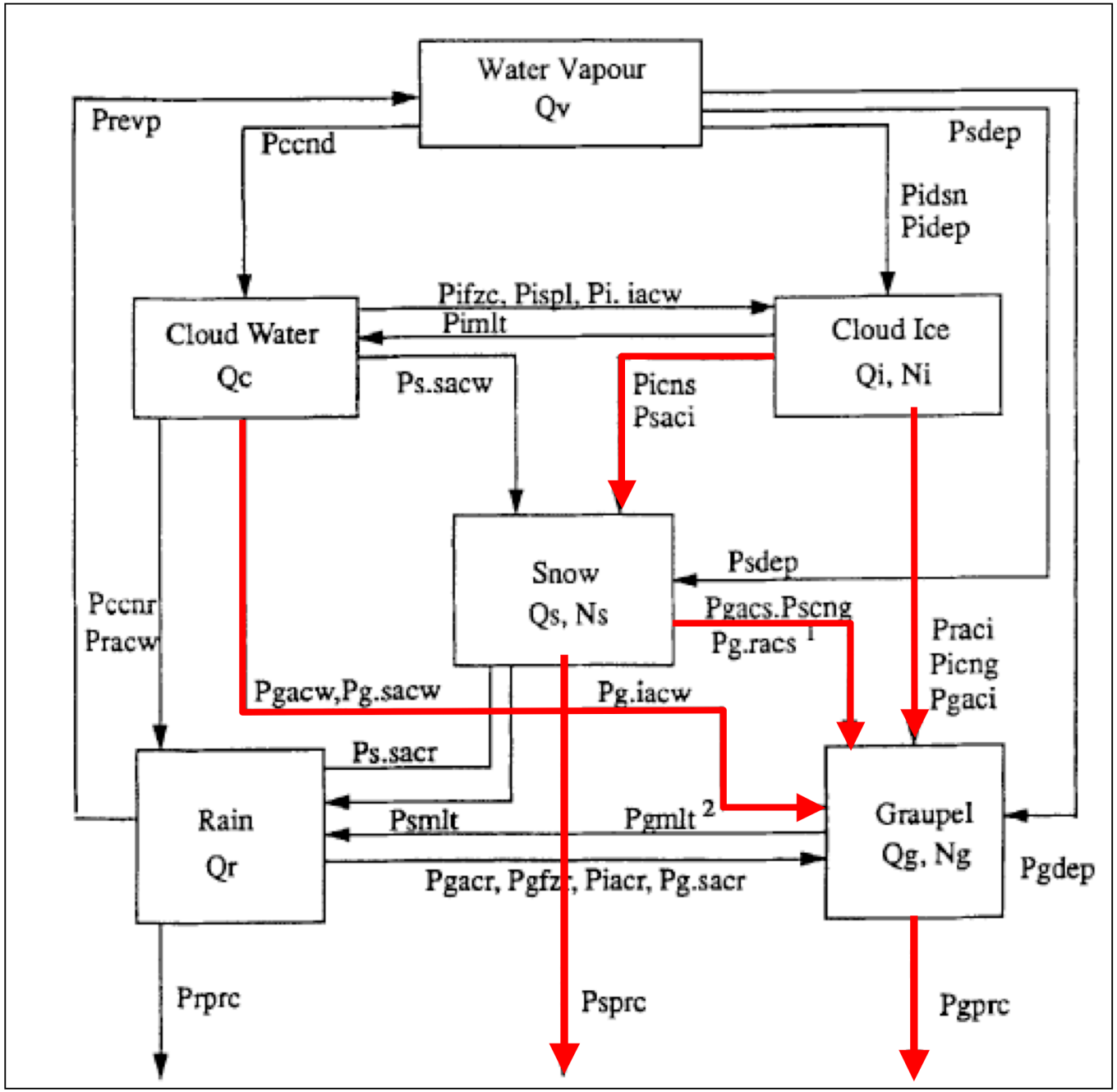
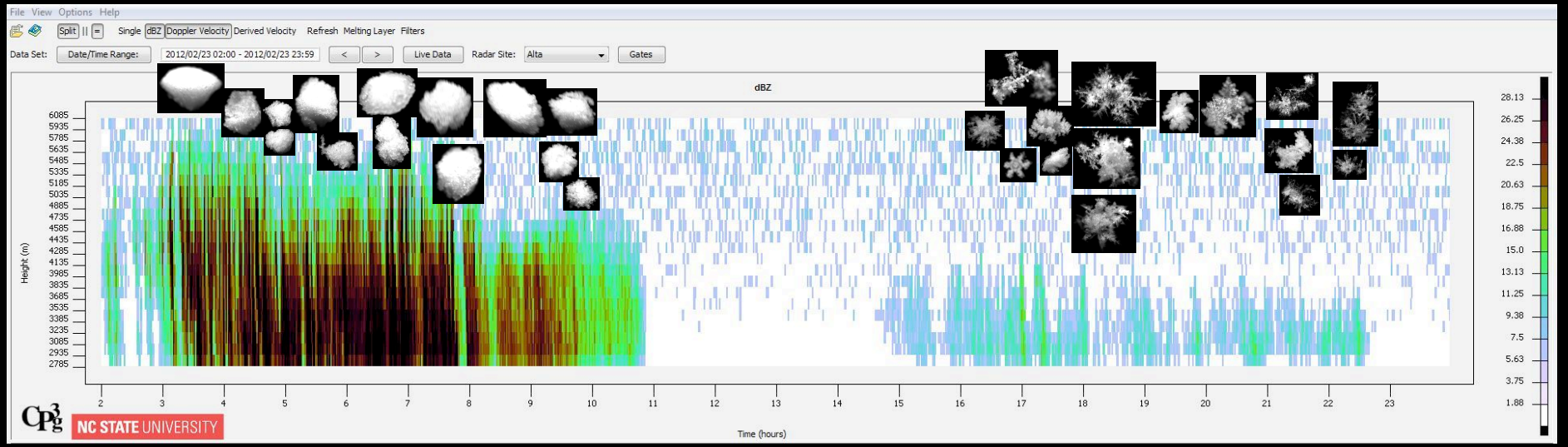
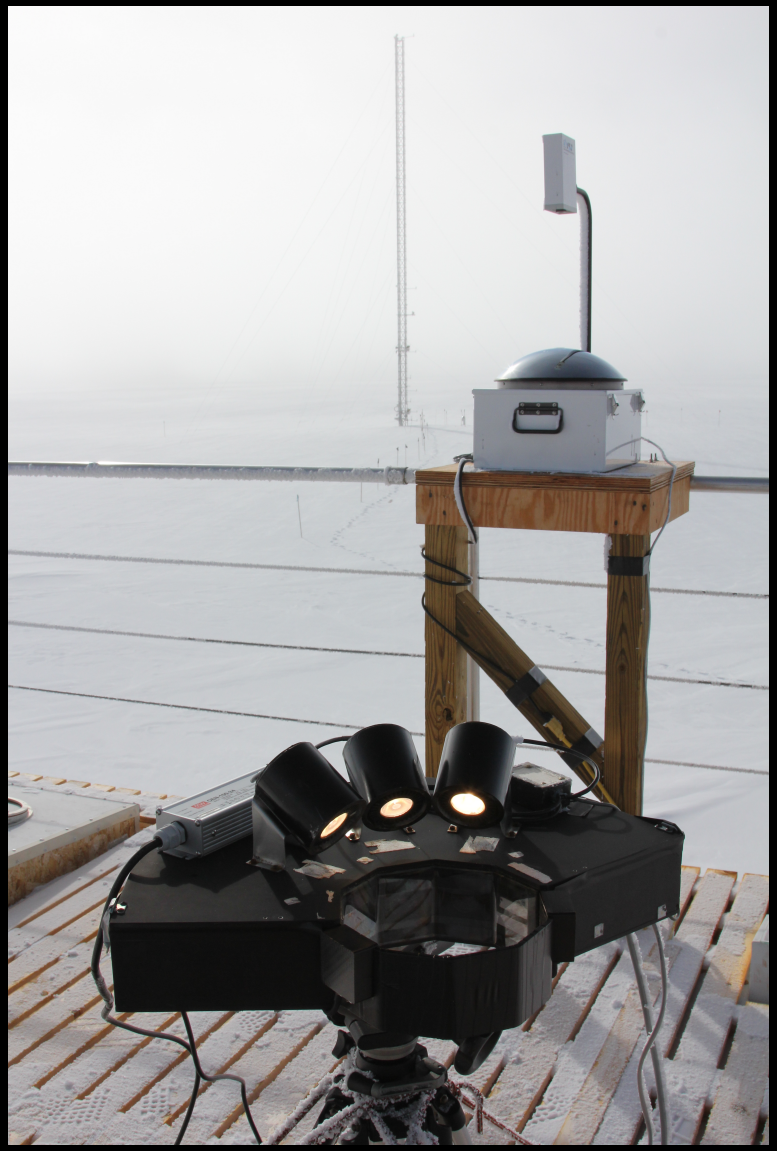

Mt Baldy 3350 m
Meteo
Top of Collins 3160 m
Meteo
Top of Wildcat 3030 m
Meteo
N
HARoLDS 3000 m
Meteo, MASC FSSP
Collins Gulch
Collins mid-mountain 2930 m
Meteo., Snowpack
Ridgeline
Prevailing flow
Little Cottonwood Canyon
Alta Base 2590 m
Meteo MASC , MRR
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 Google
Google
40°34'48.10" N 111°38'15.15" W
elev 2845 m
Jun 18, 2010
Eye alt 5.66 km

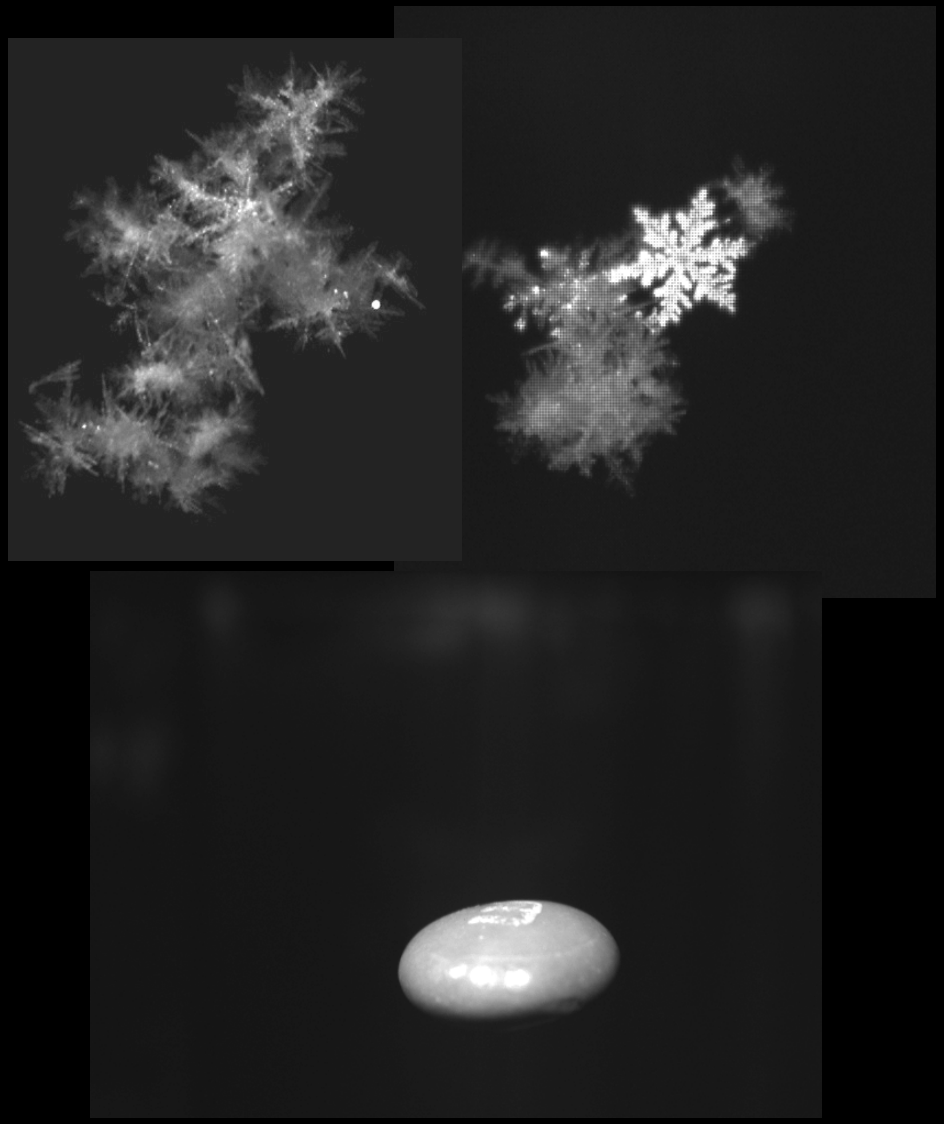

Water Vapour
Qv
Prevp
Pccnd
Psdep
Pidsn
Pidep
Cloud Water
Qc
Pifzc, Pispl, Pi. iacw
Pimlt
Ps.sacw
Cloud Ice
Qi, Ni
Picns
Psaci
Snow
Qs, Ns
Psdep
Pccnr
Pracw
Pgacs.Pscng
Pg.racs 1
Praci
Picng
Pgaci
Pgacw,Pg.sacw
Pg.iacw
Ps.sacr
Rain
Qr
Psmlt
Pgmlt 2
Graupel
Qg, Ng
Pgacr, Pgfzr, Piacr, Pg.sacr
Pgdep
Prprc
Psprc
Pgprc

Vertically pointing radar at Alta




Mt. Baldy 3350 m
Alta Collins 3160 m
HARoLDS 3000 m

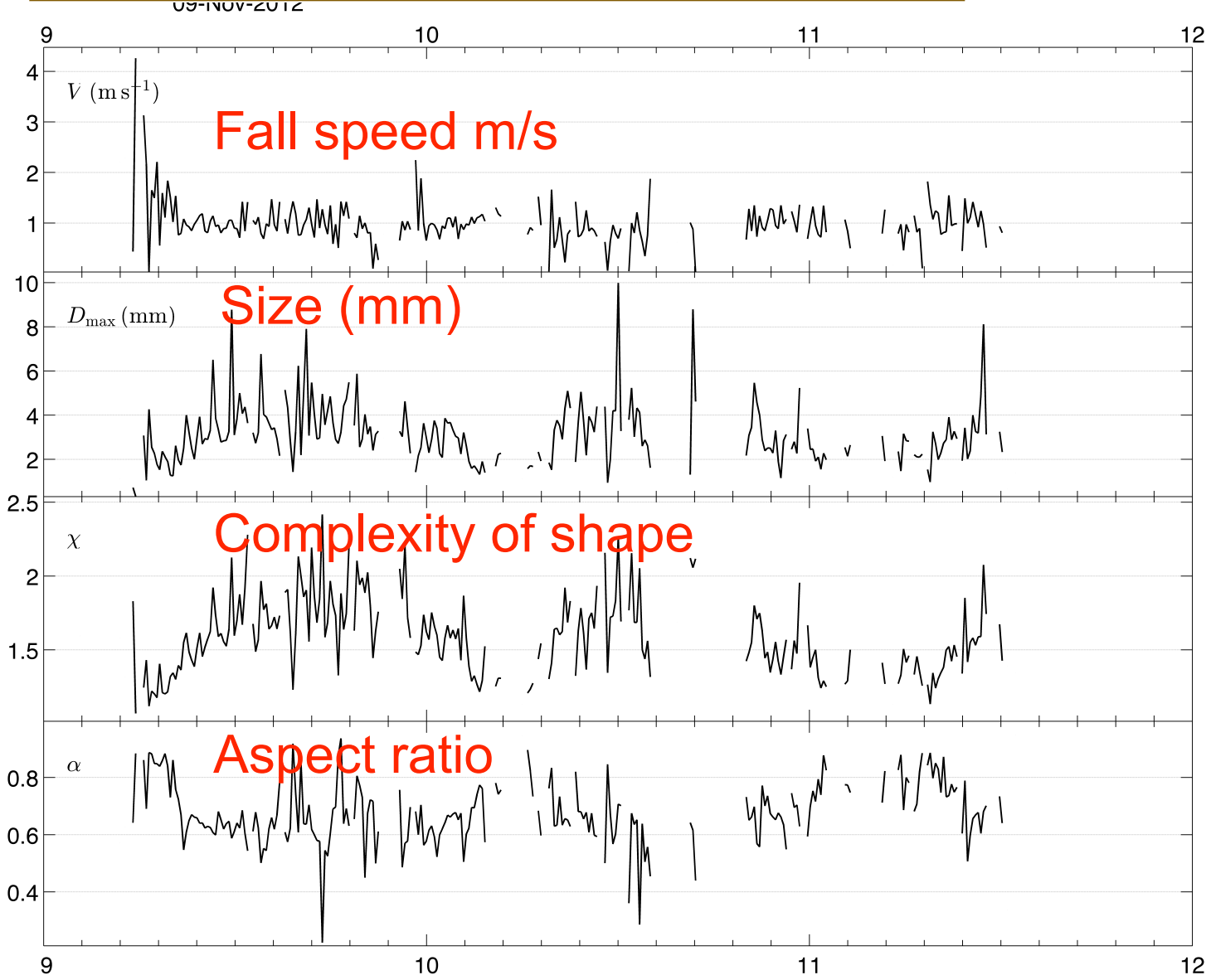




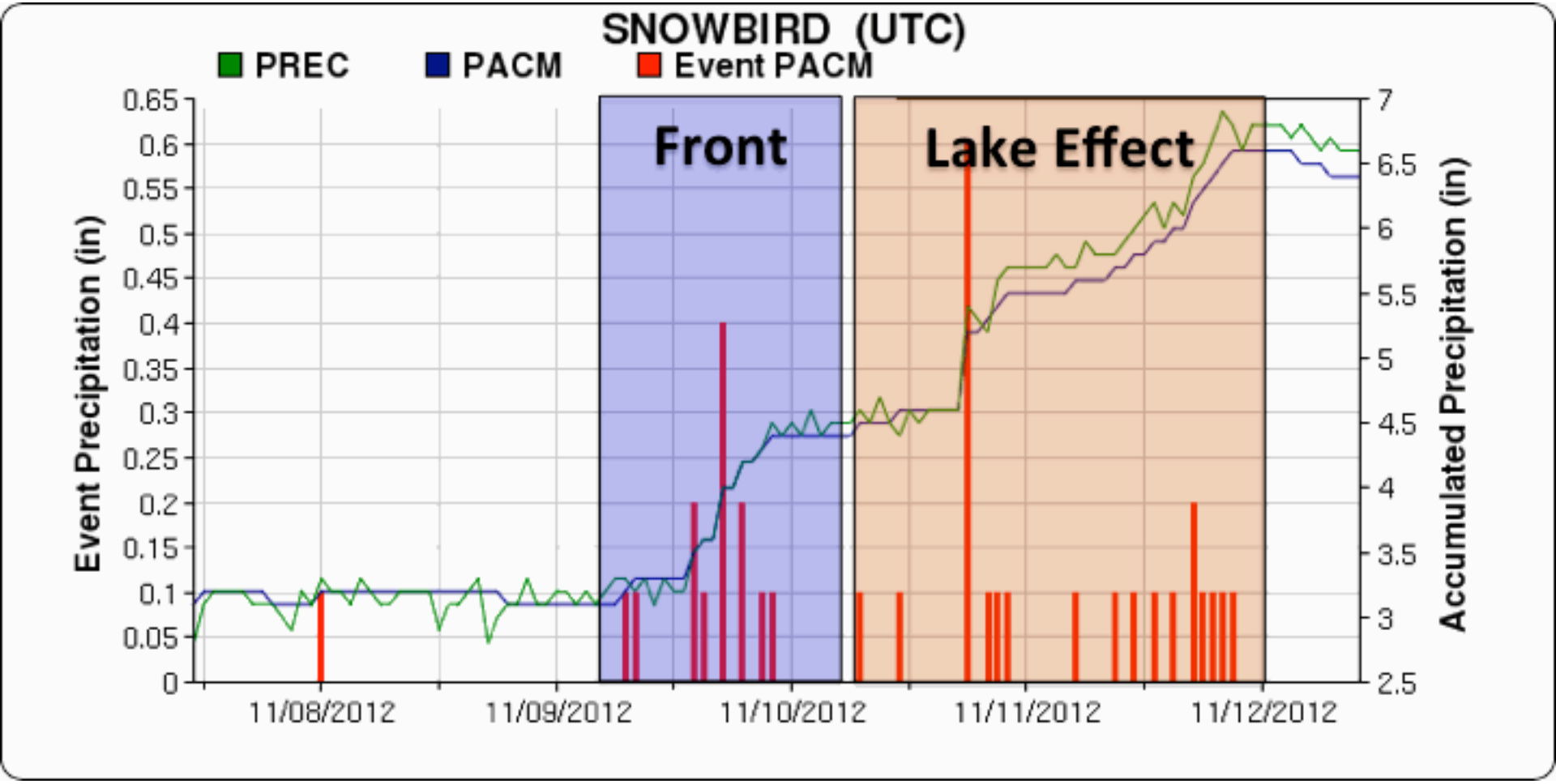
Multi-Angle Snowflake Camera (MASC) at Greenland Summit

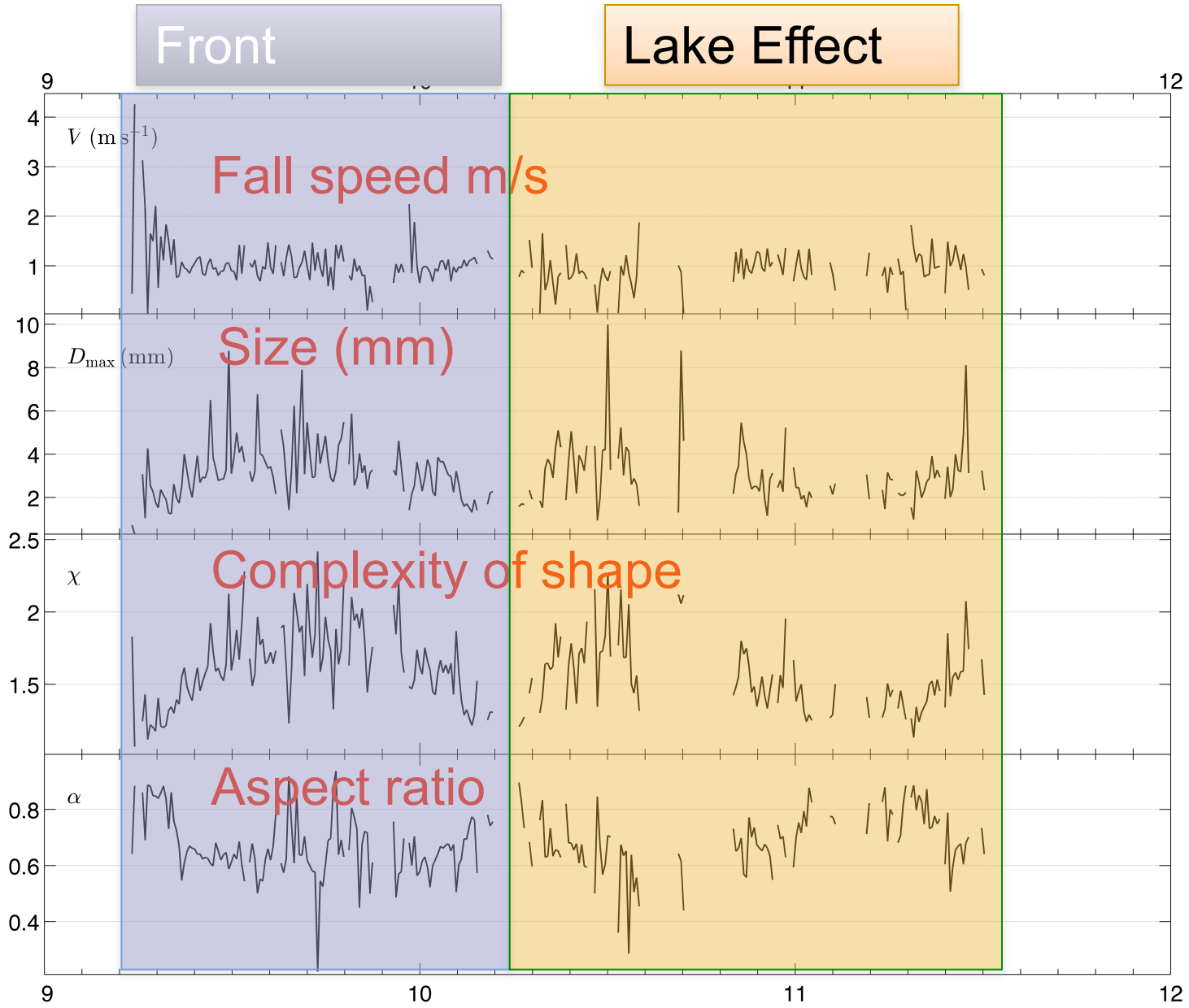

MASC at Mammoth Ski Area

Last weekends storm, local time

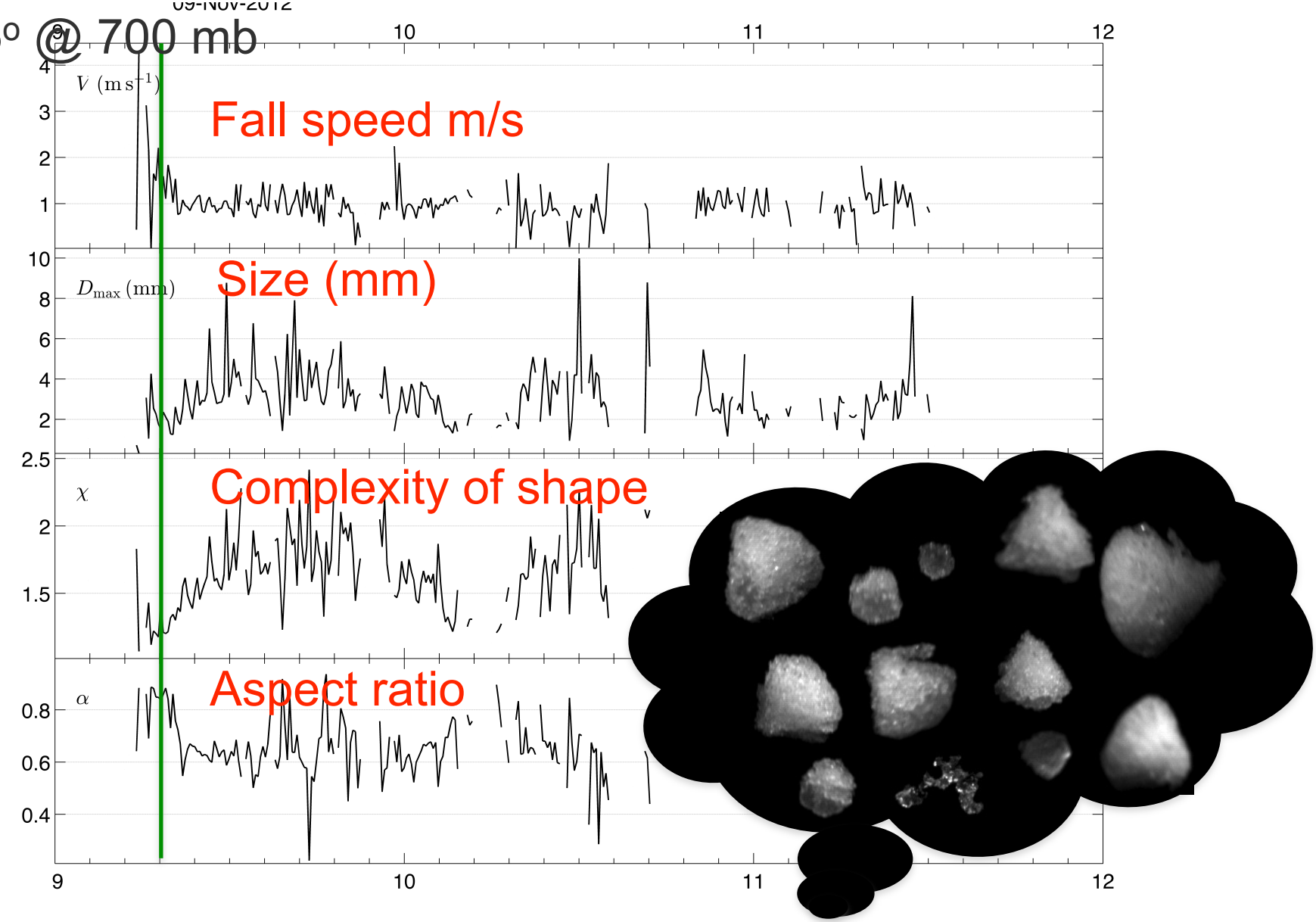


From Jim Steenburgh's Wasatch Weather Weenies




Front
Lake Effect
Fall speed m/s
Size (mm)
Complexity of shape
Aspect ratio
V (m s^{-1})
$D_{\max}$ (mm)
χ
α
9
10
11
12

~ 7:12 am
11/9 12 UTC
-0.5º @ 700 mb



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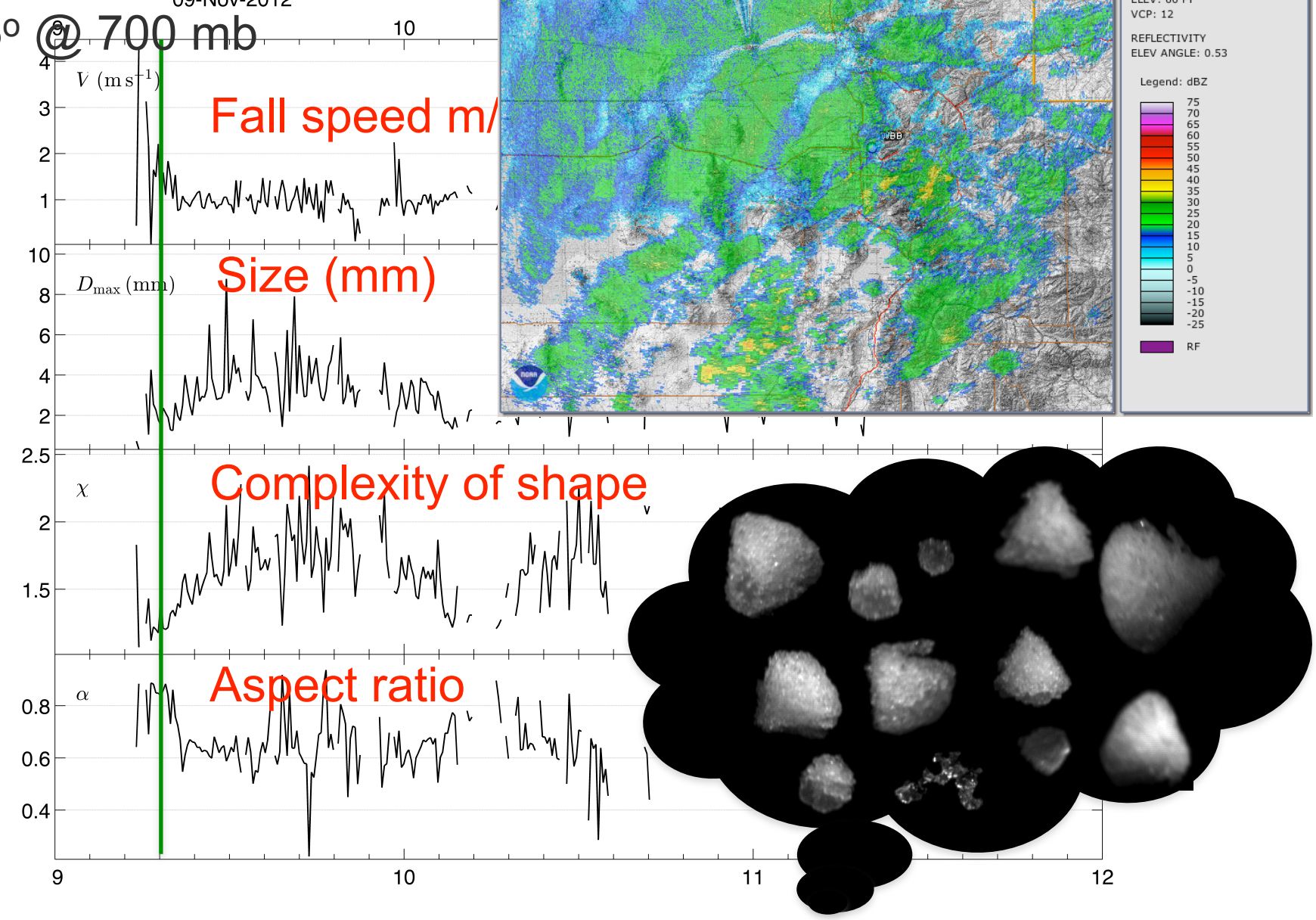

~ 4:33 pm
11/10 00 UTC
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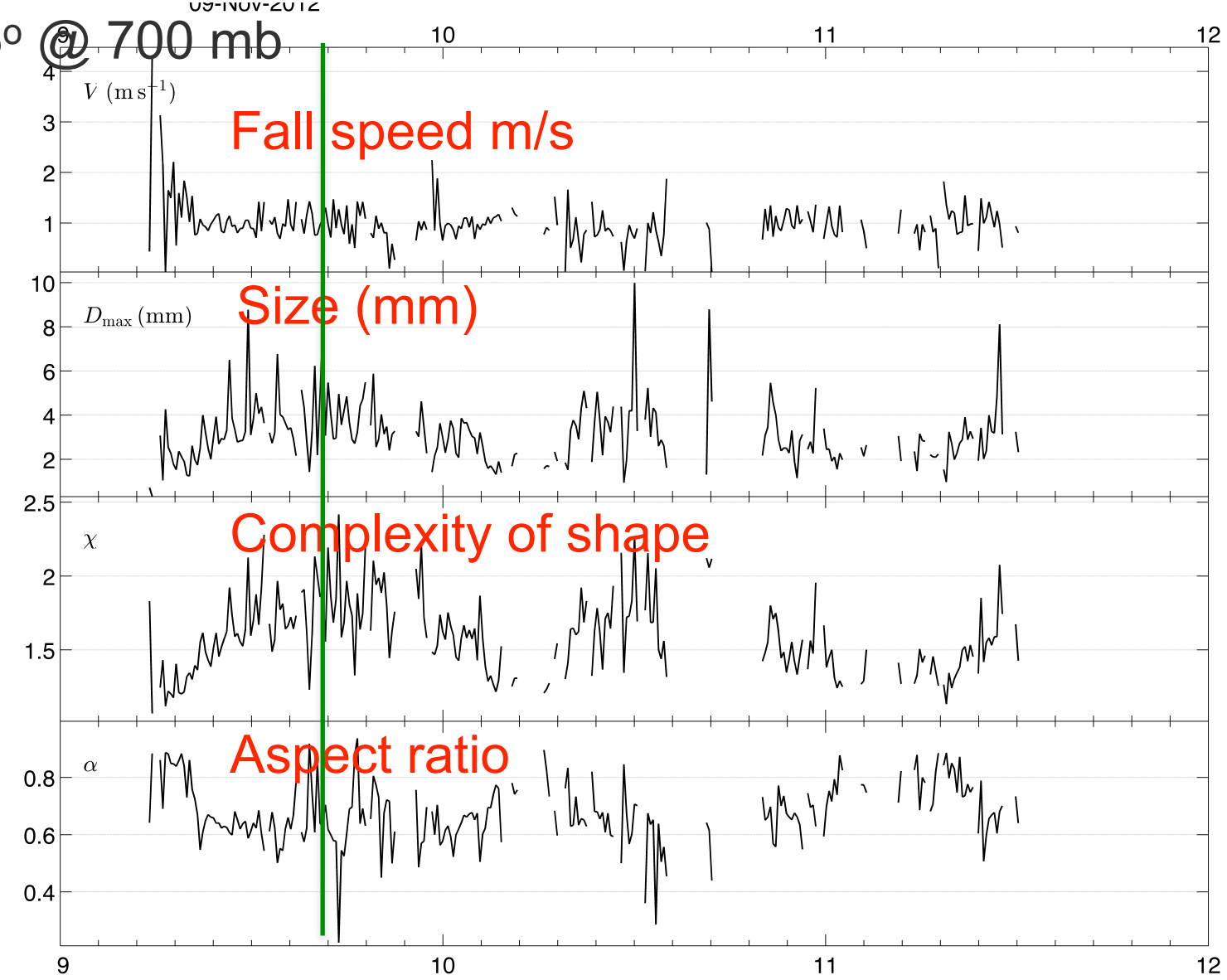

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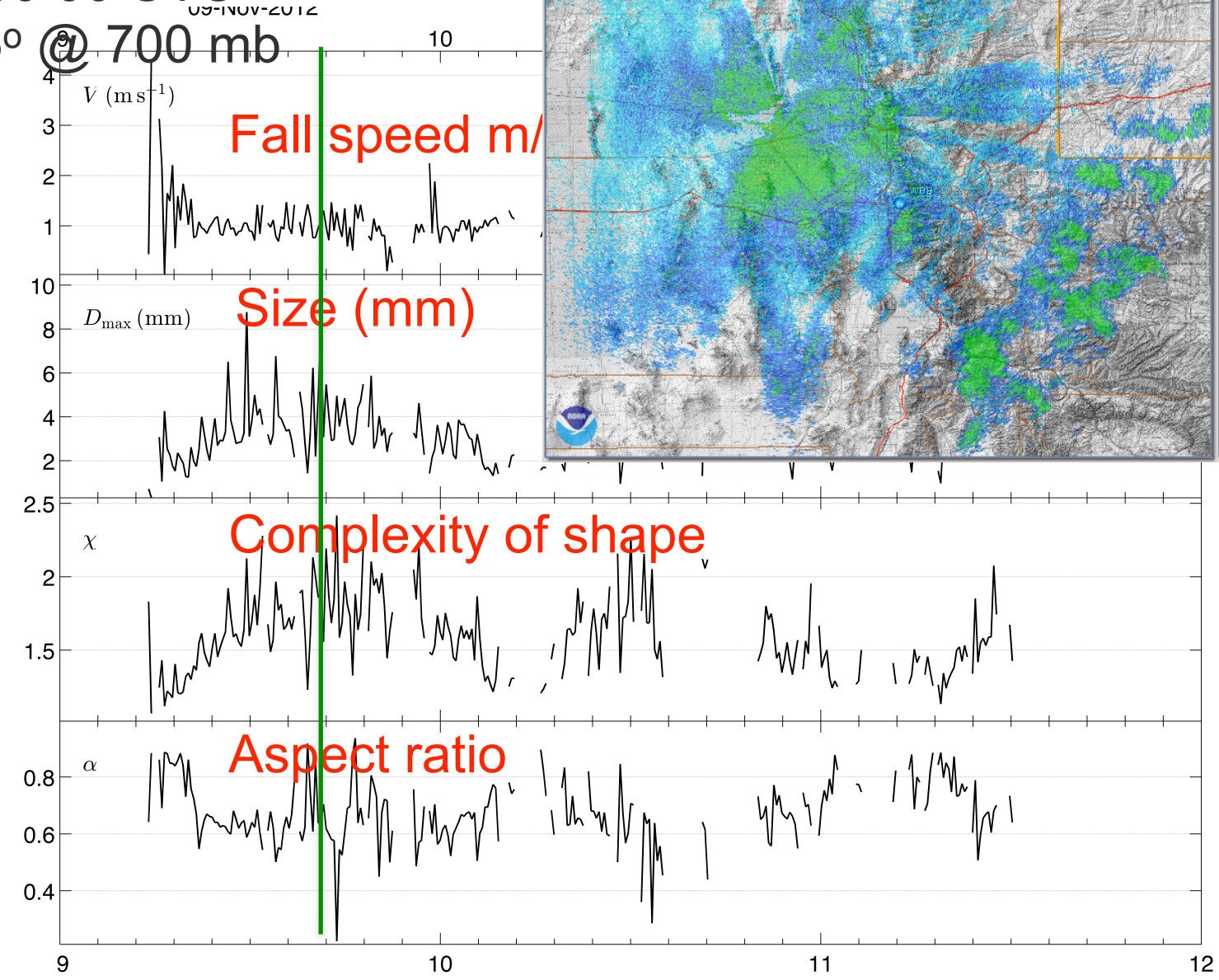

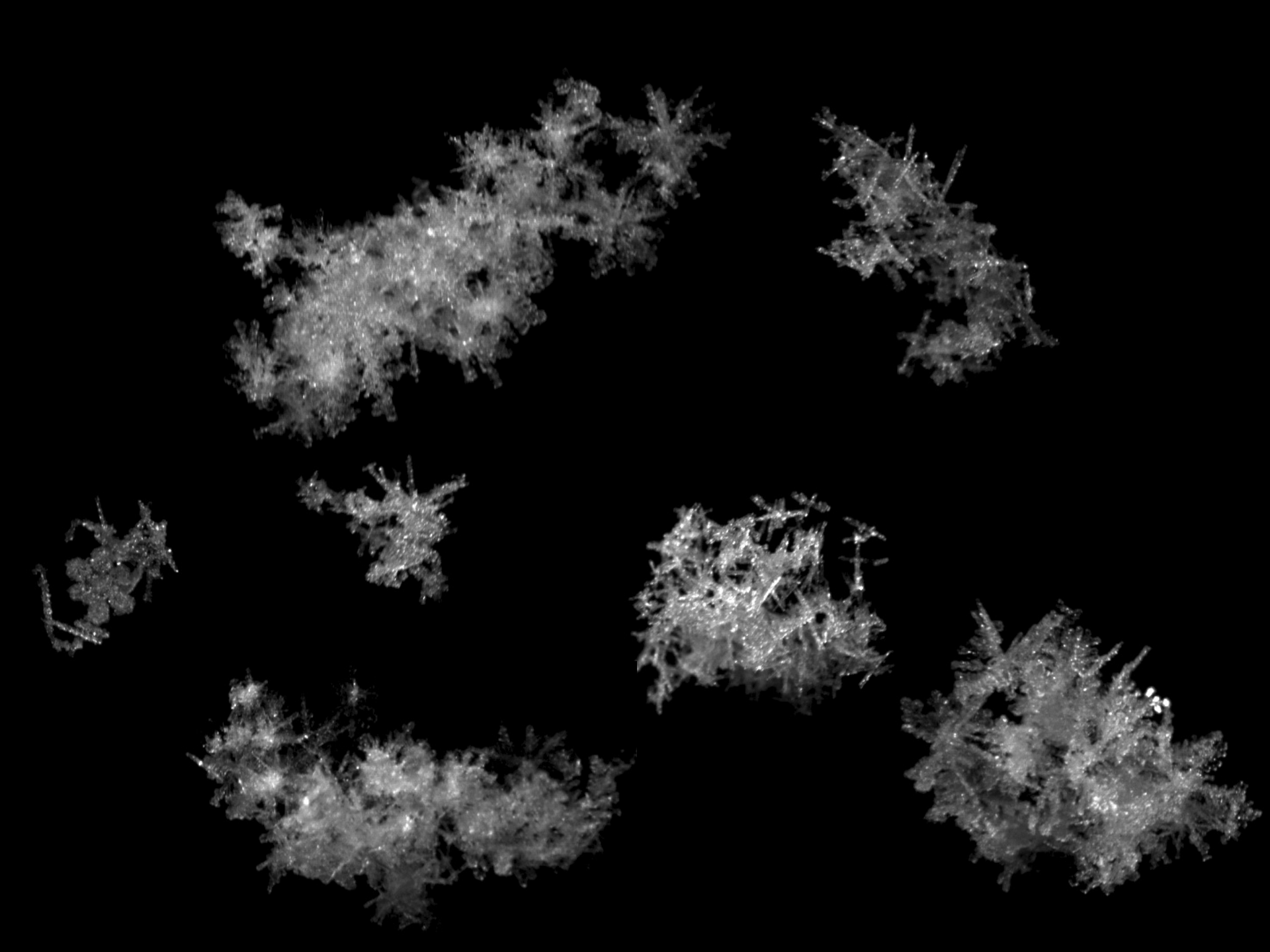

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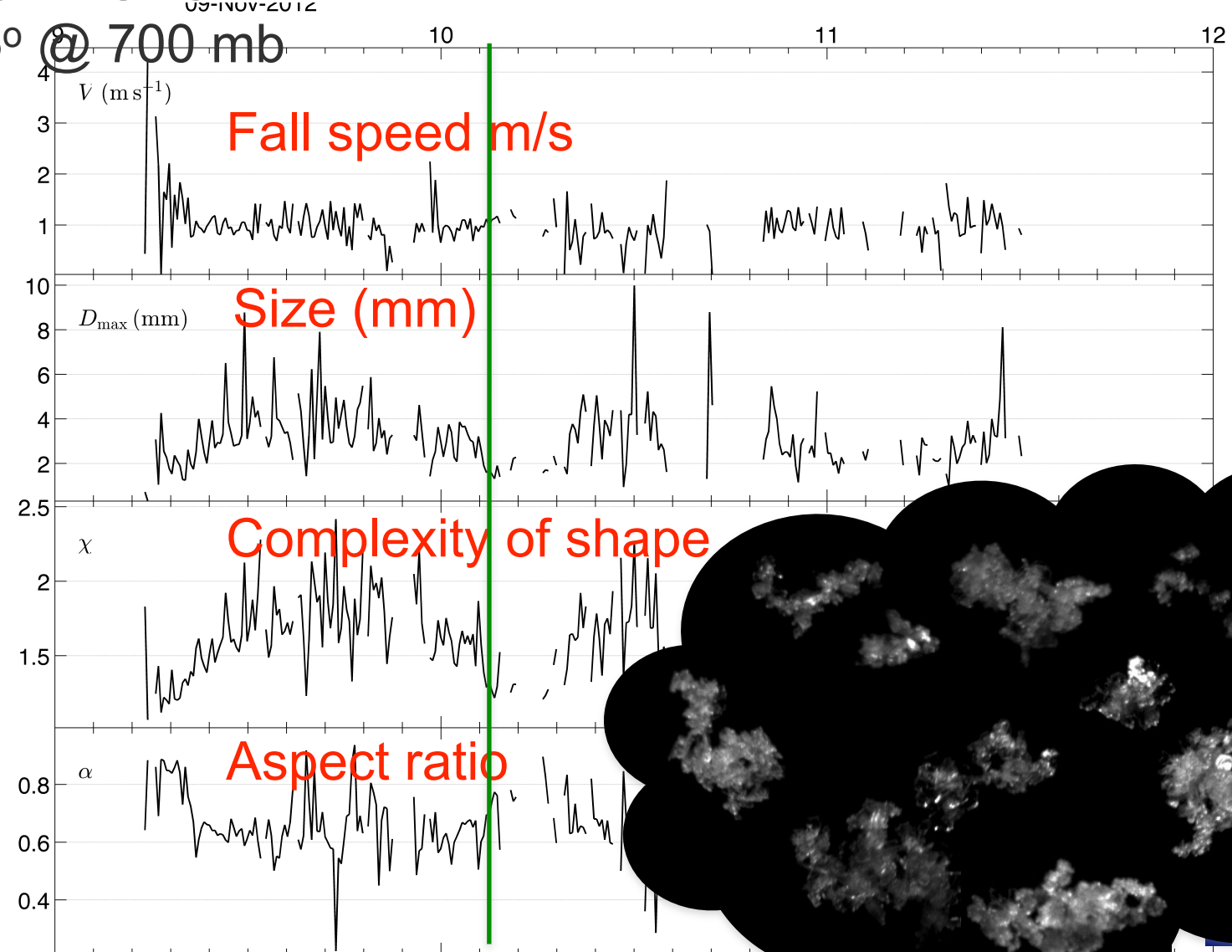

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11/10 12 UTC

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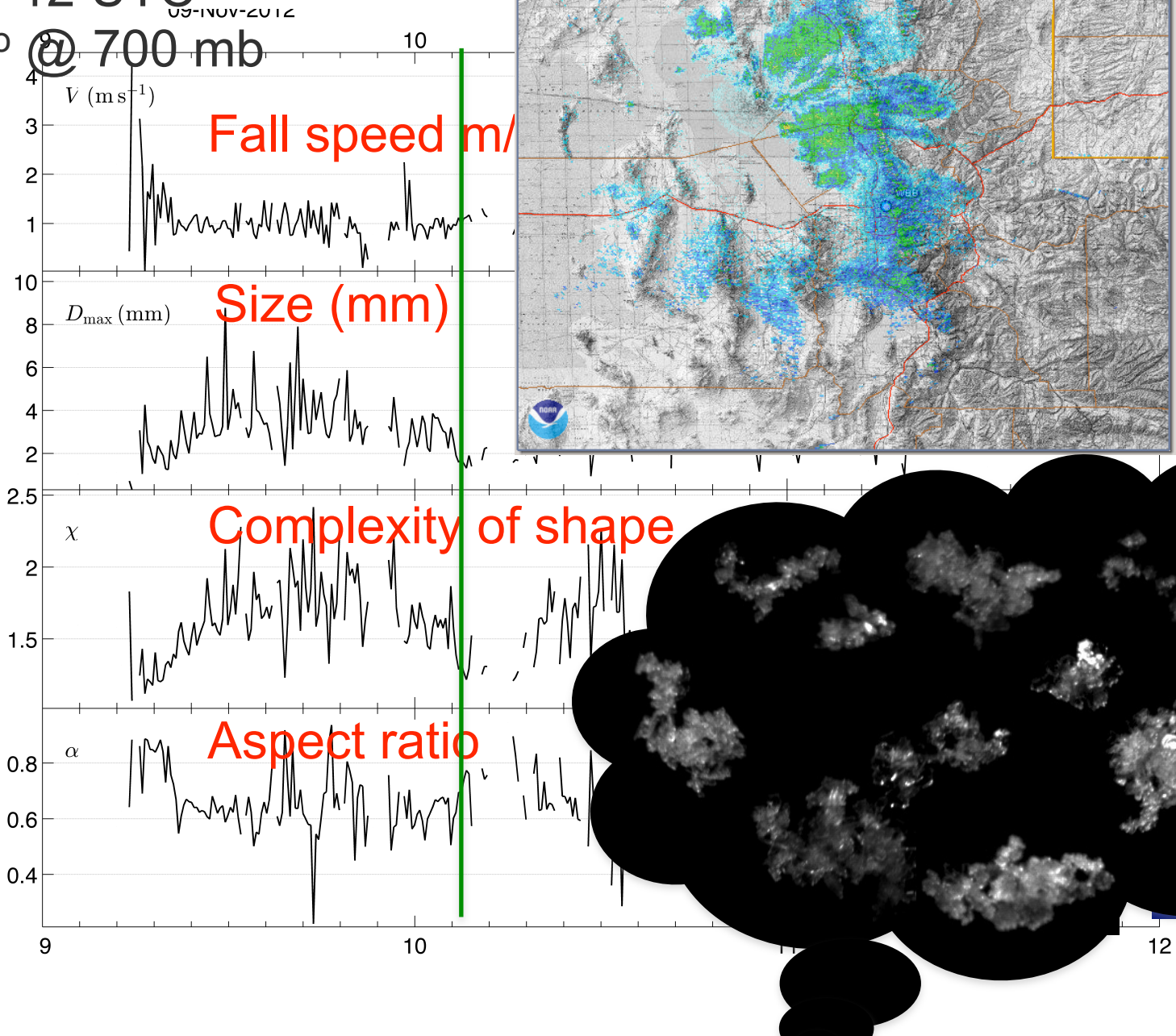

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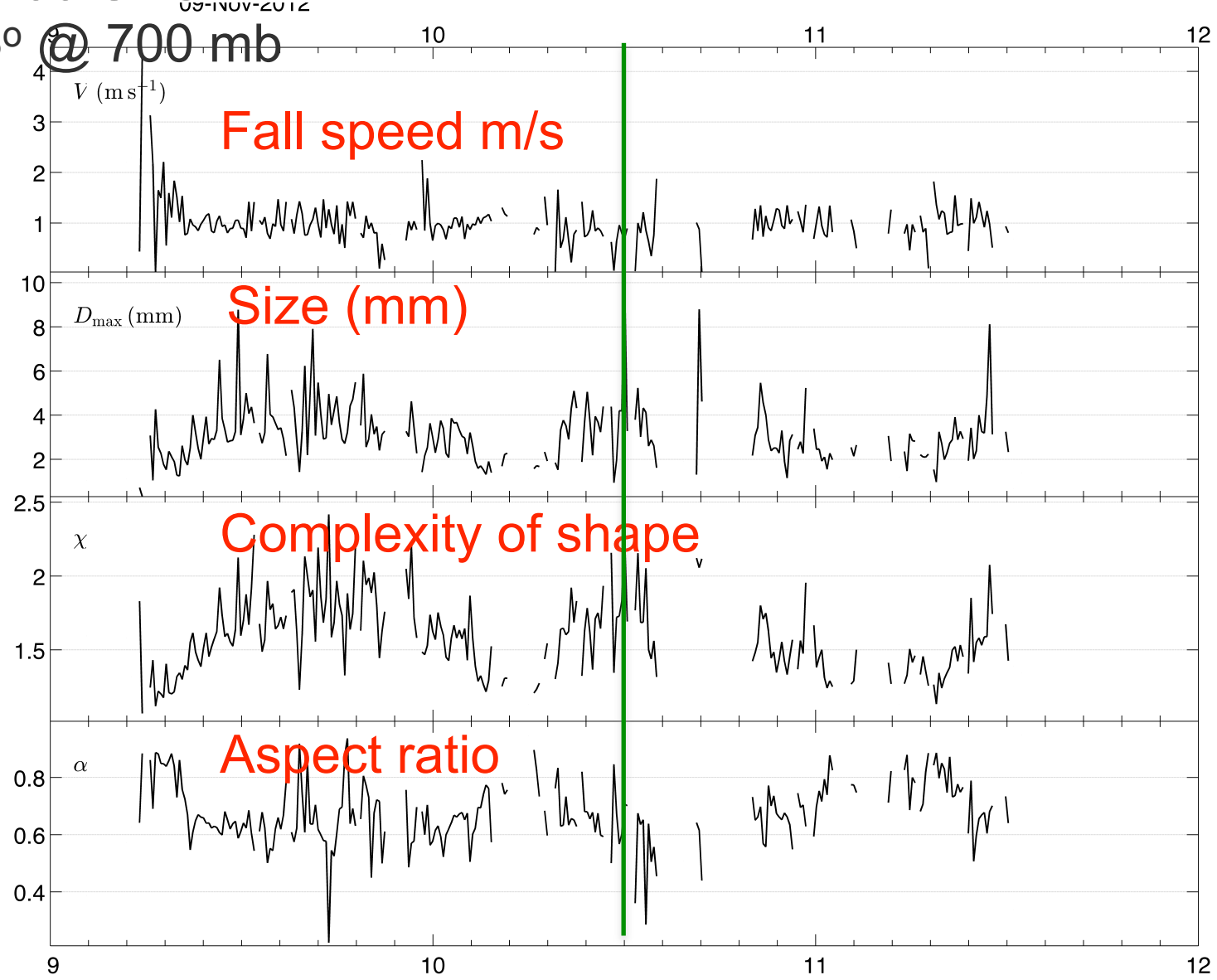

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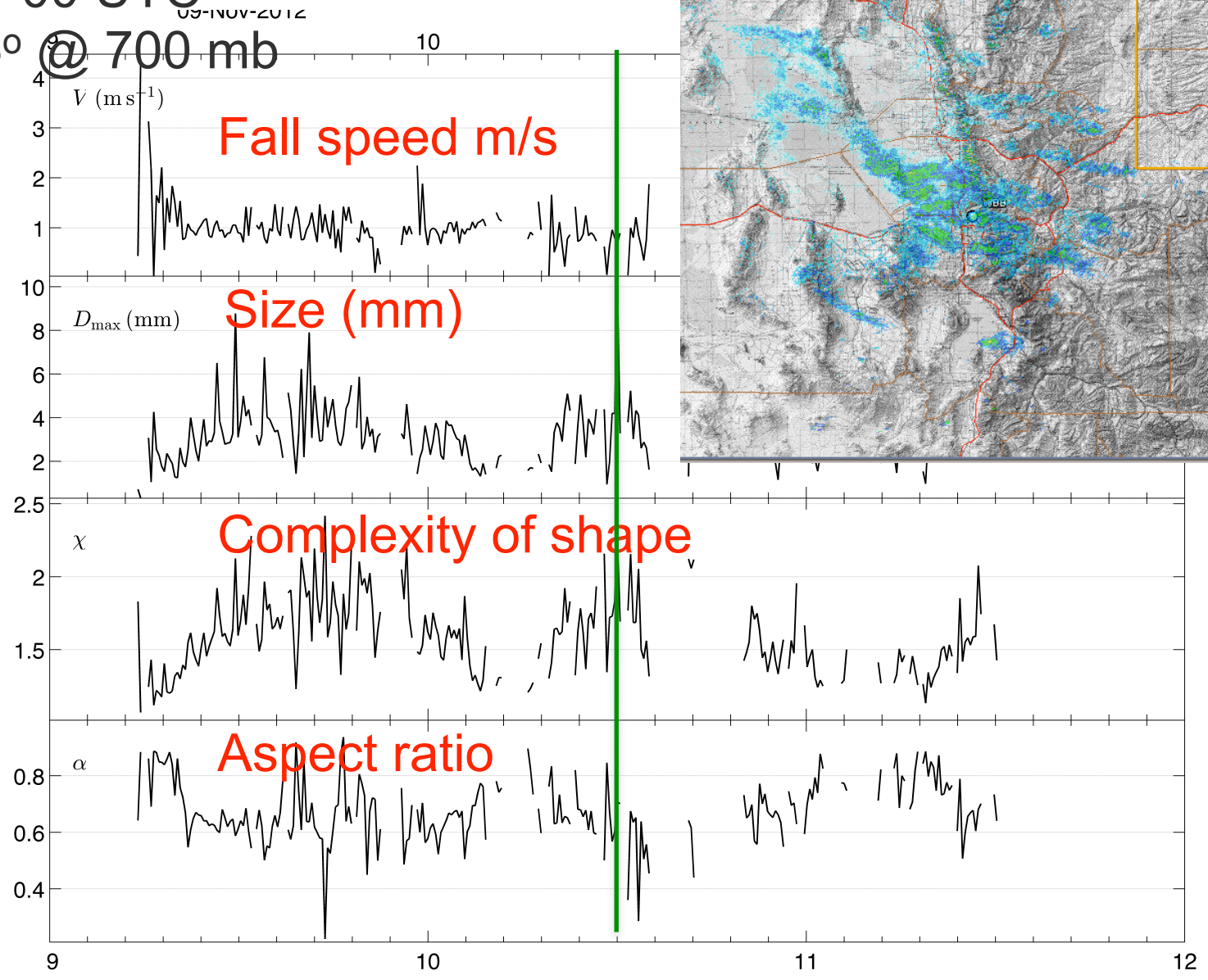

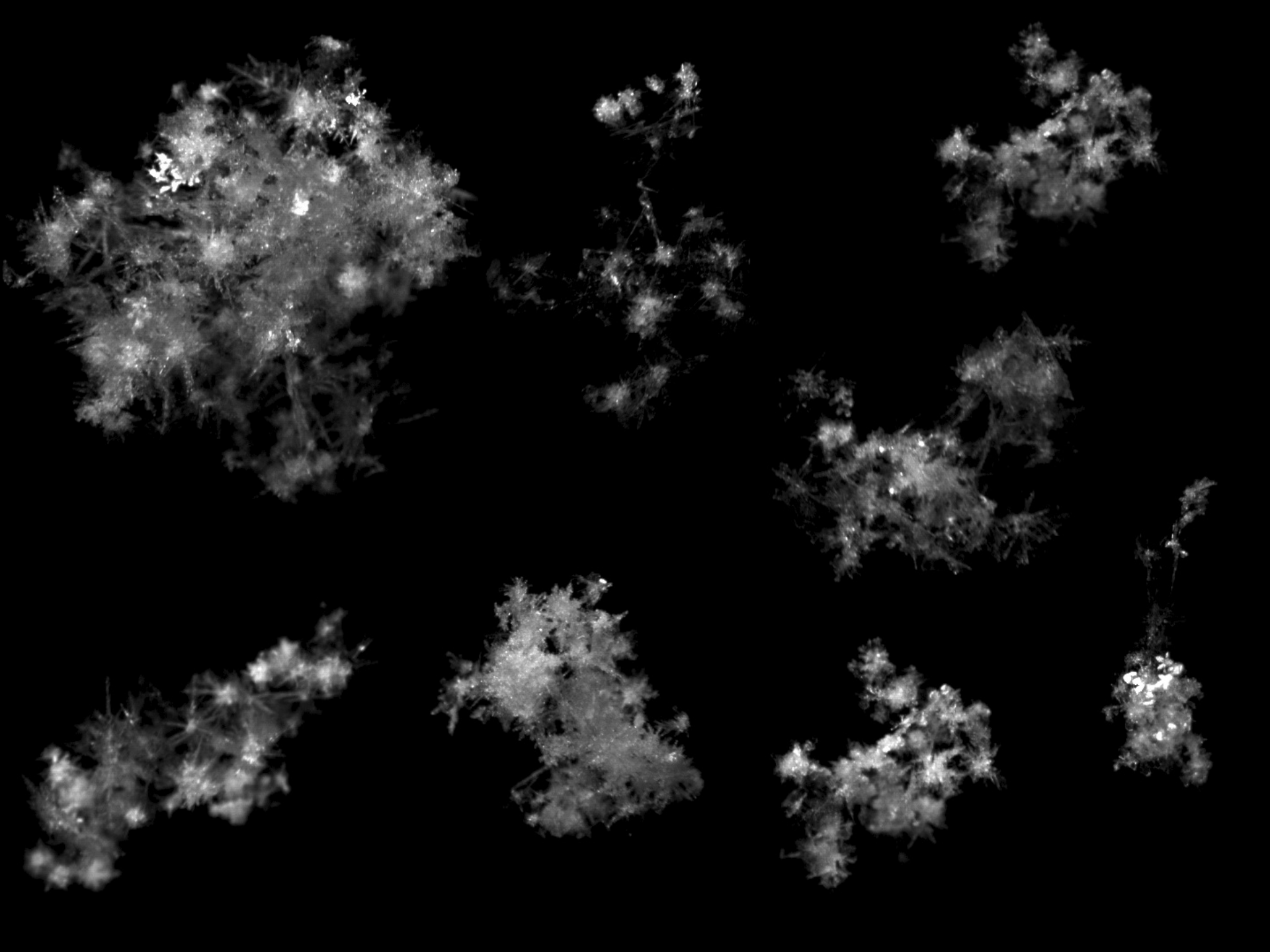

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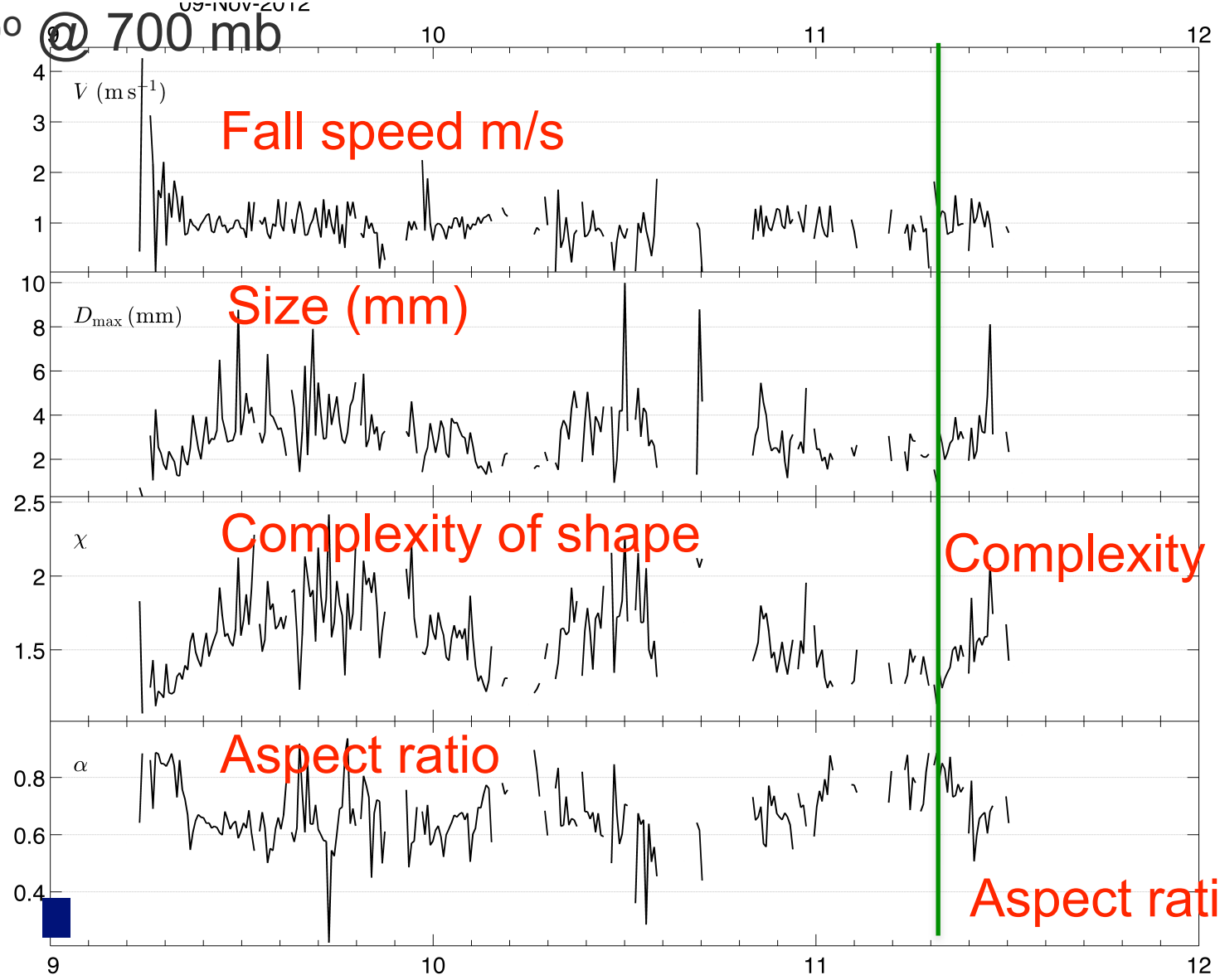

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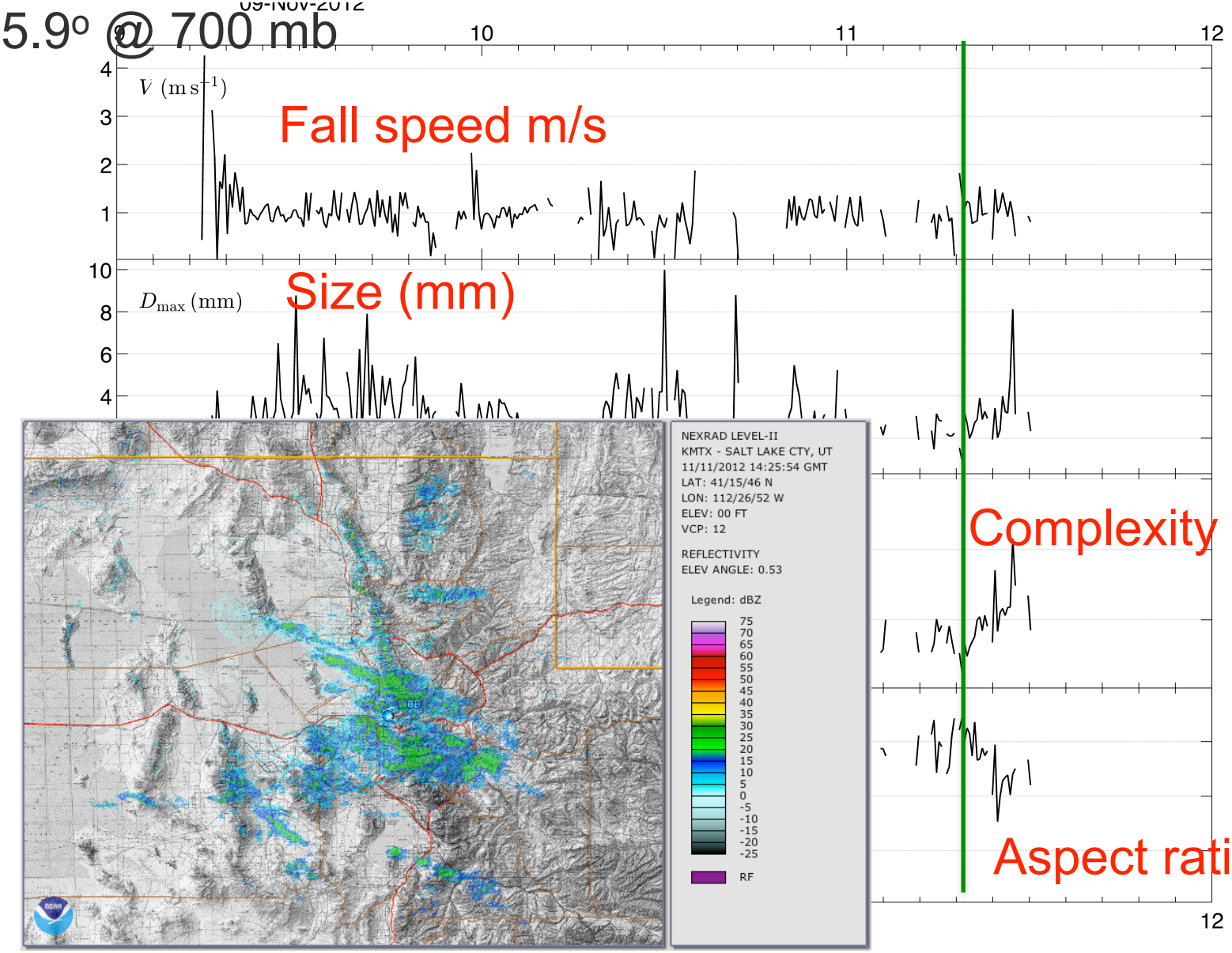

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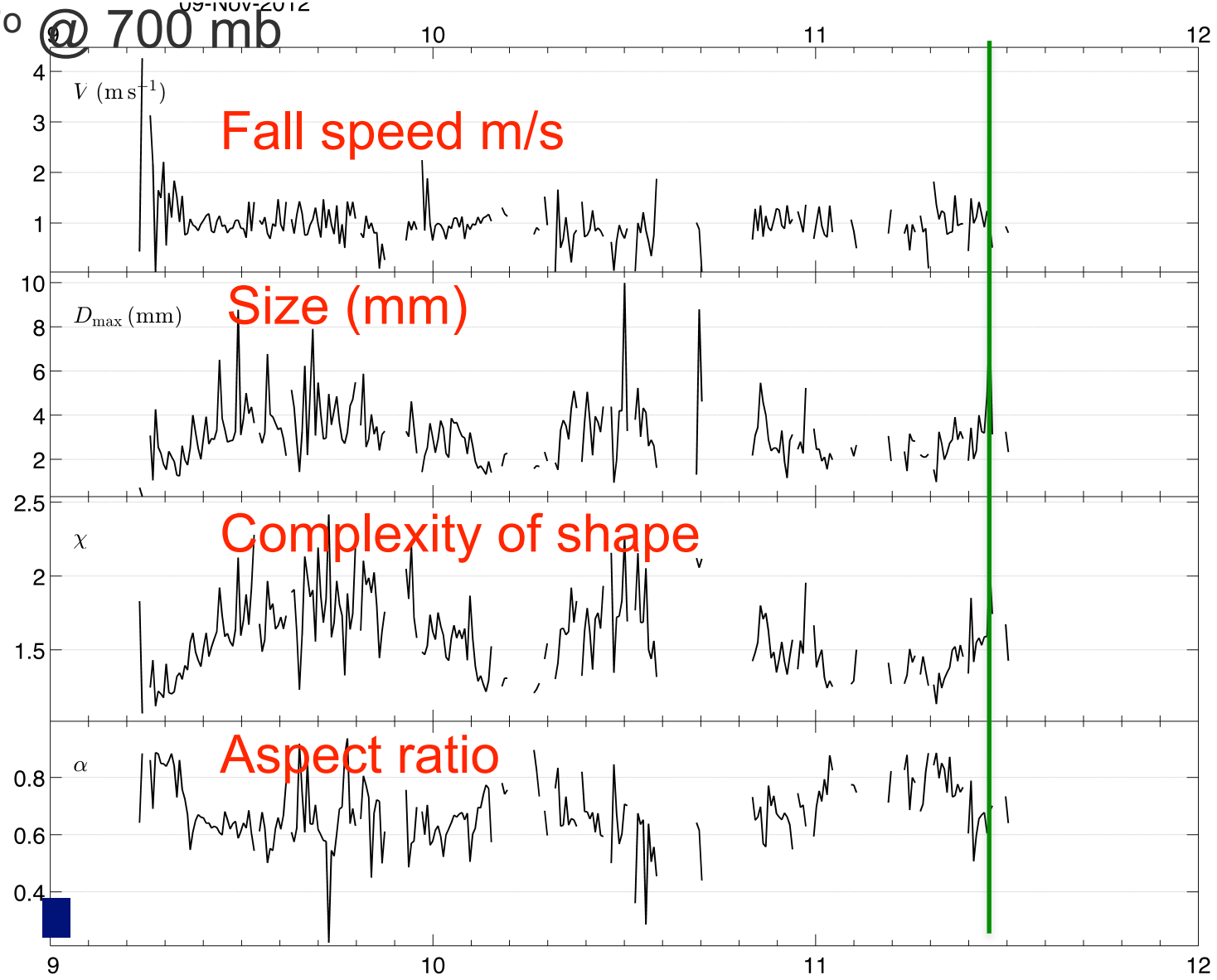
-16.7° @ 700 mb



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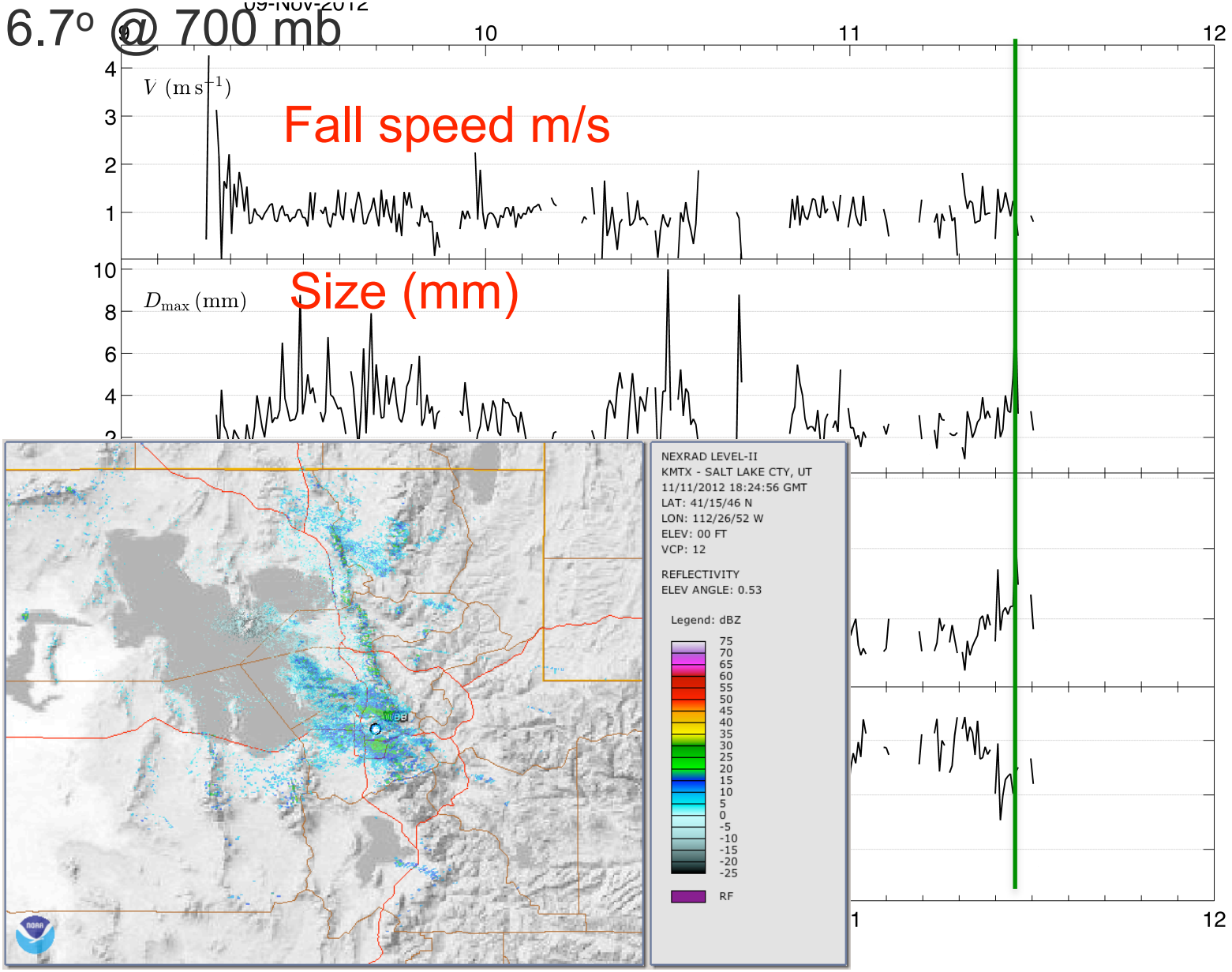
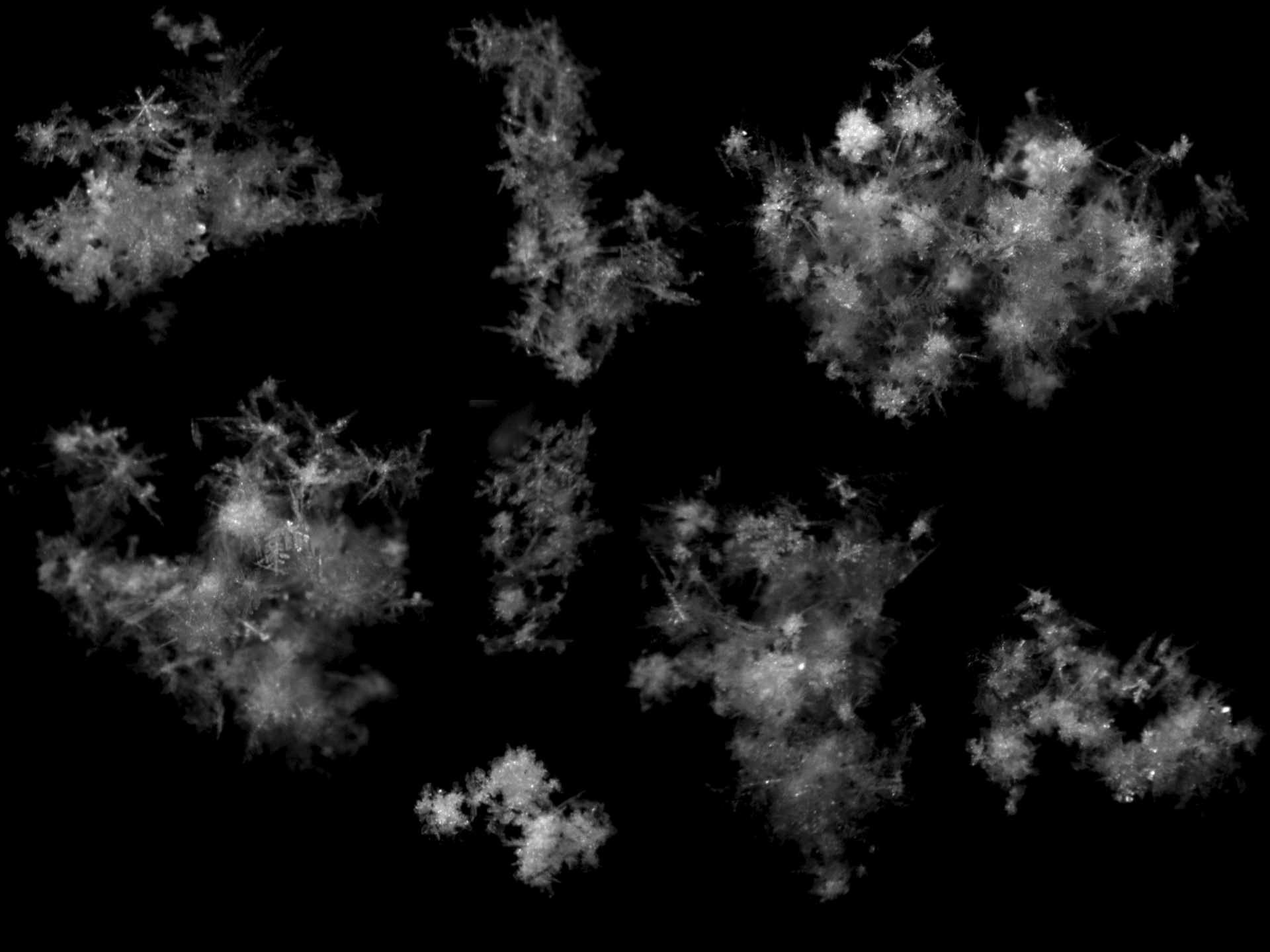
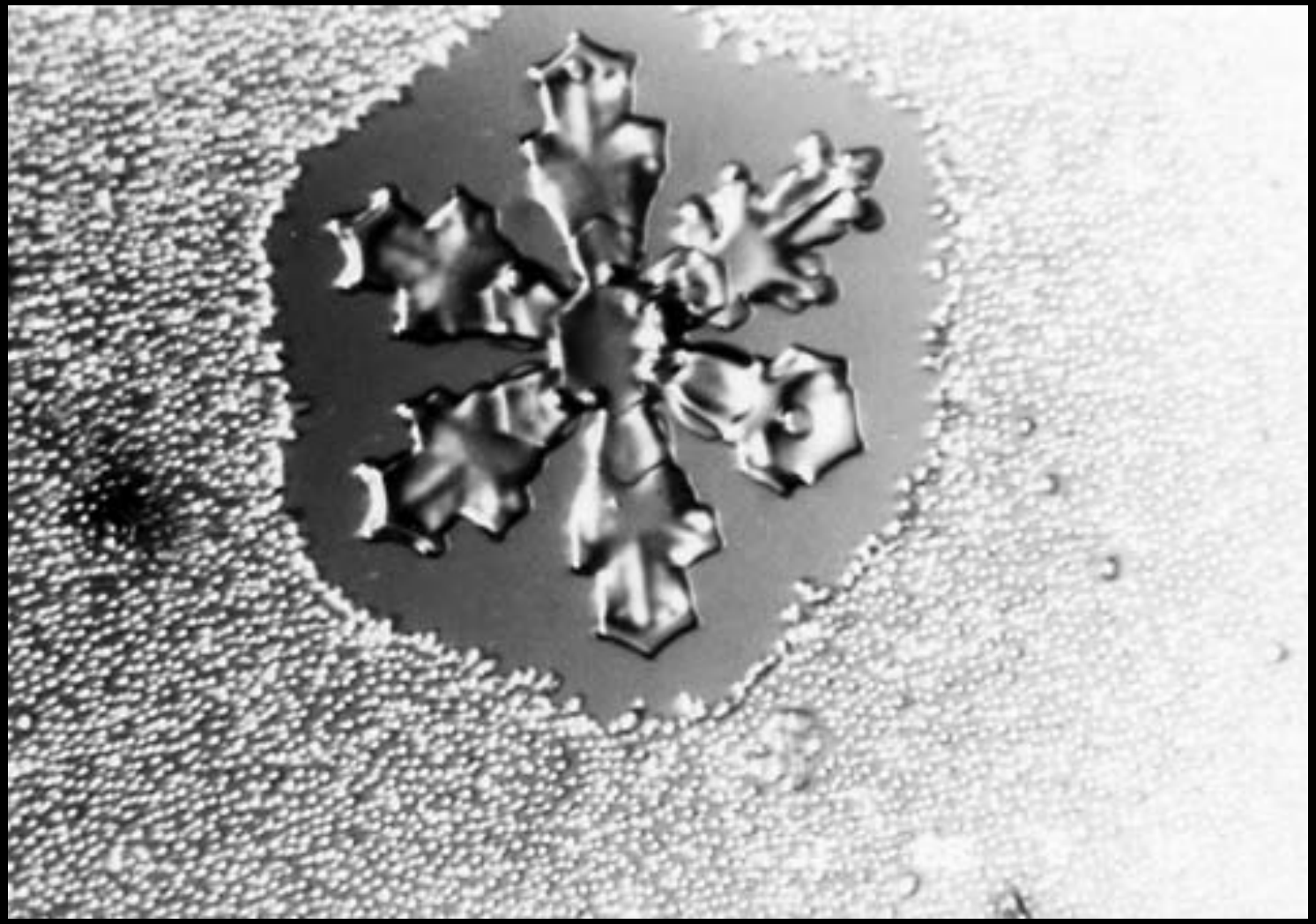




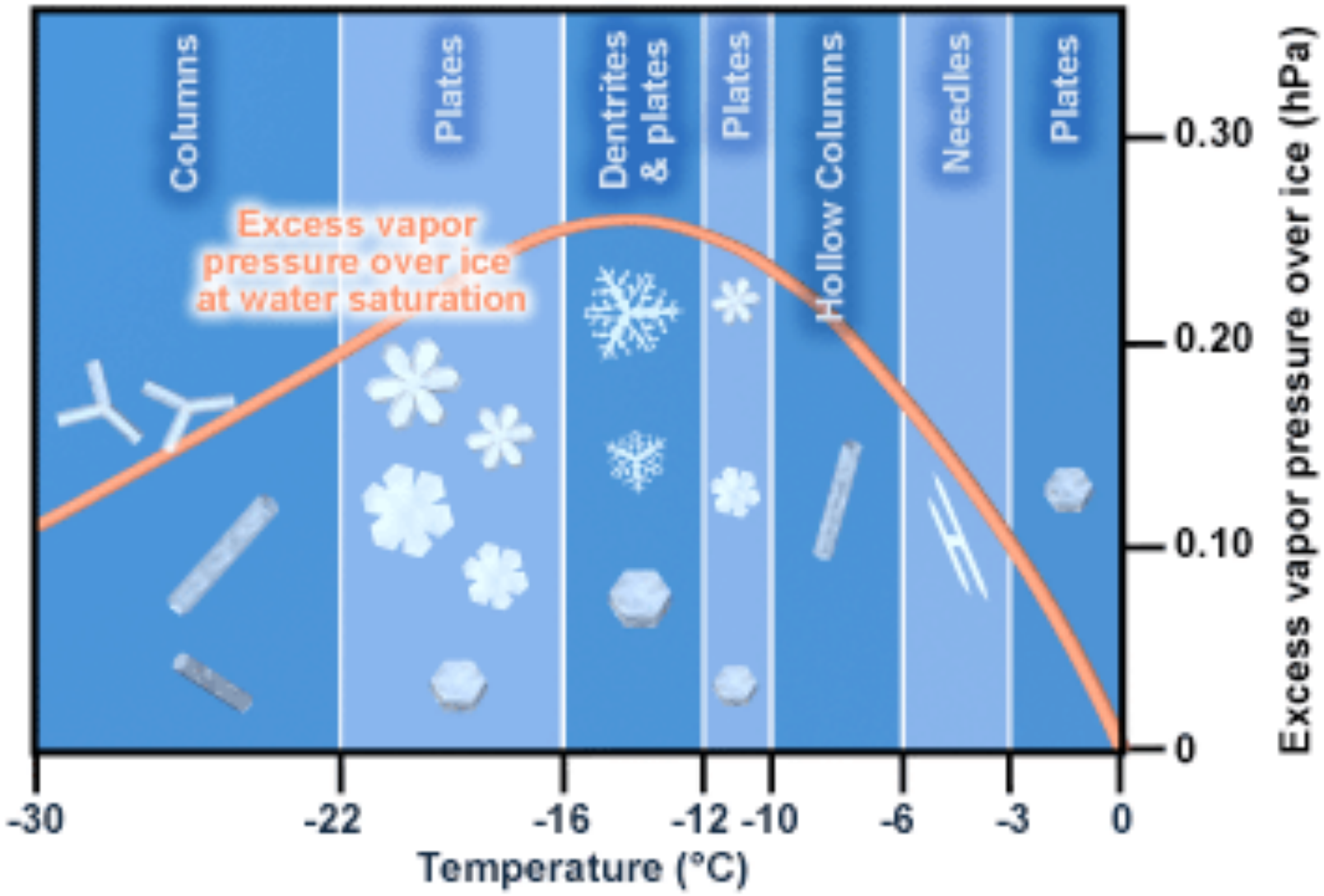

UTAH

Flakes originate from liquid clouds

Wegener-Bergeron-Findeison Process



Common Crystal Habits and Formation Conditions



The Growth of Atmospheric Ice Crystals: A Summary of Findings in Vertical Supercooled Cloud Tunnel Studies

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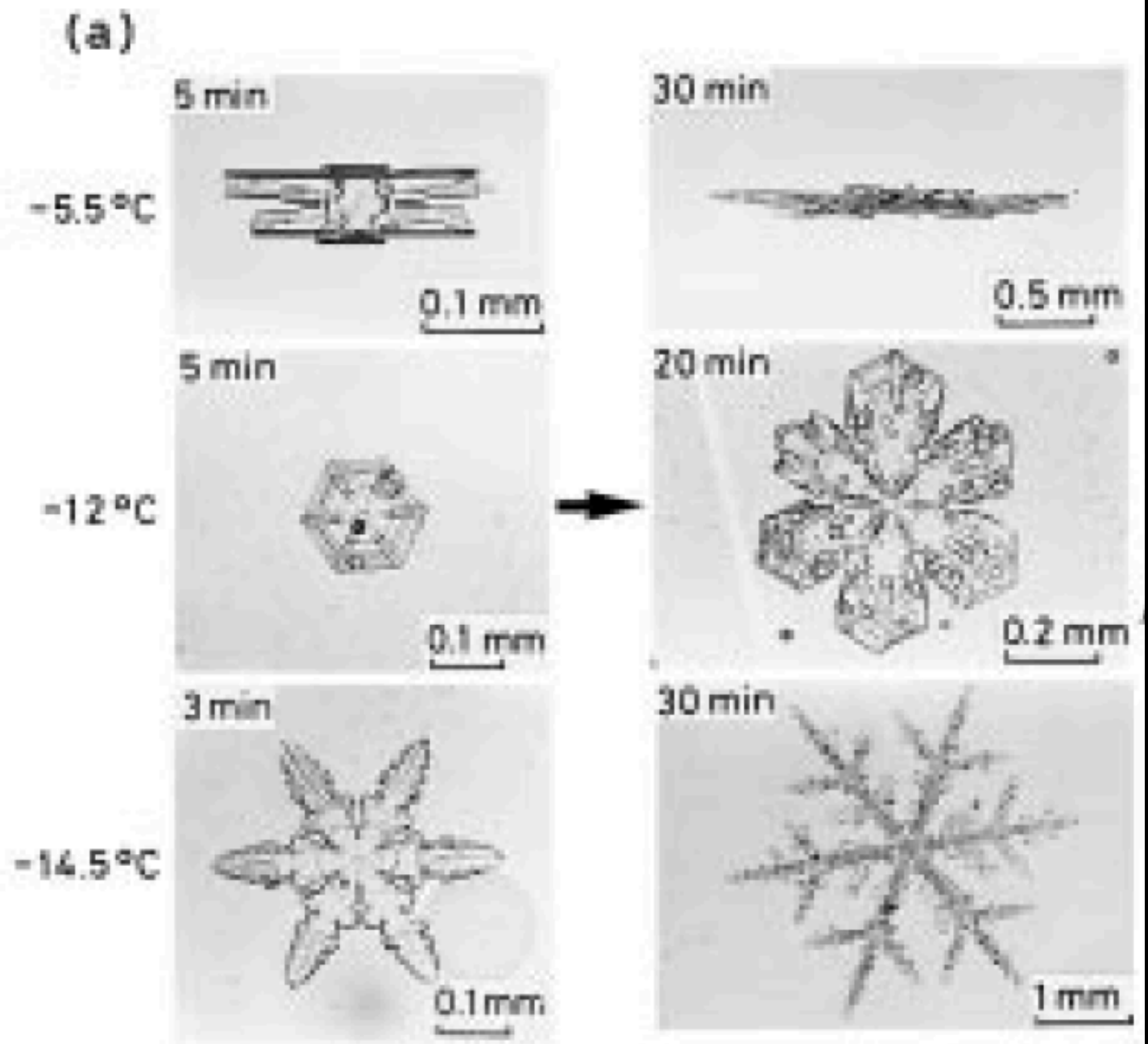
Department of Meteorology, University of Utah, Salt Lake City, Utah

TSUNEYA TAKAHASHI

Center for Educational Research and Development, Hokkaido University of Education, Sapporo, Japan

(Manuscript received 9 February 1998, in final form 10 July 1998)


(a)
5 min
-5.5 °C
0.1 mm
30 min
0.5 mm
5 min
-12 °C
0.1 mm
20 min
0.2 mm
3 min
-14.5 °C
0.1 mm
30 min
1 mm

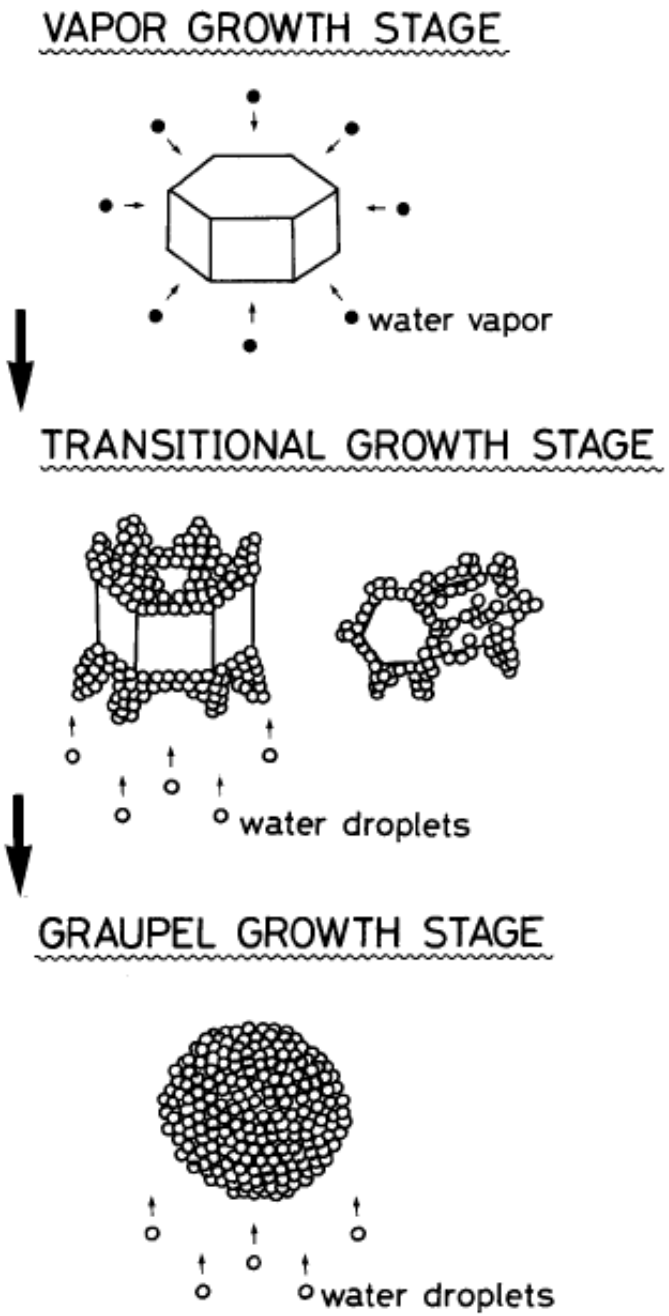
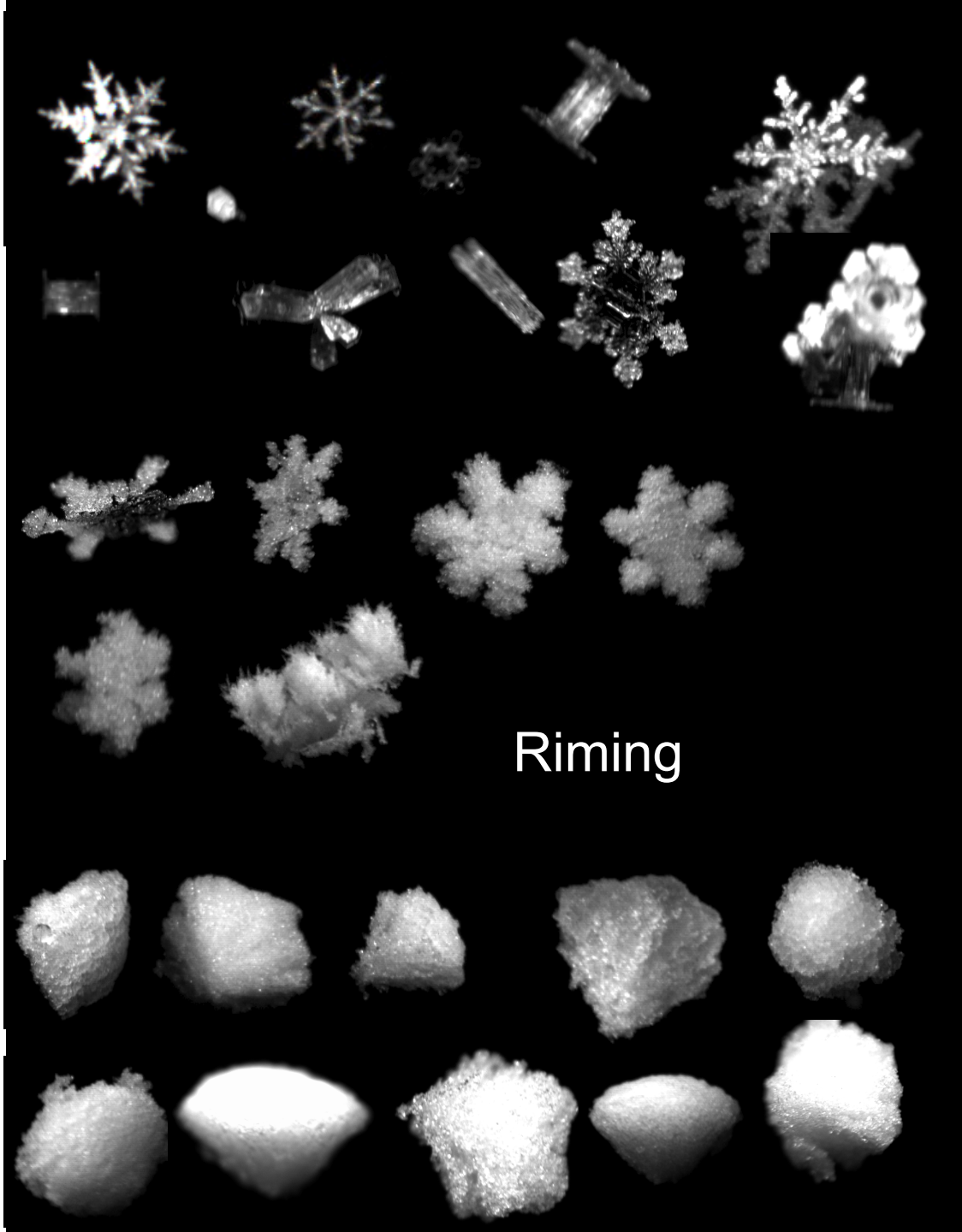


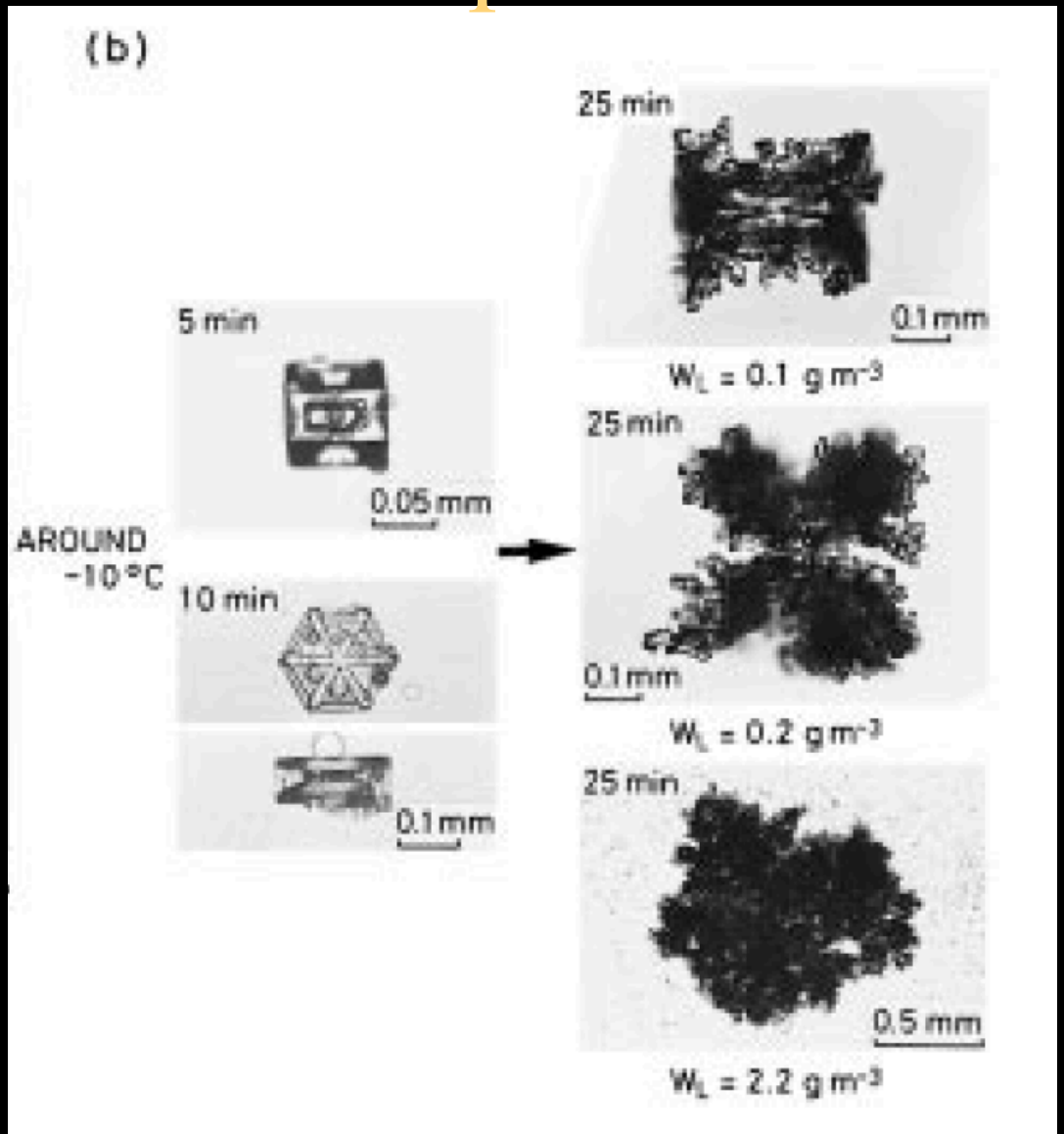
FIG. 8. Illustration of three growth stages of an isometric crystal.



Ingredients for riming

- A crystal falls
- It collects droplets
- It's cross-section grows and it gets heavier
- It falls faster with a larger cross-section
- Therefore a chain-reaction for growth
- The key limitations are too few droplets or too shallow a storm

The extent of riming is related to the concentration of liquid



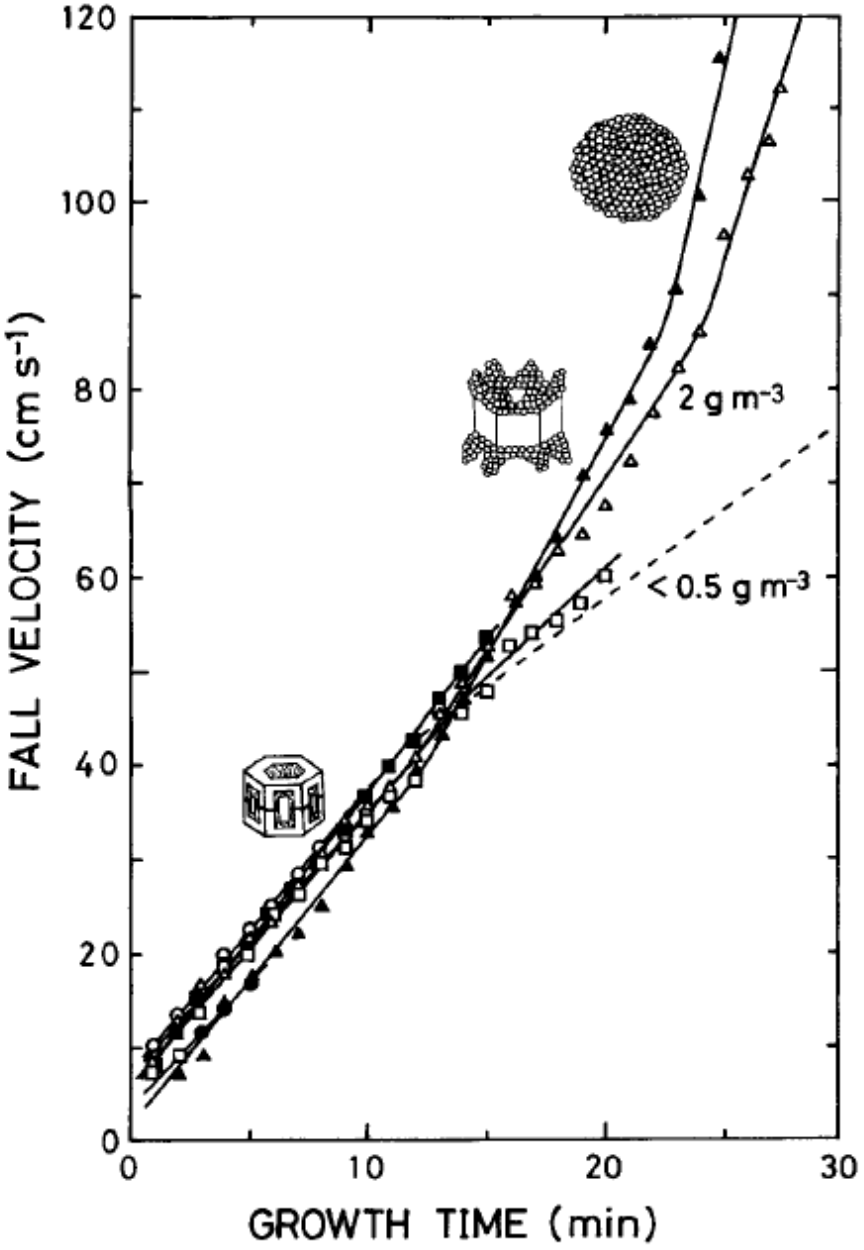


FIG. 16. Variation of crystal fall velocity with time at −10.5°C with a liquid water content of 2 g m⁻³. The dashed line shows the case with a liquid water content of less than 0.5 g m⁻³ (Takahashi and Fukuta 1988b).

Graupel can grow larger in deep juicy storms with stronger convection

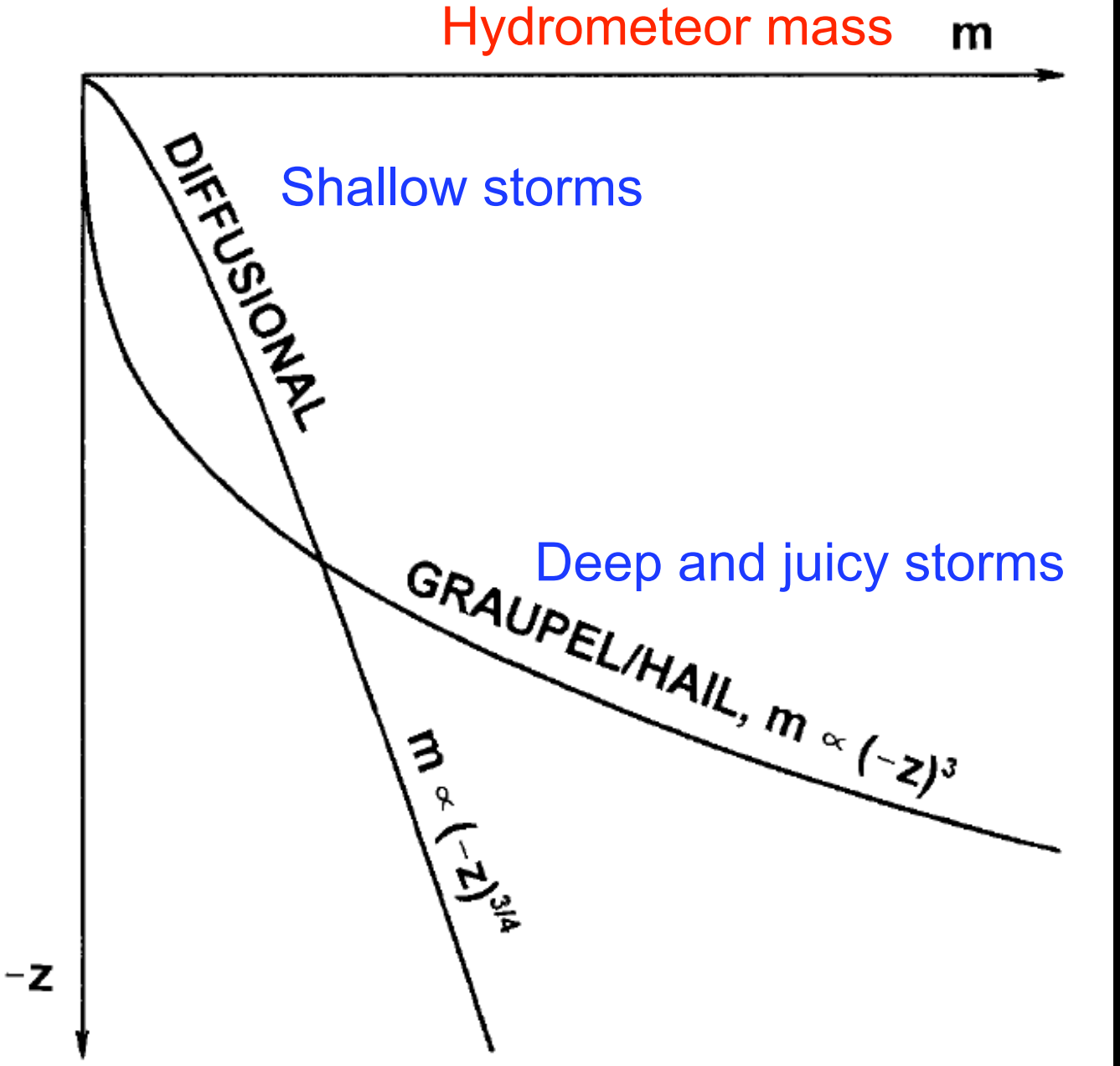
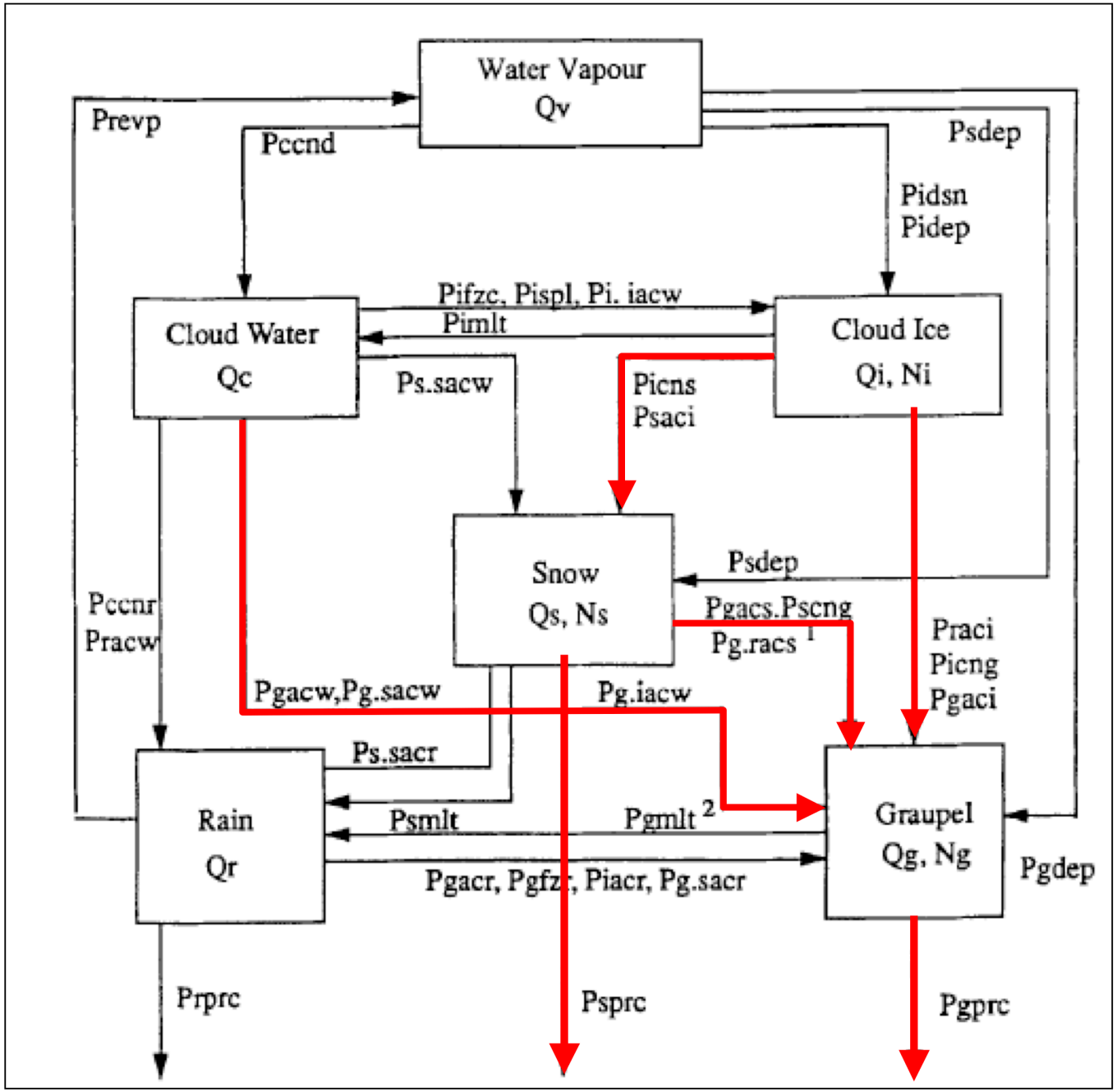


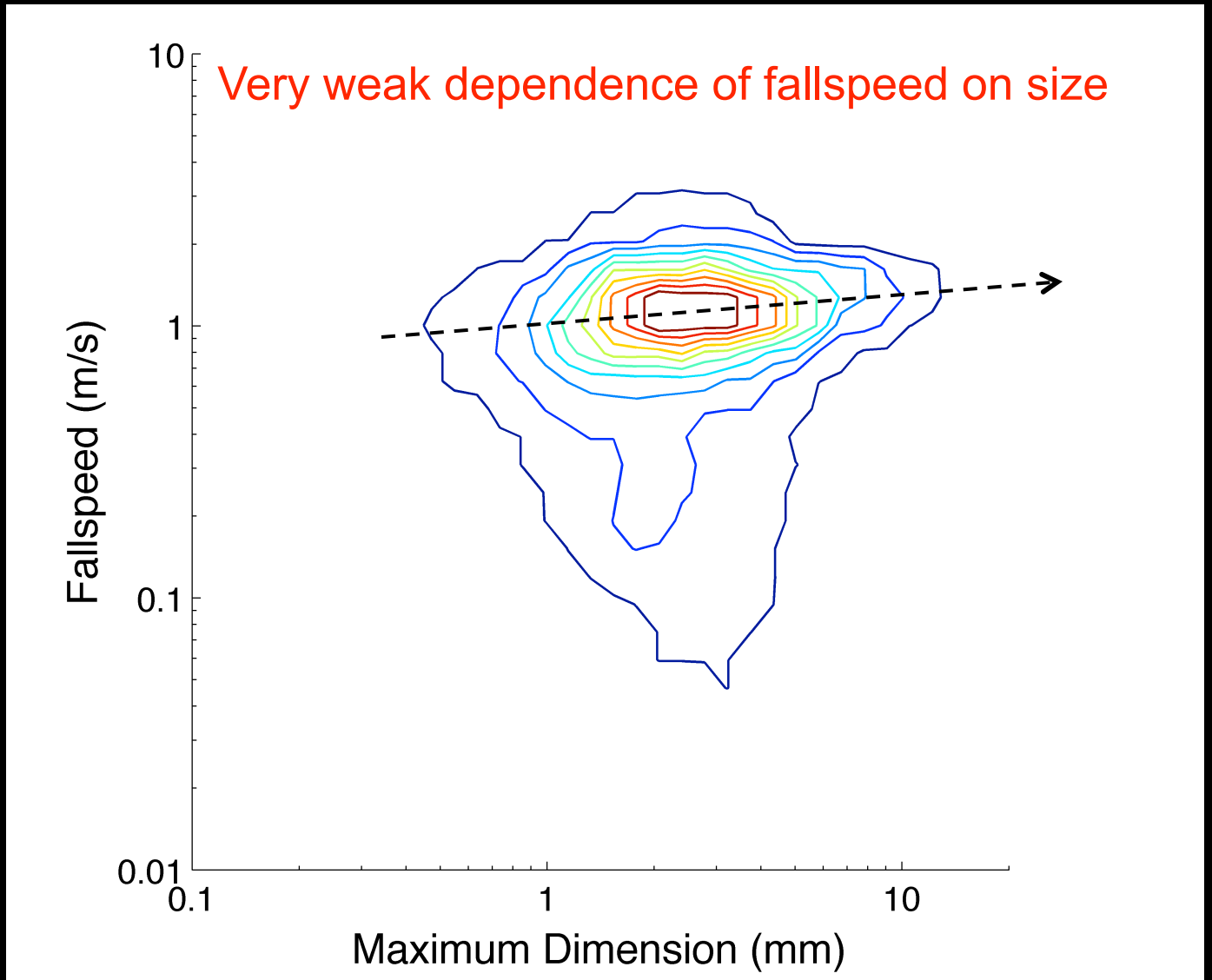
FIG. 21. Relationship between mass and fall distance for diffusional ice crystal growth and riming of graupel/hail.

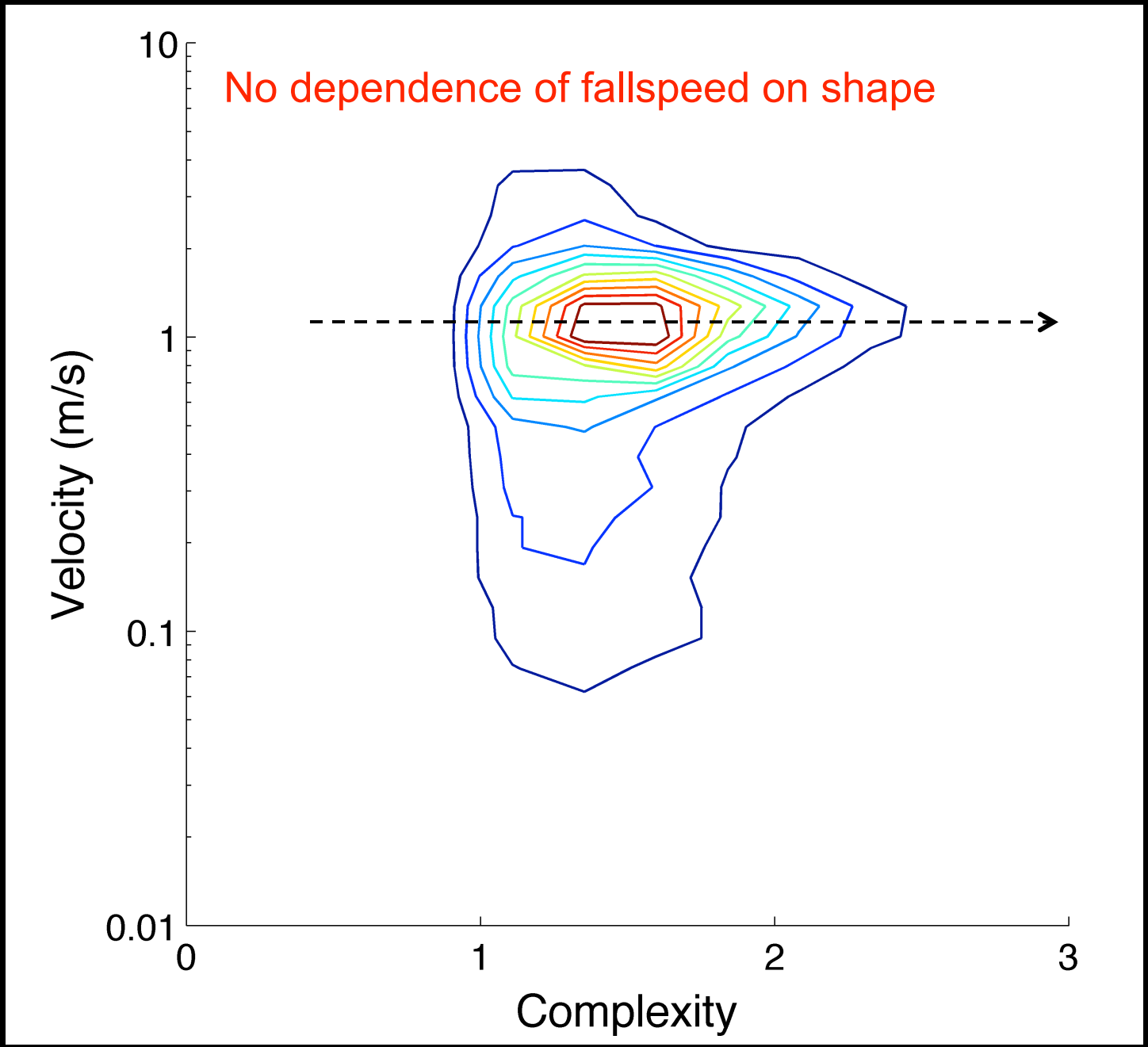

Water Vapour
Qv
Prevp
Pccnd
Psdep
Pidsn
Pidep
Cloud Water
Qc
Pifzc, Pispl, Pi. iacw
Pimlt
Ps.sacw
Cloud Ice
Qi, Ni
Picns
Psaci
Snow
Qs, Ns
Psdep
Pccnr
Pracw
Pgacs.Pscng
Pg.racs 1
Praci
Picng
Pgaci
Pgacw,Pg.sacw
Pg.iacw
Ps.sacr
Rain
Qr
Psmlt
Pgmlt 2
Graupel
Qg, Ng
Pgacr, Pgfzr, Piacr, Pg.sacr
Pgdep
Prprc
Psprc
Pgprc

In the end, prediction is hard…

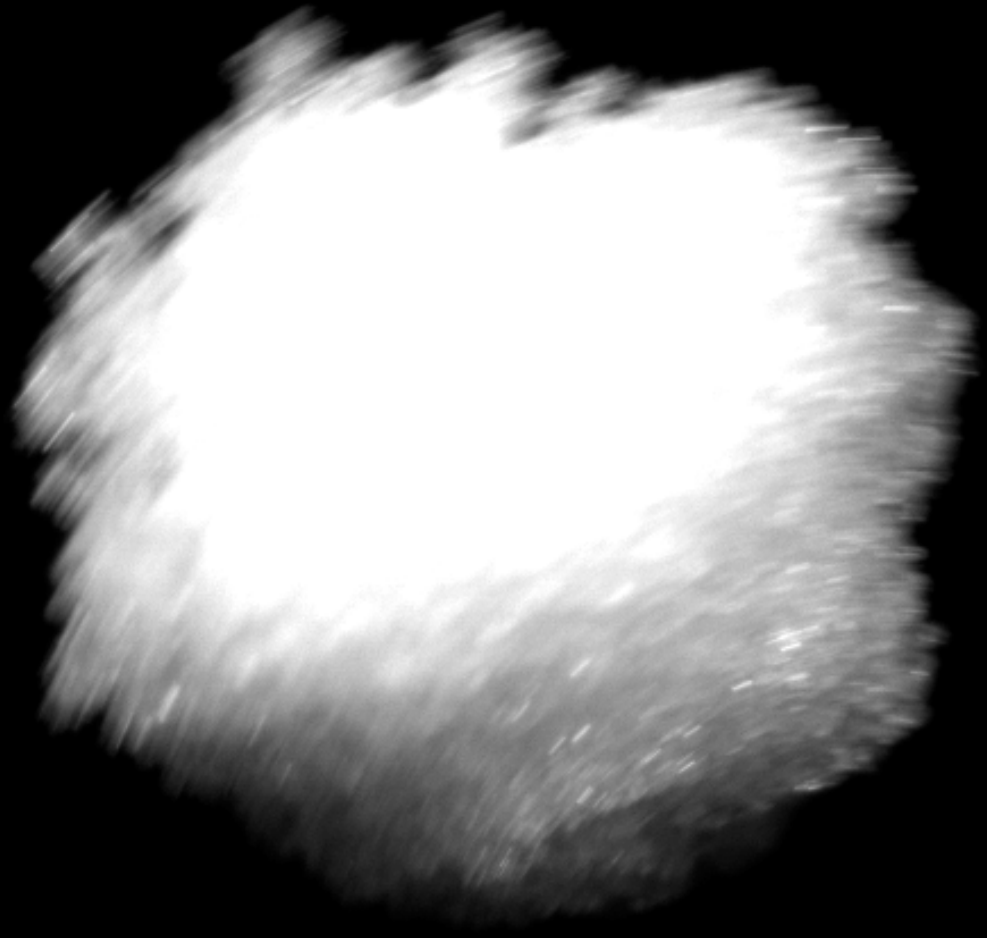
- Jim Steenburgh: *"Graupel is more common in warm storms (more cloud water) and storms with convection ***or*** intense orographic ascent"*

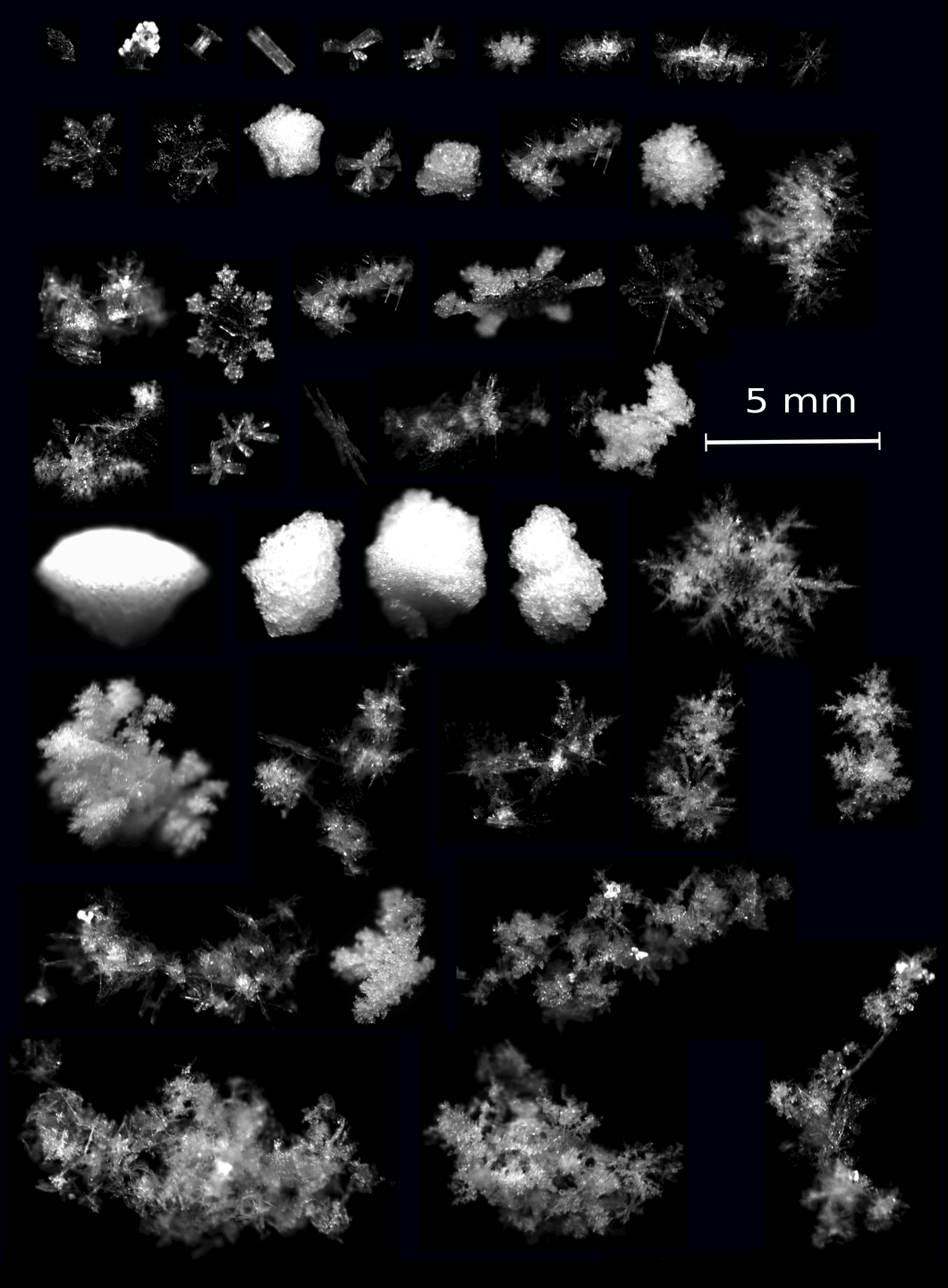
But are things actually much more simple?




No dependence of fallspeed on shape
10
1
0.1
0.01
Velocity (m/s)
0
1
2
3
Complexity

Spinning Graupel?





Thank you