Representing the Ice Fall-speed in Climate Models: Results from ISDAC, TC4 and SPARTICUS

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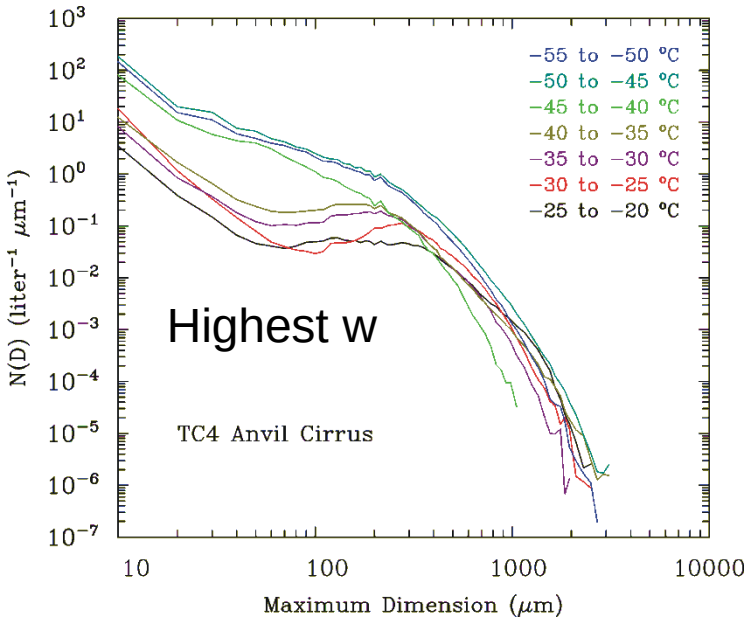
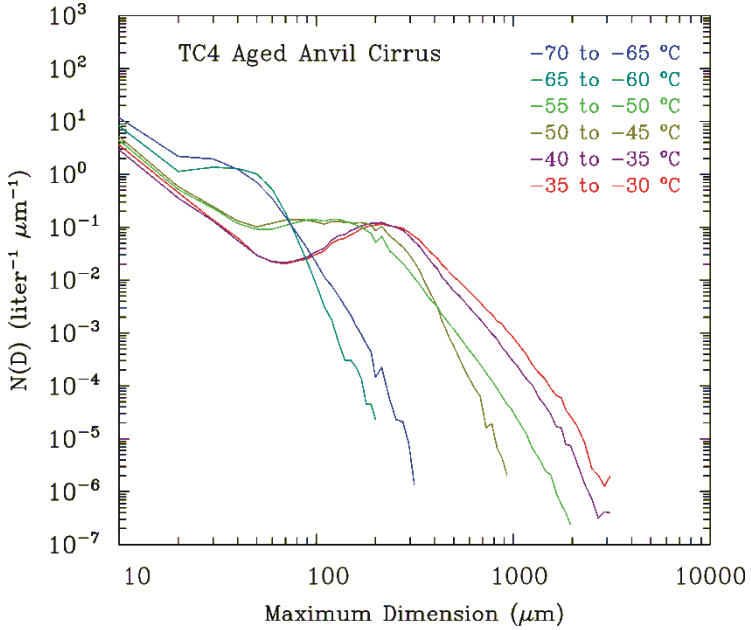
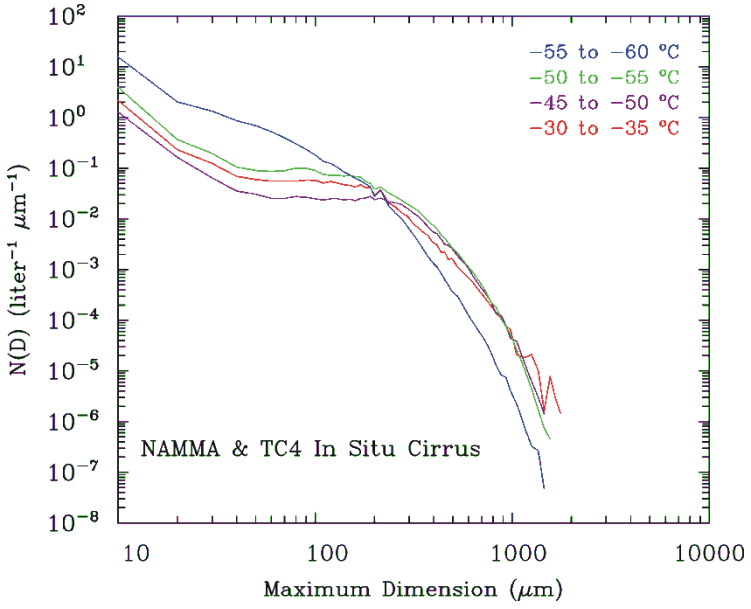
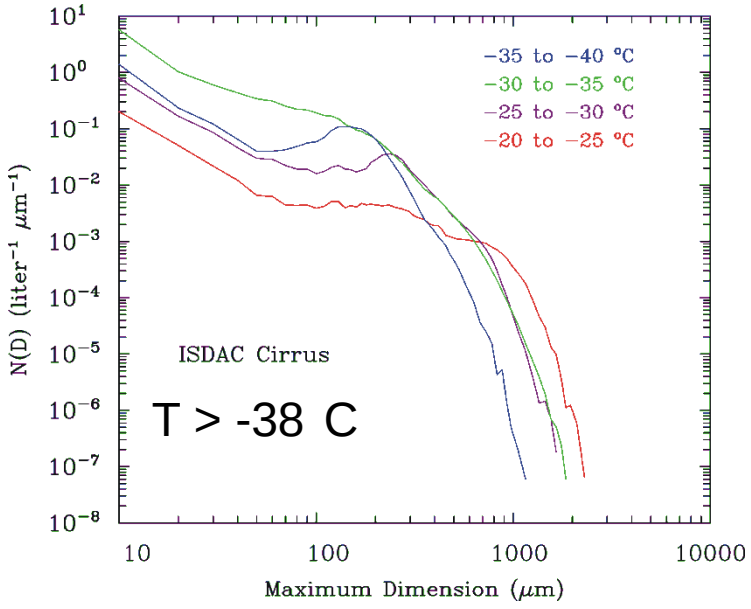
Homogeneous freezing nucleation at higher updrafts?

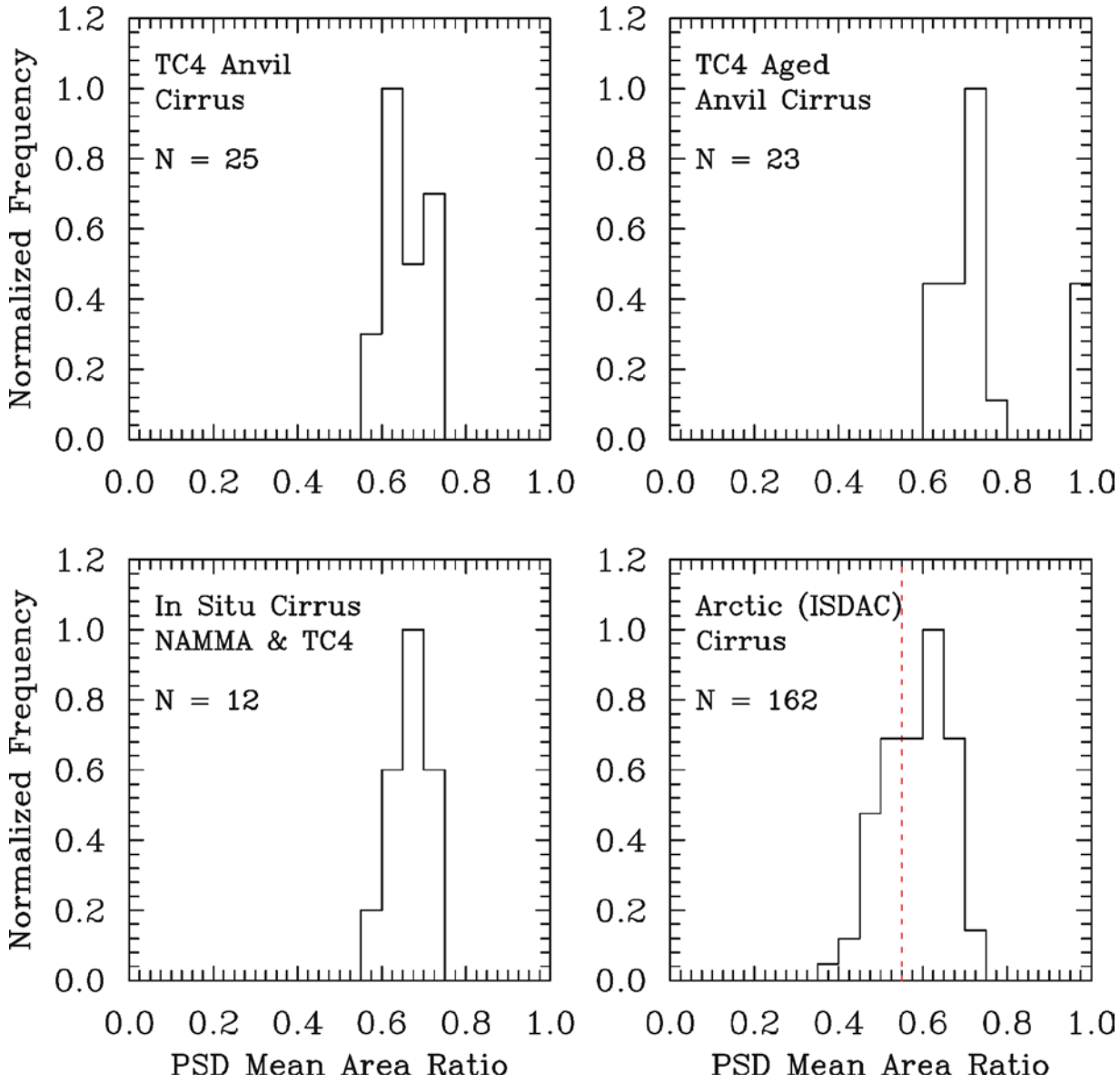


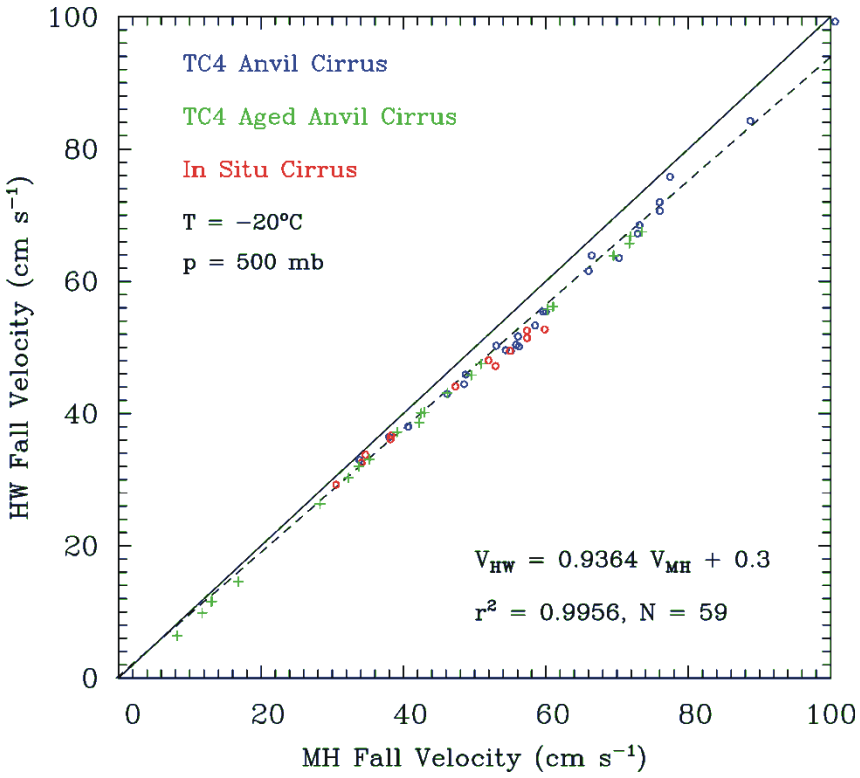


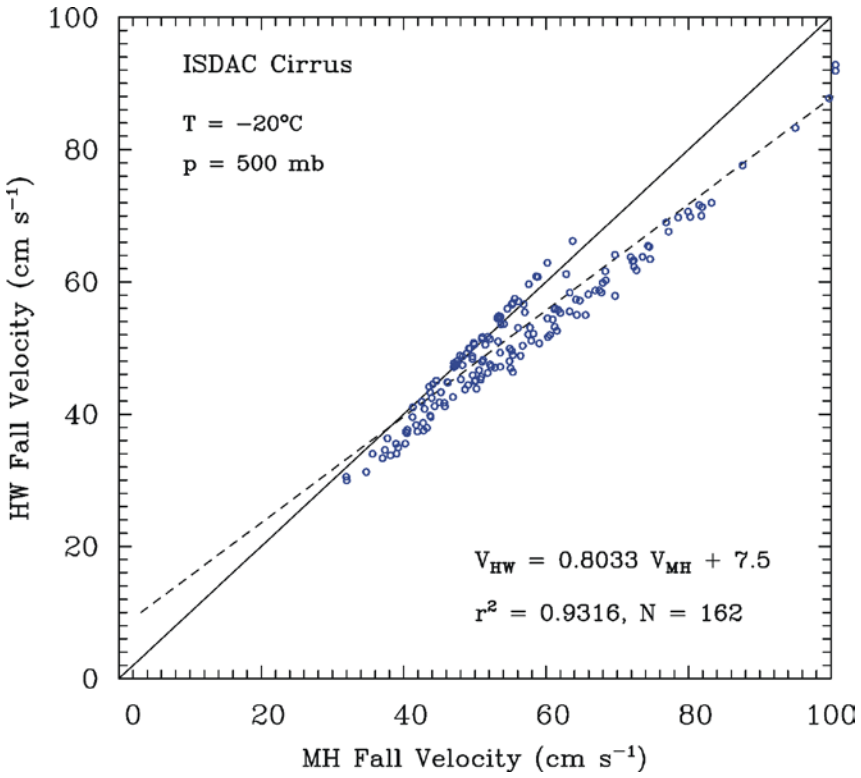




Arctic cirrus crystals have different area ratios




TC4 Anvil Cirrus
TC4 Aged Anvil Cirrus
In Situ Cirrus
T = −20°C
p = 500 mb
V_{HW} = 0.9364 V_{MH} + 0.3
r^2 = 0.9956, N = 59
HW Fall Velocity (cm s^{-1})
MH Fall Velocity (cm s^{-1})
0
20
40
60
80
100


ISDAC Cirrus
T = −20°C
p = 500 mb
V_{HW} = 0.8033 V_{MH} + 7.5
r^2 = 0.9316, N = 162
HW Fall Velocity (cm s^{-1})
MH Fall Velocity (cm s^{-1})
0
20
40
60
80
100

GENERAL APPROACH

1. The size resolved 2D-S measurements of number, projected area and mass concentration appear reasonable.
   - Ice artifacts from shattering greatly reduced
   - Good agreement between 2D-S and CVI IWC during TC4

2. Therefore calculate V_m and D_e **directly** from these measurements:

   $V_m = \Sigma\, v(D)\, m(D)\, N(D)\, \Delta D \,/\, \Sigma\, m(D)\, N(D)\, \Delta D$

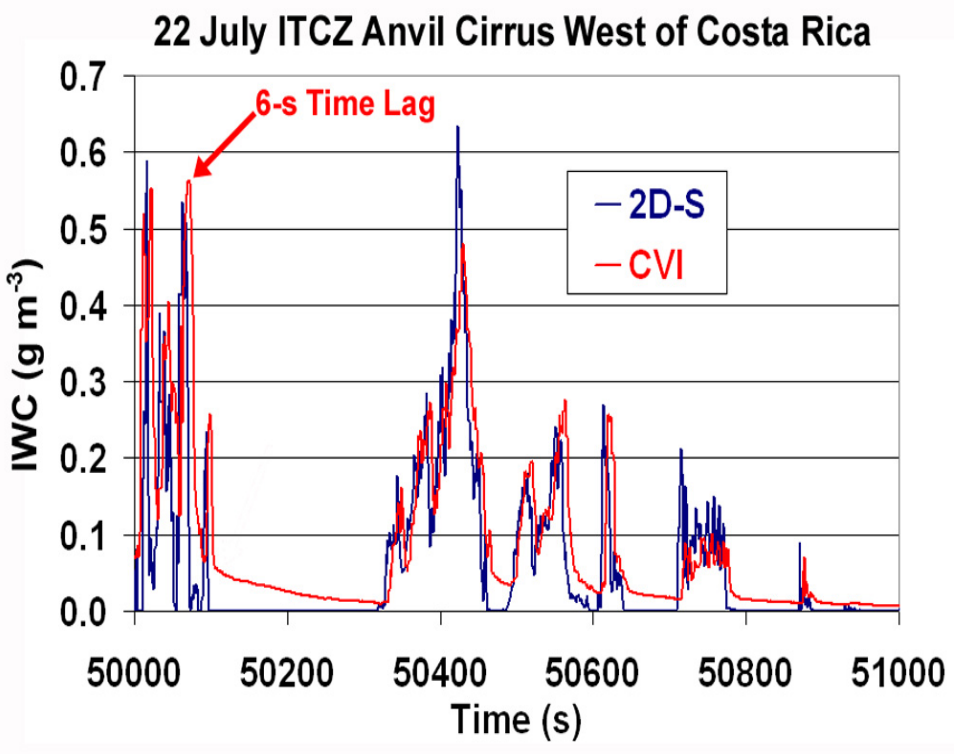
   $D_e = (3/2)\, \Sigma\, m(D)\, N(D)\, \Delta D \,/\, (\rho_i\, \Sigma\, A(D)\, N(D)\, \Delta D)$

   - m(D) & A(D) are bin mass or bin area concentration / bin number conc.

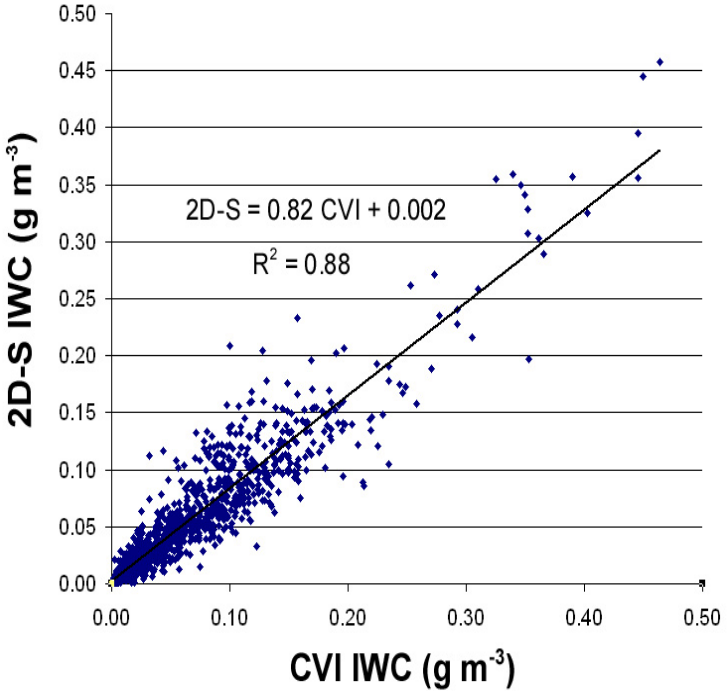
3. Relate V_m and D_e to T and IWC for model validation purposes

4. Relate V_m to D_e to predict V_m from the model microphysics scheme

COMPARISON OF 2D-S AND CVI IWCs DURING TC4



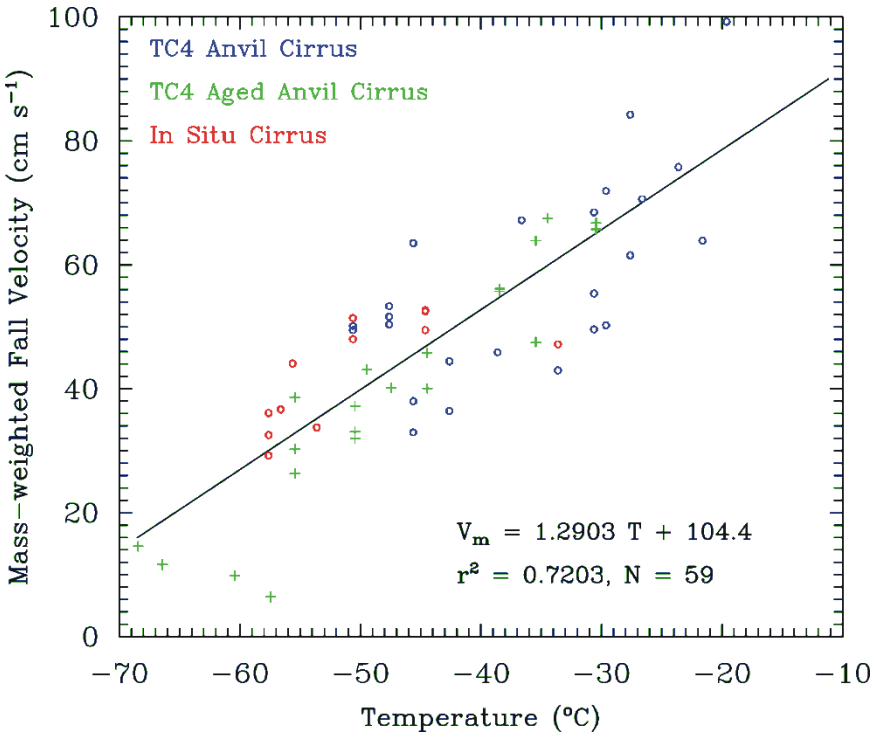
(A)

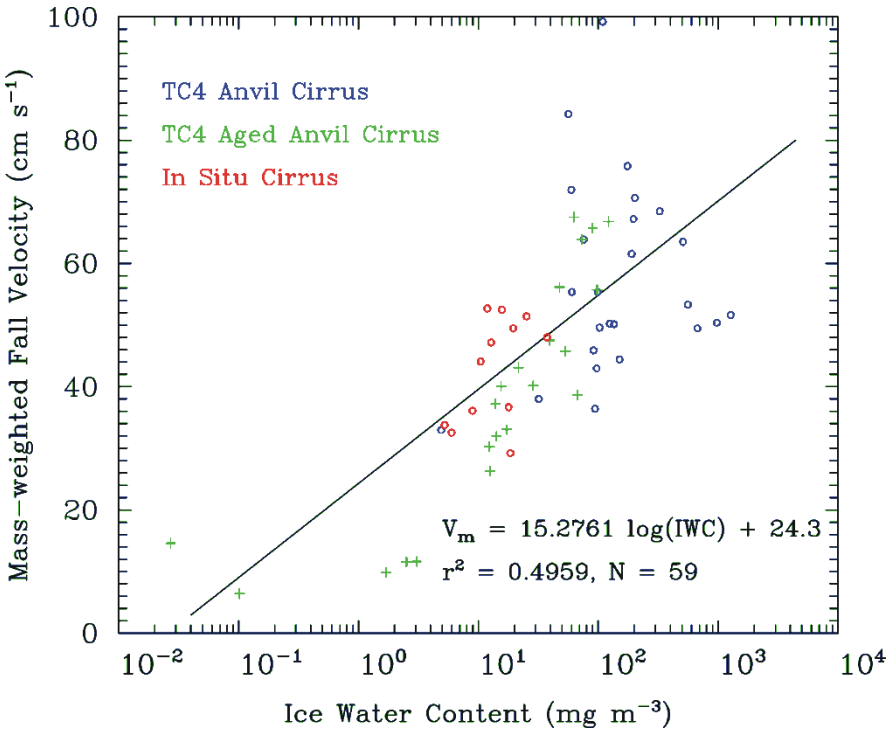


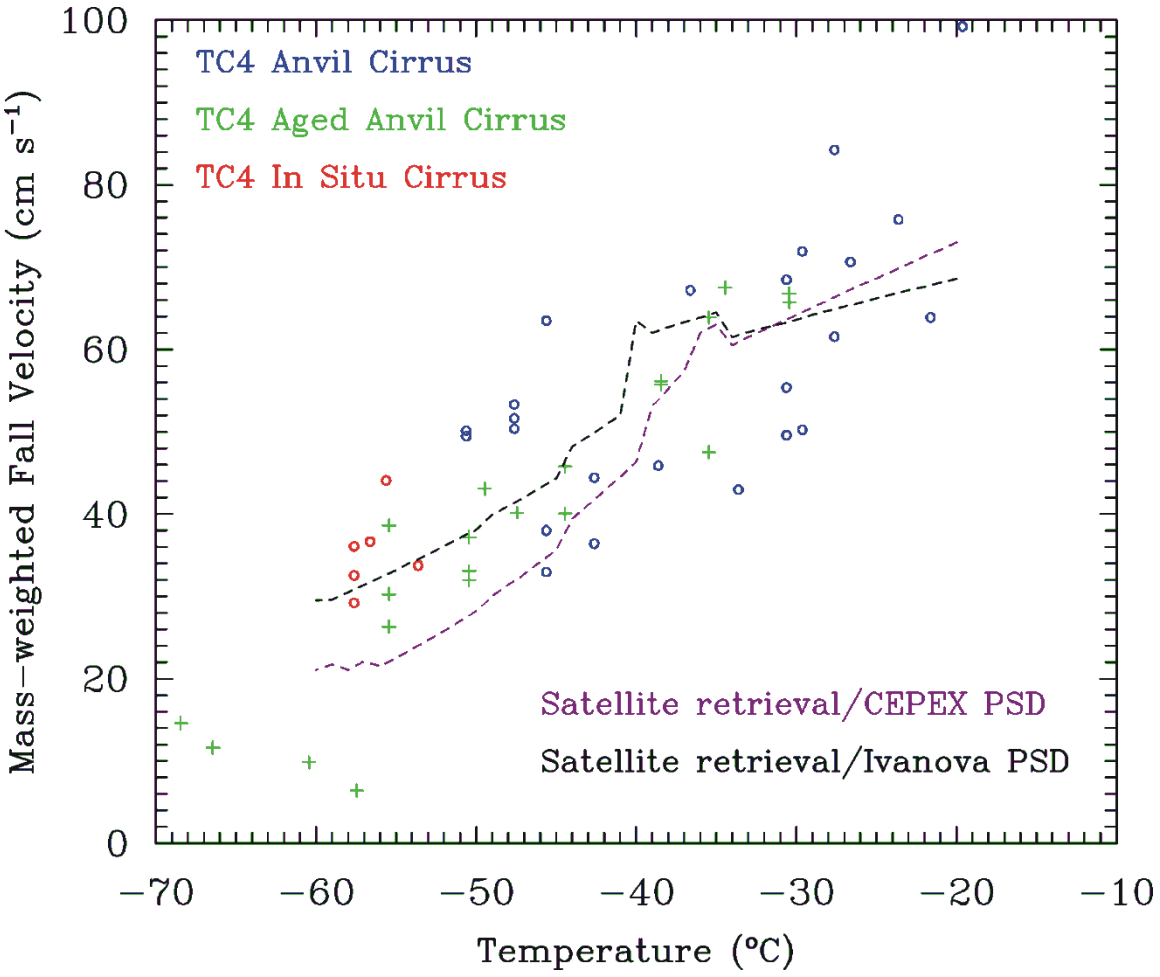
(B)

A: Time series of the 2D-S and CVI IWC for a TC4 case study. CVI response time lagged 6 seconds behind 2D-S measurements, producing a slight offset. B: 2D-S IWCs compared with CVI IWCs for 12,000 1-Hz measurements (averaged over 10-s) in TC4 anvils cirrus.

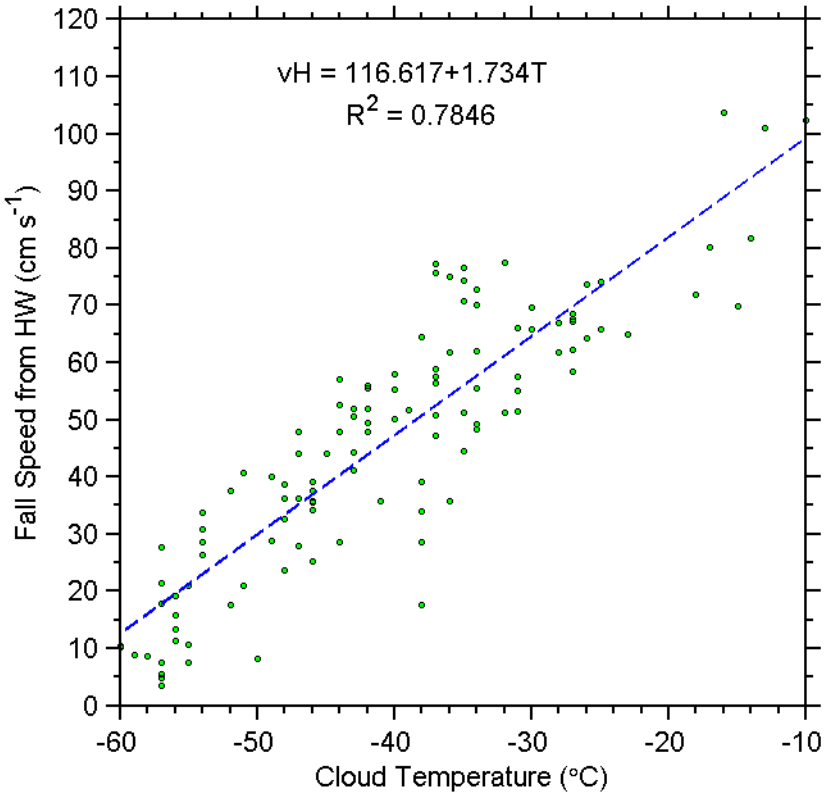
Mass-weighted fall velocity was related to both temperature and IWC during TC4 and SPARTICUS but not during ISDAC. Why?

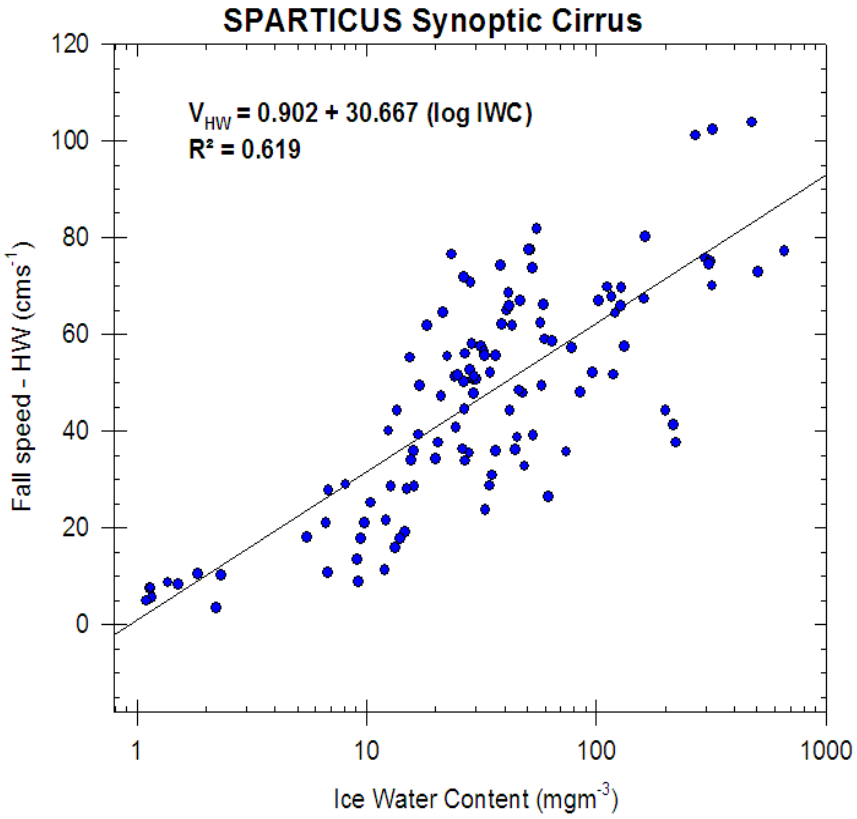




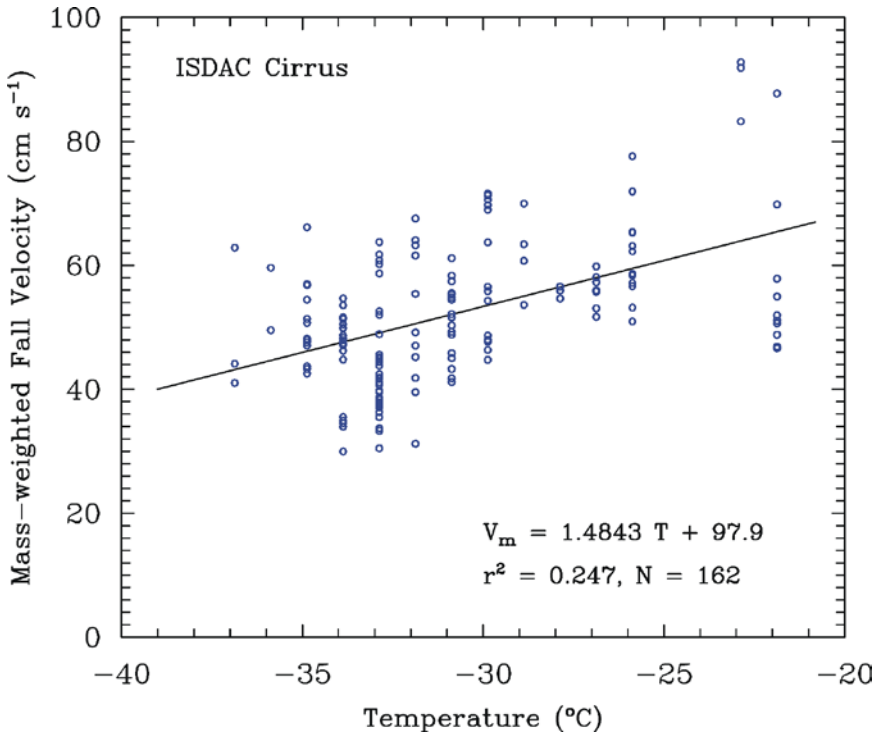

TC4 Anvil Cirrus
TC4 Aged Anvil Cirrus
TC4 In Situ Cirrus
Satellite retrieval/CEPEX PSD
Satellite retrieval/Ivanova PSD
Mass−weighted Fall Velocity (cm s⁻¹)
Temperature (°C)
100
80
60
40
20
0
−70
−60
−50
−40
−30
−20
−10

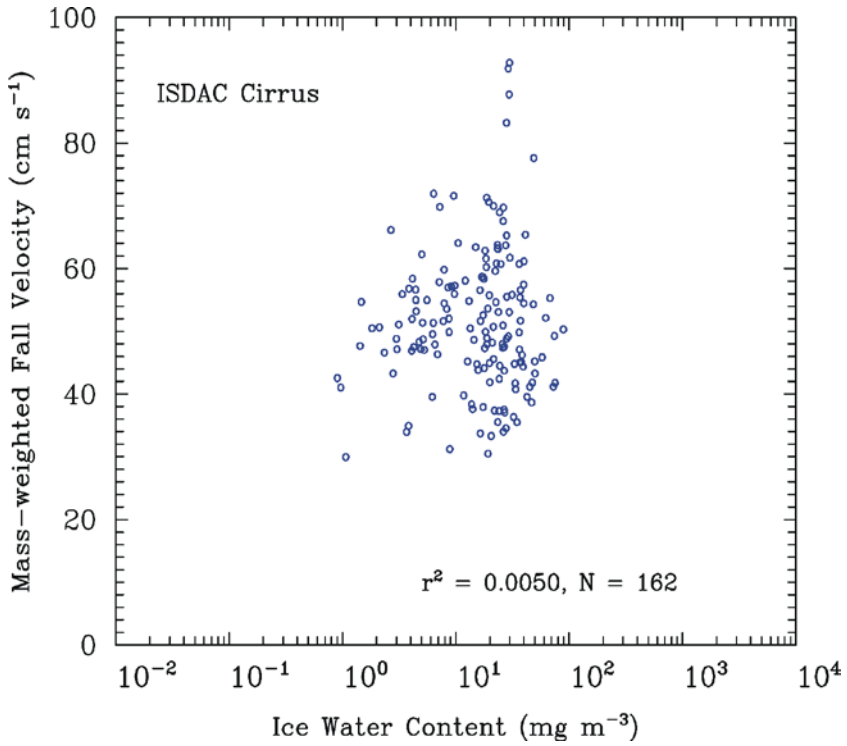
SPARTICUS SYNOPTIC CIRRUS: V_m vs. T and V_m vs. IWC

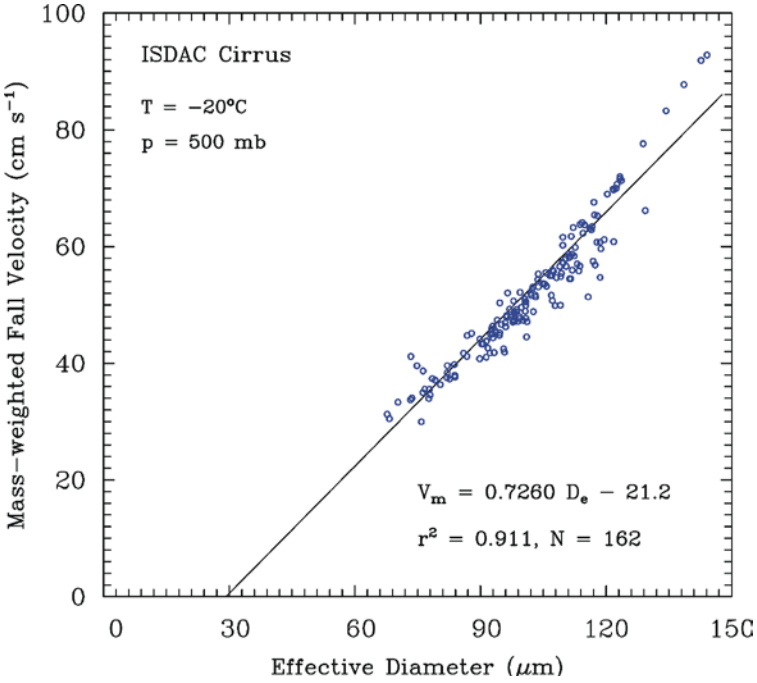


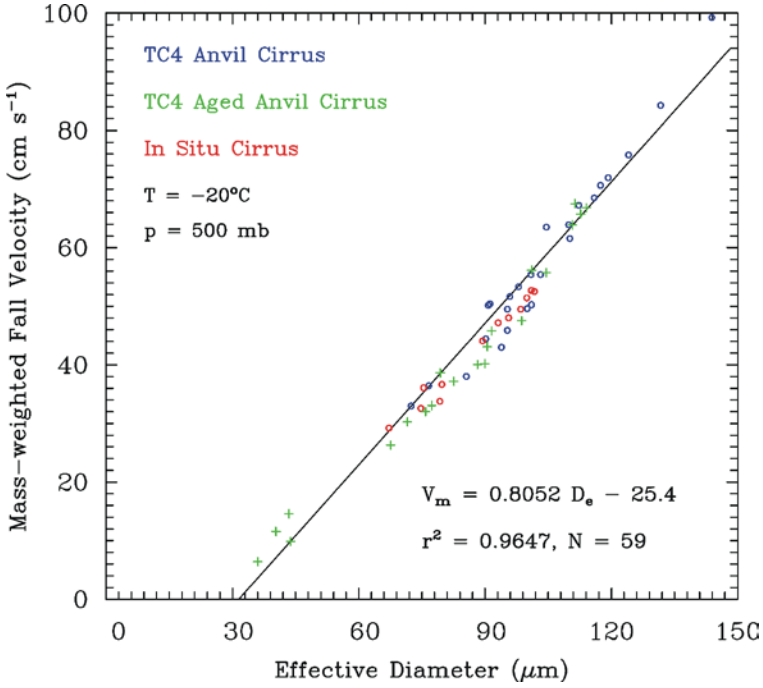


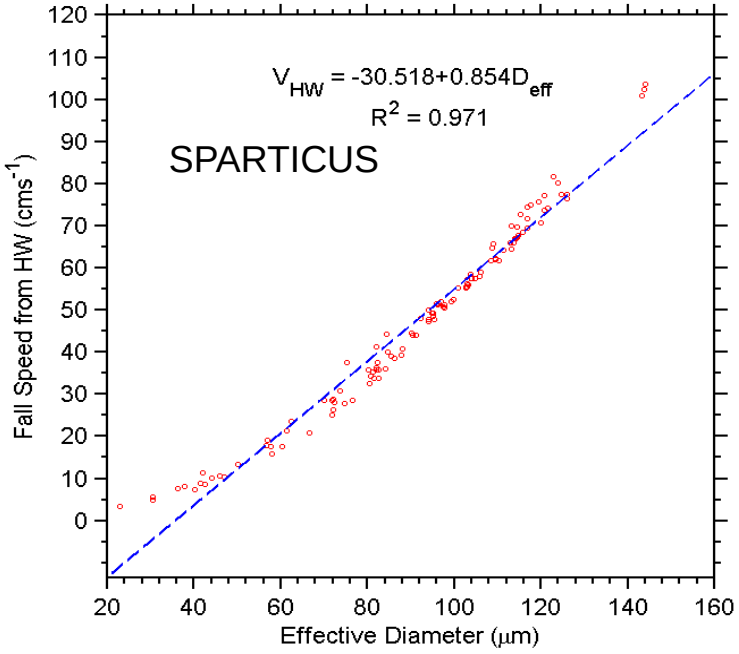
ISDAC FIELD CAMPAIGN

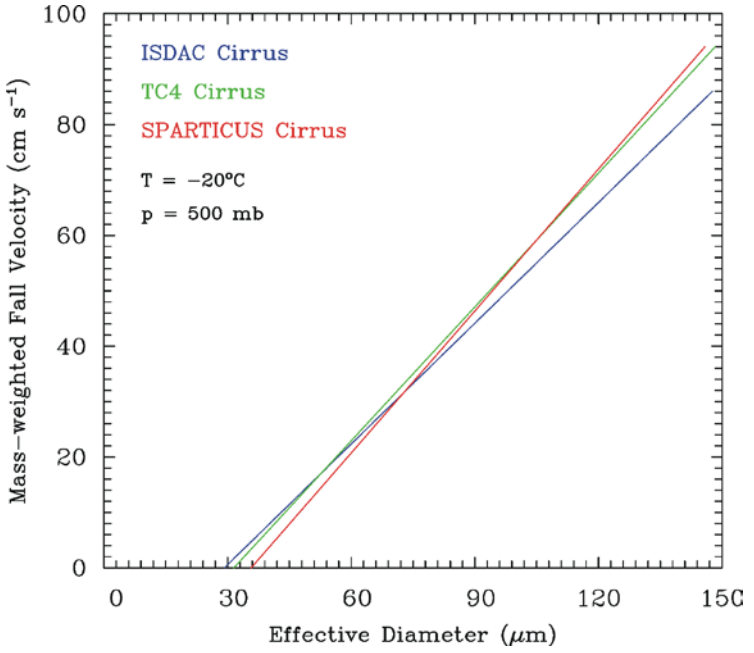


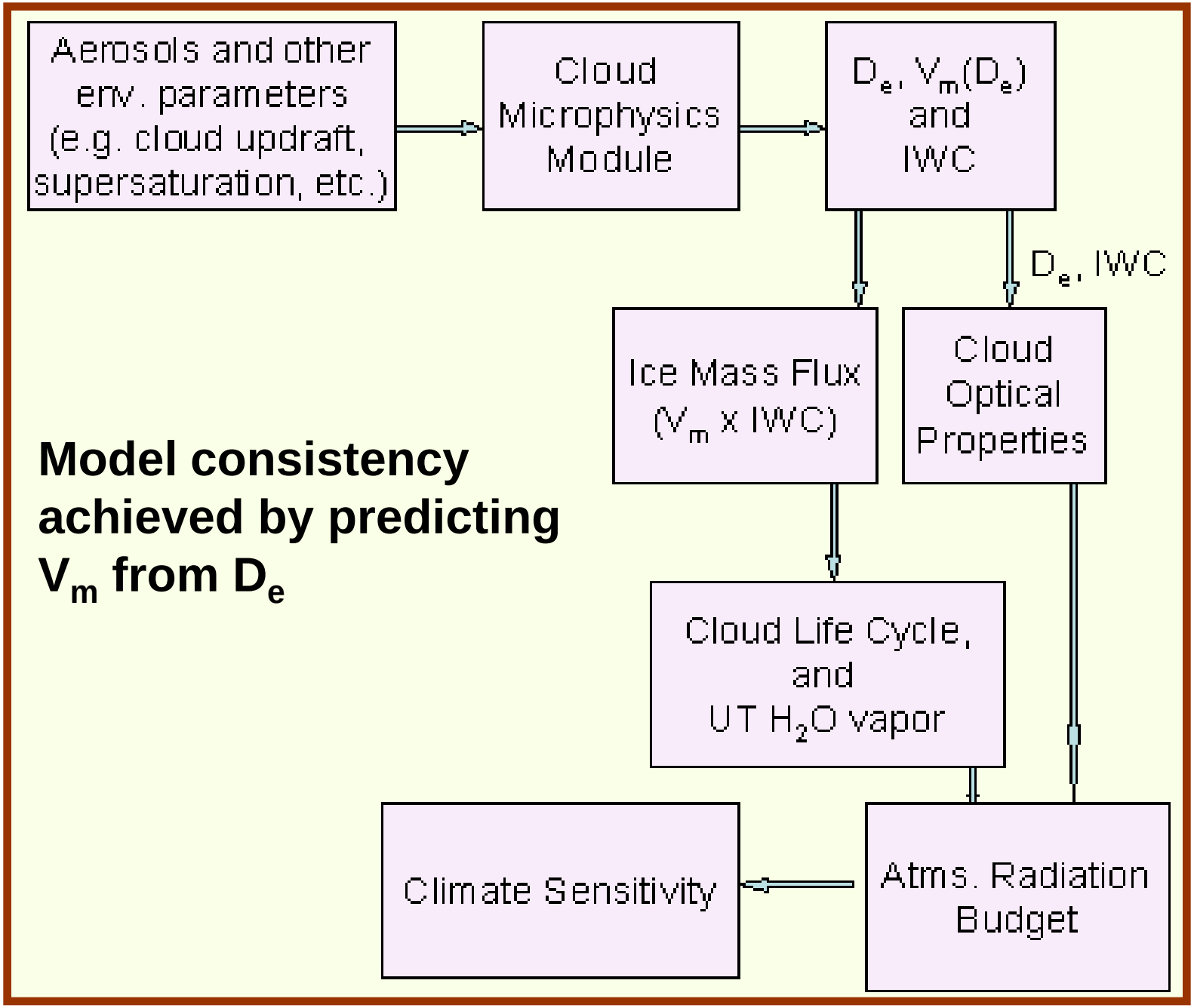



ISDAC Cirrus
T = −20°C
p = 500 mb
V_m = 0.7260 D_e − 21.2
r^2 = 0.911, N = 162
Mass−weighted Fall Velocity (cm s^{-1})
Effective Diameter (μm)


TC4 Anvil Cirrus
TC4 Aged Anvil Cirrus
In Situ Cirrus
T = −20°C
p = 500 mb
V_m = 0.8052 D_e − 25.4
r^2 = 0.9647, N = 59
Mass−weighted Fall Velocity (cm s^{-1})
Effective Diameter (μm)


V_{HW} = -30.518+0.854D_{eff}
R^2 = 0.971
SPARTICUS
Fall Speed from HW (cms^{-1})
Effective Diameter (μm)


ISDAC Cirrus
TC4 Cirrus
SPARTICUS Cirrus
T = −20°C
p = 500 mb
Mass−weighted Fall Velocity (cm s^{-1})
Effective Diameter (μm)


Aerosols and other env. parameters (e.g. cloud updraft, supersaturation, etc.)
Cloud Microphysics Module
D_e, $V_m(D_e)$ and IWC
D_e, IWC
Ice Mass Flux (V_m x IWC)
Cloud Optical Properties
Cloud Life Cycle, and UT H_2O vapor
Climate Sensitivity
Atms. Radiation Budget
Model consistency achieved by predicting V_m from D_e