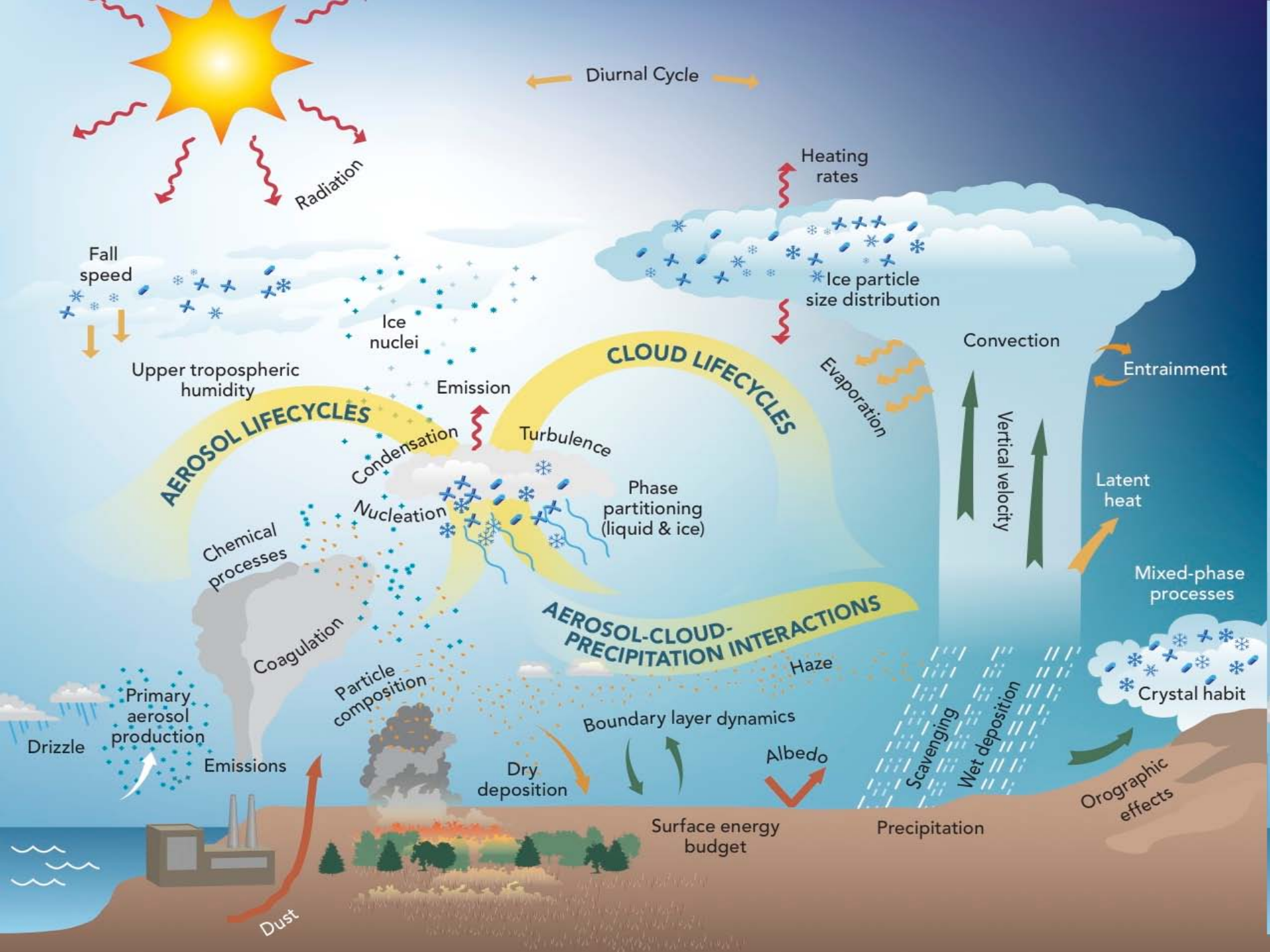
Parameterization of the Ice Cloud Mass-weighted Fall-speed Using In Situ Data from Recent Field Campaigns

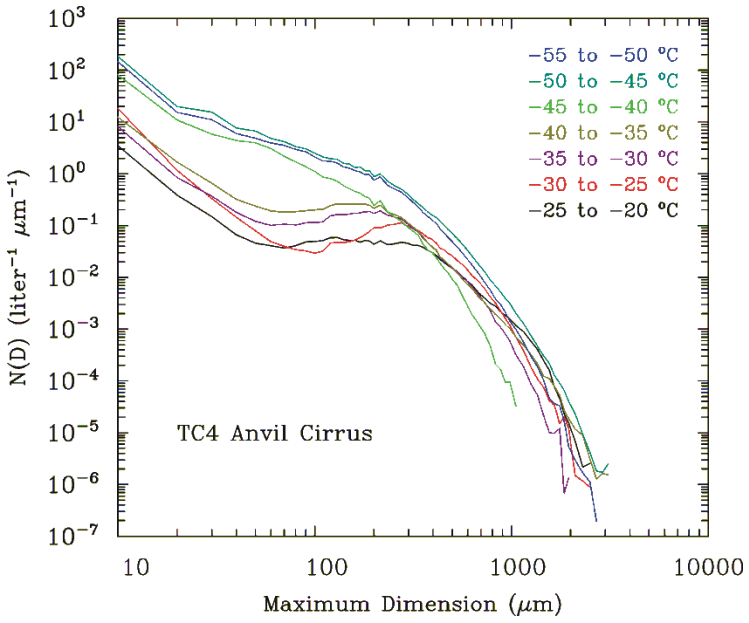
David L. Mitchell and Subhashree Mishra
Desert Research Institute, **Reno, Nevada**

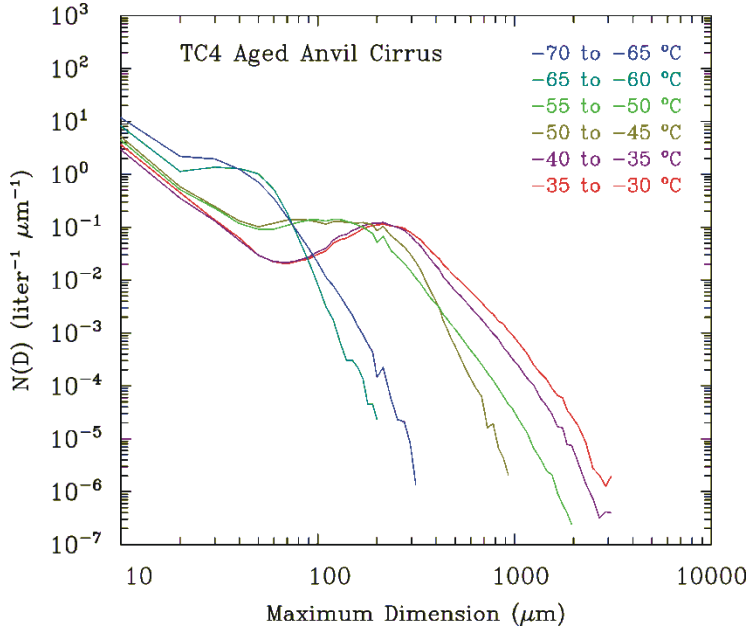
R. Paul Lawson and Brad Baker
SPEC, Inc., Boulder, Colorado

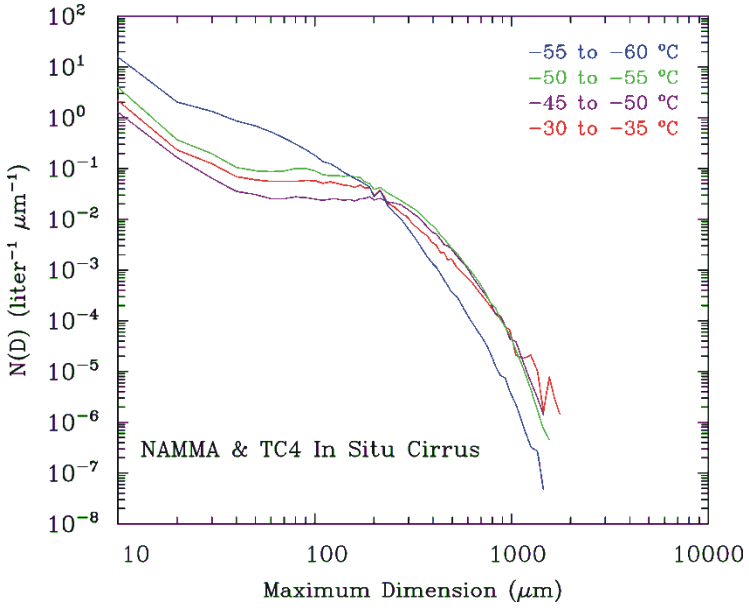
ASR
Atmospheric System Research

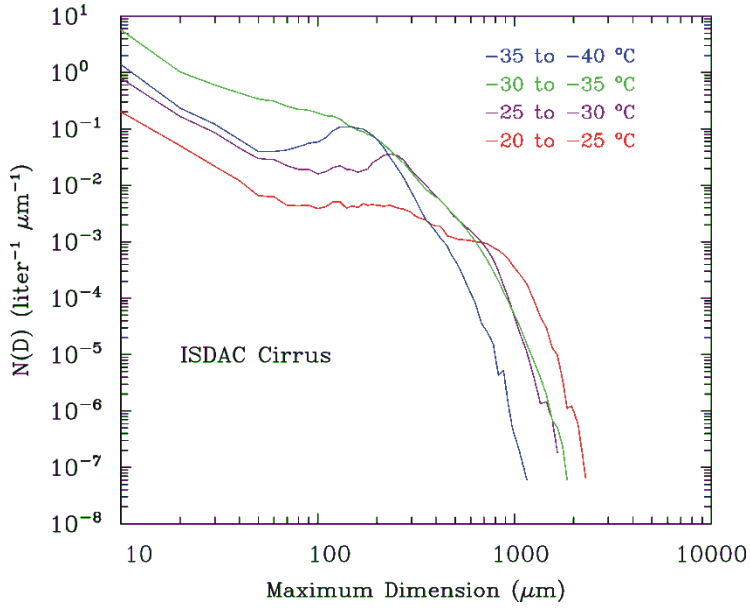
DRI
Desert Research Institute


Diurnal Cycle
Radiation
Heating rates
Ice particle size distribution
Fall speed
Ice nuclei
Upper tropospheric humidity
Emission
CLOUD LIFECYCLES
AEROSOL LIFECYCLES
Condensation
Turbulence
Nucleation
Phase partitioning (liquid & ice)
Evaporation
Convection
Entrainment
Vertical velocity
Latent heat
Chemical processes
Coagulation
AEROSOL-CLOUD-PRECIPITATION INTERACTIONS
Mixed-phase processes
Haze
Particle composition
Crystal habit
Primary aerosol production
Drizzle
Emissions
Boundary layer dynamics
Dry deposition
Albedo
Scavenging
Wet deposition
Orographic effects
Surface energy budget
Precipitation
Dust

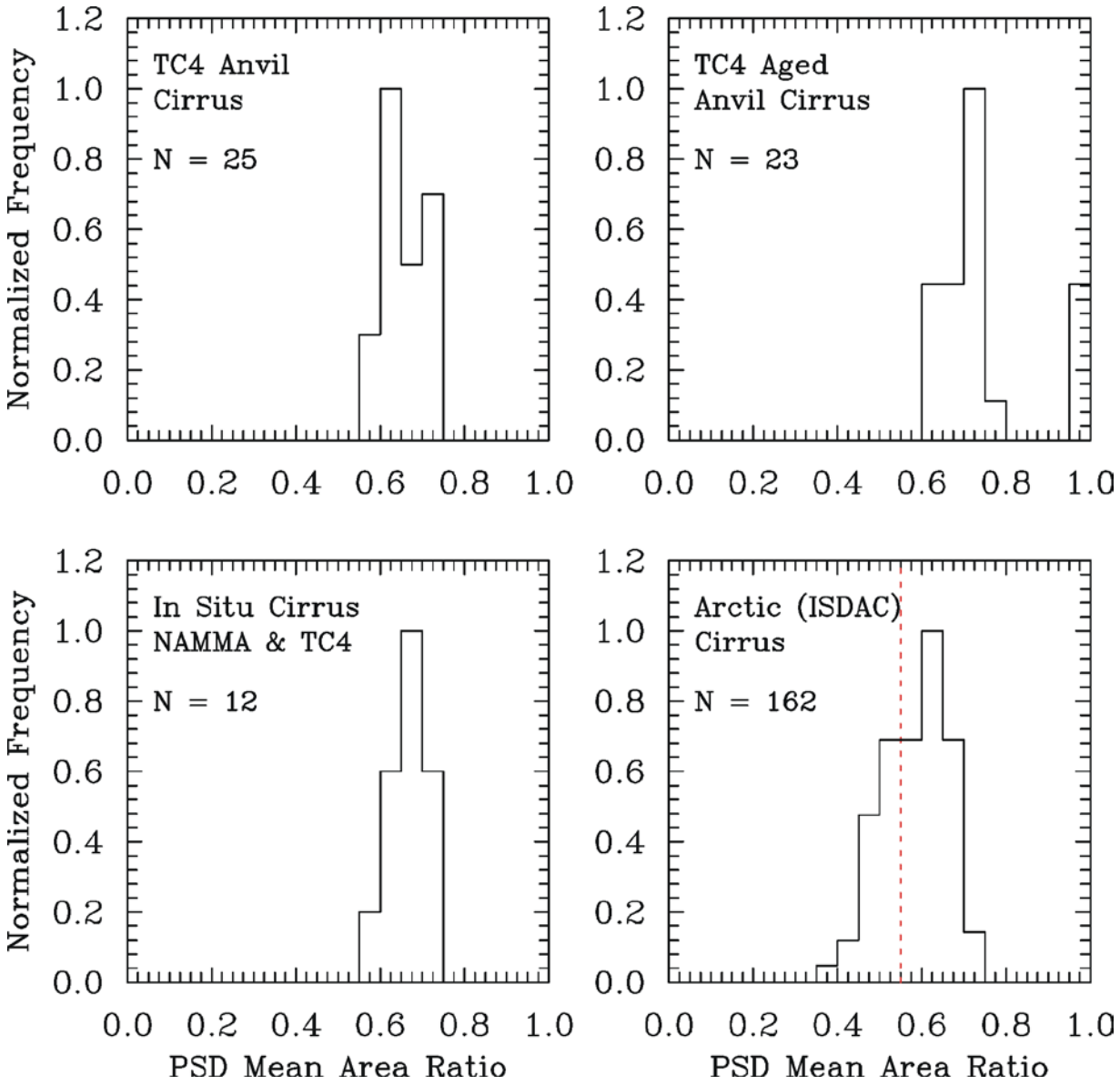

−55 to −50 °C
−50 to −45 °C
−45 to −40 °C
−40 to −35 °C
−35 to −30 °C
−30 to −25 °C
−25 to −20 °C
TC4 Anvil Cirrus
N(D) (liter^{-1} μm^{-1})
Maximum Dimension (μm)

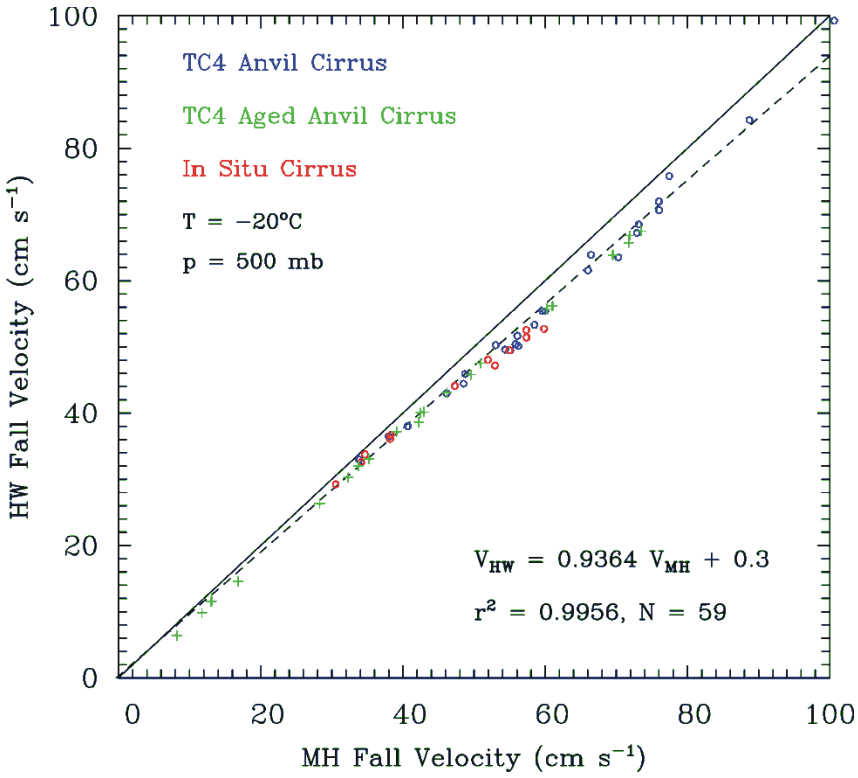

TC4 Aged Anvil Cirrus
−70 to −65 °C
−65 to −60 °C
−55 to −50 °C
−50 to −45 °C
−40 to −35 °C
−35 to −30 °C
N(D) (liter^{-1} μm^{-1})
Maximum Dimension (μm)

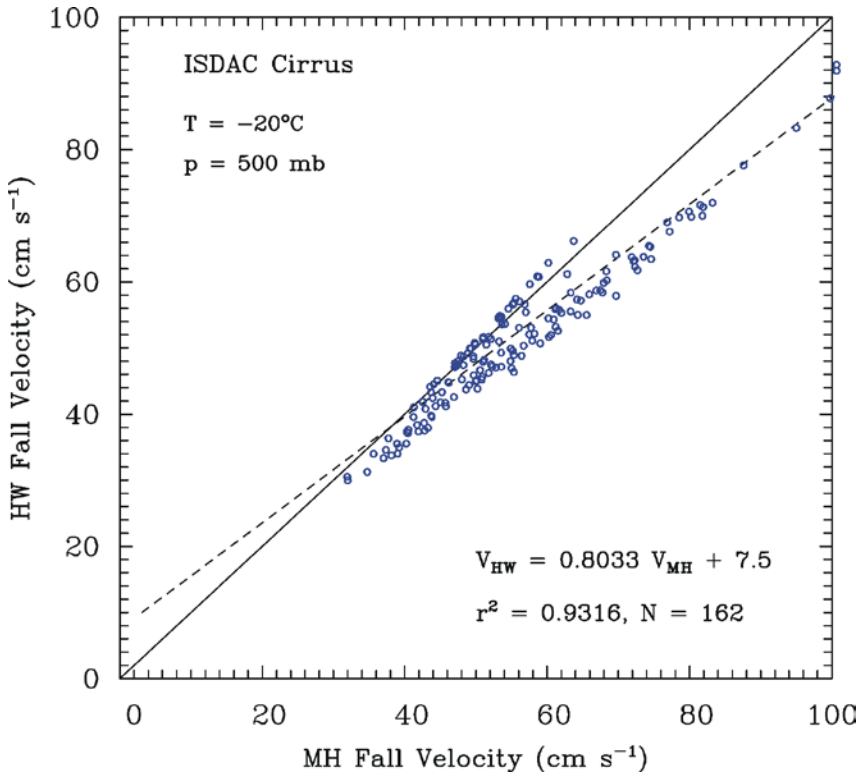

−55 to −60 °C
−50 to −55 °C
−45 to −50 °C
−30 to −35 °C
NAMMA & TC4 In Situ Cirrus
N(D) (liter^{-1} μm^{-1})
Maximum Dimension (μm)


−35 to −40 °C
−30 to −35 °C
−25 to −30 °C
−20 to −25 °C
ISDAC Cirrus
N(D) (liter^{-1} μm^{-1})
Maximum Dimension (μm)

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:

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

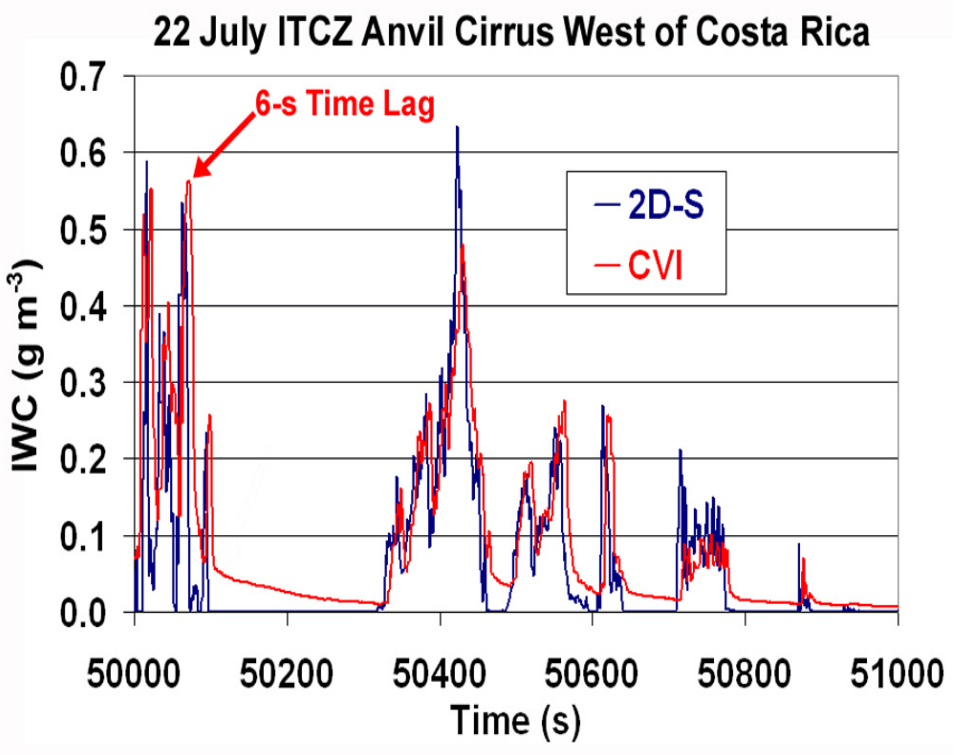
   $D_e = (3/2)\, \Sigma\, m(D)\, N(D)\, \Delta D \,/\, (\rho_i\, \Sigma\, A(D)\, N(D)\, \Delta D)$

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

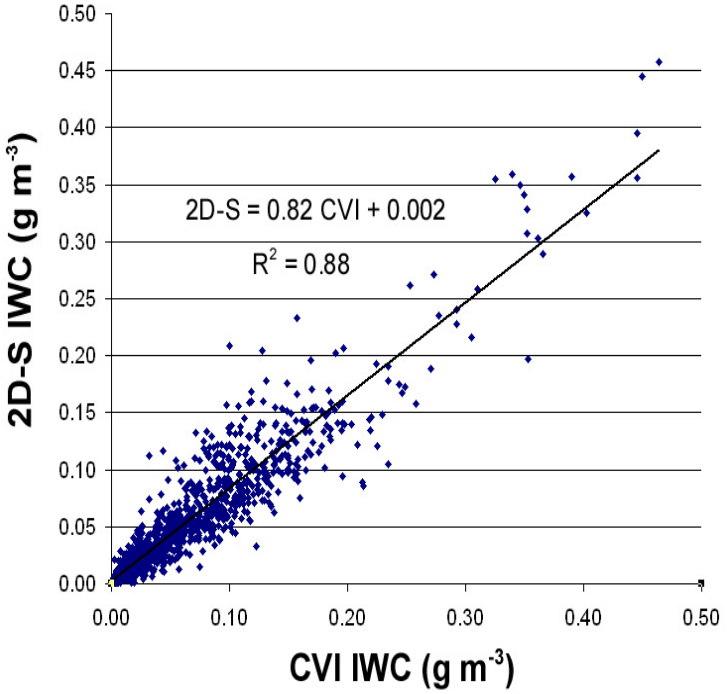
3. Relate V_m and D_e to T and IWC for model validation purposes

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



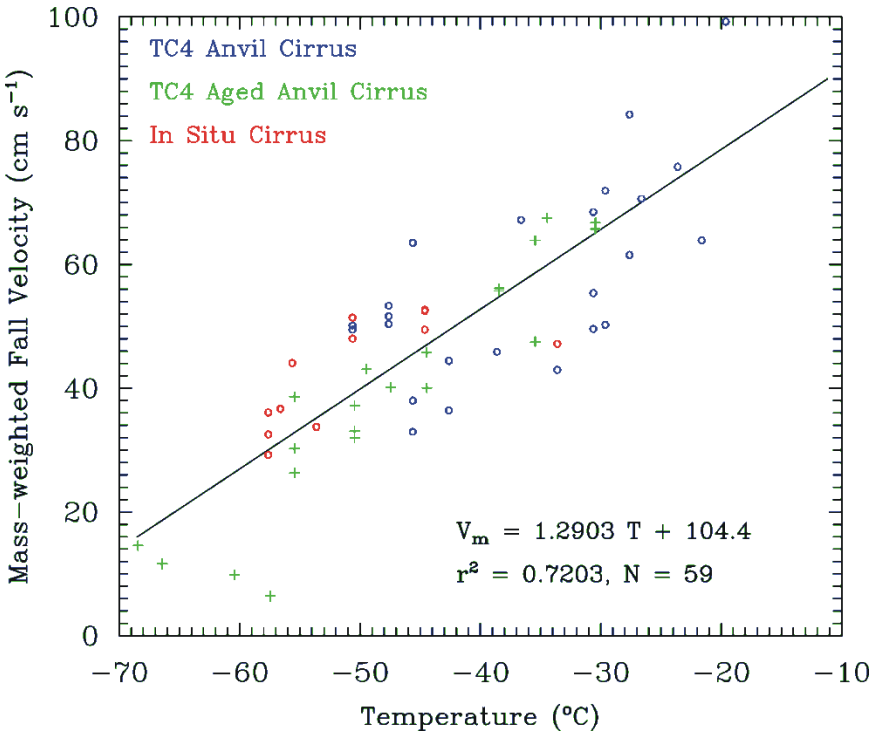
(A)

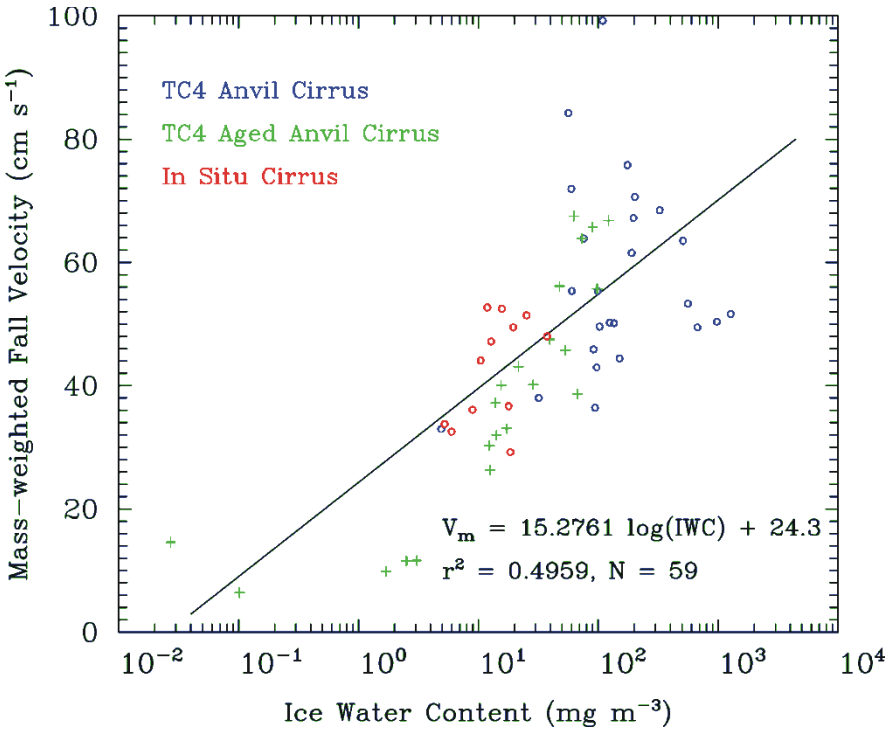


(B)

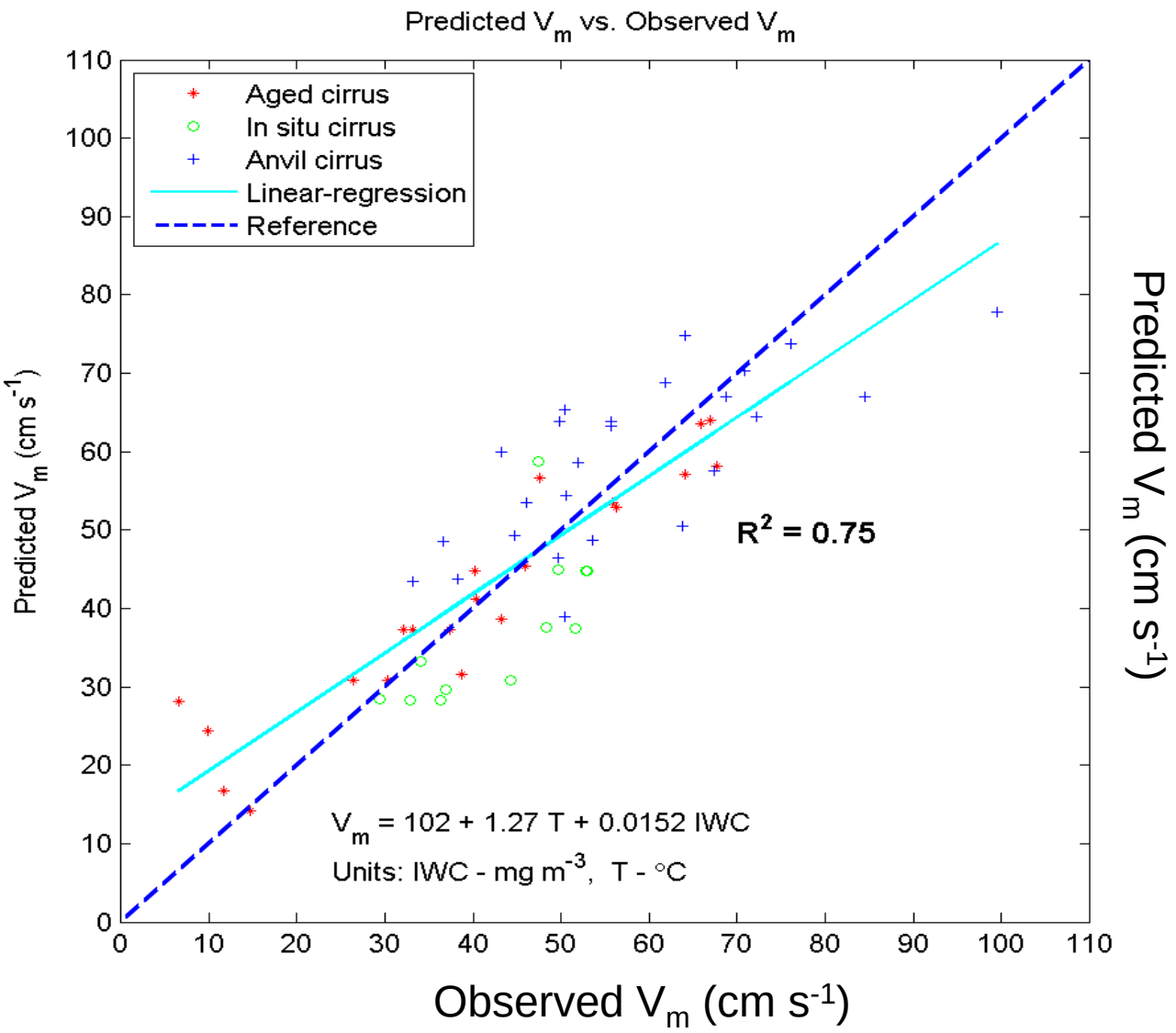
A: Time series of the 2D-S and CVI IWC for a TC4 case study. CVI response time lagged 6 seconds behind 2D-S measurements, producing a slight offset.
B: 2D-S IWCs compared with CVI IWCs for 12,000 1-Hz measurements (averaged over 10-s) in TC4 anvils cirrus.

Mass-weighted fall velocity was related to both temperature and IWC during TC4. Therefore try multiple regression using both T and IWC…

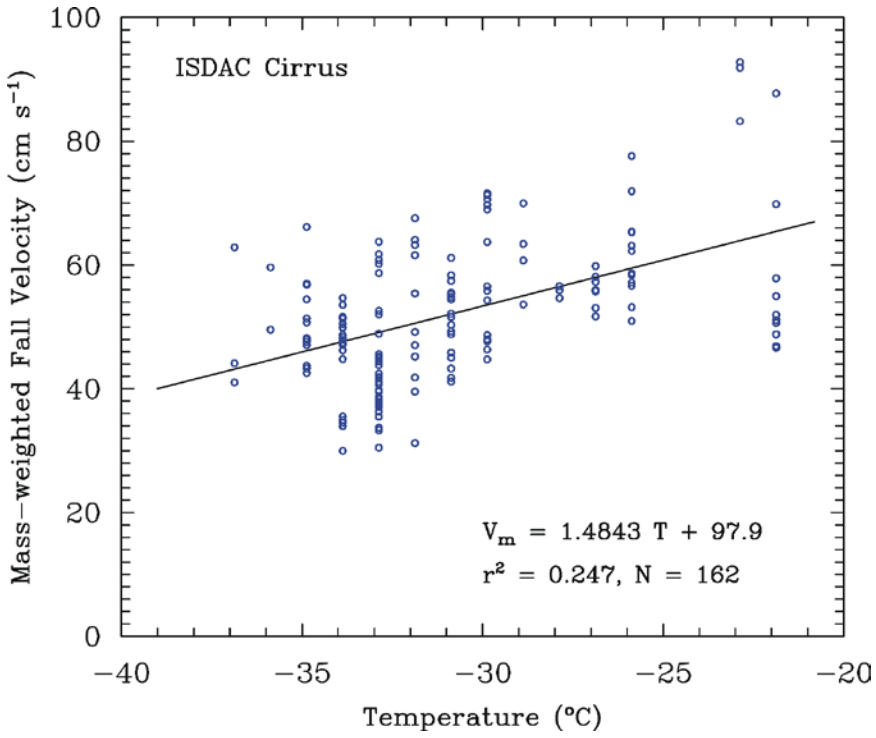


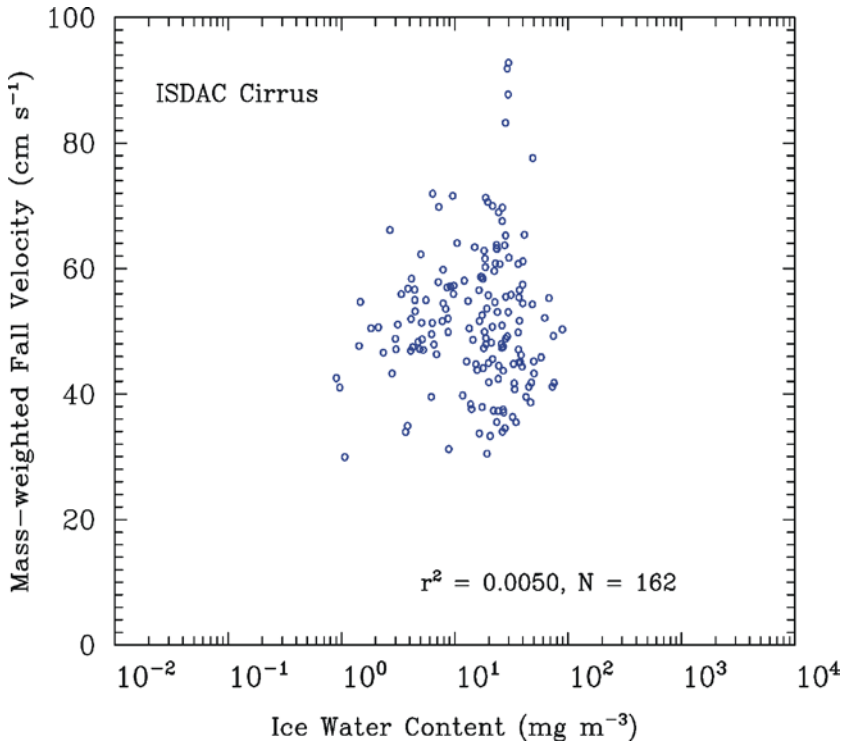


BEST METHOD FOR DIAGNOSING V_m : USE T AND IWC



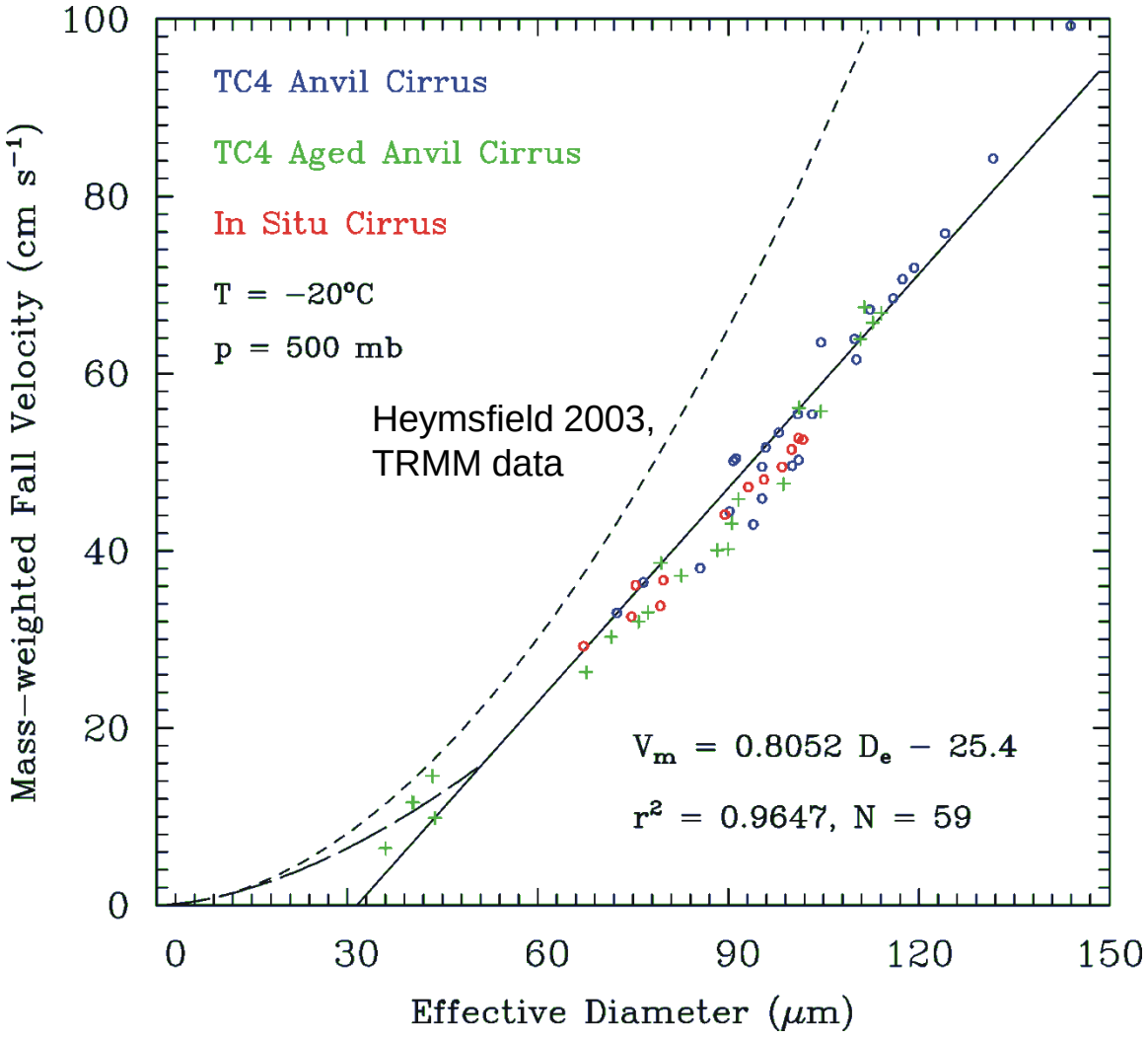
ISDAC FIELD CAMPAIGN





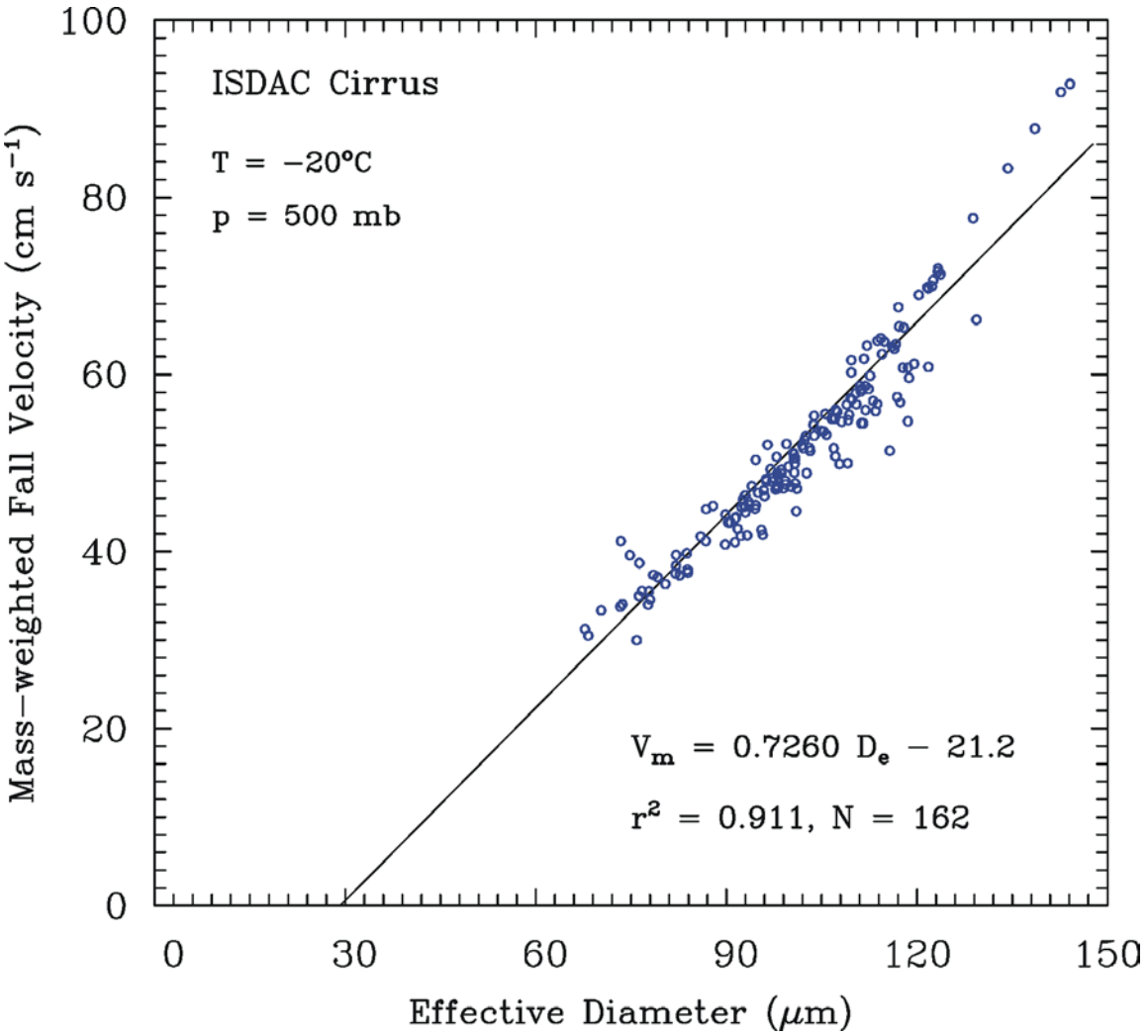
RECOMMENDED METHOD: CALCULATE V_m FROM MICROPHYSICS

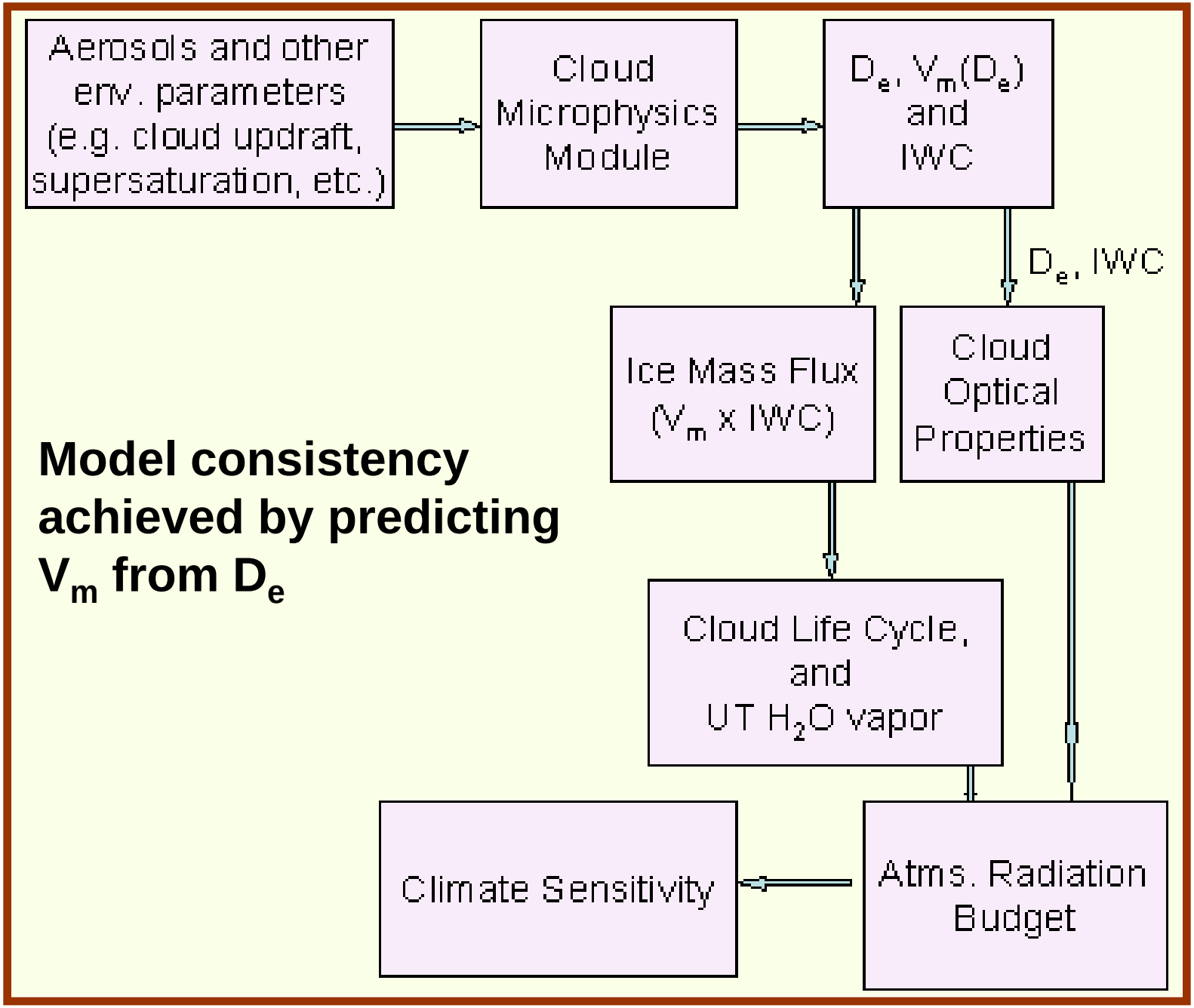
- High correlation since both D_e and V_m are based on ice particle mass/area ratio -



SIMILAR V_m CORRELATION FROM ISDAC FIELD CAMPAIGN

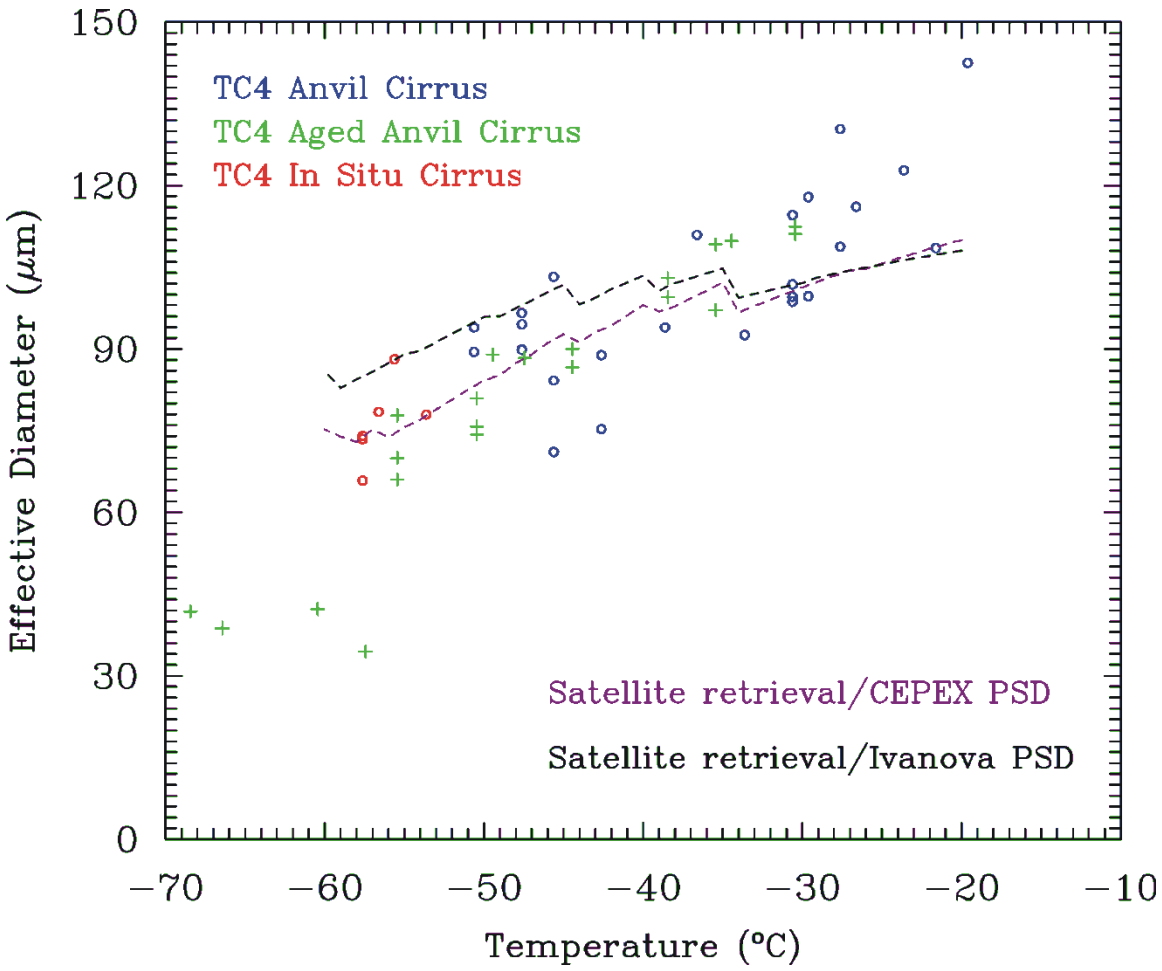
- High correlation since both D_e and V_m are based on ice particle mass/area ratio -

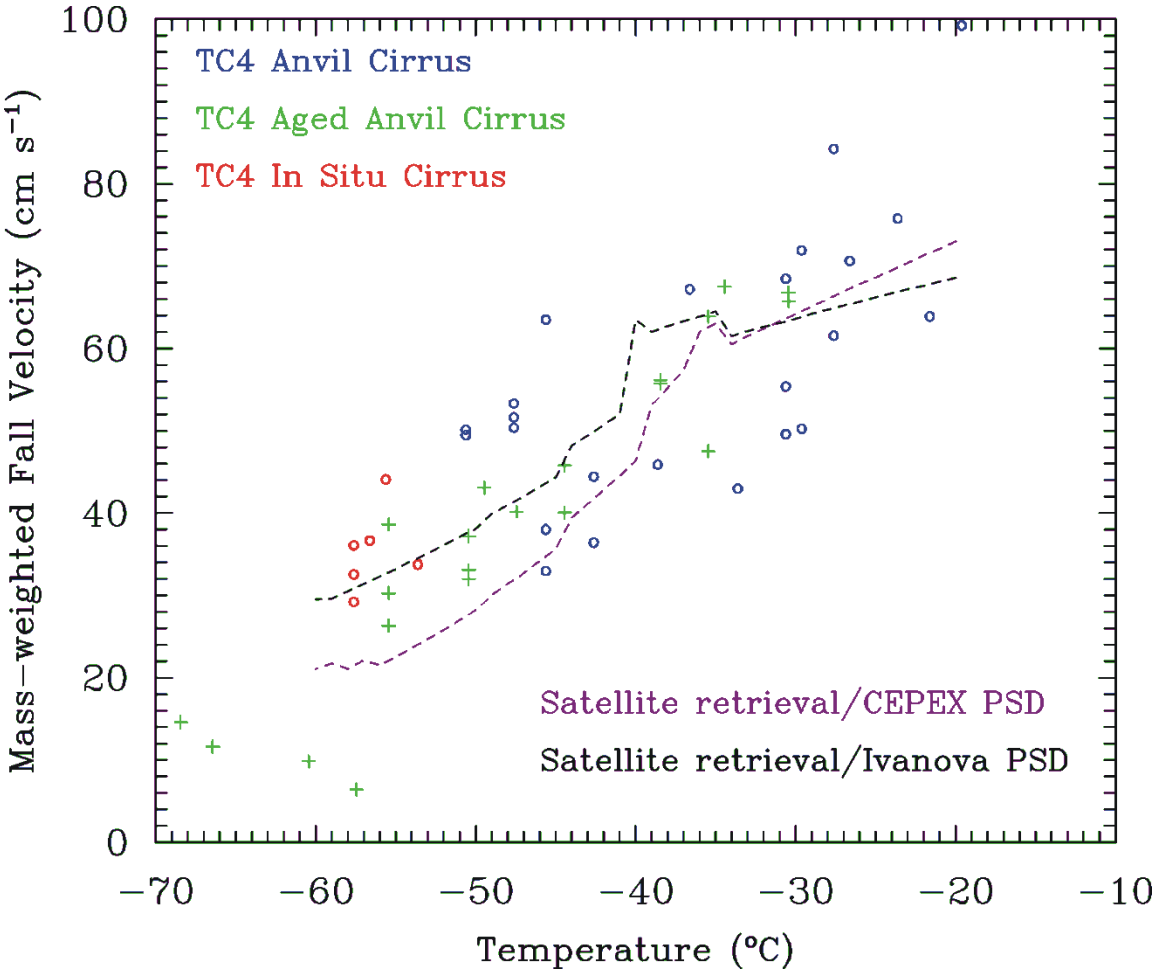




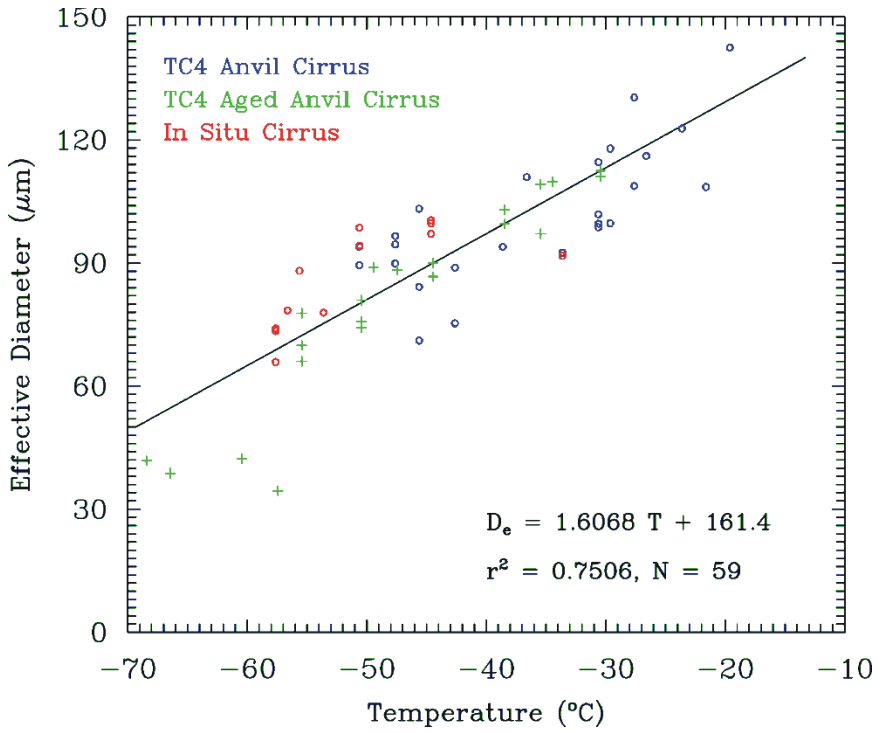
Model consistency achieved by predicting V_m from D_e

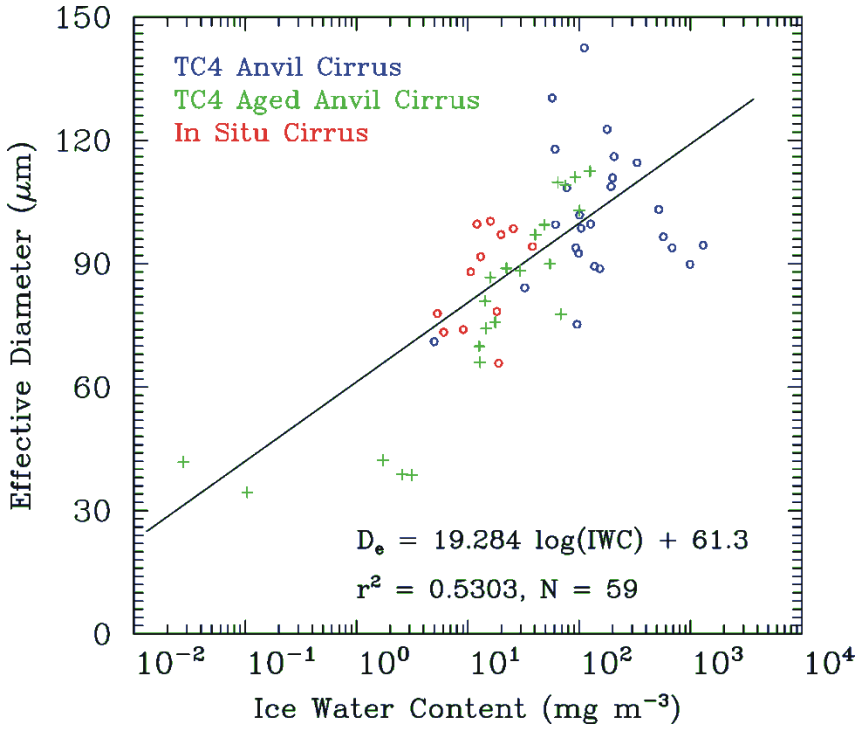
EXTRA SLIDES


TC4 Anvil Cirrus
TC4 Aged Anvil Cirrus
TC4 In Situ Cirrus
Satellite retrieval/CEPEX PSD
Satellite retrieval/Ivanova PSD
Effective Diameter (μm)
Temperature (°C)
150
120
90
60
30
0
−70
−60
−50
−40
−30
−20
−10

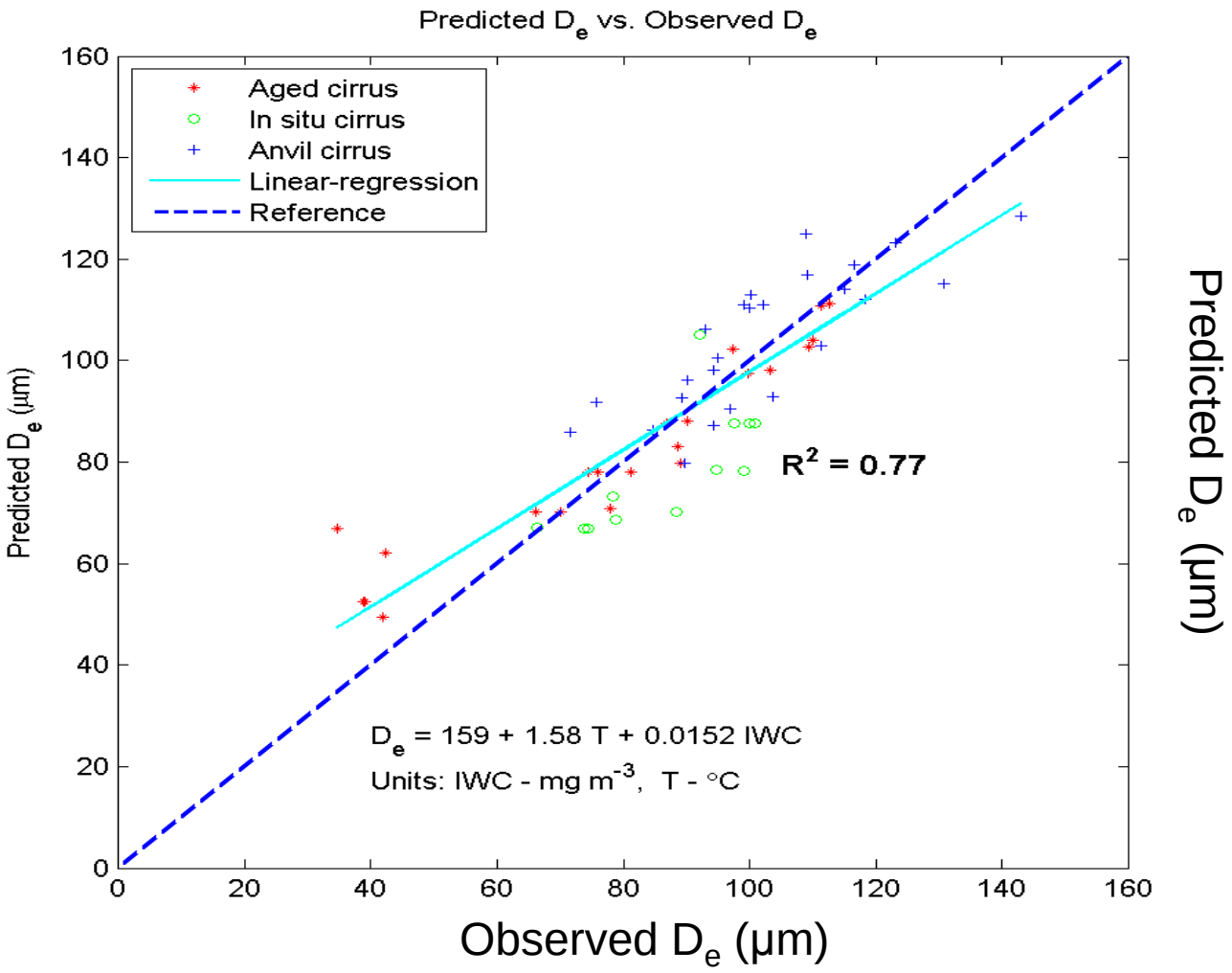

TC4 Anvil Cirrus
TC4 Aged Anvil Cirrus
TC4 In Situ Cirrus
Satellite retrieval/CEPEX PSD
Satellite retrieval/Ivanova PSD
Mass−weighted Fall Velocity (cm s−1)
Temperature (°C)
100
80
60
40
20
0
−70
−60
−50
−40
−30
−20
−10

Effective diameter was related to both temperature and IWC during TC4. Therefore try multiple regression using both T and IWC…



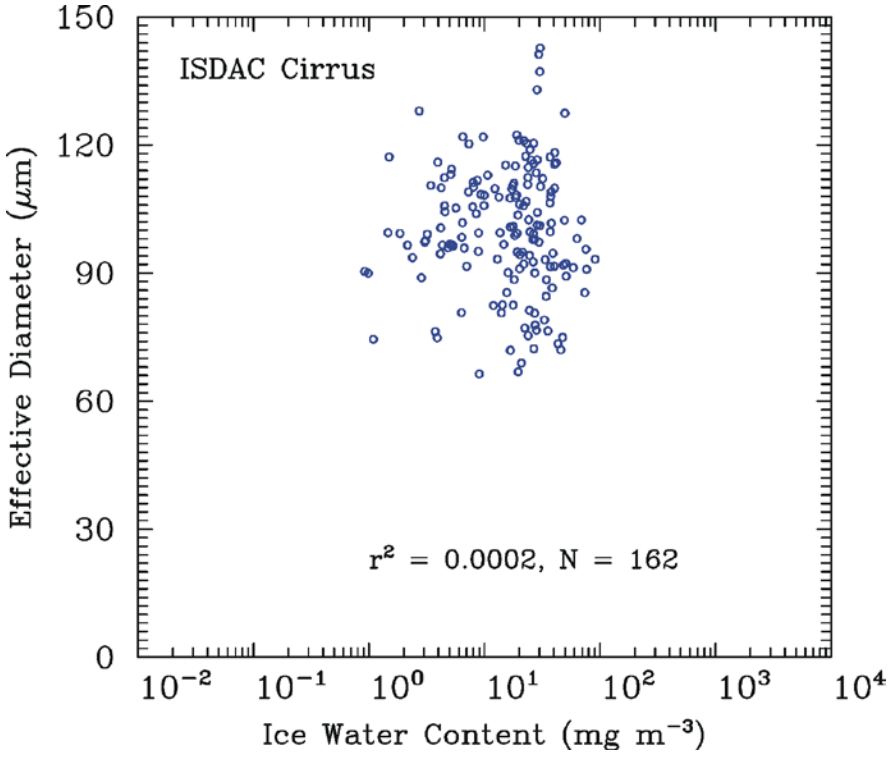


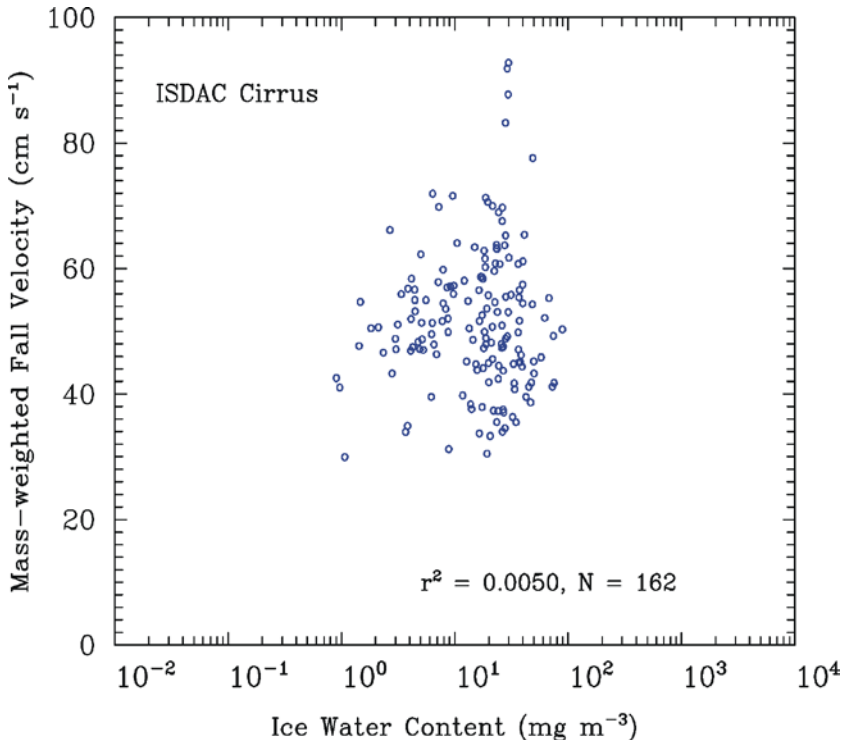
Best method for diagnosing D_e : Use T and IWC



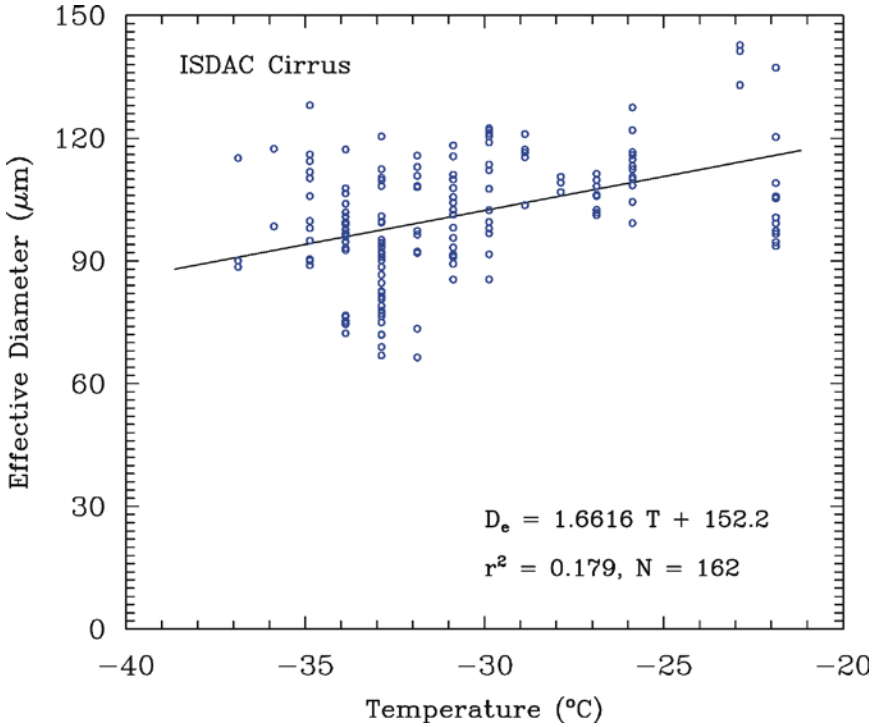
ISDAC FIELD CAMPAIGN

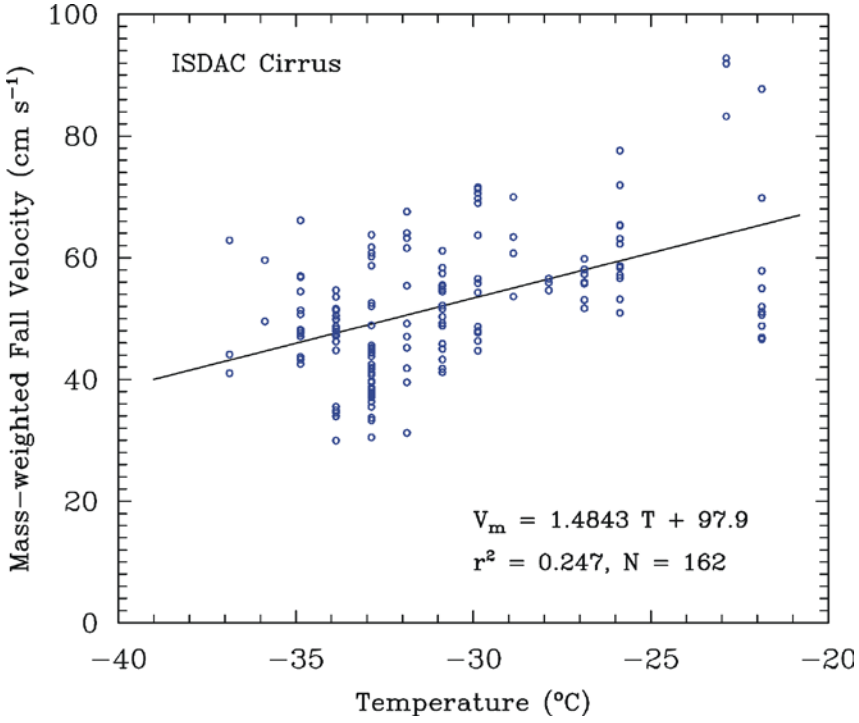
No correlation for D_e-IWC or V_m-IWC





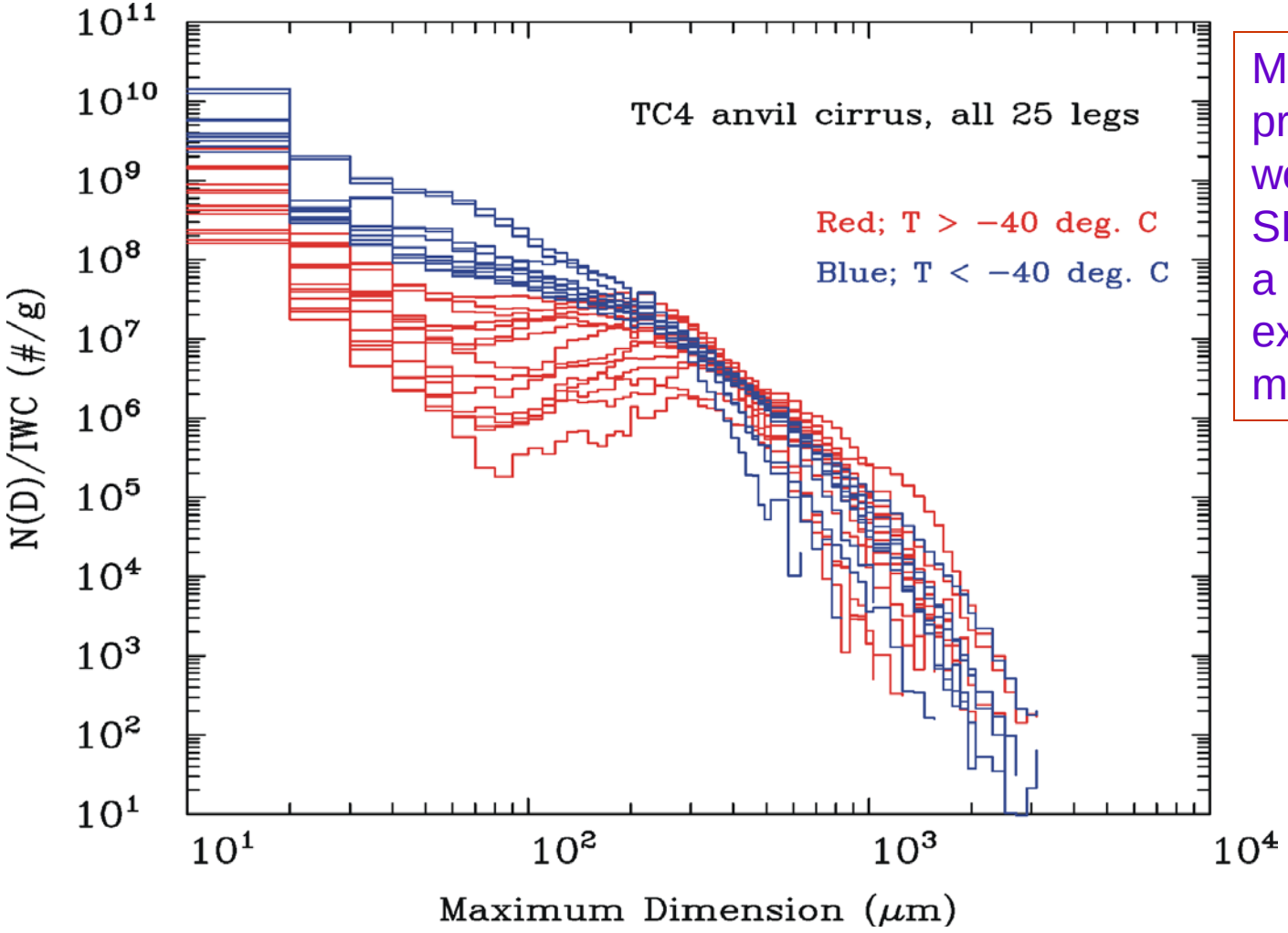
Crude diagnostics for D_e and V_m





TC4 PSD Differences for T < -40 ºC vs. T > -40 ºC

Leg-averaged PSD for anvil cirrus measured during TC4, normalized by their IWC. PSD for T < -40 C are monomodal due to higher concentrations of small crystals. For T > -40 C, these concentrations are lower and PSD are bimodal. Responsible mechanisms could be homogeneous freezing nucleation or “size sorting”.



Mitchell ASR project/SPartICus work plan: Analyze SPartICus data in a similar way to explore potential mechanisms.