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

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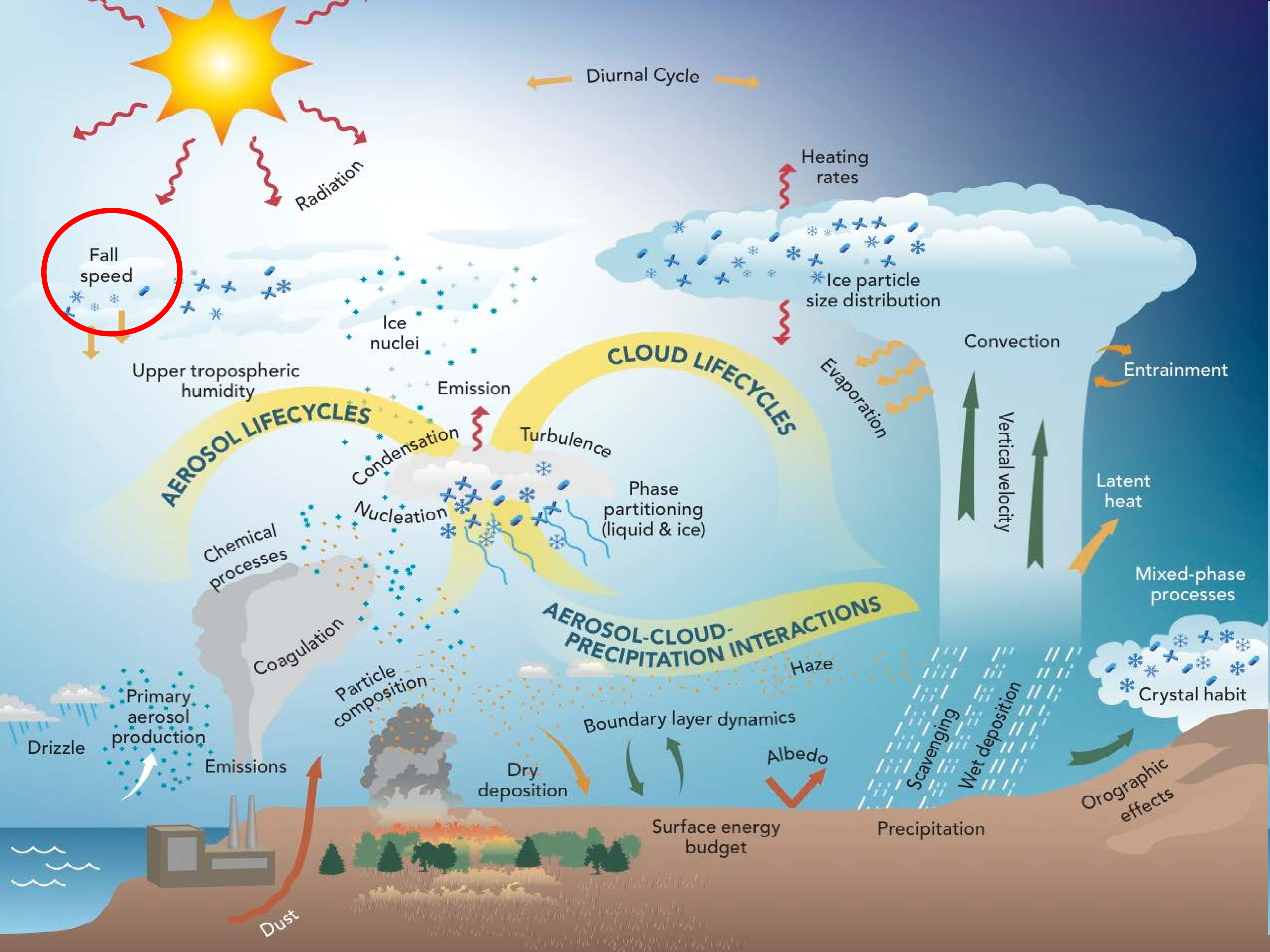
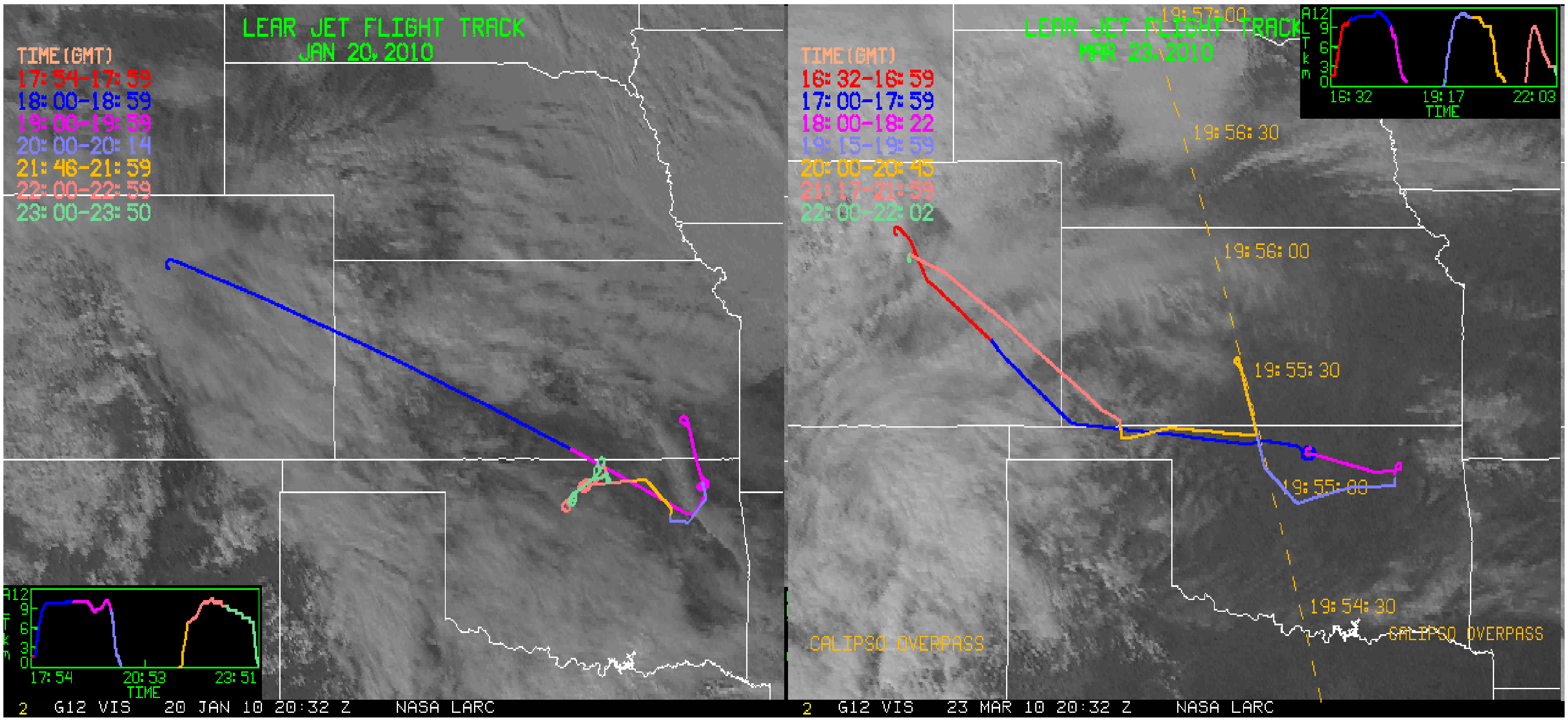
Motivation

- Global Climate Models (GCMs) are highly sensitive to the representation of clouds and their feedbacks. According to a study by Sanderson et al. (2008), the ice fall velocity (V_i) is the second most important factor affecting the climate sensitivity in GCMs.



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

Satellite Images Help Determine Cloud Type (Anvil/Synoptic Cirrus)



Source: P. Minnis (NASA Langley)

http://www-angler.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=ARM-SPARTICUS

General Approach

- 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
- This study uses 2D-S data from SPARTICUS, a recent field campaign sampling mid-latitude cirrus. The treatment of D_e (effective diameter) is general for liquid, mixed phase and ice clouds and is expressed as:

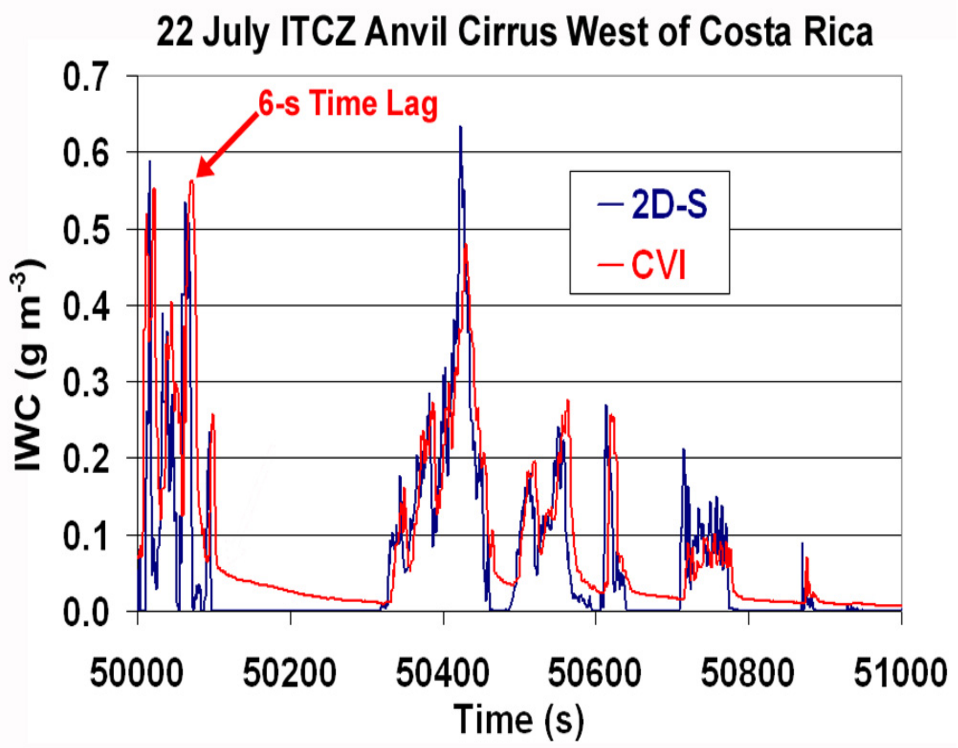
$$D_e = 3/2(IWC/\rho_i A_t)$$

- V_i (ice particle fall speed) is calculated by using two different methods, namely the Mitchell-Heymsfield (2005) method (MH) and the Heymsfield-Westbrook (2010) method (HW).
- Applying the above methods to the 2DS measurements, D_e and V_m (the PSD mass weighted fall-speed) were expressed as:

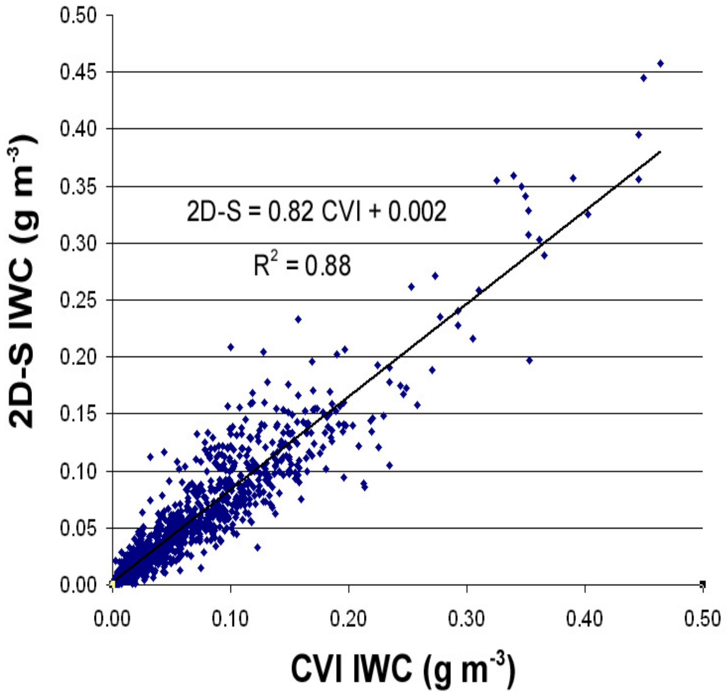
$$V_m = \Sigma\, V_i(D)\, m(D)\, N(D)\, \Delta D \,/\, \Sigma\, m(D)\, N(D)\, \Delta D$$

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

COMPARISON OF 2D-S AND CVI IWCs DURING TC4



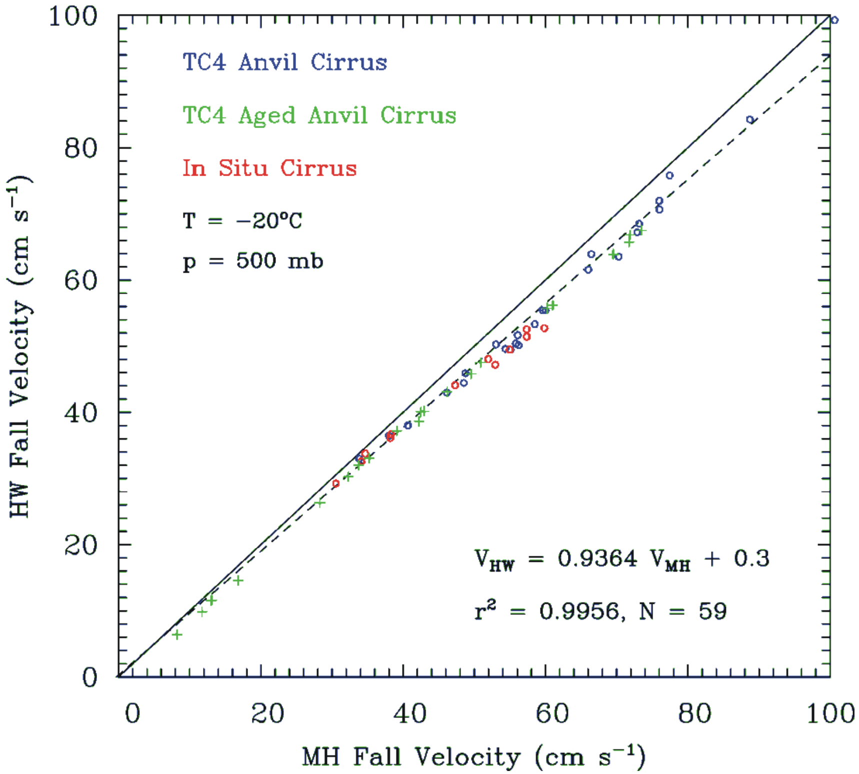
(A)

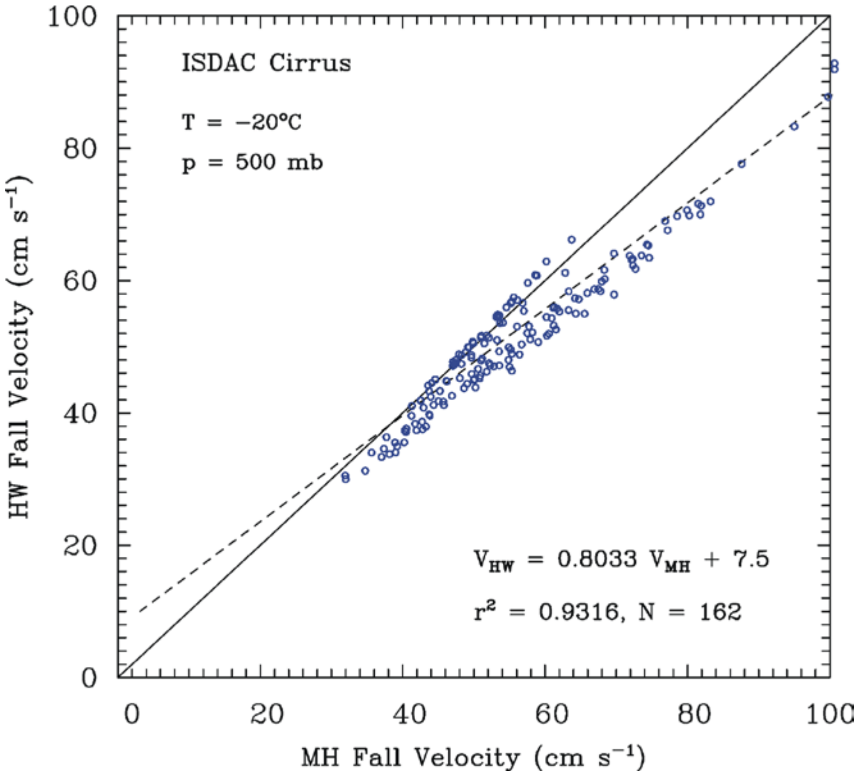


(B)

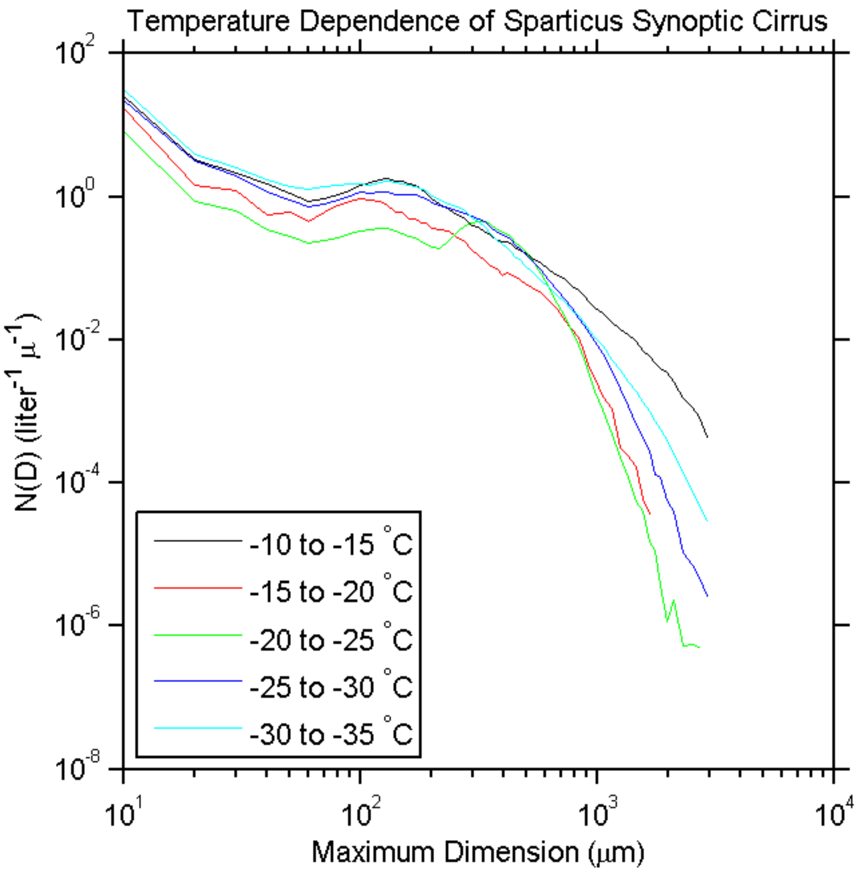
A: Time series of the 2D-S and CVI IWC for a TC4 case study. CVI response time lagged 6 seconds behind 2D-S measurements, producing a slight offset. B: 2D-S IWCs compared with CVI IWCs for 12,000 1-Hz measurements (averaged over 10-s) in TC4 anvils cirrus.

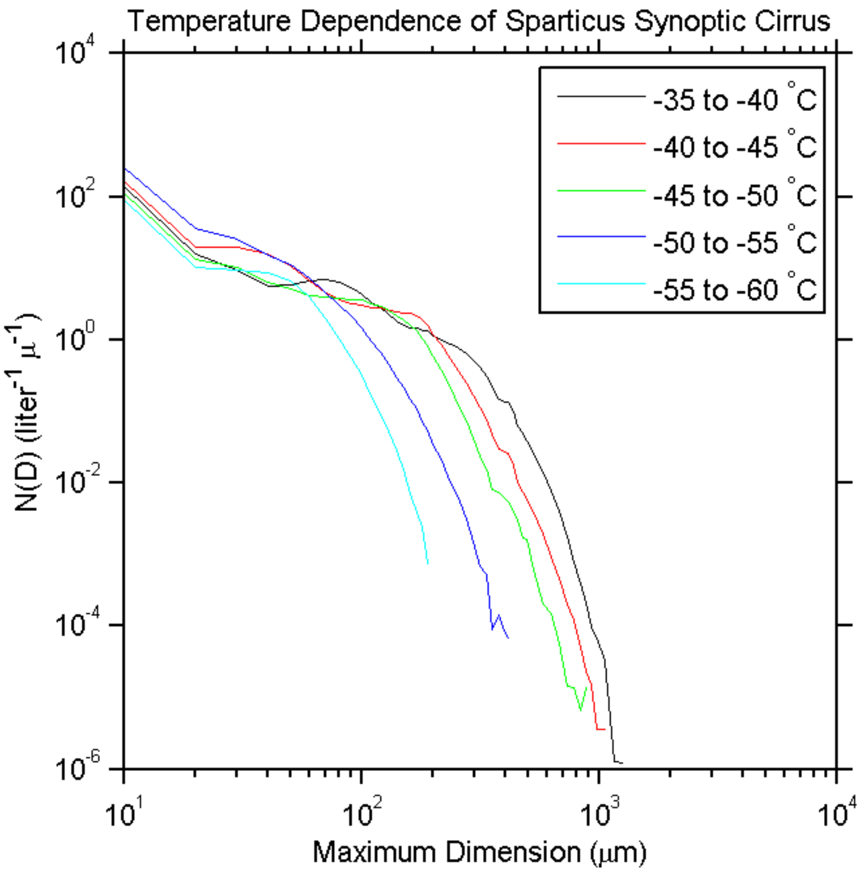
Comparison Between MH(2005) and HW(2010) schemes

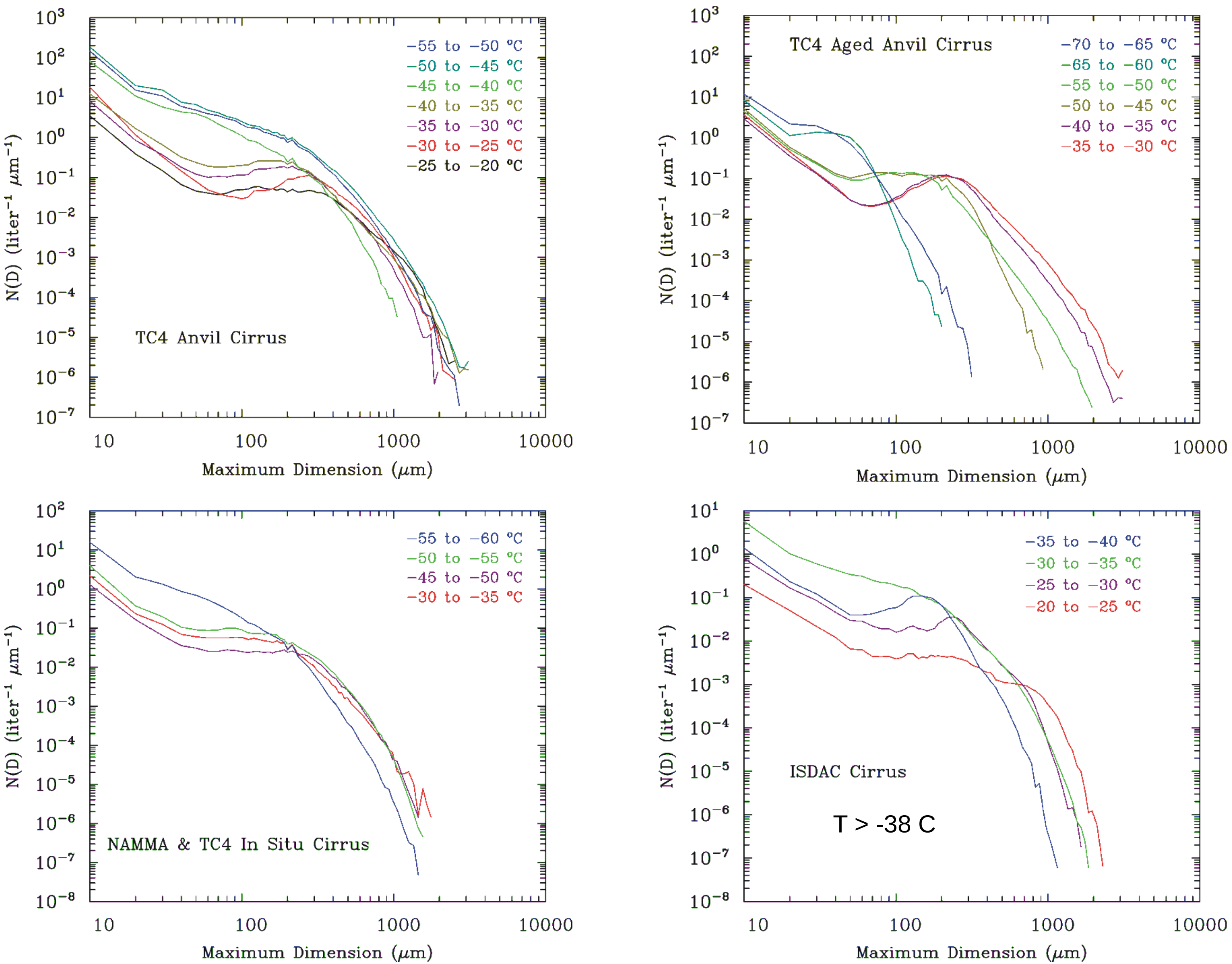




SPARTICUS Synoptic Cirrus PSDs from 2DS

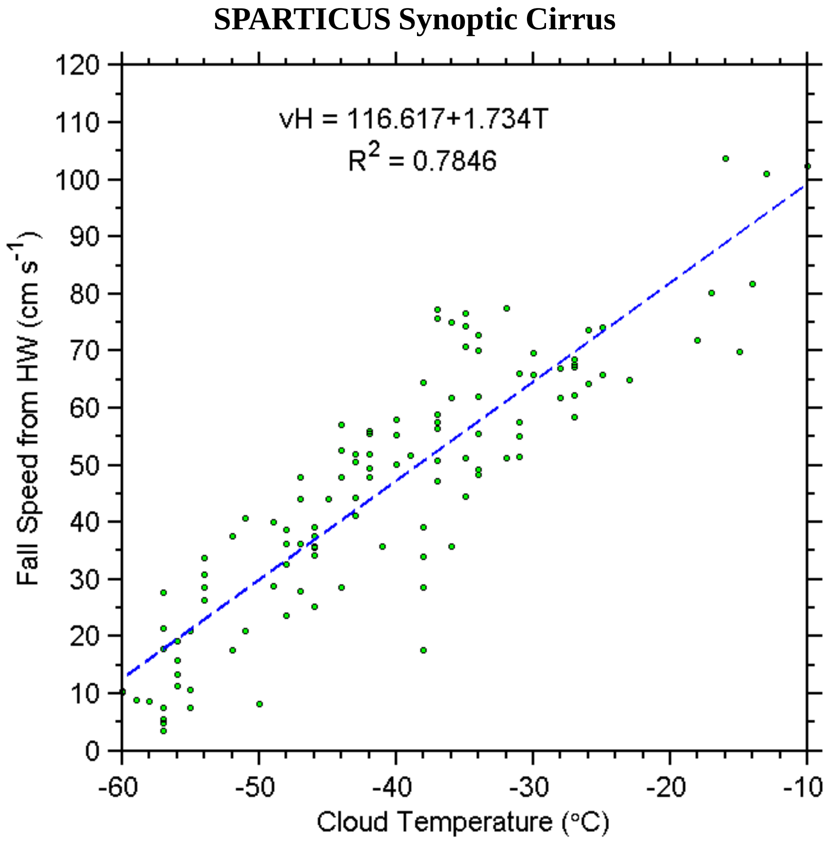


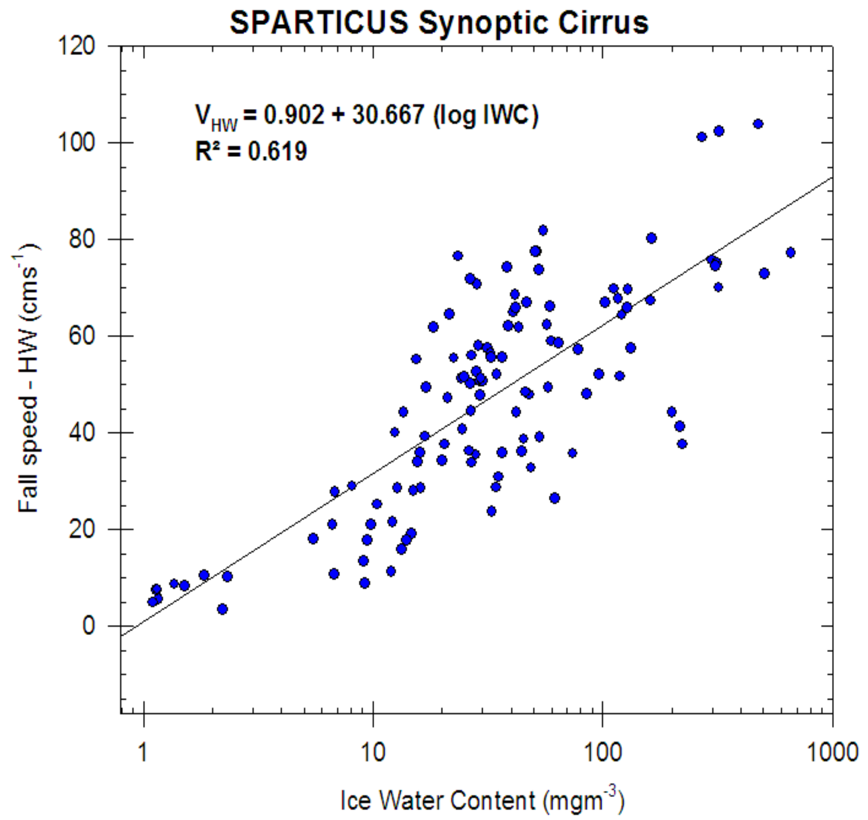




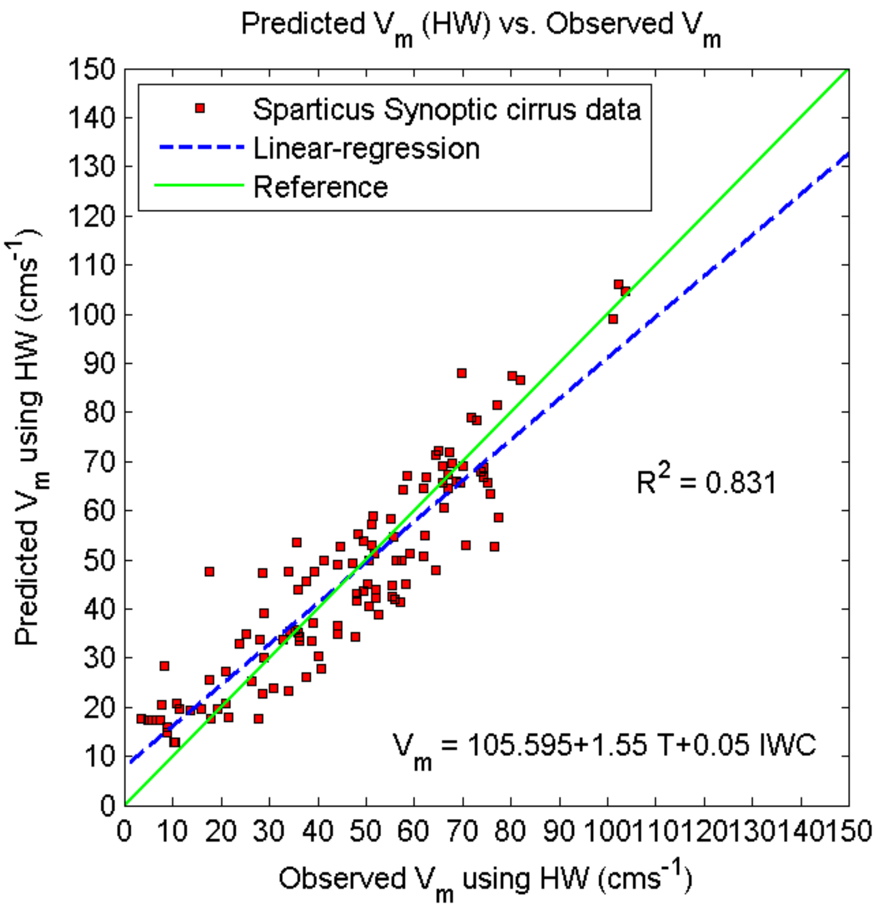
TC4 Anvil Cirrus
−55 to −50 °C
−50 to −45 °C
−45 to −40 °C
−40 to −35 °C
−35 to −30 °C
−30 to −25 °C
−25 to −20 °C
N(D) (liter⁻¹ μm⁻¹)
Maximum Dimension (μm)
10
100
1000
10000
TC4 Aged Anvil Cirrus
−70 to −65 °C
−65 to −60 °C
−55 to −50 °C
−50 to −45 °C
−40 to −35 °C
−35 to −30 °C
N(D) (liter⁻¹ μm⁻¹)
Maximum Dimension (μm)
NAMMA & TC4 In Situ Cirrus
−55 to −60 °C
−50 to −55 °C
−45 to −50 °C
−30 to −35 °C
N(D) (liter⁻¹ μm⁻¹)
Maximum Dimension (μm)
ISDAC Cirrus
T > -38 C
−35 to −40 °C
−30 to −35 °C
−25 to −30 °C
−20 to −25 °C
N(D) (liter⁻¹ μm⁻¹)
Maximum Dimension (μm)

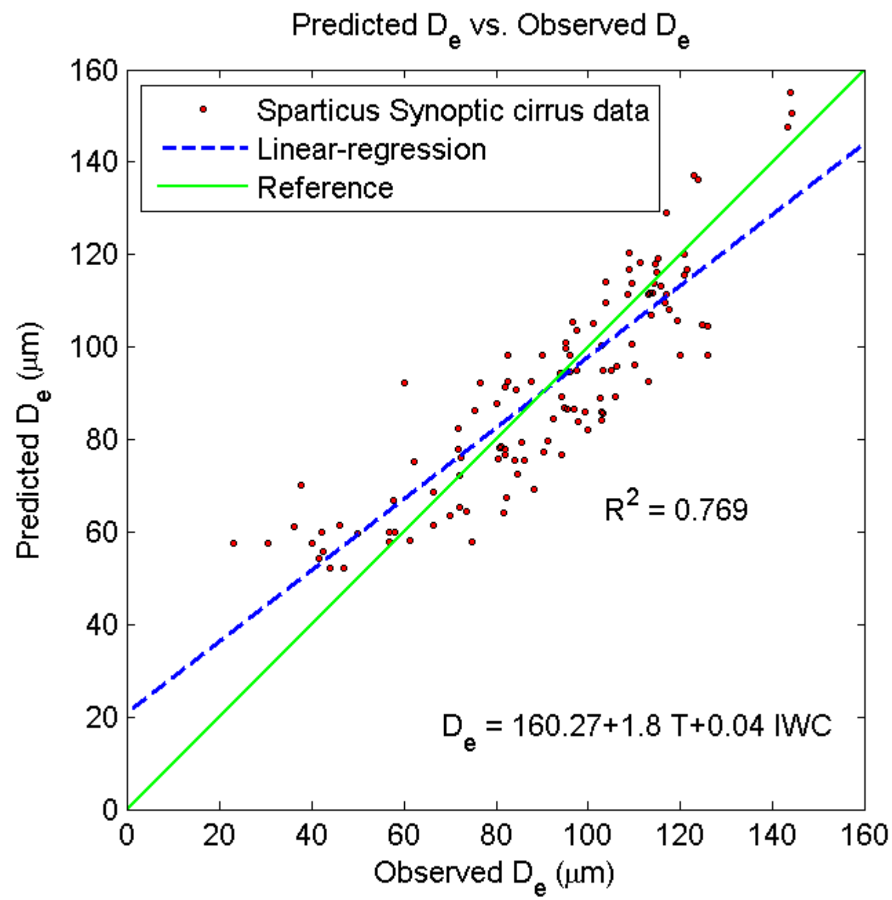
SPARTICUS SYNOPTIC CIRRUS: V_m vs. T and V_m vs. IWC



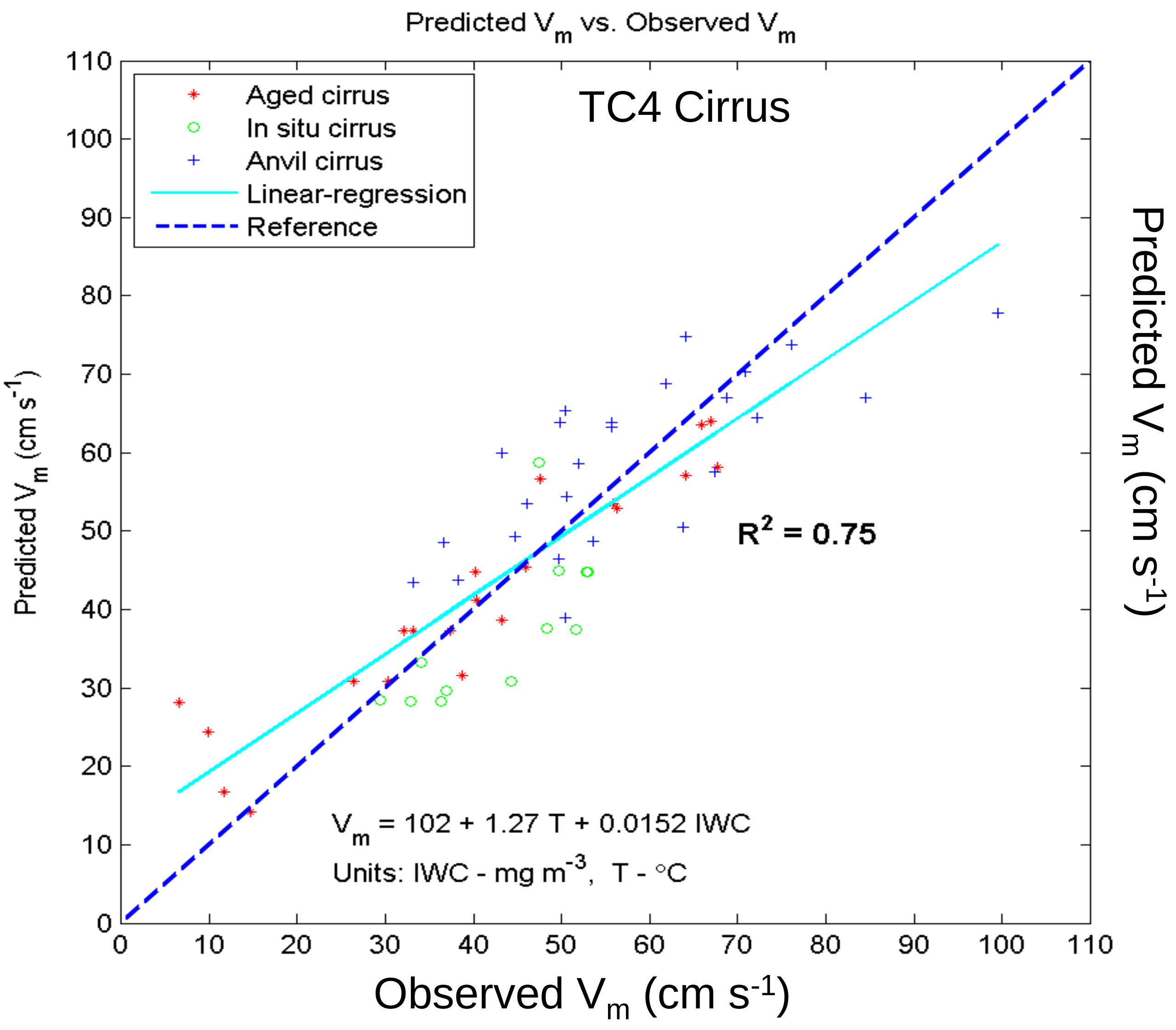


SPARTICUS V_m and D_e Related To IWC & T



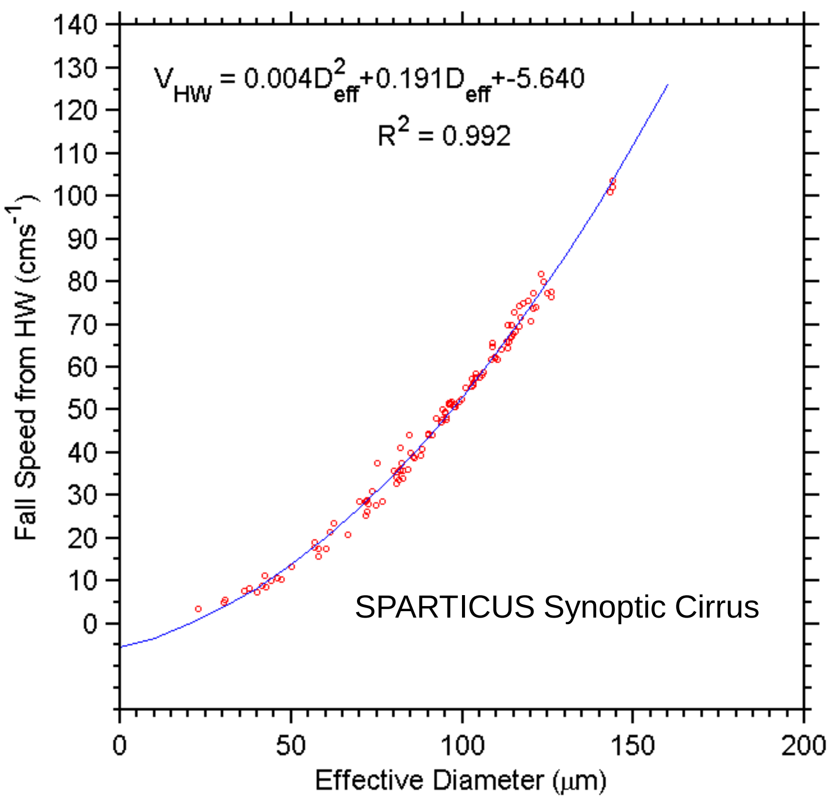


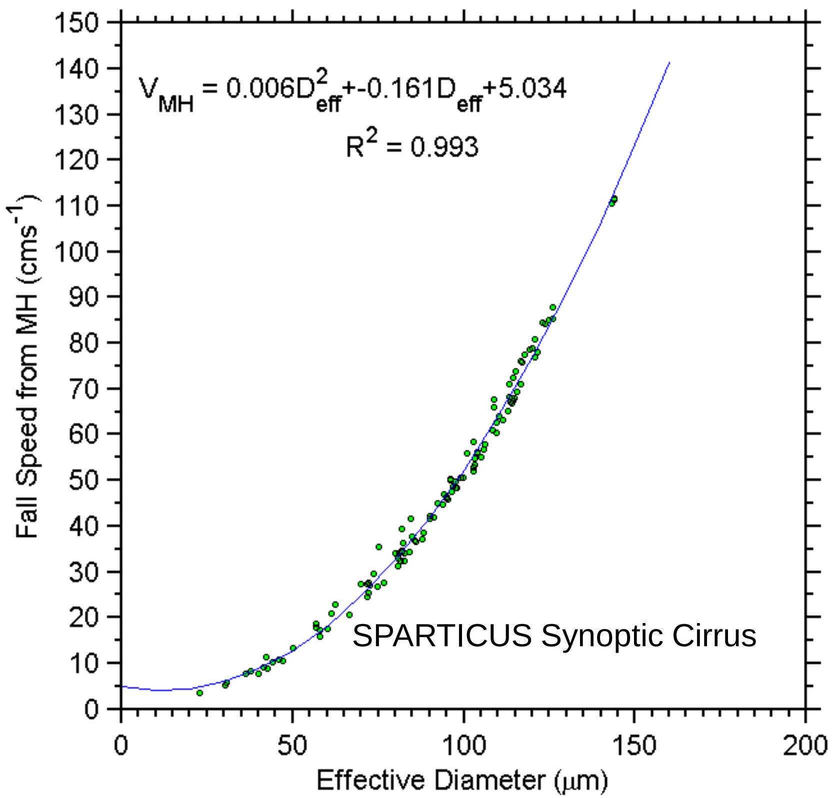
TC4 V_m Related To IWC & T



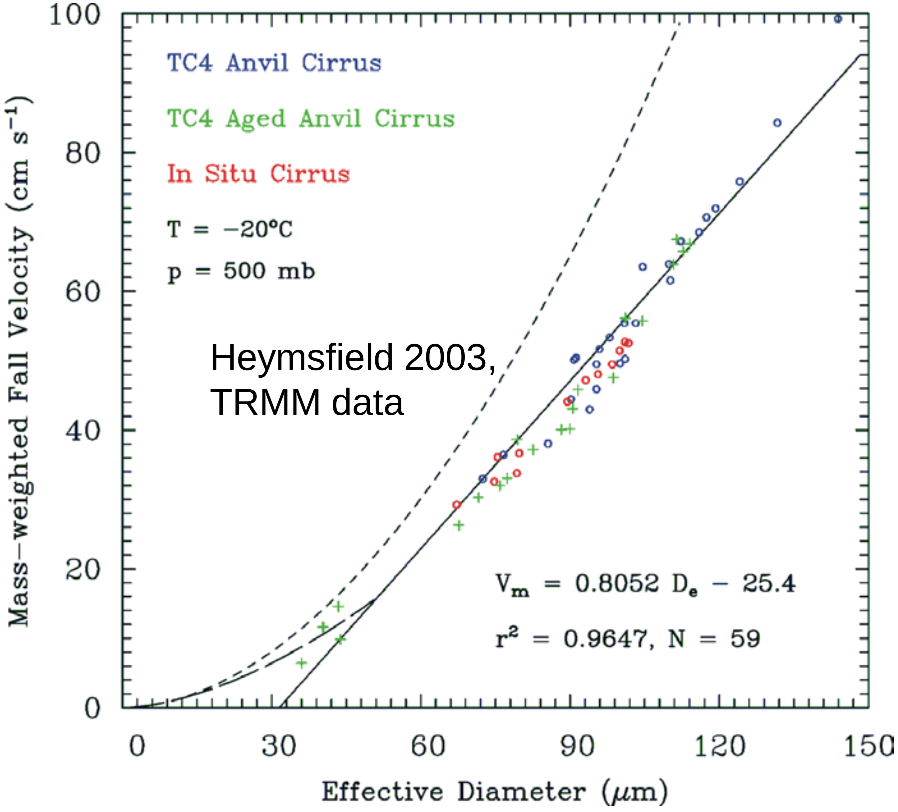
SPARTICUS Fall Speed Related To D_e Using:

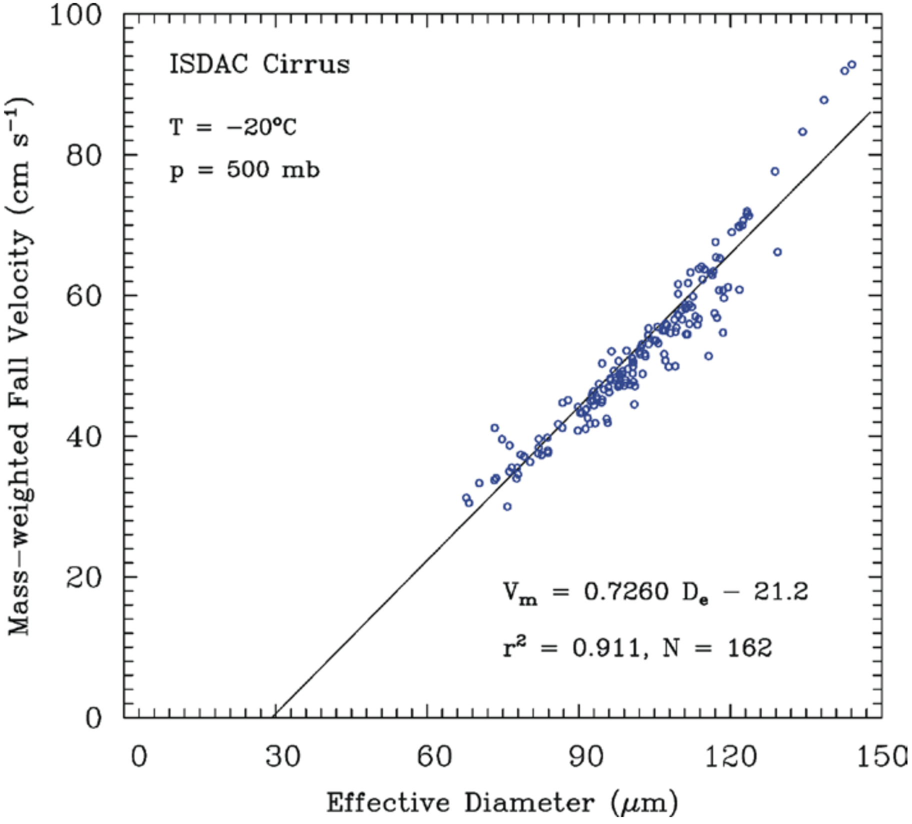
Mitchell Heymsfield (2005) & Heymsfield Westbrook (2010)

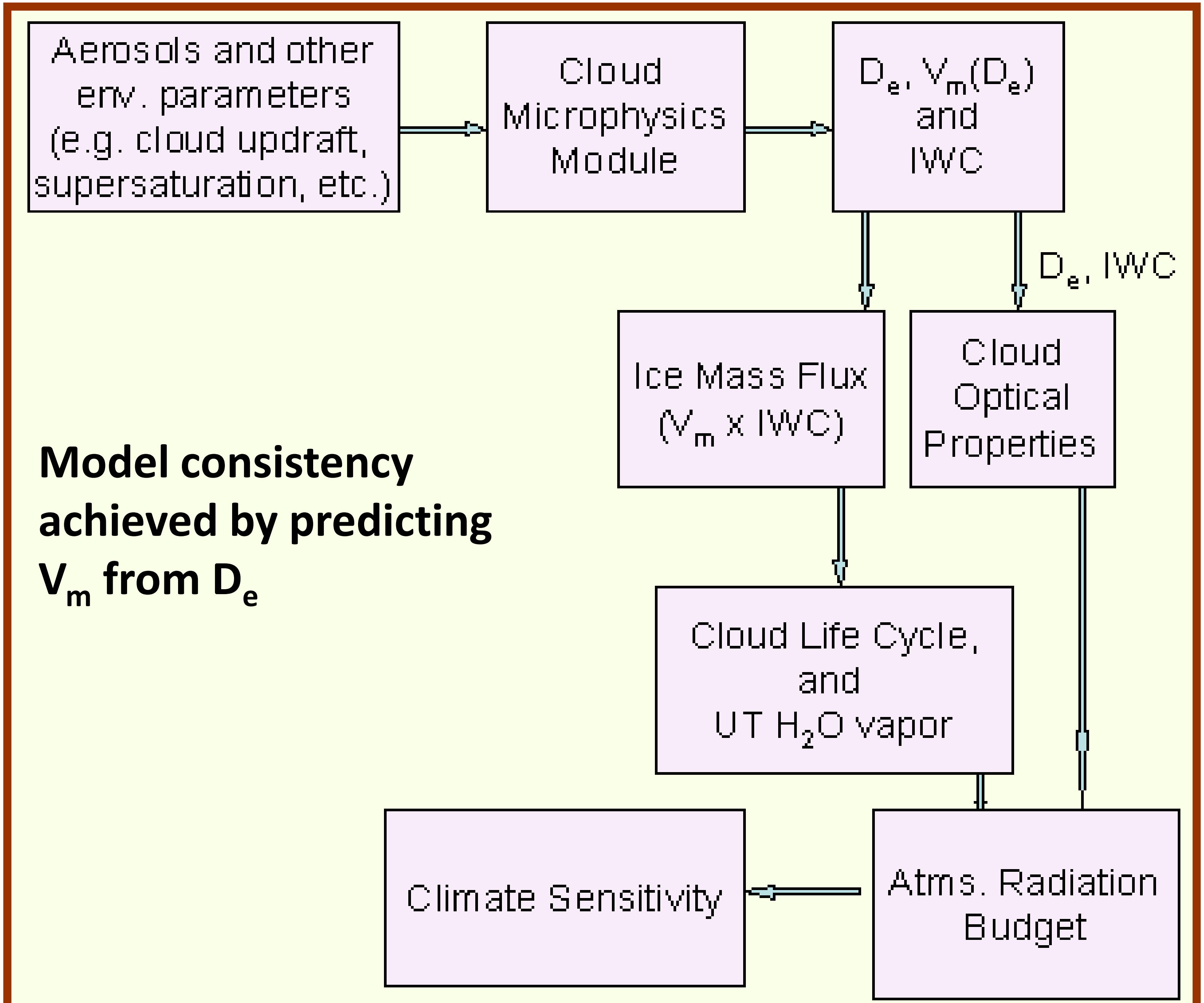




TC4 and ISDAC Fall-speed Related to D_e






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
Model consistency achieved by predicting V_m from D_e
Cloud Life Cycle, and UT H_2O vapor
Climate Sensitivity
Atms. Radiation Budget