Bridging Ice Particle Observations and Model Representations: Scattering and Integral Tables

Christopher R. Williams

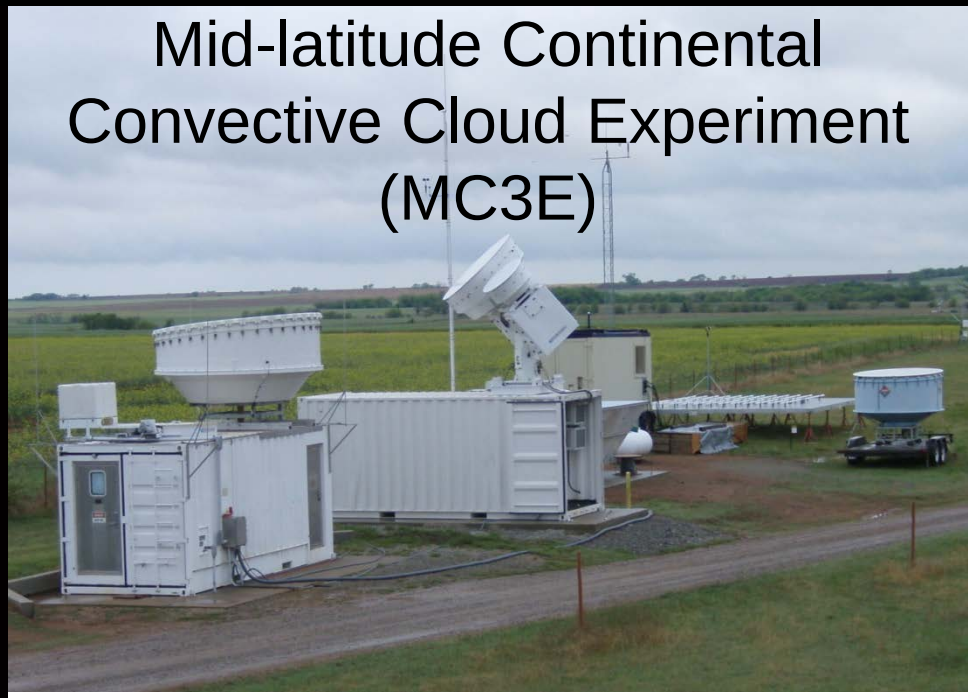
Cooperative Institute for Research in Environmental Sciences (CIRES)

Steve Nesbitt

Atmospheric Sciences

University of Illinois at Urbana-Champaign

University of Colorado Boulder



Support for this work:
DOE ASR Grant: DE-SC0007080
NASA PMM Grant: NNX13AF89G

CIRES

Bridging Observations & Algorithms

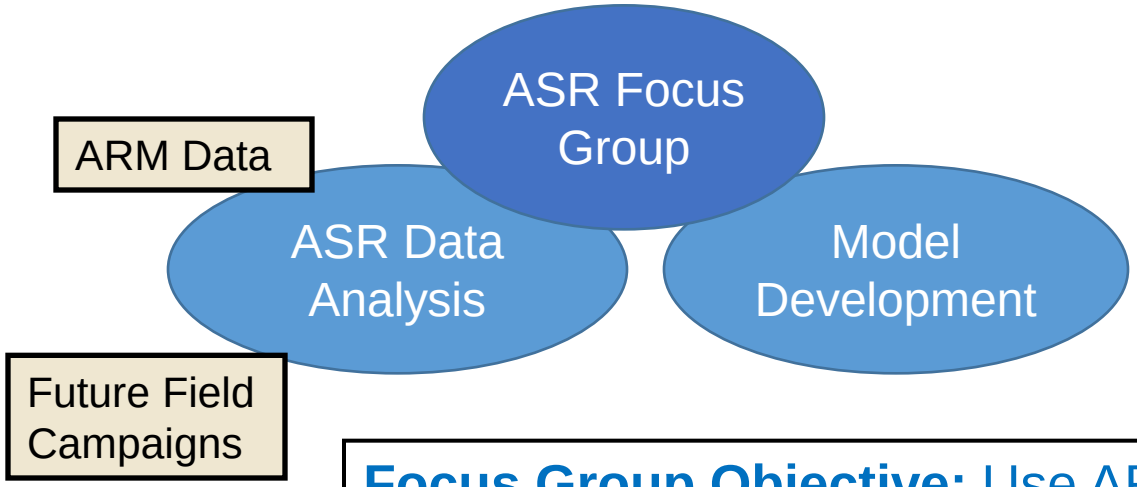
NASA Global Precipitation Mission (GPM) DSD Working Group: Bridging Ground Validation (GV) and Algorithms

DSD WG General Objective: Use Ground Validation (GV) data to support, or justify, assumptions used in satellite retrieval algorithms.

Bridging Observations & Models

NASA Global Precipitation Mission (GPM) DSD Working Group:

Bridging ARM Data and Models

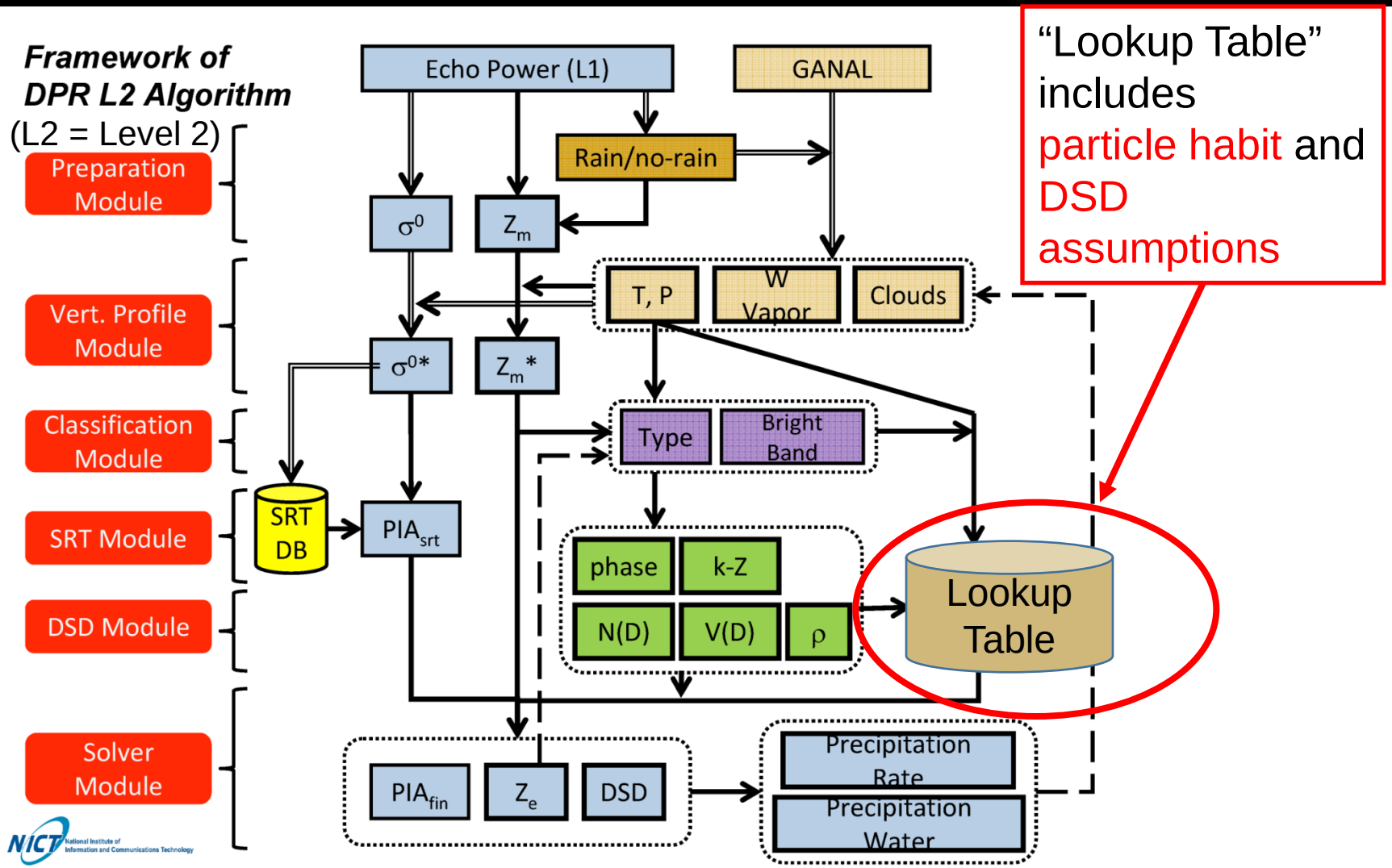


Focus Group Objective: Use ARM Data to support, or justify, assumptions (aka parameterizations) used in models.

Example of using Data to investigate assumptions:

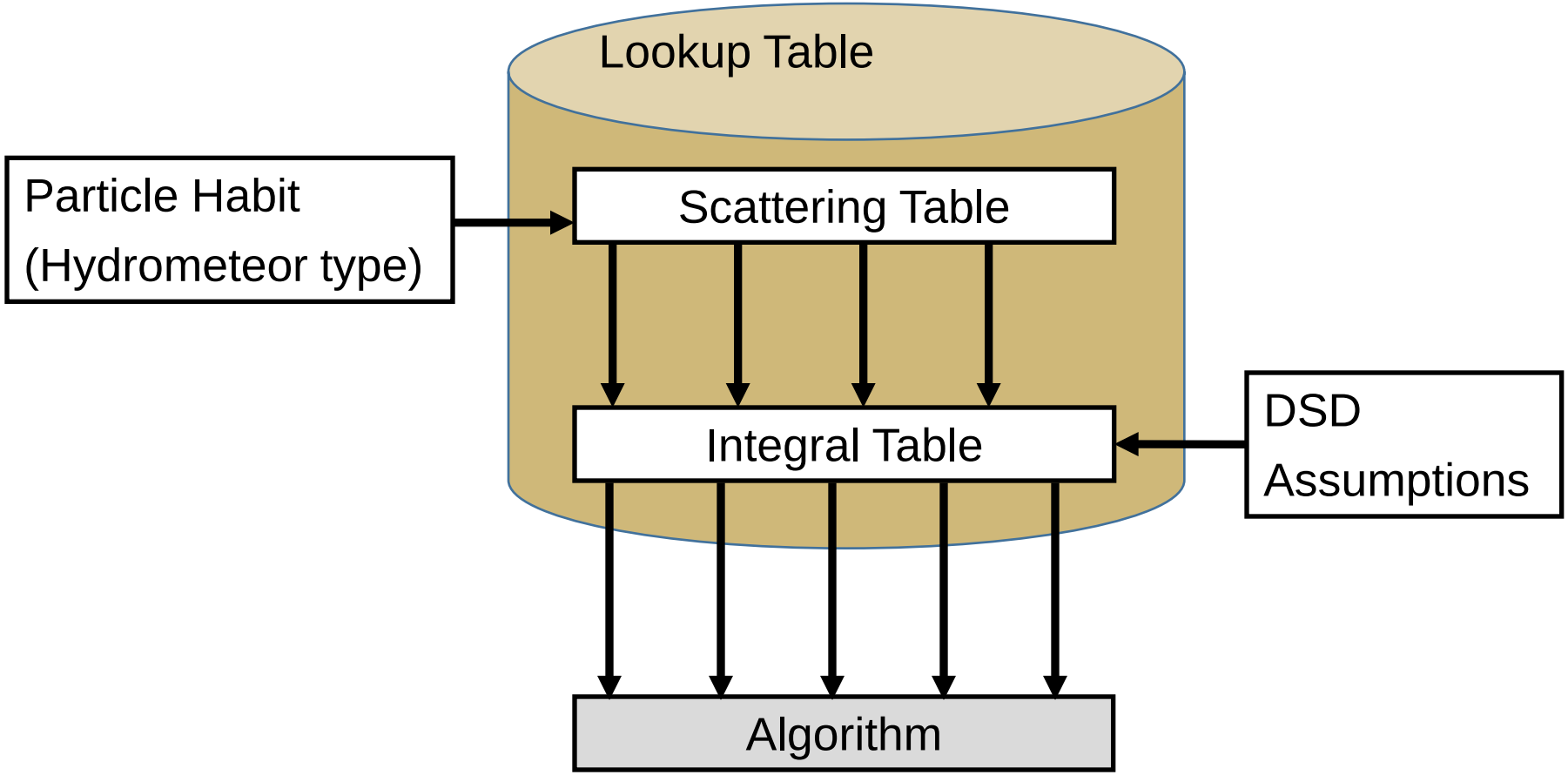
1. Monday (MC3E/Meso) - Relationships between DSD attributes.
2. Tuesday (ICEPROP) - Framework incorporating findings into Algorithms.

Getting GV findings into Algorithms



From: Toshio Iguchi (NITC) and Shinta Seto (Univ. of Tokyo)

Details of Lookup Table



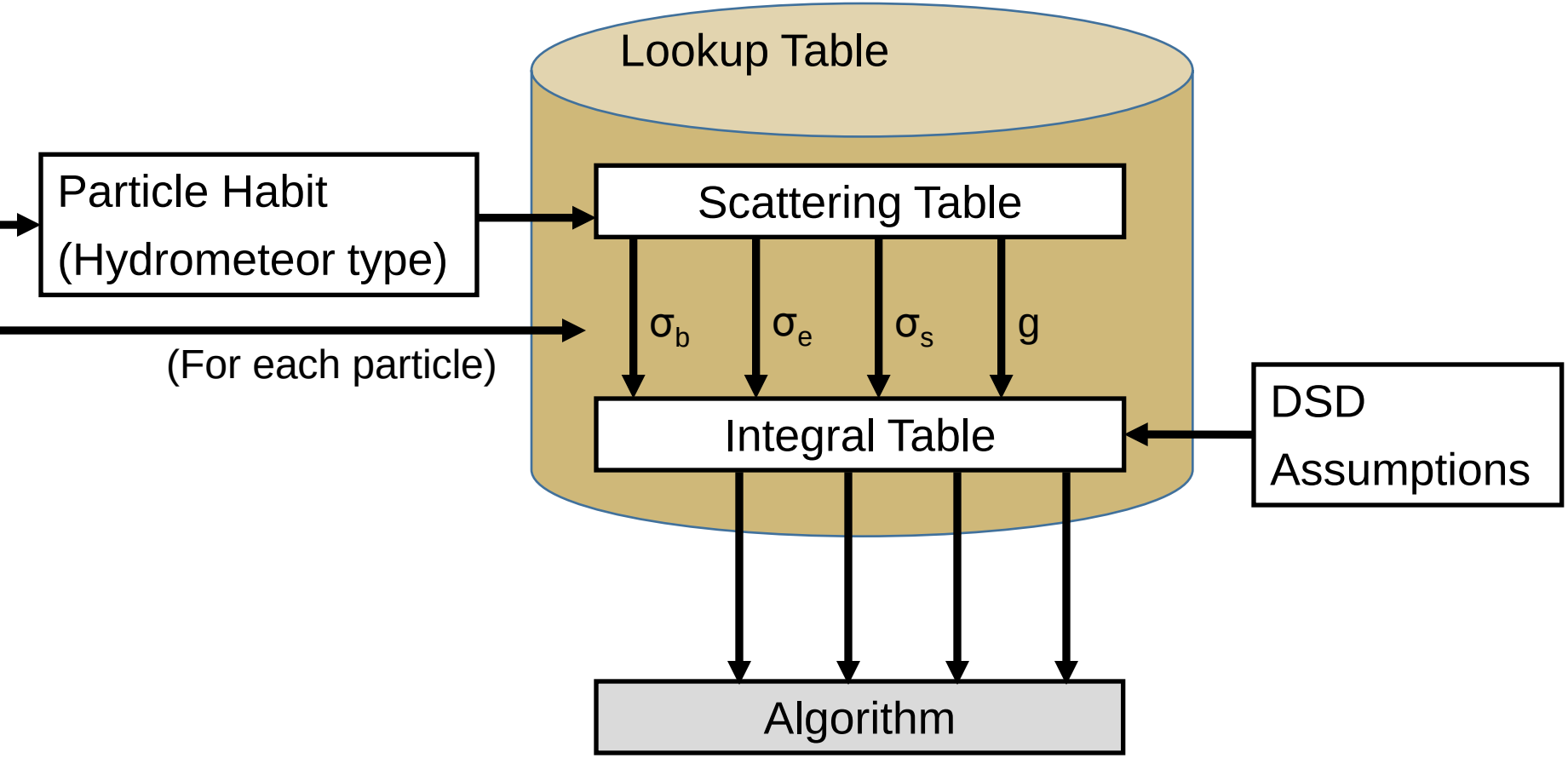
Scattering Tables

Scattering Tables

- Research: Electromagnetic Scattering
  - Interaction of electromagnetic waves with individual particles
- Vocabulary
  - Mie scattering
  - T-matrix
  - Incidence angle
  - Operating frequency
  - a/b relationship
  - Volume/mass relationship
  - Density
- Table Outputs
  - Backscattering cross section, σ_b
  - Extinction cross section , σ_e
  - Scattering cross section, σ_s
  - Asymmetry factor, g

For each particle

Details of Lookup Table



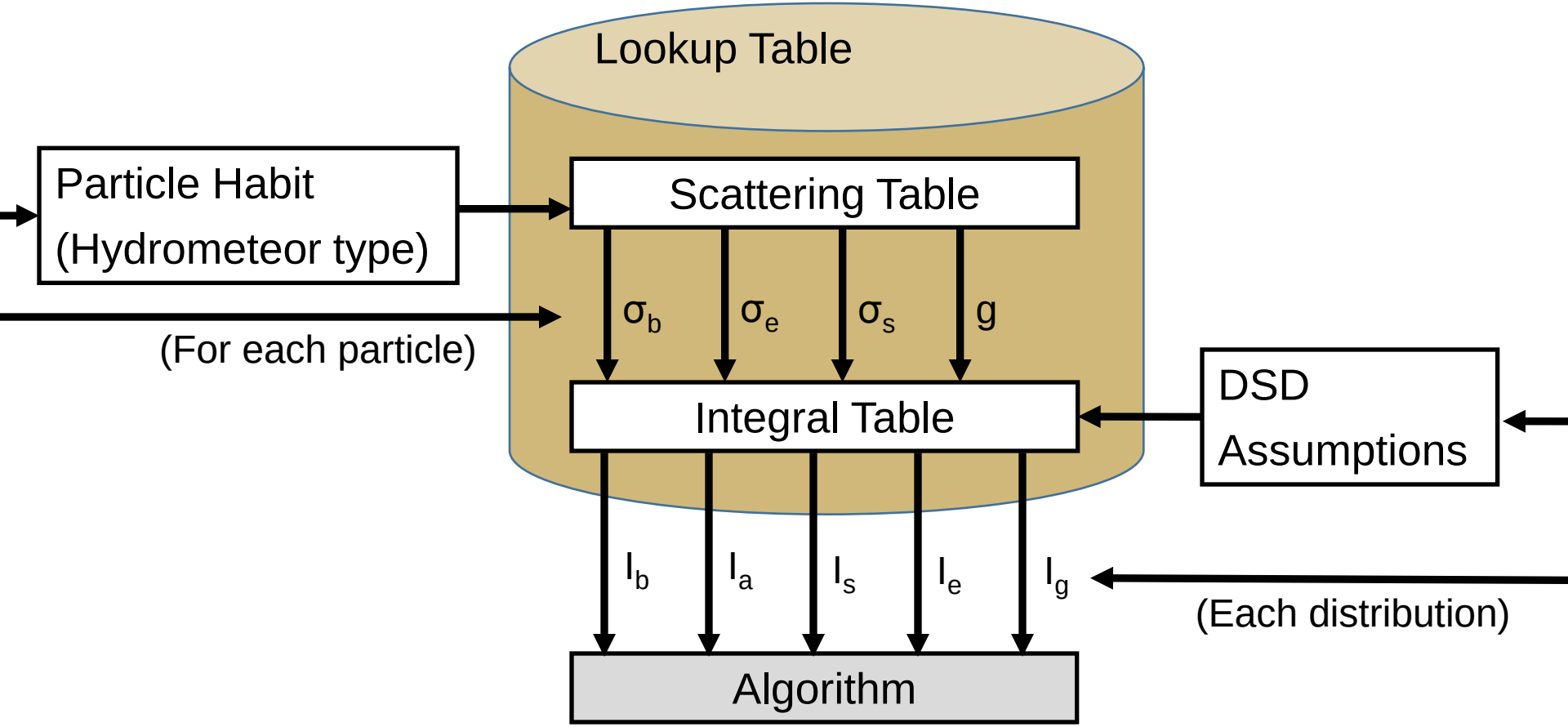
Integral Tables

Integral Tables

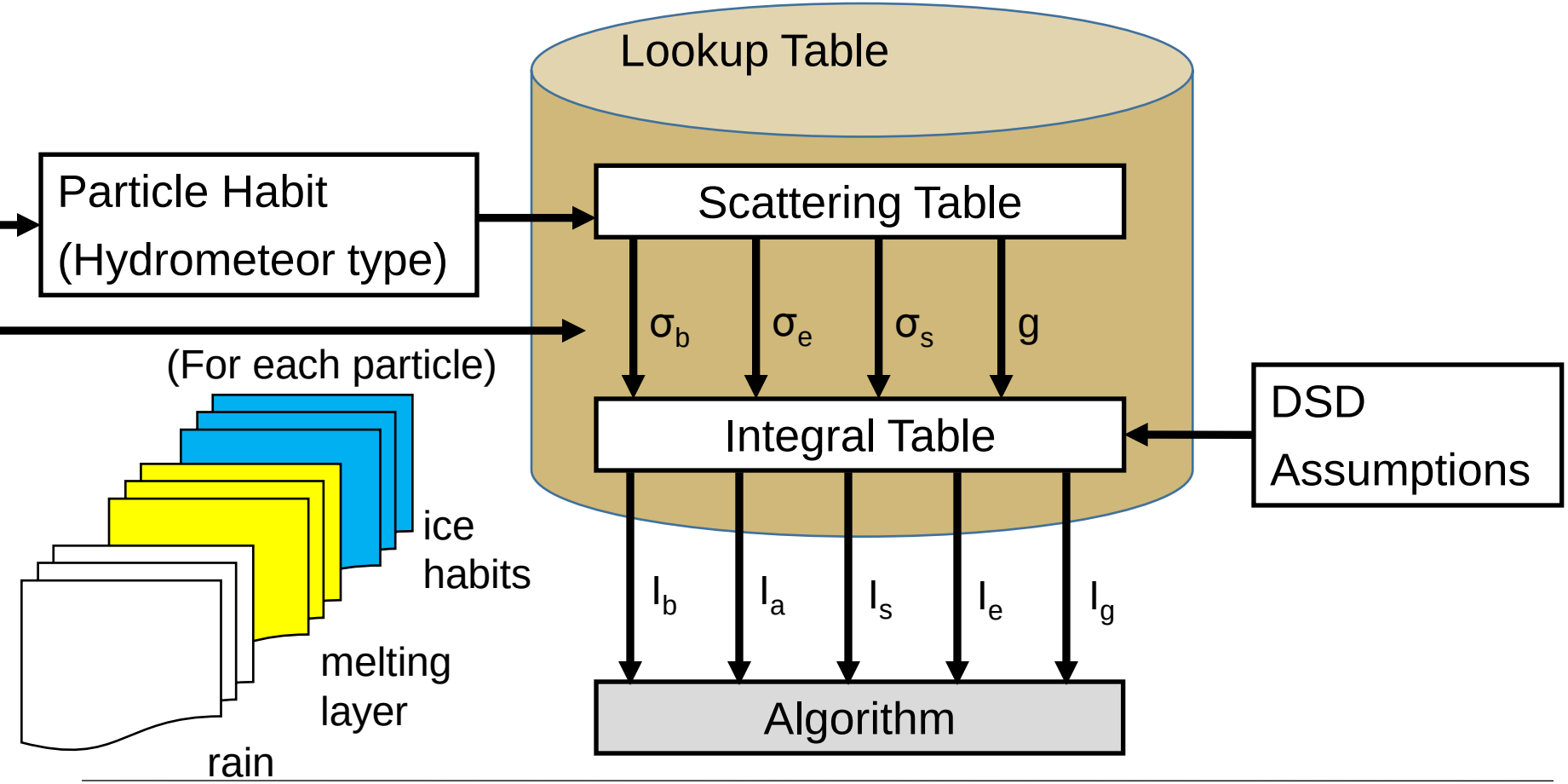
- Research: Cloud Microphysics
  - Integral quantities due to the distribution of particles
- Vocabulary
  - DSD assumption
  - N_w, D_m, μ parameters
  - μ-Λ relationship
  - σ_m-D_m relationship
  - Z, R, LWC
  - Z at Ku or Z at Ka
  - N_w-D_m or N_t-D_0 formulation
- Table Outputs
  - Normalized reflectivity coef., I_b
  - Normalized attenuation coef., I_a
  - Normalized scattering coef., I_s
  - Normalized emission coef., I_e
  - Normalized asymmetry coef., I_g

(Each distribution)

Details of Lookup Table

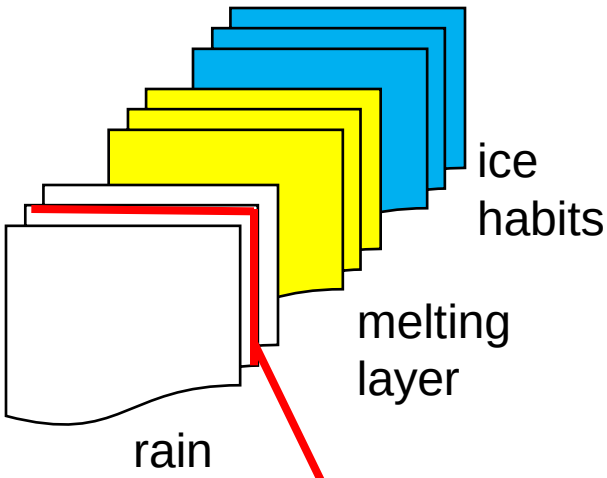


Details of Lookup Table

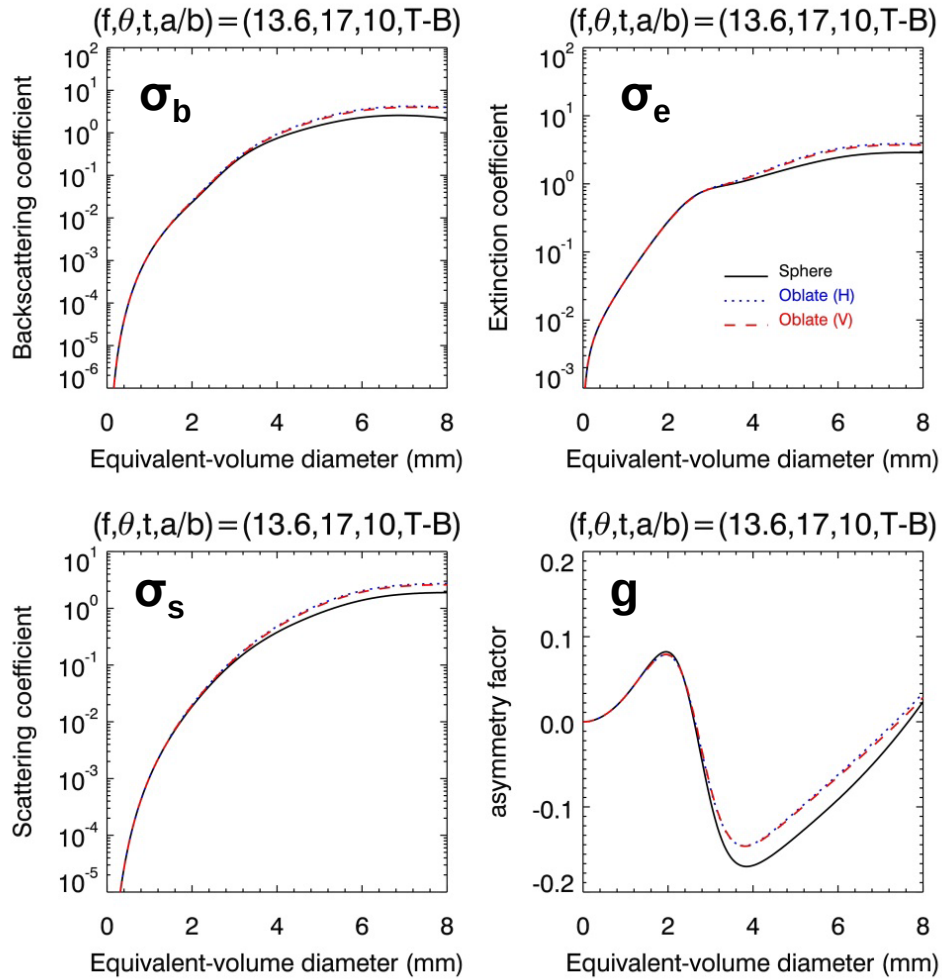


Scatter Table: One Example

Library of Scattering Tables

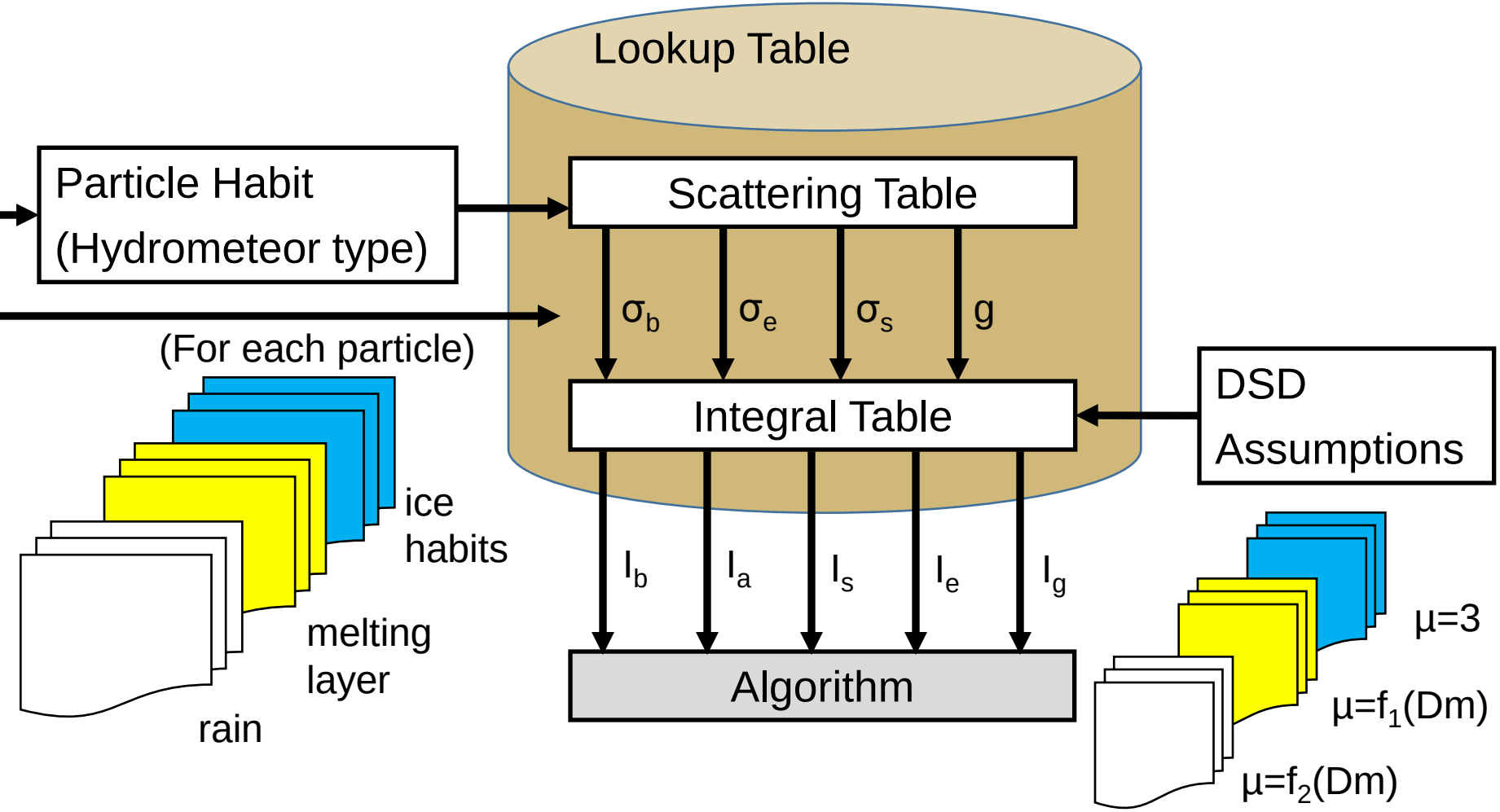


Raindrops, 13.6 GHz,
17° off Nadir, Thurai-Bringi
a/b relationship



Calculations made by Liang Liao, NASA Goddard

Details of Lookup Table



Normalized Gamma Function

Normalized Gamma Function
(Testud et al. 2001; Illingworth and Blackman 2002; Bringi et al. 2003):

$$N(D;N_w,D_m,\mu)=N_w\underbrace{\left[\frac{6(4+\mu)^{\mu+4}}{4^4\Gamma(\mu+4)}\right]\left(\frac{D}{D_m}\right)^{\mu}\exp\left[-(4+\mu)\left(\frac{D}{D_m}\right)\right]}$$

Simplify the notation: $f(D;D_m,\mu)$

Rewrite as a scaled quasi-PDF (Chandrasekar et al. 2005):

$$N(D;N_w,D_m,\mu)=N_w f(D;D_m,\mu)$$

Normalized Integral Tables

Given a DSD of the form:

$$N(D) = N_w f(D; D_m, \mu)$$

What is the reflectivity given N(D) and a radar wavelength λ?

$$Z(\lambda; N_w, D_m, \mu) = 10log\left(\frac{\lambda^4}{\pi^5|K_w|^2}\int_{D_{min}}^{D_{max}} N_w f(D; D_m, \mu)\sigma_b(\lambda, D)\, dD\right)$$

(3 parameters)

Backscattering cross section

N_w is a constant in the integral, so normalize such that N_w= 1:

$$I_b\,(\lambda; D_m, \mu) = 10log\left(\frac{\lambda^4}{\pi^5|K_w|^2}\int_{D_{min}}^{D_{max}} f(D; D_m, \mu)\sigma_b(\lambda, D)\, dD\right)$$

(2 parameters)

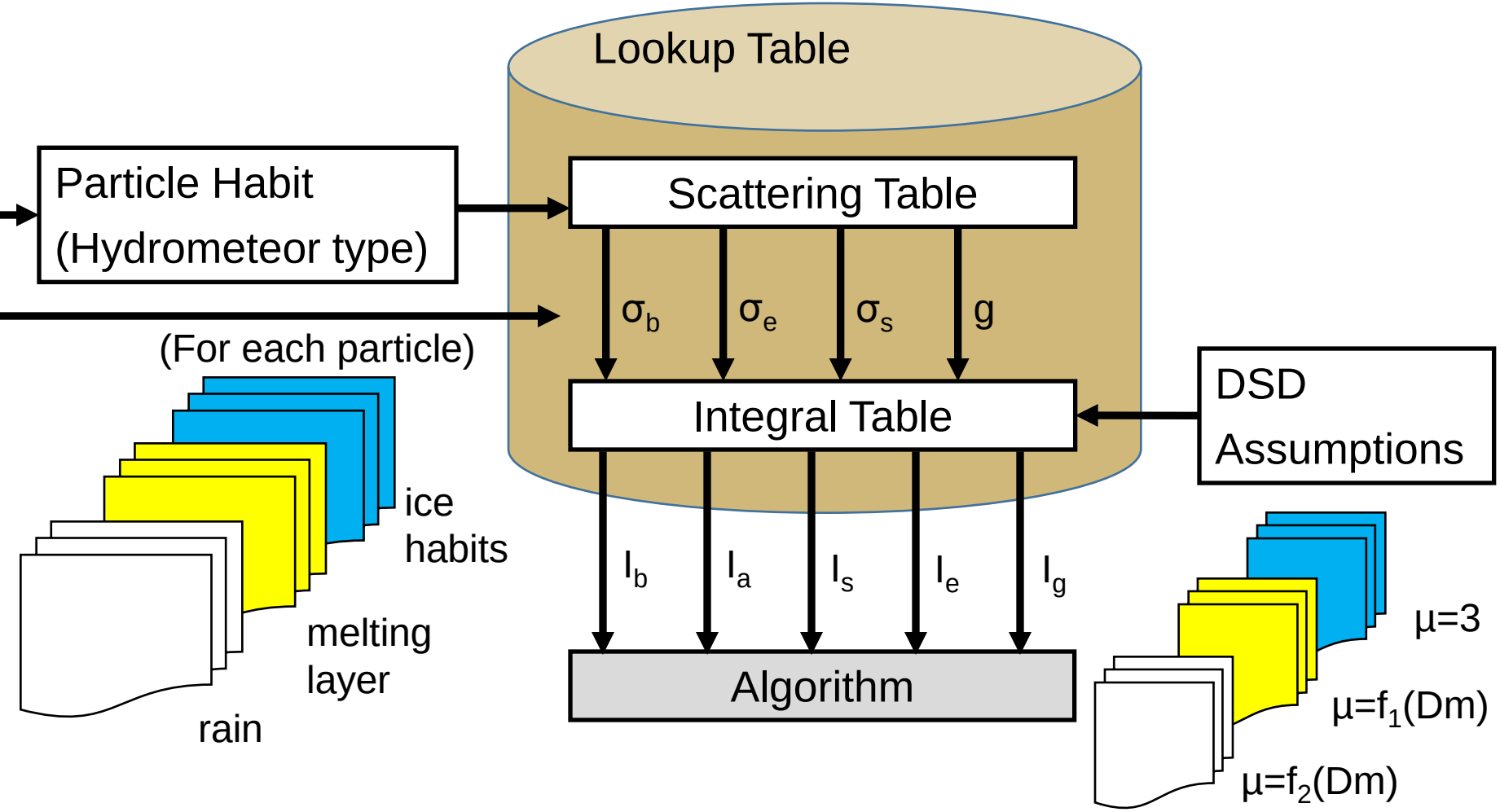
Select a μ constraint (μ = constant, μ = f(D_m)). For example, if μ=3:

$$I_b(\lambda; D_m)\Big|_{\mu=3} = 10log\left(\frac{\lambda^4}{\pi^5|K_w|^2}\int_{D_{min}}^{D_{max}} f\,(D; D_m)\Big|_{\mu=3}\sigma_b(\lambda, D)\, dD\right)$$

(1 parameter)

After setting a μ constraint, I_b is only a function of D_m

Details of Lookup Table



Concluding Remarks

- "Look-up Tables" provide a framework to change assumptions without changing model core logic.
- Scattering Tables describe electromagnetic properties of particles
  - Opportunity for particle scattering modelers
- Integral Tables describe particle size distributions
  - Opportunity for observational scientists
- Framework is valid for rain, snow, ice, mixed phase particles and their distributions