Ice Cloud Particle Parameterizations for Temperatures of 0 to -85°C

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Global mean radiative flux divergence vs Ice fallspeed

From Jakob, 1999, private communication based on refinements to the Tiedtke scheme
Overview

• Field programs, data
• PSD functional form
• Ice particle shape characteristics
• Terminal velocities
• Upscaling
• Considerations
FIELD CAMPAIGNS

TC4: The Tropical Composition, Cloud and Climate Coupling (TC4) Field Campaign, 2007
AIRS: AIRS_2, Alliance Icing Research Study II, 2003–2004
C3VP: Canadian CloudSat/CALIPSO Validation Program, 2006–2007
Rep: Replicator Observations, First ISCCP Research Experiment (FIRE)–2, 1991
SV: Experiments with CF and pre-AURA Validation Experiment, 2002 and 2004
SCOUT: Stratospheric Climate Links w/Emphasis on the Upper Troposphere/Lower Stratosphere, 2003
MPACE: Mixed-Phase Arctic Cloud Experiment, 2004
Temperature Dependence of PSD Properties

a: Max. Diam. f(T)

- Composite: $D_{\text{max}} = 2.7e^{(0.0810T)}$ all $T < -39^\circ$C
- Composite: $D_{\text{max}} = 0.7e^{(0.0480T)}$ all $-39 < T (\text{C})$

b: Number of ICE PSD

- Convective
- Stratiform
- All

# 5 Sec. PSD w/ice

T (C)

-80 -60 -40 -20 0
$N_0 D^\mu e^{-\lambda D}$
PSD Dispersion

a: \( \lambda \) Dependence

Note: \( Y \) axis = \( \mu + 3 \)

Points, Bars Stratiform
- Convective
  \( \mu = 1.4\lambda^{0.88} - 3, \mu > -0.69 \) (Strat.)
  \( \mu = 0.6\lambda^{0.98} - 3, \mu > -1.46 \) (Conv.)
  \( \mu = 0.9\lambda^{0.98} - 3, \mu > -0.92 \) All

b: Temp. Dependence

Points, Bars Stratiform
- Convective
  \( \mu \) values for different temperature ranges:
  - Strat. \( > -60 \) C, \( \mu = -0.05 - 0.028 \)
  - Conv. \( \mu = -1.68 - 0.051 \)
  - \( \mu = -20.05 - 0.320T \) \( \text{[T< -67(C)]} \)
  - \( \mu = -0.58 - 0.029T \) \( \text{[-67<T(C)]} \)

Regression line:
\( \mu = -0.62 + 0.02729T + 1.121E-03T^2 + 4.842e-05T^3 + 5.161E-07T^4 \)
PSD Dispersion

a: λ Dependence

Note: Y axis = μ+3
Points, Bars Stratiform
Convective
μ = 1.4λ^{0.582}−3, μ>−0.69 (Strat.)
μ = 0.6λ^{0.383}−3, μ>−1.46 (Conv.)
μ = 0.9λ^{0.308}−3, μ>−0.92 All

b: Temp. Dependence

Points, Bars Stratiform
Convective
Strat. >−60°C, μ=−0.05−0.028
Conv. μ=−1.68−0.051
μ=−20.05−0.320T, [T<−67°C]
μ=−0.58−0.029T [−67<T°C]

μ = −0.62−0.02729T + 1.121E−03T^2 + 4.842e−05T^3 + 5.161e−07T^4
Fractal Mass Dimensional Coefficients

a: Power b

\[ b = 2.31 + 0.0054T \]

\[ b = 2.1 \]

b: Coefficient a

\[ a = 0.0081e^{0.013T} \]

\[ a = 0.006 \]
Area Ratio Parameters

\( \alpha : \alpha \text{ vs Temp.} \)

- \( \alpha = 0.2773 + 6.667e^{-0.03T} + 7.75e^{-0.05T^2} \), \( T > -60^\circ \text{C} \)

\( \beta : \beta \text{ vs Temp.} \)

- \( \beta = -0.2070 + 9.594e^{-0.03T} + 1.16e^{-0.04T^2} \), \( T > -60^\circ \text{C} \)

\( \alpha : \alpha \text{ vs } \beta \)

- \( \beta = 2.14 + 0.26086 \ln(\alpha) \)
Summary of $V_i$ Relationships

(a) 400 hPa, Stratiform

$V_i = 0.0032D^{2.0}$, $D < 41 \mu m$

$V_i = 0.1735D^{0.8}$, $41 < D < 859 \mu m$

$V_i = 0.2470D^{0.82}$, $D > 859 \mu m$

(b) 400 hPa, Convective

$V_i = 0.0032D^{2.0}$, $D < 41 \mu m$

$V_i = 0.1094D^{1.0}$, $41 < D < 842 \mu m$

$V_i = 0.1175D^{0.99}$, $D > 842 \mu m$

(c) 800 hPa, Stratiform

$V_i = 0.0028D^{2.0}$, $D < 40 \mu m$

$V_i = 0.1631D^{0.8}$, $40 < D < 812 \mu m$

$V_i = 0.2280D^{0.84}$, $D > 812 \mu m$

(d) 800 hPa, Convective

$V_i = 0.0028D^{2.0}$, $D < 40 \mu m$

$V_i = 0.1026D^{1.0}$, $40 < D < 788 \mu m$

$V_i = 0.1132D^{0.77}$, $D > 788 \mu m$
Additional Considerations

- Ice shattering
- Sub-150 micron ice particles
  - Undersized >> Concentrations
  - Sampling Statistics
  - Shape discrimination
- 2D-S probe major improvement
- SID-2, SID-3, VIPS, Replication
- HVPS-3 big improvement
  - Sample volume, shape discrimination
- Upscaling from In-situ observations ~1km to ECMWF~16km or above
Upscaling

- Primary question: Is the mean concentration at a given size in a PSD through a horizontal slice through a cloud layer missing any preferred horizontal scale.
- Used Bayesian analysis to look for preferred PSD horizontal scales, using one very long horizontal penetration (80 km) at constant altitude through an ice layer cloud.
- An an example, took horizontal spacing of all 200-250 micron particles with 25 micron horizontal resolution based on interarrival time and found a “preferred” PDF scale of 4 km.
- Did a similar analysis for other size ranges and found that the mean concentration only fairly represents preferred scale.
- Similar analysis needed for many case studies to investigate whether there are preferred horizontal scales.