# Schultz Explicit Moisture Parameterization

Mark Decker

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# Outline

- Brief Explanation
- Input and Output
- Flow Diagram
- Equations
- Parameters
- Sensitivity Analysis
- Validation vs. RAMS scheme
- Summary

# Brief Explanation

- Explicit Microphysics parameterize phase changes of water on a resolvable scale
- Rain, Snow, Graupel, Cloud Ice, Cloud Water

# Input and Output

- Input
  - Temperature
  - Water Vapor
  - P star
  - Pressure
  - Time Step
- Output
  - Temperature Change due to Phase Changes
  - Changes in Water Vapor
  - Cloud Water
  - Total Precipitation at Surface
    - Rain + Snow + Graupel + Pristine Ice Crystals

  - Snow
  - Graupel
  - Pristine Ice Crystals
  - Rain

# Flow Diagram

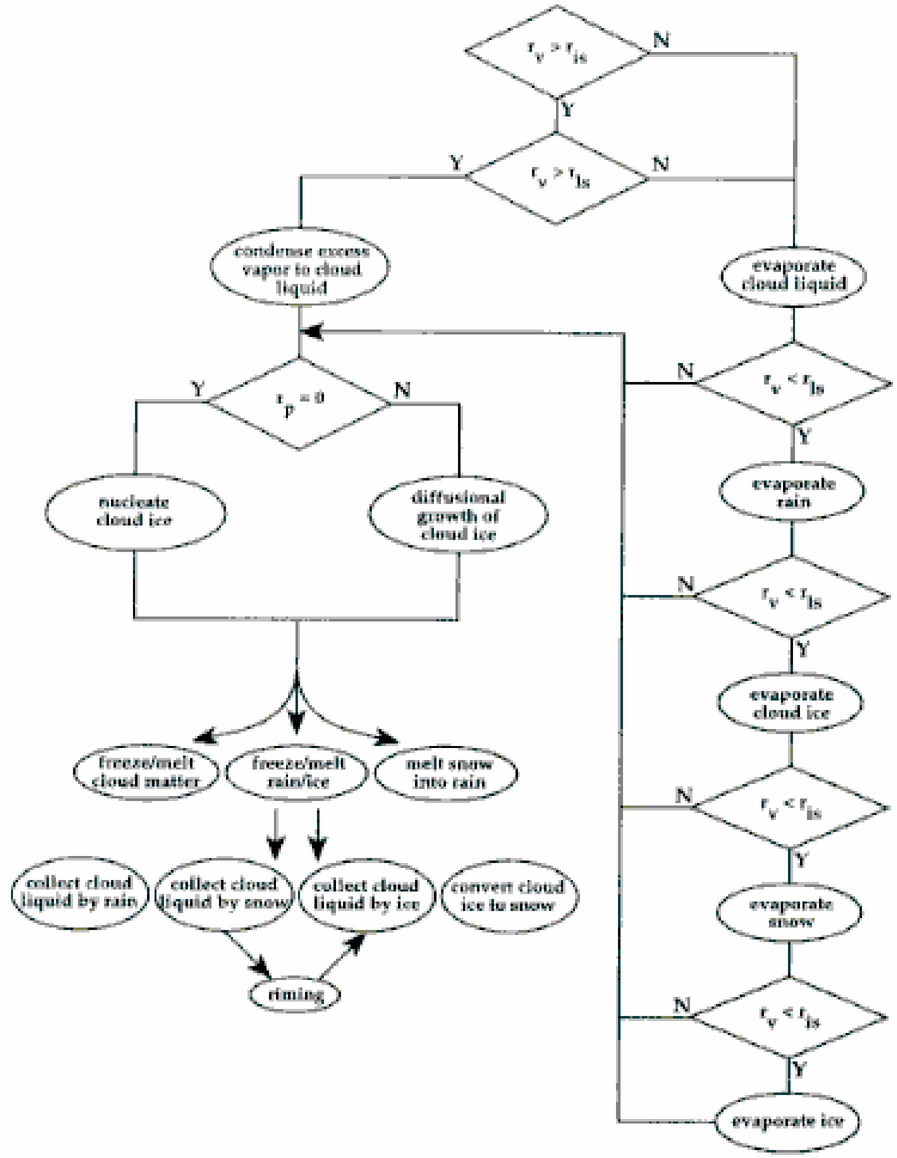



FIG. 1. Flow diagram for the NWP explicit microphysics algorithm; $r$ is mixing ratio. The subscripts are $v$, vapor; $p$, cloud ice; $ls$, liquid saturation; $is$, ice saturation.

# Equations

- Condensation
  - $R_c(t+1) = R_c(t) + (R_v(t)-R_{sat})$ if $(R_v>R_{sat})$
- Evaporation
  - Cloud Liquid then Rain ($R_c = 0$)
    - rate = $-(R2V)*R_c$
      - $R_v(t+1) = R_v(t) + rate*dt$
      - $R_r(t+1) = R_r(t) - rate*dt$

# Ice Nucleation

- $R_p < 1E\text{-}6$ and $T < 268K$
  - $R_p = q_{mass}$*EXP(-0.639*12.96*($R_v/R_{sati}$-1))/$\rho$
    - $q_{mass} = 10^{-11}$
  - Arbitrarily Limited to half the vapor excess

# Ice Growth

- $R_p$ > 1E-6
  - – rate = (V2P)*($Q_v$-$Q_{sati}$)*$Q_p$
    - $Q_p$(t+1) = $Q_p$(t) + rate*dt
    - $Q_v$(t+1) = $Q_v$ (t) – crate*dt
  - – V2P = 25.0

# Evaporation

- Ice
  - rate = $(P2V)*(R_{sati}-R_v)*dt$
    - $R_v(t+1) = R_v(t) + rate*dt$
    - $R_p(t+1) = R_p(t) – rate*dt$
  - P2V = 0.004
- Snow
  - rate = $(S2V)*(R_{sati}-R_{v)*}dt$
    - $R_v(t+1) = R_v(t) + rate*dt$
    - $R_s(t+1) = R_s(t) – rate*dt$
  - S2V = 0.002

# Evaporation (cont.)

- Graupel Evaporation
  - rate = (I2V)*($R_{sati}$-$R_v$)*dt
    - $R_v$ (t+1) = $R_v$ (t) + rate*dt
    - $R_i$ (t+1) = $R_i$ (t) – rate*dt
  - I2V = 0.001

# Melting

- Limited by (T°C)*$C_p$/L
  - Keeps Grid Point > 0°C
- Cloud Ice
  - Melts Instantly To Cloud Water
- Snow
  - rate = (S2R)*(T°C)
  - S2R = 8.33 * $10^{-6}$
- Graupel
  - rate = (I2R )*(T°C)
  - I2R = 8.33 * $10^{-6}$

# Freezing

- Cloud Water to Pristine Ice Crystals
  - Allows for Supercooled Water
  - rate = $(C2P)*((253-T)/20)^2$
    - $C2P = 16.7*10^{-6}$
- Rain to Graupel
  - rate = $(R2I)*((267-T)/14)^2$
    - $R2I = 8.33*10^{-6}$
- Temperature is Adjusted using L and $C_p$

# Collection

- Autoconversion
- No Rain and No Pristine Ice Crystals
  - $Q_c > Q_{cminimum}$
  - $Q_r(t+1) = Q_r(t) + (Q_c(t) - Q_{cminimum})$
  - $Q_p > Q_{pminimum}$
  - $Q_s(t+1) = Q_s(t) + (Q_p(t) - Q_{pminimum})$

# Collection ($Q_c$) - Competition

- Competition for $Q_c$
  - Rain
    - rate = $(C2R)*Q_c*Q_r$
      - C2R = 33.0
  - Snow
    - rate = $(C2S)*Q_c*Q_s$
      - C2S = 33.3
  - Graupel
    - rate = $(C2I)* Q_c*Q_i$
      - C2I = 16.7
- $ND_{snow} = ND_{snow}*Q_c/ND_{snow}$

# Collection ($Q_c$)- Riming

- Nucleate Cloud Ice
  - $Qp = Qp + 0.01*(ND_{snow} + ND_{graupel})$
    - 0.01 is Arbitrary
- Converts Cloud Water to Graupel
  - $Q_r(t+1) = Q_r(t) + ND_{rain}$
  - $Q_i(t+1) = Q_i(t) + ND_{graupel} + ND_{snow}$

# Collection $Q_p$

- Always Leave $10^{-6}$ kg/m$^3$
  - Produce More Condensate if Supersaturated
  - Small Size Limits Collection

- Snow (Aggregation)
  - rate = (P2S)*(1-(273-T)/50)*$Q_p$*$Q_s$
    - P2S = 5.0

# Fall Velocities and Saturation

- $V_r = R_r^{0.125} * \rho^{-0.5}$
- $V_s = R_s^{0.1} * \rho^{-0.5}$
- $V_i = R_i^{0.333} * \rho^{-0.5}$
- $V_p = \rho^{-0.5}$
- $R_{sati}$ and $R_{sat}$
  - From Empirical Seventh Order Polynomials
  - Each With Eight Constants

# Parameter Total

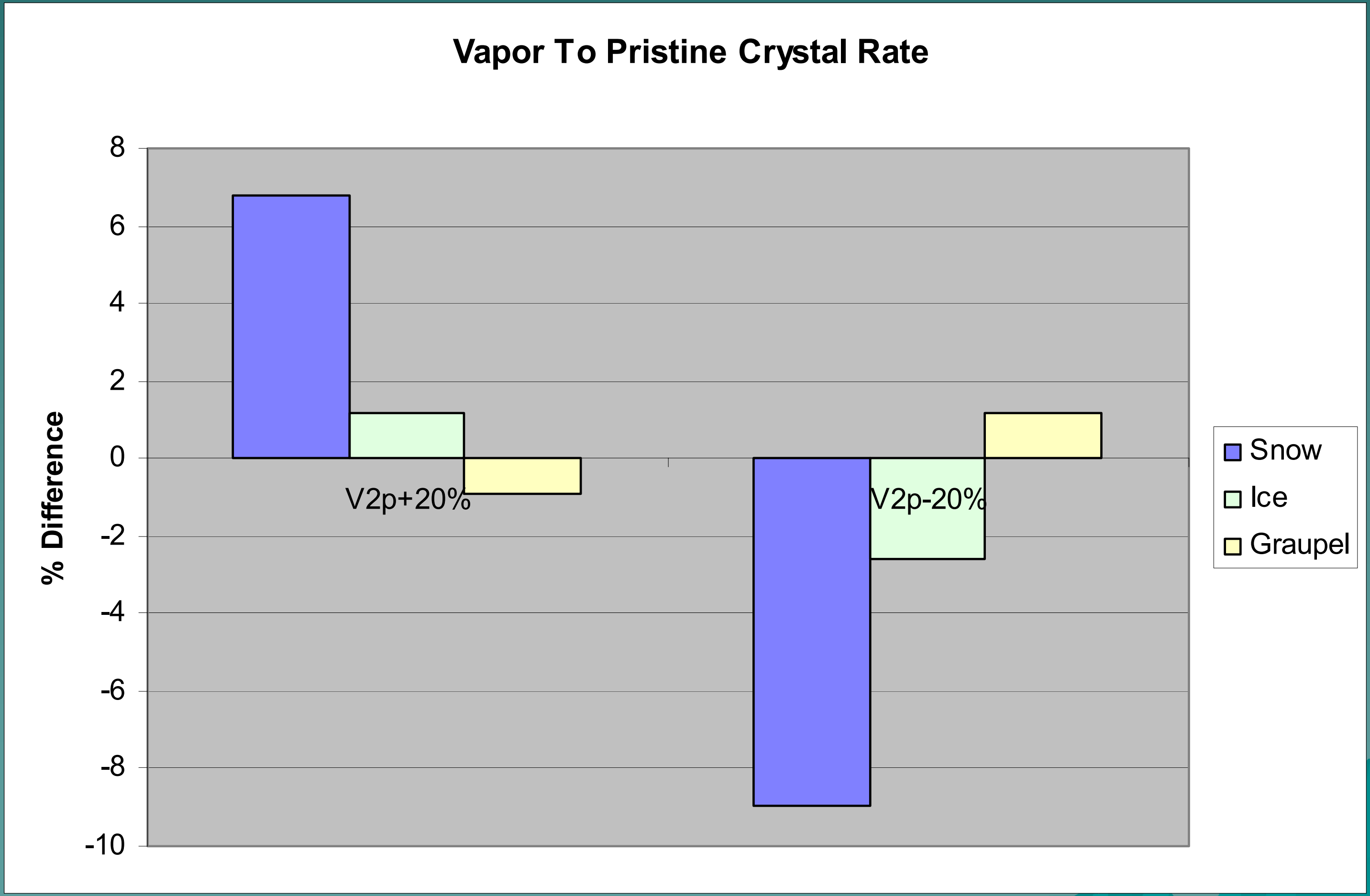
- 32 Parameters or Constants
  - "Tunable"
    - Qcmin,Qpmin,V2P,C2R,C2P,C2S,C2I,P2S,R2I,S2R,I2R,R2V,P2V,S2V,I2V
- 48 Including the Saturation Equations

# Sensitivity Analysis

- Offline
- IC from NCEP Reanalysis
  - Temperature and Humidity Profile
- 17 $\sigma$ Levels to 300 mb
- Linearly Reduced Temperature To Create Over Saturation
- Metric
  - Amount Of Total Fallen Rain,Snow,Graupel,Ice

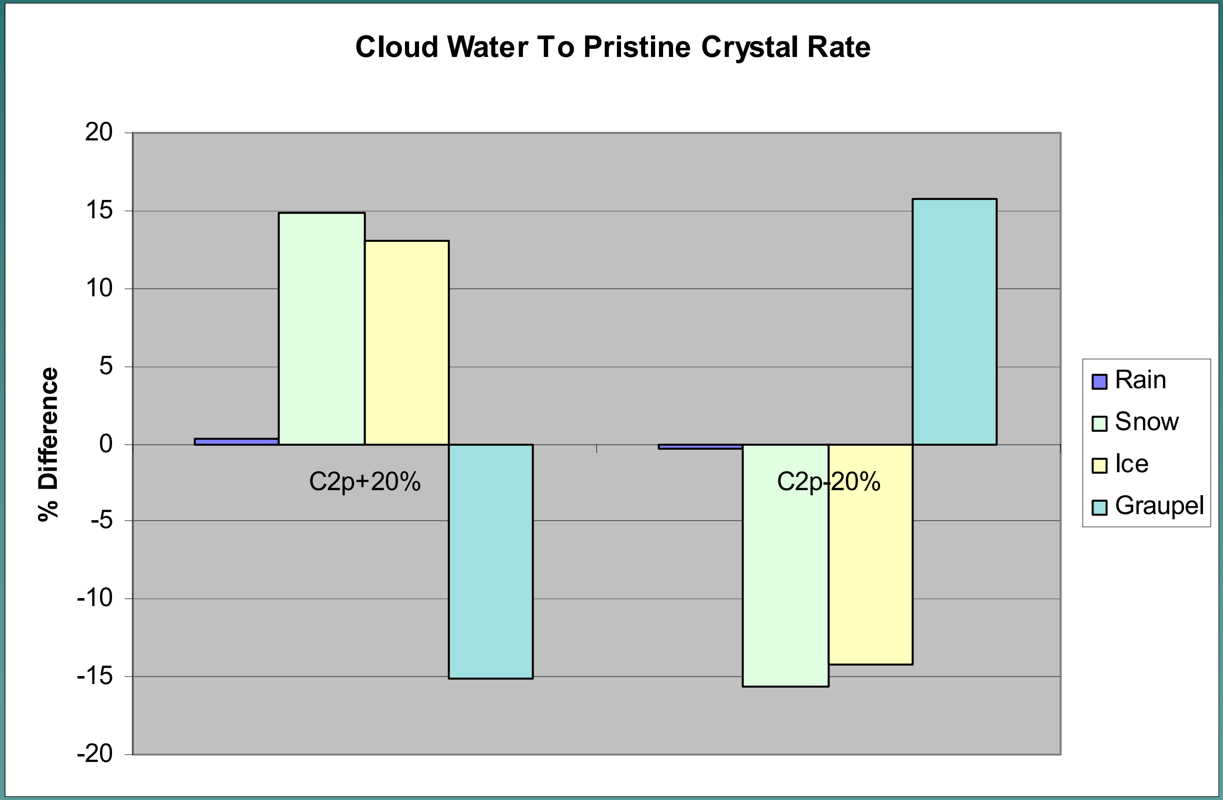
# V2P

## rate = $(V2P)*(Q_v-Q_{sati})*Q_p$



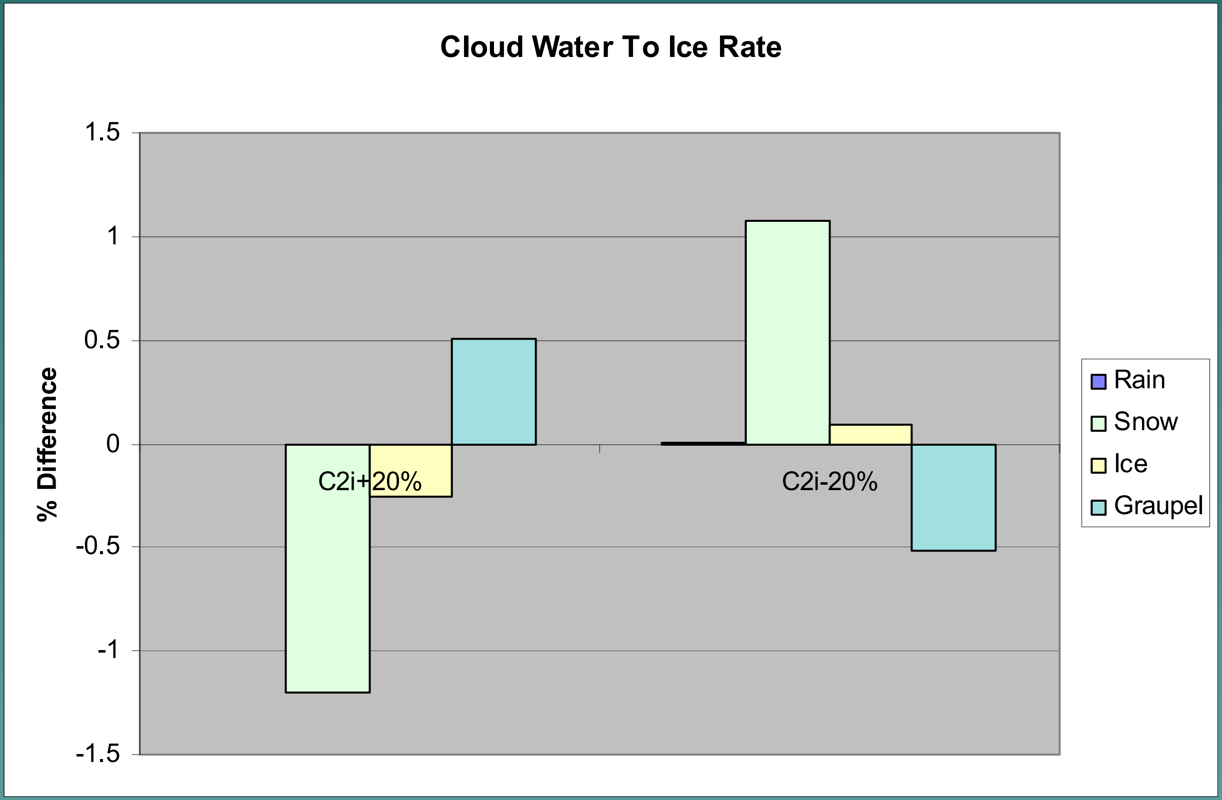
# C2P

$$rate = (C2P)*((253-T)/20)^2$$



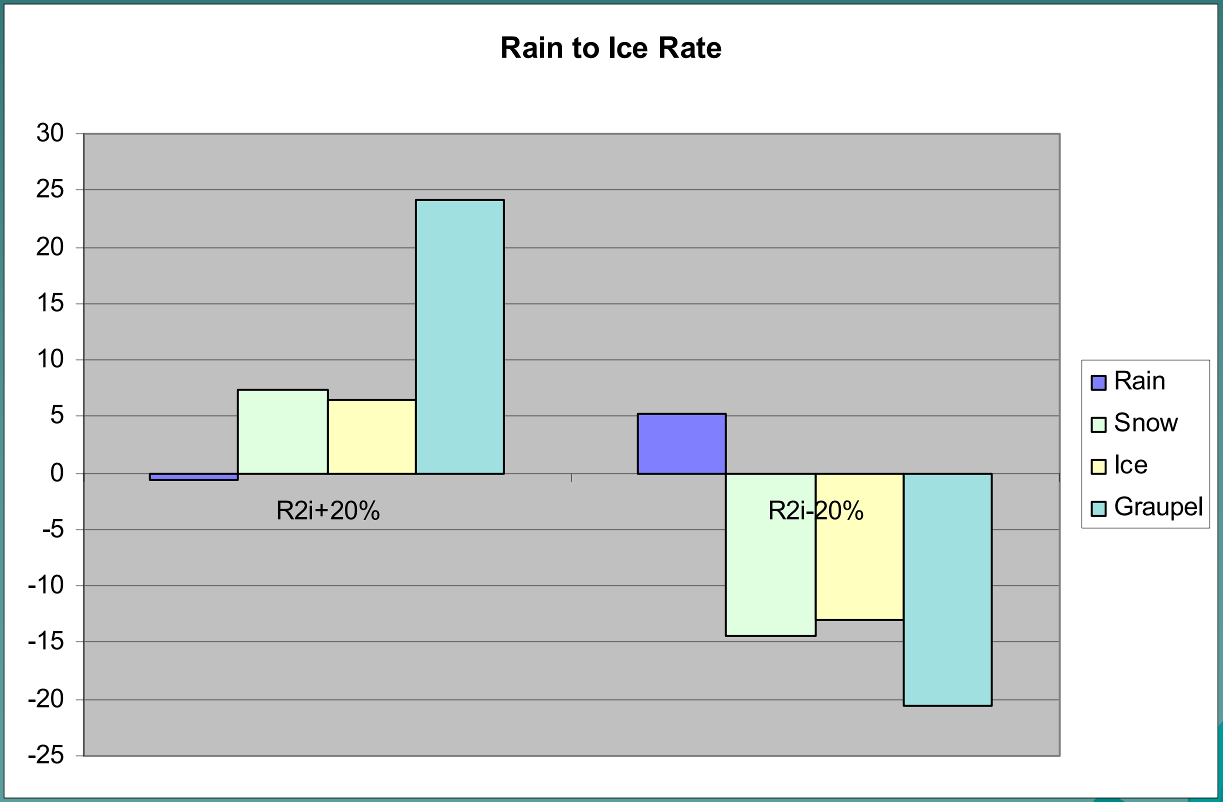
# C2I

## rate = (C2I)* $Q_c$*$Q_i$



# R2I

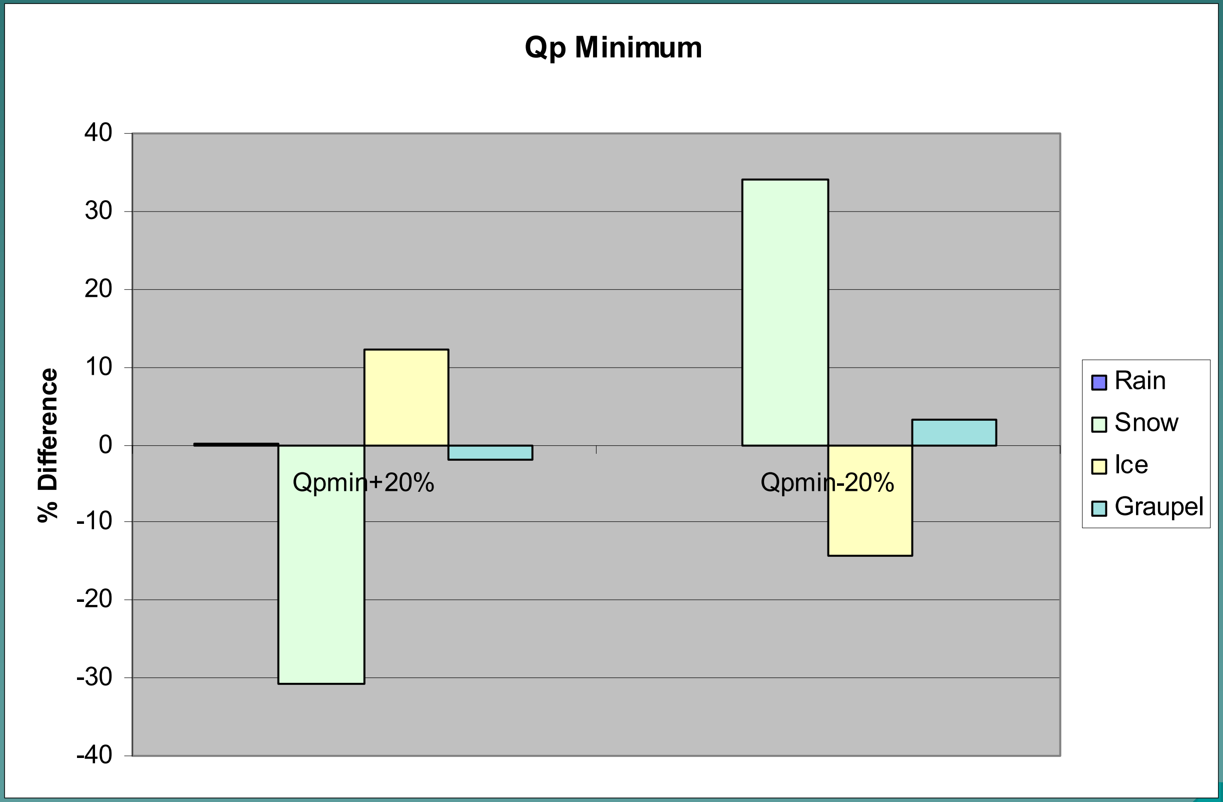
rate = $(R2I)*((267-T)/14)^2$



# $Q_{pminimum}$

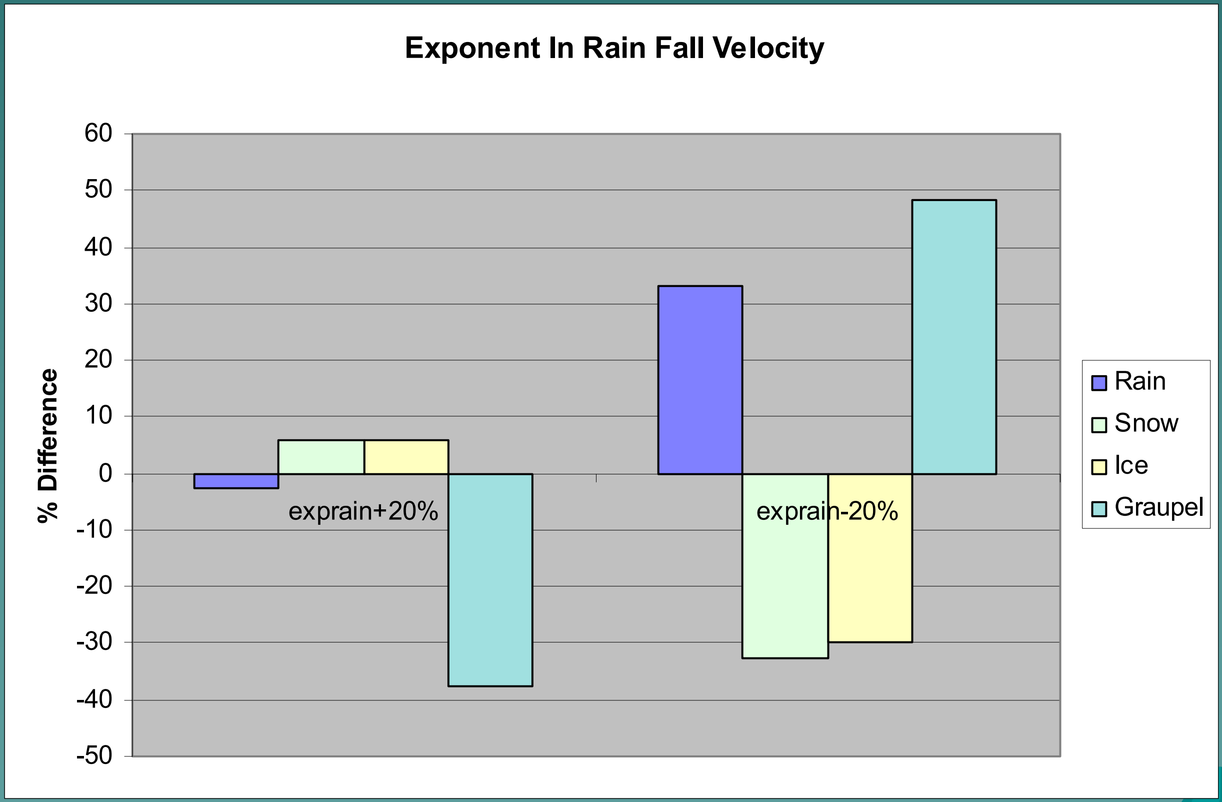
$Q_p > Q_{pminimum}$

$Q_s = Q_s + (Q_p – Q_{pminimum})$



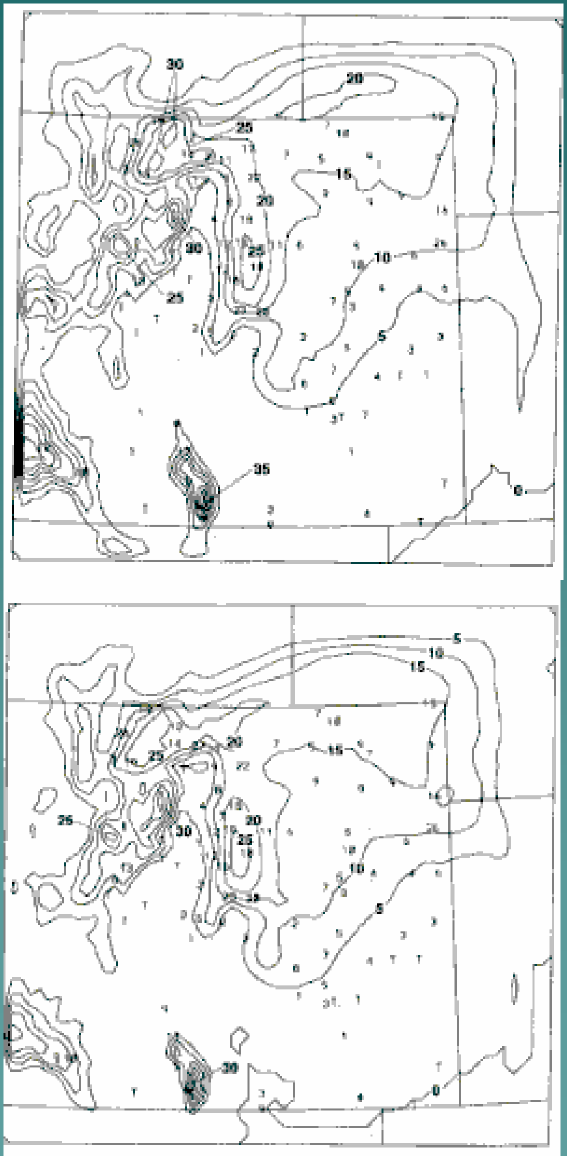
# Exponent In Rain Fall Velocity

$$V_r = R_r^{0.125} * \rho^{-0.5}$$



# Validation Against Rams (Schultz 1995)

Jan 1992



Feb 1994

FIG. 9. Twelve-hour precipitation forecast produced by the RAMS research cloud physics algorithm for 28 February 1994, as in Fig. 5.

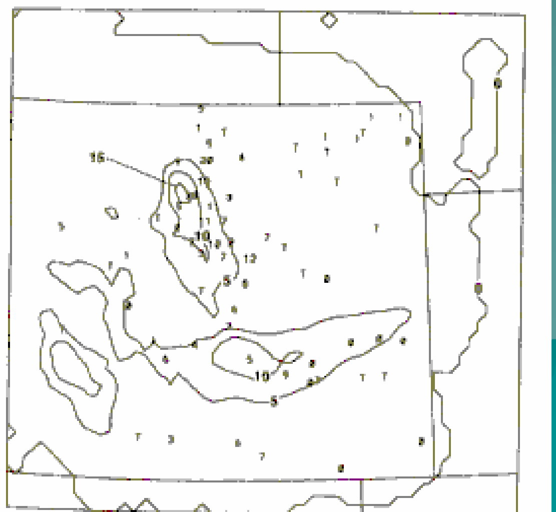


FIG. 10. Twelve-hour precipitation forecast produced by the NEM cloud physics algorithm, as in Fig. 5.

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# Reference


- Schultz, P., 1995: An Explicit Cloud Physics Parameterization for Operational Numerical Weather Prediction. *Monthly Weather Review*, 123, 3331-3342.
- MM5 Source Code