Schultz Explicit Moisture Parameterization

Mark Decker

December 2, 2004

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

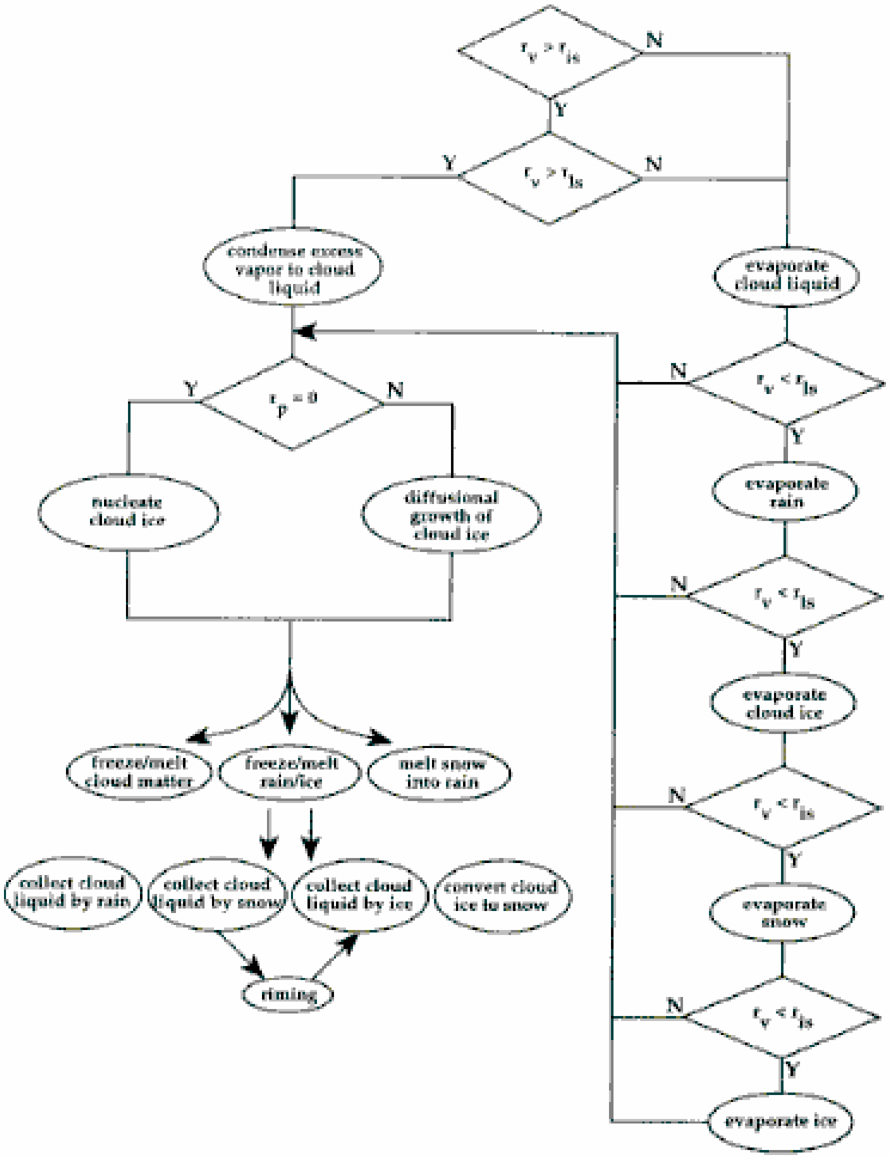


FIG. 1. Flow diagram for the NWP explicit microphysics algorithm; r is mixing ratio. The subscripts are v, vapor; p, cloud ice; ls, liquid saturation; is, ice saturation.

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

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

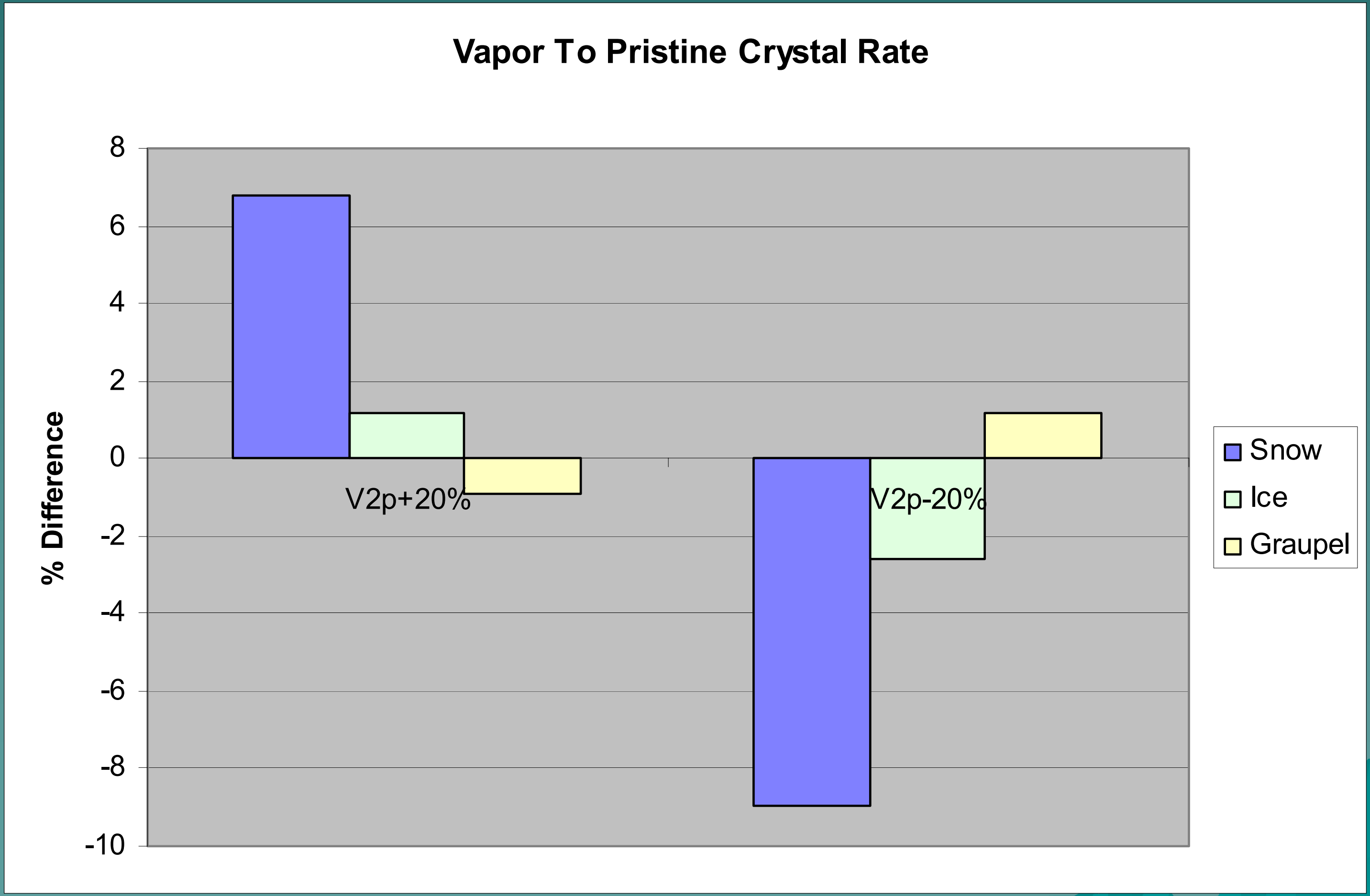
- 32 Parameters or Constants
  - "Tunable"
    - Qcmin,Qpmin,V2P,C2R,C2P,C2S,C2I,P2S,R2I,S2R, I2R,R2V,P2V,S2V,I2V
- 48 Including the Saturation Equations

Sensitivity Analysis

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

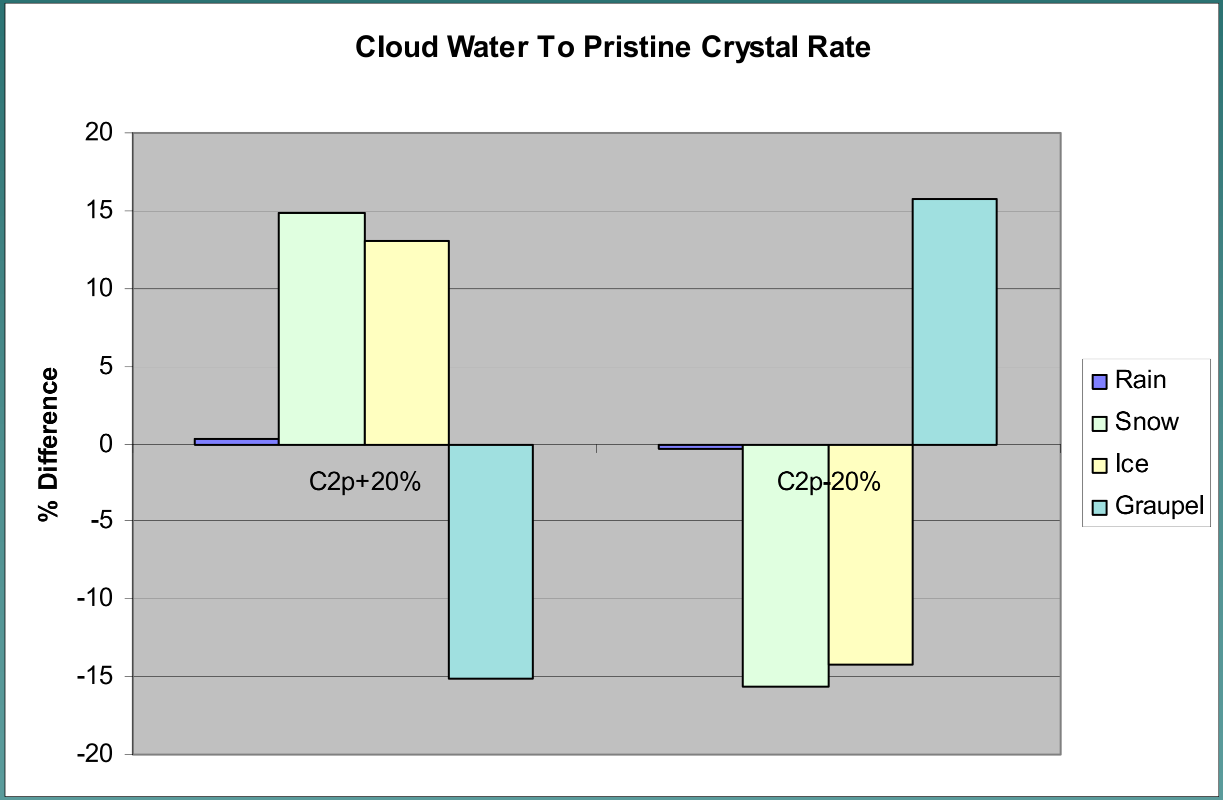
V2P

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



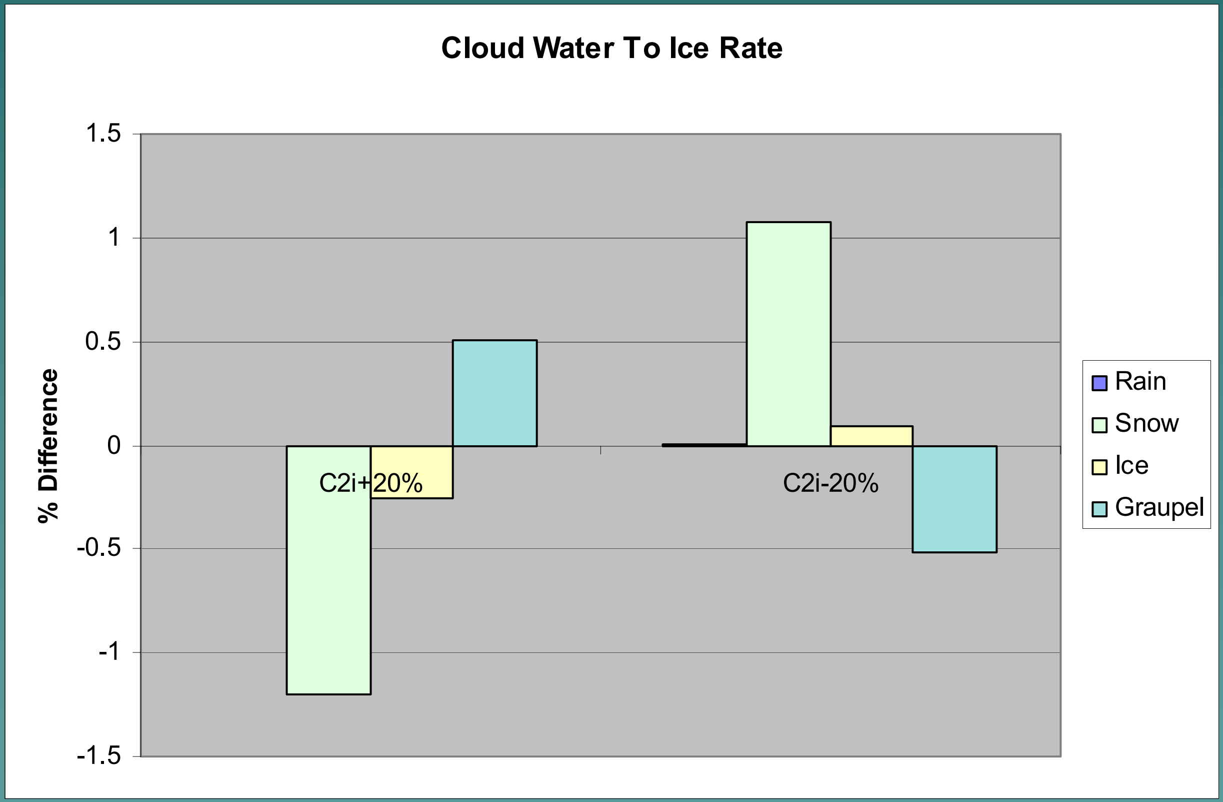
C2P

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



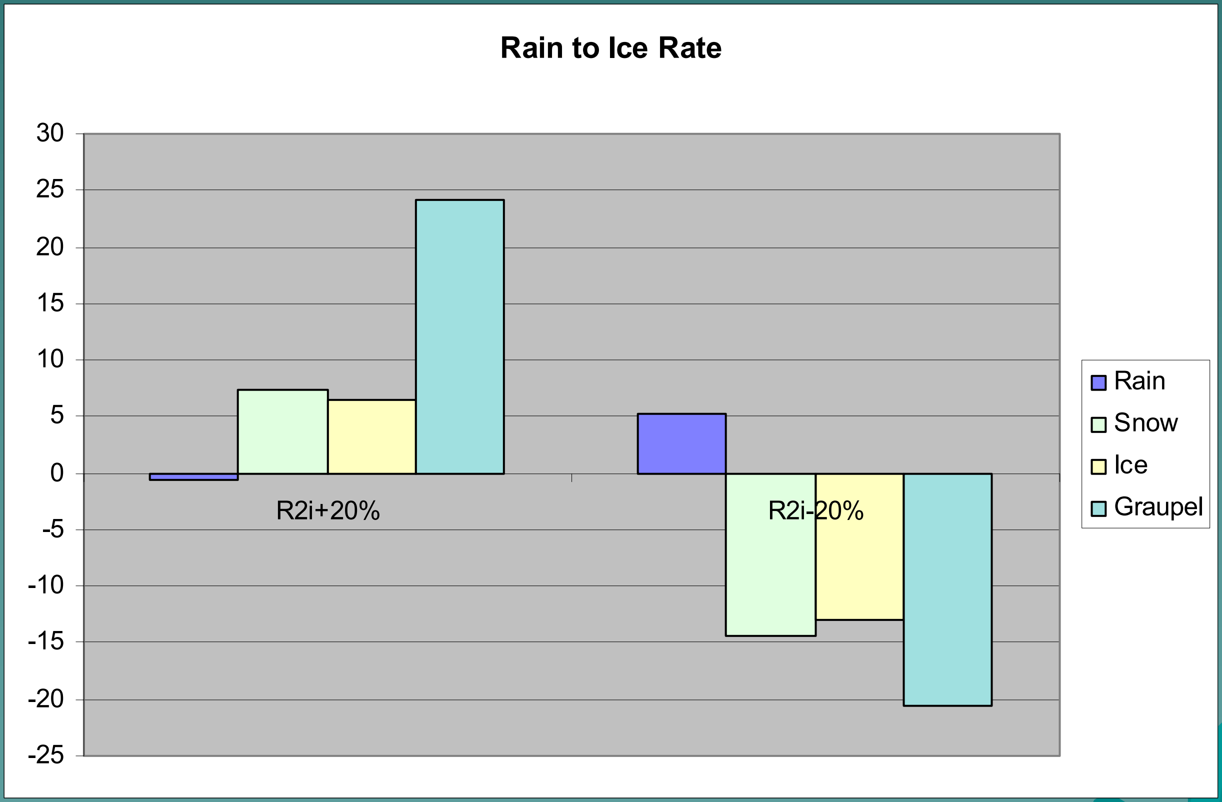
C2I

rate = (C2I)* Q_c*Q_i



R2I

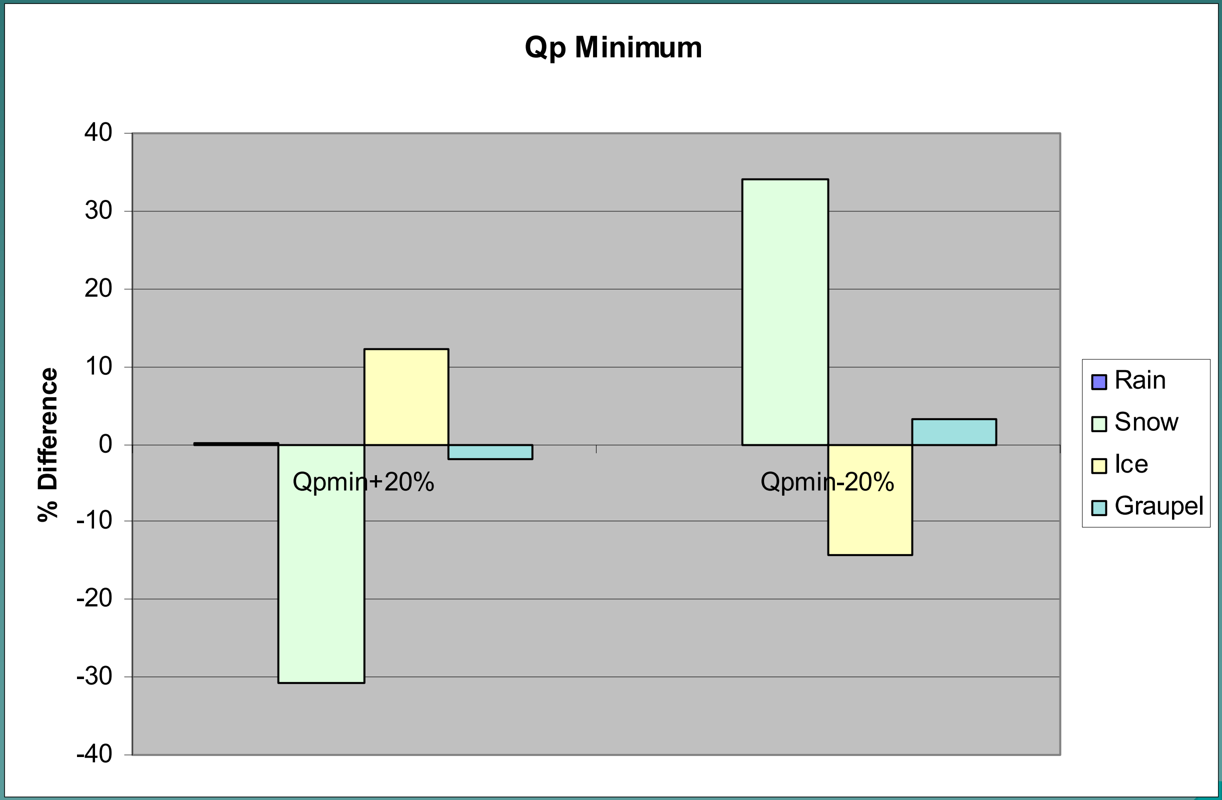
rate = $(R2I)*((267-T)/14)^2$



$Q_{pminimum}$

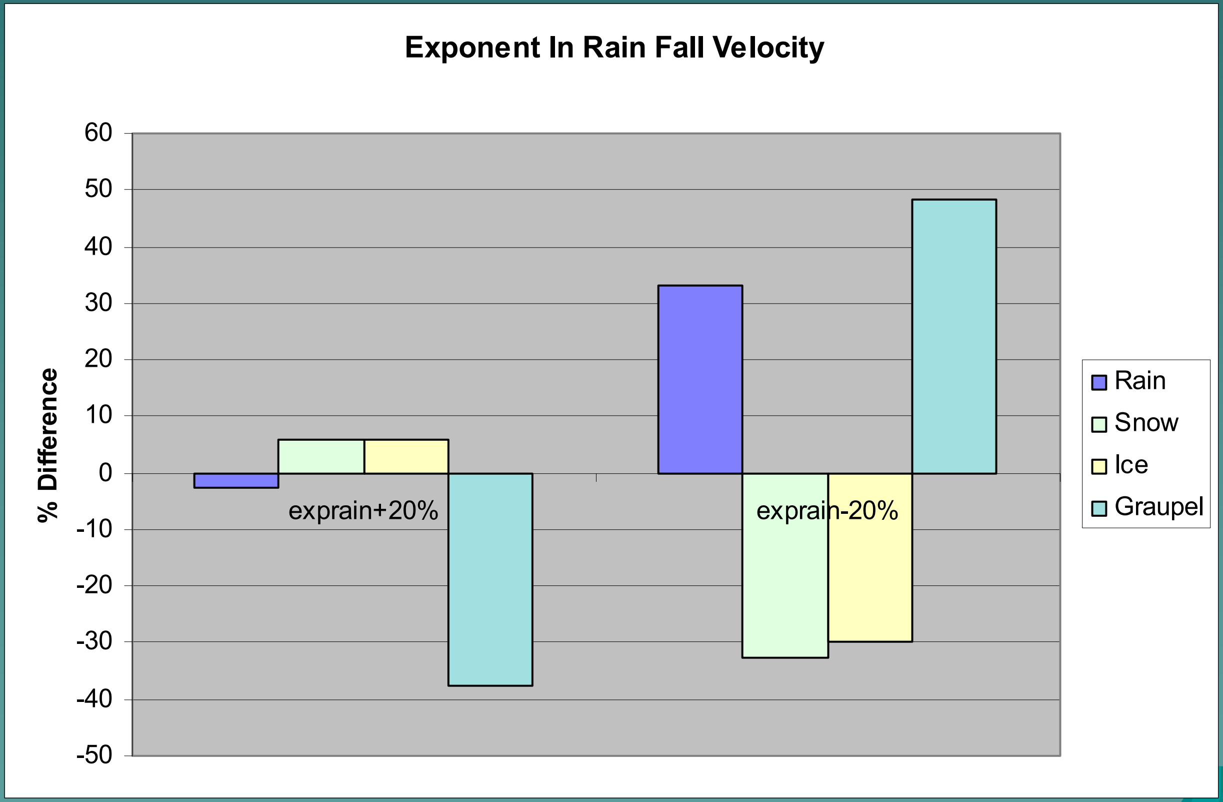
$$Q_p > Q_{pminimum}$$

$$Q_s = Q_s + (Q_p - Q_{pminimum})$$



Exponent In Rain Fall Velocity

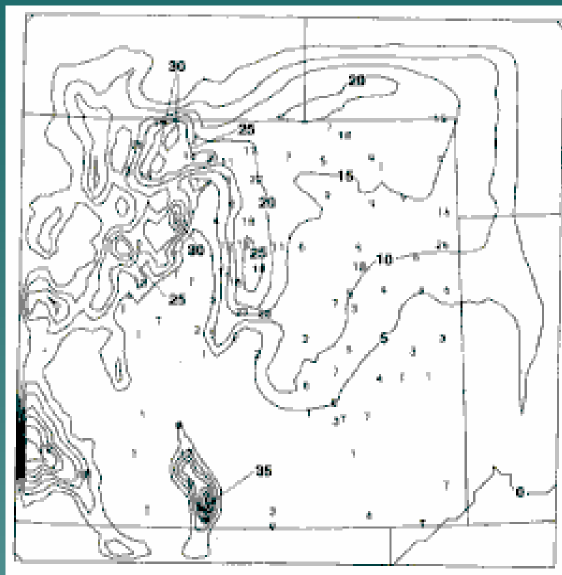
$$V_r = R_r^{0.125} * \rho^{-0.5}$$



Validation Against Rams (Schultz 1995)

Jan 1992

Feb 1994



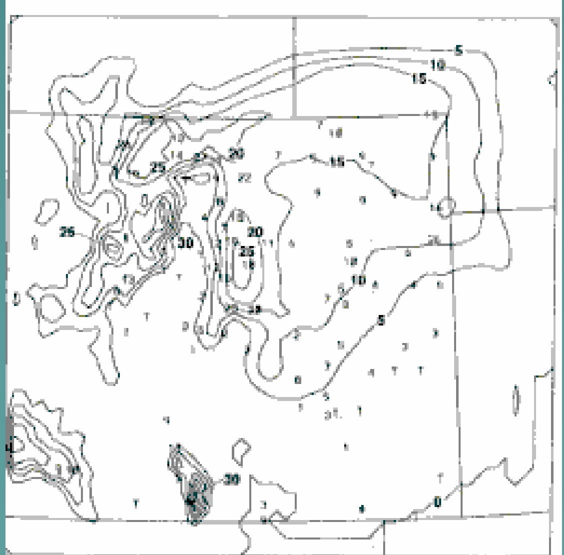


FIG. 9. Twelve-hour precipitation forecast produced by the RAMS research cloud physics algorithm for 28 February 1994, as in Fig. 5.

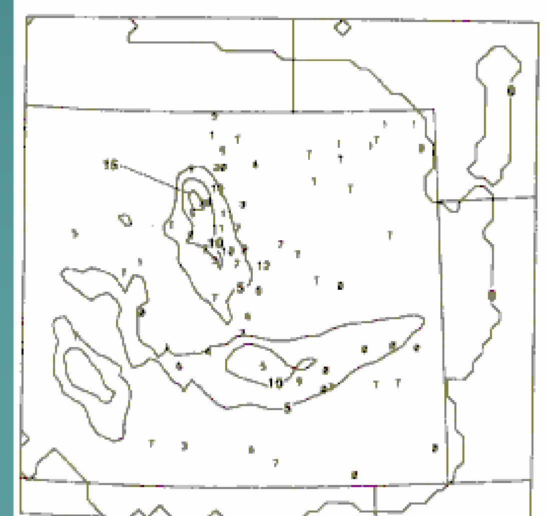


FIG. 10. Twelve-hour precipitation forecast produced by the NEM cloud physics algorithm, as in Fig. 5.

Summary

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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