WSM6 Microphysics Scheme

WRF Single-Moment 6-Class Scheme

Sarah Lynn Fingerle

Overview

- Background
- Elements
- Implementation

Background

WSM6 based on revised microphysics from the paper "A revised approach to ice-microphysical processes for the bulk parameterization of cloud and precipitation." by S. Hong

Background

2 major changes:

1) ice nuclei number concentration is a function of temperature

2) ice crystal number concentration is a function of ice amount

Background

Ice crystal number:

$$N_I\ (\mathrm{m}^{-3}) = c(\rho q_I)^d$$

Ice Nuclei Concentration:

$$N_{I0}(\mathrm{m}^{-3}) = 10^3 \exp[0.1(T_0 - T)]$$

Background

Adjusted variables:

1) Intercept parameter for snow (n_{0S})
2) Vapor Deposition of a small ice crystal $(Pisd)$
3) Accretion of cloud ice by snow $(Pacr)$
4) Conversion of ice crystals to snow $(Paut_I)$
5) sublimation and depositional growth of snow/evaporation of rain $(Pres)$
6) autoconversion of cloud water to rain $(Paut_C)$

Elements of WSM6

1) Mixing Ratio of Water Vapor
2) Cloud Water
3) Cloud Ice
4) Snow
5) Rain
6) ***<u>Graupel</u>***

Elements:

Information and Equations for the Graupel term taken from:

1) Lin et al (1983)
2) Rutledge and Hobbs (1984)
3) Houze et al (1979)
4) Locatelli and Hobbs (1974)

Interaction of all 6 terms based on Hong et al (2004)

Elements:

Graupel Particle Size:

$$n_G(D)dD_G[\mathrm{m}^{-4}] = n_{0G}\exp(-\lambda_G D_G)dD_G\,,$$

Elements:

Slope:

$$\lambda_G[\mathrm{m}^{-1}] = \left(\frac{\pi \rho_G n_{0G}}{\rho q_G} \right)^{0.25}$$

where:

$$n_{0G} = 4 \times 10^6 \ \mathrm{m}^{-4}$$

Elements:

Terminal Velocity:

$$V_{DG}[\mathrm{ms}^{-1}] = a_G D_G^{b_G} \left(\frac{\rho_0}{\rho} \right)^{\frac{1}{2}}$$

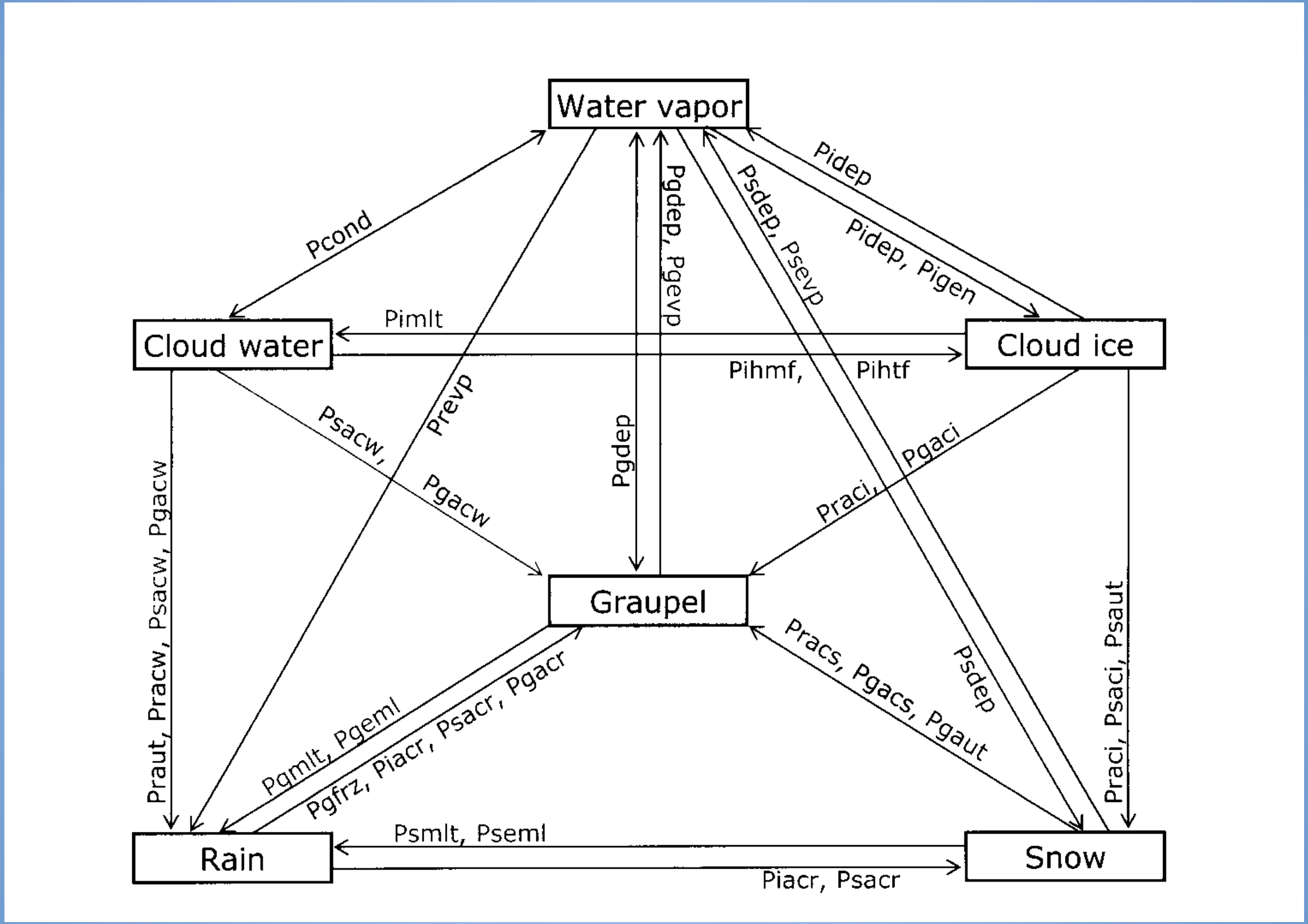
Mass-Weighted Terminal Velocity:

$$V_G[\mathrm{ms}^{-1}] = \frac{a_G \Gamma(4 + b_G)}{6} \left(\frac{\rho_o}{\rho} \right)^{\frac{1}{2}} \frac{1}{\lambda_G^{b_G}}$$

Elements:

Graupel Continuity Equation:

$$\frac{\partial q_G}{\partial t} = -\vec{V}\nabla_3 q_G - \frac{q_G}{\rho}\frac{\partial}{\partial z}(\rho V_G) + S_G$$



Water vapor
Cloud water
Cloud ice
Graupel
Rain
Snow
Pcond
Prevp
Pgdep, Pgevp
Pgdep
Psdep, Psevp
Pidep
Pidep, Pigen
Pimlt
Pihmf, Pihtf
Psacw, Pgacw
Praci, Pgaci
Praut, Pracw, Psacw, Pgacw
Praci, Psaci, Psaut
Pgmlt, Pgeml
Pgfrz, Piacr, Psacr, Pgacr
Pracs, Pgacs, Pgaut
Psdep
Psmlt, Pseml
Piacr, Psacr

Implementation

Computational Procedures:

Sedimentation of falling hydrometeors is computed first

therefore, precipitation does not cross more than one vertical level

Implementation

1) Sedimentation of falling hydrometeors
    - Fall-term Sub-step
        - freezing/melting computed

2) Microphysical processes

Implementation

All source/sink terms have a 120s time steps, regardless of the model's timestep

Implementation:

120s is reasonably close to the ideal 10s time step when:

1) sedimentation of hydrometers is considered 1st
2) melting snow & graupel computed inside the sedimentation loop

Experiments

1) Idealized Thunderstorm Experiment
2) Heavy Rainfall Experiment

Idealized Thunderstorm Experiment

1) Preset WRF model option
   a) 250 km grid spacing
   b) 80 vertical layers
   c) 60 mins
   d) 3 s time step

Thunderstorm Results

- storm structure was similar for all 3 schemes
- evolutionary features of the hydrometeors and precipitation activity was affected

1) amount of precipitation increases as the number of prognostic water substance variables increase
2) amount of volume-averaged water substance decreases as the number of variables increases
3) WSM6 has surface precipitation develop later with an increased storm intensity
    a) this is partially due to the presence of fewer hydrometeors because the WSM6 removes them

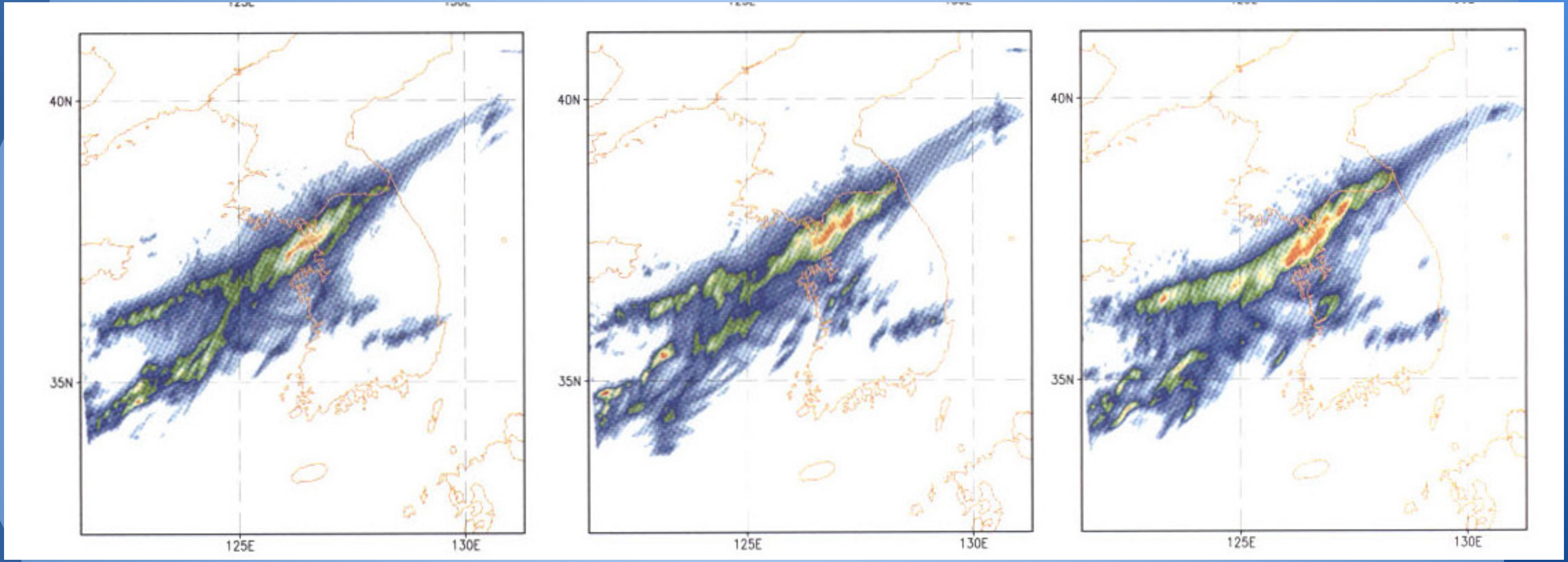
Heavy Rainfall Experiment

1) July 15th, 2001 over the Korean Peninsula
2) three grids: 5km, 15km, 45km

Heavy Rainfall Results

- All schemes underestimate maximum rainfall, WSM6 is closest
- When microphysics complexity increases, precipitation becomes 1) more localized and 2) more intense

Heavy Rainfall Results, con



5 km, 3-6 left to right

Heavy Rainfall Results, con

- WSM6 best mimics the observed event

- Low Resolution: number of variables has no effect
- High Resolution: maximum amount of precipitation and total amount of surface rain increases

Experiment Conclusions

The number of hydrometeors has a negligible impact at low resolutions, but a distinct impact at high resolutions.

Sensitivity Check

Sensitivity to graupel experiments performed, results show that graupel may not be the defining factor, but that the Hong microphysics may just be better

Future Development

In the future, work needs to be done on improving the equations, not on adding more variables

Usage

Option in the WRF model

Summation

- Background
- Elements
- Implementation

References

Hong,S., J. Dudhia, S.-H. Chen, 2004: A revised approach to ice-microphysical processes for the bulk parameterization of cloud and precipitation., *Mon. Wea. Rev.* **132**, 103-120

_______, J-O J. Lim, 2006: The WRF Single-Moment 6-Class Microphysics Scheme (WSM6)., *J Korean Met Society*. **42**, 129-151

_______, K-S Lim, J-H Kim, J-O J. Lim, J. Dudhia: WRF Single-Moment 6-Class Microphysics Scheme (WSM6). [short paper]

Reference sites:

1) http://journals.ametsoc.org/doi/pdf/10.1175/2010MWR3485.1
2) http://journals.ametsoc.org/doi/pdf/10.1175/2008JAMC1960.1
3) http://www2.mmm.ucar.edu/wrf/users/docs/WSM6-hong_and_lim_JKMS.pdf
4) http://www2.mmm.ucar.edu/wrf/users/workshops/WS2006/abstracts/PSession05/P5_4_Hong.pdf
5) http://nldr.library.ucar.edu/repository/assets/osgc/OSGC-000-000-019-391.pdf

Questions?