Representations of clouds and precipitation:
- Bulk parameterizations: Calling sequence, processes
- Examples: Comparison, process omission

Convective parameterization paper summaries (first ~4)

Reminders/announcements:
- Upcoming: MP papers and experiments
- Plan to grade midterms soon, CP paper summaries first
Re-Cap from Tuesday

Even simplest microphysical representations require knowledge of the particle size distribution.

Representation with bin schemes is too computationally expensive to be run operationally.

Observations reveal inverse exponential fit to size distributions (Marshall and Palmer 1948).

Bulk representations exploit this relation, with additional shape/dispersion options to represent additional complexities.

Single, double, and triple moment schemes allow for increasingly diverse size distribution representation.
Results: Funding Decisions

Using average student rankings: Hans and Keith ranked highest

Using student “funding recommendations”: Laura and Keith had most votes to fund

I’ll summarize comments and return them to you ASAP, probably before Monday
Parameterization of cloud and precipitation

Marshall and Palmer (1948) recognized simple analytical form of typical size distributions of rain, snow, graupel, and hail

Suggested constant intercept, slope a function of rain rate (shown here)

August 1948

SHORTER CONTRIBUTIONS

THE DISTRIBUTION OF RAINDROPS WITH SIZE

*By J. S. Marshall and W. McK. Palmer*

McGill University, Montreal
(Manuscript received 26 January 1948)

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![Graph](image)

**Fig. 2.** Distribution function (solid straight lines) compared with results of Laws and Parsons (broken lines) and Ottawa observations (dotted lines).
Single-moment bulk

Mean particle diameter is related to $\lambda^{-1}$
**Bulk method: Single, double, triple moment**

Approaches to predicting the evolution of $N(D)$:

<table>
<thead>
<tr>
<th>Single-moment</th>
<th>Double-moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predict $q$ (or $N_t$)</td>
<td>Predict both $q$ and $N_t$</td>
</tr>
<tr>
<td>$N_0 = N_0(q)$</td>
<td>$N_0 = N_0(q, N_t)$</td>
</tr>
<tr>
<td>$\lambda = \lambda(q)$</td>
<td>$\lambda = \lambda(q, N_t)$</td>
</tr>
</tbody>
</table>

$[N_t$ (or $q$) is diagnosed]

Single moment: Scale parameter, $\alpha$, is held constant, intercept also in many schemes

Double moment: Scale still held constant, but intercept and slope are allowed to vary

**Triple-moment** schemes also predict the scale parameter (or other)

\[ N(D) = N_0 D^\alpha e^{-\lambda D} \]
Single versus Double Moment Schemes:

Single moment (e.g. Lin scheme, “WSM” schemes):
- Size distribution specified by 1 variable (q, could be $N_t$)
- Number concentration (n), mean drop size both increase monotonically as function of q (mixing ratio)

Double moment (e.g., Thompson in WRF- for ice, “WDM” schemes in WRFV3.2 and higher, Millbrandt-Yau, Morrison):
- Uses 2 variables to represent distribution (e.g., q, n)
- Because q, n can vary independently, better and more diverse representation
Microphysics Section Outline

• Basics of microphysics schemes
  – MP scheme “responsibilities”
  – Distinguishing characteristics: Classes, Distribution, & Processes
  – Why classes matter: Hurricane example
  – Representation of number concentration: Bin vs. Bulk
  – Single, double, and triple moment schemes

• The WRF schemes
  – Calling sequence
  – Defining characteristics: Warm and cold-cloud processes
  – Scheme details: CCN, process representation

• Model simulated radar

• Case-study examples:
  – Winter storm
  – Convective storm
  – Tropical cyclone
Which of the following processes contributes the least to model error in quantitative precipitation forecasting?

- Representation of temperature advection
- Representation of the initial moisture field
- Representation of regions of lower tropospheric lift or convergence
- The model grid-scale precipitation scheme
- Model convective parameterization scheme
- Model planetary boundary layer scheme
Microphysics

• Why? **Vertical motions** often erroneous, but when not, moisture conservation handles vapor removal accurately

• Precipitation parameterization scheme less important than forcing parameters (vertical motion, moisture, temperature advection)- essentially driven *by* them

• Forcing fields most critical to precipitation forecasts- If erroneous, model precipitation forecast *cannot* be accurate

• Precipitation parameterizations determine how model precipitation distributed in space and time, but constrained
How do MP schemes actually work?

WRF physics calling sequence (simplified):

1.) Radiation (on theta, $T_{\text{skin}}$)
2.) LSM (on soil, skin)
3.) PBL
4.) CP scheme
5.) Dynamics – advection, diff.
6.) Microphysics

• Microphysics called last to prevent unrealistic supersaturation on grid

• Also consider that most physics routines are not called every time step, tendencies distributed between calls
How do MP schemes actually work?

Generic hydrometeor mixing ratio tendency equation:

\[
\frac{\partial q_x}{\partial t} = -\vec{U} \cdot \nabla q_x - \frac{1}{\rho} \frac{\partial V_{qx}}{\partial z} + S - \frac{1}{\rho} \nabla \cdot F_{qx} \tag{1}
\]

1a = local tendency
1b = grid-scale advection
1c = vertical hydrometeor flux divergence
1d = sources and sinks (e.g., melting is sink for snow; could have sources outside of MP, e.g., KF detrainment)
1e = turbulent (or convective) flux divergence

(multiple contributions) (outside MP) (only within MP)
How do MP schemes actually work?

Inputs: Grid-scale fields (T, mixing ratios for vapor, classes)

For WSM schemes:

ia.) Compute size distribution (will break down i. next slide)

ib.) Compute terminal velocity, sedimentation (really, fall)
   - Split time step: Hydrometeors can’t fall more than 1 vertical level per time step (CFL)
   - Determine vertical precipitation fluxes

ii.) Compute production/exchange terms (processes)
   - condensation/deposition, evaporation/melting, freezing/melting, etc.

iii.) Compute tendencies
   - T, vapor
   - Hydrometeor mixing ratios
How do MP schemes actually work?

i.) Compute size distribution (e.g., WSM6)

a.) Start with $q_x$ from dynamics, + other fields; includes advection but not yet sedimentation

b.) Intercept is specified (or diagnosed) for class (e.g., in WSM6, $N_{0\text{rain}} = 8E6 \text{ m}^{-4}$)

c.) Diagnose slope parameter from intercept, mixing ratio

d.) Compute terminal velocity

e.) Sedimentation loop using fall velocity

f.) Microphysical processes – after sedimentation, weaker tendencies
**WSM6 (Hong and Lim 2006)**

**Fig. 1.** Flowchart of the microphysics processes in the WSM6 scheme. The terms with red (blue) colors are activated when the temperature is above (below) 0 °C, whereas the terms with black color are in the entire regime of temperature.
BULK METHOD

**Typical double-moment method:**

\[ N_x(D) = N_{0x} D^{\alpha_x} \exp(-\lambda_x D) \]

Predict changes to \( Q_x \) and \( N_{Tx} \)

Implies changes to values of the \( N_{0x} \) and \( \lambda_x \)

\((\alpha_x \text{ is held constant})\)
Alternative bulk methods:

\[ N_x (D) = N_{0x} D^{\alpha_x} \exp\left(-\lambda_x D\right) \]

1. **Diagnostic-\(\alpha_x\) (double-moment)**
   - \(\alpha_x = f (Q_x, N_{Tx})\)

2. **Prognostic-\(\alpha_x\) (triple-moment)**
   - a third moment must be predicted
   e.g. add \(\frac{dZ_x}{dt}\) equation
For the prediction of $N_T$, $Z$, and $D_m$, the various bulk methods exhibit similar relative abilities for pure sedimentation (as for $Q$).

**NOTE:**
- No size-sorting mechanism exists for single-moment schemes
- For the double-moment scheme with $\alpha = 0$, excessive size-sorting results in very large $D_m$ and $Z$
CONTROL SIMULATION

MODEL:
Canadian MC2 mesoscale model (similar to WRF)
- non-hydrostatic, fully compressible
- interfaced with new microphysics scheme
  (triple-moment version for CONTROL run)

CASE:
14 July 2000 “Pine Lake storm”, Alberta, Canada
- long-lasting supercell
- F3 tornado
- golf ball-sized hail
CONTROL SIMULATION: Nesting Strategy

NOTE: No CPS, perturbation, nudging (or anything else) was used to initiate the convection.
CONTROL SIMULATION: Accumulated Total Precipitation

RADAR: Accumulated Precipitation

1-km SIMULATION: Accumulated TOTAL Precipitation

1-km CNTR
CONTROL SIMULATION: Hail Swath

RADAR:
Composite of Maximum VIL
VIL > 27 kg m$^{-2}$ $\Rightarrow$ LARGE HAIL

1-km SIMULATION:
Accumulated SOLID Precipitation

1-km CNTR

10 mm
CONTROL SIMULATION: Storm Structure: REFLECTIVITY

RADAR:
0030 UTC [6:30 pm]  
Maximum: 60 – 65 dBZ

1-km SIMULATION:
4:30 h [6:30 pm]  
Maximum: 63.6 dBZ
List of Runs:

1. **TRIPLE-MOMENT** (control run)

2. **DOUBLE-MOMENT** with **DIAGNOSED-**$\alpha$

3. **DOUBLE-MOMENT** with **FIXED-**$\alpha$
   
   ($\alpha = 2$ for $r$; $0$ for $c, i, s, g, h$)

4. **SINGLE-MOMENT** (similar parameters as Lin et al. 1983)

**ALL RUNS USE DIFFERENT VERSIONS OF THE SAME SCHEME**
SENSITIVITY EXPERIMENTS: TOTAL Precipitation

6-h ACCUMULATED TOTAL PRECIPITATION [mm]

TRIPLE-MOMENT

DOUBLE-MOMENT Diagnosed $\alpha$

SINGLE-MOMENT

DOUBLE-MOMENT Fixed $\alpha$

CONTOURS: 5, 10, 20, 30, 40 mm
SENSITIVITY EXPERIMENTS: SOLID Precipitation (HAIL)

6-h ACCUMULATED SOLID PRECIPITATION [mm]

TRIPLE-MOMENT

DOUBLE-MOMENT
Diagnosed $\alpha$

SINGLE-MOMENT

DOUBLE-MOMENT
Fixed $\alpha$

CONTOUR INTERVAL: 2 mm
SENSITIVITY EXPERIMENTS: Equivalent Hail Reflectivity,

Local time: 6:30 pm
(Simulation time: 4:30 h)

TRIPLE-MOMENT

SINGLE-MOMENT

DOUBLE-MOMENT

Diagnosed $\alpha$

Fixed $\alpha$

MAXIMUM VALUE
SENSITIVITY EXPERIMENTS: Hail Mass Content,

Local time: 6:30 pm
(Simulation time: 4:30 h)

TRIPLE-MOMENT 5.51 g m\(^{-3}\)

DOUBLE-MOMENT
Diagnosed \(\alpha\) 5.58 g m\(^{-3}\)

SINGLE-MOMENT 3.71 g m\(^{-3}\)

DOUBLE-MOMENT
Fixed \(\alpha\) 4.91 g m\(^{-3}\)

Dashed contour: 0.1 g m\(^{-3}\)

MAXIMUM VALUE
SENSITIVITY EXPERIMENTS: Hail Number Concentration

log $N_{Th} \, [m^{-3}]$

Local time: 6:30 pm
(Simulation time: 4:30 h)

TRIPLE-MOMENT 5.18

DOUBLE-MOMENT
Diagnosed $\alpha$

SINGLE-MOMENT 1.53

DOUBLE-MOMENT
Fixed $\alpha$

MAXIMUM VALUE

Dashed contour: 1.0 m$^{-3}$
SENSITIVITY EXPERIMENTS:  

**Mean Hail Diameters**,  

Local time: 6:30 pm  
(Simulation time: 4:30 h)

- **TRIPLE-MOMENT**  
  - 14.9 mm

- **SINGLE-MOMENT**  
  - 6.15 mm

- **DOUBLE-MOMENT**
  - Diagnosed \(\alpha\)  
  - 11.2 mm

- **DOUBLE-MOMENT**  
  - Fixed \(\alpha\)  
  - 67.2 mm

MAXIMUM VALUE

\(D_{mh} \text{ [mm]}\)
CONCLUSIONS

1. The value of the shape parameter is important in bulk microphysics schemes

2. For the overall QPF, storm structure, hydrometeor values, and the simulation of hail sizes:

\[
\begin{align*}
\text{SINGLE-MOMENT} & \ll \text{DOUBLE-MOMENT} \\
& \text{Fixed } \alpha \\
& \ll \text{DOUBLE-MOMENT} \\
& \text{Diagnosed } \alpha \\
& \leq \text{TRIPLE-MOMENT}
\end{align*}
\]
From Jason Milbrandt, 3/24/2016:

…My play for the MY2 scheme (2-moment version) in WRF (and GEM) is to make one final upgrade, combining the diagnostic shape parameter plus the prognostic graupel density (Milbrandt and Morrison, 2013, JAS). Hopefully I would get this in for the spring 2017 WRF release, but of course I could always provide early versions of the code.

The variable-alpha does not add much extra cost, but unfortunately it would at this point require a bit of code rearranging; it's not just flipping a switch at the moment. It's funny -- I made a big deal of it at the time, and I still think it is important, but then I did not actually ensure that that option made its way into the official scheme (public WRF) version. But it shall be done before I do the final upgrade to that scheme.

To elaborate on that last point, Hugh Morrison and I have developed a new bulk microphysics scheme which we call P3 (Predicted Particle Properties)*. It is a new way of treating the ice phase, in which we completely abandon the idea of pre-defined ice-phase categories and have one or more "free" categories, with 4 prognostic variables each. This actually allows us to model any kind of ice-phase hydrometeor but without the necessity of the artificial "conversion" between categories. We are completely convinced that this is the way to go forward (and it's computationally very efficient). BTW, P3 has a diagnostic shape parameter, but currently we're working on expanding it to 3-moment (prognostic shape parameter). So, it's a bit hard to spend time advancing or even maintaining my original MY2 scheme -- but I still want the final official version to include all the nice features I developed over the years -- so it shall be done..
Updated reference list on MEA 716 page

### Microphysics Scheme Sample References

<table>
<thead>
<tr>
<th>Reference</th>
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<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lin et al. 1983</td>
<td>Hong and Lim 2006 (WSM6)</td>
<td>Hong et al. 2010 (WDM6)</td>
<td>Lin and Colle (SBU YLin)</td>
</tr>
<tr>
<td>Milbrandt Yau Part 1</td>
<td>Milbrandt Yau Part 2</td>
<td>Milbrandt Yau Part 3</td>
<td>Tao et al. (1989) (Goddard)</td>
</tr>
<tr>
<td>Morrison and Milbrandt new P3 scheme (part 2)</td>
<td>Milbrandt and Morrison new P3 scheme (part 3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Reading on topic of model resolution:

- L. Grasso, on Resolution
- Comments and Replies on Grasso
- Weisman et al. 1997 resolution
- Bryan et al. 2003 resolution requirements

### Lecture Notes:

<table>
<thead>
<tr>
<th>Day 1 pdf (Th 1/7/16)</th>
<th>Day 2 pdf (Tu 1/19/16)</th>
<th>Day 3 pdf (Th 1/21/16)</th>
<th>Day 4 pdf (Tu 1/26/16)</th>
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<tbody>
<tr>
<td>Day 17 pdf (Th 3/17/16)</td>
<td>Day 18 pdf (Tu 3/22/16)</td>
<td></td>
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</tbody>
</table>
## Student CP paper presentations + experiments

<table>
<thead>
<tr>
<th>Student</th>
<th>Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pat</td>
<td>Grell-Freitas (2014)</td>
</tr>
<tr>
<td>Masih</td>
<td>Zheng et al. (2016) – MSKF scheme</td>
</tr>
<tr>
<td>Hans</td>
<td>Zhang et al. (2011) – Tiedtke scheme</td>
</tr>
<tr>
<td>Laura</td>
<td>Han and Pan (2006) – SAS</td>
</tr>
<tr>
<td>Lindsay</td>
<td>Ma and Tan (2009) – KF trigger</td>
</tr>
<tr>
<td>James</td>
<td>Grell (‘93) and Grell and Devenyi (‘02)</td>
</tr>
<tr>
<td>Xia</td>
<td>Han and Pan 2011 – SAS updated</td>
</tr>
<tr>
<td>Keith</td>
<td>Molinari and Dudek ‘93 - (explicit conv.)</td>
</tr>
</tbody>
</table>
The Grell-3D Cumulus Scheme:

Grell (1993), Grell and Devenyi (2002), and performance in the Winter storm 2016 case study

Summary by James Russell
MEA716
Grell Papers and Scheme

Grell (1993):
Cumulus framework:
• Dynamic control – modulation of convection by environment
• Feedback – modulation of the environment by convection
• Static control – cloud model used to determine cloud properties

Examined closure issues and developed simple scheme
• Single cloud, mass flux scheme
• Avoid issues from moisture convergence closure, weak downdrafts, lateral mixing.

Grell and Devenyi (2002)
• Ensemble of various closure assumptions and trigger functions

---

Grell (1993) Table 1: Overview of experiments

<table>
<thead>
<tr>
<th>Experiment name</th>
<th>Dynamic control</th>
<th>Feedback and static control</th>
</tr>
</thead>
<tbody>
<tr>
<td>DQEU</td>
<td>quasi-equilibrium assumption</td>
<td>( \frac{dAB}{dt} \bigg</td>
</tr>
<tr>
<td>DFC</td>
<td>instantaneous stability</td>
<td>( \frac{dAB}{dt} \bigg</td>
</tr>
<tr>
<td>DKUO</td>
<td>moisture convergence</td>
<td>( R = -\int \omega \frac{\partial q}{\partial p} dp )</td>
</tr>
<tr>
<td>FDD0</td>
<td>no downdrafts</td>
<td>( \beta(t) = 0 )</td>
</tr>
<tr>
<td>FDD1</td>
<td>weaker downdrafts</td>
<td>( \beta(t) = \beta(t) - 0.1 )</td>
</tr>
<tr>
<td>FDDS</td>
<td>stronger downdrafts</td>
<td>( \beta(t) = \beta(t) + 0.1 )</td>
</tr>
<tr>
<td>FLM</td>
<td>strong lateral mixing</td>
<td>( \lambda_{d}(t) = \lambda_{d}(t) )</td>
</tr>
<tr>
<td>DONE</td>
<td>rate of destabilization</td>
<td>no lateral mixing</td>
</tr>
</tbody>
</table>

Grell and Devenyi (2002) Table 1: Overview of ensembles

<table>
<thead>
<tr>
<th>Name</th>
<th>Part of Parameterization</th>
<th>Varied Parameter</th>
<th>Number of Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edyn1</td>
<td>dynamic control</td>
<td>larger-scale forcing tendencies</td>
<td>3</td>
</tr>
<tr>
<td>Edyn2</td>
<td>dynamic control</td>
<td>A (buoyancy)</td>
<td>4</td>
</tr>
<tr>
<td>Edyn3</td>
<td>dynamic control</td>
<td>dtc (time scale)</td>
<td>3</td>
</tr>
<tr>
<td>Edyn4</td>
<td>dynamic control</td>
<td>b (moistening)</td>
<td>3</td>
</tr>
<tr>
<td>Edyn5</td>
<td>dynamic control</td>
<td>( l_{T} ) (LCL)</td>
<td>3</td>
</tr>
<tr>
<td>Ef1</td>
<td>static control/feedback</td>
<td>\beta (precip. efficiency)</td>
<td>6</td>
</tr>
<tr>
<td>Ef2</td>
<td>static control/feedback</td>
<td>\mu_{ad}(z, \lambda) (detrainment)</td>
<td>4</td>
</tr>
<tr>
<td>Ef3</td>
<td>static control/feedback</td>
<td>\mu_{we}(z, \lambda) (entrainment)</td>
<td>6</td>
</tr>
<tr>
<td>Ef4</td>
<td>static control/feedback</td>
<td>\mu_{st}(z, \lambda) (detrainment)</td>
<td>6</td>
</tr>
</tbody>
</table>

The 16 Edyn closures are allowed to interact with any of the other closures, giving a total of 13824 ensemble members (16 x 6 x 4 x 6 x 6).
Grell Papers and Scheme

Grell and Devenyi (2002)...
• PDFs instead of averages (means etc.) to obtain feedback to model

Later additions
• Compensating subsidence in surrounding grid points
• Horizontal and vertical smoothing of tendencies

Current
• 144 member ensemble
• Use averages (not PDFs) for feedback

Physical processes
• "Grey zone" (5-20km) simulations due to 3D subsidence
• Probably not so good for climate simulations where subsidence would all occur in single grid cell
Forecast Comparison

Expectation:
• Grell likely smoothed out due to averaging of ensemble
• Grell has more but weaker widespread precipitation due to spreading of subsidence

Differences:
• Convective precipitation more widespread using Grell than using BMJ
• Convective precipitation stronger in SE using Grell than using BMJ
• Grid scale precipitation similar over land but reduced over ocean using Grell
• Grell is greedier than BMJ – more precip. from CP than MP scheme
CP Tendencies

26.5 PaK/s isosurface

Differences:

• Field is smoothed (less noise) likely due to the averaging of an ensemble (if only a few members show something the convective tendency will be much)

• Convective tendencies deeper in Grell than in BMJ – not expected

• BMJ had shallow convective tendencies persist along the Gulf coast long after the cold front passed through while Grell did not
Summary

Grell 3D Features:
• Single cloud CRM
• Mass Flux scheme
• Avoids closure issues noted in Grell (1993)
• 144 member ensemble
• Various closure and trigger functions
• 3D subsidence

Performance
• Ensemble smooths fields
• Convective rainfall more widespread
• Less rainfall from microphysics
• Unexpected – deeper convective theta tendencies
A scale and aerosol aware stochastic convective parameterization for weather and air quality modeling

Grell and Freitas 2014

Presented by Patrick Hawbecker
3/17/2016
Grell-Freitas scheme

• Objectives:
  – “Address grey scale issue” (i.e. scale aware)
  – “Transport of chemical constituents”
  – “Possible interactions with aerosols”
    • Microphysical processes
    • A so-called “aerosol aware” scheme

• Mass-flux, ensemble scheme
  – Chose ensemble to yield biggest “bang for the buck”
Aerosol Effect

- Aerosol information given through parameterized CCN
  [Rosenfeld et al. (2008) and Andreae et al. (2008)]
  - Other, more complex methods are available
- CCN effects are available
  - Cloud water → rain water
  - Evaporation efficiency of rain

Aerosol effects:
- Decrease rainfall
- Increase cloud water and ice at the top of the column
Advantages

• Developed with “grey-zone” simulations in mind
  – Useful when transitioning from coarse to fine-scale simulations
  – Do not necessarily need to “turn-off” when under 4 km

• Aerosol effects are considered
  – Seems to be more climate-based, but it sounds like the aerosol data can be changed / manipulated

• Mass-flux scheme – not as active as BMJ, or other adjustment schemes
RAINC Comparison

CONTROL

GRELL-FREITAS
RAINNC Comparison

![Comparison of RAINNC models](image)
Introduction & Methods

• Need for the model
  • Canadian Climate Centre GCM uses adjustment scheme
  • Deficiencies noted in simulated climate, especially in tropics
• Scheme uses concepts from Arakawa and Schubert (AS) scheme to represent an ensemble of cumulus clouds
• 3 assumptions
  • When unstable in lower troposphere, updraft ensemble is defined by plumes sufficiently buoyant to penetrate the unstable layer
  • All such plumes have the same upward mass flux at base of convective layer
  • Convection acts to remove CAPE at exponential rate for a specified time scale
Results & Conclusions

• Results differ from CCC GCM adjustment scheme
  • Cooler temperatures in upper troposphere
  • Cold anomaly in tropics from adjustment scheme is removed
  • Reduced cloudiness in lower troposphere and more in upper troposphere
  • Surface energy budget: increased net downward radiative flux in tropics and decreased in high latitudes

• Corrects some significant biases, but undesirable features exist
  • Radiation budget changes leads to cooler surface
  • Biased toward deep convection
CP Tendencies

* Could not decouple, couldn’t figure out how to divide 3D field by 2D field in IDV

• **U CP tendencies**
  • Mostly positive below and mostly negative aloft

• **V CP tendencies**
  • Same as *U*, but more positive values aloft

• **TH CP tendencies**
  • Heating aloft, cooling below

• **Qv CP tendencies**
  • *Some* negative below, mostly positive and smaller values
Improving High-Resolution Weather Forecasts Using the Weather Research and Forecasting (WRF) Model with an Updated Kain-Fritsch Scheme

Zheng et. al (2016)
Monthly Weather Review

Motivation: Reducing excessive precipitation within highly energetic convective systems in WRF
Primary Goal: Including the effects of parameterized scale-aware cloud dynamics in high resolutions
Secondary Goal: Sensitivity analysis to initial condition and microphysics
Methods and Improvements

• Areas improved:
  – Subgrid-scale cloud-radiation interactions
  – Dynamic adjustment time scale
  – Impacts of cloud updraft mass fluxes on grid-scale vertical velocity
  – Lifting condensation level-based entrainment that include scale dependency

• Methods
  – Southern Great Planes (SGP) 48-hour forecasts
  – 2-way nested domains 3 and 9 km grid spacing
  – a) No cumulus scheme b) Old KF c) Updated KF
  – Microphysics: Double moment 6 class scheme and Goddard
  – Two initial condition from
Results and other notes

• The excessive rainfall amounts are reduced.
• High-resolution simulation of longwave and shortwave radiation interaction with clouds are improved.
• Precipitation patterns and intensity that are closer to the observation.
• In this study, sensitivity analysis show that precipitation forecasts are more sensitive to the initialization than to grid scale microphysics or convective treatments.
• The model runs only with YSU planetary boundary layer.
RTHCUTEN and RQVCUTEN

MSKF

BMJ