Convective Parameterization Options in WRF V3.4

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NCAR/NESL/MMM
## Cumulus schemes in V3.4

<table>
<thead>
<tr>
<th>cu_physics</th>
<th>Scheme</th>
<th>Cores</th>
<th>Moisture Tendencies</th>
<th>Momentum Tendencies</th>
<th>Shallow Convection</th>
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<tr>
<td>1</td>
<td>Kain-Fritsch Eta</td>
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<td>Qc Qr Qi Qs</td>
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<td>2</td>
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Kain-Fritsch (KF)

- As in MM5 and Eta/NMM ensemble version
- Includes shallow convection
- Low-level vertical motion in trigger function
  - Also new Ma-Tan trigger option with perturbation based on local average moisture advection (kfeta_trigger=2)
- CAPE removal time scale closure
- Mass flux type with updrafts and downdrafts, entrainment and detrainment
- Includes cloud, rain, ice, snow detrainment
- Clouds persist over convective time scale (recalculated every convective step in NMM)
- Old KF is also an option in WRF
Betts-Miller-Janjic (BMJ)

- As in NMM (NAM) operational model (Janjic 1994)
- Adjustment type scheme
- Deep and shallow profiles
- BM saturated profile modified by cloud efficiency, so post-convective profile can be unsaturated in BMJ
- No explicit updraft or downdraft
- No cloud detrainment
- Scheme changed significantly since V2.1
Grell-Devenyi Ensemble (GD)

- Used in Rapid-Refresh operational model (NOAA/ESRL)
- Multiple-closure (CAPE removal, quasi-equilibrium, moisture convergence, cloud-base ascent) - 16 mass flux closures
- Multi-parameter (maximum cap, precipitation efficiency) - e.g. 3 cap strengths, 3 efficiencies
- Explicit updrafts/downdrafts
- Includes cloud and ice detrainment
- Mean feedback of ensemble is applied
- Weights can be tuned (spatially, temporally) to optimize scheme (training)
Simplified Arakawa-Schubert (SAS)

- Used in operational HWRF hurricane model
- Quasi-equilibrium scheme
- Related to Grell scheme in MM5
- Random cloud top
- Includes cloud and ice detrainment
- Downdrafts and single, simple cloud
- Shallow convection is by enhanced mixing (in ARW only)
- Part of HWRF physics in NMM up to V3.3
- Momentum transport in NMM only
Grell-3d (G3)

• As GD, but slightly different ensemble (for RR model)
• Includes cloud and ice detrainment
• Subsidence is spread to neighboring columns
  – This makes it more suitable for < 10 km grid size than other options
  – cugd_avgdx=1 (default), 3 (spread subsidence)
• ishallow=1 option for shallow convection
• Mean feedback of ensemble is applied
• Weights can be tuned (spatially, temporally) to optimize scheme (training)
Tiedtke (TDK)

U. Hawaii version
• Mass-flux scheme
• CAPE-removal time scale closure
• Includes cloud and ice detrainment
• Includes shallow convection
• Includes momentum transport
• New in V3.3
• V3.4 changes entrainment/detrainment adds trigger choice (moisture convergence or dilute parcel testing)
Zhang-McFarlane (ZM)

CAMZM scheme
• Mass-flux scheme
• CAPE-removal time-scale closure
• From current CESM 1.0 climate model physics
• Includes cloud and ice detrainment
• Includes momentum transport with pressure term
• New in V3.3
New SAS (NSAS)

• Quasi-equilibrium scheme
• Updated from SAS for current NCEP GFS global operational model
• Includes cloud and ice detrainment
• Downdrafts and single, simple cloud (no random top)
• New mass-flux type shallow convection (changed from SAS)
• Momentum transport with pressure-gradient term
• New in V3.3
• In V3.4 there is also an HWRF version of this
Bretherton-Park Shallow Cu

CAM UW shallow convection (Bretherton and Park, U. Washington)

• To be used with a TKE PBL scheme and a deep scheme with no shallow convection (e.g. CESM Zhang-McFarlane)
• From current CESM climate model physics
• Shallow convection driver added in V3.3
• Other options such as Grell ishallow to be moved here in the future
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Tests with V3.3 (April 2011)

• A mid-latitude US continental convection case for 11-12 June 2011 at 12 km grid size, 24 h run plus a 3 km explicit-only simulation

• Tropical TWP-ICE mostly oceanic active monsoon case for January 22-25 2006 at 27 km, 72 h run

• Compare heating and precipitation characteristics
  – Heating profile (convective and total)
  – Precipitation (convective, non-convective fractions)
  – Precipitation bin histograms (convective, non-convective)
12 hour Total Precipitation

Obs (ST4)  
KF  
BMJ  
G3  
Tiedtke  
NSAS  
SAS  
ZM
Domain-Averaged Precipitation Forecasts

Ratio of conv / total precip  3 h precip

12km, convective/total precip

12km, total precip rate (mm/3hr)

CAMZM  BMJ  KFETA  NSAS  SAS  TIEDTKE  TRIGGER  G3
Ratios of Convective / Total Precip Over Precip Bins

![Graph showing ratios of convective to total precipitation over precipitation bins for different categories like NSAS and ZM. Each category is represented by a different color and symbol.](image-url)
Domain- and Time-Averaged Heating and Moistening Profiles

T, convective

T, total

Qv

ATHCU (unit: k)

ATHMP + ATHCU (unit: k)

ADVU (x 1E5, unit: kg/kg)

CAMZM

BMJ

KFETA

NSAS

SAS

TIESTKE

TRIGGER

G3

ZM

NSAS
12 h total precipitation

observed

explicit

with CPS
Domain-Averaged Heating Profiles
From Various CPS and Cloud-Resolving Runs
Mid-latitude at 12 km

Tropical/Sub-tropical at 27 km
Mid-lat 12 km

Tropical / sub tropical 27 km

Precipitation Intensity Areas

24 hr precip bins
Ratios of Convective / Total Precip Over Precip Bins

Mid-Latitude

Tropical / Sub-tropical

NSAS

ZM

SAS

KF
Domain-Averaged Heating Profiles

Mid-lat

Tropical / sub tropical

G3+shallow

ZM + shallow
Summary

• Wide distribution of convective versus non-convective rainfall fractions
• Despite this, similar total rainfalls, patterns, and heating profiles
• Some outliers evident seen in both US and TWP
  • ZM, Tiedtke: low convective fraction and heating rate
  • ZM: no intense convective precip (all non-convective)
  • G3, NSAS: high convective fraction and heating top
  • G3: high precip and heating rate (tropical)[reduced in V3.3.1]
  • NSAS: high convective heating and drying rate (mid-lat)
  • SAS, BMJ: high upper total heating rate
  • BMJ: effect of no detrained cloud seen in heating profile