Chapter 8: Part II: Physics Options in MM5

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MM5 Physics

- Cumulus Parameterizations
- Planetary Boundary Layer/Vertical Diffusion
- Horizontal Diffusion
- Explicit Moisture/Microphysics
- Radiation
- Surface Schemes

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Cumulus Schemes

- Represent sub-grid scale vertical fluxes and rainfall due to convective clouds
- Generally produce column moisture and temperature tendencies and surface convective rainfall
- May also produce column cloud tendencies (KF schemes)
- Require trigger to determine where convection activates, and closure to determine strength

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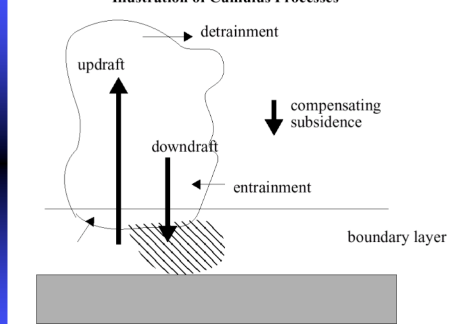
Illustration of Cumulus Processes



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Cumulus schemes (ICUPA)

- None
- Anthes-Kuo
- Grell
- Arakawa-Schubert
- Fritsch-Chappell
- Kain-Fritsch
- Betts-Miller
- Kain-Fritsch 2

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None

- No cumulus scheme required if grid size is sufficient to resolve updrafts and downdrafts
- May apply to grid lengths less than 5 km

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Anthes-Kuo

- Oldest scheme in model
- Moisture convergence closure
- Specified heating profile
- Moistening depends on environment RH
- Applicable to larger grid sizes (> 30 km)

Grell

- Rate of destabilization closure (quasi-equilibrium)
- Single updraft and downdraft properties
- Mass-flux type scheme with compensating subsidence
- Suitable for most grid sizes down to 5 km

Arakawa-Schubert

- Quasi-equilibrium closure
- Requires a library (not portable from Cray very easily)
- Multi-cloud scheme with updrafts and downdrafts (added by Grell to original scheme)
- Suitable for larger grid sizes

Fritsch-Chappell

- Old scheme: forerunner to Kain-Fritsch
- Based on releasing instability (CAPE) over a given time scale
- Updrafts and downdrafts represented
- Mass-flux type scheme with compensating subsidence
- Perhaps suitable for 20-30 km grids
- Not used much since KF scheme became available

Kain-Fritsch

- Uses sophisticated cloud-mixing scheme to determine updraft/downdraft properties
- Releases CAPE in a given time scale
- Mass-flux scheme
- Also can detrain cloud and precipitation in addition to vapor

Betts-Miller

- Relaxation adjustment to a post-convective mixed sounding in a given time scale
- More suited to tropics but can be used anywhere. (Comes from Eta model BMJ scheme)
- No explicit downdrafts (some surface cooling due to adjustment)

Kain-Fritsch 2

- New scheme as of MM5 v3.5
- Adds shallow convection and other improvements to KF scheme

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Shallow convection (ISHALLO=1)

- May help PBL-top clouds to mix
- Not clear cost of this scheme is justified by its small effect on results
- Adapted from Grell scheme
- Updrafts with high entrainment rate
- Driven by PBL tendencies only (not total rate of destabilization)

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Planetary Boundary Layer Schemes

- Represent sub-grid vertical fluxes due to turbulence. Mostly distinguished by treatment of the unstable boundary layer.
- Generally provide column tendencies of heat, moisture and momentum
- May provide cloud tendencies
- Surface layer, boundary layer, and free atmosphere
- Interacts with fluxes from surface scheme
- Provides frictional effects on momentum

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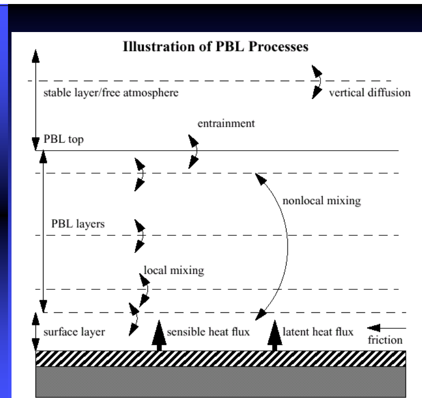

Planetary Boundary Layer Schemes (IBLTYP)

- Bulk PBL
- High-Resolution (Blackadar) PBL
- Burk-Thompson PBL
- Eta PBL
- MRF PBL
- Gayno-Seaman PBL
- Pleim-Chang PBL

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Bulk PBL

- Designed for coarse vertical resolution (dz > 250 m)
- Stable and unstable regimes
- Bulk aerodynamic drag and exchange coefficients

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High-resolution (Blackadar) PBL

- Suitable for multi-layer PBL (e.g. 5 layers in lowest km)
- Four stability regimes
- Unstable regime has nonlocal mixing between surface layer and all other layers in PBL
- PBL depth determined from temperature profile
- Entrainment at PBL top due to overshooting thermals
- Monin-Obukhov similarity theory for surface exchange coefficients

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Burk-Thompson PBL

- Also known as Navy PBL
- Mellor-Yamada scheme
- Predicts turbulent kinetic energy
- Local vertical mixing
- Has its own force-restore ground temperature routine (does not call SLAB)
- Louis scheme for surface exchange coefficients

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Eta PBL

- Also known as Mellor-Yamada-Janjic PBL
- Uses Mellor-Yamada
- Predicts TKE
- Local vertical mixing
- Monin-Obhukov similarity theory
- Can be used with Noah-LSM

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MRF PBL

- Also known as Hong and Pan PBL
- Based on Troen-Mahrt concept of nonlocal mixing (countergradient term)
- PBL depth determined from critical bulk Richardson number (shear and temperature profile)
- Can be used with Noah-LSM

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Gayno-Seaman PBL

- Predicts TKE
- Allows for cloud-topped PBL processes by using liquid water potential temperature and total water as its mixing variables

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Pleim-Chang PBL

- Currently can only be used with Pleim-Xiu LSM
- Based on Blackadar scheme
- Asymmetric Convective Model

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Moist Vertical Diffusion (IMVDIF)

- Available only in Blackadar and MRF PBL
- Default IMVDIF=1 accounts for vertical mixing in saturated layers
- Produces moist-adiabatic mixed profile

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Thermal Roughness Length (IZ0TOPT)

- Only available with MRF and Blackadar schemes
- Different treatments of thermal roughness length due to Garrett and Zilitinkevich
- Affects sensible and latent heat flux, especially over water

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Horizontal Diffusion

- Serves dual purpose in model
  - Numerical filter
  - Represents sub-grid horizontal eddy mixing
- Applies to all predicted variables

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Diffusion options (ITPDIF)

- ITPDIF=0: Diffuse all fields the same way along model levels (sigma surfaces)
- ITPDIF=1: Diffuse T' (=T-T0) to remove basic vertical gradient from horizontal diffusion in sloped coordinate
- ITPDIF=2: T, q, and cloud diffused purely horizontally allowing for sloped coordinate. More expensive but can improve results in narrow valleys. New in Version 3.7 from G. Zaengl.

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Microphysics (Explicit Moisture) Schemes

- Treatment of cloud and precipitation processes on the resolved scale
- Process rates assume uniform grid-box
- May or may not include ice phase and graupel/hail particles
- Provides tendencies of temperature, and all moist variables, and surface non-convective rainfall
- Provides information on clouds to radiation schemes

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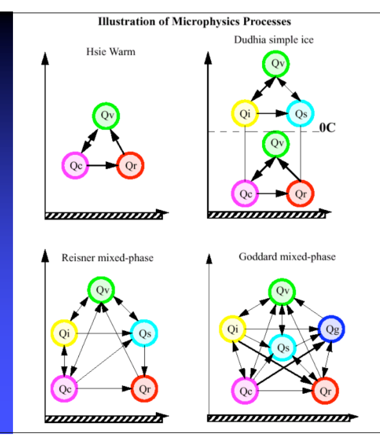


Microphysics Schemes (IMPHYS)

- Dry
- Stable Precipitation
- Warm Rain (Hsie)
- Simple Ice (Dudhia)
- Mixed-Phase (Reisner 1)
- Goddard microphysics
- Reisner 2 (graupel)
- Schultz

Dry

- No vapor or clouds
- If you want vapor as a passive advected variable, better to use IFDRY=1 (Fake dry) which turns off only latent heating, and is better for sensitivity studies.

Stable Precipitation

- Also known as the Nonconvective Rainfall scheme
- Grid-scale saturation removed and immediately put into surface rainfall
- No explicit clouds or rain evaporation
- Namelist parameter CONF can be used to control maximum RH allowed

Warm Rain

- Also known as Hsie scheme
- Original MM4 method of treating clouds and rain as separate 3d fields
- No ice phase

Simple Ice

- Also known as Dudhia scheme
- Adaptation of Hsie scheme to allow ice processes
- Cloud and ice share one array, rain and snow share another. No additional memory.
- Ice sedimentation
- No supercooled water
- Immediate snow melt at melting layer

Mixed-Phase

- Also known as Reisner 1
- Adds arrays for cloud ice and snow
- Has same processes as Simple Ice
- Treats supercooled water
- Has gradual snow melt as it falls

Goddard Microphysics

- Sophisticated scheme with graupel/hail as an additional variable
- Suitable for cloud-resolving models

Reisner Graupel

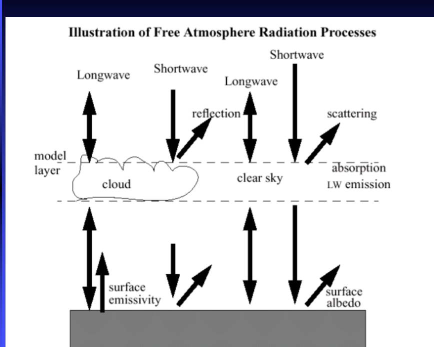
- Also known as Reisner 2
- Additional variables for graupel and ice number concentration
- Many differences in detail from Reisner 1
- Used in FSL's RUC runs
- Still being developed by R. Rasmussen, J. Brown and G. Thompson
- 3.4 – 3.7 versions contain significant differences from each other

Schultz Microphysics

- Also contains graupel field
- Simple scheme designed for efficiency and tunability with a minimum number of parameters
- Not well suited to vector machines
- Updated slightly in 3.7

Radiation Schemes

- Represent radiative effects in atmosphere and at surface
- Provides surface downwelling longwave and shortwave fluxes for surface scheme
- Provides column temperature tendencies due to vertical radiative flux divergence
- May interact with model clouds or relative humidity



Radiation Schemes (IFRAD)

0. None
1. Simple Cooling

0 or 1. Surface radiation

2. Cloud radiation
3. CCM2 radiation
4. RRTM longwave radiation

None

- No radiation effects in the atmosphere
- Surface radiation still active

Simple Cooling

- Climatological mean cooling profile in the atmosphere
- No diurnal dependence
- Only a function of temperature
- Surface radiation is active

Surface Radiation

- Used with above two options
- Surface shortwave and longwave flux provided for ground temperature prediction
- Uses column integrated water vapor
- Uses RH to determine low/mid/high cloud fractions
- Suitable for very coarse grids (> 50 km), or if microphysics is not being used

Cloud Radiation

- Also known as Dudhia scheme
- Provides atmospheric radiative effects due to modeled clouds
- Provides surface longwave and shortwave fluxes itself (does not call Surface Radiation scheme)
- LEVSLP and OROSHAW switches allow for slope and shadow effects on surface solar flux using this option. New in Version 3.7 from G. Zaengl.

CCM2 Radiation

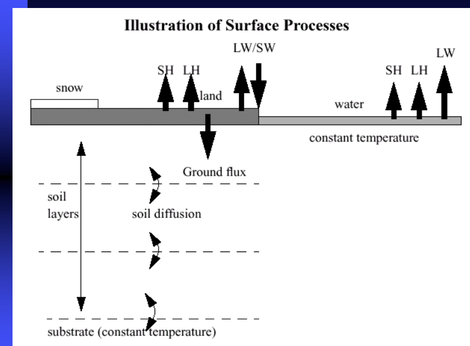
- From CCM2 climate model (old scheme)
- Better suited to coarse grid sizes and long time integrations
- Interacts either with RH or with model clouds (v3.5)

RRTM Longwave

- Rapid Radiative Transfer Model (AER, Inc.)
- Sophisticated look-up table scheme for longwave radiation
- Interacts with model clouds
- Used with Dudhia shortwave scheme when selected

Surface Schemes

- Represent effects of land and water surfaces
- Ground temperature based on heat budget using radiative fluxes and surface-layer atmospheric properties
- Provides sensible and latent heat flux
- May also represent sub-soil temperature and moisture profiles
- May provide snow-cover tendencies and surface moisture availability variation



Surface Schemes (ISOIL)

- Force-restore (Blackadar)
- Five-layer Soil Temperature
- Oregon State University/Eta LSM
- Pleim-Xiu LSM

Force-Restore (Blackadar)

- Ground temperature prediction
- 2-layer model with a constant-temperature substrate
- Substrate (reservoir) temperature is specified in INTERPF as a diurnal average surface temperature
- Tuned to represent diurnal cycle best

5-Layer Soil Model

- Predicts soil temperature in five layers
- 1, 2, 4, 8, 16 cm thick
- Can represent higher frequency changes than force-restore

NOAH Land Surface Model

- Before v3.6 was Oregon State University (OSU) LSM
- Same as that used by NCEP and AFWA in operational models
- Four layers (10, 30, 60 and 100 cm thick)
- Predicts soil temperature, soil water/ice, canopy water, and snow cover
- Needs inputs of soil texture, annual mean surface temperature, and seasonal vegetation fraction, as well as initial soil temperature and moisture

NOAH Land Surface Model (cont'd)

- Can also use albedo datasets (RDBRDALB, RDMAXALB switches)
- Version 3.7 includes
  - Emissivity effect
  - Improved urban treament

Pleim-Xiu LSM

- Simple 2-layer model
- Predicts soil temperature and soil moisture
- Can use data assimilation to initialize soil moisture
- Used at EPA

Snow Cover (IFSNOW)

0. Ignore snow cover
- Use initial snow cover
- Predict snow cover

Bucket Soil Moisture (IMOIAV)

Predict soil moisture availability using

- Initial value based on land-use
- Initial value input

Polar Physics (IPOLAR=1)

- Suite of changes for Antarctic Mesoscale Prediction System (AMPS)
- Developed mostly by Byrd Polar Research Center (Ohio State U)
- Uses 7-layers with ISOIL=1 soil model
- Takes into account snow/ice ground properties
- Accounts for sea-ice fraction (IEXSI switch)
- Modifies simple-ice and Reisner 1 microphysics to use Meyers ice number conc formula
- Should be used with Eta or MRF PBL

Interactions among physics schemes