WRF Physics Options

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WRF Physics

- Turbulence/Diffusion (diff_opt, km_opt)
- Radiation
  - Longwave (ra_lw_physics)
  - Shortwave (ra_sw_physics)
- Surface
  - Surface layer (sf_sfclay_physics)
  - Land/water surface (sf_surface_physics)
- PBL (bl_physics)
- Cumulus parameterization (cu_physics)
- Microphysics (mp_physics)

Turbulence/Diffusion

Sub-grid eddy mixing effects on all fields

ARW only

diff_opt=1

- 2nd order diffusion on model levels
  - Constant vertical coefficient (kvdif) or use with PBL
  - For theta, only perturbation from base state is diffused
- km_opt
  - 1: constant (khdif and kvdif used)
  - 2: 1.5-order TKE prediction (not recommended with diff_opt=1)
  - 3: Smagorinsky (deformation/stability based K) (not recommended with diff_opt=1)
  - 4: 2D Smagorinsky (deformation based on horizontal wind for horizontal diffusion only)

ARW only

diff_opt=2

- 2nd order horizontal diffusion
- Allows for terrain-following coordinate
- km_opt
  - 1: constant (khdif and kvdif used)
  - 2: 1.5-order TKE prediction
  - 3: Smagorinsky (deformation/stability based K)
  - 4: 2D Smagorinsky (deformation based on horizontal wind for horizontal diffusion only)

ARW only

diff_opt=2 (continued)

- mix_full_fields=.true.: vertical diffusion acts on full (not perturbation) fields (recommended, but default = .false.)
- Idealized constant surface fluxes can be added in diff_opt=2 using namelist (dynamics section). Not available for diff_opt=1.
  - tke_drag_coefficient (C_D)
  - tke_heat_flux ($=H/\rho c_p$)
  - Must use isfflx=0 to use these switches

ARW only

diff_opt=2 (continued)

- Explicit large-eddy simulation (LES) PBL in real-data cases (V3) or idealized cases
  - sf_sfclay_physics and sf_surface_physics (choose non-zero option)
  - bl_pbl_physics = 0
  - isfflx = 1 (drag and heat flux from physics) OR
  - isfflx = 2 (drag from physics, heat flux from tke_heat_flux)
  - km_opt = 2 or 3
- Not available for diff_opt=1.

Diffusion Option Choice

- Real-data case with PBL physics on
  - Best is diff_opt=1, km_opt=4
  - This complements vertical diffusion done by PBL scheme
- Idealized large-eddy resolving cases
  - km_opt=2,3 (tke or Smagorinsky scheme) is tested for hi-res eddy-resolving modeling
- Cloud-resolving modeling (smooth or no topography)
  - diff_opt=1; km_opt=2,3
- Complex topography
  - diff_opt=2 is more accurate for sloped coordinate surfaces, and prevents diffusion up/down valley sides
- Note: WRF can run with no diffusion (diff_opt=0)

ARW only

diff_6th_opt

- 6^{th} order optional added horizontal diffusion on model levels
  - Used as a numerical filter for 2*dx noise
  - Suitable for idealized and real-data cases
  - Affects all advected variables including scalars
- diff_6th_opt
  - 0: none (default)
  - 1: on (can produce negative water)
  - 2: on and prohibit up-gradient diffusion (better for water conservation)
- diff_6th_factor
  - Non-dimensional strength (typical value 0.12, 1.0 corresponds to complete removal of 2*dx wave in a time-step)

ARW only

damp_opt=1

- Upper level diffusive layer
- Enhanced horizontal diffusion at top
- Also enhanced vertical diffusion at top for diff_opt=2
- Cosine function of height
- Uses additional parameters
  - zdamp: depth of damping layer
  - dampcoef: nondimensional maximum magnitude of damping
- Works for idealized cases and real-data since 2.2 release

ARW only

damp_opt=2

- Upper level relaxation towards 1-d profile
- Rayleigh (relaxation) layer
- Cosine function of height
- Uses additional parameters
  - zdamp: depth of damping layer
  - dampcoef: inverse time scale (s^{-1})
- Works for idealized cases only

ARW only

damp_opt=3

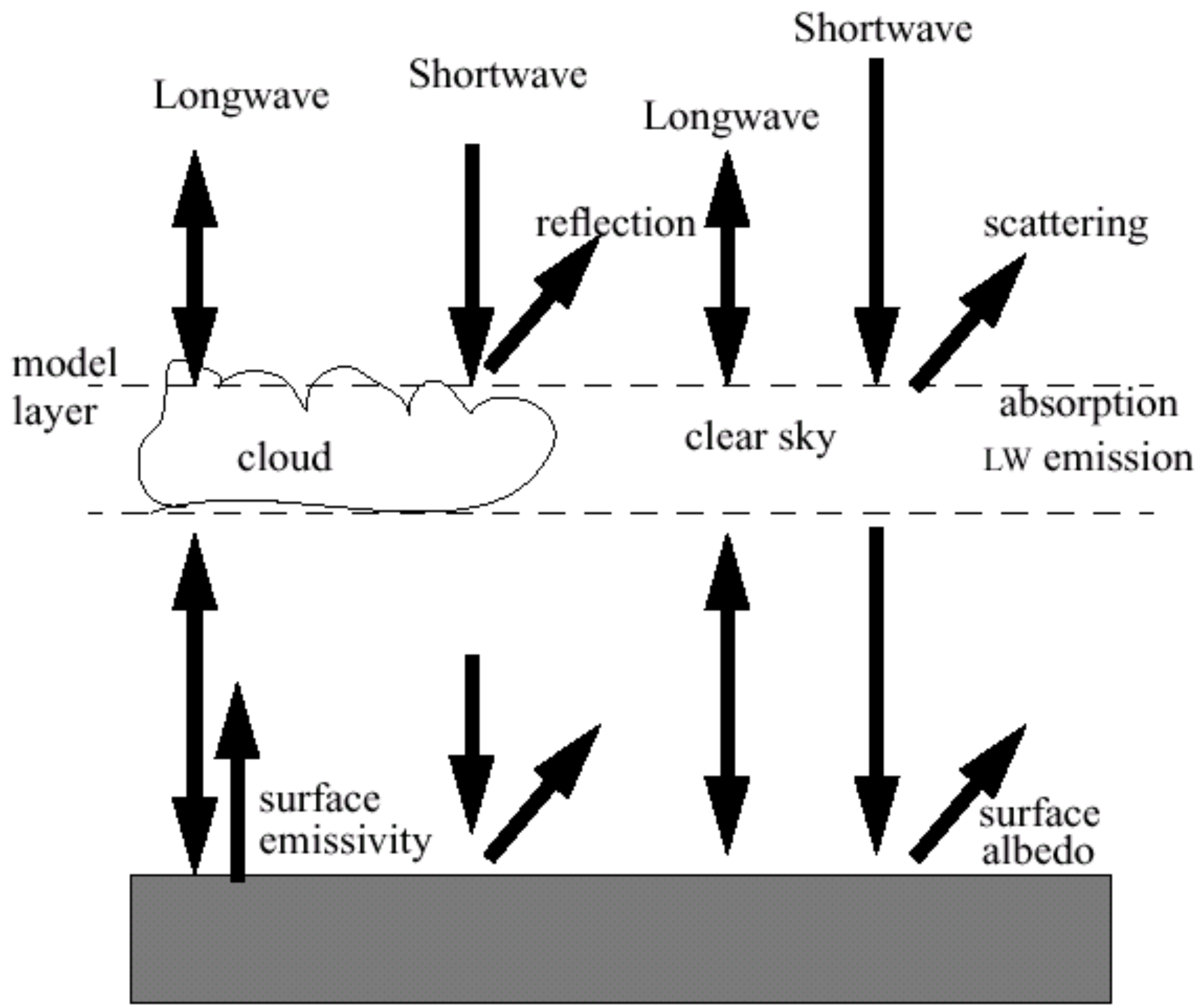
- "W-Rayleigh" (relaxation) layer
- Upper level relaxation towards zero vertical motion
- Cosine function of height
- Uses additional parameters
  - zdamp: depth of damping layer
  - dampcoef: inverse time scale (s^{-1})
- Works for idealized and real-data cases
- Applied in small time-steps (dampcoef=0.2 is stable)

Radiation

Atmospheric temperature tendency

Surface radiative fluxes

Illustration of Free Atmosphere Radiation Processes



ra_lw_physics=1

RRTM scheme

- Spectral scheme
- K-distribution
- Look-up table fit to accurate calculations
- Interacts with clouds (1/0 fraction)
- Ozone profile specified
- CO2 constant (well-mixed)

ARW only

ra_lw_physics=3

CAM3 scheme

- Spectral scheme
- 8 longwave bands
- Look-up table fit to accurate calculations
- Interacts with clouds (RH-based cloud fraction when RH<1)
- Can interact with trace gases and aerosols
- Ozone profile function of month, latitude
- CO_2 fixed constant

ra_lw_physics=99

GFDL longwave scheme

- used in Eta/NMM
- Default code is used with Ferrier microphysics
  - Remove #define to compile for use without Ferrier
- Spectral scheme from global model
- Also uses tables
- Interacts with clouds
- Ozone profile based on season, latitude
- CO2 fixed

ra_sw_physics=1

MM5 shortwave (Dudhia)

- Simple downward calculation
- Clear-sky scattering
  - swrad_scat tuning parameter
    - 1.0 = 10% scattered, 0.5=5%, etc.
- Water vapor absorption
- Cloud albedo and absorption
- Version 3 has slope_rad and topo_shading switches (0,1) to turn on slope and shading effects in this radiation option only

ARW only

ra_sw_physics=2

Goddard shortwave

- Spectral method
- Interacts with clouds
- Ozone profile (tropical, summer/winter, mid-lat, polar)
- CO2 fixed

ARW only

ra_sw_physics=3

CAM3 shortwave

- Spectral method (19 bands)
- Interacts with clouds
- Ozone/CO2 profile as in CAM longwave
- Can interact with aerosols and trace gases
- Note: CAM schemes need some extra namelist items (see README.namelist)

ra_sw_physics=99

GFDL shortwave

- Used in Eta/NMM model
- Default code is used with Ferrier microphysics (see GFDL longwave)
- Ozone/CO2 profile as in GFDL longwave
- Interacts with clouds

ARW only

radt

Radiation time-step recommendation

- Radiation is too expensive to call every step
- Frequency should resolve cloud-cover changes with time
- radt=1 minute per km grid size is about right (e.g. radt=10 for dx=10 km)
- Each domain can have its own value but recommend using same value on all 2-way nests

NMM only

nrads/nradl

Radiation time-step recommendation

- Number of fundamental steps per radiation call
- Operational setting should be 3600/dt
- Higher resolution could be used, e.g. 1800/dt
- Recommend same value for all nested domains

Surface schemes

- Surface layer of atmosphere diagnostics (exchange/transfer coeffs)
- Land Surface: Soil temperature /moisture /snow prediction /sea-ice temperature

ARW only

sf_sfclay_physics=1

Monin-Obukhov similarity theory

- Taken from standard relations used in MM5 MRF PBL
- Provides exchange coefficients to surface (land) scheme
- Should be used with bl_pbl_physics=1 or 99

sf_sfclay_physics=2

Monin-Obukhov similarity theory

- Modifications due to Janjic
- Taken from standard relations used in NMM model, including Zilitinkevich thermal roughness length
- Should be used with bl_pbl_physics=2

NMM only

sf_sfclay_physics=3

GFS Monin-Obukhov similarity theory

- For use with NMM-LSM
- Should be used with bl_pbl_physics=3

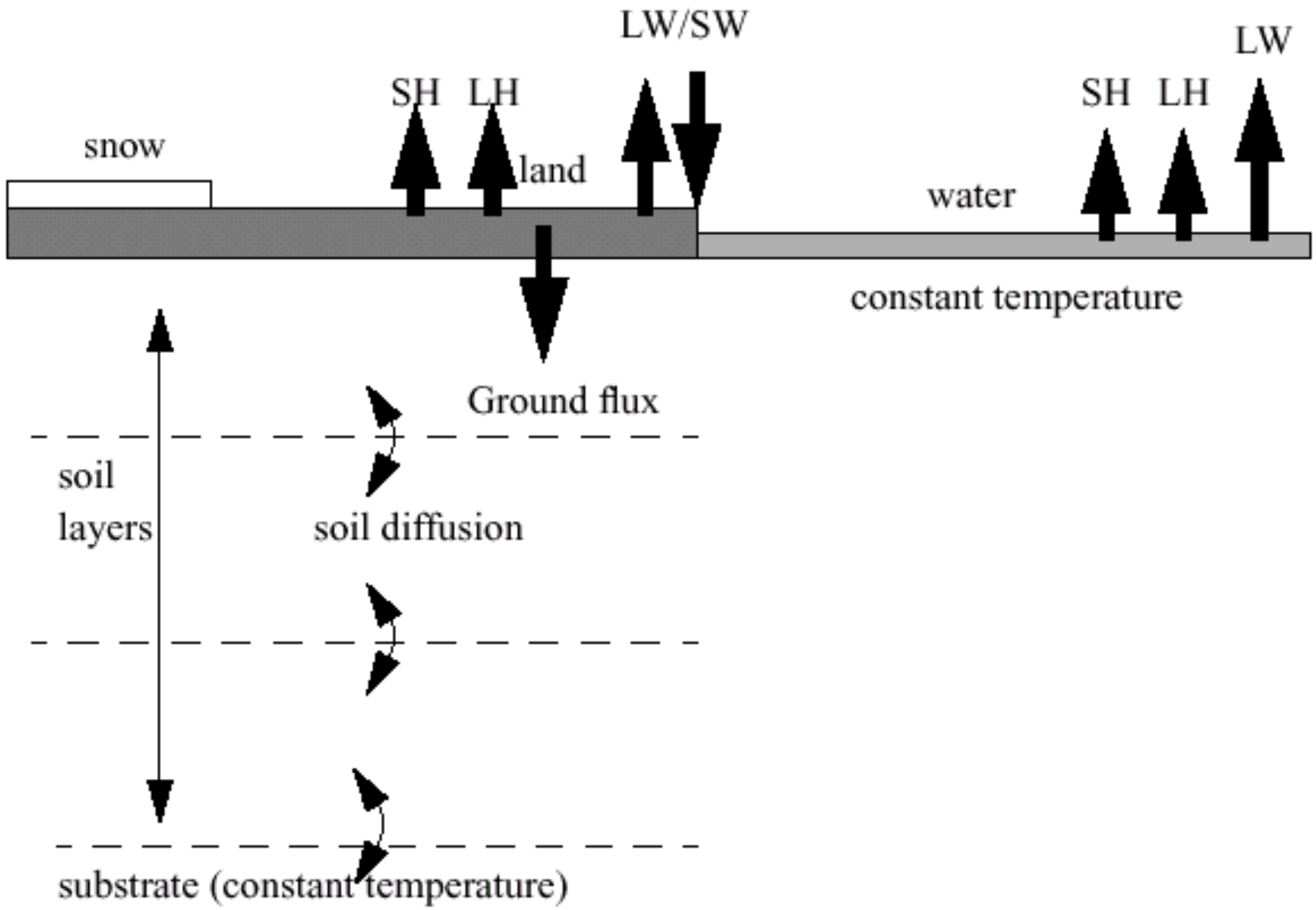
ARW only

sf_sfclay_physics=7

Pleim-Xiu surface layer (EPA)

- For use with PX LSM and ACM PBL
  - Should be used with sf_surface_physics=7 and bl_pbl_physics=7
- New in Version 3

Illustration of Surface Processes



ARW only

sf_surface_physics=1

5-layer thermal diffusion model from MM5

- Predict ground temp and soil temps
- Thermal properties depend on land use
- No effect for water (Version 3 has ocean mixed-layer model for hurricane applications)
- No soil moisture or snow-cover prediction
- Moisture availability based on land-use only
- Provides heat and moisture fluxes for PBL
- May be available for NMM in Version 3

sf_surface_physics=2

Noah Land Surface Model (Unified ARW/NMM version)

- Vegetation effects included
- Predicts soil temperature and soil moisture in four layers
- Predicts snow cover and canopy moisture
- Handles fractional snow cover and frozen soil
- Diagnoses skin temp and uses emissivity
- Provides heat and moisture fluxes for PBL
- 2.2 has Urban Canopy Model option (ucmcall=1, ARW only)

ARW only

sf_surface_physics=7

Pleim-Xiu Land Surface Model (EPA)

- Vegetation effects included
- Predicts soil temperature and soil moisture in two layers
- Simple snow-cover model
- Provides heat and moisture fluxes for PBL

NMM only

sf_surface_physics=99

NMM Land Surface Model (older NCEP Noah)

- Vegetation effects included
- Predicts soil temperature and soil moisture in four layers
- Predicts snow cover and canopy moisture
- Handles fractional snow cover and frozen soil
- Diagnoses skin temp and uses emissivity
- Provides heat and moisture fluxes for PBL

sf_surface_physics=3

RUC Land Surface Model (Smirnova)

- Vegetation effects included
- Predicts soil temperature and soil moisture in six layers
- Multi-layer snow model
- Provides heat and moisture fluxes for PBL

LANDUSE.TBL

Text (ASCII) file that has land-use properties (vegetation, urban, water, etc.)

- 24 USGS categories from 30" global dataset
- Each type is assigned summer/winter value
  - Albedo
  - Emissivity
  - Roughness length
- Other table properties (thermal inertia, moisture availability, snow albedo effect) are used by 5-layer model
- Also note
  - Other tables (VEGPARM.TBL, etc.) are used by Noah
  - RUC LSM uses same table files after Version 3

Initializing LSMs

- Noah and RUC LSM require additional fields for initialization
  - Soil temperature
  - Soil moisture
  - Snow liquid equivalent
- Best source is a consistent model-derived dataset
  - Eta/GFS/AGRMET/NNRP for Noah (although some have limited soil levels available)
  - RUC for RUC
- Optimally the resolution, land-use, soil texture, should match the data source model, otherwise there will be a spin-up issue

ARW only

sst_update=1

Reads lower boundary file periodically to update the sea-surface temperature (otherwise it is fixed with time)

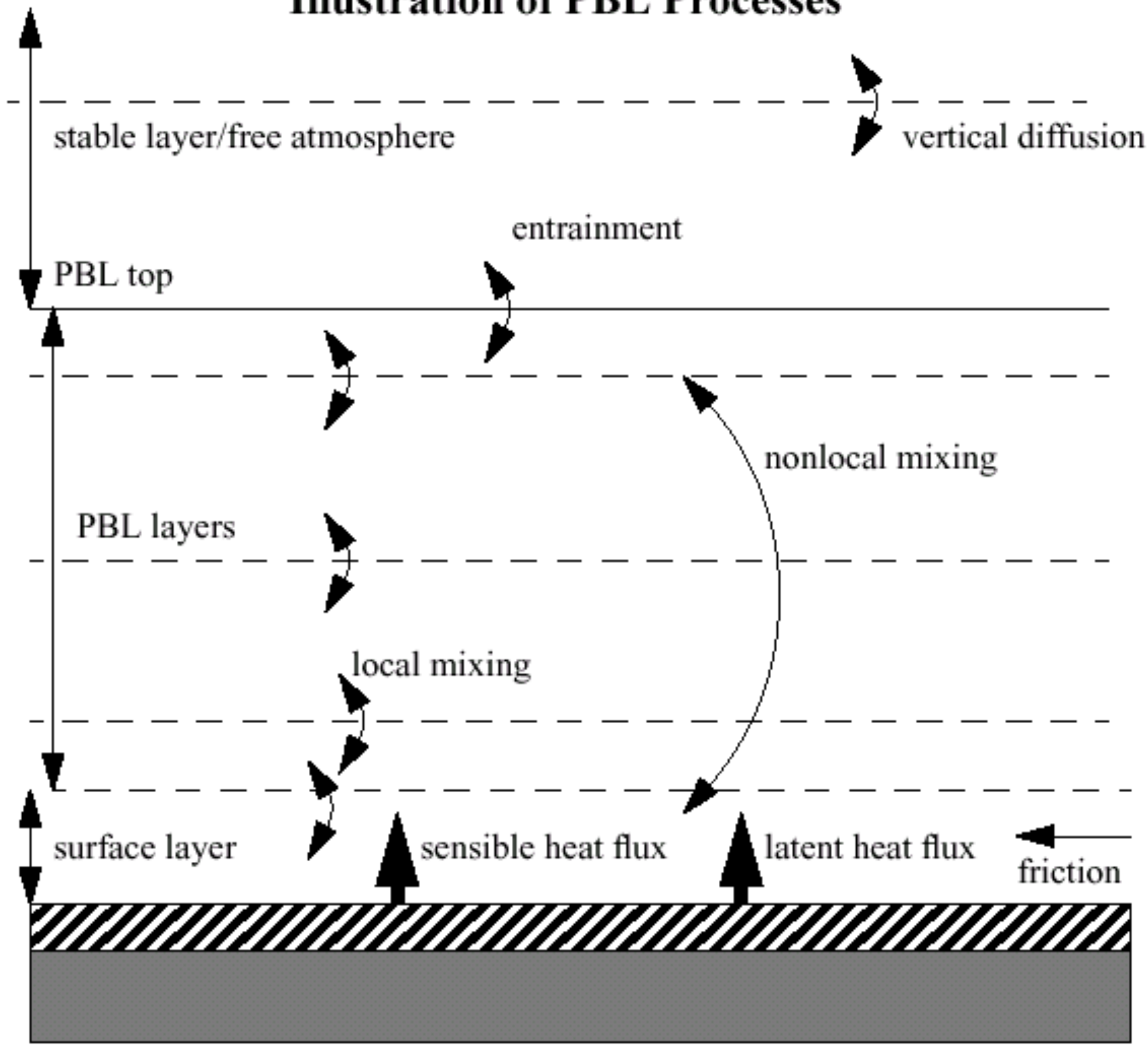
- For long-period simulations (a week or more)
- wrflowinp_d01 created by *real*
- Sea-ice not updated
  - Update available in Version 3
- Vegetation fraction update is included
  - Background albedo in Version 3

Planetary Boundary Layer

Boundary layer fluxes (heat, moisture, momentum)

Vertical diffusion

Illustration of PBL Processes



ARW only

bl_pbl_physics=1

YSU PBL scheme (Hong and Noh)

- Parabolic non-local-K mixing in dry convective boundary layer
- Troen-Mahrt countergradient term (non-local flux)
- Depth of PBL determined from thermal profile
- Explicit treatment of entrainment
- Vertical diffusion depends on Ri in free atmosphere
- May be available for NMM in Version 3

bl_pbl_physics=2

Mellor-Yamada-Janjic (Eta/NMM) PBL

- 1.5-order, level 2.5, TKE prediction
- Local TKE-based vertical mixing in boundary layer and free atmosphere

NMM only

bl_pbl_physics=3

GFS PBL

- 1st order Troen-Mahrt
- Closely related to MRF PBL
- Non-local-K vertical mixing in boundary layer and free atmosphere

ARW only

bl_pbl_physics=7

Asymmetrical Convective Model, Version 2 (ACM2) PBL (Pleim and Chang)

- Blackadar-type thermal mixing upwards from surface layer
- Local mixing downwards
- PBL height from critical bulk Richardson number

ARW only

bl_pbl_physics=99

MRF PBL scheme (Hong and Pan 1996)

- Non-local-K mixing in dry convective boundary layer
- Depth of PBL determined from critical Ri number
- Vertical diffusion depends on Ri in free atmosphere

ARW only

bldt

- Minutes between boundary layer/LSM calls
- Typical value is 0 (every step)

NMM only

nphs

- Time steps between PBL/turbulence/LSM calls
- Typical value is 10 for efficiency
- Also used for microphysics

PBL Scheme Options

PBL schemes can be used for most grid sizes when surface fluxes are present

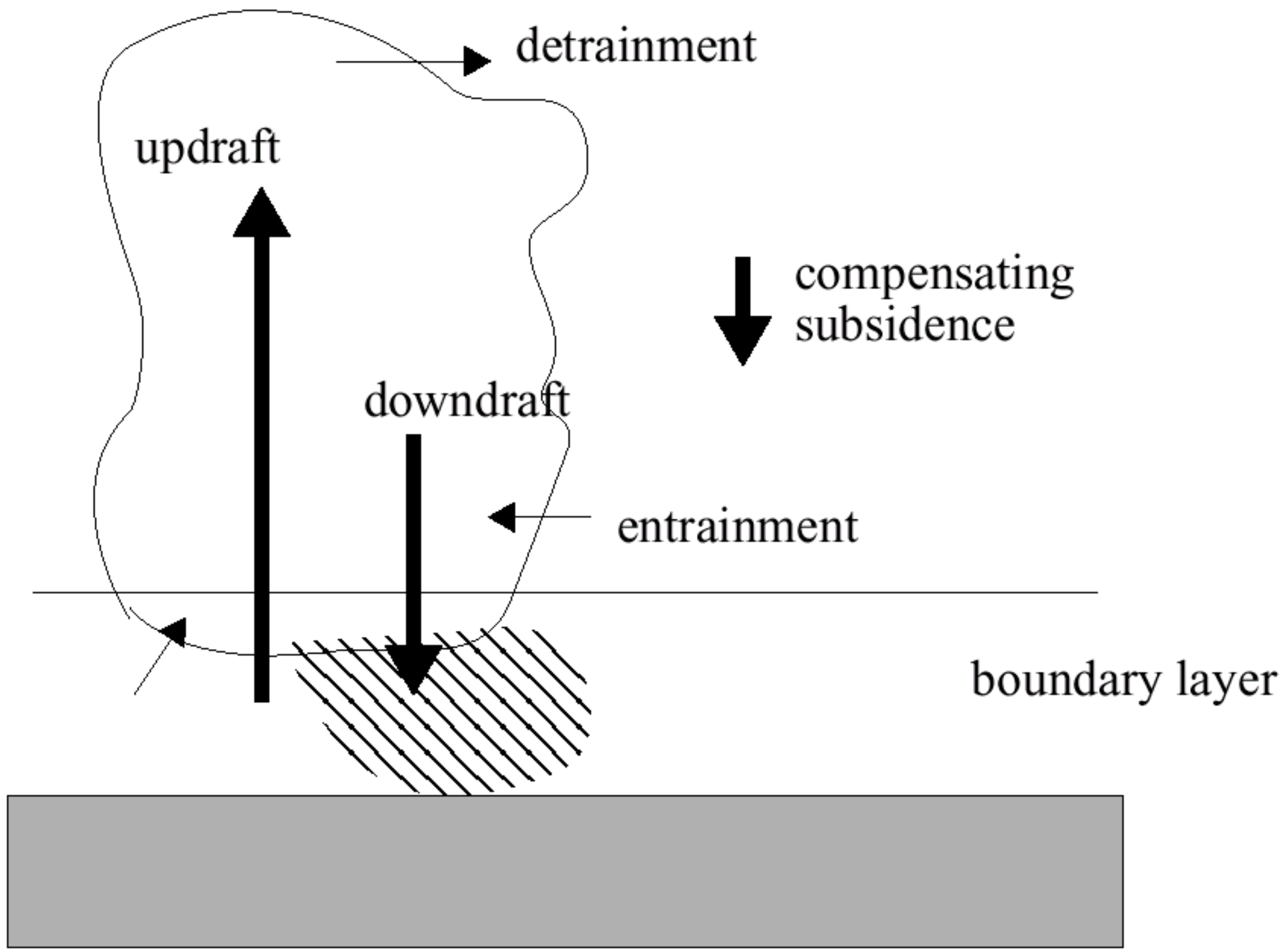
- With PBL scheme, lowest full level should be .99 or .995 (not too close to 1)
- Assumes that PBL eddies are not resolved
- At grid size dx << 1 km, this assumption breaks down
- Can use 3d diffusion instead of a PBL scheme in Version 3 (coupled to surface physics)
  - Works best when dx and dz are comparable

Cumulus Parameterization

Atmospheric heat and moisture/cloud tendencies

Surface rainfall

Illustration of Cumulus Processes



cu_physics=1

New Kain-Fritsch

- As in MM5 and Eta/NMM test version
- Includes shallow convection (no downdrafts)
- Low-level vertical motion in trigger function
- CAPE removal time scale closure
- Mass flux type with updrafts and downdrafts, entrainment and detrainment
- Includes water and ice detrainment
- Clouds persist over convective time scale (recalculated every convective step in NMM)

cu_physics=2

Betts-Miller-Janjic

- As in NMM 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
- Scheme changed significantly since V2.1

cu_physics=3

Grell-Devenyi Ensemble

- Multiple-closure (e.g. CAPE removal, quasi-equilibrium) - 16 mass flux closures
- Multi-parameter (e.g maximum cap, precipitation efficiency) - 3 cap strengths, 3 profiles
- Explicit updrafts/downdrafts
- Mean feedback of ensemble is applied
- Weights can be tuned (spatially, temporally) to optimize scheme (training)

NMM only

cu_physics=4

Simpified Arakawa-Schubert (SAS) GFS scheme

- Quasi-equilibrium scheme
- Related to Grell scheme in MM5
- Downdrafts and single, simple cloud

ARW only

cudt

- Time steps between cumulus scheme calls
- Typical value is 5 minutes

NMM only

ncnvc

- Time steps between cumulus parameterization calls
- Typically 10 - same as NPHS

Cumulus scheme

Recommendations about use

- For dx ≥ 10 km: probably need cumulus scheme
- For dx ≤ 3 km: probably do not need scheme
  - However, there are cases where the earlier triggering of convection by cumulus schemes help
- For dx=3-10 km, scale separation is a question
  - No schemes are specifically designed with this range of scales in mind
- Issues with 2-way nesting when physics differs across nest boundaries (seen in precip field on parent domain)
  - best to use same physics in both domains or 1-way nesting

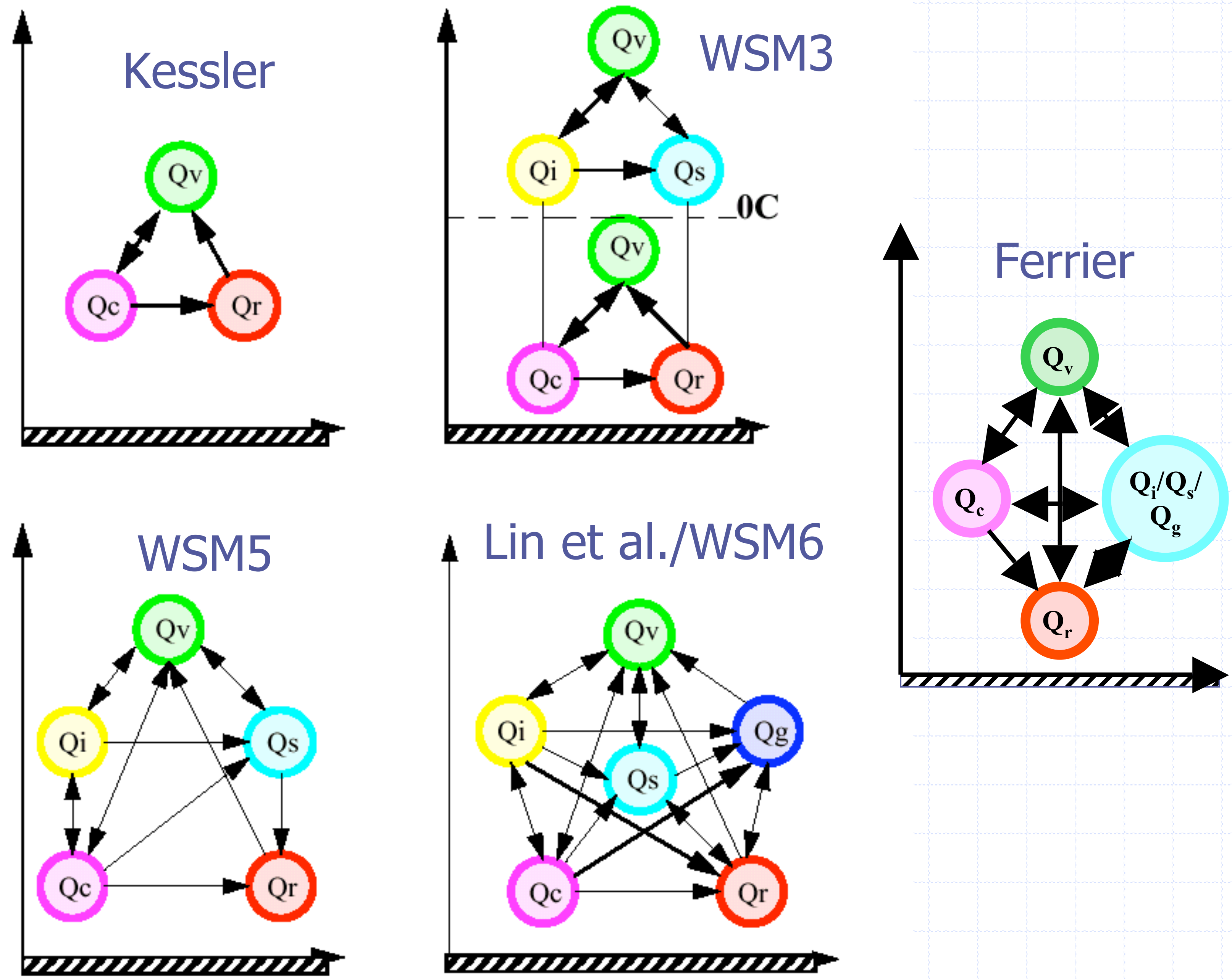
Microphysics

Atmospheric heat and moisture tendencies

Microphysical rates

Surface rainfall

Illustration of Microphysics Processes



ARW only

mp_physics=1

Kessler scheme

- Warm rain – no ice
- Idealized microphysics
- Time-split rainfall

ARW only

mp_physics=2

Purdue Lin et al. scheme

- 5-class microphysics including graupel
- Includes ice sedimentation and time-split fall terms

ARW only

mp_physics=3

WSM 3-class scheme

- From Hong, Dudhia and Chen (2004)
- Replaces NCEP3 scheme
- 3-class microphysics with ice
- Ice processes below 0 deg C
- Ice number is function of ice content
- Ice sedimentation and time-split fall terms

mp_physics=4

WSM 5-class scheme

- Also from Hong, Dudhia and Chen (2004)
- Replaces NCEP5 scheme
- 5-class microphysics with ice
- Supercooled water and snow melt
- Ice sedimentation and time-split fall terms

mp_physics=5

Ferrier (current NAM) scheme

- Designed for efficiency
  - Advection only of total condensate and vapor
  - Diagnostic cloud water, rain, & ice (cloud ice, snow/graupel) from storage arrays – assumes fractions of water & ice within the column are fixed during advection
- Supercooled liquid water & ice melt
- Variable density for precipitation ice (snow/graupel/sleet) – “rime factor”

mp_physics=6

WSM 6-class scheme

- From Hong and Lim (2006, JKMS)
- 6-class microphysics with graupel
- Ice number concentration as in WSM3 and WSM5
- Modified accretion
- Time-split fall terms with melting

mp_physics=8

Thompson et al. graupel scheme

- From Thompson et al. (2006, WRF workshop)
- Newer version of Thompson et al. (2004) scheme
- Updated significantly for 2.2
- 6-class microphysics with graupel
- Ice number concentration also predicted (double-moment ice)
- Time-split fall terms

mp_physics=10

Morrison 2-moment scheme

- New in Version 3.0
- 6-class microphysics with graupel
- Number concentrations also predicted for ice, snow, rain, and graupel (double-moment)
- Time-split fall terms

ARW only

mp_zero_out

Microphysics switch (also mp_zero_out_thresh)

- 1: all values less than threshold set to zero (except vapor)
- 2: as 1 but vapor also limited ≥ 0
- Note: this option will not conserve total water
- Not needed when using positive definite advection
- NMM: Recommend mp_zero_out=0

NMM only

nphs

- Time steps between microphysics calls
- Same as parameter for turbulence/PBL/LSM
- Typical value is 10 for efficiency

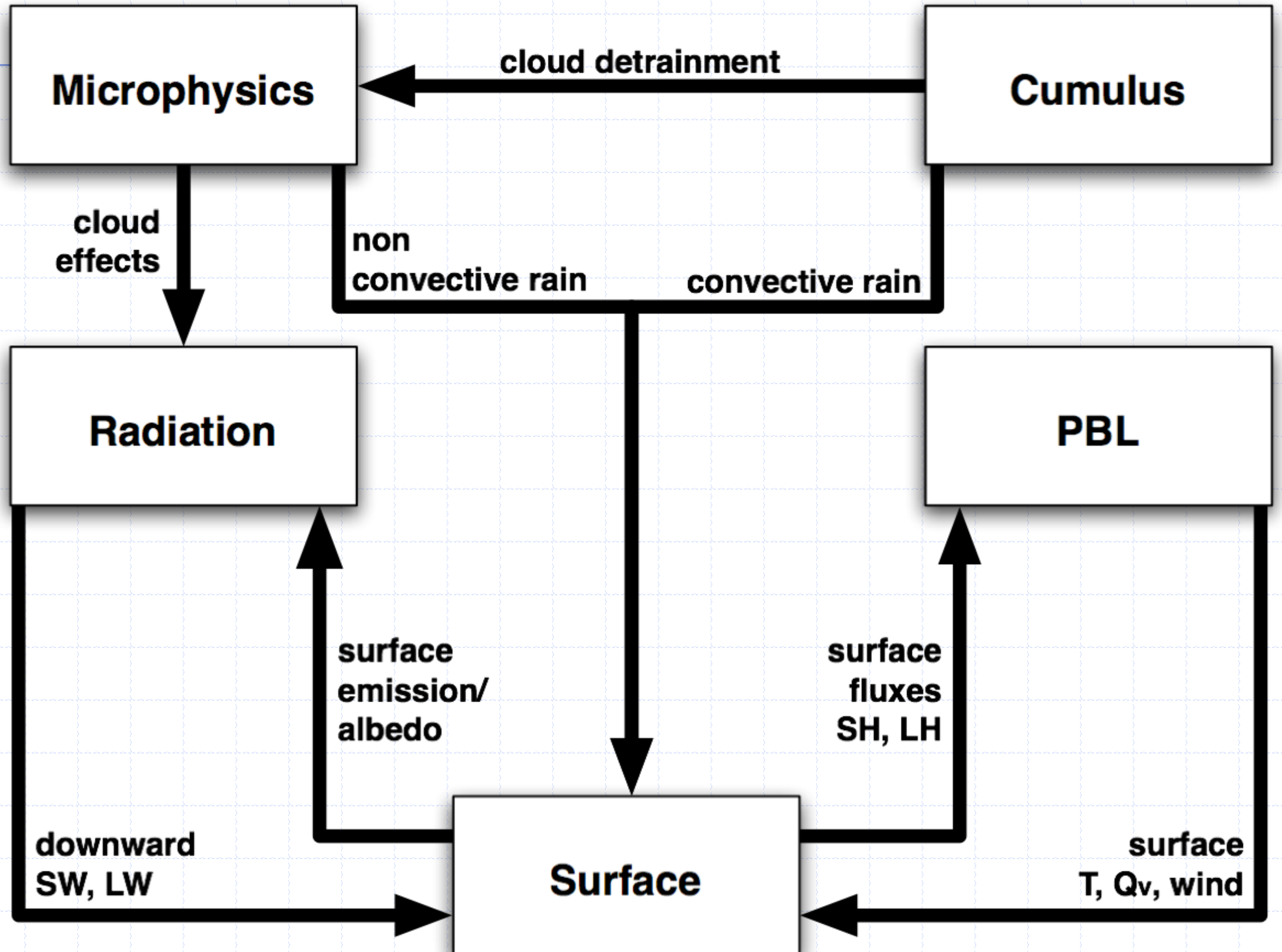
Microphysics Options

Recommendations about choice

- Probably not necessary to use a graupel scheme for dx > 10 km
  - Updrafts producing graupel not resolved
  - Cheaper scheme may give similar results
- When resolving individual updrafts, graupel scheme should be used
- All domains use same option

Physics Interactions

Direct Interactions of Parameterizations



&physics

Seven major physics categories:

- **mp_physics**: 0,1,2,3,4,5,6,8,10
- **ra_lw_physics**: 0,1,3,99
- **ra_sw_physics**: 0,1,2,3,99
- **sf_sfclay_physics**: 0,1,2
- **sf_surface_physics**: 0,1,2,3,99 (set before running **real** or **ideal**, need to match with **num_soil_layers** variable)
  - **ucm_call = 0,1**
- **bl_pbl_physics**: 0,1,2,99
- **cu_physics**: 0,1,2,3,99

End