WRF Physics Options

Jimy Dudhia

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

diff_opt=1

- 2nd order diffusion on model levels
  - Constant vertical coefficient (kvdif)
  - Or Use with PBL
- 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)

diff_opt=2

- 2^{nd} 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)

diff_opt=2 (continued)

- mix_full_fields=.true.: vertical diffusion acts on full (not perturbation) fields (recommended)
- 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 ($=H/\rho c_p$)

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 (tke scheme) is designed 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, but especially not recommended with even-order advection

damp_opt=1

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

damp_opt=2

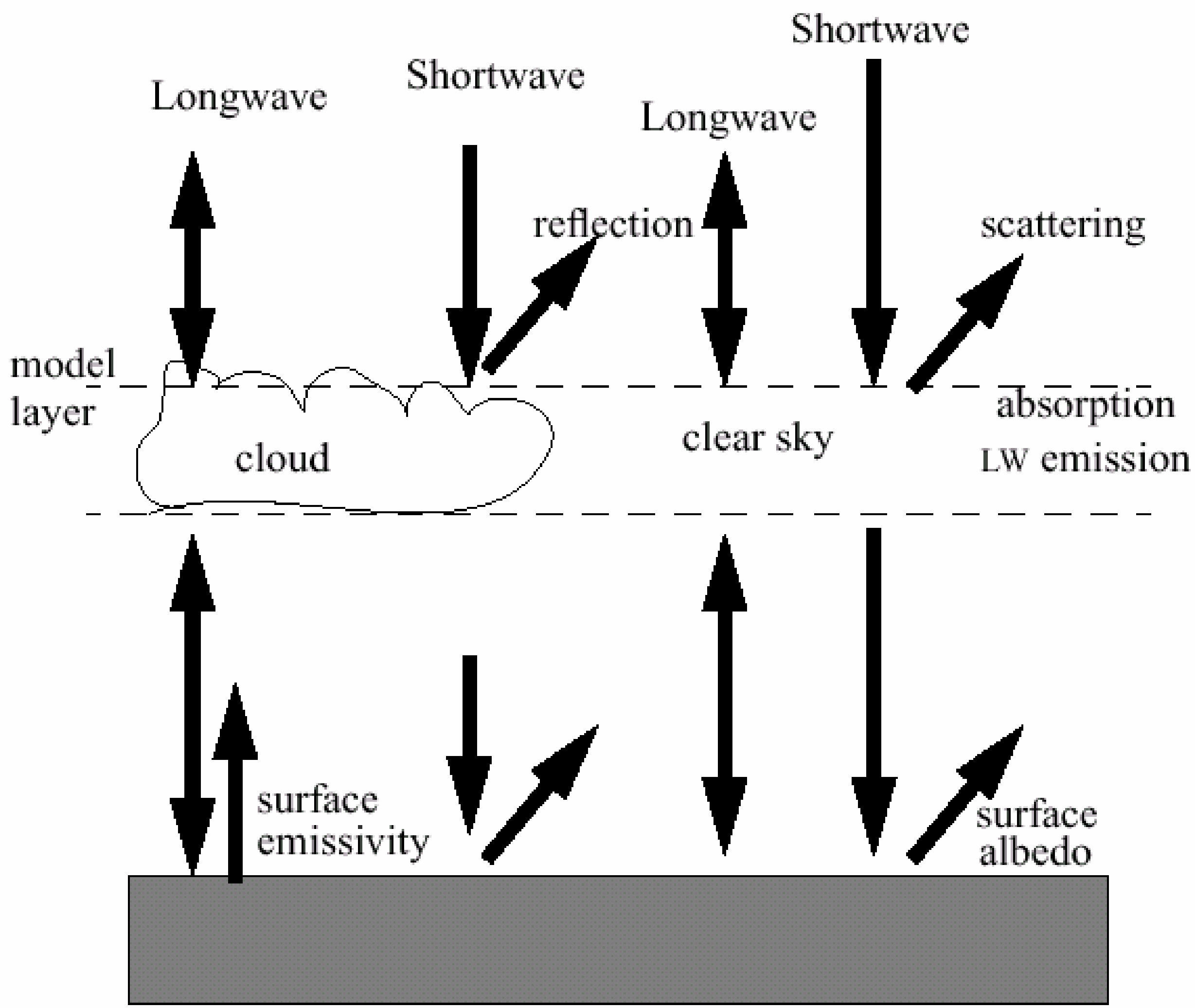
- Upper level relaxation towards 1-d profile
- Rayleigh (relaxation) layer
- Cosine function of height
- Uses additional parameters
  - zdamp: depth of damping layer
  - dampcoef: inverse time scale (s^{-1})
- Only for idealized cases (real-data in 2.2 release)

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
- Ozone/CO_2 from climatology

ra_lw_physics=99

GFDL longwave scheme

- used in Eta/NMM
- Can only be called with Ferrier microphysics
- Spectral scheme from global model
- Also uses tables
- Interacts with clouds
- Ozone/CO_2 from climatology

ra_sw_physics=1

MM5 shortwave (Dudhia)

- Simple downward calculation
- Clear-sky scattering
- Water vapor absorption
- Cloud albedo and absorption

ra_sw_physics=2

Goddard shortwave

- Spectral method
- Interacts with clouds
- Ozone effects

ra_sw_physics=99

GFDL shortwave

- Used in Eta/NMM model
- Can only be used with Ferrier microphysics
- Ozone effects
- Interacts with clouds

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)

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

Surface schemes

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

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

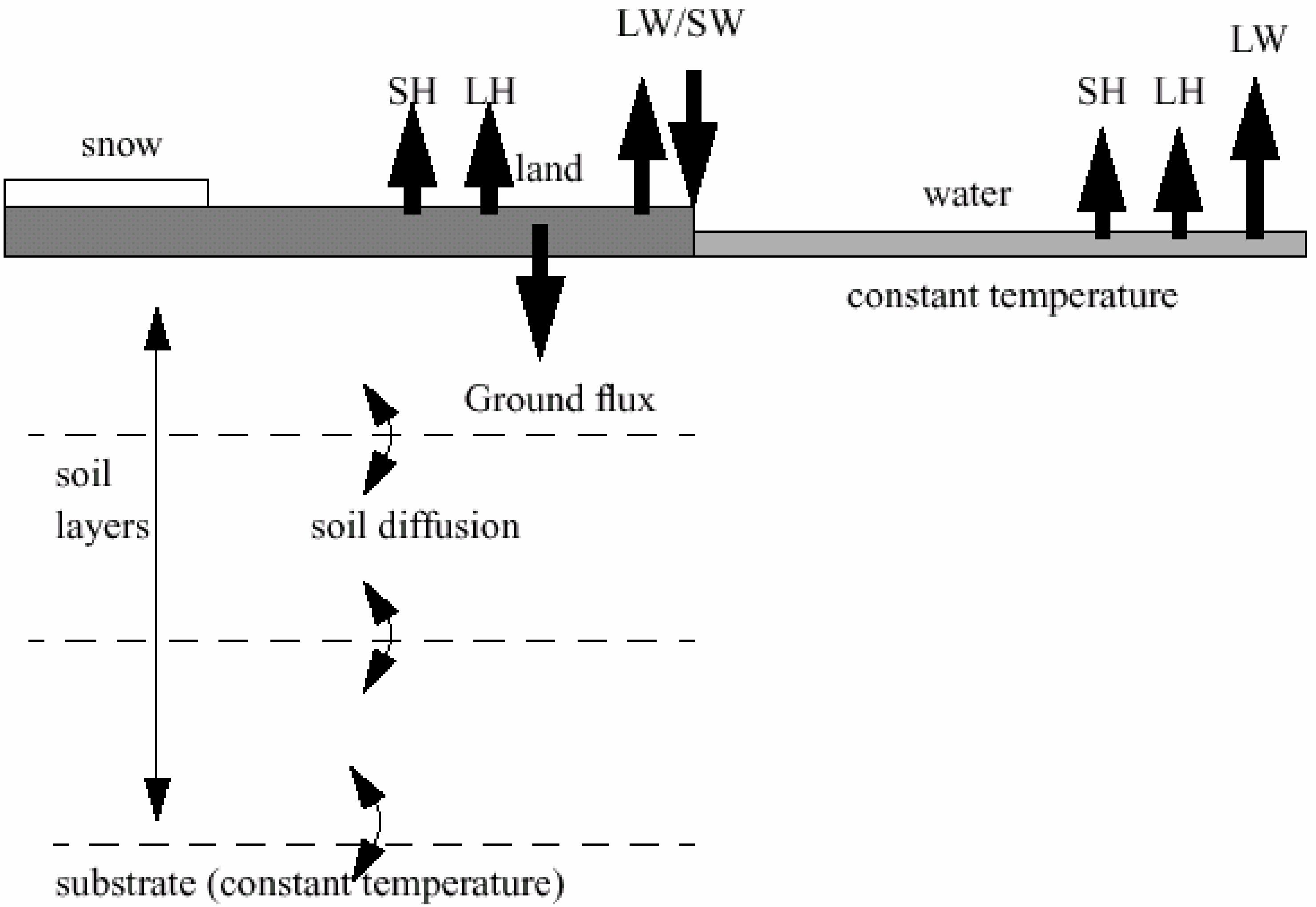
- Modifications due to Janjic
- Taken from standard relations used in NMM model, including Zilitinkevich thermal roughness length
- Should be used with bl_pbl_physics=2

sf_sfclay_physics=3

GFS Monin-Obukhov similarity theory

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

Illustration of Surface Processes



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
- Provides heat and moisture fluxes for PBL

sf_surface_physics=2

Noah Land Surface Model

- 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=99

NMM Land Surface Model (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

LANDUSE.TBL file (ascii) 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
- Other tables (VEGPARM.TBL, etc.) are used by Noah
- RUC LSM has internal values

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

sst_update=1

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

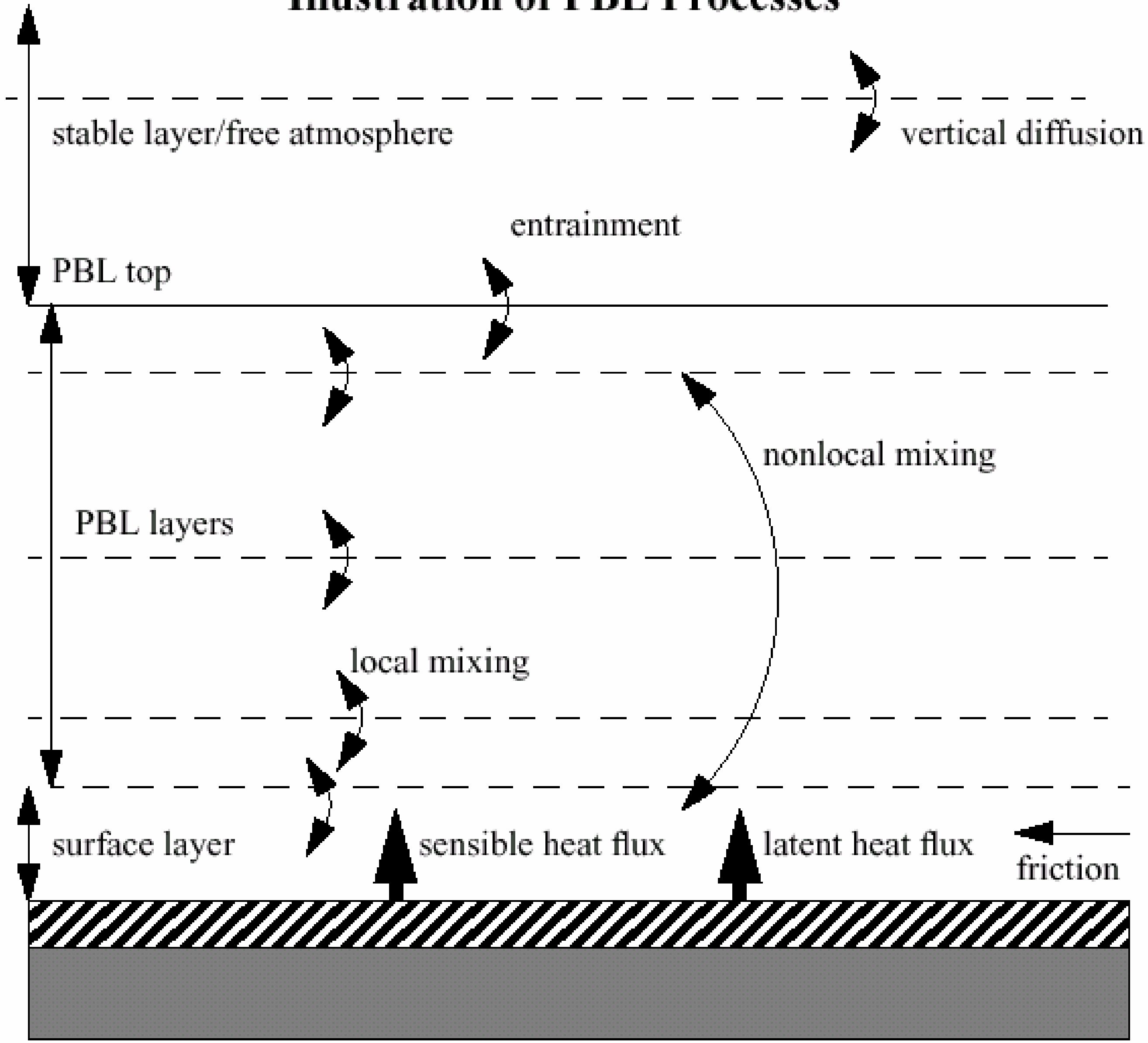
- For long-period simulations (a week or more)
- wrflowinp_d01 created by *real*
- Sea-ice
  - Cannot update sea-ice cover (yet)
  - Treat sea-ice as just cold water (no initial sea ice) if using sst_update
- Vegetation fraction update can be included in file too

Planetary Boundary Layer

Boundary layer fluxes (heat, moisture, momentum)

Vertical diffusion

Illustration of PBL Processes



bl_pbl_physics=1

YSU PBL scheme (Hong and Noh)

- Parabolic non-local-K mixing in dry convective boundary layer
- Depth of PBL determined from thermal profile
- Explicit treatment of entrainment
- Vertical diffusion depends on Ri in free atmosphere

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

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

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

bldt

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

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

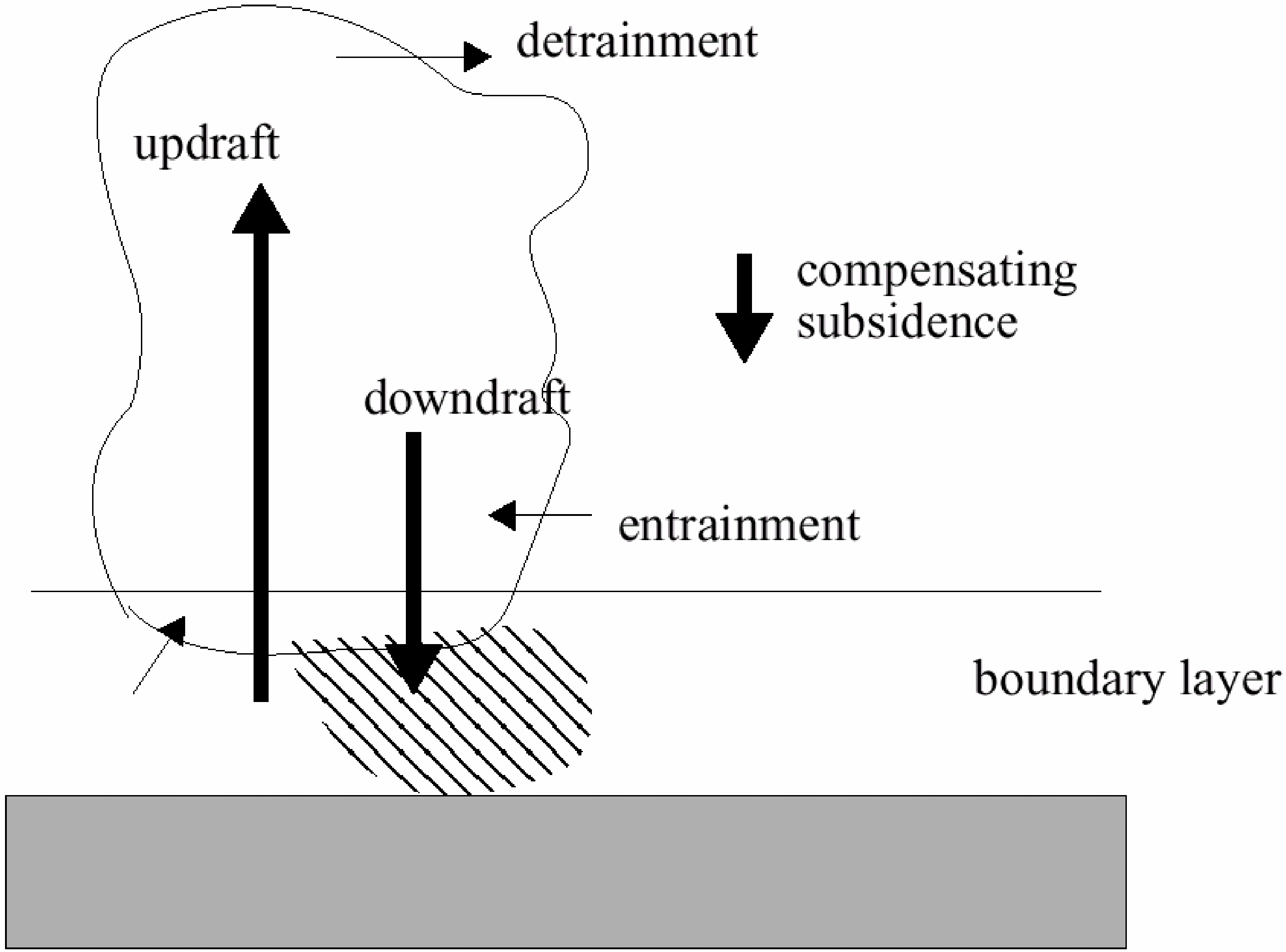
- Assumes that PBL eddies are not resolved
- With PBL scheme, lowest full level should be .99 or .995 (not too close to 1)
- At grid size dx << 1 km, this assumption breaks down
- Can use 3d tke diffusion, but, this is not yet coupled to the actual surface fluxes
- Currently 3d tke can only be used with constant specified surface fluxes

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
- Low-level vertical motion in trigger function
- CAPE removal time scale closure
- Mass flux type with updrafts and downdrafts, entrainment and detrainment
- Includes cloud detrainment

cu_physics=2

Betts-Miller-Janjic

- As in NMM model (Janjic 1994)
- Adjustment type scheme
- BM saturated profile modified by cloud efficiency, so post-convective profile can be unsaturated in BMJ
- No explicit updraft or downdraft

cu_physics=3

Grell-Devenyi Ensemble

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

cu_physics=4

Simpified Arakawa-Schubert (SAS) GFS scheme

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

cudt

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

ncnvc

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

Cumulus scheme

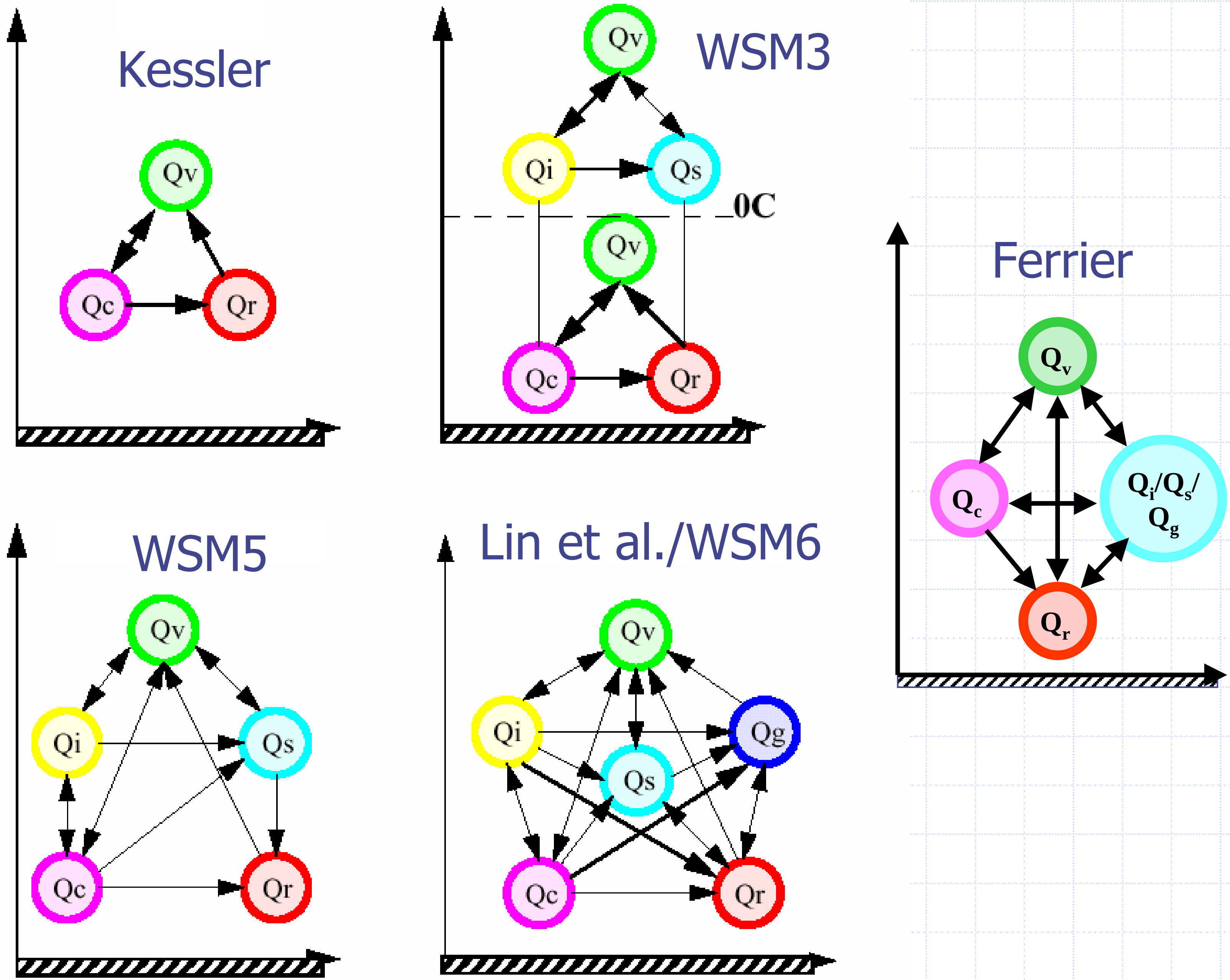
Recommendations about use

- 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 ?
  - No schemes are specifically designed with this range of scales in mind

Microphysics

- Atmospheric heat and moisture tendencies
- Microphysical rates
- Surface rainfall

Illustration of Microphysics Processes



mp_physics=1

Kessler scheme

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

mp_physics=2

Purdue Lin et al. scheme

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

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 of total condensate
  - 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. (2004, MWR)
- Newer version of Reisner2 scheme
- 6-class microphysics with graupel
- Ice number concentration also predicted (double-moment ice)
- Time-split fall terms

mp_physics=98,99

NCEP3,NCEP5

- Old options from Version 1.3 still available for comparison
- Originally from Regional Spectral Model
- To be phased out later

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
- NMM: Recommend mp_zero_out=0

nphs

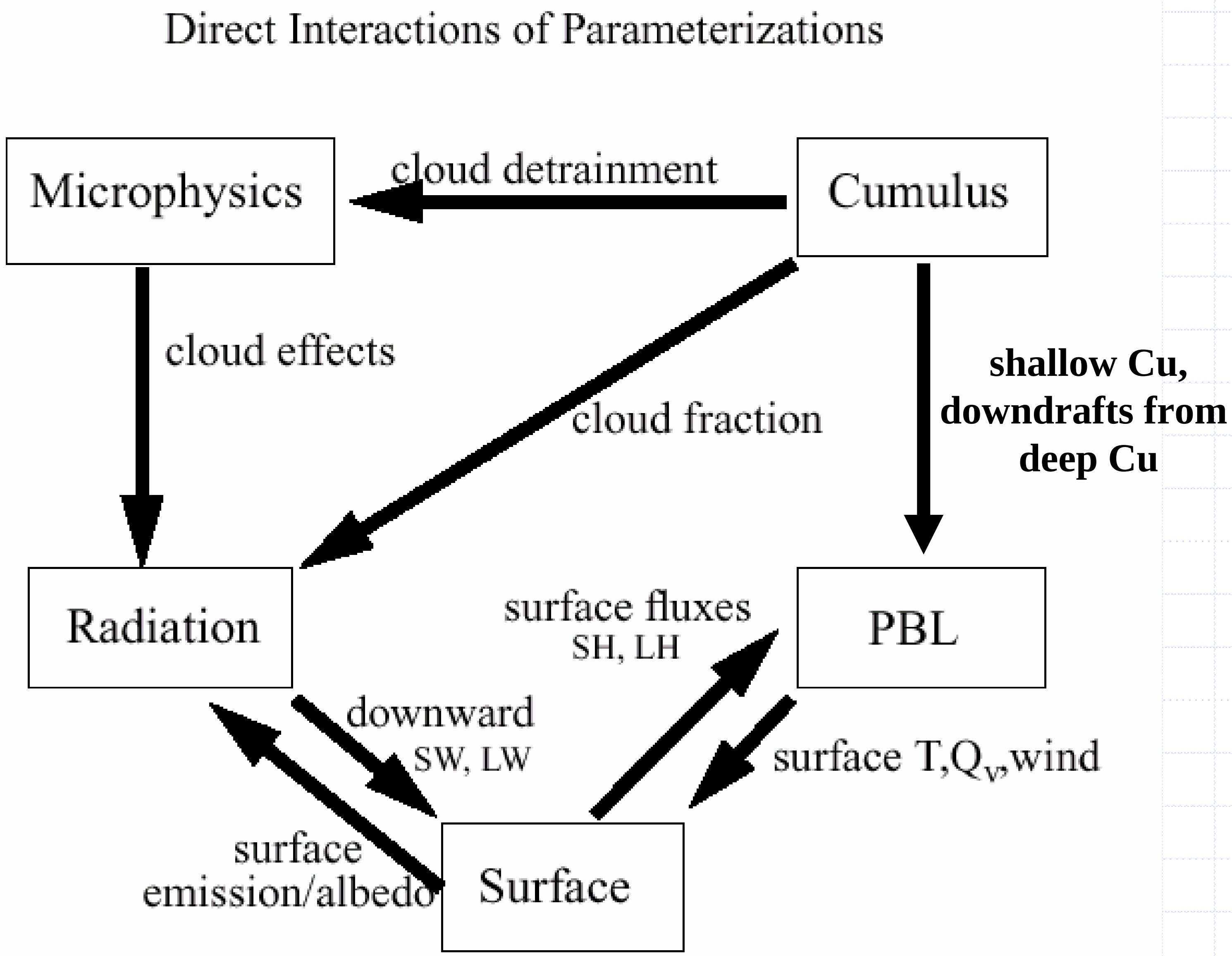
- Time steps between microphysics calls
- Same as parameter for turbulence/PBL/LSM
- Typical value is 10 for efficiency

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
Microphysics
cloud detrainment
Cumulus
cloud effects
cloud fraction
shallow Cu, downdrafts from deep Cu
Radiation
surface fluxes
SH, LH
PBL
downward
SW, LW
surface T,Q$_v$,wind
surface
emission/albedo
Surface

Physics Summary and Plans

Subgrid Turbulence

IN	WORKING ON	PLANNED
(1) Level 2.5 TKE (2)3d Smagorinsky (3) Const. coeffs. (4)2d Smagorinsky (mesoscale)		

Microphysics

IN	WORKING ON	PLANNED
(1) Kessler (2) Lin et al. [Purdue] (3) WSM3 (4) WSM5 (5) Eta (Ferrier) (6) WSM6 (8) Thompson	2-moment schemes (WSM- and Thompson-related)	Goddard

Radiation

	IN	WORKING ON	PLANNED
Long	(1)RRTM (2)Eta (GFDL)	CAM lw	Goddard lw GFS lw
Short	(1) Dudhia [MM5] (2) Goddard (3) Eta (GFDL)	CAM sw	RRTM sw GFS sw

Boundary Layer

IN	WORKING ON	PLANNED
(1)YSU (2)M-Y-Janjic (3)* GFS PBL (99)MRF		

Surface

	IN	WORKING ON	PLANNED
Surface layer	(1)MRF Similarity (2)Eta Similarity (3)* GFS surface		
Land surface	(1)5-layer soil temp (2)Noah LSM (3)RUC LSM (99)* NMM LSM	CLM Noah - urban	

Cumulus

IN	WORKING ON	PLANNED
(1)New Kain-Fritsch (2) Betts-Miller-Janjic (3) Grell-Devenyi (4)* Simplified A-S (GFS)		

End