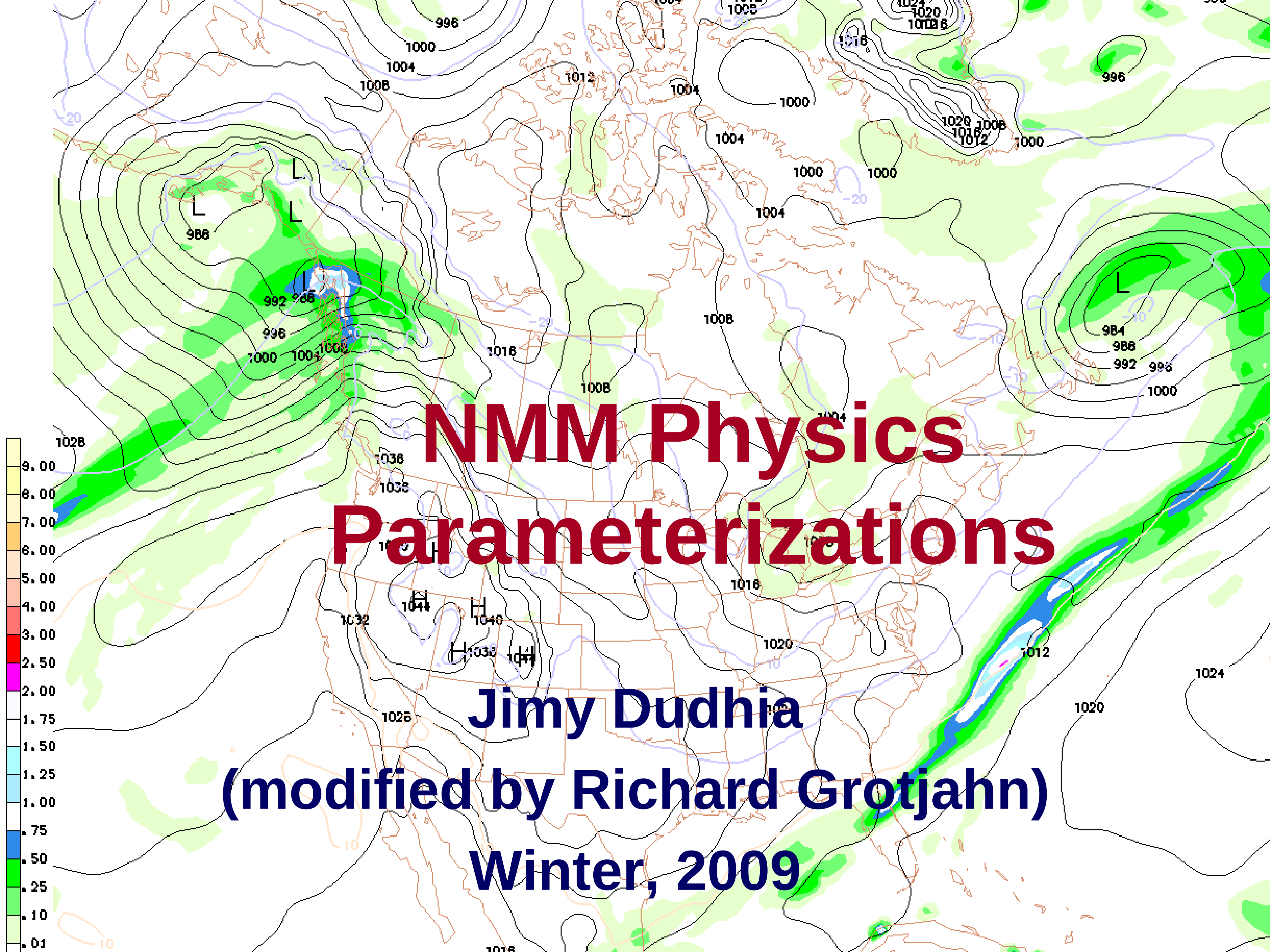

NMM Physics Parameterizations

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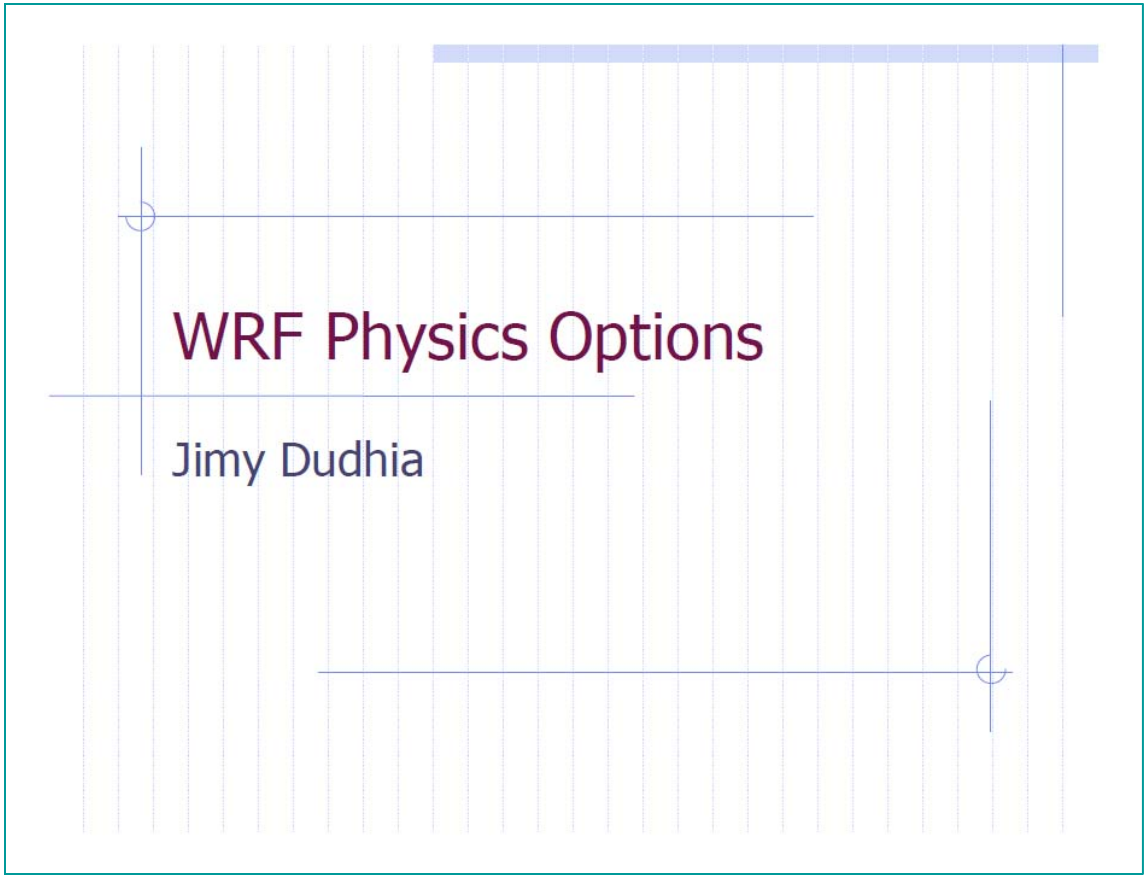
(modified by Richard Grotjahn)

Winter, 2009

Source:

- Borrowed heavily from this NCEP document.
- http://www.mmm.ucar.edu/wrf/users/tutorial/200807/WRF_Physics_Dudhia.pdf



Outline

- Overview
- Turbulence & diffusion
- Radiation (longwave & shortwave)
- Surface schemes (fluxes, land surface models: LSMs, SST)
- Planetary boundary layer (PBL fluxes, vertical diffusion)
- Cumulus parameterization (heat & moisture tendencies; surface precipitation)
- Microphysics in clouds (heat & moisture tendencies; rates; other surface precipitation)
- Interactions between physics parameterizations
- Summary

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

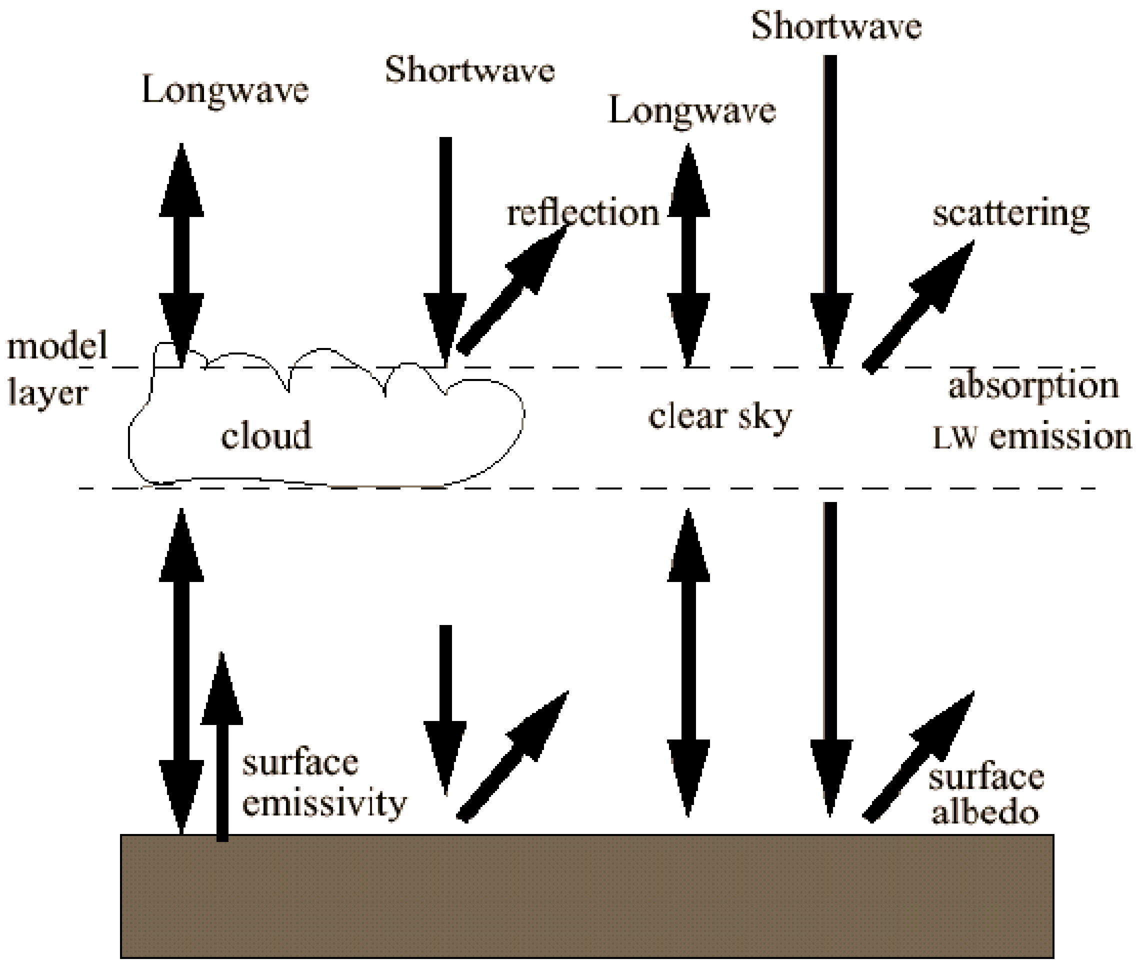
Sub-grid eddy mixing effects on all fields

Radiation

Atmospheric temperature tendency

Surface radiative fluxes

Illustration of Free Atmosphere Radiation Processes



Longwave radiation

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
- CO_2 fixed

Shortwave radiation

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

Interval between radiation calculations

NMM only

nrads/nradl

Radiation time-step recommendation

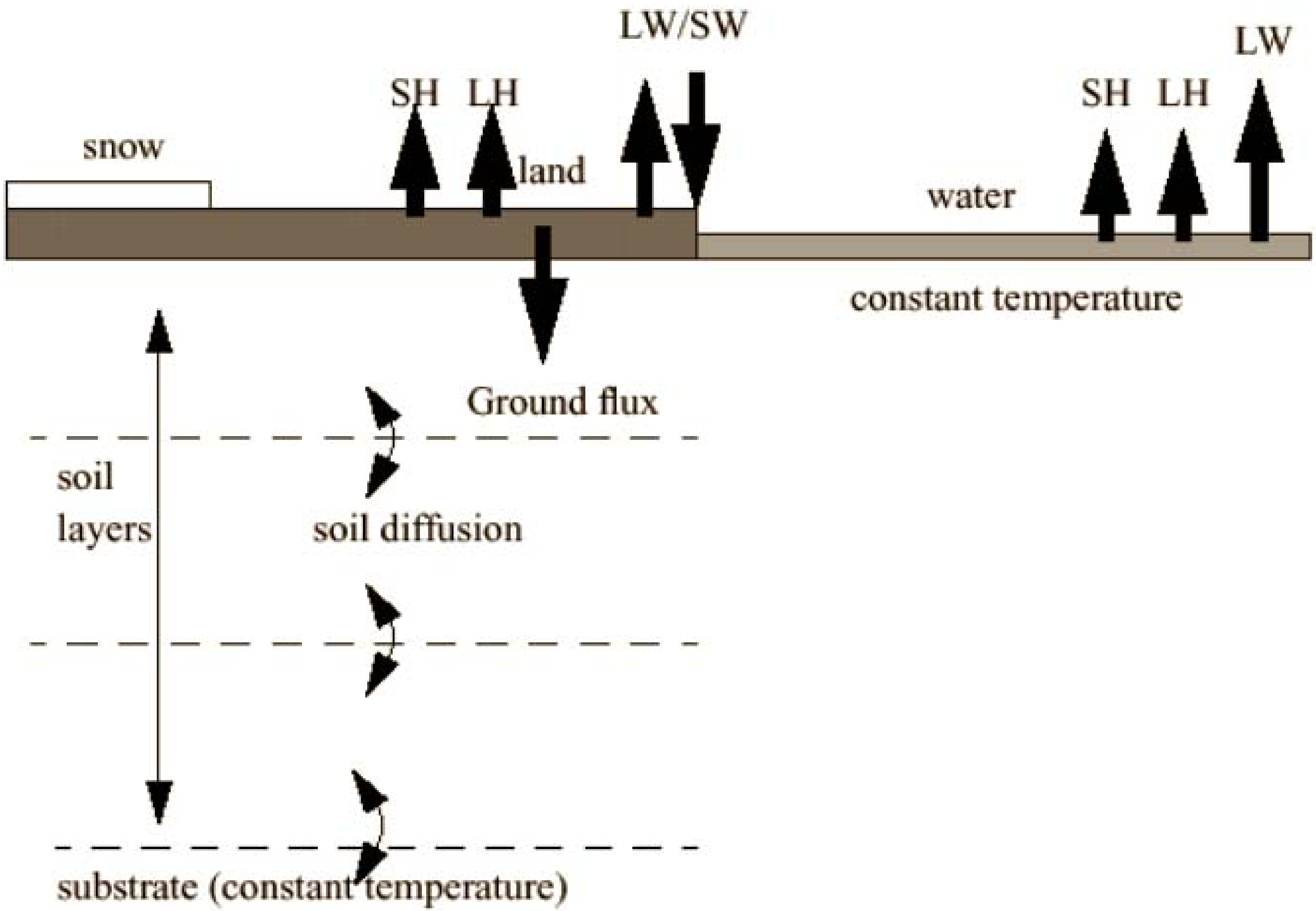
- Number of fundamental steps per radiation call
- Operational setting should be 3600/dt
- Higher resolution could be used, e.g. 1800/dt
- Recommend same value for all nested domains

Surface schemes

Surface layer of atmosphere diagnostics (exchange/transfer coeffs)

Land Surface: Soil temperature /moisture /snow prediction /sea-ice temperature

Illustration of Surface Processes



Surface Fluxes

- Heat, moisture and momentum

$$H = \rho c_p u_* \theta_* \qquad E = \rho u_* q_* \qquad \tau = \rho u_* u_*$$

$$u_* = \frac{kV_r}{\ln(z_r / z_0) - \psi_m} \qquad \theta_* = \frac{k\Delta\theta}{\ln(z_r / z_{0h}) - \psi_h} \qquad q_* = \frac{k\Delta q}{\ln(z_r / z_{0q}) - \psi_h}$$

Subscript *r* is reference level (lowest model level, or 2 m or 10 m)

z_0 are the roughness lengths

Roughness Lengths

- Roughness lengths are a measure of the "initial" length scale of surface eddies, and generally differ for velocity and scalars
- Roughness length depends on land-use type
- Some schemes use smaller roughness length for heat than for momentum
- For water points roughness length is a function of surface wind speed

$$u_* = \frac{kV_r}{\ln(z_r / z_0) - \psi_m} \qquad \theta_* = \frac{k\Delta\theta}{\ln(z_r / z_{0h}) - \psi_h} \qquad q_* = \frac{k\Delta q}{\ln(z_r / z_{0q}) - \psi_h}$$

z_0 are the roughness lengths

Exchange Coefficient

- C_{hs} is the exchange coefficient for heat, defined such that

$$H = \rho c_p C_{hs} \Delta\theta$$

It is related to the roughness length and u* by

$$C_{hs} = \frac{k u_*}{\ln\left(\frac{z}{z_0}\right) - \psi_h}$$

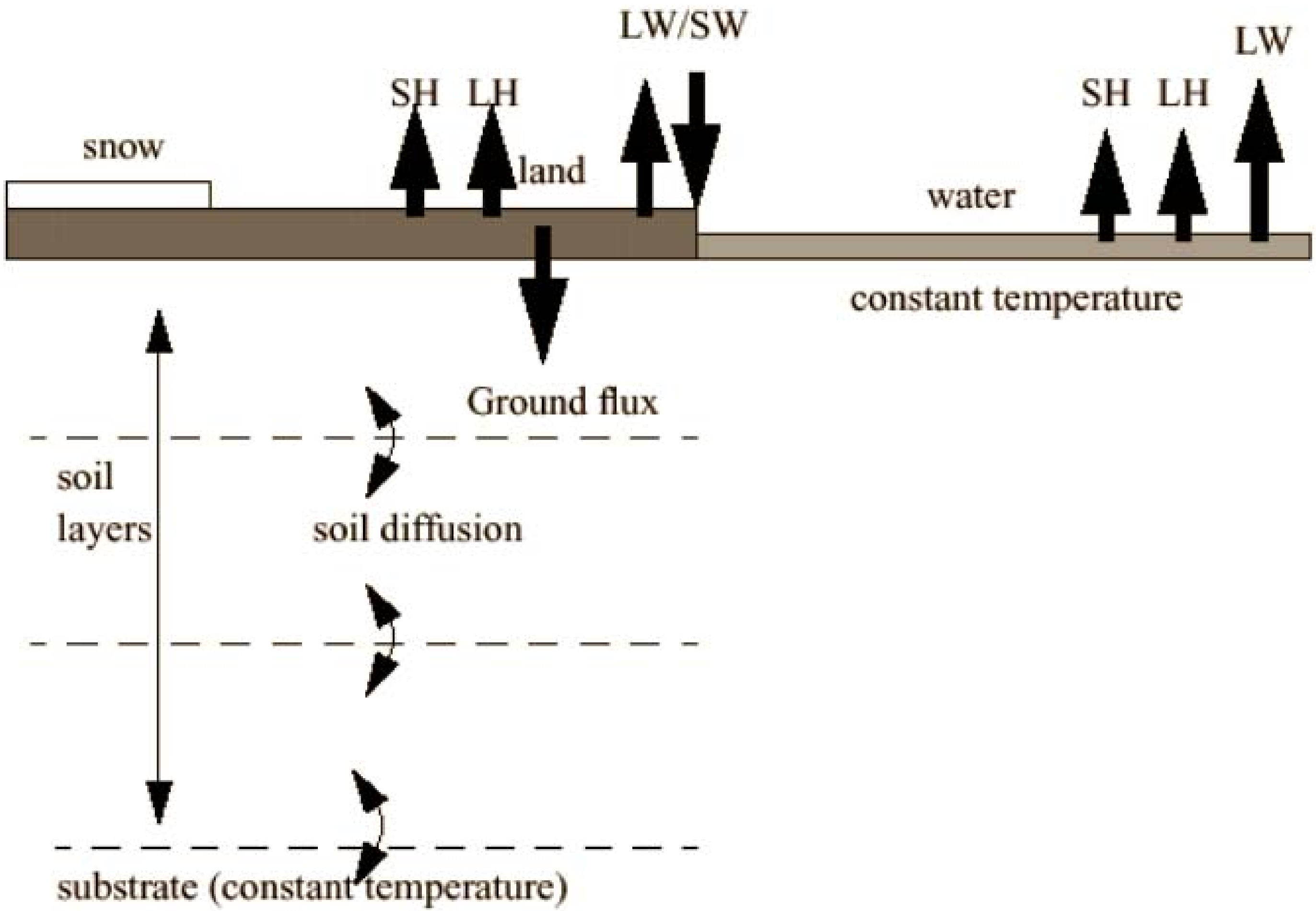
NMM only

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=2

Noah Land Surface Model (Unified ARW/NMM version in Version 3)

- 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)

Initializing LSMs

- Noah and RUC LSM require additional fields for initialization
  - Soil temperature
  - Soil moisture
  - Snow liquid equivalent
- These are in the Grib files, but are not from observations
- They come from “offline” models driven by observations (rainfall, radiation, surface temperature, humidity wind)

Initializing LSMs

- There are consistent model-derived datasets for Noah and RUC LSMs
  - Eta/GFS/AGRMET/NNRP for Noah (although some have limited soil levels available)
  - RUC for RUC
- But, resolution of mesoscale land-use means there will be inconsistency in elevation, soil type and vegetation
- This leads to spin-up as adjustments occur in soil temperature and moisture
- This spin-up can only be avoided by running offline model on the same grid (e.g. HRLDAS for Noah)
- Cycling land state between forecasts also helps, but may propagate errors (e.g in rainfall effect on soil moisture)

ARW only

sst_update=1

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

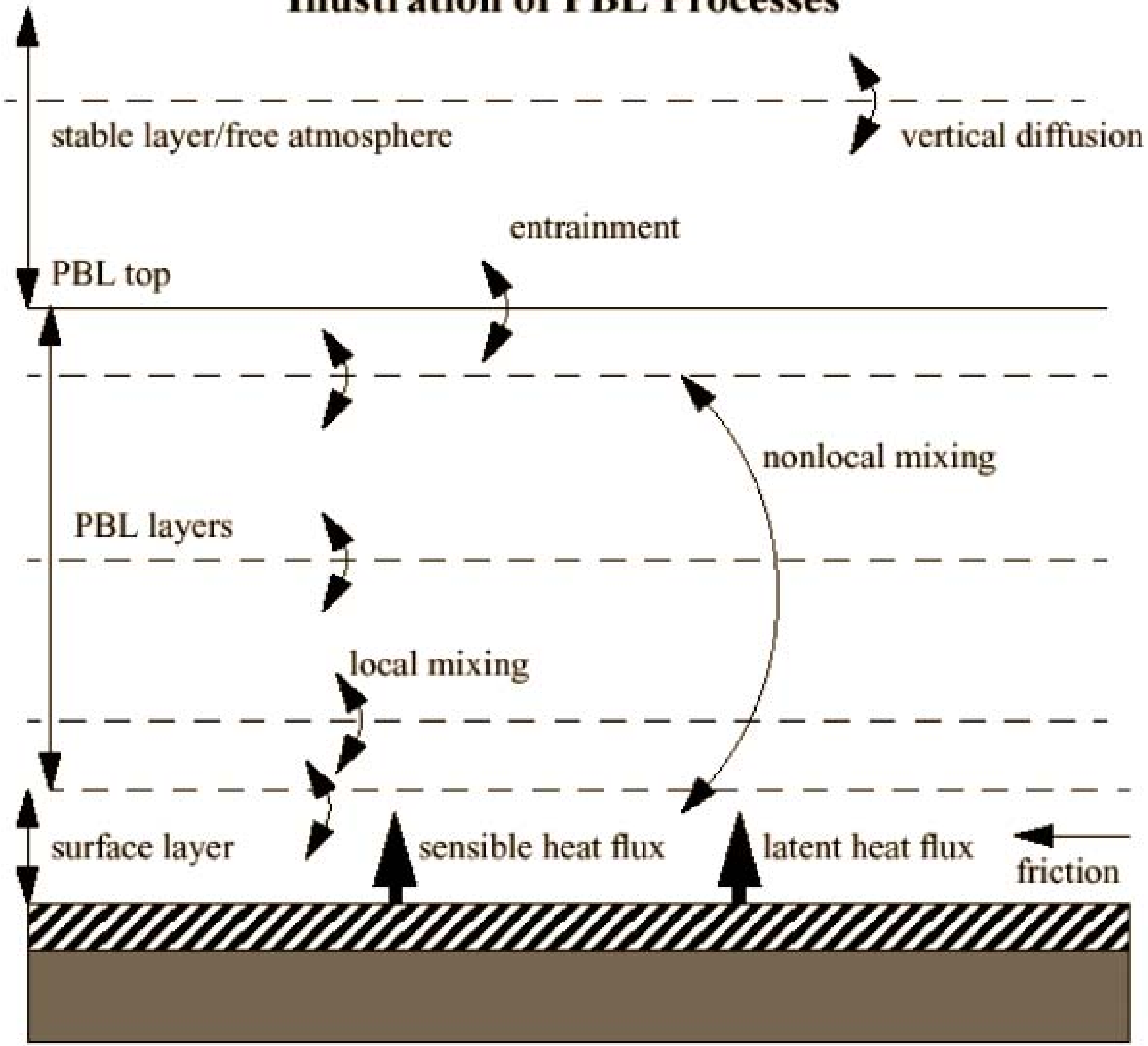
- For long-period simulations (a week or more)
- wrflowinp_d0*n* created by *real*
- Sea-ice not updated
  - Update available in Version 3
- Vegetation fraction update is included
  - Background albedo in Version 3

Planetary Boundary Layer

Boundary layer fluxes (heat, moisture, momentum)

Vertical diffusion

Illustration of PBL Processes



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

PBL Scheme Options

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

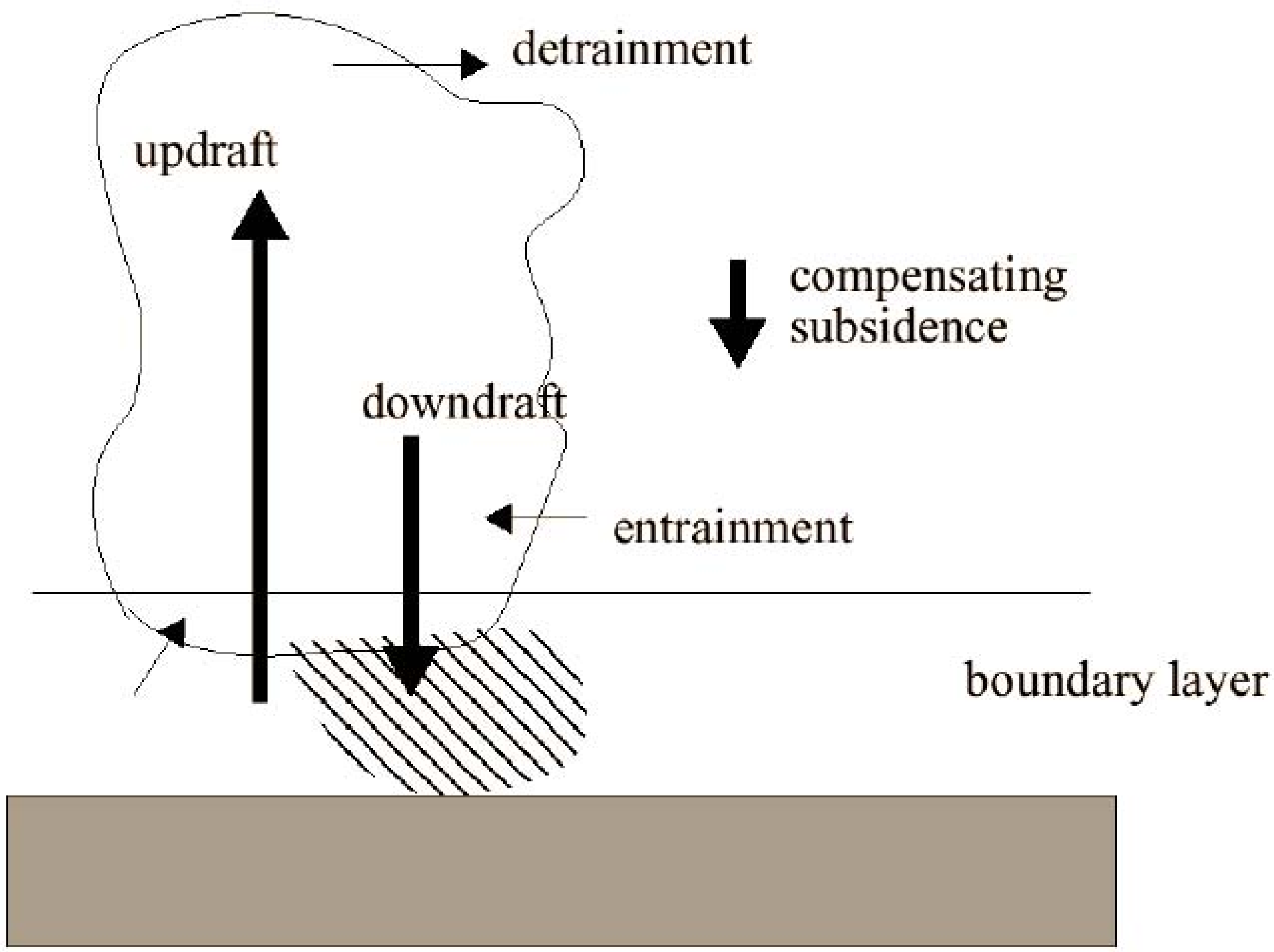
- With PBL scheme, lowest full level should be .99 or .995 (not too close to 1)
- Assumes that PBL eddies are not resolved
- At grid size dx << 1 km, this assumption breaks down
- Can use 3d diffusion instead of a PBL scheme in Version 3 (coupled to surface physics)
  - Works best when dx and dz are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

Cumulus Parameterization

Atmospheric heat and moisture/cloud tendencies

Surface rainfall

Illustration of Cumulus Processes



cu_physics=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

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

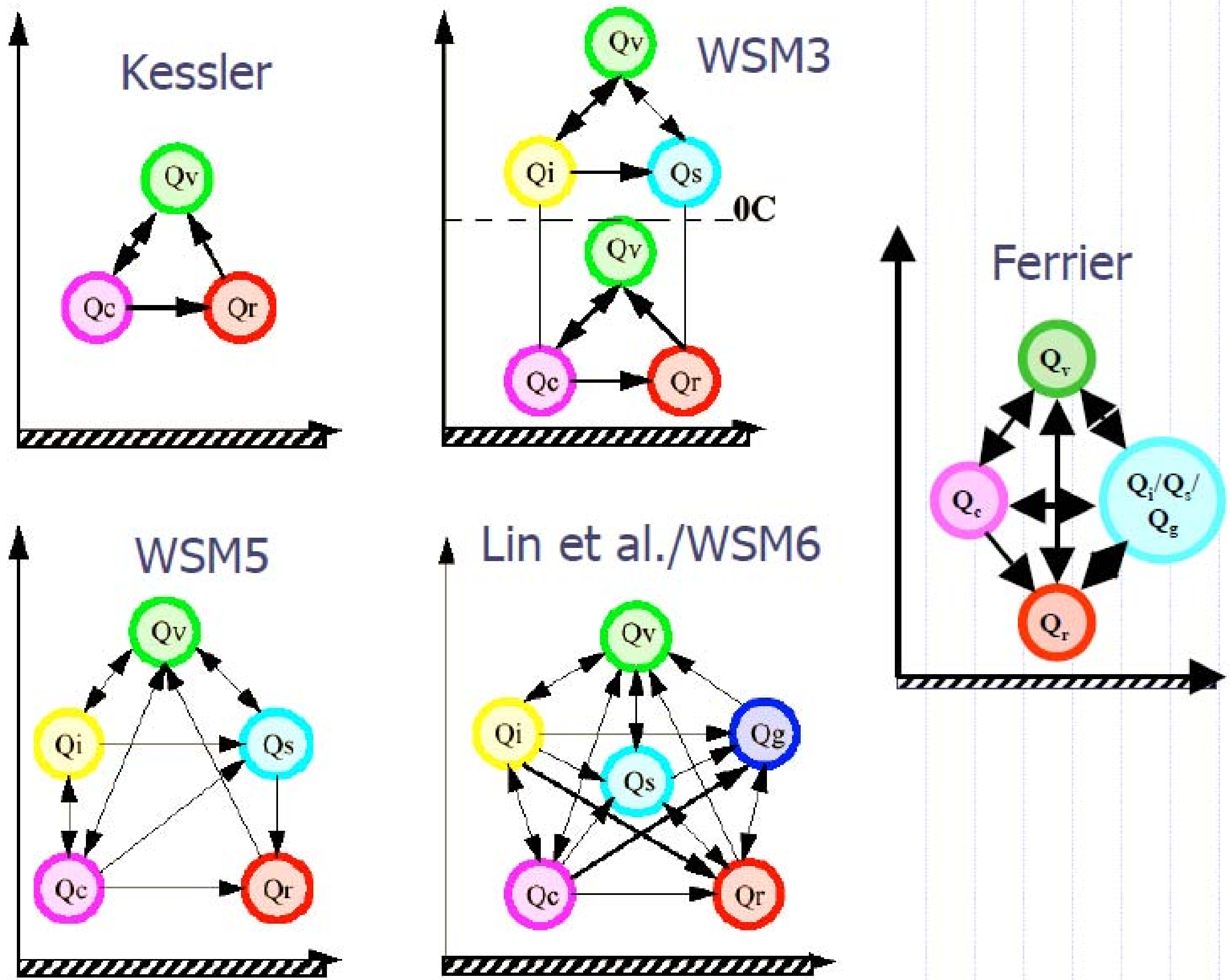
Microphysics

Atmospheric heat and moisture tendencies

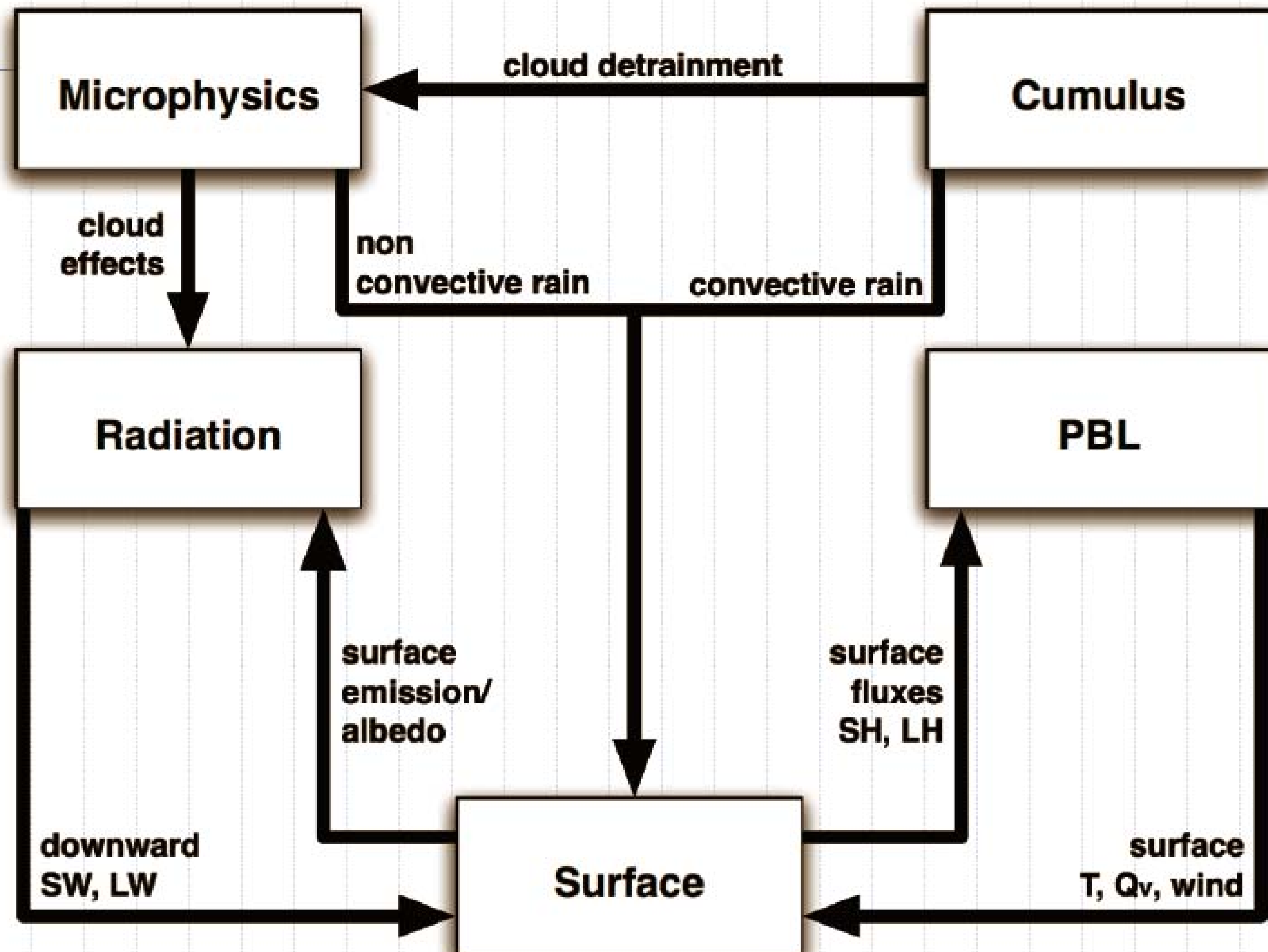
Microphysical rates

Surface rainfall

Illustration of Microphysics Processes



Direct Interactions of Parameterizations



Summary

- A ‘physics parameterization’ is an approximation of a process.
- They are often not of direct interest to a forecaster. (primary exception: precipitation)
- Process parameterized to obtain with ‘sufficient accuracy’ the impact of that process upon a primary variable. (e.g. how radiation affects primary variable T)
- Various approximations (schemes) exist for the same physical process. Different schemes have different advantages/disadvantages: speed, accuracy in certain situations, storage space, etc.
- Generally speaking, the physics parameterizations are more accurate in the regional model than the global model. (partly due to better resolution)