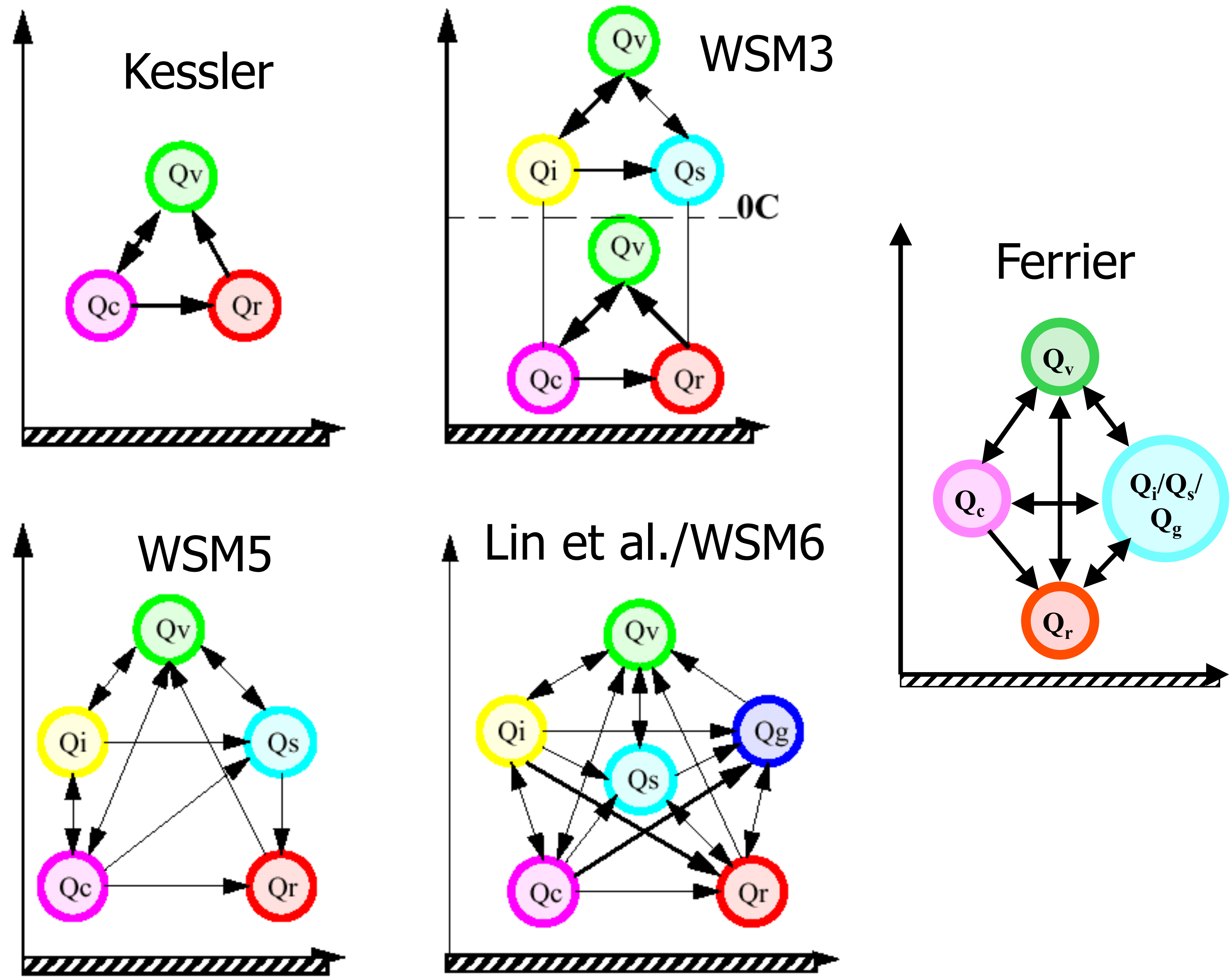
Microphysics Options in WRF

Jimy Dudhia
NCAR/MMM

Microphysics

- Provides 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
- Semi-lagrangian fall terms in V3.2

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
- Semi-lagrangian fall terms in V3.2

ARW only

mp_physics=14

WDM 5-class scheme

- Version of WSM5 that is double-moment for warm rain processes
- 5-class microphysics with ice
- CCN, and number concentrations of cloud and rain also predicted

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=85 (nearly identical) for HWRF

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
- New combined snow/graupel fall speed
- Semi-lagrangian fall terms

ARW only

mp_physics=16

WDM 6-class scheme

- Version of WSM6 that is double-moment for warm rain processes
- 6-class microphysics with graupel
- CCN, and number concentrations of cloud and rain also predicted

ARW only

mp_physics=7

Goddard 6-class scheme

- From Tao et al.
- 6-class microphysics with graupel
- Based on Lin et al. with modifications for ice/ water saturation
- gsfcgce_hail switch for hail/graupel properties
- gsfcgce_2ice switch for removing graupel or snow processes
- Time-split fall terms with melting

mp_physics=8

New Thompson et al. scheme in V3.1

- Replacement of Thompson et al. (2007) scheme that was option 8 in V3.0
- 6-class microphysics with graupel
- Ice and rain number concentrations also predicted (double-moment ice)
- Time-split fall terms

mp_physics=98

Old Thompson et al. 2007 graupel scheme

- From Thompson et al. (2007)
- Was option 8 in Version 3.0
- 6-class microphysics with graupel
- Ice number concentration also predicted (double-moment ice)
- Time-split fall terms

ARW only

mp_physics=9

Milbrandt-Yau 2-moment scheme

- New in Version 3.2
- 7-class microphysics with separate graupel and hail
- Number concentrations predicted for all six water/ice species (double-moment) - 12 variables
- Time-split fall terms

ARW only

mp_physics=10

Morrison 2-moment scheme

- Since 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

no_mp_heating=1

- Turn off heating effect of microphysics
  - Zeroes out the temperature tendency
  - Equivalent to no latent heat
  - Other microphysics processes not affected
  - Since Version 3.0

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 chosen to give a frequency of 1-3 minutes, i.e. 60/dt to 180/dt

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

Microphysics Options

Recommendations about choice (continued)

- Hurricanes may be sensitive to microphysics choice (fall-speed and radiation effects)
- Note that with model top < 5 hPa schemes may give spurious clouds unless saturation formula is fixed
  - WSM, WDM and Morrison schemes are being fixed for next bug-fix release

ARW only

Rainfall Output

- Cumulus and microphysics can be run at the same time
- ARW outputs rainfall accumulations since simulation start time (0 hr) in mm
- RAINC comes from cumulus scheme
- RAINNC comes from microphysics scheme
- Total is RAINC+RAINNC
  - RAINNCV is time-step value
  - SNOWNC/SNOWNCV are snow sub-set of RAINC/ RAINNCV (also GRAUPELNC, etc.)

ARW only

Rainfall Output

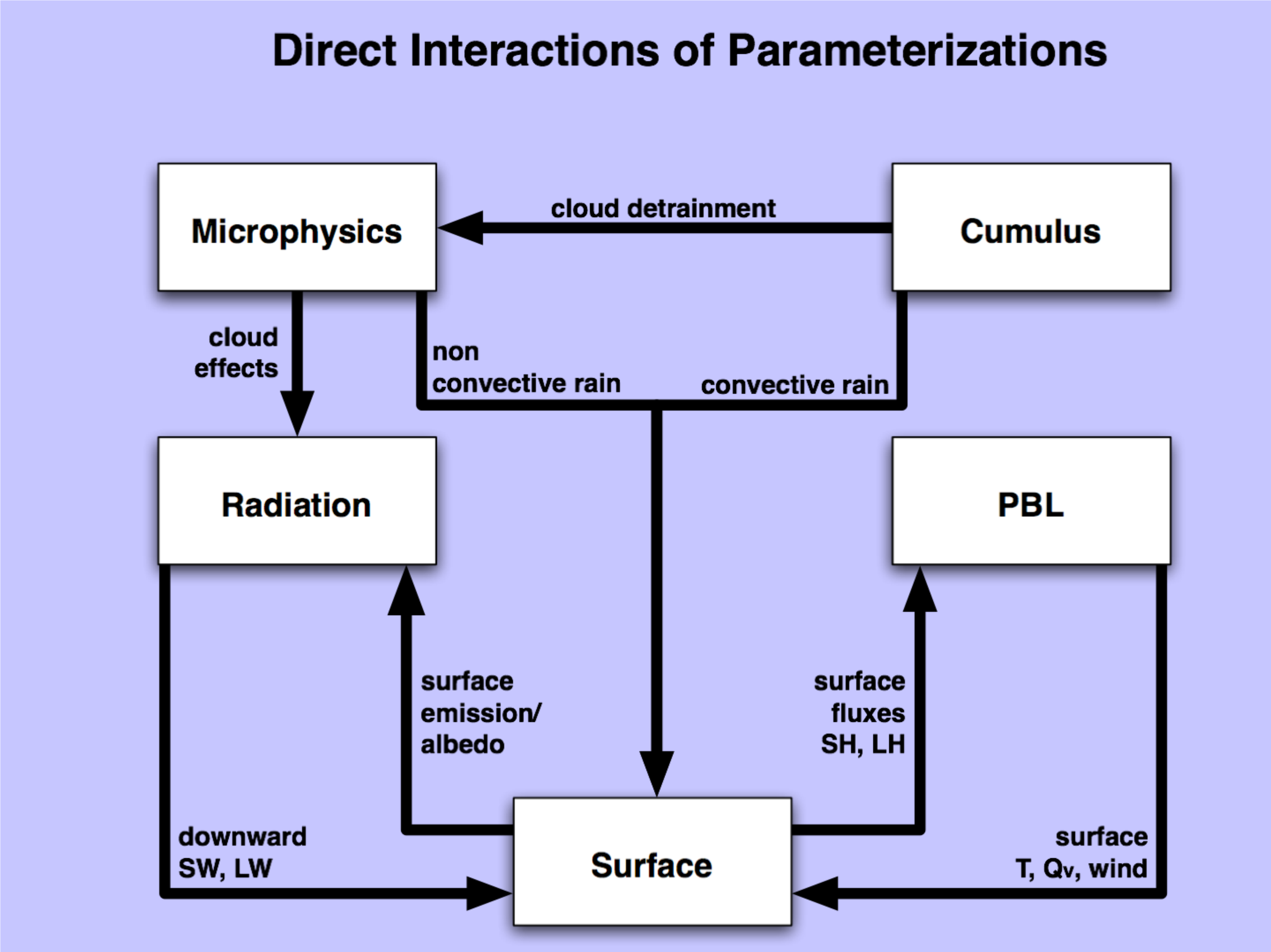
Options for “buckets”

- prec_acc_dt (minutes) - accumulates separate prec_acc_c, prec_acc_nc, snow_acc_nc in each time window (we recommend prec_acc_dt is equal to the wrf output frequency to avoid confusion)
- bucket_mm - separates RAIN(N)C into RAIN(N)C and I_RAIN(N)C to allow accuracy with large totals such as in multi-year accumulations
  - Rain = I_RAIN(N)C*bucket_mm + RAIN(N)C
  - bucket_mm = 100 mm is a reasonable bucket value
  - bucket_J also for CAM and RRTMG radiation budget terms (1.e9 J/m^2 recommended)

NMM only

Rainfall Output

- Cumulus and microphysics can be run at the same time
- NMM outputs rainfall accumulations in mm
- TPREC controls zeroing out frequency
- ACPREC is the total precipitation
- CUPREC is the part that comes from the cumulus scheme
- The microphysics part is ACPREC-CUPREC


Direct Interactions of Parameterizations
Microphysics
cloud detrainment
Cumulus
cloud effects
non convective rain
convective rain
Radiation
PBL
surface emission/ albedo
surface fluxes SH, LH
downward SW, LW
Surface
surface T, Qv, wind

Microphysics schemes in V3.2

mp_physics	Scheme	Reference	Added
1	Kessler	Kessler (1969)	2000
2	Lin (Purdue)	Lin, Farley and Orville (1983, JCAM)	2000
3	WSM3	Hong, Dudhia and Chen (2004, MWR)	2004
4	WSM5	Hong, Dudhia and Chen (2004, MWR)	2004
5	Eta (Ferrier)	Rogers, Black, Ferrier, Lin, Parrish and DiMego (2001, web doc)	2000
6	WSM6	Hong and Lim (2006, JKMS)	2004
7	Goddard	Tao, Simpson and McCumber (1989, MWR)	2008
8 (+98)	Thompson (+old)	Thompson, Field, Rasmussen and Hall (2008, MWR)	2009
9	Milbrandt 2-mom	Milbrandt and Yau (2005, JAS)	2010
10	Morrison 2-mom	Hong and Pan (1996, MWR)	2008
14	WDM5	Lim and Hong (2010,...)	2009
16	WDM6	Lim and Hong (2010,…)	2009

Microphysics schemes in V3.2

mp_physics	Scheme	Cores	Mass Variables	Number Variables
1	Kessler	ARW	Qc Qr	
2	Lin (Purdue)	ARW	Qc Qr Qi Qs Qg	
3	WSM3	ARW	Qc Qr	
4	WSM5	ARW NMM	Qc Qr Qi Qs	
5 (/85)	EtaFerrier(/HWRF)	ARW NMM	Qc Qr Qs (Qt*)	
6	WSM6	ARW NMM	Qc Qr Qi Qs Qg	
7	Goddard	ARW	Qc Qr Qi Qs Qg	
8 (/98)	Thompson(/old)	ARW NMM	Qc Qr Qi Qs Qg	Ni Nr (/Ni)
9	Milbrandt 2-mom	ARW	Qc Qr Qi Qs Qg Qh	Nc Nr Ni Ns Ng Nh
10	Morrison 2-mom	ARW	Qc Qr Qi Qs Qg	Nr Ni Ns Ng
14	WDM5	ARW	Qc Qr Qi Qs	Nn** Nc Nr
16	WDM6	ARW	Qc Qr Qi Qs Qg	Nn** Nc Nr

* Advects only total condensate   ** Nn= CCN number