Improvement and testing of WRF physics options for application to Rapid Refresh and High-Resolution Rapid Refresh

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Model physics

Code describing those processes not explicitly included in the basic dynamical and thermodynamical equations describing the earth's atmosphere

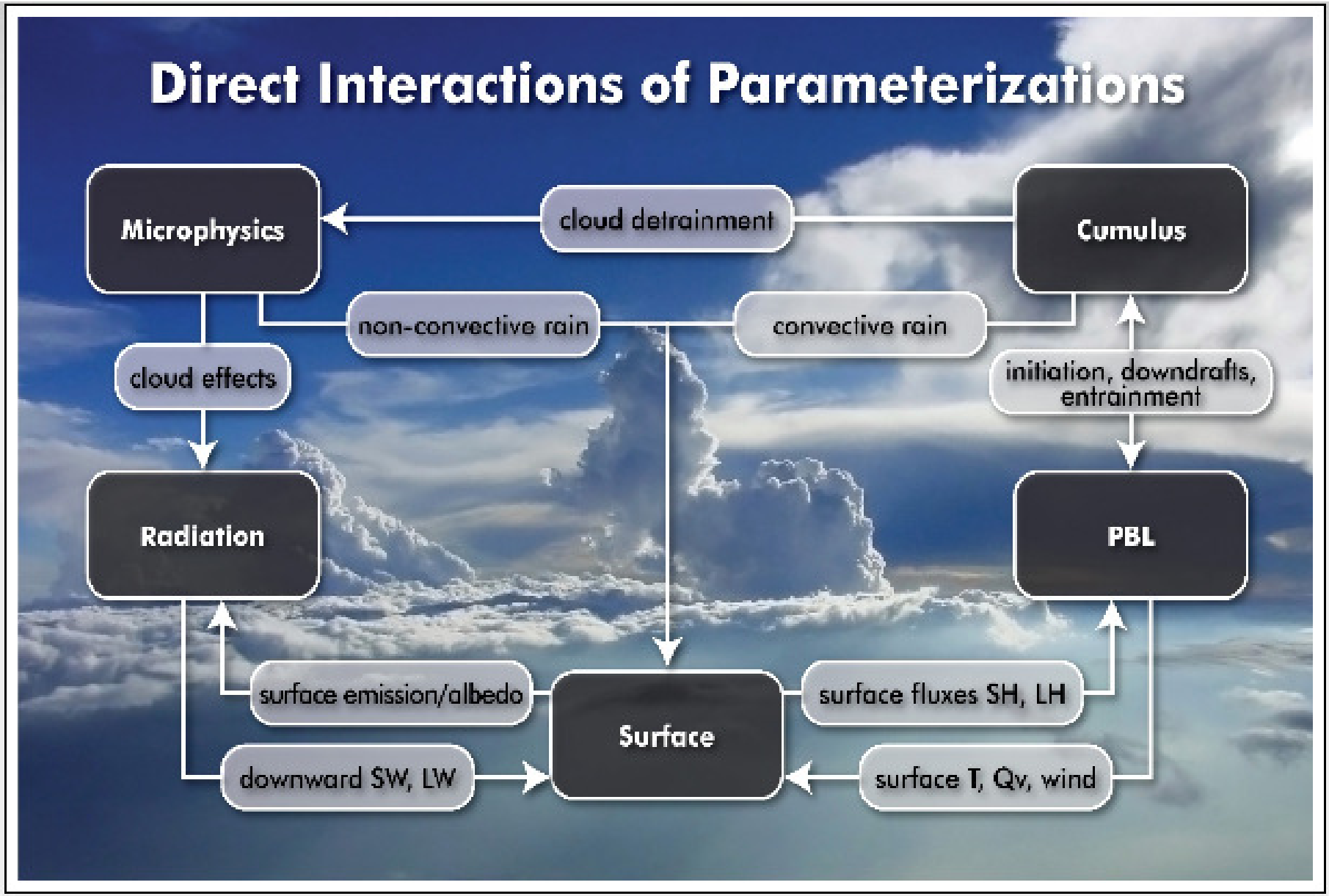
- Too complicated to be explicitly included in the model based on their most fundamental physics laws (e.g. radiation and microphysics)

or

- Finer in scale than can be adequately represented by realizable grid resolutions (sub-grid scale turbulence, PBL transport).

Effects on resolvable-scale flows and on sensible weather (e.g., precipitation amount) have to be properly included for a NWP model to accurately predict atmospheric behavior.

Interaction between separate physics schemes is a critical aspect of the challenge of parameterizations of physical processes



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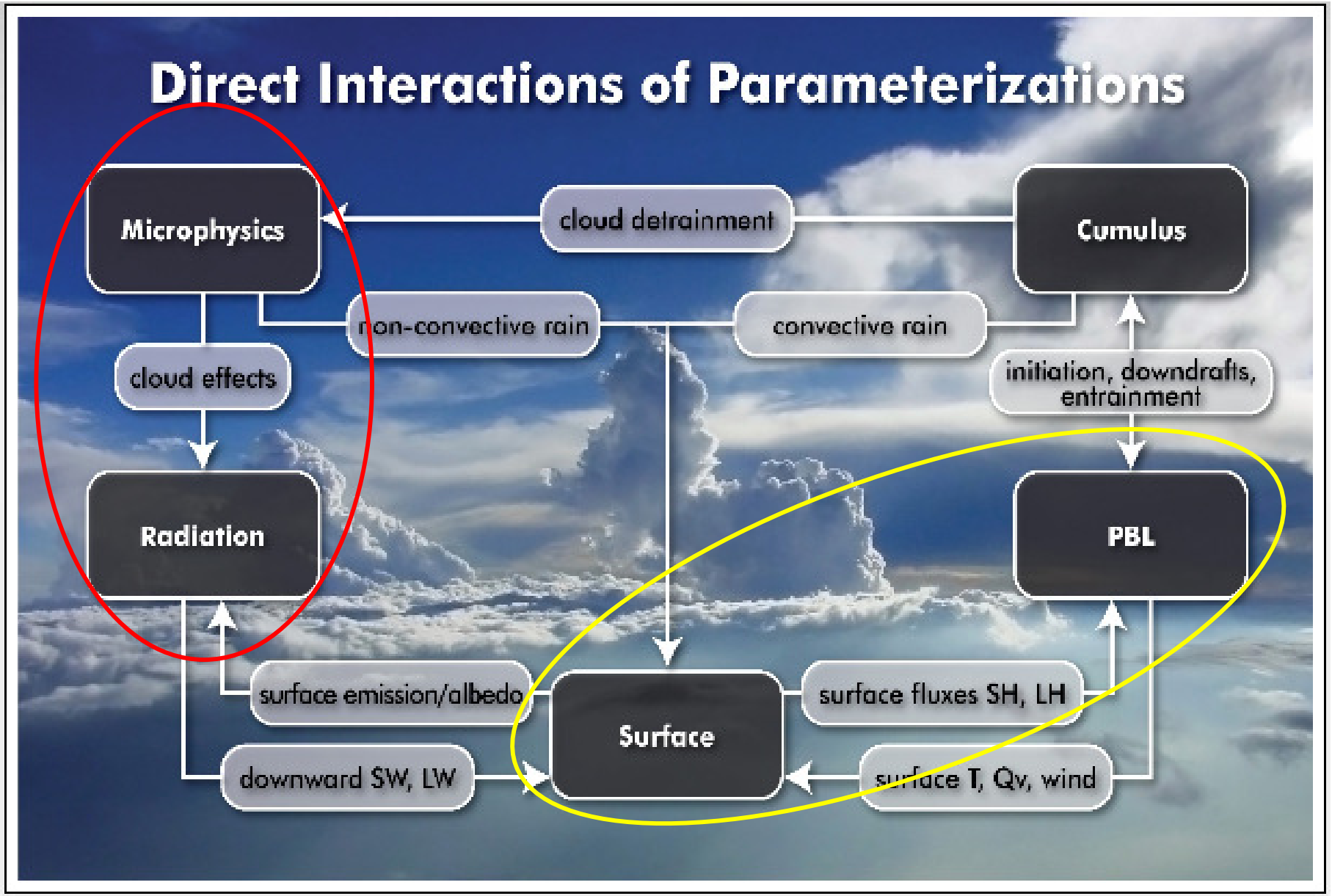


Physics options in RUC / RR / HRRR

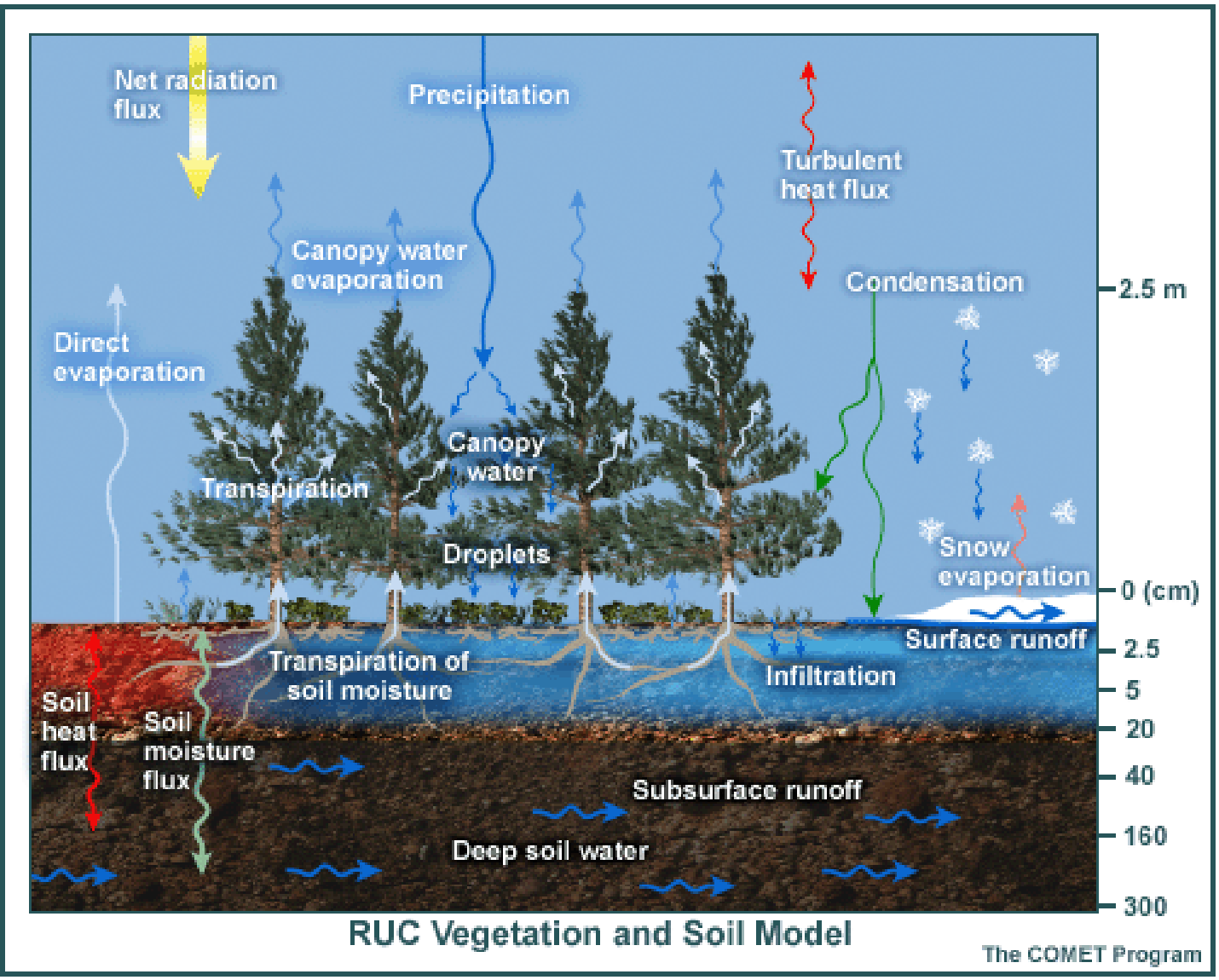
model	SW/LW Radiation	Cloud physics (# hydrometeor types)	Cumulus parm	Boundary layer (PBL)	LSM	Shallow cumulus
RUC	Dudhia / RRTM	Thompson-2004 (5)	Grell-Devenyi	Burk-Thompson	RUC-2005	none
Rapid Refresh	Goddard / RRTM	Thompson-2010 (WRFv3.2+ bugfix) (5)	Grell-3D	Mellor-Yamada-Janjic	RUC-2010	Grell
HRRR	Goddard / RRTM	" (5)	none	Mellor-Yamada-Janjic	RUC-2010	none

Some RR model namelist options

dx = 13545.087 km (758 X 567 unstaggered)
dy = 13545.087 km
p_top_requested = 1000 (10 hPa)
51 eta_levels = 1.0000, 0.9980, 0.9940, 0.9870, 0.9750, 0.9590, 0.9390,
0.9160, 0.8920, …, 0.0000
mp_physics = 8 Thompson V3.2.1 bugfix
ra_lw_physics = 1 RRTM longwave
ra_sw_physics = 2 Goddard shortwave
sf_surface_physics = 3 RUC LSM
sf_sfclay_physics = 2 MYJ
bl_pbl_physics = 2 MYJ
cu_physics = 5 Grell 3d ('G3') ensemble convection
[no deep or shallow in HRRR]
ishallow = 1 (G3 shallow scheme)
non_hydrostatic = .false. [.true. for HRRR]
damp_opt = 1,
zdamp = 5000., 5000., 5000.,
dampcoef = 0.02, 0.02, 0.01

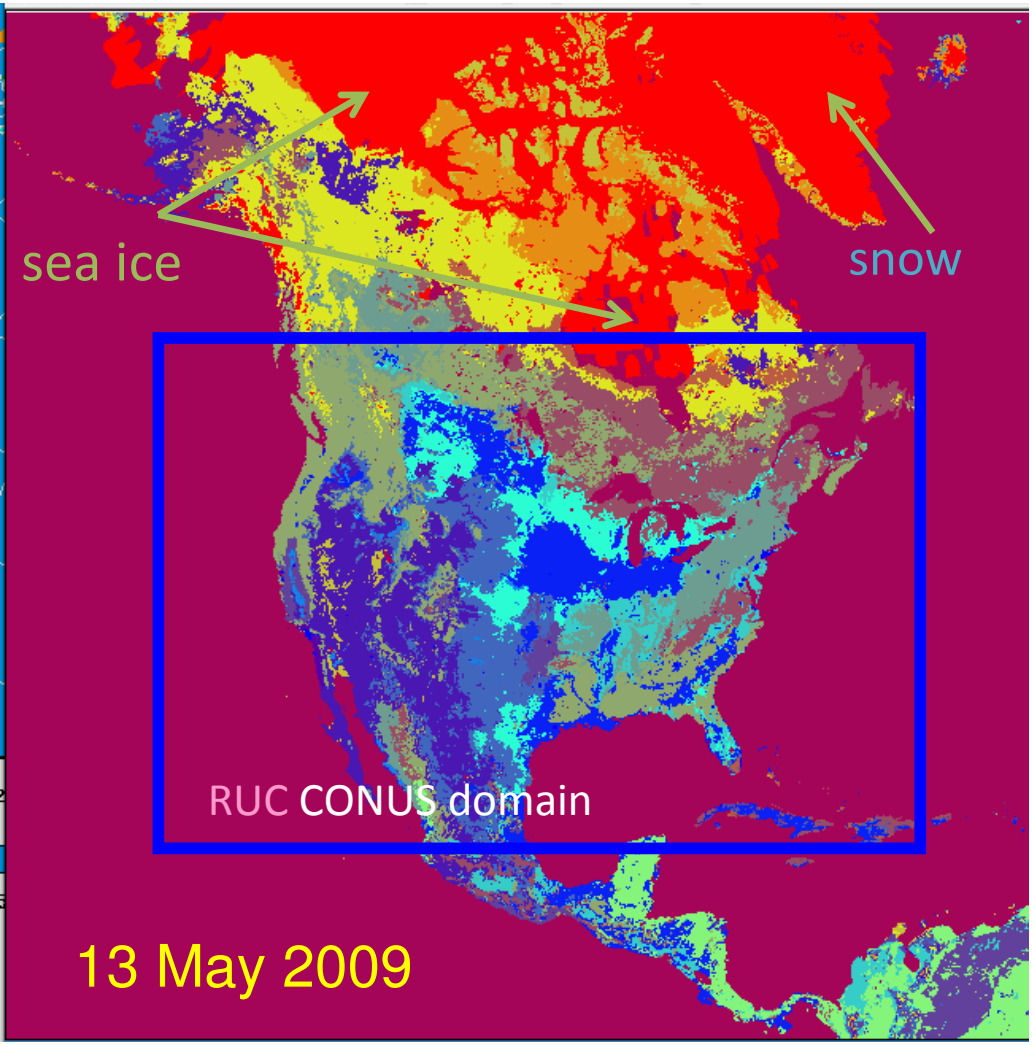
"RUC-like" physics

RUC LSM implemented in operational Rapid Update Cycle (RUC) at NCEP since 1998



Cycling of soil moisture, soil temperature, snow cover, depth, temperature in RUC 1-h cycle since 1997 [with occasional "soil surgeries"]

Further RUC LSM modifications motivated by WRF-based Rapid Refresh (RR)



RR USGS land use types

- RR polar application in Canada and Alaska including extended permafrost tundra zones and snow covered sea ice

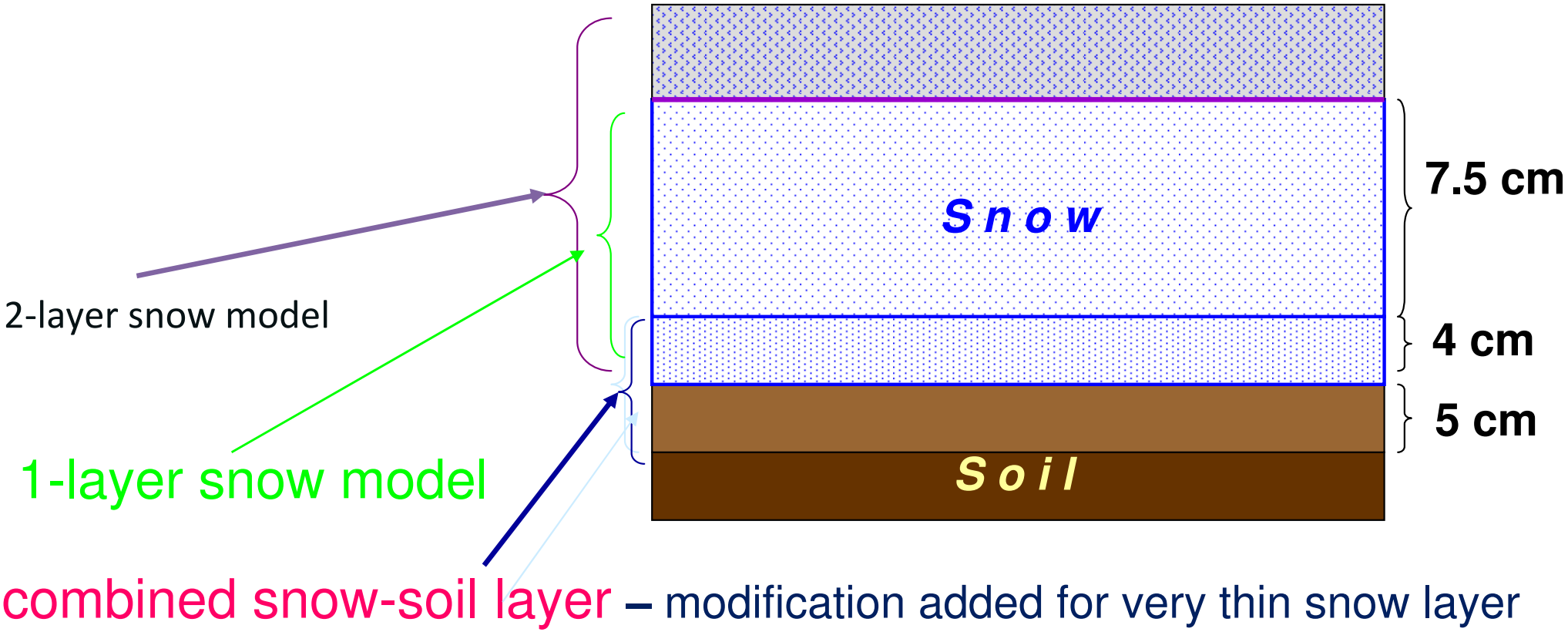
  - new treatment for sea ice in RUC LSM

  - temperature dependence of snow and ice albedo

  - cycling snow on sea ice (snow accumulation / ablation on sea-ice surface)

Modified 2-layer snow model –

- changed vertical structure of the snow model
- snow albedo reduction for thin snow layer – “patchy” snow



combined snow-soil layer – modification added for very thin snow layer

Motivation – correct excessively cold temperatures at night (with clear skies, low winds) over thin snow layer;
– improve estimation of the snow melting rate.

Main HRRR Forecast Challenges

1. Difficulty maintaining MCS propagation

microphysics? *(moderate contributor)*

mid-level moisture? *(not in general)*

1-km resolution? *(no)*

Excessive 6th-order diffusion *(some contribution)*

Latent heating magnitude in radar assim *(major contributor for MCSs underway at initial time)*

2. Difficulty initializing elevated convection

3. False alarm cases

HRRR forecasts a Derecho 11 Jul 2011

Confirmed Derecho From Storm Survey (7/11/2011)

PUBLIC INFORMATION STATEMENT
NATIONAL WEATHER SERVICE DES MOINES IA
458 PM CDT MON JUL 11 2011

...PRELIMINARY DAMAGE SURVEY RESULTS FOR STORY...MARSHALL AND TAMA
COUNTIES...

THIS STORM SURVEY INVESTIGATION IS STILL ONGOING AND SUBJECT TO
FURTHER COORDINATION WITH LOCAL EMERGENCY MANAGEMENT AGENCIES.

...WIDESPREAD AND EXTREME STRAIGHT LINE WIND EVENT...

THE FOLLOWING IS A PRELIMINARY ASSESSMENT FOR THE DAMAGE THAT OCCURRED OVER STORY...MARSHALL AND TAMA COUNTIES...OR FROM CENTRAL
INTO EAST CENTRAL IOWA...EARLY IN THE MORNING ON MONDAY...JULY 11...2011.

* EVENT DATE: 07/11/2011.

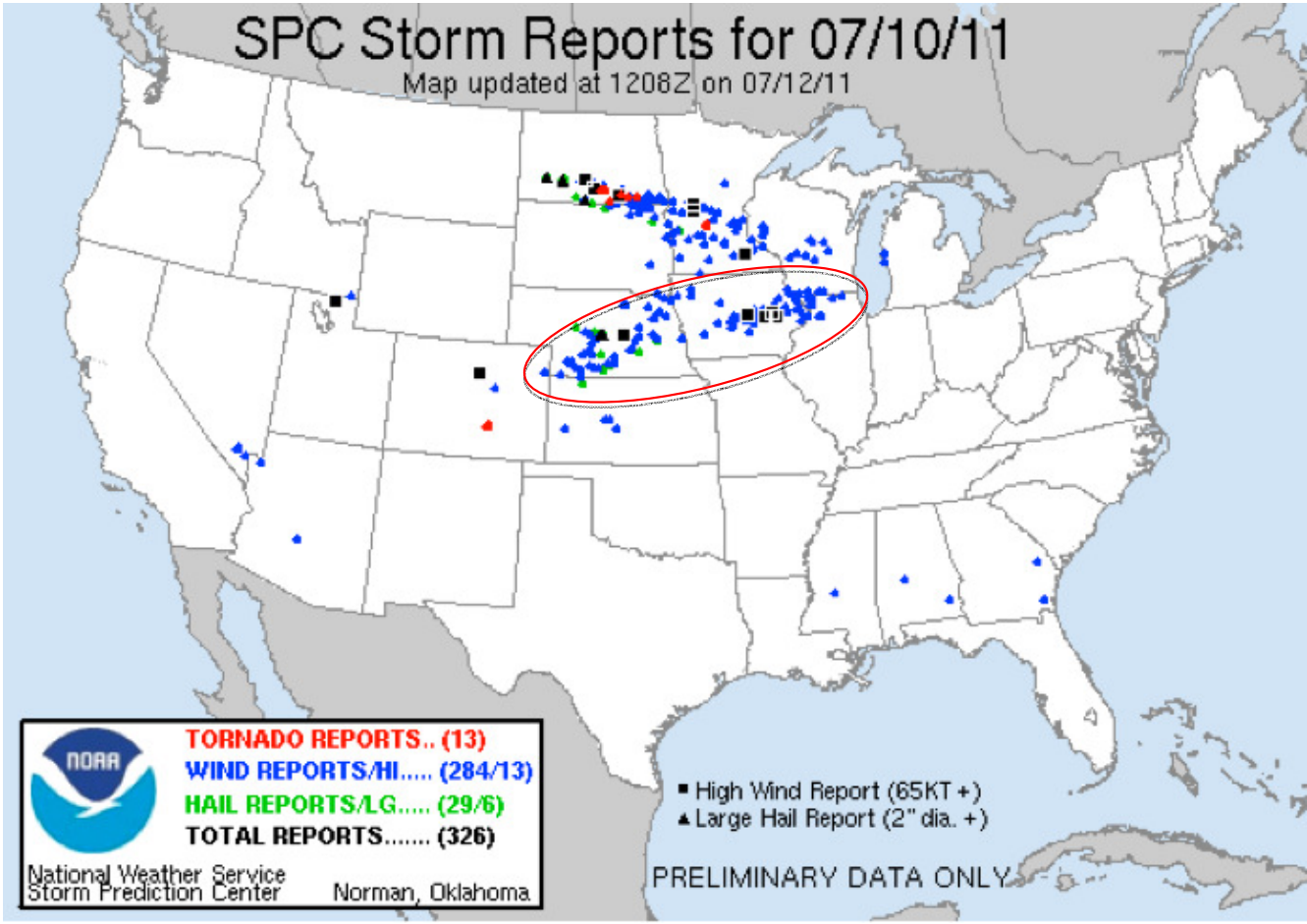
* ESTIMATED START TIME: APPROXIMATELY 320 AM CDT.

* EVENT TYPE: DERECHO. NO TORNADOES WERE INDICATED DURING THIS EVENT. THIS PARTICULAR DERECHO BEGAN IN CENTRAL IOWA AND TRAVELED ACROSS CENTRAL AND EASTERN IOWA...AS WELL AS ACROSS ILLINOIS...LAKE MICHIGAN...MICHIGAN...AND ENDED IN ONTARIO CANADA. THIS DERECHO TRAVELED FROM CENTRAL IOWA TO DETROIT MICHIGAN...OR A DISTANCE OF APPROXIMATELY 550 MILES...OVER THE TIME SPAN OF NINE HOURS. A DERECHO IS A LONG LIVED... WIDESPREAD...DAMAGING WIND STORM WHICH IS ASSOCIATED WITH RAPIDLY MOVING SHOWERS AND THUNDERSTORMS. DERECHOES ARE OFTEN CURVED OR BOWED IN THEIR SHAPE. WINDS IN DERECHOES CAN EXCEED 100 MPH. THE WINDS ASSOCIATED WITH DERECHOES ARE NOT CONSTANT AND MAY VARY CONSIDERABLY ALONG THEIR PATHS.

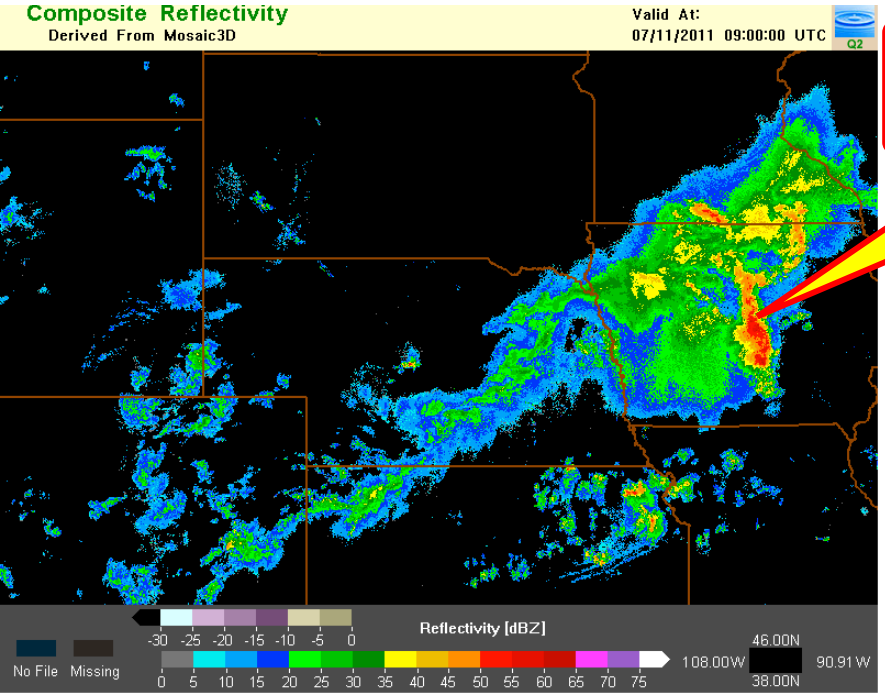
* EVENT LOCATION: BEGAN JUST WEST OF INTERSTATE 35 IN SOUTHERN STORY AND NORTHERN POLK COUNTIES. CONTINUED EASTWARD INTO MARSHALL AND TAMA COUNTIES.

* PEAK WIND: THE HIGHEST WINDS WERE AT LEAST 80 TO 105 MPH.

* PATH WIDTH: THE PATH WIDTH OF THE STRONGEST...HIGH-END WINDS WAS IN TAMA COUNTY AND WAS 5 MILES WIDE. IN ADDITION... THERE WAS A 10 MILE WIDE PATH OF WIND SPEEDS OF 70 TO 80 MPH.

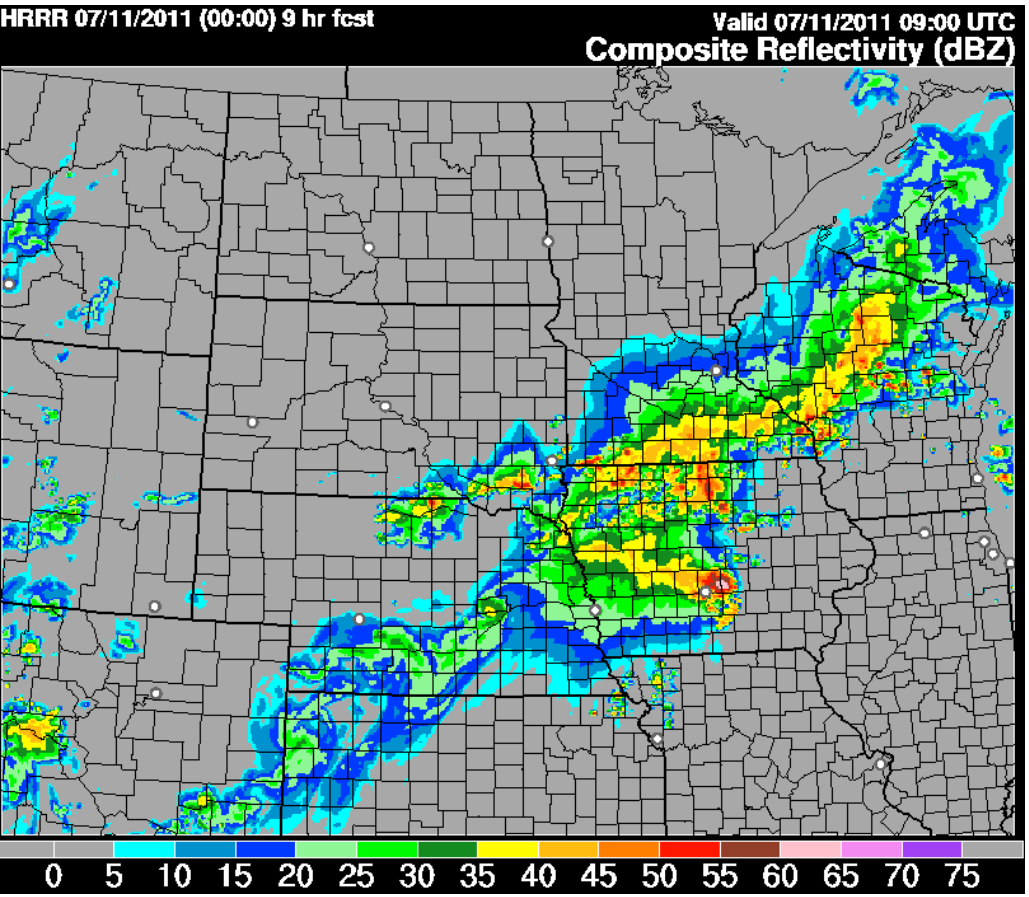


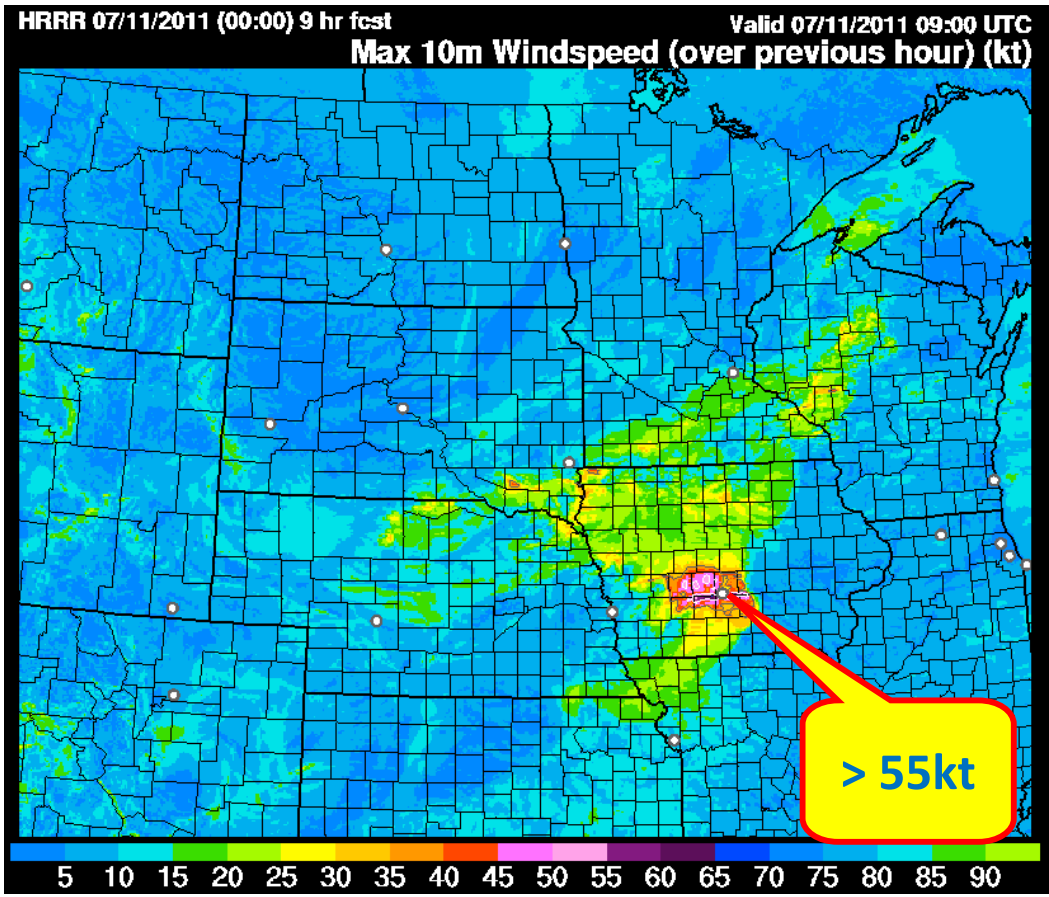
Note: damage swath continued east to the mid-Atlantic after 12z 11 Jul



Serious damage begins central IA

9-h HRRR forecast Valid 09Z 11 Jul 11 HRRR predicts salient aspects of this event





Future Work

Short term

•Test latest version of NCAR microphysics in both RR and HRRR.

•Evaluate Joe Olson's modifications to Mellor-Yamada-Nikinishi-Niino (MYNN) surface-layer / PBL scheme against MYJ .

•Evaluate Rayleigh-damping top boundary condition in HRRR
•Continued monitoring of RR and HRRR performance in relation to physics.

Longer term

•Implementation of NCAR aerosol-linked microphysics into RR and HRRR.

•Do different physics suites add useful diversity to the future North American Rapid Refresh Ensemble?

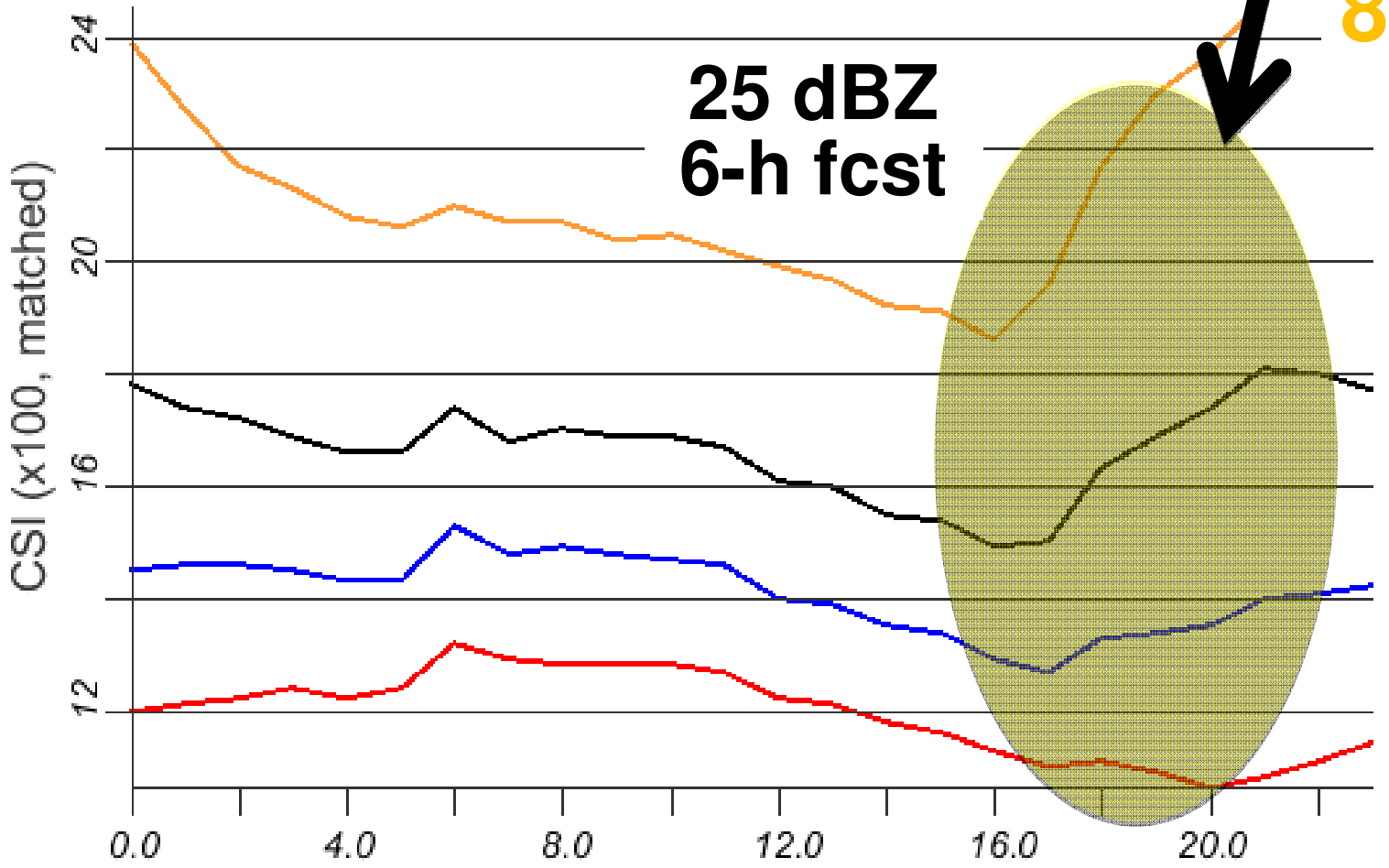
•Do we need to gently parameterize precipitating convection at 1-4km horizontal resolution?

Reserve slides

"neighborhood" verification of 6-h forecasts from 3-km HRRR

verification:10 June – 26 Sept 2010

Convective initiation and early evolution



00	02	04	06	08	10	12	14	16	18	20	22	valid (GMT)
8p	10p	12	2a	4a	6a	8a	10a	12	2p	4p	6p	valid (EDT)

Our typical procedure for evaluating physics changes* (1)

- A scheme or scheme change looks to have potential application to RR / HRRR
- Get code from WRF repository or developer, merge as necessary with our currently active WRF code, get it running.
- “Cold-start” testing (initialized off GFS, usually), run a few troublesome cases
- If results on these cases look good (subjectively and objectively), then put in our regular daily cold-start runs
- If results of cold-start testing are favorable (after a period of careful evaluation of the runs and possibly further code mods and rerunning, in collaboration with scheme developers) try on a short retro period with cycling
- Present preliminary results at formal and informal meetings (e.g., NCAR, NCEP, AMS) and find others who might have tried similar testing and compare results

* This is not a formally defined process, but rather what has evolved over the years.

Our typical procedure for evaluating physics changes (2)

- If these results are favorable (both objective and subjective verification), introduce the scheme into the RR / HRRR development cycle and monitor performance in real time in comparison to the RR / HRRR primary cycle until we have established confidence (or lack thereof) in change through objective and subjective evaluation.

  Also do a longer retro period. Evaluate objectively and subjectively.

- Candidate changes to operational systems (RUC, RR) are also extensively evaluated at EMC and must be approved by the NCEP Configuration Control Board

Key points on evaluation

Cycling often reveals model or physics issues that don't show up in individual case-study runs

We must have objective evaluation we trust

- QC of verifying observations
- Flexible, user-friendly, interactive
- We all know the precise procedures (or who in our group to ask) so that discussions about the meaning of results are more productive
- Webpages for quick intercomparison between model versions (including difference fields) maintained within our branch have also been essential
- Both retrospective and real-time testing have been extremely valuable. (retro – better control but shorter period, real-time – results in more eyeball attention to notice other good/bad behavior)