Snow and Ice Enhancements to the RUC Land-Surface model in WRF and WRF-based Rapid Refresh

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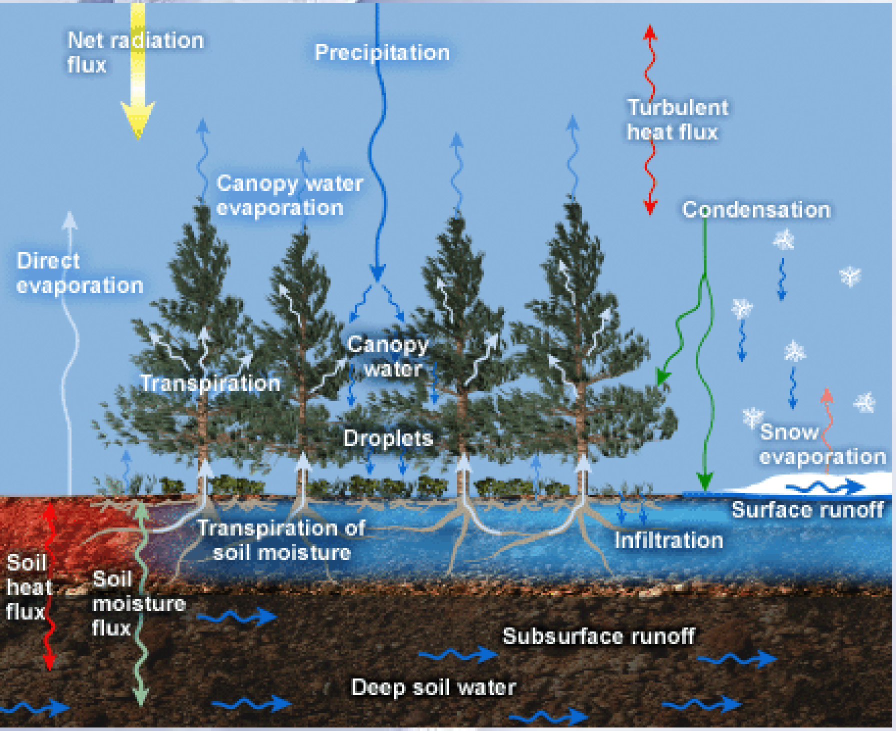
12th Annual WRF Users' Workshop, 20 June 2011

Land-Surface Models (LSM) in WRF:



sf_surface_physics (max_dom):

0 – no surface temperature prediction

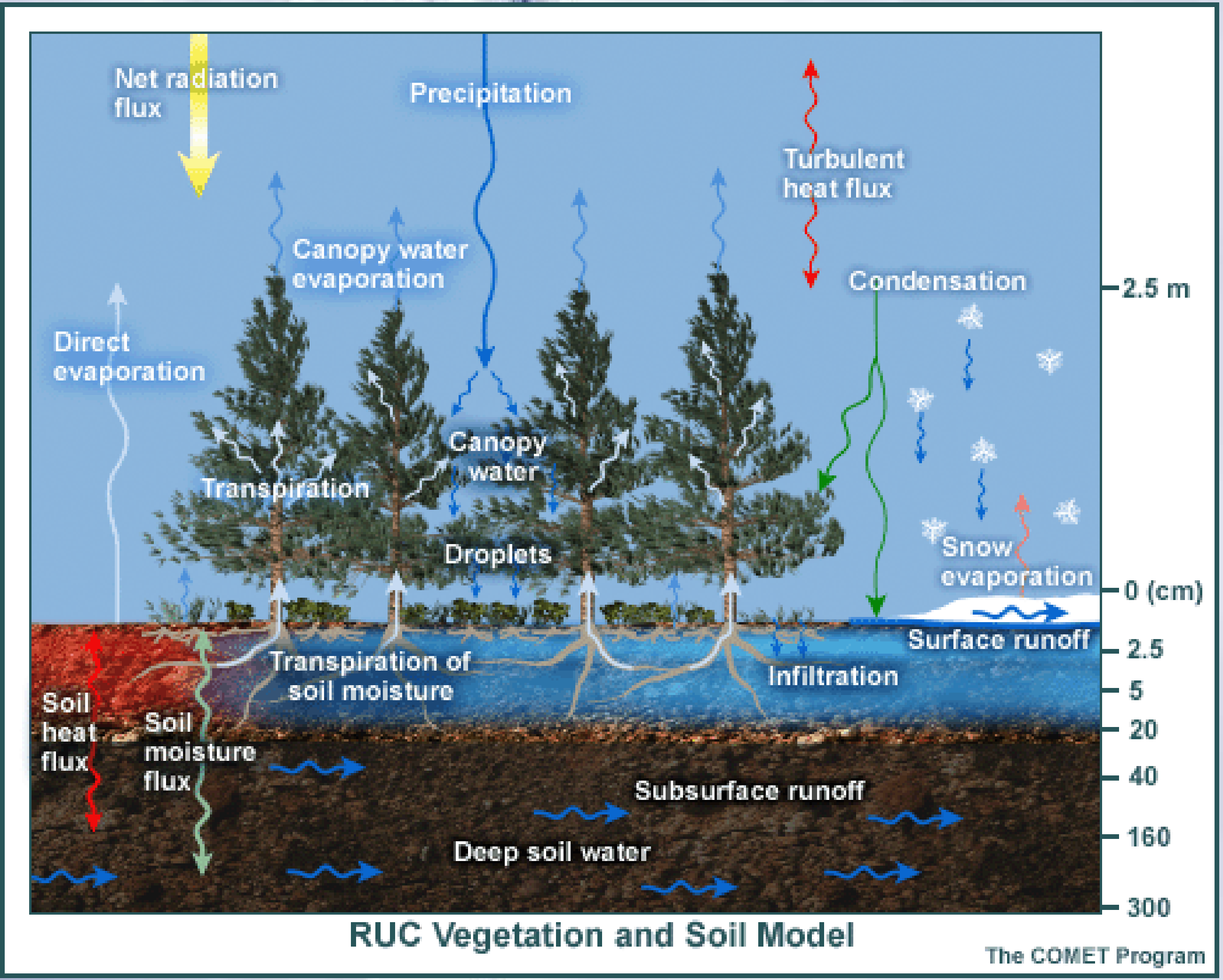
1 – thermal diffusion scheme
num_soil_layers = 5

2 – unified Noah land-surface scheme
num_soil_layers = 4

3 – RUC land-surface model
num_soil_layers = 6 or 9

7 – Pleim-Xiu scheme (only ARW)
num_soil_layers = 2

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



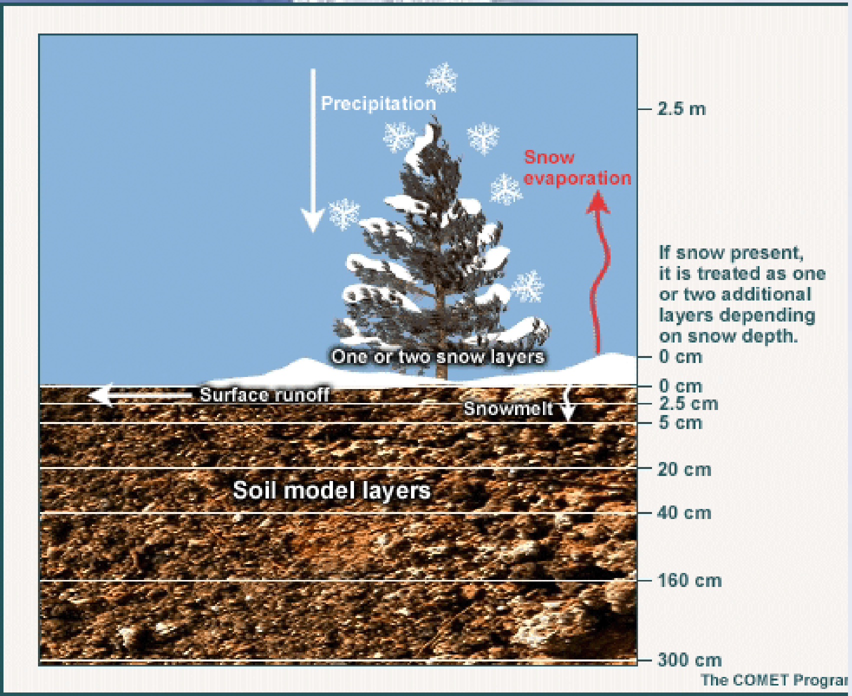
- more accurate lower boundary for weather prediction in RUC (aviation/severe weather)

- *13-year long* record of surface grids provided to GCIP/GAPP community for climate studies

Cycling of soil moisture, soil temperature, snow cover, depth, temperature in RUC 1h cycle since 1998

Snow model in RUC-LSM

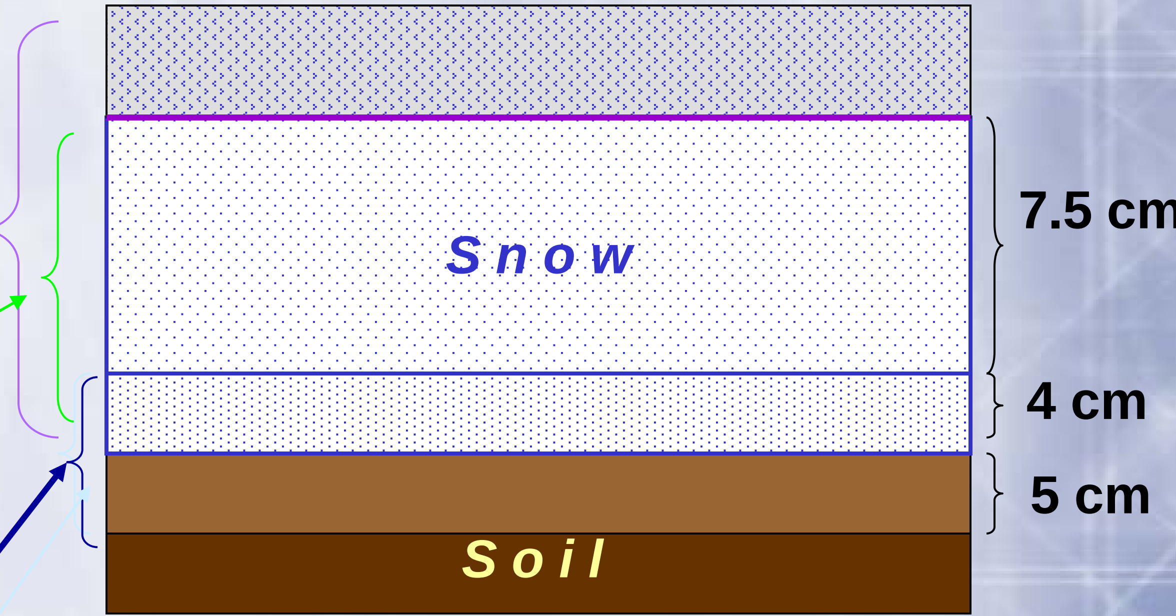
1. One- or two-layer snow model (threshold – 3 cm of snow water equivalent)
2. Changing snow density depending on snow depth, temperature, compaction parameter
3. Two-iteration snow melting algorithm; snow can be melted from the top and bottom of snow pack
4. Prescribed amount of liquid water (13%) from melting can stay inside snow
5. Melted water infiltrates into soil and forms surface runoff



6. Mixed phase precipitation
7. Falling snow can be intercepted by the vegetation canopy until the holding capacity is exceeded

Modified 2-layer snow model –

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



2-layer snow model

1-layer snow model

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.

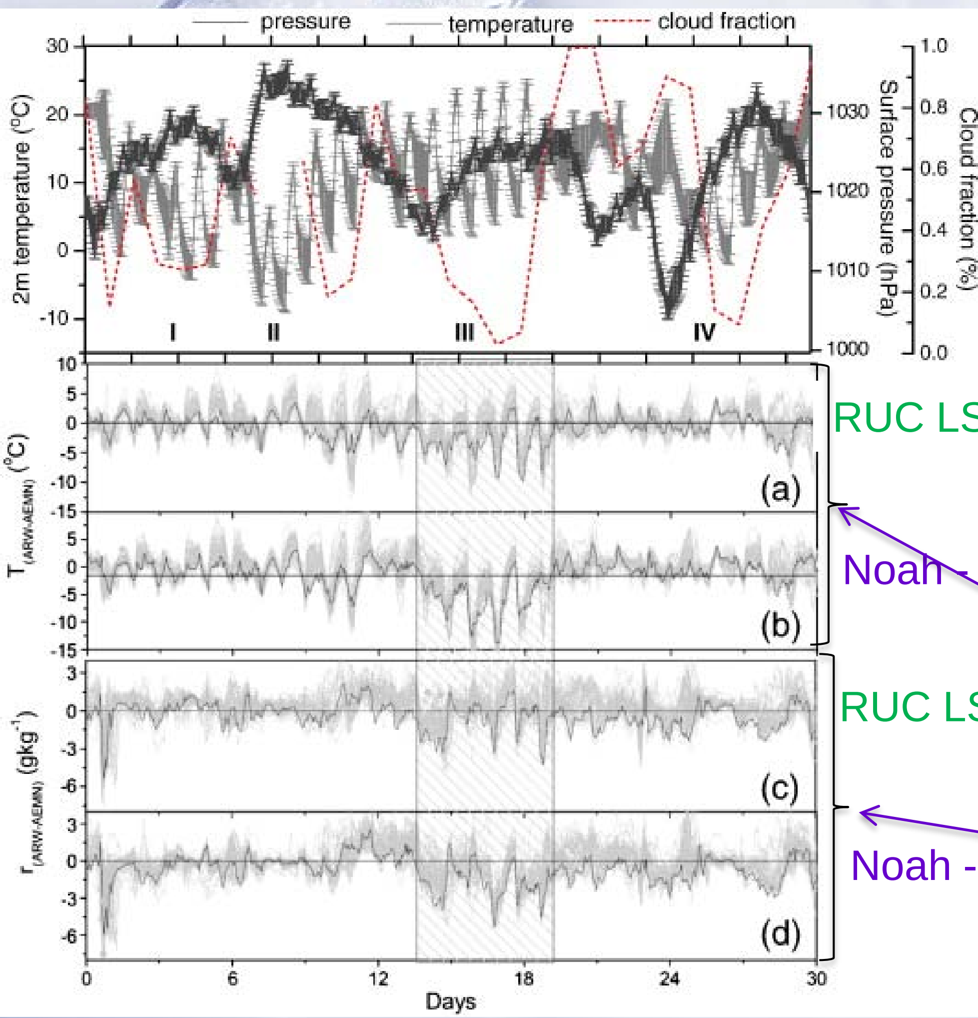
Aspects of RUC LSM that differ from Noah LSM:

- Fluxes in the surface layer
  - layer approach to energy and moisture budget with implicit solution of energy and moisture budgets
  - bare soil evaporation based on surface moisture gradient
  - transpiration (simpler formulations, less sensitivity to parameters)
- Soil model
  - higher vertical resolution, thinner top layers
  - prognostic soil moisture variable ($\theta - \theta_r$)
  - some differences in numerical approximations
- Snow model in RUC LSM versus Noah bulk snow layer
  - treatment of mixed phase precipitation
  - two iterations in melting algorithm, time dependent snow/ice albedo
- Frozen soil physics algorithm and treatment for sea ice

Role of land surface parameterizations on modeling cold-pooling events and low-level jets

Thara V. Prabha[a, b, *], Gerrit Hoogenboom[a, c] and Tatiana G. Smirnova[d, e]

Atmos. Res. (2010)
Doi:10.1016/j.atmosres.2010.09.017



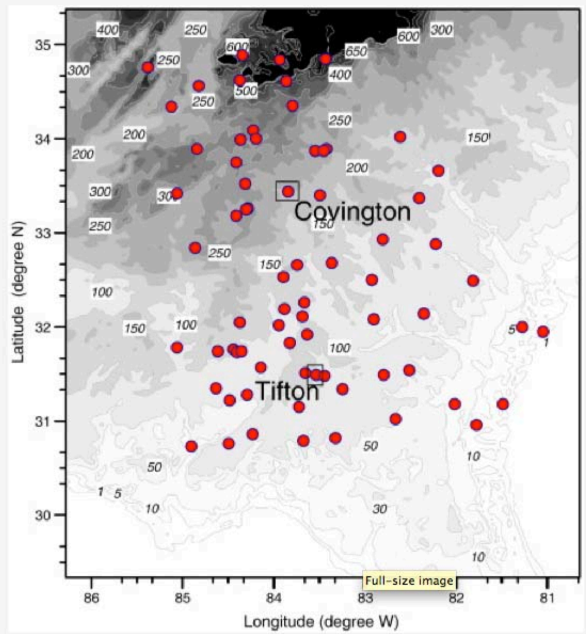


Fig. 1.
Topography of domain 2 and the surface meteorological stations of the Georgia Automated Environmental Monitoring Network (AEMN). Two stations, including Covington (33.44° N, − 83.84° E, 216 m amsl) and Tifton (31.49° N, − 83.53° E, 120 m amsl), were used for a detailed analysis.

2-m temperature biases

2-m water vapor mixing ratio biases

Elevation < 200m

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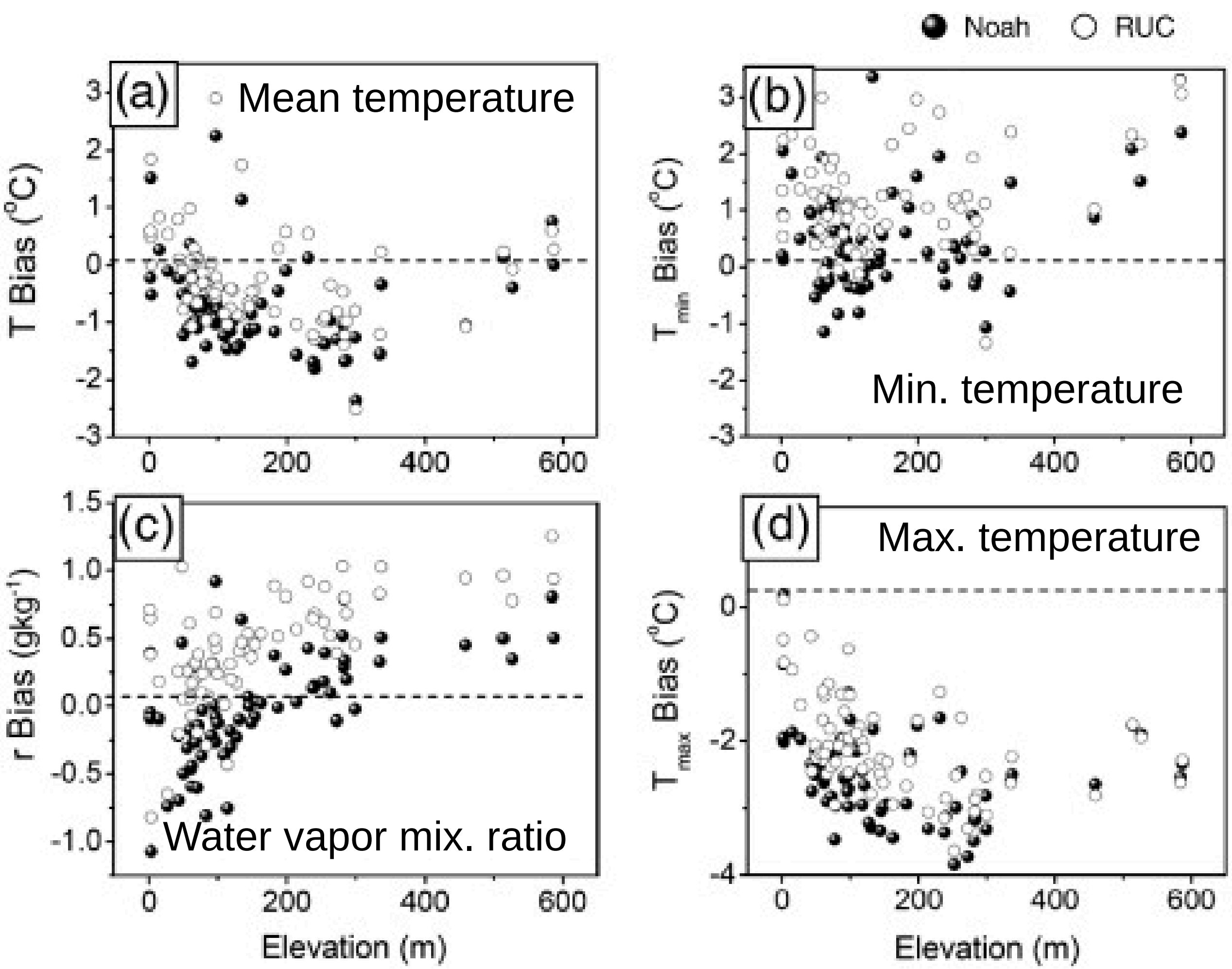
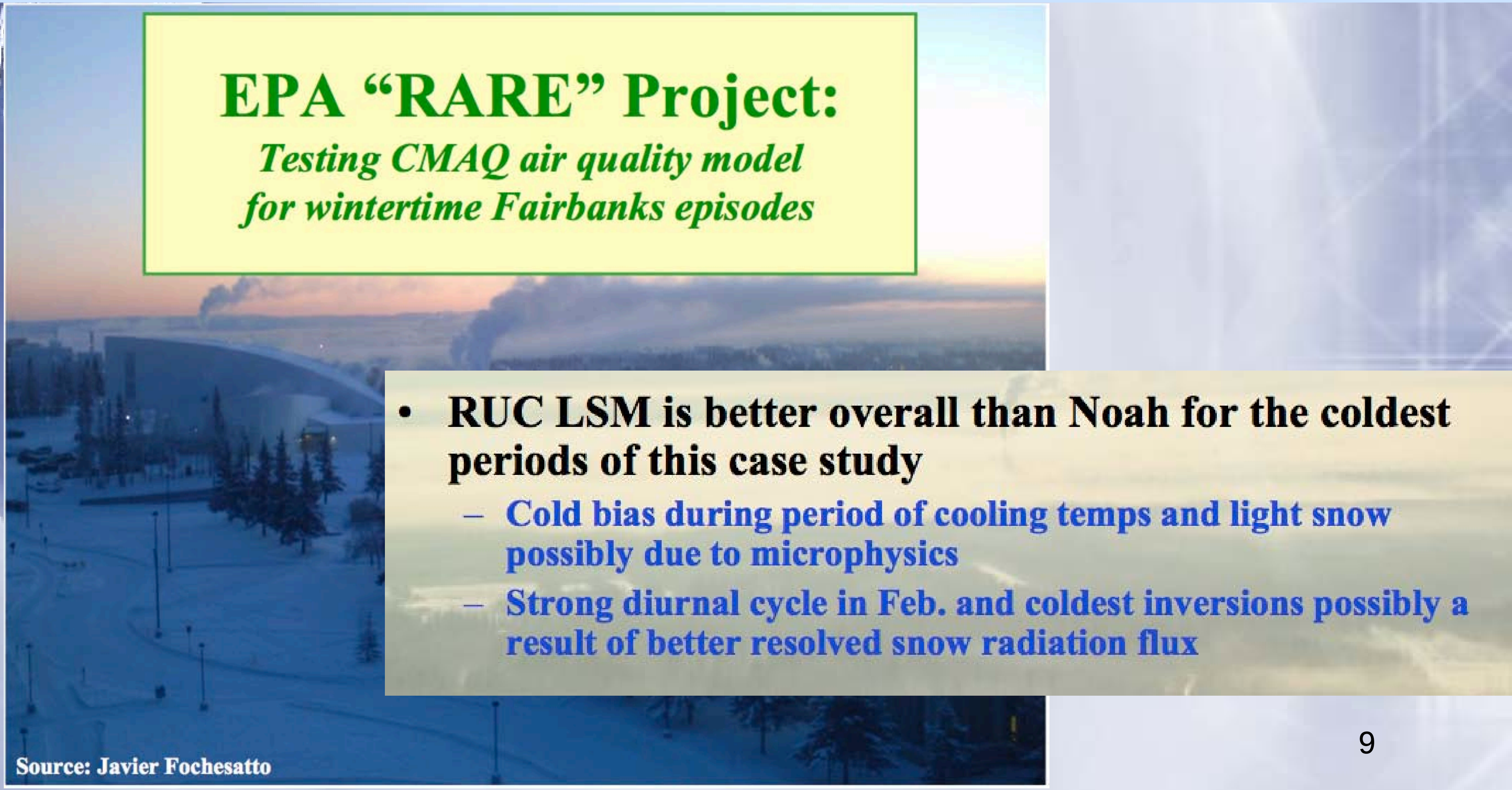


Fig. 3. Model (ARW-RUC and ARW-Noah) bias of mean temperature (a), minimum temperature (

1. Seo B., Byon J., Choi Y. : *Sensitivity evaluation of wind fields in surface layer by PBL and LSM parameterizations using WRF over the Korean Peninsula,* American Geophysical Union, Fall Meeting 2010, abstract #A41F-0164

"*LSM comparisons indicate that the RUC model performs best in predicting 10 m and 80 m wind speed. It is found that MYJ (PBL) _ RUC (LSM) simulations yielded the best results for wind field in the surface layer***."**

2.



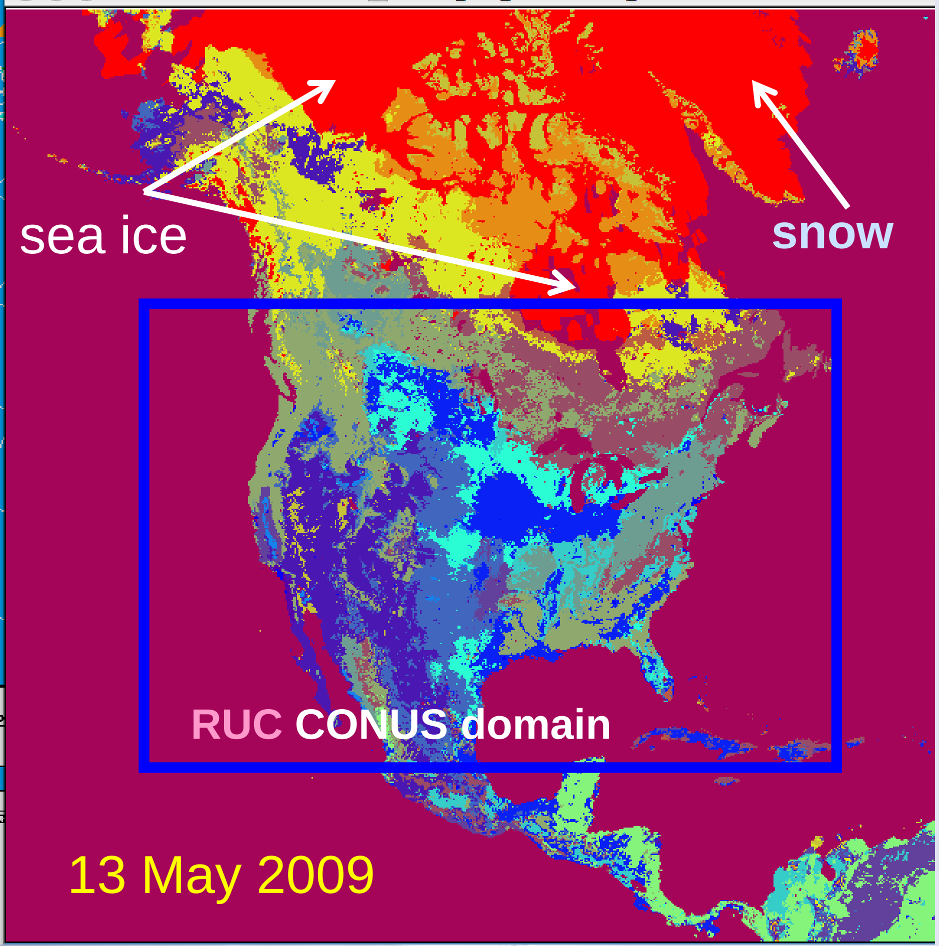
➢ **Based on statements in published results** performed for different applications and in different parts of the world (*Persian Gulf areas, Korea, Equatorial East Africa, Mexico, Iberian Peninsula, Italy, France, Russia, India and different regions of United States*) :

- RUC LSM provides better diurnal cycle, performs well for stable conditions in summer, provides good predictions of surface wind and better PBL heights, favors heavier rainfall, has better performance in deserts, provides better predictions of inversions over snow and under radiative cooling conditions

- Noah LSM performs better in unstable conditions, has good predictions of near-surface mixing ratio, provides better performance for higher elevations

- Sensitivity to combination of physics: LSM, PBL, microphysics and radiation schemes

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

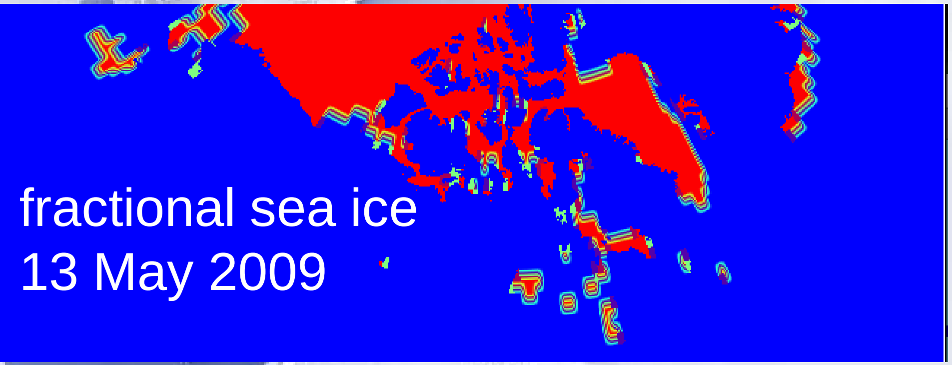


RR USGS land use types

- 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

Sea Ice Treatment in RUC LSM (available since WRF revision 3.2.1)

Sea Ice is initialized in WRF-based Rapid Refresh (RR) from NESDIS snow/ice data or from GFS



New sea ice treatment in RUC LSM

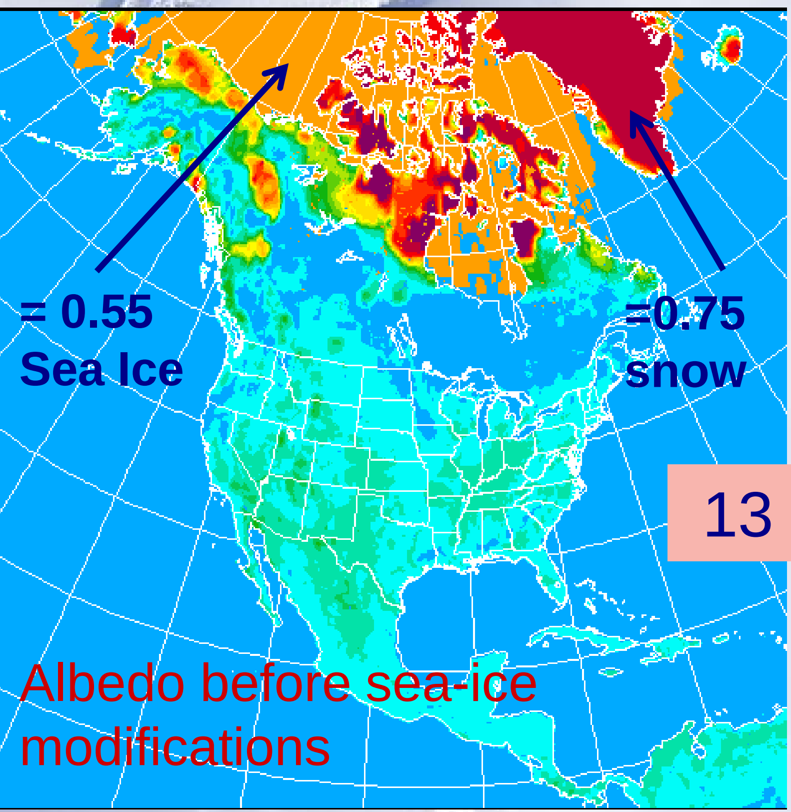
- Solution of surface energy budget and heat diffusion equation in ice
- Snow accumulation/melting on the sea ice surface
- Snow/Ice Albedo - function of snow/ice surface temperature
- Option of fractional sea ice
- No melting, drifting or building new sea ice

Old sea ice in RUC LSM

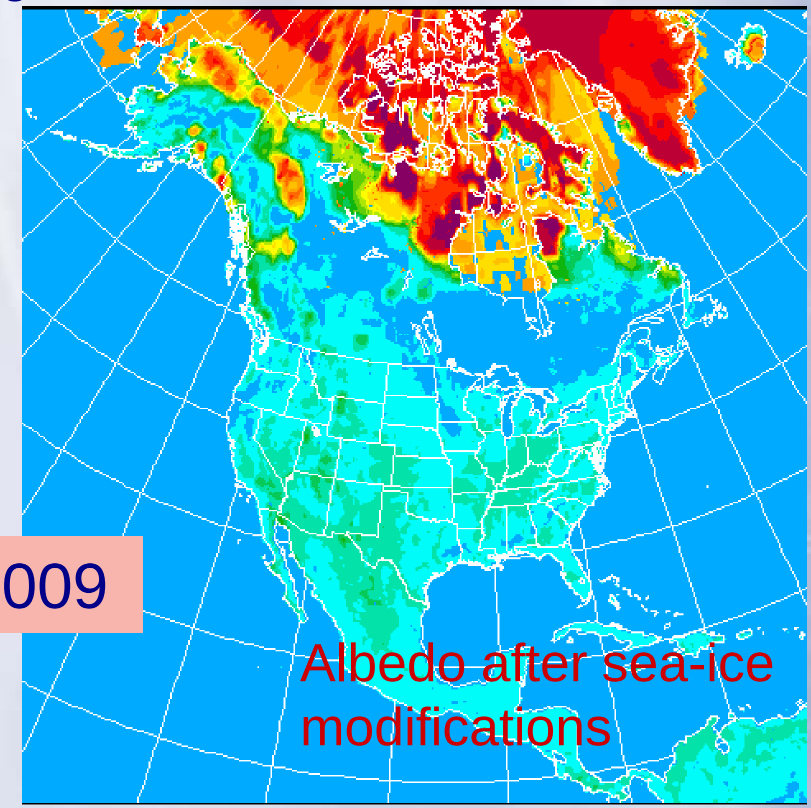
- Skin temperature is prescribed to be equal to temperature at the 1^{st} atmospheric level
- No snow on sea ice

Snow and ice albedo in RR with use of RUC LSM

1. Albedo specified from NESDIS monthly climatological albedo interpolated to a current day
2. Albedo updated for snow and ice using static field of WRF maximum snow albedo



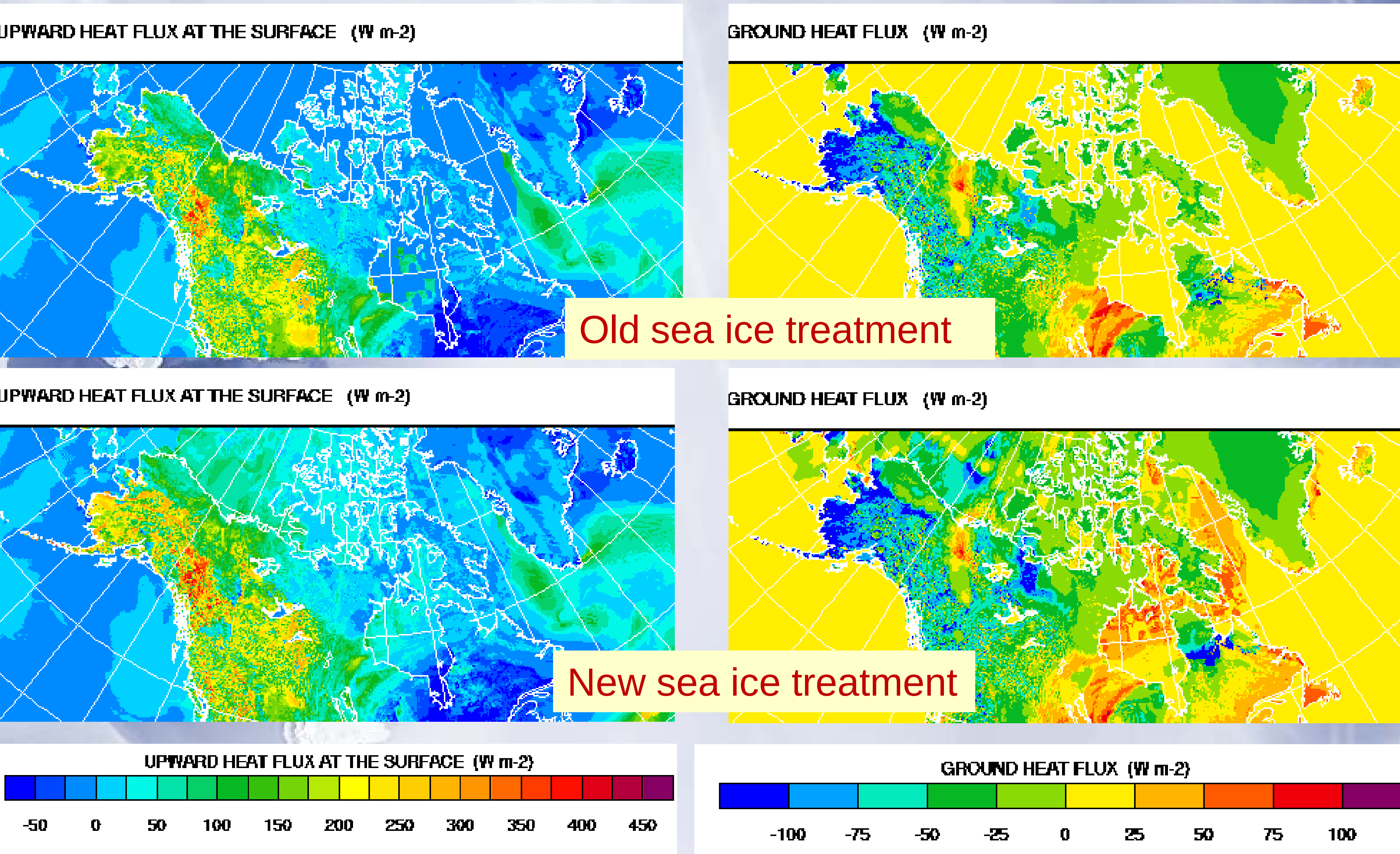
13 May 2009



3. "Patchy" Snow –
albedo reduced when
snow fraction < 1

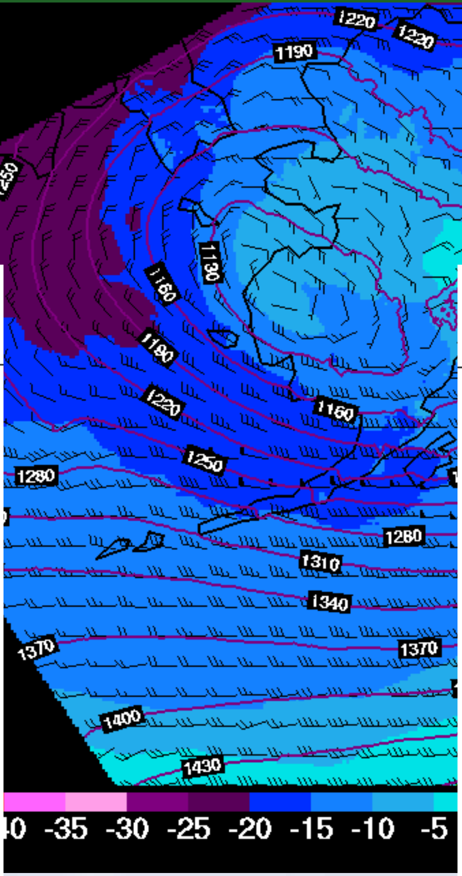
3. "Patchy" Snow plus temperature dependence of snow/sea ice albedo
when T snow/ice > -10 C
(min albedo when T = 0 C)

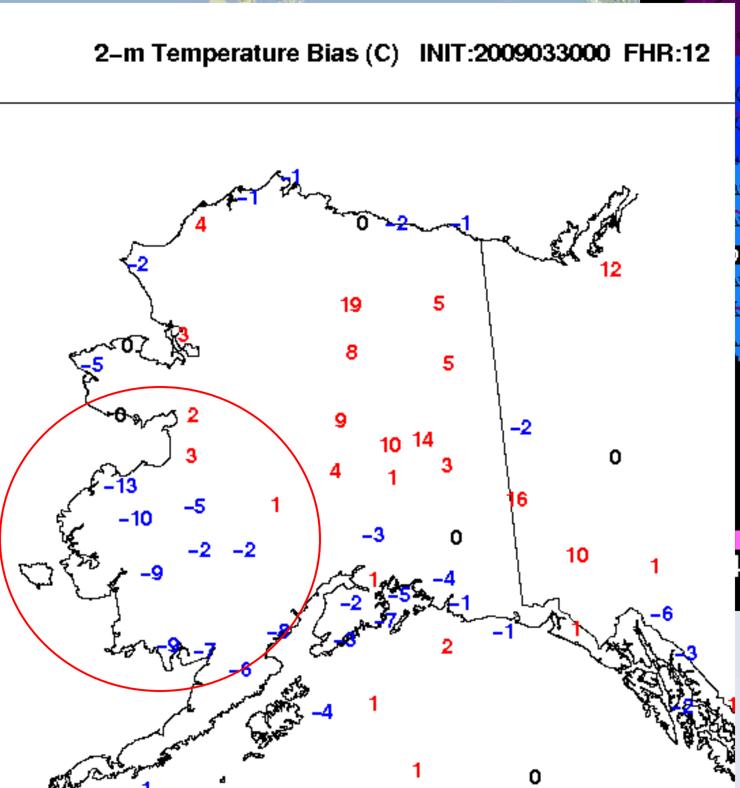
Surface Sensible and Ground Heat Fluxes



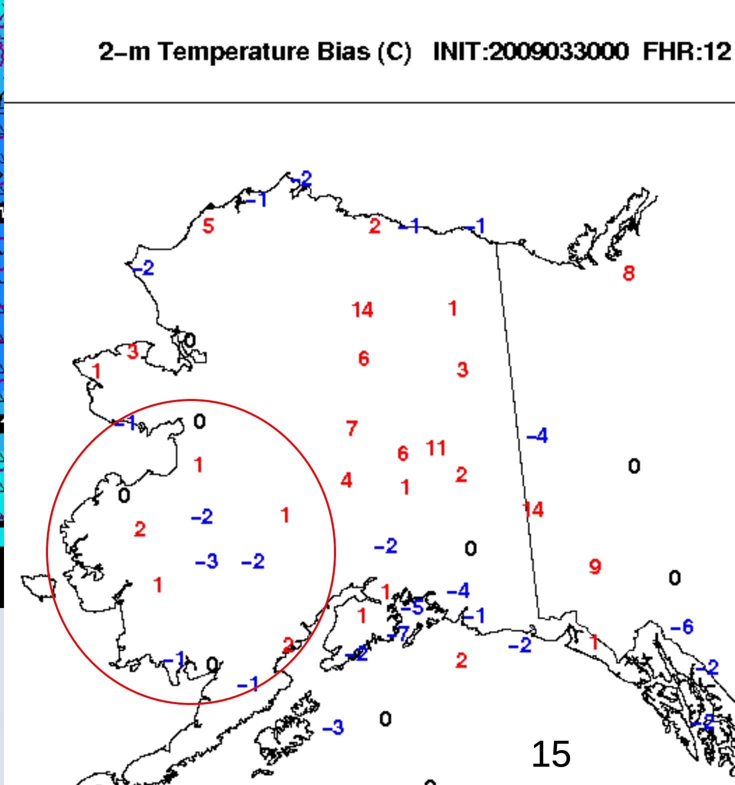
RR 12-h forecast valid at 00 UTC, 14 May 2009

2-m temperature verification for Alaska, 12h RR forecast valid at 12 UTC 30 March 2009



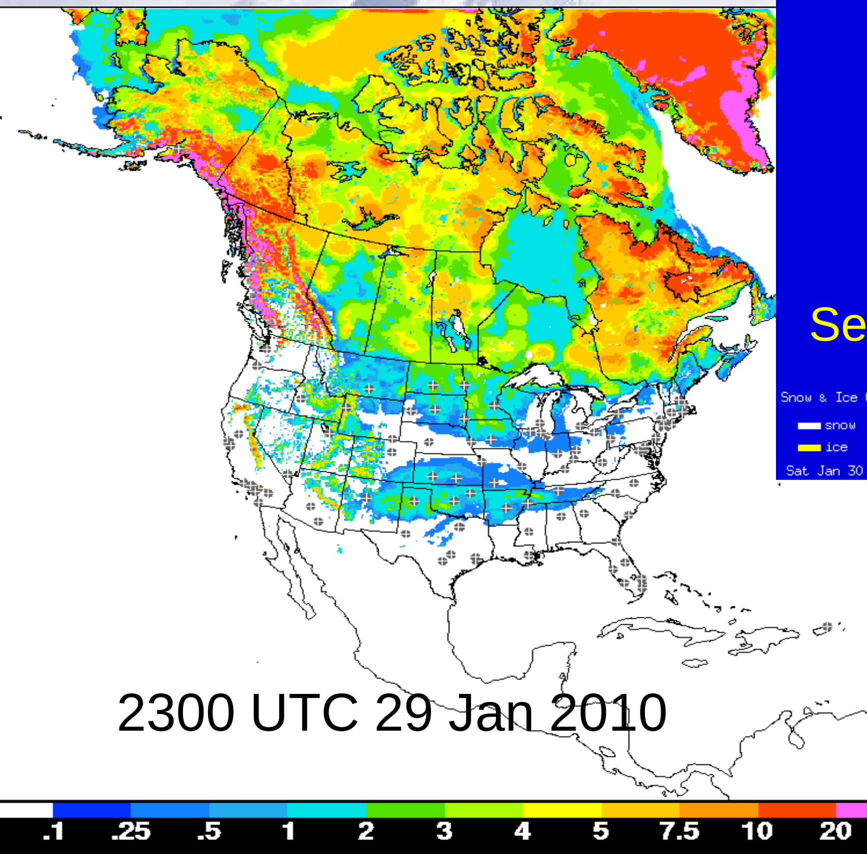


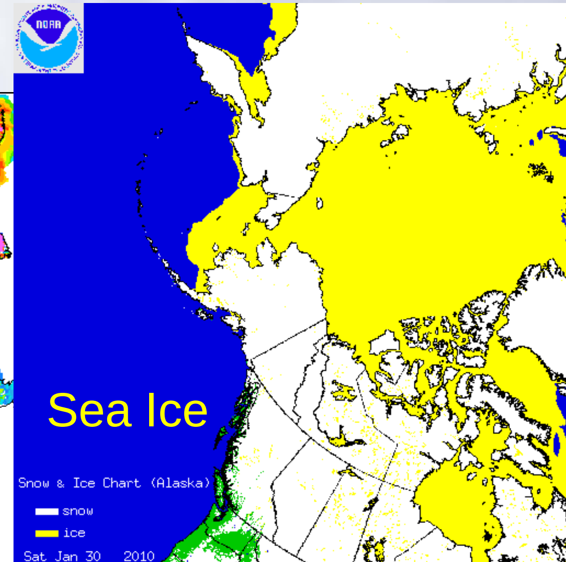
Old RUC LSM

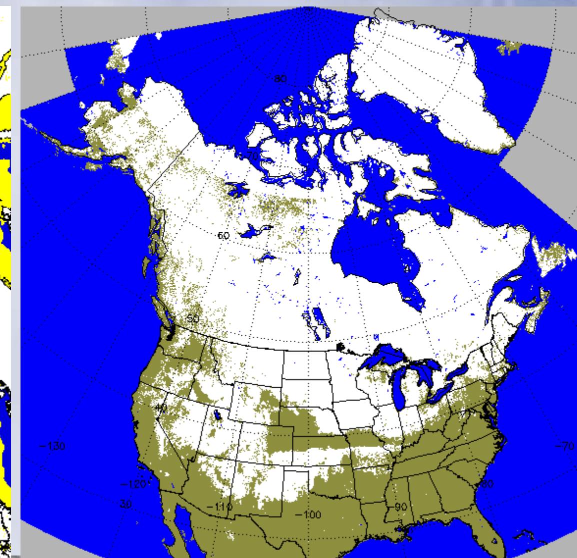


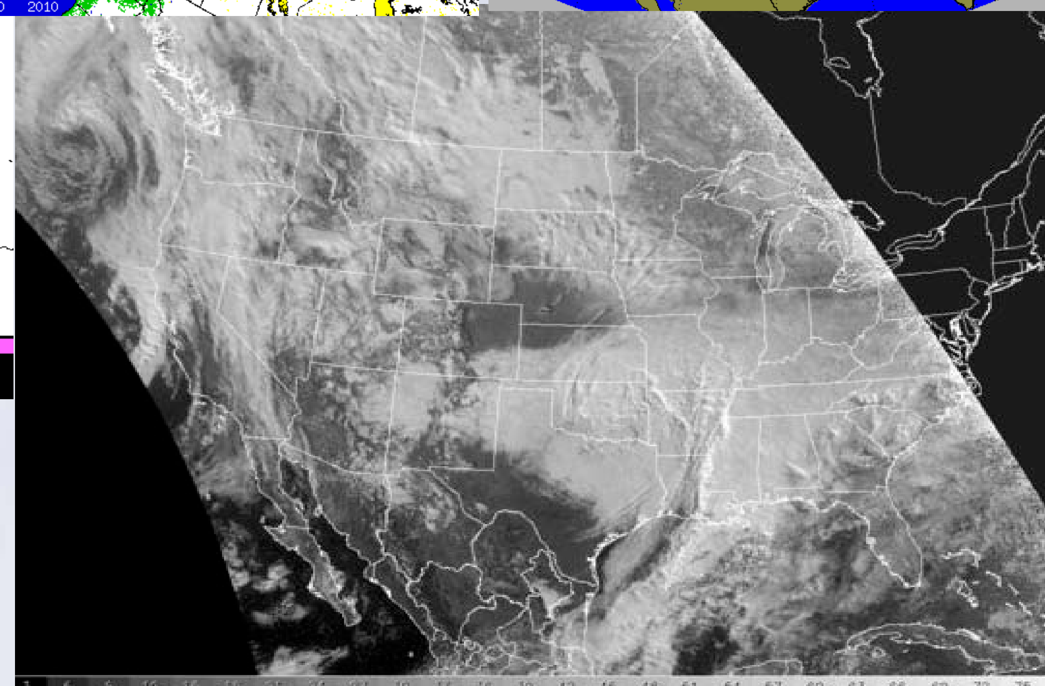
New RUC LSM

Snow water equivalent cycled in RR verified against NESDIS Automated Snow Mapping System and Visible Satellite Image

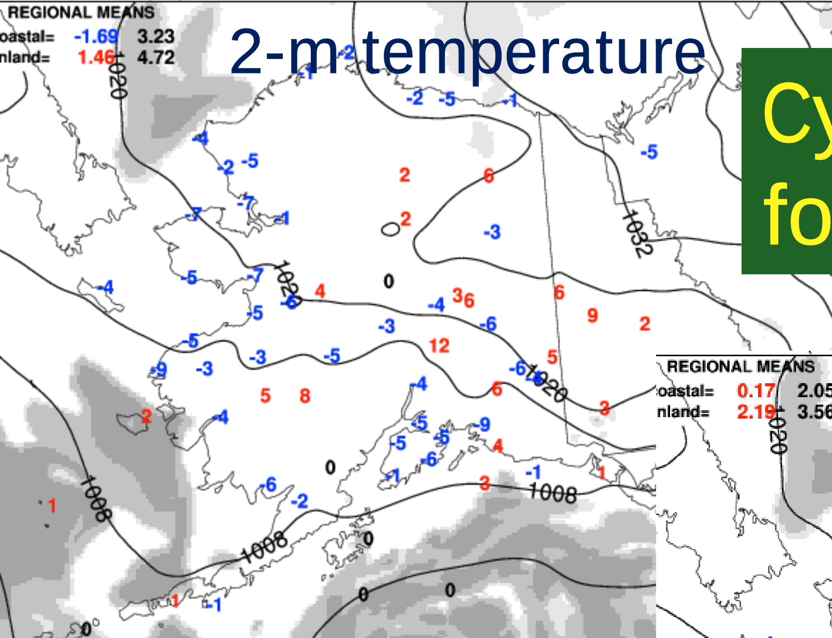


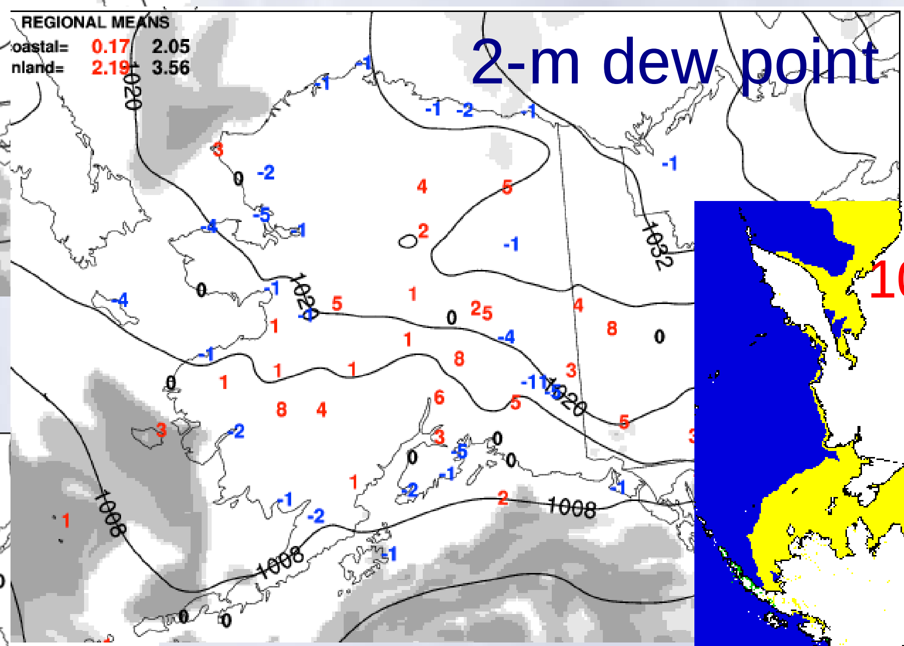


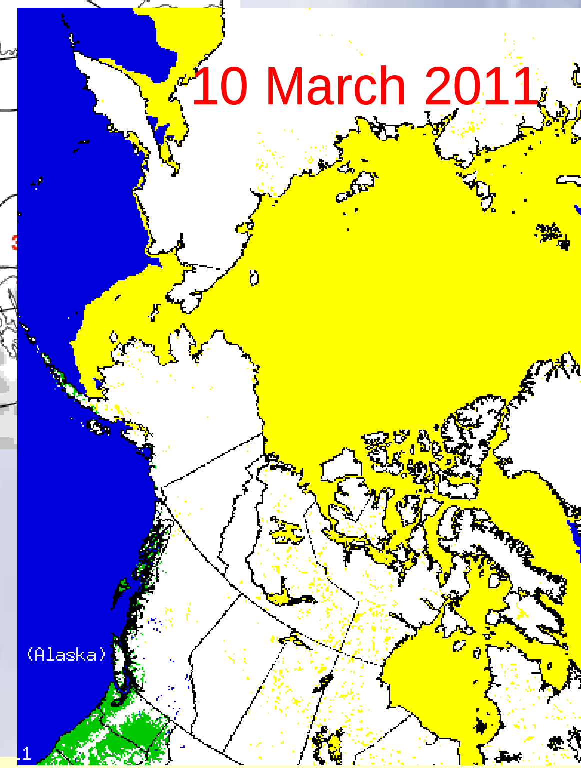


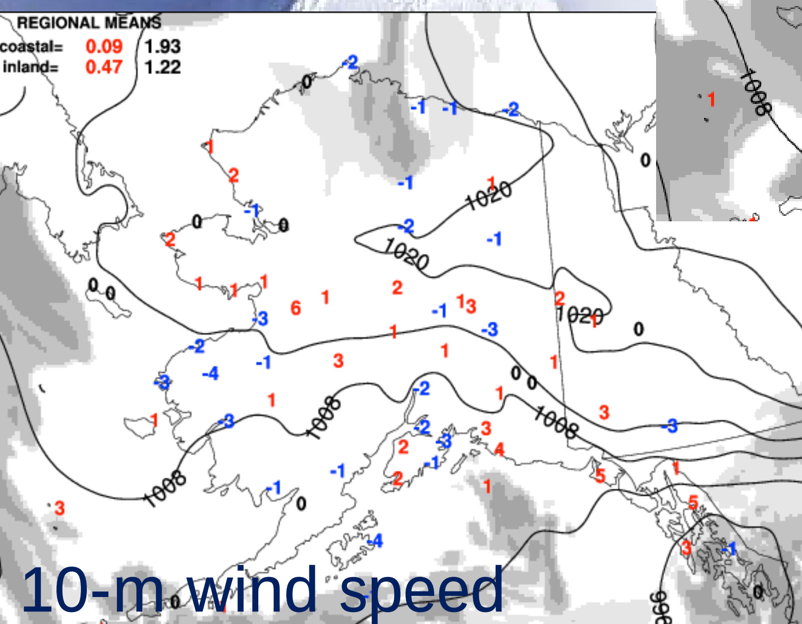


Cycled RR surface verification for Alaska



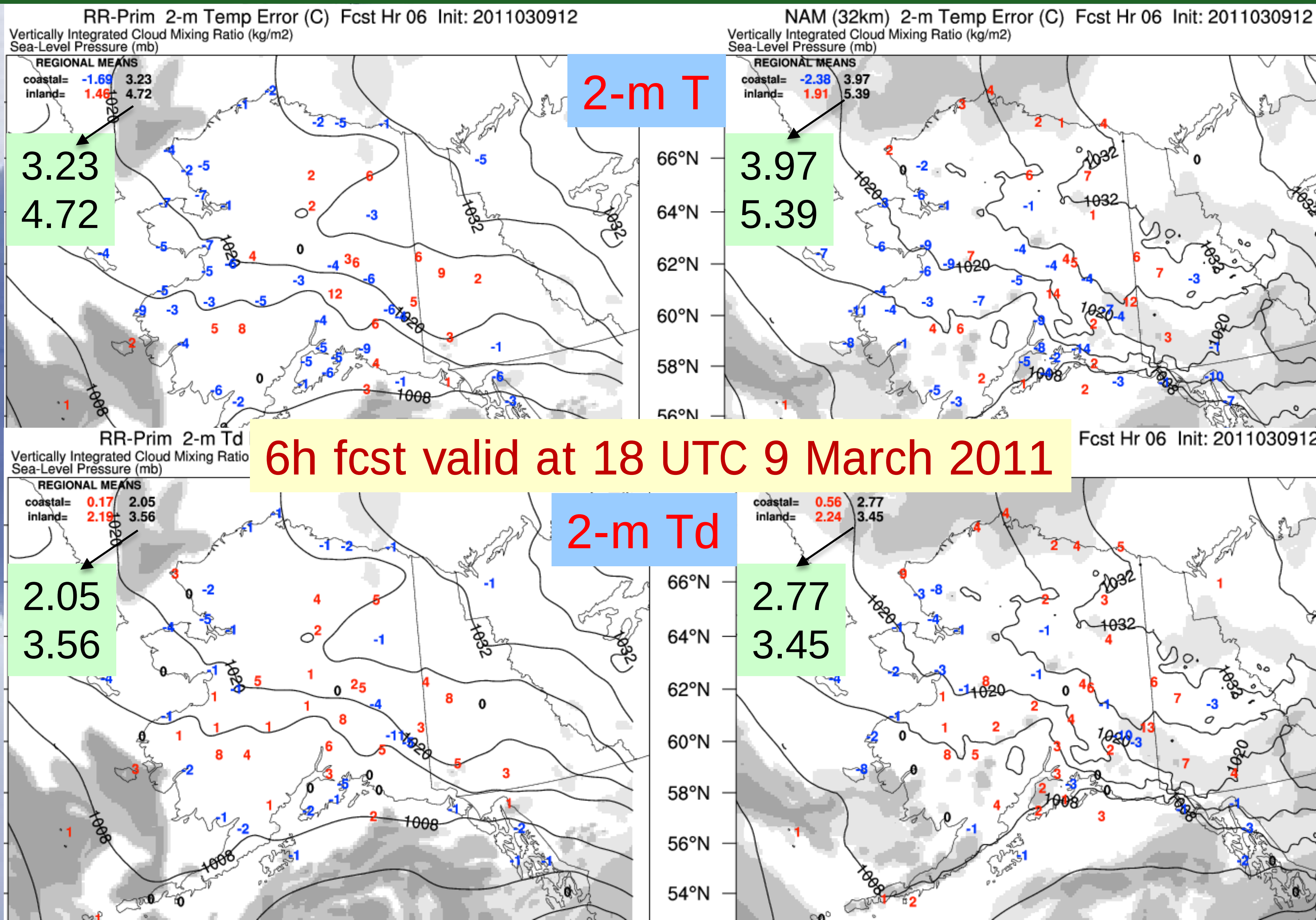






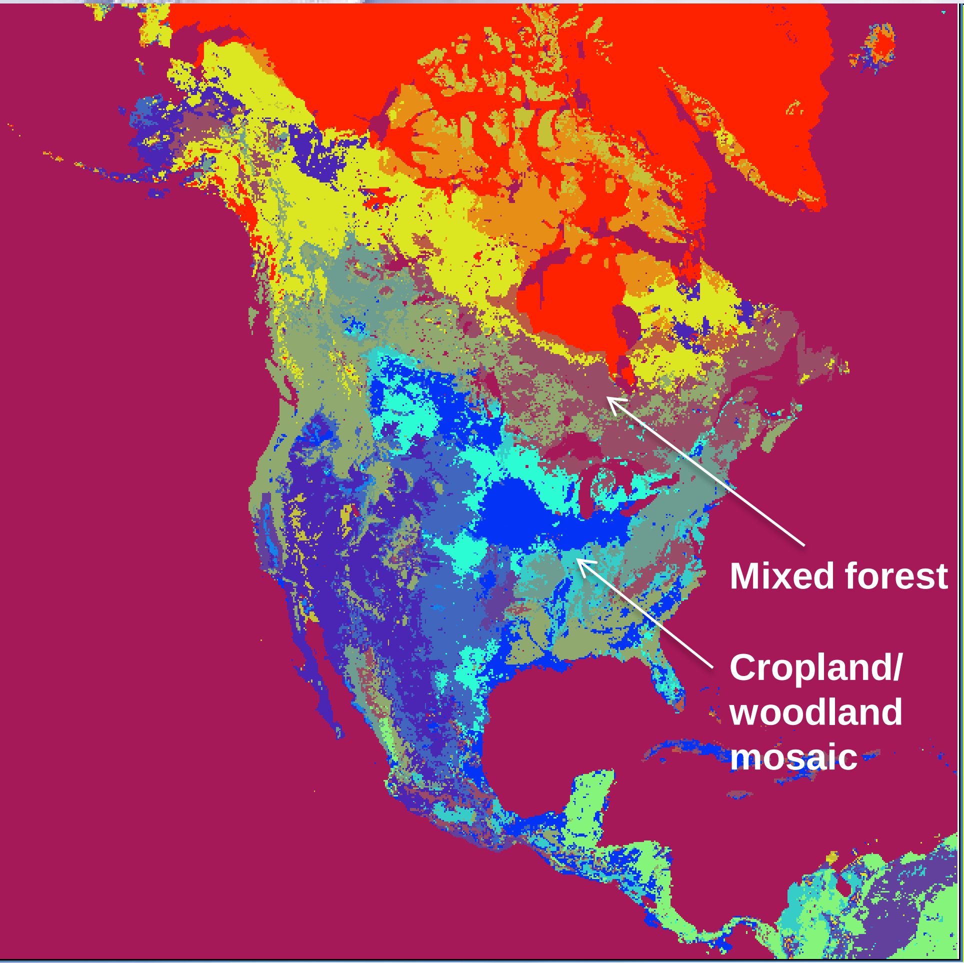
6h fcst valid at 18 UTC 9 March 2011

Comparison of RR and NAM 2-m T and Td surface verification for Alaska

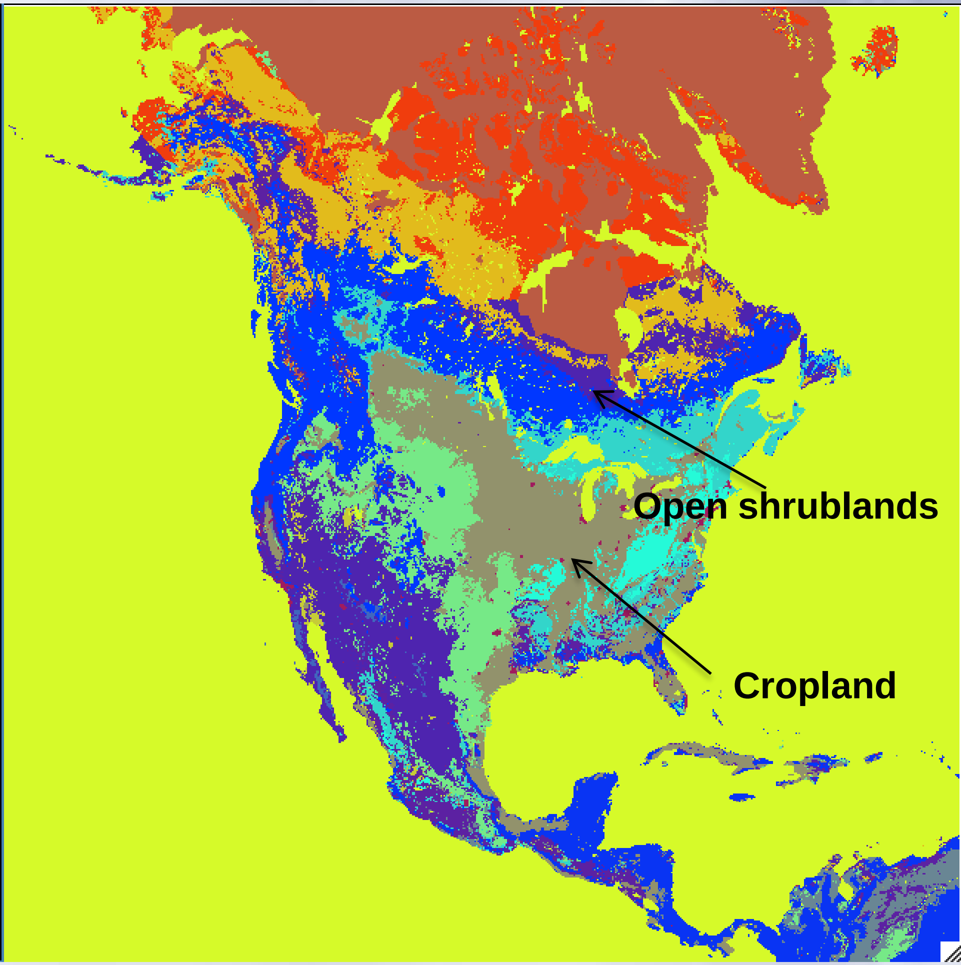


New modifications - capability to use MODIS land use categories with RUC LSM in WRF

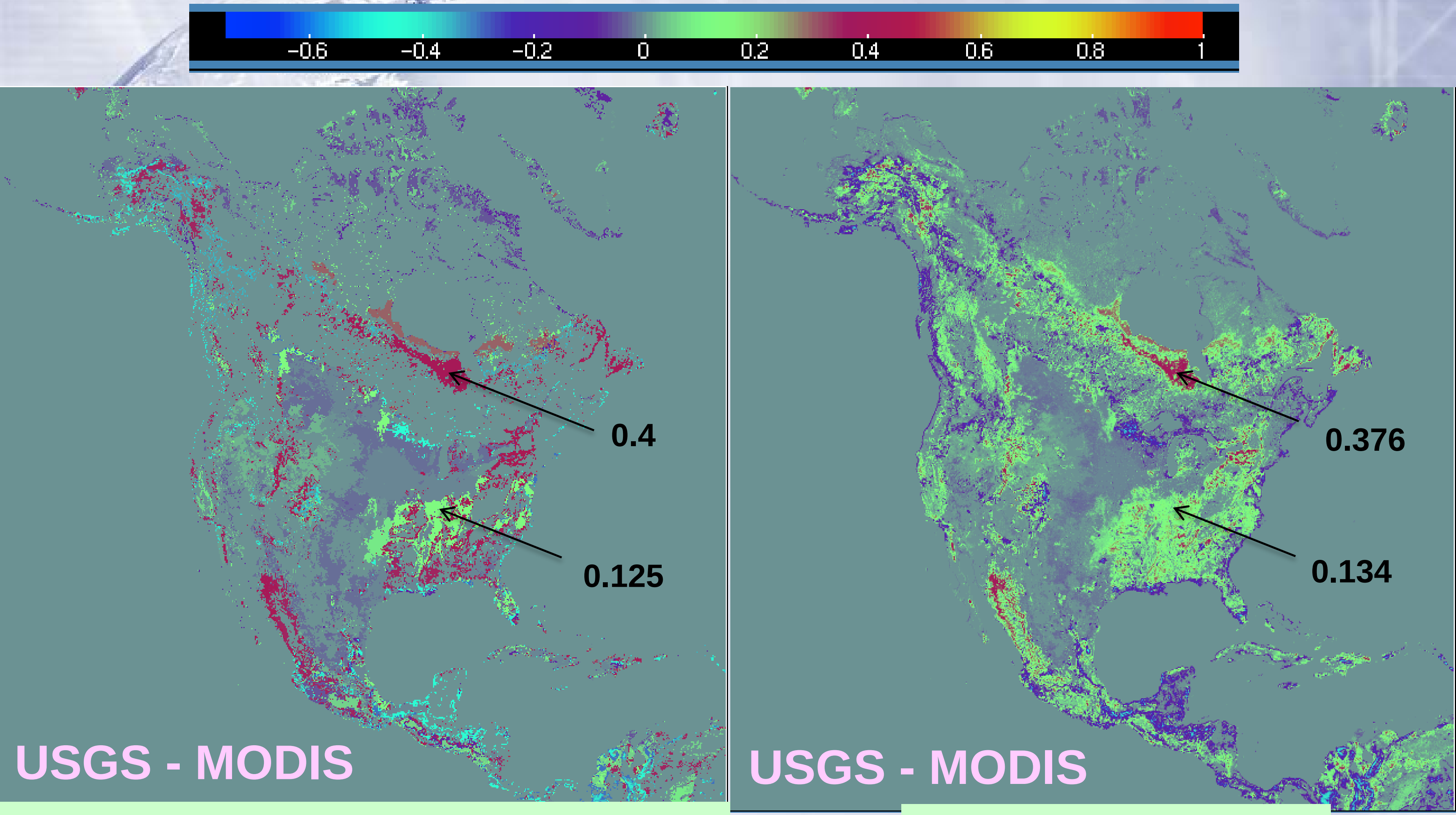
24 USGS category



20 MODIS categories



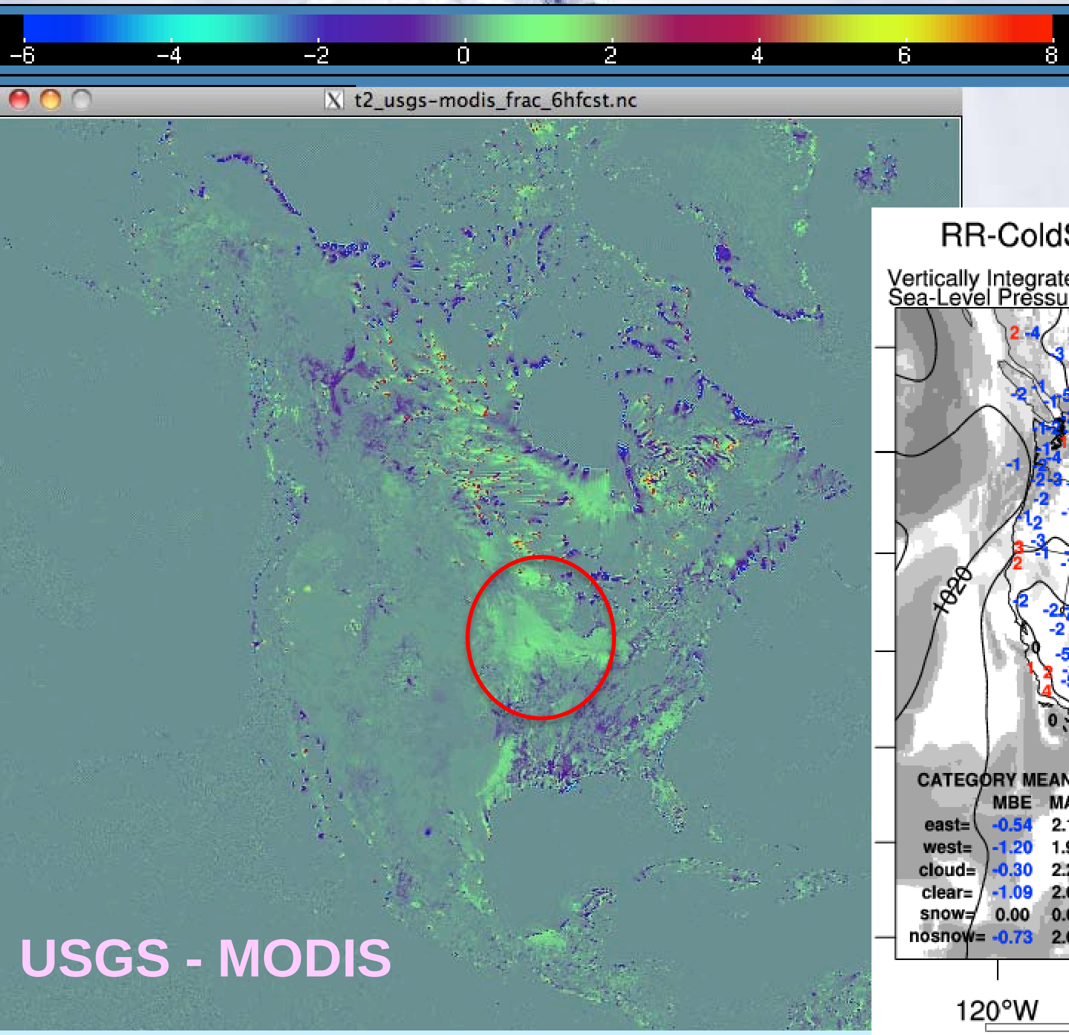
Roughness length differences between USGS and MODIS landuse

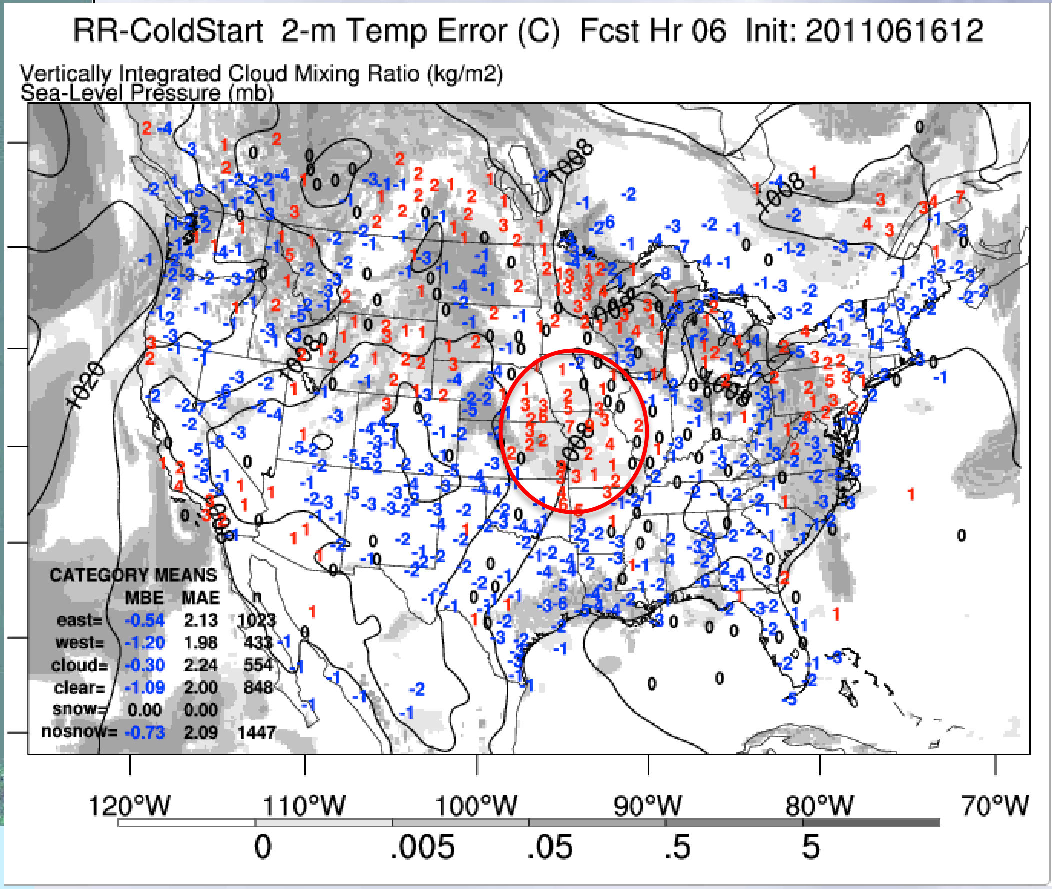


Dominant category approach

Mosaic approach

2-m temperature differences (USGS – MODIS) with mosaic approach

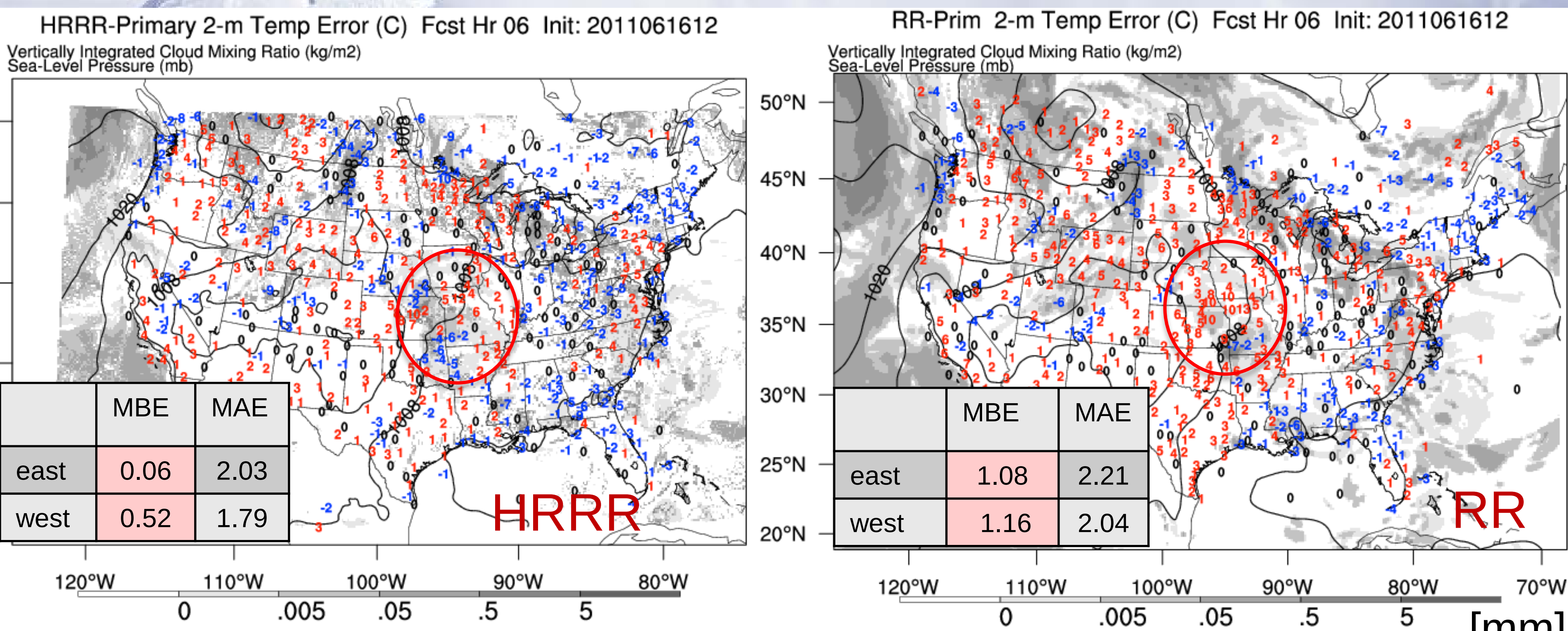




RR-cold-start

6h forecast valid at 18z 16 June 2011

Comparison of 13-km RR and 3-km HRRR 2-m temperature verification for CONUS



HRRR:

	MBE	MAE
east	0.06	2.03
west	0.52	1.79

RR:

	MBE	MAE
east	1.08	2.21
west	1.16	2.04

Shading - vertically integrated cloud water and ice mixing ratio

Valid 18 UTC 16 June 2011

Future plans

- **Continued testing and validation of RR and HRRR with the use of MODIS landuse categories**

- **Effects of mosaic approach to specification of landuse and soil parameters on surface verification at different resolutions (13km RR and 3-km HRRR)**

- **Consider modifications to evapotranspiration algorithm (use of LAI, transpiration function, etc)**

- **Committing recent RUC LSM modifications to the WRF Repository; follow up on WRF community LSM sensitivity studies**