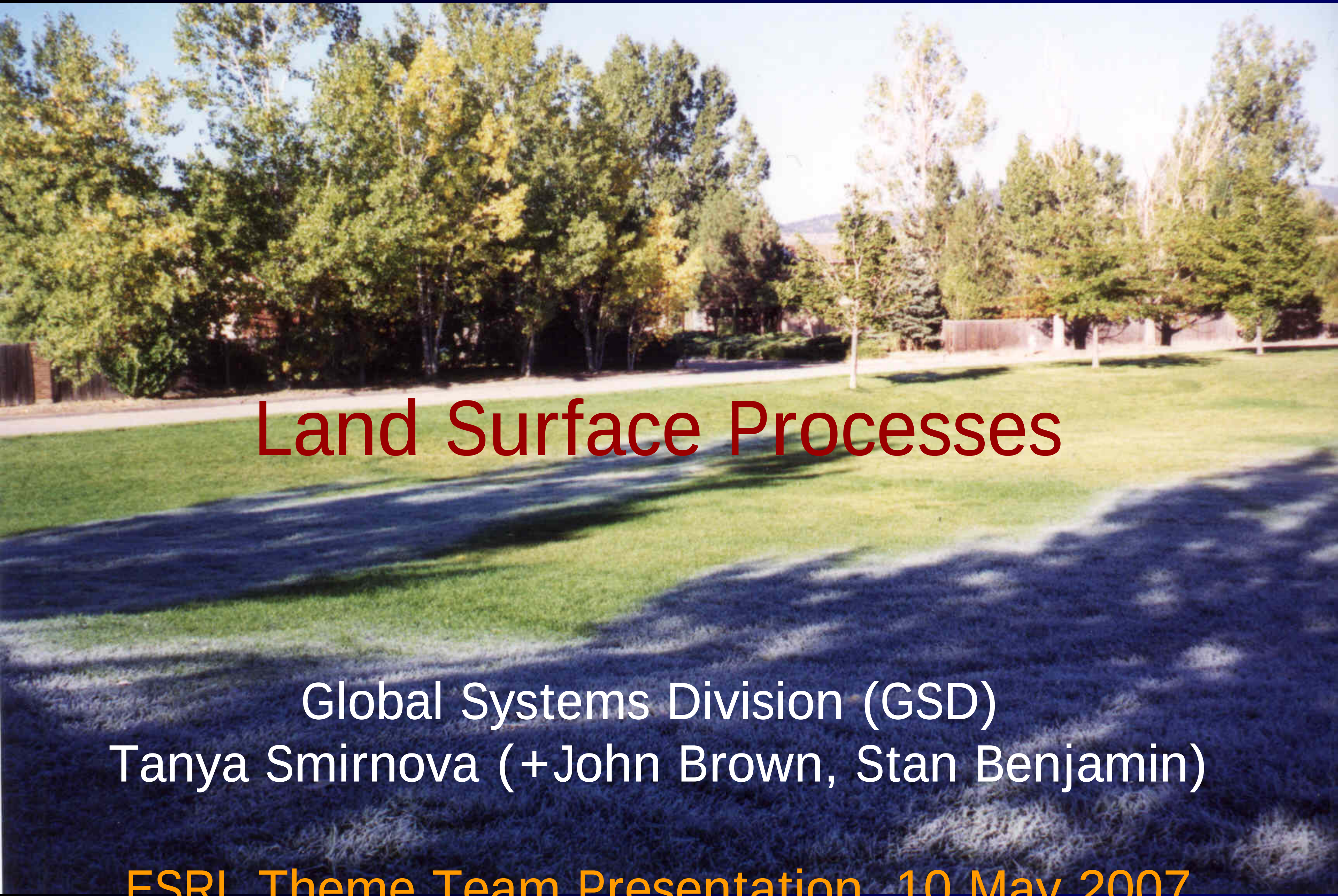
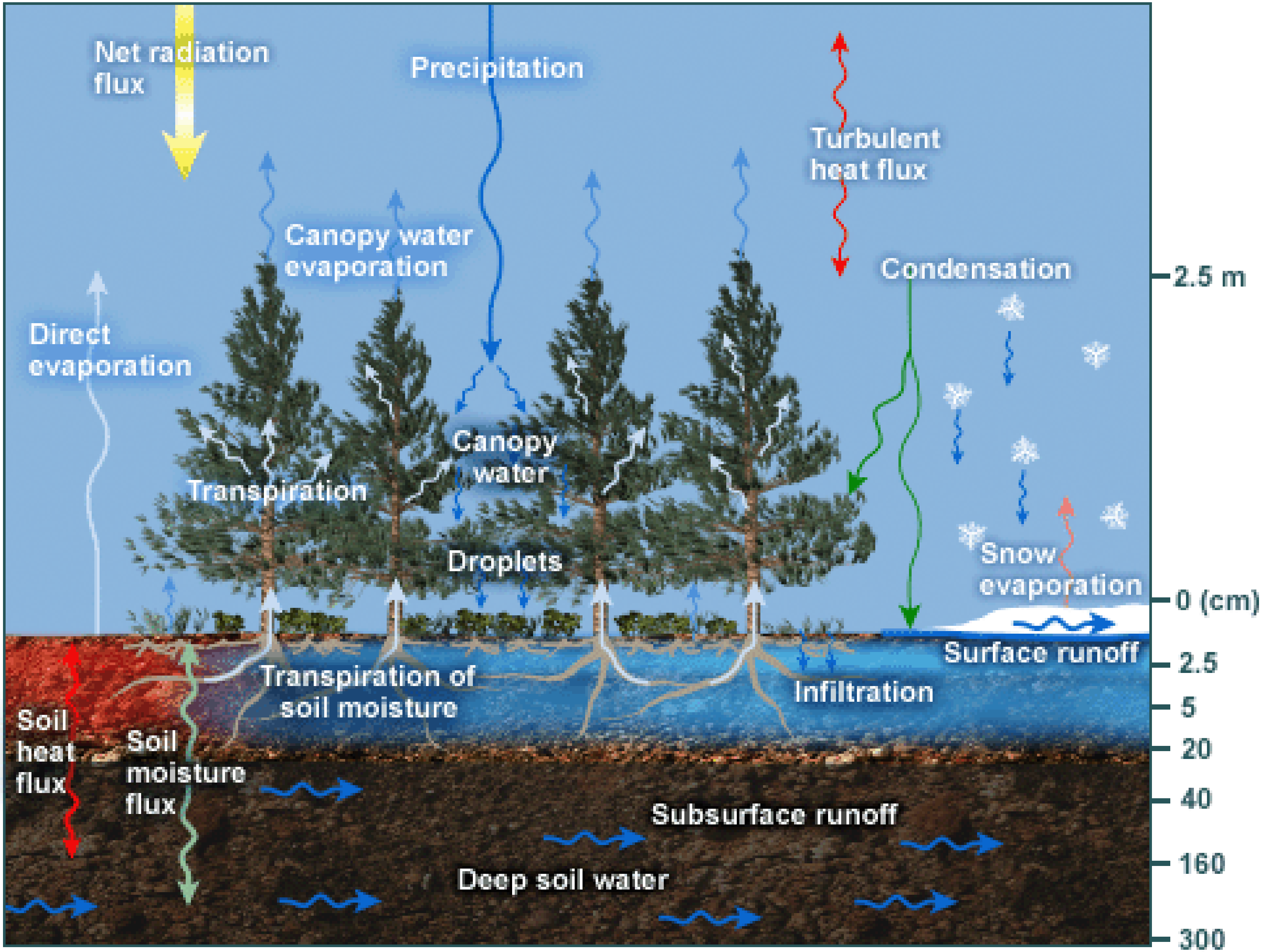


Land Surface Processes

Global Systems Division (GSD)
Tanya Smirnova (+John Brown, Stan Benjamin)

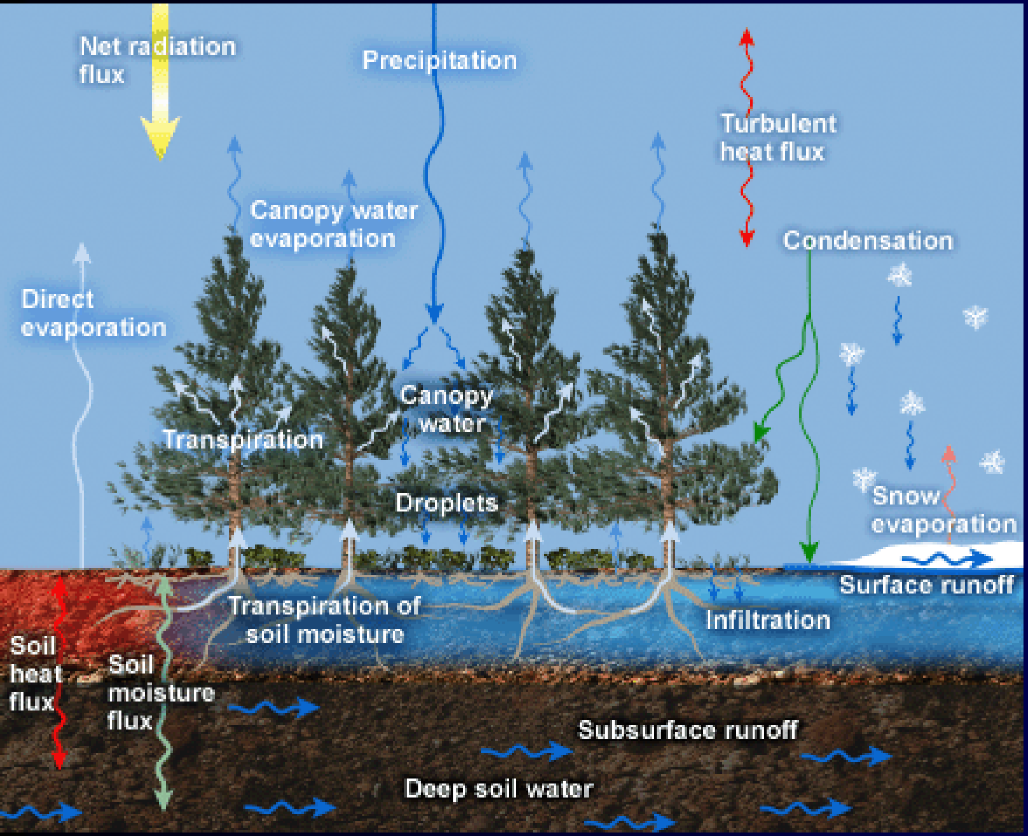
ESRL Theme Team Presentation, 10 May 2007



Vegetation and Soil Model

Atmospheric models coupled to Land-Surface Models (LSM)

NOAA weather prediction models:



GFS » Noah LSM (GFS version)

NAM » Noah LSM (NAM version)

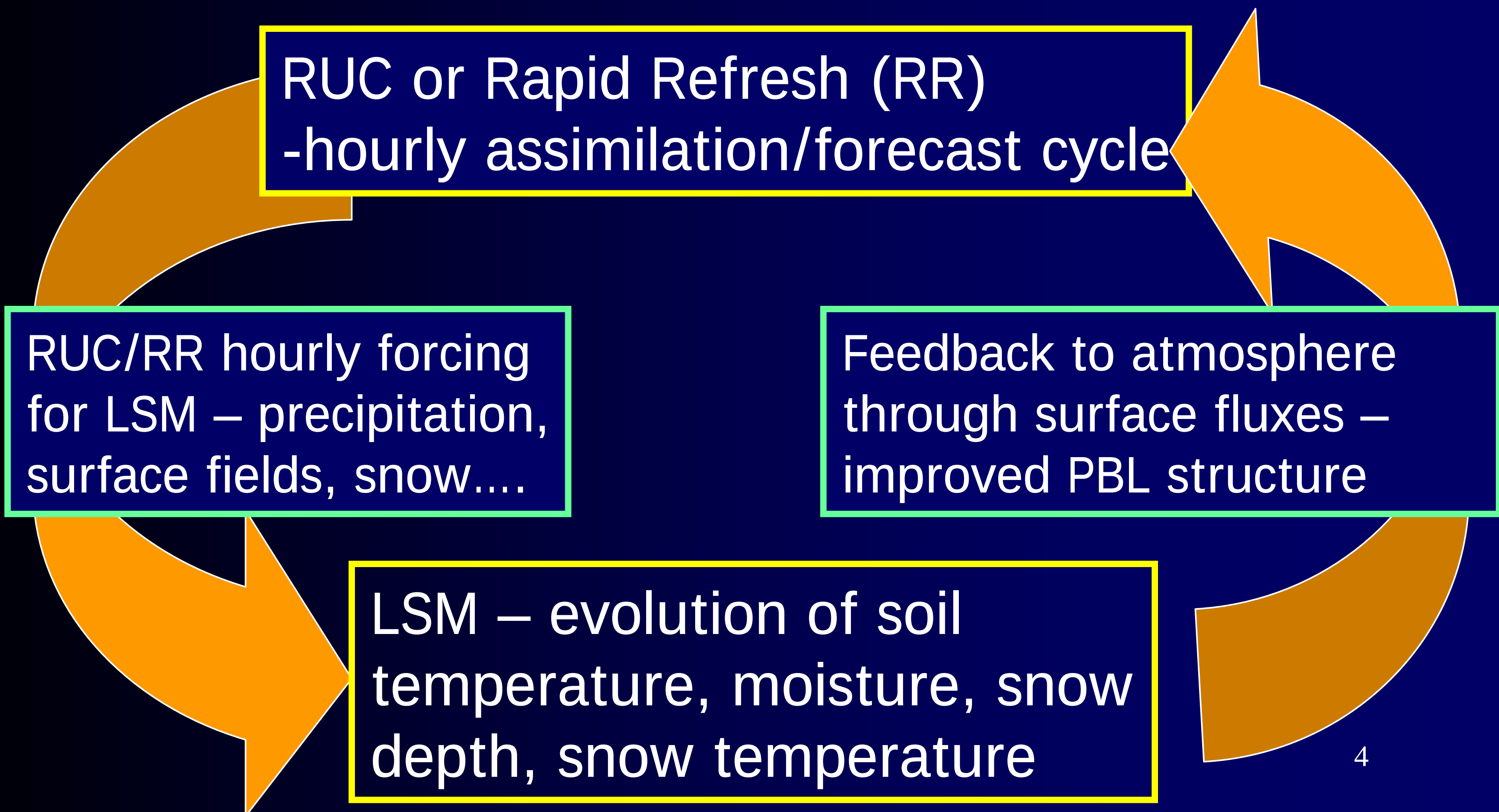
RUC » RUC LSM

WRF » "simple" LSM
Noah LSM
RUC LSM

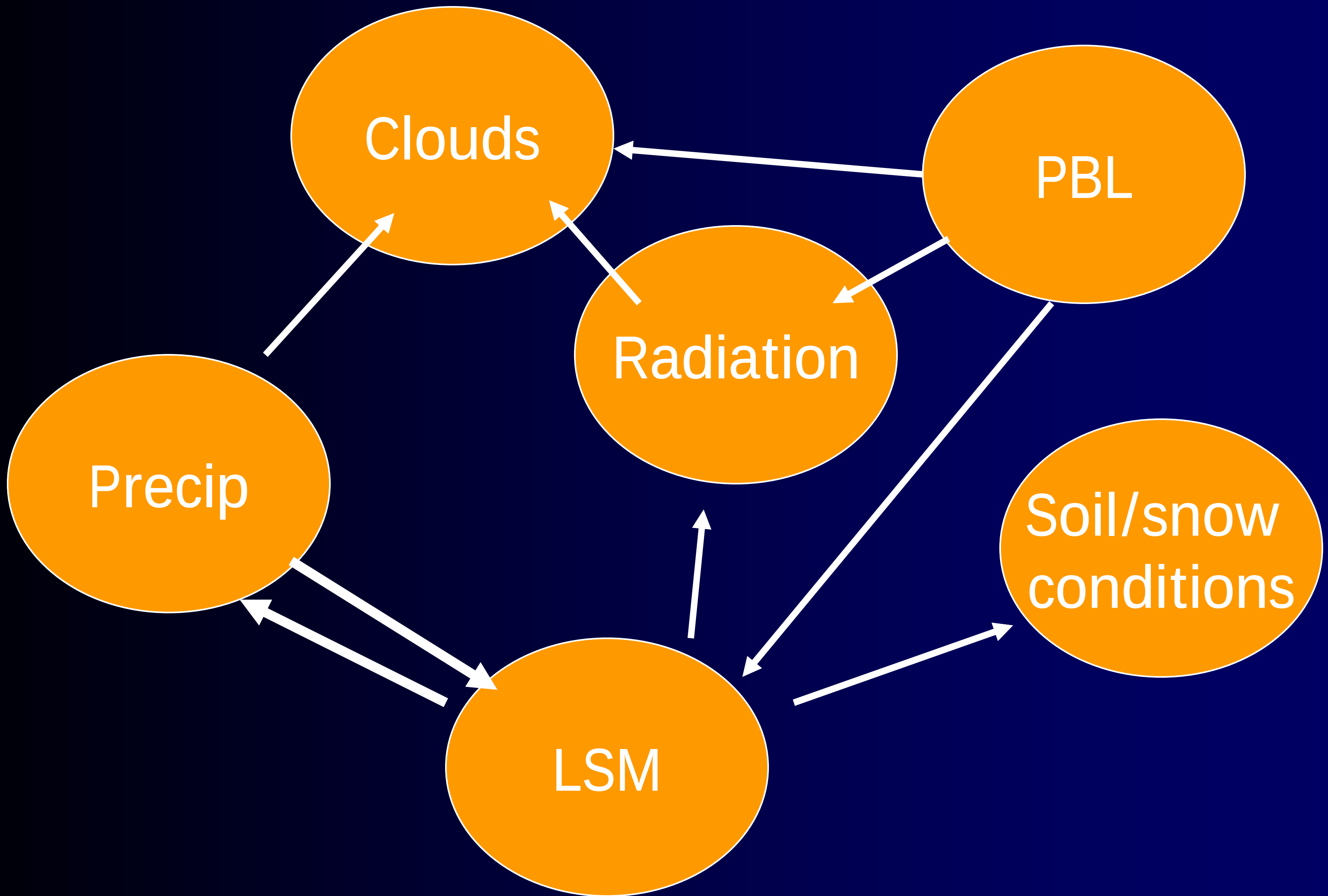
Other Land Surface Models:

SSiB, VIC, CLM, CROCUS, ISBA .....

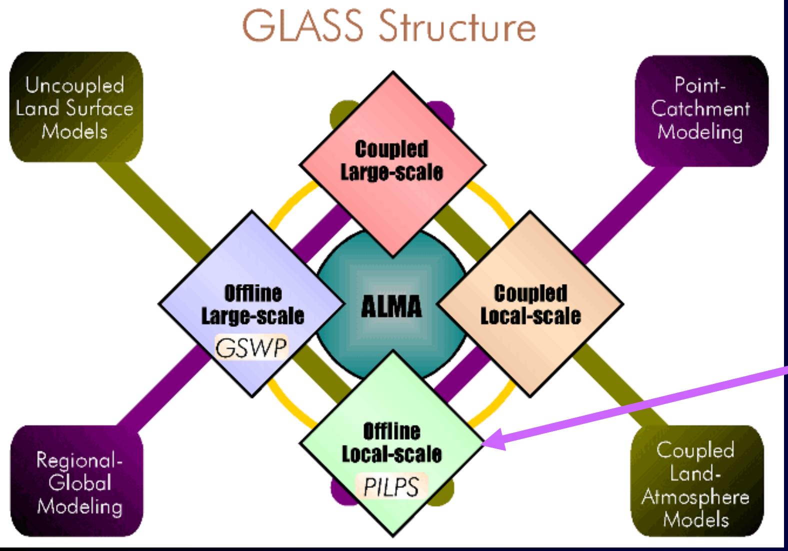
Linkage between Atmospheric Models (RUC model as example) and LSM



Blame game -
Complicated interaction of physical parameterizations and initial conditions in model

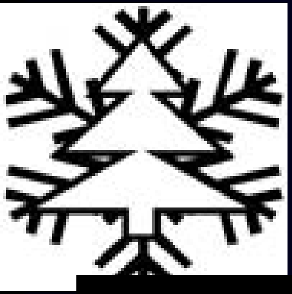


Land Surface Model validation



- Project for the Intercomparison of Land-Surface Paramaterization Schemes (PILPS), coordinated by Global Land Atmosphere System Study (GLASS)

- 21 models participated (including RUC LSM, Noah)



- Snow Models Intercomparison Project (SnowMIP and SnowMIP2), coordinated by International Commission on Snow and Ice

- 27 models participated (including RUC LSM, Noah)

Goal – *controlled* comparisons of LSM and snow models of different complexity

SnowMIP, an intercomparison of snow models:

first results - P. Etchevers, E. Martin, R. Brown et al.
ISSW meeting, August 2002

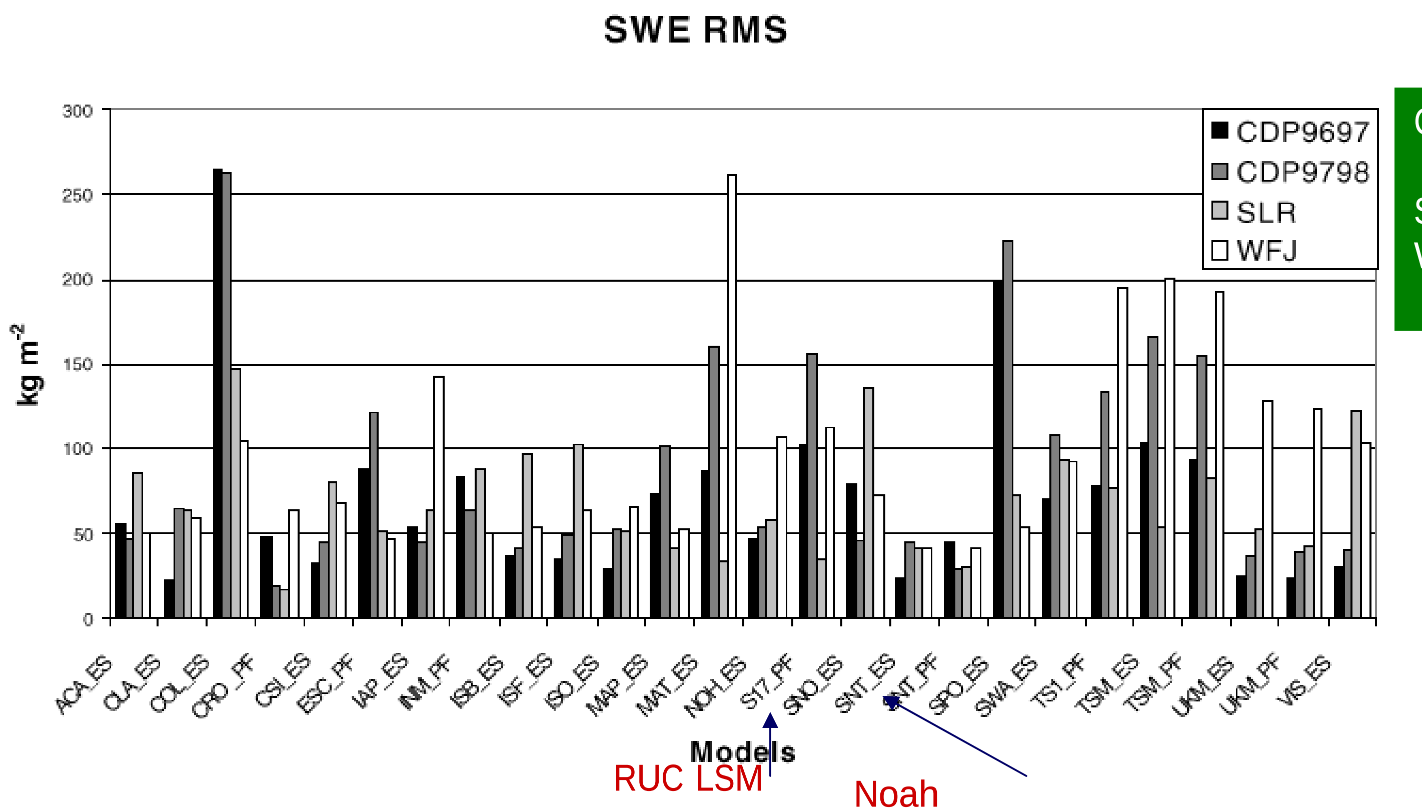


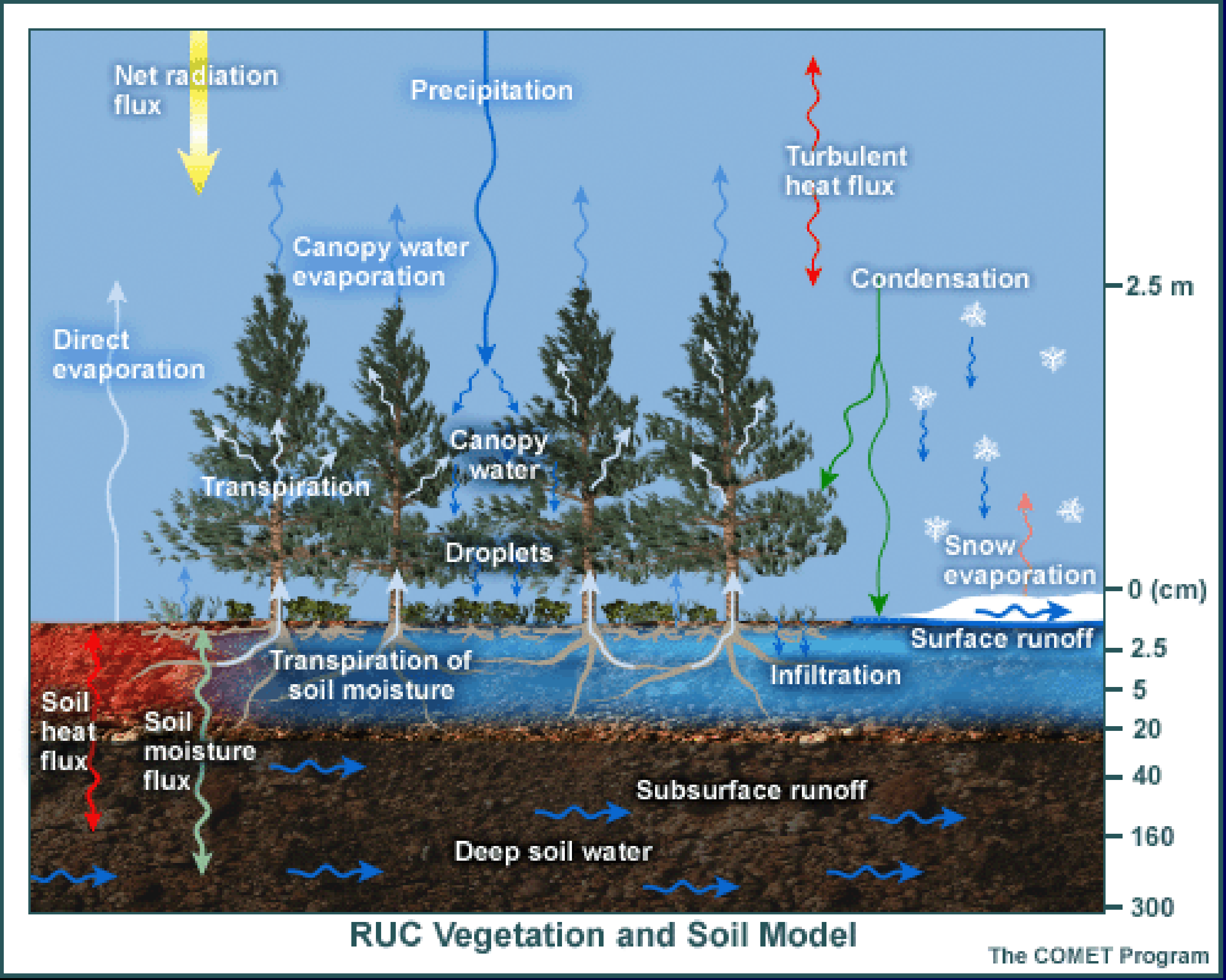
***Figure 1** : RMS of the simulated SWE for each model on the different sites (PF indicates that the model has run with a prescribed soil flux, ES that the exchanges between the soil and the snowpack have been explicitly simulated).*

Col de Porte, France

Sleepers River, Vermont
Weissfluhjoch, Switzerland

SWE – snow water equivalent

Schematic presentation of processes included into RUC-LSM

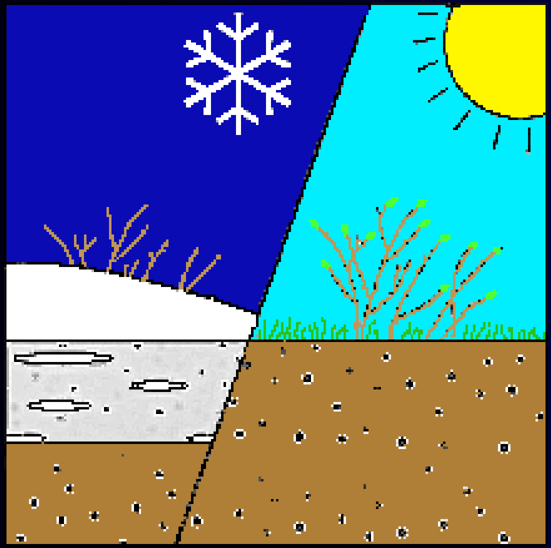


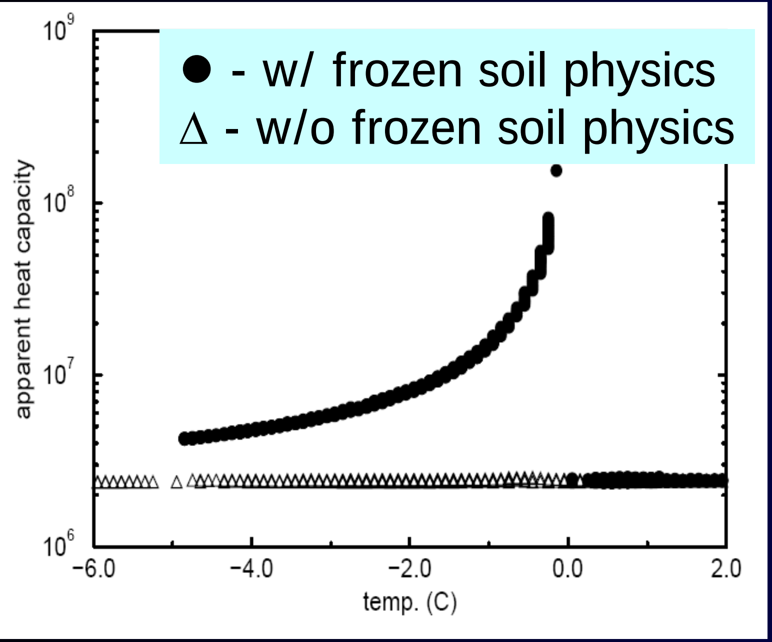
- more accurate lower boundary for weather prediction in RUC (aviation/severe weather)

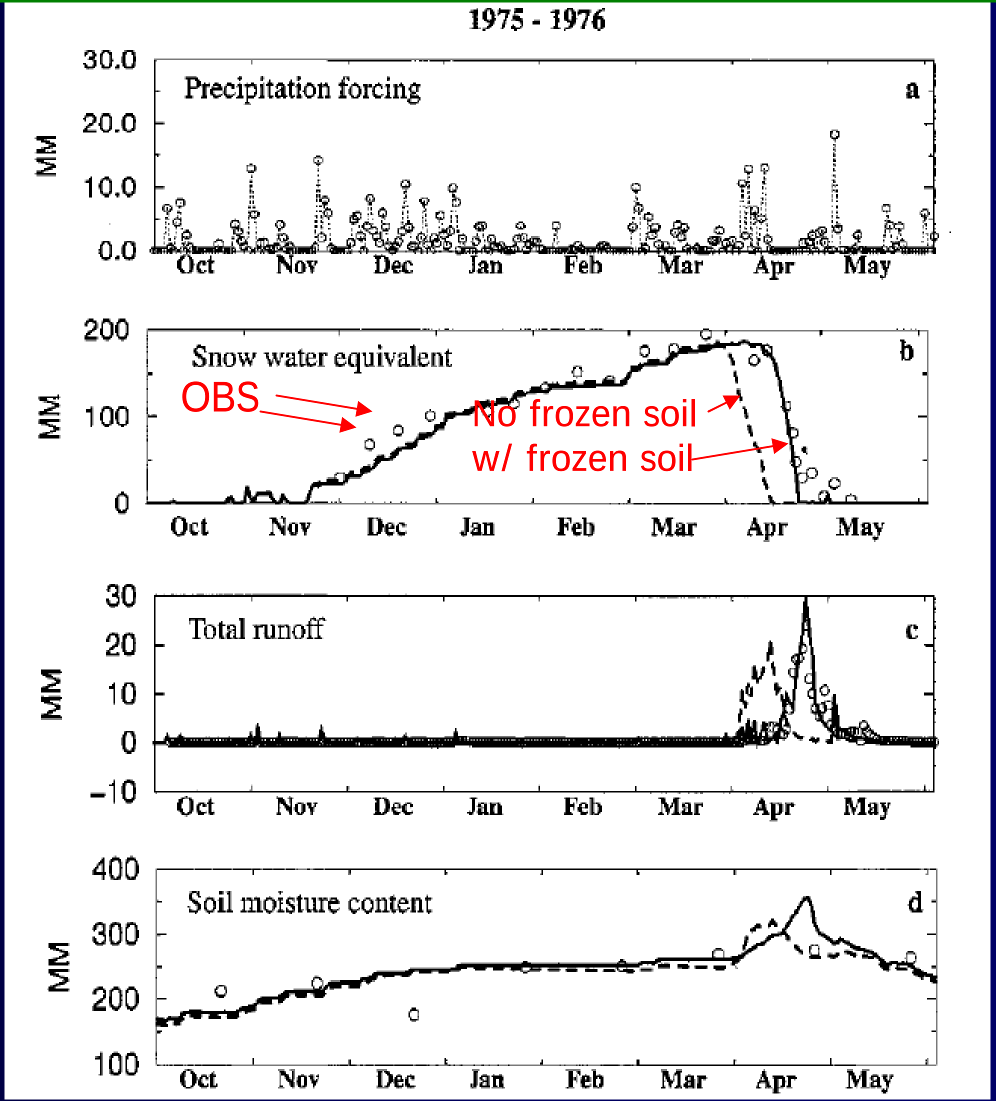
- *10-year long* record of surface grids provided to GCIP/GAPP community for climate studies

Cycling of soil moisture, soil temperature, snow cover, depth, temperature in RUC 1h cycle since 1997

Impact of *Frozen* Soil Physics in RUC LSM







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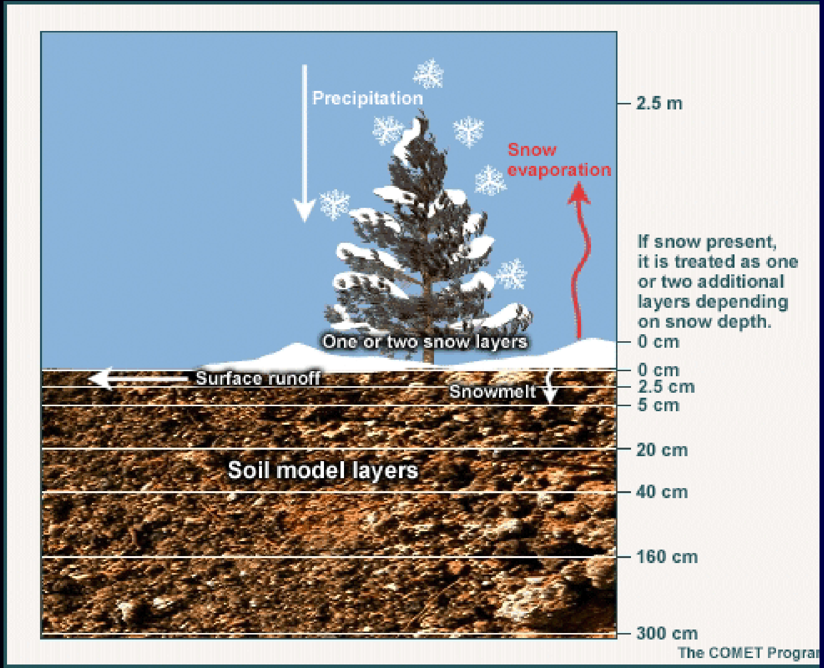
Snow model in RUC-LSM

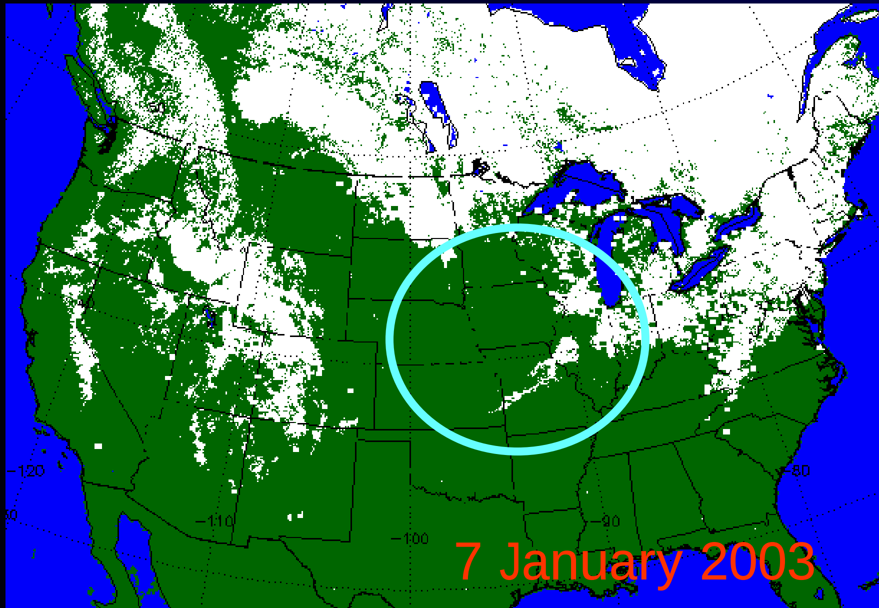
1. One- or two-layer snow model (threshold – 7.5 cm)
2. Changing snow density depending on snow depth temperature, compaction parameter
3. Snow can be melted from the top and bottom of snow pack
4. Prescribed amount of liquid water (13%) from melting can stay inside the snow pack
5. Melted water infiltrates into soil and forms surface runoff



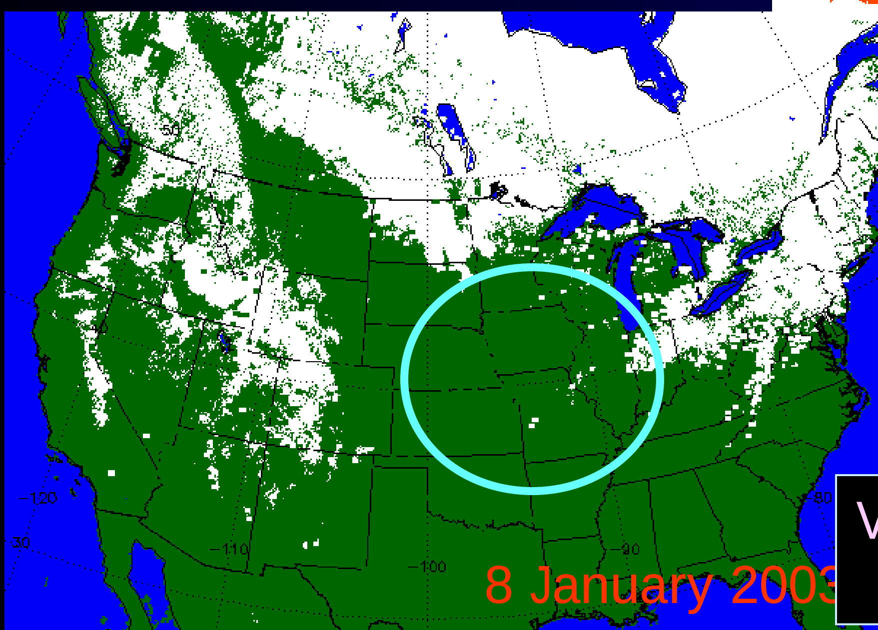
Falling snow can be ***intercepted by the vegetation canopy*** *until the holding capacity is exceeded*

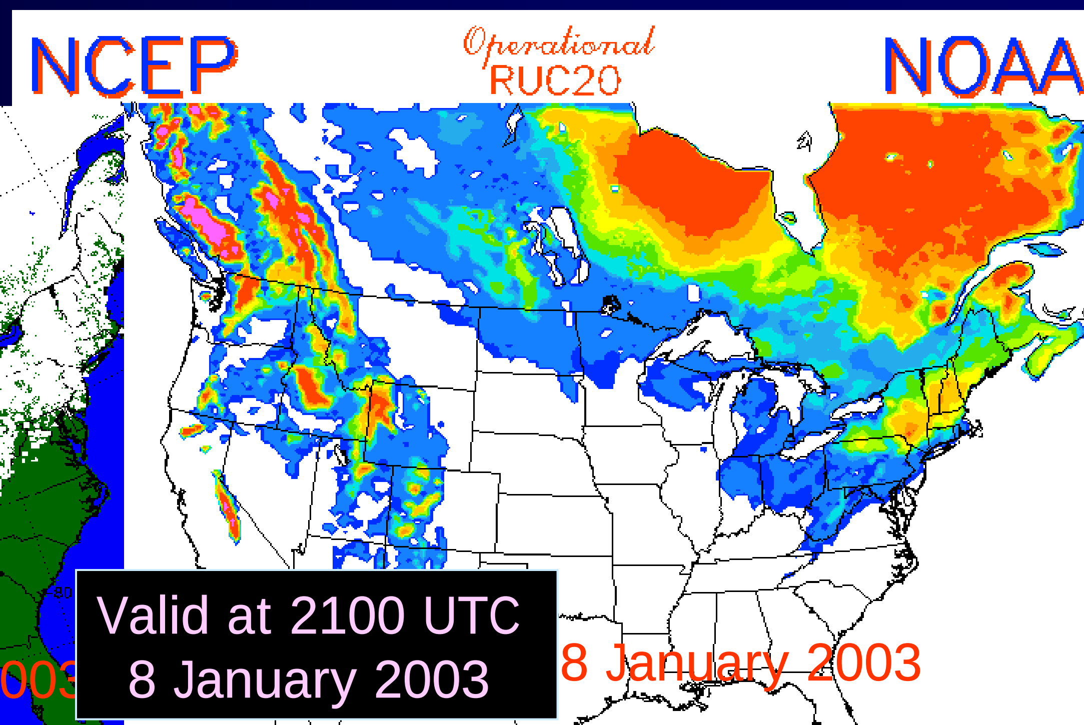
Cycled field of snow depth from operational RUC20 at NCEP

- Cycled snow matches NESDIS
- Rapid surface changes from snow melting/accumulation



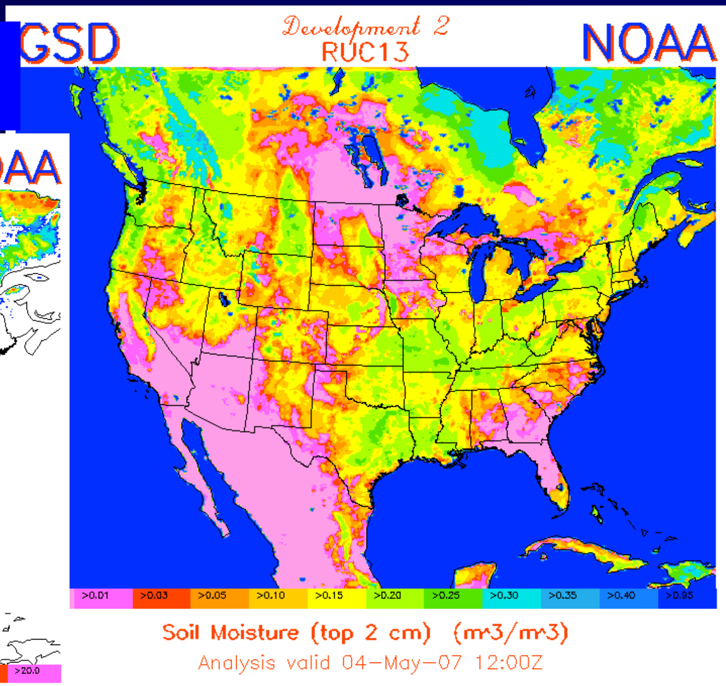
NESDIS daily snow cover



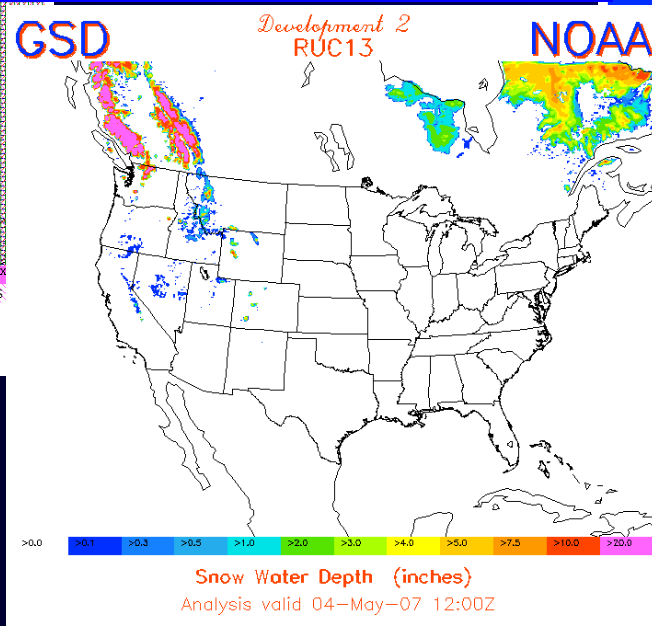


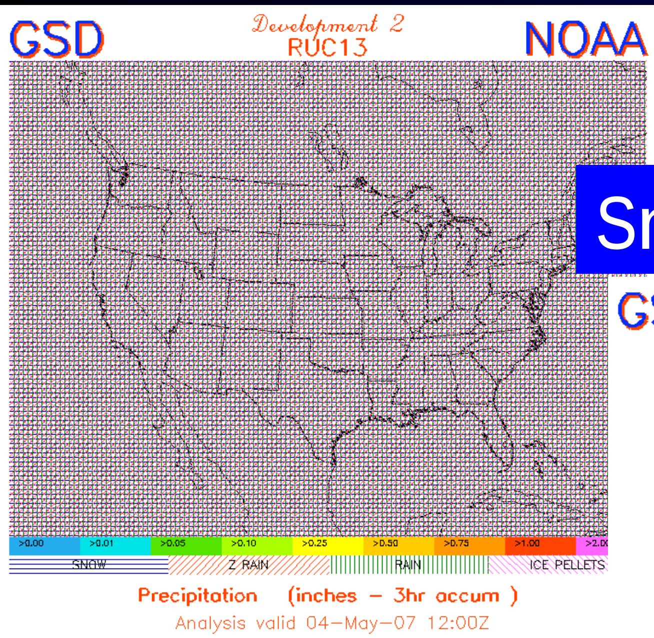
Large variation of soil moisture / snow cover within short time scale (~6h) is commonplace

Soil moisture content in the top 2.5 cm



Snow water depth



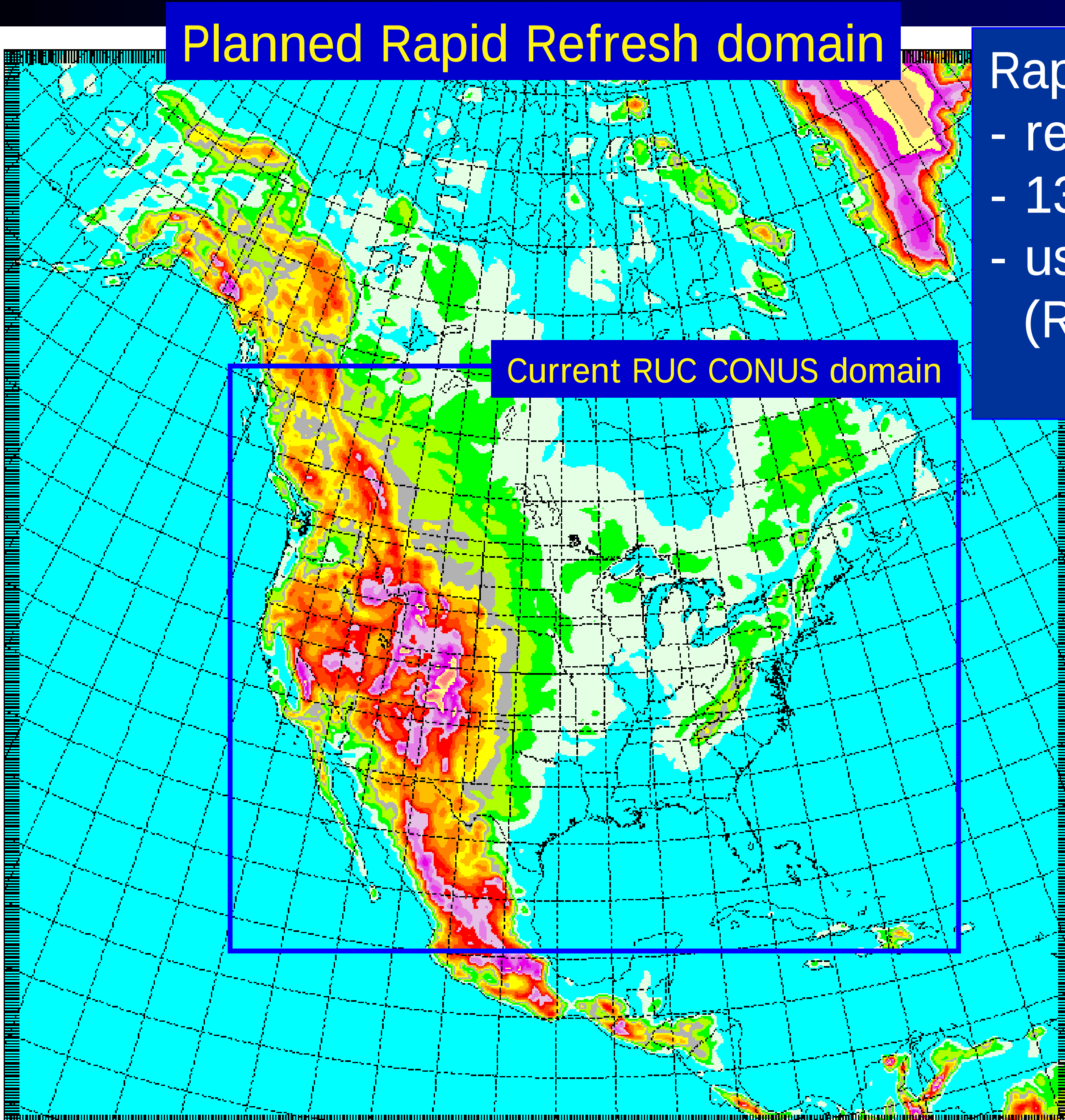


Precipitation forcing

72-h forecast loop from 13-km development RUC

http://ruc.noaa.gov

1200 UTC 4 May - 1200 UTC 7 May 2007



Rapid Refresh
- replace RUC – 2009
- 13km resolution
- use WRF model
  (RUC LSM - possible physics option)

Goals:
Hourly NWP update including
- Alaska
- Canada

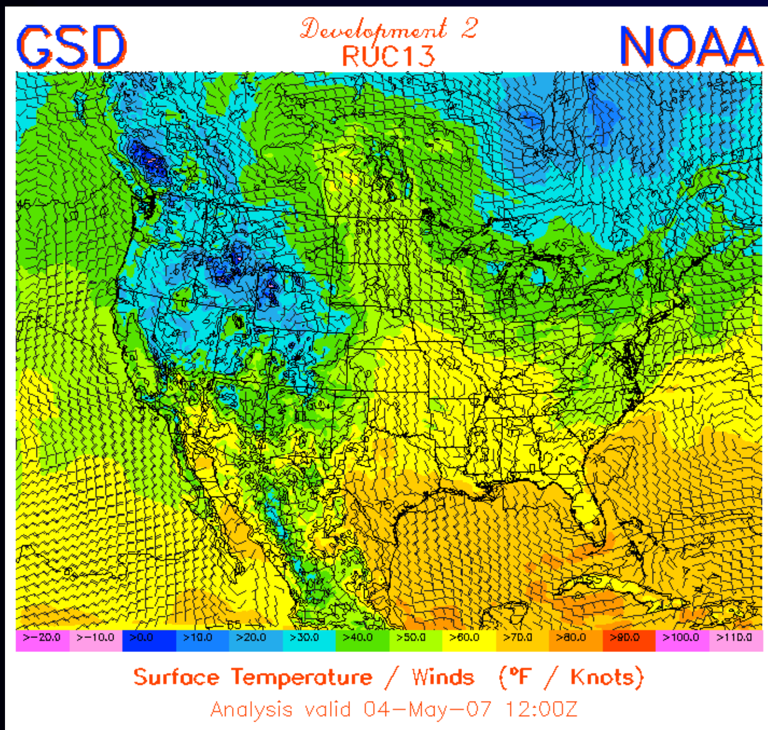
Challenges and future plans for ESRL in Rapid Refresh

- LSM validation/development for polar application in Canada and Alaska including extended permafrost tundra zones
- Improvements in hydrometeor initialization for better 1-h precipitation forecast to minimize possible model drift in soil moisture field
- Assimilation of satellite/in-situ data for snow depth, soil moisture, skin temperature
- Use of real time greenness fraction rather than climatology
- More accurate specification of surface characteristics, inclusion of sub-grid scale variability (e. g., tiling)

Challenges and future plans for ESRL in Rapid Refresh, other model applications

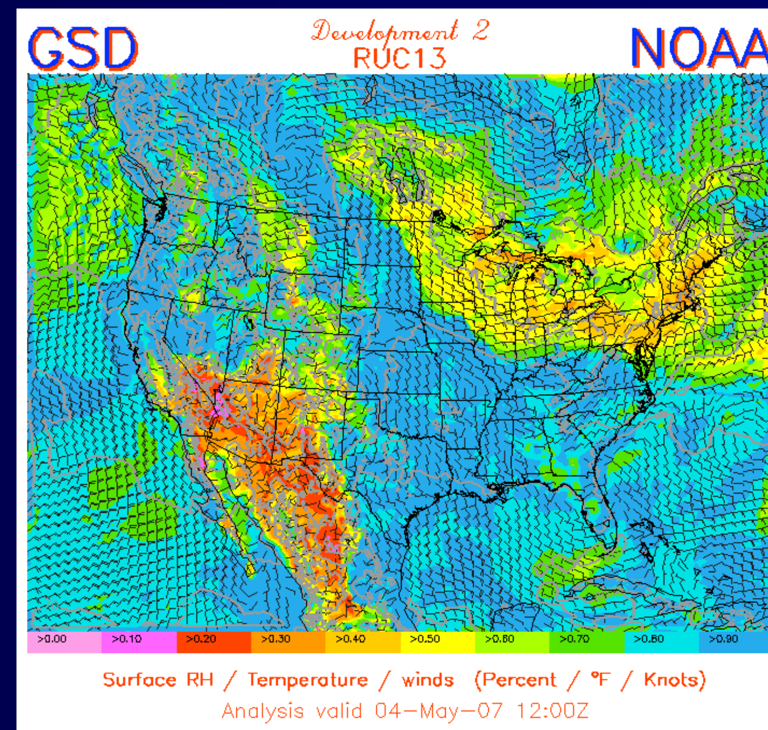
- LSM validation/development for polar application in Canada and Alaska including extended permafrost tundra zones
- Improvements in hydrometeor initialization for better 1-h precipitation forecast to minimize possible model drift in soil moisture field
- Assimilation of satellite/in-situ data for snow depth, soil moisture, skin temperature
- Inclusion of sub-grid scale variability of surface characteristics (e. g., tiling)
- Increase in LSM sophistication in transition to higher resolutions, especially for application in climate models, air quality models....

72-h forecast loop from 13-km development RUC



2-m temperature

2-m relative humidity

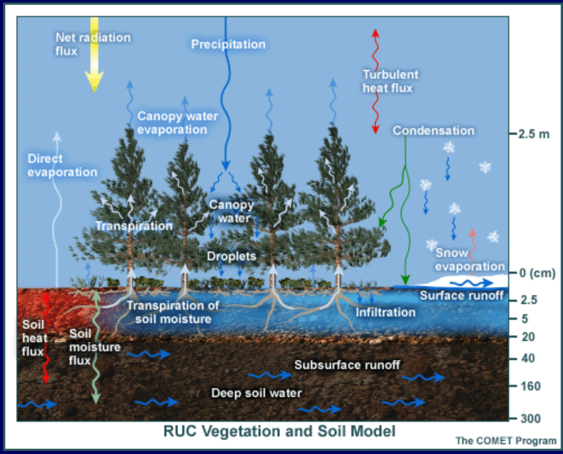


http://ruc.noaa.gov

1200 UTC 4 May - 1200 UTC 7 May 2007

Aspects of RUC LSM that differ from Noah LSM:

- **Surface layer**
  - layer approach to energy and moisture budget
  - implicit solution of energy and moisture budgets
  - bare soil evaporation
  - transpiration (simpler, less sensitivity to parameters)



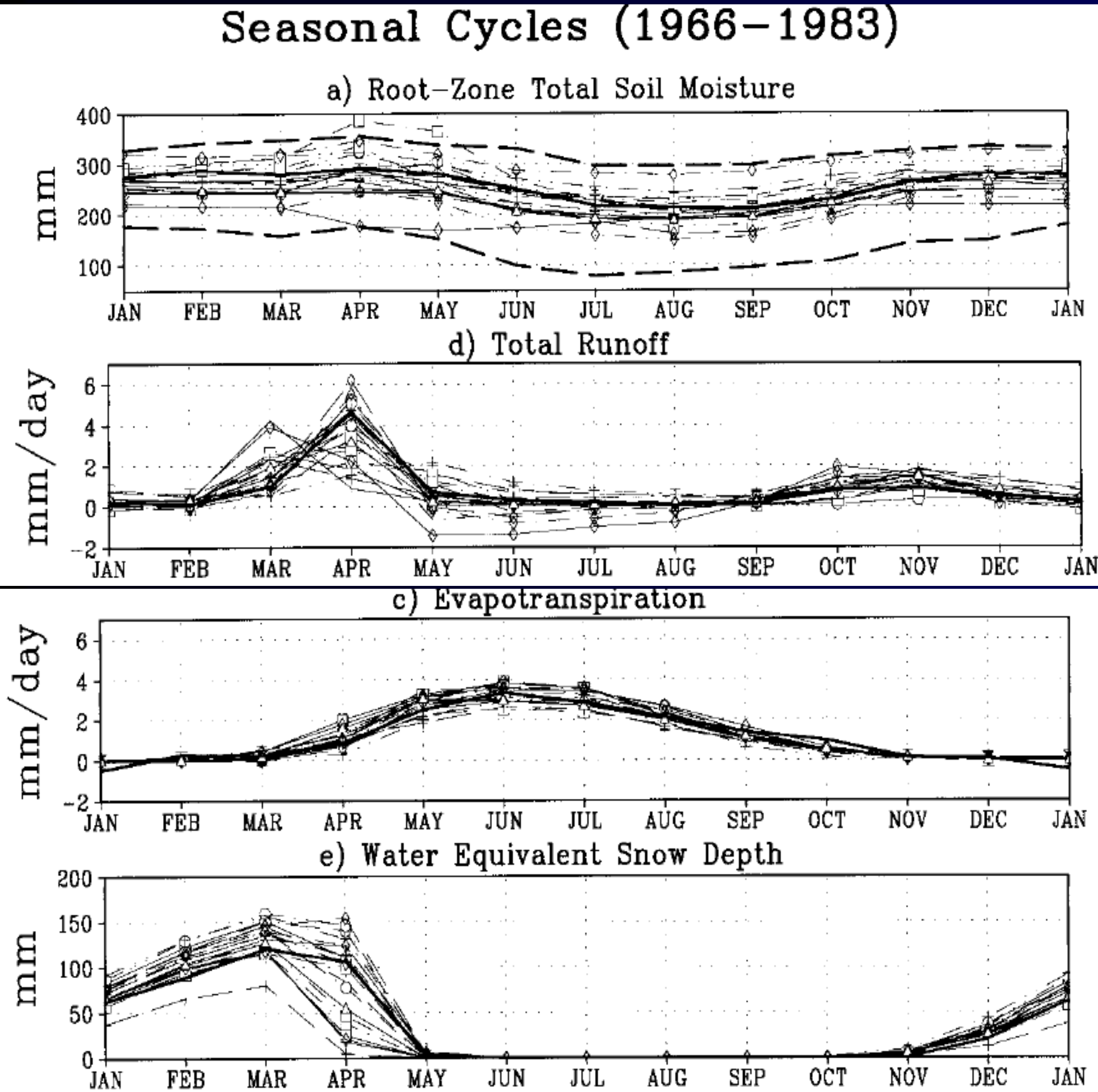
- **Soil model**
  - soil moisture variable - $(\theta - \theta_r)$
  - 2^{nd} order numerical approximation for hydraulic conductivity
  - larger number of levels, thinner top layers

Cycling of soil moisture, soil temperature, snow cover/depth/temperature in RUC 1h cycle since 1997

- **2-layer Snow model versus bulk snow layer**
  - treatment of mixed phase precipitation
- **Frozen soil physics algorithm**

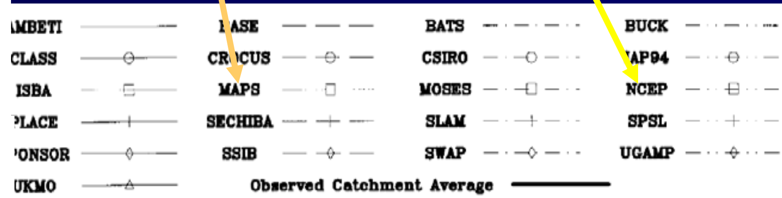
Simulations of a Boreal Grassland Hydrology at Valdai, Russia: PILPS Phase 2(d)

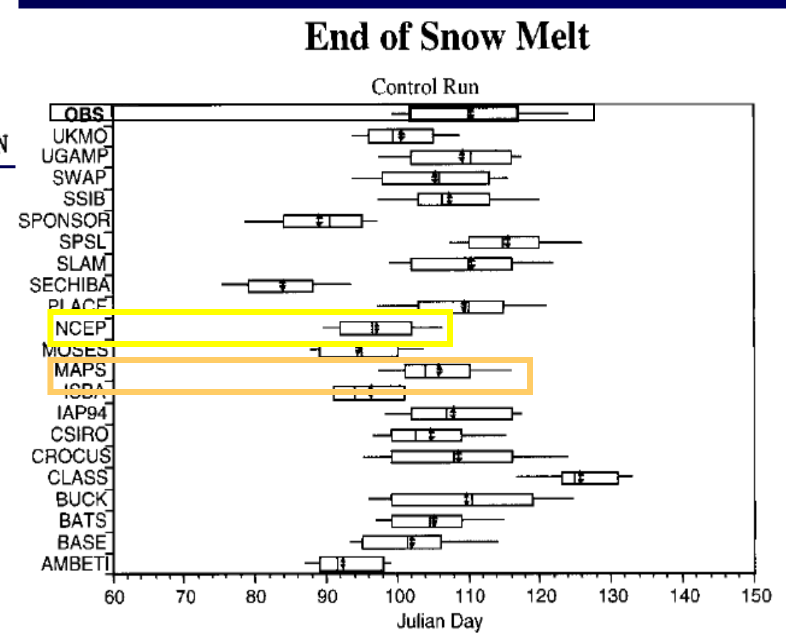
C. Adam Schlosser,* Andrew G. Slater,+ Alan Robock,# Andrew J. Pitman,+
Konstantin Ya. Vinnikov,@ Ann Henderson-Sellers,& Nina A. Speranskaya,**
Ken Mitchell,++ and The PILPS 2(d) Contributors##



RUC LSM

Noah





Monthly Weather Review, v128, 2000

Frozen Soil Physics in RUC LSM

$$C_a \frac{\partial T}{\partial t} = \frac{\partial}{\partial z} \nu_f \frac{\partial T}{\partial z}, \qquad (8)$$

where C_a is called the apparent heat capacity and is equal to

$$C_a = C + \rho_l L_f \frac{\partial \eta_l}{\partial T}. \qquad (9)$$

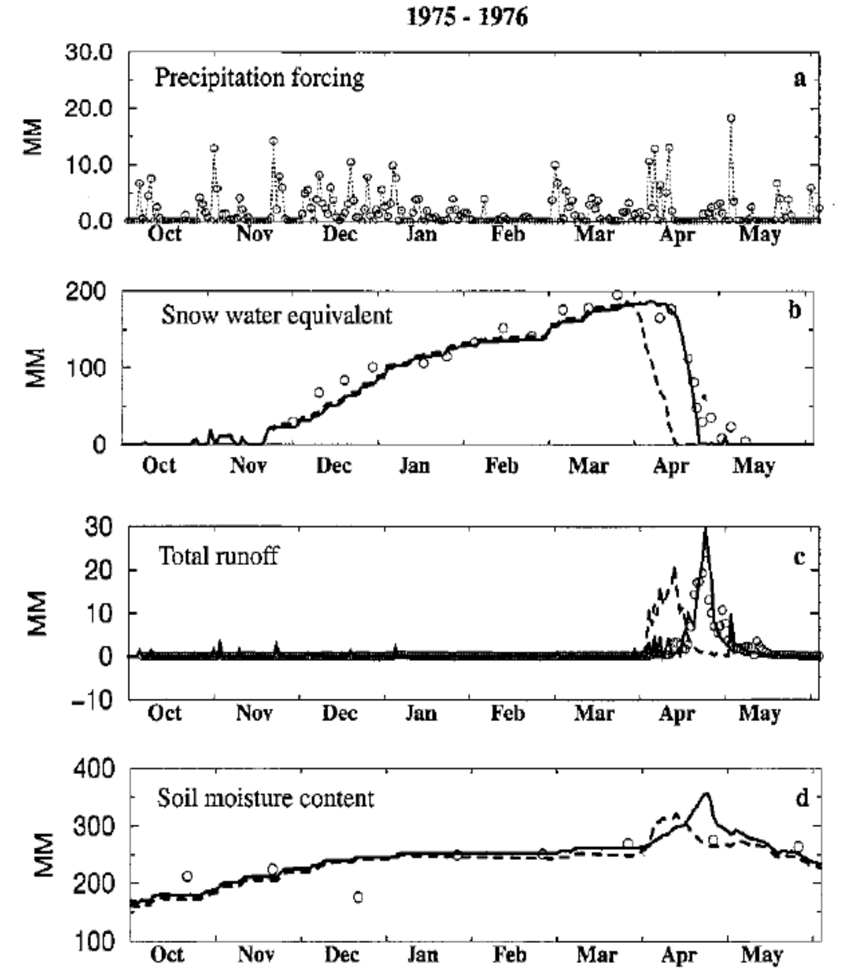
The slope of the soil-freezing characteristic curve $\partial \eta_l / \partial T$ with zero solute concentration in the soil solution can be obtained from [*Cary and Mayland*, 1972; *Flerchinger and Saxton*, 1989]

$$\eta_l = \eta_s \left[\frac{L_f (T - 273.15)}{g T \Psi_s} \right]^{-1/b}, \qquad (10)$$

where η_s is the volumetric moisture content at saturation, Ψ_s is the moisture potential for saturated soil.

The heat capacity of the soil is calculated according to the weighted contribution of the dry soil, liquid water, and ice:

$$C = (1 - \eta_s) C_s + \eta_l C_l + \eta_i C_i. \qquad (11)$$



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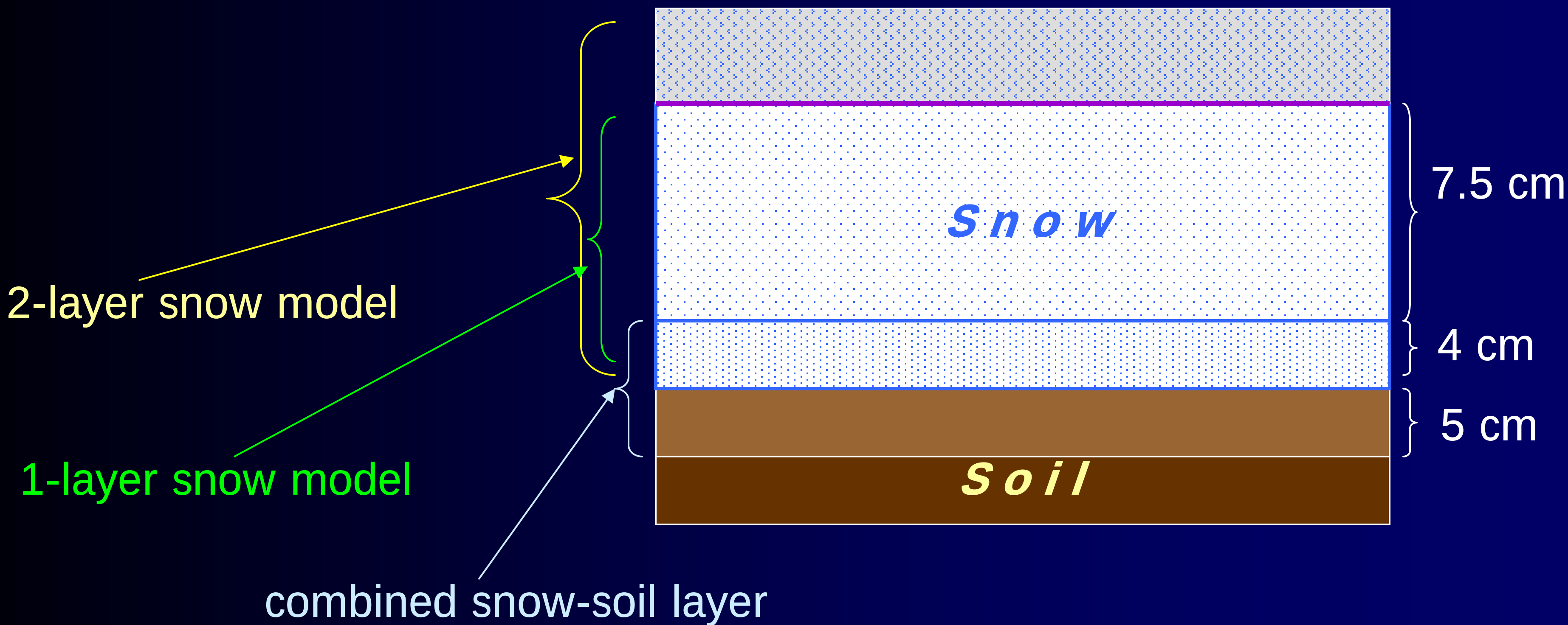
Modifications to the snow model –

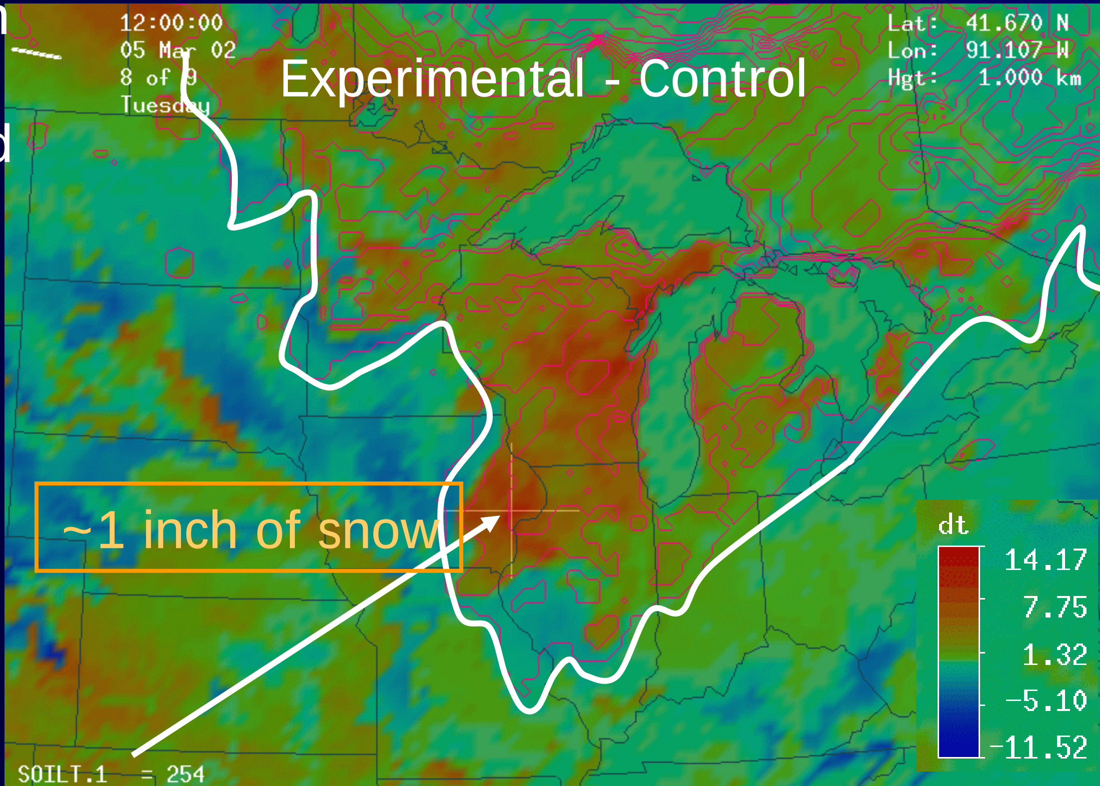
- changed vertical structure of the snow model
- snow albedo reduction for thin snow layer

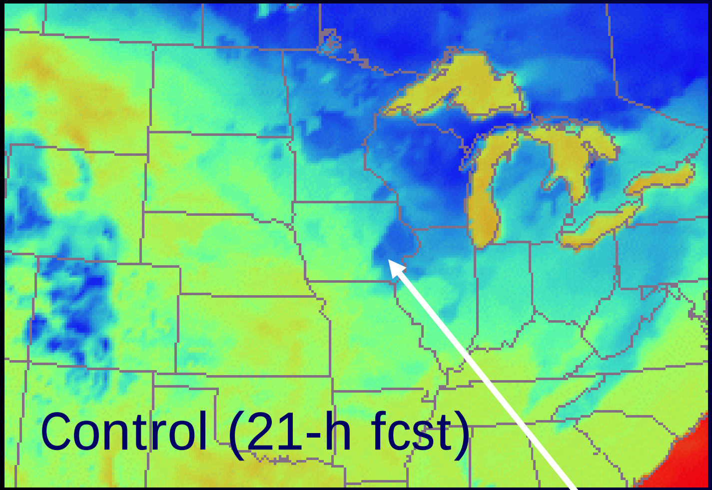


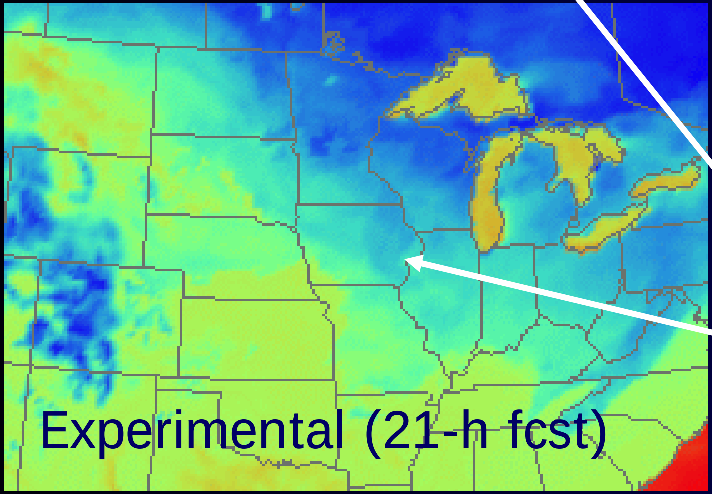
Motivation – correct excessively cold temperatures at night (with clear skies, low winds) over thin snow layer; improve estimation of the snow melting rate.

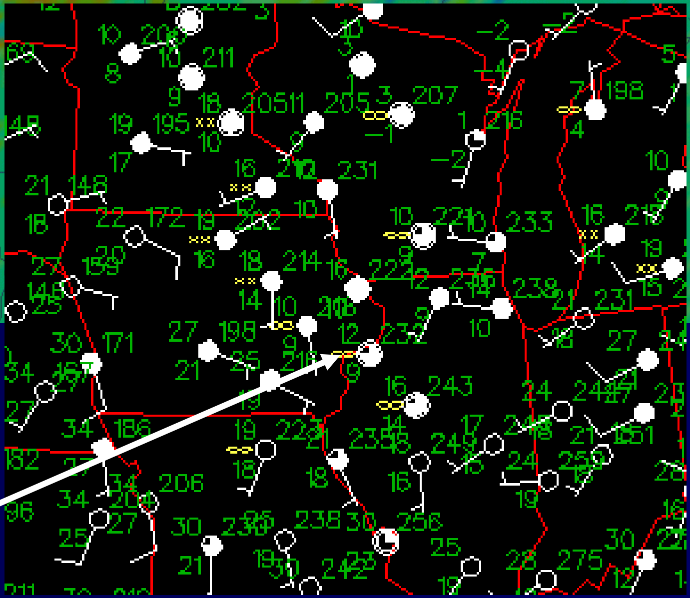
Surface temperature comparison between operational RUC and experimental RUC (with changed vertical structure of snow model)

Valid 1200 UTC 5 March 2002









Contr.	- 19 C
Exper.	- 10 C
Obs.	- 11 C (12 F)

RUC performance for surface :

- Precipitation

  Spatial patterns and magnitude of 0-1h RUC precipitation agrees relatively well with observed – prerequisite for realistic soil moisture field in RUC cycle – more improvement needed

- Snow

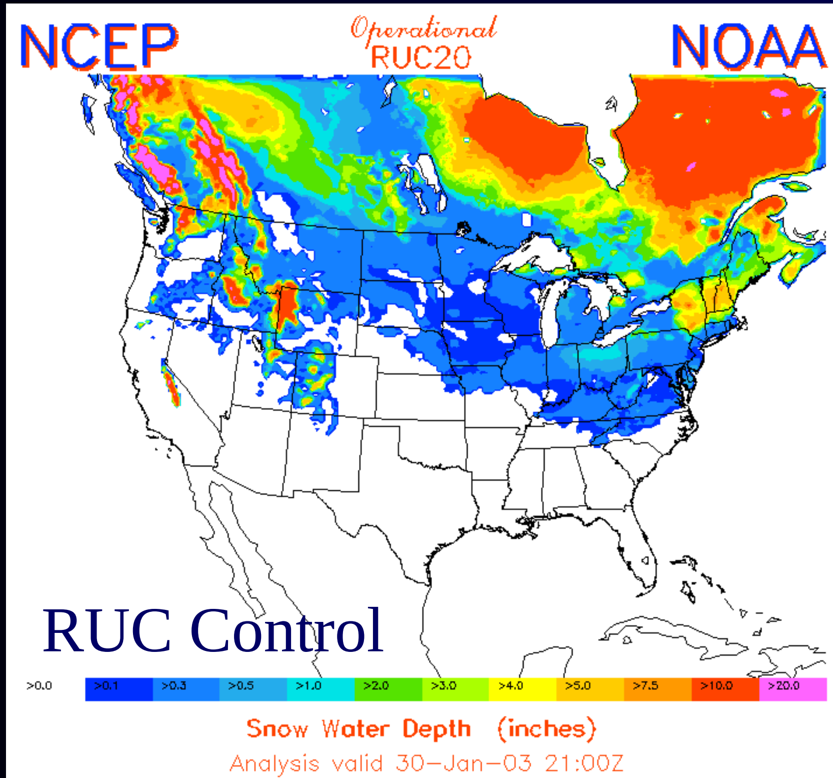
  Cycled snow-water equivalent depth is in good agreement with NESDIS (sat obs) areas of snow cover

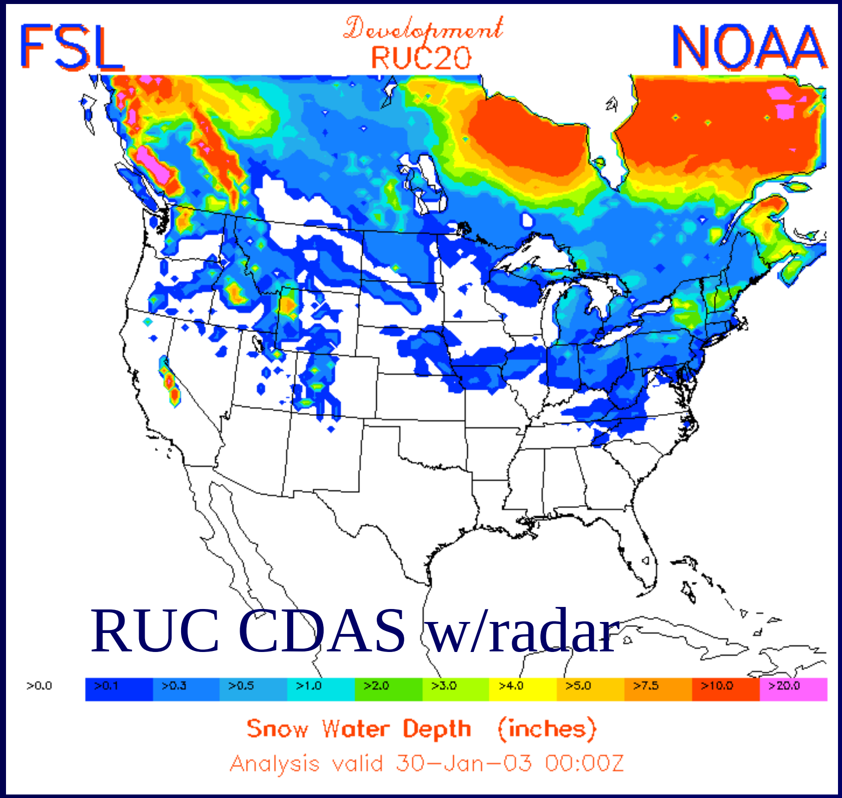
  RUC cycled snow-water depth appears very reasonable

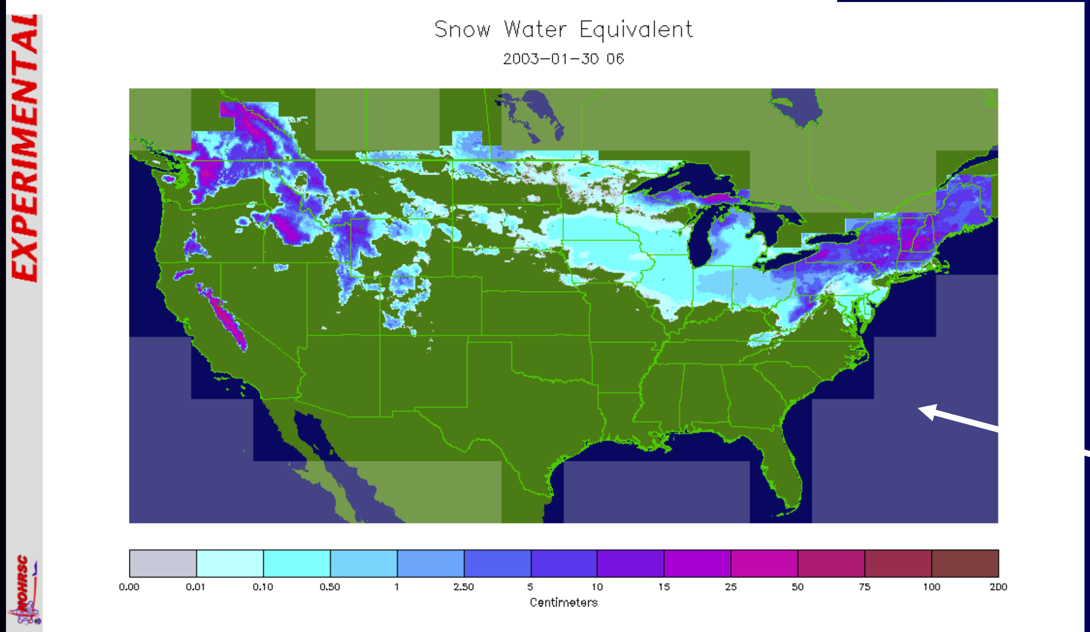
- Soil

  Soil temperature/moisture variation in RUC w/ ongoing cycle in good general agreement with in situ soil observations

  - dependent on likeness of soil type between site and model, and 1-h model precipitation





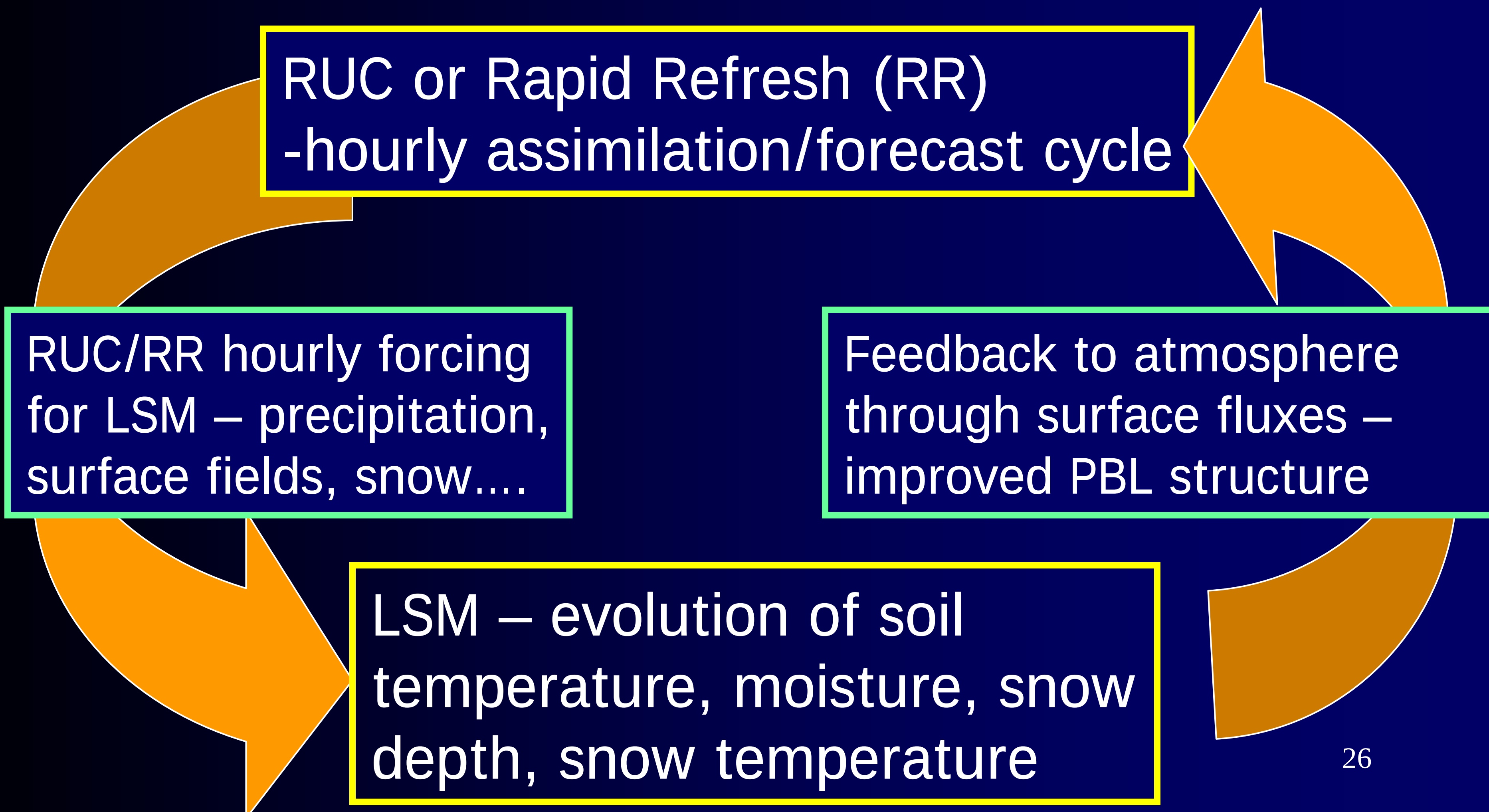


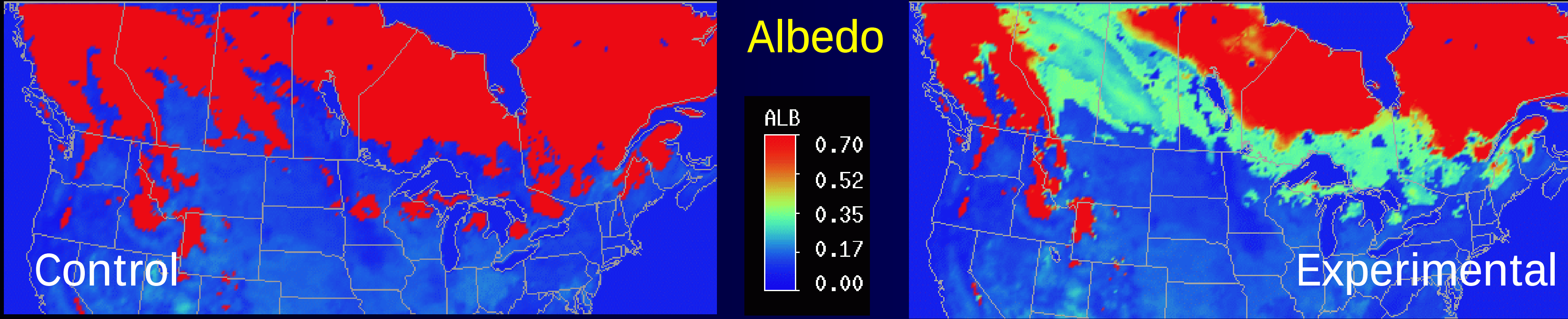
Snow water depth 30 January 2003

RUC to Rapid Refresh

- CONUS domain (13km) → North American domain (13km)
- RUC model → WRF model (ARW very likely)
- RUC 3DVAR → GSI (Gridpoint Statistical Interpolation)

Linkage between Atmospheric Models (RUC model as example) and LSM

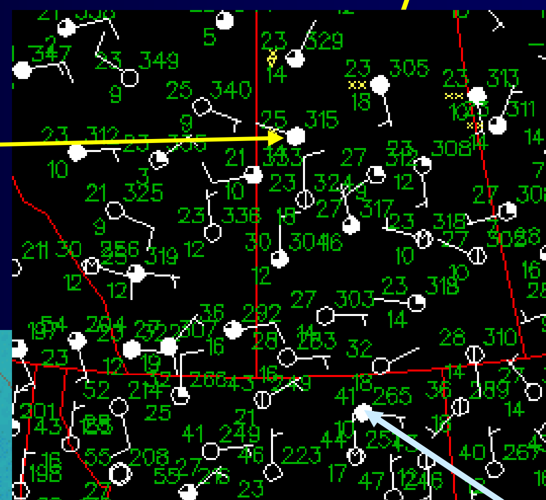


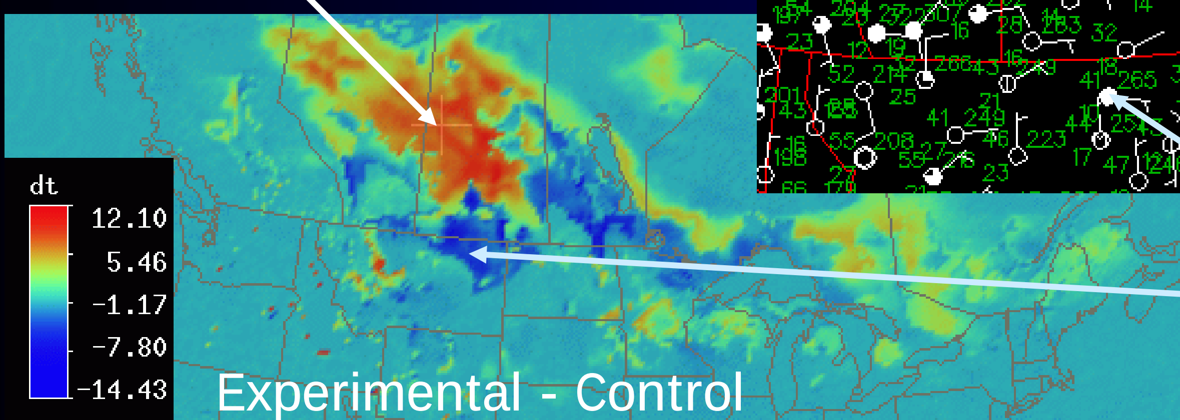


Skin temperature difference between *24-h forecasts* from RUC control and RUC experimental (*improved snow model and reduced albedo over shallow snow*).

Valid 2100 UTC 4 April 2002

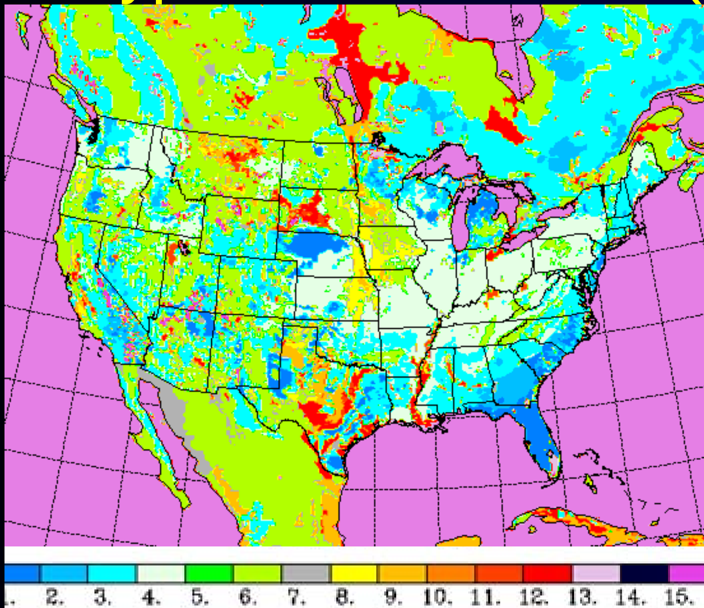
Contr. -12 C
Exper. - 4 C
Obs. - 3.8 C
(25 F)





Obs. 5 C (41 F)
Contr. 9 C
Exper. 6 C

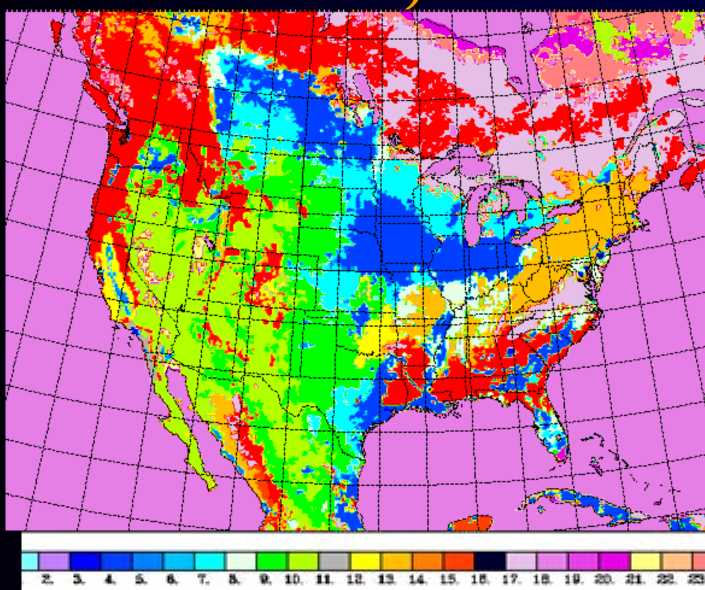
Soil types in 13-km RUC (16 classes)



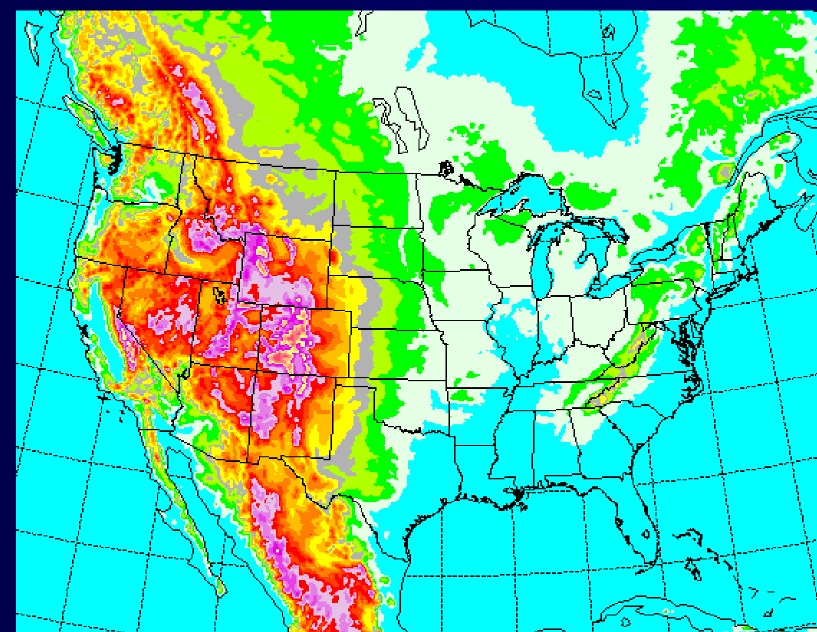
Files obtained from

WRF Standard Initialization (WRF SI)

Vegetation types in 13-km RUC (24 USGS classes)



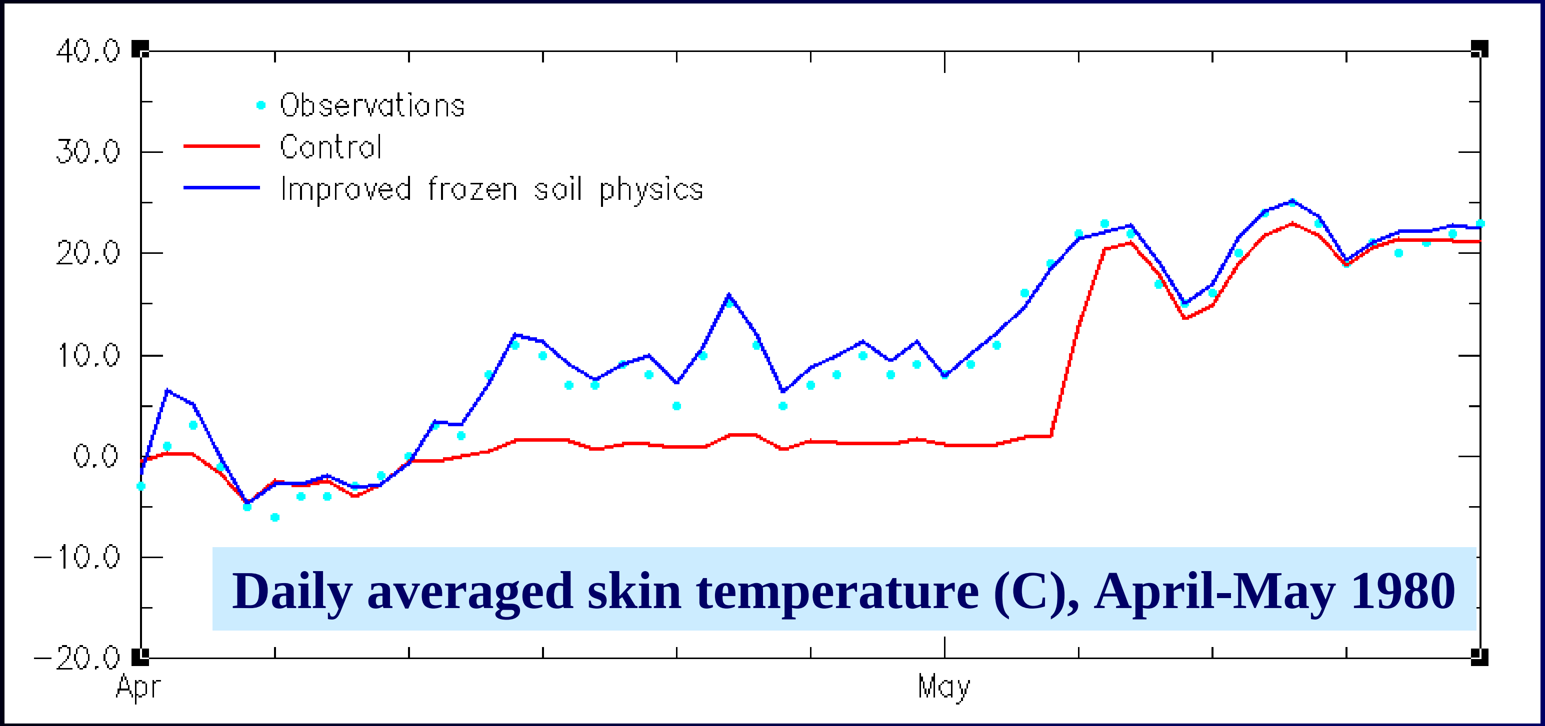
Topography in 13- km



Improvement of frozen soil physics algorithm

- needed when both soil moisture and soil temperature increase – *typical situation* for the snow melting season.

  - Tested in 1-D for Valdai, Russia



  - Tested in Experimental RUC at FSL

RUC Coupled Data Assimilation System – RUC CDAS

RUC CDAS is a four-dimensional system which:

- Uses a forward full-physics model
- Cycles surface/soil fields depending on the RUC atmospheric forcing
- Cycles 5 hydrometor species : cloud, ice, rain, snow and graupel. Cloud clearing/building based on GOES data

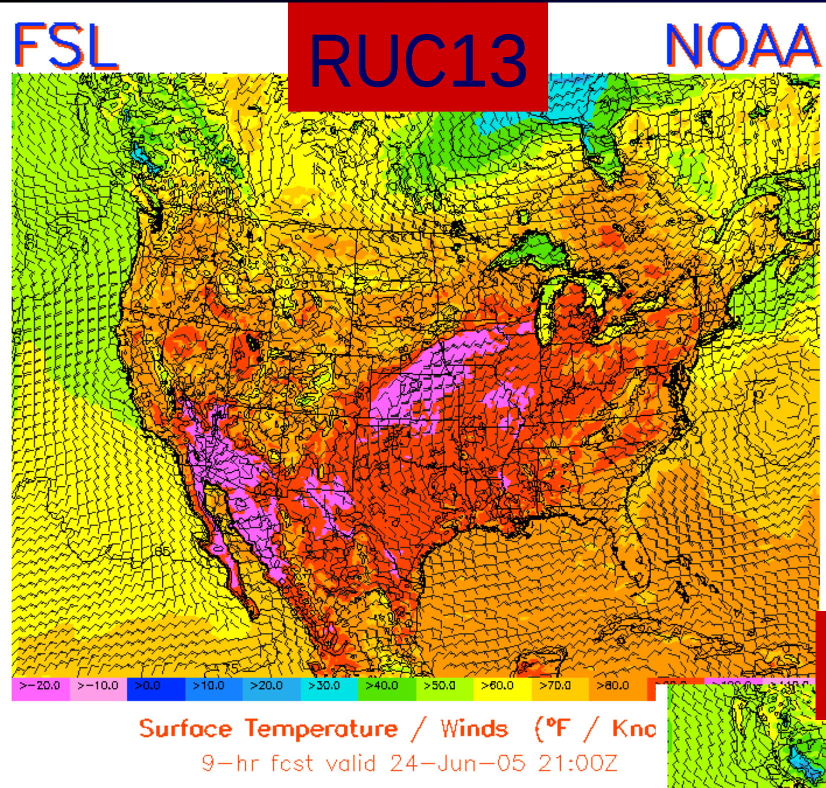
new compared to RUC Control:

- Adjusts cycled cloud and precipitation fields using NEXRAD radar reflectivity observations (Kim and Benjamin 2002, 15th NWP)

Main Goal:

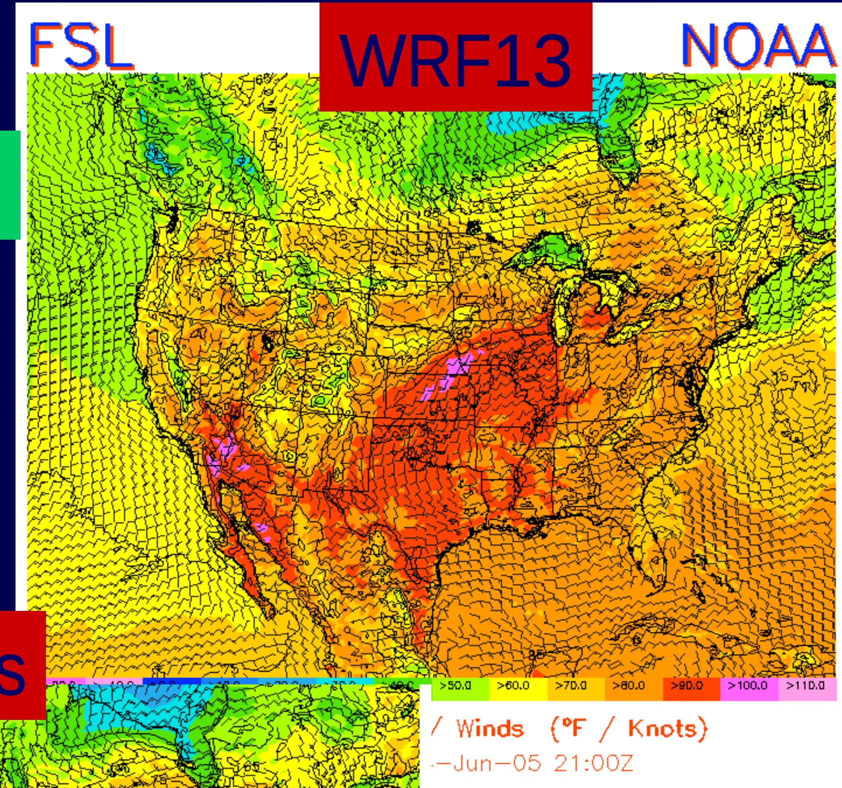
- to improve 1-h precipitation forcing and the land surface model climate

RUC13

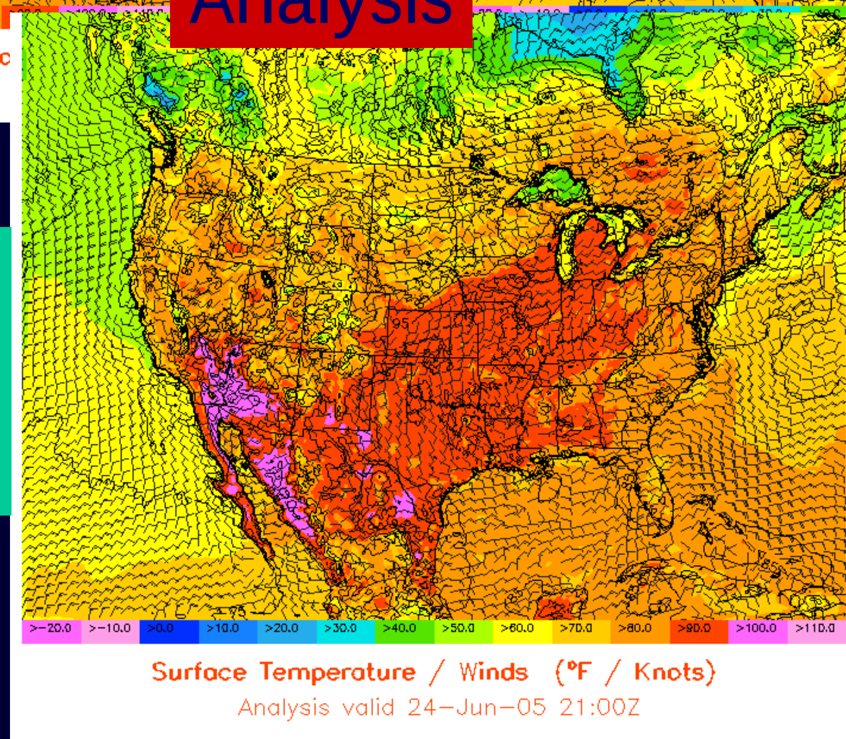


9h fcst

WRF13



Analysis



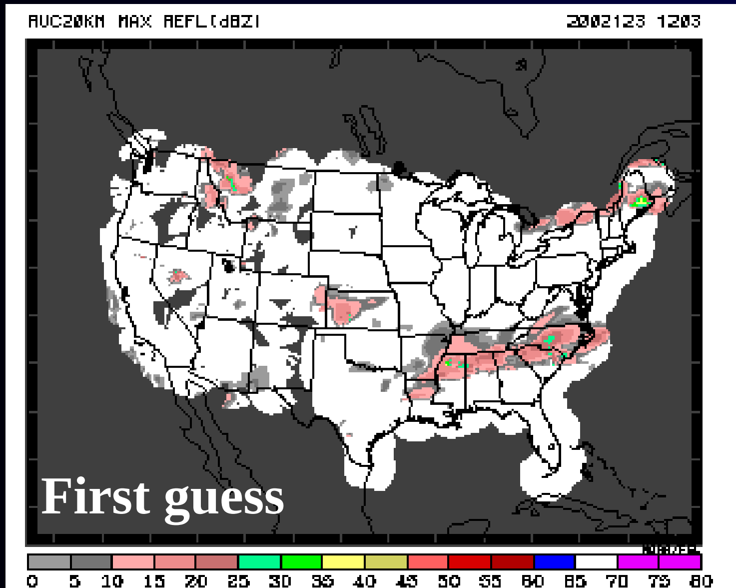
2-m temperature valid at 2100 UTC 24 June 2005

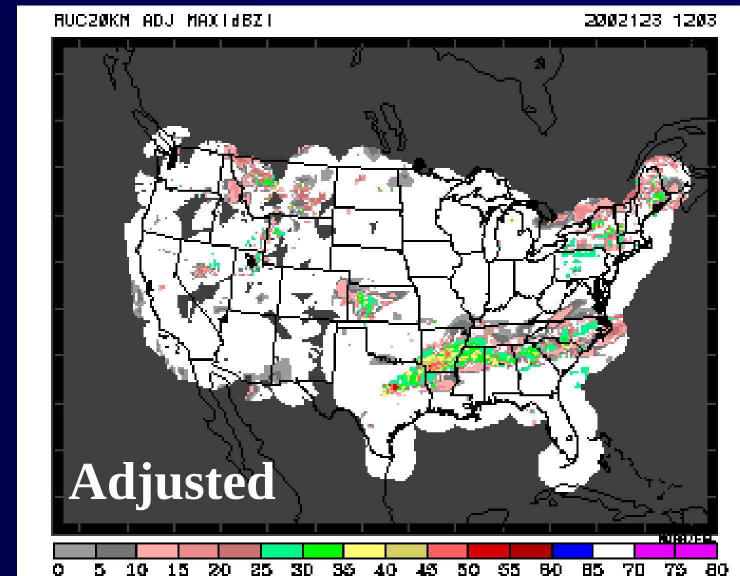
RUC CDAS hypothesis -

- Mesoscale model forecast of precipitation and precipitation type may be better than analyses from observations in some situations:
    - orographic precipitation, especially in cold season
    - data void area

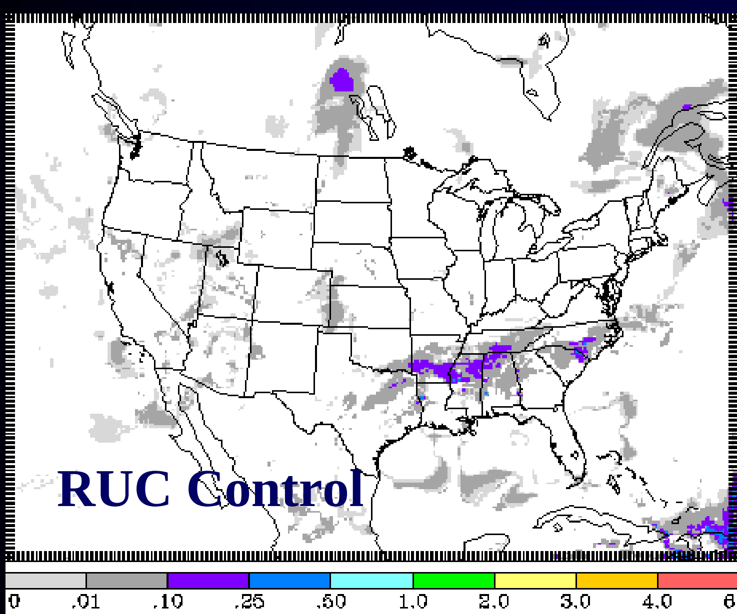
- Assimilation of radar reflectivity allows use of beam-blockage information

Maximum reflectivity (dBZ) from RUC hydrometeor fields

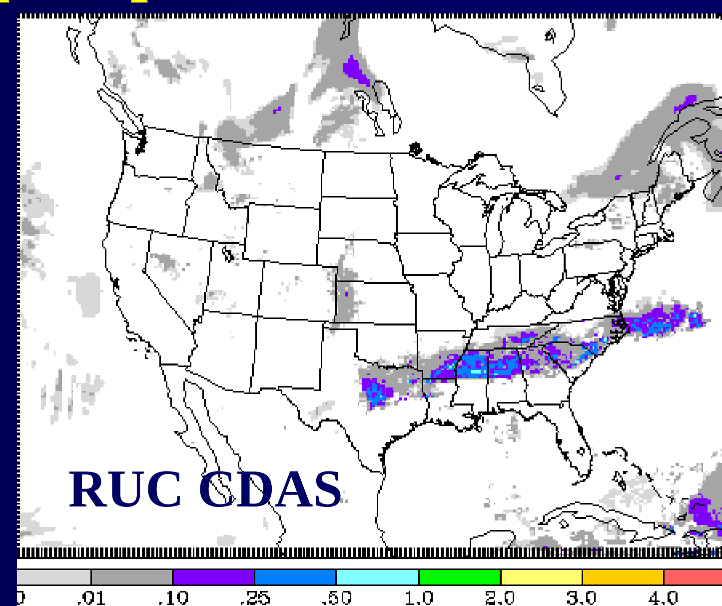


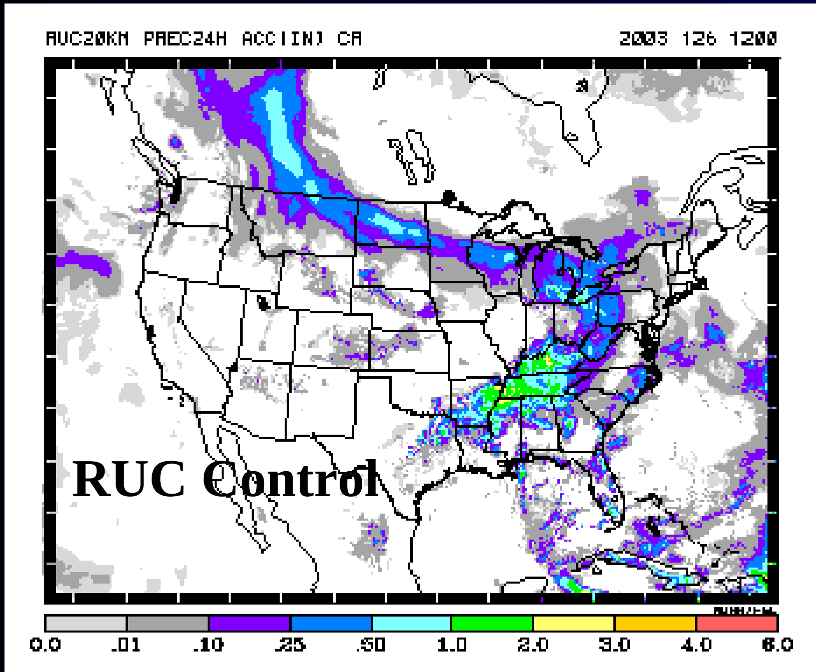


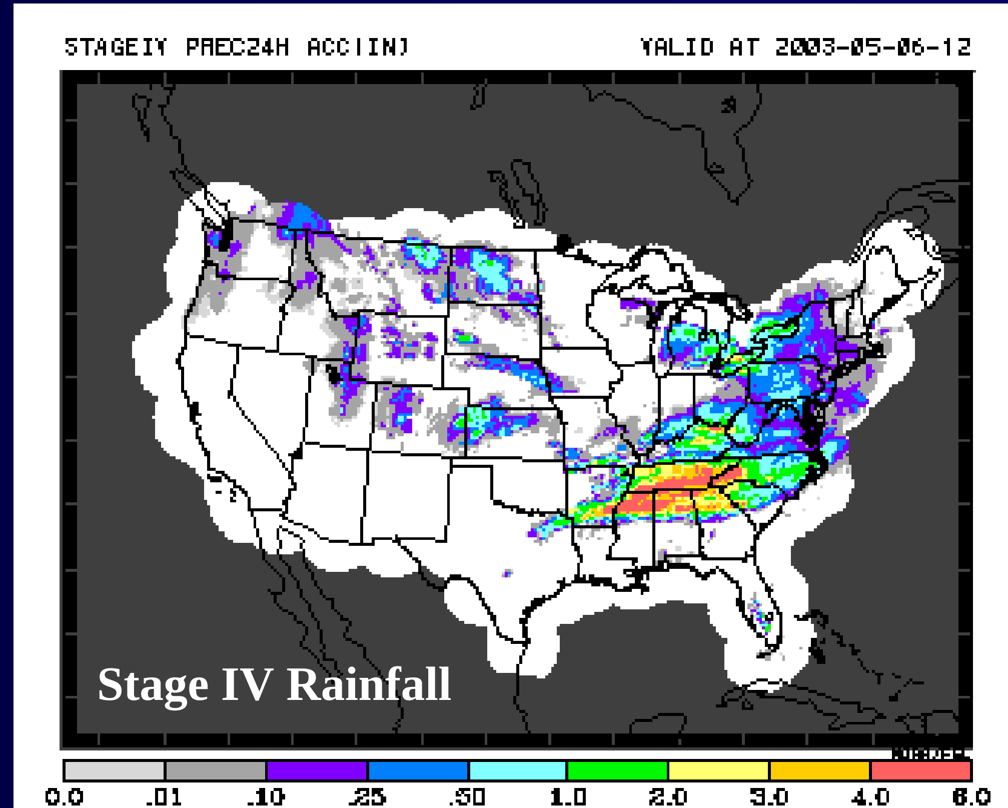
3-h Accumulated precipitation

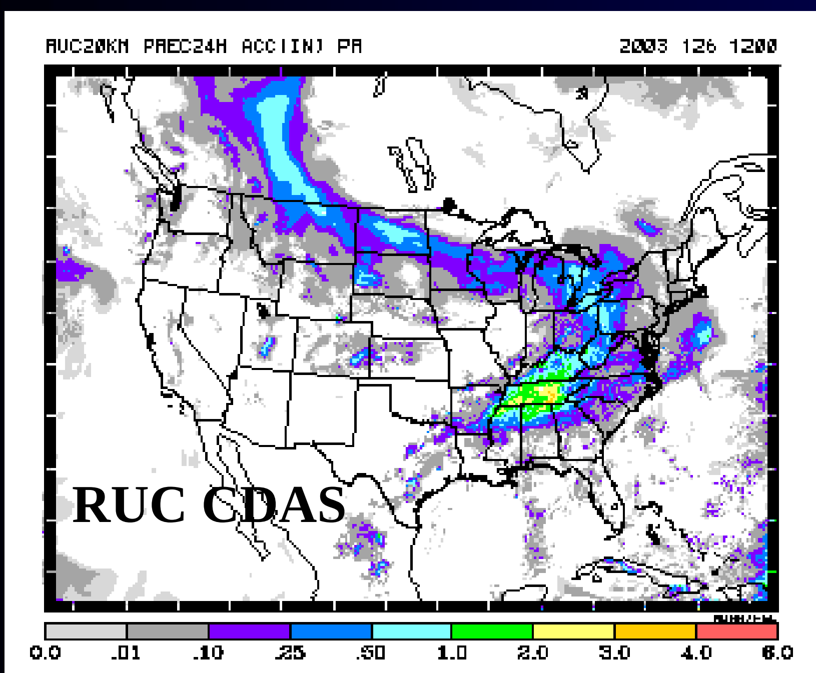


1500 UTC
3 May 2002

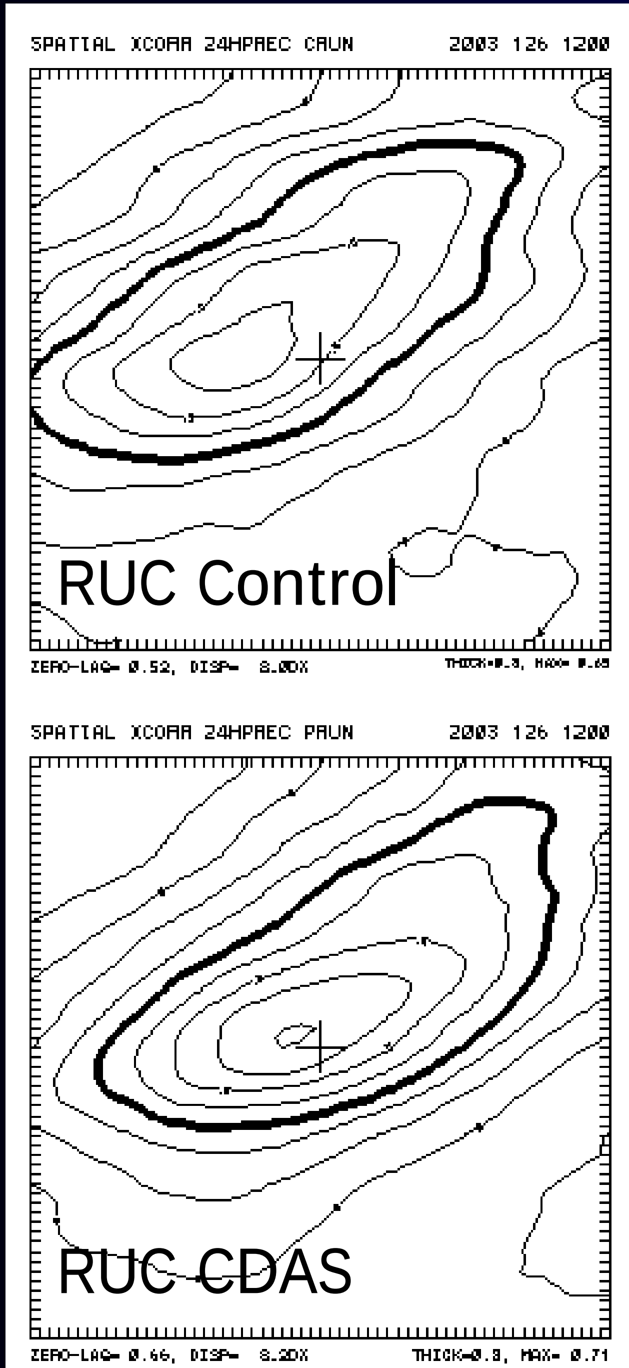


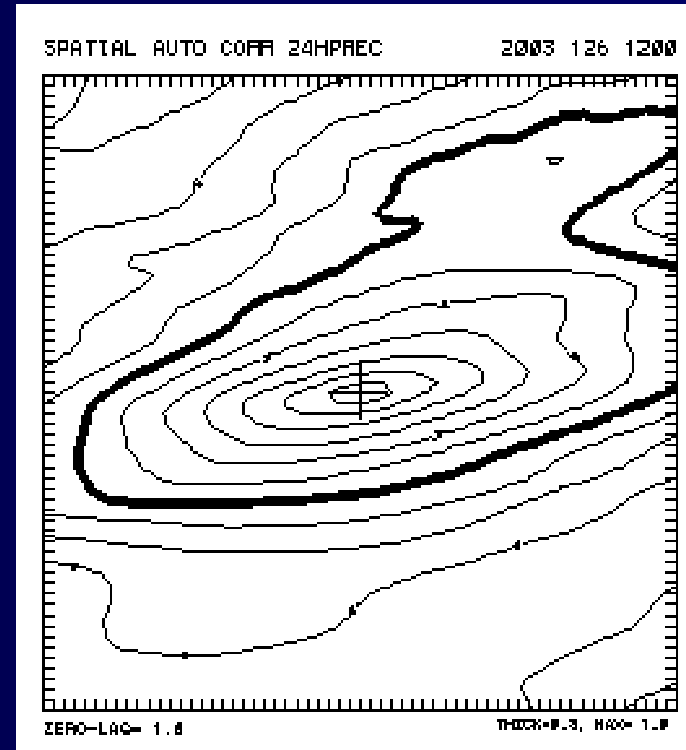






24-hour precipitation accumulation ending at 1200 UTC 6 May 2003



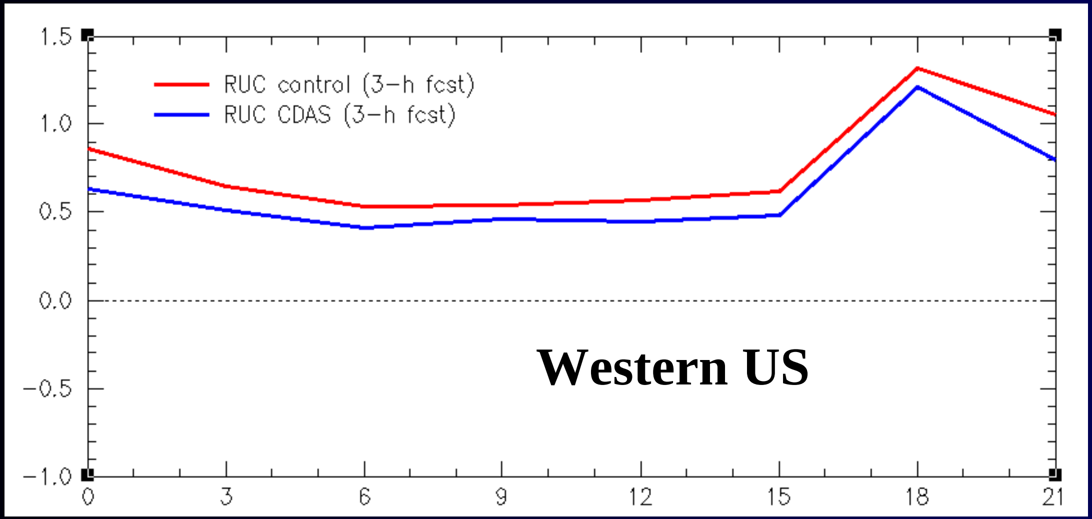


Spatial Correlation fields of 24-h Accumulated Precipitation ending at 1200 UTC 6 May 2003

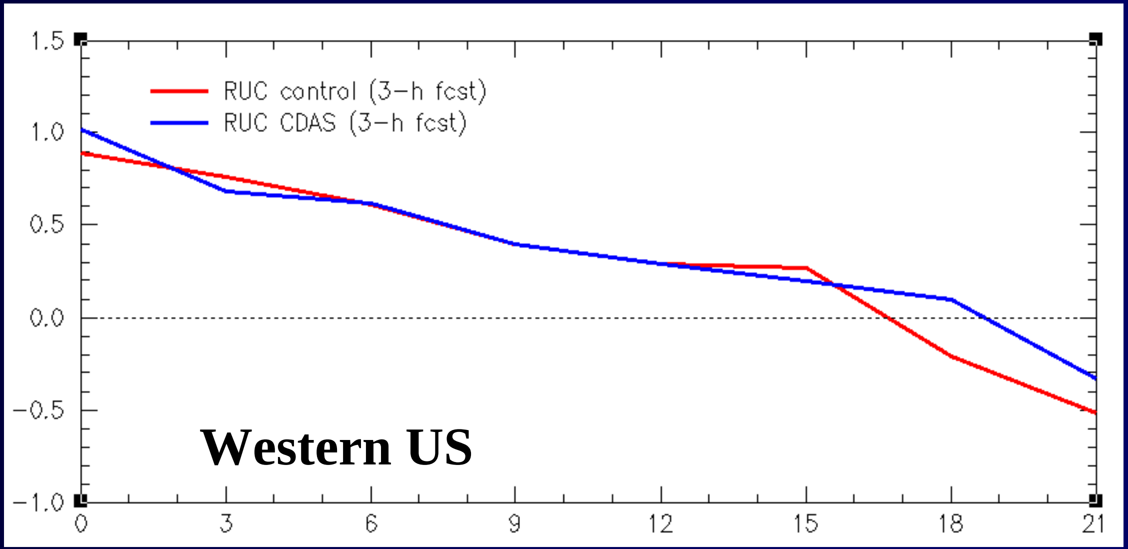
(Dongsoo Kim)

Diurnal cycle of biases from RUC control and RUC CDAS averaged for the period 1 December – 1 March 2003

2-m dew point

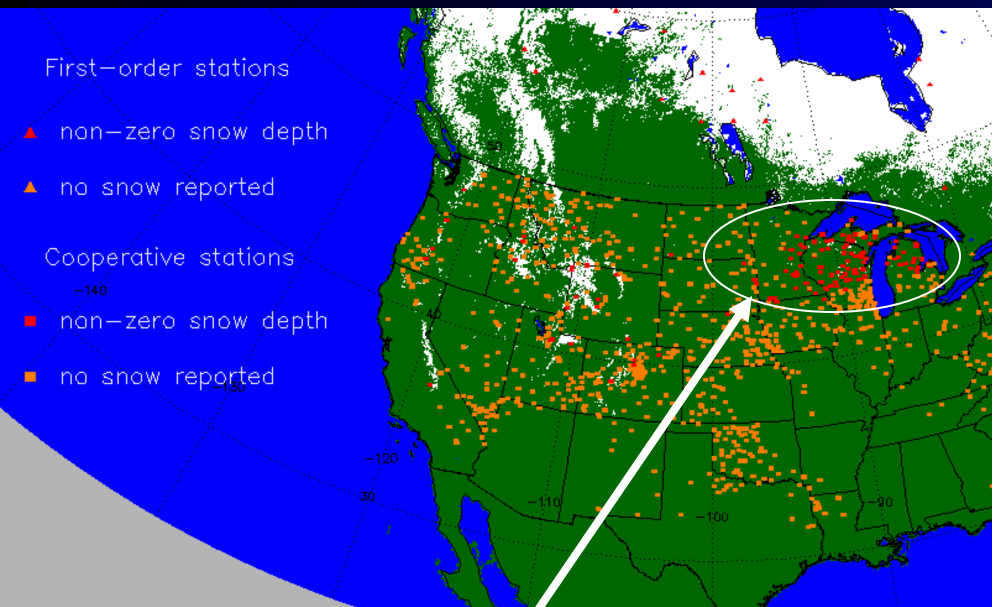


2-m temperature



RUC CDAS runs at FSL as a continuous cycle since 1800 UTC 17 April 2002

Snow cover with surface observations overlaid



Non-zero snow reported by surface stations

Valid 1800 UTC 22 April 2002
22 April 2002