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Fall Colloquium on the Physics of Weather and Climate: Regional Weather Predictability and Modelling

29 September - 10 October, 2008

Land-surface modeling in numerical weather prediction models

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Land-Surface Modelling in Numerical Weather Prediction Models

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Fall Colloquium on the Physics of Weather & Climate:
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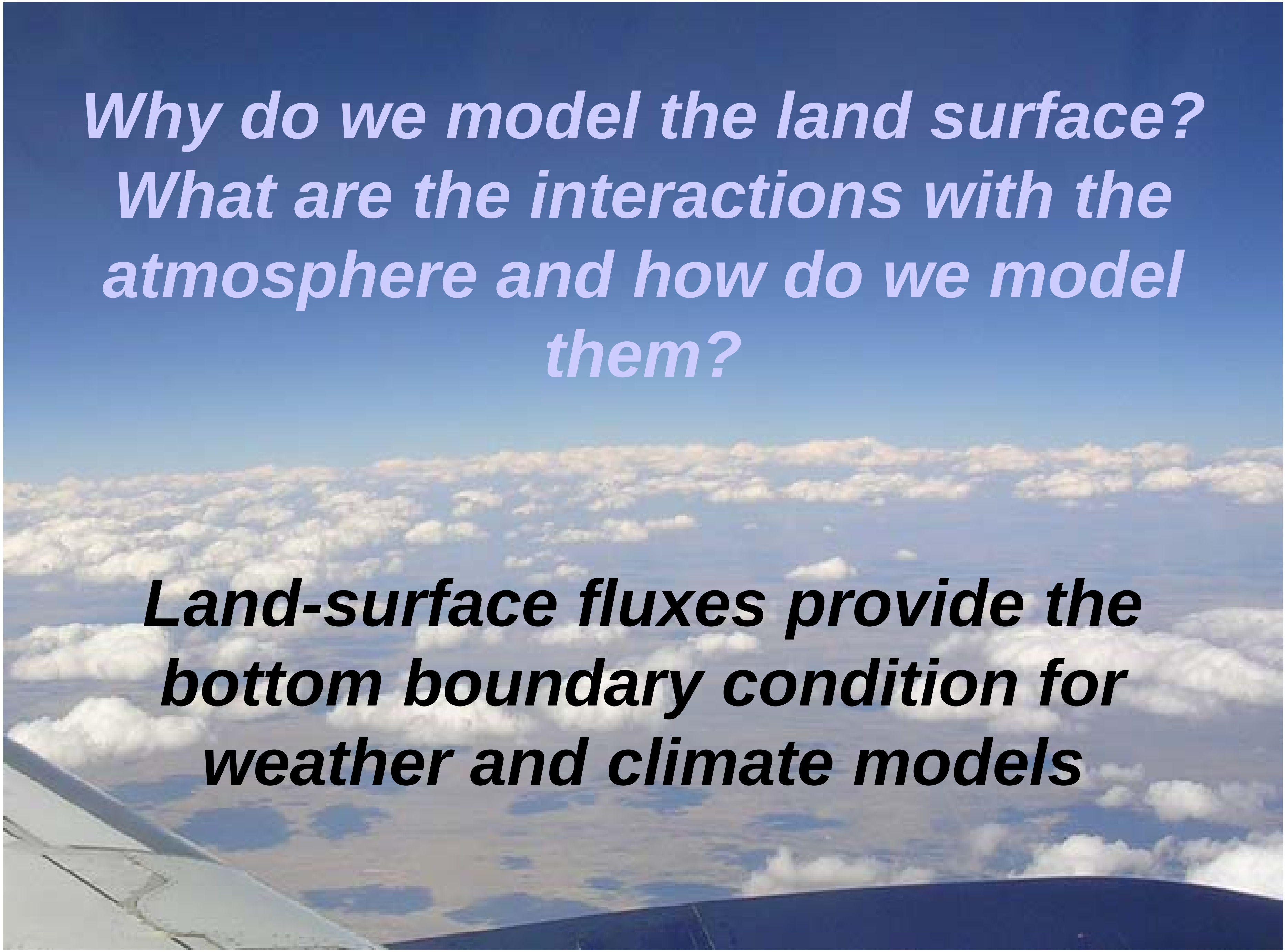
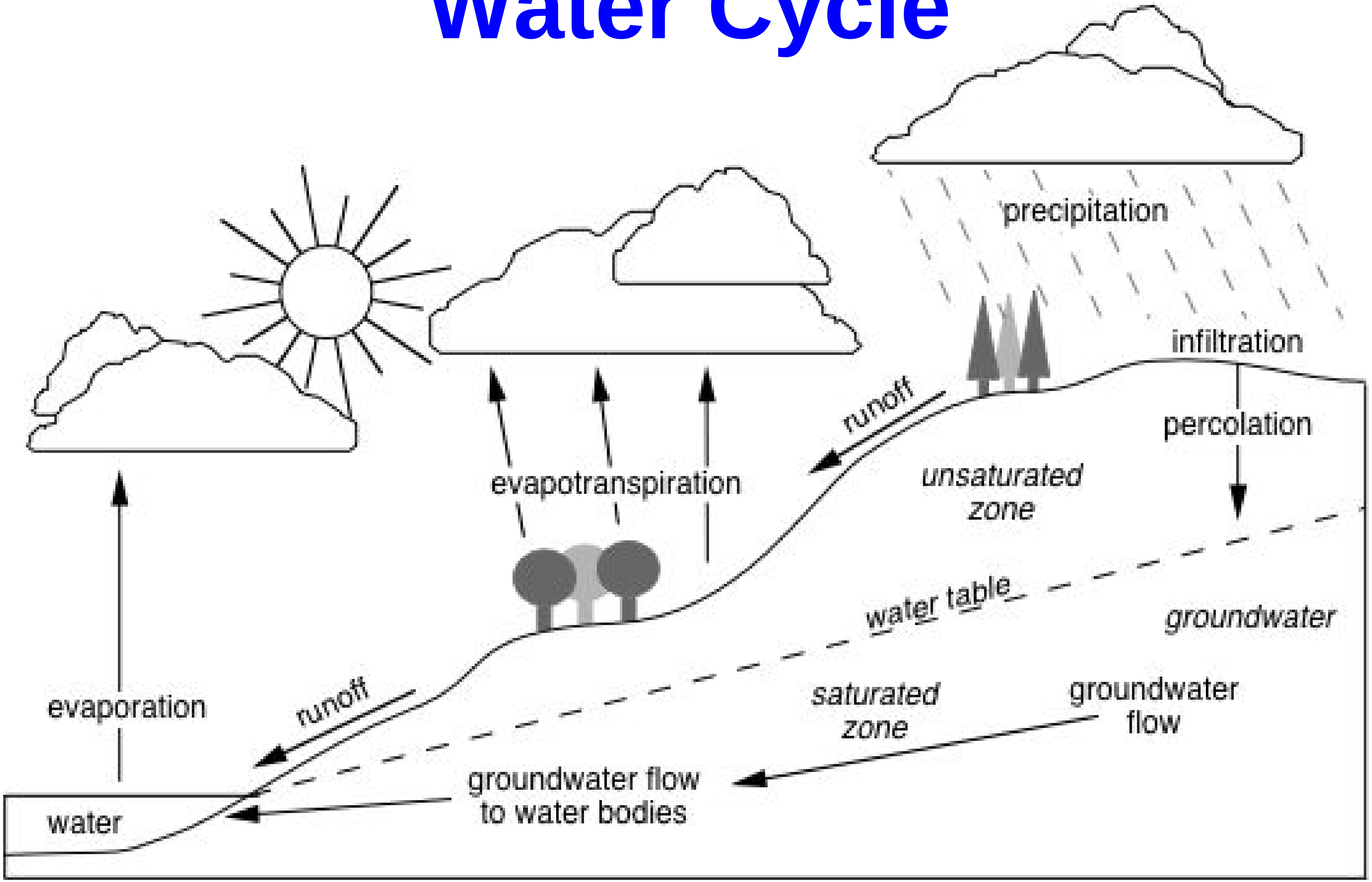

Why do we model the land surface?
What are the interactions with the atmosphere and how do we model them?
Land-surface fluxes provide the bottom boundary condition for weather and climate models


…and we live at the interface between
the land-surface and atmosphere
(at least most of us do).

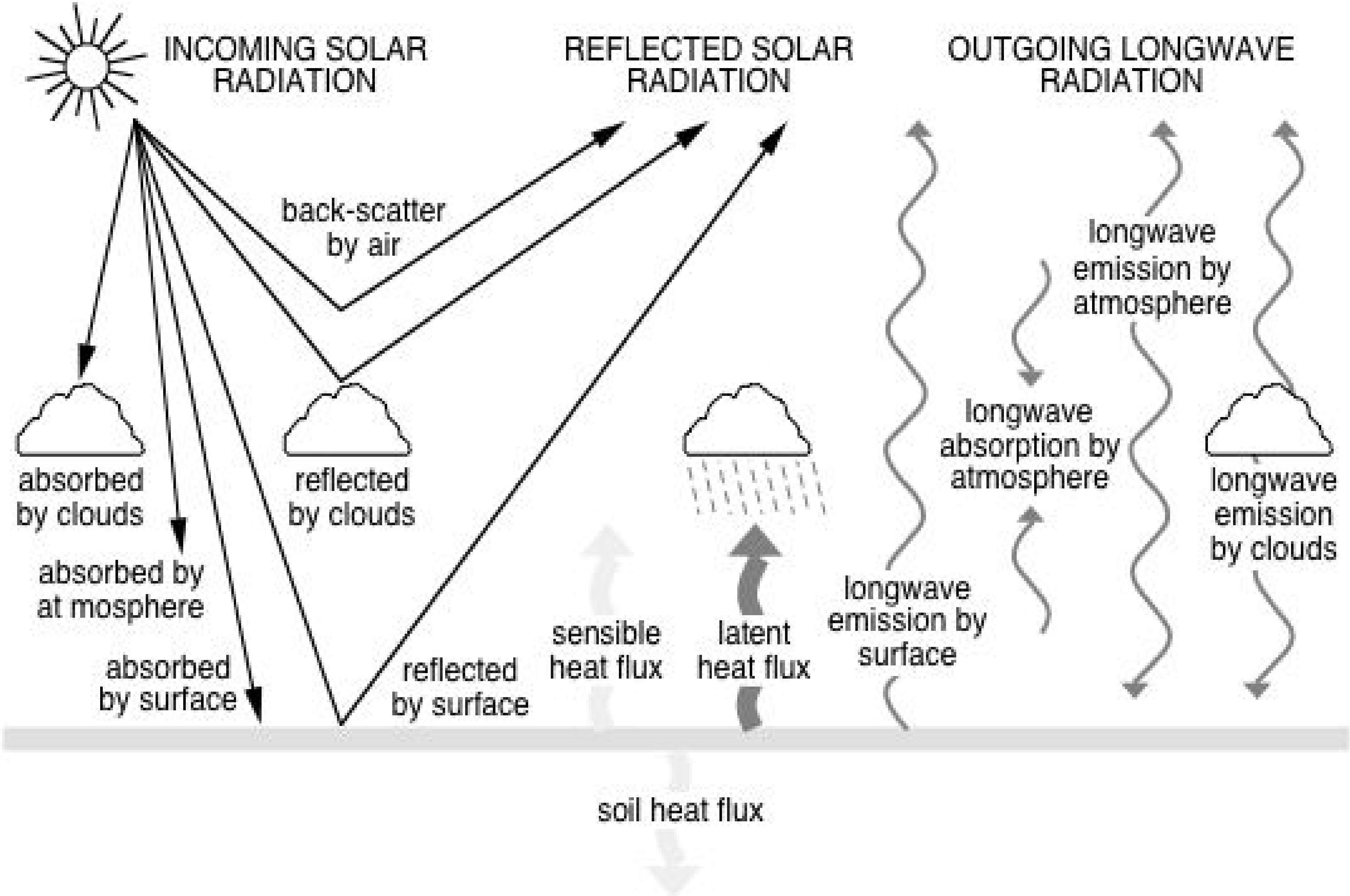
Land-surface model formulations describe components of the Water Cycle and atmospheric/ surface Heat Budget, according to surface conditions, i.e. vegetation type & coverage, soil type, snow, terrain/slope, and the movement of water and heat in the soil.

Water Cycle



precipitation
infiltration
runoff
percolation
unsaturated zone
evapotranspiration
water table
groundwater
evaporation
runoff
saturated zone
groundwater flow
groundwater flow to water bodies
water

Heat Budget



INCOMING SOLAR RADIATION
REFLECTED SOLAR RADIATION
OUTGOING LONGWAVE RADIATION
back-scatter by air
longwave emission by atmosphere
longwave absorption by atmosphere
absorbed by clouds
reflected by clouds
longwave emission by clouds
absorbed by at mosphere
longwave emission by surface
sensible heat flux
latent heat flux
absorbed by surface
reflected by surface
soil heat flux

So, to properly represent the Water Cycle and atmospheric/surface Heat Budget, land-surface modelling brings together:

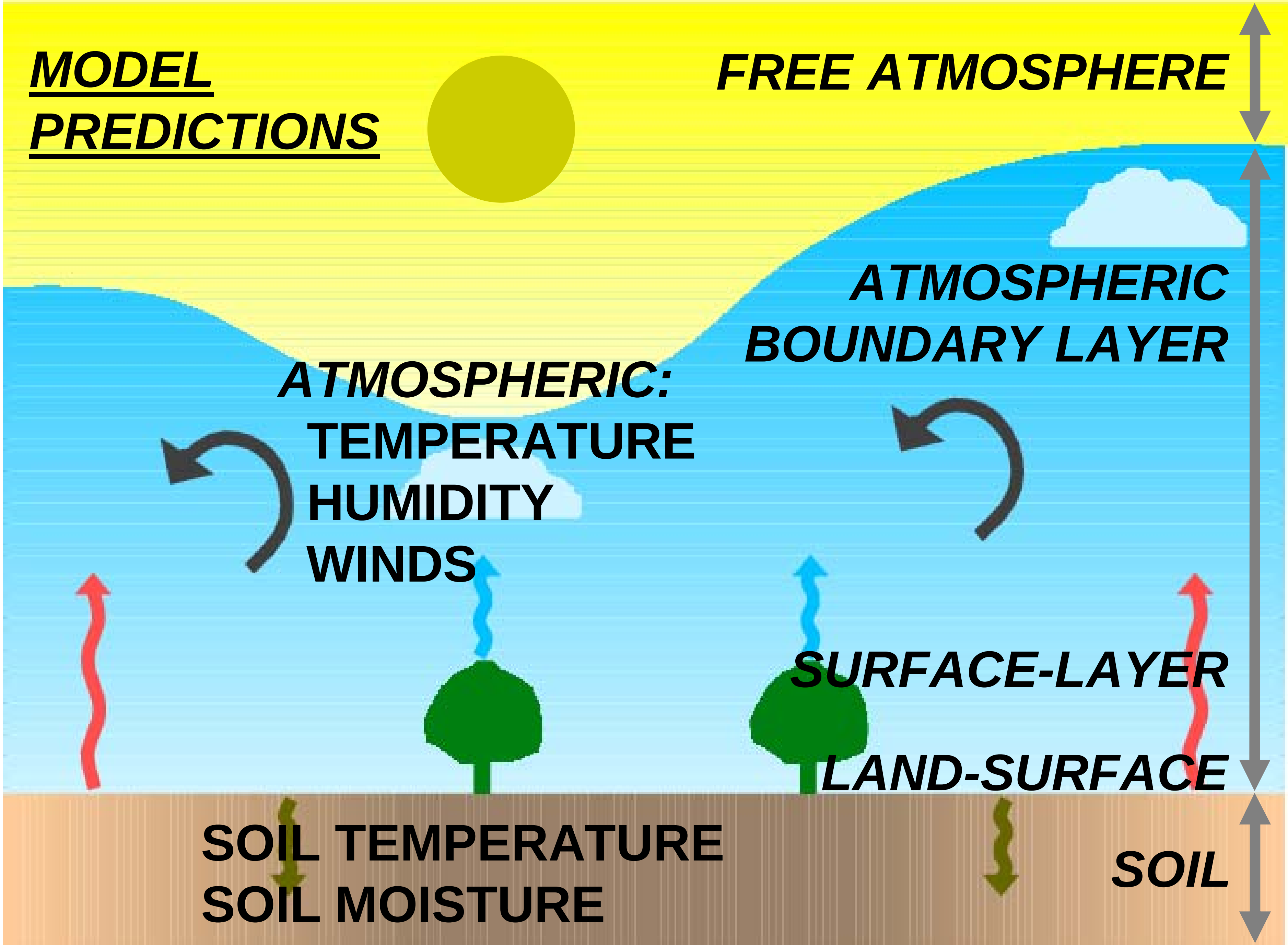
atmospheric sciences/meteorology, climatology, and oceanography

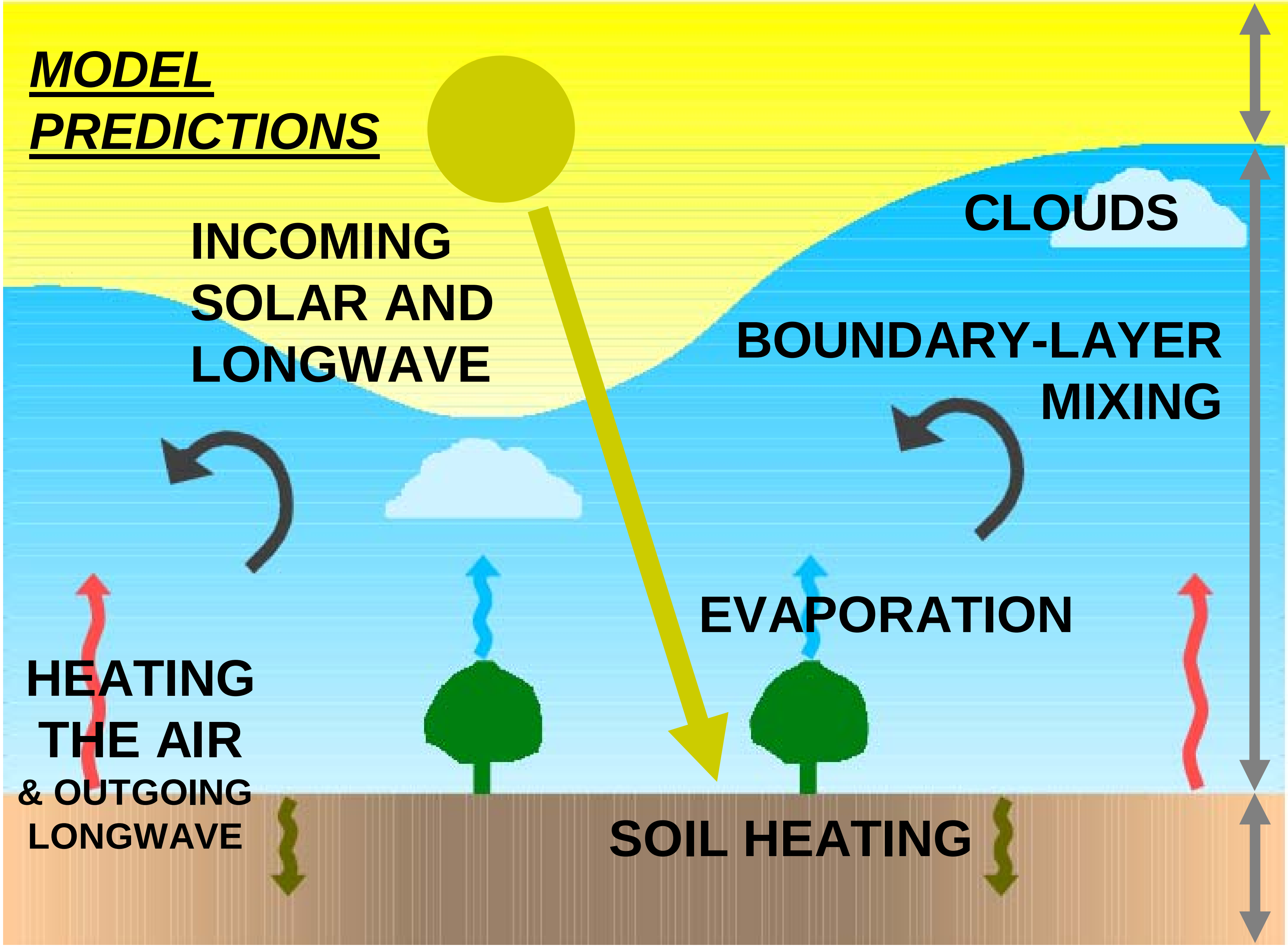
with

plant ecology, soil science, hydrology, and glacialology.

A land-surface model must provide 4 quantities to a "parent" atmospheric model:

- **surface sensible heat flux**
- **surface latent heat flux (evaporation)**
- **upward longwave radiation (via <u>skin temperature</u> and surface emissivity)**
- **upward (reflected) shortwave radiation (via <u>surface albedo</u>, including snow effects)**

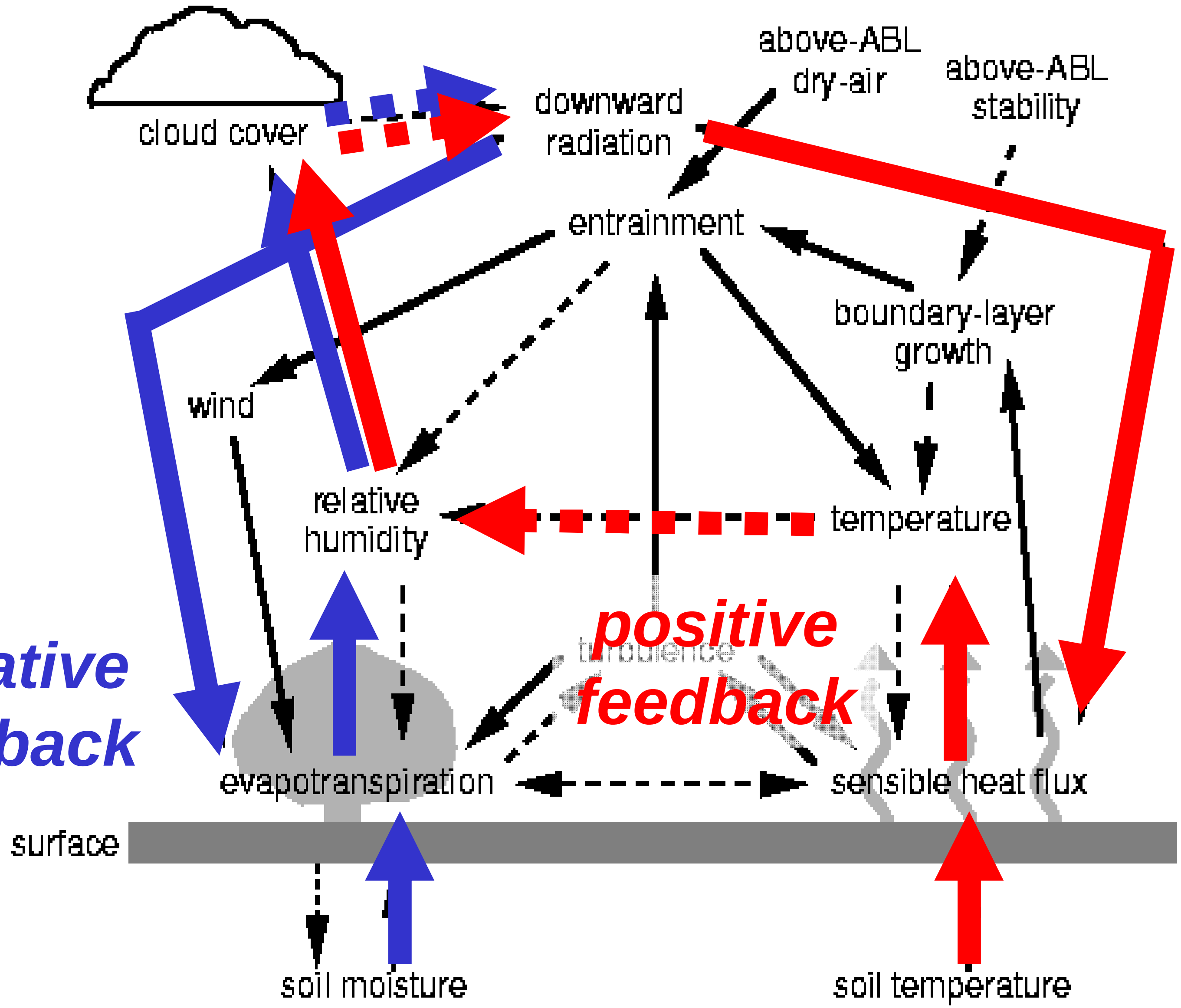

MODEL PREDICTIONS
FREE ATMOSPHERE
ATMOSPHERIC BOUNDARY LAYER
ATMOSPHERIC:
TEMPERATURE
HUMIDITY
WINDS
SURFACE-LAYER
LAND-SURFACE
SOIL TEMPERATURE
SOIL MOISTURE
SOIL


MODEL
PREDICTIONS
INCOMING
SOLAR AND
LONGWAVE
CLOUDS
BOUNDARY-LAYER
MIXING
EVAPORATION
HEATING
THE AIR
& OUTGOING
LONGWAVE
SOIL HEATING

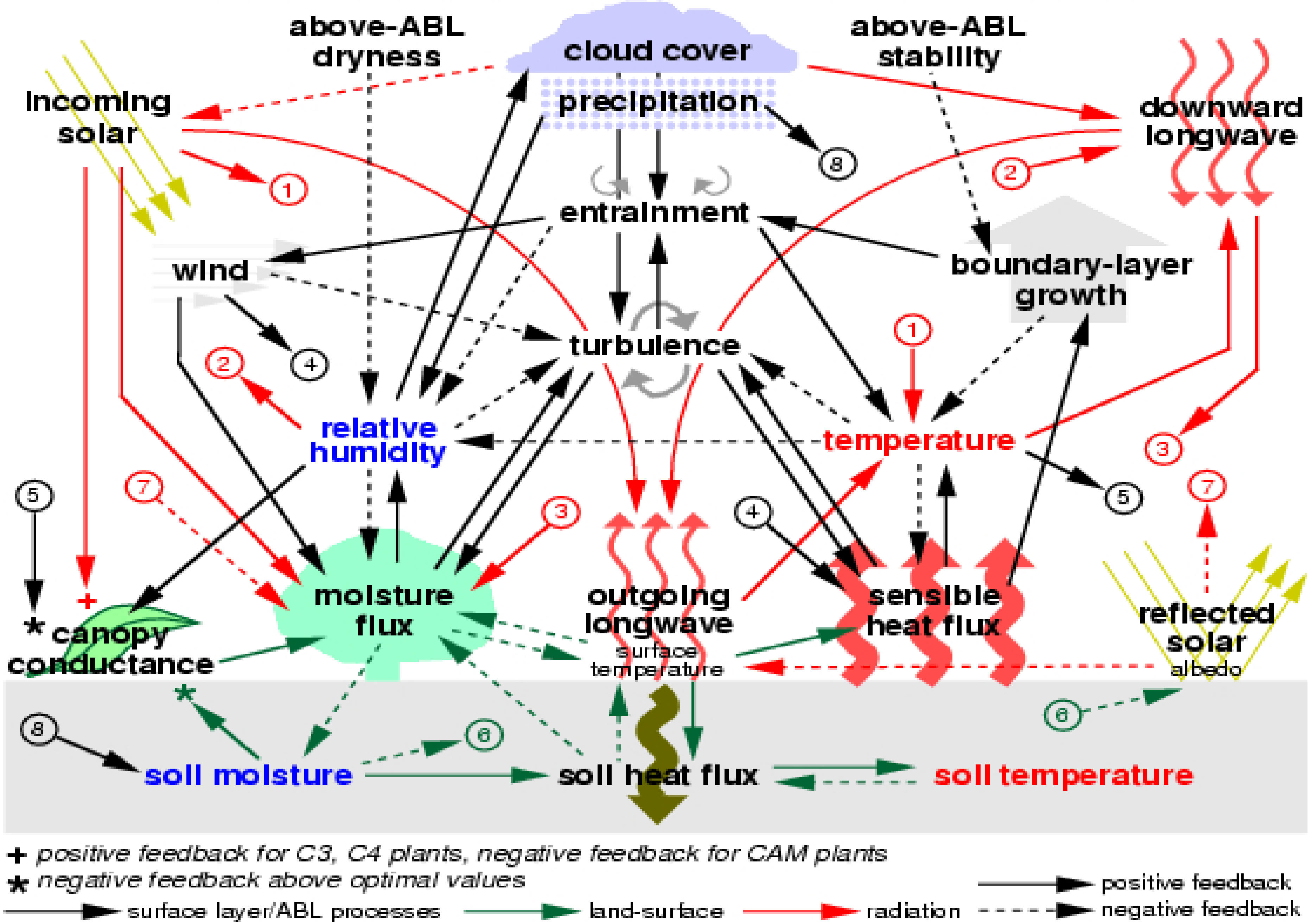
Land-atmosphere interaction

Ek & Holtslag (2005)

Simplified.



land-surface - ABL - radiation interactions



Details of land-surface modeling (LSM), e.g. the Noah LSM:

- model physics
- data sets and model parameters
- validation
- initialization and cycling land systems
- data assimilation

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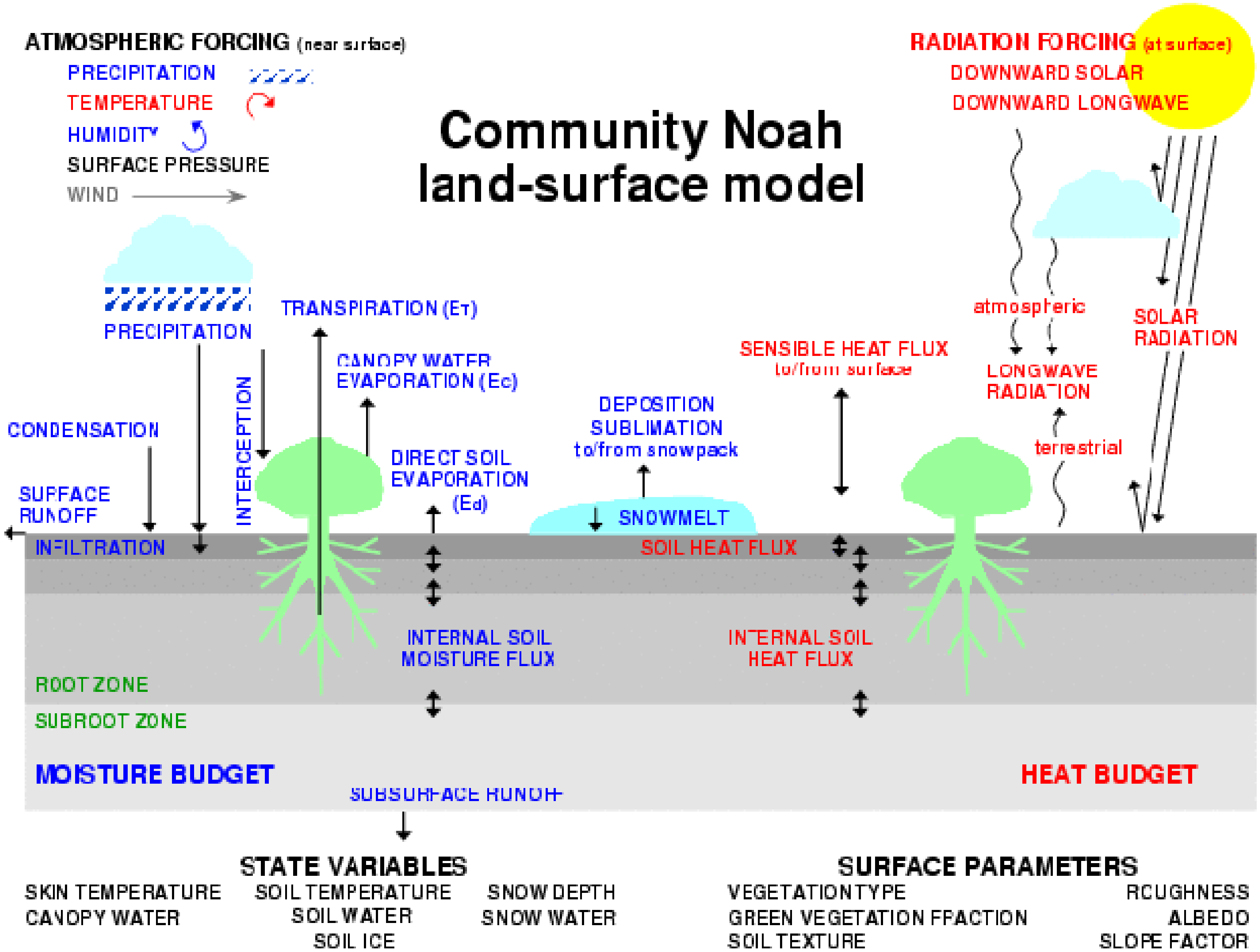


ftp://ftp.emc.ncep.noaa.gov/mmb/gcp/ldas/noahlsm

History of Land Modeling at NCEP/EMC

- 1960s (6-Layer PE model): land surface ignored
  - Aside from terrain height and surface friction effects
- 1970s (LFM): land surface ignored
- Late 1980s (NGM): first land surface model introduced (Tuccillo)
  - Single layer soil slab (“force-restore” model: Deardorf)
  - No explicit vegetation treatment
  - Temporally fixed surface wetness factor
  - Diurnal cycle is treated (as is diurnal PBL) with diurnal surface radiation
  - Surface albedo, surface skin temperature, surface energy balance
  - Snow cover (but not depth)
- Early1990s (Global Model: MRF): OSU land surface model
  - Multi-layer soil column (2-layers)
  - Explicit annual cycle of vegetation effects
  - Snow pack physics (snowdepth, SWE)
- Mid 1990s (Meso Model: Eta): Noah LSM replaces Force-Restore
- Mid 2000s (Global Model: GFS): Noah LSM replaces OSU LSM
- Mid 2000s (Meso Model: WRF): Unified Noah LSM with NCAR

History of the Noah LSM

- **Oregon State University: 1980's**
  - OSU LSM (PI L. Mahrt, co-Is H.-L. Pan and M. Ek)
  - Significant funding from Air Force Geophysics Lab (AFGL)
  - Tested in AFGL MM5 and AFGL Global Spectral Model
- **Transitioned to AFWA late 1980's**
  - Implemented operationally in AFWA AGRMET in 1990
- **Transitioned to NCEP NWP models in 1990's**
  - K. Mitchell, F. Chen, M. Ek, H.-L. Pan
  - Renamed "NOAH" LSM <u>after many NCEP and OHD upgrades</u>

    N (<u>N</u>CEP), O (<u>O</u>regon State University), A (<u>A</u>ir Force), H (<u>H</u>ydrological Development Office of National Weather Service)
  - Renamed "Noah" LSM after many additional key collaborators
    - NCAR, NASA, various universities
- **Transitioned to NCAR in late 1990's**
  - F. Chen: MM5
- **Transitioned to meso WRF**: NCAR, NCEP, AFWA, NRL

Noah Implementations at NCEP/EMC

- Eta mesoscale model: Jan 1996
- Eta Data Assimilation System (EDAS): Jun 1998
  - fully continuous cycling
- NCEP 25-year Regional Reanalysis: Apr 2004
  - EDAS-based
  - Daily realtime extension now operational
- Global Forecast System and Global DAS : 31 May 2005
- North American Mesoscale (NAM) WRF-NMM model: 21 June 2007

Associated Uncoupled Testing of Noah LSM at NCEP

- 1D site-specific testing: e.g. for various PILPS phases (2a, 2d, 2g)
- 2D testing: PILPS 2c, 2e
- 3D regional testing:
  - NLDAS
  - for PILPS-3C, PILPS-2e, PILPS-Rhone
- 3D global testing:
  - GLDAS/LIS (with NASA/GSFC/HSB)
  - GSWP 1 (1-year) and 2 (10-years)

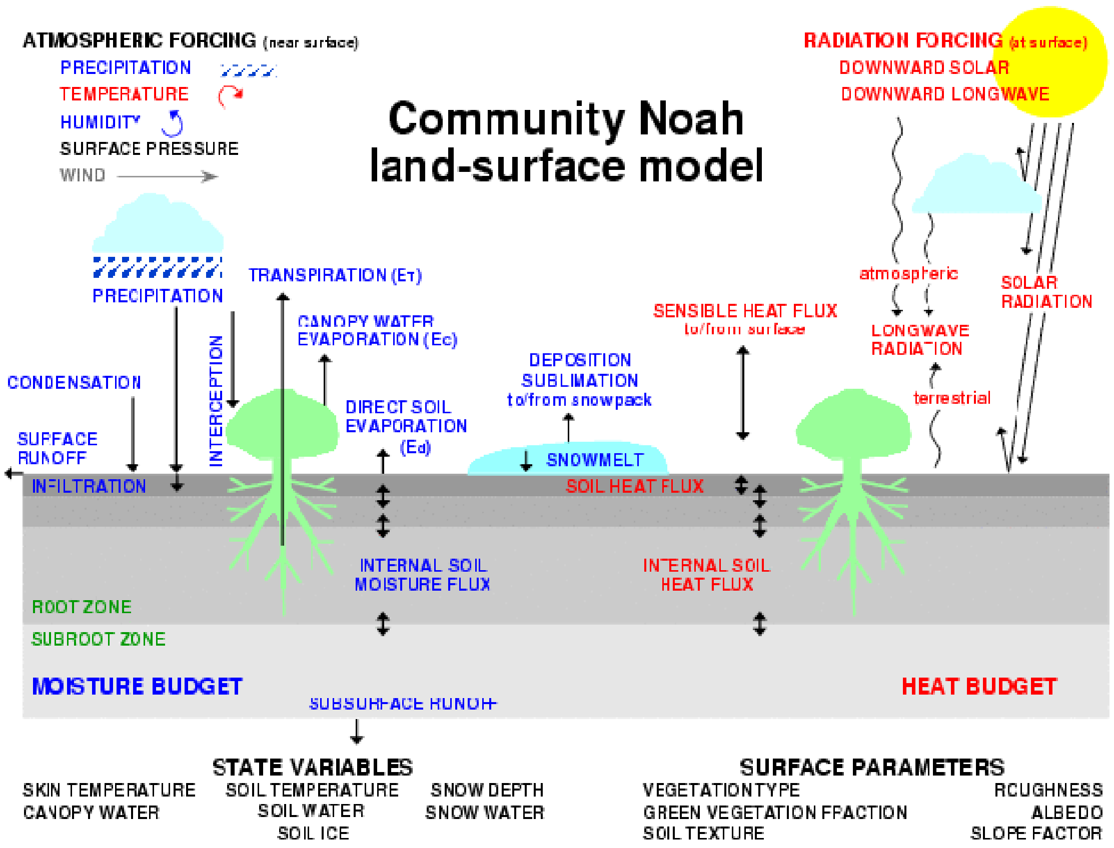
Noah LSM implementations and upgrades at the National Center for Atmospheric Research (NCAR, Boulder, Colorado, USA)

- **In meso MM5** ~ 2000
- **In meso WRF-ARW** ~ year 2003
- **Allow for surface emissivity of less than 1.0**
  - Land-use type dependent
- **Modify surface roughness length over snow**
  - decrease for increasing snow depth
- **Add treatment for urban landuse class, and explicit urban canopy model**
- **High resolution land-use and soil type maps**
  - global 1-km USGS land-use map: 24 classes
  - global 1-km STATSGO/FAO soil type: 16 classes

Key References for Noah LSM

- **Physics** (1-d column (“offline”) model):
  - Warm season
    F. Chen et al. (1996, JGR, v*101*, p7251-7268)
  - Cold season (snowpack and frozen soil)
    V. Koren et al. (1999, JGR, v*104*, p19569-19585)
- **In Mesoscale models & physics upgrades:**
  - NCEP Eta model
    M. Ek et al. (2003, JGR, v*108*)
  - NCAR MM5 model
    F. Chen & J. Dudhia (2001a, 2001b, MWR, v*129*, p569-604)

Noah land-surface model



ftp://ftp.emc.ncep.noaa.gov/mmb/gcp/ldas/noahlsm

- •Linearizes (non-iterative) surface energy budget; numerically efficient
- •Flexible soil layers: default is four soil layers (10, 30, 60, 100 cm thick), be can be specified (2 to N)
- •Soil hydraulics and parameters follow Cosby et al.
- •Canopy resistance follows Jarvis-Stewart “big-leaf”
- •Direct soil evaporation
- •Canopy interception
- •Vegetation-reduced soil thermal conductivity
- •Freeze/thaw soil physics
- •Snowpack density and water-equivalent content modeled: patchy/fractional snow cover treated as function of snowdepth & veg type
- •Flexible vegetation and soil classes and their parameters
- •Satellite-based annual cycle of vegetation greenness globally: 5-year monthly climatology (NESDIS AVHRR NDVI-based)

Noah LSM Physics

- Four soil layers (10, 30, 60, 100 cm thick)
- Prognostic Land States
  - Surface skin temperature
  - Total soil moisture each layer (volumetric)
    - total of liquid and frozen
    - bounded by saturation value (soil type dependent)
  - Liquid soil moisture each layer (volumetric)
    - can be supercooled
  - Soil temperature each layer and bottom (fixed) soil temperature
  - Canopy water (dew/frost, intercepted precipitation)
- Above prognostic states require initial conditions

Noah LSM Physics (cont.)

- Vegetation and Soil processes
  - predict soil moisture/temperature
  - Jarvis-Stewart canopy conductance (to predict transpiration)
  - deeper rooting depths in forests
  - bare-soil evaporation
  - canopy interception of precipitation
  - precipitation infiltration
  - soil heat flux reduction due to overlying vegetation
  - 24 vegetation classes & 16 soil classes
  - annual cycle of fraction of green vegetation cover

Noah LSM Physics (cont.)

- Snowpack physics
  - snow water equivalent (S.W.E.) content
  - snow depth (physical snow depth)
  - patchy snow cover affect on surface sensible heat flux, snow sublimation, soil heat flux, skin temperature (model grid-box subgrid variability)
  - albedo a function of snow depth, vegetation type
- Frozen soil physics
  - frozen ground (soil ice) treatment
  - latent heat sink/source (freeze/thaw)
  - reduces infiltration of precipitation
  - reduces vertical movement of soil water, including uptake by roots

Noah LSM Physics
Surface energy balance:

Rnet = SH + LH + GH + SPGH

Rnet = Net radiation (downward-upward shortwave & longwave radiation)
SH = sensible heat flux
LH = latent heat flux (surface evaporation)
GH = ground heat flux (subsurface heat flux)
SPGH = snow phase-change heat flux (heat sink of melting snow)

Noah LSM Physics: Land Surface Water Balance

(Example: mid-summer monthly average, central U.S.)

$$\Delta \mathbf{S} = \mathbf{P} - \mathbf{R} - \mathbf{E}$$

Δ**S**	= change in soil moisture content:	-75mm
P	= precipitation:	75mm
R	= runoff	25mm
E	= evaporation	125mm

(P-R) = infiltration

Δ**S** also includes changes in intercepted canopy moisture (small) and snowpack (winter)

Evaporation is a function of soil moisture and <u>vegetation</u> type, rooting depth/density, fractional cover, greenness.

Noah LSM Physics: Soil Prognostic Equations

- **Soil Moisture:** $$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial z}\left(D\frac{\partial\theta}{\partial z}\right) + \frac{\partial K}{\partial z} + F_\theta$$
  - “Richard’s Equation” for soil water (θ) movement
  - D, K functions (soil texture)
  - Fθ represents sources (rainfall) and sinks (evaporation)

- **Soil Temperature:** $$C(\theta)\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(K_t(\theta)\frac{\partial T}{\partial z}\right)$$
  - C, Kt functions (soil texture, soil moisture)
  - Soil temperature information used to compute ground heat flux

Noah LSM Physics: Surface Sensible Heat Flux

$$\mathbf{H} = \rho\ \mathbf{cp\ Ch\ U\ (Tsfc - Tair)}$$

where:

ρ = air density

cp = specific heat of air

Ch = surface exchange coefficient for heat (from a surface-layer turbulence formulation), larger for more unstable conditions

U = wind speed

Tsfc - Tair = surface-air temperature gradient

Noah LSM Physics: Ground (or Soil) Heat Flux

(to/from the soil to the surface)

$$\mathbf{G = (\lambda T/\Delta z)\ (Tsfc - Tsoil)}$$

where:

λT = soil thermal conductivity (function of soil texture, larger for moister soil)

Δz = upper soil layer thickness

Tsfc - Tsoil = surface-soil temperature gradient

Noah LSM Physics: Surface Evaporation

E = EDIR + ET + EC + ESNOW

where:

E = total surface evaporation from combined soil/vegetation

EDIR = direct evaporation from soil

ET = transpiration from plant canopy

EC = evaporation from canopy-intercepted rainfall

ESNOW = sublimation from snowpack

Noah LSM Physics: ET = transpiration

- **ET** represent a flux of moisture from the vegetation canopy via root uptake, that can be parameterized in terms of "resistances" to the "potential" flux.

FLUX = POTENTIAL/RESISTANCE

- Potential **ET** can roughly be thought of as the rate of **ET** from an open pan of water. In the soil/vegetation medium, what are some resistances to this?

- Available amount of soil moisture

- Canopy (stomatal) resistance: function of vegetation type & amount of green vegetation

Noah LSM Physics: Canopy Resistance

- Canopy transpiration determined by:
- Amount of photosynthetically active (green) vegetation. Green vegetation fraction (GVF) partitions direct (bare soil) evaporation from canopy transpiration:
- Et/Edir ≈ fct(GVF)
- Green vegetation in Noah LSM based on 5-year NDVI climatology of monthly values
- Not only the amount, but the TYPE of vegetation determines canopy resistance (Rc):

Canopy Resistance (continued)

- Where Rc determined by:

Rcmin ≈ f(vegetation type)

F1 ≈ fct(amount of PAR: solar insolation)

F2 ≈ fct(air temperature: heat stress)

F3 ≈ fct(air humidity: dry air stress)

F4 ≈ fct(soil moisture: dry soil stress)

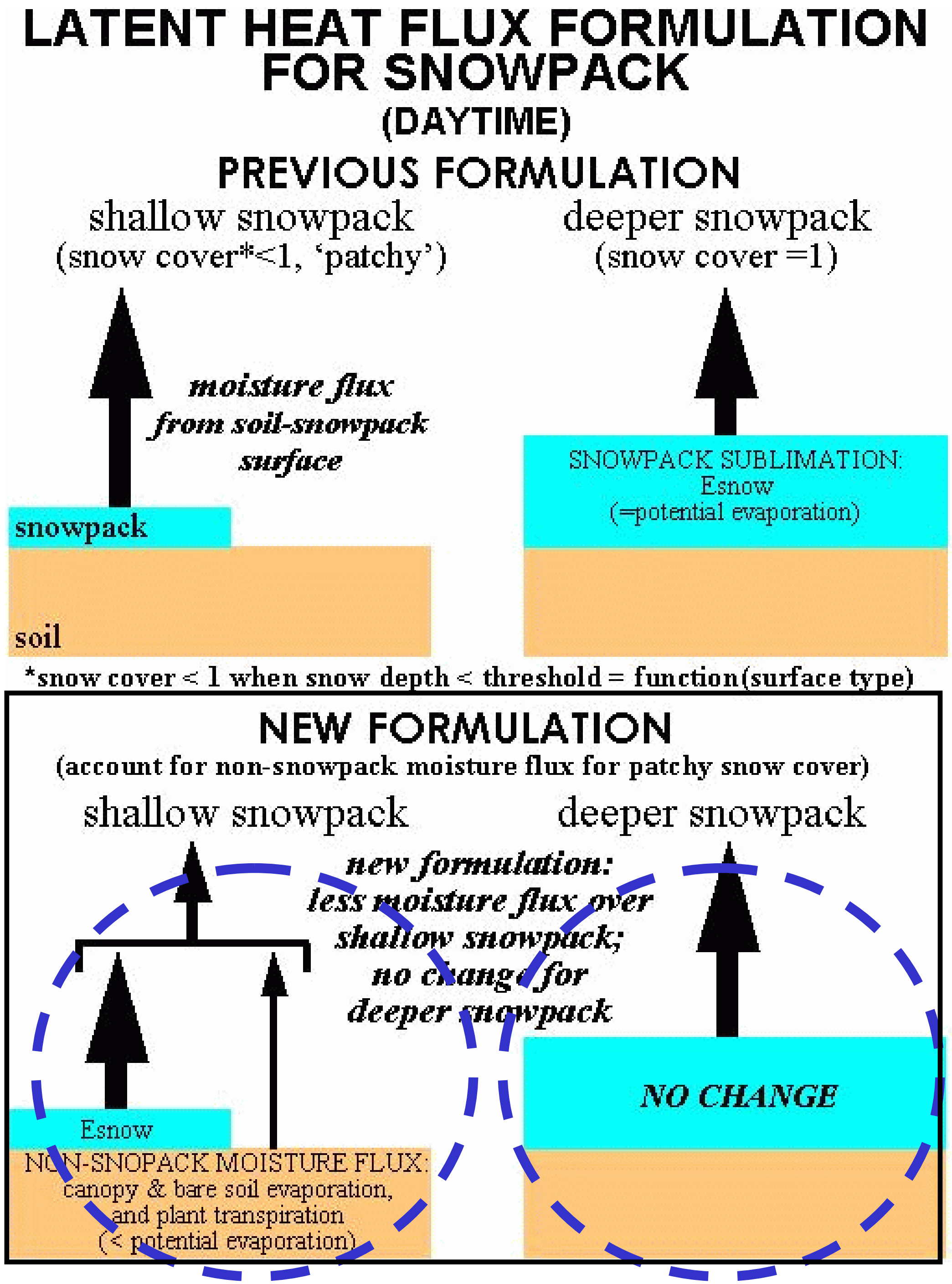
This is the common "Jarvis-Stewart" method;

Alternatively, ecosystem methods use plant uptake of CO_2 (some NWP & climate models)

- Thus: hot-dry air & dry soil lead to greater Rc, so stressed vegetation & reduced transpiration

COLD SEASON

ESNOW includes the effect of patchy snow cover in calculation of latent heat flux



Details of land-surface modeling (LSM), e.g. the Noah LSM:

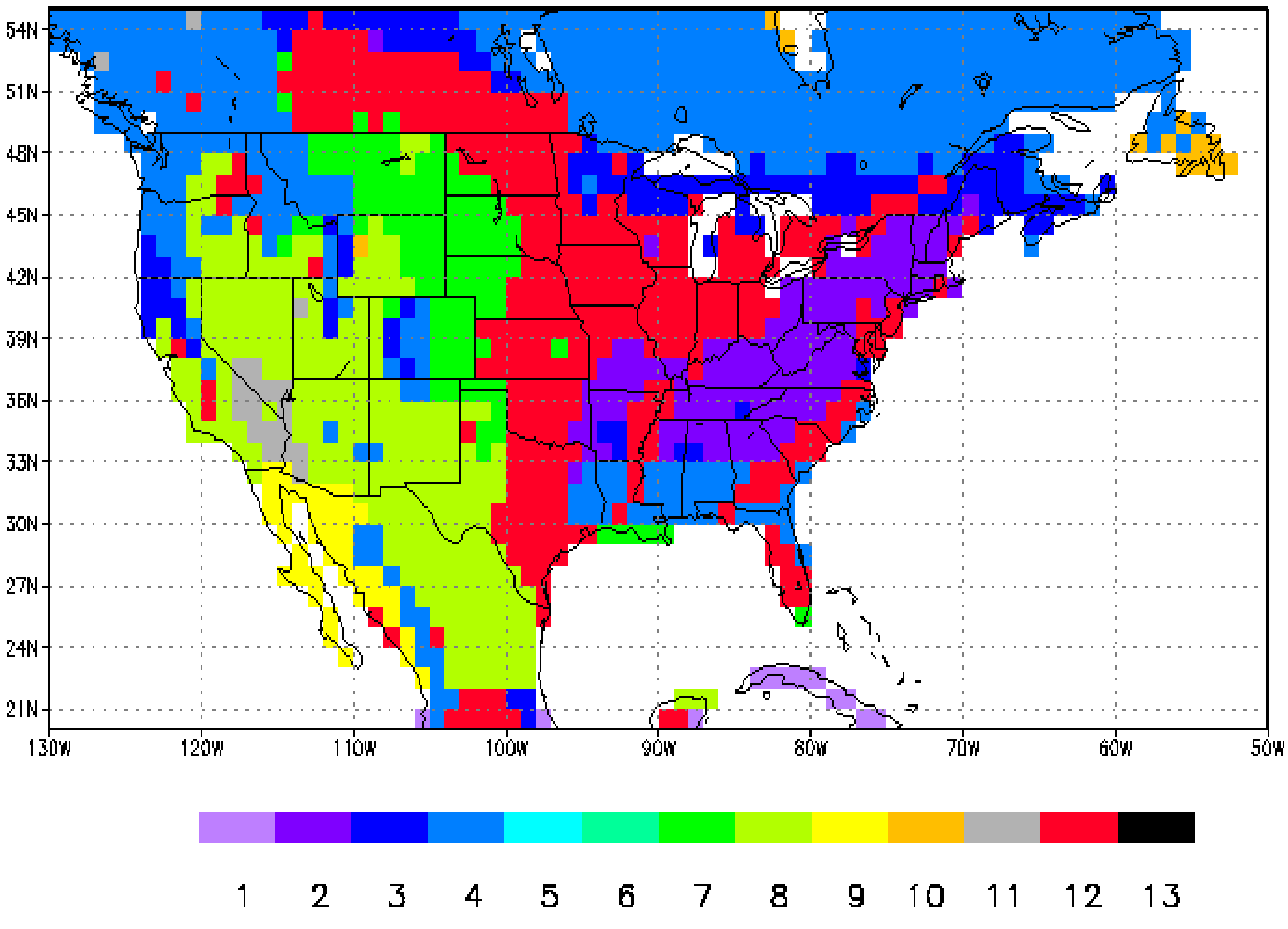
- model physics
- **data sets and model parameters**
- validation
- initialization and cycling land systems
- data assimilation

Land-surface fields
(data sets and model parameters)

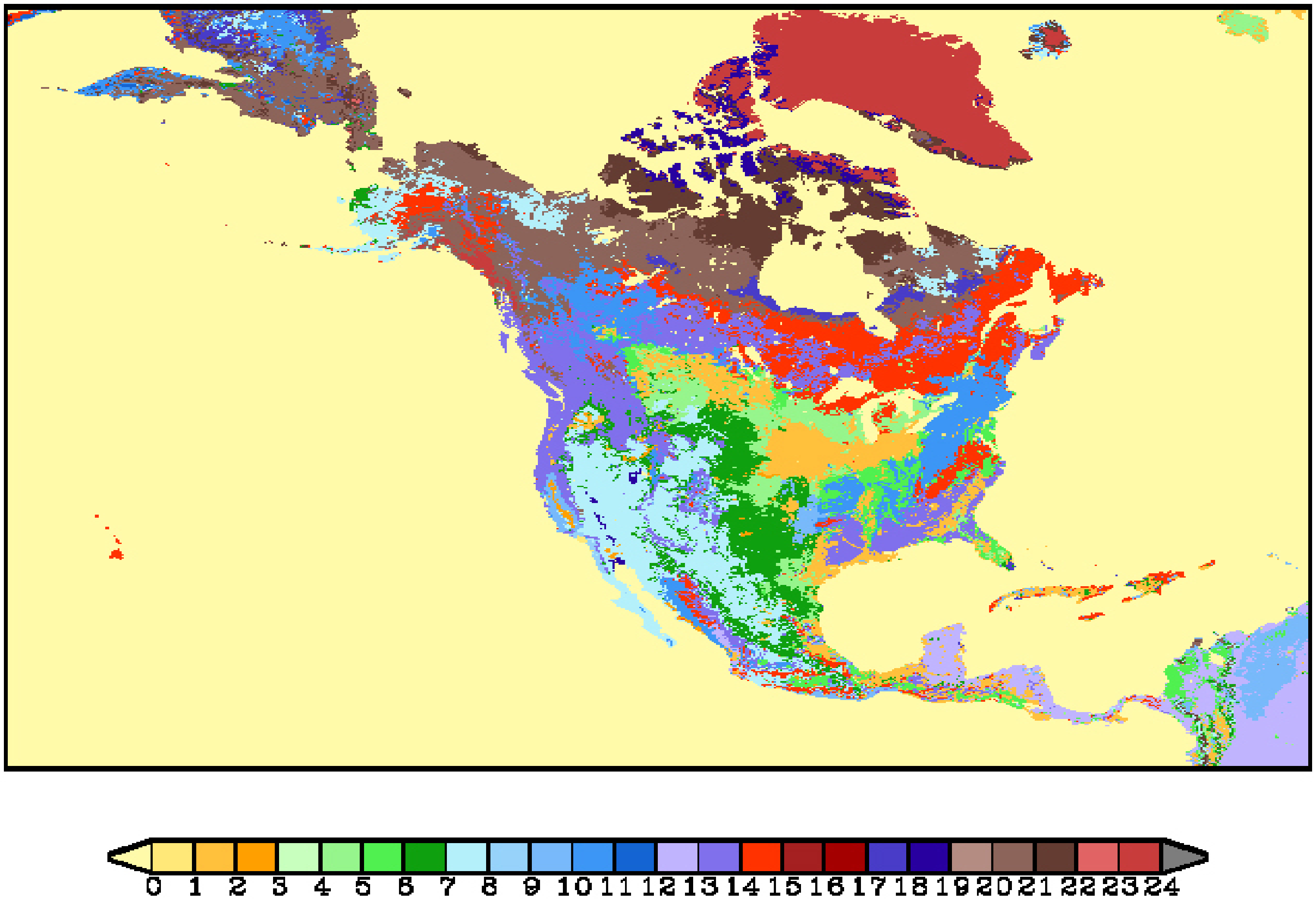
…necessary for (Noah) LSM formulations

- Vegetation type
- Soil type
- Surface slope
- Soil column bottom temperature
- Albedo (mid-day snow-free)
- Maximum snow albedo
- Green vegetation fraction

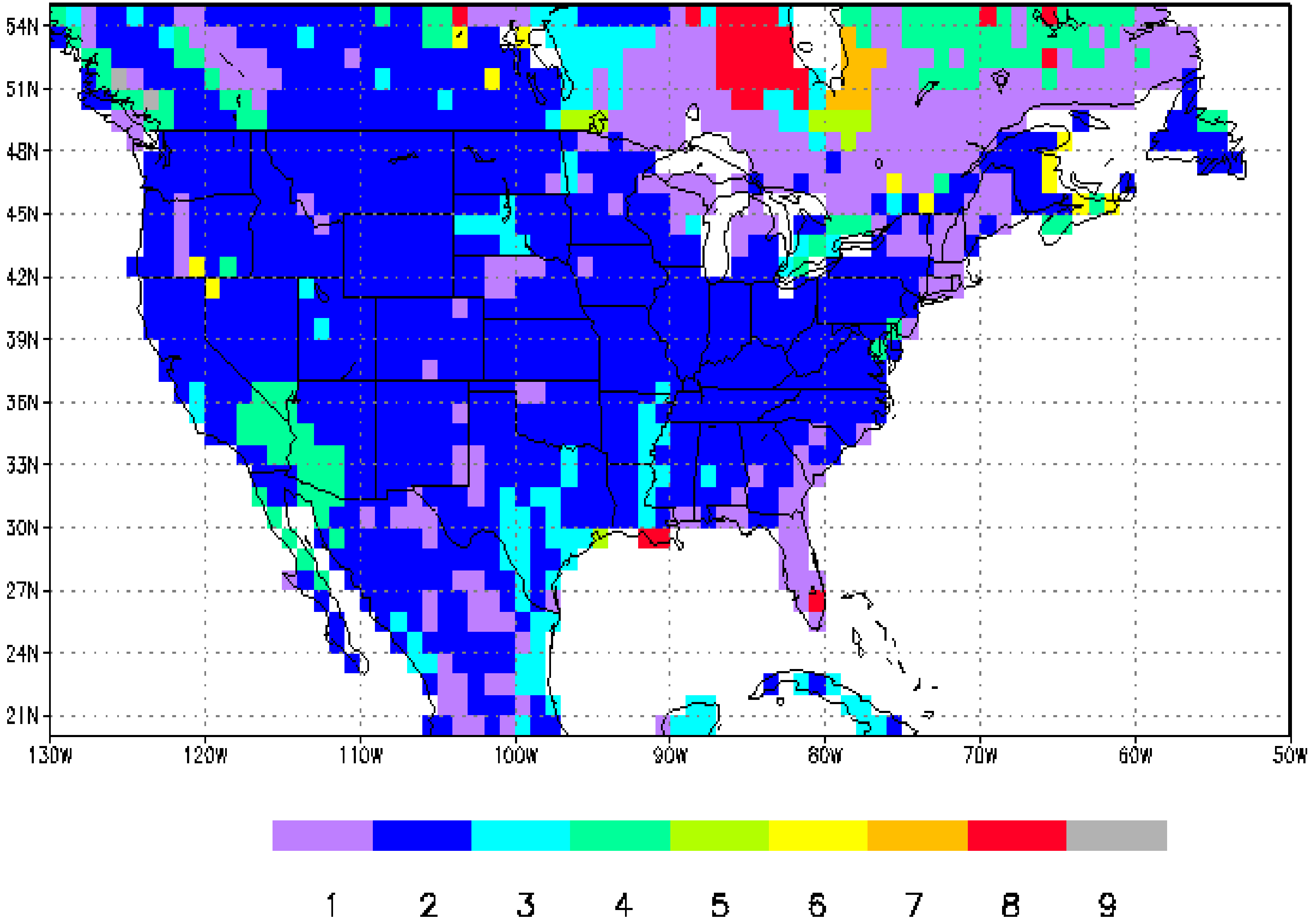
Univ. Maryland (UMD) Simple Biosphere (SiB) model 13-class 1-deg global vegetation data set



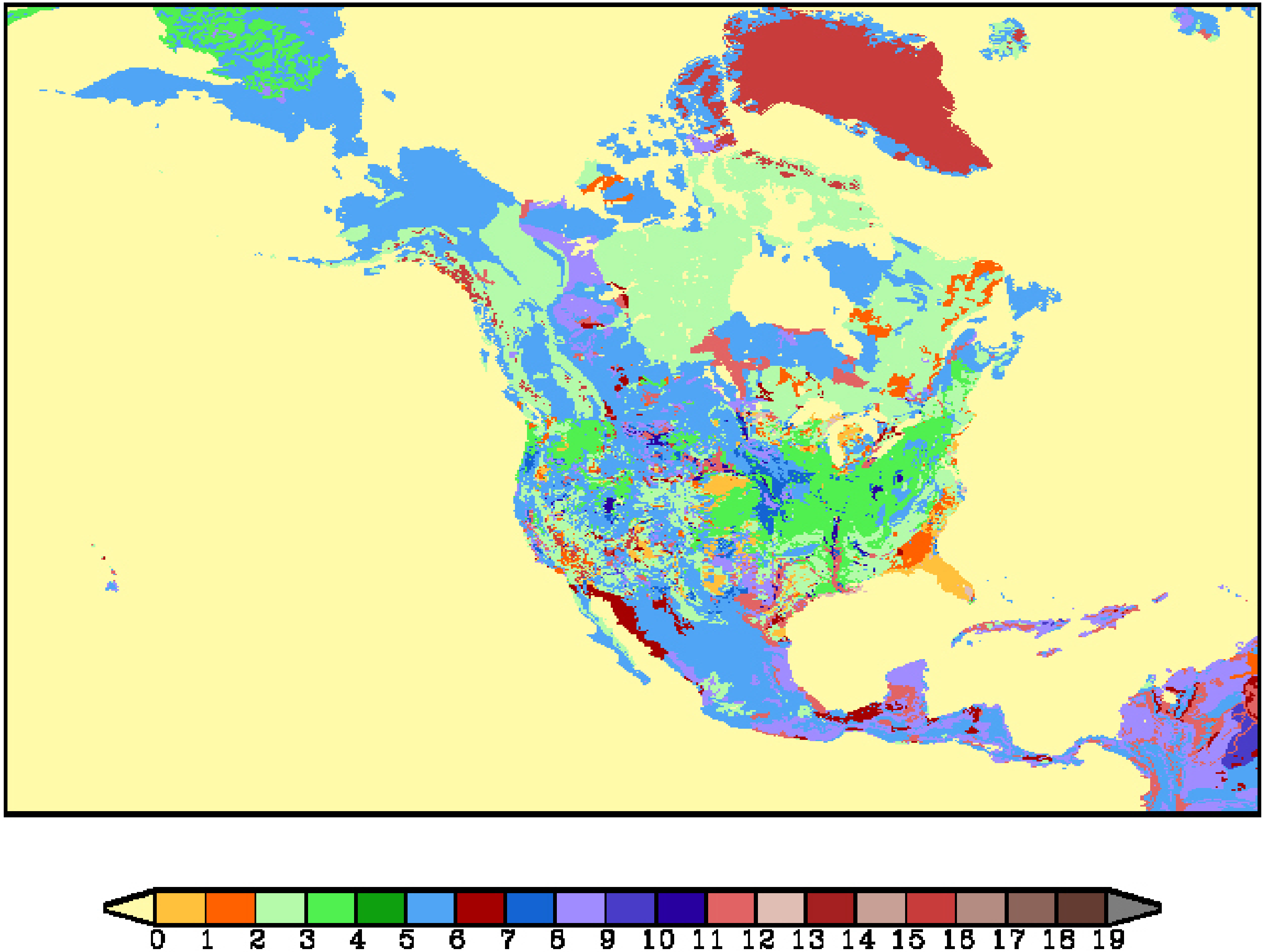
USGS 24-class high-resolution global (1-km) vegetation data set



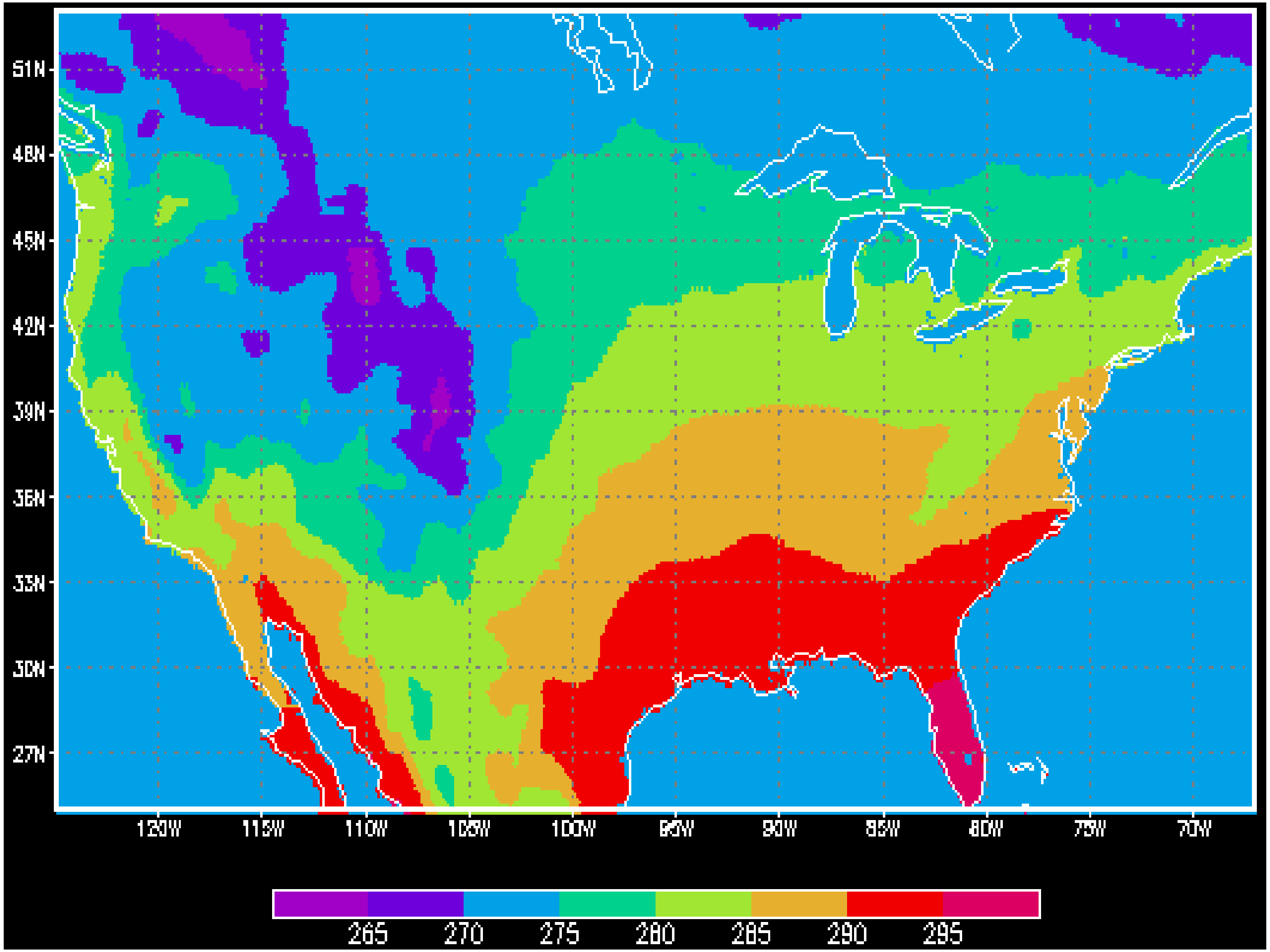
Zobler 9-class 1-deg global soil data set



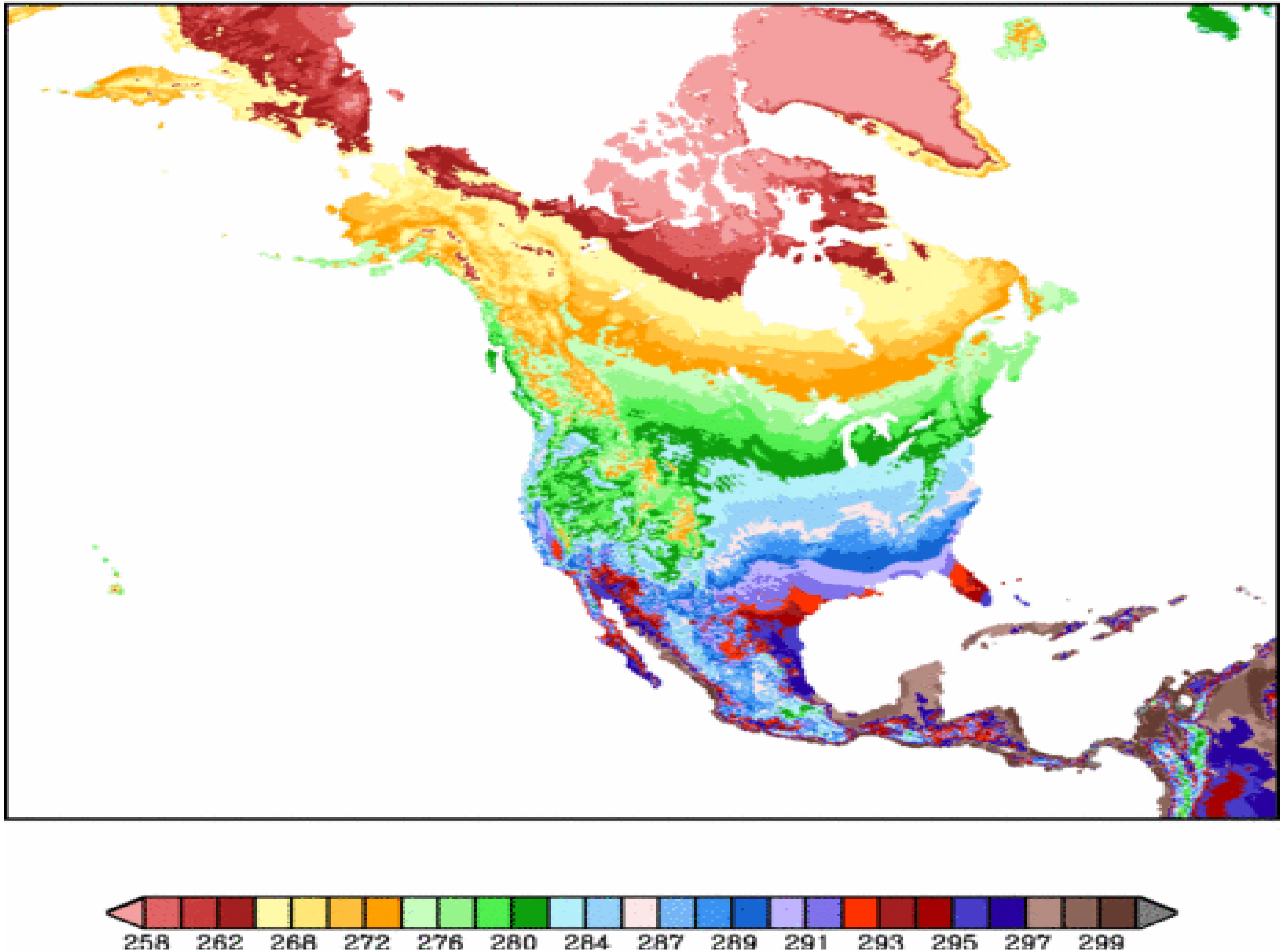
STATSGO/FAO 16-class high-resolution global (1-km) soil data set



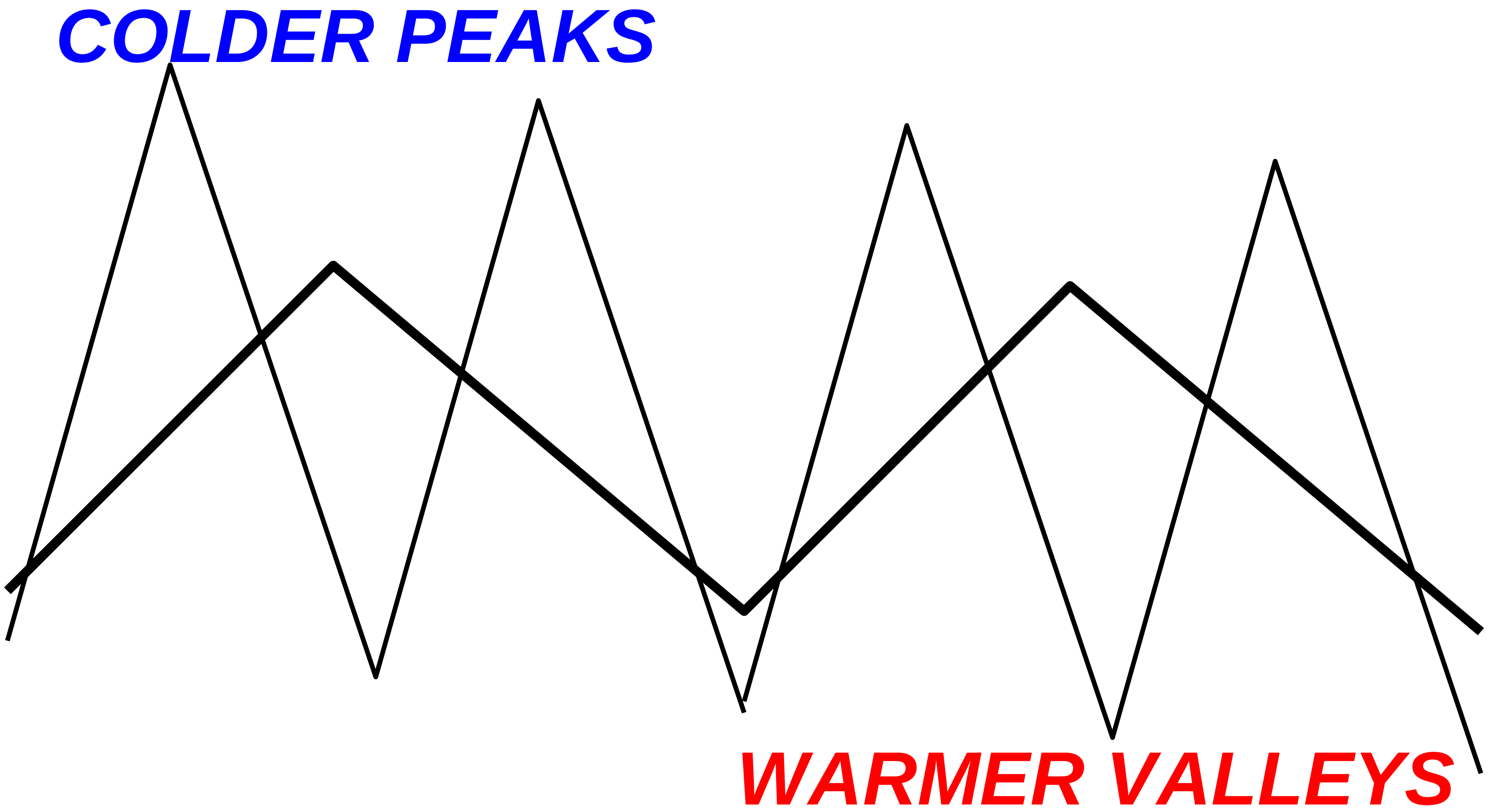
2.5-deg Global Soil Column "Bottom" Temperature (from annual mean air temperature)



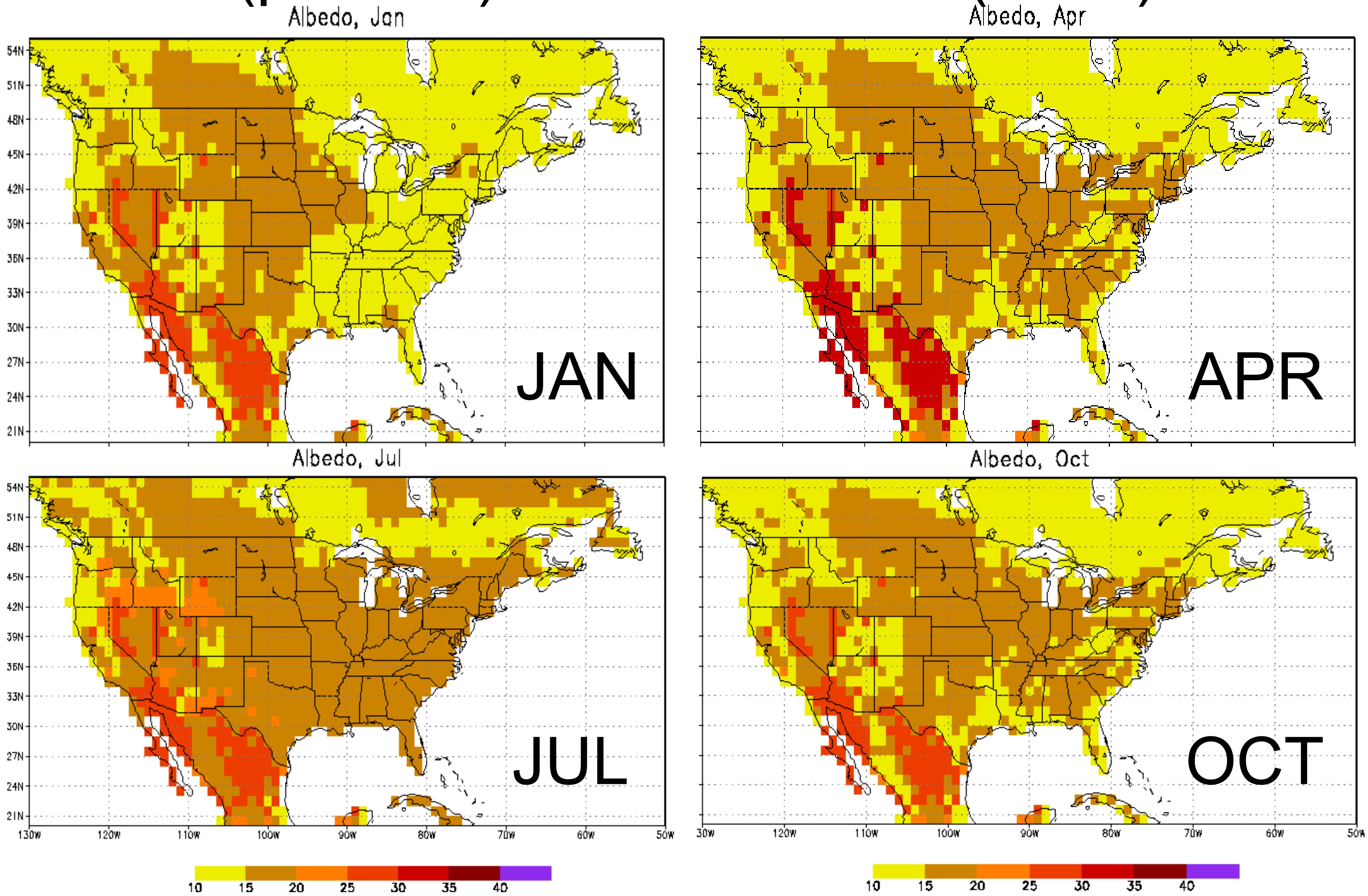
1-deg Global Soil Column "Bottom" Temperature (from annual mean air temperature)



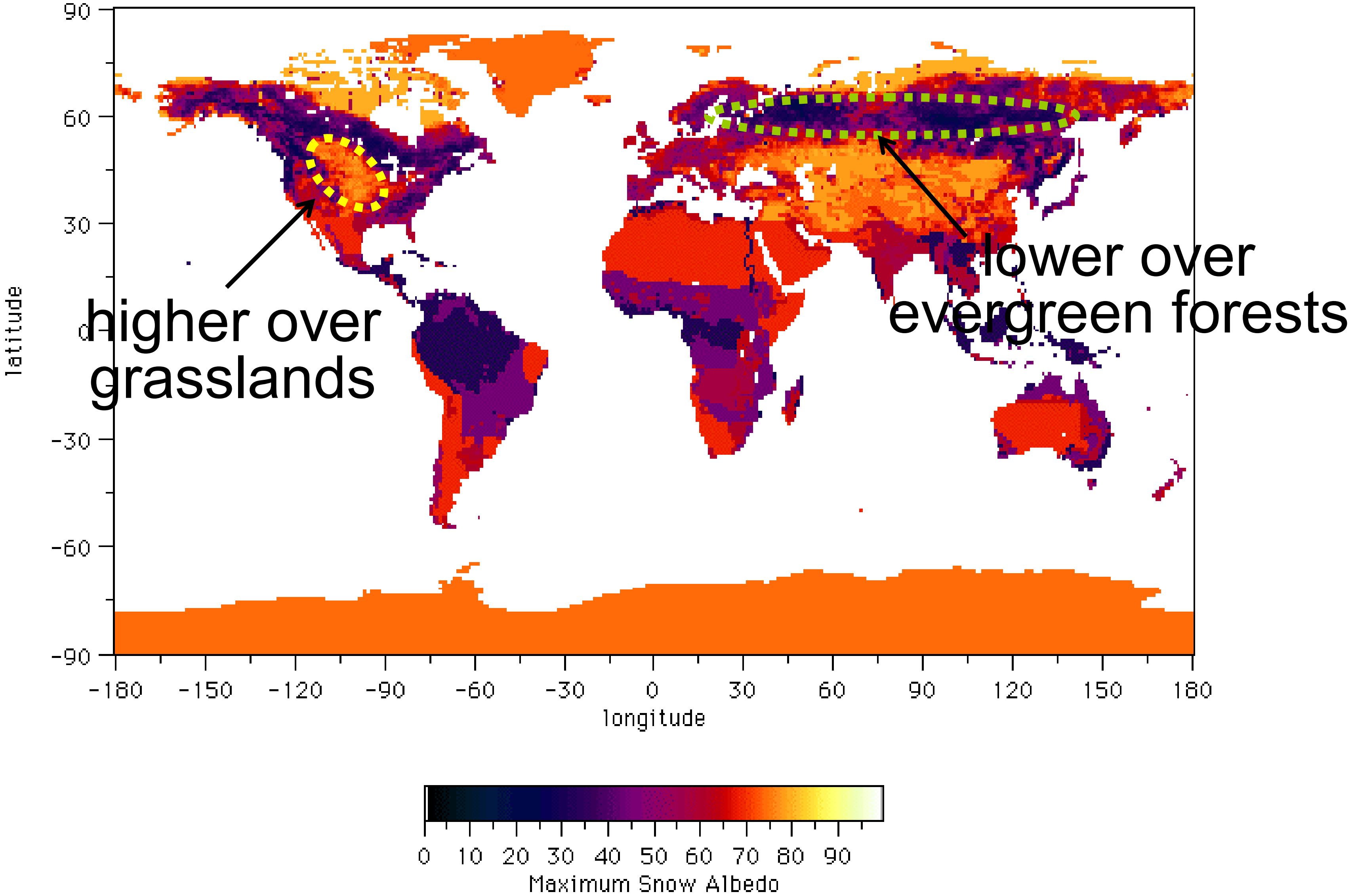
Necessary to adjust bottom temperature for a given terrain elevation (6.5C/km standard lapse rate). For model “cold start”, soil temperature states similarly adjusted for different model grid & terrain (ties in with soil moisture re-scaling).



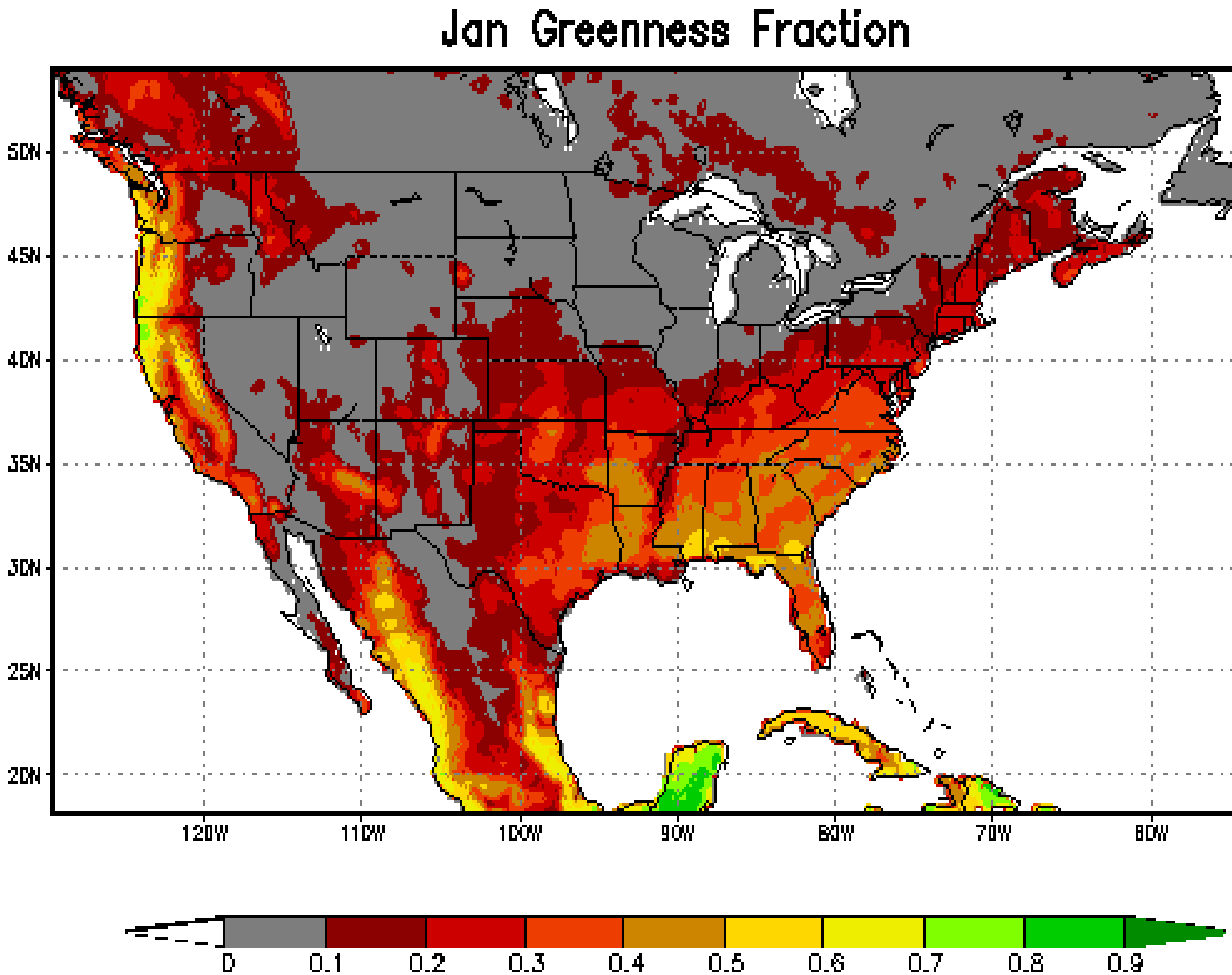
1-deg global 4-season snow-free albedo (percent) from Matthews (1983)



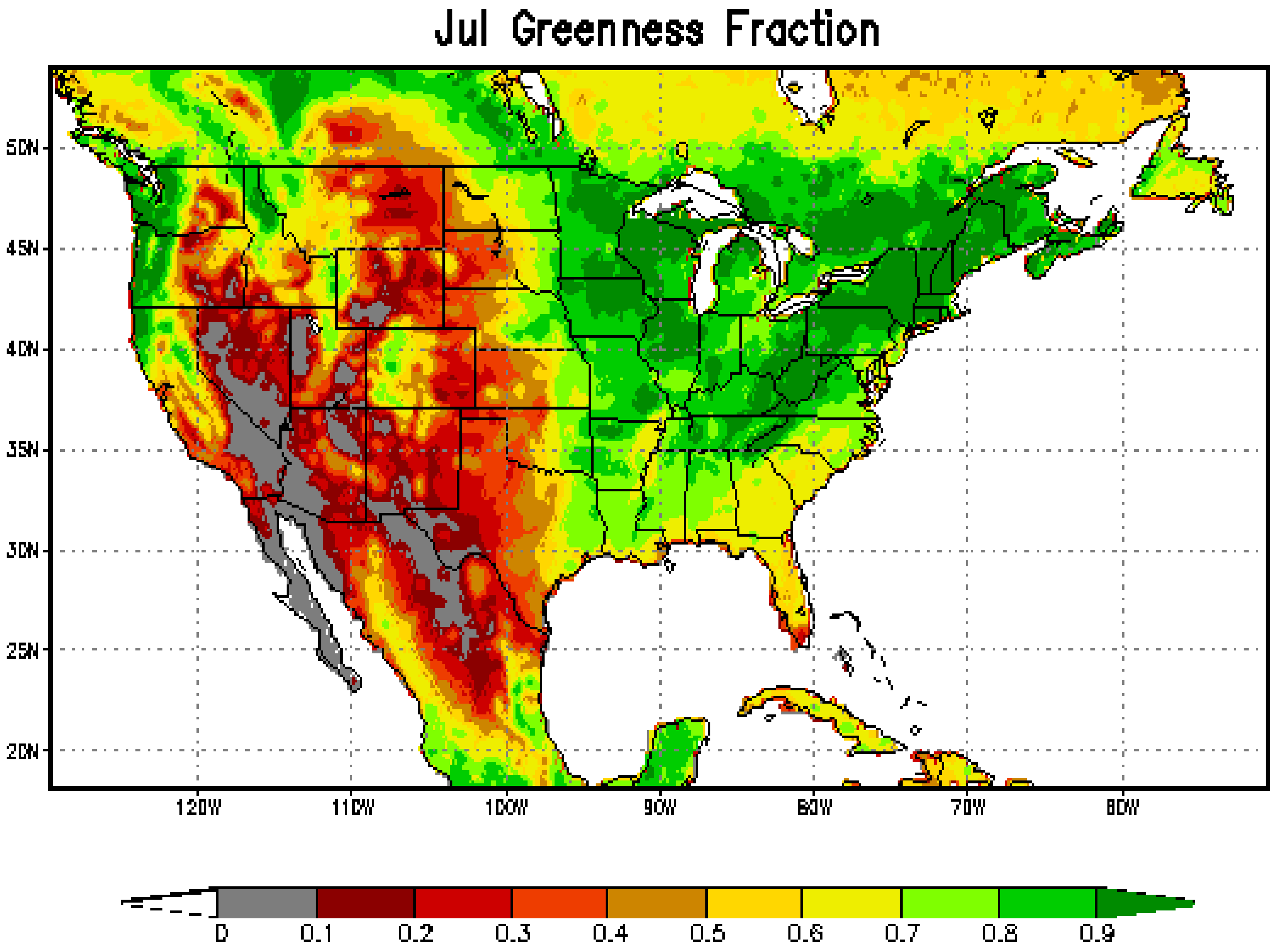
1-deg global maximum snow albedo for deep snow (from Robinson, 1986)



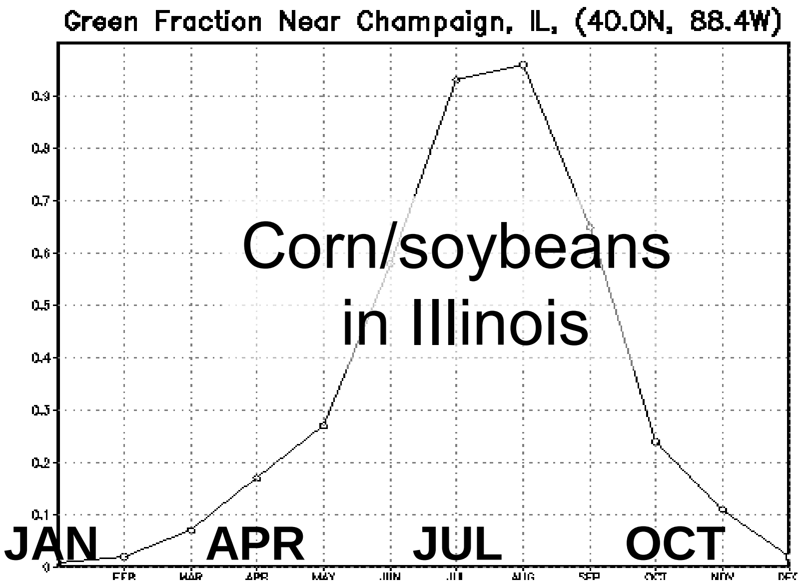
January Green Vegetation Fraction in Noah LSM

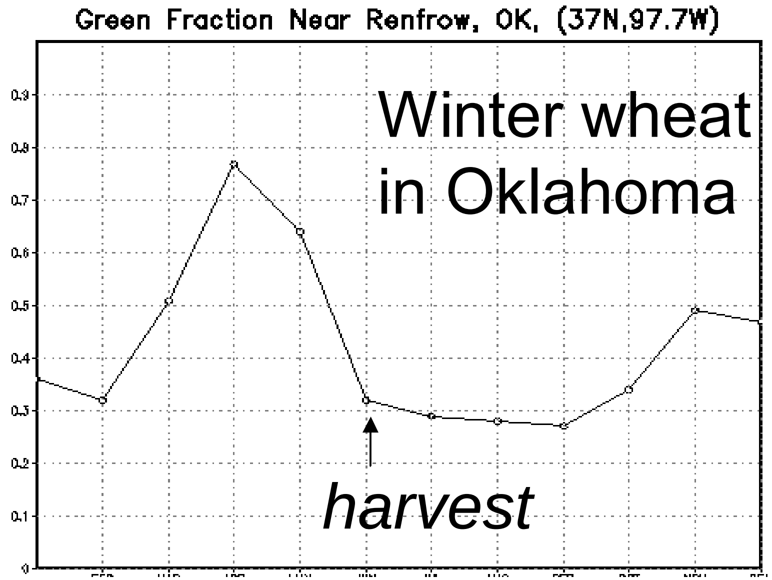


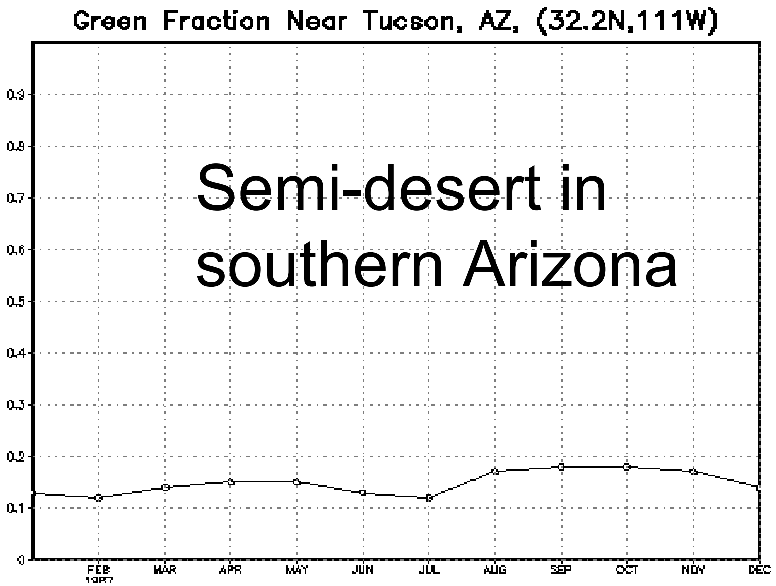
July Green Vegetation Fraction in Noah LSM

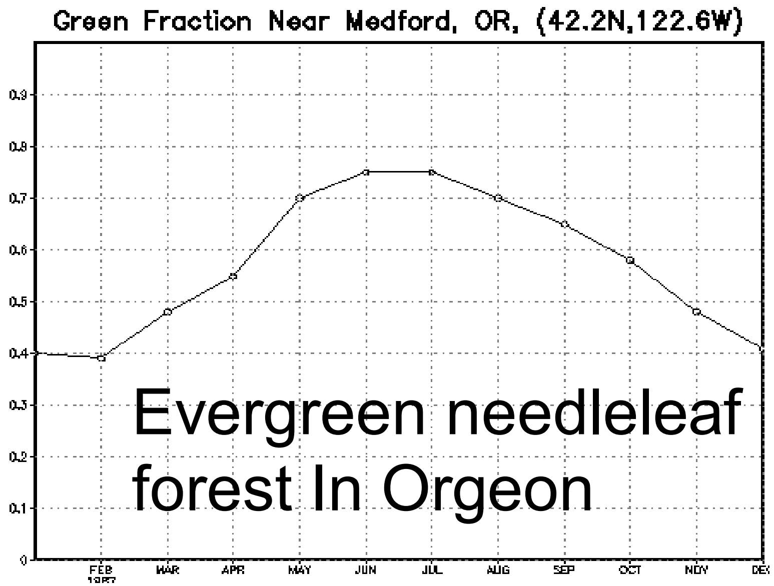


Annual Time Series of Green Vegetation Fraction









Land-surface fields
…future updates

High resolution (1-km) MODIS/IGBP:

- 20-class Vegetation type
- Albedo (mid-day snow-free)
- Maximum snow albedo (5-km)

AVHRR

- Green vegetation fraction (new longer climatology, new near-realtime product)

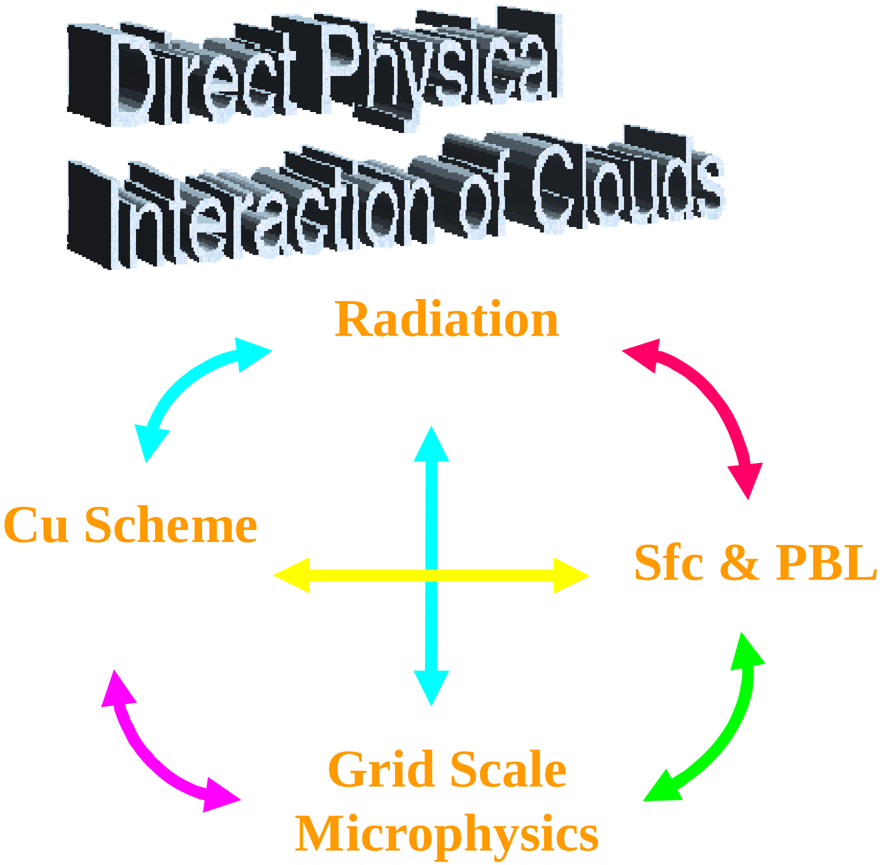
Details of land-surface modeling (LSM), e.g. the Noah LSM: *model testing and development*

- **model physics**
- data sets and model parameters
- **validation**
- **initialization and cycling land systems**
- **data assimilation**

Noah LSM Testing Hierarchy at NCEP

- In uncoupled land-only 1-D column model ("offline") at individual surface-flux observing stations from field programs
- In uncoupled land model regionally and globally in NLDAS and GLDAS (multi decadal testing)
- Test in NCEP coupled atmosphere/land short-range North American Mesoscale Model (NAM)
- Test in NCEP coupled atmosphere/land medium-range Global Forecast System (GFS)
- Test in coupled atmosphere/ocean/land seasonal-range global Climate Forecast System (CFS)
- Hydrological applications

Model testing involves "*THE PHYSICS WHEEL OF PAIN*"



1. Hydrometeor phase, cloud optical properties, cloud overlap assumptions, & cloud fractions
2. Precipitation (incl. phase) and clouds
3. Subgrid transports, stabilization, detrainment
4. Sfc energy fluxes, land & ocean surface models
5. Convection (deep & shallow), PBL evolution, precipitation

Details of land-surface modeling (LSM), e.g. the Noah LSM:
1-D column model development

- **model physics**
- data sets and model parameters
- **validation**
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Using surface fluxes to evaluate land-surface physics formulations and parameters

Sensible heat flux (bulk aerodynamic form):

$$H = \rho c_p C_h U(T_{sfc} - T_{air})$$

Latent heat flux (i.e. Penman-Monteith form):

$$LE = \frac{\Delta(R_n - G) + \rho c_p(e_{sfc} - e_{air})/r_a}{\Delta + \gamma(1 + r_s/r_a)}$$

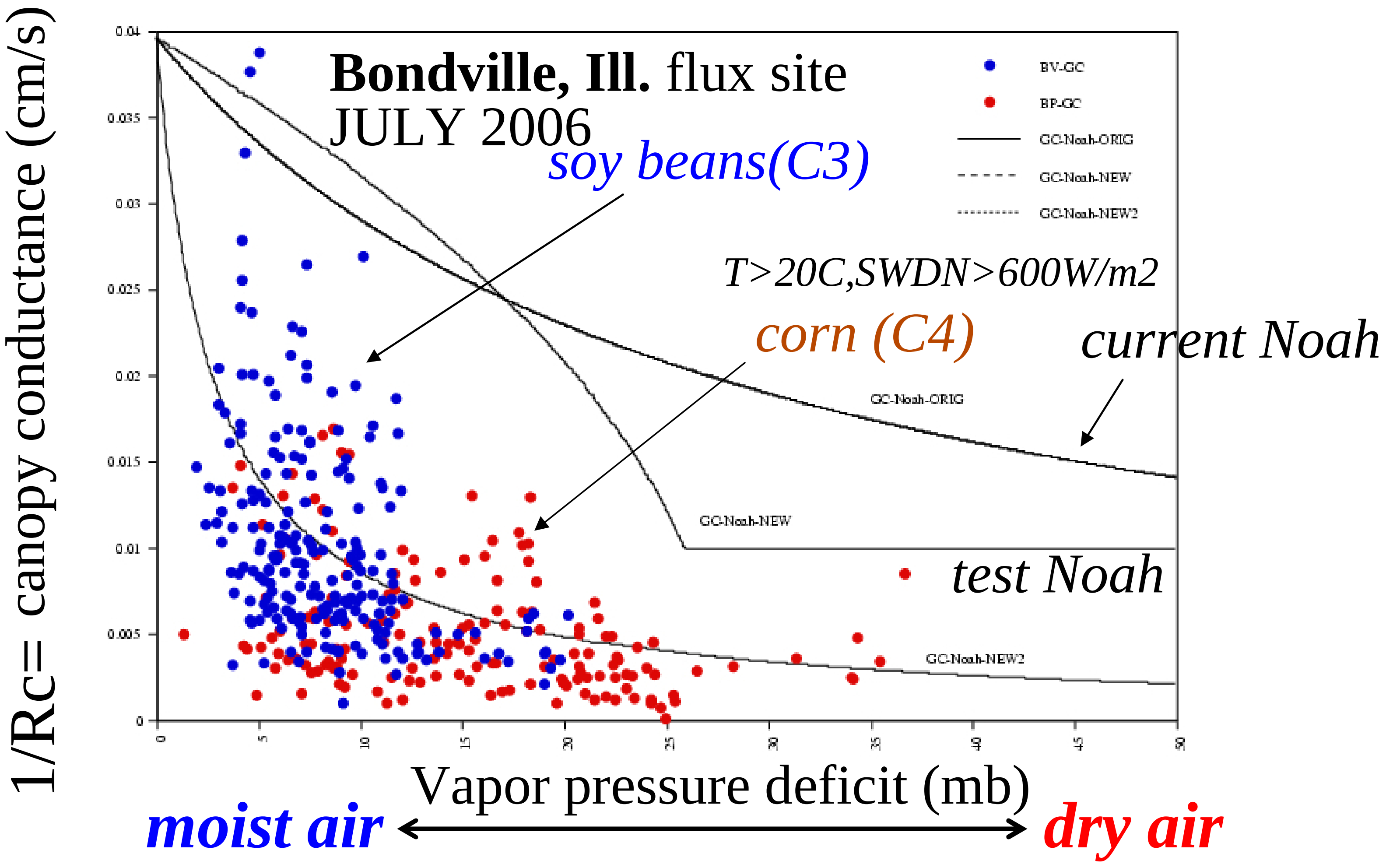
For a fully-vegetated surface:

C_h = exchange coefficient

Rc = canopy resistance (inverse canopy cond.)

Transpiration processes/parameters:

...e.g., effect of vapor pressure deficit on canopy conductance:



· Better results with new VPD option (next pages)

To reduce low LH biases during the Summer

$$R_c = \frac{R_{\text{cmin}}}{\text{LAI}F_1F_2F_3F_4},$$

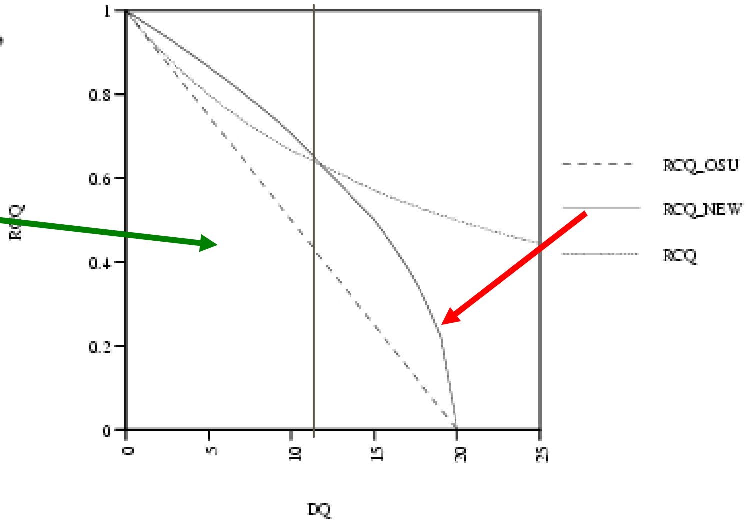
$$F_1 = \frac{R_{\text{cmin}}/R_{\text{cmax}} + f}{1 + f} \quad \text{where } f = 0.55\frac{R_g}{R_{\text{gl}}}\frac{2}{\text{LAI}},$$

$$F_2 = \frac{1}{1 + h_s[q_s(T_a) - q_a]},$$

$$F_3 = 1 - 0.0016(T_{\text{ref}} - T_a)^2, \quad \text{and}$$

$$F_4 = \sum_{i=1}^{3} \frac{(\Theta_i - \Theta_w)d_{z_i}}{(\Theta_{\text{ref}} - \Theta_w)(d_{z_1} + d_{z_2})},$$

Vapor pressure deficit function



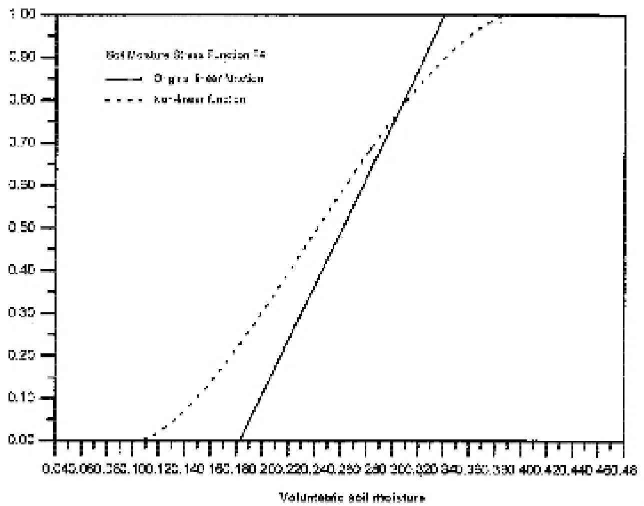


Figure 1. The nonlinear soil moisture stress function adapted for the FIFE case versus a linear soil moisture stress function.

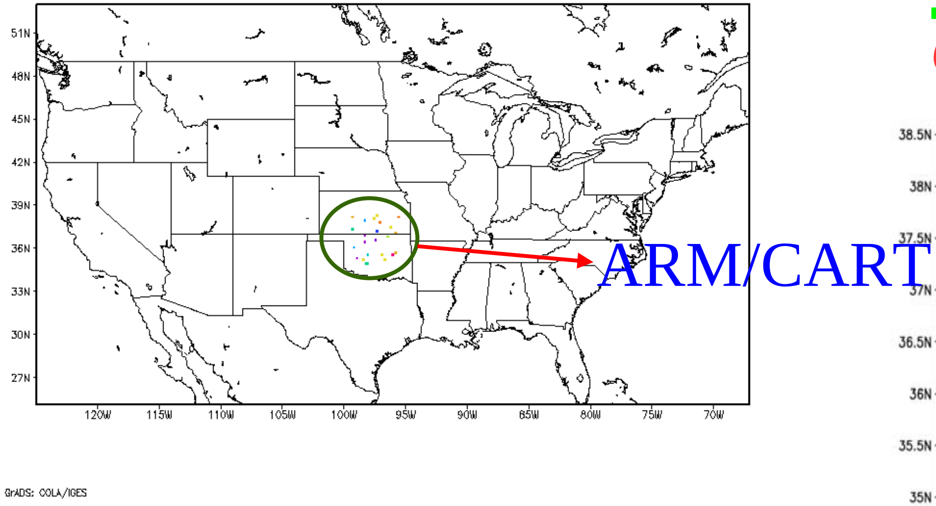
From Chen et al. 1996

Using a narrow range of this tends to overestimate the evaporation during wet periods (spring) and underestimate the evaporation during dry periods (summer).

SMHIGH and SMLOW

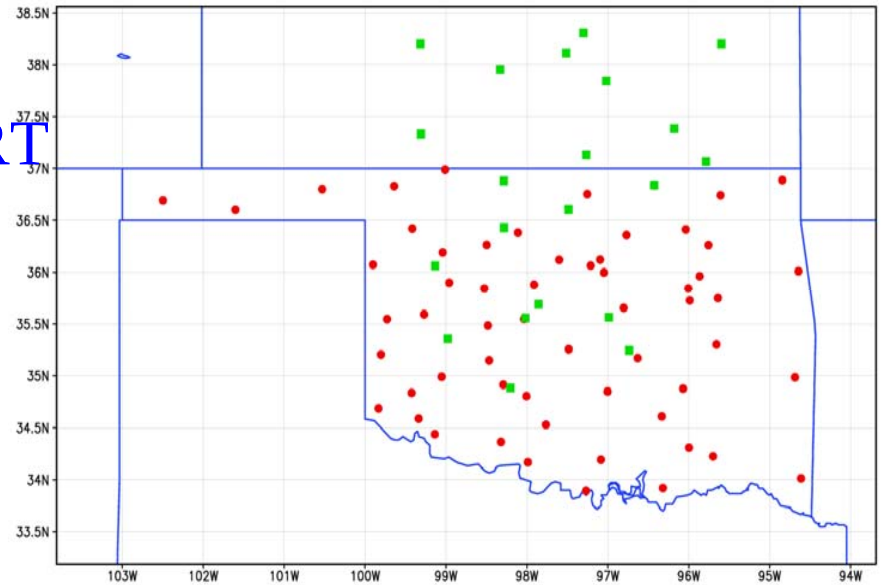
BXEXP

Experimental Design



ARM/CART sites

Oklahoma Mesonet sites



- **CONTROL**
- **TEST:**

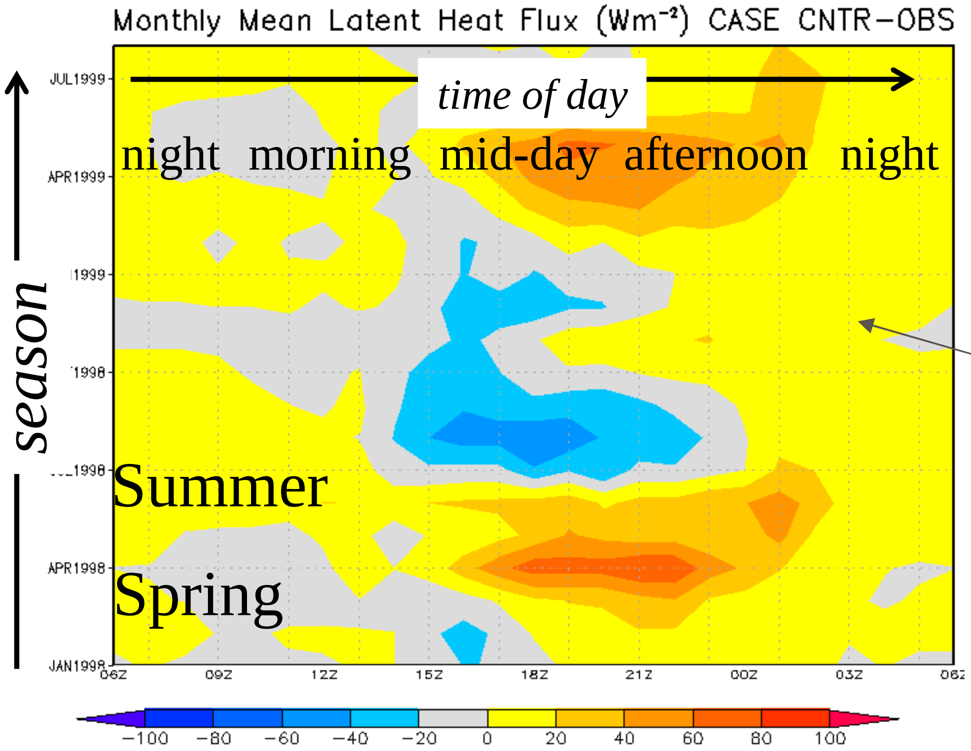
Seasonal LAI

Root Fraction

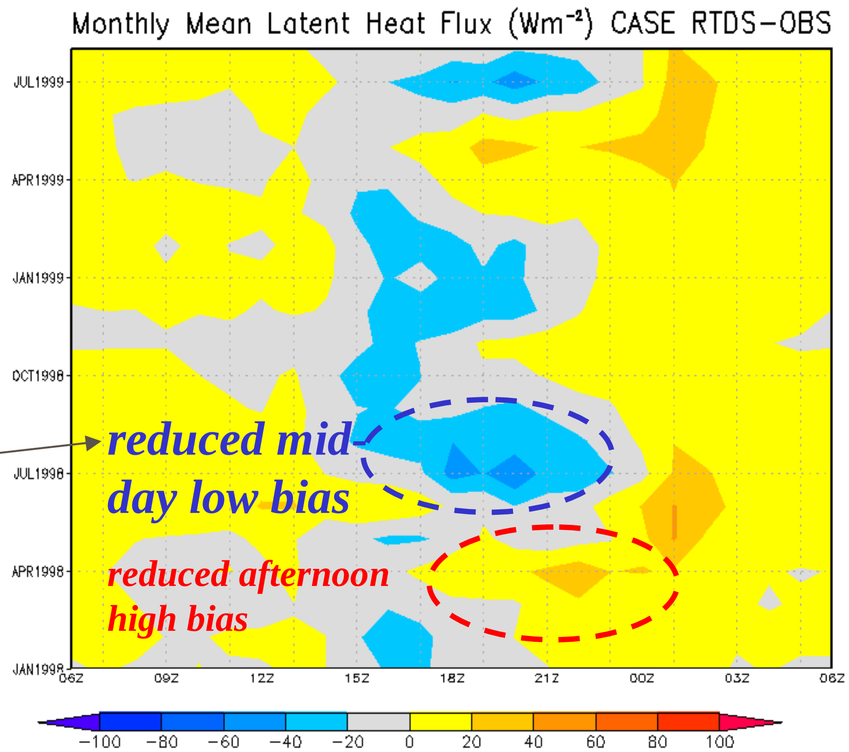
Vapor Pressure Deficit Function

SIMULATION PERIOD: OCT 1996 - SEP 1999

LATENT HEAT FLUX



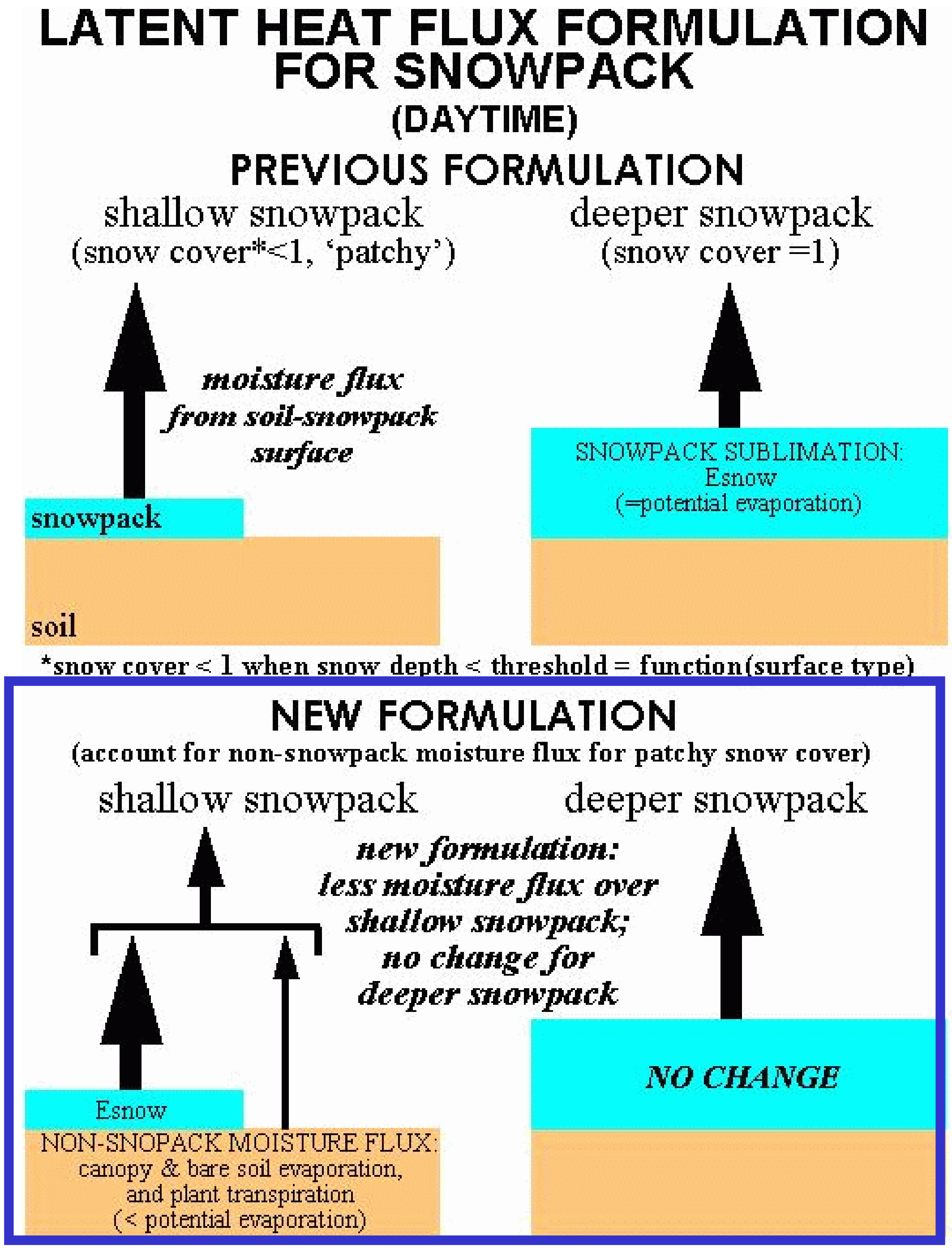
CONTROL



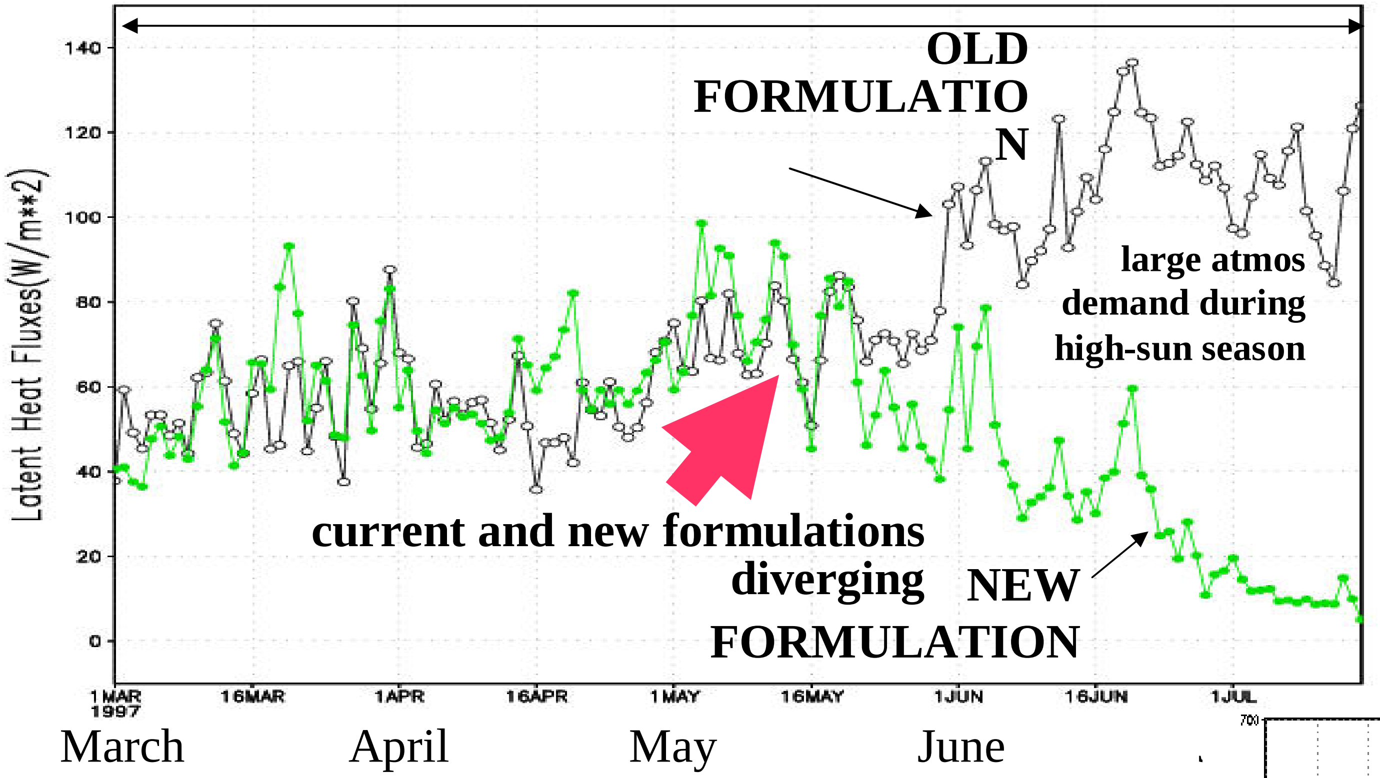
TEST

COLD SEASON

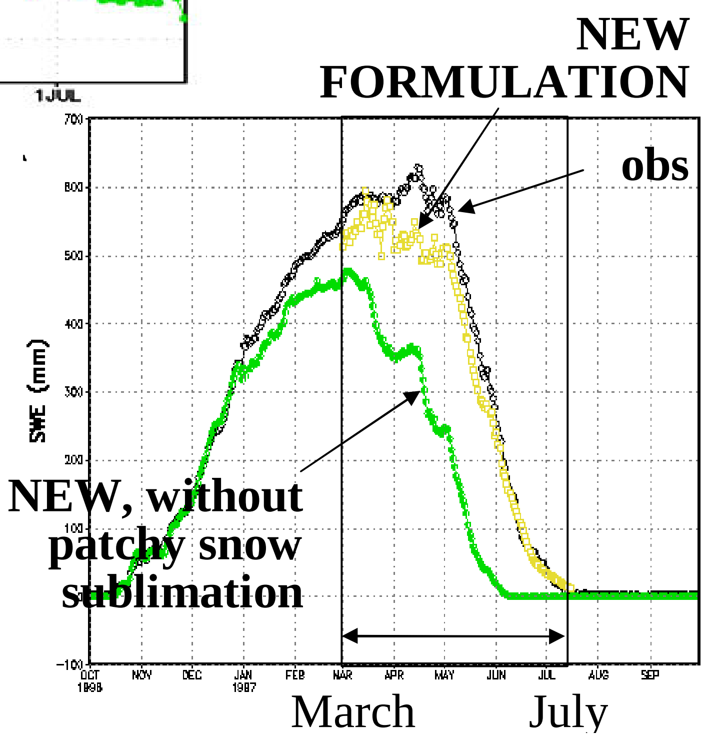
Like surface skin temperature, sensible heat flux and soil heat flux, <u>include effect of patchy snow cover in calculation of latent heat flux.</u>



DAILY BASIN-AVERAGE SURFACE MOISTURE FLUX



DAILY BASIN-AVERAGE (110 stations) SNOW DEPTH



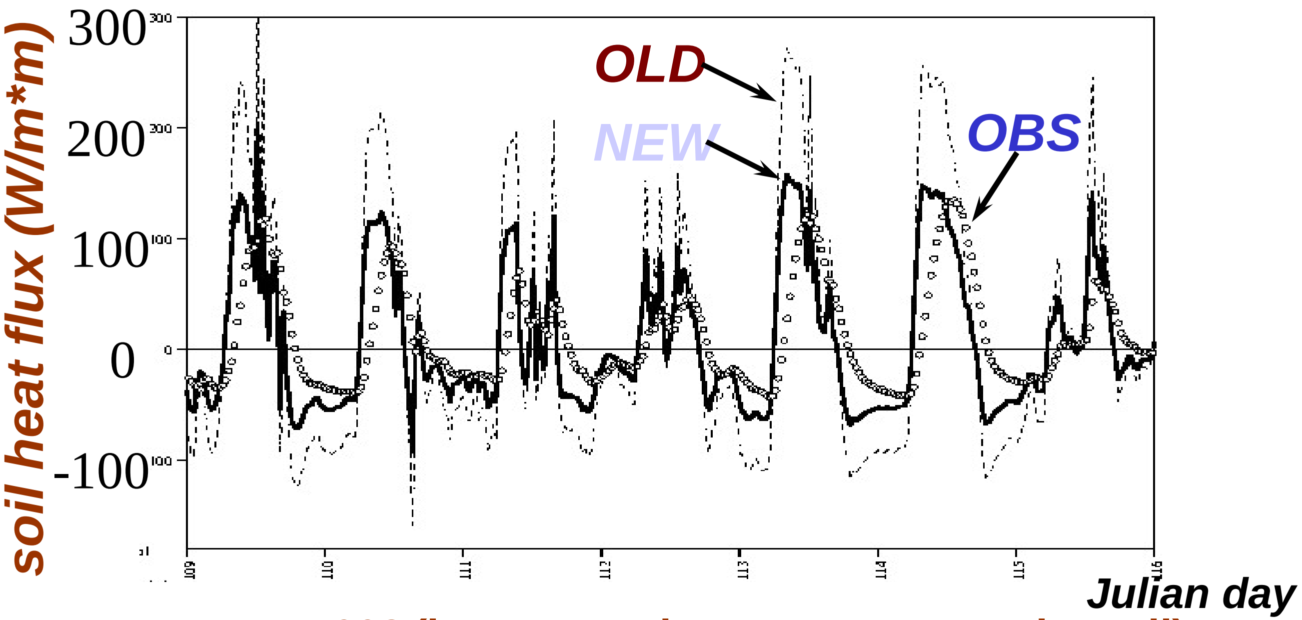
Offline (uncoupled NLDAS) results show the effect of the various cold-season changes to the Noah LSM; better snowpack evolution

Uncoupled
1-D column model
testing of Noah LSM
at single flux stations
(Exp: Soil heat flux Improvements)

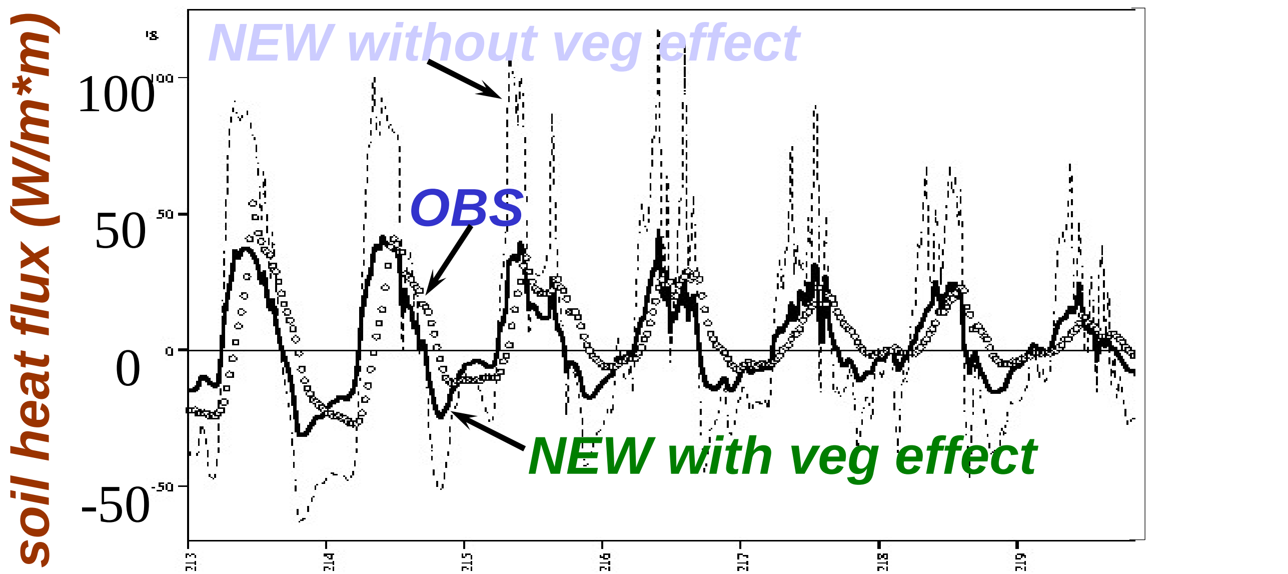
Soil heat flux improvements in uncoupled testing of the community 1-D NOAH LSM at the flux site of Meyers and Hollinger (1998), 7-day time series of observed (circles) versus modeled soil heat flux for:

Top Panel: old (dashed) versus new (solid) thermal conductivity formulation (both without new vegetation effect), during April 1998,

Bottom Panel: new thermal conductivity formulation without (dashed) and with (solid) new vegetation effect, during August 1998.



APRIL 1998 **(low vegetation greenness, moist soil)**



AUGUST 1998 **(high vegetation greenness)**

Details of land-surface modeling (LSM), e.g. the Noah LSM: *coupled mesoscale model*

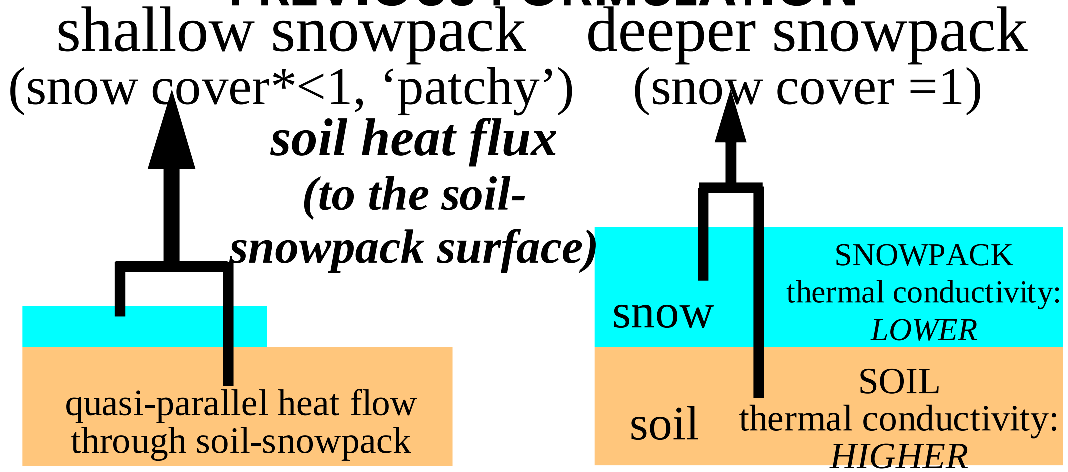
- **model physics**
- data sets and model parameters
- **validation**
- initialization and cycling land systems
- data assimilation

SOIL HEAT FLUX FORMULATION FOR SNOWPACK CASE
(NIGHTTIME)

COLD SEASON

Like surface skin temperature, sensible heat flux, <u>include effect of patchy snow cover in calculation of soil heat flux</u>.

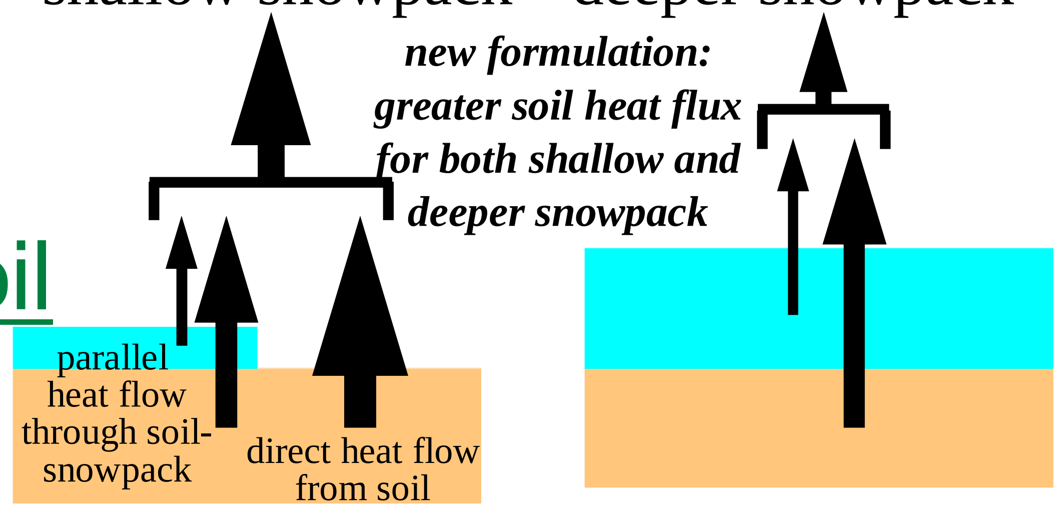
PREVIOUS FORMULATION

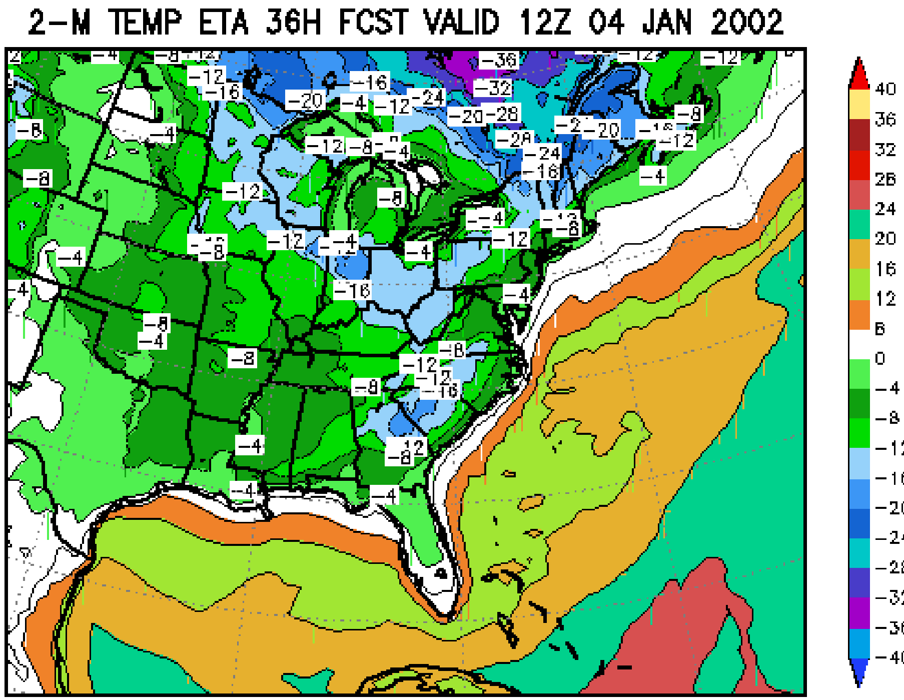


***snow cover < 1 when snow depth < threshold = function(surface type)**

NEW FORMULATION

(parallel heat flow through soil-snowpack; account for patchy snow cover)

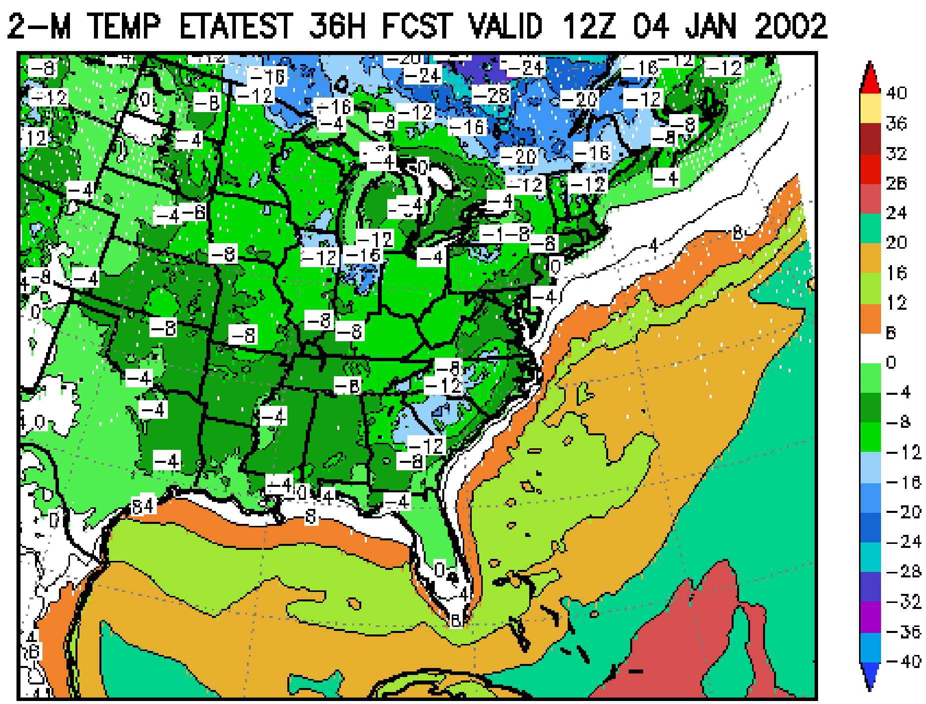




PREVIOUS SOIL HEAT FLUX FORMULATION

…to address a January 2002 cold bias

NAM-Eta model simulations…



NEW SOIL HEAT FLUX FORMULATION

Details of land-surface modeling (LSM), e.g. the Noah LSM: *coupled mesoscale model*

- model physics
- data sets and model parameters
- **validation**
- initialization and cycling land systems
- data assimilation

Model validation: flux sites

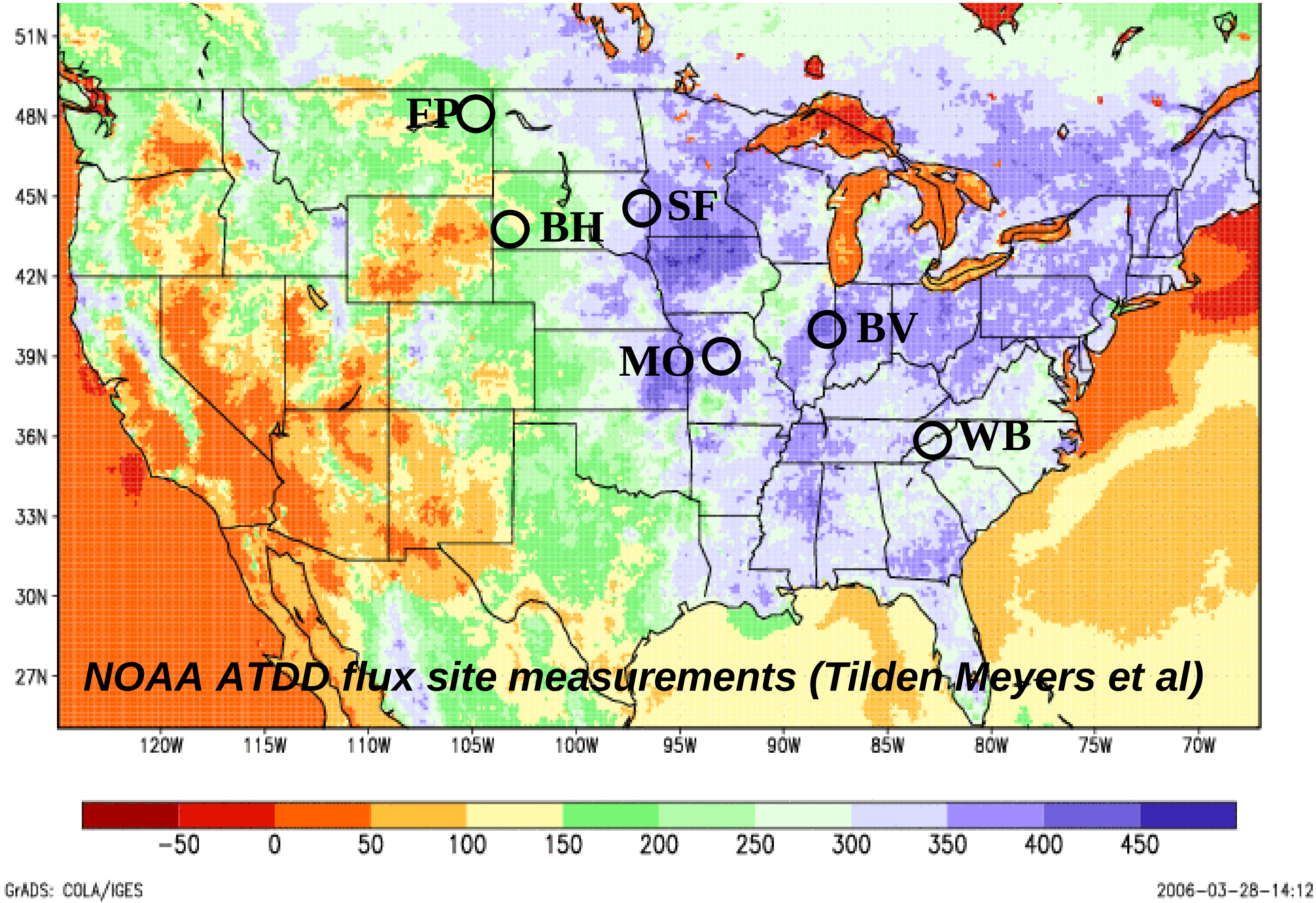
- NOAA/ATDD-SURFX flux data sets

-Components of the surface energy budget: (incoming/outgoing short/longwave radiation, latent, sensible, ground heat flux), plus meteorological observations and sub-surface temperature and soil mositure

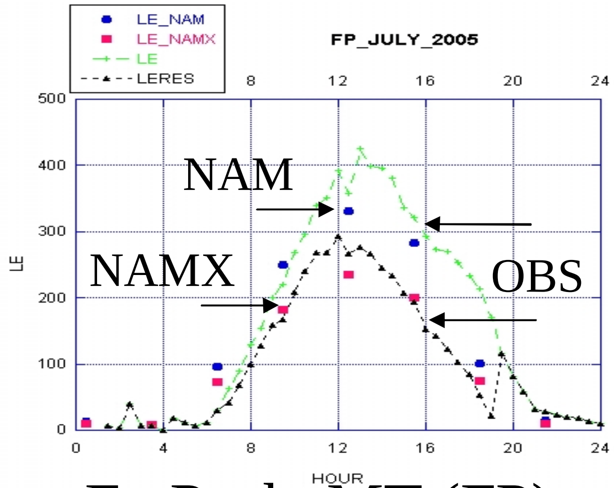
- 11 measurement sites across CONUS

- 22 months (Jan 2005 up through Oct 2006)

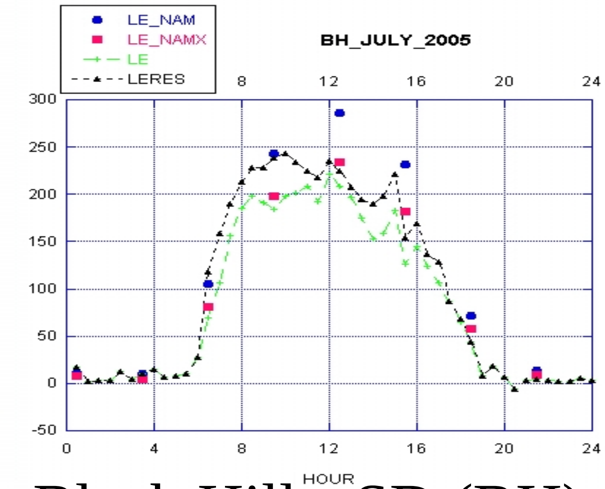
“NAMX” July05 monthly avg. mid-day **“LE”**



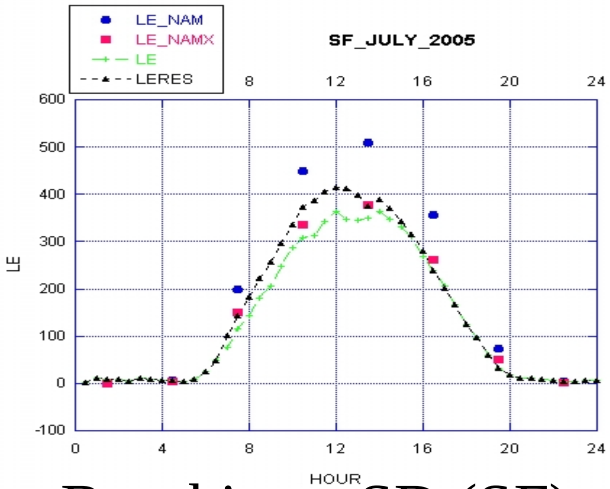
July05 **mean** diurnal avg. **latent** heat flux



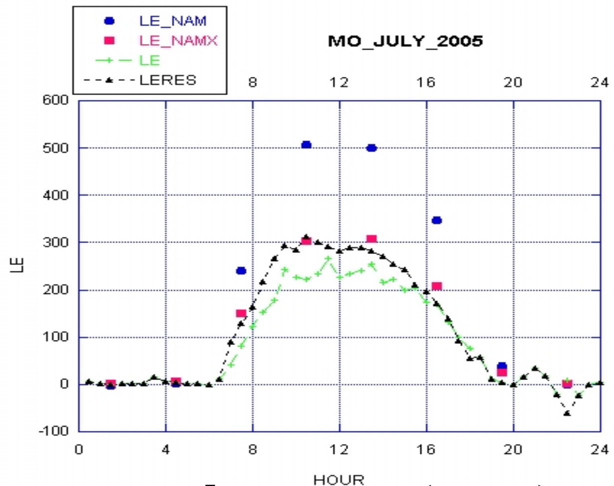
Ft. Peck, MT (FP)
grassland



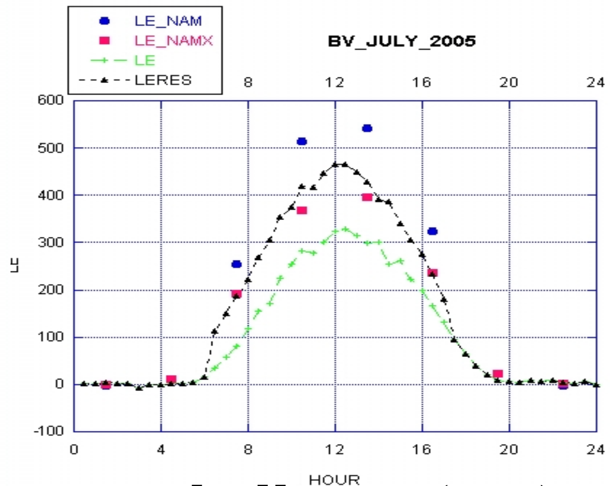
Black Hills, SD (BH)
ponderosa pine



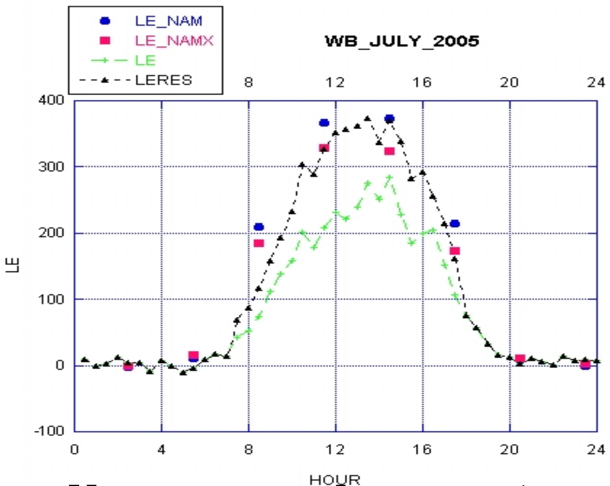
Brookings, SD (SF)
grassland



Ozarks, MO (MO)
deciduous forest

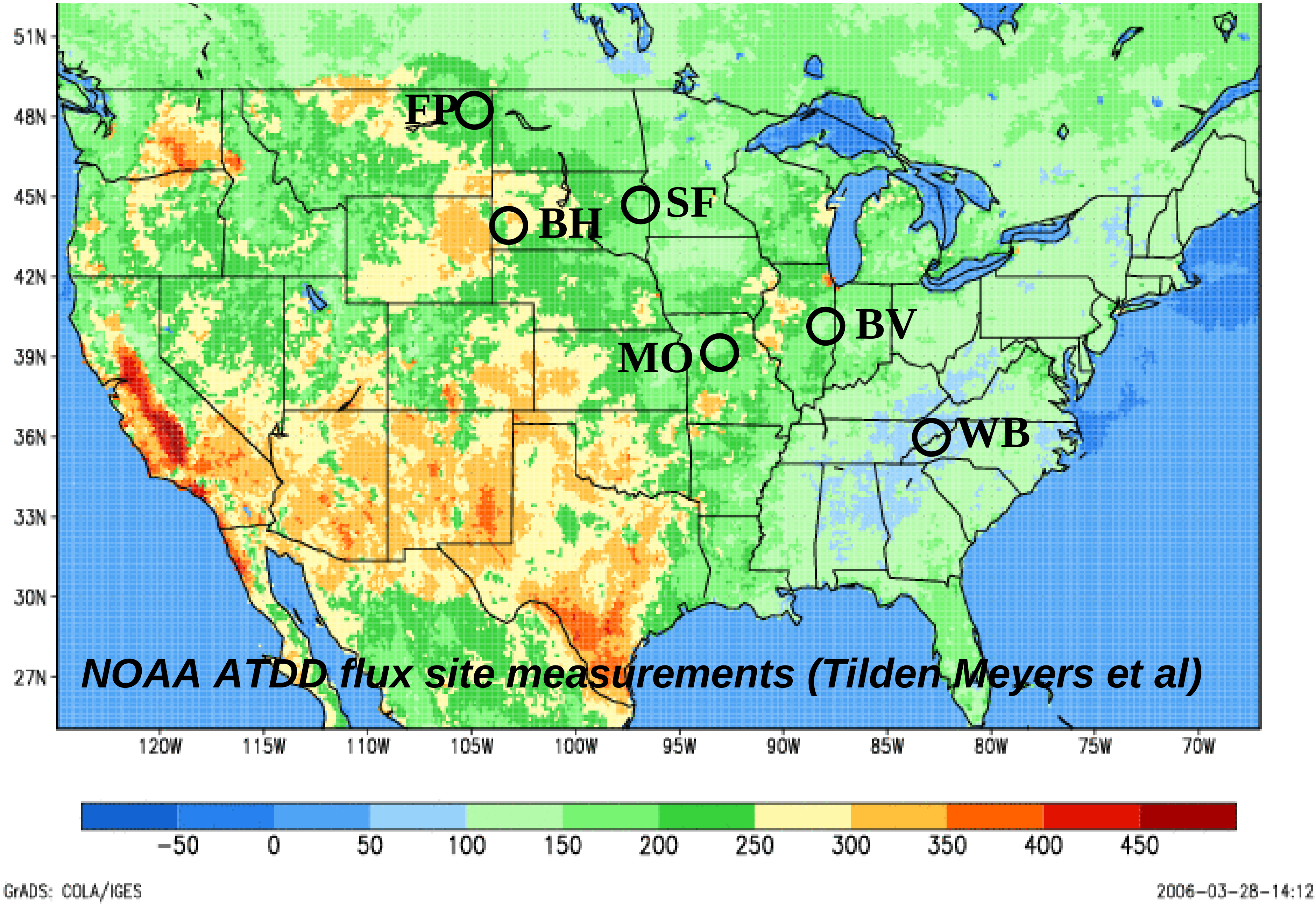


Bondville, IL (BV)
alernating crops

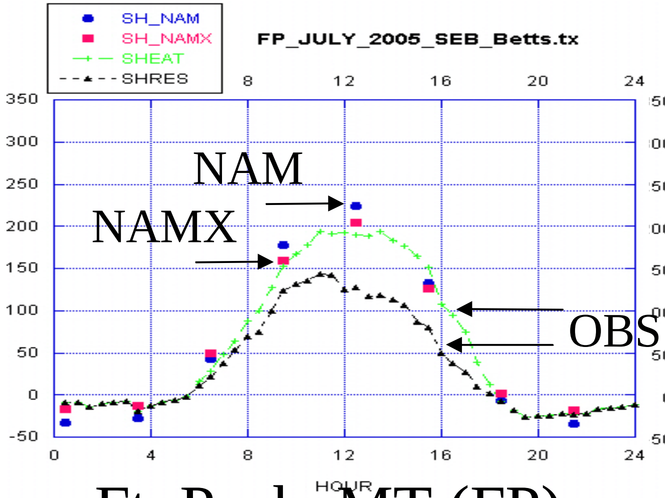


Walker Branch, NC (WB)
deciduous forest

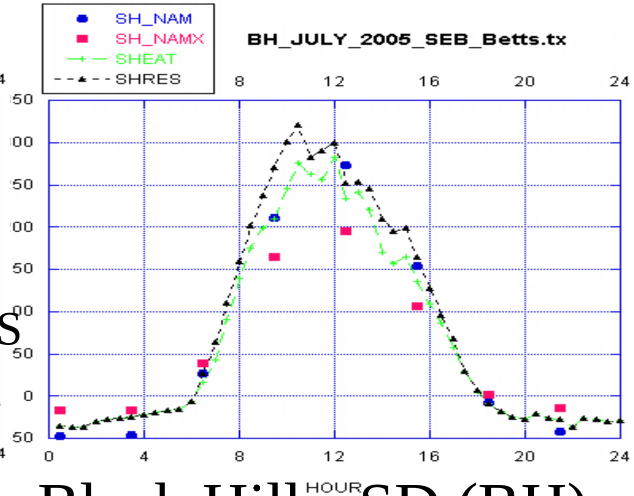
NAMX July05 monthly avg. mid-day **"SH"**



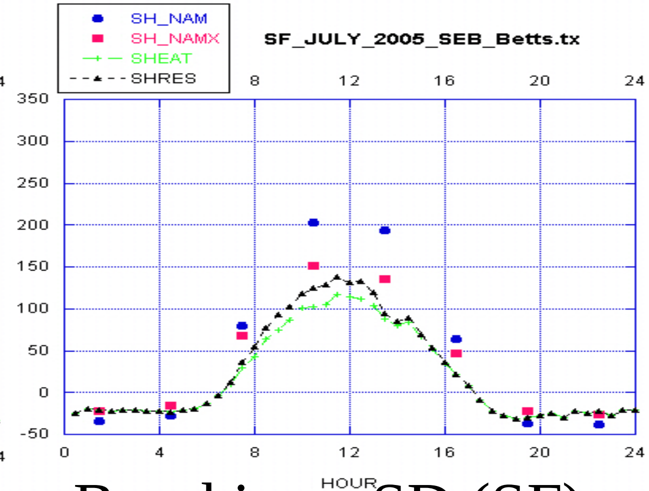
July05 mean diurnal avg. **sensible** heat flux



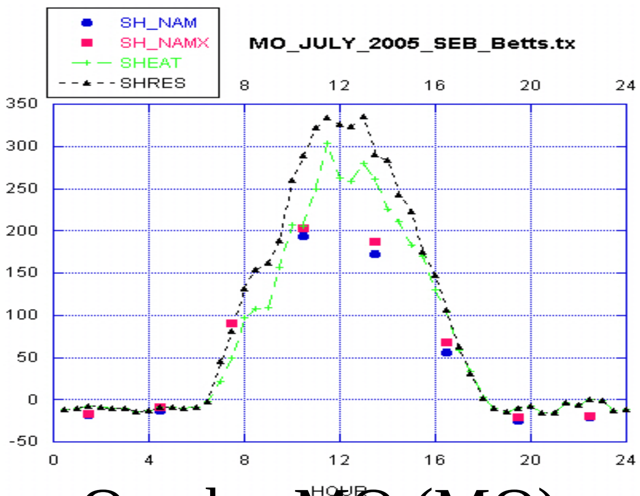
Ft. Peck, MT (FP)
grassland



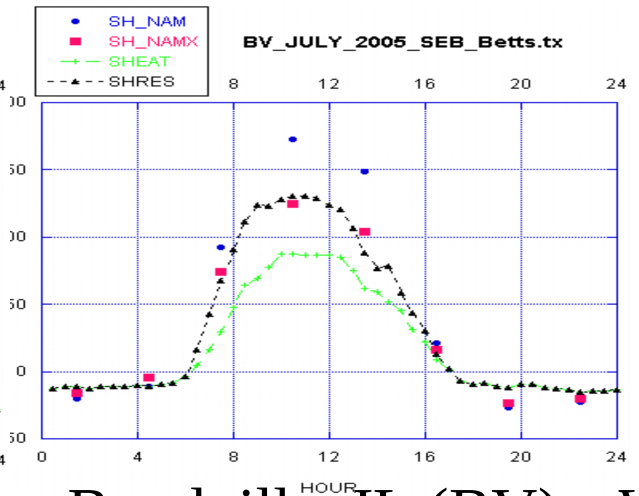
Black Hills, SD (BH)
ponderosa pine



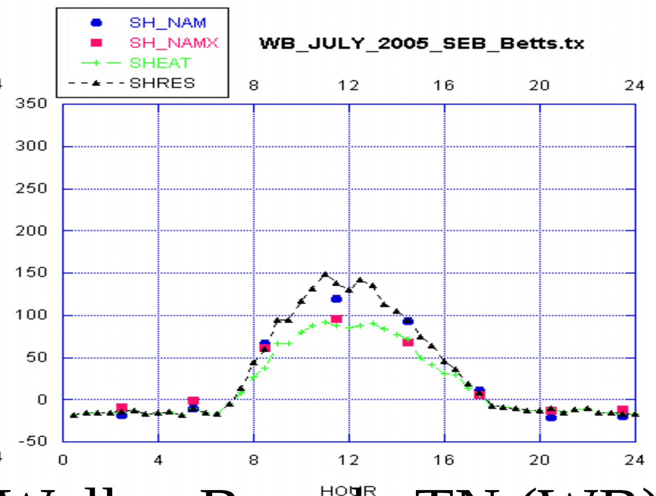
Brookings, SD (SF)
grassland



Ozarks, MO (MO)
deciduous forest

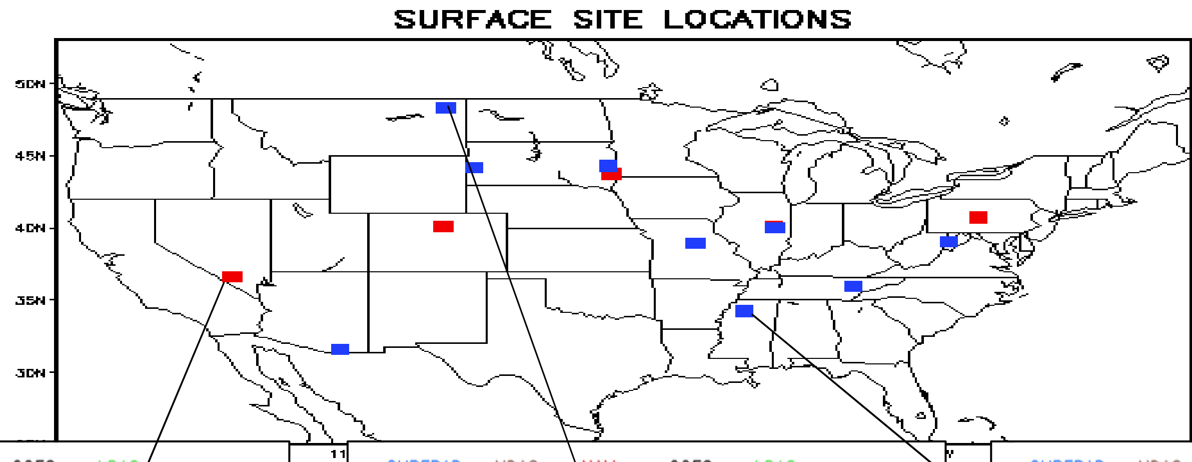


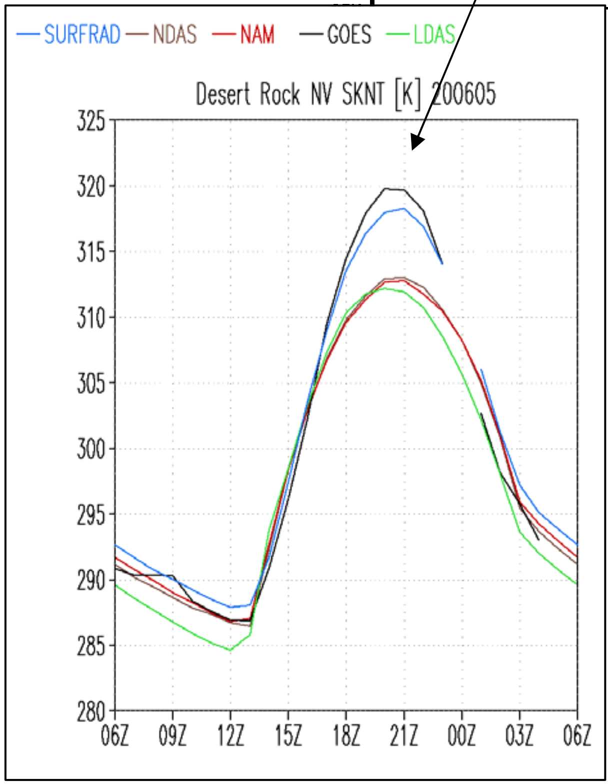
Bondville, IL (BV)
alernating crops

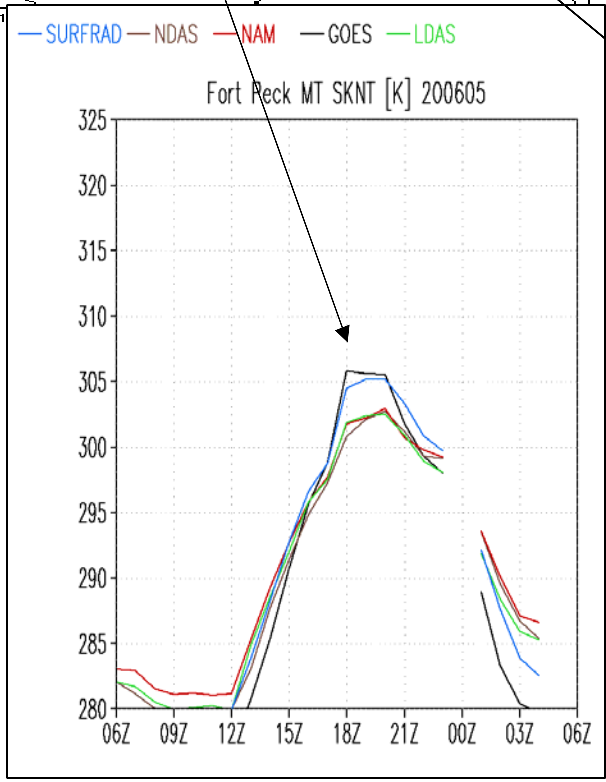


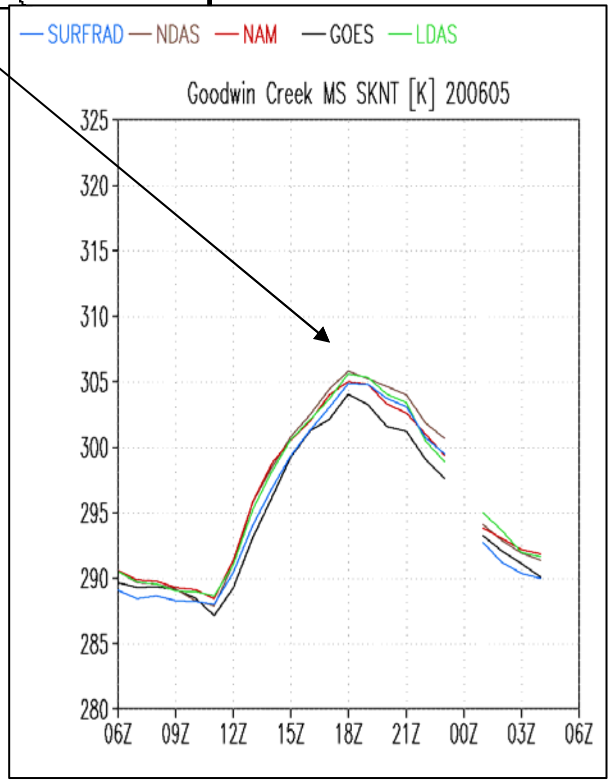
Walker Branch, TN (WB)
deciduous forest

LST verification May2006 Mean









Details of land-surface modeling (LSM), e.g. the Noah LSM: *coupled mesoscale model*

- model physics
- data sets and model parameters
- **validation**
- **initialization and cycling land systems**
- data assimilation

NORTH AMERICAN MONSOON

Example of impact of Noah LSM upgrade on CFS southwest Forecasts

Noah LSM will be implemented in next operational upgrade of CFS

Summer:

1999 (wet U.S. monsoon)

vs.

2000 (dry U.S. monsoon)

NAM/Eta

CFS/Noah/GLDAS

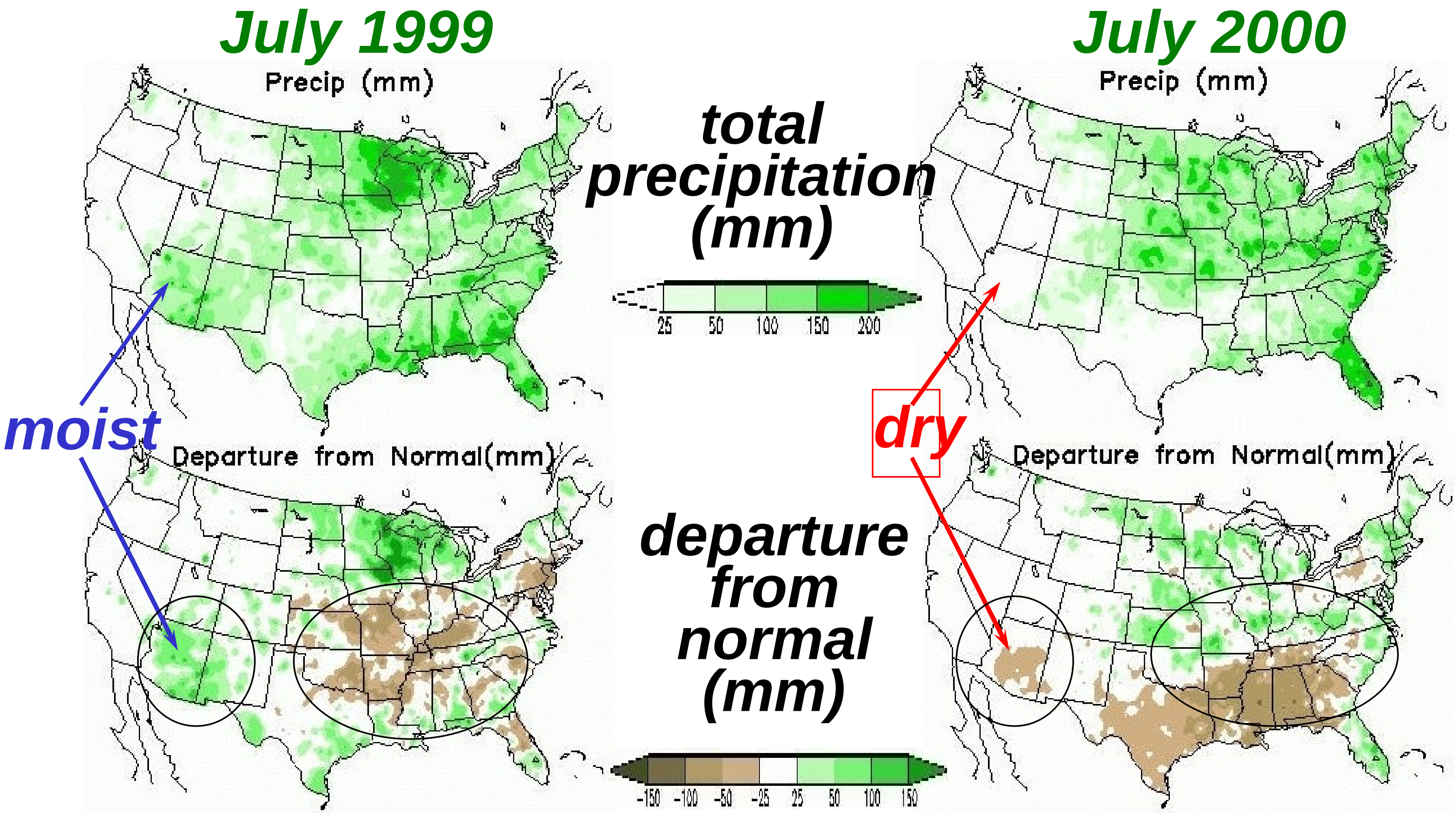
CFS/OSU/GR2 and CFS/Noah/GR2

10-members each

(initialized from late April and early May)

Monthly OBSERVED PRECIPITATION accumulations

Interannual variability of North American Monsoon - interior Southwest

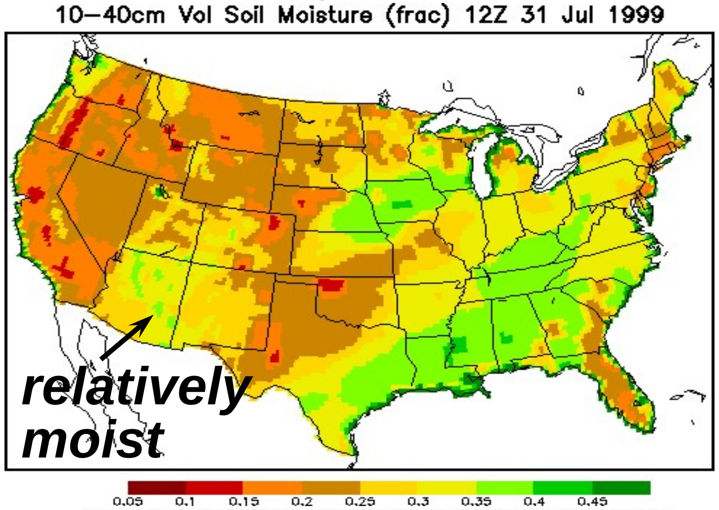


Monthly observed precipitation accumulation

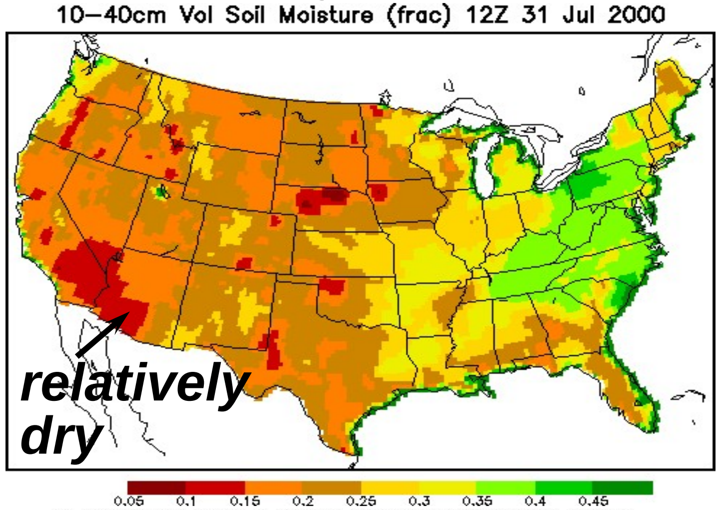
OPERATIONAL COUPLED LAND-ATMOSPHERE ETA MODEL

(Model captures interannual variability of daytime max temperature and model soil moisture)

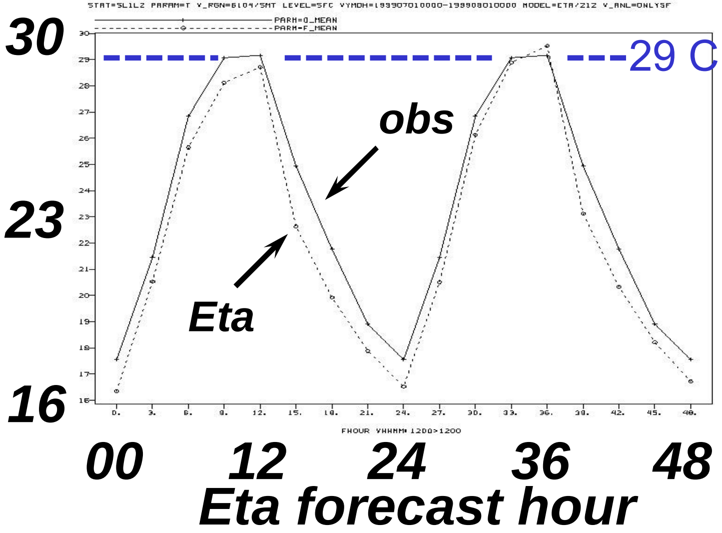
July 1999



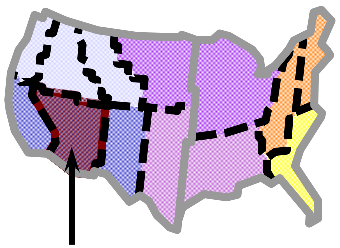
July 2000



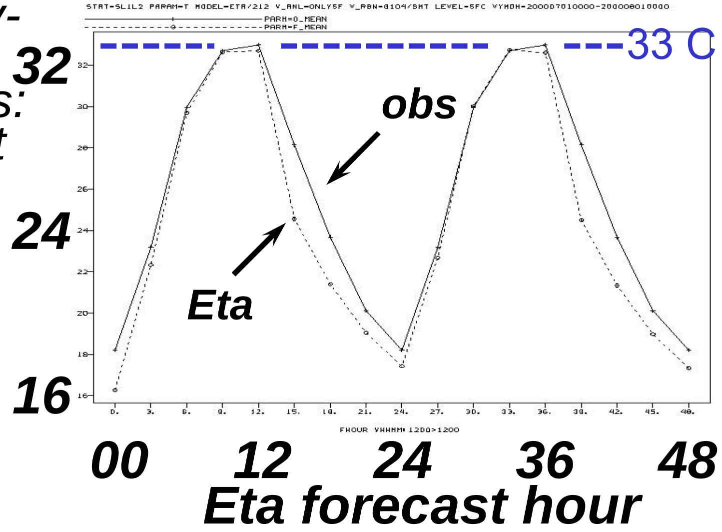
Eta model end-of-month 2nd layer volumetric <u>soil moisture</u>



Eta model monthly-mean 2-m (C) <u>air temperature</u> vs obs: interior Southwest



interior Southwest



<u>Upper</u>: Eta model layer 2 (10-40 cm) volumetric soil moisture is relatively moist (dry) in July 1999, left (July 2000, right). <u>Lower</u>: Verification of operational Eta model multi-station, monthly-mean 2-m air temperature for interior Southwest: moister and cooler (warmer and drier) conditions in July 1999, left (July 2000, right) are well-captured.

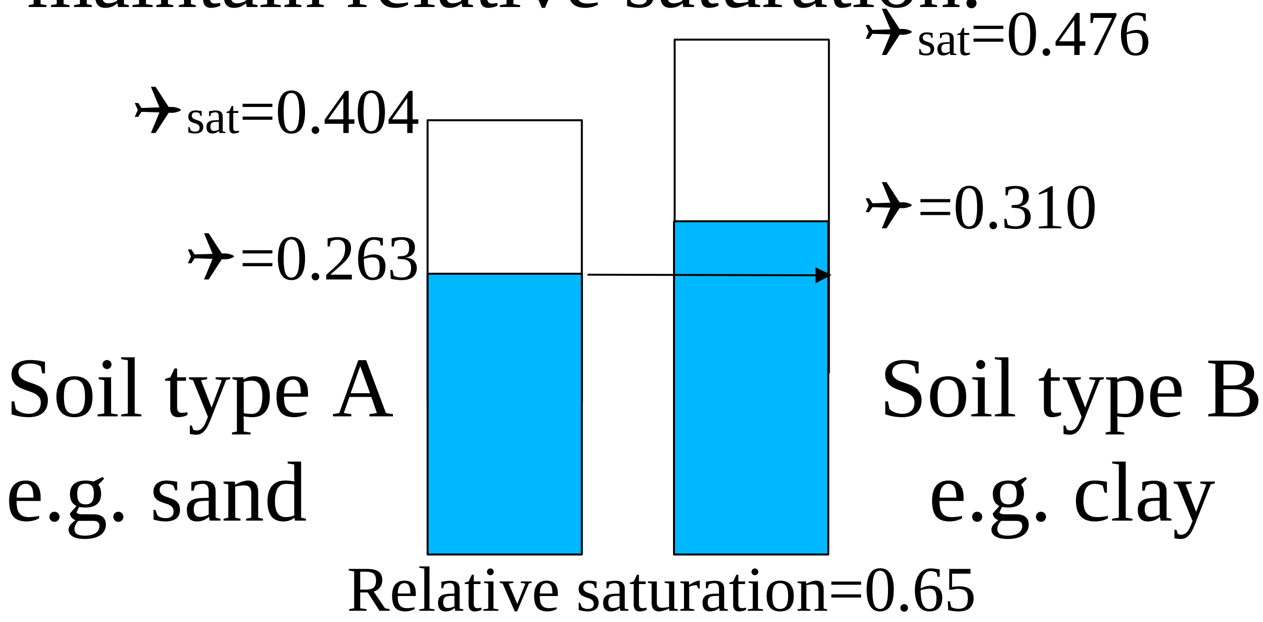
Details of land-surface modeling (LSM), e.g. the Noah LSM: *coupled mesoscale model*

- model physics
- data sets and model parameters
- **validation**
- **initialization and cycling land systems**
- data assimilation

Soil moisture re-scaling

-Necessary to re-scale soil moisture since Eta with the old soils needed to restart Eta with the new soils.

-To preserve surface evaporation (with respect to plant stress) in going from old (Zobler) to new (STATSGO) soils, convert soil moisture contents in order to maintain relative saturation.



BUT...

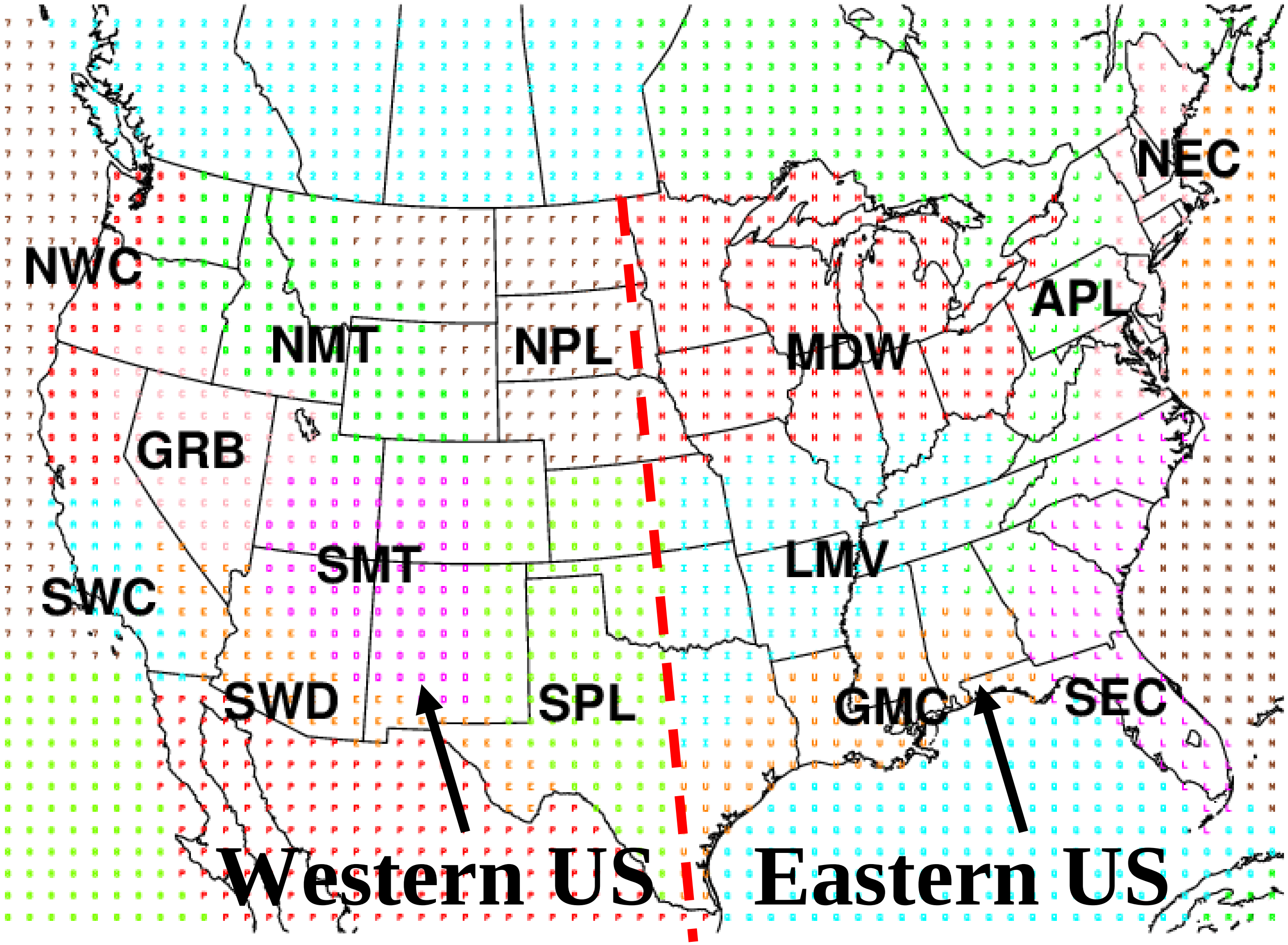
Soil moisture spin-up

BUT... the subsequent evolution of soil moisture will be different for one soil type versus another, so model spin-up is important.

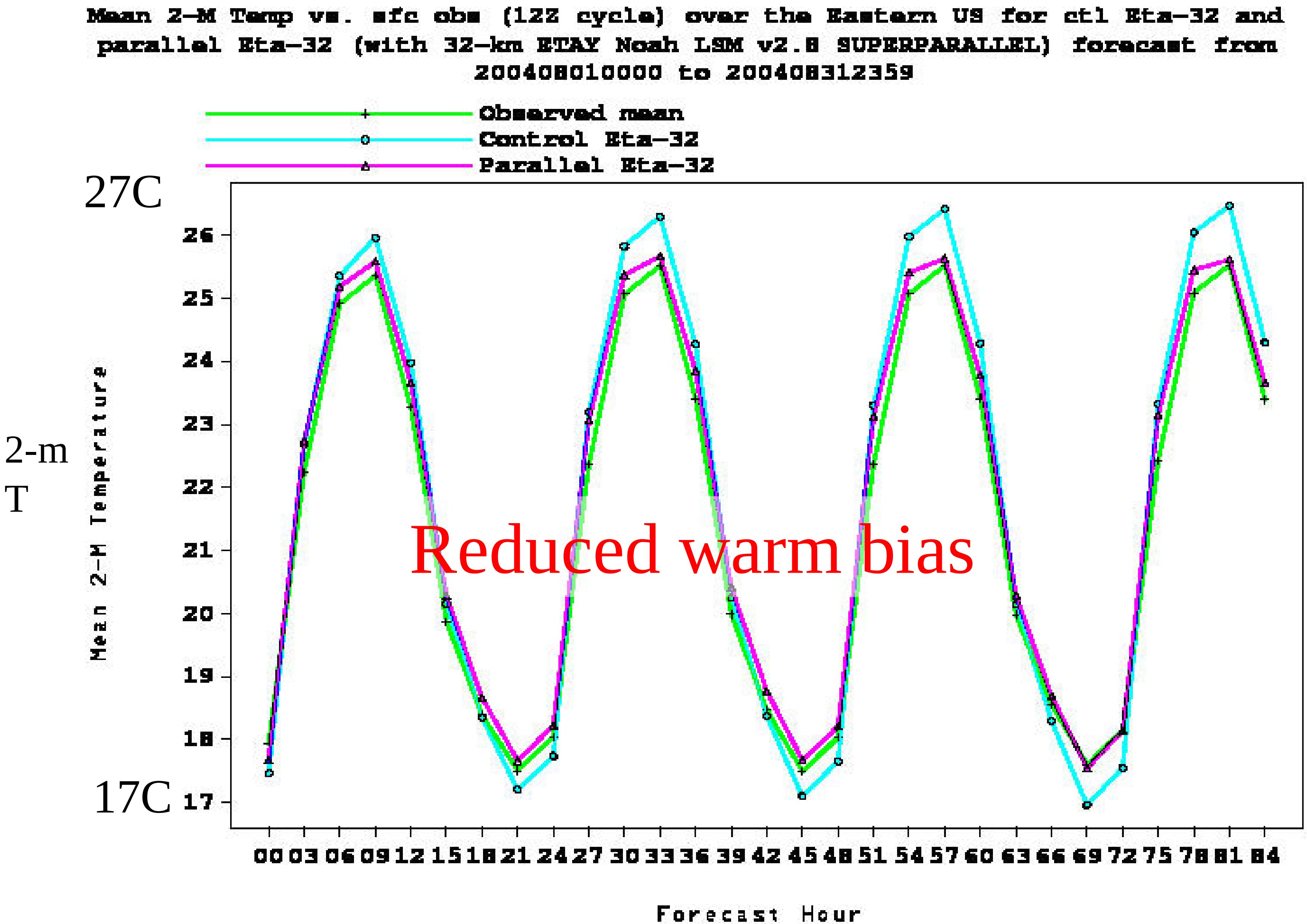
-Continuous/cycled Etax tests during July-August 2004 showed that higher latent heat fluxes (vs control Eta) over eastern CONUS die down <u>after about 1 month of cycling, as land states settle in with their own new vegetation and soil parameters.</u>

-In August, parallel Eta still had higher latent heat flux than control Eta, but difference significantly less than July.

NCEP verification regions for operational and parallel models

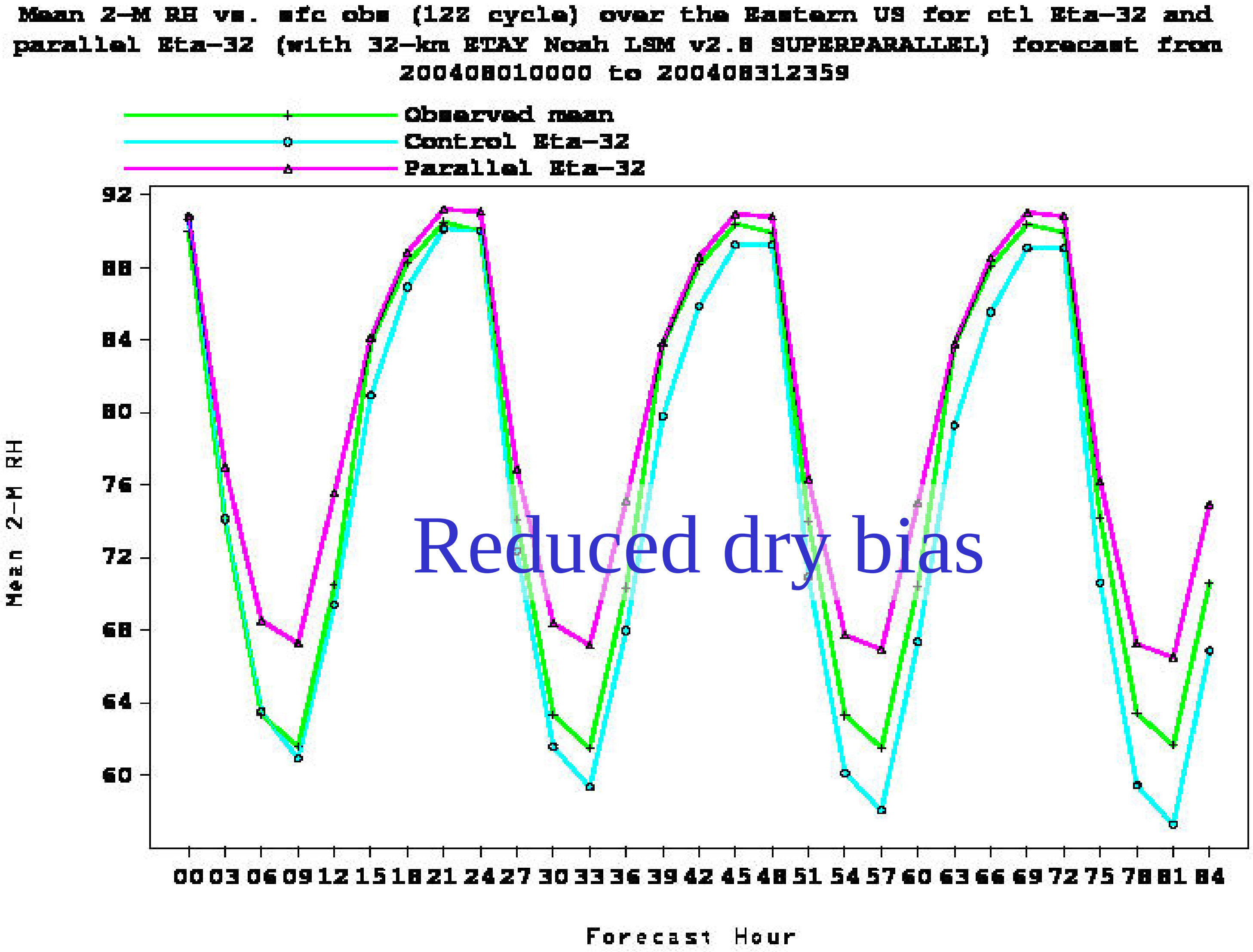


Eastern US, August 2004



Relative humidity

Eastern CONUS, August 2004



- **Source of initial conditions**
  - use NAM GRIB for <u>atmospheric initial conditions</u>
    - Unless domain outside N. America, then use GFS
  - use NAM GRIB for <u>land initial conditions</u>
    - Unless domain outside North America, then use GFS
      - AFWA global AGRMET also suitable
    - Use NCEP Regional Reanalysis for old cases
      - Use NCEP-NCAR Global Reanalysis only as last resort
- **Source of lateral boundary conditions**
  - USE GFS GRIB for lateral boundary conditions

IMPORTANT TO <u>CYCLE</u> THE LAND SURFACE & <u>INITIALIZE</u> WITH LAND-STATES FROM THE SAME LAND-MODEL WITH THE SAME PARAMETERS (E.G. SOIL, VEG, ROUGHNESS) "LAND-SURFACE INERTIA"

Details of land-surface modeling (LSM), e.g. the Noah LSM:
1-D and mesoscale model

- model physics
- data sets and model parameters
- validation
- **initialization and cycling land systems**
- **data assimilation**

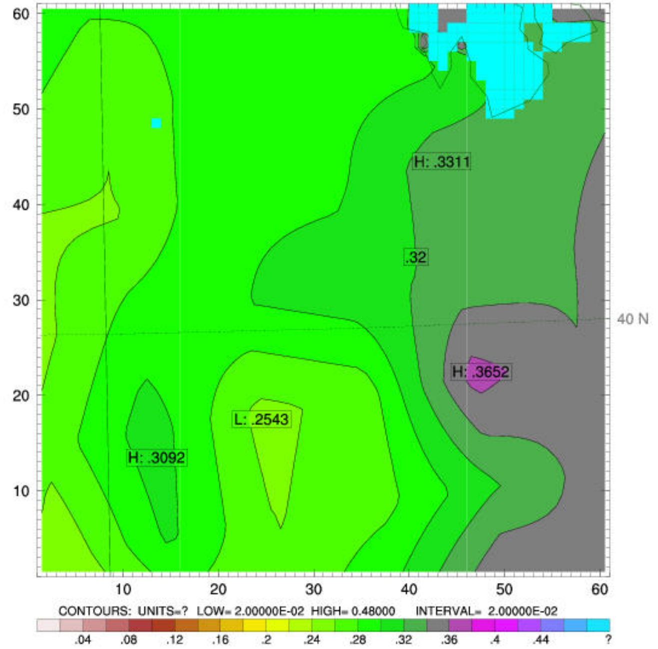
NCAR High-Resolution Land Data Assimilation System (HRLDAS) Concept

- Run uncoupled LSM on the same grid as mesoscale NWP models
  - Using the same LSM as in coupled NWP model: same soil moisture climatology
  - No Mis-match of terrain, land use type, soil texture, physical parameters between sources of soil data and NWP models
  - No interpolation and soil moisture conversion
  - Captures small-scale variability with long term evolution of multi-layer soil moisture and temperature, surface fluxes, and runoff.

Spin-up of Soil Moisture (top 10 cm soil)

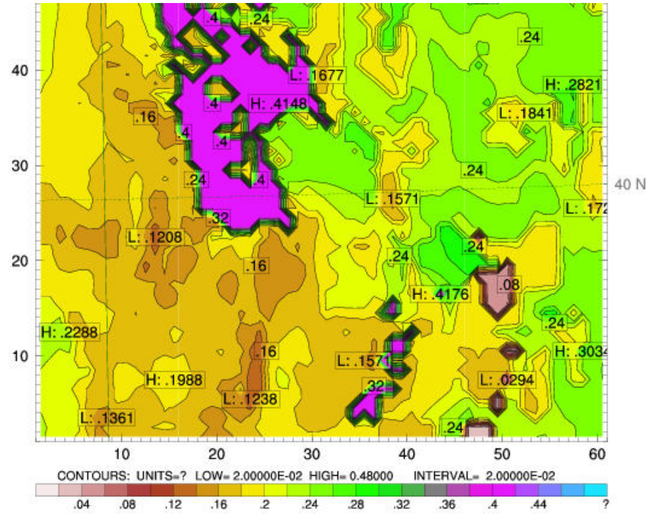
Initial time

From coarse resolution of EDAS field

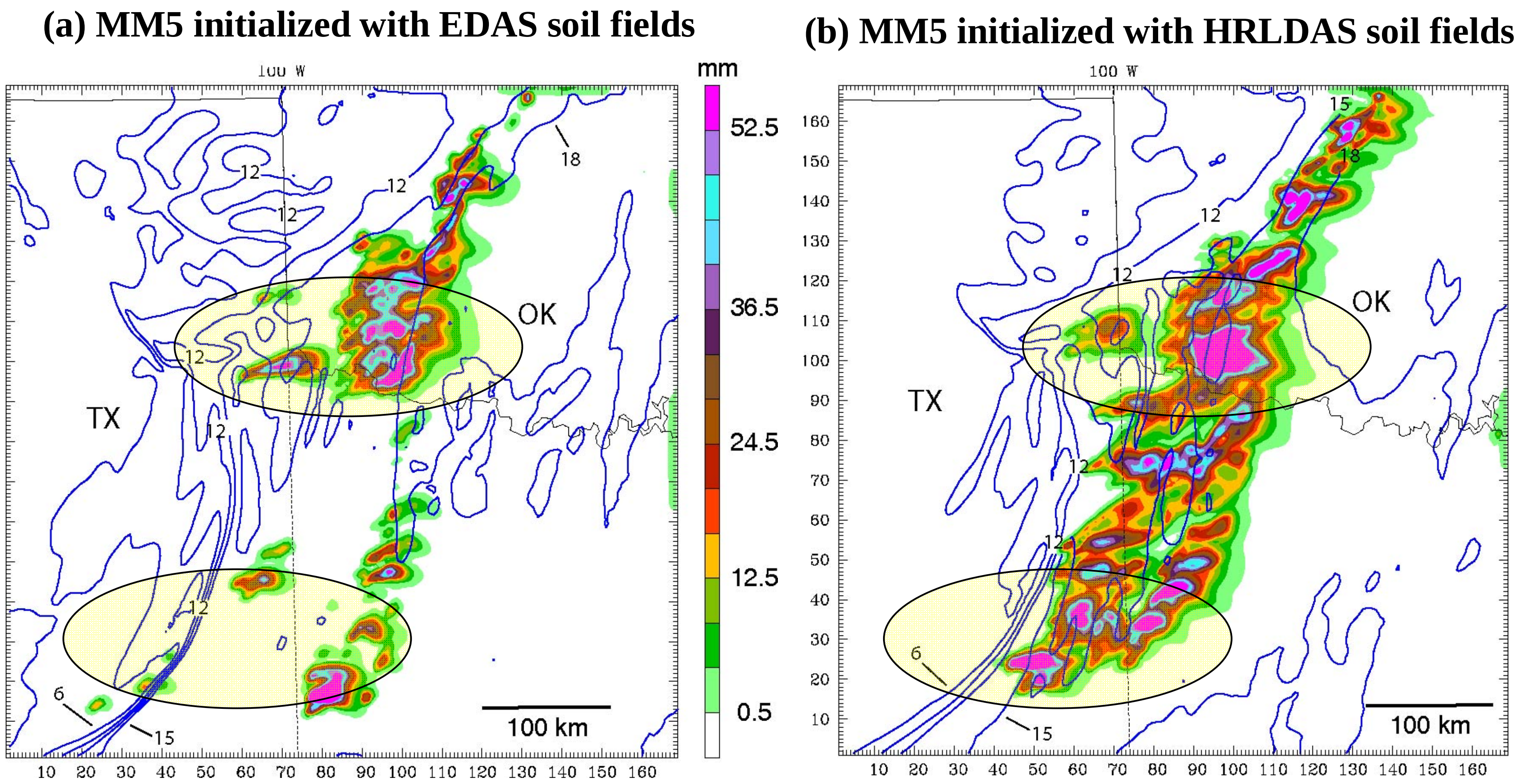


46 days later

Heterogeneity was developed in the 4-km domain

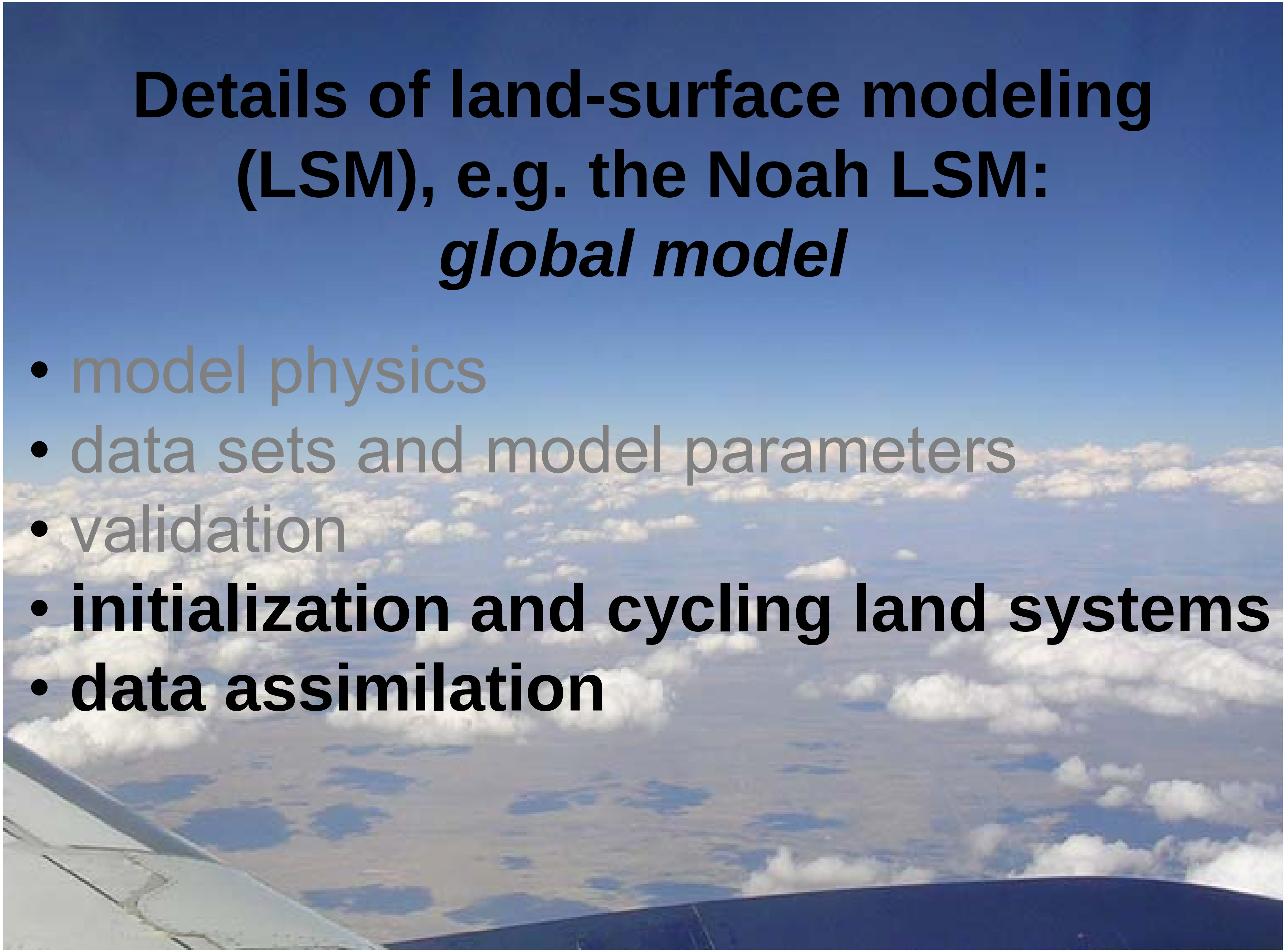


Soil Moisture Experiment: 3-h (9-12 forecast) rainfall
MM5 initialized with HRLDAS correctly reproduced dryline convection initiation



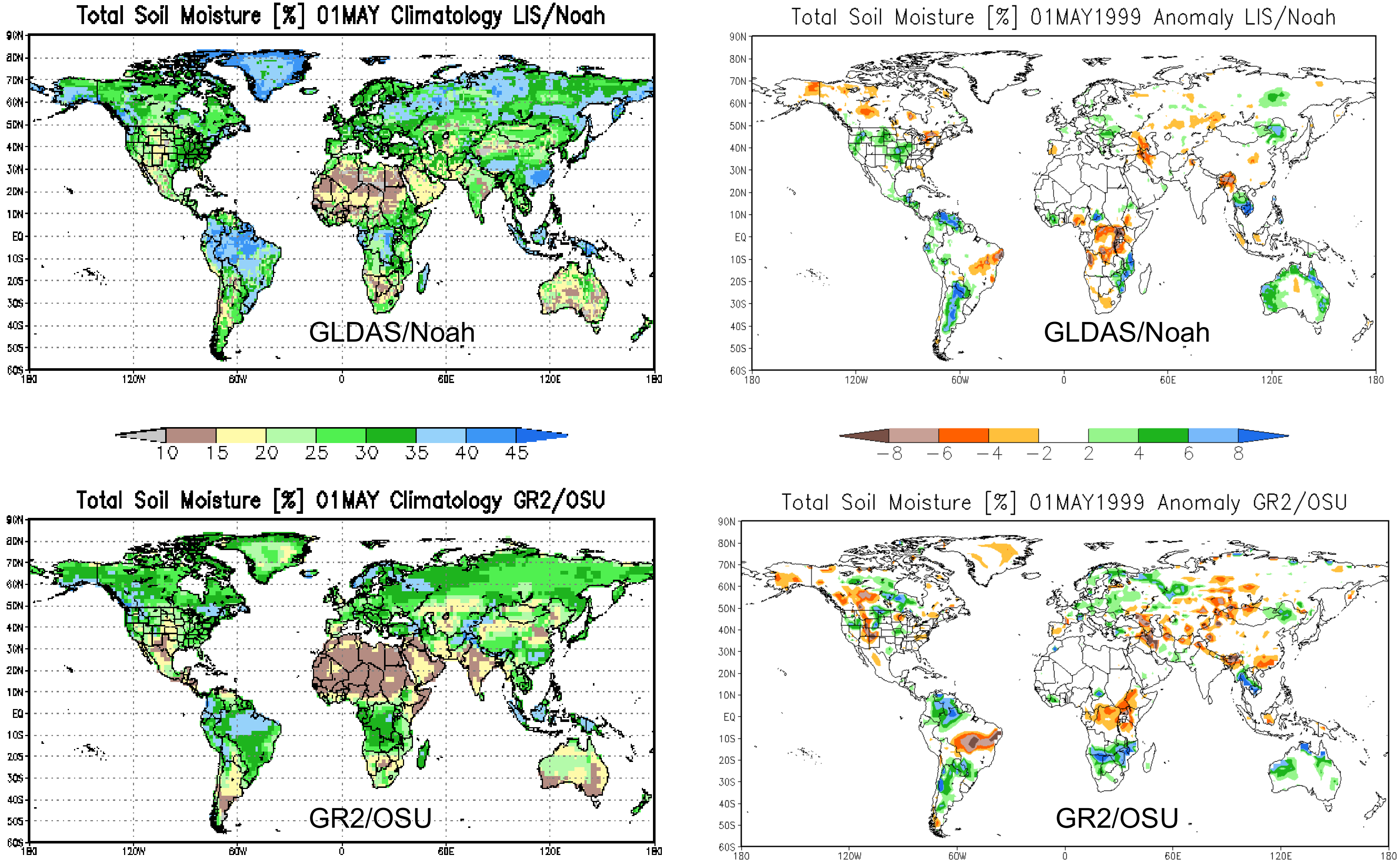
Simulation with EDAS soil fields put TX convection in wrong area

Details see Trier, Chen, and Manning, *Mon. Wea. Rev, 2004*


Details of land-surface modeling
(LSM), e.g. the Noah LSM:
global model
• model physics
• data sets and model parameters
• validation
• initialization and cycling land systems
• data assimilation

2-meter soil moisture (% vol.) 25-year climatology (1981-2005)

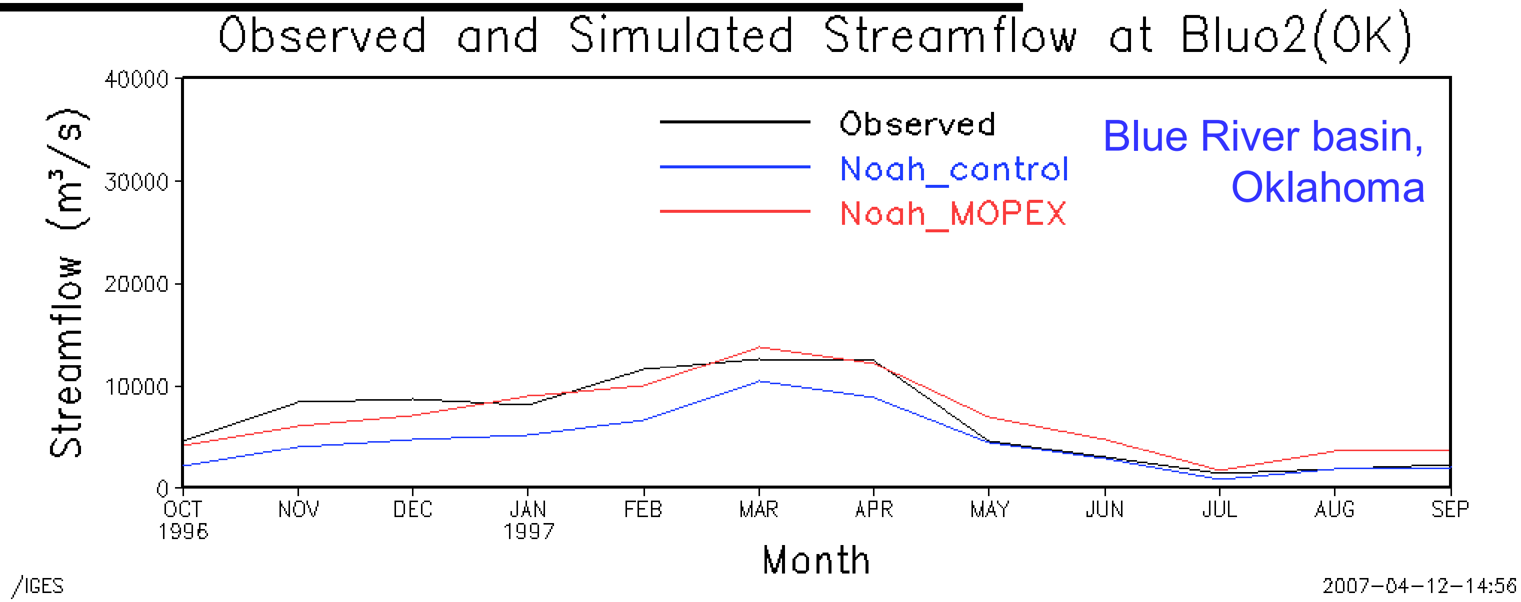
Generally, GR2/OSU < GLDAS/Noah ~ OBSERVATIONS

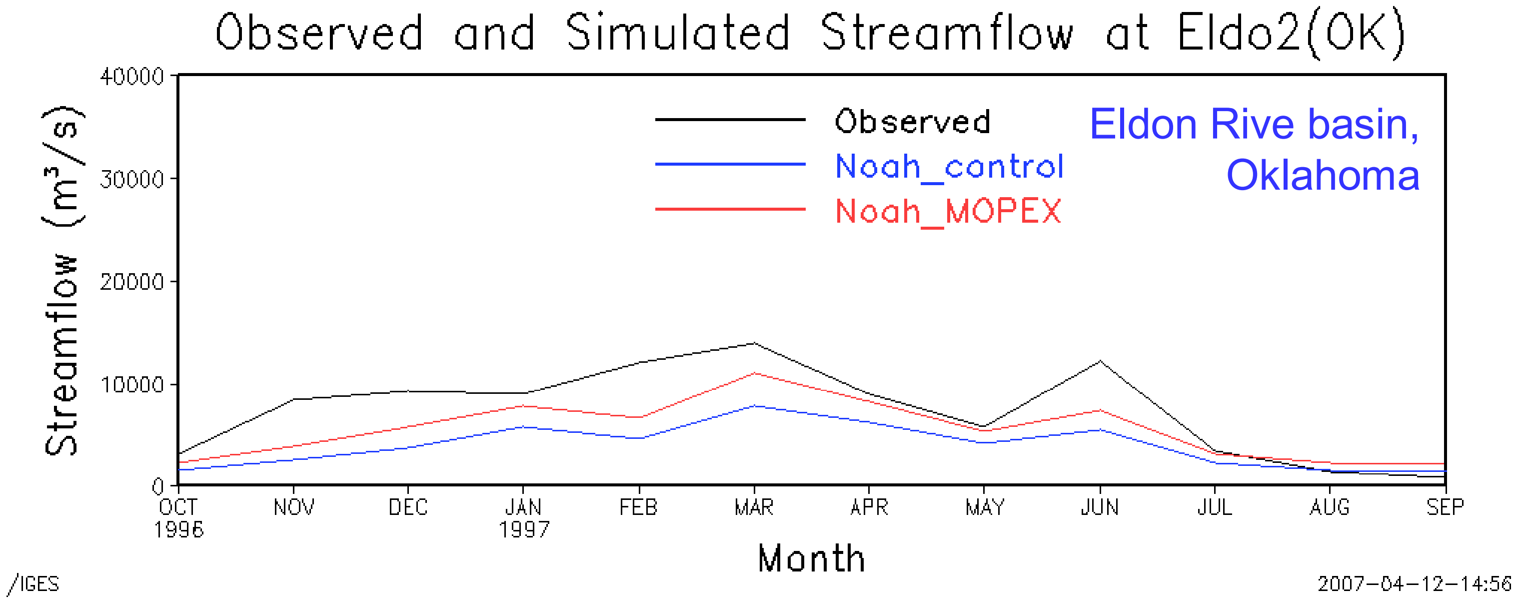


Details of land-surface modeling (LSM), e.g. the Noah LSM: *hydrology*

- model physics
- data sets and model parameters
- **validation**
- **initialization and cycling land systems**
- data assimilation

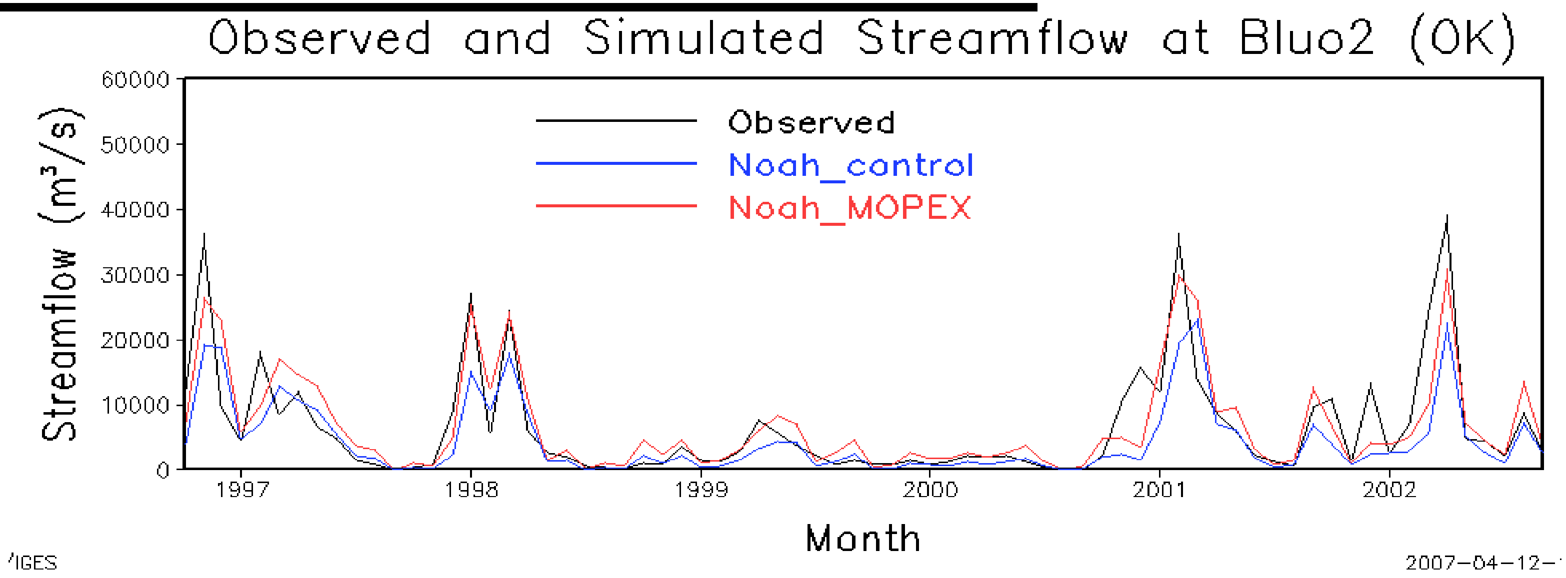
HYDROLOGY/STREAMFLOW

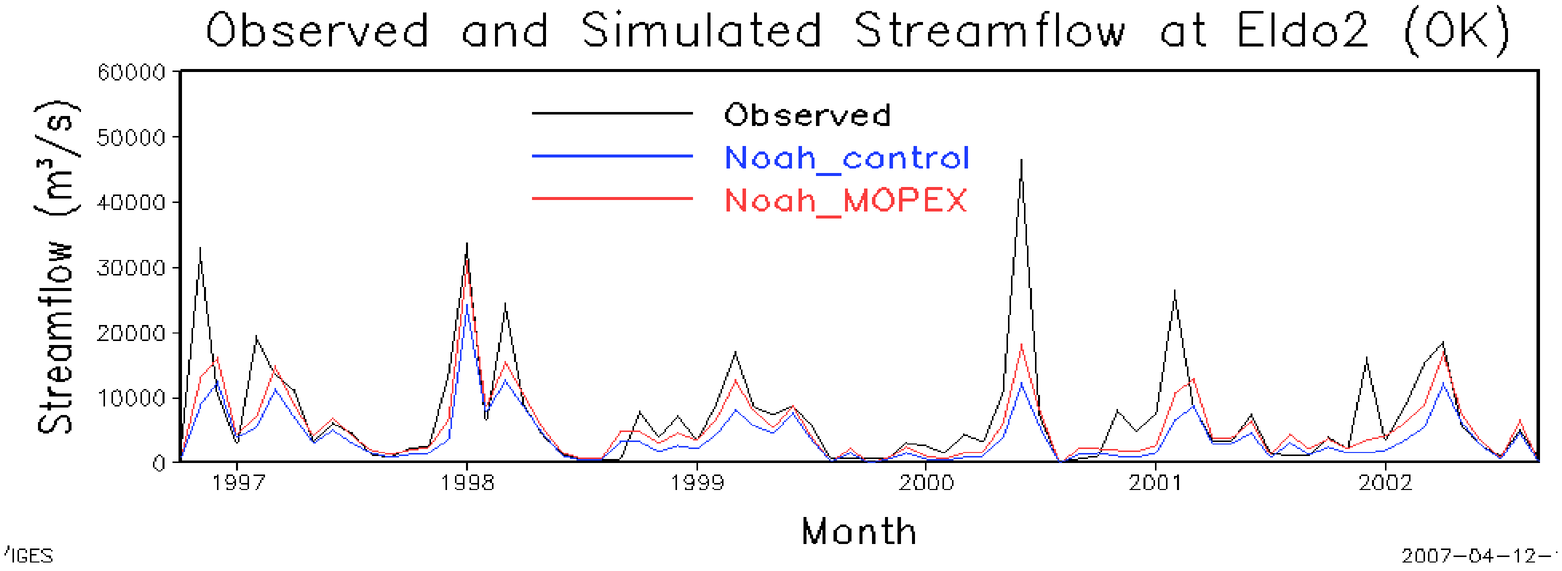




Mean annual cycle (6 YEARS: Oct 96 – Sep 02) of monthly streamflow: observed, Noah LSM simulated (default and with MOPEX recommended runoff parameters monthly to reduce low bias.

HYDROLOGY/STREAMFLOW





As in previous figure, but for the monthly time series for six years (Oct 96 – Sep 02).


END