IMPLEMENTING VARIABLE SOIL THICKNESS IN CLM4.5

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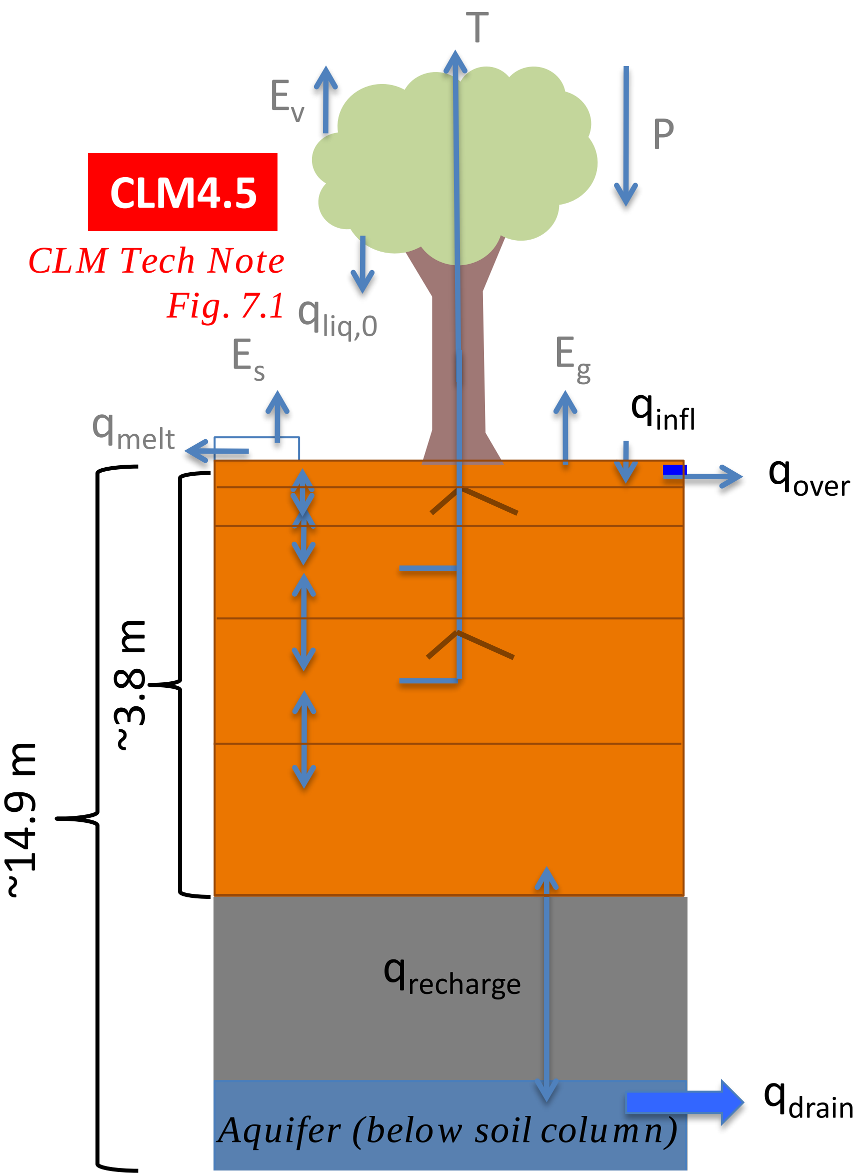
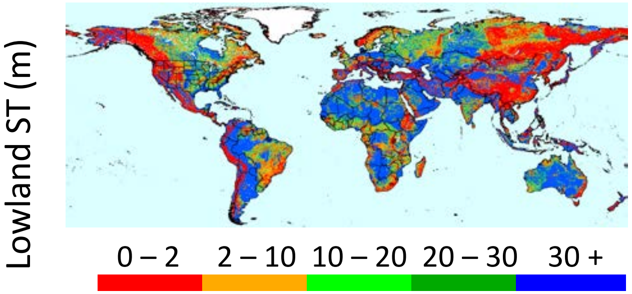
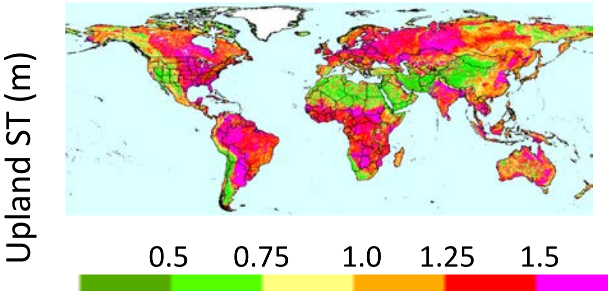
MOTIVATION

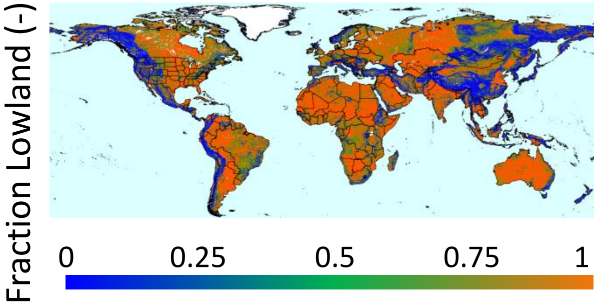


- Land surface models (LSMs) use constant soil thickness.
  - Lack of knowledge of how deep bedrock is globally.
- Represent groundwater by aquifer model.
- Inconsistencies introduced by use of aquifer model in CLM:
  - Virtual water reservoir
  - Inconsistent with thermodynamics
- Inclusion of variable soil thickness adds realism to LSMs.

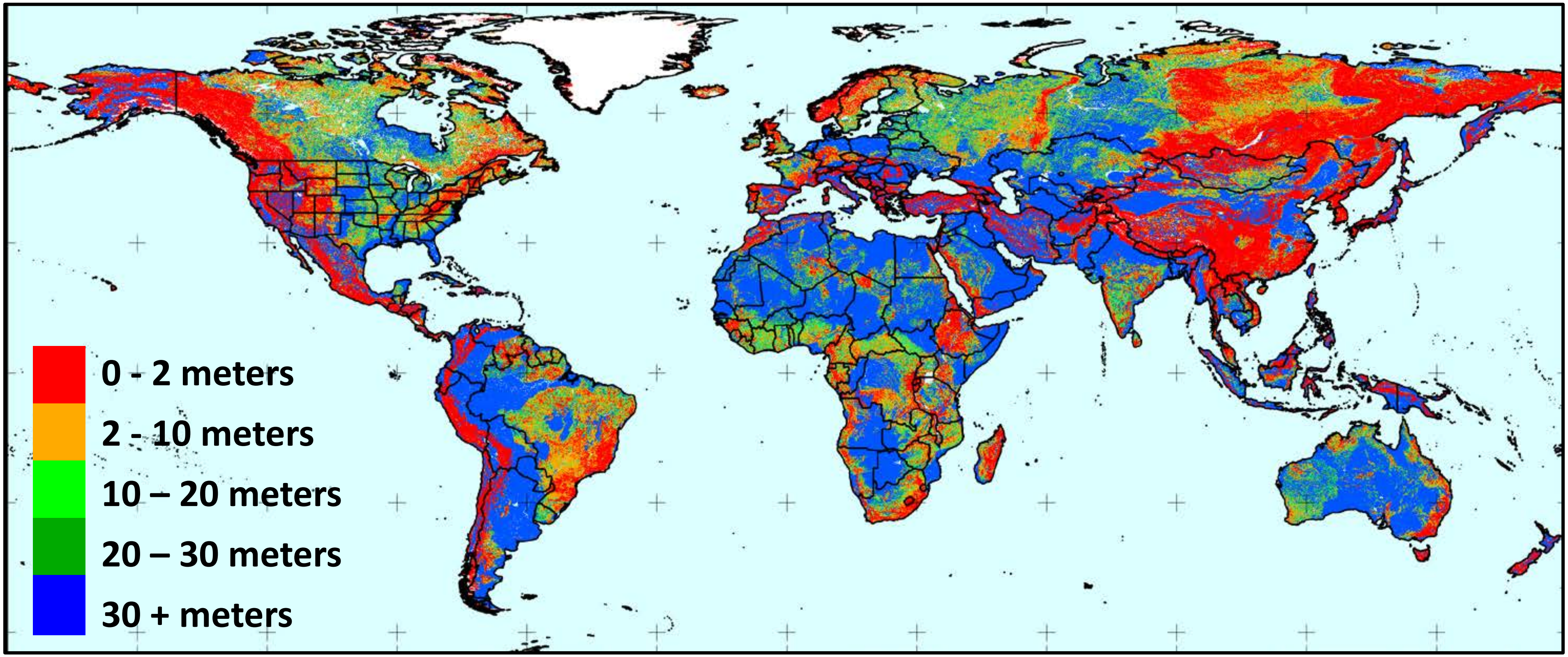
PRELIMINARY GLOBAL MAP OF SOIL THICKNESS ESTIMATES





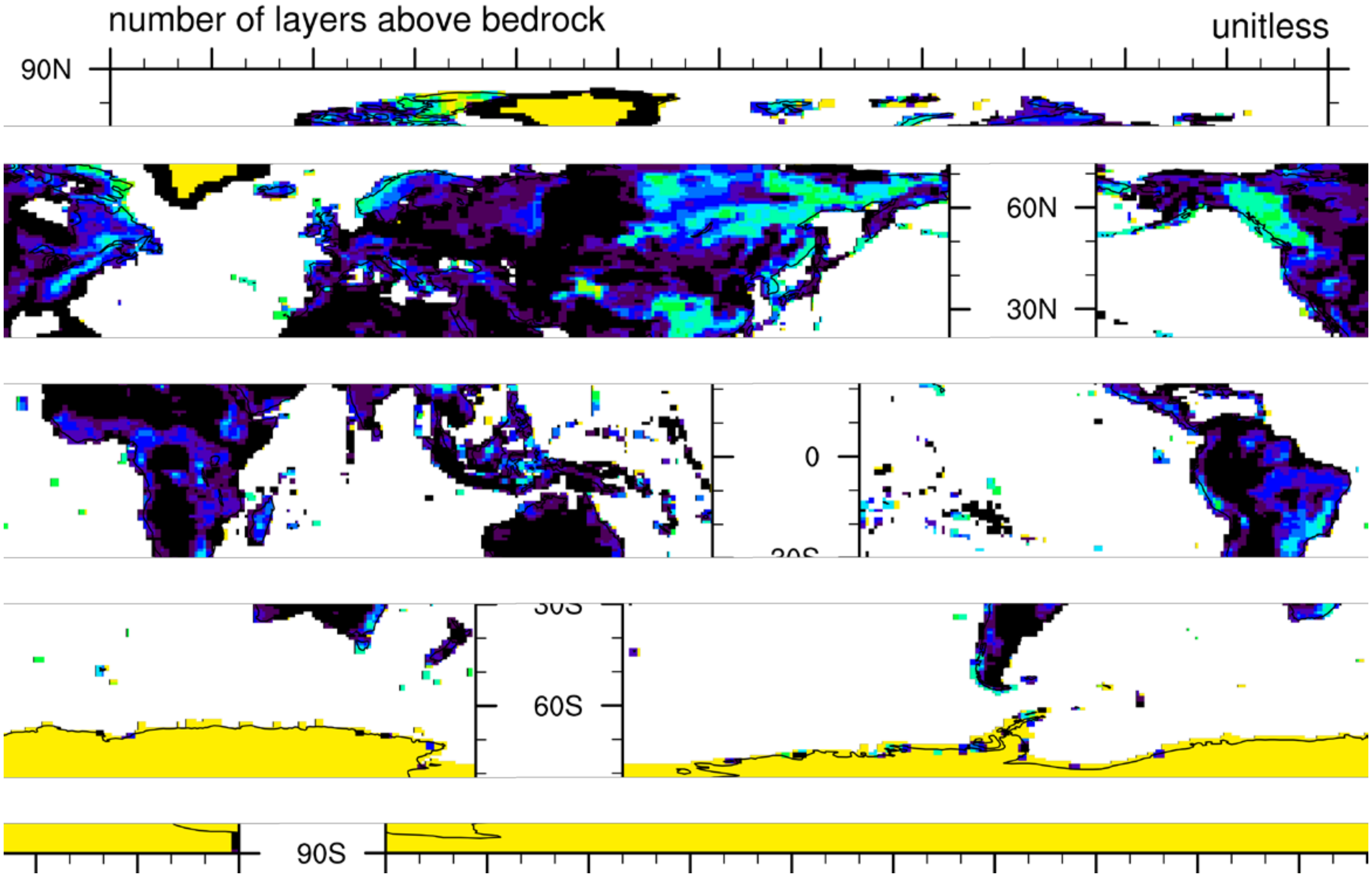


Overall Soil Thickness (dataset resolution: 30 arcsec)



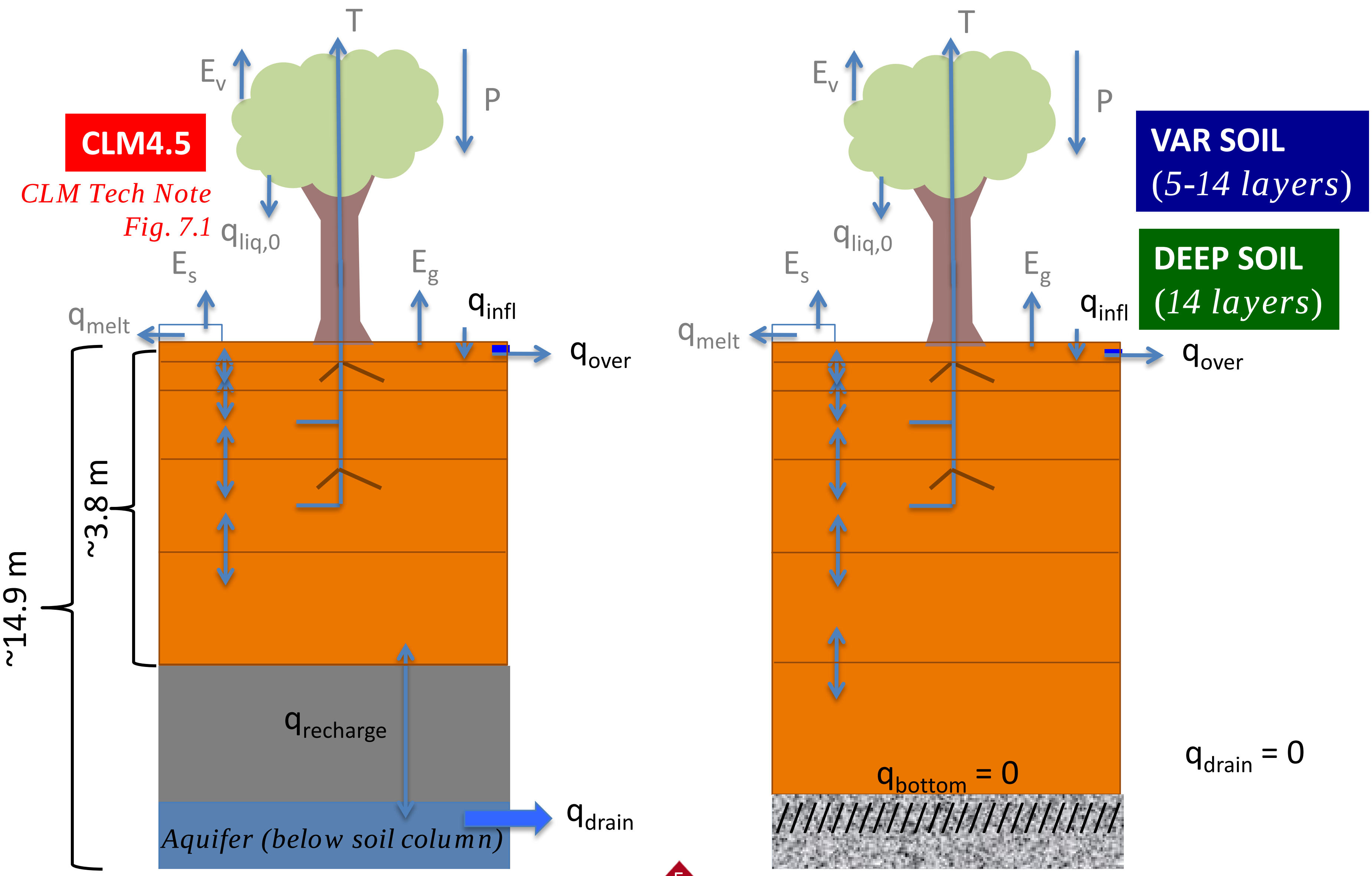
USING THE SOIL THICKNESS ESTIMATES IN THE MODEL

0.9°×1.25°

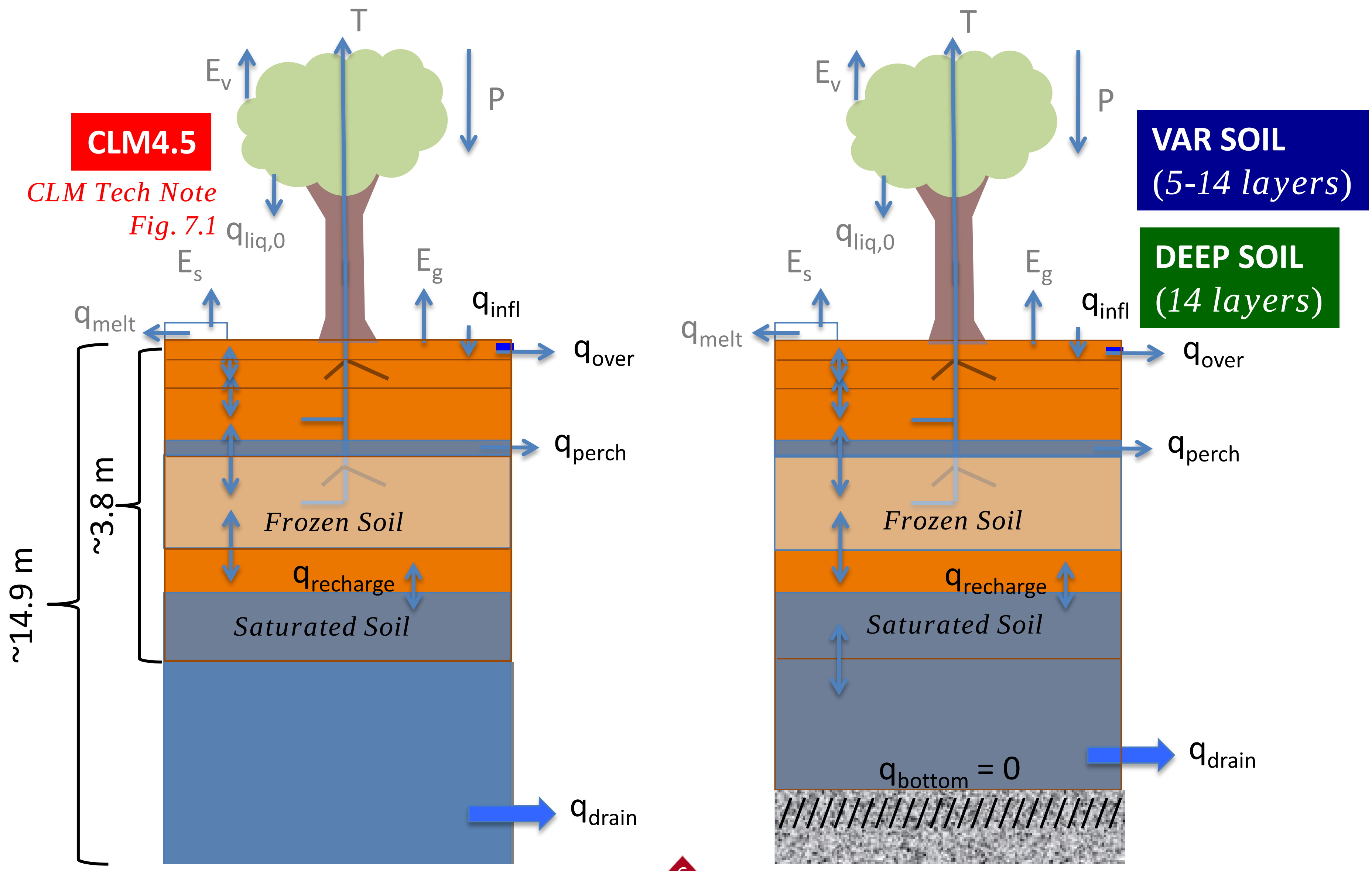


- The soil thickness map is used to determine how many CLM soil layers is needed for each grid cell.
- A minimum of 5 (0.3 m bottom) and a maximum of 14 layers (28 m bottom).

HOW THE MODEL IS CHANGED



HOW THE MODEL IS CHANGED

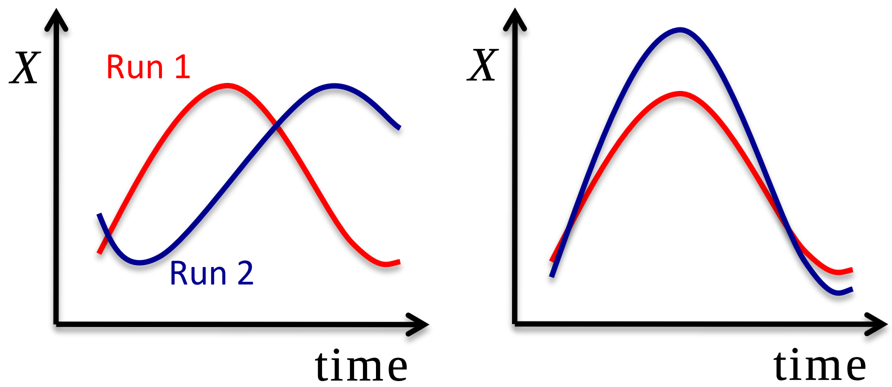


RESULTS

ANNUAL CYCLE CHANGES

$$\mathrm{MAR}(X) = \max(X) - \min(X)$$

$$\Delta\mathrm{MAR}(X) = \mathrm{MAR}(X_{\mathrm{Run\ 2}}) - \mathrm{MAR}(X_{\mathrm{Run\ 1}})$$



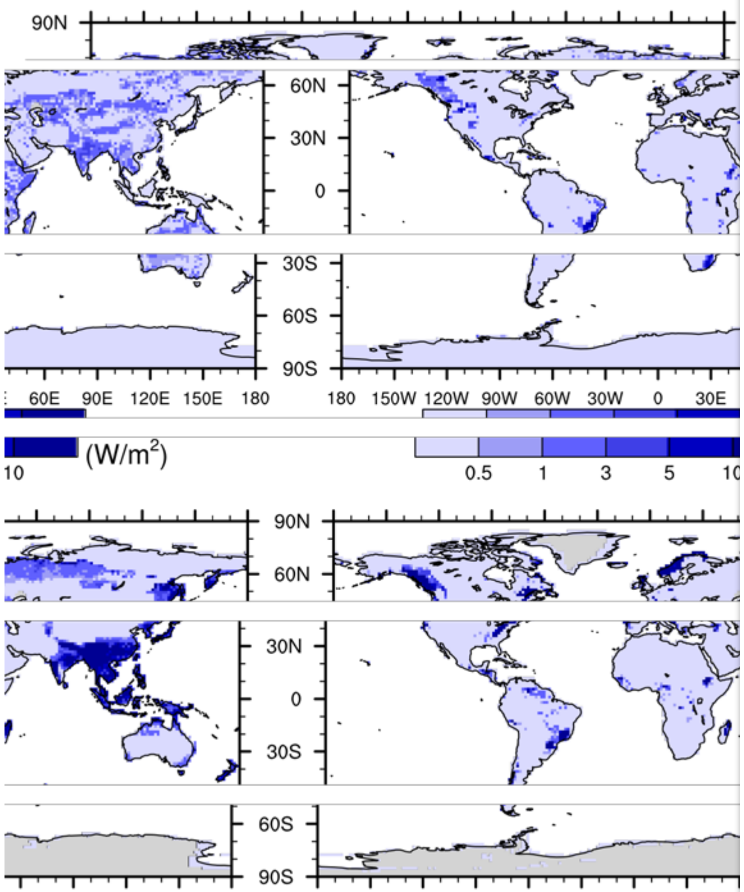
$$\mathrm{MAR}(\Delta X) = \mathrm{MAR}(X_{\mathrm{Run\ 2}} - X_{\mathrm{Run\ 1}})$$

RESULTS
ANNUAL CYCLE CHANGES

Mean ann. range in DEEP SOIL – CLM4.5

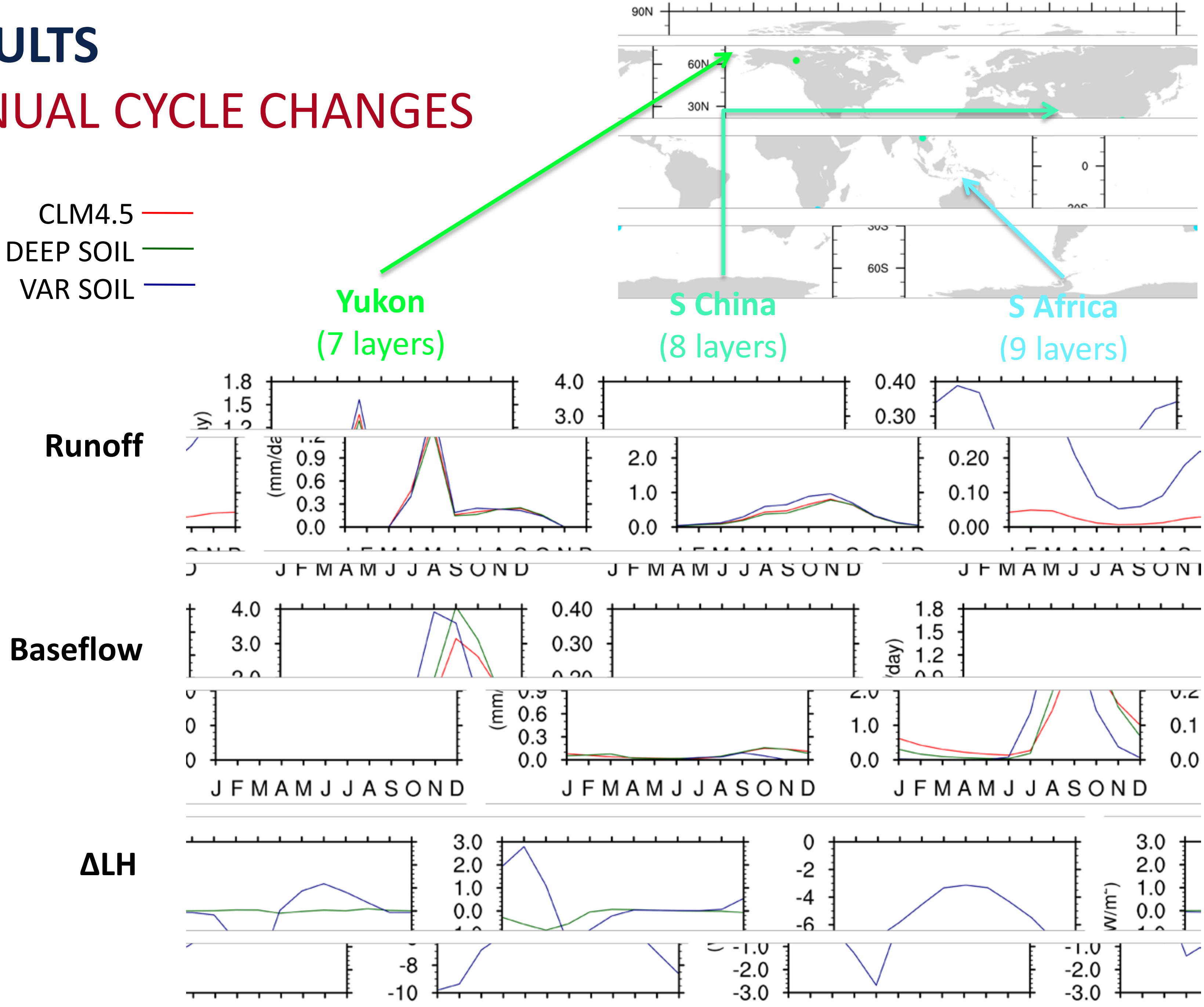
LH flux
amplitude

Baseflow
amplitude
phase shift



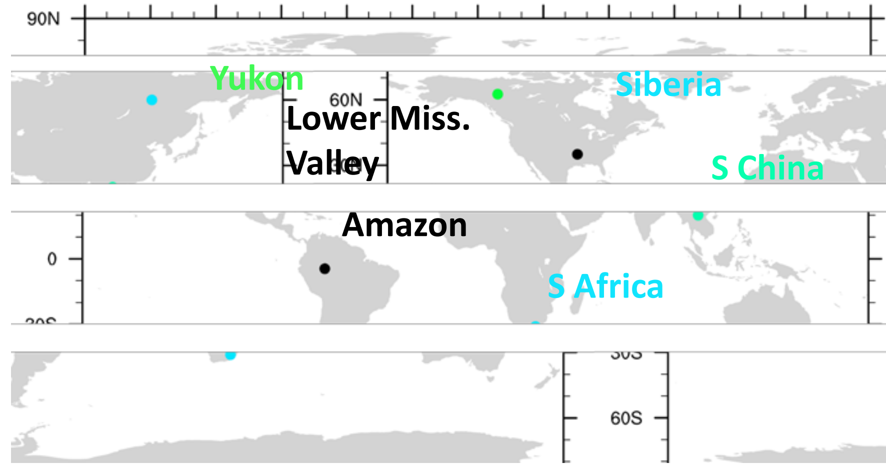
RESULTS

ANNUAL CYCLE CHANGES



RESULTS

MOISTURE PROFILE CHANGES



Yukon
(7 layers)

Siberia
(9 layers)

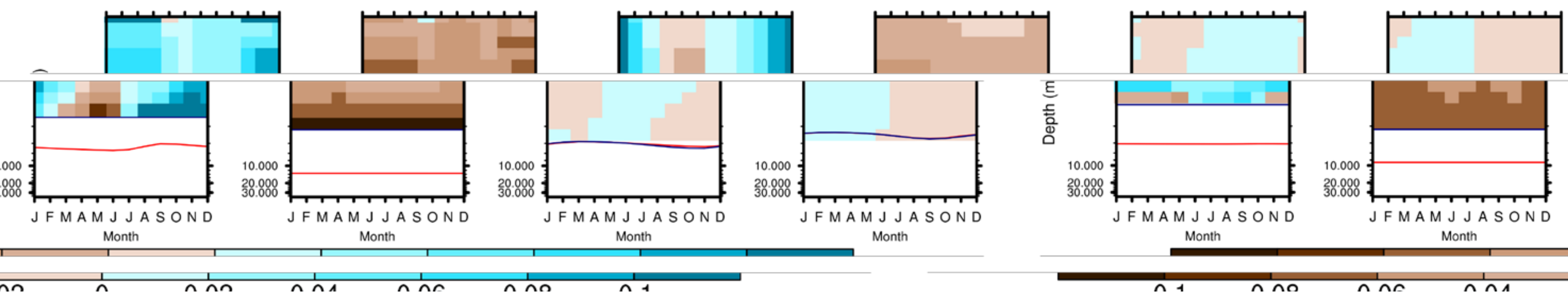
S China
(8 layers)

S Africa
(9 layers)

Lower Miss. Valley
(14 layers)

Amazon
(14 layers)

CHANGE IN SATURATION FRACTION (θ/θ_{sat}, contours, unitless)



Water table depth (m): CLM4.5 VAR SOIL

RESULTS

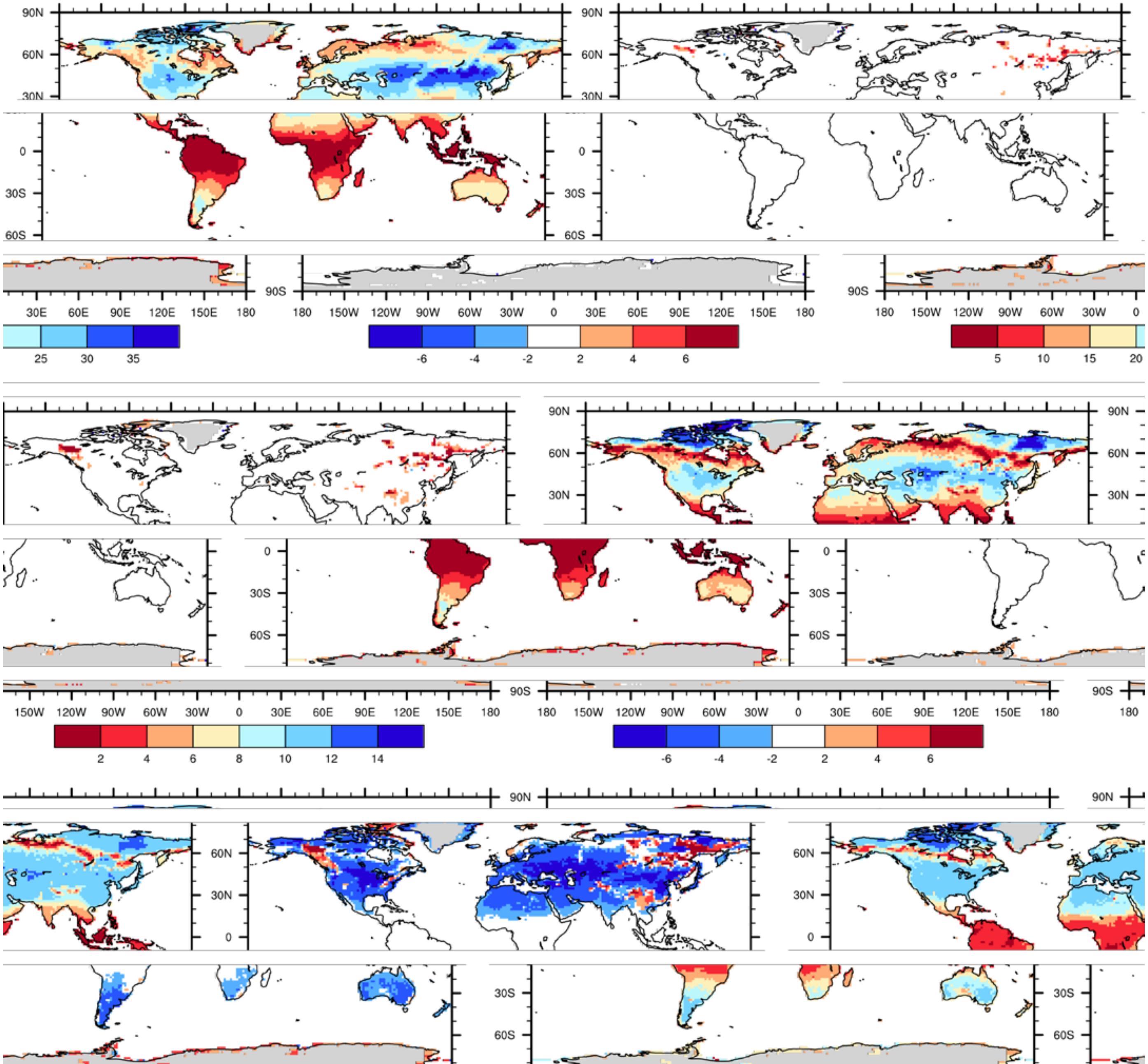
TEMP. PROFILE CHANGES

CLM4.5 | **VARSOIL – CLM4.5**

Layer 5 (~0.2 m)

Layer 10 (~3 m)

Layer 12 (~8 m)

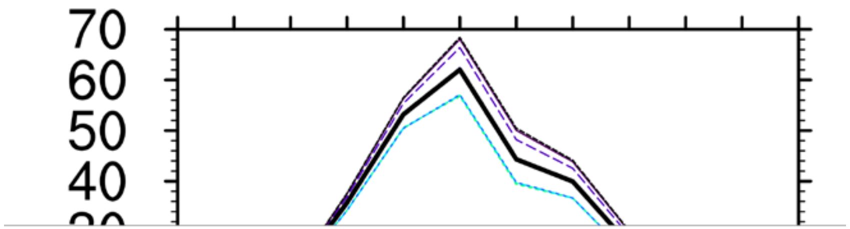


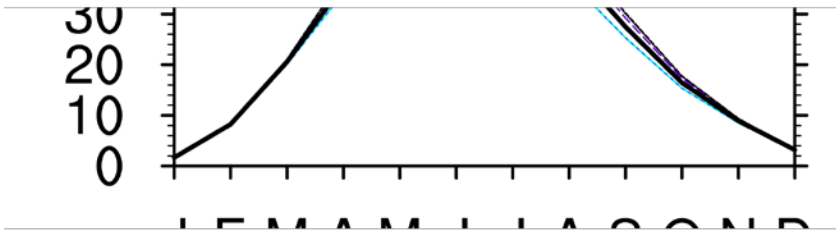
CONCLUSIONS

- Global ~1-km soil thickness data developed, included, and tested in CLM4.5 here:
  - Resolves inconsistencies in model.
  - Simulation is affected by change in bottom boundary, added to by variations in soil thickness when bedrock shallow.
  - Annual cycle changes mostly due to changes in amplitude for LH flux and runoff, mostly due to temporal phase shift for baseflow.
  - Moisture profile changes in shallow bedrock.
  - Temperature profile changes in mid- to high latitudes, shallow bedrock as well.
- ➡ Community involvement to fully assess impact of variable soil thickness.

A BETTER WAY TO REPRESENT VARIABLE SOIL THICKNESS?

LH flux (W m^{-2})



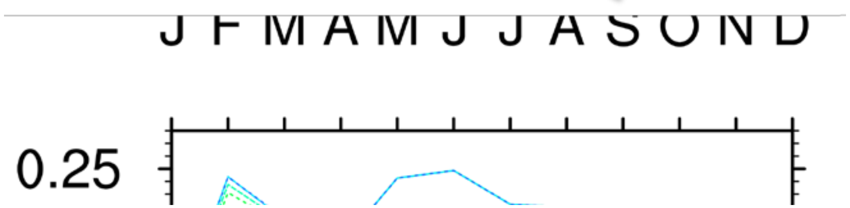


Color of thin lines corresponds to:

Runoff (mm day^{-1})

Area-weighted average

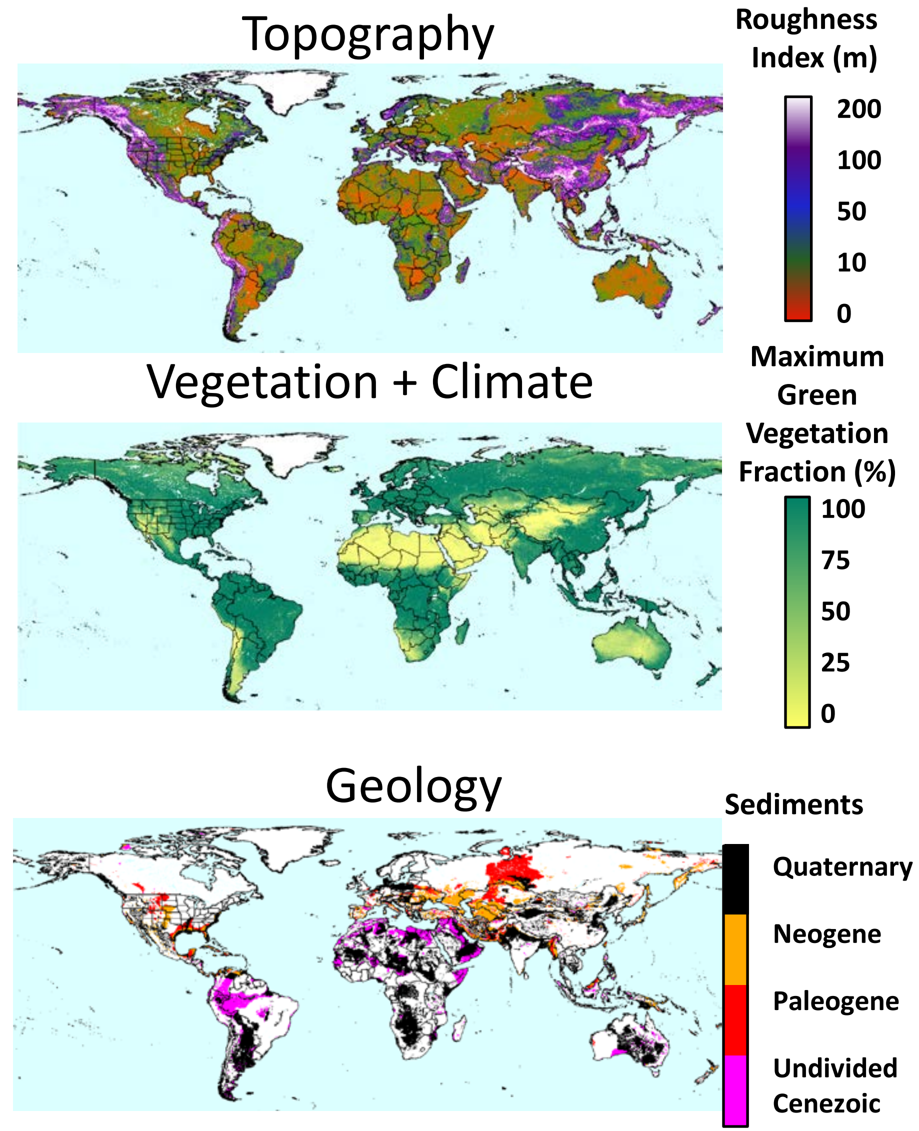
13 layers in VAR SOIL



GLOBAL SOIL THICKNESS ESTIMATES

- Estimate soil thickness(ST) globally (based on global topographic, vegetation/climate, and geologic data).
  - Topographic data has ~30 meter resolution, vegetation, climate, geologic information has ~1 km resolution
- Differentiate between soil depths in uplands vs. lowlands because:
  - Difference in soil depths.
  - Different data representative of different areas.

INPUT SPATIAL DATASETS

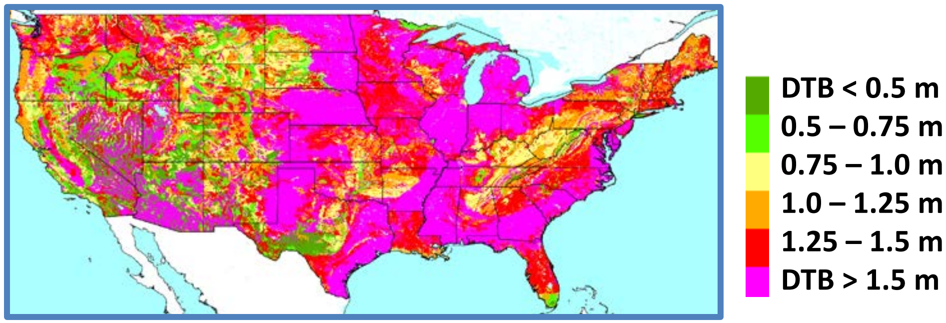


GLOBAL ST ESTIMATES

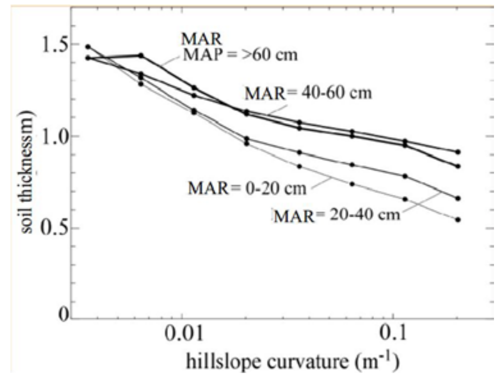
UPLAND ST MODEL

ST = *f*(topography, climate) (Pelletier and Rasmussen 2009)

Upland ST model is calibrated with STATSGO data in the US



Measured ST (from STATSGO data, Miller and White 1998)



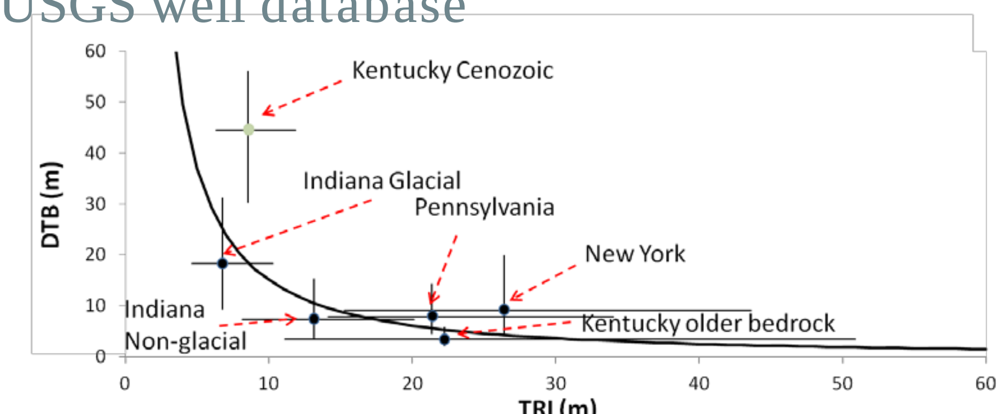
Mean soil depth vs. curvature on upland hillslopes

LOWLAND ST MODEL

ST = *f*(topography, geology)

Lowland ST model is calibrated with dense network of well data from four states and validated with national USGS well database

Locations of calibration wells in IN, KY, PA, and NY

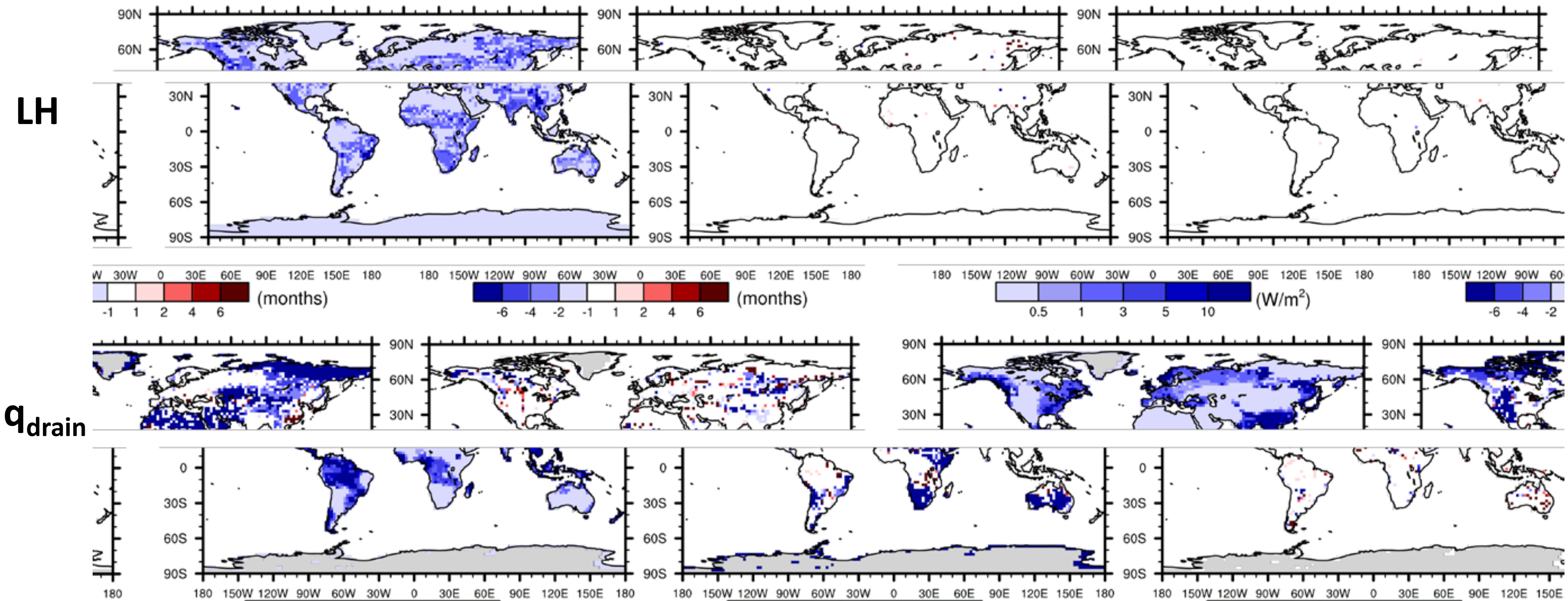


Relationship used to predict lowland ST (bedrock depth as a function of topographic roughness)

RESULTS

ANNUAL CYCLE CHANGES

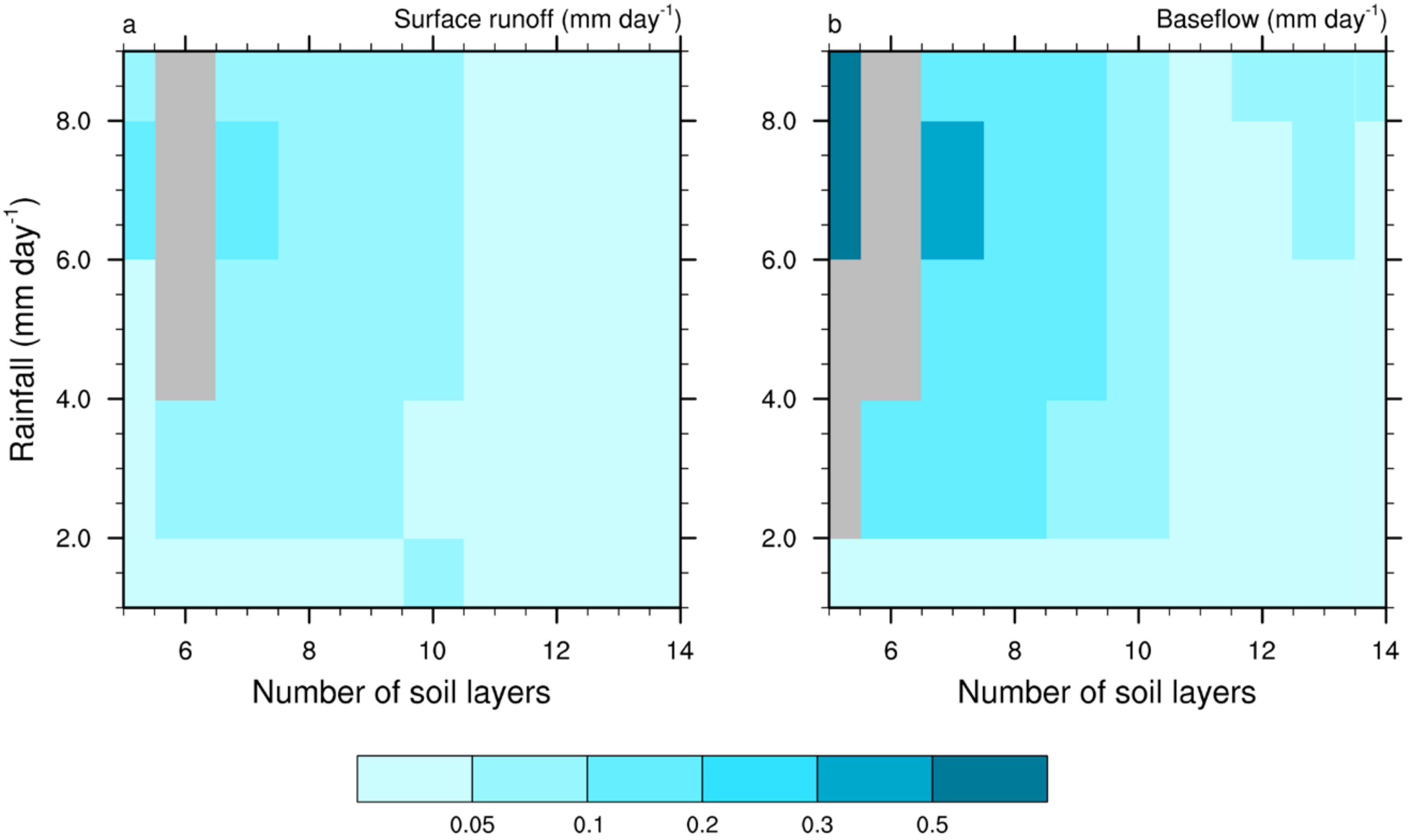
Mean ann. range in VAR SOIL - CONTROL	Change in month of min. VAR SOIL	Change in month of max. VAR SOIL



- Mean annual range in model difference represents amplitude and temporal phase shift.
- LH fluxes in VAR SOIL largely in phase with CONTROL.
- Much of baseflow changes due to bottom boundary.

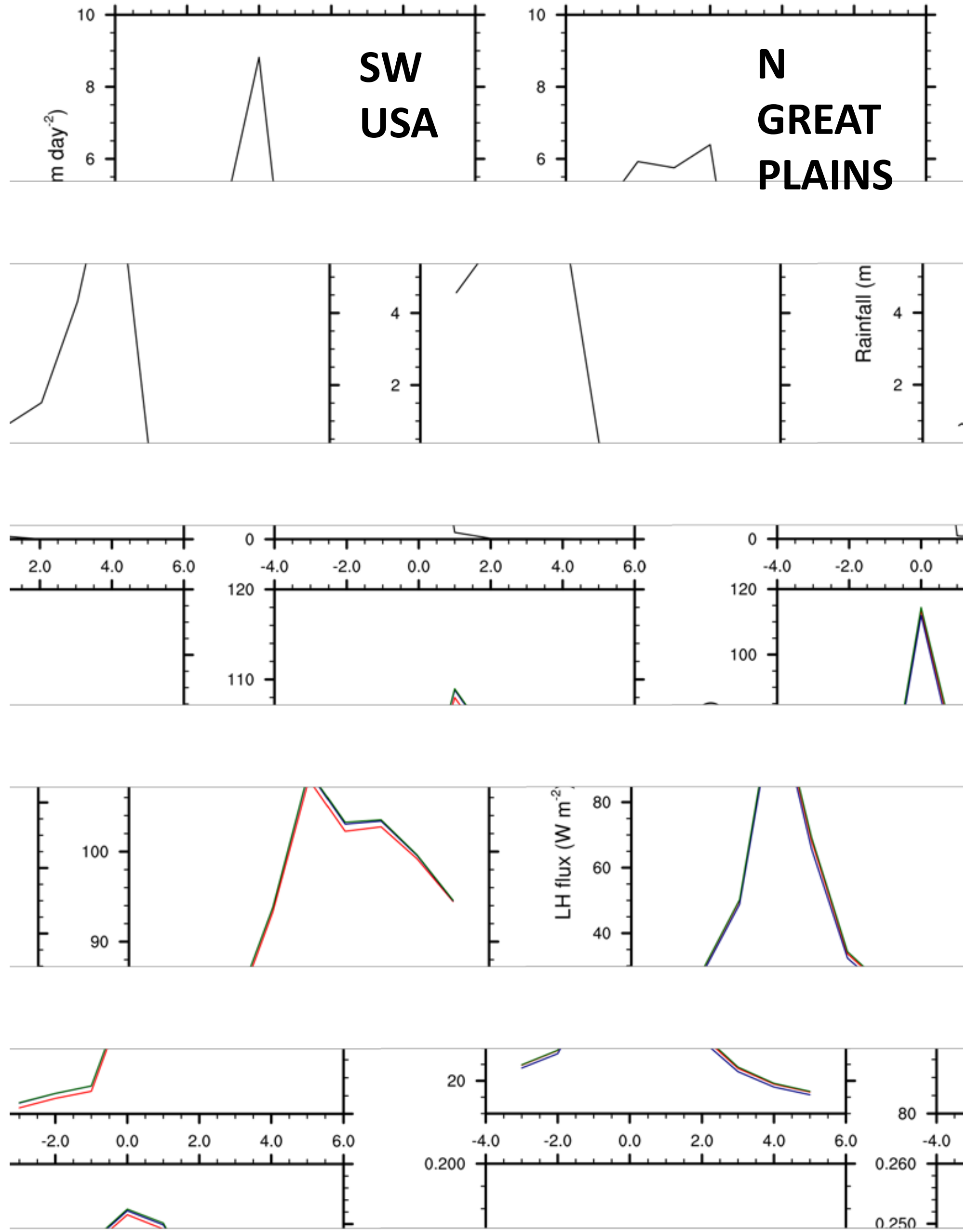
RESULTS

ANNUAL RMSDs



RESULTS

RESPONSE TO RAIN EVENTS



CLM4.5
DEEP SOIL
VAR SOIL

- LH flux slightly lower in VAR SOIL over SW US due to lower top soil moisture.
- Higher LH flux in DEEP and VAR SOIL over Plains forward of rain that returns to CLM4.5 values within 5 days.