

Increasing Soil Heat Storage Across Northern Eurasia

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Introduction

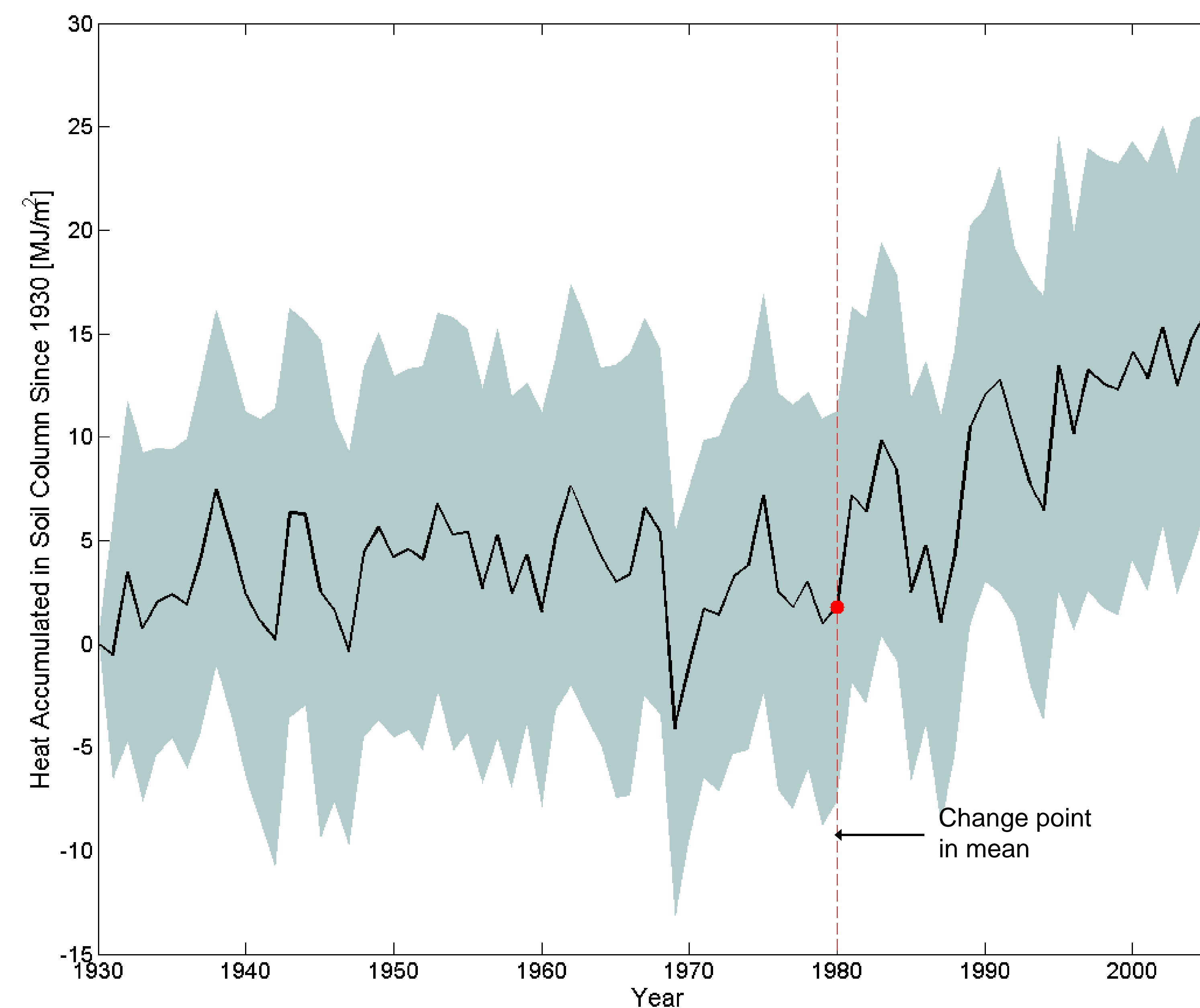
- During the 20th century, northern Eurasia has experienced a rate of warming greater than the global average, particularly in the winter.
- Although small compared to ocean heat storage, soil heat storage and its change is an important, understudied component in the global energy budget. It is also a more coherent climate change indicator than soil temperature trends, as it integrates the change in the entire soil column rather than specific depths.
- In permafrost regions, changes in soil heat states are important as this then has impacts on the hydrology and carbon storage in permafrost soils.

Observed Data for Validation

- Permafrost extent map from Brown et al. (1998)
- Historical soil temperature data from the NSIDC (Zhang et al. 2001), with 160 stations. Data extends from 1891 through 1990, with the largest coverage between 1960-1990. To validate, the model results for a station location are screened to only include months that have observed data at that station.
- Atmospheric forcing data from Sheffield et al. (2006). This is a 3-hourly dataset from 1901-2006 scaled to match monthly temperature and precipitation from the global CRU dataset.

Average Heat Accumulated Across Northern Eurasia

- Heat accumulated in top 6m soil column over the domain since 1930.
- Statistically significant change point in the mean exists at 1980, as is seen in the increase in accumulated heat after 1980.
- Heat accumulation is potentially underestimated in this figure because heat will propagate below 6m. However, information on soil properties for deep soils is lacking.

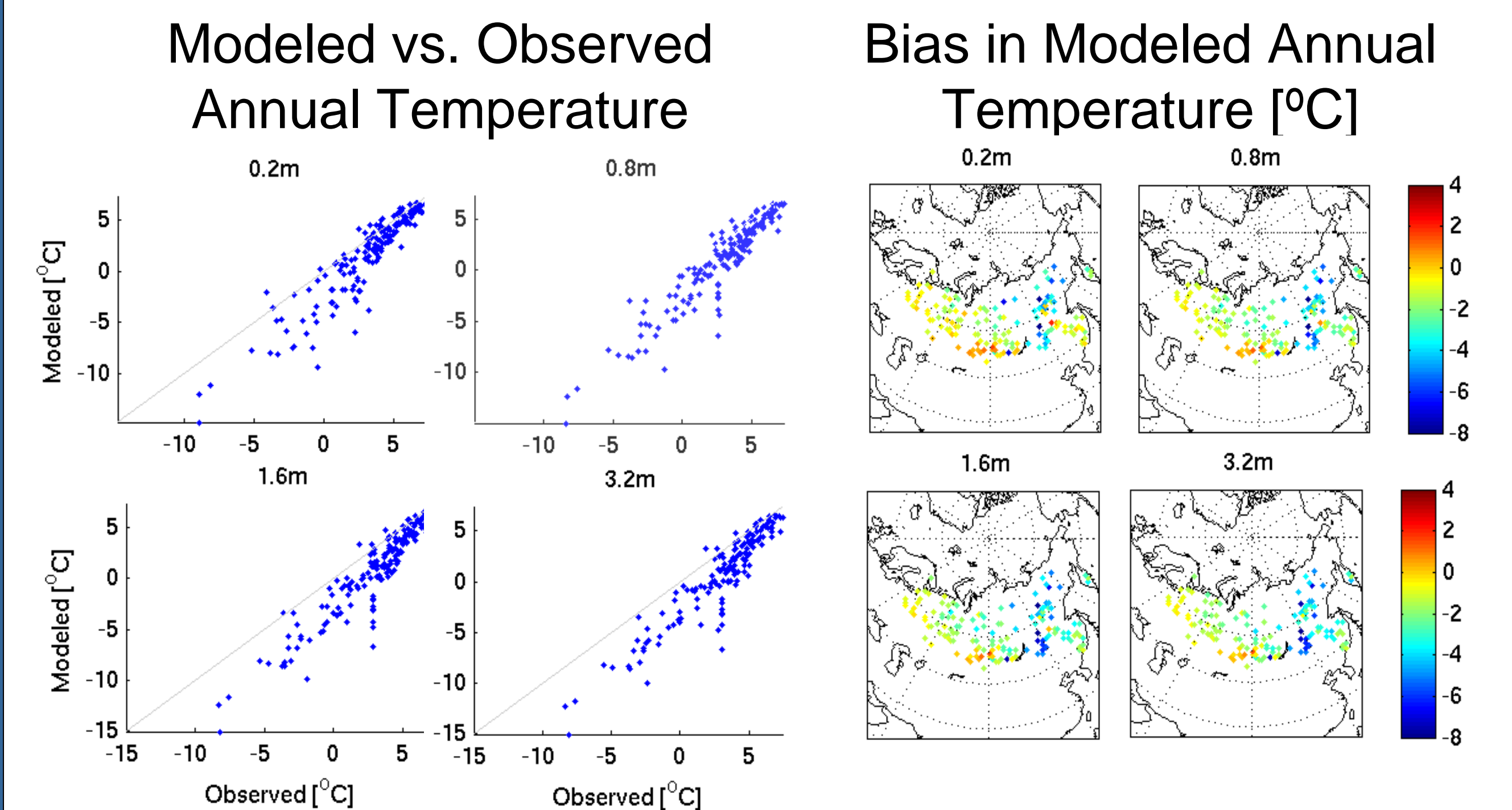


Permafrost Map

- Red line shows the modeled permafrost extent; permafrost is defined as a portion of the soil column continuously frozen for 24 months.
- The permafrost extent of Brown et al. (1997) is shown. Blue is continuous permafrost, green is discontinuous, and grey is isolated permafrost.

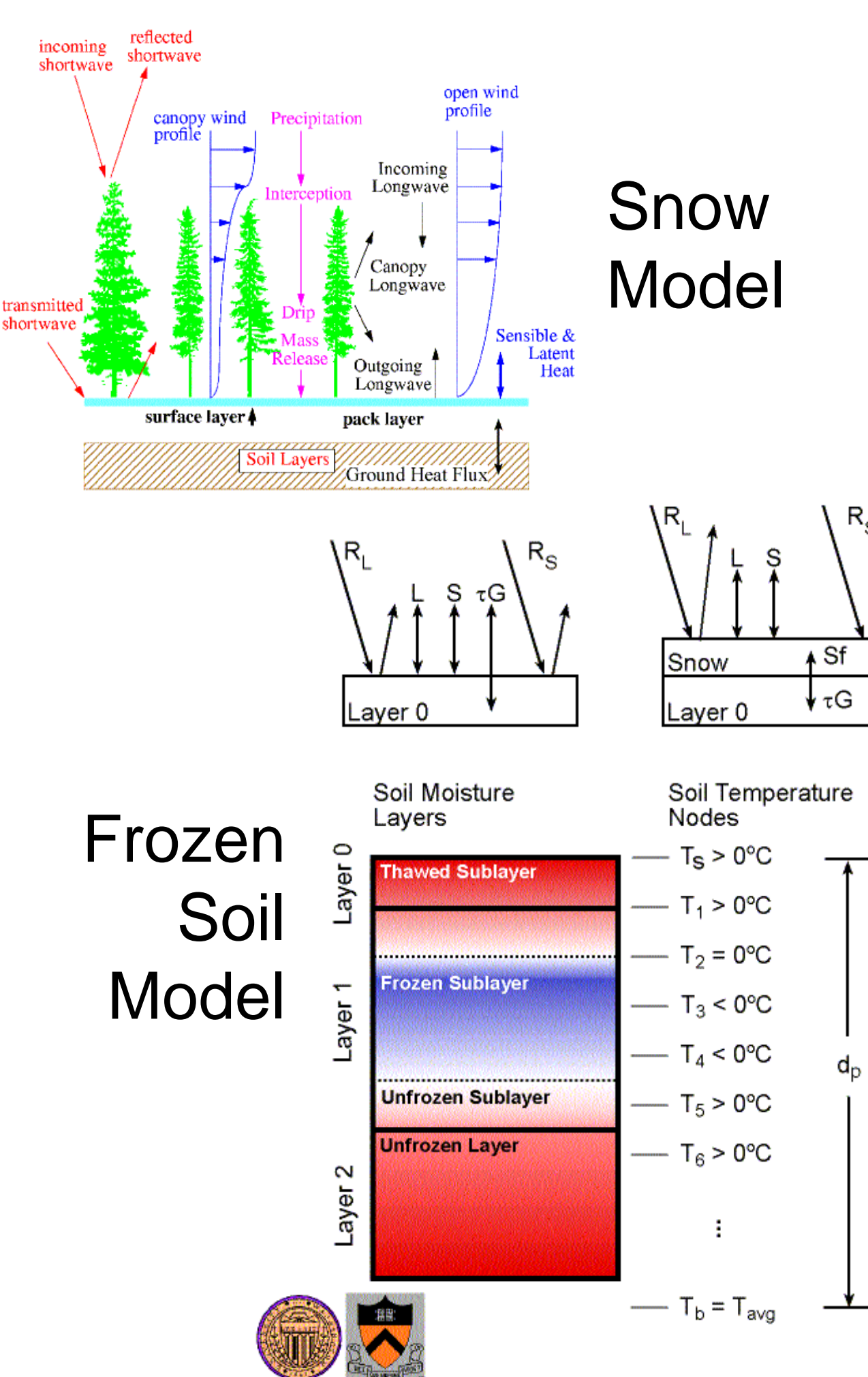


Modeled Temperature Validation



Land Surface Model

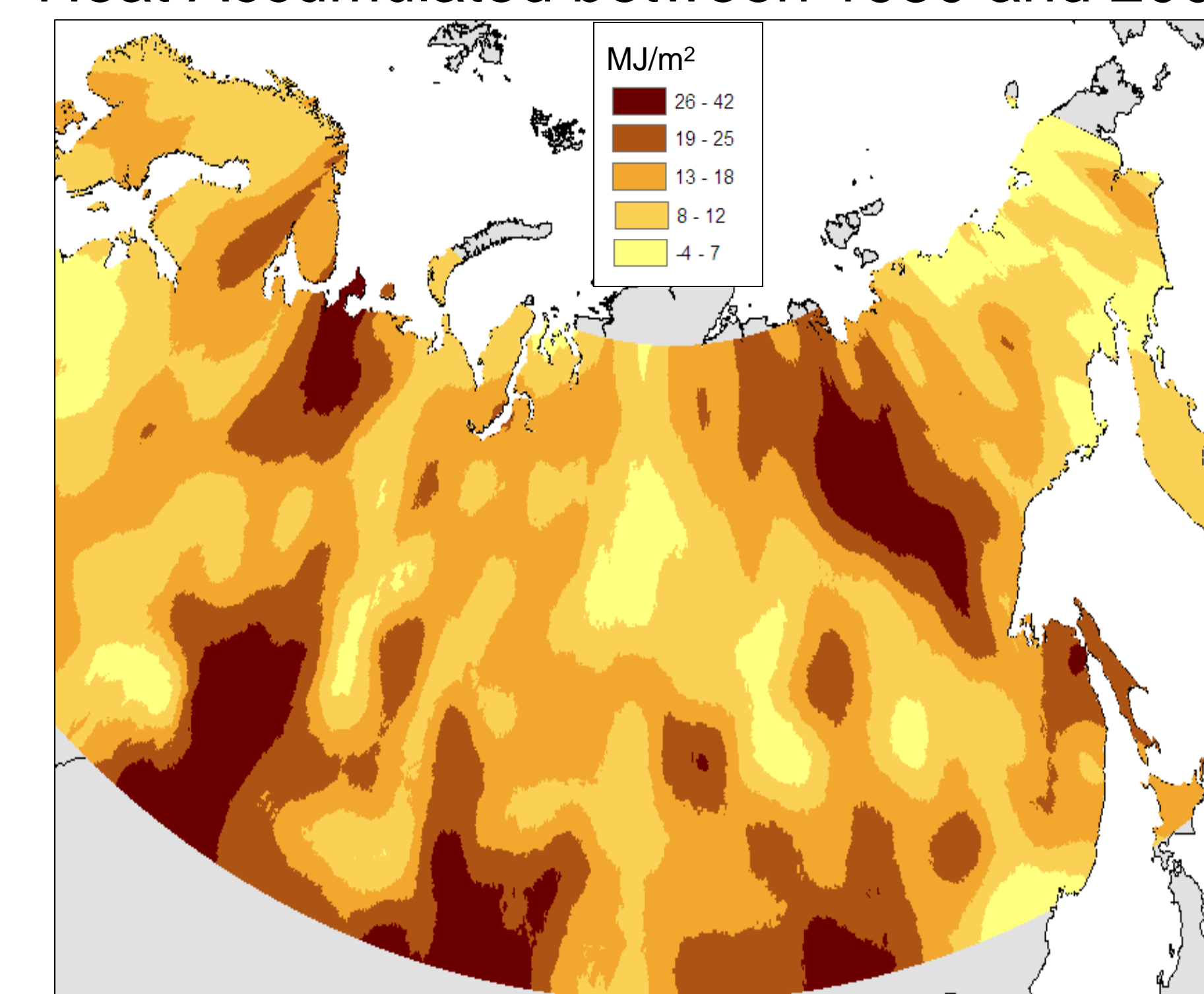
- The Variable Infiltration Capacity (VIC) land surface model (Liang et al., 1994, Cherkauer et al., 1999) was used to model the water and energy budgets of the land surface and soil column. The soil temperature solving scheme was improved for stability, and the results are validated here.
- Grid cells of 100x100km were modeled across northern Eurasia, forced by the interpolated dataset of Sheffield et al. (2006).
- The soil column is 50m deep with a no flux bottom boundary condition. A 500-year spin-up was performed.



Spatial Distribution of Heat Accumulation

- The zones with the greatest heat accumulation are the permafrost region and the area north of the Aral Sea.
- Model experiments were performed to isolate the dominant factor in the accumulation of heat. The snowpack appears to be the driving factor in the spatial pattern and temporal variation of soil heat storage.

Heat Accumulated between 1930 and 2006



Attribution and Conclusions

- The VIC model replicates the observed permafrost extent and matches observed temperature, with a cold bias in permafrost regions
- Northern Eurasia, as a region, is accumulating heat in the soil column, with an acceleration in the rate of soil heat accumulation after 1980.
- Winter precipitation and temperature changes appear to have the largest effects, based on model experiments in which specific forcings are allowed to vary while others are scaled to climatology. This is due to the interplay between the soil column and the snowpack.
- Further study is needed to fully understand the spatial patterns of heat accumulation.

Brown, J., Ferrans Jr., O.J., Heginbottom, J.A. and Meinkov, E.S., 1998. Circum-Arctic map of permafrost and ground-ice conditions. National Snow and Ice Data Center/World Data Center for Glaciology.
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