Observation and Analysis of the Zero-curtain Effect in Tiksi (Siberia).

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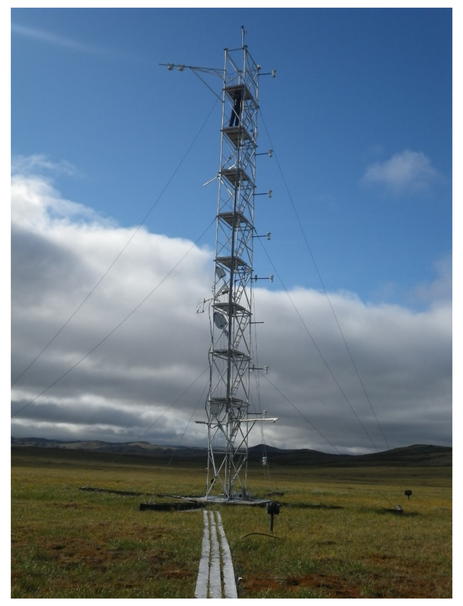
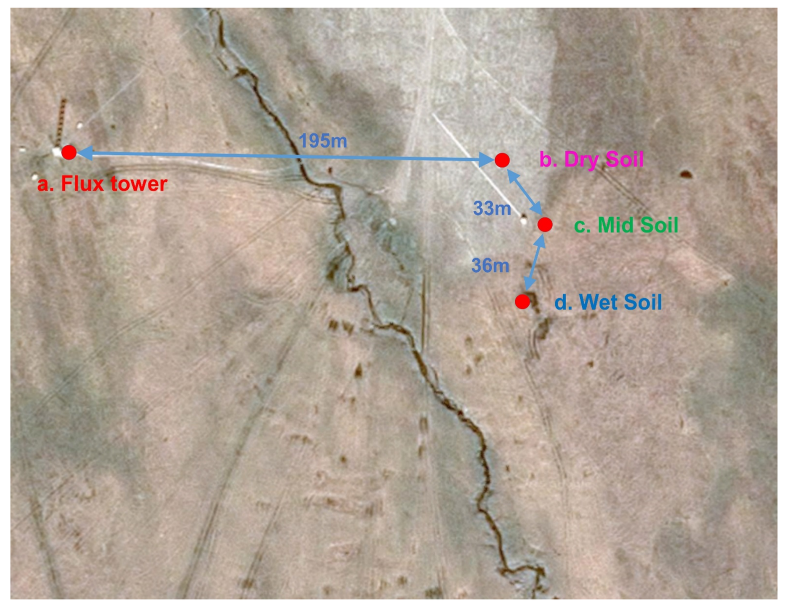
Tiksi Observatory

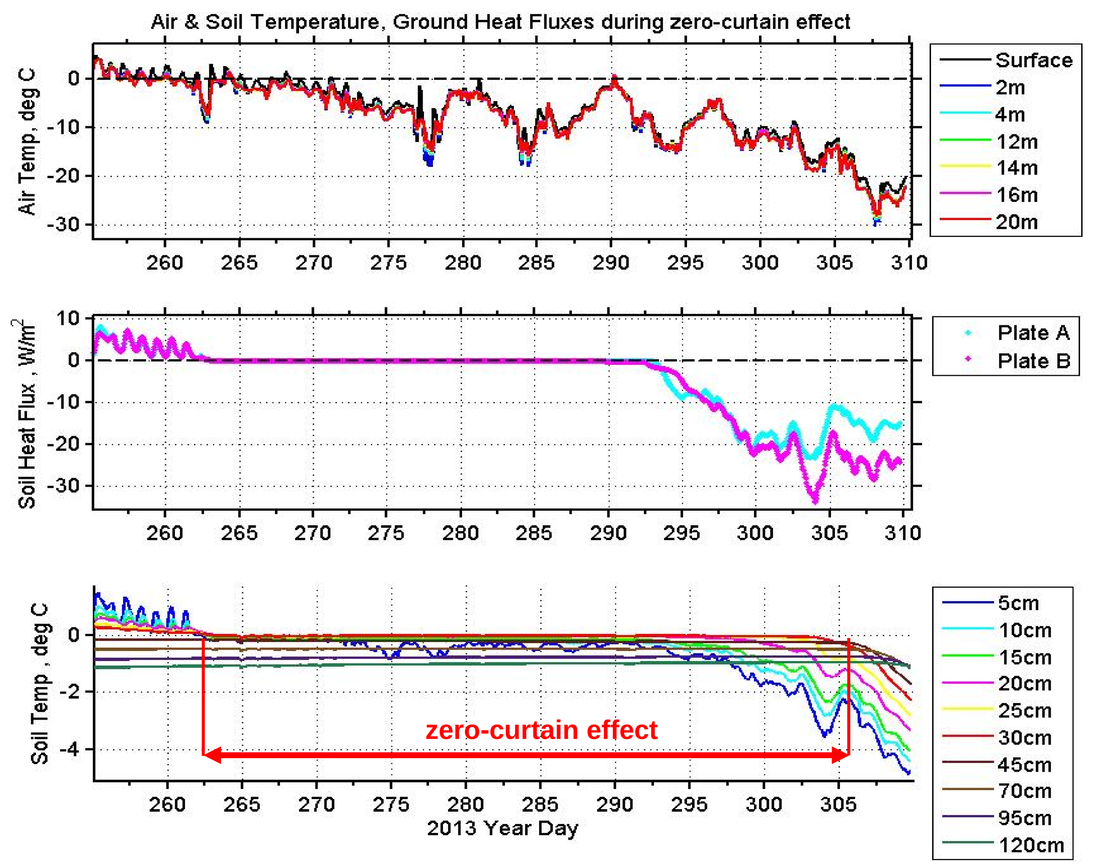




Russian Tiksi weather station located in East Siberia (71.6N, 128.9E) was established at the Polyarka settlement on August 12,1932 by the chief management of the northern sea route that began collecting geophysical data. The "Polyarka" observatory is located five miles out of town Tiksi. This is now the location for a new Intensive Arctic Observatory site representing a partnership between the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), and the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). This facility supports the research needs of the International community, across disciplines including supporting Global Atmosphere Watch measurements as well as other climate observations. A high priority has been placed on establishing Tiksi as a node for a number of global observation programs, and the science focus is on atmosphere-surface exchanges, radiation, aerosols, and climate grade meteorological measurements.

Zero-curtain Effect

a. Flux Tower Site



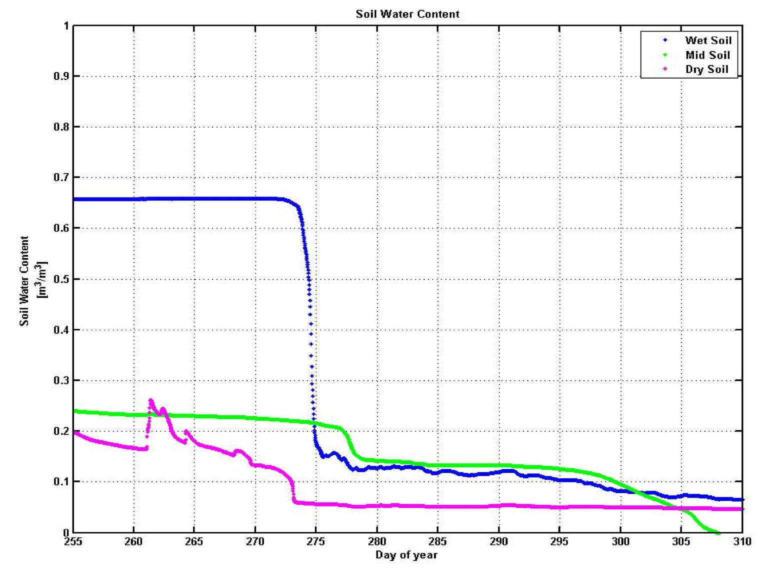
Release of latent heat associated with the freezing of pore water results in the maintenance of isothermal temperatures at or just below zero-degrees centigrade within the freezing active-layer. This period of isothermal conditions within the active layer, commonly termed the zero-curtain, is both a physical boundary preventing cooling in the underlying permafrost and a length of time (Outcalt et al. 1990). The zero curtain establishes in the active layer about the phase-equilibrium temperature and decouples the permafrost from the atmosphere for its duration (Osterkamp and Romanovsky 1997). Following the closure of the zero curtain temperature at the top of permafrost is permitted to decline at a rate governed by the thermal conductivity of the snow pack and the frozen active layer and the prevailing thermal gradient between the atmosphere and permafrost (Burn and Zhang 2009). The closure of the zero curtain, expressed by the decline in temperature at the top of permafrost, denotes the completion of active-layer freezeback and the onset of the cooling period (Burn and Zhang 2009; Karunaratne 2011). Given that the zero curtain is associated with latent heat released from water during soil freezing its development in dry material is not possible. This effect was described for the first time by Sumgin in Russian Arctic in 1940.

Abstract

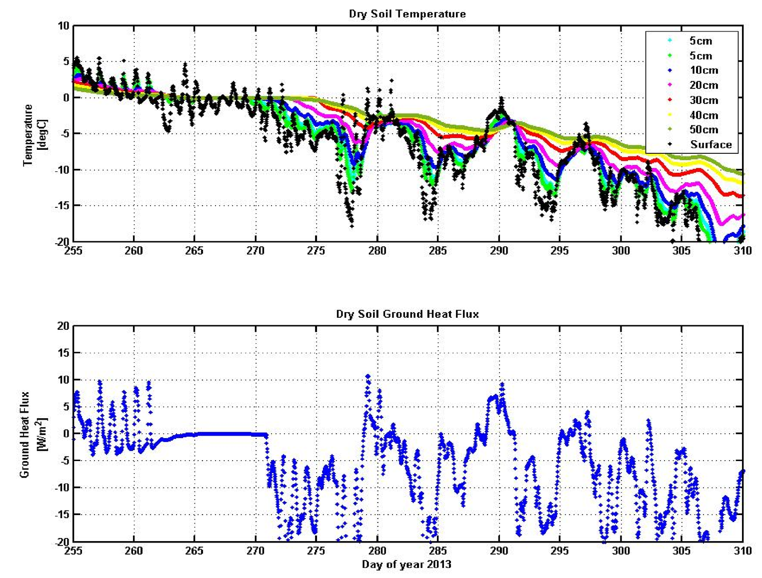
Surface-Atmosphere exchange mechanisms are critical to understanding changes in Arctic Environment.
Tiksi Arctic Observatory has a micrometeorological flux tower and is equipped with 5 surface heat flux plates, 2 active layer thermistor strings and several sets of soil temperature sensors in various closely spaced (30 m) locations. Because of the inhomogeneity of the surface in the vicinity of the tower, this placement of sensors allow comparison of the seasonally varying temperature structure for sites with different active layer moisture content.
In this study we focus on the fall freeze-up period beginning with the onset of continuous air freezing temperatures below 0C at the surface, followed by a zero curtain period, and ending with the declining temperatures at the top of the permafrost. The term zero curtain refers to the effects of latent heat maintaining soil temperatures near 0ºC over an extended period until freezing (or thawing) of the water in the active layer is complete.
We analyze the influence of morphological characteristics on the occurrence and duration of zero-curtain effect (such as active layer thickness and, soil water content) and the consequent spatial variation observed by the Tiksi sensors.

Sites with Different Soil Types

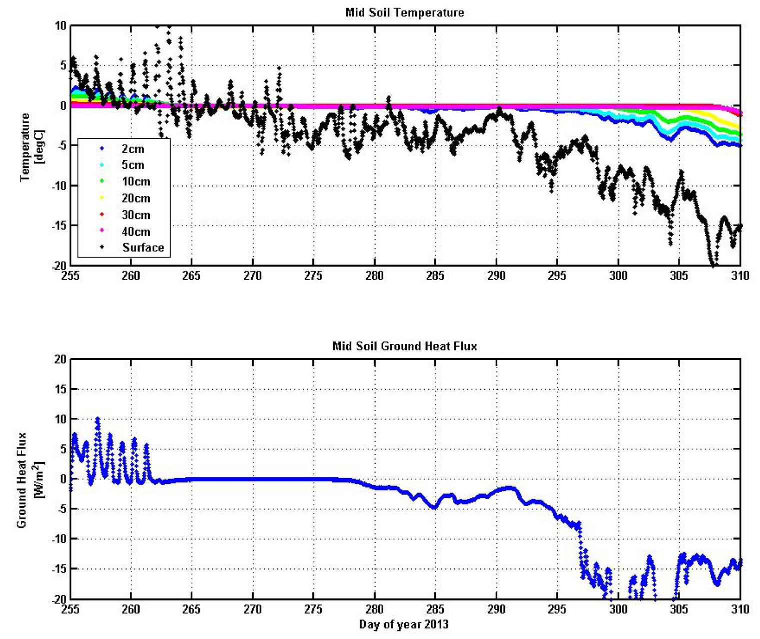
b, c, d Soil Water Content



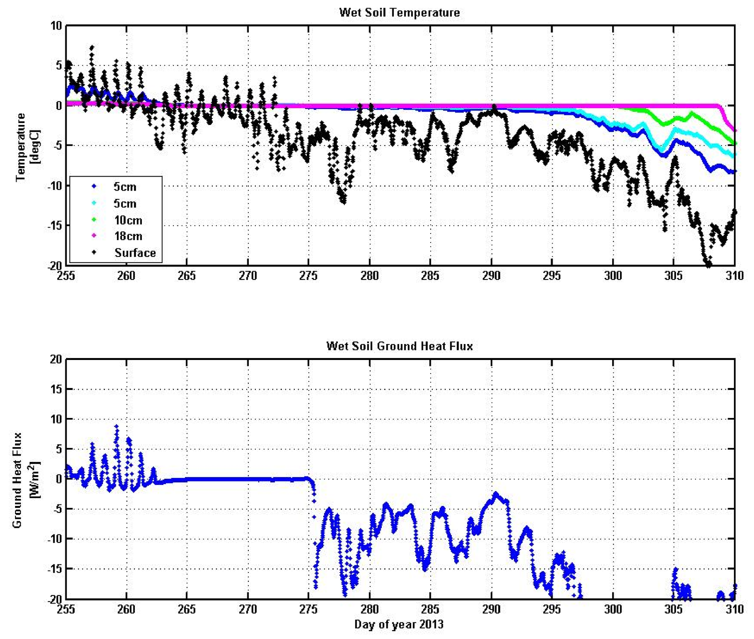
b. Dry Soil Site



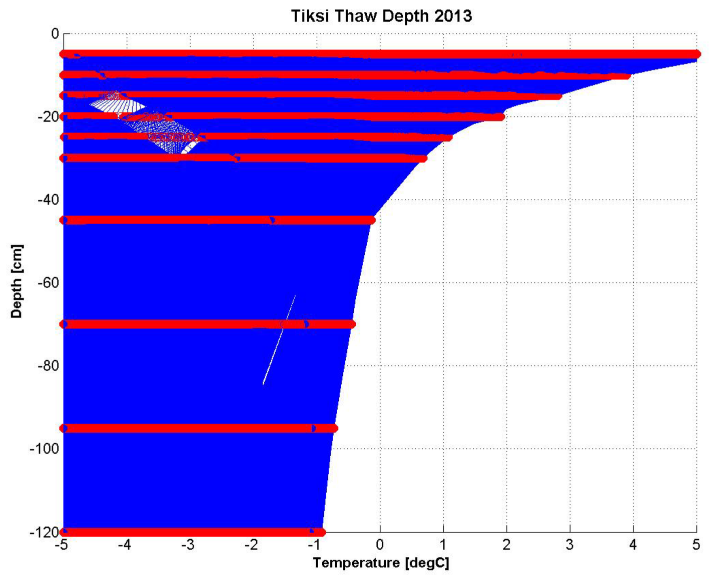
c. Mid Soil Site



d. Wet Soil Site

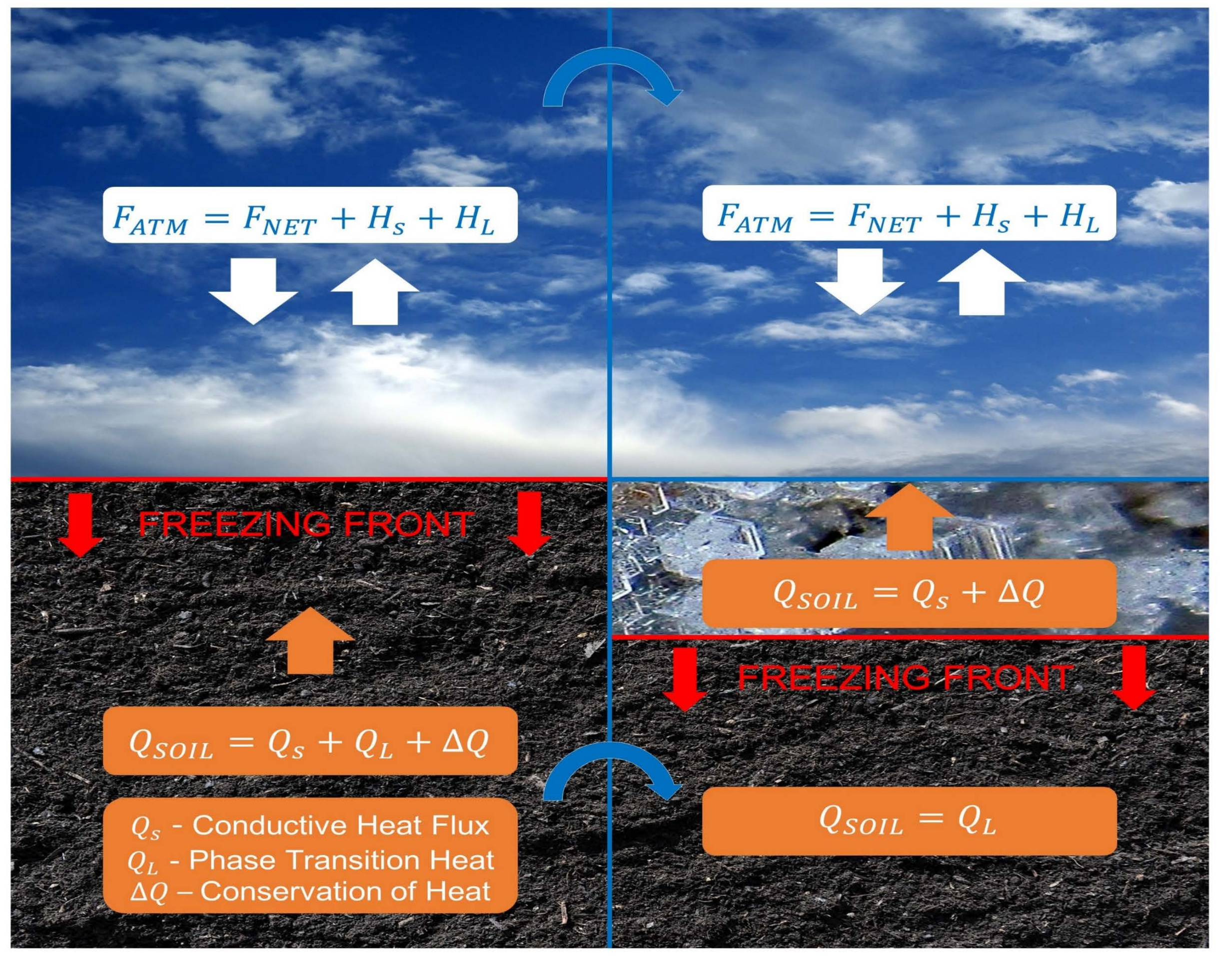


Active Layer Depth



One important variable that is being closely monitored on a circum-Arctic basis is the depth of the active layer of the permafrost. Active layer depth (ALD) is the depth to which thawing occurs each summer. Estimates are determined from temperature profiles as the deepest level that warms to 0ºC, before again refreezing. ALD is determined by finding the profile for the moment when soil temperature reaches its maximum for the year. The depth where soil reaches 0º and then begins to cool is the ALD for this year. Here is an example how this is accomplished using graphical interpolation. Although ALDs are determined to the nearest 1cm, profiles are not necessarily linear between 95 and 70 cm depth so there is an uncertainty that has not been quantified, but is considered small. Other years were analyzed consistently following this method. The results show that ALD stays the same over the years 2012-2014 at Flux tower and estimated at 43 cm. The soil temperature at wet, dry and mid soil sites were measured only within the active layer and are insufficient for ALD estimation. This ALD estimation method was suggested by Robert Stone.

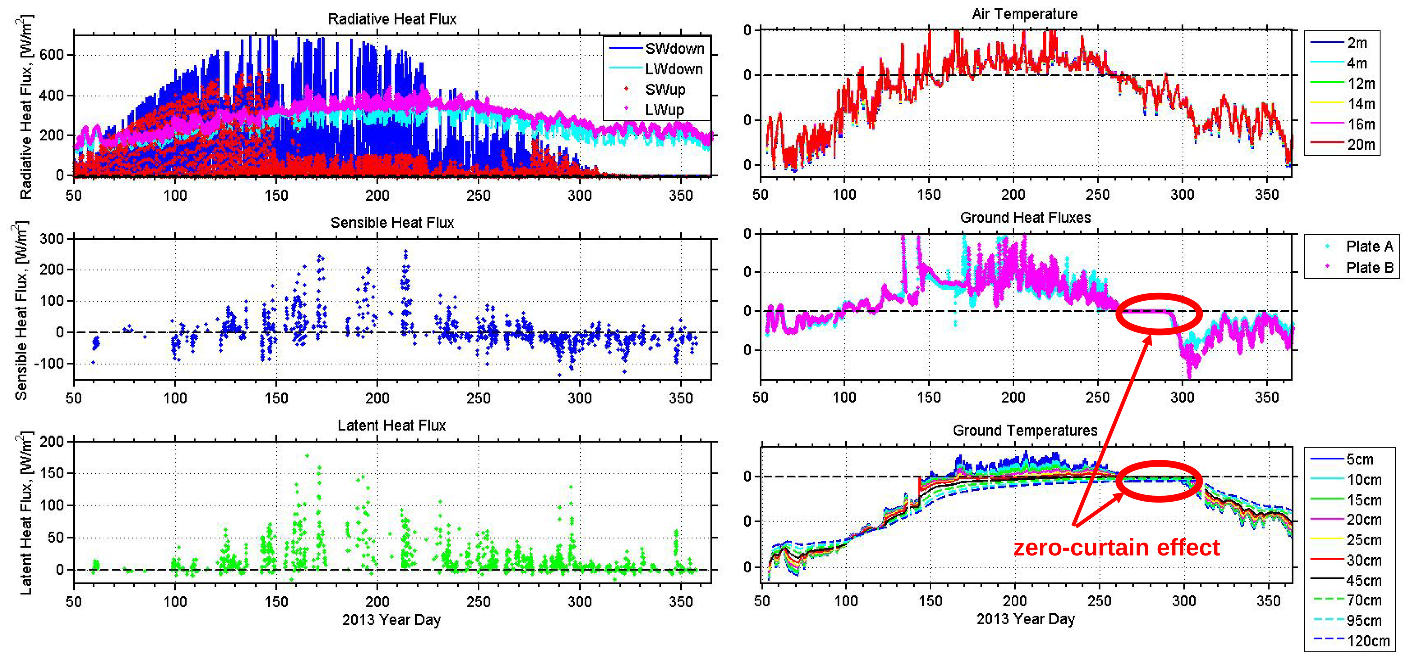
Heat Balance in Wet Soil



* one-dimensional energy balance

Annual Cycle

a. Flux Tower Site



Conclusions

- Zero-curtain effect was analyzed at 4 different sites in Tiksi during fall seasons in 2012-2014 with focus on September-October 2013. Soil water contents at these sites ranges from wet to dry depending on the site location.
- The duration of zero-curtain effect occurring in Tiksi at the 4 different locations varies from 25 to 50 days for different years. Its onset depends on the air temperature falling below 0ºC. Its duration depends on the soil water content of the specific area.
- Our study shows that Tiksi Observatory Site is horizontally inhomogeneous containing 10% dry soil and 90% wet soil regions. Depending on the soil water content different regions create different impact to the energy budget.
- Our measurements show that surface ("skin") temperature follows the air temperature profile rather than soil temperature, that is, its dependence on soil type and water content is weak. In other words, the zero-curtain effect has a weak impact on the skin temperature. This result is important for atmospheric models and bulk flux parameterization. However, the zero-curtain effect creates substantial vertical and horizontal temperature gradients in upper soil layers during transition seasons.