Abstract

Changes in the terrestrial hydrologic cycle in northern watersheds can be seen through permafrost warming. Furthermore, vegetation shifts occur with climate changes coupled with permafrost degradation. Permafrost warming is resultant from warming air temperatures and the accumulation of buffers between the atmosphere and the top of the permafrost: the active layer, snow, and vegetation. In this study, we apply the Temperature at the Top of the Permafrost model (TTOP) to examine the present and future thermal stability of permafrost and changing surface in 1 km² resolution in the 847,642 km² Yukon River watershed. In order to achieve this, we utilized output products from MicroMet and Snow Model. MicroMet is a quasi-physically based model for interpolating between air temperature measurement/climate product point locations using known temperature-elevation, wind-topography, humidity-cloudiness and radiation-cloud-topography relationships. SnowModel is a snow evolution model for generating, transporting, intercepting, sublimating, and melting snow. From these models, we generate 1 km² air temperature and snow depth rasters. The air temperature raster is then converted into freezing and thawing degree-day indices. We use the snow depth raster and a 1 km² vegetation product in conjunction with winter and summer n-factor literature values. We combined a 1 km² soils product indicating classification with a soil database indicating horizonation in order to calculate frozen and thawed thermal conductivity values. These values become the inputs into TTOP. TTOP, air temperature is related to soil surface temperature, buffered by vegetation and snow, and the resultant heat is then propagated through the horizontal of the active layer. Present compared with future top of the permafrost/ base of the active layer temperatures indicate areas of vulnerable and degrading permafrost. In future research, in order to study the changing surface we will focus on warming permafrost and ground water discharge and recharge locations.

Location

847,642 km² Yukon River watershed

Permafrost

Climate warming, changes in vegetation, thicker snow cover, and lag time experienced from earlier climate warming have warmed continuous permafrost ~2-3 °C since about the 1980s in northern Alaska, 0.6-0.7 °C in northern Russia during 1970-1990, and discontinuous permafrost 1-1.5 °C in the late 1980s-early 1990s in Interior Alaska (Hinzman et al., 2005; Romanovsky and Osterkamp, 1997; Osterkamp, 2003; Servais et al., 2006; Romanovsky and Osterkamp, 1999). The most thermally sensitive permafrost cases are warm and relic permafrost (permafrost existing in areas where permafrost can not form under present climatic conditions) (Lunardini, 1996).

Tools for the Job

1. Air
2. Snow
3. Vegetation
4. Active Layer

Expected Products

• Three 1 km² raster products:
  - Present (1997-2007) top of the permafrost temperatures
  - Future (2090-2100) top of the permafrost temperatures
  - Calculated, indexed temperature difference (future-present) showing a range of stable to mild to severe risk permafrost

Discussion

Locations where groundwater is discharging or recharging and where permafrost is at risk for thawing are potential locations where the surface will be wetter or drier in the future. We have seen examples on the landscape where increased ponding or drying has occurred due to permafrost degradation. Other intensifications/ reductions of the northern hydrologic cycle should also be considered to evaluate land surface change.

Changing Surface

In the Tanana Flats, near Fairbanks, Alaska, birch and spruce forests are being converted into minerotrophic floating mat forests with open water corridors. Permafrost was estimated to underlie 54% of the 260,000 ha area a century or more ago. The Tanana Flats, now described as groundwater-discharge wetlands, are fed by springs that upwell through taliks or un frozen areas in the permafrost. This is evidenced by cold (less than 5 °C) water (mud volcanoes) and winter icing (taigia). Similar areas have been observed by Kane and Slaughter (1973) (Isabella Creek Lake near Fairbanks) and Van Rijnsoever (1988) (perennial present all seasons of the year) springs in peatlands on alluvial and glacio-fluvial fans near the Alaska-Yukon border (Racine and Walters, 1994; Hizmann, 2005).

Although, Racine and Walters (1984) observe that most wetlands documented in the discontinuous permafrost regions of Alaska are ombrotrophic peatlands (bogs) whose water source is solely precipitation.

References

Hinzman et al., 2005. Evidence and Implications of Recent Climate Change in Northern Alaska and other Arctic Regions, Climatic Change, 72, 251-298.
Serreze et al., 2000. Observational Evidence of Recent Change in the Northern High-Latitude Environment, Climatic Change, 46, 159-207.