# STATE OF THE CLIMATE IN 2018

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# STATE OF THE CLIMATE IN 2018

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*f. Terrestrial permafrost*—V. E. Romanovsky, S. L. Smith, K. Isaksen, N. I. Shiklomanov, D. A. Streletskiy, A. L. Kholodov, H. H. Christiansen, D. S. Drozdov, G. V. Malkova, and S. S. Marchenko

Permafrost is an important component of the Arctic region, influencing landscapes, hydrological systems, and ecosystems, and presenting challenges for built infrastructure, e.g., buildings, roads, railways, airports, and pipelines (Sidebar 5.2). Permafrost is earth materials, such as soil, rock, and ground ice, that exist at or below 0°C continuously for at least two consecutive years. The active layer is the seasonally thawed layer above the permafrost. Permafrost temperature and active layer thickness (ALT) are key indicators of changes in permafrost conditions. Permafrost temperatures, at a depth where seasonal temperature variations are negligible, are powerful indicators of long-term change. On the other hand, the active layer responds to shorter term fluctuations in climate and is especially sensitive to changes in summer air temperature and precipitation.

Recent long-term changes in permafrost temperature are driven mostly by air temperature trends (Romanovsky et al. 2017). In general, the increase in permafrost temperatures observed since the 1980s is more significant in the higher latitudes and colder permafrost, where the largest increase in air temperature is observed (Fig. 5.16). Other important influences on permafrost temperatures and trends at local scales include snow depth, density, and timing; vegetation characteristics; and soil moisture. Here, changes in mean annual permafrost temperatures and ALT through 2018 are summarized for a number of sites throughout the Arctic (Fig. 5.16). Table 5.1 summarizes the rate of change for each region.

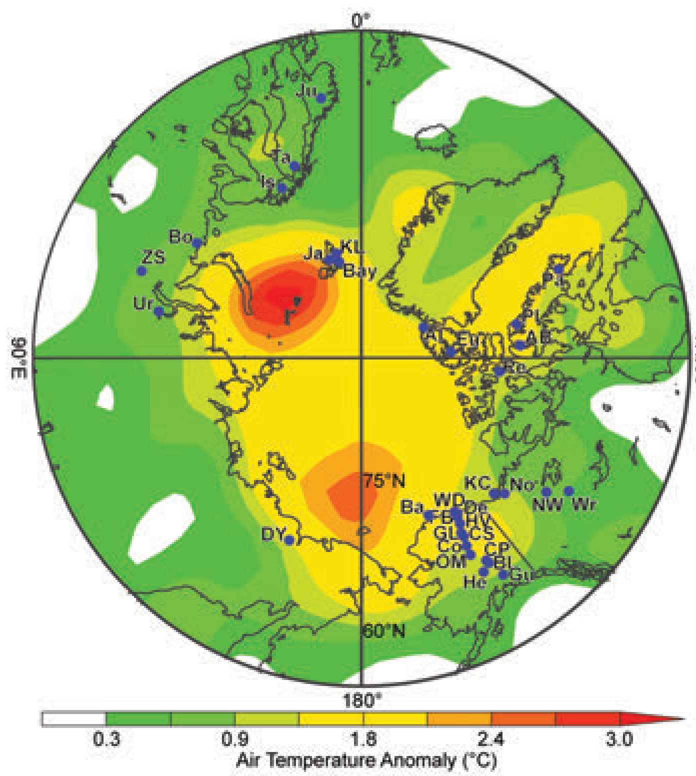


**Fig. 5.16. Location of the permafrost temperature monitoring sites shown in Fig. 5.17 superimposed on average surface air temperature anomalies (°C) during 2000–16 (with respect to the 1981–2010 mean) from the NCEP-reanalysis (Kalnay et al. 1996). Data provided by the NOAA/ESRL Physical Sciences Division (www.esrl.noaa.gov/psd/). Sites shown in Fig. 5.17 for (a) Barrow (Ba) (Utqiagvik), West Dock (WD), KC-07 (KC), Duvany Yar (DY), Deadhorse (De), Franklin Bluffs (FB), Galbraith Lake (GL), Happy Valley (HV), Norris Ck (No); (b) College Peat (CP), Old Man (OM), Chandalar Shelf (CS), Birch Lake (BL), Coldfoot (Co), Norman Wells (NW), Wrigley 2 (Wr), Healy (He), Gulkana (Gu), Wrigley 1 (Wr); (c) Eureka EUK4 (Eu), Alert BH2 (Al), Alert BH5 (Al), Resolute (Re), Alert BH1 (Al), Arctic Bay (AB), Pond Inlet (PI), Pangnirtung (Pa); (d) Janssonhaugen (Ja), Bayelva (Ba), Kapp Linne 1 (KL), Urengoy #15-10 (Ur), Juvvasshøe (Ju), Tarfalaryggen (Ta), Polar Ural (ZS), Bolvansky #59 (Bo), Bolvansky #65 (Bo), Urengoy #15-06 (Ur), Bolvansky #56 (Bo), Iskoras Is-B-2 (Is). Information about these sites is available at: http://gtnpdatabase.org/, http://permafrost.gi.alaska.edu/sites_map, https://www2.gwu.edu/~calm/data/data-links.html.**

**Table 5.1. Change in mean annual ground temperature (°C decade⁻¹) for sites shown in Fig. 5.17. For sites where measurements began prior to 2000, the rate for the entire available record is provided as well as the rate for the period after 2000. The names of the stations with record high temperatures in 2017–18 are shown in red. The periods of records are shown in parentheses.**

| Region | Sites | Entire Record | Since 2000 |
|---|---|---|---|
| Alaskan Arctic plain | West Dock (WD), Deadhorse (De), Franklin Bluffs (FB), Barrow (Ba, Utqiagvik) | +0.36 to +0.82 (1978–2018) | +0.42 to +0.69 (2000–2018) |
| Northern foothills of the Brooks Range, Alaska | Happy Valley (HV), Galbraith Lake (GL) | +0.31 to +0.41 (1983–2018) | +0.33 to +0.42 (2000–2018) |
| Southern foothills of the Brooks Range, Alaska | Coldfoot (Co), Chandalar Shelf (CS), Old Man (OM) | +0.07 to +0.34 (1983–2018) | +0.12 to +0.29 (2000–2018) |
| Interior Alaska | College Peat (CP), Birch Lake (BL), Gulkana (Gu), Healy (He) | +0.09 to +0.27 (1983–2018) | +0.04 to +0.21 (2000–2018) |
| Central Mackenzie Valley | Norman Wells (NW), Wrigley (Wr) | Up to +0.1 (1984–2017) | <+0.1 to +0.2 (2000–2017) |
| Northern Mackenzie Valley | Norris Ck (No), KC-07(KC) | — | +0.6 to +0.8 (2008–2018) |
| Baffin Island | Pangnirtung (Pa), Pond Inlet (PI), Arctic Bay (AB) | — | +0.5 to +0.7 (2009–2017) |
| High Canadian Arctic | Resolute (Re), Eureka (Eu) | — | +0.4 to +0.7 (2009–2015) |
| High Canadian Arctic | Alert (Al) at 15 m at 24 m | +0.6 +0.3 to +0.4 (1979–2018) | +1.1 +0.7 to +0.9 (2000–2018) |
| North of East Siberia | **Duvany Yar (DY)** | — | +0.3 (2009–2017) |
| North of West Siberia | **Urengoy 15-06 and 15-10 (Ur)** | +0.31 to +0.47 (1974–2018) | +0.1 to +0.19 (2000–2018) |
| Russian European North | Bolvansky 56, 59, and 65 (Bo), Polar Ural (ZS-124) | +0.18 to +0.46 (1984–2018) | +0.1 to +0.83 (2000–2018) |
| Svalbard | Janssonhaugen (Ja), Bayelva (Ba), Kapp Linne 1 (KL) | +0.7 (1998–2017) | +0.6 to +0.8 (2000–2017) |
| Northern Scandinavia | Tarfalaraggen (Ta), Iskoras Is-B-2 (Is) | — | +0.1 to +0.4 (2000–2017) |
| Southern Norway | Juvvasshøe (Ju) | +0.2 (1999–2017) | +0.2 (2000–2017) |

1) Permafrost temperatures

In 2018, record high temperatures at 20-m depth occurred at all permafrost observatories on the North Slope of Alaska [Utqiagvik (Barrow), West Dock, Deadhorse, Franklin Bluffs, Happy Valley, and Galbraith Lake; Fig. 5.17a]. The permafrost temperature increase (+0.1° – 0.2°C) between 2017 and 2018 was substantial and comparable to the highest rate of warming observed in this region during 1995–2000 (Fig. 5.17a).

Following the slight cooling of 2007–13, permafrost temperatures increased in interior Alaska and were higher in 2018 than in 2017 nearly all sites (Old Man, College Peat, Birch Lake, Gulkana, and Healy). The exception was Coldfoot, which experienced no change. The largest changes, at Birch Lake and Old Man, were associated with new record highs in 2018 for the entire 34-year measurement period (Fig. 5.17b). As a result of long-term warming and the relatively mild and snowy winter of 2017/18, the active layer did not freeze completely down to the underlying permafrost by the end of winter at many interior Alaska sites.

In northwestern Canada, the temperature of permafrost in the central Mackenzie Valley (Norman Wells and Wrigley in Fig. 5.17b) has generally increased since the mid-1980s, with less warming observed since 2000 (Smith et al. 2018). However, temperatures in 2018 were the highest observed during the period of record (1984–2018). Since 2013, warming in the colder permafrost of the northern Mackenzie region has been greater than that in the central Mackenzie Valley (Norris Ck, KC-07 in Fig. 5.17a; Smith et al. 2018). Although the temperature at the colder site (KC-07) in 2017/18 is the highest observed during the short record, the temperatures recorded at a shallower depth at Norris Ck were slightly lower in 2017/18 compared to the previous year.

In northeastern Canada, the 2017/18 mean permafrost temperatures in the upper 25 m of the ground at Alert, northernmost Ellesmere Island in the high Arctic, were among the highest recorded since 1978 (Fig. 5.17c). Permafrost at Alert has generally warmed since 1978, but temperatures have increased at a higher rate since 2000 (Smith et al. 2015), as have air temperatures (Fig. 5.16). Since 2010, there has been little change in permafrost temperatures at Alert (Fig. 5.17c), which is consistent with a period of lower mean annual air temperatures. However, at a depth of 15 m, the 2017/18 temperature is higher than the previous year, reflecting a recent increase in air temperature.

Increases in permafrost temperature over the last 30–35 years in northern Russia have been similar to those in northern Alaska and the Canadian high Arctic (Drozdov et al. 2015). In the Russian European North and western Siberian Arctic, temperatures at 10-m depth have generally increased since the late 1980s at rates that are more rapid at colder permafrost sites (Fig. 5.17d, sites Bolvansky #59, Urengoy #15-5 and #15-10) compared to sites in warmer permafrost (Fig. 5.17d, sites Bolvansky #56 and Urengoy #15-6; Drozdov et al. 2015).

In the Nordic region, ground temperatures have increased (Fig. 5.17d) and thawing of permafrost has been observed (Isaksen et al. 2011). The response of warm permafrost at close to 0°C (Iskoras Is-B-2, Fig. 5.17d) is slower than in permafrost with lower temperatures due to latent heat effects related to melting ground ice. On Svalbard, a significant temperature increase can be detected down to 80-m depth (not shown), reflecting a multidecadal permafrost warming, with 2018 clearly the warmest year in the observational record. In the discontinuous permafrost zone of southern Norway, permafrost warmed between 2015 and 2018,

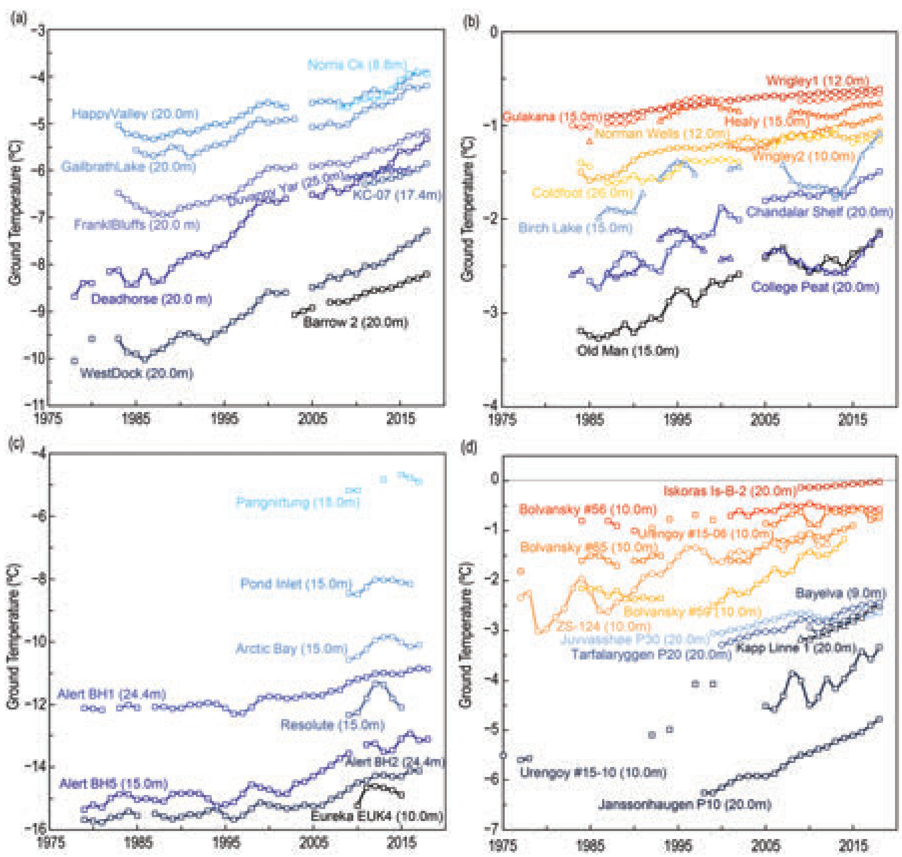


**Fig. 5.17. Time series of mean annual ground temperature (°C) at depths of 9–26 m below the surface at selected measurement sites: (a) cold continuous permafrost of northwestern North America and northeastern East Siberia (Beaufort-Chukchi region); (b) discontinuous permafrost in Alaska and northwestern Canada; (c) cold continuous permafrost of eastern and High Arctic Canada (Baffin Davis Strait); and (d) continuous to discontinuous permafrost in Scandinavia, Svalbard, and Russia/Siberia (Barents region). Temperatures are measured at or near the depth of zero annual amplitude where the seasonal variations of ground temperature are negligible. Data are updated from Christiansen et al. 2010; Romanovsky et al. 2017; Smith et al. 2015, 2018; Ednie and Smith 2015; Boike et al. 2018.**

following a period of cooling between 2011 and 2014 (Fig. 5.17d).

2) Active layer thickness

In 2018, standardized, mechanical probing of ALT was conducted at 88 Circumpolar Active-Layer Monitoring (CALM) program sites located in Alaska, the Nordic countries, and Russia (Fig. 5.18). Each site consists of a spatial grid varying from 1 ha to 1 km$^2$ in size and is representative of regional landscapes (Shiklomanov et al. 2012). Additional active-layer observations are available from 25 Canadian sites located in the Mackenzie Valley, northwestern Canada, where ALT is derived from thaw tubes (Smith et al. 2018). The Canadian ALT data are complete through 2017.

The average ALT in 2018 for 24 North Slope of Alaska sites was 0.49 m, which is above the 2003–12 mean but lower than the previous three years (2015, 2016, 2017). Previous maxima occurred in 1998, 2013, 2016, and 2017. There has been a pronounced ALT increase over the last 23 years in interior Alaska, where a new record of 0.80 m occurred in 2018.

In the Mackenzie Valley of northwestern Canada, there has been a general increase in ALT since 2008 (Duchesne et al. 2015; Smith et al. 2018). In 2017, ALT was 0.07 m thicker, on average, than the 2003–12 mean, and exceeded by 0.01 m the previous peak value measured in 2012.

Across the Nordic countries, there has been a general ALT increase of 0.12–0.30 m since 1999. The particularly warm summer of 2018 in the Scandinavian North contributed to a new maximum, while sites located in Svalbard did not reach the previous maximum recorded in 2016. A cold summer in 2018 in southern Greenland contributed to new minimum ALT in the region, where it was at least 0.2 m lower than the 2003–12 mean. This is a large deviation from the overall positive ALT trend for 1996–2017.

An increase in ALT from 2017 to 2018 was reported for all Russian regions. In the Russian European North, the 2018 ALT was 1.18 m, which is above average and 0.1 m higher than in 2017. In West Siberia, the average 2018 ALT was close to the 2017 value of 1.25 m. At the Eastern Siberia and Chukotka sites, 2018 ALT was 0.02–0.04 m higher than in 2017.

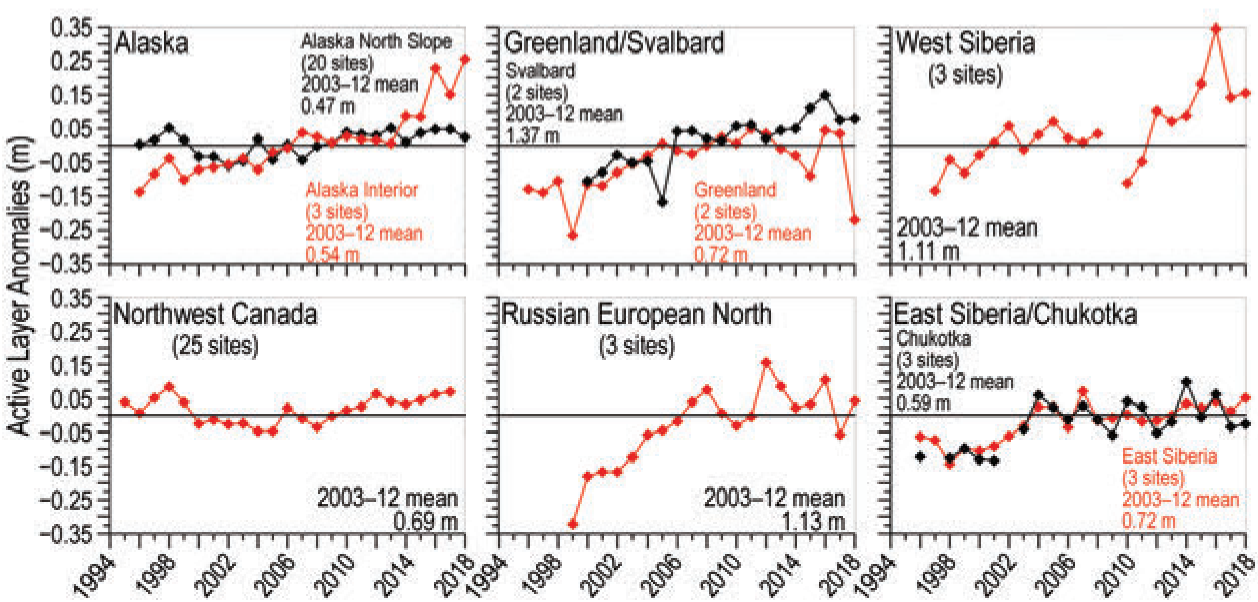


**Fig. 5.18. Long-term active-layer thickness change (m) in six different Arctic regions for 2018 as observed by the CALM program relative to the 2003–12 mean. Positive (negative) anomaly values indicate the active layer is thicker (thinner) than average. Thaw depth observations from the end of the thawing season were used. Only sites with at least 20 years of continuous thaw depth observations are shown. The number of sites used for each region varies and is shown in the figure. Site-specific data are available at www.gwu.edu/~calm.**