Year: 2015

Permafrost

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Table 2.3. Climate extremes indices discussed in this section. For a more complete discussion of the suite of ETCCDI indices see Zhang et al. (2011).

Index	Name	Definition	Unit
TX10p	Cool days	Share of days when Tmax < 10th percentile	% of days
TN10p	Cool nights	Share of days when Tmin < 10th percentile	% of days
TX90p	Warm days	Share of days when Tmax > 90th percentile	% of days
TN90p	Warm nights	Share of days when Tmin > 90th percentile	% of days
TXx	Hottest day	Warmest daily maximum temperature	°C
TXn	Coldest day	Coldest daily maximum temperature	°C
TNx	Hottest night	Warmest daily minimum temperature	°C
TNn	Coldest night	Coldest daily minimum temperature	°C

c. Cryosphere

1) Permafrost—J. Noetzli, H. H. Christiansen, V. E. Romanovsky, N. I. Shiklomanov, S. L. Smith, G. Vieira, and L. Zhao

The year 2014 continued the long-term trend of rising permafrost temperatures and generally increasing active layer thickness (ALT). The Global Terrestrial Network on Permafrost (GTN-P) brings together long-term records on ground temperatures and active layer depths from permafrost regions worldwide to document the state and changes of permafrost on a global scale.

Permafrost temperatures measured in the Arctic vary from 0°C in the southern portion of the discontinuous zone to about –15°C in the high Arctic (Romanovsky et al. 2010; Christiansen et al. 2010). Permafrost has warmed over the past two decades, and generally continues to warm across the circumpolar north. Record-high temperatures were observed in 2013–14 in the Alaskan Arctic and the Canadian Archipelago (Romanovsky et al. 2013, 2014). A detailed discussion of Arctic permafrost is provided in the Arctic chapter (section 5g).

Permafrost in the European Alps is discontinuous or patchy. Most of its area is between 2600 and 3000 m above mean sea level (asl; Boeckli et al. 2012), where permafrost temperatures have been measured for one to two decades and are typically above –3°C (Haeberli et al. 2010; PERMOS 2013; Fig. 2.8). More recently, instruments have been deployed on shaded slopes in rocky ridges and show that peaks at the highest elevations can be significantly colder. For example, permafrost temperatures of –5°C have been measured on the northwest side of the Aiguille du Midi rock pillar in the Mont Blanc Massif at 3800 m asl (Magnin et al. 2015) at 10-m depth. Annual mean temperatures as low as –10°C were recorded at 0.5-m depth on the north side of the Matterhorn summit at 4450 m asl, whereas on the south side temperatures are around 8°C higher (P. Pogliotti, Environmental Protection Agency of Valle d'Aosta, 2015, personal communication). This illustrates the pronounced spatial variability of thermal conditions within short distances in steep rock ridges and peaks (PERMOS 2013). Decadal records for European mountain permafrost show a general warming trend at depths of 20 m, which became more distinct in the past six years

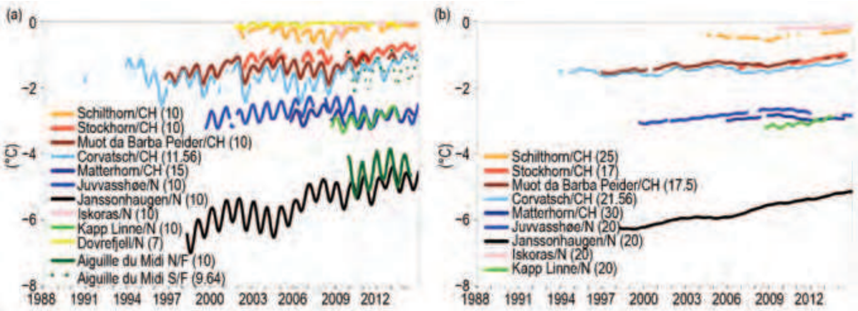

Fig. 2.8. Permafrost temperatures (°C) in daily or monthly resolution measured at (a) 10-m and (b) 20-m depth for selected boreholes in the European Alps, Scandinavia, and Svalbard showing (a) seasonal as well as (b) long-term variations of permafrost temperatures at depth. Data from Swiss sites are provided by PERMOS, for Norwegian sites by the Norwegian Meteorological Institute and the Norwegian Permafrost Database, and from the French site by EDYTEM/University of Savoie.

at many sites (Fig. 2.8). Where permafrost temperature is close to 0°C, less change is observed owing to latent heat effects masking the effect of increasing air temperature (PERMOS 2013; Haeberli et al. 2010). At 10-m depth seasonal variations reveal warmer winters at warmer sites in recent years. Pronounced warming trends are observed in Scandinavia (Isaksen et al. 2011; Fig. 2.8), which are consistent with changes in air temperatures in 2014.

In the warm permafrost of the higher altitudes of central Asia, ground temperatures have increased by up to 0.5°C decade^{-1} since the early 1990s. More than 60 additional boreholes were recently installed in the Qinghai–Xizang Plateau (Zhao et al. 2015, manuscript submitted to *Cryosphere*) and Mongolia (Sharkhuu and Sharkhuu 2012) as part of GTN-P. The average warming rate of permafrost along the Qinghai–Xizang Highway was about 0.31°C decade^{-1} from 1998 to 2010 (Zhao et al. 2015, manuscript submitted to *Cryosphere*).

Permafrost in continental Antarctica shows temperatures from below –8°C (Schirmacher Oasis) to –23°C in the McMurdo Dry Valleys (Vieira et al. 2010). The Antarctic Peninsula region has much warmer permafrost with –3°C at Adelaide Island (Guglielmin et al. 2014) and –2°C at 270 m asl in Livingston Island (Ramos et al. 2009). From Palmer to the South Shetlands, permafrost is warm and sporadic or absent in the lowest coastal areas (Bockheim et al. 2013).

Changes in ALT vary by region (Shiklomanov et al. 2012), but ALT has generally increased globally over the last 20 years. In 2014, ALT increased in some places in the Arctic but decreased elsewhere (for a more detailed description see chapter 5). On Svalbard and Greenland increases in ALT have been observed since the 1990s, but these are not spatially and temporally uniform (Christiansen et al. 2010). Here, ALT was similar or lower in 2014 compared to 2013. In the European Alps, ALT over the past five years has been greater than previously measured with record values in 2012 or 2013 at some sites. ALT changes depend strongly on surface processes and ice content (PERMOS 2013). A general increase in ALT has been observed in central Asia (e.g., Zhao et al. 2010). Based on monitoring results extended by a freezing–thawing index model, the average increase of ALT was about 1.33 cm yr^{-1} from 1981 to 2010 along the Qinghai–Xizang Highway (Li et al. 2012). The monitored average increase of ALT was about 13 cm higher from 2011 to 2014 than that from 2000 to 2010 (modified after Li et al. 2012 based on new data). In Terra Nova Bay, Antarctica, ALT has been increasing in recent years, mainly as a result of solar radiation increase (Guglielmin and Cannone 2012). In the western Antarctic Peninsula ALT shows high interannual variability and is controlled by air temperature and changing snow conditions (de Pablo et al 2013; Guglielmin et al. 2014; Guglielmin and Vieira 2014).

2) Northern Hemisphere snow cover—D. Robinson

Annual snow cover extent (SCE) over Northern Hemisphere (NH) land averaged 25.0 million km^2 in 2014. This is 0.1 million km^2 less than the 45-year average, and ranks 2014 as having the 25th largest (21st lowest) snow cover extent on record (Table 2.4; Fig. 2.9). This evaluation includes the Greenland ice sheet. SCE in 2014 ranged from 46.8 million km^2 in February to 2.6 million km^2 in August.

Eurasian SCE ranked 9th lowest of the past 45 years with 14.2 million km^2, while North American SCE was 16th largest at 10.8 million km^2. SCE across both Eurasia and North America was below average in January 2014. February SCE was above average and was 0.8 million km^2 more extensive than in January. This was the 14th time in the past 48 winters when February SCE exceeded January SCE. Spring melt began on the early side, with March through June NH extents each ranking sixth lowest on record. Eurasian SCE ranked lowest (April) to eighth lowest (June), while North America SCE ranked in the top third of all years in March and April, but falling to the lowest third in May and June.

As in 2013, snow arrived early over the NH continents during fall 2014. Hemispheric SCE was third most extensive in September and October, and fifth largest in November. Each continent had a top ten SCE ranking during these months, with North America SCE the most extensive on record in September and November, and Eurasia having its second greatest SCE in October. The SCE advanced much more slowly in December, leading to each continent ranking in the middle third.

SCE over the contiguous United States began 2014 below average, ranking in the lower third of all years. This turned around in February, which was ninth most extensive for the month, with a coverage about 0.5 million km^2 greater than in January. March–May and October were near-average. Snow cover greatly expanded over the United States in November—at almost twice the average extent, it was the most extensive on record. This changed dramatically by the end the year, with December SCE the 16th lowest. December SCE was approximately 0.3 million km^2 greater than in November, compared with the normal difference of close to 1.8 million km^2.