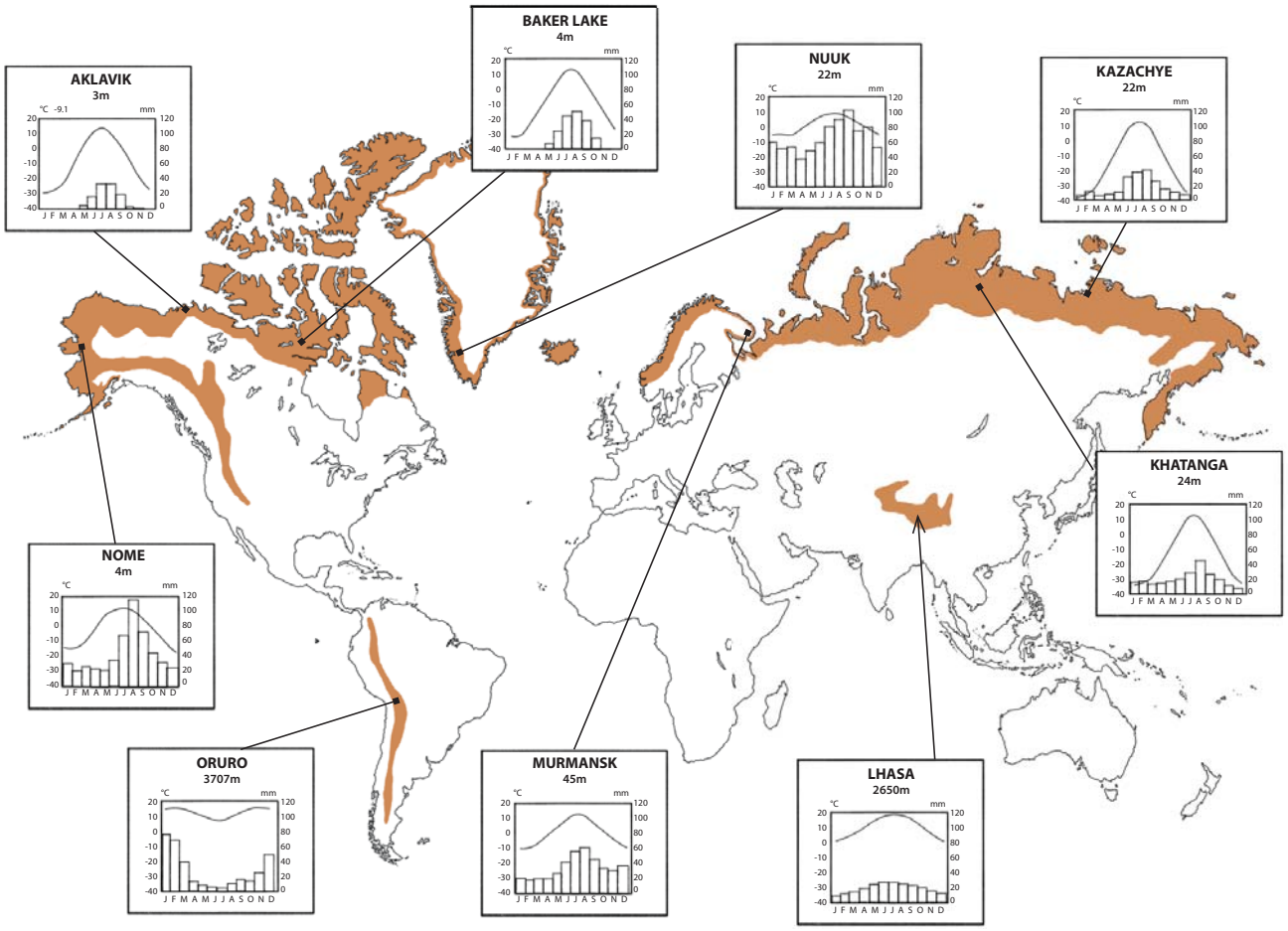
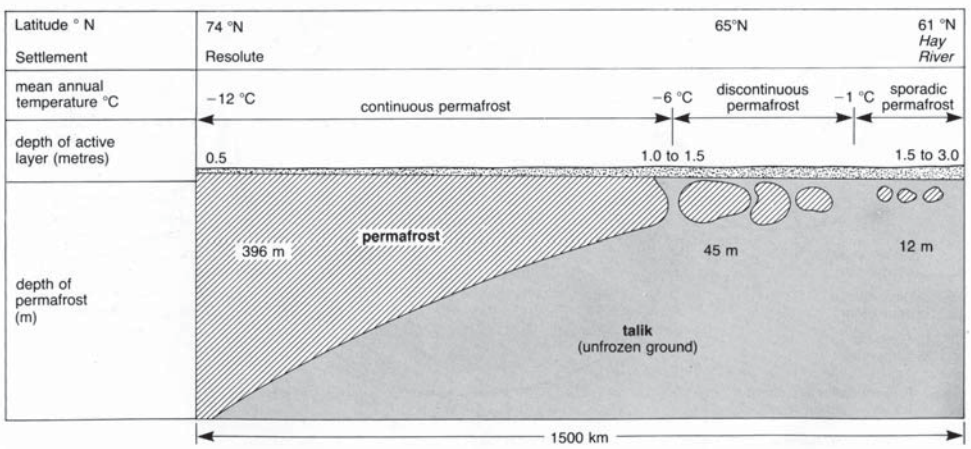
How is human activity causing pressures on the Arctic and alpine tundra environments?

Davyth Fear

The tundra ecosystem occurs in two main types of areas across the world. Firstly, it is to be found in high latitude areas, with 14.5 million km^2 located in the far north of Eurasia and North America. Tundra is also to be found in high altitude areas, with 9.5 million km^2 of alpine tundra located in the Northern Hemisphere and another 1 million km^2 in the Southern Hemisphere. Their location is shown in the shaded areas of the map below.



Tundra is characterized by low primary productivity, which is a result of the long, severe winters, low precipitation and the short growing season. A study of the climate graphs on the reference map clearly shows all three characteristics for most areas, although precipitation may be higher in alpine areas and on windward coasts.



Permafrost depth by latitude

The name tundra derives from the Lapp word for treeless. Much of the area is underlain by permafrost, which means that the underlying soil and rock are permanently frozen. Above is a thin active layer which thaws during the summer and refreezes every winter. This promotes waterlogging, which, together with the climatic severity of the

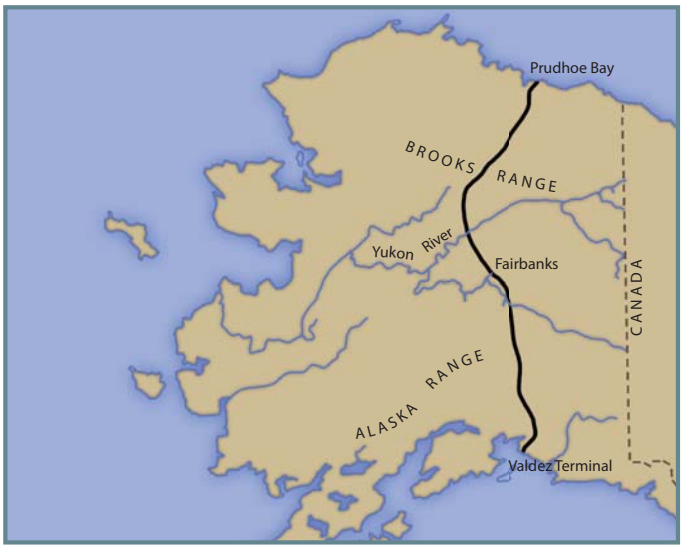
area, prevents tree growth. Areas of permanently unfrozen ground are termed talik.

The low productivity and general fragility of the tundra ecosystem means that human activity poses a number of threats to it, threats which have generally been increasing over the years. These include:

- the exploitation of minerals, including fuels both onshore and offshore
- airborne pollution from industrial areas elsewhere in the world
- global warming and climatic change
- the increasing number of tourists in both Arctic and alpine areas.

The discovery of oil at Prudhoe Bay in Northern Alaska, and subsequently elsewhere in arctic areas in Siberia and Canada, inevitably meant the opening up of the area in order to develop resources. Opinions vary as to whether resource exploitation or climate change will have the greatest impact on the ecosystem. But, without doubt, the wealth created by oil and gas recovery, and the problems created by the infrastructure needed by these industries, have changed these remote communities hugely.

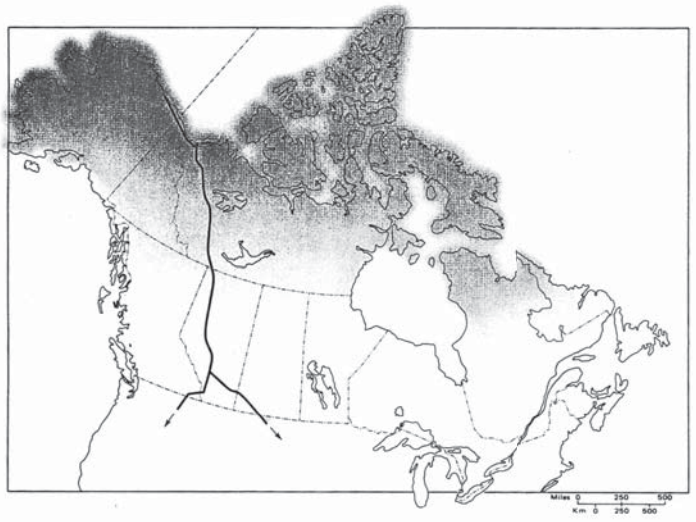
At the time of its completion, the Trans-Alaska pipeline was the largest engineering project undertaken in history. It cost over $7 billion, eight times as much as initial estimates. The main reason for this was the problem of building across permafrost, but also the range of terrain covered, including forest, swamp, mountain and tundra. Tankers could only reach Prudhoe Bay during the ice-free season, therefore a pipeline was the only way of exploiting the resources. The crude oil has a temperature of about 65°C, and if it was left to cool to air temperature it would start to block the pipe. However, if permafrost thaws, serious slumping occurs, and this could damage the pipeline. Three quarters of the Trans-Alaska route lies across permafrost. In addition, the southern part of the route lies in a zone hit by frequent earthquakes. Much work had to be done to ensure the viability of the pipeline in the vicinity of fault-lines, and also to pacify protests by protesters worried about the effect on wildlife.



Alaska. Main physical features and location of pipeline. Permafrost occurs continuously in the Brooks Range and further north and to the west. It gradually thins out and occurs irregularly throughout the rest of the state, except for a small southern coastal strip where it is absent.

Construction of the pipeline started in 1975 and it opened in 1977. By peak flow in 1978, a million barrels a day were flowing through. Great effort was made to avoid ground ice by using radar. Over half the pipeline had to be elevated in order to avoid surface thawing. Even so, there were, on average, 30 to 40 ruptures a year between 1977 and 1994, with consequent oil spills due to the unexpected collapse of the ground below the pipe as a result of the thawing of ice bodies. Other problems have also occurred, e.g. a bulldozer colliding with the pipe, and deliberate damage by shots being fired at it.

The problems which manifested themselves with the Trans-Alaska pipeline effectively made it very difficult for similar projects to occur in the Canadian Arctic. Plans for a Mackenzie Valley gas pipeline and an Alaska Highway pipeline were shelved after costly public enquiries and lobbying by environmental groups. The unknowns of coping with the problems of frost heave and soil creep, especially when the plans were for chilled gas pipelines rather than heated oil pipelines, meant that it would have become too costly and risky to continue.

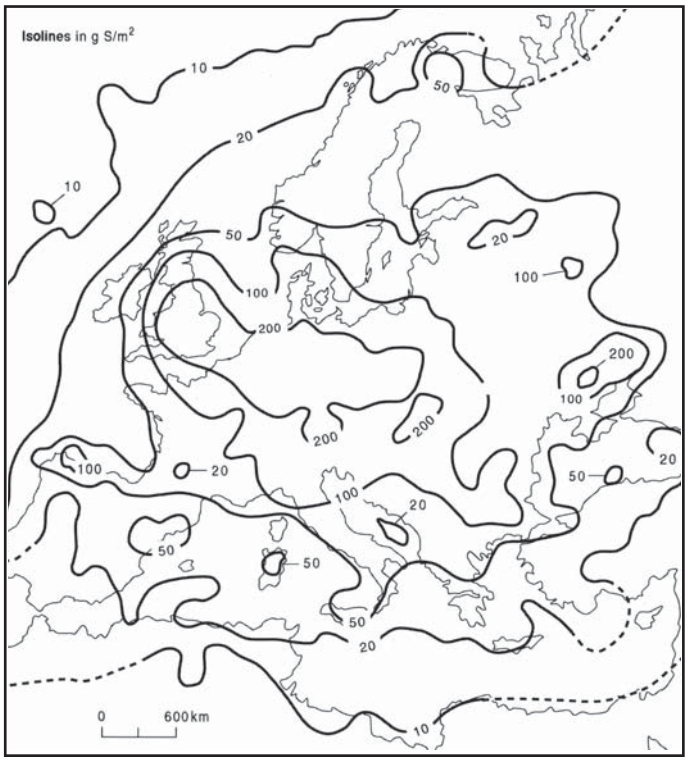


Location of proposed Mackenzie Valley gas pipeline.

The building of an above ground gas pipeline from Mastakh to Yakustk and a buried gas pipeline across the Siberian permafrost at Nadym have also not been without their problems. The thickness of the active layer has increased by up to 80%, and ravine erosion, the development of thermokarst topography (depressions resulting from the thawing of ground ice) and the slumping of thawed soil have caused displacements in the pipe and increased the difficulties of travelling along the pipelines to inspect them. The spread of the Russian petroleum industry and the lack of effective environmental control have caused Nenet reindeer herders from the Yamal peninsula in NW Siberia to fear for the future of their herds. The Nenet are a typical Arctic indigenous semi-nomadic people who follow the reindeer herds which provide them with food, skins and other products. The lives of 33 such peoples are threatened by pollution, crime and forced settlement.

The exploitation of other types of minerals has also had its problems. The use of mercury as an amalgamate to separate fine gold particles from other minerals during the 1950s and 1960s at the Discovery Mine in the Canadian North-West Territories means that nearby Giauque Lake is still designated a contaminated site by Environment Canada.

In the Sami areas of Northern Scandinavia, mining has provided income, jobs and a better infrastructure, but it has also polluted water supplies, scarred mountain landscapes, and created vast new unnatural borders in the form of railroads. The LKAB iron ore mine in Kiruna is a computer-automated, highly specialized world-class mine facility. Technology aims to increase efficiency (and hence profit), while limiting environmental damage and contamination. Unfortunately, the mining process is inherently a devastating process to the local natural environment. Railways block off pasture for the reindeer herds, soil becomes polluted with heavy metals, and watercourses suffer from increased run-off. The traditional way of life of reindeer herders has totally changed. However, legislatures have attempted to redress some of these problems by passing laws that protect the environment from mine waste, and by introducing a system of permits, fees, taxes and fines to gain revenue and to protect the environment.



Deposition of oxidised sulphur

In contrast, mining and quarrying have not been so disruptive to alpine tundra, mainly because of the difficulties in exploiting any reserves in such a mountainous terrain. A more significant problem in alpine areas is their use for hydro-electric power schemes. More advanced technology, such as high altitude helicopters, has now made the building of infrastructure and dams, even in the highest valleys, a viable proposition. Last year, an Alpine Club meet in Chamonix watched two helicopters relaying ready-mix concrete up the valley to a hydro site in the Aiguilles Rouges at ten minute intervals throughout the day.

The impact of mining tends to be local in nature. However, airborne pollution may derive from industrial areas far away. Acid rain (a misnomer, as acidic deposits can be both wet in nature, having mixed with rain and snow, etc., or dry, settling as particulate matter) is also a problem. Its effect depends greatly on the nature of the soil or vegetation in an area, with some areas able to cope with far more deposition than others. Mountain soils are thin, so they often have less chance of buffering than other environments, and they also receive more precipitation. Deposition tends to be greatest close to or downwind from the largest emitters. Since the 1980s, many countries have reduced their emissions, especially in Europe, where a combination of new technology and higher emissions standards for countries joining the EU show clear success. Other parts of the world are not so fortunate, with increasing emissions from China and India an increasing problem for mountains in East Asia. In North America, acid rain is a growing problem in the Sierra Nevada in California, with Lake Tahoe showing increasing signs of acid stress. It used to be famously blue, but increased nutrients from atmospheric pollution, and erosion in the 60 or more watersheds draining into the lake, have increased algal growth. 10 m of transparency has gone in the last 30 years, and most of it will be gone in the next 40 years.

Country	Annual emissions (thousand tonnes)			Change 1980-2000 (%)
	1980	**1990**	**2000**	
SULPHUR DIOXIDE				
China and centrally planned Asia	7 800	13 000	18 000	131
South ans South East Asia	4 000	6 400	9 400	135
USA	23 500	21 481	16 483	-30
Canada	4 643	3 236	2 534	-45
Poland	4 100	3 210	1 511	-63
UK	4 880	3 754	1 165	-76
NITROGEN OXIDES*				
USA	22 121	21 927	21 713	-2
Canada	1 959	2 104	2 058	5
UK	2 580	2 756	1 512	-41
Poland	1 229	1 280	838	-32

* Note: Emissions for nitrogen oxides are given as nitrogen dioxide equivalents
Source: UNECE/EMEP emission database at http://wwwwebdab.int/accessed August 2002 for all except Asian data from Smith *et al*. (2001)

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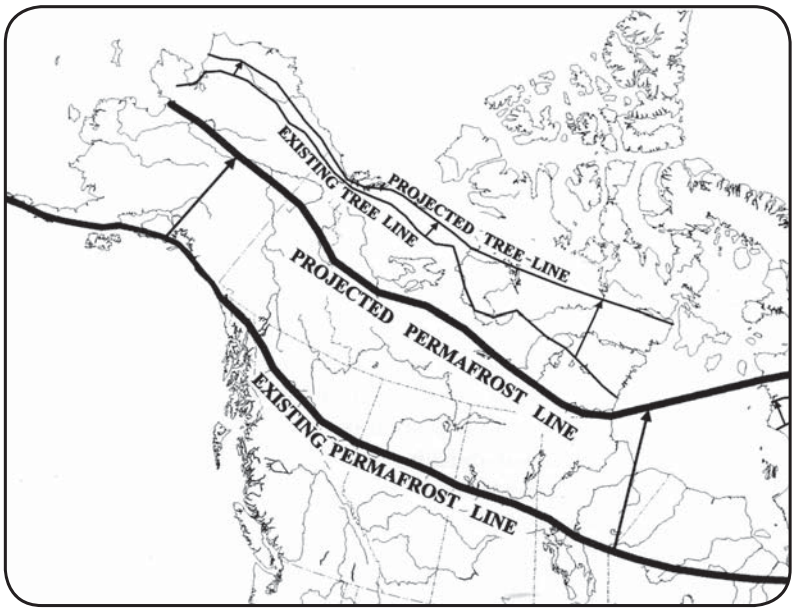
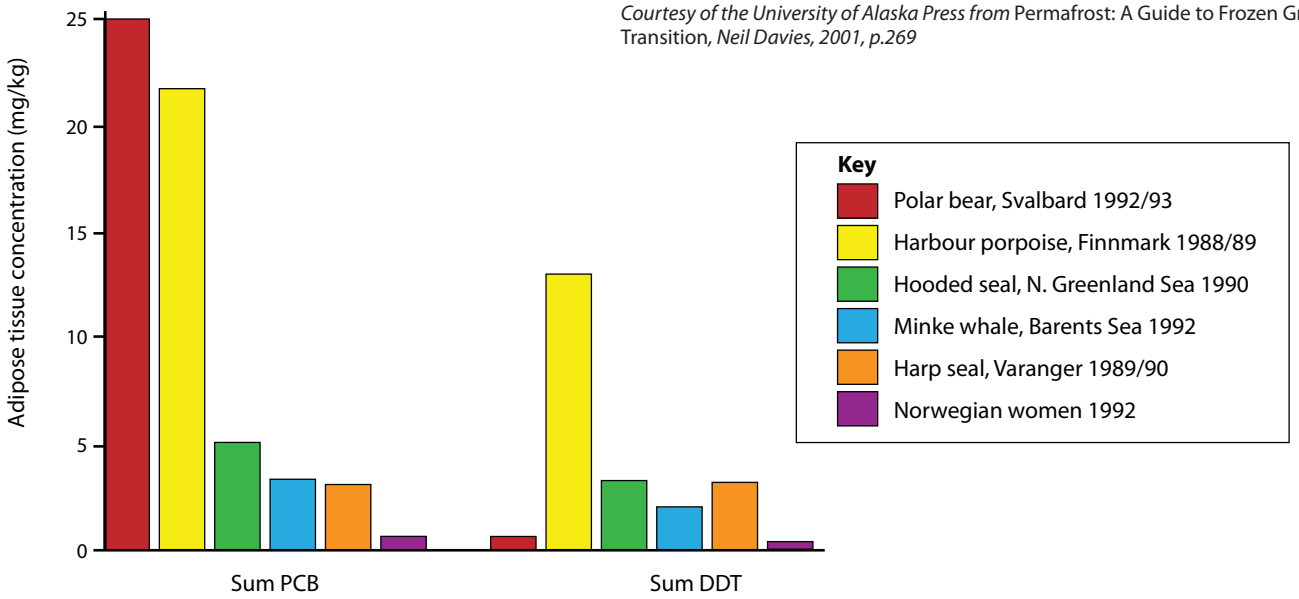
Noril'sk

A variety of other pollutants have also found their way to the Arctic tundra. Radionucleides and POPs (persistent organic pollutants) such as DDT (an insecticide of which traces have even been found in the penguins of Antarctica), PCBs and dioxins have all been found in Arctic (and Antarctic) environments. POPs are believed to reduce the level of thyroid hormones, which has a negative effect on the ability to reproduce. They tend to accumulate preferentially up the food chain and, so, the top predators are the worst affected, such as seals, cetaceans and polar bears. The increased use of catalytic converters in cars has also seen an increase in platinum group metals in Arctic ice. The long-term health risk from these is at present unknown.

One of the worst affected areas in the world has been the Siberian town of Noril'sk. This town has the highest emissions of airborne pollutants of any in Russia. It is a giant complex of smelters, refineries, mines and enrichment works, of which the smelters are the worst polluters. Attempts at pollution control have been few and hampered by lack of investment. An area of 400,000 km^2 has been seriously affected by acid deposition, and the incidence of respiratory and neurological diseases is very high, even by the standard of other polluted Russian cities. In the vicinity of the smelters, 'anthropogenic deserts' have been created, with a complete absence of plants and the development of soil erosion.



Courtesy of the University of Alaska Press from Permafrost: A Guide to Frozen Ground in Transition, *Neil Davies, 2001, p.269*



Bioaccumulation of POPs in Arctic marine animals, with levels in Norwegian women for comparison (after Hansen *et al.*, 1996)

Global warming is generally perceived to be the greatest threat to Arctic and alpine tundra ecosystems. Several recent studies have shown that it is the Arctic which will suffer the greatest temperature gains. One study predicts a decline in tundra from 8% of the world's surface to 1.8% by 2200, as climatic zones shift north. The average temperature of Alaska is estimated to have risen 36°F (2°C) between 1950 and 2000. This will cause the present northern limit of permafrost to shift northwards. The tree-line (the northerly limit at which trees can grow) will similarly move. These movements northwards can clearly be seen on the map of North America on page 4.

Photographs courtesy of the University of Alaska Press from Permafrost: A Guide to Frozen Ground in Transition, *Neil Davies, 2001, p.236-7*

The effects on tundra landforms in discontinuous permafrost areas include caved-in shorelines, submerged trees along thermokarst lakes and the deterioration of building foundations roadways and railways, as seen here.

In colder areas, such as Greenland, the effects of global warming can be divided into geographic impacts and socio-cultural impacts. The present melting of the ice-cap in places such as Kangerlussuaq has caused glacier surges which are so fast that new snowfall is not sufficient to maintain the ice-cap. The warmer sea, no longer covered by the insulating sea ice, warms up the weather, making it wetter and more unstable. Thus there are more delays and cancellations of flights because of storms and snowfall, which means that transportation is more difficult and expensive.

Sea ice traditionally lasted for upwards of 8 months each year in northern parts of Greenland. Today, because sea ice is so much thinner or more fragile, transportation is much more difficult. Ships find it more difficult to get through because of the inconsistency of the ice, whilst the conditions are impossible for dogsleds and snowmobiles. Villages are therefore becoming more isolated than before. Buildings, roads and runways have all been built on permafrost in Greenland, and all are now becoming increasingly unstable. The traditional culture and livelihood of Inuit hunters is under threat as sea ice is essential for hunting and for transportation. For example, hunters in Qaanaaq had to appeal to the government for public help because both they and their dogs were starving. The whole nation came to their support with supplies of aid sent by aeroplane. Discussions are now underway about promoting tourism in the area as an alternative way of life. However, transitions like this take time and money.

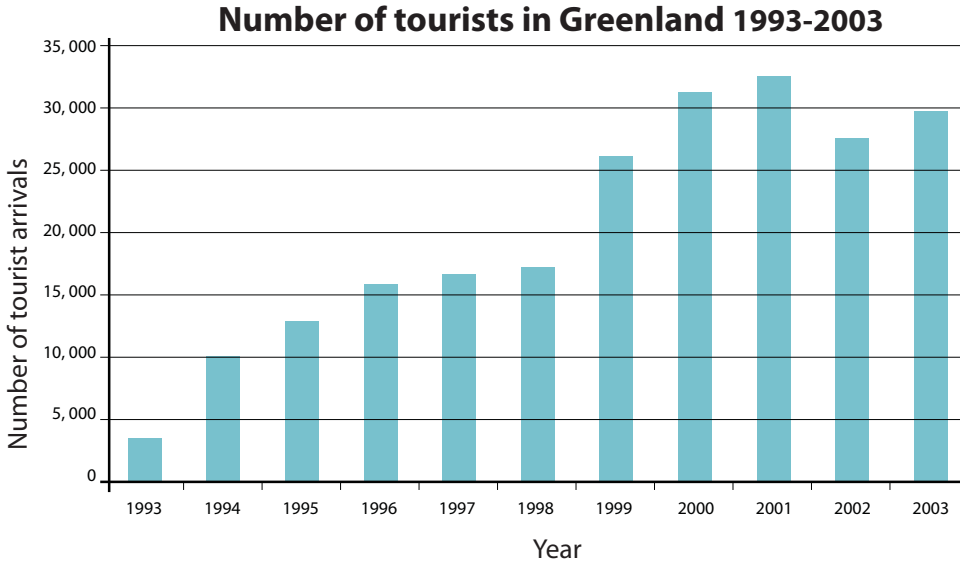
Global warming is seen as a similarly severe threat to alpine communities. According to a recent OECD (Organisation for Economic Co-operation and Development) report, recent warming has been at a rate three times greater than the global average. Future weather is likely to be warmer and wetter in winter than at present. This is likely to result in a number of serious effects:

- increasing risks of economic losses in winter tourism
- vulnerability of settlements and infrastructure to natural hazards such as avalanches, floods and landslides
- changes in biodiversity, e.g. alpine species being replaced by grassland and trees migrating upland, which will also increase the risk of forest fires
- changes in water balance, with enhanced melting of glaciers causing floods in spring, but projected declines in summer precipitation causing summer water shortages
- the increasing vulnerability of human health and tourism because of heatwaves, flash floods, pollution from traffic and energy consumption.

All countries in the Alps will be affected by a rise in the line of natural snow reliability, but Germany will be affected the most. The European ski industry caters for 70 million tourists and is worth €50 billion every year.

Country	Number of ski areas	Snow-reliable under current conditions (no. of days)	+1 °C	+2 °C	+3 °C
Austria	228	199	153	115	47
Switzerland	164	159	142	129	78
Germany	39	27	11	5	1
France	148	143	123	90	55
Italy	87	81	71	59	21
Total	**666**	**609**	**500**	**404**	**202**

Present and future natural snow-reliability of ski areas in the European Alps on a national level



Finally, tourism is seen as a both a threat and an economic necessity to both Arctic and alpine tundra ecosystems. Although cruise ships carrying tourists from the United States and France have been observed in Greenland since the 1930s, it was only after home rule that the Greenlandic government identified tourism as a key issue in diversifying the economy, and thus allocated substantial funds to tourism development. The numbers of tourists have risen steadily since then. Each of the tourist regions offers a variety of tourist attractions and activities which all focus strongly on nature. In particular, the Mid-West and the Disko Bay area are popular tourist destinations, along with South Greenland, while East and North Greenland are more remote and have limited tourism facilities and infrastructure.

North Greenland (3%)

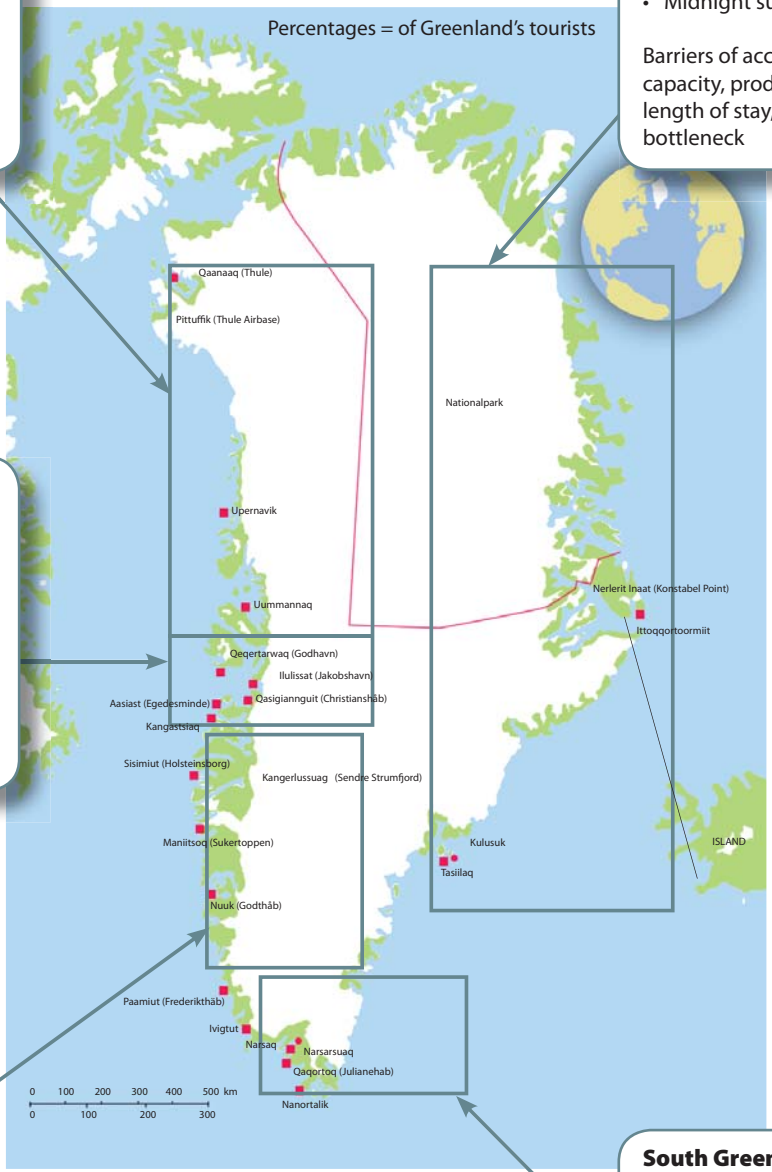
Attractions:
- Nature, flora & fauna
- Inuit hunting culture
- Inaccessible & untouched
- Expeditions, hiking, dogsledding
- Midnight sun

Barriers of access, transport conditions, military restrictions

East Greenland (3%)

Attractions:
- Hunting and fishing culture
- Hiking, dog-sledding, boating
- Climbing, angling & camping
- Handicrafts, Northern Lights
- Midnight sun

Barriers of access, overnight capacity, product development, length of stay, helicopter ride a bottleneck



Disko Bay (29%)

Attractions:
- Nature, flora & fauna
- UNESCO World Heritage Site
- Ice & glaciers
- Midnight sun & Northern Lights
- Hiking, boating, dog-sledding all year, angling, whale-watching
- Handicrafts

Barriers of overnight capacity

West Greenland (53%)

Attractions:
- Nature, flora & fauna
- Nuuk – the capital, handicrafts
- Hiking, boating, horseback riding, angling, whale-watching, musk-ox safari, heli-skiing
- Northern Lights

Relatively weak area in activities , experiences & attractions

South Greenland (12%)

Attractions:
- Nature, flora & fauna
- Ice fjords & hot-springs
- Sheep farms, seal hunters
- Norse history
- Angling, hiking, boating
- Horseback riding
- Big wall climbing
- Northern Lights

Barriers of boat access by ice-locked fjords in early summer

There have been some positive outcomes to climate change. As the sea warms up, warmer water fish species are migrating further north, leading to new opportunities. Loss of ice cover could lead to a growth in agriculture, with planning and support.

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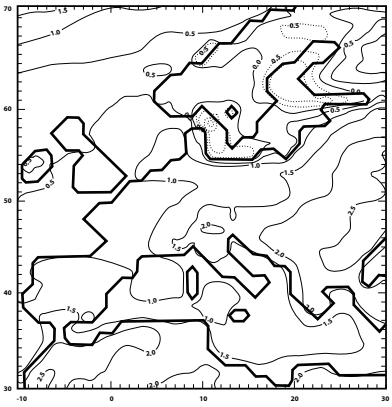
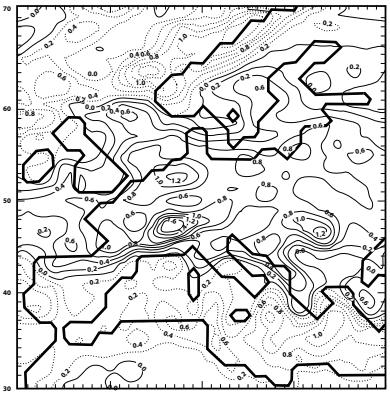


Winter mean temperature change (°C)



Winter total precipitation change (mm/day)

The emphasis on nature has meant that most activities are oriented towards ice and snow, flora and fauna, seeing the midnight sun or the northern lights, dog-sledding, using the ferries which ply the coast, angling and whale-watching. Some more specialized activities include rock-climbing, mountain biking, kayaking, ice golf and heli-skiing. Cultural experiences involve visiting the remains of early Inuit and Norse settlements, as well as present-day culture. Many visitors to Greenland are interested in limiting their footprint on the area, i.e. through ecotourism; however, it can be seen from the list above that there is potential for some environmental impact. Tourist developments may sometimes conflict with each other, e.g. the plans to build a 160 km road between Kangerlussuaq and Sisimiut which is a popular hiking and dog-sledding area.

Tundra habitats are vulnerable because of their low productivity and slow regeneration potential. Most of the protected zones are in the high Arctic, while most impacts from recreation and tourism, as well as hunting, fishing, agriculture and mineral extraction, take place in the lower latitudes and altitudes. Damage from trampling occurs in the most popular hiking areas. Tracked vehicles, e.g. snow-cats, create ruts which deepen into ponds and cause irreparable damage. Air-cushioned vehicles have less impact in winter but can depress the vegetation mat in summer, causing soil temperatures to rise and an effect similar to heavy grazing.

The development of infrastructure is also opening other areas to tourism. The inauguration of the Qingzang railway, linking China to Tibet, is expected to encourage tourism to the area, although the political troubles in Tibet since 2008 might limit this for a while. This railway line is the highest in the world, and half of it is laid on permafrost. It is so high that a special oxygen supply is built into each carriage for each passenger. The environmental impact of the railway is an on-going concern. The replacement of wood by coal, brought in by railway, will relieve the pressure on the slow growing woods of Tibet, but it might increase air pollution and associated health risks.

However, without doubt, a greater burden has been borne by alpine tundra areas because of tourism, in particular the winter sports industry. There has been a huge expansion in the number and size of ski resorts since the 1970s, especially in the Alps, but increasingly in other areas. Winter is therefore an important source of income and is big business. The 1999 report of the United Nations Commission on Sustainable Development confirmed that tourism was the world's leading industry. The Alps have about 10% of that market, even though it is an area with a delicate ecosystem. At the height of the winter season, a million and a half skiers are carried aloft every hour by ski-lifts. 800,000 participate in extreme water-sports like canyoning and rafting.

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Ice golf

The damage done in alpine areas is manifold. Hotels, shops and restaurants detract from the landscape, especially as the valley floors are now full and new development climbs up the valley sides. The traditional way of life is destroyed because hotels are run by outsiders who employ foreigners, especially in management jobs. Much of the work is seasonal and unskilled, meaning that local people move away to get better-paid jobs, and local houses become owned by absentee landlords. Services such as sewerage and water need to be supplied in a difficult physical environment.

Litter tossed from lifts or dropped from ski-runs does not degrade easily. For example, an average cigarette butt takes five years to decay, orange peel two years. Skiing past trees means branches are knocked off. Wildlife is disturbed by the initial construction of ski-trails and their nightly maintenance, as well as the daytime skier population.

Leisure activities such as skiing cause more erosion, and this may detract from summer tourism because ski areas without snow look just like quarries. Artificial snow is now necessary in virtually all alpine resorts because of climate change. This causes long-term damage to the vegetation on which it is made. In addition, because all resorts now machine-grade their slopes, all of the alpine vegetation is effectively destroyed and takes 30 years or more to recover. The destruction of vegetation means less water is stored, increasing the risk of floods. The risk is compounded by snow-moving vehicles compacting the soil, and an increase in impermeable surfaces such as roads and car-parks. Avalanching and landslides become more common, in part because of deforestation.

To cope with these effects, there have been a number of initiatives. Alp Action has been championing sustainable development and the expansion of national parks and wilderness areas where wildlife has a chance to flourish. Reforestation has been encouraged, species reintroduced, habitats protected and alpine areas restored. The Ski Club of Great Britain has launched a 'Respect the Mountain' campaign, highlighting the environmental record of over 200 ski resorts worldwide, as well as informing skiers on a wide range of environmental issues (http://www.skiclub.co.uk/skiclub/respectthemountain/default.asp). What impact they can have on such a huge scale of development across the Alps and other mountain areas worldwide remains to be seen.

Cydnabyddiaethau

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