

The Thawing of Alaska

The property of water to change phase at 32°F (0°C) is probably the most important factor in the observed and expected climate impacts in Alaska where the environment and practically all human activities are so strongly

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dominated by snow and ice. Much of Alaska's environment is close to the melting point of ice (e.g., Fairbanks has a mean annual temperature of about 28°F or -2°C) and a relatively small warming of the climate can cause major environmental changes and feedbacks. One of these is the positive feedback through the effect of climate on snow cover. Warmer temperatures decrease the area of snow cover, darkening the surface and in doing so increasing the absorption of solar radiation to further increase the air temperature.

Many components of the cryosphere (snow and ice regions of Earth) are sensitive to changes in atmospheric temperature because of their thermal proximity to melting. The projected warming of the climate will reduce the area and volume of the cryosphere. This reduction will have significant impacts on related ecosystems, associated people and their livelihoods. There will also be striking changes in the landscapes of many high mountain ranges and of lands at northern high latitudes. These changes may be exacerbated where they are accompanied by growing numbers of people and increased economic activities (IPCC, 1996).

Observations over the last few decades already confirm dramatic melting of snow and ice in the Arctic, including Alaska, due to a warmer climate.

Sea Ice:

There have been substantial reductions in both ice extent and thickness in the Arctic in recent decades:

- A recent study using passive microwave data from satellites through 1996 has shown arctic sea ice extent decreasing by 2.9% ($\pm 0.2\%$) per decade (Cavalieri et al., 1997).
- Sea-ice extent in the Bering Sea has been reduced by about 5% over the last 40 years, with the steepest decrease occurring in the late 1970s (BESIS, 1997).

- Sea ice thickness, a sensitive indicator of climate change, has decreased by more than 4 ft (about 1.3 m), from 10 ft (3.1 m) to 6 ft (1.8 m), in most of the deep water portion of the Arctic Ocean between the 1960/1970s and the 1990s, based on submarine sonar records (Rothrock et al., 1999).
- The sea ice thickness decrease is greatest in the central and eastern Arctic and less in the Beaufort and Chukchi seas (Rothrock et al., 1999).

Glaciers and Ice Sheets:

- Glaciers in the arctic and subarctic regions have generally receded, with typical ice-thickness decreases of 33 ft (10 m) over the last 40 years, but some glaciers have thickened in their upper regions (BESIS, 1997). A warming of 2°F (1°C), if sustained, appears to reduce glacier lengths by about 15%.
- The mass balance of Greenland is still uncertain, but there appears to have been a tendency towards increased melt area between 1979–1991 that ended abruptly in 1992, possibly due to the effects of the Mt. Pinatubo eruption (Abdalati and Steffen, 1997).
- Balances have been positive for European glaciers in Scandinavia and Iceland due to increased winter precipitation (Serreze et al., 1999).
- Over the period 1961–1990, small melting glaciers worldwide have contributed about 0.29 in (7.36 mm) to sea level rise, with the Arctic Islands contributing 0.05 in (1.36 mm), Alaska 0.02 in (0.54 mm), and Asia 0.13 in (3.34 mm) (Serreze et al., 1999).



Seasonal Snow Cover:

- Cyclone and anticyclone frequency has increased over the Arctic between 1952–1989 (Everett et al., 1998; section 3.2).
- Annual snowfall has increased in the same period over Northern Canada (north of 55°N) by about 20% and by about 11% over Alaska (Everett et al., 1998; section 3.2).
- While there is more snow in winter, satellite records indicate that since 1972 northern hemisphere annual snow cover on both continents has decreased by about 10%, largely due to spring and summer deficits since the 1980s (Serreze et al., 1999).
- There has also been a decrease in snow depth in Canada since 1964, especially during spring, while winter depths have declined in some areas over European Russia since the turn of the century but have increased in others (Serreze et al., 1999).

Permafrost:

- Borehole measurements in continuous permafrost have shown warming of up to 3.5–7°F (2–4°C) in northern Alaska over the last century (Lachenbruch and Marshall, 1986).
- Discontinuous permafrost throughout Alaska has warmed, and some of it is currently thawing from the top and bottom (Osterkamp, 1994; Osterkamp and Romanovsky, 1999).
- Near-surface permafrost also became warmer by 1°F (0.6–0.7°C) in Siberia during the period 1970–1990; this warming may in part be due to a deeper snow cover in winter (Pavlov, 1994).

River and Lake Ice:

- River and lake ice formation in Alaska occurs later in fall and breakup occurs earlier in spring, leading to shorter ice-covered periods. The annual break-up of the Tanana River ice in interior Alaska has been recorded since the 1920s and shows most break-up dates to occur in April in the 1990s compared with most of them occurring in May in the 1920s (Nenana Ice Classic, 1999).

Additional changes, as projected by the IPCC assessment (IPCC, 1996; Everett et al., 1998),

will include further pronounced reductions in seasonal snow, permafrost, and glacier and periglacial features with a corresponding shift in landscape processes. Increases in the thickness of the active layer of permafrost and the disappearance of most of the ice-rich discontinuous permafrost over a century-long time span will occur (Fig. 10). The IPCC report also predicts the disappearance of up to a quarter of the presently existing mountain glacier mass and less ice on rivers and lakes. Freeze-up dates will be delayed, and break-up will begin earlier. The river-ice season could be shortened by up to a month. There is likely to be substantially less sea ice in the polar oceans.

As a further result of these changes in the cryosphere, the following additional impacts are expected: Widespread loss of discontinuous permafrost will trigger erosion or subsidence of ice-rich landscapes, change hydrologic processes, and release carbon dioxide (CO₂) and methane (CH₄) to the atmosphere. Cryospheric change will reduce slope stability and increase the incidence of erosion and landslides to threaten structures, pipelines, and communication links. Engineering and agricultural practices will need to adjust to changes in snow, ice and permafrost distributions. Thawing of permafrost could lead to disruption of petroleum production and distribution systems in the tundra unless mitigation techniques are adopted. On the other hand, improved opportunities for water transport, tourism and trade are expected from a reduction in sea, river and lake ice. Reduced sea ice may aid new exploration and production of oil in the Arctic Basin. These will have important implications for the people and economies of the Arctic. Table 4 shows some of the

Table 4. Projected impacts due to a 5.5° F (3° C) warming of permafrost (modified from Weller and Lange, 1999)

FEATURE/ PARAMETER	CONTINUOUS PERMAFROST TERRAIN			DISCONTINUOUS PERMAFROST TERRAIN		
	Low	Moderate	High	Low	Moderate	High
Thaw Lakes	X					X
Coastal Processes		X				X
Eolian Activity	X			?	← X	
Vegetation		X →	X	X	→ X	
Active Layer Thickness	X					X
Permafrost Thawing	X					X
Thaw Settlement	X					X
Slope Instability		X				X
Erosion		X				X
Solifluction		X				X
Engineering Impacts		X				X



Fig. 10. Projected Northward movement of the permafrost boundary and tree-line after a doubling of atmospheric CO₂ (from Environment Canada, 1989, extrapolated into Alaska).

expected impacts (BESIS, 1997) if permafrost warms by 5.5°F (3°C). Not all of these changes are necessarily detrimental.

Water Availability

The liquid phase of water is also important in the northern environment. Alaska contains more than 40 percent of the nation's surface-water resources, much of which are undeveloped. Seasonal stream-flow variations result from precipitation and temperature fluctuations; ranges in basin elevations; and the effects of the natural storage and release from snowpack, glaciers, and lakes. For Alaskan streams, low-flow occurs during the winter when most rivers are ice-covered. Many interior and arctic rivers and lakes freeze solid, making them an unreliable water source during winter months. High-flow periods generally occur in the fall and spring, and are associated with rainfall and snowmelt, respectively. Flooding due to ice jamming during the spring break-up can cause extensive damage. Glacial rivers have a sustained period of relatively

stable summer flow due to the contribution of the glacial meltwater. Permafrost also has a profound effect on the occurrence and availability of ground water in all but the south coastal regions of Alaska. Permafrost forms a virtually impermeable layer that restricts recharge, discharge, and movement of ground water; functions as a confining layer; and decreases the volume in which water can be stored.

All of the above parameters will be affected by a continuing trend towards a warmer climate, and this in turn will affect the entire hydrological regime of Alaska. The likely future impacts are difficult to assess, however, since big rivers flowing into the Arctic have watersheds that extend well south and into quite different climatic regimes. The Mackenzie Basin studies have projected that there will be a seven percent reduction of streamflow as a result of the expected climate warming (MBIS, 1997). River levels and flow would be lower during the fall and winter and would be lower than the extremely low levels observed in 1995



Fig. 11. Severe erosion occurs along much of the coast of the Arctic underlain by permafrost.