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# Climatic inferences from glacier aspect and altitude: local asymmetry and regional trends.


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Understanding and separating the effects of aspect and altitude on present-day glaciers provides essential background to the palaeoclimatic interpretation of reconstructed former glaciers or glacial cirques. Over time, both spatial gradients and differences between aspects may change, for example as cloudiness and winds change and affect glacier mass balance.

Vector analysis of the number of glaciers with each aspect gives a good estimate of the favoured aspect, but the vector strength (consistency of direction) largely reflects the height of ridges above the Equilibrium Line Altitude (E.L.A.). A better measure of the degree of climatic asymmetry, with less topographic influence, is provided by Fourier (harmonic) regression of glacier mid-altitude against aspect, allowing for regional trends in E.L.A. This requires large data sets, for example from the World Glacier Inventory.

Analysis of 66,084 local glaciers in 51 major regions shows that favoured aspects are dominantly poleward, especially in mid-latitudes: radiation receipt is the major factor in local asymmetry, with strong wind or diurnal cycle effects more restricted.

As expected, strongest poleward asymmetry is found between 30 and 50° latitude: it is weak north of 71°N and near the Equator. At a given latitude, it is greatest in dry, sunny areas where ELA is higher, especially in the dry heart of Asia around the Tarim and Dzhungar Basins. Here north-facing glaciers have mid-altitudes often over 300 m below south-facing. This compares with contrasts of less than 100 m in the most maritime climates such as south Norway or the Olympic Mountains (Washington State). A new 'asymmetric sine-cosine power model' suggests greatest asymmetry at 36° latitude.

Poleward asymmetry is greater for steeper glaciers, up to about 30°; the increase ends at a threshold gradient which is greater at lower latitudes. Poleward tendencies are significant throughout tropical Peru and Bolivia, where they combine with westward tendencies related to increased afternoon cloudiness and easterly winds. Westerly winds are most effective in the Russian low Arctic and sub-Arctic, in Chile (limited data around 34°S), and in the Washington Cascades, the Altai, Norway and New Zealand. If present and former glaciers are compared, latitude and relief are constant and differences in the degree of asymmetry can be related to climatic changes, especially in cloudiness. This provides a valuable new palaeoclimatic tool.

A combined regression of mid-altitude on latitude, longitude and sine and cosine of glacier aspect permits more accurate measurement of both positional and aspect effects. Thus improved, positional effects give linear trends rising 4.7 m $km^{-1}$ eastward (i.e. inland) in south Norway, 4.9 m $km^{-1}$ south-eastward in northern Scandinavia, and 6.9 m $km^{-1}$ south-eastward in South island, New Zealand. ELA or mid-altitude trends this steep are believed to relate more to precipitation than to temperature differences.