A Comparative Review of the Weather and Climate of the Southern Alps of New Zealand and the European Alps

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A Comparative Review of the Weather and Climate of the Southern Alps of New Zealand and the European Alps

A comparative review is provided of the weather and climate processes and phenomena that characterize the New Zealand Southern Alps and European Alps. The general climate conditions and atmospheric circulation features that affect the 2 mountain regions are assessed. Interaction of the mountains with synoptic weather systems is described, including their dynamic and thermal effects on airflow, such as the foehn and nor'wester. The different orientations of the mountain barriers are seen as creating differences between the 2 regions, including the high frequency of cyclogenesis south of the European Alps and the marked orographic effect on fronts along the east coast of New Zealand. Other distinctive features of the regional wind field are described and explained. Mountain effects on rainfall amounts and distribution are also briefly covered, including the very high precipitation received on the west coast of the New Zealand Southern Alps and the more even spread of precipitation north and south of the European Alps. Medium- to long-term influences on the climate are examined for each region, with both affected by interregional teleconnections. El Niño–Southern Oscillation (ENSO) and North Atlantic Oscillation (NSO) are seen as strongly controlling the intradecadal climate variability experienced in the New Zealand Southern Alps and European Alps, respectively.

Keywords: *New Zealand Southern Alps; European Alps; mountain climate; orographic effects; ENSO; NAO; wind fields; precipitation.*

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Introduction

The aim of this article is to compare and contrast the weather and climate of the alpine regions of New Zealand and Europe, based only on selected aspects for reasons of space. Some general climate characteristics of the 2 areas are compared, together with mountain effects on synoptic scale circulation and local and regional airflow and precipitation patterns. Factors affecting longer term climate variability are also briefly examined. The purpose of this comparative review is to provide deeper insight into the interaction of large-scale atmospheric circulation with the complex topography of 2 mountain areas of similar size and the complex weather and climate phenomena that result. It is intended as an introduction for students or interested laypersons.

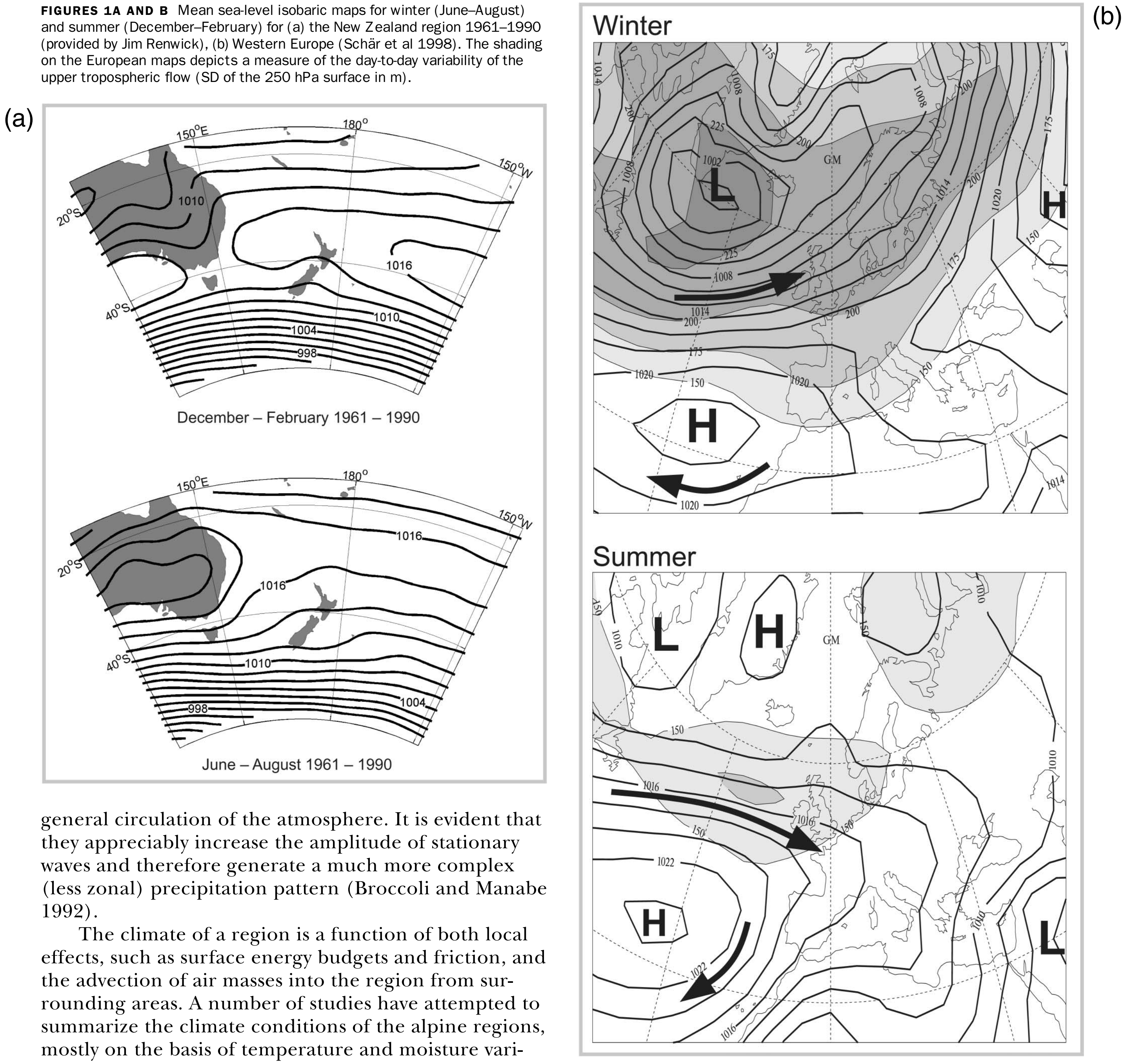
The 2 regions are located in midlatitude sections of the Northern and Southern Hemispheres. The New Zealand Southern Alps extend across a latitude range from about 41° to 47°S, while the European Alps lie between 43.5° and 48°N (see the maps on page 313 of this issue). However, the 2 mountain regions differ in their overall shape and orientation. The New Zealand alpine region is a relatively straight mountain range oriented northeast–southwest, while the European Alps are curved and oriented more west–east, although the southwestern section curves, resulting in a more north–south orientation. Another notable factor is location with reference to the major global circulation features (Figure 1a,b). The Southern Alps of New Zealand are surrounded by ocean and are located between the subtropical anticyclones and the traveling depressions of the Southern Ocean so that they experience strong westerly winds. These interact significantly with the mountains, creating a unique set of atmospheric conditions. In contrast, the European Alps lie in the western part of the Eurasian continent. Because of the influence of the much larger continental surfaces, circulation in the Northern Hemisphere is much less zonal in structure so that the European Alps do not experience such persistent and strong westerly winds. Also, the mountains of the European Alps are generally higher than those of the New Zealand Southern Alps, with more extensive areas above 2000 m (see the maps on page 341 of this issue). However, the maritime location of New Zealand is perhaps a more significant contrast. These different background conditions are part of the environment within which human activity takes place, contributing to hazards but also providing resources for such needs as hydroelectricity and agricultural production.

The 2 alpine regions have a significant influence on the atmosphere at a range of scales from the synoptic to the micro scale. The mountains have a significant effect on both the atmospheric circulation within the terrain and on surrounding sections of the 2 regions. Although the present article is concerned with the mountains themselves, it also refers to the effects of the mountains on surrounding areas such as the Canterbury Plains and the West Coast in New Zealand and the Po Valley, the Rhine Valley, and the Swiss Plateau in Europe. Following a general description of the climatic conditions of each region, synoptic- to local-scale orographic effects are described, followed by a brief assessment of longer term climate variability in the 2 regions.

General climate characteristics

The Earth's orography influences atmospheric motion by deflecting airflow horizontally and vertically, by enhancing frictional dissipation, and by providing elevated sources of latent and sensible heat (WMO 1982; Barry 1992). Field studies and model experiments as part of ALPEX (Alpine Experiment), SALPEX (Southern ALPEX), or MAP (Mesoscale Alpine Programme) confirmed that mountains can significantly modify the

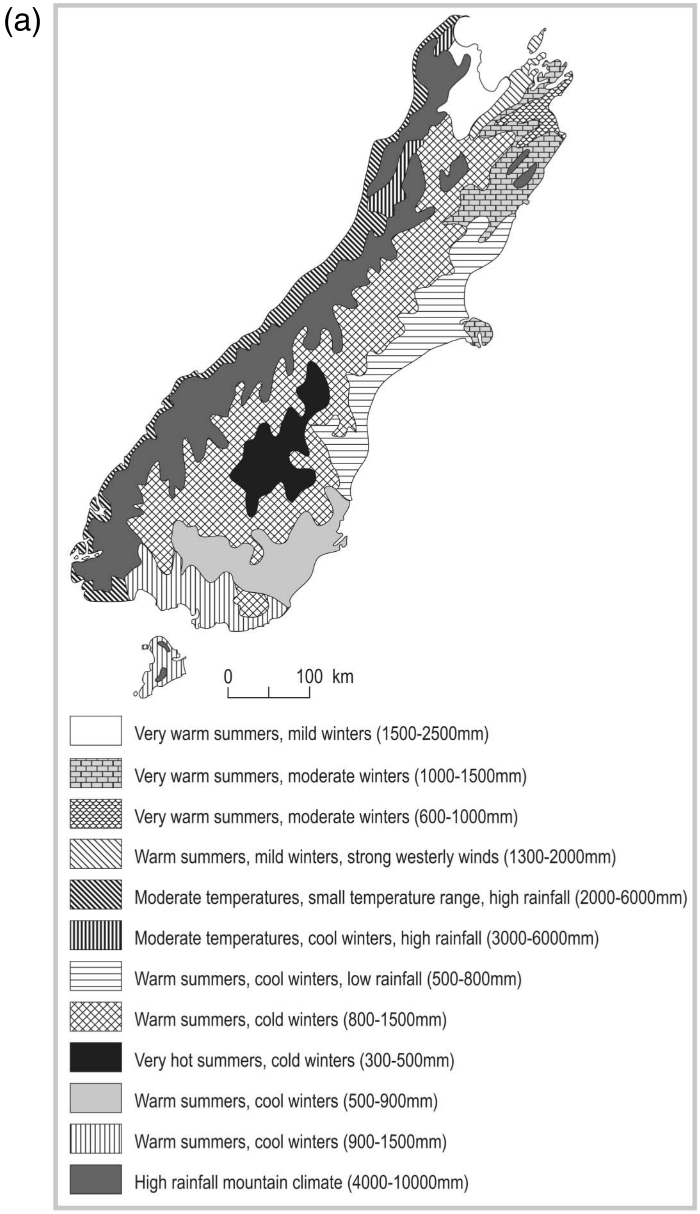
FIGURES 1A AND B Mean sea-level isobaric maps for winter (June–August) and summer (December–February) for (a) the New Zealand region 1961–1990 (provided by Jim Renwick), (b) Western Europe (Schär et al 1998). The shading on the European maps depicts a measure of the day-to-day variability of the upper tropospheric flow (SD of the 250 hPa surface in m).



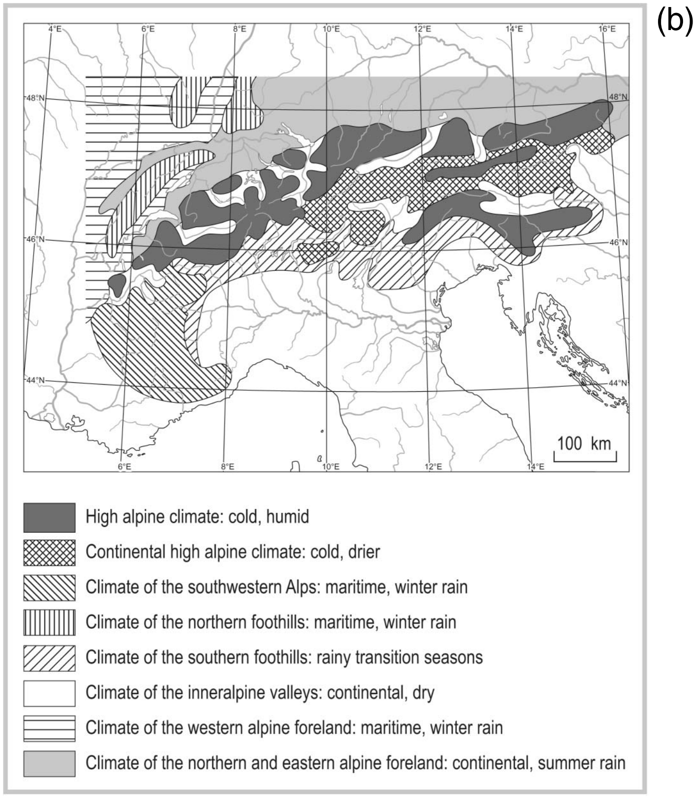
general circulation of the atmosphere. It is evident that they appreciably increase the amplitude of stationary waves and therefore generate a much more complex (less zonal) precipitation pattern (Broccoli and Manabe 1992).

The climate of a region is a function of both local effects, such as surface energy budgets and friction, and the advection of air masses into the region from surrounding areas. A number of studies have attempted to summarize the climate conditions of the alpine regions, mostly on the basis of temperature and moisture variables. It is clear that, compared with the European Alps, the extensive areas of ocean surrounding New Zealand make the climate significantly more moderate in character.

Figure 2a,b presents climate classifications for both alpine regions. The network of observation stations is significantly more dense in the European Alps than in their New Zealand counterpart, and this limits the identification of smaller scale variations. Because of the predominance of westerly flow in the New Zealand Southern Alps, the total number of hours of sunshine is much higher on the eastern side of the mountains (>2000 hours), where maximum air temperatures are also frequently greater. Foehn northwesterly conditions can produce screen-level air temperatures greater than 30°C along the eastern side, with relative humidities below 20%. The annual air temperature range is considerably greater in eastern and central areas due to the reduced moderating influence of the surrounding oceans and the decreased cloud cover. However, the complex terrain creates much microclimatic variability within the mountain region. In the European Alps, clear contrasts exist not only between the western maritime and eastern continental climates. The Mediterranean Sea is a second important source of humidity, so that the difference between the northern midlatitude and the southern Mediterranean climate, with its subtropical summer character, is also distinctive. Annual duration of sunshine higher than 2000 hours is



FIGURES 2A AND B Climate regions of the mountain regions of (a) the South Island of New Zealand (after New Zealand Meteorological Service 1983) and (b) the European Alps.



observed only in the drier inner-alpine valleys and south of the European Alps, where the temperatures are generally also higher. On clear and calm winter nights, isolated valleys and basins within the Jura and the Alps can produce screen-level air temperatures considerably below –30°C.

Synoptic pressure patterns

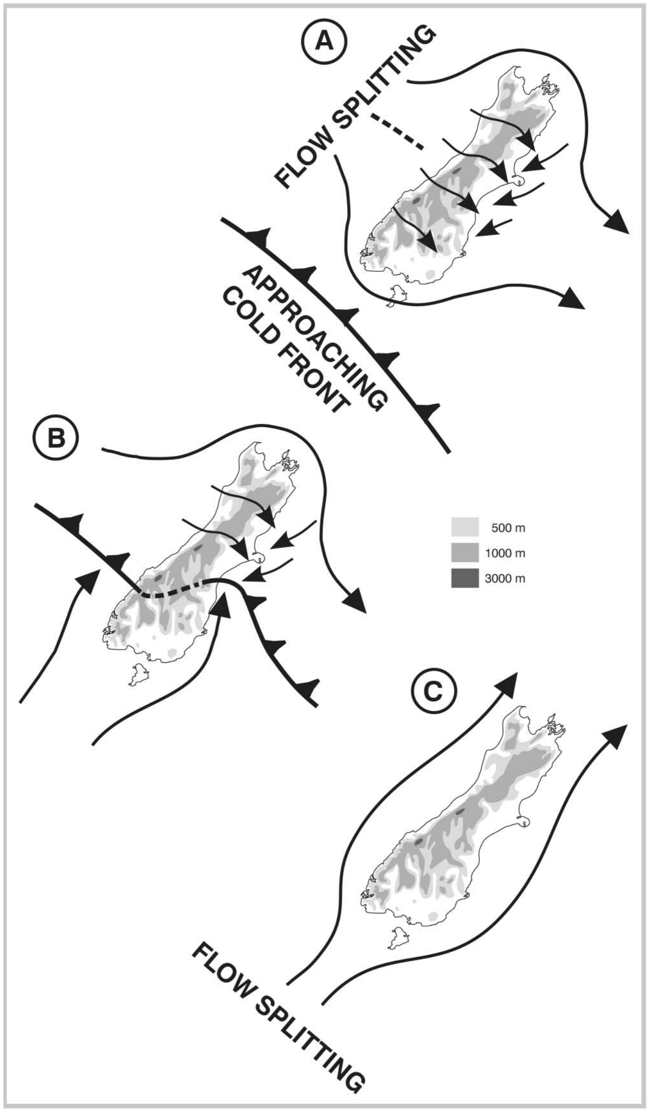
The prevailing synoptic weather systems and the ways in which they interact with the mountainous terrain have a significant effect on spatial patterns of weather and climate. The sequence of alternating depressions and anticyclones that move from west to east across the New Zealand region has a marked effect on the regional patterns of airflow, cloud, and precipitation. This is largely the result of lifting generated by interaction of weather systems with the underlying terrain.

The main features of the synoptic circulation can be identified in the mean sea-level pressure distribution shown in Figure 1a. The subtropical anticyclones tend to move further north in winter and south in summer, although seasonal changes in atmospheric circulation are less significant than those experienced in Europe because of oceanic effects (Figure 1). However, there is significant seasonal variation in the intensity of the westerly winds, which are strongest in springtime (October–November) and weakest in summer (February).

Typically, slow-moving anticyclones move across the northern section of New Zealand, with more rapidly moving frontal troughs affecting the south. The predominant westerly winds lie in between, with the most frequent synoptic situation over the alpine region being anticyclonic southwesterly (Sturman et al 1984). However, secondary lows sometimes develop in the Tasman Sea and move across the mountains, while decaying tropical cyclones may move southward between December and May, although they mostly affect the North Island. This section of the Southern Hemisphere is also well known for anticyclonic blocking, which can disturb the prevailing westerly flow for significant periods (Sturman and Tapper 1996).

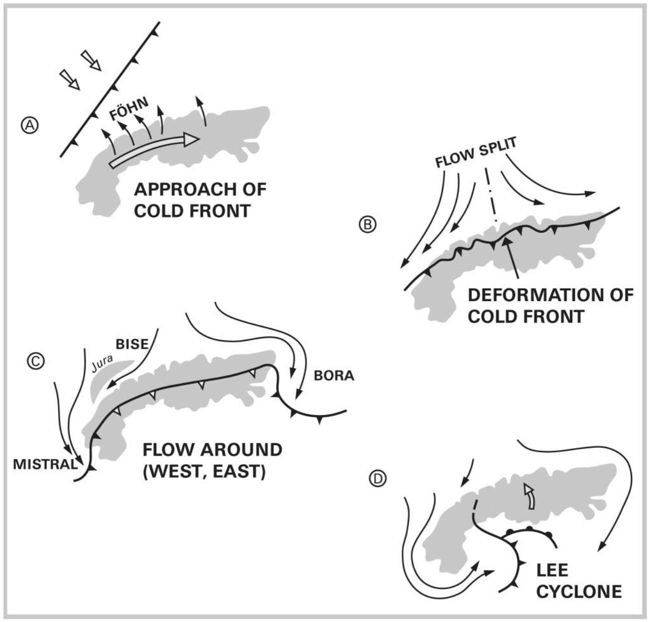
As a consequence of their position in the transition zone between the Atlantic Ocean, the Mediterranean Sea, and the Eurasian continent, the European Alps lie between and not in the center of important pressure systems (Wanner et al 1997). Figure 1b shows the winter

(a)



FIGURES 3A AND B Examples of the interaction of cold fronts with the mountains in both alpine areas: (a) the South Island of New Zealand, (b) the European Alps.

(b)



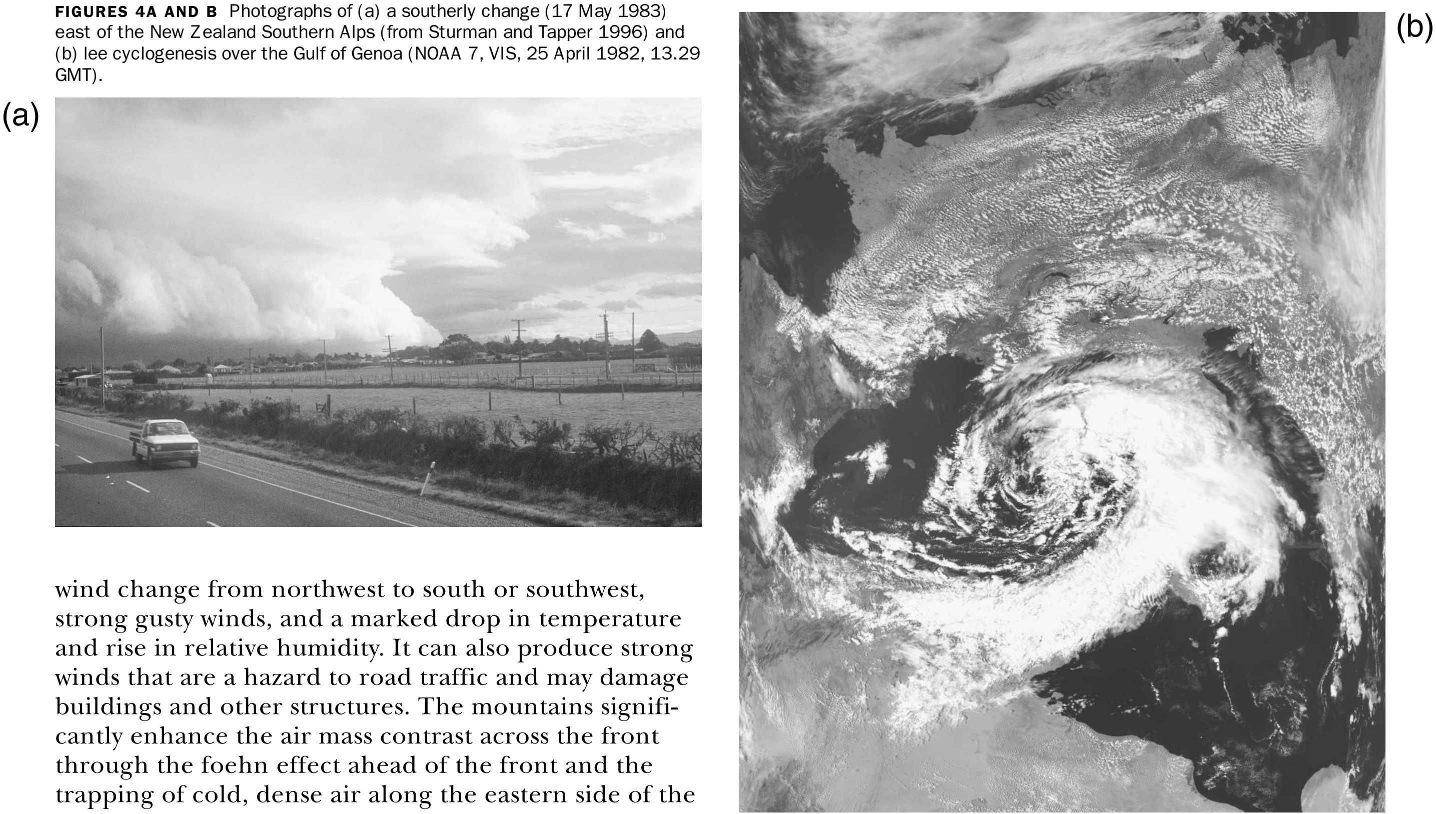
and summer seasonal mean sea-level pressure pattern in the Atlantic–European area, together with the day-to-day variability of the midtropospheric flow, which roughly represents the position of the mean storm tracks (Schär et al 1998). In winter, the Alps are strongly influenced by the Icelandic Low and the related eastward-moving cyclonic systems on its southeastern edge. The resulting westerly airflow over the European Alps is interrupted by shorter anticyclonic blocking situations due to the influence of the Azores High and particularly the cold continental Siberian High. In summer, the Azores High extends northeastward and interacts with the continental low-pressure systems over the alpine region.

Modification of synoptic circulation by both Alps

Dynamic aspects

The New Zealand Southern Alps have only a limited effect on planetary-scale circulation because their dimensions are so small. However, their effect on synoptic-scale phenomena has been known for some time (Hutchings 1944; Smith 1982). For example, surface-pressure field deformation results from both dynamic orographic effects and the diurnal heating cycle of the mountain land mass (Trenberth 1977). This is characterized by a leeside trough, which may combine with a heat low over land during summer daytime periods. Cyclogenesis downwind of the mountains is very rare, while distortion of fronts is a more important process that creates problems for local forecasting. The New Zealand Southern Alps are sufficiently high to act as a low-level air mass barrier. As a result, the orientation and direction of movement of fronts over the South Island are significant factors influencing the movement of air masses near the surface (up to 2000 m). They are frequently oriented northwest–southeast, while the Southern Alps are oriented northeast–southwest (schematic A in Figure 3a). These cold fronts frequently accelerate northward along the eastern side of the mountains (Sturman et al 1990; Smith et al 1991; Sturman 1992), as suggested by previous conceptual models of frontal deformation (Smith 1986) (schematic B in Figure 3a). This phenomenon is locally called a southerly change and is typically marked by a sudden

FIGURES 4A AND B Photographs of (a) a southerly change (17 May 1983) east of the New Zealand Southern Alps (from Sturman and Tapper 1996) and (b) lee cyclogenesis over the Gulf of Genoa (NOAA 7, VIS, 25 April 1982, 13.29 GMT).



wind change from northwest to south or southwest, strong gusty winds, and a marked drop in temperature and rise in relative humidity. It can also produce strong winds that are a hazard to road traffic and may damage buildings and other structures. The mountains significantly enhance the air mass contrast across the front through the foehn effect ahead of the front and the trapping of cold, dense air along the eastern side of the barrier (Figure 4a), although events can vary in character depending on the 3-dimensional wind and temperature structure of the frontal zone. Relatively minor variations in the orientation of the front and the airflow behind it make it difficult to forecast the occurrence and timing of these events.

Although the prevailing winds of this latitude are westerly, observed subsynoptic low-level airflow either side of the mountains runs parallel to their axis, while within the mountains, the wind is often channeled by local topography (McGowan and Sturman 1996b; McGowan et al 1996; Sturman et al 1985). Flow splitting may occur on the upstream side so that low-level flow is blocked and passes around the mountains to the north or south (McKendry et al 1986; Ryan 1987; McCauley and Sturman 1999) (Figure 3a). Air at higher levels may pass over the mountains, descending to the plains on the eastern side as the foehn nor'wester, which has long been recognized as a dominant feature of the alpine climatic environment (Davis 1887), occurring most frequently in spring. Few mountaintop observations are available in the New Zealand Southern Alps, but it is a very windy environment. Wind speeds frequently exceed 45 m/s (160 km/h) at 1800 m in the Craigieburn Range, with maximum gusts reaching 67 m/s (240 km/h) (McCracken 1980). Channeling in mountain valleys frequently produces winds in excess of 150 km/h on valley floors, especially in spring (October). Lee waves are often associated with transmountain flow, and severe downslope winds may occur over the eastern South Island. On 1 August 1975, a foehn windstorm caused extensive damage to forests and buildings east of the Southern Alps as a result of wind speeds reaching 195 km/h in some areas (Hill 1979; Reid and Turner 1997). Deep deposits of loess over parts of the Canterbury Plains and Banks Peninsula are evidence of foehn wind occurrence over many thousands of years.

As mentioned above, the European Alps do not form a simple linear barrier but rather are more horn shaped. This appears to contribute to the world's highest frequency of lee cyclogenesis events occurring to the lee of this mesoscale mountain system (Tibaldi et al 1990). This phenomenon is illustrated in Figures 3b and 4b. Most of the frontal systems associated with eastward-moving troughs or low-pressure systems approach the Alps from the northwest. Subsequent interaction of cold fronts with the mountains leads to a complicated 3-dimensional process, with frequently occurring transitions from flow-over to flow-around situations (Egger and Hoinka 1992). Schematic A in Figure 3b shows an approaching cold front. Air pressure is very low north of the Alps, strong southwesterly winds flow over the highest peaks, and the weakly stratified warm and moist air at lower levels is able to flow through the alpine passes, leading to strong south-foehn conditions in the northern alpine valleys. The cold air behind the front is often capped by a pronounced inversion and therefore has insufficient kinetic energy to climb the Alps. It is therefore retarded, deflected laterally, and starts to flow around the barrier or penetrates into the larger and lower alpine valleys (Figure 3b, schematic B). Three different cold wind systems are generated by these blocking and channeling effects: the Mistral in the western Rhone valley, the Bise between the Jura and the Alps in the north, and the Bora on the Adriatic coast east-southeast of the Alps (schematic C in Figure 3b). In the final stage (schematic D), a lee cyclone is often formed in the Gulf of Genoa. This complex process is sensitive to the meridional location of the midlatitude storm track (Schär et al 1998) as well as other important factors that influence this often explosive process (Pichler and Steinacker 1987). These include the barrier effect and related conservation of potential vorticity; the cyclonic flow around the western alpine arch and the transformation of shear into cyclonic vorticity; the advection of upper-level isentropic vorticity, which joins with a low-level vorticity center over the Mediterranean Sea; and finally, the overflow of cold air from the north (north-foehn) at low levels over the Alps and the ascent of warm and moist Mediterranean air from the southeast, generating a region of strong baroclinicity over the mountains. Wind speeds reach absolute maximum values of about 160 km/h in the plain (Swiss Midland), 175 km/h in the northern Alpine foehn valleys, and 250 km/h on mountaintop stations.

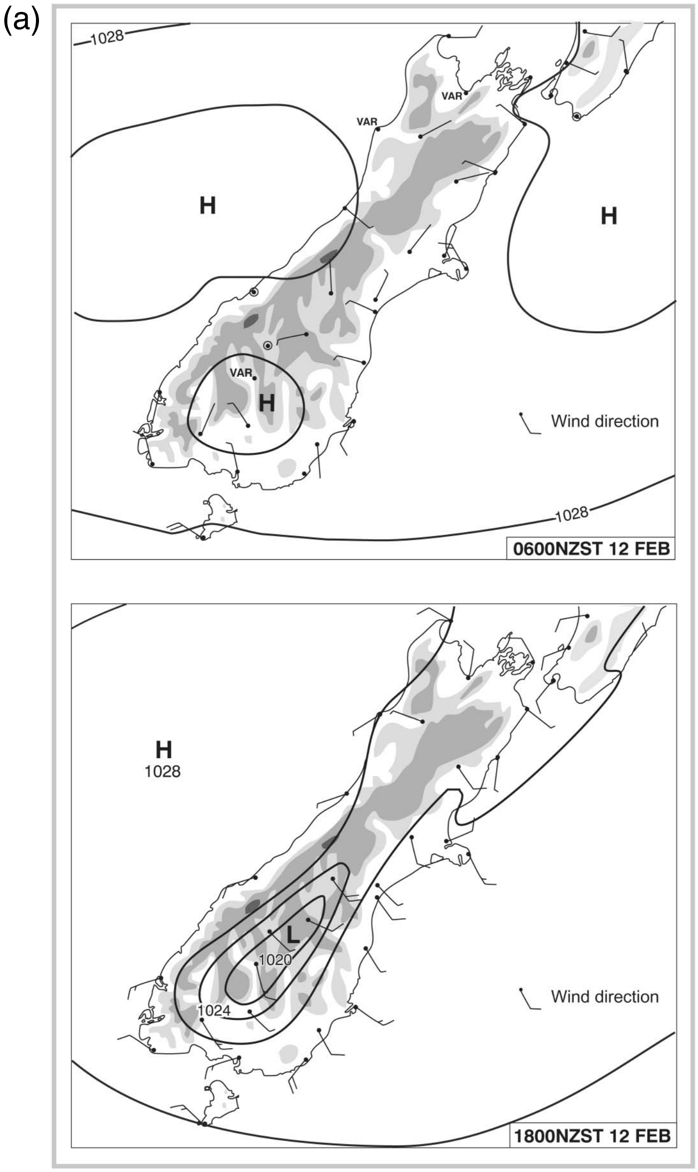
Thermal aspects

Despite the influence of strong winds, thermally generated local winds are important features of the alpine environment, particularly under weak pressure gradients (Sturman et al 1985; McGowan et al 1996; McGowan and Sturman 1996a). At the largest scale, the mountains represent an elevated heat source that can produce thermally induced regional pressure gradients between the mountain ranges and surrounding plains (Figures 5a,b), while the terrain of the valleys and basins has a significant impact on the local wind regime. Cold air drainage and katabatic (downslope) winds generated by nocturnal slope cooling are common in the mountain region, particularly in winter. The cold air fills mountain basins and spills out through valleys and gorges onto the surrounding plains to both the west and east of the mountains (McKendry 1983; McCauley and Sturman 1999). Daytime anabatic (upslope) winds are common within the mountain valleys and basins, along with mountain-valley wind systems and lake breeze circulations (McGowan et al 1995; McGowan and Sturman 1996a). There is also some evidence for the penetration of sea breezes and mountain–plain winds from the east and west coasts into the mountain valleys and basins, where heat lows may persist for several consecutive days in summer (Ryan 1987) (Figure 5a).

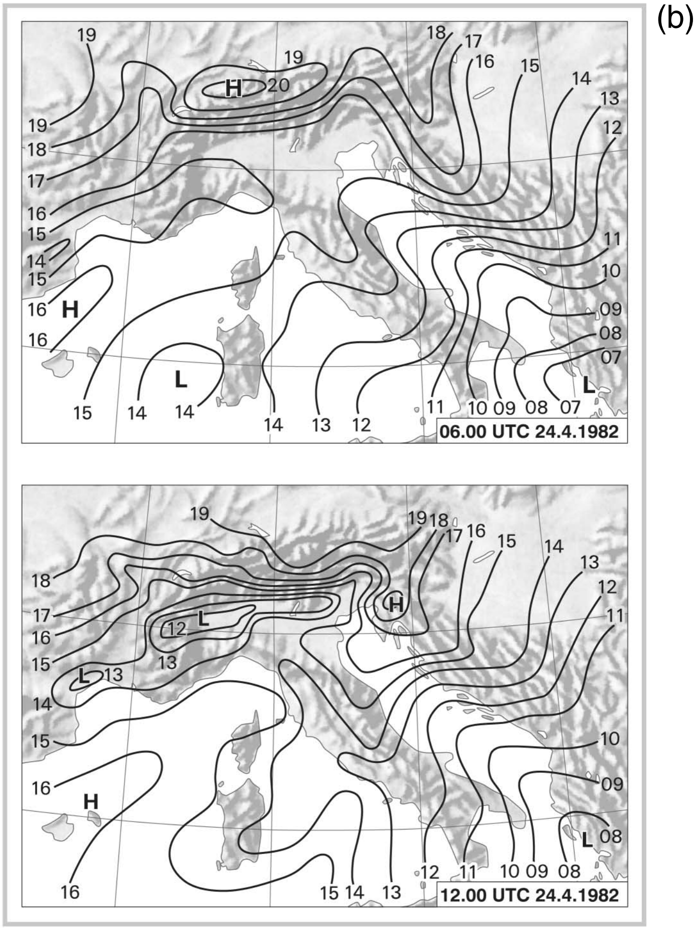
Compared with the New Zealand Southern Alps, the European Alps are more strongly influenced by continental effects. They are therefore more affected by cold near-surface anticyclones in winter and heat lows in summer. Both situations generate well-developed thermally driven (thermotopographic) wind systems with a complex hierarchy from local slope winds to valley circulations and larger scale mountain–plain wind systems (Defant 1949). Figure 5b presents the diurnal variation of the surface-pressure field between southern Germany and the Mediterranean Sea during anticyclonic conditions in April 1982. The influence of the Alps is represented by a high-pressure anomaly in the early morning and a low-pressure anomaly at noon. Mountain–plain circulation systems are typically associated with this diurnal cycle. Although the finer detailed regional- and small-scale surface-pressure distribution is not represented, one can imagine the existence of a hierarchy of flow systems with a handover of air masses from the large prealpine forelands (Po Valley, Swiss Plateau) to the alpine valleys by day and vice versa by night. Understanding these circulation systems is important for explaining episodes of strong air pollution in the region (dust and nitrogen dioxide in winter and ozone in summer).

Orographic effects on precipitation

The more oceanic environment of the New Zealand Southern Alps, together with the different shapes of the alpine systems, results in a very different precipitation distribution. Two cross-sections are shown in Figure 6. As mentioned above, westerly winds predominate in the New Zealand region, where they interact with the Southern Alps to produce an extreme contrast in average rainfall between the western and eastern sides of the mountains (Figure 6a). For example, more than 10,000 mm of rainfall per annum is typical on the upper slopes on the western side, compared with less than 600 mm on the eastern coastal plains and in the mountain basins (Griffiths and McSaveney 1983). The seasonal maximum typically occurs in spring when westerly winds are more frequent. The lifting of air over mountains is a dominant mechanism for the development of intense precipitation, although there is significant local variability associated with the complex terrain. For example, large quantities of precipitation are distributed across the Southern Alps to fall on the leeside of the mountains as a result of strong westerly winds and enhanced lifting on the upstream side. This is termed spillover (Sinclair 1997; Chater and Sturman



FIGURES 5A AND B The thermal influence of the mountains on typical mean sea-level pressure fields in (a) the New Zealand Southern Alps (provided by H.A. McGowan) and (b) the European Alps (Hafner et al 1987).

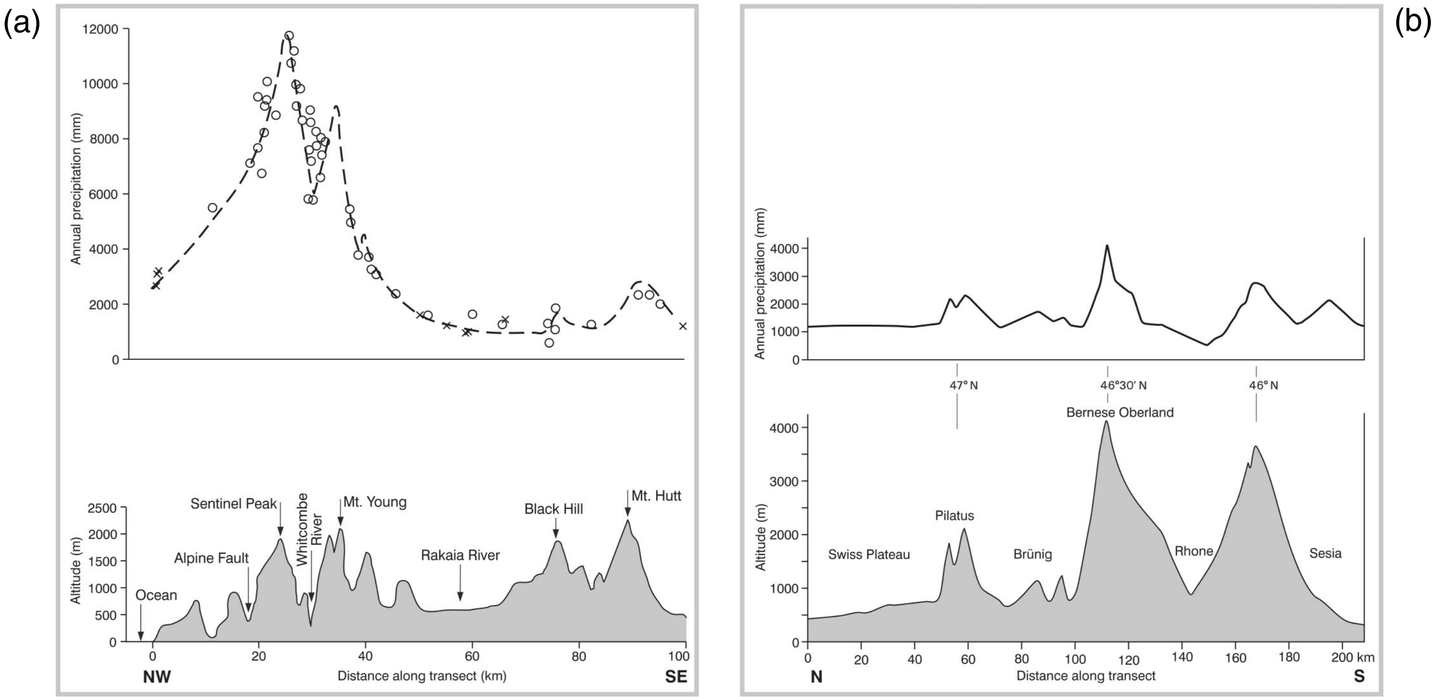


1998). Orographic lifting frequently generates thunderstorms and sometimes tornadoes on the western, or upstream, side of the mountains, while they are less common over the eastern plains.

Large amounts of precipitation fall as snow during winter, which varies spatially due to terrain effects. However, significant interannual variability in snowfall is common due to changes in synoptic weather patterns associated with larger scale atmospheric circulation variations such as the El Niño–Southern Oscillation (ENSO) phenomenon. Variations in the amount and distribution of rain and snowfall are of major significance to hydro lake management and flood control since the bulk of New Zealand's electricity is obtained from dams in the Southern Alps.

The Mesoscale Alpine Programme (MAP) investigated in detail the dynamics of orographic precipitation formation in the European Alps (see MAP science plan: www.map.ethz.ch/splan/spindex.htm), but only a cross-section through the Swiss Alps is presented here (Figure 6b). The maximum annual precipitation in the northern European Alps is seen to be about one third of the New Zealand maximum, reflecting the different climatic environments. The 2 precipitation peaks over the northern and southern alpine chains extend to the eastern end of the Alps from about the Valais in the center (see Figure 2). Rare intense events contribute substantially to the long-term mean (4% of the days contribute to about 40% of total precipitation; Schär et al 1998). There are also clear seasonal differences in the precipitation amounts of the different regions (Frei and Schär 1998). Large parts of the European Alps are mainly dry in winter and rainy in summer, although the southern region is wetter in spring and autumn (Figure 2). The French Mediterranean coast, the lower Rhone Valley, the Italian peninsula, and the eastern Adriatic coast to the south normally remain dry in summer under the influence of the subtropical Azores High. Significant interannual snowfall variability is also observed in the European Alps. The thawing that fre-

FIGURES 6A AND B Cross-sections through the central part of (a) the New Zealand Southern Alps (from Griffiths and McSaveney 1983) and (b) the European Alps, showing the mean annual precipitation amounts (Weischet 1977).



quently occurs during Christmas time is already proverbial (Wanner et al 1998).

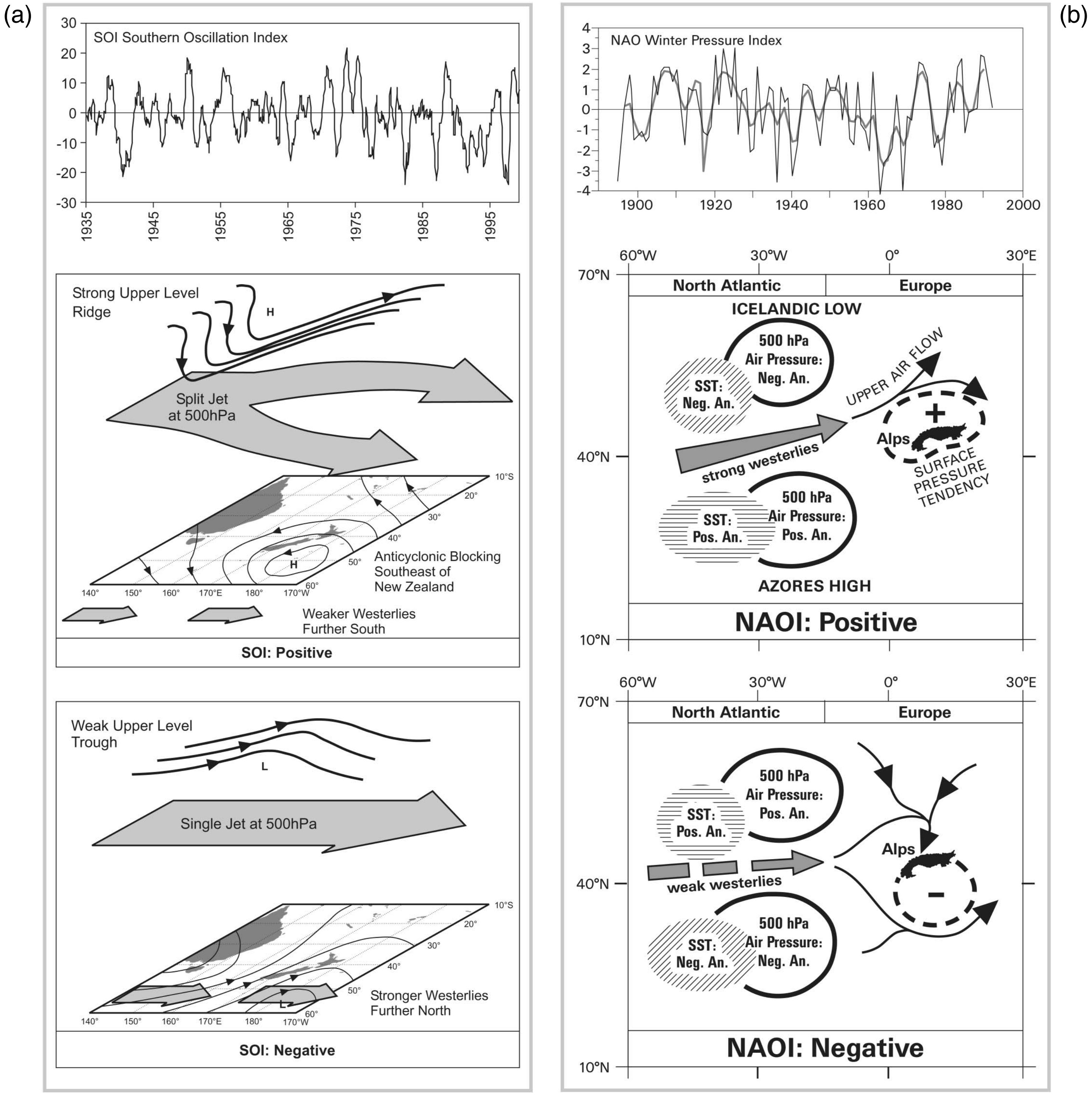
Climate variability and global–local links

In both areas, the long-term (interannual to century scale) climate variability is strongly determined by predominant climate teleconnections. The area of New Zealand is strongly influenced by the ENSO (El Niño–Southern Oscillation) phenomenon, which shows a 3–6 year cycle (Gordon 1986; Mullan 1995). The European Alps are affected by the NAO (North Atlantic Oscillation), with winter season variability experiencing periodicities around 2 and 6–10 years (Hurrell and van Loon 1997; Wanner et al 1997). Figure 7 shows the time series of the 2 teleconnections together with a schematic representation of the type of influence they exert on the 2 mountain ranges.

The Southern Oscillation is the result of a reversal in the mean sea-level pressure anomaly between the southeast Pacific anticyclone and the Indonesian region, which is related to the strength of both the southeast trade winds and the movement of ocean water across the Pacific. Changes from El Niño to La Niña conditions are associated with a reversal from predominantly west and southwesterly flow over New Zealand to flow from the northeast (Gordon 1986). These changes in dominant wind direction are associated with significant variations in the movement of synoptic weather systems through the region. The interaction of these airflow changes with the Southern Alps causes a change in the distribution of rainfall and temperature anomalies over the South Island, with the south and west colder and wetter in El Niño and the northeast generally a little cooler and dryer (Salinger and Mullan 1999). During La Niña phases, the region is generally warmer with increased rainfall over the north and east and a reduction to the southwest. Links to glacier advance and retreat have also been identified (Hooker and Fitzharris 1999). For example, the Franz Josef Glacier on the western side of the New Zealand Southern Alps started a major advance from about 1982 after a long period of general retreat. However, there are significant variations in the response of different glaciers, with mountain glaciers showing the greatest advances and large valley glaciers still retreating (Chinn 1999). Major changes in atmospheric circulation, which appear to have caused this advance, particularly increased southwesterly flow and increased snow deposition, are clearly related to ENSO events. Because of their marginal environmental conditions, the mountains of New Zealand also provide a useful source of tree ring data, presenting the slightly longer term context for recent climate variability. Despite recent glacial advances, dendrochronologies suggest that the last 40 years have experienced a significant warming compared with the period since 1500 AD (D'Arrigo et al 1998).

As mentioned above, the European Alps are influenced by the North Atlantic climate system, whose principal regional teleconnection, the NAO, is only domi-

FIGURES 7A AND B Time series of (a) the ENSO (El Niño–Southern Oscillation) and (b) NAO (North Atlantic Oscillation) indices together with schematic representations of the influence of both seesaw phenomena on the 2 alpine regions (after Tyson et al 1997; Wanner et al 1997).



nant during winter (Hurrell and van Loon 1997). The NAO is strongly dominated by meridional processes, and the classical interaction between ocean and atmosphere is additionally influenced by sea ice dynamics (Wanner et al 2001). In its positive or zonal mode, the northern North Atlantic SST anomalies are negative (see Figure 7b), the Icelandic low is strong, and the axis of the well-developed polar front jet (large arrow) is orientated southwest–northeast. The winters are therefore mild, and northern Europe registers positive precipitation anomalies. Because the European Alps are located southeast of the exit zone of the jet, they under-

TABLE 1 Summary of differences in weather and climate between the New Zealand Southern Alps and the European Alps.

Phenomenon	New Zealand Alps	European Alps
Climate variability and global/local links	ENSO climate mode	NAO climate mode
Climate character	Oceanic to semicontinental climate (Köppen’s Cfb class)	Semicontinental to continental climate (Köppen’s Cfb class)
Polar dynamics	South Pole: continental ice cap, large cold air pool	North Pole: sea ice, smaller cold air pool
Westerlies/circulation	Zonal	Zonal to meridional
Important dynamic phenomena	Cold front distortions (southerly changes)	Cold-front distortions, including lee cyclogenesis (Genoa cyclones)
Dynamic wind systems	Nor’wester	Foehn, Mistral, Bise, Bora
Local thermally driven (thermotopographic winds)	Slope, mountain/valley, mountain/plain winds, land/sea breezes	Slope, mountain/valley, mountain/plain winds
Distribution of precipitation	Very high annual amounts, strong west–east gradients with 1 high peak to the west	Moderate amounts with 2 peaks (north and south) in the central and eastern European Alps

go a remarkably reinforced cross-isobar northwest–southeast mass transport and a pressure rise, resulting in anticyclonic and warm winter weather. The jet is much weaker in the negative or meridional mode, with its axis lying further south. Cold continental air masses from the north can therefore inundate central and southern Europe, causing frigid winters in the Alps and generating positive precipitation anomalies in the Mediterranean area. The time series in the upper part of Figure 7b shows that the fluctuations of the NAO Index were irregular before 1950. Between 1950 and about 1974, the index was mostly negative and led to stronger winters with snowfall or frozen lake situations. Under the influence of a global climate shift, including also the Great Salinity Anomaly (GSA; Dickson et al 1988), the seesaw moved to its positive quasi-equilibrium around 1973/1974, leading to a longer period with very warm winters, upward moving snowlines, and dramatically retreating glaciers.

Conclusion

The 2 antipodes, the New Zealand Southern Alps and the European Alps, are of a similar size and are located at about the same latitude. Nevertheless, their climate and weather show remarkable differences that are mainly due to important geographical factors, including different land–water distribution in both hemispheres and the obvious differences in the shape and orientation of both meso-scale mountain ranges. Table 1 summarizes the phenomena described and the differences between the 2 areas. It can generally be said that the difference in continentality creates a more moderate, windy, and humid climate for the New Zealand Southern Alps and a drier climate with stronger seasonal differences for the European Alps. Medium-term climate variability experienced in both of these 2 areas is controlled by 2 different teleconnections (El Niño–Southern Oscillation and NAO), which involve ocean–atmosphere interactions remote from both mountain regions.

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