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MEASURED WIND SPEED TRENDS ON THE WEST COAST OF CANADA

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ABSTRACT

Trends in measured wind speed are discussed for four stations on the west coast of Canada. Periods of record vary with the station. They begin in the late 1940s or the 1950s and run through to the early to mid 1990s. The most prominent feature of the time series was a decline in mean annual and winter wind speeds at Cape St James, Victoria International Airport, and Vancouver International Airport during the middle portion of the record. Declines in mean annual wind speed are matched by increases in the percentage of calms and decreases in high wind speed observations. The pressure gradient between Victoria, Vancouver and Comox, the Pacific North American index, the Pacific decadal oscillation index, and other climate elements in British Columbia and the northwestern USA show trends at roughly the same time, indicating a natural cause of the wind speed decrease. Comox Airport mean wind speeds increased, however, perhaps the result of reduced friction in the vicinity of the anemometer outweighing the decrease in the regional pressure gradient.

KEY WORDS: wind speed trends; Pacific decadal oscillation; Pacific North American index; pressure triangle wind speeds

1. INTRODUCTION

Much of the effort in climate change and variability studies has so far concentrated on air temperature and precipitation. These two elements are of obvious concern and lend themselves to study through both measured and proxy data. However, most practical effects of any changes, variations, or trends in climate do not involve a single climate element but are the result of a combination of elements working together. Although the development of long time series may be difficult, we have now reached the stage in the study of atmospheric variation where it is time to focus more attention on other elements. Wind speed is one of these. There is hardly any impact of climate variation that does not involve wind speed either directly or indirectly. For example, one of the key ways that air temperature variations affect objects and living things is through sensible heat flux density, which is dependent on the wind speed. Considering air temperature in isolation is interesting, but assessment of practical effects of its variation benefits from some knowledge of coincident wind speed.

Studies on measured wind speed variations are beginning to appear. Pirazzoli and Tomasin (2003) described the trends in wind speed at a number of stations on the coast of Italy. Pryor and Barthelmie (2003) present variations in 850 hPa wind speeds determined from the National Centers for Environmental Prediction–National Center for Atmospheric Research reanalysis over the Baltic Sea region. North American examples include the following. Klink (1999) looked at the 1961–90 trend in mean monthly maximum and minimum wind speeds at several US stations. Klink (2002) presented the time series of mean annual wind speed and period-of-record trends in a number of percentiles of the wind speed distribution at seven stations in Minnesota and the Dakotas. Record lengths varied from 22 to 35 years. Keimig and Bradley (2002) reported

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the 1953–93 trends in afternoon wind speeds at 15 Canadian and Alaskan stations between 55° and 75 °N. Gower (2002) investigated the trends and variations in 6 to 27 years of wind speed data from buoys off the west coast of Canada and the USA.

The purpose of this paper is to present the recent trends and variations in measured wind speed at four land stations along the west coast of Canada. It adds to those cited above by covering a different area. It utilizes a longer period of record than Klink (1999, 2002) and Gower (2002). The entire record of hourly observations throughout the year is covered, and the actual time series, not just linear trends, are presented, thus allowing readers to assess short-term variations. Some potential causes of the trends are discussed.

2. STATIONS AND METHODS

Four stations are used (Table I). Three are airport stations located in the heavily populated coastal zone of the Vancouver metropolitan area and the east coast of Vancouver Island (Figure 1). These three stations sit on flat land, although there are hills and mountains in the vicinity. Simmons (1975: 10–11) stated that, although wind speeds at this type of location will be lower than those found at well-exposed sites, the records can be used to assess some of the general characteristics of the wind regime, including temporal variations.

The fourth station, Cape St James, is located at a remote lighthouse on the southernmost of two hills that comprise St James Island at the southern end of the Queen Charlotte Islands (Environment Canada, 1985, 1989). This hilltop station has very good exposure, with the exception of hills on the adjacent island to the north. It is representative of well-exposed coastal stations that have low-friction surroundings and high mean wind speeds. More station details are given in Tuller and Brett (1984; Brett and Tuller, 1991).

Record lengths range from 35 years (1957–91) at Cape St James to 49 years (1947–95) at Vancouver International Airport (Table I).

Hourly wind speed data from the Meteorological Service of Canada digital archive were utilized. Hourly values were combined into annual and seasonal means. Seasonal wind speed trends are similar to annual trends, although relative magnitudes vary from station to station. An example from Vancouver International Airport is given in Figure 2. A full discussion of seasonal patterns is beyond the scope of the present paper. Therefore, only the winter (December–February) results are given. Winter is the time of maximum wind speed at all stations except Vancouver, where they peak in March and April. This gives the winter months an important influence on the annual mean. Trends in atmospheric circulation and teleconnection patterns, such

Table I. Stations

	Cape St James	Comox Airport	Vancouver International Airport	Victoria International Airport
Latitude (N)	51°56′	49°43′	49°11′	48°39′
Longitude (W)	131°01′	124°54′	123°10′	123°26′
Elevation (m)	89 and 92	24	3	19
Period of record used	1957–91	1953–95	1947–95	1953–95
Missing Observations	620 (0.198%)	72 (0.019%)	191 (0.044%)	114 (0.030%)
Timing of anemometer changes				
Location	June 1963	March 1954 September 1959 August 1967	November 1959 December 1963	July 1964
Height	June 1957 June 1963	March 1954 September 1959 August 1967	November 1959 December 1963	July 1964
Type	September 1977	September 1959	November 1959 December 1963	March 1964

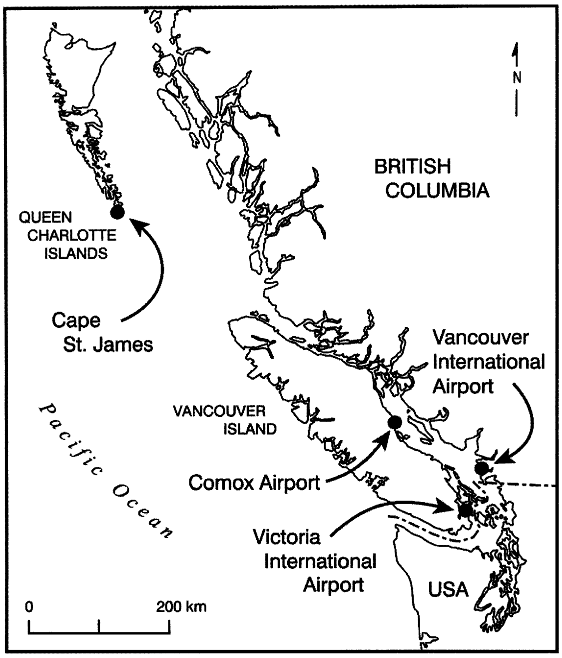

Figure 1. Stations

as the Pacific North American (PNA) pattern, are best developed in the winter. A complete analysis of wind speed trends and variations in other seasons is a subject for further research.

Missing data were few with the exception of Cape St James, which had 514 missing observations in November 1984 (Table I). Missing data were not replaced. With the exception of November 1984 at Cape St James, missing observations are scattered throughout the station records and the number is so low that replacement would have no effect on annual or winter means. Despite the high number of Cape St James missing observations in November 1984, the time series of November mean wind speeds is similar to that of October and December. The 1984 means were higher than those of the adjacent years for all 3 months. The relative magnitude of the November 1984 mean compared with October and December is not anomalous. For these reasons, it is felt that the annual wind speed time series presented for Cape St James was not seriously affected by the missing observations.

Monthly PNA index and Pacific decadal oscillation index values were obtained from the Joint Institute for the Study of the Atmosphere and Ocean (2002).

Time series are illustrated by graphs. Unweighted 5 year running means are used to smooth the series and highlight trends. The initial graphs of mean annual wind speed employ the kilometre per hour speed units of the digital archive data to indicate the actual magnitude of wind speed variations and trends. Subsequent graphs use standardized values (standard scores) to allow easier comparability of the relative variation between stations and elements.

Pearson product-moment correlation coefficients are presented to give a general indication of coincidence between station and index time series. Trends were not removed because these are the focus of this paper. The results should be viewed as giving a general indication of coincident variation with time. Significance levels are not presented because the high degree of autocorrelation within the series reduces the effective number of independent observations. Conventional measures of significance are not appropriate (Panofsky and Brier, 1963), and presenting significance levels for a reduced number of observations can sway opinion against coincidence even when some similarity in trends occurs. Therefore, the reader should view the correlation coefficients as simply an additional piece of information.

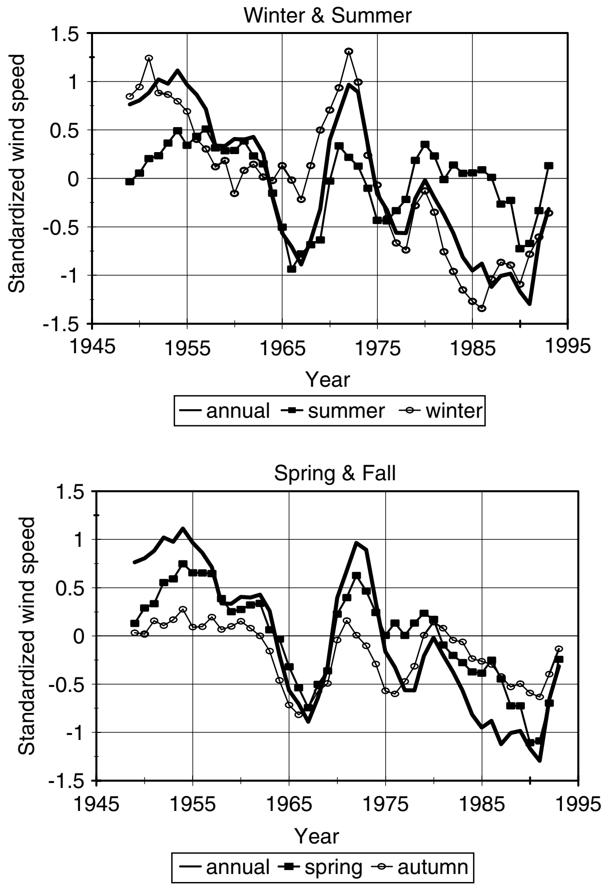

Figure 2. The 5-year running means of standardized seasonal wind speeds, Vancouver International Airport. Spring: March–May; summer: June–August; autumn: September–November; winter: December–February

3. RESULTS

Each station has its own individual pattern of wind speed variation over the time period considered here. Wind speed declined at all stations except Comox Airport.

Two intervals of decreasing mean annual wind speeds are apparent at Cape St James, Vancouver International Airport, and Victoria International Airport. The first ran from the mid-1950s through to the mid-1960s (Figure 3).

The second occurred during the middle to later portion of the record. Mean annual wind speeds of both Cape St James and Victoria declined sharply during this second period (Figure 3). The time of steepest slope occurred somewhat earlier at Victoria. Wind speed at Vancouver International Airport had a somewhat shallower trend that began later than those at Cape St James and Victoria. The magnitude of this second downward trend is much greater than that of the first at Cape St James and Victoria but is similar at Vancouver.

The period-of-record trend in mean annual wind speed is upward at Comox Airport (Figure 3). This is especially noticeable extending from a low in 1957 to a high in the late 1960s–early 1970s, with another increase to high wind speeds during 1982 and 1987–88. Cape St James and Victoria also had short-lived intervals of increasing wind speeds during the late 1960s. Also, the linear trend from the early 1980s to the ends of their records has been upward at Cape St James and Victoria, whereas that at Comox has been downward from the 1987 high.

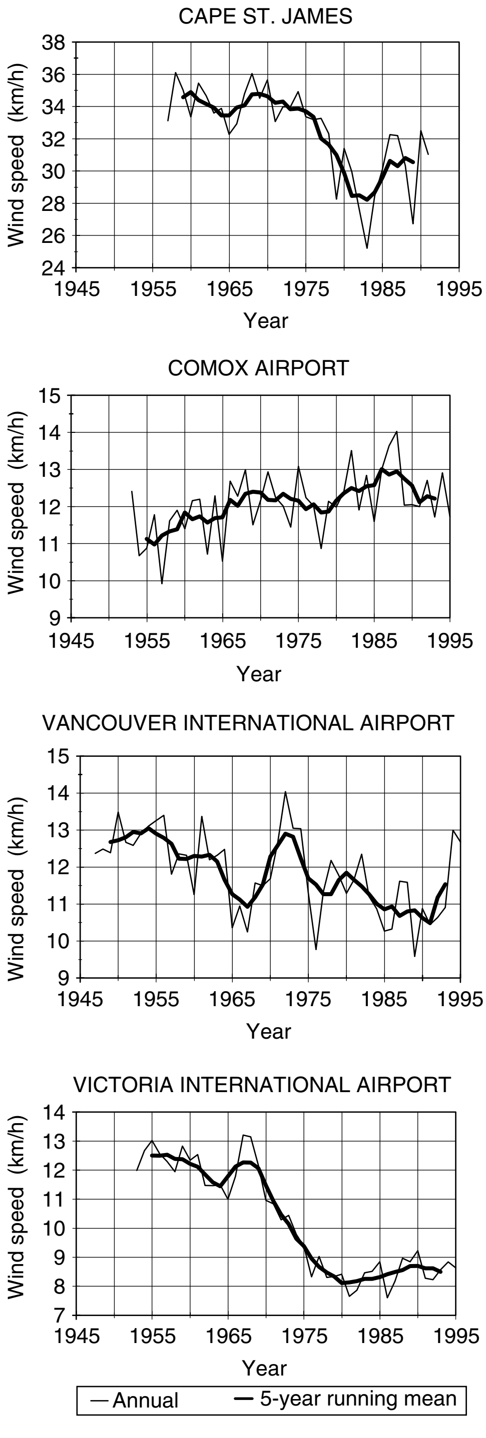

Figure 3. Mean annual wind speed (km h^{-1}). Wind speed scale varies with station

In summary, the mean annual wind speed trends at the four stations fall into three categories. Cape St James and Victoria have modest downward trends at the beginning and strong downward trends in the middle of their records. Vancouver has two periods of wind speed decline with nearly equal magnitude. Compared with

Cape St James and Victoria, the earlier trend at Vancouver was steeper, and the latter was less pronounced but of somewhat longer duration. Measured wind speeds at Comox Airport have increased. These three station groupings are illustrated by the correlation matrix (Table II). The strongest correlation is between Victoria and Cape St James. There is a weak positive correlation between these two stations and Vancouver, and negative correlations between Comox and the other three stations.

The trends in annual wind speed at the west-coast stations are found at the extremes of the distribution and in the central tendency. A decline (increase) in mean wind speed is matched by an increase (decrease) in the frequency of calms and a decrease (increase) in high wind speed observations (Figure 4). Klink (1999) also found that changes in mean monthly minimum wind speeds at a number of US stations were accompanied by the expected change in the frequency of calms, especially during the nighttime period.

Mean winter (December–February) wind speeds have trends similar to those of the annual mean (Figure 5). Comox follows some of the general winter wind speed trends seen at the other three stations, including a slight decline during the late 1950s–early 1960s and an increase from the early to late 1960s (Figure 5). However, the magnitude of its trends is not great. In recent years, Comox has had a great deal of year-to-year variability, with no extended periods of seasonal wind speeds above or below the period-of-record mean and no strong trend.

4. DISCUSSION

The dominant trend in the time series of wind speed at three of the four west-coast stations is the decline during the middle of the record. There are a number of potential causes, including changes in the height and position of the anemometer, variations in the roughness of the environment surrounding the station, and atmospheric forcing. The first two causes can be considered to be anthropogenic, and the third is considered natural for the stations utilized here.

A detailed discussion of the observation system and environment changes is beyond the scope of this paper. However, we can briefly identify some factors that indicate that human effects are not the dominant cause of the downward trend in wind speed.

Both Victoria International Airport and Vancouver International Airport had movements of the anemometer from the tops of buildings to more open sites on the airfield (Table I). The movements in 1963 (Vancouver) and 1964 (Victoria) do not coincide with, and do not seem to have initiated, the declines in wind speed starting in the mid 1950s and early 1970s at Vancouver or late 1960s at Victoria.

Victoria and Vancouver Airports have had urban development on land outside their grounds, Victoria to the east and Vancouver especially to the south and east. Increased surface roughness could have contributed to the reduced wind speeds. However, Cape St James had only a minor site movement and anemometer height change in 1963 (Table I). The site moved 25 m and height increased from 12.0 to 13.1 m. There has been no development on St James Island. Therefore, the similar trend at undeveloped Cape St James argues for atmospheric forcing as the major cause of the wind speed decrease.

Table II. Pearson product-moment correlation matrix of mean annual wind speeds. Periods of record are 1957–91 for correlation coefficients involving Cape St James and 1953–95 for those involving the other stations

	Victoria	Vancouver	Cape St James	Comox
Victoria	1			
Vancouver	0.39	1		
Cape St James	0.70	0.39	1	
Comox	−0.38	−0.11	−0.18	1

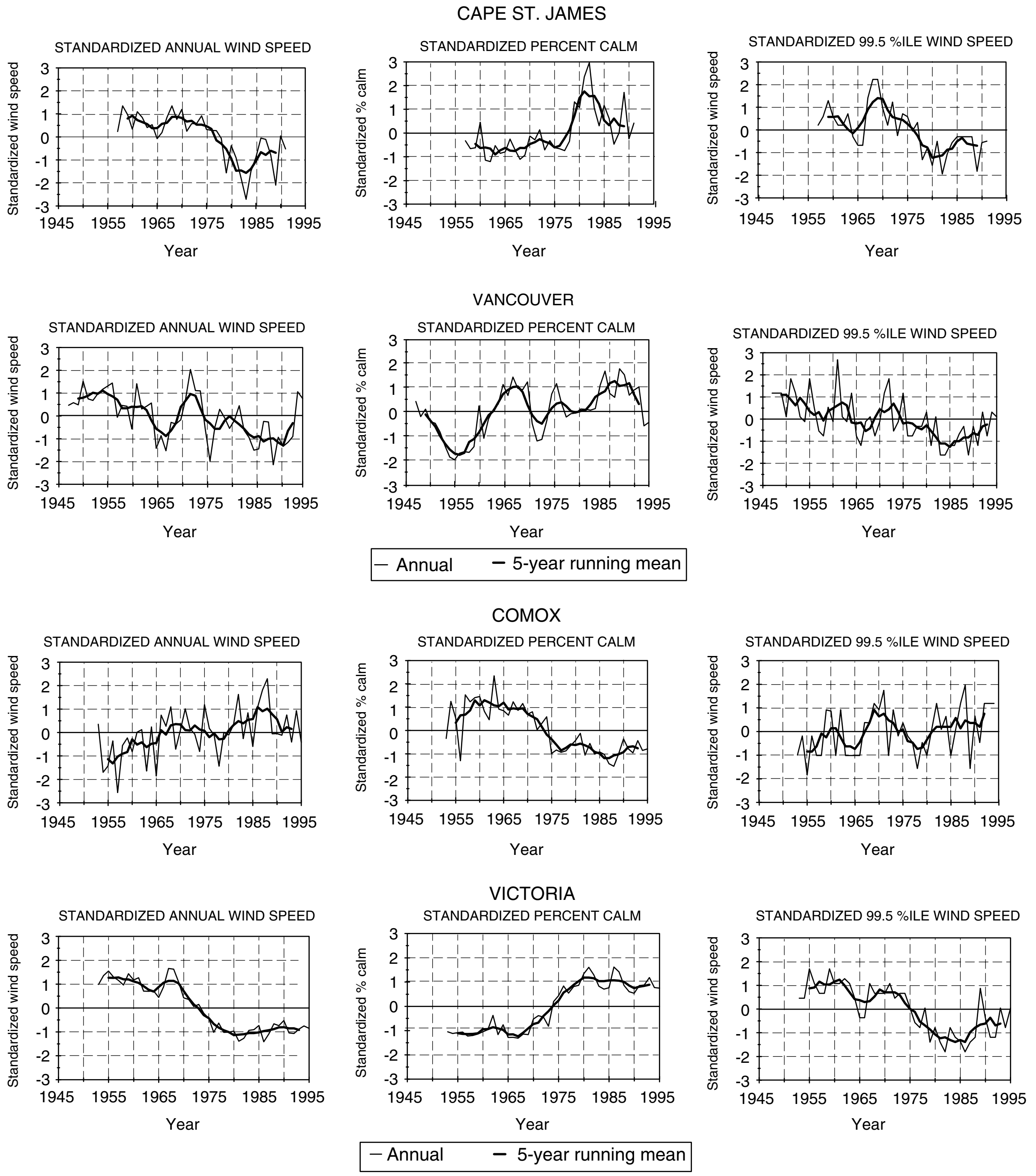

Figure 4. Standardized annual wind speed, annual percentage of calms (wind speeds less than or equal to 2 km h^{-1}) and annual 99.5 percentile wind speed

4.1. *Pressure triangle wind speed*

One test of atmospheric forcing is to look at a proxy wind speed that is not affected by anemometer site and height variations or changes in surface roughness. One candidate is the wind speed computed from the pressure gradient between a triangle of stations (herein called 'pressure triangle wind speed'). Although air

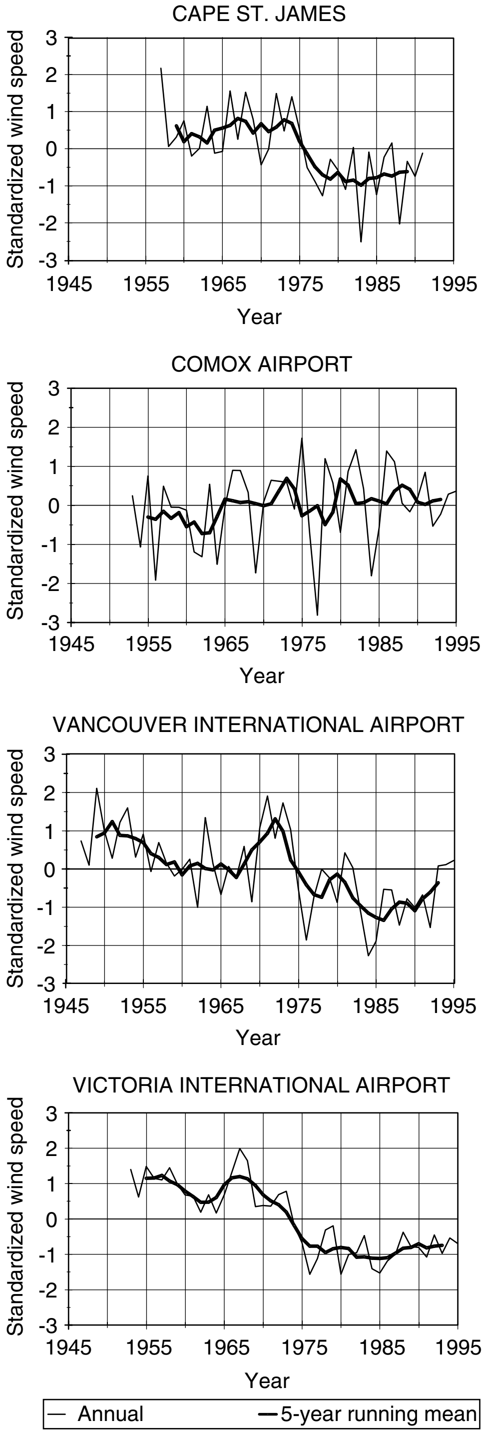

Figure 5. Standardized winter (December–February) wind speed. The year for each winter is the year of the December that began the season

pressure might be affected slightly by air temperature alterations created by surrounding land use changes, the effects would be very small (Landsberg, 1981: 134). Alterations of surface friction and placement of the barometer would not have an influence. Some applications of pressure triangle winds are found in Schmidt and von Storch (1993) and Schmith (1995).

The hourly pressure triangle wind speeds determined from the geostrophic wind equation using the pressure gradient between Victoria International, Vancouver International, and Comox Airports were provided by the Meteorological Service of Canada. Although pressure triangle wind speeds are most applicable to areas near the center of the triangle, they do give an idea of the effects of regional (as opposed to purely local) pressure gradients throughout the whole triangle area.

There is a peak in the annual and winter pressure triangle wind speeds in the late 1960s–early 1970s (Figure 6). Values declined from this time through the mid-to-late 1980s and remained at or below the period-of-record means until the end of 1995.

The downward trend is similar to the decline in mean annual and winter wind speeds at Cape St James, Victoria, and Vancouver (Figures 3, 5, and 6), although the year-to-year variations and times of the beginning and end of the trends often differ. This indicates that an atmospheric control, the regional pressure gradient, does have a connection with the lower mean wind speeds in recent years and the decline in wind speeds in the middle of the record.

4.2. *Air pressure (sea-surface temperature) pattern indices*

Indices reflecting the strength and position of major air pressure systems and, thus, atmospheric circulation patterns have become popular in recent years. These have been used to offer at least a partial explanation for some of the trends and variations in a number of climate elements in a variety of regions.

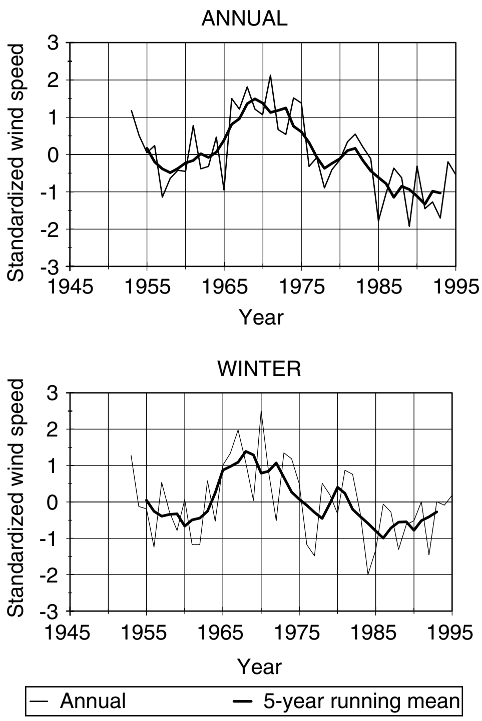

Figure 6. Standardized annual and winter pressure triangle wind speeds. The year for each winter is the year of the December that began the season

Two indices have special relevance for the west coast of Canada: the PNA index and the Pacific decadal oscillation (PDO) index. Although the two indices are defined differently, air–sea interaction and downstream teleconnections mean they have several features and associations with west-coast climate in common.

The PNA index is a direct measure of major air pressure patterns (Wallace and Gutzler, 1981). A positive PNA index indicates a deep Aleutian low and a ridge of high pressure over western Canada.

Mantua *et al*. (1997) define the PDO index in terms of the leading eigenvector of North Pacific sea-surface temperatures (see also Zhang *et al*. (1997)). Gershunov and Barnett (1998) term the PDO the North Pacific oscillation.

The PDO index represents decadal time variations. It was largely positive from 1925 to 1946, negative from 1947 to 1976, and positive from 1977 to the end of the wind speed records analysed in this report (Mantua *et al*., 1997). Short intervals of opposite sign and sea-surface temperature pattern can occur within these periods. An example is the positive PDO pattern starting in 1957–58 that lasted only into the very early 1960s (Mantua *et al*., 1997; Zhang *et al*., 1997; Chao *et al*., 2000). The North Pacific PDO sea-surface temperature pattern is repeated in the South Pacific (Zhang *et al*., 1997; Chao *et al*., 2000).

Although defined by sea-surface temperature, the PDO index is associated with air pressure patterns. Like the PNA index, a positive PDO index corresponds with a deeper than normal low-pressure cell in the North Pacific. With similar downstream connections as found with the PNA index, a positive PDO index will be associated with a ridge over western Canada.

Storm tracks tend to be located more to the north (Yarnal and Diaz, 1986; Cayan and Peterson, 1989; Moore and McKendry, 1996) and/or south, especially over the Pacific (Trenberth and Hurrell, 1994; Hurrell and van Loon, 1997) of our study area, with positive values of the PNA and PDO indices. The high-pressure system over western North America produces lower regional air pressure gradients. This, along with less storm activity, combine to produce lower mean wind speeds.

Negative PNA and PDO indices are usually associated with a more zonal upper-air flow pattern (Wallace and Gutzler, 1981; Ebbesmeyer *et al*., 1989; Rogers and Raphael, 1992). Upper-air pressure patterns over the study area are positively correlated with the PNA and PDO indices (negatively correlated with the pressure in the Aleutian low (Trenberth and Hurrell, 1994; Mantua *et al*., 1997)). Hence, the high pressure over the west coast with positive indices is absent with negative indices. Storm frequency in and near our study area is increased, producing higher mean wind speeds (Ebbesmeyer *et al*., 1989). No longer near the centre of a major high-pressure system, the regional air pressure gradient is enhanced. The result would be greater mean wind speeds on the Canadian west coast.

The downward trends in Cape St James, Vancouver, Victoria, and the pressure triangle mean annual wind speeds during the middle portion of the record are accompanied by increases in the PNA index (Figure 7). Diminished storm frequency and/or intensity is reflected in a reduction of high wind speeds and more high-pressure systems in a greater frequency of calms (Figure 4). The annual PDO index also increases, but the major upward trend began somewhat later, in the late rather than the early 1970s.

Teleconnections are often more apparent in winter than in other seasons (Horel and Wallace, 1981; Wallace and Gutzler, 1981; Yarnal and Diaz, 1986; Shabbar and Khandekar, 1996; Shabbar *et al*., 1997). The variation over time in the strength of the Aleutian low is primarily a phenomenon of winter when the subtropical high-pressure cell is located well to the south (Trenberth and Hurrell, 1994).

The winter patterns are similar to the annual patterns. Decreases in mean Cape St James, Vancouver, Victoria, and pressure triangle winter wind speeds in the middle of the record correspond with increases in the PDO and PNA indices (Figures 5, 6, and 7). The upward trend in the winter PDO index starts earlier and is slightly steeper than that of the annual index. There is, therefore, a closer match of wind speed and PDO index trends in winter than the annual period (Figures 3, 5, 6, and 7).

The short-duration period of positive PDO index beginning in 1957–58 noted by Chao *et al*. (2000), Mantua *et al*. (1997), and Zhang *et al*. (1997) is matched by a general downward trend in winter pressure triangle and measured wind speeds at Cape St James, Vancouver, and Victoria (Figures 3, 5, 6, and 7).

Running means of winter measured and pressure triangle wind speeds and PNA and PDO indices (presented individually in Figures 5, 6 and 7) are combined in Figure 8 for the three stations with wind speed declines. This will allow easier comparison of the timing of the trends.

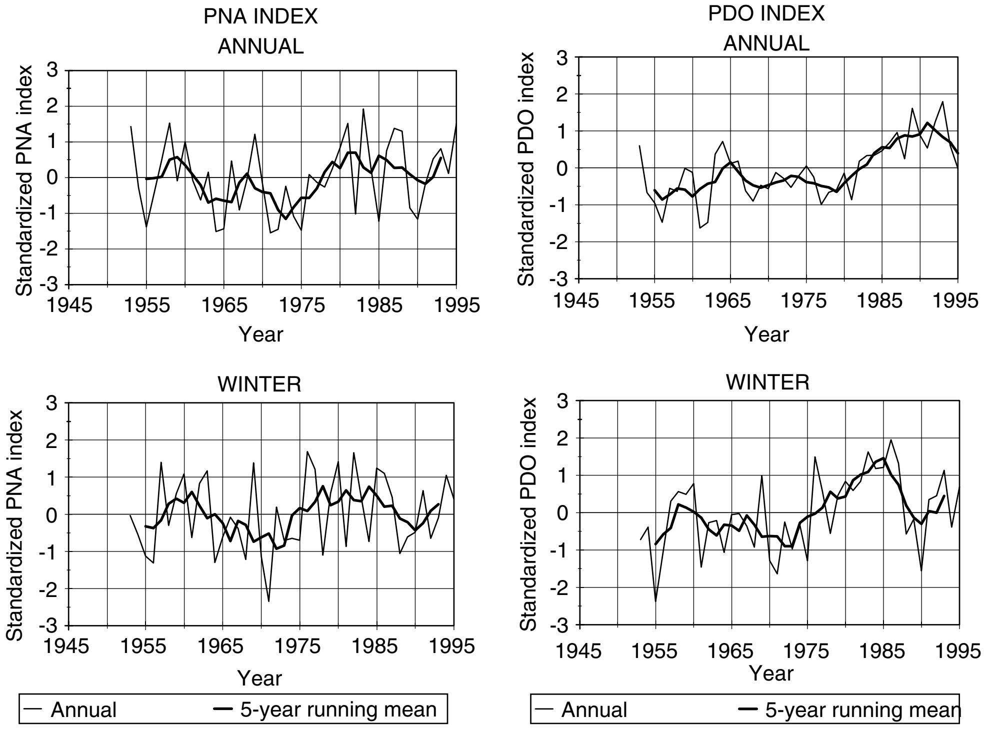

Figure 7. Standardized annual and winter PNA and PDO indices. The year for each winter is the year of the December that began the season

Comox also displays some annual wind speed trends that are similar to those of the PNA and PDO indices. In this case, however, the wind speed at Comox is increasing rather than decreasing. The winter wind speed at Comox has no extended trend.

Correlation coefficients between the air pressure indices and wind speed time series are low (Table III). Although some of the general trends are similar, year-to-year variations are frequently different.

Correlation generally improves during the middle of the record, where major trends are concentrated (Table IV).

4.3. *Trends in wind speed and other elements*

The decline in wind speeds at three of the west-coast stations over the period of record and during the 1970s–early 1980s is not unique. Ebbesmeyer *et al.* (1989) reported a decline in the frequencies of strong winds and southerly winds in the Puget Sound Basin of the northwestern USA from about 1972–73 through to the early 1980s. Cold-season wind speeds declined over the 1953–93 period at the four western Canada and Alaska stations used by Keimig and Bradley (2002) that are closest to our study area. Klink (1999) also found a 1961–90 downward trend in mean monthly minimum wind speed throughout the year at most of the northwestern USA stations utilized in her study. Mean monthly maximum wind speed had a more variable pattern. Pendleton, Oregon, however, showed a general decline in January and July mean monthly maximum and minimum wind speeds over at least a portion of the mid-1970s through to the mid-1980s.

Changes in a number of other climate elements have been reported. Some examples from British Columbia and the northwestern USA are given below. Decreases in Puget Sound Basin precipitation and river runoff during the late 1970s were noted by Ebbesmeyer *et al.* (1989). Moore (1991) found reductions in Fraser River flow, and Tuller (1990) reported a decline in Agassiz, British Columbia, annual and winter precipitation from the early 1970s into the 1980s. Lower amounts of western US precipitation and increases in 700 hPa height at 45 °N, 125 °W are given by Chen *et al.* (1996). Raphael (1993) reported increases in annual and seasonal

Figure 8. The 5-year running means of winter standardized station and pressure triangle wind speeds and PNA and PDO indices

air temperatures at Prince George, British Columbia, beginning in the early to mid-1970s. Cayan *et al.* (2001) found an earlier spring warming in the northwestern USA revealed by earlier plant flowering and spring freshets. Decreases in snowpacks throughout British Columbia, or decreases in the south and increases in the north, are given by Moore and McKendry (1996), and reductions in northwestern USA snow water equivalents are given by Cayan (1996), both beginning with the 1977 change in PDO index value.

All of the above would be consistent with more frequent positive PNA and PDO patterns. A deeper Aleutian low combined with a high-pressure system over western North America produces southwesterly air flow carrying warm air over the region (Yarnal and Diaz, 1986; Trenberth and Hurrell, 1994; Moore and McKendry, 1996; Shabbar and Khandekar, 1996; Mantua *et al.*, 1997). The high-pressure system directs cold, continental air masses to the east, away from the coast (Cayan, 1996). The diversion of storms to the north into Alaska (Cayan, 1996; Moore and McKendry, 1996) and subsidence in the high (Mantua *et al.*,

Table III. Winter-season and annual Pearson product-moment correlation coefficients between station wind speeds and PNA and PDO indices. Periods of record are 1957–91 for correlation coefficients involving Cape St James and 1953–95 for those involving the other stations

	Annual		Winter	
	PNA	PDO	PNA	PDO
Comox	0.1	0.18	−0.05	−0.06
Cape St James	−0.17	−0.52	0.09	−0.18
Vancouver	−0.1	−0.43	−0.32	−0.53
Victoria	−0.19	−0.62	−0.34	−0.52
Pressure triangle	−0.17	−0.45	−0.19	−0.27

Table IV. Pearson product-moment correlation matrix for annual and winter (in bold) wind speeds and PNA and PDO indices during the middle of the record when major trends occurred. Annual period of record is 1969–86, winter period of record is 1968–69 to 1985–86

	Victoria	Vancouver	Cape St James	Comox	Pressure triangle	PNA index	PDO index
Victoria	1						
	1						
Vancouver	0.44	1					
	0.73	**1**					
Cape St James	0.64	0.28	1				
	0.58	**0.43**	**1**				
Comox	−0.21	−0.08	−0.21	1			
	0.31	**0.50**	**0.07**	**1**			
Pressure triangle	0.65	0.56	0.39	0.25	1		
	0.62	**0.81**	**0.28**	**0.28**	**1**		
PNA index	−0.26	−0.41	−0.38	−0.20	−0.26	1	
	−0.53	**−0.62**	**−0.21**	**−0.40**	**−0.54**	**1**	
PDO index	−0.68	−0.57	−0.68	−0.12	−0.64	0.76	1
	−0.67	**−0.80**	**−0.48**	**−0.47**	**−0.70**	**0.78**	**1**

1997) reduce precipitation. The combination of higher temperature and/or lower winter precipitation produces less snow. These same factors that affect air temperature and precipitation contribute to lower air pressure gradients and reduced wind speeds.

The two downward trends in west-coast wind speeds fit the overall climate trends that would accompany a variation in atmospheric circulation. The time of initiation and duration of the trend vary from study to study. Therefore, the causes of the variations do not manifest themselves equally over all elements and all regions.

4.4. Comox Airport

The effects of regional air pressure gradients revealed by pressure triangle wind speeds and the PNA and PDO indices are not evident in the major wind speed trends at Comox Airport (Figures 3–7). The precise reasons for this are not known. However, one contributor could be site factors. Anemometer height and location have been changed. The major change that could result in increased wind speed was the movement from sites very near and among airport buildings in August 1967 to a more exposed site on the airfield (although height was also reduced). In addition, unlike Vancouver and Victoria, the local environment has become smoother rather than rougher as forest has been converted to a golf course and moderate-density residential land use (Table V).

Table V. Land area within 1.5 km of the anemometer site in three roughness categories,[a] 1954 and 1984, Comox Airport

Roughness category	Land area (%)	
	1954	1984
Smooth	44.2	71.6
Medium	9.3	14.7
Rough	46.6	13.7

[a] Smooth: crops, grass, pavement, water. Medium: scattered medium-height trees (e.g. orchards), golf courses, scattered one- to two-story buildings. Rough: forest, either tall buildings (more than two stories) or smaller buildings that are closely spaced.

5. SUMMARY AND CONCLUSIONS

Period-of-record trends in mean annual and winter wind speeds at three of the four western Canada coastal stations investigated here were negative. The decrease was not consistent over the period of record; rather, it was concentrated during a portion of the late 1960s through to the mid-1980s period. The actual timing and duration of the trend varies with the station. Another downward trend ran from the mid-1950s through to the mid-1960s. The latter trend was weak at Cape St James and Victoria International Airport, but it was well developed at Vancouver International Airport.

Overall period-of-record linear trends of climate elements are frequently presented. This makes little sense for time series such as those of wind speed at stations such as Cape St James and Victoria International Airport, where the trend is concentrated in a limited period. For example, the overall linear trend at Victoria International Airport fitted by least squares was -1.29 km h^{-1} decade^{-1} (-0.36 m s^{-1} decade^{-1}). However the time series can be better viewed as three trends (Table VI, Figure 9). An overall trend distorts the record, and a more detailed look at the actual time series is warranted in cases such as this.

Changes in measured wind speed can result from both atmospheric and ground surface controls. Variations in regional air pressure gradients, trends in the PNA and PDO indices, and the change in other climate elements suggest that the atmospheric control was dominant in the measured wind speed decline at Cape St James, Vancouver International Airport, and Victoria International Airport. However, wind speed controls are complex. Although a general agreement was found, the variation in timing of the trends suggests that no one factor was responsible for the wind speed trends.

The increase in wind speed at Comox Airport suggests that changes in surface roughness and the observation system cannot be neglected. Plans for future research include a more detailed analysis of the role of these factors in the Comox wind speed trend.

Table VI. Period-of-record (1953–95) and short-term linear trends in mean annual wind speed, Victoria International Airport

	Least squares linear trend	
	km h^{-1} decade^{-1}	m s^{-1} decade^{-1}
1953–95	−1.29	−0.36
1953–69	−0.2	−0.06
1969–77	−3.98	−1.11
1977–95	0.19	0.05

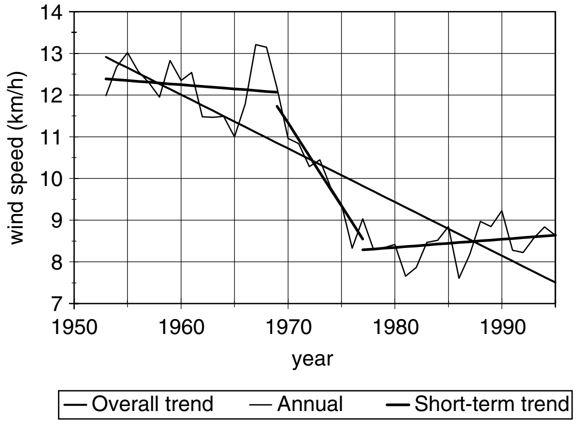

Figure 9. Period of record and short-term linear trends of mean annual wind speed, Victoria International Airport

Wind speed, like all climate elements, varies over time. Users must be aware of this variability when applying wind speed information. Data from one time interval might not be representative of those at another. Short-term records do not necessarily indicate what will occur in the future and must be used with caution.

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