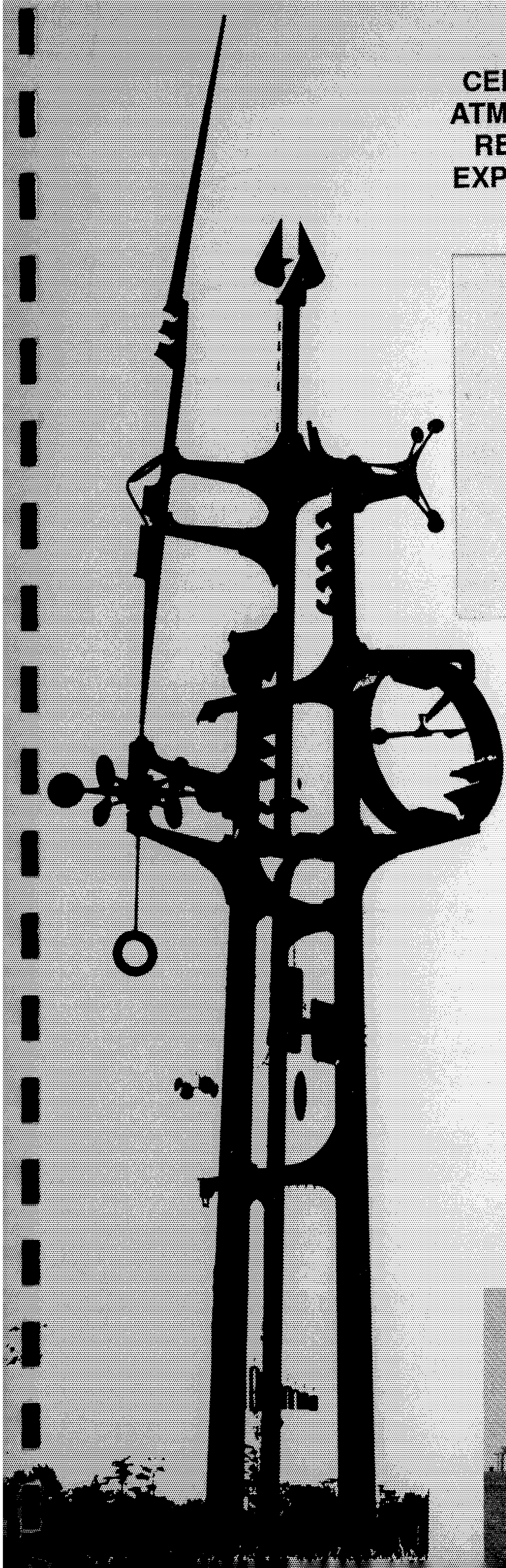

CENTRE FOR ATMOSPHERIC RESEARCH EXPERIMENTS

CENTRE DE RECHERCHE ATMOSPHÉRIQUE

Report: ARD - 93 - 002

Lower Fraser Valley Study
July 28 - August 28, 1992

by

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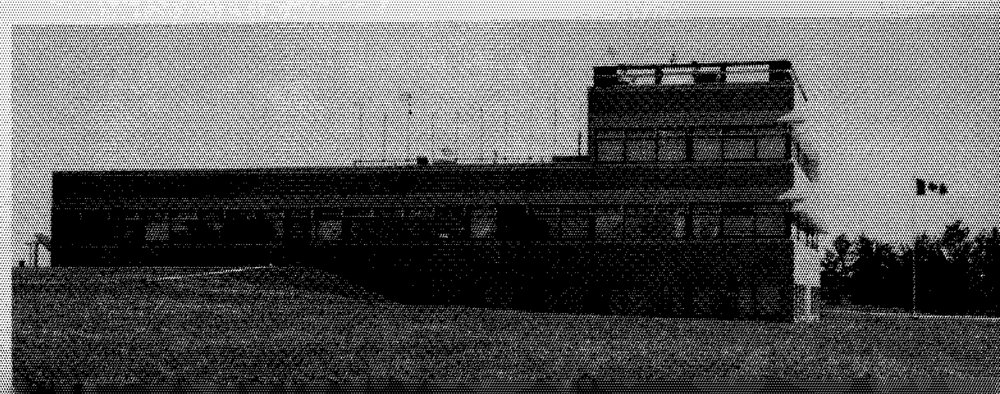
Pacific Region

Environment Canada | Environnement Canada

Atmospheric Environment Service | Service de l'environnement atmosphérique



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Date Completed: April 1993

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ABSTRACT

In the summer of 1992, a study was initiated in the Lower Fraser Valley of British Columbia to gather information relevant to the occurrence of photochemical smog. Two episodes were observed, one on July 31 and another in the period of August 12 - 13. Atmospheric profiles of tropospheric ozone, temperature, humidity and winds collected at frequent intervals during daytime are presented as well as contours of surface ozone concentrations.
At the Clearbrook B.C. sampling site, the highest observed concentration of ozone was 65 ppb, however the Greater Vancouver Regional District monitoring station at Chilliwak B.C. recorded an hourly average of 81 ppb on August 13th 1992. Contour plots of hourly averages of ozone indicate that ozone generated in the urban core is transported up the valley throughout the day. Vertical profiles show that erosion of the ozone aloft is tied in to southwesterly flows, suggesting that perhaps some NOx/O3 chemistry is also occurring.

1. Introduction:

The Lower Fraser Valley of British Columbia is one of the areas of Canada where photochemical smog is believed to be a problem. A number of cases have been noted in the past where ozone concentrations have exceeded the Canadian guideline of 82 ppb of Ozone. In the summer of 1992, a study was conducted in the Lower Fraser Valley (LFV) to gather data relative to the occurrences of ground level ozone episodes and the low level tropospheric ozone structure in this Region. This study was to be a precursor to a more intensive study scheduled for the summer of 1993.

Ground level ozone episodes in the LFV occur under unique meteorological conditions which include a well established, three dimensional sea breeze circulation pattern. To adequately describe this circulation pattern, vertical profiles of both wind speed and direction, as well as ozone concentrations are required. Temperature and relative humidity measurements were also made in the vertical to capture a meteorological data base for one of these episodes.

Staff from the Centre for Atmospheric Research Experiments (C.A.R.E.), located in Egbert Ontario, were asked to participate in this study by collecting vertical profiles of the meteorology and ozone structure in the Valley. This report deals with this aspect of the field study. It should be noted that other groups were active in the field study conducting measurements of atmospheric chemistry and surface ozone.

A member of the Pacific Region Atmospheric Issues and Services Branch (AISB) Air Quality Section joined the C.A.R.E. team to learn the W9000 system and to become proficient with it's operation. This exercise proved successful and provides the Region with an increased capability to respond to environmental measurement issues.

2. Site Description:

In June of 1992 a survey team comprised of personnel from C.A.R.E. and the Pacific Regional Office toured the Valley in search of possible locations from which to conduct the upper air soundings. The Agriculture Canada Agassiz Sub-Station (Agriculture Experimental Station) located in the rural areas of Clearbrook B.C. was chosen.

The Agassiz sub-station is located to the south of the community of Clearbrook B.C., Latitude 49° ,00′,40″ N Longitude 122° ,20′ W.

The surrounding region is primarily used for agriculture and tends to be relatively open and flat. The major land elevations lie predominantly to the south, east and north, allowing for a fairly smooth flow of air masses coming in from the coast.

The Agassiz sub-station property is approximately 50 acres in size. The buildings are located near the southwest corner of the property. To the north and east, the fields are open allowing little obstruction to balloon launches. Immediately behind the station buildings lies a grove of mature trees of considerable height. As the mean winds in this region tend to be westerly to southwesterly, this tree grove posed a siting problem for our anemometer.

The Station provided a large room in the main building for system set up as well as a bay in the tractor garage for balloon filling purposes. An on-site mobile lab was also provided. This was utilized as a store room and its roof, a platform on which to deploy the W9000 antennae.

To the west-northwest of the agriculture station is the Abbotsford airport, not more than 3 kilometres distant. For the most part of the study air traffic was sparse and did not hinder balloon operations, aside from causing minor delays in the launch schedule. The Abbotsford International Air Show however did and all balloon flights were suspended on August 7, 8, and 9th until the show concluded .

3. Project Description:

The occurrence of elevated concentrations of ground level ozone within the Lower Fraser Valley is related to a very unique set of meteorological conditions. A ridge of higher heights aloft and associated thickness ridge must be oriented to give a south to southwesterly flow over the Valley. This ridge aloft also provides a wide area of subsidence flow which effectively "caps" the Valley. As the ridge aloft becomes stronger, the surface pressure gradient weakens leaving only the local sea and land breeze circulations to move the air up and down the valley. These conditions were present on July 31st and August 12th and August 13th. History has shown that the normal number of occurrences per season is two or three. A "season" is taken to be the period from mid-May to mid-September.

In a pre-project planning meeting, the Pacific Region AISB Air Quality Section proposed that twice daily radiosonde flights (1100 and 1700 PDT) be flown for the course of the study. If an ozone episode was expected, the schedule would be intensified to five per day, with the addition of an ozonesonde for each flight during the episode. Flights then would occur at 0500, 1100, 1400, 1700, and 2000 PDT. All meteorological data would be faxed to the Pacific Weather Centre in near real time, to be used in the Ozone (SMOG) Advisory forecast preparation.

The VIZ W9000 Meteorological Processing System was used for this study. This system is PC based, using a 386DX-33 computer to process the meteorological (met.) and ozone data received from the sonde. The W9000 is a more reliable and accurate system than the W8000 system that it replaces. The radiosonde electronics includes a Loran receiver which has cross chain capabilities. The loran signals incorporate the triangulation method of direction finding to track the balloon. The two Loran chains used for the study were the Canadian West Coast Chain (GRI 5990) and the U.S. West Coast Chain (GRI 9940).

The VIZ model 1543-511 Mark II radiosonde was used for the meteorological only flights, while the model 1543-523 Mark II with ECC-5A interface card was used for the meteorological and ozone flights. The latter sonde is supplied by VIZ with an interface and a separate card which is installed in the ozonesonde. The card is linked to the radiosonde by means of a signal cable. This card converts the current generated by the ozone sensor into a digital signal which is transmitted to the ground receiver as part of the radiosonde data transmission.

3a. Ozone Profiling:

The Ozonesonde is the model ECC-5A manufactured by Science Pump Co. of Camden N.J.. Briefly, the ozonesonde uses a constant volume pump to pump ambient air through two cells containing dilute potassium iodide (KI) and potassium bromide (KBr) solutions. Within each cell is a platinum grid - one a cathode, the other an anode, linked together by means of an ion bridge. The presence of ozone in the air being pumped through the cells generates a current which is transmitted to the radiosonde where it undergoes further electronic signal conditioning. The signal is then retransmitted to the ground receiver where it is translated into a partial pressure measurement (in nanobars). The partial pressure measurements are later reconverted into the units "parts per billion" (ppb). This is achieved by importing the flight data files (ASCII format) into a Lotus spreadsheet where the conversion formula is applied.

The conversion of the partial pressure in nanobars (nb) to parts per billion (ppb) was accomplished by taking the ratio of Partial Pressure to the Atmospheric Pressure in millibars (mb) at the measurement level times 1000 or:

$$\frac{\text{(partial pressure)}}{\text{(Atmospheric Pressure)}} * 1000 = \text{ppb's}$$

Prior to each flight the ozonesonde must be conditioned, as is described in the N.O.A.A. Technical Memorandum ERL-ARL-149 (Komhyr W.D. Sept. 1986). The sonde conditioning commences 3 - 7 days before the flight. The sonde cells are injected with the KI and KBr solutions, conditioned with ozone and left to stabilize. Twelve hours before flight, the chemicals in the sonde cells are changed and the cells re-conditioned with ozone. One hour prior to release, the sonde is again conditioned with ozone.

3b. Meteorological Profiling:

The radiosonde only flights occurred twice daily on days when no ozone episodes were expected. The data from these flights were faxed to the forecast office in Vancouver and used in preparation of forecasts. The data were also archived on diskette to form a data base for modelling applications to the Lower Fraser Valley.

The data is stored in printable ASCII format with separate tables for both wind data and temperature/pressure/humidity data. Plots of the data are done in real time using the "Grapher" software package (Golden Software Inc. - version 1.79) as this is the supplied package with the W9000 system. An example of a data plot is found in figure 1.

3c. Surface Instrumentation and Measurements:

During a normal course of events, the W9000 system is supported by a surface meteorological "station". This is comprised of an RM Young aerovane for wind speed and direction, a Rotronics model MP-100 temperature and humidity probe enclosed in a 12 plate Gill radiation shield, and a Setra model 270 pressure transducer calibrated to A.E.S. standards. All instrumentation is connected to a Campbell Scientific model CR21X-L data logger. Sampling is conducted at one second intervals and averaged hourly.

Due to the presence of a grove of large trees upwind of the station posing a siting problem for the anemometer, it was decided to forego the deployment of the RM Young aerovane and to use the wind data from the Abbotsford airport as representative of the surrounding area. The remaining meteorological sensors were installed and data collection began at 8pm Pacific Daylight Time PDT on July 30th, 1992.

Co-located in the main building with the W9000 system was the Atmospheric Measurements and Analysis Research Division (ARQM) equipment, set up to provide ongoing sampling of NOx, PAN and surface ozone. The ARQM ozone analyzer is a Thermo Electron (Teco) model 49, U.V. photometric analyzer. This unit was also connected to the 21X data logger to provide hourly averages of on site surface ozone concentrations.

The ozone analyzer was calibrated in June of 1992 prior to deployment. A Dasibi model 1008-PC calibration standard was used for this function. This unit is the primary standard for the Atmospheric Processes Research Division (ARQP) and is annually calibrated against the N.I.S.T. primary standard in Washington D.C. Using a calibrated secondary standard, a check calibration was conducted in mid-August.

A calibrated Dasibi model 1008-RS ozone analyzer was employed to do surface ozone calibration checks on the ECC-5A ozonesondes. Ozone generated by the Dasibi unit was fed into the sonde as well as the analyzer inlet and the two readings then compared. The checks were a means of confirming sonde operation.

4. Results and Discussion:

4a. Ozonesonde Discussion:

During the 1992 summer season, only two episodes of ozone were encountered. An actual episode of ozone is defined as having a mean concentration of 82 ppb or greater. Although somewhat less than 82 ppb concentration, occurrences noted in this report are being referred to as "episodes". The first occurred at the beginning of the study, on July 30th, one day prior to the instrumentation setup being complete. Ozone concentrations were beginning to subside by July 31st when vertical profiling began. The second episode occurred on August 12th and continued on into the 13th. Three ozonesondes were released during the July 31st episode and a total of ten ozonesondes covered the August 12th - 13th period. At all other times during the study, twice daily radiosondes were released to provide vertical meteorological profiles for the LFV.

To the chagrin of the study team, the W9000 system developed problems that plagued some of the flights. The nature of the problem was later traced to a faulty connector between the antenna/receiver modules, however, this trace was not accomplished until some months after the end of the study. Some flight data was lost but overall, data retrieval was good. Eleven of fourteen ozonesondes launched were successful, and sixteen of twenty radiosonde only flights, produced good data.

At this time, it should be mentioned that our Flight Identification Scheme lists the Julian Day and G.M.T. Hour of the flight; thus flight 23800 is the 0000 GMT flight on Julian Day 238. The conversion from GMT to Pacific Daylight Time (PDT) is -7 hours. To avoid constant conversion to local time, all references to particular flights in this document will be expressed as Pacific Daylight Time.

The balloon flights were tracked nominally to about 12 km. - less than the base height of the main stratospheric ozone layer which is in the neighbourhood of about 20 km. This was done intentionally as the launch times for the ozonesondes were such that there would be insufficient time to prepare and set up for flights if we tracked the sondes to levels higher than 12 km. The ozonesonde pre-flight preparation schedule would conflict with longer flight times. The first flight (flight 21318) was tracked to 21,225 metres and resulted in cancellation of the 2pm (2100 GMT) release.

The layer of primary concern for this study is the first 5 km. of atmosphere above ground level. The ozone plots contained in this report are, therefore, capped at 5 km, even though data exists up to the 12 km cut-off. For the sake of comparison, figure 2a depicts a plot of flight 21318 up into the main stratospheric ozone layer. Figure 2b is the same flight, but scaled down to the 0-5 km regime. A summary of all available Aerological and Ozonesonde flight data is listed in Appendix A.

Data collections for first episode began on July 31st, 1992 (Julian Day 213). The surface ozone concentrations for that episode show a peak concentration of about 64 ppb occurring in the late afternoon, with a secondary peak near 58 ppb in the evening hours (figure 3).

The measurement of the vertical distribution of ozone, wind, temperature and humidity over Clearbrook began at 11:00 am PDT (Flight 21318) on July 31st. By this time, the west southwesterly sea breeze had reached the station and the ozone was well mixed to the base of the subsidence inversion at 700 metres (Figure 4). The 5:00 pm PDT (Flight 21400) sounding indicated a subsidence inversion was well established from 800 to 1000 metres with the ozone remaining well mixed in the convective layer below the inversion. The sea breeze had diminished somewhat by 8:00pm PDT. Considerable structure in the vertical distribution of ozone and humidity appears below the inversion as the boundary layer stabilizes. A surface based inversion topped at 200 metres has formed which caps the low level ozone. The comparatively high relative humidity of the air from the surface to a second inversion at 300 to 400 metres appears to delineate what is left of ozone rich air pushed eastward up the Valley in the sea breeze. An area of ozone between 200 and 300 metres shows noticeable erosion. This erosion is suspected to be a result of interaction with a "plume" of NO_x enriched dry air. This "plume" was associated with a region of very light southwesterly winds. Winds return to more westerly between 600 metres and 2000 metres. Hourly surface wind direction taken at the Abbotsford airport on July 31st are shown in figure 5. They indicate that the flow favoured the southwest throughout the day, with a shift to more northerly directions by late evening.

The second event occurred in the period of August 12th - 13th 1992 (Julian Days 225 & 226). A plot of surface ozone concentrations for this period (figure 6), shows near zero concentrations during the night/early morning hours followed by a gradual rise to peak in the 60 to 70 ppb range by mid afternoon, then tailing off to near zero again by late evening (classic diurnal pattern).

The composite plots of the sonde data for this 2 day episode are contained in figures 7,8, and 9. The 5am sounding on August 12th (figure 7) depicts an area of lower ozone concentrations between 3000 and 4000 metres. This area is again observed in the data from the 11am sounding. At this altitude, relative humidities are observed to be lower than those found in the air parcels above and below this area. The plot for the flight data from 2pm shows an area of ozone from surface to about 700 metres in the 60 ppb range. This area decreases above 700 metres to near 25 ppb at 1000 metres. The meteorological data for this flight shows an inversion layer from 700 to 1000 metres. At about 3000 metres, an area of slightly lower ozone concentrations begins, and extends up to near 4000 metres. This is similar to the same area noticed on the two previous flights.

The ozonesonde released at 5pm failed and no data were received. The subsequent flight at 8pm (figure 8) shows the ozone concentrations to have evened out above the boundary layer. The layer from surface to 400 metres has decreased significantly to less than 20ppb. Surface levels of ozone are also decreasing.

The August 13th 5am sounding (figure 8) shows ozone concentrations in the lower 300 metres to be at or near zero. This is substantiated by the surface ozone readings at the site which remained near zero until well after sunrise (figure 6). As the day progressed, surface ozone levels increased dramatically to about 65 ppb. The sonde data from 11am (figure 8) and 2pm (figure 9) similarly show this increase of ozone concentrations in the lowest levels. Aloft (above 1 km), there seems to be a steady layer of ozone. A strong surface inversion layer is seen at 5am, and this slowly breaks down as the day progresses.

Reminiscent of the data plot from 2pm on August 12, a layer of ozone builds during the day of August 13th and is shown to peak near 60 ppb by 2pm. This layer extends to about 400 metres before decreasing. The meteorological plot for this time interval shows an isothermal layer from 400 metres to 1000 metres. From the plot of flight data from the 8pm release, one can see that this surface based ozone layer has diminished significantly. Surface concentrations at this time are decreasing.

The upper wind direction plots for flights in this second episode show widely fluctuating directions below 1500 metres for each of the two days. Above 1500 metres however, directions tend to be consistent from the south to southwest. The mean surface wind direction taken at the Abbotsford airport for this same period is shown in figure 10. The several gaps observed in the data represent calm conditions. From mid-day on August 12 to days end on August 13, one can see that the winds were either calm or favoured a west to southwesterly direction.

4b. Upper Air Data Discussion:

A complete set of upper air data are available for the Clearbrook site and also for Vancouver International Airport and Quillayute, Washington during the ozone flight days. At the Vancouver International Airport pilot balloons are released at the main synoptic times of 00, 06, 12 and 18Z. Quillayute, an Upper Air Station operated by the National Weather Service, releases balloons at 00 and 12Z. Quillayute is on the Washington Coast west of the Olympic Mountains which rise to 1500 metres. The wind profile above mountain top height has been assumed to be representative of the Lower Mainland/Fraser Valley area; a more detailed report on this assumption will follow later.

The wind profiles of Quillayute and Clearbrook are quite similar above 1500 metres for the three days when the ozone levels were elevated. The upper level winds were blowing from the southwest at Clearbrook and Quillayute with the greatest agreement in the profiles above 2200 metres. Between 1500 metres and 2200 metres the Quillayute wind direction shows a little more of a southerly component than Clearbrook. A complete set of data is available in Appendix C.

Studies of the meteorology favourable for high ground-level ozone have found that one necessary ingredient is an upper ridge lying in a north/south line east of the Lower Fraser Valley. The ridge will produce southerly to southwesterly winds aloft over the Valley and cause widespread subsidence. The wind information available compares well with this requirement.

4c. Surface Ozone Measurements:

The Measurements and Analysis Division (ARQM) sampling program had three sites from which data was gathered. One of the sites, other than the Clearbrook site, was located at Westham Island south of the City of Vancouver at the mouth of the Fraser River. Surface ozone data from this site is included in this report. Westham Island lies predominantly west of the Clearbrook site on the coast of the Strait of Georgia and the ozone data is useful in giving a spatial distribution of surface ozone concentrations from seacoast to mid valley. It is unfortunate that the Westham Island data acquisition system was down during the 2 day episode in mid-August. The data from Westham Island and Clearbrook for the 31st of July (Julian Day 213) episode are shown in figure 11. The peak is observed occurring at Clearbrook shortly after mid-day yet not until evening is it noticed over Westham Island. A possible explanation for this could be that the ozone generated in the urban areas around Vancouver was pushed inland by the sea breeze.
The total ozone plots from both sites are shown in figures 12 and 13.

4d. Ozone Concentration Contour Discussion:

A surface ozone concentration monitoring network is operated by the British Columbia Ministry of the Environment and the Greater Vancouver Regional District (GVRD). Data from both of these networks and data supplied by the FCC for Custer, Washington was used to produce contour charts showing surface ozone concentrations for the Lower Fraser Valley. Appendix D contains a series of charts compiled to coincide with each of the ozonesonde release times.

The ozone concentration contour charts show isopleths of average hourly ozone concentration. Shaded station circles represent the locations of the GVRD, BC Environment and the Custer ozone monitoring stations. The values on the stations are the average hourly concentration of ozone at the station during the hour preceding the chart time. All times on the charts are in Pacific Daylight Time PDT. "M" or the station identification code represents missing data. Extra values added to the chart, but not on station circles, are from the Clearbrook and Westham Island chemistry sites. For interest, the Saturna CAPMoN data was added, but the actual geographic location is farther to the south. Terrain contours are at an interval of 300 metres.

Surface wind information has been added for all the stations available. AES sites include Vancouver International Airport, Sand Heads, Vancouver Harbour and Abbotsford Airport. GVRD supplied winds for Confederation Park (T5), Second Narrows (T6), Kensington Park (T4) and Kitsilano (T2). Unfortunately, other GVRD wind data was not available due to technical problems. BC Environment supplied winds from their stations at Surrey/Echo, South Langley and Annacis Island, (on top of the Alex Fraser Bridge at an elevation of 162m AGL). Wind barbs placed over the stations available represent the winds in kilometres per hour at the chart time.

Charts from the three days that ozone profiles are available in Clearbrook show an ozone concentration pattern typical of what is expected during an ozone event in the Lower Fraser Valley. Light winds are occurring at inland locations with stations along Georgia Strait reporting the highest winds. The synoptic pressure pattern is very slack with mesoscale pressure differences driving the wind pattern. Land and sea breezes along with valley circulation change during the day causing changes in the wind direction. These effects can be seen in the wind pattern on the days of interest.

Overnight, the calm or very light winds are associated with ozone concentrations less than 10 ppb. The only station that consistently does not have low ozone levels at night is Burnaby Mountain which, at 360 m ASL, is the highest station in the region. Winds at stations along Georgia Strait are typically stronger during an episode and this is also the case on these three days. Westham Island and Richmond South are reporting early morning ozone concentrations a little higher than stations reporting lighter winds in less exposed areas.

By late morning ozone levels are rising throughout the region except for Burnaby Mountain which shows an ozone decrease on two of the three mornings. The North Shore stations downwind from industrial areas and the Abbotsford-Chilliwack corridor show the greatest rises in ozone concentration. Wind speeds are also beginning to increase slightly. The late morning wind directions for July 31st and August 12th - 13th differ from each other. On July 31st light outflow winds dominate, on August 12th winds in the Fraser Valley continue light northeasterly but the stations near Burrard Inlet are westerly. The winds on August 13th are very light with Burrard Inlet stations nearly all reporting calm, winds in the Fraser Valley are light southerly.

At 2 p.m. ozone levels are continuing to rise and all winds have more of a west southwesterly component. Ozone concentrations are rising the fastest in the areas downwind of Port Moody-Port Coquitlam and also in the Custer - Abbotsford areas.

The ozone concentrations have reached their highest values by late afternoon. On all three days the highest concentrations are occurring in the Chilliwack area with concentrations reaching as high as 81 ppb. Winds upstream of the Chilliwack area are consistently from the southwest at this time. A second area of high concentration occurs on two of the three days at the eastern end of Burrard Inlet. Surface winds in the surrounding areas tend to converge on this location on the days when the high concentrations occur.

By evening ozone levels are decreasing most rapidly at the eastern end of Burrard Inlet and surrounding Abbotsford area but concentrations are still the highest in the Chilliwack-Abbotsford areas. Wind directions continue to be from the southwest in the valley but are becoming a little more variable elsewhere.

5. Summary:

The August 12th and 13th episode exhibited similar synoptic scale features to that of July 31st. An intensive profile program operating from 5:00 am (PDT) to 8:00 pm (PDT) captures more of the detailed sea and land breeze circulations. A subsidence inversion formed can be clearly identified (Figures 7 to 9) with ozone proceeding through a similar diurnal pattern in the sea and land breeze flow. By 8:00 pm (PDT) on August 12th, structure in the vertical ozone profile was observed related to a very light northwesterly flow between 400 to 600 metres. Although there were no chemistry measurements made to substantiate this, one could surmise that these light northwesterly winds may have brought NO_x enriched air over the site and that the interaction of the air parcels erodes the ozone (Figure 8). Another scenario could be that a layer of clean air migrated over the region, displacing the ozone laden airmass. The complete diurnal pattern of the sea and land breeze was documented by the soundings on August 13th (Figure 9). Vertical distributions of ozone and humidity formed similar patterns to those of August 12th. The major difference in the two days occurs with the 8:00 pm (PDT) profile. Winds shift from southwesterly to westerly at about 500 metres with speeds dropping off slightly however remaining at 6 to 8 knots. This region of westerly winds extends to 1200 metres and appears to be related to the depletion of ozone. A similar occurrence has been noted above on both July 31st and August 12th. The difference on August 13th is that wind speeds are higher indicating a better established flow. It would appear that the August 13th ozone erosion was caused by an elevated "plume" of NO_x being transported over the site in the westerly flow. The degree of erosion of ozone was considerably greater on the 13th. On July 31st and August 12th the circulation aloft that brought the suspected NO_x enriched "plume" over the site was light and likely associated with a topographically induced mesoscale circulation. A different situation appeared to develop on the 13th as the westerly flow aloft was well established. The fact that the wind speeds were slightly higher on the 13th may have been the early signs that the synoptic pattern which was supporting the development of the elevated ozone was breaking down. Without the detailed upper air data, it is difficult to confirm the above hypotheses.

In general diurnal variations of ozone are controlled by an elevated inversion which may provide decoupling between the surface based mixed layer and the layer aloft. Activity within the boundary layer produces a peak ozone concentration in the afternoon as the temperature inversion is at a minimum. During episode 2, ozone concentrations within the surface layer were capped by an inversion at 700 metres. Temporal changes in stability below the inversion resulted in a well mixed layer (flight 22521) with the peak ozone concentrations again occurring during maximum daytime heating. As the nighttime inversion developed ozone destruction occurred below 700 metres which resulted in near zero concentrations at the surface. The second day shows a weaker capping inversion with less decoupling and a more uniform profile which tends to match the concentrations aloft.

The average troposphere concentration for July 31st and August 1st is approximately 50 ppm whereas the average tropospheric concentration for August 12th to 14th started off at around 30 ppm and increased to approximately 42 ppb near the end. This may indicate that we are seeing long range transport aloft and local generated ozone below the 700 metre inversion.

The profiles for August 12th (Figure 7) shows an area of ozone depletion of approximately 18ppm between 2500 and 4000 metres. Wind direction within this layer has a noticeable shift from the SSW to WSW quadrant. Supporting data is not available at this time to pursue the cause for these occurrences.

Acknowledgements:

The authors wish to express their thanks to the many people involved in contributing to the success of the Field Study and in the completion of this report.

Thanks go out to Mr. W. Belzer of the Pacific Region - AISB - Air Quality Unit for assistance in resolving operational problems during the study.

Thanks also to Mr. A.J. Gallant (A.E.S.-ARQM) for the ozone data from Westham Island; Mr. M. Webb (Canadian Climate Centre) for the Abbotsford B.C. surface wind data, and to Mr. J. Woods (C.A.R.E.) for his advice and assistance in producing the graphical analyses contained in this report.

A special thanks to the Management and staff of the Agriculture Canada Agassiz Sub-Station for their hospitality and facilities support.

Finally, thanks go to Drs. R.M. Hoff, R.E. Mickle and Mr. J. Woods for critically reviewing this report.

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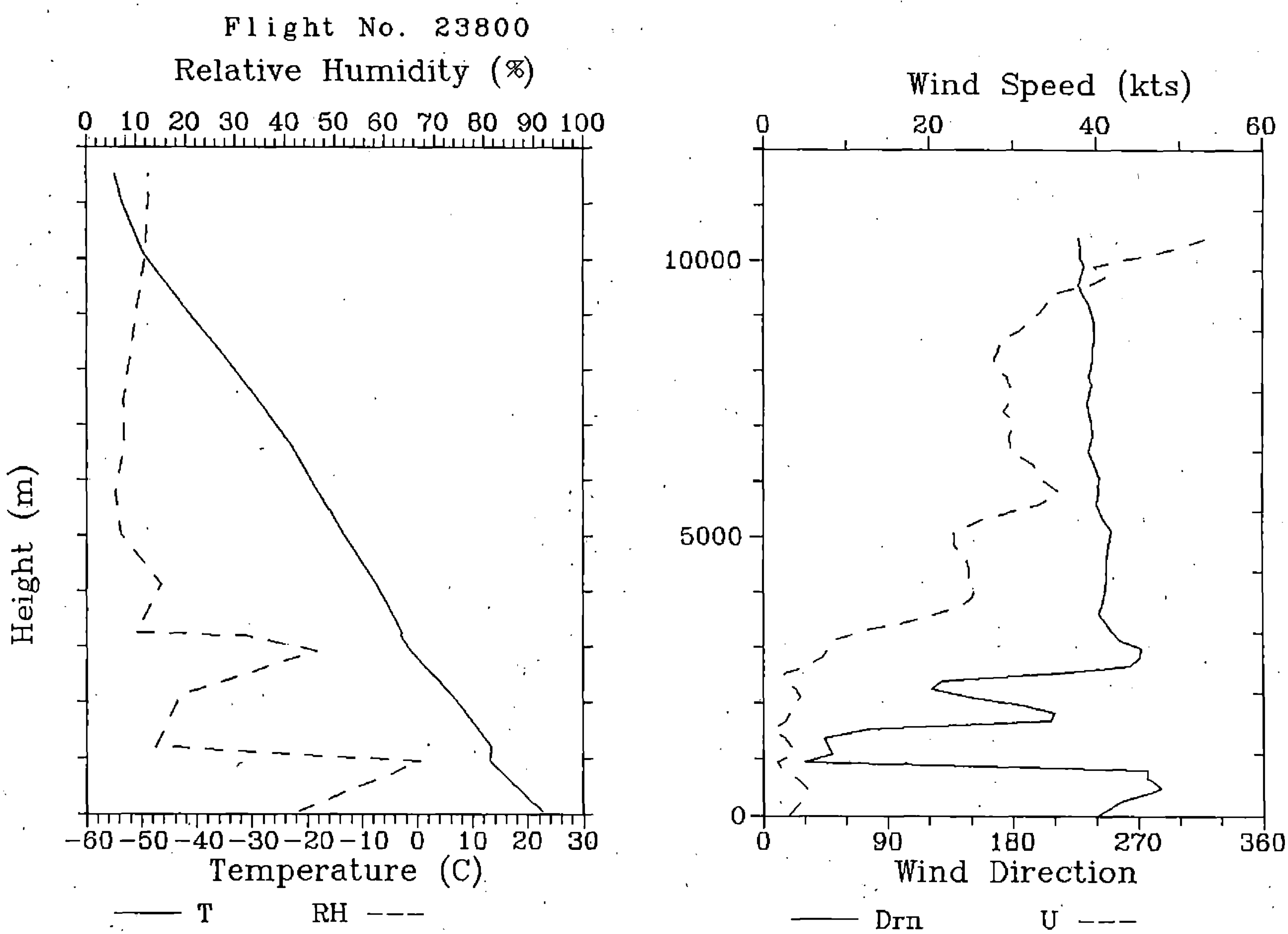


Flight No. 23800
Relative Humidity (%)
0 10 20 30 40 50 60 70 80 90 100
Height (m)
-60 -50 -40 -30 -20 -10 0 10 20 30
Temperature (C)
T
RH
Wind Speed (kts)
0 20 40 60
10000
5000
0
0 90 180 270 360
Wind Direction
Drn
U

Figure 1

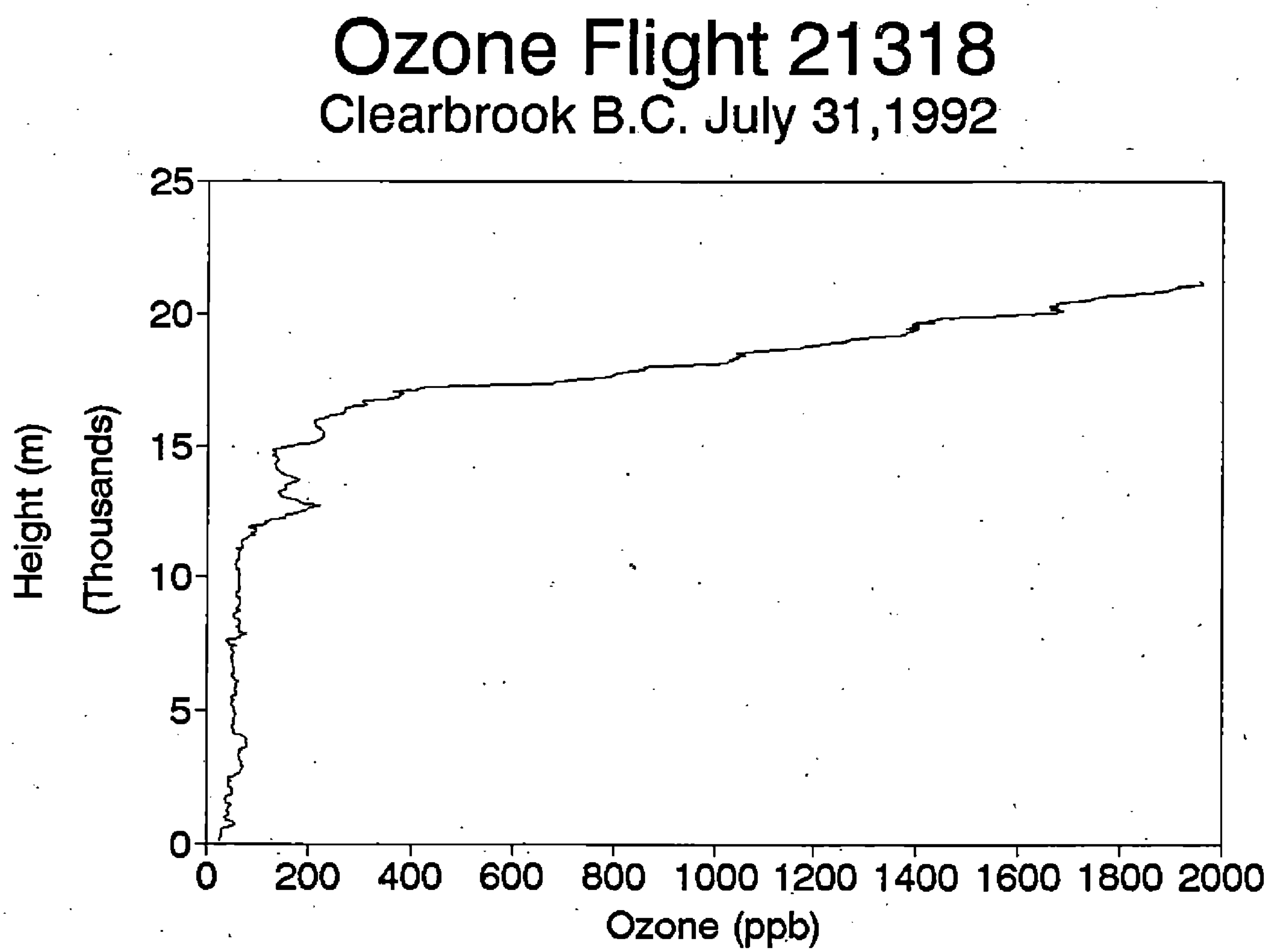

Ozone Flight 21318
Clearbrook B.C. July 31,1992
Height (m)
(Thousands)
0
5
10
15
20
25
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Ozone (ppb)

Figure 2 (a)

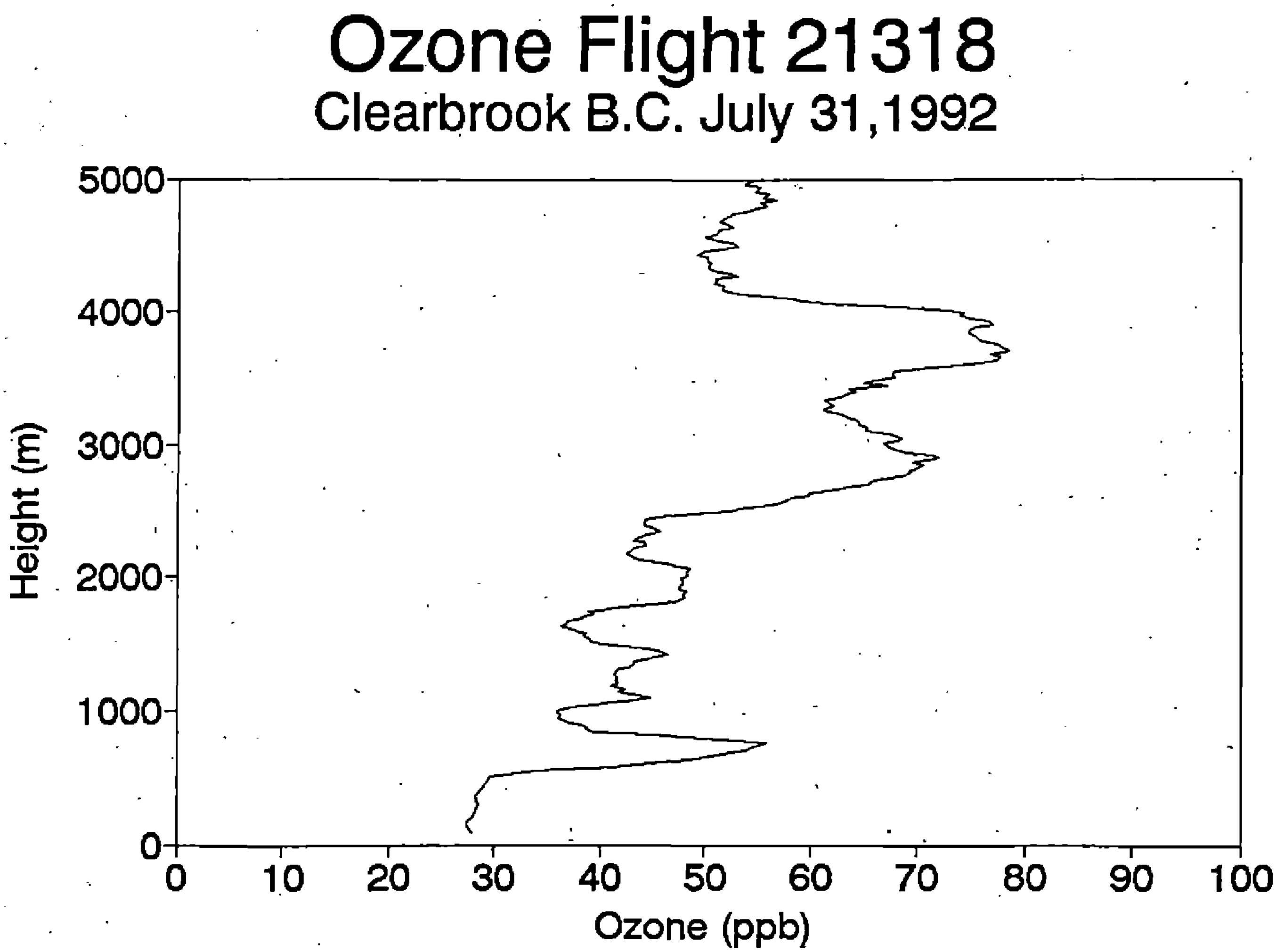
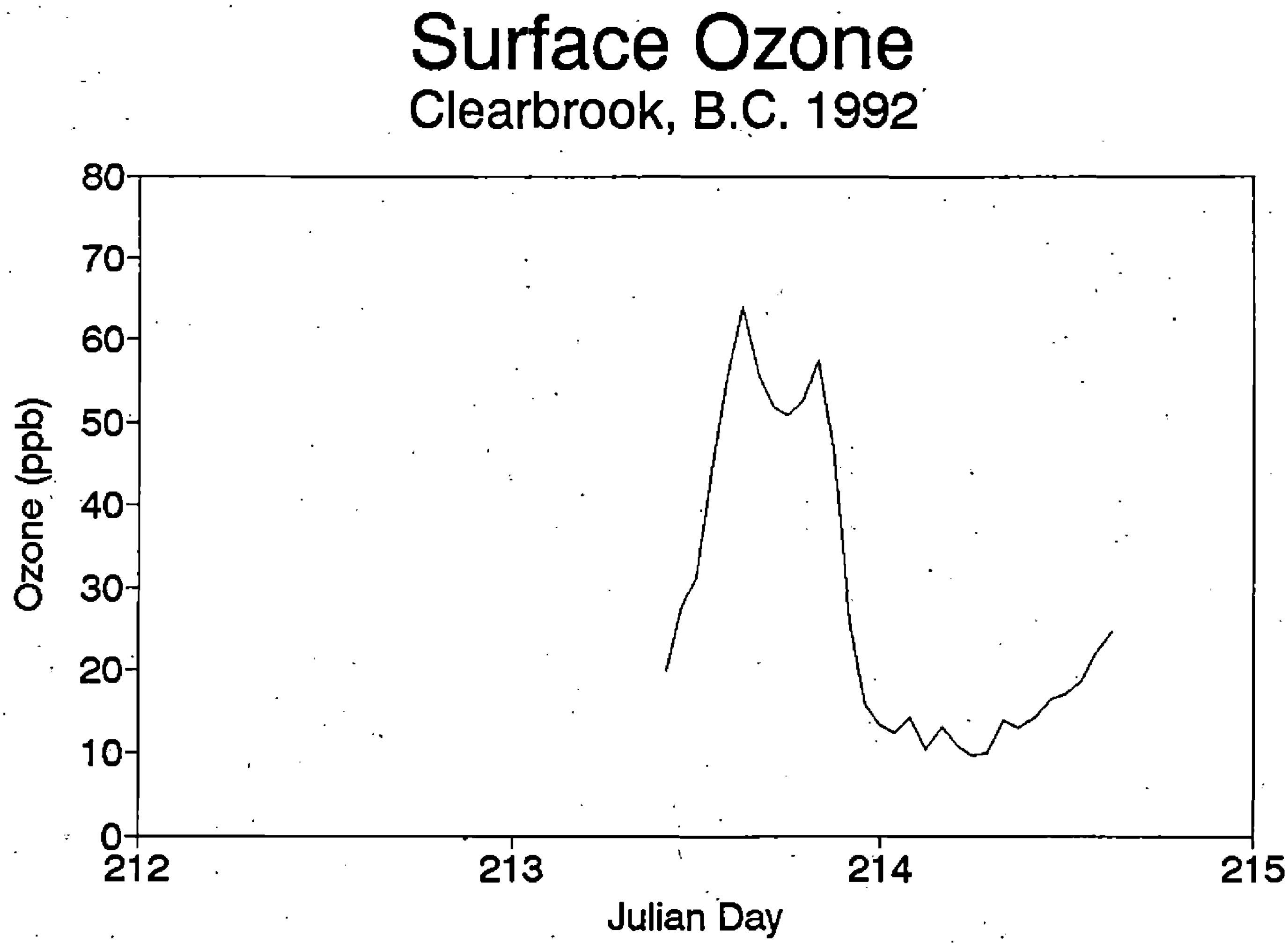
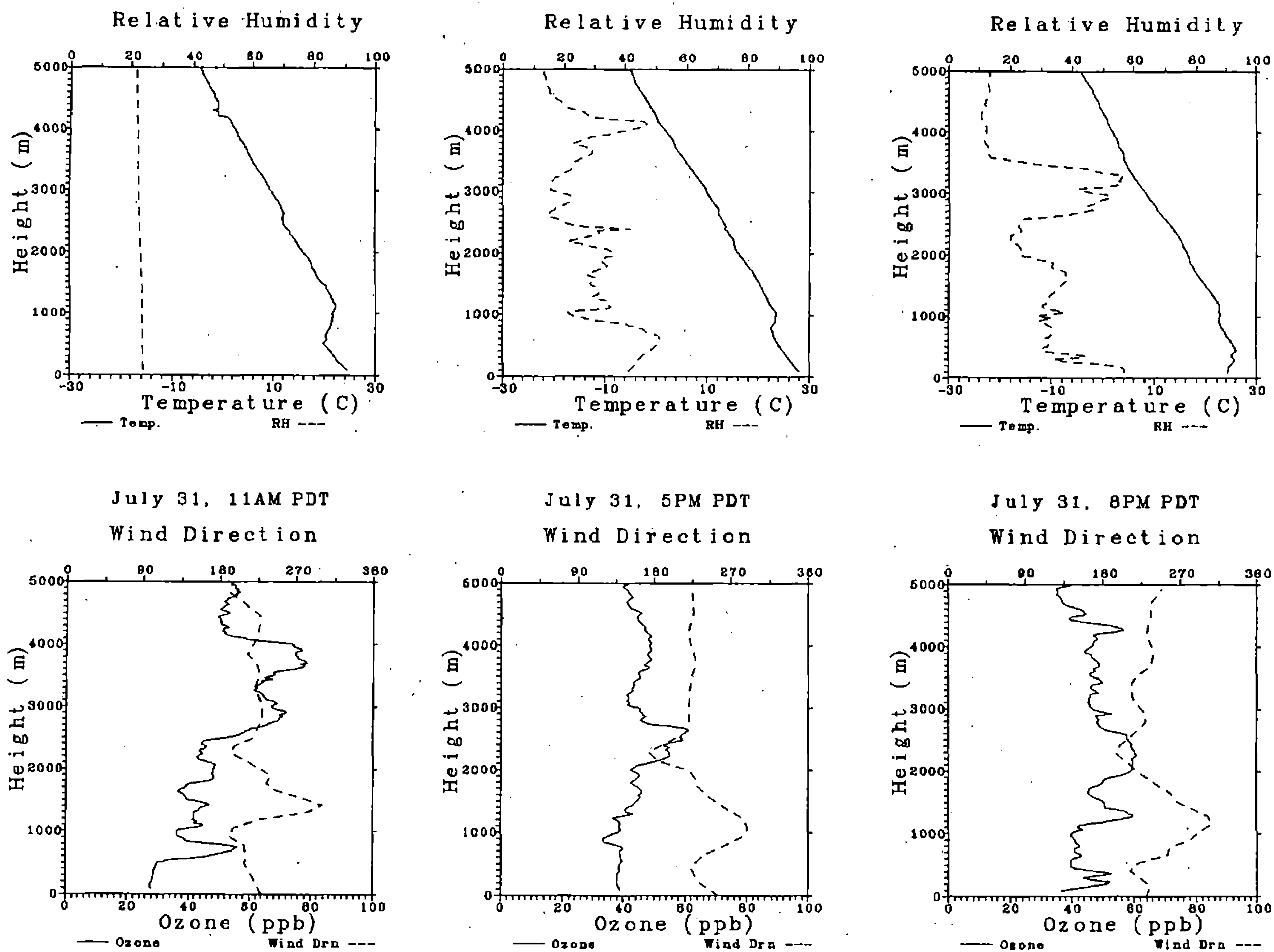

Ozone Flight 21318
Clearbrook B.C. July 31,1992
Height (m)
0
1000
2000
3000
4000
5000
0
10
20
30
40
50
60
70
80
90
100
Ozone (ppb)

Figure 2 (b)



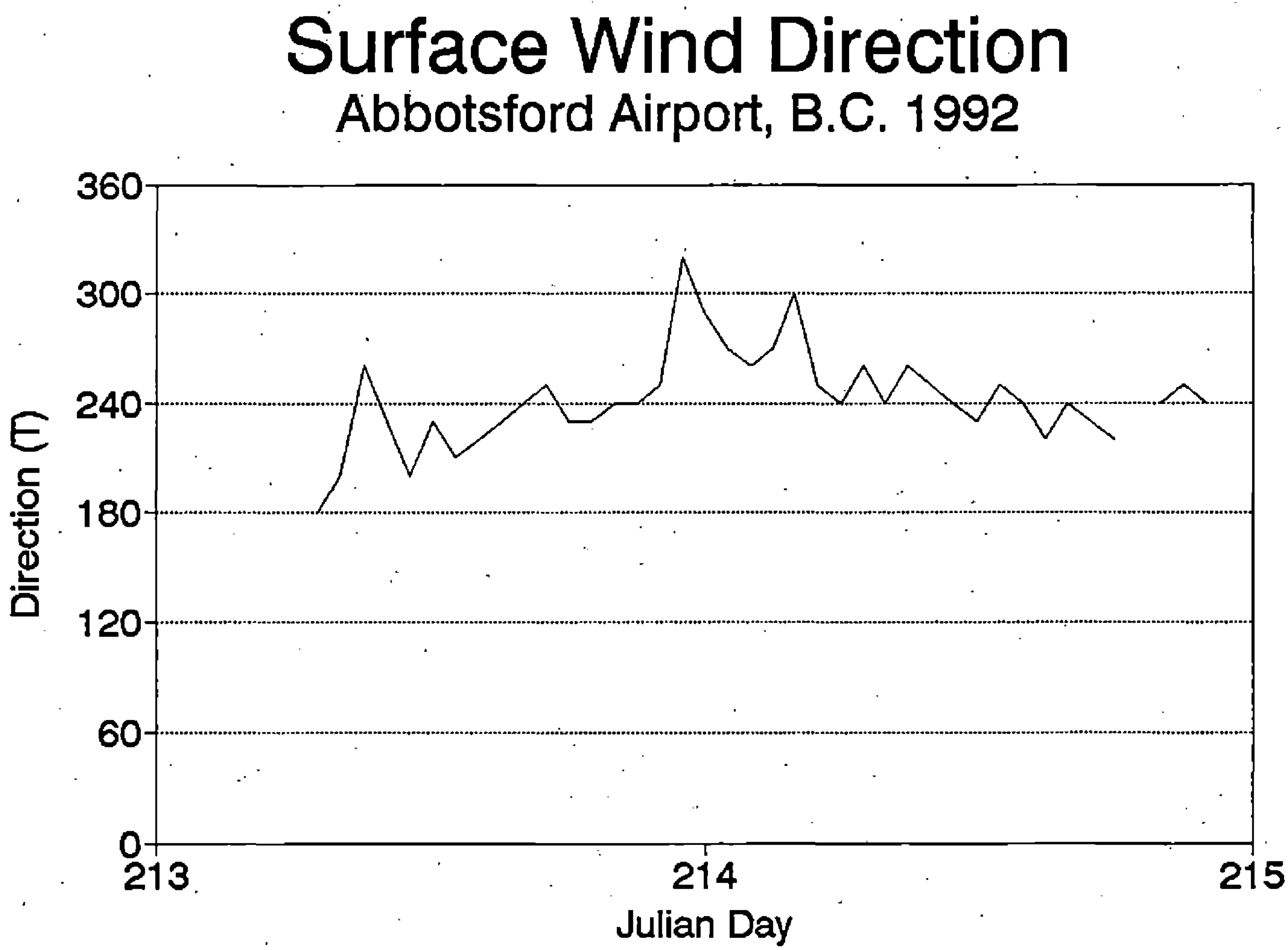
Surface Ozone
Clearbrook, B.C. 1992
Ozone (ppb)
80
70
60
50
40
30
20
10
0
212
213
214
215
Julian Day

Figure 3



Relative Humidity
Relative Humidity
Relative Humidity
0 20 40 60 80 100
Height (m)
0 1000 2000 3000 4000 5000
-30 -10 10 30
Temperature (C)
Temp.
RH
July 31, 11AM PDT
July 31, 5PM PDT
July 31, 8PM PDT
Wind Direction
Wind Direction
Wind Direction
0 90 180 270 360
0 20 40 60 80 100
Ozone (ppb)
Ozone
Wind Drn

Figure 4



Surface Wind Direction
Abbotsford Airport, B.C. 1992
360
300
240
180
120
60
0
Direction (T)
213
214
215
Julian Day

Figure 5

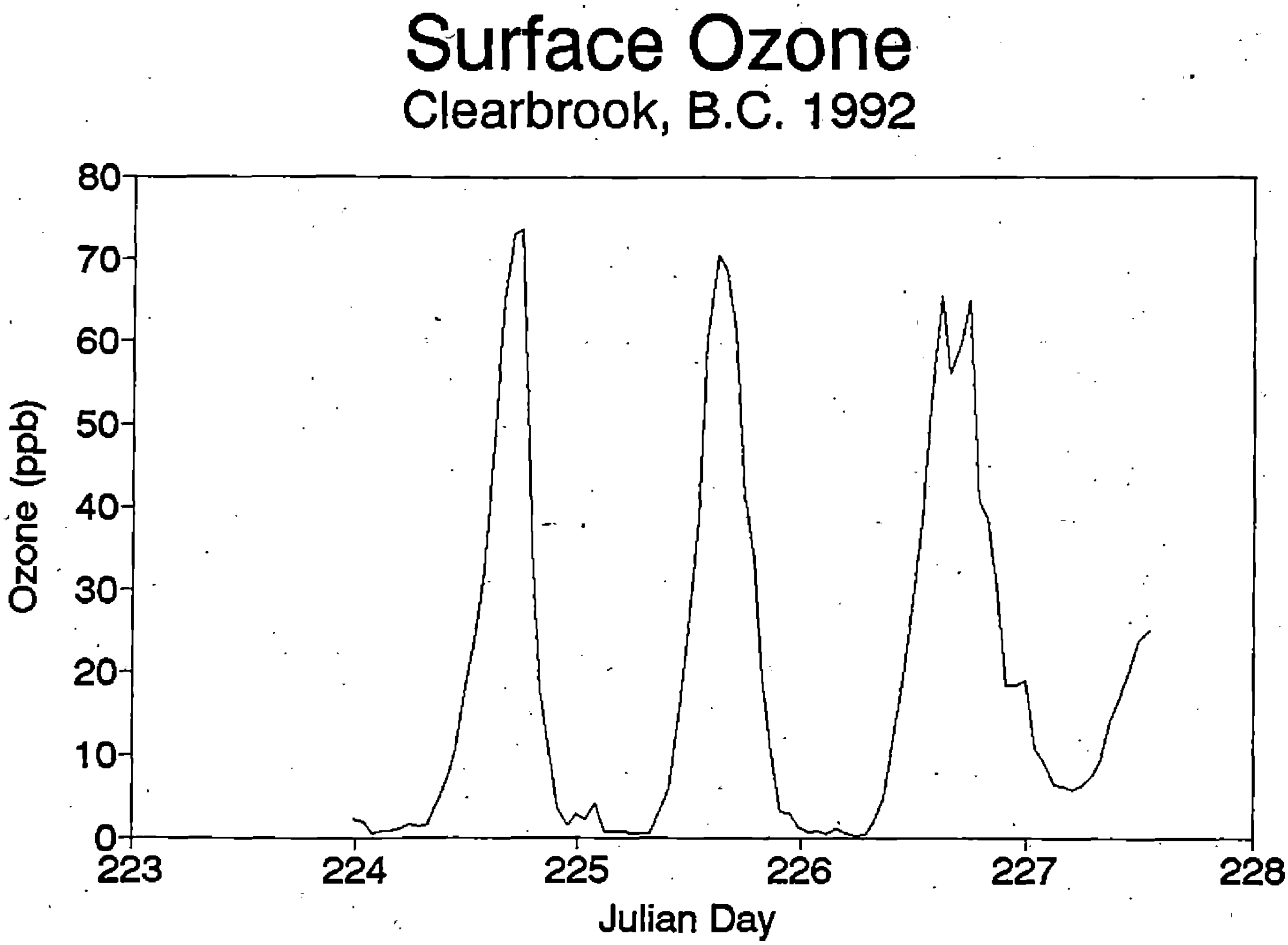

Surface Ozone
Clearbrook, B.C. 1992
Ozone (ppb)
80
70
60
50
40
30
20
10
0
223
224
225
226
227
228
Julian Day

Figure 6

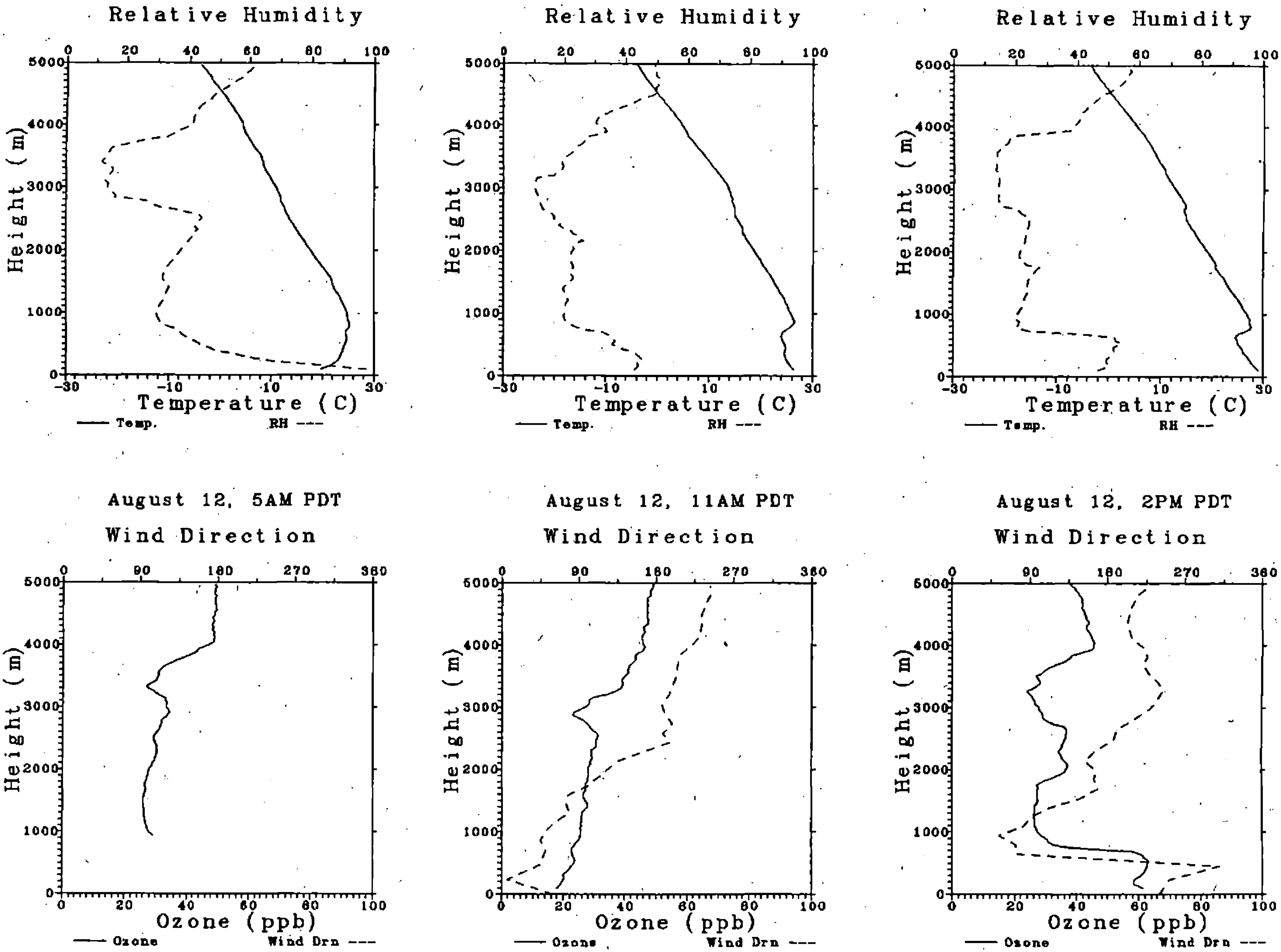

Relative Humidity
Height (m)
Temperature (C)
Temp.
RH
August 12, 5AM PDT
Wind Direction
Ozone (ppb)
Ozone
Wind Drn
Relative Humidity
Height (m)
Temperature (C)
Temp.
RH
August 12, 11AM PDT
Wind Direction
Ozone (ppb)
Ozone
Wind Drn
Relative Humidity
Height (m)
Temperature (C)
Temp.
RH
August 12, 2PM PDT
Wind Direction
Ozone (ppb)
Ozone
Wind Drn

Figure 7

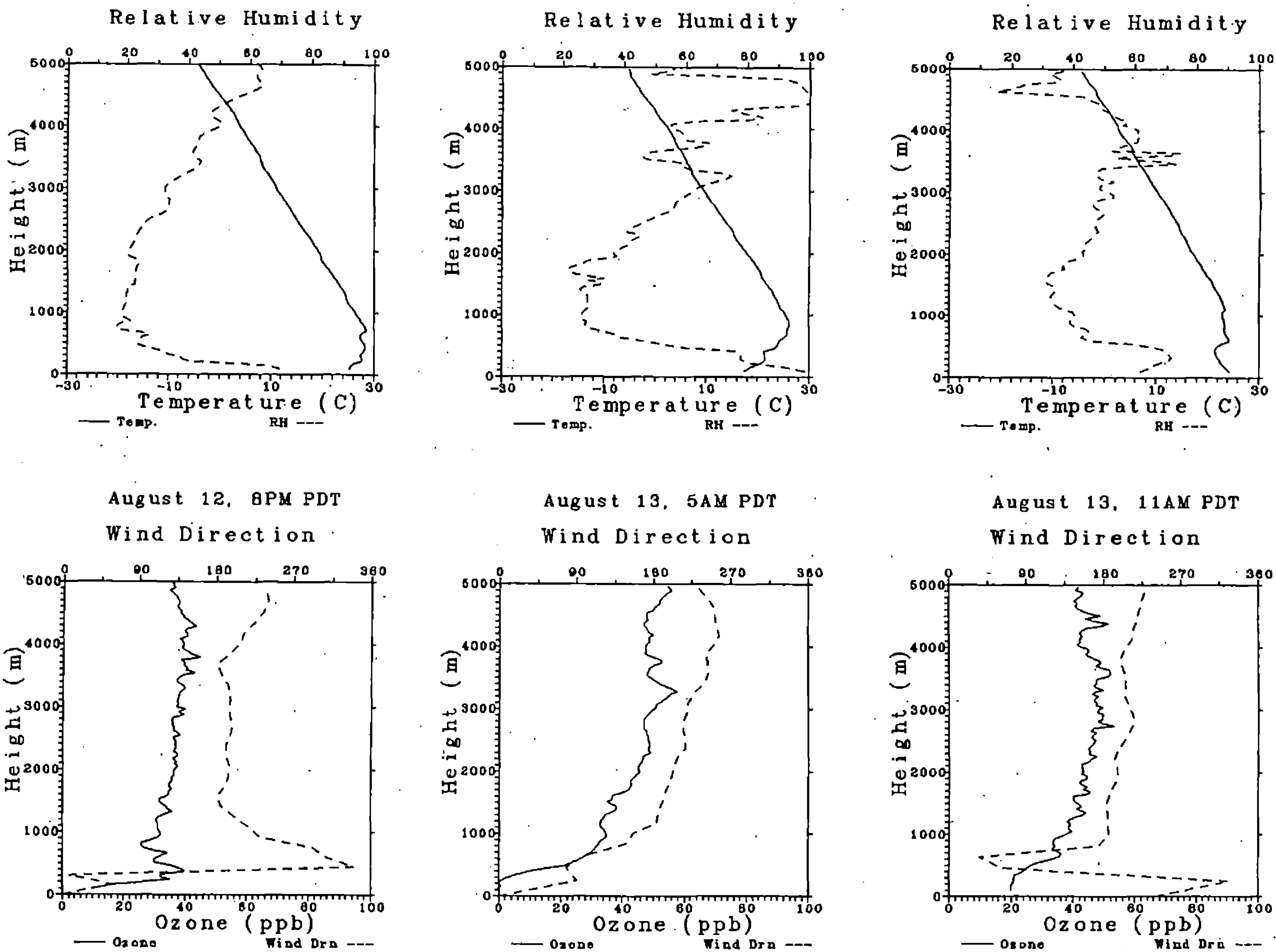
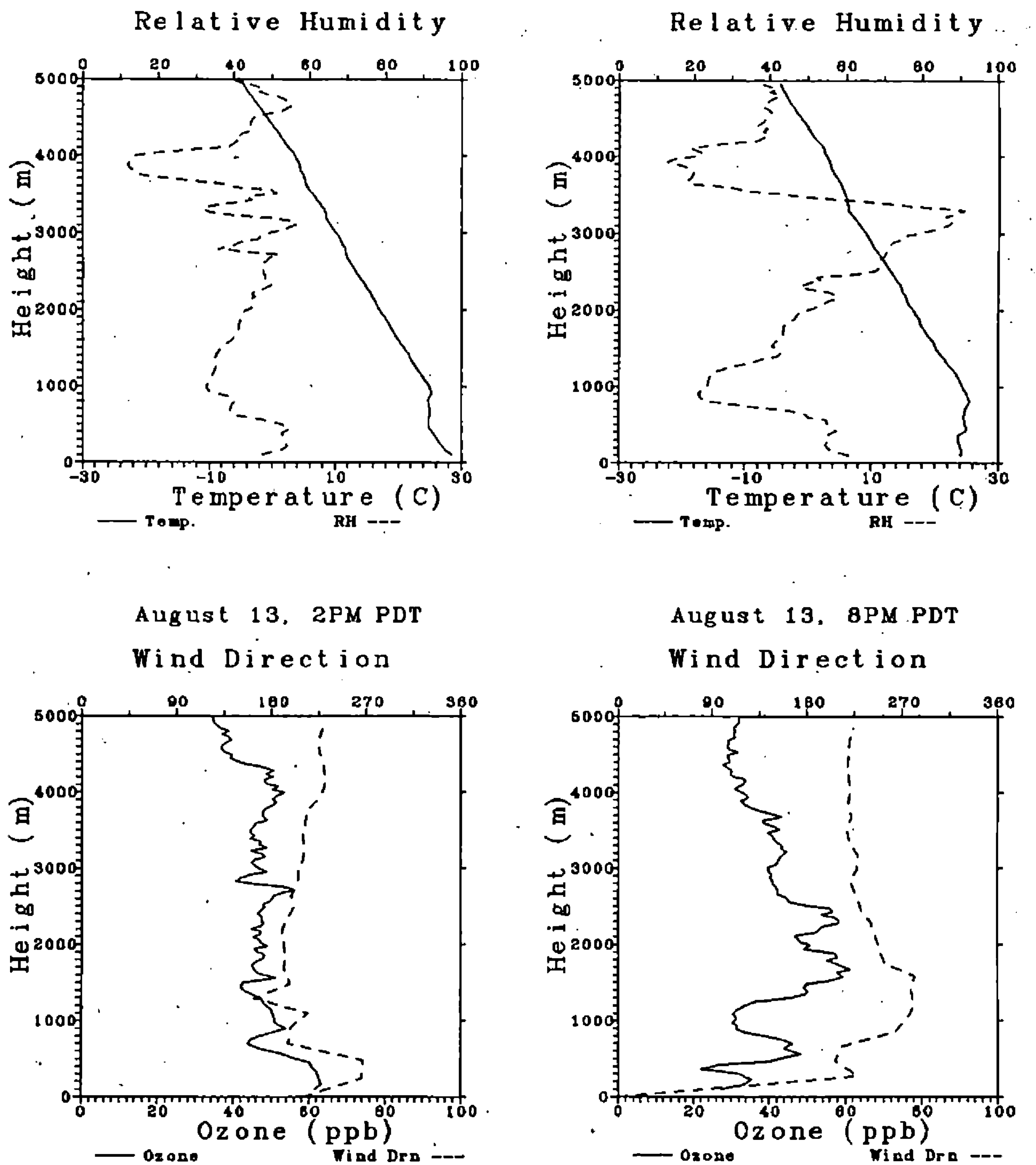

Relative Humidity
Height (m)
Temperature (C)
Temp.
RH ---
August 12, 8PM PDT
August 13, 5AM PDT
August 13, 11AM PDT
Wind Direction
Ozone (ppb)
Ozone
Wind Drn ---

Figure 8



Relative Humidity
0 20 40 60 80 100
5000
4000
3000
2000
1000
0
Height (m)
-30 -10 10 30
Temperature (C)
Temp.
RH
Relative Humidity
0 20 40 60 80 100
5000
4000
3000
2000
1000
0
Height (m)
-30 -10 10 30
Temperature (C)
Temp.
RH
August 13, 2PM PDT
Wind Direction
0 90 180 270 360
5000
4000
3000
2000
1000
0
Height (m)
0 20 40 60 80 100
Ozone (ppb)
Ozone
Wind Drn
August 13, 8PM PDT
Wind Direction
0 90 180 270 360
5000
4000
3000
2000
1000
0
Height (m)
0 20 40 60 80 100
Ozone (ppb)
Ozone
Wind Drn

Figure 9

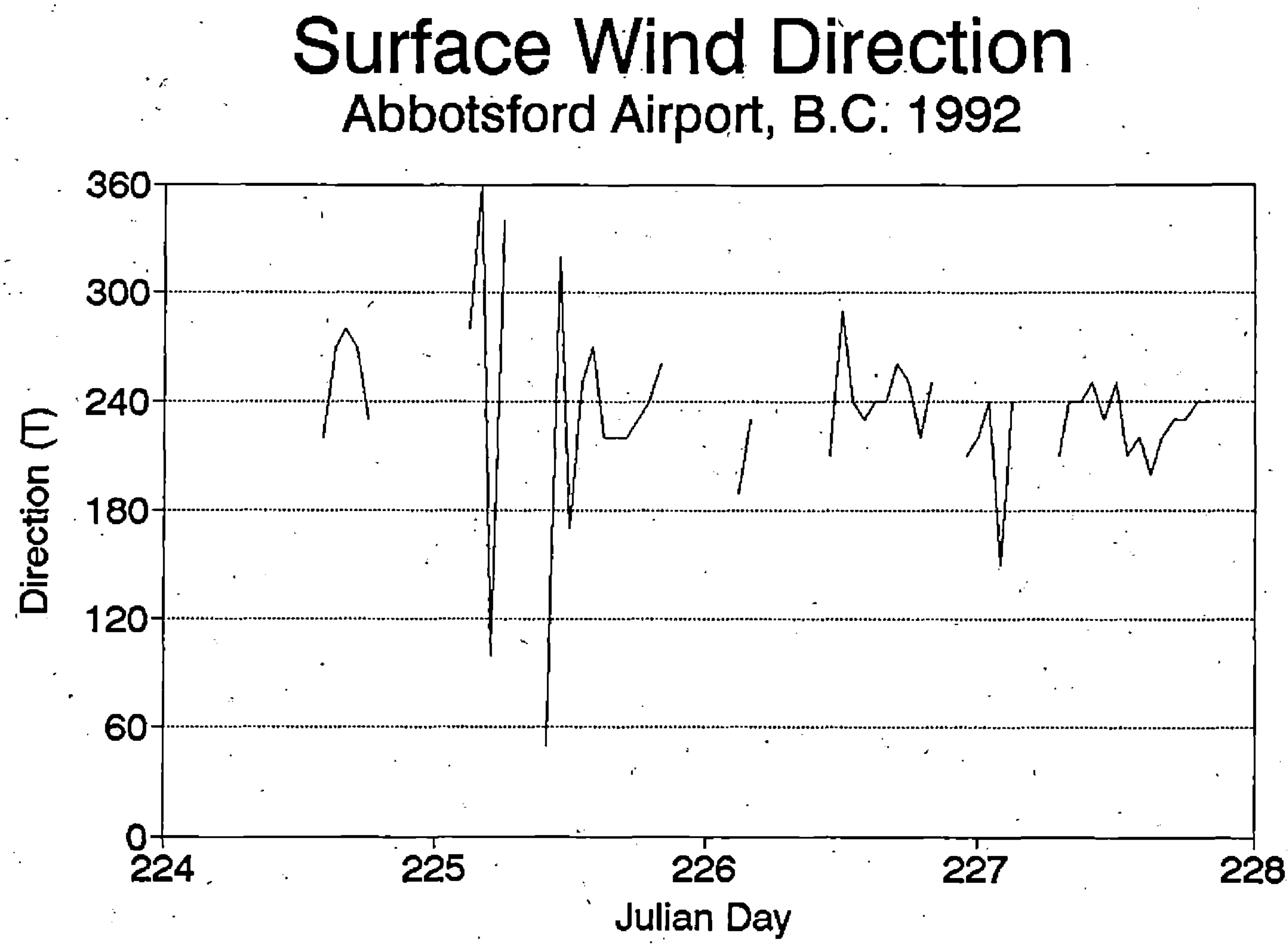

Surface Wind Direction
Abbotsford Airport, B.C. 1992
Direction (T)
360
300
240
180
120
60
0
224
225
226
227
228
Julian Day

Figure 10

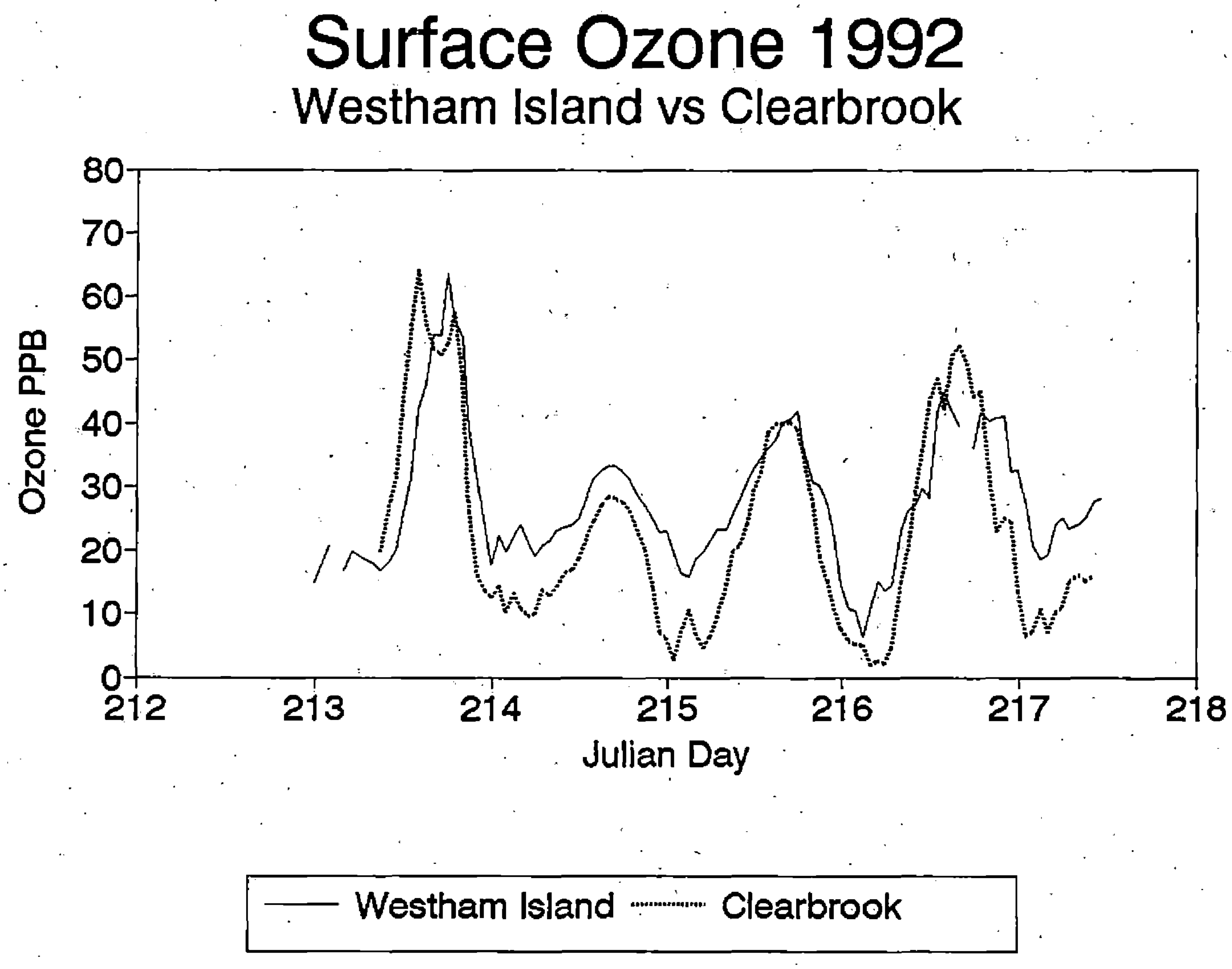

Surface Ozone 1992
Westham Island vs Clearbrook
Ozone PPB
80
70
60
50
40
30
20
10
0
212
213
214
215
216
217
218
Julian Day
Westham Island
Clearbrook

Figure 11

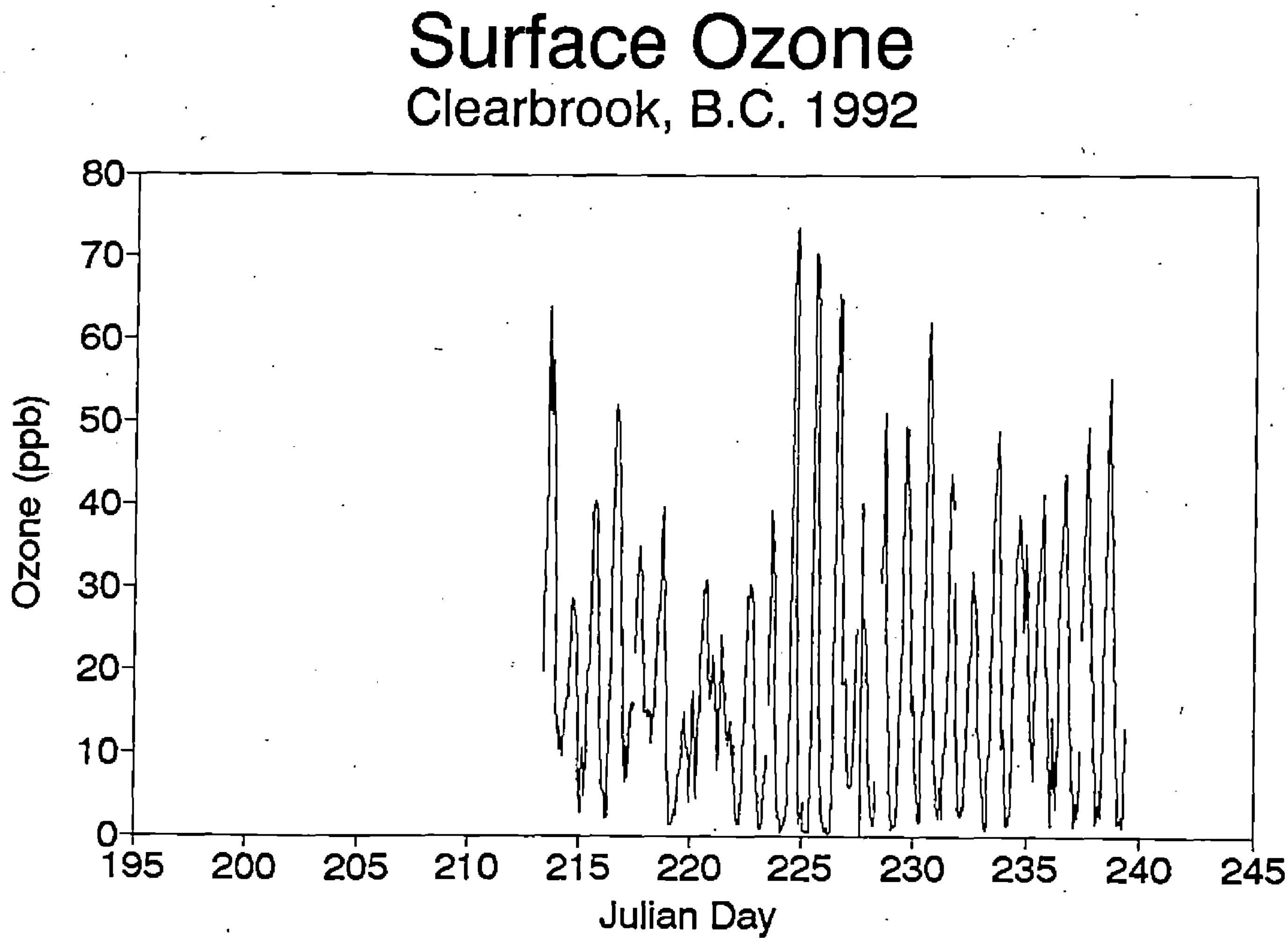
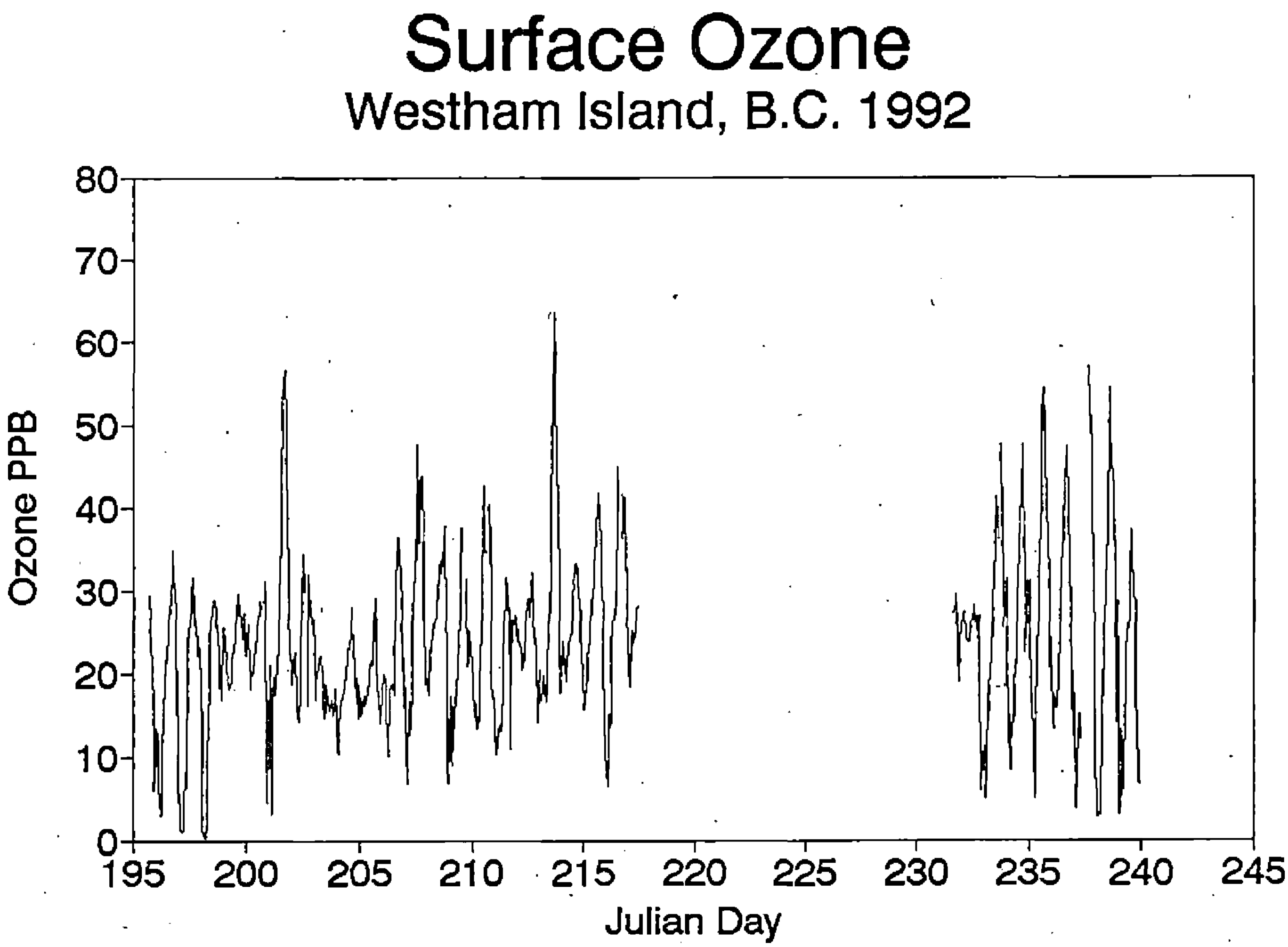

Surface Ozone
Clearbrook, B.C. 1992
Ozone (ppb)
80
70
60
50
40
30
20
10
0
195
200
205
210
215
220
225
230
235
240
245
Julian Day

Figure 12



Surface Ozone
Westham Island, B.C. 1992
Ozone PPB
0
10
20
30
40
50
60
70
80
195
200
205
210
215
220
225
230
235
240
245
Julian Day

Figure 13

APPENDIX A

Lower Fraser Valley Study
Aerological and Ozonesonde Flights

Available Data from Aerological
and Ozonesonde Flights

Lower Fraser Valley Study
July 31 - August 25 1992

Julian Day	GMT Hour	Data Set	Max.Height (m)
213	1800	Met.+ Ozone	21,277
	2100	" "	10,550
214	0300	" "	7,883
217	1900	Met. Only	2,186
218	0000	" "	4,719
	1800	" "	15,669
223	2100	" "	13,200
224	0000	" "	9,437
	1800	" "	10,300
225	0000	" "	9,400
	1200	Met.+ Ozone	11,178
	1800	" "	11,800
	2100	" "	11,000
226	0000	Met. Only	10,900
	0300	Met.+ Ozone	7,234
	1200	" "	9,655
	1800	" "	10,800
	2100	" "	13,200
227	0300	Met.+ Ozone	6,381
230	2000	Met. Only	600
231	0000	" "	12,051
	1800	" "	12,182
232	0000	" "	12,314
	1800	" "	12,174
233	0000	" "	10,700
	1800	" "	12,052
[A234	0000	" "	10,617
235	0000	" "	11,400
237	1800	" "	12,000
238	0000	" "	12,000

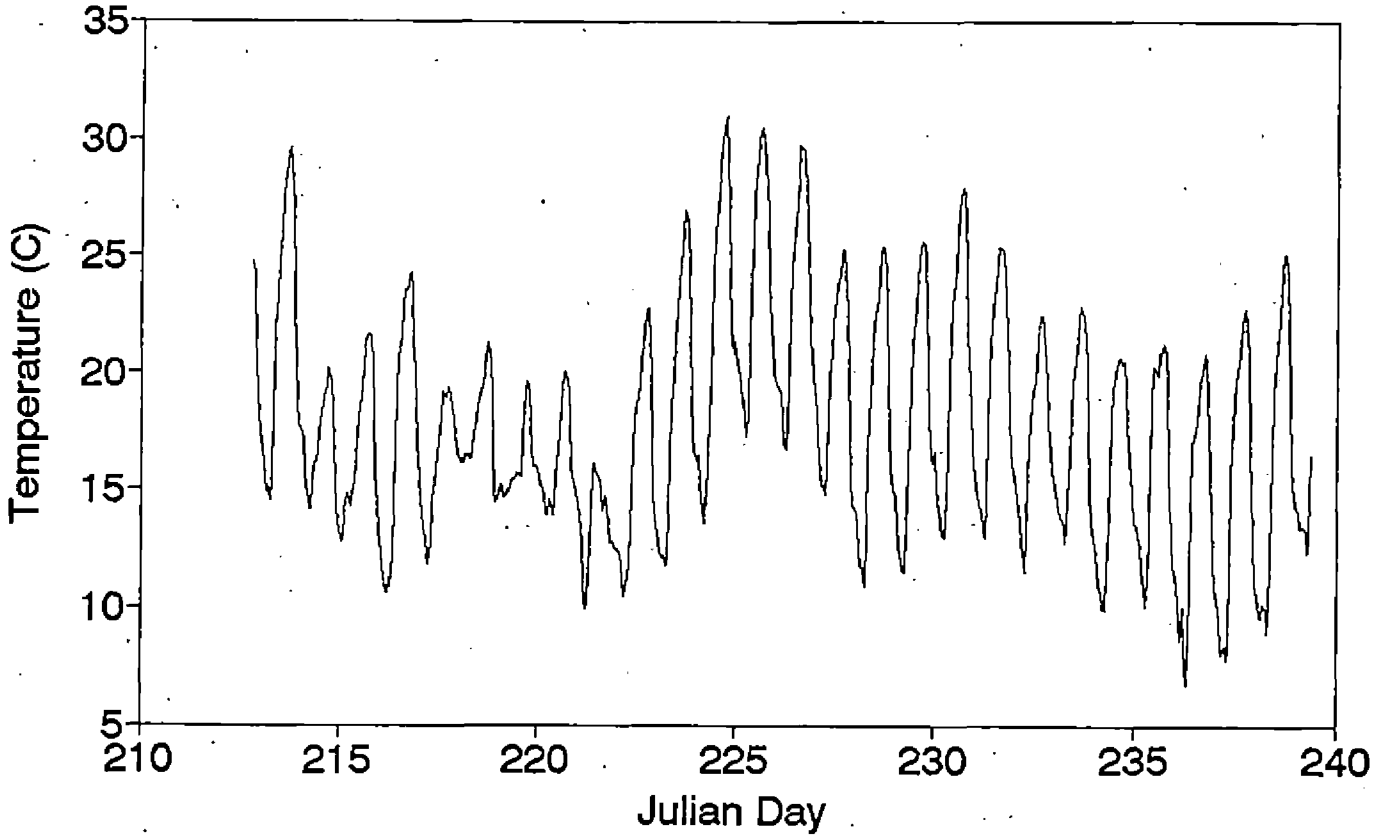
APPENDIX B

Surface Meteorological Data

Clearbrook B.C.

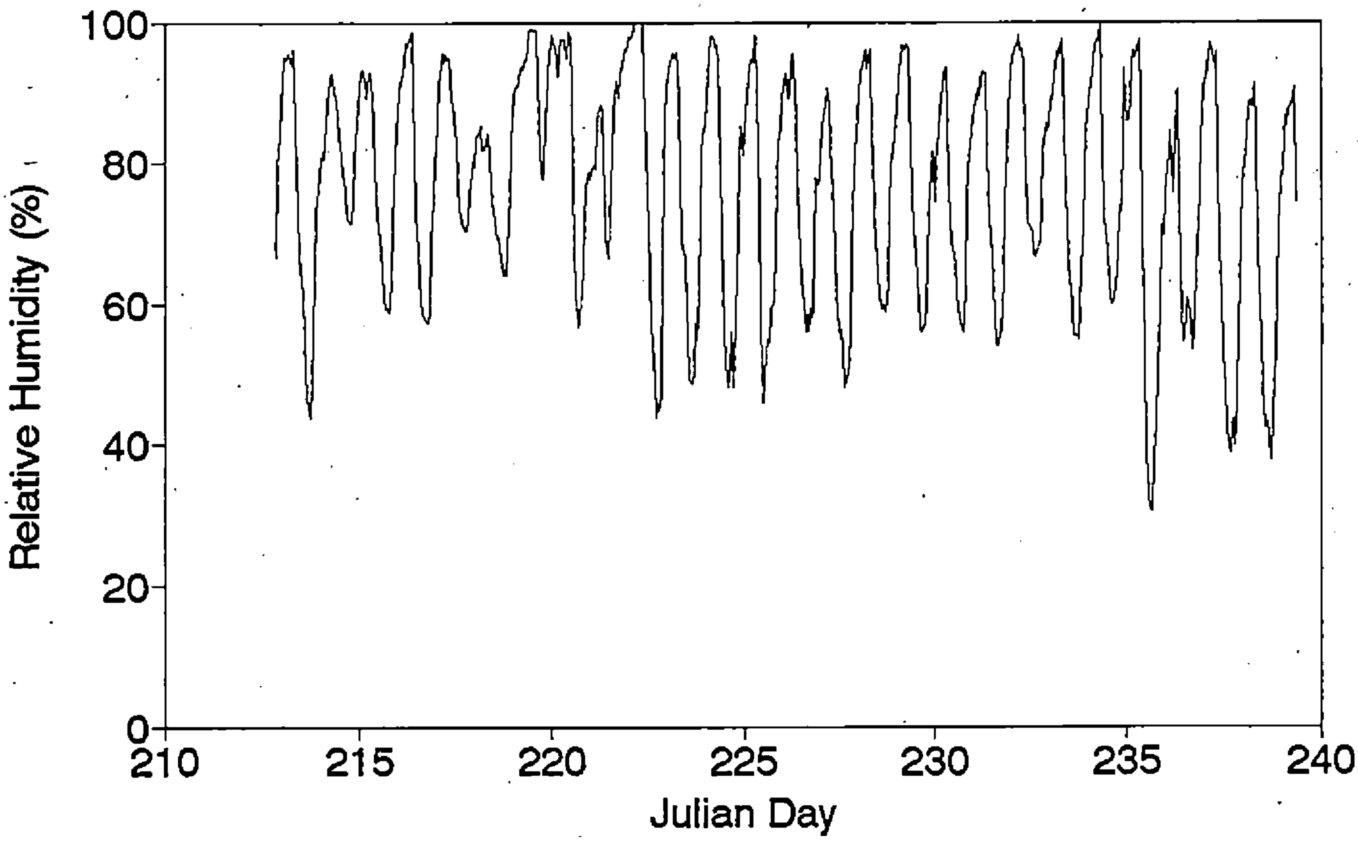
Surface Temperature

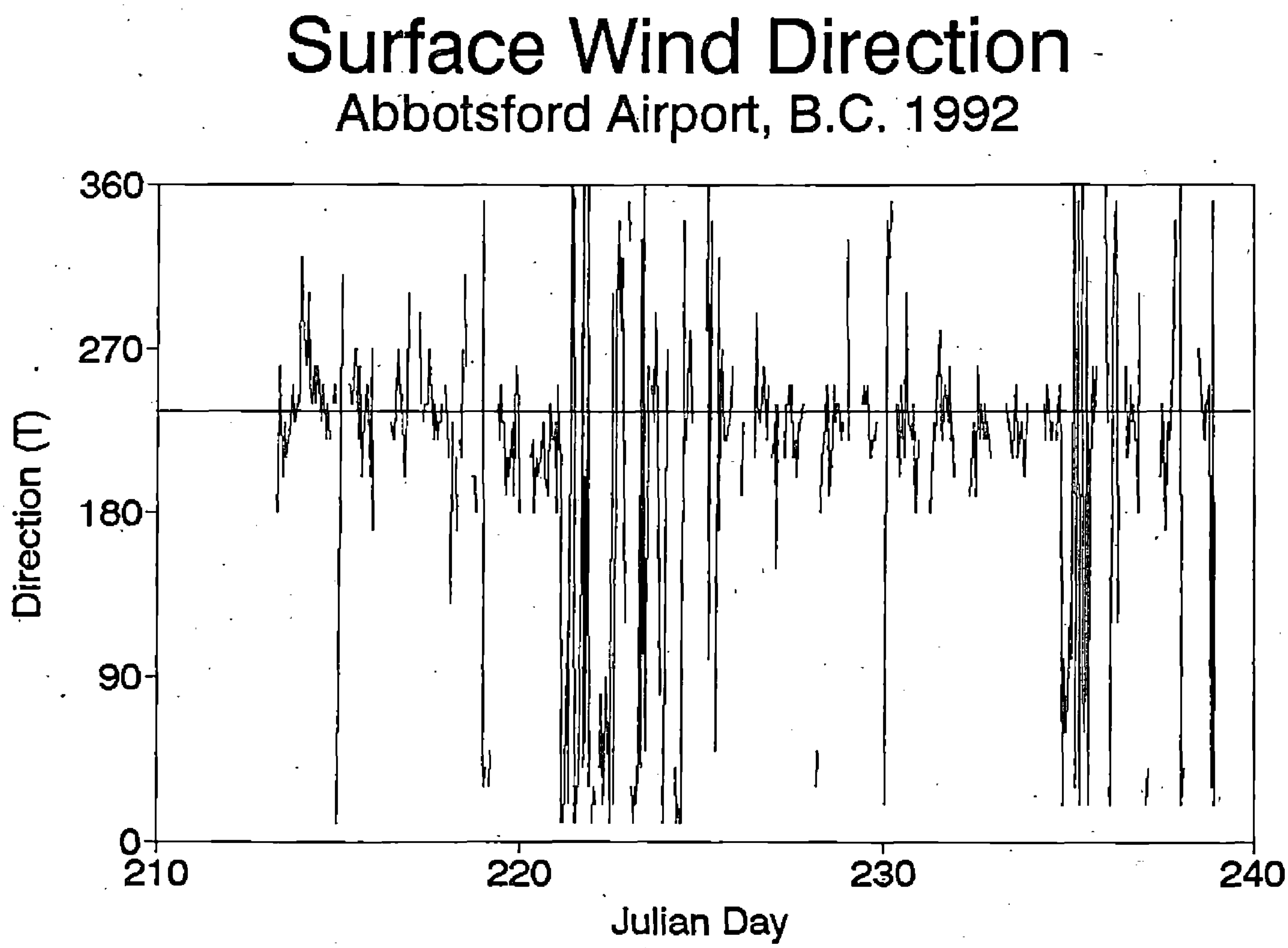
Clearbrook, B.C. 1992

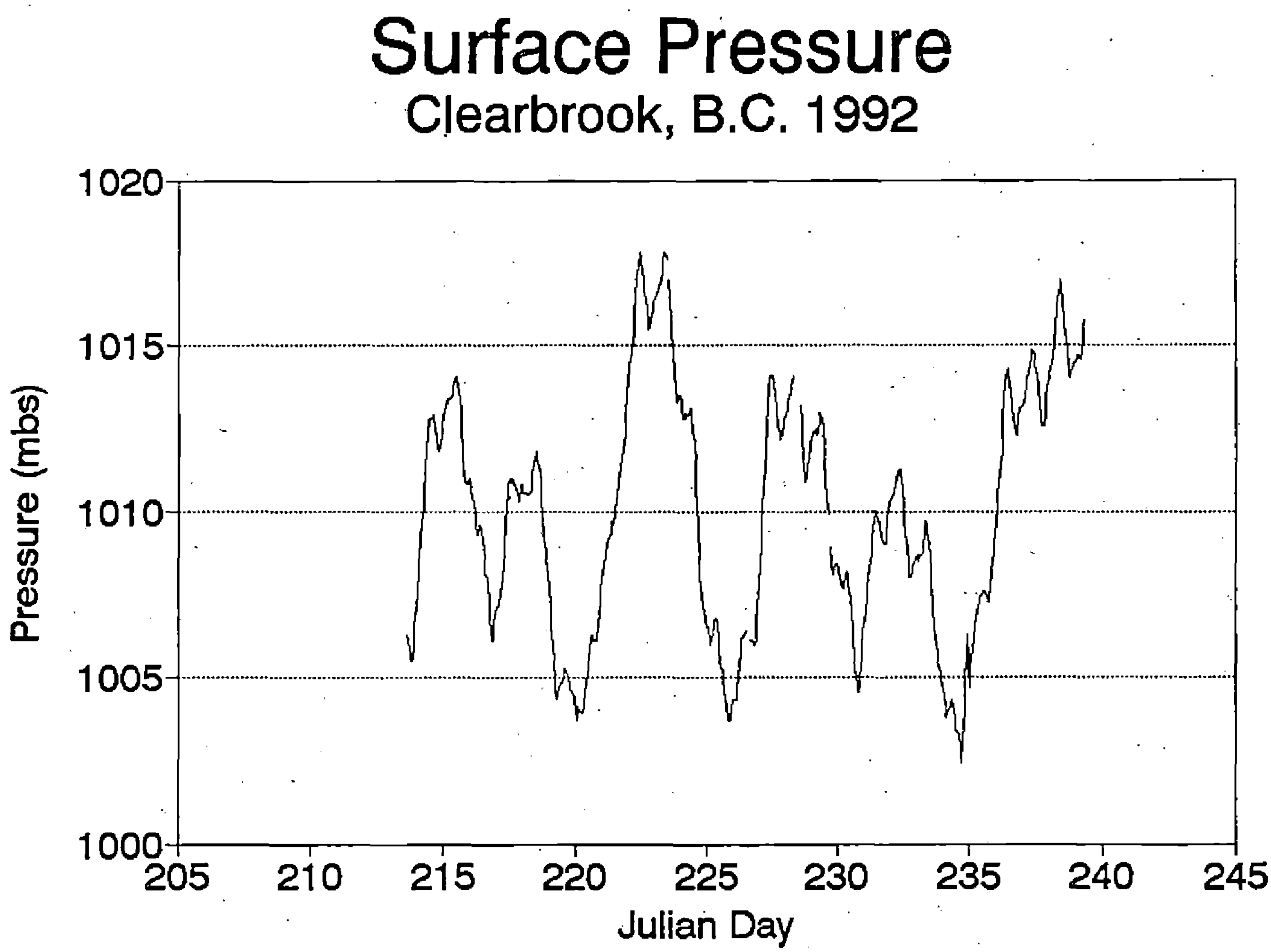


Surface Relative Humidity

Clearbrook, B.C. 1992

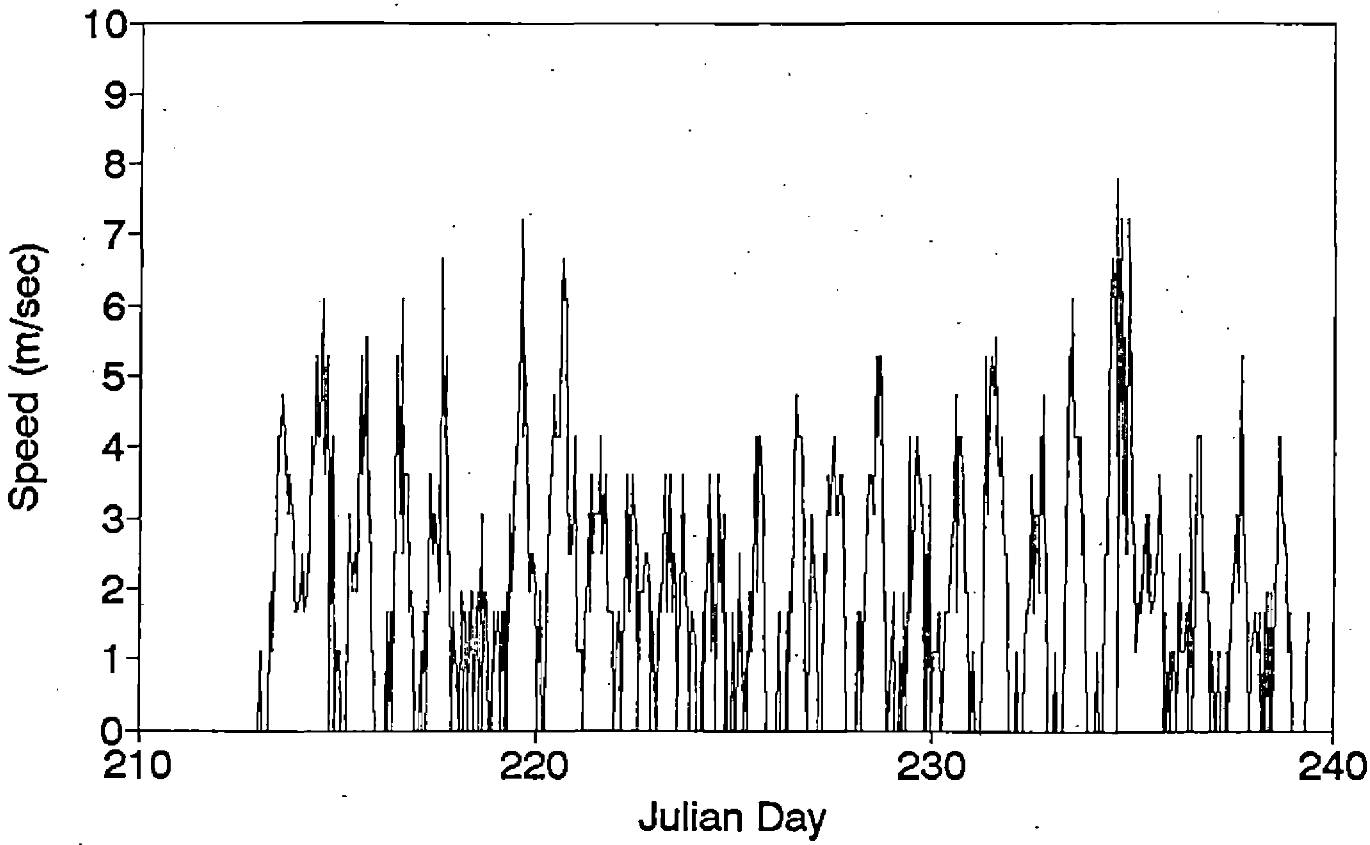



Surface Wind Direction
Abbotsford Airport, B.C. 1992
360
270
180
90
0
Direction (T)
210
220
230
240
Julian Day


Surface Pressure
Clearbrook, B.C. 1992
1020
1015
1010
1005
1000
Pressure (mbs)
205
210
215
220
225
230
235
240
245
Julian Day

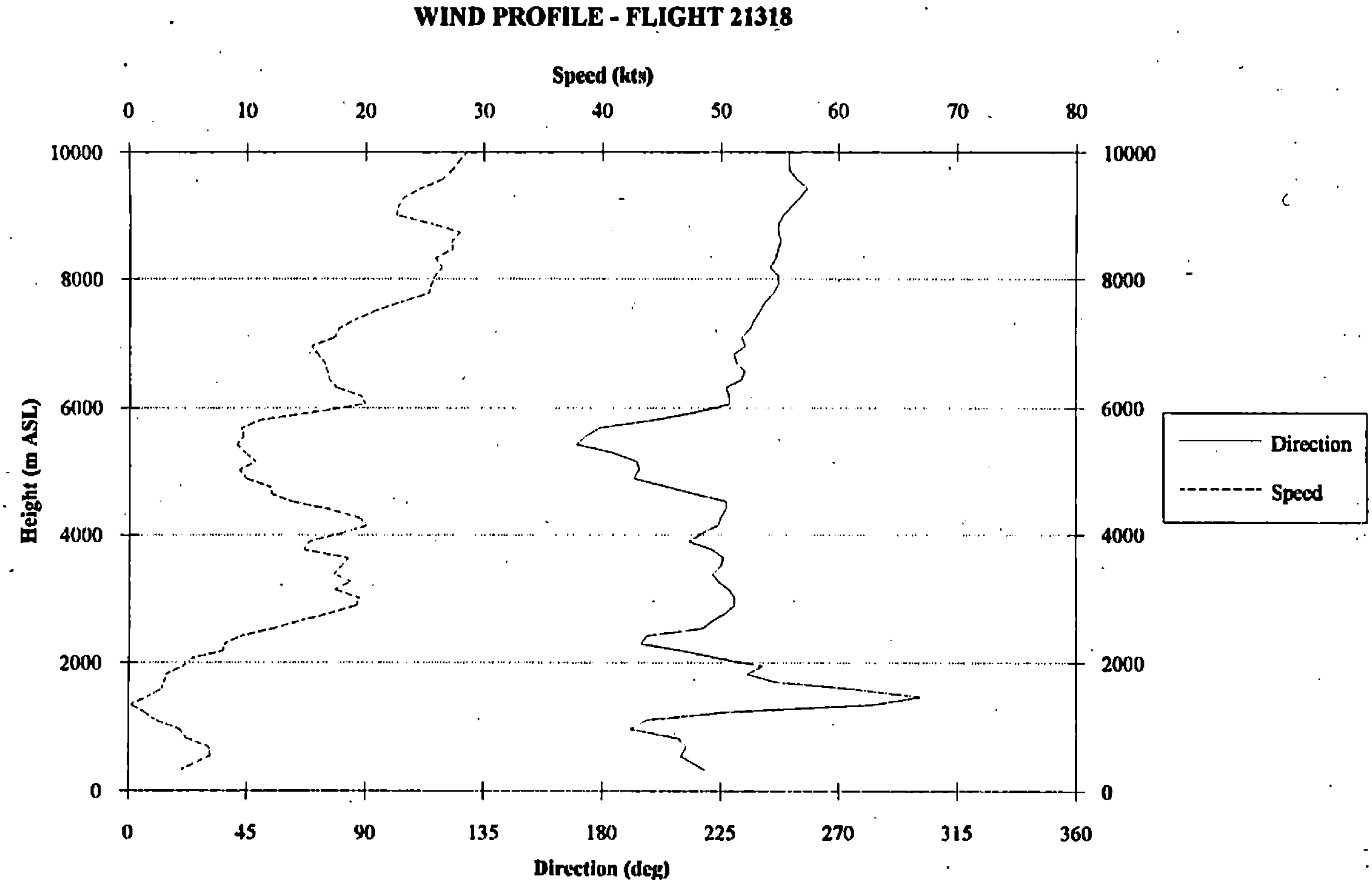
Surface Wind Speed

Abbotsford Airport, B.C. 1992



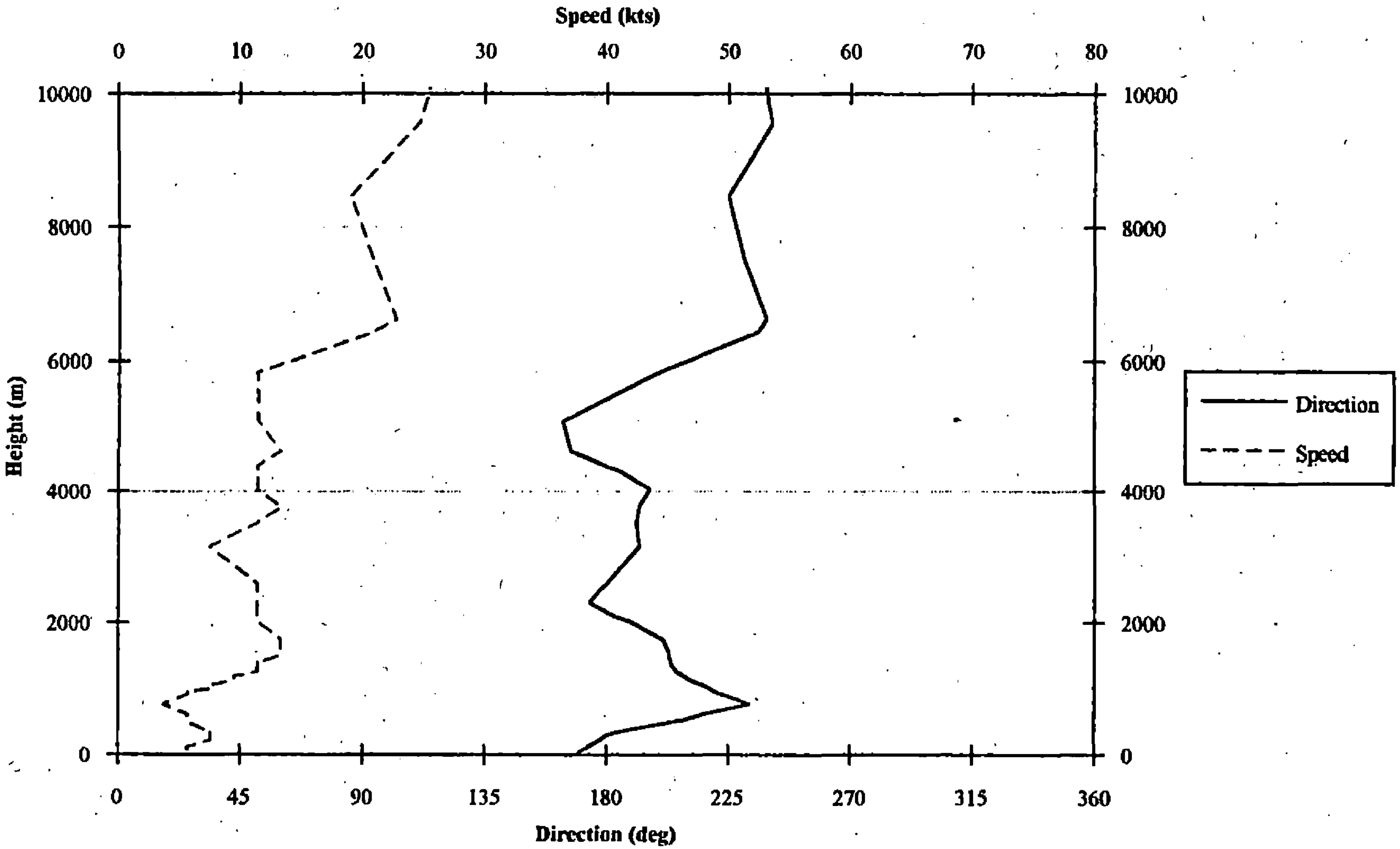
APPENDIX C

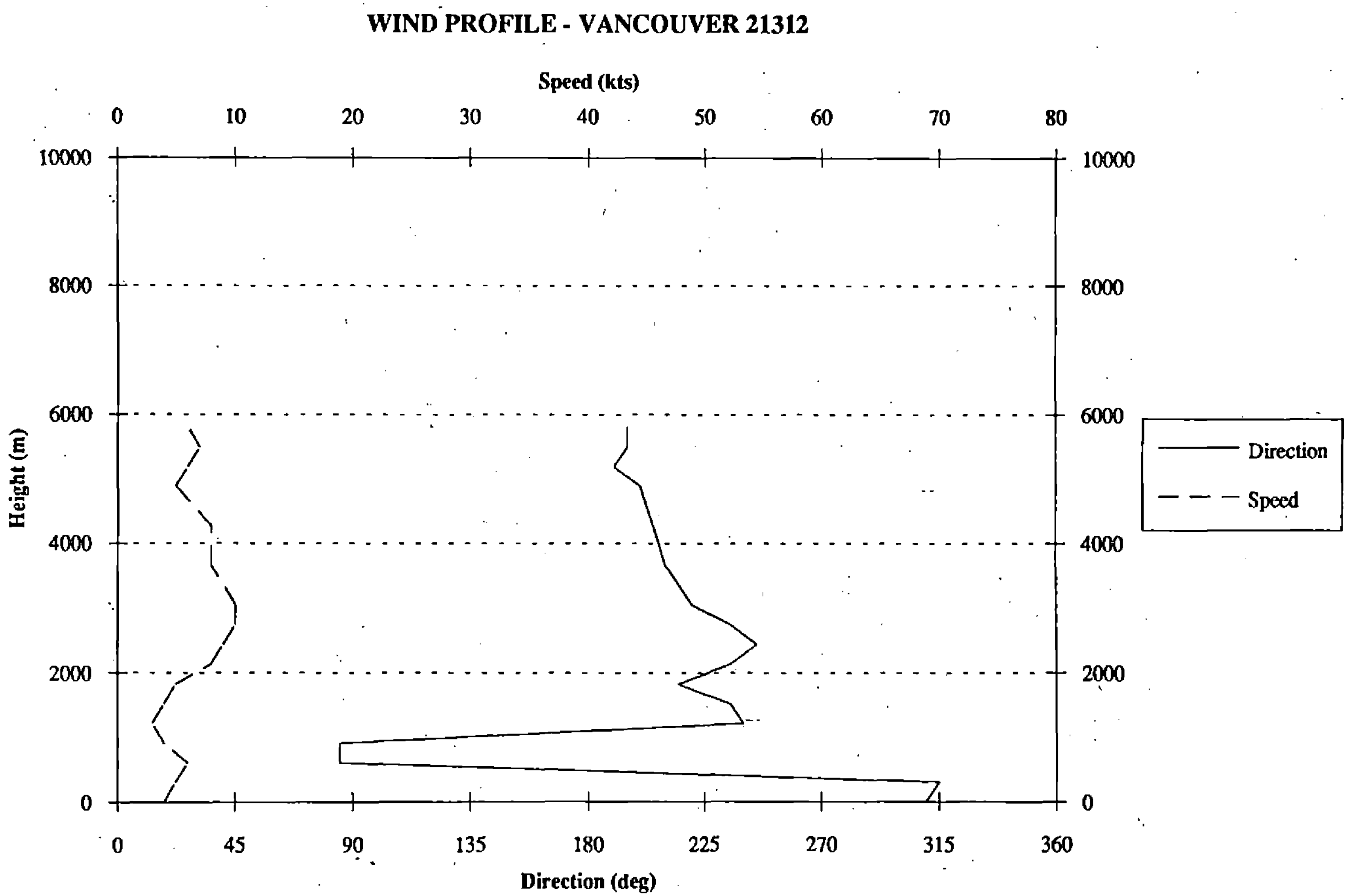
Upper Air Data



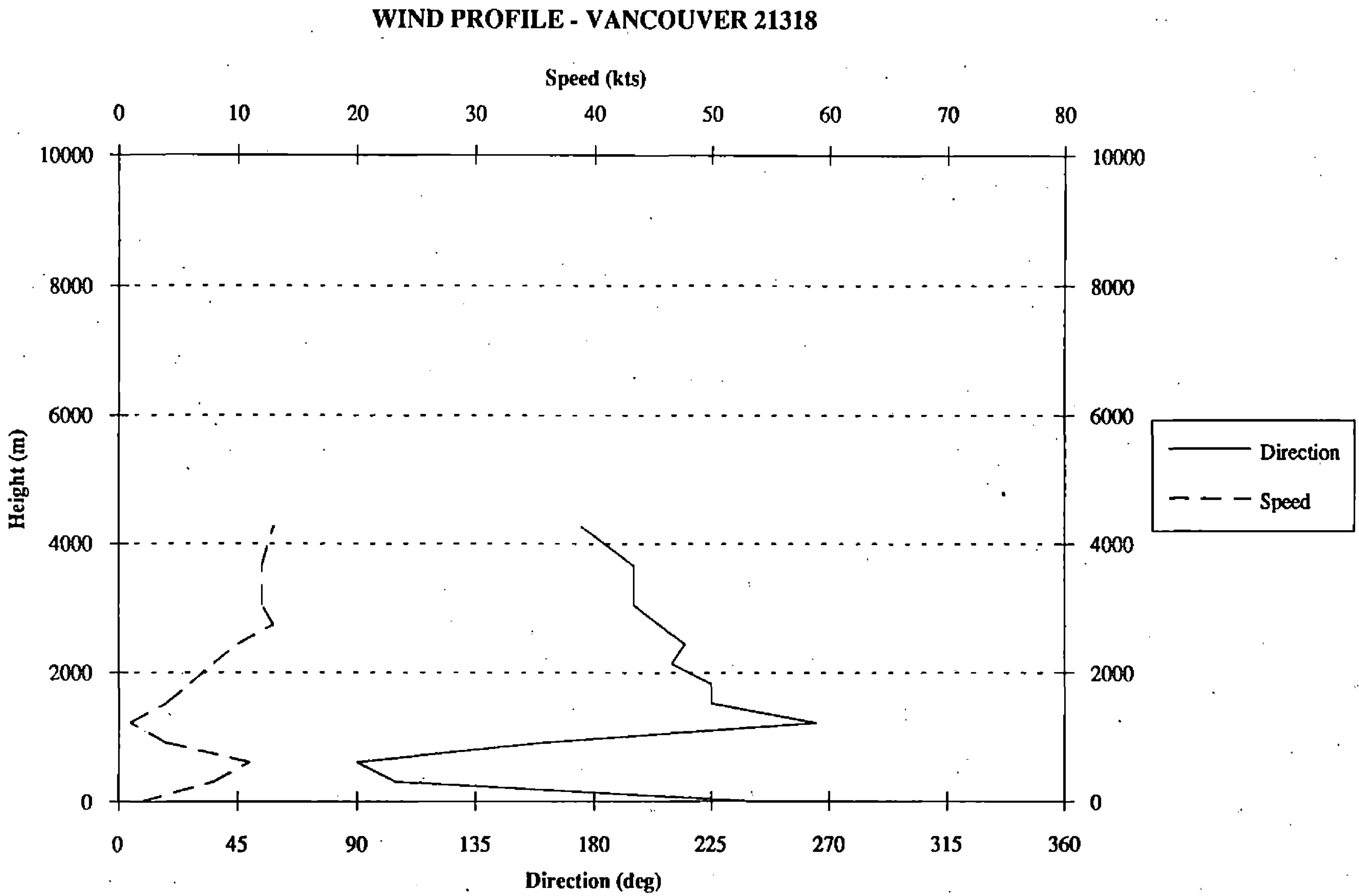
WIND PROFILE - FLIGHT 21318
Speed (kts)
0
10
20
30
40
50
60
70
80
10000
8000
6000
4000
2000
0
Height (m ASL)
0
45
90
135
180
225
270
315
360
Direction (deg)
Direction
Speed

WIND PROFILE - QUILLAYUTE FLIGHT 21312

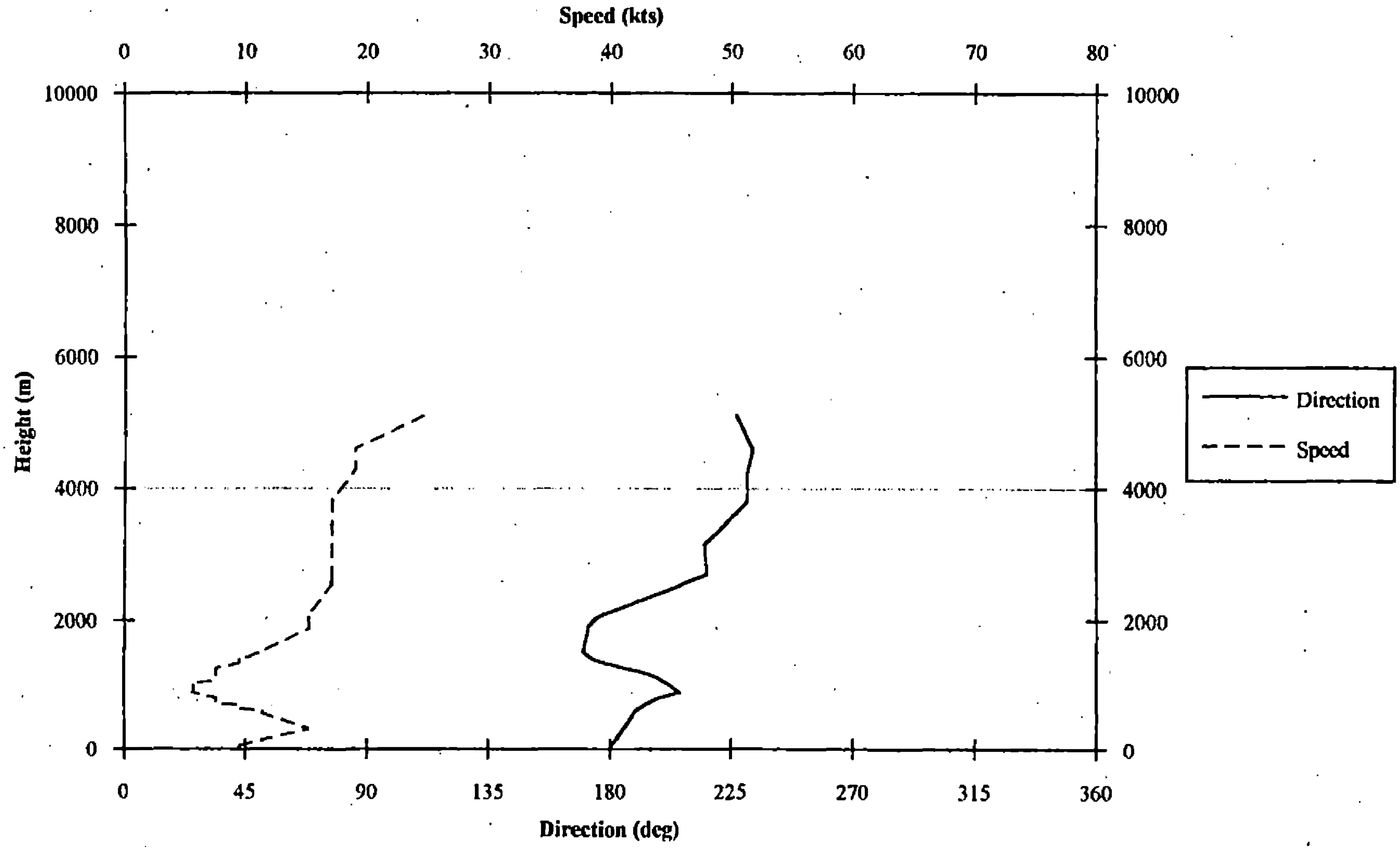




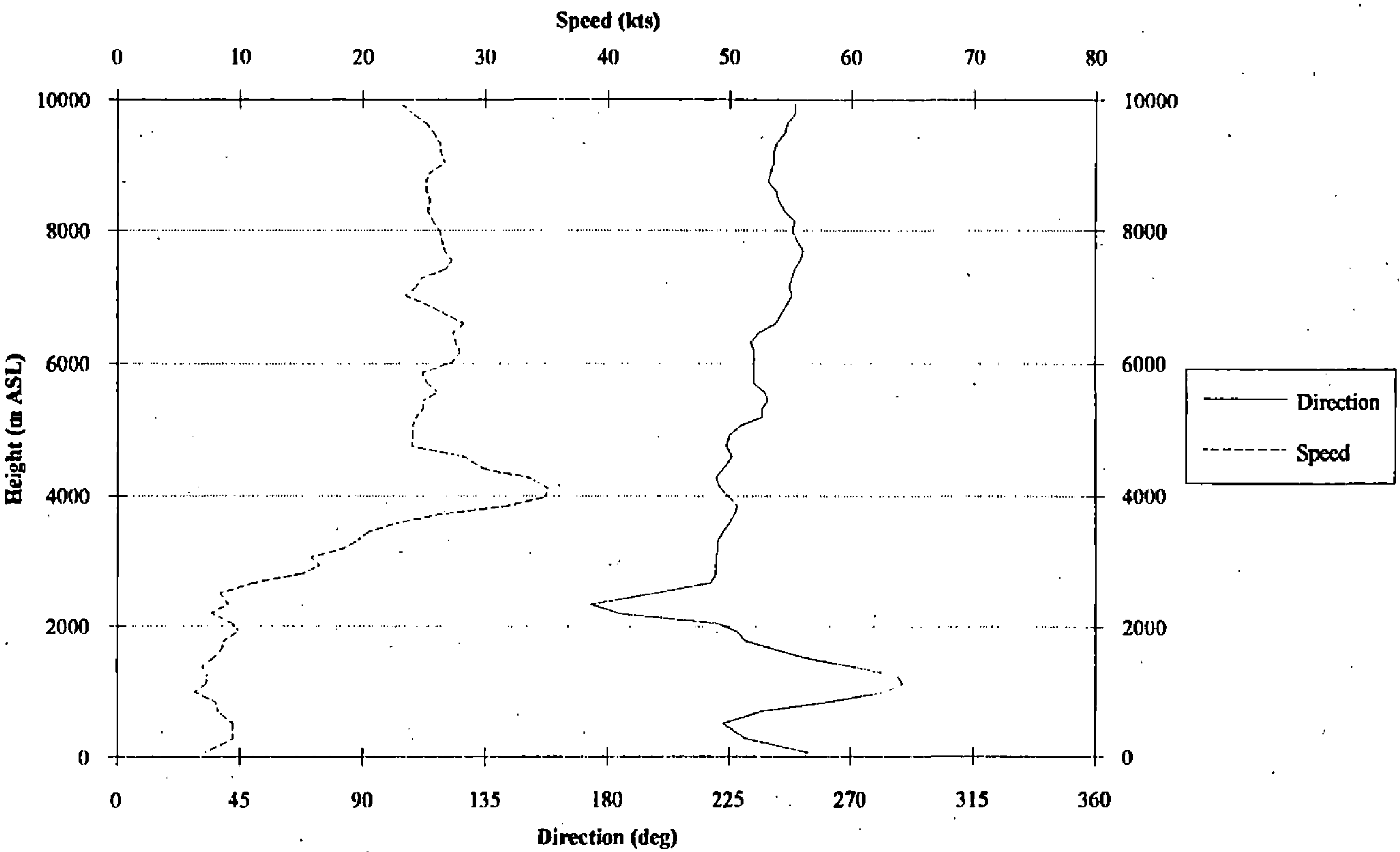
WIND PROFILE - VANCOUVER 21312
Speed (kts)
0
10
20
30
40
50
60
70
80
10000
8000
6000
4000
2000
0
Height (m)
Direction
Speed
0
45
90
135
180
225
270
315
360
Direction (deg)


WIND PROFILE - VANCOUVER 21318
Speed (kts)
0
10
20
30
40
50
60
70
80
10000
8000
6000
4000
2000
0
Height (m)
0
45
90
135
180
225
270
315
360
Direction (deg)
Direction
Speed

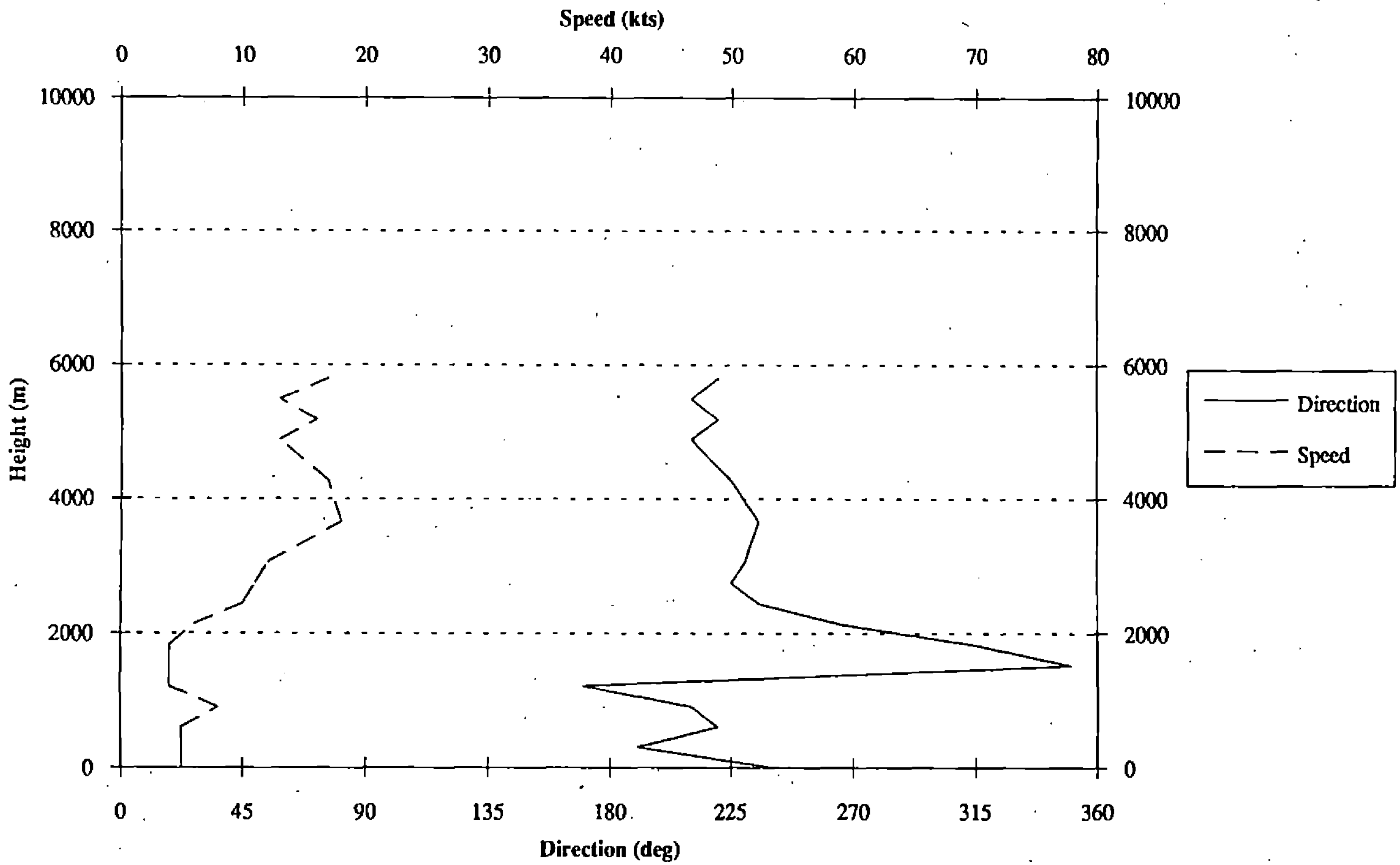
WIND PROFILE - QUILLAYUTE FLIGHT 21323



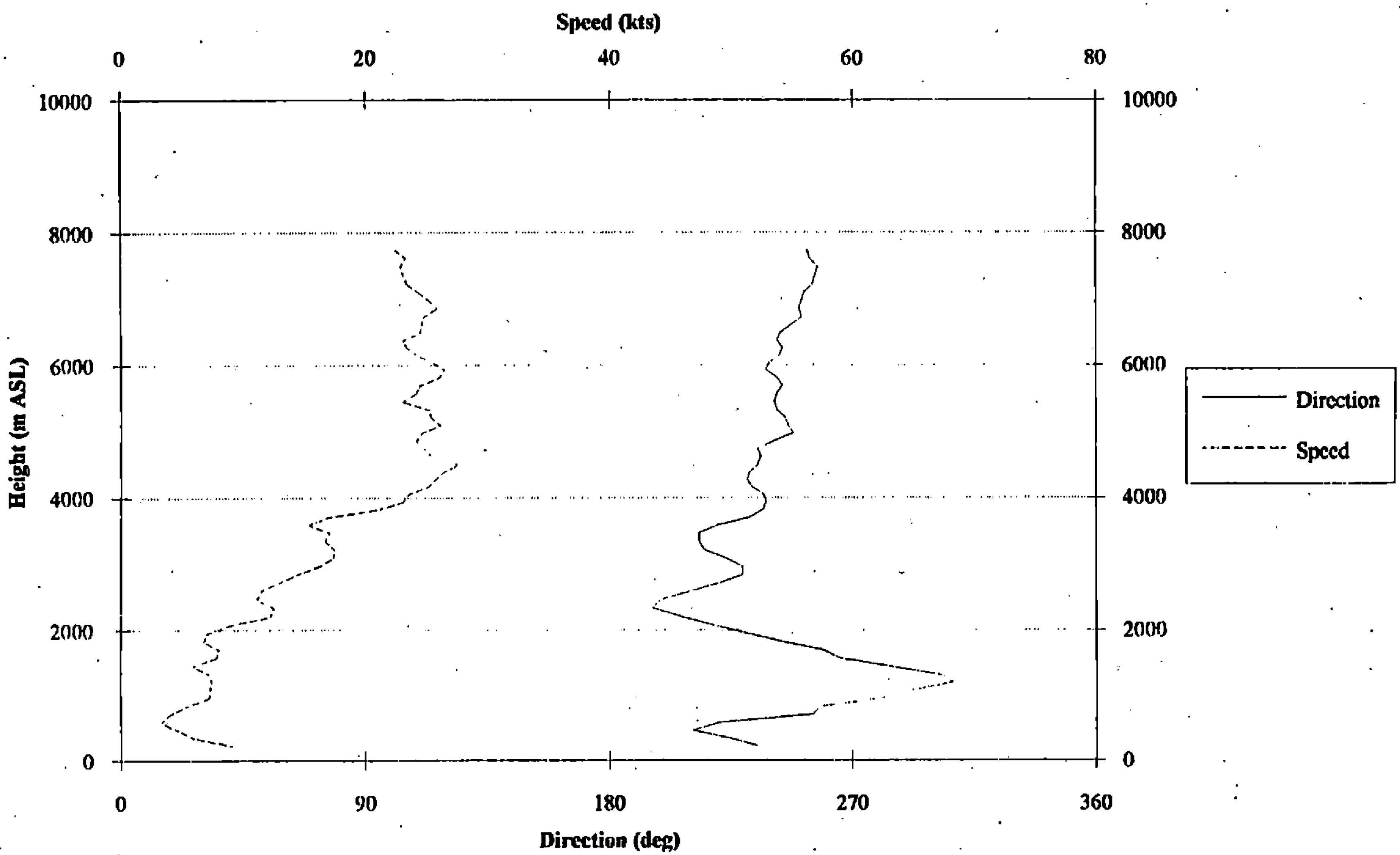
WIND PROFILE - FLIGHT 21400



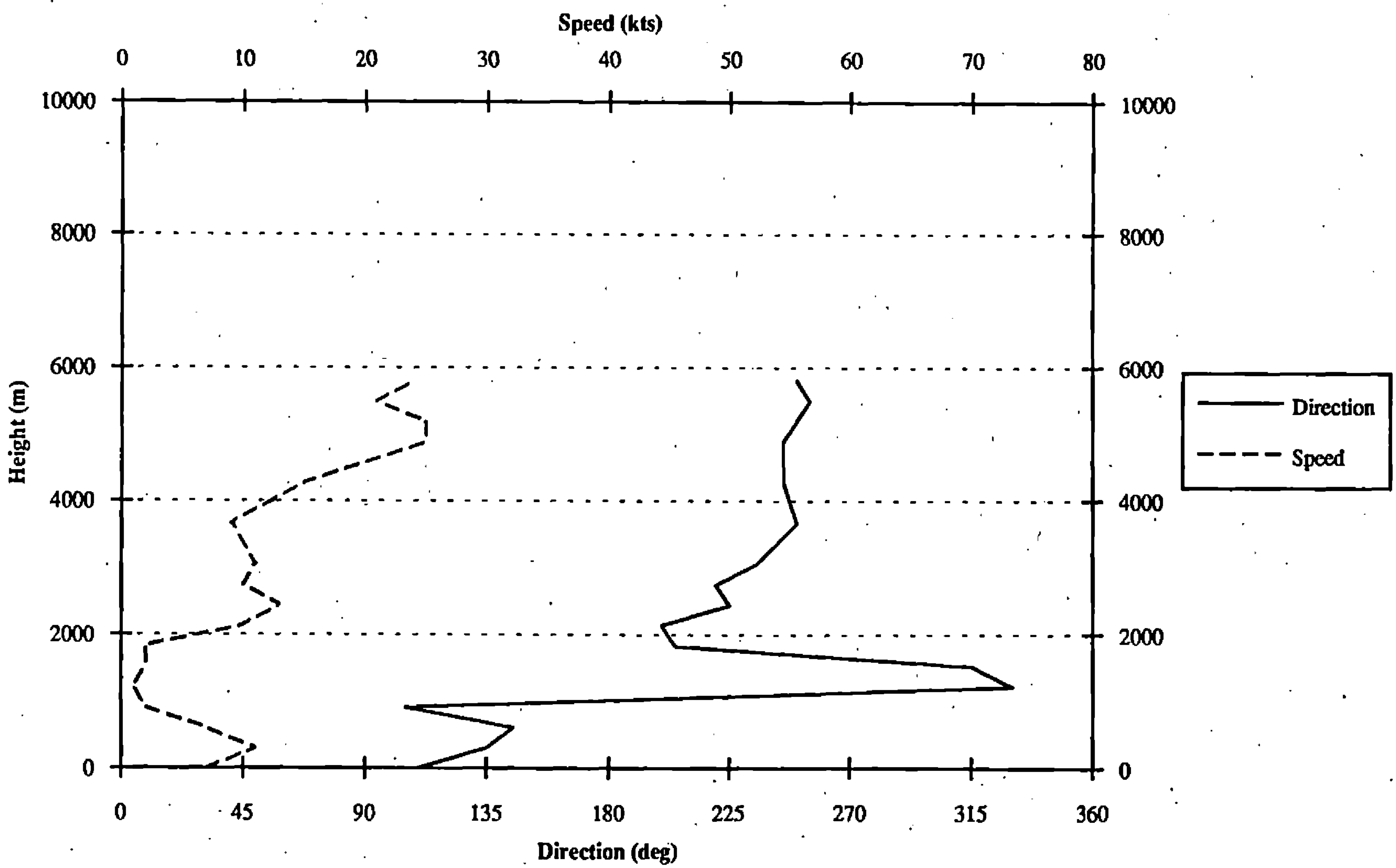
WIND PROFILE - VANCOUVER 21400



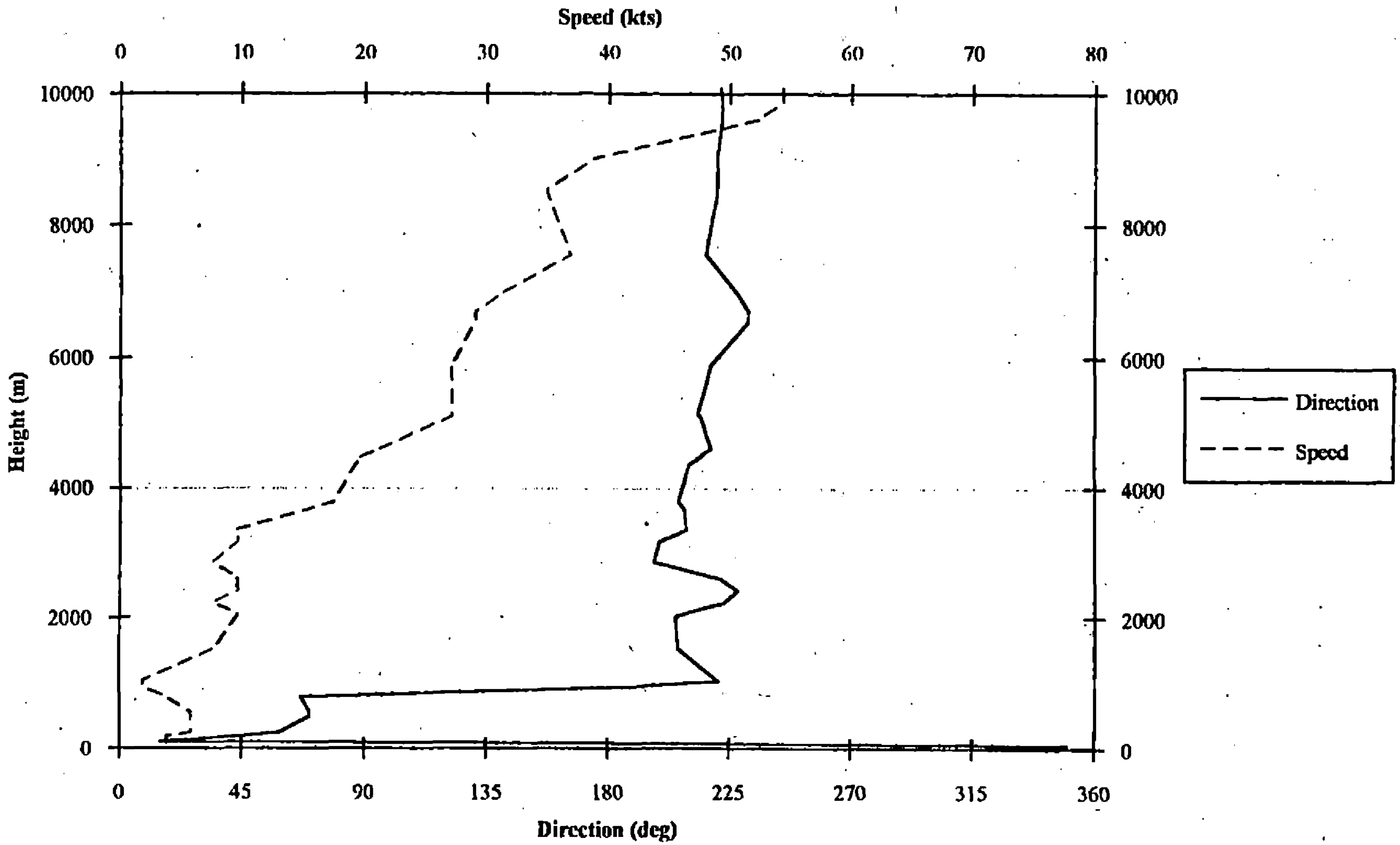
WIND PROFILE - FLIGHT 21403



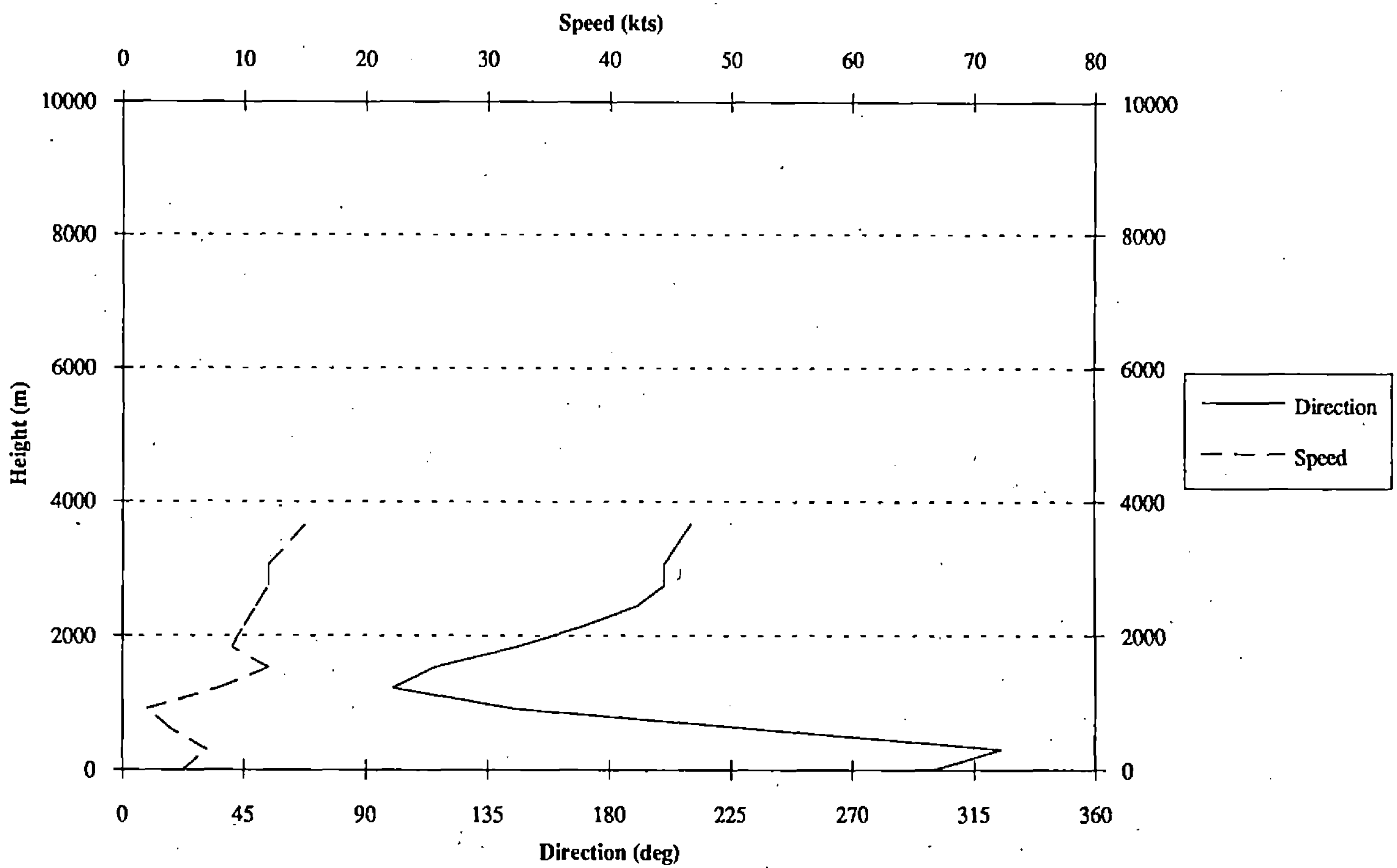
WIND PROFILE - VANCOUVER 21406



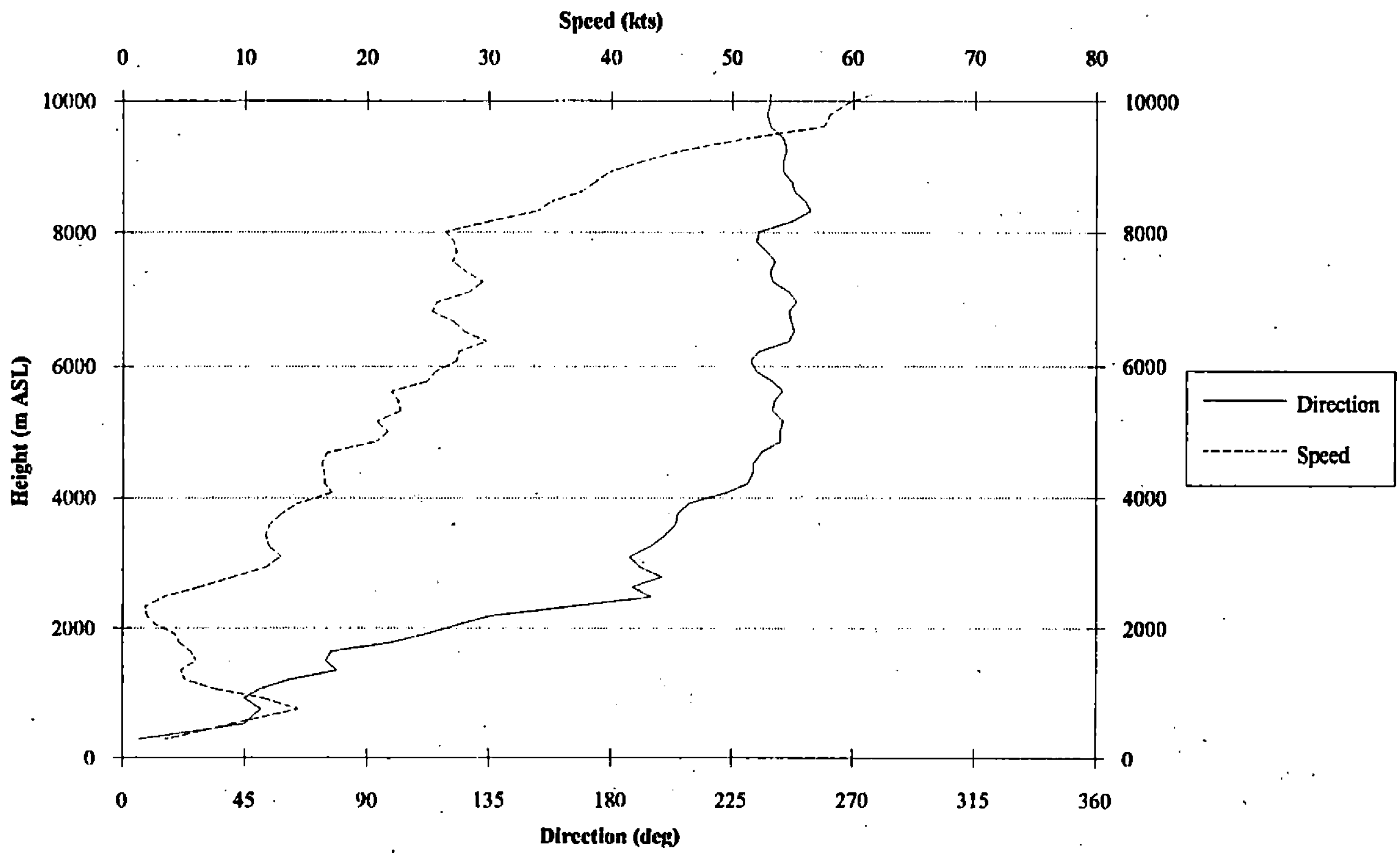
WIND PROFILE - QUILLAYUTE FLIGHT 22511

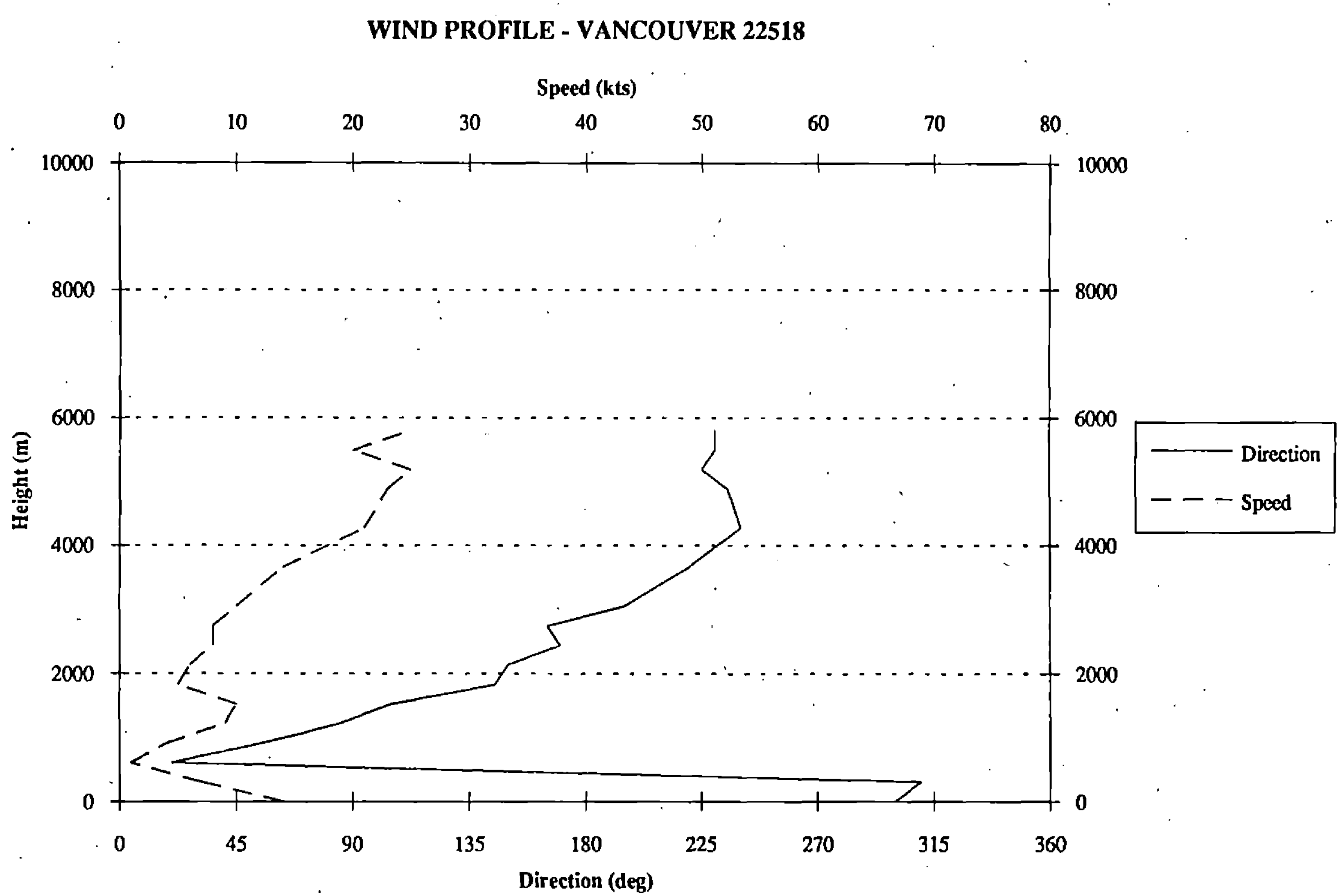


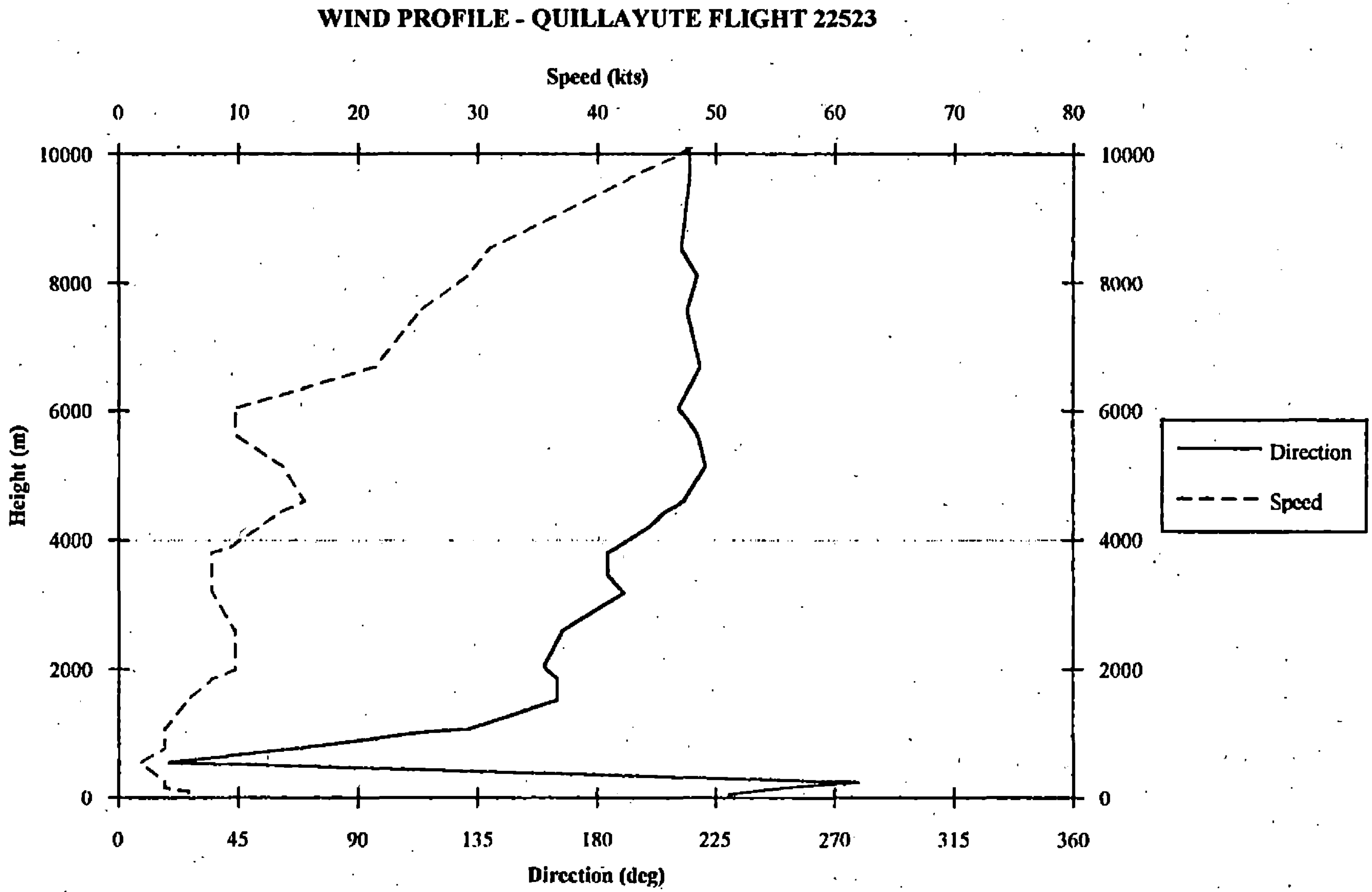
WIND PROFILE - VANCOUVER 22512



WIND PROFILE - FLIGHT 22518

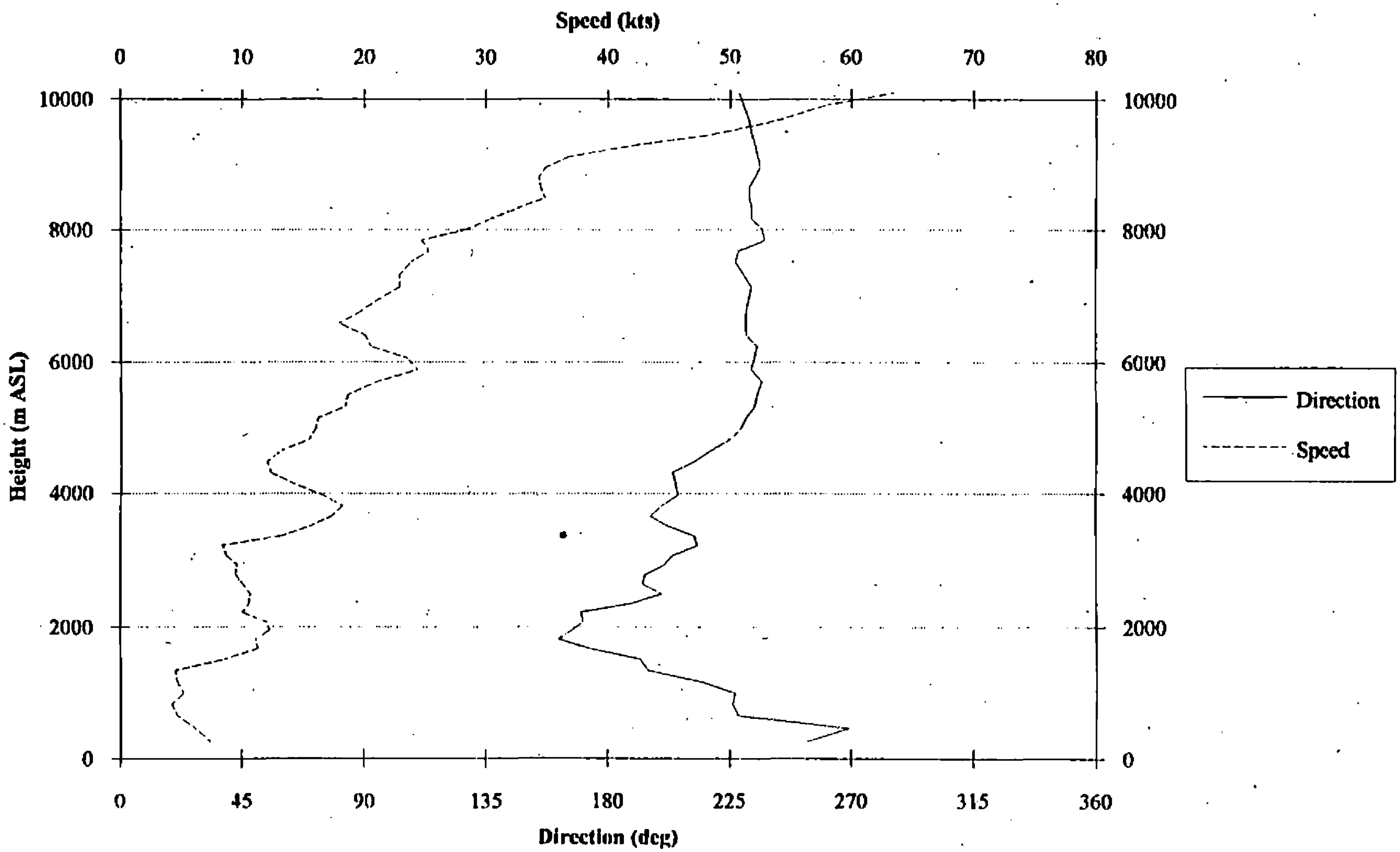



WIND PROFILE - VANCOUVER 22518
Speed (kts)
0
10
20
30
40
50
60
70
80
10000
8000
6000
4000
2000
0
Height (m)
Direction
Speed
0
45
90
135
180
225
270
315
360
Direction (deg)

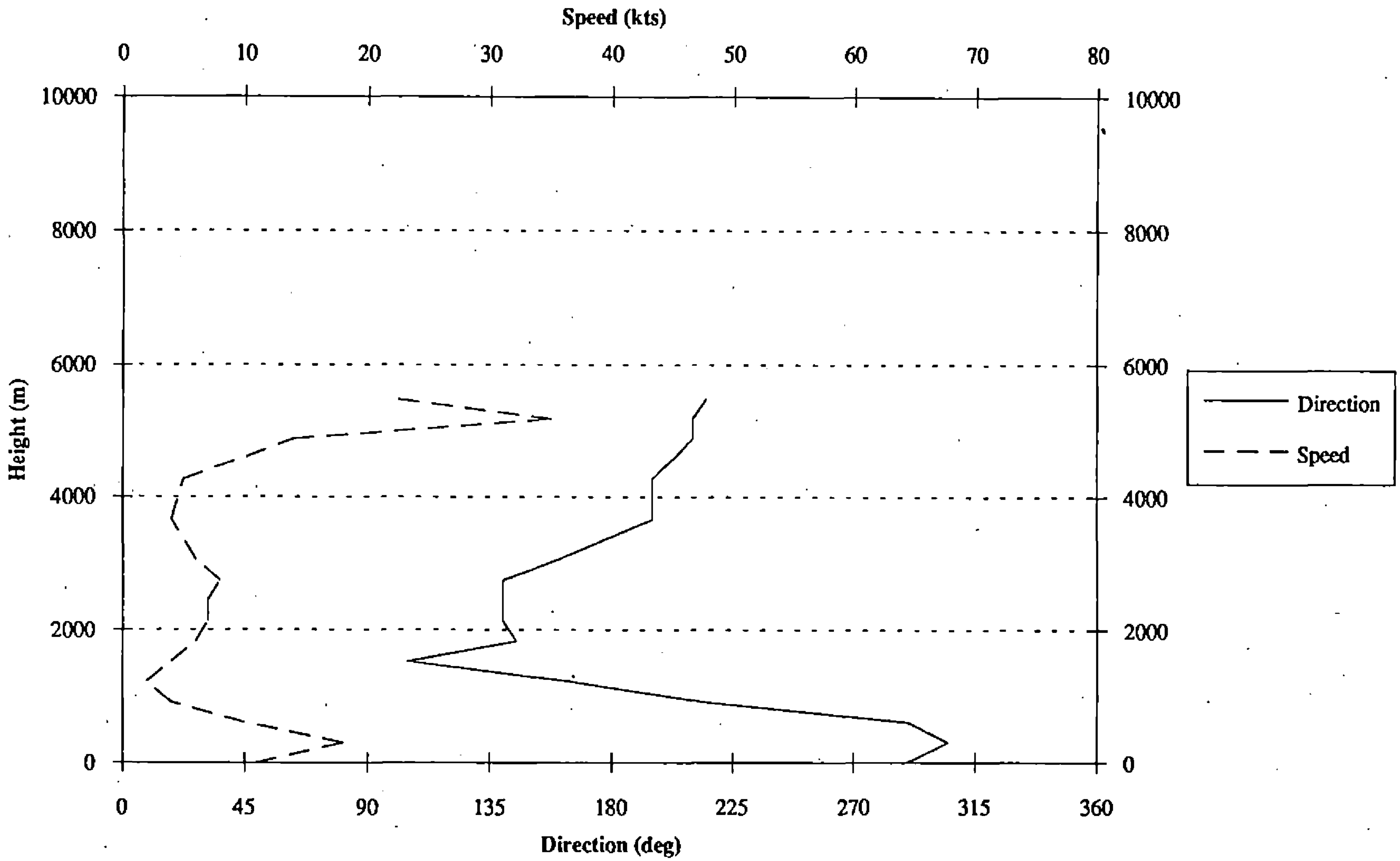


WIND PROFILE - QUILLAYUTE FLIGHT 22523
Speed (kts)
0
10
20
30
40
50
60
70
80
Height (m)
10000
8000
6000
4000
2000
0
Direction
Speed
0
45
90
135
180
225
270
315
360
Direction (deg)

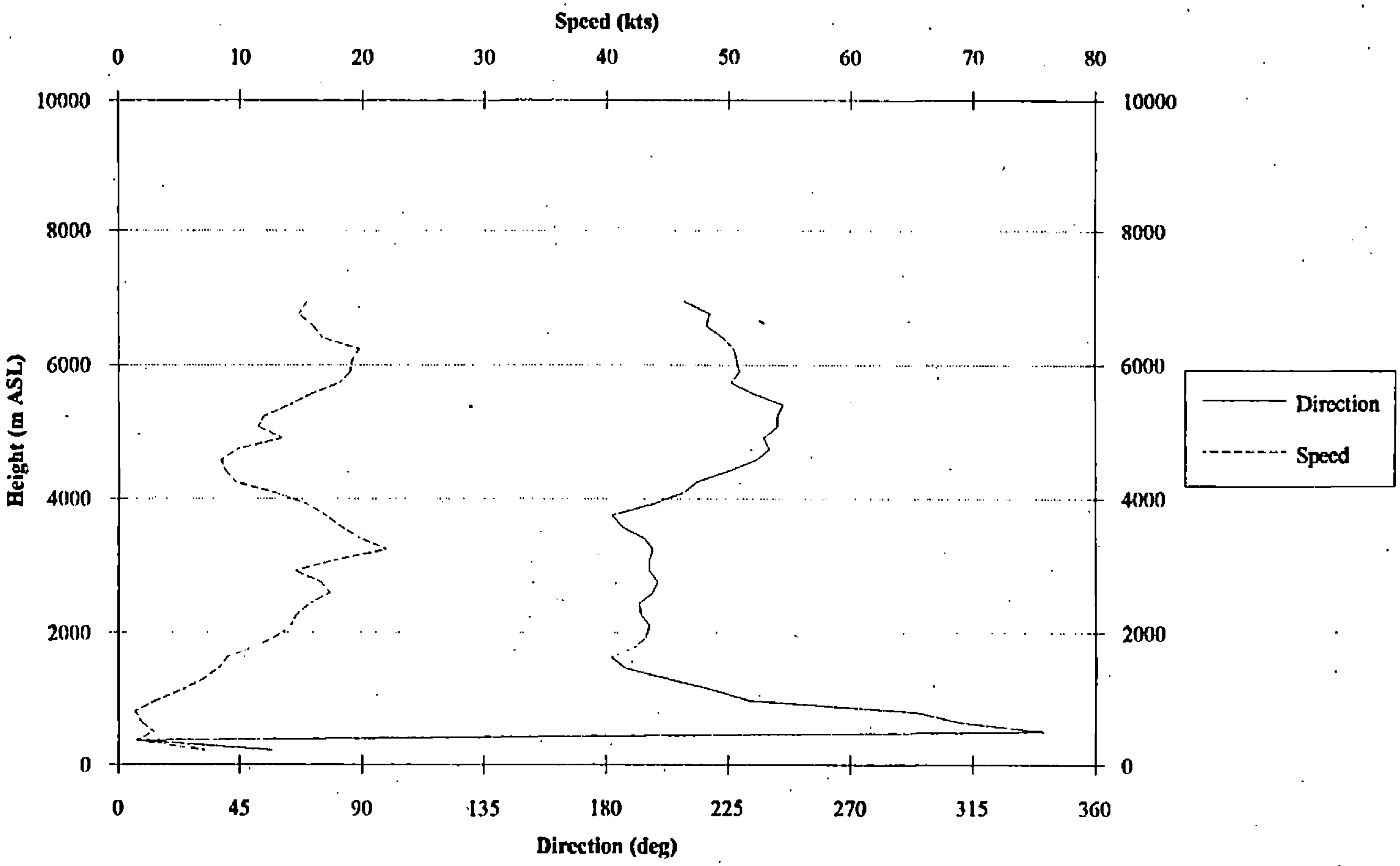
WIND PROFILE - FLIGHT 22600

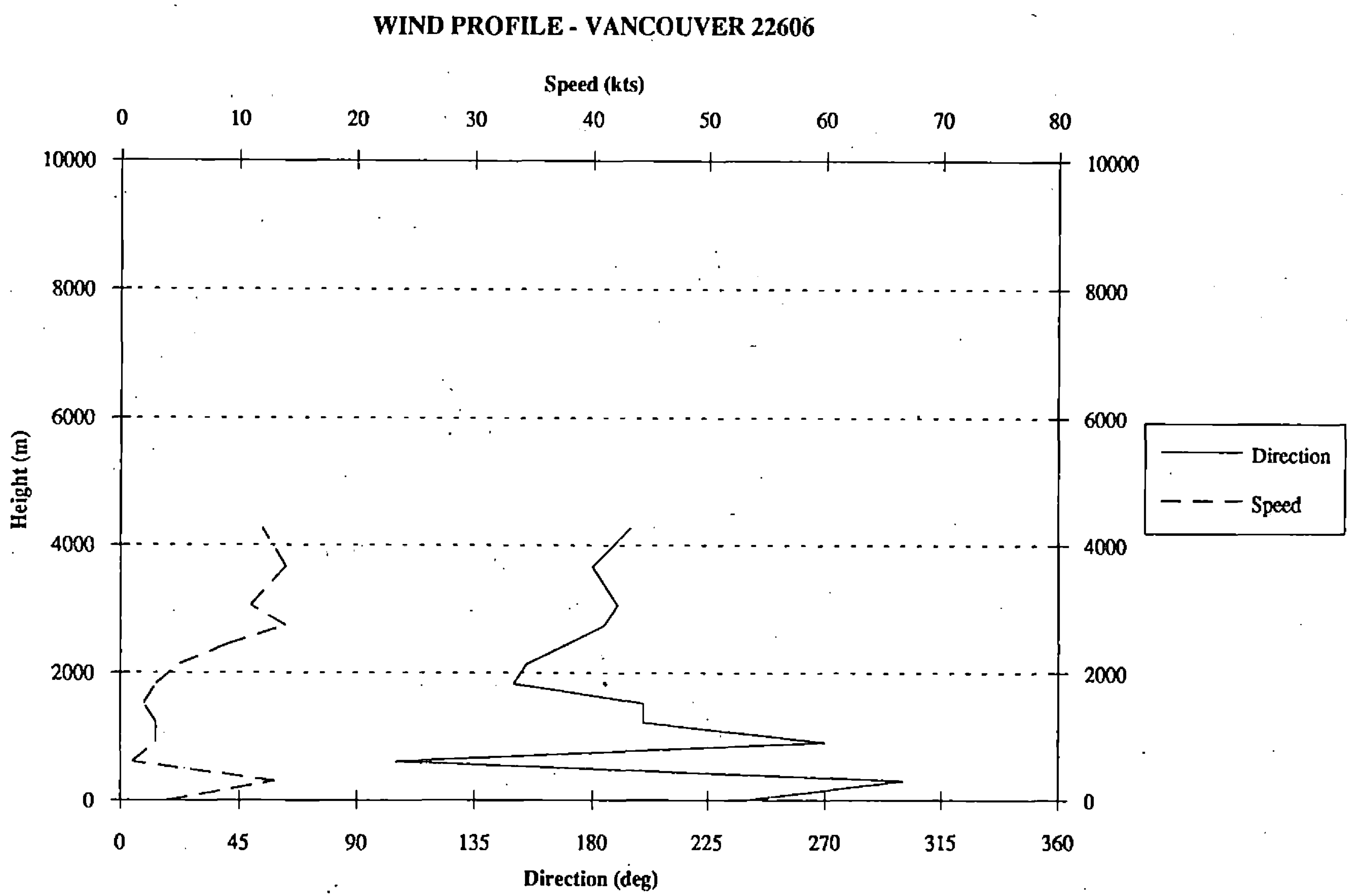


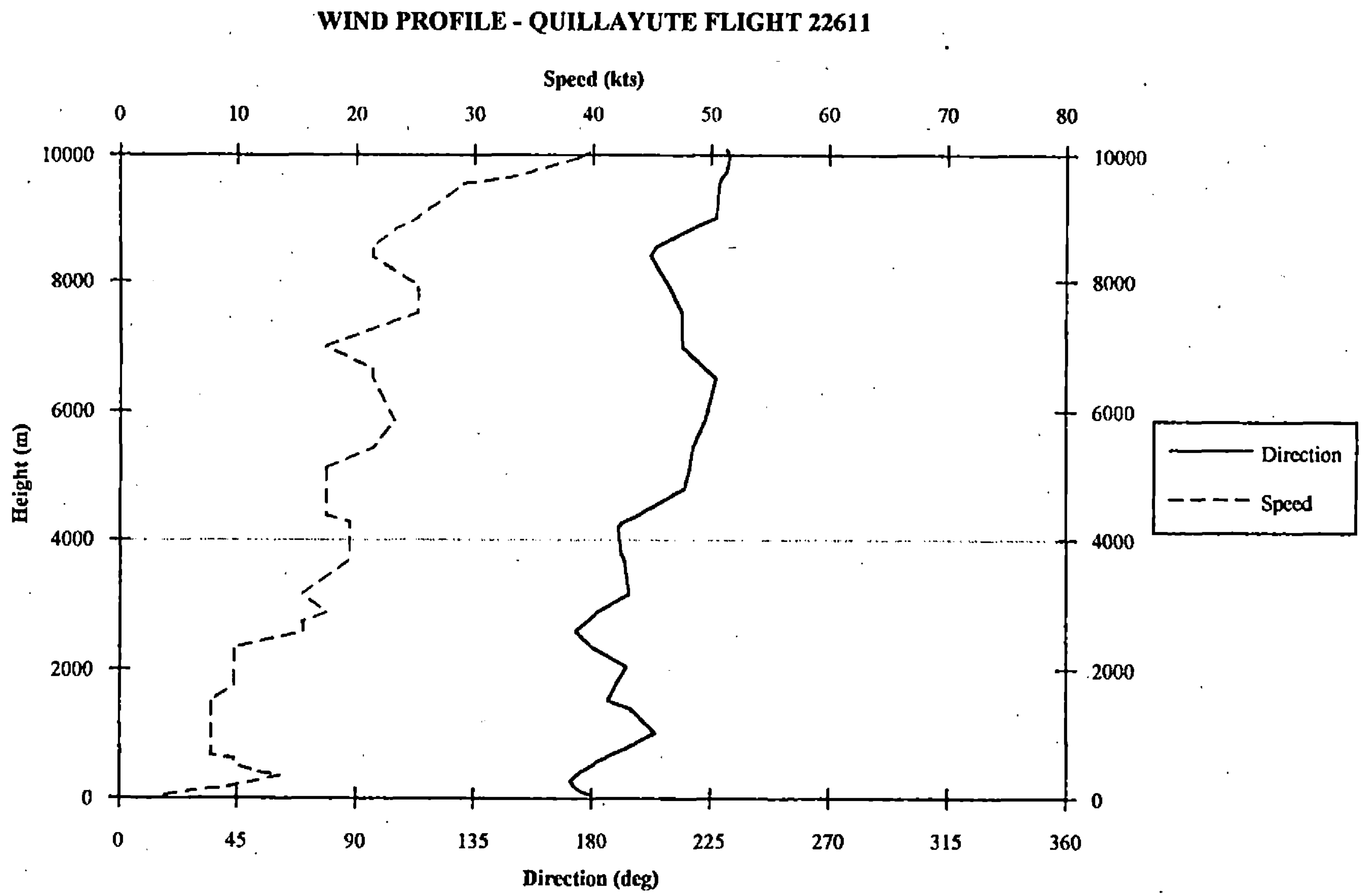
WIND PROFILE - VANCOUVER 22600



WIND PROFILE - FLIGHT 22603

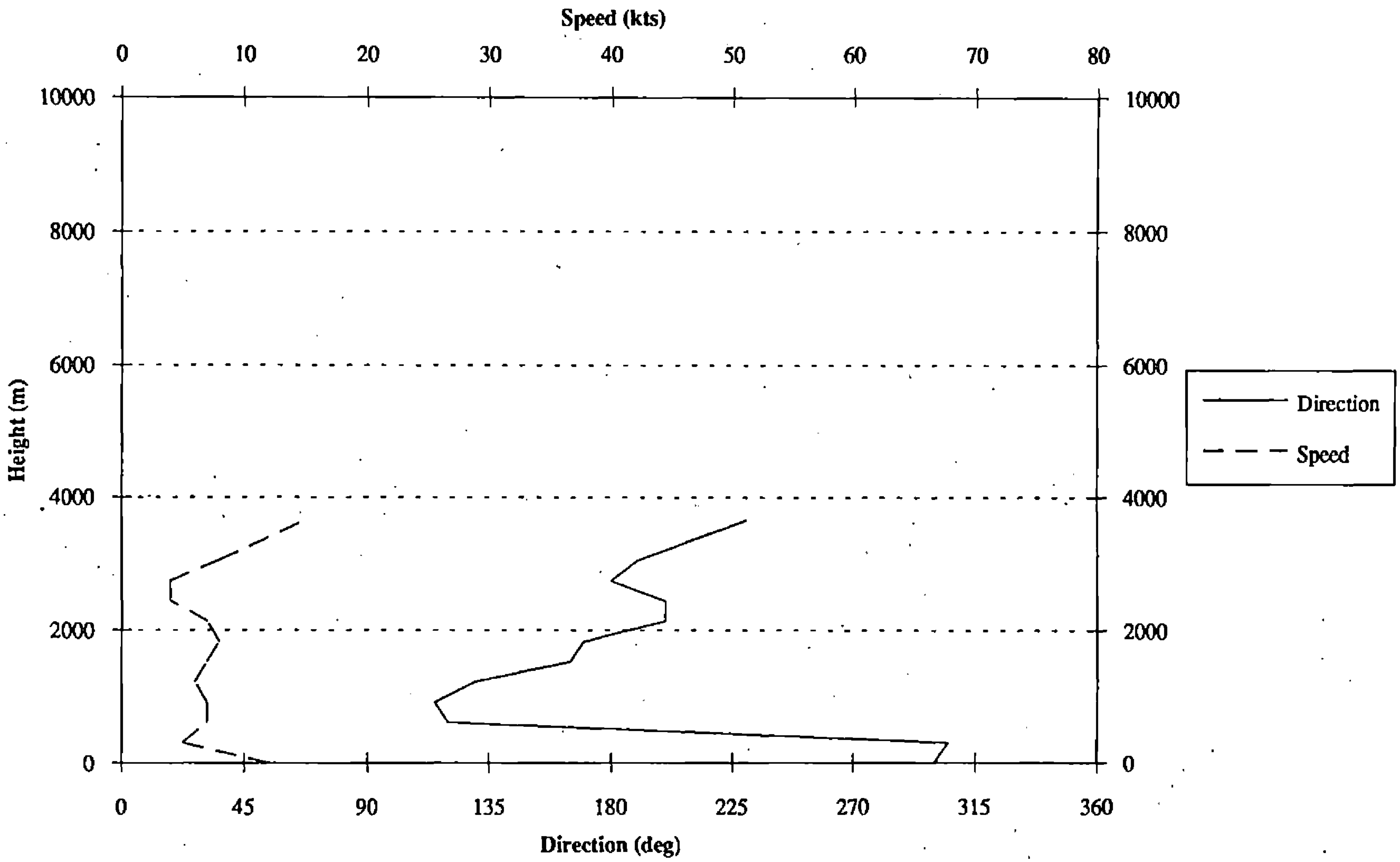


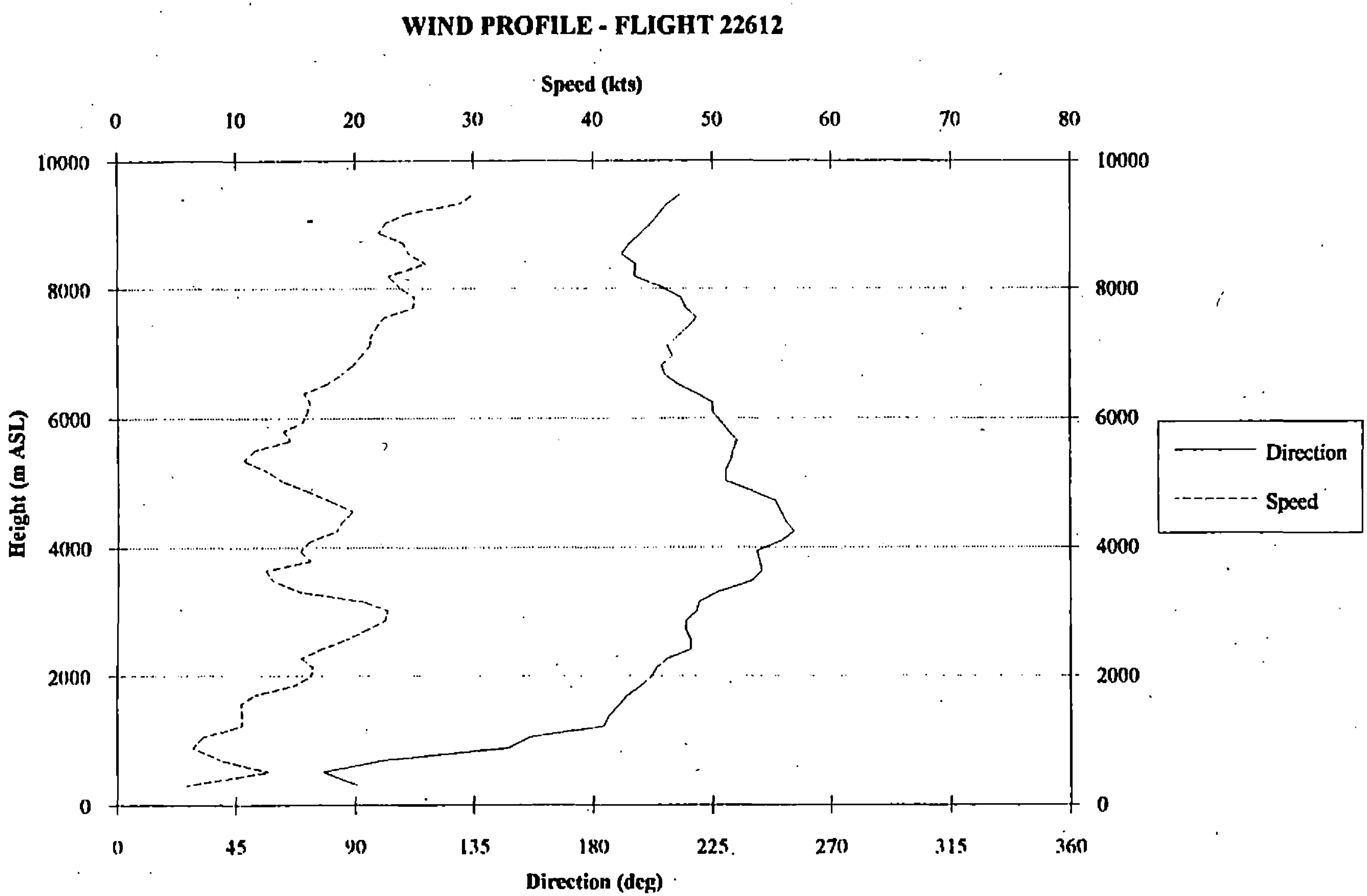

WIND PROFILE - VANCOUVER 22606
Speed (kts)
0
10
20
30
40
50
60
70
80
Height (m)
10000
8000
6000
4000
2000
0
0
45
90
135
180
225
270
315
360
Direction (deg)
Direction
Speed



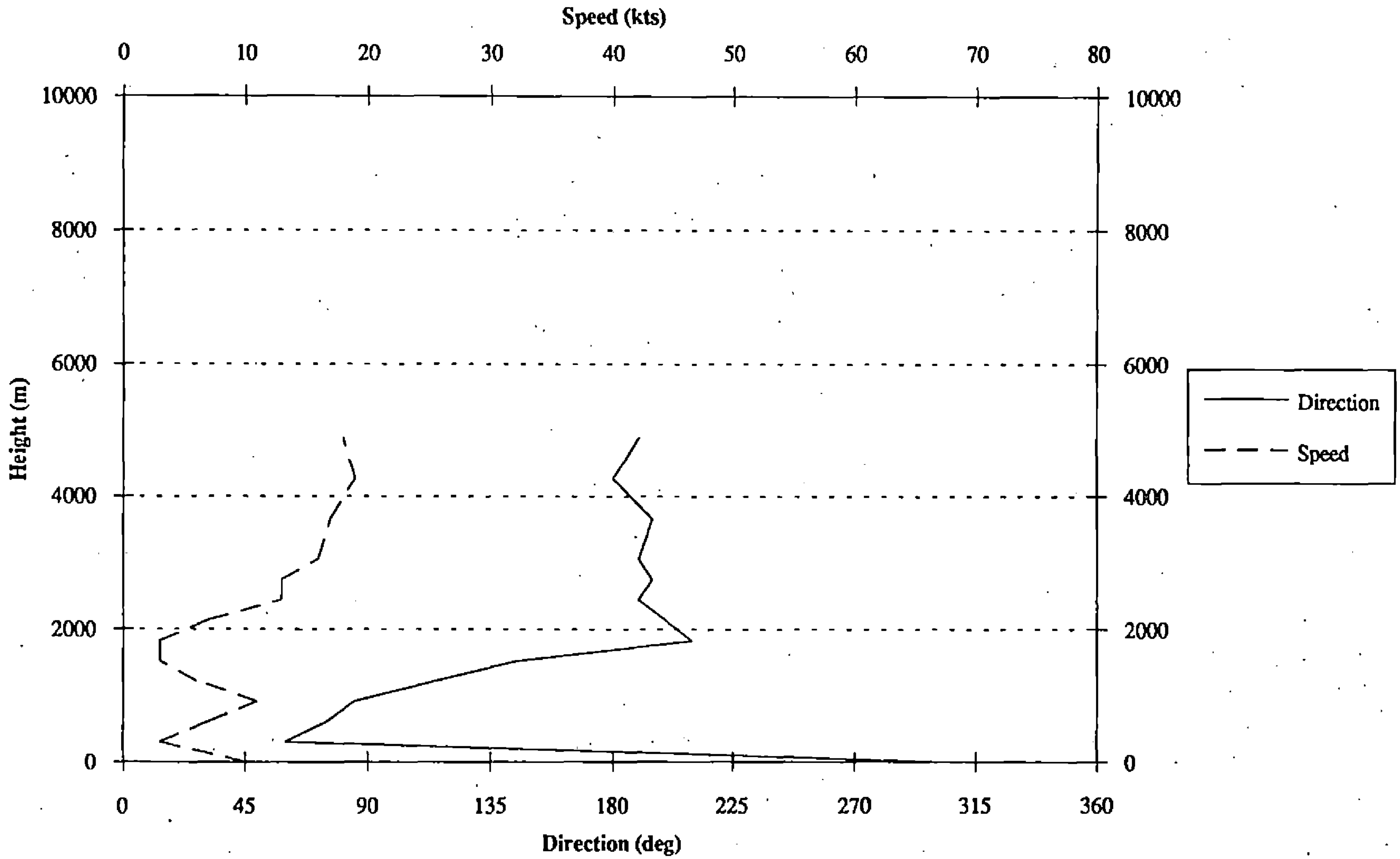
WIND PROFILE - QUILLAYUTE FLIGHT 22611
Speed (kts)
0
10
20
30
40
50
60
70
80
10000
8000
6000
4000
2000
0
Height (m)
Direction
Speed
0
45
90
135
180
225
270
315
360
Direction (deg)

WIND PROFILE - VANCOUVER 22612

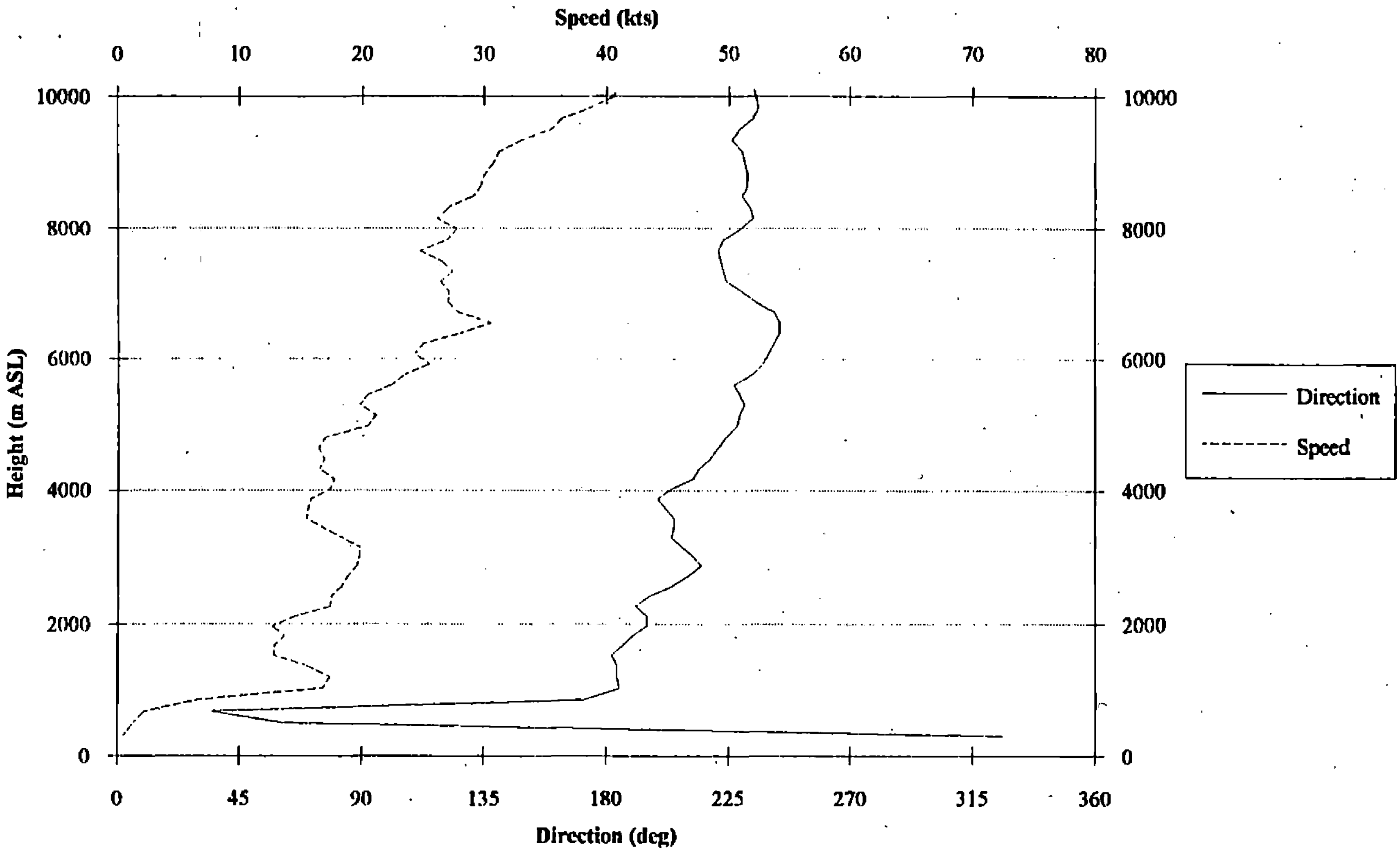


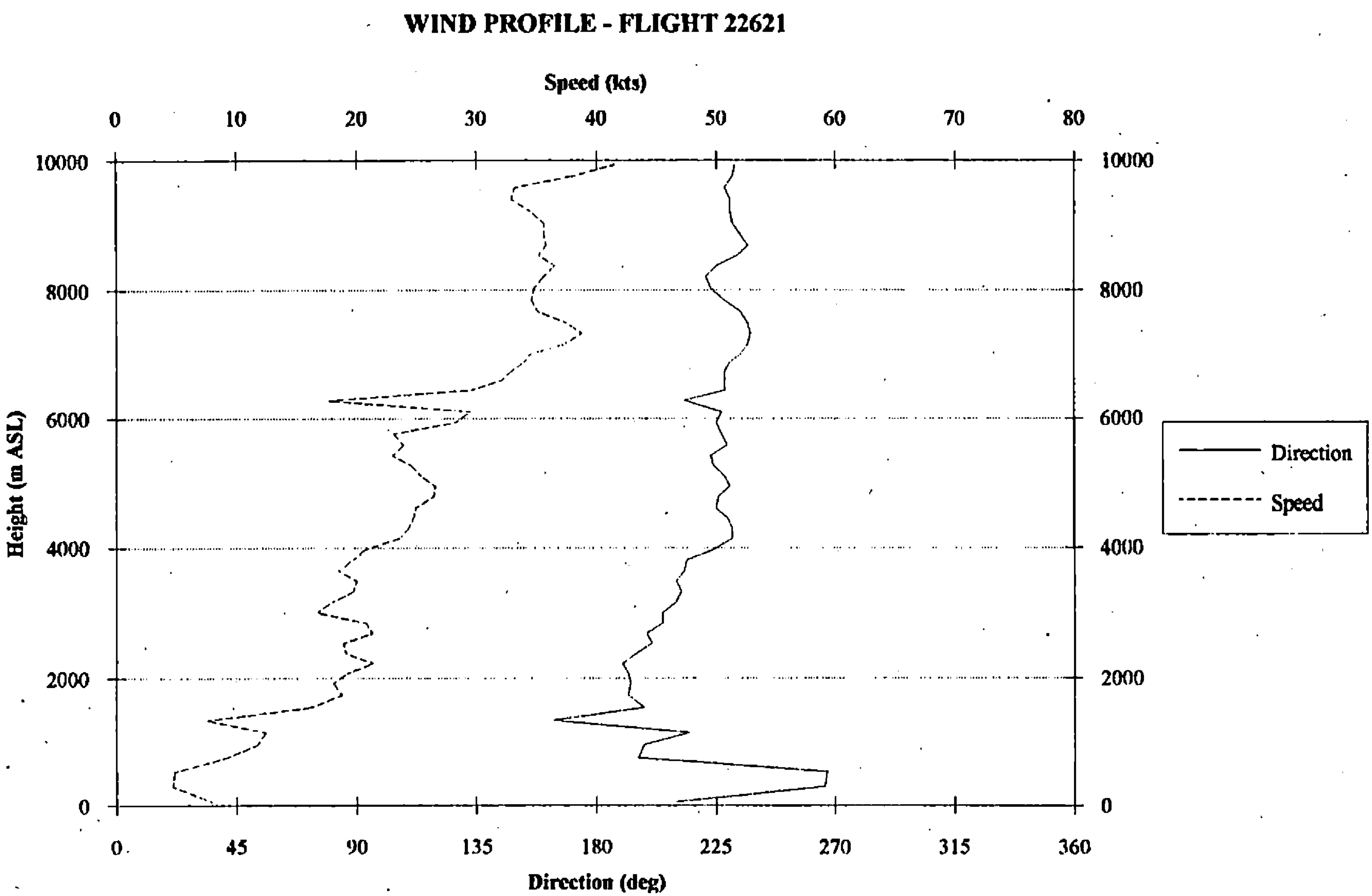

WIND PROFILE - FLIGHT 22612
Speed (kts)
0
10
20
30
40
50
60
70
80
10000
8000
6000
4000
2000
0
Height (m ASL)
Direction
Speed
0
45
90
135
180
225
270
315
360
Direction (deg)

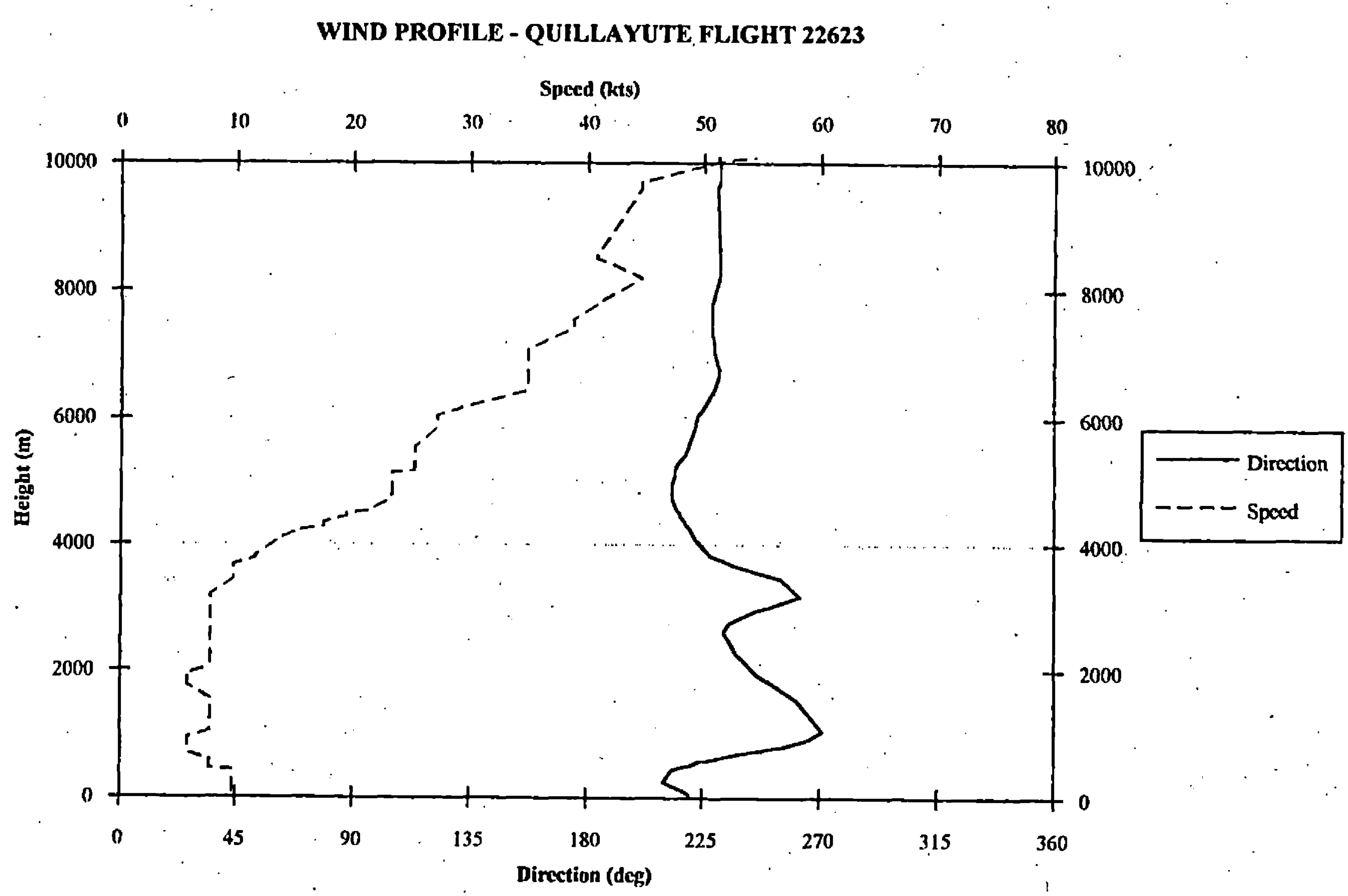
WIND PROFILE - VANCOUVER 22618

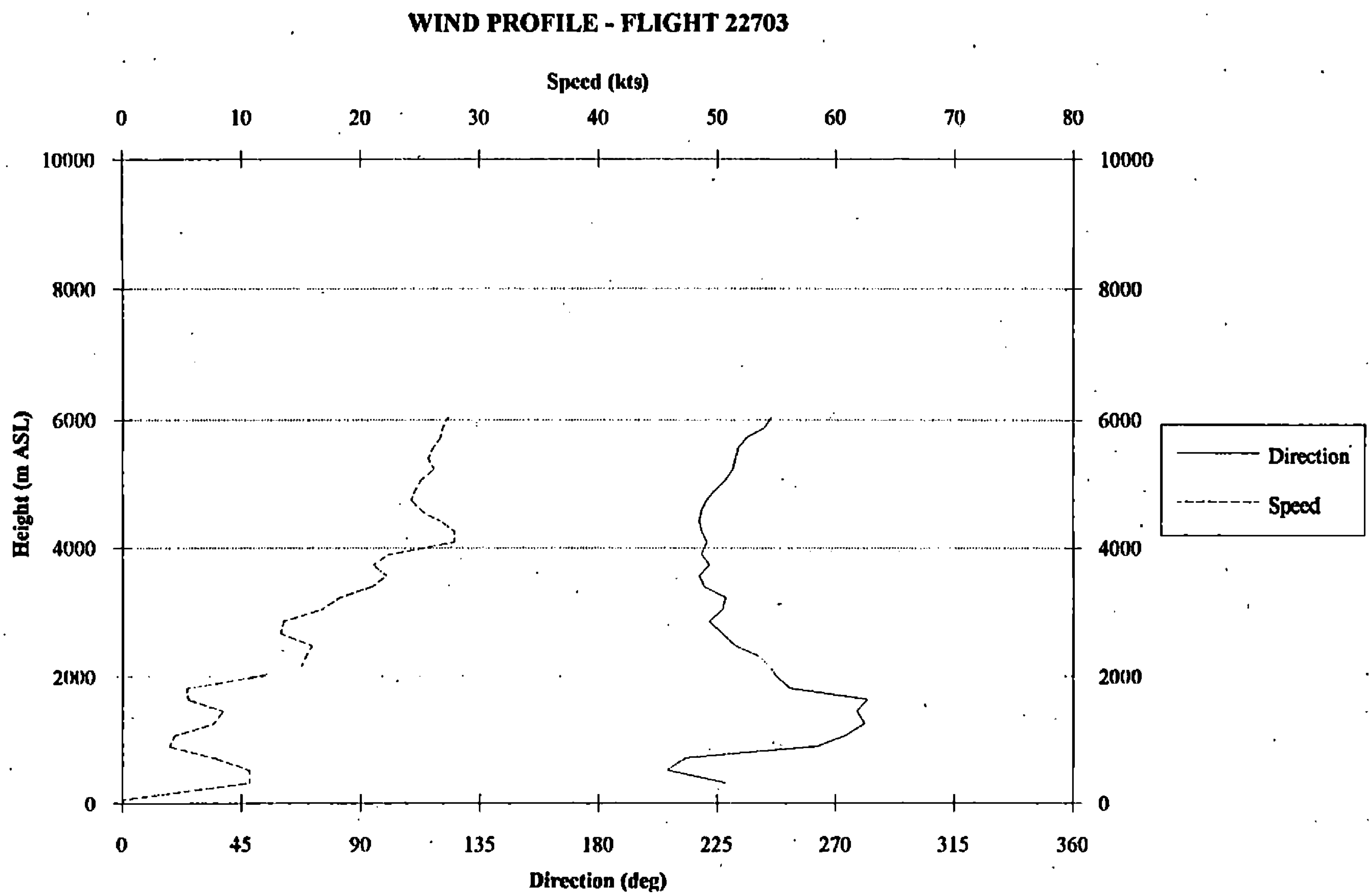


WIND PROFILE - FLIGHT 22618

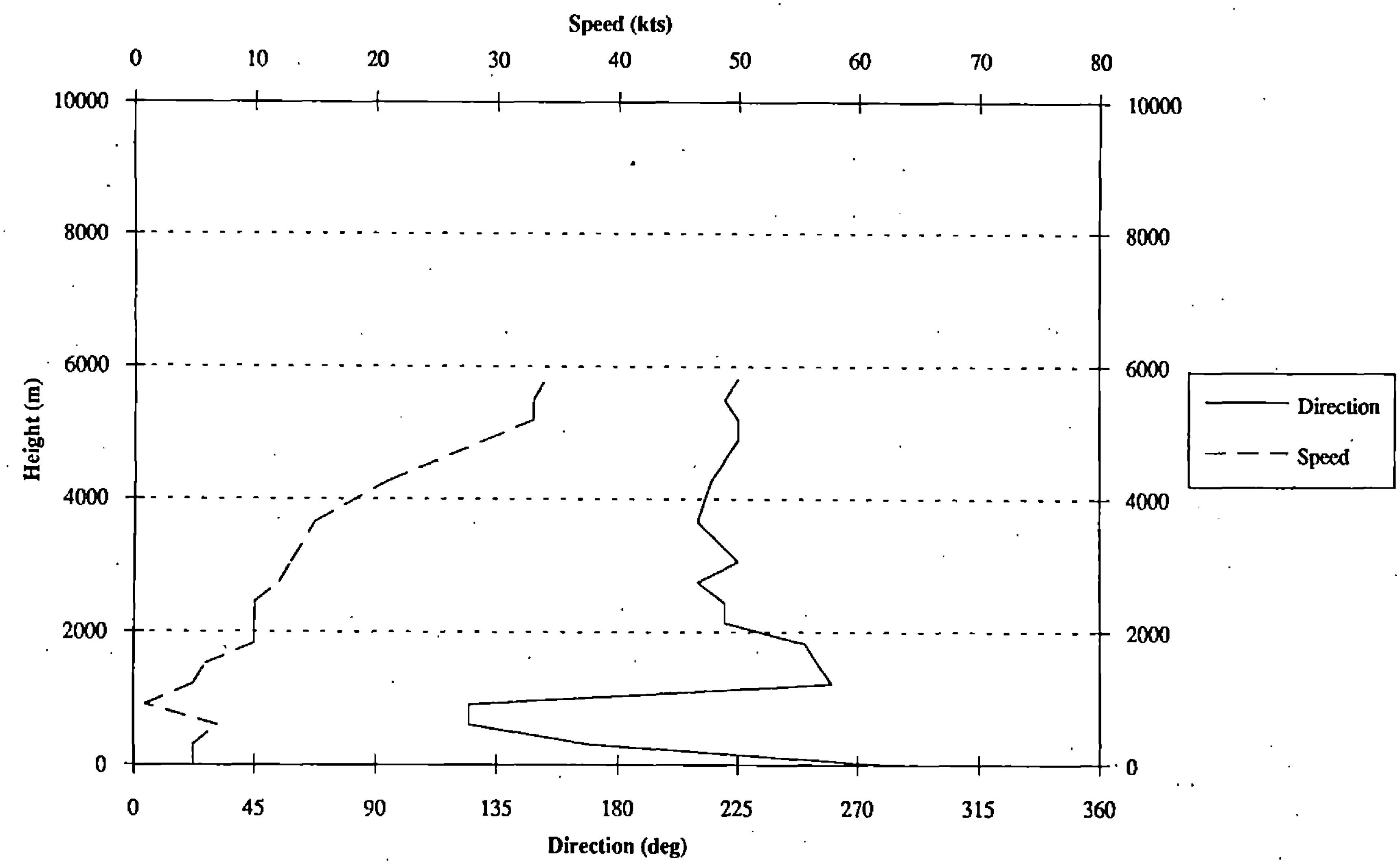


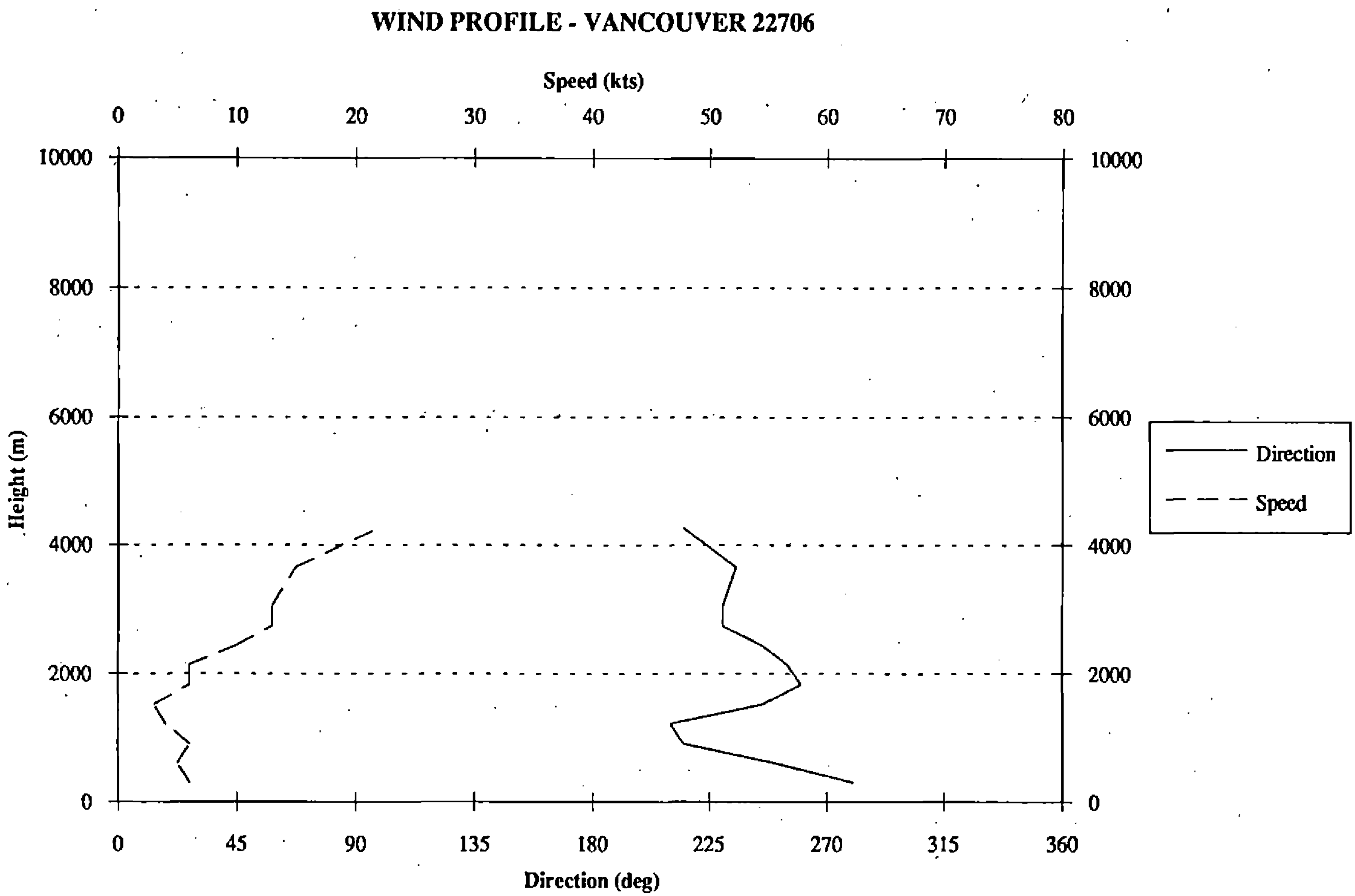

WIND PROFILE - FLIGHT 22621
Speed (kts)
0 10 20 30 40 50 60 70 80
Height (m ASL)
10000 8000 6000 4000 2000 0
Direction
Speed
0 45 90 135 180 225 270 315 360
Direction (deg)


WIND PROFILE - QUILLAYUTE FLIGHT 22623
Speed (kts)
0
10
20
30
40
50
60
70
80
10000
8000
6000
4000
2000
0
Height (m)
0
45
90
135
180
225
270
315
360
Direction (deg)
Direction
Speed


WIND PROFILE - FLIGHT 22703
Speed (kts)
0
10
20
30
40
50
60
70
80
Height (m ASL)
10000
8000
6000
4000
2000
0
Direction
Speed
0
45
90
135
180
225
270
315
360
Direction (deg)

WIND PROFILE - VANCOUVER 22700

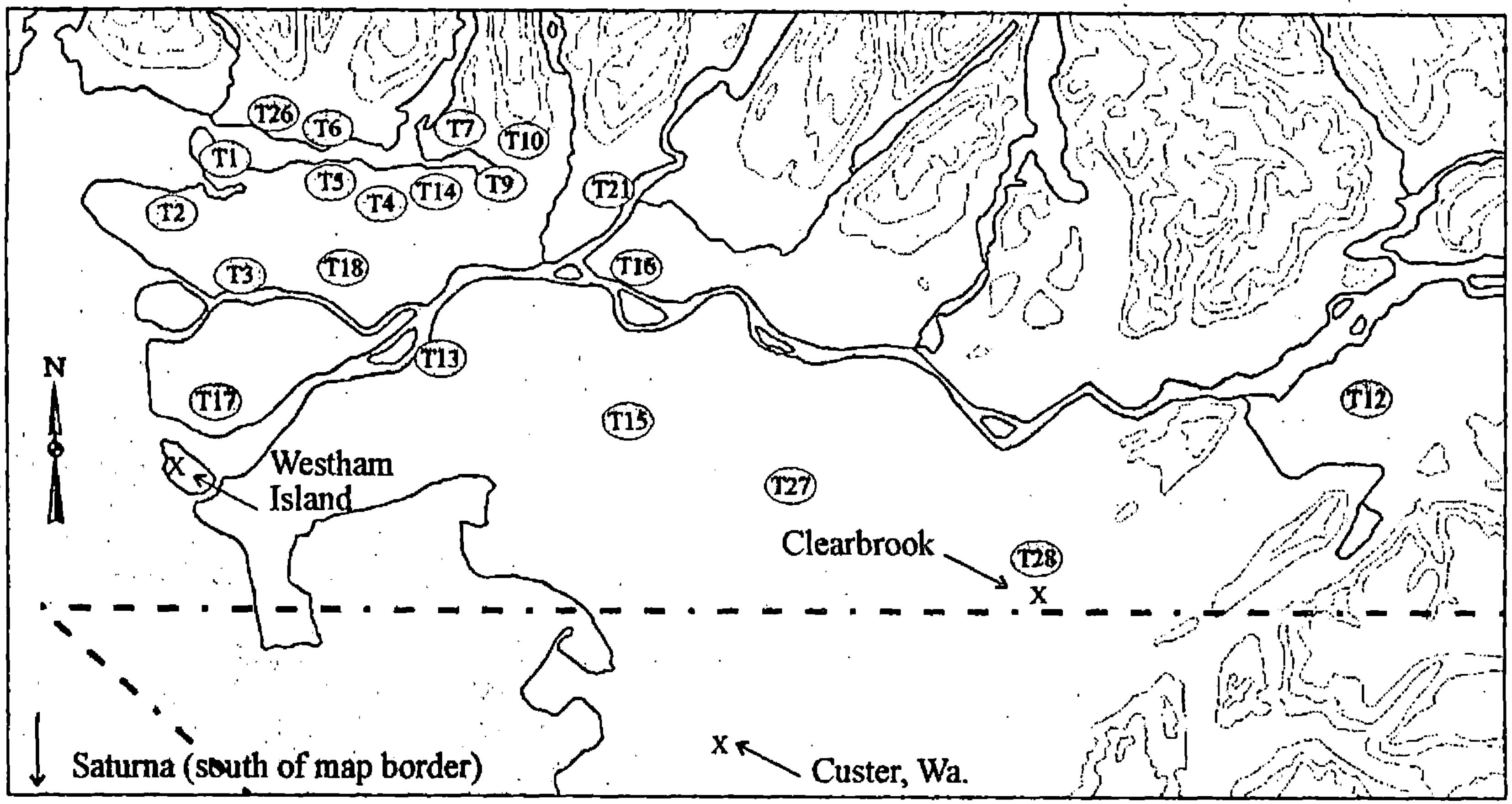




WIND PROFILE - VANCOUVER 22706
Speed (kts)
0
10
20
30
40
50
60
70
80
10000
8000
6000
4000
2000
0
Height (m)
0
45
90
135
180
225
270
315
360
Direction (deg)
Direction
Speed

APPENDIX D

Ozone Concentration Contours

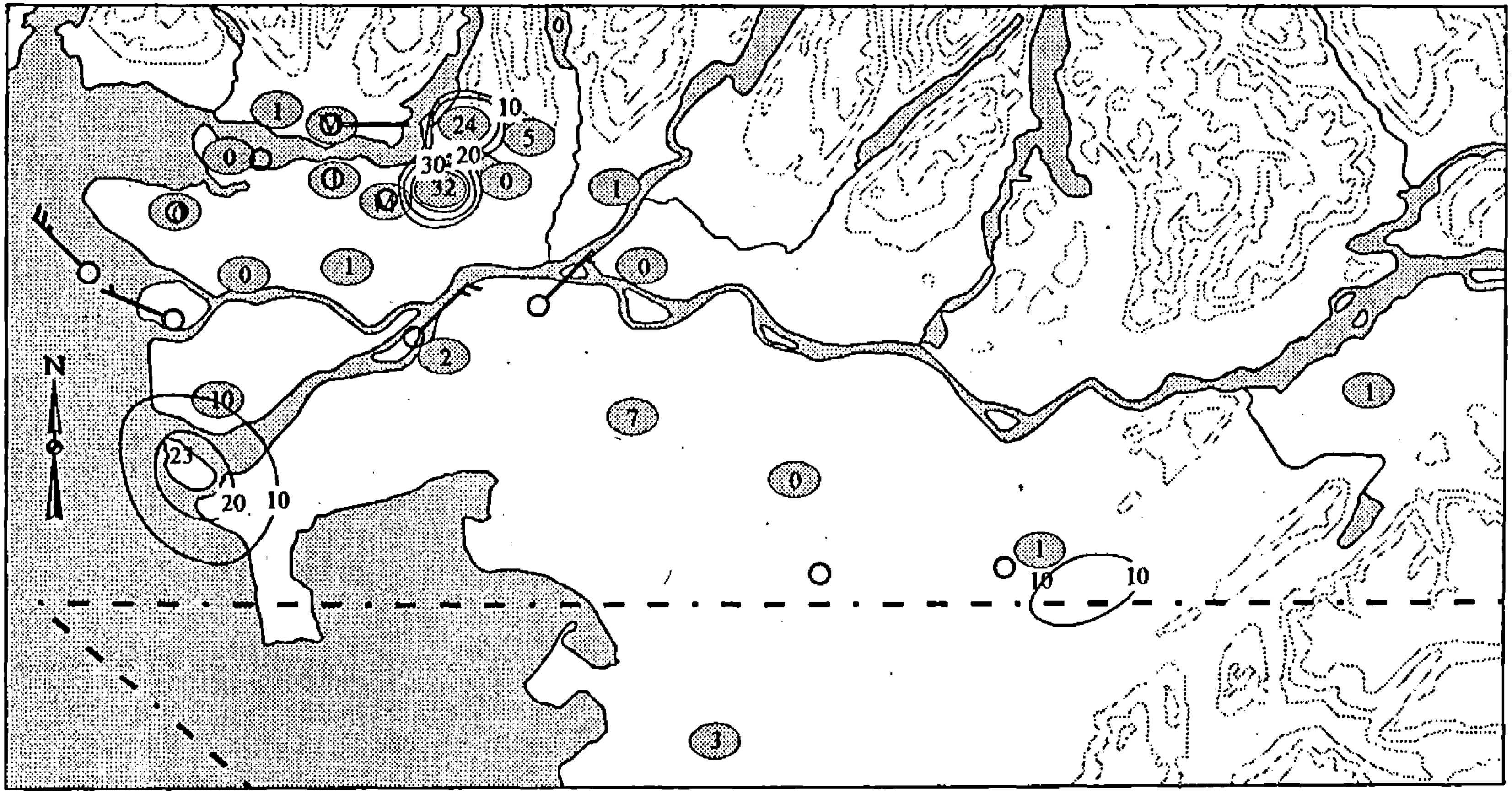


LEGEND

T1	Robson Square	T13	North Delta
T2	Kitsilano	T14	Burnaby Mountain
T3	Marpole	T15	Surrey East
T4	Kensington Park	T16	Pitt Meadows
T5	Confederation Park	T17	Richmond South
T6	Second Narrows	T18	Burnaby South
T7	Anmore	T21	Port Coquitlam North
T9	Rocky Point Park	T26	Mahon Park
T10	Eagle Ridge	T27	Langley
T12	Chilliwack Works Yard	T28	Downtown Abbotsford

Contour Interval = 300 metres

0 10 20 km



OZONE CONCENTRATION CONTOURS (ppb)
5 A.M. 31 JULY 1992

Values at Stations = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

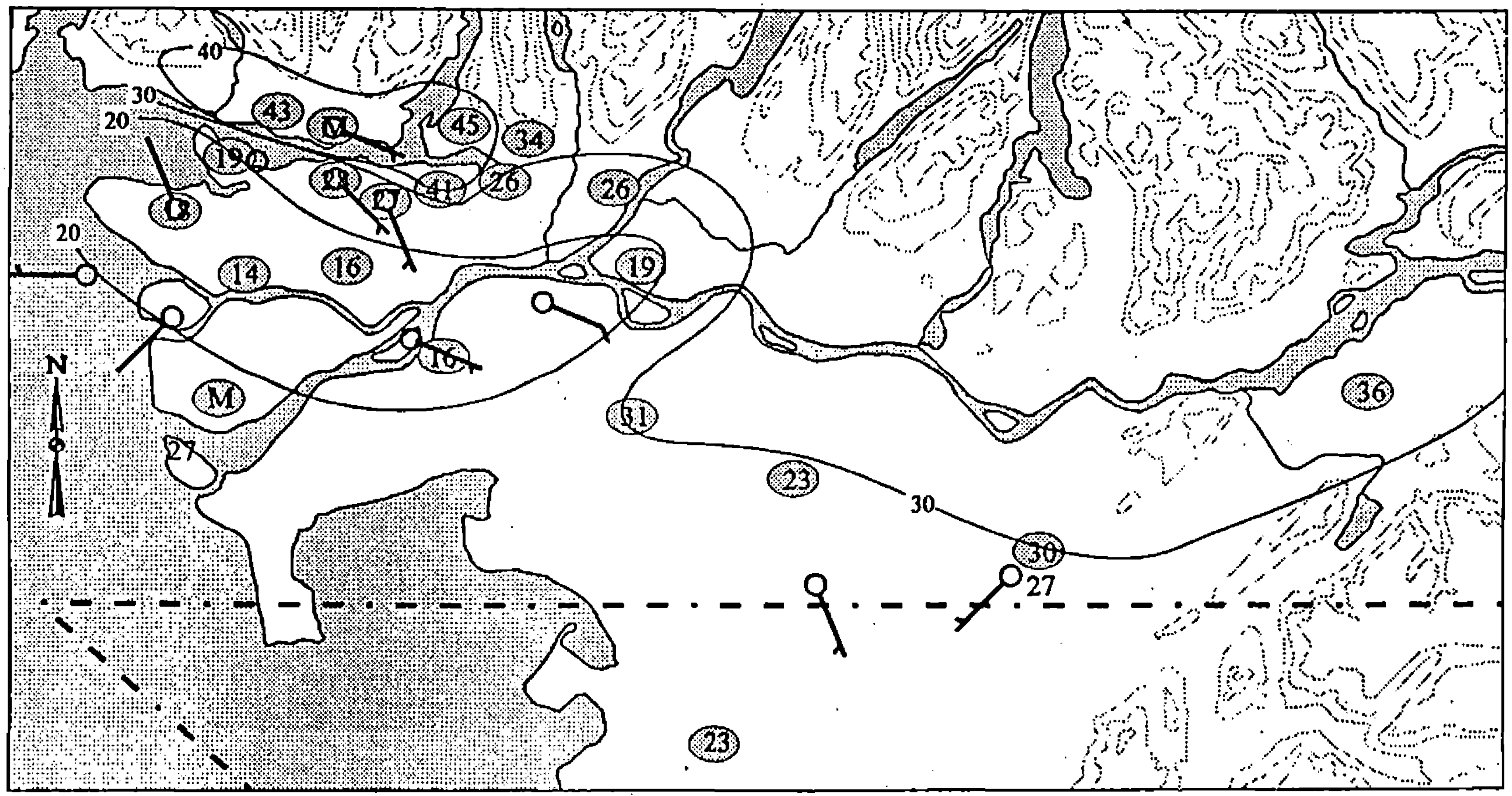
Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

Rev. 03/93 CE

Environment Canada
A.E.S. Pacific Region



OZONE CONCENTRATION CONTOURS (ppb)
11 A.M. 31 JULY 1992

Values at Stations = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

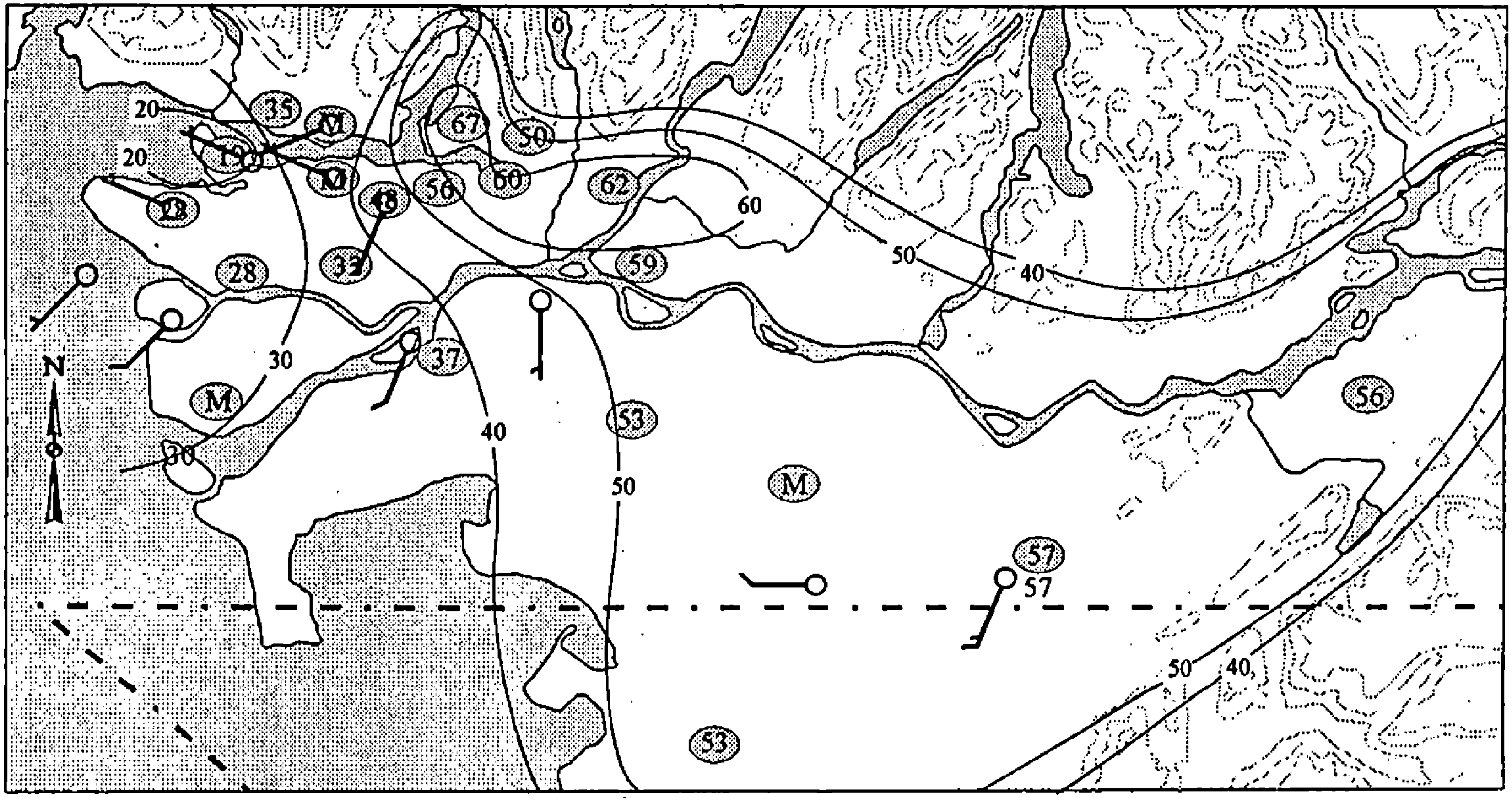
Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

Rev. 02/93 CE

Environment Canada
A.E.S. Pacific Region



OZONE CONCENTRATION CONTOURS (ppb)
2 P.M. 31 JULY 1992

Values at Stations = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

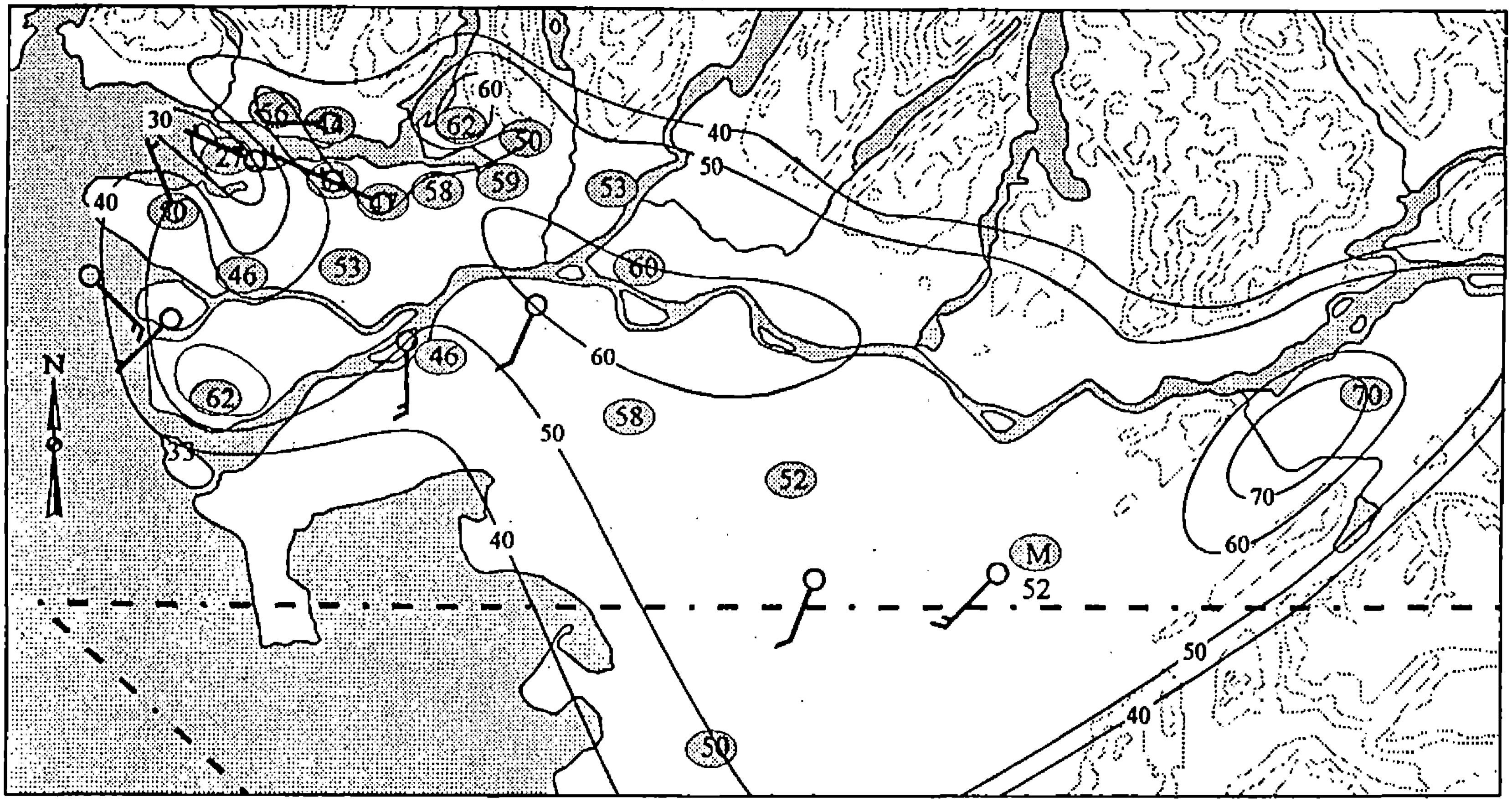
Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

Rev. 03/93 CE

Environment Canada
A.E.S. Pacific Region



OZONE CONCENTRATION CONTOURS (ppb)
5 P.M. 31 JULY 1992

Values at Stations = Average Hourly Ozone Concentration (ppb)

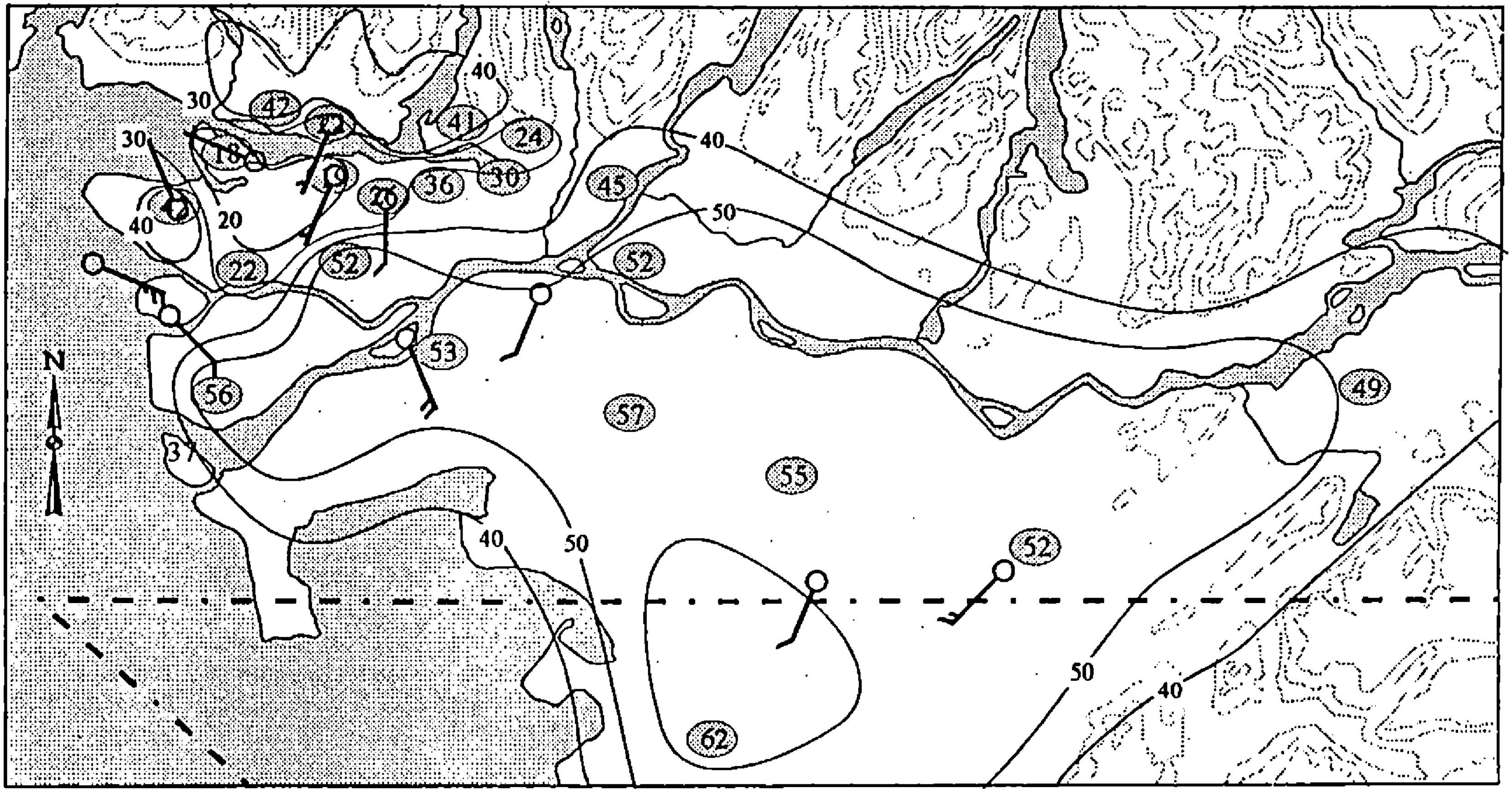
Ozone Concentration Contour Interval = 10 ppb

Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

Environment Canada
A.E.S. Pacific Region



OZONE CONCENTRATION CONTOURS (ppb)
8 P.M. 31 JULY 1992

Values at Stations = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

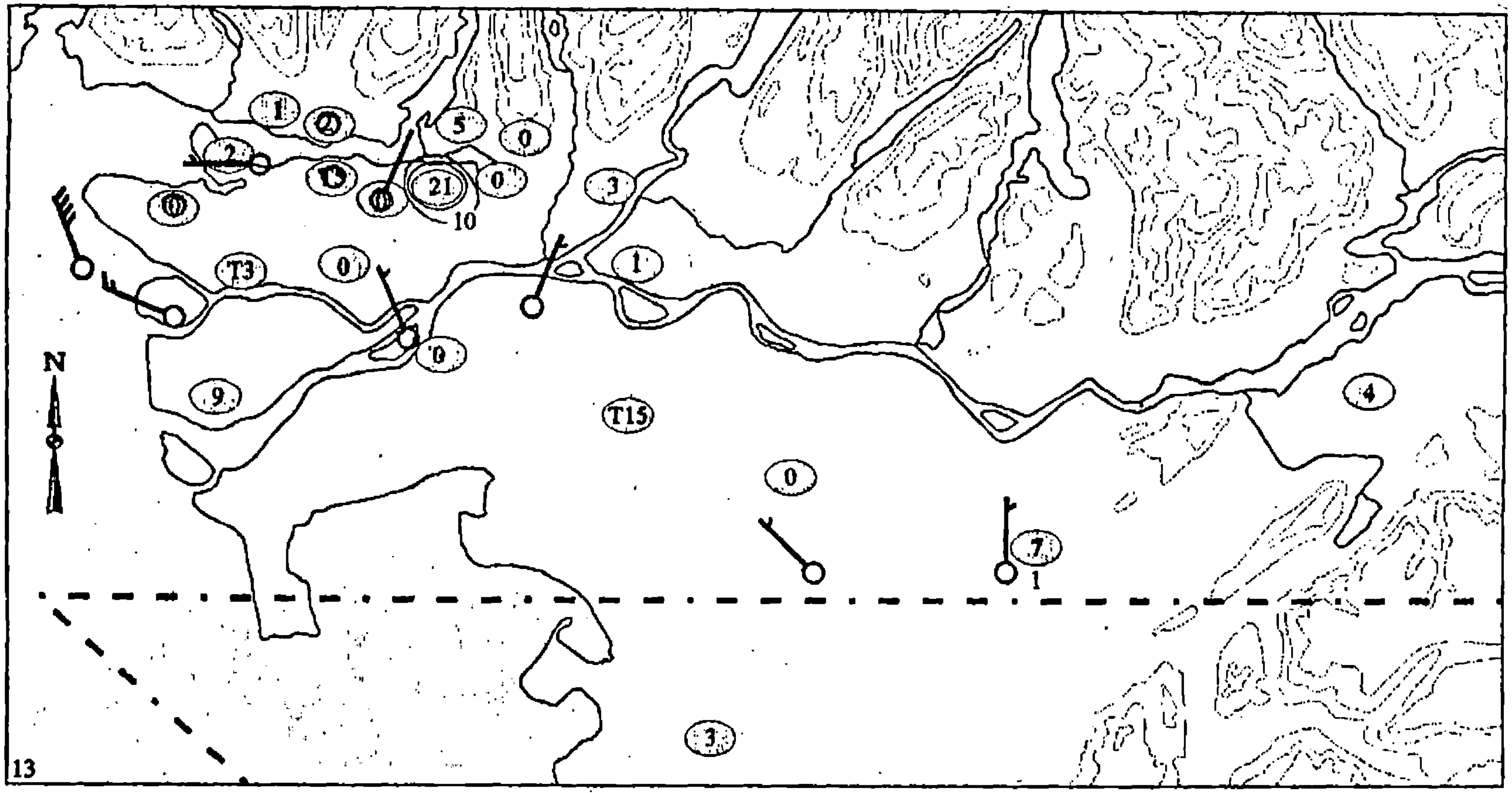
Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

Rev. 03/93 CE

Environment Canada
A.E.S. Pacific Region



OZONE CONCENTRATION CONTOURS (ppb)
5 A.M. 12 AUGUST 1992

Values at Stations = Average Hourly Ozone Concentration (ppb)

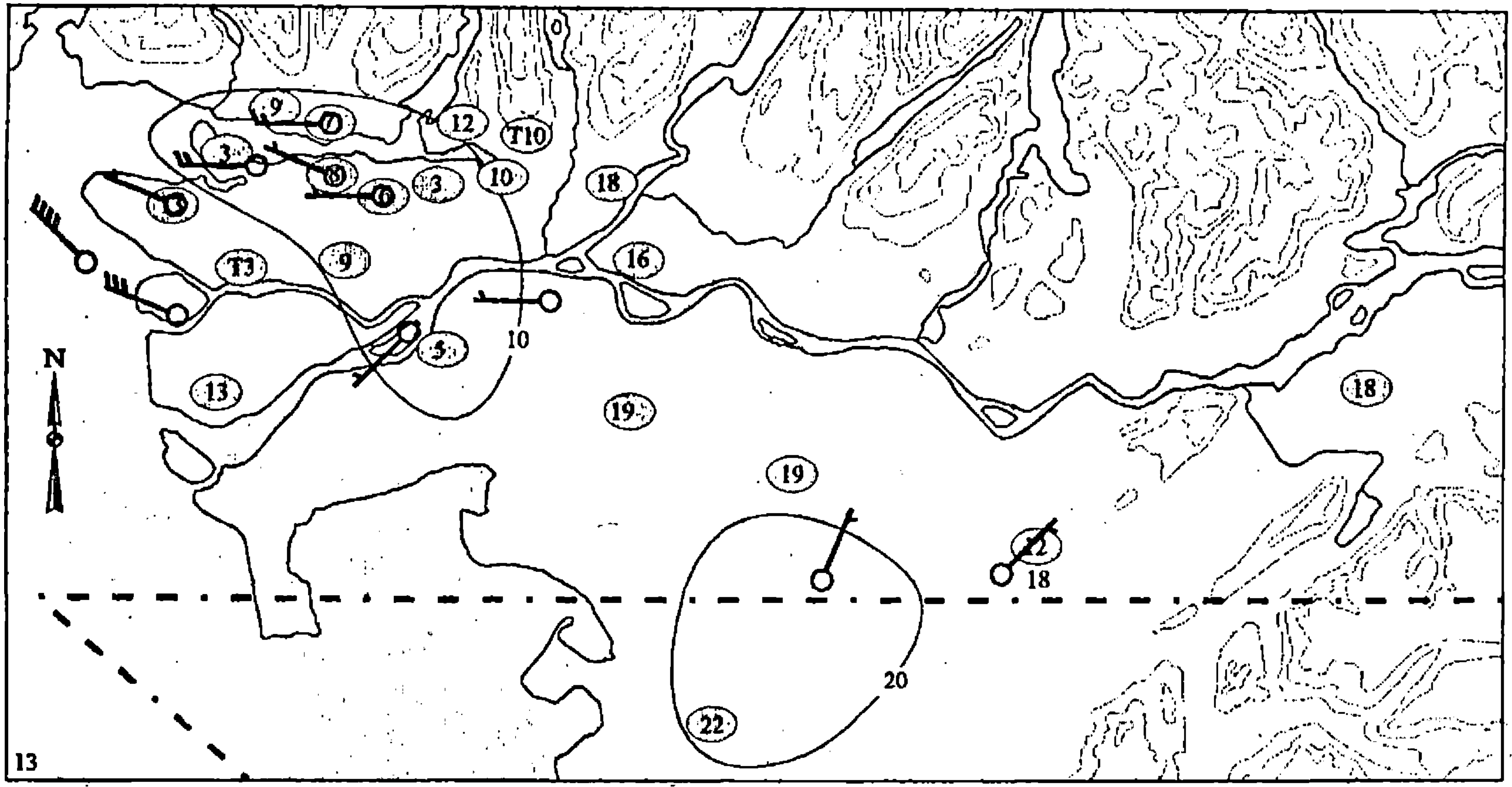
Ozone Concentration Contour Interval = 10 ppb

Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

Environment Canada
A.E.S. Pacific Region



OZONE CONCENTRATION CONTOURS (ppb)
11 A.M. 12 AUGUST 1992

Values at Stations = Average Hourly Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

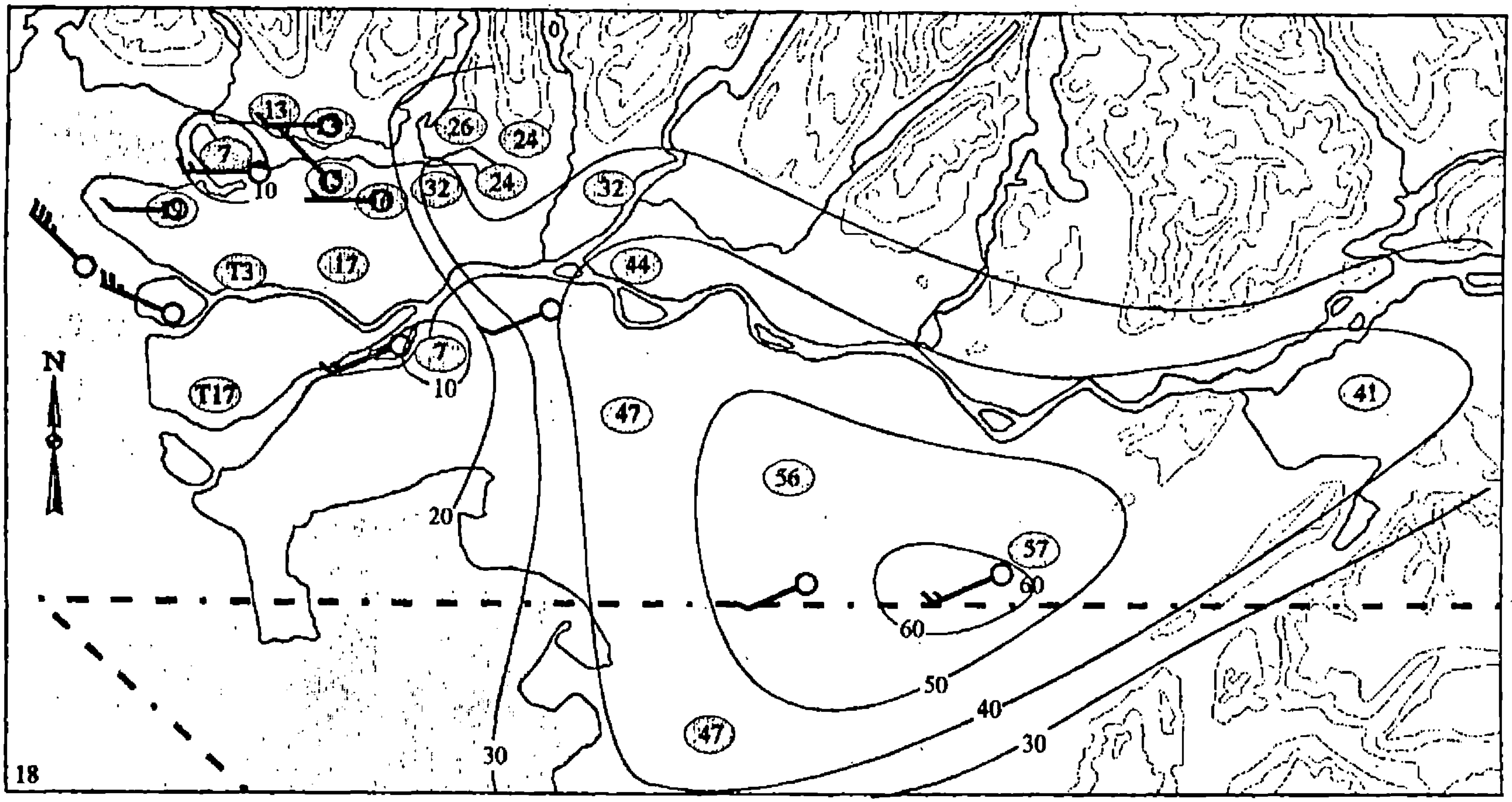
Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

Rev. 03/93 CE

Environment Canada
A.E.S. Pacific Region



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OZONE CONCENTRATION CONTOURS (ppb)
2 P.M. 12 AUGUST 1992

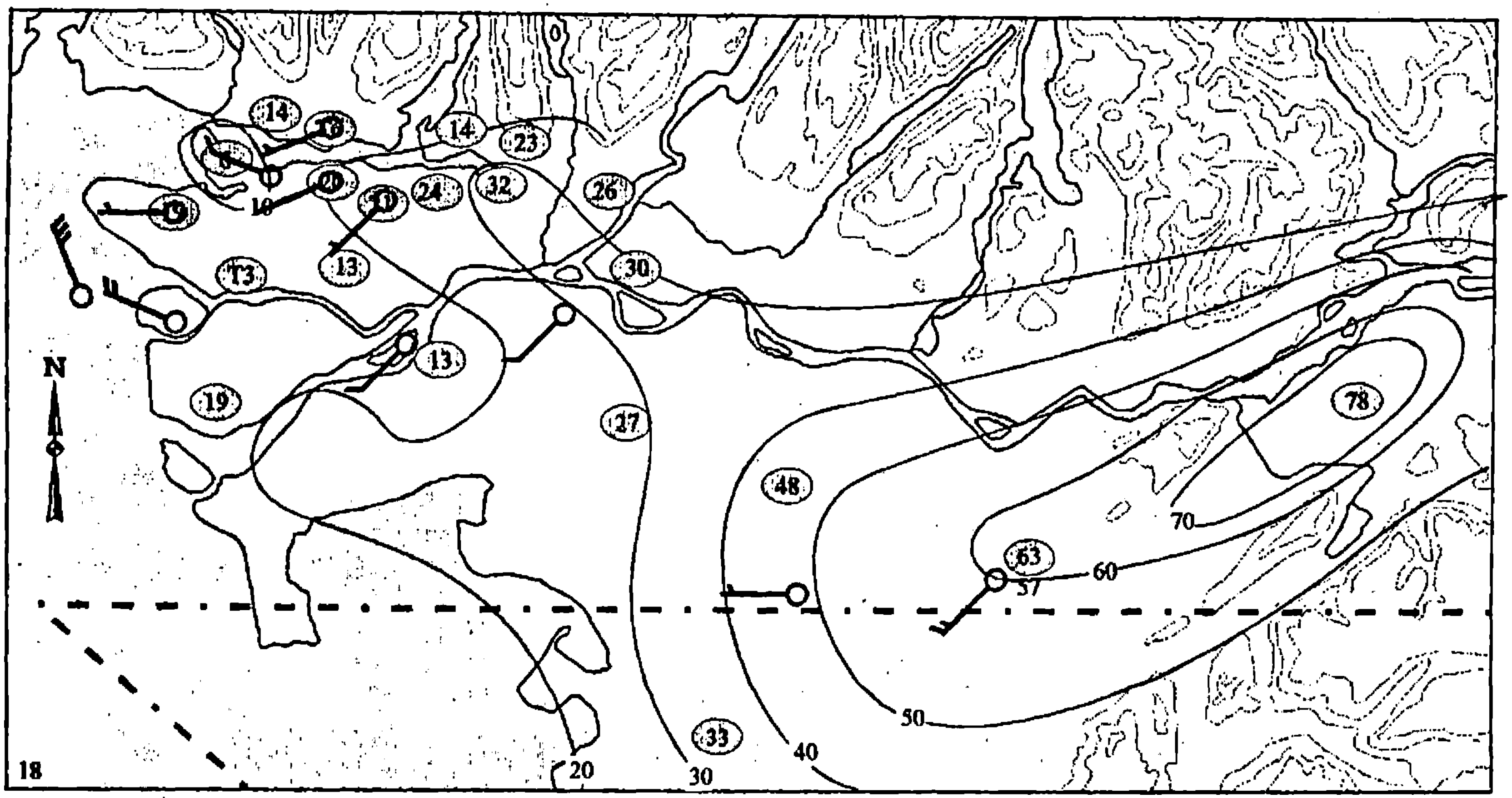
Values at Stations = Average Hourly Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km



OZONE CONCENTRATION CONTOUR (ppb)
5 P.M. 12 AUGUST 1992

Values at Stations = Average Hourly Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

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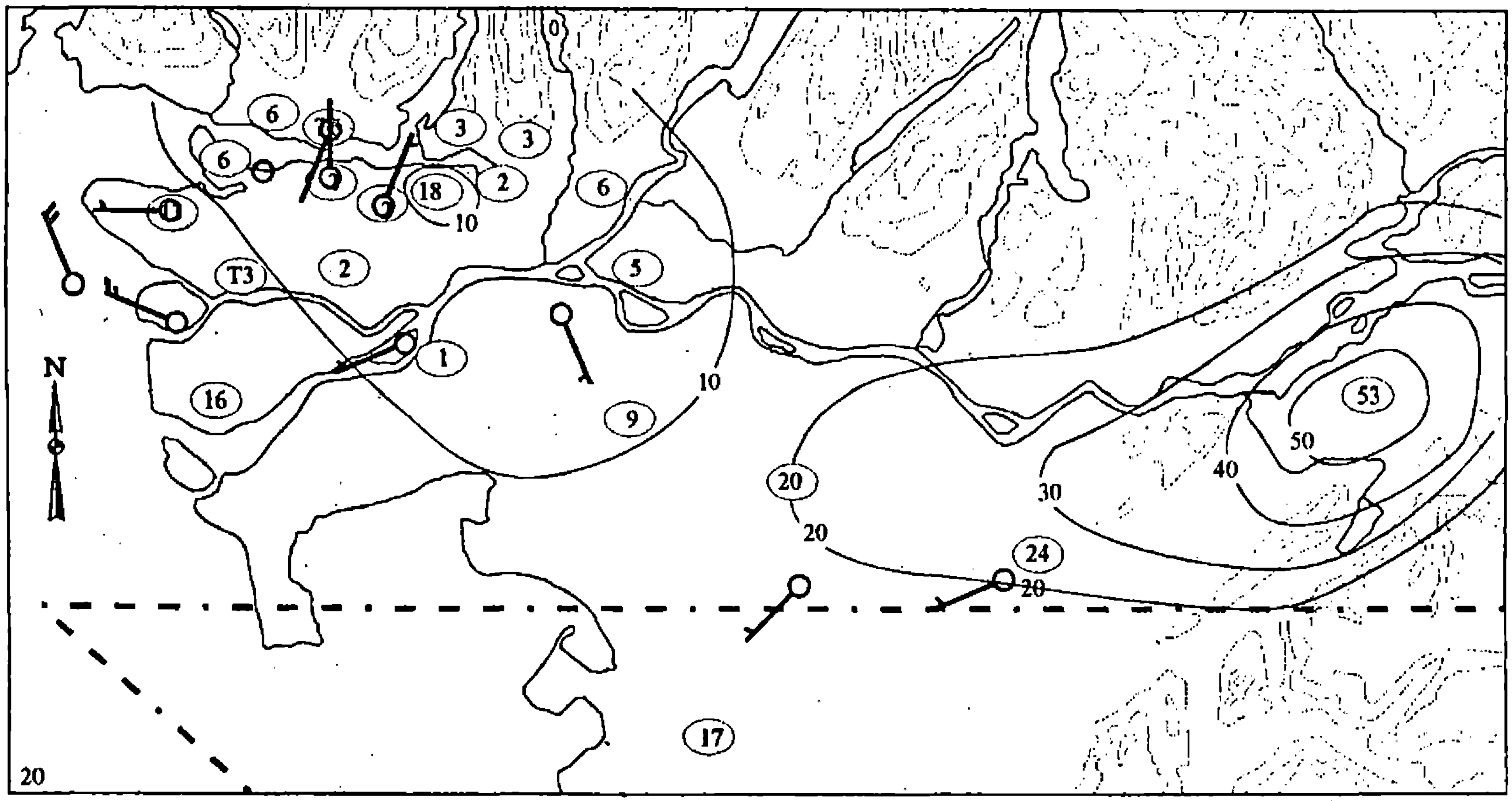
Environment Canada
A.E.S. Pacific Region



OZONE CONCENTRATION CONTOURS (ppb)
8 P.M. 12 AUGUST 1992

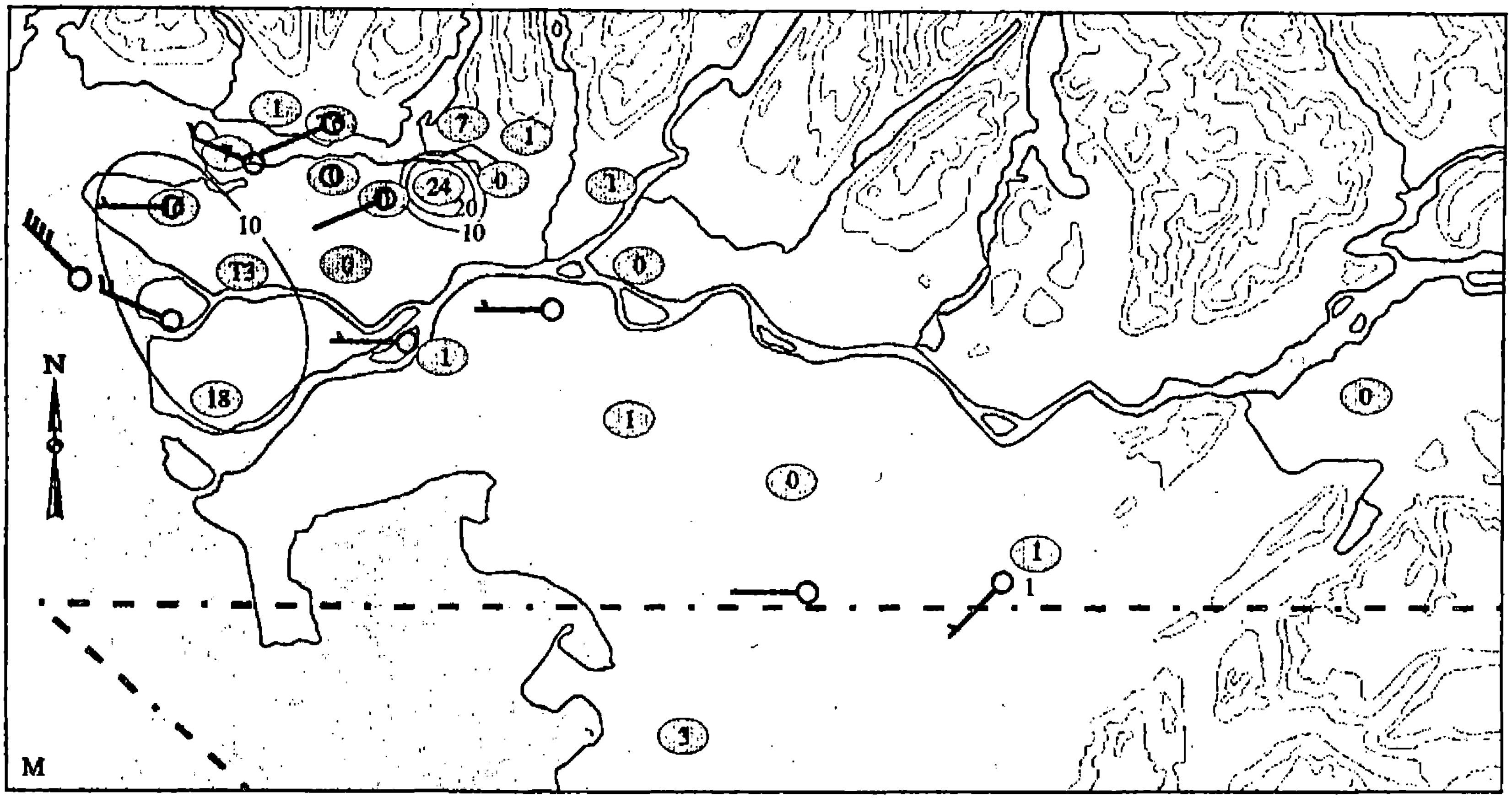
Values at Stations = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km



OZONE CONCENTRATION CONTOURS (ppb)
5 A.M. 13 AUGUST 1992

Values at Stations = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

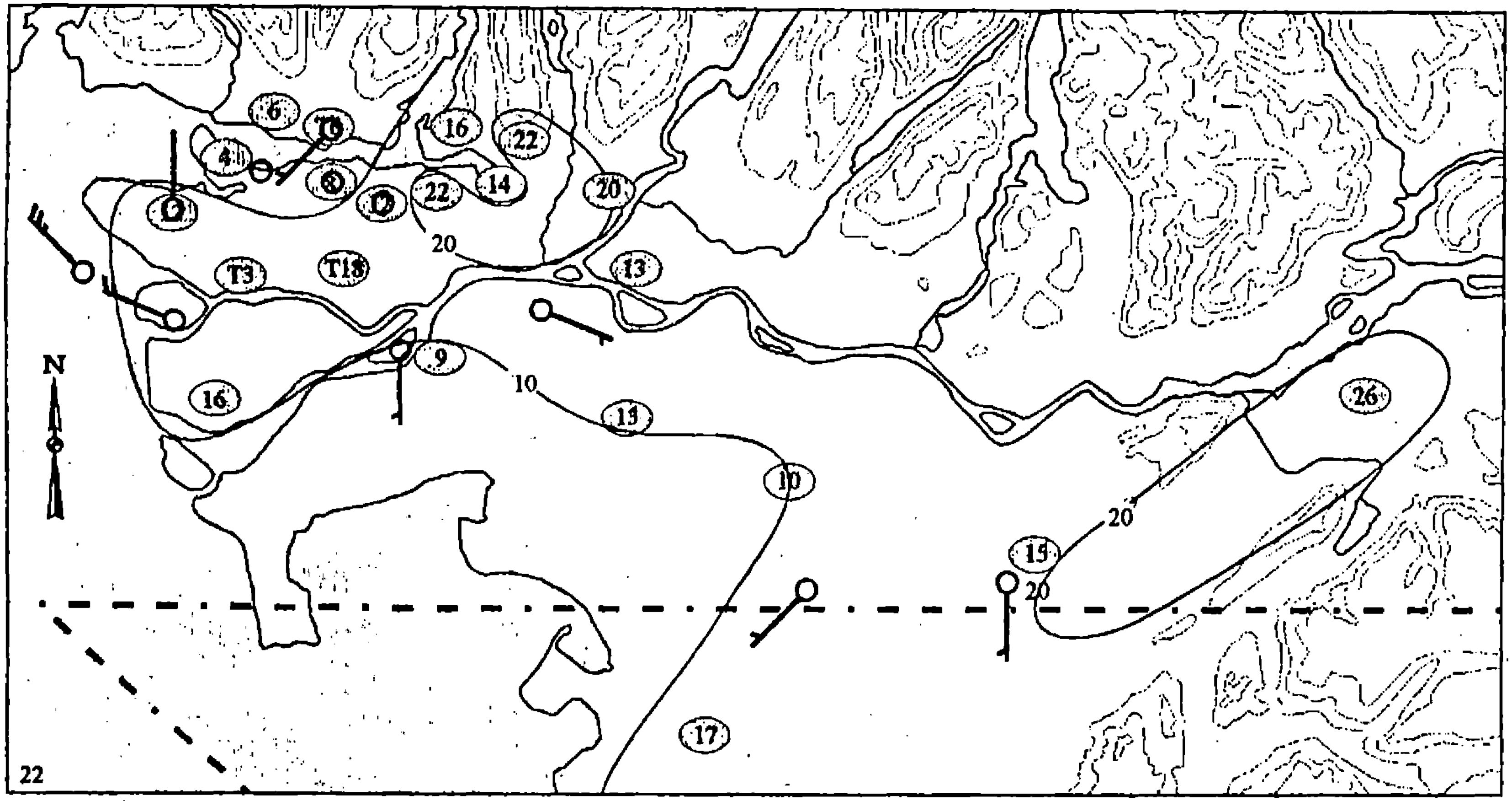
Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

Rev. 03/93 CE

Environment Canada
A.E.S. Pacific Region



OZONE CONCENTRATION CONTOURS (ppb)
11 A.M. 13 AUGUST 1992

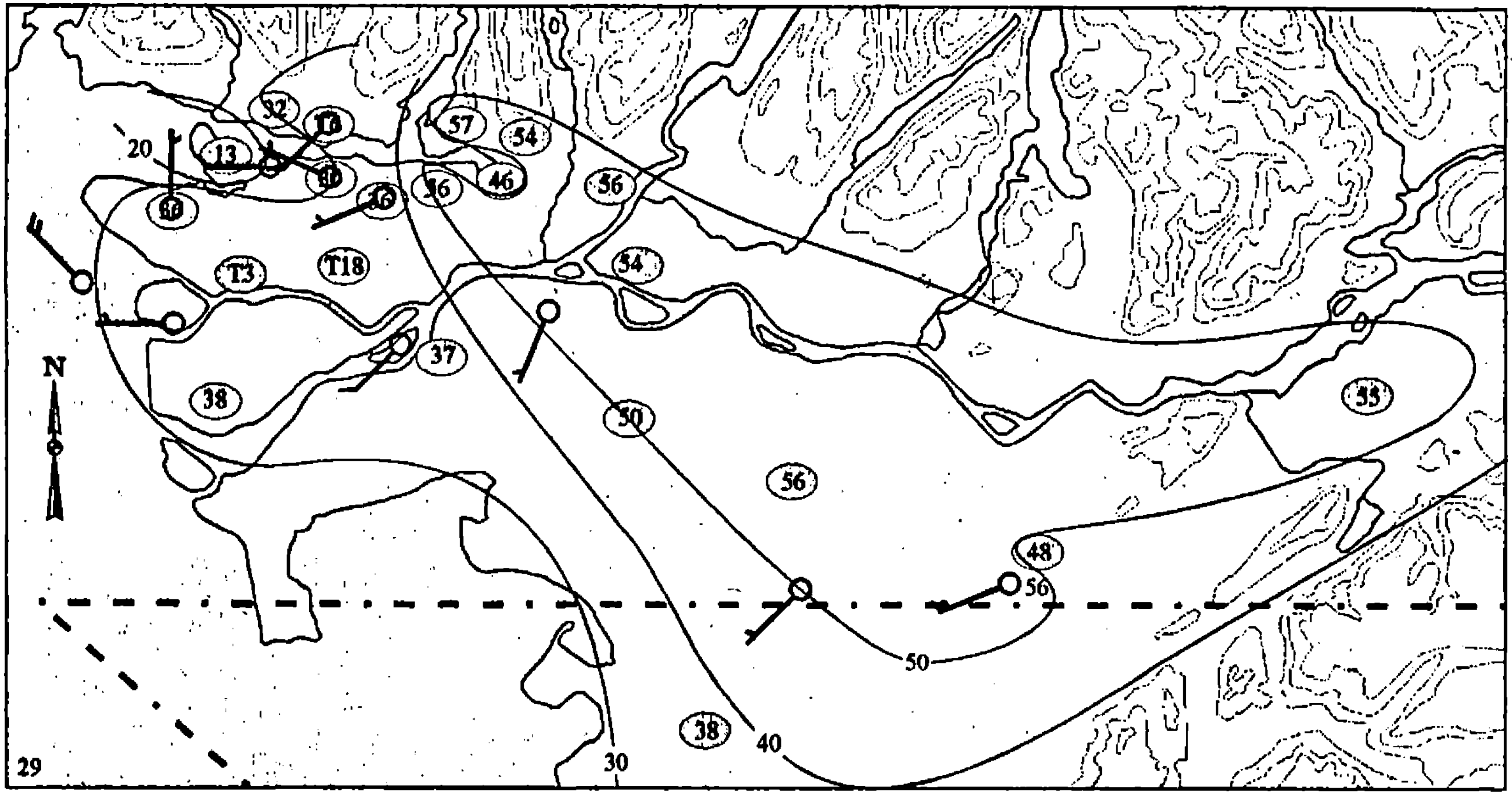
Values at Stations = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Countour Interval = 10 ppb

Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km



OZONE CONCENTRATION CONTOURS (ppb)
2 P.M. 13 AUGUST 1992

Values at Station = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

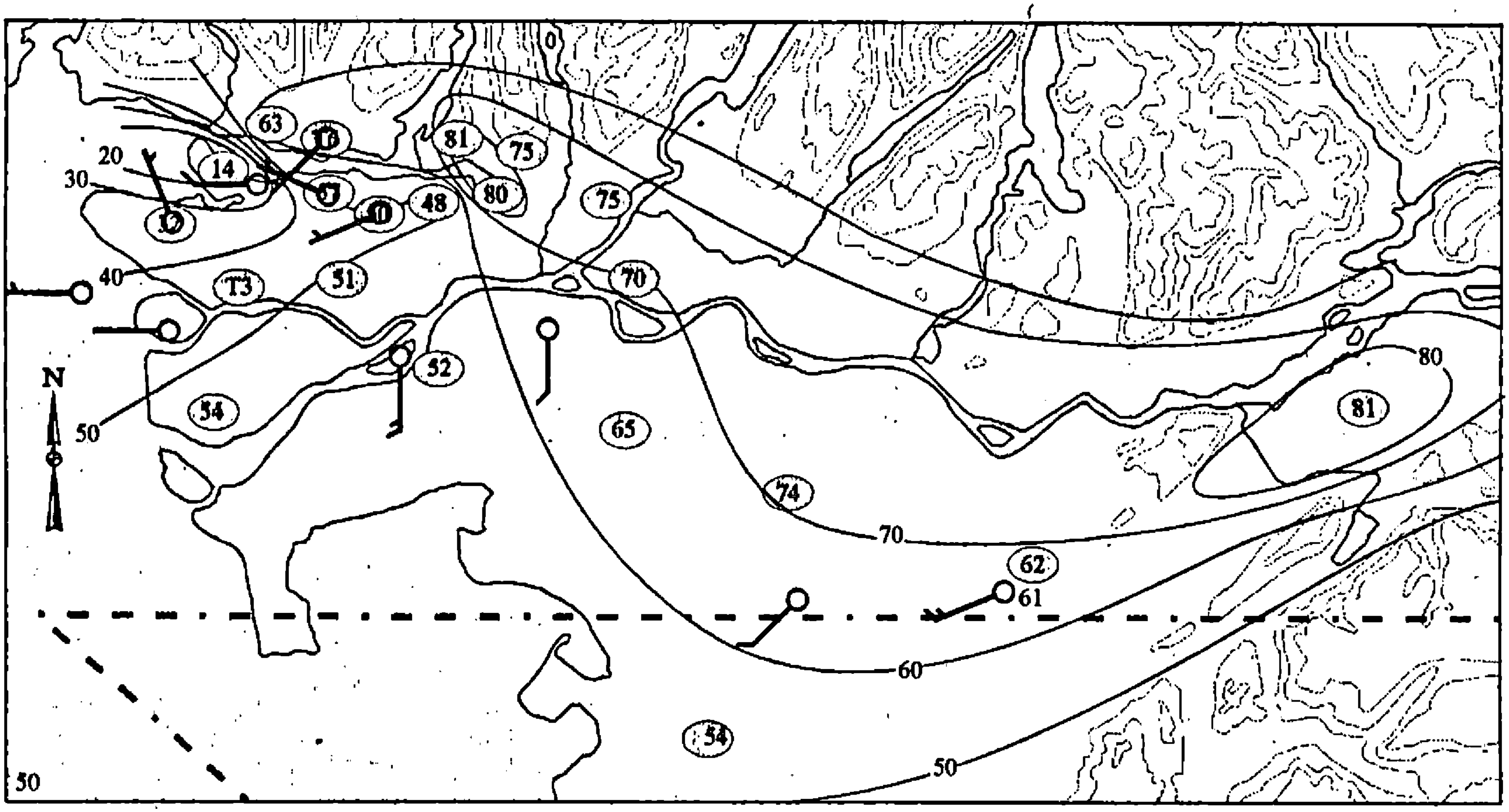
Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km

Rev. 03/93 CE

Environment Canada
A.E.S. Pacific Region



OZONE CONCENTRATION CONTOURS (ppb)
5 P.M. 13 AUGUST 1992

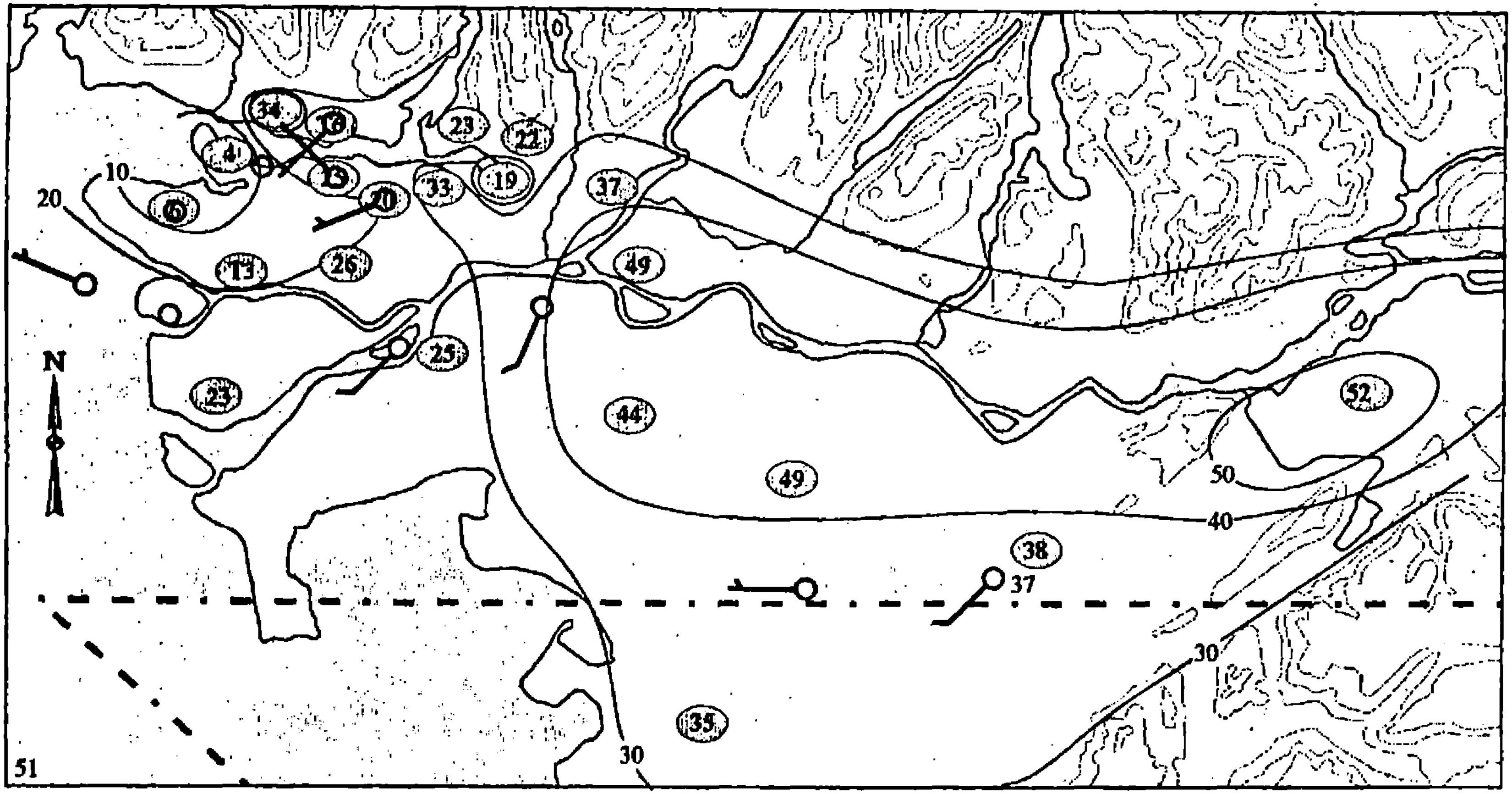
Values at Stations = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km



OZONE CONCENTRATION CONTOURS (ppb)
8 P.M. 13 AUGUST 1992

Values at Stations = Average Hourly Ozone Concentration (ppb)

Ozone Concentration Contour Interval = 10 ppb

Height Contour Interval = 300 metres

Windspeed in kmh

0 10 20 km