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MESOSCALE OBSERVATIONS OF AN OUTFLOW WIND OVER THE SOUTHERN STRAIT OF GEORGIA

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INTRODUCTION

Outflow winds are a common winter occurrence along the B.C. coast, however, the fine structure of these winds has not, to the knowledge of the author, been investigated. An opportunity to do this arose from a weather research flight February 13, 1980. This note is a short discussion of the observations made on that flight and mini-sonde soundings that same day.

The research flight was conducted as a part of a study initiated by Pacific Marine Environmental Laboratory (PMEL) of Seattle to investigate low-level air flow in Juan de Fuca Strait and Puget Sound. For the period of the study, February 10 to March 10, the routine observational program was supplemented with extra upper air soundings, buoy surface measurements and lidar wind measurements. On "special" occasions, in order to study air flows under specific synoptic conditionds, more intensive observations by means of a NOAA research aircraft were recorded. AES Pacific Region co-operated in the project; the Victoria Weather Office took daily mini-sonde soundings and on the the days of intensive observation, SSD staff took 2-3 soundings in which the balloon was tracked by the double theodolite method.

One day of special observations was February 13, 1980. On that date, an outflow wind from the Fraser Valley developed and spread across the southern Strait of Georgia.

2. DATA

The INS-equipped WP-3 aircraft measures winds, temperatures, humidity, longitude and radar altitude. Observations, made at 10-second intervals, are recorded on magnetic tape for later processing.

On February 13, the aircraft route included a leg extending northward over water to just south of Texada Island. For the most part, the flight was at 40-55 m altitude at a ground speed of approximately 110 kt.

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Selected data from this flight are plotted on Figure 1 using the standard upper air plotting model. Observation times are indicated in GMT; flight levels in metres are shown in parentheses. All wind speeds are in knots. Surface winds from a number of observing stations are alos plotted. Times of the latter are 2200 - 2400 GMT.

Two special mini-sonde ascents were taken on the afternoon of February 13. A computer-plotted graph of winds and temperatures for the second flight (release time 0015 GMT) at a time when the outflow was well developed is reporduced as Figure 2.

3. SYNOPTIC SITUATION

The synoptic situation of February 13, 1980 was typical for winter outflow conditions. An Arctic high (104.2 kpA) was centred south of Lake Athabaska giving a southeasterly gradient over much of B.C. Afternoon temperatures in the Interior ranged from 0°C in the Okanagan to -14°C at Fort St. John. The air mass was dry and skies generally clear except for middle cloud over the southern Interior.

A weak outflow wind of 5-10 kt at Abbotsford increased in strenth by late morning (1900 GMT) to northeast 15-25 kt gusts as high as 34 kt. At Victoria Airport, the day began with low cloud and fog and a light westerly wind. The outflow wind set in about noon (2000-GMT) as is evident from Table 1. Thereafter it increased in strength to about 15-20 kt.

4. DISCUSSION

The contrast between the northeasterly outflow winds in the extreme southern part of the Strait and the westerly or northwesterly winds further north is evident from Figure 1. The low-level (50m) winds measured by the aircraft reached a peak speed of 17.5 m sec (34 kt); at a higher level (629m) one speed of 20.2 m sec $^{-1}$ (39 kt) was recorded.

Perhaps most striking, certainly most interesting, is the narrow width of the transition zone from the outflow winds to the weaker northwesterlies. On the norther bound crossing of the zone, the wind backed from 077 degrees at 18 kt to 314 at 4 kt within 20 seconds of flight time, i.e. over a distance of about 1 km. On the southbound crossing, further west, the change was less dramatic and the aircraft did not encounter the strong northeasterly until abeam of Mayne Island.

Another aspect to be noted is the contrast in temperature and humidity between the air masses on either side of the transition zone. South of the zone the air is about 2-3°C warmer, the dew points some 8-10°C lower than north of the zone. This points out the difference in origins of the two air masses. The drier air of the south obviously has recently arrived from the land. The northern air, although probably of Arctic origin, likely has had a longer over-water trajectory. The reason for the lower temperatures to the north is not obvious; likely

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this is because the air there traversed a cold land surface over northern B.C. before reaching the water.

Figure 2 depicts the vertical structure of the boundary layer in the outflow stream at the time it was fully developed. On this chart a free-hand smooth curve of wind speeds has been superimposed on the originally computer-produced curve. As well, a line representing the day adiabatic lapse rate has been drawn on the temperature curve.

The strongest outflow winds of about 13 m sec $^{-1}$ (25 kt) are below 1000 m. Above that the speeds decline steadily. These are somewhat less than the 39 kt measured at 600 m by the aircraft. This would suggest that the outflow wind has spread over a wider area crossing the Strait and some of the jet-like structure is lost at Victoria.

The strong winds have mixed the boundary layer thoroughly and a dry adiabatic lapse rate up to 800 m has resulted.

(The temperatures recorded by the aircraft appear to be 3-4^{o} higher than the minisonde temperatures at the same levels. There is no physical reason to expect this and one suspects measurement error. Since afternoon temperatures at Bellingham and Abbotsford reached 5-6^{o}C and an adiabatic lapse rate would be expected, one would anticipatetemperatures as recorded by the mini-sonde. It is concluded that in the absolute sense the aircraft temperatures are in error, however, the aircraft temperatures should still be useful for areal comparisons along the flight path.)

5. SUMMARY

In this case study of an outflow wind, a narrow zone separated the warmer, drier and stronger northeasterlies of the southern Strait of Georgia from the cooler, more moist northwesterlies of the more northern part of the Strait. Soundings indicated the strongest winds of upto 40 kt (as was evident from the aircraft measurements) occurred below 1000m. A dry adiabatic lapse rate extended from the surface to about 800m.

The aircraft measurements of turbulence do not indicate any significant variation from the outflow wind to the northwesterly. Nevertheless, one might anticipate turbulence in the outflow below about 2000 m because of (a) the steep lapse rate below 1000 m and (b) strong shear above that. One might also anticipate turbulence in the transition zone, an area of marked lateral shear.

It should be noted that the outflow circulation discussed was a dynamic system, one that obviously evolved with time. It would be interesting to investigate the evolution of this system but such a study would require considerably more time.

ACKNOWLEDGEMENT

My thanks are offered to Mr. Bernie Walter of PMEL, Seattle for making the aircraft data available.


Texada Island
Clowhom Falls
Squamish
Squamish FMC Chemicals
Woodfibre
Britannia Beach
Tunnel Camp
Port Mellon
Sechelt
Hopkins Landing
Merry Island
Gambier Harbour
Gibsons
Gibsons Gower Point
Ballenas Light Station
Seymour Falls
Capilano Intake
Hollyburn Ridge
Bowen Island
Bowen Bay
Bowen Isl Arbutus Bay
Point Atkinson
Mount Seymour
Buntzen Lake
Coquitlam Lake
Burnaby Curtis
Burnaby Simon Fraser U
Ioco Refinery
Port Moody Gulf Oil Rfy
Port Moody Centre
Burnaby Mtn Terminal
Burnaby Capitol Hill
Burnaby Brentford
Haney UBC RF Loon Lake
Haney UBC Rf Spur 17
Pitt Polder
Haney UBC RF Marc.
Haney UBC RF Admin
Haney Corrl Instn
Alouette Lake
Stave Falls
Agassiz CDA
Nanaimo Departure Bay
Nanaimo
Nanaimo CHUBC
Entrance Island
Gabriola Island
Pitt Meadows Lougheed
New Westminster
New Westminster Pen
Surrey Kwantlen Park
Haney East
Haney Microwave
Whonnock Thorn Hill
Whonnock 269 St
Mission West Abbey
Mission
Chilliwack Yale Rd East
Chilliwack Gibson Rd
Rosedale
Richmond McLennan Road
Richmond River Road East
Whalley Forest Nursery
Surrey Newton
Port Kells
Milner AIC
Langley Prairie
Aldergrove
Sumas Canal
Chilliwack
Chilliwack Microwave
Chilliwack R Foley Creek
Steveston
Sand Heads Light Station
Ladner Port Guichon
Ladner
Ladner Monitor Stn.
Surrey Municipal Hall
Kensington Prairie
Surrey Sunnyside
White Rock
White Rock Brearley
White Rock STP
Langley Lochiel
Sumas Prairie
Cultus Lake
Sardis
Chilliwack R Mt Thurston
Abbotsford A
Abbotsford King Road
Nanaimo A
Tsawwassen
Tsawwassen Ferry
Delta Pebble Hill
Chemainus
Saltspring Vesuvius
Galiano Island
Cowichan Lake Weir
Cowichan Lake Forestry
Crofton
Saltspring Island
Mayne Island
Duncan
Duncan Forestry
Pender Island
Saturna Island Light
Bellingham
South Pender Island
Cowichan Bay
Cobble Hill Delourne Road
Sidney
Deep Cove
Victoria Int A
Shawnigan Lake
Saanichton CDA
James Island
Port Renfrew BCFP
Bamberton Ocean Cement
Sooke Lake North
Central Saanich Veyaness
Central Saanich Isl View
Saanich Dom Astro Obs
Cordova Bay
Sooke Lake
Victoria Highland
Elk Lake
Saanich Densmore
Beaver Lake
Bear Creek
Victoria Shelbourne
Victoria Gordon Head
Goldstream Lake
Langford Lake
Victoria Quesnel Ave
Victoria Tillicum
Victoria Willows Park
River Jordan
Esquimalt PNL
Esquimalt
Victoria Gonzales Hts
Muir Creek 1 W
Metchosin Happy Valley
Metchosin
Victoria Marine Radio
Sooke
East Sooke Anderson Cove
William Head
Milnes Landing
Becher Bay
Race Rocks Light Station
1. Vancouver City Hall
2. Vancouver Dunbar
3. Vancouver P.M.O.
4. Vancouver South Fraser
5. Vancouver U.B.C.
6. Vancouver Dunbar South
7. Vancouver First Narrows
8. Vancouver Kerrisdale
9. Vancouver Oak 53
10. Vancouver WPG BYNG
11. N. Vancouver Capilano
12. N. Vancouver City Firehall
13. N. Vancouver Cleveland
14. N. Vancouver Cloverley
15. N. Vancouver Lonsdale Park
16. N. Vancouver Lynn Creek
17. N. Vancouver Neighbourhood
18. N. Vancouver Second Narrows
19. N. Vancouver Seymour Blvd.
20. N. Vancouver Upper Lynn
21. N. Vancouver Wharves
22. West Vancouver
23. West Vancouver MacBeth
24. West Vancouver Millstream
25. West Vancouver Palmerston

VICTORIA (A) DATE 13/ 2/1980 TIME 1615 PST

WIND/TEMPERATURE VS. HEIGHT(M)

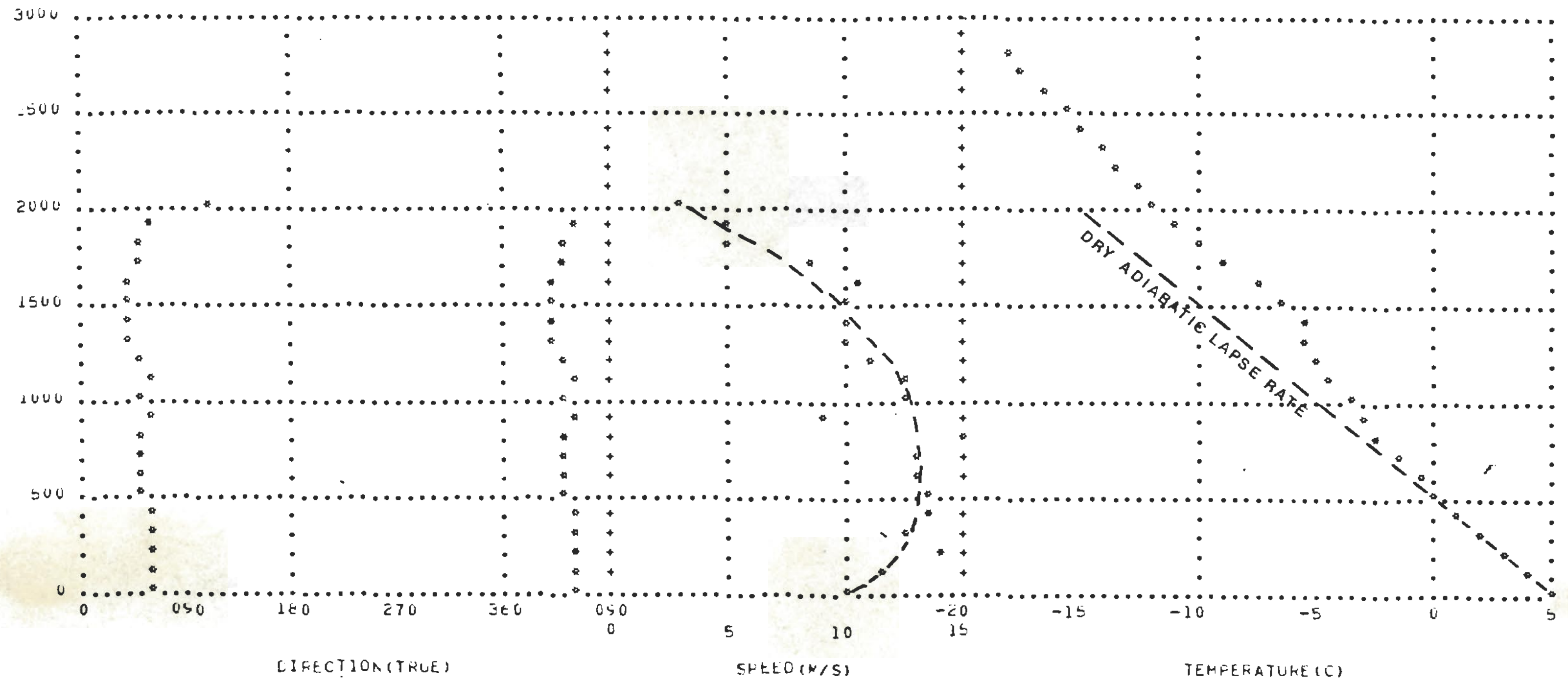

FIGURE 2

PACIFIC WEATHER CENTRE

Table I

24 HOUR ARCHIVE WEATHER FOR CLIMATE DAY FEBRUARY 13, 1980

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1407  YYJ SA 0700 M70 BKN 40 074/4/-6/0622/976/AC9 8999=
1406  YYJ SA 0600 M85 OVC 40 076/4/-7/0622/976/AC10 101 27XX=
05
1404  YYJ SA 0400 10 SCT 50 SCT E120 OVC 40 075/4/-7/0518G28/975/CF1SC2AC7    =
1403  YYJ SA 0300 30 SCT E110 BKN 40 076/5/-7/0519/975/CU1AC6 501 =
1402  YYJ SA 0200 30 SCT E80 BKN 40 075/5/-6/0519/975/CU1AC6 =
1401  YYJ SA 0100 30 SCT 80 -SCT 40 075/6/-5/0620/975/CU1AC3 =
1400  YYJ SA 0000 30 SCT 80 SCT 40 077/6/-5/0715G20/976/CU1AC1 714 =
1323  YYJ SA 2300 30 SCT 90 SCT 40 081/7/-4/0615/977/CU1AC1 =
1322  YYJ 2200 20 SCT 90 SCT 50 085/7/-2/0312/978/CU1AC1 TR AC E =
1321  YYJ SA 2100 20 SCT 90 SCT 50 091/7/0/0412/980/CF1AC1 TR AC E 812 =
1320  YYJ SA 2000 20 SCT 90 SCT 50 095/7/1/0508/981/CF1AC1 TR CF =
19
1318  YYJ SA 1800 15 SCT 15 103/4/1/3408/983/CF1 400 =
1317  YYJ SA 1700 5 SCT 14 SCT 10 105/2/2/2606/984/SF1CF1 VSBY LWR SE FK    =
1316  YYJ SA 1600 3 SCT 12 SCT 6FK 104/0/-1/2807/983/SF1CF1 TR SF CF    VSBY SW 10 =
1315  YYJ SA 1500 10 SCT 5F 103/0/-1/2505/983/CF2 F BNK NW-NE VSBY 2 608    =
1314  YYJ SA 1400 -X 10 SCT E140 BKN 6F 104/0/-1/3006/983/F2ST2AC2  ROOF    VSBY HIR =
1313  YYJ SA 1300 -X 5 SCT 20 SCT E140 OVC 6F 106/1/0/2804/984/F1ST1SC1AC7    FOOF VSBY HIR =
1312  YYJ SA 1200 -X 4 SCT 20 SCT E140 OVC 6F 111/1/0/2604/986/F1ST2SC2AC5    FOOF VSBY HIR
1311  YYJ SA 1100 -X 4 SCT E20 BKN 140 OVC 4F 112/1/0/2604/986/F2ST2SC2AC4    =
1310  YYJ SA 1000 -X 4 SCT E20 BKN 140 OVC 4F 119/1/1/2704/988/F2ST2SC2AC4    =
1309  YYJ SA 0900 4 SCT M6 BKN 2F 122/1/1/2505/989/ST5ST4  703 =
1308  YYJ SA 0800 M4 BKN 6 BKN 21/2F 124/1/1/2806/989/ST7ST2 =

1407  YVR SA 0700 E62 BKN 45 088/4/-11/0712/979/SC9 =
1406  YVR SA 0600 E62 BKN 45 089/4/-11/0710/979/SC8 301 =
1405  YVR SA 0500 E58 BKN 45 088/4/-11/0714/979/SC8 VIRGA N =
1404  YVR SA 0400 E58 BKN 45 088/4/-10/979/SC8 =
1403  YVR SA 0300 40 SCT 55 -SCT 45 088/2/-8/0809/979/CF1SC2 306 =
1402  YVR SA COR 0200 40 SCT 55 SCT 45 085/4/-9/0814/978/CF1SC1 =
1401  YVR SA 0100 53 SCT 45 080/5/-8/0711/977/SC1 =
1400  YVR SA 0000 42 SCT 45 082/6/2/2706/977/SC1 CU ASOCTD 712 =
1323  YVR SA 2300 40 SCT 20 085/6/1/3009/978/SC1 =
1322  YVR SA 2200 40 SCT 90 SCT 20 090/6/1/2911/980/CU1AC1 =
1321  YVR SA 2100 40 SCT 90 SCT 20 094/5/2/2814/981/CU1AC1 813 =
1320  YVR SA 2000 40 SCT 90 SCT 20 100/6/2/2709/983/CU1AC1 =
1319  YVR SA 1900 40 SCT 15 105/5/1/2705/984/SC1 =
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