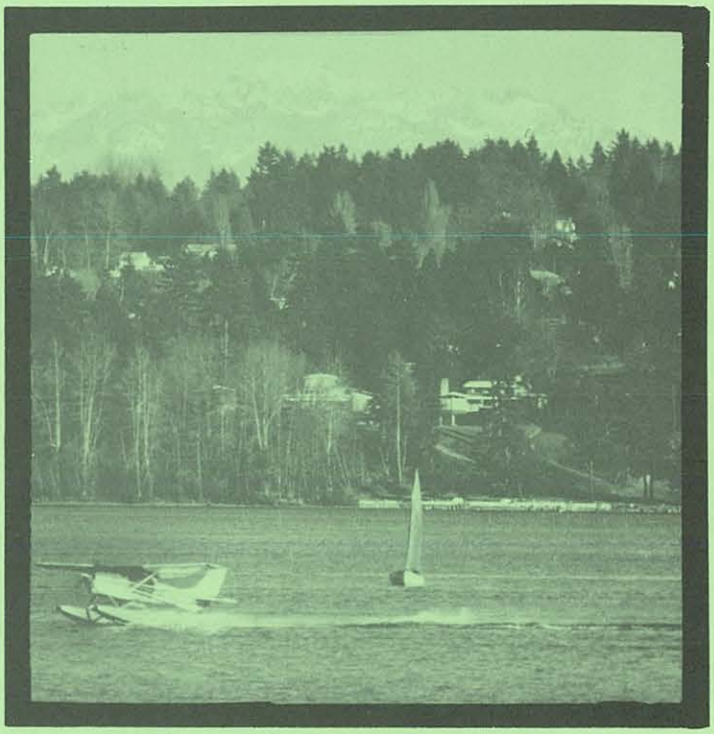
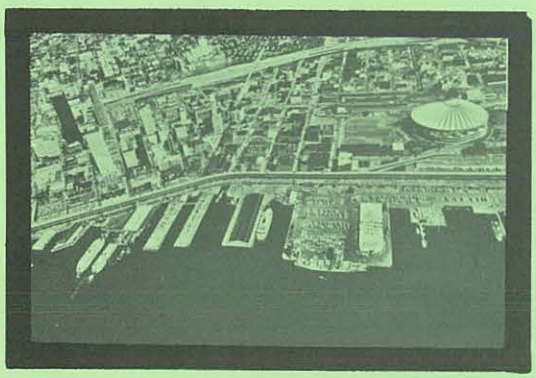
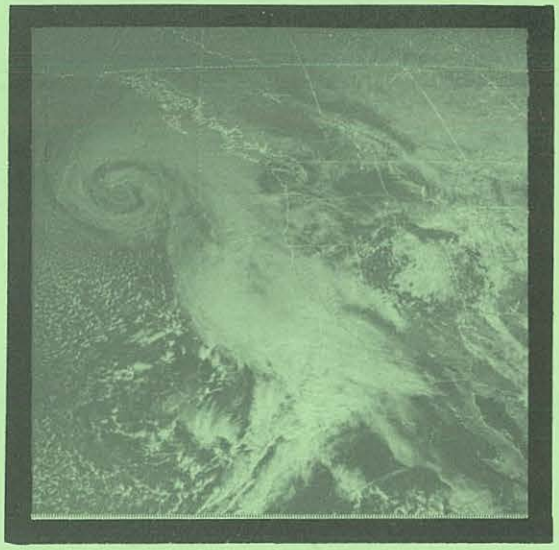
Marine Environmental Assessment

PUGET SOUND

ANNUAL SUMMARY 1983







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CLIMATE IMPACT ASSESSMENT

UNITED STATES

The AISC/Marine Environmental Assessment Division (MEAD), Marine Assessment Branch (MAB), produces periodic assessments of environmental impacts on economic sectors of marine related activities. The Chesapeake Bay region served as a prototype for assessment development for which there are now quarterly and annual issues. There is an annual issue for the Gulf of Mexico area. This first issue for the Puget Sound is the prototype for that area. As such it could benefit from reader's comments and suggestions.

Please send comments or subscription queries to the Chief, Marine Assessment Branch, Marine Environmental Assessment Division, NOAA/NESDIS/AISC, E/AI32, 3300 Whitehaven Street, NW, Washington, DC 20235, or call (202) 634-7379.

Front Cover Photographs

Harbor and downtown Seattle - NOAA file photo
Satellite cloud picture - NOAA/NESDIS photo
January 28, 1983
Puget Sound - Seattle area - NOAA file photo
Fishing fleet - NOAA file photo

Marine Environmental Assessment

PUGET SOUND
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Washington, D.C.
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PUGET SOUND MARINE ENVIRONMENT
1983 ANNUAL SUMMARY

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1983 PUGET SOUND ASSESSMENT

1. INTRODUCTION

This assessment of the Puget Sound region presents an analysis of the effects of weather and climate during 1983 on the economy, environment, and natural resources of the area. As a prototype, the report is an initial effort to select and analyze what we consider to be the most significant relationships between the marine environment and economic activity. The data are presented, wherever possible, at a level of detail which permits inferences to be made about causal relationships between economic activities and the natural environment.

The report begins with a summary of the impacts of environmental events in the region in 1983 (Section 2), followed by a brief description of the development of Puget Sound (Section 3), and its economy (Section 4).

Subsequent sections (Sections 5 to 12) focus upon specific industries and describe the environmental events and impacts of the region's weather and climate in 1983.

2. SUMMARY

Weather and climate impacts in the Pacific Northwest were dominated in 1983 by an unusual oceanographic phenomenon, possibly associated with a similar, nearly simultaneous event, "El Niño", which occurred off the coast of Peru. Occurrences of El Nino have usually been noticed in the equatorial Pacific, off the South American coast, at Christmas time, thus many years ago Peruvian fishermen from the port of Paita began referring to it as "Corriente del Niño" - which in English means "Current of the (Christ) Child".

Beginning in 1982, and continuing into the summer of 1983, an anomalous northward surge of unseasonally warm ocean surface water pushed its way along the full length of the West Coast of the United States, all the way to Alaska. This ocean surge led to the concurrent suppression of colder, nutrient-rich, ocean up-welling along the coast. Marine biota, and the commercial fisheries which depend upon them, were deprived of their normal food supplies.

Fisheries

Major fisheries, such as salmon, were substantially displaced from their normal fishing areas. The result was smaller fish and greatly reduced landings by both commercial fisheries and recreational anglers, in Washington State generally, and Puget Sound in particular.

Despite the devastating impact of this event on West Coast fisheries, there were extenuating circumstances which helped to mitigate the impact on prices, and therefore consumers, and to exacerbate it as far as commercial fisheries were concerned.

The suppression of continental coastal upwelling had the effect of shifting West Coast salmon supplies northward to Alaska. Alaska is the major source of salmon landed and processed in the United States. Furthermore, in recent years, the size of Alaskan sockeye and pink runs have been extremely high. Thus, while West Coast troll catches in the vicinity of Washington were down during 1983, landings by the Alaskan troll fishery were up. The ocean surge of warmer waters tended to redistribute the catch away from Washington in favor of Alaska, and Washington's losses were to a certain extent Alaska's gain.

In contrast, major ocean fisheries, such as salmon, which are international as well as interstate, tended to mitigate the impact on the consumer. Normally when supply is restricted due to an environmental, or any other, factor goods become scarcer and the price to consumers increases. But, as we have already noted, when fishery supplies decline in one region they may increase in another, thus neutralizing the effect on price. The availability of foreign fish catches coupled with the growing strength of the U.S. dollar relative to foreign currencies maintained a downward pressure on salmon prices despite the oceanographic disruption of West Coast fisheries.

Recreation

Recreational salmon fishermen spent fewer days fishing in the region in 1983 than in 1982, possibly in response to declining average angler fish landings per fisherman day. Attendance at marine-oriented State parks in the Puget Sound region did not increase in 1983, despite a 7 percent increase for Washington State parks as a whole. This relative disparity may also have been a result of the poor fishing prospects of 1983, combined with higher than normal precipitation, which could have decreased outdoor recreation generally, recreational fishing and boating in particular.

Agriculture

The warm coastal ocean waters contributed a flow of warm, moist air together with above normal precipitation and snow melt in mountain areas during the growing season. Cool, dry weather occurred during harvest in Washington agricultural areas to the west of Puget Sound. This combination of robust growing conditions and dry harvesting conditions produced an exceptionally good weather scenario for most farming within the region.

In terms of agricultural production the weather was quite good overall, particularly for wheat, and barley. Harvests in many produce categories led to a record-setting total for Washington's agricultural production in 1983.

A graphical summary of 1983 changes in economic performance of weather-sensitive sectors of Puget Sound and Washington is presented below (Figure 1, also Table 1).

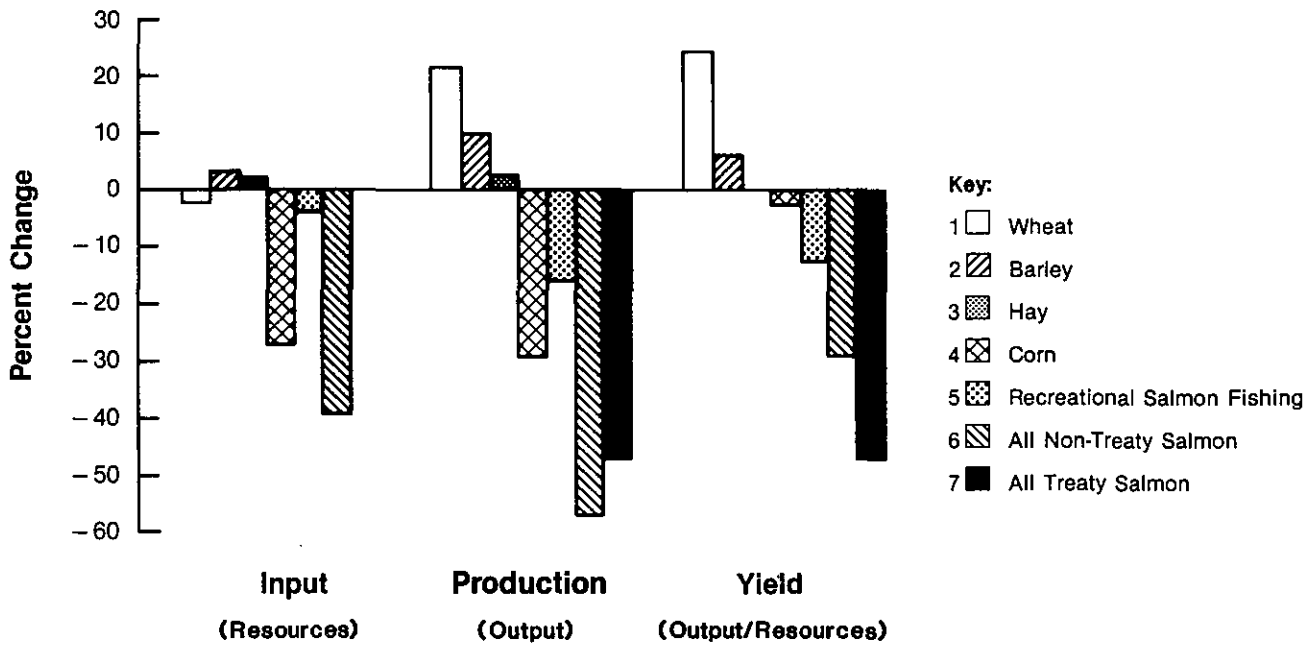

Figure 1 - 1983 Changes in economic performance relative to 1982, by weather-sensitive sector.

Table 1.--1983 Summary of economic changes, by selected weather-sensitive sectors. Input refers to fisherman days of commercial treaty or recreational fishing, and to number of deliveries in the case of commercial non-treaty fishing. In agriculture it refers to acreages.

	(In percent relative to 1982)			
Economic sector	Input	Production	Yield	Value
Salmon fisheries (1)				-49.2
Commercial treaty	0.2	-47.1	-47.0	
Excluding pink			-59.4	
Commercial non-treaty	-39.1	-57.3	-29.1	
Excluding pink			-67.0	
Recreational fishing	-3.9	-16.2	-12.6	
Agriculture				6.8
Wheat	-2.3	21.9	24.8	14.3
Barley	3.5	10.1	6.4	42.4
Corn (2)	-27.3	-29.2	-2.6	-22.7
Hay	2.4	2.8	0.0	21.3

(1) Value for Salmon Fisheries is for Puget Sound region only, all others are for Washington as a whole.

(2) Corn production declined largely due to a 27.3 percent reduction in acreage.

3. THE DEVELOPMENT OF THE PUGET SOUND REGION

Puget Sound has been characterized as an inland sea. Linked to the Pacific Ocean through the Strait of Juan de Fuca, the Sound - including the straits - encloses 2500 square miles of water, 2350 miles of U.S. shoreline, and over 200 islands. The Sound extends south for over 100 miles in a fjordlike wedge between the Cascade and Olympic mountains (Figure 2). Northern Puget Sound reaches depths of over 900 feet and includes a number of natural harbors such as Elliot Bay in Seattle and Commencement Bay in Tacoma. Southern Puget Sound, extending from the Tacoma Narrows to the Nisqually Delta, Olympia, and Shelton, is characterized by vast tidelands and extensive mudflats - an excellent habitat for oysters and clams, and popular for recreational boating and fishing.

The people of the region share a unique and extensive history of concern for the vitality of their marine environment. The federal government formally acquired the land around Puget Sound from native Indians in 1855. From the beginning, the Sound was perceived as the central conduit through which would come economic development for the people living along its shores. The earliest settlers were attracted by the seemingly endless stands of enormous Douglas firs - with diameters as great as twelve feet - growing at the very edge of the water. These extensive timber resources would have been of minimal economic value in the early days had it not been for their accessibility via the water transportation resources of the Sound.

Together, these two natural resources - timber and water transport - dominated the attention of the Puget Sound region for generations. The closest substantial market for the lumber was San Francisco; however, even in the earliest days lumber was shipped regularly as far away as Hawaii and the Orient, as well as Europe. The completion of the Northern Pacific Railroad in 1883 and the Great Northern Railroad in 1893 established Puget Sound as the undisputed commercial hub and transport staging area for the Pacific Northwest with Seattle at its center and having direct rail links to midwestern markets.

Gradually, other natural resources of the Sound were exploited, such as coal which like timber was also conveniently located for water transport, and salmon whose exploitation was much enhanced by the introduction of new technologies like fish traps and the iron chink - a device which beheaded and gutted salmon automatically. Thus, the economy of the Puget Sound region has its roots in a history of adaptation to and exploitation of a unique configuration of natural marine-based resources to satisfy markets largely external to the region. Successive waves of technological change transformed the natural resource base and trade of the region. In the passage of time, each of the Sound's natural resources spawned a family of related industries - water transport led to ship building and maintenance, salmon led to canning, timber led to pulp and paper - and each industry attracted new immigrants and a larger population with its own market demands and claims on the Sound for services as both a source of recreation and a receiver of sewage.

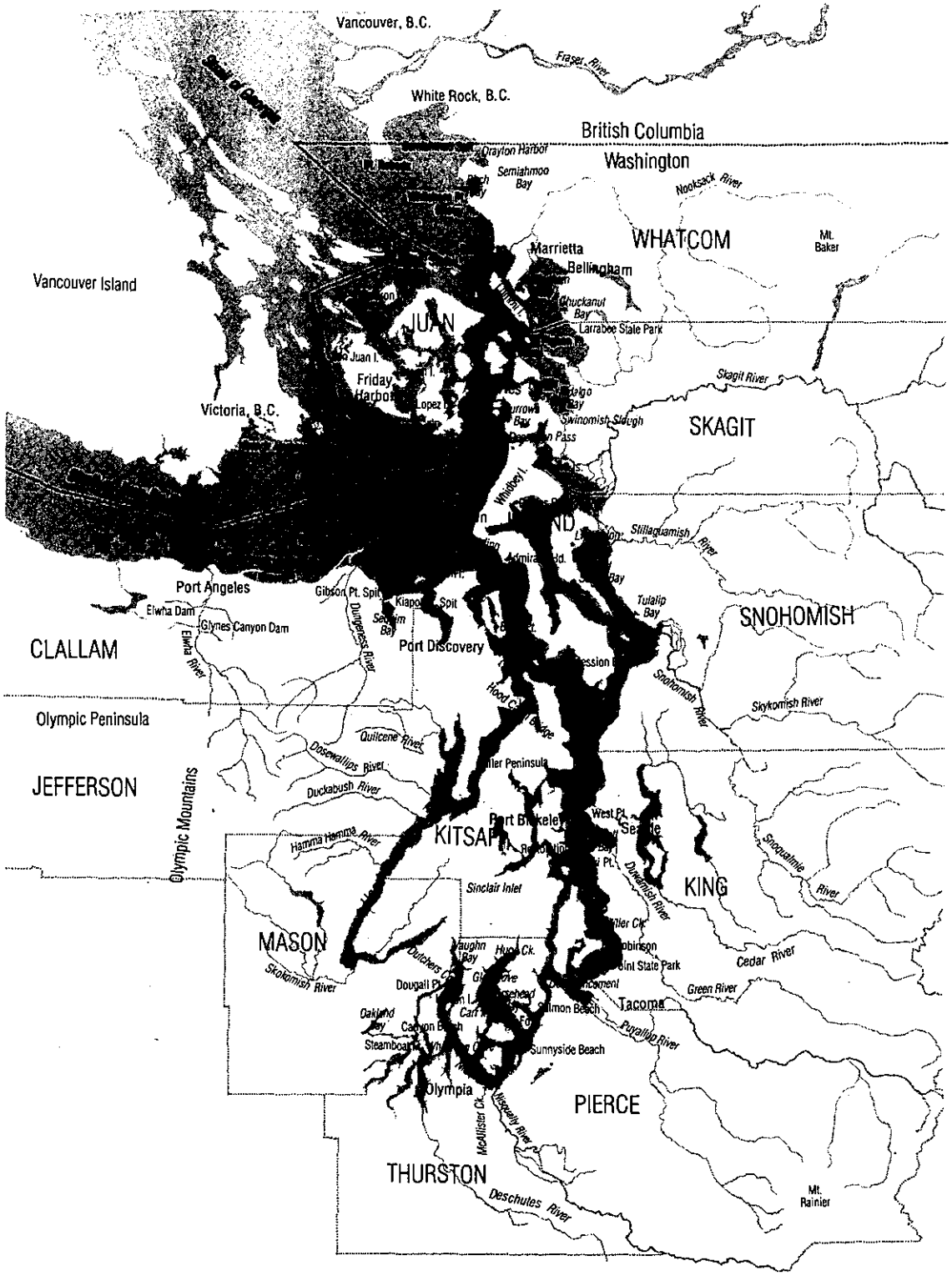

Figure 2 - Puget Sound and its approaches.

Differences in patterns of urbanization, industrialization, and development within the Sound have led to different priorities among competing interests for the use of the Sound's resources. The exceptional natural beauty of Puget Sound has made it a popular tourism and recreation center as well as the hub of the economy of the Pacific Northwest. As a multiple-use resource, the Sound embraces a wide variety of sometimes complementary and possibly conflicting demands on its marine resources.

A primary aim of this assessment is to highlight the multiple economic uses of the Sound - transportation, fisheries, recreation, disposal - with a special emphasis upon the impacts of the region's weather and climate. In view of the many complex tradeoffs, exchanges, and possible conflicts underlying such use, there is a heightened need to comprehend the impacts of potential as well as actual perturbations in the environment which might be due to weather extremes or climatic variations.

4. THE PUGET SOUND ECONOMY

4.1 Economic Base

Today, the Puget Sound region's economic base spans a variety of manufacturing activities, complemented by the area's leading role as the distribution and service support center for the rest of Washington and the Pacific Northwest. Tables 2 and 3 summarize the employment base, by industry, of the Puget Sound region. In this report, the region has been defined to include each of the eleven counties contiguous to the boundaries of the Sound, excluding the Strait of Juan de Fuca.

Nearly 17 percent of nonfarm jobs in the region are in manufacturing. Most of these jobs are in industries related to capital goods investment in new equipment. A past leader, aerospace, has declined considerably, from an industry concentration standpoint, from its peak in 1968. The balance of manufacturing employment includes defense hardware, metals, machinery, ship building, trucks, instruments, forest products, and food processing.

Reflecting its function as the preeminent distribution and service support center for the Northwest, Seattle is a favorite location for service and trade firms. Puget Sound ports provide staging areas for goods moving north to Alaska and east to the Pacific Rim nations. The Port of Seattle, in particular, is a major gateway for bulk and container cargo in transit from the Far East to the U.S. interior.

The U.S. Navy has a substantial presence in Puget Sound. Bremerton, in Kitsap County, is the site of Puget Sound Naval Shipyard, the Naval Underseas Warfare Engineering Station, and the Naval Regional Medical Center. Tacoma hosts a number of military instalations, including the U.S. Army's Fort Lewis and McChord Air Force Base.

The capital of Washington is in Olympia, located at the southern tip of Puget Sound, in Thurston County. State government employment dominates the economy of Olympia, providing over 40 percent of nonfarm employment there. In total, Federal and State employment amounts to more than a quarter of all employment in the Puget Sound region.

Weather and climate conditions in and around the Puget Sound region influence many of the attributes and uses of its marine resources in ways which may be very complex and difficult to separate. Rainfall and mountain snow runoff influence river runoff into the Sound, which in turn may affect sewage levels or other factors determining the quality of water. Precipitation, temperature, wind, and humidity have diverse and critical effects on transport, agriculture, and fishing, as well as on tourism and recreation. This is particularly true whenever the weather departs from normal seasonal patterns.

Table 2.--Number of persons employed in Puget Sound counties in 1982, by industry.

	County									
Industry	Island	Jefferson	King	Kitsap	Mason	Pierce	San Juan	Skagit	Snohomish	Thurston
Agri,forest,&fish	142	74	4364	475	207	1685	65	2169	1053	998
Mining & quarry			269	90		114		14	103	25
Construction	432	142	29869	1394	227	6572	221	1018	4415	1358
Manufacturing	553	806	135020	1802	2294	22480	117	3852	31222	3120
Utilities	271	84	44132	1237	191	6219	161	1299	4825	1255
Trade	1756	1106	166379	8213	1389	33318	430	5356	23055	8764
Finance,ins.&r.e.	384	120	53612	1641	244	6783	95	656	3216	1706
Services	946	555	131107	8487	877	28491	586	3160	14543	6649
Government	2679	1080	92723	22901	1886	32061	441	4306	15540	18051
Other	8				8		22			
Total	7171	3966	657476	46240	7324	137724	2138	21828	97975	41928

Industry	Whatcom	Regional Total
Agri,forest,&fish	982	12214
Mining & quarry	106	721
Construction	1692	47340
Manufacturing	7052	208318
Utilities	1519	61193
Trade	9268	259034
Finance,ins,&r.e.	1482	69939
Services	6397	201798
Government	5622	197290
Other		38
Total	34120	1057890

Source: Seattle First National Bank, Seattle, Wa.

Table 3.--Employment distribution in Puget Sound counties in 1982, by industry. (In percent)

	County									
Industry	Island	Jefferson	King	Kitsap	Mason	Pierce	San Juan	Skagit	Snohomish	Thurston
Agri,forest,&fish	1.98	1.87	0.66	1.03	2.83	1.22	3.04	9.94	1.07	2.38
Mining & quarry			0.04	0.19		0.08		0.06	0.11	0.06
Construction	6.02	3.58	4.54	3.01	3.10	4.77	10.34	4.66	4.51	3.24
Manufacturing	7.71	20.32	20.54	3.90	31.32	16.32	5.47	17.65	31.87	7.44
Utilities	3.78	2.12	6.71	2.68	2.61	4.52	7.53	5.95	4.92	2.99
Trade	24.49	27.89	25.31	17.76	18.97	24.19	20.11	24.54	23.53	20.90
Finance,ins,&r.e	5.35	3.03	8.15	3.55	3.33	4.93	4.44	3.01	3.28	4.07
Services	13.19	13.99	19.94	18.35	11.97	20.69	27.41	14.48	14.84	15.86
Government	37.36	27.23	14.10	49.53	25.75	23.28	20.63	19.73	15.86	43.05
Other	0.11				0.11		1.03			

Industry	Whatcom	Regional Total
Agri,forest,&fish	2.88	2.63
Mining & quarry	0.31	0.12
Construction	4.96	4.79
Manufacturing	20.67	16.66
Utilities	4.45	4.39
Trade	27.16	23.17
Finance,ins.&r.e.	4.34	4.32
Services	18.75	17.23
Government	16.48	26.64
Other		0.42

Source: Seattle First National Bank, Seattle, Wa.

4.2 Seasonality of the Economy

Employment statistics are usually smoothed out to remove seasonal trends over the course of a year in order to better gauge underlying movements in the economy. In Washington, economic activity and employment are more seasonal than is the case nationwide.

The prevalence of seasonal industries such as forest products, food processing, construction, and tourism has contributed to the State's monthly unemployment rate averaging 1.5 percentage points higher than the national average since 1960.[1] Tables 4(a) and 4(b) and Figures 3 and 4 present the record of monthly unemployment rates for 1982 and 1983 for the Puget Sound region, by county, and in comparison with the U.S. as a whole.

The counties with the most pronounced seasonal unemployment, i.e. Jefferson, Mason, San Juan, Skagit, and Whatcom, are also the counties with the lowest population densities, as shown in Table 5. In contrast, the counties with the least seasonal unemployment, namely King and Kitsap, have the highest population densities. The most rural communities are the most seasonally sensitive.

In general, the most seasonal areas of the Sound lie to the west, north, and northeast and the least seasonal lie in the center, the east, and the south. During the period under review, the greatest interannual seasonal variability, as well as the highest levels of unemployment within the region, were recorded in 1983 in Skagit. It ranged nearly 11 points, from a high of 20.7 percent in January to a low of 9.8 percent in August of that year. The lowest interannual seasonal variability and lowest overall unemployment occurred in Kitsap and ranged only 1.7 points, from a high of 8.9 percent in January to a low of 7.2 percent in September of 1983.

Since seasonality is, in part, a reflection of the general weather and climate environment, it is likely that the most "seasonal" economies would also be the most "sensitive" in terms of the responsiveness of employment to local environmental events.

Figure 5 illustrates the comparative seasonality of unemployment in the Puget Sound region relative to that of the U.S. economy in general. Each bar represents the difference in the monthly deviation in Puget Sound unemployment expressed as a percent of monthly deviations for the U.S. While the general seasonal pattern is the same in both 1982 and 1983, month-to-month differences between the years could be due to a variety of sources at the regional level, including differences in annual weather patterns.

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[1] Quarterly Summary of Pacific Northwest Industries, Seattle First National Bank, February 1983.

Table 4(a).--1982 Unemployment rates in Puget Sound counties, by month (in percent).

Month/year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Island	10.3	10.6	10.1	9.7	9.1	9.1	9.7	9.8	10 .6	10.1	9.8	9.9	9.9
Jefferson	16.3	14.9	14.5	13.2	11.9	10.7	10.6	10.9	10 .5	12.2	12.7	13.8	12.6
King	9.0	9.4	9.4	9.3	9.8	9.7	10.3	10.2	10 .2	10.5	10.5	10.3	9.9
Kitsap	8.4	8.5	8.9	8.6	8.6	8.6	8.6	8.5	8 .7	9.4	8.9	8.8	8.7
Mason	16.9	15.3	17.5	14.9	14.0	13.4	12.9	12.0	12 .5	15.9	14.5	16.9	14.7
Pierce	11.9	12.0	11.8	11.5	12.2	12.3	12.5	12.3	12 .6	13.1	13.3	13.7	12.4
San Juan	13.9	12.9	11.8	10.0	8.3	6.3	5.5	5.9	6 .0	7.5	9.3	13.2	9.0
Skagit	20.3	19.2	16.9	16.5	14.5	13.9	11.9	12.1	13 .1	14.9	16.5	19.0	15.6
Snohomish	11.8	11.6	11.6	11.5	12.3	11.9	12.1	11.2	11 .3	11.5	12.0	12.5	11.8
Thurston	12.3	12.6	12.3	11.8	12.0	11.6	11.6	11.3	11 .6	12.4	13.0	13.2	12.1
Whatcom	15.3	14.2	13.7	13.1	12.1	11.9	11.6	11.3	11 .4	12.2	13.3	15.0	12.9
Region	10.6	10.7	10.6	10.4	10.8	10.6	10.9	10.7	10 .8	11.3	11.5	11.6	10.9
U.S.	8.6	8.8	9.0	9.3	9.4	9.5	9.8	9.9	10 .2	10.5	10.7	10.8	9.7

Source: Washington Bureau of Labor Statistics.

Table 4(b).--1983 Unemployment rates in Puget Sound counties, by month (in percent).

Month/year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Island	10.5	10.6	10.1	10.1	9.8	9.2	9.2	8.2	8.6	8.5	9.1	8.9	9.4
Jefferson	15.3	14.2	13.5	11.0	9.9	9.4	9.4	8.5	7.8	8.7	9.5	9.6	10.5
King	10.4	10.5	10.4	9.8	9.7	9.5	9.1	9.2	8.6	8.4	8.4	8.1	9.3
Kitsap	8.9	8.9	8.7	8.2	8.1	8.0	7.7	7.4	7.2	7.3	7.7	7.4	8.0
Mason	17.0	16.4	15.5	13.6	12.4	11.8	11.6	10.6	10.1	11.2	10.3	13.4	12.8
Pierce	14.2	14.1	13.6	12.6	12.4	12.0	11.8	11.1	11.2	11.4	11.4	11.1	12.2
San Juan	13.8	12.6	12.0	9.5	8.0	6.3	5.9	5.0	5.5	6.4	7.4	8.0	8.0
Skagit	20.7	19.5	17.8	16.1	14.7	12.6	11.4	9.8	9.9	11.3	13.3	14.8	14.2
Snohomish	13.8	13.0	12.9	12.3	12.3	11.8	10.8	10.2	9.6	9.3	9.7	9.9	11.3
Thurston	13.4	13.0	13.2	11.5	11.0	11.7	11.4	11.0	10.6	10.7	11.3	11.2	11.7
Whatcom	16.1	15.2	14.3	12.8	11.8	11.0	10.6	9.1	9.3	10.8	11.0	11.6	12.0
Region	12.1	11.9	11.7	10.9	10.7	10.4	9.9	9.6	9.2	9.2	9.4	9.3	10.3
U.S.	10.4	10.4	10.3	10.2	10.1	10.0	9.5	9.5	9.2	8.8	8.4	8.2	9.6

Source: Washington Bureau of Labor Statistics.

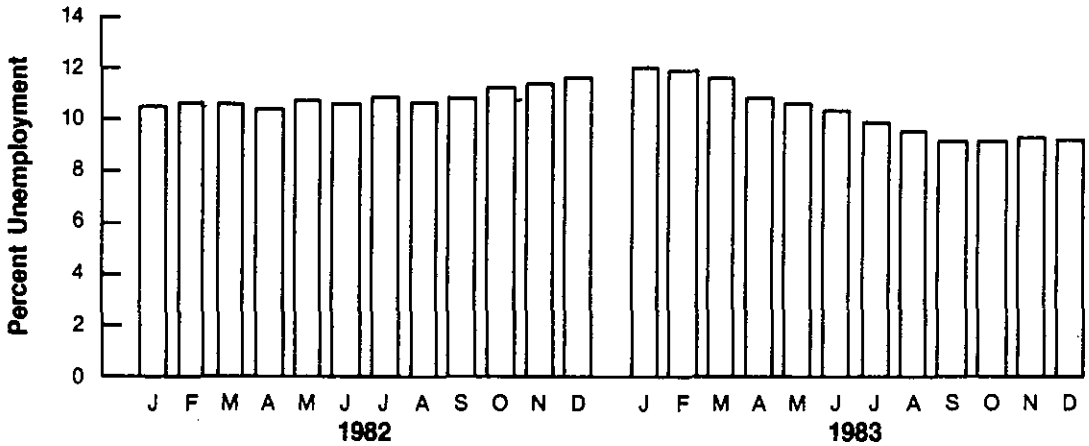


Figure 3 - Puget Sound region monthly unemployment rates

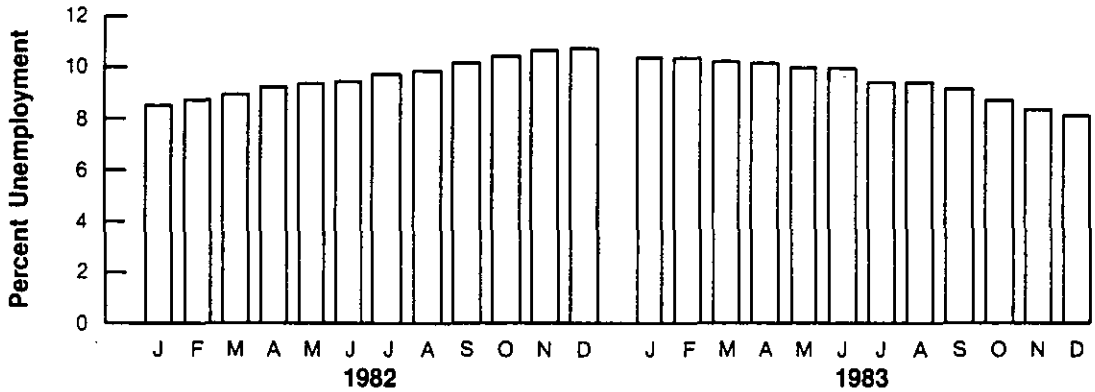


Figure 4 - U.S. monthly unemployment rates

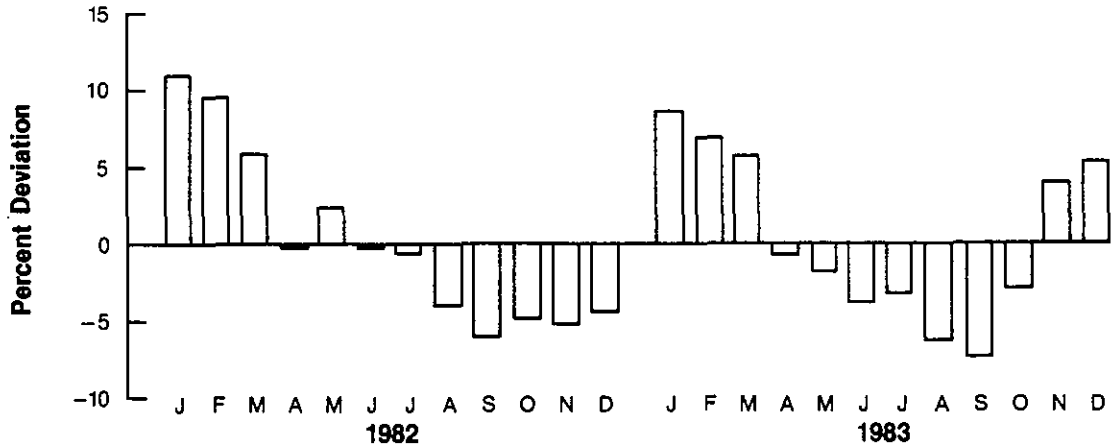


Figure 5 - Puget Sound unemployment deviations from U.S. rates.

The difference in monthly deviations in Puget Sound unemployment expressed as a percent of monthly deviations for the U.S.

Table 5.--Population, labor, and income distribution in Puget Sound counties.

County	Land area	Population	Pop. density	Total income	Per capita income	Labor
Island	212	47000	222	470.2	10006	15401
Jefferson	1805	16800	9	163.6	9739	6693
King	2128	1315800	618	17993.5	13675	708740
Kitsap	393	161600	411	1758.2	10880	64392
Mason	962	33600	35	317.3	9446	11083
Pierce	1676	507000	303	5152.6	10163	191704
San Juan	179	8700	49	98.2	11294	3926
Skagit	1735	66100	38	762.0	11529	34497
Snohomish	2098	360900	172	3518.7	9750	192235
Thurston	714	133500	187	1458.2	10923	58856
Whatcom	2162	112100	52	1059.4	9451	51502
Region	14064	2763100	196	32752.2	11853	1339029
Washington	68192	4285100	63	48310.2	11274	2061390

Source: Seattle First National Bank, Seattle, Wa.; land area in square miles, population density in number of people per acre, total income in millions of 1981 dollars, per capita income in dollars.

5. INTERNATIONAL TRADE

5.1 Major Ports of Puget Sound

Seattle Harbor is the fifth largest port in the United States, based on the value of waterborne foreign trade it handles (Table 6). The total value of 1983 goods transiting Seattle Harbor exceeded $25 billion, of which over $14 billion was in foreign trade (imports plus exports).

Of some fourteen ports in the Seattle Customs District, nearly 80 percent of all imports, by value, pass through the Port of Seattle, and 15 percent are handled by the Port of Tacoma. The value of imports by month for these two leading ports is displayed in Table 7.

The year-to-year monthly percent changes from 1982 to 1983 reflect the resurgence of the nation's general economy in the latter half of 1983 when Seattle's monthly imports showed increases ranging from 16 to 73 percent. Tacoma's monthly import increases ranged between 2 percent and 106 percent in the second half of the year.

These trends are also borne out by the relative increases in monthly ship arrivals at Port of Seattle between 1982 and 1983 (Table 8). Although total arrivals declined by one percent during the year at Port of Tacoma, most of that decline occurred in the first four months of 1983.

Due to its role as the leading gateway to Alaska and the Orient, Seattle is one of the three busiest container ports in the United States, and ranks ninth worldwide.

Table 6.--The top ten ports of the United States, 1983.

Rank	Port	Value of Foreign Trade (Millions of dollars)
1.	New York	42,272.1
2.	Long Beach	19,963.3
3.	Houston	17,699.2
4.	Los Angeles	15,402.3
5.	Seattle	14,352.7
6.	Baltimore	12,643.7
7.	New Orleans	11,100.1
8.	Oakland	9,459.8
9.	Norfolk	8,543.6
10.	Gramercy	8,143.2

Source: Facts and Figures On Commercial Sea/Air Traffic Of Seattle, July 1984, Port of Seattle Planning and Research.

Table 7.--Value of imports at Seattle and Tacoma ports, by month.

Port	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Seattle in 1982	855	860	1235	754	900	783	703	982	886	951	945	614	10468
Seattle in 1983	816	734	822	711	1023	865	1214	1145	1092	1128	1310	994	11854
Seattle (percent chg.)	-5	-15	-33	-6	14	10	73	17	23	19	39	62	13
Tacoma in 1982	173	81	161	151	159	172	229	145	156	189	220	131	1967
Tacoma in 1983	173	117	143	205	N/A	165	234	171	322	351	258	161	N/A
Tacoma (percent chg.)	0	44	-11	36	N/A	-4	2	18	106	86	17	23	N/A

Source: U.S. Census Bureau; Values in millions of dollars.

Table 8.--Ship arrivals at Seattle and Tacoma Ports, by month.

Port	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Seattle in 1982	109	98	97	105	100	98	89	90	95	102	103	90	1176
Seattle in 1983	72	84	106	99	112	100	98	118	104	123	116	117	1249
Seattle change (pct)	-34	-14	9	-6	12	2	10	31	9	21	13	30	6
Tacoma in 1982	79	75	110	76	57	78	76	82	66	80	105	62	946
Tacoma in 1983	76	68	88	69	76	86	74	84	83	79	86	64	933
Tacoma change (pct)	-4	-9	-20	-9	33	10	-3	2	26	-1	-18	3	-1

Source: Seattle and Tacoma Ports.

Seattle began handling containerized cargo traffic in 1971, and it has continued to expand substantially since then to a level of approximately ten percent of all cargoes in 1983 (Table 9). Total containerized cargo traffic which had remained level from 1981 through 1982, increased by 18 percent in 1983, another reflection of the improving economy in conjunction with the relative expansion of containerized cargo handling capabilities in Pacific Rim nations.

Inborne foreign container traffic increased from 29 percent of all Seattle cargoes in 1973 to 36 percent in 1983, while outborne foreign container traffic rose from 24 percent to 28 percent of the total. Whereas domestic and foreign container traffic had shown approximately equal percentages a decade before, foreign traffic was nearly twice as great as domestic by 1983.

5.2 Major Trading Partners of the Port of Seattle

The ten countries listed in Table 10 were the source of over 95 percent of the total value of imports into the Port of Seattle and, except for Italy, they are located on the Pacific Ocean. Nearly a half of all imports are from Japan and a fifth are from Taiwan.

In terms of the value of exports, the major trading partners with Seattle Harbor in 1983 were nearly the same as shown in Table 11 below. In exports, as in imports, the top four trading nations include Japan, Korea, Taiwan, and Hong Kong. Note also that the Port's balance of trade (the value of exports minus the value of imports) with each of these countries is negative, a result in part of the strong U.S. dollar.

Commodities imported into Port of Seattle are predominantly manufactured goods as shown in Table 12.

In terms of the value of commodities exported out of the Port of Seattle, fishery, agricultural and forestry products predominate as shown in Table 13.

The difference in the character of imports (which are largely manufactured) and exports (which are largely natural resource-derived) suggests that exports from Seattle Harbor could be more sensitive to weather, climate and environmental conditions than are imports into Seattle Harbor. Manufacturing, unlike most agriculture and fishing, takes place extensively within man-made and protected environments and is thus largely immune to perturbations in the natural environment.

Due to the multiplicity of possible geographical origins of exports as well as of imports, the relevance of such distinctions in weather sensitivity is not clear. The composition of export cargoes at Seattle Harbor may be influenced as much by weather events outside the region as those within. Because different kinds of shipments may require different kinds of cargo handling, port operations could conceivably be affected in unexpected ways by weather events both far and near.

Table 9.--Seattle harbor container traffic, 1973 - 1983.

Traffic	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1983 Pct chg
Foreign (in)	106	114	107	158	188	188	207	255	277	276	340	23.2
Foreign (out)	89	97	93	132	151	154	167	228	225	222	266	19.8
Domestic (in)	84	102	131	146	132	155	151	149	151	151	160	6.0
Domestic (out)	86	103	133	138	136	151	144	150	152	156	184	17.9
Total (in)	190	215	238	304	321	343	359	404	428	427	500	17.1
Total (out)	174	200	226	271	286	305	311	378	377	377	450	19.4
Total (all)	364	415	464	575	607	648	670	782	805	804	950	18.2

Source: Port of Seattle: Units are twenty-foot equivalent units (TEU).

Table 10. 1983 Ranking of major trading partners, by value of imports into Seattle harbor.

Rank	Country	Value (Millions of U.S. dollars)	Share (in %)
1.	Japan	$5,653.4	47.7
2.	Taiwan	2,281.9	19.3
3.	Korea	1,317.6	11.1
4.	Hong Kong	1,155.3	9.7
5.	Singapore	315.2	2.7
6.	Canada	183.2	1.5
7.	China	161.7	1.4
8.	Philippines	124.9	1.0
9.	Italy	78.6	0.7
10.	Malaysia	76.2	0.6
11.	All Others	506.3	4.3
	TOTAL	$11,854.1	100.0

Source: Facts and Figures on Commercial Sea/Air Traffic of Seattle.

Table 11. Exports from Seattle harbor, by destination, in 1983.

Rank	Country	Value (Millions of dollars)	Share (in %)
1.	Japan	950.9	38.0
2.	Korea	440.7	17.7
3.	Taiwan	287.8	11.5
4.	Hong Kong	145.0	5.8
5.	Philippines	88.1	3.5
6.	Singapore	72.4	2.9
7.	Canada	69.3	2.8
8.	United Kingdom	59.9	2.4
9.	India	54.3	2.2
10.	Thailand	35.0	1.4
11.	All Others	295.2	11.8
	TOTAL	$2,498.6	100.0

SOURCE: Facts and Figures On Commercial Sea/Air Traffic of Seattle, July 1984, Port of Seattle Planning and Research Department.

Table 12. Top ten commodity imports, ranked by value, Seattle harbor, 1983.

Rank	Commodity	Value (Millions of dollars)	Share (in %)
1.	Telecommunications	$1,897.7	16.0
2.	Clothing	1,534.7	12.9
3.	Road Vehicles	1,267.1	10.7
4.	Misc. Consumer Goods	1,159.1	9.8
5.	Footwear	637.4	5.4
6.	Misc. Manuf. Metal	505.5	4.3
7.	Office Mach. & Equip.	445.5	3.7
8.	Other Mach. & Equip.	385.7	3.2
9.	Textile Fibers	363.1	3.1
10.	Clinker	3,437.1	29.0
	TOTAL	$11,854.1	100.0

Source: Facts & Figures on Commercial Sea/Air Traffic of Seattle

Table 13. Top ten commodity exports, ranked by value, Seattle harbor, 1983.

Rank	Commodity	Value (Millions of dollars)	Share (in %)
1.	Fish	236.8	9.5
2.	Cereals, Grains	236.7	9.5
3.	Fruits & Veg	208.2	8.3
4.	Pulps & Waste Paper	160.5	6.4
5.	Paper & Paperboard	129.9	5.2
6.	Hides	117.5	4.7
7.	Nonferrous Metals	114.1	4.6
8.	Logs & Lumber	110.2	4.4
9.	Metal Scrap & Ores	78.0	3.1
10.	Other Mach. & Equip.	69.9	2.8
	All Others	1,036.8	41.5

Source: Facts and Figures, July 1984, Port of Seattle Planning and Research Department

6. COMMERCIAL FISHERIES

6.1 Oceanographic Effects on Landings

The local salmon industry suffered from depressed foreign demand due to the strong dollar in international markets, and rising supply costs as unfavorable oceanographic conditions made fish less abundant, and smaller in size. These conditions resulted in fewer landings, smaller fish at market, and less fishing effort in 1983.

6.1.1 Salmon

Commercial fisheries are an important component of the Puget Sound economy. The landings statistics reported here (Table 14 and 15) are for the Puget Sound only, although these commercial species are not necessarily caught in, or restricted to, the Sound. Pacific ocean cod is primarily caught off of Alaska, while many species such as salmon and groundfish (lingcod, sablefish, whiting, rockfish, flatfish) are predominantly coastal Washington fisheries. In addition, the major fisheries (salmon, Dungeness crab, groundfish) are intensely managed, resulting in annual variations due to gear restrictions, quotas, and length of the fishing season. Consequently, the landings data are difficult to interpret in relation to inter-annual variations and trends.

In 1983, a severe sea surface temperature anomaly, possibly associated with an El Nino event off the coast of Peru, resulted in a strong, northward intrusion of warm, high salinity water into the northern hemisphere (see Section 11, entitled, "Marine Environment"). This intrusion moved along the west coast of the United States as far as the Gulf of Alaska. Washington's coastal waters were 1-2°C warmer than normal from January to August. In the fall, sea surface temperatures dropped 1-3°C below normal. Onshore drift also exhibited some anomalous patterns. From January to March the onshore drift was 2-3 times greater than the normal. In April, onshore drift ceased altogether. During the summer the normal longshore drift bringing cooler water from the north did not occur. Consequently, upwelling of the nutrient rich deeper waters was very limited. Although the impact of this oceanographic event has not yet been completely evaluated, most salmon stocks originating from California, Oregon and Washington streams were severely depressed and the traditional salmon runs were spatially and temporally displaced.

The Puget Sound total salmon landings (Table 16 and 17) experienced dramatic declines of over 44 percent in weight and 50 percent in value in 1983. Landings for all five species of salmon (Figures 6 and 7) were depressed from 1982 (Note: pink salmon are a biennial, or alternate year, fishery; thus pink salmon data are compared to 1981 data). But not only were yields down sharply in 1983, the average weights of the salmon actually declined as well. The average weight of troll-caught chinook salmon declined from 12.9 pounds in 1982 to 12.0 pounds in 1983 (Table 18). Troll-caught silver (coho) salmon declined from an average of 5.8 pounds in 1982 to 4.7 pounds in 1983.

The warm, higher salinity water suppressed the upwelling of cooler, higher nutrient water during the springtime, thus reducing primary productivity. The resulting changes in the food web apparently reduced the growth rates in the salmon and increased mortality rates. Physiological stress was evidenced by reports from California and Oregon of the poor physical conditions and reduced fecundity of the salmon.

Table 14.--Puget Sound landings, in thousands of pounds.

Species	1981	1982	1983
Cod, Pacific	21892	24647	22008
Flatfish	7336	10527	10787
Halibut, Pacific	3304	4319	3585
Lingcod	1321	1456	2306
Rockfish	9873	11454	11269
Sablefish	2971	5765	5826
Salmon	41150	41810	23398
Salmon, aquaculture	1921	1495	1836
Tuna, albacore	386	175	275
Whiting, Pacific	2044	7302	13983
Clams, hardshell	2446	2122	2637
Crab, dungeness	1509	1247	1445
Geoducks	4290	5303	3523
Oysters	2246	2332	2295
Shrimp	966	170	389
Other	18699	16036	10476
Total	122354	136160	116038

Source: Preliminary data from National Marine Fisheries Service.

Table 15.--Puget Sound landings, in million dollars.

Species	1981	1982	1983
Cod, Pacific	4164	5469	5216
Flatfish	1609	2285	2534
Halibut, Pacific	3891	5517	5028
Lingcod	307	393	558
Rockfish	1664	2019	2320
Sablefish	1056	1753	1565
Salmon	37540	32198	16161
Salmon, aquaculture	724	1347	2678
Tuna, albacore	336	99	154
Whiting, Pacific	42	201	417
Clams, hardshell	1147	1059	1015
Crab, dungeness	1261	1147	1852
Geoducks	438	501	380
Oysters	2281	2619	2799
Shrimp	565	211	345
Other	1808	1718	1492
Total	58833	58536	44514

Source: Preliminary data from National Marine Fisheries Service.

Table 16.--Puget Sound salmon landings, in thousands of dollars.

Species	1981 Value	1982 Value	1983 Value
Chinook	6614	6434	3218
Chum	4245	5757	3581
Pink	9262	1	2859
Red (Sockeye)	11498	11604	1927
Silver (Coho)	5921	8402	4576
Total	37540	32198	16161

Source: Preliminary data from National Marine Fisheries Service.

Table 17.--Puget Sound salmon landings, in thousands of pounds.

Species	1981 Weight	1982 Weight	1983 Weight
Chinook	3720	3763	2628
Chum	5324	10448	5016
Pink	19628	1	8274
Red (Sockeye)	7456	18376	2261
Silver (Coho)	5022	9222	5219
Total	41150	41810	23398

Source: Preliminary data from National Marine Fisheries Service.

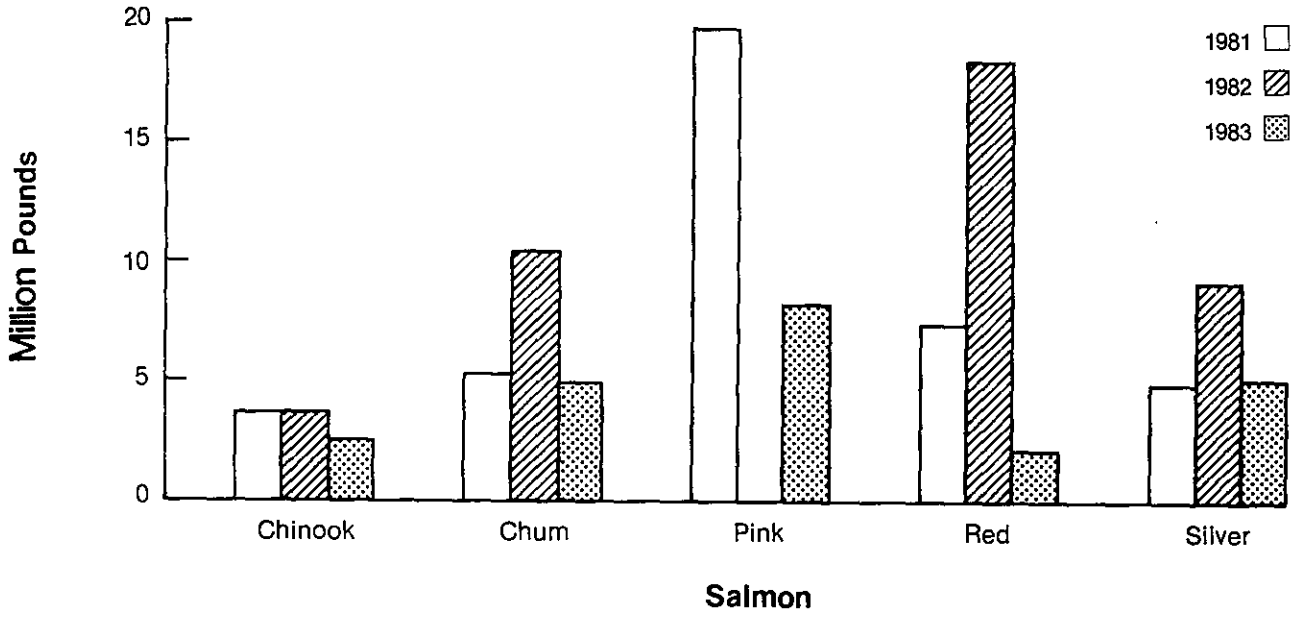


Figure 6 - Puget Sound salmon landings, by weight.

Figure 7 - Puget Sound salmon landings, by value.

Table 18.--Washington commercial troll chinook and silver (coho) salmon round (whole fish) weight, in pounds.

	1981	1982	1983
Chinook	13.2	12.9	12.0
Silver (Coho)	5.1	5.8	4.7

Preliminary data from Pacific Fishery Management Council.

Despite the impact on salmon fisheries, there were at least two circumstances which helped to mitigate those impacts as far as consumers were concerned. First of all, Alaska is the source of the majority of salmon landed and processed in the United States. The flow of warm ocean water had the effect of shifting the West Coast salmon runs more in favor of Alaska, as the salmon followed the cooler temperatures north. Secondly, the Alaska red (sockeye) and pink salmon runs have been very high in recent years. In 1983, the red (sockeye) salmon catch in Alaska reached a record-breaking 307.9 million pounds, up 69 percent from 1982. Chinook landings also increased, but declines occurred in the other three salmon species: chum salmon landings decreased 8 percent, pink salmon 16 percent and silver (coho) salmon 45 percent. The impact of these events on the Alaska salmon landings is difficult to determine since the fluctuation in landings over the past three years has been similar to that of 1983. Overall, the Alaska landings increased 12 percent in weight from 1982, but that was primarily due to the increased red (sockeye) salmon landings.

The anomalous ocean conditions of 1983 had a major effect on the salmon fisheries, but were not the only cause of the decline in landings. Poor weather and greatly increased rainfall (Section 9, entitled, "Weather and Climate of Puget Sound") during the salmon season (May - August) also affected the fishing effort. Market conditions were also poor, with declines in both import and export prices for salmon (Section 6.3), which may have decreased fishing effort even further.

The data presented in Tables 14 and 15 show the decline in landings in Puget Sound in 1983. The impact was much greater on the salmon fisheries. When the salmon catch is excluded from the total landings data (of which salmon is 21.5 percent), the value of production of the remaining fisheries increased overall (Table 19). Value increased by 2.0 million dollars in 1983, while landings weight decreased by 1.7 million pounds. The unit landed price of salmon continued a decline from 0.91 dollars per pound in 1981, to 0.69 dollars per pound in 1983, while the unit price of the remaining combined fisheries steadily increased.

Table 19.--Puget Sound landings.

A) Puget Sound Landings By Value: Thousand Dollars.

	1981	1982	1983
Total	58833	58536	44514
Salmon Only	37540	32198	16161
Total Less Salmon	21293	26338	28353

B) Puget Sound Landings By Weight: Thousand Pounds.

	1981	1982	1983
Total Pounds	122354	136160	116038
Salmon Only	41150	41810	23398
Total Less Salmon	81204	94350	92640

C) Puget Sound Landings by Price: Dollars/Pound

	1981	1982	1983
Total Landings	.48	.43	.38
Salmon Only	.91	.77	.69
Total Less Salmon	.26	.28	.31

Data preliminary from National Marine Fisheries Service.

6.1.2 Shellfish

Shellfish landings in Puget Sound increased over 15 percent in value from 1982, although the total weight landed decreased by nearly 8 percent. The decline in geoduck clam landings (Figure 8) was the major contributor to the decline in total pounds of shellfish landed. Geoduck landings dropped 33 percent, or nearly 1.8 million pounds from 1982. This drop was precipitated not by environmental factors, but by economic factors. The commercial geoduck fishery has been expanding since 1974, when a Japanese market developed for geoducks. In 1982, Japan began its own geoduck fishery, resulting in the the 1983 decline in demand for Puget Sound landings. Unit prices for geoducks have remained relatively stable (Table 20).

The hardshell clam fishery is comprised of manila, littleneck butter, horse and razor clams. Landings were up by 0.5 million pounds but total value declined 4 percent from 1982. Puget Sound landings followed the nation-wide trend of increased hard clam landings, but decreased prices.

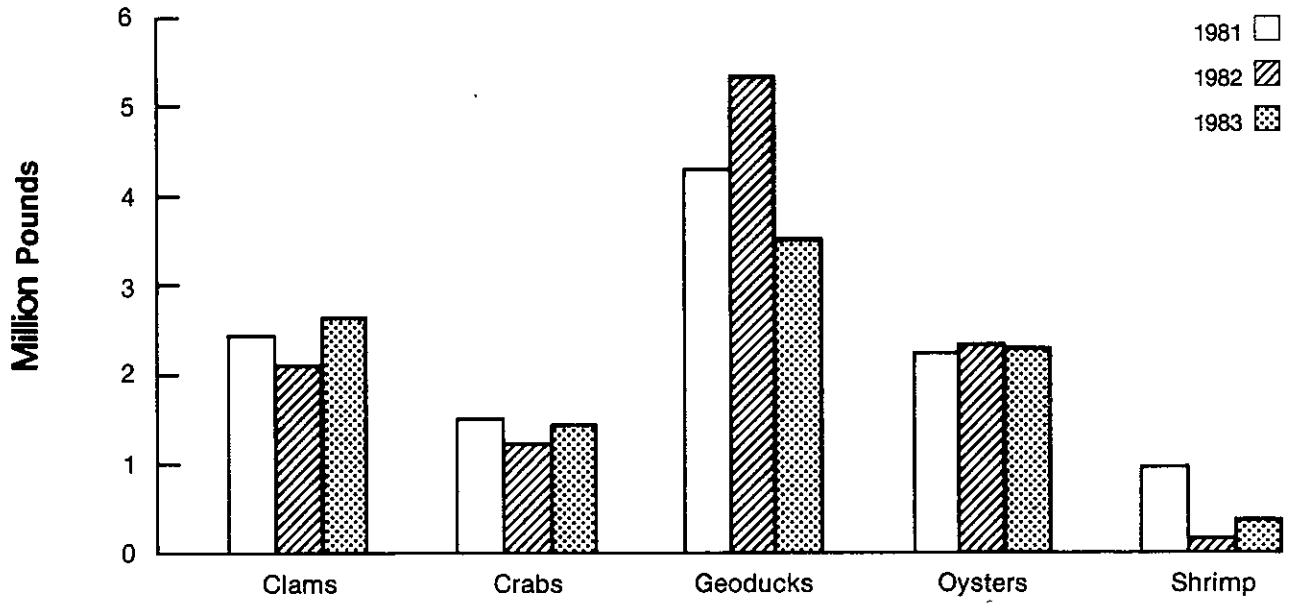


Figure 8 - Puget Sound shellfish landings, by weight.

Table 20.--Unit prices for Puget Sound shellfish (Dollars/Pound).

	1981	1982	1983
Clams, Hardshell	.47	.50	.38
Crabs, Dungeness	.84	.92	1.28
Geoducks	.10	.09	.11
Oysters	1.02	1.12	1.22
Shrimp	.58	1.24	.89

Based on preliminary data from National Marine Fisheries Service.

The 1982 landings of dungeness crab saw a record bad year for the entire Pacific coast, including Washington. In 1983, the Pacific coast landings continued to decline another 12 percent (4.1 million pounds) from the low catch of 1982. Only the state of Washington had an increase in the quantity of crabs landed. In Puget Sound, landings were up 15 percent or 198,000 pounds. Prices continued to increase in 1983 (Table 20).

National oyster landings declined in 1983 by 4.2 million pounds (8 percent) in weight and $9.2 million (12 percent) in value from 1982. The Pacific coast region, which includes California, Oregon, and Washington, provided 11 percent (5.4 million pounds) of the national oyster catch. The state of Washington supplied 77 percent of the Pacific coast catch. Puget Sound oyster landings composed 192,000 pounds, over 54 percent of the total Washington landings, and 4.6 percent of the national figure. The oyster catch has increased steadily in value from 1981 (Figure 9).

Pacific coast shrimp landings declined 53 percent in 1983, due in part to the effects of the ocean warming. Washington was an exception, with Puget Sound shrimp landings increasing 128 percent by weight, and 63 percent by value, from 1982, but this seemingly large increase must be viewed in the context of management decisions that governed the 1982 shrimp season. Shrimp landings in 1982 dropped dramatically (Figure 8 and 9) from 1981 because the 1982 season was shortened and size limitations were imposed. As a result, effort decreased as fishermen switched into other fisheries. Consequently, it is not possible to ascertain what effect the oceanographic anomaly had, specifically, on the 1983 shrimp landings from Puget Sound.

6.2 Fishing Productivity and Yield

Tables 21, 22, and 23 summarize data on landings by all treaty and non-treaty troll salmon fisheries in Washington State. In the case of treaty troll fisheries, the number of salmon per delivery declined 47 percent from 42.9 in 1982 to 22.8 in 1983. If pink salmon is excluded (it is only fished in alternative years, hence, there could be no catch in 1982), the decline is 51 percent, to 17.4 salmon per delivery.

The number of salmon landed per fisherman day in non-treaty troll fisheries declined 30 percent from 22.4 to 15.7 in the same period. Again, if pink salmon is excluded, the decline is even more severe, falling to 7.4 salmon per fisherman day, or barely 33 percent of its 1982 value.

Not only were yields down sharply in 1983, but the average weights of fish actually caught declined as well. The average round (whole) weight of chinook salmon declined from 12.9 lbs. in 1982 to 12.0 lbs. in 1983. The impact on silver (coho) was even greater. The weight of the average silver harvested declined from 5.8 lbs. in 1982, to 4.7 lbs. in 1983.

6.3 Foreign Exchange Effects on Price

The strengthening of the U.S. dollar relative to foreign currencies in foreign exchange markets since 1980 has tended to reduce the overall demand for U.S. exports generally, including salmon. Table 24 illustrates how the exchange rate of the U.S. dollar has risen in recent years.

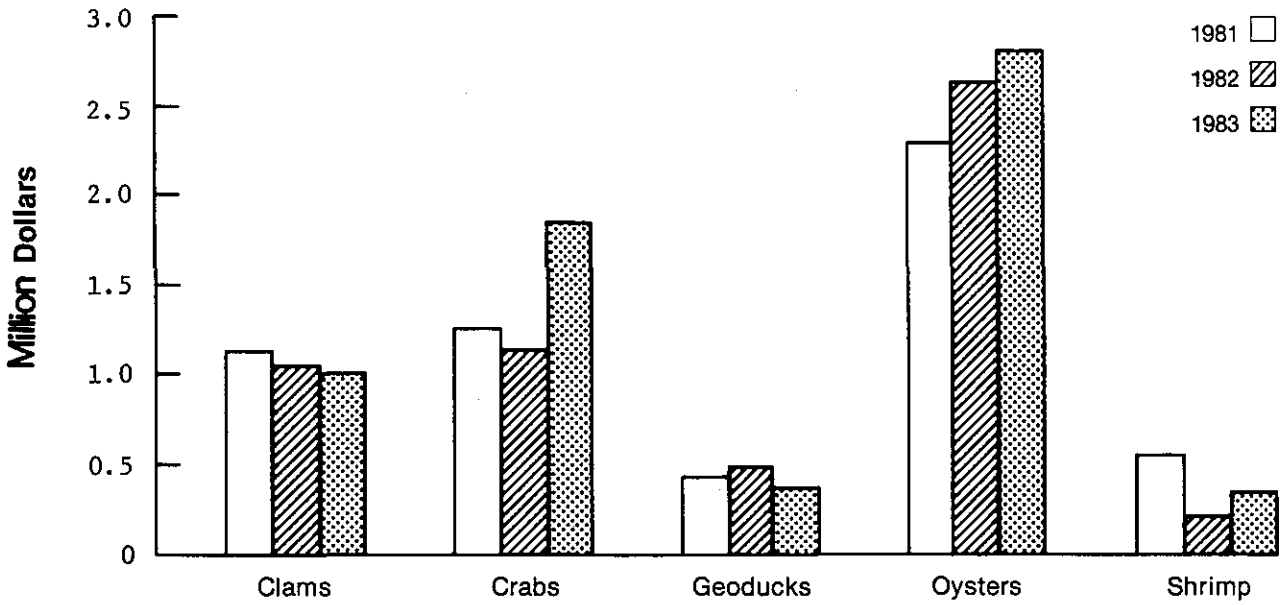


Figure 9 - Puget Sound shellfish landings, by value.

Table 21.--Washington treaty salmon troll deliveries and landings.

Month	Deliveries	Chinook	Coho	Pink	All salmon	Salmon/delivery
Jan-Apr 1982	993	16356	27	0	16383	16.50
May 1982	290	2424	41	0	2465	8.50
Jun 1982	389	2947	15672	0	18619	47.86
Jul 1982	621	9002	22861	0	31863	51.31
Aug 1982	615	1743	38316	0	40059	65.14
Sep 1982	648	2593	45273	0	47866	73.87
Oct 1982	43	380	98	0	478	11.12
Nov-Dec 1982	90	660	16	0	676	7.51
1982 Total	3689	36105	122304	0	158409	42.94
Jan-Apr 1983	1538	16665	34	0	16699	10.86
May 1983	351	2648	83	1	2732	7.78
Jun 1983	439	3037	5104	36	8177	18.63
Jul 1983	312	1389	5242	1564	8195	26.27
Aug 1983	547	755	15936	17600	34291	62.69
Sep 1983	354	435	11472	688	12595	35.58
Oct 1983	9	25	17	0	42	4.67
Nov-Dec 1983	133	1067	4	0	1071	8.05
1983 Total	3683	26021	37892	19889	83802	22.75

Source: Pacific Fishery Management Council. Deliveries are number of occurrences. Landings are number of fish.

Table 22.--Comparison of treaty salmon troll deliveries, 1982 & 1983.

	Number of fish per delivery		
Month	1982	1983	Pct. change
Jan-Apr	16.5	10.8	-34
May	8.5	7.7	-8
Jun	47.8	18.6	-61
Jul	51.3	26.2	-48
Aug	65.1	62.6	-3
Sep	73.8	35.5	-51
Oct	11.1	4.6	-58
Nov-Dec	7.5	8.0	7
Year	42.9	22.7	-47

Source: Pacific Fisheries Management Council.

Table 23.--Washington non-treaty salmon troll effort and landings (in hundreds).

Month	Effort	Chinook	Silver (coho)	Pink*	All salmon	Salmon/effort
May 1982	43	555	0	0	555	12.9
Jun 1982	7	87	0	0	87	12.4
Jul 1982	111	575	2244	0	2819	25.4
Aug 1982	1	4	147	0	151	151.0
Sep 1982	0	0	1	0	1	
1982 Total	161	1220	2391	0	3611	22.4
May 1983	40	283	0	0	283	7.0
Jun 1983	6	59	0	0	59	9.8
Jul 1983	28	135	39	1	175	6.2
Aug 1983	18	12	58	817	887	49.2
Sep 1983	6	4	134	0	138	23.0
1983 Total	98	493	231	818	1542	15.7

Source: Pacific Fisheries Management Council.

*Pink is 0 in 1982 because they are only fished in alternate years.

Table 24. Trade-weighted exchange rate of the U.S. dollar. (March 1973 = 100)

Year	Exchange Rate
1978	92.4
1979	88.1
1980	87.4
1981	102.9
1982	116.5
1983	125.3

Source: Quarterly Trade & Economic Trends, 1983:IV; Port of Seattle, Planning and Research Department

Salmon exports through the Port of Seattle declined 15.3 percent, from 45,186 metric tons in 1982, to 38,283 metric tons in 1983. The increased relative strength of the U.S. dollar favored increased U.S. imports of foreign-caught fish. Imports of fresh and frozen salmon combined, from foreign sources, increased 13.1 percent from 3,649 metric tons in 1982 to 4,126 metric tons in 1983 (Tables 25 and 26).

Except for imported fresh salmon, which increased in price from $3,163 per metric ton to $3,580 per metric ton in 1983, there was a general decline in prices of both imports and exports of salmon. Import prices of frozen salmon declined 9.4 percent, while export prices declined for fresh red (sockeye) salmon by 9.3 percent, for fresh chinook by 16.5 percent, for fresh chum by 15.1 percent, for fresh pink salmon by 7.7 percent, and for all exported salmon combined by 12 percent.

The increasing strength of the U.S. dollar relative to foreign currencies put downward pressure on salmon export prices in dollar terms worldwide as imports became more competitive and relatively cheaper to obtain. This was true, of course, for all other U.S. goods and services, including other categories of fish, traded in international markets. This strong dollar trend tended to squeeze the profit margins of U.S. commercial fisheries and might have led to cutbacks in fishing effort by the industry whether or not anomalous oceanographic conditions had occurred along the Pacific coast within the same period. The simultaneous occurrence of anomalous oceanographic conditions pushing the fishery towards Alaska and away from the continental West Coast, tended to depress profits even more for commercial fisheries based in Washington, Oregon, and California.

In summary, the local salmon industry was caught between depressed relative market demand prices in foreign markets due to the strengthening dollar, and increased relative market supply costs in fisheries operations, as fish became less abundant and smaller in size due to unfavorable oceanographic conditions. The result was fewer landings, smaller fish, and less fishing effort in 1983.

Table 25.--Salmon imports at Port of Seattle, 1982 & 1983.

Category	1982	1983
Tons fresh	1760	1730
Value fresh ($)	5567426	6191228
Price fresh ($/metric ton)	3163	3580
Tons frozen	1889	2397
Value frozen ($)	9075304	10431622
Price frozen ($/metric ton)	4803	4352

Source: National Marine Fisheries Service, NOAA.

Table 26.--Salmon exports at Port of Seattle, 1982 & 1983.

Category	1982	1983
Tons red fresh	19736	17323
Value red fresh ($)	82418507	65637788
Price red fresh ($/metric ton)	4176	3789
Tons chinnok fresh	819	1085
Value chinook fresh ($)	4972134	5510706
Price chinook ($/metric ton)	6068	5078
Tons chum	7040	7035
Value chum fresh ($)	24403407	20691493
Price chum ($/metric ton)	3466	2941
Tons pink fresh	5441	2200
Value pink fresh ($)	14136773	5276191
Price pink ($/metric ton)	2598	2398
Tons other	12150	10640
Value other ($)	51455810	35222489
Price other ($/metric ton)	4235	3311
Tons all salmon	45186	38283
Value all salmon	177386600	132338700
Price all salmon	3926	3457

Source: National Marine Fisheries Service, NOAA.

7. AGRICULTURE, LIVESTOCK, AND FORESTRY

7.1 Weather Effects On Growing and Harvesting

The predominant agricultural growing areas of Washington State are not located in the immediate Puget Sound area, but in the central and eastern regions of the State. However, the Sound is a major Pacific Northwest staging area for the transport and distribution of State-wide agricultural produce and general agricultural weather may be influenced by changes in oceanographic conditions along the West Coast. Consequently, commercial activities in Puget Sound and in Seattle particularly, can be affected by changes in regional agricultural weather conditions beyond the immediate vicinity.

During the first half of 1983 the surge of warm water along the West Coast produced a flow of warm, moist air, above normal precipitation, and above normal mountain snow melt during the State's agricultural growing season. The result was a record-setting year for agriculture in Washington.

The 1983 crop season began with the seeding of fall grains in late August 1982. Soil moisture conditions were adequate at the time of seeding and favorable growing conditions during the spring resulted in good crop outlooks. However, heavy precipitation, which was as much as 200 percent above normal in Yakima, hindered seeding of spring-seeded crops during March. Heavy, snowfall in the fruit-producing areas of eastern Washington limited early fruit planting in some areas.

Warm weather during the first week of June preceded a gradual cooling trend during the latter half of the month. Cool, wet weather conditions predominated on both sides of the Cascades during July. Constant rainfall that delayed cutting State-wide plagued hay farmers all month. Warm sunny weather prevailed throughout most of the month of August. Temperatures were above normal with a minimum of rainfall. Winter wheat and barley harvest continued through the month with most areas reporting above average yields.

September temperatures were generally on the cool side and weather conditions during October were variable. By the end of the month, fall seeding of the 1984 winter wheat crop was complete.

A more detailed, quantitative, accounting of weather conditions in the western part of the State is presented in Section 9 of this report, entitled, "The Weather and Climate of Puget Sound".

7.2 Agricultural Productivity and Yield

The total value of all agricultural commodities produced in Washington State during 1983 set a new record of 3.3 billion dollars, a seven percent increase over 1982. Field crops, representing 46.5 percent of the total, yielded substantial gains in both value and production: barley increased 42.3 percent in value and 10.1 percent in production. Similarly, hay increased 21.3 percent in value and 2.8 percent in production, wheat grew 14.3 percent in value and 21.9 percent in production, and potatoes gained 10.5 percent on a production increase of 1.4 percent.

Acreage reductions - which tend to reduce marginal land - when combined with high production due to good growing conditions, led to increased yields in some crops such as wheat. The wheat yield increased 24.8 percent from 46.0 bu. per acre to 57.4 bu. per acre. See Table 27 and Table 28 of planting acreages, production, and yields for selected crops in Washington State.

The only substantial decline was in grain corn which declined 22.7 percent in value due to an even greater decrease in production of 29.2 percent, in response to acreage reductions. In view of the fact that the average quality of corn acreage increased in 1983 as marginal land was withdrawn, the decline in corn yield could have been due to differences in the weather between the years.

Table 27.--Value of Washington farm products, 1982 & 1983.

Product category	1982 ($ million)	1983 ($ million)	% Change	1982 Production	1983 Production	Pct. chg. prod.
Field crops	1358.9	1517.1	11.6			
Wheat (1000's bu.)	555.5	635.0	14.3	138880	169320	21.9
Potatoes (1000's cwt.)	218.1	241.0	10.5	52800	53560	1.4
Hay (000's tons)	187.4	227.3	21.2	2889	2971	2.8
Barley (1000's bu)	101.3	144.2	42.3	49410	54400	10.1
Hops (1000's lbs.)	93.1	92.1	-1.0	58167	51145	-12.0
Grain corn (1000's bu.)	82.7	63.9	-22.7	27550	19500	-29.2
Silage corn	30.4	28.7	-5.5			
Other	90.4	84.9	-6.0			
Livestock & dairy	906.5	942.7	3.9			
Milk (millions of lbs)	440.0	472.3	7.3	3222	3482	8.0
Cattle & calves (1000's)	348.0	356.2	2.3	563830	589850	4.6
Eggs (millions)	60.3	58.1	-3.6	1334	1232	-7.6
Other	58.2	56.1	-3.6			
Fruit,nuts & berries	467.5	503.1	7.6			
Apples (1000's tons)	297.4	311.6	4.7	1300	1500	15.3
Pears (1000's tons)	60.3	61.8	2.4	266	280	5.2
Sweet cherries (1000's)	37.9	55.7	46.9	66	89	34.8
Grapes	31.3	34.8	11.1			
Other	40.6	39.2	-3.4			
Specialty	170.5	171.8	0.7			
Vegetables	153.9	129.2	-16.0			
Sweet corn	36.4	23.5	-35.4			
Green peas	31.3	18.1	-42.1			
Asparagus	29.7	35.2	18.5			
Other	56.5	52.4	-7.2			
Total	3057.2	3263.9	6.7			

Source: Foreign Agricultural Service, USDA.

Table 28.--Planting acreages, production, and yield for selected crops in Washington State.

CROP	(Thousands of acres)					
	1982			1983		
	Acres	Prod.	Yield	Acres	Prod.	Yield
All Wheat	3,020	138,880	46.0	2,950	169,320	57.4
Winter	2,730	N/A	N/A	2,750	N/A	N/A
Spring	290	N/A	N/A	200	N/A	N/A
Barley	850	49,410	58.1	880	54,400	61.8
Oats	68	N/A	N/A	75	N/A	N/A
Corn	220	27,550	125.2	160	19,500	121.9
Dry Beans	33	N/A	N/A	16	N/A	N/A
All Hay	830	2,889	3.5	850	2,971	3.5

Source: USDA, Statistical Reporting Service

Note: Units of production are in thousands of bushels, except for hay which is in thousands of tons.

Yields are in units of production per acre.

N/A indicates data is not available.

Fruit, nuts, and berries rose 7.6 percent in value, with apples enjoying a production increase of 15.4 percent in response to ideal apple growing conditions.

Vegetable products, however, declined 16 percent in value led by green peas which declined 42.2 percent and sweet corn which was off 35.4 percent. Nonetheless, asparagus increased 18.5 percent in value in 1983. Data on changes in vegetable production is not available.

Livestock and Dairy products together yielded 28.9 percent of the State's total value of farm production and grew 4 percent from 1982 to 1983 reflecting production increases of 8.1 percent for milk and 4.6 percent for cattle and calves.

Forestry products, including lumber, paper, and furniture products increased 3.8 percent in value to $6.2 billion. A major component was lumber production which increased nearly 32 percent since 1982. Forest product exports from Port of Seattle are displayed in Table 29. The value of forest product exports out of Seattle remained virtually level in 1983 at $831.8 million, up only 0.4 percent from 1982. The major export markets, i.e. Japan (55.9 percent), China (19.8 percent), Canada (10.0 percent), and Korea (9.9 percent) remained the same in both years.

Table 29.--Value of forest product exports from Port of Seattle, in thousands of dollars.

Destination	1982	1982 Pct. dist.	1983	1983 Pct. dist.
Canada	65845	8.0	83249	10.0
China	138274	16.7	164993	19.8
Japan	510025	61.6	464718	55.9
Korea	70548	8.5	81940	9.9
Other	43397	5.2	36850	4.4
Total	828089	100.0	831750	100.0

Source: Facts and Figures, 1983; Port of Seattle, Seattle, Wash.

Despite the national housing industry's recovery since the bottom of the recession in 1982, and although production levels were up in 1983, the forest industry in Washington and Oregon has continued to languish. Since 1979, the Pacific Northwest's forest industry has suffered a number of substantial economic setbacks. These have led to the closing of more than 150 out of 800 sawmills, and a concomitant decline in workforce from 200,000 to fewer than 150,000, which would have overwhelmed any conceivable weather impacts during the period.

Reasons include over-investment in expensive advance contracts by timber companies prior to the recession, increasing competition from lower cost producers in the southern states, and the strengthening dollar.

Nonetheless, the industry appears to have good prospects in the future for continuing expansion of more profitable exports to Pacific nations.

8. TOURISM AND RECREATION

Tourism is a very important sector of the Puget Sound economy. Roughly 10 percent of Washington State's employment is dependent upon meeting the demands of visitors from outside the Northwest region. The scope of the tourism industry is widening. The natural scenic beauty and availability of outdoor activities continue to attract tourist dollars but they are being increasingly enhanced by the urban attractions of the greater Puget Sound region as well. For example, hotel space in the Puget Sound area virtually doubled in 1982, the Takoma Dome was opened in the spring of 1983, and plans are underway for a $90 million convention center in Seattle.

Recreation in the Puget Sound region is largely oriented toward the out-of-doors. Among the major attractions are downhill and cross-country skiing; coastal fishing for salmon, tuna and bottom fish; fresh water fishing for trout, steelhead and bass; camping, hiking, boating, city sightseeing, river rafting, Indian culture and historic sites. Popular spectator sports include professional baseball, basketball, football, hockey, rodeos and volleyball. Golf and tennis are enjoyed year around.

Hotel and lodging service employment in the Puget Sound region increased 8.2 percent during the first nine months of 1983 compared to the same period the previous year (Table 30(a) and 30(b)). Within the region, King County, the seat of Seattle, has dominated the hotel and lodging service trade with nearly 70 percent of the region's hotel and lodging service employment. Pierce County ranks second with eight percent.

Visitations to the twenty-two State parks in the Puget Sound region remained virtually unchanged from 1982 to 1983 at 8.7 million (Table 31, Figures 10(a)-10(b)). This was so despite a 6.6 percent increase in visitations in the same period for the State of Washington as a whole, and despite the fact that the Puget Sound region represented twenty percent of the State's total in 1983.

Increasing Puget Sound hotel and lodging service employment and rising Washington State park attendance are explainable as reflections of the generally improving condition of the economy. The contrast between these overall gains and no growth in visitations at Puget Sound State parks during 1983 may be explained by the fact that marine-oriented parks cater more to recreational fishermen than do either urban hotels or non-marine parks. The oceanographic effects which devastated commercial salmon fisheries in the region during 1983 may have had similar, though lesser, effects on the recreational fishermen who normally visit such parks. Poor fishing expectations may have led them to cut short their stays or not go fishing at all, at either State parks or other fishing sites within Puget Sound.

Indeed, angler's recreational fishing effort as measured by the total number of recreational fisherman days spent, declined by nearly four percent between 1982 and 1983 (Table 32, Figures 11-12). The total recreational salmon catch declined for all species except coho which increased only slightly by 1.6 percent. The chinook catch declined by nearly 55 percent and the combined catch for all salmon species fell off more than 16 percent. The result was that the average angler's daily catch declined over 12 percent from 1.43 salmon

Table 30(a).--1982 Hotel and lodging service employment in Puget Sound counties, by month.

County	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Island	55	56	61	59	58	65	109	123	65	59	54	51
Jefferson	91	86	92	108	123	127	137	153	147	129	118	106
King	7179	7133	7289	7134	7278	7649	7700	7751	7952	7684	7870	7942
Kitsap	216	215	212	221	228	225	280	293	289	241	223	222
Mason	86	114	120	132	127	136	151	150	127	124	104	91
Pierce	845	878	862	840	756	907	984	998	985	841	883	975
San Juan	207	207	248	245	308	345	544	601	482	329	269	220
Skagit	121	125	120	131	154	169	174	172	156	144	137	133
Snohomish	453	446	453	361	397	404	398	423	409	407	397	404
Thurston	538	565	565	542	554	550	560	566	540	508	502	511
Whatcom	405	391	408	418	423	436	452	411	432	342	328	324
Total	10196	10216	10430	10191	10406	11013	11489	11641	11584	10808	10885	10979

Source: Washington Employment Security Department.

Table 30(b).--1983 Hotel and lodging service employment in Puget Sound counties, by month.

County	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Island	64	61	66	59	64	77	101	128	71
Jefferson	213	223	235	289	309	345	359	366	346
King	7870	7805	8048	8184	8244	8373	8445	8592	8606
Kitsap	208	214	214	246	245	258	253	254	258
Mason	104	97	115	126	125	142	144	146	132
Pierce	968	1008	970	1021	854	996	1052	1048	1021
San Juan	203	193	238	264	319	440	557	603	496
Skagit	116	119	125	135	140	159	159	175	177
Snohomish	295	297	302	328	321	373	368	384	418
Thurston	502	508	515	517	521	524	516	508	485
Whatcom	279	298	318	341	347	376	367	376	359
Total	10822	10823	11146	11510	11489	12063	12321	12580	12369

Source: Washington Employment Security Department.

Table 31.--Attendance at Puget Sound State Parks, 1982 & 1983 (number of visitations).

State park	1982	1983	Percent change
Belfair	281373	163499	-42
Blake Island	218662	253062	16
Camano Island	363475	357847	-2
Dash Point	469221	446482	-5
Dosewallips	446880	373621	-16
Fay Bainbridge	241819	190003	-21
Fort Casey	484041	490313	1
Fort Ebey	160781	185687	15
Fort Flagler	503083	596238	19
Fort Worden	1316311	1231852	-6
Illahee	586900	664618	13
Kitsap Mem.	313898	281221	-10
Kopachuck	123473	114286	-7
Manchester	246341	338883	38
Old Fort Town	141331	135382	-4
Penrose Point	195734	160419	-18
Potlatch	307869	279601	-9
Saltwater	571117	696808	22
Scenic Beach	166932	166395	0
Sequim Bay	881642	912967	4
South Whidbey	195284	172836	-11
Twanoh	442192	451054	2
Region total	8658359	8663074	0
State total	39696139	42311476	7

Source: Washington State Parks and Recreation Commission.

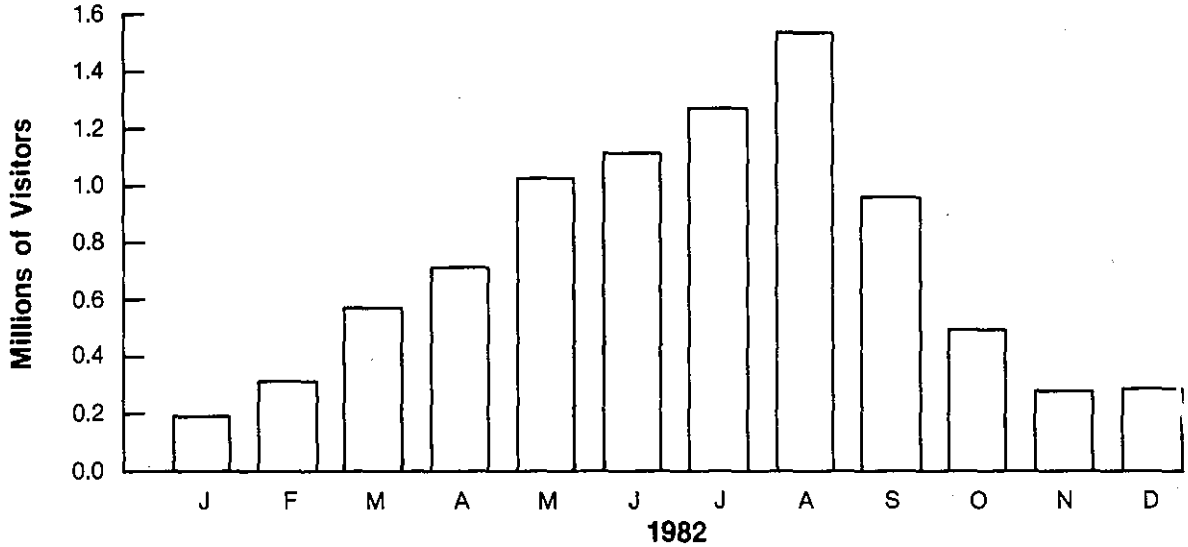


Figure 10(a) - Monthly visits to State parks in Puget Sound, 1982.

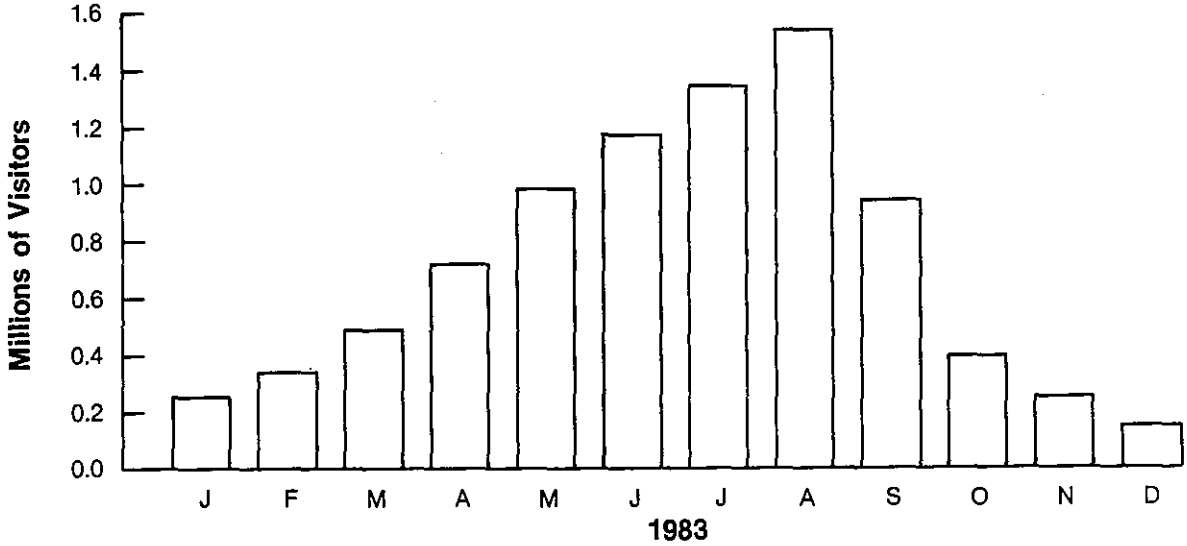


Figure 10(b) - Monthly visits to State parks in Puget Sound, 1983.

Table 32.--Washington marine recreational salmon fishing effort and landings, by month.

Month/year	Effort	Chinook	Silver (Coho)	Pink*	All salmon	Total landings/ effort
Apr 82	0	0	0	0	0	
May 82	2700	700	100	0	800	0.30
Jun 82	41600	41900	20600	0	62500	1.50
Jul 82	107900	50700	112700	0	163400	1.51
Aug 82	55300	13100	58700	0	71800	1.30
Sep 82	10300	200	13400	0	13600	1.32
Oct 82	300	0	500	0	500	1.67
Apr 83	0	0	0	0	0	
May 83	3200	900	400	0	1300	0.41
Jun 83	34100	24900	22000	0	46900	1.38
Jul 83	79000	14200	82200	400	96800	1.23
Aug 83	72500	6400	80000	3900	90300	1.25
Sep 83	20700	2000	24700	200	26900	1.30
Oct 83	0	0	0	0	0	
1982 Total	218100	106700	206000	0	312700	1.43
1983 Total	209500	48300	209300	4500	262100	1.25

Source: Pacific Fisheries Management Council; Effort: Angler fishing days.

*Pink is 0 in 1982 because they are only fished in alternate years.

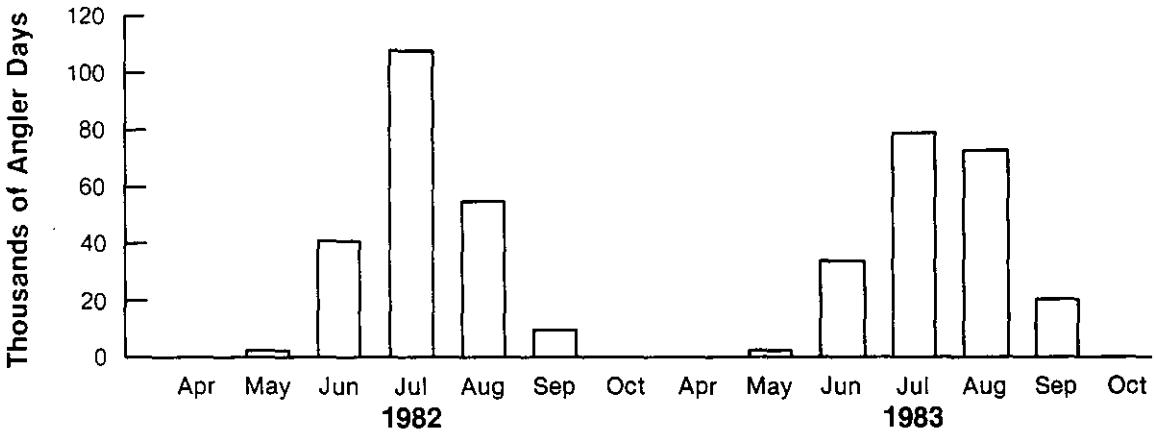


Figure 11 - Monthly salmon angler fishing days in Washington State, 1982.

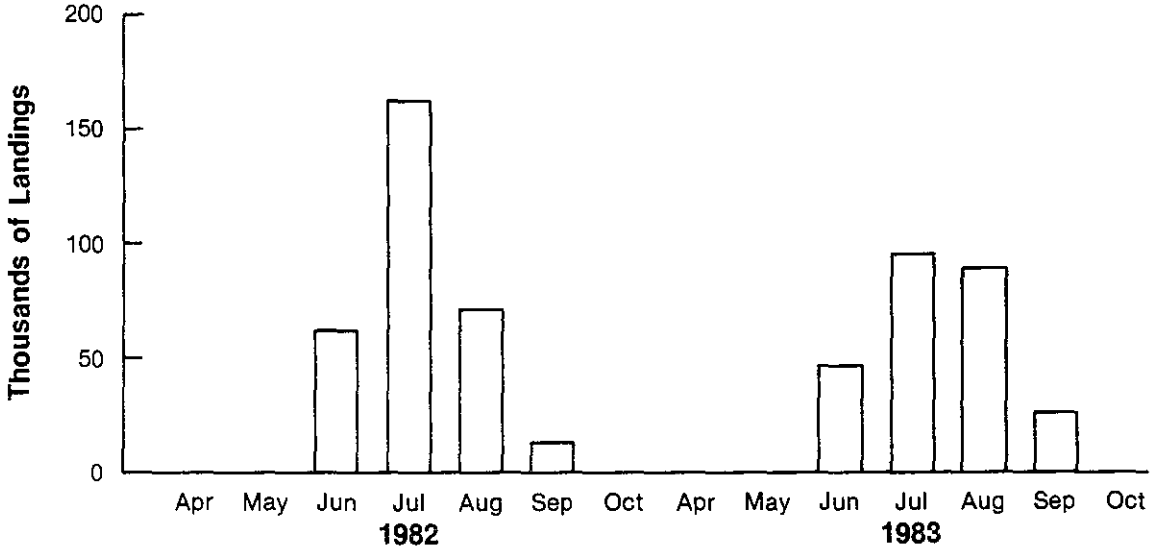


Figure 12 - Monthly salmon landings in Washington State, 1983.

per angler day to 1.25 salmon per angler day. To the extent that recreational fishing is consumptive in nature, the motivation to fish will tend to decline.

This interpretation is further supported by U.S. Coast Guard data on the number of search and rescue operations conducted in Puget Sound during 1982 and 1983 (Table 33). The total number of search and rescue operations declined by 3.1 percent between the years and the number of recreation-related search and rescue operations, representing over three-quarters of the total, declined by 6.5 percent in the same period. This could be attributed to an overall decline in recreational fishing activity as a result of the anticipated sharp decline in the salmon catch in 1983.

Table 33.--Search and rescue operations in Puget Sound, by month.

	1982		1983	
Month	All cases	Recreation only	All cases	Recreation only
Jan	41	28	38	26
Feb	42	32	50	35
Mar	59	43	60	40
Apr	70	57	67	46
May	112	95	114	89
Jun	116	94	91	76
Jul	158	132	147	116
Aug	133	106	150	128
Sep	99	85	83	65
Oct	60	43	42	33
Nov	35	21	61	38
Dec	40	22	32	17
Total	965	758	935	709

Source: U.S. Coast Guard.

9. WEATHER AND CLIMATE OF PUGET SOUND

Introduction

The following section discusses the weather and climate in Puget Sound and other parts of the State of Washington based largely on the data of four National Weather Service observing sites for which Monthly and Annual Local Climatological Data Summaries are published by NOAA's National Climatological Data Center (NCDC). These are supplemented by four additional sites in the upper part of Puget Sound, Whidbey Island Naval Air Station, Bellingham, Washington, Victoria, and Vancouver, British Columbia, Canada. Figure 13 shows names and locations of the eight stations used.

Monthly precipitation totals and monthly average temperature data are presented for the first eight of the stations for both 1982 and 1983, while data for the latter four stations is presented only for 1983. Normals for the period 1951 to 1980 are presented for all eight of the stations. The precipitation and temperature data for the eight stations are presented in Tables 34 and 35.

General Summary

Numerous storms, fueled by warmer than average surface water temperatures in the eastern north Pacific, struck the west coast of Washington during January and February of 1983. The gale force winds and heavy rains in these storms caused flooding and wave damage along coastal areas and flooding and wind damage inland. The warm water along the coast, attributed to the "El Niño" phenomenon, added additional heat and moisture to the normally moist flow of air inland in these storms. This resulted in very heavy precipitation and melting of snow in certain mountain areas. Heavy rains and high winds occurred in March, May, July, September, November and December. The months of April, July, and October each had a day in which one or more tornadoes occurred somewhere in the State of Washington.

Precipitation for the entire year was significantly above normal at five of the eight weather stations shown in Figure 13. Precipitation was near normal at Seattle-Tacoma International Airport, and below normal at Stampede Pass on the crest of the Cascade Mountains, Bellingham, and Whidbey Island. Figure 14 presents yearly totals for 1982, 1983, and normal yearly precipitation totals for the eight of the 12 stations. Note that the precipitation for 1982 falls between amounts for 1983 and normal amounts for each of the stations shown. During the year November was the wettest month in total precipitation, while July was wettest relative to normal.

Temperatures were above normal throughout the first six months of the year, but were below normal during July, September, October, and December. Figure 15 shows average yearly temperatures at the stations for 1982, 1983, and the normal values for the thirty-year period ending in 1980. The region was overall above normal in temperature for 1983 ranging from 0.6° above normal at Walla Walla, to 4.3° above normal at Whidbey Island. Only Stampede Pass in the mountains showed near normal temperatures over the year.

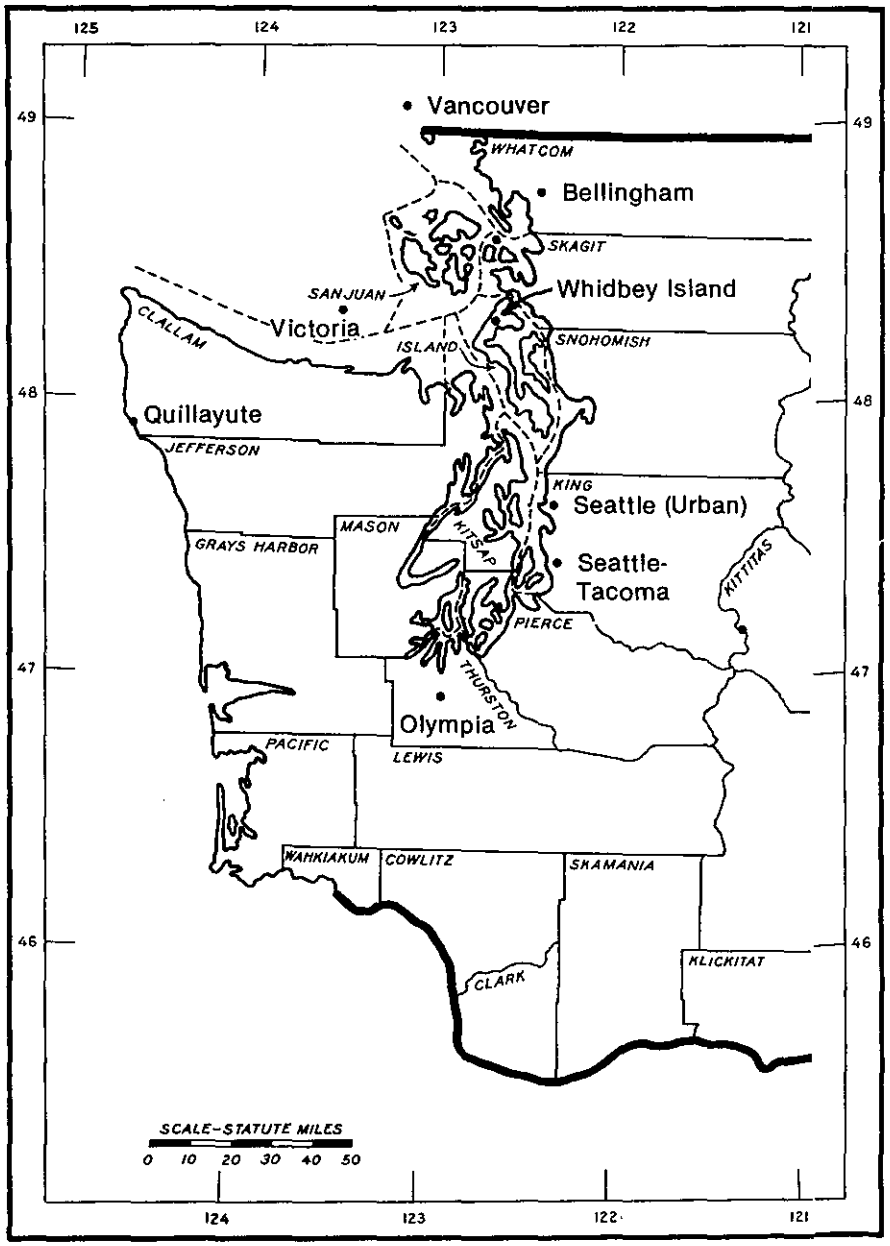


Figure 13 - Selected meteorological stations in Washington State and in Canada. (Modified NWS Hydrological Services map).

Table 34.--Monthly and annual precipitation totals for selected stations in Washington State and in Canada: (A) Normal amounts for 1951-80; (B) Precipitation totals in 1982; (C) Precipitation totals in 1983; (D) Percent departures from normal precipitation in 1983. Precipitation data for the four stations in upper Puget Sound were not obtained for 1982.

(A) Monthly Precipitation Normals for 1951-80 (inches).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Victoria, BC, Can.	4.21	2.98	2.48	1.32	1.06	1.18	0.69	0.87	1.27	2.83	4.20	5.02	28.11
Vancouver, BC, Can.	5.80	4.59	3.69	2.40	1.87	1.78	1.17	1.46	2.41	4.81	5.56	6.51	42.05
Bellingham, WA	4.79	3.51	2.97	2.43	2.01	1.71	1.11	1.41	2.05	3.49	4.64	5.14	35.26
Whidbey Island, WA	2.55	1.71	1.79	1.62	1.47	1.23	0.76	1.00	1.30	1.66	2.35	3.00	20.44
Seattle (Urban), WA	5.94	4.20	3.70	2.46	1.66	1.53	0.89	1.38	2.03	3.40	5.36	6.29	38.85
Seattle-Tacoma, WA	6.04	4.22	3.59	2.40	1.58	1.38	0.74	1.27	2.02	3.43	5.60	6.33	38.60
Olympia, WA	8.50	5.77	4.85	3.13	1.85	1.44	0.76	1.34	2.36	4.68	7.58	8.70	50.96
Quillayute, WA	15.07	12.10	11.27	7.10	4.70	3.06	2.32	2.85	5.27	10.51	13.94	16.31	104.49

(B) Monthly Precipitation in 1982 (inches).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Seattle (Urban), WA	4.68	7.50	3.86	2.48	0.57	1.07	0.80	0.63	1.68	4.20	5.30	8.99	41.76
Seattle-Tacoma, WA	5.35	7.57	3.73	2.07	0.63	1.03	0.59	0.62	1.49	4.07	5.31	6.86	39.32
Olympia, WA	7.79	9.91	4.67	3.89	0.51	1.15	0.54	0.55	1.89	6.12	5.74	10.64	53.40
Quillayute, WA	19.34	20.60	9.10	9.72	1.55	2.39	1.53	2.54	3.81	13.61	12.71	12.25	109.15

(C) Monthly Precipitation in 1983 (inches).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Victoria, BC, Can.	5.85	6.33	3.76	1.38	0.98	1.22	1.34	0.40	3.34	1.85	10.28	3.68	40.40
Vancouver, BC, Can.	6.54	9.05	5.88	5.05	1.48	2.50	3.13	0.96	3.02	3.56	13.81	3.12	58.11
Bellingham, WA	3.76	2.15	2.33	1.99	1.30	1.50	2.03	0.53	3.92	1.48	6.15	2.48	29.61
Whidbey Island, WA	2.64	0.53	1.15	1.63	1.53	1.37	0.72	0.27	3.13	0.21	2.08	1.41	16.66
Seattle (Urban), WA	6.84	5.26	4.37	0.91	2.18	1.99	2.07	2.08	2.55	1.11	11.20	5.52	46.08
Seattle-Tacoma, WA	7.07	4.57	3.81	1.06	2.10	1.03	2.39	1.90	1.85	1.34	7.97	5.02	40.11
Olympia, WA	9.99	7.09	6.63	2.26	1.51	2.80	3.00	2.18	1.89	1.66	12.84	7.28	59.13
Quillayute, WA	13.77	20.11	12.97	3.91	3.81	4.08	11.02	2.09	5.73	5.44	29.14	8.93	121.00

Table 34. (Continued) Monthly and annual precipitation totals for selected stations in Washington State and in Canada: (A) Normal amounts for 1951-80; (B) Precipitation totals in 1982; (C) Precipitation totals in 1983; (D) Percent departures from normal precipitation in 1983. Precipitation data for the four stations in upper Puget Sound were not obtained for 1982.

(D) Monthly Precipitation Percent Departure from Normal, 1983 (percent).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Victoria, BC, Can.	39	112	52	5	-8	3	94	-54	163	-35	145	-27	44
Vancouver, BC, Can.	13	97	59	110	-21	41	168	-34	25	-26	148	-52	38
Bellingham, WA	-22	-39	-22	-18	-35	-12	83	-62	91	-58	32	-52	-16
Whidbey Island, WA	3	-69	-36	1	4	11	-6	-73	141	-87	-11	-53	-18
Seattle (Urban), WA	15	25	18	-63	31	30	133	51	26	-67	109	-12	19
Seattle-Tacoma, WA	17	8	6	-56	33	-25	223	50	-8	-61	42	-21	4
Olympia, WA	18	23	37	-28	-18	94	295	63	-20	-65	69	-16	16
Quillayute, WA	-9	66	15	-45	-19	33	375	-27	9	-48	109	-45	16

(E) Monthly Precipitation Averaged for Areas.

San Juan Island Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1951-80 Normals	4.34	3.20	2.73	1.94	1.60	1.48	0.93	1.19	1.76	3.20	4.19	4.92	31.46
1982 Precipitation													
1983 Precipitation	4.69	4.51	3.28	2.51	1.32	1.65	1.80	0.54	3.35	1.77	8.08	2.67	36.20
1983 Departure from Normal	8	41	20	29	-17	12	93	-54	91	-45	93	-46	15

Puget Sound	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1951-80 Normals	6.83	4.73	4.05	2.66	1.70	1.45	0.80	1.33	2.14	3.84	6.18	7.11	42.80
1982 Amounts	5.94	8.33	4.09	2.81	0.57	1.08	0.64	0.60	1.69	4.80	5.45	8.83	44.83
1983 Amounts	7.97	5.64	4.94	1.41	1.93	1.94	2.49	2.05	2.10	1.37	10.67	5.94	48.44
1983 Departure from Normal	17	19	22	-47	14	34	212	54	-2	-64	73	-16	13

Table 35.--Monthly and annual average temperatures for selected stations in Washington State and in Canada: (A) Normal average temperatures for 1951-80; (B) Average temperatures in 1982; (C) Average temperatures in 1983; (D) Departures from normal temperatures in 1983. Average temperatures for the four stations in upper Puget Sound were not obtained for 1982.

(A) Monthly Average Temperature Normals for 1951-80 (°F).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Victoria, BC, Can.	38.5	40.3	43.3	48.6	54.7	58.3	61.9	61.5	57.9	51.3	44.2	40.8	50.1
Vancouver, BC, Can.	36.3	39.9	42.4	48.0	54.3	59.5	63.3	62.8	57.6	50.2	43.0	38.8	49.7
Bellingham, WA	36.3	39.6	42.6	47.7	53.4	58.5	62.1	61.9	57.4	50.2	43.2	39.2	49.3
Whidbey Island, WA	38.5	41.7	43.6	47.9	53.1	57.4	60.8	61.0	57.2	50.3	43.7	40.6	49.6
Seattle (Urban), WA	40.6	44.2	45.7	50.4	56.3	61.0	65.3	65.0	61.1	53.8	46.2	42.6	52.7
Seattle-Tacoma, WA	39.1	42.8	44.2	48.7	55.0	60.2	64.8	64.1	60.0	52.5	44.8	41.0	51.4
Olympia, WA	37.2	40.8	42.2	47.3	53.1	58.4	63.0	62.5	58.1	50.1	42.6	39.0	49.6
Quillayute, WA	39.0	41.7	46.0	46.0	51.0	55.1	59.0	59.2	56.8	50.4	43.8	40.8	48.7

(B) Monthly Average Temperatures in 1982 (°F).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Seattle (Urban), WA	40.9	43.3	45.6	48.7	56.1	64.2	64.0	65.1	61.3	53.6	43.7	42.1	52.4
Seattle-Tacoma, WA	39.3	42.1	44.1	47.4	54.7	63.1	62.8	65.1	60.6	52.7	43.2	40.8	51.3
Olympia, WA	38.0	40.6	42.6	45.8	54.1	62.9	63.1	64.4	59.5	50.8	40.2	38.6	50.1
Quillayute, WA	37.8	40.6	41.5	43.1	49.8	56.6	57.1	59.5	57.7	50.3	41.2	39.4	47.9

(C) Monthly Average Temperatures in 1983 (°F)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Victoria, BC, Can.	43.3	43.5	46.4	48.0	55.4	58.3	61.2	62.2	55.6	48.2	45.5	34.5	49.6
Vancouver, BC, Can.	43.2	43.5	46.6	48.6	56.7	59.4	62.1	63.9	56.3	48.9	45.9	33.3	50.9
Bellingham, WA	43.5	44.6	47.8	48.6	55.8	58.5	60.8	63.0	55.0	48.0	46.0	31.3	53.0
Whidbey Island, WA	45.1	46.4	48.7	48.7	54.9	57.7	59.7	60.4	57.2	50.0	47.7	35.1	53.9
Seattle (Urban), WA	46.0	47.9	50.2	52.6	59.1	61.6	64.6	66.6	59.2	53.2	48.9	37.1	53.9
Seattle-Tacoma, WA	45.0	46.9	49.4	50.7	57.7	63.1	63.3	65.6	58.3	51.7	47.8	36.1	53.0
Olympia, WA	42.6	45.3	47.5	48.9	56.5	58.7	62.0	64.1	56.3	49.2	46.0	33.9	50.9
Quillayute, WA	44.4	44.5	46.2	47.7	53.5	55.8	59.6	60.2	54.4	47.8	45.8	35.2	49.6

Table 35. (Continued) Monthly and annual average temperatures for selected stations in Washington State and in Canada: (A) Normal average temperatures for 1951-80; (B) Average temperatures in 1982; (C) Average temperatures in 1983; (D) Departures from normal temperatures in 1983. Average temperatures for the four stations in upper Puget Sound were not obtained for 1982.

(D) Monthly Average Temperature Departures from Normal, 1983 (°F).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Victoria, BC, Can.	4.9	3.2	3.1	-0.5	0.7	0.0	-0.7	0.7	-2.3	-3.1	1.3	-6.3	-0.5
Vancouver, BC, Can.	6.8	3.6	4.1	0.5	2.3	-0.2	-1.3	1.1	-1.3	-1.3	2.9	-5.6	1.2
Bellingham, WA	7.2	5.0	5.2	0.9	2.3	0.0	-1.3	1.1	-2.3	-2.2	2.9	-7.9	3.6
Whidbey Island, WA	6.6	4.7	5.1	0.8	1.8	0.3	-1.1	-0.6	0.0	-0.3	4.0	-5.5	4.3
Seattle (Urban), WA	5.4	3.7	4.5	2.2	2.8	0.6	-0.7	1.6	-1.9	-0.6	2.7	-5.5	1.2
Seattle-Tacoma, WA	5.9	4.1	5.2	2.0	2.7	2.9	-1.5	1.5	-1.7	-0.8	3.0	-4.9	1.6
Olympia, WA	5.4	4.5	5.3	1.6	3.4	0.3	-1.0	1.6	-1.8	-0.9	3.4	-5.1	1.3
Quillayute, WA	5.4	2.8	0.2	1.7	2.5	0.7	0.6	1.0	-2.4	-2.6	2.0	-5.6	0.9

(E) Monthly Precipitation Averaged for Areas.

San Juan Island Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1951-80 Normals	37.4	40.4	43.0	48.0	53.9	58.4	62.0	61.8	57.5	50.5	43.5	39.9	49.7
1982 Precipitation													
1983 Precipitation	43.8	44.5	47.4	48.5	55.7	58.5	60.9	62.4	56.0	48.8	46.3	33.5	51.9
1983 Departure from Normal	6.4	4.1	4.4	0.4	1.8	0.0	-1.1	0.6	-1.5	-1.7	2.7	-6.3	2.2

Puget Sound	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1951-80 Normals	39.0	42.6	44.0	48.8	54.8	59.9	64.4	63.9	59.7	52.1	44.5	40.9	51.2
1982 Amounts	39.4	42.0	44.1	47.3	55.0	63.4	63.3	64.9	60.5	52.4	42.4	40.5	51.3
1983 Amounts	44.5	46.7	49.0	50.7	57.8	61.1	63.3	65.4	57.9	51.4	47.6	35.7	52.6
1983 Departure from Normal	5.6	4.1	5.0	1.9	3.0	1.3	-1.1	1.6	-1.8	-0.8	3.0	-5.2	1.4

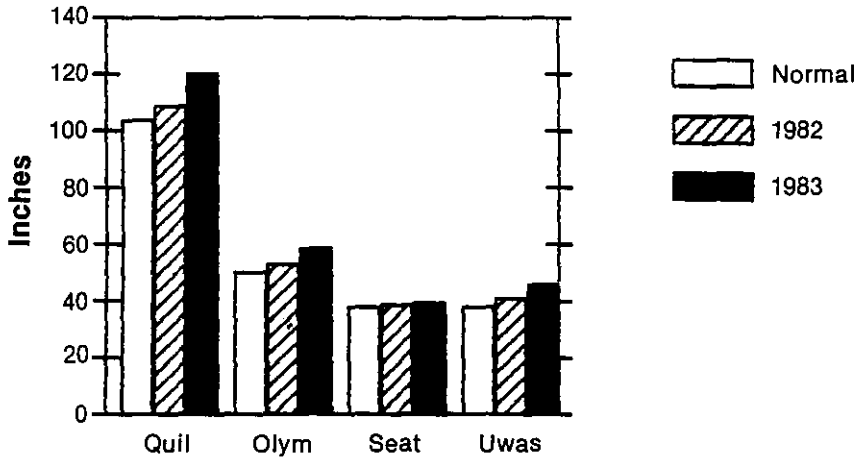


Figure 14 - Normal annual total precipitation (1951-80), and annual total precipitation in 1982 and 1983 at four weather observing stations in Washington State. (Key to stations: Quil - Quillayute, Olym - Olympia, Seat - Seattle-Takoma Int'l AP, Uwas - Seattle (Urban).

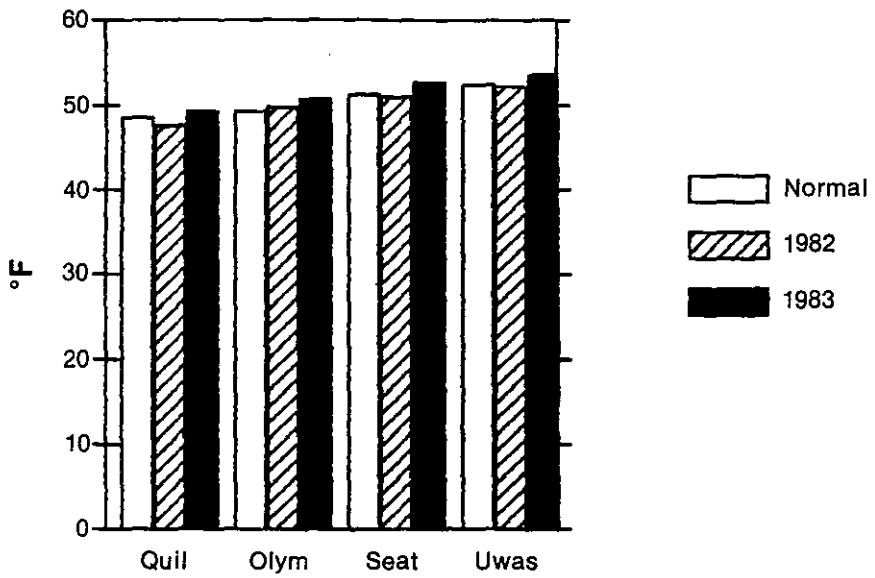


Figure 15 - Normal annual mean air temperatures (1951-80), and annual mean air temperatures in 1982 and 1983 at four weather observing stations in Washington State. (Key to stations: Quil - Quillayute, Olym - Olympia, Seat - Seattle-Tacoma Int'l AP, Uwas - Seattle (Urban).

Events

Numerous storms moved across Washington in January, especially during the first and the last thirds of the month, bringing high winds and heavy rains. Mud and rock slides of the rain-saturated slopes buried one man and caused the death of numerous cattle in a crushed barn, besides destroying other structures and closing several roads. Flooding, from a combination of heavy rain and high storm tides, resulted in the drowning deaths of two individuals, the destruction or closing of many roads, and the damage of many homes and other structures. Besides flooding and mud slides, high winds destroyed or damaged trees, homes, vehicles, boats, farm equipment, and many other types of structures. Along the coast the additional effect of heavy surf atop the heightened water surface destroyed coastal bulkheads and roads, and hurled rocks, large logs, and mounds of debris upon the beaches. The cost of weather related damages in the state amount to many millions of dollars.

Storms continued to batter the coast of Washington during February. As in January, temperatures were warmer than normal, largely as a result of the warm coastal waters, part of the anomalous sea surface condition affecting the west coast of the United States.

In March above-average temperatures and precipitation continued, supported by warm southwesterly winds, but without widespread damages.

April brought seasonal warming, above-normal temperatures, and below-normal precipitation to all but one of the eight stations in Figure 13. A tornado did minor damage east of the Cascades.

In May much-above-normal temperatures the latter part of the month melted snows, which caused flooding along streams near the Cascades and the drowning of two women rafters on the Methow River. A brief wind storm on the 14th downed trees and damaged buildings in the upper Puget Sound area.

Apart from a funnel cloud sighting June 11 in upper Puget Sound, weather in the area and throughout the State was uneventful.

July was marked by instances of violent weather - a tornado in northeast Washington and damaging hail near Yakima - besides much-heavier-than-normal rainfall, especially along the coast and in the mountains. Temperatures were cooler than normal.

In August above-normal temperatures prevailed throughout Washington, but precipitation was more variable. Very heavy rainfall on the 10th north of Lake Chelan caused extensive flood damage to homes, roads, and agriculture. Late in the month large hail fell in Olympia.

Heavy rain the first of September from one of a series of Pacific storms during the first two-thirds of the month caused flooding and rock slides in the islands of upper Puget Sound. Below normal temperatures prevailed throughout the State during the month.

Generally cool and dry weather prevailed during October in Puget Sound and the western part of the State. A tornado mid-month caused moderate damage in the Spokane area.

In contrast to October, November was warm and very wet throughout the State. Storm winds gusting to 80 mph lashed the Puget Sound area and western Washington on both the 10th and 24th felling trees and powerlines and causing other property damage and injury. Numerous other storms brought heavy rain during the month.

In December, cold, relatively dry weather characterized Puget Sound and Washington State. Strong destructive winds battered the western slopes of the Cascades during an intense storm on the 24th. Damages to homes and businesses in the town of Enumclaw east of Tacoma were estimated at about $10 million from this storm.

Precipitation

Precipitation totals for the year 1983 were above normal for all but two of the eight stations shown in Figure 13. Bellingham and Whidbey Island, the northern part of Puget Sound ended the year near 20 percent below normal precipitation. The remaining stations all had excess amounts for the year, ranging from 4 percent above normal at Seattle-Tacoma International Airport to 44 percent above normal at Victoria (Table 34 (D)). Monthly precipitation was quite variable during the year relative to normal. All stations except Vancouver and Victoria maintained near normal annual totals of precipitation for 1983, although individual monthly amounts varied greatly from 375 percent above normal (Quillayute-July) to 87 percent below normal (Whidbey Island-October). The year began with all stations showing near normal amounts in January, Victoria, B.C., being well above normal (39 percent).

During February all stations except Bellingham and Whidbey Island received well-above-normal precipitation, Victoria and Vancouver getting twice normal amounts. Bellingham and Whidbey often remain in a rainfall shadow of the Olympic Mountains for the regional atmospheric flow, evidenced by the considerably smaller yearly and monthly totals for precipitation for those stations. During March all stations except the shadowed stations were again above normal though not by as great a percentage.

April precipitation showed a pattern of two distinct regions, the northern stations being wetter than normal and the southern stations being drier than normal. Vancouver was especially wet with more than twice normal rainfall.

May and June showed generally normal rainfall throughout the area.

July is normally the driest month of the year for the Puget Sound region. Due to changes in the atmospheric flow offshore with more onshore flow, July 1983 was much wetter than normal at all stations. Olympia experienced nearly four times normal rainfall. However, absolute amounts of rainfall for July were still near adjacent monthly figures, except at Quillayute which received 11 inches of rain (475 percent of normal).

During August the rainfall again developed into two regimes, drier than normal in the north and wetter than normal in the south. The northern stations experienced very dry conditions with the area averaging only 50 percent of normal rainfall. Southern stations averaged 50 percent above normal for the month.

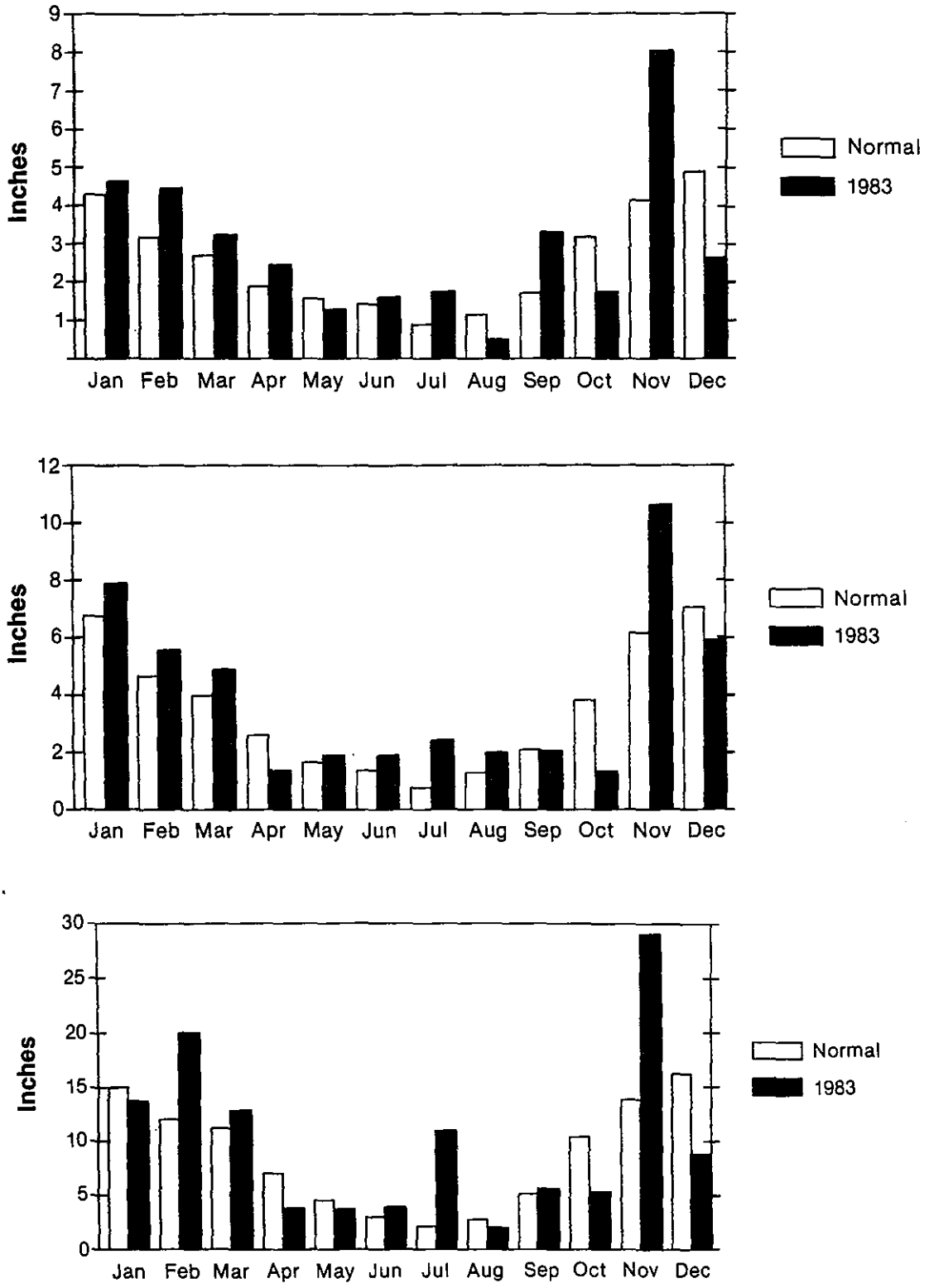


Figure 16 - Normal monthly total precipitation (1951-80), and monthly total precipitation in 1983, selected regions or stations, Washington State. (A) San Juan Island Region - Mean of totals for Victoria, B.C., Vancouver, B.C., Bellingham, and Whidbey Island; (B) Puget Sound - Mean of totals at Seattle (Urban), Seattle-Tacoma Int'l AP, and Olympia; (C) Quillayute.

September was a mirror image of August with southern stations receiving near normal or slightly less than normal precipitation while northern stations recorded almost twice normal rainfall.

October was the driest month relative to normal for the year. Almost all stations experienced drought or near-drought conditions. The region overall received less than 45 percent normal rain; and Whidbey Island received less than 13 percent of normal.

November 1983 was very wet throughout the Sound region. Four stations received more than twice normal rainfall with some approaching record amounts (Quillayute received 29.14 inches). Only Whidbey Island remained slightly below normal during the month.

Conditions returned to drier than normal in December with northern stations receiving only about 50 percent of normal rainfall and southern stations staying around 10 to 15 percent below normal.

Temperature

During the first three months of 1983, when the influence of warm water along the coast was strong, temperatures were above normal at all stations.

January was a very warm month throughout the State of Washington, averaging 6.0°F above normal in the Puget Sound region (7.2°F above at Bellingham; 5.4°F above at both Seattle (Urban) and Olympia. During the month average temperatures reached as high as 15°F above normal daily highs (6th at Olympia).

February and March continued warmer than normal, but not as much as January. February temperatures averaged 4.1°F above normal and temperatures in March averaged 4.7°F above normal in the Puget Sound region.

April temperatures averaged near normal for Puget Sound, except at Seattle and Tacoma which each recorded the month two degrees above normal.

Temperatures in the Puget Sound region averaged 2.3°F above normal in May, ranging from 0.7°F above normal at Victoria to 3.4°F above normal at Olympia (Table 9-2(D)). Daily temperature departures in the Puget Sound area ranged from 7°F below normal on the 8th to 21°F above normal on the 28th at Olympia.

Average temperatures for June, July, and August were near normal throughout the region, except at Seattle-Tacoma Airport which showed an average temperature in June almost three degrees above normal.

September and October records show near-normal temperatures except at Bellingham, Victoria, and Quillayute each of which experienced average temperatures more than two degrees below normal in each month.

Temperatures in response to strong onshore airflow during November, rose an average of 2.9°F above normal in the Puget Sound area, ranging from 1.3°F above normal at Victoria, B.C. to 4.0°F above normal at Whidbey Island.

In December 1983 average temperatures fell to 5.8°F below normal in the Puget Sound region, with a range from 4.9°F below normal at Seattle-Tacoma Airport to 7.9°F below normal at Bellingham. Daily temperature departures in the Puget Sound area ranged from 10°F above normal on the 13th at Olympia to 28°F below normal on the 23rd at the same city.

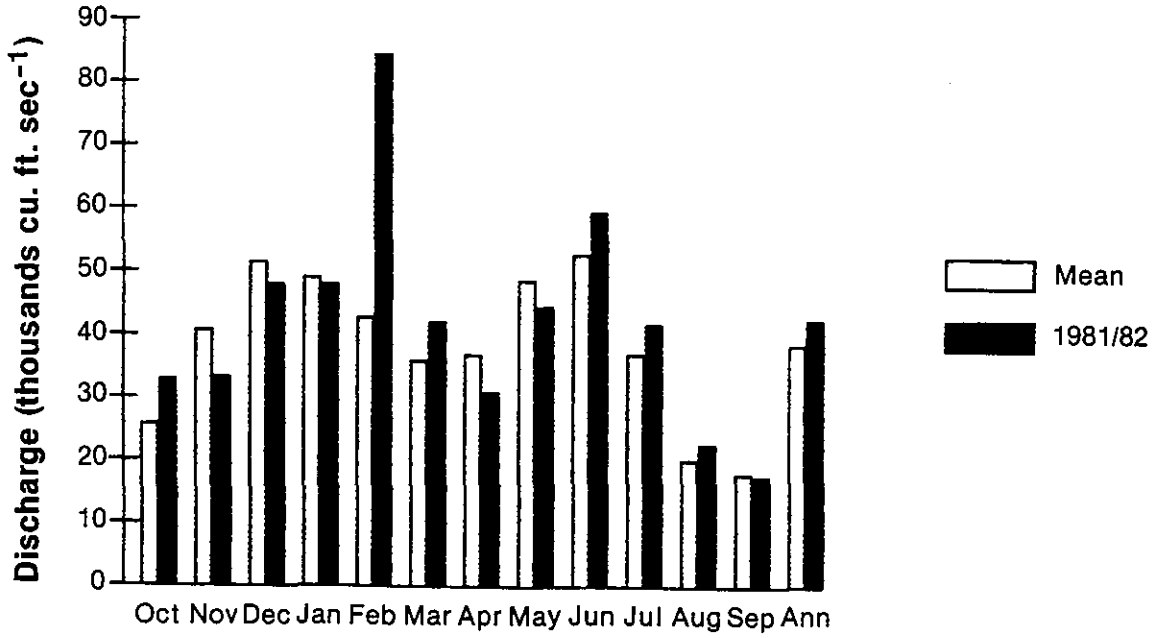
10. PUGET SOUND RIVER FLOW

The streamflow into the Sound is shown in Table 36 in the mean (1948-79) and for the October through September 1981-82 and 1982-83 water seasons (Rivers are shown in Figure 2). This flow is summed and shown in figure 17 for the 1982-83 compared to the mean. In general, the 1982-83 flows followed the normal seasonal flow pattern - a peak in December (or January) due to the increase in precipitation at that time and then a second peak in May-June due to runoff from snowmelt at higher elevations. Deviations in these seasons occurred in February 1982 when warm temperatures and heavy rains in late January and mid- to late-February combined to give heavy river flow and some flood conditions; and July 1983 which had precipitation values in the area up to four times normal for that month. Total flow for 1982-83 is near normal.

The rivers in the northern section of the Sound contribute about 70 percent of the fresh water that flows into the intercoastal waters. Because of the volume of flow and the nature of the drainage basins approximately 70 percent of the sediment that goes into the Sound comes from these rivers (Skagit, Stillaguamish, Snohomish). Table 37 presents the 1981-82 and 1982-83 flows for each river as a percent departure from the normal flow (1948-79). Data for last quarter of calendar year 1983 are not yet available.

Table 36.--Streamflow values (cu ft sec^{-1}) for selected areas of Puget Sound Basin 1 is the Deschutes, Nisqually, Cedar, Green and Puyallup Rivers. Basin 2 is the Skagit, Snohomish, and Stillaguamish Rivers plus Basin 1.

	River Discharge			
	Long-Term Mean		1982-83 Water Year	
Month	Basin 1	Basin 2	Basin 1	Basin 2
October	4123	24365	3737	21078
November	7851	37746	4939	27711
December	11310	47699	10157	45807
January	11459	45320	14058	58285
February	10324	39227	7529	36989
March	8155	33036	8856	39418
April	7855	34397	5679	28072
May	8339	45859	4966	32600
June	7798	50158	5752	35609
July	4878	35295	6231	41484
August	3185	19336	3722	20029
September	3037	17479	3518	20842
Annual	7360	35827	6595	33994



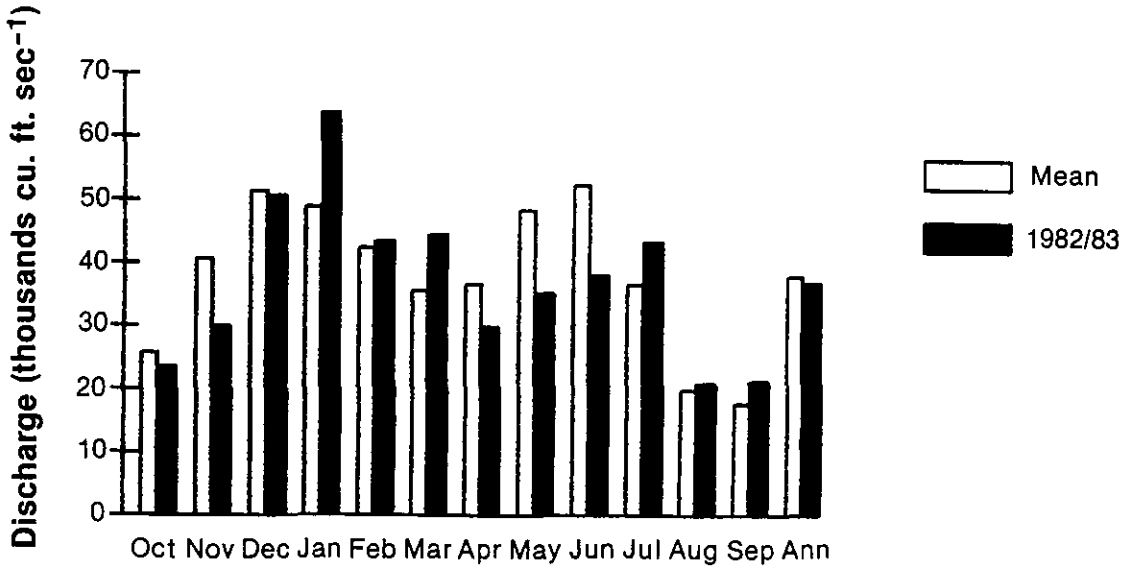


Figure 17 - Riverflow into Admiralty Inlet by month for (a) 1981-82 and (b) 1982-83 water years compared to long-term mean.

Table 37.--Monthly and annual mean river discharges in percent departure from long term means for the 1982-83 water year.

River	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Nooksack	-11	-34	-13	34	5	-1	-12	-23	-21	32	-5	-10	-5
Skagit	-14	-22	-0	25	12	38	-9	-25	-28	10	6	15	-2
Stillaguamish	-34	-28	7	70	15	2	-41	-45	-9	118	9	16	2
Snohomish	-10	-26	-6	30	-15	6	-20	-26	-35	20	-17	33	-8
Whidbey Basin	-14	-24	-2	31	2	23	-16	-26	-30	16	1	20	-4
Cedar	8	-28	-25	36	-26	-14	-46	-50	-52	-17	-9	58	-18
Duwamish/Green	-1	-24	-28	23	-28	1	-22	-56	-42	40	32	41	-14
Puyallup	-11	-38	-13	17	-35	3	-31	-34	-17	27	19	9	-11
Main Basin	-7	-33	-19	21	-31	0	-30	-42	-25	26	18	20	-13
Nisqually	-26	-52	12	25	-28	29	-29	-44	-42	25	5	-5	-10
Deschutes	75	-25	26	33	39	47	30	41	75	210	31	49	35
South Basin	-16	-48	14	26	-15	33	-19	-34	-31	43	8	-1	-3
Skokomish	-3	-29	28	33	69	66	-18	-34	-17	60	34	21	21
Duckabush	125	-21	27	83	123	114	-12	13	22	42	52	15	45
Hood Canal (Est)	59	-26	27	54	91	86	-15	-4	12	47	46	18	33

11. MARINE ENVIRONMENT

11.1 Sea Surface Temperature Anomalies

The NOAA Oceanographic Monthly Summary[2] provides plots of monthly mean sea surface temperature (SST) for one degree squares of latitude and longitude and the differences between monthly mean SST and the climatological mean.[3] For the Puget Sound assessment we provide a summary discussion of these data for 1983 in the region 40 to 55 degrees north latitude and 120 to 135 degrees west longitude.

11.1.1 Annual Surface Water Temperature Cycle

Anomalously warm surface waters were present off the coast of Washington and Oregon from mid-January through August 1983 (Figure 18). Temperature anomalies exceeded two degrees Celsius through the first five months of the year. Maximum anomalies of three degrees Celsius appeared in May when the area of warmer-than-normal water reached its largest extent.

The anomalous surface water temperatures experienced during 1983 appear to be related to changes in the wind-induced mass transport of the surface layers. In our mass transport model these changes are related to changes in the large scale distribution of wind stress in the North Pacific. For the months of January through April wind induced onshore (northeastward) flow resulted in the transport of warmer waters located to the south and southwest into the coastal regions. For the period May through August, (1) wind induced longshore flow from the northwest bringing cooler waters southward was replaced with onshore (northeastward) flow along the Canadian coast, and (2) winds generating upwelling (northeasterly winds) along the Oregon and California coasts were replaced with more longshore (northerly winds) resulting in longshore transport of surface waters, not the climatological offshore flow. The lack of upwelling and southward transport of cooler waters possibly allowed the seasonal insolation to continually warm the surface waters without mixing with cooler waters. After July-August the anomalous warming of the surface waters diminished. The natural variability of the ocean-atmosphere again controlled the temperature distribution which showed a return to near normal distribution of surface water temperature.

11.1.2 Monthly Mean Temperature Anomalies

A one to two degree Celsius warming of the coastal waters of the western U.S. occurred in the second half of January 1983. The majority of the study region experienced higher than normal mean temperatures. The southwest corner of the study area showed negative anomalies of 0.5-1.0°C and cooling was also observed along the Canadian coast north of Vancouver Island of 0.5°C.

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[2] U.S. Department of Commerce, NOAA, Oceanographic Monthly Summary, Vol. III, NOS 1-12, January-December 1983.

[3] Robinson, M. K., Atlas of North Pacific Ocean Monthly Mean Temperatures and Mean Salinities of the Surface Layer, NavOceano. Ref. Pub. 2.

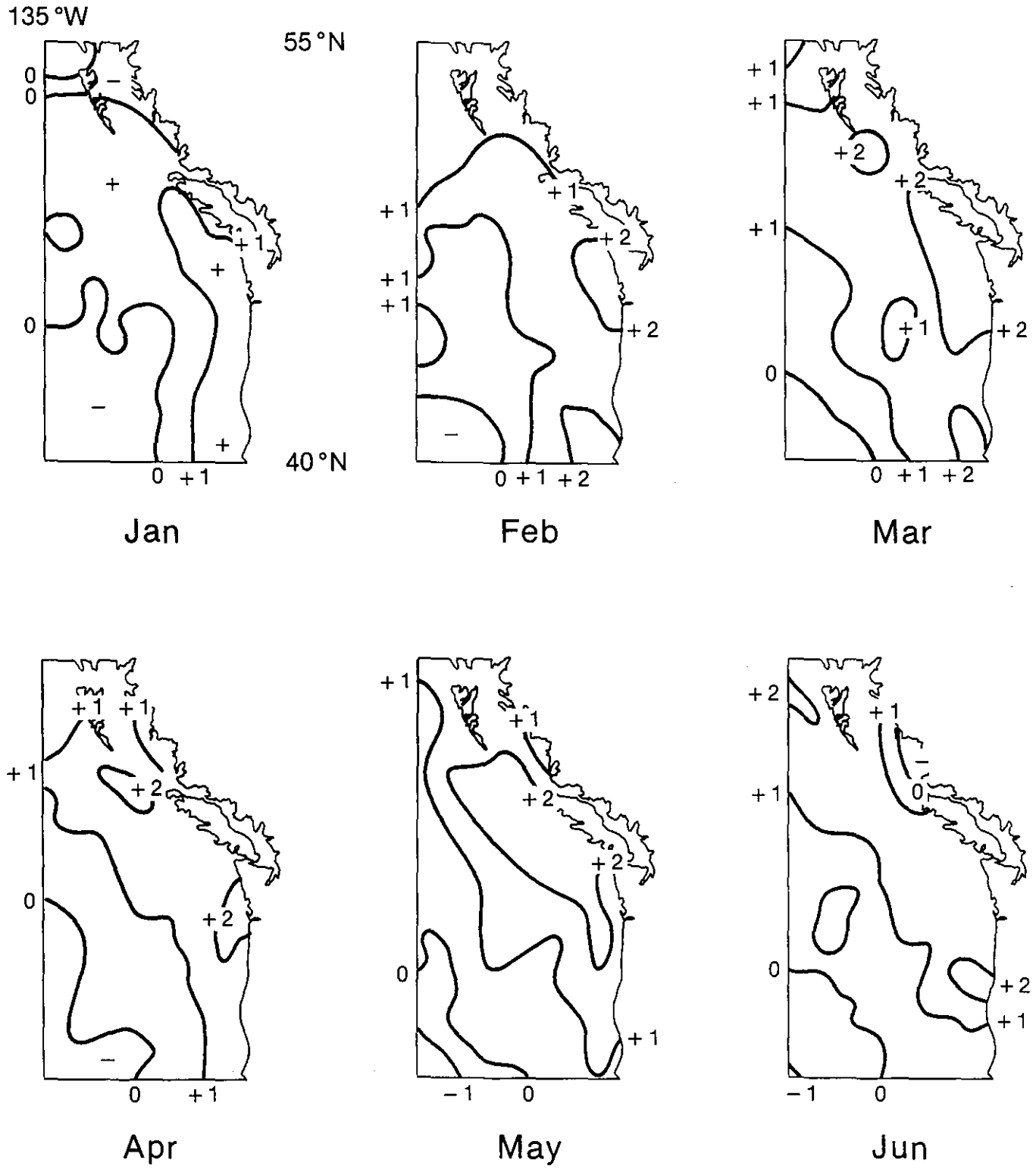

Figure 18 - Sea surface temperature anomaly (°C) for 1983.

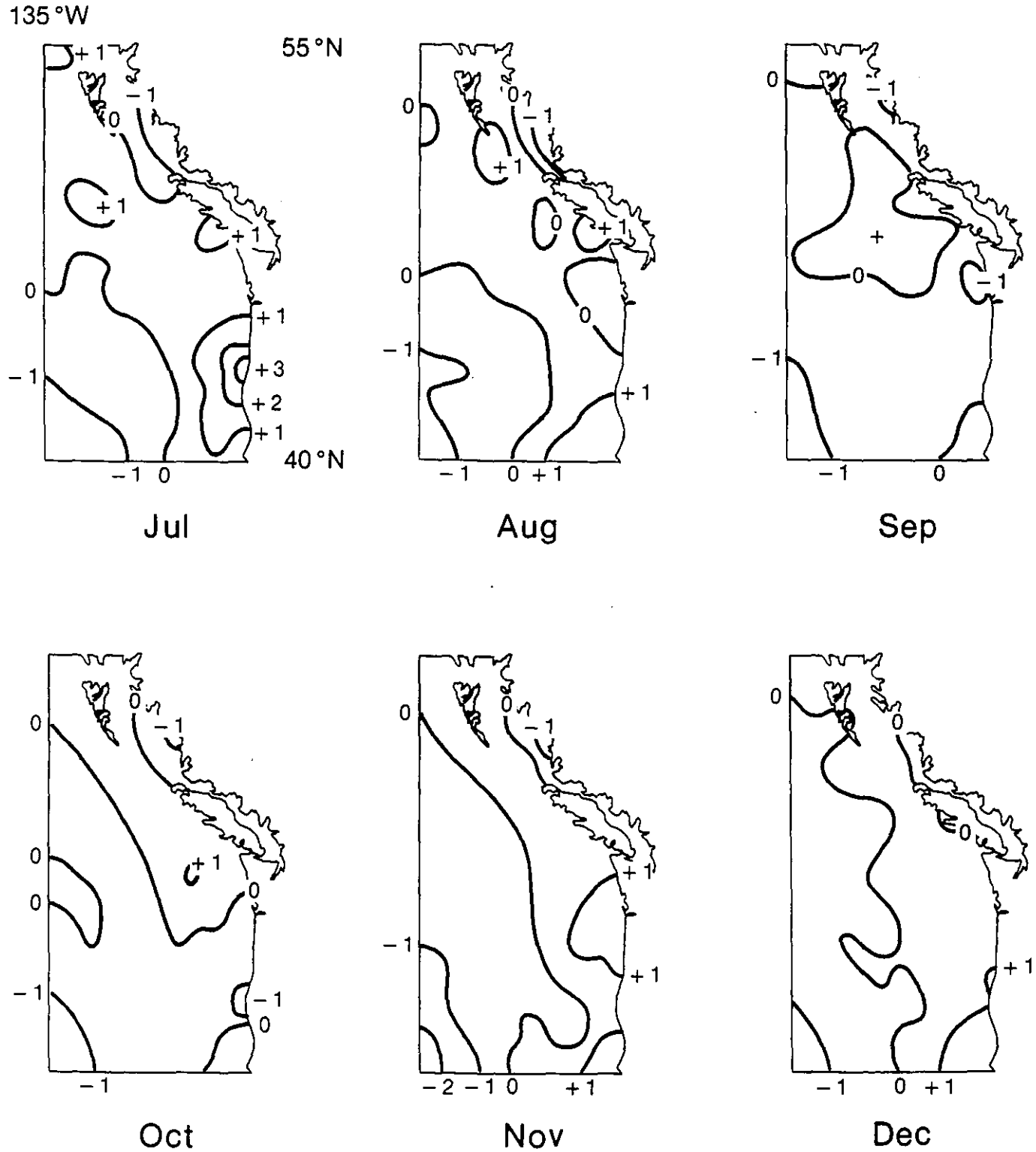

Figure 18 (Continued) - Sea surface temperature anomaly (°C) for 1983.

Coastal warming continued in February with 1.2-2.6°C positive temperatures anomalies along the U.S. coast. Positive anomalies of 0.5°C. and greater along the entire Canadian coastal region replaced the negative anomalies of January. The positive anomalies of 0.5-1.9°C were present over the majority of the study area. The extreme southwest corner of the region experienced the only negative temperature anomalies.

The anomalous warming continued in March with Northwest Pacific U.S. coastal waters 1.5-2.9°C above normal. Canadian coastal waters were approximately 1°C above normal as well. The area coverage of the greater than 1°C above normal temperatures continued to increase while the only area of cooling remained in the southwest corner of the study region.

The seasonal warming of the surface waters via solar insolation begins in April, but the U.S. coastal waters continued to experience 1-2°C warming over the climatological mean. Canadian coastal waters were also 1°C above normal. The study region was still dominated by the above normal temperatures but the area of negative anomalies in the southwest expanded northward by 4 degrees latitude and the area covered by water temperatures of 2°C and warmer was reduced.

Periods of wind-induced upwelling result in reductions in the sea surface temperatures due to surfacing of cooler subsurface waters. Weak upwelling was experienced off the northern California and Oregon region. This upwelling resulted in cooler surface waters being observed in April.

Seasonal warming continued into May, but so did the anomalous warm surface water. The positive 2°C anomaly expanded greatly in May off both the U.S. and Canadian coasts, resulting in 1-2°C positive anomalies along the entire coast. Temperatures of 3°C and greater above normal were experienced at coastal sites in Washington State. Winds favoring upwelling were more persistent that month but still not at the climatological mean resulting in reduced scale of upwelling activity along the coast.

The influence of the anomalous warm surface waters was reduced to +1°C and less in the coastal and offshore waters of southern Oregon and northern California during June 1983. Coastal Washington and northern Oregon states continued to experience 2-3°C positive anomalies. Canadian waters continued to be +1°C and warmer except for a pool of slight negative anomaly water north of Vancouver Island. The area coverage of 2°C and warmer waters was greatly reduced compared to May and the cooler than normal waters in the southwest corner of the study area expanded northeastward.

The beginning of the end of the anomalous warm surface waters was evident in the July 1983 temperature field. Significant positive temperature anomalies were limited to a pool west of the Straits of Juan De Fuca (approximately +2°C) and south of the Columbia River (+1-3°C). The area of negative temperature anomalies north of Vancouver Island expanded southward to the Island and westward. The southwest corner of persistent negative anomalies also expanded eastward and northward that month. The remainder of the area was at near hormal temperature.

The region of positive anomalies south of the Columbia River in July moved southward to the Oregon and California border in August with 1-2°C anomalies. Negative anomalies were persistent from the Columbia River northward to just south of the Straits of Juan De Fuca. The pocket of warmer waters off the entrance to the Straits was still present. The Canadian negative anomaly contracted to the size it was in June. The distribution of the negative and positive anomalies appears to show that the strong positive temperature anomaly period was over and that the natural random variations were again dominating the waters in the study region.

Seasonal cooling along with coastal upwelling resulted in monthly mean negative temperature anomalies along the majority of the coastal area in September. Positive anomalies of less than 1°C were located offshore of Washington State and Vancouver Island and northern California. Estimates of wind-induced transport predicted strong upwelling from the Columbia River southward which was confirmed by rapid cooling of coastal sites near this upwelling zone.

Seasonal cooling continued in October with temperature anomalies over the study region being generally less than 1°C. Coastal sites near river discharges showed the largest decrease in temperature due to cool runoff; e.g., north of the Columbia River temperatures decreased 2-3°C compared to the climatological mean.

Near normal mean surface water temperatures prevailed over the majority of the region in November. Near shore positive anomalies of +1°C can be attributed to the strong onshore transport of warmer offshore waters (Oceanographic Monthly Summary, November 1983). Large negative anomalies were evident in the extreme southwest corner of the study region. (This area was persistently below normal through-out the year and that month had the largest negative anomaly of 2.5°C for the year.)

Fall/winter surface water cooling continued in December with temperature anomalies generally less than 1°C. The only major warming was off the northern California coast of 1-1.4°C possibly due to onshore advection of warmer offshore waters.

The Davidson Current which was observed at the end of November was well established in December. Cold waters flowed northward along the coast from the Columbia River. "7-8 degree centigrade water was consistently observed north of Vancouver Island along the British Columbia coast" (Oceanographic Monthly Summary, December 1983) in December.

11.2 Wind-Induced Mass Transport

Estimates of wind-induced transport, via an analytic model developed by Huang,[4] were generated with National Weather Service Limited Area Fine Mesh (LFM) modeled winds. This model assumes that the "Ekman" type mass transport is 45° to the right of the wind and estimates the magnitude of the transport

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[4] Huang, N. E., On surface drift currents in the ocean, Journal of Fluid Mechanics, vol. 91, part I, pp. 191-208.

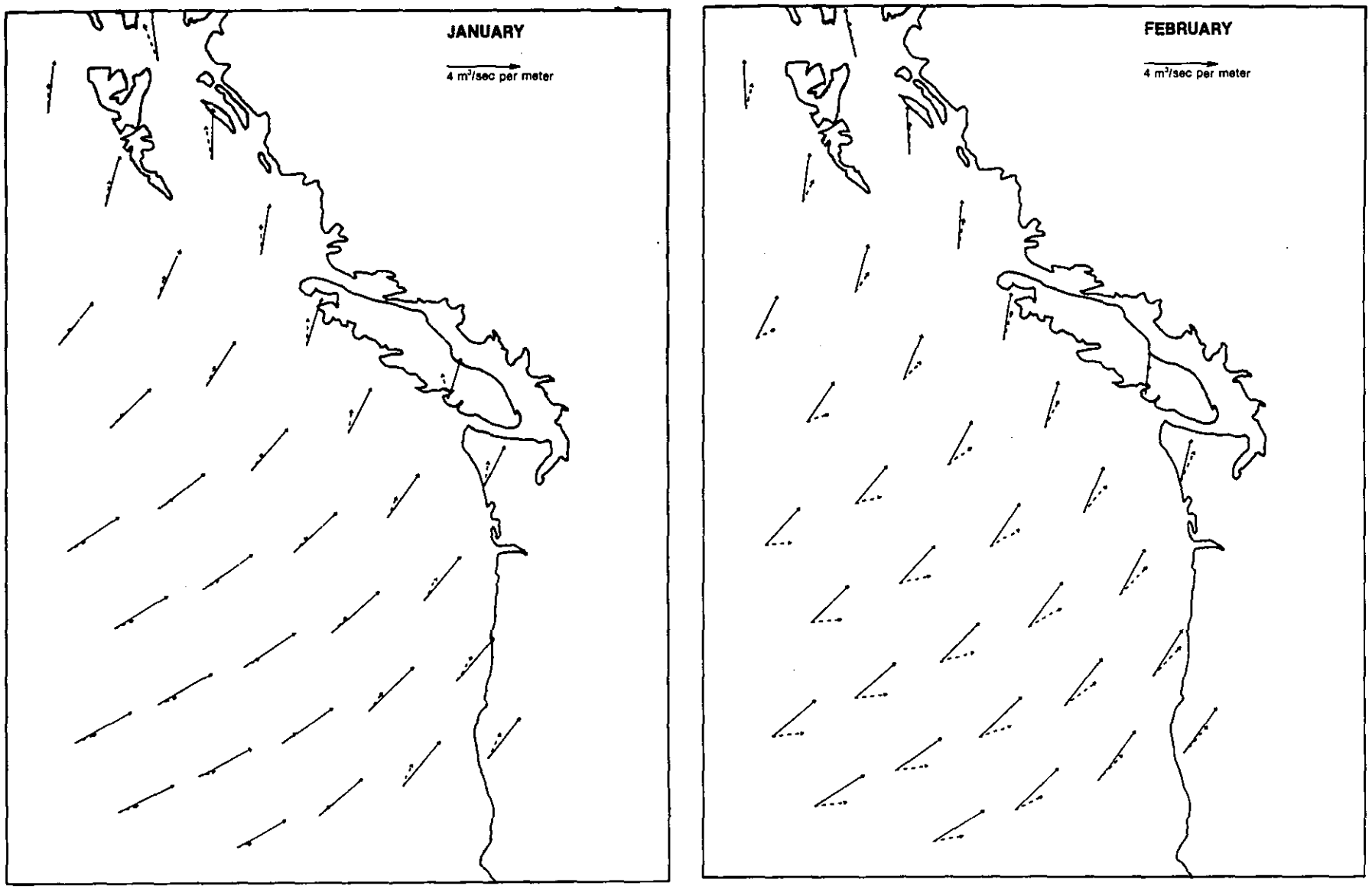


Figure 19 - Mean monthly mass transport, 1983, and 1977-82. (Solid line, 1983 data, dashed line, September 1977-December 1982 mean)

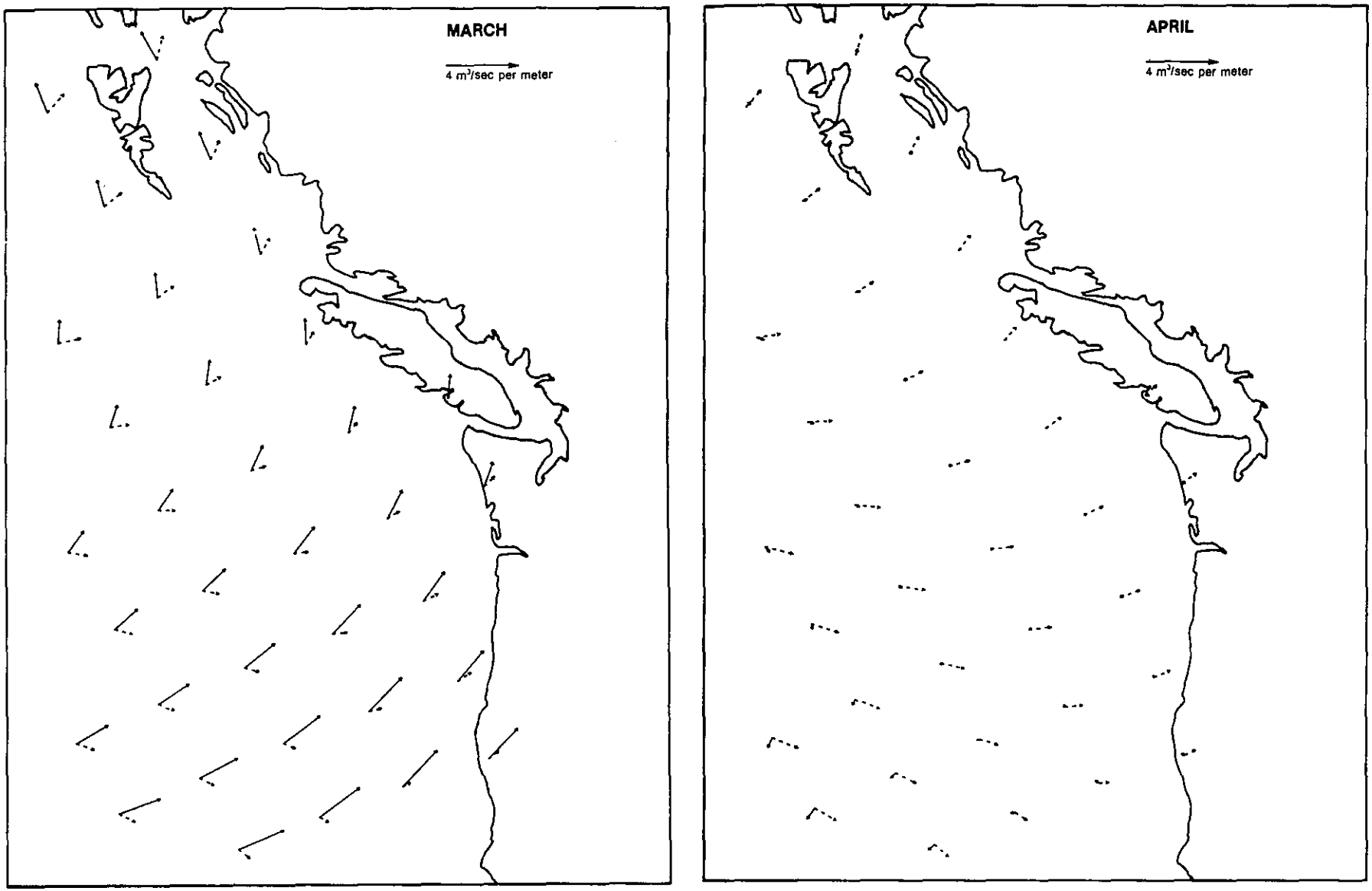


Figure 19 (Continued) - Mean monthly mass transport, 1983, and 1977-82.

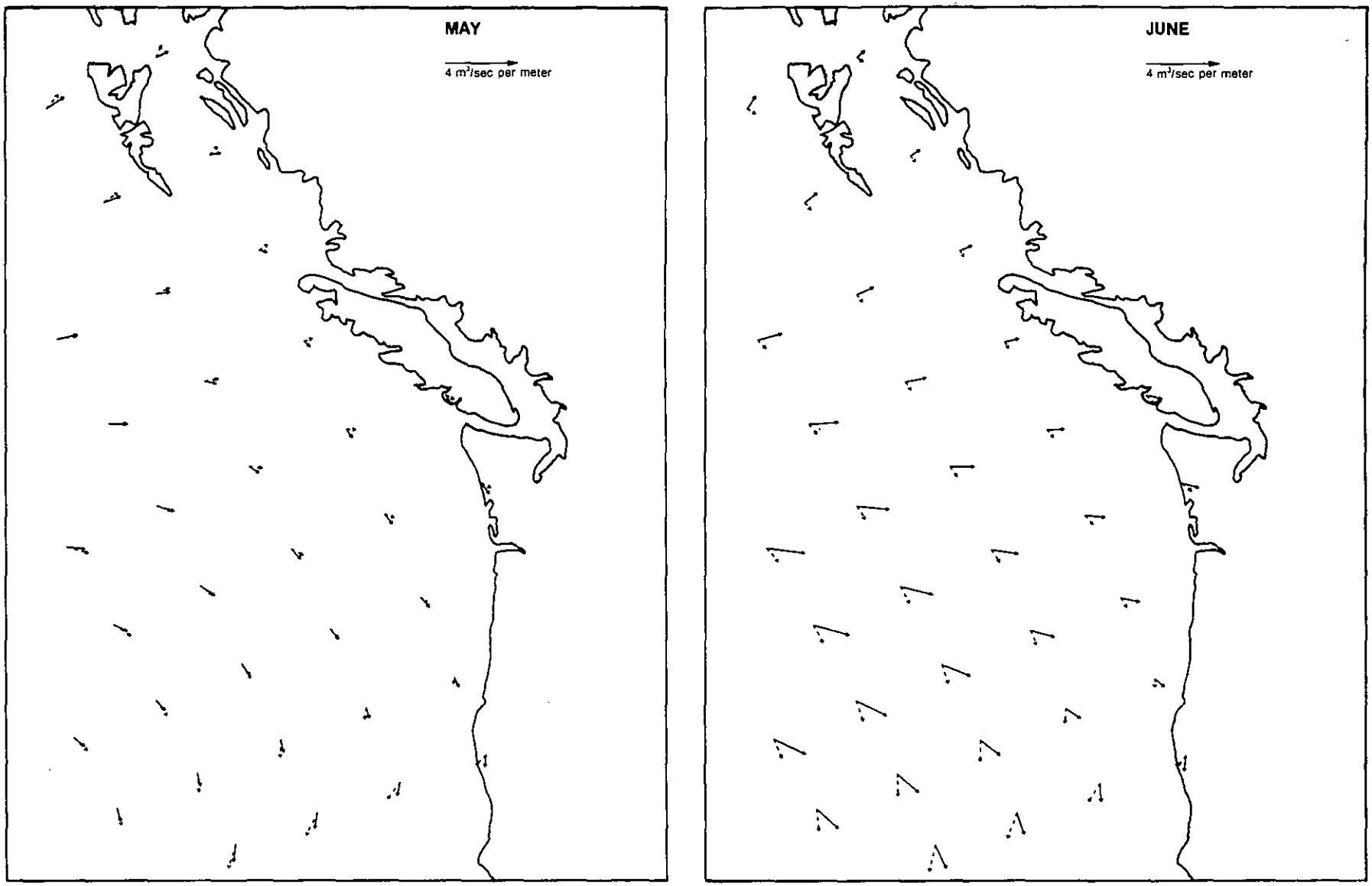


Figure 19 (Continued) - Mean monthly mass transport, 1983, and 1977-82.

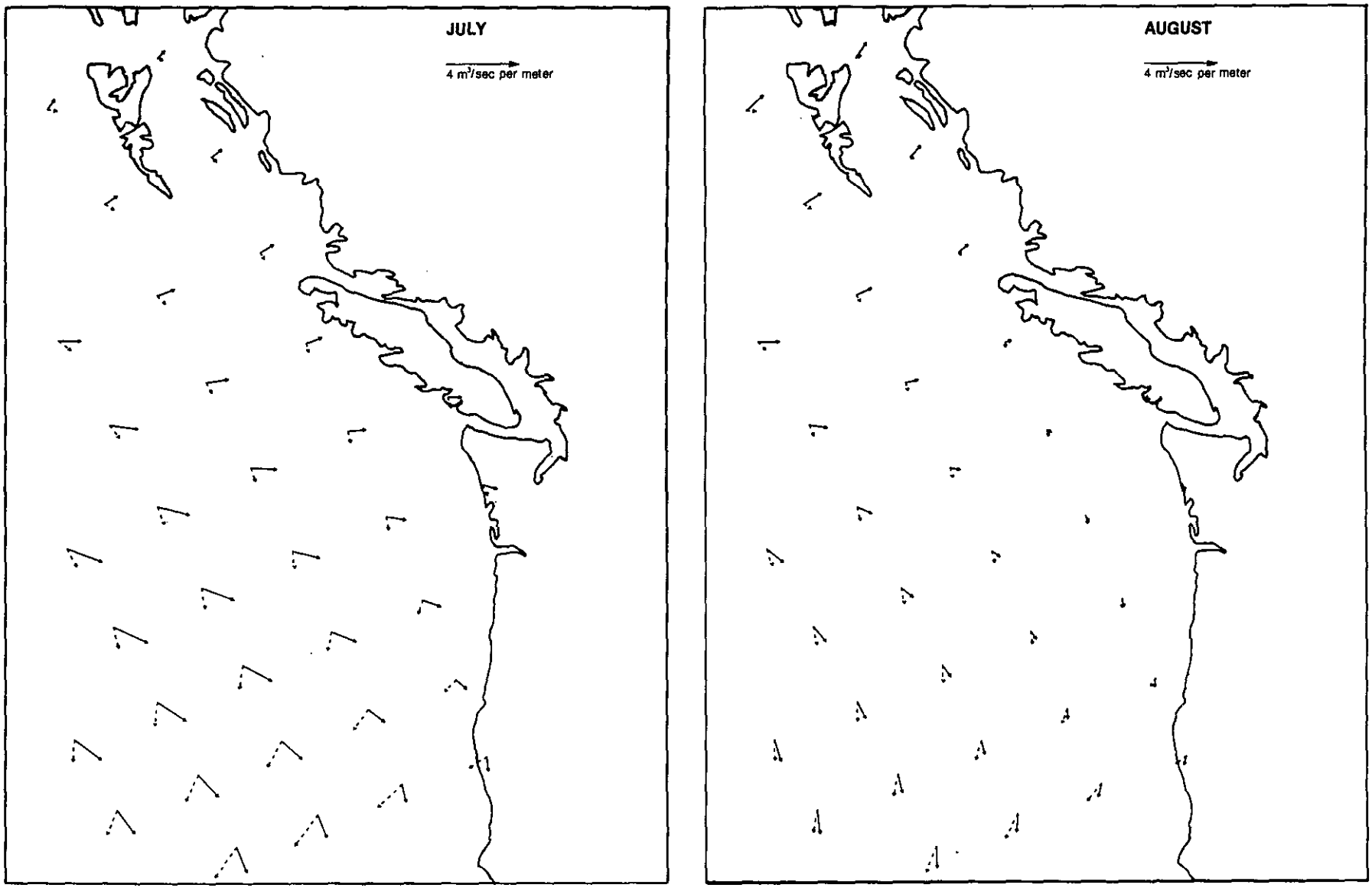


Figure 19 (Continued) - Mean monthly mass transport, 1983, and 1977-82.

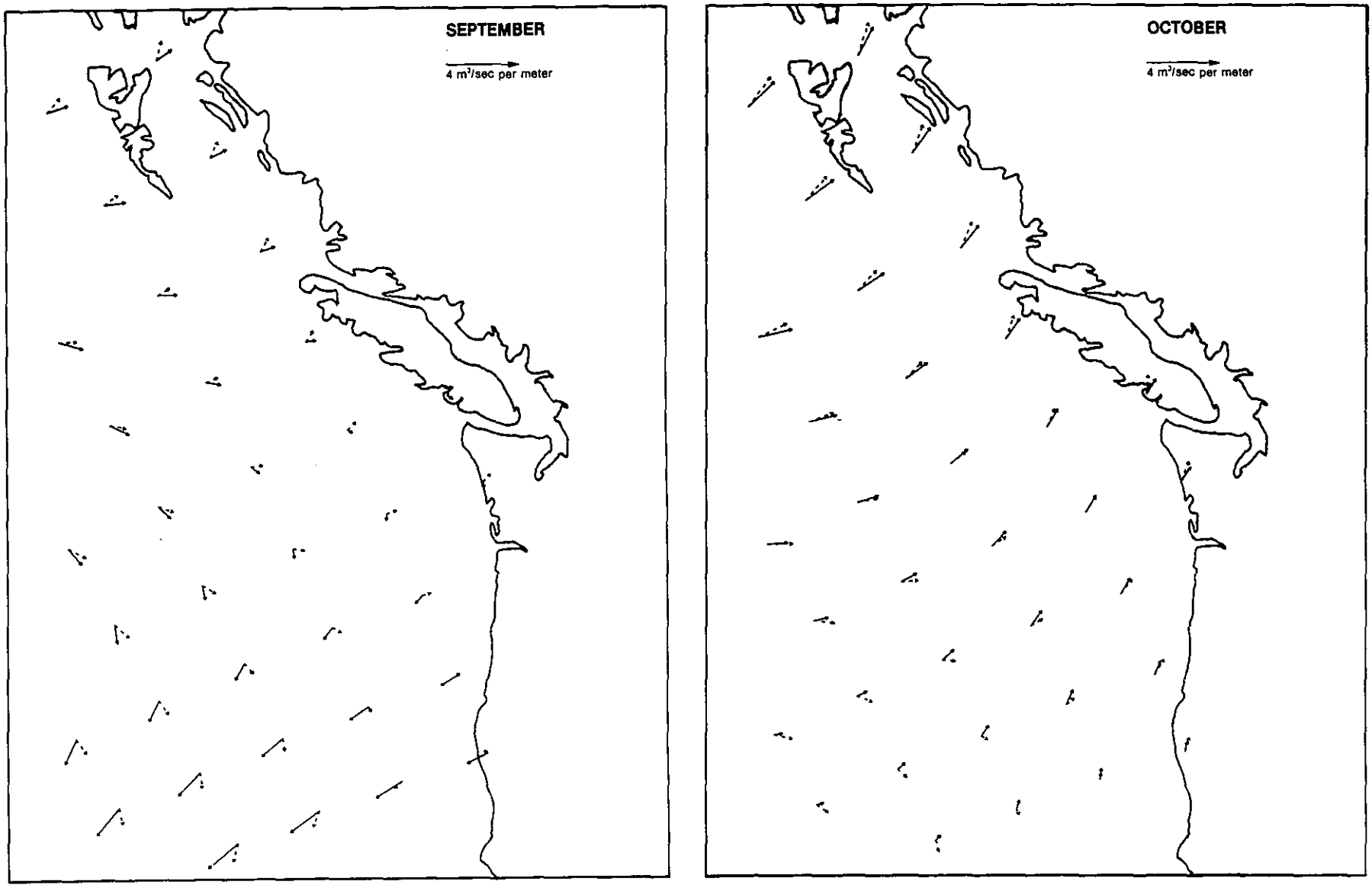
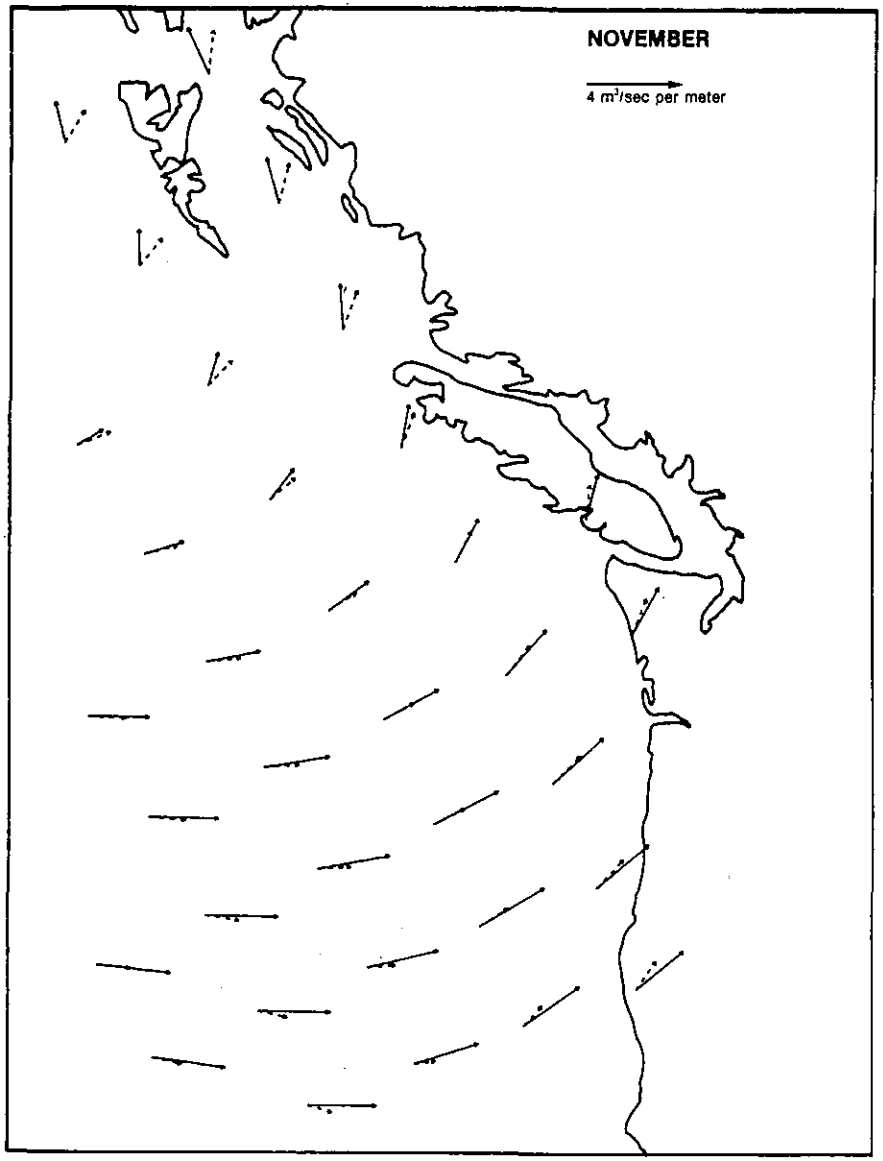


Figure 19 (Continued) - Mean monthly mass transport, 1983, and 1977-82.



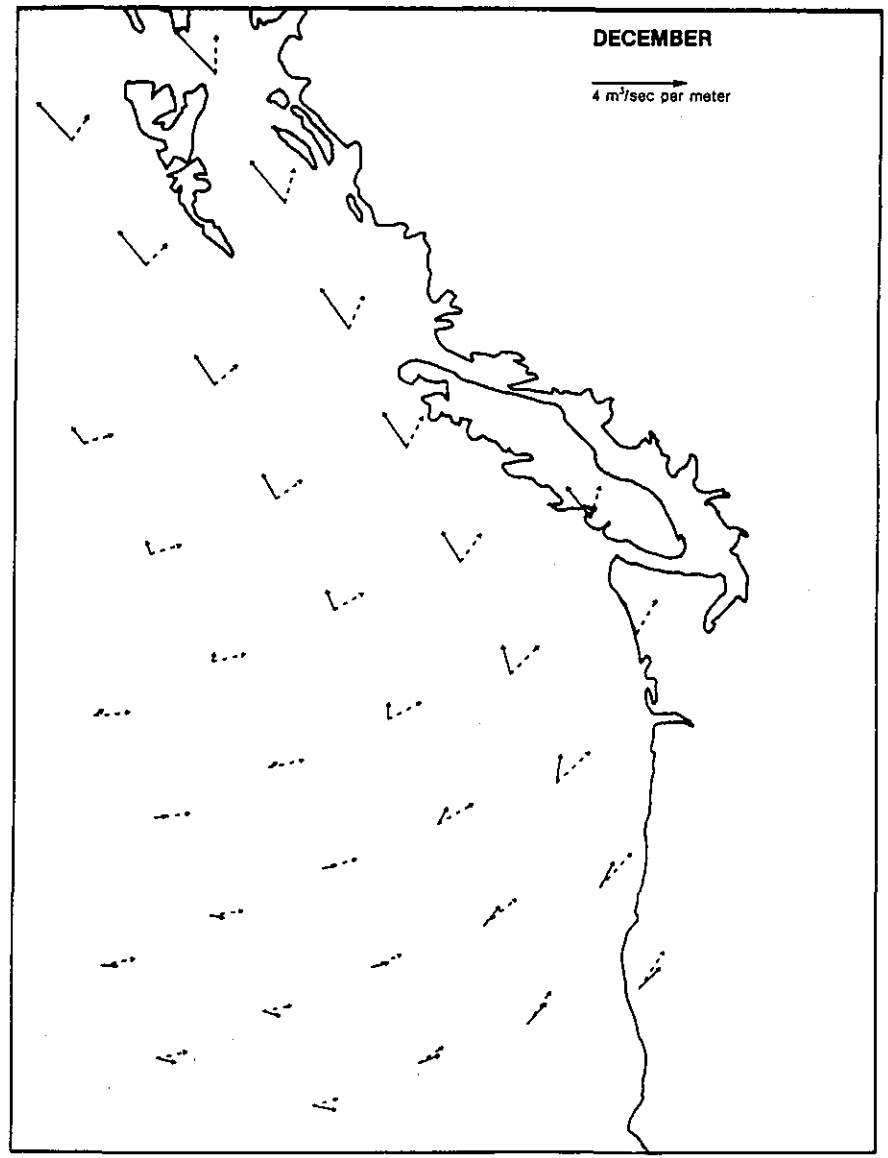


Figure 19 (Continued) - Mean monthly mass transport, 1983, and 1977-82.

from the surface wave field induced by the wind. The influence of the larger scale density driven flows is not discussed. Large scale changes in the meteorological conditions seem to have influenced the surface mass transport. Initial analysis of the mass transport model estimates appears to explain a portion of the sea surface temperature anomaly data for the study region (Section 11.1.2).

The wind speed and direction data used as inputs to this model are the average values of those parameters over the lowest 50 millibars of the atmosphere. No attempt was made to correct for veering of the winds and reduction in speed as the sea surface is approached. Monthly mean vector transport values are generated from twice-a-day modeled wind data. Figure 19 contains both the 1983 monthly mean wind-induced transports for the LFM sites located over water as solid line arrows and the climatological mean as dashed line arrows. The climatological mean is the monthly average estimated wind-induced mass transports for the period September 1977 through December 1982. The study region, 40-55 North latitude 120-135 West longtiude, was divided into four equal quadrants for description of flow patterns. The following discussion of the estimated wind-induced mass transports is on a monthly mean transport basis and compares the 1983 data to the climatology.

January's estimated mass transports predicted strong (onshore) northeastward flow over the majority of the region veering to longshore (northward) flow at the extreme northern sites. A uniform cyclonic pattern of estimated transport is expected due to the Aleutian Low centered to the West of this study region. Compared to the climatological mean monthly mass transports, the magnitude was 2 to 3 times the expected values in the southern quadrants and upwards of 50 percent greater in the northern quadrants. Directions were comparable except at the entrance to Puget Sound where more onshore flow was predicted.

Onshore (northeastward) flow veering to northward flow was predicted for the month of February. The transition from onshore to longshore flow moved southward to the northern end of Vancouver Island compared to January. The magnitude of the mass transport vectors were larger than the climatological mean but were reduced compared to January's. A counter-clockwise rotation of approximately 45 degrees was noted between February 1983 and the 1977-82 mean directions of transport (more northward transport).

March saw a reduction in the magnitude of the estimated transport over the entire region compared to January and February. The same cyclonic pattern as seen in the previous two months was again present. This reduction in magnitude can be attributed to the reduction in the gradient wind field over the region. Significant differences in direction and magnitude of estimated transports between 1983 and the climatology were observed. The climatological divergence in flow in the southern quadrants did not occur, i.e. the increased northeastward flow as the coast is approached with east-southeastward flow further offshore. The cyclonic pattern present in the previous three months was still persisting with differences of 45 degrees to approximately 90 degrees occurring between the mean monthly and March 1983 transports. The excessive magnitude difference in the southern quadrants is a significant feature.

April saw no significant wind induced mass transport over the region. What transport did occur was in the climatological direction, except in the southwest quadrant, which had the direction of transport rotated 90 degrees clockwise from the mean direction. It appears that the climatological diverence in flow did occur that month but was directed in an offshore - not onshore - direction.

Anticyclonic wind induced circulation occurred in May 1983 as the climatology indicated. Onshore, east to east-northeastward flow, occurred in the northern LFM sites. Eastward to southward veering flow occurred as the coastline was approached over the remainder of the study area. This was the first month for which wind-induced upwelling off the northern California coast was predicted. NOAA's Oceanographic Monthly Summary reported reduced upwelling compared to the mean for May for the entire region. The nearshore wind-induced transports were more onshore south of the Columbia River. The magnitude of the transports compared favorably to the mean.

Flow over the majority of the region in June and July was directed onshore. Northeastward flow in the northwest quadrant shifted to eastward flow in the region offshore of the Columbia River. Progressing southward, east-southeast to southward flows were predicted for these months. A divergence in flow occurs offshore of the Straits of Juan De Fuca with more northeastward flows to the north and southward flows to the south of the Straits.

Compared to the climatological mean anticyclonic pattern of transports, rotations of upwards of 90 degrees counter-clockwise were predicted. The northwest quadrant experienced strong onshore flows instead of slow southward longshore-directed flows. The expected longshore transport did not become established except at the near coastal sites in Northern California. Otherwise, onshore transport was predicted. The longshore flow in the Northern California Oregon region would allow wind-induced upwelling to occur.

August had weak southward longshore transport (possible wind-induced upwelling) along the entire coast from the Straits of Juan De Fuca to Northern California. Divergent flow west of the Straits of Juan De Fuca was predicted with northeastward flows northward up the Canadian coast and east-southeastward to southward flows progressing southward to California.

The northwest quadrant showed the greatest departure in direction and magnitude between August 1983 and 1977-82 climatology. Counterclockwise rotations up to 90 degrees were predicted and magnitudes of 2 to 3 times larger than normal. South of the Straits the departures between August data and its monthly mean are reduced and could be considered as not being significant.

East-northeastward veering to east-southeastward flows were evident in the northwest quadrant for September. This onshore flow shifted to a more longshore direction and reduced in magnitude in the northeast quadrant of the study area. Longshore flow continued near the coast to the Columbia River where the wind-induced transport shifted to offshore flow in the southwestward direction. Wind-induced upwelling could be expected along the entire U.S. coast line with the magnitude of the upwelling increasing in a north to south progression. The strong offshore flow was also evident in the southwest quadrant. A cyclonic flow pattern was again present. The expected divergent flow did not

occur. The magnitude of the wind induced transports were comparable to the mean except for the offshore flows which were noticeably larger than the mean.

October had a cyclonic pattern of wind-induced transport. Strong onshore flows were evident in the northwest quadrant, reducing in magnitude and shifting to longshore (north-northeastward) flow, at the southern limit of the study area. No upwelling was predicted for October. Compared to the climatological mean the transport was similar for the northern region and the LFM sites closest to shore while the offshore sites in the southwest quadrant were quite different. Forty-five to greater than 90 degree counter-clockwise rotations were noted for this southwest quadrant. The divergent flow field present in the climatological data in this southwest quadrant did not occur.

Strong cyclonic circulation was predicted for November with northeastward (onshore) flows in the south and north to north-northwestward (longshore) flows in the north. The magnitudes of the 1983 northeastward flows in the southern two quadrants were significantly larger than the mean, while directions were similar. The northwest quadrant showed the only significant differences between 1983 and the November monthly mean circulation, with counter-clockwise rotations of approximately 45 degrees (more northward flow). The magnitudes of the transports were similar.

December continued to show a cyclonic circulation pattern as observed in November. The magnitude of the transports was reduced compared to November, except for the northwest quadrant, where it was similar. Eastward flows, veering northeast to north-northeastward as the coast was approached, were evident in the southern quadrants. Northwestward (longshore) flows were present in the northern quadrants. Large departures in direction were observed between the climatology and 1983 data in the northern quadrants of the study area. The upwards of 90 degree counter-clockwise rotations in the north resulted in longshore flows instead of onshore flows being present. The differences in direction reduce to insignificant values near the California Oregon region. The magnitude of the transports also showed a north to south trend, larger than the mean in the north and smaller than expected in the south.

12. WATER QUALITY

While many areas of Puget Sound are still considered pristine, there is a substantial urban establishment and industrial presence, particularly along the eastern shore. Seattle has a number of heavy industries and manufacturing plants, and Everett and Tacoma are centers for the forestry, pulp, and paper industries. Research has shown that high concentrations of potentially toxic chemicals are present in some areas of Puget Sound sediment.[5] Many of these same chemicals, such as metals and aromatic hydrocarbons, have been found to accumulate in the liver and muscle tissue of bottom-dwelling fish and are highly correlated with the incidence of carcinomas in English sole and other bottom fish in urban bays and estuaries of the Sound.

These studies give some initial insights into possible cause-effect relationships, but definitive information does not yet exist as to which chemicals, or groups of chemicals, may be responsible for fish diseases in Puget Sound.

Studies have shown that primary sewage treatment removes 57 percent of lead, 46 percent of cadmium, and 37 percent of mercury. Secondary treatment, on the other hand, can achieve reductions of 83 percent of lead, 89 percent of cadmium, and 87 percent of mercury.

Table 38 presents an example of the kind of monthly discharge measures which are routinely measured at industrial and urban sewage plants in Puget Sound. The Seattle Metropolitan sewage facility at West Point is the largest such plant in Puget Sound. The table shows how quantities and concentrations of sewage flow, biological oxygen demand, and total suspended solids have varied from 1981 through 1983.

Limits on oxygen demand and suspended solids were exceeded three times in the first five months of 1983. Nonetheless, that record was considerably better in both degree and frequency than was the case in 1981.

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[5] Malins, D.C., et al, Chemical Pollutants in Sediments and Diseases of Bottom-dwelling Fish in Puget Sound, Environmental Science and Technology (no. 18), Washington, 1984, pp. 705-713.

Table 38.--Seattle discharges at West Point, Jan - Apr, 1981-1983.

Discharge	Jan BOD	Jan TSS	Jan flow	Feb BOD	Feb TS	Feb flow	Mar BOD	Mar TSS	Mar flow
1981 Average quantity	79165.0	62448.0	130.0	78784.0	65153.0	150.1	96143.0	65580.0	120.2
1982 Average quantity	86734.0	73671.0	152.0	105651.0	96856.0			80682.0	152.9
1983 Average quantity	92797.0	39308.0	167.9	101989.0	100040.0	170.6	92262.0	75998.0	152.2
1983 Percent change	7.0	-46.6	10.5	-3.5	3.3			-5.8	-0.5
1981 Average conc.	74.0	57.0		69.0	52.0		98.0	65.0	
1982 Average conc.	70.0	58.0		71.0	62.0		72.0	63.0	
1983 Average conc.	69.0	61.0		75.0	69.0		76.0	59.0	
1983 Percent change	-1.4	5.2		5.6	11.3		5.6	-6.3	
1981 Maximum conc.	88.0	65.0		88.0	61.0		112.0	79.0	
1982 Maximum conc.	87.0	68.0		82.0	63.0		83.0	68.0	
1983 Maximum conc.	87.0	76.0		100.0	78.0		91.0	64.0	
1983 Percent change	0.0	11.8		22.0	23.8		9.6	-5.9	
EPA Ave. conc. limit	85.0	65.0		85.0	65.0		85.0	65.0	
EPA Max. conc. limit	100.0	75.0		100.0	75.0		100.0	75.0	

Discharge	Apr BOD	Apr TSS	Apr flow	May BOD	May TSS	May flow
1981 Average quantity	109307.0	103763.0	112.6	101541	101541	106.8
1982 Average quantity	79418.0	63836.0	129.4			101.2
1983 Average quantity	96745.0	59064.0	113.7	91693	56974	108.8
1983 Percent change	21.8	-7.5	-12.1			7.5
1981 Average conc.	119.0	113.0		114	114	
1982 Average conc.	76.0	59.0				
1983 Average conc.	62.0	102.0		63	103	
1983 Percent change	-18.4	72.9				
1981 Maximum conc.	169.0	187.0		129	127	
1982 Maximum conc.	83.0	69.0				
1983 Maximum conc.	65.0	112.0		68	114	
1983 Percent change	-21.7	62.3				
EPA Average conc. lim	85.0	65.0		85	65	
EPA Maximum conc. lim	100.0	75.0		100	75	

Note: BOD - biological oxygen demand; TSS - total suspended solids; Flow - total sewage flow; All quantities in lbs./day; All concentrations in mg/liter.

Source: Environmental Protection Agency.

ACKNOWLEDGMENTS

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Northwest Power Planning Council
Pacific Fishery Management Council
Port of Seattle
Port of Tacoma
Public Ports Association
San Juan Island National Park
Seattle First National Bank
U.S. Coast Guard
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Washington State Boating Safety Administration
Washington State Department of Commerce and Economic Development
Washington State Department of Ecology
Washington State Department of Employment Security
Washington State Department of Fisheries
Washington State Department of Natural Resources
Washington State Department of Revenue
Washington State Department of Transportation
Washington State Parks & Recreation Commission