

CHAPTER 5

A WEATHER SUMMARY FOR THE PACIFIC NORTHWEST, JULY 6 - SEPTEMBER 6, 1990

5.1 THE CLIMATE

Puget Sound and the Straits of Georgia together comprise a 200 mile deep-water fjord connected at right angles to the Pacific Ocean through the Straits of Juan de Fuca near latitude 49 north and 124 west. The north and south legs of the resulting "Lazy T" are nestled between the Olympic and Cascade coastal mountains, over and around which flow moist westerly air masses that impinge on the continent after a 6000 mile fetch across the Pacific Ocean.

The net on-shore, midlatitude, westerly flow, however, is modulated by seasonal contrasts between the continental and ocean temperatures. In the summer and fall, the western continental edge is warmer than the ocean, which results in a semi-stationary dipole contrast between an eastern Pacific "high" within diverging low-level marine air, and a western continental "low" within converging near-surface air.¹ In the winter and spring, and often well into the early summer, this pattern is reversed. Puget Sound has "monsoons."

Owing to coriolis effects, the low-level winds diverging from the offshore summertime "High" circulate clockwise, with the effect that in Puget Sound these winds may be northerly, roughly parallel to the north-south axis of the Cascade ridge. This summer air is at least *relatively* dry, owing to two effects: first, the near-surface air flowing outward from the high has earlier subsided from the drier, middle troposphere; second, the on-shore flow north of Puget Sound has had a chance to dump its rain on the northern Cascades. Thus, northerly winds are associated with relatively clear skies.

Conversely, the near-surface air flows counter-clockwise and inward towards the winter offshore "low," with the effect that winter winds are southerly over Puget Sound. This air is relatively moist, associated with frontal storms.

5.2 THE WEATHER

¹Careful about conventions here: the "Eastern Pacific High" is west of the "Western Continental Low."

Weather is never simple. When speaking of the "semi-stationarity" of the climate's dipole system, one should emphasize the prefix. In the summer, especially, the dipole weakens episodically, overcome by mid-latitude westerlies that in turn are driven by the global contrast between the equatorial and polar temperatures. At this season, generally weak Rossby waves propagate eastward and southward from frontal disturbances generated in the Gulf of Alaska and Bristol Bay. The dipole may disappear, may drift eastward, and may reform. The sequence of these relatively gentle vacillations drive the summer weather of Puget Sound and the maritime Pacific Northwest.

Despite these complications, perhaps one may characterize the summer weather in western Washington and northwestern Oregon as generally in one of three regimes:

1. With the maritime high positioned to the west of Vancouver Island, the near-surface winds are northerly, and the sky is sunny.
2. With the high either weakened or positioned relatively to the north, weak low-pressure air approaches the coast with fog, marine stratus and drizzly rain.
3. "Other." This may occur in transition between the first two modes, or it may result from traveling components of the Rossby waves, or from any other caprice to confound the naive.

5.3 DATA

Daily 850 mb geopotential weather maps of the North American Continent were examined for the PREVENT period of June 21 through September 7, 1990, characterizing roughly every third day (a "persistence time") by one of these three categories (Table 5-1), as follows: Figures 5-1 through 5-3 show selected (not "typical") examples of the 850 mb maps for the corresponding modes.

The near-surface weather responds to these synoptical scaled weather systems. For simplicity, the weather summaries from Seattle, which are included as photocopies in Appendix 4, are examined and from which some summary numbers are abstracted. In Table 5-2, the entry dTemp records the difference between the current daily averaged temperature and the last decade's averaged temperature for the current date. PPT is the precipitation, in inches; pressure is the surface pressure in inches of mercury; direction is the daily-averaged direction of the wind vector (360 is northerly, 90 is easterly, etc.); velocity is the daily-averaged wind vector velocity; and sun is the fraction of the available daily hours with direct sunshine.

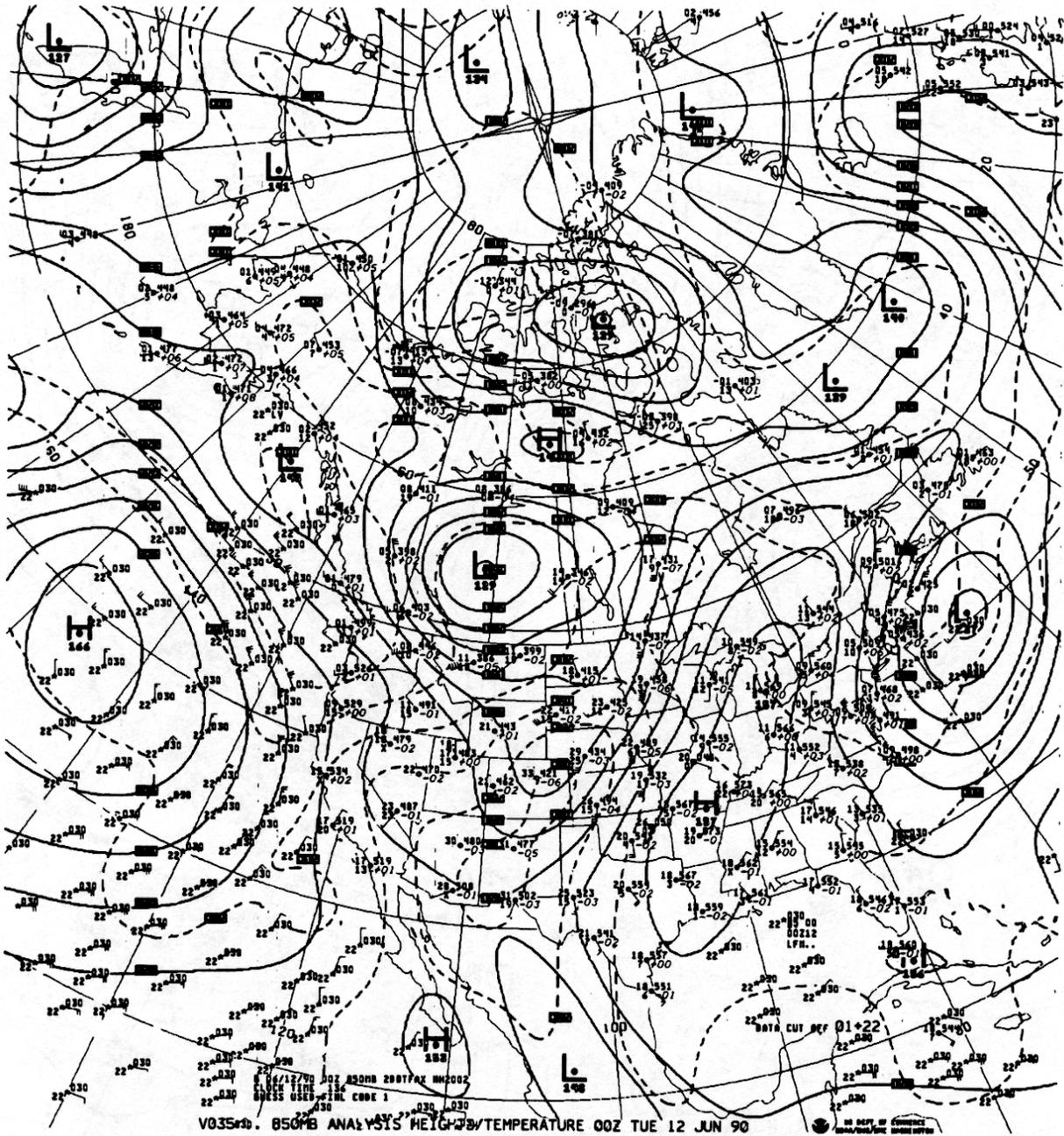


Figure 5-1. Mode 1 of daily 850 mb geopotential weather map of North American Continent. (Northerly near-surface winds and sunny skies.)

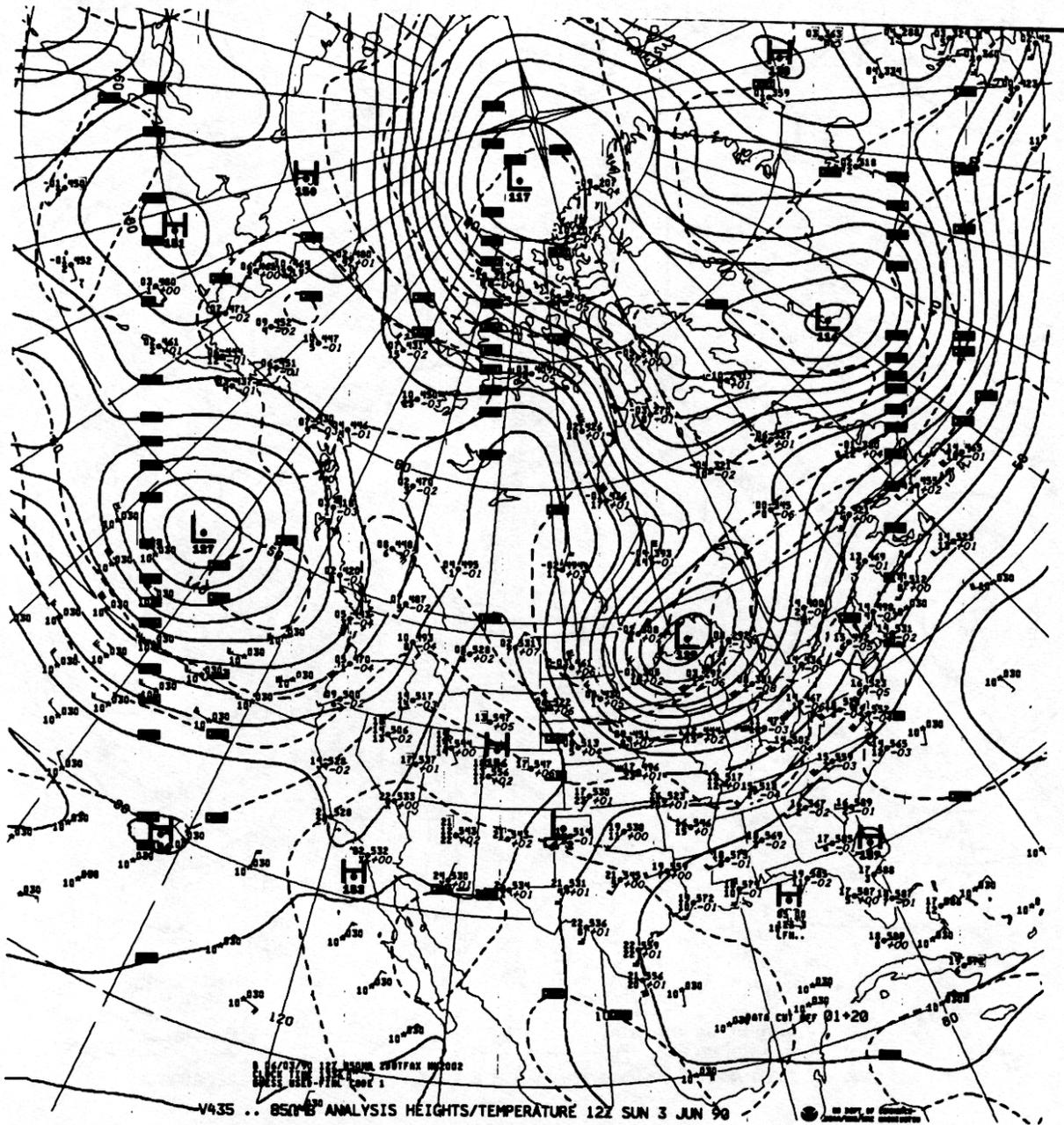


Figure 5-2. Mode 2 of daily 850 mb geopotential weather map of North American Continent. (Weak low pressure approaching coast with fog, marine stratus, and rain.)

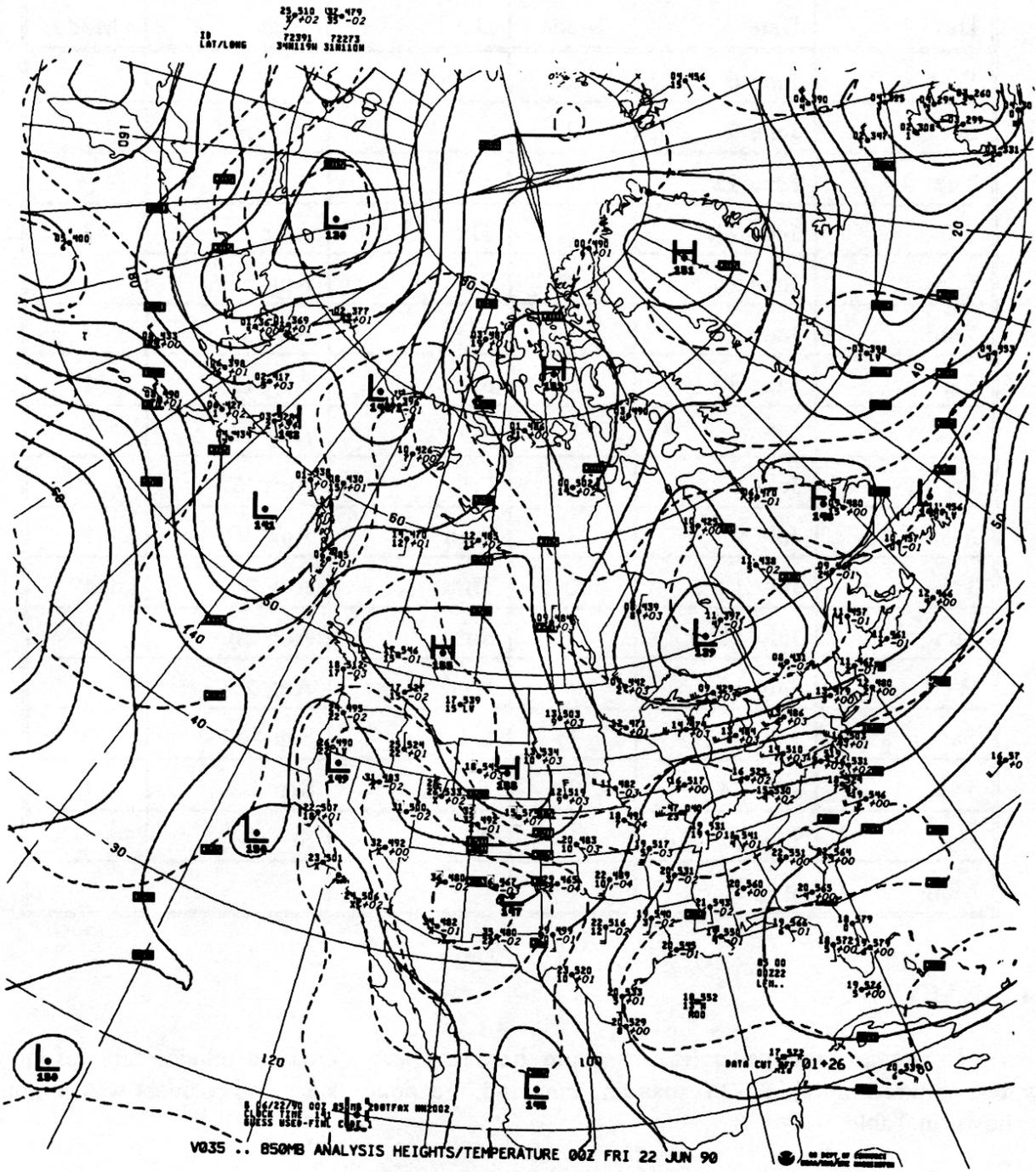


Figure 5-3. Mode 3 of daily 850 mb geopotential weather map of North American Continent. (Other)

Table 5-1. Categorization of 850 mb weather patterns into three modes for June 21 through September 7, 1990 for roughly every third day. Mode 1 is shown in Figure 5-1, Mode 2 is shown in Figure 5-2, and Mode 3 is shown in Figure 5-3.

Day	Date	Mode	Day	Date	Mode
Wed	June 6	3			
Sat	June 9	2			
Tue	June 12	1			
Thr	June 21	1	Thr	Aug 2	3
Sun	June 24	3	Sun	Aug 5	3
Wed	June 27	3	Wed	Aug 8	1
Sat	June 30	2	Sat	Aug 11	1
Tue	July 3	2	Tue	Aug 14	2
Fri	July 6	2	Fri	Aug 17	1
Mon	July 9	3	Mon	Aug 20	3
Thr	July 12	1	Thr	Aug 23	1
Sun	July 15	1	Sun	Aug 26	2
Wed	July 18	1	Wed	Aug 29	1
Sat	July 21	1	Sat	Sep 1	3
Tue	July 24	3	Tue	Sep 4	1
Fri	July 27	1	Fri	Sep 7	1
Mon	July 30	1			

5.4 ANALYSIS

To attempt some generalizations from these numbers, a cross-correlation table of the last six data columns in Table 5-2 (expanding the wind direction in sines and cosines) was computed as shown in Table 5-3.

Some of these correlations are quite obvious: for example, sunlight correlates with positive temperature anomalies and anti-correlates with rain. Others are less so. Seeking insight into the less obvious, an eigenvector rotation of Table 5-3 is performed to recover orthogonal combinations of the weather observable in Table 5-2 that may usefully characterize weather modes in the same spirit as with the subjective classification applied to the 850 mb geopotential charts. The result of this rotation is listed as Table 5-4.

Table 5-2. Temperature, precipitation, wind speeds and directions, and fraction of available daily hours with direct sunshine for each day is shown.

Julian Day	Month	Day	dTemp (deg F)	PPT (inches)	Pressure (inches)	Direction (deg)	Velocity (mph)	Sun (%)
157	6	6	-2	0.57	29.36	200	7.8	22
158	6	7	-2	0.01	29.63	220	7.7	69
159	6	8	0	0.14	29.57	210	7.1	51
160	6	9	-5	0.70	29.40	300	3.5	5
161	6	10	-7	0.07	29.48	200	14.4	34
162	6	11	-2	0.01	29.59	210	14.2	51
163	6	12	-4	0.23	29.50	160	4.4	17
164	6	13	-1	0.01	29.61	30	2.8	45
165	6	14	4	0.00	29.53	350	5.2	83
166	6	15	1	0.00	29.46	210	8.9	53
167	6	16	-3	0.01	29.53	210	9.0	47
168	6	17	1	0.01	29.62	300	4.3	70
169	6	18	1	0.00	29.71	210	3.7	45
170	6	19	2	0.00	29.78	250	4.5	61
171	6	20	6	0.00	29.68	360	9.7	83
172	6	21	10	0.00	29.45	10	10.7	92
173	6	22	3	0.02	29.33	240	5.1	30
174	6	23	0	0.01	29.51	240	5.5	65
175	6	24	-1	0.00	29.55	210	6.1	89
176	6	25	-3	0.00	29.64	220	4.8	70
177	6	26	-1	0.00	29.64	290	3.9	89
178	6	27	0	0.01	29.50	220	4.2	78
179	6	28	3	0.02	29.46	220	5.1	69
180	6	29	4	0.00	29.40	220	5.2	84
181	6	30	2	0.01	29.53	230	5.7	56
182	7	1	-1	0.01	29.55	220	4.7	56
183	7	2	-6	0.39	29.50	190	6.1	45
184	7	3	-2	0.00	29.50	350	5.0	87
185	7	4	4	0.01	29.41	310	3.9	76
186	7	5	3	0.17	29.42	210	7.0	57
187	7	6	0	0.01	29.54	210	7.1	64
188	7	7	2	0.01	29.56	360	6.5	90
189	7	8	5	0.00	29.52	360	7.8	91
190	7	9	5	0.00	29.61	10	7.6	95
191	7	10	7	0.00	29.63	10	8.6	95
192	7	11	11	0.01	29.53	360	4.6	93
193	7	12	12	0.00	29.57	280	1.5	93
194	7	13	4	0.00	29.71	340	5.0	95
195	7	14	6	0.00	29.58	360	7.1	96
196	7	15	8	0.00	29.46	360	6.9	95
197	7	16	1	0.00	29.55	250	4.4	93
198	7	17	0	0.00	29.63	290	3.9	94
199	7	18	4	0.00	29.61	350	7.8	96
200	7	19	8	0.00	29.55	10	9.4	96
201	7	20	10	0.00	29.53	350	4.8	95
202	7	21	13	0.00	29.49	350	6.0	94

Table 5-2. Continued.

Julian Day	Month	Day	dTemp (deg F)	PPT (inches)	Pressure (inches)	Direction (deg)	Velocity (mph)	Sun (%)
203	7	22	8	0.00	29.44	210	7.5	87
204	7	23	-2	0.00	29.46	220	8.2	26
205	7	24	-5	0.00	29.45	210	6.6	5
206	7	25	-7	0.01	29.52	190	6.9	0
207	7	26	-4	0.00	29.67	210	6.7	11
208	7	27	-1	0.00	29.68	320	5.4	78
209	7	28	4	0.00	29.60	360	6.4	92
210	7	29	11	0.00	29.49	10	7.9	92
211	7	30	8	0.00	-99.00	-99	-99.0	83
212	7	31	0	0.00	29.60	220	9.5	36
213	8	1	-2	0.01	29.61	220	7.3	54
214	8	2	0	0.00	29.67	330	1.4	93
215	8	3	7	0.00	29.65	10	9.6	96
216	8	4	12	0.00	29.55	360	7.0	79
217	8	5	8	0.00	29.55	200	6.7	92
218	8	6	1	0.00	29.68	280	0.7	67
219	8	7	5	0.00	29.63	360	7.7	96
220	8	8	6	0.00	29.60	350	5.6	72
221	8	9	6	0.00	29.58	330	4.6	72
222	8	10	10	0.00	29.51	310	4.2	92
223	8	11	14	0.00	29.48	350	6.1	92
224	8	12	10	0.00	29.48	210	6.5	92
225	8	13	3	0.00	29.56	200	7.1	81
226	8	14	4	0.00	29.43	250	2.6	95
227	8	15	2	0.00	29.42	210	8.7	87
228	8	16	5	0.00	29.47	220	5.6	83
229	8	17	2	0.01	29.41	210	3.2	78
230	8	18	4	0.08	29.50	330	2.2	58
231	8	19	2	0.03	29.56	350	4.1	34
232	8	20	0	0.00	29.46	290	3.0	63
233	8	21	-1	0.12	29.50	200	9.6	0
234	8	22	0	0.01	29.63	190	7.2	36
235	8	23	-3	0.00	29.56	210	3.8	79
236	8	24	-1	0.00	29.41	220	4.1	67
237	8	25	-1	0.00	29.42	220	1.8	87
238	8	26	1	0.00	29.51	340	3.5	87
239	8	27	1	0.00	29.60	320	3.2	72
240	8	28	7	0.00	29.60	350	4.9	92
241	8	29	-1	0.27	29.52	190	6.4	8
242	8	30	1	0.12	29.53	190	11.6	34
243	8	31	3	0.08	29.57	200	6.9	70
244	9	1	0	0.01	29.57	340	2.3	40
245	9	2	3	0.00	29.60	360	8.2	87
246	9	3	3	0.00	29.58	10	8.8	93
247	9	4	7	0.00	29.53	10	7.9	95
248	9	5	5	0.00	29.52	210	4.2	95
249	9	6	4	0.00	29.59	310	3.8	79

Table 5-3. Correlation matrix for data from Table 5-2.

	dTemp	PPT	Pressure	cos D	sin D	Velocity	Sun
dTemp	1.00	-0.33	0.00	0.29	0.53	0.00	0.67
PPT		1.00	-0.32	0.00	-0.20	0.00	-0.50
Pressure			1.00	0.00	0.28	0.00	0.16
cos D				1.00	0.43	0.42	0.13
sin D					1.00	-0.15	0.52
Velocity						1.00	-0.01
Sun							1.00

Table 5-4. Eigenvector rotation of Table 5-3.

Eigenvectors							
dTemp	0.498	0.068	0.318	-0.214	0.413	-0.640	0.142
PPT	-0.367	0.252	0.399	0.500	0.581	0.180	0.149
Pressure	0.209	-0.199	-0.741	0.429	0.322	-0.103	0.264
cos D	0.256	0.663	0.001	0.220	-0.448	0.017	0.494
sin D	0.485	0.066	0.129	0.525	-0.107	0.054	-0.673
Velocity	-0.020	0.648	-0.394	-0.379	0.357	0.132	-0.369
Sun	0.522	-0.170	0.138	-0.227	0.219	0.726	0.231
Eigenvalues							
	2.609	1.449	1.094	0.885	0.438	0.281	0.245
Fractional Variances							
	0.373	0.207	0.156	0.126	0.063	0.040	0.035

Note that only the first three of the eigenvectors are associated with eigenvalues exceeding one: that is, only these three vectors carry more variance than would vectors of random numbers. Furthermore, only the first two do so with significant confidence.

The first of these vectors, which carries 37% of all the weather variance (for these 7 observables), is clearly associated with high temperatures, low pressures, light winds, and sunny sky. This is in fact the same weather as the Mode 1 systems subjectively identified in the 850 mb geopotential maps.

The second vector, which carries 21% of the weather variance, is roughly the converse of the first and is associated with Mode 2. All the rest are other, or Mode 3.

This analysis suggests that the "summer monsoon" described in the first section of this report is collectively responsible for about 58% of the weather variance, and that all other physics accounts for about 42%.

Continuing along these lines, the first two eigenvectors of the data were computed from Table 5-2 and their associated daily variance fractions. The latter were plotted in Figure 5-4 and listed in Table 5-5 together with the sum of variance fractions attributable to the remaining eigenvectors. In Table 5-5, VFmode1 corresponds to the variance fraction of Mode 1, and so on. Thus, on Julian day (JD) 158, for example, the weather pattern was predominantly Mode 3, on JD159 it was predominantly Mode 1, and on JD177 it was predominantly Mode 2. Note that on JD211 missing data forced default entries of -888.

5.5 SUMMARY

The weather in the Pacific Northwest during the summer of 1990, vacillated between two characteristic patterns that together accounted for slightly over half of all the variance. The first of these patterns was associated with high surface pressures, light northerly winds, and clear skies. The second was associated with lower pressure, southerly winds, and overcast skies. This was a fairly typical year. El Nino was not active.

Table 5-5. Daily variance fractions of eigenvectors for Modes 1, 2 and other for Mode 3 from Table 5-4.

Julian Day	Month	Day	VFModel	VFMode2	VFOther
157	6	6	0.50134	0.16213	0.33653
158	6	7	0.17763	0.05230	0.77007
159	6	8	0.71039	0.01955	0.27006
160	6	9	0.42970	0.00855	0.56176
161	6	10	0.35326	0.32948	0.31726
162	6	11	0.12505	0.21596	0.65899
163	6	12	0.40495	0.18866	0.40639
164	6	13	0.02795	0.05802	0.91404
165	6	14	0.66401	0.01047	0.32553
166	6	15	0.35176	0.10809	0.54015
167	6	16	0.53410	0.05568	0.41021
168	6	17	0.00127	0.68983	0.30890
169	6	18	0.06280	0.21837	0.71883
170	6	19	0.00083	0.37667	0.62250
171	6	20	0.44200	0.20567	0.35233
172	6	21	0.35660	0.50379	0.13961
173	6	22	0.30921	0.01959	0.67120
174	6	23	0.35467	0.42048	0.22484
175	6	24	0.08431	0.12550	0.79019
176	6	25	0.15710	0.35596	0.48694
177	6	26	0.00450	0.71689	0.27860
178	6	27	0.21195	0.43805	0.35001
179	6	28	0.21708	0.15235	0.63057
180	6	29	0.03626	0.06789	0.89584
181	6	30	0.39357	0.31212	0.29432
182	7	1	0.52399	0.34204	0.13397
183	7	2	0.57478	0.10147	0.32375
184	7	3	0.09372	0.00101	0.90527
185	7	4	0.00390	0.19216	0.80394
186	7	5	0.45282	0.08313	0.46405
187	7	6	0.46080	0.00242	0.53679
188	7	7	0.52198	0.14667	0.33135
189	7	8	0.60087	0.31275	0.08638
190	7	9	0.64594	0.22315	0.13091
191	7	10	0.64163	0.25136	0.10701
192	7	11	0.73555	0.02211	0.24234
193	7	12	0.16108	0.52094	0.31798
194	7	13	0.47843	0.08169	0.43988
195	7	14	0.81843	0.13912	0.04245
196	7	15	0.55682	0.18947	0.25371
197	7	16	0.00635	0.76605	0.22760
198	7	17	0.02064	0.74058	0.23878
199	7	18	0.69060	0.07484	0.23456
200	7	19	0.58324	0.40597	0.01079
201	7	20	0.80112	0.00075	0.19813
202	7	21	0.65220	0.03299	0.31481

Table 5-5. Continued.

Julian Day	Month	Day	VFModel	VFMode2	VFOther
203	7	22	0.00846	0.01066	0.98087
204	7	23	0.64414	0.01680	0.33907
205	7	24	0.69149	0.00818	0.30033
206	7	25	0.58113	0.05482	0.36404
207	7	26	0.38045	0.00489	0.61465
208	7	27	0.05129	0.25429	0.69442
209	7	28	0.72959	0.08135	0.18906
210	7	29	0.58185	0.30204	0.11611
211	7	30	-888	-888	-888
212	7	31	0.30823	0.01579	0.67598
213	8	1	0.38114	0.04711	0.57175
214	8	2	0.14282	0.45980	0.39738
215	8	3	0.56365	0.27321	0.16314
216	8	4	0.66504	0.15155	0.18341
217	8	5	0.12479	0.00015	0.87506
218	8	6	0.00024	0.81791	0.18185
219	8	7	0.69720	0.12265	0.18015
220	8	8	0.69139	0.01244	0.29617
221	8	9	0.48796	0.18648	0.32556
222	8	10	0.32681	0.23846	0.43473
223	8	11	0.59906	0.03850	0.36244
224	8	12	0.07606	0.00315	0.92079
225	8	13	0.00335	0.00549	0.99116
226	8	14	0.00098	0.49459	0.50443
227	8	15	0.05265	0.05045	0.89690
228	8	16	0.00893	0.13800	0.85307
229	8	17	0.09499	0.12961	0.77540
230	8	18	0.00327	0.17009	0.82664
231	8	19	0.00050	0.00568	0.99382
232	8	20	0.08472	0.52584	0.38944
233	8	21	0.62280	0.23088	0.14633
234	8	22	0.21881	0.05897	0.72222
235	8	23	0.18112	0.34687	0.47201
236	8	24	0.30268	0.13711	0.56020
237	8	25	0.09054	0.33597	0.57348
238	8	26	0.21022	0.13084	0.65894
239	8	27	0.05303	0.61697	0.32999
240	8	28	0.88454	0.00259	0.11287
241	8	29	0.65448	0.15174	0.19378
242	8	30	0.28949	0.52745	0.18306
243	8	31	0.17428	0.04741	0.77831
244	9	1	0.00185	0.11837	0.87978
245	9	2	0.51172	0.25442	0.23386
246	9	3	0.44937	0.38466	0.16598
247	9	4	0.63403	0.33953	0.02644
248	9	5	0.02303	0.27871	0.69826
249	9	6	0.14868	0.69645	0.15487

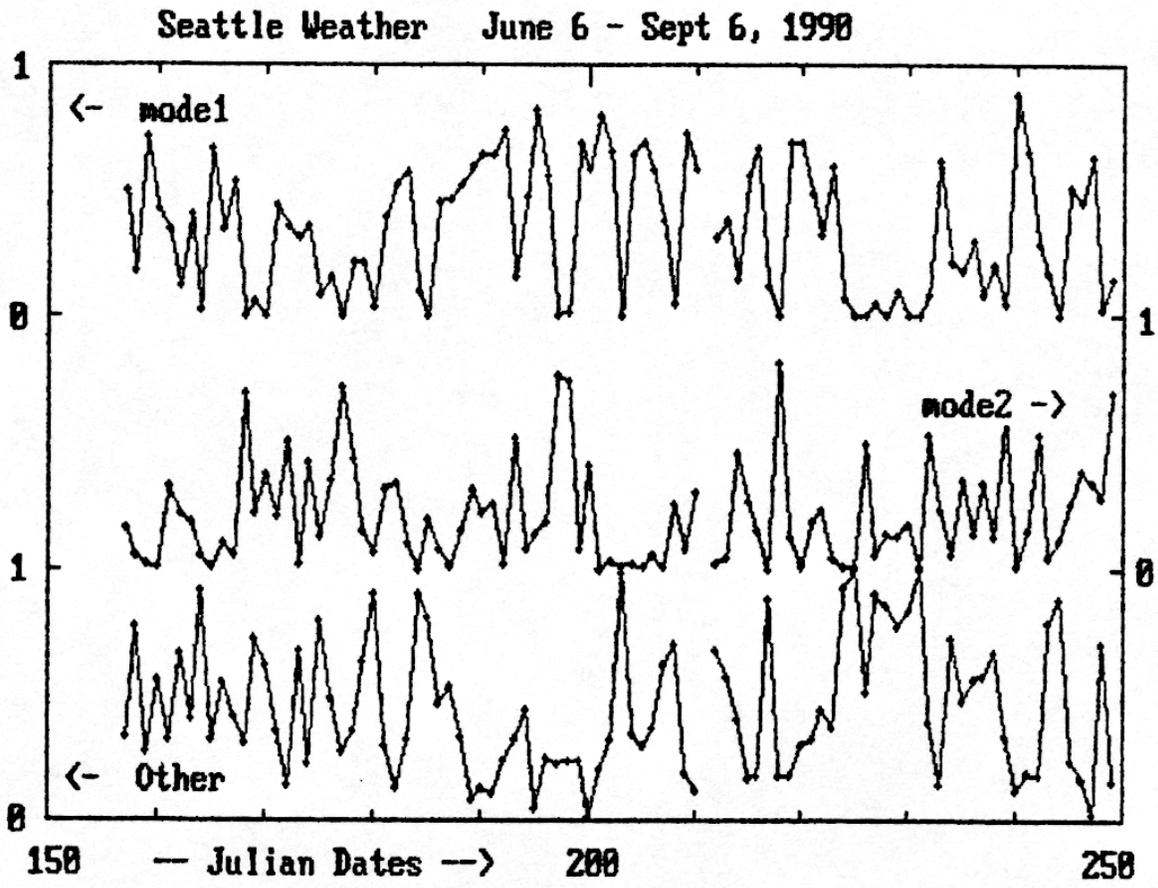


Figure 5-4. Variance fractions attributable to Modes 1, 2, and "other."