CALIFORNIA'S SANTA CRUZ ISLAND WEATHER

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ABSTRACT

Statistics are developed from five weather stations on Santa Cruz Island. Record length is 94 years for one station and between two and eight years for the other four. Temperature and humidity variations are limited by the marine layer influence, except for the interior island valley which is isolated by topography. The 1997-1998 water year was the fourth largest rainfall total recorded since 1904. During a large storm on December 5 and 6, 1997, these weather stations recorded precipitation values ranging from 152 mm (6 in) to 254 mm (10 in) over a 36-hour period. This event was responsible for a large debris flow, which inundated a National Park Service campground and moved historic buildings off their foundations in Scorpion Harbor. Observations by park rangers reported rain totals of over 305 mm (12 in) in that time period.

Keywords: Santa Cruz Island, weather, El Niño.

INTRODUCTION

Although significant climatological research has been completed on coastal southern California, studies of the climatology of the Channel Islands have been limited and have not addressed specific islands (Figure 1). The climate of Santa Cruz Island is especially difficult to generalize because of its many microclimates. This study, still in its preliminary stages, examines air temperature, relative humidity, wind and precipitation data collected at four recently installed weather stations and a longer (94-year) record of precipitation from the Main Ranch, located in the central valley of the island. Particular attention is paid to a recent flood event, which affected Santa Cruz Island in December of 1997.

METHODOLOGY

Data for this study were collected from five sites located on Santa Cruz Island: National Park Service (NPS) Central Valley, Christy Airfield, Christy Pines, Prisoners Harbor, and the Main Ranch (Figure 2). Automated as well as standard meteorological instruments administered by NPS, California State University Northridge, and the U.C. Reserve System were used. At the Main Ranch, temperature and precipitation data have been manually collected. In this paper, only the precipitation record is analyzed. At the four automated sites hourly readings of temperature and relative humidity were recorded at standard heights of 1.5 meter (m), whereas wind speed/direction were recorded at heights varying between 2.5 and 6 m. In the vicinity of the Main Ranch manual station, the National Park Service automated weather station was established in April of 1990. However, it has been moved three times from its original location near Centinela (elev. 155 m), to the vicinity of the U.C. Research Station approximately 1 km west of the Main Ranch (elev. 62 m), and finally to just south of the Main Ranch on a north-facing slope (elev. 152 m). This change was noted in the record but the move was not judged to be significant enough to warrant separation of the data. The Prisoners Harbor weather station was originally located in the Central Valley

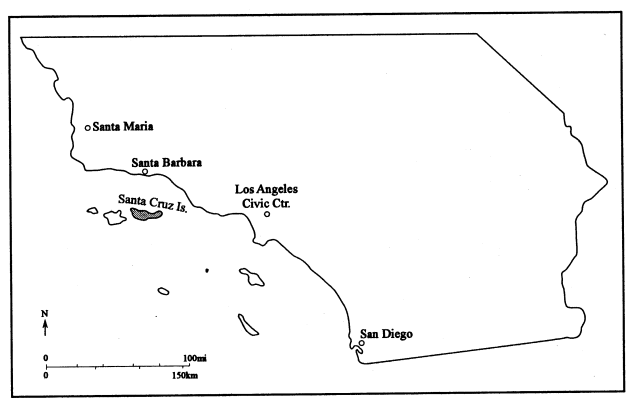

Figure 1. Southern California coastal region.

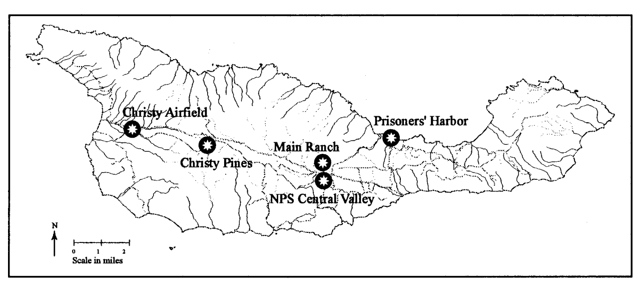

Figure 2. Location map of Santa Cruz Island weather stations.

near Cañada de la Portezuela (elev. 137 m) in the late 1980s, but in June of 1995 the station was moved to the coast (elev. 122 m) to fill a gap that existed in the coverage of the island. Only the later data by the coast was analyzed for this report. Two more stations, maintained by California State University Northridge, were added in December of 1996: Christy Pines (elev. 419 m) and Christy Airfield (elev. 64 m) (Figure 2). The siting of these new stations was designed to fill in gaps that existed in the climatic coverage of the island. Thus, data are presently being collected from four distinct geographic regions: the central valley, coastal plain, mountain peak, and northern coast.

CLIMATE

Santa Cruz Island is the largest of the California Channel Islands, with an areal extent of 248 km^2. It is located approximately 25 km from the coast of Santa Barbara (Figure 1) and reaches a maximum elevation of 753 m. The island is aligned approximately east-west, roughly parallel with the prevailing winds. A large fault controlled valley runs down the central axis of the island, bounded by mountains that rise to elevations of 700 m or more. The climate of Santa Cruz Island is Mediterranean Dry Summer Subtropical, with a cool summer regime (Kimura 1974; Ryan 1994). The surrounding Pacific Ocean effectively moderates seasonal and diurnal temperature and humidity ranges. A steady inflow of marine air minimizes temperature changes over much of the island. Diurnal temperature ranges tend to be small, with relatively cool days and warm nights (Kimura 1974). Seasonal variations in wind in the region are related to shifts in the location of a semi-permanent anticyclone over the eastern Pacific Ocean and the intensification of a semi-permanent thermal low over California and the Great Basin (Nelson 1977). The semi-permanent Pacific subtropical anticyclone or Pacific High is extremely important to southern California weather. The Pacific High deflects storms and produces a prevailing onshore flow of moist Pacific air at the surface into the region. At elevation, the Pacific High produces subsidence of warm, dry air restricting the location of moist marine air to the lowest few hundred meters above the surface (Rosenthal 1972).

Topography plays an important role in defining the island's microclimate. The central valley has greater temperature and humidity extremes due to its isolated location. The central valley is hotter and drier in the summer and receives more precipitation in the winter months than any other coastal station. Along the immediate Santa Cruz Island coast, low clouds predominate during the summer months, while inland valleys remain generally clear.

Summer Pattern

The most dominant climatic control for coastal southern California during both summer and winter is the semi-permanent Pacific subtropical anticyclone or Pacific High (Kimura 1974; Ryan 1994). In summer, this high pressure cell strengthens and moves northward from over the eastern Pacific Ocean toward the northern California/Oregon coast. A clockwise flow of air around the high results in persistent northwest winds over most of the offshore area (Rosenthal 1972). Active subsidence with the high pressure results in air warmed by compression and the creation of a temperature inversion (Neiburger et al.1961; Baynton et al. 1965; Rosenthal 1972; Kimura 1974; Nelson 1977). The inversion base near the coast of southern California is approximately 400 to 600 m but rises gradually westward and is slightly higher at Santa Cruz Island. Cool water flowing southward from the California Current helps maintain this inversion at low elevations along the southern California coast (Neiburger et al. 1961; Nelson 1977). Fog and low stratus clouds are created as the overlying air is chilled by cool water. These inversions create very stable atmospheric conditions which limit convective activity and turbulent diffusion above the inversion base. Thus, during the summer months the only precipitation is light drizzle from stratus clouds.

Infrequently, during non-winter months a deepening of the marine layer known as a Catalina Eddy occurs off the coast of the southern California. An eddy is the rotational movement occurring in a flowing fluid that appears as irregular whirls. The Catalina Eddy is responsible for creating a thick persistent marine layer with stratus clouds and a weak cyclonic flow throughout the offshore region (Bosart 1983; Dorman 1985; Wakimoto 1987; Mass and Albright 1989; Clark and Dembek 1991; Thompson et al. 1996). During such events, Santa Cruz Island is inundated with a thick marine layer that persists at mountain summit locations as well as in the interior reaches of the Central Valley.

Winter Pattern

Toward the end of October and early November the stable atmosphere of summer is broken down. The Pacific anticyclone weakens and migrates southward, permitting frontal systems to enter southern California (Kimura 1974). As a result, precipitation is concentrated in the winter months, with 94% of all rainfall occurring between the months of November to April. The 94-year precipitation table at the Main Ranch (Table 1) shows an average annual rainfall of 515 mm (20.26 in). Precipitation totals increase with elevation giving the island a diverse rainfall total. Average rainfall along the coast is approximately 380 mm (14.96 in). Prevailing winds are generally from the west or northwest with surface wind patterns modified by local topography. In late fall and early winter as the Pacific anticyclone cell begins to move northwest and surface high pressure develops over the Great Basin, light offshore winds develop bringing relatively clear days to southern California (Nelson 1977; Dorman and Winant 1995). If the surface pressure over the Great Basin greatly exceeds that found along the southern California coast, very strong winds develop known as Santa Ana winds (Small 1995). These high winds create an offshore flow strong enough to reach the Channel Islands and be potentially dangerous to boaters (Small 1995).

DATA ANALYSIS

Air Temperature

Central valley temperatures were analyzed from the 1990-1998 record of the NPS automated weather station. For the time period analyzed, the mean annual temperature was 13.4°C. The highest mean monthly temperature (17.5°C) occurred in August, while the lowest mean monthly temperatures (9.4°C) occurred in December and January. During winter in the central valley, it is not uncommon to find minimum temperatures on the coldest days to be well below freezing. Extreme minimum temperatures have reached as low as –8.3°C. During summer and fall, central valley air temperatures are warm, as cool marine air is held back by the surrounding mountains. Maximum recorded temperatures reached 39.4°C.

The Christy Airfield weather station is located on a narrow coastal plain at the western end of Santa Cruz Island. The climate at this site is influenced by its proximity to the coast and location on the prevailing wind side of the island. Temperatures are moderated by the cool sea breeze throughout most of the year. Daily temperatures gradually increase as the marine layer dissipates. The mean annual temperature for Christy Airfield was 16.2°C. This relatively high annual average is principally a result of the moderating effect of the ocean and the low elevation (64 m) of the station. Mean monthly temperatures were highest in August (18.4°C) and September (19.1°C), while the extreme maximum temperature occurred on November 2, 1997 (37.2°C). Mean annual minimum temperatures in winter were as low as 9°C in December, with the extreme minimum temperature of 2.2°C recorded on February 26, 1997.

The Christy Pines weather station is also located in western Santa Cruz Island, but at approximately 419 m elevation, it is the highest weather station used in this study and the only station located on a mountain crest. The station is sited in an open area among pine trees just below a north-facing crest. A thick marine layer and the station's proximity to the coast are the strongest factors in moderating temperatures at this location. The Christy Pines mean annual temperature was 15.0°C, which is less than the Christy Airfield and Prisoners Harbor mean, but above the longer-term record of the central valley (13.4°C). This difference in mean annual temperatures is primarily due to colder winter temperatures and less influence of the marine layer in the Central Valley. The highest mean monthly temperature (21.2°C) occurred in September, and the extreme high temperature (36.0°C) occurred in August. Annual mean monthly temperatures vary according to the depth and penetration of the marine layer. For example, a significant drop in the mean monthly temperature occurred in June 1997, when the temperature averaged 13.9°C. This drop was due to an increase in the marine layer, which effectively lowered temperatures. The following July mean monthly temperature rose to 17.1°C. The lowest mean monthly temperatures (11.1°C) were recorded in February. The extreme minimum temperature reached a low of 3.7°C in March. In autumn, mean

Table 1. Precipitation record from Santa Cruz Island Main Ranch (courtesy L. Laughrin). Data taken with a standard four inch rain gauge.

	Season	Total	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
	1904	269.2							18.3	119.9	91.7	39.4	0.0	0.0
1904	1905	629.7	0.0	0.0	56.4	11.2	0.0	34.8	119.1	200.4	158.5	4.8	44.5	0.0
1905	1906	732.8	0.0	0.0	0.0	0.0	45.2	0.0	166.9	138.2	291.8	12.4	76.7	1.5
1906	1907	611.4	0.0	0.0	0.0	0.0	12.7	113.8	195.1	57.9	231.9	0.0	0.0	0.0
1907	1908	742.4	0.0	0.0	0.0	108.7	0.0	78.7	175.3	346.7	2.5	30.5	0.0	0.0
1908	1909	860.6	0.0	0.0	35.6	0.0	33.3	80.5	365.3	253.0	93.0	0.0	0.0	0.0
1909	1910	462.5	0.0	0.0	0.0	7.1	49.3	243.6	80.8	0.0	75.4	6.4	0.0	0.0
1910	1911	798.3	1.3	0.0	64.8	9.1	13.2	40.9	328.7	115.8	153.7	69.6	0.0	1.3
1911	1912	363.2	0.0	0.0	4.3	0.0	2.5	25.1	12.7	0.0	215.1	73.2	30.2	0.0
1912	1913	388.1	0.0	0.0	0.0	9.4	1.3	0.0	98.6	221.2	7.6	39.1	0.0	10.9
1913	1914	686.6	0.8	1.5	0.0	0.0	50.8	145.8	275.6	151.1	25.9	30.7	0.0	4.3
1914	1915	834.9	5.8	0.0	0.0	0.0	5.3	163.1	154.4	277.4	89.2	99.3	40.4	0.0
1915	1916	780.8	0.0	0.0	5.1	0.0	14.2	74.4	559.6	68.6	58.9	0.0	0.0	0.0
1916	1917	515.9	0.0	0.0	63.5	68.3	5.6	126.2	86.9	151.9	4.8	8.6	0.0	0.0
1917	1918	527.8	0.0	0.0	2.0	0.0	4.6	1.3	15.0	173.2	325.6	0.0	6.1	0.0
1918	1919	306.8	0.0	2.5	40.6	0.0	90.2	18.3	23.9	69.3	35.8	0.0	26.2	0.0
1919	1920	224.0	0.0	0.0	0.0	0.0	1.8	19.3	0.0	91.7	94.0	17.3	0.0	0.0
1920	1921	529.1	0.0	0.0	0.0	8.4	50.0	46.5	247.9	36.1	67.3	6.6	66.3	0.0
1921	1922	601.5	0.0	0.0	10.7	18.5	1.3	259.3	91.4	168.4	45.0	0.0	6.9	0.0
1922	1923	444.0	0.0	0.0	0.0	8.9	48.5	247.1	15.0	51.1	4.6	68.1	0.0	0.8
1923	1924	165.9	0.0	0.0	4.8	0.0	13.5	19.6	31.0	0.0	61.5	35.6	0.0	0.0
1924	1925	316.2	0.0	0.0	0.0	19.8	19.3	49.5	17.5	57.7	53.3	21.6	73.7	3.8
1925	1926	511.8	0.0	0.0	0.0	0.0	17.8	68.6	68.1	157.0	9.9	190.5	0.0	0.0
1926	1927	587.0	0.0	0.0	0.0	0.0	121.9	66.0	67.1	282.2	49.8	0.0	0.0	0.0
1927	1928	361.4	0.0	0.0	0.0	64.5	94.5	82.0	0.0	44.5	65.3	10.7	0.0	0.0
1928	1929	318.0	0.0	0.0	0.0	8.1	50.0	71.6	39.9	62.0	71.1	0.0	0.0	15.2
1929	1930	431.8	0.0	0.0	8.4	0.0	0.0	0.0	181.1	91.7	82.8	8.9	58.9	0.0
1930	1931	401.8	0.0	0.0	0.0	0.0	67.1	0.0	125.7	121.9	0.0	56.6	30.5	0.0
1931	1932	682.2	0.0	2.5	0.0	0.0	49.3	294.4	118.6	205.0	6.1	5.8	0.5	0.0
1932	1933	313.7	0.0	0.0	25.7	1.5	0.0	29.7	176.8	0.0	16.8	11.7	1.0	50.5
1933	1934	509.3	0.0	9.7	0.0	28.2	0.0	193.8	38.1	176.3	0.0	0.0	0.0	63.2
1934	1935	610.9	0.0	0.0	0.0	23.4	112.5	66.3	130.3	29.7	137.9	110.7	0.0	0.0
1935	1936	412.2	0.0	0.0	3.6	13.5	40.6	0.0	54.9	223.0	46.2	30.5	0.0	0.0
1936	1937	808.2	0.0	9.1	0.0	101.3	0.0	116.6	83.3	339.6	158.2	0.0	0.0	0.0
1937	1938	724.4	0.0	0.0	0.0	0.0	0.0	134.6	39.9	290.8	259.1	0.0	0.0	0.0
1938	1939	367.8	0.0	0.0	0.0	16.5	3.8	118.1	100.3	57.2	68.1	3.8	0.0	0.0
1939	1940	599.7	0.0	0.0	0.0	86.9	13.2	0.0	38.6	162.6	264.9	22.4	11.2	0.0
1940	1941	1426.2	0.0	0.0	0.0	41.4	18.5	366.3	401.6	226.3	231.1	139.4	1.5	0.0
1941	1942	486.2	0.0	0.0	0.0	57.9	9.4	202.2	26.9	36.3	59.9	93.5	0.0	0.0
1942	1943	583.9	0.0	0.0	0.0	14.0	5.1	52.1	313.9	81.0	76.7	41.1	0.0	0.0
1943	1944	685.5	0.0	0.0	0.0	23.4	5.6	248.4	91.7	203.5	85.1	27.9	0.0	0.0
1944	1945	445.8	0.0	0.0	0.0	0.0	98.6	17.0	23.9	123.7	182.6	0.0	0.0	0.0
1945	1946	341.4	0.0	0.0	0.0	8.1	0.0	227.6	5.6	17.8	82.3	0.0	0.0	0.0
1946	1947	254.3	0.0	0.0	0.0	6.1	115.6	68.6	10.7	15.7	37.6	0.0	0.0	0.0
1947	1948	203.2	0.0	0.0	0.0	12.4	0.0	27.9	0.0	12.7	90.4	56.6	3.0	0.0
1948	1949	303.5	0.0	0.0	0.0	0.0	0.0	64.0	117.3	38.1	69.1	0.0	15.0	0.0
1949	1950	467.9	0.0	0.0	0.0	0.0	27.2	182.4	110.5	110.0	28.2	9.7	0.0	0.0
1950	1951	319.5	0.0	0.0	7.6	27.9	37.8	18.3	80.0	57.2	24.9	61.2	4.6	0.0
1951	1952	761.2	0.0	0.0	0.0	9.7	33.8	167.4	286.3	37.8	159.8	66.5	0.0	0.0
1952	1953	425.7	0.0	0.0	0.0	2.5	97.0	184.2	56.6	6.9	25.7	52.8	0.0	0.0
1953	1954	460.2	0.0	0.0	0.0	0.0	45.2	0.0	152.7	134.1	110.0	18.3	0.0	0.0
1954	1955	459.7	0.0	0.0	0.0	0.0	74.7	56.4	96.0	48.0	63.2	94.7	26.7	0.0
1955	1956	742.7	0.0	0.0	0.0	0.0	6.4	287.8	331.2	33.5	0.0	61.0	22.9	0.0
1956	1957	407.7	0.0	0.0	0.0	0.0	0.0	0.0	176.0	122.2	29.7	50.8	29.0	0.0
1957	1958	899.4	0.0	0.0	0.0	40.1	2.8	84.8	116.8	246.1	278.1	117.6	13.0	0.0
1958	1959	290.1	0.0	0.0	2.5	0.0	0.0	5.6	42.2	189.0	0.0	50.8	0.0	0.0
1959	1960	442.5	0.0	0.0	8.4	0.0	0.0	66.3	128.5	176.8	8.9	53.6	0.0	0.0
1960	1961	225.3	0.0	0.0	0.0	0.0	151.4	12.2	40.6	0.0	18.0	1.8	1.3	0.0
1961	1962	731.3	0.0	0.0	2.3	0.0	111.8	41.1	66.5	412.0	97.0	0.0	0.5	0.0
1962	1963	381.3	0.0	0.0	0.0	11.7	0.5	10.7	93.2	134.9	70.9	55.6	1.8	2.0
1963	1964	309.4	0.0	3.0	21.8	6.4	93.0	0.8	77.0	1.0	89.7	11.2	1.8	3.8
1964	1965	603.5	0.0	0.5	0.0	18.3	50.8	265.2	24.6	10.4	67.3	166.4	0.0	0.0
1965	1966	372.1	0.0	0.0	0.0	0.0	242.6	28.7	69.1	27.4	4.3	0.0	0.0	0.0
1966	1967	418.6	0.0	0.0	1.3	0.0	43.7	80.0	134.1	9.4	24.1	126.0	0.0	0.0
1967	1968	398.3	0.0	0.0	0.0	0.0	118.6	29.2	34.0	59.9	143.0	13.5	0.0	0.0
1968	1969	705.4	0.0	0.0	0.0	35.6	26.7	49.0	361.7	189.7	12.7	30.0	0.0	0.0
1969	1970	277.4	0.0	0.0	0.0	2.0	58.4	5.1	105.2	67.6	39.1	0.0	0.0	0.0
1970	1971	417.6	0.0	0.0	0.0	0.8	162.8	150.1	29.2	30.0	16.0	15.2	13.5	0.0
1971	1972	227.3	0.0	0.0	0.0	0.0	7.9	189.0	20.8	5.6	0.0	3.6	0.0	0.5
1972	1973	537.0	0.0	0.0	0.0	5.3	94.2	33.3	166.1	186.7	51.3	0.0	0.0	0.0
1973	1974	422.9	0.0	0.0	6.1	23.4	52.3	44.7	204.5	81.8	10.2	0.0	0.0	0.0
1974	1975	380.0	0.0	0.0	0.0	16.5	5.8	136.7	17.3	87.9	83.6	32.3	0.0	0.0
1975	1976	174.5	0.0	0.0	0.0	9.1	9.4	1.5	0.0	88.4	30.0	21.6	0.8	13.7
1976	1977	302.5	0.0	1.5	61.7	0.0	11.9	24.1	92.5	4.8	33.0	0.0	72.4	0.5
1977	1978	1113.3	0.0	18.8	17.8	0.0	3.8	121.7	200.9	280.9	392.4	77.0	0.0	0.0
1978	1979	644.7	0.0	0.0	27.7	0.3	65.5	77.2	246.4	86.9	140.7	0.0	0.0	0.0
1979	1980	648.5	0.0	0.0	1.5	7.6	67.3	39.9	235.5	229.4	61.7	5.6	0.0	0.0
1980	1981	407.9	5.1	0.0	0.0	0.0	0.0	71.4	52.3	138.7	133.1	7.4	0.0	0.0
1981	1982	426.0	0.0	0.0	4.1	12.7	73.2	23.4	134.1	11.9	119.1	47.5	0.0	0.0
1982	1983	970.8	0.0	0.0	35.6	19.3	117.3	66.0	247.9	162.1	205.0	117.6	0.0	0.0
1983	1984	413.0	0.0	32.8	34.5	41.9	146.8	147.8	0.0	1.0	2.3	5.8	0.0	0.0
1984	1985	406.7	0.0	19.8	44.7	20.1	85.9	127.0	38.9	39.9	30.0	0.5	0.0	0.0
1985	1986	805.4	0.0	0.0	0.5	17.5	164.1	57.7	121.4	299.0	138.2	7.1	0.0	0.0
1986	1987	355.3	0.0	0.0	48.5	0.0	13.5	35.1	53.8	79.8	120.1	2.3	0.0	2.3
1987	1988	397.0	1.8	0.0	0.0	51.8	17.3	134.6	62.7	34.8	3.0	90.9	0.0	0.0
1988	1989	226.6	0.0	0.0	0.0	0.0	37.3	64.8	33.3	61.0	19.6	5.6	5.1	0.0
1989	1990	161.3	0.0	0.0	0.0	13.5	8.1	0.0	63.5	28.4	0.0	22.4	25.4	0.0
1990	1991	395.6	0.0	0.1	12.2	0.0	7.9	7.1	37.3	95.5	219.2	0.8	0.0	15.5
1991	1992	519.4	0.0	0.0	0.0	7.1	5.3	109.0	52.1	196.6	149.4	0.0	0.0	0.0
1992	1993	639.3	11.7	0.0	0.0	23.1	0.3	118.9	246.4	143.0	86.4	0.0	0.0	9.7
1993	1994	390.4	0.0	0.0	0.0	2.5	22.4	46.7	15.5	205.5	48.8	16.0	33.0	0.0
1994	1995	1146.3	0.0	0.0	6.6	0.0	45.7	40.6	777.7	21.3	229.1	4.6	9.9	10.7
1995	1996	395.2	0.0	0.0	0.0	2.5	0.0	66.8	72.1	170.9	47.0	31.0	4.8	0.0
1996	1997	593.1	0.0	0.0	0.0	35.1	64.3	226.1	267.7	0.0	0.0	0.0	0.0	0.0
1997	1998	1101.9	0.0	0.3	3.8	0.3	80.8	305.1	76.2	435.1	85.3	39.9	72.6	2.5

	Total	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mean	514.5	0.3	1.1	7.2	13.2	41.3	88.8	120.9	116.1	85.1	31.3	8.8	2.2
St Dev	234.1	1.4	4.5	15.7	21.8	48.3	85.5	126.3	100.2	83.4	40.7	18.8	8.7
Var	2155.4	0.1	0.8	9.7	18.7	92.0	288.1	629.9	399.3	276.9	66.0	14.1	3.0

monthly temperatures begin to decline, but mean maximum and extreme monthly maximum temperatures stay high due to a less persistent marine layer.

The Prisoners Harbor weather station location greatly affects its temperature regime. Located at an elevation of 122 m, the station sits on a north-facing coastal bluff overlooking the harbor (Figure 2). Station temperatures are moderated by nearness to the coast and are consistent throughout the year. The mean annual temperature for Prisoners Harbor is 16.1°C, just below that of Christy Airfield. The highest mean monthly temperature (19.1°C) was recorded in September. The extreme maximum temperature (34.8°C) was recorded in October. The lowest mean monthly temperature (13.6°C) was recorded in January and February. The extreme low temperature (5.5°C) was recorded in February. As with the Christy Airfield and Christy Pines stations, Prisoners Harbor weather station also exhibits a drop in mean monthly temperatures in June due to an increased marine layer. Interestingly, the central valley weather station shows no dip in mean monthly temperature in June owing to its interior position remote from the invading coastal marine layer.

Relative Humidity

Central valley relative humidity is mainly affected by the surrounding Pacific Ocean, but is also modified greatly by its inland valley location. Geographically surrounded by mountains, the central valley does not receive as much daily influence from marine intrusion, and as temperature rises humidity begins to decrease. The mean annual relative humidity of 72% is lower than any of the other stations (Figure 3). Humidity tends to drop slightly in April (68%) and in October/November (68 and 65%) but remains high in the intervening summer months. In June, humidity readings increase as the marine layer develops, creating early morning fog that burns off during the day. With the development of a Catalina Eddy, the thicker than normal marine layer allows fog to persist in the Central Valley for the entire day. In the late fall/early winter offshore winds develop bringing dry continental air to the island decreasing humidity. During periods of very strong offshore flow and high temperatures, relative humidity has reached minimum values of 3 to 4%.

Christy Airfield has the highest mean annual relative humidity (79%) of any weather station (Figure 3). Daily humidity remains high over the course of the year, except for October when mean monthly humidities drop to 67% associated with an increase in temperature and a change in wind direction as off-shore flow creates dryer conditions in this part of the island. During May through September, extreme minimum relative humidities remain high (35 and 51%) due to a deep persistent marine layer.

Christy Pines has a mean annual relative humidity of 75% (Figure 3). Humidities remain high through winter and peak in June with a mean monthly relative humidity of 92%, the highest monthly average of any weather station. In June mean monthly humidities never dropped below 49%, indicating a thick persistent marine layer. Near the end of

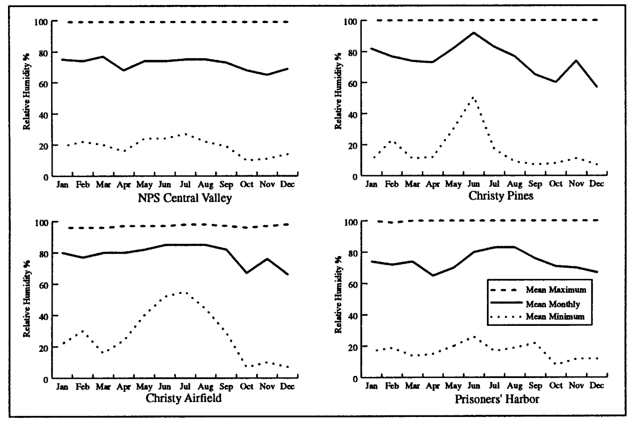

Figure 3. Mean monthly relative humidity comparison of four automated weather stations on Santa Cruz Island.

October humidities begin to fall as the marine layer breaks down due to increased offshore winds.

The mean annual relative humidity is 74% at Prisoners Harbor (Figure 3). Values of average relative humidity remain relatively constant throughout the year, and do not exhibit the drops in humidity seen at the Christy Airfield and Christy Pines stations during the winter. Summer humidities (June to September) remain high (80%) due to a persistent marine layer with the highest monthly mean relative humidities (83%) occurring in July and August with a range of 65 to 83%. The lowest mean monthly relative humidity (65%) was recorded in the month of April. Average monthly relative humidity values on Santa Cruz Island are high throughout the year at all stations. Values of maximum relative humidity are 99 to 100% for every month of the year. The greatest difference between the stations occurs in the summertime minimum values, which average about 10 to 12% at Prisoners Harbor and NPS Central Valley, but reach 48 to 50% at Christy Airfield and Christy Pines. These differences can be attributed to proximity to the coast and a prevailing west-northwest wind which brings moist marine air to Christy Airfield and Christy Pines throughout the summer.

Wind

Wind speed and direction within the central valley are strongly influenced by local topography. A windrose of average hourly wind direction for 1997 displays how the prevailing west-northwest wind is aligned parallel to the valley axis (Figure 4). A smaller easterly component of air flow results principally from cold air drainage within the central valley. Drainage down the axis of the central valley from east to west and input from nearby canyons helps to change wind direction from predominantly west to east in the early morning hours. Average wind speeds in the central valley are 4 to 6 m s^{-1}. Average hourly wind gusts ranging from 6 to 8 m s^{-1} are fairly common and are recorded from both the east and the west.

Winds at the Christy Airfield are predominantly from the west and west-northwest. Almost 84% of all winds

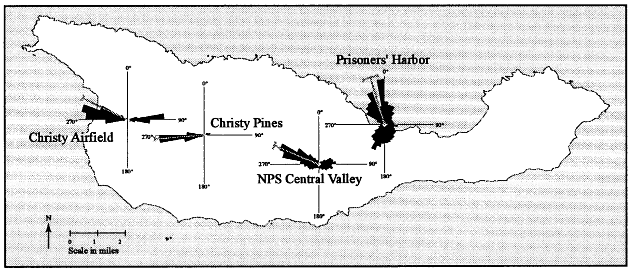

Figure 4. Average hourly wind direction in 1997 from four automated weather stations on Santa Cruz Island.

recorded flow from that direction. A smaller wind component comes from the east and east-southeast direction. The origin of this easterly component of flow is as yet unclear. It may result from downslope flow from the mountain peaks above the Christy Airfield and or from a contribution of strong Santa Ana winds. Average wind speeds at the Christy Airfield are between 4 and 6 m s^{-1} with gusts of up to 15 m s^{-1}. The strongest winds come from the east.

Wind speed and direction for the Christy Pines weather station are incomplete. In August of 1997, the wind speed sensor failed, leaving only values for wind direction. The wind speed and direction data for the Christy Pines are from January 1, 1997 to August 1, 1997. For this period, west winds predominated with values from the west, west-southwest, and west-northwest making up approximately 84% of all wind readings (Figure 4). Easterly winds made up a very smaller percentage of the total average, approximately 13%. Average wind speeds were between 4 and 6 m s^{-1}. Wind gusts of over 20 m s^{-1} were from the west, although most gusts greater than 16 m s^{-1} were from the east.

Wind speed and direction at Prisoners Harbor are highly modified by local topography. The Prisoners Harbor weather station recorded 50% of its total wind direction from the north and north-northwest as prevailing westerly winds are topographically modified to curl around the island. A smaller wind component is seen from the south, south-southwest and south-southeast. This wind from the south is mainly due to cold air drainage, occurring in the early morning hours. An easterly component of wind is also recorded approximately 12% of the time. Easterly air flows are due to both offshore flow and as frontal storms pass over the island. Average hourly wind speeds are between 4 and 6 m s^{-1}, with gusts of up to 21 m s^{-1}. Most high winds at Prisoners Harbor are seen during the passage of frontal storms over Santa Cruz Island.

Precipitation

Hand-recorded precipitation for the Main Ranch dates back to January 1904. This 94-year record was well maintained over the years and represents the longest precipitation record for any Channel Island (Table 1). The rainfall record was kept by the Caire Family, Stanton Family, and L. Laughrin. The rainfall patterns during the 94-year record at the Main Ranch are very similar to those for Santa Barbara (elev. 34 m), although rainfall totals at Santa Cruz Island slightly exceed those at Santa Barbara. Santa Barbara's average rainfall total (431 mm) is nearly 85 mm less than that for Santa Cruz Island's Main Ranch station (515 mm). The greatest annual total (1426 mm) at the Main Ranch occurred in the 1940-1941 water year (July 1 to June 30), whereas Santa Barbara's greatest rainfall total (1194 mm) occurred in the 1997-1998 water year. The second-ranked largest precipitation total at Santa Barbara was 1148 mm for the 1940-1941 water year, 278 mm less than recorded at the Main Ranch. The Main Ranch's 1997-1998 water year total was its fourth greatest recorded total with 1102 mm. The lowest recorded rainfall total (161 mm) at the Main Ranch took place during the 1989-1990 water year and Santa Barbara's lowest rainfall total since 1904 was 162 mm in the 1923-1924 season. Santa Barbara's all-time lowest rainfall total was 114 mm in the 1876-1877 season, before records were kept on Santa Cruz Island (Ryan 1994). The greatest single monthly total for Santa Barbara was 615 mm in January of 1995 and in that same January, the Main Ranch recorded its greatest single month's precipitation total, 778 mm.

Rainfall totals for the Christy Airfield were recorded from January 1997 to August 1998. During the 1997-1998 water year Christy Airfield received 764 mm of precipitation (Figure 5). This was the lowest rainfall total from any weather station and is primarily due to its low elevation along the western coast of the island. The greatest monthly total was 333 mm, recorded in February of 1998. During the large two day storm of December 5 and 6, 1997, this station received 145 mm of rainfall in the first 24-hours and 170 mm total in 48-hours (Figure 6). This storm total was the lowest of all stations on the island.

For the 1997-1998 water year the Christy Pines station recorded the largest rainfall total (1082 mm) of any automated weather station (Figure 4). This water year total was just below that of the Main Ranch's 1102 mm total. The largest monthly rainfall total recorded at the Christy Pines was 469 mm in February of 1998. During the December 5 and 6, 1997 storm, this weather station recorded 217 mm of rainfall in 24-hours and 258 mm in 48-hours (Figure 6). Between 6 and 7 PM PST, this station recorded the greatest

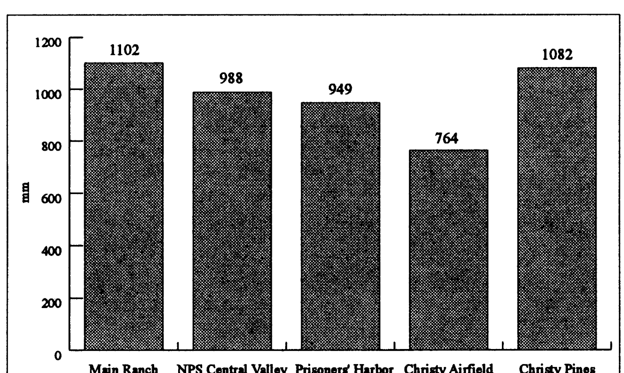

Figure 5. Santa Cruz Island 1997-1998 water year precipitation totals.

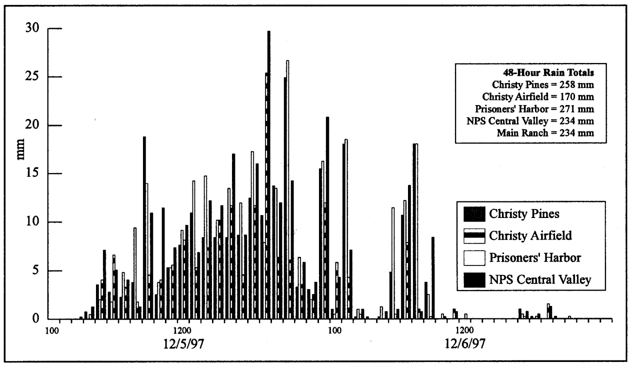

Figure 6. Hourly precipitation totals for Santa Cruz Island December 5 and 6, 1997.

hourly rainfall during the storm with 30 mm of recorded precipitation.

Prisoners Harbor precipitation record is slightly longer than Christy Airfield and Christy Pines, covering the period between June 1995 and August 1998. The 1995-1996 water year is invalid due to mechanical problems with the rain gauge. This problem was corrected for the 1996-1997 and 1997-1998 water years. During the 1997-1998 water year Prisoners Harbor received 949 mm of rainfall (Figure 4). The highest monthly total rainfall recorded (413 mm) occurred in February 1998. During the December 5 and 6, 1997 storm event, Prisoners Harbor received 205 mm of rainfall in the first 24-hours and 271 mm for the entire 48-hours period (Figure 6).

1997-1998 El Ñino Event

The 1997-1998 El Ñino event had a very significant impact on Santa Cruz Island. Besides the above average water year, Santa Cruz Island recorded its largest single day and two-day precipitation event in recorded history. The December 5 and 6 storm brought a record 170 to 271 mm of rain to parts of Santa Cruz Island (Figure 6). In the first 24-hours of the storm totals ranged from 145 mm at Christy Airfield, 217 mm at the Christy Pines, 176 mm at the National Park Service station, 227 mm at the Main Ranch, and 205 mm at Prisoners Harbor. The event began as an area of low pressure in the Gulf of Alaska. As the frontal storm moved toward the southern California coast, it began to intensify as it passed over the northeast Pacific Ocean. Early on December 5, the system began to tap moisture from the subtropical jet stream. This along with the typical slow down of frontal systems as they near the southern California coast allowed this storm to drop record moisture over the central and southern half of the island. Reports from the National Park Service Ranger at Scorpion Harbor detailed heavy rainfall, as much as 305 mm in the 48-hour event. This storm caused a large flash flood and debris flow through Scorpion Canyon and into the harbor. Buildings were moved off foundations, while vehicles and National Park Service equipment and data sheets were washed into the harbor.

Brumbaugh (1983) detailed significant storm events for Santa Cruz Island from 1898 to 1980. A modified version of Brumbaugh's table (Table 2) includes significant storm events from 1980 to 1998. Two more entries into the table were made from 1980 to 1998. The December 5, 1997 storm total of 227 mm would rank first over the 100 year precipitation record. The second entry from January 4, 1995 would be tied with two other storm events at 140 mm. This storm was ranked tenth although in that month of January 1995, the all-time maximum monthly total rainfall occurred on Santa Cruz Island with 777 mm (Table 1).

CONCLUSIONS

A preliminary analysis of the climate of Santa Cruz Island has been derived from four automated weather stations with records of between two and eight years and a 94-year manual rainfall record. The data suggest that there are notable microclimatic differences on the island which relate to distance from the coast, altitude, and position with respect to the east-west fault controlled the central valley. Additionally, it appears that the climate of Santa Cruz Island differs from mainland southern California coastal communities, with significantly higher relative humidities owing to the year-round influence of a marine layer, and rainfall totals that exceed those of the nearest neighboring mainland cities such as Santa Barbara.

Annual mean monthly temperatures on Santa Cruz Island vary according to altitude, nearness to the coast, and the depth and penetration of the marine layer. During summer, the marine inversion keeps coastal sites cool while the interior valley, protected from invading maritime air, warms rapidly. During winter strong westerly winds help dissipate the marine layer allowing temperatures to drop, especially in the interior valley.

The considerable thickness of the marine layer in the vicinity of Santa Cruz Island exerts a strong control on relative humidities, even at elevations of 400 m or more. All of the stations recorded mean maximum humidities of 99 to 100% during all months of the year, average relative humidity ranged from 65 to 83%, and mean minimums only reached very low values when strong offshore wind penetrated the island.

Recorded wind direction were strongly related to station position. The prevailing winds for the region are westerly, and this wind direction was clearly recorded at Christy Airport. These stations are located along the axis of the east-west trending central valley, which tends to topographically enhance wind flow. This control can be seen in the tendency of the secondary winds, related to cold air drainage and strong off-shore flow from the east. Prisoners Harbor, on the north coast, does not lie in the central valley, and its winds are principally from the north and south due to the prevailing wind being diverted around the island and cold air drainage.

Rainfall patterns on the island are similar to those recorded at Santa Barbara, but in general the totals are somewhat higher. The influence of island topography is shown in the somewhat higher rainfall totals at Christy Pines (elev. 419 m) with respect to the other stations.

Table 2. Extreme one-day rainfall on Santa Cruz Island, California 1904-1905 to 1980-1981, 1990-1991 to 1997-1998. Pre-1904 rainfall data are not from diaries, but from a loose note in the files at the Main Ranch. The note includes rainfall data from September 1898 to June 1900. It is not known whether the data represent a complete tally of that duration (Modified from Brumbaugh, 1983).

Rank	One-day (mm)	Year
1	227	1997
2	198	1956
3	178	1908
4	164	1941
5	163	1938
6	161	1962
7	158	1940
8	145	1979
9	141	1955
10	140	1926 1978 1995
13	130	1954
14	128	1899*
15	127	1968
16	122	1900*
17	120	1913
18	117	1964
19	114	1959
20	112	1907
21	110	1964
22	109	1937
23	104	1980
24	100	1958

The 1997-1998 El Ñino event brought record rainfall totals to Santa Cruz Island. The largest single day rainfall event was recorded on December 5, 1997. A devastating flood resulted, damaging equipment and property. With the addition of new weather stations in 1995 and 1996, this event was captured throughout the island and warrants further examination. Future weather stations are planned for Santa Cruz Island, which will help develop a more complete understanding of its many microclimates.

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