Fog Drip Collection in Coastal Central California

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Abstract: Fog and low stratus are the dominant climatic feature along the central California coastline during the summer months. This moisture source is not only a critical feature in the local hydrologic cycle, but has proven to be a valuable source for augmenting water supplies. Measurements of fog deposition are rarely made and where they do exist comparisons of deposition rates in different locations have been hampered by the use of different types of collection devices. Fog drip data were collected during the summers of 1991 and 1992 at Ox Mountain (137°33' N 122°25'W and 308 m MSL) on the San Francisco Peninsula. Screen-like harp collectors were used to collect fog drip to study the diurnal and monthly variations of fog drip. On the average, one can expect to collect between 1.5 to 4 liter m^{-2} day^{-1}, which is comparable with previous results from Montara Mountain (550 m MSL) and El Tofo, Chile (700 m MSL).

1. INTRODUCTION

Fog and low clouds at higher elevations contribute to the water budget of watersheds directly by water deposition, and indirectly by reducing potential evapotranspiration. Efforts have been made to estimate fog water deposition in view of the potential ecological significance of fog water (Nagel,1956; Vogelmann, 1973; Schemenauer, 1986: Schemenauer et al., 1987; Cereceda and Schemenauer, 1991; Schemenauer and Cereceda, 1991). These field measurements, however, are fragmentary and at different locations, and usually daily fog drop yield per unit area is about the same. Therefore, the contribution of fog drip to water budget or feasibility of augmenting local water supply depends on the annual fog frequency of occurrence. Part I of this paper presents the general climatology of central California fog and stratus, and includes statistical data on fog frequency and microstructure. Part II provides a detailed analysis of fog drip amounts and a discussion on the diurnal and monthly variation of collected drip amounts.

Part I: Climatology of California Coastal fog and Stratus.

The advection fog common to the Central California coast is a primary summertime weather phenomenon and is most common at locations that are unobstructed from the prevailing northwesterly winds. For coastal stations the advection fog season is June to September with monthly fog frequency maximum occurring in August (Patton, 1956). Generally it is assumed that the top of the coastal fog/stratus cloud deck coincides with the base of the prevailing subsidence temperature inversion. The height of the stratus cloud base (ceiling) is more variable, at least diurnally, than the height of the stratus cloud tops. The maximum stratus cloud thickness occurs at night and the minimum occurs in the afternoon. The typical height for the base of the stratus is about 500 feet and the typical cloud top height is approximately 1700 feet above sea level.

The typical California coastal stratus/advection fog drop size distribution is rather broad, with a mean diameter between 8-12 μm and 60-70% of the droplets less than 20 μm in diameter. Frequently at night and during the early morning hours the fog droplet size distribution develops a "tail" produced by drizzle size drops which extends to drop sizes to 80 μm and beyond (Mack et al., 1973, 1974; Pillie, 1979; Goodman, 1977). Typically, the liquid water content (LWC) increases and droplet size distribution broadens with height and during its onshore life cycle. Observed LWC ranges between 0.02-0.52 gm^{-3} with the highest LWC most often observed close to the top of the marine layer in the early morning hours. Large variations in droplet concentrations were observed (80 to 450 droplets per cm^3; Goodman, 1977) depending on the air parcel trajectory. Northwesterly trajectories along the coastline produce the highest concentration, while more westerly trajectories produce the lowest. The frequency of fog occurrence in the proximity of the Pillar Point and Ox Mountain sampling site is given in Table 1.

Table 1. Number of Days of Fog Occurrence

	June	July	August	Sept	June-Sept(%)	# of years
Pillar Point	19.5	21.7	23.5	19.5	66.0	8
Ox Mountain	22.0	24.5	28.5	22.0	79.5	2

Ox Mountain at 308 m above mean sea level had a frequency of fog/stratus occurrence 14% higher than Pillar Point at sea level. Generally, the frequency of observed fog increases with altitude and decreases rapidly as one moves inland.

Part II: Fog Drip Amounts

Fog drip data were collected during the summers of 1991 and 1992 at the Ox Mountain landfill (37°33'N, 122°25' W, 308 m MSL) in Central California coastal Montara Range. The experiment was designed to study the diurnal and monthly variations of fog drip. Screen-like harp collectors, designed by Goodman (1985), were used to collect fog drip. The fog collectors were placed perpendicular to the mean summer wind (290°) and spaced 8 cm apart. Each harp consisted of 500 vertically strung wires at 1.2 mm intervals. The selection of the optimal 0.8 mm wire diameter was based upon computations of the collection efficiency for prevailing wind speeds of 5 to 7 ms^{-1} and a typical fog drop size distribution (Goodman, 1977; 1985). To record fog drip each collector was connected to a tipping bucket rain gauge. The collected fog drip amounts are presented in Table 2. Table 2 gives monthly amounts (liter m^{-2} day^{-1}) for collector #1 and #2, respectively. Collector #2, placed 8 cm behind collector #1, collected 35-40% of the total amount of water collected by collector #1 for the entire summer period. During the summer of 1992 collector #2 was malfunctioning. Furthermore, there was a difference in fog frequency between the two summers; 87% fog days in 1991 between June-September and only 72% fog days in 1992. The collected fog drip amounts recorded by the rain gauge for the summer of 1991 are displayed in Figure 1. The diurnal variation of monthly total collected water for 3-hours intervals during July is displayed in Figure 2. Maximum collection occurred between the 0100-0400 time period, which is due to a combination of cloud top cooling and moderate onshore wind speeds during this period. Although maximum fog thickness occurs just prior the sunrise (0400-0700 LST), onshore wind speeds are less than the proceeding period due to relaxed surface pressure gradients in the east-west direction. Daily minimum collection occurred during the 1300-1600 time period due to solar heating that resulted in fog dissipation.

Table 2. Ox Mountain Fog Drip

1991	June	July	August	September
Collector #1 (liter m-2 month-1)	20.01	89.15	47.37	36.83
Collector #2 (liter m-2 month-1)	7.74	34.80	13.18	-
Total (liter m-2 month-1)	27.75	123.95	60.55	-
Average per day (liter m-2 day-1)	1.28	4.27	2.31	1.47*
1992	June	July	August	September
Collector #1 (liter m-2 month-1)	26.03	16.17	22.04	17.25
Average per day (liter m-2 day-1)	1.18*	0.18*	0.82*	0.91*

* Collector #2 was malfunctioning

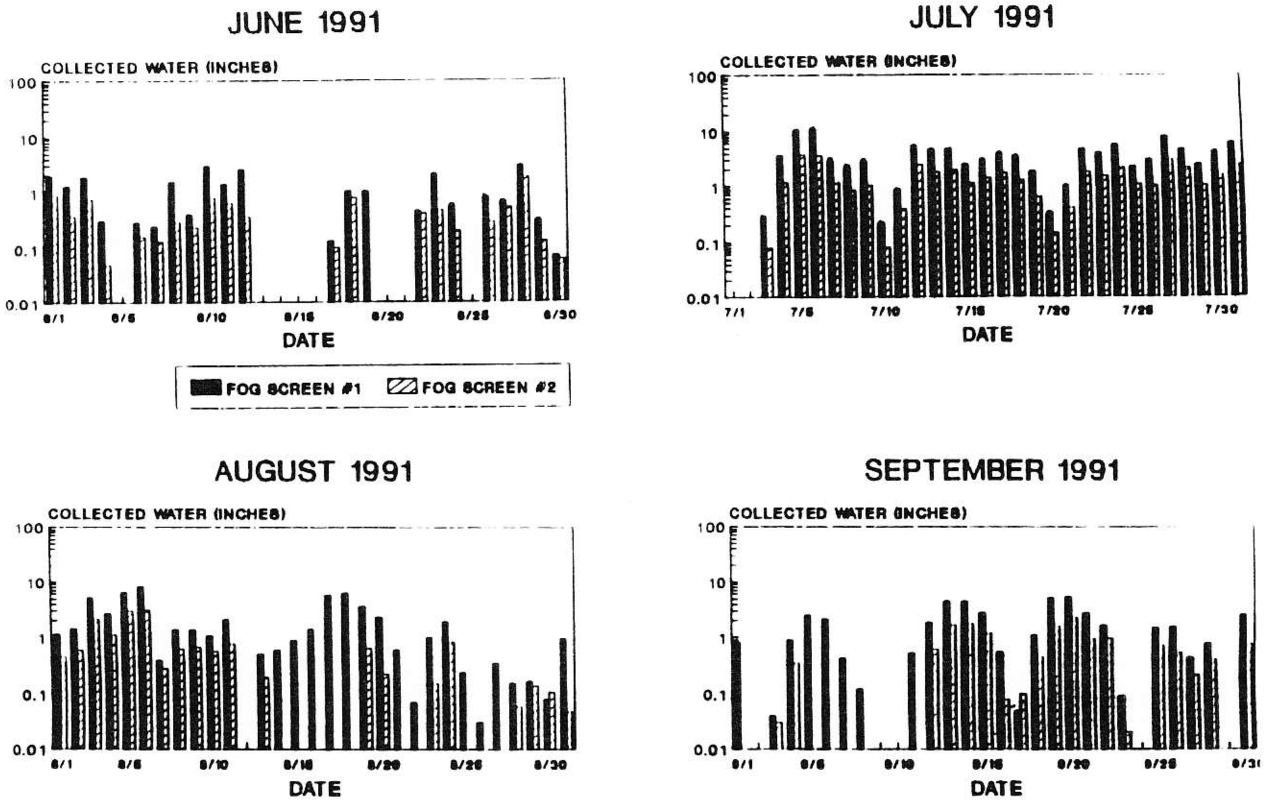

Figure 1. Collected Fog Drip

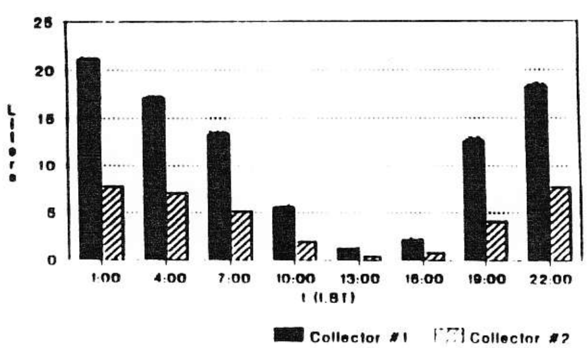

Figure 2. Diurnal Variation of Fog Drip (July 1991)

Conclusion

The Ox Mountain experiment demonstrated that on the average one can expect to collect between 1.5 to 4 liters m^{-2} day^{-1} of fog drip during summer months. Ox Mountain data may slightly underestimate the collected amounts by 10 to 20% due to evaporation losses from the rain gauge. Results agree well with previous studies on Montara Mountain (550 m MSL) in 1982, when similar instruments collected 2 to 4 liters m^{-2} day^{-1} (Goodman, 1985) and with El Tofo, Chile (700 m MSL) studies reported by Schemenauer et al. (1988).

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