J3.8   DETERMINING FOG TYPE IN THE LOS ANGELES BASIN USING HISTORIC SURFACE
OBSERVATION DATA

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1. INTRODUCTION

Statistics on fog occurrence and severity that have been gathered through historic observations are vitally important in the development of operating parameters for the deployment of free-space optics (FSO) equipment in a given location. However, the actual types of fog that have occurred during these observations are often not considered. Knowing the fog type is important when estimating low-visibility occurrences in locations where there are no observations. This is particularly true in a location such as Los Angeles, where certain fog types will extend through the Los Angeles Basin, while others will be limited to ocean-side locations. Also, knowing the fog type could prove important for the seasonal forecasting of fog, inasmuch as certain fog types may be more correlated with large scale forcing such as the Pacific Decadal Oscillation (PDO) or El Niño. Finally, the exercise of determining fog type forces the further understanding of a region's fog climatology.

2. BACKGROUND

While the concept of fog type is often discussed in climatology, it is not a regularly measured variable at surface observation stations. Assigning a "type" to a given fog is essentially a matter of determining its formation mechanism (i.e. how moisture was added to air to produce fog, or how air was cooled to its dew point temperature to produce fog). Often, multiple processes are at work in a given fog situation. For example, it is well known that sea fog is maintained through radiational cooling from the fog top. Sea fogs may also be enhanced by radiational cooling over land. For this study, the initial formation mechanism is used for the fog type of a given fog throughout the event.

3. METHODS

Criteria for various fog types were determined through analysis of data from two surface data stations in the Los Angeles Basin, Los Angeles International Airport (LAX) and Long Beach Airport (LGB) (see map in Figure 1). Hourly surface observations during fog events were initially examined manually to determine fog types at LAX and LGB.

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Fog was defined as visibility less than 1000-m. Factors such as the distance to the ocean, wind direction, cloud cover, temperature, dew point temperature, visibility fluctuations, time of year, and time of day were all considered. Conditions many hours prior to the fog event were included. For example, cloud cover could exist prior to the formation of advection fog, but not prior to the formation of a radiation type of fog. Also, light winds were required for a radiation fog type to be considered. An algorithm for determining fog type was developed from these examinations of the data, and computer code was written in order to fog type all data available.

FIGURE 1. Map of Los Angeles Basin, including Los Angeles International (LAX) and Long Beach (LGB) Airports.

An independent, manual assessment of the fog type algorithm was performed on three years of surface data. Results showed greater than 95% agreement at LAX, and 89% agreement at LGB.

After testing the algorithm, the computer code was run on 30 years of data from LAX (1961-90), and four years of data from LGB (1961-64). The period of record used for LGB is necessarily short because that is the only period we had available with consistent, hourly data, without airport closure times, at that airport. This period is also one of higher fog occurrence. The two years of highest severe fog frequency from 1961-90 were 1961 and 1963.

It should be noted that surface meteorological observations might sometimes be inadequate for determining fog type. Larger scale phenomena cannot be considered solely using surface

observations. This may be particularly detrimental when using surface-measured (10-m) wind data for advection. The abundance of surface observations (in time and in space) their use desirable however in order to determine reliable long-term averages.

3.1 Fog Type in the Los Angeles Basin

Byers (1959) produced a detailed description of eleven fog types that occur throughout the United States. Only advection (sea) fog was mentioned to occur in the Los Angeles Basin area. Inspection of several years of LAX data suggest the occurrence of other fog types, with a form of advection-radiation fog being the most common fog type at LAX other than sea fog. This type was seen in the surface observation data as occurring mostly in the early morning hours during the cold season. A distinct marine layer was over the station during this type of fog, ceilings were "unlimited" prior to fog formation, and winds were not blowing from the ocean.

3.1.1 Advection-Radiation Fog

Byers (1959) describes advection-radiation fog as fog that forms by radiational cooling in "air that has come inland from the sea during the day." This type of fog is commonly thought to occur over the Southeastern United States, but appears to also occur in the Los Angeles Basin. In Los Angeles however, the ocean air that has come inland during the day is transported via sea breeze. Cereceda et al. (2001) saw evidence of a similar type of advection-radiation fog near the coast in Northern Chile that was caused by the radiational cooling of marine air.

Below are the criteria determined for advection radiation fog at LAX and LGB:
- Sky is clear in previous hour.
- Time of day: sunset through seven hours after sunrise (to include a lag before fog dissipation).
- Time of year: August through May.
- In the previous 11 hours:
  - Visibility < 8000-m, or visibility decreasing
  - Wind is blowing from the ocean
  - Wind speed > 1 ms^{-1}.

The sky cover, time of day, and time of year criteria look for causes of radiational cooling. The criteria for the previous eleven hours look for a marine layer being in place of the station.

3.1.2 Advection (Sea) Fog

Advection (Sea) fog occurs when warm air advects over cool ocean air, cooling the air from below to its dew point temperature and producing fog. Typically this occurs in regions of cold ocean currents to the west of continents, such as over the northeast Pacific Ocean off of the coast of California. This type of fog would be expected to appear in the data as a distinct "wall" of fog with a sharp decrease in visibilities, or as

low clouds followed by fog. Sea fog could come in any time of year or any time of day. The full criteria that were found to determine advection fog are as follows:

In the current or previous hour:
- Wind is blowing from the ocean.
- Wind speed > 1.0 ms^{-1}.
Or, in the previous eight hours:
- Ceiling height < 270-m.
- Wind is blowing from the ocean.
- Wind speed > 1.0 ms^{-1}.

The first set of conditions account for fog coming into station as a "wall." The second set of conditions account for fog that initially comes in as low clouds.

3.1.3 Frontal (Precipitation) Fog

All fogs occurring when precipitation was occurring at the station were considered precipitation fog, unless the fog type in previous hours was determined to be advection fog. This latter constraint was used to take into account drizzle or light rain, which sometimes falls during advection type fogs.

4. RESULTS

Percent frequencies of each fog type found at LAX and LGB are given in Table 1.

TABLE 1. Percent frequency of occurrence of four fog types at LAX, 1961-90, and LGB, 1961-64.

	LAX (%)	LGB (%)
Advection Fog	67.1	49.3
Advection-Radiation Fog	27.8	42.6
Precipitation Fog	0.7	0.2
Indeterminate	4.3	7.9

We believe that the lower frequency of occurrence of advection fog at LGB to be caused by the longer fetch across land that typical advection fogs must travel to reach LGB. Typical larger scale flow in the region is northwesterly. While the land-fetch to the south for LGB is only a few kilometers, it is about 20 km in this predominant flow direction. Often what is advection fog at LAX does not reach LGB. However, the marine layer does often reach LGB, which then appears to form into advection-radiation fog during late evening and early morning hours. Also, the hills of the Palos Verdes Peninsula, which extend to over 120-m, may block some advection fogs that approach LGB from west-southwest.

The correlation coefficient between the monthly visibility data from LAX and LGB for 1982-90 was 0.91. However, the correlation coefficient between fog types for 1961-64 was much lower, at 0.14 for advection-radiation fog and 0.24 for sea fog. This

shows that the two main fog types often occur concurrently at the two stations.

The severity of each fog type was seen to vary. The average visibility in advection fogs at LAX from 1961-90 was 422-m, while the average visibility in advection-radiation fogs was 289-m. At LGB the average visibility in advection fogs was 362-m and the average visibility in advection-radiation fogs was 207-m. This could be due to the difference in condensation nuclei found over the ocean versus those found over land. Land condensation nuclei are smaller and more abundant, causing higher concentrations of smaller drops, which leads to an increase of the overall scattering area, causing lower visibilities.

A common attribute of advection fogs was the occurrence of a wind shift from westerly to easterly flow at the observation station at the time of fog formation. A wind rose from LAX during all observations of visibility < 400-m (for all fog types) is shown in Figure 2, shows these easterly winds.
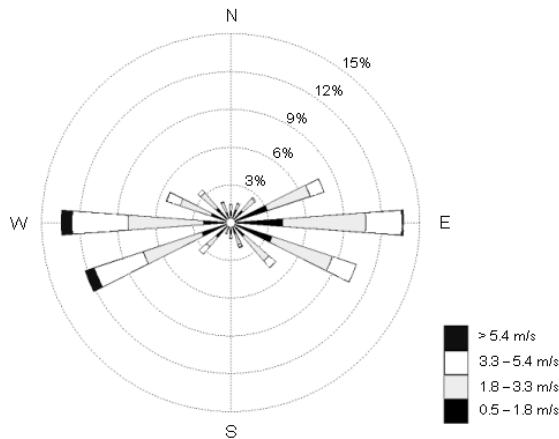

FIGURE 2. Wind rose from LAX, 1961-90, during observations of visibility < 400-m.

Several factors may cause these easterlies. During winter months, and at times when the land may be colder than the ocean, the shift to a land breeze at night can provide the necessary cooling to cause fog formation. Also, the easterlies, which blow from areas of more polluted urban air, may provide condensation nuclei, which trigger the formation of fog. A third explanation for these easterlies may be simply be that land breezes occur at night, which is of course the time when radiational cooling is also occurring. Radiational cooling is a primary formation mechanism in the case of advection-radiation fog. For advection fog, nighttime marks a decrease in the turbulent motions which advection fogs must overcome as the advect inland, thus easing the path for such fogs.

A wind rose from LGB during all observations of visibility < 400-m (for all fog types) is shown in Figure 3. The northwesterlies primarily show the advection

fogs that come from the vicinity of LAX, from the Santa Monica Bay. The blocking of the Palos Verdes Peninsula can be seen by the lack of winds from the west through west-southwest directions. The easterlies and east-southeasterlies are apparently the land breezes, although the more southeasterly winds are nearly along-coast in direction.
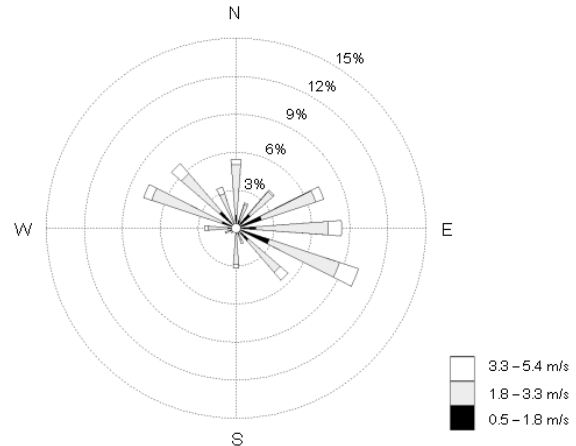

FIGURE 3. Wind rose from LGB, 1961-64, during observations of visibility < 400-m.

5. FUTURE WORK

More verification of these results is needed. Satellite data could potentially be used for this verification. It should be possible to observe whether a fog event is advection fog or advection-radiation fog with satellite data. Surface data could be observed during these cases and the fog type algorithm could be verified or adjusted accordingly. Other data might also be useful, such as upper air soundings and sea surface temperature data.

The next step for this study is to map FSO availabilities in the Los Angeles Basin through the understanding of fog type variability there. It has been seen in this work that mean large-scale flow is as important as distance from water, and this would have to be considered.

Santa Ana sea fogs, which form following Santa Ana wind episodes, have been noted to be particularly severe in terms of visibility (Noonkester 1979). These low visibilities are probably in part aided by the smaller condensation nuclei, which are advected over the ocean during Santa Ana events. Santa Ana sea fogs could potentially be extracted from the dataset by looking for advection fogs that showed strong easterly winds, low dew point temperatures, and high air temperatures in the days preceding fog events.

Finally, it would be useful to expand this work to other areas. It is apparent that areas with diverse geographical features, such as bodies of water and complex terrain, will be much more complicated for the development a fog type algorithm.

6. REFERENCES

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