Western Region Technical Attachment
No. 93-15
May 25, 1993

A STATISTICAL FORECASTING METHOD FOR FOG AT OLYMPIA, WASHINGTON

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Introduction

Olympia, Washington, is among the foggiest places in the country. Of all the cities for which Local Climatological Data are published, Olympia has the second greatest frequency of visibilities of one-quarter mile or less, with dense fog 91 days a year on average (Charleston, WV, is the foggiest city with 111 days a year). While dense fog occurs during all seasons, it is most likely in the fall and winter, with a peak in October, averaging 14 dense fog days.

The fog climatology at Olympia is quite different from surrounding stations, which presents forecasting problems. Quillayute, a much wetter site on the coast, has only 50 dense fog days a year. The adjacent interior cities of Seattle and Portland average 47 and 33 dense fog days a year, respectively. There are a number of reasons Olympia is a favored location for fog. While it typically resides in a marine air mass, the site: 1) has few bodies of water in the immediate vicinity; 2) is sheltered from the wind; and 3) is not highly urbanized. In addition, the airport is on the south edge of town in a flat prairie area. These factors cause the diurnal variation in temperature to be much greater than at surrounding stations. On a typical clear night, Olympia will be 10 degrees colder than the Seattle-Tacoma Airport for most of the night. There are many nights when Olympia and Toledo (30 miles to the south) are the only stations in the region that have fog.

This study was designed to assist in the preparation of the evening terminal forecast for Olympia. While the original intent was simply to alert the forecaster to the greater likelihood of fog at Olympia, the technique works well enough to also help predict the timing and extent of the fog development.

Procedure

Six years of surface aviation observations, from 1980 to 1985, were used in this study. All 1452 nights without measurable rain during this period were included in the data set. The 0000 UTC observation was chosen as the predictor. This is the last observation before public forecasts are issued in winter. The dew-point depression and wind speed and direction at 0000 UTC were recorded. The wind direction was classified as "onshore" (160-330 degrees) or "offshore" (340-150 degrees) in accordance with the two basic wind regimes at Olympia. These data adequately described late afternoon conditions in most cases, and the statistical guidance based on them performed well enough that a more complex set of predictors was not investigated. In situations where significant changes in temperature, moisture, or wind during the night might make the 0000Z observation unrepresentative, the forecaster must adjust the statistical guidance.

The mean opaque cloud cover from 0000 UTC to 1200 UTC was calculated from hourly observations. When the sky became obscured by fog during the night, the cloud cover was only averaged for those hours prior to fog being reported as an obstruction to visibility. When the sky was obscured at 0000 UTC, cloud cover from the previous night was used as an estimate.

Early in this project, a decision was made to try to predict the simplest and most important aspect of the phenomenon, which is the progressive development of fog due to radiational cooling at night. For this reason, nights with measurable rain were excluded from the database. Nights with a trace of precipitation were retained so that occasions where drizzle occurred in conjunction with dense fog would be included.

Once these forecast parameters were recorded, the visibility and ceiling data were gathered. The lowest visibility and ceiling, reported in any observation between 0000 UTC and 1800 UTC, were recorded, along with the times at which visibility first fell below three miles and below half a mile. No provision was made for other obstructions to visibility. Smoke and drizzle at this site are dependent on the same conditions as fog and tend to occur with fog, so this was not considered to be a major issue.

The data were stratified into four, three-month seasons (beginning in December, March, June, and September), five degree blocks for the 0000 UTC dew-point depression, five knot blocks for the wind speed, onshore/offshore wind direction, and cloud cover. The sky was classified as clear if mean opaque cloud cover was less than six-tenths, and cloudy otherwise. Statistics were compiled for each combination of these variables.

Output

The results are a set of statistics based on the 0000 UTC observation and expected cloud cover. Specifically, the forecast parameters are the probabilities of occurrence for fog, visibility less than 3 miles, visibility less than half a mile, and ceiling less than 1000 feet. These probabilities are all determined for the period between 0000 UTC and 1800 UTC, as well as the median times of first occurrence of visibility less than 3 miles and less than half a mile. These times are the guidance for timing the development of the fog. The program output is available in two forms. The first is a series of tables for each season. The second is a computer program called OLMFOG that gives probabilities based on the input of an observed (or forecast) 0000 UTC observation. The tables are useful for quality control and show all of the possible conditions; the OLMFOG program is the operational version.

Table 1 for the chance of fog on clear winter nights. The probabilities decrease with higher dew-point depressions, as expected. The relationship between the chance of fog and the wind has proven to be more complex. In most cases the highest probabilities are at light wind speeds. Under certain conditions, however, a stronger wind may be favorable for fog. Examples of this include a marine push at the end of a dry summer day, or winds that bring clearing without drying the surface air. In general, onshore winds in summer and offshore winds in winter are more favorable for fog.

Table 2 is a sample run of the OLMFOG program. The output is two columns of statistics, one for "clear" nights and one for "cloudy" nights. The number of cases for each sample is also given. The forecaster should check the sample size to assess the quality of the guidance and the weight it is given in the decision-making process.

Verification

Two verification experiments were conducted. The first used independent data from 1986 and 1987 to test the predictive value of OLMFOG. The second was a comparison between forecasts based on OLMFOG, the evening terminal forecasts (FTs) from WSFO Seattle, and the LFM model output statistics (MOS) for a set of 97 nights in 1991 and 1992.

The first assessment showed that categorical forecasts (using a 50% or greater probability as a "yes" prediction) performed best in the fall and winter, with lower skill in spring (Table 3). During these seasons, categorical forecasts were correct 70-80% of the time. Forecasts of less than half a mile visibility and IFR ceilings were not quite as good. Timing forecasts in fall and winter (not shown) were within 3 hours 40-50% of the time. During the dry summer season, categorical forecasts showed much lower skill. The guidance still had value, however. The average probability for fog was 32% on nights when it occurred versus 18% when there was no fog. A similar relationship was seen for the other forecast categories in summer. Note that the poor summer statistics have a great impact on the overall verification scores. The scores are much better in the peak fog season.

The comparison with other forecasts (Table 4) showed that the OLMFOG program alone had slightly lower skill than the FTs. OLMFOG had a lower false alarm rate for fog and IFR forecasts. The program was better than the FTs at predicting visibilities below half a mile, but also had a much higher false alarm rate. The OLMFOG forecasts were much better than MOS in every area, except for higher false alarm rates due to MOS badly underforecasting fog at this site. One of the reasons for poor MOS performance is that the equations for ceiling and visibility were developed based on regional data (the Pacific Northwest Coast in summer and the whole West Coast in winter). In this case, a more unrefined set of statistics based only on Olympia data performed better.

Use

The OLMFOG output should be interpreted as basic statistical guidance, or an initial indication of the possibility of fog formation. Simply stated, out of so many nights with similar conditions, fog occurred on a certain percentage of those nights. When the sample size is large, many of the possible outcomes are represented. A small sample size may result in unrepresentative statistics. The number of nights in the sample is included in the output and should be checked.

The guidance incorporates typical phenomena, such as the diurnal decrease in wind speed. Values should be adjusted for atypical changes. These will usually be wind shifts or rapidly changing pressure gradients that make the 0000 UTC wind unrepresentative.

Other points to remember about the program:

1. The statistics are for nights without measurable precipitation.
2. This method has much lower skill in the dry season.
3. Fog is overforecast in early fall (September) when the ground is still dry.

References

National Climatic Data Center, Local Climatological Data Annual Summaries for 1991.

National Weather Service, Technical Procedures Bulletin No. 303, The use of model output statistics for predicting ceiling, visibility, cloud amount, and obstructions to vision.

Table 1. Probability of fog on clear winter nights. Probabilities are rounded to the nearest 5%. The sample size for each set is in parenthesis. DPD = 0000 UTC dew-point depression.

% CHANCE OF FOG (NUMBER OF CASES)

DPD	OFFSHORE WIND		ONSHORE WIND		
	0-5 kt	6-10 kt	1-5 kt	6-10 kt	11-15 kt
<5	100 (28)	100 (5)	*	65 (3)	*
5-9	100 (17)	85 (7)	100 (6)	60 (5)	50 (2)
10-14	80 (20)	100 (9)	50 (2)	50 (4)	65 (3)
15-19	60 (10)	65 (12)	*	50 (2)	*
20-24	35 (6)	0 (4)	*	*	*
25-29	0 (2)	15 (6)	*	*	*

* means insufficient data (fewer than 2 cases)

Table 2. Sample run of the OLMFOG program. Read across for the probabilities for each event on a clear or cloudy night.

FOG STATISTICS FOR OLYMPIA

ENTER MONTH (1-12) **1**
ENTER 0000 UTC TEMPERATURE **42**
ENTER 0000 UTC DEW POINT **35**
ENTER 0000 UTC WIND DIRECTION (TENS OF DEGREES) **04**
ENTER 0000 UTC WIND SPEED (KNOTS) **04**

CHANCE BETWEEN 0000 UTC AND 1800 UTC	CLEAR	CLOUDY
FOG	100	60
VISIBILITY < 3 MI	95	45
VISIBILITY < 1/2 MI	80	45
CEILING < 1000 FT	75	75
FIRST OCCURRENCE TIME (Z)		
VISIBILITY < 3 MI	3	-
VISIBILITY < 1/2 MI	6	-
NUMBER OF CASES	17	15

Table 3. OLMFOG verification statistics based on 1986-87 data. POD=probability of detection; FAR=false alarm rate; CSI=critical success index; NA=not applicable (no IFR ceilings in the sample).

	FALL	WINTER	SPRING	SUMMER	OVERALL
FOG/NO FOG					
POD	.87	.90	.50	.23	.57
FAR	.19	.19	.42	.45	.23
CSI	.72	.74	.37	.19	.46
% CORRECT	77	76	75	84	80
IFR					
POD	.81	.85	.43	.11	.53
FAR	.12	.25	.44	.60	.27
CSI	.66	.66	.48	.08	.54
% CORRECT	73	76	78	86	78
<1/2 MILE					
POD	.60	.77	.24	.09	.63
FAR	.40	.31	.64	.50	.35
CSI	.43	.58	.17	.08	.41
% CORRECT	63	68	79	93	78
IFR CEILING					
POD	.75	.65	.21	NA	.52
FAR	.28	.45	.69	NA	.40
CSI	.58	.43	.14	NA	.39
% CORRECT	71	53	75	NA	73

Table 4. Comparison between OLMFOG, FTs, and FPC guidance based on 1991-92 data.

	OLMFOG	FTs	FPC
FOG/NO FOG			
POD	.57	.84	.31
FAR	.19	.27	.06
CSI	.50	.64	.31
% CORRECT	70	75	63
IFR			
POD	.55	.86	.33
FAR	.21	.27	.00
CSI	.48	.65	.33
% CORRECT	74	80	71
<1/2 MILE			
POD	.58	.32	.29
FAR	.39	.09	.00
CSI	.47	.31	.29
% CORRECT	81	77	77
IFR CEILING			
POD	.37	.61	.20
FAR	.42	.31	.33
CSI	.29	.48	.18
% CORRECT	62	72	62