J6.1 THE TEMPORAL AND SPATIAL VARIABILITY OF DRIZZLE IN NORTH AMERICA

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1. INTRODUCTION

Drizzle occurs everywhere in North America and can present an unexpected threat to motorists and aviation interests. The presence of drizzle at the surface in near-freezing to subfreezing temperatures can indicate that supercooled drizzle exists aloft, increasing the potential for hazardous aircraft icing (e.g., Cober et al. 1996; Bernstein 2000). Despite the hazards of drizzle, very little information exists about its spatial and temporal variability in North America.

Many recent studies on drizzle have focused on the effect of cloud condensation nuclei on the growth and size distribution of drizzle droplets in marine stratocumulus and stratus clouds (e.g, Frisch et al. 1995; Feingold et al. 1996; Gerber 1996; Ferek et al. 1997; Feingold et al. 1999; Galloway et al. 1999; Hudson and Yum 2001). Ferek et al. (1997), for example, observed in the Monterey Area Ship Track study that there was a reduction in drizzle drops in ship tracks due to the increase in cloud condensation nuclei from the ship's emissions. Other research has examined the effect that the concentration and size distribution of drizzle droplets in stratus clouds has on the earth's solar radiation budget (Feingold et al. 1999). A study documenting the temporal and spatial variability of drizzle in the lower atmosphere has not been performed. An analysis of the temporal and spatial variability of drizzle at the surface across North America is the objective of this study.

2. DATA AND METHODOLOGY

The surface dataset consisted of hourly surface observations during drizzle and freezing drizzle from 1976 to 1990 from the National Oceanic and Atmospheric Administration/National Climatic Data Center (NOAA/NCDC). The reason for using this 15-y period was to ensure consistency in the data collection. Before 1976, many stations reported weather observations one out of every three hours. By 1990, most National Weather Service stations in the United States had begun using the Automated Surface Observing System (ASOS) to take present weather conditions instead of a human observer.

The dataset was constructed by merging DATSAV2 and TD-3280 formats into a single format. Although it consisted of both freezing drizzle and non-freezing drizzle observations, it was then filtered for only observations of non-freezing drizzle occurrence. This is called the full dataset. The full dataset consisted of drizzle observations from about 2000 stations. Following the method of Robbins and Cortinas (2001), stations that reported at least 80% of the current surface observations for 10 of the 15 years were separated into a reduced dataset. This reduced dataset consisted of 584 stations (Fig.1). Some stations that did not report hourly still met the 80% criteria and are included in this reduced dataset. Unless otherwise noted, the reduced dataset was used throughout this work.

3. ANNUAL CYCLE

Drizzle can occur anywhere throughout North America at any time of the year. A monthly distribution of drizzle using the full dataset shows that, over all of North America, the most active month for drizzle is November, and the least active month is July (Fig. 2). An animation of the annual cycle can be found at: (www.nssl.noaa.gov/~schultz/drizzle). In the contiguous United States alone, east of 100°W, the highest values for the average number of hours of drizzle per month are in November (Fig. 3a). Drizzle occurrence remains high through January, but, towards March, most of the activity begins to shift towards the northeastern United States and Canada. During April, drizzle occurs most frequently in the northeastern United States and the Atlantic Provinces of Canada. By July, drizzle is occurring most frequently in southern Oregon and northeastern California, southeastern North Dakota, and southeast Maine. Elsewhere across the United States during the summer, drizzle is infrequent perhaps because temperatures are higher, and precipitation becomes more convective in nature (Fig. 3b).

In Canada, there is a transition in the month of maximum drizzle from east to west across the country from December in the region around Montreal, QC to September in the area near Calgary, AB (Fig. 4). The eastern part of the country has higher temperatures during the winter than the central part of the country due to the moderating effects of the Atlantic Ocean. We speculate that during the winter in central Canada, near surface temperatures are more conducive to freezing drizzle than warm drizzle. Cortinas et al. 2000 showed a maximum of freezing drizzle in central Canada.

4. DAILY CYCLE

The most active hour for drizzle in North America is 10-11 UTC in the east (Fig. 5a), 11-12 UTC in the midsection of the continent (Fig.5b), and 14-15 UTC in the west (Fig. 5c). This shift of the hour of maximum drizzle from east to west suggests a relationship between sunrise and the diurnal cycle. We hypothesize that, at sunrise, instability produces turbulence in the

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boundary layer. The effect of this turbulence is an increased chance for the collision-coalescence processes in the clouds that produce drizzle (Pinsky and Khain 1997).

Cortinas et al. (2000) found a similar result with their study on freezing drizzle. They observed that freezing drizzle occurs most frequently just *before* sunrise. We further hypothesize that the increase in temperature at sunrise may be enough to inhibit the continuation of freezing drizzle after sunrise.

A composite map of the average number of hours of drizzle at 12 UTC reveals tight gradients that surround several local drizzle maxima across North America (Fig. 6). These areas are located in the Probilof Islands of Alaska, northeast British Columbia, south-central Quebec, southeastern South Dakota, south-central Oregon, the border of Colorado and Utah near Grand Junction, CO, and southeastern Texas near Victoria, TX. An analysis of two of these maxima, Victoria, TX and Klamath Falls, OR, indicates that there is substantial variability in the hourly distribution of drizzle in high-frequency drizzle locations (Fig. 7). Drizzle in Victoria, TX gradually increases from 2 UTC to 13 UTC, but, in Klamath Falls, OR, the increase in drizzle frequency in the morning occurs more rapidly and later in the day from 10 to 14 UTC. The reason for the sharper morning increase in drizzle at Klamath Falls, OR is unclear.

The longest and most pronounced gradient of drizzle in North America begins in northern Manitoba, runs due south along 100°W, and ends near the Texas-Mexico border (Fig. 3a, 6). The locations to the east and west of this line have major differences in drizzle frequency. For example, whereas North Platte, NE has 7 hours of drizzle per year, Grand Island, NE, 236 km away, has 124 hours of drizzle per year. This gradient is also apparent in the diurnal cycle (Fig. 8). It is not clear why this gradient exists.

In addition to the high frequency locations for drizzle, there are several areas that receive very little drizzle. The intermountain west, the western high plains, and the desert southwest of the United States all have maxima of only 2-3 hours of drizzle per year at even the most active hour for that region, 13-14 UTC. Drizzle in the Florida peninsula, which maximizes at 12 UTC, is also infrequent (Fig. 6). The following web site contains an animation of the daily cycle of drizzle over the U.S. and Canada: (www.nssl.noaa.gov/~schultz/drizzle).

4. CONCLUSIONS

We examined the temporal and spatial variability of drizzle in North America in this paper. Our analysis revealed key trends across the continent as well as possible explanations for the occurrence of these trends:

- In North America, drizzle occurs most often in November.
- In the United States alone, drizzle occurs most often November-January.
- In Canada, maximum drizzle occurrence is September-December.
- Large seasonal differences in temperature in Canada from the eastern part of the country to the central part appear to be playing a large role in the temporal variability of maximum drizzle frequency.
- July is the least active month for drizzle in North America perhaps because temperatures are higher and precipitation tends to be more convective in nature.
- Both freezing drizzle and nonfreezing drizzle appear to be related to the diurnal cycle. But, while freezing drizzle occurs most frequently immediately before sunrise (Cortinas et al. 2000), drizzle occurs most often *at* sunrise. Increased temperatures at sunrise may be inhibiting the continuation of freezing drizzle after sunrise.
- The frequency of drizzle increases rapidly east to west across 100°W in North America. The reason for this gradient is unclear.

ACKNOWLEDGEMENTS

Steve Fletcher and Doug Kennedy prepared the dataset. I also wish to thank the following individuals for their support and contributions to this research project; John Cortinas for providing the list of stations in the reduced dataset; and Robert Coggins and Kim Elmore for their technical assistance. The National Science Foundation supported this research through NSF REU grant 0097651.

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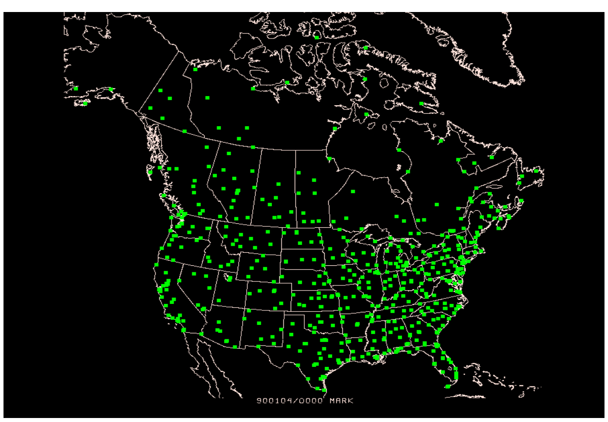


Figure 1. The location of all of the stations in North America used in the reduced dataset (584 stations).

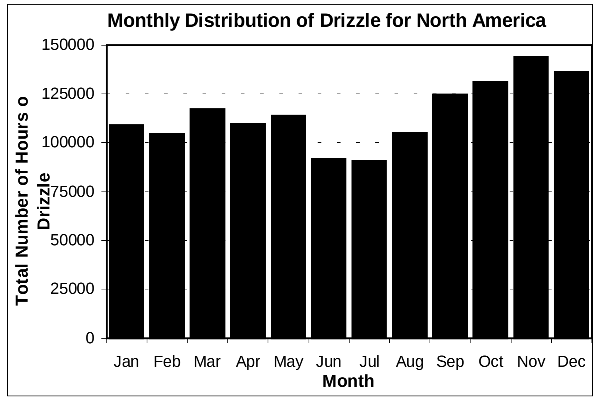
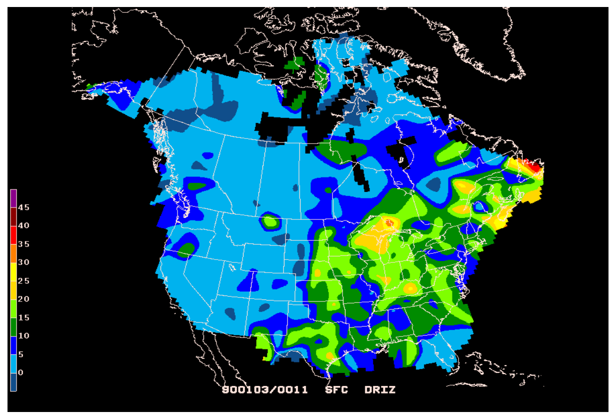


Figure 2. Total number of hours of drizzle for each month over the 15-y period.

A.



B.

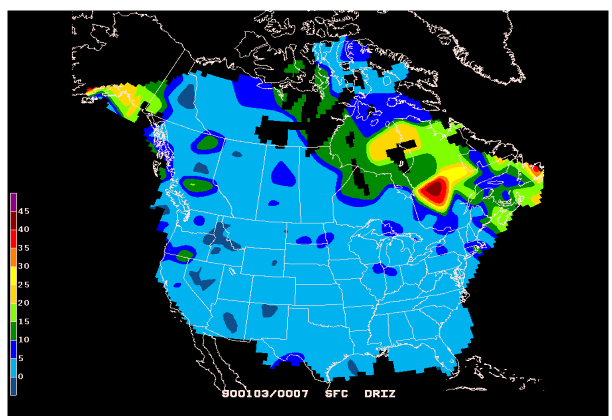


Figure 3. Average number of hours of drizzle in (a) November (the most active month in North America) and (b) July (the least active month in North America) each year that drizzle was reported.

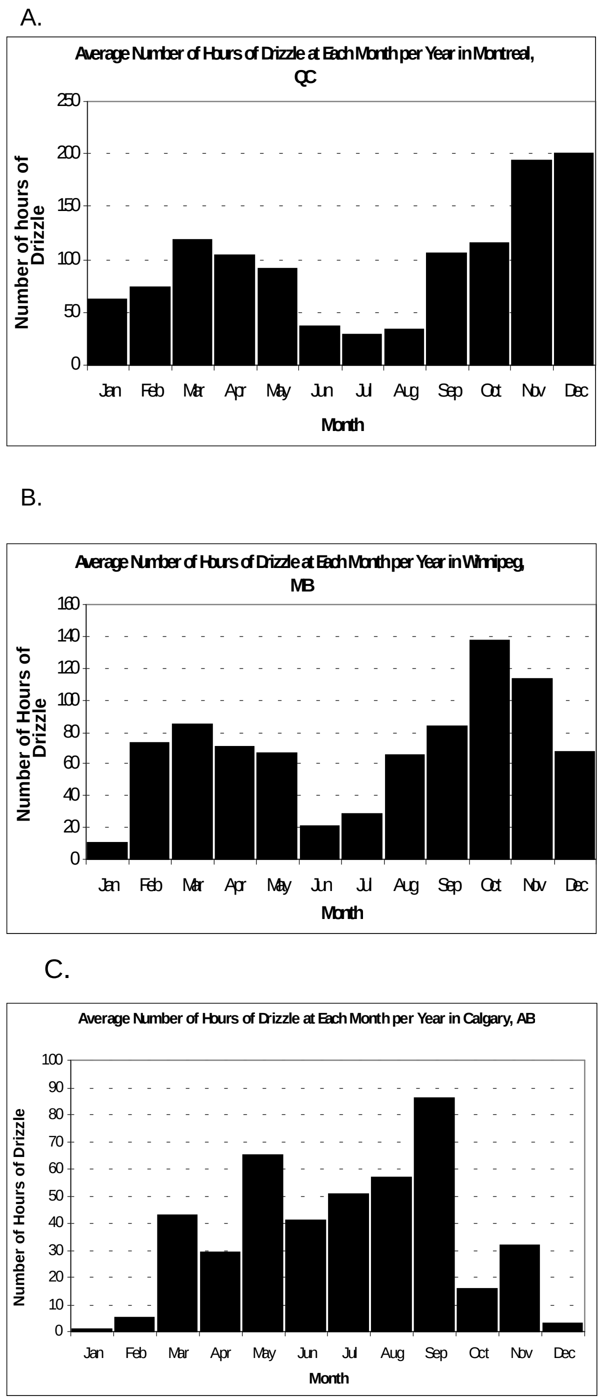


Figure 4. Average number of hours of drizzle at each month per year in (a) Montreal, QC (b), Winnipeg, MB and (c) Calgary, AB.

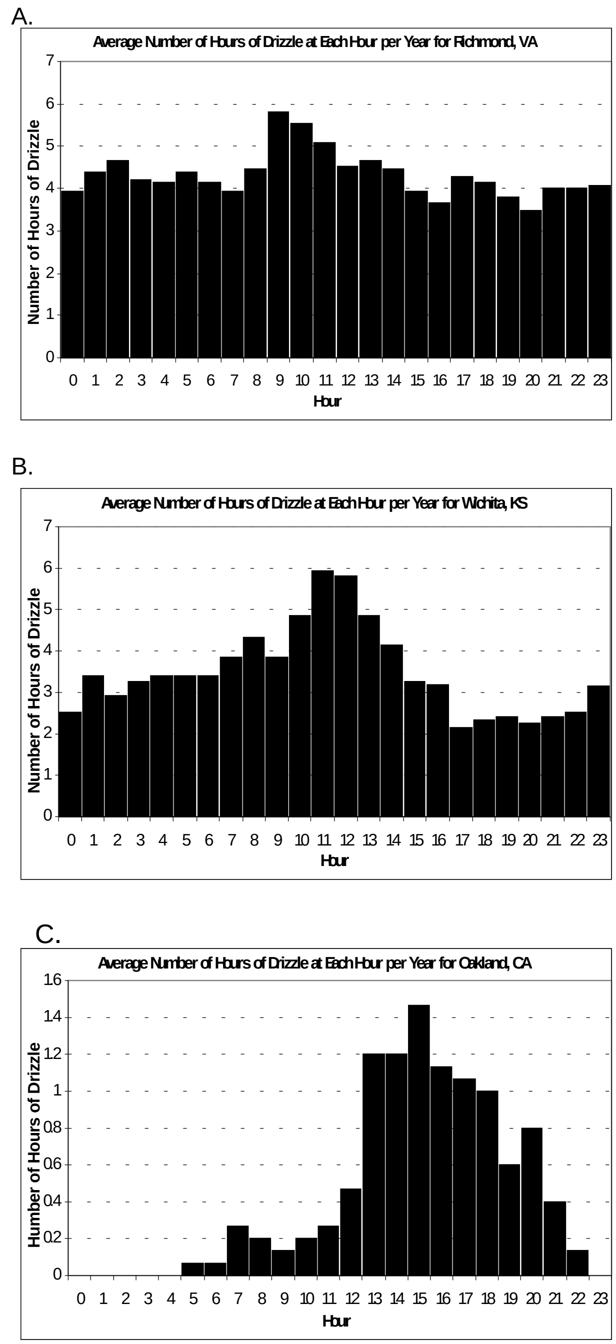


Figure 5. The average number of hours of drizzle at each hour per year for (a) Richmond, VA, (b) Wichita, KS, and (c) Oakland, CA.

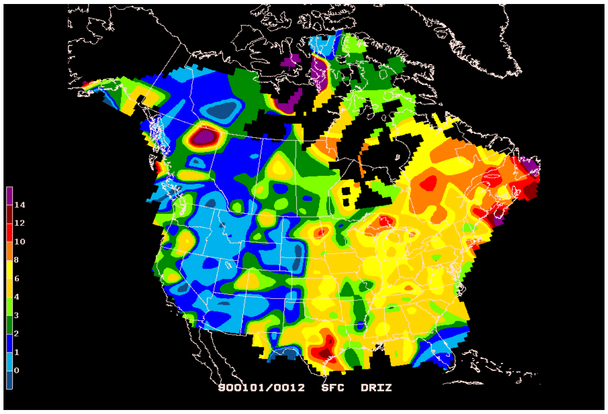


Figure 6. Average number of hours of drizzle at 12 UTC each year that drizzle was reported.

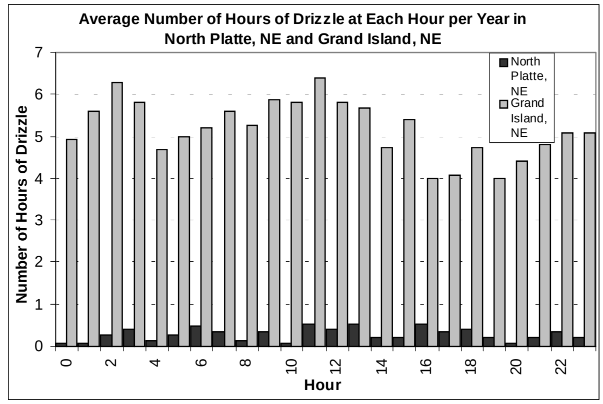


Figure 8. Average number of hours of drizzle at each hour per year in North Platte, NE and Grand, Island, NE.

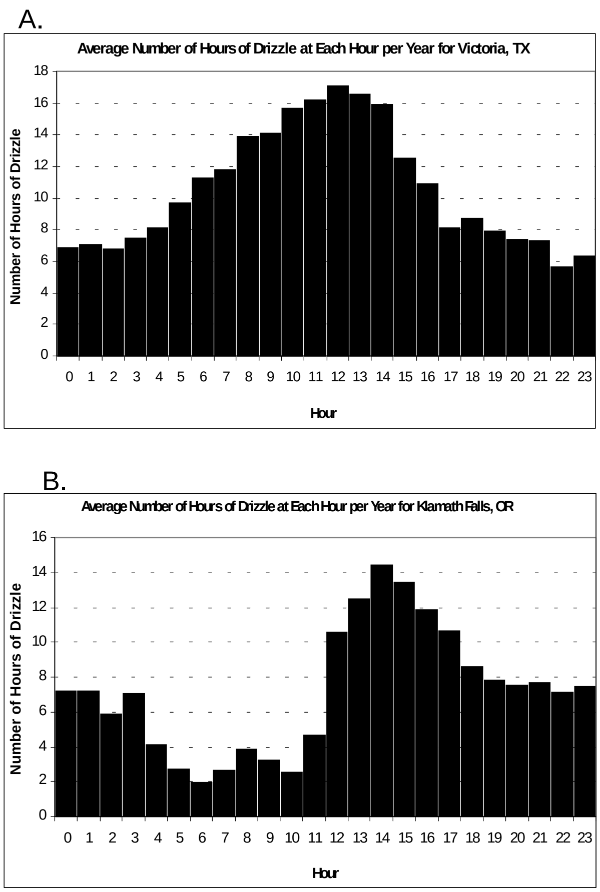


Figure 7. The average number of hours of drizzle at each hour per year for (a) Victoria, TX and (b) Klamath Falls, OR.