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SHORT CONTRIBUTION

# Some characteristics of precipitation and dry periods on Long Island

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ABSTRACT

Six years of sequential hourly precipitation data are used to investigate the frequency functions of precipitation and dry periods at Brookhaven National Laboratory on Long Island, New York. The dry period frequency function is exponentially distributed when the precipitation and dry periods are classified by events based on meteorological and synoptic conditions. The ensemble precipitation frequency function is not exponentially distributed but is a composite of several distinct frequency functions which are characteristic of non-convective and convective precipitation types. These precipitation-type frequency functions are exponentially distributed; hence individually they may be modeled as Markov processes.

## 1. Introduction

Several authors have applied analytical and statistical techniques to estimate the residence time of soluble atmospheric pollutants (Junge and Gustafson, 1957; Rodhe and Grandell, 1972, 1981; Scriven and Fisher, 1975; Bolin and Persson, 1975; Henmi and Reiter, 1978; Fisher, 1982, 1983; and Venkatram et al., 1982). In these models, residence time would best be estimated using Lagrangian rainfall statistics. However, to date, the available data have been taken from fixed locations, i.e., in the Eulerian frame. Hamrud et al. (1981) and Rodhe and Grandell (1981) have indicated that the mean length of a dry period, $t_d$, in the Lagrangian reference frame may be within a factor of two of its value in the Eulerian reference frame. The complex convective nature of precipitating systems makes it difficult to even qualitatively relate the mean length of a precipitation period, $t_p$, in the two reference frames. As a first estimate of Lagrangian time scales, the Eulerian estimates of $t_p$ and $t_d$ have been used in the residence time calculations of Rodhe and Grandell (1972, 1981), Bolin and Persson (1975) and Henmi and Reiter (1978), as recommended by Hamrud et al. (1981).

Using six years of sequential precipitation data with hourly time resolution, we will explore the frequency functions of precipitation and dry periods, hence investigating if weather may be treated as a Markov process at Brookhaven National Laboratory (BNL). The manner in which the lengths of individual precipitation periods are determined (and therefore dry periods) will not only have an effect on the estimate of $t_p$ and $t_d$ but will also alter the respective frequency functions, thus affecting estimates of the residence times of soluble species.

The frequency function of precipitation has components of various precipitation types. The BNL data set specifies the precipitation type for each hourly sample; thus we investigate the frequency functions of rain, rainshower, thundershower and snow precipitation.

## 2. Sample and data acquisition

Precipitation samples were obtained using an automatic sequential precipitation sampler designed and built at Brookhaven National Laboratory, Long Island in New York State (Raynor and McNeil, 1978, 1979; Raynor and Hayes, 1984). BNL is located on central Long Island approximately 90 km east of the New York City metropolitan area.

Upon the onset of precipitation, a sensor is activated which opens the cover and allows the collection of precipitation for 1 h (or less if the precipitation ends within the hour) before rotating to the next collection bucket. A new collection bucket is introduced every hour until the precipitation ceases. The beginning and ending times for the sampling of each collection bucket were automatically recorded. We refer the reader to Raynor and Hayes (1984) for further details of the data acquisition, analysis and methods involved in the Sequential Precipitation Chemistry Sampling Program at BNL.

## 3. Frequency functions of precipitation and dry periods

The precipitation samples obtained at BNL "include nearly all possible hours during the 6-year period having precipitation amount great enough for at least one chemical measurement of the sample" (Raynor and Hayes, 1984), typically a sample obtained when 0.1 mm or more of precipitation fell during the hour. The variation of the frequency function with the manner in which precipitation durations are determined may be investigated in this data set. The durations may be determined from the continuity of ending and beginning times of sequential samples. In this case, any break in time continuity (other than to introduce a new precipitation receptacle) signals the end of a precipitation episode. Alternately, the durations may be determined on an event basis, since the samples were also categorized with respect to prevailing meteorological and synoptic conditions. The precipitation durations classified by event include short dry periods, usually less than 1 h, but up to 2 h in some cases. Alexander (1981) argues that "since breaks in precipitation of 2 h or less do not necessarily represent a true separation between storms, these breaks may be ignored", since it is the duration of precipitation events (whole storm systems) and the intervals between them that are assumed to be exponentially distributed. As indicated in Table 1, 873 precipitation periods occurred based on sample continuity and 551 if durations are classified according to events. The solid curve in Fig. 1 is the frequency function of the lengths of precipitation periods based on the continuity of ending and beginning times of successive precipitation samples. The frequency is defined as the fraction of the total number of precipitation periods whose durations lie in a given 1 h interval and is plotted at the mean value of their durations. The dashed curve is the frequency function when the precipitation duration was

Table 1. *Comparison of the effect of classification of data on the basis of meteorological events versus sample continuity on the mean length, standard deviation (h) and number of cases of precipitation and dry periods*

| | $t_d$ | $\sigma_d$ | $\#d$ | $t_p$ | $\sigma_p$ | $\#p$ |
|---|---|---|---|---|---|---|
| Events | 85.77 | 91.52 | 550 | 9.08 | 9.98 | 551 |
| Sample continuity | 55.18 | 82.96 | 872 | 4.64 | 5.27 | 873 |

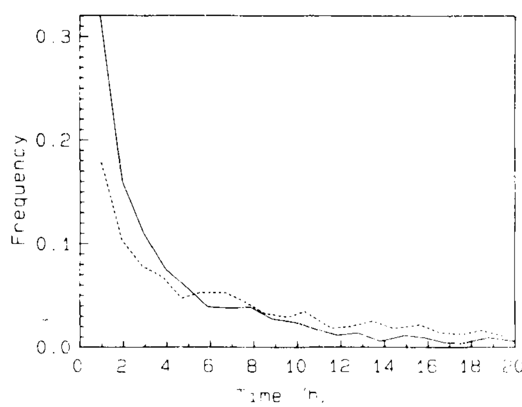


*Fig. 1.* The frequency function of precipitation periods based on event classification (dashed line) indicates a lower frequency of precipitation periods of short duration with a corresponding increase in periods of long duration as compared to the frequency function based on sample continuity.

determined with respect to meteorological and synoptic conditions. The solid line shows a greater frequency of short precipitation periods since any break in sample continuity signaled the end of a precipitation period. Consequently, on an event basis, the decrease in the frequency of short precipitation periods results in an increase in the frequency of events of longer duration. Fig. 2 presents the corresponding frequency functions of the dry periods (in view of the much longer durations of dry periods 20-h intervals are used in Fig. 2). The corresponding decrease in the frequency of short dry periods determined from event classification is evidenced by the dashed curve.

Table 1 contains the mean lengths of precipitation and dry periods, their respective standard deviations and the number of cases for data classified by event and sample continuity. For event data, the mean length of a precipitation period is greater as is the mean length of a dry period, since most of the very short intervening dry periods have been ignored. The 50–100% increase in the mean length of dry and precipitation periods and the different frequency functions of the event data have ramifications for estimating residence times of soluble species in the atmosphere. The estimate of residence time from the models of Rodhe and Grandell (1972, 1981) is very sensitive to the mean value $t_d$ and the frequency function of dry periods for the range of observed scavenging coefficients of nitrate, sulfate and ammonium (Sperber, 1985; Hameed and Sperber, 1986; Sperber and Hameed, 1986). Residence time varies in a linear fashion with $t_d$ while an order of magnitude increase of the scavenging coefficient results in a factor of two decrease in residence time (Rodhe and Grandell, 1972, 1981; Fisher, 1983; Sperber, 1985).

The Markov residence time model of Rodhe and Grandell (1972, 1981) assumes weather to be a Markov chain, i.e., the probability of a future condition is independent of the past condition, given the present condition, with the frequency functions of precipitation and dry periods being exponentially distributed. Attempts to least square fit exponentials to the precipitation frequency functions in Fig. 1 yielded unsatisfactory fits (based on the $\chi^2$ goodness of fit test at the 95% confidence level). Annual averaged precipitation includes several types of precipitation. The precipitation types fall into 2 categories, convective showers (rainshower and thundershower) and non-convective precipitation (rain and snow). Depicted in Fig. 3 are the frequency functions of rain (solid curve) and rainshower precipitation (dashed curve). We observe that convective precipitation originating in cumulus clouds is on the average of a shorter duration

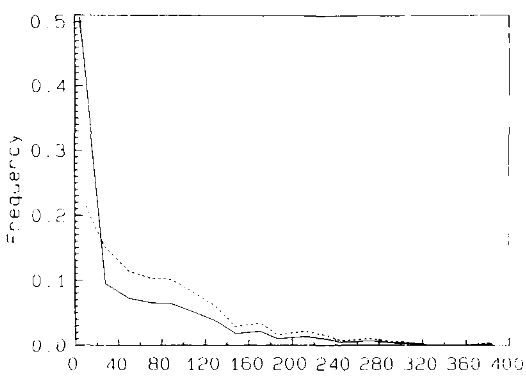


*Fig. 2.* The frequency function of dry periods based on event classification (dashed line) indicates a lower frequency of short dry periods as compared to the frequency function based on sample continuity. This results since these short periods occurred during the passage of a precipitation event.

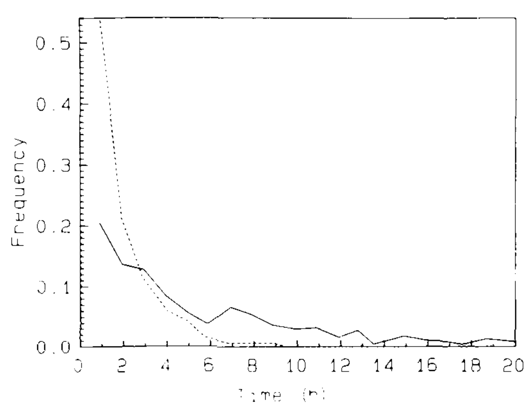


*Fig. 3.* The frequency function of rainshowers (convective precipitation, dashed line) is compared to that of rain (non-convective precipitation). Convective precipitation is generally shorter in duration than non-convective precipitation.

Table 2. *Least square fits of the exponential a exp(bt) to the frequency functions of lengths of dry and precipitation periods; the time range of the fit t (h), the $\chi^2$ value and the degrees of freedom ν, are given*

| | $a$ | $b$ | $t$ | $\chi^2$ | ν |
|---|---|---|---|---|---|
| Dry—events | 0.250 | −0.0126 | 320 | 16.02 | 13 |
| Dry—sample continuity | ------ | ------- | ----- | ----- | -- |
| Precipitation—events | ------ | ------- | ----- | ----- | -- |
| Precipitation—sample continuity | ------ | ------- | ----- | ----- | -- |
| Rain | 0.199 | −0.195 | 18 | 24.57 | 15 |
| Snow | 0.244 | −0.228 | 13 | 10.16 | 10 |
| Rainshower | 0.856 | −0.666 | 8 | 8.43 | 5 |
| Thundershower | 1.423 | −0.912 | 5 | 0.74 | 2 |

than non-convective precipitation originating in altrostratus clouds. Table 2 gives the exponential fits for the precipitation types rain, snow, rainshower and thundershower. Using the mean duration of precipitation periods ending in a given 1-h interval, the fitted exponential predicts the total frequency of these periods. The sum of the frequencies over the range of fit is $\leqslant 1$. The rate of decrease of the frequency function, $b$, for convective showers is much greater than that of non-convective precipitation. This indicates that in order to properly parameterize precipitation in residence time models, separate frequency functions for different types of precipitation are necessary. An exponential was fitted to the frequency of dry periods for durations of up to 320 h (with intervals of 20 h) based on the separation according to events. No fit was possible for dry periods based on sample acquisition discontinuity (see Table 2). These results indicate that reduction of precipitation data for use in these types of models must be made with respect to meteorological and synoptic conditions. With this provision, intermittent precipitation and dry periods at BNL may be treated as a Markov chain.

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