Markov Models and Polygon Diagrams for Climatological Interpretations of Cyclones and Anticyclones over the Northern Hemisphere

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With 6 Figures

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Summary

Annual cyclone and anticyclone numbers in addition to the temperature data for the northern hemisphere are processed through simple models leading to meaningful interpretations. Historical climatological characteristics of the cyclone and anticyclone numbers are modeled by a first order Markov process. Statistically indistinguishable synthetic cyclone and anticyclone numbers are generated. Polygon diagrams which show the mutual relationships between average cyclone (anticyclone) numbers and the temperature are employed for finding possible relevant climatological changes during the record period. A polygon diagram concept is proposed and applied in order to identify sub-period warming and cooling spells of any desired short or long term durations and their relationship to the annual number of cyclone (anticyclone) occurrence numbers. The results indicate a decrease (increase) in the cyclone and anticyclone numbers during cooling (warming) periods. The methodologies proposed in this paper can be easily adopted for cyclone and anticyclone numbers modeling in any part of the world.

1. Introduction

In general, a depression is a synoptic feature with cyclonic (counterclockwise) air circulation around a low pressure centre. Near the surface the air spirals inwards the centre, creating convergence, uplift and a tendency for cloud formation. The exact definition of a cyclone is of much significance for statistical studies of cyclones.

The reader is referred to Alpert et al. (1990) for two distinct procedures in estimating the number of cyclones.

The interactions between different air masses lead to the creation of cyclonic and anticyclonic systems. Cyclones have their origin on the fronts separating the major air masses. Anticyclones are characterized by small horizontal pressure gradients and light winds in the inner portion of the systems. Annual cyclone and anticyclone numbers are good indicators of the weather phenomena in addition to other meteorological variables such as temperature, pressure and humidity. In order to benefit from the relationships between these numbers and the meteorological variables many researchers (Petterssen, 1956; Hosler and Gamage, 1956; Klein, 1957; Zishka and Smith, 1980; Whittaker and Horn, 1982; Parker et al., 1989; Agee, 1980, 1991; Jones et al., 1986; Hansen and Lebedeff, 1987, 1988) have presented empirical studies on the basis of observed data. Most of these studies were concentrated on the cyclones and anticyclones in the northern hemisphere and north American continent. Stein and Hense (1994) discussed increase of violent storms over the North Atlantic by considering two time series in order to present more reliable evaluation of these extreme events. The increase in the number of violent storms over the
Northern Atlantic is observed from a time series of low pressure events published by the German Seewetteramt in Hamburg (Dronia, 1991). On the other hand, Schinke (1992, 1993) showed that cyclones for the period 1930–1991 exhibit a decrease of the average central pressure connected with an increasing number of intense lows since 1970s. In the literature, the evaluations of the available data were achieved by long-term average and trends. In this paper, however, the same data are treated with some stochastic and new concepts. The stochastic generating mechanism of the annual cyclone and anticyclone numbers are identified and controlled by statistical tests and then employed for the generation of future likely synthetic cyclone and anticyclone numbers. On the other hand, a polygon diagram concept is proposed and implemented for identifying various sub-period cooling and warming spells and the annual number of cyclones and anticyclones during these periods.

2. Data and Statistical Features

Two air masses flowing in parallel to each other but possessing different temperatures may become coupled with an initially local instability near their interface that grows as the air masses intertwine and start to rotate together in an immerse spiral called a cyclone. Alpert et al. (1990) have shown that the frequencies of annual cyclone numbers change with location and time. Later, the same data as adopted by Agee (1991) are used for the application of the methodologies in this paper. Herein, paper cyclone and anticyclone data presented by different sources are employed. Among these sources are surface cyclone and anticyclone frequency data presented by Zischka and Smith (1980) over North American ocean environments during January and July from 1950 to 1977 inclusive. Parker et al. (1989) data from 1950 to 1985 are also considered for the annual 500-hPa cyclone and anticyclone frequency over the western half of the Northern Hemisphere. Statistical data concerning surface cyclone frequencies from 1905 to 1954 are also incorporated into this study. The data have been checked for possible inhomogeneities by Agee (1991) and it is found that all the variabilities are real changes not the changes in the way of obtaining these data. Such reliable data given by him are available up to 1977. These data include annual cyclone and anticyclone numbers at earth surface and 500-hPa levels for North America and ocean environments based on January and July events between 1950 and 1977. Figure 1 indicates the annual change of cyclone and anticyclone numbers in the northern hemisphere as given by Agee (1991). In any comparative interpretation of cyclone and anticyclone numbers in this figure periods of records must be considered. For instance, in Figure 1c annual number of surface cyclones for the United States from 1905 to 1940 does not match with others (Fig. 1a, b and d) since they start from 1950. For instance, comparison of Fig. 1a with Fig. 1c is not possible timewise but on the basis of frequency (histogram) domain where time variations are not considered. From such a comparison, it appears that the number of cyclones over the US is larger than the number over North America. The number of surface cyclones in Fig. 1a is for North America and the ocean environments based on January and July events only (Zishka and Smith, 1980). However, in Fig. 1c the number of surface cyclones is for the United States but for 12 months. The following two independent views are considered in the statistical analysis of cyclone and anticyclone numbers just for the purpose of identifying the generating mechanism of these numbers.

(a) the conventional statistical analysis for identifying the frequency distributions, autocorrelation structures and trend components which are prerequisites for any effective stochastic modeling and

(b) the joint statistical properties including the regression analysis, if necessary, of the relationships between two variables through polygon diagram concepts.

The former approach provides means of exploring internal time evolution structure of individual meteorological events whereas the latter tries to provide mutual interactions between different events.

General statistical summary for the data considered between 1950 and 1977 are given in Table 1. By considering these basic statistical parameters together with Fig 1, the following relevant conclusions can be drawn: