

**A SYNOPTIC CLIMATOLOGY OF
EASTERN NORTH AMERICA WITH
MESOSCALE RESOLUTION**

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and Roger A. Pielke**

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Abstract

A subjective synoptic classification scheme has been used to categorize the dominant daily synoptic weather pattern for each grid square in a 5-square $\times$ 7-square grid placed over eastern North America for the five-year period from 1975 to 1979. Seven synoptic categories were used in the classification scheme: (1) warm sector of an extratropical cyclone; (2) region of overrunning north of a warm front; (3) region of cyclonic isobaric curvature behind a cold front; (4) polar anticyclone; (5) subtropical anticyclone or ridge; (6) tropical cyclone; and (7) unclassifiable pattern. The grid extends from 36°N to 48.5°N and from 68°W to 89°W; this area includes much of the Great Lakes region, Ohio Valley, St. Lawrence Valley, central and northern Appalachians, and U.S. northeastern seaboard. One of four surface geostrophic wind-speed classes was also assigned to each grid cell for each of the 1,826 study days.

A variety of statistics have been calculated for this climatological data set, including joint frequency tables, category persistence probabilities, and category transition probabilities. A comparison of statistics for different grid squares, rows, or columns reveals mesoscale variations in the synoptic climatology with latitude, longitude, and season. For instance, the seasonal movement of the polar front and its mean position over this region can be identified, as can the northward and westward extent of the Bermuda High. Climatic modifications due to the presence of the Great Lakes and the Appalachian Mountains are also evident in the statistics.

This climatology was prepared in order to determine the frequency of occurrence of synoptic conditions which favor the generation of terrain-forced mesoscale circulations such as lake-land breezes and mountain-valley winds, as part of a larger investigation into the impact of mesoscale atmospheric circulations on the long-range transport of air pollutants. However, this climatology can also be applied to such areas as air pollution potential evaluations, wind energy 'prospecting', and environmental impact assessments.

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1. INTRODUCTION

Synoptic-scale weather patterns significantly influence both local weather conditions and the transport and diffusion of air pollutants. Under some synoptic situations, atmospheric pollutants will remain close to their source, while under others, the long-range transport of air pollutants (LRTAP) may be favored. The presence of terrain inhomogeneities may drive smaller-scale atmospheric circulations under some synoptic conditions due to differential surface heating. These terrain-forced mesoscale circulations, such as lake-land breezes and mountain-valley winds, can significantly modify the long-range transport and diffusion of air pollutants (e.g., Lyons and Cole, 1976; Moran *et al.*, 1986; Segal *et al.*, 1988). However, current LRTAP numerical models cannot resolve these smaller-scale circulations, i.e., circulations with scales < 150 km, raising questions as to the magnitude of the error introduced into LRTAP model results by this limitation.

Considerable attention has been focused over the past decade on the impact of the long-range transport of air pollutants, especially oxides of sulfur and nitrogen, in eastern North America. This region includes such major terrain inhomogeneities as the Great Lakes and the Atlantic coast, the Appalachian Mountains, many large urban areas, and the St. Lawrence Valley. Terrain-forced mesoscale circulations will thus occur much of the time in this area. In order to determine how much of an impact such circulations are likely to have on LRTAP in this region, it is first necessary to determine precisely how frequently they occur. Accordingly, a regional synoptic climatology with mesoscale resolution has been constructed for eastern North America based on a simple subjective synoptic classification scheme. Mesoscale spatial resolution has been obtained by using a 5-square $\times$ 7-square grid to subdivide this region and then examining and classifying the daily synoptic-scale weather patterns over each grid square. This procedure serves to quantify the frequency of air mass types and frontal boundaries in this region. The frequency of synoptic patterns favorable for terrain-forced mesoscale circulations can then be obtained from this synoptic climatology and combined with mesoscale dispersion modelling studies to quantify the importance of terrain-forced mesoscale circulations for LRTAP in this region.

The rest of this report describes this regional synoptic climatology for eastern North America. Section 2 describes the methodology and data sources employed in preparing the climatology, and Section 3 discusses basic features of the climatology. Earlier studies are also reviewed in these sections. The application of the climatology to terrain-forced mesoscale circulations is described in Section 4 and a summary and conclusions are given in Section 5. Finally, three extensive appendices provide a complete listing of the gridded climatological data set used in this study, numerous additional statistical tables, and a listing of the computer code used to perform the statistical calculations.

This regional synoptic climatology should be of interest to those interested in North American climatology, air pollution meteorology, wind power potential, and other climatological and meteorological applications.

2. METHODOLOGY

2.1 Synoptic Classification Scheme

The synoptic classification scheme utilized in this study was introduced by Lindsey (1980) and Garstang *et al.* (1980) and developed further by Pielke (1982), Yu and Pielke (1986), Segal *et al.* (1986, 1988), and Pielke *et al.* (1987a). It is based on the division of a surface weather map into synoptic air masses with the aid of a simple conceptual model of the polar front. Seven synoptic categories are considered in this study (see Table 2.1). The first five of these categories are illustrated in Figure 2.1 and described in detail in Table 2.2. Tropical cyclones have been included as a special sixth category because of their meteorological interest, but they are infrequent visitors to eastern North America and have not been treated in as much detail as the first five synoptic categories. The seventh category is for anything left over, that is, ambiguous or extremely complex patterns which do not fit easily into any of the other six categories.

This synoptic classification scheme is based on the observation that eastern North America's weather is generally influenced by polar highs, disturbances on the polar front, and the subtropical ridge. Synoptic-scale extratropical cyclones develop and propagate along the polar front about once or twice a week as a result of the horizontal temperature gradient across the polar front and subsequent baroclinic instability (Pielke *et al.*, 1987a). The scheme is thus in the tradition of the Bjerknes polar-front conceptual model. Three of the five primary synoptic categories correspond to the sectors of an extratropical cyclone, namely the warm or pre-cold-frontal sector (Category 1), the overrunning or pre-warm-frontal sector (Category 2), and the post-cold-frontal sector (Category 3). The other two primary categories, Categories 4 and 5, correspond to the polar anticyclone and the subtropical anticyclone, respectively, and Category 6 represents tropical cyclones.

The synoptic classification scheme is simple, manual, and subjective. Only surface weather maps are required (although upper-air maps can sometimes be helpful) and relatively few categories are defined; in contrast, Barry and Perry (1973) discuss a variety of more complicated classification schemes involving numerous categories. It is manual, as opposed to automated, because a human

Table 2.1: Synoptic classification scheme categories and their characteristics (adapted from Pielke *et al.*, 1987a).

Category	Air Mass	Reason for Categorization*
1	<i>mT</i>	<i>In the warm sector of an extratropical cyclone.</i> In this region the thickness and vorticity advection is weak with little curvature to the surface isobars. There is limited low-level convergence with an upper-level ridge tending to produce subsidence. Southwesterly low-level winds are typical.
2	<i>mT/cP, mT/cA, mP/cA</i>	<i>Ahead of the warm front in the region of cyclonic curvature to the surface isobars.</i> Warm air advecting upslope over the cold air stabilizes the thermal stratification while positive vorticity advection and low-level frictional convergence can add to vertical lifting. Because of the warm advection, the geostrophic winds veer with height. Low-level winds are generally northeasterly through southeasterly.
3	<i>cP, cA</i>	<i>Behind the cold front in the region of cyclonic curvature to the surface isobars.</i> Positive vorticity advection and negative thermal advection dominate, with the result of cooling causing strong boundary-layer mixing. The resulting thermal stratification in the lower troposphere is neutral, or even slightly superadiabatic. Gusty winds are usually associated with this sector of an extratropical cyclone. Because of the cold advection, the geostrophic winds back with height. Low-level winds are generally from the northeast through southwest.
4	<i>cP, cA</i>	<i>Under a polar high in a region of anticyclonic curvature to the surface isobars.</i> Active vorticity advection, weak negative thermal advection and low-level frictional divergence usually occur, producing boundary-layer subsidence. Because of relatively cool air aloft, the thermal stratification is only slightly stabilized during the day, in spite of the subsidence. At night, however, the relatively weak surface pressure gradient associated with this category causes very stable layers near the ground on clear nights due to long-wave radiational cooling. The low-level geostrophic winds are usually light to moderate varying slowly from northwesterly to southeasterly as the ridge progresses eastward past a fixed location.
5	<i>mT</i>	<i>In the vicinity of a subtropical ridge.</i> Vorticity, thickness advection, and the horizontal pressure gradient at all levels are weak in this region. The large upper-level ridge, along with the anticyclonically curved low-level pressure field, produces weak but persistent subsidence. This sinking causes a stabilization of the atmosphere throughout the troposphere. Low-level winds over the eastern United States associated with these systems tend to blow from the southeast through southwest.
6	<i>mT</i>	<i>Tropical storm or hurricane.</i> A warm-core tropical disturbance with closed surface isobars, cyclonic circulation, and surface wind speeds of at least 30 knots. Accompanied by extensive cloud cover, heavy precipitation and a well-mixed, gusty boundary layer.
7	?	<i>Ambiguous or unclassifiable.</i> Either a very weak, ambiguous pattern or a complex one in which three or more of the above categories are present within an analysis box (see discussion in Section 2.2.5).

* This discussion applies to the Northern Hemisphere.

Table 2.2: Overview of meteorological aspects of the five main synoptic categories (from Pielke *et al.*, 1987a).

Category Characteristics	Category 1	2	3	4	5
Category Class	mT: In the warm sector of an extratropical cyclone	mT cP, mT cA, mP cA: Ahead of the warm front in the region of cyclonic curvature at the surface	cP, cA: Behind the cold front in the region of cyclonic curvature to the surface (isobars)	cP, cA: Under a polar high in a region of anticyclonic curvature at the surface	mT: In the vicinity and west of a subtropical ridge
Surface winds	Birsk SW surface winds	Light to moderate SE to ENE surface winds	Strong NE to SW surface winds	Light and variable winds	Light SE to SW winds
Vertical motions	Weakening synoptic descent as the cold front approaches	Synoptic ascent due to warm advection and negative vorticity advection aloft becomes positive vorticity advection aloft closer to low center, resulting in enhanced vertical motion	Synoptic ascent due to positive vorticity advection aloft (in this region this ascent more than compensates for the descent due to cold advection)	Synoptic descent (due to warm advection and/or negative vorticity advection aloft)	Synoptic subsidence (descending branch of the Hadley cell). Descent becomes stronger as you approach the ridge axis
Temperature advection	Little temperature advection at the surface	Warm advection above the frontal inversion	Cold advection at the surface	Weak temperature advection at the surface	Weak temperature advection at the surface
Inversion	Weak synoptic subsidence inversion caps planetary boundary layer	Boundary layer capped by frontal inversion	Deep planetary boundary layer	Synoptic subsidence inversion and/or warm advection aloft create an inversion which caps the planetary boundary layer	Synoptic subsidence inversion
Diurnal variation in boundary-layer stability	Moderate diurnal variability in the boundary-layer stability	Little diurnal variability in boundary-layer stability because of cloud cover	Little diurnal variability in the boundary-layer stability because of strong winds and destabilizing of boundary layer by cold advection	In the absence of snow cover, because of clear skies and light winds, there is large diurnal variability in boundary-layer stability	Moderate diurnal variability in boundary-layer stability
Diurnal variation in surface layer stability	Moderately unstable surface layer during the day Moderately stable surface layer during the night	Stably stratified surface layer day and night	Near neutral surface layer day and night	Weakly to moderately unstable surface layer during the day unless snow cover present or low Sun angle, in which case surface layer tends to be stably stratified. Very stable surface layer at night	Moderately to strongly unstable surface layer during the day. Moderately to strongly stable surface layer during the night
Humidity near the surface	Often humid in relative and absolute sense	Often dry in absolute sense, but humid in relative sense	Dry in the absolute sense; usually dry in the relative sense	Dry in the absolute sense, humid in the relative sense at night; dry in relative sense during the day except when ground is snow-covered	Humid in relative and absolute sense
Cloud cover	Clear to partly cloudy skies except near squall lines	Mostly cloudy to cloudy	Clear to scattered or broken shallow to medium depth convective clouds	Clear except tendency for fog at night	Day: scattered fair weather cumulus Night: clear (except near the mesoscale systems listed below)
Dominant mesoscale systems	Squall lines	Embedded lines of convection	Forced airflow over rough terrain systems; lake effect storms	Mountain-valley flows, land-sea breezes, urban circulations (thermally-forced systems)	Mountain-valley flows, land-sea breezes, urban circulations (thermally-forced systems)
Precipitation types	Organized lines of convective precipitation	Often stable cloud types and precipitation. Overcast in general	Medium to shallow depth convective clouds, showery precipitation	No precipitation	Shallow low convective clouds with deeper convective clouds and precipitation organized by thermally forced mesoscale systems such as listed above
Ventilation	Moderate to good ventilation	Poor ventilation of low level (i.e. below frontal inversion) emissions	Excellent ventilation	Night or snow-covered ground: poor ventilation Day: poor to moderate ventilation	Day: moderate to good ventilation Night: moderate to poor ventilation
Deposition	Dry deposition except wet deposition in showers	Dominated by wet deposition	Dry deposition except in showers	Dry deposition	Dry deposition except wet deposition in showers and thunderstorms
Transport	Long range	Long range above inversion	Long range	More local as you approach the centre of the polar high	More local as you approach the centre of the subtropical high

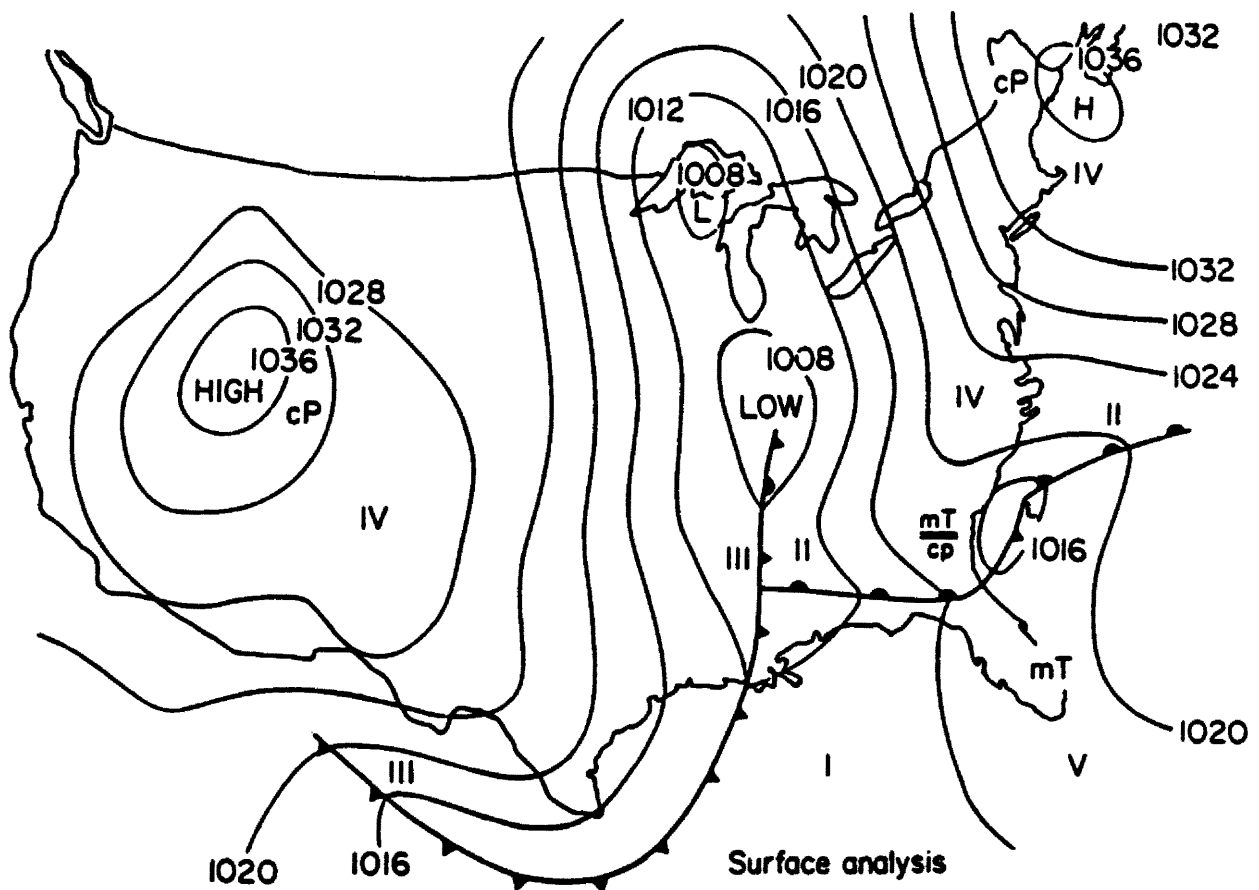


Figure 2.1: Synoptic classification of a sample surface weather map (Jan. 9, 1964). Five synoptic categories are shown: (I) warm sector; (II) overrunning sector ahead of a warm front; (III) region of cyclonic curvature behind a cold front; (IV) region of anticyclonic curvature under a polar high; (V) region under a subtropical high (adapted from Garstang et al., 1980).

analyst must go over individual surface weather maps. It is subjective in that human judgement is required to interpret and apply the synoptic conceptual model, and different analysts, or one analyst at different times, may produce different categorizations for a number of specific locations on the same weather map. This question of consistency and reproducibility is discussed further in Section 2.2.6. Objective map analysis schemes are available that use statistical classification methods combined with computer-based meteorological fields (e.g., Lund, 1963; Kalkstein *et al.*, 1987), but such schemes have their own weaknesses, including a tendency to produce non-physical synoptic categories and an inability to classify a significant fraction of the input fields.

The synoptic classification scheme used in this study has been employed previously for a variety of purposes. Garstang *et al.* (1980) applied it in an evaluation of wind power potential along the U.S. Atlantic and Gulf coasts. Diab and Garstang (1984) used a modified version for a similar study in southern Africa. Barchet (1982) and Barchet and Davis (1984) employed a modified version of the synoptic classification scheme in wind power potential studies for the Great Plains and for the continental United States, respectively. Pielke (1982) described how this scheme could be used in conjunction with a mesoscale meteorological model to produce mesoscale climatologies. Segal *et al.* (1986, 1988a) have used it to determine climatologically realizable, worst-case meteorological scenarios for mesoscale pollutant transport in southern Florida. Yu and Pielke (1986) employed this scheme to characterize the synoptic conditions associated with wintertime air pollution episodes in the Lake Powell area of northern Arizona and southern Utah, and Lindsey and Glantz (1986) used it to analyze local meteorology at three U.S. nuclear facilities for application to emergency-response atmospheric dispersion models. Pielke *et al.* (1987a) suggested its use as a means to define local seasons meteorologically, that is, based on the average location of the polar front, rather than by astronomical definition for all latitudes as is normally done. Forbes and Pielke (1985) surveyed the use of various schemes for identifying synoptic-scale weather regimes, including this scheme, in very-short-term weather forecasting. Finally, Stocker *et al.* (1990) used the scheme to characterize

prevailing dispersion conditions during a massive, simultaneous, continent-wide launch of tagged helium balloons in 1986.

2.2 Preparation of the Gridded Climatological Data Set

The first step in the analysis of the synoptic climatology of eastern North America was to prepare a gridded data set of daily synoptic category and surface geostrophic wind-speed class values. The characteristics of this data set and the methodology used to prepare it are described in this section.

2.2.1 Study area

The geographic region chosen for this study is shown in Figure 2.2. It encompasses 21° of longitude and 12.5° of latitude centered at 42.3°N , 78.5°W – a domain roughly 1700 km wide by 1400 km high. It can be separated into seven geographical subregions. These are the Great Lakes, the Appalachian Mountains, the Atlantic coast, the Atlantic piedmont, the midwestern plains, the Laurentian Upland, and the Atlantic Ocean.

A five-square-by-seven-square latitude-longitude grid overlay was used to subdivide the study area into 35 grid boxes. Each grid box is 2.5° of latitude by 3° of longitude, or approximately 280 km north-south by 250 km east-west (Figure 2.3). Use of the grid permitted the synoptic climatology of the region to be determined with mesoscale spatial resolution as the synoptic pattern and the surface geostrophic wind-speed were classified once per day for each grid box.

2.2.2 Study period

The time period of the study covered five years, 1975-1979, for a total of 1826 days (1976 was a leap year). A ten-year period is the normal minimum for climatological studies; five years was a compromise between the conflicting demands of climatological representativeness and time and cost constraints. Obviously, a climatology constructed for a different five-year period would produce slightly different results. For example, the time period of this study (1975-79) included two severely

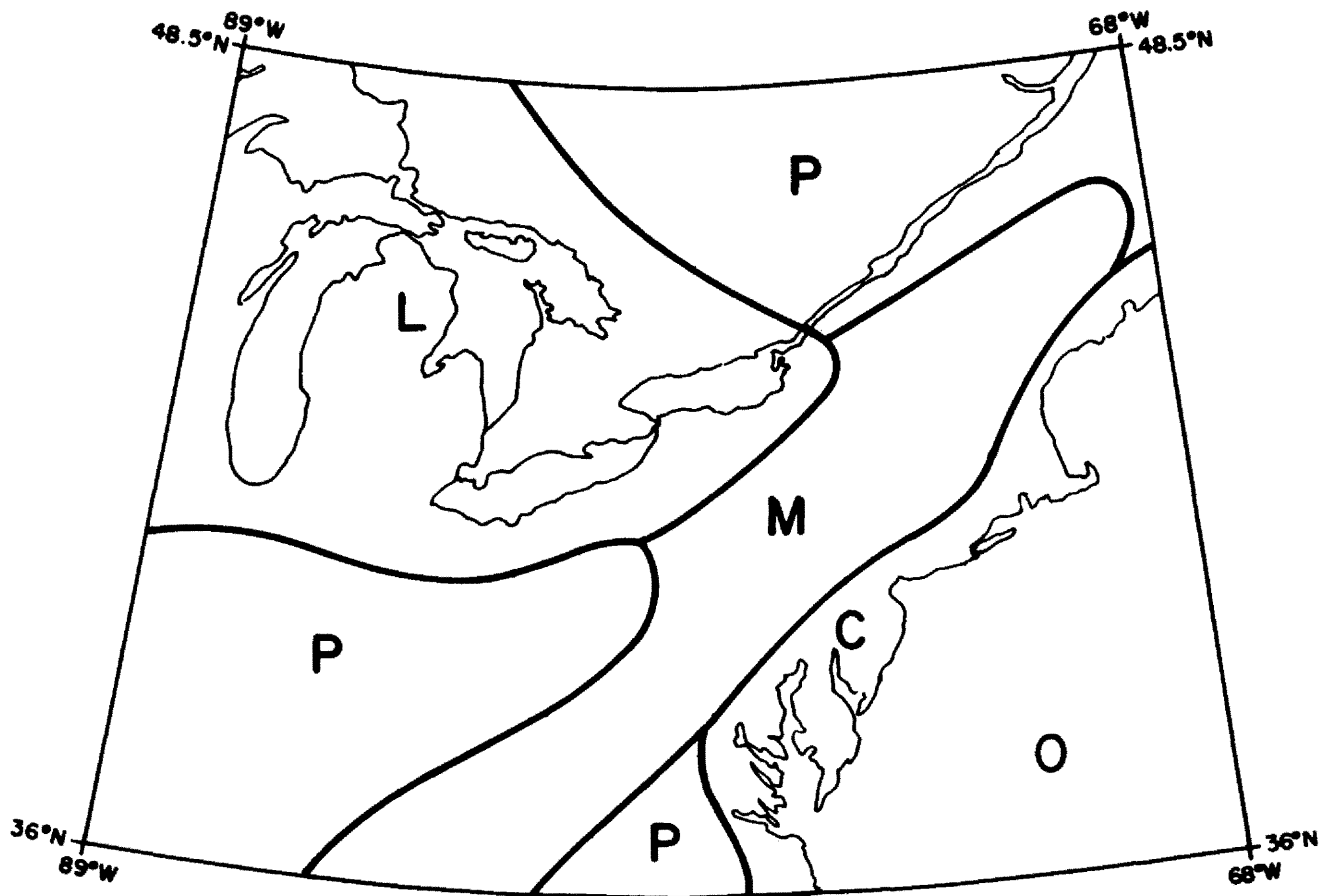
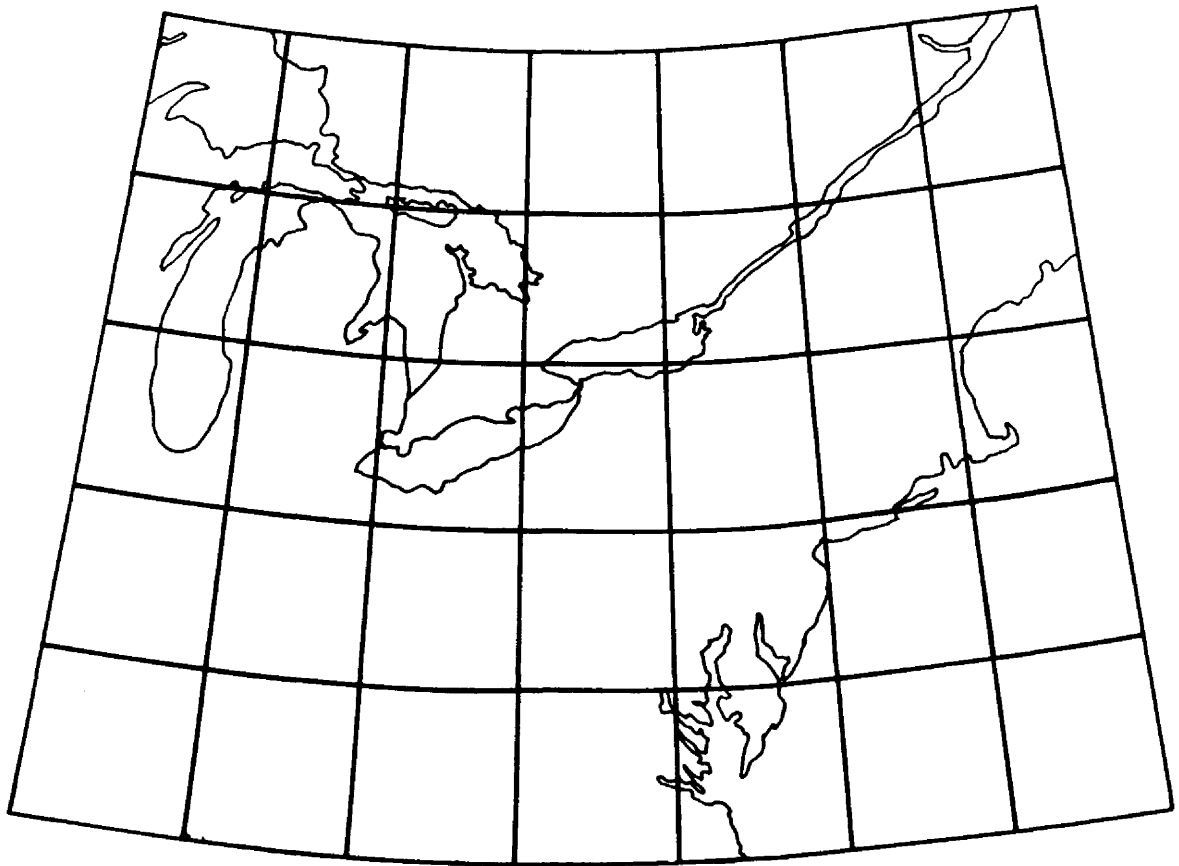


Figure 2.2: Primary physiographic subregions of the study area: "L" denotes the Great Lakes subregion, "M" the Appalachian Mountains, "C" the Atlantic coast, "O" the Atlantic Ocean, and "p" the midwestern plains, Atlantic piedmont, and Laurentian Upland.



36°N–48.5°N
68°W–89°W

Figure 2.3: Overlay of the 5-square × 7-square latitude-longitude grid on the study area.

cold winters (1976-77 and 1977-78) in eastern North America (e.g., Wiesnet and Matson, 1979; Namias, 1978; Diaz and Quayle, 1978). These anomalies undoubtedly have influenced the statistical results obtained for the synoptic categories and geostrophic wind-speed classes. Nevertheless, the climatological statistics obtained for this five-year period appear quite robust and display relatively small interannual variations (see Section 3.1.1). Previous synoptic climatological studies based on five years of data include Reed (1960) and Segal *et al.* (1986).

There is some overlap between the five-year period selected for this study and those of similar studies. Barchet and Davis (1984) considered the ten-year period 1969-78 while Lindsey and Glantz (1986) considered the two-year period 1974-75. Similarities and differences between their results and those of this study will be discussed in the next chapter.

2.2.3 Data source

The primary data source for this study was the *U.S. Daily Weather Map* series prepared by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce. This series is published weekly by the U.S. Government Printing Office and consists of daily 1200 GMT surface and 500 mb weather maps for North America plus daily maps of precipitation areas and amounts and station maximum-minimum temperatures for the continental United States. These maps are legible, concise, and readily available.

2.2.4 Synoptic categories and surface geostrophic wind-speed classes

Two meteorological parameters were considered in this study, synoptic pattern type and surface geostrophic wind speed. Synoptic pattern type has already been discussed in the previous section. Surface geostrophic wind speed, easily obtained from a surface weather map, was chosen as a parameter of interest because it is a measure of surface pressure gradient, a useful proxy for gauging mean, areal wind speeds at the top of the planetary boundary layer. Terrain-forced mesoscale circulations tend to occur in regions of weak synoptic-scale pressure gradients and low synoptic-

scale wind speeds, so that surface geostrophic wind speed is a useful adjunct to synoptic category in determining the likelihood of occurrence of these mesoscale features (see Chapter 4).

The following four ranges were used to classify surface geostrophic wind speed:

- | | |
|--|---|
| (1) 0-3 m s ⁻¹ – light winds | (3) 9-11 m s ⁻¹ – strong winds |
| (2) 4-8 m s ⁻¹ – moderate winds | (4) >11 m s ⁻¹ – very strong winds |

The calculation of the surface geostrophic wind speed, V_g , utilized the following equation:

$$V_g = \left(\frac{1}{\rho f} \right) \frac{\partial p}{\partial n}, \quad (2.1)$$

where ρ is air density, f is the latitude-dependent Coriolis parameter, p is sea-level reduced pressure, and n is distance along an axis normal to the isobars. Curvature and isallobaric effects were not considered. Since the above four wind-speed classes are not defined by equal-sized intervals, one must be careful when interpreting the relative frequencies of these classes. This concern will be discussed further in Sections 3.1 and 3.4.

The reader should also be aware of the following convention. In order to distinguish more easily between the two meteorological parameters, that is, synoptic pattern and surface geostrophic wind speed, in the rest of this report, particular synoptic patterns will be referred to as synoptic *categories* while particular surface geostrophic wind-speed intervals or ranges will be referred to as wind-speed *classes*.

2.2.5 Map analysis and classification

Synoptic patterns were identified by first overlaying each surface weather map in the *U.S. Daily Weather Map* series for the study period with a transparent acetate grid. The principal analyst (D.A. Wesley) then used a water-soluble marker to write the category number of the dominant synoptic pattern for each grid square on that square. Many times a frontal boundary crossed a grid square so that two synoptic categories were present (e.g., Categories 1/2, 1/3, or 2/3). In such cases both categories were recorded. For complex situations where more than two categories could

be identified or for very ambiguous patterns, Category 7 ('undefined') was assigned instead. Note that the synoptic category or categories assigned were representative of the grid-square area. In Barchet and Davis's (1984) study, synoptic categories were identified at grid *points* instead. Point classification avoids double categories but also discards information about frontal positions.

Surface geostrophic wind-speed classes were identified for each grid square based on surface isobar spacing. These classes were also marked on the acetate sheet. The sheet was then photocopied to record the analysis and washed for reuse.

Figure 2.1 shows a typical synoptic situation over the United States with all of the first five synoptic categories present. An example of Category 7, the ambiguous or unclassifiable category, is shown in Figure 2.4. In this latter case, a complex succession of disturbances passing over the study area led to an unclear and rapidly changing synoptic situation over the central and southern Appalachian Mountain region. Specifically, neither synoptic Categories 3 nor 1 dominate the area of extreme southwestern Virginia, southern West Virginia, eastern Kentucky, eastern Tennessee and western North Carolina, although they both are apparently exerting some influence. Furthermore, there are hints of Category 2 southeast of New England although no well-defined warm front is apparent. For these reasons this region received a Category 7 designation. Figure 2.5 shows a sample pressure pattern over the northeastern U.S. with the surface geostrophic wind-speed classes listed for each grid box.

Mesoscale influences on the synoptic weather pattern are very evident in the surface weather maps for many situations. For example, lake-effect systems can create a trough in the synoptic pressure pattern over the Great Lakes. In these situations, the obvious mesoscale influences on the analyzed pressure pattern were ignored, if possible, and the larger-scale dominant synoptic category was assigned instead. For example, in Figure 2.6, synoptic Category 4 was assigned throughout the Great Lakes with the exception of the ambiguous northwestern region. The mesoscale influence of lake-effect circulations has created conditions similar to Category 3 in this region, but in reality this is superimposed on the polar anticyclone, Category 4. Note that east of the Lakes (or toward

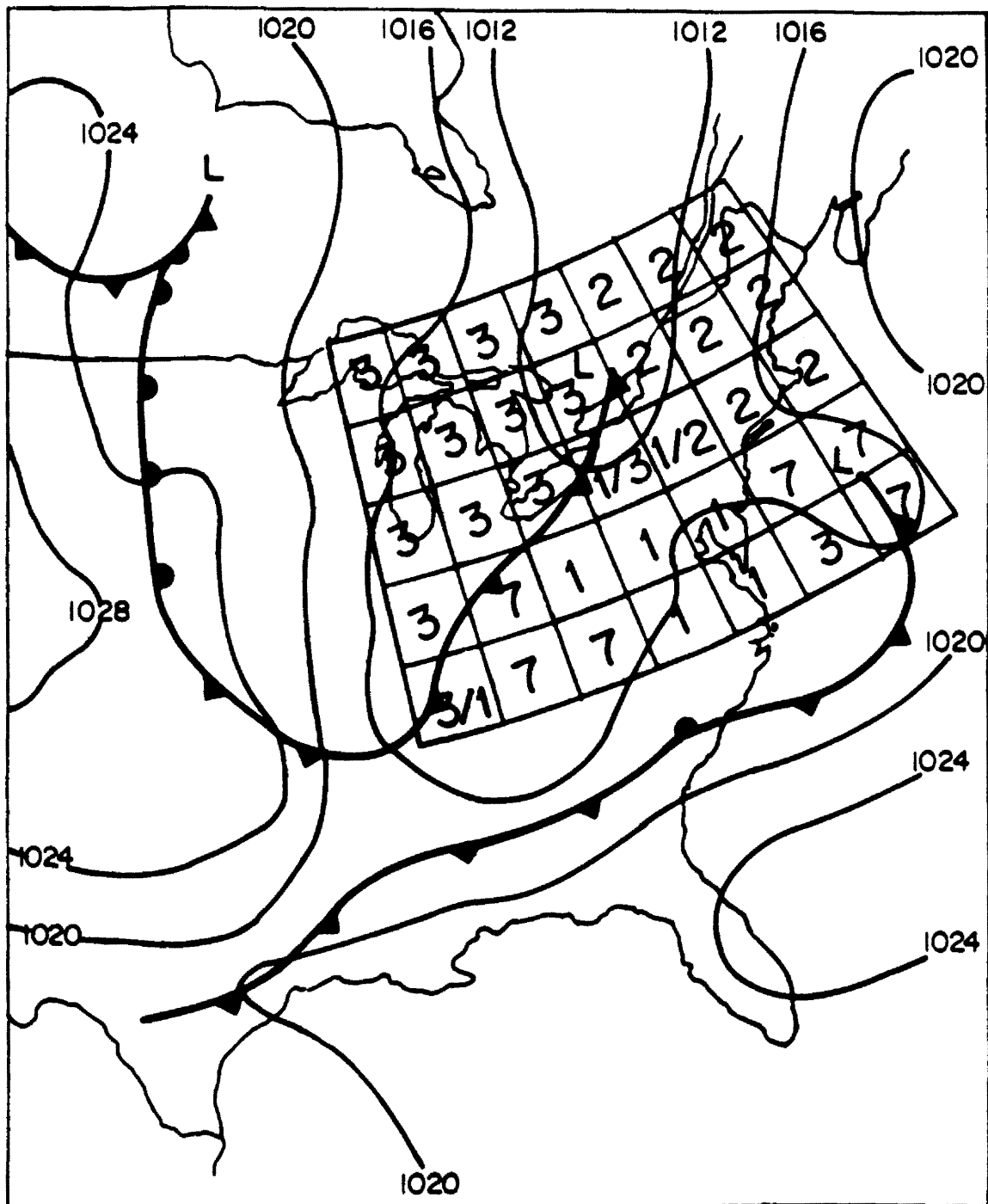


Figure 2.4: Gridded synoptic categories, including Category 7, for a sample surface weather map (Feb. 19, 1977). Frontal positions are indicated by heavy lines while surface isobars (mb) are shown by light lines. See Table 2.1 for category code definitions.

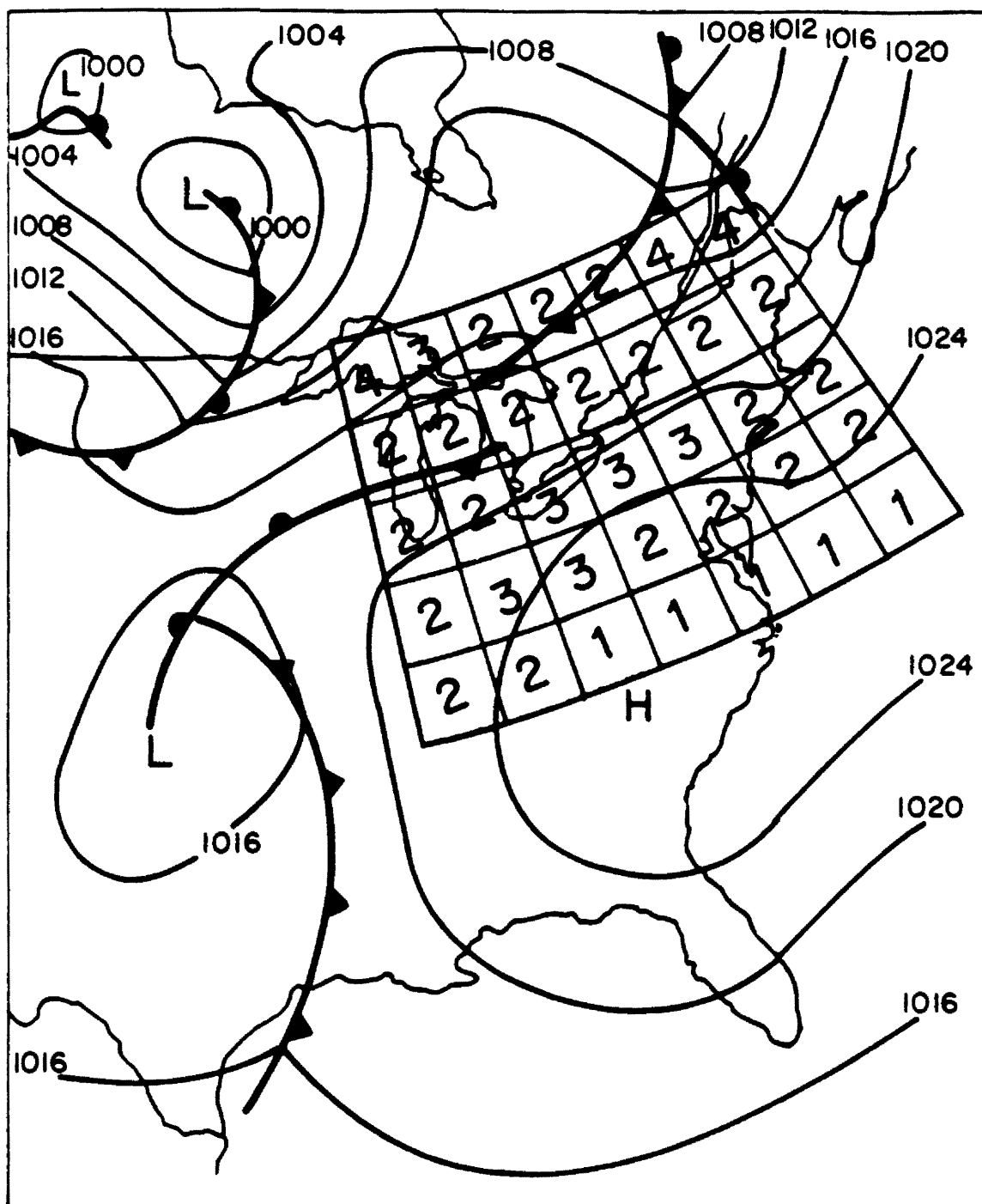


Figure 2.5: Gridded surface geostrophic wind-speed classes for a sample surface weather map (Nov. 3, 1975). A “1” indicates the 0-3 m s⁻¹ speed class, a “2” indicates the 4-8 m s⁻¹ speed class, a “3” indicates the 9-11 m s⁻¹ speed class, and a “4” indicates the >11 m s⁻¹ speed class.

the retreating cyclone) Category 4 is more apparent. Time continuity was another important consideration in the analyses. Previous maps were referred to if necessary when analyzing a particular map so that the classifications reflected a realistic and physically plausible evolution of synoptic weather systems.

2.2.6 Subjectivity, consistency, and reproducibility

When using a subjective classification scheme, consistency and reproducibility are important concerns. There are actually two sources of subjectivity: (1) the original analysis of synoptic station data by meteorologists with the National Weather Service as part of the preparation of the surface weather maps printed in the *U.S. Daily Weather Map* series, and (2) the subsequent manual synoptic classification and categorization of these surface weather maps (Lindsey and Glantz, 1986, p. 16). The first source of subjectivity was beyond the control of this study. With regard to the second source, Pielke *et al.* (1987a) report that there is usually 90% agreement between classifications prepared independently by two experienced analysts for a set of maps. Through intercomparisons of the synoptic classification of a number of test maps chosen at random and analyzed by all three authors for the study grid, this 90% level of agreement was confirmed for this study. Special effort was made to maximize consistency and reproducibility; the principal analyst reviewed all classifications at least once and discussed difficult cases with the other two authors.

2.3 Statistical Analysis of the Gridded Climatological Data Set

Appendix A lists the synoptic-category and surface geostrophic wind-speed class values assigned for each of the 35 grid boxes for each of the 1826 study days from January 1, 1975 to December 31, 1979. After the initial categorization of the *U.S. Daily Weather Maps*, the data in Appendix A were keyboarded onto six 5-1/2" magnetic diskettes and transferred to a mainframe computer data file. This file was then statistically analyzed for single-parameter frequencies and joint frequencies (both two-way and three-way) of the synoptic categories and geostrophic wind-speed classes, persistence probabilities, and time transition probabilities. The results were stratified in several ways: tempo-

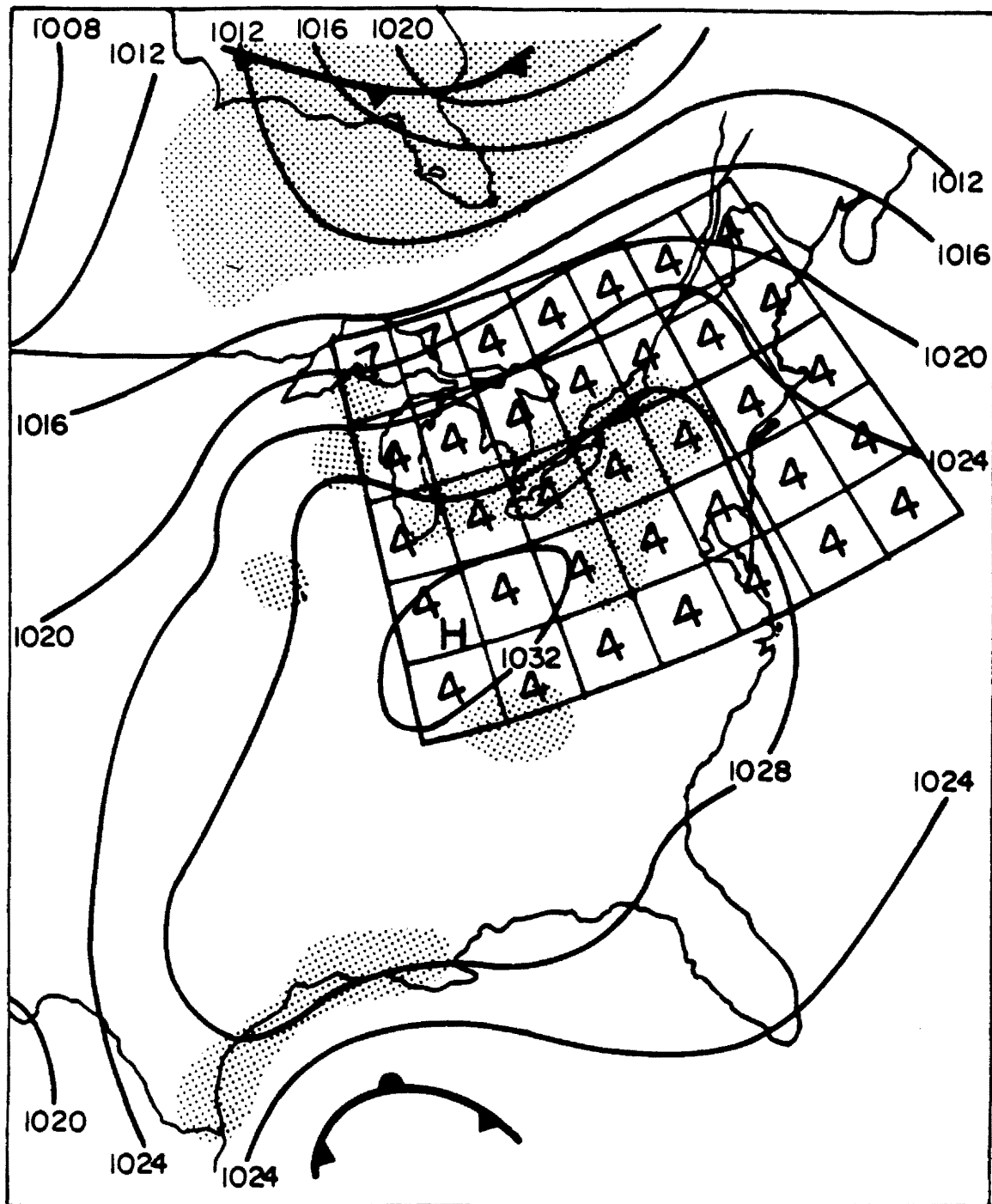


Figure 2.6: Mesoscale lake-effect perturbations on a sample surface weather map (Jan. 22, 1978). Numbers in grid boxes indicate analyzed synoptic categories. Stippled areas mark precipitation.

rally by month, season, year, and full five-year period, and spatially by grid box, multiple-grid-box corners, grid row, and entire domain. The basic unit used in the various analyses was the “grid-box day”, that is, the occurrence of a particular category or class in one grid box or grid square on one day. The full data set contains 63,910 grid-box days (i.e., 35 boxes $\times$ 1826 days). Appendix C contains a listing of the computer program used to prepare all of the statistical tables.

2.3.1 Frequency tables

Each data-set value has a number of associated characteristics: meteorological parameter considered (either synoptic category or surface geostrophic wind-speed class), time (especially month and year), and location (grid row, grid column). Accordingly, there are a wide variety of variable combinations possible in preparing frequency tables. For instance, the number of occurrences of the different synoptic categories could simply be tabulated for all grid squares and the entire study period, or for the entire grid and individual years, or for a particular grid row and the entire study period, and so on. Synoptic category could also be cross-tabulated against surface geostrophic wind-speed class or year or grid row. Another possibility would be to cross-tabulate synoptic category against both grid row and grid column.

These different combinations correspond to frequency tables based on one variable or to joint frequency tables involving two or more variables. Three different types of frequency tables are referred to in this report: one-way, two-way and three-way tables. A one-way (or one-variable) table is listed in row format, where the number of occurrences for each class or category of the variable of interest (the “primary row” variable) are listed across the page along with a total number of occurrences (e.g., “1975-1979” line in Table 3.1). In a two-way or two-variable frequency table, there is both a “primary row” variable and a “primary column” variable. The table is presented in a row-column or array format and there are also so-called marginal totals given for each row and column (e.g., Table 3.1). In a three-way or three-variable table, a “secondary column” variable

is included in addition to the “primary row” and “primary column” variables (e.g., Table B.23 of Appendix B).

Selection of the variables to be tabulated is not sufficient to define a frequency table uniquely. A decision must also be made as to the ranges of the remaining variables or their attributes. For example, in tabulating synoptic category vs. surface geostrophic wind-speed class, all data values could be considered or only those data values belonging to a given year or given month or a selected grid box. This specification of nontabulated variable values is termed “stratification”. Judicious use of stratification allows the influence of latitude and longitude, time of year, continentality, and other factors to be examined. All frequency table headers contained in this report provide information on ranges for all variables so that the choice of stratification is clear.

2.3.2 Persistence tables

Another type of analysis is to consider how many days in a row an “episode” (i.e., the persistent, unbroken occurrence of a particular synoptic category or surface geostrophic wind-speed class) lasts. For instance, if a grid square experienced the following sequence of synoptic categories – 3, 4, 4, 4, 1, 1, 4 – we would say that there had been a three-day Category 4 episode and a two-day Category 1 episode. A one-day episode is considered to have occurred when the synoptic category or surface geostrophic wind-speed class is different from both that of the day preceding it and the day following it. The persistence tables, which have been prepared to provide information about the length of episodes, are listed in a two-way array format with synoptic category or surface geostrophic wind-speed class as the primary column variable and length of episode (i.e., number of days duration) as the primary row variable (e.g., Table 3.12). The number of occurrences of both episodes and episode days have been tabulated (e.g., Table 3.12 vs. Table 3.18).

2.3.3 Transition tables

A third type of analysis is to examine the frequency with which one synoptic category or surface geostrophic wind-speed class changes into a different category or class at a particular location from one day to the next (a temporal transition) or on a particular day from one grid square to another (a spatial transition). A time transition table will thus provide information about the likelihood of different synoptic categories or surface geostrophic wind-speed classes following each other at a fixed location. Given the normal pattern of travelling extratropical cyclones crossing the study area in a generally west-to-east fashion, we would expect some synoptic-category sequences (e.g., 1/4, 2/3) to be likelier than others (e.g., 2/5, 1/5). A space transition table, on the other hand, will give some indication of the spatial extent of different synoptic categories or surface geostrophic wind-speed classes. If a particular category or class tends to cover a wide area, then the probability of transition from that category or class to itself from one grid square to an adjacent square will tend to be large.

The transition tables in this report are presented in a two-way array format, where the primary column variable gives the possible category values at a particular grid square on a particular day and the primary row variable gives the possible category values for either the next day (time transition table) or the adjacent grid squares (space transition table). Table 3.20 is an example of a time transition table and Table 3.27 is an example of a space transition table. Transition tables can also be constructed with different "lags". In the case of a time transition table, the table could be constructed on the basis of what synoptic category was present two days hence or five days hence instead of one day hence. Time lags of one to eight days have been considered. In the case of a space transition table, the size of the space "lag" or "step" is limited by the size of the grid. In Table 3.27, both one-grid-square lag and two-grid-square lag statistics are shown.

2.3.4 Treatment of multiple categories and end effects

One complicating aspect of this study is that two different synoptic categories may have been assigned to a grid square on any given day. A decision must be made as to how to handle such an occurrence when preparing the different statistical tables. In the case of frequency tables, two options are available. One option is to give each category a count of one-half or 0.5 for its contribution to the number of occurrences of that category instead of the normal count of 1. The other option is to count just the first (or the second) of the two synoptic categories. Note that this second option could introduce some bias towards either the lower or higher numbered categories. A double synoptic category could be recorded in either order (e.g., 2/1 or 1/2) no matter which pattern was judged to be dominant, but the analyst's choice of order may have been biased. The option chosen to handle double synoptic categories is indicated on each joint frequency table in this report; in most cases, the first option has been used. No double categories were assigned for surface geostrophic wind speed.

Compilation of the persistence and transition tables was less flexible with respect to double synoptic categories. For calculations of persistence, if a day being checked for the length of a synoptic pattern episode was a double-category day and if either category matched the episode category, then the episode was taken to have continued to that day and the other category was ignored. If neither category matched the episode category, then the episode was taken to have ended and a new episode was started for the first of the two categories. The second category was ignored. Thus, no attempt was made to consider "branching" in the persistence calculations. A similar approach was used in constructing the transition tables. If the "old" synoptic category was a double category, then only the first category was considered. However, if a "new" synoptic category was a double category, then each was counted for a one-half count in building the transition table.

End effects were also a concern in the persistence calculations. That is, how should an ongoing episode be treated when the end of the tabulation time period being considered was reached (e.g., one-year period, five-year period)? The two choices were to assume that the episode also ended at

that time or to treat it as an episode of indeterminate length and not include it in the persistence tables. The second choice was adopted because it appeared to introduce less bias.

3. BASIC FEATURES OF THE SYNOPTIC CLIMATOLOGY

This section presents the basic statistical results of the study for the three different types of analyses discussed in Section 2.3. Many of the tables contained in this section are summaries of more detailed statistical tables which have been collected and attached as Appendix B. Note that the quantity *Number of Occurrences* referred to in the various tables is the number of grid-box days on which a particular category or class occurred, while the *Frequency of Occurrence* is the *Number of Occurrences* divided by the total number of grid-box days. Note also that there is a slight imprecision in the synoptic category tables due to the presence of double synoptic categories in the climatological data set and the resulting half-counts. Individual values listed for *Number of Occurrences* have been truncated to their integer value (the first decimal place may be a “0” or “5”) so that row total or column total *Number of Occurrences* may appear to be slightly too large. However, some tables in Appendix B list *Number of Occurrence* values to one decimal place, thus preserving full precision. *Frequency of Occurrence* values, on the other hand, are rounded either up or down to two significant figures. Synoptic Category 6 (tropical cyclones and hurricanes) is denoted in the tables by the letter ‘H’ while synoptic Category 7 (unclassifiable) is denoted by the letter ‘U’.

3.1 Frequency of Synoptic Categories and Geostrophic Wind-Speed Classes

3.1.1 Mean distribution and interannual variability

Table 3.1 lists synoptic category frequencies summed over the entire grid for the full five-year study period and for each individual year. Overall, Category 4, the polar anticyclone category, is the most common synoptic pattern over eastern North America with about a 34% frequency. Post-cold-frontal conditions (Category 3) follow closely behind at 26%. The warm sector of an extratropical cyclone and the overrunning region (Categories 1 and 2, respectively) occur approximately 19% and 12% of the time. The subtropical ridge dominates on only 5% of the grid-box days during the study, and 5% of the grid-box patterns were so ambiguous that a category could not be assigned.

The tropical cyclone/hurricane category (Category 6 or *H*) occurred with a frequency of only 0.1%, not surprising considering how few Atlantic hurricanes or tropical storms make landfall north of Cape Hatteras (Neumann *et al.*, 1987).

Table 3.1 also contains information about the year-to-year or interannual variation of the synoptic categories over the study area. The hurricane category ranges in number of occurrences from no grid-box days in a year (1977) to a high of 35 grid-box days in 1975. Synoptic Category 3, the post-cold-frontal category, exhibits the second-greatest year-to-year variability with a 19% to 31% range (highest in 1979, lowest in 1975). Category 2, the overrunning category, ranges from 9% in 1979 to slightly over 14% in 1975. The polar high pattern, Category 4, is fairly steady at 30% to 37%. The subtropical high (Category 5) ranges from 2% (1979) to 8% (1975). The number of ambiguous cases (Category 7 or *U*) remains fairly constant at about 5% throughout the five years of the investigation.

These results indicate that year-to-year variation in synoptic category frequency can be important. Two years of the study, 1975 and 1979, exhibit a substantial overall variation in four of the synoptic categories; such a variation is not nearly so apparent for the intervening three years. The one exception is the subtropical anticyclone category (Category 5), which steadily decreased in frequency from 1975 to 1979 over the grid; the annual number of Category 5 grid-box days are 1060, 835, 622, 417, and 211, respectively.

Table 3.2 presents the corresponding frequency statistics for surface geostrophic wind-speed class. As shown in the last row of Table 3.2, the moderate and very strong surface geostrophic wind-speed classes ($4-8 \text{ m s}^{-1}$, $>11 \text{ m s}^{-1}$) dominate the wind-speed class frequencies, occurring on average about 50% and 40% of the time, respectively. Light wind speeds ($0-3 \text{ m s}^{-1}$) are present during only 6% of the days during the study, while strong wind speeds ($9-11 \text{ m s}^{-1}$) rank lowest in frequency at 5%. However, the frequency of this latter class is reduced at least partly because its interval width is smaller than those of the other wind-speed classes. Note again that these classes are measures of surface pressure gradient strength, not observed surface wind speeds.

Table 3.1: Number of occurrences/frequency of occurrence of daily synoptic categories for all grid squares for each of the five years of the study period. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). Double synoptic categories are weighted equally (from Tables B.1 – B.6 in Appendix B).

Year	Daily Synoptic Category							Row Total
	1	2	3	4	5	H	U	
1975	2148/0.17	1804/0.14	2463/0.19	4686/0.37	1060/0.08	35/0.00	577/0.05	12775/1.00
1976*	2607/0.20	1412/0.11	3137/0.24	4225/0.33	835/0.07	21/0.00	571/0.04	12810/1.00
1977	2183/0.17	1760/0.14	3625/0.28	3864/0.30	622/0.05	0/0.00	719/0.06	12775/1.00
1978	2322/0.18	1635/0.13	3238/0.25	4673/0.37	417/0.03	7/0.00	481/0.04	12775/1.00
1979	2653/0.21	1206/0.09	3960/0.31	4112/0.32	211/0.02	26/0.00	606/0.05	12775/1.00
1975-79	11915/0.19	7819/0.12	16424/0.26	21561/0.34	3146/0.05	90/0.00	2954/0.05	63910/1.00

* Leap year.

Table 3.2: Number of occurrences/frequency of occurrence of daily surface geostrophic wind-speed classes for all grid squares for each of the five years of the study period (from Tables B.1 – B.6 in Appendix B). Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded).

Year	Daily Surface Geostrophic Wind-Speed Class (m s^{-1})				Row Total
	0-3	4-8	9-11	> 11	
1975	940/0.07	6312/0.49	534/0.04	4989/0.39	12755/1.00
1976	729/0.06	5973/0.47	507/0.04	5601/0.44	12810/1.00
1977	698/0.05	6410/0.50	571/0.05	5096/0.40	12755/1.00
1978	731/0.06	6595/0.52	534/0.04	4915/0.38	12755/1.00
1979	726/0.06	6372/0.50	958/0.07	4719/0.37	12755/1.00
1975-79	3824/0.06	31662/0.49	3104/0.05	25320/0.40	63910/1.00

Table 3.2 also shows the individual yearly totals for the surface geostrophic wind-speed classes. The year-to-year variation in these classes is not nearly as great as for the synoptic categories. Slack pressure gradients and light geostrophic wind speeds occur from 5% to 7% of the time, and moderate winds from 47% to 52%. Strong winds were found from 4% to 7% and very strong winds from 37% to 44% of the time, respectively.

3.1.2 Seasonal variability

It is also possible to tabulate the climatological data set in other ways than by individual year in order to reveal patterns and relationships hidden in Tables 3.1 and 3.2. The climatological data set was also tabulated by season to investigate the variation of the various synoptic pattern and geostrophic wind-speed class frequencies over the annual cycle. For simplicity, astronomical definitions of the seasons were used (Table 3.3) although these do not truly reflect meteorological seasons (see Section 3.3 and Pielke *et al.*, 1987a).

Table 3.4 presents the synoptic category frequencies for the entire grid and full five-year study period stratified by season. When compared to the overall frequencies for all five years (i.e., "All Seasons" values), some interesting tendencies are apparent. Pre-cold-frontal or warm sector conditions (Category 1) are observed over eastern North America only 12% of the time in the winter, as opposed to 19% of the time for the total year. On the other hand, with the polar front apparently in its southernmost position at this season, the three synoptic categories located north of the polar front in the conceptual synoptic model (Categories 2, 3, and 4) are all more frequent in the winter than at other times of the year. The occurrence of overrunning or pre-warm-frontal conditions (Category 2) increases in the winter to 15%, post-cold-frontal patterns (Category 3) increase in frequency to 31%, and polar anticyclone (Category 4) occurrence increases to 38%. No hurricane or tropical storm was observed during these five winters and the subtropical ridge (Category 5) was virtually absent. Only about 4% of the grid-box patterns were classified as ambiguous.

Table 3.3: Definition of seasons as used in this study for stratification purposes.

Season	Dates	Length (days)
Winter	Dec. 21 – Mar. 20	90*
Spring	Mar. 21 – June 20	92
Summer	June 21 – Sept. 20	92
Autumn	Sept. 21 – Dec. 20	91

* 91 days in 1976 (a leap year).

Table 3.4: Number of occurrences/frequency of occurrence of daily synoptic categories for all grid squares for each season* for all years (from Tables B.1 and B.7 – B.10 in Appendix B). Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). Double synoptic categories are weighted equally.

Season*	Daily Synoptic Category							Row Total
	1	2	3	4	5	H	U	
Winter	1933/0.12	2380/0.15	4824/0.31	5975/0.38	2/0.00	0/0.00	670/0.04	15785/1.00
Spring	2882/0.18	2315/0.14	4164/0.26	5142/0.32	900/0.06	0/0.00	696/0.04	16100/1.00
Summer	4086/0.25	1067/0.07	2950/0.18	4876/0.30	2119/0.13	83/0.01	917/0.06	16100/1.00
Autumn	3013/0.19	2056/0.13	4486/0.28	5567/0.35	124/0.01	7/0.00	671/0.04	15925/1.00
All Seasons	11914/0.19	7818/0.12	16424/0.26	21560/0.34	3145/0.05	90/0.00	2954/0.05	63910/1.00

* as defined in Table 3.3.

For the summer months, warm-sector (Category 1) occurrences increase dramatically to 25%. This is reasonable since the polar front position is at its northernmost extent at this time of the year (see also Section 3.3). Overrunning (Category 2) occurs only about 7% of the time, as opposed to 12% for the total year. Post-cold-frontal (Category 3) conditions are observed only 18% of the time since frontal passages are much less frequent in this region during the summer. The frequency of the polar high pattern (30%) is 4% less than its average during the entire year and 8% less than its average during the winter. Subtropical high (Category 5) frequency jumps from nearly zero during the winter to about 13% in the summer (vs. 5% for the entire year). Tropical cyclones/hurricanes occurred on a total of 83 grid-box days during these five summers: an average frequency of 0.5%. The ambiguous category frequency jumps slightly to almost 6%. This is a result of the overall synoptic pattern being less well defined during the summer than at other times of the year (i.e., weak fronts and slack pressure gradients are much more common).

The seasonal totals for the spring are also shown in Table 3.4. The totals are very similar to the all-season totals; Category 2 frequency is slightly higher (14% vs. 12%) and Category 4 frequency is slightly lower (32% vs. 34%). The subtropical anticyclone (Category 5) occurs about 6% of the time. Ambiguous patterns occur only about 4% of the time. For autumn, the only significant differences from the all-season totals are an increase in Category 3 (by 2% to 28%) and a drastic reduction of the frequency of Category 5 to a value of only 1% from its summer high of 13%.

The seasonal totals for the surface geostrophic wind-speed classes (Table 3.5) also show some significant variations. During the winter, light surface geostrophic winds ($0-3 \text{ m s}^{-1}$) are less frequent than their annual average (3% vs. 6%). Moderate geostrophic winds, at about 37% frequency, are also reduced; they occur about 49% of the time for the entire year. The very-strong-wind class, on the other hand, occurs 55% of the time in the winter compared to 40% for the all-season average. The summer statistics reveal the dominance of light to moderate geostrophic wind speeds ($0-8 \text{ m s}^{-1}$) in that season with a frequency of 75%; the corresponding total for the all-season statistics is 55%. The frequency for very strong geostrophic winds is reduced by a factor

Table 3.5: Number of occurrences/frequency of occurrence of daily surface geostrophic wind-speed classes for all grid squares for each season* for all years (from Tables B.1 and B.7 – B.10 in Appendix B). Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded).

Season*	Daily Surface Geostrophic Wind-Speed Class (m s^{-1})				Row Total
	0-3	4-8	9-11	> 11	
Winter	517/0.03	5770/0.37	743/0.05	8755/0.55	15785/1.00
Spring	877/0.06	8076/0.50	841/0.05	6306/0.39	16100/1.00
Summer	1685/0.10	10516/0.65	725/0.05	3174/0.20	16100/1.00
Autumn	745/0.05	7300/0.46	795/0.05	7085/0.44	15925/1.00
All Seasons	3824/0.06	31662/0.49	3104/0.05	25320/0.40	63910/1.00

*as defined in Table 3.3.

of two for the summer months compared to the annual value (20% vs. 40%). For the springtime, averages for the various geostrophic wind-speed classes are nearly equal to the all-season totals. In autumn, the very strong geostrophic wind-speed class increases to about 44% compared to the all-season value of 40% while the moderate geostrophic wind-speed class decreases to 46% from 49%. Such a result is consistent with the aforementioned slight increase in synoptic Category 3 frequency for the autumn months (Table 3.4), since strong geostrophic winds are often associated with post-cold-frontal conditions (e.g., Table 3.10).

3.1.3 Spatial variability

In addition to interannual and seasonal variability, there is also significant spatial variability present in the gridded synoptic climatological data set. Figure 3.1 shows the variations in the frequency of occurrence of the different synoptic categories across the study area for the entire year, and Figure 3.2 shows the corresponding variations in the frequency of occurrence of the different surface geostrophic wind-speed classes. Latitudinal and longitudinal variations are evident in both figures.

Synoptic Category 1 (warm sector) is one of the south-of-the-polar-front categories (along with Categories 5 and 6). As might be expected, it decreases in frequency with increasing latitude (Figure 3.1a). In addition, there is a pronounced east-west asymmetry evident in the Category 1 frequency pattern in the southern part of the domain. Category 1 is significantly more frequent west of the terrain barrier formed by the Appalachians than east of them (see Figure 2.2), suggesting the tendency of the Appalachian Mountains to deflect extratropical cyclones northeastward along their western flank and to induce cold air damming along their eastern flank (Richwein, 1980). This frequency pattern is consistent with the climatological storm tracks determined by Reitan (1974), Zishka and Smith (1980), and Whittaker and Horn (1984) and with the results of studies by Colucci (1976) and Hayden (1981a). The three sets of storm tracks have been reproduced here as Figures 3.8, 3.9, and 3.10, and Figure 3 shows some of Hayden's results. Category 2 (ahead of

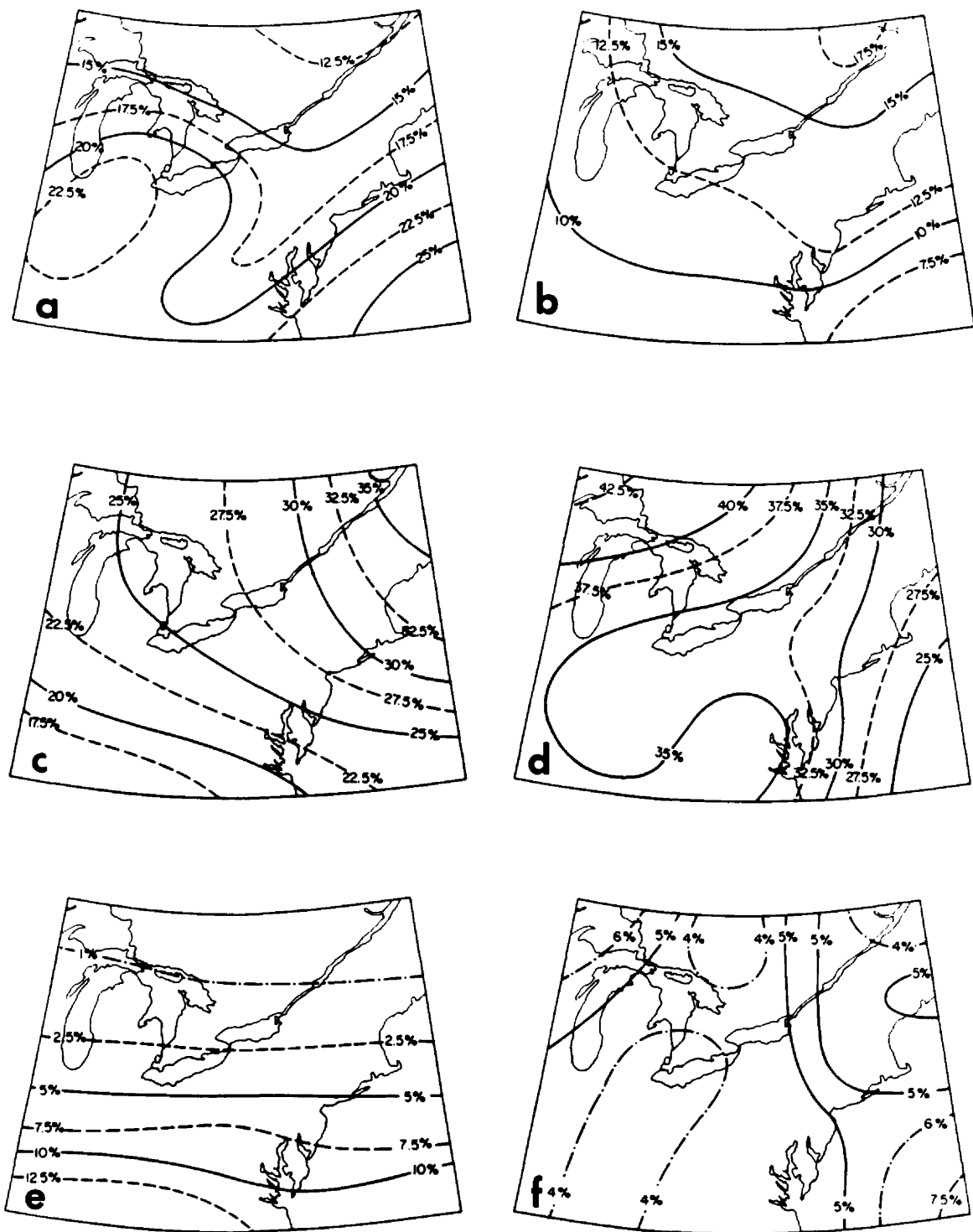


Figure 3.1: Spatial variation of the synoptic category frequency distributions for the full five-year study period 1975-1979: (a) Category 1 - warm sector; (b) Category 2 - overrunning sector; (c) Category 3 - behind cold front; (d) Category 4 - polar high; (e) Category 5 - subtropical high; (f) Category 7 - ambiguous. No panel has been included for Category 6 (tropical storm/hurricane) because of the small sample size.

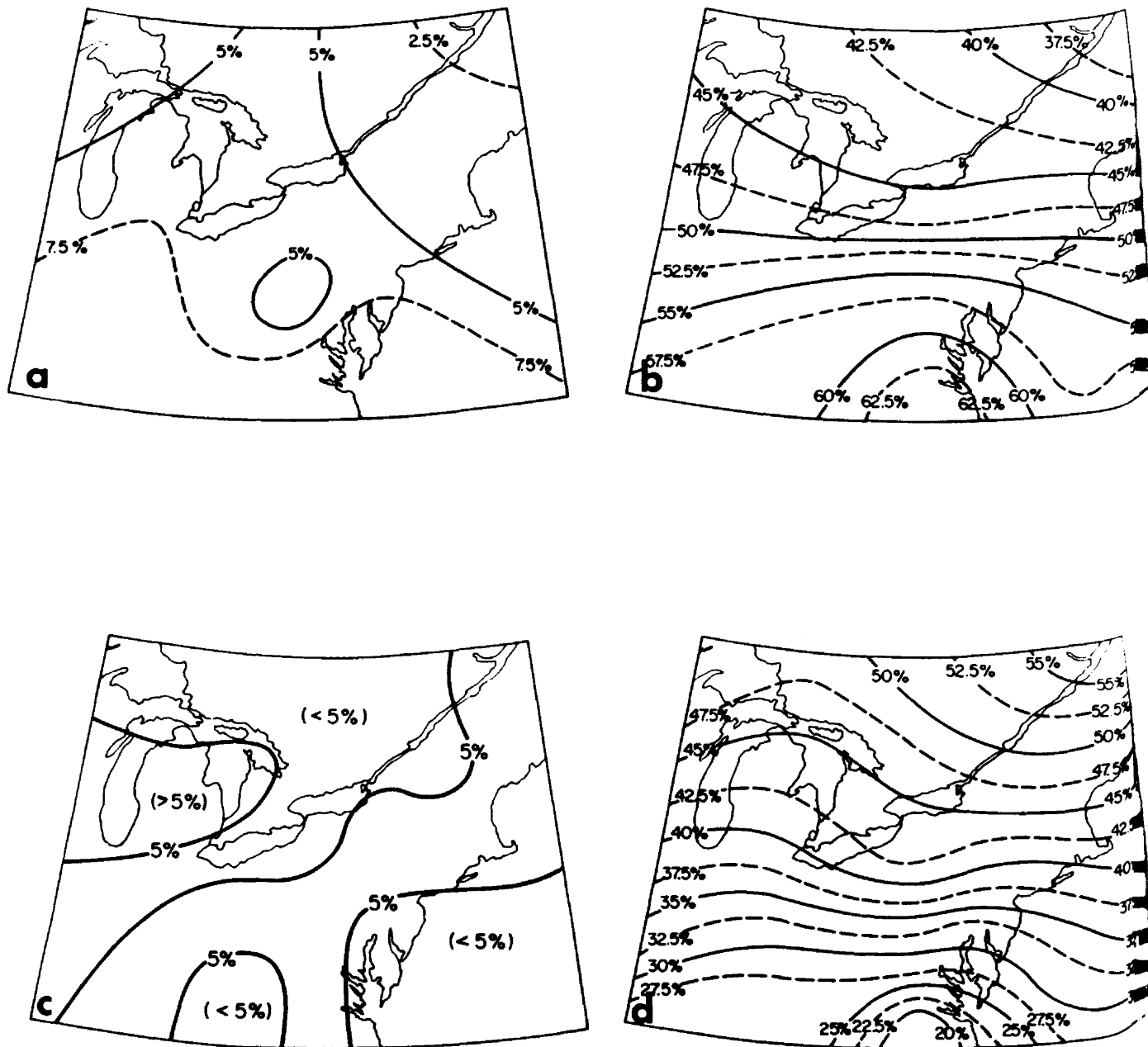


Figure 3.2: Spatial variation of the surface geostrophic wind-speed class frequency distributions for the full five-year study period 1975-1979: (a) light winds ($0-3 \text{ m s}^{-1}$); (b) moderate winds ($4-8 \text{ m s}^{-1}$); (c) strong winds ($9-11 \text{ m s}^{-1}$); (d) very strong winds ($> 11 \text{ m s}^{-1}$).

warm front), on the other hand, is one of the north-of-the-polar-front categories (3 and 4 being the others) and occurs more frequently with increasing latitude as shown in Figure 3.1b. There is also some longitudinal variation evident, likely due to the confluence of two storm tracks, one up the St. Lawrence Valley and one up the East Coast (see Figures 3.8, 3.9, and 3.10). Category 3 (behind cold front) shows a marked southwest-to-northeast gradient (Figure 3.1c) similar to that for Category 2, and likely for the same reason since both categories are directly related to the tracks of cyclone centers.

Category 4 (polar high) has a very interesting annual frequency pattern (Figure 3.1d). There is a marked northwest-to-southeast gradient in the frequency isopleths, reflecting these cold-core system's source region over Arctic and central Canada and their resulting modification by the Atlantic Ocean (e.g., Pettersen, 1956, p. 327). In addition, the local maximum of occurrence of Category 4 in Virginia and Maryland to the east of the Appalachian Mountains again strongly suggests the influence of cold-air damming by the Appalachians during the winter (e.g., Stauffer and Warner, 1987).

The frequency pattern for Category 5 (subtropical high) is basically zonal (Figure 3.1e). There is slightly more than a 10% chance of this synoptic category affecting the southernmost portion of the study area and less than a 1% chance of it reaching to the top of the study area. A panel (Figure 3.1f) has been included for Category 7, the "ambiguous" or "unclassifiable" category. There is a slightly greater likelihood that a synoptic pattern cannot be classified over the southeastern corner of the study area (the Atlantic Ocean), but this category occurs with effectively the same frequency throughout the study area.

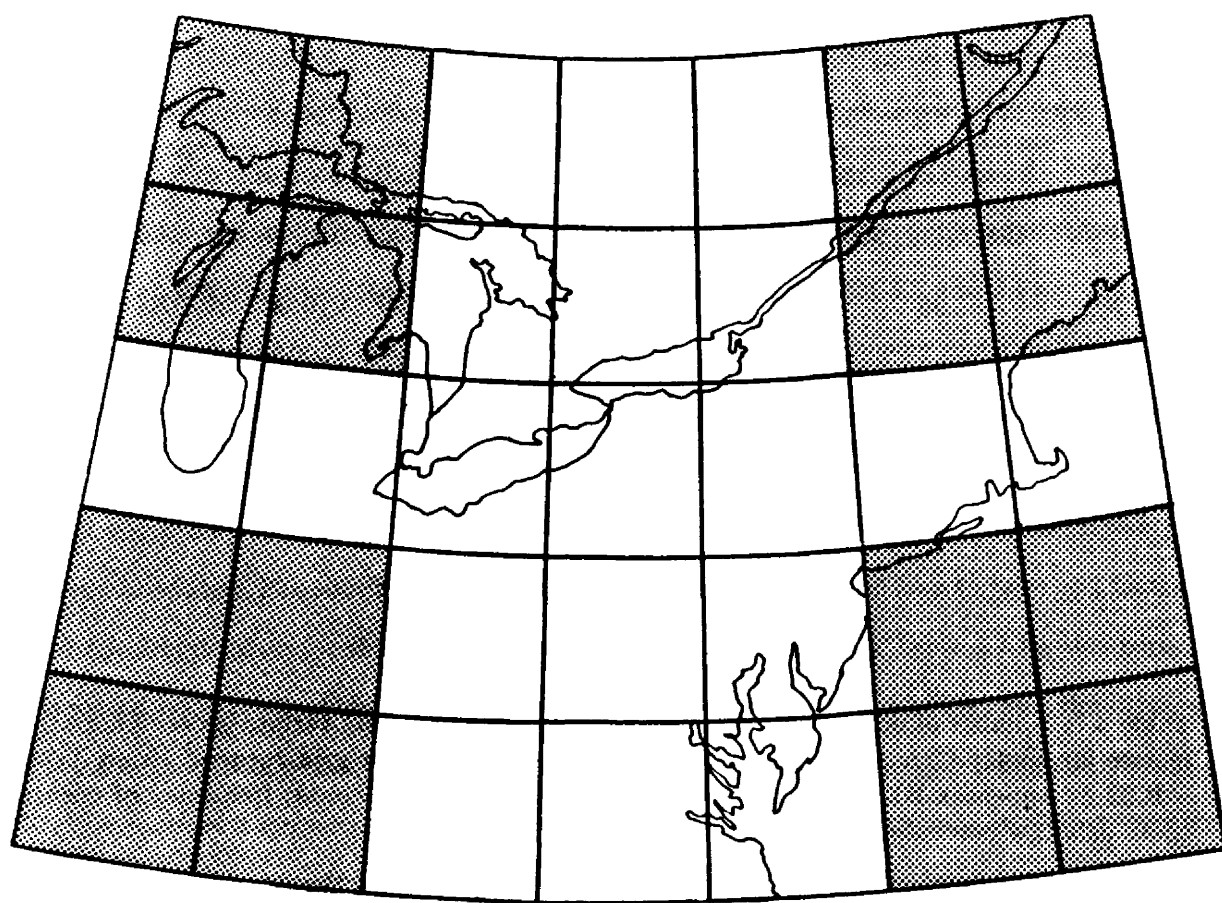
Figure 3.2 also shows some interesting frequency patterns. The moderate surface geostrophic wind-speed class ($4-8 \text{ m s}^{-1}$) basically decreases in frequency with increasing latitude (Figure 3.2b); it has a maximum value over the Virginia coastal plains and a minimum over the upper St. Lawrence Valley. The light and strong surface geostrophic wind-speed classes ($0-3, 9-11 \text{ m s}^{-1}$, respectively) occur so infrequently that it is unsafe to accord any significance to their spatial patterns (Figures

3.2a,c). However, the very strong surface geostrophic wind-speed class ($> 11 \text{ m s}^{-1}$) exhibits a marked north-south gradient (Figure 3.2d) that is approximately the complement of the frequency pattern for the moderate surface geostrophic wind-speed class. There is a frequency minimum over the Virginia coastal plain for very strong surface geostrophic winds and a frequency maximum over the upper St. Lawrence Valley. Very strong surface geostrophic winds are often associated with synoptic Category 3; comparison of Figures 3.1c and 3.2d shows that both of these quantities have maxima over the northeast.

3.1.4 Joint seasonal-spatial variability

In order to assess spatial variations in the seasonally tabulated data, the four 4-box corner regions of the grid (i.e., northeast, northwest, southeast, southwest) were isolated for a separate statistical evaluation. These corners are shown in Figure 3.3. Table 3.6 shows the five-year totals for the synoptic categories in each of these 4-box regions for the winter season. In the northwest corner, synoptic category frequencies are 11%, 14%, 28%, and 41% for the first four categories. For this mid-latitude, continental location, polar anticyclonic conditions are more common, leading to a 3% increase in Category 4 over the winter totals for the entire grid (Table 3.4). Table 3.7 shows the corresponding totals for the surface geostrophic wind-speed classes for the corner regions and winter season. Surface geostrophic wind-speed classes occurred (in order of increasing pressure gradient) 3%, 34%, 4% and 59% of the time for the northwestern corner; the corresponding winter totals for the entire grid are 3%, 37%, 5% and 55% (Table 3.5). Note the increased dominance of the very strong surface geostrophic wind-speed class during the winter months for this region.

The synoptic category frequency distribution for the northeast corner is quite different than that for the northwest corner. As compared to the northwest 4-box corner, there are fewer than half the number of Category 1 grid-box days, fewer Category 4 days, and more Category 3 and Category 2 days. These differences may be attributed to the northeast corner's position along a primary wintertime cyclone track (Figures 3.8–3.10) and hence a greater likelihood of this area



36°N–48.5°N
68°W–89°W

Figure 3.3: Location of the four 4-box corner regions used to stratify the climatological data set spatially.

Table 3.6: Number of occurrences/frequency of occurrence of daily synoptic categories for (Dec. 21 – Mar. 20) for all years for the four grid corners* (from Tables B.59 – B.62 in Appendix B). Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). Double synoptic categories are weighted equally.

Grid Corner	Daily Synoptic Category							Row Total
	1	2	3	4	5	<i>H</i>	<i>U</i>	
NW	198/0.11	250/0.14	513/0.28	746/0.41	0/0.00	0/0.00	96/0.05	1804/1.00
NE	96	330	713	609/0.34	0/0.00	0/0.00	55/0.03	1804/1.00
SE	300/0.17	178/0.10	614/0.34	617/0.34	2/0.00	0/0.00	92/0.05	1804/1.00
SW	324/0.18	276/0.15	409/0.23	729/0.40	0/0.00	0/0.00	65/0.04	1804/1.00

*see Figure 3.3.

Table 3.7: Number of occurrences/frequency of occurrence of daily surface geostrophic wind-speed classes for winter (Dec. 21 – Mar. 20) for all years for the four grid corners* (from Tables B.59 – B.62 in Appendix B). The number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded).

Grid Corner	Daily Surface Geostrophic Wind-Speed Class (m s^{-1})				Row Total
	0-3	4-8	9-11	> 11	
NW	52/0.03	615/0.34	67/0.04	1070/0.59	1804/1.00
NE	40/0.02	501/0.28	76/0.04	1187/0.66	1804/1.00
SE	49/0.03	726/0.40	85/0.05	944/0.52	1804/1.00
SW	72/0.04	757/0.42	111/0.06	864/0.48	1804/1.00

*see Figure 3.3.

being traversed by a cyclone's center. With regard to the surface geostrophic wind speeds, the very strong surface geostrophic wind-speed class ($> 11 \text{ m s}^{-1}$) dominates, occurring 66% of the time. This climatological characteristic can be explained by the high wintertime frequency (40%) over this corner of synoptic Category 3, a synoptic pattern that is typically associated with large pressure gradients and strong winds. Furthermore, the center of the climatological polar vortex is located to the northwest of this region during the winter months (e.g., Lahey *et al.*, 1958). A corresponding reduction is observed in the frequency of the two weakest surface geostrophic wind-speed classes, with a total of 30% compared to about 40% for the entire grid (Tables 3.5 and 3.7).

For the southeast corner, the biggest changes in the synoptic category distribution compared to the wintertime grid mean is the increase (17% vs. 12%) in Category 1, a south-of-the-polar-front category, and the decrease (10% vs. 15%) in Category 2, a north-of-the-polar-front category (Tables 3.4 and 3.6). These changes suggest a tendency for this corner to lie south of the polar front, even in winter. The southeast corner was also the only one of the four to have any Category 5 (subtropical high) days for the winter season. Immediately evident in Table 3.7 for this corner is the decreased occurrence of very strong geostrophic wind-speeds (55% to 52%) and the increased occurrence of moderate winds (37% to 40%) compared to the wintertime grid mean (Table 3.5).

For the southwest corner of the grid, the increase in Category 1 frequency is almost identical to that for the southeast corner (Table 3.6). However, unlike the southeast corner, the Category 2 frequency in the southwest corner is not reduced. The Category 3 reduction is about 8%, when compared to the wintertime grid mean value of 31% (see Table 3.4) and 11% when compared to the southeast corner wintertime value of 34%. These differences suggest that extratropical cyclone centers are more likely to pass directly south of this region. This is consistent with the January mean cyclone tracks shown in Figures 3.8, 3.9, and 3.10. Very strong geostrophic winds were observed only 48% of the time for this area in winter (Table 3.7); this frequency is significantly less than those for both the entire grid and for the southeast corner (55% and 52%, respectively). The moderate surface geostrophic wind frequency, on the other hand, is 42% compared to the wintertime

grid mean of 37%. Apparently, the more organized cyclonic storms tend to occur further to the east or north of this corner during the winter.

Tables 3.8 and 3.9 present corresponding five-year summertime statistics for synoptic category and surface geostrophic wind-speed class for the four corners of the grid. Significant, latitudinal and longitudinal variations are evident in these tables as well.

Synoptic Category 4 is present with a 43% frequency in the northwest corner during summer, compared to values of only 30% for both the entire grid and the northeast corner (Tables 3.4, 3.8). The difference in frequency of Category 5 (subtropical high) in the summer between the two northern and two southern corners is striking (3% and 3% vs. 29% and 22%), reflecting the infrequent incursion of this pattern north of 40°N latitude. Category 2 occurs 11% of the time in the northeast corner during the summer and Category 3 occurs 27% of the time; both values are considerably higher than those for the other corners (Table 3.8). This difference may be attributable to the occasional tendency of the polar front to dip southward along the northern Atlantic coast during the summer.

For the southwest corner, synoptic Categories 2, 3, and 4, all north-of-the-polar-front categories, exhibit significantly reduced frequencies of occurrence (3%, 12%, 25%) compared to the grid mean (7%, 18%, 30%; Table 3.4), while the frequency of the subtropical anticyclone category (Category 5) jumps from 13% for the entire grid to 29% in the southwest corner. Category 4 occurrence in the summer is only 14% for the southeast corner, compared to 25% for the southwest corner and 30% for the entire grid, while Category 1 frequency reaches 33% as opposed to 25% for both the entire grid and the southwest corner. The frequency of occurrence of Category 5 is not quite as high for the southeast corner as for the southwest corner (22% vs. 29%). This is somewhat surprising, considering the proximity of the southeast corner to the climatological high pressure system over Bermuda, but the summertime frequency of Category 5 is still much higher for the two southern corners than for the two northern ones. The tropical storm/hurricane category (Category 6) is most likely to occur in the southeast corner of the grid, although it is still a rare event.

Table 3.8: Number of occurrences/frequency of occurrence of daily synoptic categories for (June 21 – Sept. 20) for all years for the four grid corners* (from Tables B.67 – B.70 in Appendix B). Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). Double synoptic categories are weighted equally.

Grid Corner	Daily Synoptic Category							Row Total
	1	2	3	4	5	<i>H</i>	<i>U</i>	
NW	393/0.21	156/0.08	333/0.18	793	58/0.03	0/0.00	106/0.06	1840/1.00
NE	428/0.23	196	492	559	48/0.03	6/0.00	110/0.06	1840/1.00
SE	610	71/0.04	326/0.18	251/0.14	408	35/0.02	138/0.07	1840/1.00
SW	467/0.25	46/0.03	212/0.12	454/0.25	535	3/0.00	121/0.07	1840/1.00

*see Figure 3.3.

Table 3.9: Number of occurrences/frequency of occurrence of daily surface geostrophic wind-speed classes for (June 21 – Sept. 20) for all years for the four grid corners* (from Tables B.67 – B.70 in Appendix B). The number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded).

Grid Corner	Daily Surface Geostrophic Wind-Speed Class (m s^{-1})				Row Total
	0-3	4-8	9-11	> 11	
NW	156/0.09	1033/0.56	95/0.05	556/0.30	1840/1.00
NE	67/0.04	1022/0.55	120/0.07	631/0.34	1840/1.00
SE	206/0.11	1338/0.73	62/0.03	234/0.13	1840/1.00
SW	326/0.18	1364/0.74	49/0.03	101/0.05	1840/1.00

* see Figure 3.3.

As can be seen by comparing Tables 3.7 and 3.9, very strong pressure gradients and surface geostrophic wind speeds occur much less frequently during the summer season than during the winter season. In the southwest corner of the grid, light to moderate surface geostrophic winds ($0-8 \text{ m s}^{-1}$) dominate, occurring 92% of the time during the summer, and very strong winds are uncommon (5% vs 20% for the entire grid). For the southeast corner, light to moderate surface geostrophic wind speeds also occur more often than for the entire grid (84% vs. 75%) but not as often as for the southwest corner. The frequency of very strong pressure gradients is reduced to about 13% in the southeast corner compared to 20% for the entire grid.

For the northwest corner, light surface geostrophic winds are slightly less common than for the total grid (9% vs. 10%). Moderate surface geostrophic winds are significantly less common (56% vs. 65%) and very strong surface geostrophic winds are much more common (30% vs. 20%) than the summertime total grid frequencies (Table 3.5). These trends are even more pronounced for the northeast corner with light geostrophic winds occurring 4% of the time and very strong surface geostrophic winds 34% of the time in the summer. Thus, Table 3.9 suggests that the pressure gradient frequency distribution differs significantly between the two southern grid corners and the two northern corners.

In summary, the seasonal frequency statistics for the four corner regions of the grid indicate some pronounced spatial variations in the occurrence of the various synoptic categories, largely due to the location of the individual corner with respect to the mean seasonal polar front position. This is particularly true of the southwestern grid corner (northern Tennessee, southern Illinois and Indiana, western Kentucky). The northwestern corner is also influenced by continentality effects, the southeastern corner by the Appalachian barrier and the cyclogenetic region along the Atlantic seaboard, and the northeastern corner by its location astraddle the confluence of two mean storm tracks.

3.1.5 Frequency of double synoptic categories

As discussed in Section 2.2.5, the synoptic pattern over a grid box sometimes had features of more than one synoptic category, as in the case when a surface front crosses the box. In cases where two synoptic categories were identifiable, both were recorded. More confused or complex patterns were assigned the “ambiguous” designation (Category 7 or *U*). Although this practice allowed the analyst more freedom in assigning representative categories, it made the subsequent statistical analysis more difficult in that decisions had to be made as to how to count the double category cases (see Section 2.3.4). It is thus of interest to know how often these double classifications occurred.

Table B.76 of Appendix B lists joint frequency statistics for double categories only. A total of 8,827 grid-box days were included out of the possible 63,910 grid-box days, so that approximately 14% of the grid-box days had double categories analyzed. Broken down by synoptic category, the distribution of double categories was 27%, 19%, 28%, 23%, 4%, 0%, and 0% (i.e., 27% were Category 1, 19% were Category 2, etc.). The overall synoptic category frequency distribution was 19%, 12%, 26%, 34%, 5%, 0%, and 5% (Table 3.1). Thus there are significantly more frontal categories (Categories 1, 2, and 3) and fewer air mass categories (Categories 4 and 5) represented in the double categories than would be expected based on climatology. Accordingly, the 14% figure provides an upper limit to the average frequency with which a frontal boundary crosses one of the 280 km × 250 km study grid boxes.

More detailed frontal climatologies which include the study area are available in two other articles. Reed (1960) calculated the wintertime and summertime frequency of fronts over the Northern Hemisphere based on hemispheric surface map analyses using a much coarser grid for a five-year period (see Figure 3.7). Morgan *et al.* (1975) prepared maps of warm frontal and cold frontal occurrence by climatic month over North America for a ten-year period based on a grid with similar resolution to this study and the *U.S. Daily Weather Map* series.

3.1.6 Comparison with earlier studies

A number of previous synoptic climatological studies have used geographic domains which include or overlap this study's domain, allowing some comparison of results with the important caveat that the time periods are different for the other studies. The study most similar to the present one is that of Barchet and Davis (1984). Barchet and Davis used a modified and more elaborate version of the synoptic classification scheme employed in this study to classify daily surface maps for the continental United States for the 10-year period 1969-1978 as part of a country-wide wind power potential evaluation. They categorized the weather pattern once per day at 120 grid points on a 3° latitude by 4° longitude grid. Their grid was subdivided into six regions, with the northeastern region corresponding most closely to the domain used in the present study (Figure 3.4a). No surface geostrophic wind-speed categorization was performed.

Their synoptic classification scheme contained nine synoptic categories and was based primarily on surface-pressure pattern analysis (Figure 3.4b). Some of these synoptic categories corresponded closely to those used in this study but there were several additional classes: (i) the polar anticyclone was divided into east and west sections; and (ii) occluded fronts and regions of an occluded low and (iii) stationary fronts were treated as separate categories.

These additional synoptic categories certainly do exist at various times but the present study did not require such a detailed classification to develop a climatology of synoptic patterns favorable for terrain-forced mesoscale circulations. We feel that any categorization more detailed than the seven-category scheme used here only increases the subjectivity and diminishes the usefulness of the study.

In cases where a well-defined occluded low was present in this study, Category 3 was usually assigned. When an occluded front had retained its identity, Category 2 was assigned to the north of the front and Category 3 to the south and west. True stationary fronts occur very infrequently. In cases where a stationary front had been analyzed, it was treated in this study as a warm or cold front. For truly stationary fronts with no wind convergence or divergence, Category 7 was assigned.

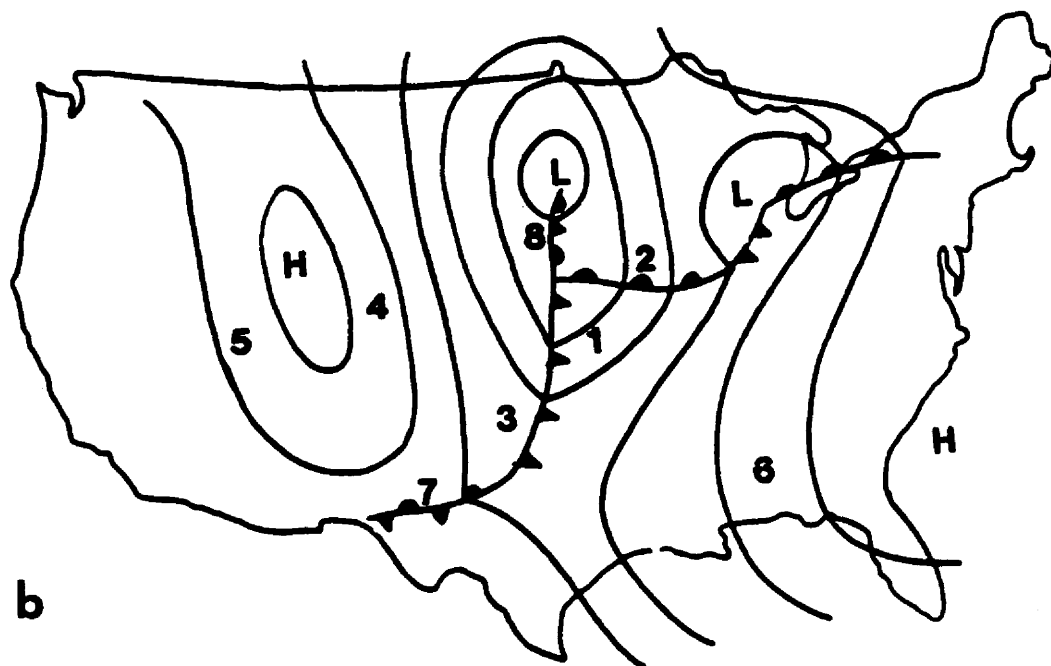
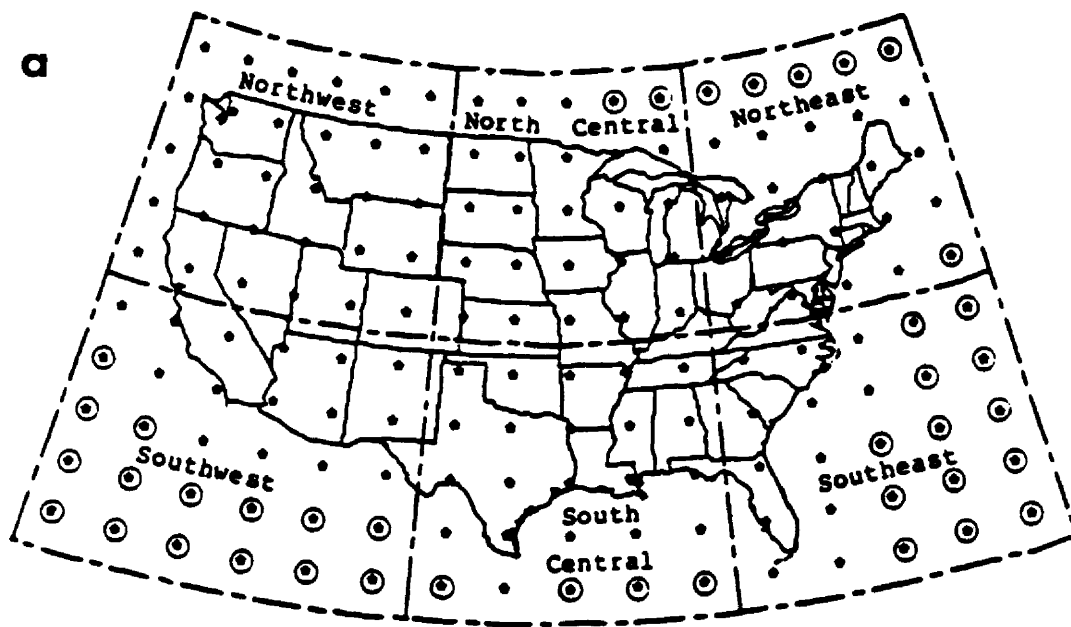


Figure 3.4: Grid and synoptic classification scheme used by Barchet and Davis (1984): (a) 120-point array, 3° latitude spacing, 4° longitude spacing; and (b) sample surface weather pattern classification. Their synoptic categories were the following: (1) warm sector; (2) ahead of a warm front; (3) behind a cold front; (4) east of a continental high; (5) west of a continental high; (6) maritime high; (7) stationary front; (8) occluded front and region west of occluded low; and (9) not determinable.

Table 2 in Barchet and Davis (1984) presents the overall frequency of occurrence of their synoptic category by grid region. Given the difference in the two synoptic classification schemes, it is difficult to make an exact comparison of results. However, an approximate correspondence can be achieved by equating their Category 1 (warm sector) to our Category 1, their Category 2 (ahead of warm front) to our Category 2, their Categories 3 and 8 (behind cold front; occluded front and regions west of occluded low) to our Category 3, their Categories 4 and 5 (east of continental high; west of continental high) to our Category 4, their Category 6 (maritime high) to our Category 5, and their Category 9 (not determinable) to our Category 7. Using this correspondence, the synoptic frequency distribution for their northeast region during the years 1969-1978 in terms of this study's Synoptic Categories 1, 2, 3, 4, 5, and 7 is 5%, 11%, 17%, 43%, 8%, and 9%, respectively, for a total of 93%. The equivalent numbers for this study from Table 3.1 are 19%, 12%, 26%, 34%, 5% and 5% for a total of 101%. Note that the 7% frequency of occurrence for Barchet and Davis's Category 7 (stationary front) has not been included. In our scheme these occurrences could be counted as Categories 1, 2, 3, or 4 depending on the pattern. The most striking difference is for Category 1 (warm sector): 5% vs. 19%. This difference may be partly due to Barchet and Davis's grid *point* classification of synoptic patterns versus the grid *area* classification employed in this study but the size of this difference is still surprising.

It is also possible to compare Barchet and Davis's plots of synoptic category frequency patterns (Figure 3.5) with Figure 3.1 of this report if allowance is again made for the difference in classification schemes. The panels for Category 2 (ahead of warm front; their category 2) and Category 5 (subtropical high; their category 6), categories where there is a one-to-one correspondence between the two studies, agree well and the influence of continentality is evident in their polar high frequency plots (their Categories 4 and 5). Poorer agreement is found for the Category 1 (warm sector) plots.

Another closely related study was carried out by Garstang *et al.* (1980). They used the same basic synoptic classification scheme as used in this study to categorize synoptic patterns at nine

sites along the U.S. Atlantic and Gulf coasts from twice-daily surface weather maps for the ten-year period 1955-1964. Three of their chosen sites, Portland, Maine, JFK International Airport, New York, and Hampton, Virginia, lie within the study grid for this study.

Table 9 in Garstang *et al.* (1980) presents their synoptic-category frequency statistics on an annual and seasonal basis. It is difficult to compare seasonal results because of their definition of seasons by meteorological characteristics rather than the astronomical definition used in this study. However, their annual values can readily be compared with individual grid-box statistics from Table B.23 of Appendix B. Agreement is good despite the difference in time periods considered. For example, Garstang *et al.* (1980) obtained annual frequencies of occurrence for Categories 1 through 5 at Hampton, Virginia of 21%, 6%, 20%, 40%, and 7%. The corresponding values from Table B.23 for the grid box on row 5 and column 5 are 23%, 9%, 21%, 32%, and 10%. Values at JFK are 17%, 9%, 26%, 42% and 3% vs. 18%, 13%, 31%, 30%, and 3% for row 3, column 6. Values at Portland are 13%, 11%, 34%, 39%, and 2% vs. 16%, 14%, 34%, 29%, and 1% for row 2, column 7. The biggest difference seems to be the lower polar high or Category 4 frequencies in the present study compared to Garstang *et al.*'s values.

Quite a number of studies on the climatology of cyclones and anticyclones have also been carried out over larger domains with coarser resolution. Petterssen (1956) studied cyclone and anticyclone frequency of occurrence and genesis over the Northern Hemisphere in summer and winter for the 40-year period 1899-1939. Klein (1957, 1958) extended this work by determining mean cyclone and anticyclone tracks and by considering individual months for the 20 years 1909-1914 and 1924-1937. Hosler and Gamage (1956) studied cyclone frequency over the United States on a 5° mesh for individual months for the 50 years 1905-1954. Reed (1960) took a slightly different tack and tabulated summer and winter frontal frequencies over the Northern Hemisphere for the five-year period 1952-1957. Reitan (1974) considered the frequency of cyclones and cyclogenesis over North America for 5 selected months for the 20-year period 1951-1970. Morgan *et al.* (1975) compiled a climatology of surface fronts (broken down into cold fronts, warm fronts, occluded

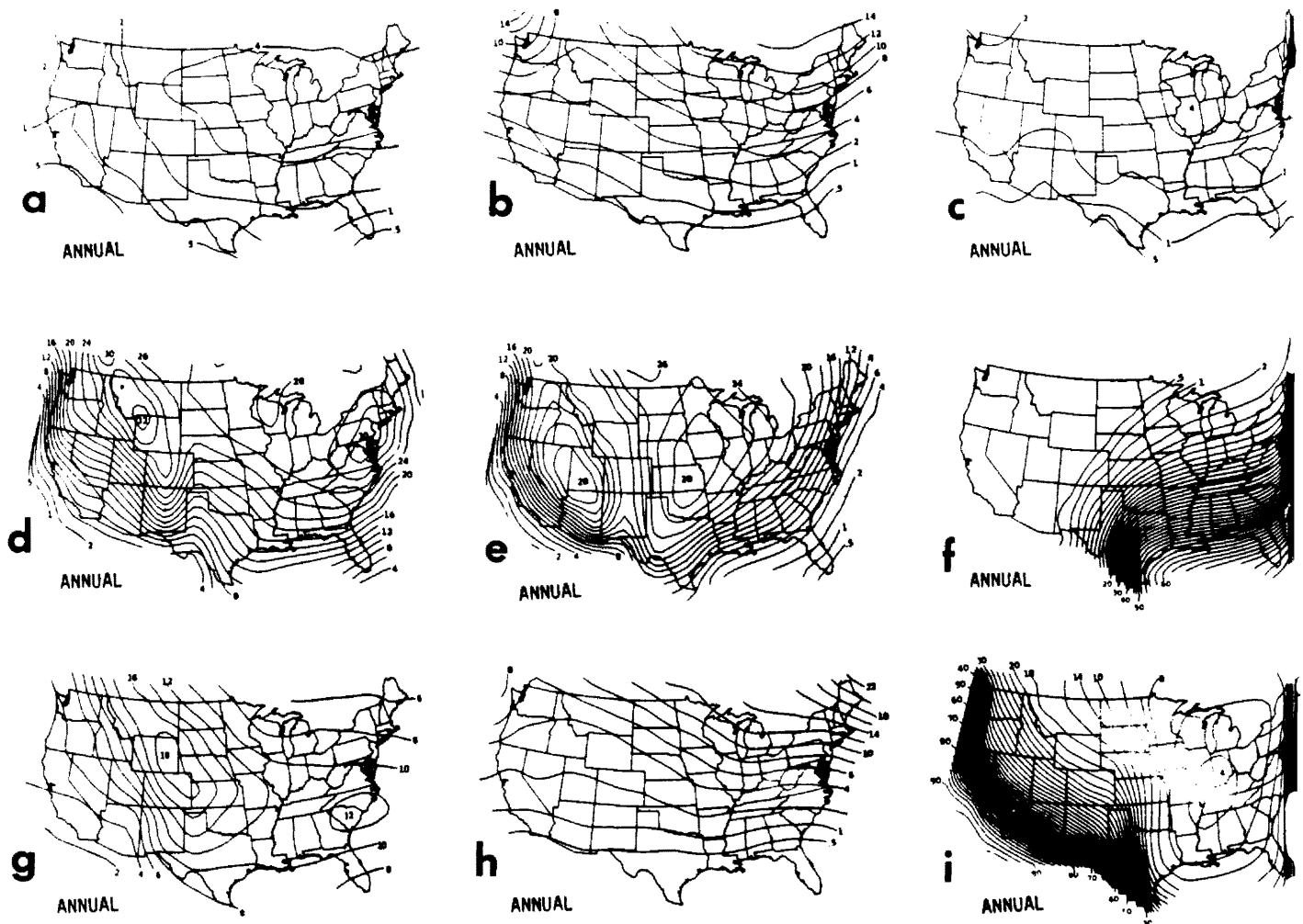


Figure 3.5: Spatial variation of Barchet and Davis's synoptic category frequency distribution for the ten-year period 1969-1978: (a) warm sector; (b) ahead of a warm front; (c) behind a cold front; (d) east of a continental high; (e) west of a continental high; (f) maritime high; (g) stationary front; (h) occluded front and regions west of occluded low; and (i) not determinable (from Figures 3-11; Barchet and Davis, 1984).

fronts, and stationary fronts), squall lines, and high- and low-pressure centers over North America by climatological month on a 60×60 nautical mile grid for the 1961-1970 decade. Colucci (1976) determined wintertime cyclone frequencies and deepening rates for the eastern United States on a 1° mesh for the nine-year period 1964-1973.

Zishka and Smith (1980) prepared a climatology of cyclones and anticyclones over North America, including number of events, genesis, decay, relative variability, and propagation tracks, on a 2° mesh for the months of January and July, 1950-1977. Hayden (1981a) examined cyclone frequency on a 2.5° latitude – 5° longitude mesh over the eastern United States for the 94-year period 1885-1978. Finally, Whittaker and Horn (1981, 1984) considered cyclogenesis over North America and cyclone frequency, cyclogenesis, and primary/secondary tracks within the Northern Hemisphere for four mid-season months for the period 1958-1977 on a 5° latitude – longitude grid. All of these studies have some relevance to the present study because they deal with extratropical cyclones or surface fronts, the basic elements of the synoptic conceptual model employed in this study. Note that the choice of grid in all of these studies will influence the results obtained to some extent (Hayden, 1981b; Taylor, 1986).

Figure 3.6, taken from Hayden (1981a), shows mean annual cyclone frequency and standard deviations of annual cyclone frequency over eastern North America based on nearly a century of data. The influence of the Appalachian Mountains is the striking feature in Figure 3.6a; there is a relative minimum in the frequency of occurrence of cyclones along the axis of the Appalachians (see Figure 2.2), suggesting a tendency for cyclones moving eastward across North America to be directed up the St. Lawrence Valley due to blocking. This is consistent with Figs. 3.1a and 3.1d for the distribution of synoptic Categories 1 and 4. Klein and Winston (1958) also remarked on a relative minimum in 700 mb trough frequency along the Appalachians and east coastal plain, especially in January, February, March, and April.

Figure 3.7, taken from Reed (1960), shows the percentage frequency of fronts for a five-year period in the winter and summer in the Northern Hemisphere. The two panels show the high

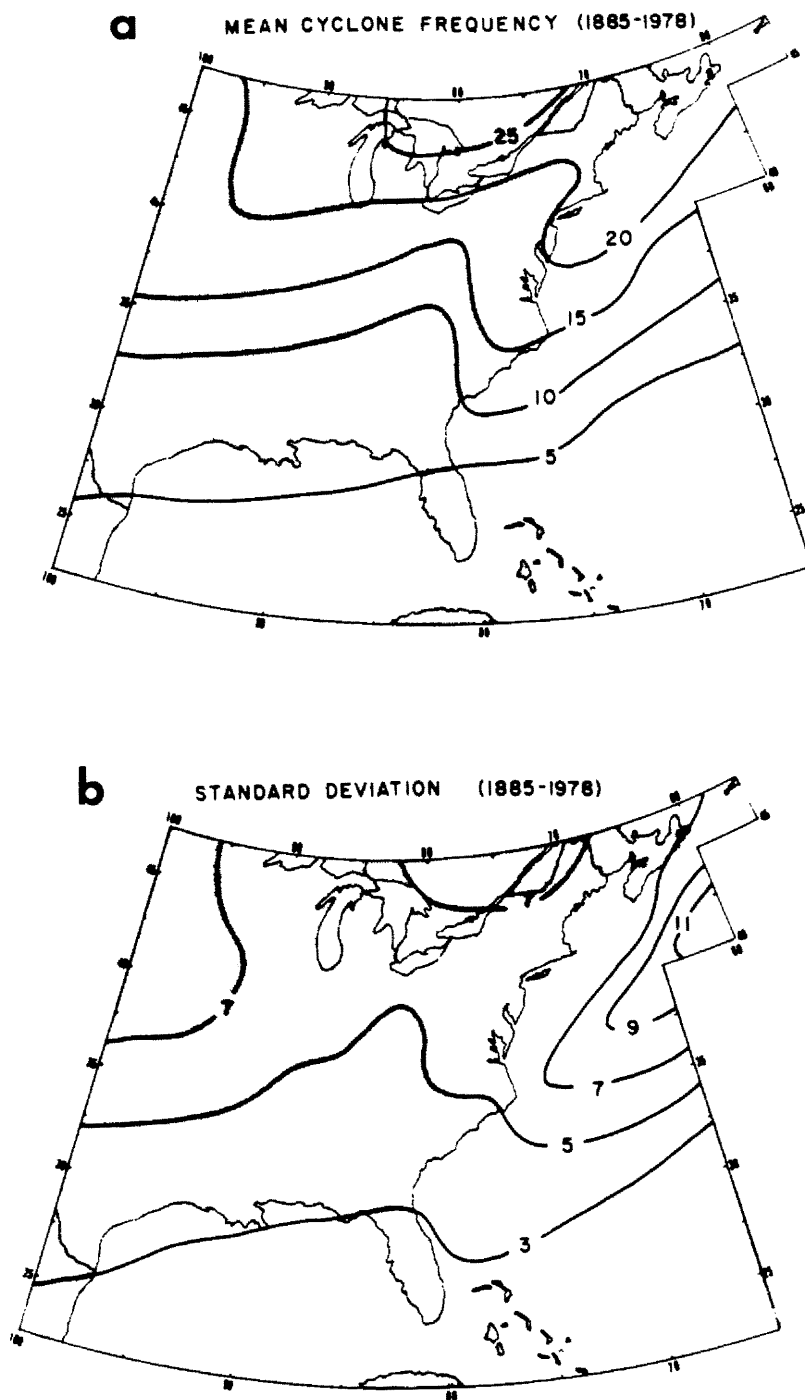


Figure 3.6: (a) Mean annual cyclone frequency for the years 1885-1978; and (b) standard deviations of the annual cyclone frequencies for the same period. Figures are based on annual totals of cyclones passing through seventy-four, 2.5° latitude by 5° longitude grid cells comprising the study area shown in this figure (from Hayden, 1981a).

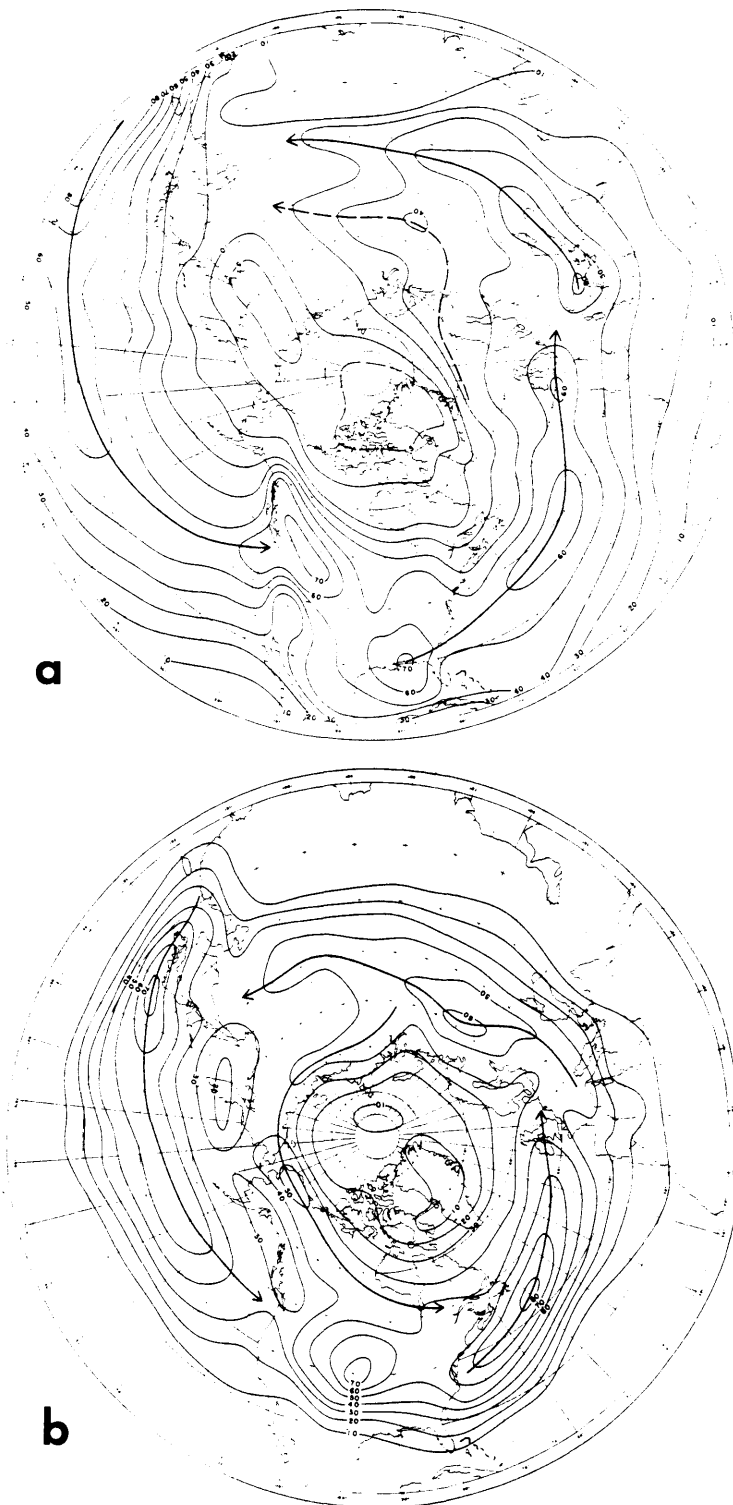


Figure 3.7: Percentage frequency of fronts in squares of $400,000 \text{ km}^2$ (642-km mesh size) in the Northern Hemisphere: (a) December–February, 1952–1957; and (b) June–August, 1952–1956. Heavy lines denote axes of maximum frequency corresponding to principal frontal zones (from Reed, 1960).

frequency of frontal passages across eastern North America and also indicate the seasonal movement of the polar front. This figure is consistent with the strong latitudinal dependence and seasonal dependence of the various behind-front and ahead-of-front synoptic categories discussed in Section 3.1.4.

Figure 3.8, adapted from Reitan (1974), shows principal cyclone paths over North America for four mid-season months for the period 1951-1970. Figure 3.9, adapted from Zishka and Smith (1980), shows relative variability and principal cyclone and anticyclone tracks for January and July, 1950-1977. Figure 3.10, adapted from Whittaker and Horn (1984), shows primary and secondary cyclone paths over the Northern Hemisphere for four mid-season months for the period 1958-1977. All of these figures support the existence of two main cyclone paths through the study area, one across the Great Lakes and up the St. Lawrence Valley and a second up the Atlantic seaboard. This is consistent with the discussion in Sections 3.1.3 and 3.1.4. As an aside, Wallace *et al.* (1988) have also looked at cyclone and anticyclone tracks in a very different way through their studies of baroclinic waveguides. They find that synoptic-scale disturbances with periods ranging from 2.5 days to 6 days propagate along distinct, zonally-oriented wave guides for both positive and negative 1000 mb height anomalies even though corresponding cyclone and anticyclone paths on conventional weather maps are oriented quite differently. They explain this difference on kinematic grounds as a reflection of changes in the climatological mean basic state (see also Lau, 1988, and Hoskins and Valdes, 1990).

3.2 Correlation of Geostrophic Wind-Speed Classes With Synoptic Patterns

The likelihood of the occurrence of a particular surface geostrophic wind-speed class with one of the seven synoptic categories is an important concern of this study. Table 3.10 shows the overall joint frequency distribution of these two variables for the entire study area and full study period. Appendix B contains a number of additional joint frequency tables for different stratifications of the data set (Tables B.2 – B.22, B.55 – B.76). Figure 3.11 presents the frequency distributions from Table 3.10 in graphical form.

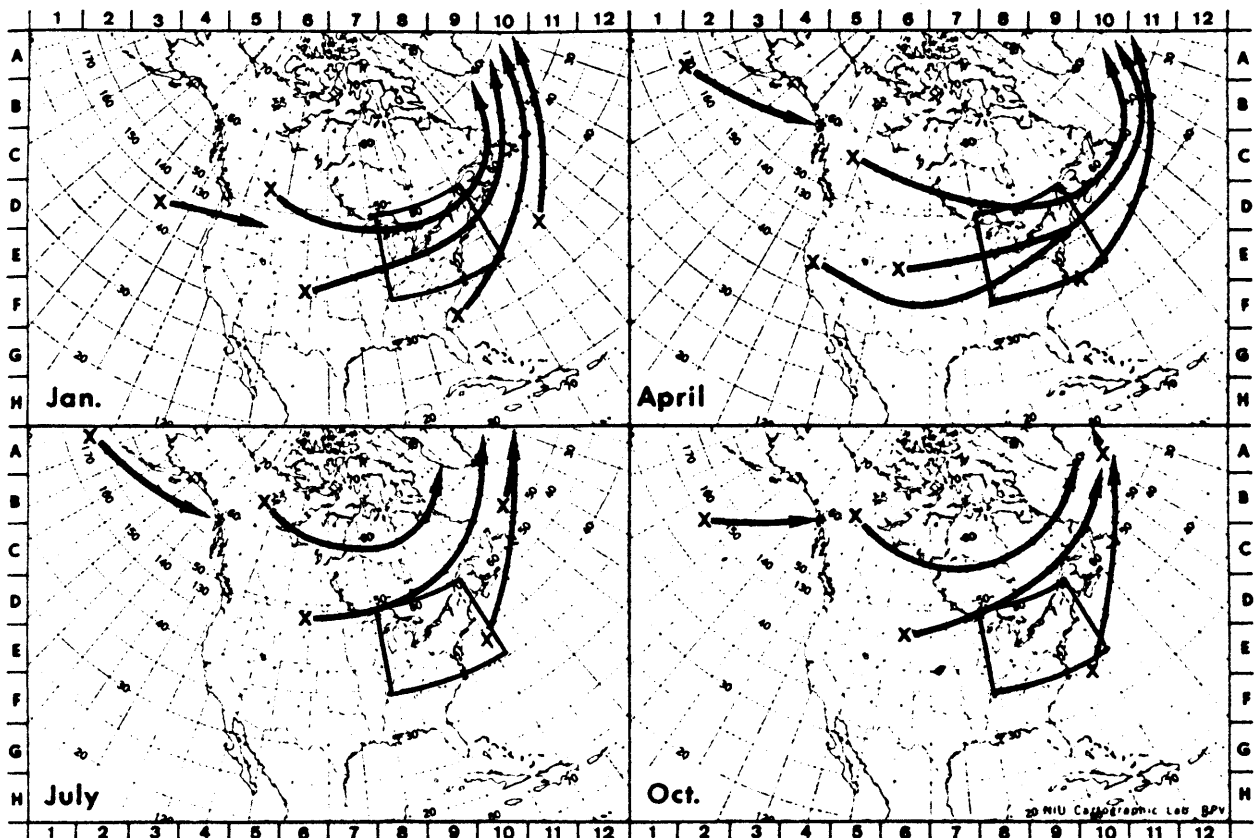


Figure 3.8: Primary cyclone tracks for four mid-season months, 1951-1970. The study area for this report has been marked for ease of reference (adapted from Reitan, 1974).

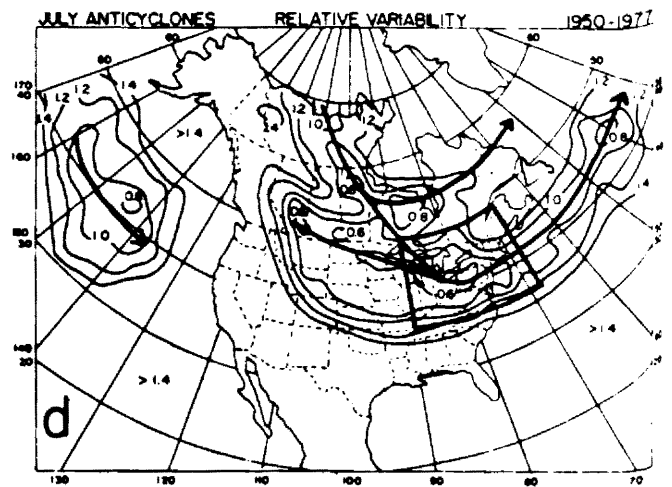
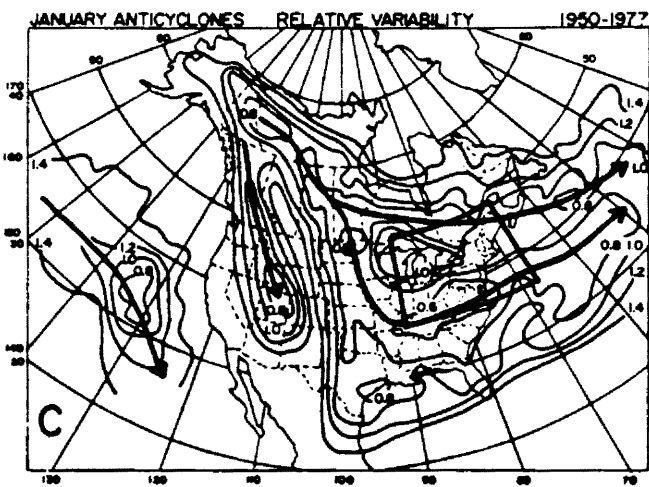
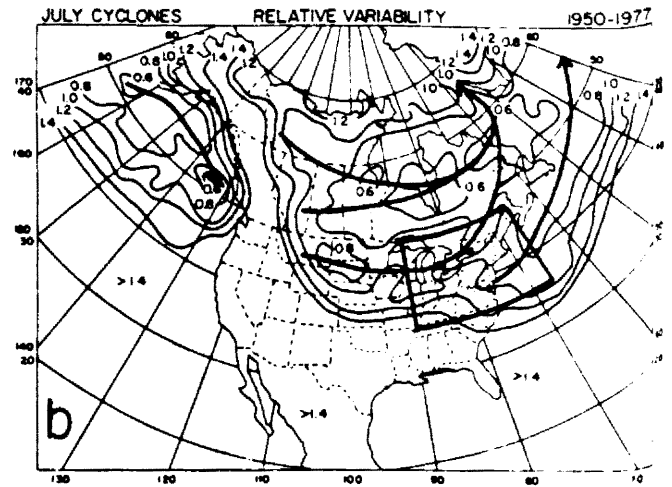
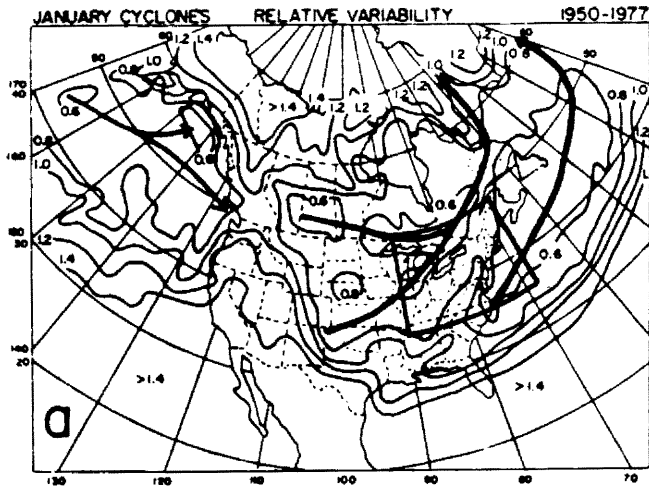


Figure 3.9: Relative variability and preferred cyclone and anticyclone tracks for January and July, 1950-1977: (a) January cyclones; (b) July cyclones; (c) January anticyclones; and (d) July anticyclones. Relative variability is defined here as the mean absolute difference of individual year frequencies from the 20-year mean divided by the mean for each 2° lat-long quadrangle. The study area for this report has been marked for ease of reference (adapted from Zishka and Smith, 1980).

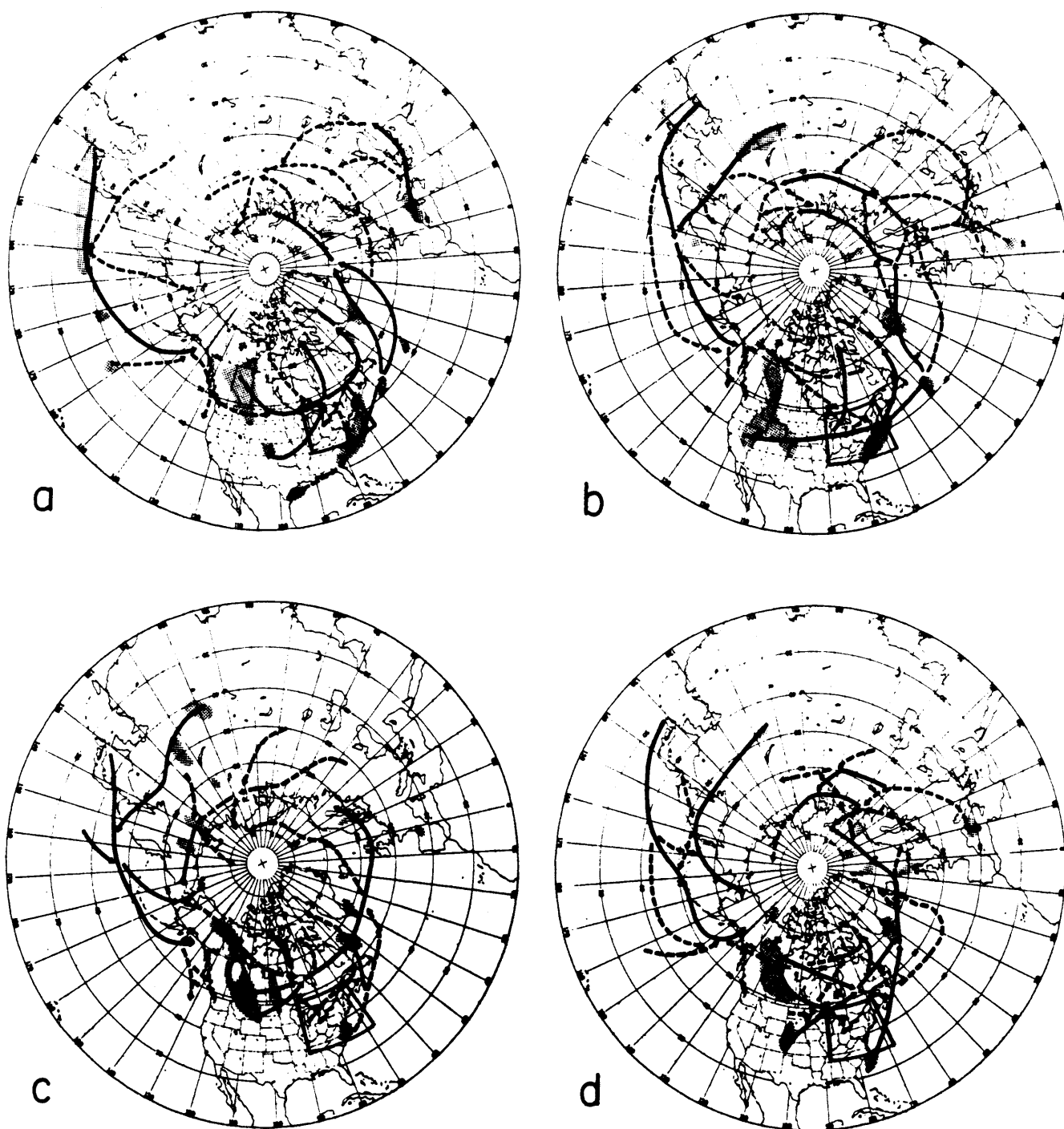


Figure 3.10: Analysis of primary (solid) and secondary (dashed) cyclone tracks and areas of principal cyclogenesis (stippled) over the Northern Hemisphere for the period 1958-1977 for four mid-season months: (a) January; (b) April; (c) July; and (d) October. Primary tracks are positioned along axes of highest cyclone frequency and secondary tracks along axes of lesser maxima; note that the actual width of a track is one 5° latitude $\times$ 5° longitude grid box. The study area for this report has been marked for ease of reference (adapted from Whittaker and Horn, 1984).

Table 3.10: Joint frequency table of synoptic category versus surface geostrophic wind-speed class for entire grid and five-year period 1975-79. The number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). Double synoptic categories are weighted equally (from Table B.1 of Appendix B).

Synoptic Category	Daily Surface Geostrophic Wind-Speed Class (m s^{-1})				Row Total
	0-3	4-8	9-11	> 11	
1	173/0.02	5141/0.43	715/0.06	5885/0.49	11915/1.00
2	82/0.01	2410/0.31	364/0.05	4962/0.63	7819/1.00
3	182/0.01	5503/0.34	853/0.05	9885/0.60	16424/1.00
4	2404/0.11	14244/0.66	1024/0.05	3888/0.18	21561/1.00
5	742/0.24	2271/0.72	42/0.01	91/0.03	3146/1.00
<i>H</i>	0/0.00	10/0.12	3/0.03	76/0.85	90/1.00
<i>U</i>	240/0.08	2081/0.71	101/0.03	532/0.18	2954/1.00
All	3824/0.06	31662/0.49	3104/0.05	25320/0.40	63910/1.00

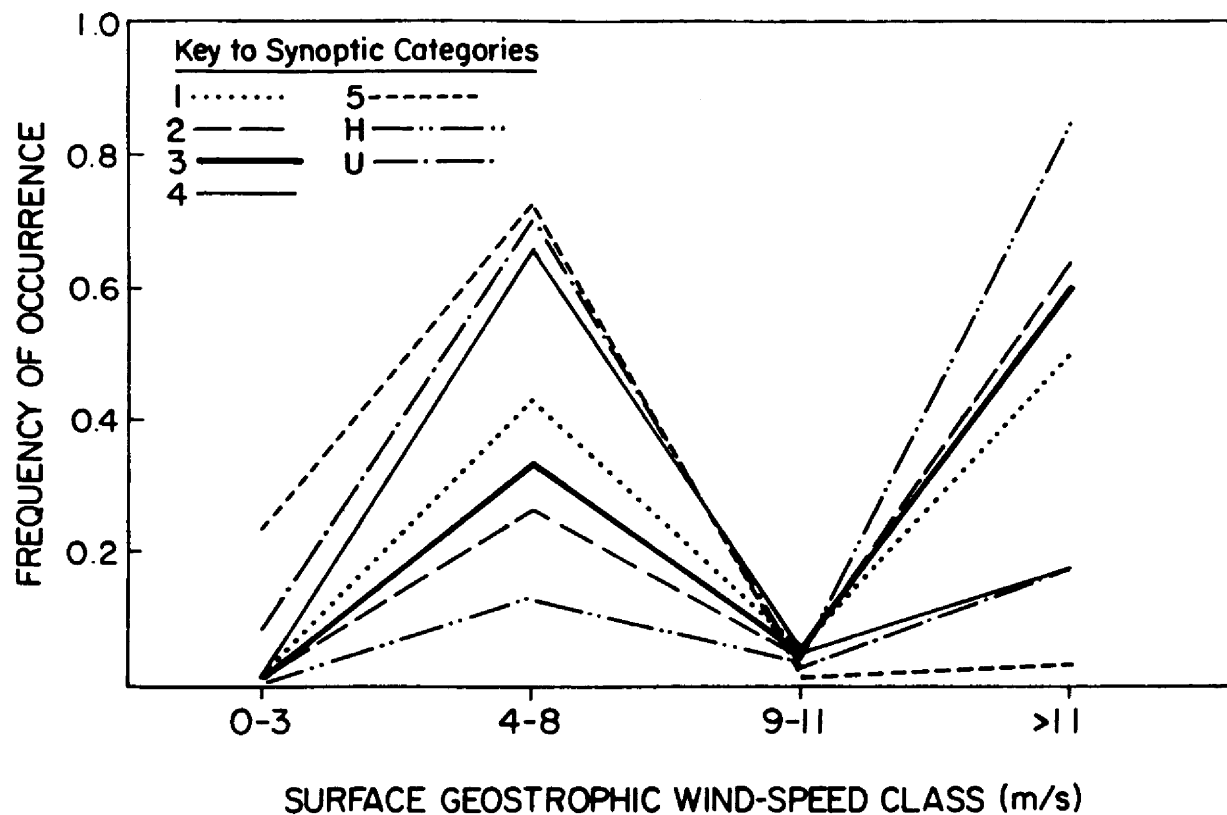


Figure 3.11: Frequency of occurrence of the four surface geostrophic wind-speed classes for each synoptic category for the entire grid and entire study period 1975-1979.

Several tendencies are noteworthy in Figure 3.11. The frequency lines of the four synoptic patterns associated with cyclonic curvature of the isobars, Categories 1, 2, 3, and *H*, are grouped apart from those associated with the two anticyclonic categories, Categories 4 and 5. Such a result agrees with the findings of classical dynamical meteorology in that high-pressure systems exhibit decreasing pressure gradients and hence lighter winds closer to the center of the high (assuming gradient balance; see, for example, Section 3.2 of Holton, 1979). As shown in Figure 3.11, the cyclonic synoptic categories are associated with moderate surface geostrophic wind speeds 12% to 43% of the time and with very strong surface geostrophic winds 49% to 85% of the time, depending on the category. Of these four cyclonic categories, Category 1 is associated with the weakest surface geostrophic wind speeds followed by Category 3 and Category 2. As expected, the tropical storm/hurricane surface geostrophic wind-speeds are the strongest.

For the anticyclonic categories (4 and 5), surface geostrophic wind speeds or pressure gradients are much weaker. For instance, very strong surface geostrophic winds occur together with Category 4 only 18% of the time and with Category 5 only 3% of the time. Overall, the subtropical anticyclone exhibits slightly weaker surface geostrophic wind speeds than the polar high. Moderate surface geostrophic wind-speed frequencies are 66% and 72% for Categories 4 and 5, respectively. Ambiguous conditions (Category 7 or *U*) are also most frequently associated with weaker pressure gradients (e.g., about 71% in the moderate category).

3.3 Climatology of the Polar Front

The conceptual model used for synoptic pattern classification in this study is based on an idealization of mid-latitude meteorology in which transient extratropical cyclones are assumed to form and propagate along a preexisting baroclinic zone called the polar front. The cold-core and warm-core anticyclone categories (Categories 4 and 5) lie to the north and to the south of this polar front, respectively. This study has produced a set of statistics which can be used to delineate the mean position of the polar front throughout the year.

In Table 3.11 the number of occurrences of synoptic categories which lie to the north (Categories 2, 3, and 4) and to the south (Categories 1, 5, and *H*) of the polar front are shown for the four 4-box corners of the grid. (Note that the difference in totals between corners is due to the different number of ambiguous patterns for each). The ratios of total number of occurrences of north- and south-of-the-front categories for these four regions during the summer indicate that the mean summer position of the polar front crosses the middle of the study domain. Averaged over the entire grid, the summer polar front is located south of any particular grid location 57% of the time (Table 3.4). For the southern portion of the study area during the summer (based on the SE and SW corners), however, the mean position of the polar front lies to the north. For example, the polar front is located to the south of the northwest corner of the grid (the western Great Lakes region) 74% of the time, but for the southwestern corner of the grid (the lower Ohio River valley), the polar front lies to the north 59% of the time and to the south only 31% of the time. The statistics also reveal a small longitudinal variation in the mean summer polar front position. The western side of the grid is slightly more likely to be located south of the polar front than the eastern side, though the difference is only 1% to 2% for the eastern and western grid extremes.

During the five winters of this study, the average polar front position was south of an average grid square approximately 87% of the time (see Table 3.4). The longitudinal tendency that was noted for the summer is also present in the winter. The polar front position tends to be located slightly further south in the northeastern corner of the grid than in the northwestern corner. For the northwestern corner, the front is located to the south 95% of the time; the frequency for the northwestern corner is 88%. These conclusions appear consistent with the results of Reed (1960), given the differences in methodology and time period (see Figure 3.7).

The climatology of the polar front was further examined by stratifying the data by month (Tables B.33 – B.44 of Appendix B). Figure 3.12 shows the fraction of time for each month that the grid squares in three grid rows are located north of the polar front (i.e., assigned Categories 2, 3, or 4). The rows considered are numbers 1, 3, and 5, or the northernmost, middle, and

Table 3.11: Number of occurrences of synoptic categories to the north and to the south of the polar front for the grid corner regions* in summer and winter, 1975-79 (from Tables B.59 – B.62 and B.67 – B.70 in Appendix B).

Season	Location Relative to Polar Front	Grid Corner				Row Total
		NW	NE	SE	SW	
Summer	North	1282	1247	648	712	3889
	South	451	482	1053	1005	2991
	All	1733	1729	1701	1717	6880
Winter	North	1509	1652	1409	1414	5984
	South	198	96	302	324	920
	All	1707	1748	1711	1738	6904

*see Figure 3.3

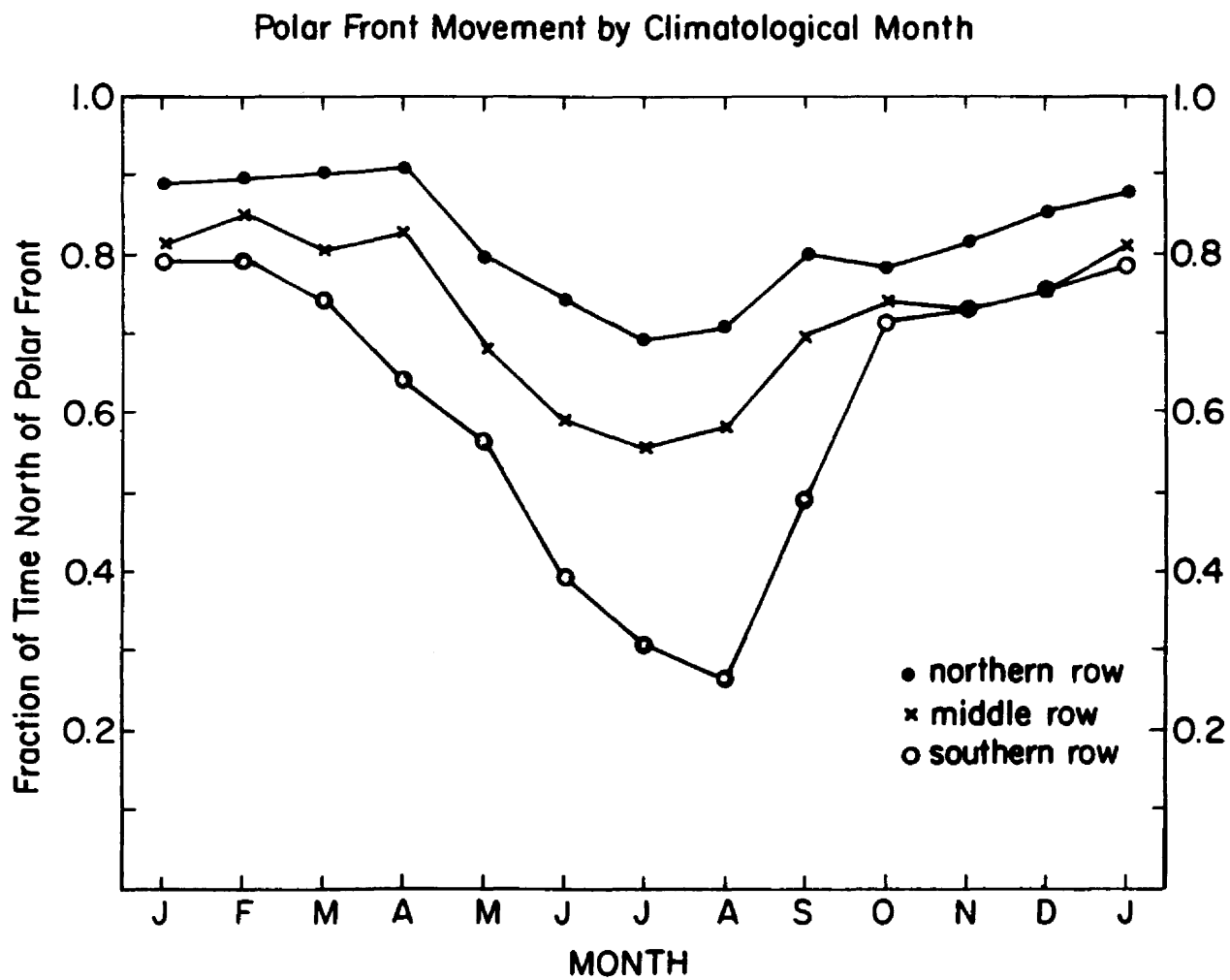


Figure 3.12: Polar front movement by climatological month for three grid rows (based on Tables B.33 - B.44 of Appendix B). The ordinate axis is the fraction of the month that the polar front lies to the south of a grid row (seven boxes). The mean latitudes of the three grid rows are 37.25°N, 42.25°N, and 47.25°N.

southernmost rows, respectively (Figure 2.3). Note the strong north-south deviation during the astronomical summer (June 21 to September 20), which indicates the strong latitudinal dependence of the position of the polar front (up to 44% difference in frequency over 10° of latitude). This dependence is much weaker for the winter (only about 10% difference in frequency over 10° of latitude). Another important aspect of these seasonal dependencies is the marked difference in mean polar front position between astronomical spring and autumn. It is evident from Figure 3.12 that astronomical spring is a time of marked transition, while for astronomical autumn, the main polar front transition has already passed. This finding is consistent with the discussion in Section 3.1.2, which highlighted the contrast in Category 5 frequency between astronomical spring and autumn.

Garstang *et al.* (1980) and Pielke *et al.* (1987) have proposed a meteorological definition of season based on the movement and mean position of the polar front. In their scheme, winter and summer are periods when the mean position of the polar front is stable while spring and autumn are periods of transition between the polar front's mean summer and winter positions. They applied this definition to a synoptic category data set compiled for the U.S. Gulf and Atlantic Coast states for a ten-year period, 1955-1964. Their proposed autumn season (based on the time period when the mean polar front position was moving southward most rapidly) began during late August and September, which is consistent with Figure 3.12. By the middle of October, the polar front has already settled into its southernmost position (i.e., a frequency of the north-of-the-front categories higher than 70% for the entire grid). The beginning and end of winter proposed by Pielke *et al.* (late October – early November, late March – early April) also agrees with the findings of the present study. As shown in Figure 3.12, the polar front position is fairly constant during this time period, lying to the south of row 5 of the grid 70% to 90% of the time. During the month of March, the polar front position begins to move rapidly northward and a late March beginning for spring appears appropriate. The beginning of summer (late May to early June) proposed by Pielke *et al.*

also corresponds well to the establishment of the mean polar front position at its northernmost point found in the present study.

Pielke *et al.* (1987) also reported that for the Gulf and Atlantic Coast states, the meteorological definitions of seasons were comparatively invariant with latitude. As shown in Figure 3.12, this is also true for the northeastern states for the period 1975-1979. The three curves generally exhibit the same month-to-month tendencies throughout the year. One exception is the late September – early October time period, when the polar front appears to continue to move rapidly northward for row 5 but actually moves slightly southward for row 1. Another difference occurs in late March to mid-April, when only the southern row exhibits strong temporal changes. With these exceptions, the trends for the entire year support the meteorological definitions of season mentioned previously.

3.4 Persistence of Synoptic Categories and Geostrophic Wind-Speed Classes

A weather feature is said to be persistent if it is present in one place for a long, unbroken period. This quality has been measured in this study by tabulating the number of unbroken runs of different lengths of a synoptic category or surface geostrophic wind-speed class at a particular grid square. For instance, how many times during the study period did synoptic Category 1 (warm sector) occur exactly three days in a row at a particular grid square before being replaced by another synoptic category? Such multiday runs of a synoptic category or surface geostrophic wind-speed class will be referred to as episodes. In the case of a one-day episode, a particular category or class will only occur on one day at a grid square – the next day a different category or class will have taken its place at that grid square.

Tables 3.12 and 3.13 present the number of episodes and frequency of episodes for the synoptic categories and surface geostrophic wind-speed classes, respectively, for the five years of data and entire grid. The number of multiday episodes for the synoptic categories tails off rapidly with episode length; 64% of the total number of episodes lasted for only one day while the two-day tally is only 22%. The rapid decrease continues for the three-, four- and five-day episodes; their frequencies are 8%, 3% and 1%, respectively. For the surface geostrophic wind-speed classes, the

dropoff is also rapid but not quite so dramatic. The one- through five-day episode frequencies are, 57%, 21%, 10%, 5%, and 3%, respectively. Thus, the wind-speed classes are slightly more persistent than the synoptic categories, but the difference is only a few percentage points and is likely due mostly to the smaller number of wind-speed classes.

The statistics for the individual synoptic categories indicate some interesting trends. For example, Categories 4 and 5 are more persistent than the other five categories. One-day events of these types make up only about 50% of the total occurrences. Overall, 64% of the synoptic pattern episodes are of the one-day variety. The anticyclonic categories are more persistent because the other categories (Categories 1, 2, and 3), all cyclonic patterns, are transient in nature, being associated with a cyclone propagating along the polar front. The subtropical anticyclone (Category 5) dominates the longer episodes. Categories 1 and 3, the pre- and post-cold-frontal patterns, exhibit little difference in their persistence features; they tend to be relatively transient patterns, with only about 13% of the total episodes being longer than two days. Category 2 is slightly more transient than Categories 1 and 3. The overrunning region is usually smaller than the pre-cold-frontal region and less persistent than the frequently widespread post-cold-frontal region associated with an occluding winter cyclone east of the Great Lakes. The tropical storm/hurricane category, Category 6, exhibits nearly the same degree of persistence as Category 2. Interestingly, the ambiguous category, Category 7, is extremely transient, with 93% of its occurrences being one-day events and only about 6% two-day events. Thus, synoptic patterns tend to be ill-defined for a given region for only a day or less before an air mass clearly establishes itself.

The results for individual surface geostrophic wind-speed classes apparently are strongly influenced by the choice of wind-speed intervals for this classification. The moderate and very strong wind-speed classes are much more persistent than the light and strong surface geostrophic wind classes. As shown in Table 3.13, the latter two speed intervals experience one-day episodes about 90% of the time. The dropoff of the distribution is rapid; two-day episodes occur less than 10% of the time and the frequency for three-day events is 1% to 2%. The moderate and very strong

Table 3.12: Number of occurrences/frequency of occurrence of synoptic-pattern multiday episodes by synoptic category and episode length for all grid squares during the five-year period 1975-79. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Table B.77 in Appendix B.

Synoptic Category	Episode Length (days)							Row Total
	1	2	3	4	5	6	>6	
1	5135/0.64	1927/0.24	555/0.07	217/0.03	74/0.01	26/0.00	38/0.00	7972/1.00
2	4465/0.74	1198/0.20	306/0.05	78/0.01	16/0.00	4/0.00	4/0.00	6071/1.00
3	6524/0.66	2053/0.21	804/0.08	334/0.03	110/0.01	71/0.01	61/0.01	9957/1.00
4	5826/0.52	3064/0.27	1266/0.11	548/0.05	229/0.02	157/0.01	135/0.01	11225/1.00
5	554/0.45	250/0.20	201/0.16	85/0.07	43/0.03	26/0.02	81/0.07	1240/1.00
<i>H</i>	47/0.72	12/0.19	5/0.08	1/0.00	0/0.00	0/0.00	0/0.00	65/1.00
<i>U</i>	2528/0.93	176/0.06	16/0.01	5/0.00	0/0.00	0/0.00	0/0.00	2725/1.00
Column Total	25079/0.64	8680/0.22	3153/0.08	1268/0.03	472/0.01	284/0.01	319/0.01	39225/1.00

surface geostrophic wind-speed classes, on the other hand, drop off much more slowly with length of episode, from about 49% for one-day episodes to 23-25% for two-day episodes, 11-12% for three-day episodes, and 6-7% for four-day episodes.

Table 3.14 presents synoptic pattern persistence frequencies for each of the five years (1975-1979) of the study. Although 1975 and 1979 were anomalous with respect to synoptic category frequency distribution (see Section 3.1.1), in terms of episode length distribution the five years are remarkably similar. The same is true of the surface geostrophic wind-speed class persistence frequencies for each of the five years (Table 3.15).

Synoptic pattern persistence statistics for the four corners of the grid (all five years) are shown in Table 3.16. For these all-category values, the southwest corner stands out as having fewer one-day occurrences than the other three corners and the entire grid (60% vs. 65%). Consequently, multiday events are slightly elevated in frequency for the southwest corner. For the surface geostrophic wind-speed classes, the persistence frequencies for each of the four grid corners are presented in Table 3.17. Slightly longer episodes are evident for the southeast corner. Otherwise, the all-class grid corner totals exhibit nearly identical statistics to those for the entire grid (Table 3.13).

It is also useful to present these persistence statistics in a slightly different form, namely weighted by episode length. A reasonable question to ask is, "Given a day on which the pattern is so and so, what is the probability that that day is part of a three-day episode? A five-day episode?" To answer this question, we need to tabulate the number of episode days rather than the number of episodes. For instance, if we count 200 three-day episodes of synoptic Category 1, we then have 600 episode days for that category and episode length (i.e., 3 days/episode $\times$ 200 episodes).

Table 3.18 shows a tabulation of number of episode days by synoptic category and episode length.

It is based on Table 3.12, the corresponding tabulation of number of episodes, but Table 3.18 throws a different light on our conclusions from Table 3.12. For instance, in Table 3.12 we saw that 64% of the synoptic pattern episodes were only one day long. However, the likelihood that the

Table 3.13: Number of occurrences/frequency of occurrence of surface-geostrophic-wind-speed multiday episodes by surface geostrophic wind-speed class and episode length for all grid squares during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Table B.87 in Appendix B.

Surface Geostrophic Wind-Speed Class (m s^{-1})	Episode Length (days)							Row Total
	1	2	3	4	5	6	>6	
0-3	2947/0.89	311/0.09	57/0.02	13/0.00	3/0.00	1/0.00	1/0.00	3333/1.00
4-8	6769/0.49	3163/0.23	1576/0.11	898/0.07	516/0.04	307/0.02	587/0.04	13816/1.00
9-11	2758/0.94	149/0.05	14/0.00	1/0.00	0/0.00	0/0.00	0/0.00	2922/1.00
>11	6057/0.49	3103/0.25	1511/0.12	762/0.06	408/0.03	232/0.02	236/0.02	12309/1.00
Column Total	18531/0.57	6726/0.21	3158/0.10	1674/0.05	927/0.03	540/0.02	824/0.02	32380/1.00

Table 3.14: Number of occurrences/frequency of occurrence of synoptic-pattern multiday episodes by year and episode length for all synoptic categories and grid squares during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Tables B.78 – B.82 in Appendix B.

Year	Episode Length (days)							Row Total
	1	2	3	4	5	6	>6	
1975	4824/0.63	1706/0.22	637/0.08	232/0.03	105/0.01	59/0.01	82/0.01	7645/1.00
1976	5256/0.65	1766/0.22	624/0.08	231/0.03	80/0.01	54/0.01	55/0.01	8066/1.00
1977	5120/0.65	1687/0.21	682/0.09	262/0.03	88/0.01	41/0.01	56/0.01	7936/1.00
1978	5139/0.65	1710/0.22	622/0.08	260/0.03	78/0.01	55/0.01	61/0.01	7925/1.00
1979	4719/0.62	1793/0.24	572/0.08	265/0.03	118/0.02	71/0.01	63/0.01	7601/1.00
1975 - 1979*	-/0.64	-/0.22	-/0.08	-/0.03	-/0.01	-/0.01	-/0.01	-/1.00

*from Table 3.12. Included for purposes of comparison, but this row is not simply the total of the statistics for the five individual years because calculations were done for an unbroken five-year period allowing runs to continue from one year into the next (see Section 2.3.4).

Table 3.15: Number of occurrences/frequency of occurrence of surface-geostrophic-wind-speed multiday episodes by year and episode length for all surface geostrophic wind-speed classes and grid squares during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Tables B.88 – B.92 in Appendix B.

Year	Episode Length (days)							Row Total
	1	2	3	4	5	6	>6	
1975	3807/0.58	1399/0.21	637/0.10	336/0.05	181/0.03	92/0.01	156/0.02	6608/1.00
1976	3683/0.56	1425/0.22	665/0.10	328/0.05	207/0.03	105/0.02	143/0.02	6556/1.00
1977	3681/0.58	1292/0.20	609/0.10	346/0.05	182/0.03	110/0.02	174/0.03	6394/1.00
1978	3566/0.57	1337/0.21	566/0.09	348/0.06	190/0.03	112/0.02	172/0.03	6291/1.00
1979	3790/0.59	1268/0.20	650/0.10	304/0.05	159/0.02	117/0.02	169/0.03	6457/1.00
1975 - 1979*	-/0.57	-/0.21	-/0.10	-/0.05	-/0.03	-/0.02	-/0.02	-/1.00

*from Table 3.13. Included for purposes of comparison but this row is not simply the total of the statistics for the five individual years because calculations were done for an unbroken five-year period allowing runs or episodes to continue from one year into the next (see Section 2.3.4).

Table 3.16: Number of occurrences/frequency of occurrence of synoptic-pattern multiday episodes by grid corner* and episode length for all synoptic categories during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Tables B.83 – B.86 in Appendix B.

Grid Corner	Episode Length (days)							Row Total
	1	2	3	4	5	6	>6	
NW	3019/0.66	928/0.21	307/0.07	163/0.04	44/0.01	33/0.01	34/0.01	4582/1.00
NE	3061/0.66	1014/0.22	346/0.07	135/0.03	56/0.01	28/0.01	19/0.00	4659/1.00
SE	2933/0.65	1006/0.22	314/0.07	146/0.03	59/0.01	17/0.00	52/0.01	4527/1.00
SW	2525/0.60	942/0.23	402/0.10	163/0.04	65/0.02	41/0.01	48/0.01	4186/1.00

*see Figure 3.3

Table 3.17: Number of occurrences/frequency of occurrence of surface-geostrophic-wind-speed multiday episodes by grid corner* and episode length for all surface geostrophic wind-speed classes during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Tables B.93 – B.96 in Appendix B.

Grid Corner	Episode Length (days)							Row Total
	1	2	3	4	5	6	>6	
NW	2223/0.58	818/0.21	389/0.10	182/0.05	100/0.03	62/0.02	76/0.02	3850/1.00
NE	2101/0.57	702/0.19	374/0.10	223/0.06	118/0.03	54/0.01	97/0.03	3669/1.00
SE	1894/0.54	790/0.23	357/0.10	187/0.05	117/0.03	59/0.02	104/0.03	3508/1.00
SW	2042/0.57	758/0.21	332/0.09	202/0.06	100/0.03	61/0.02	108/0.03	3603/1.00

*see Figure 3.3

synoptic pattern over a given grid square lasts only one day is only 39%. Conversely, Table 3.12 indicated that only 3% of all synoptic episodes last five days or more, but Table 3.18 shows that such extended episodes constitute 11% of all days. Table 3.18 also shows how important extended episodes are for the two anticyclonic synoptic categories, Categories 4 and 5. 25% of all Category 4 days and fully 45% of all Category 5 day belong to episodes lasting 4 days or more. In fact, over 20% of all Category 5 days belong to episodes lasting a week or more.

Table 3.19 presents the corresponding tabulation of episode days for surface geostrophic wind-speed class and is based on Table 3.13. Similar conclusions can be drawn – although long-lived episodes are much less common than short episodes, these persistent episodes contribute a significant fraction of episode days. While only 12% of wind-speed-class episodes last 4 days or more, such episodes make up 34% of all wind-speed-class episode days and fully 41% of moderate wind-speed-class ($4-8 \text{ m s}^{-1}$) days.

One other question which might be asked is, “A certain Category 1 episode has already lasted three days – what is the likelihood that it will last two more days? Three more days?” Barchet and

Table 3.18: Number of occurrences/frequency of occurrence of synoptic-category episode days by synoptic category and episode length for all grid squares during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is derived from Table 3.12. The number of episode days is obtained by weighting the number of episodes by episode length.

Synoptic Category	Episode Length (days)							Row Total
	1	2	3	4	5	6	> 6*	
1	5135/0.42	3854/0.31	1665/0.14	868/0.07	370/0.03	156/0.01	304/0.02	12,352/1.00
2	4465/0.54	2396/0.29	918/0.11	312/0.04	80/0.01	24/0.00	32/0.00	8,227/1.00
3	6524/0.41	4106/0.26	2412/0.15	1336/0.08	550/0.04	426/0.03	488/0.03	15,842/1.00
4	5826/0.28	6128/0.29	3799/0.18	2192/0.10	1145/0.05	942/0.05	1080/0.05	21,111/1.00
5	554/0.18	500/0.17	603/0.20	340/0.11	215/0.07	156/0.05	648/0.22	3,016/1.00
<i>H</i>	47/0.52	24/0.27	15/0.17	4/0.04	0/0.00	0/0.00	0/0.00	90/1.00
<i>U</i>	2528/0.86	352/0.12	48/0.02	20/0.01	0/0.00	0/0.00	0/0.00	2,948/1.00
Column Total	25079/0.39	17360/0.27	9460/0.15	5072/0.08	2360/0.04	1704/0.03	2552/0.04	63587/1.00

*assumed to be 8 days in length in this table

Table 3.19: Number of occurrences/frequency of occurrence of wind-speed-class episode days by surface geostrophic wind-speed class and episode length for all grid squares during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is derived from Table 3.13. The number of episode days is obtained by weighting the number of episodes by the episode length.

Surface Geostrophic Wind-Speed Class (m s^{-1})	Episode Length (days)							Row Total
	1	2	3	4	5	6	> 6*	
0 – 3	2947/0.77	622/0.16	171/0.04	52/0.01	15/0.00	6/0.00	8/0.00	3821/1.00
4 – 8	6769/0.22	6326/0.21	4728/0.15	3592/0.12	2580/0.08	1842/0.06	4696/0.15	30533/1.00
9 – 11	2758/0.89	298/0.10	42/0.01	4/0.00	0/0.00	0/0.00	0/0.00	3102/1.00
> 11	6057/0.24	6206/0.25	4533/0.18	3048/0.12	2040/0.08	1392/0.05	1888/0.08	25164/1.00
Column Total	18531/0.30	13452/0.21	9474/0.15	6696/0.11	4635/0.07	3240/0.05	6592/0.11	62620/1.00

*assumed to be 8 days in length in this table

Davis (1984) have presented their persistence statistics in this "run duration exceedance" format. Such conditional probability statistics for episode length can be calculated based on Tables 3.18 and 3.19. For example, the answer to the question just posed is 11% and 5%. To see this, note from Table 3.18 that there were 3,363 grid-box days on which a synoptic Category 1 pattern was identified which belonged to an episode of at least three days duration. Out of these, 3,363 grid-box days, 370 belonged to a five-day episode (i.e., three days plus two more days) and 156 to a six-day episode (three days plus three more days). Some additional persistence statistics for synoptic Category 4 are given in Section 4.2 of this report.

It should also be noted that the method used to tabulate these persistence statistics has produced some apparent discrepancies with respect to the simple frequency statistics discussed in Section 3.1. Comparing Table 3.18 to Table 3.1, we see that there are fewer total episode days reported in Table 3.18 than in Table 3.1 (63,587 vs. 69,910) but that there are more synoptic Category 1 and 2 days in Table 3.18 than in Table 3.1 (12,352 and 8,227 vs. 11,915 and 7,819). There are three reasons for these differences.

First, in calculating runs or episodes, there was an end-point problem; it was impossible to say how many more days episodes in progress on December 31, 1979 would have lasted since no map classifications were produced past this date. Therefore, episodes in progress on December 31, 1979 were not included in the persistence statistics, resulting in a loss of at least 35 episode days (i.e., the number of grid-square days for December 31, 1979 plus episode days belonging to runs which began before this date).

Second, as already discussed in Section 2.3.4, the presence of double-category synoptic grid-square days in the gridded climatological data set required special handling. Double-category values were considered in calculating episode lengths, but when a new episode started at a grid square on a double-category day, only the first of the two categories was considered. This is the reason for the increase in Table 3.18 of the number of occurrences of synoptic Category 1 and

Category 2 days. Note that this problem was not a concern in preparing Table 3.19 since there were no double-category assignments made for surface geostrophic wind-speed class.

Finally, the last episode length category, “> 6”, is of indefinite length since runs falling into this category could have lasted 7 days, 8 days, 9 days, or even longer. An arbitrary decision was made to assume the expected number of days for this category to be 8 in preparing Tables 3.12 – 3.19. This uncertainty also contributed to differences between the frequency statistics and persistence statistics. Nevertheless, the persistence statistics appear to be robust enough that these three problems are unlikely to have had a significant impact on the results obtained. For instance, in Table 3.14, the end-point problem would have affected each of the five years differently but the number of episode distributions obtained were, nevertheless, remarkably similar.

3.5 Transition Probabilities For Synoptic Categories and Geostrophic Wind-Speed Classes

Transition probability tables have also been prepared. These give the frequency with which a particular synoptic category or surface geostrophic wind-speed class changes to another category or class, including itself, (i) at a particular grid square on consecutive days (time transition probabilities), or (ii) between neighboring grid squares on the same day (space transition probabilities). Multiday lags, for which the gap between two sets of gridded synoptic categories was greater than one day, and multi-square lags, for which the gap between grid boxes was larger than one box, were also considered in preparing transition probability tables. The mechanics of preparing these tables have already been presented in Section 2.3.3. The resulting transition probability statistics are presented in this section.

3.5.1 One-day lag

Table 3.20 presents the synoptic-category time transition statistics for the entire grid and full study period for a one-day lag. The values shown in this table reflect the frequent progression of extratropical cyclones across eastern North America throughout the year. For example, a synoptic

Table 3.20: Number of occurrences/frequency of occurrence of synoptic-category time transitions for a one-day lag and all grid squares during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Table B.97 in Appendix B.

Old Synoptic Category	New Synoptic Category					<i>H</i>	<i>U</i>	Row Total
	1	2	3	4	5			
1	3789/0.30	739/0.06	4141/0.33	3043/0.24	426/0.03	13/0.00	567/0.05	12719/1.00
2	1193/0.13	2048/0.23	3856/0.43	1299/0.15	35/0.00	7/0.00	502/0.06	8941/1.00
3	1207/0.08	1267/0.08	5423/0.34	7349/0.46	168/0.01	6/0.00	604/0.04	16026/1.00
4	4290/0.21	3277/0.16	2007/0.10	8961/0.45	545/0.03	3/0.00	943/0.05	20026/1.00
5	819/0.26	46/0.02	161/0.05	143/0.05	1815/0.58	30/0.01	107/0.03	3123/1.00
<i>H</i>	12/0.13	0/0.00	15/0.17	5/0.06	32/0.35	24/0.26	2/0.02	91/1.00
<i>U</i>	590/0.20	438/0.15	815/0.28	752/0.26	123/0.04	6/0.00	224/0.08	2949/1.00
Column Total	11902/0.19	7816/0.12	16419/0.26	21553/0.34	3146/0.05	90/0.00	2949/0.05	63875/1.00

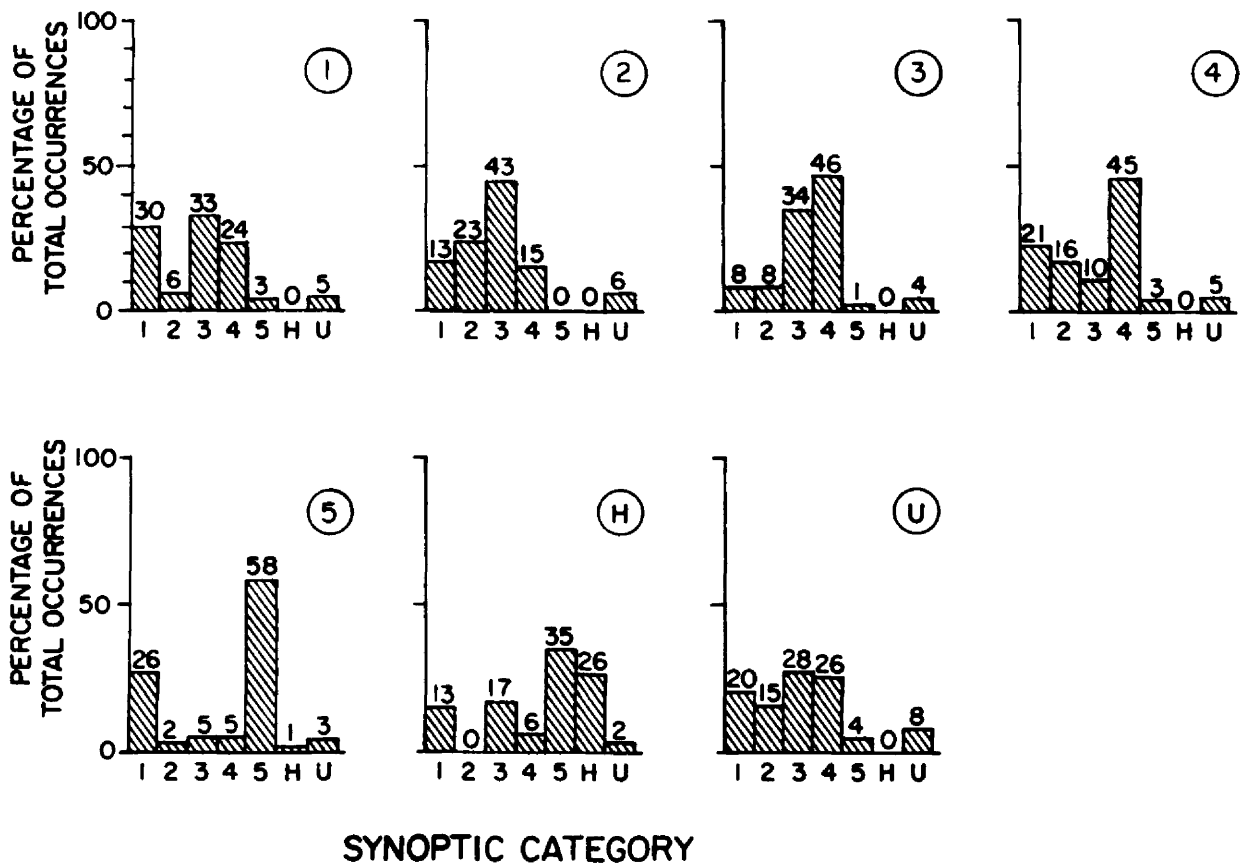


Figure 3.13: One-day-lag transition frequencies for the seven synoptic categories (based on Table 3.20): (1) warm sector; (2) overrunning sector; (3) post-cold-front; (4) polar high; (5) subtropical high; (*H*) tropical storm/hurricane; and (*U*) ambiguous. The abscissas give the new synoptic categories, the ordinates the frequency of transition.

Category 1 pattern (warm sector) on one day is most frequently followed one day later by synoptic Categories 3, 1, and 4 in decreasing order of likelihood (33%, 30%, and 24%, respectively). For a given location, the progression from pre-cold-frontal to post-cold-frontal conditions is the most common. Quite frequently, however, a cold front is moving so swiftly that Category 4 dominates as early as 24 hours after the cold frontal passage, producing the relatively high likelihood of transition from Category 1 to Category 4. The frequent transition of Category 3 to Category 4 (46%) also supports this cyclone progression explanation.

For the pre-warm-frontal or overrunning category (Category 2), the transition probabilities are clearly dominated by Category 3 (43%). Category 2 is usually a transient situation and indicates the passage of an extratropical cyclone to the south without the appearance of Category 1 unless the warm front moves northward. The latter situation is not common; the transition from Category 2 to Category 1 only occurs in 13% of the overrunning cases. As mentioned in Section 3.4, Category 2 is the least persistent synoptic pattern with the exception of the ambiguous category (Category 7). This finding is supported by Table 3.20; look along the upper-left to lower-right diagonal of the table to see how often each synoptic category succeeds itself. The passage of extratropical cyclones is also evident in the polar anticyclone (Category 4) transition statistics. The transition of Category 4 to either Categories 1 or 2 constitutes about 37% of the total Category 4 cases, or nearly 70% of the cases in which this category changes to a different pattern (45% of the time a Category 4 pattern does not change from one day to the next).

It is also apparent that an upper-air trough frequently breaks down the subtropical anticyclone from the west; the frequency of occurrence for the transition of Category 5 to Category 1 is 26%. Category 5 persists for at least two days more than 58% of the time. For the tropical storm/hurricane category, subtropical anticyclone conditions are the most frequent "successor" pattern at 35%, as expected. The significant 17% likelihood of Category 3 following a hurricane by the next day may seem surprising, but at these latitudes most hurricanes that do occur are taking on midlatitude characteristics as they proceed north. Thus, the conditions after the tropical (or

subtropical) storm passage may resemble post-cold-frontal conditions within one day. As far as the current classification scheme is concerned, however, the tropical storm must still be treated as a Category 6 pattern until it becomes predominantly cold-core. The exact time and location of this structural transition is a source of subjectivity in this study.

Transition statistics for the ambiguous category (Category 7 or *U*) are quite similar to the overall statistics for the other synoptic categories, indicating that this category is not strongly associated with any of the primary synoptic categories. The one exception is that the ambiguous category is less likely to change to a Category 4 than simple chance would dictate (i.e., 26% vs. 34%), indicating that the synoptic conditions preceding Category 4 were well defined more often than those preceding the other synoptic categories.

Figure 3.13 shows the time transition percent frequencies from Table 3.20 graphically. It is evident from this figure that the most persistent category is the subtropical anticyclone (Category 5), with an average of 58% of the occurrences being of two or more days in length. The next most persistent category is the polar anticyclone (45%). The two anticyclonic categories were the only ones which were more likely to succeed themselves than to change to one of the other categories. However, there was a degree of persistence to all categories except the ambiguous category, which followed itself over one day only 8% of the time. In contrast, Category 3 followed itself 34% of the time. Normally, Category 3 is transient in nature as a cold front moves away from a region; however, with occluding storms being fairly common in the northeastern U.S. during the winter, spring and fall, post-cold-frontal conditions are apparently persistent to some degree, as the extratropical cyclones frequently slow down as they propagate northeastward into the Canadian Maritimes.

Table 3.21 gives the corresponding surface-geostrophic-wind-speed-class time transition statistics for the entire grid and full study period for a one-day lag. Evidence of persistence is apparent in the diagonal entries because each surface-geostrophic-wind-speed class is more likely to follow itself on the next day than the climatological frequencies would suggest (cf. *Column Total* percentages). As well, there is a suggestion in this table that the transition from one surface geostrophic wind-

speed class to another tends to be to an adjacent class. The light surface geostrophic wind-speed class remains the same or changes to the moderate wind-speed class over one day more often than expected from climatology statistics would suggest (Table 3.2); the very strong surface geostrophic wind-speed class also remains the same or changes to the strong class more often than expected from climatology.

Table 3.21: Number of occurrences/frequency of occurrence of surface-geostrophic-wind-speed class time transitions for a one-day lag and all grid squares during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Table B.105 in Appendix B.

Old Surface Geostrophic Wind-Speed Class (m s^{-1})	New Surface Geostrophic Wind-Speed Class (m s^{-1})				Row Total
	0-3	4-8	9-11	> 11	
0-3	487/0.13	2193/0.57	150/0.04	990/0.26	3820/1.00
4-8	2275/0.07	17820/0.56	1472/0.05	10069/0.32	31636/1.00
9-11	184/0.06	1505/0.48	180/0.06	1233/0.40	3102/1.00
>11	874/0.03	10135/0.40	1300/0.05	13008/0.51	25317/1.00
Column Total	3820/0.06	31653/0.50	3102/0.05	25300/0.40	63875/1.00

3.5.2 Multiday lags

Synoptic-category time transition statistics were also computed for two- to eight-day lags (a two-day lag, for example, refers to the occurrence of a particular synoptic category followed two days later by another category). The tabulations for these multiday lags are shown in Tables B.97 to B.104 in Appendix B. Tables 3.22 to 3.26 were then constructed for the five primary synoptic categories to examine how quickly the conditional frequency distribution approaches the climatological synoptic category frequency distribution (Table 3.1) with increasing lag time. (The time transition statistics give conditional frequency distributions in the sense that, given a particular synoptic category at a grid square, they describe the probability of any of the synoptic categories being found at that same square after a lag of one day, two days, three days, etc.) *A priori* we would expect the conditional frequency distributions for all synoptic categories to approach the climatological synoptic category frequency distribution as the lag time increases. The extent of the difference between the conditional and climatological frequency distributions is then a measure of the “memory” of the atmosphere on the synoptic scale.

To make this concept clearer, consider Table 3.22. The probability of finding a Category 1 pattern over a grid square one day after it was first identified (i.e., a lag of one day) is 30%. This decreases to 21% for a lag of two days. All five primary synoptic categories display this decrease between lags of one and two days. For longer lags, however, an interesting difference is evident in Tables 3.22 – 3.26 between the first four synoptic categories and Category 5, the subtropical high pattern. The first four categories exhibit a maximum in their probability of “repeating” themselves for a lag of one day, a minimum for a lag of two days, and then a slight increase for longer lags. The chance of Category 5 repeating, on the other hand, decreases monotonically with increasing lag length.

This behavior is consistent with our conceptual synoptic model. The first four synoptic categories are associated with transient extratropical cyclones. Such systems tend to cross a fixed site every three to seven days (e.g., Hartmann, 1974; Wallace *et al.*, 1988). A particular synoptic

Table 3.22: Number of occurrences/frequency of occurrence of synoptic Category 1 (warm sector) time transitions for lags of one to eight days over all grid squares during the five-year period 1975-1979. The number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Tables B.97 - B.104 of Appendix B. Note that the last row (Climatology) is taken from Table 3.1 and is reproduced here for ease of comparison.

Lag Length (days)	New Synoptic Category							Row Total
	1	2	3	4	5	H	U	
1	3789/0.30	739/0.06	4141/0.33	3043/0.24	426/0.03	13/0.00	567/0.05	12719/1.00
2	2681/0.21	1182/0.09	3221/0.25	4456/0.35	595/0.05	24/0.00	558/0.04	12719/1.00
3	2859/0.22	1285/0.10	2886/0.23	4339/0.34	742/0.06	33/0.00	573/0.05	12719/1.00
4	3003/0.24	1310/0.10	3070/0.24	3963/0.31	768/0.06	28/0.00	576/0.05	12719/1.00
5	2931/0.23	1335/0.10	2988/0.23	4063/0.32	758/0.06	28/0.00	615/0.05	12719/1.00
6	2990/0.24	1291/0.10	2943/0.23	4111/0.32	794/0.06	30/0.00	558/0.04	12719/1.00
7	2843/0.22	1239/0.10	3041/0.24	4093/0.32	869/0.07	30/0.00	599/0.05	12715/1.00
8	2729/0.21	1290/0.10	3030/0.24	4097/0.32	944/0.07	29/0.00	585/0.05	12707/1.00
Climatological Frequencies*	-/0.19	-/0.12	-/0.26	-/0.34	-/0.05	-/0.00	-/0.05	-/1.00

* from Table 3.1

Table 3.23: Number of occurrences/frequency of occurrence of synoptic Category 2 (pre-warm-frontal) time transitions for lags of one to eight days over all grid squares during the five-year period 1975-1979. The number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Tables B.97 – B.104 of Appendix B. The last row is taken from Table 3.1 and is reproduced here for ease of comparison.

Lag Length (days)	New Synoptic Category							Row Total
	1	2	3	4	5	H	U	
1	1193/0.13	2048/0.23	3856/0.43	1299/0.15	35/0.00	7/0.00	502/0.06	8941/1.00
2	1070/0.12	1340/0.15	3292/0.37	2741/0.30	74/0.01	14/0.00	408/0.05	8941/1.00
3	1175/0.13	1297/0.15	2798/0.31	3139/0.35	140/0.02	13/0.00	377/0.04	8941/1.00
4	1351/0.15	1388/0.16	2490/0.28	3150/0.35	181/0.02	5/0.00	374/0.04	8941/1.00
5	1372/0.15	1474/0.16	2557/0.29	2930/0.33	203/0.02	0/0.00	404/0.05	8941/1.00
6	1391/0.16	1433/0.16	2508/0.28	2984/0.33	222/0.02	3/0.00	399/0.04	8941/1.00
7	1343/0.15	1404/0.16	2541/0.28	3015/0.34	220/0.02	4/0.00	406/0.05	8934/1.00
8	1475/0.17	1303/0.15	2593/0.29	2903/0.33	230/0.03	3/0.00	412/0.05	8920/1.00
Climatological Frequencies*	-/0.19	-/0.12	-/0.26	-/0.34	-/0.05	-/0.00	-/0.05	-/1.00

* from Table 3.1

Table 3.24: Number of occurrences/frequency of occurrence of synoptic Category 3 (post-cold-frontal) time transitions for lags of one to eight days over all grid squares during the five-year period 1975-1979. The number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Tables B.97 – B.104 of Appendix B. The last row is taken from Table 3.1 and is reproduced here for ease of comparison.

Lag Length (days)	New Synoptic Category						<i>H</i>	<i>U</i>	Row Total
	1	2	3	4	5				
1	1207/0.08	1267/0.08	5423/0.34	7349/0.46	168/0.01	6/0.00	604/0.04	16026/1.00	
2	2395/0.15	2020/0.13	4360/0.27	6172/0.39	295/0.02	6/0.00	758/0.05	16008/1.00	
3	2744/0.17	2251/0.14	4404/0.28	5508/0.34	361/0.02	2/0.00	717/0.04	15987/1.00	
4	2656/0.17	2220/0.14	4643/0.29	5377/0.34	353/0.02	7/0.00	709/0.04	15966/1.00	
5	2733/0.17	2051/0.13	4623/0.29	5427/0.34	358/0.02	7/0.00	747/0.05	15948/1.00	
6	2690/0.17	2069/0.13	4678/0.29	5354/0.34	379/0.02	13/0.00	739/0.05	15923/1.00	
7	2802/0.18	2037/0.13	4635/0.29	5245/0.33	455/0.03	9/0.00	715/0.04	15900/1.00	
8	2782/0.18	2010/0.13	4489/0.28	5487/0.35	444/0.03	5/0.00	676/0.04	15896/1.00	
Climatological Frequencies*	-/0.19	-/0.12	-/0.26	-/0.34	-/0.05	-/0.00	-/0.05	-/1.00	

* from Table 3.1

Table 3.25: Number of occurrences/frequency of occurrence of synoptic Category 4 (polar high) time transitions for lags of one to eight days over all grid squares during the five-year period 1975-1979. The number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Tables B.97 – B.104 of Appendix B. The last row is taken from Table 3.1 and is reproduced here for ease of comparison.

Lag Length (days)	New Synoptic Category						<i>H</i>	<i>U</i>	Row Total
	1	2	3	4	5				
1	4290/0.21	3277/0.16	2007/0.10	8961/0.45	545/0.03		3/0.00	943/0.05	20026/1.00
2	4329/0.22	2806/0.14	4384/0.22	6889/0.34	675/0.03		9/0.00	920/0.05	20012/1.00
3	3770/0.19	2489/0.12	5089/0.25	7037/0.35	633/0.03		5/0.00	973/0.05	19998/1.00
4	3555/0.18	2445/0.12	4964/0.25	7394/0.37	628/0.03		16/0.00	980/0.05	19984/1.00
5	3589/0.18	2472/0.12	5007/0.25	7302/0.37	685/0.03		31/0.00	879/0.04	19967/1.00
6	3431/0.17	2482/0.12	5062/0.25	7270/0.36	759/0.04		19/0.00	935/0.05	19959/1.00
7	3497/0.18	2550/0.13	4907/0.25	7368/0.37	707/0.04		10/0.00	919/0.05	19959/1.00
8	3423/0.17	2652/0.13	5020/0.25	7170/0.40	703/0.04		12/0.00	973/0.05	19954/1.00
Climatological Frequencies*	-/0.19	-/0.12	-/0.26	-/0.34	-/0.05		-/0.00	-/0.05	-/1.00

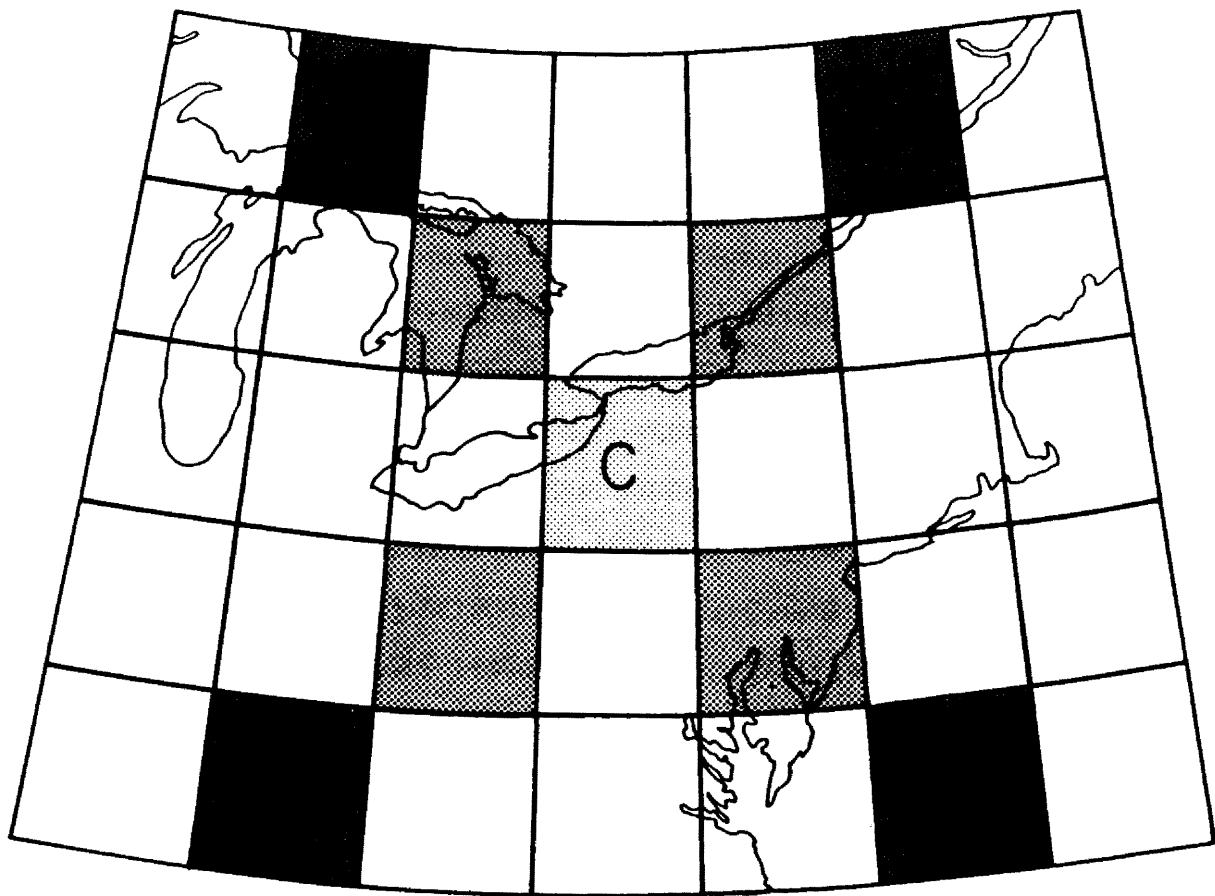
* from Table 3.1

category may thus be more likely four or five days after its first occurrence than after two days. A pattern repetition after two days would require either a very slow-moving system or a very fast-moving one. The subtropical high, on the other hand, is a quasi-stationary, persistent pattern. Rather than crossing the domain periodically, it will tend to enter from the southeastern quadrant, persist for a while, and then be forced to retreat to the southeast by an eastward-moving cyclone or shift in the polar front.

3.5.3 Space lags

Transition statistics were also calculated between synoptic categories at neighboring grid squares for the same day. Both direction and distance were considered as illustrated in Figure 3.14. The detailed statistics are shown in Tables B.113 and B.114 in Appendix B. As might be expected from the conceptual synoptic model, there are strong directional dependences evident in these two tables. For instance, a Category 5 pattern is much likelier to be found to the southeast or southwest of a Category 1 pattern than to the northeast or northwest. A Category 1 pattern is also much likelier to occur to the southwest of a Category 2 pattern than to the northwest, northeast, or southeast.

The space transition statistics also contain information about the spatial extent of the various synoptic categories. Given a particular synoptic category, what percentage of the time can the same category be found one grid square away in either the northwest, northeast, southeast, or southwest directions? Two grid squares away? These percentages can easily be calculated from Tables B.113 and B.114 and are presented in Table 3.27. As might be expected, the two anticyclonic categories, Categories 4 and 5, tend to have the largest spatial extent while the ambiguous category, Category 7 or *U*, and the overrunning category, Category 2, have the smallest spatial extent. Note that the values given for the tropical storm/hurricane category are based on a single occurrence and cannot be considered significant. That is, there was only one day out of the entire study period on which the tropical storm/hurricane synoptic category was identified as occurring at the *center* square of the grid.



36°N–48.5°N
68°W–89°W

Figure 3.14: Grid square patterns used in calculating space transition statistics. The four grid squares diagonally adjacent to the center square (indicated by the letter “C”) were used in calculating the one-square-lag statistics. The four grid squares on the top and bottom grid rows marked by the darkest stippling were used in calculating the two-square-lag statistics.

Table 3.26: Number of occurrences/frequency of occurrence of synoptic Category 5 (subtropical high) time transitions for lags of one to eight days over all grid squares during the five-year period 1975-1979. The number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). This table is based on Tables B.97 – B.104 of Appendix B. The last row is taken from Table 3.1 and is reproduced here for ease of comparison.

Lag Length (days)	New Synoptic Category						<i>H</i>	<i>U</i>	Row Total
	1	2	3	4	5				
1	819/0.26	46/0.02	161/0.05	143/0.05	1815/0.58	30/0.01	107/0.03	3123/1.00	
2	849/0.27	106/0.03	339/0.11	330/0.11	1346/0.43	28/0.01	123/0.04	3123/1.00	
3	750/0.24	142/0.05	409/0.13	542/0.17	1103/0.35	33/0.01	141/0.05	3123/1.00	
4	715/0.23	124/0.04	414/0.13	651/0.21	1042/0.33	30/0.01	145/0.05	3123/1.00	
5	655/0.21	116/0.04	464/0.15	763/0.24	970/0.31	20/0.01	134/0.04	3123/1.00	
6	727/0.23	163/0.05	424/0.14	799/0.26	839/0.27	22/0.01	147/0.05	3123/1.00	
7	798/0.26	198/0.06	460/0.15	762/0.24	734/0.24	32/0.01	136/0.04	3123/1.00	
8	806/0.26	147/0.05	477/0.15	842/0.27	676/0.22	33/0.01	140/0.04	3123/1.00	
Climatological Frequencies*	-/0.19	-/0.12	-/0.26	-/0.34	-/0.05	-/0.00	-/0.05	-/1.00	

* from Table 3.1

Table 3.27: Frequency of repetition of each of the synoptic categories with one- and two-square space lags summed over four directions (northwest, northeast, southeast, and southwest) for the center grid square and all five years 1975-1979. This table is based on Tables B.113 and B.114 in Appendix B.

Space Lag	Synoptic Category					<i>H</i> *	<i>U</i>
	1	2	3	4	5		
1	0.53	0.44	0.63	0.68	0.65	0.75*	0.15
2	0.30	0.27	0.43	0.49	0.46	0.25*	0.08

* based on a single occurrence.

4. APPLICATION TO TERRAIN-FORCED MESOSCALE CIRCULATIONS

As discussed in the Introduction, the primary goal in compiling this synoptic climatology of eastern North America was to determine the relative frequency of occurrence within the study area of synoptic conditions favorable to the generation of terrain-forced mesoscale atmospheric circulations such as lake-land breezes and mountain-valley winds.

As can be seen from Table 2.2, the two synoptic categories most favorable for the generation of such mesoscale circulations are the two anticyclonic categories, Categories 4 (polar high) and 5 (subtropical high). Both of these synoptic categories are generally associated with synoptic-scale subsidence, clear skies or skies with scattered, fair-weather cumulus clouds, strong diurnal heating and cooling, and light winds.

This chapter will examine the climatology of these two categories in more detail, particularly for light ($0-3 \text{ m s}^{-1}$) and moderate ($4-8 \text{ m s}^{-1}$) surface geostrophic winds. Stronger synoptic-scale flows will normally overwhelm and prevent the generation of mesoscale circulations (e.g., Moran *et al.*, 1986).

4.1 Probability of Favorable Synoptic Conditions

Table 3.10 presents a two-way joint frequency table for synoptic category vs. surface geostrophic wind-speed class. If we now concentrate only on synoptic Categories 4 and 5 and light and moderate surface geostrophic wind-speed classes, we note from this table (appropriate values are also shown in last row of Table 4.1) that for the entire grid and five-year period, such conditions occurred 31% of the time. Breaking this down slightly further, the polar high category and light surface geostrophic wind combination occurred with an overall frequency of 4%, the polar high category and moderate surface geostrophic winds with a frequency of 22%, the subtropical high category and light surface geostrophic winds with a frequency of 1%, and the subtropical high category and moderate surface geostrophic winds with a frequency of 4%.

Table 4.1 shows a *seasonal* breakdown for the frequency of occurrence of these same category/class pairs for the entire grid and study period. The polar-high/light-surface-geostrophic-wind pair and polar-high/moderate-surface-geostrophic-wind pair exhibit relatively little seasonal variability in their frequency of occurrence while the subtropical-high/light-surface-geostrophic-wind and subtropical-high/moderate-surface-geostrophic-wind pairs are highly variable with season. Of these four category/class pairs, the polar high/moderate wind pair is the most common with an annual frequency of 22%. Either anticyclonic synoptic pattern together with light surface geostrophic wind speeds (i.e., weak pressure gradients) provides the most favorable environment for terrain-forced mesoscale circulations. Such conditions occur 3%, 5%, 8%, and 4% of the time in winter, spring, summer, and autumn, respectively.

Table 4.2 shows the frequency of occurrence of the two anticyclonic synoptic categories grid box by grid box. It is basically the tabular equivalent of Figures 3.1d and 3.1e. The combined frequency of occurrence of these two categories ranges from a minimum value of 29% on the central east side of the grid to a maximum value of 49% near the southwestern corner. There is gradual decrease in anticyclone frequency from west to east across the grid.

Table 4.3 shows the frequency of occurrence of the light and moderate surface geostrophic wind-speed classes. It is the tabular equivalent of Figures 3.2a and 3.2b. The combined frequency of occurrence of these two weaker surface geostrophic wind-speed classes ranges from a minimum of 38% at the northeast corner of the grid to a maximum of 75% along the central south side (Virginia Piedmont region). There is a gradual decrease in the total frequency of these two wind-speed classes from south to north.

Table 4.4 summarizes the seasonal and spatial variations in the total frequency of occurrences of the four favorable synoptic category/surface geostrophic wind-speed class pairs. They are least likely to occur in winter in the northeast corner of the grid (19%) and most likely to occur in the summer in the southwest corner of the grid (52%). Out of the four corners, these favorable

conditions are most likely to occur in the southwest grid corner and least likely to occur in the northeast grid corner in all four seasons.

4.2 Persistence of Favorable Synoptic Conditions

Table 4.5 shows the frequency of occurrence of anticyclonic episode days for both the entire grid and for the four 4-box grid corners. Over the entire grid, a significant number of anticyclonic category days (28%) belong to episodes of 4 days or more in length. For the four grid corners, the corresponding frequencies are 31% (NW), 18% (NE), 23% (SE), and 36% (SW). It appears then that persistent anticyclonic episodes occur more frequently on the western side of the domain and that such episodes constitute a significant number of the grid-box days classified as anticyclonic.

4.3 Implications for Modeling the Long-Range Transport of Air Pollutants

Sections 4.1 and 4.2 dealt with the frequency of occurrence over eastern North America of the anticyclonic, weak-pressure-gradient synoptic conditions which are most favorable for the formation of terrain-forced mesoscale circulations. Such favorable conditions appear to occur frequently (31% of the time) and often can persist for periods of four days or more. In addition to a favorable synoptic environment, surface differential heating is also needed to generate terrain-forced circulations. Such heating inhomogeneities will be found in the study area, especially in the summer, in the vicinity of the Great Lakes and Atlantic Ocean and along the Appalachian mountain chain (see Figure 2.2). Thus, terrain-forced mesoscale circulations such as sea-land breezes and mountain-valley winds might be expected to occur in the study area on average one day out of three.

The significance of terrain-forced mesoscale circulations for LRTAP calculations is that (1) they can modify pollutant transport and diffusion through differential advection, vertical motion, and enhanced turbulence, (2) they are not resolvable by current LRTAP models, and (3) they tend to occur in the same locations so that their neglect will introduce systematic rather than random errors.

Pielke *et al.* (1987b) have discussed the influence of mesoscale circulations on LRTAP in some detail, and Moran *et al.* (1986) carried out some two-dimensional modeling case studies in which the impacts on pollutant transport of summertime lake-land breezes on one of the Great Lakes, Lake Ontario, and of the mountain-valley winds along the Appalachians were numerically simulated. The latter study found that these two types of terrain-forced mesoscale circulations could affect pollutant transport speed, horizontal and vertical dispersion rates, and dry deposition rates, thus producing a significant impact on the long-range transport of air pollutants. Segal *et al.* (1988a) used three-dimensional mesoscale model simulations to examine sea-breeze influences on mesoscale transport over southern Florida. Segal *et al.* (1988b) carried out generic two-dimensional mesoscale simulations of the effect of mountain-valley circulations on LRTAP and Arritt *et al.* (1988) have considered the impact of mesoscale circulations on dry deposition rates.

Mesoscale modeling studies start with a selected synoptic-scale base state which is often assumed to be steady on the time scale of mesoscale perturbations. If a different synoptic base state is selected, then a new simulation must be run. A common approach is to use only a few representative, or archetypal, synoptic base states in these modeling studies (e.g., Segal *et al.*, 1988a). The usefulness of a synoptic climatology is that it provides the information needed to quantify how often a particular synoptic base state can be expected to occur in a particular region. This knowledge then permits an estimate of the frequency with which the mesoscale phenomena simulated in numerical case studies will occur. One immediate application of the present study is to estimate the climatological frequency of occurrence of the anticyclonic synoptic base states employed for the Great Lakes and the Appalachian cases by Moran *et al.* (1986).

A second application is to apply the synoptic classification scheme used in this study to weather maps for several case studies which have been run by the NCAR Acid Deposition Modeling Project. These same cases are being run again with the CSU Regional Atmospheric Modeling System (RAMS) to investigate and evaluate the importance of terrain-forced mesoscale circulation effects in LRTAP. Classification of the weather maps will suggest where in the simulation domain terrain-

forced mesoscale circulations may be expected to occur; the climatological frequency of comparable synoptic conditions can then also be estimated on the basis of the statistics compiled in the present study.

Table 4.1: Number of occurrences/frequency of occurrence of the two anticyclonic synoptic categories and the light and moderate surface geostrophic wind-speed classes by season for the entire grid during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is a fraction of the total number of grid-square days in the climatological season or year (rounded). Values are taken from Tables B.1 and B.7 – B.10 in Appendix B.

Season	Synoptic Category/Wind-Speed Class Pair				Row Total
	(4, Light)	(4, Moderate)	(5, Light)	(5, Moderate)	
Winter	433/0.03	3440/0.22	0/0.00	1/0.00	3874/0.25
Spring	580/0.04	3518/0.22	168/0.01	688/0.04	4954/0.31
Summer	797/0.05	3536/0.22	550/0.03	1488/0.09	6371/0.40
Autumn	592/0.04	3749/0.24	23/0.00	93/0.01	4467/0.28
All Seasons	2404/0.04	14244/0.22	742/0.01	2271/0.04	19661/0.31

Table 4.2: Number of occurrences/frequency of occurrence of the two anticyclonic synoptic categories by individual grid square* during the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is the fraction (rounded) of total grid-square days for each grid-square (1,826) or row (12,782) or column (9,130). This table is based on Table B.23 in Appendix B.

Grid Row	Synoptic Category	Grid Column							Row Totals
		1	2	3	4	5	6	7	
1	4	781/0.43	737/0.40	738/0.40	710/0.39	658/0.36	590/0.32	528/0.29	4742/0.37
	5	18/0.01	16/0.01	14/0.01	12/0.01	10/0.01	8/0.00	10/0.01	91/0.01
2	4	746/0.41	683/0.37	662/0.36	662/0.36	637/0.35	565/0.31	536/0.29	4492/0.35
	5	27/0.01	32/0.02	33/0.02	32/0.02	29/0.02	24/0.01	21/0.01	200/0.02
3	4	646/0.35	629/0.34	615/0.34	589/0.32	595/0.33	550/0.30	475/0.26	4101/0.32
	5	53/0.03	61/0.03	64/0.04	62/0.03	66/0.04	56/0.03	51/0.03	415/0.03
4	4	635/0.35	618/0.34	639/0.35	656/0.36	600/0.33	529/0.29	441/0.24	4119/0.32
	5	129/0.07	136/0.07	143/0.08	147/0.08	115/0.06	101/0.06	111/0.06	883/0.07
5	4	640/0.35	636/0.35	656/0.36	666/0.36	584/0.32	494/0.27	428/0.23	4105/0.32
	5	242/0.13	254/0.14	246/0.13	220/0.12	189/0.10	189/0.10	215/0.12	1557/0.12
Column Total	4	3386/0.37	3303/0.36	3310/0.36	3283/0.36	3074/0.34	2728/0.30	2408/0.26	21559/0.34
	5	469/0.05	499/0.05	500/0.05	473/0.05	409/0.04	378/0.04	408/0.04	3146/0.05

*see Figure 2.3

Table 4.3: Number of occurrences/frequency of occurrence of the light and moderate surface geostrophic wind-speed classes by individual grid square* during the five-year period 1975-1979. Number of occurrence is a simple count; frequency of occurrence is the fraction (rounded) of total grid-square days for each square (1,826) or row (12,782) or column (9,130). This table is based on Table B.45 of Appendix B.

Grid Row	Wind-Speed Class	Grid Column							Row Total
		1	2	3	4	5	6	7	
1	1	77/0.04	84/0.05	92/0.05	105/0.06	82/0.04	53/0.03	39/0.02	532/0.04
	2	783/0.43	800/0.44	806/0.44	735/0.40	739/0.40	692/0.38	660/0.36	5215/0.41
2	1	88/0.05	98/0.05	107/0.06	104/0.06	76/0.04	48/0.03	66/0.04	587/0.05
	2	840/0.46	848/0.46	817/0.45	807/0.44	801/0.44	792/0.43	745/0.41	5650/0.44
3	1	123/0.07	136/0.07	93/0.05	99/0.05	108/0.06	72/0.04	80/0.04	711/0.06
	2	876/0.48	859/0.47	875/0.48	837/0.46	861/0.47	896/0.49	872/0.48	6076/0.48
4	1	145/0.08	148/0.08	98/0.05	77/0.04	145/0.08	104/0.06	81/0.04	798/0.06
	2	974/0.53	994/0.54	1040/0.57	1067/0.58	1032/0.57	988/0.54	967/0.53	7062/0.55
5	1	191/0.10	166/0.09	175/0.10	187/0.10	193/0.11	146/0.08	138/0.08	1196/0.09
	2	1062/0.58	1074/0.59	1092/0.60	1185/0.65	1129/0.62	1040/0.57	1077/0.59	7659/0.60
Column Total	1	624/0.07	632/0.07	565/0.06	572/0.06	604/0.07	423/0.05	404/0.04	3824/0.06
	2	4535/0.50	4575/0.50	4630/0.51	4631/0.51	4562/0.50	4408/0.48	4321/0.47	31662/0.50

*see Figure 2.3

Table 4.4: Number of occurrences/frequency of occurrence of the two anticyclonic synoptic categories and light or moderate surface geostrophic wind-speed classes by 4-box grid corner* and season for the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is a fraction of the total number of grid-square days in the climatological season† (rounded). Values are taken from Tables B.55 – B.74 in Appendix B.

Grid Corner	Season				Row Total
	Winter	Spring	Summer	Autumn	
NW	435/0.24	620/0.34	723/0.39	462/0.25	2240/0.31
NE	336/0.19	370/0.20	500/0.27	410/0.23	1616/0.22
SE	443/0.25	546/0.30	633/0.34	501/0.28	2123/0.29
SW	480/0.27	664/0.36	964/0.52	654/0.36	2762/0.38
Column Total	1694/0.23	2200/0.30	2820/0.39	2027/0.28	8741/0.30

*see Figure 3.3

†see Table 3.3

Table 4.5: Number of occurrences/frequency of occurrence of anticyclonic episode days (synoptic categories 4 and 5) by grid corner and episode length for the five-year period 1975-1979. Number of occurrences is a simple count; frequency of occurrence is given as a row percentage (rounded). The number of episode days is obtained by weighting the number of episodes by the episode length. This table is derived from Tables B.83 – B.86 in Appendix B. The last row is derived from Table 3.18.

Grid Corner	Episode Length (days)							Row Total
	1	2	3	4	5	6	> 6*	
NW	764/0.26	798/0.27	465/0.16	396/0.13	150/0.05	114/0.04	272/0.09	2959/1.00
NE	801/0.36	688/0.31	330/0.15	176/0.08	100/0.04	114/0.05	16/0.01	2225/1.00
SE	763/0.31	686/0.28	423/0.17	248/0.10	115/0.05	36/0.01	176/0.07	2447/1.00
SW	643/0.20	762/0.24	654/0.20	400/0.13	215/0.07	192/0.06	328/0.10	3194/1.00
Entire Grid	-/0.26	-/0.27	-/0.18	-/0.10	-/0.06	-/0.05	-/0.07	-/1.00

* assumed to be 8 days in length in this table.

5. SUMMARY AND CONCLUSIONS

A subjective synoptic classification scheme has been applied to five years (1975-1979) of synoptic surface weather maps over the northeastern United States and surrounding regions. A rectangular grid composed of 35 boxes (5 rows by 7 columns) was overlaid on the domain which stretched from 36.0°N to 48.5°N latitude and from 68°W to 89°W longitude. Each box covered an area 3° of longitude wide and 2.5° of latitude high (approximately 250 km by 280 km), yielding meso- α spatial resolution. Each grid box was assigned two values for each of the 1826 days of the study based on a manual analysis of the daily 1200 GMT surface weather map. These values were one of seven synoptic pattern categories and one of four surface geostrophic wind-speed classes.

The statistical analysis reveals a wealth of information concerning the synoptic weather regimes of this region. Statistical calculations in this report include transition and persistence statistics, joint frequency tables for seasonal, annual, and monthly stratifications of the data set, and extended analyses for the corners of the grid.

During the five years of the study, significant year-to-year differences existed in synoptic category frequency. The years 1975 and 1979 exhibited strong variation in occurrences of the subtropical high category (Category 5) and post-cold-frontal conditions (Category 3). Surface geostrophic wind-speed statistics, however, showed much smaller variations for the duration of the study. The temporal and spatial behavior of the location of the polar front suggested a meteorological definition of the seasons much different than the conventional astronomical seasons, with winter beginning by early November and lasting until late March, spring ending in late May or early June, and summer lasting until late August to late September. Latitudinal variation of these meteorological seasons was small.

Statistics for the four corner regions of the grid and maps of synoptic category frequencies clearly indicated the influence of continentality. A longitudinal perturbation in the frequency of occurrence of two of the synoptic categories due to blocking by the Appalachian Mountains was also evident in these maps, as were preferred climatological storm tracks. Previous synoptic climatologies for

North America and the Northern Hemisphere were reviewed and were found to be consistent with the results of this climatology.

One result of this study is that synoptic-scale atmospheric conditions favorable or very favorable for the generation of terrain-forced mesoscale circulations appear to occur frequently in this region (about 31% of the time) and often persist for periods of three days or more. These conditions are less likely in the northeast corner of the grid (northeast Maine/southeastern Quebec) and more likely in the southwest corner (Ohio River valley) during all seasons. If, as has been suggested by preliminary mesoscale modeling studies, lake-land breezes and mountain-valley winds modify the long-range transport of air pollutants, then these mesoscale circulations occur often enough to be a significant source of error in LRTAP calculations which cannot resolve them or parameterize them.

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APPENDICES

Appendix A

Listing of Gridded Five-Year Synoptic Category/Surface Geostrophic Wind-Speed Class Data Set

This appendix gives a complete, day-by-day listing of the synoptic pattern categories and surface geostrophic wind-speed classes assigned to each of the 35 individual grid squares based on manual analysis of 1,826 daily 12 GMT surface weather maps for the five-year period 1975-1979. This climatological data set contains a total of 127,820 values ($= 1,826 \text{ days} \times 35 \text{ grid squares} \times 2 \text{ variables}$). The 5×7 grid is shown in Figure 2.3.

The format used to display these values is as follows. Values for 40 days are given on each page in grid-like data blocks, one block per day, five blocks per row, eight rows per page, beginning with January 1, 1975. Each data block consists of a date line (DD/MM/YYYY format) and ten data lines. The first data line in a data block gives values of the synoptic categories for the seven grid boxes in the top (or northernmost) row of the study grid from west to east, the second data line gives values of the surface geostrophic wind-speed classes for each grid box in the top row of the grid from west to east, the third data line gives values of the synoptic categories for each grid box in the second row from the top from west to east, and so on, alternating between rows of synoptic category values and surface geostrophic wind-speed class values down to the tenth data line, which gives values of the surface geostrophic wind-speed class for each grid box in the bottom-most (or southernmost) row of the grid from west to east.

Data blocks are arranged from left to right in chronological order. The first row of five data blocks gives analyzed, gridded surface map categories from January 1-5, 1975, the second row of data blocks lists gridded values for January 6-10, 1975, and so on.

Category and class values are represented by the following codes. Synoptic categories are given by integer values from 1 to 7 corresponding to the seven synoptic categories 1, 2, 3, 4, 5, *H* (or 6), and *U* (or 7). In the case of a double synoptic category, a two-digit integer is shown where the units

digit corresponds to the value of the first synoptic category and the tens digit corresponds to the value of the second synoptic category. For example, a “41” corresponds to a Category 1 – Category 4 pair while a “23” corresponds to a Category 3 – Category 2 pair (the order of categories in these cases is not important). Surface geostrophic wind-speed classes are represented by four character codes: a “<” symbol corresponds to the light wind-speed class ($0-3 \text{ m s}^{-1}$), a “–” corresponds to the moderate wind-speed class ($4-8 \text{ m s}^{-1}$), a “10” corresponds to the strong wind-speed class ($9-11 \text{ m s}^{-1}$), and a “>” corresponds to the very strong wind-speed class ($>11 \text{ m s}^{-1}$).

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6/12/1979 4 34 3 1 3 7 3 - - - - - 4 3 3 3 13 1 21 - - - - - 43 43 13 1 1 1 1 - - - - - 3 13 1 1 1 1 1 - - 10 - - - 13 1 1 1 1 1 1 - - - - - 10 -	7/12/1979 7 7 24 4 4 4 3 - - - - - 10 7 7 24 4 4 34 3 - - - 10 - - - 13 1 1 14 4 3 3 - - - 10 - - - 1 1 1 4 4 3 3 - - - - - 1 1 4 4 3 3 13 - - - - -	8/12/1979 4 4 34 3 3 1 2 - - - - - 4 4 3 3 3 3 7 - - - - - 10 4 34 3 3 3 3 13 - - - - - 4 34 3 3 3 3 13 10 - - - - - 4 4 34 3 3 13 1 - - - 10 - 10 10	9/12/1979 21 7 24 4 4 4 4 - - - 10 10 10 - 1 21 1 7 4 4 4 - - - - - 1 1 1 4 4 4 34 - - - 10 - - - 1 14 4 4 4 4 4 - - - - - 4 4 4 4 4 4 4 - - - - -	10/12/1979 2 7 24 4 4 4 3 - - - - - 2 7 24 4 4 4 3 - - - 10 - - - 1 21 4 4 4 34 3 - - - 10 - - - 1 1 4 4 4 34 13 - - - - - 14 4 4 4 4 4 4 - - - - -	11/12/1979 3 3 7 21 2 2 2 - - - - - 1 1 1 1 21 2 2 - - - - - 1 1 1 1 1 1 21 - - - - - 1 1 1 1 1 1 1 - - - - - 1 14 4 4 4 4 4 - - - - -	12/12/1979 4 34 3 3 3 23 2 - - - - - 4 3 3 3 13 1 1 - - - - - 34 3 13 13 1 1 1 - - - - - 3 13 1 1 1 1 1 - - - - - 13 1 1 1 1 1 1 - - - - -	13/12/1979 24 4 4 4 4 4 4 - - - - - 4 4 4 4 4 4 34 - - - 10 - - - 4 3 3 3 3 3 3 - - - - - 10 - 3 3 3 3 3 13 13 - - - - - 3 13 13 13 1 1 1 - - - - -	14/12/1979 4 4 4 4 4 3 3 10 - - - - 10 - 4 4 4 4 4 34 3 10 - - - - - 4 4 4 4 4 3 3 - - - - - 4 4 4 4 34 3 3 - - - - - 4 4 4 34 3 3 3 - - - 10 - - -	15/12/1979 1 1 21 2 24 4 4 - - - - - 1 1 1 1 14 4 4 - - - - - 1 14 4 4 4 4 4 - - - - - 4 4 4 4 4 4 4 10 - - - - 10 - 4 4 4 4 4 4 4 - - - - -	16/12/1979 3 3 3 3 13 1 1 - - - - - 3 3 13 13 1 1 1 - - - - - 3 13 1 1 1 1 1 - - - - - 3 1 1 1 1 1 14 - - - - - 13 1 1 7 7 7 14 - - - - -	17/12/1979 4 4 4 4 34 3 3 - - - - - 4 4 4 4 34 3 3 10 - - - 10 - - - 4 4 34 3 3 3 3 - - - - - 4 4 34 3 3 3 13 - - - - - 4 34 3 3 3 3 13 - - - - -	18/12/1979 4 4 4 4 3 3 3 10 - - - - - 4 4 4 4 3 3 3 10 - - - - - 4 4 4 4 4 3 3 - - - - - 4 4 4 4 4 4 3 - - - 10 - - - 4 4 4 4 4 43 4 - - - - 10 -	19/12/1979 3 23 2 2 24 4 4 - - - - 10 - - 3 3 2 2 2 4 4 - - - - - 13 13 13 2 2 24 4 - - - - - 1 1 1 21 7 7 7 - - - 10 - - - 14 14 14 14 14 14 - - - 10 - - -	20/12/1979 1 1 14 4 4 4 4 - - - - 10 - - 4 4 4 4 4 4 4 - - - 10 - - - 4 4 4 4 4 34 134 - - - - - 4 4 4 4 3 3 3 - - - - - 4 4 4 3 3 3 3 - - - - -	21/12/1979 1 1 1 1 1 1 4 - - - - - 1 1 1 14 4 4 4 - - - - - 1 1 1 1 4 4 34 - - - 10 - - - 1 4 4 4 4 34 3 - - - 10 - - - 1 4 4 4 3 3 3 - - - 10 - - -	22/12/1979 1 1 1 1 1 1 14 - - 10 - - 10 10 1 1 1 1 1 1 4 - - 10 - - - 1 1 1 1 4 4 4 - - - - - 1 1 1 14 4 4 34 - - - 10 - - - 1 1 1 4 4 4 3 - - - 10 - - 10	23/12/1979 2 2 2 2 2 24 4 - - - - - 21 21 1 21 21 7 4 10 - - - - - 1 1 1 1 1 14 4 - - - 10 - - - 1 1 1 14 4 4 4 - - - - - 1 1 1 14 4 4 4 - - - - - 1 1 1 14 4 4 4 - - - - -	24/12/1979 3 37 2 2 7 7 7 - - - - - 3 2 2 2 2 24 4 - - - - - 3 7 2 2 2 24 4 - - - - - 13 1 1 21 21 7 4 - - - - - 13 1 1 1 1 4 4 - - - - -	25/12/1979 3 3 3 3 32 2 2 - - - - - 3 3 3 3 23 2 2 - - - - - 3 3 3 3 7 21 21 - - - - - 3 3 3 3 3 1 1 - - - - - 3 3 3 3 3 1 1 - - - - -	26/12/1979 7 3 3 1 3 3 3 - - - - - 7 3 3 3 3 3 3 - - - - - 4 4 4 3 3 3 3 - - - - - 4 4 4 34 3 3 3 - - - - - 4 4 4 1 3 3 3 - - - - -	27/12/1979 4 4 4 34 3 3 3 - - - 10 - - - 4 4 4 34 3 3 3 - - - 10 - - - 4 4 4 34 3 3 3 - - - 10 10 - - - 4 4 4 34 3 3 3 - - - 10 10 - - -	28/12/1979 4 3 3 3 3 3 3 - - - - - 4 4 14 3 3 3 3 - - - - - 4 4 4 34 3 3 3 - - - - - 4 4 4 34 3 3 3 - - - 10 - - - 4 4 4 4 4 3 3 - 10 10 10 - - -	29/12/1979 4 34 3 3 3 3 3 - - - - - 4 4 4 34 3 3 3 10 - - - - - 4 4 4 34 3 3 3 - - - - - 4 4 4 34 3 3 3 - - - - - 4 4 4 4 3 3 3 - - - - -	30/12/1979 4 4 34 3 3 3 3 - - - - - 4 4 34 3 3 3 3 - - - - - 4 4 4 3 3 3 3 - - - - - 7 4 4 4 43 3 3 - - - 10 - - - 7 7 4 4 4 3 3 - - - - -	31/12/1979 4 4 7 7 7 7 3 - - - - - 4 4 4 4 4 4 43 - - - - - 4 4 4 4 4 4 3 - - - - - 4 4 4 4 4 4 3 - - - - - 7 4 4 4 4 4 3 - - 10 - - -
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Appendix B

Statistical Tables for Various Analyses and Data Stratifications

This appendix contains “raw” computer-generated statistical tables, some of which were used to prepare the summary tables presented in the body of this report. These raw tables are both more numerous and more detailed than the summary tables. They follow from the analysis options described in Section 2.3. There are 114 tables in this appendix. The index table on the next page gives their order of presentation. Joint frequency tables are listed first, followed by persistence tables and then transition tables. Note that in some of the table headings, the term “pressure gradient” is used as equivalent to the term “surface geostrophic wind-speed”. Appendix C contains a listing of the FORTRAN program used to generate these tables.

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Appendix C

Listing of Computer Program Used to Prepare Statistical Tables

INTEGER PSTART, ROW, TABNUM

INTEGER ENDGCOL, ENDGROW, ENDPRSG, ENDSYNC
INTEGER ENDOTH1, ENDOTH2, ENDPOL, ENDPROW, ENDSROW
INTEGER NUMGCOL, NUMGROW, NUMSYNC, NUMPRSG
INTEGER NUMOTH1, NUMOTH2, NUMPCOL, NUMPROW, NUMSROW
INTEGER OTHER1, OTHER2, PRITCOL, PRITROW, SECTROW
INTEGER STAGCOL, STAGROW, STAPRSG, STASYNC
INTEGER STAOH1, STAOH2, STAPCOL, STAPROW, STASROW
INTEGER VPRSG, VSYN1, VSYN2

LOGICAL CLIMPER, FIRST, JNTFREQ, PRSISTN, PRC2CAT, SPACELG
LOGICAL TRNSITN

EQUIVALENCE (ENDVAR(1),ENDSYNC), (ENDVAR(2),ENDPRSG),
* (ENDVAR(3),ENDGROW), (ENDVAR(4),ENDGCOL)
EQUIVALENCE (STAVAR(1),STASYNC), (STAVAR(2),STAPRSG),
* (STAVAR(3),STAGROW), (STAVAR(4),STAGCOL)
EQUIVALENCE (FORMATN(1,1),FOR640), (FORMATN(1,2),FOR700),
* (FORMATN(1,3),FOR710), (FORMATN(1,4),FOR720)

COMMON /DATES/ DAY1ST, DAYLST, MN1ST, MN1LAST, PERBEG,
* PEREND, YR1ST, YRLAST
COMMON /FLAGS/ CLIMPER, PRC2CAT
COMMON /LABELS/ CATNAME, RLABEL, SEASON, TABNUM, VARNAME
COMMON /LIMITS/ STASYNC, STAPRSG, STAGROW, STAGCOL,
* ENDSYNC, ENDPRSG, ENDGROW, ENDGCOL
COMMON /JNTFRQT/ ENDPOL, ENDPROW, ENDOTH1, ENDOTH2, ENDSROW,
* NUMPCOL, NUMPROW, NUMOTH1, NUMOTH2, NUMSROW,
* PRITCOL, PRITROW, OTHER1, OTHER2, SECTROW,
* STAPCOL, STAPROW, STAOH1, STAOH2, STASROW

DATA BIN/980*0.0/
DATA CATNAME/' 1',' 2',' 3',' 4',' 5',' H',' U',
* '<',' -',' 10',' >',' 3'???'
* 'ROW 1','ROW 2','ROW 3','ROW 4','ROW 5','ROW 6'
* 'ROW 7'
* 'COL. 1','COL. 2','COL. 3','COL. 4','COL. 5','COL. 6'
* 'COL. 7','1 DAY', '2 DAYS', '3 DAYS', '4 DAYS',
* '5 DAYS', '6 DAYS', '> 6 DAYS'
DATA RLABEL/'ROW TOTALS'/
DATA VARNAME/'SYNOPTIC CATEGORY','PRESSURE GRAD.',
* 'GRID ROW','GRID COLUMN'/
DATA NUMINP/0/, NUMVAL/0/
DATA SEASON/'ANNUAL '/

INITIALIZATION: SPECIFY THE VARIABLES FOR WHICH A JOINT FREQUENCY TABLE IS
TO BE CONSTRUCTED (I.E., PRITCOL, PRITROW, SECTROW), THE VARIABLES WHICH ARE
ARE TO BE HELD FIXED OR SUMMED OVER (OTHER1, OTHER2), AND THE RANGES OF
THESE VARIABLES (N.B., 1 = SYNCAT, 2 = PRESGRD, 3 = GRID ROW, AND
4 = GRID COLUMN). FOR A 2-WAY TABLE, 'SECTROW' = 0; FOR A 3-WAY TABLE,
'OTHER2' = 0.

PRITCOL = 1
PRITROW = 2
SECTROW = 0
OTHER1 = 3
OTHER2 = 4

STASYNC = 1
ENDSYNC = 7
STAPRSG = 1
ENDPRSG = 4
STAGROW = 1
ENDGROW = 5
STAGCOL = 1
ENDGCOL = 7

STAPCOL = STAVAR(PRITCOL)
ENDPOL = ENDVAR(PRITCOL)
STAPROW = STAVAR(PRITROW)
ENDPROW = ENDVAR(PRITROW)
STAOH1 = STAVAR(OTHER1)
ENDOTH1 = ENDVAR(OTHER1)

ENDSROW = 0
STAOH2 = 0
ENDOTH2 = 0
IF (SECTROW .EQ. 0) THEN
STAOH2 = STAVAR(OTHER2)
ENDOTH2 = ENDVAR(OTHER2)
ELSE
STASROW = STAVAR(SECTROW)
ENDSROW = ENDVAR(SECTROW)
ENDIF

NUMGCOL = ENDGCOL - STAGCOL + 1
NUMGROW = ENDGROW - STAGROW + 1
NUMPRSG = ENDPRSG - STAPRSG + 1
NUMSYNC = ENDSYNC - STASYNC + 1

NUMPCOL = ENDPOL - STAPCOL + 1
NUMPROW = ENDPROW - STAPROW + 1
NUMSROW = ENDSROW - STASROW + 1

WRITE(6,600) PRITCOL, STAPCOL, ENDPOL, NUMPCOL,
* PRITROW, STAPROW, ENDPROW, NUMPROW,
* SECTROW, STASROW, ENDSROW, NUMSROW,
* OTHER1, STAOH1, ENDOTH1,
* OTHER2, STAOH2, ENDOTH2

JNTFREQ = .FALSE.
PRSISTN = .FALSE.
TRNSITN = .TRUE.
CLIMPER = .FALSE.
PRC2CAT = .TRUE.
ECHO = 0
TABNUM = 138
FIRST = .TRUE.
PRSTVAR = 1
IF (PRSTVAR .EQ. 1) THEN
PSTART = STASYNC
PEND = ENDSYNC
ELSE
PSTART = STAPRSG
PEND = ENDPRSG
ENDIF
LAG = 8
SPACELG = .FALSE.
CENX = 3
CENY = 4

WRITE(6,675) ECHO, CLIMPER, PRC2CAT, JNTFREQ, PRSISTN, TRNSITN

IF (CLIMPER) THEN

DAY1ST = 21
MN1ST = 12
YR1ST = 74
DAYLST = 20
MN1LAST = 3
YRLAST = 80
WRITE(6,603) SEASON, MN1ST, DAY1ST, MN1LAST, DAYLST, YR1ST,
* YRLAST

C2345678901234567890123456789012345678901234567890123456789012
ELSE
PERBEG = 750101
PEREND = 791231
WRITE(6,606) PERBEG, PEREND
ENDIF

100 READ(5,500,END=250,ERR=950) YEAR, MONTH, DAY,
* ((SYNCAT(I,J),J=1,7), (PRESGRD(I,J),J=1,7),1=1,5)
NUMINP = NUMINP + 1

C
C CHECK FOR MEMBERSHIP IN SAMPLING PERIOD;
C (IF) ==> CLIMATOLOGICAL PERIOD, {ELSE} ==> CHRONOLOGICAL PERIOD
C
IF (CLIMPER) THEN
IF (YEAR.LT.YR1ST .OR. YEAR.GT.YRLAST) GOTO 100
IF (MN1ST.LE.MN1LAST) THEN


```

      WRITE(6,900) PRITROW, SECTROW, PRITCOL, OTHER1,
      *      OTHER2, I1, I2, J, OH1, OH2
      STOP
    ENDIF

    IF (PRITROW .GE. 1 .AND. PRITROW .LE. 4) THEN
      VALUE(PRITROW) = I1
    ELSE
      WRITE(6,900) PRITROW, SECTROW, PRITCOL, OTHER1,
      *      OTHER2, I1, I2, J, OH1, OH2
      STOP
    ENDIF

    IF (SECTROW .NE. 0) THEN
      IF (SECTROW .GE. 1 .AND. SECTROW .LE. 4) THEN
        VALUE(SECTROW) = I2
      ELSE
        WRITE(6,900) PRITROW, SECTROW, PRITCOL, OTHER1,
        *      OTHER2, I1, I2, J, OH1, OH2
        STOP
      ENDIF
    ENDIF

    IF (OTHER1 .GE. 1 .AND. OTHER1 .LE. 4) THEN
      VALUE(OTHER1) = OH1
    ELSE
      WRITE(6,900) PRITROW, SECTROW, PRITCOL, OTHER1,
      *      OTHER2, I1, I2, J, OH1, OH2
      STOP
    ENDIF

    IF (OTHER2 .NE. 0) THEN
      IF (OTHER2 .GE. 1 .AND. OTHER2 .LE. 4) THEN
        VALUE(OTHER2) = OH2
      ELSE
        WRITE(6,900) PRITROW, SECTROW, PRITCOL, OTHER1,
        *      OTHER2, I1, I2, J, OH1, OH2
        STOP
      ENDIF
    ENDIF

    IF (SYNC*PRSG*ROW*COLUMN .GT. 0) THEN
      BINVALU = BIN(SYNC,PRSG,ROW,COLUMN)
    ELSE
      WRITE(6,950) SYNC, PRSG, ROW, COLUMN
      STOP
    ENDIF

    RETURN

900 FORMAT('/// ** ERROR ** TABLE PARAMETER IS OUT OF BOUNDS'//
* ' PRITCOL, PRITROW, SECTROW, I, J, K:', 615//)
950 FORMAT('/// ** ERROR ** BIN PARAMETER IS OUT OF BOUNDS'//
* ' 10X, ' SYNC, PRSG, ROW, COLUMN:', 416 ///)
END

SUBROUTINE JNTFOUT(BIN)

THIS SUBROUTINE PRINTS OUT THE SPECIFIED 2-WAY OR 3-WAY JOINT
FREQUENCY TABLE

COLST - TOTALS OF SECONDARY ROW VARIABLE SUBTOTALS IN COLUMN FOR
SPECIFIED PRIMARY ROW VARIABLE
COLTOT - TOTALS OF COLUMNS
INTOUT - LOGICAL FLAG TO SPECIFY TRUNCATION OF TABLE ENTRIES TO
INTEGER VALUES (.TRUE.) OR TO ONE DECIMAL PLACE (.FALSE.)
ROWST - TOTALS OF SECONDARY ROWS (I.E., NUMSROW VARIABLES)
ROWTOT - TOTALS OF PRIMARY ROWS (I.E., SUM OF 'ROWST' VALUES FOR
EACH PRIMARY CATEGORY)
TABLE - NUMBER FREQUENCIES FOR TWO-WAY OR THREE-WAY JOINT FREQUENCY
TABLE; FIRST SUBSCRIPT IS PRIMARY ROW, SECOND SUBSCRIPT
IS SECONDARY ROW, AND THIRD SUBSCRIPT IS PRIMARY COLUMN

CHARACTER*17 VARNAME(4)

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```

CHARACTER*8 SEASON

REAL BIN(7,4,5,7), TABLE(1:7,0:7,1:7)
REAL COLST(7,7), ROWST(7,7)
REAL COLTOT(7), ROWTOT(7)
REAL PERCENT(8), BINVALU, TABLTOT

INTEGER COLNO
INTEGER DAY1ST, DAY1ST, MN1ST, MNLAST, PERBEG, PEREND, YR1ST, YRLAST
INTEGER ENDOTH1, ENDOTH2, ENDPOL, ENDPROW, ENDSROW
INTEGER OH1, OH2, OTHER1, OTHER2, PRITCOL, PRITROW, SECTROW
INTEGER STAOTH1, STAOTH2, STAPCOL, STAPROW, STASROW
INTEGER TABLNUM, TBLPCOL, TBLPROW, TBLSROW

LOGICAL CLIMPER, PRC2CAT, INTOUT

COMMON /DATES/ DAY1ST, DAY1ST, MN1ST, MNLAST, PERBEG,
* PEREND, YR1ST, YRLAST
COMMON /FLAGS/ CLIMPER, PRC2CAT
COMMON /LABELS/ CATNAME, RLABEL, SEASON, TABLNUM, VARNAME
COMMON /JNTFRQT/ ENDPOL, ENDPROW, ENDOTH1, ENDOTH2, ENDSROW,
* NUMPCOL, NUMPROW, NUMOTH1, NUMOTH2, NUMSROW,
* PRITCOL, PRITROW, OTHER1, OTHER2, SECTROW,
* STAPCOL, STAPROW, STAOTH1, STAOTH2, STASROW

DATA COLST/49*0.0/, ROWST/49*0.0/, TABLE/392*0.0/
DATA COLTOT/7*0.0/, ROWTOT/7*0.0/, TABLTOT/0.0/
DATA INTOUT/.FALSE./

C2345678901234567890123456789012345678901234567890123456789012

C
C POST-BINNING CALCULATION OF MARGINAL TOTALS
C
C IF (SECTROW .EQ. 0) THEN
C
C CALCULATE SUBTOTALS AND TOTALS FOR A TWO-WAY TABLE
C
      DO 300 J = STAPCOL, ENDPOL
      DO 320 I = STAPROW, ENDPROW
      DO 325 OH1 = STAOTH1, ENDOTH1
      DO 330 OH2 = STAOTH2, ENDOTH2
      TABLE(I,0,J) = TABLE(I,0,J) +
      * BINVALU(BIN,PRITROW,0,PRITCOL,
      * OTHER1,OTHER2,I,0,J,OH1,OH2)
C2345678901234567890123456789012345678901234567890123456789012
      330 CONTINUE
      325 CONTINUE
      COLTOT(J) = COLTOT(J) + TABLE(I,0,J)
      ROWTOT(I) = ROWTOT(I) + TABLE(I,0,J)
      320 CONTINUE
      TABLTOT = TABLTOT + COLTOT(J)
      300 CONTINUE
      ELSE

C
C CALCULATE SUBTOTALS AND TOTALS FOR A THREE-WAY TABLE
C
      DO 340 J = STAPCOL, ENDPOL
      DO 360 I1 = STAPROW, ENDPROW
      DO 380 I2 = STASROW, ENDSROW
      DO 390 OH1 = STAOTH1, ENDOTH1
      TABLE(I1,I2,J) = TABLE(I1,I2,J) +
      * BINVALU(BIN,PRITROW,SECTROW,PRITCOL,
      * OTHER1,0,I1,I2,J,OH1,0)
      390 CONTINUE
      COLST(J,I1) = COLST(J,I1) + TABLE(I1,I2,J)
      ROWST(I1,I2) = ROWST(I1,I2) + TABLE(I1,I2,J)
      380 CONTINUE
      COLTOT(J) = COLTOT(J) + COLST(J,I1)
      360 CONTINUE
      TABLTOT = TABLTOT + COLTOT(J)
      340 CONTINUE
      DO 392 I1 = STAPROW, ENDPROW
      DO 394 I2 = STASROW, ENDSROW
      ROWTOT(I1) = ROWTOT(I1) + ROWST(I1,I2)

```

```

392     CONTINUE
      ENDIF
C
C   OUTPUT FREQUENCY TABULATION TABLES
C
      WRITE(6,625)TABLNUM
      IF (CLIMPER) THEN
        IF (SECTROW.EQ. 0) THEN
          WRITE(6,630) VARNAME(PRITROW), VARNAME(PRITCOL),
            VARNAME(OTHER1), STAOOTH1, ENDOTH1,
            VARNAME(OTHER2), STAOOTH2, ENDOTH2
        ELSE
          WRITE(6,631) VARNAME(PRITROW), VARNAME(SECTROW),
            VARNAME(PRITCOL), VARNAME(OTHER1), STAOOTH1,
            ENDOTH1
        ENDIF
        WRITE(6,635) SEASON, YRIST, YRLAST
      ELSE
        IF (SECTROW.EQ. 0) THEN
          WRITE(6,630) VARNAME(PRITROW), VARNAME(PRITCOL),
            VARNAME(OTHER1), STAOOTH1, ENDOTH1,
            VARNAME(OTHER2), STAOOTH2, ENDOTH2
        ELSE
          WRITE(6,631) VARNAME(PRITROW), VARNAME(SECTROW),
            VARNAME(PRITCOL), VARNAME(OTHER1),
            STAOOTH1, ENDOTH1
        ENDIF
C2345678901234567890123456789012345678901234567890123456789012
        WRITE(6,645) PERBEG, PEREND
      ENDIF
      IF (INTOUT) THEN
        WRITE(6,640) (CATNAME(COLNO, PRITCOL), COLNO=1, NUMPCOL), RLABEL
      ELSE
        WRITE(6,1640) (CATNAME(COLNO, PRITCOL), COLNO=1, NUMPCOL), RLABEL
      ENDIF

      IF (TABLTOT.LE. 0.0) THEN
        WRITE(6,930)
        STOP
      ENDIF

      IF (INTOUT) THEN
C
C   PRINT TABLE WITH INDIVIDUAL ENTRIES TRUNCATED TO INTEGER VALUES
C
        IF (SECTROW.EQ. 0) THEN
          DO 400 TBLPROW = STAPROW, ENDPROW
            PERCENT(8) = ROWTOT(TBLPROW) / TABLTOT
            WRITE(6,700) CATNAME(TBLPROW, PRITROW),
              (INT(TABLE(TBLPROW,0,TBLPCOL)), TBLPCOL =
                STAPCOL, ENDPCOL), INT(ROWTOT(TBLPROW)),
                PERCENT(8)
          CONTINUE
          DO 420 TBLPCOL = STAPCOL, ENDPCOL
            PERCENT(TBLPCOL) = COLTOT(TBLPCOL) / TABLTOT
          CONTINUE
          PERCENT(8) = 1.0
          WRITE(6,720) (INT(COLTOT(TBLPCOL)), PERCENT(TBLPCOL),
            TBLPCOL = STAPCOL, ENDPCOL), INT(TABLTOT),
            PERCENT(8)
        ELSE
          DO 450 TBLPROW = STAPROW, ENDPROW
            WRITE(6,725) CATNAME(TBLPROW, PRITROW)
            DO 460 TBLSROW = STASROW, ENDSROW
              PERCENT(8) = ROWST(TBLPROW, TBLSROW) / TABLTOT
              WRITE(6,705) CATNAME(TBLSROW, SECTROW),
                (INT(TABLE(TBLPROW, TBLSROW, TBLPCOL)),
                  TBLPCOL = STAPCOL, ENDPCOL),
                  INT(ROWST(TBLPROW, TBLSROW)), PERCENT(8)
            CONTINUE
          DO 470 TBLPCOL = STAPCOL, ENDPCOL
            PERCENT(TBLPCOL) = COLST(TBLPCOL, TBLPROW) / TABLTOT
          CONTINUE
          PERCENT(8) = ROWTOT(TBLPROW) / TABLTOT
          WRITE(6,710) (INT(COLST(TBLPCOL, TBLPROW)),
            PERCENT(TBLPCOL), TBLPCOL=STAPCOL, ENDPCOL),
            PERCENT(TBLPCOL), TBLPCOL=STAPCOL, ENDPCOL),
            PERCENT(8)
        ENDIF
      ENDIF

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      INT(ROWTOT(TBLPROW)), PERCENT(8)
450     CONTINUE
      DO 480 TBLPCOL = STAPCOL, ENDPCOL
        PERCENT(TBLPCOL) = COLTOT(TBLPCOL) / TABLTOT
      CONTINUE
      PERCENT(8) = 1.0
      WRITE(6,720) (INT(COLTOT(TBLPCOL)), PERCENT(TBLPCOL),
        TBLPCOL = STAPCOL, ENDPCOL), INT(TABLTOT),
        PERCENT(8)
      *
      *
      *   ENDIF
      *   ELSE
C
C   PRINT TABLES WITH INDIVIDUAL ENTRIES GIVEN TO ONE DECIMAL PLACE
C
      IF (SECTROW.EQ. 0) THEN
        DO 1400 TBLPROW = STAPROW, ENDPROW
          PERCENT(8) = ROWTOT(TBLPROW) / TABLTOT
          WRITE(6,1700) CATNAME(TBLPROW, PRITROW),
            (TABLE(TBLPROW,0,TBLPCOL), TBLPCOL =
              STAPCOL, ENDPCOL), ROWTOT(TBLPROW),
              PERCENT(8)
        CONTINUE
        DO 1420 TBLPCOL = STAPCOL, ENDPCOL
          PERCENT(TBLPCOL) = COLTOT(TBLPCOL) / TABLTOT
        CONTINUE
        PERCENT(8) = 1.0
        WRITE(6,1720) (COLTOT(TBLPCOL), PERCENT(TBLPCOL),
          TBLPCOL = STAPCOL, ENDPCOL), TABLTOT,
          PERCENT(8)
      ELSE
        DO 1450 TBLPROW = STAPROW, ENDPROW
          WRITE(6,725) CATNAME(TBLPROW, PRITROW)
          DO 1460 TBLSROW = STASROW, ENDSROW
            PERCENT(8) = ROWST(TBLPROW, TBLSROW) / TABLTOT
            WRITE(6,705) CATNAME(TBLSROW, SECTROW),
              (TABLE(TBLPROW, TBLSROW, TBLPCOL),
                TBLPCOL = STAPCOL, ENDPCOL),
                ROWST(TBLPROW, TBLSROW), PERCENT(8)
          CONTINUE
        DO 1470 TBLPCOL = STAPCOL, ENDPCOL
          PERCENT(TBLPCOL) = COLST(TBLPCOL, TBLPROW) / TABLTOT
        CONTINUE
        PERCENT(8) = ROWTOT(TBLPROW) / TABLTOT
        WRITE(6,1710) (COLST(TBLPCOL, TBLPROW),
          PERCENT(TBLPCOL), TBLPCOL=STAPCOL, ENDPCOL),
          ROWTOT(TBLPROW), PERCENT(8)
      CONTINUE
      DO 1480 TBLPCOL = STAPCOL, ENDPCOL
        PERCENT(TBLPCOL) = COLTOT(TBLPCOL) / TABLTOT
      CONTINUE
      PERCENT(8) = 1.0
      WRITE(6,1720) (COLTOT(TBLPCOL), PERCENT(TBLPCOL),
        TBLPCOL = STAPCOL, ENDPCOL), TABLTOT,
        PERCENT(8)
      *
      *
      *   ENDIF
      *   ENDIF
      *   RETURN
625     FORMAT(1H1,17(/),62X,'TABLE ',I3///)
630     FORMAT(30X, 'TWO-WAY TABULATION OF', A24, ' VS.', A17///
      *       47X, A17, ' RANGES FROM', I3, ' TO', I3//
      *       47X, A17, ' RANGES FROM', I3, ' TO', I3//)
631     FORMAT(22X, 'THREE-WAY TABULATION OF ', A24, '/', A20, ' VS.', A18///
      *       47X, A17, ' RANGES FROM', I3, ' TO', I3//)
635     FORMAT(20X, 'CLIMATOLOGICAL SAMPLING PERIOD IS ', A8,
      *       ' YEARS 19', I2, '-19', I2//)
640     FORMAT(/1X,131('-')/ 1X,'PRIME : SECON. =', 3X, A12, 6A12,
      *       12X, A10 / 1X, 131('-') / )
645     FORMAT(35X, 'CHRONOLOGICAL SAMPLING PERIOD IS FROM 19', I6,
      *       ' TO 19', I6//)
700     FORMAT(1X, A10, 5X, '=', I9, 6I12, 10X, '=', I9, 2X, '(', F5.3,
      *       ')')
705     FORMAT(10X, A6, '=', I9, 6I12, 10X, '=', I9, 2X, '(',
      *       F5.3, ')')
710     FORMAT(9X,123('-')/16X,'=', 2X,7(I7,'/',F4.2),4X,' =', I9,
      *       2X, '(', F5.3, ')')
720     FORMAT(1X,131('-')/1X,' COLUMN TOTALS', 2X, '=', 2X,7(I7,'/',F4.2),

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      *      SX,'=',I9,2X,'(','F5.3,')'/1X,131('-')
725 FORMAT(1X,A10, 5X,'=',91X,'=')
930 FORMAT(///' ERROR - NO ENTRIES IN TABLE'//)
1640 FORMAT(//1X,131('-')/ 1X,'PRIME : SECON. =', 3X, A12, 6A13,
      *      8X, A10 / 1X, 131('-') / )
1700 FORMAT(1X, A10, 5X,'=',F9.1, 6F13.1, 7X, ' ',F9.1, 2X,'(','
      *      F5.3, ')')
1705 FORMAT(10X, A6, ' ',F9.1, 6F13.1, 7X, ' ',F9.1, 2X,'(','
      *      F5.3, ')')
1710 FORMAT(9X,123('-')/16X,'=',1X,7(F8.1,'/',F4.2),1X,' ',F9.1,
      *      2X,'(','F5.3,')')
1720 FORMAT(1X,131('-')/1X,'COLUMN TOTALS',2X,'=',1X,7(F8.1,'/',
      *      F4.2),2X,' ',F9.1,2X,'(','F5.3,')'/1X,131('-')
END

SUBROUTINE PERSIST(GRIDCAT,FIRST,PRC2CAT,ECHO)

C THIS SUBROUTINE COMPARES THE VALUES OF THE CURRENT DAY'S GRID
C CATEGORY VALUES TO THE PREVIOUS DAY'S TO SEE IF A RUN OF A PARTICULAR
C CATEGORY IS CONTINUING, IN WHICH CASE 'RUNDAYS' IS AUGMENTED BY 1,
C OR HAS FINISHED, IN WHICH CASE 'TPRSIST' IS INCREMENTED AND
C 'RUNDAYS' IS RESET TO 1.
C
C IN CASES OF TWO SYNOPTIC CATEGORIES, A RUN MAY OR MAY NOT BE CONSIDERED
C TO HAVE CONTINUED DEPENDING ON THE VALUE OF 'PRC2CAT' IF ONE OF THE
C TWO CATEGORIES IS THE SAME AS THE PREVIOUS DAY'S VALUE.
C
C GRIDCAT - 5 X 7 ARRAY OF CATEGORY VALUES FOR CURRENT DAY
C RUNCAT - 5 X 7 ARRAY OF CURRENT PERSISTENT RUN CATEGORIES
C RUNDAYS - 5 X 7 ARRAY OF LENGTHS OF CURRENT RUNS (IN DAYS)
C TPRSIST - 7 X 7 ARRAY FOR NUMBER OF RUNS OF DIFFERENT
C           LENGTHS FOR DIFFERENT CATEGORIES
C
C INTEGER GRIDCAT(5,7), RUNCAT(5,7), RUNDAYS(5,7), TPRSIST(7,7)
C INTEGER ECHO, GC, GR, GRDCAT1, GRDCAT2
C INTEGER STASync, STAPRSG, STAGROW, STAGCOL
C INTEGER ENDSync, ENDRSG, ENDGROW, ENDGCOL
C LOGICAL FIRST, PRC2CAT
C
C COMMON /LIMITS/ STASync, STAPRSG, STAGROW, STAGCOL,
C *             ENDSync, ENDRSG, ENDGROW, ENDGCOL
C COMMON /PERSTNC/ TPRSIST
C23456789012345678901234567890123456789012345678901234567890
C
C   INITIALIZATION OF ARRAY VALUES IF FIRST IS .TRUE.
C
C   IF (FIRST) THEN
C
C     DO 10 J = STAGCOL, ENDGCOL
C     DO 20 I = STAGROW, ENDGROW
C       RUNCAT(I,J) = GRIDCAT(I,J)
C       IF (RUNCAT(I,J).GT.7) RUNCAT(I,J)=RUNCAT(I,J)/10
C       RUNDAYS(I,J) = 1
C     CONTINUE
C   CONTINUE
C     DO 30 J = 1, 7
C     DO 40 I = 1, 7
C       TPRSIST(I,J) = 0
C     CONTINUE
C   CONTINUE
C
C ELSE
C
C   DO 50 GR = STAGROW, ENDGROW
C   DO 60 GC = STAGCOL, ENDGCOL
C     GRDCAT1 = GRIDCAT(GR,GC)
C     GRDCAT2 = 0
C     IF (GRDCAT1.GT.7) THEN
C       GRDCAT1 = GRIDCAT(GR,GC) / 10
C       GRDCAT2 = GRIDCAT(GR,GC) - 10 * GRDCAT1

```

```

      IF ( (GRDCAT1.EQ. RUNCAT(GR,GC)) .OR.
      *      (PRC2CAT .AND. (GRDCAT2.EQ. RUNCAT(GR,GC))) ) THEN
        RUNDAYS(GR,GC) = RUNDAYS(GR,GC) + 1
        IF (RUNDAYS(GR,GC).GT.7) RUNDAYS(GR,GC) = 7
      ELSE
        TPRSIST(RUNCAT(GR,GC), RUNDAYS(GR,GC)) =
      *      TPRSIST(RUNCAT(GR,GC), RUNDAYS(GR,GC)) + 1
        RUNCAT(GR,GC) = GRDCAT1
        RUNDAYS(GR,GC) = 1
      ENDIF
60 CONTINUE
50 CONTINUE
ENDIF

IF (ECHO.GE.1) THEN
  WRITE(6,600) ((RUNCAT(I,J), J=1,7), I=1,5)
  WRITE(6,610) ((RUNDAYS(I,J), J=1,7), I=1,5)
  WRITE(6,620) ((TPRSIST(I,J), J=1,7), I=1,7)
ENDIF
C23456789012345678901234567890123456789012345678901234567890123456789012
C
C   RETURN
600 FORMAT(//1X,'RUNCAT' / (1X,7I4))
610 FORMAT(//1X,'RUNDAYS' / (1X,7I4))
620 FORMAT(//1X,'TPRSIST' / (1X,7I4))
C   END
C
C
C   SUBROUTINE PRSTOUT(PRSTVAR,STAPROW,ENDPROW)
C
C THIS SUBROUTINE PRINTS OUT THE TABLE OF PERSISTENCE FREQUENCIES
C
C CHARACTER*17 VARNAME(4)
C CHARACTER*10 CATNAME(7,5), RLABEL
C CHARACTER*8 SEASON
C
C REAL PERCENT(8), TABLTOT
C
C INTEGER COLTOT(7), ROWTOT(7), TPRSIST(7,7)
C INTEGER ENDPROW, PRSTVAR, STAPROW, TBLCOL, TABINUM, TBLROW
C INTEGER DAY1ST,DAY1ST,MN1ST,MN1LAST,PERBEG,PEREND,YR1ST,YR1LAST
C INTEGER STASync, STAPRSG, STAGROW, STAGCOL
C INTEGER ENDSync, ENDRSG, ENDGROW, ENDGCOL
C
C LOGICAL CLIMPER, PRC2CAT
C
C COMMON /DATES/ DAY1ST, DAY1ST, MN1ST, MN1LAST, PERBEG,
C *             PEREND, YR1ST, YR1LAST
C COMMON /FLAGS/ CLIMPER, PRC2CAT
C COMMON /LABELS/ CATNAME, RLABEL, SEASON, TABINUM, VARNAME
C COMMON /LIMITS/ STASync, STAPRSG, STAGROW, STAGCOL,
C *             ENDSync, ENDRSG, ENDGROW, ENDGCOL
C COMMON /PERSTNC/ TPRSIST
C
C DATA COLTOT/7*0/, ROWTOT/7*0/
C23456789012345678901234567890123456789012345678901234567890123456789012
C
C   TABLTOT = 0.0
C   DO 100 J = 1, 7
C     DO 150 I = STAPROW, ENDPROW
C       COLTOT(J) = COLTOT(J) + TPRSIST(I,J)
C       ROWTOT(I) = ROWTOT(I) + TPRSIST(I,J)
C     CONTINUE
C   TABLTOT = TABLTOT + FLOAT(COLTOT(J))
C 100 CONTINUE
C   WRITE(6,625) TABINUM
C   WRITE(6,600) VARNAME(PRSTVAR)
C   WRITE(6,610) STAGROW, ENDGROW, STAGCOL, ENDGCOL
C   IF (CLIMPER) THEN
C     WRITE(6,635) SEASON, YR1ST, YR1LAST
C   ELSE
C     WRITE(6,645) PERBEG, PEREND
C   ENDIF
C   WRITE(6,640) (CATNAME(TBLCOL,5),TBLCOL=1,7), RLABEL

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```

      WRITE(6,700) CATNAME(TBLROW,PRSTVAR),
      (INT(TRANSITN(TBLROW,TBLCOL,L)),TBLCOL=1,7),
      INT(ROWTOT(TBLROW,L)),PERCENT(8)
250  CONTINUE
      PERCENT(8) = 1.0
      WRITE(6,720) (INT(COLTOT(TBLCOL,L)),PERCENT(TBLCOL),TBLCOL=1,7),
      INT(TABLTOT(L)), PERCENT(8)
200  CONTINUE
      WRITE(6,750) NUMCALL
      RETURN

600  FORMAT(/,42X, A17, ' SPACE TRANSITION FREQUENCIES'/)
605  FORMAT(54X, 'SPACE LAG IS', I3, ' BOX')
610  FORMAT(/,40X, ' GRID LIMITS :  ROWS', I2, ' - ', I2,
      ' COLUMNS', I2, ' - ', I2)
615  FORMAT(/,44X, 'CENTER BOX GRID COORDINATES ARE  (', I2,',',
      I2,',') )
625  FORMAT(1H1,14(/),62X,'TABLE ',I3//)
635  FORMAT(20X,'CLIMATOLOGICAL SAMPLING PERIOD IS  ',A8,
      ' ,YEARS  19', I2, '-19', I2//)
640  FORMAT(/,1X,131('-')/ 1X,'OLD SC / NEW SC=', 3X, A12, 6A12,
      ' 12X, A10 / 1X, 131('-') )
645  FORMAT(35X,'CHRONOLOGICAL SAMPLING PERIOD IS FROM  19',I6,
      ' TO 19', I6//)
675  FORMAT(/ 1X, A2, ' BOX' /)
700  FORMAT(1X, A10, 5X,'-',I9, 6I12, 10X, '- ',I9, 2X,'( ',F5.3,
      ')')
720  FORMAT(1X,131('-')/1X,'COLUMN TOTALS',2X,'-',2X,7(I7,'/',F4.2),
      ' 5X,'-',I9,2X,'( ',F5.3,'')/1X,131('-')//)
750  FORMAT(/, ' TOTAL NUMBER OF CALLS TO  S/R STRNSTN WAS', I6)
      END

```

```

      SUBROUTINE  TTRNSTN(GRIDCAT,FIRST,PRC2CAT,ECHO,LAG)

```

```

      THIS SUBROUTINE UPDATES THE TIME TRANSITION MATRIX 'TRANSITN' FOR ONE
      DAY'S VALUES OF 'GRIDCAT' TO TRACK WHAT NEW CATEGORY THE PREVIOUS
      DAY'S HAS CHANGED TO

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```

      LAG      - NUMBER OF DAYS SEPARATING THE TWO FIELDS TO BE COMPARED
      NEXTUPD  - NEXT ARRAY OF 'PREVCAT' TO BE UPDATED
      NEXTCMP  - NEXT ARRAY OF 'PREVCAT' TO BE COMPARED WITH 'GRIDCAT'
      NUMCALL  - NUMBER OF TIMES THIS SUBROUTINE HAS BEEN CALLED
      PREVCAT  - ARRAY HOLDING PREVIOUS WEEK'S VALUES OF 'GRIDCAT'

```

```

      REAL      TRANSITN(7,7)
      INTEGER   PREVCAT(5,7,8)
      INTEGER   GRIDCAT(5,7)
      INTEGER   ECHO, GRDCAT1, GRDCAT2, LAG
      INTEGER   NEXTCMP, NEXTUPD, NUMCALL, OLDCAT
      INTEGER   STASYN, STAPRS, STAGROW, STAGCOL
      INTEGER   ENDSYN, ENDPRS, ENDGROW, ENDGCOL
      LOGICAL   FIRST, PRC2CAT

```

```

      COMMON /LIMITS/ STASYN, STAPRS, STAGROW, STAGCOL,
      ENDSYN, ENDPRS, ENDGROW, ENDGCOL
      COMMON /TRANSITN/ TRANSITN, NUMCALL, NEXTUPD, NEXTCMP

```

```

      IF (LAG.GT.8) THEN
        WRITE(6,987) LAG
987  FORMAT(/,1X,'LAG = ', I3, ' IS TOO LARGE'//)
        STOP
      ENDIF

```

```

      IF (.NOT.FIRST) THEN

```

```

        IF (NUMCALL .GE. LAG) THEN
          DO 10 J = STAGCOL, ENDGCOL
            DO 20 I = STAGROW, ENDGROW
              GRDCAT1 = GRIDCAT(I,J)
              GRDCAT2 = 0
              IF (GRDCAT1 .GT. 7) THEN
                GRDCAT1 = GRDCAT1 / 10
                GRDCAT2 = GRDCAT1*10 - 10*GRDCAT1

```

```

            ENDIF
            OLDCAT = PREVCAT(I,J,NEXTCMP)
            IF (OLDCAT.GT.7 .OR. OLDCAT.LT.1) THEN
              WRITE(6,900) I, J, NEXTCMP
              STOP 91
            ENDIF
            IF (GRDCAT2 .GT. 0) .AND. PRC2CAT) THEN
              TRANSITN(OLDCAT,GRDCAT1)=TRANSITN(OLDCAT,GRDCAT1)+0.5
              TRANSITN(OLDCAT,GRDCAT2)=TRANSITN(OLDCAT,GRDCAT2)+0.5
            ELSE
              TRANSITN(OLDCAT,GRDCAT1)=TRANSITN(OLDCAT,GRDCAT1)+1.0
            ENDIF
          CONTINUE
        CONTINUE
        NEXTCMP = NEXTCMP + 1
        IF (NEXTCMP .EQ. 9) NEXTCMP = 1
      ENDIF
C23456789012345678901234567890123456789012345678901234567890123456789012
      ELSE

```

```

        NEXTCMP = 1
        NEXTUPD = 1
        NUMCALL = 0
        DO 30 J = 1, 7
          DO 32 I = 1, 7
            TRANSITN(I,J) = 0.0
          CONTINUE
        CONTINUE
        DO 36 J = 1, 8
          DO 38 I = 1, 7
            DO 40 L = 1, 5
              PREVCAT(L,I,J) = 0
            CONTINUE
          CONTINUE
        CONTINUE

```

```

      ENDIF
      IF (ECHO .GE. 1) THEN
        WRITE(6,630) NUMCALL, NEXTUPD, NEXTCMP
        WRITE(6,600) ((PREVCAT(I,J,NEXTUPD),J=1,7), I=1,5)
        WRITE(6,610) ((GRIDCAT(I,J),J=1,7), I=1,5)
        WRITE(6,620) ((TRANSITN(I,J),J=1,7), I=1,7)
      ENDIF

```

```

      DO 50 J = STAGCOL, ENDGCOL
        DO 60 I = STAGROW, ENDGROW
          GRDCAT1 = GRIDCAT(I,J)
          IF (GRDCAT1 .GT. 7) GRDCAT1 = GRDCAT1 / 10
          PREVCAT(I,J,NEXTUPD) = GRDCAT1
        CONTINUE
      CONTINUE
      NEXTUPD = NEXTUPD + 1
      IF (NEXTUPD .EQ. 9) NEXTUPD = 1
      NUMCALL = NUMCALL + 1
C23456789012345678901234567890123456789012345678901234567890123456789012

```

```

      RETURN
600  FORMAT(/,1X,'PREVCAT' / (1X,7I5))
610  FORMAT(/,1X,'GRIDCAT' / (1X,7I5))
620  FORMAT(/,1X,'TRANSITN' / (1X,7F5.1))
630  FORMAT(/,1X,'NUMCALL, NEXTUPD, NEXTCMP:',3I6)
900  FORMAT(/, ' *** ERROR ***  INVALID SUBSCRIPT VALUE FOR "PREVCAT"',
      ' /' I,J,NEXTCMP:',3X,3I5//)
      *
      END

```

```

      SUBROUTINE  TRNSOUT(PRSTVAR,STAPROW,ENDPROW,LAG)

```

```

      THIS SUBROUTINE PRINTS OUT THE TABLE OF TIME TRANSITION FREQUENCIES

```

```

      CHARACTER*17  VARNAME(4)
      CHARACTER*10  CATNAME(7,5), RIABEL
      CHARACTER*8    SEASON

```

```

      DATA  SEASON / 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000

```

```

REAL      COLTOT(7), ROWTOT(7)
INTEGER   ENDPROW, PRSTVAR, STAPROW, TBLCOL, TABLNUM, TBLROW
INTEGER   DAY1ST, DAY1ST, MN1ST, MN1LAST, PERBEG, PEREND, YR1ST, YRLAST
INTEGER   STASync, STAPRSG, STAGROW, STAGCOL
INTEGER   ENDSync, ENDPMSG, ENDGROW, ENDGCOL
INTEGER   LAG, NUMCALL

LOGICAL   CLIMPER, PRC2CAT

COMMON   /DATES/ DAY1ST, DAY1ST, MN1ST, MN1LAST, PERBEG,
*         PEREND, YR1ST, YRLAST
COMMON   /FLAGS/ CLIMPER, PRC2CAT
COMMON   /LABELS/ CATNAME, RLABEL, SEASON, TABLNUM, VARNAME
COMMON   /LIMITS/ STASync, STAPRSG, STAGROW, STAGCOL,
*         ENDSync, ENDPMSG, ENDGROW, ENDGCOL
COMMON   /TRANSITN/ TRNSITN, NUMCALL, NEXTUPD, NEXTCMP

DATA     COLTOT/7*0.0/, ROWTOT/7*0.0/

```

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```

TABLTOT = 0.0
DO 100 J = 1, 7
  DO 150 I = STAPROW, ENDPROW
    COLTOT(J) = COLTOT(J) + TRNSITN(I,J)
    ROWTOT(I) = ROWTOT(I) + TRNSITN(I,J)
  150 CONTINUE
  TABLTOT = TABLTOT + COLTOT(J)
100 CONTINUE
  WRITE(6,625) TABLNUM
  WRITE(6,600) VARNAME(PRSTVAR)
  WRITE(6,605) LAG
  WRITE(6,610) STAGROW, ENDGROW, STAGCOL, ENDGCOL
  IF (CLIMPER) THEN
    WRITE(6,635) SEASON, YR1ST, YRLAST
  ELSE
    WRITE(6,645) PERBEG, PEREND
  ENDIF
  WRITE(6,640) (CATNAME(TBLCOL,PRSTVAR),TBLCOL=1,7), RLABEL
  DO 200 TBLROW = STAPROW, ENDPROW
    PERCENT(8) = ROWTOT(TBLROW) / TABLTOT
    PERCENT(TBLROW) = COLTOT(TBLROW) / TABLTOT
    WRITE(6,700) CATNAME(TBLROW,PRSTVAR),
*              (INT(TRNSITN(TBLROW,TBLCOL)),TBLCOL=1,7),
*              INT(ROWTOT(TBLROW)),PERCENT(8)
  200 CONTINUE
  PERCENT(8) = 1.0
  WRITE(6,720) (INT(COLTOT(TBLCOL)),PERCENT(TBLCOL),TBLCOL=1,7),
*              INT(TABLTOT), PERCENT(8)
  WRITE(6,750) NUMCALL
  RETURN

600 FORMAT(/// 42X, A17, ' TIME TRANSITION FREQUENCIES'//)
605 FORMAT(// 56X, 'TIME LAG IS', I3, ' DAYS')
610 FORMAT(// 40X, ' GRID LIMITS :  ' ROWS', I2, ' - ', I2,
*         ' COLUMNS', I2, ' - ', I2)
625 FORMAT(1H1,18(/),62X,'TABLE ',I3//)
635 FORMAT(20X,'CLIMATOLOGICAL SAMPLING PERIOD IS ',A8,
*         ' YEARS 19', I2, '-19', I2//)
640 FORMAT(//1X,131('-')/ 1X,'OLD SC ! NEW SC=', 3X, A12, 6A12,
*         12X, A10 / 1X, 131('-') / )
645 FORMAT(35X,'CHRONOLOGICAL SAMPLING PERIOD IS FROM 19',I6,
*         ' TO 19', I6//)
700 FORMAT(1X, A10, 5X,'=',I9, 6I12, 10X, ' ',I9, 2X,'( ', F5.3,
*         ')')
720 FORMAT(1X,131('-')/1X,'COLUMN TOTALS', 2X,'-', 2X,7(I7,'/',F4.2),
*         5X,'=',I9,2X,'( ',F5.3,')' /1X,131('-')
750 FORMAT(// ' TOTAL NUMBER OF CALLS TO  S/R TTRNSTN WAS', I6)
END

```