9B.3 USING A SYNOPTIC CLASSIFICATION SYSTEM TO ASSESS CLIMATE TRENDS AND VARIABILITY IN TEXAS

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1. INTRODUCTION

The Spatial Synoptic Classification (SSC) system is a recently-developed scheme designed to determine air mass types on a station-by-station level, and integrate these over a larger domain into spatially cohesive air mass regions (Kalkstein et al. 1996). Spatial cohesiveness is an important benefit in using the SSC, as it fosters easy comparison from station to station within a region as well as from region to region.

This paper examines the characteristics of and recent trends in air masses, as defined by the SSC, for thirteen stations in Texas for the summers (June, July, and August) of 1961-1990. Texas is a good region for this initial evaluation, for its diversity promotes numerous possibilities to examine, and the stations' relative proximity also promotes an examination of the cohesiveness of the SSC system itself.

2. METHODS AND DATA

The methodology involved with the Spatial Synoptic Classification (SSC) procedure is quite complex; please refer to Kalkstein et al. (1996) for detailed explanation. Following identification of 'seed days' typical of each of the six air masses listed below, the SSC then classifies each day into one category based on discriminant function analysis. It incorporates six meteorological parameters (at six hour intervals): temperature, dew point temperature, pressure, cloud cover, and the u- and v- components of the wind vector. The air masses are:

- **DP (Dry Polar),** synonymous with the traditional cP classification.
- **DT (Dry Tropical)**, synonymous with cT.
- **DM (Dry Temperate)** has no analog in the historical classification system. It has been defined for the Continental U.S. as 'transformed Pacific air', or orographically dried Pacific air. This air mass is usually more humid than DP or DT air, and features temperatures somewhere between the two.
- **MP (Moist Polar)** and **MM (Moist Temperate)** together comprise the traditional mP air mass. MM air typically contains somewhat higher dew points and temperatures than MP air.
- **MT (Moist Tropical)** is the same as mT.

A **transition (TR)** day is also defined to account for days in which a change in air mass occurs.

The data used in this study have been extracted from several sources. The six-hourly values of the six meteorological parameters mentioned above are extracted from the National Climate Data Center (NCDC) records of Surface Airways observations. Precipitation data for the different climate regions is also based on NCDC records.

3. RESULTS AND DISCUSSION

3.1 Air mass climatology

During the summer, three of the six air mass categories dominate (84% of all days) Texas: DM, DT, and MT. MT air is the most abundant overall; although its frequency is highly variable. Along the coast, MT air is present on more than eight of ten days, in Central Texas the value falls to slightly less than half of all days, and on the Edwards Plateau and in the Panhandle less than one in five days feature MT air. No MT air is identified in El Paso. Mean temperature with MT air ranges from 24° in the Panhandle to 29°C along the coast; dew points range from 17° to 23°C.

DT air mass frequency displays a pattern somewhat opposite of MT. El Paso, on the flank of the DT source region, is under the influence of this air mass most often, once every three days. The frequency decreases eastward, stations in the central part of the state observe DT between 18% and 28% of days. The frequency declines in the Panhandle to near 15%; the sharpest distinction, however, is noted between Waco and Austin, where mean DT frequency falls from 25% to 8%. Values continue to decrease towards the coast to near 0% by Brownsville and Corpus Christi. Unsurprisingly, the mean conditions with DT air are the hottest and driest of the air masses, with mean temperatures ranging from 28° (coast) to 32°C (west) and dew points between 7° in El Paso and 21° in Brownsville. The large dew point gradient suggests that DT air is more easily modified than MT air with regards to moisture characteristics.

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The DM air mass is the second most prominent in the state. The frequency distribution is somewhat similar to DT: highest frequencies occur in the western half of the state, with values higher for DM (39% - 53%) than DT (15% - 34%). In the eastern half of the state, values are once again near zero at the coast, however, among the Central Texas stations, frequencies *increase* southward (San Antonio 35% vs. Dallas-Fort Worth 16%), directly opposite the pattern of DT frequencies. It appears that in Western Texas DM air represents monsoonal flow; in the rest of the state it appears to be a classification midway between MT and DT. Mean temperatures with DM air are between 25° and 29°C, dew points between 14° and 19°C.

The other three air masses comprise only approximately 10% of summertime days statewide. DP air has a frequency of greater than 3% at only two stations, Amarillo and El Paso. MP and MM air masses together occur on 3% to 9% of days. Transition (TR) days comprise the remaining 4% to 8% of days.

3.2 Air mass frequency trends

As expected, during the 30-year period studied, annual frequencies of different air masses are highly variable. For instance, Dallas - Fort Worth had 65 days of DT air in 1980, and no days in 1973. Yet over the 30 years, very few statistically significant trends in air mass frequency occurred. Most of those identified were associated with air masses which rarely occur. However, one decline deserves further attention: the decrease in frequency in DM air in Austin and Waco.

Austin's records show the single most significant trend. From 1961-1970, DM air appears on 35% of days; in the following decades, this frequency falls to 28% and 20%. The decrease appears to be associated partially with an increase in MT air mass, whose decade averages are 38%, 50%, and 50%. As mean dew points and temperatures of the two air masses are rather similar (MT air masses are 0.6° cooler and 1.7° more humid), it is possible that a minor change could lead to these significant results, although, as mentioned, the trend also appears in Waco's record, albeit not as extreme (14% over 30 years).

An examination of nearby San Antonio's record yields different results. A drop similar to Austin's from the 1961-1970 period to 1971-1980 period occurs (41% to 23%), but this value rebounds back to 40% during 1981-1990. Two "breaks" in the DM pattern, a sharp fall in the early 1970s, and a sharp rise in the early 1980s are noticeable. While the timing of the first decline matches that of the first decline in Austin, the rebound in the 1980s has no analogue in Austin; there is no reported station move or instrumentation change at either city which corresponds to this latter discrepancy.

3.3 Air mass character trends

Statistical analyses show no significant trend in mean temperature for any air mass at any station, however, two instances of statistically significant increases in mean DM air mass dew point appear, at El Paso and Midland. Both stations also show statistically significant increases in their overall mean dew point. These sharp increases in (2.0°C over 30 years), depicted in Figure 1, apparently began in both cities sometime between 1975 and 1980. No such increase occurs with any other air mass at either of these stations. As DM air in West Texas is largely advected in, and both stations report similar trends, it promotes the possibility that this is not a microclimate problem but rather a regional phenomenon; more stations in the Desert Southwest need to be examined to evaluate its extent. In Texas, though, the effect is cohesive but drops off sharply: there are 30-year increases (not statistically significant) of dew point of 0.5° - 0.7°C in both Amarillo and Lubbock; further eastward, in San Angelo and Abilene, there is no trend.

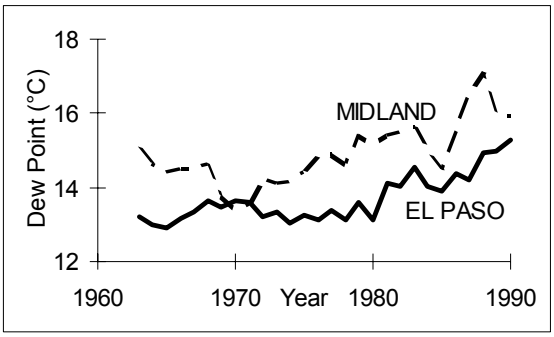

Figure 1. Three year running means of average dew point of DM air masses for El Paso and Midland.

3.4 Anomalous years

Individual seasons have also been examined to determine if air mass frequency differences occur in conjunction with extreme seasonal conditions. As temperature is already included in the evaluation of air masses, this examination focuses only on precipitation anomalies. As expected, a strong negative correlation between precipitation and dry air mass frequency and a positive relationship between precipitation and moist air mass frequency are observed.

Two anomalous years from the period studied, 1980 and 1973, are analyzed in order to assess the applicability spatially. Summer 1980 was one of the hottest and driest summers in recent decades throughout much of eastern Texas. Precipitation totals for the entire summer are well below average in this area. Regions of north central Texas from Dallas-Fort Worth to Lubbock both feature the largest positive DT frequency anomaly (up to 3.5 times the 30-year mean) and the smallest percentage of normal precipitation (less than 40 percent). Values of both parameters become less extreme further south.

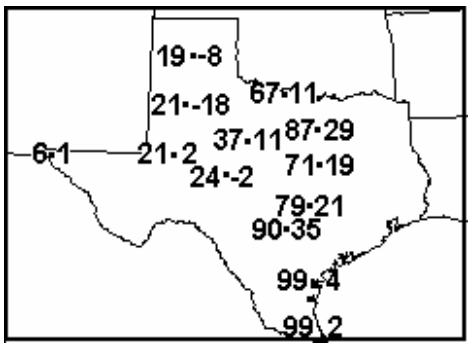

Figure 2. Percentage of days during Summer 1973 with MM, MP, or MT air masses (left), and departure from 1961-1990 mean (right).

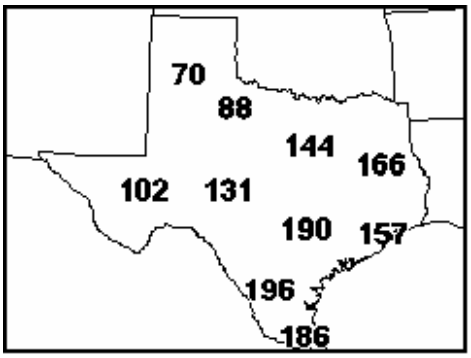

Figure 3. Percentage of normal precipitation for Texas climate zones during Summer 1973.

Summer 1973, conversely, was one of the wettest summers in the 1961-1990 period for eastern and central parts of Texas; stations in the Panhandle generally reported below normal precipitation. (See Figures 2 and 3.) This same dichotomy is indicated in air mass frequency; the highest moist air mass anomalies - ranging from Dallas - Fort Worth to San Antonio, coincide with the regions of well above average precipitation. The only two stations well below mean values - Lubbock and Amarillo - are both located in a climate zone whose mean precipitation was only 70 percent of normal. The usefulness of this procedure obviously wanes as one moves towards the Gulf Coast, where moist air masses are almost always present in summer.

4. SUMMARY AND FURTHER RESEARCH

The application of the SSC to summer air masses in Texas has produced the following results:

- The mean dew point of the DM (monsoonal) air mass appears to be increasing over western Texas. A 2.0°C increase in the mean dew point occurred in El Paso and Midland, with smaller increases further eastward. This pattern is not believed to be a consequence of local desert land use change, due to its spatial cohesiveness and advective nature of the air mass, but instead perhaps of longer term circulation changes.

- The frequency of DM air in Central Texas is on the decline at several stations. Austin, and to a lesser degree Waco, report a significant decline in DM frequency through the three decades. San Antonio shows a similar pattern for the first 15 to 20 years of the period, and then observes a significant increase during the 1980s. There is no station move or instrument change at any of the cities to explain this.

- On a season by season level, air mass frequency appears to correlate well with total precipitation, the primary meteorological variable not included as an SSC categorization criterion.

There are myriad possibilities for the extension of this research. First, air mass moisture trends for other areas in the desert southwest need to be analyzed to assess if the observations noted in this paper are truly regional. A longer-term application of the SSC involves analyzing teleconnection pattern trends, especially the Pacific North America (PNA) and Southern Oscillation Index (SOI) patterns, for connections with air mass frequencies on a seasonal level. Ye and Leathers (1995) have already demonstrated a relationship between winter air mass frequency and PNA index values over the Southeastern United States; a continuation of that study, for all of North America, for both winter and summer, could provide valuable insight to the climate system.

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