10.5 REDEVELOPMENT OF A SPATIAL SYNOPTIC CLASSIFICATION FOR YEAR-ROUND APPLICATION

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1. INTRODUCTION

The Spatial Synoptic Classification (SSC) system is a recently-developed method for classifying days at a particular location into distinct air mass categories, and integrating these classifications over a larger domain into spatially cohesive air mass regions (Kalkstein *et al.* 1996). It has been used in pure climatological studies, including assessments of air mass frequency and character trends (Kalkstein *et al.* 1998, Sheridan 1997), as well as applied studies, including the impact of weather on heat-related mortality (Greene and Kalkstein 1996).

The SSC is a **hybrid** categorization system, employing both manual and automated segments. The initial stage requires manual identification of air masses; once this is completed, an automated classification of days then occurs. The system was originally developed using discriminant function analysis (see Kalkstein *et al.* 1996) for classification purposes. This method restricted the production of calendars to the fairly homogeneous periods of winter (December, January, February) and summer (June, July, August). Subsequent redevelopment, for use in future studies, has sought to extend the calendar year-round. Different procedures for both seed day selection and classification have been developed accordingly. This paper outlines the process by which the SSC now operates, and future plans in its development.

2. AIR MASSES

The SSC identifies six air masses affecting the North American continent:

- **DP (Dry Polar),** synonymous with the traditional cP classification.
- **DT (Dry Tropical)**, synonymous with cT.
- **DM (Dry Temperate)** has no analogue 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, associated with overrunning conditions, typically contains somewhat higher dew points and temperatures than MP air.
- **MT (Moist Tropical)** is the same as mT.

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

3. SEED DAYS

The foundation of the SSC rests upon the proper identification of **seed days** for each location, which represent days with the typical meteorological characteristics of a given air mass at that location. In order to obtain seed days, these typical characteristics need to be initially determined. Based on careful analysis of weather data and maps, six different criteria are chosen - Table 1 presents an example. An automated program selects days which satisfy all criteria. Weather maps for the selected days are then analyzed to confirm that the days chosen do indeed represent the particular air mass for the given location. If the days are deemed to be non-representative, the seed day criteria are then adjusted and the procedure repeated.

The original SSC selected days from the entire three-month period which comprises the season examined. The inadequacy of this method during transition seasons is apparent - "typical" air mass character changes over the course of weeks. To facilitate year-round applicability, a method known as **sliding seed days** was developed. This method involves the identification of seed days in four two-week "windows" throughout the year, and the creation of an algorithm to produce an artificial seed day for each air mass for each day of the year. This method assures the gradual change inherent in the climate system, yet does not involve a burdensome amount of air mass identification. The four periods shift based on location, and correspond roughly to the hottest and coldest two weeks and the halfway points between them.

To obtain the sliding seed days, two different annual curves are created and superimposed for each air mass for each of the twelve variables listed in Table 2. The long-term (period of record) mean of a particular variable for each day of the year is calculated, and this annual march is fit by a tenth-order polynomial. An adjustment curve is then calculated for each variable for each air mass. This curve starts with four points: for each of the air mass selection periods, the difference between the mean overall value and the mean seed day value is calculated. A linear function is then fit to these differences. The overall curve and difference curve are then summed, and a new polynomial is fit to these data.

This process is repeated for every air mass for every variable. The resultant curves can then be evaluated for any particular day of the year, and produce a "typical" set of characteristics for each air mass on that day.

Table 1. Example of seed day selection criteria. DP air mass, Wilmington, DE, winter period 15 - 28 January.

Parameter	**Lower limit**	**Upper limit**
Maximum temperature	-3°C	3°C
Minimum temperature	-13°C	-7°C
16 h EST dew point	none	none
16 h EST dew point depression	8°C	none
Mean daily cloud cover	0 tenths	7 tenths
Diurnal dew point range	none	7°C

Table 2. The twelve variables used in daily evaluation.

04 h EST Temperature	04 h EST Dew Point
10 h EST Temperature	10 h EST Dew Point
16 h EST Temperature	16 h EST Dew Point
22 h EST Temperature	22 h EST Dew Point
Daily Dew Point Range	Daily Temperature Range
Daily Cloud Cover	Daily Sea Level Pressure

As the spatial cohesiveness of the SSC is paramount, much effort is placed in assuring that neighboring stations have similar criteria for the same air mass, adjusting for local climatic factors. With the original SSC, seed days were picked individually for each station using similar criteria. However, no attempt was made to try to obtain the *same* days for seed days. For the redeveloped system, this is done so that a better assessment of local climatological differences could be made. By using the same day when the same air mass is present over two stations, the local meteorological differences between the two locations can naturally be accounted for.

This procedure begins by analyzing seed day criteria at a new station compared to a neighboring one already completed. Days with similar character (according to several thresholds) are retained, and days in which the character varies markedly are eliminated. An initial evaluation of days is then run; the differences between the two stations are used to modify seed day selection criteria at the second station. Supplemental days are then chosen at the new station, and the SSC is then run again. In general, over 50 percent of days are retained in transfer from one station to another.

Transitional seed days are picked according to three criteria: dew point range, sea level pressure range, and a measure of wind shift. Any day for which all three parameters are at least 1.3 standard deviations above the period mean becomes a TR seed day.

4. EVALUATION

Discriminant analysis, requiring a pool of seed days for each air mass, could not be used as the redeveloped system only produces one "mean seed day" for each day of the year.

Among the several methods evaluated, the simplest method of air mass evaluation, a sum of squared *z*-scores, has produced the best results. For each of the six air masses, the actual conditions on a particular day are compared with the seed day created for that particular day of the year. The squares of the z-scores for each of the variables in Table 2 are then summed, and the air mass with the lowest sum total is the "winning" air mass for the day.

The decision on whether a day is transitional or not is done after the original evaluation. This method is similar to the primary evaluation, except only the three previously mentioned variables are examined for all days. If the transitional sum score is lower, the day is transitional. If it is higher, it retains its original designation.

Results using this new methodology are encouraging. One of the most important evaluation statistics is the "match" percentage, or the percentage of days on which neighboring stations have the same air mass. With the redeveloped SSC, a higher "match" percentage results in virtually all cases. During winter, Philadelphia, PA and Wilmington, DE match on 87 percent of days with the redeveloped system, compared to 73 percent with the old SSC system.

5. FUTURE DEVELOPMENT

The original SSC produced calendars for six months of the year for 150 stations in the contiguous US for the period 1948-1993. In addition to the procedural changes to enable year-round air mass evaluation, the SSC is also undergoing geographic expansion. Additional stations from the contiguous US will be examined, and data for over 100 stations from Canada and Alaska has been obtained. Upon completion, the SSC will include over 340 North American stations; US stations will have calendars from 1948-1997; Canadian stations, 1953-1993.

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