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DISPLAYING THE LATEST CHANGES IN THE TREND OF MIDWEST PRECIPITATION AND IN THE TREND OF LOW-LEVEL FLOW FROM THE GULF OF MEXICO

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1. INTRODUCTION

It has long been established that most of the summer precipitation over the Midwestern United States comes from moisture that originates over the Gulf of Mexico. Information about the daily precipitation outlook is less important from a crop's perspective than information about the weekly precipitation outlook. The precipitation in the Midwestern United States is related to the Great Plains low-level jet (LLJ) (e.g., Blackadar 1957; Bonner 1968; Helfand and Schubert 1995; Higgens et al. 1996, 1997; Mitchell et al. 1995) and to the consistent flux of moist air into the central United States. Schubert et al. (1998) studied moisture transport with the GEOS-1 Data Assimilation System (DAS) (Schubert et al. 1993) and found the LLJ preconditions the Great Plains boundary layer for thunderstorms by providing a major contribution to the time-mean moisture influx. Precipitation was linked to the LLJ on timescales of synoptic or longer because the diurnal scale does not allow enough time for moisture to reach the central United States and be involved in the day's thunderstorms (Schubert et al. 1998). This direct link, on a synoptic or longer timescale, establishes a basis for monitoring the LLJ flow in order to anticipate changes in central United States precipitation.

Changes in the trend of precipitation over the central United States have the potential to change the outlooks for central United States crops and thus have great economic importance. Because of the strong relationship between low-level southerly flow and central United States precipitation, the precipitation trend should change soon after a change in the trend of the low-level flow. Climatologies of low-level flow and precipitation seem to support this, so following trends of low-level flow should be useful for evaluating future growing season precipitation fluctuations and subsequent crop outlook.

2. METHODOLOGY AND DATA

Schubert et al. (1998) studied the moisture flux at a grid point near the location of Fort Worth, Texas as a simple means of evaluating different timescale signals of moisture transport into the Great Plains. Besides the benefits of simplicity, Schubert et al. (1998) felt that the overall flux would be adequately represented with the flux at a single grid point because of the strong spatial coherence of the LLJ. Wind variations mostly account for the flux variation over Texas, and the wind is mostly geostrophic at synoptic and longer timescales are other conclusions from Schubert et al. (1998) that impart further foundation for the variable utilized in this study. Other investigators have also observed the large dependence of moisture flux on the wind (e.g., Wang and Paegle 1996; Whiteman et al. 1997; Hu and Feng 2001). Therefore, a single wind variable should also be adequate to represent the low-level flow.

The vicinity of Fort Worth, Texas and the area south is generally the location with highest northward moisture flux (e.g., Helfand and Schubert 1995; Mo et al. 1997; Higgens et al. 1997). Because of the substantial moisture flux and the upstream position (upstream of important southerly flow) from the Midwest, the east central Texas region is the place focused on for finding reliable wind information for the desired period. Thus, a first consideration of a low-level flow variable, for first establishing climatology and then for monitoring, would be the radiosonde winds reported at Fort Worth or stations south. However, using measured winds was dismissed upon consideration of calculating the average geostrophic wind over the east central Texas area.

The 850 hPa level was selected for use in calculation of the geostrophic wind because although the 1400-1600 m height of the 850 hPa level is significantly higher than the height of the diurnal LLJ (e.g., Bonner 1968; Michell et al. 1995; Whiteman et al. 1997) it has potential to be a steady wind data source for long climatologies since it is a mandatory level for radiosonde observations. An example time series shown by Schubert et al. (1998) displays the diurnal LLJ smoothed over at 850 hPa, but the event that enhances the stronger diurnal LLJs is still clear. Because of the interest here in subweekly and submonthly scales, the smoothing is desirable. Higgens et al. (1997) and Helfand and Schubert et al. (1995) show similar examples, but the diurnal signal is still intact at about the 850 hPa level. On longer scales, such as seasonal (Hu and Feng 2001b) or the duration of a wet or dry event (Mo et al. 1997), the peak meridional wind tends to be at about the 850 hPa level for the concerned area.

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position (upstream of important southerly flow) from the Midwest, the east central Texas region is the place focused on for finding reliable wind information for the desired period. Thus, a first consideration of a low-level flow variable, for first establishing climatology and then for monitoring, would be the radiosonde wind observations reported at Fort Worth or stations south. However, it is not uncommon for data to be missing for several days, so in the interest of improving consistency, it would be beneficial to involve more than one station. Except for a station at Stephensville, Texas from 1974 to 1994, no other consistent stations are close to and south of the Fort Worth station for the selected time period. Station spacing is such that there is a relatively large region in east central Texas with no radiosonde stations. The stations at Del Rio, Texas (DRT; 29.4 N, 100.9 W), Midland, Texas (MAF; 31.9 N, 102.2 W), Corpus Cristi, Texas (CRP; 27.7 N, 97.1 W), and Lake Charles, Louisiana (LCH; 30.1 N, 93.2 W) are quite far from Fort Worth, Texas (FWD; 32.8 N, 97.4 W) and it does not seem logical to guess the wind data from those stations would have strong ties to the FWD wind data. Therefore, using measured winds was dismissed upon consideration of calculating the average geostrophic wind over the east central Texas area. Radiosonde stations at DRT, MAF, LCH, and Jackson, Mississippi (JAN; 32.3 N, 90.1 W) have provided reasonably consistent data for the 1958 to 1999 period and look to be stable in upcoming years. For these four stations, 850 hPa radiosonde height observations were assembled from Radiosonde Data of North America 1946 to 1992 (1993), Radiosonde Data of North America 1994 to 1997 (1998), http://raob.fsl.noaa.gov/, and http://weather.uwyo.edu/upperair/sounding.html. Heights from DRT and MAF (LCH and JAN) were averaged into one western (eastern) height to be used in Equation 1 to calculate the meridional 850 hPa geostrophic wind (V_g).

$$V_g = (Z_e - Z_w)\, g\, (\Delta x)^{-1}\, f^{-1} \qquad (1)$$

Z_e is the average of the geopotential heights at the 850 hPa pressure level for LCH and JAN, Z_w is the average of the geopotential heights at the 850 hPa pressure level for DRT and MAF, g is gravitational acceleration, Δx is the approximate distance between the eastern stations and the western stations, and f is the Coriolis parameter ($g\,(\Delta x)^{-1}\, f^{-1} \sim 0.14$).

When the height was missing from a particular station and reporting time, the average height was derived as a function of the non-missing height. The function was determined by linear regression of all average heights that were computed and the corresponding individual station height data. This methodology provided a calculated 850 hPa meridional geostrophic wind data set that was quite consistent. Data set gaps at this time include one day in May 1998 and three days in July 1998 where both western stations' heights were missing. During the summer of 1963 and parts of the summers of 1969 and 1970, JAN heights were missing, but all of the corresponding LCH heights were archived.

Hu and Feng (2001a) found high teleconnections of central United States rainfall to El-Niño Southern Oscillation (ENSO) from 1870 to 1916 (Epoch 1) and from 1949 to 1978 (Epoch 3). From 1917 to 1948 (Epoch 2) and from 1979 to 1997 (Epoch 4), they found that the ENSO teleconnection to central United States rainfall broke down even though the rainfall continued to have consistent interannual variations. To explain central United States rainfall variations when a relationship to ENSO was found to be insignificant, Hu and Feng (2001b) investigated the role of low-level southerly flow from the Gulf of Mexico with composites constructed from wet years and from dry years. Hu and Feng (2001b) found the low-level southerly flow had a significant relationship to central United States rainfall when the role of ENSO decreased (Epoch 4), and that the southerly flow connection to central United States rainfall was insignificant when the ENSO connection was significant (Epoch 3). Though the composites from Hu and Feng (2001b) were for entire summers, weekly contributions to the composites may be discernable. Based on this interesting possibility, the years 1958 to 1999 were selected for the base low-level flow climatology, which puts 21 years into Epoch 3 and, assuming 1998 and 1999 are consistent with Epoch 4, 21 years into Epoch 4. One hundred twenty five summer days, namely May 1 to September 2, were selected as the study period for each year. Between the two radiosonde reporting times, 0000 UTC and 1200 UTC, the 850 hPa flow climatology was based on the 0000 UTC reports because they were usually earlier than any daily precipitation reporting times, which may have happened to change during the years. The 0000 UTC radiosondes miss the time of the peak LLJ (about 0800 UTC or 0200 CST) (e.g., Mitchell et al. 1995; Whiteman et al. 1997), and thus helps to smooth the diurnal signal in the 850 hPa meridional wind.

The calculated wind acts as a low-level flow index and somewhat represents both anomalous cyclones in the lee of the Rocky Mountains and westward extension of the Bermuda High. The circulation associated with the subtropical ridge is an explanation for large scale forcing of low-level southerly flow into the United States (Wexler 1961). Although the Atlantic subtropical high is mentioned in a causal context from time to time (e.g., Helfand and Schubert 1995; Mo et al. 1997; Walters 2001), Mitchell et al. (1995) make the observation that the LLJ tends to occur in the warm sector of the extratropical cyclone and summarize how a major contribution to the LLJ by the subtropical high contradicts findings by Uccellini (1980) and Chen and Kpaeyeh (1993) that lee side troughing and surface cyclogenesis are key factors. Schubert et al. (1998) associate LLJs on different time scales with interaction between various scale troughs and the Rocky Mountains.

Precipitation data was downloaded from NOAA National Data Center Climate Data Online (http://cdo.ncdc.noaa.gov/) which provides archives of daily National Weather Service Cooperative Observers Program station data. The studied precipitation region was defined according to climate district, such that all available stations in the southern three districts in Minnesota, the southern six districts in Wisconsin, the northern two districts in Missouri, the northeast and east central districts in Kansas, the eastern three districts in Nebraska, the southeast and east central districts in South Dakota, and all nine districts in Illinois, Indiana, and Iowa were included (Figure 1). The daily total precipitation was averaged over all stations for the same summer period (May 1 to September 2) and years (1958 to 1999).

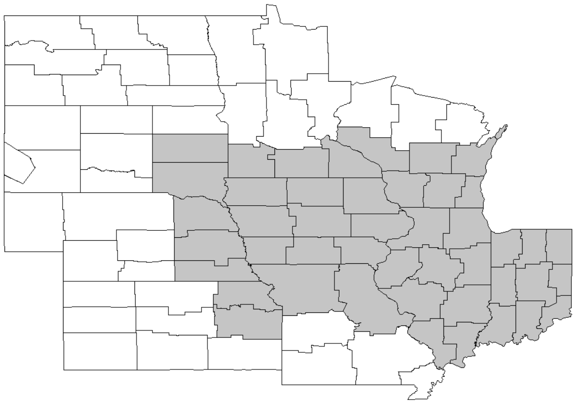

Figure 1. Shaded area is the region from which all available precipitation stations were selected.

Although the wind was calculated once daily instead of twice, the different precipitation reporting times for different stations and different years make direct interpretation on a daily scale difficult. Roads et al. (1994) treated this timing problem by considering only particular 5-day averages of the hydrological variables called pentads. Gutowski et al. (1997) also followed this methodology. Mo et al. (1997) used 5-day running average precipitation to select wet and dry events for the composites they assembled. Because of the interest in a precipitation outlook, the trend analysis section will deal with 5-day running average instead of pentads. A running average over a 10-day scale is also utilized. The daily low-level flow is displayed in the product at the time of publication, but no attempt was made to find a direct relationship to daily precipitation.

3. TREND ANALYSIS

"The moving average convergence-divergence trading method (usually abbreviated to MACD) was originally developed in 1979 by Gerald Appel as a stock market timing device. ... The basic MACD signal is the crossover. Buy signals are generated when the faster line crosses the slower line from below, and sell signals are just the opposite....One very interesting way of using a MACD is to get a jump on a crossover signal by drawing a trendline on the MACD itself and then trading when the trendline is broken, rather than waiting for the crossover. A break in an MACD trendline can precede an important break in the market, and it serves as an early warning signal that a market is turning. MACD crossovers that are preceded by or in conjunction with a trendline break tend to have much more technical importance than MACD crossovers alone....Remember, if you trade based solely on a break in the trendline without waiting for the crossover, the trade will have little justification if the crossover fails to occur in the near future." (LeBeau and Lucas 1992)

Instead of strictly applying the specifics of Appel's (1985) system, a simple dual moving average analysis was performed on the low-level flow variable. For the longer term average, a 10-day moving average was selected while a 5-day moving average was selected for the short term. Not surprisingly, the 10-day precipitation and the 10-day meridional wind followed each other closely as did the daily precipitation and meridional wind. Quite often the same information could be attained from the precipitation trend as the trend of the meridional wind. However, the utility of "index" data is associated with forecast user confidence. Decision makers more readily accept forecasts when the principal forcing factor(s) is(are) annunciated.

4. RESULTS

About 80% of the times that the meridional wind 10-day running average was at a relative maximum (minimum), the 5-day running average trend break and subsequent crossover indicated the next 7 to 10 days would indeed be drier (wetter) than the last 7 to 10 days (a success; Figure 2). Only about 20% of the trend breaks and subsequent crossovers indicated the next 7 to 10 days would be as dry or wet than the last 7 to 10 days (a failure; Figure 3). For many of the successes, a 2-4-day lag occurred between the beginning (ending) of precipitation days and the meridional wind running average minimum (maximum). Short term operational numerical weather prediction models would likely have no problem forecasting the 2-day lag, but the indication of precipitation persistence out to 10 days might have advantages over operational medium range forecasts. For drier years, when the 5-day trend break and crossover successfully indicated a change in precipitation, the lag between precipitation change and the meridional wind change was generally longer. This is important because an increasing meridional wind would allow justifiable anticipation of a break in a dry spell.

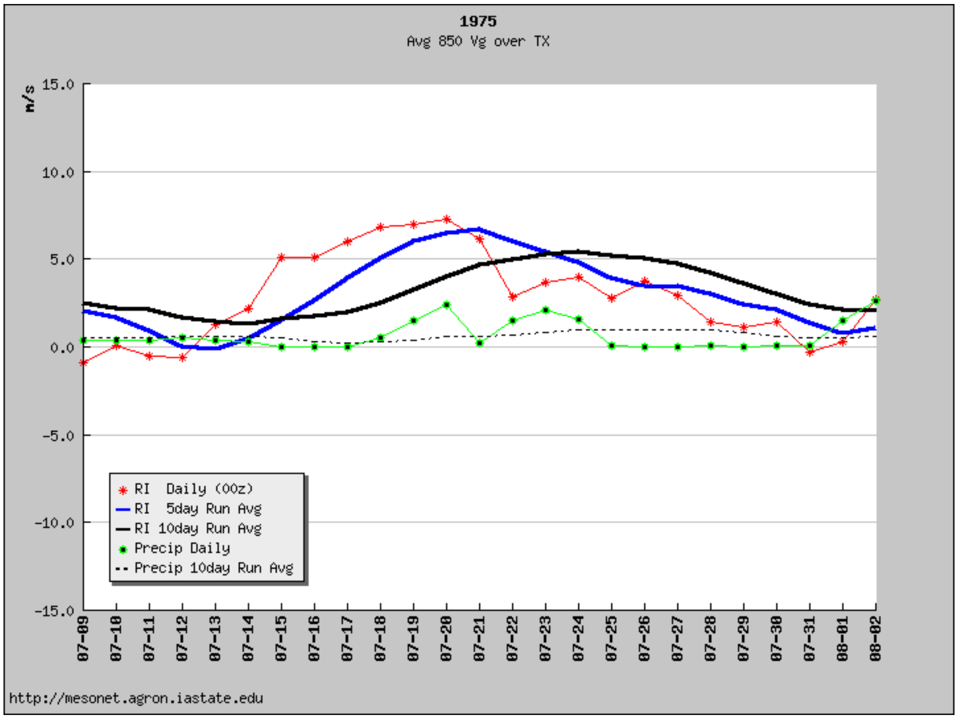

Figure 2 Examples of a downward trend break (07-13) and crossover (07-16) and subsequent increase in precipitation and of an upward trend break (07-21) and crossover (07-24) and subsequent decrease in precipitation.

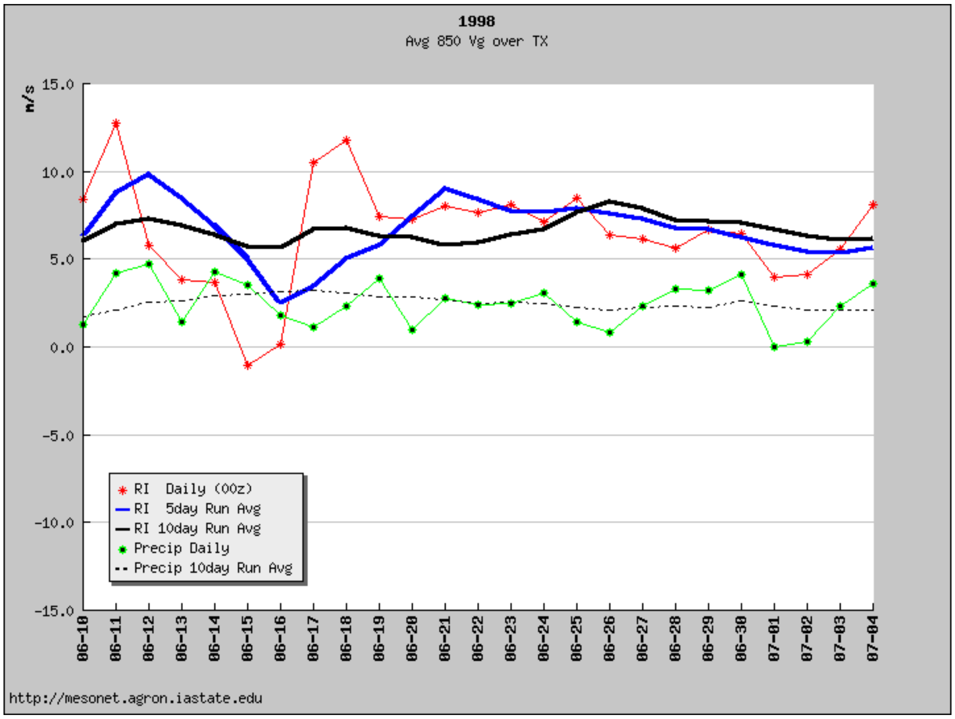

Figure 3 Examples of a downward trend break (06-17) and crossover (06-20) and no subsequent increase in precipitation and of an upward trend break (06-22) and crossover (06-25) and no subsequent decrease in precipitation.

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