P5.14 CONVECTIVE SIGNIFICANT METEROLOGICAL ADVISORY (SIGMET) CLIMATOLOGY

Jonathan W. Slemmer* and Steven R. Silberberg
Aviation Weather Center, Kansas City, Missouri

1. INTRODUCTION

The Aviation Weather Center and its predecessor have been issuing convective SIGMETs (CSIG) since 1978 to define lines and areas of thunderstorms that meet criteria deemed hazardous to aviation (Weiss 1983). This study presents results of a CSIG climatology which complements the thunderstorm and lightning climatologies of e.g. Rassmusson 1971, Wallace 1975, and Bothwell 1998. Because the issuance of a CSIG affects tactical air traffic flow management by denying airspace, the CSIG climatology has the additional feature of quantifying the impact of thunderstorms on the National Airspace System (NAS).

2. DATA AND METHODOLOGY

CSIG are text bulletins routinely issued on an hourly basis at 55 min past the hour. They are also issued whenever an area of convection develops rapidly between routine issuance times. CSIG are subjectively drawn polygons, lines, and circles depicting convection based on the following criteria (http://www.faa.gov/avr/afs/afs400/ac00-45e.pdf):

1. Severe thunderstorms due to:
    a. Surface wind greater than or equal to 50 kt
    b. Hail at the surface greater than or equal to ¾ inches in diameter
    c. Tornadoes
2. Embedded thunderstorms
3. A line of thunderstorms
4. Thunderstorms producing precipitation greater than or equal to heavy precipitation affecting 40% or more of an area at least 3000 square miles.

The CSIG climatology incorporates data from January 1999 through July 2004. Each CSIG was assigned a time at the top of the hour. Non-routine issuances of CSIG were ignored to simplify data processing, and because they are issued infrequently, non-routine CSIG are assumed to have a negligible impact on the CSIG climatology. Each CSIG is interpolated to an 8 km grid covering a CONUS domain from 22ºN, 130ºW in the lower left to 50ºN, 62ºW in the upper right. The interpolation matches CSIG endpoint(s) to VOR locations relative to the grid. The distance and direction from the VOR determines which grid cells are contained in the CSIG. Each grid cell found to be a part of a CSIG object (isolated cell, line, area) is counted as a "hit" and only one "hit" per grid cell is allowed per CSIG object.

The CSIG frequency is the total number of "hits" per grid cell divided by the total number of hours during a time period. For example, if a particular grid cell had 50 hits during May 2004, the frequency of time a CSIG was in effect for that grid cell would be 50 hits divided by 744 hours or 6.72 percent. Additional analyses conducted were percent frequency of severe, mean cloud top height, and mean movement. Mean cloud top height and mean movement per grid cell were determined by having a running total of the cloud top height or movement associated with each CSIG that covers a particular grid cell and dividing by that grid cell's total number of "hits."

3. RESULTS

Plots of CSIG geographic frequency by month during the convective season illustrate the annual cycle of convection (Figs. 1a-h). A plotted color at the lowest threshold means that a grid cell had a CSIG at least 0.5 percent of the time during the month. This means that a grid cell must have at least 4 "hits" for the month to have the lowest threshold color assigned to it.

In March (Fig. 1a), CSIGs are confined to the southeastern US, Southern Plains, and Gulf Stream along the Carolinas. By April (Fig. 1b), the activity spreads further north to the Great Lakes region. The area with the largest frequency

* *Corresponding author address*: Jonathan W. Slemmer, NOAA/National Weather Service, National Center for Environmental Prediction, Aviation Weather Center, 7220 NW 101st Terrace, Room 118, Kansas City, MO 64153-2371; email: Jonathan.Slemmer@noaa.gov

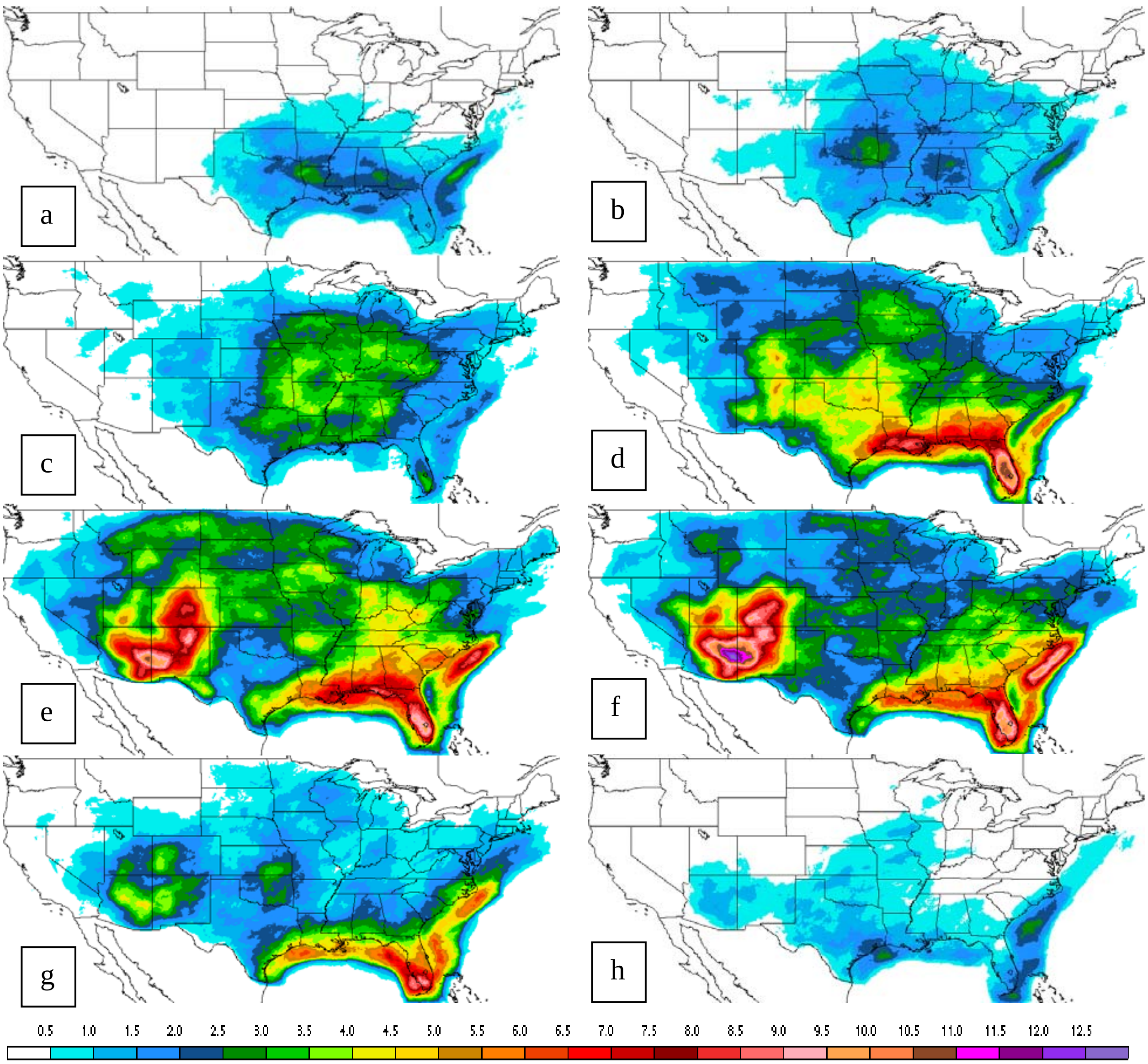

Figure 1. Monthly CSIG Percent Frequency during the convective season (a) March (1999-2004) (b) April (1999-2004) (c) May (1999-2004) (d) June (1999-2004) (e) July (1999-2004) (f) August (1999-2003) (g) September (1999-2003) (h) October (1999-2003).

expands and shifts to the Mississippi and Ohio River Valleys in May (Fig. 1c), with the Northeast and Rockies becoming active. Poleward and longitudinal expansion continues into June (Fig. 1d), with CSIG frequency increasing dramatically along the Gulf and Southeast coastal regions and also over the southern Rockies. By July (Fig. 1e), CSIG frequency reaches its greatest geographical extent and magnitude across the CONUS. The High Plains and Rockies are active and the monsoon is evident over Arizona and New Mexico. In August (Fig. 1f), the same pattern remains but the far northern areas have become less active. As autumn arrives in September (Fig. 1g), CSIG frequency and geographical extent have begun to decrease over much of the CONUS with the exception of the Gulf coastal region. By October (Fig. 1h), CSIGs are limited to Arizona, the Southern Plains, the Gulf Coast, and the Gulf Stream along the Carolinas.

Monthly means of CSIG frequency for six Julys from 1999 – 2004 show large interannual variability of CSIG frequency over the CONUS (Figs. 2a-f). The interannual variability of CSIG frequencies is associated with the concurrent mean 500 hPa height field. In July 2001 (Fig. 2c) much of the western CONUS exhibited high CSIG frequencies partially due to 500 hPa circulation anomalies. A region of low CSIG frequency was displaced northward into the central Plains in July

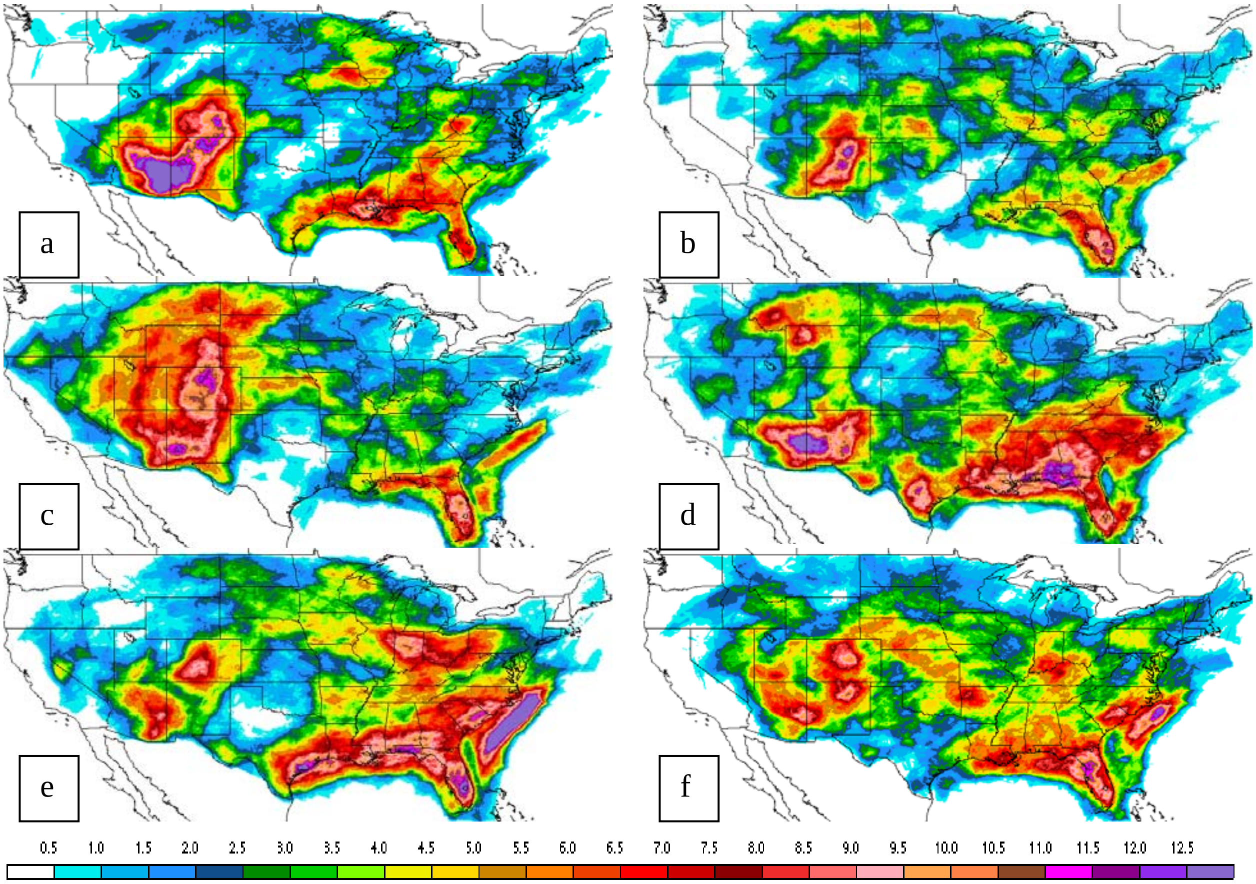

Figure 2. July CSIG Percent Frequency (a) 1999 (b) 2000 (c) 2001 (d) 2002 (e) 2003 (f) 2004.

2002 (Fig. 2d). In July 2003 (Fig. 2e), the eastern third of the CONUS showed higher CSIG frequency than in other years, while July 2004 (Fig. 2f) shows that that central plains had a much higher CSIG frequency than the previous 5 years.

A counterpart to the interannual variation of CSIG frequency for Julys (Fig. 2) is the departure of CSIG frequency from the July average (Fig. 3). The departures quantify the interannual variation for the six Julys of the existing CSIG climatology. In July 1999 (Fig. 3a), CSIG frequency was above average in the Southwest, northern Great Lakes, the southern Appalachians, and the western Gulf of Mexico coast, while elsewhere CSIG frequency was below average. CSIG frequency for July 1999 was much below average over the Gulf Stream off the east coast from the Carolinas to Florida. In July 2000 (Fig. 3b), CSIG frequency was below average in the western mountains, southern and southeast US, with the exception of parts of the central and northern plains. In July 2001 (Fig. 3c), CSIG frequency was above average over the western half of the CONUS and below average in the eastern half of the nation. In particular the CSIG frequency was well below average over the southern and southeastern US. In July 2002 (Fig 3d), higher than average CSIG frequency was diagnosed over the northern and southern tiers of the CONUS with a well defined minimum of CSIG frequency over Colorado and the Ohio River Valley. Higher than average CSIG frequency was observed over the eastern CONUS, over the Gulf Stream off the east coast from the Carolinas to Florida, and southern Texas during July 2003 (Fig. 3e). Below average CSIG frequency was observed over New Mexico, the Northern Rockies and the central plain in July 2003. The July 2004 departures (Fig. 3f) are approximately the reverse of the July 2002 departures. The departures shown in Fig. 3 quantify the monthly impacts on air traffic because greater than average CSIG frequency denies airspace, and depending on the location of the CSIG, may result in regional air traffic delays that may then ripple throughout the NAS.

The diurnal cycle for the month of July is shown for three hour periods throughout the day (Figs. 4a-g). Different dynamic and thermodynamic processes generate convection across the CONUS during different times of the day such as land/sea breeze interaction, destabilization through diurnal heating, synoptic systems,

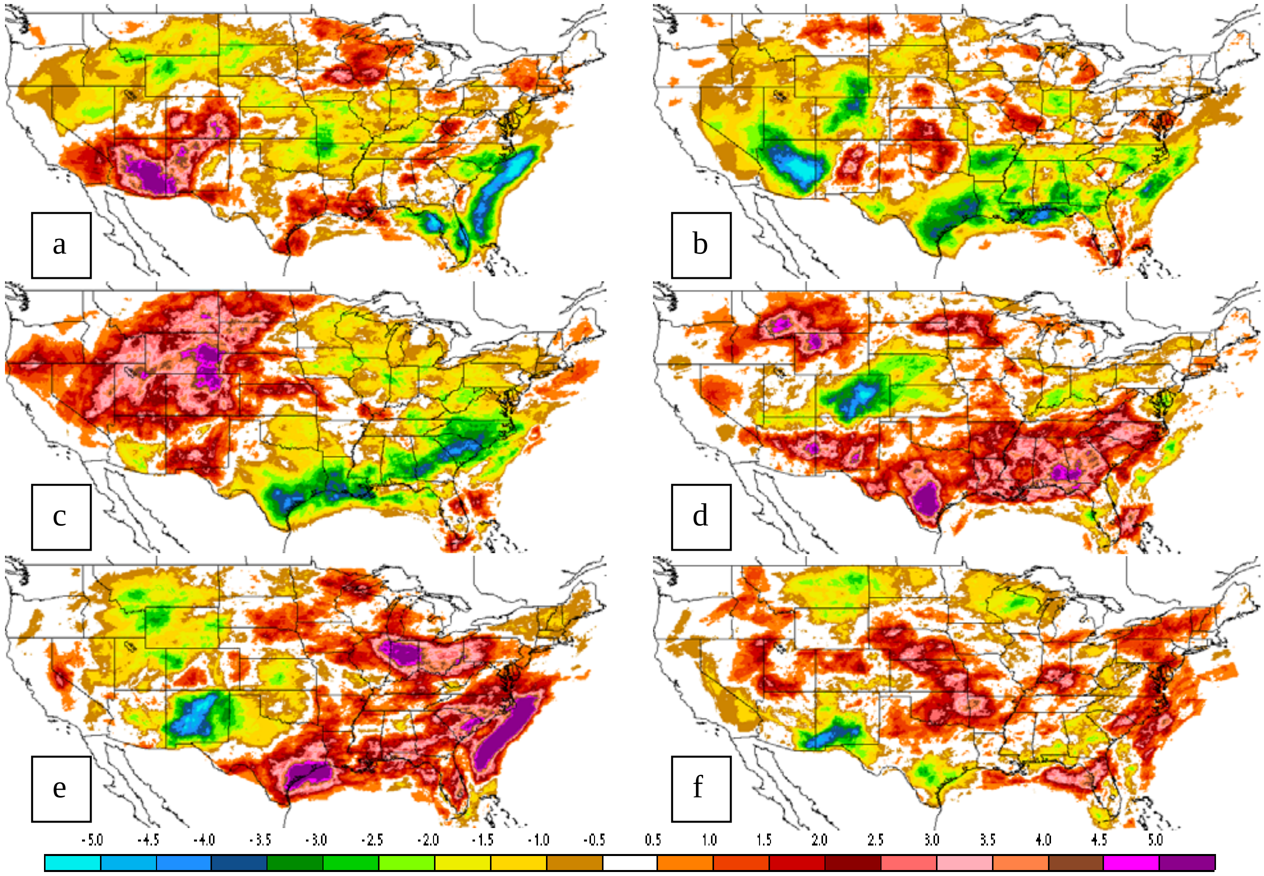

Figure 3. July CSIG Percent Frequency Departure from Mean (a) 1999 (b) 2000 (c) 2001 (d) 2002 (e) 2003 (f) 2004.

mesoscale boundaries, orographic effects, and the nocturnal low-level jet (Bonner 1968).

During the night (Fig. 4a), there are three notable regions of higher CSIG frequency over the north central portion of the CONUS, the Gulf Stream, and Desert Southwest. The higher frequency over the north central CONUS is primarily due to the nocturnal low-level jet which develops and maintains nocturnal convection (Bonner 1968 and Maddox 1983). Convection along the Gulf Stream and the Carolinas is active while convection over the Desert Southwest is diminishing. In the late night hours (Fig. 4b), convection in the north/central CONUS is shifted eastward from the previous period, convection over the Gulf Stream along the Southeastern CONUS and Gulf coastal areas is increasing, while convection over the desert Southwest has diminished. In the early morning (Fig. 4c), convection over the north/central CONUS is diminishing and continues to move eastward and convection over the coastal areas of the eastern Gulf of Mexico and along the Gulf Stream off of the Carolinas Coast region has increased.

By mid-morning (Fig. 4d), remnants of nocturnal convection exist over the Midwest while convection in the Gulf coastal waters has peaked and is beginning to spread inland. The central Appalachians are also becoming more active as diurnal heating increases. At approximately noon in the eastern and central CONUS (Fig. 4e), convection increases over the southeast, especially along the coastal regions and higher terrain. The active area extends northeastward to near the New York and Pennsylvania border along and just west of the Appalachians. Convection has developed rapidly over the Desert Southwest with this region reaching a CSIG frequency of 6 percent.

By the early afternoon (Fig. 4f), most of the CONUS east of the Rocky Mountains has reached maximum CSIG frequency and aerial coverage. Much of the Southeast has at least 10 percent CSIG frequency. Coastal sections extending from the Louisiana and Alabama border to the Florida/Georgia border and most of central and southern Florida exhibit frequencies of 20 to 30 percent. CSIG frequency has blossomed over the higher terrain of the Desert Southwest with CSIG frequencies increasing dramatically to as high as

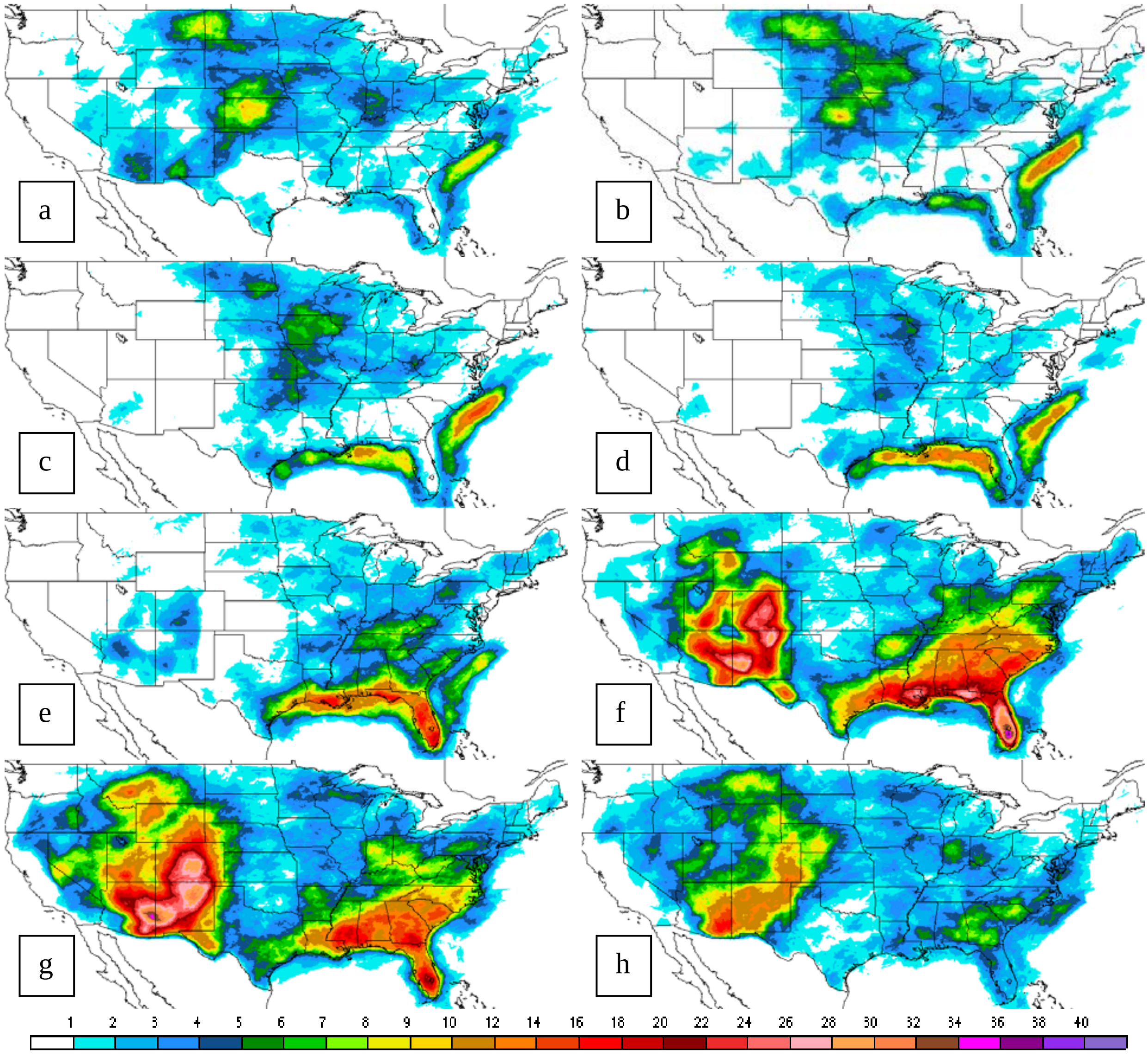

Figure 4. July 3-hourly CSIG Percent Frequency (1999-2004) (a)05-07z (b) 08-10z (c)11-13z (d) 14-16z (e) 17-19z (f) 20-22z (g) 23-01z (h) 02-04z.

40 percent along the southern Arizona and New Mexico border. Various regions of higher terrain standout in the West as these are frequently convective initiation points due to orographic forcing. Some of the noticeable terrain features include the Black Hills, Rockies of Colorado and New Mexico, Mogollon Rim, Wasatch and Uinta Ranges, Tetons and Yellowstone, southwestern Montana, east-central Nevada, the central Sierras, and the Siskiyous.

By late afternoon and early evening (Fig. 4g), convection in the eastern CONUS is diminishing while the geographical extent of highest CSIG frequency reaches its peak. As convective temperatures are reached, CSIG frequency has increased over the High Plains due to diurnal heating. However, the CSIG frequency is relatively low because the cap is usually strong enough to preclude convective development. Convection in the West is becoming more consolidated and is beginning to move eastward into the High Plains making it harder to depict higher terrain features. In the late evening (Fig. 4h), low CSIG frequency covers much of the CONUS with the exception of the southern Desert Southwest, the eastern portion of the mountains and northern and central High Plains.

Figure 5 synthesizes the diurnal cycle of CSIG by showing the hour (GMT) in which the highest hourly CSIG frequency occurs per grid cell from July 1999-2004. The Gulf and Southeast Atlantic coastal waters peak in the morning. The Northeast

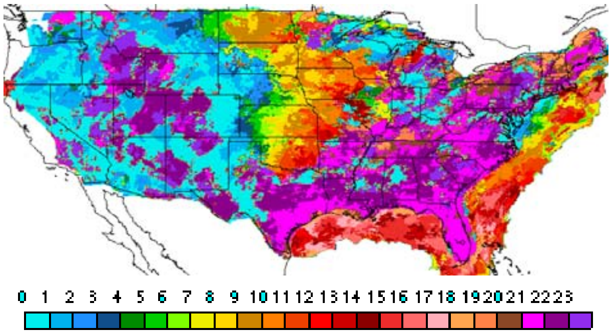

Figure 5. Hour (GMT) in which highest CSIG frequency occurred in July (1999-2004).

and portions of the Great Lakes peak in afternoon with the exception of the coastline and coastal waters which tend to peak in late evening to early morning. The South peaks in mid-afternoon to early evening. The highest terrain of the West peaks in afternoon while surrounding locations tend to peak in early evening. The central and northern Plains and much of the Midwest and some of the Great Lakes peak around midnight on the western side and around mid-morning on the eastern side.

4. SUMMARY AND DISCUSSION

A climatology of convective SIGMETs issued by the AWC from January 1999 through July 2004 has been conducted over the CONUS and surrounding coastal waters. The climatology illustrates the variation of CSIG frequency and because CSIGs deny airspace, the climatology illustrates monthly, interannual, and diurnal impacts on air traffic and its flow management. The climatology captures most convection. This was confirmed when CSIG climatology was compared to the Bothwell (1998) lightning climatology. In addition, the geographical locations of peak CSIG times compare favorably with the diurnal peaks of convection produced by Rassmusson (1971).

The annual march of CSIG-defined convection shows the northward and westward expansion of convection during the spring, the development of maximum convection over the southeastern CONUS and the Desert Southwest during the summer monsoon, and the rapid contraction of convection over the CONUS and shifting of convection to just off the Gulf coast during autumn. Interannual variability of CSIG frequency during six Julys shows how variations in the large-scale circulation impact the location and frequency of CSIG-defined convection. Analysis of diurnal variations of CSIG convection illustrate the different dynamic and thermodynamic processes that generate convection across the CONUS during different times of the day such as land/sea breeze interaction, destabilization through diurnal heating, synoptic systems, mesoscale boundaries, orographic effects, and the nocturnal low-level jet.

The CSIG climatology is useful for retrospective analysis of CSIG frequency and its impacts on air traffic. When greater than normal CSIG frequency occurs over sensitive air routes, air traffic delays increase. In the future, the CSIG climatology could be incorporated into an air traffic management matrix that would generate recommendations on the best air traffic routes to use in order to avoid climatologically preferred regions of convection.

5. ACKNOWLEDGEMENTS

The authors wish to thank Nicole Haglund and William Hirt of the Aviation Weather Center for reviewing this manuscript.

6. REFERENCES

Bonner, W. D., 1968: Climatology of the low-level jet. *Mon. Wea. Rev.,* **96**, 833-850.

Bothwell, P. D., 1998: New diagnostic and prognostic tools for predicting lightning location from zero to twelve hours and beyond. International Lightning Detection Conf., Tucson, AZ, Global Atmospherics, Inc., Paper #12, 10 pp.

Maddox, R. A., 1983: Large-Scale Meteorological Conditions Associated with Midlatitude, Mesoscale Convective Complexes. *Mon. Wea. Rev.,* **111**, 1475-1493.

Rassmusson, E. M., 1971: Diurnal variation of summertime thunderstorm activity over the United States. U.S. Air Force Environmental Technical Applications Center Tech. Note 71-4, 15 pp.

Wallace, J. M., 1975: Diurnal variations in precipitation and thunderstorm frequency over the conterminous United States. *Mon. Wea. Rev.,* **103**, 406-419.

Weiss, S. J., 1983: Thunderstorms and Aviation: Operational Forecasting Programs at the National Severe Storms Forecast Center. AIAA 21st Aerospace Sciences Meeting, Reno, NV, 19 pp.