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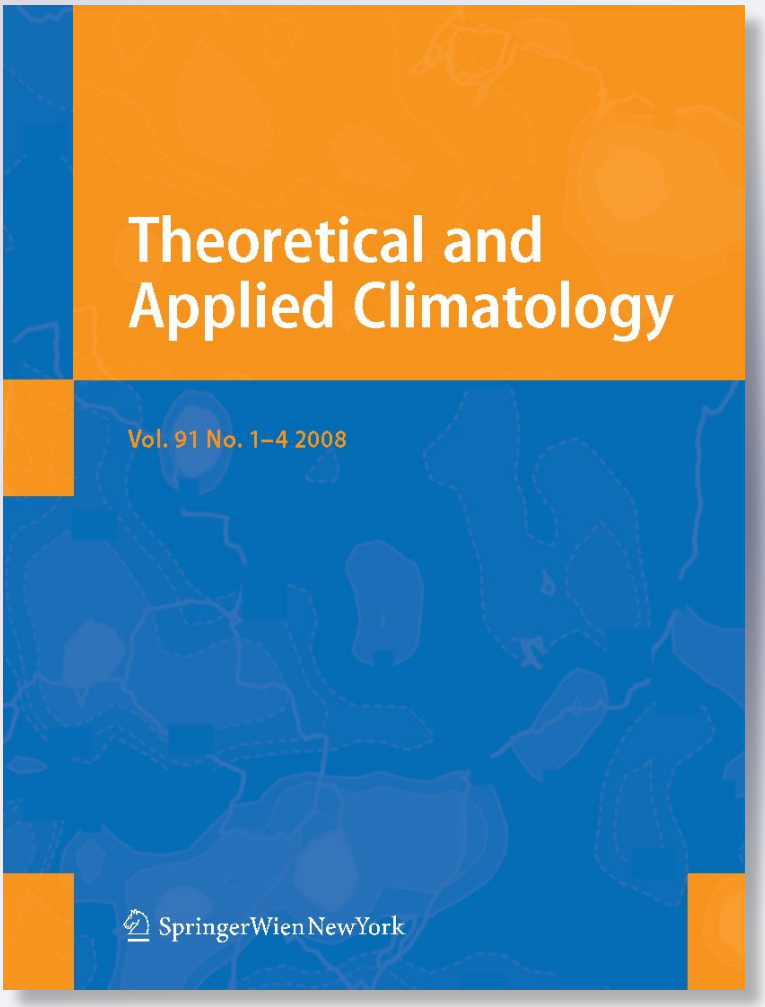

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ORIGINAL PAPER

Examination of diurnal temperature range at coterminous U.S. stations during Sept. 8–17, 2001

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Abstract The tragic events of Sept. 11, 2001 resulted in suspension of commercial flights over North America. It has been suggested that the diurnal temperature range (DTR) increased due to an absence of airplane contrails. This study examined hourly data observed at 288 stations. The average DTR, temperature, maximum/minimum temperature and relative humidity were found for each day in 2001 and compared to the average value occurring during 1975–2005. For the coterminous U.S., the DTR averaged over the period Sept. 11–14, 2001 was about 1°C larger than that found for the 3 days prior and after the flight ban. However, the day-to-day DTR does not correlate well with the flight ban. Plots of the change in DTR throughout North America during Sept. 8–17 show changes consistent with the natural progression of weather systems.

1 Introduction

Detecting anthropogenic effects on climate is complicated by the weather's variability and the difficulty of observing a climate unaffected by human activities. A unique opportunity unfortunately arose after Sept., 11, 2001 when flights over North America were severely restricted for the following 3 days. One study (Travis et al. 2002; Travis et al. 2004) found that the diurnal temperature range (DTR) increased over the coterminous U.S. during the 3 days when commercial flights were suspended. They compared the DTR found during Sept. 8–17 for 2001 to the average occurring during 1971–2000. The DTR increased by about 1.1°C during Sept. 11–14, 2001 as compared to the value for the previous 30-year period. Moreover, the corresponding changes in the DTR during Sept. 8–11 and Sept. 14–17 were about −0.2 and −0.8°C, respectively. The authors attributed the change in DTR to a lack of aircraft contrails (De Grand et al. 2000).

Some studies have questioned the conclusions of Travis et al. The effect of unusually clear weather following Sept. 11, 2001 was suggested to have increased the DTR (Kalkstein and Balling 2004). Our previous work (van Wijngaarden 2008) examined data observed at stations located throughout Canada where flights were also restricted. No change in DTR similar to that found by Travis et al. corresponding to the flight restrictions imposed after Sept. 11, 2001 was observed. These conclusions did not change when only stations located south of 50 °N latitude, i.e., near the U.S. border, were considered.

Another study (Hong et al. 2008) examined surface temperature and cloud cover over the coterminous United States for the period 1971–2001. They found the changes in DTR for the 3-day intervals in Sept. 2001 are within one standard deviation of the average value observed during the previous 30-year period. The changes in DTR during Sept. 2001 were attributed to changes in low level cloudiness. The same result was obtained using a global climate model that included parameterization of contrails (Dietmüller et al. 2008).

This work computed not just the DTR but also the average temperature, maximum/minimum temperature and relative humidity in 2001 that were compared to the averages occurring during 1975–2005. This was done for each day in 2001, not just for the 10 days surrounding Sept. 11, 2001. High quality, hourly data was used rather than datasets derived from daily measurements or using parameterized models. Finally, maps of North America were made showing the DTR during Sept. 8–17, 2001 minus the average DTR computed for 1975–2005.

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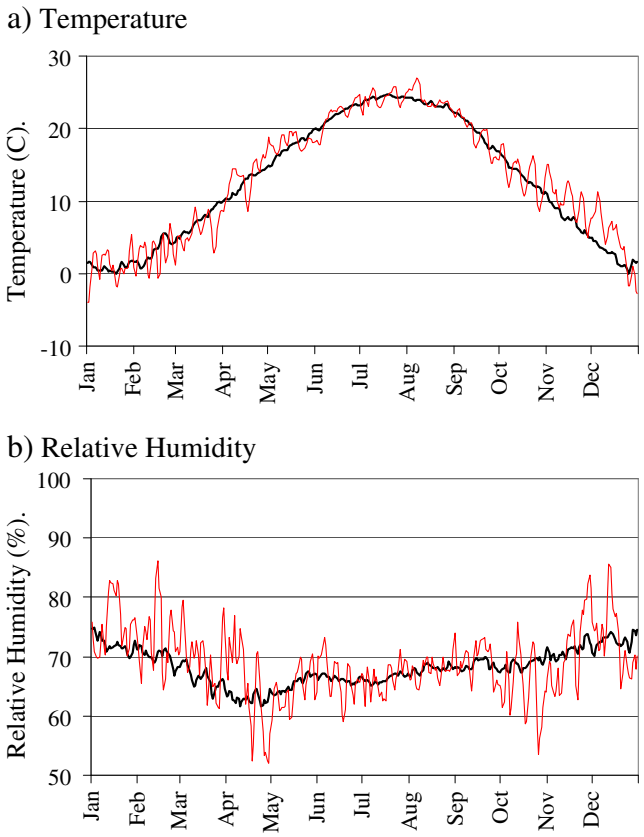

Fig. 1 The daily **a** temperature and **b** relative humidity averaged over the stations located in the coterminous U.S. as a function of time throughout the year. The *black curve* represents data averaged for 1975–2005 while the *red curve* is data for 2001

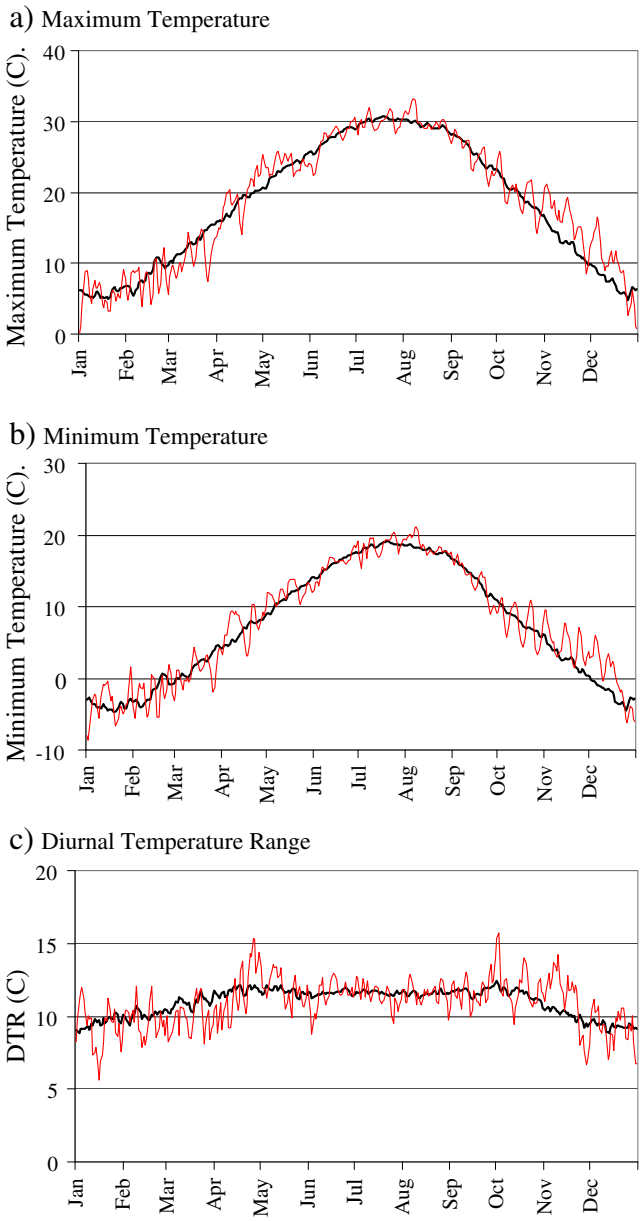

Fig. 2 The daily **a** maximum temperature, **b** minimum temperature and **c** diurnal temperature ranges averaged over the stations located in the coterminous U.S. as a function of time throughout the year. The *black curve* represents data averaged for 1975–2005 while the *red curve* is data for 2001

This study examined data observed at 288 stations located throughout North America. The dataset comprised 202 stations located in the coterminous U.S., 12 in Alaska and 74 in Canada. These stations are primarily located at airports and were subject to periodic inspection to ensure proper maintenance and calibration of instruments. The reliability of these datasets has been further checked for inhomogeneities that can arise due to changes in instruments and/or procedure (Vincent et al. 2007; Isaac and van Wijngaarden 2011). For example, the replacement of the psychrometer by the dewcel in Canada in the early 1970s led to an abrupt reduction in winter relative humidity by >10% at many stations (van Wijngaarden and Vincent 2005). Temperature and relative humidity records were available for American stations until 2005 from the University Corporation for Atmospheric Research and for Canadian stations from the National Climate Data and Information Archive of the Meteorological Service of Canada, Environment Canada. The 1975–2005 period was selected because it is the same length as the study by Travis et al. and data were present for over 92% of all possible hours.

2 Data analysis

The average daily temperature and relative humidity was found for each station provided observations were present for all 24 hours. These values were then averaged over all stations located in the coterminous U.S. producing the results shown in Fig. 1. The data for 2001 are scattered close to the average observed during 1975–2005. Neither graph exhibits any indication of anomalies during September 2001.

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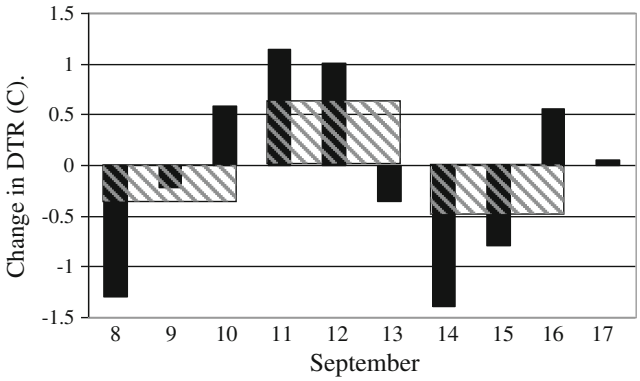

Fig. 3 Change in diurnal temperature range averaged over the stations located in the coterminous U.S. during Sept. 8–17, 2001 compared to the value during 1975–2005. The *cross hatched bars* denote the 3-day average values

The daily maximum and minimum temperatures occurring at each station was found and used to compute the DTR. The results are shown in Fig. 2. The September 2001 data are very close to the 31-year averaged values. The largest departures of the 2001 data from the averaged values occur in months other than September. All the graphs shown in Figs. 1 and 2 exhibit fluctuations of the 2001 data about those averaged over 1975–2005 with a time constant of several days.

Figure 3 shows the change in DTR observed for stations located in the coterminous U.S. for Sept. 8–17, 2001 relative to the average DTR observed during 1975–2005. The DTR increased during each of the 4 days from Sept. 8–11 and then decreased until Sept. 14, whereafter it increased. This does not correlate well with the flight ban. Figure 3 also displays the 3-day averaged values. The changes in DTR averaged during Sept. 8–10, 11–13 and 14–16 were −0.3, 0.6 and −0.5°C, respectively. These results are comparable to those observed in the earlier study (Travis et al. 2002) that found the change in DTR to be about −0.2 and −0.8°C for the 3-day periods

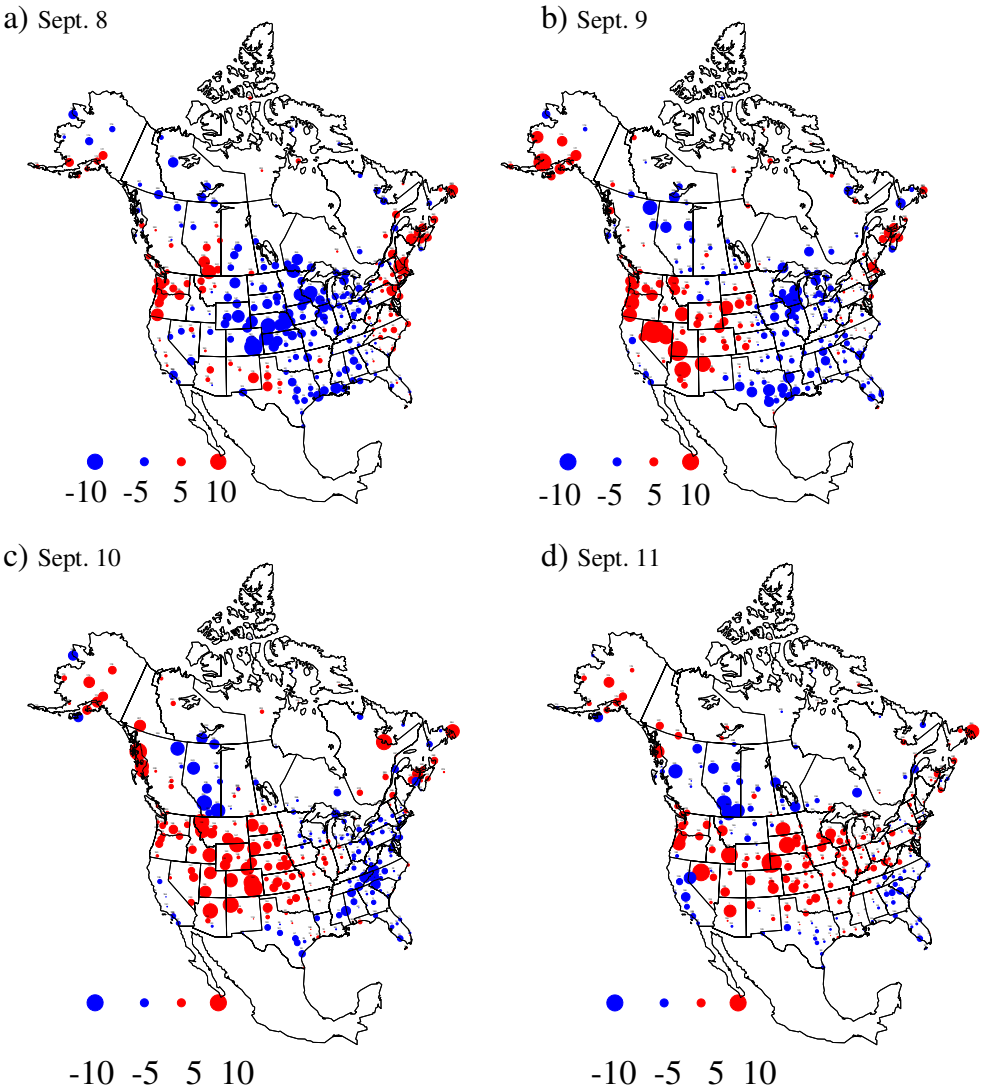

Fig. 4 Diurnal temperature range during Sept. 8–17, 2001 minus the average value computed for 1975–2005. Units are in degrees Celsius and the *dot size* is proportional to the temperature difference. For convenience, *dots* corresponding to ±5, ±10°C are shown

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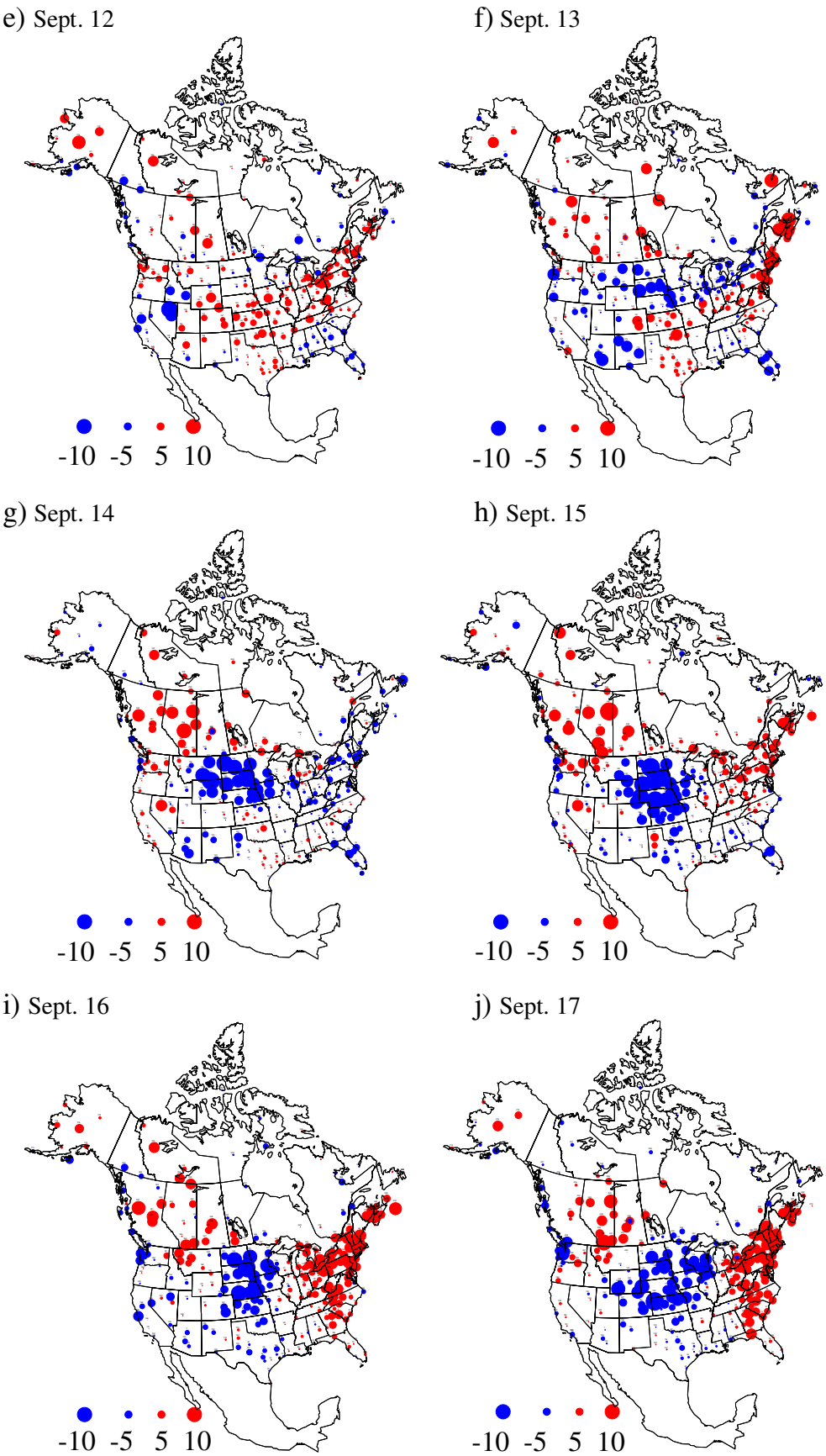
Fig. 4 (continued)



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immediately before and after the flight ban, respectively and a value of +1.1°C when airplanes were grounded.

Figure 4 shows maps of North America showing the change in DTR during Sept. 8–17, 2001. For each station, the Sept. 2001 DTR was computed and the average DTR on the same day that occurred during 1975–2005 was subtracted. The maps reveal that stations experiencing a large negative (positive) DTR change generally have neighboring stations with similar results. In addition, stations experiencing the smallest DTR change are generally close to stations reporting smaller positive or negative DTR changes. Hence, the maps are consistent and it is reasonable to conclude the patterns would not change if data from more stations were available.

The maps in Fig. 4 show day-to-day changes. For example, on Sept. 8, 2001, stations in the Pacific Northwest experienced a positive change in DTR. On the next day, a positive DTR change occurred at additional stations in the western U.S. This pattern of positive DTR change continued to shift eastward during Sept. 10–12. Similarly, on Sept. 13, a number of stations in the north-central part of the U.S. experienced a small negative DTR change. These negative DTR changes became larger in magnitude and affected stations encompassing a larger geographic area during the next several days.

3 Conclusions

This study did not find any unusual change in average daily temperature, minimum/maximum temperature or average relative humidity in the coterminous U.S. during September, 2001 when compared to the average values occurring during 1975–2005. For the Sept. 8–17, 2001 period, values found for the 3-day average change in DTR have comparable magnitudes to those found previously by Travis et al. However, the correlation with the flight ban disappears when one considers the daily change in DTR. The DTR increased for each of the 3 days prior to the annunciation of the flight ban and decreased each day until Sept. 14 when flights resumed. The DTR changes during Sept. 8–17, 2001 plotted on a map of North America show day-to-day changes that are consistent with the natural progression of weather systems across the continent.

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