J1.9 AN ANALYSIS OF THE TEMPORAL AND SPATIAL DISTRIBUTION OF ACARS DATA IN SUPPORT OF THE TAMDAR PROGRAM

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1. INTRODUCTION

Fully automated weather reports from commercial aircraft, commonly known as ACARS (Aircraft Communications Addressing and Reporting System), are collected and quality controlled at the Forecast Systems Laboratory (FSL) in Boulder, Colorado. ACARS reports include much more than meteorological information; however, here the term ACARS will relate only to reports with meteorological information. Though the ACARS data have been proven to be quite valuable due to their quality, temporal frequency, and vertical resolution, limitations can be seen in diurnal and spatial coverage. The TAMDAR (Tropospheric Airborne Meteorological DAta Reporting) program was developed in part to address these issues. One of FSL's tasks within the TAMDAR program is to investigate the current data-sparse regions, and assess the potential of TAMDAR reports to fill these data voids.

2. BACKGROUND

The ACARS data sensors and communications systems are installed on approximately 1600 aircraft within the United States. The current participating commercial airlines are American, Delta, Northwest, United Airlines, and package carriers United Parcel Service and Federal Express. The meteorologically relevant variables reported are latitude, longitude, altitude, time, temperature, wind direction and wind speed. A small number of these aircraft (~101) also report eddy dissipation rate and an even smaller number (~15) report reliable dewpoints. Frequencies of the reports vary, especially between the passenger and package carriers. Most passenger carriers report every 3 to 6 min during their entire flight, including ascent and descent. Package carriers, however, report approximately every 3 min during cruise, and every 10 to 30 s during ascent and descent. The observations from the package carriers account for about 50% of the total number of observations during typical weekdays.

3. ACARS QUALITY

The meteorological variables from ACARS are subject to quality control procedures at FSL (Moninger and Miller, 1994) employing temporal and spatial consistency checks. Comparisons with radiosonde data (Schwartz and Benjamin, 1995) revealed ACARS accuracy to be within 4 m s^{-1} for vector winds and $0.6^{o}C$ for temperatures. Collocation studies (Benjamin and Schwartz, 1999) between ACARS reports from separate aircraft within 10 km and 10 min showed rms accuracy of 1.8 m s^{-1} for vector winds and $0.5^{o}C$ for temperatures. Observations of this quality are extremely useful to forecasters, and improvements in forecasts have been noted on several occasions (Mamrosh, 1998; Labas et al., 1999; Mamrosh et al., 2001; Martin, 2000). Weather models, such as the Rapid Update Cycle (RUC) which provide hourly updates, depend very highly on ACARS data particularly during asynoptic times (Benjamin et al., 1994).

4. METHODOLOGY

Three weeks of ACARS data, over 2 million observations, covering the period of Sunday 13 May - Saturday 2 June 2001 were collected and analyzed. The initial set of data is worldwide, but since the TAMDAR program is currently planned for the contiguous United States (CONUS), this study will focus on only those observations within CONUS, reducing the sample size to approximately 1.5 million observations. Figure 1 shows the number of total observations by hour during the first four days of the period. Large hourly fluctuations are present; however, the total number of observations during the weekend (the first two days) is noticeably lower, due to the absence of package carrier activity. The hourly mean of the observations for the entire 21-day period (Fig 2.) shows an evening peak at 0300 UTC and a late evening/early morning drop at 0600 UTC. The nighttime peak at 0800-0900 UTC is due largely to package carrier activity and the morning peak at 1400 UTC can be attributed to business flyers. Based on the time of lowest flight activity, we redefined a typical flight "day" as occurring from 0600 UTC to 0559 UTC the following day (both times are noted as 6Z in the figures for brevity). The total observations using the redefined "day" are shown in Fig. 3. The effect of the lack of package carrier activity is clearly evident on the week-

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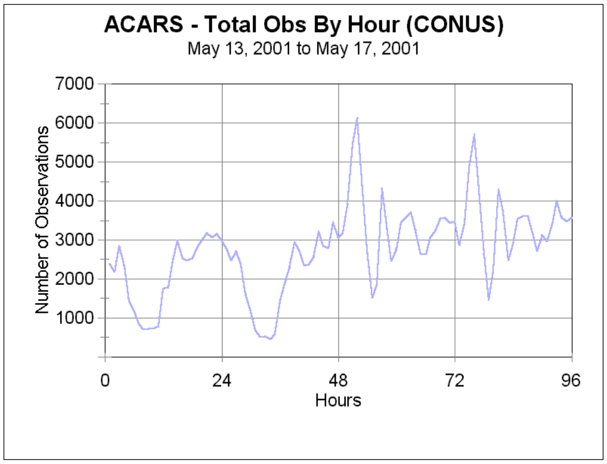

Figure 1. Total number of ACARS observations by hour for the first four days of the sample period.

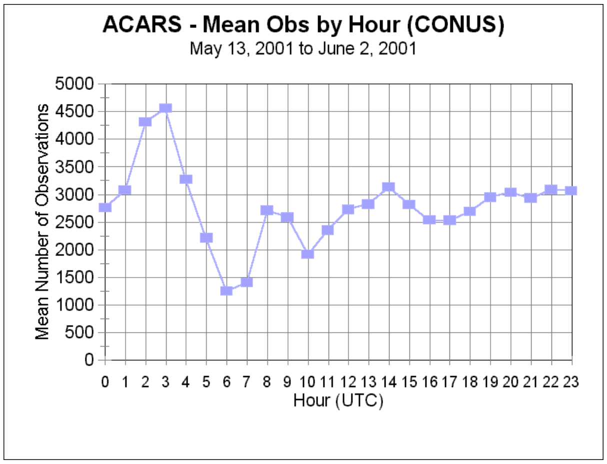

Figure 2. Mean number of ACARS observations normalized by hour for the entire sample period.

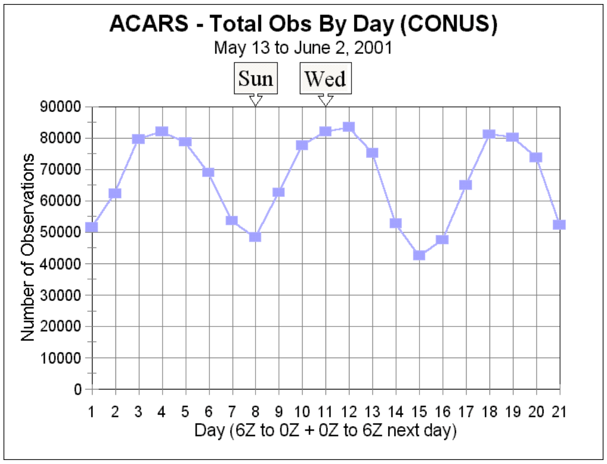

Figure 3. Total number of ACARS observations by day, where "day" has been redefined as occurring from 0600 UTC to 0559 UTC on the following day.

ends, and peak activity occurs in midweek. The third Monday in the sample (day 16) is atypically low due to the Memorial Day holiday. From the sample, a typical "Wednesday" and a typical "Sunday" were chosen for further analysis. The data from these two days were stratified by 5000 ft. altitude layers. Figures 4 and 5 show the total number of observations in our chosen "Sunday" and "Wednesday," respectively. Lower numbers of total observations are evident overall during "Sunday," and large differences can be clearly seen below 25 000 ft, showing the effect of the higher resolution ascent/descent data from the package carriers.

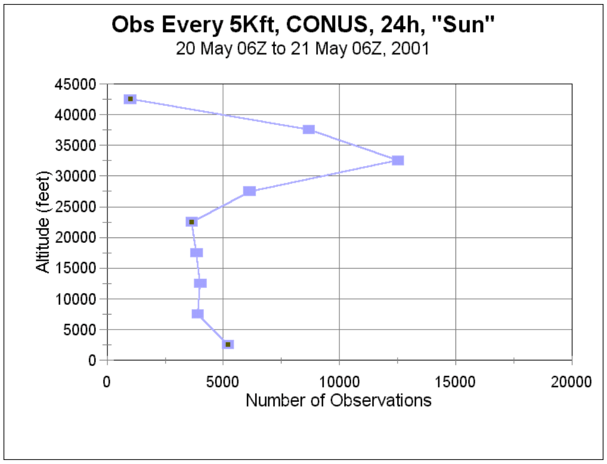

Figure 4. Number of ACARS observations stratified by 5000 ft layers for a typical "Sunday." Points are plotted at the midpoints of the layer.

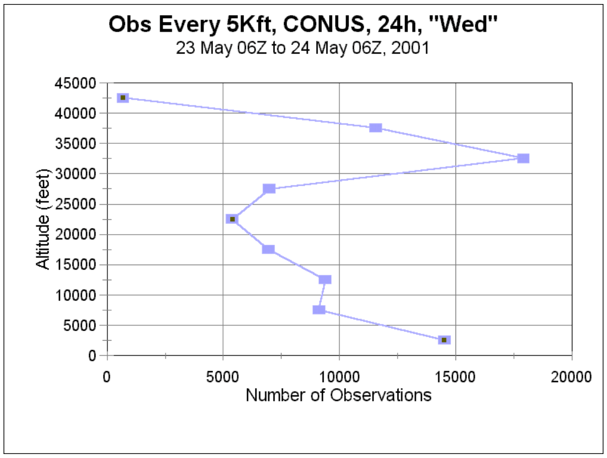

Figure 5. Same as figure 4, but for a typical "Wednesday."

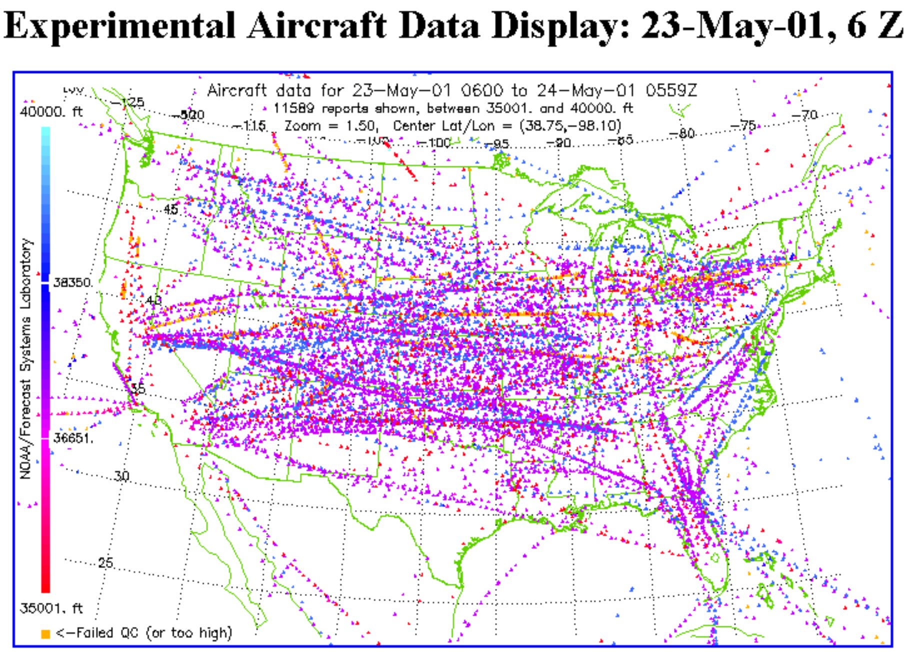

Figure 6. Plan view of ACARS observations between 35 000 ft and 40 000 ft altitude over the CONUS.

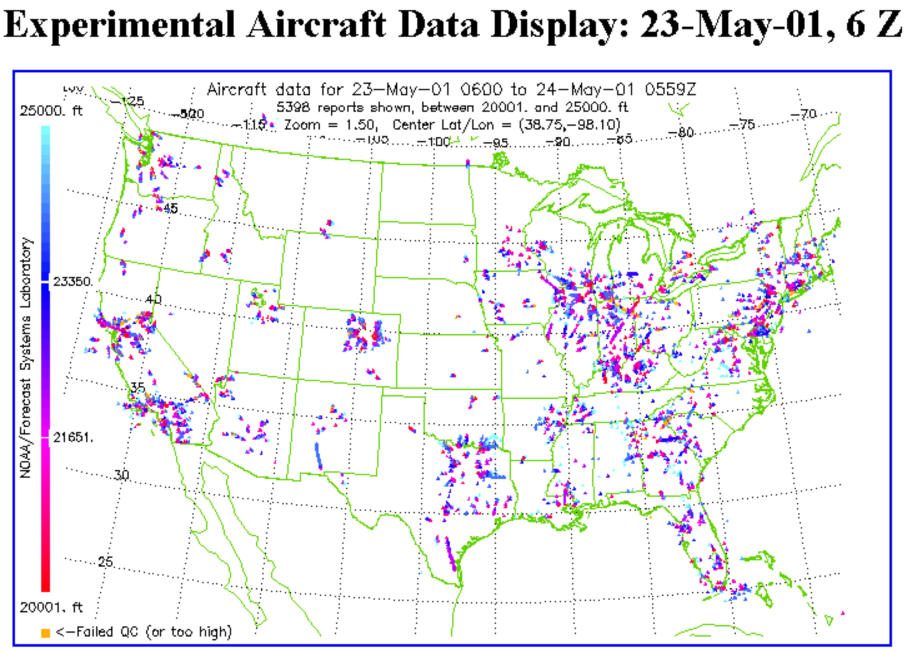

Figure 7. Same as figure 6, but for observations between 20 000 ft and 25 000 ft altitude.

The effect of altitude on spatial resolution is given in Figures 6 and 7. Figure 6 depicts a plan view of the ACARS observations between 35 000 ft and 40 000 ft for "Wednesday," where aircraft are at cruise altitude. With few exceptions, the reports are well distributed over the CONUS. Figure 7 is the plan view of reports between 20 000 ft and 25 000 ft, and shows localized coverage around major airports, with the most uniform representation around the Northeastern seaboard. Localization around major airports is even more pronounced at lower altitudes (not shown). ACARS systems on regional jets, which use smaller airports, would provide more uniform spatial distribution at these lower levels as well as increase the amount of ascent/descent data.

5. SUMMARY

The TAMDAR program was designed to investigate the potential contribution of meteorological observations from regional aircraft to improve aviation weather services. One task of the TAMDAR program is to assess temporally and spatially data-sparse regions of ACARS observations. Weekend days were noted to be lower in observations due to the lower activity from UPS and Federal Express package carriers. Weekend reports by altitude show a pronounced peak above 25 000 ft, and weekdays in addition show a peak at lower levels due to the data from package carriers. Spatial distribution of observations is rather uniform at altitudes above 25 000 ft, but concentrated around major airports in the lower troposphere. The inclusion of TAMDAR reports from regional jets would greatly enhance lower level spatial coverage, and provide asynoptic data in areas not near major airports.

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