P1.31 REGIONAL AND SEASONAL CLIMATOLOGIES OF METEOROLOGICAL SURFACE PARAMETERS AS DEREIVED FROM METARS

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1. Introduction

The meteorological parameters of most significance to surface transportation and low – level aircraft are probably wind speed, gust speed, and visibility. One way of gaining a better understanding of how these parameters vary regionally and temporally is to construct climatologies. Documenting the regional and seasonal trends of these observations was the main goal of this paper, as these may prove useful for those involved in surface transportation route planning and maintenance by better preparing them for potential problems.

Strong wind speeds at the surface (sustained or gust) should be correlated to more frequent and stronger low-level turbulence. If this correlation can be substantiated, forecasts of surface wind speed and/or gusts may be used to infer the likelihood of low-level turbulence.

2. Dataset and Analysis

Aviation Routing Weather Reports (METARs) were used to construct the climatologies. The METAR data were obtained from the National Climatic Data Center (NCDC) for the years 1982 – 1997. There were 536 stations across the continental U.S. included in the dataset (Fig. 1). These stations were selected based on the amount of data available and the population density near the station. The resolution is fairly uniform except for some areas in the West where the population density is quite low.

First, the observations were sorted by station and broken down to include only one observation per hour per station. Then the parameters were further divided into three-month periods so that seasonal average and median values could be calculated for each station. The periods (months) were winter (DJF), spring (MAM), summer (JJA), and fall (SON). The wind information was put into speed and direction bins for both the sustained winds and gusts. Wind roses could then be plotted to determine the climatologically favored direction for wind gusts as a function of location and time of year.

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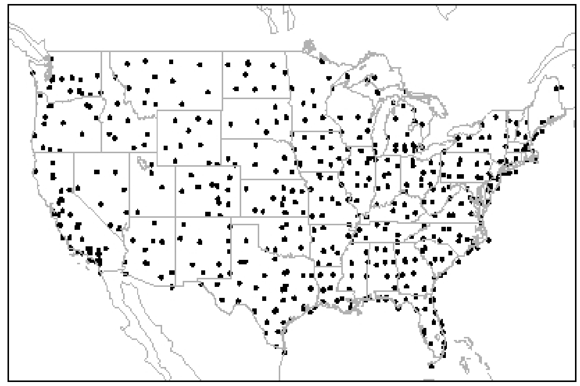

Figure 1. Location of the 536 stations used in the climatology.

3. Wind and Gust Speeds

a. Wind and Gust Distribution

For reference, a gust is defined as a variation of 10 kts. or more between peaks and lulls in a 10 minutes for a human observer. For an Automated Surface Observing System (ASOS), a gust is reported when a 5 second average wind speed is at least 5 kts. greater than the current 2-minute average wind speed (NWS, 1998).

The average sustained wind and gust speeds were calculated for each station along with a count of direction vs. wind and gust speed in ten degree and 5-kt. bins, respectively. It was found that the vast majority of wind speeds reported are light (< 10 kts.) and have no gusts associated with them. 79% of all METARs reported wind speeds less than 10 kts. and only 7% of the total had a gust reported with them. When the minimum sustained wind speed was increased to 10 kts. the observations with gusts increased significantly to 26% of the total.

Figure 2 shows a distribution of the wind gust speeds in 5-kt. increments by percentage of

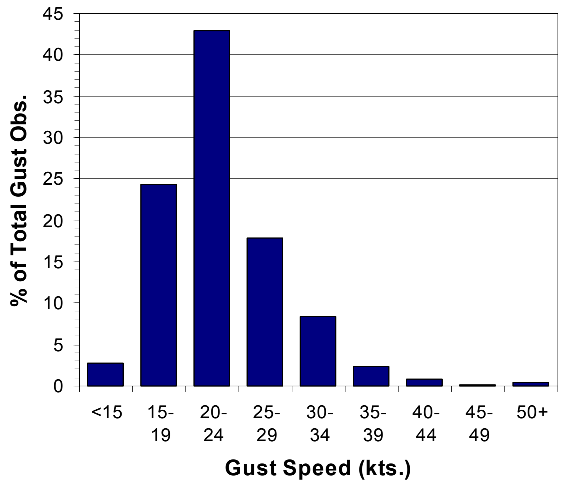

Figure 2. Distribution of gusts for all stations from 1982 – 1997.

the total gust count for all stations. The majority of reported gust speeds were in the 15 – 29 kt. range with the highest percentage (43%) from 20 – 24 kts. Gusts over 40 kts. are increasingly rare, as expected, due to the rarity of widespread and long-lived windstorms. These high gusts, while making up a small portion of the total, are important because they can adversely affect transportation by reducing visibility from blowing dust or snow, making it difficult to control high profile vehicles, or possibly increasing low-level turbulence. The lack of gust observations below 15 kts. is due to the fact that ASOS does not report gusts less than 14 kts. (NWS, 1998). For stations that have observers, gusts less than 14 kts. can be reported but are very rare.

b. Regional and Seasonal Distributions

The average wind speeds show varying seasonal and regional distributions (Fig. 3). The central U.S. has the highest averages during the course of the year with the maximum occurring in the spring (Fig. 3b). Many of the stations in this region and time of year have average winds in excess of 10 kts. The southeast U.S. has the lowest average winds year round due to the lack of strong cyclones that move through this region, which is often under the influence of strong anticyclones (Zishka and Smith, 1980). The summer appears to be the calmest season.

Figure 4 shows the average gust speed at all stations for each season. Not surprisingly, the highest average gusts are in the winter (Fig. 4a), especially along the Rocky Mountain Front Range and into the adjacent plains. This is most

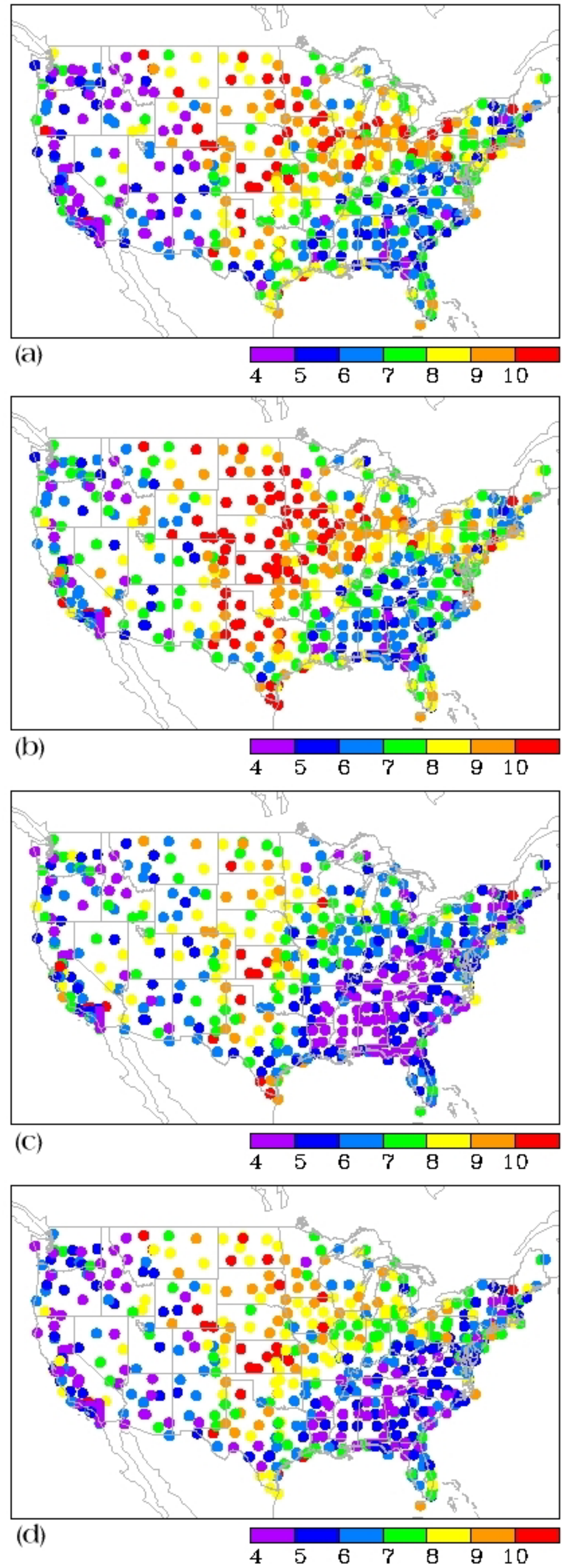

Figure 3. Average wind speed for (a) DJF, (b) MAM, (c) JJA, (d) SON. Speeds are in kts.

likely due to the strong downslope winds that are common during the winter months in these areas. Also the Pacific Northwest shows higher average gust speeds during this time because of the intense low pressure systems making their way on shore, while southern CA has higher average gust speeds due to the Santa Ana winds that are prevalent in winter. Another maxima can be seen across the central and northern plains into the Midwest in the winter and spring (Figs. 3b & 4b). This follows the preferred propagation track of the strong midlatitude cyclones that move out of the Rockies bringing snow and strong winds to these areas (Zishka and Smith, 1980).

There is a marked decrease in average gust speed during the summer and fall across these regions (Fig. 4c & 4d). In the summer the number of cyclones decreases and their central pressure increases (Zishka and Smith, 1980). This contributes to the fall off in the intensity and number of gust observations during this season. There are also less wind reports of > 10 kts. during the summer months, but only 19% of the total have a gust associated with them, compared with 27% and 29% in the winter and spring, respectively.

These finding are consistent with the seasonal sustained wind speed averages (Fig. 3). However, the seasonal variation in average wind speed from station to station did not appear to be as large as for the gusts.

c. Comparison to Turbulence PIREPs

Wind and gust data were then compared to low-level turbulence pilot reports (PIREPs), specifically those at and below 5000 ft. AGL. The comparison was done by looking for a METAR station from the dataset that was within 50 km of the location of the PIREP and had a weather observation no more than half an hour before or after the PIREP report time. If such an observation was found, the wind data (direction, speed, and gust) and PIREP turbulence intensity were saved and this became a correlated PIREP. The data were then broken down into the same bins for speed and direction as before, but this time the turbulence intensity was used as well. This was done as a total for all gusts as well as for each station.

PIREP data were only available from 1992 to the present while the METAR data spanned the years 1982 – 1997. Therefore, the years for this correlation study were limited to 1992 – 1997. Figure 5 shows a climatology of turbulence reports below 5000 ft. for these

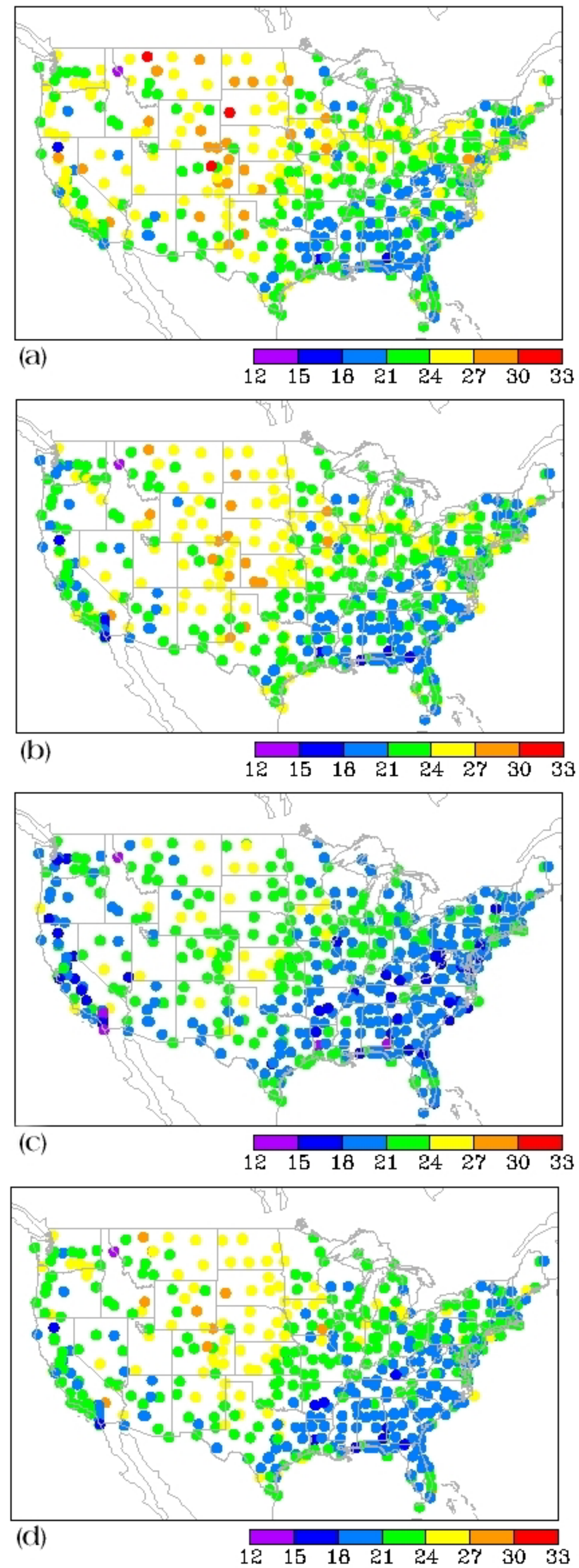

Figure 4. As in Fig. 3 but for average gust speed.

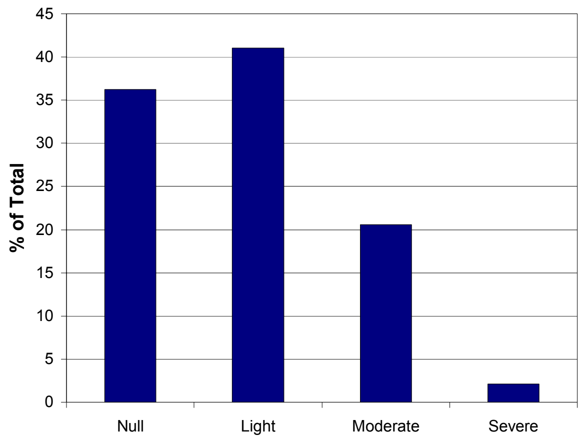

Figure 5. Distribution of turbulence intensities at altitudes ≤ 5000 ft.

years. There are less null reports and more lights than Sharman et al. (2002) found at altitudes above 20,000 ft. This difference may be attributed to the prevalence of lighter aircraft at low altitudes, which are more susceptible to small-scale atmospheric motions than larger aircraft that fly above 20,000 ft. The moderate or greater (MOG) reports show about the same percentages at low and high altitudes as those previously calculated by Sharman et al.

Figure 6 shows the average wind and gust speed associated with each turbulence intensity from the PIREPs. Both fields show an increase in the average speeds from null to severe turbulence. However, the overall increase is not very dramatic for either wind or gust speed. Examining the distributions of wind and gust speed for each turbulence intensity illustrates

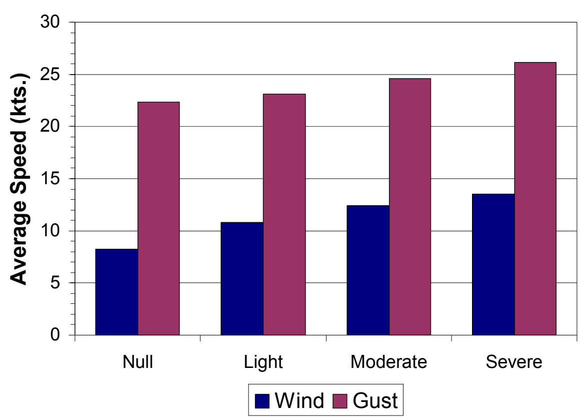

Figure 6. Average wind and gust speed vs. turbulence intensity for the correlated observations.

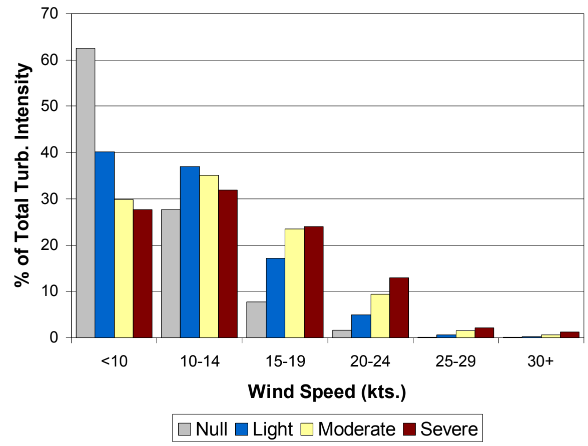

Figure 7. Distribution of wind speeds for each turbulence intensity in correlated PIREPs.

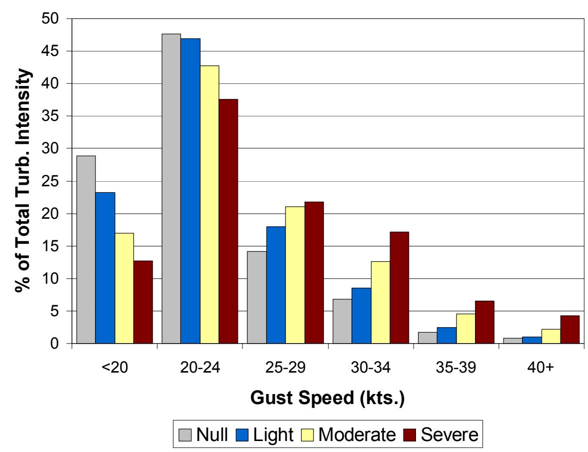

Figure 8. As in Fig. 7 but for gust speed.

the problem (Figs. 7 & 8). For every wind and gust speed bin there are turbulence reports of all intensities, many times with percentages that are very close. However, these percentages also show a correlation between increasing speeds and turbulence intensity. The distribution of wind speeds changes once the speeds become greater than 15 kts. (Fig. 7). For winds lighter than this there are a greater percentages of null and light turbulence while a greater percentage of MOG turbulence is found with wind speeds greater than 15 kts. For gust speeds (Fig. 8) this same trend is found with the MOG reports becoming more prevalent with gust speeds over 25 kts.

4. Visibility

Visibility is defined as the maximum distance that an object can be seen and identified with the naked eye and is closely related to the visual range (NWS, 1998). During the day a dark object against a light sky is required, while at night a light source is necessary for the observation.

Obviously, low visibility can have a great impact on surface transportation. However, it can be transient and the result of many different weather patterns. For example, low visibility can be caused by fog, which is usually associated with light winds and high relative humidity, or by blowing dust or snow caused by strong, gusty winds. Certain types of weather, e.g. heavy rain or snow, can also cause lower visibilities. Therefore, taking an average or median value doesn't give much information on the weather patterns or mechanisms that cause it. What it can do, though, is give an idea of which places in the U.S. see the most hours of less than unlimited visibility.

The term "unlimited visibility" must first be quantified. To a human observer this might mean, in numerical terms, anywhere from 10 to 60 (or more) statute miles. To an ASOS this term means 10 statute miles as this is the maximum visibility that will be reported by the station (NWS, 1998). There are two ways to go about getting the data from the METAR dataset (which includes some ASOS and some human observations) into the same context. The first is to take the median value of the visibility for each station. Because the median is less sensitive to extreme values it can help with a skewed dataset such as this. The other way is to replace any observations greater than 10 miles with 10 miles, just as the ASOS does, and then take the mean.

For purposes of this paper the latter method was chosen because it treated all observations the same no matter what their source. Capping the visibility at 10 miles meant that this was considered "unlimited visibility". If we assume that this was the most common visibility reported at each station then the average values should be an indicator of the number of hours that the station reported a visibility that was less than unlimited with lower values meaning more hours of less than unlimited visibility.

Figure 9 shows the average visibility for the stations in the dataset in each of the four seasons. The largest variability occurs on the Pacific Coast and east of the Mississippi River.

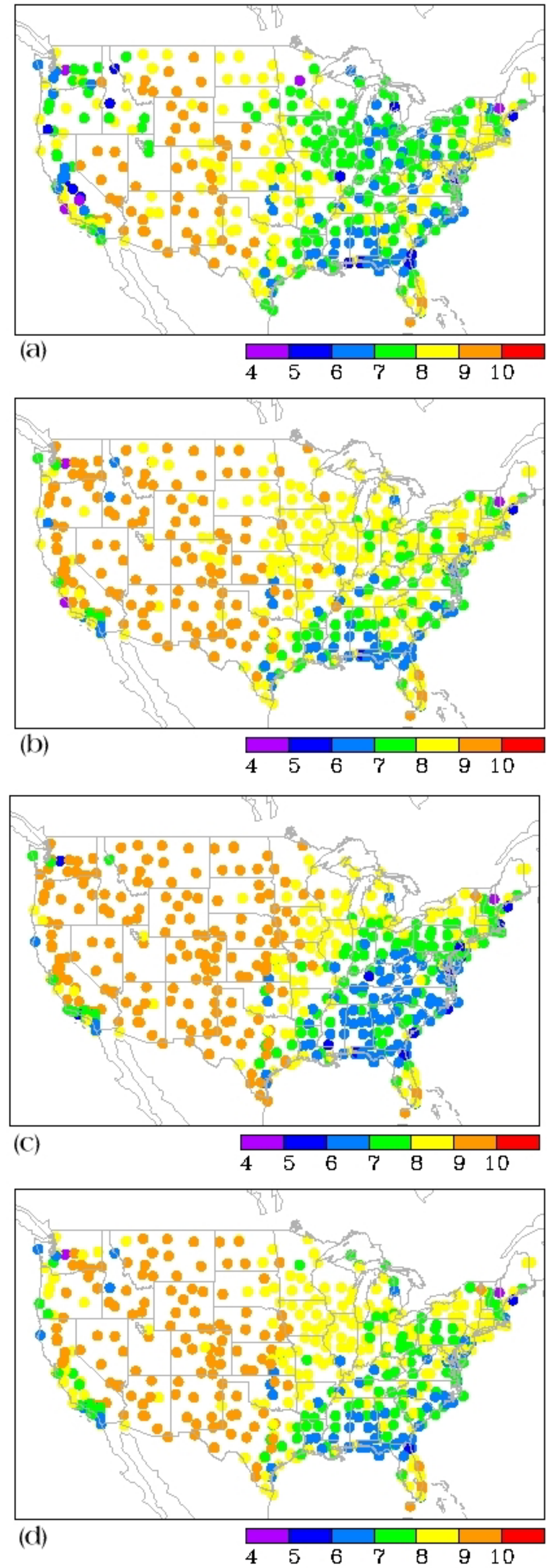

Figure 9. Average visibility for (a) DJF, (b) MAM, (c) JJA, (d) SON. Values are in miles.

The relatively constant values in the Rocky Mountains and out into the plains are due mainly to the dry air found in this region nearly year round. Because of this, fog is quite rare at those stations. Most of the low visibility reports are likely from blowing dust or snow.

In the far west the lowest average visibilities occur during the winter months, which is when the bulk of the precipitation falls. The excess moisture makes this region especially susceptible to fog and the strong storms moving onshore in the winter bring added visibility effects from heavy snow and/or rain and strong winds.

Further east, along the Appalachians and in the southeast, the highest average visibilities can be found during the winter months with a minimum during the summer. The reason for this is the high dewpoints experienced by this region during the summer. Haze and visibilities from 5 – 7 miles during clear conditions are quite common.

The spring and fall appear to have the most days of unlimited visibility with their high average values throughout most of the U.S. At this time, it is not easily explained why this is the case.

High relative humidity can be correlated to reports of fog and lowered visibility. Average relative humidity (not shown) was calculated for the stations as well. In the east and southeast the highest values were found during the summer with very low values across the west at this time. This correlates well with the average visibilities reported in these regions in the summer. On the west coast average relative humidity was highest in the winter, during the rainy season. There was also an increase in the central U.S. in winter due to the lower temperatures and may be partly responsible for the lower average visibilities.

5. Summary

We have presented climatologies of sustained winds, gusts, and visibility for the continental U.S. All of the fields studied, while important to transportation, are not easily quantified because of their highly variable nature. However, areas of possible problems have been outlined.

The average sustained winds and wind gusts are highest during the seasons of increased cyclone activity and over the favored paths of these storms. At this time it does not appear that the surface wind data shows a strong enough correlation to be used as a diagnostic tool for low-level turbulence. Part of the lack of a strong correlation is due to the nature of PIREPs, which are sporadic, but constitute the only measure of turbulence currently available. We will continue to investigate this linkage as more PIREPs become available. To improve on this perhaps sounding data could be analyzed to examine the static stability of the low levels of the atmosphere. In regions with high low-level stability the gusts at the surface may not be able to have an effect on the lower atmosphere due to a lack of mixing. This could constitute a future study.

Visibility also showed a seasonal and spatial variation that is likely linked to the amount of moisture and the weather patterns common to each region. The average visibility can be related to the number of observations below unlimited, which can give a better idea of the likely impact of this parameter when planning routes. The causes of the low visibilities at various stations could also be investigated as part of a future study to examine trends in fog reports and other reasons for decreased visibility.

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6. References

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