Moisture Transport by the Low-Level Jet

C.D. Whiteman, X. Bian, S. Zhong, and J.C. Liljegren
Pacific Northwest National Laboratory
Richland, Washington

Introduction

The Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site near Lamont, Oklahoma, frequently experiences low-level jets (LLJ). These recurring boundary layer jet wind maxima play an important role in transporting moisture northward from the Gulf of Mexico to the central United States, where the moisture is processed by convective cloud systems to produce precipitation. The research reported here is focused on determining the characteristics of the LLJ at the SGP central site (CS). The CS is nearly ideally situated for this purpose, as it is on the axis of the climatological maximum of LLJ occurrence, and a suite of new remote wind and moisture profiling instruments is now available there. Additionally, up to 8 rawinsonde soundings per day (more typically, 5 per day) have been launched from the CS since March 1994.

Comparison Between Rawinsonde and Radar Profiler Data

We have compared CS rawinsonde wind data with hour-average wind data from the 915-MHz CS radar profiler operated in both the high- and low-resolution modes and with the 404-MHz radar profiler operated at Lamont, Oklahoma, 9.5 km north of CS (Figure 1). Significant measurement discrepancies appear between the rawinsonde- and radar profiler-derived winds. These discrepancies are indicated in Figure 2 as vector differences between the rawinsonde and 915-MHz radar profiler winds, as shown over a 7-day period. The discrepancies are currently under investigation. Hypotheses are focusing on possible radar wind measurement errors caused by migrating birds or insects and on basic differences in the characteristics of the two measurement techniques (e.g., the radar profilers provide area- and time-averaged wind profiles, while the rawinsondes provide nearly-instantaneous "snapshots" of the wind profiles).

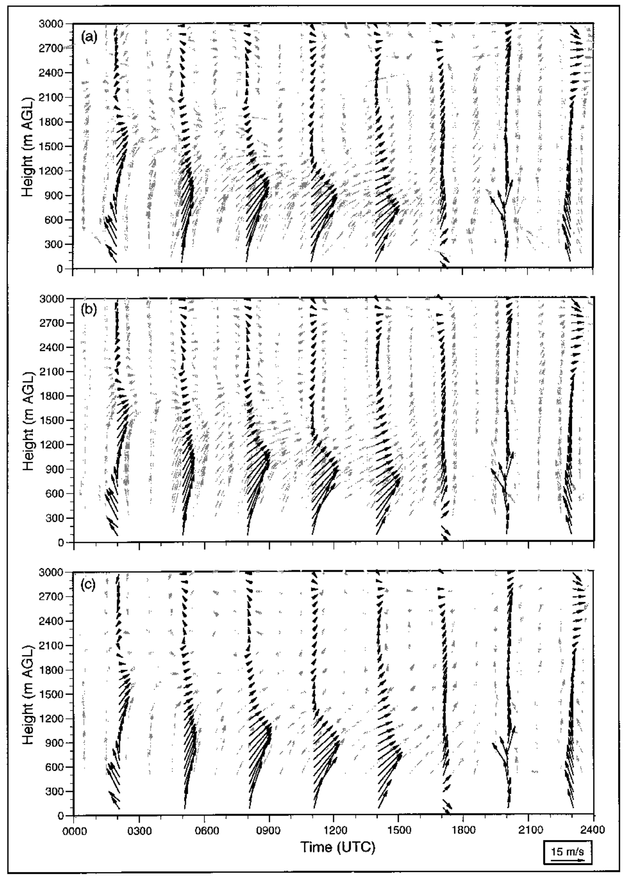

Figure 1. Rawinsonde- and radar profiler-derived wind vectors on a height-time cross section for the 915-MHz high-resolution, 915-MHz low-resolution and 404-MHz high-resolution radar profilers for August 1, 1994. Three hourly rawinsonde winds (dark arrows) are plotted over the hourly radar profiler winds (gray arrows) to facilitate intercomparisons. Each vector is an average over 100 m of altitude and is plotted at the midpoint of the 100-m interval. A vector pointing to the right indicates a wind which blows from the west, a vector pointing up indicates a wind from the south, etc.

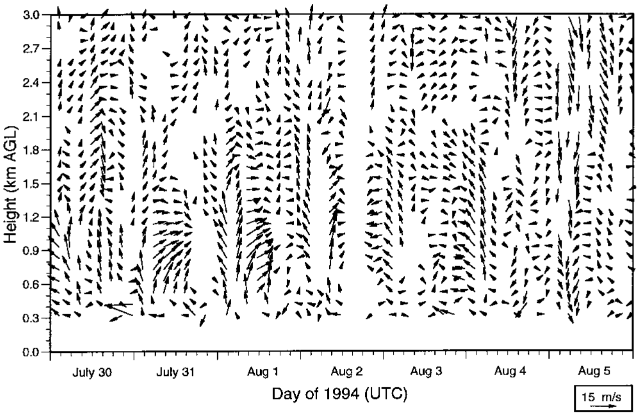

Figure 2. Time-height cross section of vector wind differences between radar profiler- and rawinsonde-derived wind vectors at the SGP CART site during the period from July 30 through August 5, 1994. The vectors indicate horizontal wind directions and speeds. Radar profiler winds were interpolated in time and rawinsonde data were averaged over the same height intervals as the radar profiler before the vector differences were computed. CST = UTC - 6 hrs.

Table 1. Percentage of rawinsonde soundings exhibiting jets.

	Definition[a]		warm season	cold season	all seasons
LLJ Category	V_{max} (m/s)	ΔV (m/s)	%	%	%
0	$\geq$10	$\geq$5	12.6	10.1	11.7
0	$\geq$12	$\geq$6	18.6	12.9	16.5
2	$\geq$16	$\geq$8	9.0	7.1	8.3
3	$\geq$20	$\geq$10	6.5	10.6	8.0
jets	$\geq$10	$\geq$5	46.7	40.7	44.5
non-jets	--	--	53.3	59.3	55.5

(a) Vmax is the maximum speed at the nose of the jet, and ΔV is the difference between the jet max speed and the minimum speed above the jet max height, but below 3 km AGL. A jet sounding is assigned to only one category - the highest category possible. Categories 1-3 are the same as Bonner's (1968) categories.

Characteristics of LLJs Over the Site

Rawinsonde data have been used for initial analyses of the low-level CS wind field. The available 18-month period of rawinsonde records is quite short for climatological analyses, although our computed statistics should prove useful for initial indications of LLJ characteristics.

The frequency distribution of LLJ occurrences in the rawinsonde record is provided in Table 1 for the period of record from 21 March 1994 through 19 October 1995. To produce Table 1, each of the rawinsonde soundings was categorized in terms of the occurrence of jet features in the vertical wind profile, using jet strength categories provided by Bonner (1968), but with an added category for weaker jets. Analyses were completed for both the warm (April through September) and cold (October through March) seasons. Note that the definition of jet categories takes no account of wind direction.

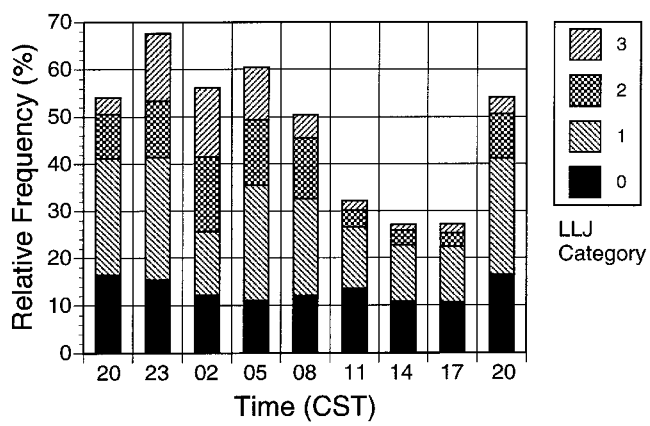

Figure 3. Relative frequency of jets (category 0-3 jets) in the warm season as a function of rawinsonde sounding time.

Low-level jets are present in 47% of the warm season soundings and in 41% of the cold season soundings. LLJs are most frequent at night (Figure 3), and are present in over 50% of the soundings at 20, 23, 02, 05, and 08 Central Standard Time (Figure 3). They also have a significant presence during daytime. The maximum jet wind speeds are typically 12-14 m/s during the warm season, but over 20% of the rawinsonde jet soundings have maximum jet winds exceeding 20 m/s (Figure 4). The warm season LLJ wind directions are typically from the south-southeast through the southwest (Figure 5), and the height of the jet maximum is typically 250-450 m above ground level (Figure 6). The jets tend to attain their maximum heights when the winds become strongest, and the jet profiles usually do not extend above 1000 m (not shown). Because the 404- and 50-MHz wind profilers cannot resolve winds near the ground where

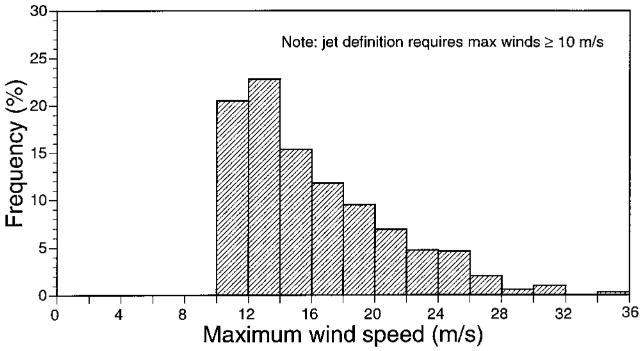

Figure 4. Maximum jet wind speeds for the warm season jet soundings.

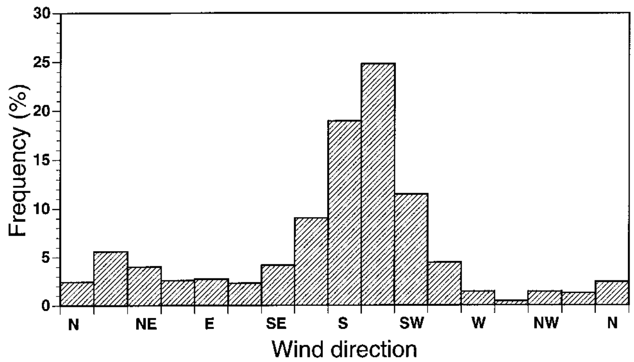

Figure 5. Relative frequency of wind directions for the warm season jet soundings. The wind directions are obtained at the nose of the jet.

much of the LLJ mass flux is carried, they will not be particularly useful in many LLJ studies.

Moisture Characteristics

During the warm season, jet profiles exhibit higher specific humidity (7.79 g/kg) than non-jet profiles (7.01 g/kg). The strong jet winds combine with the higher humidity to produce strong horizontal moisture fluxes. The mean moisture flux for jet soundings during the warm season, for example, is 2.5 times the mean moisture flux for non-jet soundings. The moisture flux for the jet profiles can exceed that for the non-jet profiles by an order of magnitude during the night (not shown). A strong diurnal pattern in northward moisture flux is seen in the jet soundings, corresponding to the higher wind speeds and humidities when the LLJ is present (Figure 7).

Reference

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

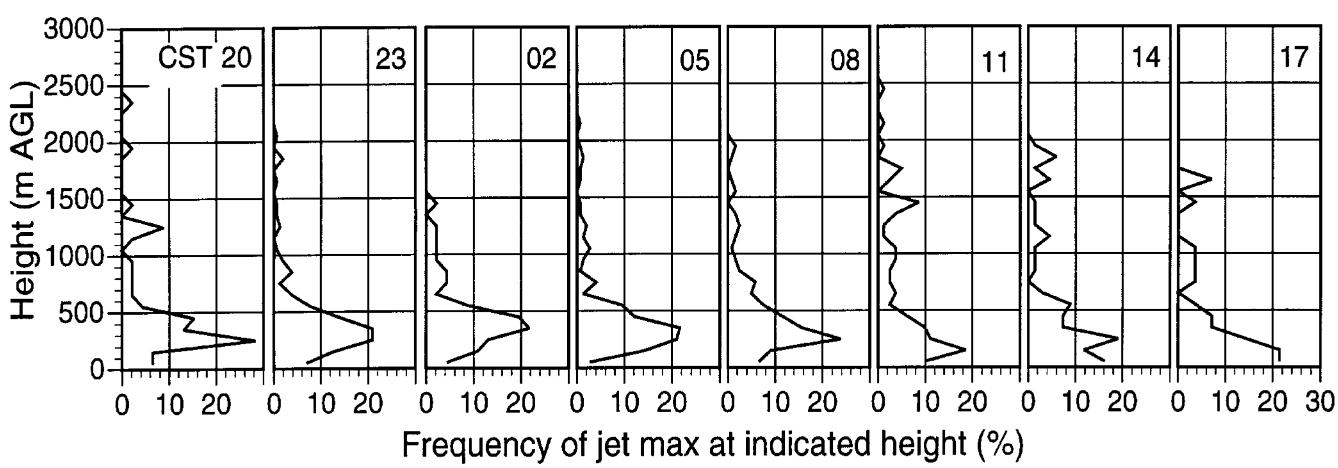

Figure 6. Height of the jet maximum, as observed with rawinsondes during the warm season. The abscissa indicates the relative frequency of rawinsonde observations of the jet at the indicated heights.

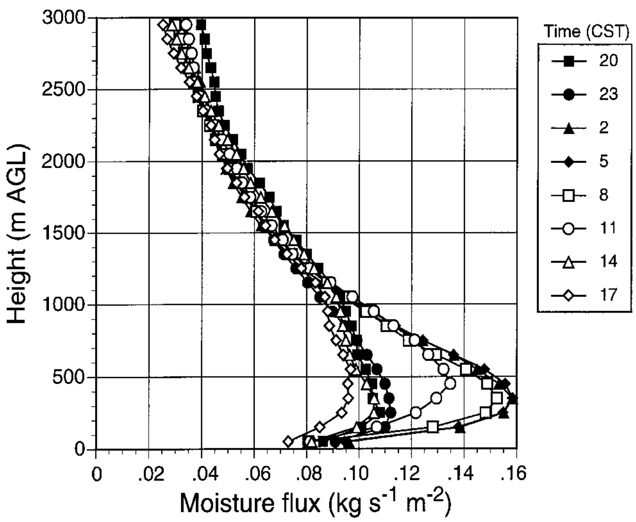

Figure 7. Moisture flux as a function of height at the SGP CART site for warm season rawinsonde soundings exhibiting a category 0-3 jet (see Table 1) at the observation times indicated.