Exchanges
- Scientific Contributions -

Influence of cross-Andes flow on the SALLJs and application of real-time scatterometer observations to forecasting the SALLJs*

Hui Wang[1], Rong Fu[1], Wenqing Tan[2], and W. Timothy Liu[2]
[1]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA
[2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
corresponding e-mail: fu@eas.gatech.edu

1. Introduction

South American low-level jets (SALLJs) frequently occur to the east of the Andes throughout the year, and they are strongest in austral winter (Li and Treut, 1999; Nogues-Paegle et al., 2002). These features are different from LLJs occurring in many other places that exist only during summer (Stensrud, 1996). Several recent studies have independently suggested mechanical blocking by the Andes as an important controlling factor of the SALLJs (Byerle and Paegle, 2002; Campetella and Vera, 2002; Wang and Fu, 2004). In this study, we use the 15-year (1979–93) ECMWF Reanalysis data to show that the changes in the SALLJs are largely determined by the upstream zonal flow of previous days under the influence of the Andes. This provides an explanation of the seasonal and intraseasonal variations of SALLJs due to the changes of the upstream wind pattern. The mechanism is also a basis for making LLJ forecasts using NASA QuikSCAT ocean surface winds over the subtropical South Pacific.

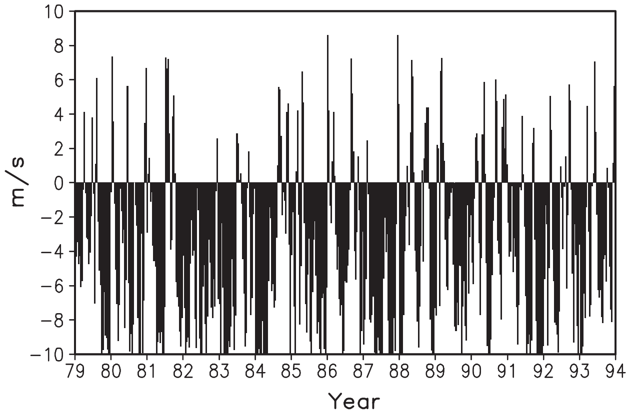

Fig. 1: Time series of 850-hPa daily mean meridional winds averaged over the LLJ region (15°–25°S, 55°–65°W) for July from 1979 to 1993.

2. Mechanism of SALLJs

Since SALLJs are oriented poleward, we use daily 850-hPa meridional winds averaged over (55°–65°W, 15°–25°S) as an LLJ index to represent the SALLJ variability. In this way, LLJs are a part of meridional wind variations in some

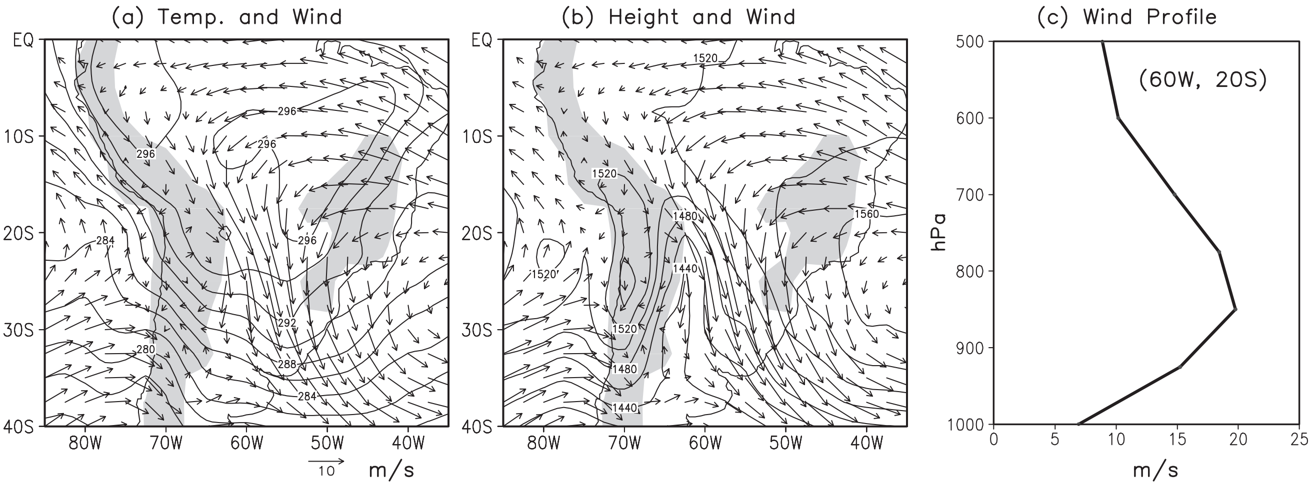

Fig. 2: Composites of (a) 925-hPa temperature, (b) 850-hPa height (contours) with 850-hPa wind (vectors), and (c) vertical profile of horizontal wind at (20°S, 60°W), based on top 20% of poleward wind events in the LLJ index. Contour interval is (a) 2 K and (b) 20 m. Shadings indicate topography.

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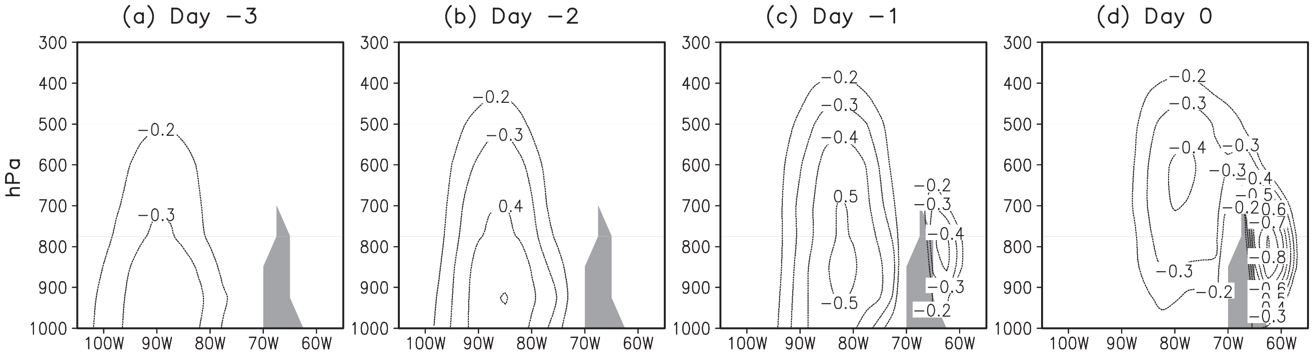

Fig. 3: Correlations between zonal wind at 20°S and the LLJ index, using 15-yr daily data for July. Correlation maps are shown for zonal wind leading the LLJ index by (a) 3 days, (b) 2 days, (c) 1 day, and (d) 0 day. Contour interval is 0.1 with negative values dashed. Contours between –0.2 and 0.2 are omitted. Shadings are topography.

extreme phase. The following analyses focus on July since the SALLJs are strongest in this month. The 15-year daily LLJ index (Fig. 1) is dominated by poleward winds (80%). There is a high variation in the intensity of the low-level meridional winds to the east of the Andes.

Figure 2 shows the composites of 925-hPa temperature (Fig. 2a) and 850-hPa height (Fig. 2b) with 850-hPa wind for July. The composites are made based on the cases of top 20% poleward winds in the LLJ index (Fig. 1). These extremes have the major LLJ feature with maximum winds near 850 hPa (Fig. 2c). The LLJs are largely normal to the lower-level isotherms. This suggests that the jets may not be caused by lower-level zonal temperature gradients through the thermal wind, which is a major mechanism for LLJs occurring in many other places during summer. The 850-hPa height field displays a ridge on the upwind side of the Andes and a trough on the lee side, a typical flow pattern disturbed by orography. The LLJs around 60°W are nearly along the height contours. The strong northerly flow is thus maintained by the large zonal height gradients associated with the lee trough through geostrophic balance. The latter is closely related to orographically induced pressure disturbance and lee cyclogenesis.

The effect of the upstream flow on SALLJs through lee trough is supported by the evidence that the LLJ index highly correlates with the upstream zonal winds of preceding days (Fig. 3). Significant negative correlations are found over South Pacific when zonal winds lead the LLJ index. The negative correlations indicate that the larger the westerly winds upstream, the stronger the northerly LLJs downstream. The strong zonal winds in the South Pacific are actually a part of the lower-level cyclonic circulation associated with an upper-level trough (Wang and Fu 2004). The intensification of the lee trough involves both pressure decreases caused by the baroclinic development of the upper-level trough crossing the Andes and by strong zonal winds associated with the trough deflected by the Andes. The mechanism explains the seasonal variation of SALLJs. In austral summer, the circulation is dominated by subtropical highs over South Pacific. Westerly winds are weak. The northerly meridional winds to the east of the Andes are thus weak in January. In winter the upstream circulation is characterized by strong westerlies that favor strong LLJs downstream.

3. Forecasting SALLJs based on observed winds over the Southeast Pacific

Significant correlations between the LLJ index and zonal winds of previous days suggest that the upstream zonal winds may be used as a predictor for SALLJs. The correlations are stronger near the surface (Fig. 3). Given a surface zonal wind pattern obtained from the NASA QuikSCAT satellite observations, the LLJ index can be predicted based on the relationship depicted by linear regressions.

The ECMWF Operational Analysis data from 1993–2003 and the QuikSCAT ocean surface winds of 1999–2002,

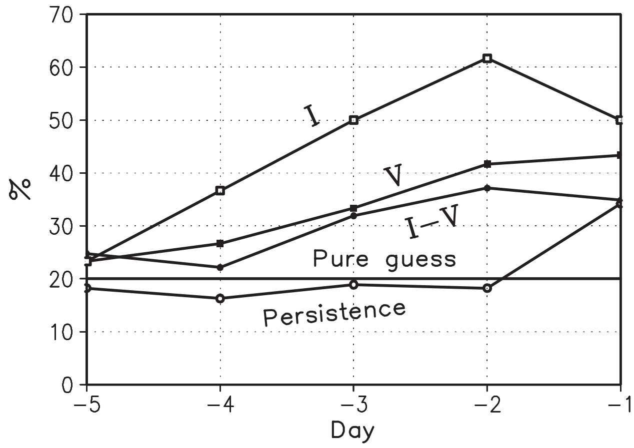

Fig. 4: Percentages of hit between the LLJ index and those of hindcasts based on pure guess, persistence, and upstream zonal winds for all five-category LLJs, and for categories I and V, respectively. These hindcasts are made in different days from day –5 to day –1.

both of which have a 4-year overlap, are employed for making LLJ forecasts. First, we construct a set of 11-year (1993-2003) daily zonal wind index by averaging surface zonal winds over the regions exhibiting strong correlations with the LLJ index. We take both the zonal wind index and the LLJ index of one target month out of the data and perform a linear regression on the rest of the 10-year daily data. Hindcasts of daily LLJ index are then made for the target month using the zonal wind index of that month constructed from the QuikSCAT surface winds and the relationship between the zonal wind index and LLJ index depicted by the linear regression. The same procedure is repeated for austral summer months of 1999–2002 and for different lead times of zonal winds with respect to LLJs. Both the observed and predicted LLJ indices are then evenly divided into 5 categories, respectively. Class I (upper 20%) represents the strongest northerly LLJs and class V (lower 20%) the strongest southerly winds. A hit rate is then used to measure the predictive skill, which is the ratio of number of hits when both LLJ index and hindcast fall into the same category to the total number of events. Figure 4 shows the hit rates for hindcasts made at different days from day –5 to day –1. The hit rates based on QuikSCAT surface winds are higher than those based on persistence and pure guess. The forecasts are better for the extreme cases (I and V).

4. Conclusions

We demonstrated that SALLJs are largely maintained by strong zonal height gradients caused by upstream zonal flow crossing the Andes and lee cyclogenesis. This mechanism explains the seasonal variation of the SALLJs due to the seasonal changes of upstream flow pattern. We have also introduced a method for up to 5-day forecasts of SALLJs based on NASA QuikSCAT ocean surface winds over South Pacific. A cross validation indicates a significant predictability of SALLJs.

References

Byerle, L.A., and J. Paegle, 2002: Description of the seasonal cycle of low-level flows flanking the Andes and their interannual variability. *Meteorologica*, **27**, 71–88.

Campetella, C.M., and C.S. Vera, 2002: The influence of Andes mountains on the South American low-level flow. In Extended Abstracts of the VAMOS/CLIVAR/WCRP Conference on South American low-level jets. 5–7 February 2002. Santa Cruz de la Sierra, Bolivia. (Available at http://www-cima.at.fcen.uba.ar/sallj/index.html).

Li, Z. X., and H.L. Treut, 1999: Transient behavior of the meridional moisture transport across South America and its relation to atmospheric circulation patterns. *Geophys. Res. Lett.*, **26**, 1409–1412.

Nogues-Paegle, and Coauthors, 2002: Progress in Pan American CLIVAR research: Understanding the South American monsoon. *Meteorologica*, **27**, 1-30.

Stensrud, D. J., 1996: Importance of low-level jets to climate: A review. *J. Climate*, **9**, 1698-1711.

Wang, H., and R. Fu, 2004: Influence of Cross-Andes Flow on the South American Low-Level Jet. *J. Climate*, **17**, in press.