NOTES AND CORRESPONDENCE

The Southern Oscillation in the Stratosphere

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ABSTRACT

The signal of the Southern Oscillation in the lower half of the Northern Hemisphere stratosphere in winter appears to be as follows: In the extreme of the Southern Oscillation when the trade winds are comparatively weak in the South Pacific Ocean, stratospheric geopotential heights and temperatures tend to be higher over the Arctic and lower in middle latitudes than in the opposite extreme. At the same time, the polar-night stratospheric jetstream tends to be weaker and the subtropical westerlies to be stronger. The conclusions are based on 11 extremes within a 15-year period and on data at standard pressure levels as high as 10 mb.

1. Introduction

It has long been known that the Southern Oscillation (SO) affects the atmospheric circulation at the earth's surface all over the world. It was therefore not surprising to find that the signal of the oscillation appears both in the middle troposphere (Horel and Wallace, 1981; van Loon and Rogers, 1981) and in the stratosphere of the Northern Hemisphere (van Loon *et al.*, 1981). In the latter paper we gave a description of the SO at the standard pressure levels from 100 to 10 mb, treating temperature, geostrophic wind, geopotential height, stationary long waves, and eddy fluxes of sensible heat and angular momentum. We refer the reader to this publication for the details and present here only material enough to illustrate the major features.

Our data cover 15 northern winters, beginning with the winter of 1963–64, when the SO was vigorous and its extremes often followed each other at intervals shorter than those common in the last 80 years (see Table 1 in van Loon and Madden, 1981). The 15 years of our sample contain 11 extremes of the SO (see Fig. 4). Following van Loon and Madden (1981), we named the extremes LOW/WET and HIGH/DRY (LW and HD), where the LOW and HIGH refer to the sea level pressure at stations in the region of the South Pacific subtropical high, and the WET and DRY to the rainfall at islands near the equator in the central and western Pacific Ocean. LOW/WET is thus the extreme when the pressure at our key stations tends to be low, the southeast trades to be comparatively weak, upwelling on the equator reduced or stopped, and the water temperature and rainfall over large parts of the equatorial Pacific above normal. In HIGH/DRY the opposite circumstances prevail (see van Loon and Madden, 1981). We made an average of the element investigated for either extreme of the SO, and subtracted the averages of the two extremes from each other. This is a rather strong filtering because the signal is not only freed from much noise by the averaging, but it is further enhanced by the taking of the difference.

2. Stratospheric temperatures, winds and geopotential heights in the Southern Oscillation

The difference between the average 100 mb temperature in the seven LW years and that in the four HD years is shown in Fig. 1a. The temperature tends to be higher in LW than in HD over the Arctic and North America, but lower in a zone lying east-northeast from ~15°N 150°W to 45°N 180°. In lower latitudes over the eastern half of the hemisphere the sign of the difference is the same as over the Arctic. The results of a Student's *t*-test in Fig. 1b indicate that all the major differences are statistically significant beyond the 95% confidence level. From the above distribution of temperature differences it is clear that in middle and high latitudes the thermal wind is weaker and that in lower latitudes stronger

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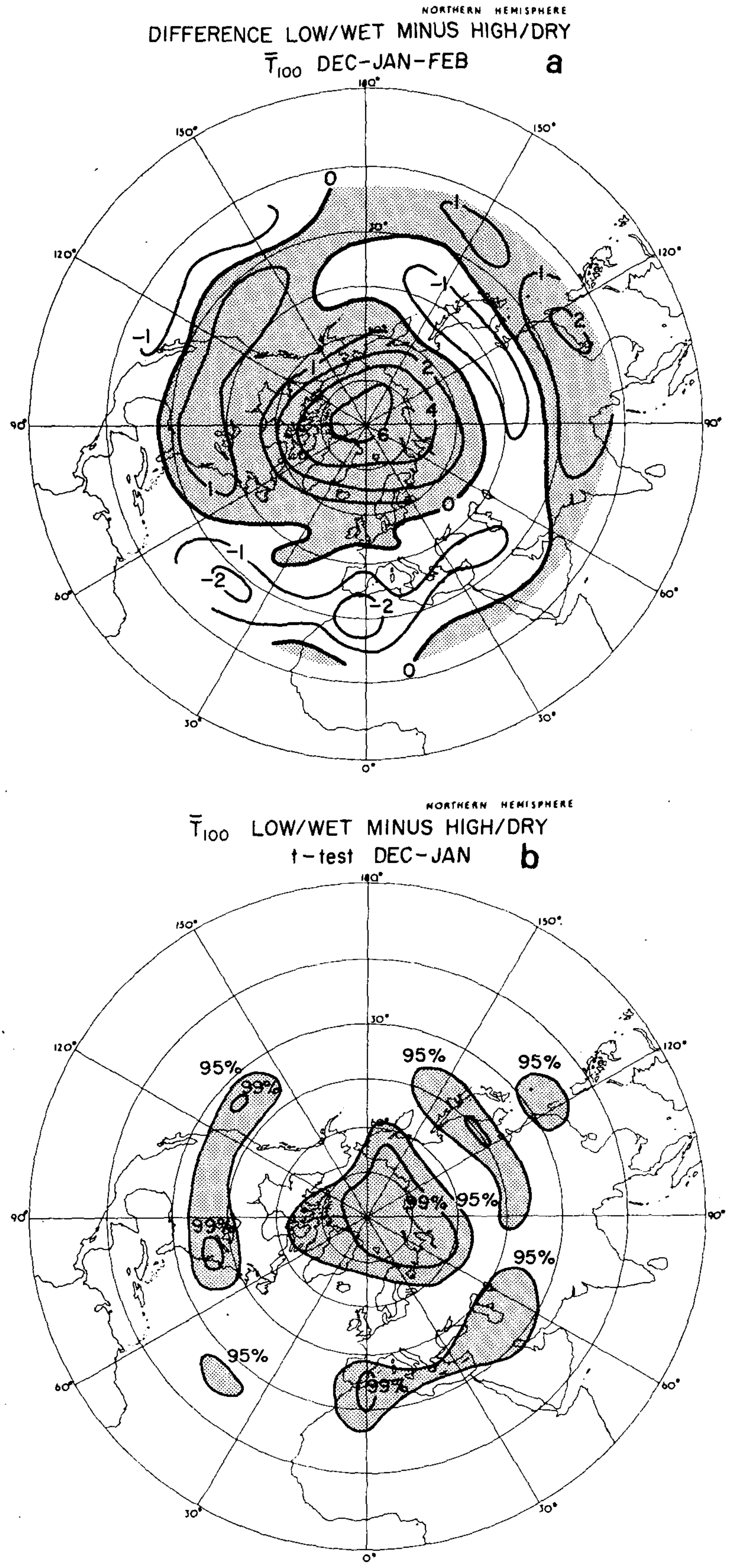

FIG. 1. (a) The difference in 100 mb temperature between the two extremes of the Southern Oscillation. LW minus HD, Dec-Jan-Feb (°C). (b) A Student's *t*-test of (a).

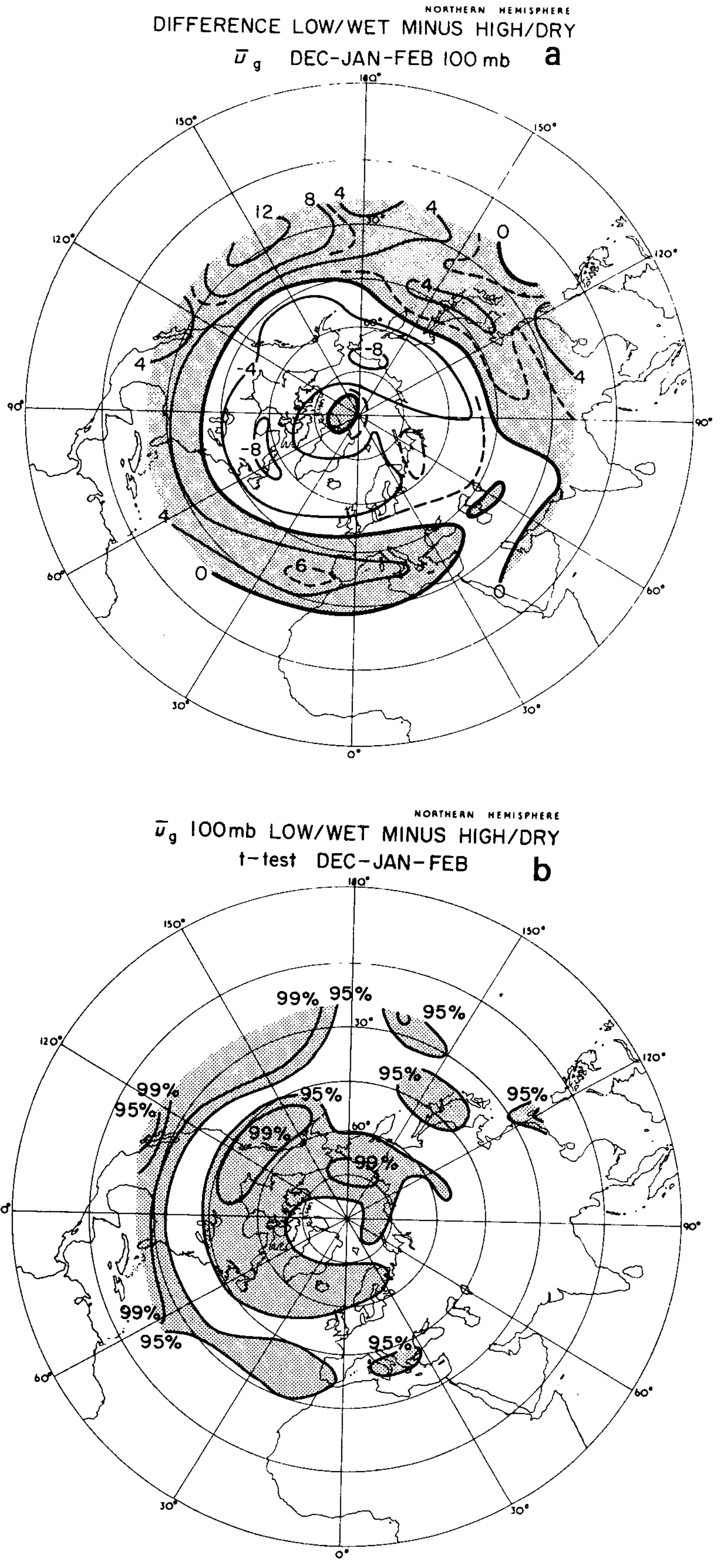

FIG. 2. (a) As Fig. 1a, but for zonal geostrophic wind (m s^{-1}). (b) A Student's *t*-test of (a).

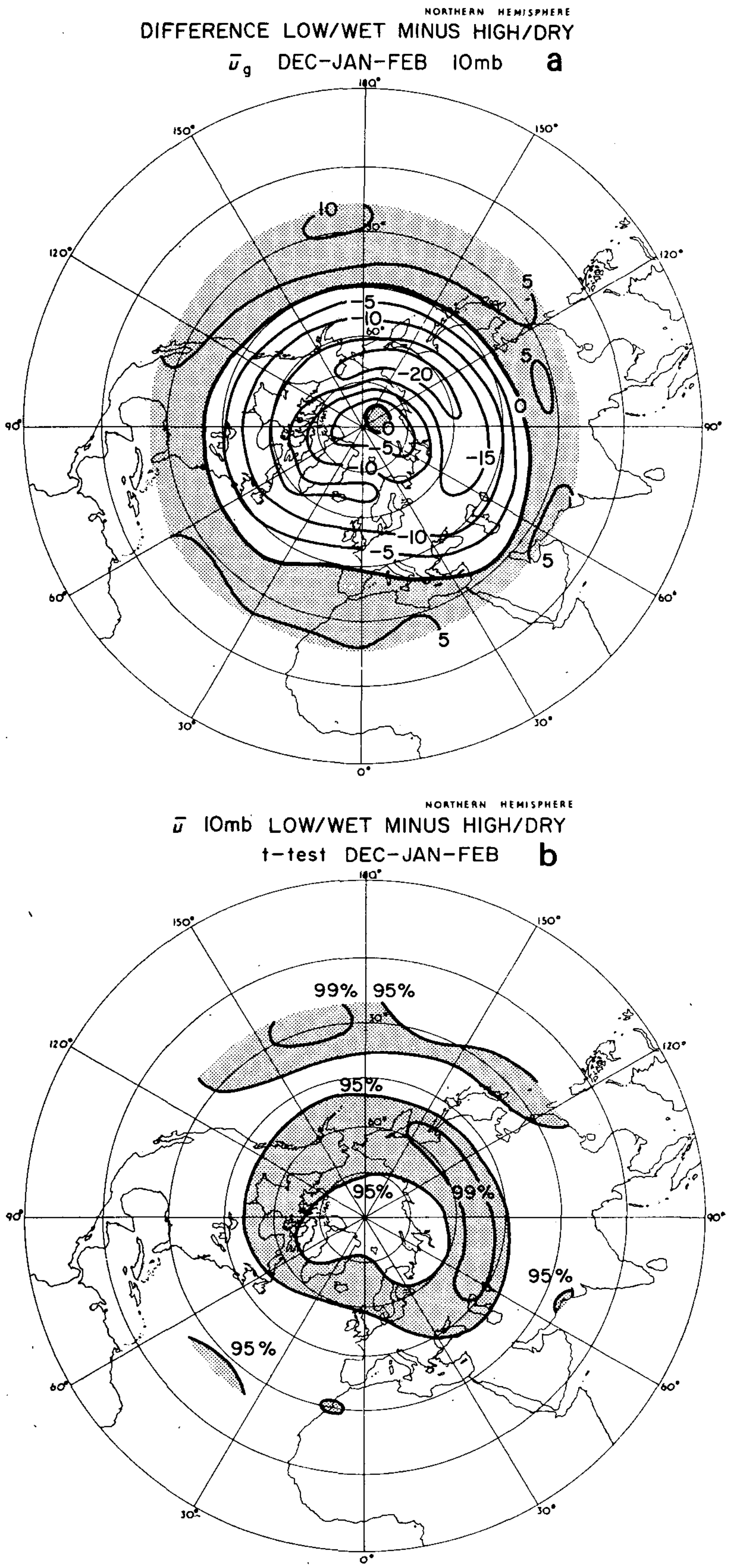

FIG. 3. (a) As in Fig. 2a, but for 10 mb. (b) A Student's *t*-test of (a).

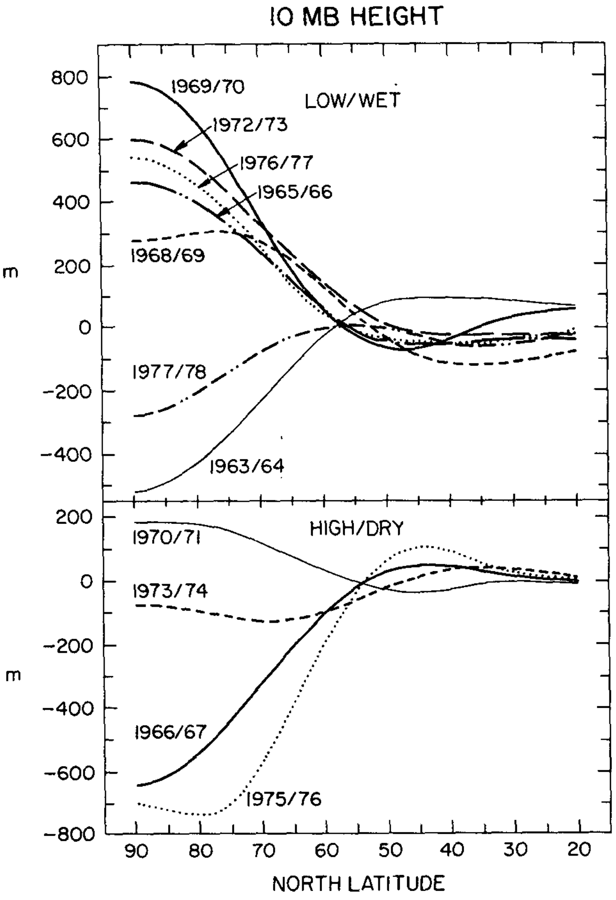

FIG. 4. Meridional profiles of the deviation of geopotential heights (m) from a 15-year mean. Top: LW years. Bottom: HD years.

in LW than in HD. This difference in thermal wind together with the difference in 100-mb zonal geostrophic wind in Fig. 2a (Student's *t*-test in Fig. 2b), is reflected in the fact that the average geostrophic west wind at 10 mb is as much as 22 m s^{-1} weaker in LW than in HD in the latitudes of the polar-night jetstream (Fig. 3a), and 5–10 m s^{-1} stronger in LW over most of the area south of ~45°N. A Student's *t*-test of the zonal geostrophic wind difference at 10 mb is given in Fig. 3b.

One may deduce from the description above that the geopotential heights in the stratosphere in LW, at least as high as the 10 mb level, often were above the 15-year mean in the Arctic and below the mean in middle and low latitudes. The converse applied in HD. The mean differences in geopotential height between the two extremes of the SO which are shown for the standard pressure levels in van Loon *et al.* (1981) confirm this deduction. The deviation of the zonally averaged 10 mb height from the 15-year mean is given for the LW and HD years in Fig. 4. It is obvious that not every year conforms to the pattern indicated by the composites: two out of the seven LW and one out of the four HD years have zonal profiles which rather fit the opposite category. There are at least two possible reasons for this lack of conformity: one may be that the criteria used for defining the extremes of the SO are flawed; the other, that other influences may at times overwhelm that of the SO.

Holton and Tan (1980) have investigated the influence of the equatorial Quasi-Biennial Oscillation (QBO) on the extratropical circulation at 50 mb. They composited the 50 mb heights according to the phase of the QBO in the wind at Balboa for the 16 years 1962–77, which period is nearly the same as ours: 1963/64–1977/78. Holton and Tan's monthly mean differences of 50 mb height, westerly minus easterly phase of the QBO, are similar to those we obtained by compositing the heights according to the extremes of the SO. The reason for the similarity may be that the SO during this period occurred with a frequency approaching that of the QBO, and that of the seven easterly winters of Holton and Tan, five coincided with LW winters in our period.

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