4.1 WAVEGUIDES AND THE REMOTE RESPONSE TO TROPICAL SST ANOMALIES

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1. INTRODUCTION

1.1 *Background*

The concept of a waveguide is fundamental to our understanding of the extratropical response to interannual variations in SST. Two common applications of this concept are 1) the bending of tropically stimulated wavetrains away from the poles with smaller scale features experiencing the refraction at lower latitudes than large scale features and 2) the confinement of tropical quasi-stationary Rossby waves to those regions where there are mean westerlies. In this investigation we consider a third way that waveguides influence the remote response to tropical heating. From linear analysis we know that the climatological subtropical jet should meridionally trap medium scale disturbances. This trapping has the potential to broadcast the influence of tropical SST anomalies to distance points on the globe.

1.2 *Internal Variability*

That the dynamical waveguiding effect of the subtropical jet is strong enough to influence interannual variability, independent of any organizing effects arising from tropical forcing, can be seen by focusing on disturbances generated through intrinsic atmospheric variability. Using one point correlation plots, Branstator (2002) has shown that for intrinsic DJF upper tropospheric interannual variability there are patterns of variability consisting of east-west oriented chains of highs and lows confined to the band of mean jets and encircling the Northern Hemisphere. This behavior is discernible in observations from nature as well as in AGCMs. These patterns are especially noticeable in fields that are prominent in the subtropics like streamfunction and the v-component of the wind.

Further analysis demonstrates how important the subtropical jet waveguide is in shaping interannual variability. It produces a peak at zonal wavenumber five in spatial spectra. And it leads to local maxima in intrinsic interannual variance along the core of the mean jets (Fig. 1 top).

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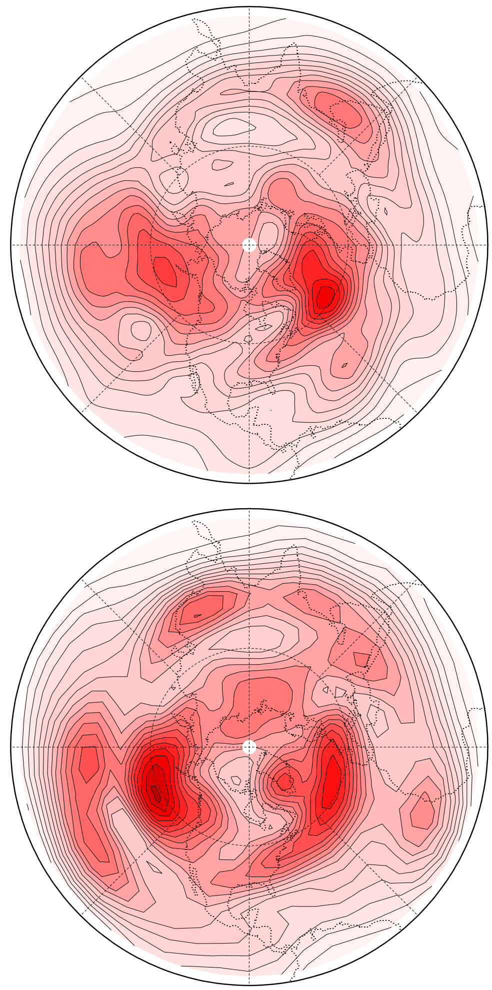

FIG. 1: Variance of 300hPa streamfunction from reanalysis data. Top: Dec, Jan and Feb means with DJF means removed. Bottom: DJF means.

2. RESULTS

2.1 *Response to Tropical Heating*

With the subtropical waveguide having such a strong effect on intrinsic interannual variability, one would expect it to also influence externally forced variability. In particular the extratropical response to tropical heating should be affected. To quantify this effect we first examine external interannual variability in the same ways used to analyze intrinsic variability. We find that for both observations of nature, and for states generated by AGCM AMIP runs, signatures of the waveguide's effects similar to those found for intrinsic variability carry over to externally forced circulation anomalies. For example, there is enhanced variance in the vicinity of the mean jets (Fig. 1 bottom). In fact in the AGCM simulations, where the separation between internal and external variance can be accurately carried out, the waveguides have especially large ratios of external to internal variance suggesting they may be regions of enhanced potential predictability.

To identify the regions that are responsible for forcing the waveguide we use two approaches. First we perform an SVD analysis of the covariance matrix that relates interannual variability of the v-component of the wind in the Asian subtropical jet to SST variability. We find that interannual wind disturbances in this region are associated with SST anomalies in the eastern half of the tropical Pacific and in the Indian Ocean (Fig. 2 top). We also see (Fig. 2 bottom) that these wind anomalies are part of a hemispheric-wide circulation pattern. This pattern has the unmistakable structure of a disturbance forced from the tropical Pacific with a possible contribution from the Indian Ocean. These results pertain to observations from nature but AGCM AMIP integrations show similar behavior making the interpretation of cause and effect less problematic.

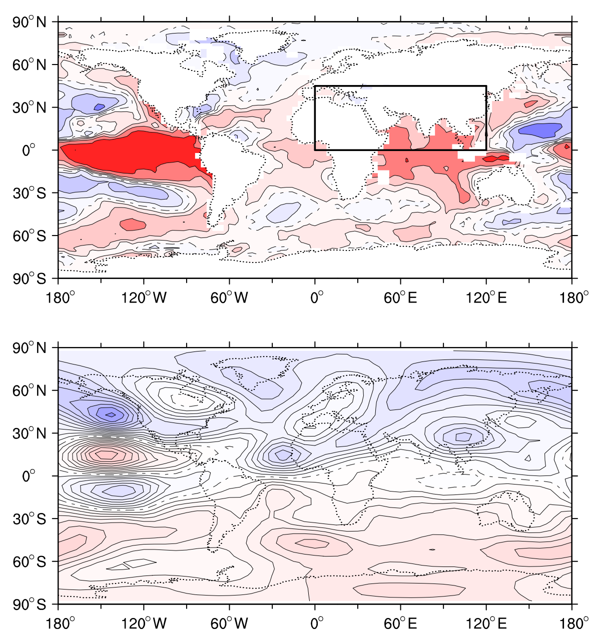

FIG. 2: Fields associated with the leading right singular vector of the South Asian sector v/global SST covariance matrix. Top: Correlation of SST with right SV1 (contour interval is .2). Bottom: Regression of 300hPa streamfunction with right SV1 (contour $5 \times 10^5 m^2 s^{-1}$).

In order to examine the role of the waveguide in tropical forcing situations that may not happen frequently in nature we next perform a suite of AGCM experiments in which a steady equatorial heat source is artificially imposed in the model at various longitudes. We find that Northern Hemispheric-wide midlatitude anomalies are produced for heating in many locations and that as a rule these circumglobal responses have structures that indicate they occur as a result of the action of the waveguide. Just as in the SVD analysis, it is the tropical Pacific and Indian Ocean that are most efficient at exciting a circumglobal waveguide response.

2.2 *El Niño / La Niña*

One of the most striking attributes of the AGCM equatorial heating experiments is that there is great sensitivity to the exact longitude of the imposed heating for cases when the heating is in the vicinity of the dateline. In Fig. 3 are anomalies generated in two experiments in which the position of the heating differs by only 30 degrees of longitude. For heating on the dateline a global, waveguide influenced response is produced. For heating at 150W the waveguide is not stimulated and a more familiar arch confined to the Pacific and North America is induced.

In nature the exact location of the SST anomaly and associated tropical rainfall varies enough from one El Niño/La Niña event to another that either of the Fig. 3 examples could correspond to individual observed events. The Fig. 3 result then suggests the effect of the waveguide may be a major contributor to event-to-event variability in the extratropical response to El Niño and La Niña events. To determine whether there is observational evidence for this sensitivity, we subdivide tropical Pacific events according to the longitude of the SST anomaly. Figure 4 shows composites of the most easterly (top) and westerly (bottom) positioned cases. On average there is roughly a 40 degree shift in the position of the SST anomaly maximum for these two composites. And just as in the AGCM the western cases are associated with a hemispheric circulation anomaly while the eastern cases produce a much more longitudinally confined response.

One does not need to resort to statistically derived fields to see the effect of the waveguide. Once one recognizes its importance, its influence on the circulation anomalies of individual years is evident.

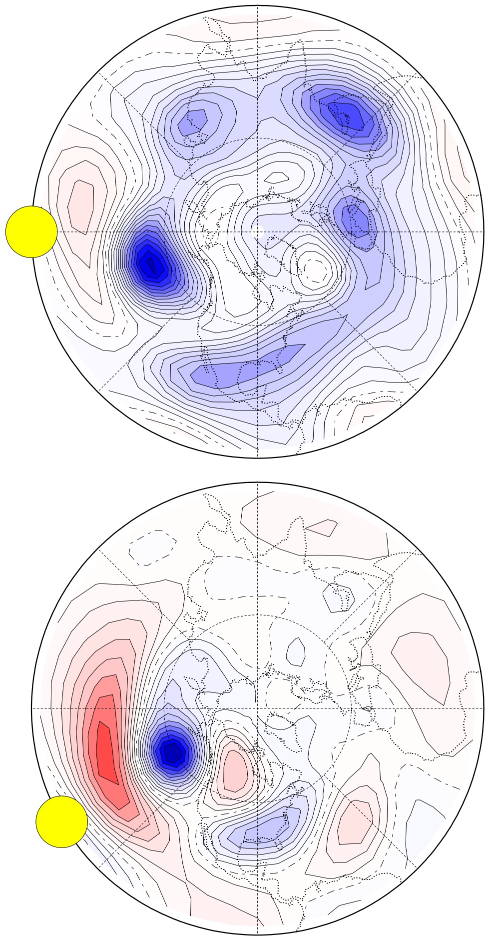

FIG. 3: Anomalous 300hPa streamfunction response of the AGCM NSIPP1 to equatorial heating at (top) 180W and (bottom) 150W. Contour interval is $1 \times 10^6 m^2 s^{-1}$.

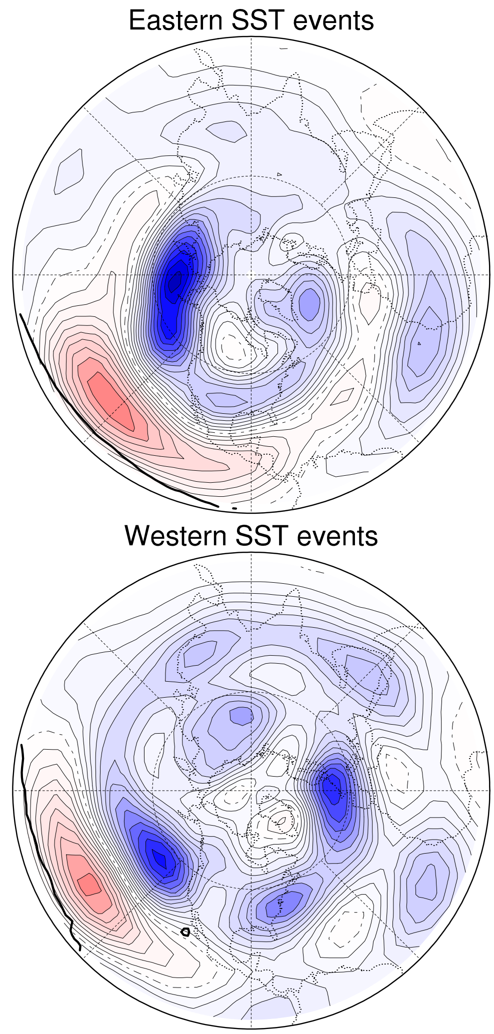

FIG. 4: Composite 300hPa streamfunction and SST anomalies for cases with tropical Pacific SST located in the eastern part of the domain (top) and farther to the west (bottom). (Light) streamfunction contour interval is $1 \times 10^6 m^2 s^{-1}$. Heavy line is the 1C SST contour.

The La Niña of 1988/89 and the El Niño of 1991/92 are two of many prominent examples.

3. SUMMARY

As predicted by linear theory, the climatological mean subtropical DJF jets act as a waveguide for medium scale disturbances. Not only does this help organize intrinsic interannual variability, it also strongly influences interannual variability forced by tropical heating anomalies. Of particular interest is the fact that it can make it possible for local heat sources to influence an entire hemisphere. It also means the extratropical response to tropical heating can be very sensitive to the exact location of the forcing since some locations excite the waveguide while other nearby locations do not.

4. REFERENCES

Branstator, G., 2002: Circumglobal teleconnections, the jet stream waveguide, and the North Atlantic Oscillation. *J. Climate*, **15**, 1893-1910.