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Satellite-Based Observations of the SPCZ

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1. Introduction:
The South Pacific Convergence Zone (SPCZ) is observed as a northwest-to-southeast oriented region of persistent cloudiness and rainfall extending from New Guinea southeastward across the international dateline into middle latitudes. The sub-tropical and mid-latitude portions of the SPCZ are known to be difficult to faithfully simulate in models, commonly appearing too zonal overall. An attempt has been made to get a clearer view of processes which may be important in maintaining the SPCZ using a combination of satellite based observations. Here we report on the spatial distribution of surface convergence, rain rates and Sea Surface Temperatures (SSTs) as well as correlation patterns in rain rates and mid-latitude height fields.

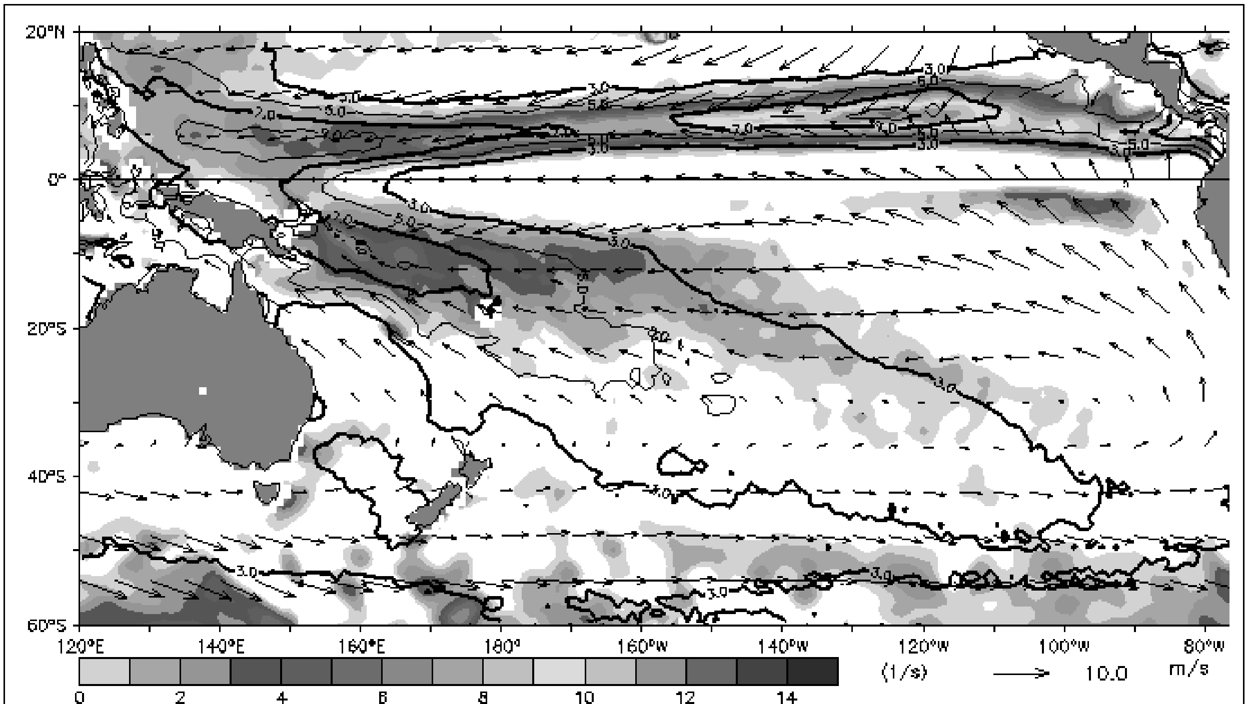

Figure 1: Two year average of scatterometer derived convergence only (shaded & in units * 10^6) and rain rates (contoured) over the tropical North and the South Pacific. Wind vectors are plotted as arrows. The period of record is 1 September 1999 to 31 August 2001.

2. Data Sets and Methods: The data sets used for this study were QuikSCAT scatterometer estimated low-level (~10 m level) winds, TRMM satellite microwave radiometer estimated SST's, and the Global Precipitation Climatology Project rain-rate estimates, which are based on a blend of microwave and infrared brightness temperatures. The period of analysis was Sept 1998 - Aug 2001, a period when La Nina or neutral conditions existed in the Pacific. Annual and seasonal averages of convergence, height, SSTs and rain rate fields were made to investigate the horizontal and vertical structure of the SPCZ. Test regions, measuring 10° lat. by 15° lon., were defined along the SPCZ to denote tropical (TR), sub-tropical (ST) and mid-latitude (ML) sections. Variables within these test regions were spatially averaged prior to lag correlation and composite analysis. Lag correlation analysis using rain rate, convergence and height anomaly fields were completed to determine if a natural relationship exists between the TR and ML SPCZ. Days where the average rain rate, in a given section of the SPCZ, was one standard deviation above the mean were used to make composites. Variability on timescales greater than 31 days was filtered out for lag correlation and composite analysis so as to examine the higher frequency phenomenon.

3. Annual and Seasonal Analysis: It was expected that the surface convergence and rain rate field maxima would be more or less co-located in the SPCZ. Figure 1 shows this is not always the case. In tropical latitudes, the convergence and rain rate maxima are co-located, but at higher latitudes there is a longitudinal offset. Much of the rain rate maximum in sub-tropical and higher latitudes is characterized by near zero or weak surface divergence. Wind barb patterns reveal a good portion of the weak divergence field is associated with anti-cyclonic flow. Note that in the Northern Hemisphere the axes of maximum surface convergence and rain rates are co-located. The interesting offset between the rain rate maximum and surface convergence in the SPCZ is also present in the NCEP analysis data. Figure 2 shows a vertical profile of convergence for three regions along the SPCZ rain rate diagonal. Moving southeastward along the SPCZ rain rate maximum, surface convergence decreases and becomes divergence in mid-latitudes. There is a suggestion that the convergence maximum shifts upward with height from the tropics to higher latitudes. Seasonal analysis also indicated an offset between surface convergence and rain rate maxima with the greatest differences observed in Austral Spring and Fall. During Summer, much of the rain rate maximum is located in tropical and sub-tropical latitudes. The corresponding divergence profile revealed deep convergence coupled with upper level divergence. During Spring and Fall, there is a distinct region of near surface divergence which changes to convergence by 850 HPa in the ST SPCZ. As in the annual analysis, wind barbs indicate that the surface divergence is associated with the sub-tropical ridge axis. Comparisons of surface convergence and SSTs reveal that maxima are co-located throughout much of the tropical Pacific in both annual and seasonal analysis (not shown) indicating a close relationship in these latitudes. We have found NCEP rain rates are more zonally oriented than satellite rain rates and in fact are more closely co-located with surface convergence (see figure 3) and SSTs in tropical latitudes. Our interpretation is that the NCEP precipitation algorithm may be overly dependent on the SST field, and therefore underestimates rain in the sub-tropical and higher latitudes of the SPCZ. As climate models tend to have difficulty simulating the diagonal like SPCZ, we suspect that the problem lies with how the precipitation algorithm uses SSTs to generate rain.

4. Lag Correlation and Composite Analysis: Analysis correlating rainfall in a given portion of the SPCZ to rain in the rest of the Pacific basin showed little evidence of the SPCZ being convectively active from the tropical to mid-latitudes simultaneously. Instead, it appears that a portion of the SPCZ becomes active, with subsequent propagation 1500 to 2500 km east-southeastward. Hence there is not much relationship between convection in the TR and ML SPCZ. On the other hand, there is some evidence convection propagated from the ST to ML SPCZ. Similar results were found with lag correlation analysis using convergence fields. Lag correlation analysis using convergence and 500 HPa height anomalies revealed a series of correlation maxima and minima in the ST (see figure 4) and ML SPCZ.

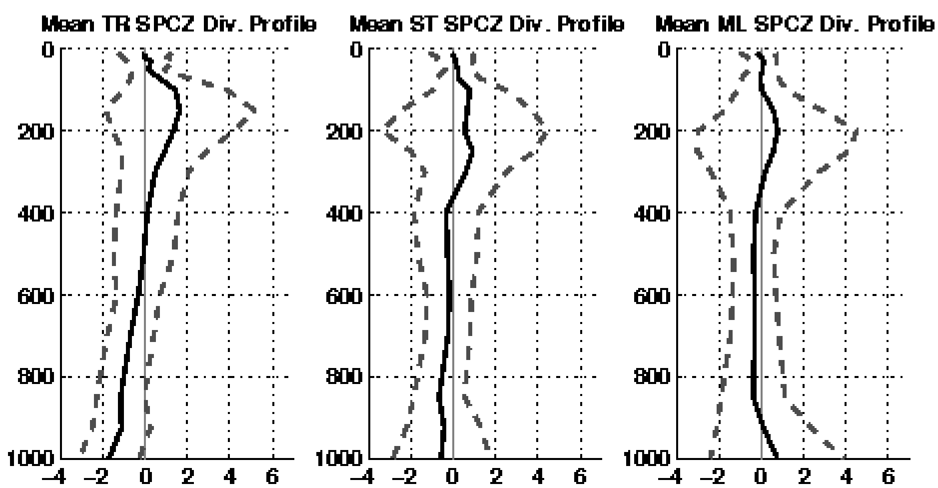

Figure 2: Mean divergence profile for tropical (7S:17S, 160E:175E), sub-tropical (15S:25S, 175W:160W) and mid-latitude (25S:35S, 150W:135W) sections of the SPCZ. Dashed lines represent the first standard deviation.

These wave trains were quasi-stationary in the ST SPCZ and moving east-southeastward at 4 to 6 m/s elsewhere. The pattern's orientation is from west-southwest to east-northeast into the test region, then eastward or southeastward out from it. The distance between two maxima ranged from 5000 to 6000 km, comparable to the spatial scales of the waves found by Kalnay et al (1986). This length scale remained fairly constant throughout the analysis period (1 Sept. 99 til 31 August 01). In the ST and ML SPCZ, a negative correlation anomaly was found to the west-southwest of the correlation test region. This implies low level convergence (divergence) was correlated with negative (positive) height anomalies. As extra-tropical cyclones and their associated low-level convergence are typically found east of upper level troughs, these results suggest the systems have baroclinic characteristics. Composites of days when rain rates were one standard deviation above the mean in a given portion of the SPCZ also revealed wave trains at sub-tropical and middle latitudes. The strongest wave train pattern is seen in the ST SPCZ (see figure 5) and has a wavelength similar to that seen in the correlation analysis.

5. Summary: The results suggest convection in the tropical SPCZ may be, as in the Northern Hemisphere ITCZ, to a large extent dependent upon SST distribution and moisture convergence. In sub-tropical and higher latitudes the SPCZ appears to be largely due to the interaction between passing mid-latitude cyclones and their associated fronts with a moisture field "preconditioned" by the South Pacific High, an idea first proposed by Trenberth (1976) and expanded upon by Kiladis et al (1992).

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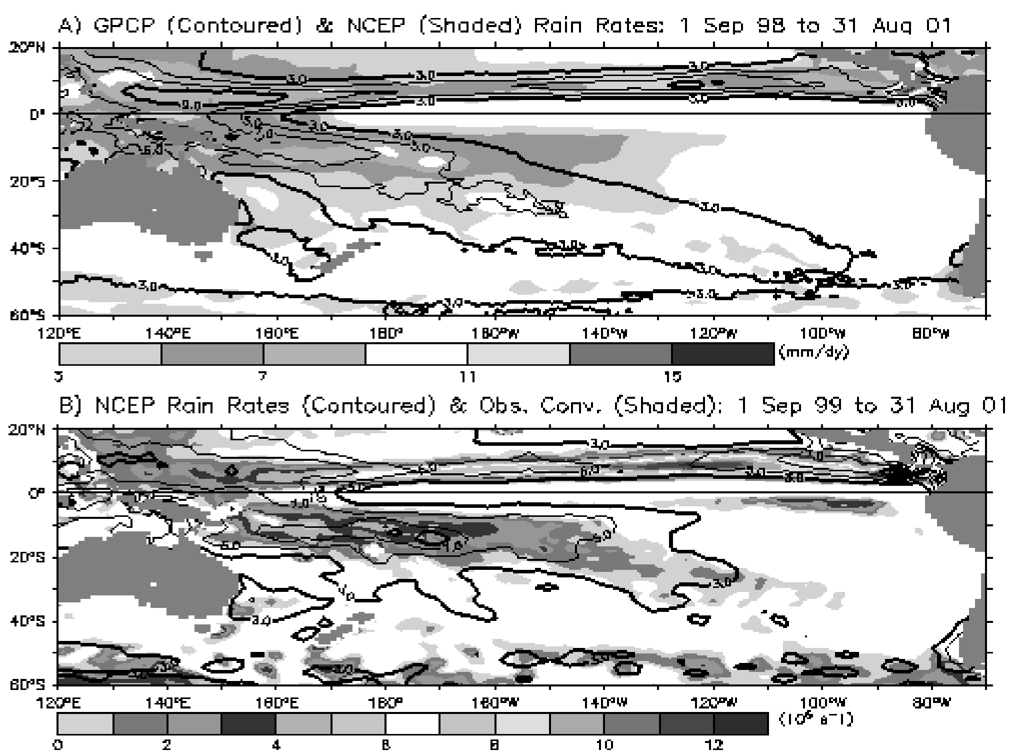

Figure 3: Comparison of GPCP and NCEP rain rates to Scatterometer derived convergence (only) as follows: A) three year average of GPCP and NCEP rain rates; B) two year average of NCEP rain rates and convergence. Shading and contouring are as annotated.

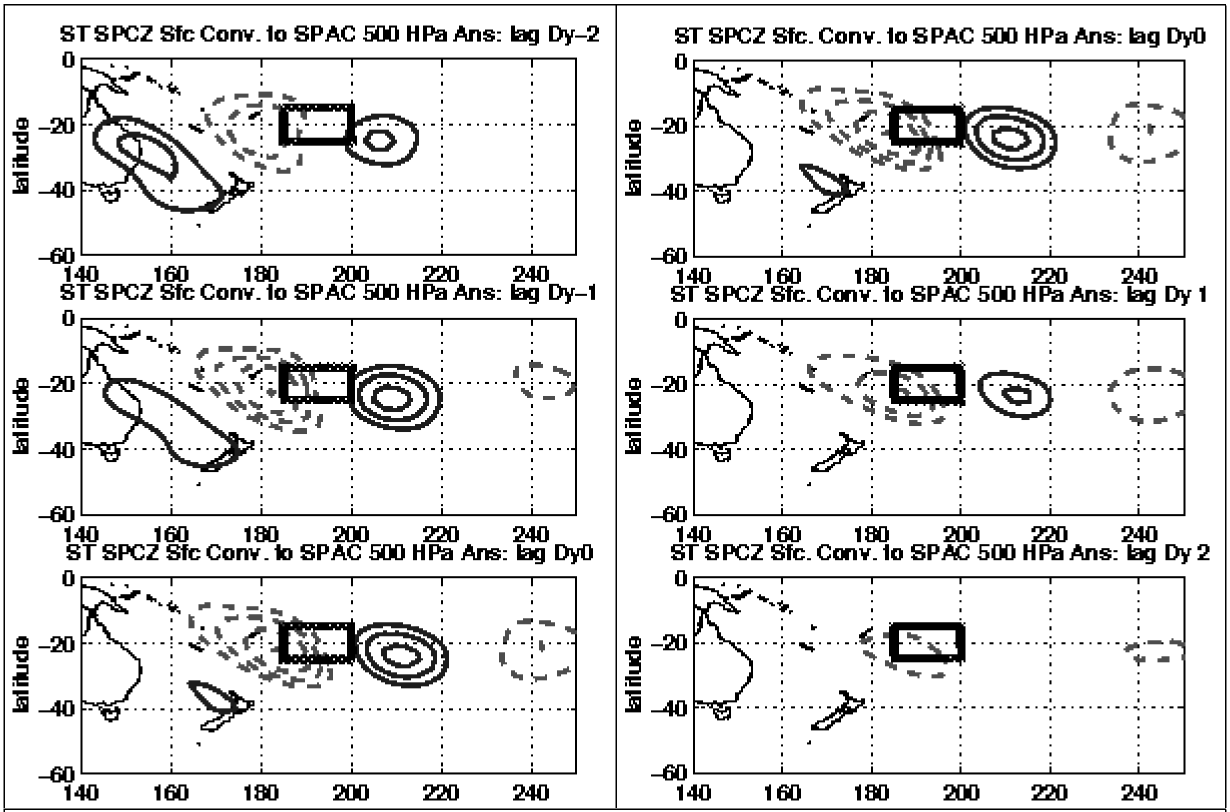

Figure 4: Backward and forward lag correlation results of surface convergence within the ST SPCZ test region (black box) and 500 HPa height anomalies over the South Pacific. Each solid and dotted contour begins with the value 0.2 and is incremented by 0.1. Lag days are annotated on the figure.

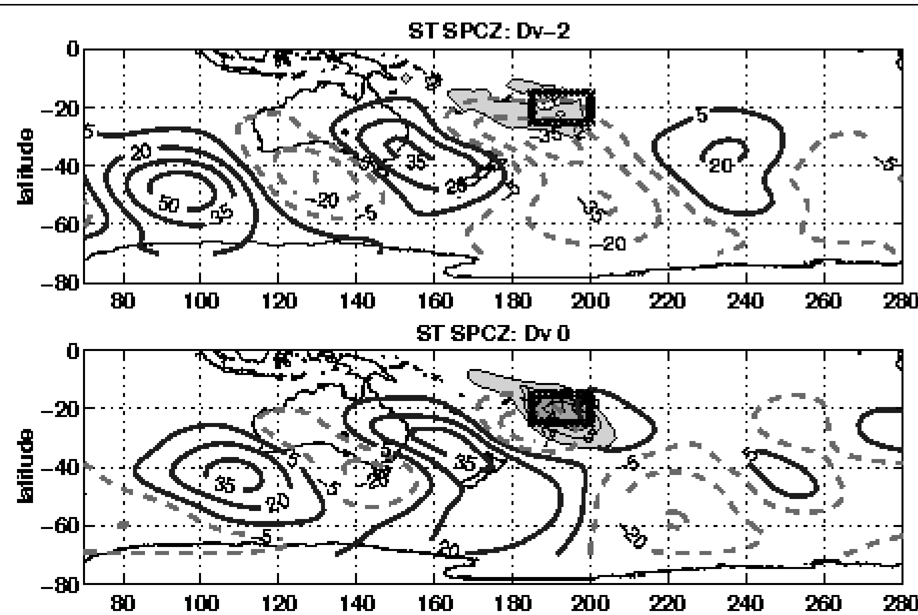

Figure 5: Composite of rain rates (shaded) and 200 HPa height anomalies (solid/dashed lines) two days prior to and at the time of high rain rates in the ST SPCZ. Height anomalies begin at ± 5 meter contour and incremented every ± 15 meters.