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ITCZ BREAKDOWN: AN OBSERVATIONAL STUDY OVER THE TROPICAL EAST PACIFIC

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1. Introduction and datasets

This research uses three independent remote sensing datasets, QuikScat scatterometer wind, Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) vertical integrated cloud liquid water, and GOES-west visible and infrared images, to identify occurrances of ITCZ breakdown. It is postulated that the dynamic ITCZ may undulate and break down into 2 or more disturbances on a timescale of approximately 10 days. This process referred to as ITCZ breakdown and is suggested as one way of pooling vorticity in the tropical atmosphere. The produced disturbances either dissipate or move away and a new ITCZ may re-form in the same location. ITCZ breakdown in the tropical East Pacific may be caused by: (1) Interaction with easterly waves that have propagated from the Atlantic basin, (2) interaction with tropical disturbances excited by flow over orography in central America, and (3) instability due to a potential vorticity anomaly produced by heating in the ITCZ (hereafter referred to as vortex rollup). The last factor has been further studied by Wang and Magnusdottir (2004), P1.47 in this preprint, in a 3-D model. We believe that ITCZ breakdown can be initiated by this effect in the absence of easterly waves. Our goal is to identify ITCZ breakdown in observations and determine the possible reasons for breakdown. This is a work in progress and only preliminary results will be presented in this paper.

ITCZ breakdown has been largely ignored due to the difficulty in identifing the event in observations. The horizontal resolution of reanalyses data ($2.5^\circ \times 2.5^\circ$) is not fine enough to catch the event and the data is usually contaminated by model assumptions where observations are sparse, such as in the tropical East Pacific. Thus, we propose to use remote sensing datasets to do the observational study. QuikScat wind is available from Jul 1999 to the present. It provides 10-meter surface wind vectors over the global ocean with resolution of $0.25^\circ \times 0.25^\circ$. TMI is available from Dec 1997 to the present and covers from 40°S to 40°N with the same resolution. Daily GOES images are available back to 1980. The region of interest stretches from equator to 20°N, and 90°-160°W.

2. Methodology

The first step is to define an elongated ITCZ in the datasets. We calculate relative vorticity using QuikScat wind and fill in some of the missing points by linear interpolation. We then use cluster analysis to define the vorticity pieces that have relative vorticity larger than $5 \times 10^{-5} s^{-1}$. The cluster analysis starts with each data point as an individual group and combines groups according to their similarity, which is distance in our case. The clustering method we chose is single-linkage, or minimum-distance clustering (Wilks 1995, Subsection 9.6). This method tends to form elongated groups, which is appropriate for our purpose. The 25-cluster level is chosen to be the termination criterion. This means that the merging process will terminate when there are 25 groups left in the domain. Fig. 1 shows the relative vorticity field and the defined cluster groups (only the largest 8 groups are shown) in different symbols on 22 Aug 2000. In the second step, we require that an ITCZ should be zonally extended for more than 20° longitude and its meridional displacement be less than 10° latitude. Therefore, the group indicated by dots in Fig.1 is a tentative ITCZ as seen in the low-level relative vorticity field. The same cluster algorithm is applied on TMI cloud liquid water content. The threshold is set at 0.4 mm (column liquid water of approximatly $400 g/m^2$). Table 1 shows the dates that match the two criteria. Since it is not possible to fill in all the missing points in both datasets, and the missing points sometimes cause an elongated ITCZ to be determined as two shorter pieces, we only require that the ITCZ can be identified for at least two days in one of the two datasets and

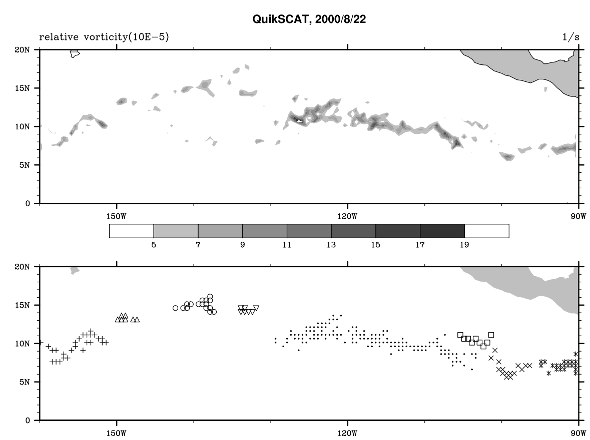

FIG. 1: Upper panel: Relative vorticity from QuikScat wind on 22 Aug 2000. The contour interval is $2 \times 10^{-5} s^{-1}$. Lower panel: The defined cluster groups indicated by different symbols. The group indicated by dots is a tentative ITCZ. Cloud liquid water is used to confirm result.

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for at least one day in the other. The dates that pass this requirement are shown in bold in Table 1. For instance, the ITCZ shown in Fig.1 appears from 21-23 Aug 2000 in TMI and on 22 Aug in QuikScat. Once we indentify an ITCZ, we can concentrate on its evolution over the following week and visually determine whether it is an ITCZ breakdown using GOES visible and infrared images. It is very important to visually screen all the cases picked up by our statistical method because we have not found a statistical method that can perfectly filter the information we need.

Table 1: Date of the occurrence of an elongated ITCZ.

Year/month	QuikScat	TMI
1999/08	2, **3**, 17	**3-5**, 28
1999/09	1, 3, 5, 24	6, 20, 27
1999/10	6, **8**, 13, 19, 20	**8-10**
2000/08	6, **9**, 11, **22**, 26, **28**, 30, 31	4, 6, **8, 9**, 11, **21-23**, 25, **27, 28**
2000/09	1-4, 7, 22	7, 10
2000/10	13, 20	13, 18
2001/08	5, 10, 13, 20, 21, 29	9, 12, 19, 25, 31
2001/09	**1-4**, 8, **18-20**	**2-4**, 13, **19**, 30
2001/10	4, 8, **11, 12**, 19, 20, 26, 28	7, **11, 12**
2002/08	**22**, 24	13-15, **22, 23,** 27, 30
2002/09	**10-12**, 18, 23	3, **12**, 14, 15, 20, 21, 26
2002/10	15, **18-20**, 28	4, 8, 9, 12, 13, **18, 20**
2003/08	5, 10, 11, 17, 19, **21, 22, 24-29**	1, 4, 13, 16, 19, **21, 22, 26**
2003/09	1, 4, 16, 17, **26, 27**	1, 3, 11, 15, 20, **26, 27**, 30
2003/10	19, 25	22, 25

3. Result and discussion

We have applied our algorithm to both QuikScat and TMI datasets for Aug-Oct from 1999-2003. The result is shown in Table 1. There are 14 ITCZs in 1999-2003. After carefully examining GOES images, we found that three of them (on 8-10 Oct 1999, 10-12 Sept 2002, and 21-22 Aug 2003) did not break down. The other 11 cases all showed an ITCZ that broke into 2 or more pieces. We will discuss the possible reasons for ITCZ breakdown briefly in the following. The figures and satellite images for each case can be obtained from our website (http://essgrad.ps.uci.edu/∼ccwang/ITCZ.html).

The ITCZ occurring on 3-5 Aug 1999 broke into three disturbances possibly due to easterly waves. There are three cases in 2000. The ITCZ that was present on 8-9 Aug 2000 was disturbed by a tropical disturbance excited by the orography in central America. The ITCZ broke into two elongated pieces after a hurricane, Gilma, shed off. A perfect ITCZ breakdown occurred later during 21-26 Aug 2000. The ITCZ broke into several disturbances and one of them intensified into a tropical storm, John. This case has been examined and shown not to have been triggered by easterly waves (Lawrence et al. 2001). While the disturbances were dissipating, a new ITCZ re-formed (27-28 Aug), and broke down very quickly. One of the disturbances then intensified when a tropical wave moved in a few days later and formed the tropical storm, Kristy (31 Aug-3 Sept) (Lawrence et al. 2001). The three cases in 2001 were all disturbed by easterly waves originating from the Atlantic ocean (Avila et al. 2003). There are two cases in 2002. The ITCZ on 22-23 Aug broke down into several disturbances due to interaction with an easterly wave that can be traced back to Africa. The other case, occurred on 18-20 Oct, was partially affected by a disturbance originating around 70°W. This disturbance moved into East Pacific and disturbed the eastern part of the ITCZ. Hurricane Kenna was formed due to this disturbance (Franklin et al 2003). The western part of the ITCZ broke apart possibly due to vortex rollup. There are two cases in 2003. We highly suspect that the breakdown occurring in Sept was due to vortex rollup, but it needs further study.

It appears that ITCZ breakdown occurring in the central Pacific has a different pattern from that occurring in the eastern Pacific. The central Pacific is less affected by easterly waves and its ITCZ tends to produce two or more equal-size disturbances, while the ITCZ breakdown near central America tends to form one large disturbance on the eastern end, and a few small disturbances to the west. Thus, we suggest that ITCZ breakdown due to the vortex rollup is what we observe in the central Pacific, and breakdown due to easterly waves is more prevalent in the eastern Pacific. We will examine these ITCZ breakdown cases in further detail and apply our experience to earlier GOES images when the other high resolution remote sensing datasets are not available.

4. Acknowledgment

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