4B.2 A COMPARISON OF TYPHOON BEST-TRACK DATA IN THE WESTERN NORTH PACIFIC: IRRECONCILABLE DIFFERENCES

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Global warming has taken on major political ramifications, and many world leaders and other institutions claim it to be one of the greatest threats to modern human civilization. In general, warming of the planet is considered to be dangerous, even catastrophic. The greatest harm is not so much from warmer temperatures per se (although recent deadly heat waves have been attributed to global warming), but from the effects of warmer temperatures on such things as the mean sea level, the distribution of insects and other macro and microbial pests, and changes in the spatial distribution, annual number, and intensity of the world's tropical cyclones.

When the number of hurricanes experienced in the North Atlantic jumped dramatically in 1995, and remained generally much above average in the years since then, global warming was automatically suspected to be aiding and abetting this change. The TC community split into two camps: (1) those who saw the increased Atlantic hurricane activity as part of a natural inter-decadal oscillation in the numbers of Atlantic hurricanes, and (2) those who viewed the increase in Atlantic hurricane activity to be an artifact of rising global temperatures. Not only has the number of Atlantic hurricanes been linked by some to global warming, in addition, theoretical results show that in a warmer world one might expect to see a small increase in the average intensity of hurricanes. While not every tropical cyclone is expected to have its intensity boosted in a warmer world, there is theoretical support for the notion that there will be an increase in what is known as the Maximum Potential Intensity (MPI). Since wind power rises in proportion to the cube of the wind speed, a small increase of wind speed in a high-end hurricane could have magnified consequences. Increasing a high-end 150 mph CAT 4 hurricane by only 10 mph to a minimal 160 mph CAT 5 hurricane yields a wind power in the latter that is 21% higher than in the former.

While the North Atlantic basin may have entered an active period of more TCs and more intense TCs, it is not so clear that the rest of the globe has done so. The world's other TC basins: the western North Pacific, the eastern North Pacific, the North Indian Ocean, the South Indian Ocean, and the South Pacific Ocean seem to be behaving as usual, and in the past several years, have been relatively quiet. There are some statistics in these other global basins that have shown decreased activity in the most recent decade. At the time of this writing (August 2007), the entire Southern Hemisphere had just finished a lack-luster season with fewer than average number of TCs, and the globe had experienced a record for the longest time period with no active TC.

Oddly (and probably not widely known), only the North Atlantic Ocean basin is currently having an over-abundance of TCs. The 28 named TCs

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of 2005 broke a long-standing record for the highest annual TC count. The SST has gone up in all of the ocean basins by approximately 0.5° C over the past several decades. During the prolific 2005 hurricane season in the North Atlantic, the SST across much of tropics of that basin was at an all-time historical high. In a recent paper, Webster et al. (2005) claim that there are already observed increases in the number of very intense tropical cyclones in most of the global TC basins. The release of W2005 caused an immediate firestorm in the tropical cyclone community. Some of the TC data sets do indeed show an increase in the proportion among all TCs of CAT 4 and CAT 5 cyclones. The strongest rebuttal to the findings of W2005 came from the community of those researchers and forecasters with great depth of knowledge in the development of the TC best track data sets. Such individuals claimed that the best track data sets were of insufficient quality to derive meaningful information on secular trends, or that there were inherent biases in the record so as to negate the statistical significance of the findings of W2005. In this presentation, the focus will be the TC record of the western North Pacific. It will be shown that the best track data sets of the two primary agencies responsible for basin-wide TC coverage — the Joint Typhoon Warning Center (JTWC) and the Japan Meteorological Agency (JMA) — are so incompatible as to call into question the utility of this data for climate studies.

Many have suggested adjustments be made for the procedural differences between the JMA and the JTWC so as to reconcile the discrepancies in their best-track data (e.g., one-minute VS ten-minute wind averages and different conversions for Dvorak "T" numbers). It is the thesis of this presentation that this effort will prove to be futile. The differences between these agency's typhoon best-track data sets have irreconcilable differences. Perhaps the creation of an independent data set, such as the one produced by Kossin (2007) is the only way to examine trends in western North Pacific tropical cyclone activity.

There are many changes over time in the way that TCs were observed, reconnaissance aircraft have come and gone from the western North Pacific, many classes of meteorological satellites entered and exited, and image acquisition technology changed over time from low-resolution, few-times-per-day images from low earth orbit to a suite of high-resolution imagery available from low-earth orbit and from geosynchronous orbit with continuous coverage. A steady increase in available frequency bands (active and passive microwave imagers, multi-channel infrared, and remotely retrieved ocean surface winds) has also occurred.

The U.S. Hurricane Research Division (HRD) is well underway in a project to revise the Atlantic basin hurricane database (or HURDAT). HURDAT is the official record of tropical storms and hurricanes for the Atlantic Ocean, Gulf of Mexico and Caribbean Sea, including those that have made landfall in the United States. This database is utilized for a wide variety of purposes: setting of appropriate building codes for coastal zones, risk assessment for emergency managers, analysis of potential losses for insurance and business interests, intensity forecasting techniques, verification of official and model predictions of track and intensity, seasonal forecasting, and climate change studies. There are many reasons why a

reanalysis of the HURDAT dataset was both needed and timely. HURDAT contained many systematic and random errors that needed correction. Additionally, as our understanding of tropical cyclones developed, analysis techniques at the National Hurricane Center changed over the years, and led to biases in the historical database. Recent efforts led by the late Jose Fernandez-Partagas uncovered previously undocumented historical tropical cyclones in the mid-1800's to early 1900's.

In the western North Pacific, there are several institutions that archive statistics of the tropical cyclones. The Joint Typhoon Warning Center (JTWC), now located in Pearl Harbor, Hawaii, has a nearly 50-year record of tropical storms and typhoons for the western North Pacific Basin. The JTWC is jointly manned by the U.S. Navy and U.S. Air Force to provide tropical cyclone reconnaissance and forecast support to the U.S. Military and other U.S. Government agencies and assets in the eastern Hemisphere. The JTWC has a continuous record of tropical cyclone activity in the western North Pacific extending from 1959 to present. Until the year 2000, it also provided the names for the TCs of that basin. The Tokyo Typhoon Center is the Regional Specialized Meteorological Center (RSMC) for the analysis, tracking and forecasting of western North Pacific tropical cyclones within the framework of the World Weather Watch Programme of the World Meteorological Organization (WMO). The Tokyo Typhoon Center was established at the Headquarters of the Japan Meteorological Agency (JMA) in July 1989, following the designation by the WMO Executive Council at its 40th session held in Geneva in June 1988. It has a record of tropical storms and typhoons in western North Pacific that extends back to 1951.

There are substantial differences in the best-track archives of these two institutions, sufficient to negate the trend found by W2005 in the JTWC data. There are many substantial differences in the locations, intensities, and wind distributions of the tropical cyclones that these agencies both diagnosed and tracked. Intensities are sometimes found to vary by two Saffir-Simpson Categories. The archived distribution of gales and typhoon-force winds can vary by hundreds of kilometers. The objective of the work reported in this paper is to examine and summarize the differences that are found between the JTWC and JMA best track archives, and to attempt to explain them. The ultimate goal is to establish a working group of tropical cyclone diagnostic experts to undertake a project similar to the HRD Hurricane Re-Analysis Project for the historical record of the tropical cyclones of the western North Pacific.

The historical record of tropical cyclones has become important in the scientific and political challenges of climate change, and the risks of the ever-increasing human habitation in cyclone-prone regions. It is of the utmost importance to make the record as accurate as possible. Real-time validation data are often not available. Despite efforts to minimize conflicting information, the JMA and the JTWC are often quite far from each other in their diagnostic assessments of tropical cyclone intensity and wind distribution. Part of this conflict results from the use of different wind averaging periods for the warning intensity. The JMA warnings give 10-minute sustained

values, whereas the JTWC provides a 1-minute sustained wind on its advisories. The relationship between the 10-minute sustained wind and the 1-minute sustained wind is such that the 1-minute wind is approximately 112% of the 10-minute sustained wind speed. Other agencies use slightly different conversions such as the Hong Kong Observatory, which uses a factor of approximately 114%. This is not the only source of conflict, however. The basic tools – Dvorak's methods -- used to assign wind speeds to tropical cyclones based on their characteristics as seen on meteorological satellite imagery are quite different as used by the JMA versus the JTWC. Dvorak's techniques for estimating tropical cyclone intensity from visible and infrared satellite imagery (Dvorak, 1975, and Dvorak 1984) provide a T number that is related to the cyclone s intensity. The differences in the intensities given by the JMA and by the JTWC to specific T numbers (Table 1) cannot be entirely reconciled by considering the 10-minute/1-minute conversion. The JMA wind speeds are lower than those of the JTWC for the higher T numbers/wind speeds even when a correction is made for the different averaging intervals. This has led to some complaints that the JTWC typhoon intensities are too high, or conversely, that the JMA typhoon intensities are too low.

Table 1. Wind speed conversions for Dvorak T numbers. Note that a CAT 5 TC is not possible in the JMA relationships until T8 is reached.

T Number	JTWC	JMA	10 to 1
2	30	30	33.6
2.5	35	35	39.2
3	45	45	50.4
3.5	55	55	61.6
4	65	65	72.8
4.5	77	70	78.4
5	90	77	86.2
5.5	102	85	95.2
6	115	93	104.2
6.5	127	100	112.0
7	140	107	119.8
7.5	155	115	128.8
8	170	122	136.6

TWO EXAMPLES OF LARGE DIFFERENCES AMONG TC BEST-TRACK STATISTICS.

TYPHOON VAMEI

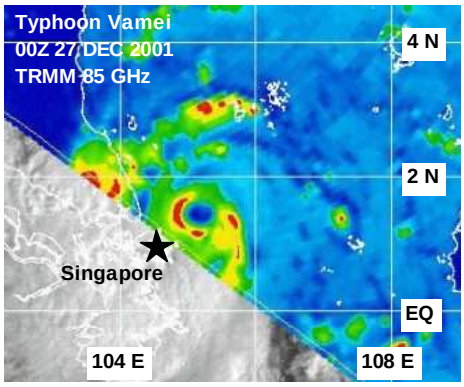

Figure 1. Typhoon Vamei. Microwave image courtesy of NRL Monterey: (http://www.nrlmry.navy.mil/tc_pages/tc_home)

Typhoon Vamei is a more striking example of the differences among warning agencies. This record-breaking low-latitude TC was carried by the JTWC as a typhoon with a maximum intensity of 75 kt, while the JMA records a maximum intensity of 45 kt.

The following is a quote from the JTWC Annual Tropical Cyclone report for 2001:

"At 270000Z, JTWC classified the system as a typhoon based on naval ship observations indicating sustained winds within the small eyewall of 75 knots with gusts to 105 knots."

In this case, the ship observations corroborated what one might have expected given the MI signature (Fig. 1).

TYPHOON MARK
Midget tropical cyclones present to all agencies a difficult diagnostic scenario. Typhoon Mark (1995) was such a TC. A comparison of JTWC and JMA best track Data for Typhoon Mark (JTWC 1995) (Table 2) reveals intensity differences of 45 kt! Positive values in JTWC-JMA columns indicate JTWC higher.

Table 2. Typhoon Mark

Lat.	Lon.	Int.	JTWC - JMA		
(N)	(E)	(Kt)	**D Lat**	**D Lon**	**D Int**
28.3	151.9	30			
29.1	152.8	35			
29.6	153.5	40			
30.1	154.2	55	0.1	-0.6	20
30.5	155.1	60	0	-0.4	20
31.0	156.1	65	-0.1	0	20
31.5	157.1	65	-0.1	0.3	15
32.4	158.0	70	0.3	0.6	15
33.4	159.0	80	0.1	0.2	15
34.9	160.8	95	0.1	0.1	30
36.4	163.4	95	0	0.2	30
37.9	166.0	95	-0.1	-0.8	45
39.3	169.1	80	-0.1	-0.2	40
40.3	172.6	65	-0.2	0.3	30
40.7	176.0	45			
41.0	179.2	45			

1996 Annual Statistics

The annual statistics for the western North Pacific TCs (Figs. 3, 4 and 5) well illustrate the substantial differences between the JMA and the JTWC. Note that for that year, the JTWC warned on 11 more TCs than did the JMA. The intensity of the JTWC TCs was nearly always higher than the JMA, in some cases greater by 55 kts!! A linear trend fit to the differences between the JTWC Vmax versus the JMA Vmax show that they differ by a factor of approximately 1.5, which is far greater than the 1-min to 10-min wind conversion.

Conclusions

The differences of wind intensities between the JTWC and the JMA are irreconcilable. There is no uniform or physically meaningful correction that can be applied to the two data sets to bring them into line with each other.

RECOMMENDATIONS.

In order to have a TC database for the western North Pacific that is useful for climate studies (such as W2005), the following actions are recommended:

(1) Establish a working group of tropical cyclone diagnostic experts to undertake a project similar to the HRD Hurricane Re-Analysis Project for the historical record of the tropical cyclones of the western North Pacific.

(2) Undertake a comprehensive project to archive all satellite data (on the order of completeness as the COADS project for ship observations) and make it readily available to the working group.

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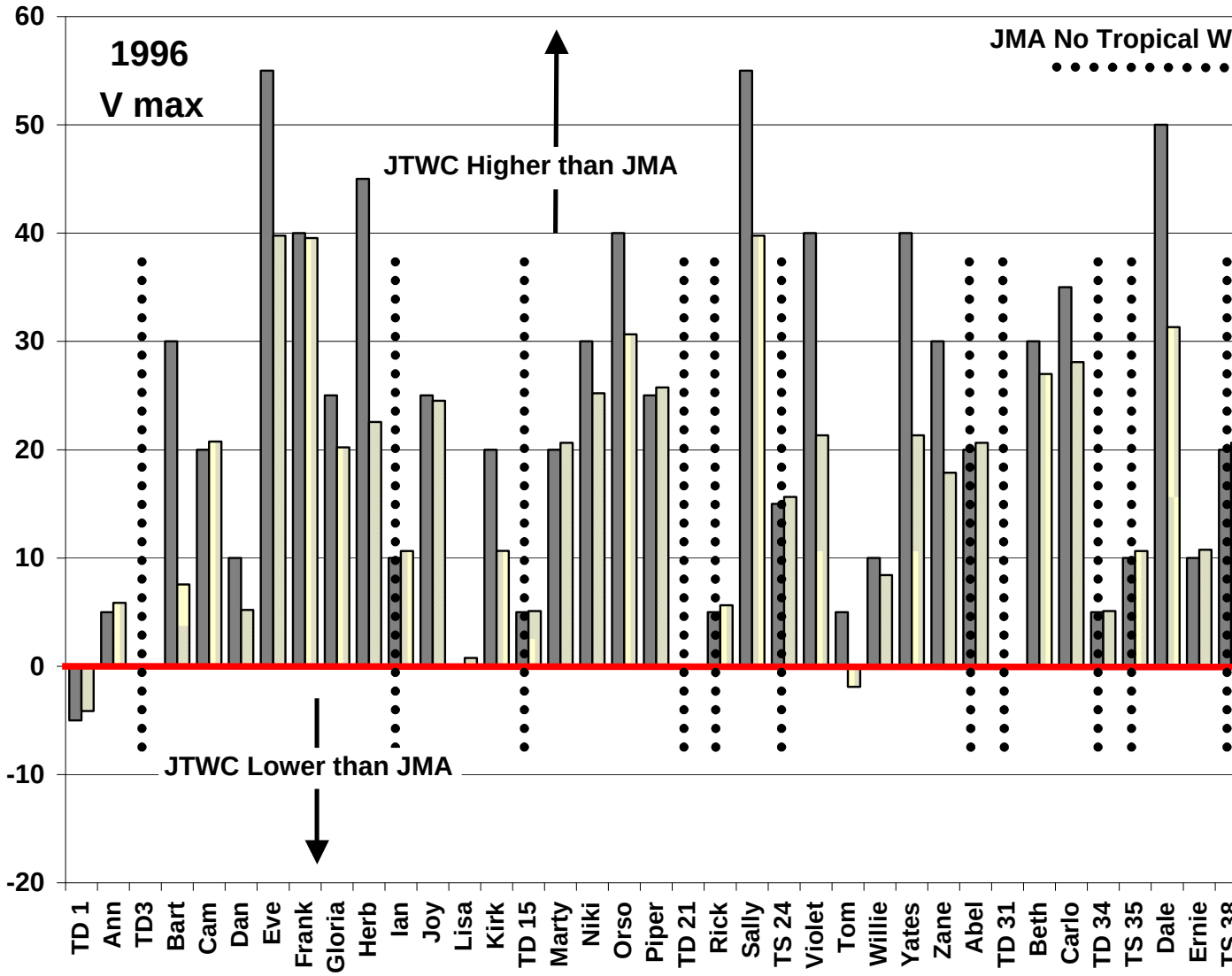

Figure 3. The tropical cyclones of 1996. A comparison of JTWC verus JMA peak intensity. Dotted li
JTWC was the only agency to warn on the cyclone. Bars above the red line indicate JTWC peak inten

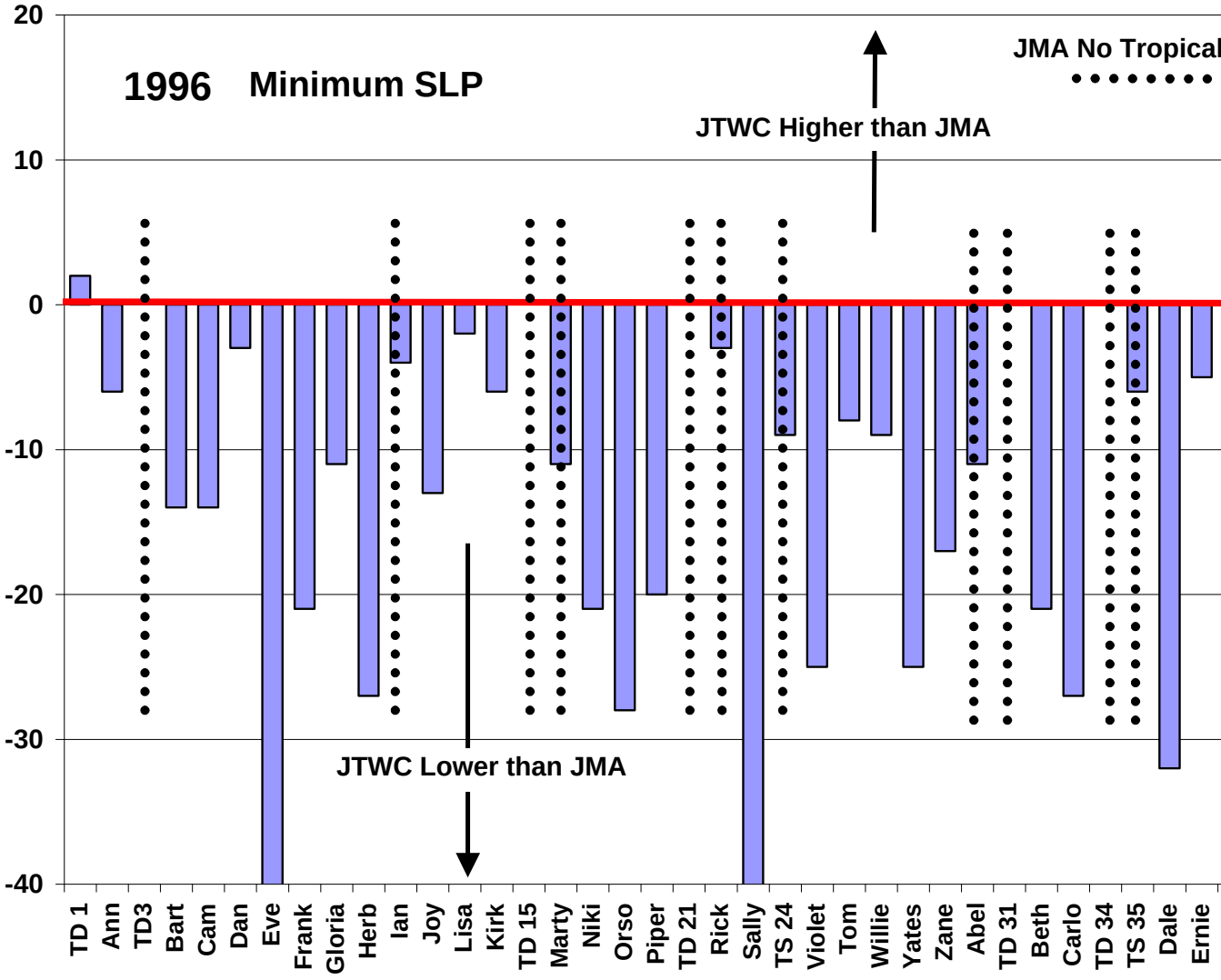

Figure 4. The tropical cyclones of 1996. A comparison of JTWC verus JMA minimum SLP. Dotted li
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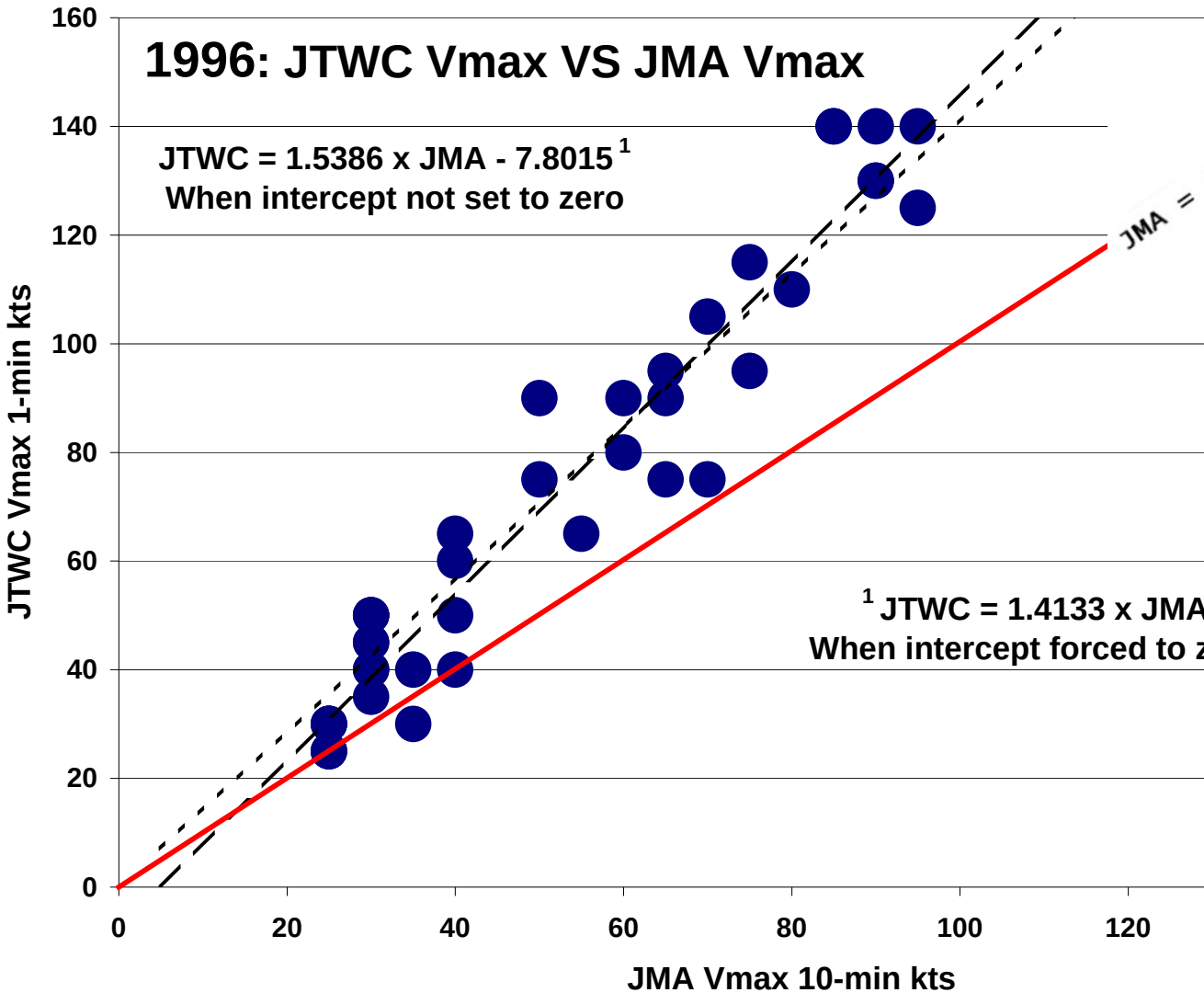

Figure 5. Comparison of JTWC versus JMA 1996 TC peak intensity.