P2.19 A method for integrated satellite reconnaissance fix accuracy

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1. INTRODUCTION

This paper provides the background and reasoning for the need to develop a new method to conduct satellite-based reconnaissance and fix support for the tropical cyclone (TC) warning centers. The current procedures in use in most of the world's TC centers were developed over 30 years ago when there were far less sophisticated satellite technology and processing methods. Outside of regions that have regular reconnaissance by aircraft, satellite-based intensity estimates are still largely dependent upon the work of Dvorak (Dvorak 1975, 1984). These methods were developed when animation did not exist and the only data regularly available were relatively coarse visual (and then later) infrared imagery. Similarly, TC positioning procedures were based on work conducted years ago (Fritz 1966; Anderson et al., 1969 (AWSTR 212); Gentry et al. 1970; and Arnold et al. 1974 (1WWP 105-10)) and by a handful of in-house procedures that were written since in order to try to keep up with the new technologies (Sheets 1986). This presentation addresses the positioning issue only (intensity will be discussed in a future paper) and the need for a new integrated method to perform reconnaissance support to the TC warning centers. It advocates the use of an ensemble of satellite reconnaissance data that all contribute in a continuous and collective manner towards the knowledge of a TC's location.

2. BACKGROUND

Since the 1950s aircraft reconnaissances has been the main stay of TC warning and fix support for the National Hurricane Center (NHC) in the Caribbean/Gulf of Mexico and Western Atlantic and up until 1987 for the Joint Typhoon Warning Center (JTWC) in the western North Pacific. Although aircraft were not always available to support every TC warning, depending upon basin and distance from where the aircraft were based, aircraft reconnaissance missions were typically tasked to meet the time frames for an 'on time', every-other-6-hourly warning (typically ½ hour prior, to 1 hour after the synoptic hour of the TC warning position time). For other warning times and for all other TC warning centers, satellites have been the primary source for reconnaissance, fix and warning support. Similar to what was tasked for aircraft fix support, satellite fix position times were expected to meet the same 'on-time' criteria. Prior to global-wide access to the geostationary satellite, dependency upon polar orbiting satellites did not always fit these time frames and warning positions were often considered to be 'extrapolated' from these 'off-time' positions. The accuracies of warning positions from these off-time visual and infrared (IR) fixes were usually stated to be in excess of 60-100 n mi, based on previous experience with TCs in the area. For on-time fixes, a more formal method was used which related the accuracy of the warning position to that of the accuracy of the fixing method. A method to estimate satellite-based IR and visual fix accuracy was developed in the early 1970s at JTWC (1WWP 105-10). A position code number (PCN) was developed to provide guidance for position accuracy to the warning based on the characteristic structure of the TC image and how well it verified against the 'best track' data. A PCN (Table 1) provides quantified guidance to the anticipated accuracy of the fix based on the structure of the TC (eye, well defined, and poorly defined), and the method of gridding the imagery. PCN accuracies are typically between 25 and 60 n mi, with the expectation that 90% of all fixes fall within 1.52 times the Standard Vector Deviation (SVD) for each category. The original PCN development in the mid-70s was primarily for polar orbiting visual and infrared imagery. Over time, geostationary imagery and animated geostationary imagery were assimilated into the PCN categories, and current statistics show that positioning errors have improved (JTWC 2001). However, since 1987 when the aircraft reconnaissance mission ended in the western North Pacific, it has been difficult to distinguish between actual changes in accuracy and fix variability and consistency. The relevance of these two types of measurements is described in Martin (1994). Without ground truth, a consistent grouping of 'poorly-defined' fixes will influence the final best track, and thus the fix statistics, as much as a consistent grouping of eye fixes.

PCN	CLASS	Mean Dev (n mi)	SVD (n mi) (63%)	1.52 SVD (n mi) (90%)
1-2	Eye	15	16.5	25
3-4	Well-defined	20	26	40
5-6	Poorly-defined	30	36	55

Table 1. TC Position Code Number (PCN) Accuracy (Adapted from 1 WWP 105-10). Odd numbers for geo-located imagery, even numbers for ephemeris data only.

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3. NEW TECHNOLOGIES

a) Capabilities. Now, new types of polar orbiting data have become available: microwave imagery and scatterometer-derived sea surface winds (Cocks et al. 1999; Edson and Hawkins 2000; Edson 2000). Such data can be used to see through the thick obscuring upper cloud decks that had previously hindered the IR and visual imagery (Fig. 1). These new technologies have revealed low-level cloud organization, and provide a measure of the surface wind (and pressure). In addition when associated with IR or visual imagery, they improve the confidence (and position) of the 'on-time' fix.

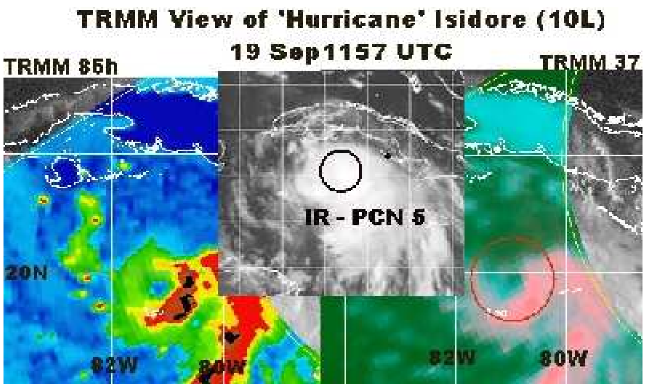

Figure 1. Comparison of microwave and IR imagery. Often a 'microwave eye' will appear well before the appearance of an eye in either the IR or visual imagery. In this case, the microwave imagery was available for the 'on-time' fix.

b) Availability and frequency of use. Even though microwave imagery and scatterometer-derived winds have come into routine use within the TC warning system; these data are often treated as only supporting (or supplemental) imagery because they don't meet the 'on-time' criteria. In other situations, the fact that the polar orbiting imagery is available so much less frequently than the geostationary imagery, creates an allusion of the 'imagery of choice' for the geostationary images. In any case, less detailed (although 'on-time') infrared or visual imagery are often used to reflect the accuracy of the warning position (and knowledge of the forecaster) even though far greater information is known. An example of the frequency of use and accuracy (as compared to the best track) for each type satellite platform used for the 2001 Western Pacific season by the JTWC is shown in Fig. 2.

c) Accuracy. Figs 1 and 2 show that the accuracies of these new technologies are often as good as or better than the current process using only IR or visual imagery. In these cases, a method is required to use these precise (but off-time) fixes to that reflect the warning position accuracy. In other cases, the interpretation of these new technologies is not completely understood or documented, and this contributes to the forecaster's dependency on the

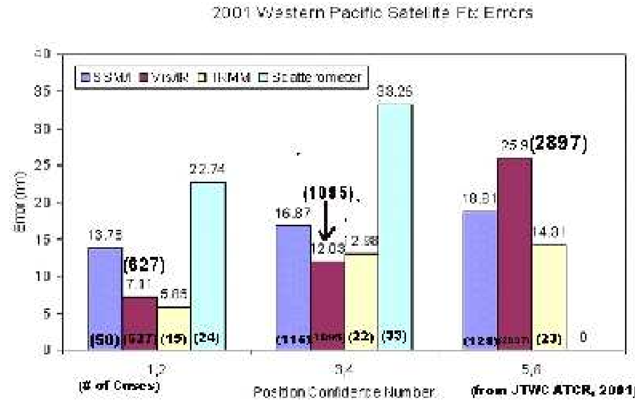

Figure 2. Satellite fix errors stratified by platform and by PCN. Numbers are those of the Joint Typhoon Warning Center for 2001. Visual and IR fixes dominate the number of fixes provided each year. Note the very low errors for the microwave imagery, especially those falling in the PCN 5,6 Category. (Note: Mean errors provided are expected to be less than the criteria-derived 1.52 SVD.)

more 'traditional' imagery. In addition, some new data, such as the scatterometer-derived sea surface winds, need to be correctly interpreted; the techniques to do this are not as widely known. A recent test of a new methodology for using scatterometer data (Edson et al. 2002) compared the 2001 Atlantic season best tracks to scatterometer fix errors where aircraft were also available. The results show fix errors (Fig.3) that fall within the accuracy of PCN 3 and 4 (well-defined circulation).

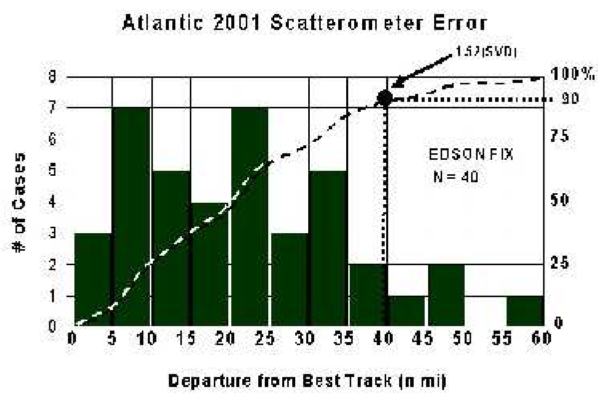

Figure 3. Bar graph of the error distribution of fixes made from scatterometer passes versus the NHC best track for the 2001 Atlantic season where aircraft fixes were within 12 hours of the fix position. Note that 90% of fix errors fall within 40 n mi, which qualify the fixes from this platform as well-defined, or PCN 3,4.

4. CONCEPT OF OPERATION

A methodology is required to integrate all available reconnaissance data into a statement reflecting the TC forecaster's current knowledge of the TC. Too often the requirements for an 'on-time' fix dictate the warning position accuracy when, in reality, more information is available. Two things have to be understood in order to fix this situation. A method needs to be developed to translate knowledge obtained from an earlier 'off-time' fix with elements (or conservative features) of an image from an on-time fix. And, more confidence and knowledge are required to better use the microwave imagery in direct support (versus supplemental support) of the warning position.

Figures 4 and 5 offer illustrations of how a process can be mastered that uses the accuracy from the earlier, polar orbiting microwave data to improve the accuracy of the on-time geostationary IR or visual imagery. In addition, a method is required to integrate all data in a continuous and collective manner versus treating each piece of data independently. Where any piece of data (including MI images or scatterometer data) may seem confusing in itself, a collection of images leads to increasing knowledge with each pass. An 'apparent eye' becomes a 'legitimate' eye with evidence from either succeeding passes of the same imagery, or complementary images from other types of data. At this point, the knowledge of the current state of the TC needs to reflect the ensemble and not that of one of the platforms by itself. Finally, with each new piece of data, the analyst must integrate this new knowledge with what currently exists and determine whether any new information is gained. A string of new but poorly defined fixes will not improve upon a well defined or eye fix from an earlier pass.

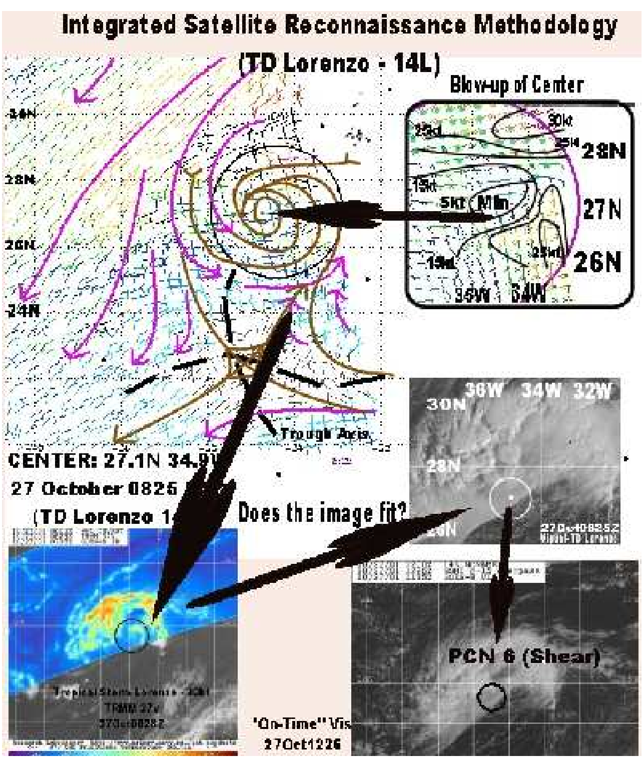

Figure 4. An example of how an integrated approach to satellite reconnaissance can improve the knowledge of the TC and of each of the 'fix' mediums. Data over TC04S include scatterometer, scatterometer ambiguities, 85 and 37GHz TRMM imagery and the GMS Vis 'on-time' imagery.

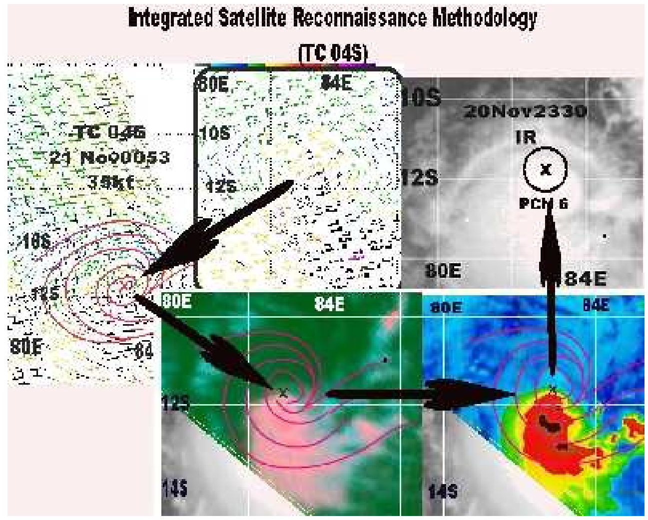

Figure 5. An integrated approach to satellite reconnaissance. In this case, the scatterometer positioning method was used to help direct the fix for the 37 GHz low level position. It was then translated to a visual image that was closest to the MI data, and then compared to the on-time image that was to support the next warning. Confidence in the fix position is clearly higher than if the IR image was used by itself.

5. SUMMARY.

Given the advancements in satellite-based technologies, TC advisories are too frequently posting large warning position accuracies (60 n mi based on the PCN of the warning support fix; or, listing the accuracy as 'poor' as derived from a poorly defined geostationary infrared image). The use of the microwave imagery and scatterometer data could easily reduce this perception. Future research will advance the methodology shown here to try to tie in these new data sources to best reflect the forecaster's knowledge at warning time. Using the closest 'on-time' reconnaissance platform available as a baseline, we are developing methods to 'increase' the accuracy of the warning with the best available reconnaissance data over the preceding interval. In this manner, knowledge is gained (or lost) depending upon the quality of the particular platform, time difference from other qualifying data, and the consistency of successive data that may increase a forecaster's confidence. Various examples and estimates of warning support-fix improvement will be presented at the conference, and in forthcoming operations manuals already in preparation.

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