Tropical cyclone wind retrieval using modified TREC method with radial velocity data added

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1. Introduction

Totally 384 typhoons hit Taiwan since 1897 to 2004, 3 to 4 per year, and 60% come from south China sea or northeastern sea of Philippine. CWB（Central Weather Bureau）in Taiwan finished deployment of Doppler weather radar network in 2001. Kenting radar station is located at southernmost of Taiwan to monitor typhoon as early as possible. 19 typhoons had been observed by Kenting radar from 2001 to 2004. A single-Doppler radar wind retrieval method, based on traditional TREC（Tracking Radar Echoes by Correlation）, is developed for the purpose of monitoring intensity of tropical cyclone and in consideration of timesaving computation.

When we look at an animation of radar echoes, by intuition, it seem that echoes move with a certain speed depend on environmental wind. A cross-correlation algorithm so-called TREC used to quantitatively determine the movement between two consecutive radar images. TREC was first developed to determine internal motions of storms by Rinehart and Garvey（1978）. It made it possible to retrieve wind field with a non-Doppler（conventional） radar because TREC needs reflectivity information only. TREC is not a direct measurement of the wind, but infers wind vector from the motions of reflectivity patterns which being tracked will often be precipitation generated at a higher altitude. In anther word, TREC determines reflectivity pattern motion different from instantaneous air motion by Doppler analysis. TREC can fail when tracking precipitation, where the hydrometeors may be falling in a strongly sheared environment. TREC was later modified by Tuttle and Foote（1990）for boundary layer studies. TREC works in the lower few kilometers of tropical cyclone where the vertical shear is relatively weak. Tuttle and Gall（1999）used TREC to estimate winds in tropical cyclones but also indicated that TREC produced rather chaotic results in the eyewall. Harasti et al.（2004）used arch-shaped correlation areas to alleviate the problem found by TG. TREC only needs reflectivity information, it does can provide wind field out to longer range. However, does radial velocity do any better help, especially on eyewall and rainband, to TREC? It will be the focal point of this paper.

2. Methodology

TREC (Tracking Radar Echoes with Correlation) tracks echo movement by finding the maximum in cross-correlation function between two consecutive radar imageries. The motion vectors could be considered as approximate wind vectors. Base on current scan strategy of Kenting radar, it is divided into two stages and takes 8 minutes totally: first, it execute 460km radius scan using two low elevation angles（0.5° and 1.4°）with low PRF（349Hz）; second, it execute 230km radius volume scan using 9 elevation angles（0.5°,1.4°, 2.4°…19.5°）with dual PRF（625Hz and 469Hz）. In this paper, we use low-level low PRF scans, as Time1 image, and low-level dual PRF scans, as Time2 image, for retrieving typhoon wind field by TREC.

The Doppler radar measure radial component of instantaneous flow directly, and each radial wind value represents the projection of numerous possible real wind vectors on radial direction at that point. Negative value (positive value) indicates approach to (away from) radar. So the end points of all possible real wind vectors at that point should be located on a straight line. Utilizing aforementioned characteristics, we create a weighting matrix for every point where we perform TREC analysis. The straight line formed by all possible real wind vectors end points with highest value 1, then according to Gaussian distribution decrease progressively to both sides. The correlation coefficient matrix（decided by TREC）multiplied by weighting matrix（decided by radial velocity data）become a new matrix, maximum in this new matrix decide end point of wind vector. In another word, end point of TREC vector is determined by correlation coefficient matrix and weighting matrix. To avoid contamination, we filter out spikes in radial velocity data before we create weighting matrix. After derived wind vectors had been decided by new matrix smoothing technique will be applied to remove a few vectors that are apparently in error. Aerosonde is a compromise between reconnaissance craft and radiosonde. It possesses advantages of long-range flight and disposability. On 8 June 2004, TAT（Taiwan Aerosonde Team） Aerosonde aircraft took off at 2310Z and passed through a rainband of typhoon CONSON with a constant altitude about 1500 m. On 9 June, the aircraft lost contact at 0154Z, Aerosonde collected almost 2 hours flying data before it crashed southeast of Kenting radar around 90 km. The flying track of Aerosonde shown in Fig 1.Accuracy evaluation will be perform between aircraft data and TREC vectors without and with radial velocity information added.

3. Summary

To see the influence, with or without radial velocity data added, on derived wind fields, we first apply these methods to typhoon DUJUAN data shown in Fig 2. DUJUAN has concentric eyewalls, diameter of inner eye about 40 km, with maximum wind speed 80 m/s observed by radar. On inner eye, traditional TREC vectors overlaid with reflectivity shown in Fig 3b. It is apparent that traditional TREC failed to depict cyclonic circulation and underestimate wind speed on inner eye. On the other hand, TREC vectors with radial velocity information added shown salient cyclonic feature in Fig 3a. The maximum wind speed on inner eyewall is 77 m/s in good agreement with radar observation. To evaluate the accuracy of those methods, the wind vectors measured by Aerosonde in typhoon CONSON are compared with traditional TREC vectors and TREC vectors with radial velocity information added. The results show that RMS errors of wind direction and magnitude derived from traditional TREC are 28.91° and 10.68 m/s respectively. But RMS errors of wind direction and magnitude derived from TREC with radial velocity information added are 30.27° and 5.00 m/s. With adding radial velocity information TREC vectors seem to reduce magnitude error. It is unknown at this time what reasons cause such disagreement of wind direction between derived winds and aircraft winds. For comparison, traditional TREC vectors, aircraft wind vectors and TREC vectors with radial velocity added shown in Fig 4.

We have applied traditional TREC and modified TREC（with radial velocity data added）to two typhoons and have shown the later will get more reasonable result on eyewall and rainband. For a costal radar like Kenting, modified TREC is a viable method for remotely monitoring the intensity of typhoons. How to implement in real time should be a future work in Kenting.

References

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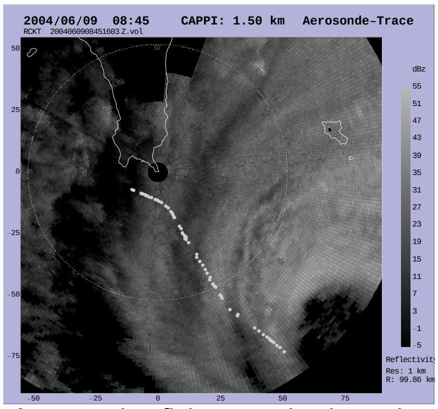

Fig 1. Aerosonde flying track through typhoon CONSON overlaid with reflectivity.

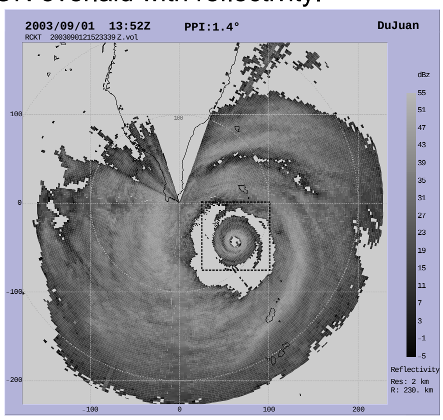

Fig 2.Concentric eyewalls of typhoon DUJUAN, the area bounded by dash （whole inner eye）line perform pure and modified TREC.

（a）　　　　　　　　　　　　　　　　（b）

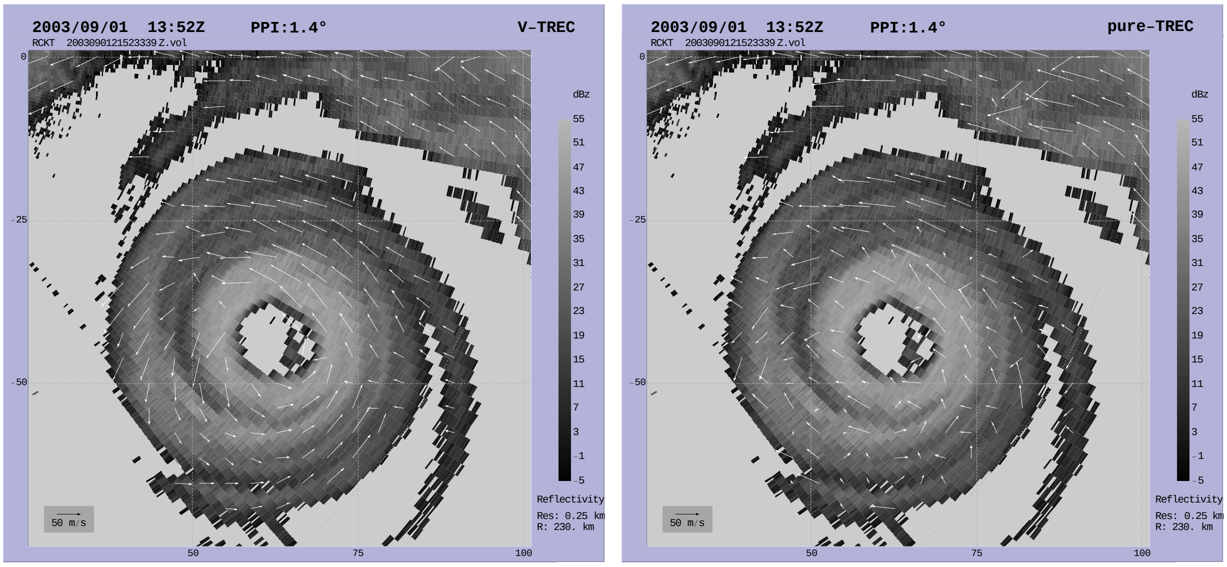

Fig 3. Derived wind field on inner eye of typhoon DUJUAN
（a）TREC with radial velocity data added（b）pure TREC

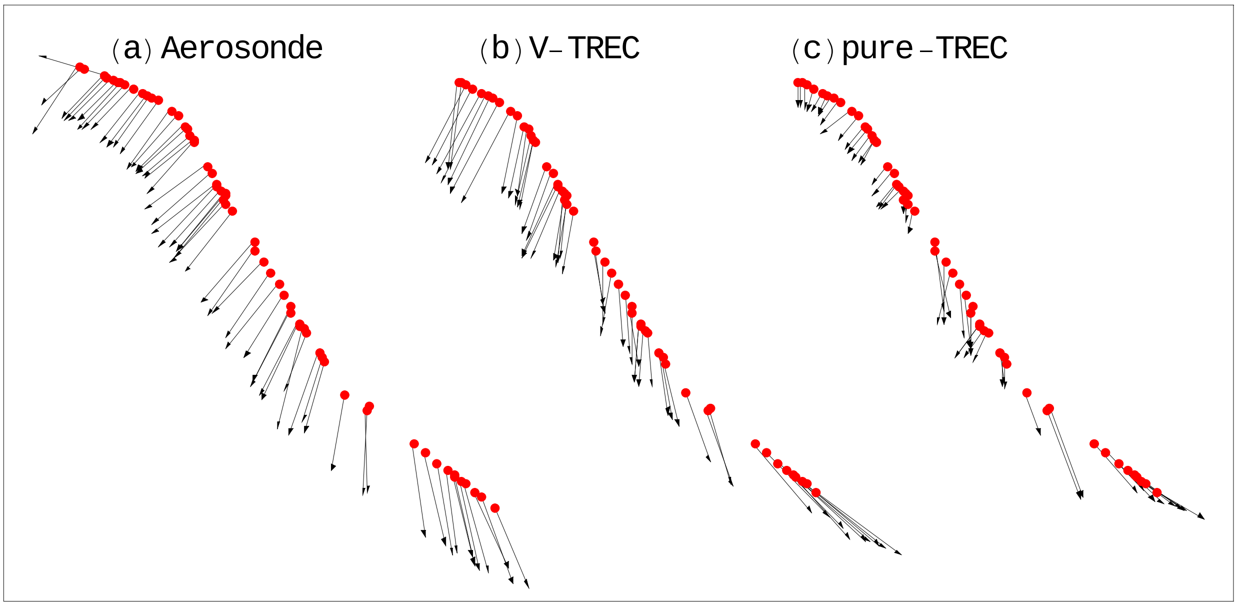

Fig 4. Wind vectors on flying track comparison between Aerosonde, TREC with radial velocity data added and pure TREC.