OPERATIONAL PROCEDURES OF TC SATELLITE ANALYSIS AT HONG KONG OBSERVATORY

1. INTRODUCTION

The Hong Kong Observatory (HKO) has long been using manual Dvorak analysis (1984) on satellite imagery for operational estimation of the intensity of tropical cyclones (TCs). Once a potential TC is suspected to soon form, a Dvorak analysis will be performed as often as deemed appropriate for assessing the current intensity of the TC. For TCs within 0-36 N, 100-140 E, Dvorak analysis will be performed at least for 00, 06, 12 and 18 UTC imageries. For TCs within the HKO area of responsibility (viz. 10-30 N, 105-125 E), additional analysis will be performed for 03, 09, 15 and 21 UTC imageries. Operational position and intensity are provided in Hong Kong Tropical Cyclone Warning for Shipping and local tropical cyclone warnings for the public.

A post-season reanalysis of storms is carried out and the information is incorporated into the TC best track dataset. HKO's best track records started as early as 1884, but more complete records were kept since 1961. HKO produces best tracks for TCs within 0-45 N, 100-160 E until 1960 and 0-45 N, 100-180 E from 1961 onward. The maximum 10-minute surface mean wind and the minimum pressure of TCs are given in the best track dataset at 6-hourly intervals.

2. LOCAL VARIATIONS TO DVORAK (1984)

The Enhanced IR Dvorak technique has been in use operationally in HKO since early 1980s. Prior to that, the Dvorak analysis was initially carried out using the visible imageries.

While there is no formal reference in the Dvorak technique about its application to TCs making landfall, Dvorak analysis is being applied in Hong Kong to TCs over the sea as well as over land. Beginning the TC season of 2014, a modified version of the original scheme by Dvorak for the weakening stage of TCs is followed (Shum and Chan, 2013). The original scheme only gives direction on handling CI-number when the TC weakens but no explicit guidance is given when the TC stops weakening and the final T-number has flattened for some period of time. In the modified scheme, when the final T-number has already plateaued for more than 12 hours, CI is held the same as the final T-number. For weakening TCs over land, there is no need to hold CI constant for 12 hours. Instead, it is immediately held 0.5 higher than the final T-number.

According to Dvorak (1984), the eye adjustment factor is determined using the eye temperature and the coldest surrounding ring temperature that meets the "narrowest width" requirement. This "narrowest width" requirement has been relaxed in 2014 following Dvorak (1995), i.e. the surrounding ring temperature is defined as any cold band surrounding the eye, regardless of width.

Currently, no Dvorak analysis will be performed after a TC has transitioned into an extratropical low. Extratropical systems are not included in the HKO best tracks.

3. UNIFORMITY IN APPLICATION OF DVORAK TECHNIQUE

The HKO forecasters will carry out Dvorak analysis and fill in the tropical cyclone analysis worksheet as described in the appendix of Dvorak (1984) during operation. SAREP reports in BUFR format, including information such as CI and the final T-number, are issued eight times a day to other meteorological centres when a TC enters within the HKO area of responsibility.

Prior to the introduction of the modified weakening rules described in the preceding section, the CI of a TC would be held constant for 12 hours) during initial weakening according to Dvorak (1984). Normally, the HKO forecasters followed this weakening rule even when the TC had made landfall or was crossing large landmasses such as the Philippines. However, the forecasters could ignore the rule for landfalling TCs on a case-by-case basis.

4. CHANGES IN PROCEDURES OVER TIME

Following Harper et al. (2010), a conversion factor of 0.93 was adopted in Hong Kong from February 2013 to convert 1-minute mean winds from the Dvorak wind table into 10-minute mean winds for reporting and warning purposes. Prior to that, a fixed conversion factor of 0.9 had been used.

5. DETERMINATION OF TC FINAL INTENSITY

In determining the final intensity of a TC, surface wind and pressure reports are regarded as ground truth but the quality of the observations are also taken into account (for example, pressure reported by ships can sometimes be suspicious). For TCs over the ocean where such observations are sparse, Dvorak analysis is used as the main tool for TC intensity determination. Other satellite intensity estimates, e.g. wind scatterometer, ADT, etc., are used as references.

Tropical cyclone's central pressure is estimated based on the surface pressure reported by land stations and ships, reconnaissance aircraft reports when available and Dvorak analysis via the wind-pressure conversion table.

The maximum surface mean wind speed is estimated based on the surface winds reported by land stations and ships, Doppler wind observations from radars, reconnaissance aircraft reports when available and Dvorak analysis. Estimates from wind scatterometer data, ADT, SATCON and the Multi-platform Tropical Cyclone Surface Wind Analysis by NOAA are also referenced.

6. INFLUENCES OF TECHNOLOGICAL ADVANCEMENTS ON DVORAK ANALYSIS

One notable influence is due to the advent of microwave imageries in recent years. Microwave imageries are less frequently available, but can serve as a supplement to Dvorak analysis. They enable the forecasters to see through clouds and view rainbands and eye of the TCs even when obscured by upper-level clouds, thereby helping to reveal the best pattern (e.g. banding versus shear or an eye pattern under a central cold cover) to use in the Dvorak classification. In addition, sea-level winds measured by ASCAT or previously QuikSCAT serve as a check on the location and strength of TCs.

7. ANCILLARY DATA CONSIDERED IN PRODUCING FINAL SATELLITE INTENSITY ESTIMATE

Since 2009, HKO has incorporated the "Advanced Dvorak Technique (ADT)" developed by the University of Wisconsin-Madison / Cooperative Institute for Meteorological Satellite Studies (CIMSS) as an objective reference tool for weather forecasters. ADT makes use of computer-based algorithms to objectively identify cloud pattern types, calculate the eye/convective cloud temperatures, apply selection rules, and derive intensity estimate for TC. One advantage of this tool is that it can be fully automated. The ADT is presently applied to the TC positions determined by the forecasters.

Scatterometer winds such as ASCAT or previously QuikSCAT, NOAA Multiplatform satellite surface wind analysis, images from microwave sensors available in the NRL website (http://www.nrlmry.navy.mil/TC.html), other resources from the web such as satellite-derived winds and dropwindsonde observations are also referenced by HKO forecasters.

8. PRESSURE WIND RELATIONSHIP IN USE

The empirical relationship between CI, the minimum sea level pressure (MSLP) for the Western North Pacific Basin and the 1-minute maximum mean wind speed (MWS) given in Dvorak (1984) is in operational use at HKO. A conversion factor of 0.93 is applied to convert the 1-minute mean winds to 10-minute mean winds.

Conversion of the Dvorak CI number to MSLP and MWS

CI Number	MWS (10-minute mean in knots)	MSLP (hPa)
1.0	23	
1.5	23	
2.0	28	1000
2.5	33	997
3.0	42	991
3.5	51	984
4.0	60	976
4.5	72	966
5.0	84	954
5.5	95	941
6.0	107	927
6.5	118	914
7.0	130	898
7.5	144	879
8.0	158	858

9. SYSTEMS TO ENTER THE BEST TRACK RECORDS

Best tracking has been carried out by HKO officers who have rich experience in TC operation. The best tracks are determined independently from the operational environment. An advantage of best tracks over operational tracks is that the analyst can look back and forth to ensure a more reasonable and consistent track. References are also made to additional information such as tropical cyclone passage reports and best track data issued by RSMC Tokyo, which are not available operationally. Currently, there is no periodic re-visit of the best track record from previous years - this is only done on an ad-hoc and need-only basis.

The best track intensity will not normally differ too much from the warning intensity. Strong evidence is required for large changes in intensity.

REFERENCES

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