7B.1 An Overview of the International Best Track Archive for Climate Stewardship (IBTrACS)

Michael C. Kruk*
STG Inc., Asheville, North Carolina

Kenneth R. Knapp, David H. Levinson, Howard J. Diamond
NOAA National Climatic Data Center, Asheville, North Carolina

James P. Kossin
Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison, Madison, Wisconsin

1. INTRODUCTION

While numerous studies have investigated the global climatology of tropical cyclones, prior research generally has used a small subset of available best track data. For example, Emanuel (2005) and Klotzbach (2006) referenced data from two centers: the Joint Typhoon Warning Center (JTWC, Chu et al. 2002), and the Hurricane Database (HURDAT, Jarvinen et al. 1984) of the National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center (NHC). Although gathering and merging data from these two centers may seem complete for a global analysis, numerous other agencies also compile best track data. Despite the importance and impact which TCs have worldwide, there has been no single dataset which incorporates TC best track (BT) data for all TC-prone basins from all available agencies.

The term “best track” specifically refers to the best estimate of the TCs location, maximum sustained winds, central pressure and other parameters on a 6-hr basis (at 00, 06, 12 and 18 UTC) during the lifetime of a TC. Best track data are compiled and archived by many agencies from around the world, although each one records slightly different TC characteristics in various formats. As such, numerous issues arise when producing a global dataset, such as identifying TCs tracked by multiple centers while reporting vastly different positions and intensities. Furthermore, the reported maximum sustained wind speeds from the various agencies have differing definitions.

Despite these issues, the merging of best track data from multiple centers was needed to meet existing needs and fill gaps in the historical global tropical cyclone records. To address these issues, the NOAA’s National Climatic Data Center (NCDC) has developed a new, homogeneous and comprehensive global tropical cyclone best track dataset. This new global best track dataset is based, not on just a few centers, but on all available best track data, and is called the International Best Track Archive for Climate Stewardship (IBTrACS, Kruk et al. 2008a, 2008b). Unlike any other global tropical cyclone best track dataset, the IBTrACS dataset utilizes complex merging techniques which necessarily account for the inherent differences between forecast centers while applying meticulous, objective quality control procedures to flag potentially erroneous data points. This paper briefly describes the methods used to combine these disparate datasets into this centralized repository of global TC best track data.

* *Corresponding author address:* Michael C. Kruk, STG Inc., Asheville, NC 28801; email: michael.kruk@noaa.gov

2. COMBINING BEST TRACK DATA

Best track data were received in a variety of formats and were converted to netCDF format (Rew and Davis 1990). The first step toward a global dataset was identifying large errors in track positions. The term “large” refers to gross errors that are approximately 111 km (1° latitude) or more, while smaller errors in storm tracks were ignored. Once the large errors were corrected, an automated algorithm then identified storms reported by multiple centers by sorting tracks in time and space. As shown in Fig. 1, each storm position for the entire period of record is color-coded by the number of centers tracking the storm. This provides an overview of the number of forecast centers providing information on any one storm. The North Atlantic is the lone basin containing tracks with a single source (i.e., HURDAT). Conversely, storms in the Western Pacific were often tracked by four centers. The Southern Hemisphere storms are less cohesive with any number of centers tracking each storm. Lastly, the Northern Indian Ocean basin is generally tracked by two centers: JTWC and New Delhi.

Once individual storms were identified, best track data were processed by merging time coordinates, addressing storm positions and storm intensities via maximum sustained wind (MSW) and minimum central pressure (MCP).

For most storms, tracks from multiple centers are merely multiple estimates of the same storm position. In these instances, the IBTrACS position is the average position for each observation time. An example of this simple merge is shown in Figure 2a. Four forecast centers tracked the storm: Hong Kong Observatory (HKO), Japan Meteorological Administration (JMA), JTWC and Shanghai Typhoon Institute (STI). The first few observations are solely from JMA, so IBTrACS positions were derived from the JMA positions. Later IBTrACS positions are the mean position of the reported positions from the four centers.

However, tracks which merged with or split from the main storm track required special processing. In these cases, averaging the track positions was erroneous, for instance, when the positions represented two separate storms prior to a merger. In this case, the set of all tracks, which at some time are coincident in time and space (as identified in Fig.2b), was called an aggregate storm. An objective algorithm was used to determine portions of the tracks which were, in fact, separate storms (e.g., prior to merger). The procedure used herein was to define a storm as a unique storm track. So in the instance of two storms merging, IBTrACS contains two storms: one track before and after the merge, termed the main, and another track which ends at the merger, termed the spur. Storm splits were handled in a similar way with the spur occurring only after the split. An example of a storm identified as a storm split and merger are shown in Fig. 2b and 2c (respectively) where the main tracks as solid lines and the spurs as dashed lines.

The resultant central pressure provided in IBTrACS is simply the average from each of the reporting centers (though the ranges in pressures are also provided). However, the merging process was more complex for MSW due to differences in operating procedures at the forecast centers.

The World Meteorological Organization (WMO) standard is the 10-min average MSW, which is used at many of the forecast centers. Variations from the WMO standard include the 1-min average in use by the U.S. (JTWC, NHC and the Central Pacific Hurricane Center) and India, and the 2-min average used at STI. Since a primary goal of the project was to produce a homogeneous best track dataset, all non-10-min winds (V) were normalized to the 10-min average (V_{10}) via:

$$V_{10} = 0.88 \cdot V$$

The factor 0.88 (Sampson 1995) was chosen since it is the median of the values used by Neumann (1993, 0.87), La Reunion (0.88) and HKO (0.9). The conversion of all basins' MSW to a 10-min average is also consistent with Neumann (1993) and allows for a globally-consistent approach to tropical cyclone statistics. In the IBTrACS data, the reported wind is a 10-min sustained wind which is the mean of all available wind reports, although a statistical median and range of wind speeds is also reported. Based on these initial conclusions, it is conceivable that the factor of 0.88 may not be appropriate for all times and forecast centers, however, until the operating procedures at each forecast center are completely documented, a more accurate conversion cannot be made.

Finally, objective automated quality control algorithms were developed and incorporated for the MSW and MCP for each time step. Values that are identified through the quality control tests are not removed from the final IBTrACS dataset; rather they are flagged as questionable.

For the MSW, the bounds of rapid intensification (Kaplan and DeMaria 2003) were modified for 6-hr instead of 24-hr intensity changes, and for the MCP, a base intensity change of 50 hPa was selected and applied to the data.

3. DISCUSSION

The result of the best track dataset merging process is a new global tropical cyclone dataset - the International Best Track Archive for Climate Stewardship (IBTrACS). The best track data provided in this archive are the positions and intensities (via minimum central pressure and/or maximum sustained wind) of each storm available from all resources and was derived using meticulous quality assessments. In the process of merging the data from each of the forecast centers, statistics were calculated to provide information on the variations in position and intensities. Also, prior to merging the best track data, quality assessments of the position and intensity were made. While some gross position errors were corrected, all intensity values were retained in the final data along with the quality assessment results. The IBTrACS positions and intensities are, therefore, the average position and intensity from available forecast centers. One major advantage the IBTrACS dataset has over other available best track data is that it provides the full range of reported values for pressure, intensity, and position, for each 6-hr time step.

It has been demonstrated that in creating a new global tropical cyclone best track dataset, it is imperative that best track data be included from all forecast centers. This is especially critical when analyzing global tropical cyclones since using data from any one center will likely result in missed TCs. The IBTrACS dataset is thus the most comprehensive dataset available.

3.1 Future work

Outside of a complete reanalysis of all global tropical cyclones, there are improvements to the existing IBTrACS best track record that could be made. Presently, the IBTrACS dataset only reports MSW and MCP. However, other parameters are available, such as the radius of maximum winds (RMW), radius of outermost closed isobar (ROCI) and intensity at landfall. This would presumably be of great value to more users, especially those that require detailed statistics or climatologies on coastal storm surge impacts, near-shore wave modeling, evacuation routes, etc. Such enhancements to IBTrACS could set the stage for a more thorough and complete global reanalysis of tropical cyclones.

Acknowledgements

This effort could not have been done without the provision of data from many data centers. The data centers that graciously provided data include:

- RSMC Nadi, Fiji and Alipate Waqaicelua for providing BT data from the South Pacific Ocean;

* RSMC La Reunion and Philippe Caroff for providing BT data from the Southern Indian Ocean;
* TCWC Wellington and Peter Kreft for making BT data available for the Southern Pacific Ocean;
* RSMC Honolulu (CPHC) and James Weyman for providing BT data for the Central Pacific Ocean;
* Australian BoM and Blair Trewin for providing a preliminary version of a revised Australian BoM Best Track;
* Charlie Neumann for providing BT data for the Southern Hemisphere;
* RSMC New Delhi, B. K. Bandyopadhya and Charan Singh for working to provide BT data for the Northern Indian Ocean;
* Tom Ross and NOAA Climate Database Modernization Program for keying the New Delhi data;
* Hong Kong Observatory and W. H. Lui for providing BT data for the Western North Pacific, and
* NHC, JTWC, JMA and CMA for making their data publicly available via the internet.

We also acknowledge those who have helped to guide this work, including Bruce Harper, Chris Landsea, and Carl Schreck, and James Rich for his programming assistance. We also wish to thank Trevor Wallis who provided insightful comments throughout the data development process.

4. REFERENCES

Chu, J.-H., C.R. Sampson, A.S. Levin, and E. Fukada, 2002: The Joint Typhoon Warning Center tropical cyclone best tracks 1945-2000, report, Joint Typhoon Warning Center, Pearl Harbor, Hawaii.

Emanuel, K., 2005: Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, **436**, 686-688.

Jarvinen, B. R., C. J. Neumann, and M. A. S. Davis, 1984: A tropical cyclone data tape for the North Atlantic Basin, 1886–1983: Contents, limitations and uses. NOAA Tech. Memo. NWS NHC 22, NOAA/National Hurricane Center, Miami FL, 21 pp. [Available from NOAA/Tropical Prediction Center, 11691 S.W. 17th St., Miami, FL 33165-2149.].

Kaplan, J., and M. DeMaria, 2003: Large-Scale Characteristics of Rapidly Intensifying Tropical Cyclones in the North Atlantic Basin. *Wea. Forecasting*, **18**, 1093–1108.

Klotzbach, P.J., 2006: Trends in global tropical cyclone activity over the past twenty years. *Geophys. Res. Lett.*, **33**, L10805, doi:10.1029/2006GL025881.

Kruk, M.C., K.R. Knapp, D.H. Levinson, and J.P. Kossin, 2008a: National Climatic Data Center Global Tropical Cyclone Stewardship. Preprints, *28th Conf. on Hurricanes and Tropical Meteorology*, Orlando, FL, Amer. Meteor. Soc.

Kruk, M.C., K.R. Knapp, and D.H. Levinson, 2008b: A technique for merging global tropical cyclone best track data. *J. Atmos. Oceanic Tech.,* (submitted)

Rew, R., and G. Davis, 1990: NetCDF – an interface for scientific data access. *Computer Graphics and Applications, IEEE,* **10**, 76-82.

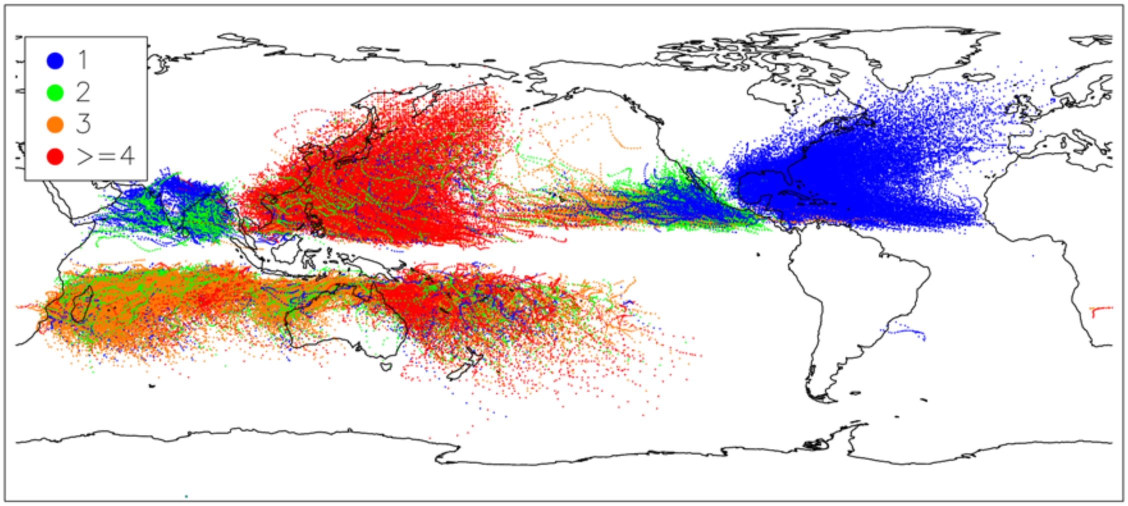

Figure 1 – Storm positions from all unique storms within the IBTrACS dataset where shading represents the number of centers providing information for the storm.

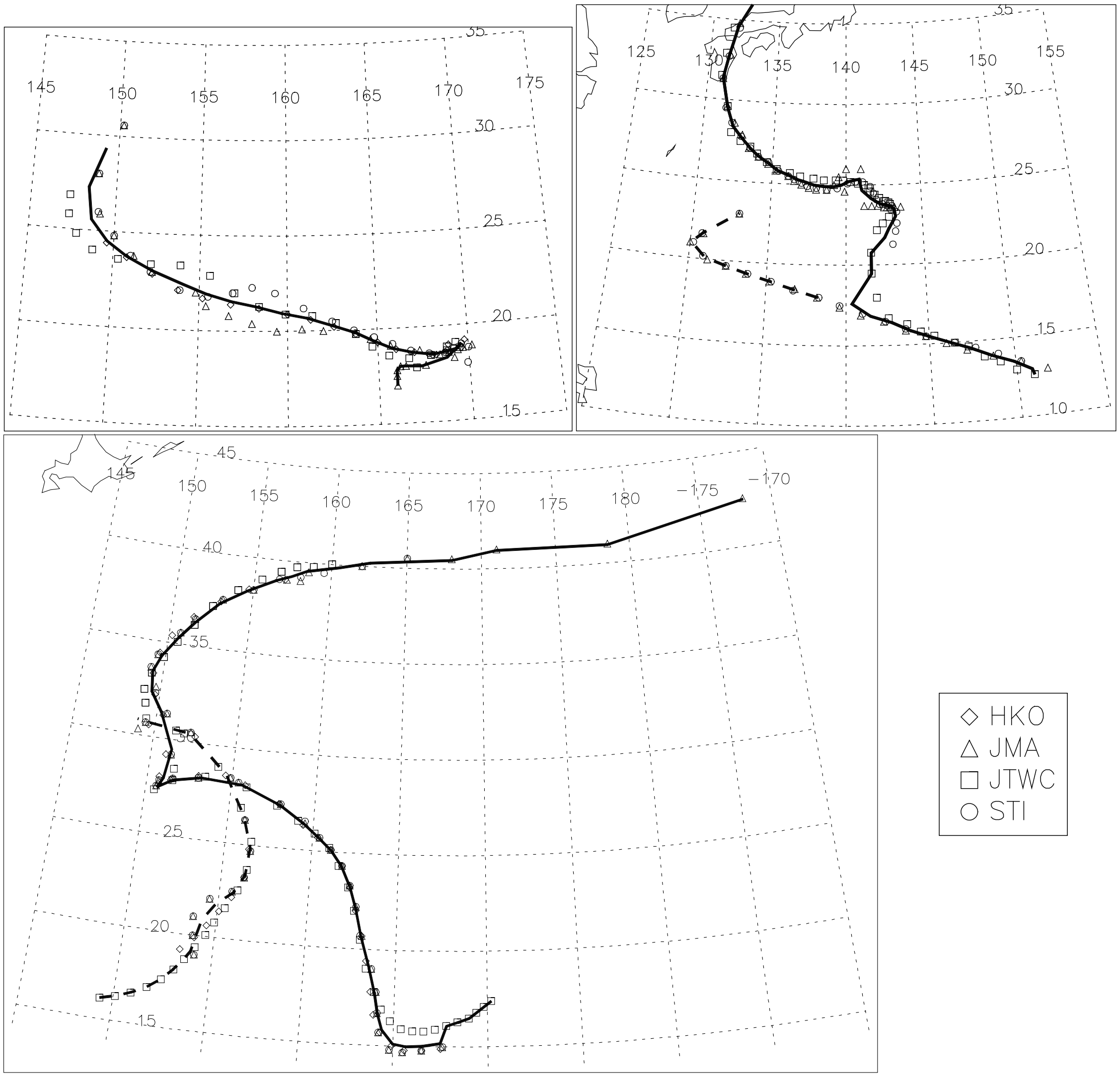

Figure 2 – Result of the IBTrACS merge algorithm for: a) a storm tracked by four centers. b) a storm which split and c) two storms which merged.