WMO/CAS/WWW

SIXTH INTERNATIONAL WORKSHOP on TROPICAL CYCLONES

Topic 3 : **TROPICAL CYCLONE MOTION**

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3.0.1 **Introduction**

Already at IWTC-V, this topic was focused on tropical cyclone (TC) track prediction rather than on observational, theoretical, or numerical simulations of TC motion, as had been the case in the early IWTCs. The focus in this report will again be on TC track prediction rather than TC motion.

One of the highlights of Topic 3 at IWTC-V was the report on operational consensus track forecasting at the Joint Typhoon Warning Center (JTWC) that had resulted in dramatic improvements in 72-h track forecast accuracy in the western North Pacific (Jeffries and Fukada 2002). R. Jeffries also presented a special focus session on consensus forecasting that was well attended.

Jeffries and Fukada (2002) also presented the internal tests of 96-h and 120-h track forecasts at JTWC. Based on the success of these tests, and similar testing at the U. S. National Hurricane Center, both warning centers announced their plans to begin issuing official forecasts to 120 h during the 2003 season.

3.0.2 **Advances in operational track prediction**

The improvements in track prediction are often attributed to better guidance from Numerical Weather Prediction (NWP) models. Improved NWP track guidance by the Japan Meteorological Agency (JMA) and the United Kingdom Meteorological Office (UKMO)is documented in Topic 3.1. In addition, the forecasters are making better use of the NWP guidance through multiple-model consensus forecasting, as the consensus track errors over a season are smaller than any of the individual model errors.

Ensemble prediction system (EPS) track forecasts are also becoming available in some warning centers. Some post-processing of the EPS output has improved the strike probability maps generated from the European Center for Medium-range Forecasts (ECMWF)EPS, which includes 50 members.

The improvements in 24-, 48-, and 72-h TC track forecasts by various warning centers and for various ocean basins are then documented in Topic 3.1. Particularly dramatic improvements in 24-h and 48-h track forecasts have been achieved in the North Indian Ocean and the Southern Hemisphere from the 1990s to the present. Long-term trends in the 72-h errors may only be evaluated for the U.S. warning centers since the only non-U.S. center to make 72-h forecasts is the JMA and they have only been issuing 72-h track forecasts since 2001. Particularly large improvements are again noted in the 72-h forecasts for the North Indian Ocean and the Southern Hemisphere. The differences among the basins are now much smaller than during the 1990s, and the remaining differences are probably related to the degree of difficulty in the basins, and/or small sample sizes.

In summary, several operational warning centers in the developed nations have made use of improved NWP track guidance to make more accurate track forecasts through 72 h in all ocean basins.

The 120-h track forecast accuracy for the U.S. warning centers is summarized in Topic 3.2. The 120-h errors are generally about 300 n mi, which was a typical value for 72-h errors in 1990. This is another dramatic improvement in tropical cyclone track forecasting, which is attributed to better NWP guidance and better use of this guidance via consensus forecasting. Given the importance of the NWP guidance, Topic 3.2 includes a summary of recent upgrades in the numerical models in many countries.

Because of the importance of consensus track forecasting, a special focus session 3a on this topic will be offered at IWTC-VI to share experiences. Both weighted and non-weighted methods of combining multiple NWP model tracks will be described. A selective consensus approach at JTWC for the 72-h forecasts described at IWTC-V (Jeffries and Fukada 2002) has been dropped in favor of a non-selective 10-member consensus. However, only four NWP model tracks are available at JTWC for 96-h and 120-h forecasting. When one or more of these NWP models has a significant error, the selective consensus of the remaining models may be more accurate. Payne et al. (2006) indicate that the average improvement in the 120-h selective consensus forecasts relative to the non-selective consensus forecasts would be 222 (239) n mi during 2005 (2004), and the corresponding average improvement relative to the JTWC forecasts would be 282 (203) n mi. Even though these selective consensus forecasts would have been appropriate for only 20-25% of the 120-h forecasts, their proper formulation would have significantly improved the seasonal error statistics.

A new method by Jim Goerss of the Naval Research Laboratory-Monterey for determining the track forecast confidence based on the spread of the dynamical model guidance will also be described in the special focus session 3a. Whenever the spread is small, a smaller circle can be drawn around the consensus mean position to indicate the likelihood that about 72-74% of the time the storm center will be inside the circle. This representation of the track forecast confidence takes into account the degree of difficulty of the forecast, as opposed to drawing the same confidence circle in every situation.

The NWP model guidance is not always accurate at 120 h. Since many of the verifiable 120-h forecasts involve an interaction with the midlatitude circulations, a large fraction of the 120-h errors arise from an improper prediction of this interaction. For example, Kehoe et al. (2006) found 83% (85%) of the U. S. Navy global (regional) model errors in the western North Pacific during the 2004 season were due to midlatitude errors. Similarly, about 90% of all large (> 500 n mi at 120 h) errors by these two models and the NCEP and UKMO global models during the 2005 western North Pacific season were attributed to midlatitude-related sources (Payne et al. 2006). Frequent, systematic errors in the Navy regional model and the NCEP global model could have been recognized from examining the fields.

A further description of the various EPS that might be used to extract tropical cyclone tracks is given in Topic 3.2. These EPSs may involve a single model with perturbed initial conditions for each member, or a multiple model variation may also be included. In the near future, a THORPEX Interactive Grand Global Ensemble (TIGGE) that may include the combined EPSs of perhaps 11 countries will become available. Tropical cyclone tracks might be requested as an output from the TIGGE since this might give an estimate of the track uncertainty.

3.0.3 **Data assimilation**

Plans at seven NWP centers for data assimilation of satellite data were presented at IWTC-V. While these data assimilation systems were not specifically for tropical cyclones, Topic 3.2 also describes some recent three-dimensional variational and four-dimensional variational systems and Ensemble Kalman Filter systems that may have specific applications for tropical cyclone prediction.

Some data assimilation issues are also discussed in Topic 3.3, and especially the need for flow-dependent background error covariance in the region of the tropical cyclone. When targeted observations from aircraft (radar data as well as dropwindsondes) and other special satellite instruments are available, special data assimilation considerations will be necessary. The data assimilation system can be used to determine which observations have the greatest contribution to the tropical cyclone track forecast.

3.0.4 **Targeted observations**

Recent progress in the use of targeted observations to improve tropical cyclone track prediction is summarized in Topic 3.3. Whereas the capability to deploy dropsondes in the environment of tropical cyclones had previously been limited to the U.S., the Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region (DOTSTAR) program has opened the possibility of targeted observation. Four techniques for determining the most sensitive regions at the observation time are described in Topic 3.3. Sometimes the sensitive areas are in the region of the tropical cyclone and at other times the sensitive areas are remote from the cyclone. Whereas some preliminary comparisons of the forecast errors for analyses based on different targeted techniques are presented, it appears that larger sample sizes are required for conclusive results as to the superior technique.

3.0.5 **Recommendations**

Whereas multiple recommendations are given in Topics 3.1 and 3a, the consistency between these recommendations is noteworthy. Because of the success in reducing track forecast errors by the operational centers in developed countries, these recommendations are intended to provide the tracks, tools, and training to warning centers in other countries. Given the improvements in track forecasting described in Topic 3.1, it can be confidently expected that similar improvements would also be achieved in other countries.

Ensemble prediction systems continue to be developed that have potential for tropical cyclone track prediction. Research and training on how to most effectively use these ESP tracks is required.

A recommendation to continue and expand the targeted observation programs would be appropriate.

3.0.6 **References**

Jeffries, R. A., and E. J. Fukada, 2002: Consensus approach to track forecasting. Paper TP3.2, Extended abstracts, *Fifth International Workshop on Tropical Cyclones*, Cairns, Australia, World Meteorological Organization (Geneva).

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