10A.7 CLUSTER ANALYSIS OF WESTERN NORTH PACIFIC TROPICAL CYCLONE TRACKS

Suzana J. Camargo[⋆∗], Andrew W. Robertson[⋆], Scott J. Gaffney[†], and Padhraic Smyth[†]
⋆ International Research Institute for Climate Prediction, Columbia Earth Institute, Palisades, NY
† Department of Information and Computer Science, University of California, Irvine, CA

1. Introduction

Typhoons have a large socio-economic impact in many countries in Asia. Depending on the trajectory of the typhoon or tropical storm, landfall will occur or not. While it is well known that these trajectories vary strongly with season, and tend to be affected by ENSO, the probabilistic behavior of tropical cyclone trajectories needs to be better understood in order to isolate potentially predictable aspects of landfall.

In this study, we apply a new clustering technique to the best track dataset of the Joint Typhoon Warning Center for the period 1950-2002. Only tropical cyclones (TCs) with at least tropical storm intensity were included, a total of 1393 TCs. The aim of this analysis is to identify different types of track, their seasonality, and their relationship to the large-scale circulation and ENSO.

The clustering technique consists of building a mixture of polynomial regression models (i.e. curves), which are used to fit the geographical "shape" of the trajectories (Gaffney and Smyth, 1999). This technique is an extension of the standard multivariate finite mixture model to allow for the representations of mixture of underlying functions (in this case, quadratics), from which the observed TC tracks might have been generated. Finite mixture models enable highly non-Gaussian multimodal density functions to be expressed as a mixture of a few unimodal component PDFs. The model is fit to the data by maximizing the likelihood of the parameters, given the dataset. The mixture model framework allows the clustering problem to be posed in a rigorous probabilistic context, and to easily accommodate tropical cyclone tracks of different lengths, giving advantages over the K-means method used in previous studies (e.g. Harr and Elsberry (1985); Elsner and Liu (2003)).

2. Results

Although the out-of-sample likelihood estimates do not provide a precise answer, the best number of clusters appears to be about 6. Fig. 1 shows the 6 underlying regression models, relative to their starting points. The two main trajectory-types identified correspond to "straight-movers" and "recurvers", with the additional clusters corresponding to more detailed differences in shape among these two main types. We analyzed a variety of properties in each cluster and compared them among the clusters and with the properties of the basin as a whole. The main variables analyzed were: number of tropical cyclones, number of tropical cyclones with tropical storm (TS), typhoon (TY - Dvorak's scale 1-2), and super-typhoon (STY - Dvorak's scale 3-5) intensities, location and distribution of first position (genesis), tracks types and density, ACE (accumulated cyclone energy) (Bell et al., 2000), and lifetime.

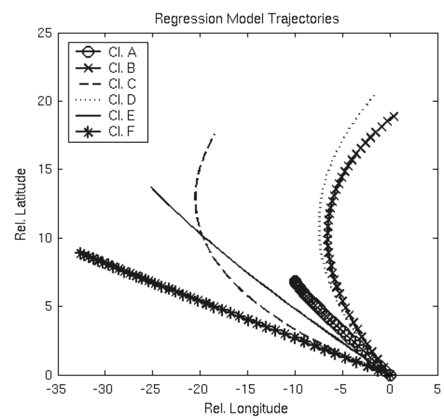

Figure 1: Mean regression trajectories relative to the initial position.

Clusters A and B are the two dominant clusters in the number of tropical cyclones (NTC) having 333 (24% of total NTC) and 303 (22%) tropical cylones respectively (Fig.2). The trajectories in cluster A tend to exist and form in the Philippines sea and especially the South China Sea. With most of the tracks being straight moving northwestward, almost all tropical cyclones in cluster A make landfall either in the Philippines, South of China, Taiwan or Vietnan, with a few crossing over to the Indian Ocean. The genesis region for cluster B is north and east of the Philippines. The dominant trajectory type in cluster B is long and recurving, with many of them making landfall in China, Taiwan, Korea and Japan.

Tropical cyclones in the western North Pacific occur year round, with a peak in the months of July to October (maximum in August), and a minimum in February. The different clusters tend to peak in different times of the year. The dominant clusters A and B have an annual cycle very similar to the whole basin, as expected.

The average NTC per year in the basin with intensities TS, TY and STY is very similar, with a slight dominance of STY typhoons: 8.8 TS (33%), 8.0 TY (30%), 9.5 STY (37%). However, the distribution of TS, TY and STY in each cluster varies significantly. Cluster A is dominated by tropical cyclones that are not over the ocean long enough to intensify. Though cluster A has the largest NTC, its contribution to the total ACE per year is the smallest of all clusters (11%), reflecting both the dominance of

∗ *email*:suzana@iri.columbia.edu

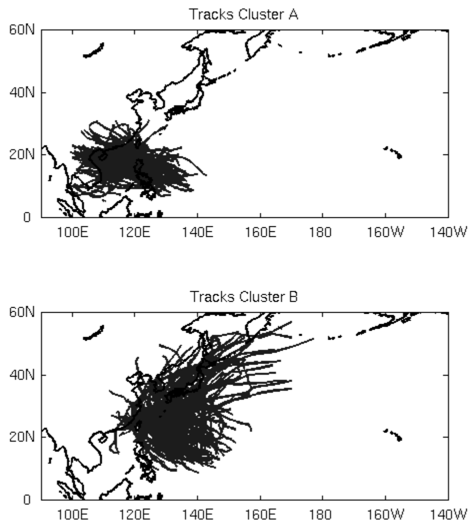

Figure 2: Tracks in the dominant clusters (half of the TCs in each cluster are shown here).

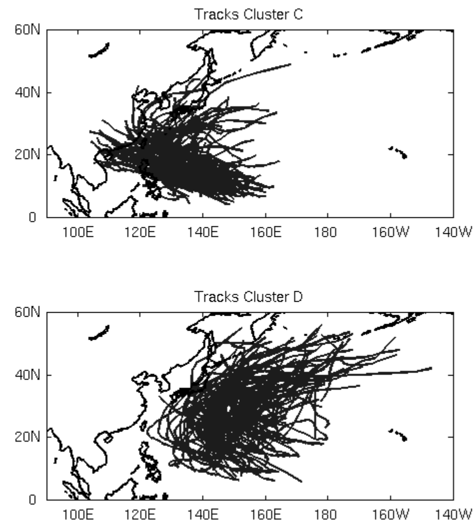

Figure 3: Tracks in clusters C and D (half of the TCs in each cluster are shown here).

tropical storms and their short lifetime. Cluster B has a high contribution to ACE (20%), and this is mainly due the high NTCs.

Clusters C and D (Fig.3) have 232 and 228 tropical cyclones each, representing 17% and 16% of the total. The genesis region of cluster C is mainly in a narrow strip east of the Philippines, while the cluster D genesis region is spread over the middle of the basin. Though most of the tropical cyclones in cluster C have straight trajectories making landfall in China between the latitudes of Hainan and Taiwan, a large portion of them recurve and can reach Korea and Japan. In contrast, almost all the tracks in cluster D recurve and a few make landfall, mainly in Japan. Cluster C has mostly intense tropical cyclones, and therefore the highest contribution to the total ACE (22%), with a high percentage of STY and slightly above average lifetime (8.6 days).

The two clusters with the least number of tropical cyclones are clusters E and F (not shown), with 153 (11%) and 144 (10%) respectively. Both clusters have genesis region near the equator with cluster E genesis region being more to the central Pacific than cluster F. Cluster E is dominated by recurvers with very few landfall cases, mainly in Japan. On the other hand, cluster F consists mainly of straight trajectories, most making landfall in the Philippines, Vietnam, and a few crossing to the Indian Ocean. The two clusters with the longest average lifetime is cluster E (12.1 days), followed by cluster F (10.3 days). Both clusters E and F are dominated by STY intensity.

The total NTC per year is not significantly correlated with Nino34 in JASO. However, cluster E is strongly correlated with Nino34 (0.69 in 1971-2002) and cluster B is anti-correlated with that index (-0.45 in 1971-2002). There are peaks of NTC in cluster E in most El Niño years (after the 1970), but that does not occur in 1982. The well known shift of the tropical cyclone activity in ENSO years (to southeast in El Niño years and northwest in La Niña years) is expressed as by the significant anti-correlation of these clusters.

3. Conclusions

A new cluster analysis is applied to the best track dataset in the western North Pacific. The dependence of the track clusters on season and ENSO phases are analysed. Depending on the ENSO phase and season different cluster types have a higher incidence and these are associated with different preferential regions of landfall. Characteristics in each cluster type are studied, such as first position, mean track, landfall, intensity, lifetime and speed. Large-scale circulation anomalies composites for different track clusters will also be analyzed in the future.

References

Bell, G. D., M. S. Halpert, R. C. Schnell, R. W. Higgins, J. Lawrimore, V. E. Kousky, R. Tinker, W. Thiaw, M. Chelliah, and A. Artusa, 2000: Climate assessment for 1999. *Bull. Amer. Meteor. Soc.*, **81**, S1–S50.

Elsner, J. B. and K. B. Liu, 2003: Examining the ENSO-typhoon hypothesis. *Climate Research*, **25**, 43–54.

Gaffney, S. J. and P. Smyth, 1999: Trajectory clustering with mixture regression models. *Fifth ACM SIGKDD International Conference on Knowledege Discovering and Data Mining*, S. Chaudhuri and D. Madigan, eds., ACM Press, New York, NY, 63–72.

Harr, P. A. and R. L. Elsberry, 1985: Large-Scale circulation variability over the tropical western North Pacific. Part I: Spatial patterns and tropical cyclone characteristics. *Mon. Wea. Rev.*, **123**, 1225–1246.