Complex Network Approach for Detecting Tropical Cyclones

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Abstract

Tropical cyclones (TCs) are one of the most destructive natural hazards that pose a serious threat to society around the globe, particularly to those in the coastal regions. In this work, we study the temporal evolution of the regional weather conditions in relation to the occurrence of TCs using climate networks. Climate networks encode the interactions among climate variables at different locations on the Earth's surface, and in particular, time-evolving climate networks have been successfully applied to study different climate phenomena at comparably long time scales, such as the El Ni~no Southern Oscillation, different monsoon systems, or the climatic impacts of volcanic eruptions. Here, we develop and apply a complex network approach suitable for the investigation of the relatively short-lived TCs. We show that our proposed methodology has the potential to identify TCs and their tracks from mean sea level pressure (MSLP) data. We use the ERA5 reanalysis MSLP data to construct successive networks 20 of overlapping, short-length time windows for the regions under consideration, where we focus on the north Indian Ocean and the tropical north Atlantic Ocean. We compare the spatial features of various topological properties of the network, and the spatial scales involved, in the absence and presence of a cyclone. We find that network measures such as degree and clustering exhibit significant signatures of TCs and have striking similarities with their tracks. The study of network topology over time scales relevant to TCs allows us to obtain useful insights into the individual local signature of changes in the flow structure of the regional climate system.

Full Text

This preprint is available for download as a PDF.

Figures

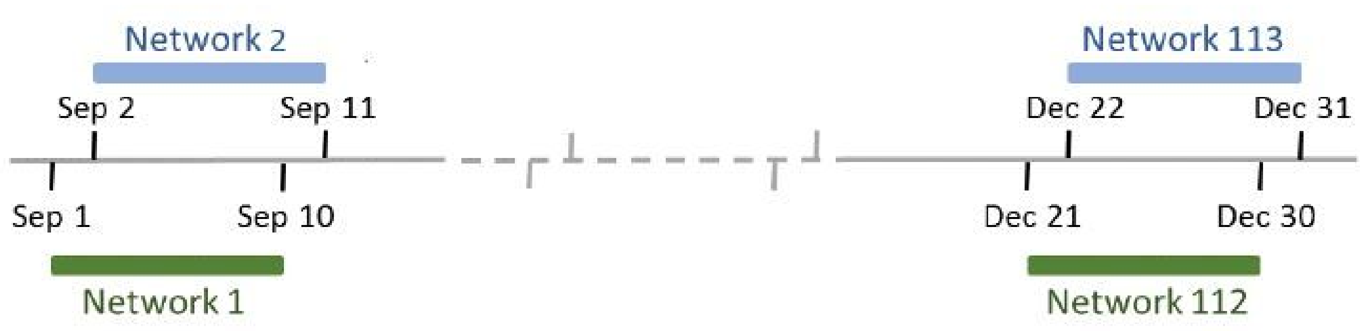

Figure 1

Evolving networks for the Sep-Oct-Nov-Dec season. Networks are constructed over a time window of 10 days. Successive windows have 9 days of overlap.

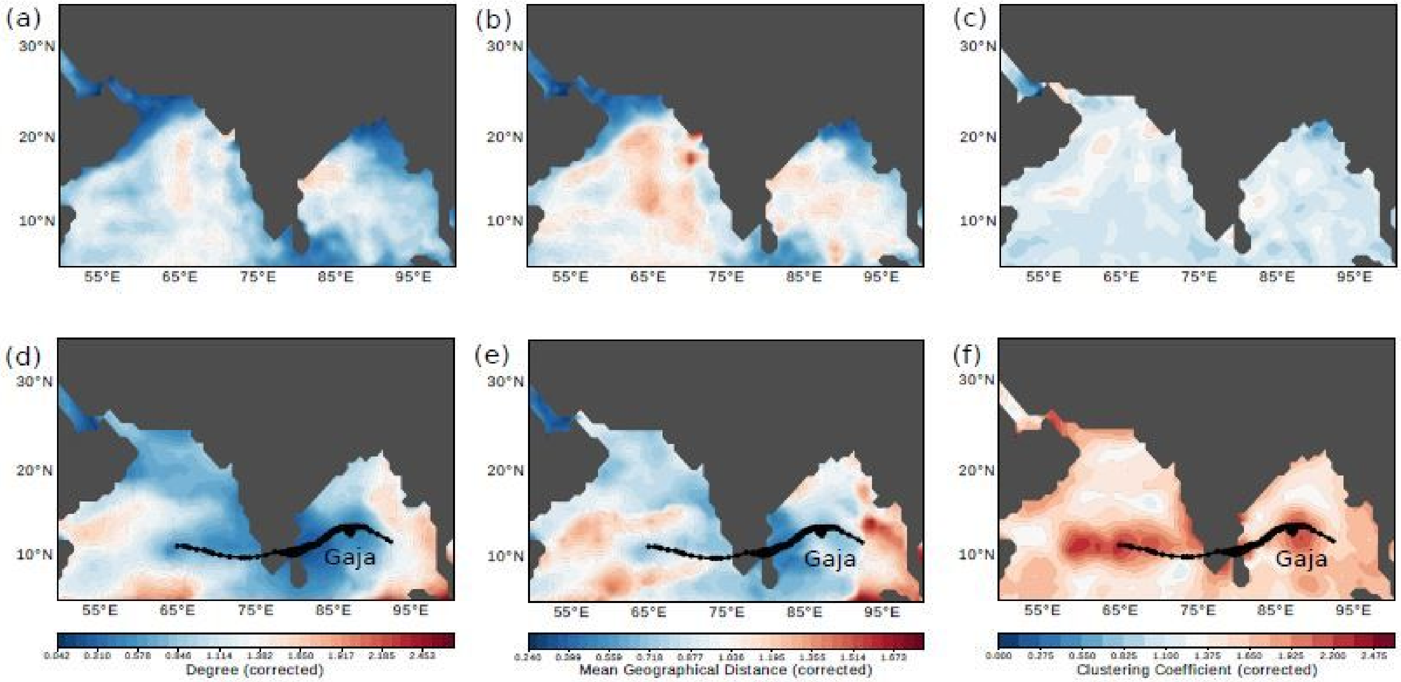

Figure 2

Comparison of degree [(a) and (d)], mean geographical distance [(b) and (e)] and local clustering coefficient [(c) and (f)] elds before and during Very Severe Tropical Cyclone Gaja (Nov 10-19, 2018). Figures in a given column have the same colour scale. (a)-(c) shows the network measures before the cyclone for the period Oct 29-Nov 7, 2018. (d)-(f) gives the network measures for the period Nov 10-19, 2018 during the cyclone. The TC tracks are represented by solid black circles whose sizes are scaled according to the cyclone intensity.

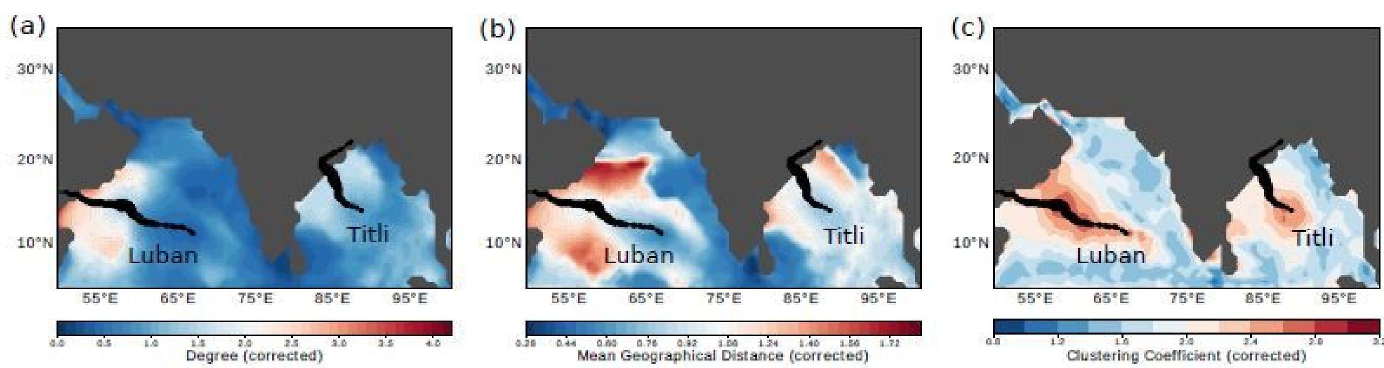

Figure 3

(a) Degree, (b) mean geographical distance and (c) local clustering coefficient elds for network constructed over the period Oct 2-11, 2018, during Very Severe Tropical Cyclones Luban (Oct 6-15, 2018) in the Arabian Sea and Titli (Oct 8-12, 2018) in the Bay of Bengal. The TC tracks are represented by solid black circles whose sizes are scaled according to the cyclone intensity.

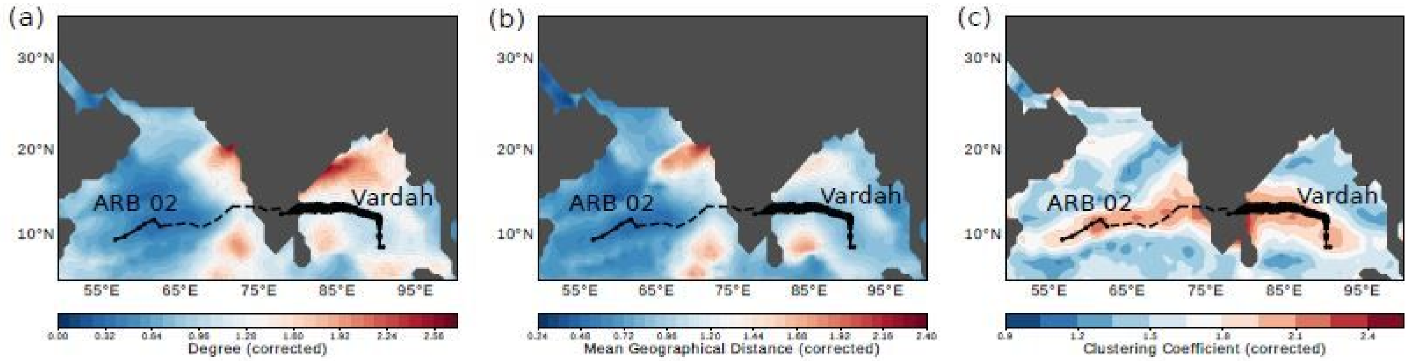

Figure 4

(a) Degree, (b) mean geographical distance and (c) local clustering coefficient elds for network constructed over the period Dec 9-18, 2016, during Very Severe Cyclonic Storm Vardah (Dec 6-13, 2016) in the Bay of Bengal which crossed the Indian peninsula and formed Depression ARB 02 (Dec 17-18, 2016). The TC tracks are represented by solid black circles whose sizes are scaled according to the cyclone intensity.

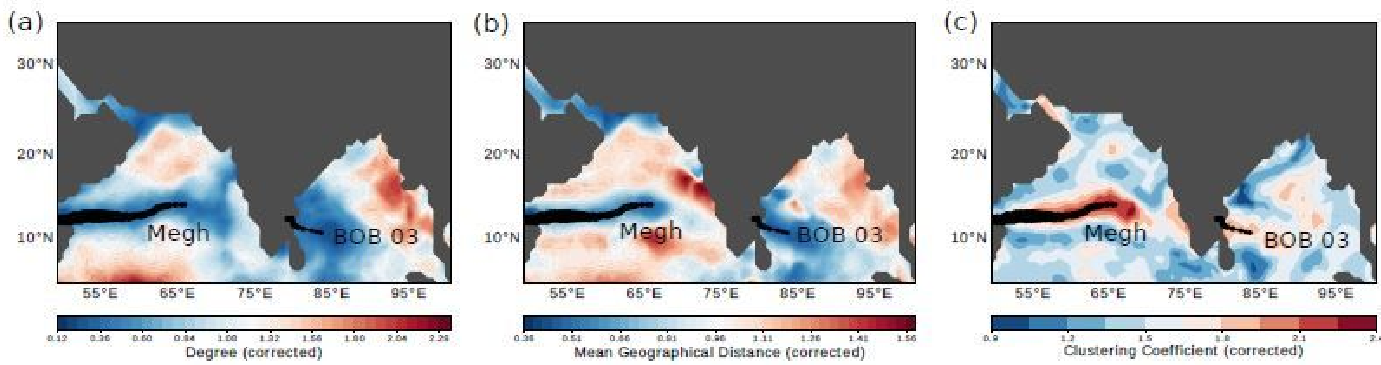

Figure 5

(a) Degree, (b) mean geographical distance and (c) local clustering coefficient elds for network constructed over the period Nov 3-12, 2015, during Extremely Severe Tropical Cyclones Megh (Nov 5-10, 2015) in the Arabian Sea and Deep Depression BOB 03 (Nov 8-10, 2015). The TC tracks are represented by solid black circles whose sizes are scaled according to the cyclone intensity.

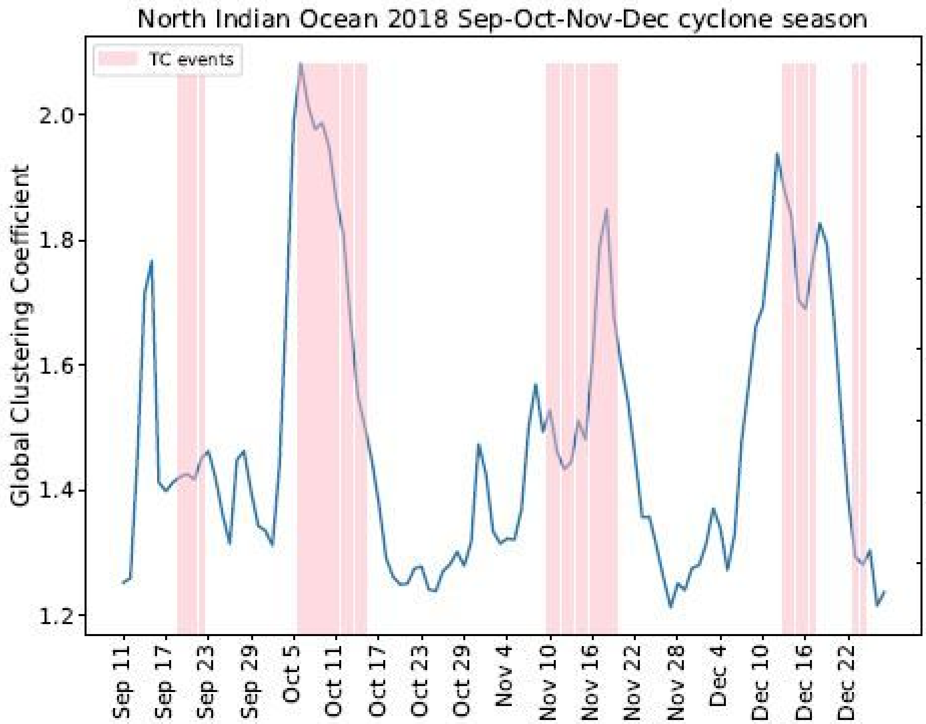

Figure 6

Global Clustering Coefficient (blue) for evolving networks of 2018 NIO TC post-monsoon (Sep-Oct-Nov-Dec) season plotted against the date corresponding to the middle day of the network period. Networks containing TC events show high global clustering coefficients.

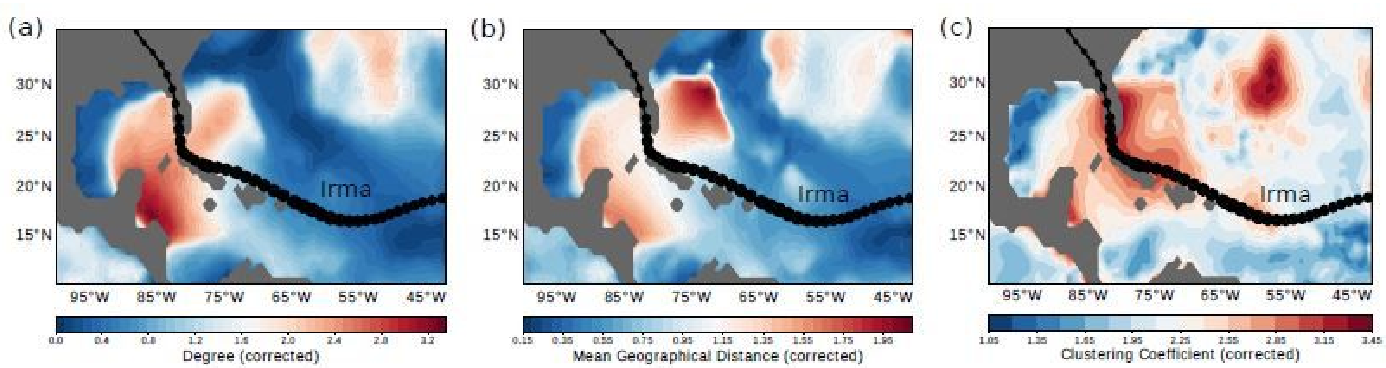

Figure 7

(a) Degree, (b) mean geographical distance and (c) local clustering coefficient fields for network constructed over the period Sep 1-10, 2017, during Hurricane Irma (Aug 30- Sep 13, 2017) in the North Atlantic Ocean. The TC tracks are represented by solid black circles whose sizes are scaled according to the cyclone intensity.