Complex Network Analysis of Synchronized Extreme Precipitation during the Australian Summer Monsoon

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Introduction

- As a part of the global monsoon, the **Australian Summer Monsoon (AuSM)** develops with the establishment of wet westerlies in the tropical Australian region (blue box in Figure 1). The average onset date is 25 December. The synoptic factors responsible for the onset include land-sea thermal contrast, barotropic instability, midlatitude trough and the Madden-Julian Oscillation (Hung and Yanai 2004).
- Preliminary results have been obtained in Cheung and Ozturk (2020) on applying complex network to analyze the mean AuSM development based on extreme precipitation. Land-sea contrast has been revealed by network measures such as degree centrality, and evolution of organized convection was depicted in the clustering coefficient.

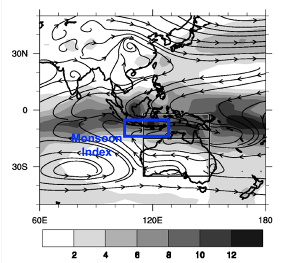

Fig 1. Mean low-level circulation and precipitation associated with the AuSM development (modified from Hung and Yanai 2004; monsoon index region from Kajikawa et al. 2010)

- **AIMS:**
  - To further understand the structural change in the precipitation network associated with the AuSM
  - To identify network measures that correlate with the AuSM onset

Method – Event Synchronization

Event Synchronization (**ES**; Quiroga et al. 2002) technique was applied to construct a network based on precipitation time series:

- TRMM 3-hourly satellite precipitation (1998-2015) was used (daily used in analysis)
- Sliding time windows of 60 days starting from 1 November, shifted every 5 days, are analyzed until the end of March
- Extreme precipitation larger than the 90th percentile is defined as an event
- Synchronized events between two grid points were counted to define the ES strength (Figure 2)
- The top-5% ES strength was then used to define the network adjacency matrix

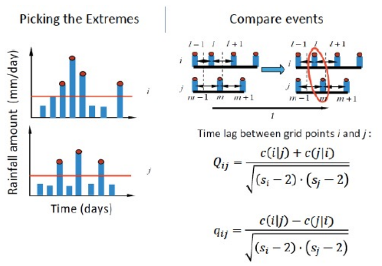

Fig 2. Illustration of the Event Synchronization technique for network construction (courtesy U. Ozturk and V. Stolbova)

Degree Centrality

- While Cheung and Ozturk (2020) found that the spatial distributions of degree centrality do not change much during AuSM development, its distribution is shifting the peak towards lower degree (Figure 3)
- **This implies that extreme precipitation is more locally connected during AuSM development**

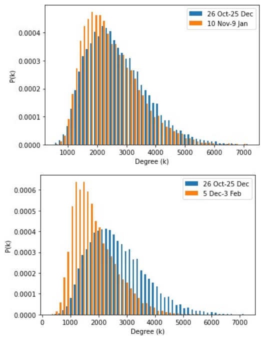

Fig 3. Distribution of the degree centrality for the reference period 26 October – 25 December (blue) and that for 10 November – 9 January (upper orange) and 5 December – 3 February (lower orange)

Communities

Network communities identified based on maximizing modularity (Ozturk et al. 2019):

- Seven communities identified (Figure 4)
- Community #2 is about where the AuSM wind-based monsoon index is calculated
- **Note the eastward and westward extension of community #7 after the mean AuSM onset date**

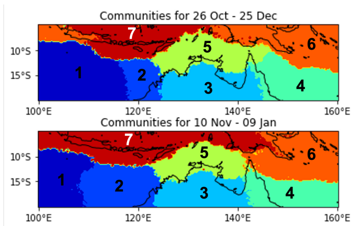

Fig 4. Network communities identified for the period 26 October – 25 December and that for 10 November – 9 January

Link Density

Links between communities #3, #5 and #7 are found important to indicate the AuSM onset. They are in the region where land-sea thermal contrast plays a critical role (Figure 5).

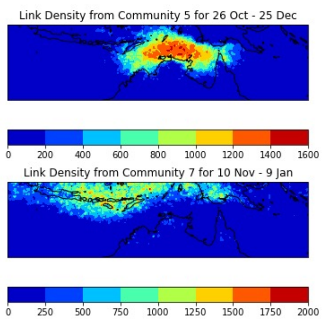

Fig 5. Link density from the grid points of community #5 (upper) and those of community #7 (lower)

Inter-community Cross-Degree

The links between each pair of the communities have been identified (Figure 6).

- It is found that strengthening of the connection between communities #3, #5 and #7 characterizes the AuSM onset
- During onset, links between the communities to the west (monsoon index region) are strengthened
- After the monsoon onset, moderate links are then established among the other communities, indicating the large-scale monsoon precipitation in the region and/or the migration of mesoscale convective systems.

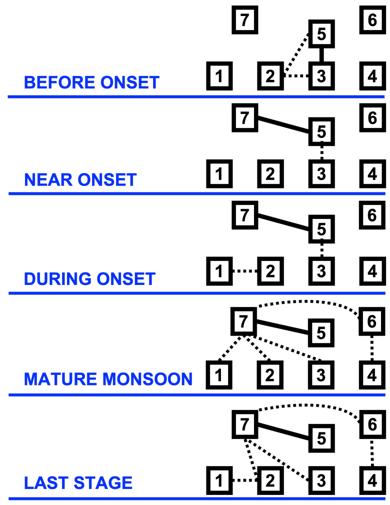

Fig 6. Schematic of the representative links between the seven network communities (boxes). The solid lines represent the largest number of links, while the dash lines represent moderate number of links. The other links not shown are much weaker.

Summary & Future Work

Summary

- Synchronization-based, extreme precipitation network is able to reveal the mean AuSM development
- There are characteristic changes in the network measures and connections between the communities during AuSM onset

Future Work

- Network flux, which may be related to moisture convergence and is based on the event delay patterns, will be examined
- Additional network measures, such as vulnerability, will be analyzed in relation with the timing of AuSM onset
- Interannual variability of network behavior will also be investigated

References

1. Cheung, K. K. W., and U. Ozturk, 2020: Synchronization of extreme rainfall during the Australian summer monsoon: Complex network perspectives. *Chaos*, **30**, 063117, doi:10.1063/1.5144150.
2. Hung, C.-W., and M. Yanai, 2004: Factors contributing to the onset of the Australian summer monsoon. *Quart. J. Roy. Meteor. Soc.*, **130**, 739-758.
3. Kajikawa, Y., B. Wang and J. Yang, 2010: A multi-time scale Australian monsoon index. *Intl. J. Climatol.*, **30**, 1114-1120.
4. Quiroga, R. Q., T. Kreuz, and P. Grassberger, 2002: Event Synchronization: A simple and fast method to measure synchronicity and time delay patterns. *Phys. Rev.*, **E66**, doi:10.1103/PhysRevE.66.041904.
5. U. Ozturk, N. Malik, K. Cheung, N. Marwan, and J. Kurths, 2019: A network-based comparative study of extreme tropical and frontal storm rainfall over Japan. *Climate Dyn.*, **53**, 521-532.