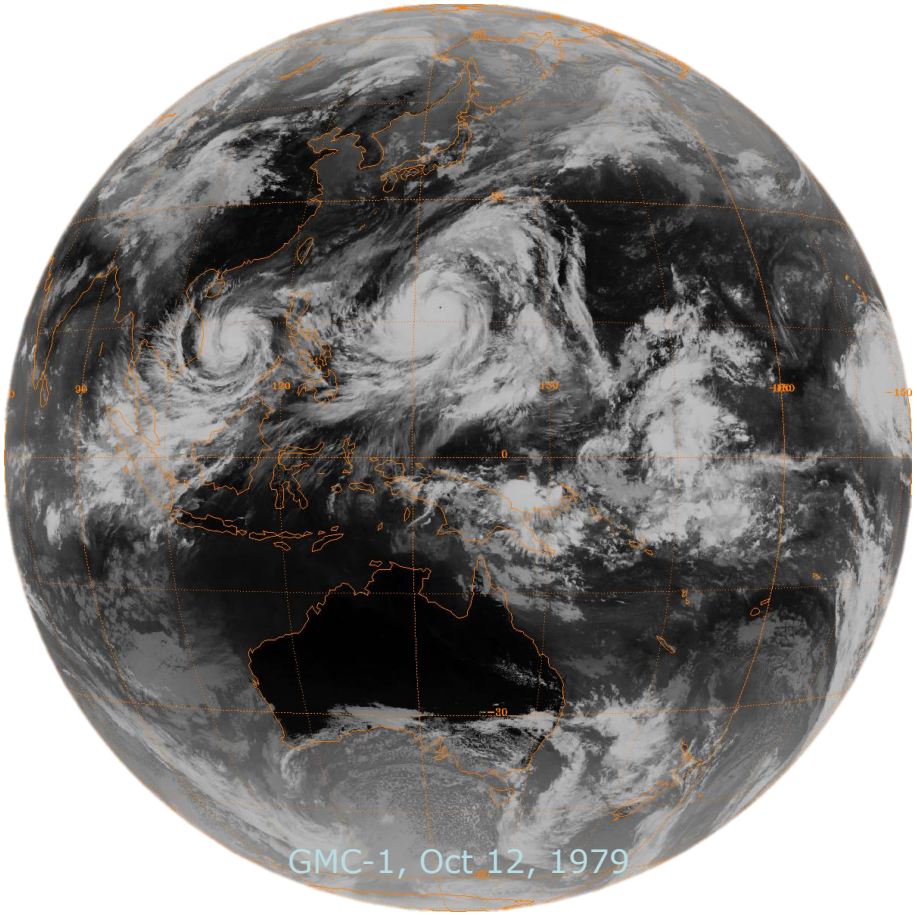
Tracking Tropical and Frontal Storms Driven Extreme Rainfalls over Japan Using Complex Networks



GMC-1, Oct 12, 1979

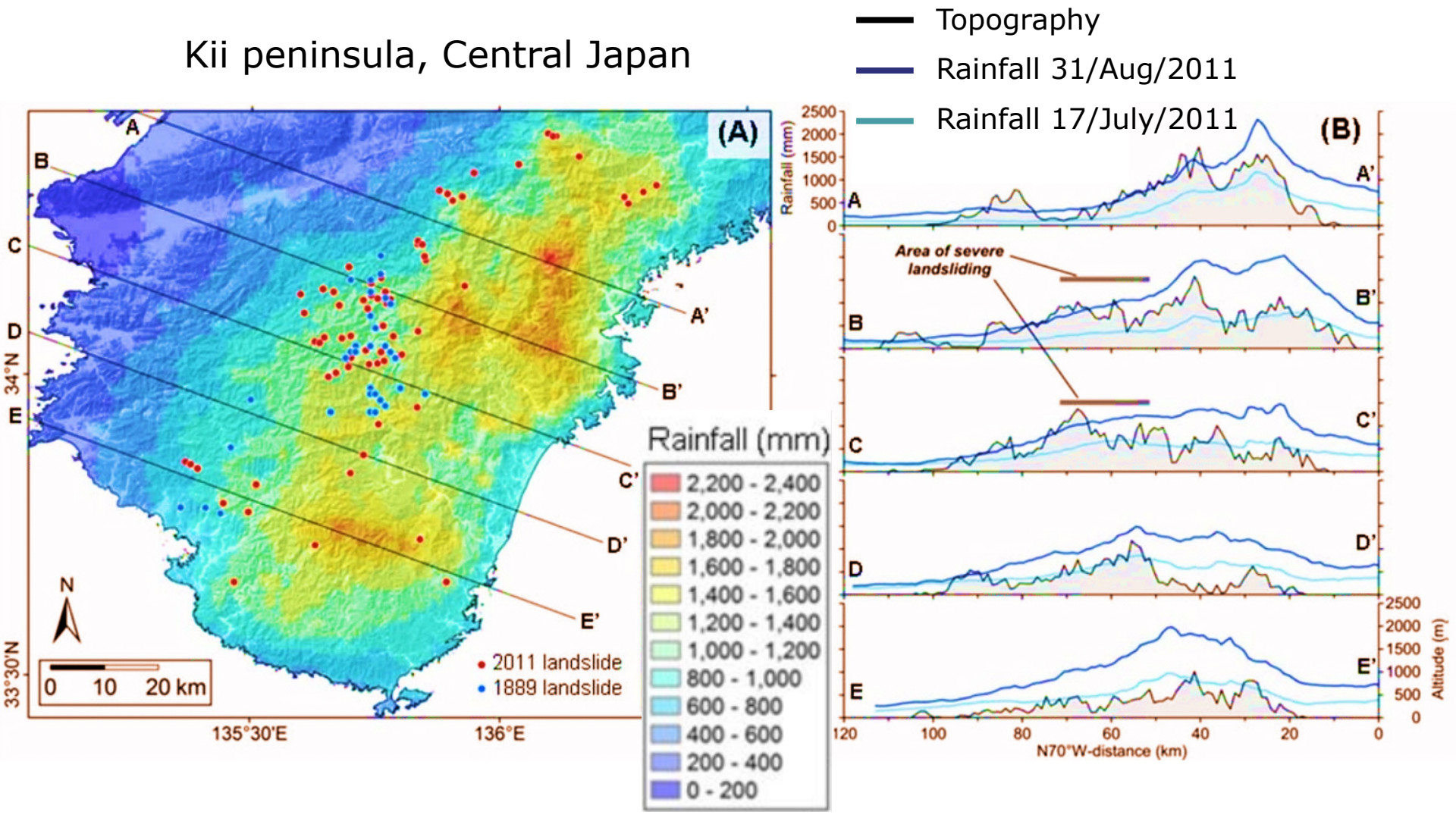
UGUR ÖZTÜRK

Universität Potsdam

PIK Potsdam Institute for Climate Impact Research

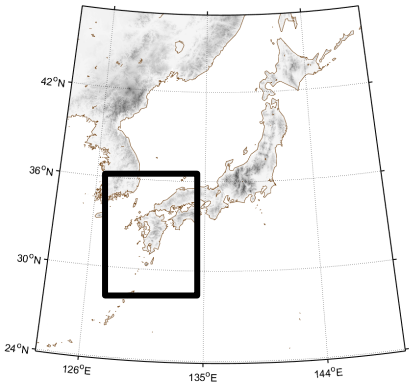
RAINFALL INDUCED LANDSLIDES

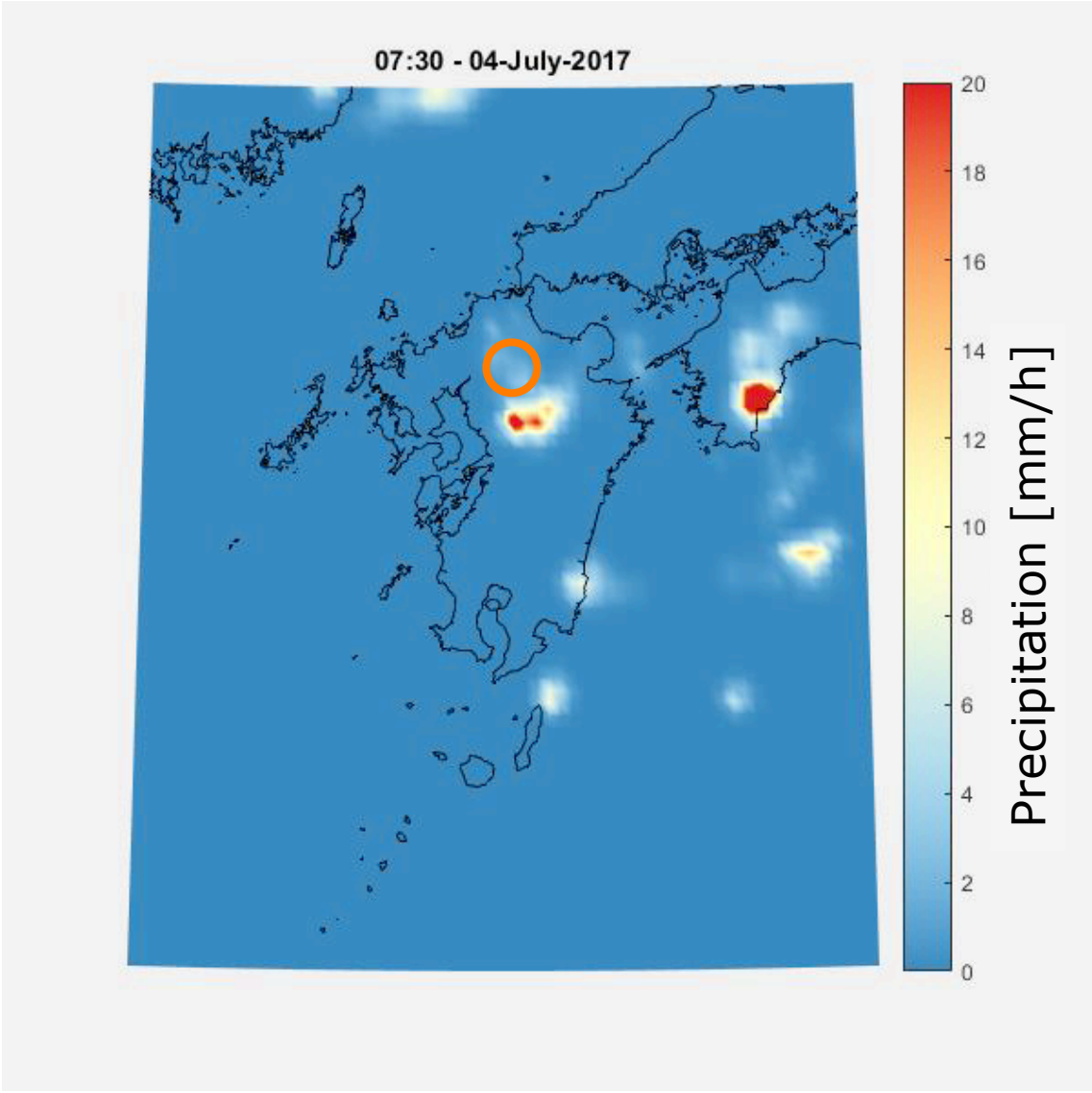
Kii peninsula, Central Japan



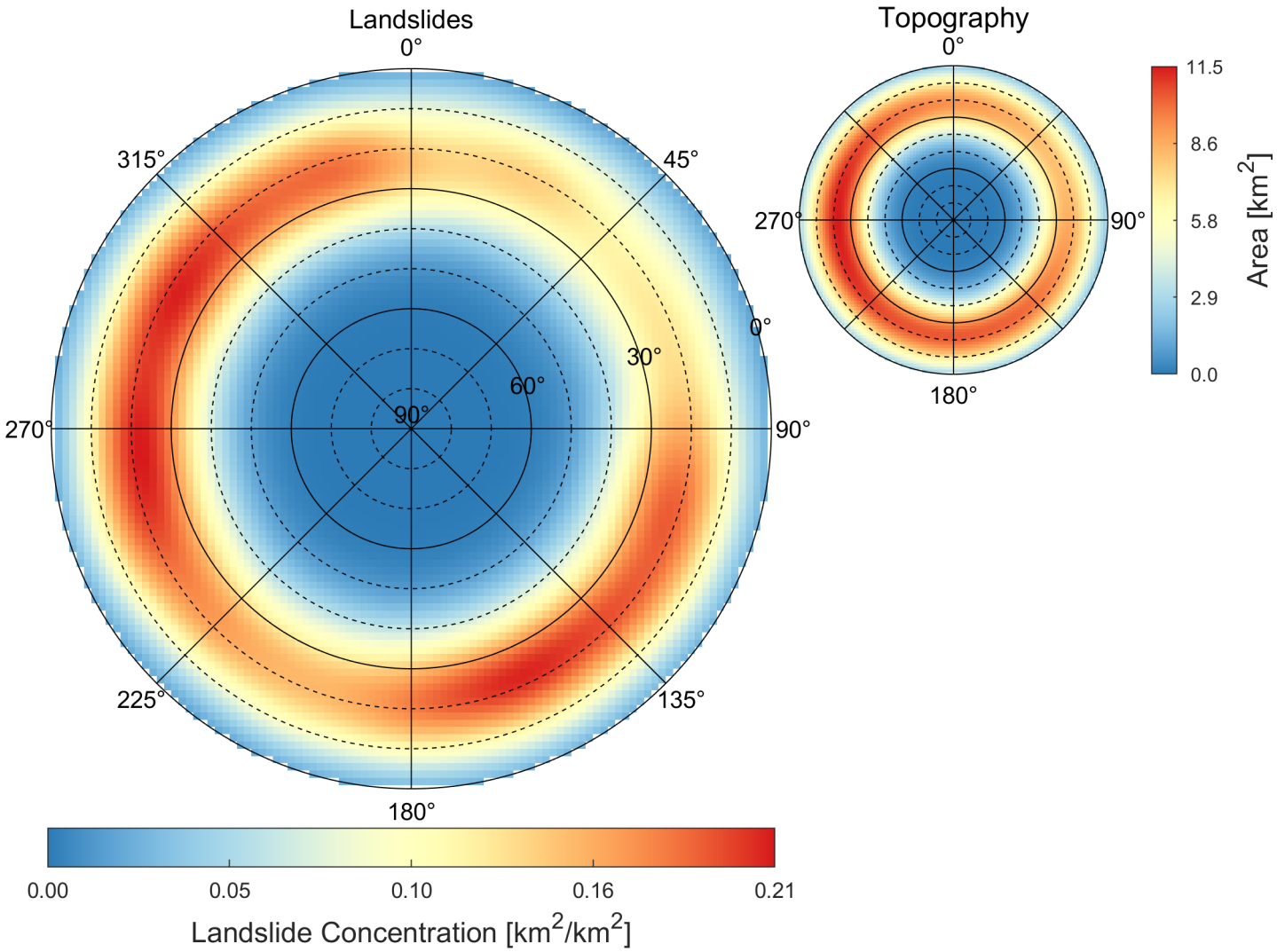
Matsushi et al., 2014

EXTREME RAINFALL (e.g. KYUSHU)





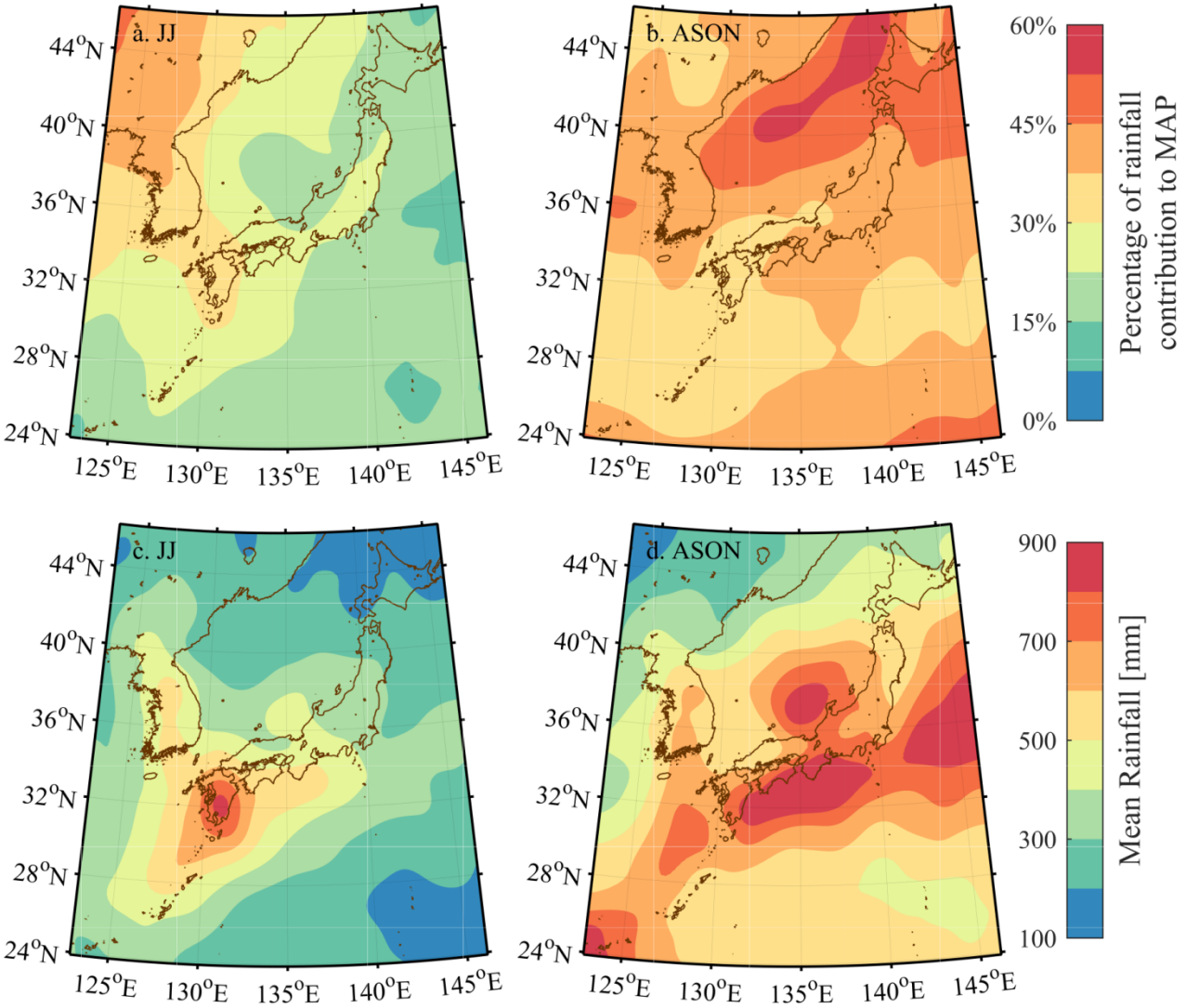
LANDSLIDES AWAY FROM THE STREAMS



DAILY TRMM DATA (1998-2015)

(Baiu Season) June – July

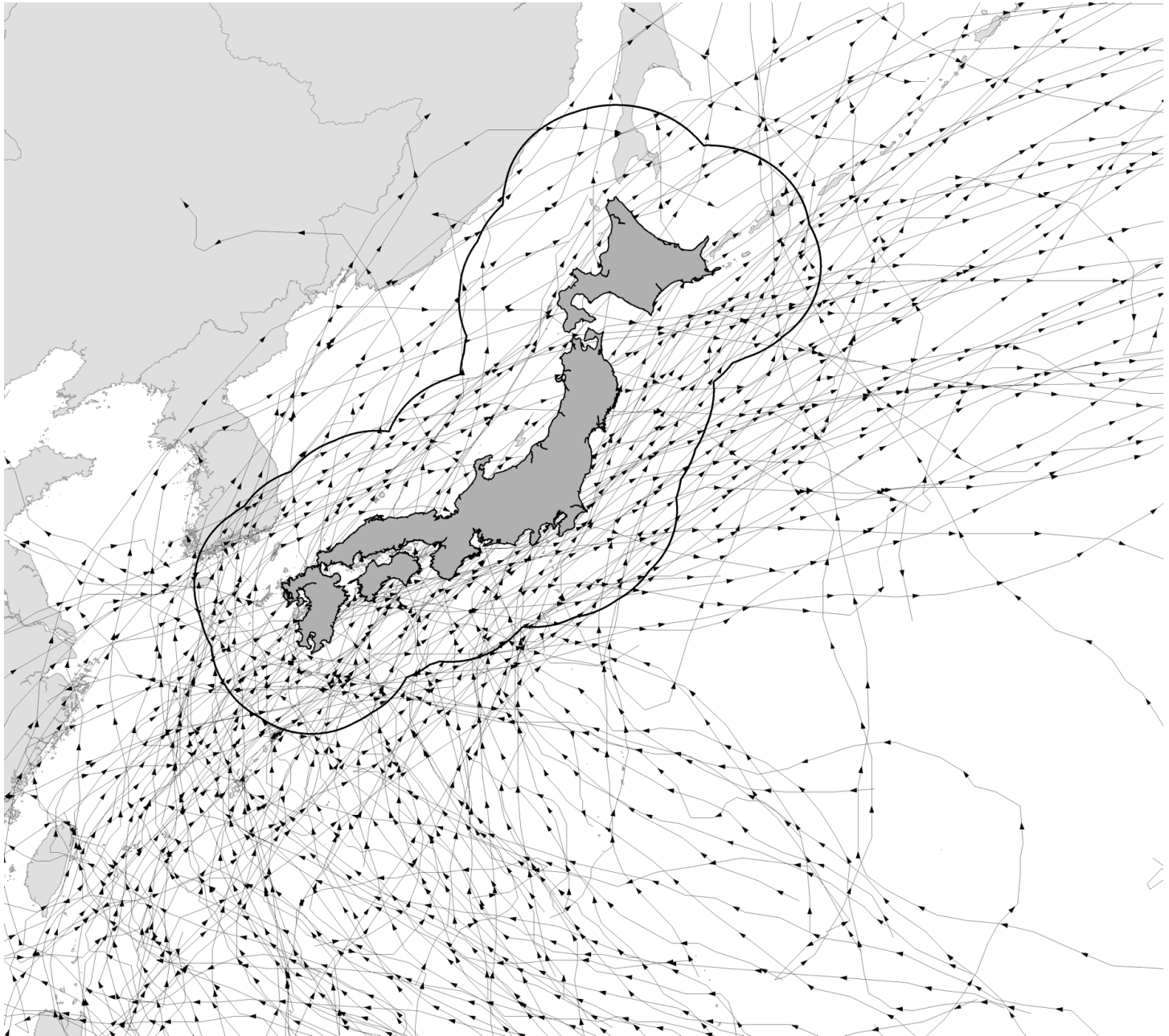
August – November (Typhoon Season)



Based on daily TRMM Data (1998-2015)

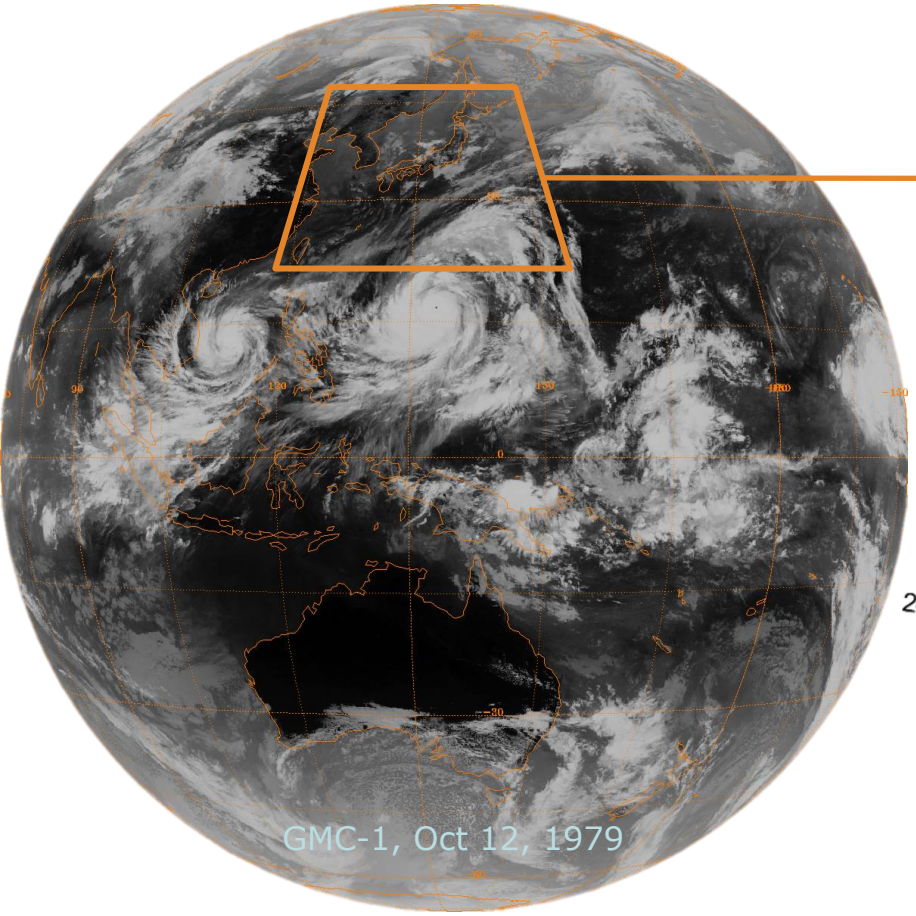
Ozturk et al., 2019, Climate Dynamics

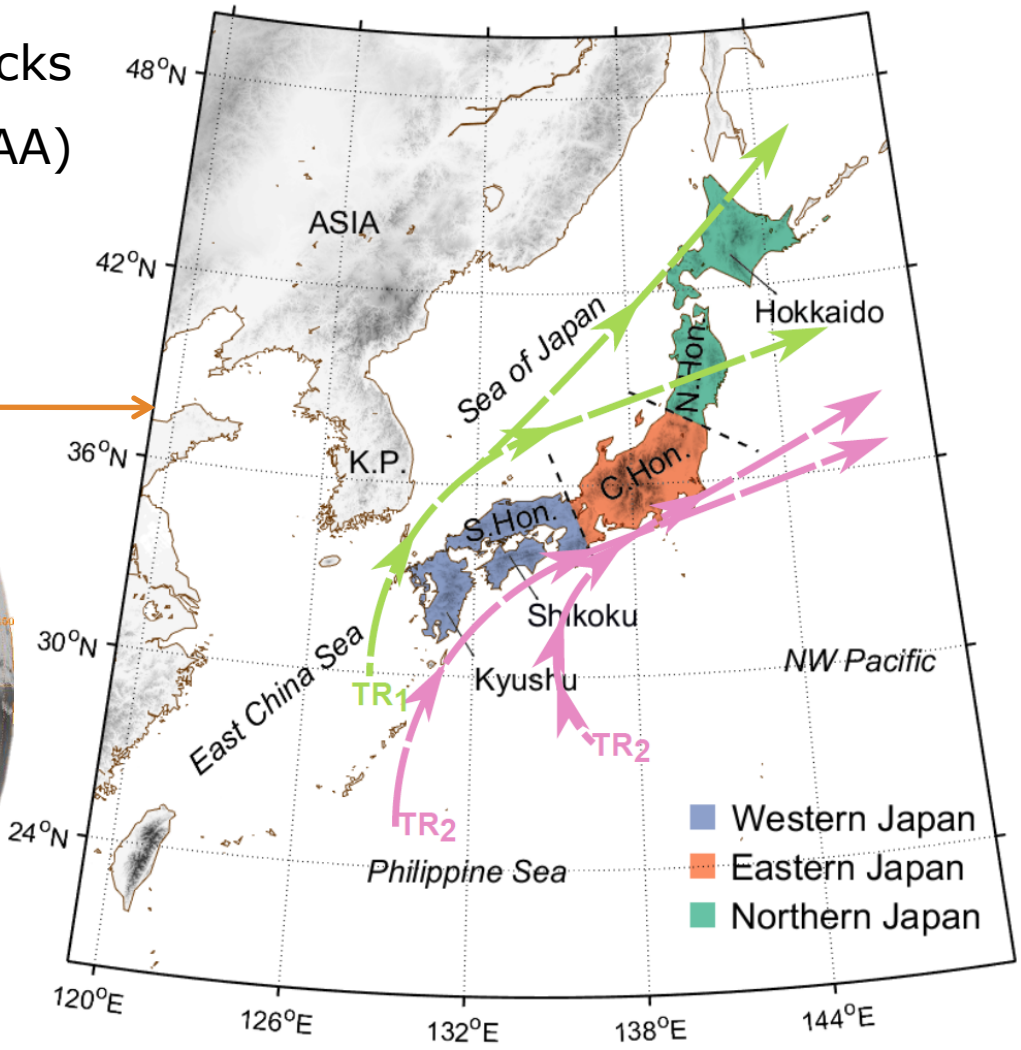
TYPHOON TRACKS



TYPHOON SEASON

Generalized Typhoon Tracks
based on IBTrACS (NOAA)

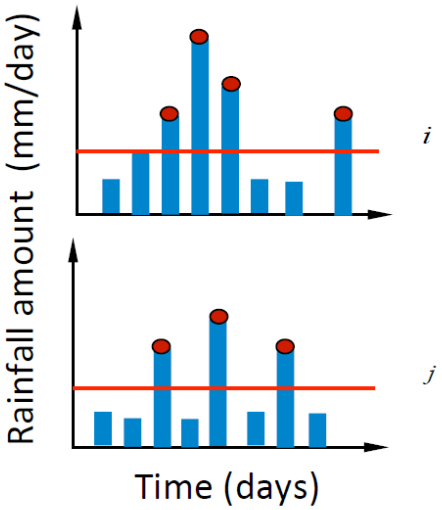




Ozturk et al., 2019, Climate Dynamics

EVENT SYNCHRONIZATION

Picking the Extremes | Compare events | Construct the network

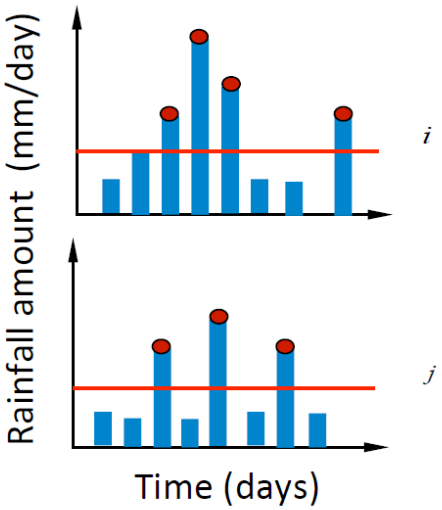


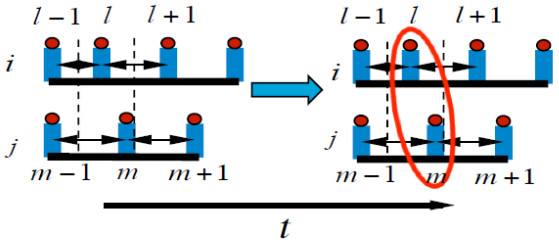
Quian Quiroga, 2002

Malik et al., 2010

EVENT SYNCHRONIZATION

Picking the Extremes | Compare events | Construct the network





$$Q_{ij} = \frac{c(i|j) + c(j|i)}{\sqrt{(s_i - 2) \cdot (s_j - 2)}}$$

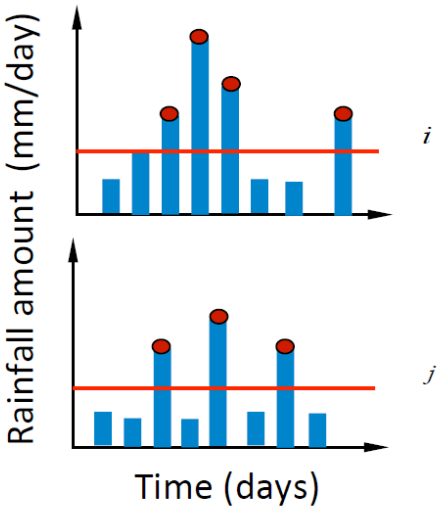
Quian Quiroga, 2002

Malik et al., 2010

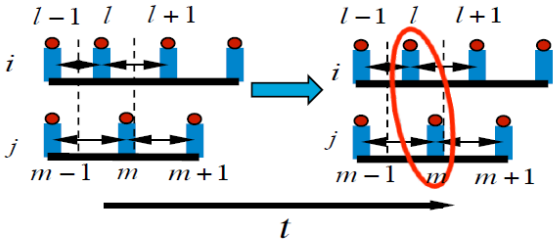
EVENT SYNCHRONIZATION

Network Construction (Stolbova, Pers. Comm., 2015)

Picking the Extremes

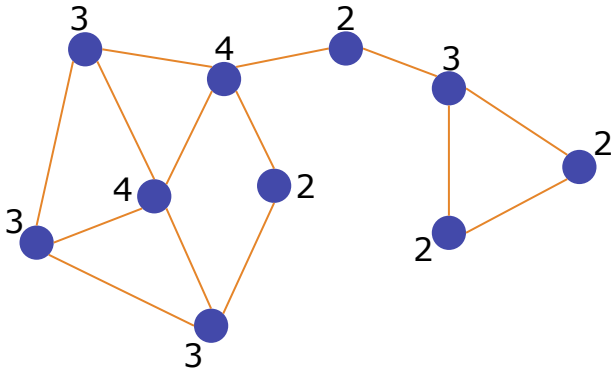


Compare events



$$Q_{ij} = \frac{c(i|j) + c(j|i)}{\sqrt{(s_i - 2) \cdot (s_j - 2)}}$$

Construct the network

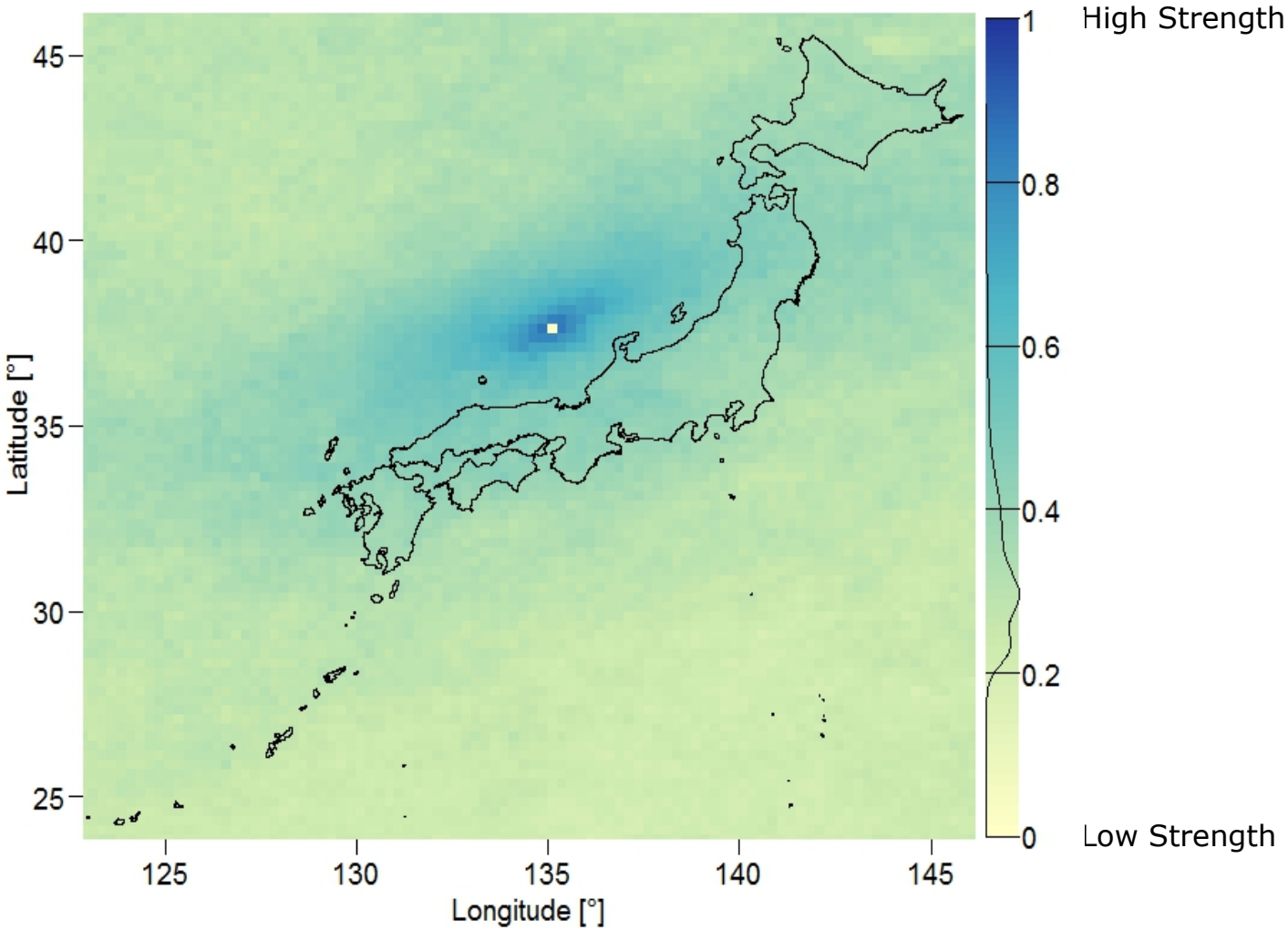


Quian Quiroga, 2002

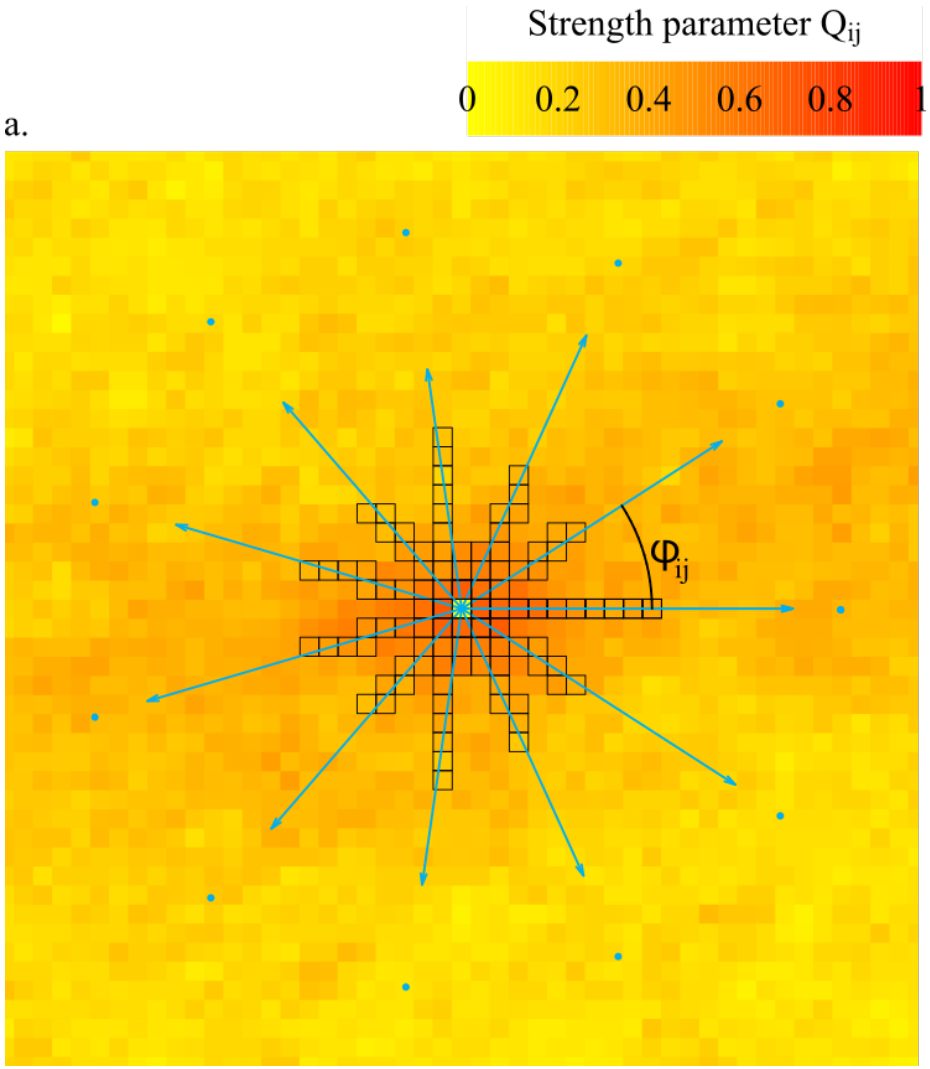
Malik et al., 2010

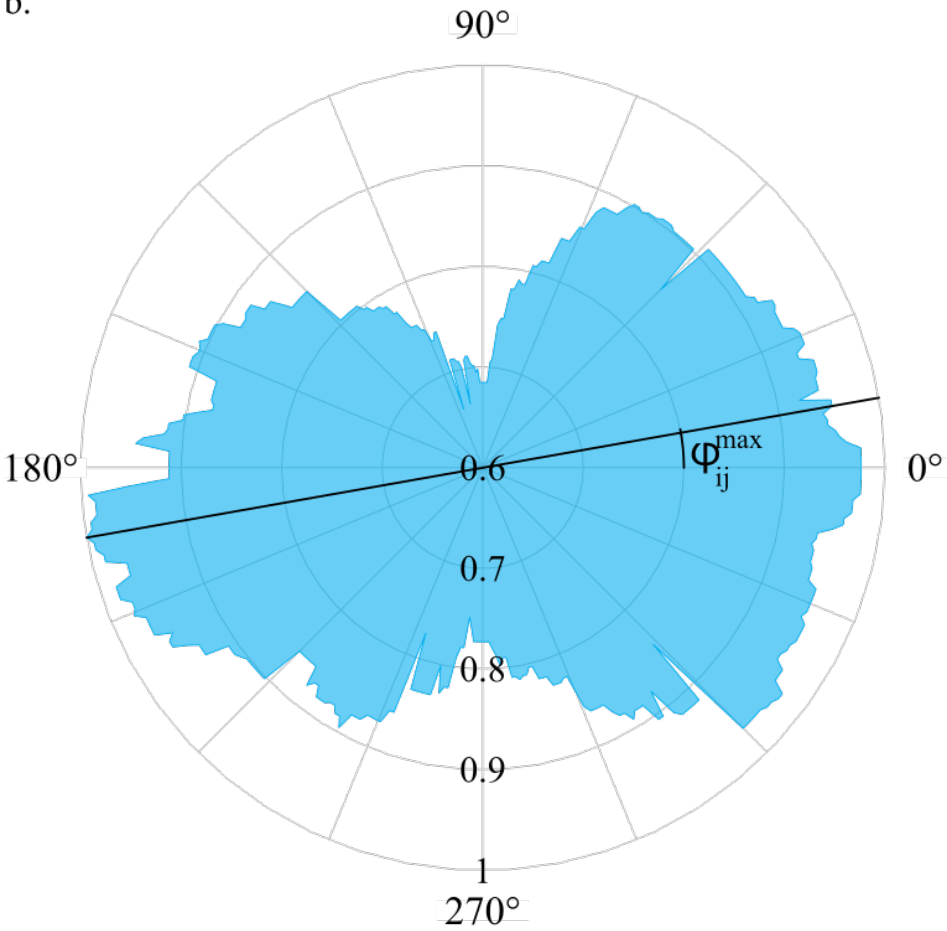
Q MATRIX

Spatial projection of a single row



RADIAL RANKS



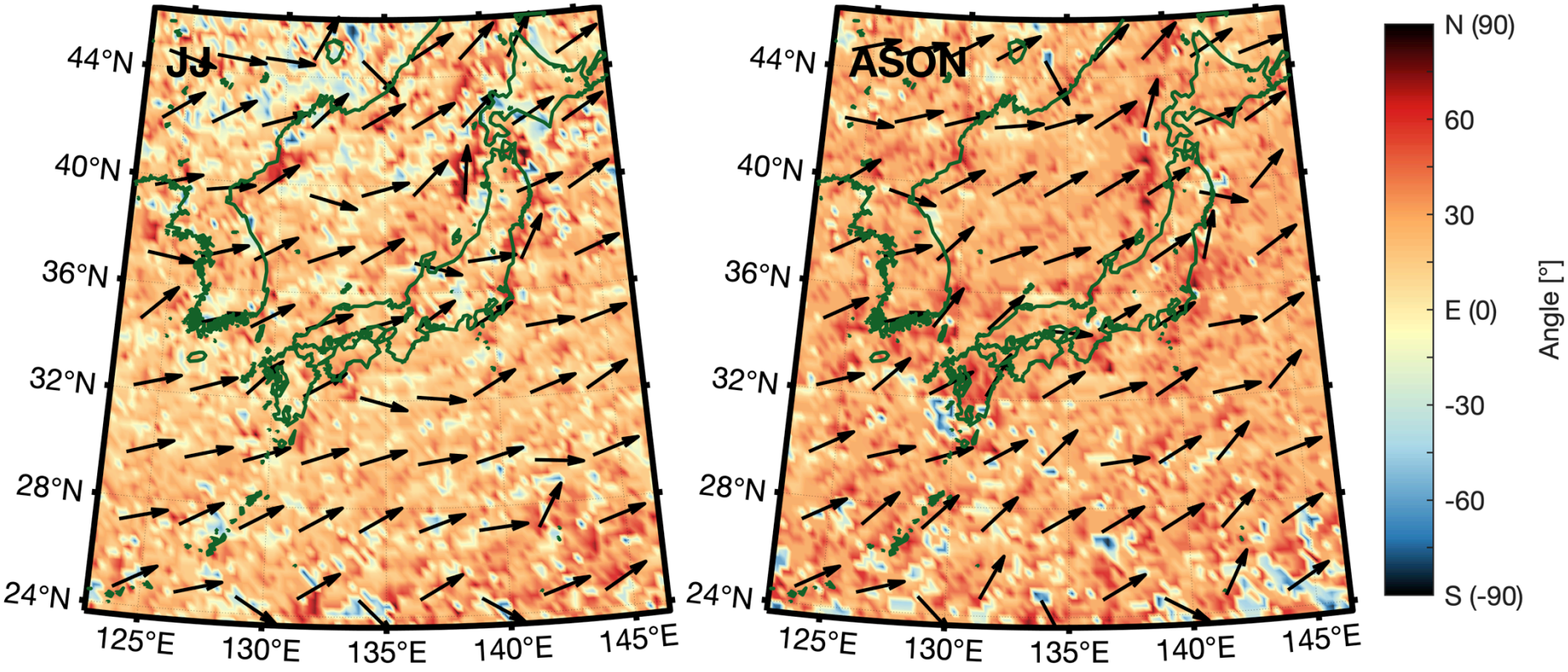


Ozturk et al., 2018a, Chaos

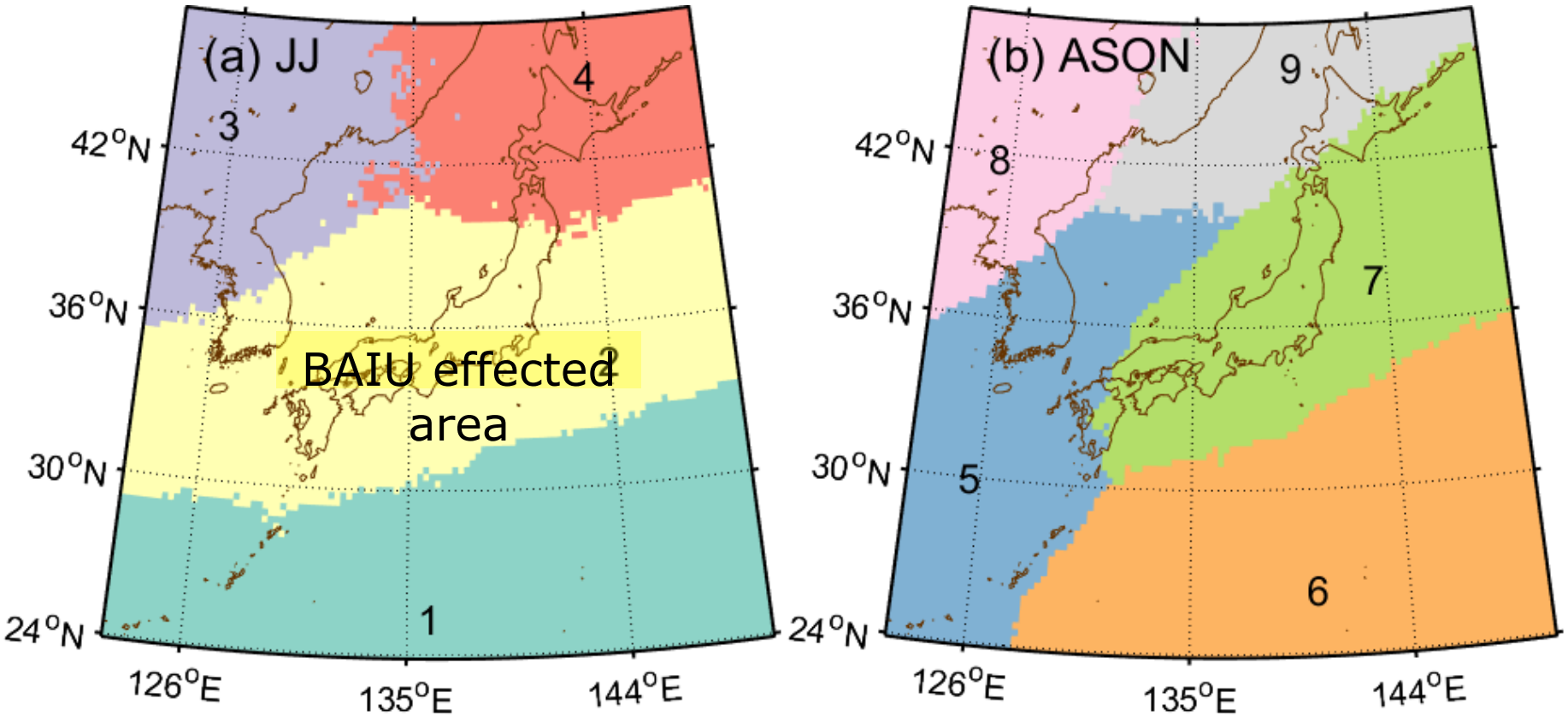
RADIAL RANKS

June-July

August-November

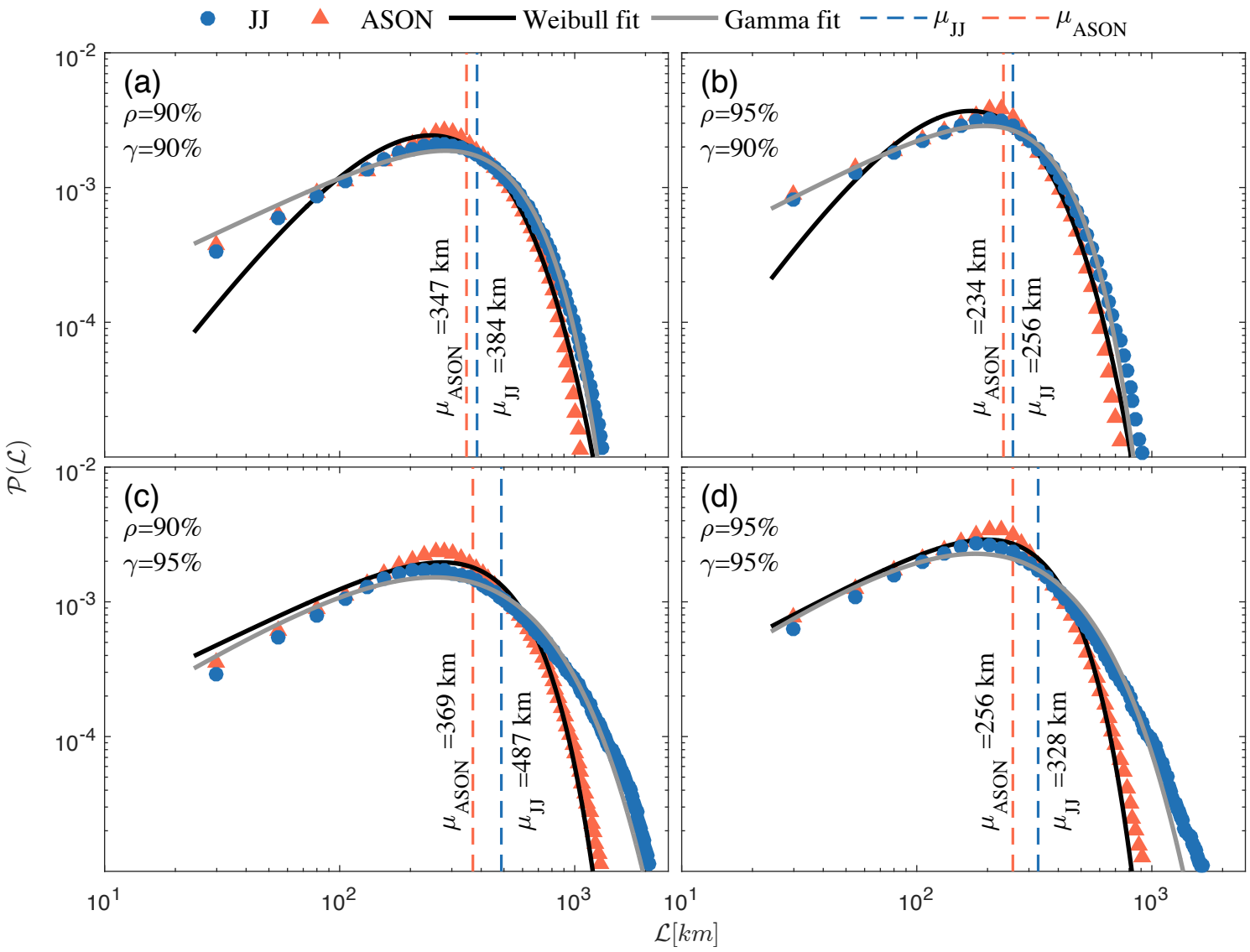


COMMUNITIES

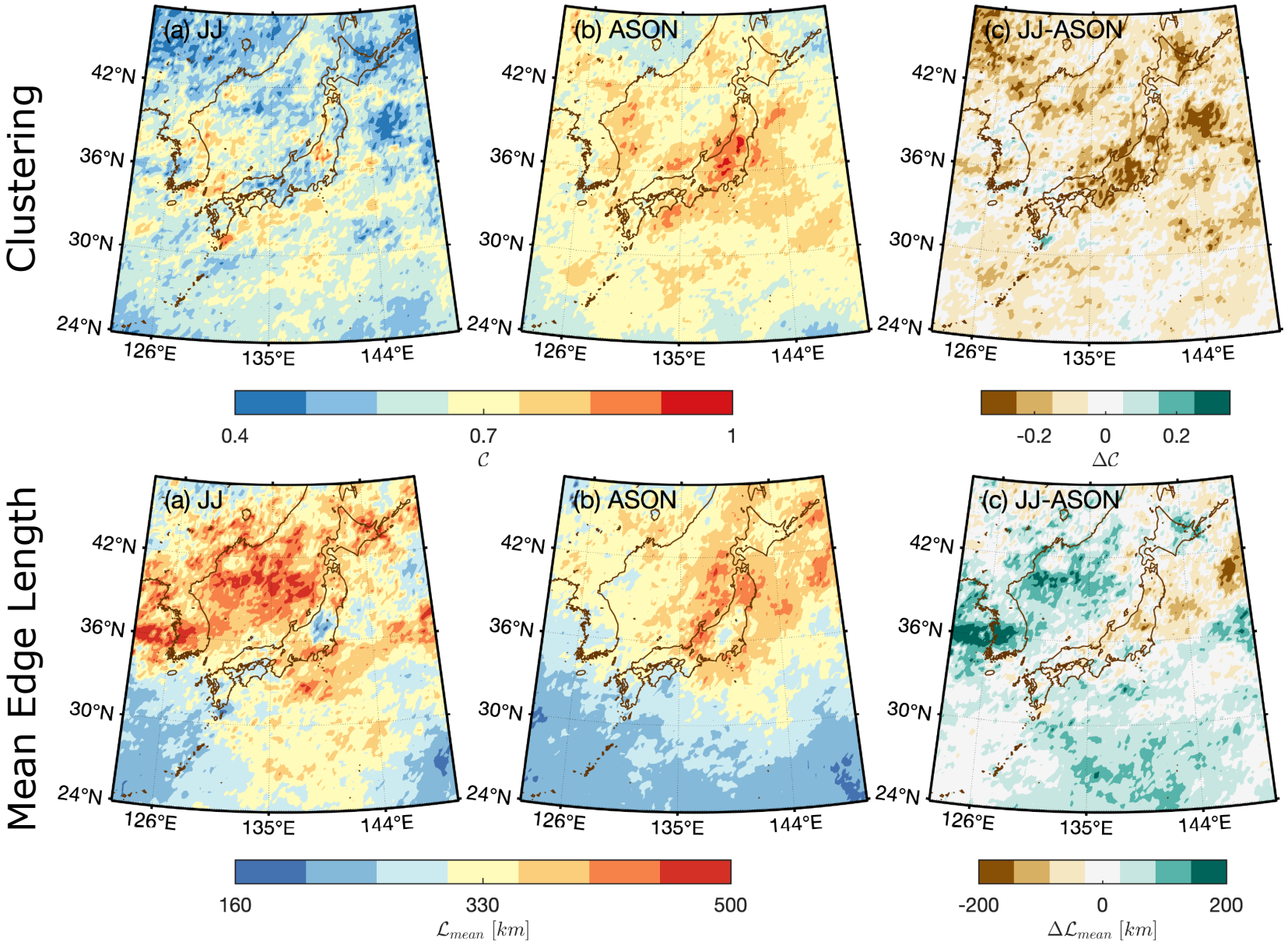


Ozturk et al., 2019, Climate Dynamics

LINK-LENGTH DISTRIBUTION



CENTRALITY


Clustering
(a) JJ
(b) ASON
(c) JJ-ASON
42°N
36°N
30°N
24°N
126°E
135°E
144°E
0.4
0.7
1
$\mathcal{C}$
-0.2
0
0.2
$\Delta\mathcal{C}$
Mean Edge Length
(a) JJ
(b) ASON
(c) JJ-ASON
160
330
500
$\mathcal{L}_{mean}$ $[km]$
-200
0
200
$\Delta\mathcal{L}_{mean}$ $[km]$

CONCLUSIONS

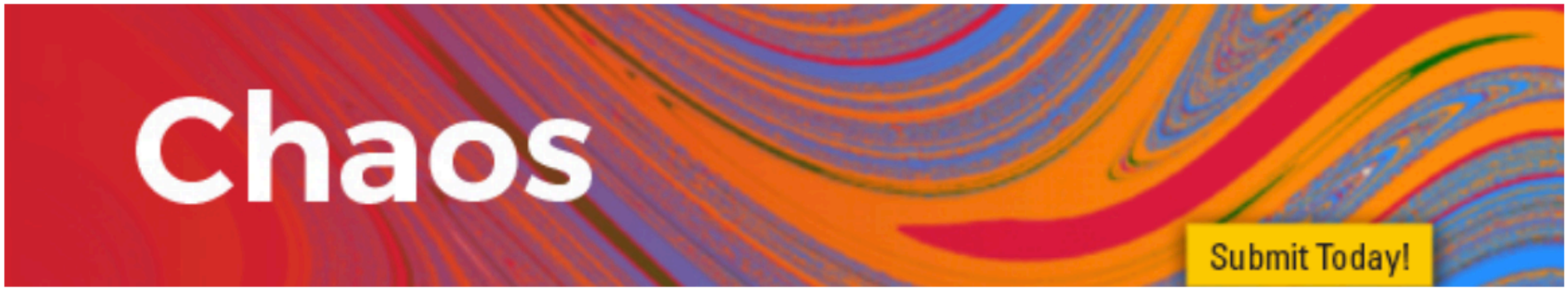
→ Network Theory + Radial Ranks
= Extreme rainfall trajectories

→ Seasonality (Baiu, Typhoon)

→ Landslide early warning

Ozturk, U., Malik, N., Cheung, K., Marwan, N., Kurths, J. (2019) A network-based comparative study of extreme tropical and frontal storm rainfall over Japan, Climate Dynamics.

Ozturk, U., Marwan, N., Korup, O., Saito, H., Agarwal, A., Grossman, M. J., Zaiki, M., Kurths, J. (2018). Complex networks for tracking extreme rainfall during typhoons, Chaos.



Invitation to Submit: Rare Events in Complex Systems: Understanding and Prediction

September 1, 2019	Submissions Opens
November 17, 2019	Submission deadline
January 12, 2019	Decision deadline
May 10, 2020	Issue Publishes

Ugur Öztürk | oeztuerk@gfz-potsdam.de
https://www.researchgate.net/profile/Ugur_Ozturk

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Matsushi, Y., Chigira, M., and Kosugi, K. (2014). Orographic rainfall, deep-seated catastrophic landslides, and landscape evolution: Geomorphic hazard assessment in active orogens. Technical report, INTERPRAEVENT.

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Ozturk, U., Wendi, D., Crisologo, I., Riemer, A., Agarwal, A., Vogel, K., López-Tarazón, J. A., Korup, O. (2018b). Rare flash floods and debris flows in southern Germany, Science of the Total Environment.

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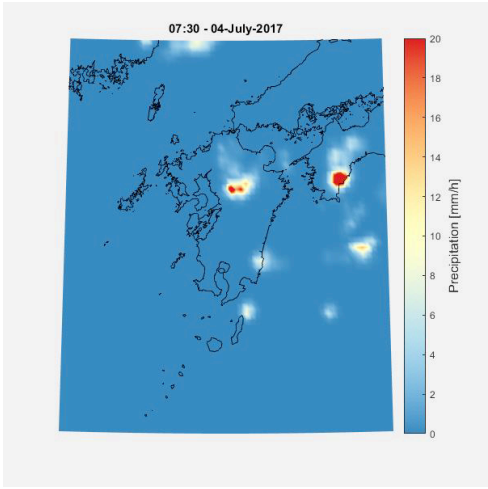
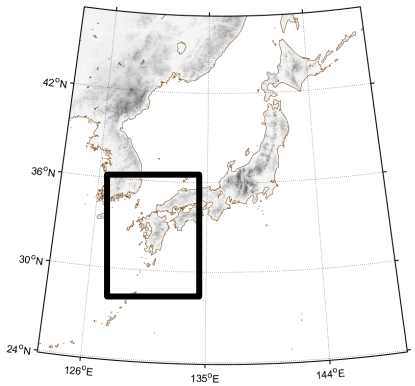
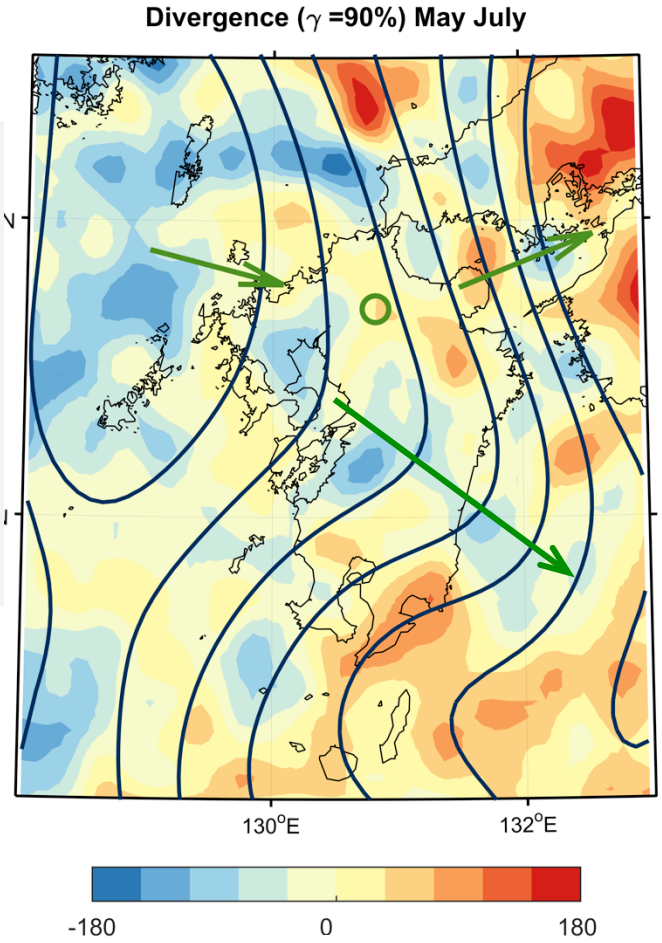
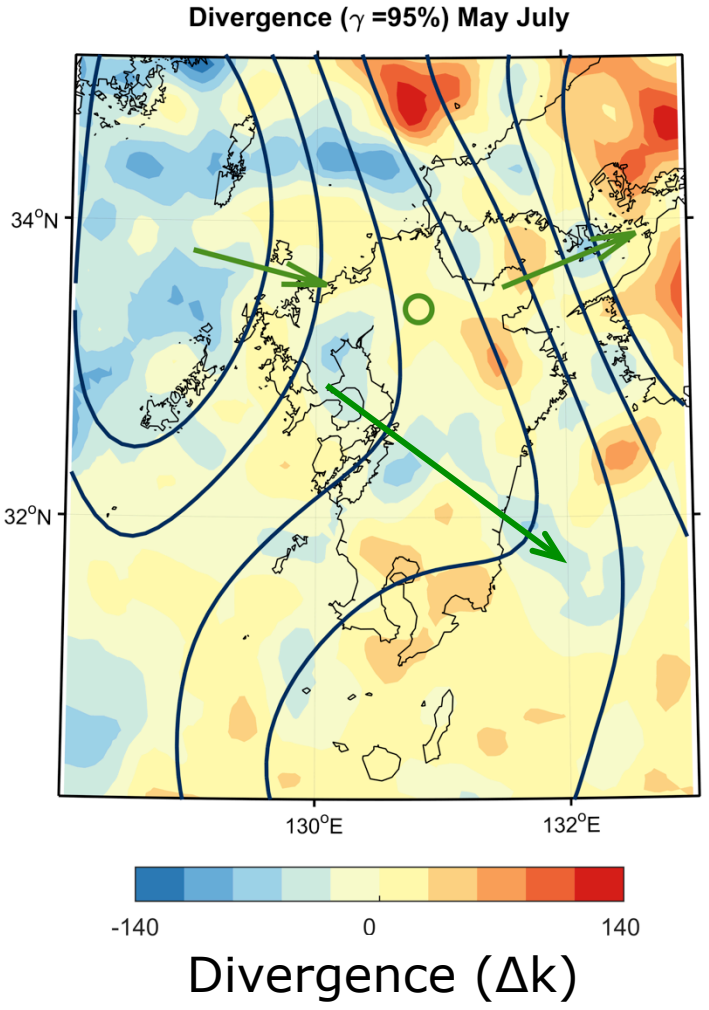
NETWORK DIVERGENCE



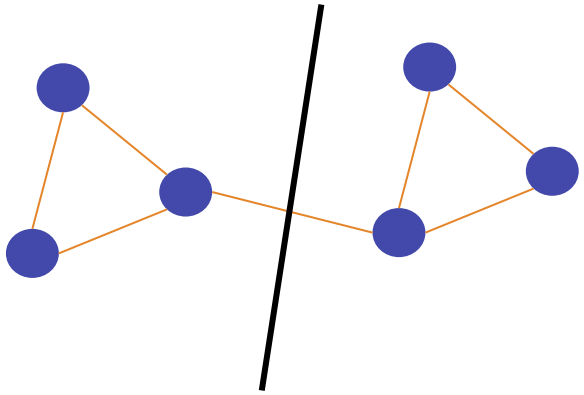






$$\Delta k_i = k_i^{in} - k_i^{out} \qquad k_i = \sum_{j=1}^{n} A_{ij}$$

MODULARITY



$$M \rightarrow \sum_{C=1}^{N_C} \left[\frac{l_s}{L} - \left(\frac{d_s}{2L} \right)^2 \right]$$

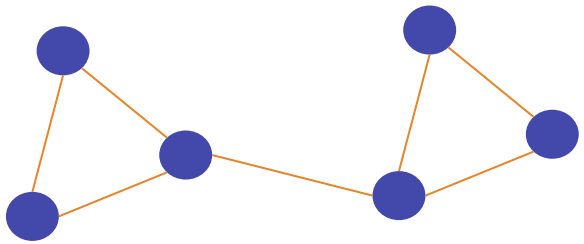
$l_s \rightarrow$ observed links in a selected community

$L \rightarrow$ total number of links in the network

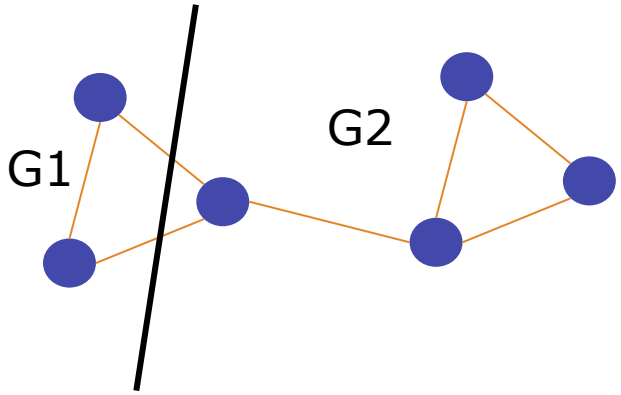
$N_C \rightarrow$ total number of communities

$d_s \rightarrow$ observed degree in the selected community

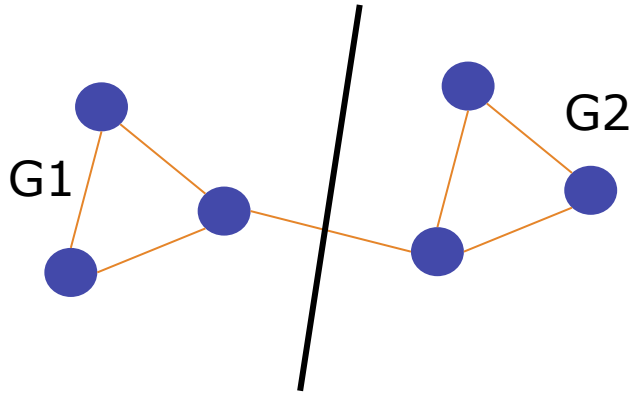
MODULARITY



$$M \rightarrow \sum_{C=1}^{N_C} \left[\frac{l_s}{L} - \left(\frac{d_s}{2L} \right)^2 \right]$$



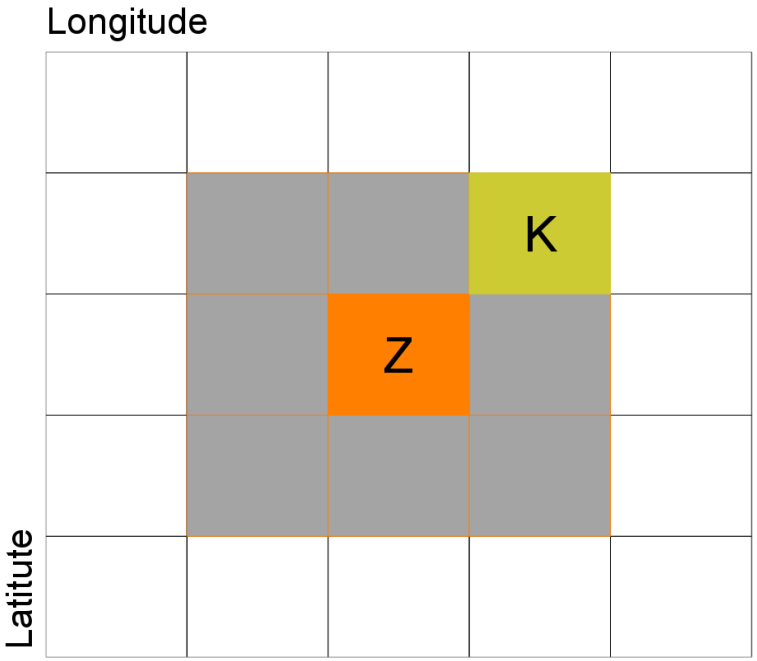
$$M = \overbrace{\left[\frac{1}{7} - \left(\frac{4}{2 \cdot 7} \right)^2 \right]}^{C=1} + \overbrace{\left[\frac{4}{7} - \left(\frac{10}{2 \cdot 7} \right)^2 \right]}^{C=2} = 0.06 + 0.06 = 0.12$$

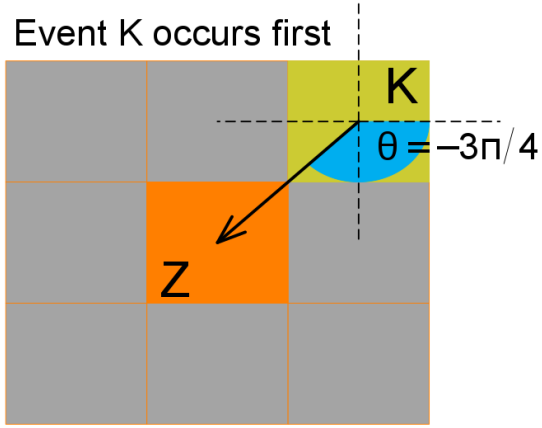


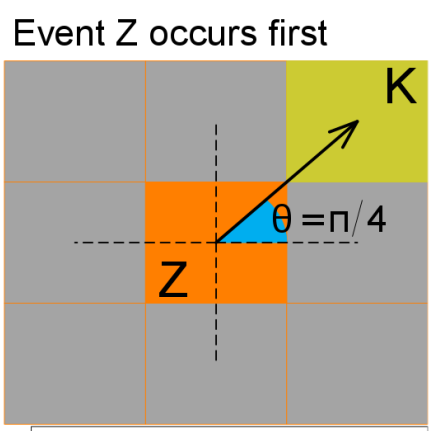
$$M = \overbrace{\left[\frac{3}{7} - \left(\frac{7}{2 \cdot 7} \right)^2 \right]}^{C=1} + \overbrace{\left[\frac{3}{7} - \left(\frac{7}{2 \cdot 7} \right)^2 \right]}^{C=2} = 0.18 + 0.18 = 0.36$$

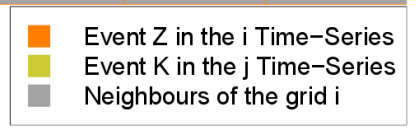
„q“ Matrix

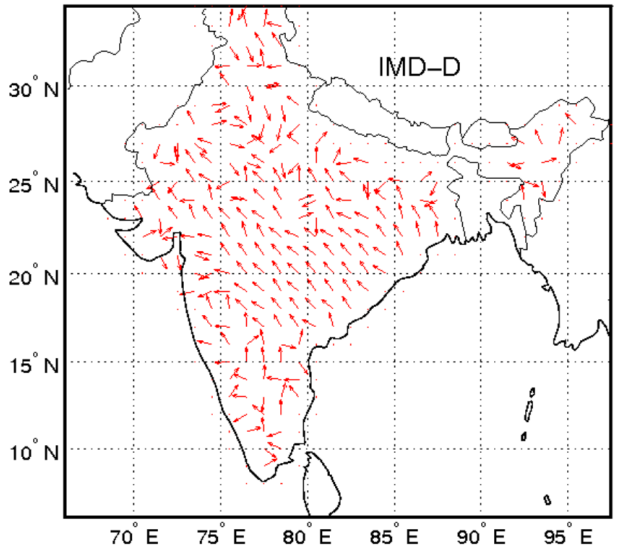
Directions Based on „q“ MATRIX (Malik et al., 2010)











PEARSON – LINEAR CORRELATION

$$\rho_{X,Y} = \frac{cov(X,Y)}{\sigma_X \cdot \sigma_Y}$$

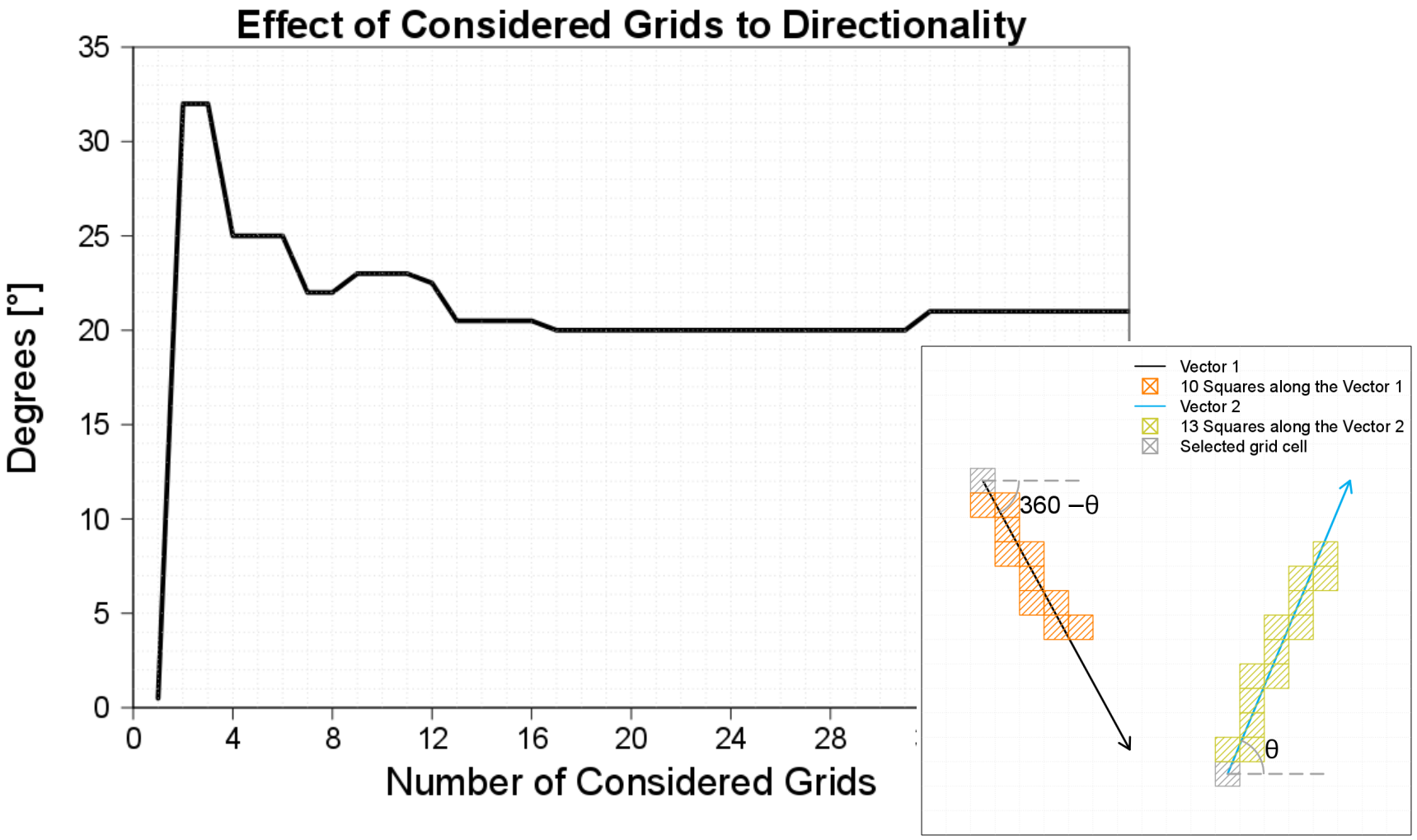
applied to a **population**

$$r_{xy} = \frac{\sum[(x_i - \bar{x}) \cdot (y_i - \bar{y})]}{\sqrt{\sum(x_i - \bar{x})^2 \cdot \sum(y_i - \bar{y})^2}}$$

applied to a **sample**

RADIAL RANKING OF „Q“ MATRIX

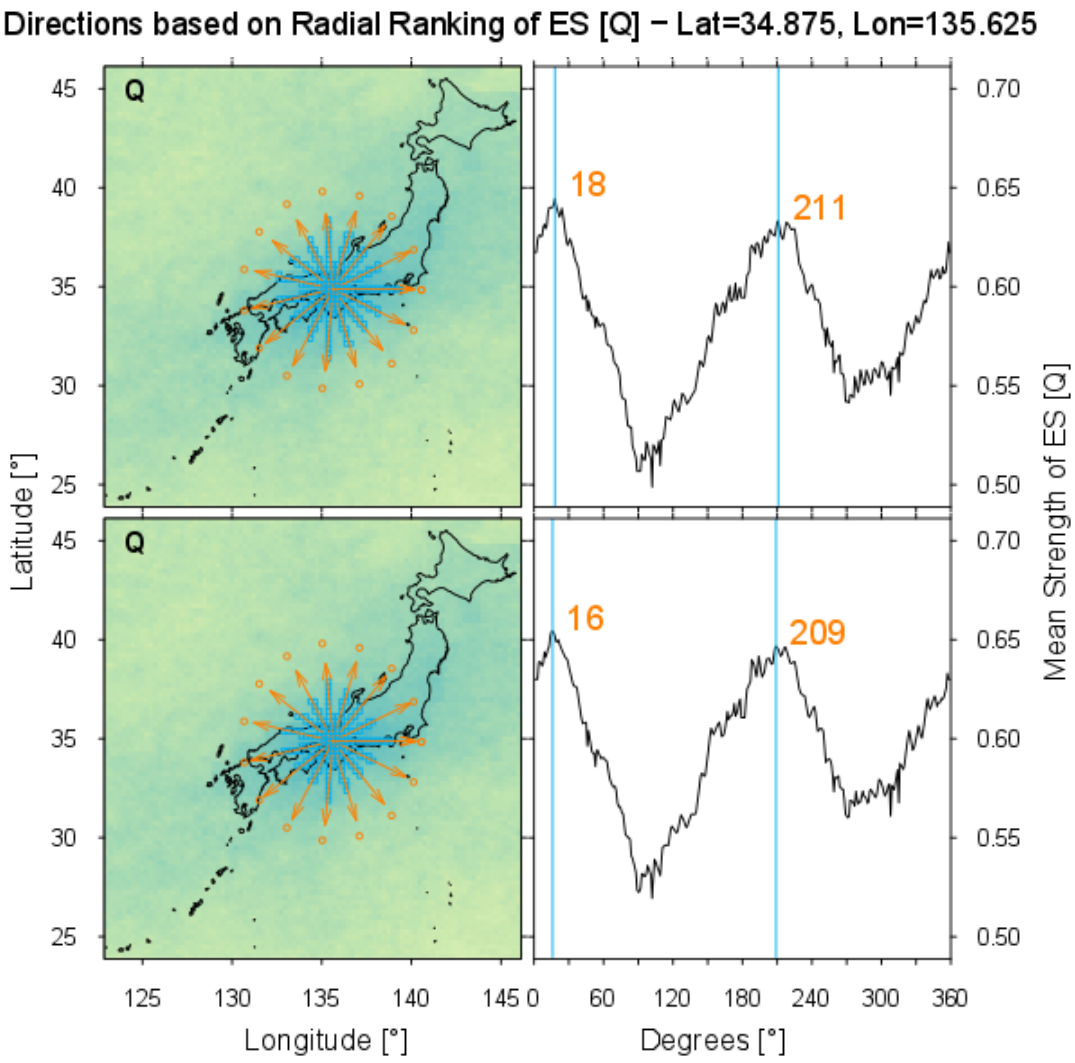
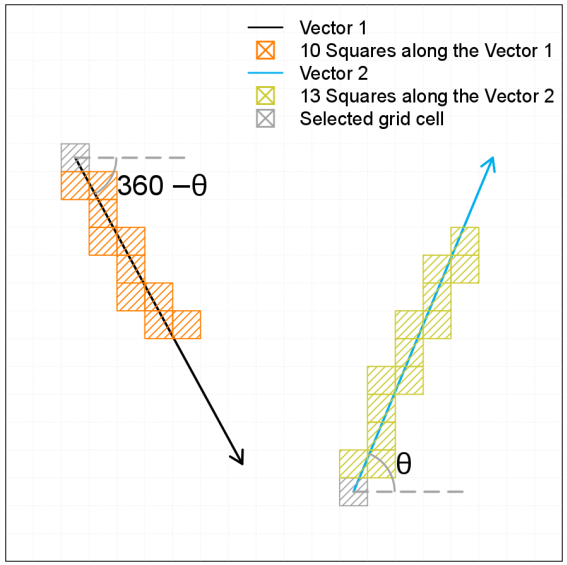
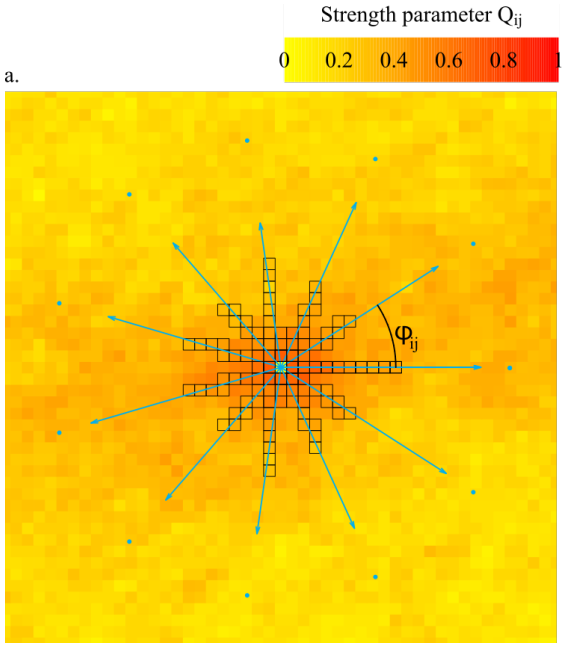
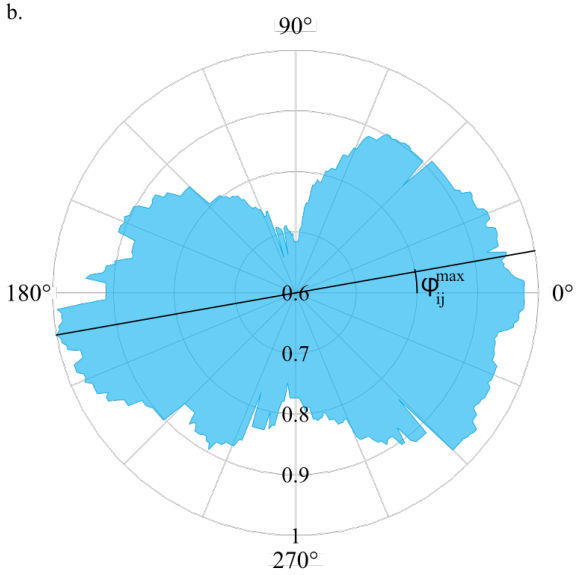
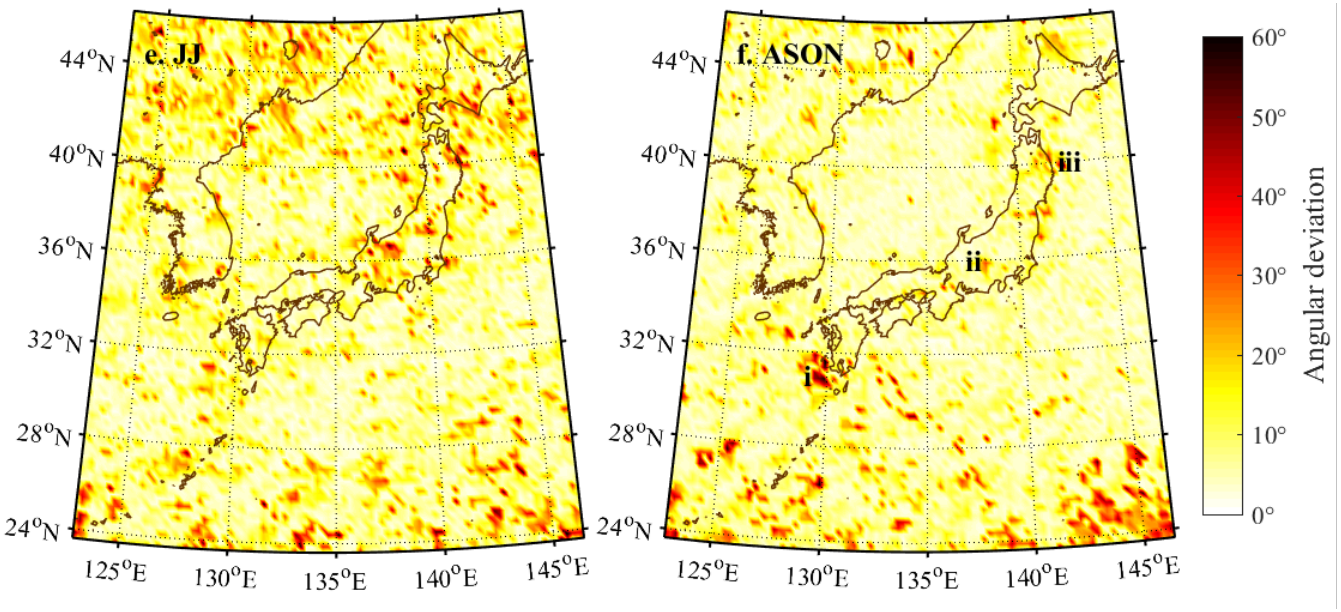
Radial Ranking of „Q“ Matrix



RADIAL RANKING OF „Q“ MATRIX

13 Cells

15 Cells



DEVIATION OF RADIAL RANKS