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Disentangling synchrony from serial dependency in complex climate networks: Comparing Event Synchronization and Event Coincidence Analysis

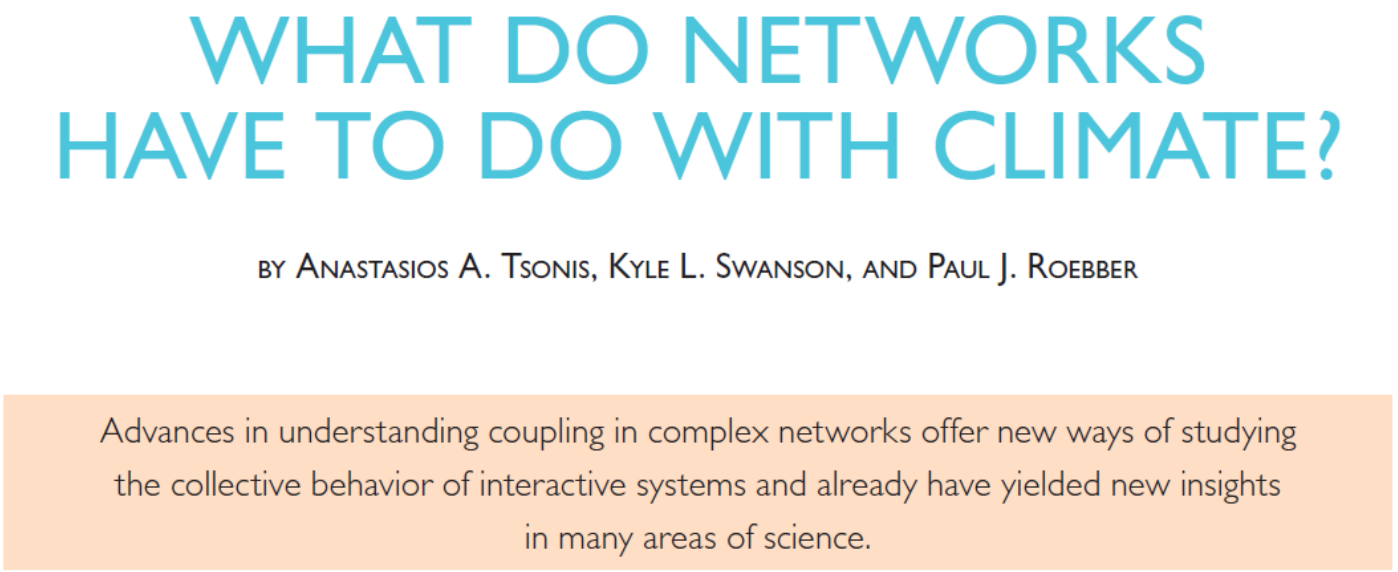
Adrian Odenweller, Reik V. Donner

EGU 2020 SGO – Session NP4.1 – Display 2848

Complex networks in the geosciences

1990s: graph theory meets statistical mechanics - complex network theory

Early 2000s: first applications to diverse geoscientific problems like climate variability (Tsonis & Roebber 2004), earthquakes (Abe & Suzuki 2004), etc.



WHAT DO NETWORKS HAVE TO DO WITH CLIMATE?

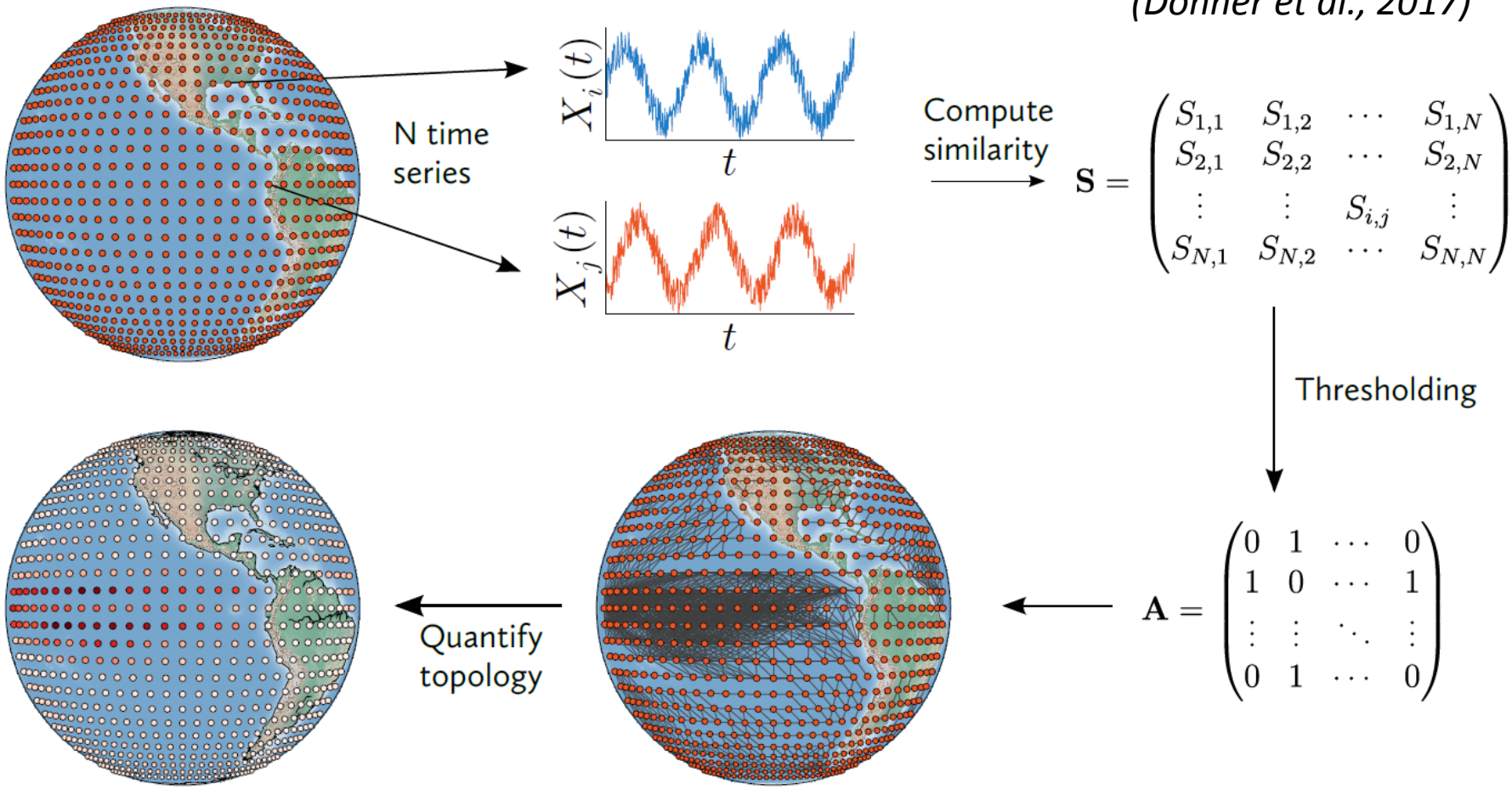
BY ANASTASIOS A. TSONIS, KYLE L. SWANSON, AND PAUL J. ROEBBER

Advances in understanding coupling in complex networks offer new ways of studying the collective behavior of interactive systems and already have yielded new insights in many areas of science.

(Bull. Amer. Meteor. Soc., 2006)

Functional climate networks: General workflow

(Donner et al., 2017)



Functional climate networks

- **Difference to other common network analysis subjects: links represent statistical associations between "units" (neuroscience: "functional connectivity" of brain regions)**

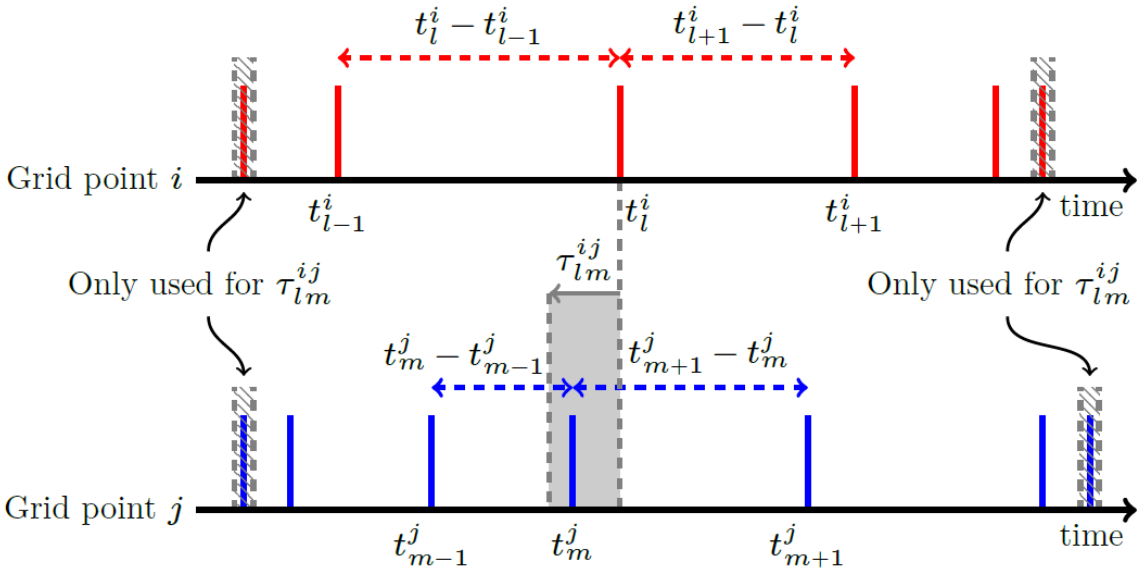
- **Correlations as similarity measure: relationship with EOF analysis (Donges et al. 2015), but potentially more informative (spatial placement of strong interrelationships remains transparent)**

- **Relevant achievements:**
  - **prediction of El Nino events (Ludescher et al. PNAS 2013, 2014)**
  - **advanced ENSO diagnostics and classification (Wiedermann et al. GRL 2017)**
  - **spatio-temporal organization of heavy rainfall (Boers et al. – several GRL/NatComm/… papers since 2013)**

- **Transfer to other geophysical problems like earthquakes, geomagnetism (Dods et al. 2015),…**

Applications to natural hazards

- **Data represent point processes in time (and space) – need dedicated similarity measures for network construction**
- **Neurophysiology: event synchronization (Quiroga et al. 2002)**

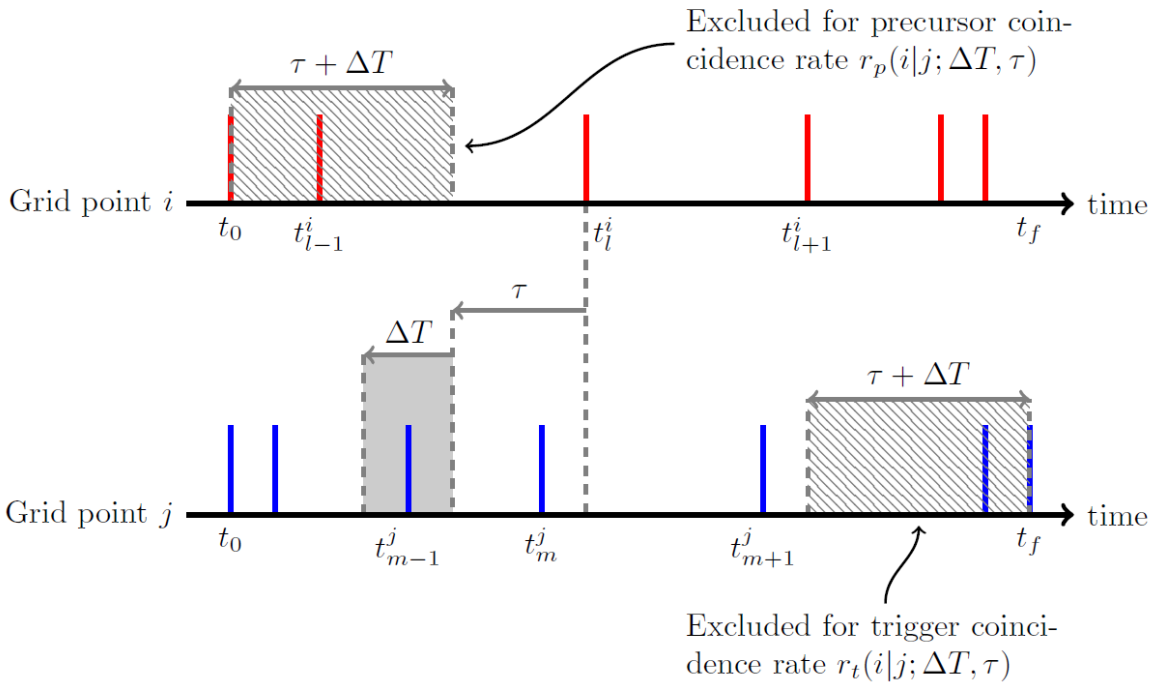


(Odenweller and Donner, in press)

- **Uses dynamical (local) coincidence interval for counting co-occurrences – restrictive definition for "slow" event propagation, no analytics**

Alternative: Event coincidence analysis

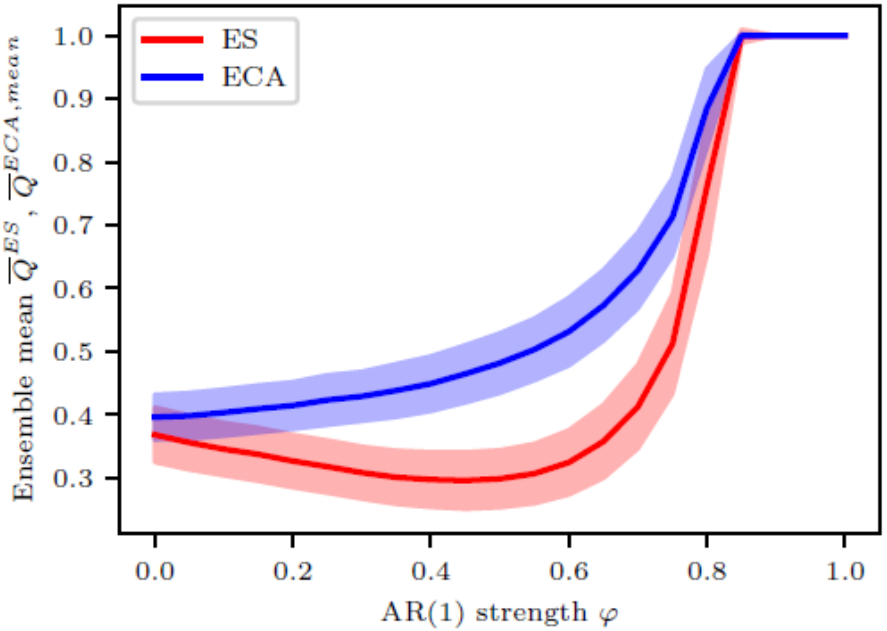
- **Static/global coincidence interval: analytical theory for rare and uncorrelated events**



(Odenweller and Donner, in press)

Alternative: Event coincidence analysis

Numerical results for coupled AR(1) processes: ES strength is not a proper coupling measure, whereas ECA event coincidence rate performs as expected

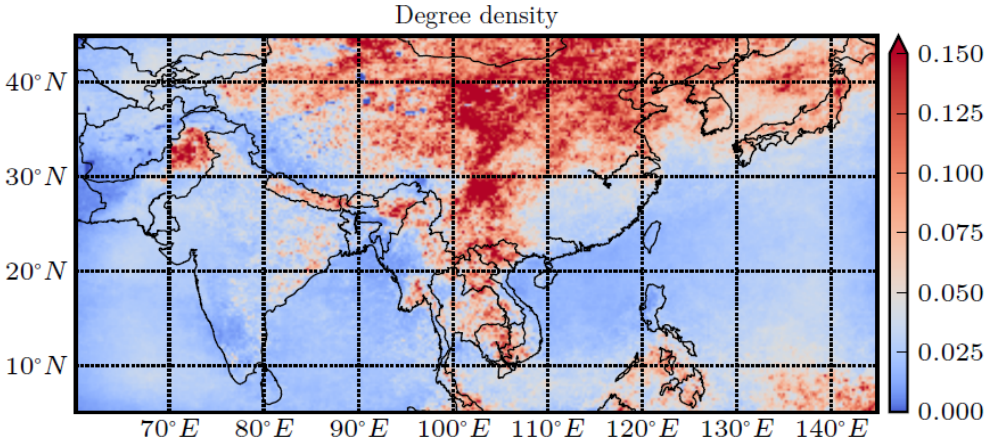


(Odenweller and Donner, in press)

Reason: underestimation of coupling strength in case of temporally clustered events

Agrees with results for stochastic propagation models on networks (Hassanibesheli & Donner, Chaos, 2019) and real-world precipitation data (Wolf et al., Chaos, 2020)

ES vs. ECA-based climate networks

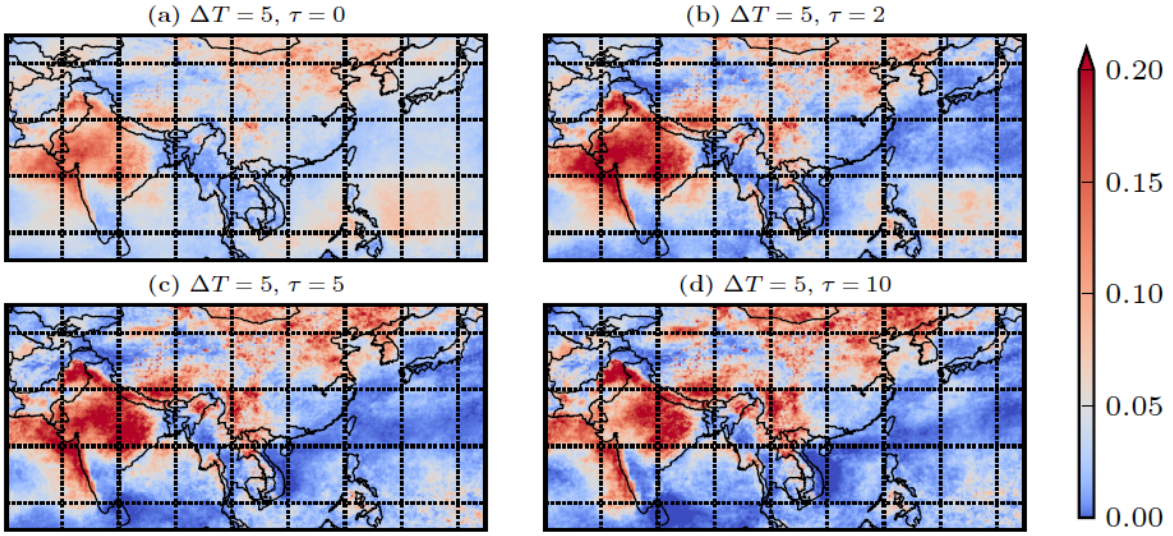


Example: Daily precipitation extremes in the Asian monsoon domain

(Odenweller and Donner, in press)

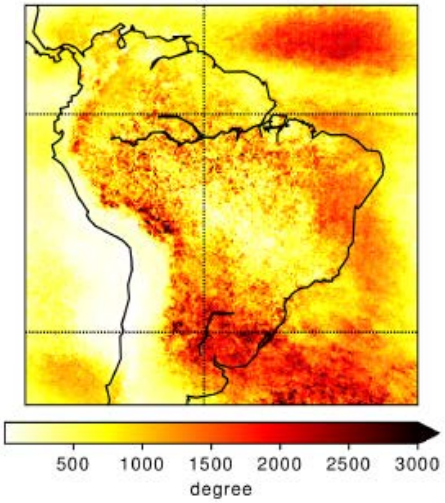
ES: underestimation of connectivity at sites with strong event clustering

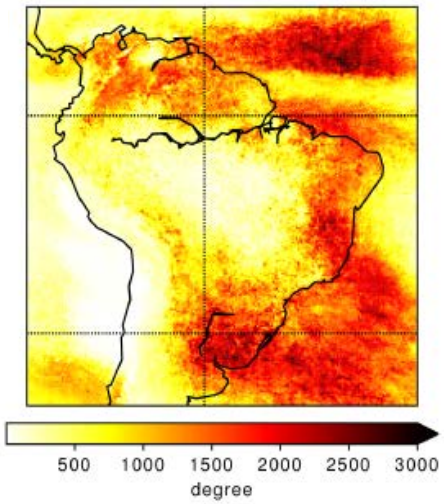
ECA allows resolving different time scales by selecting definition of co-occurrence window



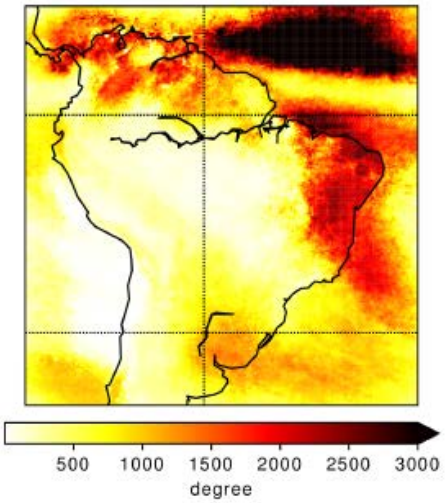
Event declustering: better consistency

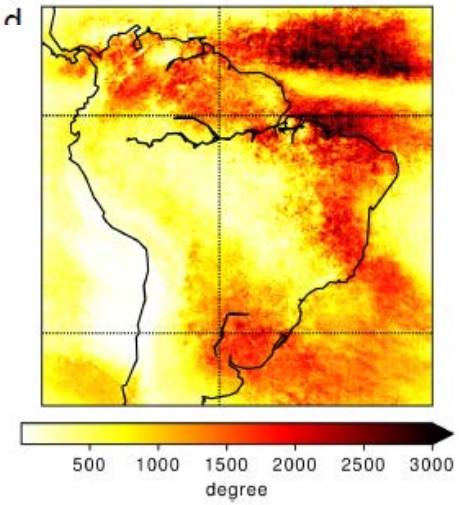
ES





ECA





Example: Daily precipitation extremes in the South American monsoon season

(left: original event definition, right: only use first day of persistent heavy precipitation)

(Wolf et al., Chaos, 2020)

Take home messages

- **Complex network approaches allow different perspectives on the spatio-temporal dynamics of natural hazards**
- **Choice of similarity measure for network construction crucially matters depending on serial correlation properties among events**
  - **Uncorrelated/non-clustered and sufficiently rare: ES and ECA consistent**
  - **Clustered/too frequent events: underestimation of connectivity by ES**
- **Practical considerations:**
  - **Need different event definition for "persistent" events (e.g., climate extremes)**
  - **Data-adaptive significance testing instead of global threshold to similarity measure (also proposed for correlation-based networks, cf. Palus et al. 2011)**
- **Outlook: extension to marked point processes (utilize amplitude information)**

Details: A. Odenweller & R.V. Donner, Phys. Rev. E, in press

Preprint: https://arxiv.org/abs/1910.12343

Job opening for 3-year postdoc position

3-year full-time postdoc position on nonlinear time series analysis of coupled ocean-atmosphere variability, starting 1 June 2020 or as soon as possible thereafter

<u>Please contact me if you are interested!</u>