Learning about Interacting Networks in Climate: the LINC project

1. What is LINC?

LINC is a 4-year Marie Curie Initial Training Network (ITN) funded by EU 7FP. Marie Curie ITNs aim at improving the career perspectives of young researchers through a transnational networking training program.

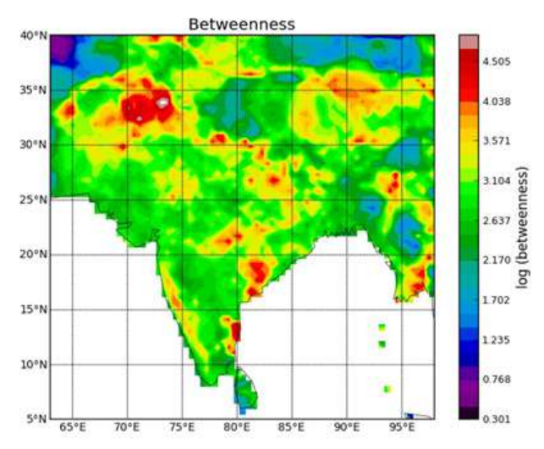
The LINC consortium includes 6 academic partners and 3 private-sector partners with expertise ranging from complex systems (networks, nonlinear time series analysis), environment and geosciences (climate, ocean and atmosphere dynamics) to commercial applications.

The LINC network is training 15 young researchers and will organize workshops, schools and a final conference.

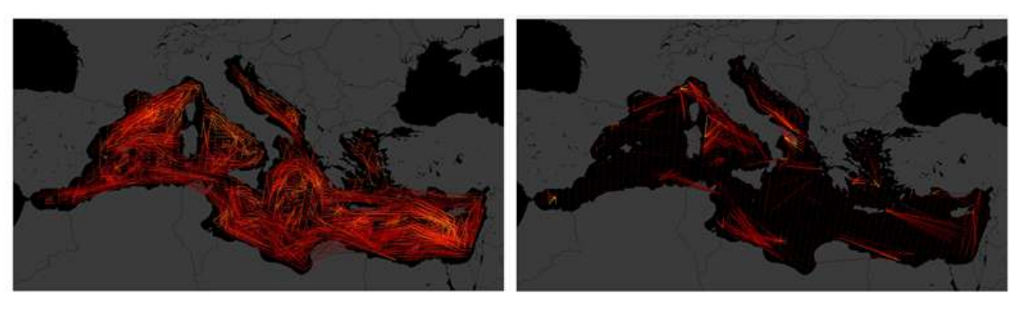
The next LINC school (open to external participants) will take place in April 2013 in The Netherlands.

2. Interdisciplinary research

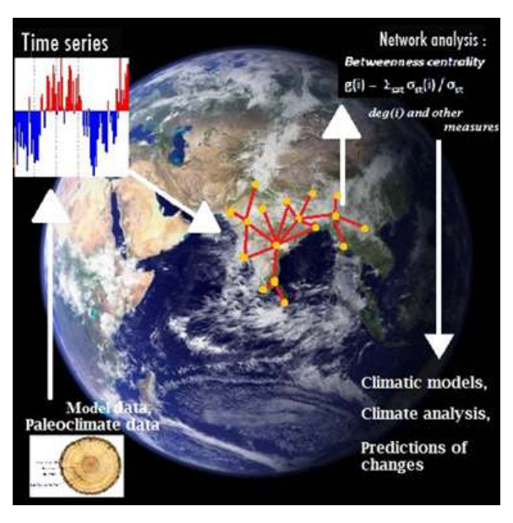
The complex network paradigm has proven to be a fruitful tool for the investigation of complex systems in various areas of science, e.g., the internet, neural networks, social networks, etc. The application of complex network theory to climate science is advancing the understanding of the Earth complex climate phenomena, such as *El Niño-Southern Oscillation* (ENSO). This has a huge economic and social impact for present and future generations, and can underpin advances in areas such as energy, environment, agricultural and marine sciences. Given the complexity of the inter-relations between the subsystems which constitute our climate, it is important to approach the problem from an interdisciplinary perspective.



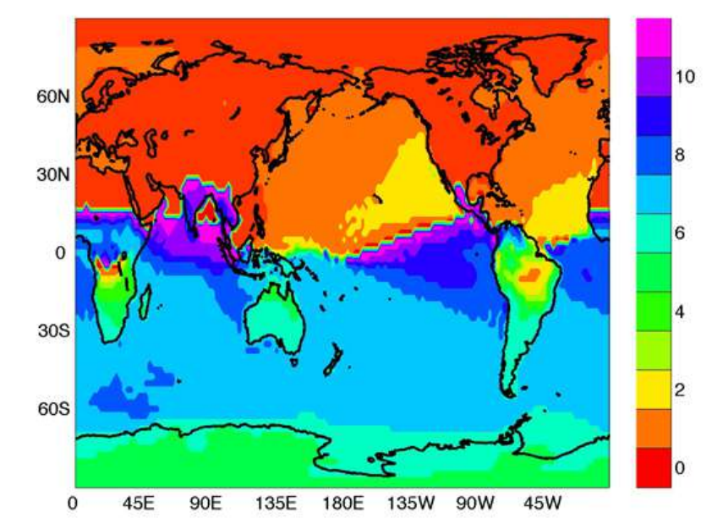
Veronika Stolbova (at Potsdam Institute for Climate Impact Research, Germany) is using the network approach for studying the Indian Monsoon. The analysis reveals important patterns in the sense of water transport through the network of precipitation and could be useful for prediction of the onset of Indian Summer Monsoon and switching to Winter Monsoon.



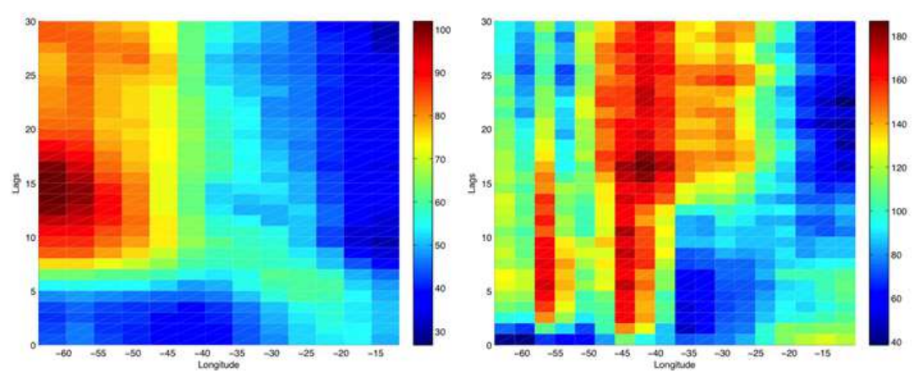
Enrico Ser Giacomi (at Universitat de les Illes Balears, Spain) is studying geophysical transport networks that represent connectivity patterns given by fluid advection in the Earth's atmosphere, focusing on surface currents in the Mediterranean Sea. By simulating the motion of > 1.000.000 particles during several months (1 left, 6 right), the research could characterize the relationship between transport barriers and avenues, and network quantifiers.



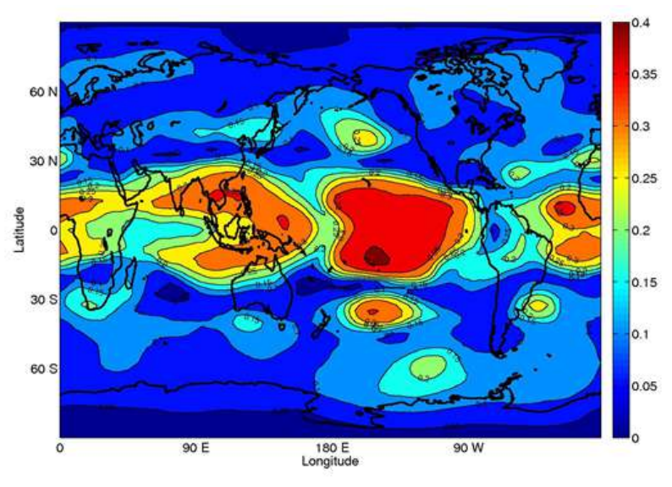
Liubov Tupikina (at Potsdam Institute for Climate Impact Research, Germany) is studying the Indian Summer Monsoon (ISM) rainfall by using paleorecords which could yield light on monsoon variability during past periods of Earth climate: the Medieval Warm Period (9001100 AD) and the Little Ice Age (15151715 AD).



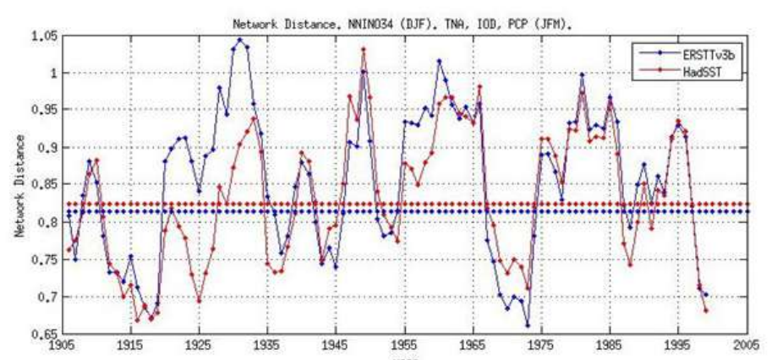
Giulio Tirabassi (at Universitat Politecnica de Catalunya, Spain) is studying the seasonal cycle effects in similarity measures of surface air temperature anomalies. The map of seasonal cycle phases (in the plot, the *lag-times* with respect to a node in the Mongolian Desert) reveals clear climate regions, the ocean memory, and the 6 months symmetry between the NH and SH.



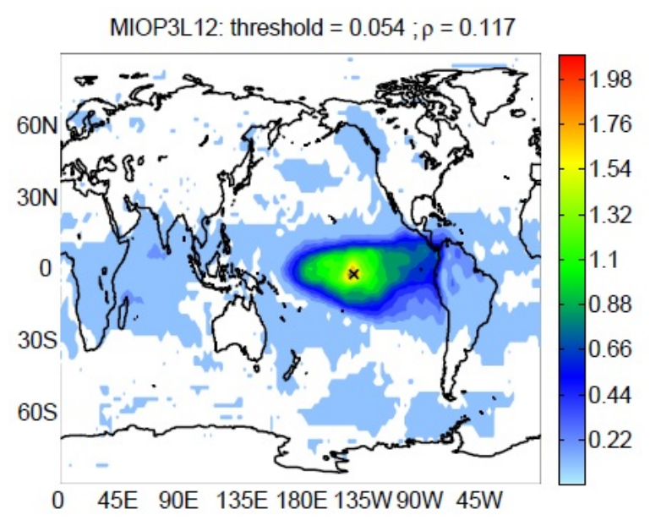
Qingyi Feng (at Utrecht University, The Netherlands) is studying the propagation of North Atlantic Multidecadal SST Anomalies. The analysis reveals that networks constructed from mutual information capture the main features of westward propagating patterns existing in an idealized model (left) and in the observations (right).



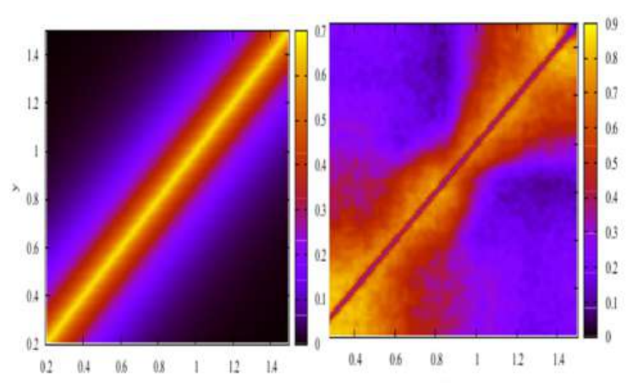
Fernando Arizmendi (at Universidad de la Republica, Uruguay) is studying climate networks build from time series of the eddie geopotential height at 200 mb. The Area Weighted Connectivity (AWC, in the plot) represents the fraction of Earth that each node is connected to. The analysis shows that the most connected regions have certain interdecadal variability."



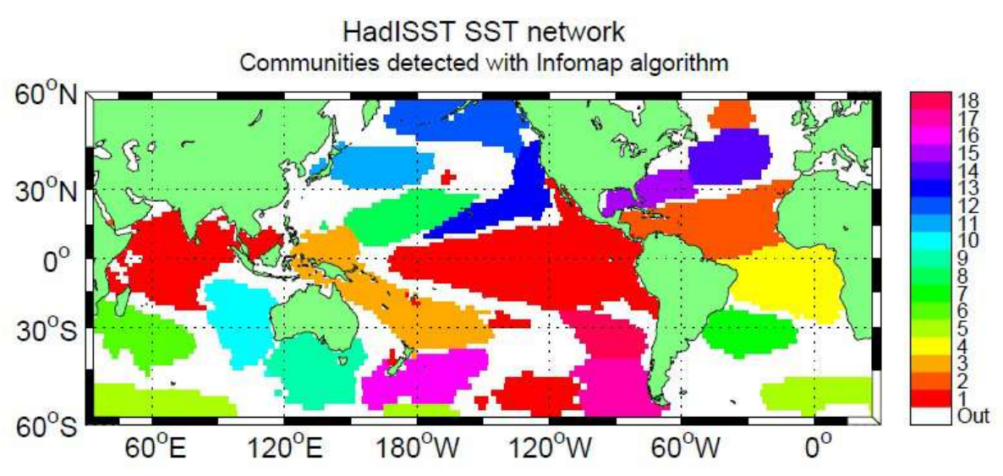
Veronica Martin Gomez (at Universidad de la Republica, Uruguay) is studying network distances using two datasets (HadSST and ERSSTv3b) from El Nino3.4, the Tropical North Atlantic (TNA), the Indian Ocean Dipole and the rainfall over northeast of Argentina (PCP) indices covering the period 1901-2006. The analysis reveals strong periods of synchronization, for example, from 1911 to 1919 and from 1968 to 1974.



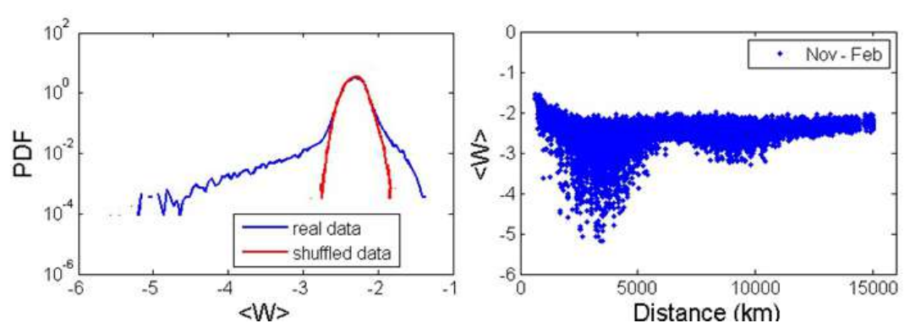
Juan Ignacio Deza (at Universitat Politecnica de Catalunya, Spain) is studying climate networks constructed from surface air temperature anomalies using ordinal time-series analysis. The map shows the worldwide correlation of ENSO, as measured with mutual information.



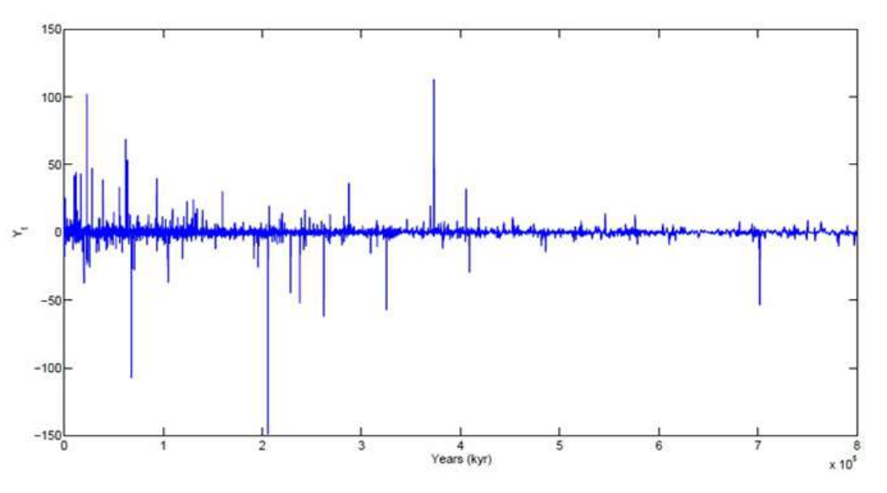
Victor Rodriguez (at Universitat de les Illes Balears, Spain) is studying a method to infer structure in networks based on Expectation Maximization (EM) with the aim of applying it to networks whose nodes are embedded in a metric space. The method has been tested when the connectivity depends on the distance between nodes in a 1D space (left). Combining EM and Metric Multidimensional Scaling allows recovering the connectivity function (right).



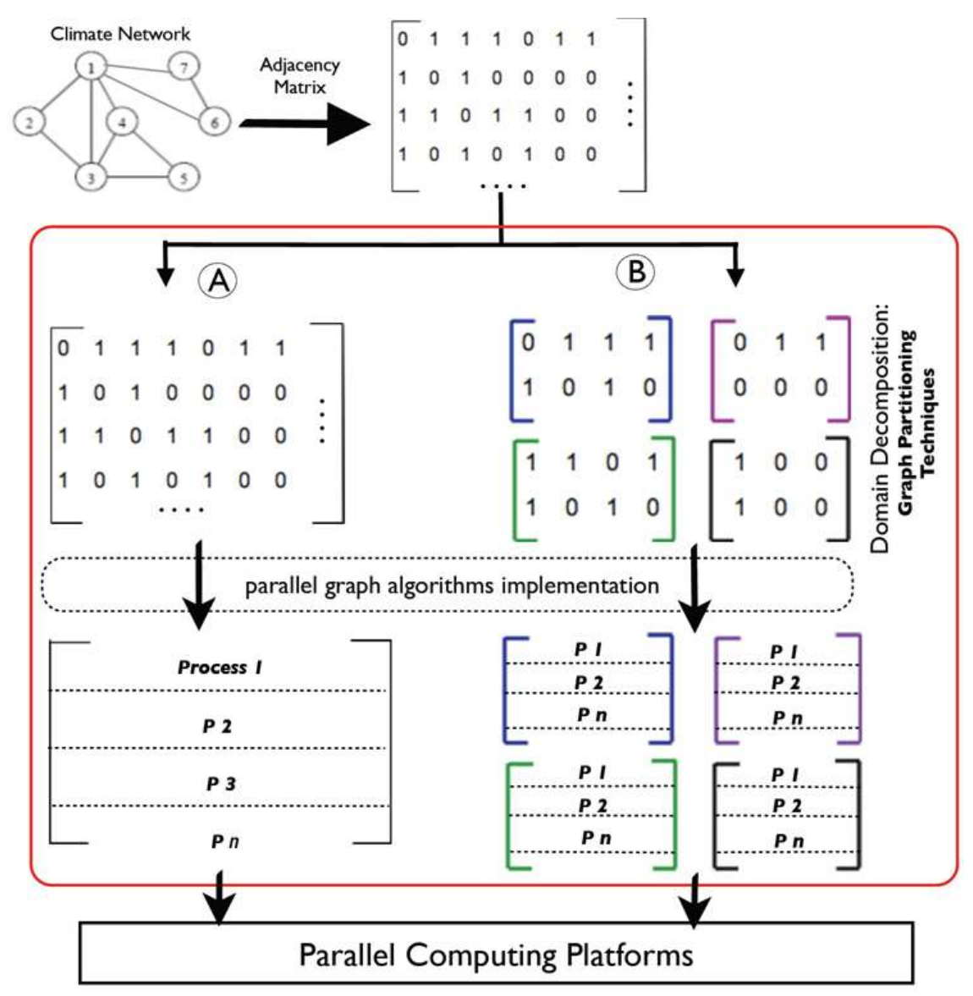
Alexis Tantet (at Utrecht University, The Netherlands) is studying community detection by the Infomap algorithm in networks built from detrended monthly anomalies of SST (HadISST Hadley dataset, 1870 -2011). Intra-seasonal variability previously filtered so as to focus on interannual to decadal timescales. the analysis reveals that the largest community (in red) corresponds to ENSO, the dominant pattern of variability.



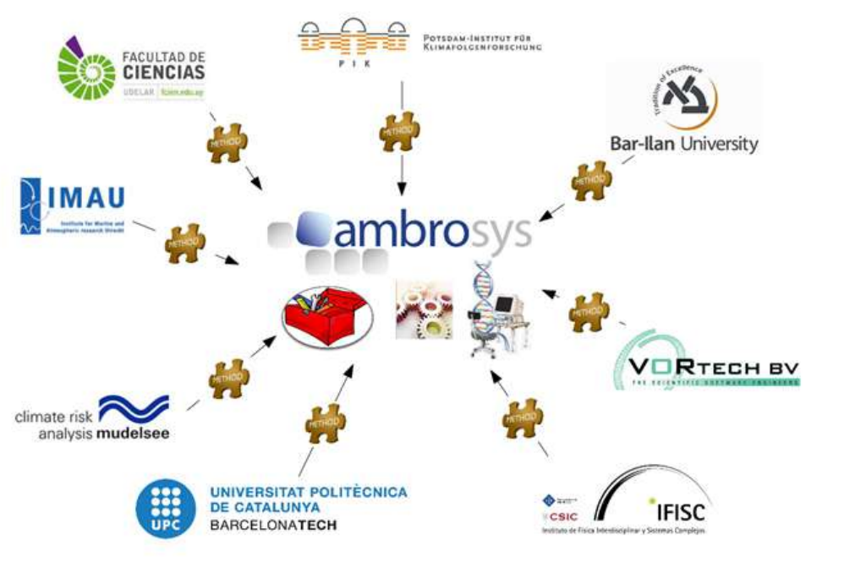
Yang Wang (at Bar Ilan University, Israel) is analyzing climate networks built from daily temperature data at 1000 hPa isobar. The plot shows the probability density function of the mean weight of negative links in the globe (left) and the dependence of the weight of negative links on the distance (right), in the SH during SH summer months.



Miguel Bermejo (at Climate Risk Analysis, Germany) is analyzing the possible existence of heavy tails in climate data to try to answer the question does climate have heavy tails?". The figure displays a time series of a Levy process that allows the existence of large values, which could be a relevant feature in climate modeling.



Hisham Ihshaish (at VORtech, The Netherlands) is developing efficient parallel graph-analyzing algorithms that exploit the benefits of nowadays supercomputing architectures. Parallel processing is crucial to overcome the resource limitations (processing and memory) of single processors. The figure depicts two main approaches of parallelization in the context of graph computation.



Marc Segond (at Ambrosys, Germany) is working on casting the processes and network topologies developed by the LINC partners into software using standardized processes. This includes creating a framework that integrates various tools and algorithms in several programming languages and make then communicate in order to interchange data. He is also working on exploring climatological data using machine learning and data analysis techniques such as Genetic Programming, Ant Colony Algorithms, Innovative Graph Mining Algorithms or Frequent Pattern Mining.

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