UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Group on Dynamics,
Nonlinear Optics and Lasers (DONLL)
UPC Campus Terrassa
www.donll.upc.edu

RESEARCH LINES:

- DYNAMICS OF SEMICONDUCTOR LASERS
- CLIMATE NETWORKS

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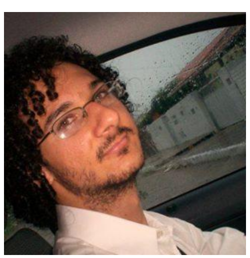
Semiconductor lasers lab

People involved: Taciano Sorrentino, Carlos Quintero, Andres Aragoneses, Jose Maria Aparicio Reinoso, Carme Torrent, Ramón Vilaseca, Cristina Masoller

Research topics:
- Optical neurons
- Optical rogue waves

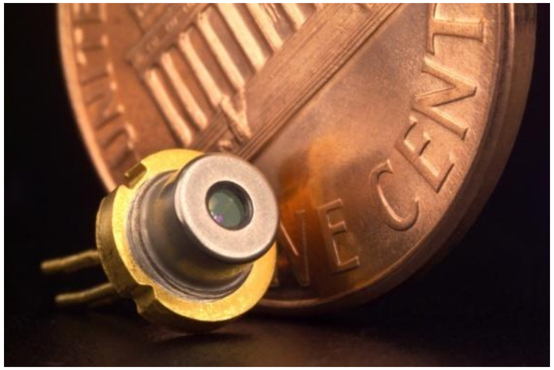






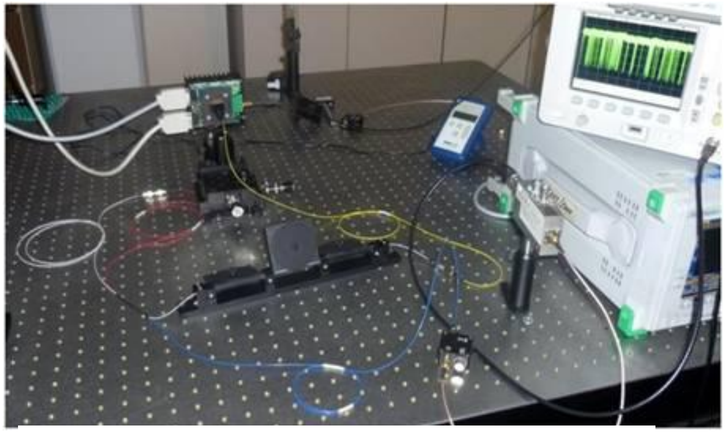
Semiconductor lasers

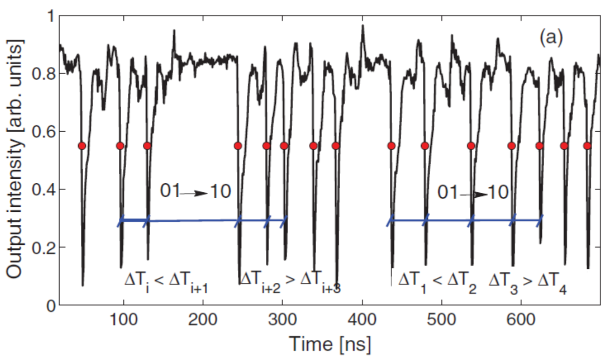
- Since lasers were invented in 1960, many different types have been developed.
- Semiconductor lasers (diode lasers) represent more than 90% of the laser market because:
  - Cover wide range of wavelengths
  - Are compact, fast, reliable and inexpensive



- Diode lasers changed the way we live and work, by being used in
  - Telecommunications (Internet)
  - Optical data storage (CDs, DVDs)
  - Barcode scanners, laser printers
  - Sensing
  - Biomedical applications
- In the presence of external perturbations diode lasers display nonlinear behaviors.
- Studying these behaviors can lead to
  - Better understanding of light-matter interactions
  - Improved laser performance
  - Novel applications

Feedback-induced spiking intensity: Potential for laser-based optical neurons





- ❑ Controllable experiment
- ❑ Spiking, neuronal-like activity
- ❑ We use **advanced statistical tools** to assess the similarity with neuronal spikes.

INVESTIGACIÓN Y CIENCIA
Edición española de SCIENTIFIC AMERICAN

La revista científica de referencia

Revistas | Noticias | SciLogs | Materias | Boletines | Catálogo | Suscripciones

Noticias | 01/10/2014

NEUROCIENCIA

Semejanzas entre las neuronas y el láser

Demuestran las similitudes entre la comunicación neuronal y el comportamiento de la luz láser.

Scientific Reports

Twittear 70 Compartir 2 g+1 6 Menear Compartir 2

Entender mejor el comportamiento de la luz láser ayuda a comprender la conducta de las neuronas. A esta conclusión ha llegado en fecha reciente un grupo de la Universidad Politécnica de Cataluña BarcelonaTech en el Campus de Terrassa. Los investigadores se han basado en un modelo matemático que reproduce algunos aspectos importantes del comportamiento de la luz láser cuando se la somete a perturbaciones. El modelo matemático es el mismo con el que otros científicos han explicado el comportamiento de algunas neuronas.

El reciente estudio confirma que la comunicación eléctrica entre neuronas se asemeja al comportamiento de la luz láser. [Thinkstock/ iStock]

Comportamiento similar

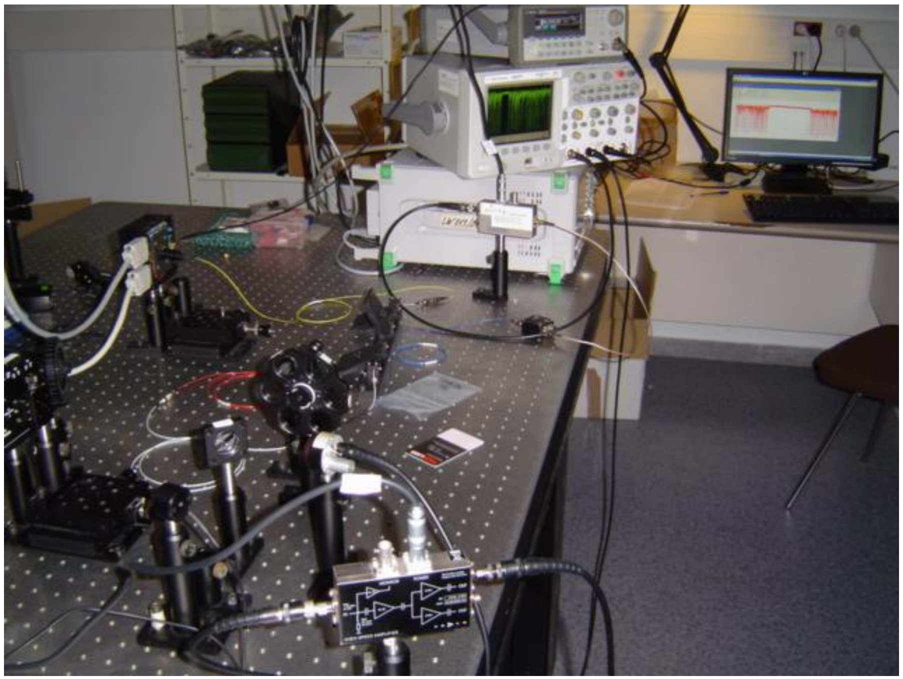
Los láseres de semiconductor, que suponen más del 90 por ciento de los láseres que se fabrican en todo el mundo para producir todo tipo de dispositivos en el ámbito de las telecomunicaciones (ratones de ordenador, lectores de códigos de barras, televisión por cable, etcétera), presentan comportamientos caóticos cuando reciben una perturbación externa.

Cuando la luz de un láser refleja en un espejo, el láser se desestabiliza de una manera, en apariencia, Divendres, 31 d'octubre de 2014

http://universitatsirecerca.gencat.cat/ca/detalls/noticia/

Demostren similituds entre el comportament de les neurones i de la llum làser

Investigadors de la UPC han fet servir un model matemàtic per modelitzar el comportament de la llum làser sotmesa a pertorbacions. Aquest model és el mateix que han utilitzat altres científics per descriure el comportament d'algunes neurones i permetrà estudiar millor com respon el sistema neuronal humà a estímuls externs.



La UPC crea un sistema para distinguir el orden del caos

La técnica podría ser útil en medicina y redes sociales

Redacción

Un equipo de investigadores del campus de la Universitat Politècnica de Catalunya (UPC), junto con científicos de la Universidad de Aberdeen de Escocia, han desarrollado un nuevo método, basado en la escala temporal, con el que se puede distinguir comportamientos ordenados dentro de secuencias caóticas. El trabajo se ha publicado en la revista de referencia "Scientific Reports". tificado el grupo de inestabilidades que se manifiesta con una distribución aleatoria y de otro, el grupo de inestabilidades con una fase de secuencias y una estructura nítida.

Los investigadores de la UPC que han llevado a cabo el trabajo son Andrés Aragoneses, Cristina Masoller y Maria Carme Torrent, del grupo de Dinàmica no Lineal, Óptica no Lineal y Làsers (DONLL); y Jordi Tiana-Alsina, del departamento de Teoria del Señal y Co- minar unas estabilidades de las obras se basa en la escala temporal. El orden escondido provoca que las inestabilidades inducidas estén más juntas que las que están producidas de forma aleatoria por el ruido. De hecho, nuestro método puede predecir que alteraciones están producidas por el ruido y cuáles inducidas".

EJEMPLOS PRÁCTICOS

Sobre ello ha explicado que"es lo mismo que detectar una me-

Por la izquierda, los investigadores Cristina Masoller, Carme Torrent y Andrés Aragoneses.

Cuando el comportamiento del láser se parece al de las neuronas

Experimento científico de investigadores del campus de la Politècnica en Terrassa

El avance permitirá estudiar mejor cómo responde el sistema neuronal a factores externos

Redacción

Un equipo de investigadores del campus de la Universitat Politècnica de Catalunya (UPC) en Terrassa han utilizado un modelo matemático muy sencillo que reproduce algunos aspectos importantes del comportamiento de la luz láser sometida a perturbaciones. La relevancia de los resultados logrados recae en que el sistema matemático es el mismo con el que otros científicos han descrito el comportamiento de algunas neuronas. "La similitud ha-

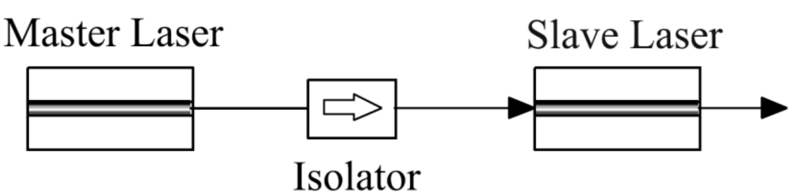
Los investigadores Andrés Aragoneses y Taciano Sorrentino muestran resultados de su experimento.

Video at: http://tv.upc.edu/continguts/continguts/neurones-optiques/

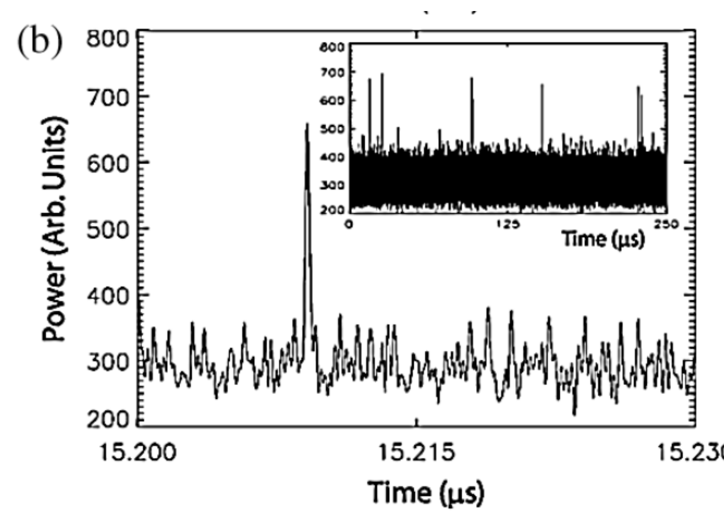
Read more at: http://www.fisica.edu.uy/~cris/lasers2.htm

Optical Rogue Waves

- ❑ Rogue waves (extreme freak waves) occasionally occur in ocean waters.
- ❑ Extreme events with similar characteristics occur in other systems (acoustics, optics, financial markets).
- ❑ In laser systems, optical rogue waves are anomalous, ultra-high intensity pulses.



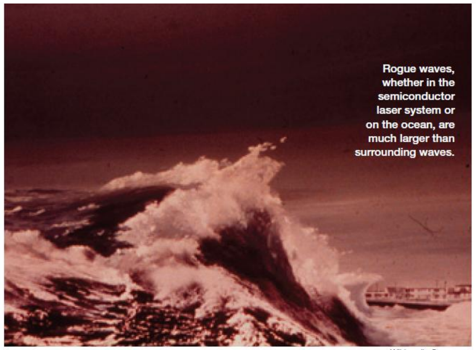
Detection system: photo detector, Oscilloscope & PC



- ❑ First demonstration of deterministic optical rogue waves (PRL 2011)
- ❑ Demonstration of <u>control</u> and total <u>suppression</u> of optical rogue waves (Physical Review A 2014, Optics Express 2014).

SCATTERINGS | NEWS

Deciphering Rogue Waves



Rogue waves, whether in the semiconductor laser system or on the ocean, are much larger than surrounding waves.

Wikimedia Commons

Rare pulses with giant intensities—the optical equivalent of rogue ocean waves—have been shown to occur in common laser systems. A team of researchers from Spain, France and Brazil found a way to generate rogue waves and developed a model for understanding them as a result of a deterministic nonlinear process (Phys. Rev. Lett. **107**, 053901). Extremely high waves have been a subject of interest over the past decade in oceanography as well as in other fields (including optics), but we still don't fully understand what triggers them and how they develop.

Rogue waves on the ocean are typically twice the height of surrounding waves and have steep sides, like "a wall of water." They have high amplitude, with a fast rise and fast fall. In the laser system demonstrated by the researchers, a rogue wave has an intensity so high that—according to Gaussian statistics—it should be vanishingly improbable. Such waves are unusual, but occur more often than Gaussian statistics can explain. Rogue waves also can be destructive: paper coauthor Jorge Tredicce at the Université de Nice Sophia Antipolis (France) says, "in mode-locked lasers, those extreme pulses may damage the optics and the crystal … it is the death of the laser!"

Light from a continuous wave master laser is injected into a stabilized vertical cavity surface-emitting laser (VCSEL) with stabilized pump current and temperature. The VCSEL emitted at 980 nm in a single transverse mode.

Researchers detuned the injection laser from the VCSEL and found that the slave laser output falls into four regions—one of which is stable-locked behavior. As the VCSEL current is increased, the output becomes more and more chaotic. Near the border of the mode-locked region, the researchers found a series of small pulses interrupted by occasional extremely large pulses. Coauthor Cristina Masoller at the Universitat Politècnica de Catalunya (Spain) explains, "we identify two types of optical chaos: one in which rogue waves are rare but they certainly appear and one in which practically they do not exist." There appear to be areas where rogue waves don't occur even if the behavior is chaotic.

The experiments were inspired by Tredicce's theoretical paper that suggested the existence of huge intensity pulses in this laser system. The researchers found that a simple noise-free rate equation model produced results that agree with the experiments. This allowed them to interpret the sporadic high amplitude pulses as the result of a deterministic nonlinear process.

The group now has a simple system that allows them to experiment with optical rogue waves, as well as a model for describing them. Because rogue waves occur in other systems, ranging from ocean surface to acoustic waves to economics, their work could have implications far beyond the realm of optics. Next, they want to find a mechanism that creates rogue waves in their system, as well as whether they can increase or decrease their likelihood.

—Yvonne Carts-Powell

Optics and Photonics News,
Optical Society of America,
February 2012

Nature Photonics

Full text access provided to Universite de Nice Sophia Antipolis by Documentation electronique

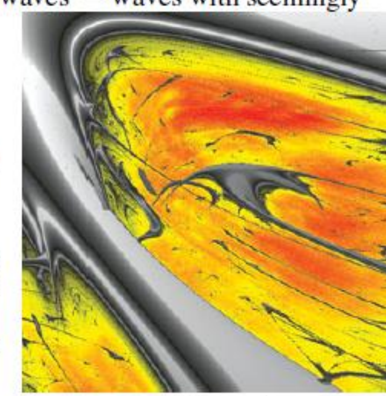
Rogue waves

Surely deterministic

- Rachel Won

Journal name: Nature Photonics Volume: 5, Page: 571 Year published: (2011)
DOI: doi:10.1038/nphoton.2011.240, Published online 30 September 2011

Phys. Rev. Lett. **107**, 053901 (2001)



The physical mechanism behind the formation of rogue waves — waves with seemingly spontaneous large amplitudes — has long been an interesting research topic for oceanologists and physicists, including those working in photonics. An important question is whether rogue waves can be described by a fully deterministic process with noise as a driving force. Cristian Bonatto and co-workers from Spain, France and Brazil recently carried out an investigation into the generation of rogue waves using a semiconductor laser that received optical injection from a continuous-wave master laser. The researchers not only showed that sporadic high-amplitude pulses can be observed with such a simple and inexpensive laser set-up, but also concluded that the rogue waves they observed are generated from deterministic nonlinearities. Their conclusion was based on good qualitative agreement between experimental results and simulated results from a simple, deterministic noise-free rate equation model.

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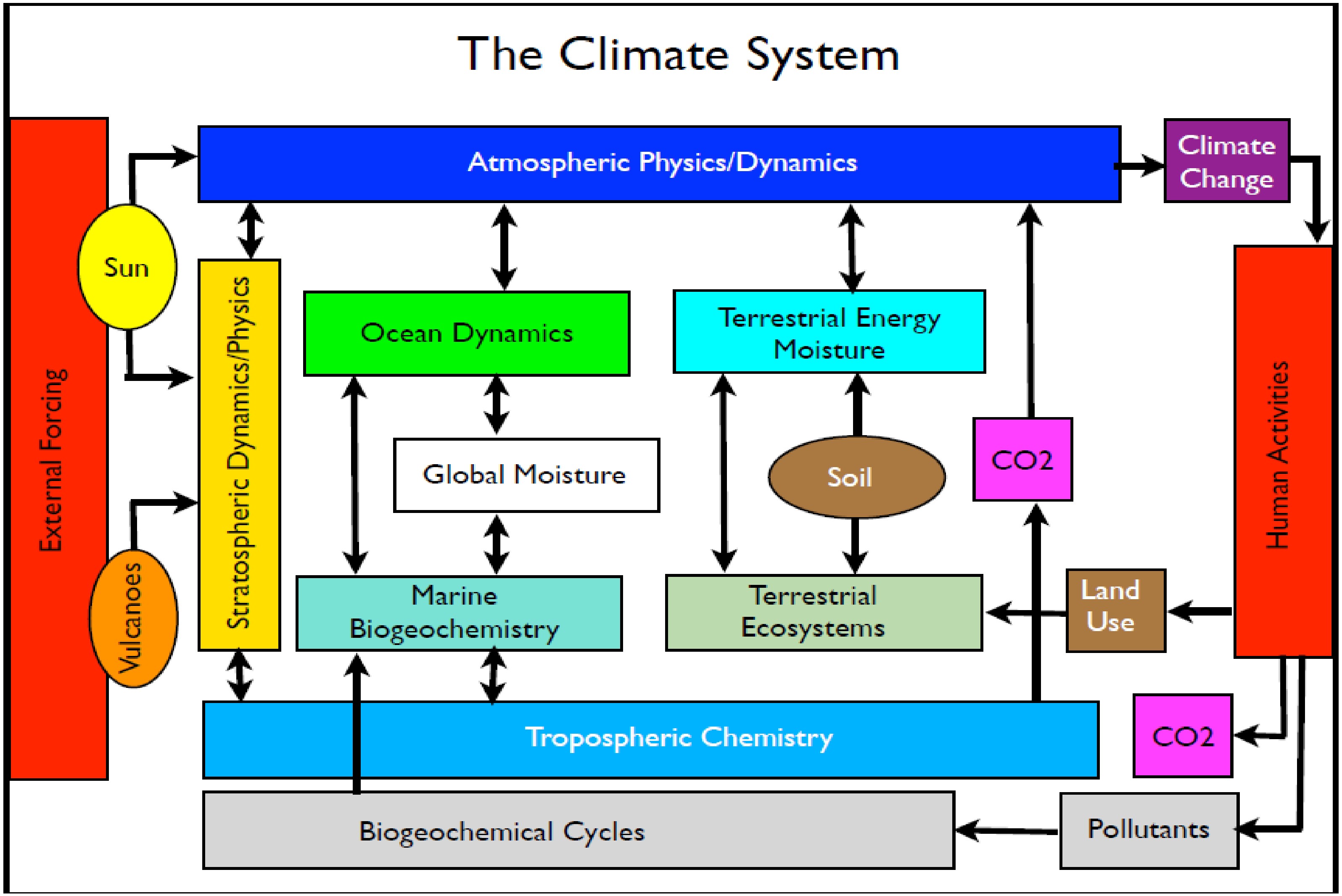
Climate Networks

People involved: Ignacio Deza, Giulio Tirabassi,
Laura Carpi, Cristina Masoller



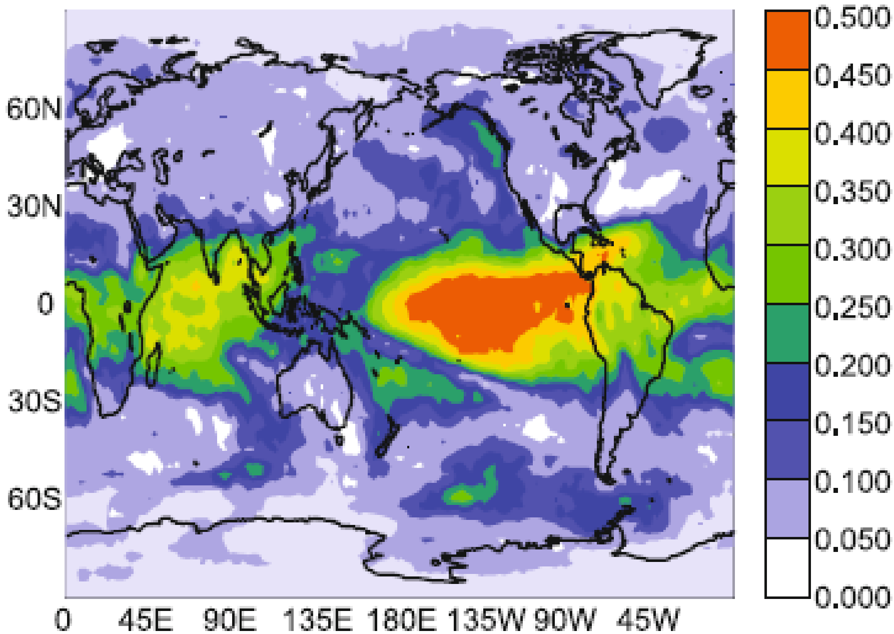

Our climate: a very complex system of interacting sub-systems acting on a wide range of time-scales



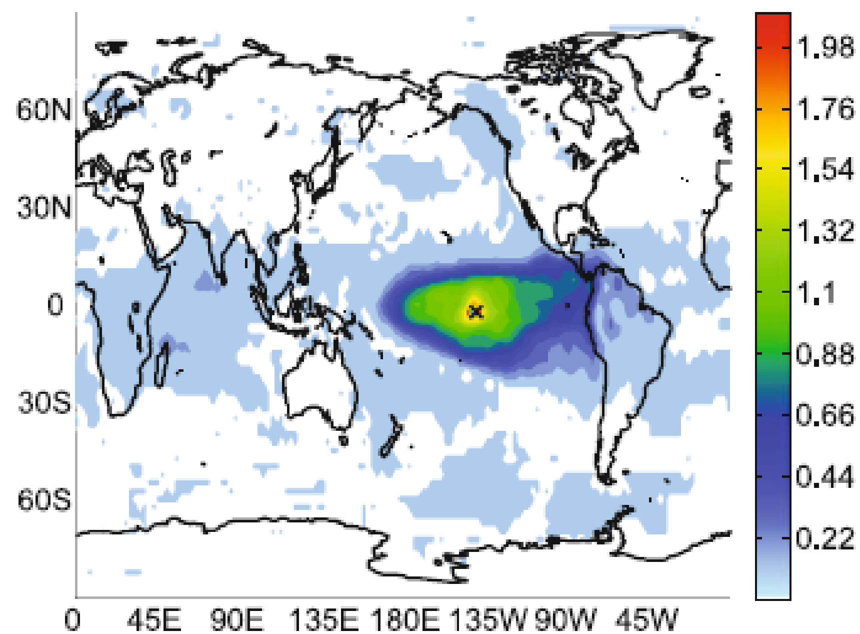
Courtesy of Henk Dijkstra (Ultrech University)

Complex network representation of climate dynamics

We use **<u>advanced statistical tools</u>** to analyze empirical climate data and to construct networks where the nodes cover the Earth surface and the links represent climate interdependencies (teleconnections).



Network Degree Distribution: *El Niño* region is the main hub.



Teleconnections of *El Niño* region

Short Video on the directionality of teleconnections (red: outgoing links; blue incoming links)

First school of LINC Training Network

- Studying these long-range teleconnections can lead to
  - Better understanding of ocean-atmosphere phenomena
  - Climate model testing and inter-comparison
  - Improved climate predictions

- Collaborators
  - S. Havlin, A. Gozolchiani (Israel)
  - J. Kurths (Germany)
  - E. Hernandez-Garcia (Mallorca)
  - H. Dijkstra (The Netherlands)
  - M. Barreiro (Uruguay)

Read more at: climatelinc.eu

El campus UPC lidera la formación científica en fenómenos climáticos

El programa internacional, coordinado por Cristina Masoller, acogerá a quince jóvenes

- La iniciativa se enmarca en un proyecto europeo valorado en 3,7 millones de euros

Redacción

Una investigadora del campus de la Universitat Politècnica de Catalunya (UPC) en Terrassa, Cristina Masoller, coordina un proyecto de investigación internacional, titulado Learning About interacting Network in Climate (LINC), destinado a la formación de quince jóvenes científicos en fenómenos climáticos complejos. El proyecto, que tiene un duración de cuatro años y está dotado con más de 3,7 millones de euros, se enmarca en el programa europeo Marie Curie.

Masoller, doctora en Física por el Bryn Mawr College de Pensylvania de Estados Unidos, forma parte del repu-

La coordinadora, Cristina Masoller, con Ignasi Deza, uno de los jóvenes elegidos para esta formación de élite.

Funding

- EOARD Project FA9550-14-1-0359 (2014-2016).
  "**Semiconductor laser complex dynamics: from optical neurons to rogue waves**". Principal Investigator: C. Masoller

- **ICREA Academia award**, Generalitat de Catalunya (2010-2014).

- MCI Spain Project FIS2012-37655-C02-01(2013-2015).
  "**Stochasticity in Nonlinear Complex Systems**"

- European Union FP7-PEOPLE-2011-ITN-289447 (2011-2015).
  "**Marie Curie Initial Training Network: Learning about Interacting Networks in Climate**". Principal Investigator: C. Masoller