Mathematics in Action B: Mathematics of Climate

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Mathematics in action

Mathematics is central to much of everyday life: it underpins digital communications, internet searches, medical imaging, computer animations, weather and climate predictions and many more technological advances. At the heart of this impact lies the capability of mathematics to model complex systems, to process information and to provide predictions as well as solutions. This course will introduce the key steps that lead from the formulation of mathematical models to the development and implementation of numerical solutions. This will be achieved in the context of a specific theme of contemporary interest which varies from year to year: the 2018–19 theme is *Mathematics of Climate*. The course will be assessed continuously through regular assignments and one project. The numerical computations required will be carried out using MATLAB.
Note: the course is available for 4^{th} and 5^{th} year students; 5^{th}-year students who took Mathematics in Action A in 2017–18 can take the course since it is on a different theme.

Mathematics of climate

Understanding the Earth's climate and predicting how it will change is a key challenge for 21^{st} century science. The problems to solve involve several disciplines (physics, biology, computer sciences...), and they are tackled using a broad range of mathematical tools: statistics, probability, differential equations, and numerical methods in particular. The course will introduce some of these problems, formulate them as mathematical models and consider solving them through analytical and numerical methods. It will answer questions such as: how do climate models work; what are tipping points; the distinction between weather and climate, and predictability; what is El Niño (see Figure 1), its physical, biological and economical impacts, and can it be predicted?

Course focus and learning outcomes

- Mathematical techniques motivated by and used in climate sciences
- Awareness of the indispensable role of mathematics in climate sciences
- Practice with computation-assisted modelling (e.g., MATLAB or equivalent)
- Developing presentation skills (e.g., document preparation through LaTeX)

Sample topics

- Existence of multiple past/future climates (energy balance models)

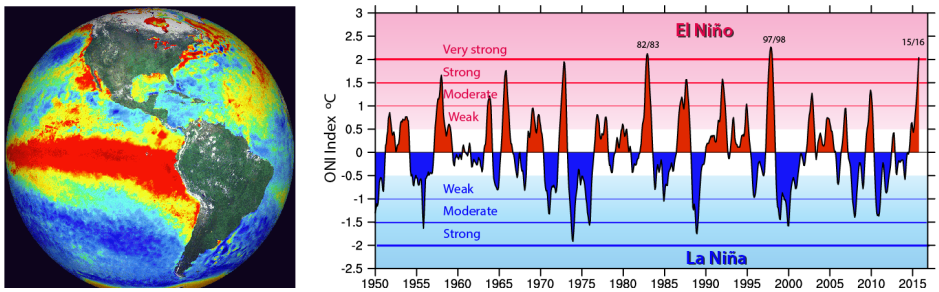

Figure 1: (a) El Niño 1998 episode showing sea surface temperature (SST) anomalies (from NASA SVS). (b) 55 year time series of El Niño index showing "averaged" SST in tropical Pacific ocean (from K. Trenberth, NCAR).

- Natural variability of climate (Milankovitch cycle)
- Transition from one climate to another (Stommel's model for the ocean circulation)
- "Weather" vs. "climate" (chaos and Lorenz's model)
- Mid-term climate varability (toy models for El Niño)

Course organisation and assessment

The course consists in 16 lectures, two guest lectures presented by climate experts, and five two-hour workshops. It is continuously assessed through five assignments (typically brief reports of computational work in the form of MATLAB and/or LaTeXdocuments, making up 70% of the final mark) and a project (30% of the final mark).

Level: 11; **Credits:** 10.

Pre-requisites: Honours Differential Equations, Honours Complex Variables, Computing & Numerics, Probability (or their equivalent)

References and links

- PATH link for previous Mathematics in Action:
  https://path.is.ed.ac.uk/courses/2016/MATH11181_SV1_SEM2
- "Mathematics & Climate" by Kapler & Engler (2012)
  http://epubs.siam.org.ezproxy.is.ed.ac.uk/doi/book/10.1137/1.9781611972610