University of California, Los Angeles
Atmospheric and Oceanic Sciences

AOS 271 Seminar

Date: Thursday, October 13, 2016
Time: 3:30 – 4:30 pm
Location: MSB 7124A

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" Causality as a Rigorous Physical Notion and Causality Analysis with Time Series"

Given two time series, can one faithfully tell, in a rigorous and quantitative way, the cause and effect between them? With a recently rigorized physical notion namely information flow/transfer, we show that this important and challenging question, which is of interest in a wide variety of disciplines, has a positive answer. Here causality is measured by the time rate of information transferring from one series to the other. Let the series be X_1 and X_2. The resulting formula for the information flow from X_2 to X_1, $T_{2\to 1}$, turns out to be concise in form:

$$T_{2\to 1}=\frac{C_{11}C_{12}C_{2,d1}-C_{12}^2C_{1,d1}}{C_{11}^2C_{22}-C_{11}C_{12}^2}$$

where C_{ij} $(i,j=1,2)$ is the sample covariance between X_i and X_j, and $C_{i,dj}$ the covariance between X_i and ΔX_j, the difference approximation of dX_j/dt using the *Euler forward scheme*. An immediate corollary is that causation implies correlation, but not vice versa, resolving the long-standing debate over causation versus correlation.

The above formula has been validated with touchstone series purportedly generated with one-way causality that evades the classical approaches such as Granger causality test and transfer entropy analysis. It has also been applied successfully to the investigation of many real problems. Through a simple analysis with the stock series of IBM and GE, an unusually strong one-way causality is identified from the former to the latter in their early era, revealing to us an old story, which has almost faded into oblivion, about "Seven Dwarfs" competing with a "Giant" for the computer market.

Another example presented here regards the cause-effect relation between the two climate modes, El Niño and Indian Ocean Dipole (IOD). In general, these modes are mutually causal, but the causality is asymmetric. To El Niño, the information flowing from IOD manifests itself as a propagation of uncertainty from the Indian Ocean.

In the third example, an unambiguous one-way causality is found between CO_2 and the global mean temperature anomaly. While it is confirmed that CO_2 indeed drives the recent global warming, on paleoclimate scales the cause-effect relation may be completely reversed.

Also will be mentioned are a few other applications, e.g., a simple pattern underlying a chaotic attractor, and a study of the causal structure in the near-wall turbulence.