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Multiscale Information Transfer in Turbulence.

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Description :

In physics and engineering, one ubiquitous question when dealing with a system having several components is the measurement and estimation of the "information" that is transferred between the different components of the system. "Information" is voluntarily used here in a large and encompassing way : it can be energy of observables in physical systems, it can be entropy (or fluctuations) between systems when adopting a statistical physics point-of-view, it can be information when dealing with informative systems such as in neurosciences or telecommunications. Many of the most popular methods to assess for the dependences between observed variables are nondirectional, e.g. correlation, partial correlation, or mutual information measures. Although these methods have been extensively used, they do not offer any way to capture the directionality of the dependence because they are symmetric. The most popular directional method is transfer entropy, proposed in (Schreiber, 2000), discussed and reinterpreted in (Vicente, 2011) for Neurosciences ; it allows for the estimation of conditional quantities, in which directionality of the dependence can be assessed by this conditioning. In information theory, there is a long history towards defining causality with the Granger Causality (Granger, 1969) and the directional information theory (Marko 1973 ; Massey, 1990, Amblard & Michel, 2013).

The first issue is to study, compare and refine existing method for information transfer estimation. The second one, is to study and revisit the question of directly measuring the information transfer between scales in turbulence. It is known that, statistically, there exists a direct energy transfer from the large scales to the smaller scales in turbulent fluids, that ends up in dissipation of the energy at Kolmogorov scales (Frisch, 1995). However, despite efforts to estimate it directly from observations (e.g., Baudet, 1999), direct measurement of the cascade has not been obtained yet. In this context, the different observables are extracted from the signal observed at different scales of resolution. Thanks to all the developments made in scaling and multifractal analysis (e.g., Lashermes, 2008) of turbulence through wavelets, statistical properties of the velocity are well known. The coupling and causality between the scales is less explored. The question of information transfer is then relevant as it would help to understand at which point this cascade departs from its statistical average. Also, the various information transfer measurements would have to be considered in a local manner, so as to be able to study along time the energy cascade. For coupling the multiscale study of velocity signals in turbulence and information transfer, we will be able to leverage on multiscale versions of information transfer, e.g. (Costa, 2002 ; Lungarella, 2007).

This projet will be conducted in collaboration with Olivier Michel (Gipsa-lab, Grenoble) and Christophe Baudet (LEGI, Grenoble).

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