The notion of predictibility , associated to turbulent phenomena, and their acquisitions by sensors, is the subject of intense research in relation to complex systems; it opens new directions of research in the processing of signals displaying multiscale properties .

It is a wide field of research possessing a strong potential for deriving new methods in the analysis of multiscale complex signals. These works show the limitations inherent to classical methods, such as ordinary Lyapunov exponents, to characterize unpredictibility in datasets related to the acquisitions of stochastic signals highly intermittent such as those we are studying. In GEOSTAT, certain theoretical developments around the notion of predictibility in the presence of coherent structures are being studied, along with the new approaches able to characterize, in complex signals having multiscale properties, geometric subsets related to the statistical information content. The MMF is not the sole approach, of course, so that GEOSTAT will also investigate new characterizations of intermittency which tend to localize spatially geometrical subsets in the signal domain, associated to information content.

Although approximation methods using techniques inherited from dynamical systems theory are in use in the analysis of some turbulent signals, some recent works insist on the limitations brought by classical Lyapunov exponents w.r.t. predictibility: a Lyapunov exponent is a global quantity measuring an average divergence rate. In the general case, there are some fluctuations in finite time, which play an important role in predictibility, which lead to the consideration of large deviations . A major goal in GEOSTAT is to characterize, in a single spatial realisation of the signal the singularity exponents, and to relate that information to others tools in the analysis of non-linear systems such as multiplicative cascading, Lyapunov exponents in finite time and large deviations.

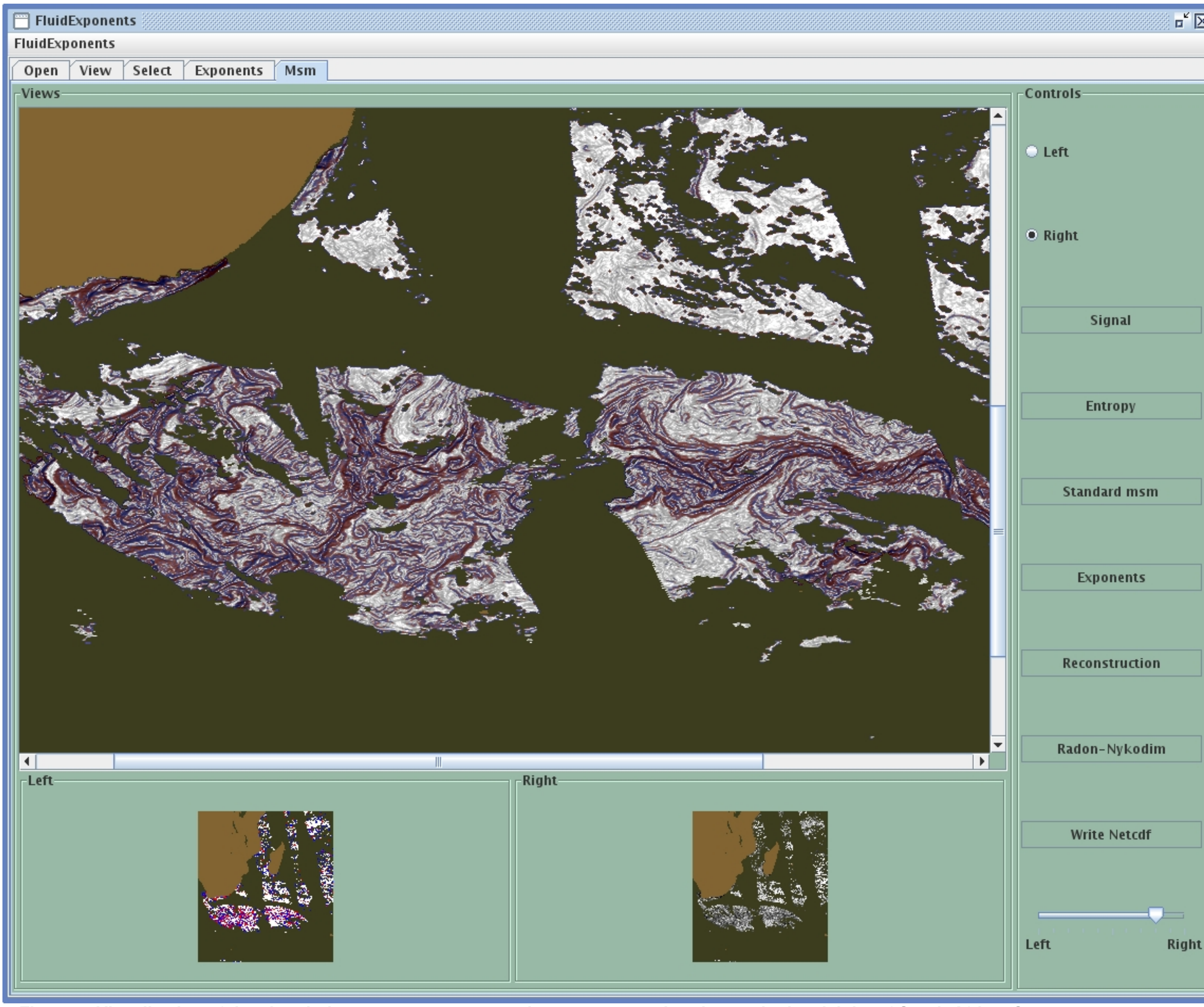

Figure 1. Visualization of the singularity exponents, computed on an ocean colour image, in the vicinity of South Africa. Green areas correspond to missing data (clouds, among others). This image displays, at least qualitatively, how the singularity exponents bring information on the oceanic flow, because chlorophyll concentration acts as a passive tracer.

The domain of applicability of the MMF is restricted to those signals having certain multiscale geometric structures, and they form a large set of natural signals; a celebrated example is found in turbulent signals, in which a hierarchy of geometric structures is related to the Legendre spectrum, according to the famous paper of Paris and Frisch. Without trying to delimitate precisely the range domain of the theory, we can mention a broad class of natural signals which fall within its scope: geophysical fluids in the fully developped turbulence regime. In this type of intermittent systems, some geomeric structures dominate the general organization of the temporal dynamics. In the classical approach to fully developped turbulence, statistical tools are used in first instance. The MMF tends to localize, in the signal domain, characteristics that goes beyond a purely statistical description attainable through the moments (structure functions) of variables. Of course, fully developped turbulence is given here as a standard example, and

GEOSTAT is interested in a broader class of complex signals .

The determination of geometrical "super-structures" is not new in itself. However, in the GEOSTAT proposal, the statistical signifiance of the geometric super-structures is emphasized by the type of singularity exponents computed in the MMF. GEOSTAT is looking for stable, robust algorithms and methods for the determination of the exponents and the geometric structures associated with them. GEOSTAT proposes a new type of approach to temporal evolution in complex signals, the understanding of complex dynamics in relation to reconstruction formula, and the combination of these new techniques with existing methodologies in classification and statistical modeling. The study of reconstructible systems from a theoretical point of view, the derivation of fast real-time algorithms and their integration, the use for the automatic processing of the immense datasets of satellite data, and the study of the MMF's ability to automatically derive high-level semantic properties in complex signals are also important lines of research in GEOSTAT.

GEOSTAT corresponds to a new phase in the analysis of complex signals, with the systematical use of paradigms coming from Statistical Physics and renormalization techniques about the emergence of multiscale properties and singularity exponents, which allow not only to determine complexity inside signals but also to localize geometrically, inside these signals, the information content related to the emergence of complexity.