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Harmonizable representations of nonstationary random processes and inhomogeneous random fields

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Harmonizable representations are useful for a huge class of nonstationary random processes and inhomogeneous random fields. In this presentation, we will discuss the properties of, and examine some consequences of employing a natural choice of complex valued densities to characterize the harmonizable class. We argue that the quest for representation of power or energy as a function of time and frequency is in many cirumstances problematic from a fundamental point of view. To remedy these problems, we will rely on the Hilbert space geometry of a complex valued time-frequency description (related to the Rihaczek distribution), and of a complex valued dual-frequency description (related to the Lo\‘{e}ve spectrum). The proposed geometric interpretation shows that the associated time-frequency and dual-frequency densities are distributions of inner-product, rather than distributions of power or energy. Furthermore, the geometry tells us how to construct useful generalized coherences. Several important generalizations will be highlighted, e.g., complex valued processes, multivariate processes, generalized higher-order spectra, and random waves in dispersive media. Finally, the theoretical framework will be illustrated by the presentation of high-quality multitaper based time-frequency and dual-frequency density estimates, applied to various interesting geophysical data sets.