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Outlook brighter on weather forecasts

SIR—Our recent paper "Fractal characterization of inhomogeneous geophysics measuring networks" addressed the fundamental geophysical problem of sparse measuring networks, and pointed to new ways of overcoming longstanding difficulties[1]. Although pleased to have stirred interest in the weather forecasting community, we were therefore somewhat surprised by the pessimistic ("bleak") interpretation given to our findings in Hollingsworth's *News and Views* article[2]. Since this interpretation could be due to a misunderstanding, we would like to clarify our position.

By quantifying the sparseness of the meteorological observing network, we showed that no matter how large, phenomena sufficiently intense and sparse (with fractal dimension $D<0.25$) would slip through the network undetected. The errors due to this limited dimensional resolution are more subtle than Hollingsworth seems to indicate. We implied neither that the network misses storms, nor the most energetic areas but rather, the most intense regions. Indeed, fundamental characteristics of the various levels of energy density (or more precisely, the flux of energy to smaller scales), are their multiple fractal dimensions which decrease as the intensity level increases. Since any set with $D<1$ is a totally disconnected set of points, the regions missed, are the most active cores of storms. These low dimensional (sparse, core) regions play a crucial role in the future evolution of the atmosphere.

Hollingsworth seems to minimize the impact of this lack of dimensional resolution, first by citing the utility of existing forecasts 6–7 days ahead, second, by pointing to the increasing role of satellite data. Let us examine these points one by one.

Hollingsworth admits that even in the vague terms of "economical usefulness" forecasts are limited to periods of one week or less. Even without a precise discussion of predictability and its limits, is it unreasonable to suppose that at least part of our current difficulties are related to our inability to detect sparse but violent events?

Hollingsworth is obviously correct in pointing out the importance of satellite data. Indeed, since remotely sensed data generally have very high dimensional resolutions, our findings add a new argument in their favour. Unfortunately, the satellites themselves, are calibrated by sparse *in situ* networks, and current calibration methods do not recognize the problem of dimensional resolution. Furthermore, the existing four-dimensional data assimilation techniques that are used to mix *in situ* and satellite data take no quantitative account of the various dimensions involved.

Perhaps, if we abandon the routine ways of dealing with the problem of sparse networks and phenomena, the future can be faced with optimism. New and mushrooming interest in techniques of multi (fractal)-dimensional analysis and simulation may ultimately help clarify basic problems in predictability. In the short term, we may expect rapid development of statistical techniques to provide important corrections to data lacking in dimensional resolution. Improved forecasts over a wide range of timescales could be possible.

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2. Hollingsworth, A. *Nature* **319**, 11-12 (1986).