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The scaling of wild events in stochastic models: The Fisher limit, the Mandelbrot limit, and FARIMA as a model of the intermediate cases

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Stochastic modelling is of increasing importance, both specifically in climate science and more broadly across the whole of nonlinear geophysics. Traditionally, the noise components of such models would be spectrally white (delta-correlated) and Gaussian in amplitude, and their variance (first named by Fisher in 1918) would well

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Compound Extremes and Bunched Black (or Grouped Grey) Swans.

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Observed “wild” natural fluctuations may differ substantially in their character. Some events may be genuinely unforeseen (and unforeseeable), as with Taleb’s “black swans”. These may occur singly, or may have their impact further magnified by being “bunched” in time. Some of the others may, however, be the rare extreme events from a light-tailed underlying distribution. Studying their occurrence may then be tractable with the methods of extreme value theory [e.g. Coles, 2001], suitably adapted to allow correlation if that is observed to be present.

Yet others may belong to a third broad class, described in today’s presentation [reviewed in Watkins, GRL Frontiers, 2013, doi: 10.1002/grl.50103]. Such “bursty” time series may show comparatively frequent high amplitude events, and/or long range correlations between successive values. The frequent large values due to the first of these effects, modelled in economics by Mandelbrot in 1963 using heavy- tailed probability distributions, can give rise to an “IPCC type I” burst composed of successive wild events. Conversely, long range dependence, even in a light-tailed Gaussian model like Mandelbrot and van Ness’ fractional Brownian motion, can integrate “mild” events into an extreme “IPCC type III” burst.

I will show how a standard statistical time series model, linear fractional stable motion (LFSM), which descends from the two special cases advocated by Mandelbrot, allows these two effects to be varied independently, and will present results from a preliminary study of such bursts in LFSM. The consequences for burst scaling when low frequency effects due to dissipation (FARIMA models), and multiplicative cascades (such as multifractals) are included will also be discussed, and the physical assumptions and constraints associated with making a given choice of model.

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Mapping the changing pattern of local climate as an observed distribution

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It is at local scales that the impacts of climate change will be felt directly and at which adaptation planning decisions must be made. This requires quantifying the geographical patterns in trends at specific quantiles in distributions of variables such as daily temperature or precipitation. Here we focus on these local changes and on the way observational data can be analysed to inform us about the pattern of local climate change. We present a method[1] for analysing local climatic timeseries data to assess which quantiles of the local climatic distribution show the greatest and most robust trends. We demonstrate this approach using E-OBS gridded data[2] timeseries of local daily temperature from specific locations across Europe over the last 60 years. Our method extracts the changing cumulative distribution function over time and uses a simple mathematical deconstruction of how the difference between two observations from two different time periods can be assigned to the combination of natural statistical variability and/or the consequences of secular climate change. This deconstruction facilitates an assessment of the sensitivity of different quantiles of the distributions to changing climate. Geographical location and temperature are treated as independent variables, we thus obtain as outputs the pattern of variation in sensitivity with temperature (or occurrence likelihood), and with geographical location. We find as an output many regionally consistent patterns of response of potential value in adaptation planning. We discuss methods to quantify and map the robustness of these observed sensitivities and their statistical likelihood. This also quantifies the level of detail needed from climate models if they are to be used as tools to assess climate change impact.

[1] S C Chapman, D A Stainforth, N W Watkins, 2013, On Estimating Local Long Term Climate Trends, Phil. Trans. R. Soc. A, in press

[2] Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D.
Jones and M. New. 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201

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An observationally centred method to quantify local climate change as a distribution

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For planning and adaptation, guidance on trends in local climate is needed at the specific thresholds relevant to particular impact or policy endeavours. This requires quantifying trends at specific quantiles in distributions of variables such as daily temperature or precipitation. These non-normal distributions vary both geographically and in time. The trends in the relevant quantiles may not simply follow the trend in the distribution mean. We present a method[1] for analysing local climatic timeseries data to assess which quantiles of the local climatic distribution show the greatest and most robust trends. We demonstrate this approach using E-OBS gridded data[2] timeseries of local daily temperature from specific locations across Europe over the last 60 years. Our method extracts the changing cumulative distribution function over time and uses a simple mathematical deconstruction of how the difference between two observations from two different time periods can be assigned to the combination of natural statistical variability and/or the consequences of secular climate change. This deconstruction facilitates an assessment of the sensitivity of different quantiles of the distributions to changing climate. Geographical location and temperature are treated as independent variables, we thus obtain as outputs how the trend or sensitivity varies with temperature (or occurrence likelihood), and with geographical location. These sensitivities are found to be geographically varying across Europe; as one would expect given the different influences on local climate between, say, Western Scotland and central Italy. We find as an output many regionally consistent patterns of response of potential value in adaptation planning. We discuss methods to quantify the robustness of these observed sensitivities and their statistical likelihood. This also quantifies the level of detail needed from climate models if they are to be used as tools to assess climate change impact.

[1] S C Chapman, D A Stainforth, N W Watkins, 2013, On Estimating Local Long Term Climate Trends, Phil. Trans. R. Soc. A, in press

[2] Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones and M. New. 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201