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The Cryosphere Discussions

Interactive comment on "A recent bifurcation in Arctic sea-ice cover" *by* V. N. Livina and T. M. Lenton

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The idea of changing regimes through bifurcations and identification of tipping points in the Arctic climate is interesting and important. Often the complex dynamics is unknown and has to be (attempted) resolved through time series analysis of observed variables. The method developed by Livina and Lenton is in this respect powerful.

Their analysis of the Arctic sea ice area indicates a change from a single state regime prior to 2007 to a two state regime after 2007. This could indicate a bifurcation in the climate system. The essence of their method is to assume the dynamics driven by an effective 1D stochastic differential equation, corresponding to noise driven motion of a mass-less particle with friction in a potential. The potential is solely derived from the probability density derived from the observed time series. This description

has been quite successful in capturing the essential behavior of many time series of observables from high dimensional complex dynamical systems. However, there are obviously situations where this description dos not apply. One example is a harmonic signal (with a small noise), such as any climate signal dominated by the seasonal cycle. The probability density for a signal $x(t) = \sin \omega t$ will be strongly bimodal with $pdf(x) = 1/\cos(\arcsin(x))$, thus with singularities for $x = \pm 1$ (These corresponds to the van Hove singularities in electronic densities of states in a solid).

The authors are well aware of this, thus they analyze the residual ice area signal where the seasonal cycle is removed. The way they remove the seasonal cycle is to remove the cycle obtained from the period 1979-2008 from the whole series 1979-2011. This is a standard procedure, which is fine. However, if the change in the signal is such that the amplitude of the seasonal cycle change through the series a part of the seasonal signal will remain in the residual. In this case the bi-modality found in part of the record could be a result of the seasonal cycle rather than the result of a two state dynamics. The problem is illustrated in Figure 1. Top figure reproduce their residual signal (except that I chose to remove the 1979-2006 seasonal cycle rather than the 1979-2008 cycle). It is, as in their paper, clear to see that the last part of the curve for 2007-2011 (rightmost red part) has a seasonal variation. In the second plot I removed the seasonal cycles obtained from the period 2007-2011. Here it is clear to see that the period 1979-2006 still has a seasonal residual (leftmost red and blue part of the curve).

By doing a poor man's version of their analysis; just calculating the pdf for five year windows of the data (the red part), I confirm their results in the first case (leftmost pdf is uni-modal, while rightmost pdf is (weakly) bi-modal. The two bottom panels show the same analysis for the case where the 2007-2011 cycle is removed. Here it is opposite; the transition is from bi-modal to uni-modal.

Thus the conclusion, that we see a bifurcation should be cautioned, it seems as if we are seeing a change in the seasonal cycle.

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Interactive Comment

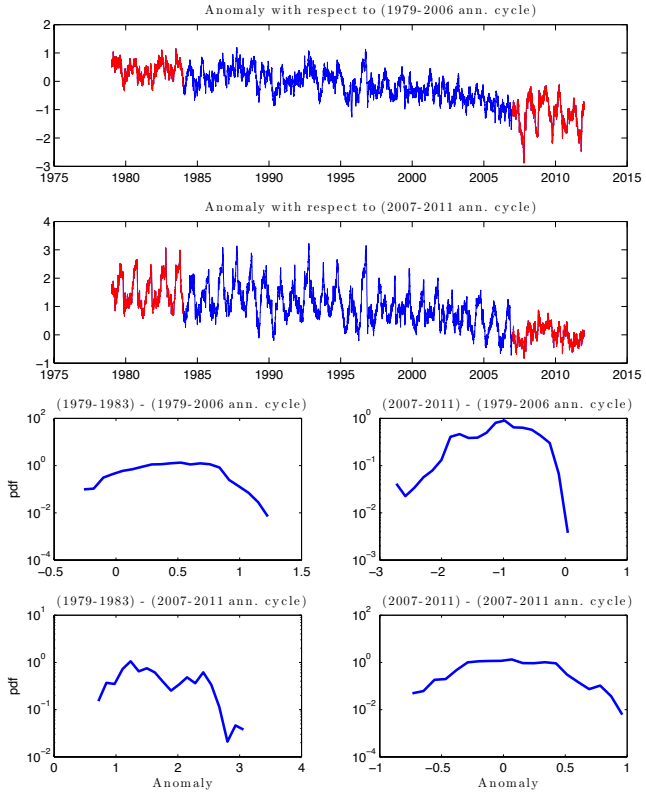

Fig. 1.

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