DETECTING CAUSALITY IN MAGNETOSPHERIC DYNAMICS USING TRANSFER ENTROPY

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Understanding causal relationships in space plasmas is a key ingredient of modeling, but can often be difficult to establish. Frequently, causality is investigated by looking at the cross-correlation and checking for a shift in the peak as a function of lag time or by examining differences in the forward and backwards directions. Some of the shortcomings of this method can be illustrated by cross-correlations that exhibit multiple peaks that are large in the non-causal direction and causal systems that do not exhibit asymmetries in the cross-correlation. Furthermore, cross-correlations only reveal linear dependency and may not be as useful for a nonlinear storage and release dynamics (such as might be expected for the magnetospheric response to the solar wind). An alternative choice for studying causality is the one-sided transfer entropy which is highly directional and accounts for static internal correlations so that it is possible to examine whether two variables are driven by a common driver or whether they are causally connected. We apply the transfer entropy to several test systems to illustrate its utility for detecting causality and to space data to illustrate causality in space systems with examples from solar wind-magnetosphere coupling.

Causality, Magnetospheric Response, Transfer Entropy

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