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Correlated signals and causal transport in ocean circulation

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This paper presents a framework for interpreting the time-lagged correlation of oceanographic data in terms of physical transport mechanisms. Previous studies have inferred aspects of ocean circulation by correlating fluctuations in temperature and salinity measurements at distant stations. Typically, the time-lag of greatest correlation is interpreted as an advective transit time and hence the advective speed of the current. In this paper we relate correlation functions directly to the underlying equations of fluid transport. This is accomplished by expressing the correlation functions in terms of the Green's function of the transport equation. Two types of correlation functions are distinguished: field-forcing correlation and field-field correlation. Their unique relationships to the Green's function are illustrated in two idealized models of geophysical transport: a leaky pipe model and an advective-diffusive model. Both models show that the field-forcing correlation function converges to the Green's function as the characteristic (time or length) scale of forcing autocorrelation decreases. The leaky pipe model provides an explanation for why advective speeds inferred from time-lagged correlations are often less than the speed of the main current. The advective-diffusive model reveals a structural bias in the field-field correlation function when used to estimate transit times.