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Synchronization and Coupling in Climate Networks

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Theoretical and experimental results have established that a network of coupled nonlinear oscillators may synchronize, at some appropriate coupling strength. Once a synchronous state is in place, an increase in the coupling strength may lead to a bifurcation, which destroys the synchronous state. Here we show that this mechanism is present in the climate system and is responsible for major climate shifts. First, we construct a network of observed climate indices in the period 1950–2005 and investigate their collective behavior. The results indicate that this network synchronized at around 1975. The synchronous state was followed by a steady increase in the coupling strength until the system bifurcated and the network was destroyed, upon which a new climate state emerged. This significant event is known as the great climate shift of the 1970s. We have also discovered the evidence for such type of behavior in a 100-yr climate simulation using a state-of-the-art model. During this period, the network becomes synchronized three times. In one of the cases, the synchronous state was followed by a decrease in coupling strength and no climate shift was observed, consistent with the theory. In the other two cases, the synchronous state was followed by an increase in coupling strength and in both these cases a major shift occurred. Thus, the combination of theory, observations and model simulations consistently suggest that synchronization of climate modes followed by an increase in their coupling strength is a mechanism for climate shifts. This is the first time that this mechanism, which is known as the short-wavelength bifurcation, is discovered in a physical system of the size and complexity of the climate system.