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The parametric behavior of the mean state and low-frequency variability.

S. Lee (1), S.-W. Son (2)
The Pennsylvania State University (sl@meteo.psu.edu)

In idealized general circulation model is used to study the parametric behavior of both the zonal-mean flow and low-frequency variability. The parameters are: localized tropical heating (H) and high-latitude cooling (C). The tropical heating controls the intensity of the subtropical jet, while the high-latitude cooling modulates the meridional width of the extratropical baroclinic zone.

The results show that there are two statistically steady regimes in the H-C parameter space. One regime is characterized by a double-jet state that resides only within the small H/large C part of parameter space. The other regime appears when H is large, and is characterized by a single-jet state. A linear theory offers an explanation for this regime behavior, and indicates that the characteristics of the state in each regime depend upon the strength of the subtropical jet. Moreover, the transition across these two regimes is often found to be abrupt. Again, this behavior is consistent with the bifurcation found in the linear theory. The implication is that the degree of climate sensitivity to heat sources/sinks depends on where the climatic state of interest resides in the parameter space. An attempt is made to determine the location of the atmosphere in this parameter space. The result indicates that the observed time-mean flow for the Southern Hemisphere resembles the model atmosphere near the transitional zone.

Perhaps more importantly, systematic changes are also found in the internal variability within each regime. In the single-jet regime (high H), the dominant form of internal variability represents north-south meander of the jet, known as the zonal index. As shown in previous studies, this fluctuation shares a broad resemblance to a red noise process, with a decorrelation timescale of about 10 days. On the other hand, in the double-jet regime (small H/large C), the internal variability is dominated by a remarkably periodic poleward propagation of zonal-mean flow anomalies. Since both

the zonal index and the quasi-periodic poleward propagation have been frequently observed in the atmosphere, the above parametric behavior for the internal variability also suggests that the observed atmospheric flow, as a whole, spans the transitional zone. This possibility is consistent with recent statistical analysis of ‘low-frequency’ variability/teleconnection patterns, and more importantly offers insight into a key inconsistency amongst those results.The physical processes that drive the quasi-periodic poleward propagation of the double jet regime are examined with a reduced version of the same model. It is found that nonlinear wave breaking in low latitudes initiates the poleward propagation. This quasi-steady poleward propagation can be explained by an orchestrated combination of linear Rossby wave propagation, nonlinear wave breaking, and radiative relaxation. In this regime, the potential vorticity gradient is relatively weak. This allows for large particle displacements and wave breaking. Ironically, it is this seemingly chaotic wave behavior that results in the quasi-periodic behavior of the zonal-mean flow. On the other hand, the waves in the single-jet regime are less chaotic, yet the zonal mean flow variability is much less predictable.

In summary, the above analyses, while carried out with an imperfect physical system and an incomplete parameter space, provides a macroscopic view of the climate states, internal variability, and associated physical processes. It is hoped that some of the insights gained in this study can be used for further theoretical development of the nonlinear processes in the climate system.