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Seasonal variability of global atmospheric teleconnection patterns

J.S. Frederiksen (1) and G. Branstator (2)

(1) CSIRO Atmospheric Research, Aspendale, Victoria, Australia (Jorgen.Frederiksen@csiro.au / Phone: +61 3 9239 4683), (2) National Center for Atmospheric Research, Boulder, Colorado, USA (branst@ucar.edu / Phone: +1 303 497 1365)

New and current statistical analysis methods are employed for determining the seasonal variability of large-scale low-frequency global atmospheric teleconnection patterns. The methodologies are applied to long data sets taken from observations and general circulation model (GCM) simulations and are used as validation techniques of the GCMs.

The seasonal variability of 300-hPa global streamfunction fields taken from a 40-year period of reanalysed observations starting on 1 January 1958 and from long 497- and 900-year GCM data sets forced by sea surface temperatures (SSTs) is examined and analysed in terms of empirical orthogonal functions (EOFs), principal oscillation patterns (POPs) and particularly finite-time principal oscillation patterns (FTPOPs). The FTPOPs are the eigenvectors of the propagator, over a one year period covering the annual cycle, that has been constructed by fitting a linear stochastic model with a time-dependent matrix operator to atmospheric fluctuations based on the daily or twice-daily 300-hPa streamfunction data sets.

The leading FTPOPs are large-scale teleconnections patterns and by construction they are the empirical analogues of finite-time normal modes (FTNMs) of linear instability theory. Hence by comparing FTPOPs to FTNMs the study provides insight into the ability of linear theory to explain seasonal and intraseasonal variability in the structure and growth rates of large-scale disturbances. We find that the leading FTPOP teleconnection patterns have similar seasonal cycles of relative growth rates and amplitudes to the leading FTNMs of the barotropic vorticity equation with 300-hPa basic states that change with the annual cycle; largest amplitudes of both theoretical and empirical

modes occur in late boreal winter or early spring and minimum amplitudes in boreal autumn, with the GCM-based FTPOPs having additional secondary maxima in early boreal summer. In each month, there are leading POPs and EOFs that closely resemble the leading FTPOPs. As well, the growth rates of leading FTNMs and FTPOPs during each season are generally similar to those of respective leading normal modes and POPs calculated for that season. Thus the perturbations are reacting to the seasonally varying basic state faster than the state is changing and this appears to explain why linear planetary wave models with time-independent basic states can be useful. Nevertheless, *intermodal* interference effects, as well as *intramodal* interference effects between the eastward and westward propagating components of single travelling modes, can play important roles in the evolution of FTPOPs and FTNMs, particularly in boreal spring.

We have examined the roles of internal instability and interannual SST variability in the behavior of leading FTPOPs. We have also used comparisons of FTPOPs and FTNMs for GCM simulations with and without interannually varying SSTs to assess the role of internal instability and SST variations in organizing interannual atmospheric variability. The comparison indicates that both factors are significant. Our results also support a close relationship between the boreal spring predictability barrier of some models of climate prediction over the tropical Pacific Ocean and the amplitudes of large-scale instabilities and teleconnection patterns of the atmospheric circulation.