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The role of dynamical instability vectors in atmospheric dynamics and predictability

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The roles of dynamical instability vectors in atmospheric dynamics and predictability are discussed. The focus is on the genesis of large-scale disturbances on evolving atmospheric states and their analysis in terms of finite-time normal mode instability theory. Three applications of the theory are discussed.

Firstly, the structural organization of initially random perturbations evolving in baroclinic and barotropic tangent linear models with time-dependent flows taken from observations is examined in cases of block development, maturation and decay. Statistical results relating the structures of evolved perturbations to leading finite-time normal modes (FTNMs), singular vectors (SVs) and Lyapunov vectors (LVs) are presented for periods ranging from a few days to several weeks.

Secondly, the properties of modes of the barotropic vorticity equation with time-dependent 300-hPa observed global basic states covering the complete annual cycle are analyzed. The leading FTNMs are found to be large-scale low-frequency modes with largest growth rates in early northern winter and largest amplitudes in boreal spring.

Finally, the seasonal variability of finite-time principal oscillation patterns (FTPOPs) is examined based on 300-hPa global streamfunctions from reanalysed observations and general circulation model data sets forced by sea surface temperatures. The leading FTPOPs are large-scale teleconnections patterns that are the empirical analogues of FTNMs of linear instability theory. They have similar annual cycles of relative growth rates and amplitudes to the leading FTNMs of the barotropic vorticity equation. In each month, there are also leading principal oscillation patterns and empirical orthogonal functions that closely resemble the leading FTPOPs. It is found that there

is a close relationship between the boreal spring predictability barrier of some coupled models of seasonal climate prediction and the amplitudes of large-scale FTNM instabilities and FTPOP teleconnection patterns of the atmospheric circulation.