# *Observed Modes of Storm Track Variability and their Relationship to the Background Flow on Daily and Monthly Time Scales*

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Extratropical atmospheric variability is dominated by fundamental modes (e.g., the North Atlantic Oscillation: NAO / Northern Annular Mode: NAM, Pacific North America: PNA pattern and the Southern Annular Mode: SAM) at monthly and longer time scales. Month-to-month variability in observed storm tracks is, however, also dominated by primary "pulsing" and secondary "latitudinally shifted" modes over ocean basins in each hemisphere. The pulsing mode overlays the climatological storm track while the latitudinally shifted mode straddles the mean. These patterns are useful simplifications of the full variability in the storm track and are ubiquitous through the depth of the troposphere using a variety of indicator variables. Both are considered to be fundamental modes of climate variability. Even in the Southern Hemisphere, the zonal extent of these modes is mostly limited to the ocean basin over which they are analyzed. Similarly coherent and dynamically intuitive modes are not generally obtained if the analysis is performed over all longitudes in either hemisphere.

At monthly time scales, both the pulsing and latitudinally shifted modes are associated with zonal wind / geopotential height anomalies consistent with acceleration of the zonal wind by the eddies, though the patterns associated with the latitudinally shifted mode are stronger and more closely linked to the dominant modes of background flow variability. At daily time scales, positive values of the pulsing mode index are associated with an evolution of observed zonal wind anomalies that shift poleward over a storm's life cycle much like those in idealized life cycle experiments. The evolution of these shifting zonal winds is spatially and temporally consistent with momentum forcing of the background flow by eddies. It is therefore hypothesized that the dominant modes of low-frequency flow variability are coherently linked to the combined momentum forcing associated with both the "pulsing" and "latitudinally shifted" storm track modes averaged over a month. If this is true, the relative prominence of the latitudinally shifted mode in month-to-month variability and its stronger association with the fundamental modes of climate variability (e.g., the NAO/NAM, PNA and SAM) could be a reflection of the positive eddy-mean flow feedbacks that exist when the zonal winds (and the storm tracks) are anomalously poleward.