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## Unlocking the dynamics of extreme wind speeds of North Atlantic storms

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North Atlantic extra-tropical storms are some of the most severe weather systems, causing enormous economic damages and threatening human lives. In general, these storms are characterized by strong cyclonic convergent surface winds, upward vertical flow, and precipitation. In specific confined areas inside the storm where downward flows occur with clear sky, extreme surface wind speeds are observed. Such a horizontal variation of vertical wind direction and surface wind speed can cause severe and damaging impacts; however, the underlying key dynamics are not understood. Here we show the dynamical and thermodynamical linkage between the horizontal wind impinging on the frontal surface at the lower troposphere, downward flow, and very intense surface wind speeds inside the storm. The anti-clockwise cyclonic wind into the cold frontal area is mainly responsible for generating the downward flow, which transports the high-altitude horizontal momentum to the surface layer causing intense surface wind speeds. About half of North Atlantic storms accompany the downward wind, and that downward flow is more frequently observed in the southern and western part of the storm center. Overall results illuminated in this paper have a far-reaching impact in multiple ways to enhance forecasting skills for devastating weather events associated with extra-tropical storms.