Western Region Technical Attachment
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JETS AND SEVERE CONVECTION IN THE WEST

The number of severe convective events that appear somehow connected to a nearby "jet" is no coincidence. In most cases in the West, the jet is at high levels, usually near 250 mb or 300 mb. In the central and eastern United States, a low-level jet is often cited as one cause of severe convection, and at times the interaction between a high-level and low-level jet has been documented as a significant factor in development of widespread severe convection (Uccellini and Johnson, 1979). This Technical Attachment will briefly discuss the relationship between jets and severe convection. A more thorough (but still relatively brief) treatment of this subject may be found in a preprint from the 1990 AMS Severe Local Storms Conference in a paper by Uccellini.

High-level Jets

The feature of interest is actually referred to as a jet streak, which is defined as an isotach maxima embedded within a jet stream. The significance of a jet streak to severe convection is three-fold:

1. Upper-level jet streaks are associated with vertical motion that may provide enough lift to release potential instability and hence initiate thunderstorms.

2. The upper-level divergence pattern associated with a high-level jet streak may create a low-level pressure pattern that results in enhanced low-level transport of warm, moist air, thus, further destabalizing the pre-convective environment.

3. Strong upper-level winds result in a vertical shear profile that is favorable for the generation and maintenance of tilted, long-lived thunderstorms which are capable of producing severe weather.

The vertical motion associated with a jet streak is due to the fact that the jet streak itself does not move as fast as the air. In other words, an isotach maximum of 100 knots does not move along in the flow at a speed of 100 knots. Thus, air moves into, through, and out of a jet streak. Hence, the terminology, entrance region of the jet for the upstream side of a jet streak, and, conversely, the downstream side of a jet streak is referred to as the jet exit region. Air entering the jet must accelerate, while air in the exit region decelerates. In order to accelerate, air will move towards lower pressure (turn to the left), while in the exit region air will decelerate by moving towards higher pressure (to the right). These departures in direction result in divergence and convergence patterns associated with a straight jet streak which are familiar to most forecasters as the "four-quadrant jet pattern". Another way to look at it which may be familiar to many forecasters is to visualize vorticity maxima and minima on either side of the jet streak and note the areas of PVA and NVA (Fig. 1). Since most jets are not exactly straight, the four-quadrant argument is only a rough approximation. When looking at gridded model output, it is possible to examine the geostrophic, ageostrophic, and total wind separately. In cases with a jet streak, the ageostrophic wind can be seen to be directed to the right of the total wind in the exit region and vice versa in the entrance region, as might be expected from theory.

The second factor listed above is really a further consequence of the divergence pattern associated with jet streaks. Areas beneath high-level divergence will experience pressure falls as mass is evacuated from the column. The pressure falls result in isallobaric accelerations in the low-level wind which in some cases may be realized as a low-level jet. In areas where moist air is present near the surface, this increase in low-level flow will often result in moisture convergence and decreased stability. Furthermore, it can be argued that this low-level flow or air will be rising since it will be following isentropes if unsaturated (it is moving adiabatically), and in cases of saturation, the diabatic heating will also produce ascent (Fig. 2). This process is referred to as jet interaction or jet coupling. Documented cases of this jet interaction in severe convection have all been east of the Rocky Mountains. It is somewhat difficult to identify low-level jets in the complex terrain of the West, but they do exist, and in some cases are enhanced as air is channeled by the topography. A study of low-level jets by Bonner (1968) actually identified a local maximum in low-level jet occurrence at Seattle, and although higher elevation sites were not included in the study, they undoubtedly exist. However, in most cases in the West, the air being transported and lifted is relatively dry and may not be a significant factor in the development of severe convection.

Finally, jet streaks will produce vertical speed shear in the wind profile. This shear is a key factor in whether a thunderstorm will be tilted or not. If it is tilted, then the updraft and downdraft are more likely to coexist side-by-side, producing a longer-lived cell. The longer a cell persists, the greater likelihood of producing large hail and other severe weather. In an environment with little vertical shear, the storm will not be tilted and the updraft will be destroyed by the downdraft as precipitation begins to fall out of the storm. These storms typically last an hour or less, and the only severe weather they are likely to produce would be due to microburst-type winds if the low-levels are dry and nearly adiabatic.

Summary

If the sufficient instability exists to support convection, the addition of an upper-level jet streak may be just the extra feature necessary to produce severe convection.

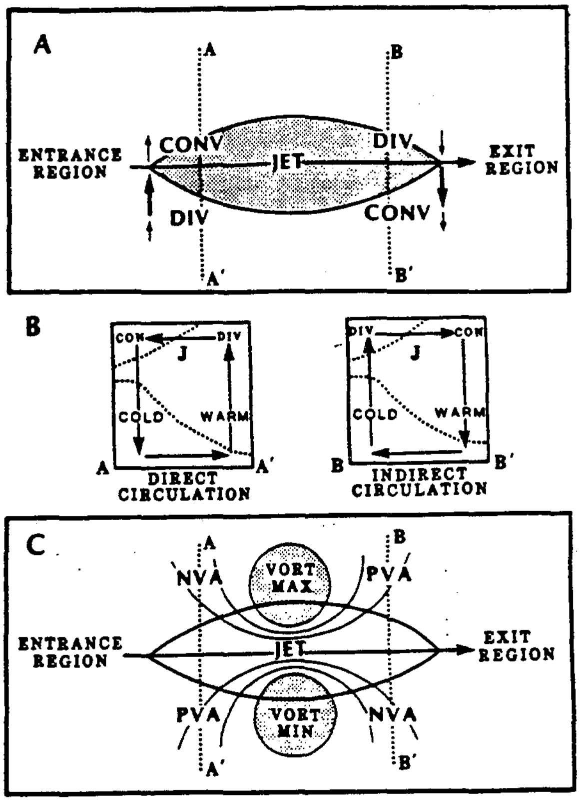
References

Bonner W. D., 1968: Climatology of the low level jet. *Mon. Wea. Rev.*, **96**, 833-850.

Uccellini, L. W., 1990: The relationship between jet streaks and severe convective storm systems. Preprints, 16th Conf. Severe Local Storms. *Amer. Meteor. Soc.*, Boston, MA., 121-130.

Uccellini, L. W., and D. R. Johnson, 1979: The coupling of upper- and lower-tropospheric jet streaks and implications for the development of severe convective storms. *Mon. Wea. Rev.*, **107**, 682-703.

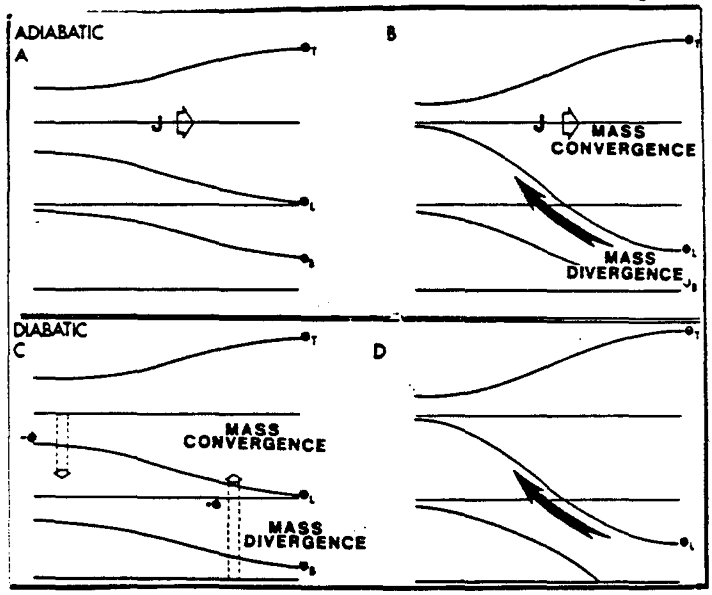
Readers may wish to consult the bibliography of the second reference for further reading about both upper- and lower-level jets.



(a) Schematic of transverse ageostrophic wind components and patterns of divergence associated with the entrance and exit regions of a straight jet streak [after Bjerknes (1951)]. (b) Vertical cross sections illustrating direct and indirect circulations in the entrance region [along dotted line labeled A–A' in (a)] and exit region [along dotted line labeled B–B' in (a)] of a jet streak. Cross sections include two representative isentropes (dotted), upper-level jet location (marked by a J), relative positions of cold and warm air, upper-level divergence, horizontal ageostrophic components, and vertical motions (arrows) within the plane of each cross section. (c) Schematic of maximum (cyclonic) and minimum (anticyclonic) relative vorticity centers and associated advection patterns associated with a straight jet streak. (NVA represents negative or anticyclonic vorticity advection. PVA represents positive or cyclonic vorticity advection.)

(After Uccellini and Kocin, 1987)

Fig. 1



A-B: Vertical cross section normal to axis of jet (J) showing adiabatic mass transports (light arrow in A) in exit region of approaching jet streak and resultant isallobaric wind (heavy arrow in B). C-D: Diabatic mass transports contributing to isallobaric wind (heavy arrow in D).

(After Uccellini, 1990)

Fig. 2