10.1 ON THE IMPORTANCE OF PROCESSES IN THE DRY AIR UPON CONVECTIVE INITIATION ALONG THE DRYLINE

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1. INTRODUCTION

The dryline is known to be a favored boundary for the initiation of thunderstorms during spring months within the Great Plains region of the United States. Relatively little is known, however, concerning the mechanisms affecting the exact location and timing of thunderstorm development along the dryline if initiation does indeed occur on a given day. During the spring of 1991 an intensive field program was conducted over portions of Oklahoma, Texas, and Kansas that specifically addressed the question of why storms formed at specific along-line locations. Data from research aircraft, mobile sounding platforms, and special surface mesonetwork sites were combined with operationally available data sets to address this question. On three operational days, in particular, intensive observations were collected when severe convection developed along the dryline. On each of these days a process or processes in the dry air (west of the dryline) were identified that influenced the location of thunderstorm development. Interestingly, these processes were different on each day. This paper summarizes observational analysis and modeling research carried out roughly over the last decade that addressed (among other things) these dry air processes.

2. CASE STUDY DAYS

2.1 *26 May 1991*

On 26 May 1991 a north-south dryline was located over the eastern portion of the Texas Panhandle (Fig. 1). A cluster of tornadic thunderstorms formed during late afternoon near the Texas-Oklahoma border in the north-

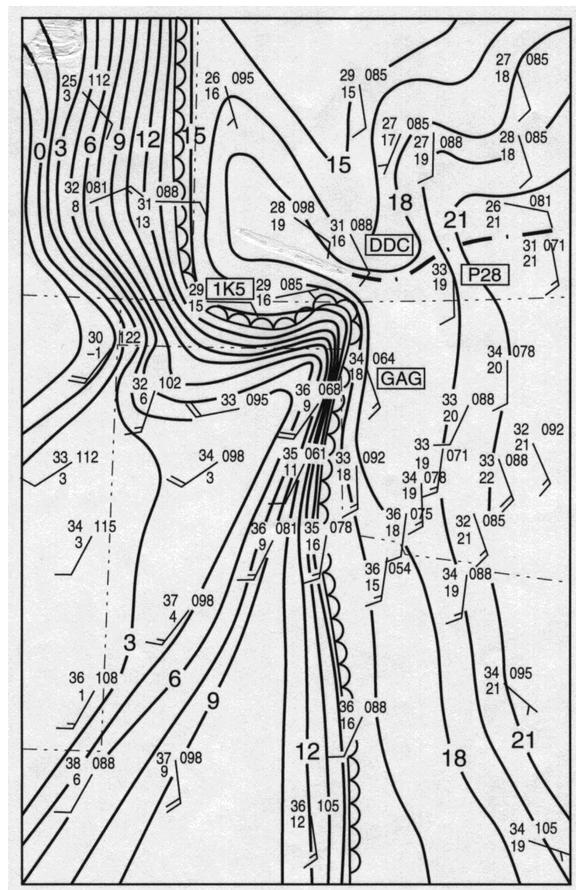

Figure 1. Surface dewpoint (°C) analysis at 2100 UTC on 26 May 1991. Dryline is denoted by scalloped line.

east part of the panhandle and moved into northwest Oklahoma. Initiation occurred at the intersection of the dryline and a convergence line (observed by aircraft and characterized by a convective cloud line) that extended west-southwestward from the intersection point. The convective cloud line can be seen in the visible satellite image (Fig. 2), generally to the west of more vigorous convection beginning to develop along the dryline. Measurements from a research aircraft were analyzed to produce the mesoscale divergence field near the intersection of the dryline and

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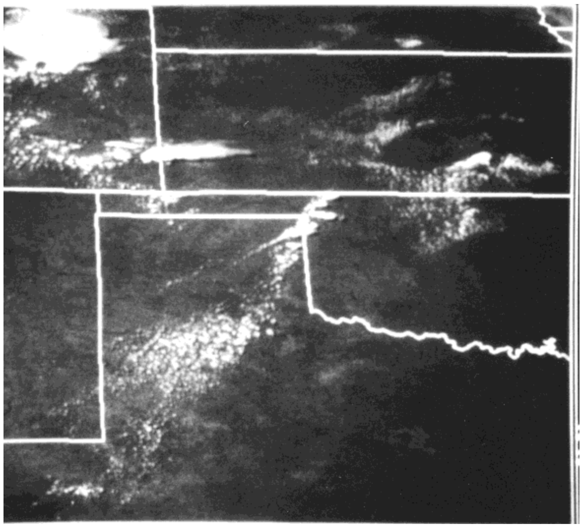

Figure 2. Visible GOES-7 satellite image at 2101 UTC on 26 May 1991.

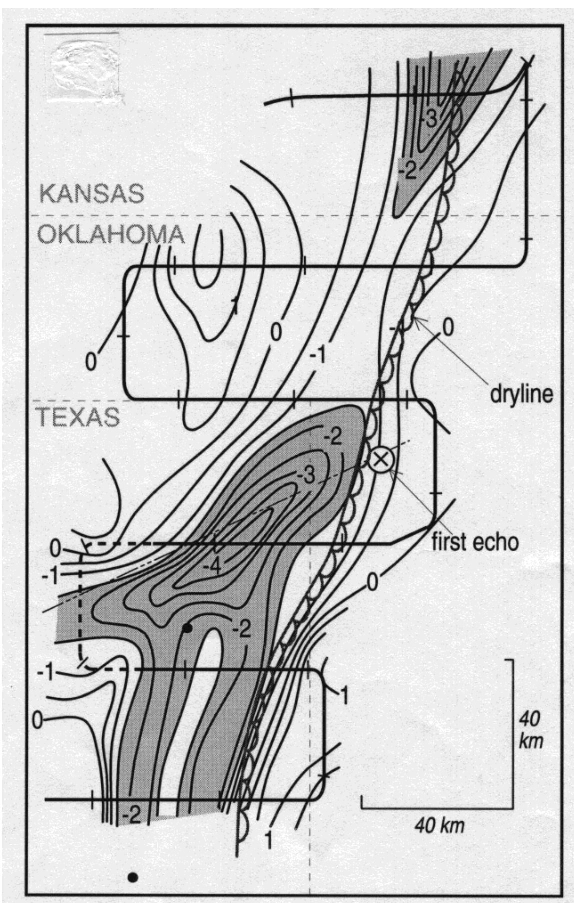

Figure 3. Analyzed divergence field (10^{-4} s^{-1}) from aircraft sawtooth pattern (heavy solid line) flown at 860 hPa. Divergence values less than $-1.5X10^{-4}$ s^{-1} are shaded. Dryline and convergence line are denoted by scalloped and dash-dotted lines, respectively.

convergence line (Fig. 3). The general convergence along the dryline can be seen as well as the enhanced convergence near the intersection point.

The convergence line very likely formed in response to heterogeneities in the underlying surface characteristics in the along line direction. Specifically, the surface was covered with sparse vegetation over about 100 km in the north-south direction (Canadian River Valley) west of the dryline with more vegetated areas both to the north and south. Over this dryer area the atmosphere heated more efficiently, as verified by infrared measurement of surface temperature via satellite (Fig. 4). Vertical mixing was therefore

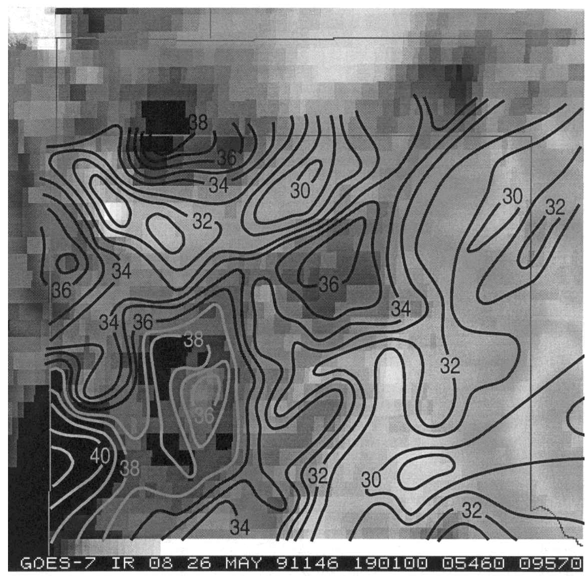

Figure 4. Surface radiative temperature from GOES-7 infrared image on 26 May 1991 at 1901 UTC. Darker shades indicate warmer temperatures; white areas are cloud. Smoothed contours of temperature (^{o}C) are included in cloud-free areas.

more efficient over this region. This resulted in preferential downward transport of westerly momentum over the same area (as verified by the presence of a mesoscale dryline bulge) in comparison to surrounding areas, and a line of convergence along the southern edge of the sparsely vegetated area within the dry air.

2.2 *16 May 1991*

In the second case (16 May 1991) the dryline extended southward from a surface low that was associated with a translating upper level trough. A surface analysis at 20 UTC is shown in Fig. 5. During midday the dryline

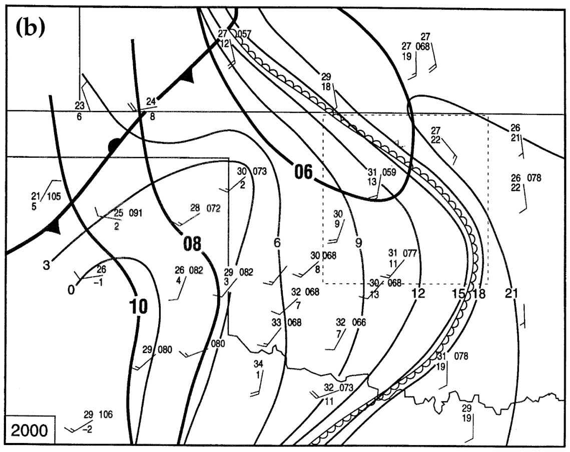

Figure 5. Surface dewpoint (^{o}C, thin solid) and pressure (hPa, heavy solid) analyses at 2000 UTC on 16 May 1991.

moved rapidly across western Oklahoma and a synoptic scale bulge developed. In the early afternoon (between 1900 and 2000 UTC) a discontinuous "jump" in position took place wherein a second dryline developed farther east while the original one to the west lost definition. This displacement along with the motion of the dryline both earlier and later is illustrated in Fig. 6. A "jump" back to the west is also indicated in the late afternoon. The rapid motion of the dryline was determined to

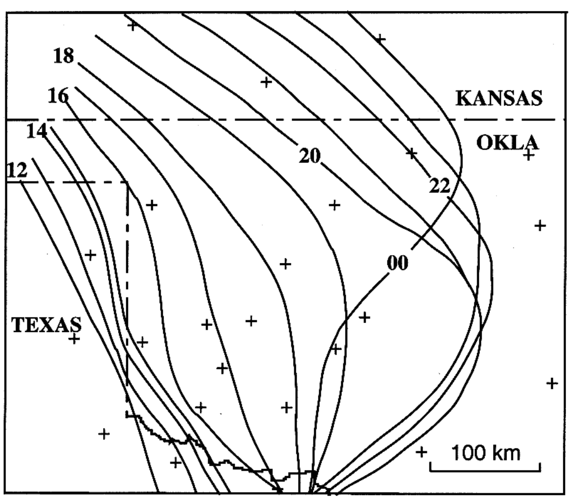

Figure 6. Isochrone analysis of dryline location on 16 May 1991. Surface station locations are also indicated (+).

be a result of horizontal advection of dry air aloft in combination with vertical mixing. The dynamics associated with the "jumps" remains open to speculation.

To the north of the bulge an elongated swath of cooler air oriented approximately normal to the dryline was present and resulted from the passage of thunderstorms over the swath during the previous night (Fig. 7). Just to the south of the cool swath and just west of the dryline, preferential warming was observed through the depth of the boundary layer by aircraft (Fig. 8a) and by satellite (Fig. 7).

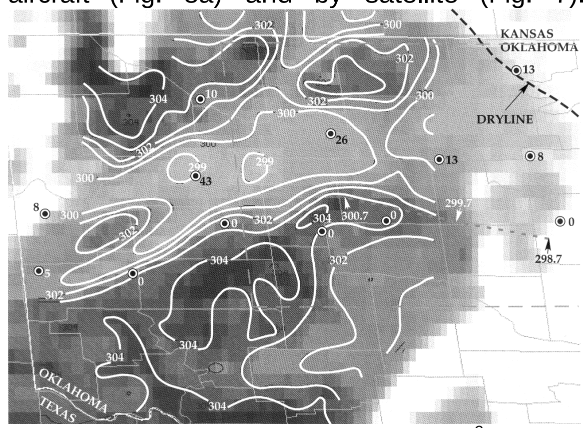

Figure 7. Surface temperature (^{o}K) from infrared satellite measurement at 2201 UTC indicated by shades of gray, where darker areas are warmer. Contours at 1^{o}K intervals are added. Dryline location is indicated. Points marked by double circles denote rainfall total (mm) during the past 24 hours.

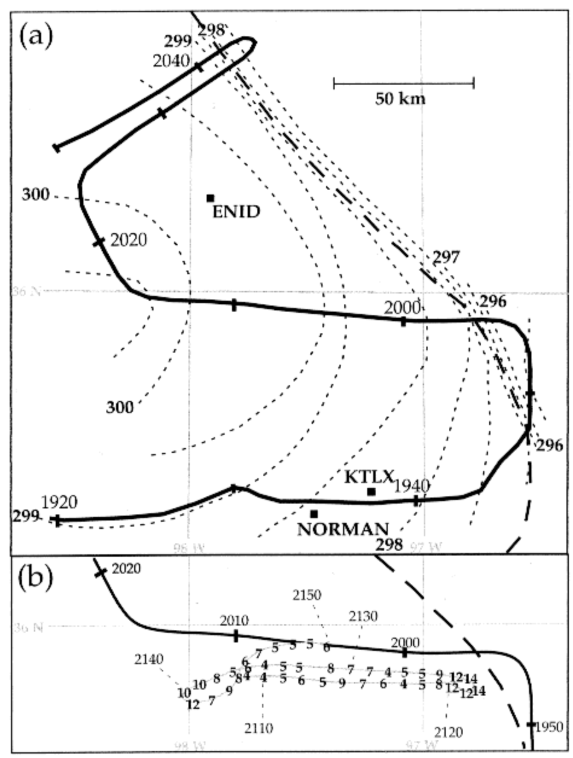

Figure 8. (a) Temperature (^{o}K, dashed) pattern at about 930 hPa from aircraft data along track shown (solid). (b) Temperature change (0.1^{o}K) over about 90 minutes.

Fig. 8b is included to show that temperatures warmed significantly in this region during roughly the 2100-2200 UTC period. Both the aircraft data and the satellite measurements indicated an area west of the dryline (long-dashed line in Fig. 8) where temperatures were significantly warmer than adjacent areas to the north and south. Lowered pressure in this warm area just west of the dryline bulge likely backed the winds ahead of the dryline and produced enhanced convergence along a short dryline sector (consistent with pronounced clear air radar return along this sector, not shown). As a result this sector was an along-line location where thunderstorms developed.

Convective cloud development was suppressed along the section of the dryline that passed over the cool swath, owing to increased latent heat flux and reduced sensible heat flux over the wetted soil, and consequently a shallower and more moist boundary layer. On the north side of the cool swath along the northern border of Oklahoma another cluster of thunderstorms developed at the intersection of the dryline and a short cloud line that extended into the dry air. Low-level convergence was enhanced at this

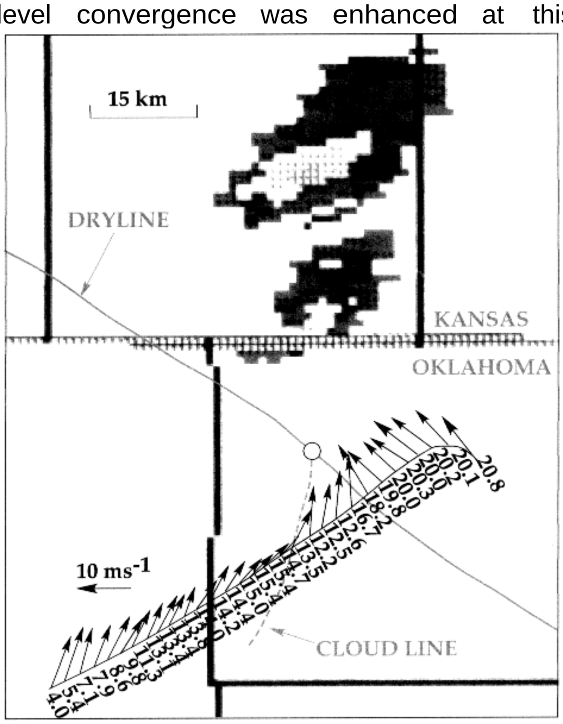

Figure 9. Reflectivity (maximum greater than 45 dBZ) at 2039 UTC on 16 May 1991 along with an aircraft leg that intersected both the cloud line and dryline (2040 UTC). Dewpoint temperature (^{o}C) and wind vectors are indicated along the flight leg at 20-s intervals.

intersection as verified by aircraft measurements (Fig. 9). The short cloud line existed for 2.5 hours prior to the development of deep convection, and appears to have originated over the region that received the heaviest rainfall on the previous night. The mechanism responsible for development of this short line is unknown, but likely related to enhanced evaporation of water from the very wet surface in this locale linked with some unidentified process producing low-level convergence along a line segment.

2.3 *15 May 1991*

On a third day (15 May 1991) another quiescent north-south dryline was located in the eastern Texas Panhandle (Fig. 10). The MM5 model was run in triple-nested (18, 6, and 2 km grid spacings) format from initial conditions specified on the large scale at 12 UTC that morning in an attempt to simulate the

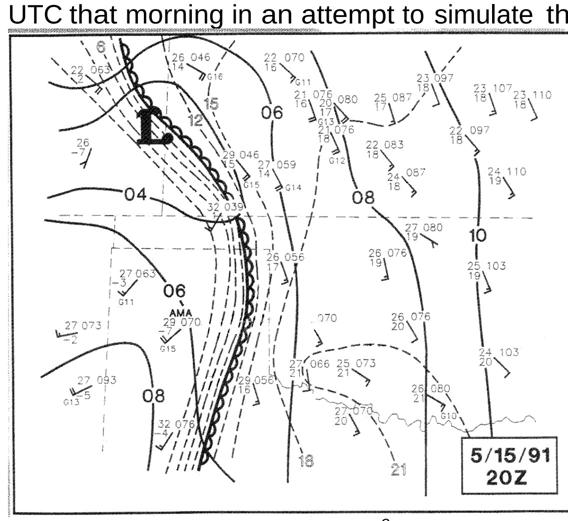

Figure 10. Surface dewpoint (^{o}C, dashed) and pressure (hPa above 1000, solid) at 20 UTC on 15 May 1991.

dryline location and convective initiation along it. The simulation produced a late afternoon dryline that was about 30 km farther west than observed, and deep convective initiation occurred about 90 minutes earlier in the simulation than was observed by radar. The character of modeled and observed convection (scattered line) was similar.

Prior to convective initiation the simulation included pronounced boundary layer horizontal convective rolls in the dry air west of the dryline (Figure 11). Deep convection first occurred just east of the dryline near the intersections of particularly vigorous rolls and the dryline. The downdraft portion of the roll circulations to the immediate west of the

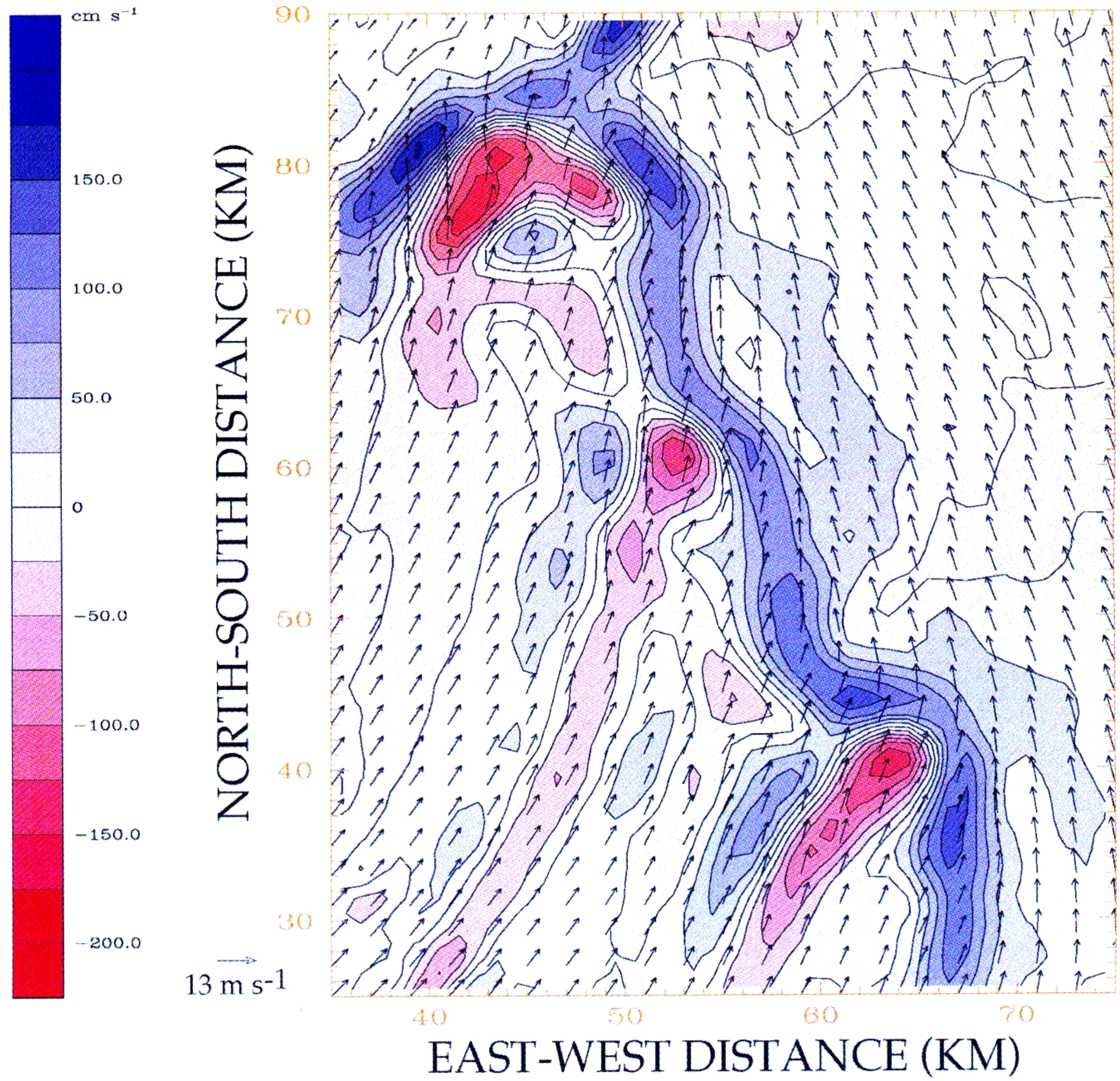

Figure 11. MM5 model vertical velocity at 2 km MSL (red downward and blue upward) over a 40 X 65 km^2 region containing the 15 May 1991 dryline. Range in values is from –2 to +2 m s^{-1}.

surface dryline appears to have preferentially transferred westerly momentum from aloft to the surface, as indicated by mesoscale bulges in the dryline near these roll intersections. Enhanced low-level convergence and upward motion ahead of these bulges appear to have provided a favorable environment for convective initiation. Unfortunately, the initiation region of the observed convection was not within range of any radar that could sample clear air return.

3.SUMMARY

The common thread among all these dryline storm initiation cases is that processes in the dry air (in a variety of forms) appear to have increased low-level convergence in local areas along the dryline leading to convective initiation. These processes included differential heating owing to differences in vegetative character and differences in liquid water available for evaporation on the earth's surface. In another case horizontal convective roll development in the dry air appears to have been important.

Additional details concerning these analyses are available in the following papers: Hane et al. (1993, 1997, 2001, 2002), Richter and Hane (2003), and Hane (2004).

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