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MCS DEVELOPMENT WITHIN CONTINENTAL-SCALE ELONGATED DRY FILAMENTS IN GOES WATER VAPOR IMAGES

Edward I. Tollerud, Fernando Caracena, Adrian Marroquin[1], and Steven E. Koch
NOAA Research-Forecast Systems Laboratory
Boulder, Colorado
[1][in collaboration with the Cooperative Institute for Research in the Atmosphere (CIRA),
Colorado State University, Fort Collins, Colorado]

Jennie L. Moody and Anthony J. Wimmers
University of Virginia, Charlottesville, VA

1. INTRODUCTION

GOES water vapor images frequently show exceptionally dark filaments, ranging in size from short “dry slots” curling into cyclonic centers to equally narrow but very long regions extending longitudinally for many hundreds of kilometers. The implied midlevel dryness within these filaments suggests air with a history of subsidence. Furthermore, the largest of these longitudinal filaments indicate the presence of a jet stream immediately to the south, and recent studies show them to be closely collocated with similarly shaped filaments of enhanced potential vorticity (“PV streamers”) on the cyclonic side of the jet. Occasionally there is dramatic convective development over the central United States within and toward the nose of the streamers/filaments. For instance, Caracena *et al*. (2000) and Tollerud *et al*. (2000) describe such a filament which persisted across the western U. S. for six days and spawned large mesoscale convective systems (MCSs) on four of those days (Fig. 1). As the winds and the contours of pressure on the 2 PV-unit surface on Figure 2 demonstrate, the filament coincides with an undulating PV surface that is slightly subsided relative to its surroundings over the southern borders of Utah and Colorado in the western U.S. To the east, three distinct regions of strongly lowered PV are found. The westernmost of these regions, over eastern Kansas, coincides with the western edge of a large MCS that produced heavy rainfall and flooding in the Kansas City area. The other two regions, one over southern Illinois and another extending from central Alabama into Georgia, are also associated with areas of convection. Both appear to be the result of residual midlevel PV from the previous day that drifted eastward overnight and redeveloped during the next heating cycle.

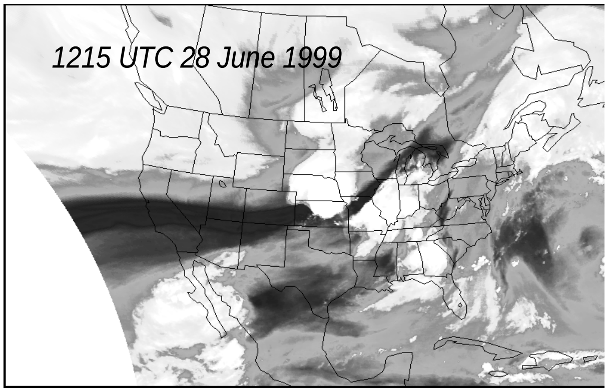

Fig. 1. GOES 8 water vapor image. Light colors indicate clouds and high water vapor content; black indicates low values of integrated water vapor. Figure taken from Caracena et al. (2000).

As this particular case of serial MCSs and a long-lived streamer suggest, filaments of this kind and the PV streamers they imply may have prognostic value as an indicator of likely MCS development. Previous studies of smaller-scale potential vorticity structures in Europe have reached the same conclusion. Appenzeller and Davies (1992) and Appenzeller *et al*. (1996), for instance, relate lee cyclogenesis to features of the upper level PV fields, and Massacand *et al*. (1998) suggest that the occurrence of PV streamers may be useful as precursor signals for heavy precipitation in the lee of the Alps. Mansfield (1994) describes a possible way to make operational model corrections using dry zones on water vapor imagery. Rodgers *et al.* (1988) present analyses and possible explanations of a large MCS that formed within a dry filament.

The value of this particular kind of mesoscale “trigger” is of course dependent on the frequency with which it occurs. Thus, a first step toward determining forecast utility for dry filaments in water vapor imagery is at least a qualitative assessment of their ubiquity. In this paper we follow water vapor

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Corresponding author address: Edward Tollerud, NOAA/FSL, R/FS1, 325 Broadway, Boulder, CO 80305-3328. E-mail: tollerud@fsl.noaa.gov. Tel: 303-497-6127.

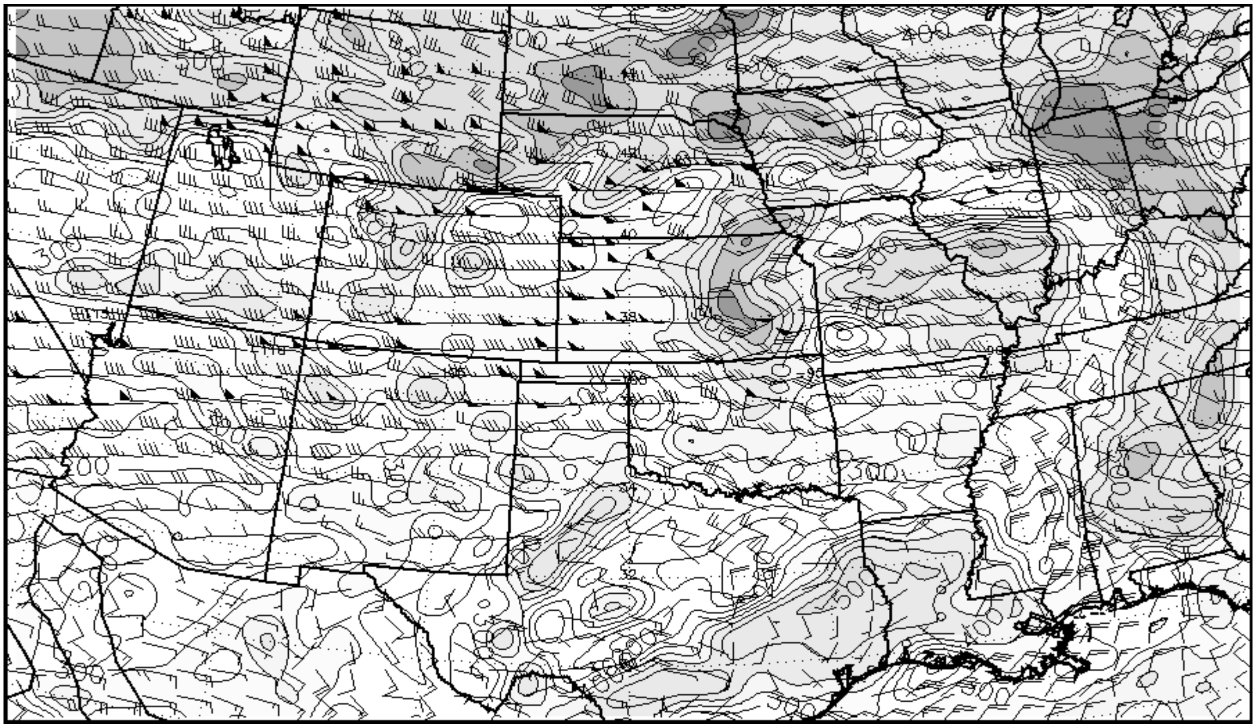

Fig.2. Atmospheric pressure (hPa) and winds on the 2-PV-unit (K $kg^{-1}s^{-1}10^{-6}$) surface at 1200 UTC 28 June 1999 as analyzed from Eta-Model initialization fields. Pressure contour intervals are 50 mb; white areas are above 300 hPa while areas of darkest shading are below 550 hPa.

imagery during several months of 2001 and present representative images of the exceptionally large or persistent filaments that also seemed related to significant MCS development. In addition to becoming a seasonal inventory of sorts, these cases also serve as a set of days for which future detailed analyses of the associated meteorological fields may help to explain the elusive physical mechanisms that relate the dry filament, the PV streamer, and subsequent MCS development.

2. MCS'S AND FILAMENTS DURING 2001

During the period April to July 2001, there were roughly six episodes of a persistent (two days or longer) continental-scale dry filament over the U.S. with associated MCS development. One of these episodes(July15-20)persisted for six days. Imagery for several of these cases are displayed in Figures 3-5.

The early-season (mid-April) example shown in Figure 3 extends essentially east-west across virtually the entire U.S. Its orientation and the coinciding PV contours are reminiscent of the 1999 case discussed in the Introduction and displayed on Figure 1. In contrast, the filament on 20 July (Fig. 4) has a pronounced latitudinal component, following the upper-level flow around the persistent midcontinent ridge that developed during this period. This streamer produced MCSs at its terminus in Minnesota and southern Canada for several consecutive nights.

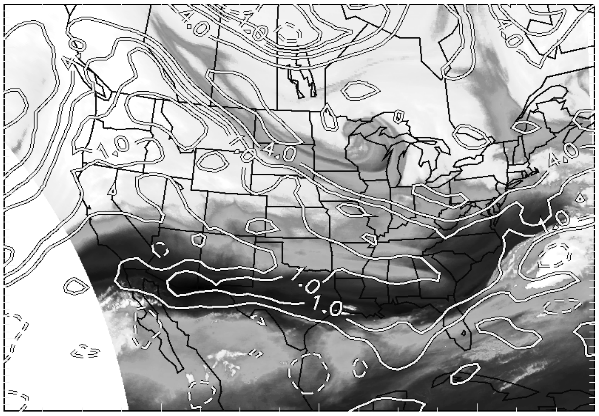

Fig. 3. As in Figure 1 except for 0000 UTC 16 April 2001. Contours of potential vorticity (PV units; K $kg^{-1}s^{-1}10^{-6}$) are superposed.

The third example (Fig. 5), from 22 April, is displayed using altered water vapor (AWV; Moody *et al.*, 1999) imagery. The AWV is a derived product that represents a vertically weighted average of specific humidity at a fixed pressure layer in the mid-to-upper troposphere. The weighting function that represents the derived product's sensitivity to water vapor covers the pressure levels of approxi-

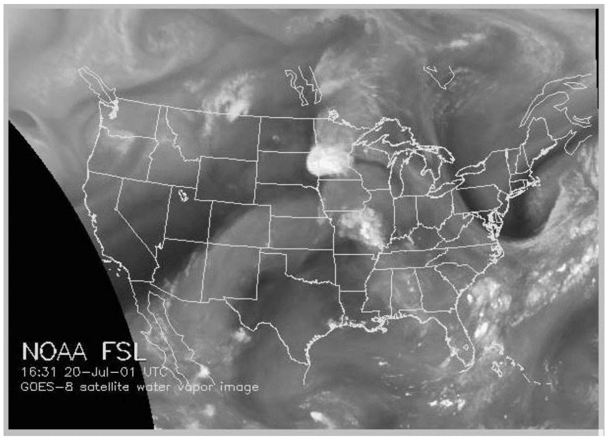

Fig. 4. GOES-8 water vapor imagery from 1630 UTC 20 July 2001.

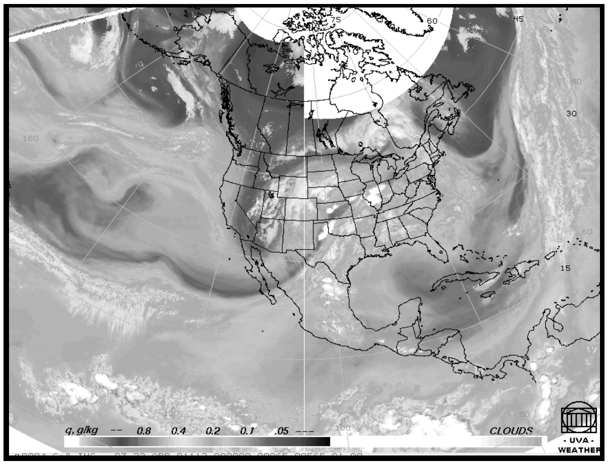

Fig. 5. Mid-to-upper tropospheric specific humidity at 0000 UTC 22 April 2001. See text for explanation.

mately 200 to 500 hPa, with a peak sensitivity at 400 hPa. It is developed from the water vapor channel and ancillary temperature fields from the 6-h MRF. In the color images, specific humidity varies logarithmically along a cool-to-hot colorscale, with a mask of high-level clouds in greyscale according to cloud-top temperature. The natural advantage of the AWV product is that it contains information on humidity variations at the same resolution as the water vapor channel, but does not carry the influences of atmospheric temperature and zenith angle that happen to compromise the interpretability of the image as a depiction of water vapor. The larger domain in the figure reveals that the filament is an extension of a much larger feature of the large-scale flow pattern. At the time of this observation, organized convection in the center of the thin filament is forming over Texas, Oklahoma, and Kansas.

3. TROPICAL STORM ALLISON

Figure 6 reveals another fascinating feature of water vapor and upper-level potential vorticity fields during 2001. Tropical Storm Allison (shown in the figure) and, to a lesser extent, Barry, were located downstream from regions of dry air with high PV. Although not as clearly a dry filament as the other examples, these regions were nonetheless prominent features during much of the lives of these storms. As with earlier studies of Hurricane Floyd, there is strong circumstantial evidence to suggest that the surprising longevity of and rainfall in these storms derived in part from the existence of these upstream regions. Confirmation of this hypothesis awaits closer analysis of the corresponding wind and thermodynamic fields.

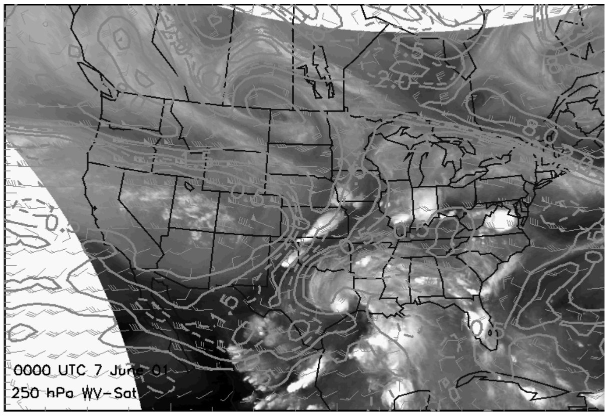

Fig. 6. GOES-8 water vapor imagery and 250 hPa potential vorticity (PV units; K kg^{-1}s^{-1}10^{-6}) at 0000 UTC 7 June 2001. Potential vorticity contours are shown at .5 PV-unit intervals.

4. CONCLUSIONS

In this paper we have discussed the possibility that MCSs form preferentially within long, narrow filaments of dry, and PV-rich, subsiding air. The examples shown do not in themselves, however, offer a pysical explanation for how this works. On the contrary, it might seem more likely, as Thiao *et al*. (1993) suggest, that MCSs would form at the terminus of filaments (more often called plumes) of *moist* air. A clue to how the MCSs might have evolved in the dry air is provided by the Fort Worth profile (Fig. 7) denoted by a white asterisk within the dry filament of Figure 8 shortly before a convective system developed. Lifting of parcels into the nearly adiabatic layer between 450 and 550 hPa could have been the critical factor leading to strong convective development, particularly in this region of very favorable vertical wind shear.

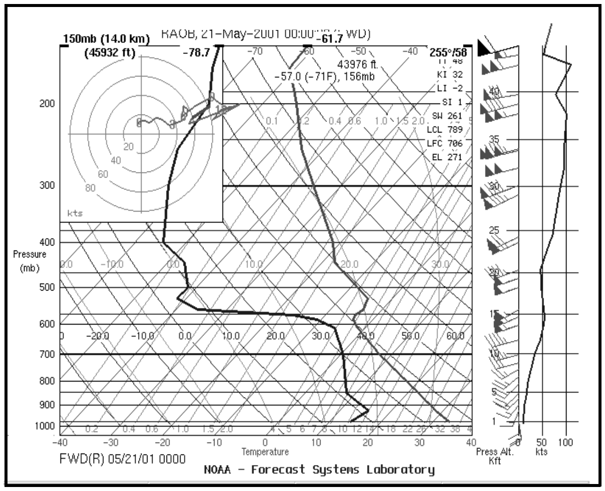

Fig.7. Radiosonde observation at 0000 UTC 21 May 2001 at Fort Worth, Texas.

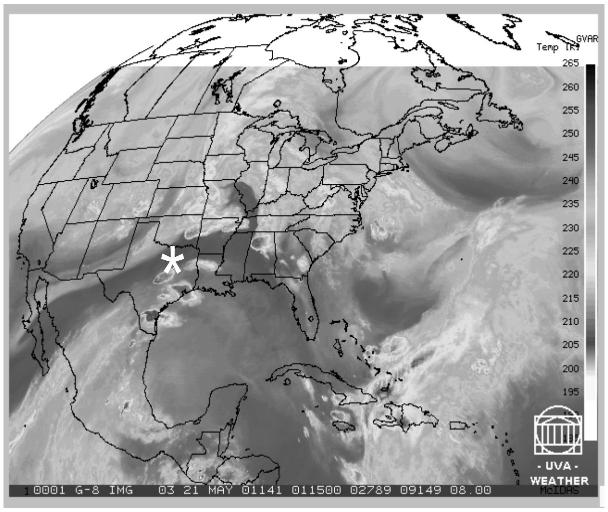

Fig. 8. GOES-East water vapor imagery at 0115 UTC 21 May 2001. White asterisk indicates location of radiosonde ascent made at Fort Worth, Texas (see Figure 7).

Among other mechanisms that may play a role in these cases of MCS development are dynamical processes involving jet interactions and potential vorticity (*e.g.*, circulations driven by superposed upper-level and low-level jetstreams; see Uccellini 1980). Another possibility is that the critical factor promoting MCS development is simply the dryness and location of the descending jet as it interacts with precipitation. Diagnostic analyses including potential vorticity budgets of these cases may help to resolve these possibilities. In any event, the cases inventoried here suggest the usefulness of dry filaments in water vapor imagery as precursors of MCS development.

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