MIPS AND RADAR OBSERVATIONS OFBOUNDARIES DURING IHOP-2002

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1. Introduction

Boundaries such as gust fronts (outflow boundaries), drylines, sea-breeze fronts and their intersection points with one another have long been recognized locations for potential convective initiation. The dryline is commonly referred to as the near-surface confluence zone between moist air from the Gulf of Mexico and dry air of semiarid high-plateau regions of Mexico and southwest United States. Drylines exhibit large perturbation along-line directions. Atkins et al. (1998), with ELDORA airborne Doppler radar observations revealed this fact and hypothesized that most of the dryline along-line variability was created by the interaction with horizontal convective rolls formed in the hot, dry boundary layer west of the dryline. They also showed that higher vertical velocities and reflectivities coincided with intersection points. Previous studies shown great variability in vertical velocities associated with drylines varying from 0.5 m/s up to 5 m/s (e.g., Atkins et al., 1998; Parsons et al., 1991, 2000)

In this paper, two convection initiation cases associated with cold fronts, drylines, and merger of these two boundaries will be presented. These two cases took place during the International H_2O Project, IHOP and were observed by the Mobile Integrated Profiling System (MIPS). IHOP took place over the central U.S between May 13 and June 25, 2002. Extensive analysis on convection initiation along the boundaries and preferable CI locations were one of the goals of the project IHOP. Strategy to delineate boundaries from the MIPS point of view was to position the MIPS ahead of a moving boundary detected as a radar fineline and to measure kinematic and thermodynamic variations ahead and behind the boundary.

The MIPS houses several active and passive remote instruments on its 24-ft trailer: 915 MHz Doppler radar (wind profiler), 2 KHz Doppler sodar, 12-channel microwave profiling radiometer, CT-25K ceilometer, electric field mill. It also measures typical surface parameters such as temperature and relative humidity, pressure, horizontal wind speed and direction, total solar radiation, rainfall. Detailed instruments characteristics and more about MIPS can be found at http://vortex.nsstc.uah.edu/mips.

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2. Case I: A Cold Front-Dryline on May 24, 2002

Storm Prediction Center forecasted surface cold front at 1900-2100 UTC was extending from Kansas/Oklahoma border into Texas panhandle and curling up into eastern New Mexico. Dryline at this time was at central Texas It was predicted to intersect the cold front midway along the cold front in northern part of TX. The MIPS was set up ahead of the cold front 25 mile east of Amarillo, close to the OK border. The MIPS observed the boundary passage at around 2004 UTC with sudden wind shift and increased wind speed. Temperature (dew point temperature) dropped (increased) about 18^{o}C (8^{o}C) during the frontal passage. S-SSE flow east of the boundary turned to N-NW flow after the boundary passage with observed wind gust of 13 m/s. A scatter Cu field was in the immediate vicinity of the MIPS. Ceilometer backscattering indicated an increase in cloud base height from 1.5 km to 2 km as the boundary approached. It also suggested an increase in Cu cloud depth. No CI occurred during this time but right after the boundary passed the MIPS, the first cell formation was seen by Frederick, OK WSR-88D Doppler radar at around 2019 UTC about 30 miles south of MIPS location. Cold front-dryline intersection and

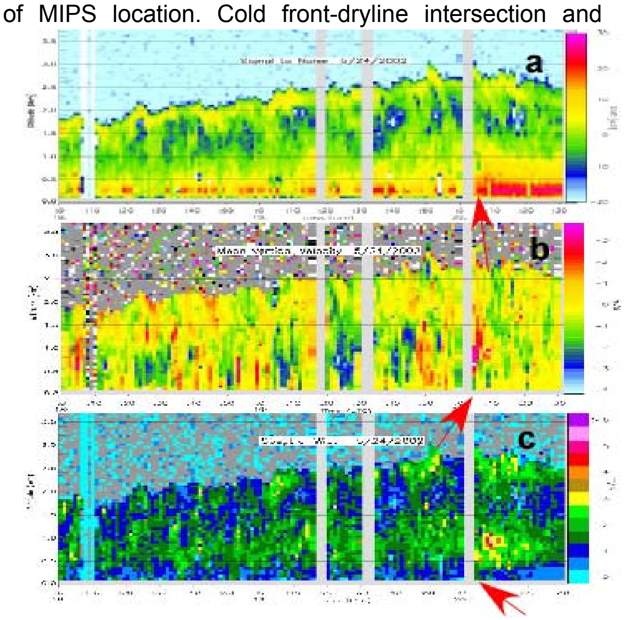
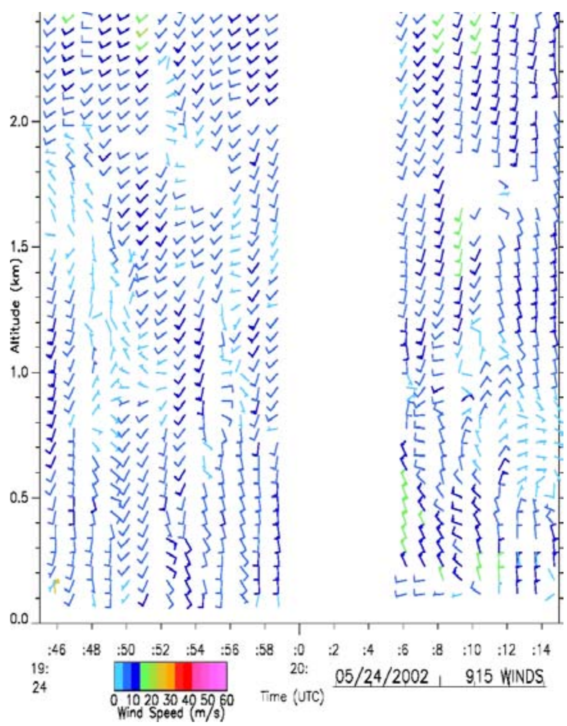


Fig. 1a,b,c. Time-height cross sections of 915 MHz Doppler radar from 1800 to 2030 on 24 May, 2002. Parameters shown are signal-to-noise ratio (top panel [scale: -20/+30 dB]), mean vertical Doppler velocity (middle [scale: -4/+4m/s]) and Doppler spectrum width (bottom [scale: 0-6m/s]). The arrows show the time of the boundary passage merging of the two boundaries occurred further south-southwest of the MIPS and initiated convection along the merged boundary. This rapid development of organized convective storms formed a NE-SW oriented squall line and entered west central OK moving rapidly to Northeast.

Fig. 1a,b,c indicates active rising thermals within turbulent and convective boundary layer. As seen in the mean vertical velocity figure (Fig. 1b), updrafts are strong enough to form clouds under dry conditions. The signatures of these updrafts and downdrafts within the boundary layer are also verified by 915 SNR values with slightly higher spikes. 915 SNR, spectral width and mean vertical velocities in and around the cloud structures are consistent with findings of Kollias et al. 2001 on cumulus cloud structure. Less turbulence within the core of the cloud updrafts and significant increase in spectral width and SNR values around the cloud edges are prominent.



At the time of the boundary passage, MIPS observed the strongest vertical velocities (>4 m/s) and highest spectral width values (5-6 m/s) from 0.5 km to 1.0 km AGL. Doppler sodar derived horizontal velocities (not shown) indicates 2-5 m/s southerly winds up to 300 m before the boundary. Northerly to north-northwesterly 10-20 m/s winds after the boundary passage was measured up to 300 m AGL. These variations in the wind field were detected by high-resolution wind profiler and are shown in at Fig.2. The figure indicates more southerly flow above 1km altitude after 2000 UTC, which indicates that kinematic boundary of the cold front aloft exists at about 1km altitude. Based on 12-channel radiometer observations (not shown), cold frontal entrance within the 1km AGL reduces the water vapor amount above 0.5 km from 11 g/kg to 9 g/kg but increases the surface water vapor amount from 9 g/kg to 12.5 g/kg. Decrease in water vapor just above 0.5 km is most probably due to the turbulent mixing which can be seen from 915 MHz spectral data from 0.5 km to 1 km AGL between 2005-2010 UTC time period. Spectral data at higher altitudes also shows increasing cloud depths during the frontal passage.

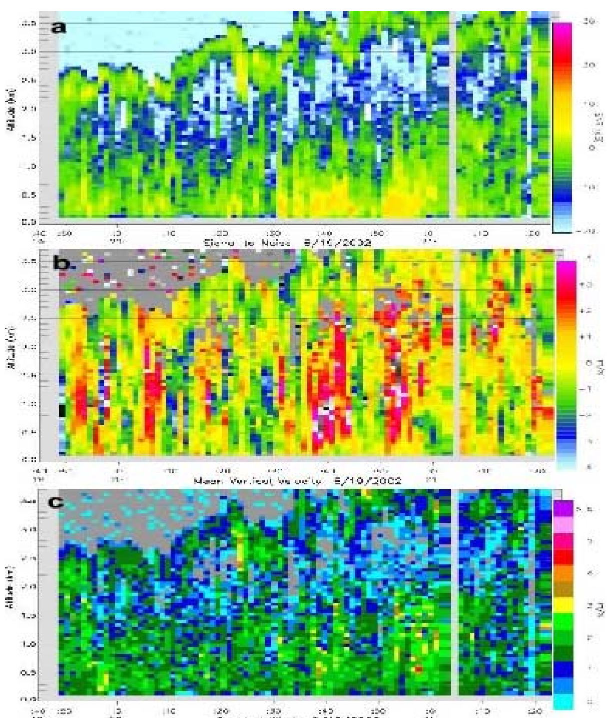
Thermodynamic and kinematic variations due to the cold frontal passage around 2004 can also be seen by an increase in 915 SNR values. This 10-15 dB increase between 0.5km-1km level may be because of increase in insect or particulate concentration due to the low-level convergence or due to the refractive index variations during the frontal passage, or combination of both. Variations in water vapor of 2-3 g/kg, dew points of 2^{o}C, and mixing ratio of 1.5 g/kg would be high enough to create high refractive index gradient that leads to higher SNR values. Meanwhile, prefrontal south-southeasterly flow of 5-10 m/s and post frontal north-northwesterly flow of 10-15 m/s forms a significant convergence that might lead higher insect and dust concentration consequently higher Rayleigh scattering. This process can also cause increase in 915 MHz SNR values. High time-height wind field data (Fig. 2) indicate S-Southeasterly flow dominating above 1 km height up to 2.5 km. This observation implies that warm dry prefrontal air slides over the cold frontal surface creating some degree of temperature increase. MPR derived temperature profile (not shown) indicates about 15^{o}C at 2 km before the boundary arrival. After the boundary passage, temperature at 2 km warm up to 17 ^{o}C, while surface temperature dropped from 32 to 24 ^{o}C.

Vertical velocities derived from the profiler shows short lasted moderate to high upward motions (2-3 m/s) with longer duration of downdrafts with 2-3 m/s. Frontal updrafts at 2005 UTC with over 4 m/s exist between 0.5 km and 1.5 km heights. 915 MHz profiler and Sodar were in RASS mode shortly before this time. The exact time when the frontal updrafts started could not be determined. This intense frontal updrafts seem to be more erect and most intense in the lowest 0.5-1 km layer.

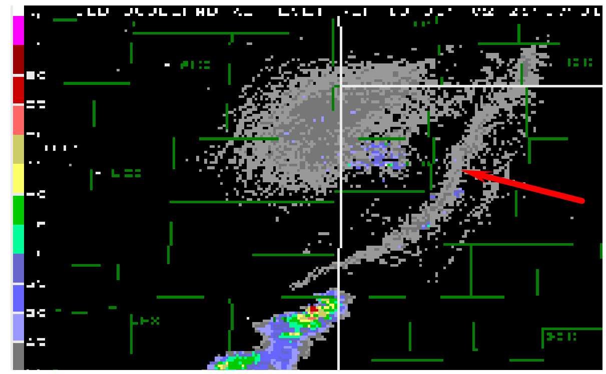
3. Case II: Cold Front-Dryline on June 19, 2002

A cold front was forecasted to move into the NE Kansas, then slow down and become quasi-stationary. Storm Prediction Center forecasted a dryline, which had NNE-SSW orientation, to intersect the cold front between 1900-2100UTC half the way along the CO and KS border. Goodland, KS 88D radar observed the first storm cell initiation at 2000UTC on the west of the CO/KS border, and later new cell formations right on the east side of the dryline boundary.

MIPS made two deployments to sample atmospheric conditions ahead of and behind the dryline. The first was east of a fineline moving eastward. As the boundary moved eastward over MIPS, Cu clouds formed and grew to Cu mediocris and Cu congestus stages. The boundary had a distinct wind shift and thermodynamic change. Shortly after the passage, the growing Cu developed light precipitation**.** The second deployment was set up 20 km to the east expecting that the boundary would keep moving eastward, but by the time the MIPS was operational, the boundary movement had reversed direction. Based on the observed fineline by the Goodland, KS 88D, the boundary started moving northwest after 2137 UTC. The storm cells initiated at the dryline boundary and moved quickly toward the northeast.



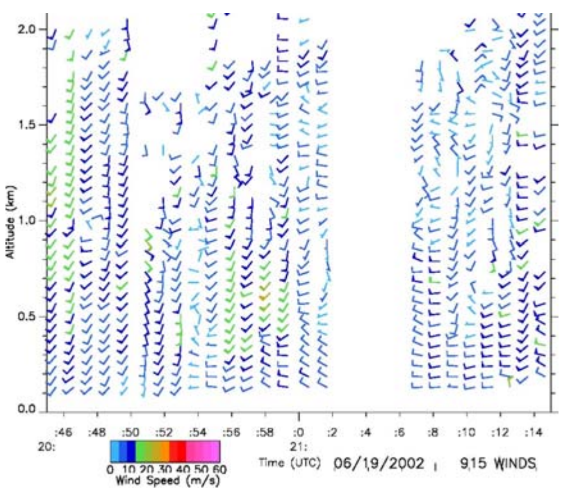
MIPS set up 24 miles east of the Goodland, KS 88D radar site and took the observations between 1945 and 2125 UTC for the first deployment. Dryline passage was associated with slight temperature increase of 1 ^{o}C, dew point decrease of 3^{o}C), decrease in mixing ratio (from 8.5 g/kg to 6.5 g/kg). Surface average winds east of the dryline were 8 m/s mostly SSW with 13 m/s gust. After the boundary passage winds veered significantly having westerly direction at 5 m/s. One of the most important



part of this deployment was to be able to stay within the dryline boundary for a long time of period. MIPS observed east of the boundary from 1945 to 2000UTC. The boundary stayed over the MIPS from 2000 UTC to 2100 UTC, then the MIPS sampled the west edge of the dryline later on. This observation was the first time-height observational studies of dryline as far as the time duration concerns. The Fig. 3 shows time-height section of 915 profiler SNR, vertical velocity, and spectral width data. Intense vertical velocities just east of the eastward moving dryline and within the dryline boundary can be seen at the figure. Vertical velocities at the eastern edge of the dryline and within the dryline boundary were about 5-6 m/s. After 2100 UTC, vertical velocities dropped to 2 m/s. For the second deployment, vertical velocities east of the dryline between 2216-2236 UTC (not shown) were about 4-5 m/s.

Fig. 4 shows formation of the squall line, fineline signature (dryline), and also the location of the MIPS at this time. During the second deployment, surface stations observed pockets of dry air within the east of the dryline. Winds were mostly northerly at 10 m/s with 15m/s gust. Vertical extends of updrafts east of the dryline for the both deployments were about 3 km. Cloud development and depths are well sampled and shown by 915-SNR signatures shown at Fig.3. Within the dryline boundary (between 2000 and 2100 UTC) Cloud top heights are increased from 2.5 km to more than 4.0 km. This Cu mediocris to Cu congestus development is also evident from the spectral width plot. More turbulent cloud edges and higher cloud top with very low turbulence within the cores of the clouds are shown in the figure.

High-resolution time-height variation of the wind during the first deployment is shown at Fig.5. SW to WSW winds with 10 m/s exceeding 20 m/s occasionally, were evident before 2100 UTC from the surface up to 2.0 km. After the boundary passage (western edge of the dryline), MIPS sampled weak westerly winds. The second deployment wind time-height variations (not shown) were rather more complex. Wind speed and directional shear was highly increased and variable. Wind speed varied between 15 m/s and 40 m/s. Wind directional change was extremely variable: Northerly low level flow, southerly above it, and northerly flow again at 1.5 km. During this time, A squall line type organized convective storm was moving toward NE direction while dryline with possible outflow forcing was moving northwest. We speculate that high directional and speed shear was a result of multiple mesoscale phenomenon such as possible outflow emanated from thunderstorms south and north of the MIPS site, dryline circulation, general southerly flow, etc.



4. Conclusion

Vertical structures of drylines and associated boundary layer characteristics were sampled by a variety of remote sensing instruments during the IHOP project. Convective initiation associated with dryline and intersection points with cold fronts is the primary subjects of this paper. With vigorous vertical velocities, as high as 6 m/s, a high turbulent boundary layer was typical for these two cases. Ceilometer and 915 MHz profiler sampled cloud development and depths during the boundary passage. Due to the intense turbulent boundary layer, ceilometer backscattering intensity, for the most of the cases, attenuated greatly because of the wind blowing dust, small insects etc. Wind profile of 915 MHz Doppler radar reveals hot, dry air being forced to lift and slide along the cold frontal boundary aloft. Unpredictable dryline movement was still a problem for decision of set up locations. The second case study showed fast moving retrograded dryline after it initiated convective cells on its East Side (moist side). The MIPS, on this case, was able to observe the vertical structure of the dryline for almost more than an hour. The dryline boundary zone mostly consists of updrafts of 3-5 m/s as the MIPS was under this boundary zone. Spectral width values have increased within the boundary and east of the dryline, the moist side.

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