Using Dual Polarimetric Radar to Assess Prescribed and Wildland Fire Intensity in Florida

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Introduction

Plumes associated with fires have been frequently observed using Doppler radar. Most studies have involved horizontally polarized radars (as examples, Banta et al 1992, Hufford et al 1998, Jones and Christopher 2010a and 2010b, Rogers and Brown 1997, and Tsai et al 2009). Literature involving polarimetric radar is much more limited. Jones et al (2009) observed an apartment fire using a C-band polarimetric radar. Melnikov et al (2008, 2009) used the S-band KOUN radar to investigate a grass fire in Central Oklahoma.

Since January 2012, as radars across the state of Florida have been upgraded to dual polarization, Florida has been an ideal place for radar observations of wildfires. The state sees a median of over 4,600 wildfires and authorizes over 120,000 prescribed burns annually with a diverse set of fuels. Visible plumes from these fires on radar are a frequent occurrence, and can be easily matched to known wildfires and authorized burns thanks to detailed records kept by the Florida Forest Service (FFS). Polarimetric radar data can be investigated to discover what information can be determined about the fire and potentially its future behavior.

Table 1. Completion Dates of Florida WSR-88D radars. Eglin Air Force Base (KEVX) and Mobile, Alabama (KMOB) are still scheduled.

Radar Site	Upgrade Completion Date
Melbourne (KMLB)	January 27, 2012
Key West (KBYX)	January 30, 2012
Miami (KAMX)	February 6, 2012
Jacksonville (KJAX)	February 24, 2012
Tampa (KTBW)	March 8, 2012
Tallahassee (KTLH)	October 25, 2012

Dataset

91 days were selected from four upgraded Florida radars (KAMX, KJAX, KMLB, and KTBW) to investigate the polarimetric character of fires in the state. These days were selected by first finding fires that were both large and located relatively close to the radar. This would ensure the highest likelihood of finding visible plumes on radar. Level II data was then obtained from NCDC, and viewed with the GR2Analyst software from Gibson Ridge. A few of the most interesting examples are displayed on this poster.

County Line Fire

The County Line fire was a lightning-ignited fire that started on April 5, 2012. A large, multiple-day fire, it ultimately burned nearly 35,000 acres in Northeast Florida. About three hours before the moment in Figure 1, the size of the fire was estimated at 312 acres, and by the next day, had grown to over 4,500 acres.

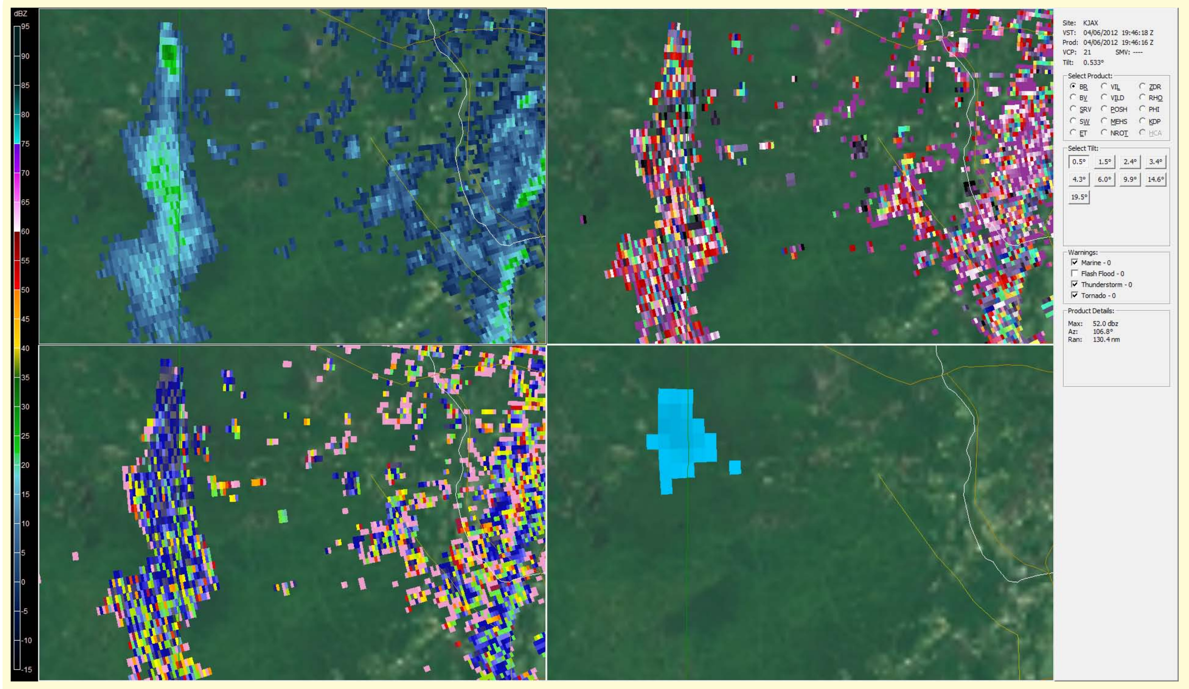

Figure 1. KJAX at 1946 UTC on April 6, 2012. Panels are, clockwise from upper left: reflectivity, differential reflectivity, echo tops, correlation coefficient.

At this time, the fire was growing, but only had a maximum reflectivity of 31 dBZ. It did, however, have an established updraft column, with echo tops at nearly 16,000 feet. At the fire, the plume demonstrated typically positive differential reflectivity (Z_{DR}), but did also have an area of generally near-zero, or even negative Z_{DR}. This area near the updraft may have had tumbling debris, and like hail, this may have created the anomalous area of differential reflectivity. Downstream, Z_{DR} was considerably larger. This was common in observed plumes, and often large values come to dominate the plume after a fire is no longer actively burning. Correlation Coefficient (CC) was quite low, as expected for a non-meteorological return. Near the fire column, CC was very low – as low as 0.2 – and increased downstream. This increase was also common in the observed plumes.

Interaction with Clutter and Noise

Radar detection of fire plumes is most effective at gauging fire intensity near the radar, where the 0.5 degree scan is nearest the ground. However, this can also introduce challenges because of noise. Sometimes more traditional products like reflectivity and spectrum width display the plume best.

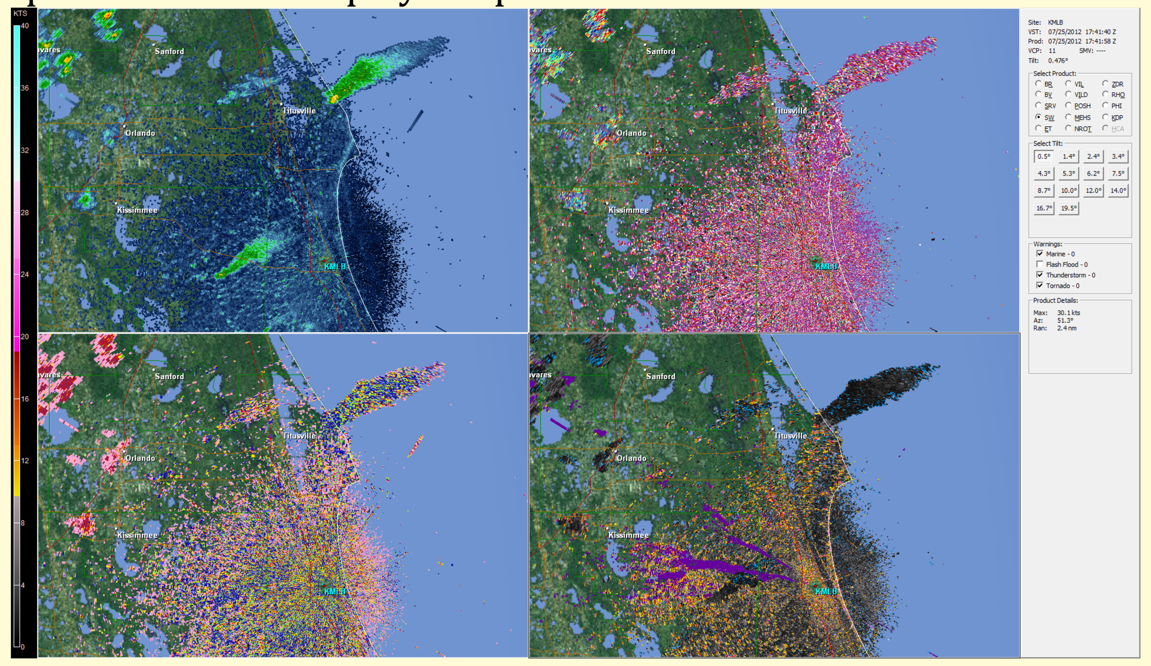

Figure 2. KMLB on July 25, 2012 at 1741 UTC. Clockwise, from upper left: reflectivity, differential reflectivity, spectrum width, and correlation coefficient.

January 31 Merritt Island Prescribed Burn

On January 31, FFS authorized a 2,100 acre prescribed fire on Merritt Island. Because of its size and proximity to KMLB, the plume became a major feature. Smoke was quite heavy, and even forced the closing of the nearby Kennedy Space Center for a time.

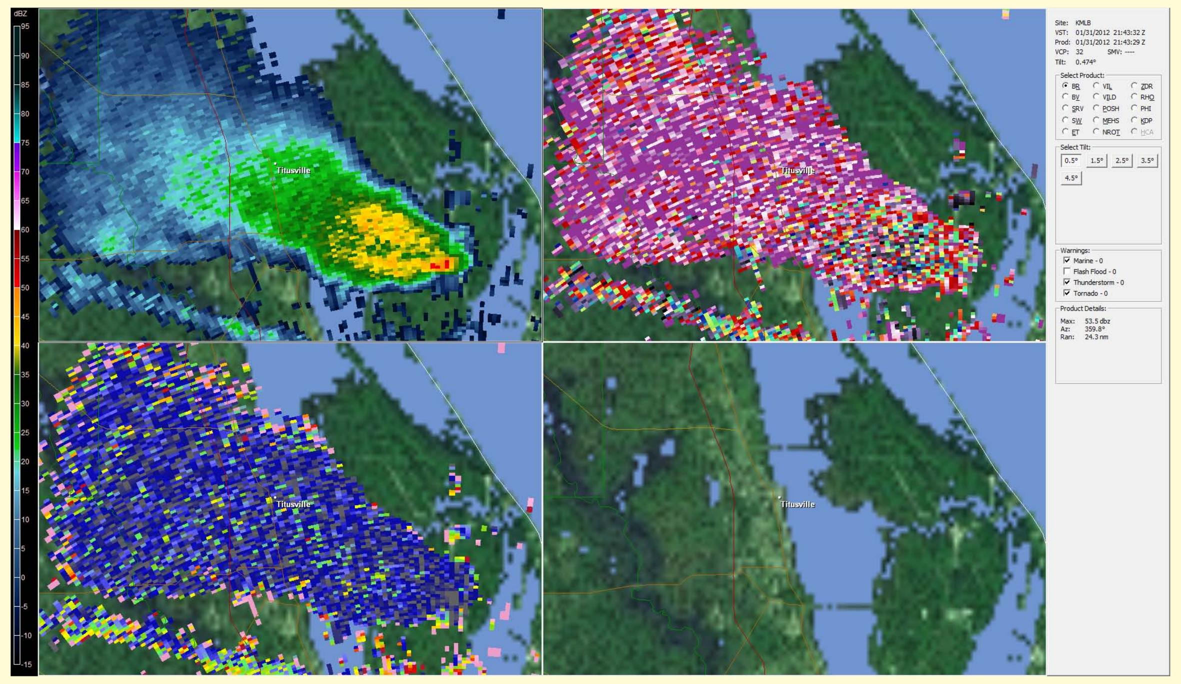

Figure 3. KMLB on January 31, 2143 UTC. Panels are as in Figure 1.

This plume is very intense, with a maximum reflectivity of 53 dBZ. Like the County Line fire, it also demonstrates lower Z_{DR} near the fire column and much larger values downstream, though there is no contiguous area of negative Z_{DR}. CC is also very low near the fire column, and grows downstream.

Rain-Fire Discernment

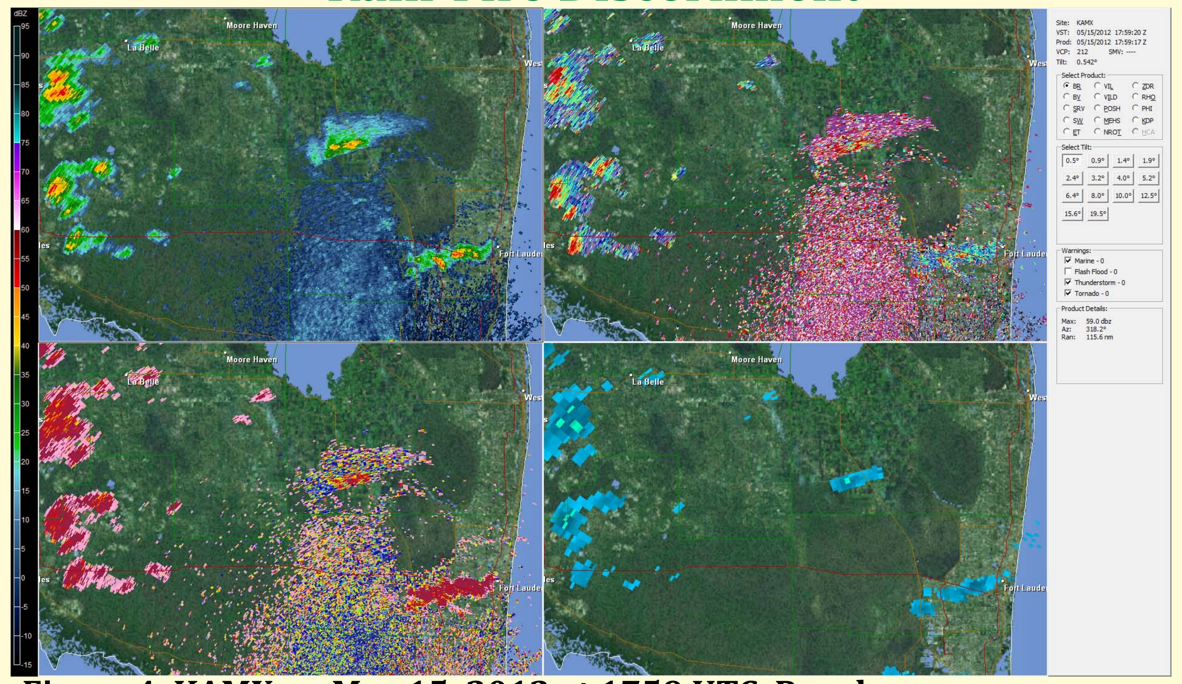

Figure 4. KAMX on May 15, 2012 at 1759 UTC. Panels are as described in Figure 1.

This example from the West Holey Lands fire in southwest Palm Beach County highlights a key usefulness of polarimetric data. In Florida, the period of highest fire activity blends with the onset of the summer rainy season. Plumes and isolated thunderstorms are often seen together during this time. Using reflectivity alone, it can be difficult to differentiate between the two. However, the polarimetric variables make this task simple. The higher Z_{DR} and lower CC values in plumes are in stark contrast to the generally lower Z_{DR} and much higher CC seen in rain.

Summary

Dual polarization upgrades to the WSR-88D network have created a greater potential for observing wildland fire plumes than has been seen before. Investigating plumes from wildfires and prescribed burns in Florida during 2012 have mostly confirmed findings from previous studies in other areas, but have also revealed additional interesting features:

- Differential reflectivity is usually higher than in rain, and are generally close to what was described in previous instances. Correlation coefficient is also similarly low to previous descriptions.
- Near more intense fire columns, Z_{DR} is lower, and can even be near zero or even slightly negative in very intense fires. CC also tends to be lower than usual. This may be caused by tumbling of the needle-shaped predominant scatterers, as we see with hail. Also, the strong updrafts could be lofting other debris that is not present in the plume downstream.
- Well downstream, Z_{DR} and CC increase, and are often larger than described previously. This area also tends to dominate the entire plume after the fire becomes less active or stops. This could be because the part of the plume where upward motion is weaker becomes dominated by a particular piece of debris that is very non-spherical, horizontally oriented and is very easily carried. In some instances, particularly when CC rises to levels seen by meteorological echoes, this increase might be enhanced by the scattering particles become glaciated or water covered, which would also increase differential reflectivity and CC.
- Scanning strategy impacts the polarimetric characteristics, and need to be considered. CC reacts most strongly to change in VCP, with the greatest difference between precipitation and clear air scans, though some differences can also be seen between particular scans of one type. This also impacts Z_{DR} to a smaller extent, resulting in larger values. Since smoke plumes are working at the margins of the WSR-88D's sensitivity, it's possible that this occurs because some scanning strategies can no longer "see" some scatterers, and preferentially select a certain, more homogeneous population, likely those that dominate the downwind portions of the plume.

These results confirm that polarimetric radar is very useful in identifying plumes from wildfires. They are also imply that it may be possible to gauge the relative intensity of fires based on their polarimetric characteristics. This could potentially be of significant use to forecasters and fire management personnel. The noisy nature of the polarimetric variables, particularly in areas of low CC, a key feature of the plumes, make more definitive conclusions difficult without more quantitative work.

A caveat exists for the National Weather Service. Because of this noise, the polarimetric variables are processed before being seen in AWIPS. The data visualized in GR2Analyst has not undergone this processing, which could potentially diminish or eliminate these features.

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