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Observations of Negative Z_{DR} in Sandstorms

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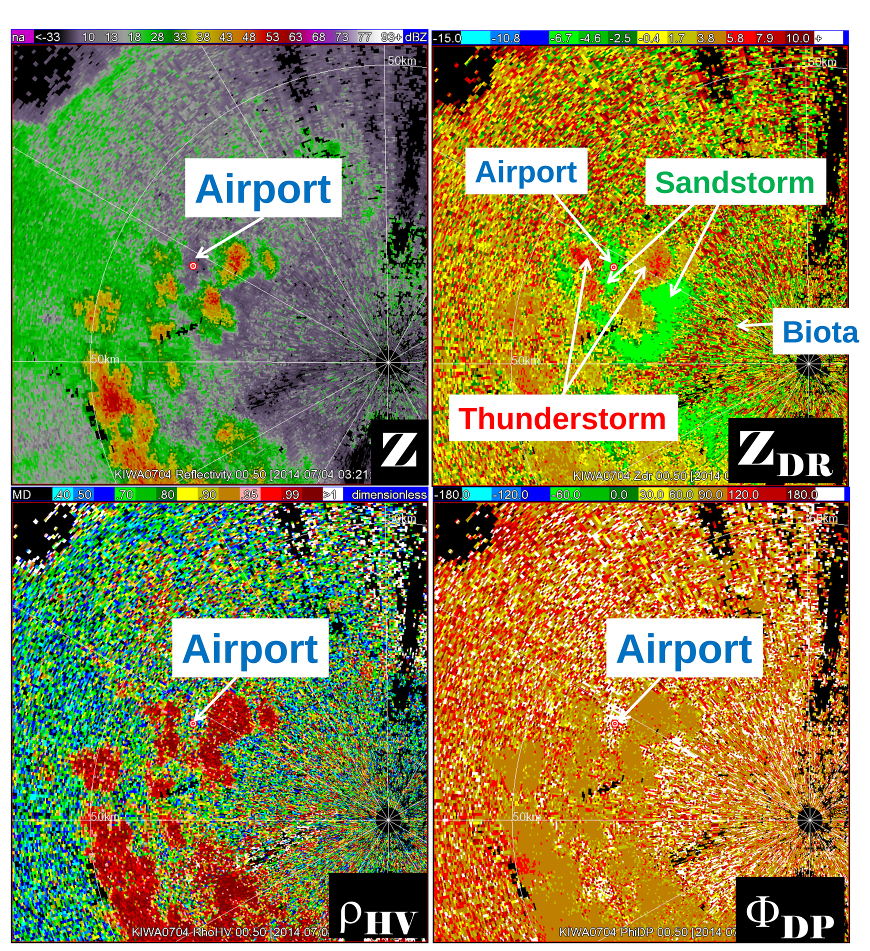
Abstract

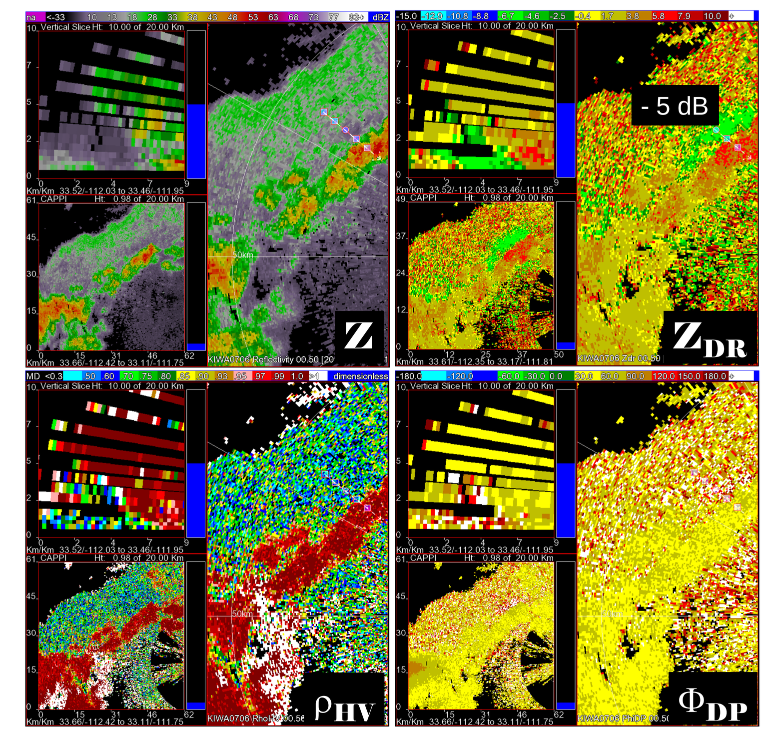
Polarimetric observations from a great variety of weather events became available upon the upgrade of the national WSR-88D radar network to this new technology. Herein are reported unusual regions of negative differential reflectivity within storm outflow in continental and desert areas. Three outflows that created sandstorms in Phoenix are observed to indicate the regions with large negative differential reflectivity Z_{DR} down to -5 dB. Negative Z_{DR} in one of these three sandstorms was also observed simultaneously by the NSSL X-band dual-polarization mobile radar. Our hypothesis is that scatterers such as pieces of grass, sticks, insects, and chaffs lofted by outflow were vertically oriented in electric field induced by the charged dust particles within the sandstorm. Rather than dust and sand, these scatterers produced negative Z_{DR} in S- and X-band dual-polarization radar observations. Previous studies documented significant vertical electric fields caused by charged dust in sandstorms (Williams et al., 2009). The electric fields reported in sandstorms are more than an order of magnitude larger than fair weather electric fields. Thus such large negative Z_{DR} values can be considered as an indicator of the location and movement of sandstorms. Observations of Z_{DR} in gust fronts over vegetated areas reveal very different signatures of Z_{DR}. For most part the values in the outflow are relatively large and positive suggesting that insects are prime contributors. Occasional negative values are also observed likely associated with lofted dust. Preferential location appears to be at the leading edge of outflow region. It could be that the electric field is also causing vertical orientation of large scatterers, or it could be that the wind shear at the leading edge is responsible.

Negative Z_{DR} in Sandstorms at Phoenix, AZ

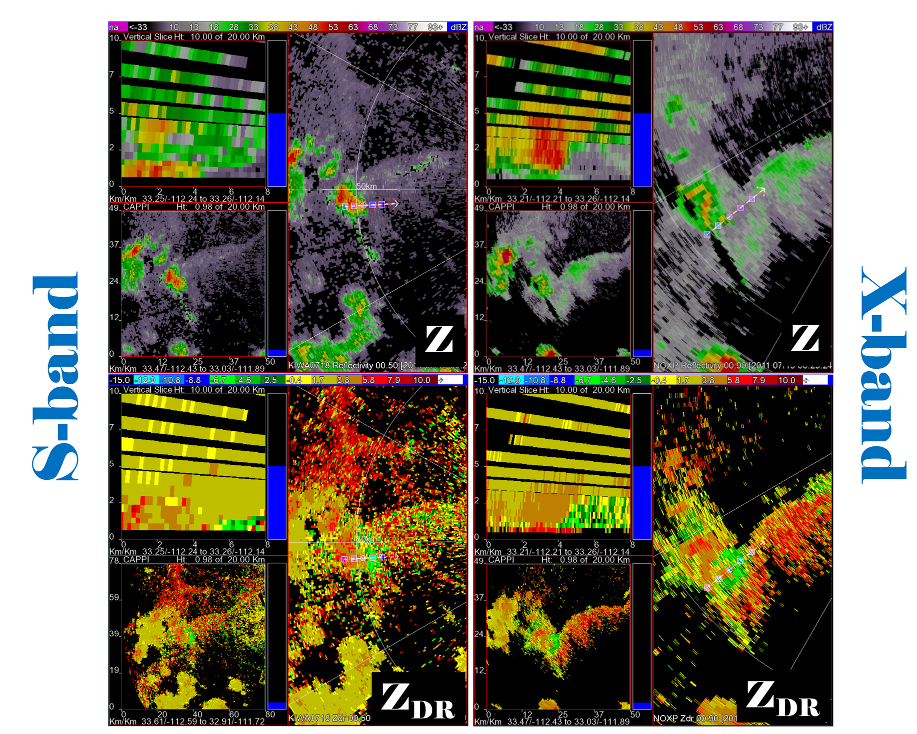
Picture of the sandstorm approaching the Phoenix Sky Harbor International Airport on July 4, 2014.
Capture from the video on https://www.youtube.com/watch?v=wMNZimmNnMY



Composite PPI of Z, Z_{DR}, ρ_{HV} and Φ_{DP} for the sandstorms and associated thunderstorms observed by S-band KIWA radar at Phoenix, AZ at 03:21 UTC on 04 July 2014. The large negative Z_{DR} was observed in the sandstorm region (green area in the Z_{DR} panel).

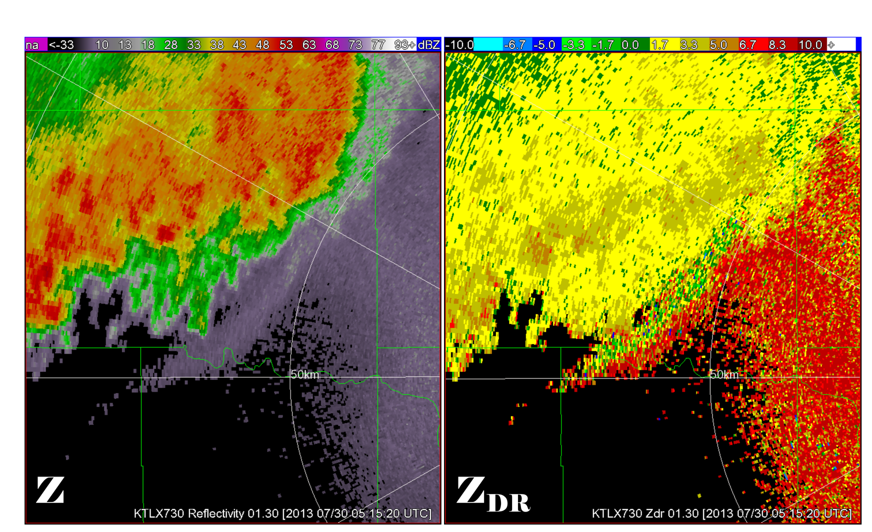


Composite PPI and RHI of Z, Z_{DR}, ρ_{HV} and Φ_{DP} for the sandstorms and associated thunderstorms observed by S-band KIWA radar in Phoenix, AZ at 03:13 UTC on 06 July 2011. The RHI cross-sections are reconstructed along the dashed lines indicated in the PPI panels. The large negative Z_{DR} (down to -5 dB) was observed in the sandstorm region (green area in the Z_{DR} panel). The height of sandstorm reaches about 3 km.



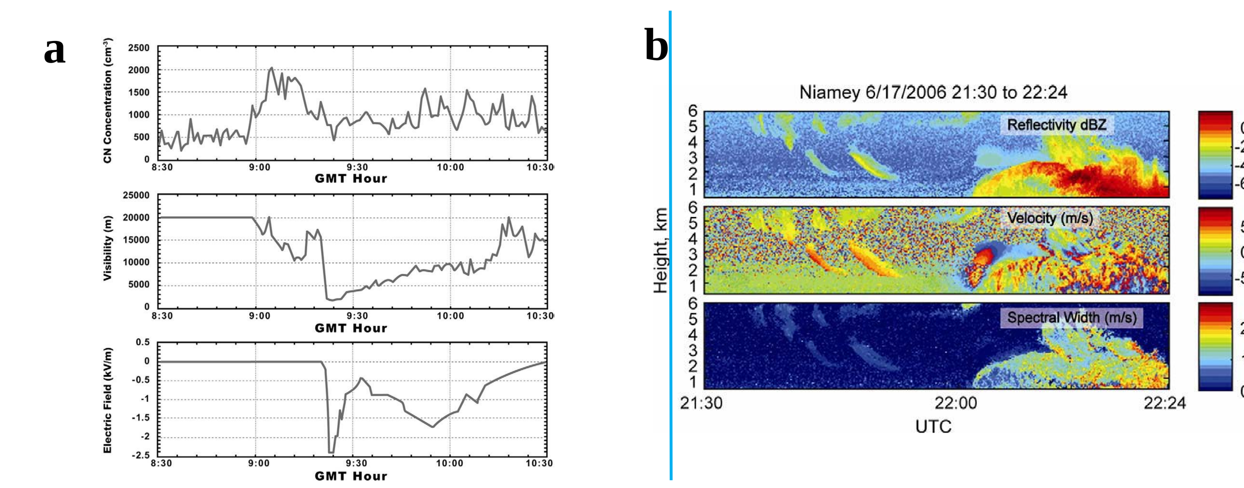
Composite PPI and RHI of Z and Z_{DR}, for the sandstorms and associated thunderstorms simultaneously observed by S-band KIWA radar (left panel) and X-band NOXP mobile radar (right panel) at Phoenix, AZ at 00:29 UTC on 19 July 2011. The RHI cross-sections are reconstructed along the dashed lines indicated in the PPI panels. The large negative Z_{DR} was observed by both of radars (green area in the Z_{DR} panels).

Negative Z_{DR} in thunderstorm outflow at Oklahoma



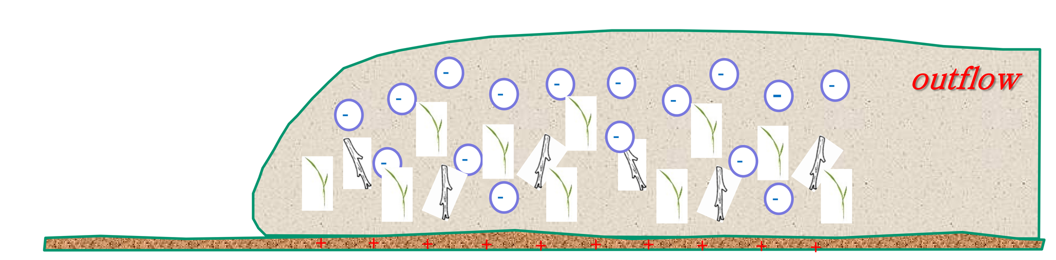
Reflectivity and Z_{DR} for thunderstorm and outflow observed by S-band KTLX radar at Oklahoma City, OK at 05:15 UTC on 30 July 2013. Scattered negative Z_{DR} was observed along the leading edge of the outflow boundary (bright green pixels in the Z_{DR} panel).

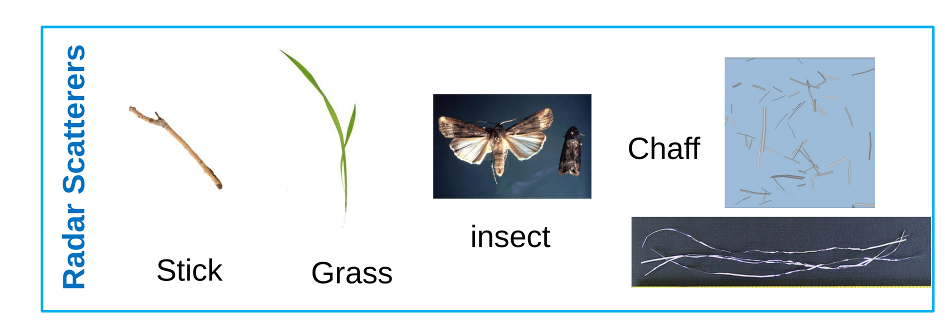
Electric Field in Sandstorm



(a) The evolution of condensation nuclei, visibility and electric field for sandstorm that passed over the observation site on July 21, 2006. (b) The evolution of vertical profiles of reflectivity, mean Doppler velocity and Doppler spectral width for a gust front on June 17, 2006, the radar operating frequency is 95 GHz. *Adapted from Williams et al., 2009.*

Our Hypothesis





Most dust and sand lifted by thunderstorm outflow are composed of clay particles with sizes between 1 and 100 micron and other silicate minerals in the size range of 0.1 mm to several mm. However, most of these scatterers are mainly polarimetrically isotropic and can not produce such magnitudes of Z_{DR} regardless of their orientation. Much larger anisotropic scatterers like pieces of grass or insects caught in the gust front updraft and mixed with much smaller dust and sand particles are likely responsible for anomalous negative Z_{DR} observed by X- and S-band radars. Dust and sand particles act as charge separators producing vertically oriented electric field which orients accordingly the much bigger anisotropic scatterers. These are the cause of observed negative Z_{DR}.

Reference:

Williams, E. et al., 2009: The electrification of dust-lofting gust fronts ('haboobs') in the Sahel. *Atmospheric Research*, **91**, 292-298.

Acknowledgment:

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