Investigations of Hail Damage Swaths using Various Satellite Remote Sensing Platforms

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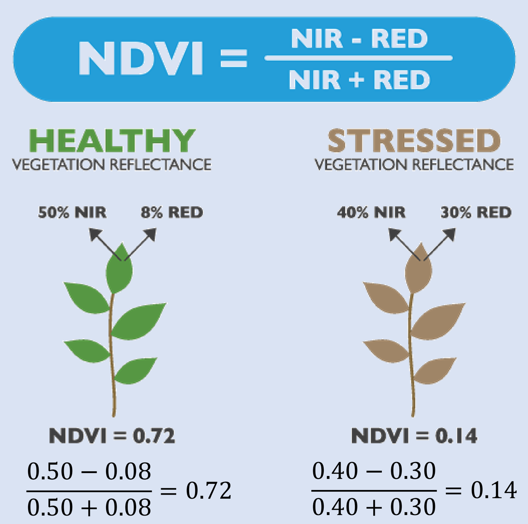
Introduction

- Severe thunderstorms that bring damaging winds and large hail can cause significant damage to agricultural crops. Severe thunderstorms can cause upwards of several hundreds of millions of dollars in damage to agricultural areas.
- Formal ground surveys are not conducted on these areas of damage, like they are for suspected tornado damaged areas. IF ground surveys were conducted, they would likely be time and resources consuming due to their large spatial extent.
- Satellite remote sensing has been frequently used in identification and analysis of these hail damage swaths. Previous analysis have looked at the simple change in damaged vegetation (Gallo et al. 2012) to looking at the damage areas in satellite imagery with varying spatial resolutions (Molthan et al. 2013). One study has even looked at the impacts that these damage swaths can have on the land surface, associated fluxes and how they affect numerical weather prediction (Parker et al. 2005).
- Previous studies have focused on using optical remote (VIS, NIR, SWIR) sensing instruments and derived indices, such as Normalized Difference Vegetation Index (NDVI) for analysis. NDVI is used to monitor the health (greenness) of the vegetation.
- Optical sensors however are limited by sky conditions over the areas they are imaging and certain bands are further limited by the diurnal cycle. These limitations can lead to sometimes upwards of 7 to 10 day gaps of the surface not being imaged, especially during the height of summer convection.



$$\frac{0.50-0.08}{0.50+0.08}=0.72 \qquad \frac{0.40-0.30}{0.40+0.30}=0.14$$

Figure 1. Example of NDVI calculation (Antognelli, 2018).

- One way to obtain more views of the surface, regardless of the sky conditions or time of day is through the use of synthetic aperture radar (SAR).
- SAR sensors are active instruments that transmit in the microwave portion of the EM spectrum. The surface and its characteristics will determine the amount of energy scattered back to the sensor. The SAR sensors then measure amplitude and phase of wavelength coming back from surface.

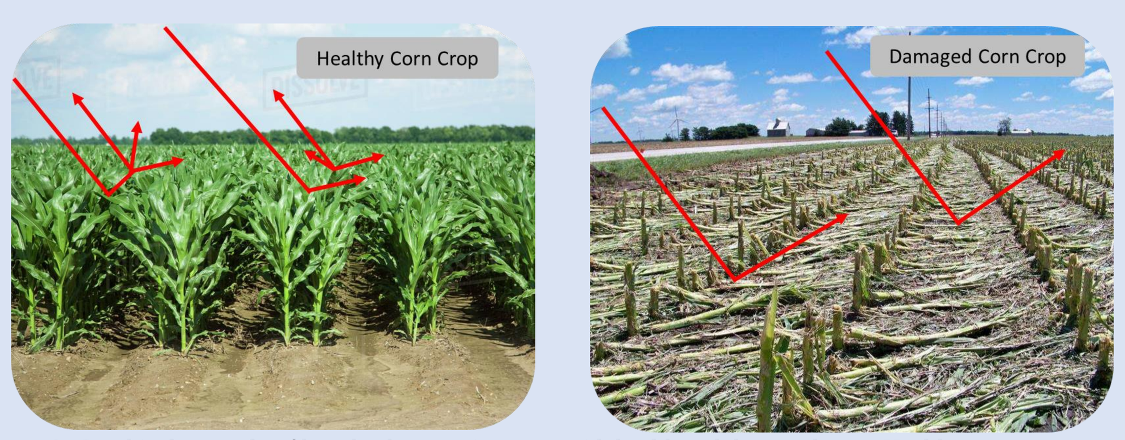


Figure 2. Graphical example of how backscatter interacts with health and damaged corn. Healthy corn provides more volume scattering (higher power returned) whereas damaged agriculture areas experience more surface scattering (lower power returned).

Data

Data	Details	Source
NDVI	250m MODIS product	NASA LP-DAAC
SAR	30m Sentinel-1 Co-polarizations (VV, VH)	European Space Agency; Alaska Satellite Facility
MRMS	24-hour, 1-km gridded Maximum Estimated Size of Hail (MESH)	NOAA
Crop	30-m Cropland Data Layer (CDL)	USDA NAAS

Table 1. Table of data layers used to perform analysis with spatial resolution and source of data.

- Using MODIS True Color and False Color RGBs, suspected damaged areas were identified and hand digitized using GIS software
  - MESH data used to constrain hand analysis to make sure identified areas were impacted by thunderstorms
- All data sets were resampled to 30 meters to match the resolution of the SAR and crop data layers
- Analysis were performed on dominant crop types
  - Corn, soybeans, and grasslands

17 June 2016—Northwest Iowa

- A complex of severe thunderstorms moved through the northwest Iowa region during the evening and overnight hours of 17 June 2016.
- Winds in excess 60 mph and hail larger than 1 inch was reported
- The same system also brought 2 to 4 inches of rainfall across the region.

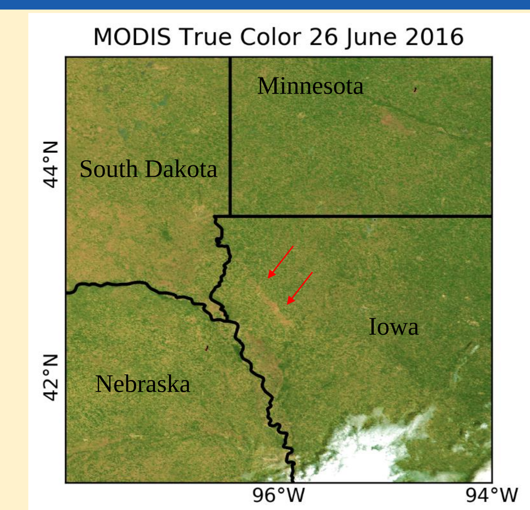


Figure 3. 26 June 2016 Terra MODIS true color image with hail damage in northwest Iowa.

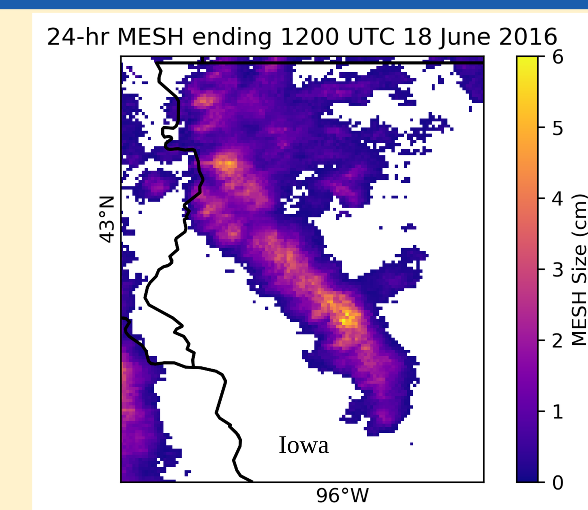


Figure 4. 24 hour Maximum Estimated Size of Hail ending 1200 UTC 18 June 2016.

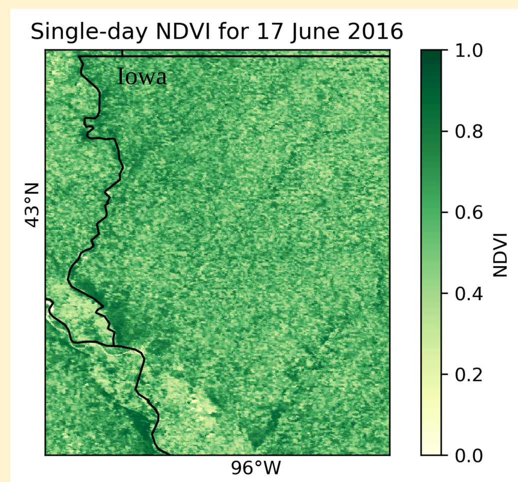


Figure 5. 17 June 2016 single-day MODIS NDVI image from just prior to severe thunderstorms moving through the area.

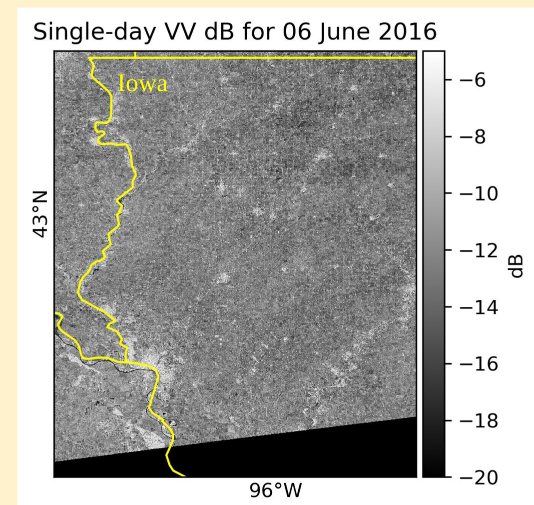


Figure 6. 6 June 2016 Sentinel-1 VV dB image was the closest pre-event Sentinel-1 pass.

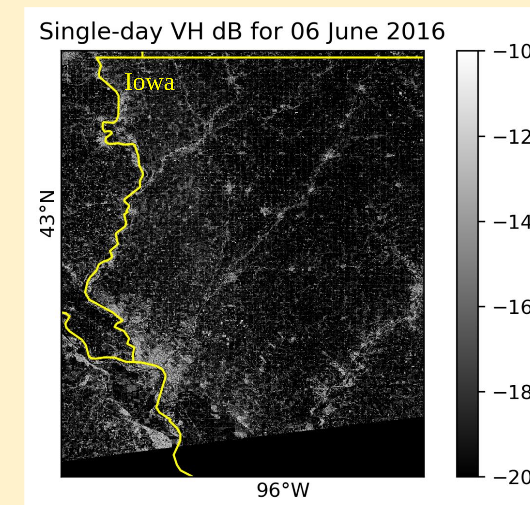


Figure 7. 6 June 2016 Sentinel-1 VH dB image was the closest pre-event Sentinel-1 pass.

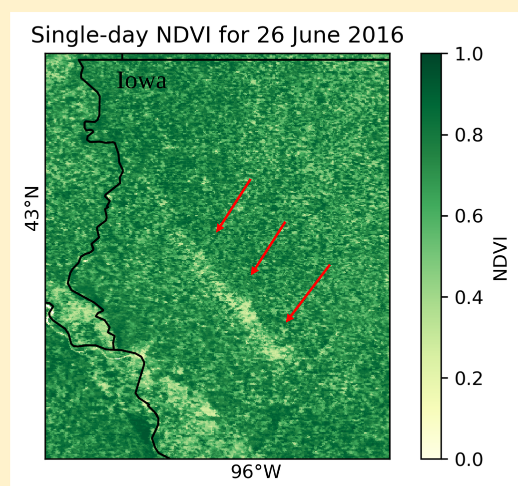


Figure 8. 26 June 2016 single-day MODIS NDVI image show hail damage swath in northwest Iowa.

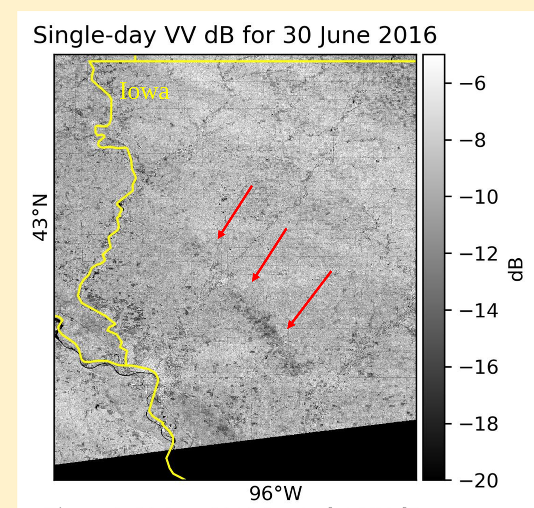


Figure 9. 30 June 2016 Sentinel-1 VV dB image showing the hail damage swath in northwest Iowa.

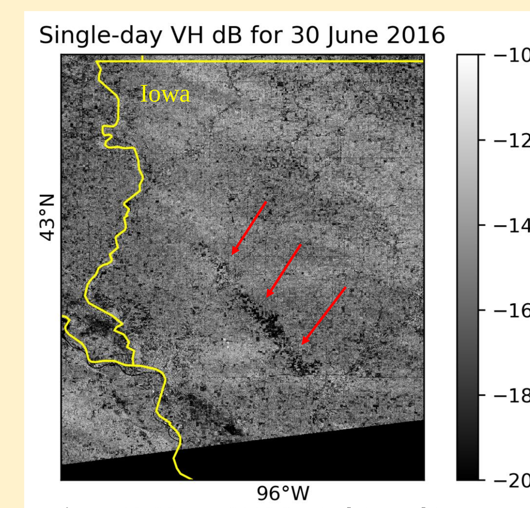


Figure 10. 30 June 2016 Sentinel-1 VH dB image showing the hail damage swath in northwest Iowa.

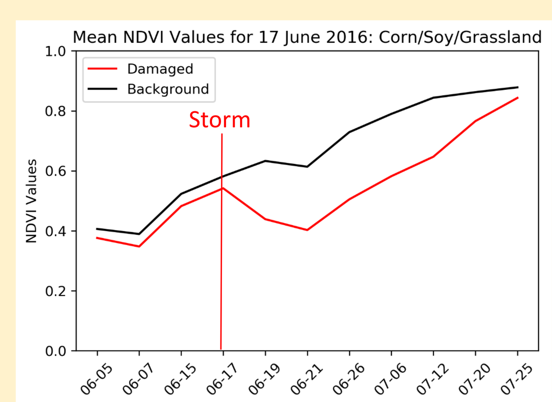


Figure 11. Time series plot showing the trends of the mean NDVI values of all land classes in the damaged and undamaged areas.

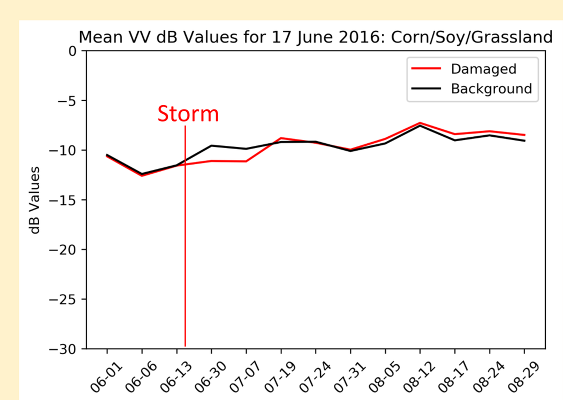


Figure 12. Time series plot showing the trends of the mean dB values in the Sentinel-1A VV imagery of all land classes in the damaged and undamaged areas.

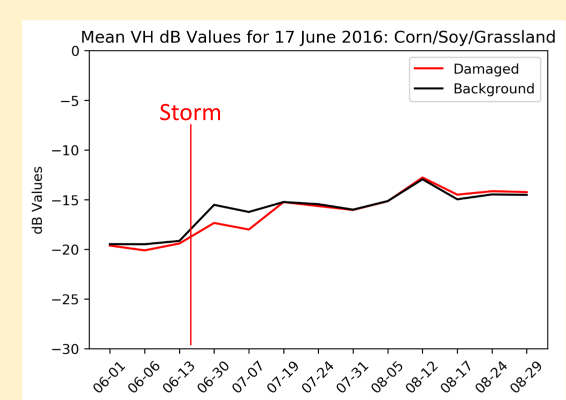


Figure 13. Time series plot showing the trends of the mean dB values in the Sentinel-1A VH imagery of all land classes in the damaged and undamaged areas.

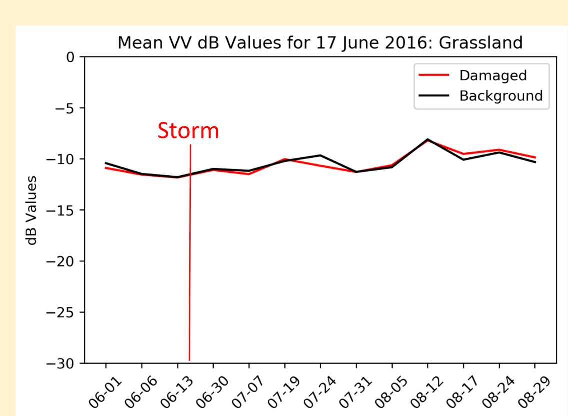


Figure 14. Time series plot showing the trends of the mean Sentinel-1 VV dB values of the grassland areas only.

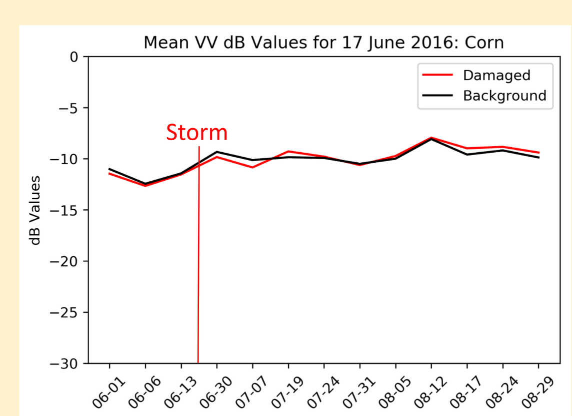


Figure 15. Time series plot showing the trends of the mean Sentinel-1 VV dB values of the corn areas only.

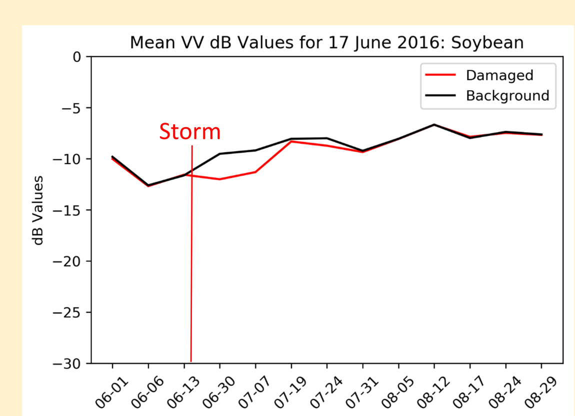


Figure 16. Time series plot showing the trends of the mean Sentinel-1 VV dB values of the soybean areas only.

Contains modified Copernicus Sentinel data (2018)

21 June 2017-South Dakota/Minnesota

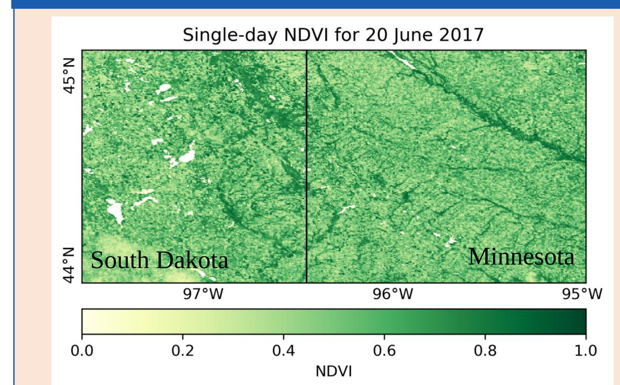


Figure 17. 20 June 2017 single-day MODIS NDVI image from just prior to sustaining damage.

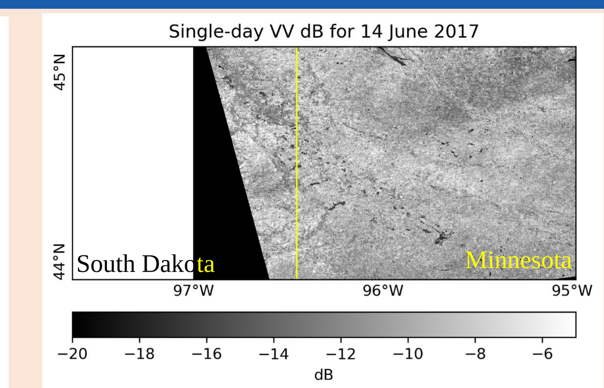


Figure 18. 14 June 2017 Sentinel-1 VV dB image was the closest pre-event Sentinel-1 pass.

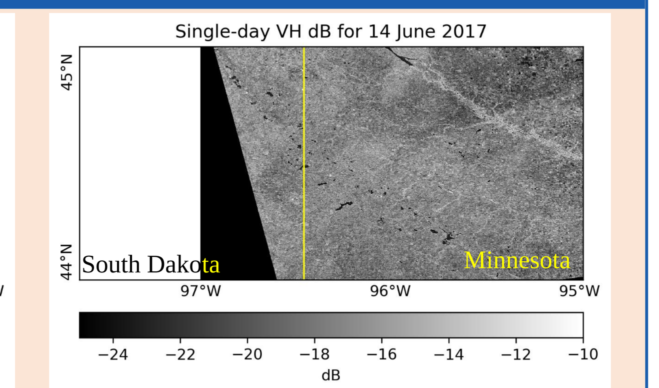


Figure 19. 14 June 2017 Sentinel-1 VH dB image was the closest pre-event Sentinel-1 pass.

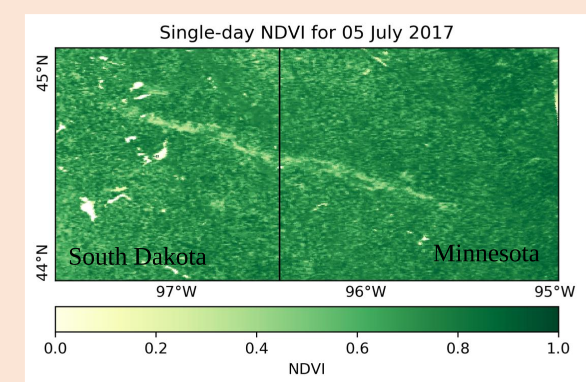


Figure 20. 5 July 2017 single-day MODIS NDVI image shows a hail damage swath spanning two states.

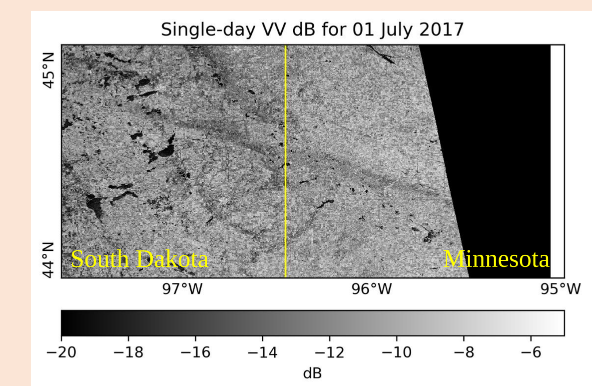


Figure 21. 1 July 2017 Sentinel-1 VV dB image shows hail damage swath.

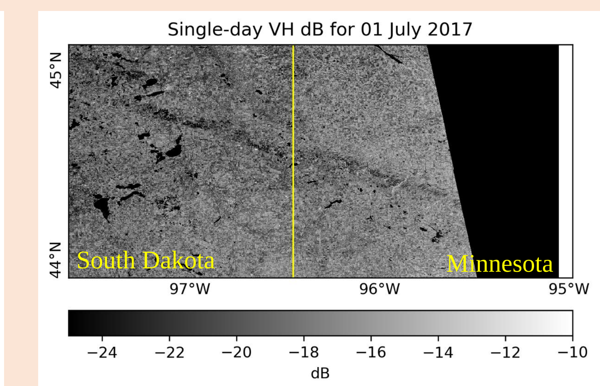


Figure 22. 1 July 2017 Sentinel-1 VH dB image shows hail damage swath.

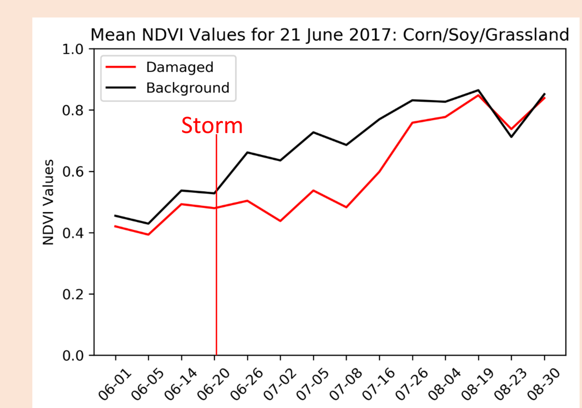


Figure 23. Time series plot showing the trends of the mean NDVI values of all land classes in the damaged and undamaged areas.

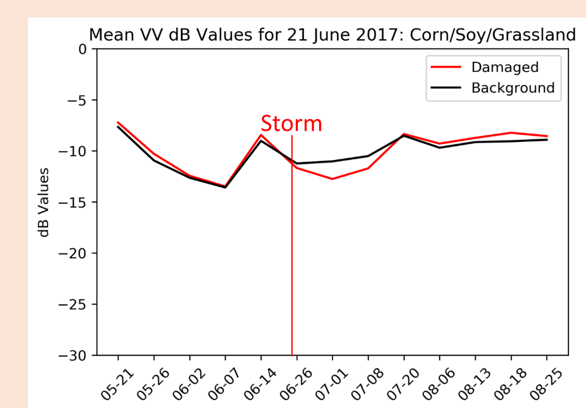


Figure 24. Time series plot showing the trends of the mean dB values in the Sentinel-1A VV imagery of all land classes in the damaged and undamaged areas.

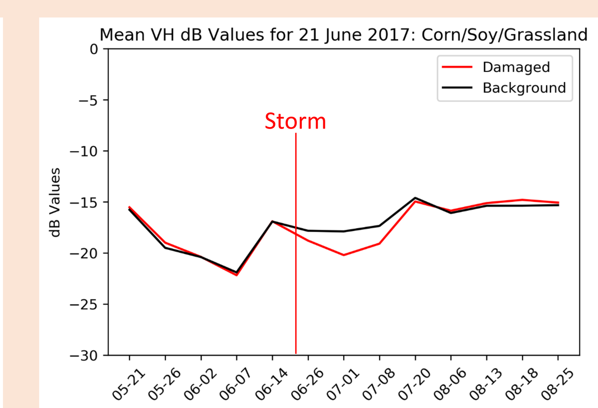


Figure 25. Time series plot showing the trends of the mean dB values in the Sentinel-1A VH imagery of all land classes in the damaged and undamaged areas.

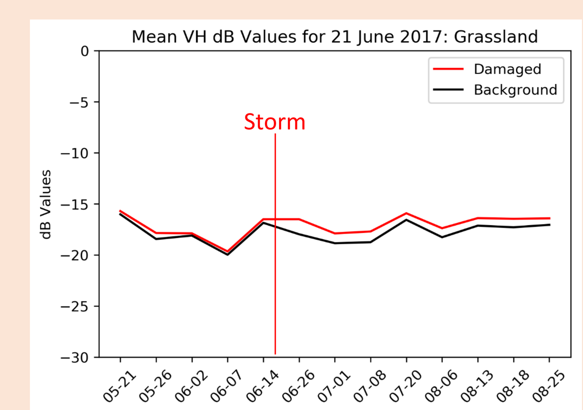
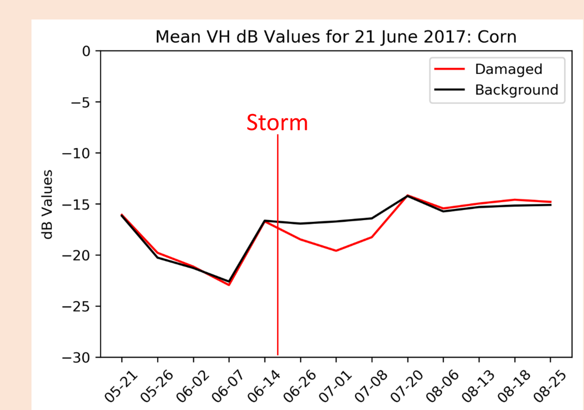


Figure 26. Time series plot showing the trends of the mean Sentinel-1 VV dB values of the grassland areas only.



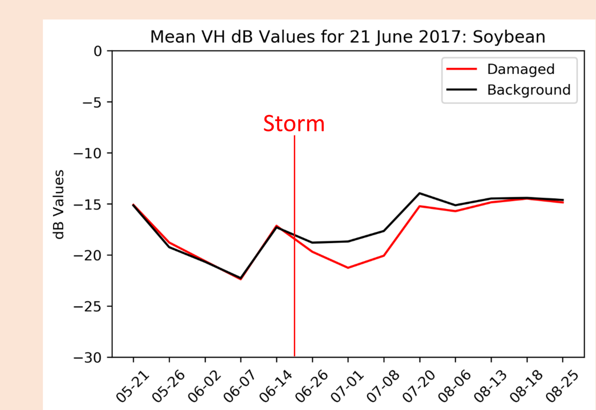


Figure 28. Time series plot showing the trends of the mean Sentinel-1 VV dB values of the soybean areas only.

16 May 2017 EF-3 Clear Lake, WI Tornado

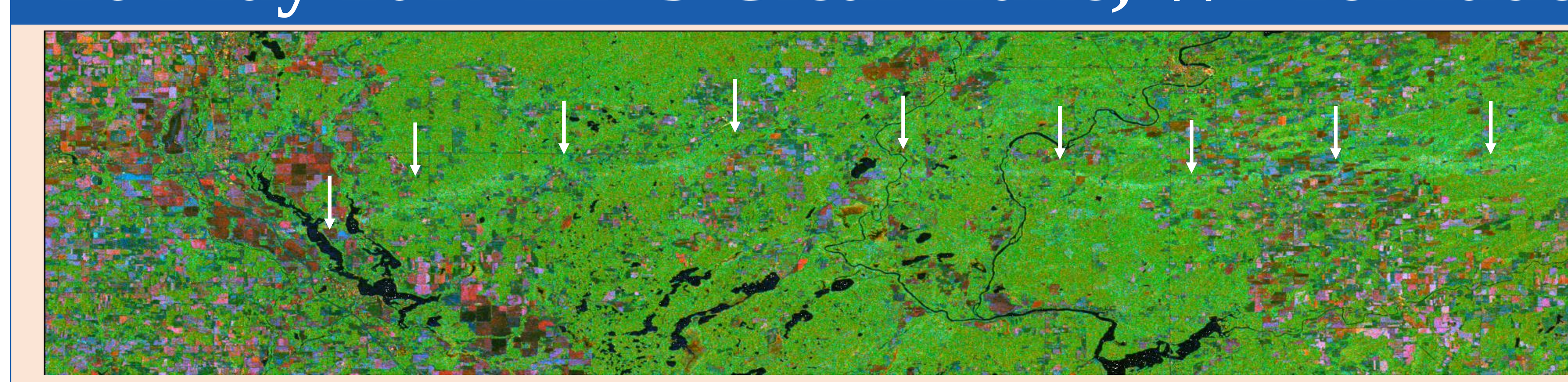


Figure 29. Sentinel-1 Change Detection RGB composition from Sentinel-1 post tornado in late May 2017.

- Future work includes analyzing tornado tracks through the use of synthetic aperture radar data. Tornado tracks can be harder to identify due to size. Like hail storms, not all tornadoes produce a signature that can be detected by moderate to coarse spatial resolution satellite.

Citations:

Antognelli, S., 2018: NDVI and NDMI vegetation Indices: Instructions for use. Accessed 15 August 2018, https://www.agricolus.com/en/indici-vegetazione-ndvi-ndmi-istruzioni-luso

Gallo, K., T. Smith, K. Jungbluth, and P. Schumacher, 2012: Hail Swaths Observed from Satellite Data and Their Relation to Radar and Surface-Based Observations: A Case Study from Iowa in 2009. Weather Forecast., 27, 796–802.

Molthan, A., J. Burks, K. McGrath, and F. LaFontaine, 2013: Multi-sensor examination of hail damage swaths for near real-time applications and assessment. J. Oper. Meteorol., 1, 144–156

Parker, M. D., I. C. Ratcliffe, and G. M. Henebry, 2005: The July 2003 Dakota Hailswaths: Creation, Characteristics, and Possible Impacts. Mon. Weather Rev., 133, 1241–1260.