Introducing a Satellite Agnostic Approach to Identifying and Quantifying Hail Damage Swaths over the Central United States

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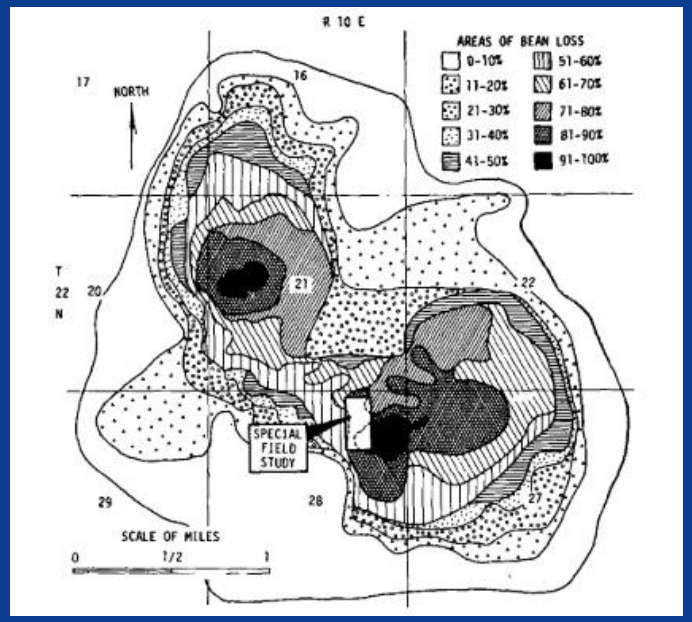
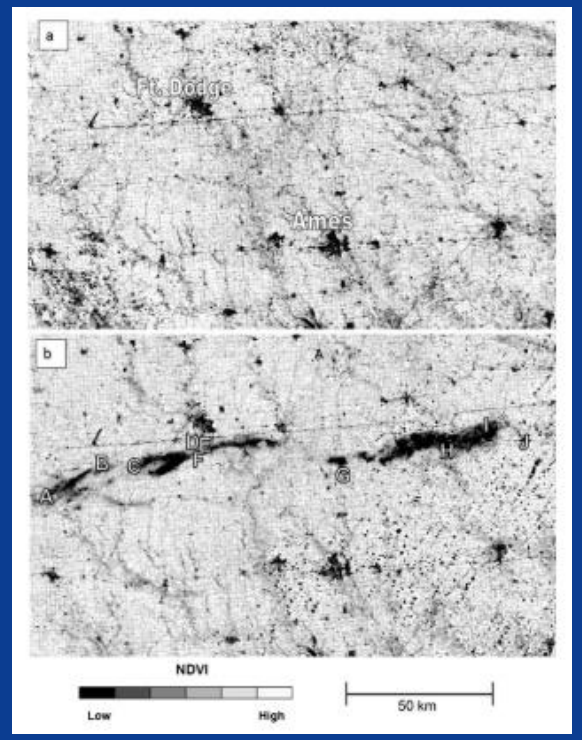
Background

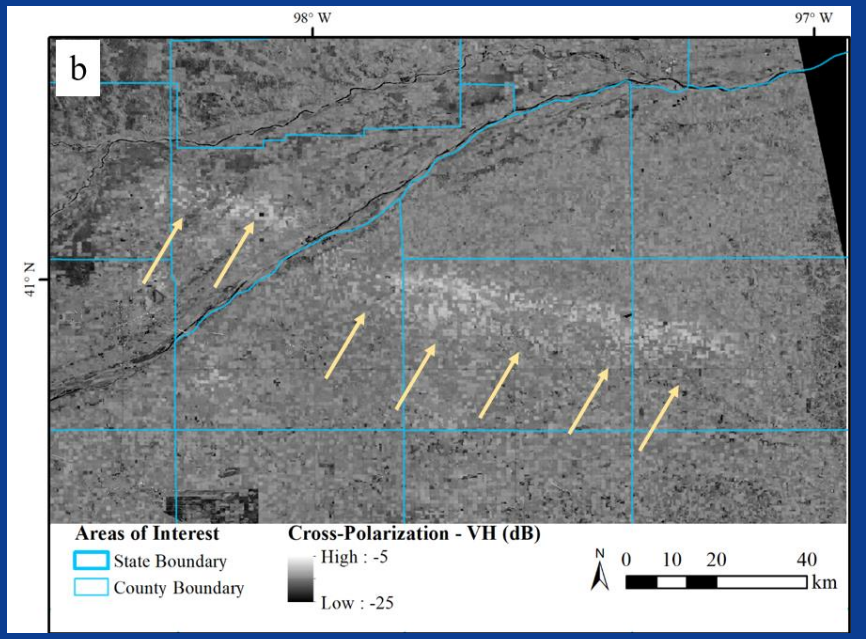
- Intense thunderstorms can produce damaging winds and large hail across major agricultural areas, especially during the prime growing season.
  - In some cases, large swaths of damage are left behind and can be viewed by satellite remote sensors (Jedlovec et al 2006, Gallo et al. 2012, Molthan et al. 2013, Bell and Molthan 2016, Bell et al. 2020).
  - Nearly all of these studies have been over the United States, but hail and the damage to agricultural crops is not just a United States problem.



Changnon and Baron 1971



Gallo et al. 2012



Bell et al. 2020 (under review)

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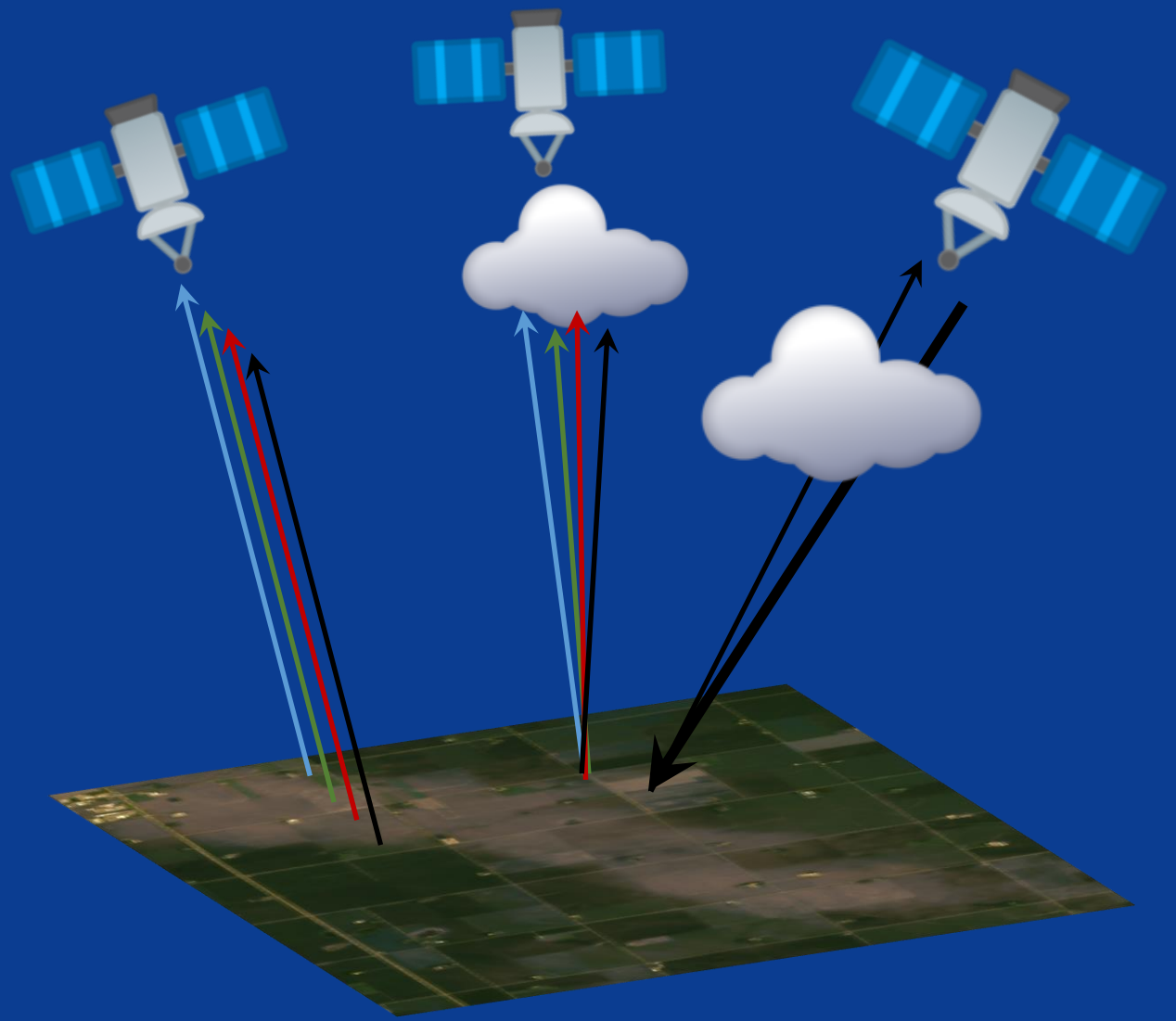
  - Nearly all of these studies have been over the United States, but hail and the damage to agricultural crops is not just a United States problem.
- As the number of satellite remote sensors in orbit increase, they can be a useful resource for evaluating damaged areas both qualitatively and quantitatively.
  - Optical remote sensors are useful as their spectrum of channels can generate an array of derived indices (e.g. NDVI) but are limited by atmospheric conditions.
  - Synthetic Aperture Radar (SAR) instruments can be used regardless of atmospheric conditions, but the availability of data and ease of use can be limiting.
  - Combination of moderate to high-resolution optical and SAR sensors provide high temporal resolution.
- This work attempts to develop a satellite-agnostic approach for evaluating agricultural regions for suspected hail damaged areas regardless of sensor type.

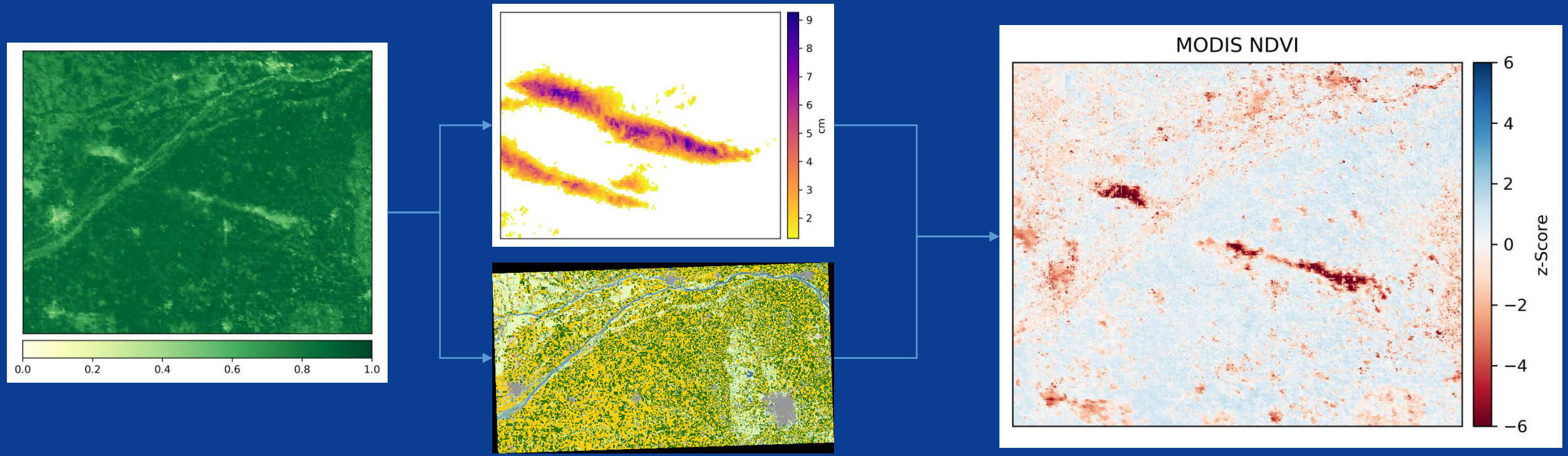
Background

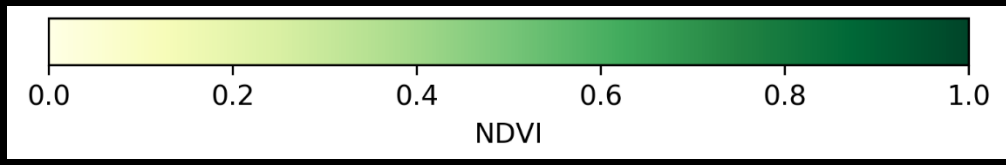


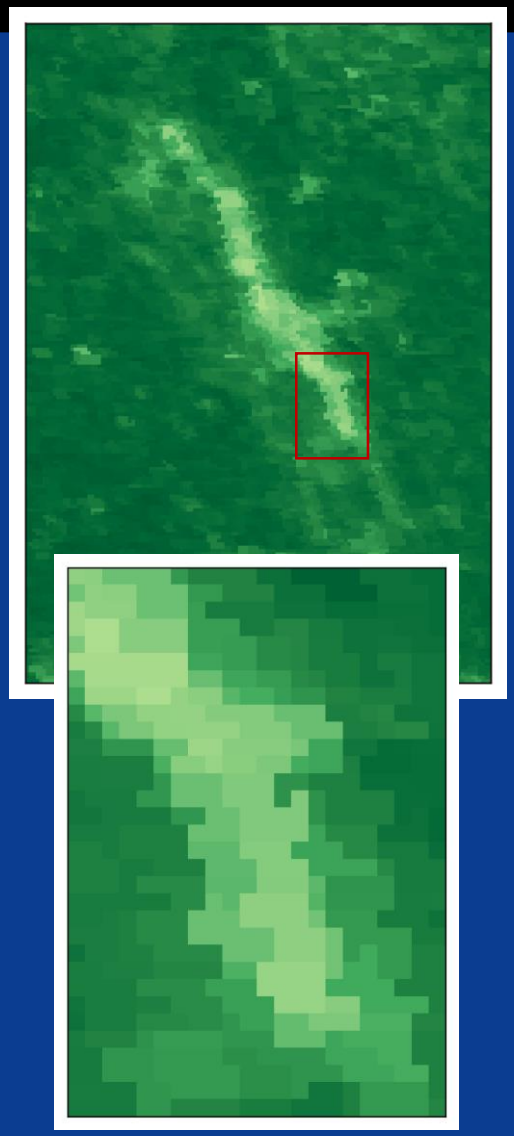
- What do we mean by satellite-agnostic?
  - For optical sensors, what common spectral bands and/or derived products can be used from the majority of operational sensors?
  - For SAR, what current polarizations are currently available and how do they compare with soon to be available SAR instruments?
- What additional datasets can be utilized to support the development of identifying damaged areas?
  - Land-cover/Land-use
  - Thunderstorm data

Methodology

- Statistical analysis of the damaged areas, specifically looking at z-score
  - Description of the z-score
  - Utilized USDA's Cropscape Crop Data Layer (CDL)* and Maximum Estimated Hail Size (MESH) to perform analysis on the pixels of like crop types and to differentiate potential hail impacted pixels vs non-hail damaged pixels







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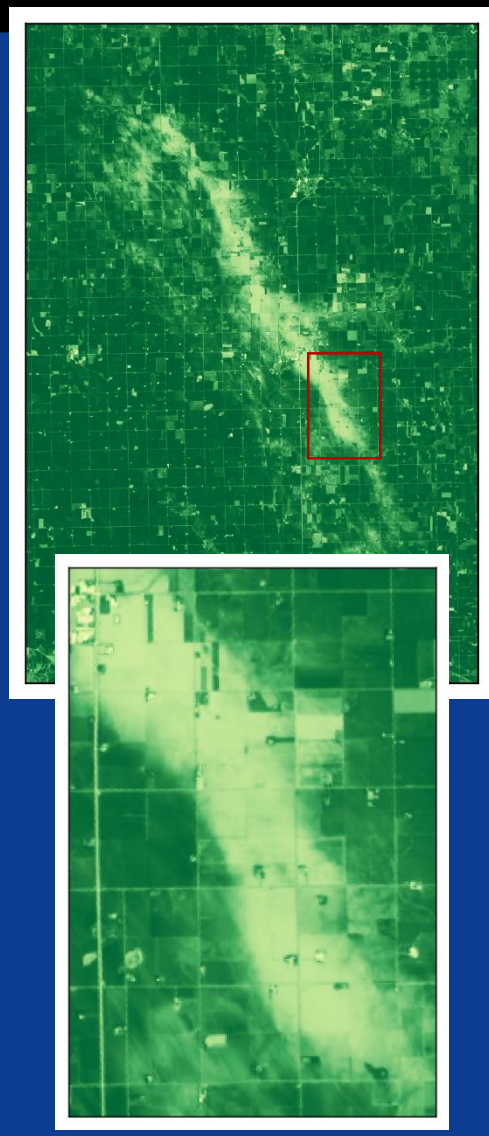
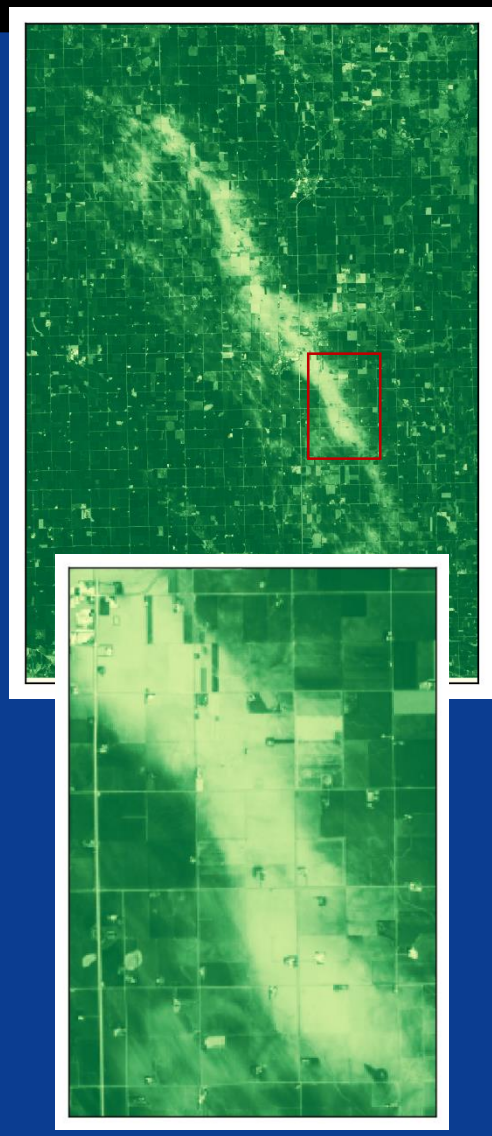
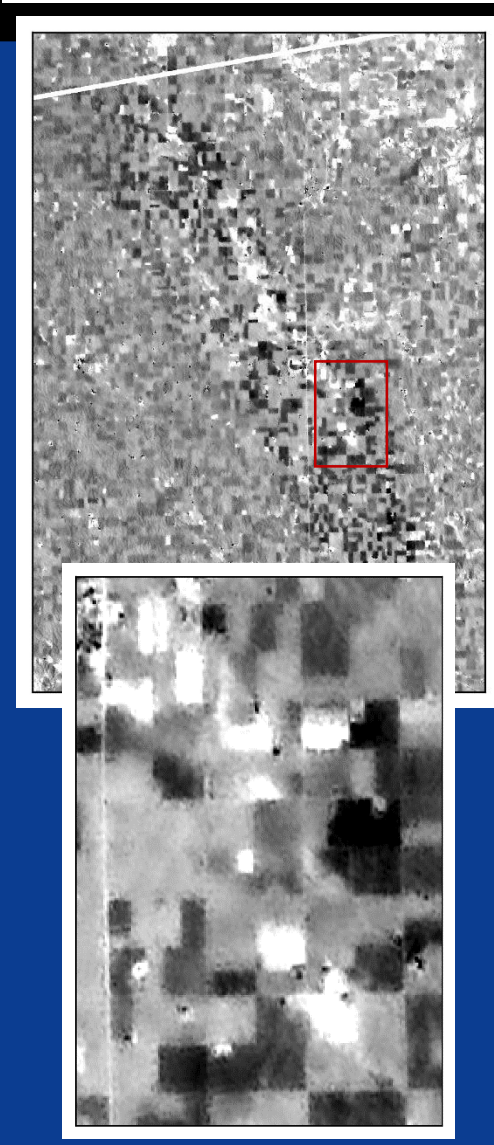


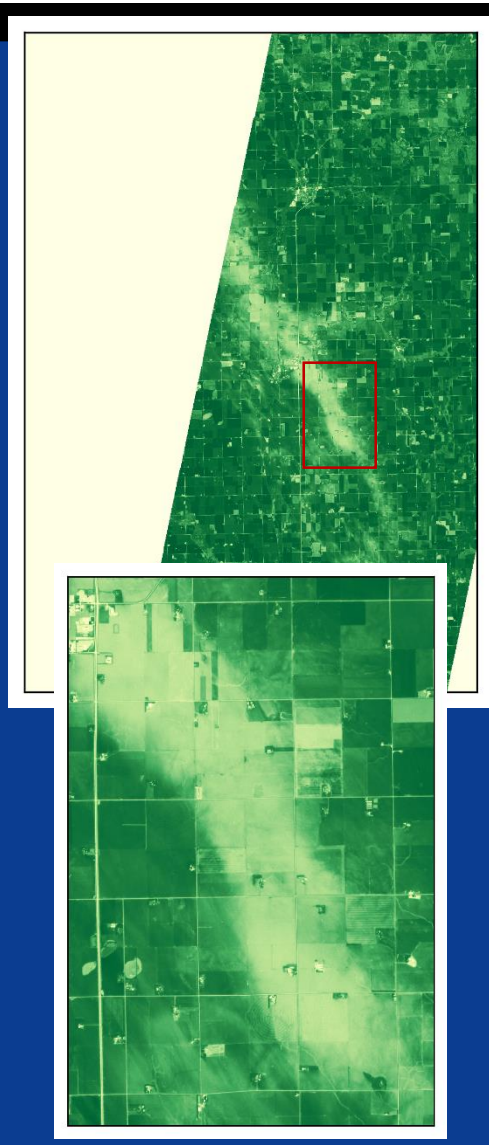
Landsat-8



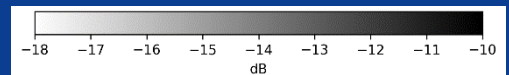
Sentinel-2



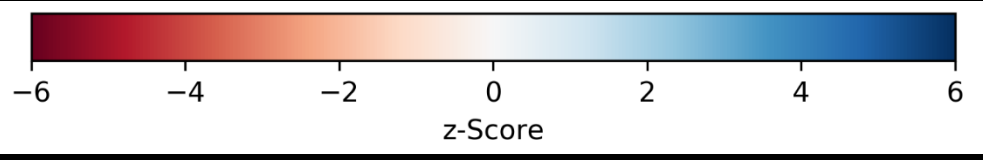
Sentinel-1

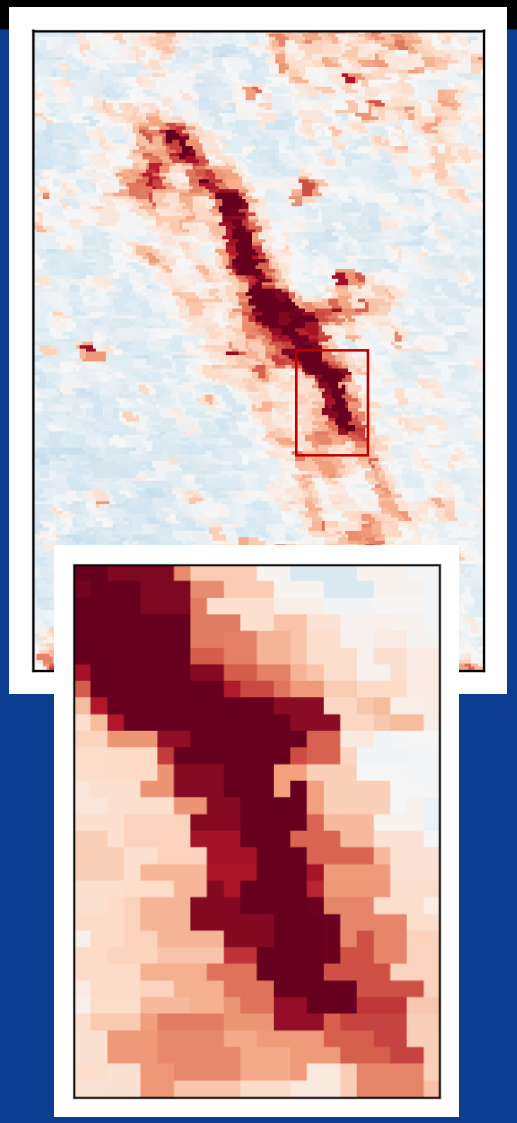


Planet Labs



z-score Comparison





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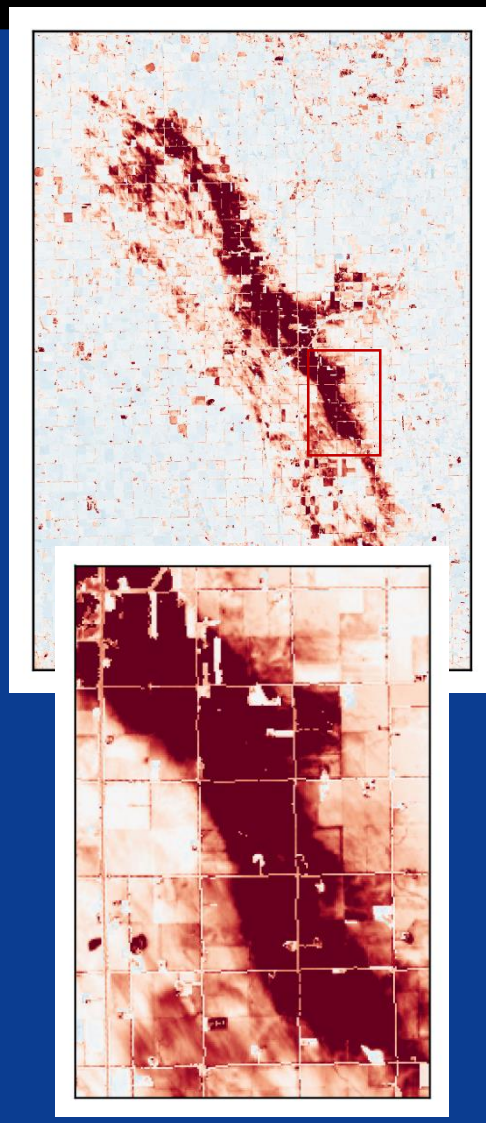
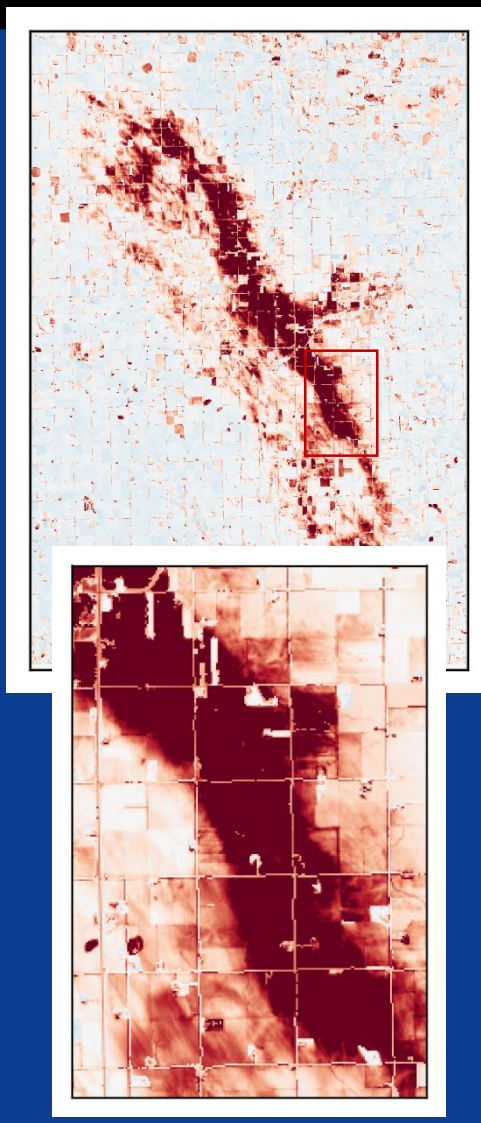
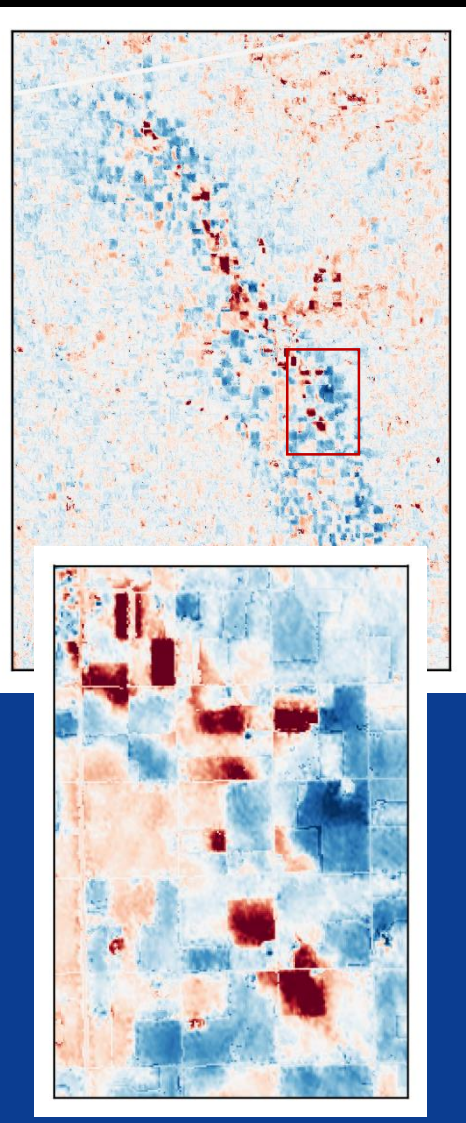


Landsat-8



Sentinel-2



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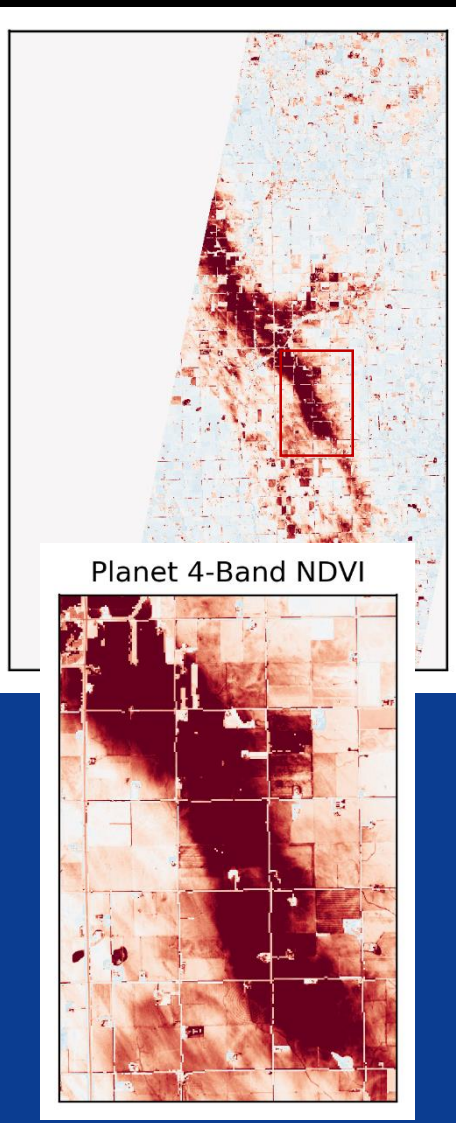
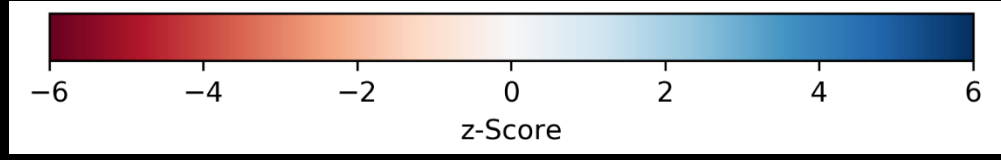
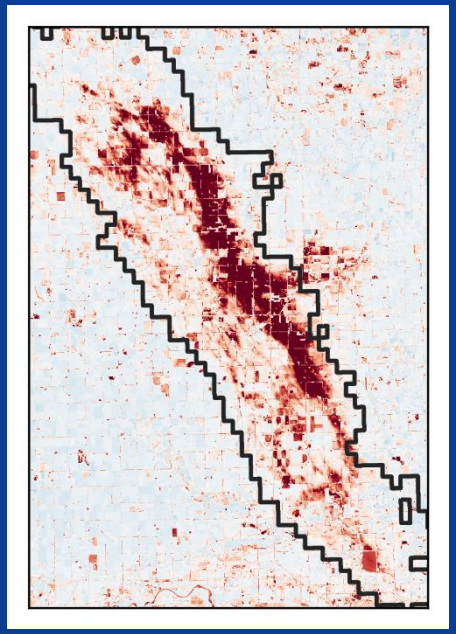


Planet Labs

How do discern damage?

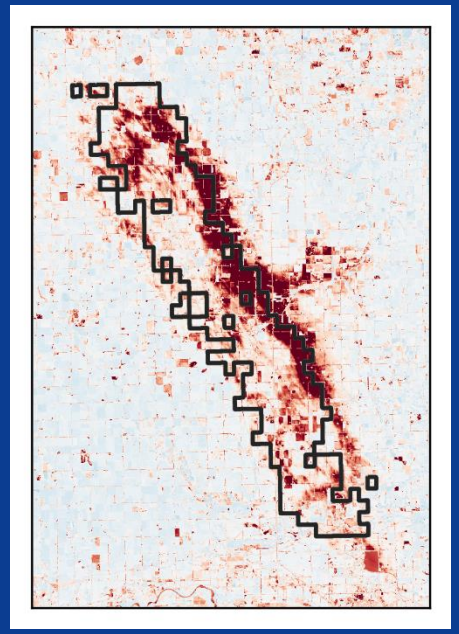


MESH ≥ 1.27 cm



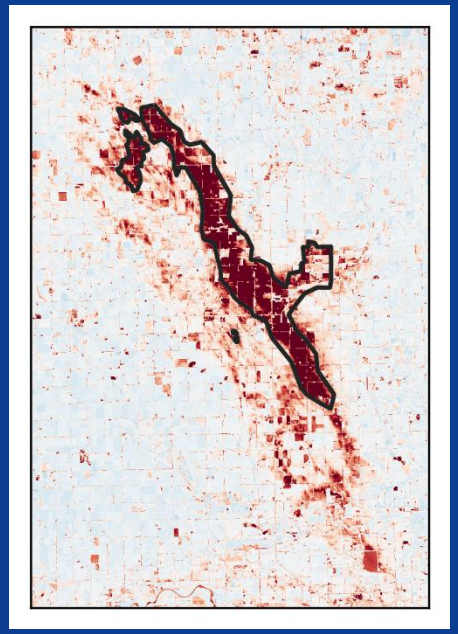
μ z-score: -1.56

MESH ≥ 2.54 cm

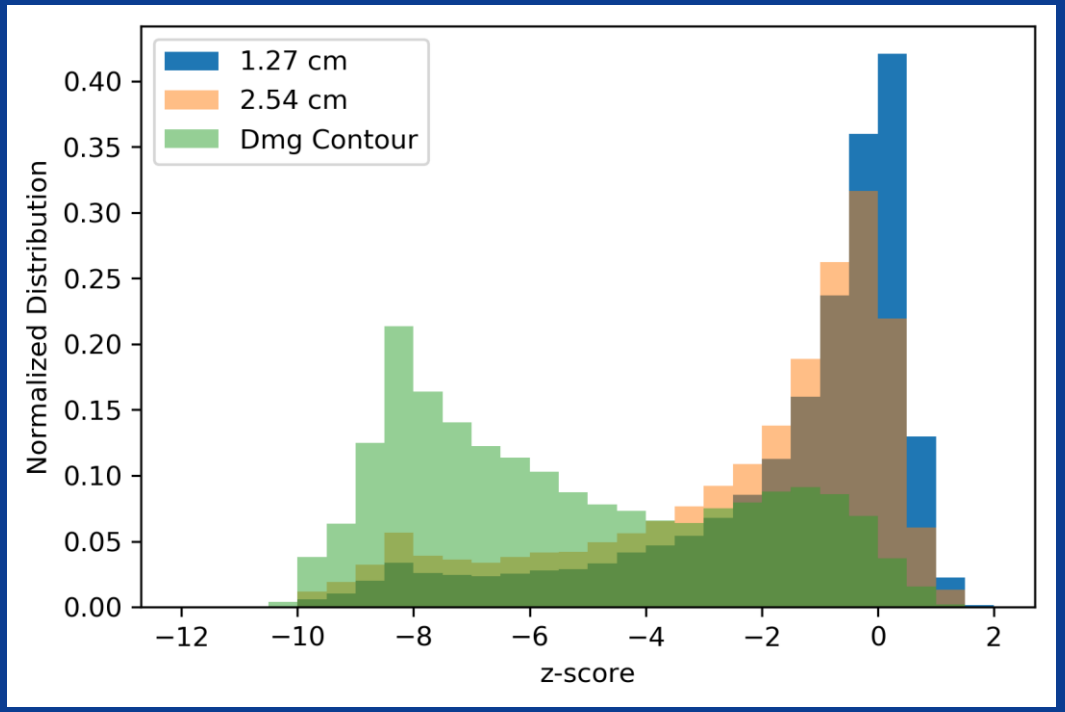


μ z-score: -2.32

Hand Analysis



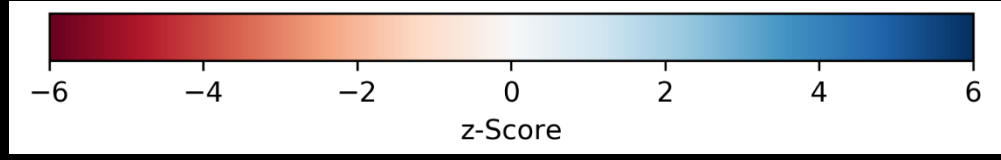
μ z-score: -5.29



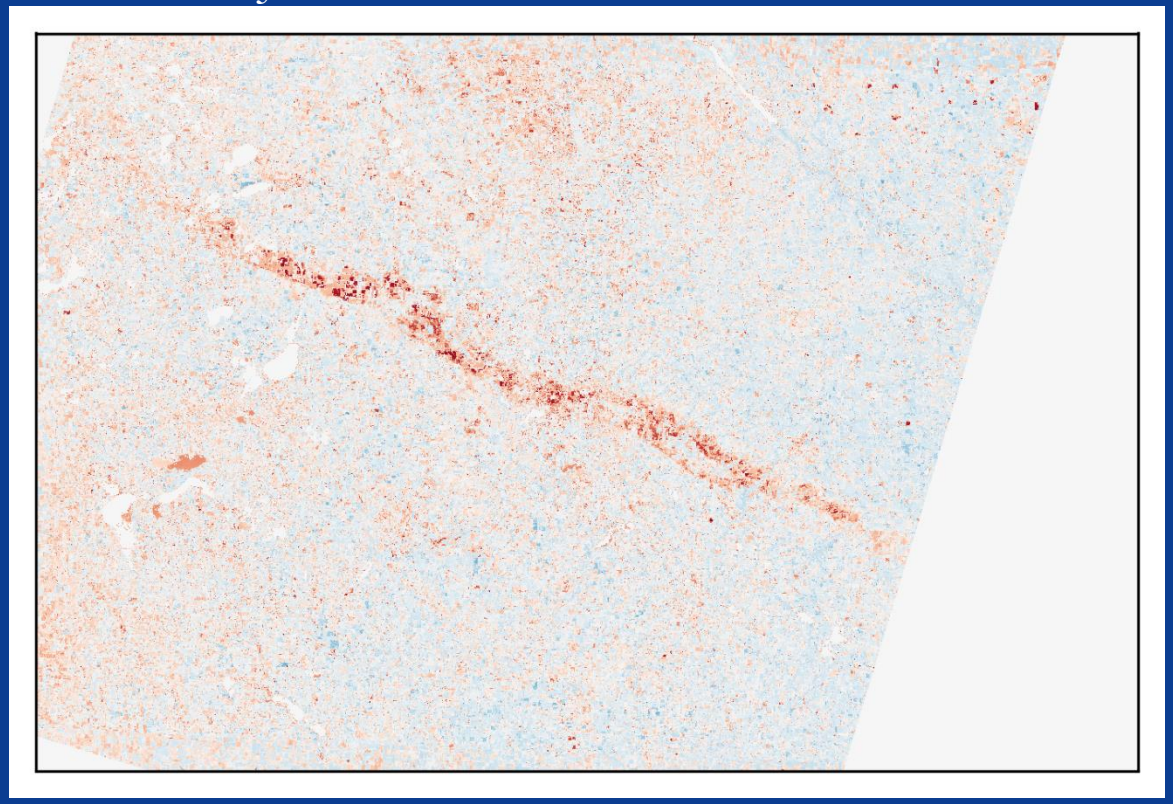
Histogram of z-scores by thresholds

- Hand drawn contours are time consuming and miss areas of potential damage identified through the use remote sensors
- Storm derived products (i.e. MESH) provide great spatial coverage, but determining what minimum MESH value is chosen, could lead to missed damaged areas.
- One tailed p-value could be considered, but low end-damaged areas may be overlooked depending on p-value chosen.

Examples of other recent events

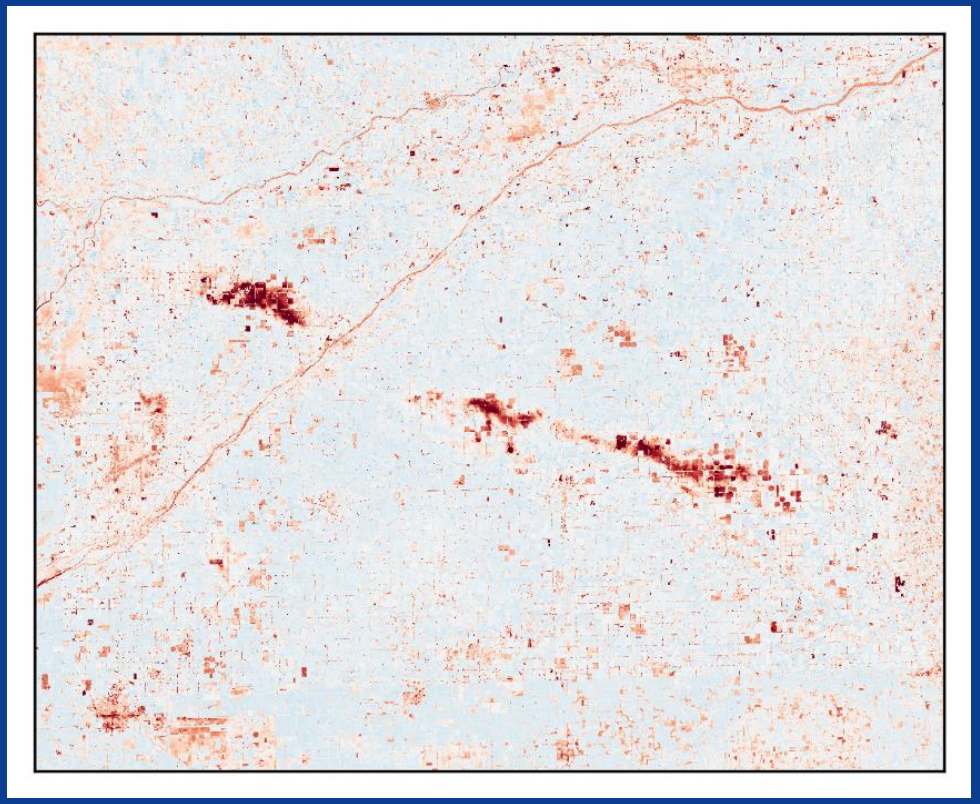


21 June 2017—South Dakota/Minnesota



Methodology detects hail damage swath in early growing season case study, but not to the same magnitude as cases later in the growing season.

5 August 2018--Nebraska



Hail damage swaths that occur late in the growing season have greater variability in damage magnitudes

Final Thoughts

- This presentation covered the development of a satellite-agnostic methodology that detects agricultural areas that are damaged as a result of intense thunderstorms that bring damaging winds and large hail.
  - Variability in vegetation conditions from event to event
- How to build upon this initial work?
  - Additional statistical analysis
  - Incorporate machine learning into the delineation of damage (e.g. classification, clustering, feature extraction)
  - Work industry to understand more about the relationship between degree of damage observed on the surface and what is seen from satellite remote sensors.

References

- Bell, J. R., E. Gebremichael, A. L. Molthan, L. A. Schultz, F. J. Meyer, C. R. Hain, S. Shrestha, and K. C. Payne, 2020: Complementing Optical Remote Sensing with Synthetic Aperture Radar Observations of Hail Damage Swaths to Agricultural Crops in the Central United States. *J. Appl. Meteor. Climatol.* (under review)
- Changnon, S. A. and N. A. Barron, 1971: Quantification of Crop-Hail Losses by Aerial Photography. *J. Appl. Meteor. Climatol.* **10** (1) 86-96.
- 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. *Wea. Forecasting*, 27 (3), 796–802.

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