Development of a Near-Real Time Hail Damage Swath Identification Algorithm for Vegetation

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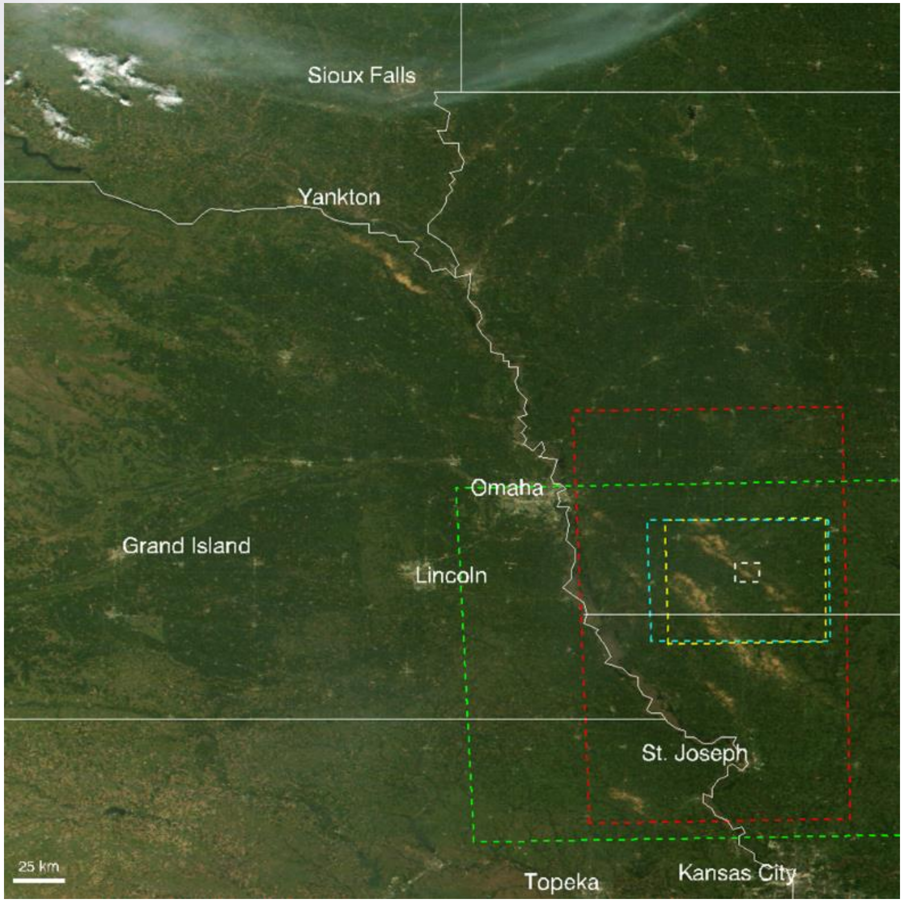
Joint Session of 20th Conference on Satellite Meteorology and Oceanography; 11th Annual Symposium on New Generation Operational Environmental Satellite Systems; 3rd Symposium on the Joint Center for Satellite Data Assimilation

Background & Previous Work

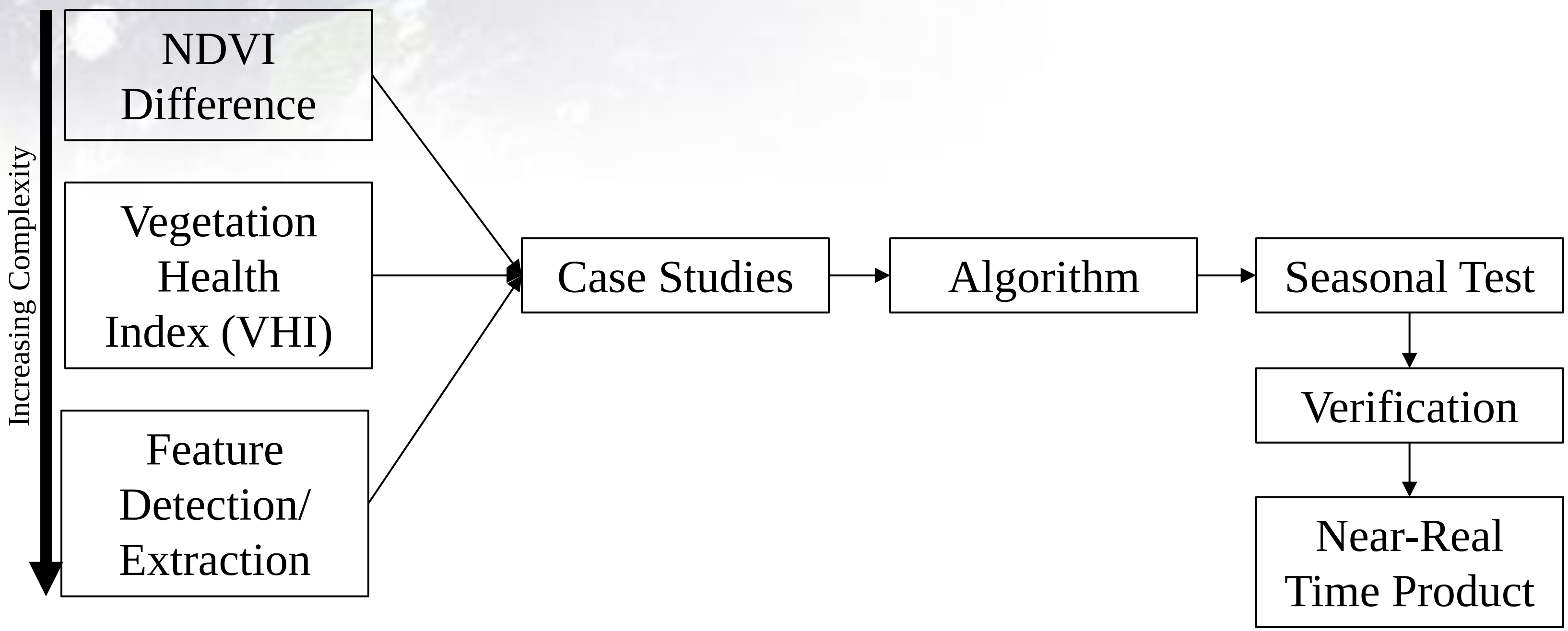
- Severe thunderstorms that bring damaging winds and large hail can cause significant damage to surface vegetation, especially agriculture.
- Work to identify hail damage to vegetation by observing changes first done by aerial surveys and now by using satellite imagery
    - Changnon et al. (1971), Gallo et al. (2012) and Molthan et al. (2013)
- Damage to crops become identifiable when the vegetation begins to stress or is no longer visible to the sensors.
    - Normalized Difference Vegetation Index (NDVI) anomalies
    - Land Surface Temperature (LST) anomalies.



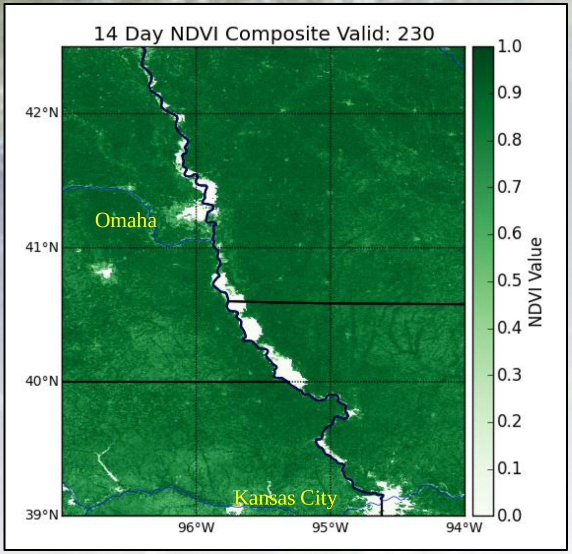
True color MODIS image depicting hail streaks caused by storms on 18 August 2011. (Molthan et al 2013)

Current Work

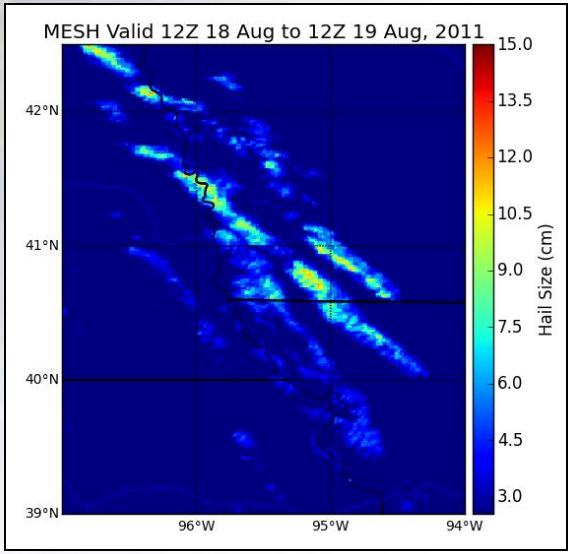
- Manual analysis of the imagery can be tedious and time consuming and/or inconsistent.
- Goal is to develop an objective and automatic algorithm to detect areas of damage in a more efficient and timely manner using Aqua MODIS and Suomi NPP VIIRS
- Focus is on using three different approaches to come up with best algorithm



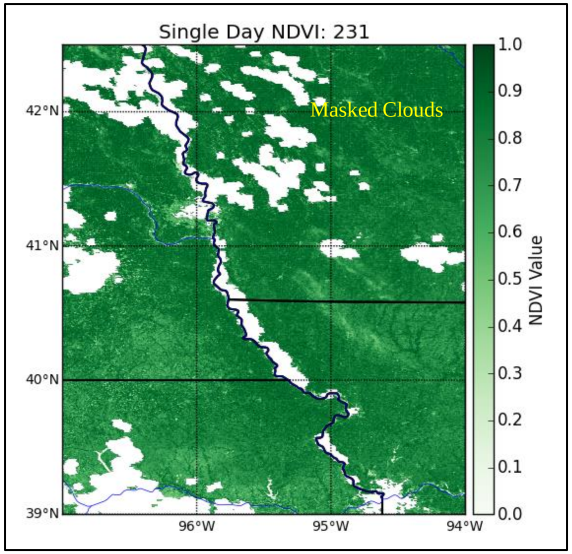
NDVI Difference



14 Day NDVI Composite for 18 Aug 2011

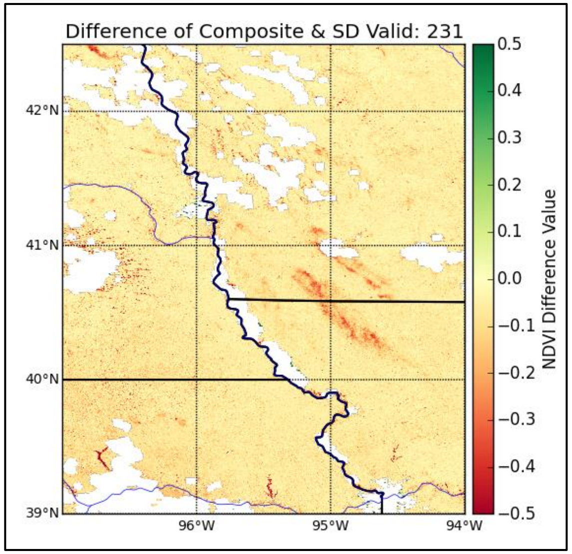


MESH valid 12Z 18 Aug to 12Z 19 Aug 2011

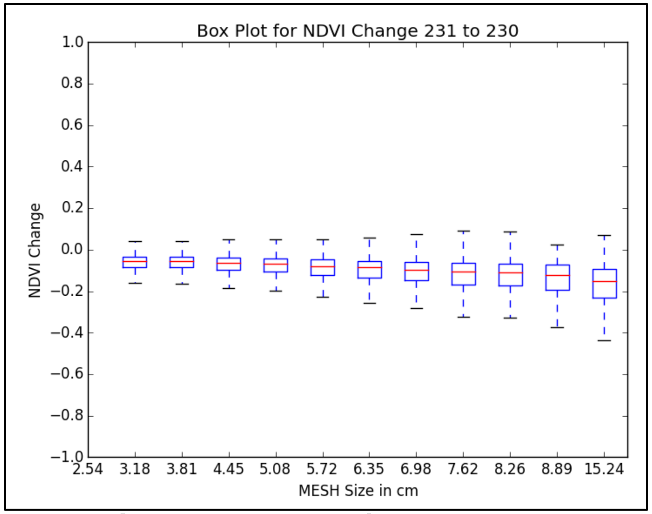


Single Day NDVI for 19 Aug 2011

- Short-term NDVI differences are by far the easiest way to identify damage that may have been caused by hail and wind
- Coupled with radar derived products, i.e. Maximum Estimated Size of Hail (MESH), specific trends can be observed.



Single Day NDVI Difference for 19 Aug 2011



Box Plot comparing NDVI Change to MESH Size

Vegetation Health Index (VHI)

- Parker et al (2005). noted localized surface temperature warming in and around hail damage swaths
- Can land surface temperature information lead to improved detection? If so, how?
- Kogan et al. (2001) developed the Vegetation Health Index (VHI), a combination of the Vegetation Condition Index (VCI) and Temperature Condition Index (TCI). VHI was originally developed to detect vegetation stress as a result of drought conditions.

Original → ***Modified***

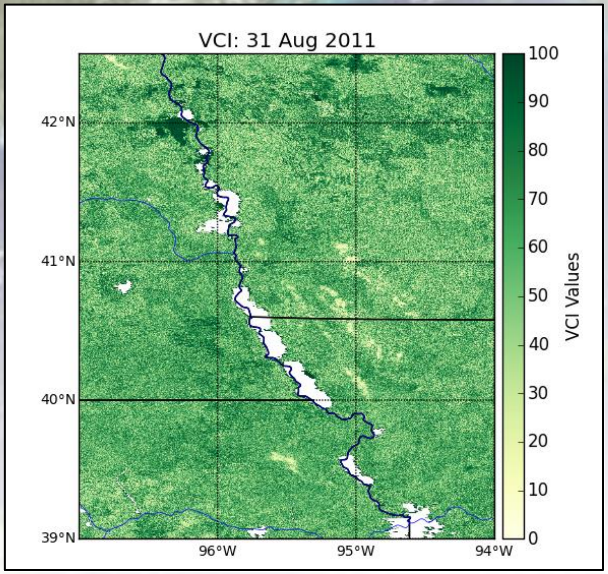
$$VCI = 100 * \frac{NDVI_{mean} - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \longrightarrow VCI = 100 * \frac{NDVI_{50} - NDVI_{10}}{NDVI_{90} - NDVI_{10}}$$

$$TCI = 100 * \frac{BT_{max} - BT_{mean}}{BT_{max} - BT_{min}} \longrightarrow TCI = 100 * \frac{LST_{90} - LST_{50}}{LST_{90} - LST_{10}}$$

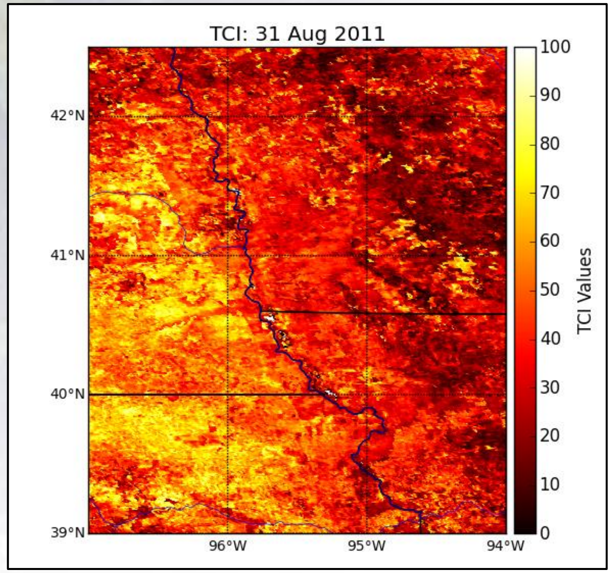
$$VHI = 0.5(VCI) + 0.5(TCI) \longrightarrow VHI = 0.6(VCI) + 0.4(TCI)$$

- Modified approach for this work, by replacing multiple year minimums, means and maximums with 14 day 10th 50th, and 90th percentiles. Coefficients on new VHI can be adjusted for optimized results.

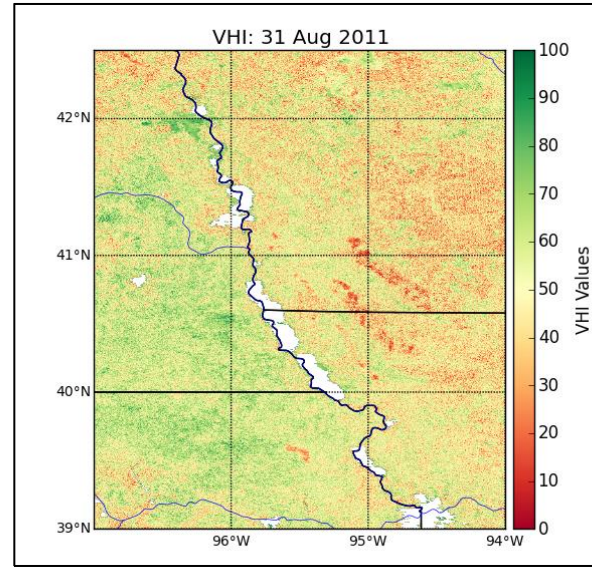
Vegetation Health Index (VHI)



Vegetation Condition Index (VCI) for 31 August 2011



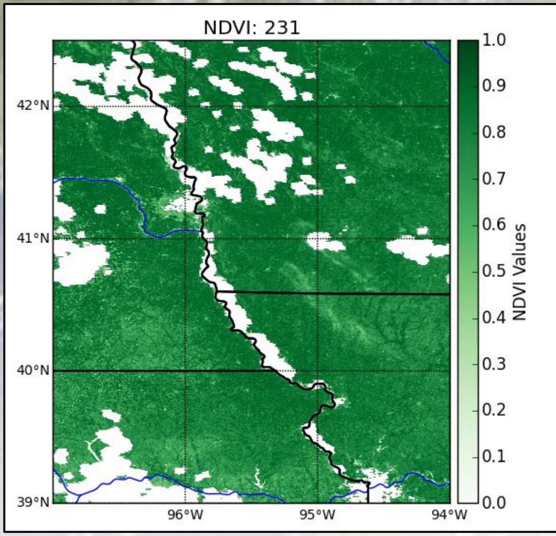
Temperature Condition Index (TCI) for 31 August 2011



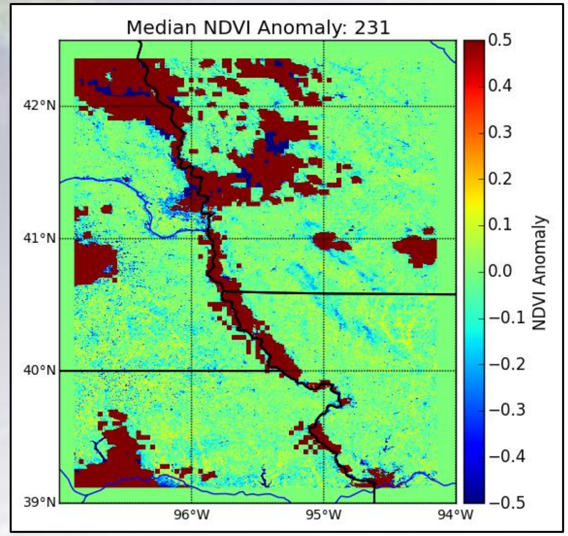
Vegetation Health Index (VHI) for 31 August 2011

- Inclusion of LST through VHI benefits detection of potential damage
- Still need to address several challenges:
  - Removing clouds from NDVI and LST prior to generating VCI and TCI
  - Determining number of observations to include in these products
    - 14 days vs 28 days
    - Aqua MODIS only vs Aqua and Terra MODIS (and S-NPP VIIRS)

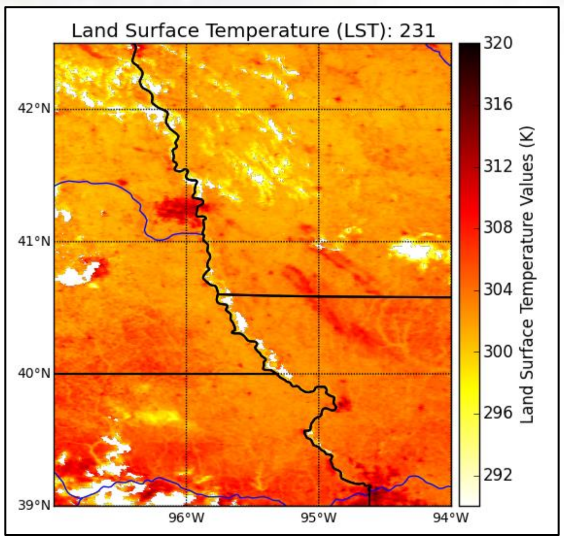
Feature Detection



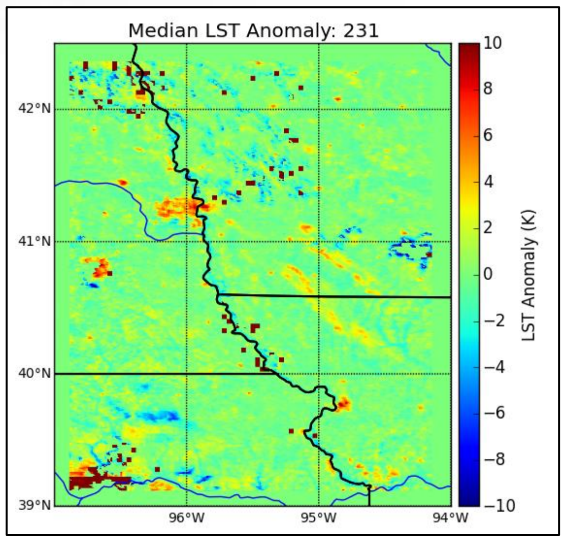
NDVI for 19 August 2011



NDVI Anomaly for 19 August 2011



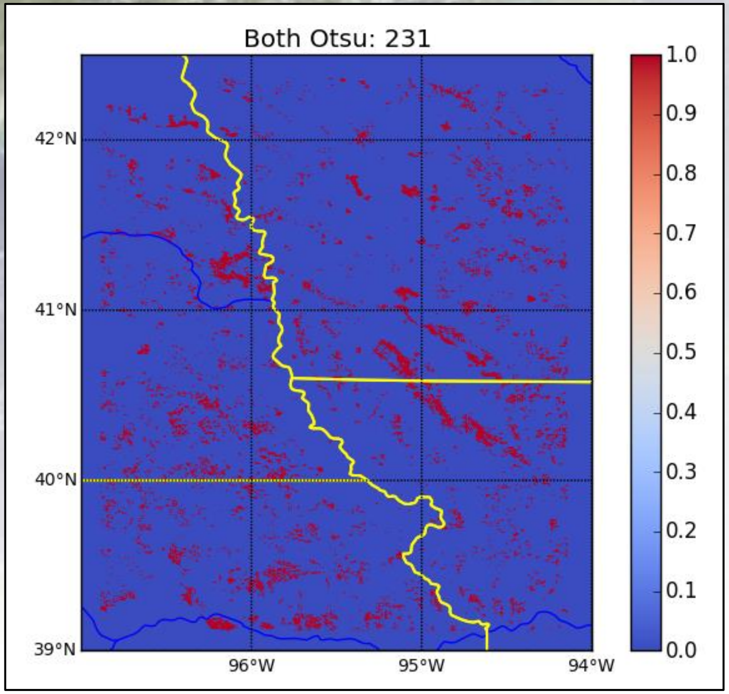
Land Surface Temperature for 19 August 2011



Land Surface Temperature Anomaly for 19 August 2011

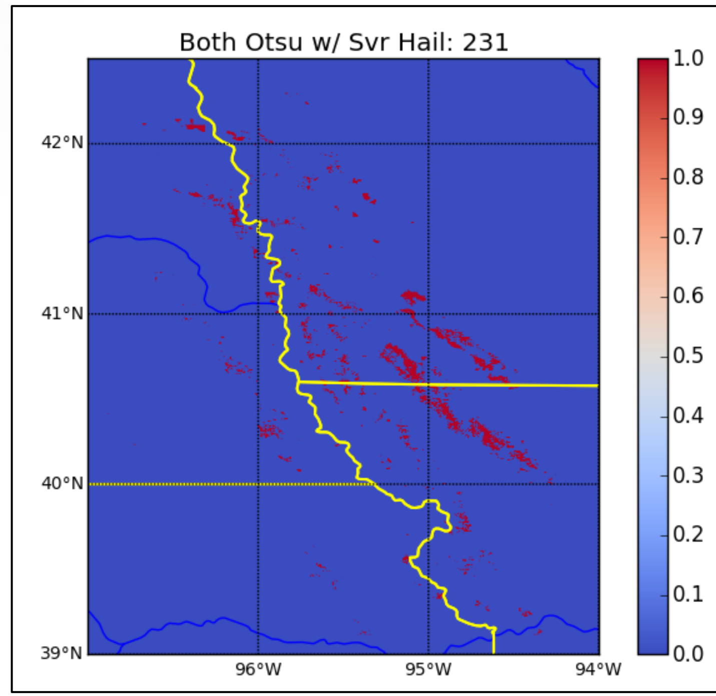
- Image classification provides another way of finding potential hail damage in vegetation.
- Many of these techniques are unsupervised as opposed to using supervised classification
- Anomalies are calculated using a moving box, this helps to rid the image of some noise and identify damage areas where they contrast with the background (lower NDVI, higher LST)
- Otsu’s Method is used for this work
  - Filter determines whether pixel is or is not a local anomaly

Feature Detection



Otsu filter after using a 200 x 200 pixel box for 19 August 2011.

- Size of box that computes image statistics is key to success of detection by Otsu filter.
- Otsu Filter does pick up on false detections
  - Crop Harvesting
  - Urban Areas
  - Clouds and Cloud Shadows



Otsu filter after using a medium sized box on both NDVI and LST for 19 August 2011. Using MESH > 2.54 cm to extract swath.

- Using MESH to extract anomalous areas in both NDVI and LST shows possible areas of damage not picked up on by other methods
- Refine detections by characteristics of the identified damaged clusters

Summary

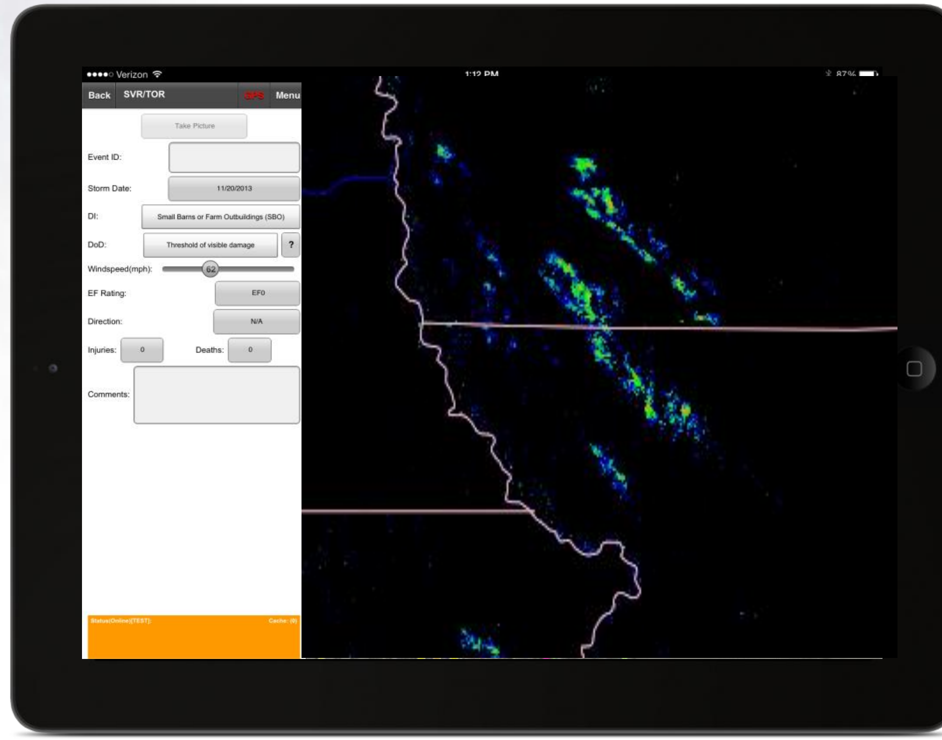
- Severe storms that bring large damaging hail and high winds can cause large areas of damage to surface vegetation, especially in the Midwest and Great Plains during the growing season.
- Aerial surveys and now satellite imagery has been used to identify these hail streaks. Previous work focused on short-term NDVI differences
- Detection of damage by incorporating land surface temperature is explored. The Vegetation Health Index combines both NDVI and LST in a single vegetation product.
- Feature detection using Otsu's Method was explored for a detection methodology as well. This methodology focuses on finding features that contrast from the background and highlighting them.
- Biggest challenge that remains is validating what is hail damaged and what is not. With no formal ground surveys conducted by the NWS, determining what is exactly hail damage and what is not can be hard.

Future Work

- Finish up work on case studies. Determine methodology for automated algorithm. Obtain datasets for the recent growing seasons and evaluate the performance of the algorithm.

- Incorporate additional datasets such as land cover and agricultural crop type datasets to measure extent of identified hail streaks.

- After testing pseudo near-real time seasons, begin transitioning algorithm to near-real time product and distributing it to end users (i.e. NOAA/NWS Damage Assessment Toolkit, storm surveys) that will benefit from this product.



Proof of concept showing what automated hail detection algorithm could look like in the DAT interface.

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Questions or Comments

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