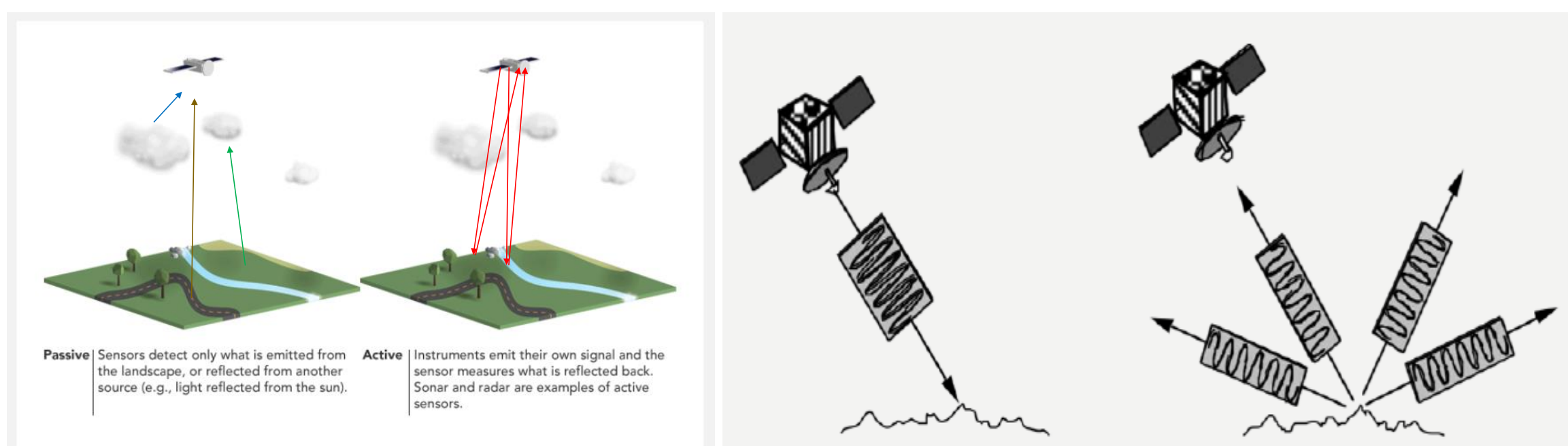


## Introduction

- Satellite remote sensing can provide large-scale mapping of areas impacted by a disaster, contributing value to situational awareness, monitoring the event, and decision support services.
- The constellation of NASA, NOAA, commercial, and international partner satellites provides a wide range of information at varying wavelengths, spatial resolutions, and repeat cycles.
- Many efforts focus on optical remote sensing (VIS, NIR, IR) but in weather-related disasters are often blocked by cloud cover.
  - For example, a major hurricane or long-term rainfall event produce widespread cloud cover that blocks the view of resulting floods

## Synthetic Aperture Radar (SAR)

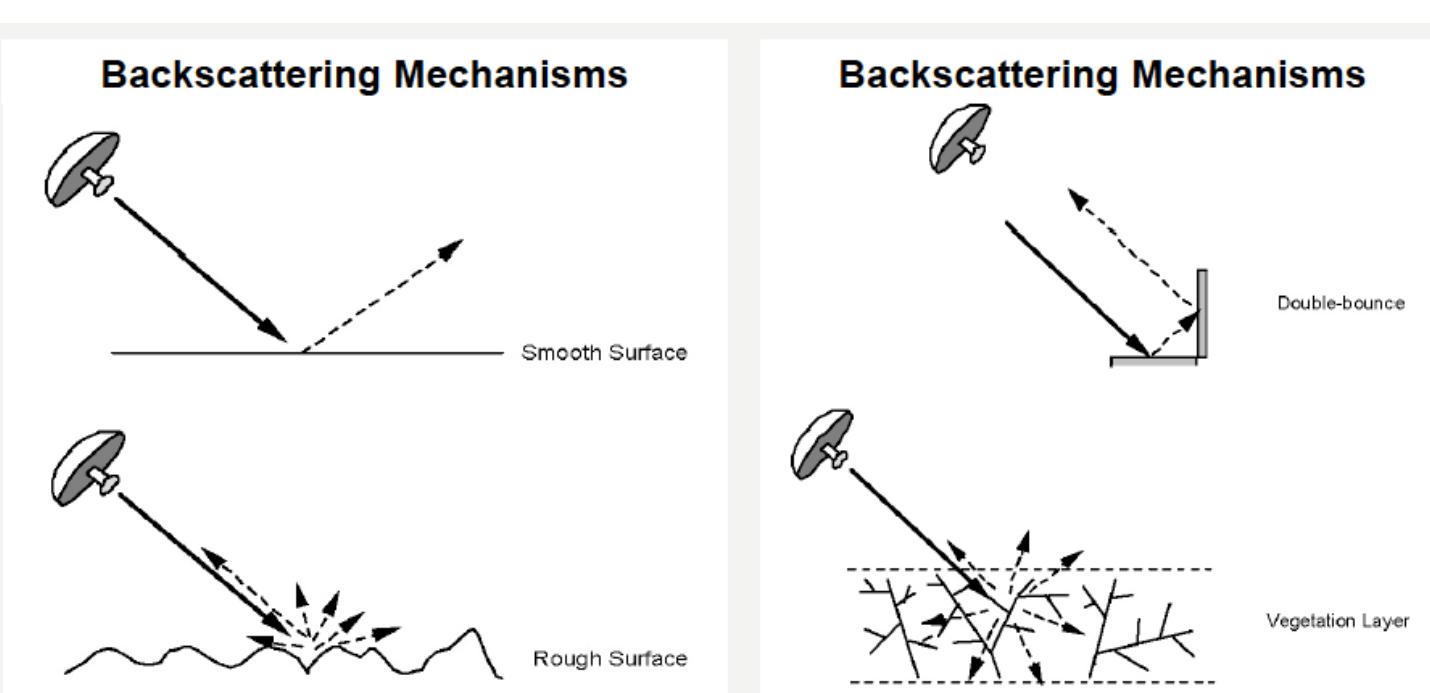
- Synthetic aperture radar is an **active** remote sensing approach that, sending out a signal with known wavelength and measures backscatter.
- Compared to a **passive** system that receives thermal emissions or reflected components, SAR allows for penetration through most clouds and precipitation, varying with wavelength.



**Figure 1.** Comparison of passive and active remote sensing, this and other figures courtesy of NASA ARSET training module on Synthetic Aperture Radar.

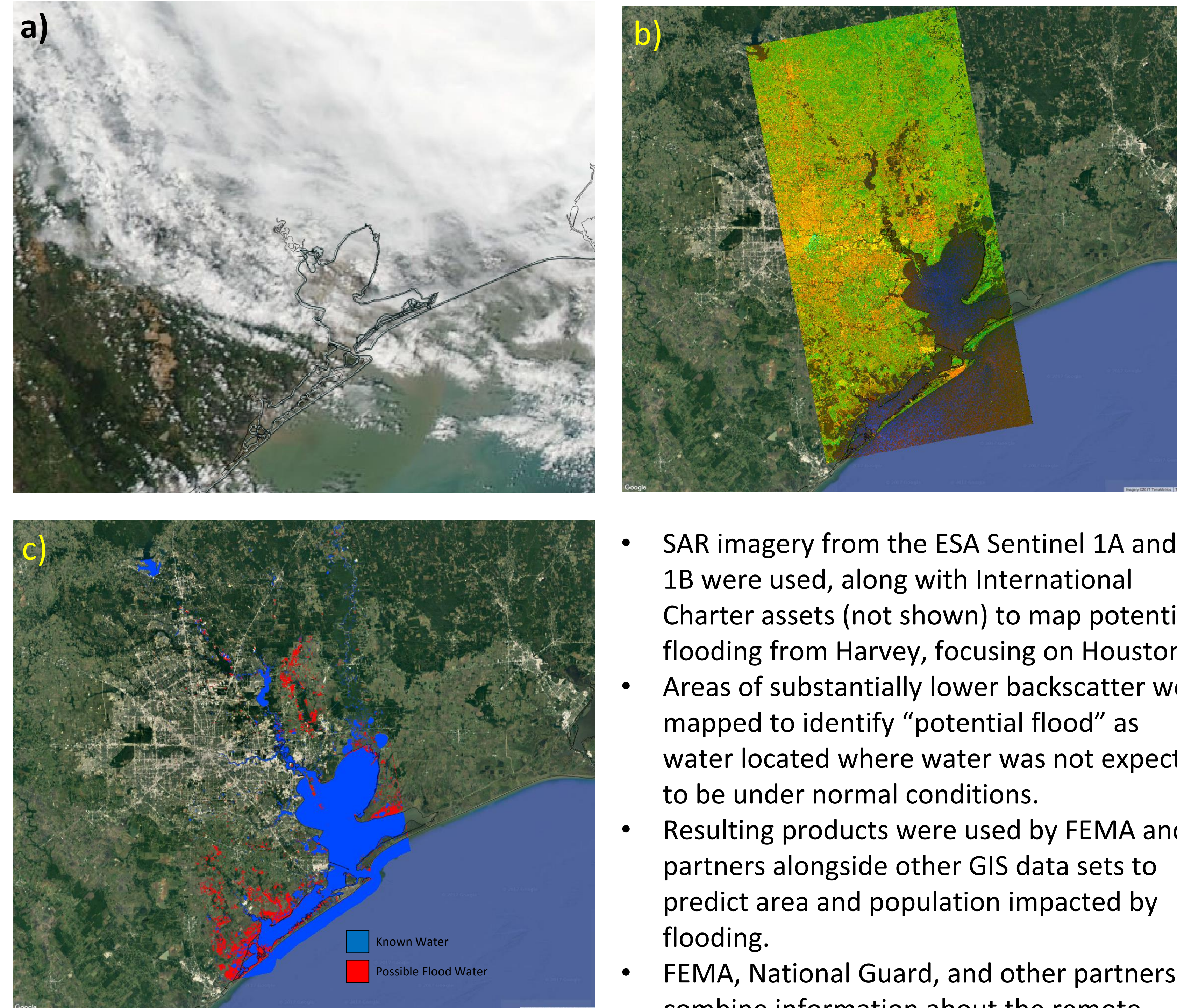
**Figure 2.** Example of a SAR system transmitting a signal (left) and receiving a backscattered component (right) based upon the surface that has been intercepted by the signal, similar to weather radar.

- Some SAR systems also penetrate through dense vegetation canopy, depending on wavelength.
- Allows for through-cloud observations of floods and other severe weather damage.
- Backscattering mechanisms depend upon the surface that is being sampled:
  - Smooth surfaces like undisturbed water can appear dark (low dB)
  - Vegetation orientation impacts dB return from various polarizations.



**Figure 3.** Various types and styles of backscattering mechanisms that contribute to the strength of signal received, as a function of what has been sampled.

## Hurricane Harvey

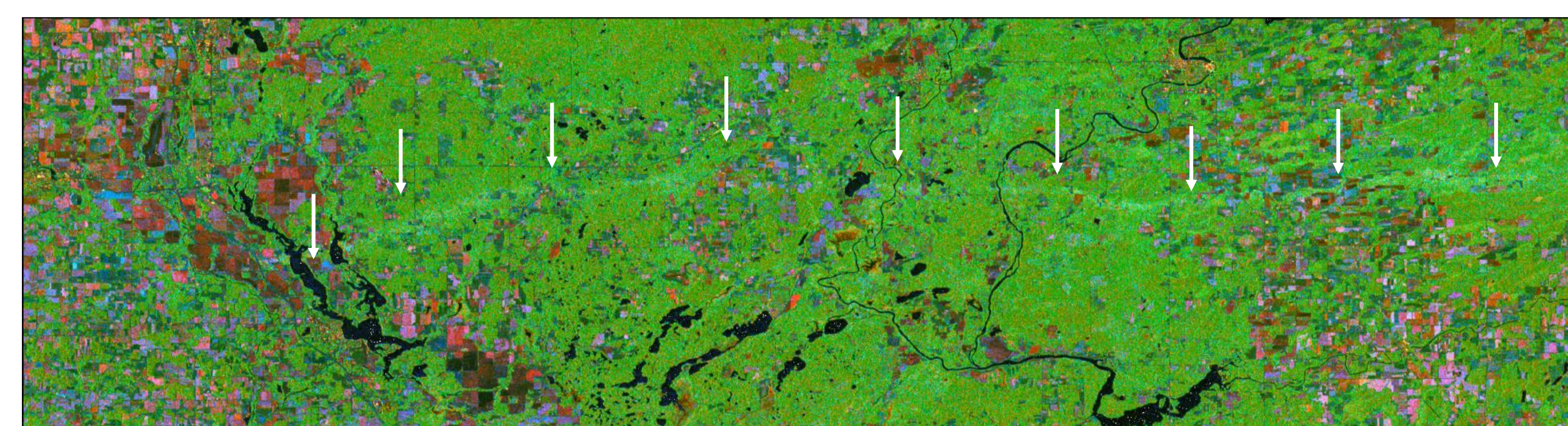


**Figure 4.** a) Aqua MODIS image of T.S. Harvey producing cloud cover over the Houston area, b) Sentinel 1B mapping (false color image) of the Houston area despite cloud cover with water depicted in blue shades and other darkening, and c) final threshold-based map of water and flooding in the region.

- SAR imagery from the ESA Sentinel 1A and 1B were used, along with International Charter assets (not shown) to map potential flooding from Harvey, focusing on Houston.
- Areas of substantially lower backscatter were mapped to identify “potential flood” as water located where water was not expected to be under normal conditions.
- Resulting products were used by FEMA and partners alongside other GIS data sets to predict area and population impacted by flooding.
- FEMA, National Guard, and other partners combine information about the remote sensing of a flood with other population and structure information to develop preliminary assessments.
- Assessment information feeds into the broader response process and planning.

## EF-2 Tornado near Clear Lake, WI

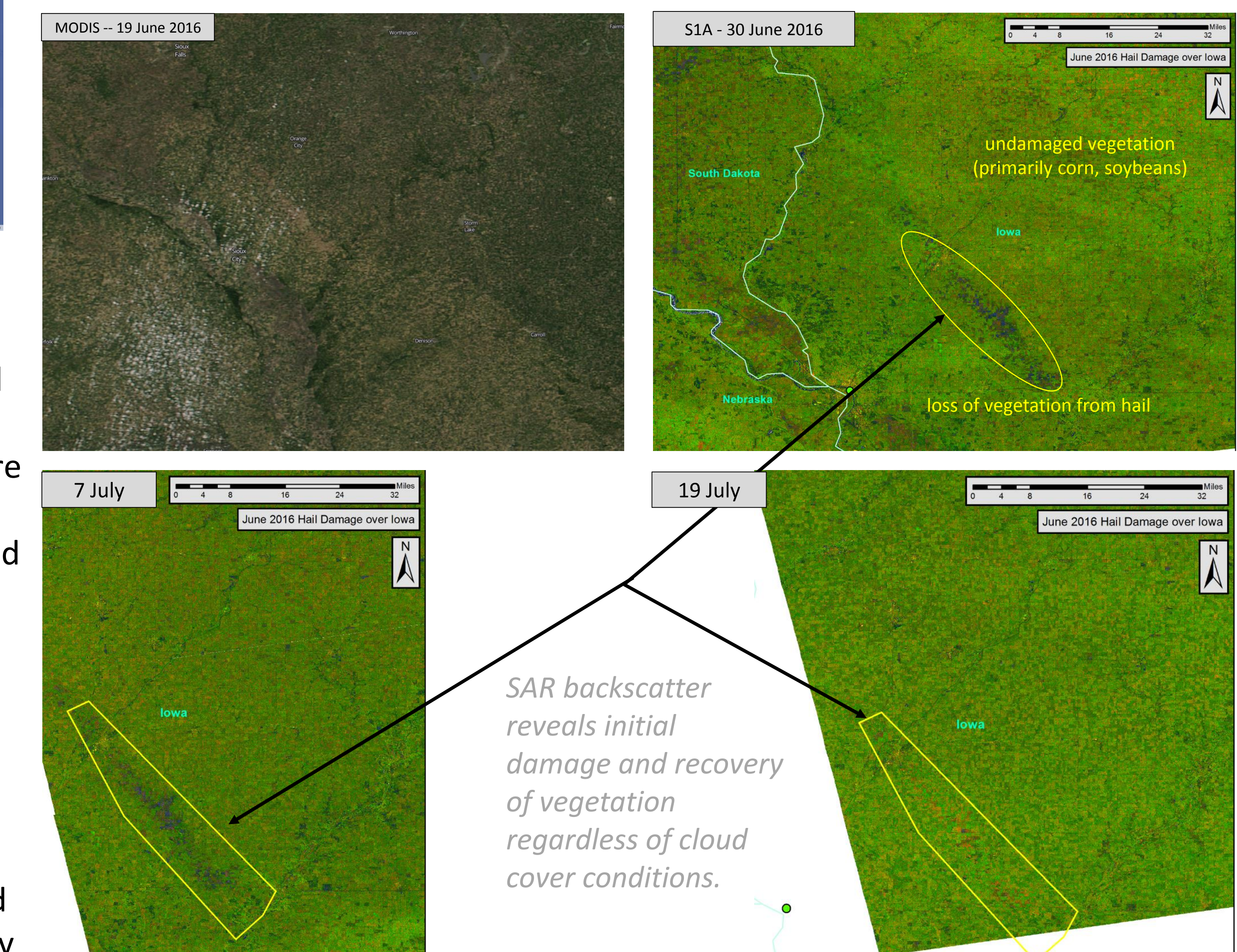
- SAR backscatter is sensitive to the reflecting surface, and because vegetation provides unique differences in co-polarized and cross-polarized returns, damage to vegetation is apparent in SAR imagery, particularly where the vegetation has been changed by the tornado.
- Changes in backscatter among different images and false color compositing of parameters identified a tornado damage track near Clear Lake, WI.



**Figure 5.** False color compositing of backscatter and change over time identifies an east-west oriented pattern of change associated with a tornado near Clear Lake, WI, data provided to the NWS for their assessment.

## 18 June 2016 Hail Damage in NW Iowa

- Severe thunderstorm winds, combined with hail, led to corn and other crop damage in northwestern Iowa on 18 June 2016 and was evident as a scar (browns) in MODIS imagery the following day.
- In MODIS vegetation index imagery, the scar remains apparent through much of the growing season when compared to surrounding vegetation.
- Because SAR backscatter is sensitive to the amount of vegetation and orientation of leaves, height of crop, etc., damage to the corn is evident in false color compositing of co- and cross-polarized backscatter.
- Development work continues to extract these signals as damage maps.



**Figure 6.** a) MODIS image of hail damage scar in northwestern Iowa from 19 June 2016. b-d) Temporal evolution of the hail damage scar as depicted in false color compositing of co-polarized and cross-polarized backscatter of the Sentinel 1A instrument through mid-July.

## Future Work

- Continued development of SAR RGBs for qualitative analysis for decision makers as well as supplemental training for interpretation.
- Work with end users on how quantitative products can be best integrated into their analysis and response activities, including training with end users so that they can draw the correct inference from the imagery products.
- Expanding the use of SAR products presented in this research to also cover DSS support of wildfires, as both optical remote sensing and SAR analysis provide numerous opportunities for mapping wildfires.
- Focus on objective algorithms for automatic extraction of affected regions.

## Acknowledgements

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