Development of VIIRS Flood Detection Software

River Ice and Flooding Initiative

Aug. 01, 2017 to July 31, 2018

(FY-17 Annual review)

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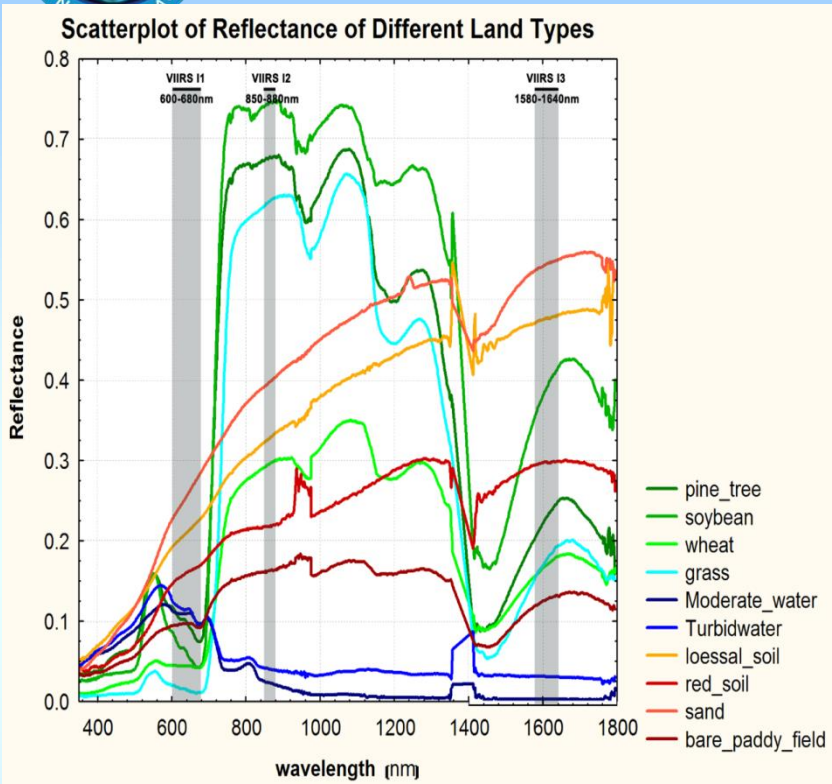
Outline

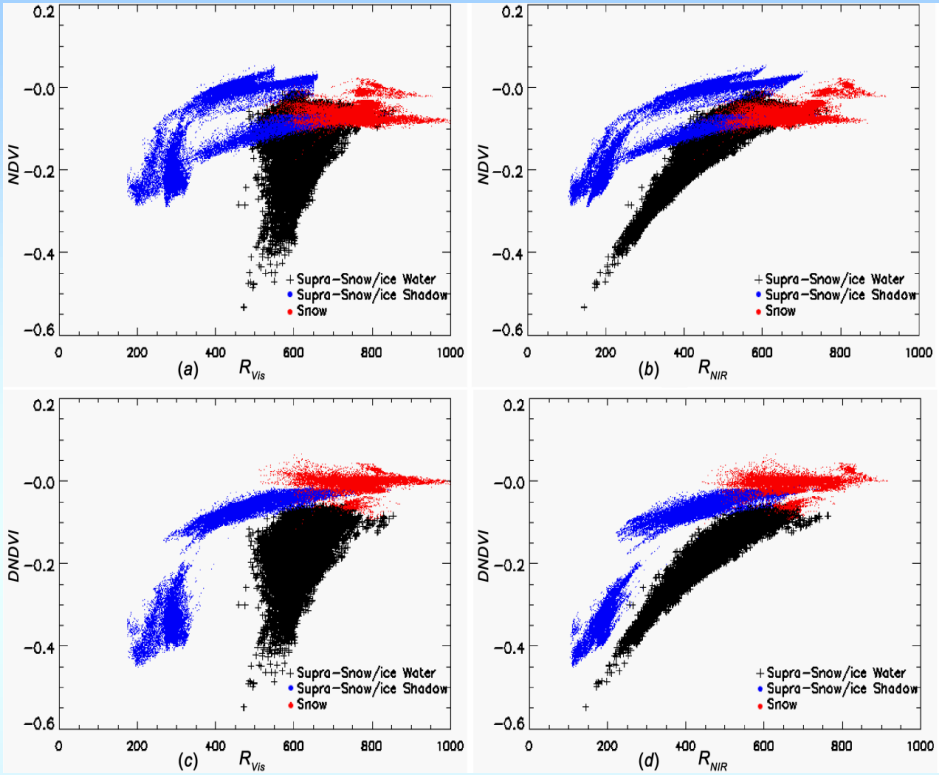
- Project Overview and Objectives
- Scientific Basis/Approach
- Key Results/Accomplishments
- Future plan
- Summary

Project Overview and Objectives

- Goal(s): Deliver global VIIRS flood product and integrate NOAA-20/VIIRS in the software
- Satellite sensors used: SNPP/VIIRS Imager and NOAA-20/VIIRS Imager
- Targeted NOAA (and non-NOAA) users:
  - NOAA/NWS-River Forecast Centers
  - NOAA/NWS-National Water Center
  - Federal Emergency Management Agency (FEMA)
  - US Army Corps of Engineers (USACE)
  - International Charter
- Period of Performance: Aug. 01, 2017 – July 31, 2018
- Budget: $100K (FY-17)

Scientific Basis/Approach





- Water detection is based on the spectral features of water surface over different underlying conditions.
- Cloud shadows and terrain shadows are differentiated by using geometry-based and object-based methods instead of spectral characteristics.
- Water fraction retrieval is based on the linear combination model by considering the mixing structure of sub-pixel land portion.

Water level calculation

- Pixel water level:

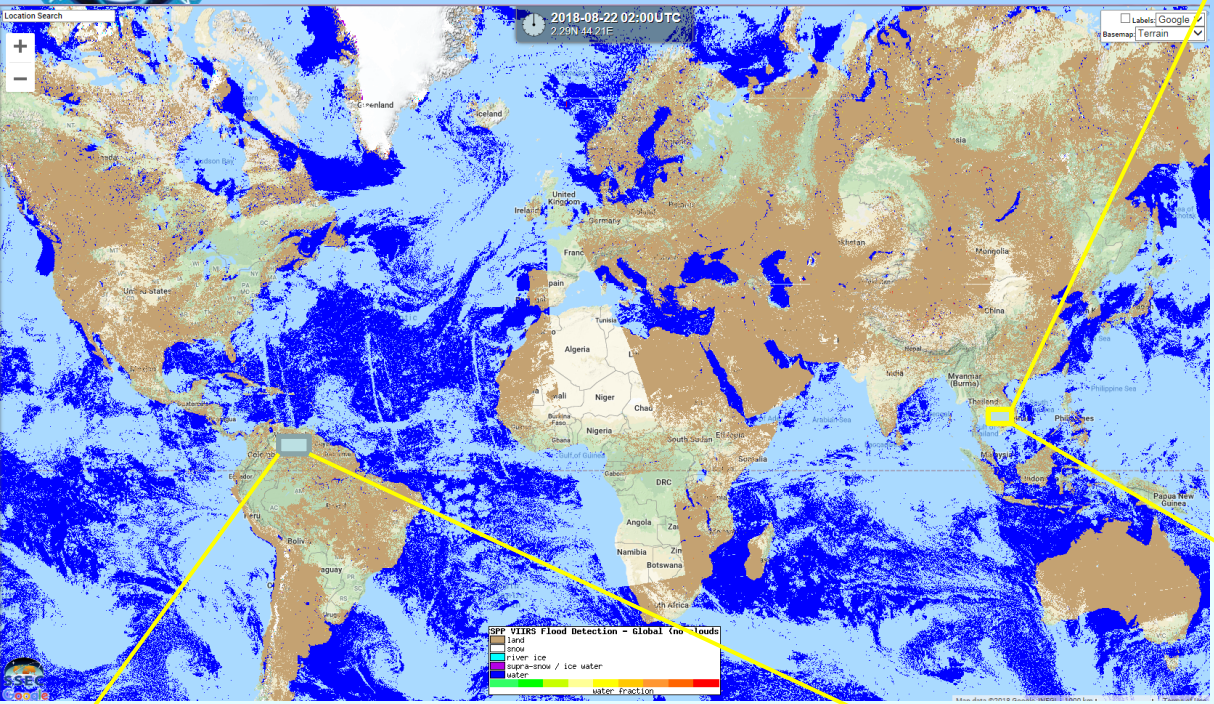
$$A = \int_{\min\_h}^{\max\_h} \int_{1}^{N} w_i(h) f_i(h)\, didh$$

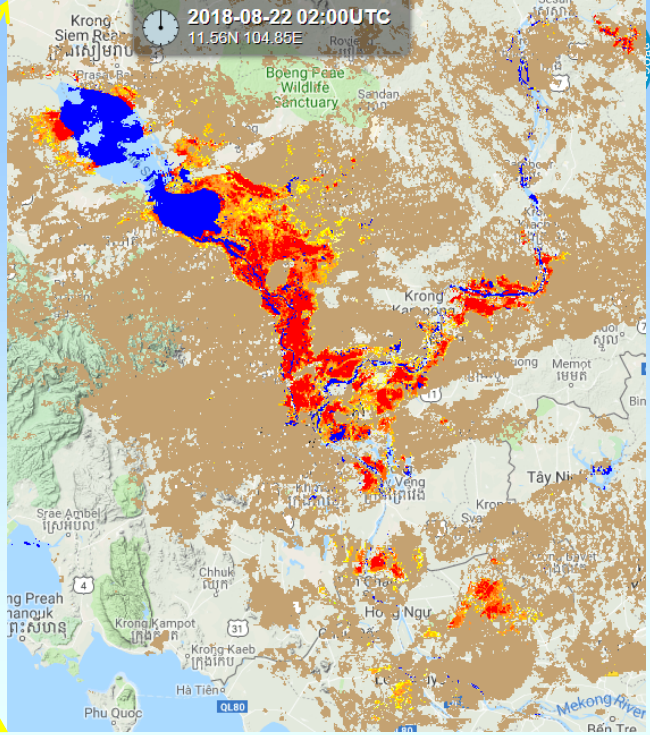
Where, A is satellite-based total water area between the minimal surface elevation, $\min\_h$, and maximal inundated surface elevation, $\max\_h$, $w_i(h)$ is the weight of land type i at height h in a VIIRS 375-m pixel, and $f_i(h)$ is the total area of land type i at height h.

- Polygon water level: Water polygon is defined as a group of adjacent water pixels with similar water levels. Pixels within a water polygon have the same water level.
- Polygon water levels decrease from upstream to downstream. The relationship between water levels and the distance to the starting point of a river (x), can be simulated by least square error methods:

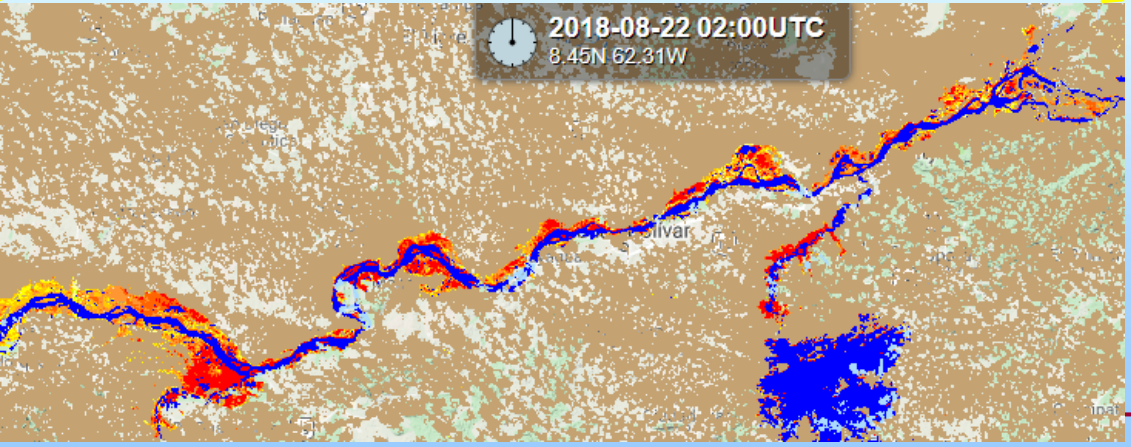
$$f(x) = a_0 + a_1(x - \bar{x}) + a_2(x - \bar{x})^2 + \cdots a_n(x - \bar{x})^n$$

Key Results/Accomplishments





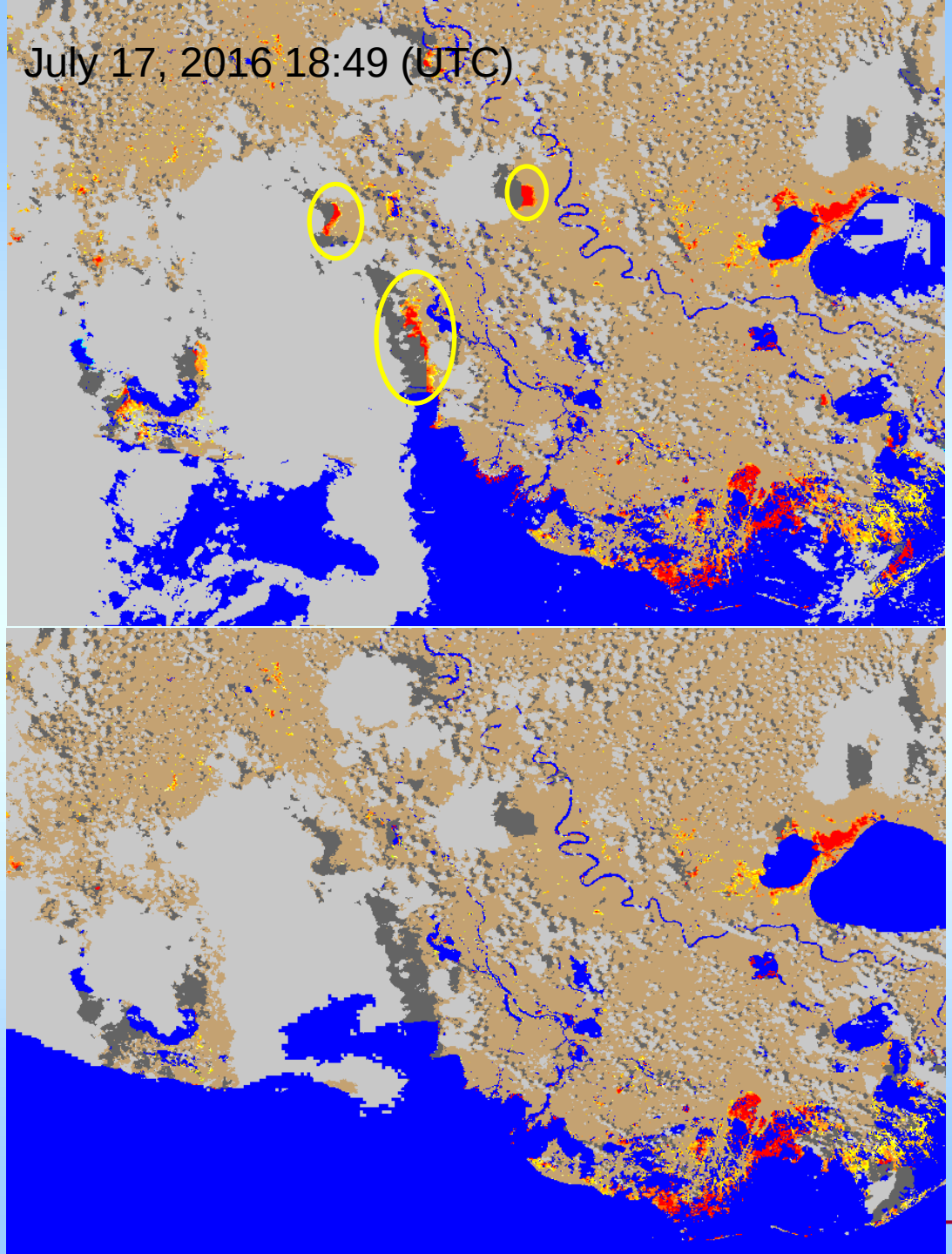
https://re.ssec.wisc.edu/s/xHfKq



- VIIRS global flood maps are now available:
  - With the delivered VIIRS flood software, CSPP group helps run the software globally and distributes global VIIRS flood maps via Real Earth

Key Results/Accomplishments

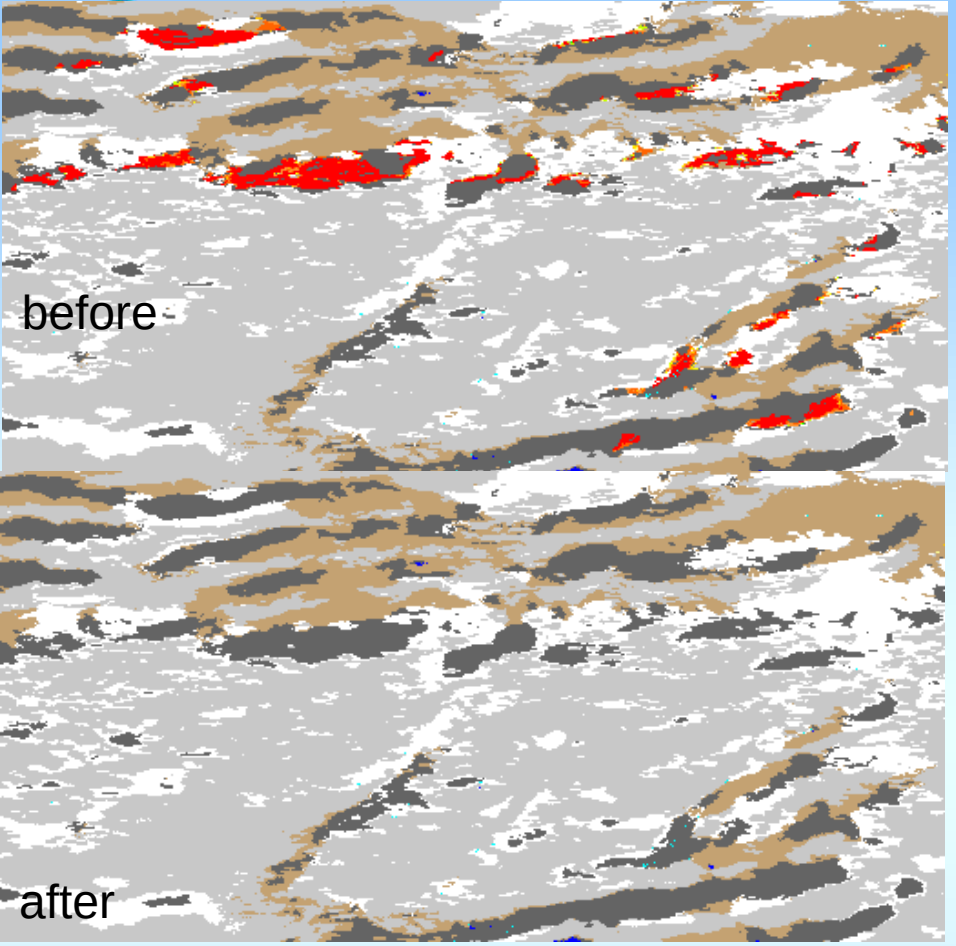
- Issues with the current version 1.0 algorithms:
  - About 10% Cloud shadows remain unremoved.
  - RFCs complain about the detection of supra-snow/ice water or mixed ice&water may not be detected accurately.
  - Water detection and fraction retrieval under complex conditions such as sun-glint-contaminated water surface.
  - IICMO does not work well in complex situations.
- Algorithm improvement on the version 1.0 algorithms:
  - Improve the cloud shadow removal algorithm
  - Improve the detection of the supra-snow/ice or mixed ice & water
  - Improve the classification algorithms on detecting cloud, snow cover and water surface



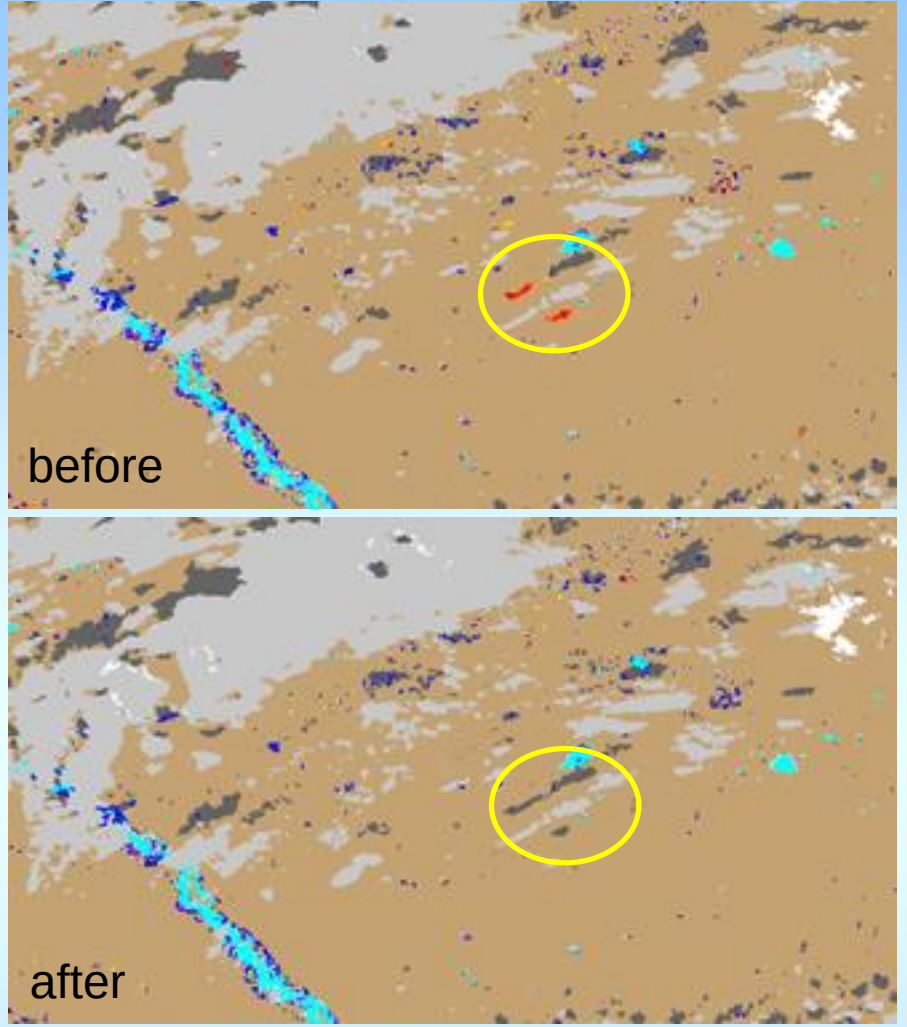
before

after

- Overall, the new cloud shadow fixes three issues existing in the current version 1.0 algorithms:
  - Shadows along the edges.
  - Shadows cast over snow surface.
  - Shadows cast by thin clouds.

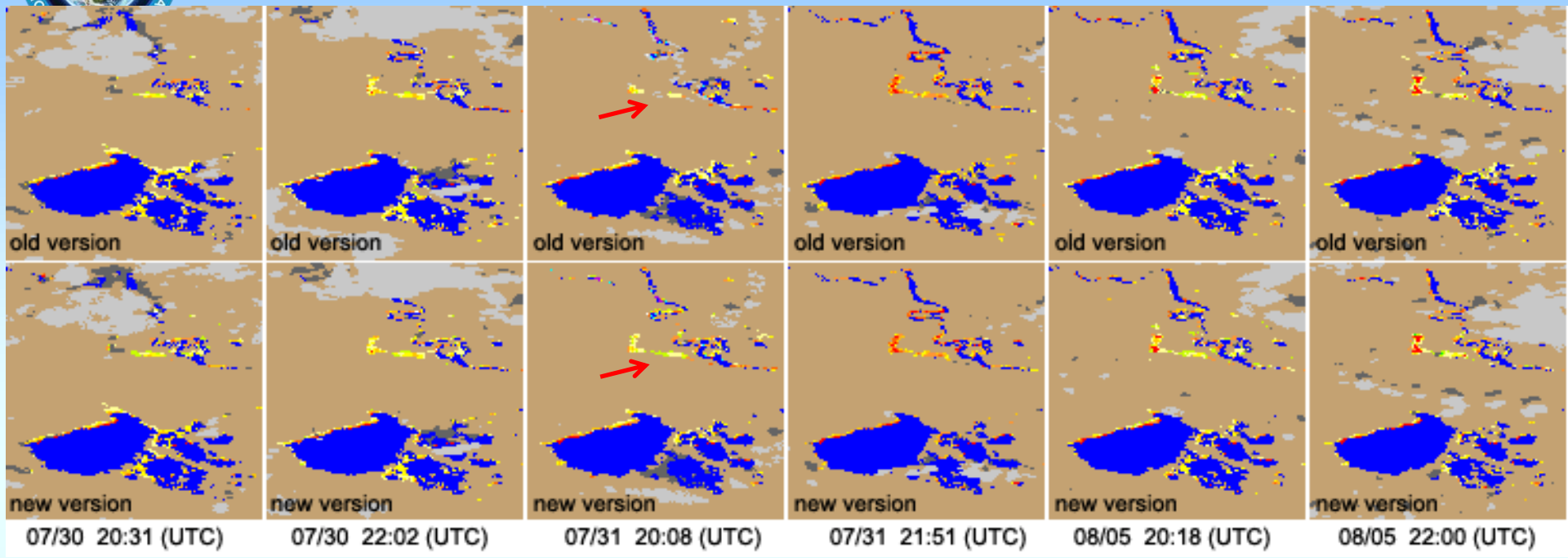


Oct. 13, 2017 22:04 (UTC)



- Cloud shadows cast over snow surface that were not removed have been removed with the new algorithm.

- Cloud shadows cast by thin clouds that were not removed have been removed with the new algorithm.

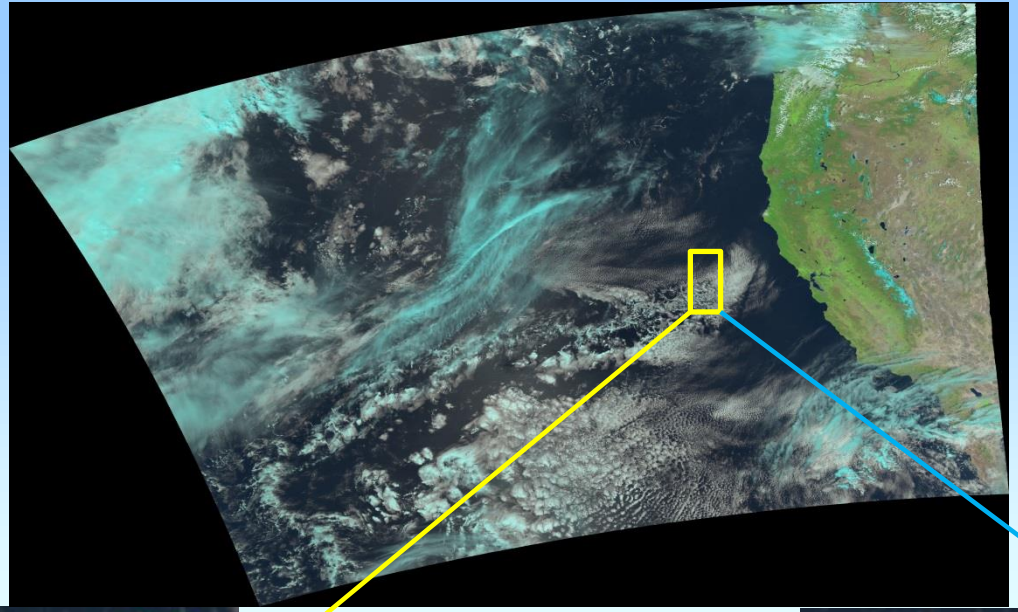


Tetlin flood in Alaska, July 2017

- The new algorithm shows more consistent water detection results by improving the classification algorithm among cloud cover, snow cover and water surface.

Key Results/Accomplishments

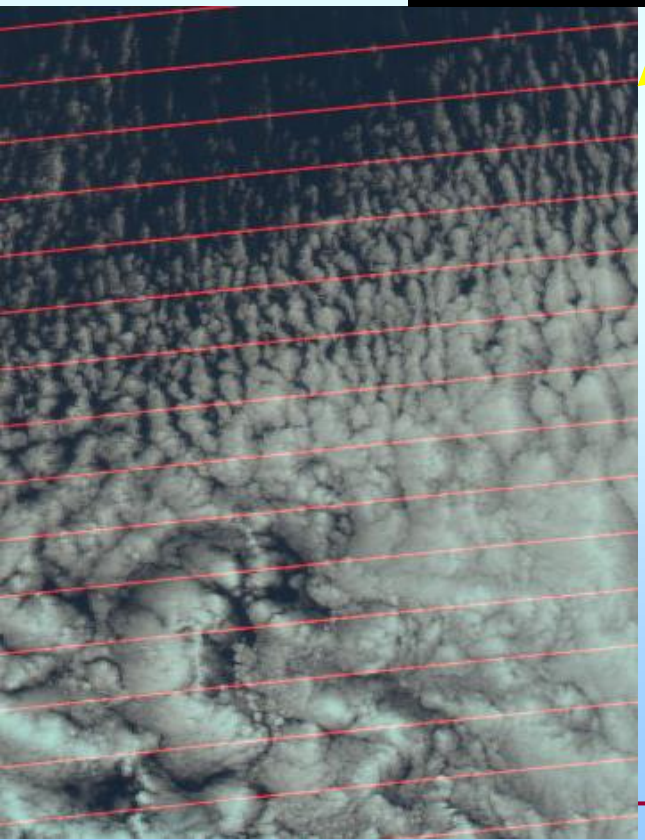
- NOAA-20/VIIRS data has been integrated into the flood software
  - De-striping on the Imager band 3
  - Adjustments to the algorithms and software have been made to process NOAA-20/VIIRS data
  - Software test has been done globally to check the quality of NOAA-20/VIIRS flood maps.



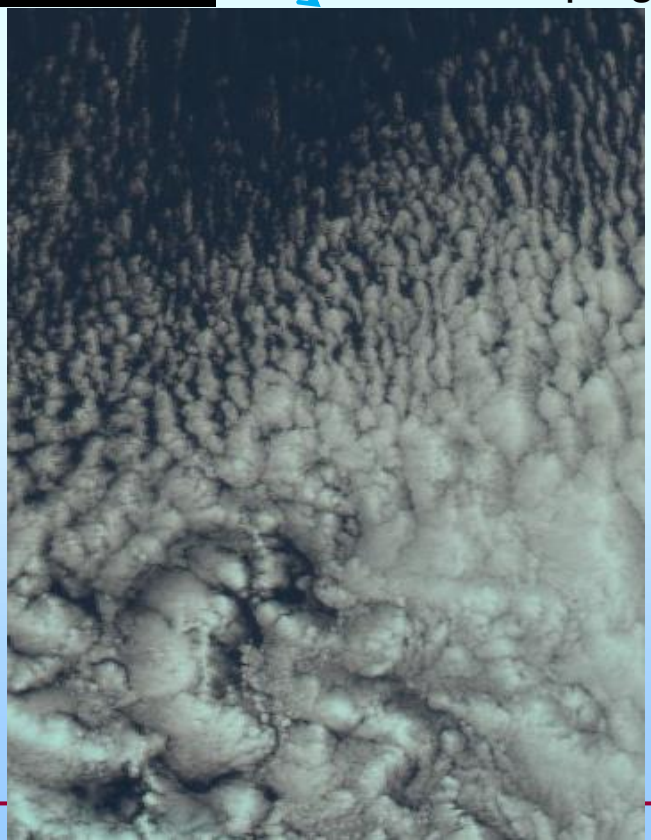
NOAA-20/VIIRS image on April 21, 2018 at 21:45 (UTC) with de-striping process on the SDR data

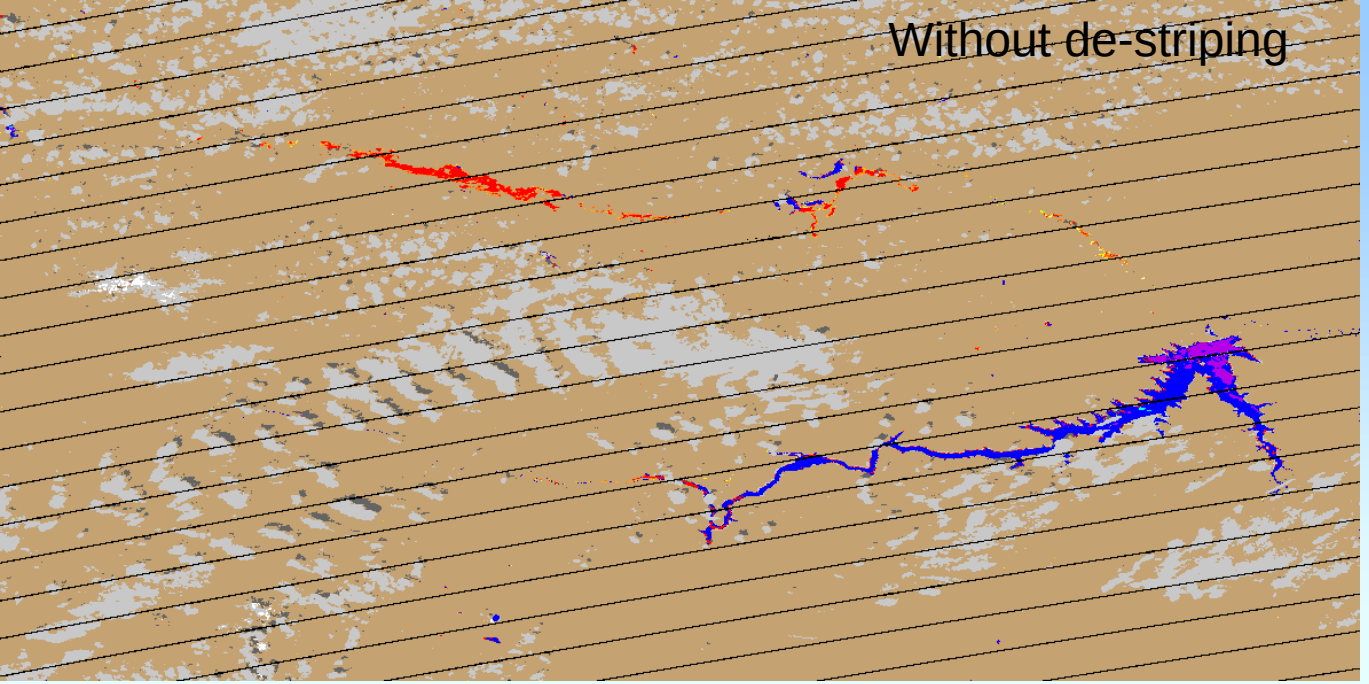
Before de-striping

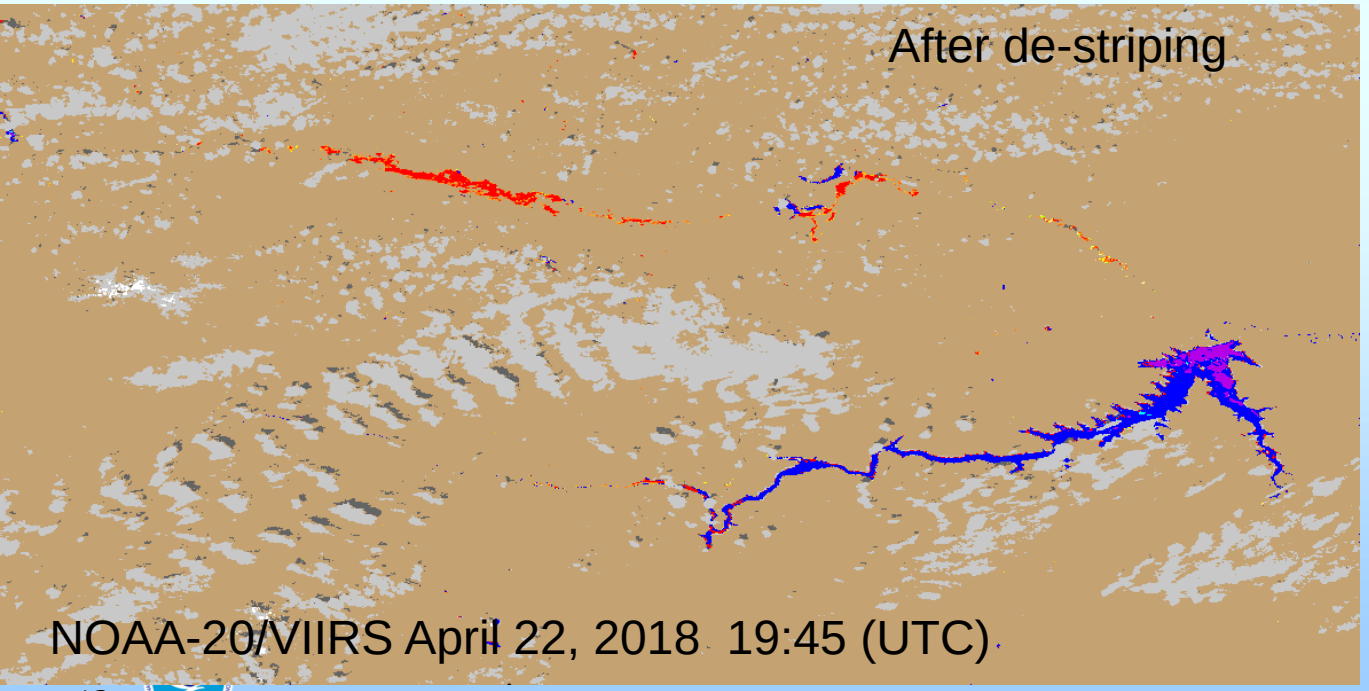
After de-striping



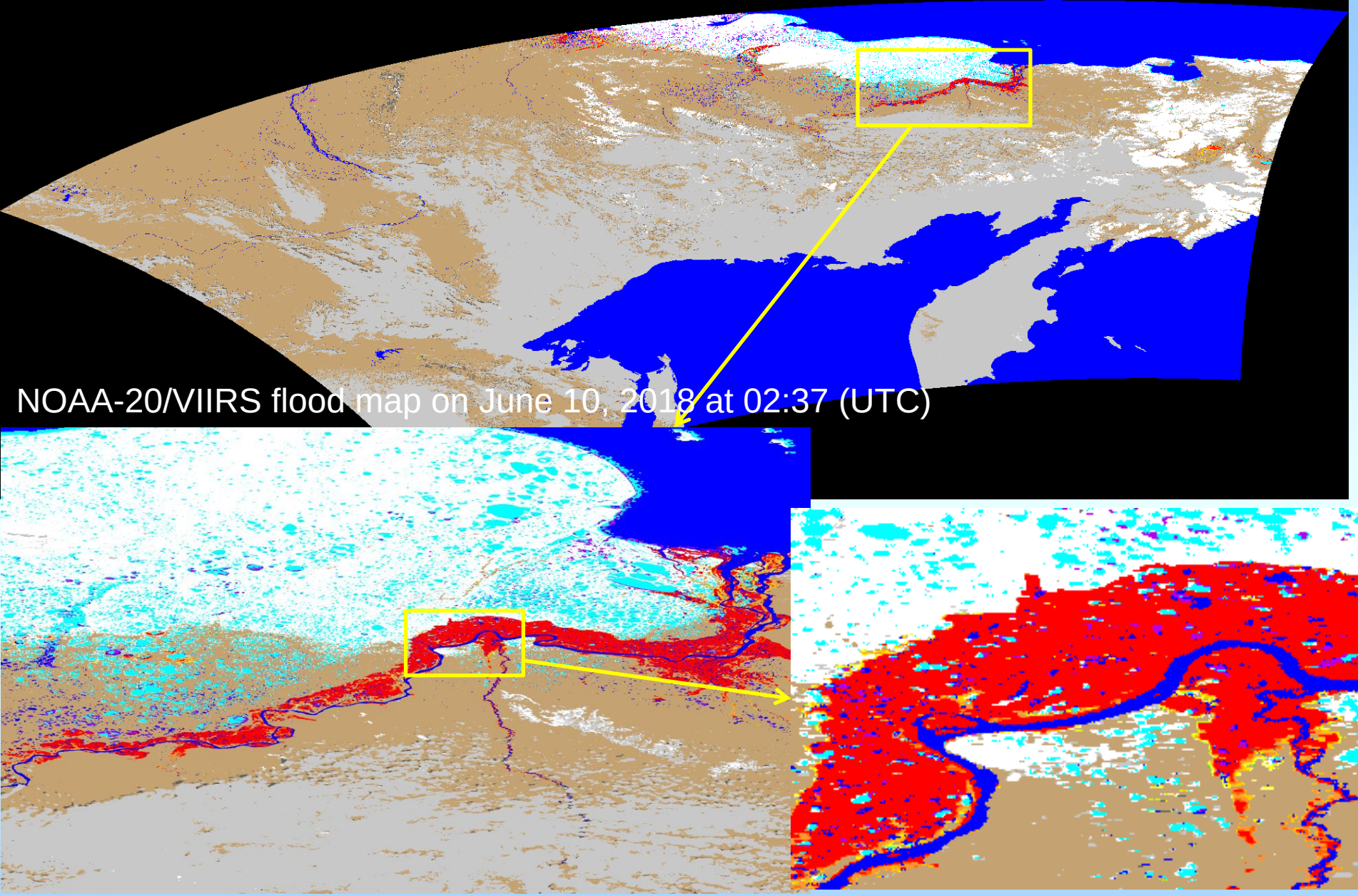
De-striping on the NOAA-20/VIIRS SDR data.





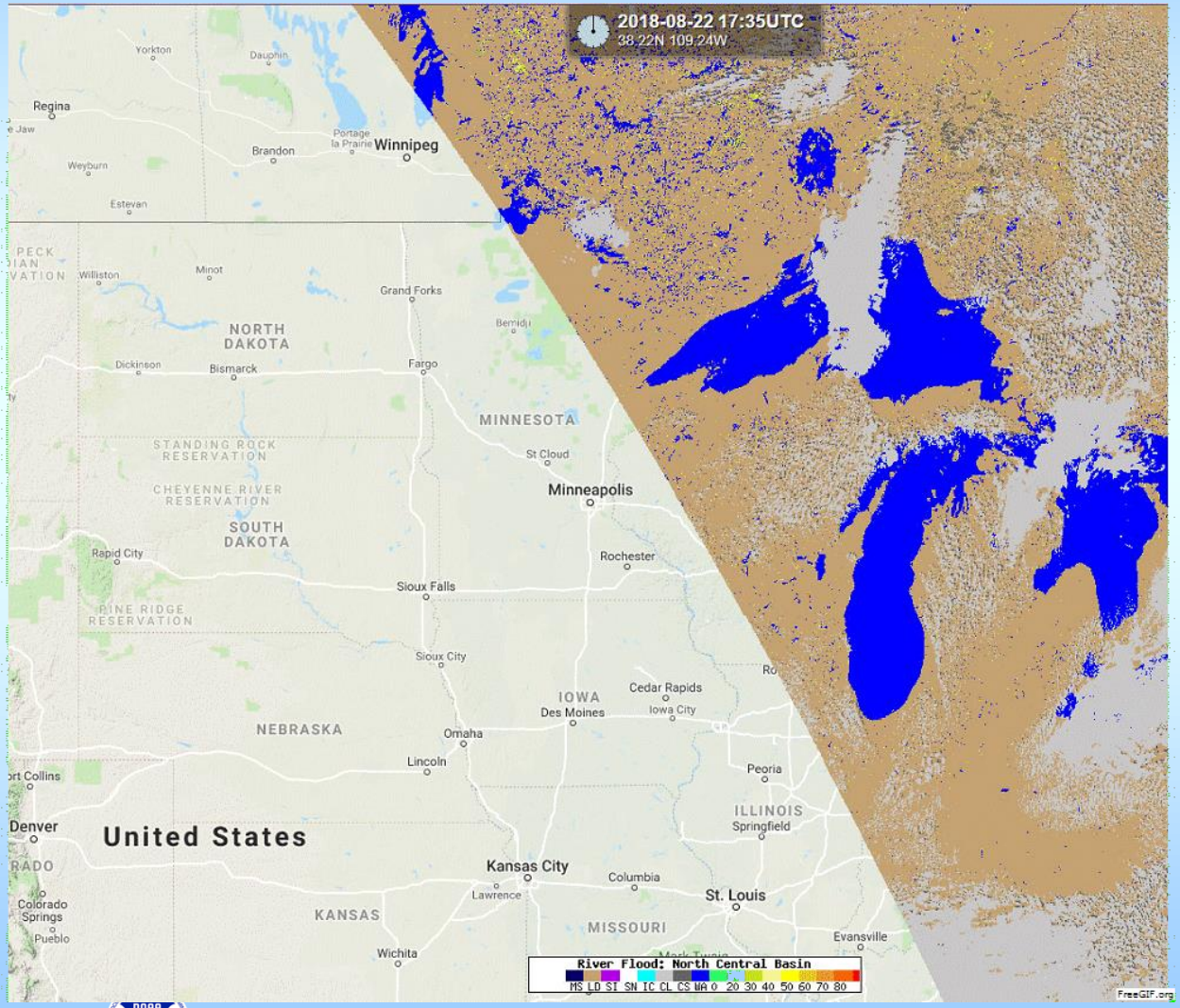


- The de-striping process on NOAA-20/VIIRS Imager band 3 produces flood maps with better quality.

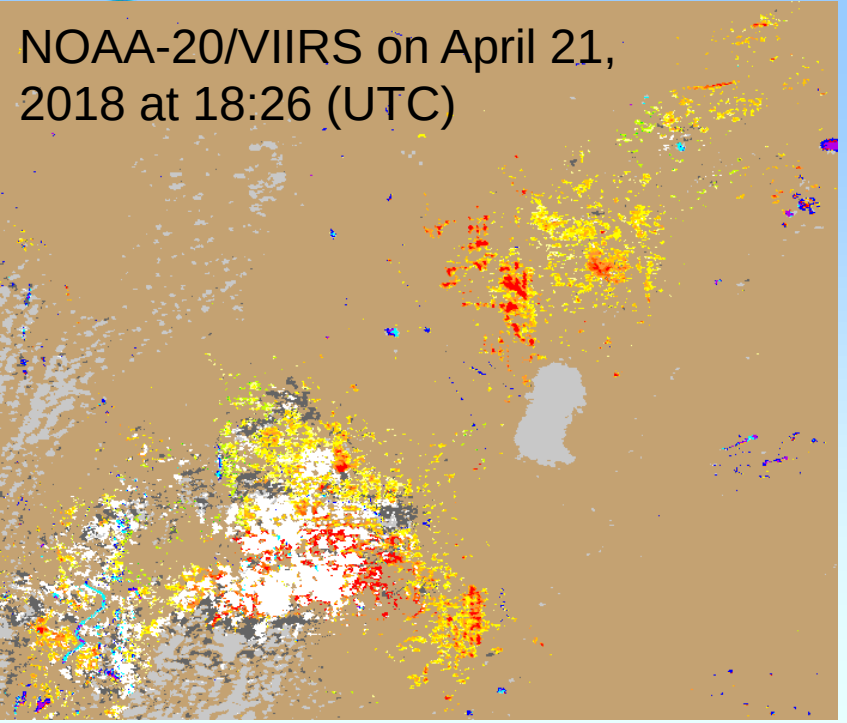


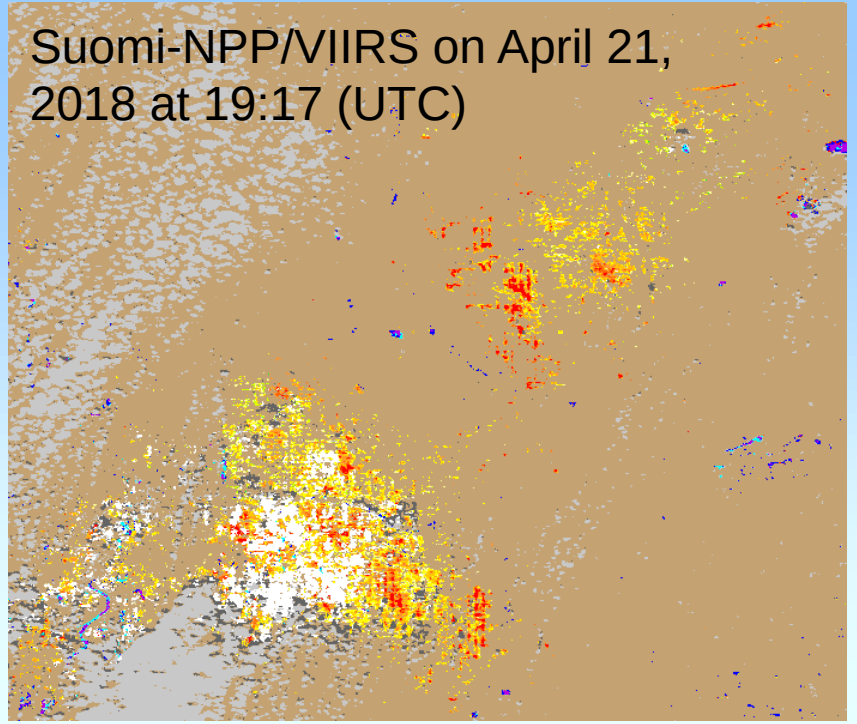
- Global test on NOAA-20/VIIRS flood maps shows reasonable results.

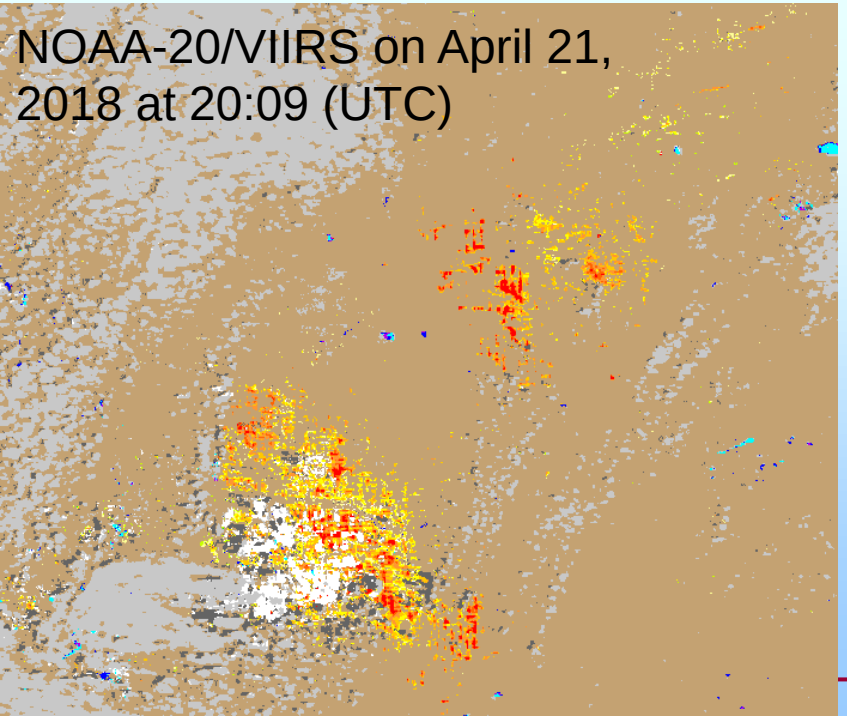
Key Results/Accomplishments



- New release in July 2018:
  - We released a new version of VIIRS flood mapping software with the improvements on the algorithms as well as new data source from NOAA-20/VIIRS.
  - In mid-latitudes, at least three observations are available for flood mapping from SNPP & NOAA-20/VIIRS.

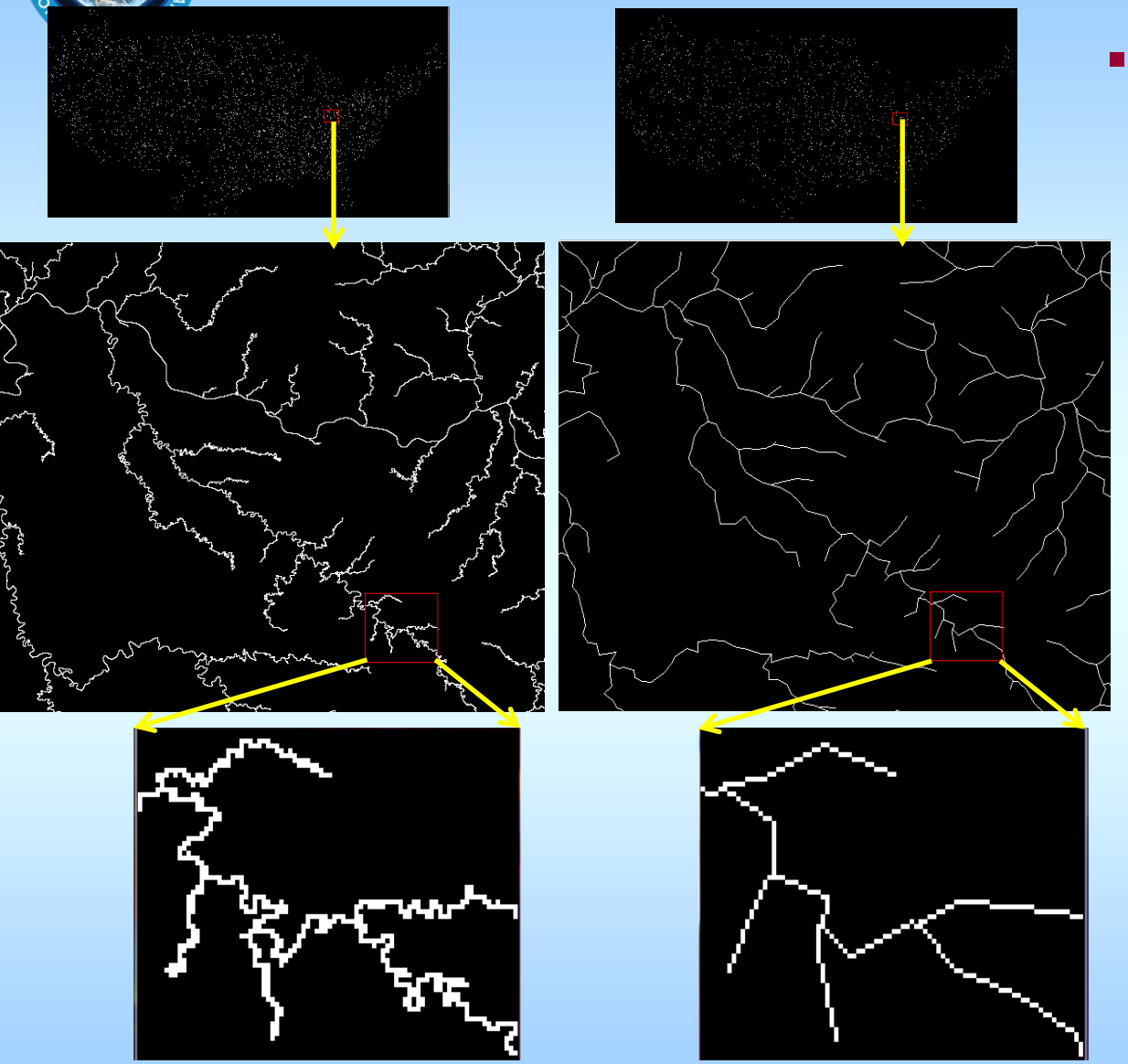






- With the new version which processes NOAA-20/VIIRS and Suomi-NPP/VIIRS imagery, VIIRS flood observations have been doubled than before. And thus, the doubled observations allows more dynamic detection on the water flow due to snow-melting in the north central region.

Key Results/Accomplishments

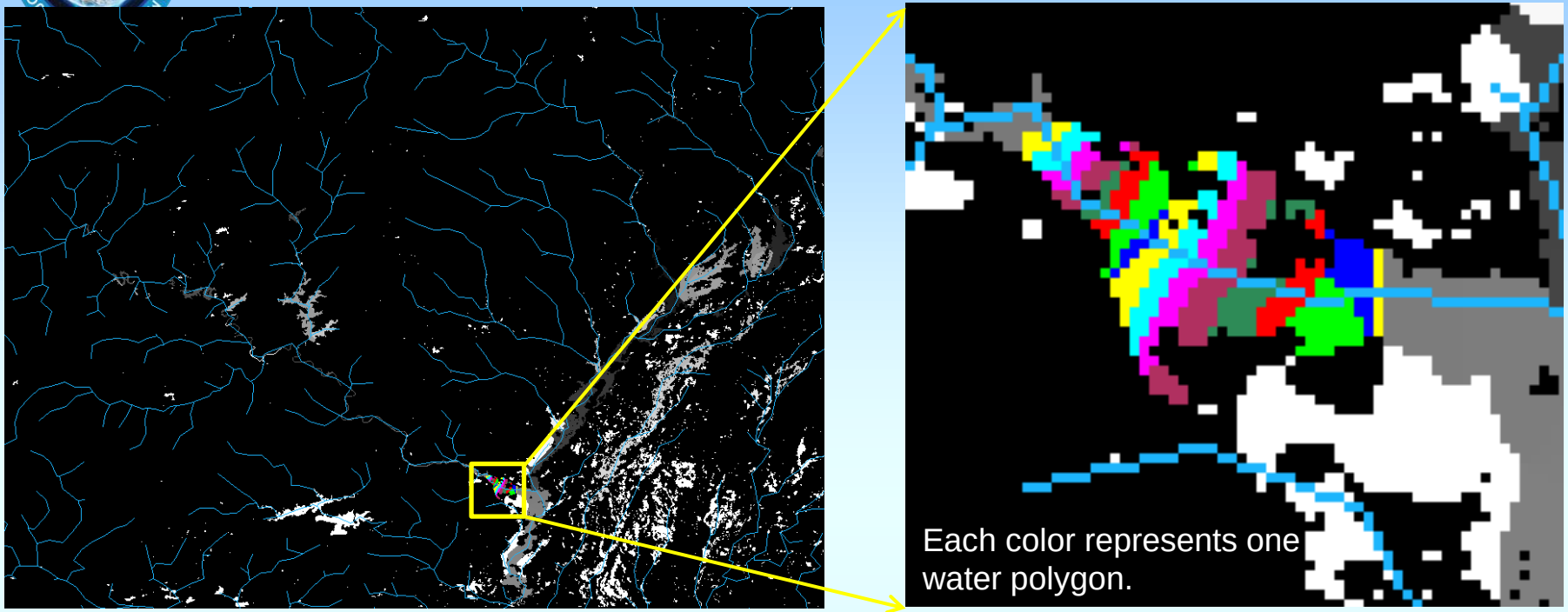


Original 375-m river lines

filtered 375-m river lines

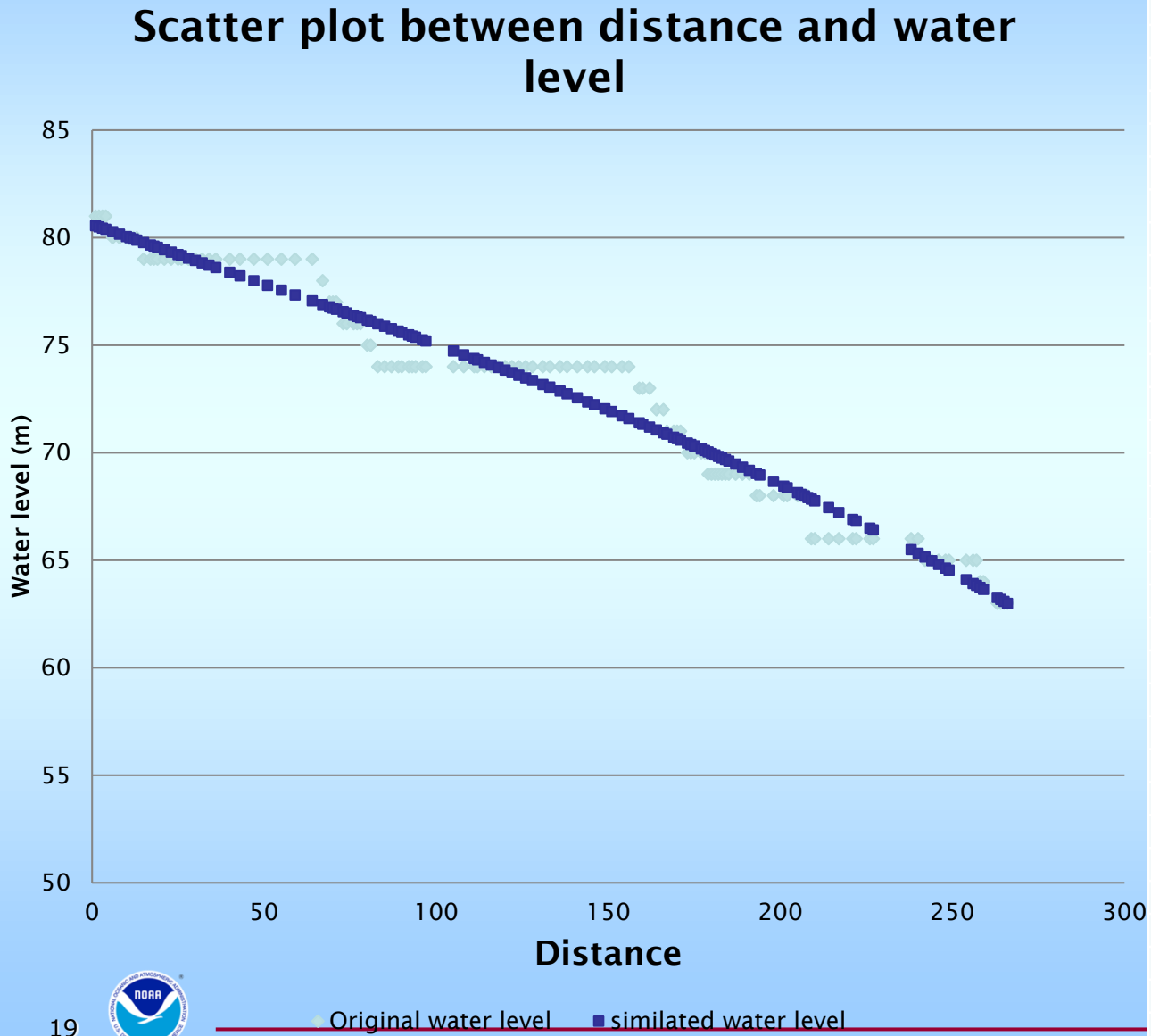
- Apply NHD Plus V2.0 data in the downscaling process. Several datasets have been generated in the CONUS based on the original NHD Plus V2.0 dataset :
  - 375-m filtered river line dataset with river link attributes (upstream and downstream)
  - 375-m river/lake normal water level dataset
  - 375-m river line distance dataset (distance to the starting point of a river)

Pixel clustering and river network construction



- Floodwater pixels are clustering into different water polygons according to four factors:
  - the adjacency among pixels
  - hydrologic Unit Code level-8 (HUC8)
  - distance to the most upstream point of a river
  - flow direction.
- Calculate water levels by using moving average and least square error methods.

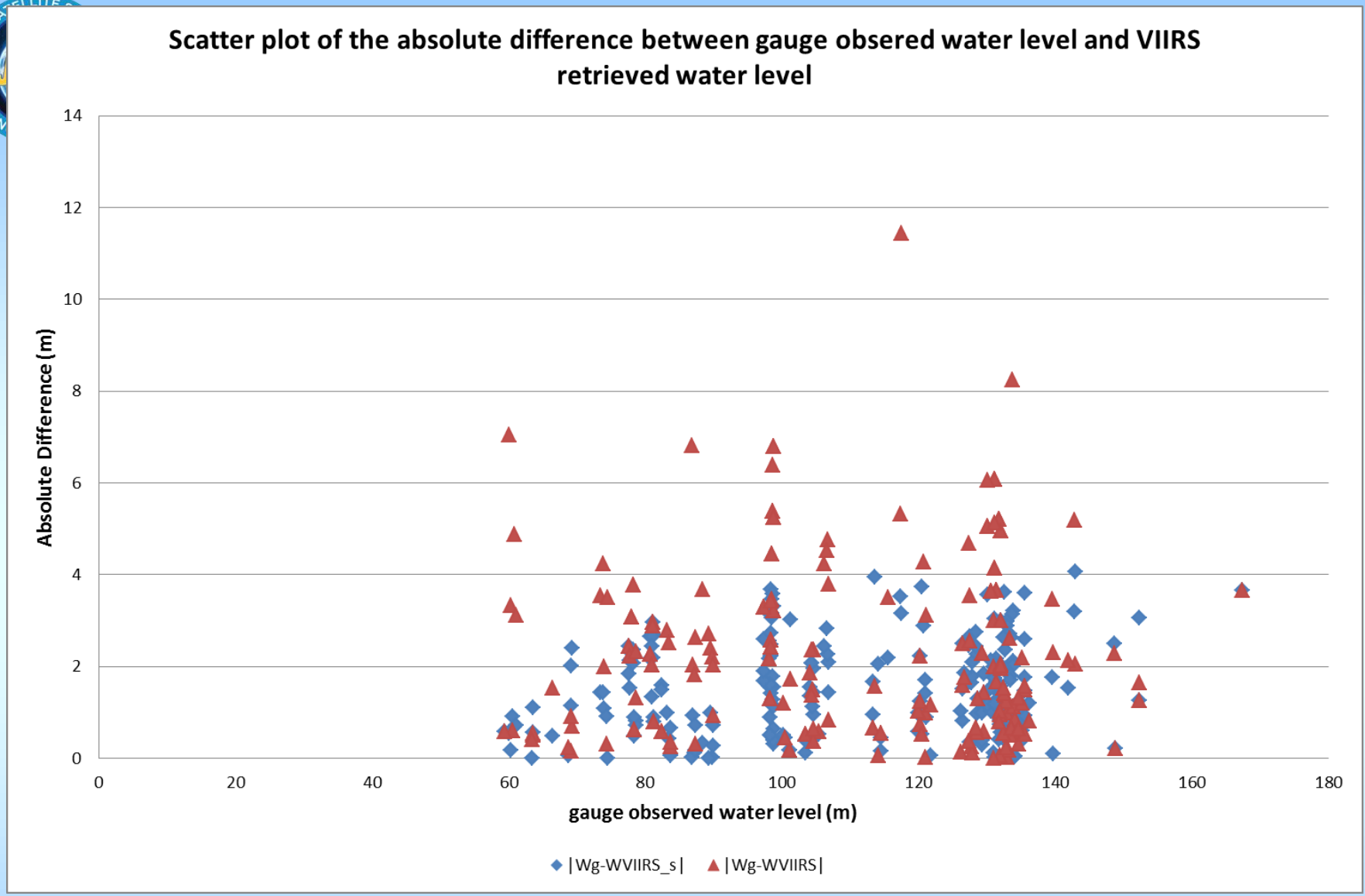
Water level simulation



Distance	adjusted polygon water level	similated water level
1	81	80.55619
2	81	80.49986
3	81	80.44359
4	81	80.38738
6	80	80.27511
8	80	80.16306
10	80	80.05119
11	80	79.99532
12	80	79.93951
13	80	79.88373
15	79	79.77229
17	79	79.66101
18	79	79.60542
19	79	79.54987
21	79	79.43886
23	79	79.32796
25	79	79.21716
26	79	79.1618
28	79	79.05113
30	79	78.94054
32	79	78.83001
34	79	78.71952
36	79	78.60908
40	79	78.38825
43	79	78.22263
47	79	78.00172
51	79	77.78066
55	79	77.55933
59	79	77.33762
64	79	77.05985
67	78	76.89275
69	77	76.78115
70	77	76.72528
71	77	76.66937
73	76	76.55741

Gauge	gauge observed water level	simulated water level	water level without simulation	Date
Mississippi River @ New Madrid, MO	88.324944	88	92	20170502
Mississippi River @ New Madrid, MO	89.300301	89.3	92	20170505
Mississippi River @ New Madrid, MO	89.605103	90.6	92	20170506
Mississippi River @ New Madrid, MO	89.787987	89.8	92	20170507
Mississippi River @ New Madrid, MO	89.970863	89.7	92	20170509
Mississippi River @ New Madrid, MO	89.919044	89.2	89	20170508

Gauge	gauge observed water level	simulated water level	water level without simulation	Date
Ohio River @ Cairo,IL	97.292	95.6	94	20170502
Ohio River @ Cairo,IL	98.161	96.6	96	20170505
Ohio River @ Cairo,IL	98.298	97.8	97	20170506
Ohio River @ Cairo,IL	98.42	96.9	96	20170507
Ohio River @ Cairo,IL	98.46	95.4	95	20170508
Ohio River @ Cairo,IL	98.42	97	95	20170509

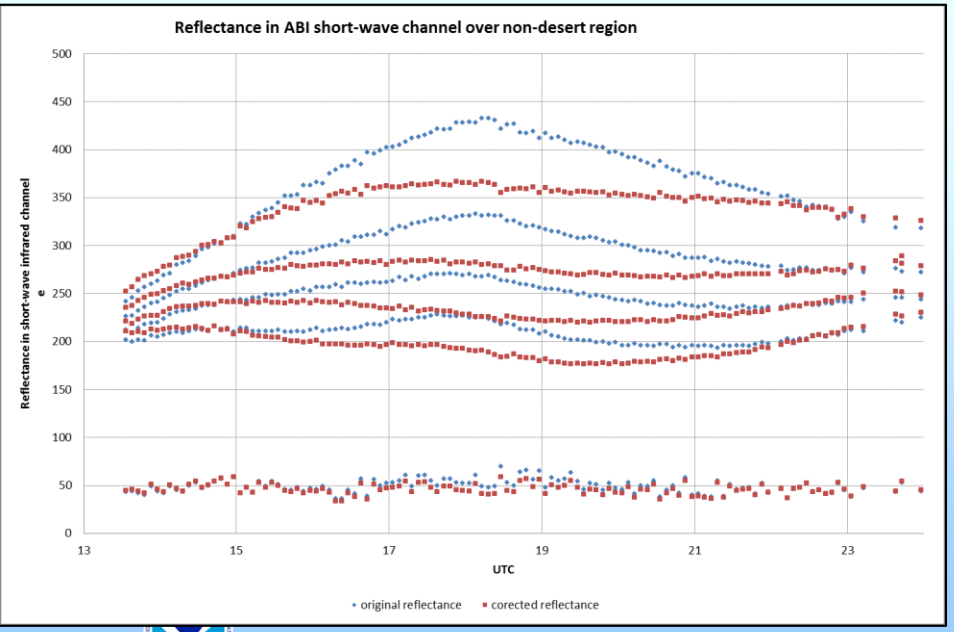


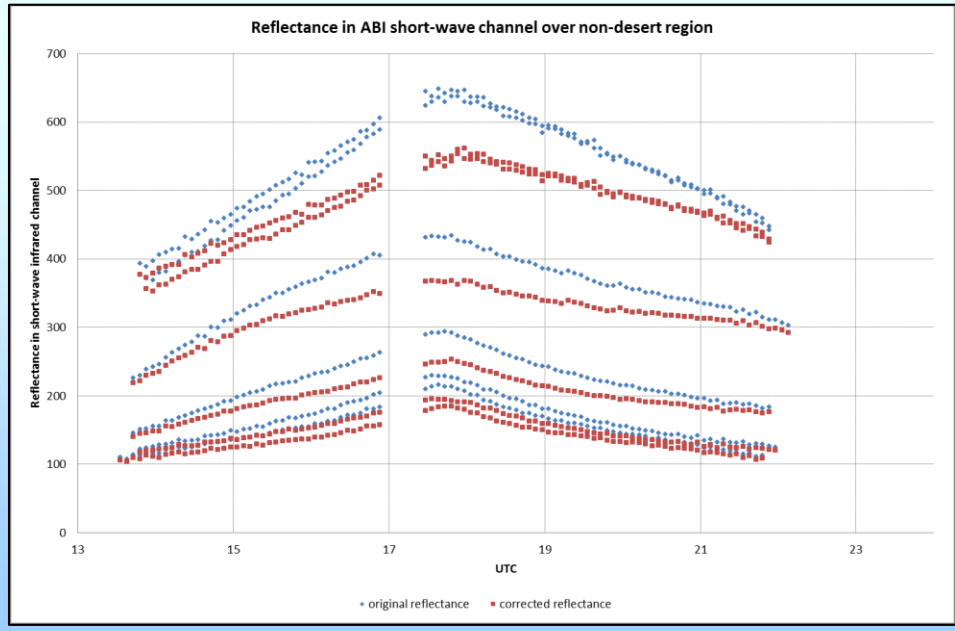
Average absolute difference between gauge observed water levels and VIIRS retrieved water levels of the 249 samples:

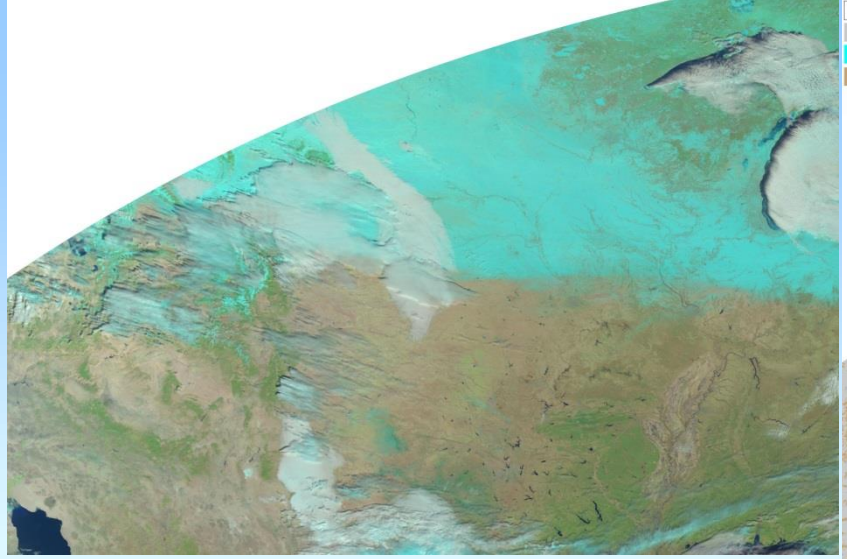
$\overline{|W_g - W_{VIIRS_s}|}$ = 1.48m $\overline{|W_g - W_{VIIRS}|}$ = 2.2m

Key Results/Accomplishments

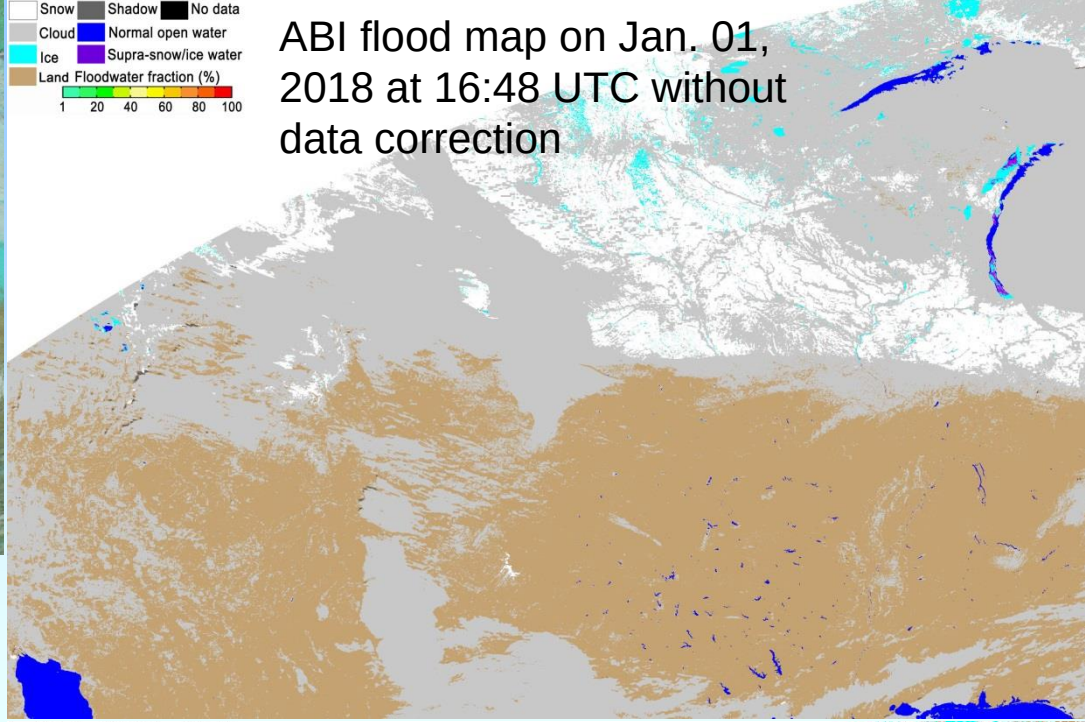
- GOES-16/ABI flood mapping algorithm and software development
  - GOES-16/ABI imagery have been integrated in the flood mapping software: projection, data correction, detection, visualization



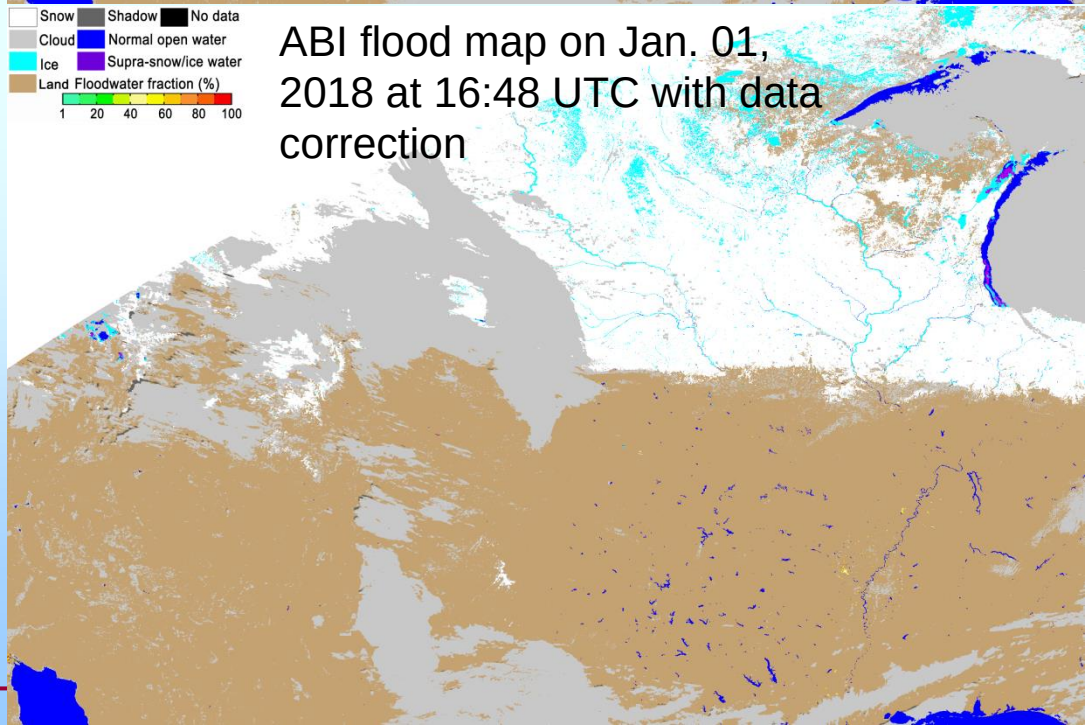




ABI false-color image on Jan. 01, 2018 at 16:48 UTC



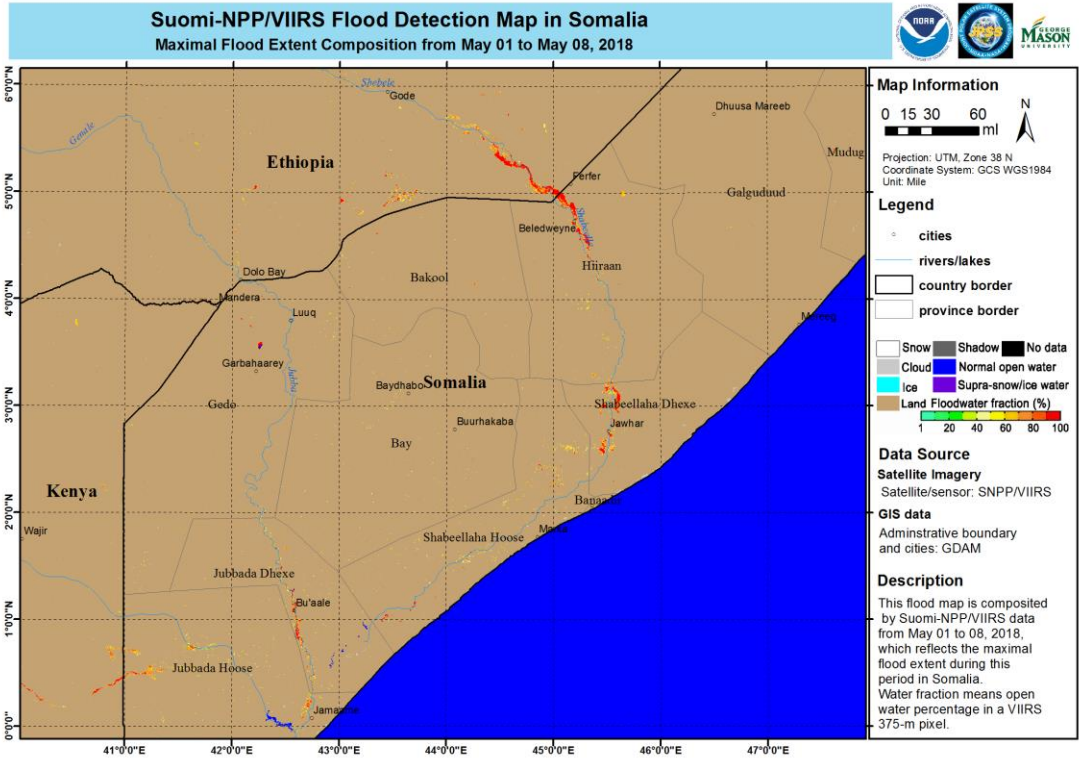
ABI flood map on Jan. 01, 2018 at 16:48 UTC without data correction

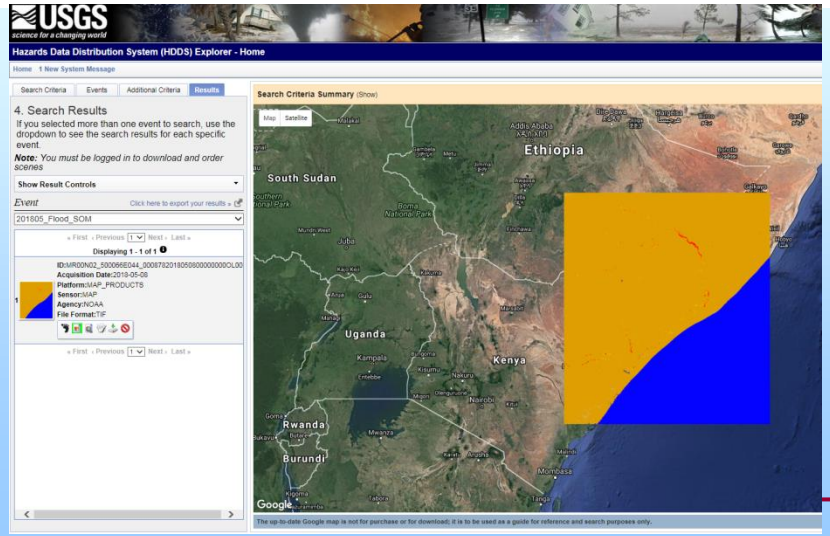


ABI flood map on Jan. 01, 2018 at 16:48 UTC with data correction

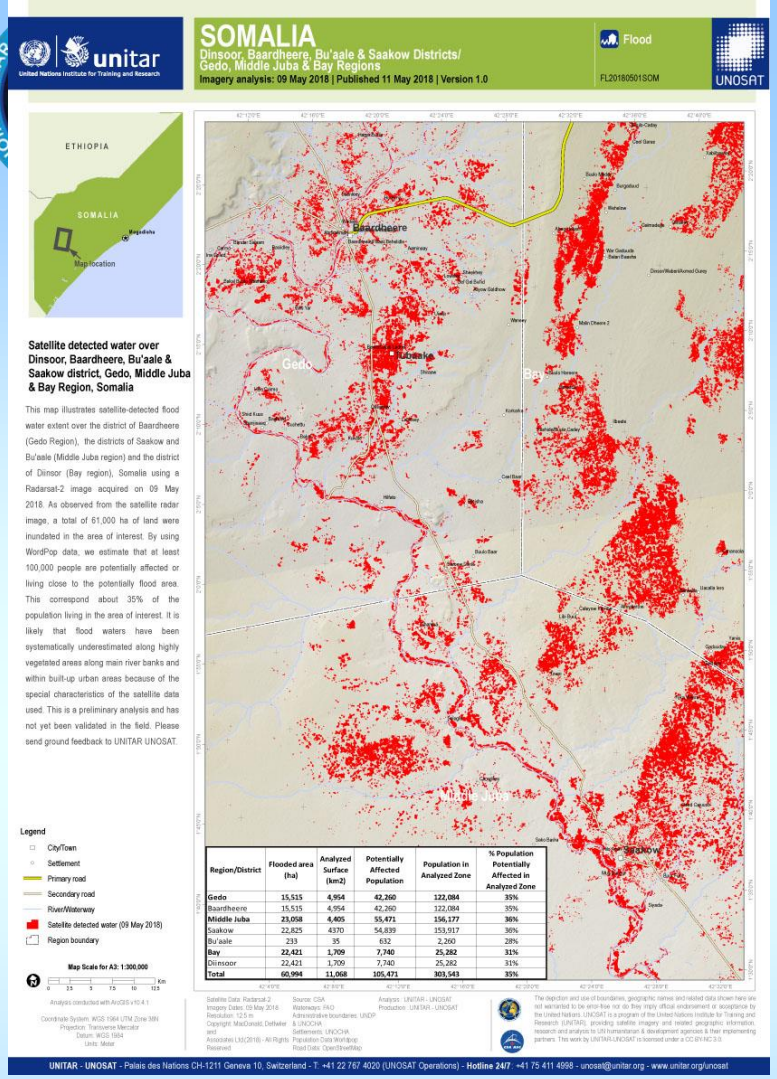
- ABI imagery shows different diurnal change patters on the surface reflectance over different land cover types.
- An correction method on the data has been developed to stabilize the flood detection performance.

Key Results/Accomplishments

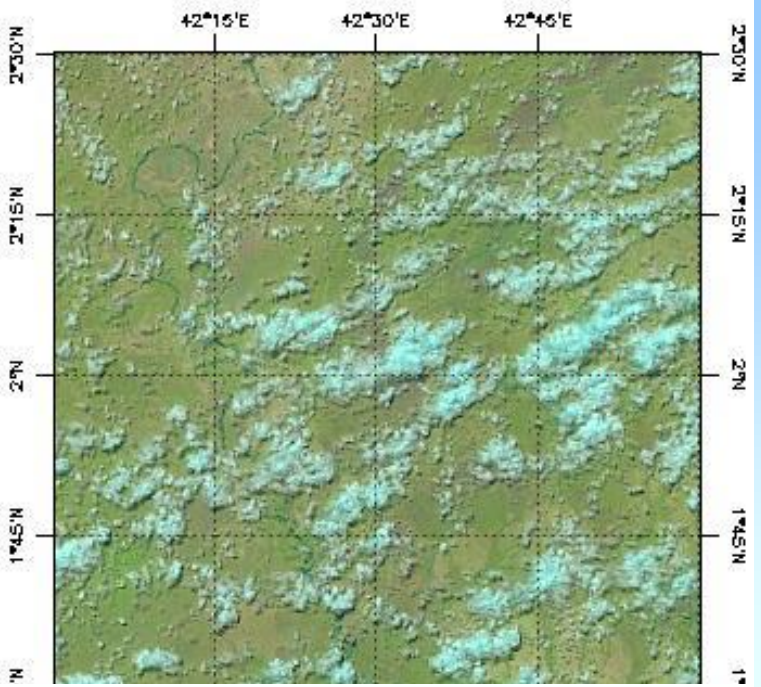




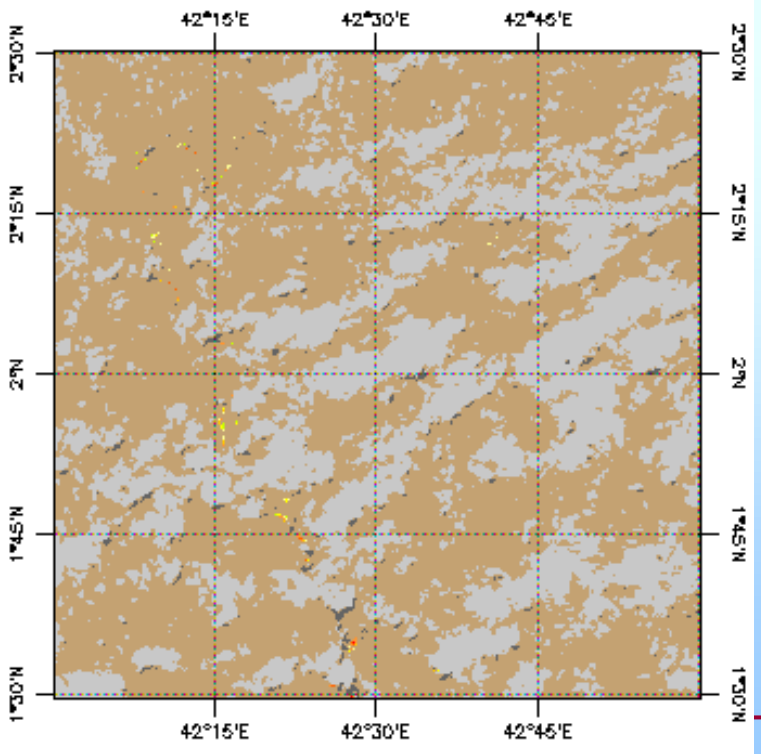
- Develop connections with WMO's International Charter to use VIIRS flood maps for flood activations' response.
  - VIIRS flood maps are generated to respond the flood activations distributed by the coordinators of Disaster Charter in NOAA and USGS.
  - Since Aug. 2016, we have responded more than 15 flood activations from International Charter.



UNOSAT flood map on May 09, 2018

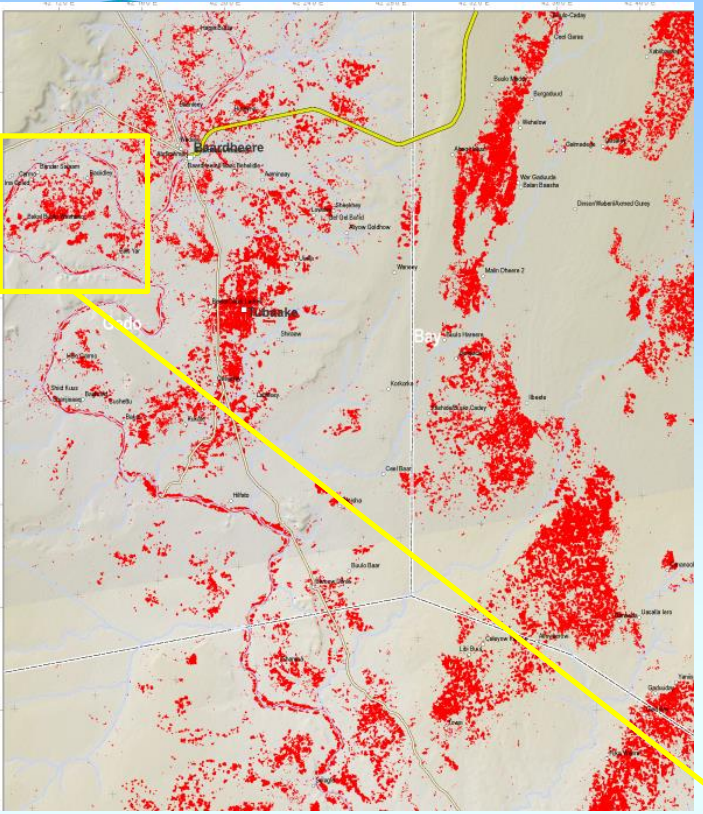


VIIRS false-color image on May 07, 2018 10:33 (UTC)

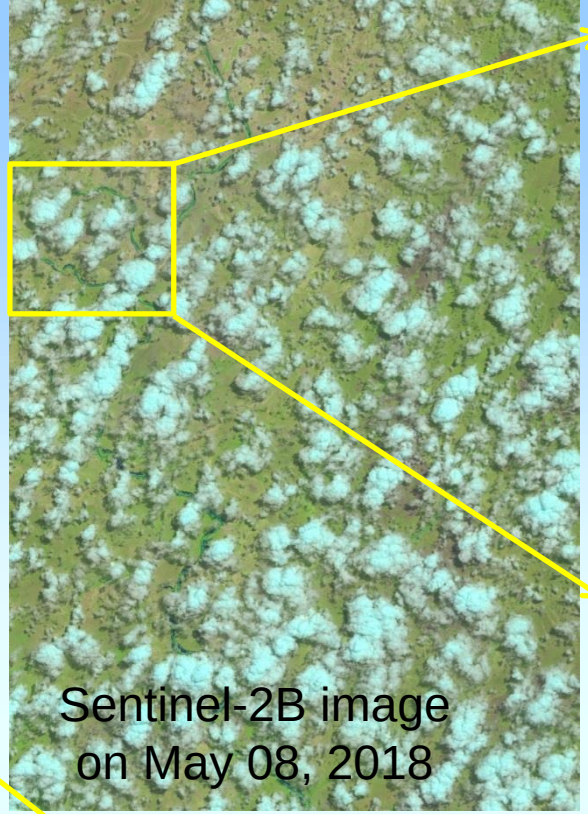


VIIRS flood map on May 07, 2018 10:33 (UTC)

- Compare VIIRS results (no significant flooding) with Radarsat flood results (major flooding) on Somalia flood.

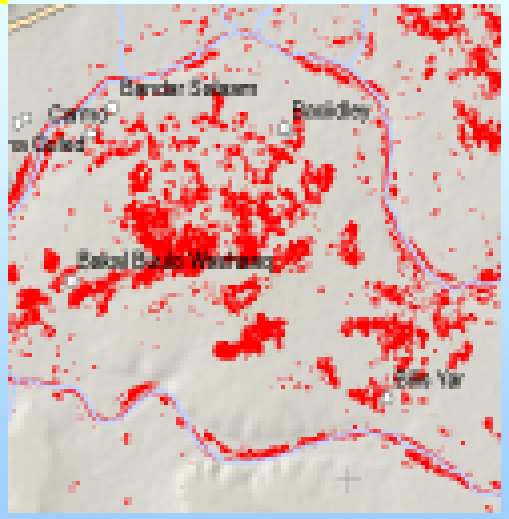


UNOSAT flood map
on May 09, 2018



Sentinel-2B image
on May 08, 2018

Sentinel-2B May 08, 2018



Sentinel-2B May 03, 2018

- VIIRS can still help even though the flood mapping has been dominated by radar satellite imagery.

Key Results/Accomplishments

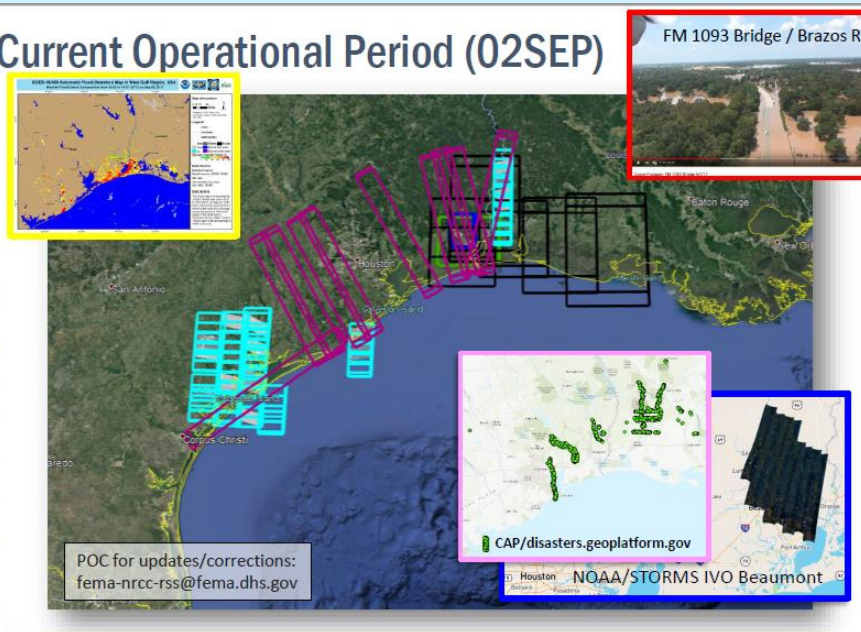
- Develop connections with FEMA and deliver flood products routinely to them for emergency response and disaster mitigation.

FEMA MDARNG

Collection Synchronization – Current Operational Period (02SEP)

PIR #	Description
1	What are the locations of personnel in distress?
2	How many residences have been impacted and to what degree have they been impacted?
3	How has critical infrastructure been impacted (including list of critical sites, oil rigs, power, transportation, chemical spills)?
4	What are the flood extents of reservoirs and rivers in the AOI?
5	What is the impact of the Arkema chemical facility explosion?

Satellite Platforms	PED	Collection Information	PIR
COSMOSKYMED	Copernicus	1 SAR Product Available	2
RADARSAT-2	NASA/JPL	No Action	2
PALSAR	NASA/JPL	No Action	2
TERRASAR-X	NASA/JPL	No Action	2
WORLDVIEW-1	UNKNOWN	No Action	2
WORLDVIEW-2	UNKNOWN	No Action	2
WORLDVIEW-3	UNKNOWN	Over 100 MSI/PAN Collects	2
WORLDVIEW-4	UNKNOWN	No Action	2
SENTINEL-1	NASA/JPL	No Action	2
SENTINEL-2	NASA/JPL	No Action	2
SPOT-6	NASA/JPL	32 MSI/PAN Collects	2
LANDSAT-7	UNKNOWN	No Action	2
LANDSAT-8	UNKNOWN	No Action	2
GEOEYE-1	UNKNOWN	No Action	2
UKDMC-2	UNKNOWN	No Action	2
GOES-16 & JPSS	NOAA & GMU	Flood Detection	2



Airborne Platforms	PED	Collection Information	PIR
Civil Air Patrol	FEMA/States	Operational (Cumulative Imagery Displayed Above)	4
NOAA (N68RF King Air)	FEMA/States	Operational	2
NOAA (N48RF Twin Otter)	FEMA/States	No Action	2
NASA/JPL (UAVSAR)	NASA/JPL	Operational	2
National Guard (3X RC-26)	TX NG	Operational (focused on SAR)	1
EPA (ASPECT)	EPA	Operational	5
DOI BLM (Small UAS)	Unknown	Operational	1

Future plan

- Release of GOES-16/ABI flood detection software
- Development of Himawari-8/AHI flood detection software
- Development of the blended algorithm to merge VIIRS, ABI and AHI flood products together to produce a blended 375-m flood product
- Development of the downscaling model with the NHD Plus V2.0 datasets
- Development of a website for VIIRS/ABI/AHI flood products distribution
- SPSRB process to make the VIIRS flood product operational in NESDIS if possible

Summary

- A new update of VIIRS flood Version 1.0 software has been released, in which algorithm improvements have been made and NOAA-20/VIIRS data has been integrated.
- VIIRS global flood maps are now available and distributed by CSPP group through SSEC's Real Earth.
- NHD Plus V2.0 dataset has been implemented in the downscaling model and helps improve the accuracy of water level retrieval.
- VIIRS flood product have been applied for emergency responses under the developed interactions with WMO's International Charter and FEMA.
- GOES-16/ABI flood software is under development and will be available soon. A geostationary-JPSS flood product will be developed with the availability of VIIRS, ABI and AHI flood products.

Thanks!