Global Flood Analysis and Forecasts Using Satellite Rainfall Coupled with Land Surface and Routing Models—Recent Results

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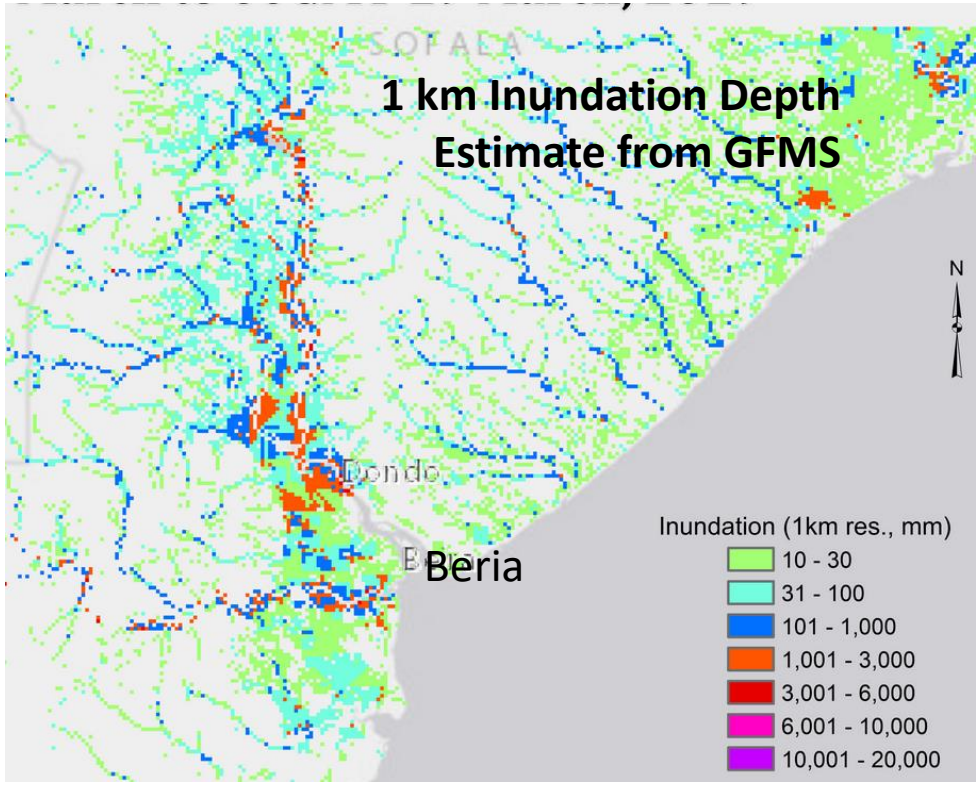


Mozambique

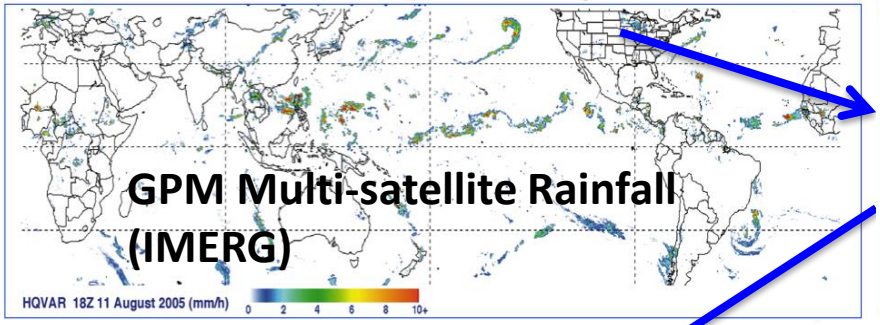
Cyclone Idai

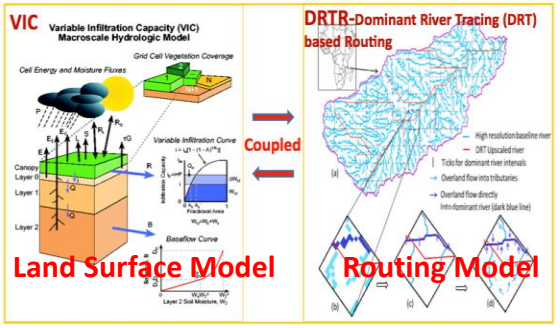
14-19 March 2019

Global Flood Monitoring System (GFMS)

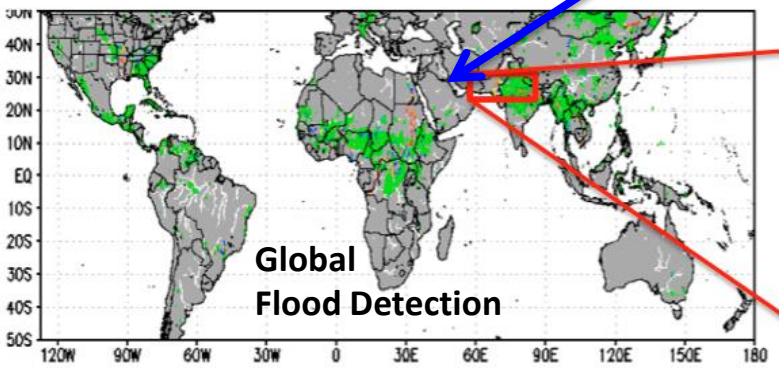
http://flood.umd.edu/

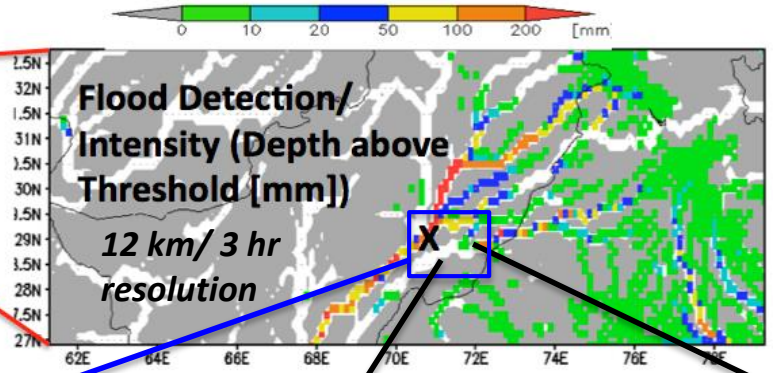
Global Real-time Flood Calculations Using Satellite Rainfall and Hydrological Model



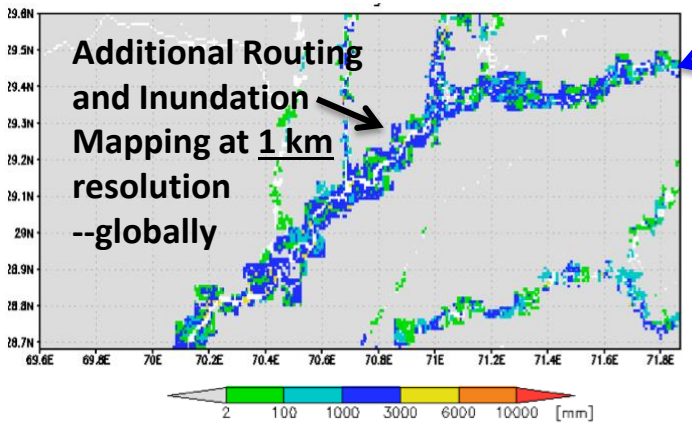


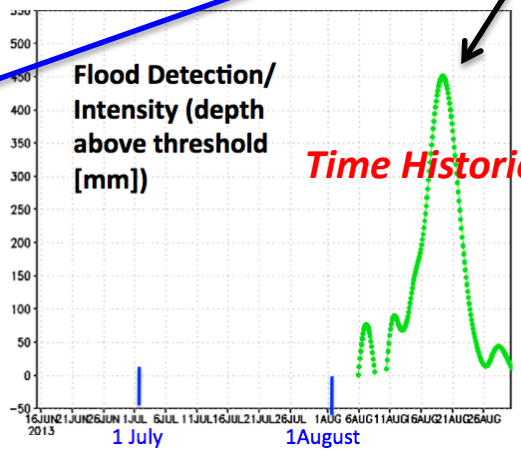
GPM rainfall into land surface and routing models for water depth and stream flow calculations compared to flood thresholds

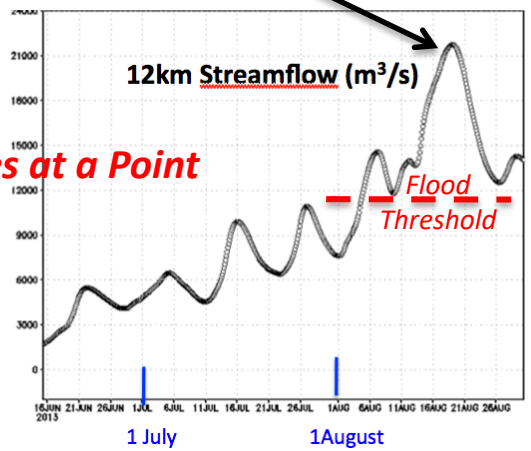




Indus River basin







Developed by Huan Wu (SYSU)

Global Flood Monitoring System (GFMS)

- GFMS now uses NASA's Global Precipitation Measurement (GPM) mission IMERG multi-satellite rainfall product in "real-time" system with flood thresholds values based on long-term retrospective calculations (flood.umd.edu)

- IMERG is used at 1/8th degree lat./long., 3-hour resolution as input to VIC land-surface model and routing at 12 and 1 km resolution

- Products include 1 km inundation/depth calculation

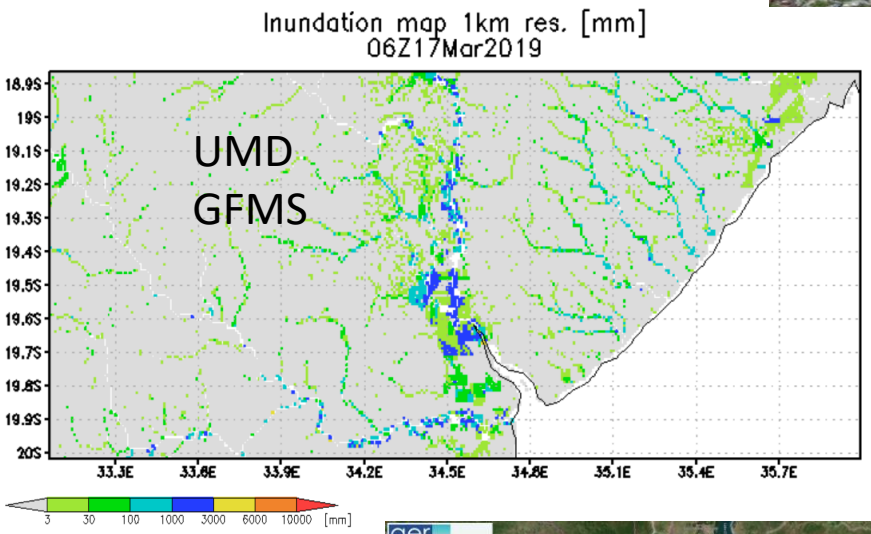
- Analyses are available at flood.umd.edu and various data are available for download

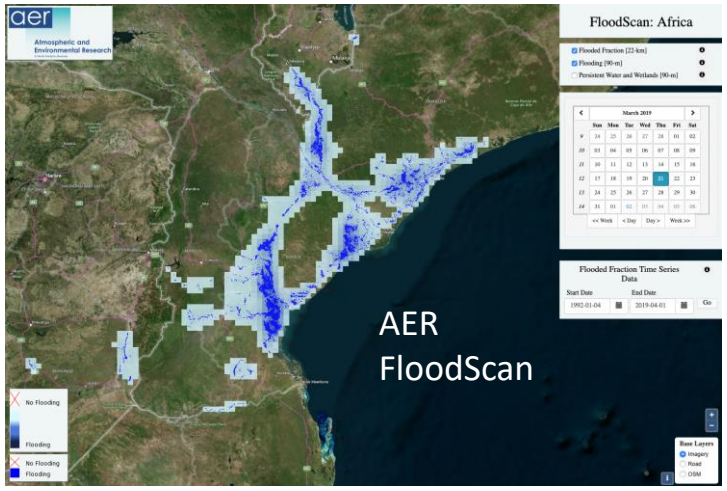
- Connected to GPM website, NASA Disasters Portal, Flood Observatory (U. of Colorado), Global Flood Partnership (GFP)

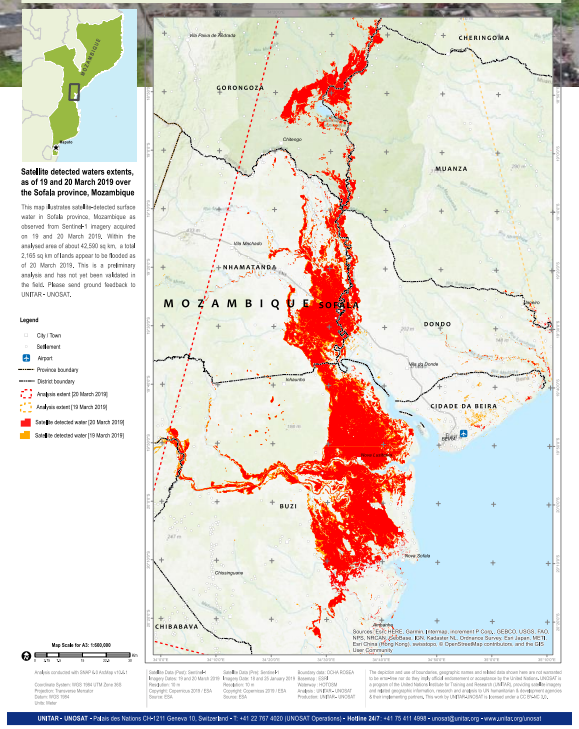
- Focus here is on examples of recent events and potential for integration with other remote-sensing flood observations

Mozambique Cyclone Idai March 2019

Numerous Remote Sensing-based flood products

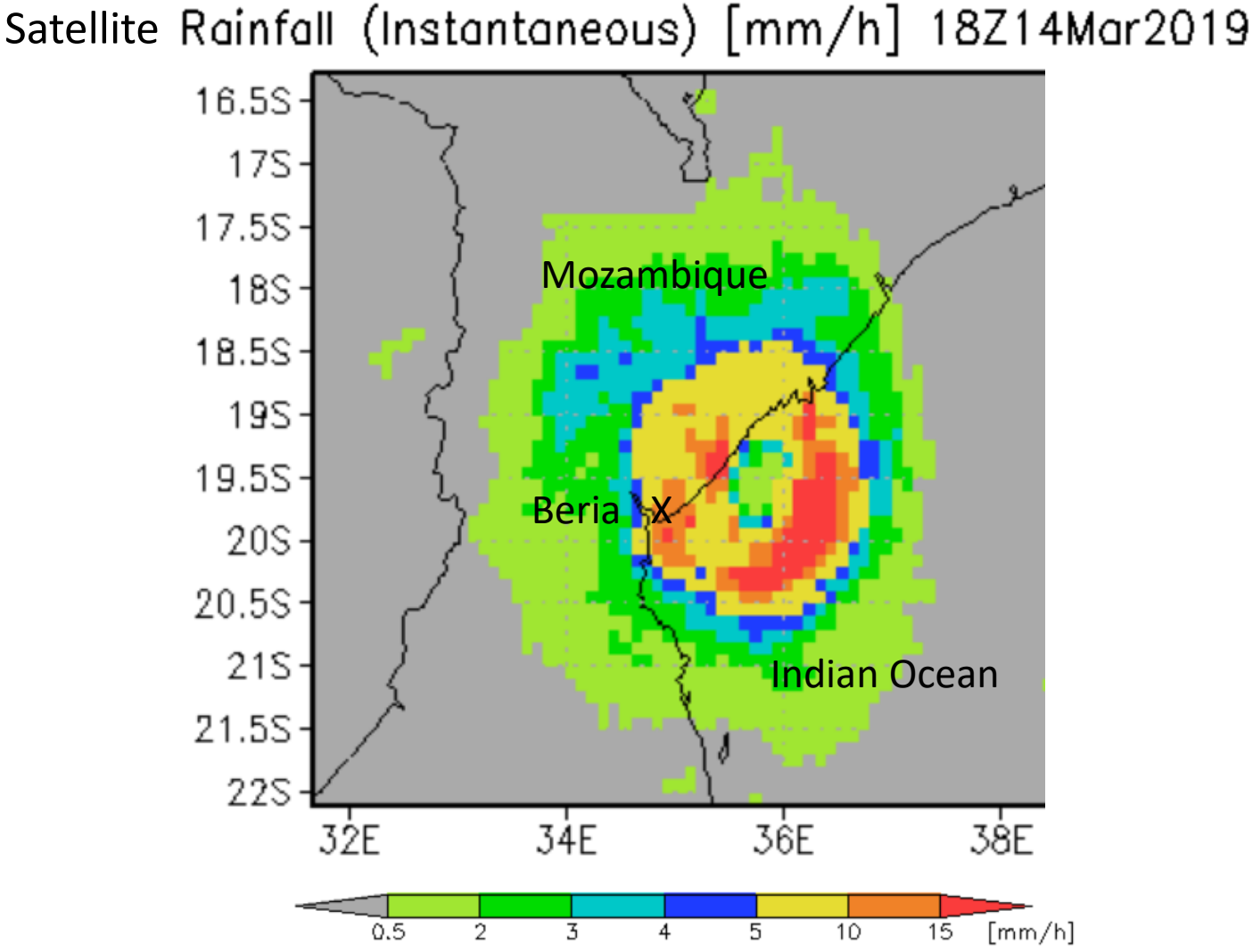




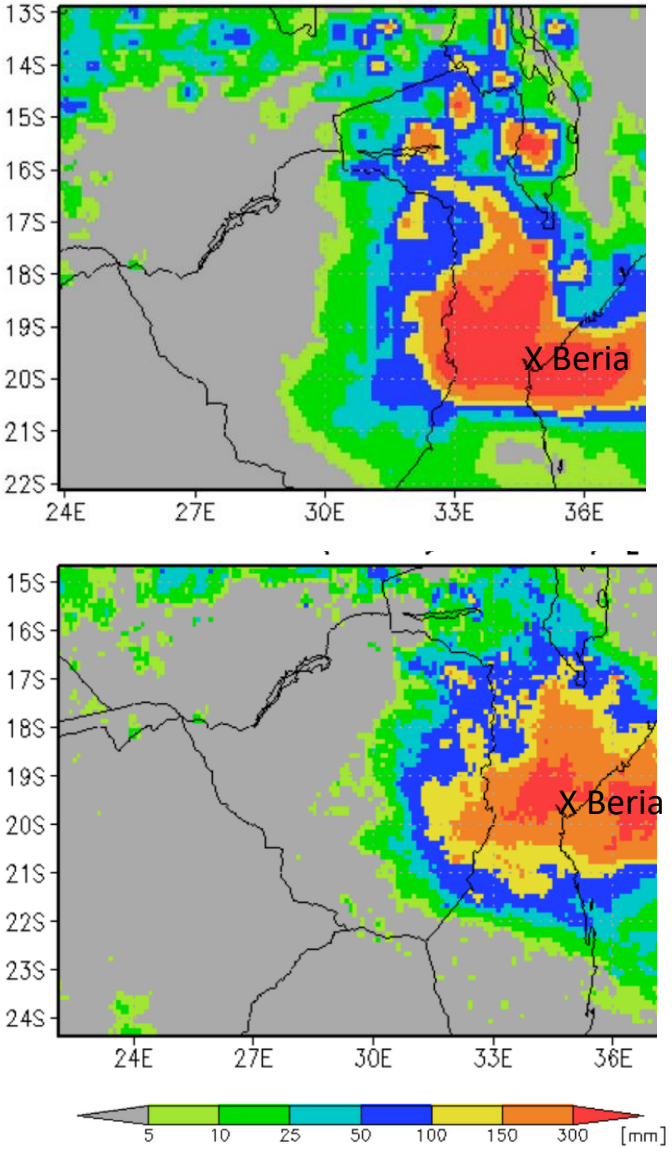



MOZAMBIQUE
River Map
TANZANIA
ZAMBIA
MALAWI
ZIMBABWE
BOTSWANA
SOUTH AFRICA
SWAZILAND
Lake Nyasa
Rovuma
Lugenda
Messalo
Lurio
Capoche
Lago Chilwa
Ligonha
Licungo
Lake Cahora Bassa
Zambezi
Pungwe
Revue
Save
Changane
Limpopo
MAPUTO
Beria
INDIAN OCEAN
0 100 200 Km
0 50 100 Miles
LEGEND
International Boundary
Capital
River
Copyright© 2013 www.mapsofworld.com
(Updated on 9th March, 2013)

Cyclone Idai Just Before Landfall (14 March 2019)



Forecast Rain Before Cyclone Hit



3-Day Forecast Rain from 14 March (from NASA GEOS NWP model)

NWP forecast peak totals were ~ 1000 mm, while peak satellite estimates (IMERG) were ~ 600 mm. Ground validation was missing/questionable.

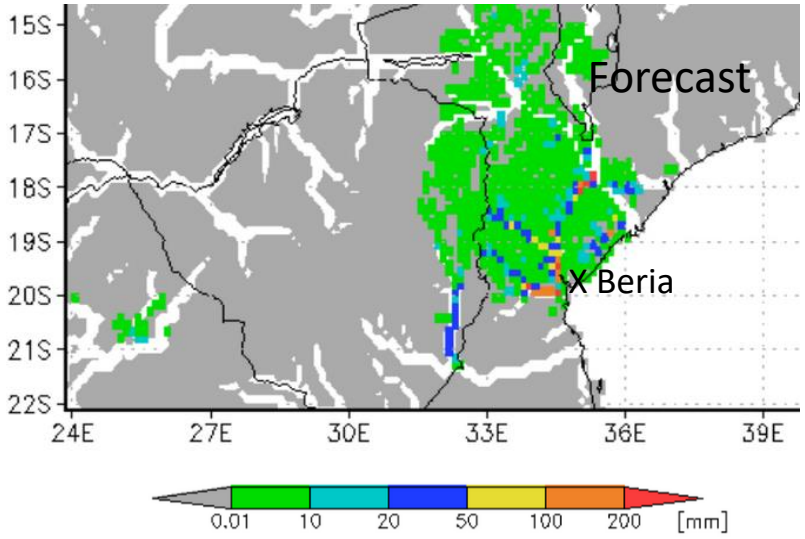
3-Day Satellite-based Rain from 14-17 March

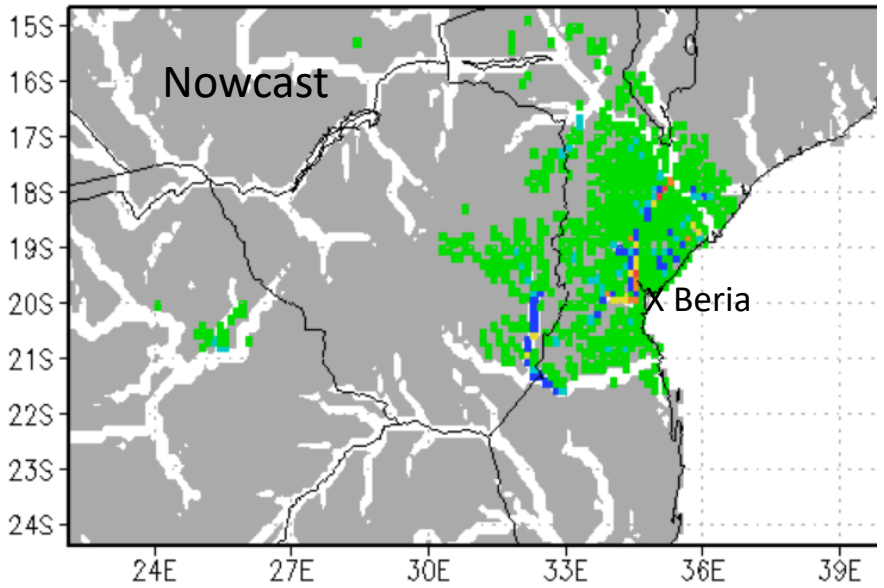
Flood Forecasts from NWP Rain vs. Nowcast Using Satellite Rain

Forecast from 14 March
for 17 March

Nowcast using Satellite Rainfall
for 17 March

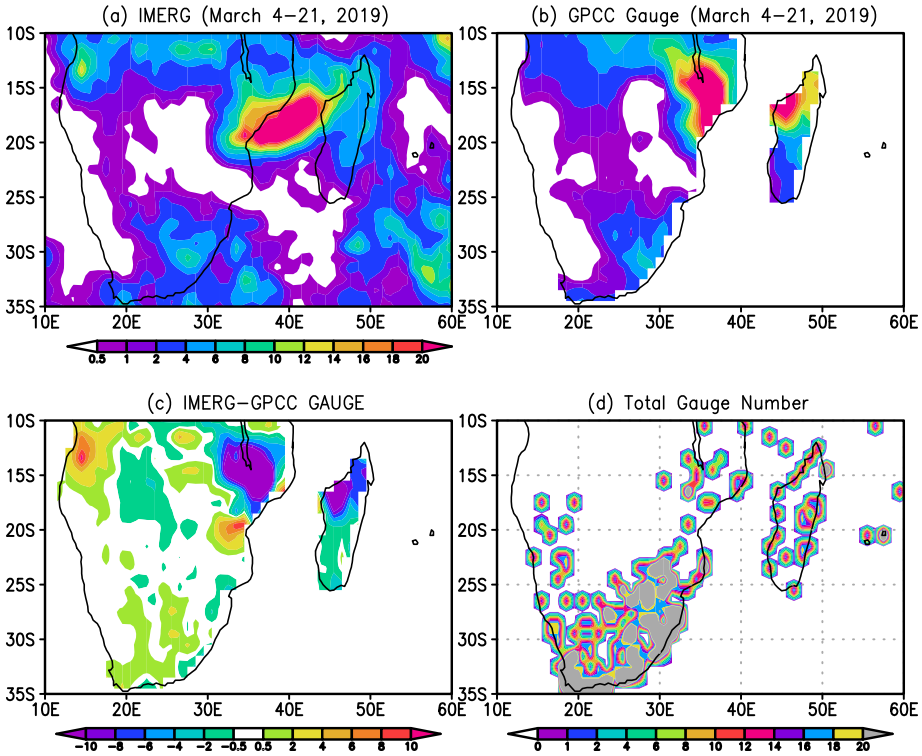
Flood Detection/Intensity (Depth)

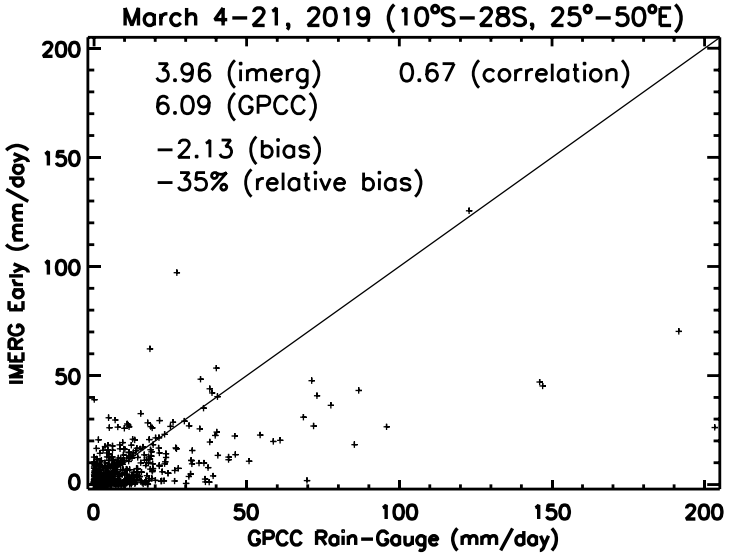


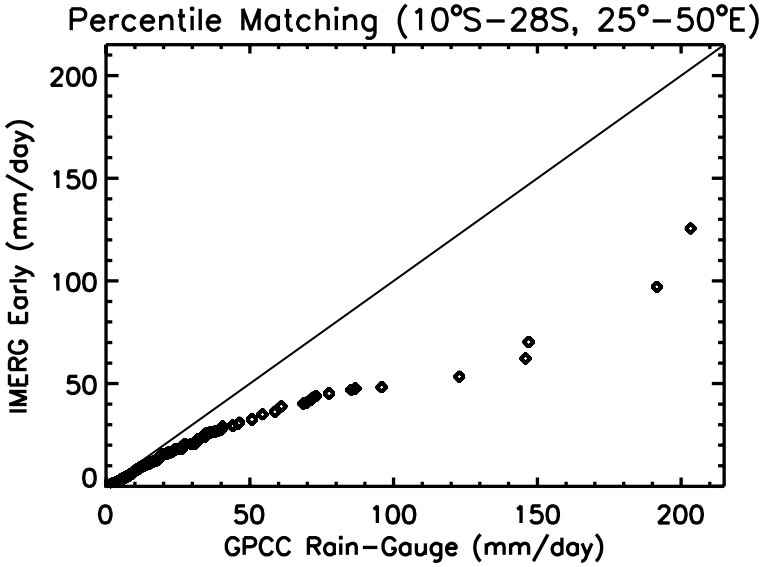


Forecast at coarse (12 km) resolution gives good warning of where flooding may occur both in Mozambique and Zimbabwe, with less intensity due to difference in peak rain amounts

Mean Rainfall During March 4-21, 2019
IMERG (satellite) vs GPCC (gauges)







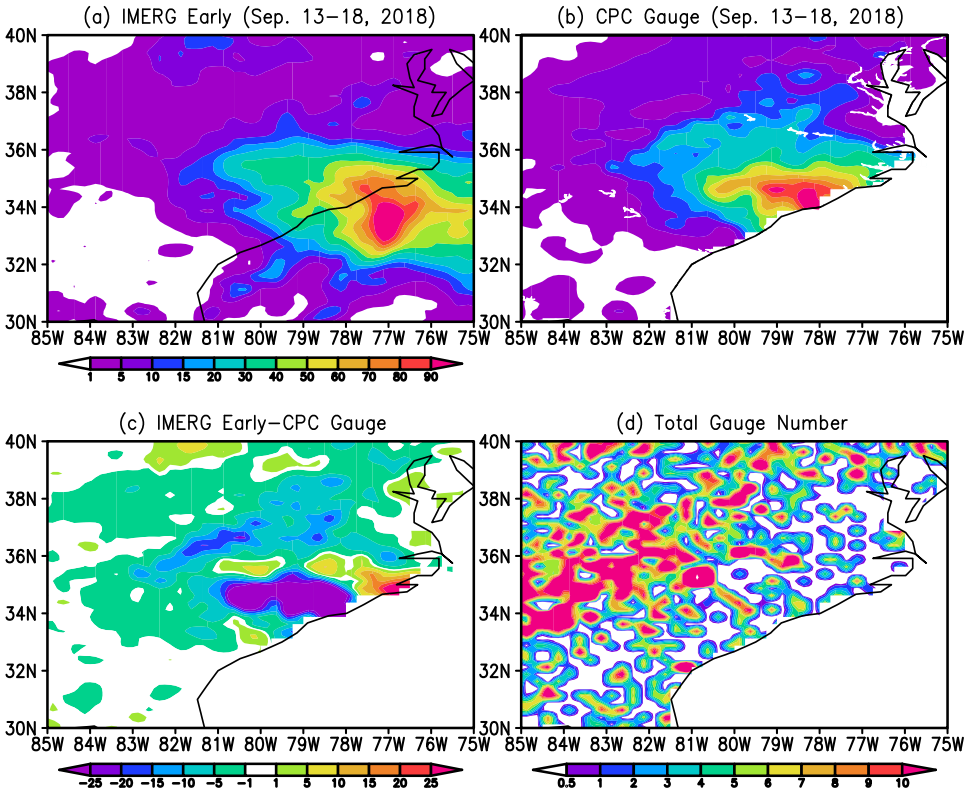
Although validation (gauges) are missing/questionable, it appears IMERG underestimated, especially at high end.

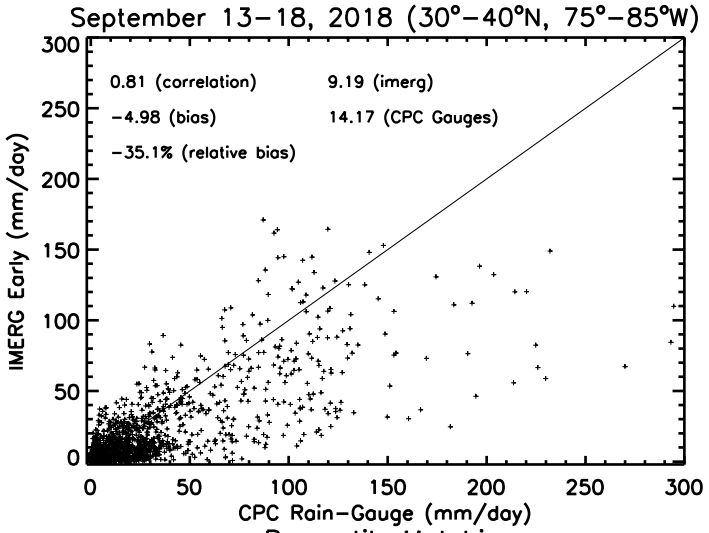
At least one gauge in each 1º grid

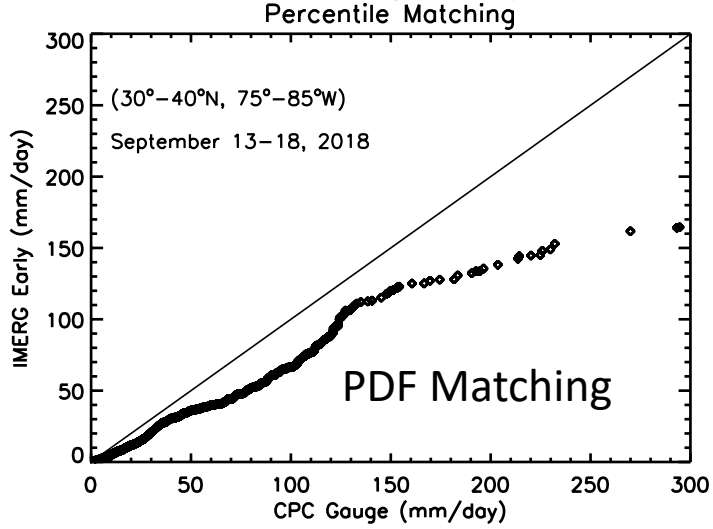
Hurricane Florence (Carolinas, USA)

Mean precipitation during September 13-18, 2018

IMERG vs CPC Gauge

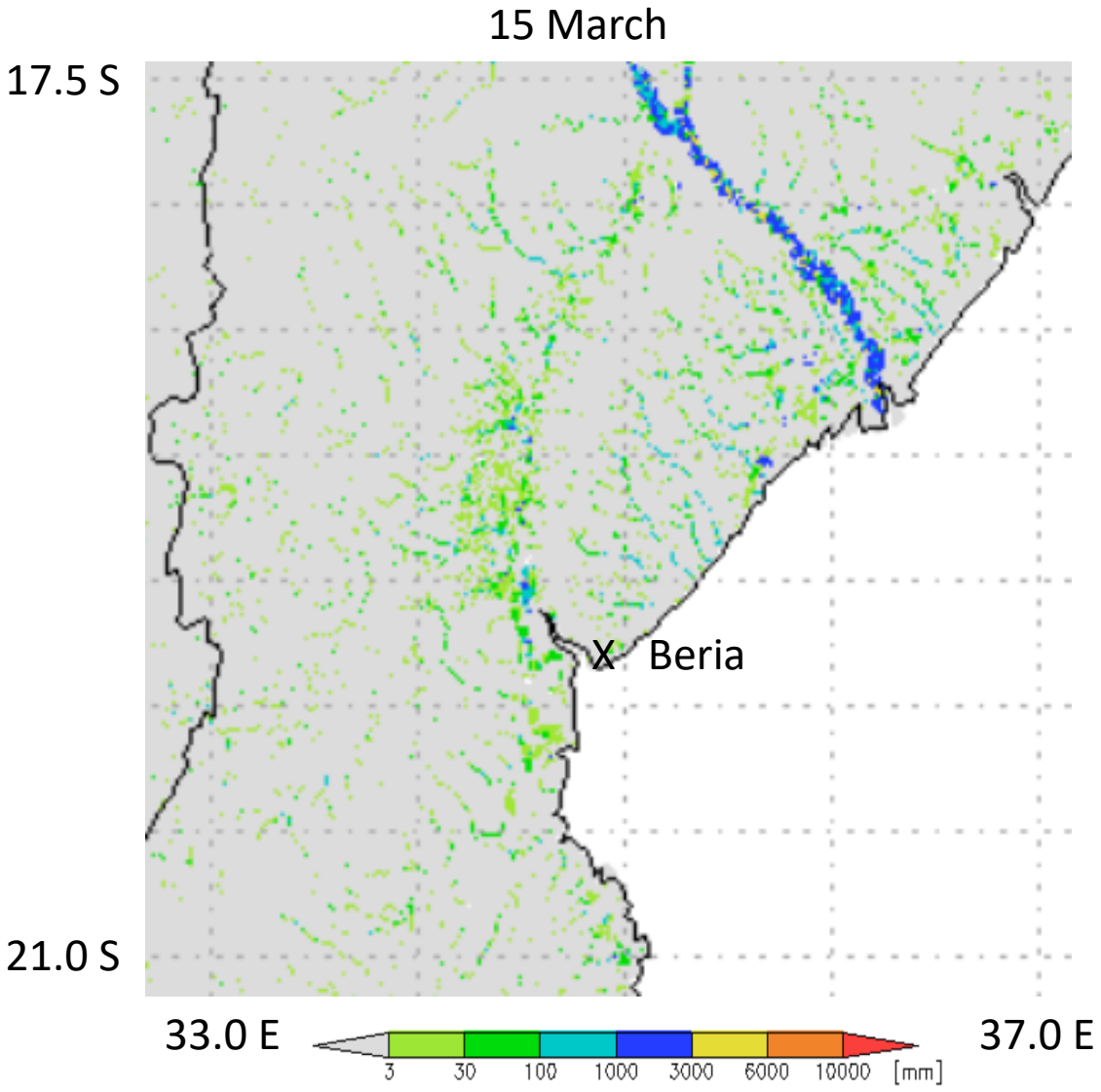






At least one gauge in each 0.25º grid

First Estimate of Inundation—from GFMS



Timeline of Useful Inundation Maps

15 March--GFMS 1 km (calculation based on Satellite rainfall and land-surface/routing models—every 3 hrs.)

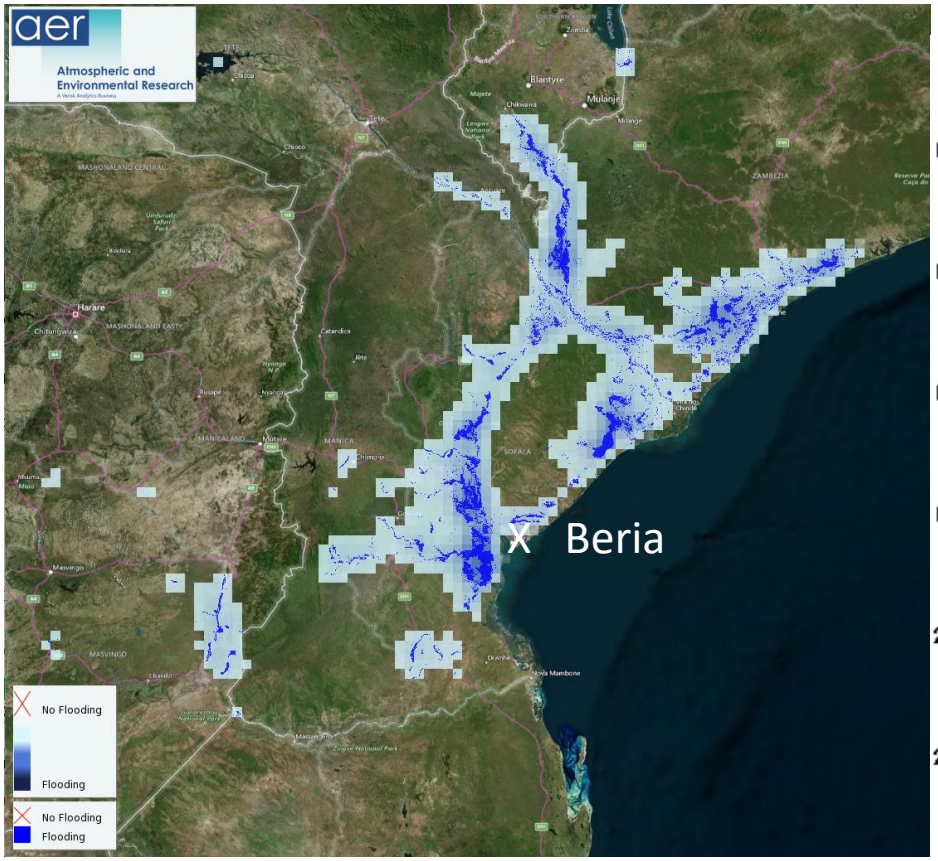
17 March—AER FloodScan (surface passive microwave signal disaggregated spatially by terrain, but obscured by rain [not cloud]

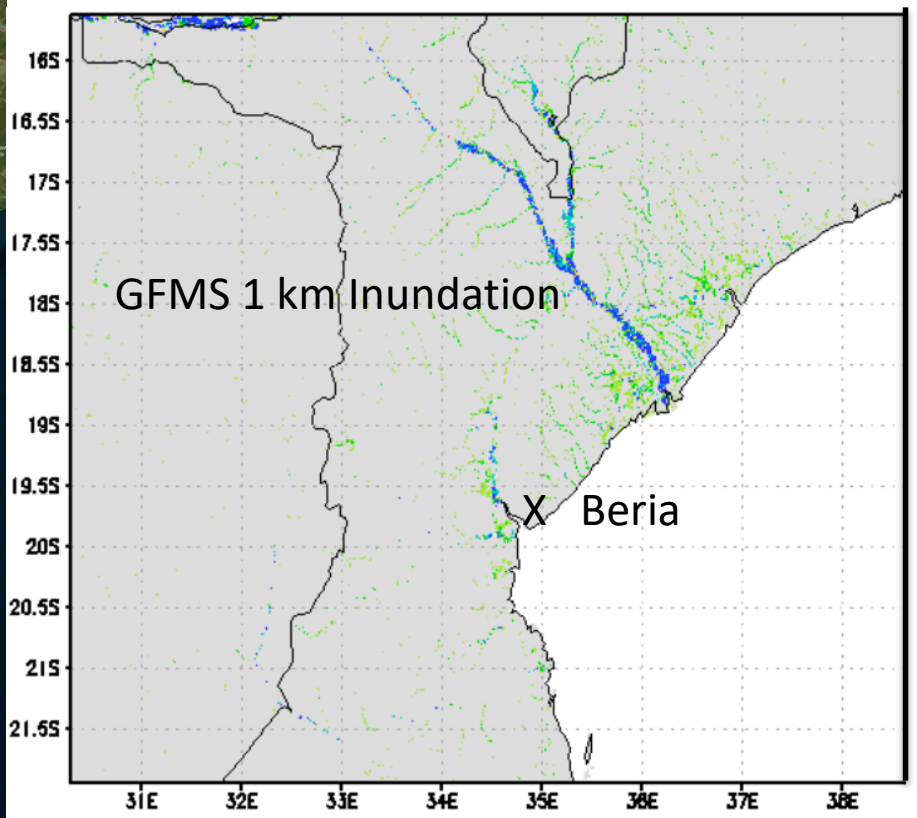
20 March—Synthetic Aperture Radar (SAR) published by UNOSAT from Sentinel-1 data 19-20 March.
Number of groups analyzing Sentinel and other SAR data

Later—Optical (e.g., MODIS) obscured by clouds

How to use these resources in an integrated fashion taking into account timelines and quality??

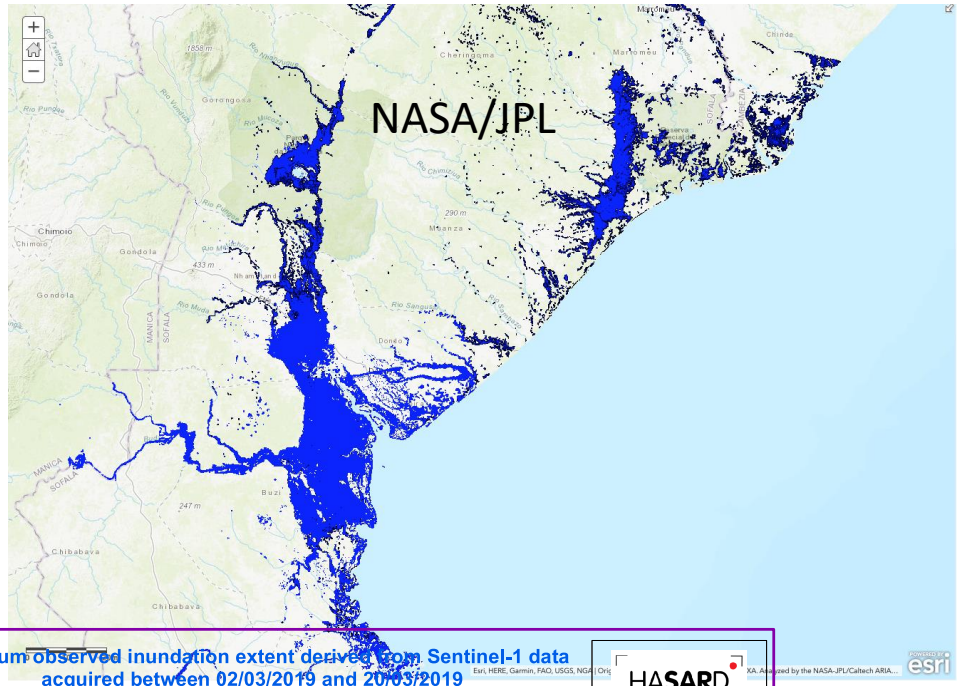
AER FloodScan 19 March

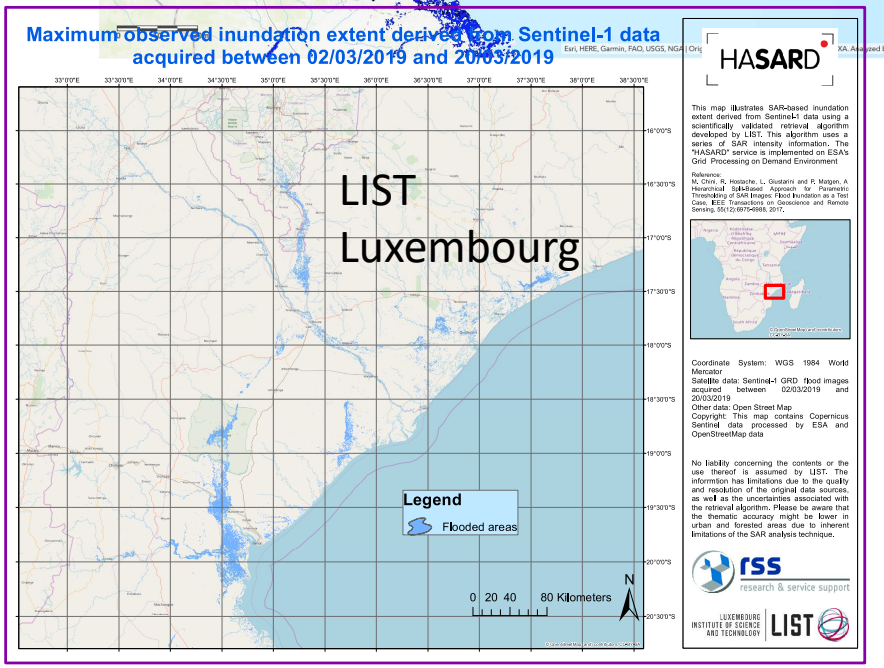


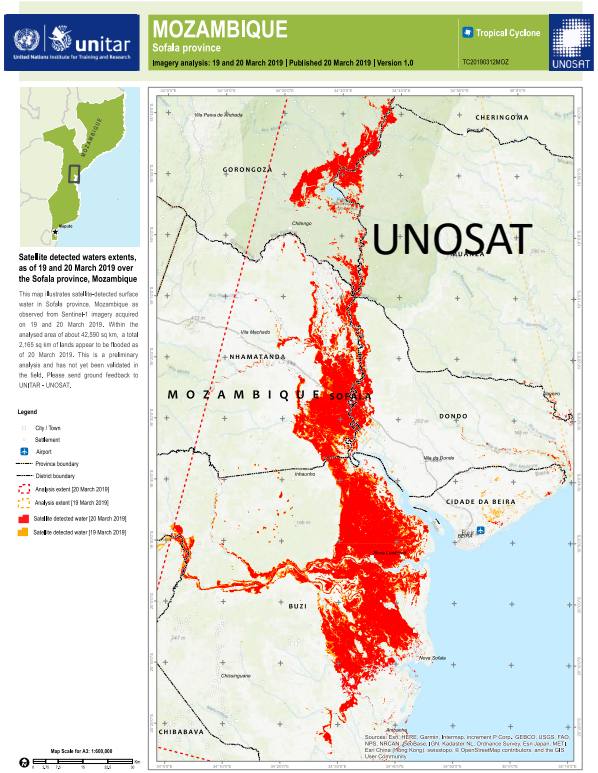


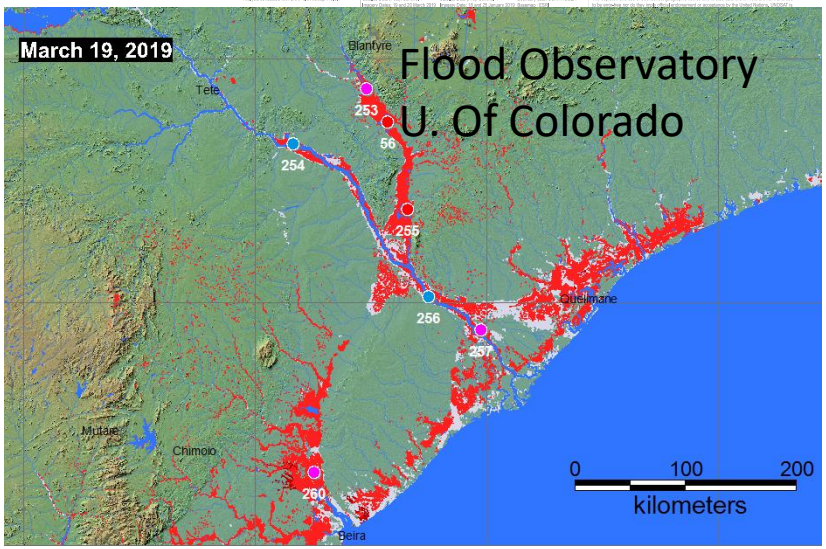
Passive microwave surface signals relate to non-typical surface water, very high soil moisture at coarse (15 km) resolution. Fine-scale inundation uses coarse-scale fractional water and topography

SAR-based Inundation Maps

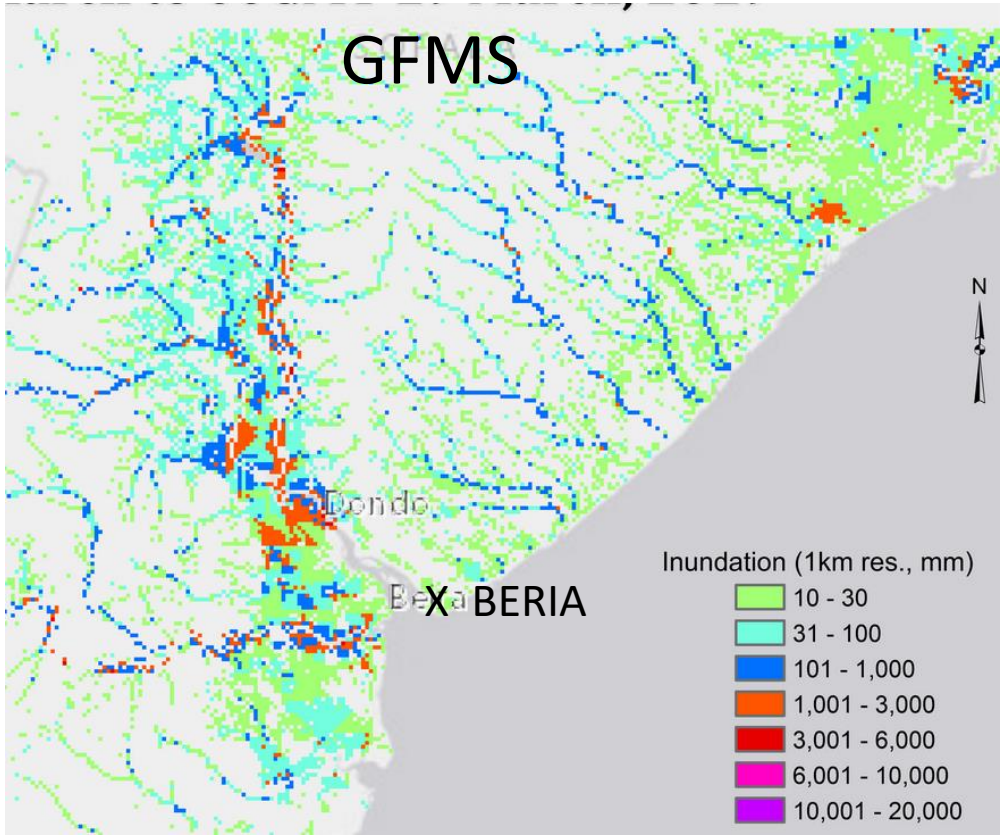






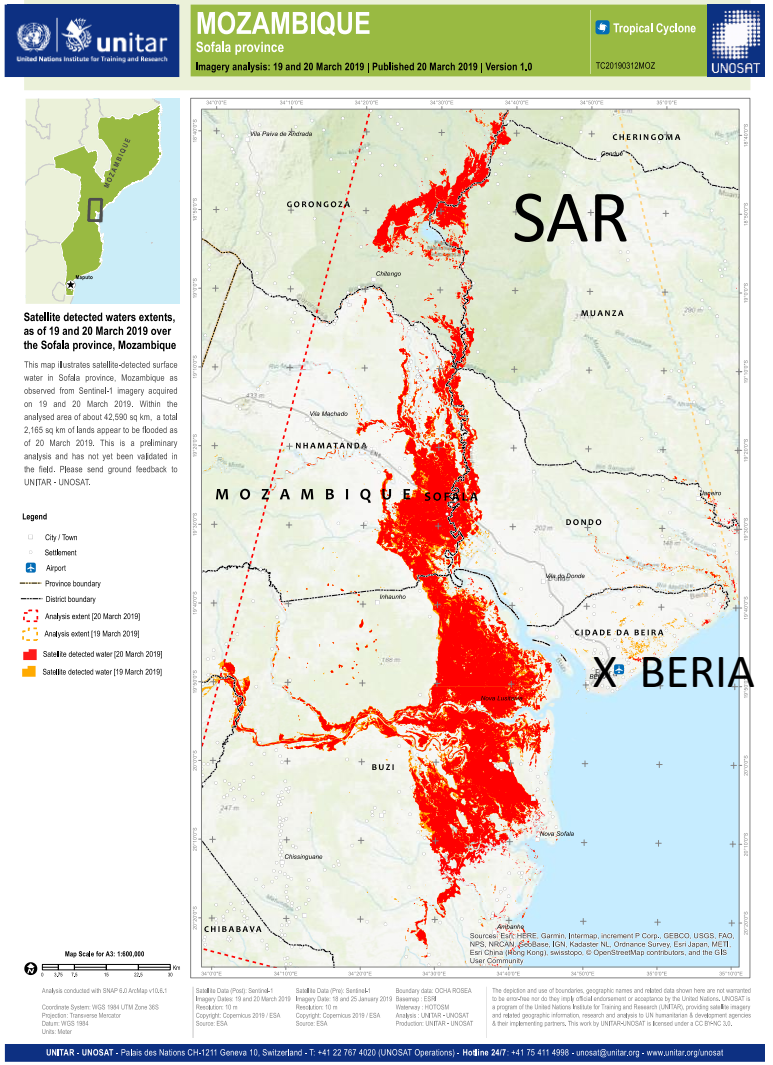


Mozambique Floods—
Inundation/Water Depth from GFMS
(Max 14-19 March 2019)

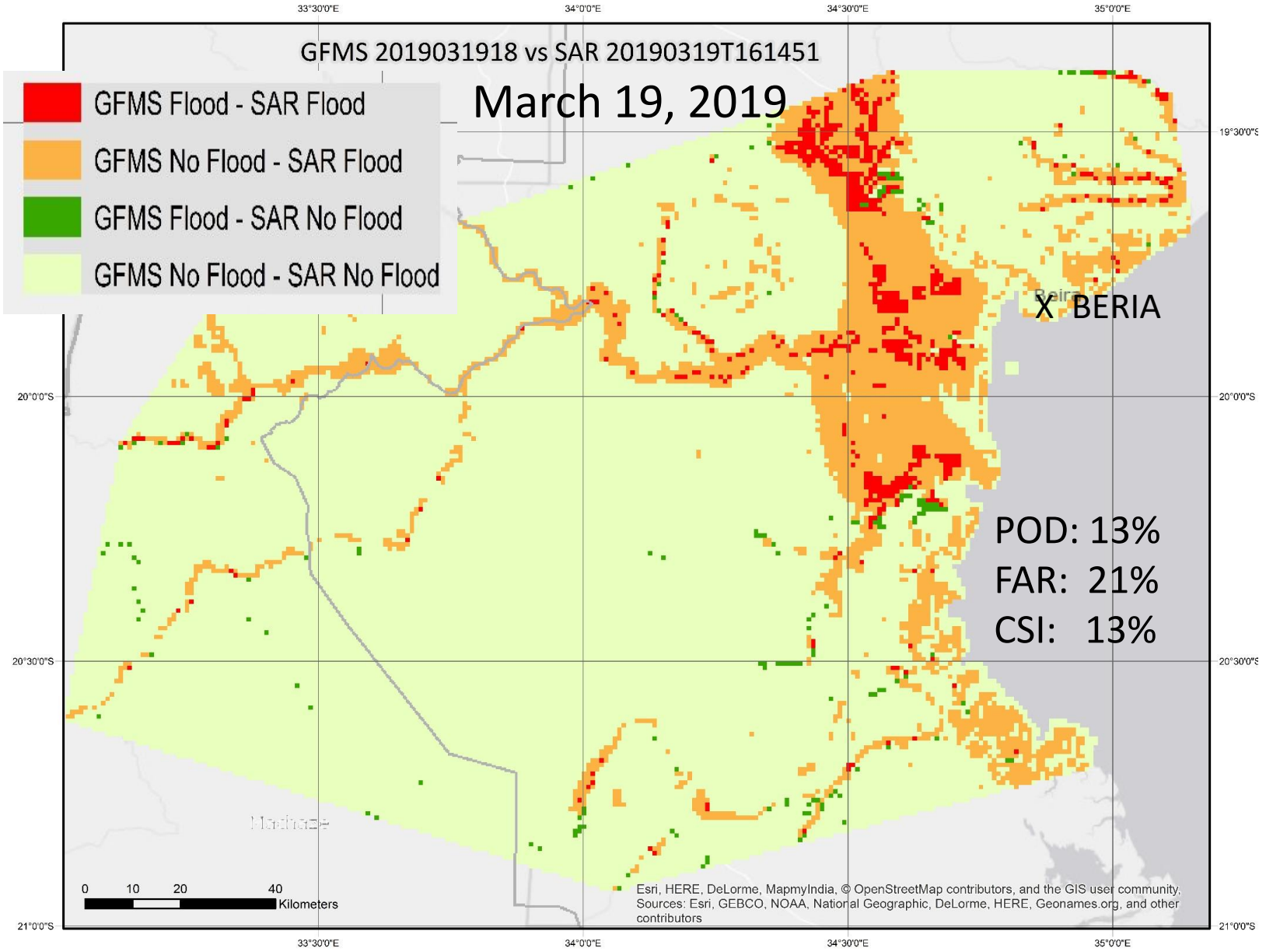


50 km

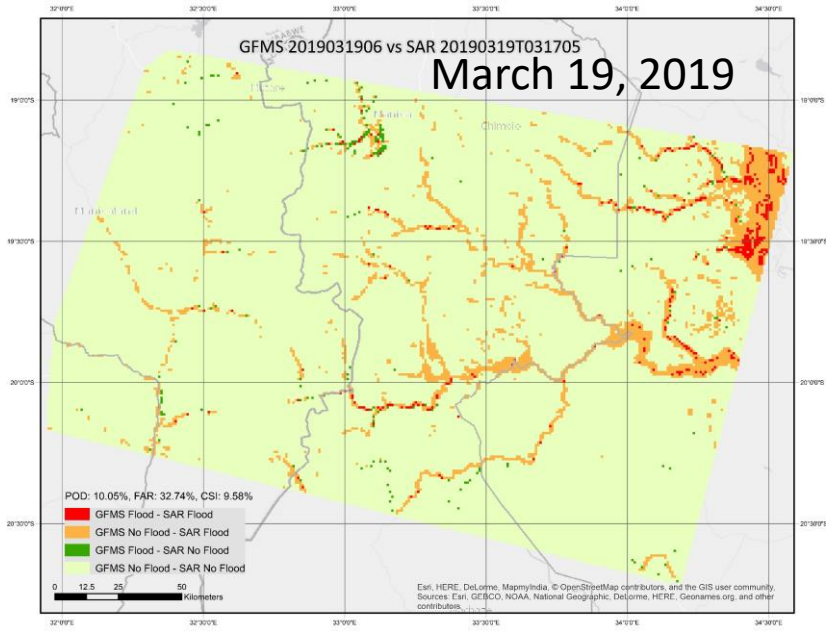
19-20 March

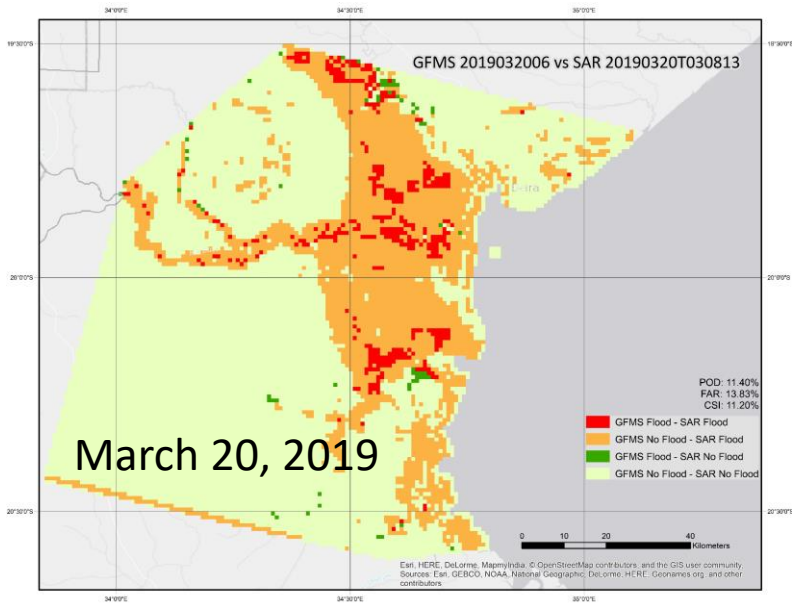


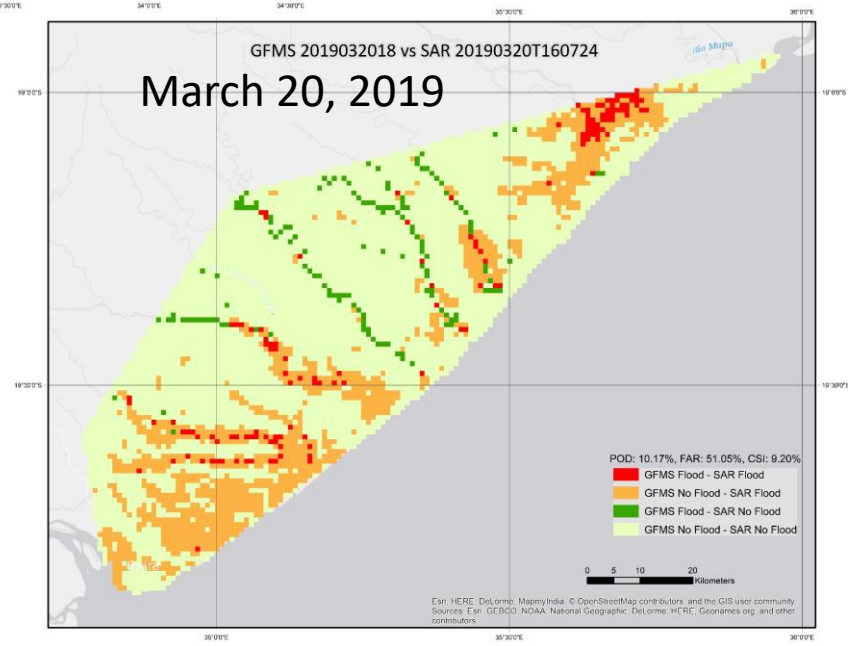
GFMS and SAR (LIST) Inundation Comparison



Other Examples (with similar results)

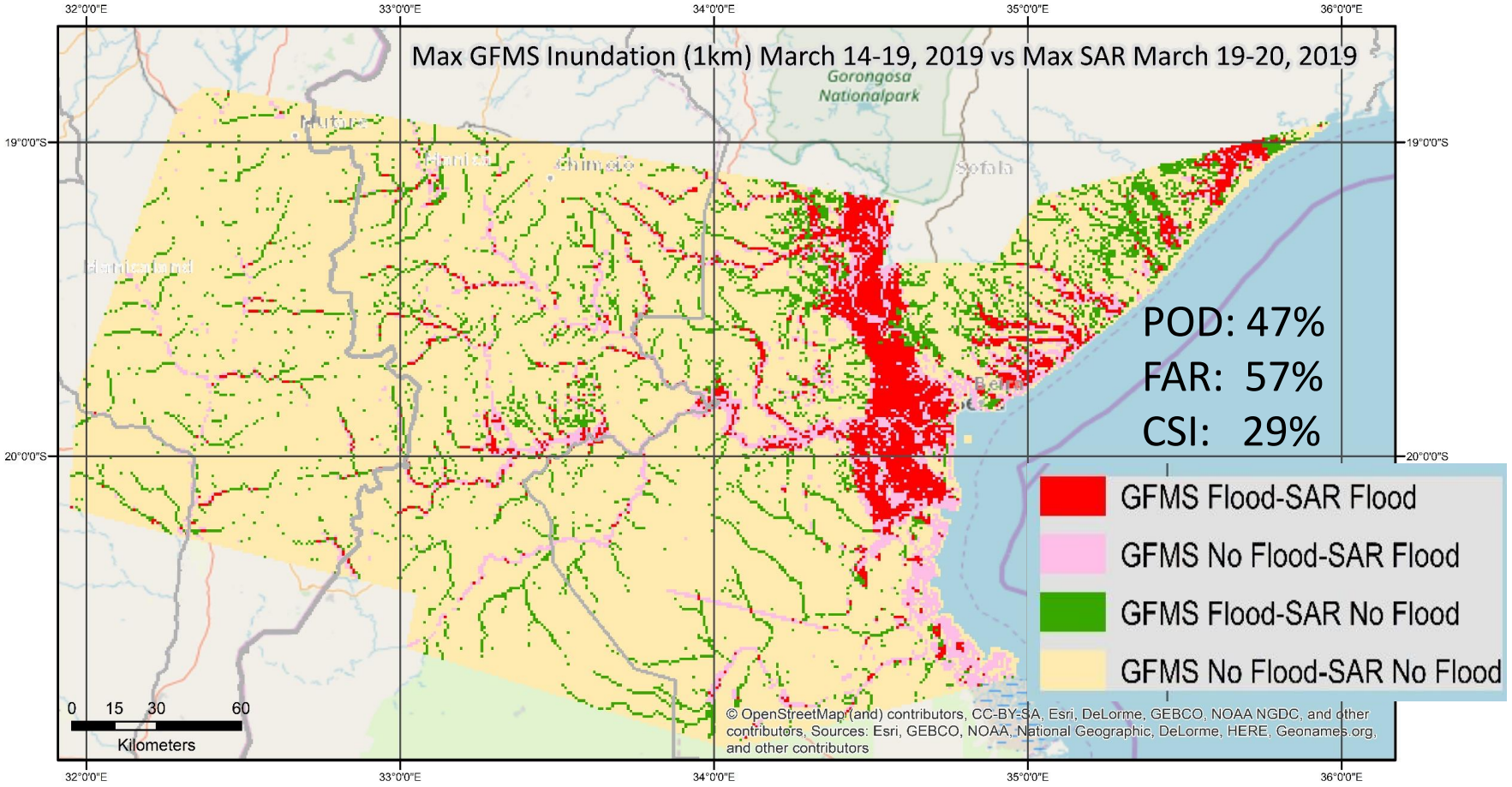






Time Integrated Inundation from GFMS

Maximum Inundation from GFMS (14-19 March) vs. Max Inundation from SAR (LIST)

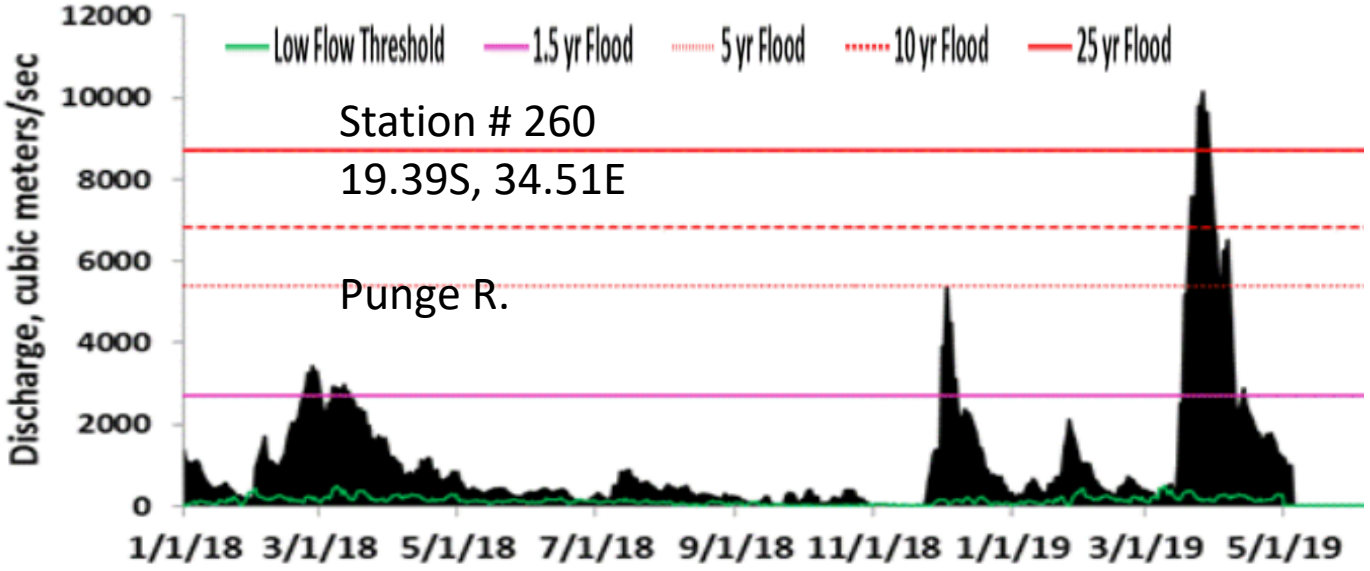


Better agreement with SAR—Higher POD, but lower FAR

Streamflow/Flood Estimates from RiverWatch (Flood Observatory) and GFMS

RiverWatch

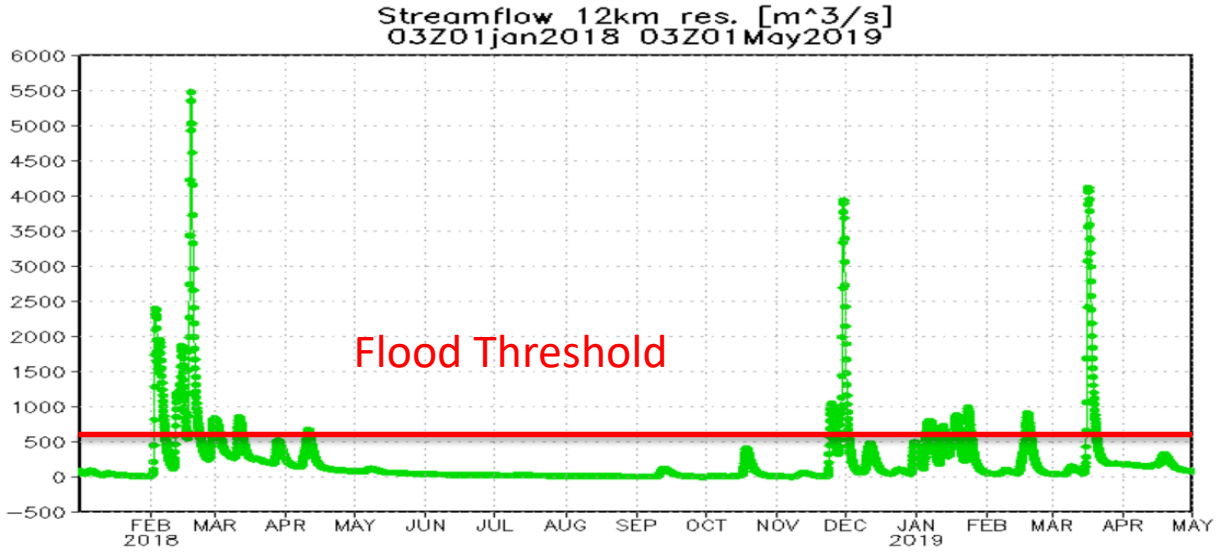
Uses surface microwave observations related to streamflow



GFMS

Streamflow

Satellite rainfall into land surface/routing models



Mozambique Flood Example → Next Steps?

Real-time users need accurate information, quickly. Multiple sources are available, at different time and space resolutions (and different latencies) and with different positive qualities and limitations.

With multiple sources, users need info. to be "easy to compare" or integrated.

Integrated Products

Individual products (e.g., inundation estimates) will continue to improve with better observations, algorithms and modeling—but there will always be limitations in accuracy, availability, etc.

So, we also need to be working toward melding or integrating our multiple estimates into a "best" estimate.

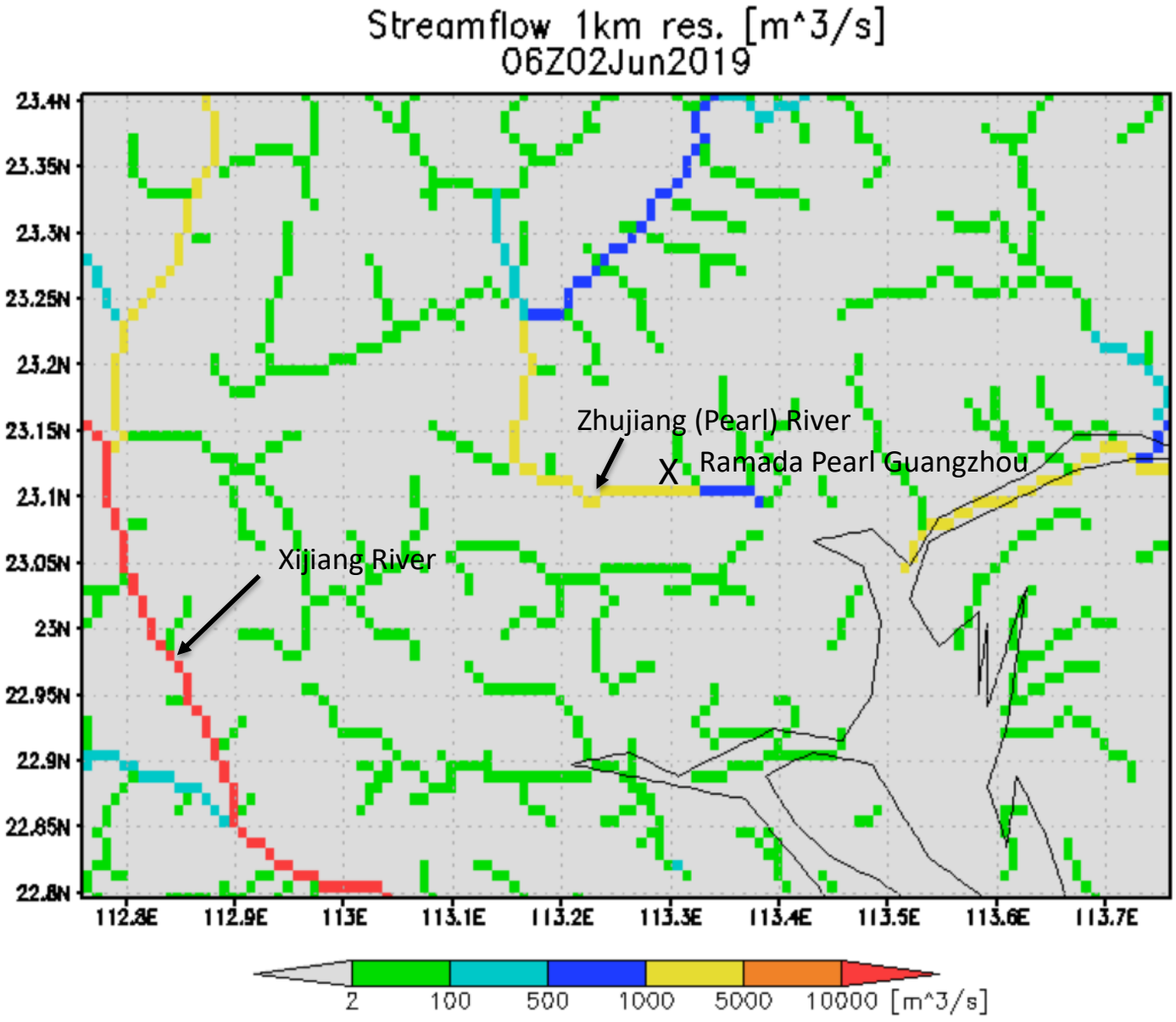
For inundation, one possible approach: Daily, model-based estimate as base, with optical and SAR products as additional options where/when available. All remapped and available as layers (if available); possible merger or best estimate as separate product.

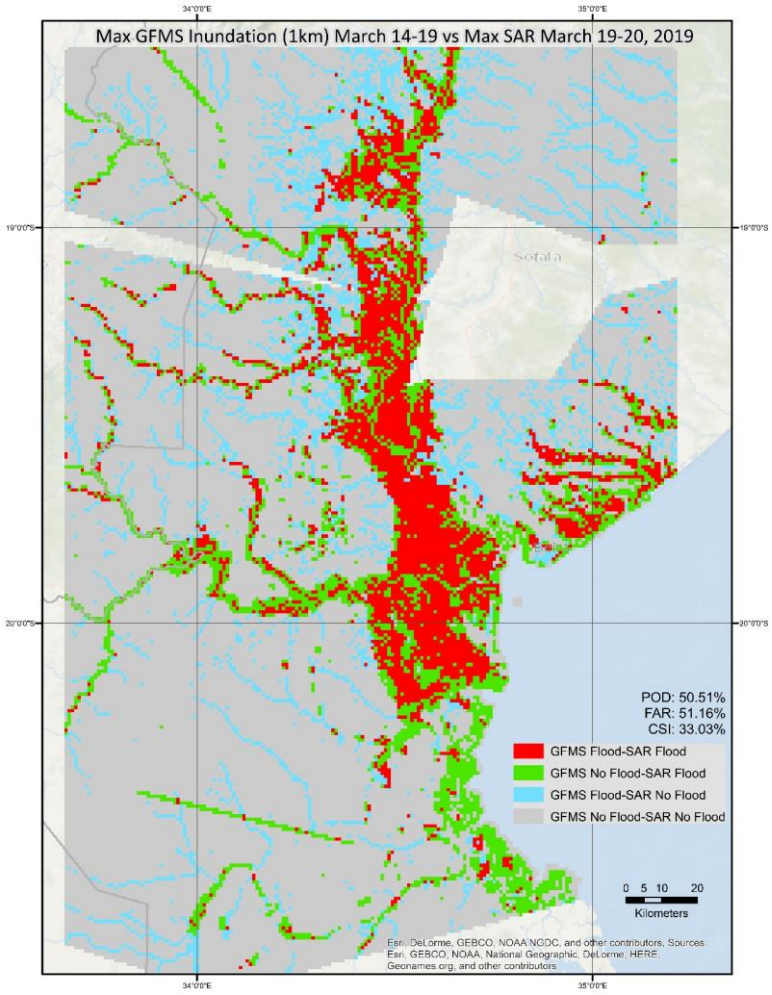
A technical starting point is simple comparisons to understand strengths/weaknesses, with possible product approaches driven by user interests.

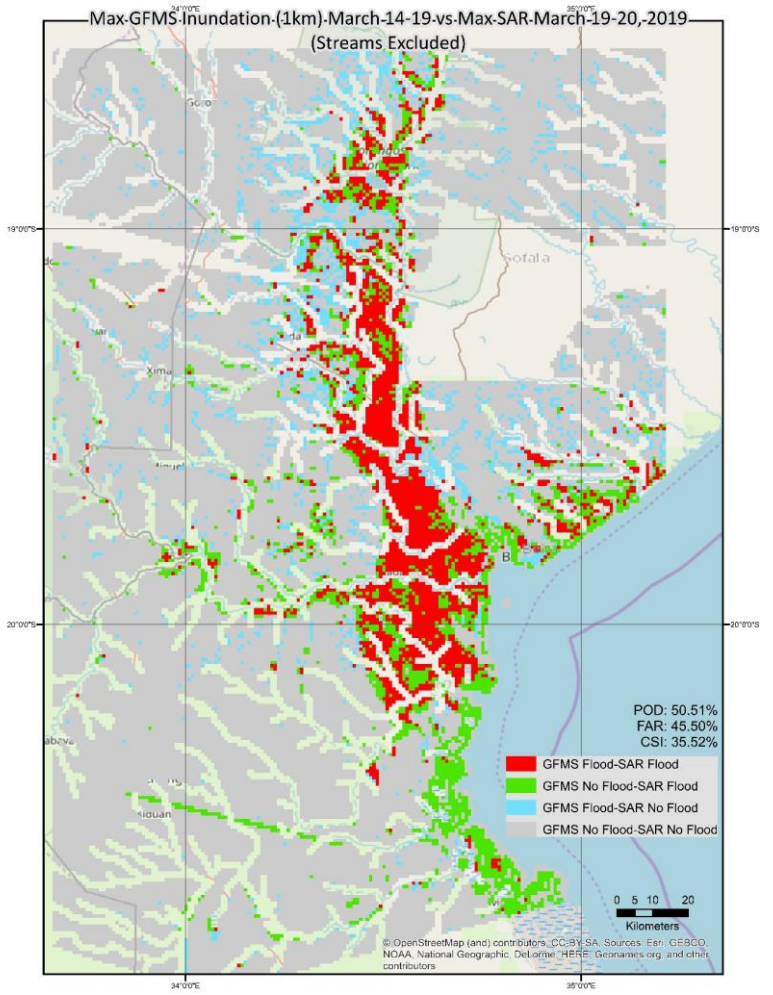
Some ideas are being tested/applied at Flood Observatory

This type of work needs programmatic integration too; a great place for leadership by certain funding agencies working together, but also "steering" by entities like the Global Flood Partnership (GFP)


CHINA
VIETNAM
South China Sea
Yangtze
Guiyang
Beipan
Kunming
Nanpan
Hongshui
Long
Rong
Gulin
Liuzhou
Liu
You
Qian
Gui
He
Lian
Shaoguan
Bei
Dong
Wuzhou
Xi
Guangzhou
Huizhou
Xun
Yu
Yong
Zuo
Nanning
Zhaoqing
Jiangmen
Hong Kong
Zhu
Macau

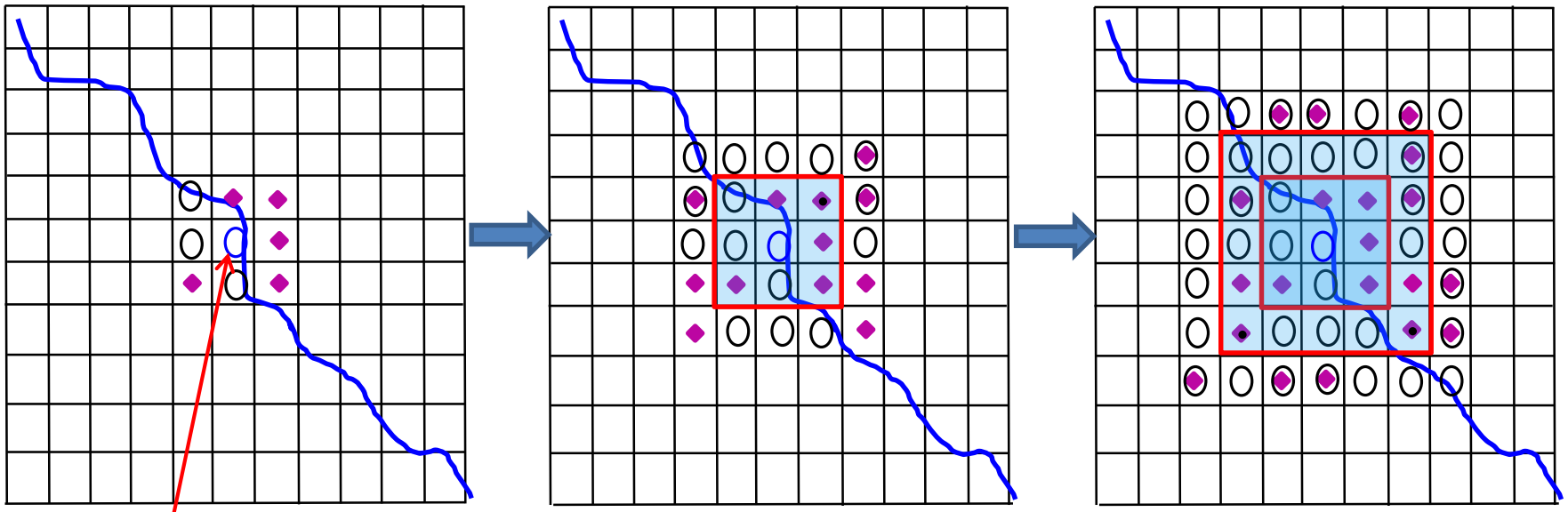

Streamflow 1km res. [m^3/s]
06Z02Jun2019
23.4N
23.35N
23.3N
23.25N
23.2N
23.15N
23.1N
23.05N
23N
22.95N
22.9N
22.85N
22.8N
112.8E
112.9E
113E
113.1E
113.2E
113.3E
113.4E
113.5E
113.6E
113.7E
Zhujiang (Pearl) River
Ramada Pearl Guangzhou
Xijiang River
2
100
500
1000
5000
10000 [m^3/s]

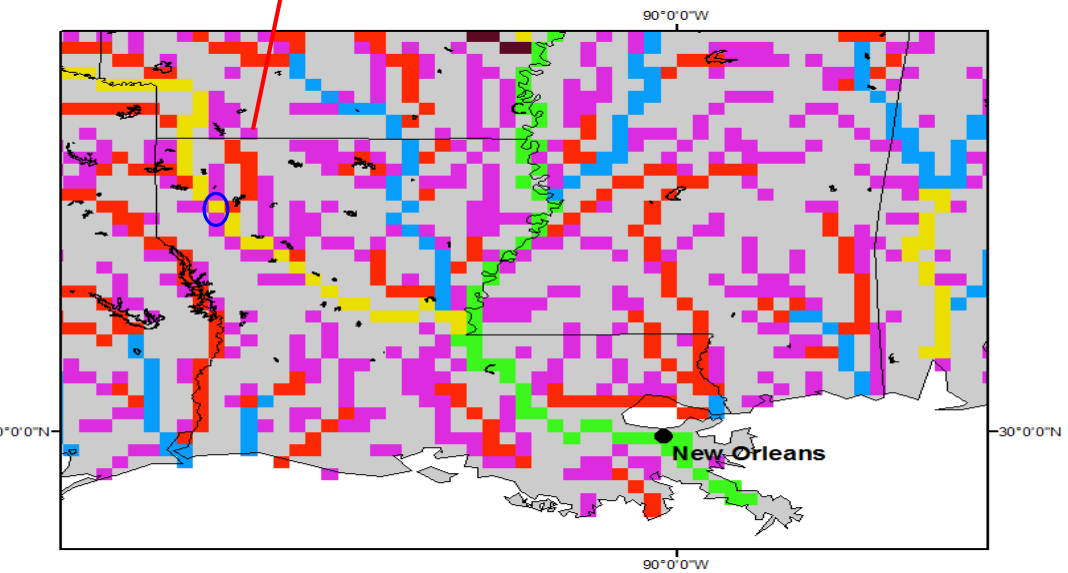

Max GFMS Inundation (1km) March 14-19 vs Max SAR March 19-20, 2019
34°0'0"E
35°0'0"E
19°0'0"S
20°0'0"S
Sofala
POD: 50.51%
FAR: 51.16%
CSI: 33.03%
GFMS Flood-SAR Flood
GFMS No Flood-SAR Flood
GFMS Flood-SAR No Flood
GFMS No Flood-SAR No Flood
0 5 10 20
Kilometers
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors, Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors


Max-GFMS-Inundation-(1km)-March-14-19-vs-Max-SAR-March-19-20,-2019
(Streams Excluded)
34°0'0"E
35°0'0"E
19°0'0"S
20°0'0"S
Sofala
POD: 50.51%
FAR: 45.50%
CSI: 35.52%
GFMS Flood-SAR Flood
GFMS No Flood-SAR Flood
GFMS Flood-SAR No Flood
GFMS No Flood-SAR No Flood
0 5 10 20
Kilometers
© OpenStreetMap (and) contributors, CC-BY-SA, Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

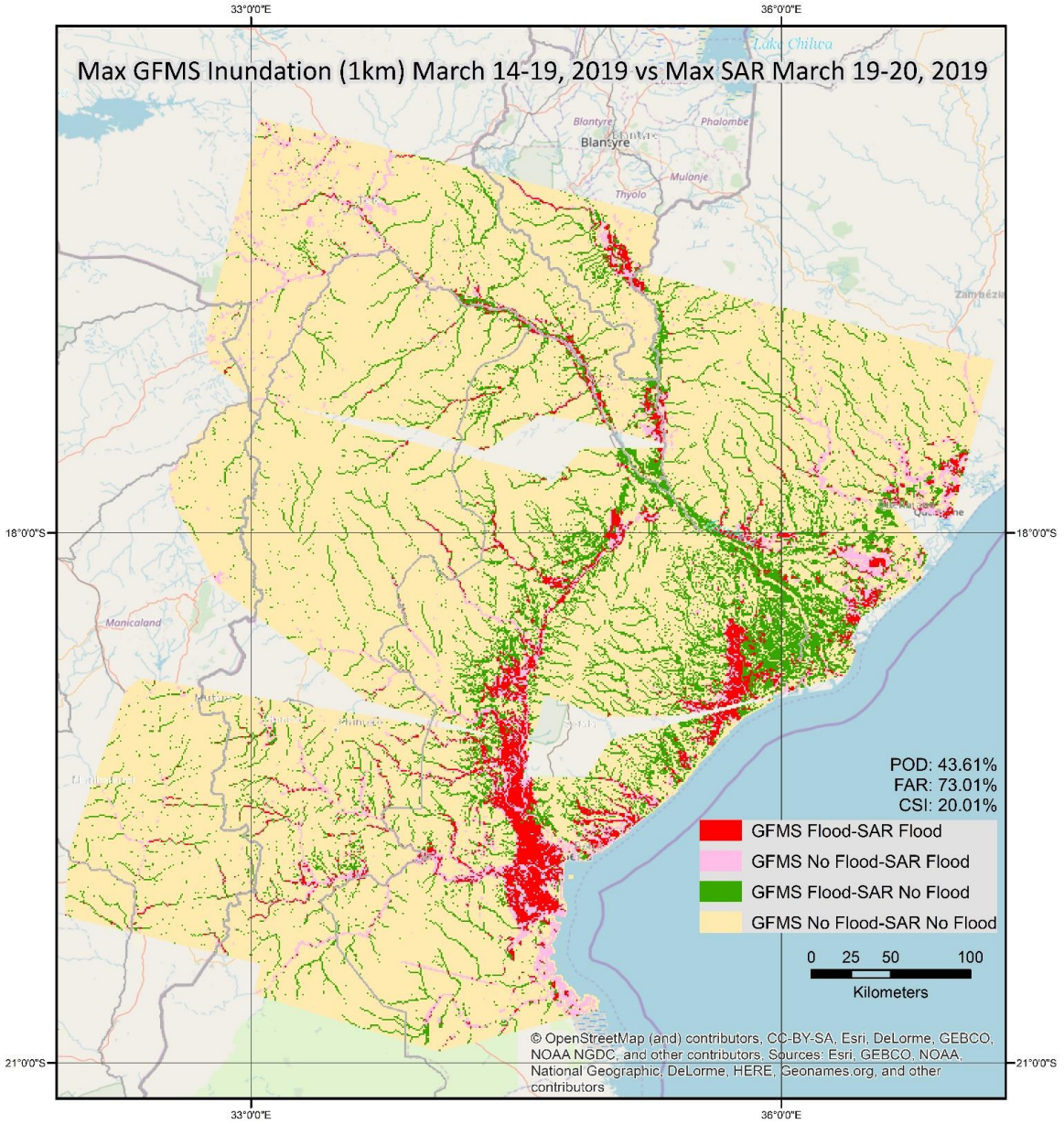
GFMS Inundation Algorithm 1 km Streamflow

Overbank flooding
Not inundated
Inundated cell
Inundated cell without expanding
Non-inundated potential flooding





Criteria and assumption: (1) mass balance; (2) inundation only happens in floodplain across the river reach with a level water surface; (3) inundation process finishes within the same time interval as the routing model; (4) inundation buffer area doesn't include the grid cells with higher river order.


Max GFMS Inundation (1km) March 14-19, 2019 vs Max SAR March 19-20, 2019
33°0'0"E
36°0'0"E
18°0'0"S
21°0'0"S
Lake Chilwa
Blantyre
Phalombe
Mulonje
Thyolo
Zambézia
Manicaland
POD: 43.61%
FAR: 73.01%
CSI: 20.01%
GFMS Flood-SAR Flood
GFMS No Flood-SAR Flood
GFMS Flood-SAR No Flood
GFMS No Flood-SAR No Flood
0 25 50 100
Kilometers
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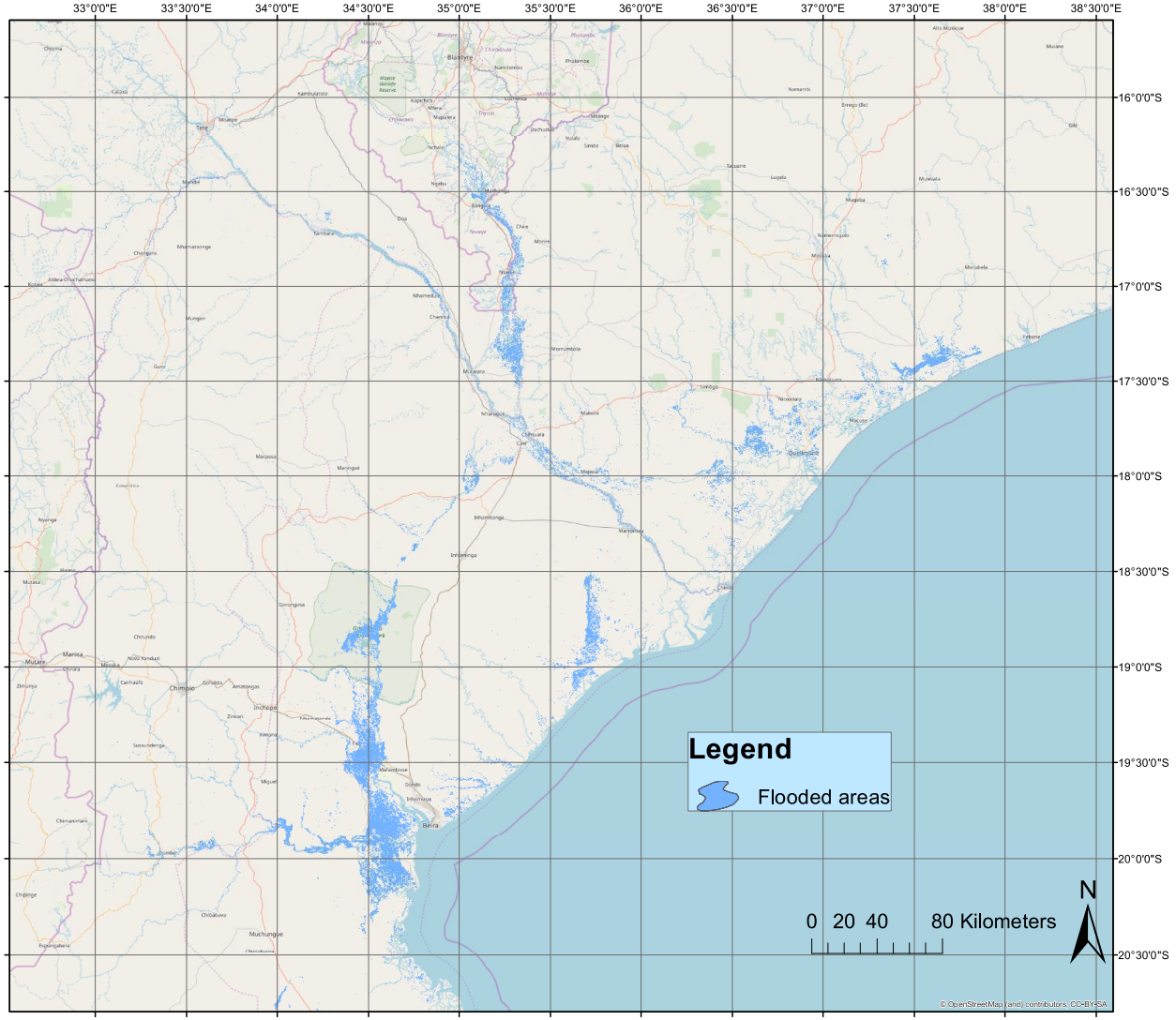
Maximum observed inundation extent derived from Sentinel-1 data acquired between 02/03/2019 and 20/03/2019



HASARD

This map illustrates SAR-based inundation extent derived from Sentinel-1 data using a scientifically validated retrieval algorithm developed by LIST. This algorithm uses a series of SAR intensity information. The "HASARD" service is implemented on ESA's Grid Processing on Demand Environment

Reference:
M. Chini, R. Hostache, L. Giustarini and P. Matgen, A Hierarchical Split-Based Approach for Parametric Thresholding of SAR Images: Flood Inundation as a Test Case, IEEE Transactions on Geoscience and Remote Sensing, 55(12):6975-6988, 2017.

Coordinate System: WGS 1984 World Mercator
Satellite data: Sentinel-1 GRD flood images acquired between 02/03/2019 and 20/03/2019
Other data: Open Street Map
Copyright: This map contains Copernicus Sentinel data processed by ESA and OpenStreetMap data

No liability concerning the contents or the use thereof is assumed by LIST. The informtion has limitations due to the quality and resolution of the original data sources, as well as the uncertainties associated with the retrieval algorithm. Please be aware that the thematic accuracy might be lower in urban and forested areas due to inherent limitations of the SAR analysis technique.

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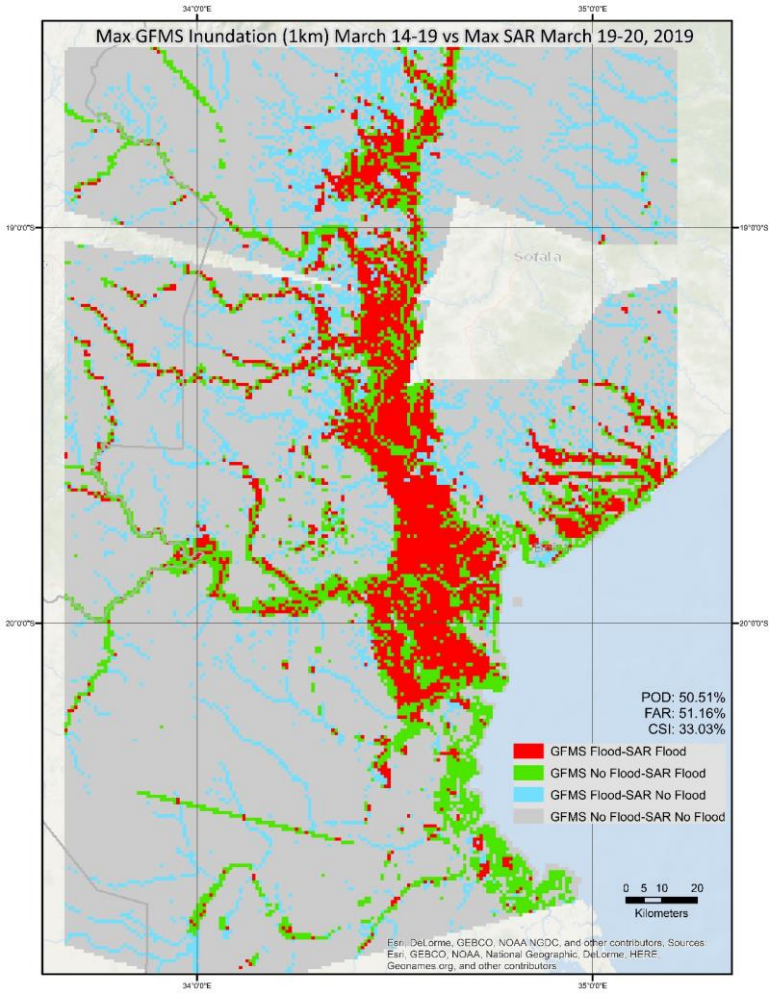
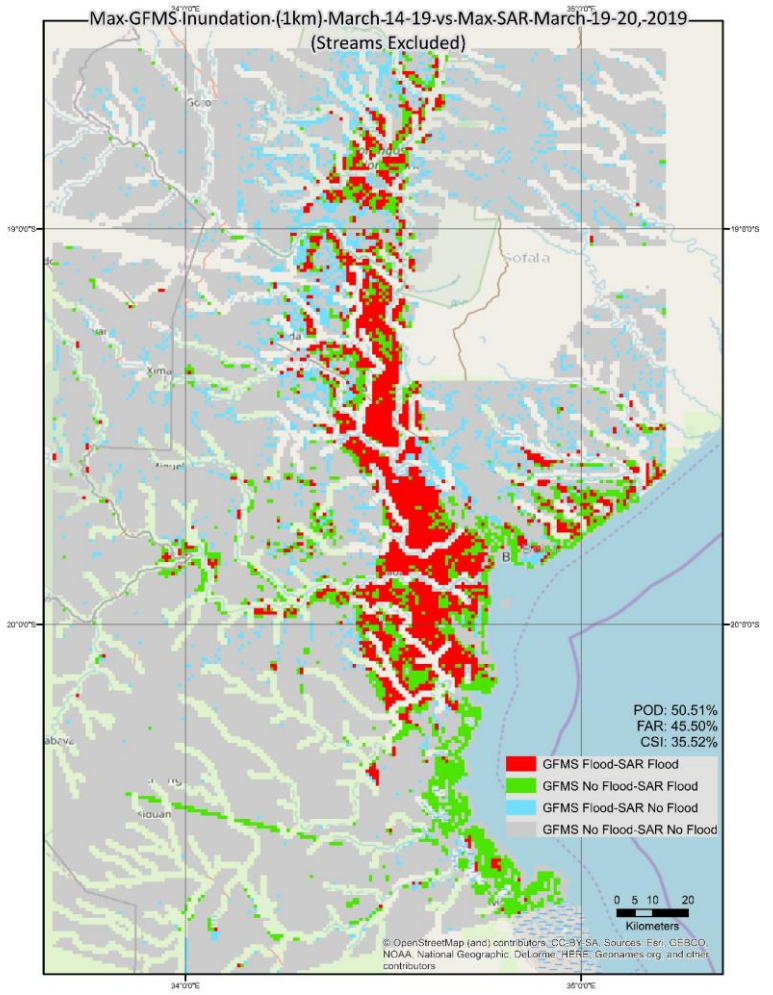

Max GFMS Inundation (1km) March 14-19 vs Max SAR March 19-20, 2019
34°0'0"E
35°0'0"E
19°0'0"S
20°0'0"S
Sofala
POD: 50.51%
FAR: 51.16%
CSI: 33.03%
GFMS Flood-SAR Flood
GFMS No Flood-SAR Flood
GFMS Flood-SAR No Flood
GFMS No Flood-SAR No Flood
0 5 10 20
Kilometers
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors, Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors


Max-GFMS-Inundation-(1km)-March-14-19-vs-Max-SAR-March-19-20,-2019
(Streams Excluded)
34°0'0"E
35°0'0"E
19°0'0"S
20°0'0"S
Sofala
POD: 50.51%
FAR: 45.50%
CSI: 35.52%
GFMS Flood-SAR Flood
GFMS No Flood-SAR Flood
GFMS Flood-SAR No Flood
GFMS No Flood-SAR No Flood
0 5 10 20
Kilometers
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