Real-time Global Flood Estimation System Using Satellite Rainfall Information and a Hydrological Model

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Outline

- What is Global Flood Monitoring System (GFMS)?

  Inputs, Models, and Outputs

- Flood detection technique in GFMS

- GFMS evaluation

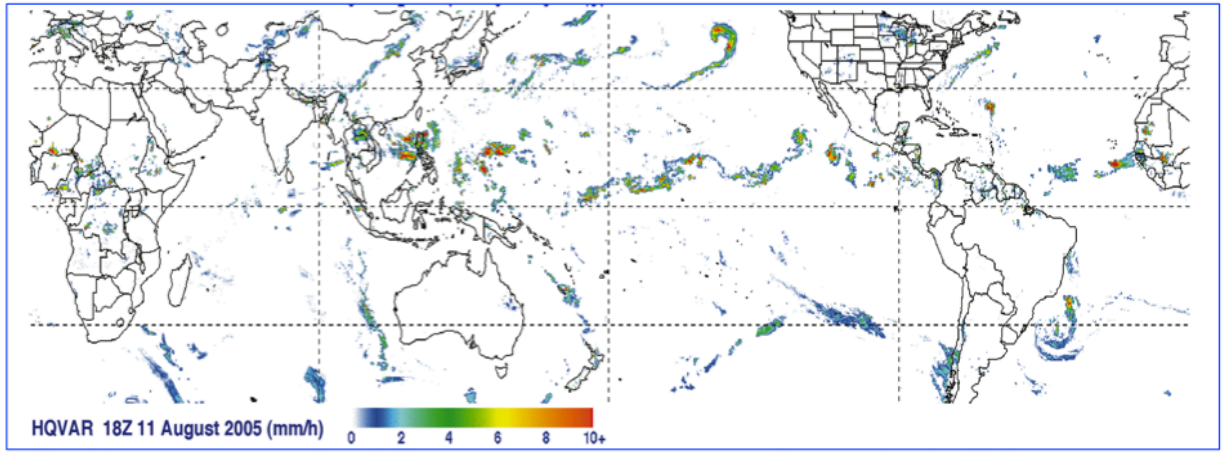
- Examples/case studies of flooding events

  Near-real time flooding event from GFMS and GDACS

Description of the GFMS System

Global Flood Calculations Using Satellite Rainfall and Hydrological Model

Global Flood Monitoring System (GFMS)



- **Rainfall input from satellite information (TRMM + other satellites [TMPA])**
- **Runoff generation uses U. of Washington VIC model**
- **Routing uses U. of Maryland (Wu) DRTR routing**

  (Routing=movement of the water)

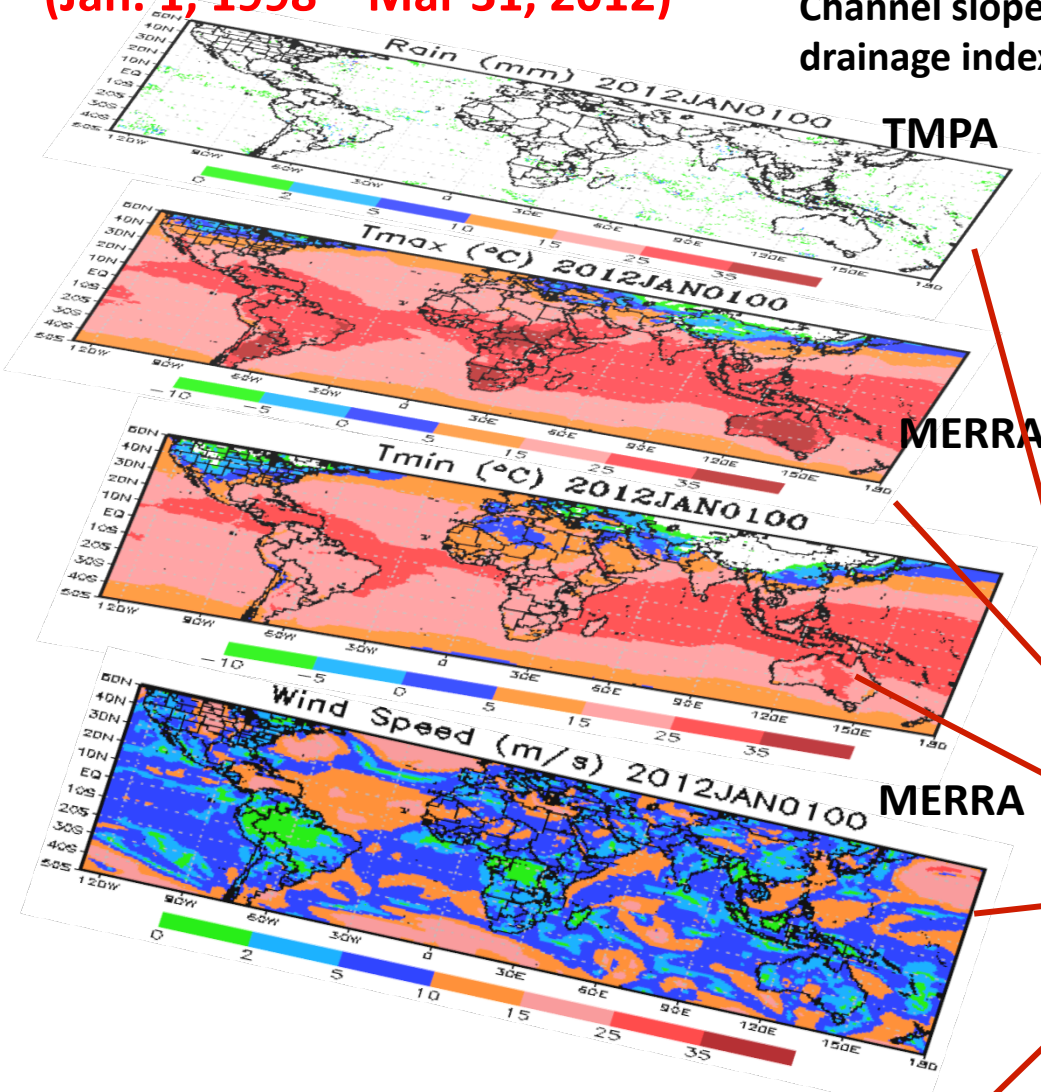
- **1/8th degree**
- **50 deg. N-50 deg. S**
- **3-hr time steps**

Model Set-up

Quasi-Global, 3-hourly, 1/8th deg.
(Jan. 1, 1998 – Mar 31, 2012)

Hierarchical Dominant River Tracing algorithm (DRT)
(Wu et al., 2011,2012, Water Resour. Res.)

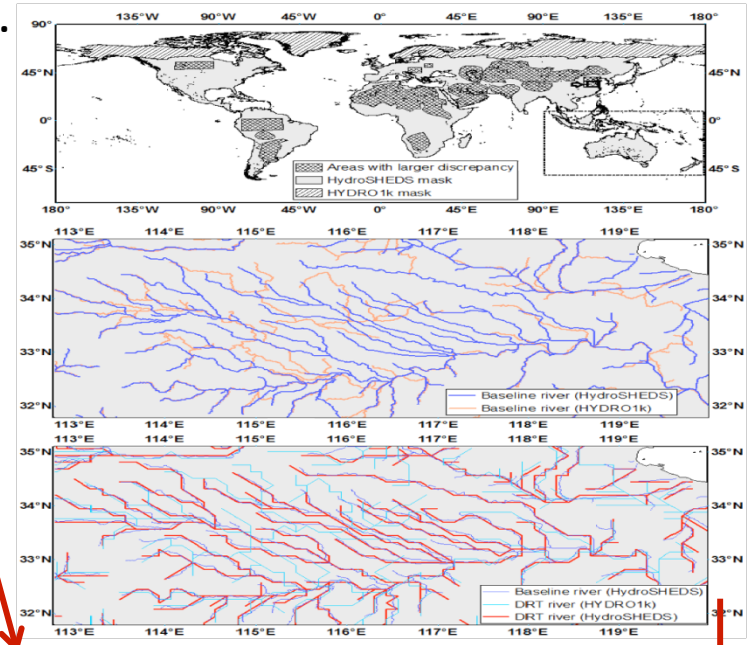
Flow direction, Drainage area, Flow length, Channel width, Channel slope, overland slope, Flow fraction, River order, drainage index…

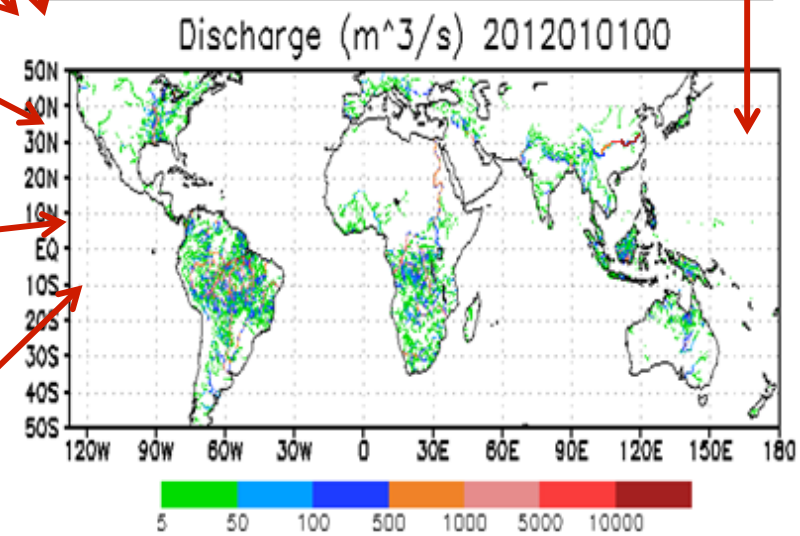


TMPA

MERRA

MERRA

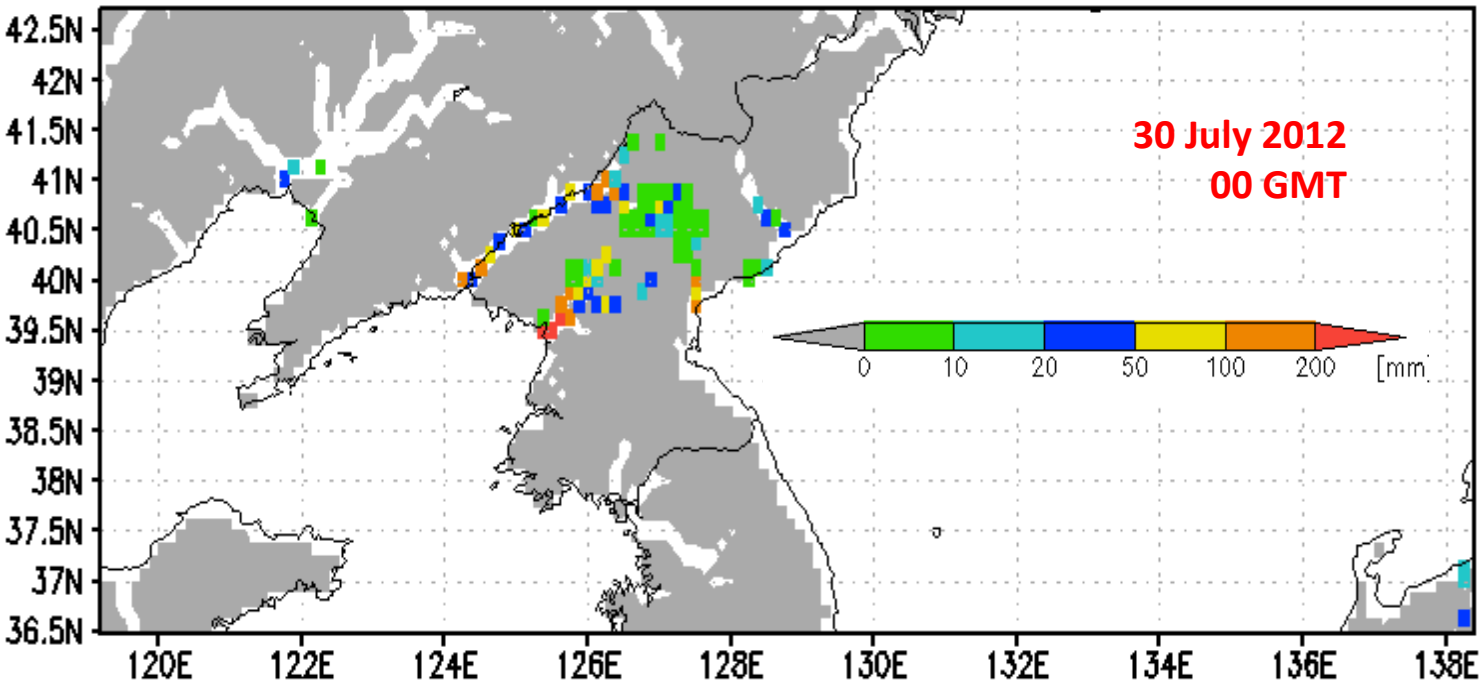




Soil & Veg. data from VIC community
(Justin Sheffield, U. of Princeton**)**

Flood Detection in GFMS

Flood Detection/Intensity (Depth above Threshold [mm])



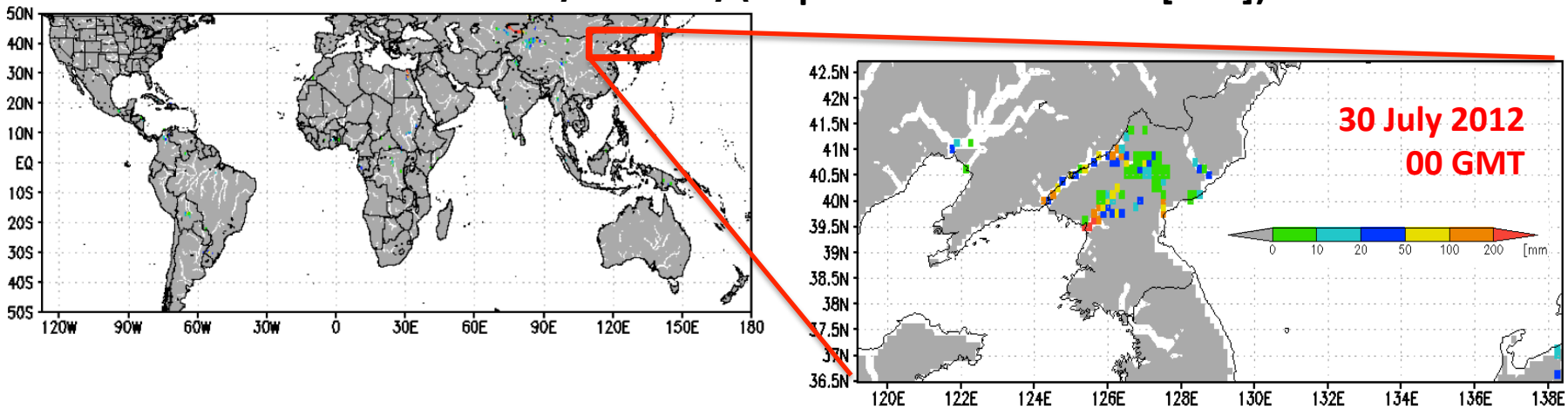
FLOOD IDENTIFICATION uses the calculated water depth (mm) relative to the Reference Level at each grid (1/8th degree)

REFERENCE LEVEL at each grid calculated from 12-year global hydrology model run using satellite rainfall data. Reference Level is 95th percentile of Routed Runoff (water depth) + factors related to basin size

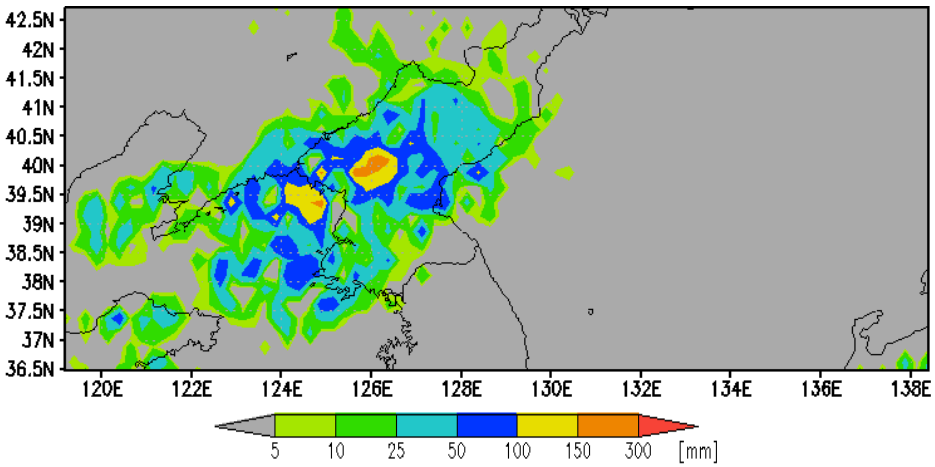
Global to Regional Flood Detection

Example: Detection of Flooding over North Korea

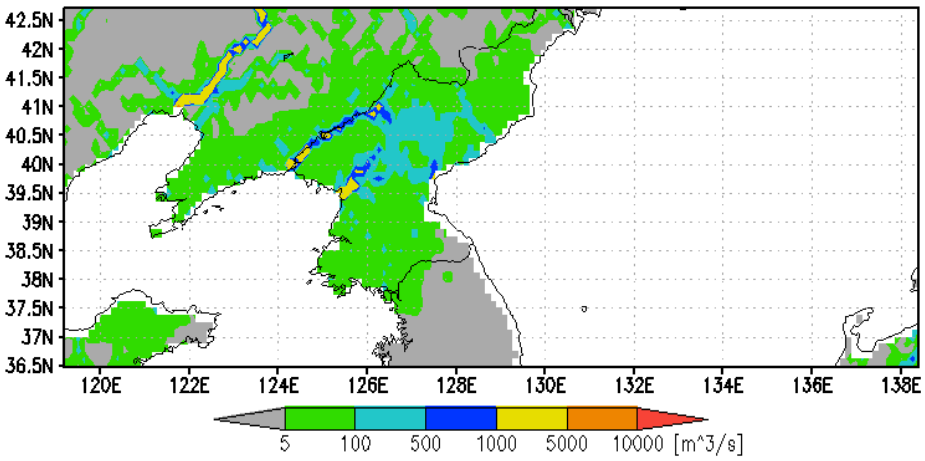
Flood Detection/Intensity (Depth above Threshold [mm])



Rainfall (1 day Accumulation [mm])



Streamflow [m³/s]



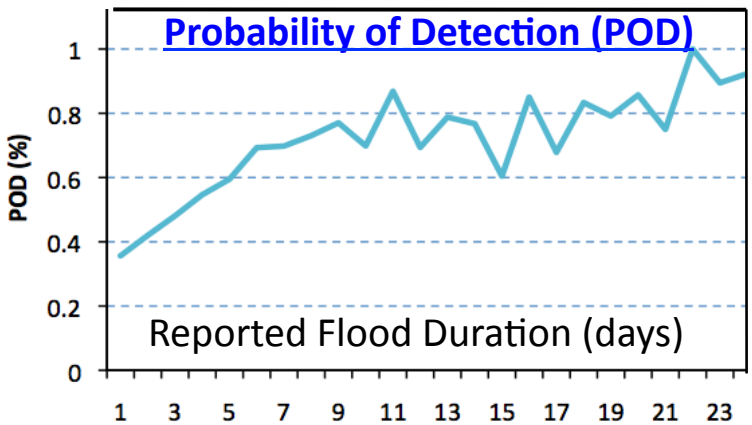
Evaluation of the GFMS Model

Evaluation of Flood Model vs. Global Flood Inventory Data

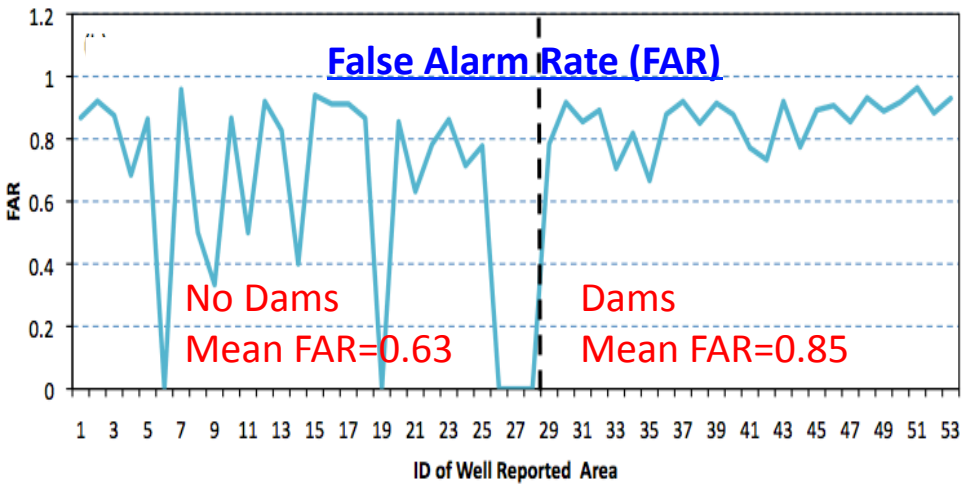
Wu et al., (2012) J. Hydromet.

Dartmouth Flood Observatory and U. of Oklahoma

Flood Threshold: 95th percentile + variables related to basin size



Finding 1: Flood detection probabilities improve with larger, longer floods (current satellite rainfall data has coarse time and space resolutions).



Finding 2: False alarms frequent in basins with large dams (hydrological model currently only contains natural rivers).

For floods with durations > 3 days and in areas without large dams

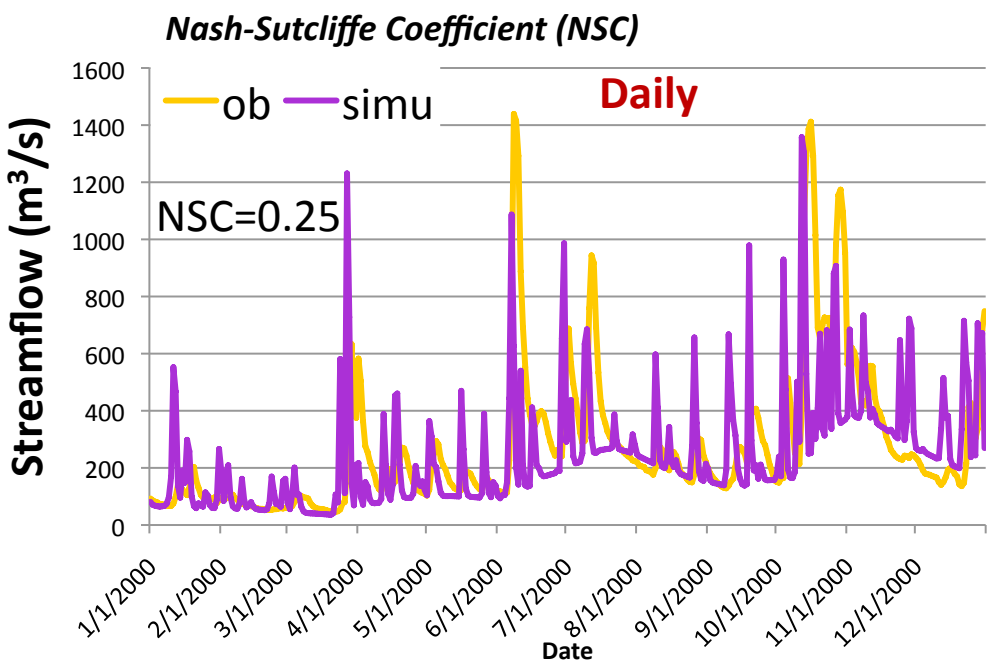
POD: 0.74

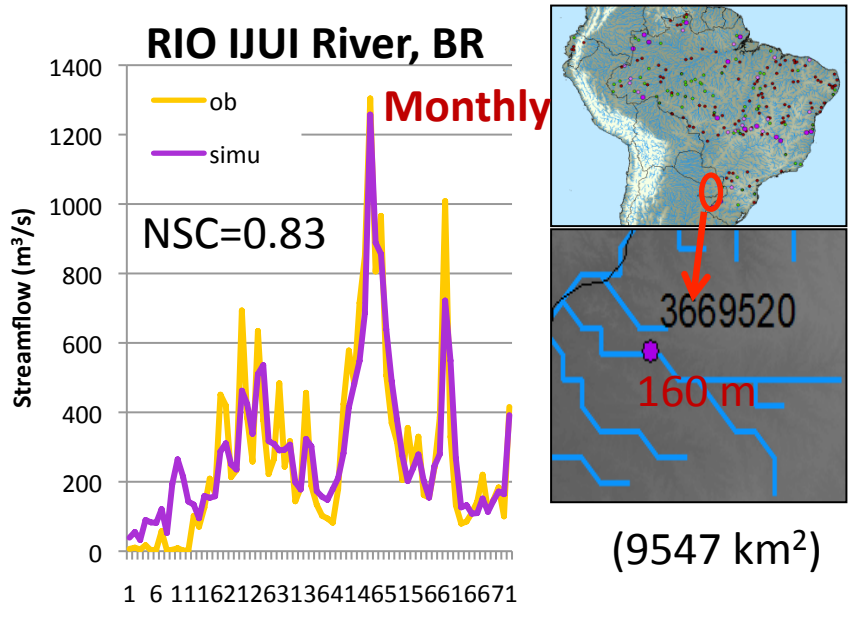
FAR: 0.63

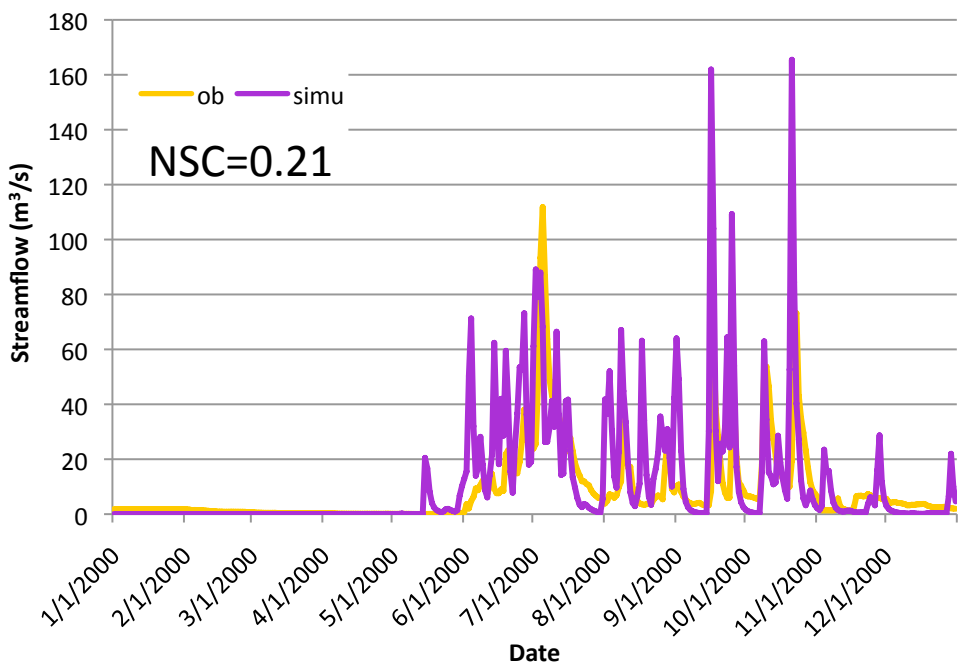
CSI: 0.32

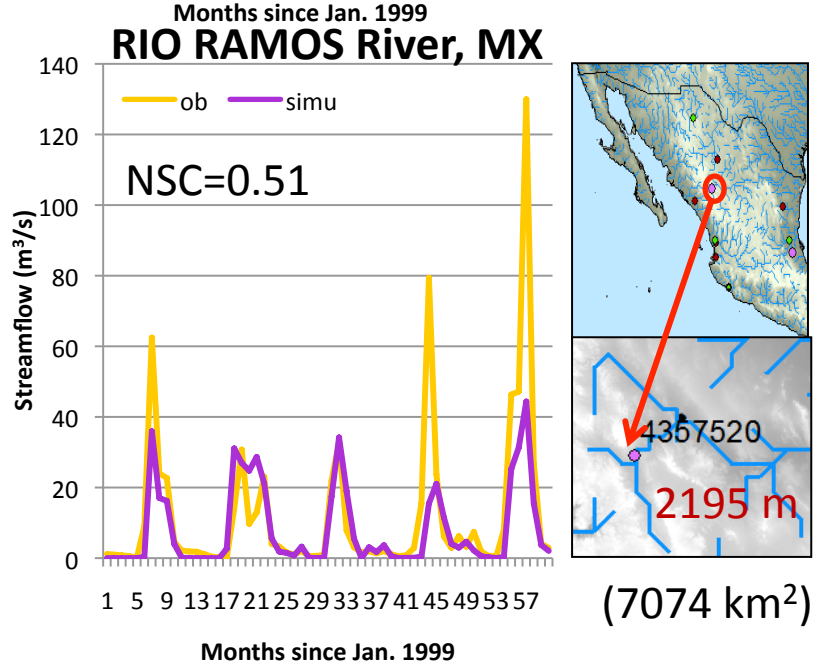
Critical Success Index (CSI)

Example of hydrographs for relatively natural rivers



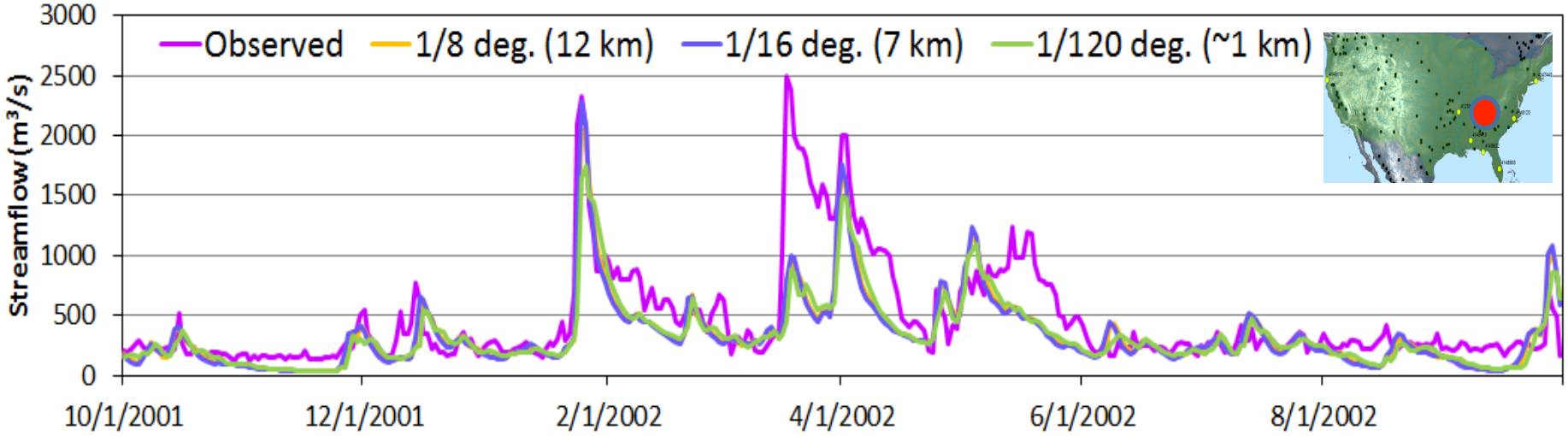






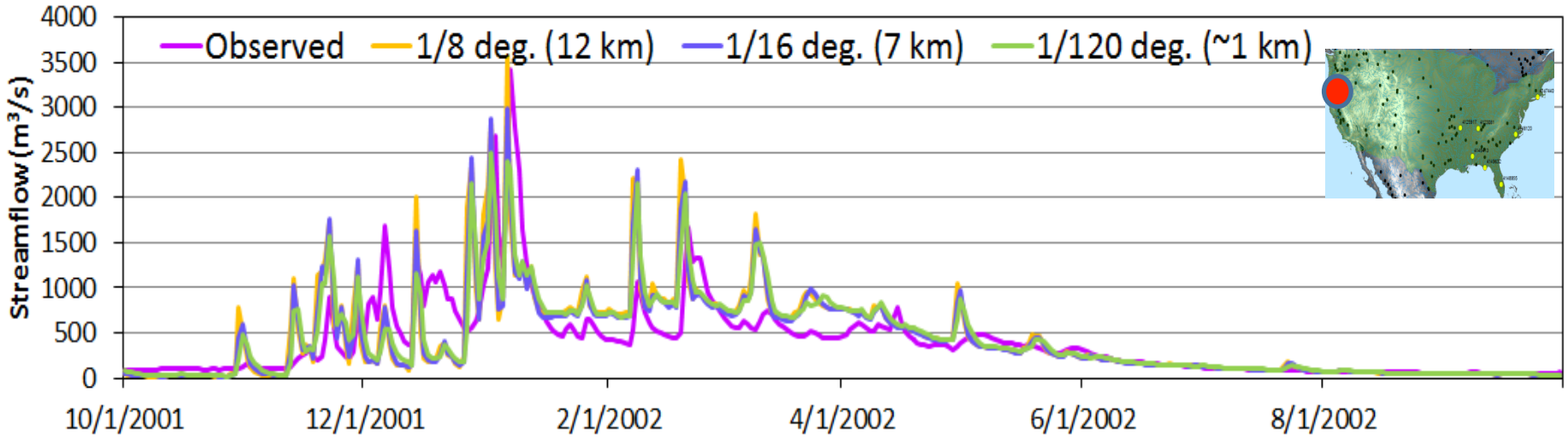
GRDC 4123081 at CUMBERLAND RIVER, TN

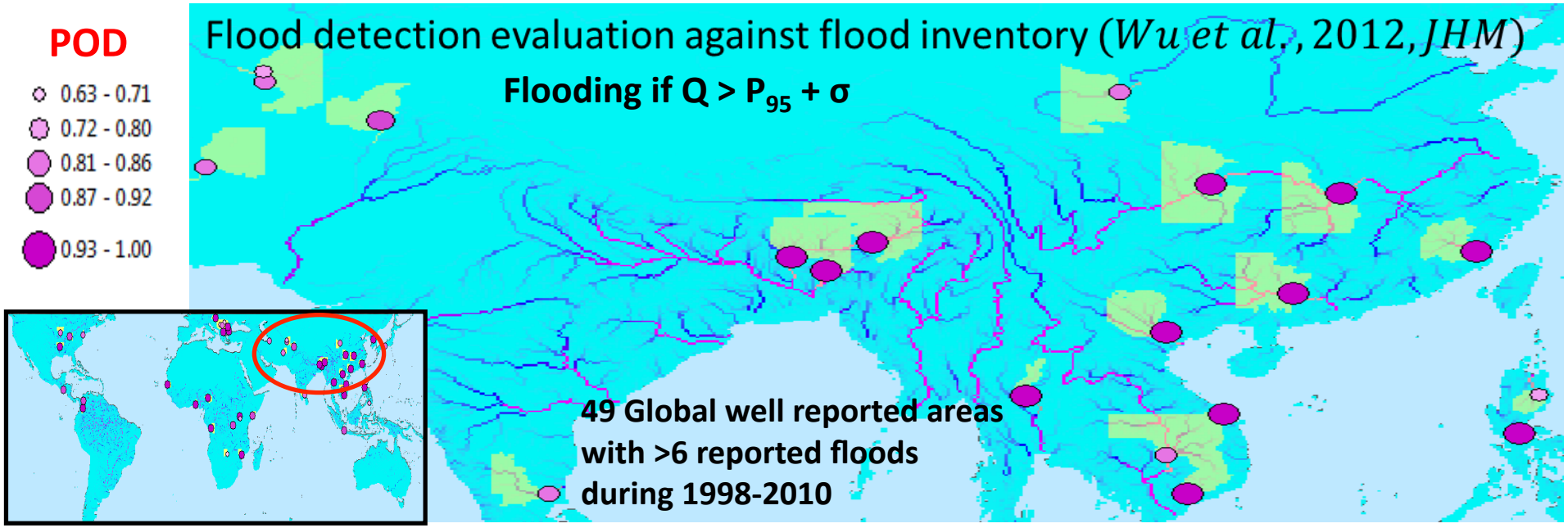
Drainage Area 30,334 km^2



GRDC 4146110 at KLAMATH RIVER, CA

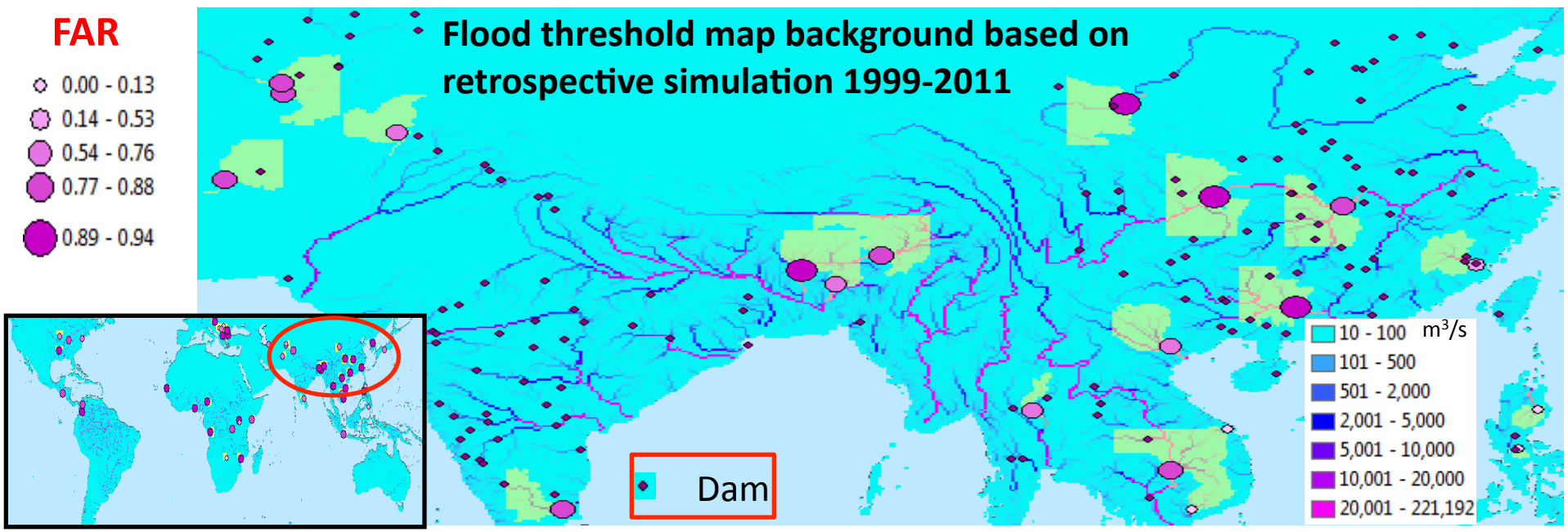
Drainage Area 31,233 km^2





Mean POD 0.91 and mean FAR 0.65 for all reported Floods >3 days

Mean POD 0.92 and mean FAR 0.85 for all reported Floods >1 days



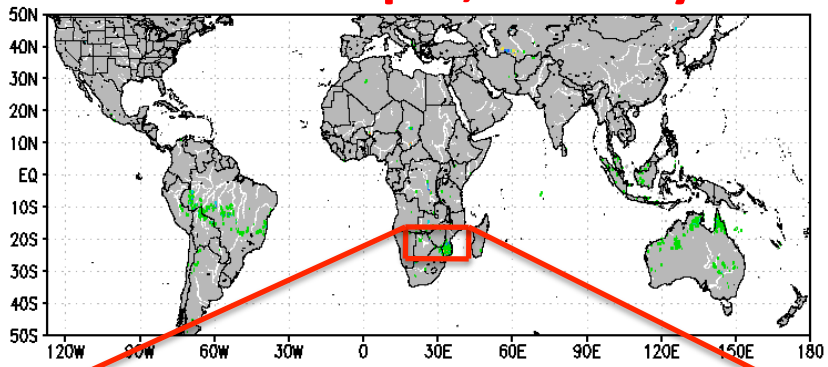
GFMS Flood Detection Examples

Real-time Global Flood Estimation System

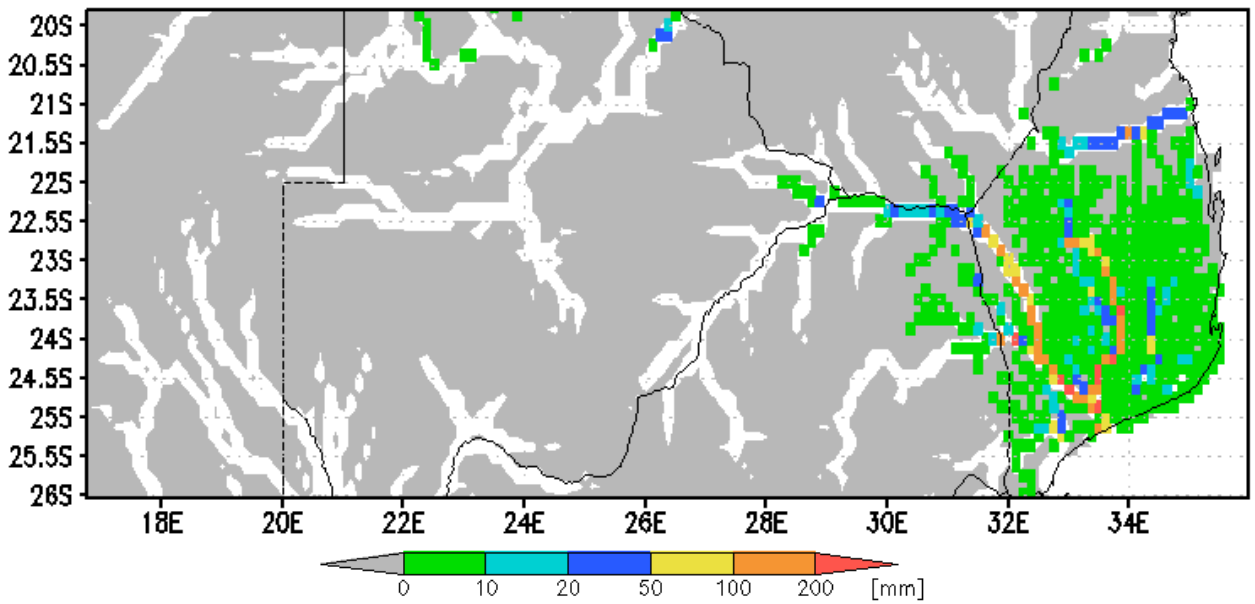
Global Flood Monitoring System (GFMS)

http://flood.umd.edu/

Mozambique, January 2013

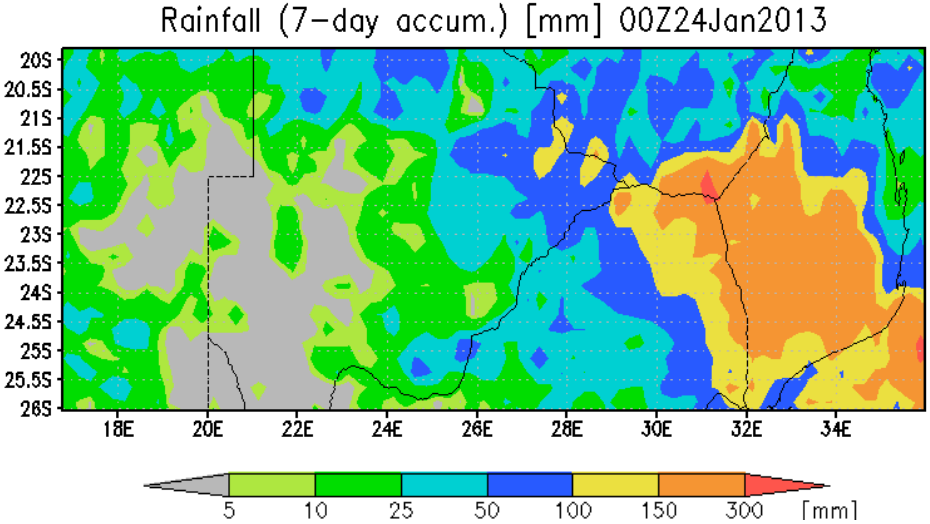


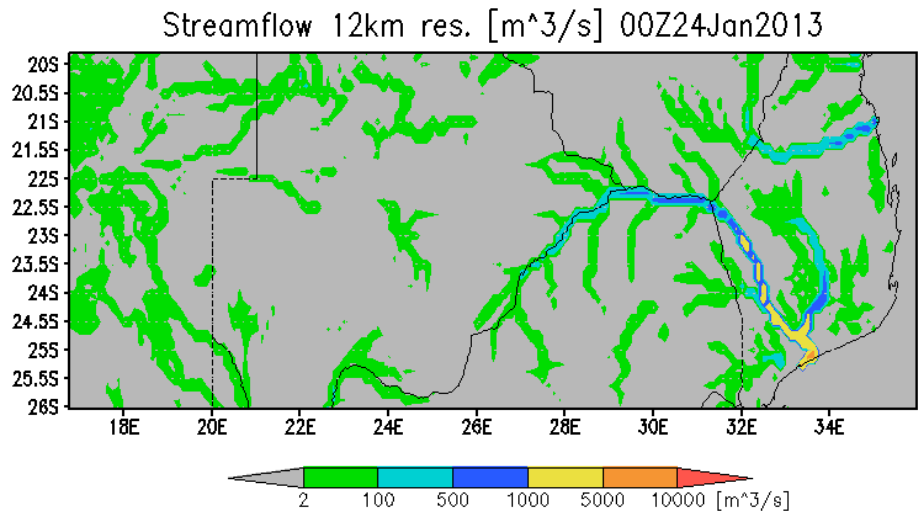
Flood Detection/Intensity (Depth above Threshold [mm])



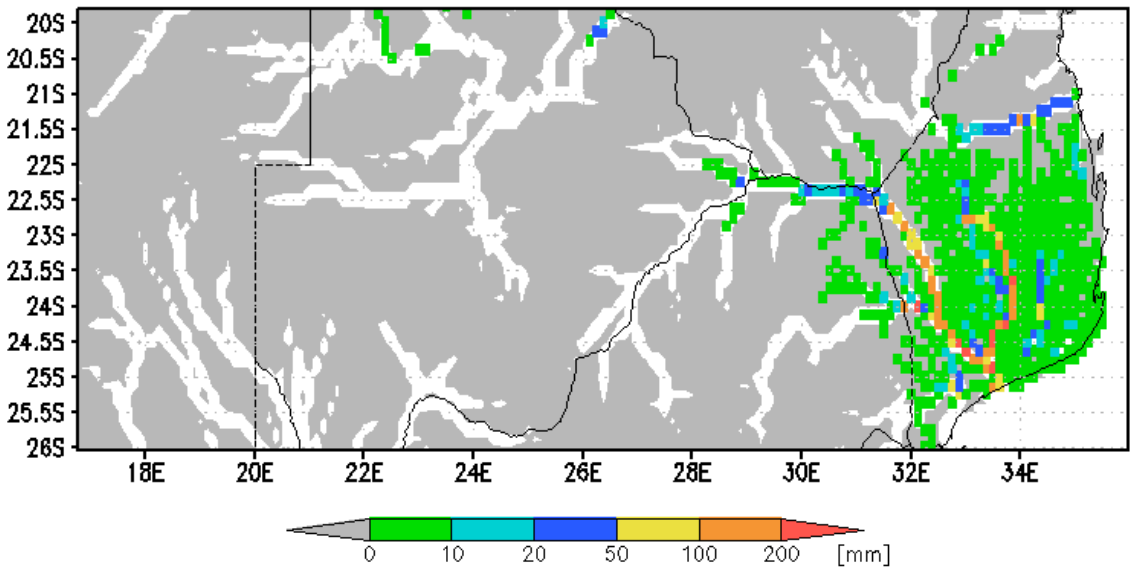
Detection of Flooding in Mozambique

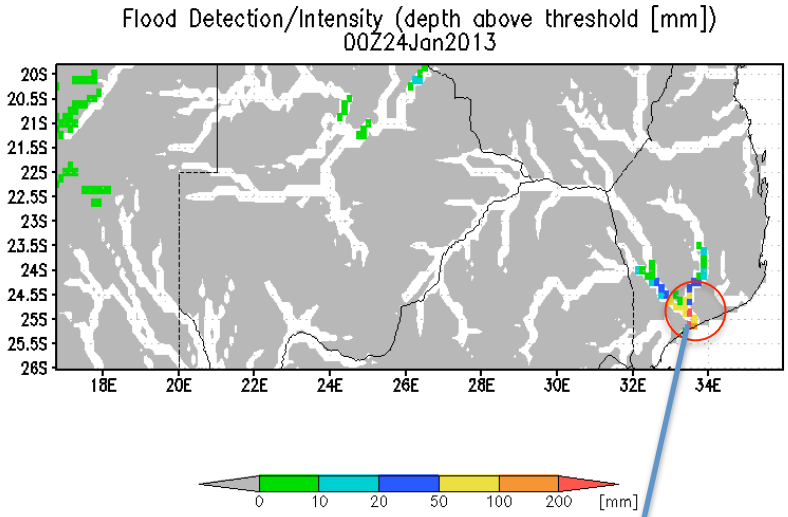
21 January 2013
12 GMT

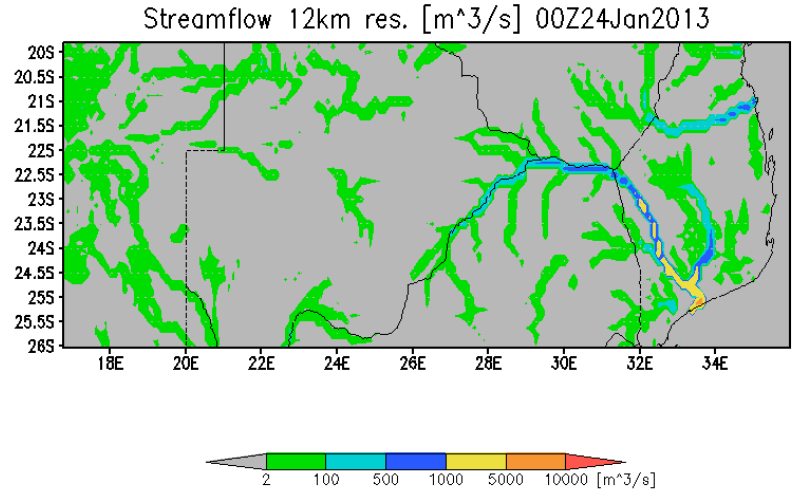




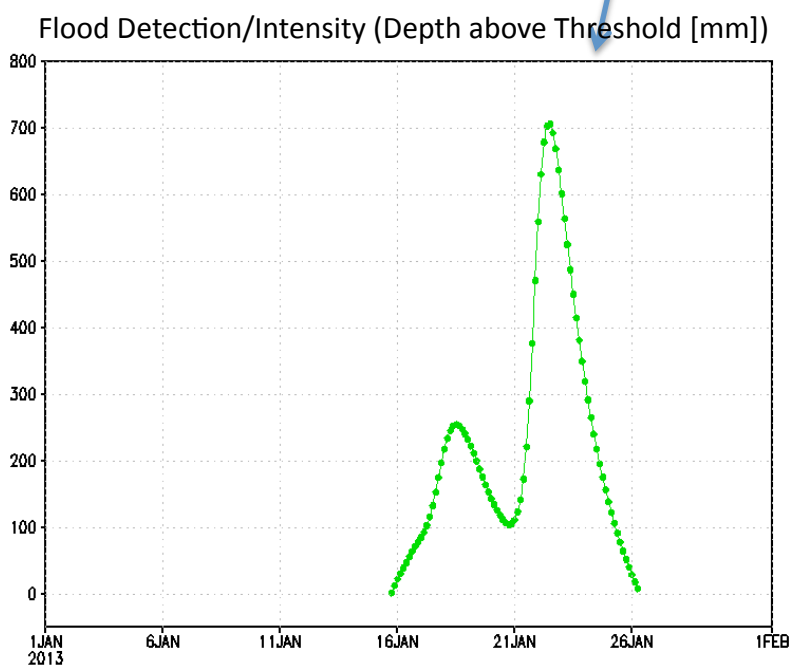
Flood Detection/Intensity (Depth above Threshold [mm])

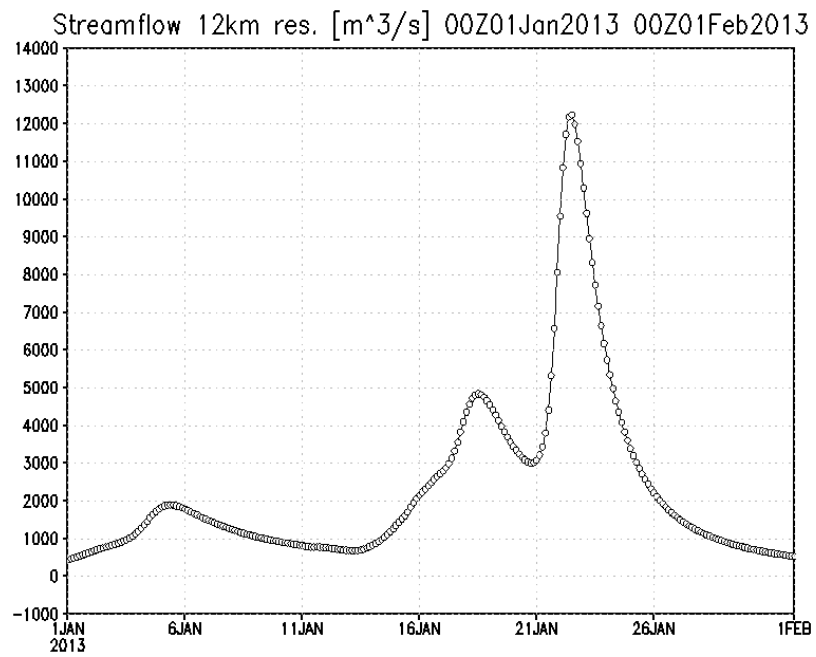




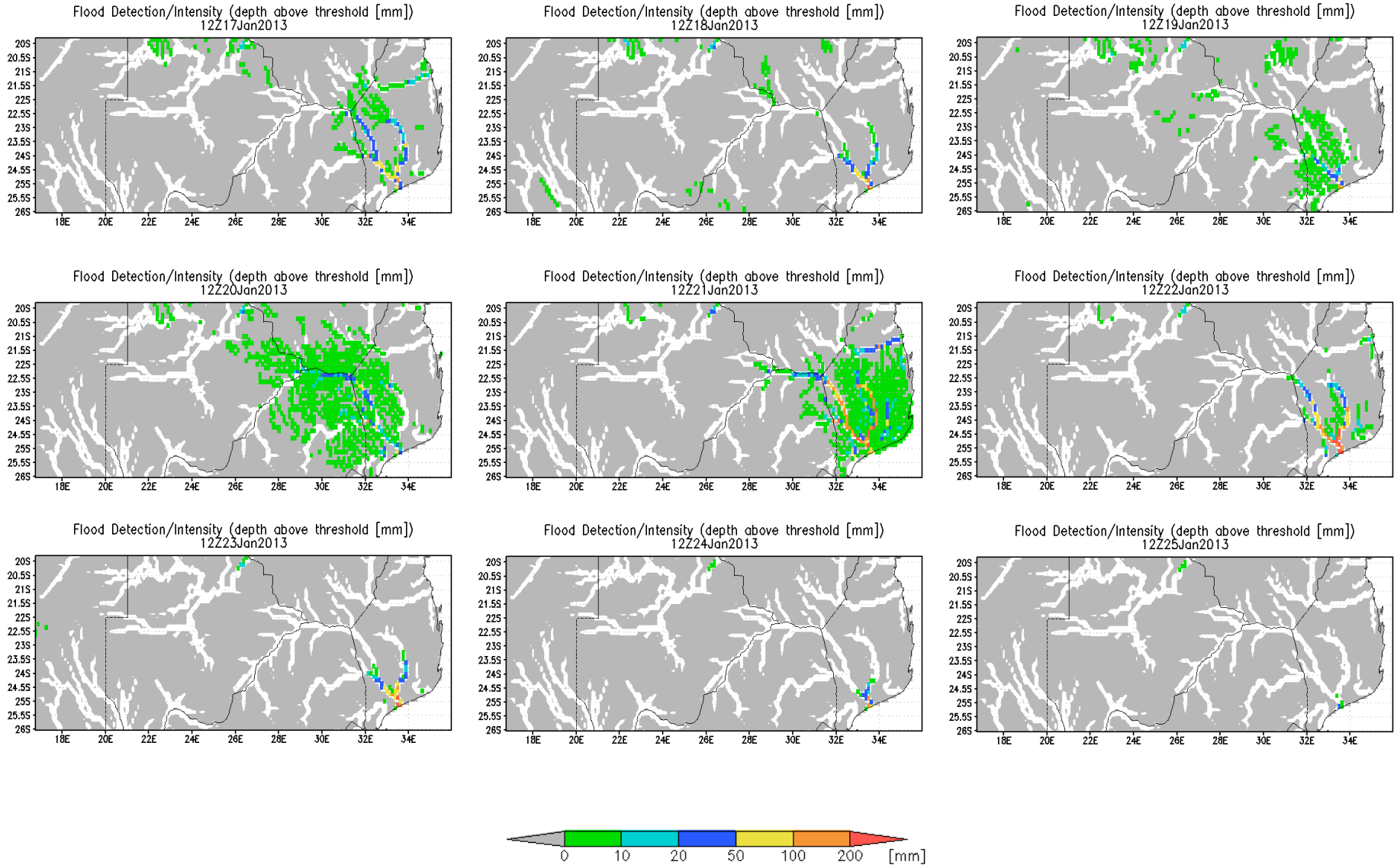


Time History at a Point: Limpopo River (-25.1 S, 33.5 E)

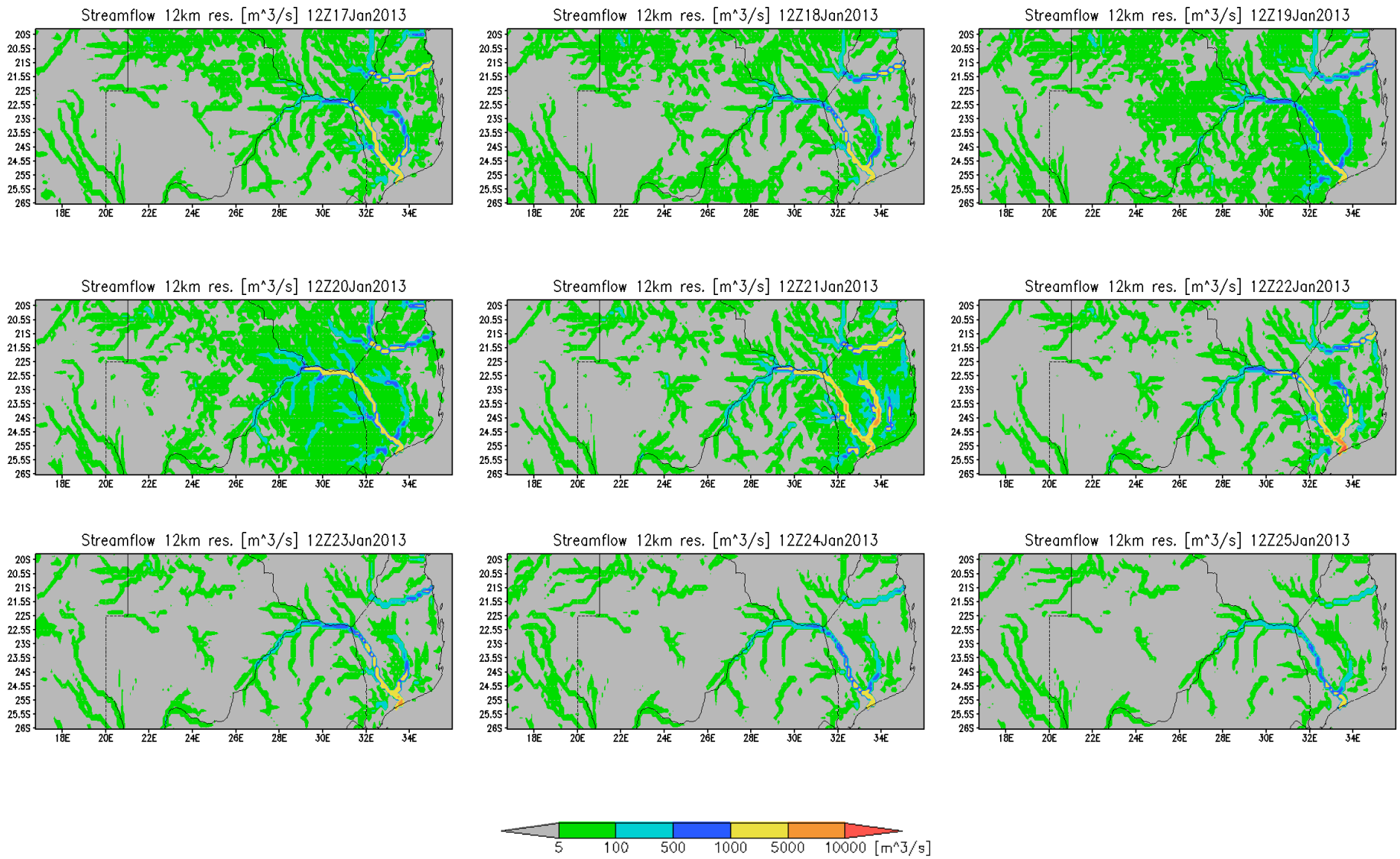




Flood Detection/Intensity (depth above threshold [mm]) every 24-hrs
January 17-25, 2013



Streamflow [m^3/s] every 24-hrs
January 17-25, 2013

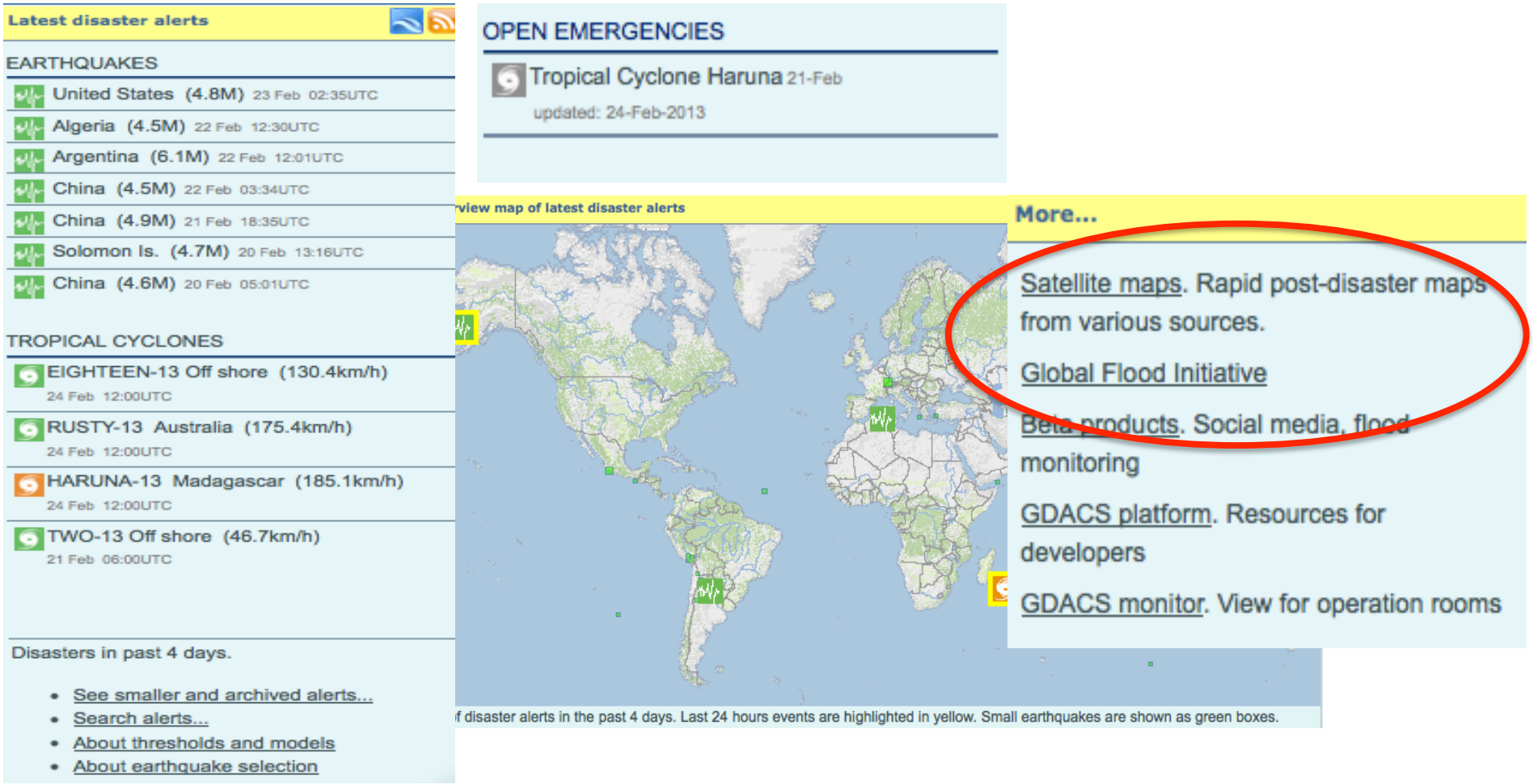


Recent Flood Event
(Mozambique, January 2013)

Comparison with GDACS, DFO,
MODIS Inundation Maps, etc.

Global Disaster Alert and Coordination System (GDACS)

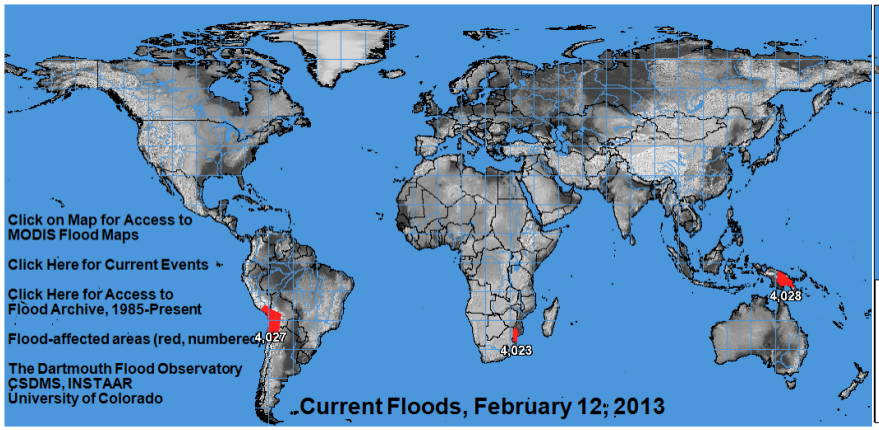
(http://www.gdacs.org/)

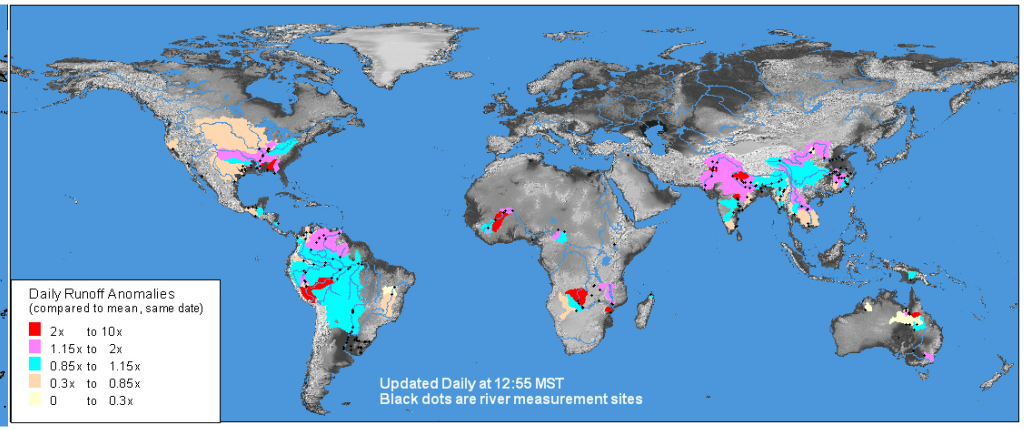


Cooperative effort between the United Nations, the European Commission and disaster managers worldwide

Dartmouth Flood Observatory (DFO)

(http://floodobservatory.colorado.edu/index.html)



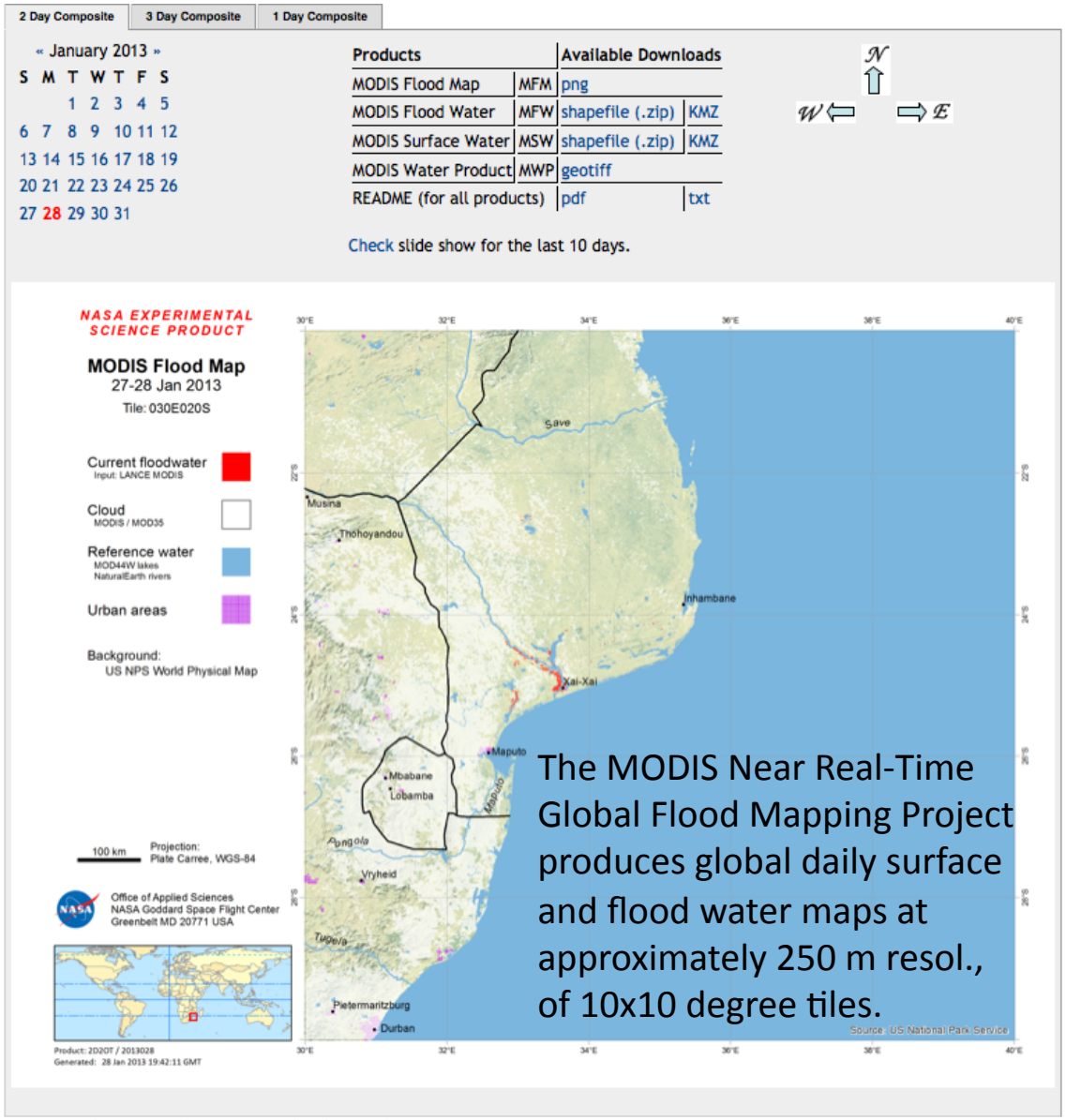


Space-based Measurement and Modeling of Surface Water
For Research, Humanitarian, and Water Management Applications

- Satellite-based River Discharge Measurements
- Surface Water Runoff Measurements
- Active Archive of Large Floods
- Flood Mapping
- Rapid Response Inundation Maps, for individual flood events

NRT Global MODIS Flood Mapping

(http://oas.gsfc.nasa.gov/floodmap/home.html)



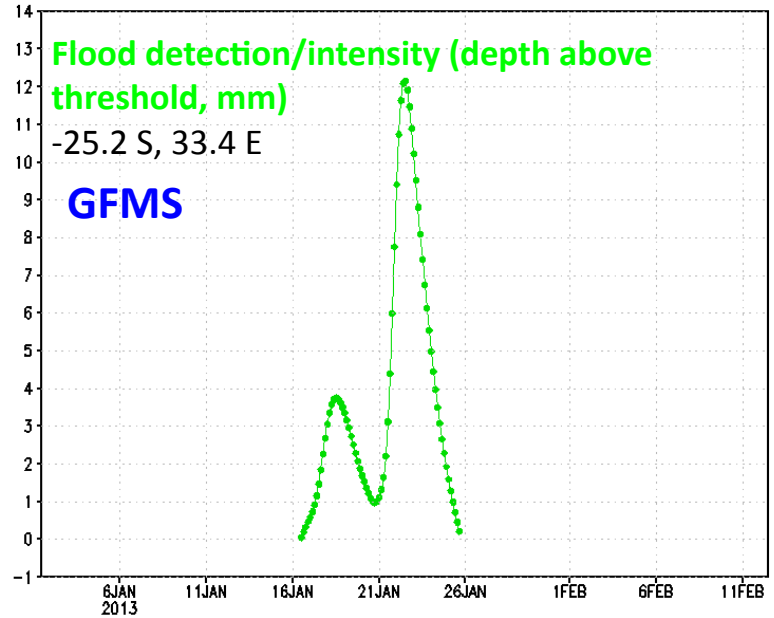
For more information, please contact floodmap at lists.nasa.gov

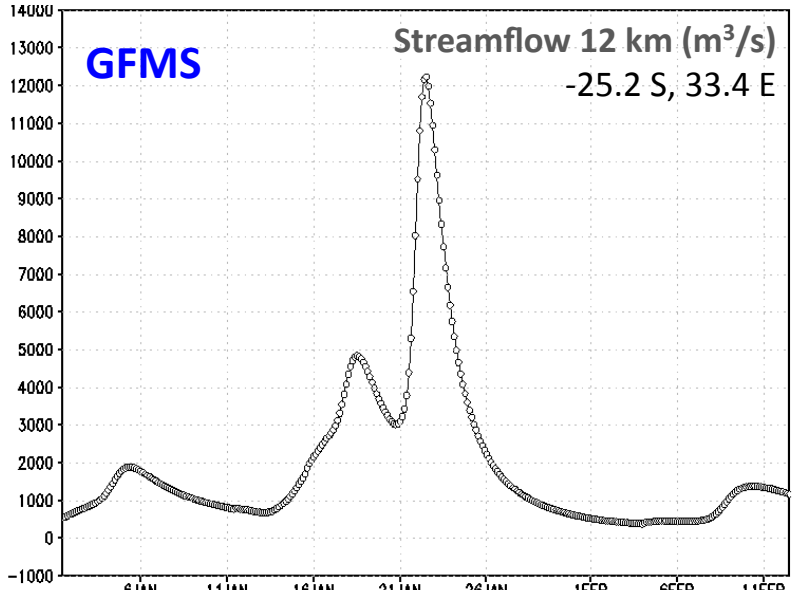
NASA Goddard's Office of Applied Science is working to operationalize near real-time global flood mapping using available satellite data resources -- currently the twice daily overpass of the MODIS instrument, on the Terra and Aqua satellites.

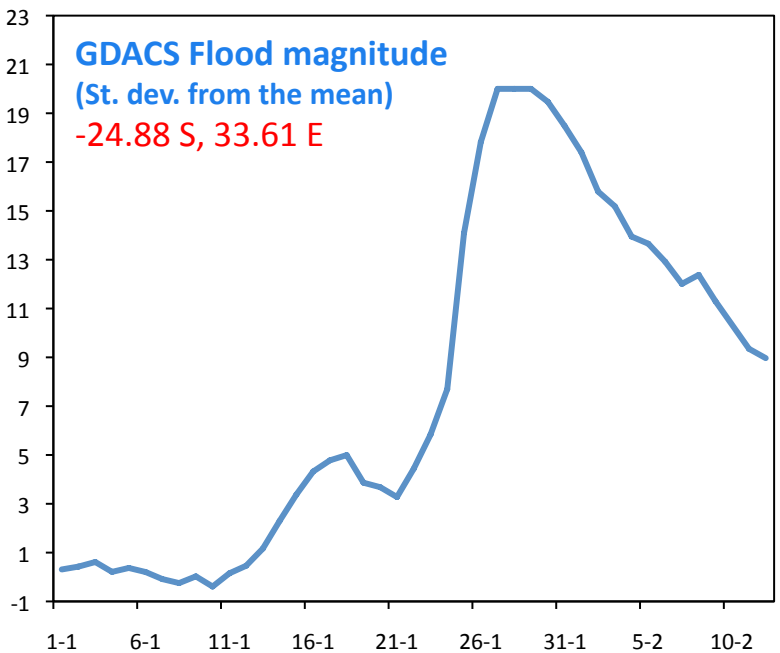
Also is working to include additional data sources, such as radar, to improve coverage and accuracy.

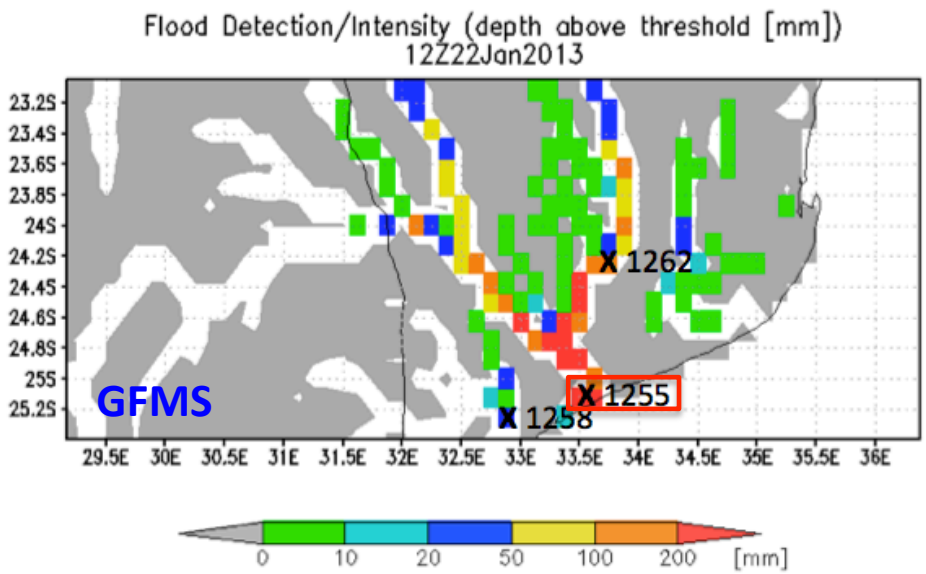
Comparison between GFMS and GDACS

Site 1255 - Limpopo River in Mozambique



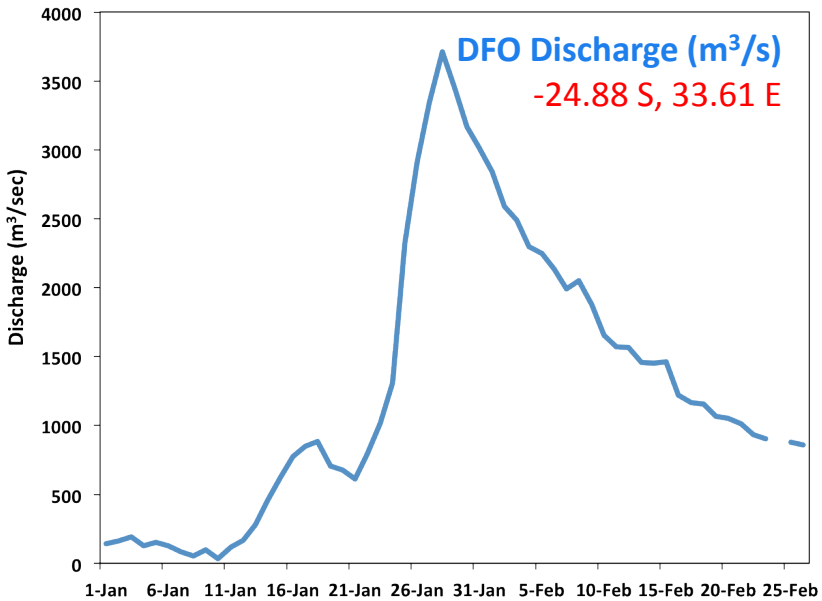


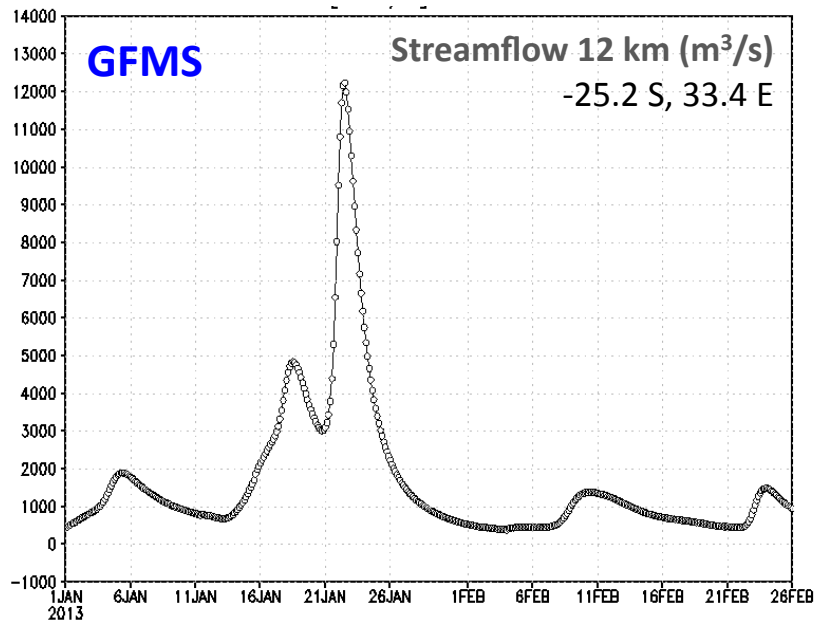


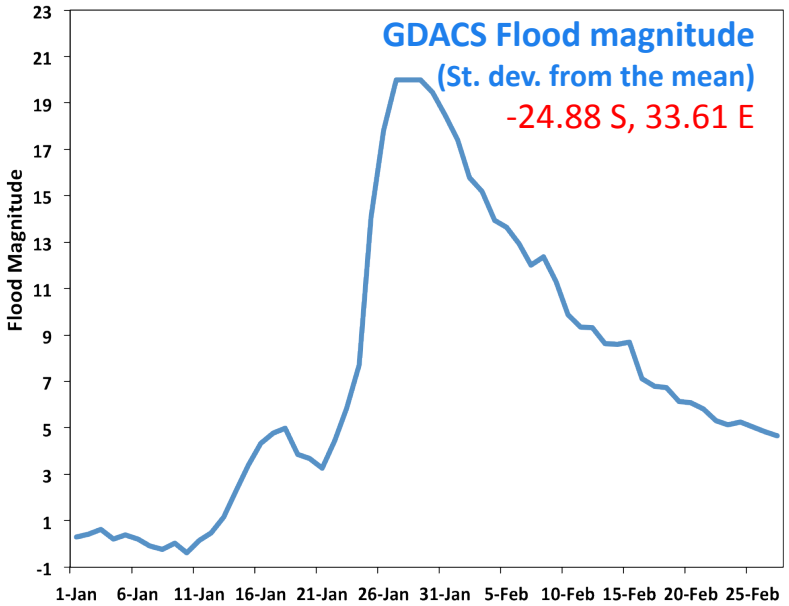


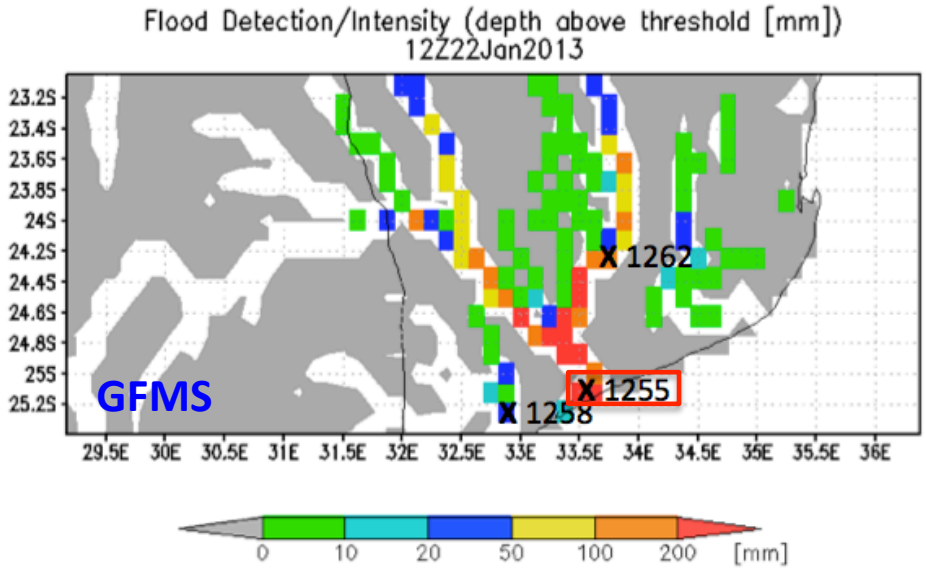
Comparison between GFMS, DFO and GDACS

Site 1255 - Limpopo River in Mozambique



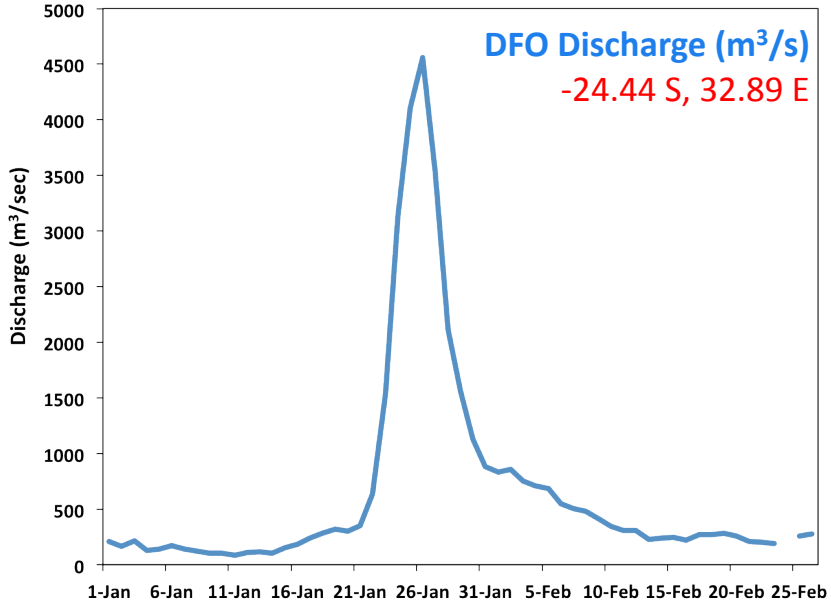


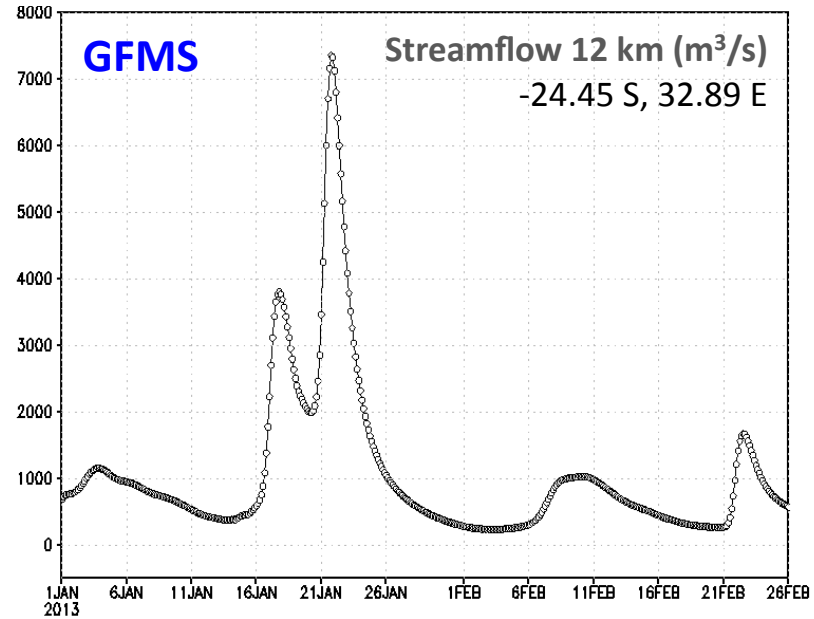


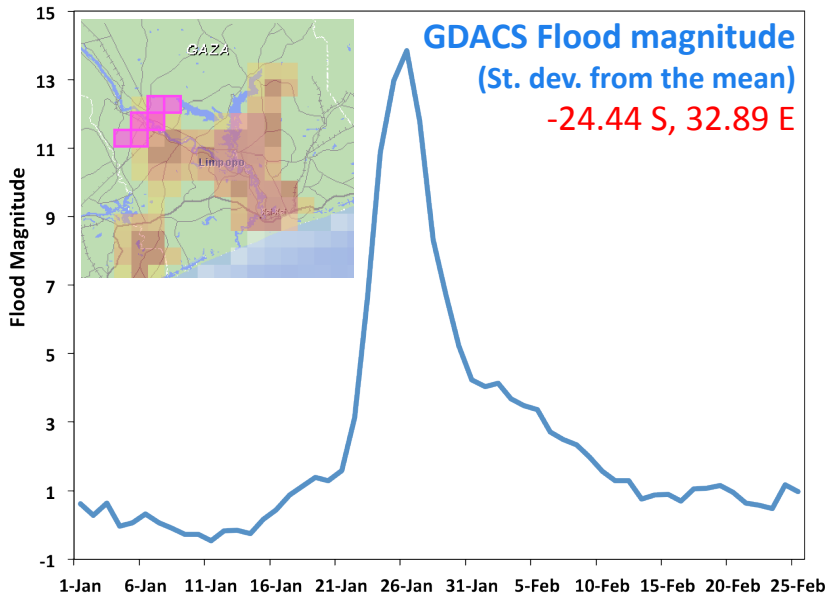


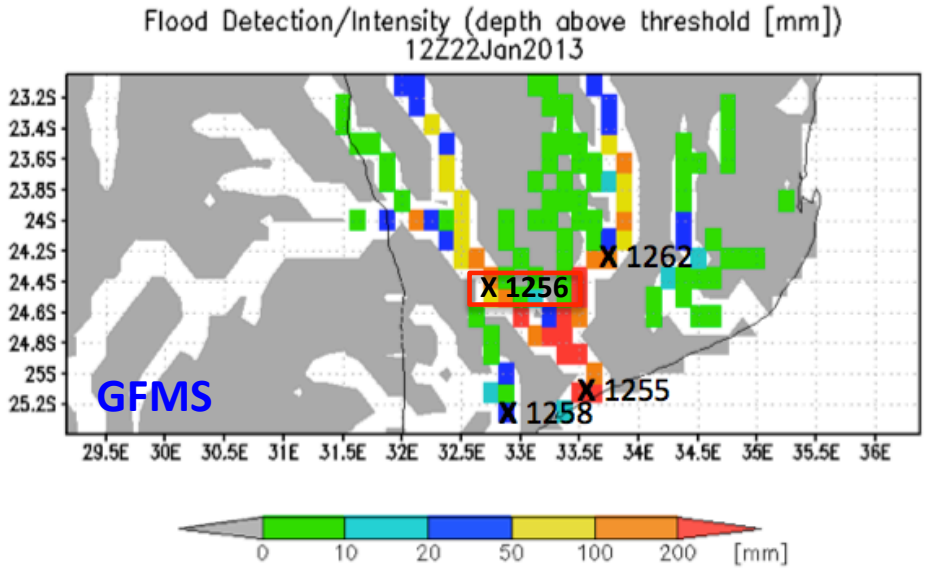
Comparison between GFMS, DFO and GDACS

Site 1256 - Limpopo River near Chokwe in Mozambique



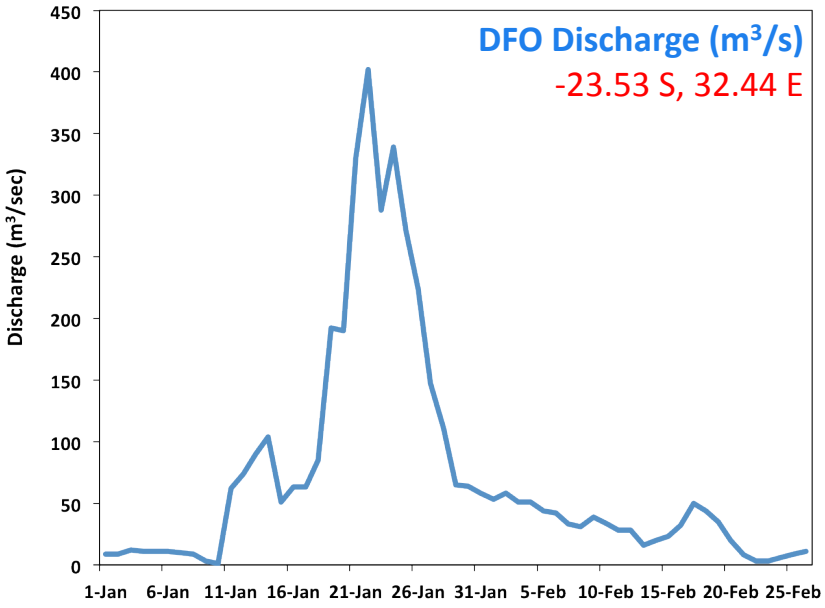


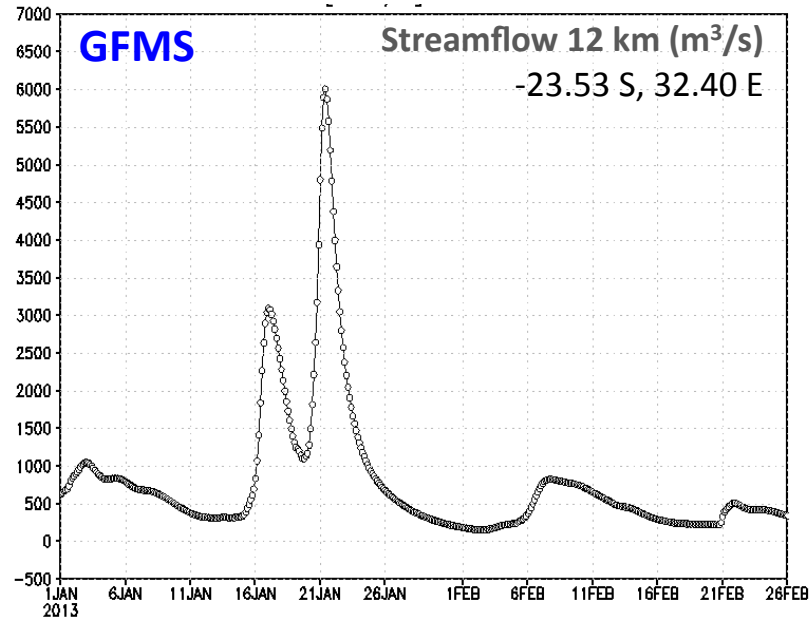


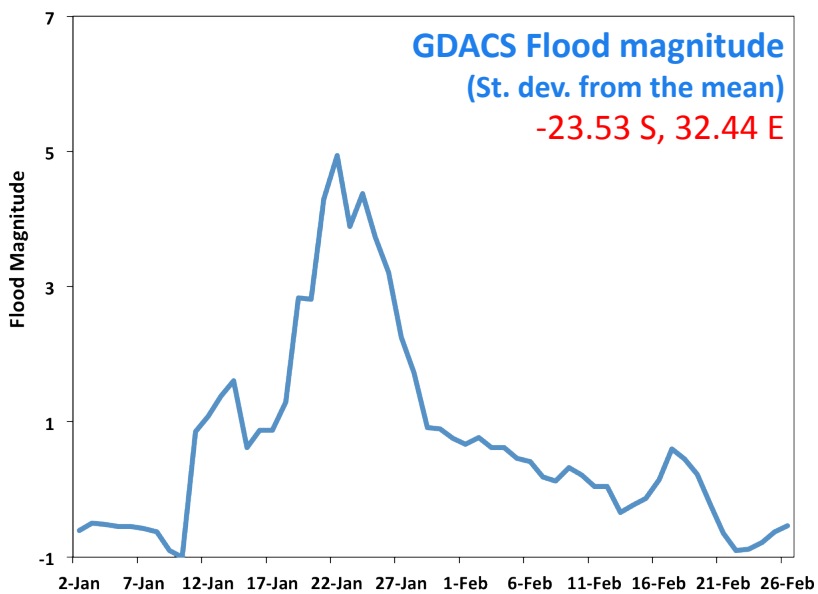


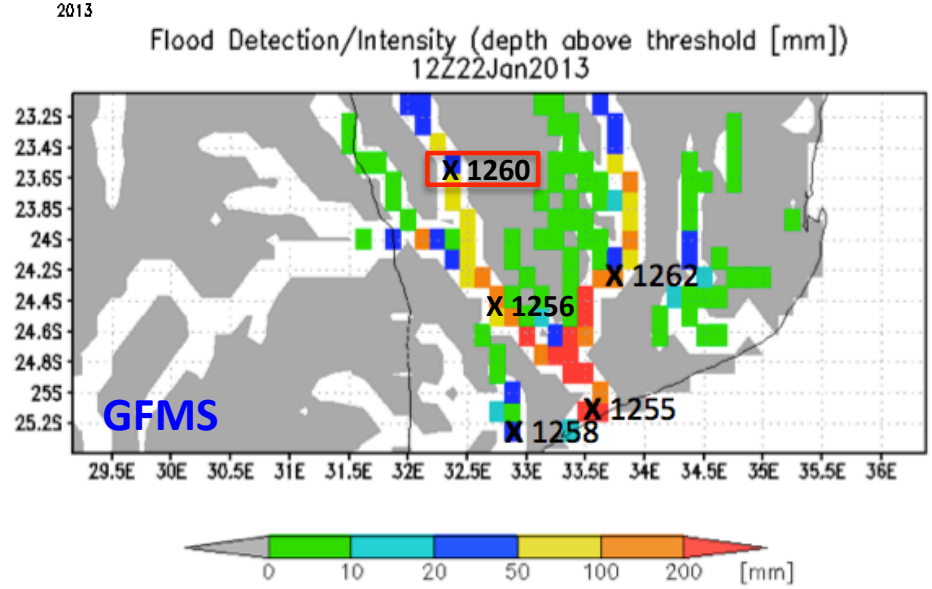
Comparison between GFMS, DFO and GDACS

Site 1260 - Limpopo River in Mozambique







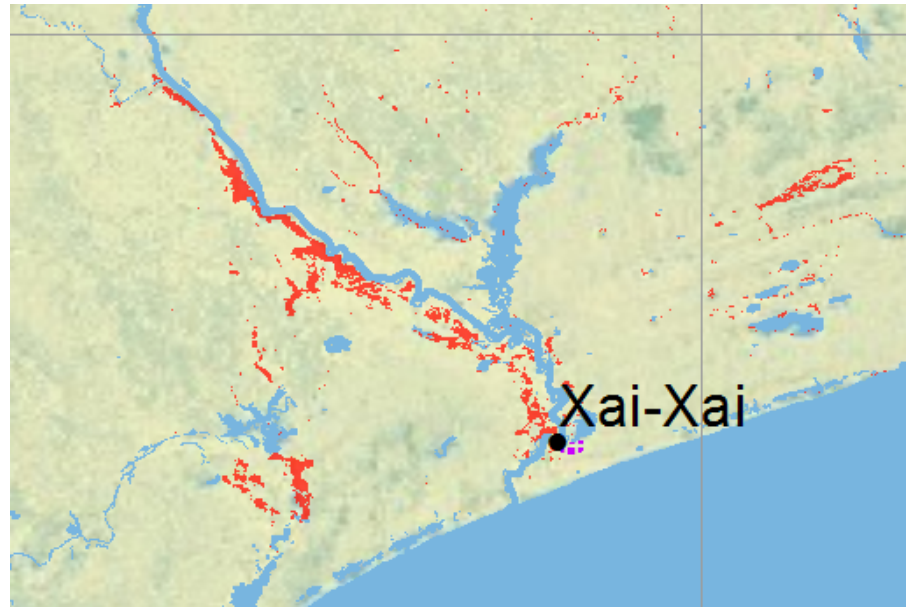


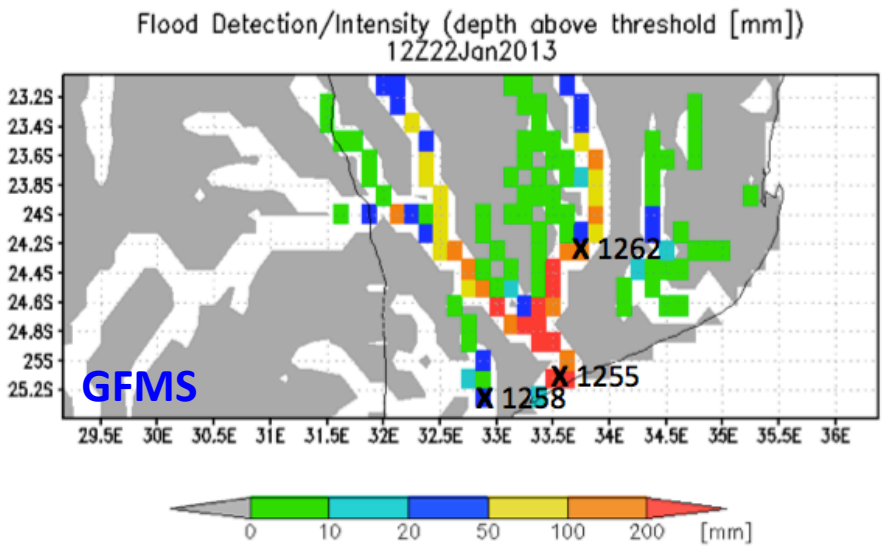
Comparison between GFMS and MODIS mapping

Limpopo River in Mozambique

9-10 Jan 2013

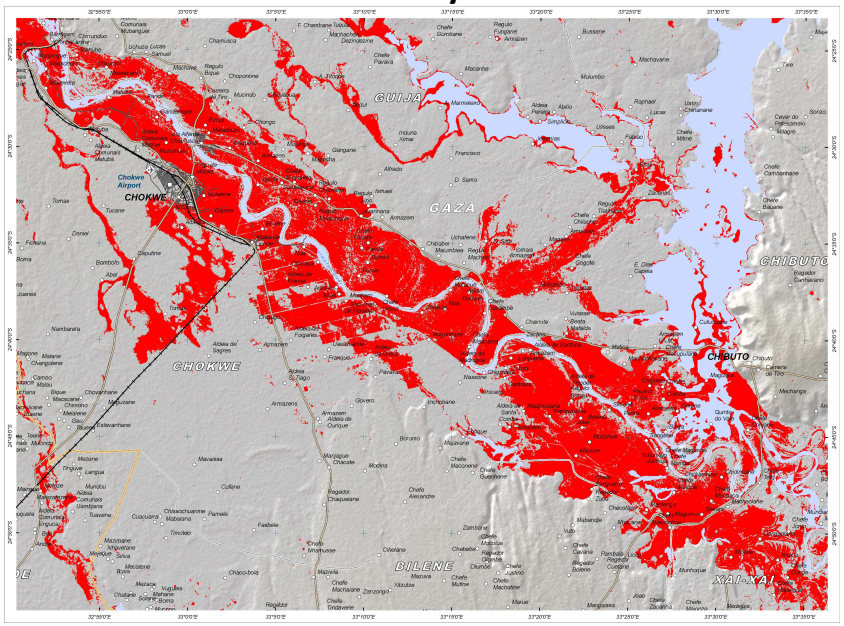
23-24 Jan 2013





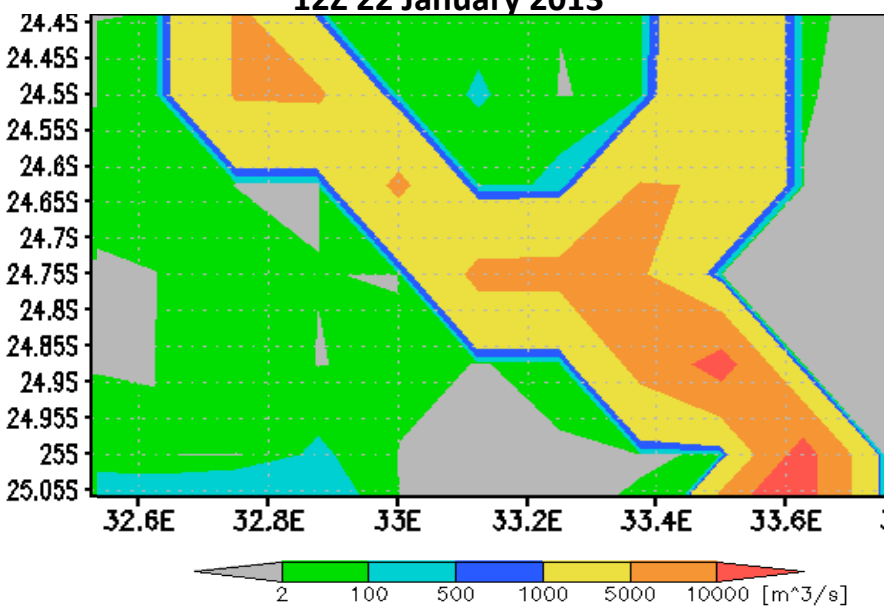
26-27 Jan 2013

Flood Waters detected by TerraSAR-X Data
24 January 2013

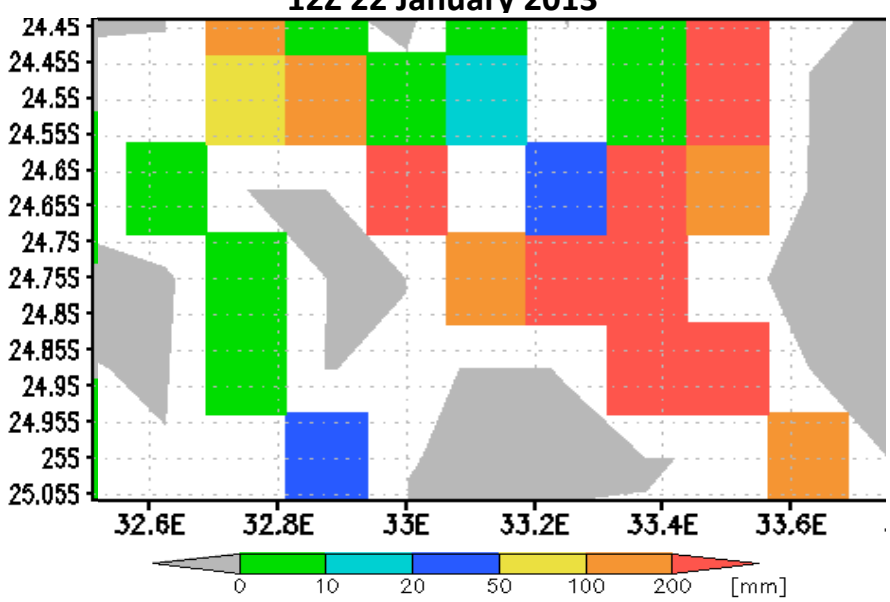


MODIS map
23-24 January 2013

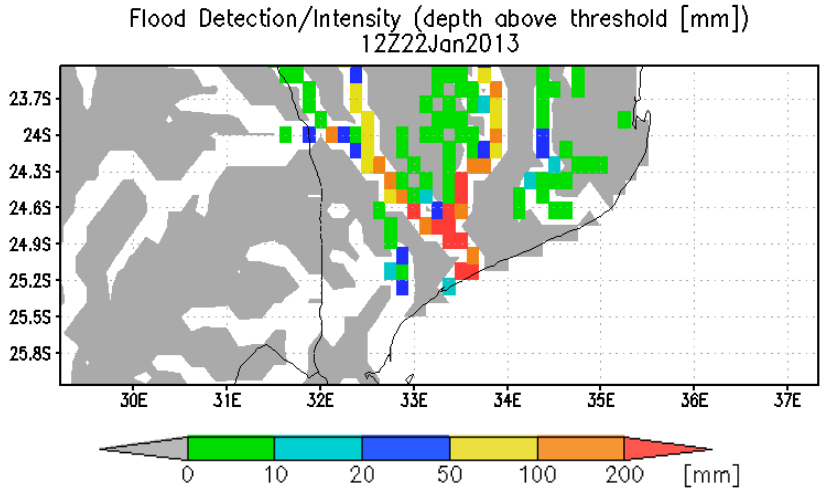
GFMS Streamflow 12 km res. (m^3/s)
12Z 22 January 2013

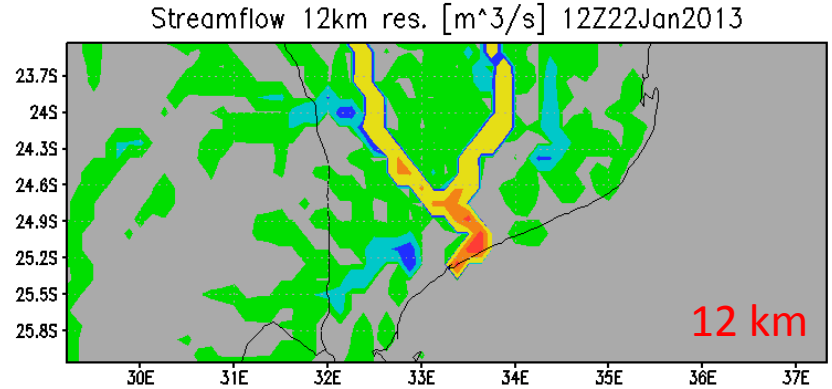


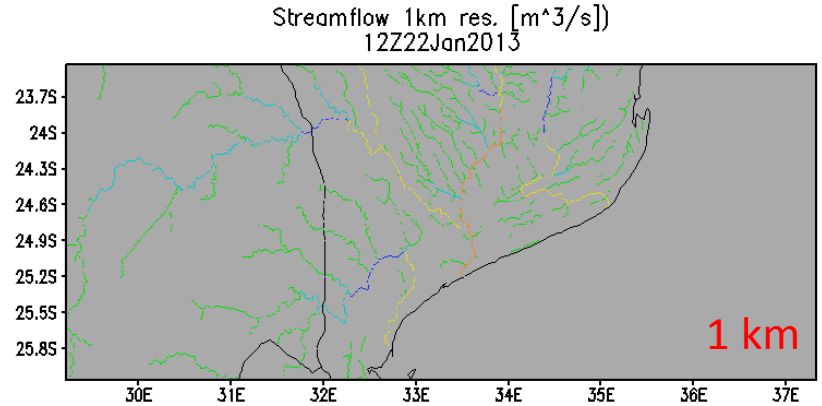
GFMS Flood detection/intensity (depth above threshold [mm])
12Z 22 January 2013

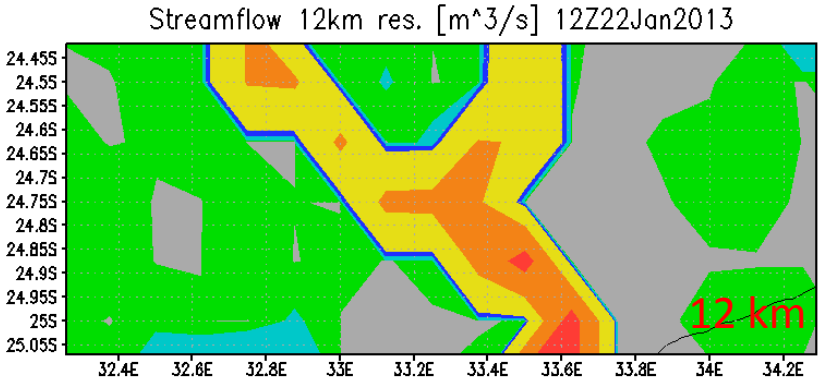


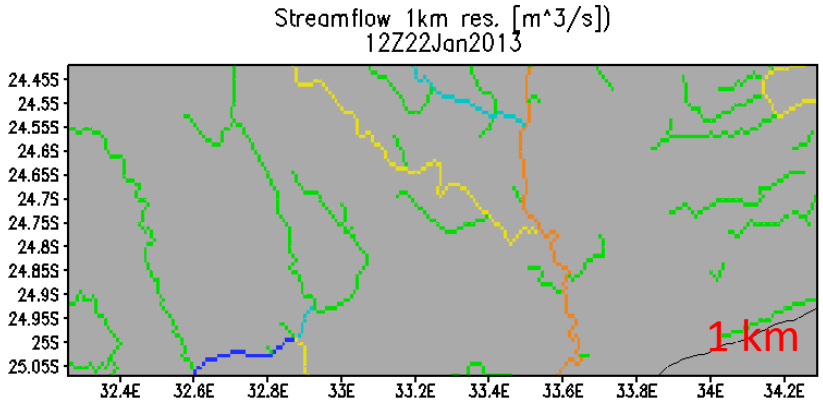
GFMS Streamflow at 12 km and 1 km

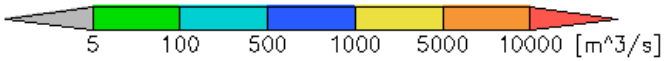












Summary and Conclusion

1. A new version of the Global Flood Monitoring System (GFMS) has been implemented using the U. of Washington VIC community Land Surface Model and a new physically based DRTR routing model from the U. of Maryland for more accurate flood calculation. The new coupled VIC/DRTR model has a great flexibility in deriving flood information at various spatial-temporal scales and resolutions with *a priori* parameters from the VIC community.

2. The evaluation of the VIC/DRTR model shows very promising performance in retrospective runs vs. observed streamflow records and a better performance in flood event detection with higher POD while having similar FAR than the previous system according to the same available flood event archives.

3. The consistent model performance across spatial resolutions indicates a promising potential of the new satellite precipitation-driven GFMS in deriving more useful real-time flood information at high spatial resolutions (e.g. 1 km) .

Current Use, Future Improvements and Possible Applications

- The current or past versions of the system have been used by: EC/JRC GDACS, Int'l Red Cross, World Food Program, Bureau of Meteorology (Australia), NOAA NESDIS, RCMRD (Kenya), and others. The current system is new and improved and will hopefully see many additional users to help us continually define or develop new features to meet requirements.

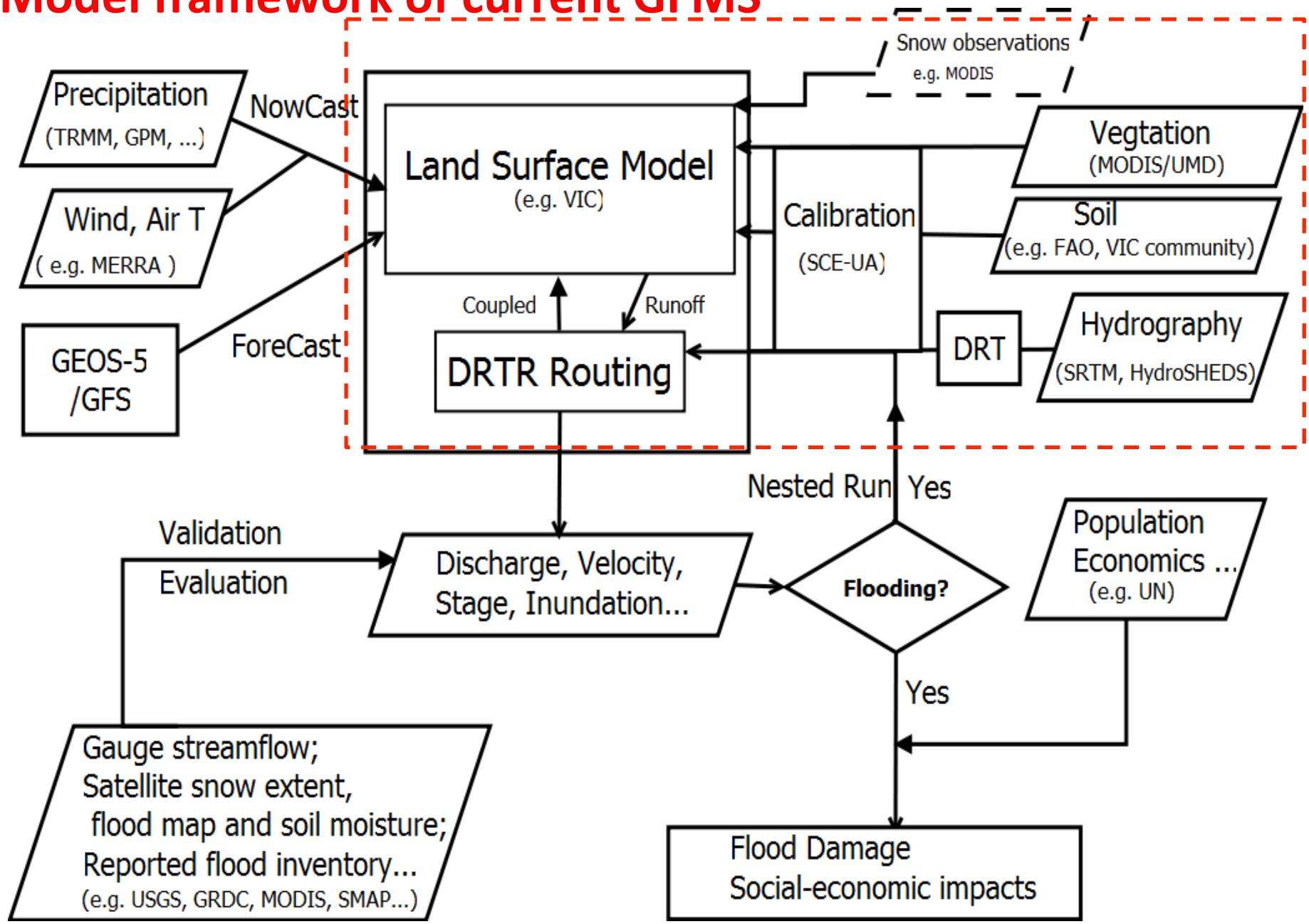
- We are currently working on implementing and testing 1 km resolution water routing that will make the calculations more useful. We may develop a system that will identify potential floods at the coarse resolution (12 km), but then show results at 1km resolution over a selected number of the current most important flood events. We are also developing high resolution inundation mapping based on the calculations to complement the streamflow and other data, and for more direct comparison with satellite mapping of floods. We will also be implementing a "dam module" to try to include the impact of man-made structures on the calculations.

- We are also developing the use of forecast precipitation info. from numerical models (adjusted by the satellite estimates) to extend the calculations a few days into the future.

- This type of system could also be used to do more regional applications, provide information for routine water management calculations, make estimates of precipitation and streamflow available in situations of cross-border "missing" data.

Extra slides

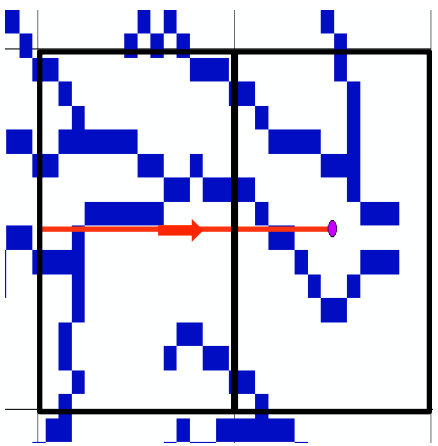
Model framework of current GFMS



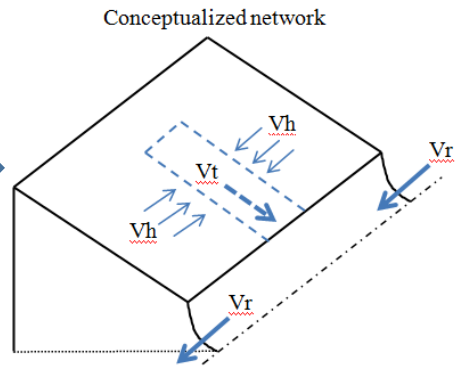
Land Surface and Routing Models Interaction

Dominant River Tracing-based Routing (DRTR)

St. Venant equation based (Kinematic/Diffusion wave); Real-time; Flexible in spatial-temporal resolution; Sub-grid routing; Parameterization from finer resolution inputs.



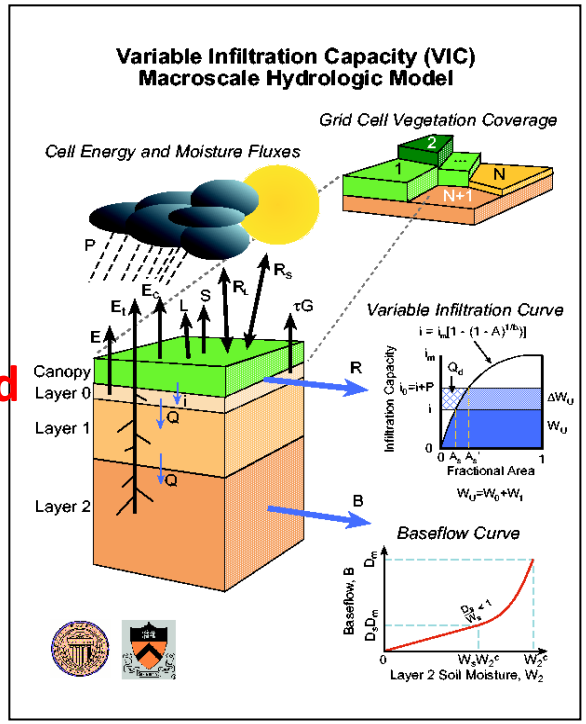
High Res. River



Coarse Res. River

Coupled

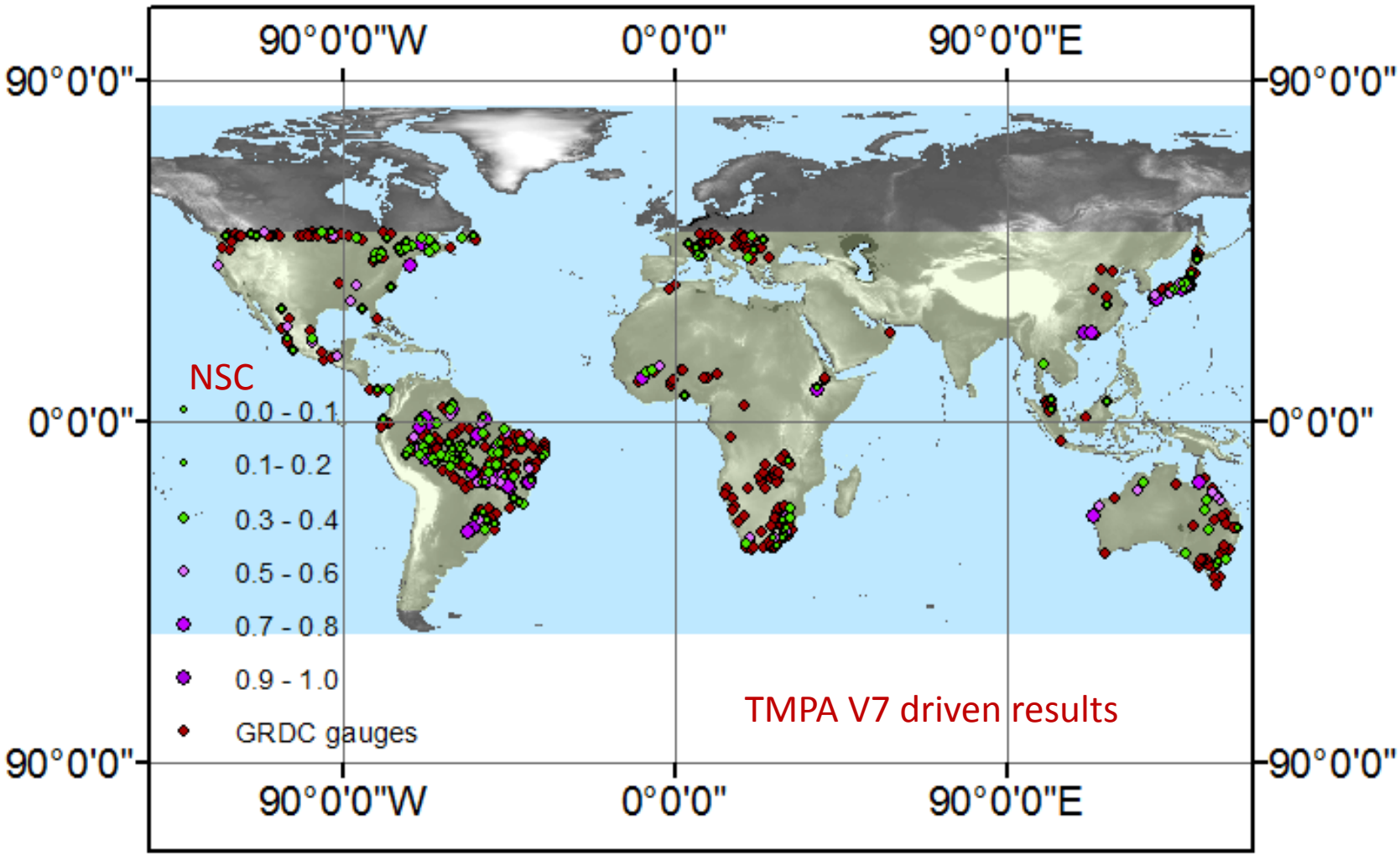
Runoff (VIC)



System is running quasi-globally <u>every three hours at 1/8th degree</u>, and soon will run at 1km resolution for <u>selected areas</u> where flooding is estimated with possibility of the <u>global domain.</u>

Streamflow evaluation

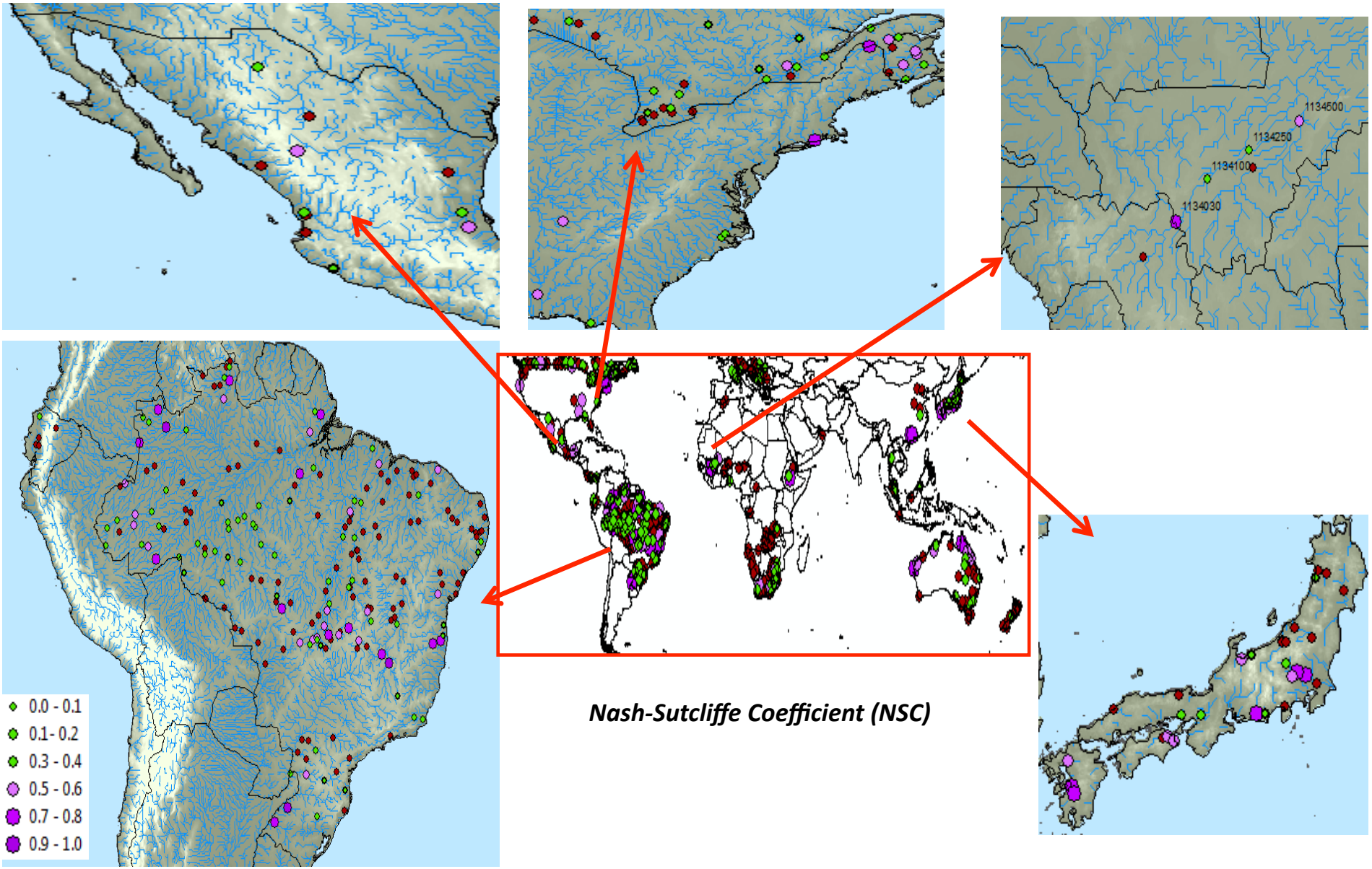
Gauge selection criteria: (1) Gauge data are available from 1999; (2) Gauge can be well located in DRT upscaled river network, which serves the geo-mask for all model simulations; (3) Gauge upstream drainage area>200 km^2



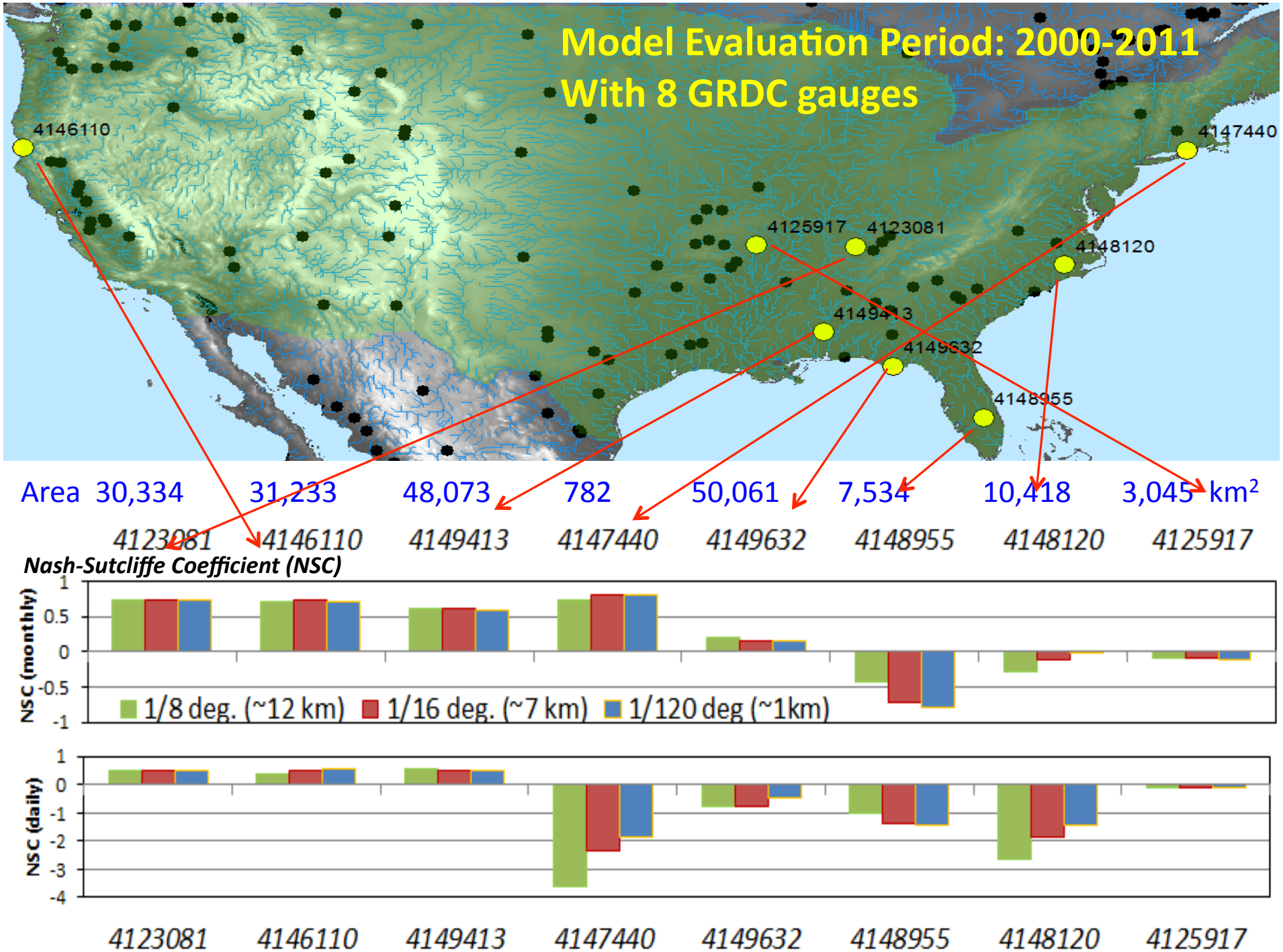
580 gauges selected for evaluating simulated streamflow

TMPA V7 driven (1999-2011) model evaluation against GRDC gauge data

There are 220 (out of 580) gauges with <u>monthly</u> NSC > 0 with a mean of 0.32,
and 76 gauges with NSC > 0.4 with a mean of 0.57.
There are 123 (out of 580) gauges with <u>daily</u> NSC > 0 with a mean of 0.17.

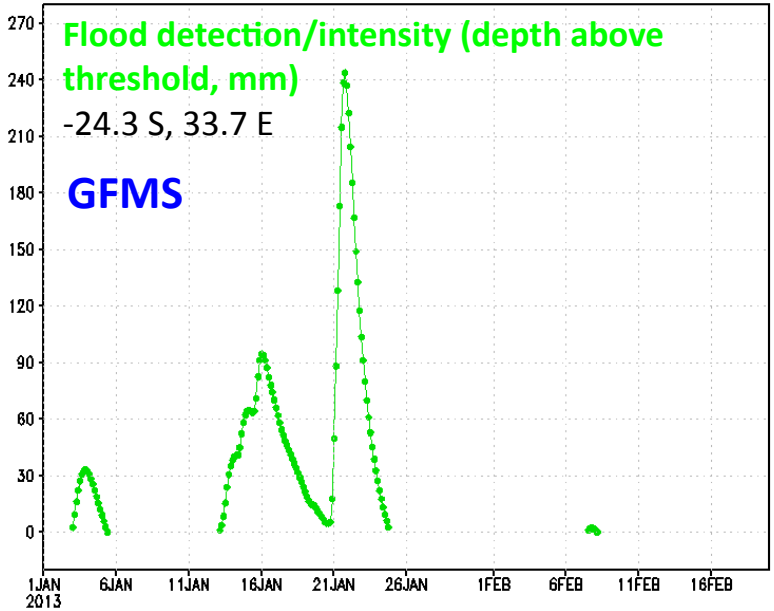


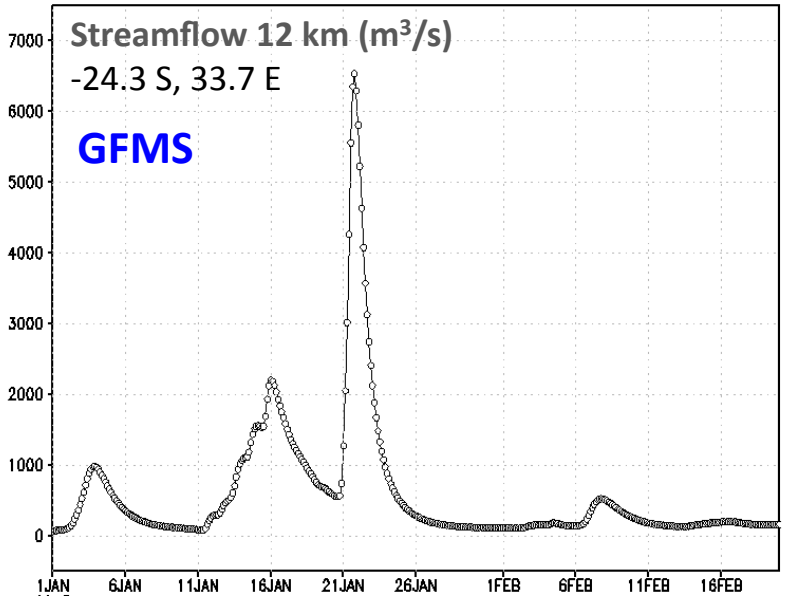
Nash-Sutcliffe Coefficient (NSC)

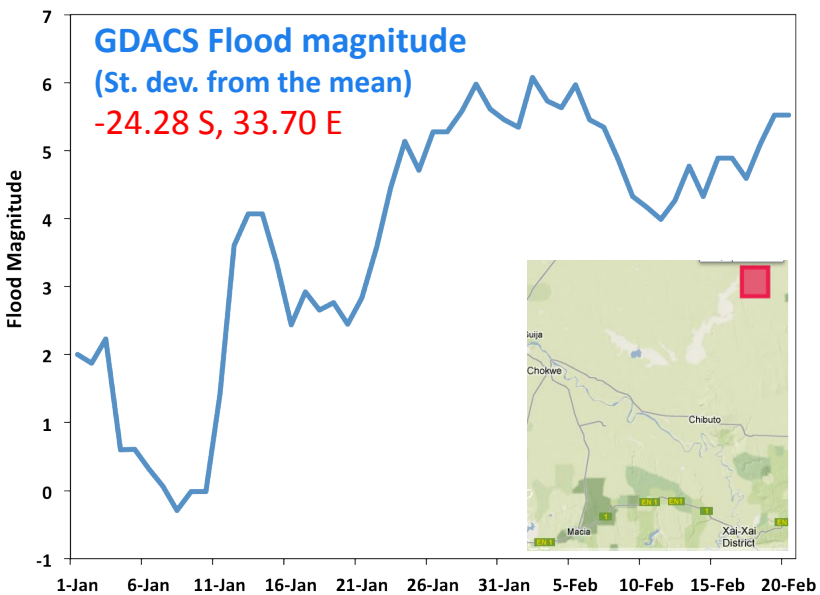

Model Evaluation Period: 2000-2011
With 8 GRDC gauges
4146110
4147440
4125917
4123081
4148120
4149413
4149632
4148955
Area 30,334 31,233 48,073 782 50,061 7,534 10,418 3,045 km²
4123081 4146110 4149413 4147440 4149632 4148955 4148120 4125917
Nash-Sutcliffe Coefficient (NSC)
NSC (monthly)
1/8 deg. (~12 km)
1/16 deg. (~7 km)
1/120 deg (~1km)
NSC (daily)
4123081 4146110 4149413 4147440 4149632 4148955 4148120 4125917

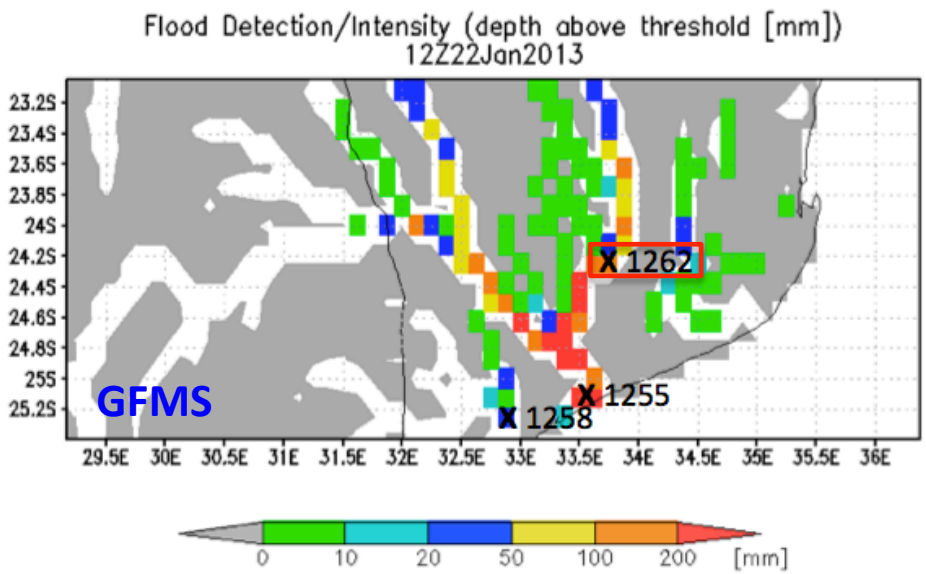
Comparison between GFMS and GDACS

Site 1262 - Changane River in Mozambique



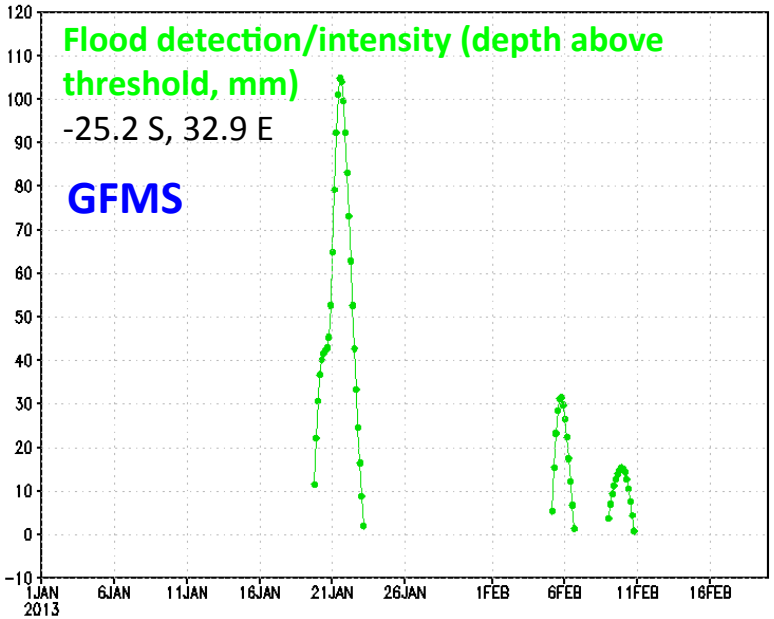


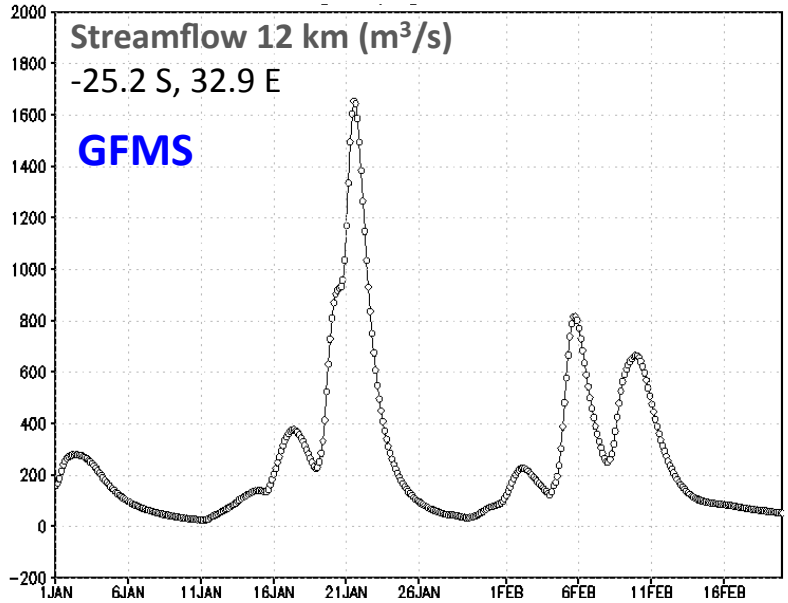


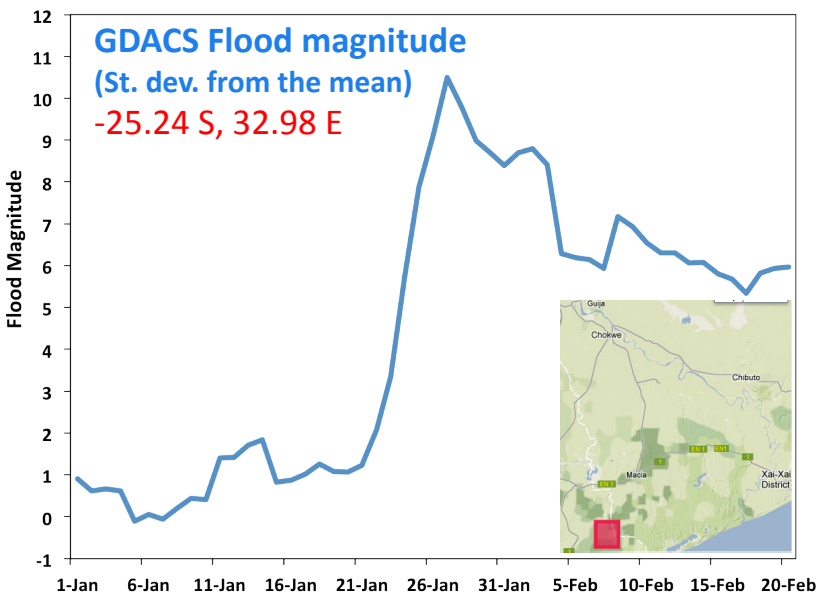


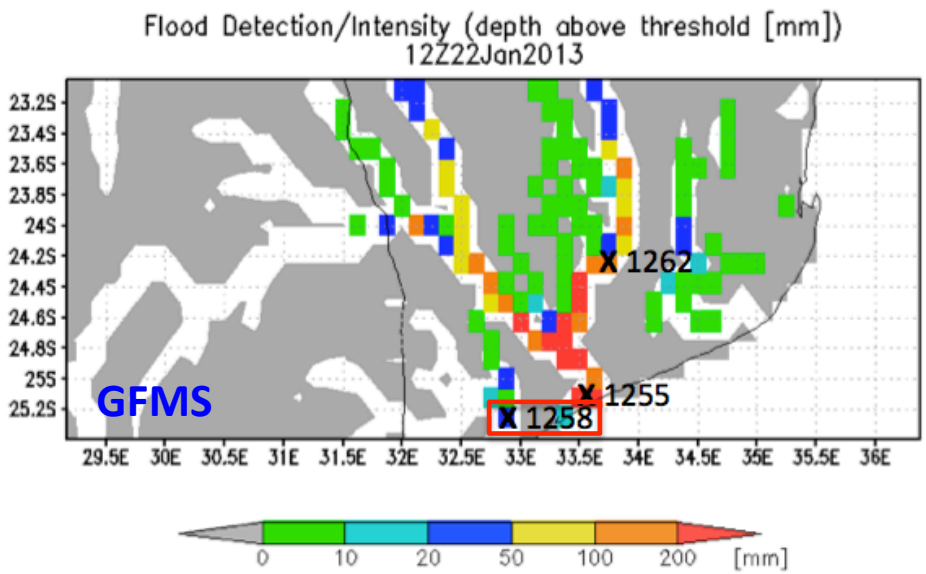
Comparison between GFMS and GDACS

Site 1258 - Incomati River in Mozambique









FLOOD WATERS OVER CHOKWE, GUIKA, BILENE, AND XAI-XAI DISTRICTS, GAZA PROVINCE, MOZAMBIQUE

Analysis with TerraSAR-X Data Acquired 24 January 2013

This map illustrates satellite-detected flood waters along the Limpopo River in the Guija, Chokwe, Bilene, and Xai-Xai districts of Gaza Province, Mozambique, as detected by TerraSAR-X imagery acquired the 24 January 2013 at 16:14 GMT. This analysis indicates a considerable flood extent due to swelling of the Limpopo River as waters flow towards the coast. Waters are also flowing south of the river and into surrounding agricultural areas and town, particularly around Chokwe city and in Xai-Xai district.There was a dramatic increase of flood waters from the 23rd to 24th January 2013. Multiple villages and Chokwe city are inundated by flood waters along the river. Large sections of road and railroad are potentially affected, including highway 208 which runs along the east bank of the Limpopo River and appears to be inundated to the north and east of Chokwe. It is likely that flood waters have been systematically underestimated in highly vegetated areas along main river banks, and within built-up urban areas due to the characteristics of the satellite data used. This analysis has not yet been validated in the field. Please send ground feedback to UNITAR /UNOSAT.

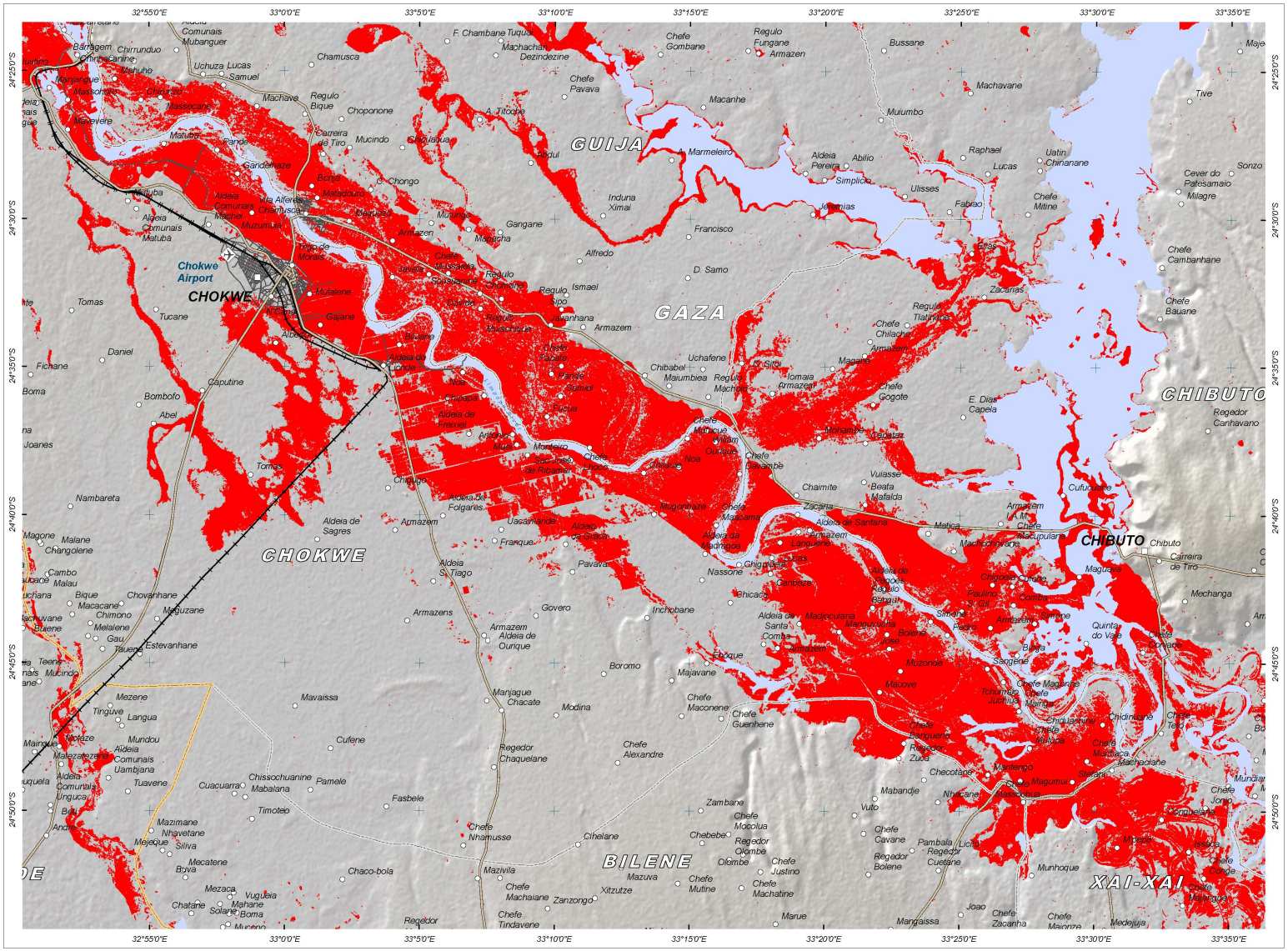
Disaster coverage by the International Charter 'Space and Major Disasters'. For more information on the Charter, which is about assisting the disaster relief organizations with multi-satellite data and information, visit www.disasterscharter.org

Heavy Rains & Flooding

Production Date: 25/01/2013

Version 1.0

Activation Number: FL-20130121-MOZ



LEGEND

- City
- Town
- Airport
- Primary Road
- Local Road
- Railroad
- District
- International Border

FLOOD WATER EXTENT ANALYSIS
(Satellite-Based Classification)

- *Probable Standing Flood Waters: [TerraSAR-X 24 Jan 2013]*
- *Pre-Crisis Water Extent*

Map Scale for A3: 1:235,370

0 1 2 4 6 8 10 Km

Satellite Data (1): TerraSAR-X
Imagery Dates: 24 January 2013
Resolution: 8.25 m
Copyright: DLR
Source: DLR
Road Data : Google Map Maker / OSM / ESRI
Other Data: USGS, UNCS, NASA, NGA
Analysis : UNITAR / UNOSAT
Production: UNITAR / UNOSAT
Analysis conducted with ArcGIS v10.1

Coordinate System: WGS 1984 UTM Zone 36S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

The depiction and use of boundaries, geographic names and related data shown here are not warranted to be error-free nor do they imply official endorsement or acceptance by the United Nations. UNOSAT is a program of the United Nations Institute for Training and Research (UNITAR), providing satellite imagery and related geographic information, research and analysis to UN humanitarian and development agencies and their implementing partners.

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United Nations Institute for Training and Research

UNOSAT

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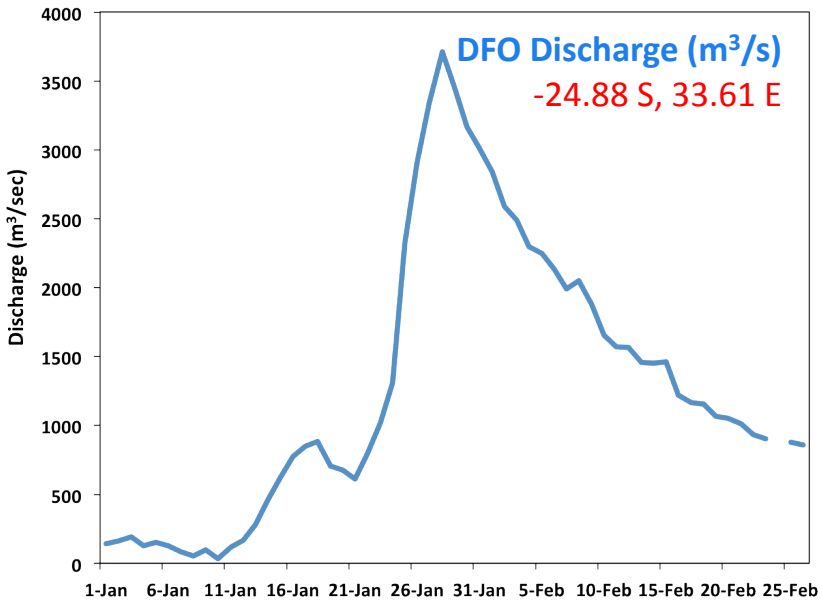
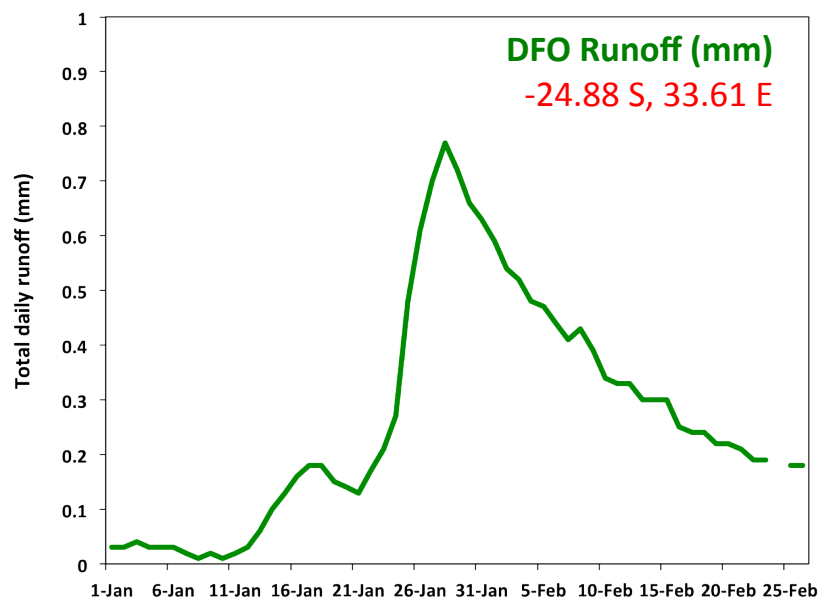
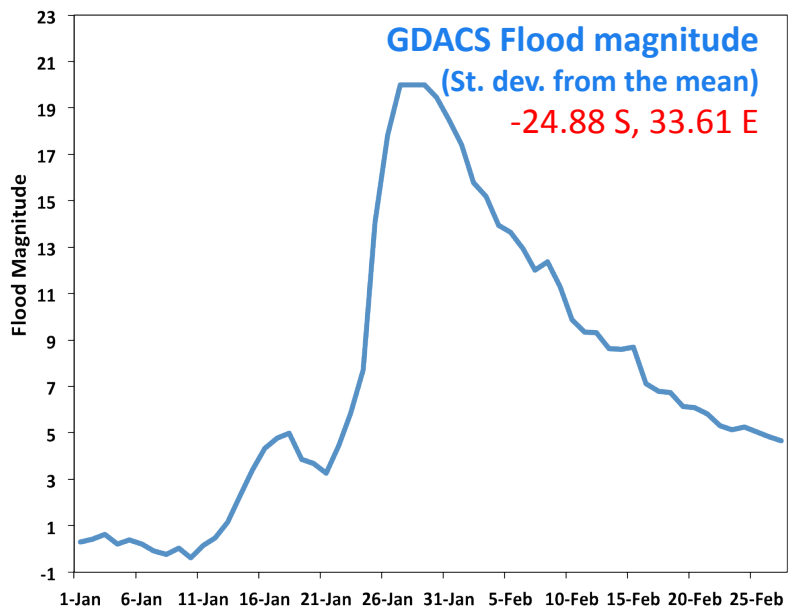
24/7 Hotline: +41 76 487 4998
www.unitar.org/unosat

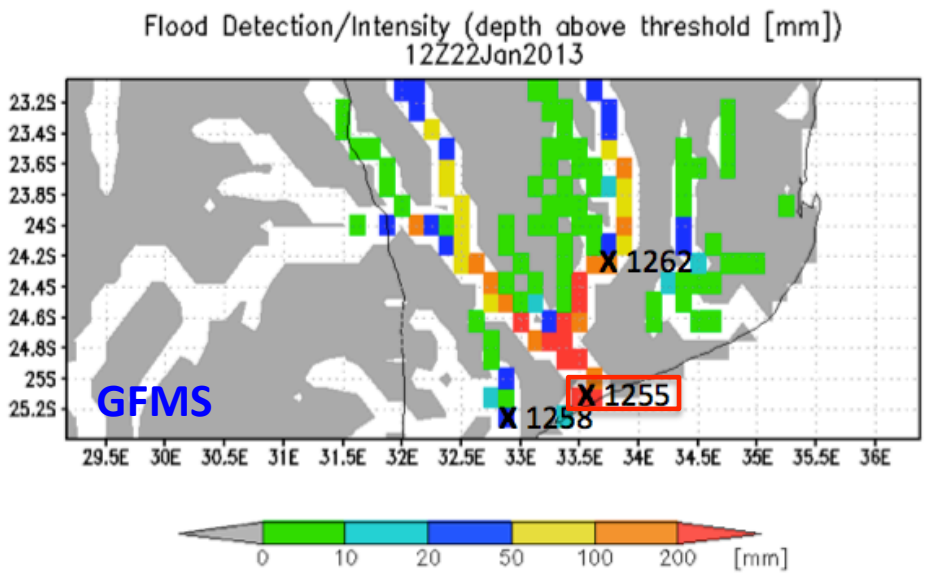
Comparison between DFO and GDACS

Site 1255 - Limpopo River in Mozambique



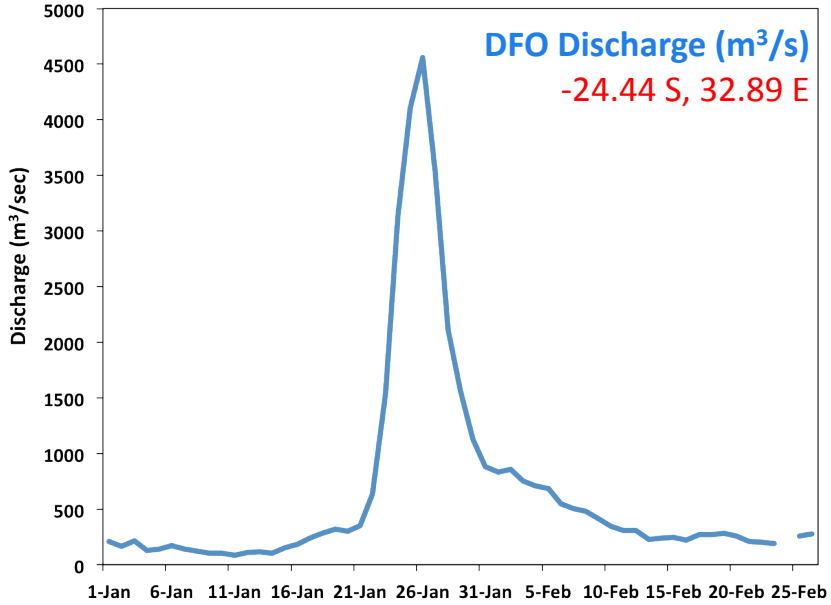


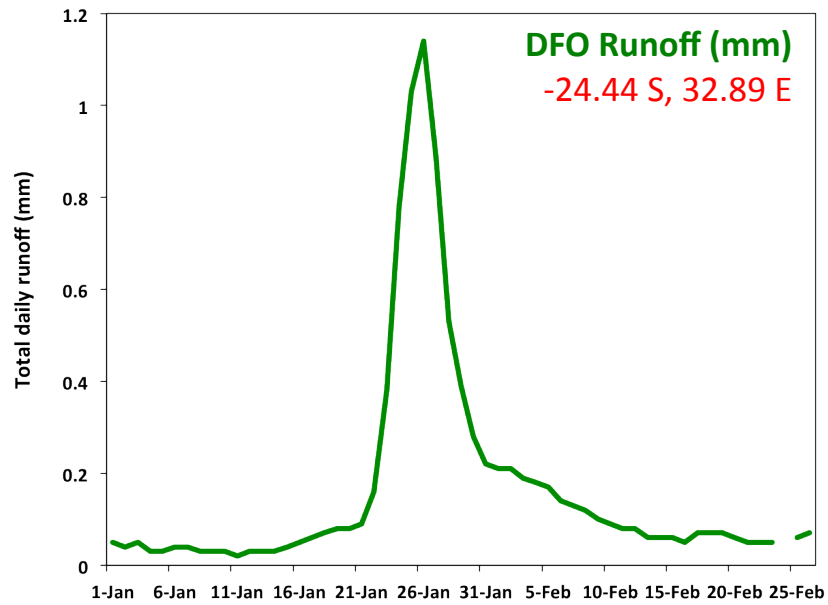


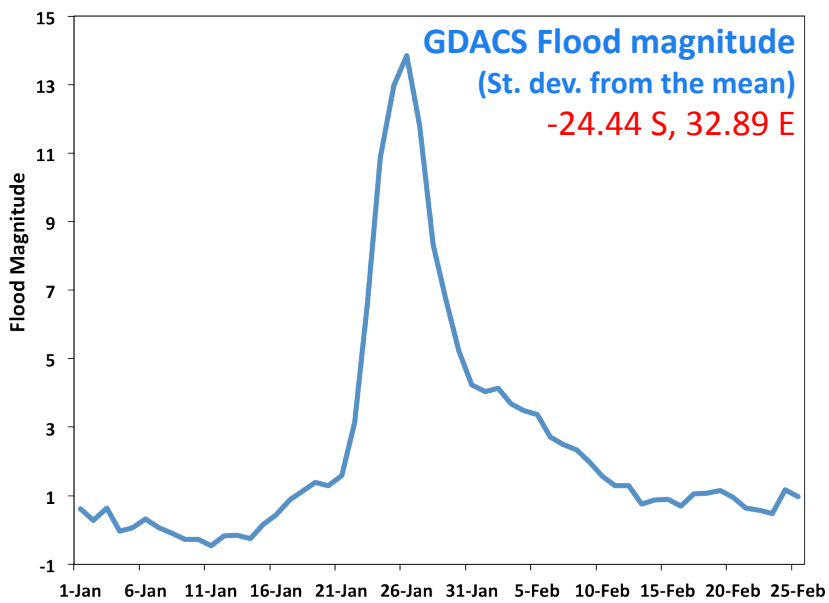


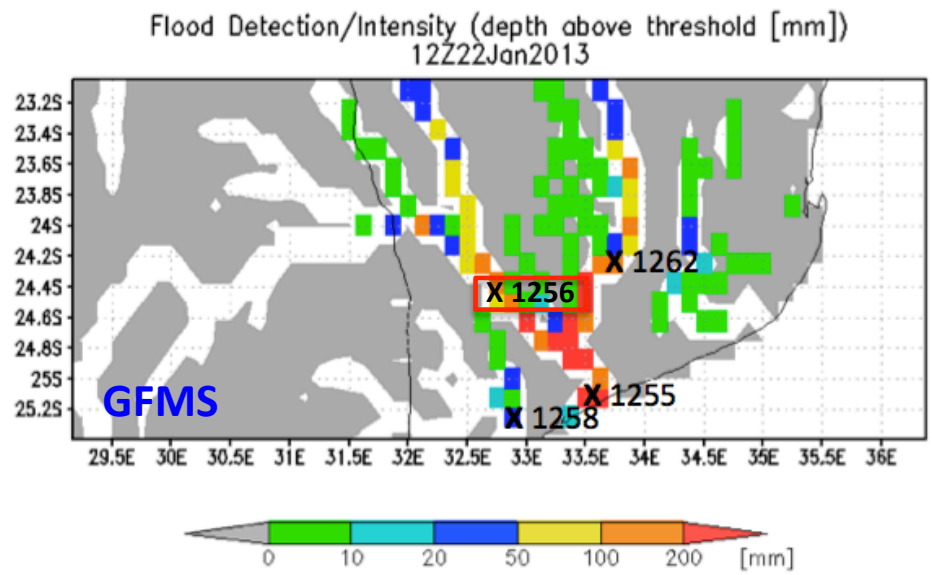
Comparison between DFO and GDACS

Site 1256 - Limpopo River near Chokwe in Mozambique



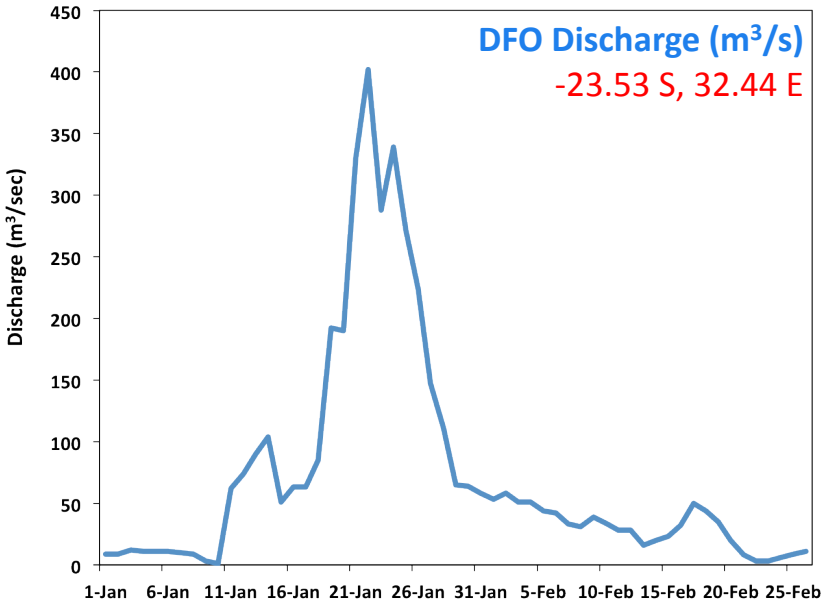


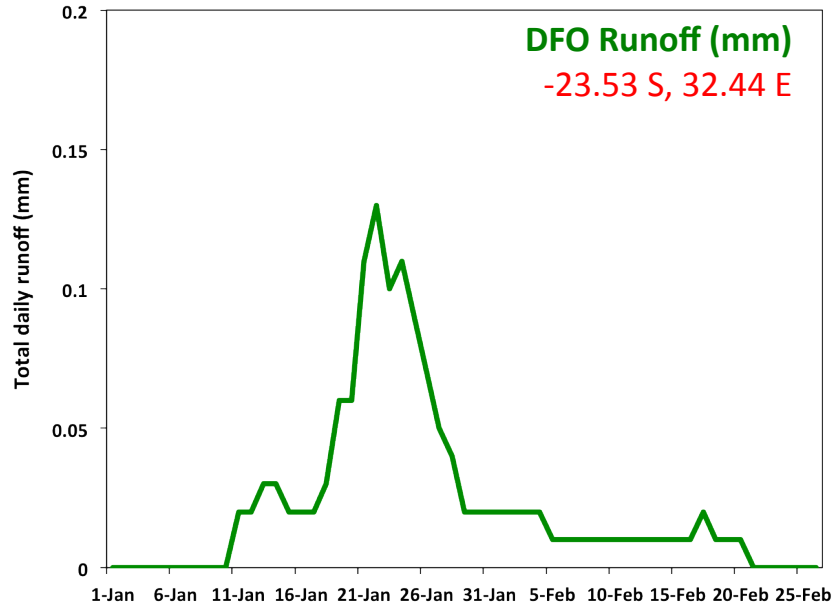


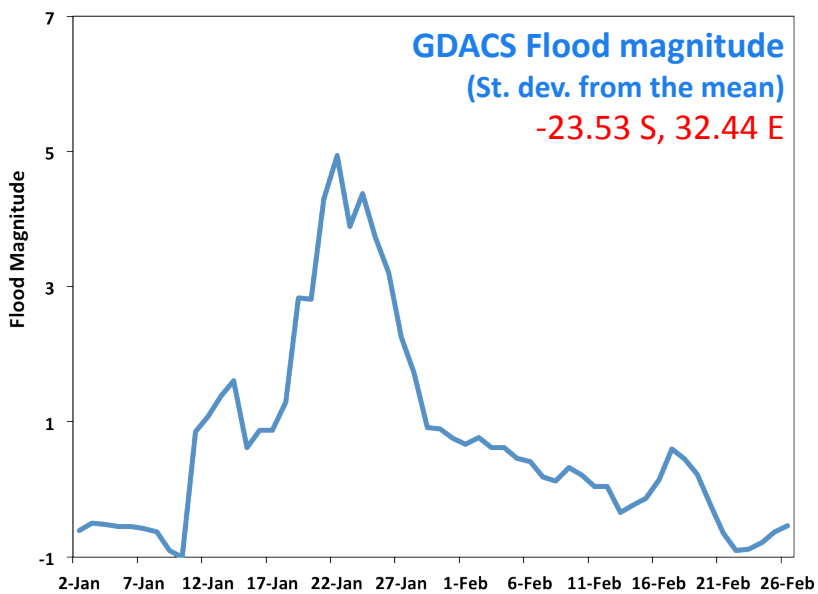


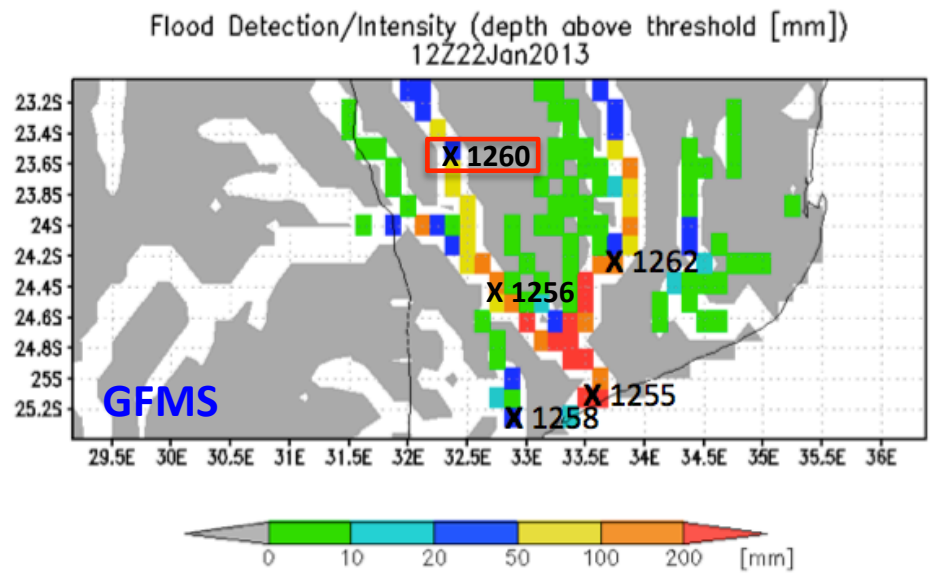
Comparison between DFO and GDACS

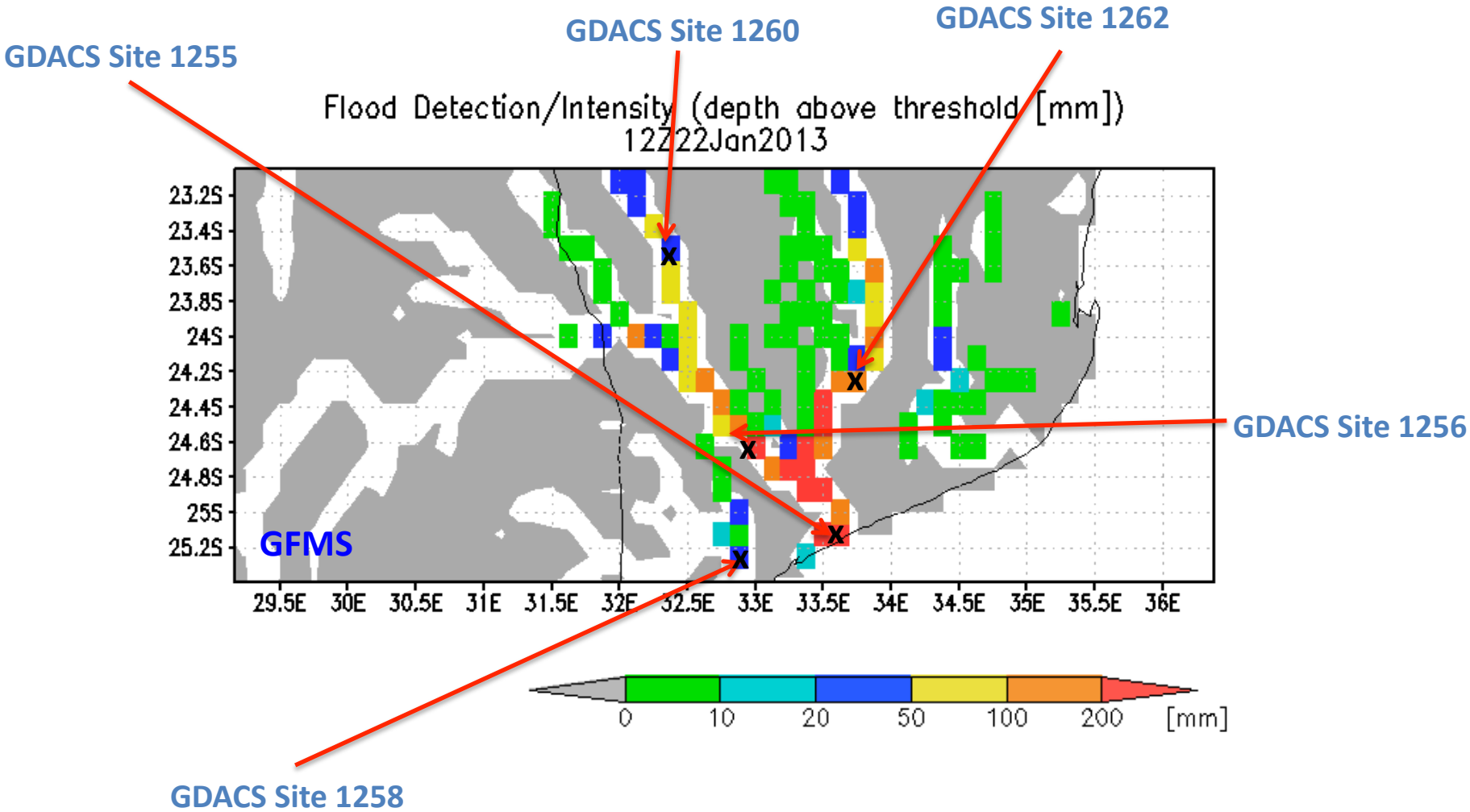
Site 1260 - Limpopo River in Mozambique










GDACS Site 1255
GDACS Site 1260
GDACS Site 1262
Flood Detection/Intensity (depth above threshold [mm])
12Z22Jan2013
23.2S
23.4S
23.6S
23.8S
24S
24.2S
24.4S
24.6S
24.8S
25S
25.2S
29.5E
30E
30.5E
31E
31.5E
32E
32.5E
33E
33.5E
34E
34.5E
35E
35.5E
36E
GFMS
GDACS Site 1256
0
10
20
50
100
200
[mm]
GDACS Site 1258