GLOBAL FLOOD AND LANDSLIDE NOWCASTS AND FORECASTS USING SATELLITE PRECIPITATION OBSERVATIONS

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- *Experimental system running routinely last few years in quasi-realtime with information publicly available*
- *Hydrological models/algorithms driven by satellite rainfall estimates*
- *Results so far are interesting and are being used by various national and international organizations to help monitor disaster situations in less developed areas.*
- *However, we are really just at the beginning—there is a lot of room for improvement*

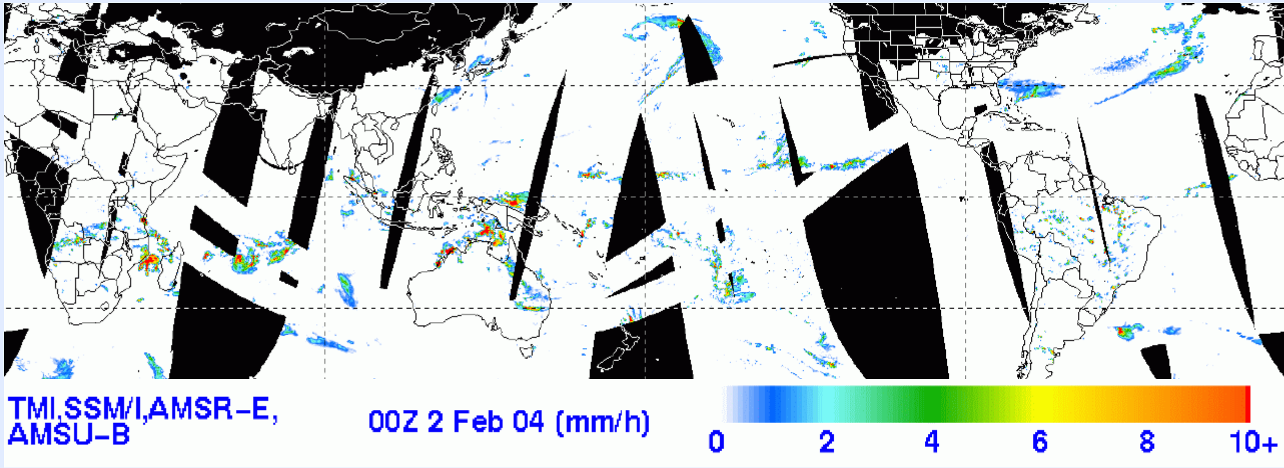
TRMM: Tropical Rainfall Measuring Mission

The TRMM Multi-Satellite Precipitation Analysis

(TMPA or 3B42 [TRMM product number]) [Adler/Huffman]

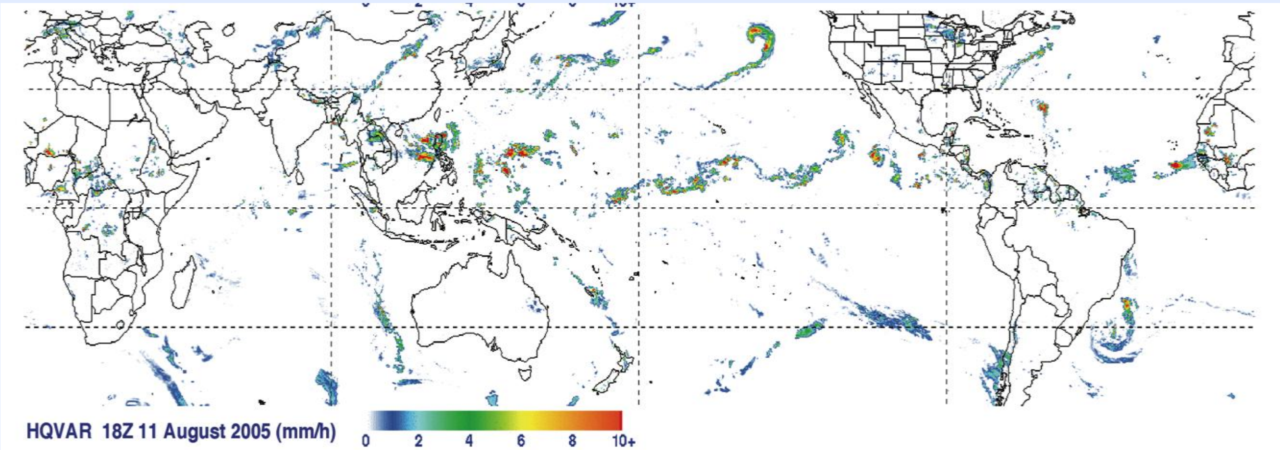
3-hr window with passive microwave (gaps filled with Geo-IR) calibrated by TRMM

(0.25° grid)



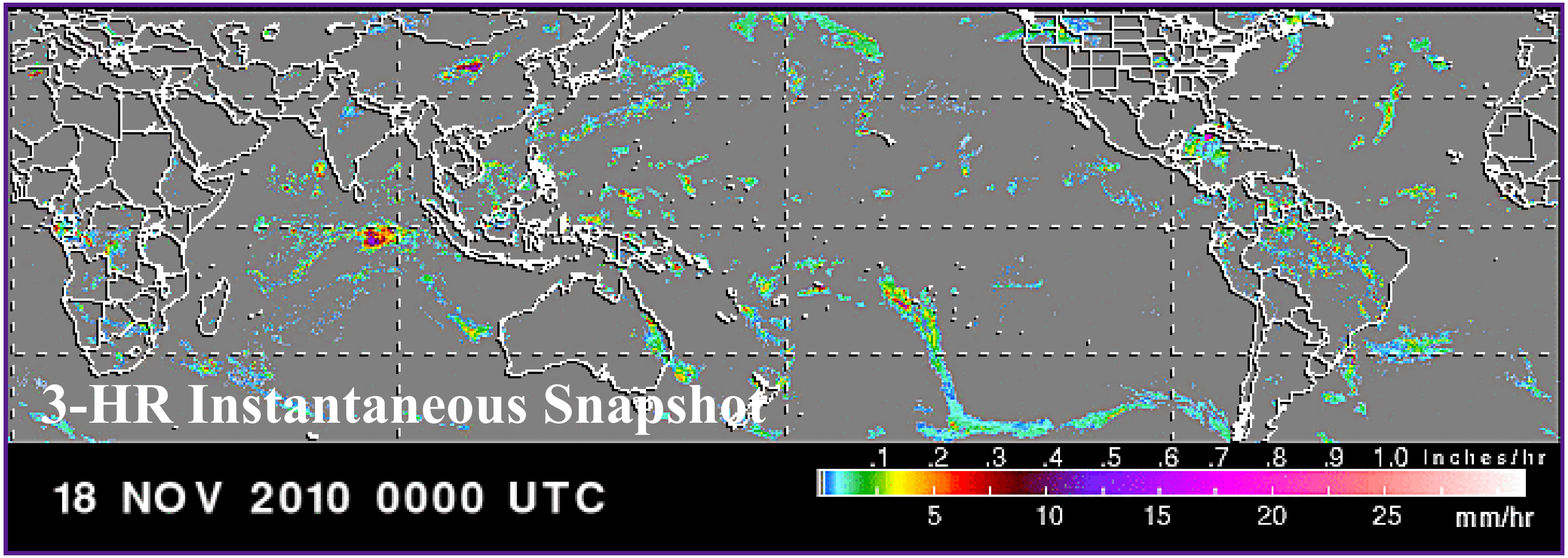
Research product uses TRMM radar information and monthly gauges; real-time product produced ~ 6 hrs after obs. time by TRMM/GPM data system

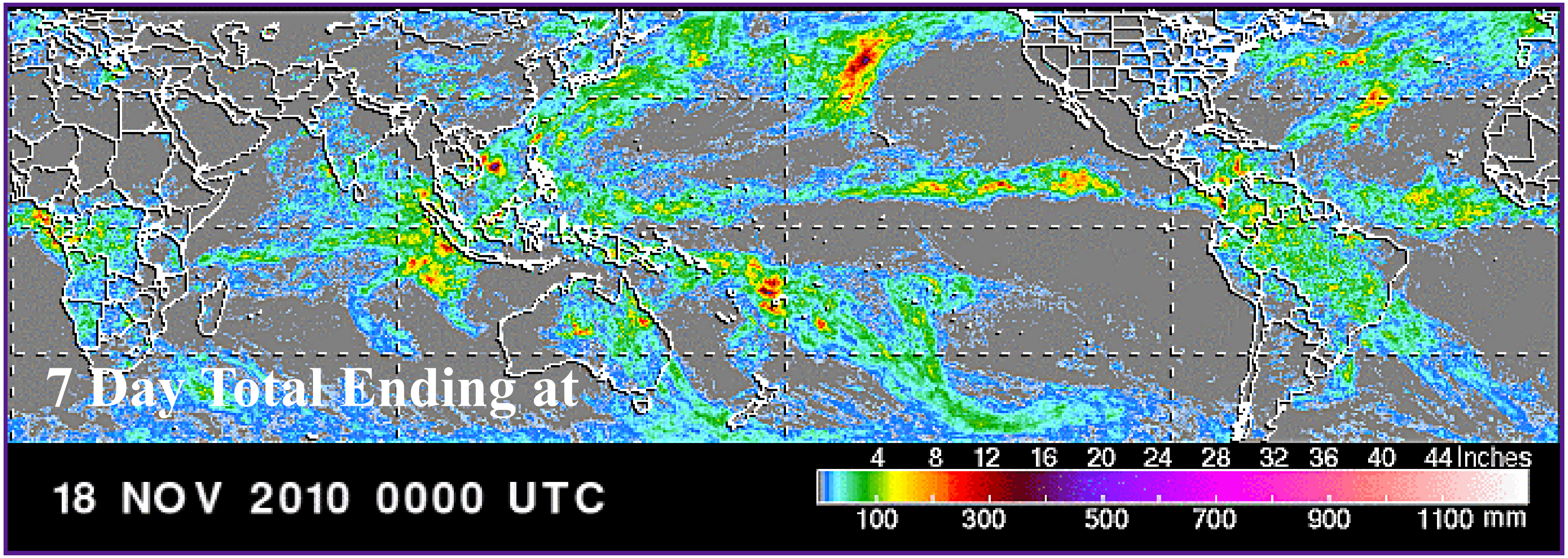
Huffman et al., 2007, J. Hydromet.



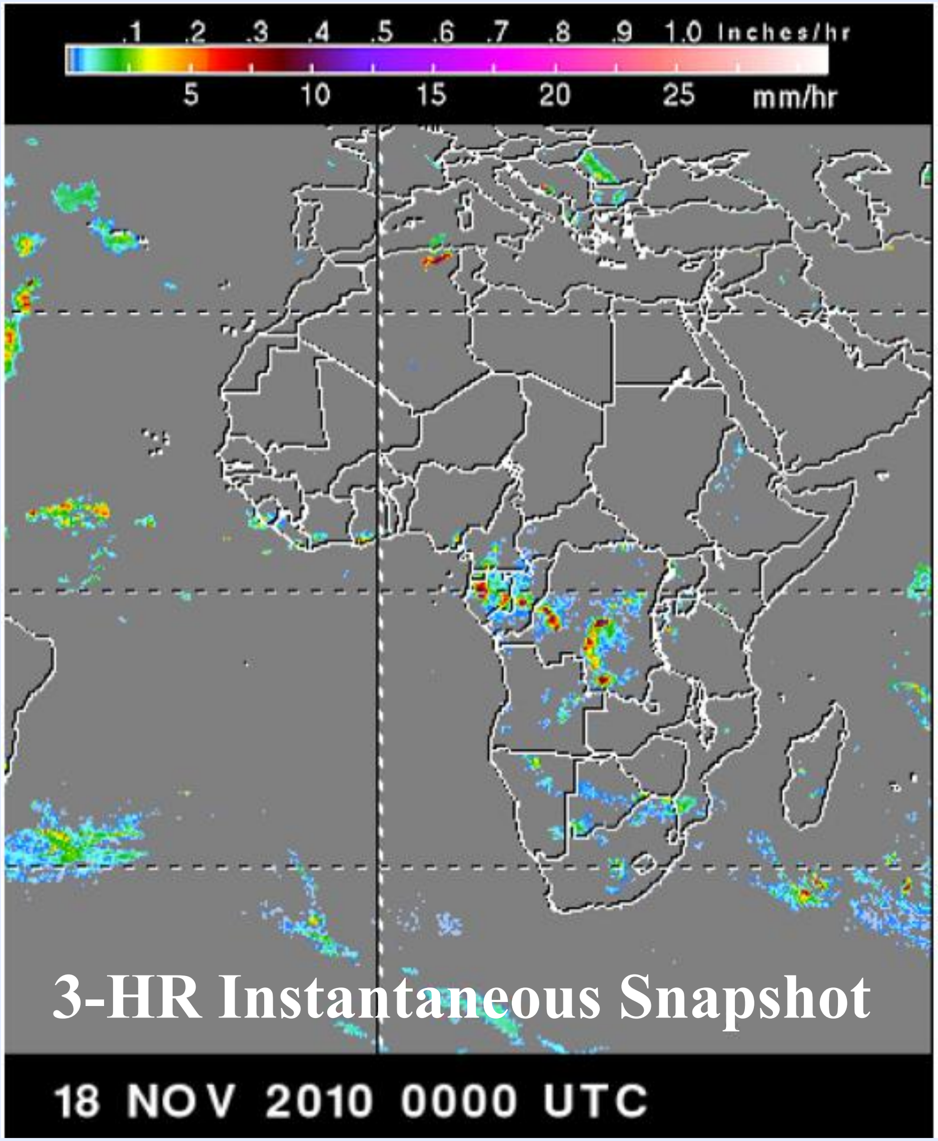
Almost 13 years ('98-'10) of 3-hr analysis available.

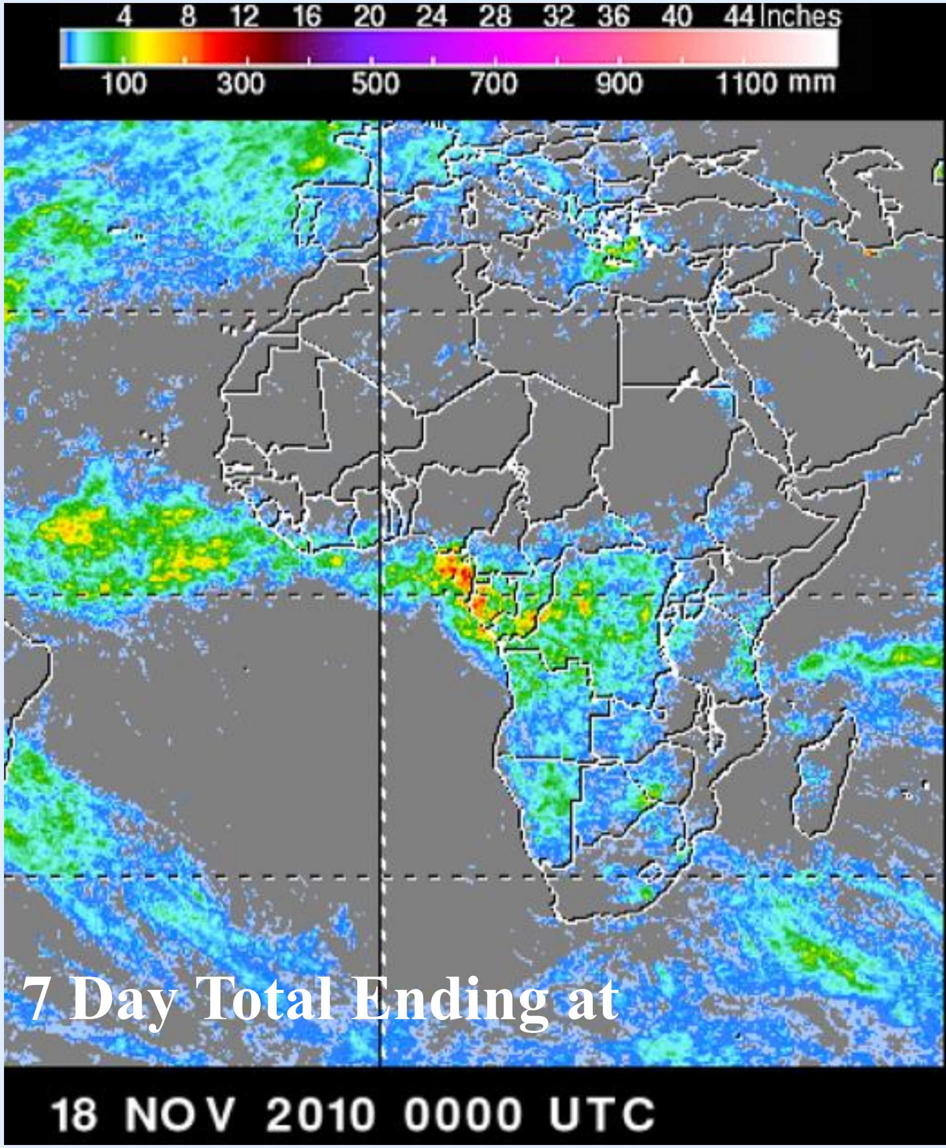
From TRMM Web Site (trmm.gsfc.nasa.gov)



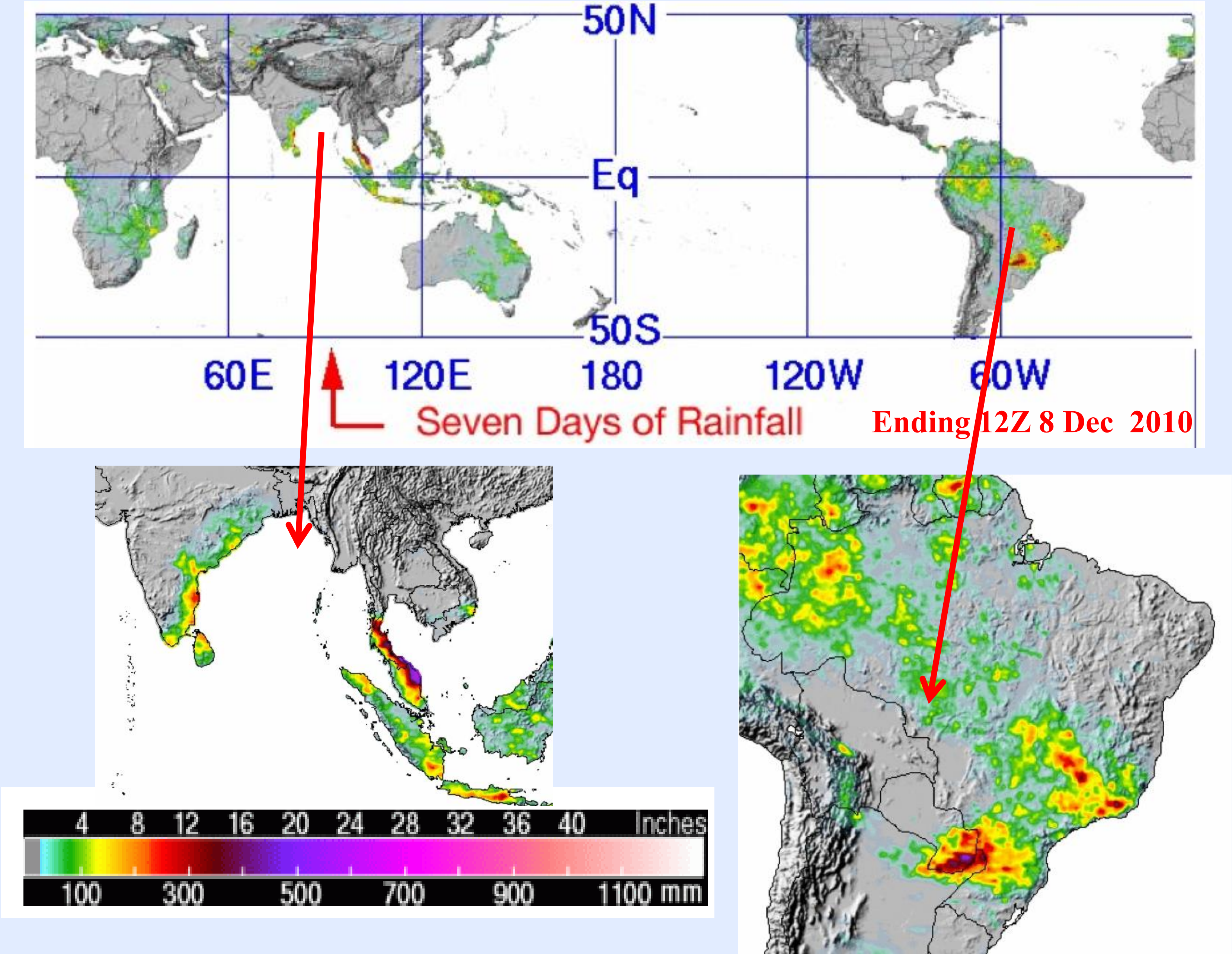


Regional Real-Time Data





Monitoring Heavy Rainfall Events with Satellite Rainfall



Flood Calculations using Current (Curve Number [CN]) Hydrological Model

1) The CN-Model[1]

(Curve Number Model)

Geospatial Datasets

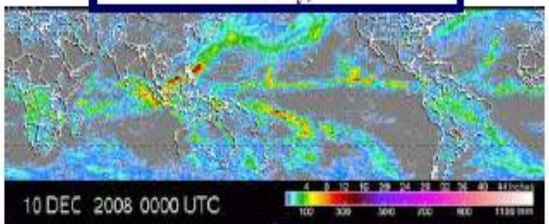
Topography (HYDRO1K)
Elevation, Slope, Flow Direction (Grid-to-grid routing)

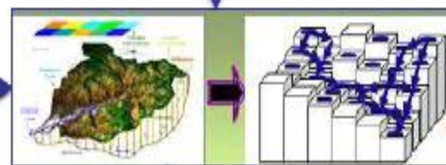
Soil Property (Source: FAO)
Sand, Foam, Silt, Clay

Land Cover (MODIS)
Shrub, barren, urban etc.

Antecedent Moisture Conditions
Concept of Antecedent Precip. Index

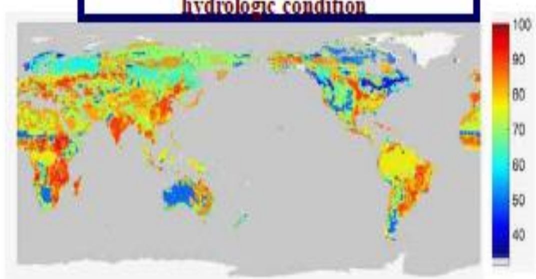
NASA TRMM-based [2]
Near Real-time Rainfall Estimates (3-hourly)





"Curve Number" approach to infiltration

NRCS Runoff Curve Number Map
USDA Soil Groups, under fair hydrologic condition



Near Real Time Global Flood Potential Map

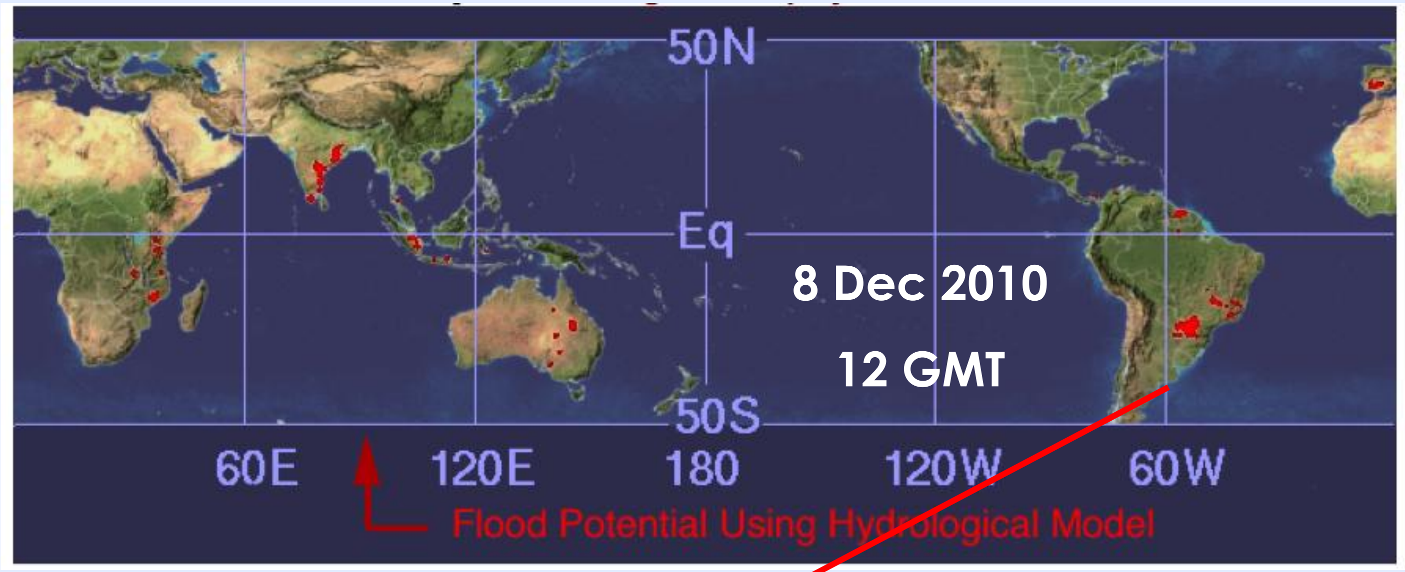
Hong, Y., et al. (2007), A first approach to global runoff simulation using satellite rainfall estimation, Water Resour. Res., 43, W08502, doi:10.1029/2006WR005739

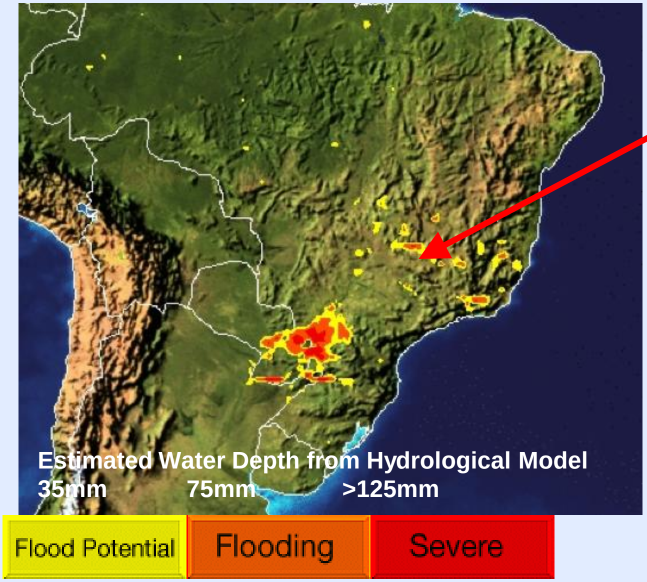
Hydrological Model Algorithmic Steps:

Step I: Rainfall-infiltration Partitioning (Distributed and Time-variant)
Step 2: Flow Routing using Macro-scale Grid-to-Grid Algorithm
Step 3: Result: Grid Point Hydrographs--Flood Inundation Mapping

On-line Global Flood Monitoring Every Three Hours at 0.25 Degrees (Yesterday)

http://trmm.gsfc.nasa.gov (Floods and Landslides)



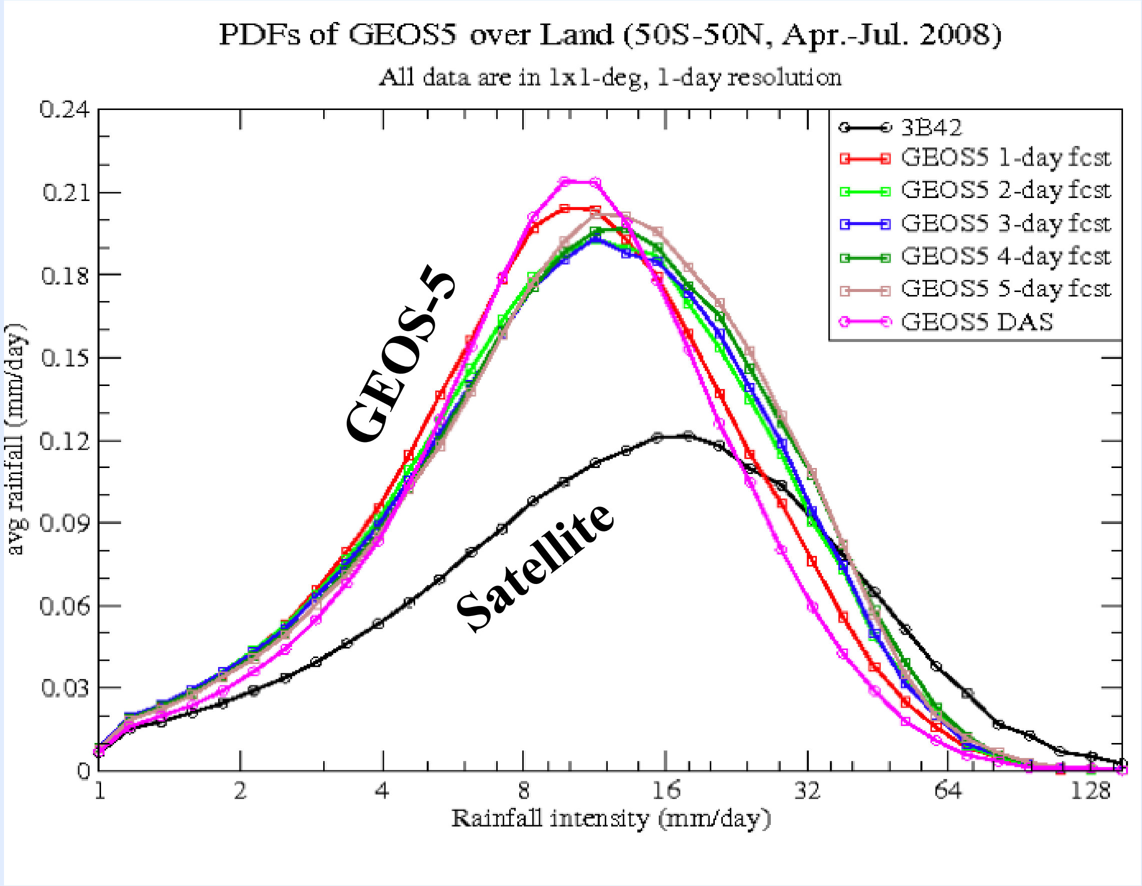


<u>Real-time</u> global estimation of <u>flood areas</u> using satellite-based rainfall and <u>a hydrological model</u> running globally, every three hours at 0.25°.

Adjusting NWP using satellite rainfall data

GEOS-5 : **Goddard Earth Observing System Model Version 5**

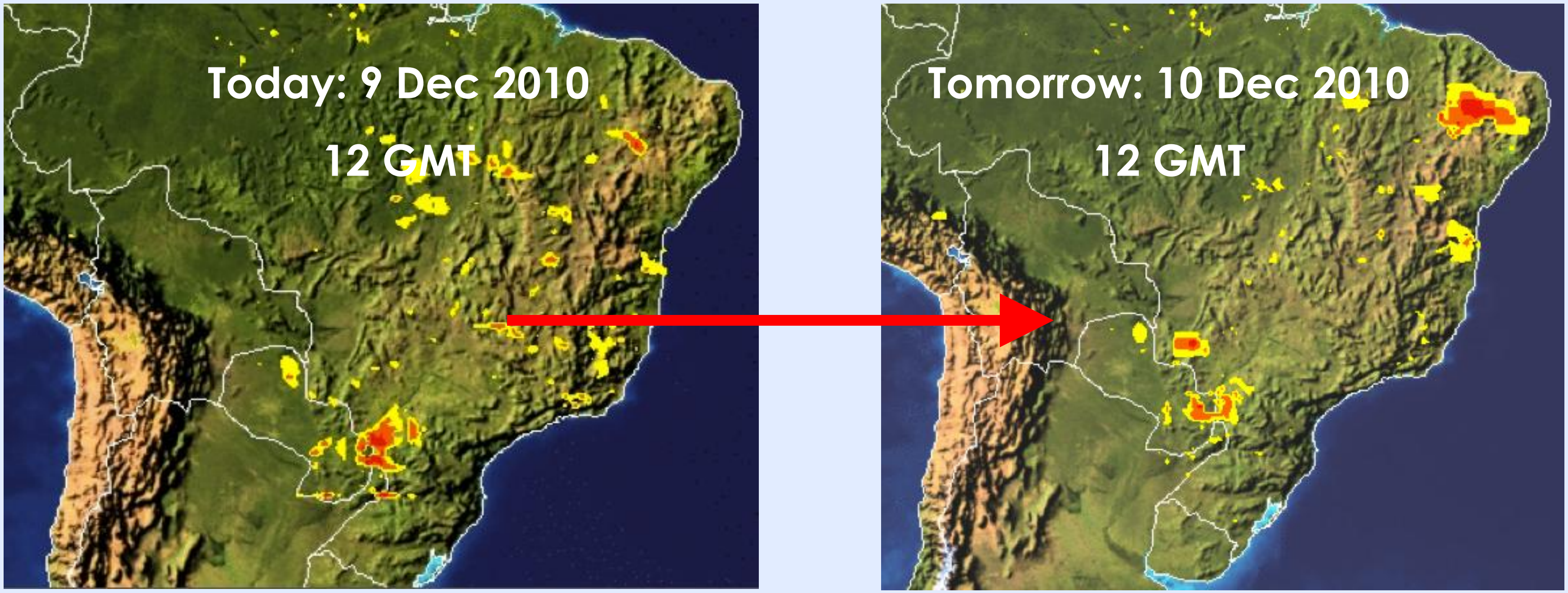
PDF Matching: GEOS-5 PDF is corrected using Satellite (TMPA) PDF



- **NWP Model outputs must be corrected before using for hydrologic applications**

24-HR Flood Forecast Using Precipitation Forecast from Global NWP Model (NASA GEOSS-5) and Hydrological Model

Model Precipitation Adjusted to Satellite Rainfall via Histogram Matching

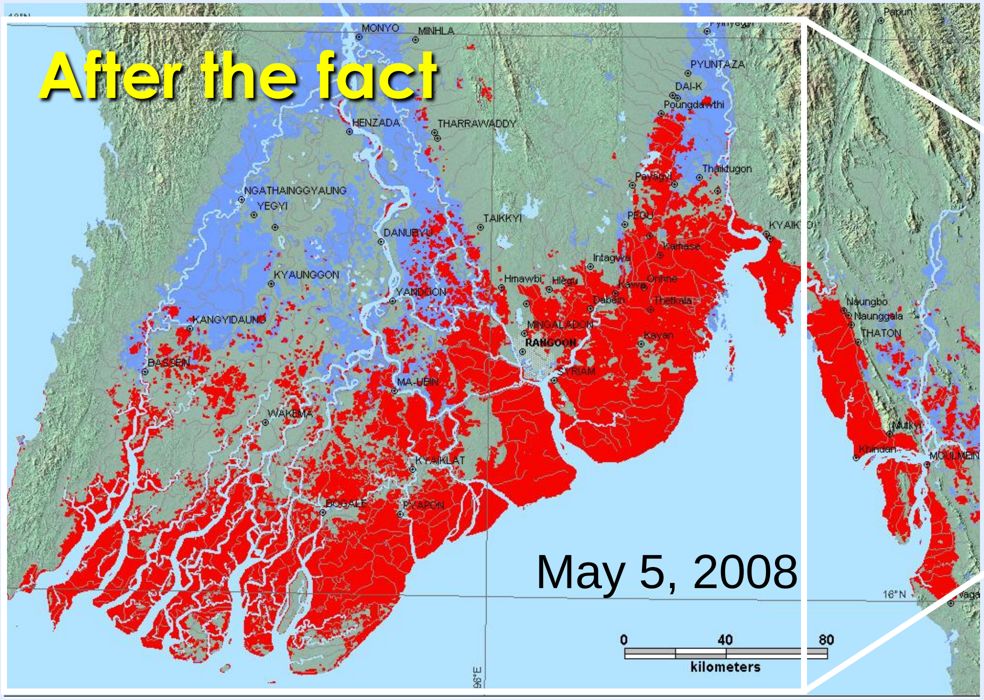


Estimated Water Depth from Hydrological Model

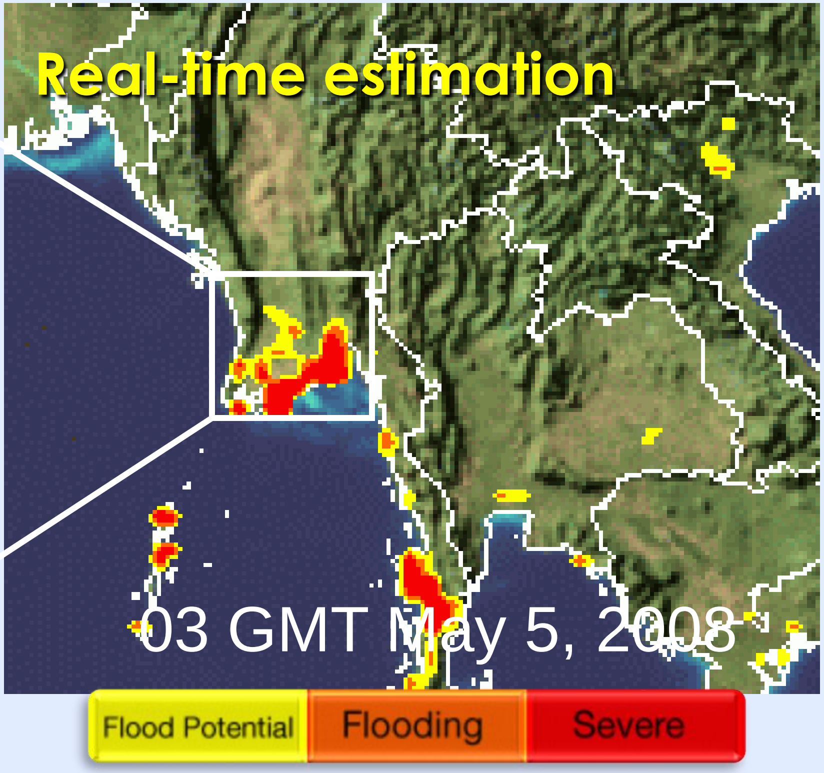
35mm	75mm	>125mm
Flood Potential	Flooding	Severe

Two Satellite Views of Burma Flood

Post Analysis Inundation Map from Dartmouth Flood Observatory (using MODIS data)



Real-time Inundation Estimate from Hydrological Model and Satellite Rainfall

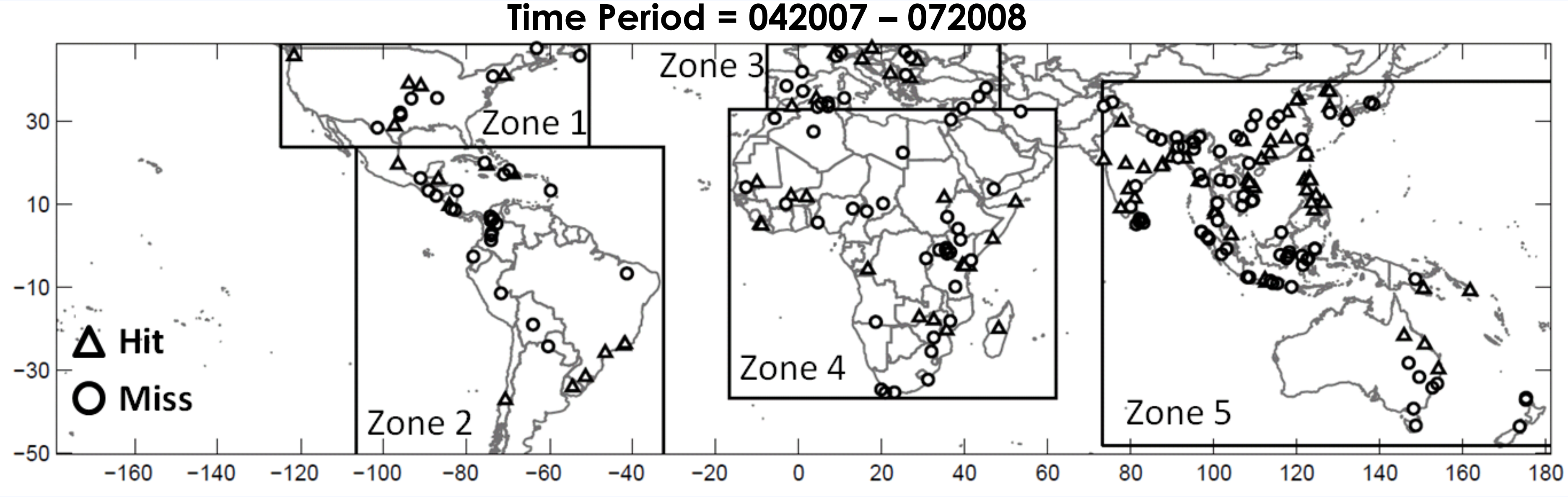


Evaluation using Dartmouth Flood Archive

- Flood Archive compiled by Dartmouth Flood Observatory
  - based on news reports, remote sensing sources, etc.
- Provides begin-end date & centroid of large flood events

Probability of Detection

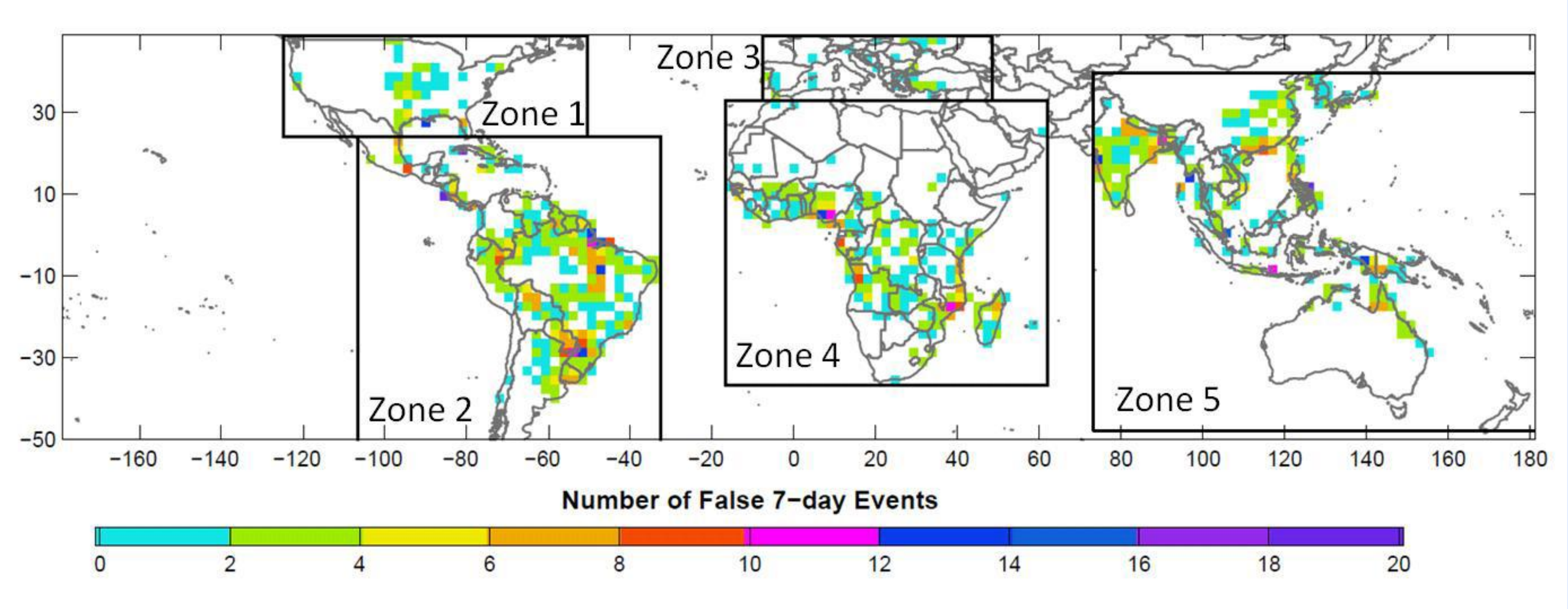
Flood = At least 2 contiguous cells > 75mm; Time window :±1 days



93 events were detected out of 247
(38% probability of detection over the globe)

Yilmaz, K., R. Adler, Y. Tian, Y. Hong, H. Pierce, 2010. Evaluation of a Satellite-based Global Flood Monitoring System. International Journal of Remote Sensing.

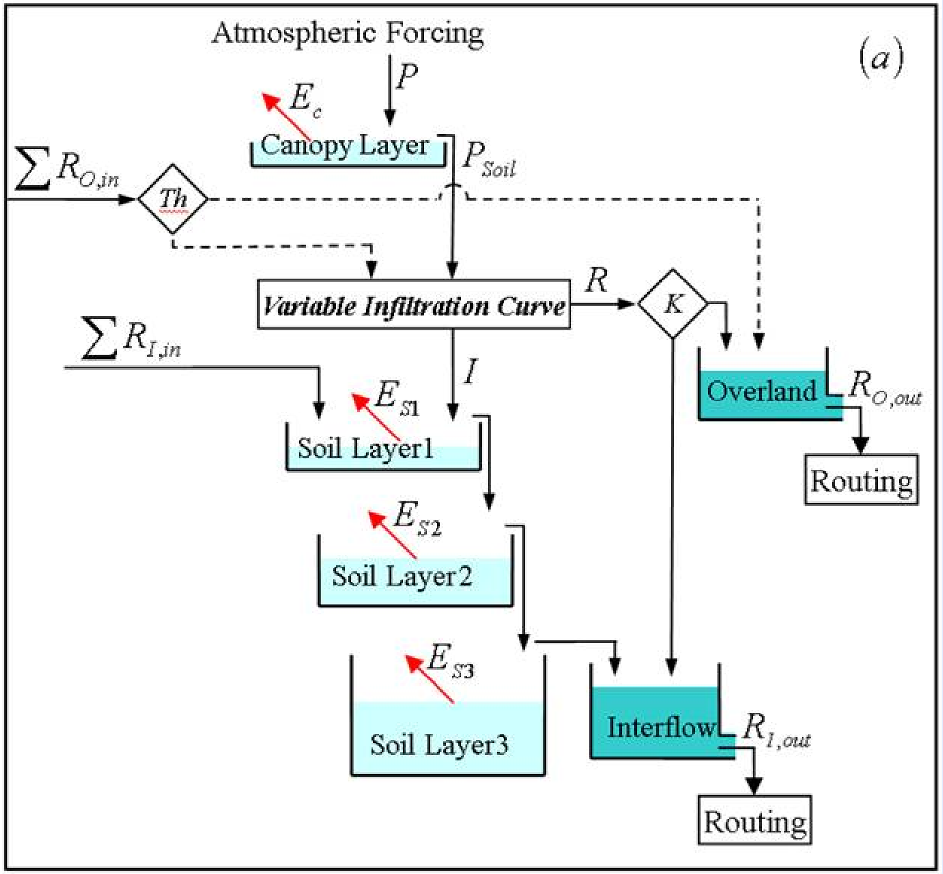
False Alarms



Map showing the number of simulated false 7-day events over the globe. Boxes denote the zones with different runoff threshold

New Hydrological Model Under Testing

NASA-OU CREST Distributed Hydrologic Model



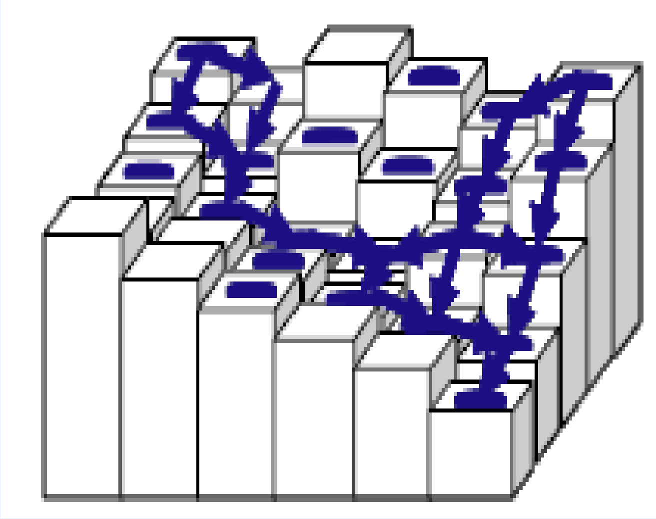
Coupled **R**outing and **E**xcess **ST**orage (CREST):

- **rainfall-runoff generation module, modified from UW-VIC model[1],**
- **parallel multi-linear storage module, modified from Xinanjiang model[2]**
- **newly developed grid-to-grid routing scheme.**

[1]Liang,et al. 1994
[2]Zhao & Liu, 1995

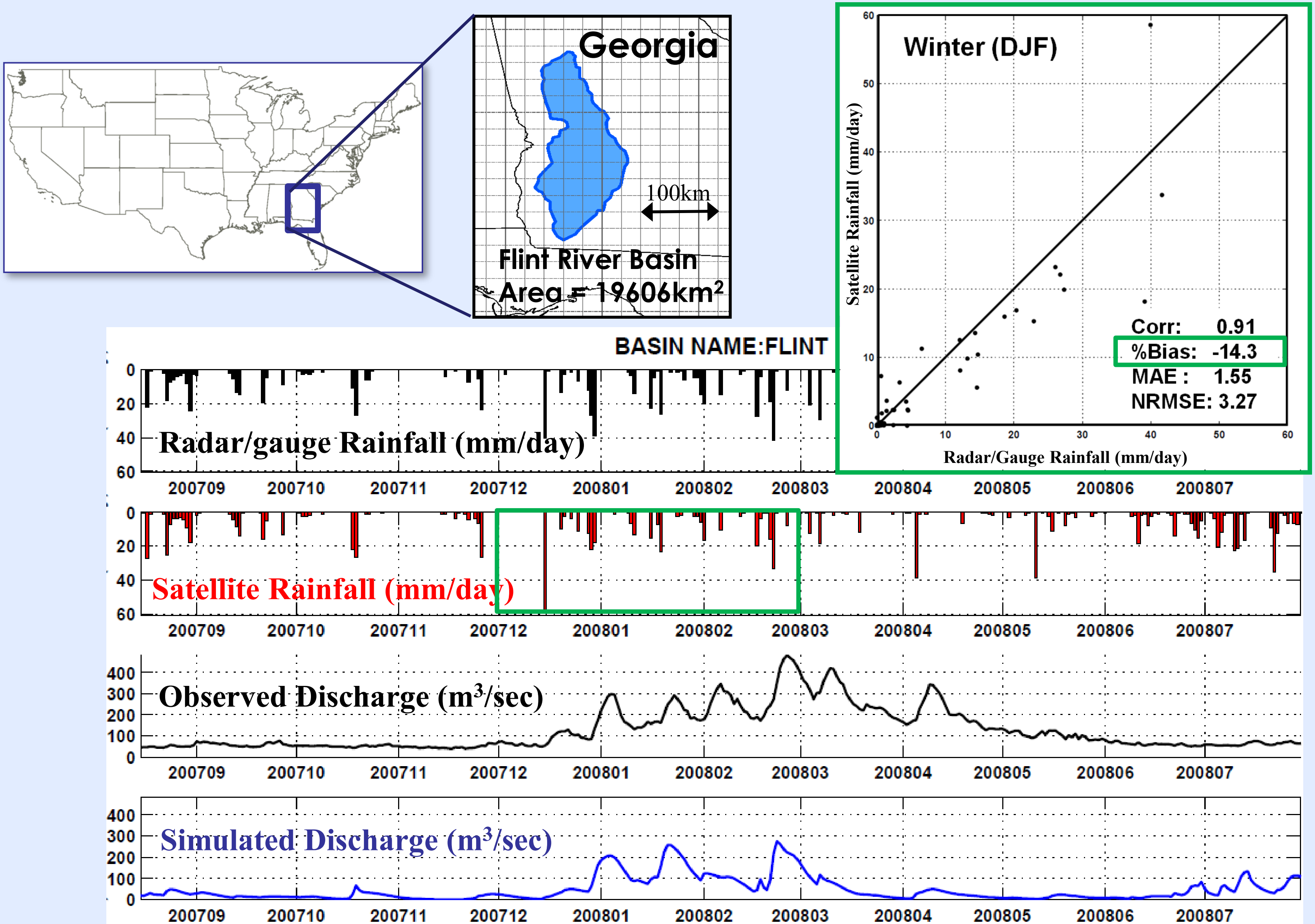
- **1/8th degree global**

Cell-to-Cell Flow Routing

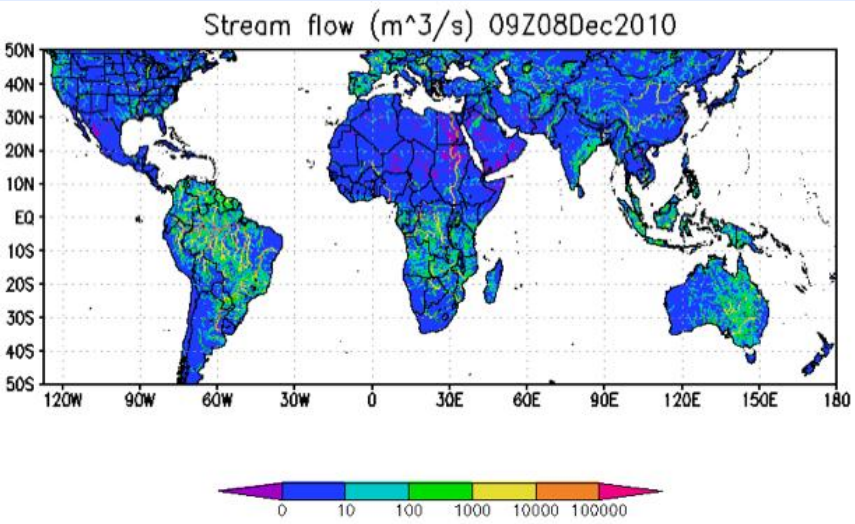


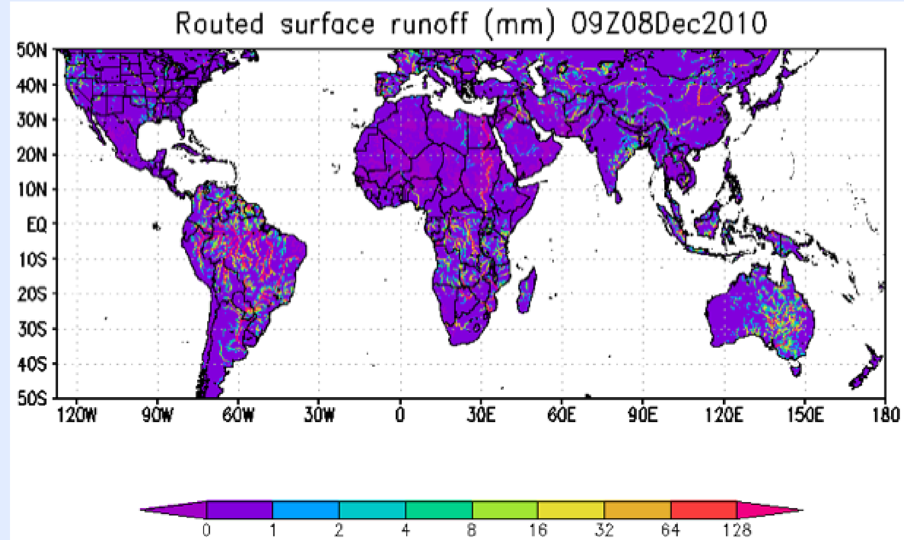
Wang J., Y. Hong., L. Li., J.J. Gourley., K. Yilmaz., Khan S. I., Policelli. F. S, Adler R. F., Habib S., Irwin. D., Limaye. S. A., Korme.T , and L. Okello, 2010, The Coupled Routing and Excess STorage (CREST) Distributed Hydrological Model. Hydrol. Science Journal (in press)

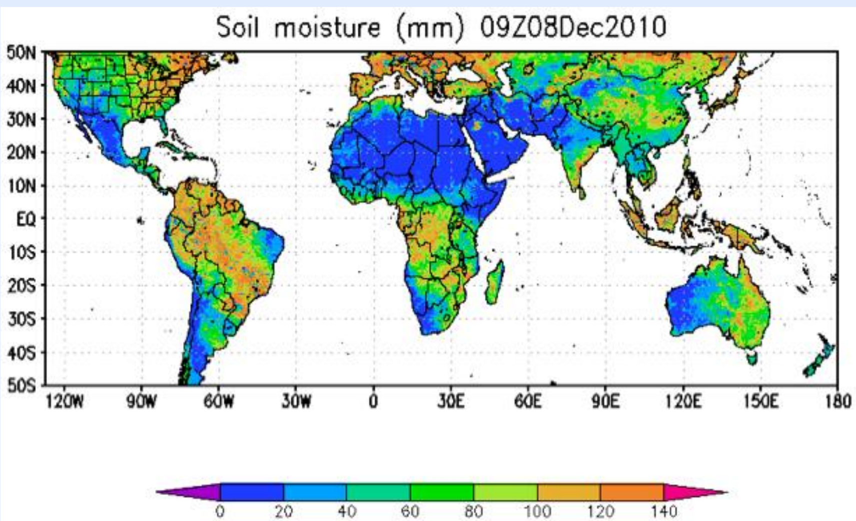
Initial Results with CREST Model using Default Parameters

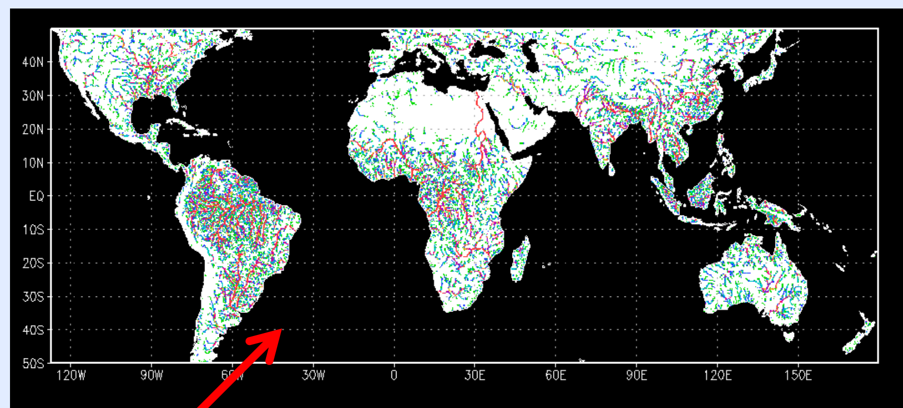


CREST Model Example Results (Yesterday)





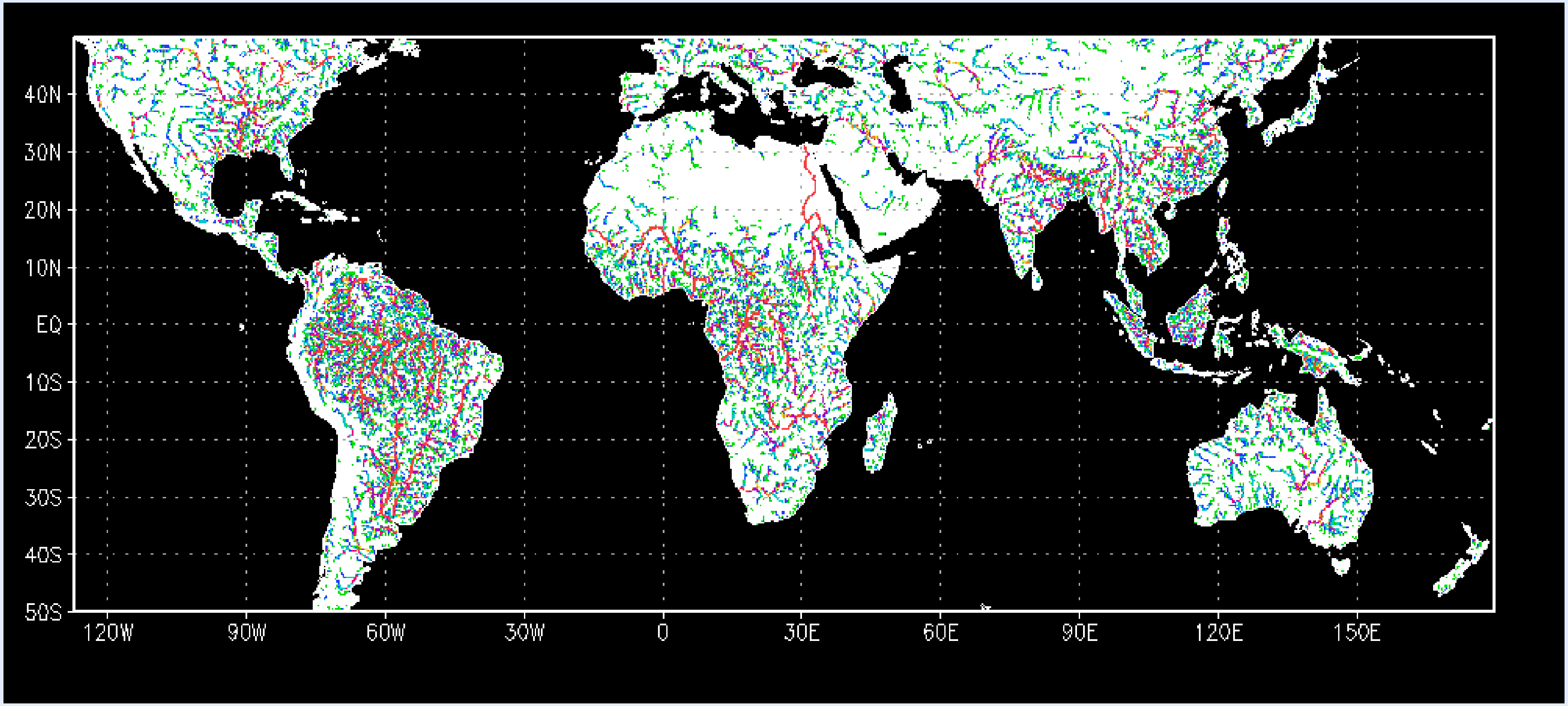




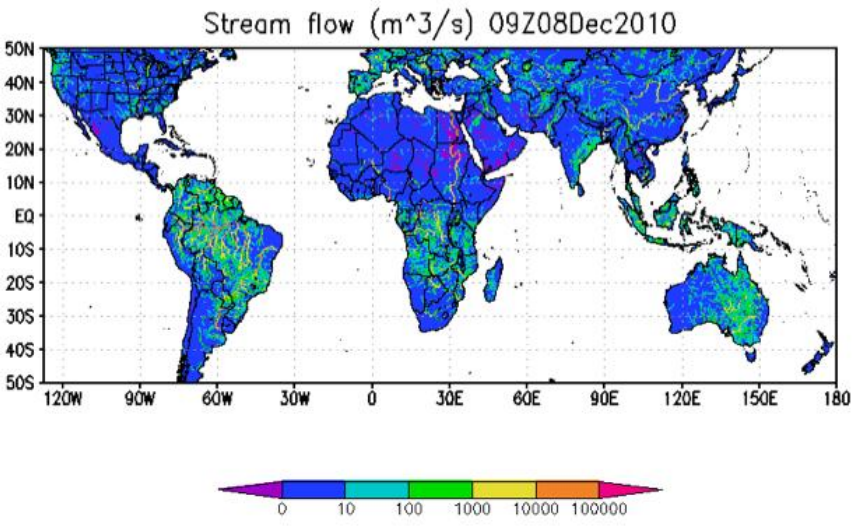
Reference Level: 95^{th} percentile of Routed Runoff from 10-year global hydrology model run using satellite rainfall data

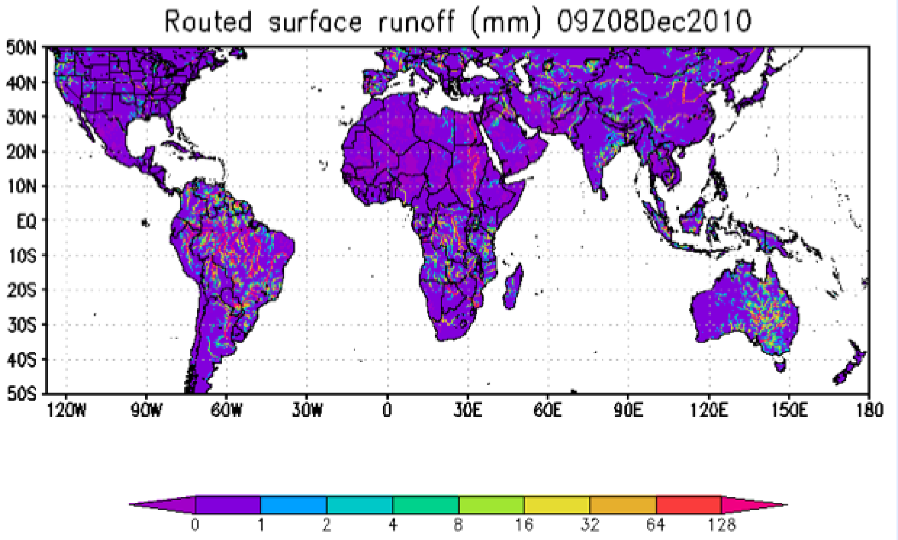
95% Routed Runoff Map

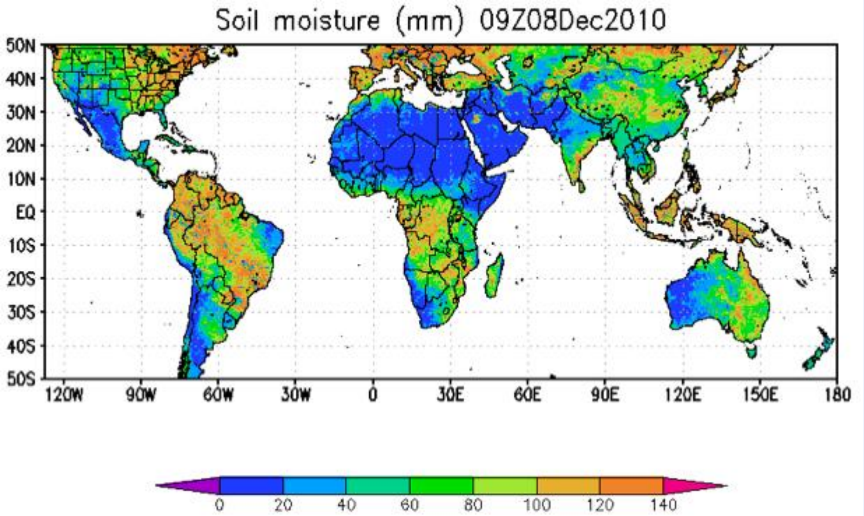
(from 10-year retrospective model run)

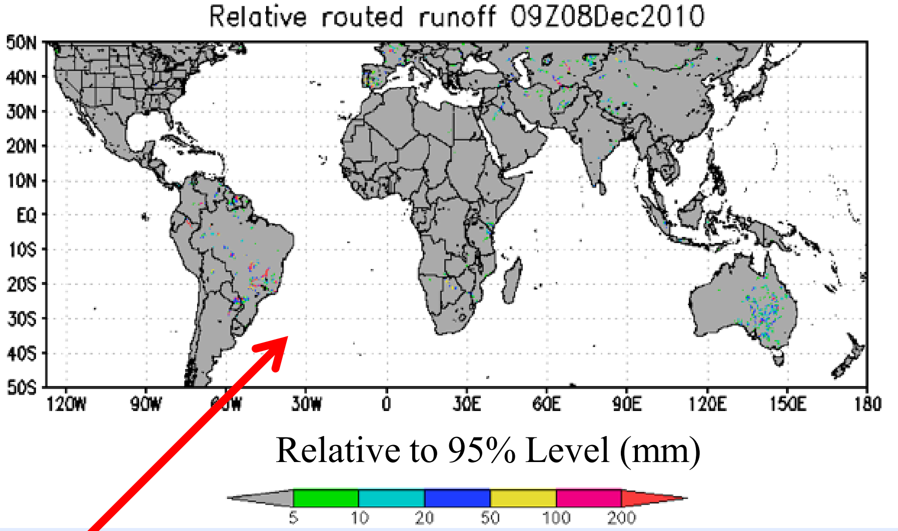


CREST Model Example Results (Yesterday)



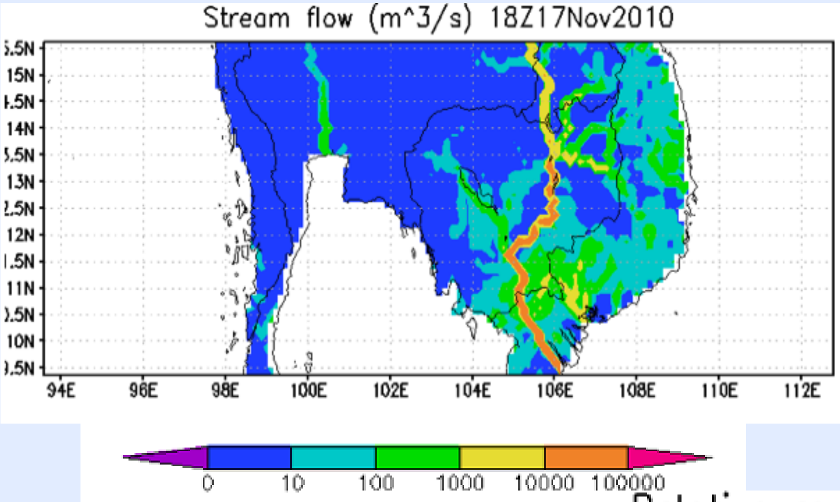


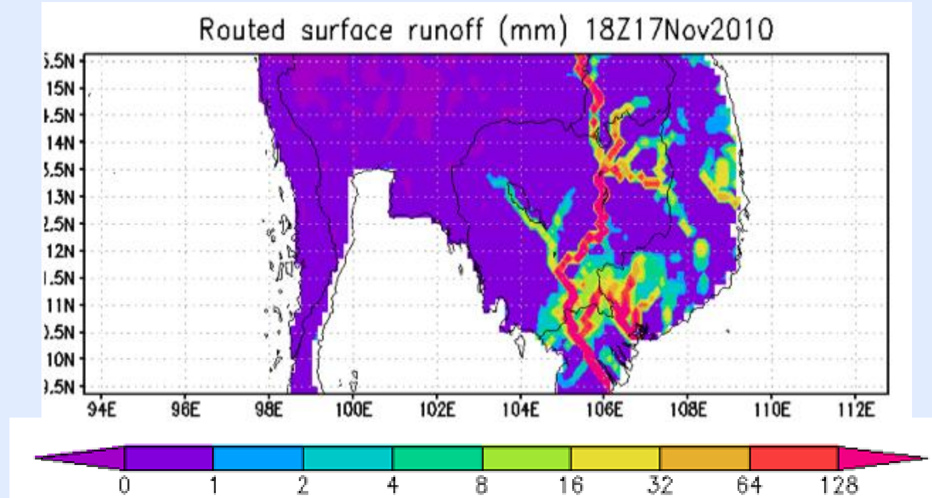


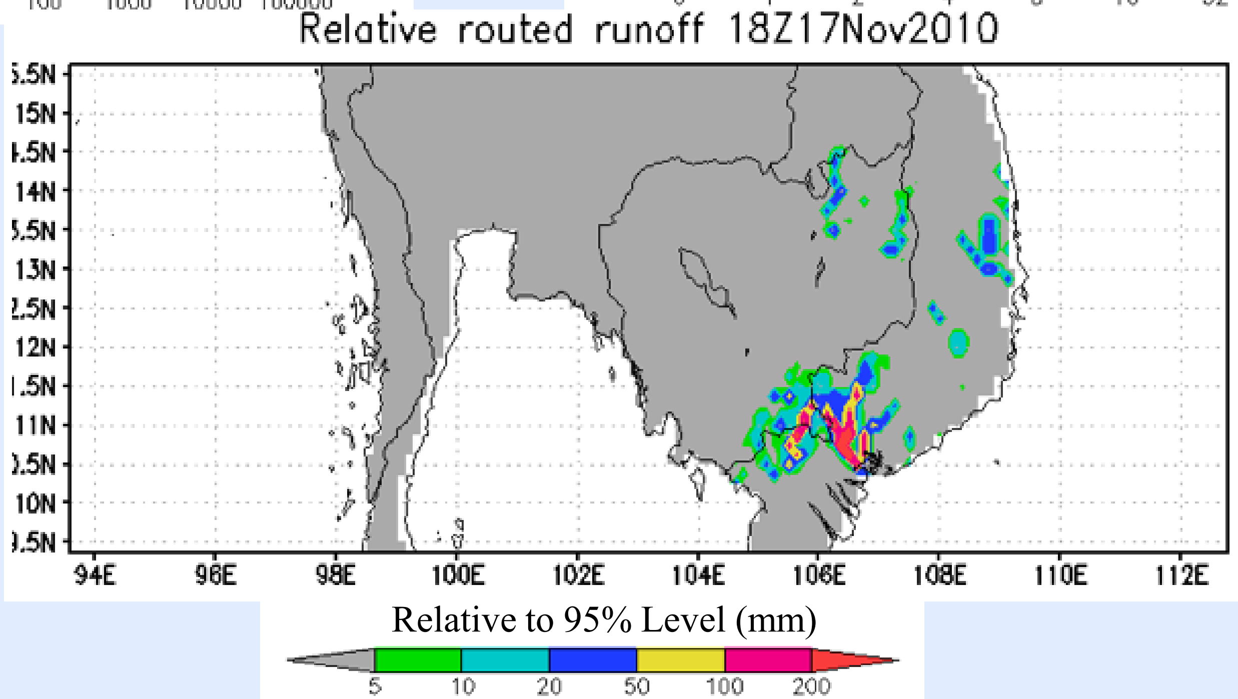


Reference Level: 95th percentile of Routed Runoff from 10-year global hydrology model run using satellite rainfall data

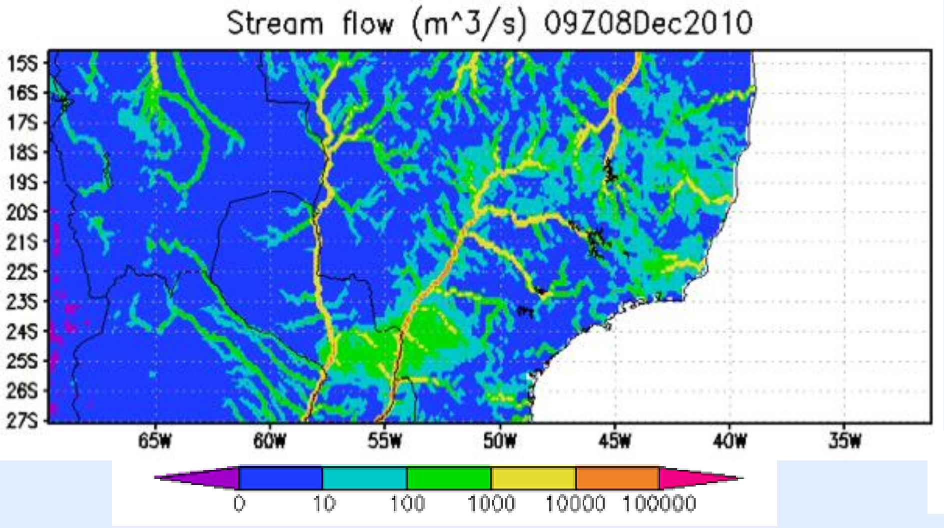
CREST Model Result Example from a Few Weeks Ago

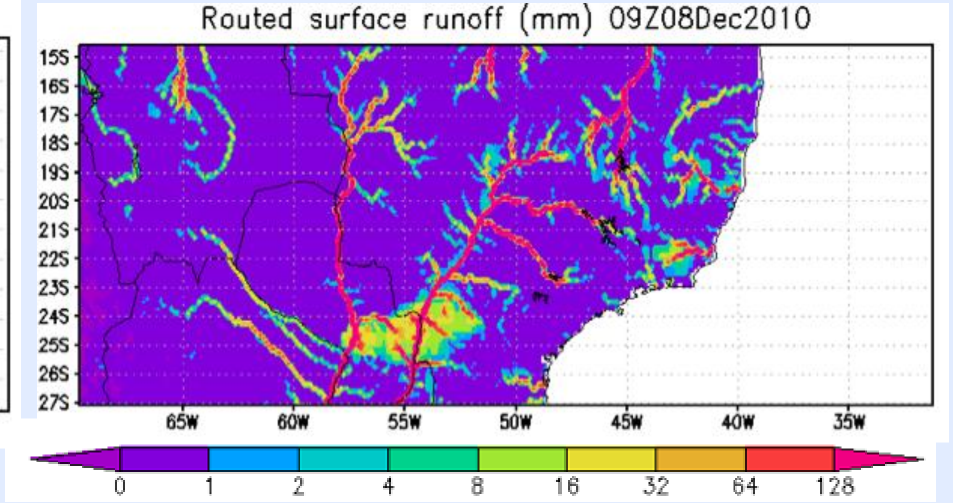


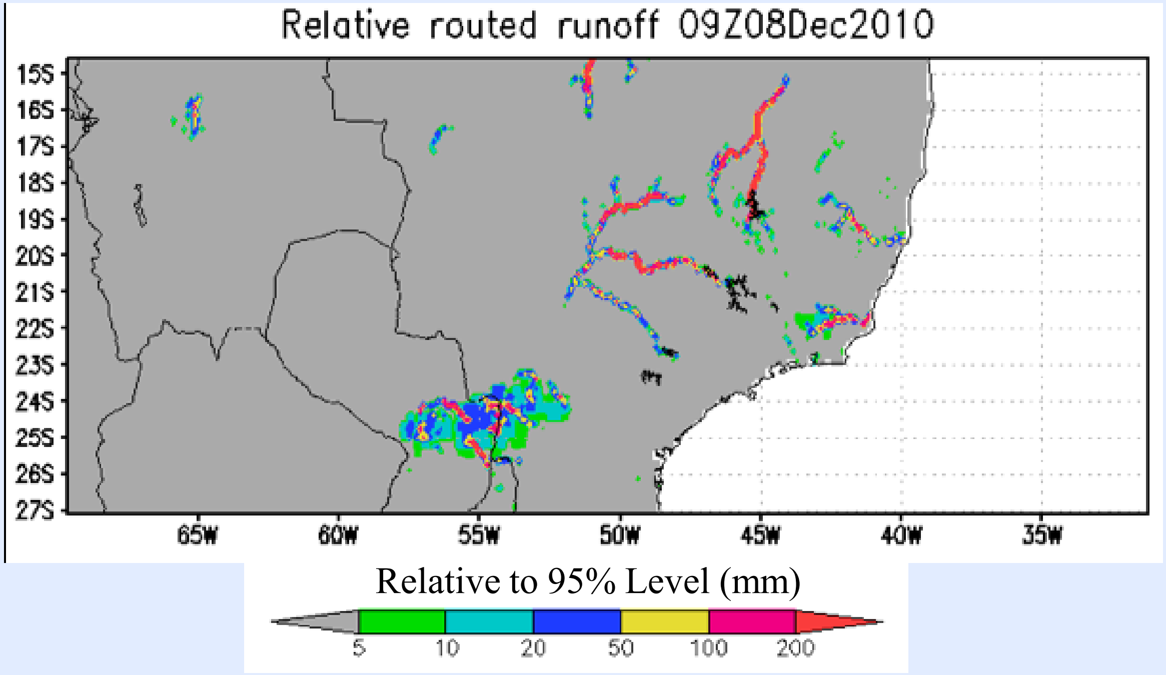




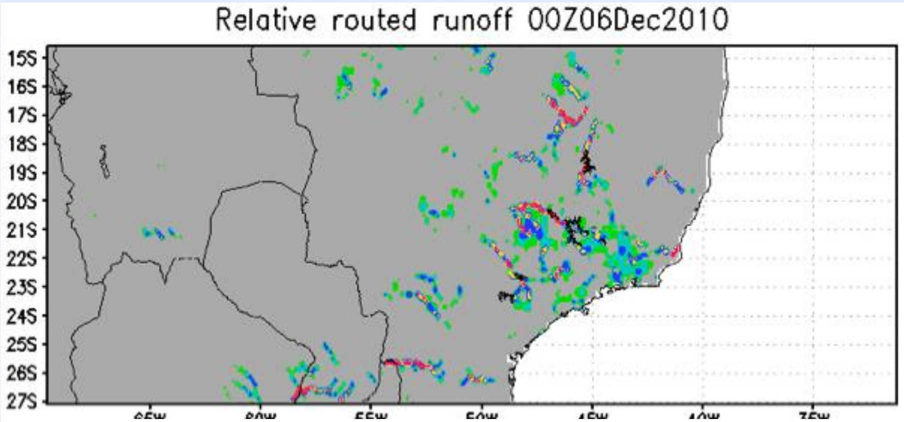
CREST Model Results for Yesterday

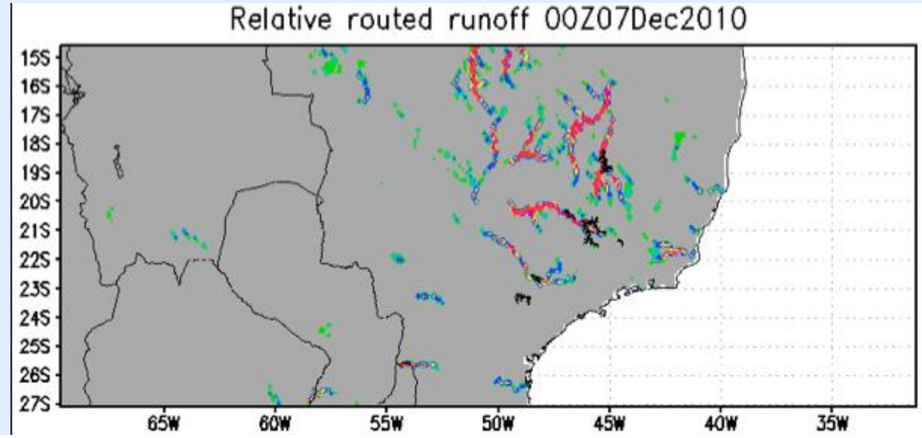


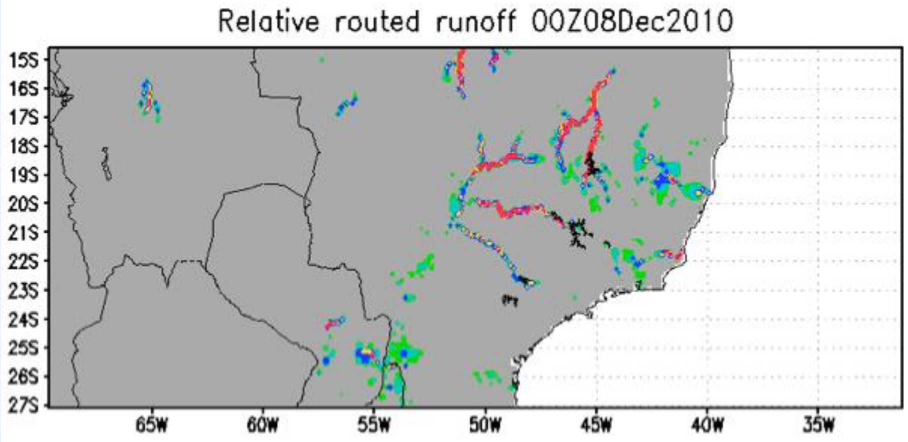


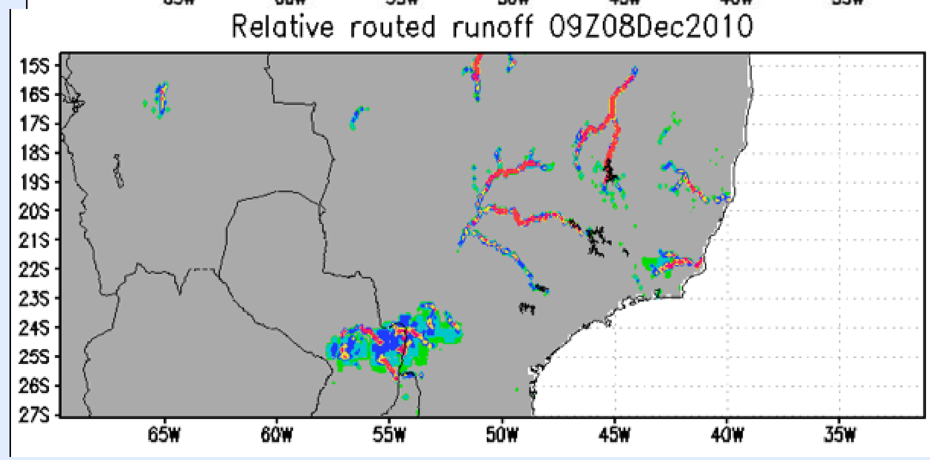


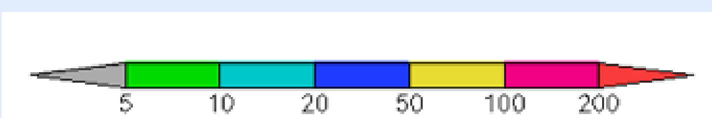
CREST Model Results for Last Few Days



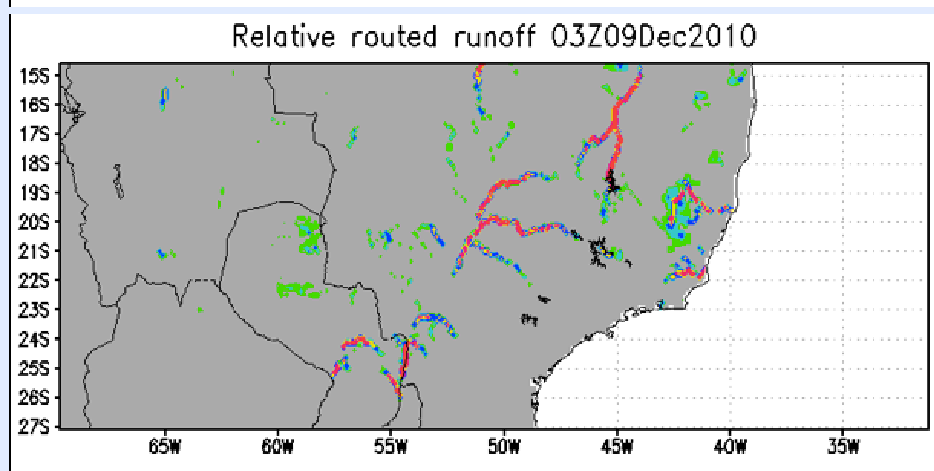








Relative to 95% Level (mm)

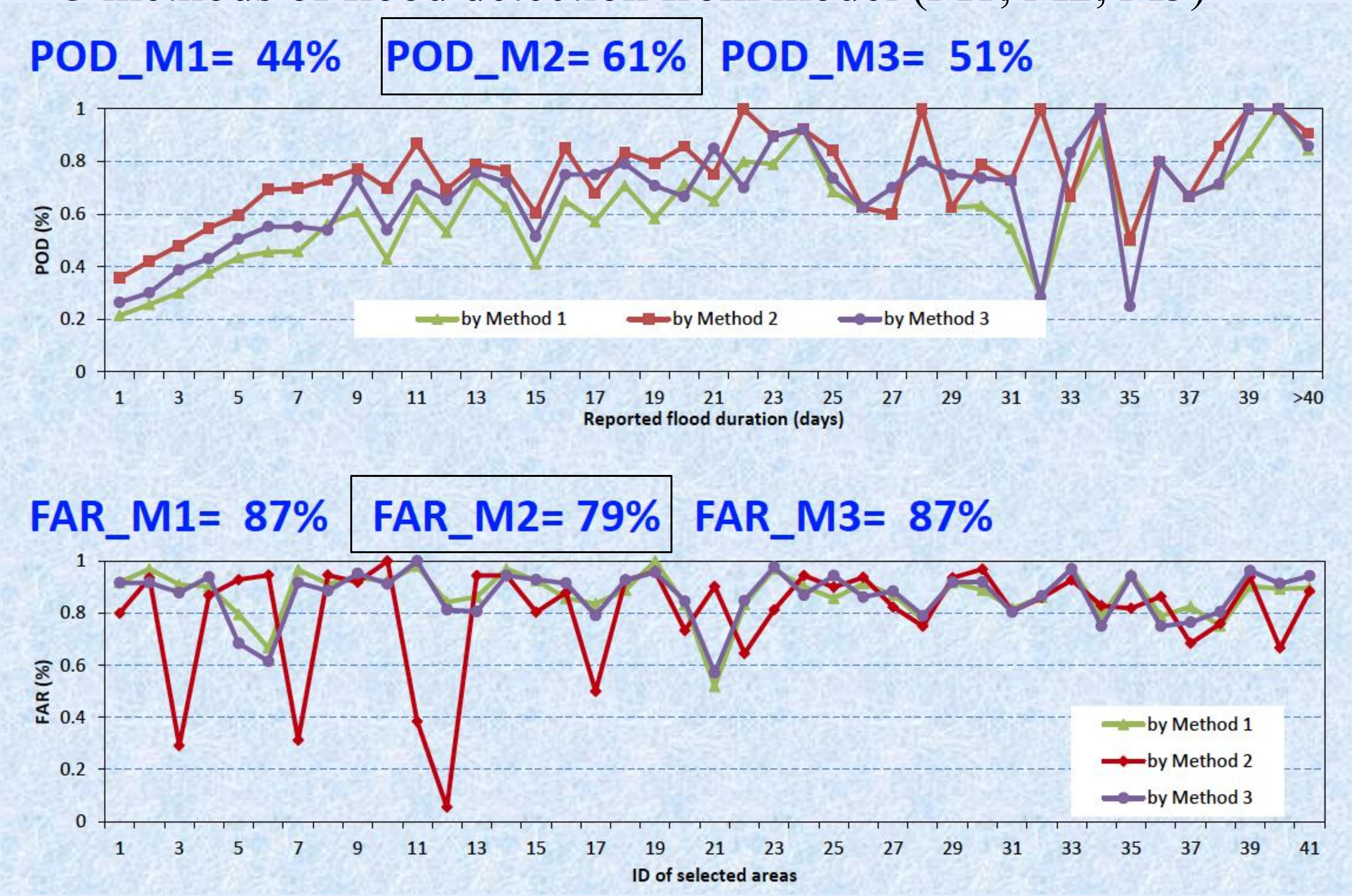


Evaluation of New Model vs. Flood Inventory Data—Ongoing Work

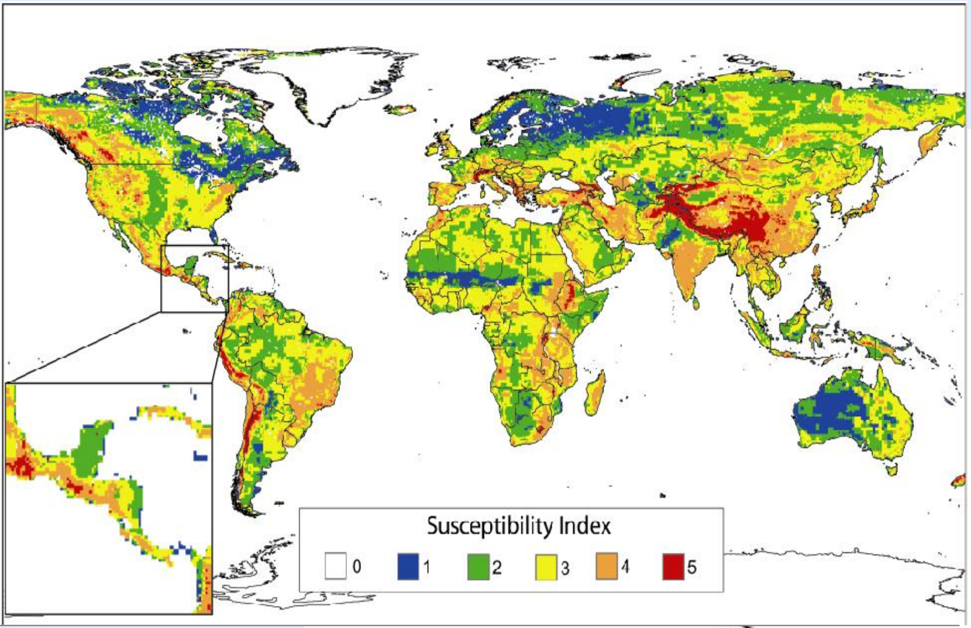
3 methods of flood detection from model (M1, M2, M3)

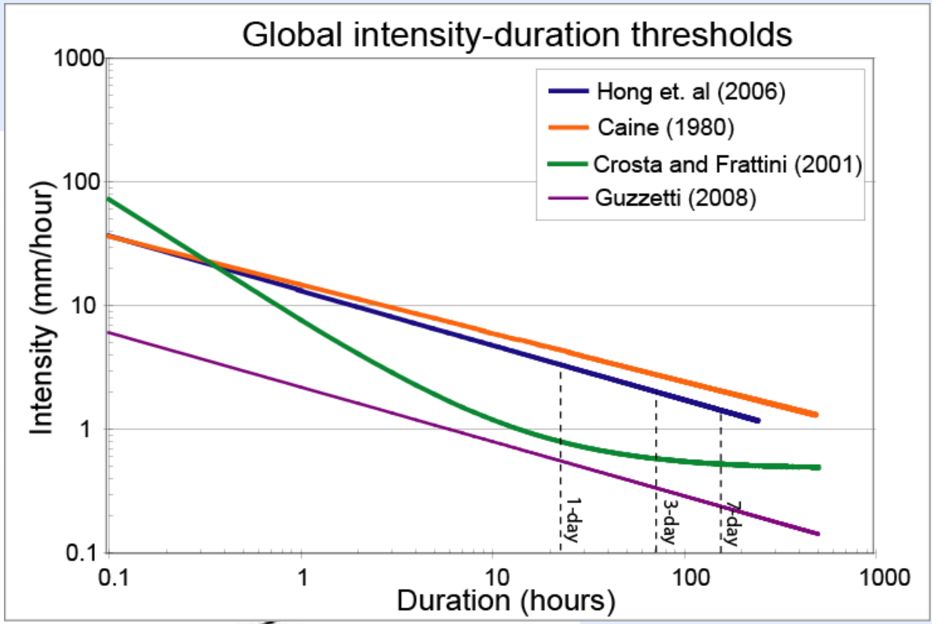
POD goes up with flood duration

FAR lower in "well monitored" areas without dams



Global Landslide Occurrence Algorithm





Circles enclose small areas of estimated landslide locations

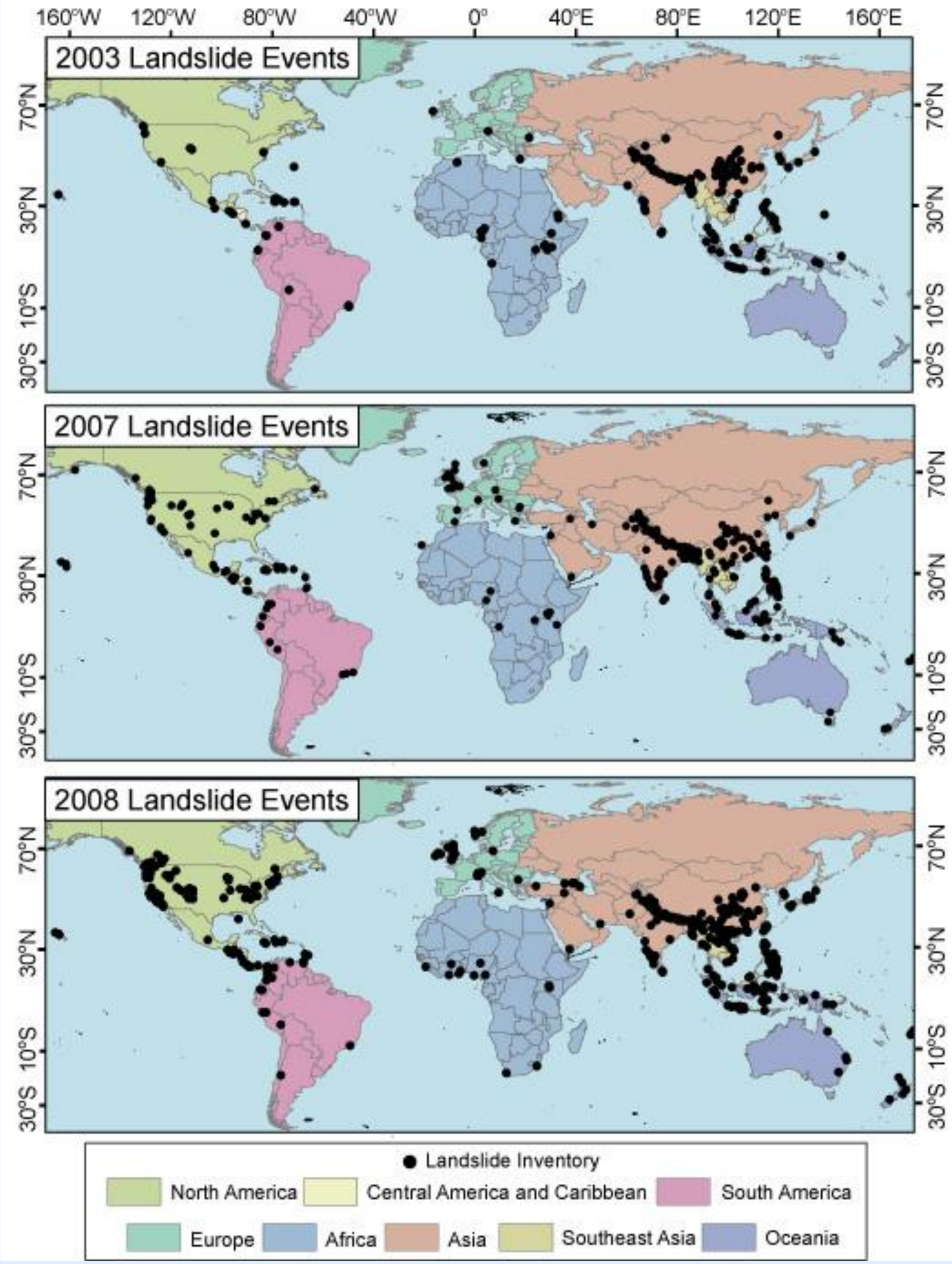
Surface Data:

- Topographic variables
- Land cover
- Soil Type and Texture
- Drainage Density

Rainfall Data:
TRMM Multi-Satellite Precipitation Analysis (TMPA)
0.25° pixel resolution, 3-hourly

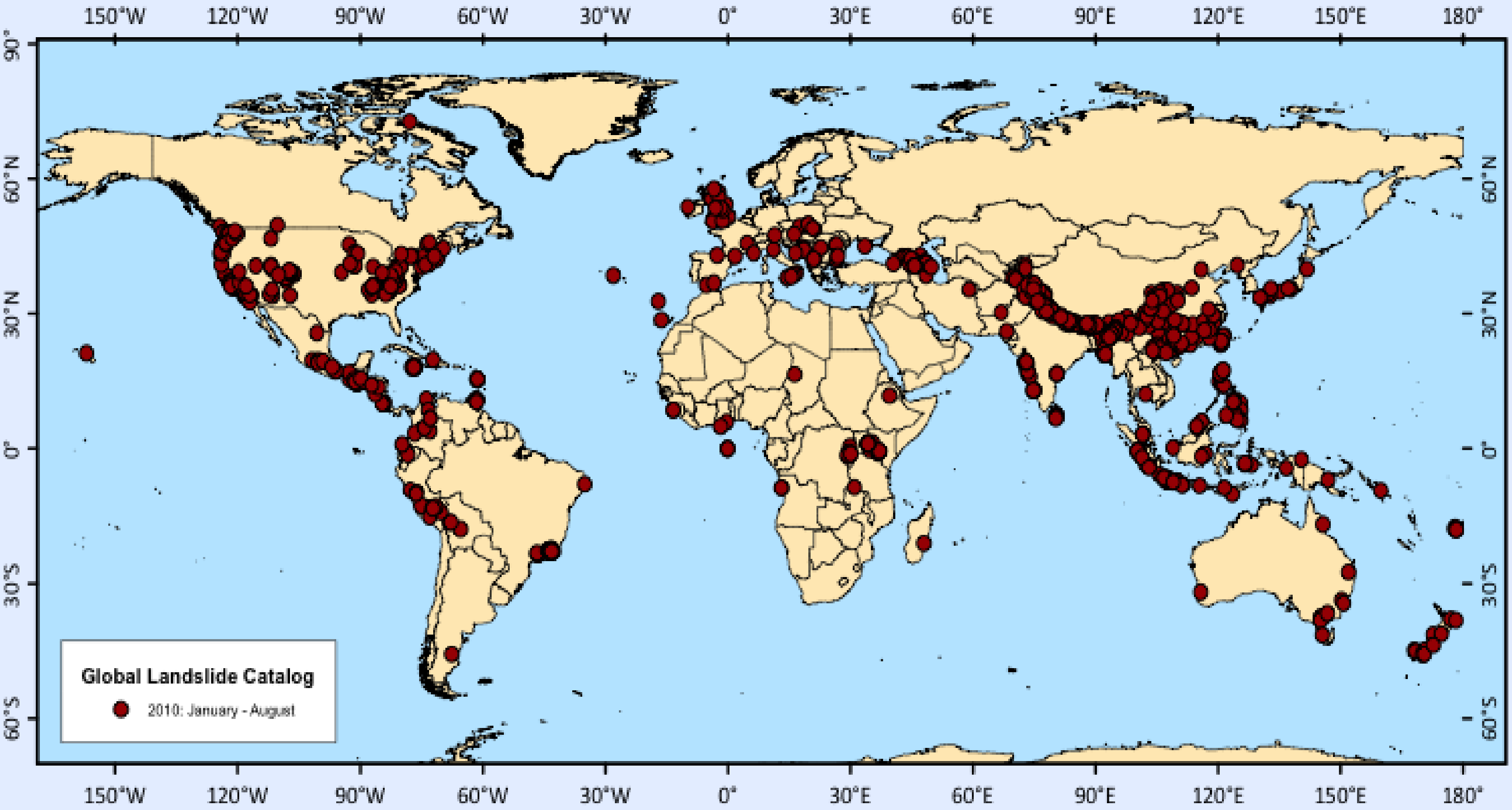
Global Landslide Event Inventory

- Three Year Database:
  - **1,181** events
  - **6,366** fatalities
- Reports from 67 countries
- Work is ongoing for 2010



Kirschbaum, D. B., R. Adler, Y. Hong, S. Hill and A. L. Lerner-Lam (2009). Journal of Natural Hazards

Landslide Inventory for January through August, 2010



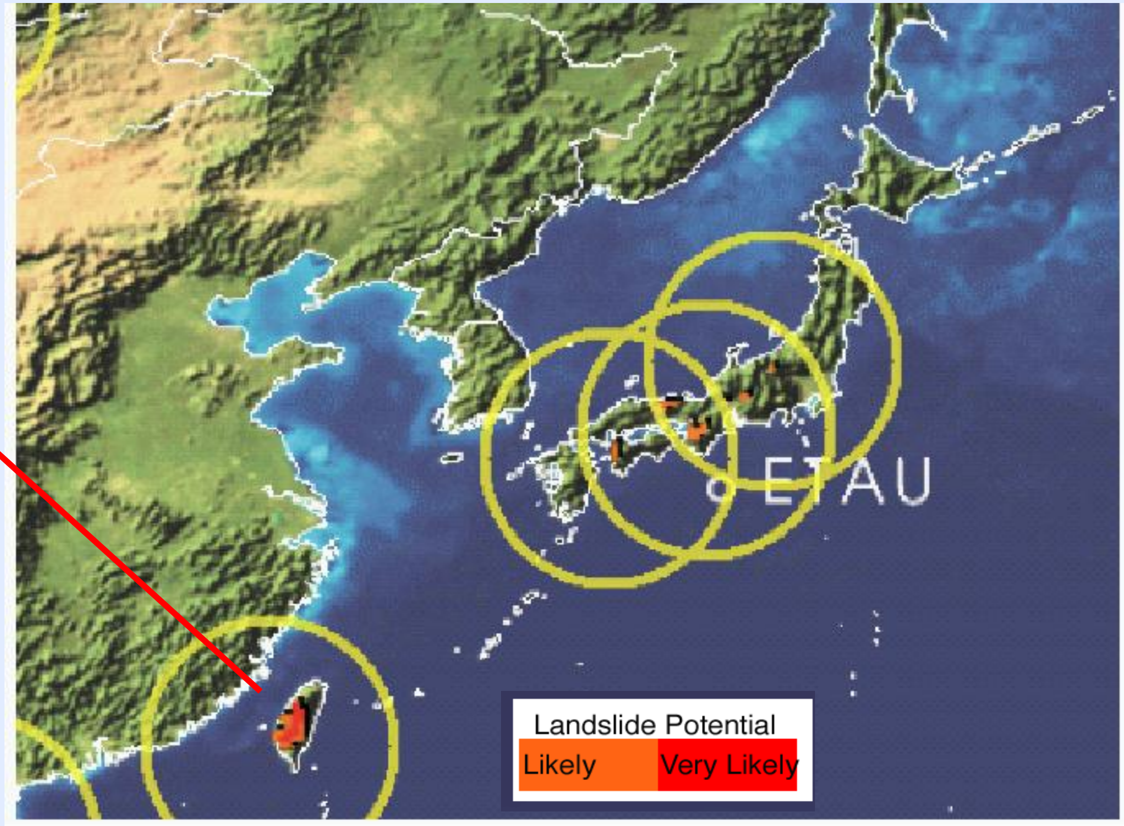
925 Events 239 fatal events 4306 fatalities

Kirschbaum, D. B., R. Adler, Y. Hong, S. Hill and A. L. Lerner-Lam (2009). Journal of Natural Hazards

Example of Landslide Nowcast/Forecast

Typhoon Morakot (Etau) August 8, 2009

Numerous and **massive landslides** throughout Southern and Central Taiwan. Over 500 people killed in Shiao Lin



Evaluation of Global Landslide Algorithm

Skill Ratio

Forecast Density

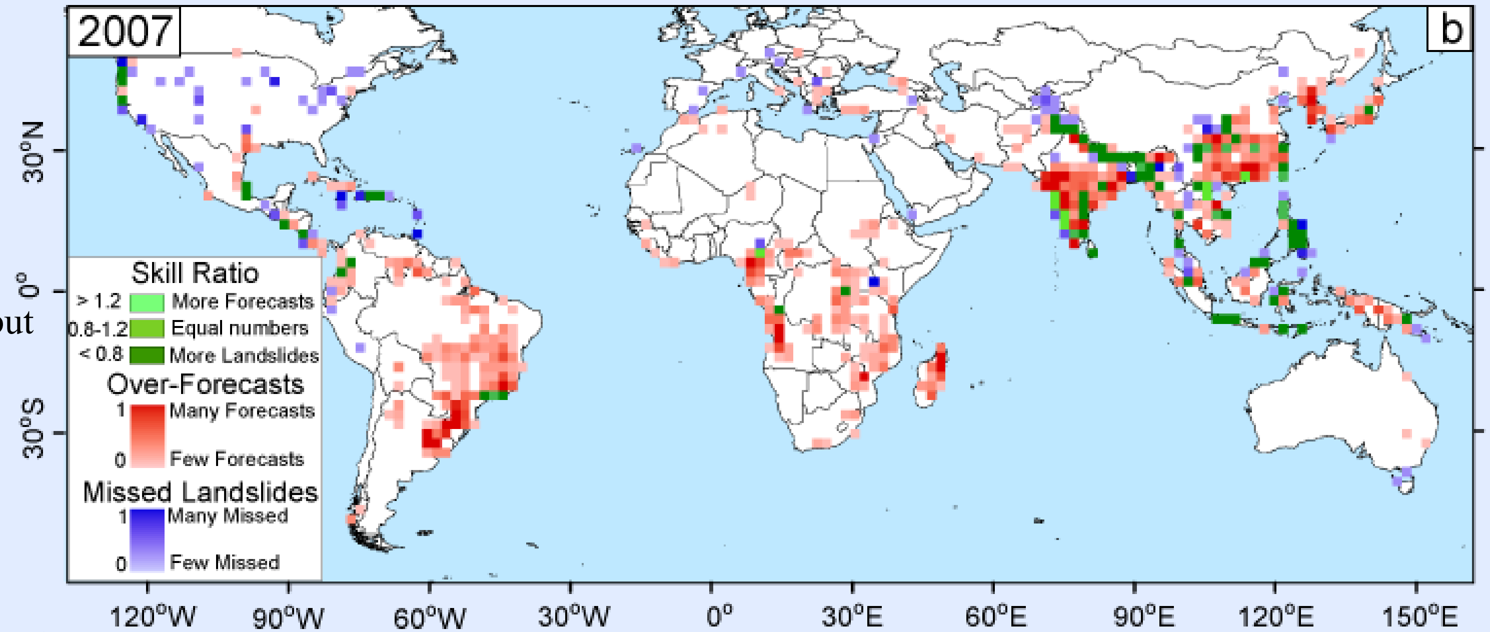
Landslide Density

Over-Forecasts

Pixels with forecasts but no landslides, norm.

Missed Landslides

Pixels with landslides but no forecasts, norm.



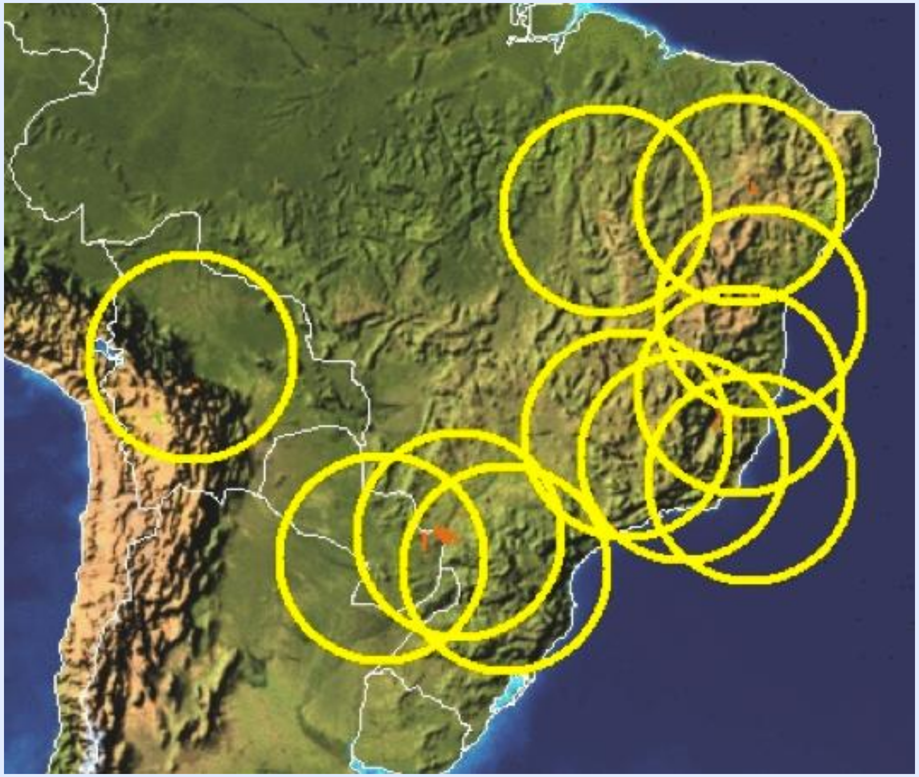
Kirschbaum, D. B., R. Adler, Y. Hong and A. L. Lerner-Lam (2009). "Evaluation of a Satellite-based Landslide Algorithm using Global Landslide Inventories." Natural Hazards and Earth System Sciences **9**: 673-686.

Today

9 DEC 2010 1200 UTC
(Observation Time Of Last Data)

Landslide Potential

Likely	Very Likely



After 3 Days of Rainfall

Main Reasons for Flood/Landslide Estimation Failures

- Errors/limitations in satellite rain estimates
  - coarse time resolution, especially affects small-scale events (e.g., flash floods)
  - shallow orographic rain underestimated by micowave
  - false rain signatures in mountains
- Flood model limitations
  - coarse spatial resolution (definition of river basins)
  - dams, levees not accounted for
- Landslide algorithm limitations
  - coarse resolution of susceptibility map (easy to improve)
  - need for very fine spatial resolution in rain fields
  - road cuts, other human impacts not accounted for

Global Precipitation Measurement (GPM) mission

U.S. (NASA)   Japan (JAXA/NICT)

Unify and advance precipitation measurements from space to provide next-generation global precipitation products within a consistent framework

U.S. Project Scientist: Arthur Hou - NASAGoddard

Low Inclination Observatory (40°)

GMI (10-183 GHz)
(NASA & Partner, 2014)

- Enhanced capability for near-realtime monitoring of hurricanes & midlatitude storms
- Improved estimation of rain accumulation

GPM Core Observatory (65°)

DPR (Ku-Ka band)
GMI (10-183 GHz)
(NASA-JAXA, Launch 2013)

- Precipitation physics observatory
- Transfer standard for inter-satellite calibration of constellation sensors

Partner Satellites:

GCOM-W1
DMSP F-18, F-19
Megha-Tropiques
MetOp, NOAA-19
NPP, JPSS (sounders)

Coverage & Sampling

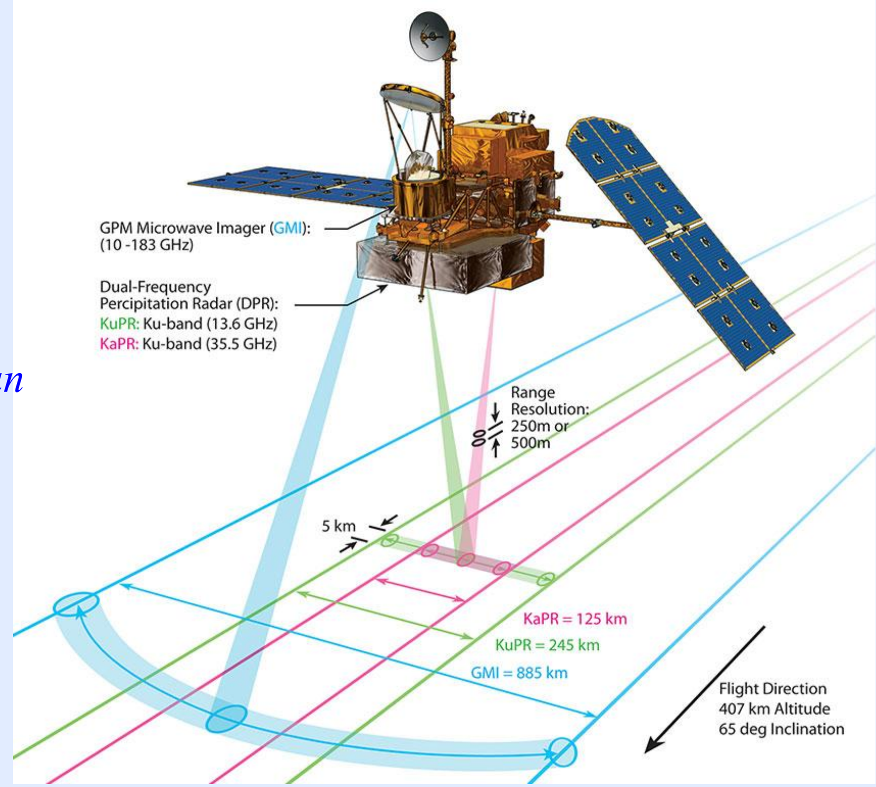
- 1-2 hr revisit time over land
- < 3 hr mean revisit time over 90% of globe

NOAA scientists involved, e.g., Xie (NCEP/CPC), Ferraro (NESDIS)

NASA-JAXA GPM Core Observatory

Dual-Frequency (Ku-Ka band) Precipitation Radar (DPR):

- *Increased sensitivity (~12 dBZ) for light rain and snow detection relative to TRMM*
- *Better measurement accuracy with differential attenuation correction*
- *Detailed microphysical information (DSD mean mass diameter & particle no. density) & identification of liquid, ice, and mixed-phase regions*



Multi-Channel (10-183 GHz) GPM Microwave Imager (GMI):

- *Higher spatial resolution (IFOV: 6-26 km)*
- *Improved sensitivity to light rain*
- *Improved signals of solid precipitation over land (especially over snow-covered surfaces)*
- *4-point calibration for nonlinearity removal and backup calibration reference during hot load anomalies*

Combined Radar-Radiometer Retrieval

- *DPR & GMI together provide greater constraints on possible solutions to improve retrieval accuracy*
- *Observation-based a-priori cloud database for constellation radiometer retrievals*

Conclusions

- Initial global flood and landslide models running in real-time with satellite precipitation estimates. Results are generally positive, but areas for significant improvement.
- Satellite precipitation estimation via passive microwave (workhorse of multi-satellite, merged products) has limits in shallow (warm) rain and coarse time (and space) resolutions. Solutions include use of ancillary data, geo-IR, model-generated (high res.) estimation

Future

- Improved precipitation information via time-space integration, geo-IR, ancillary data, model input, GPM
- Improved global hydrological modeling via finer resolution, nested approach, regional and basin tuning, accounting for water management (dams)
- Improved landslide estimation via better (higher resolution) suceptibility map, more physically-based algorithm, improved rainfall info.
- Use of NWP precip. info. in both global and regional context—as models improve joint use of satellite and model rainfall and these type of applications will improve