

WCRP VAMOS/CORDEX Workshop on Latin-America and Caribbean.
CORDEX LAC: Phase I - South America. September 11-13, 2013, Lima, Perú

Terrestrial Flood Risk and Climate Change in the Yallahs River, Jamaica

An assessment of future flood risk using hydrodynamic models driven by projections of future climate

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Introduction



- Flooding is one of the major natural hazards affecting Jamaica.
 - Has been negatively affected by severe weather events
 - Repeated flooding (2004, 2007, 2008, 2010) has been very costly both in terms of lives and livelihoods.
- Analysis of the number of hurricanes/ tropical storms affecting Jamaica and the variability of the rainfall pattern has shown changes in trends in the years 2001-2012.
 - Shifts in traditional peak rainfall months of May and September-October has shifted to June and November in some years.
 - Shorter duration high intensity rainfall associated with stationery fronts and troughs
 - IPCC outlook shows an increasing likelihood of more intense hurricanes, which would result in increased frequency of flooding due intensive rainfall.

Introduction: Jamaica



Jamaica has a tropical maritime (marine) climate. Mean daily temperature ranges from a seasonal low of 26 °C in February to a high of 28° C in August (33 °C in recent years).

Islandwide long term mean annual rainfall exhibits a characteristic pattern, with the primary maximum in October and the secondary in May. The main dry season lasts from December to April.

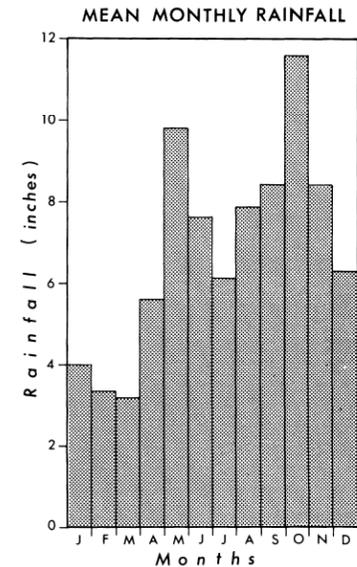


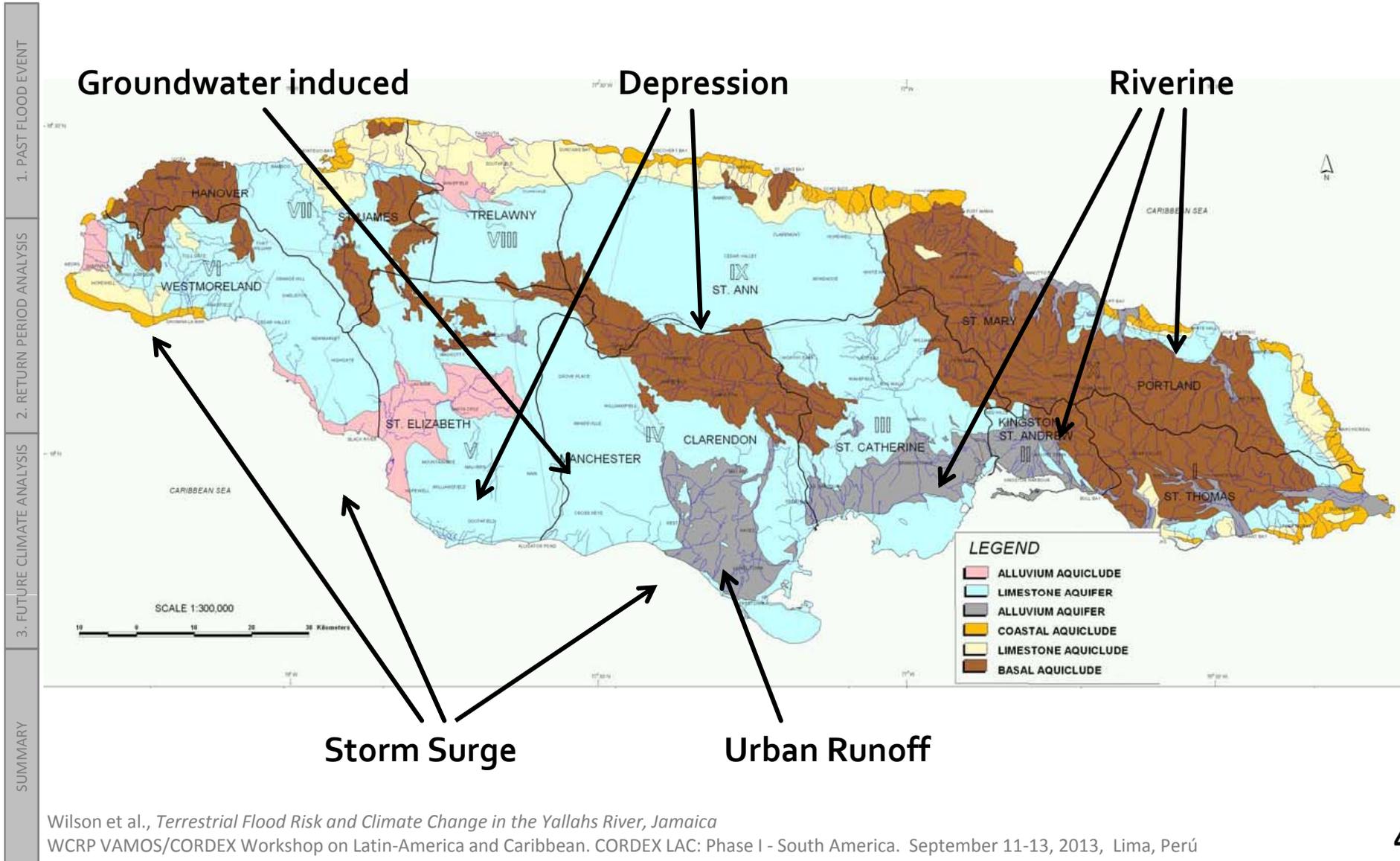
FIG. 4—Mean monthly rainfall. Source: Compiled from data obtained from Jamaica Meteorological Service.

Wilson et al., *Terrestrial Flood Risk and Climate Change in the Yallahs River, Jamaica*

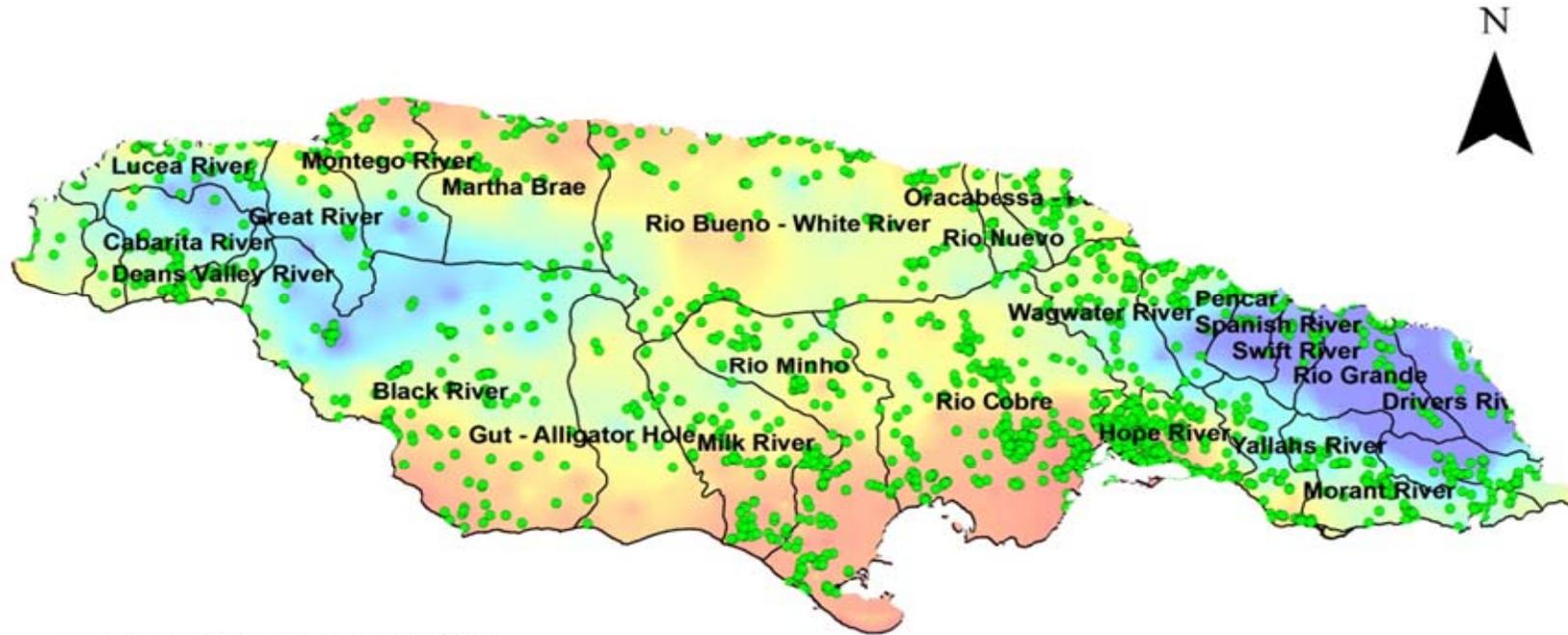
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Types of flooding in Jamaica



Reported flood events



● REPORTED FLOOD EVENTS

Legend

30YEAR ANNUAL RAINFALL (mm)

Value



0 15 30 60 Kilometers

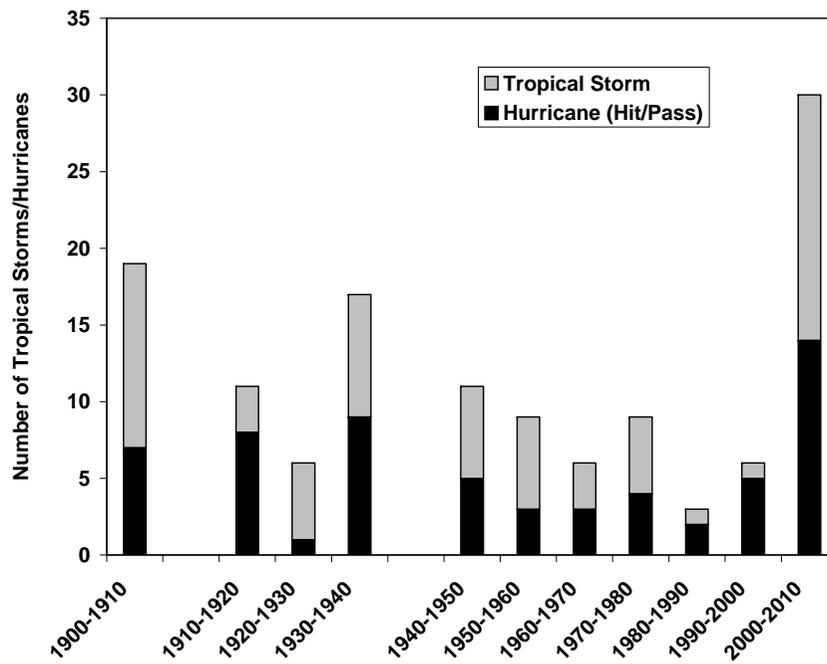


Data from Mona Geoinformatix Institute, CEAC Solutions Ltd, ODPEM and Water Resources Authority of Jamaica

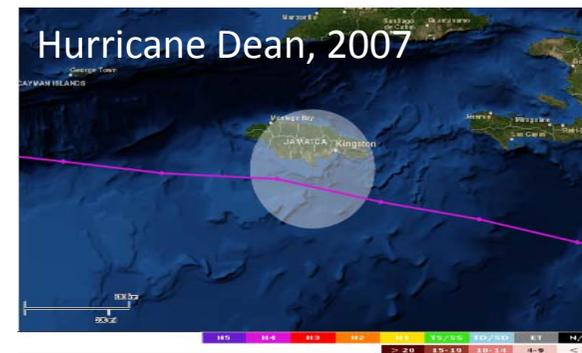
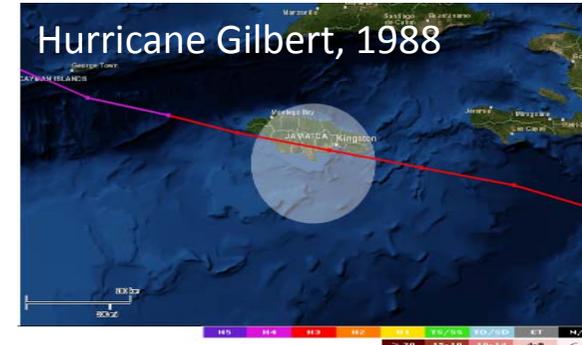
Hurricanes and tropical storms affecting Jamaica



Jamaica is located in the Atlantic Hurricane belt and is exposed to severe flooding from high intensity rains associated with tropical storms and hurricanes.



Data from Metservice of Jamaica



Wilson et al., *Terrestrial Flood Risk and Climate Change in the Yallahs River, Jamaica*

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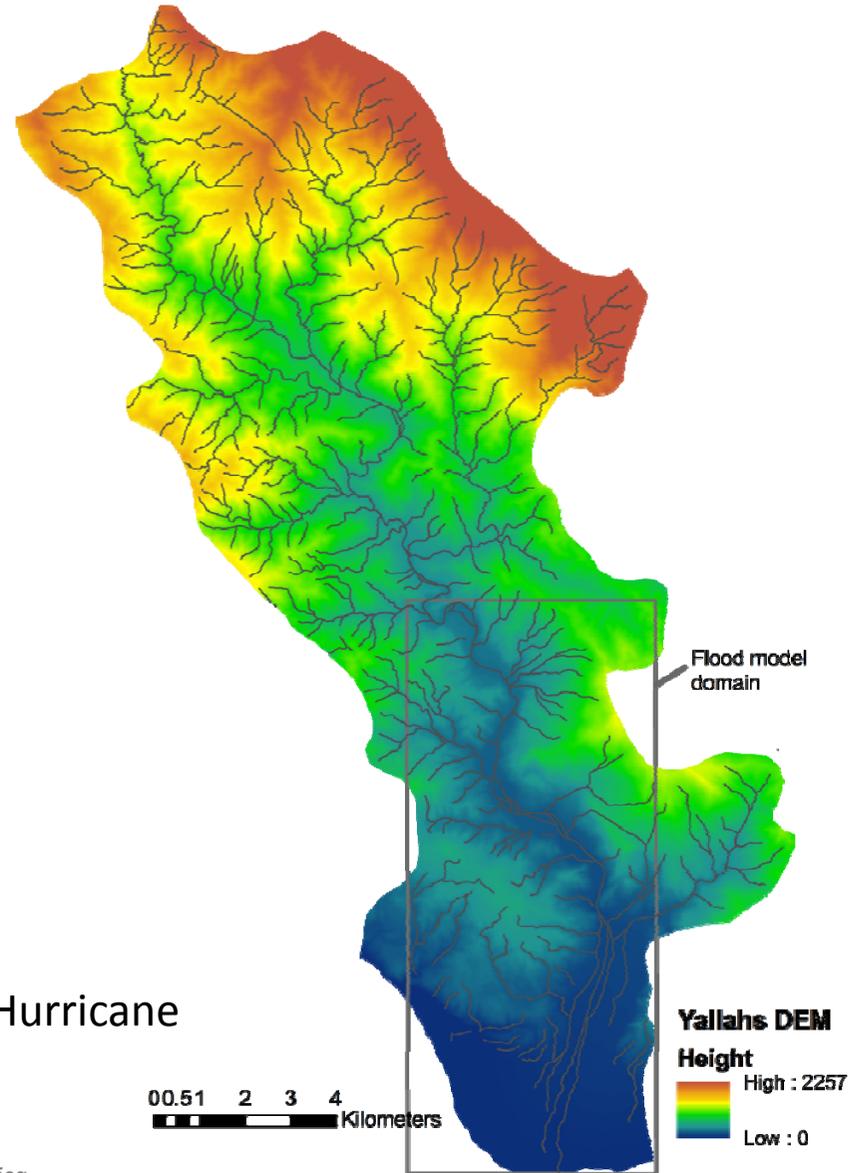
Project background



- Driving questions:
 - *What are the potential impacts of climate change on Jamaica's vulnerability to flooding from extreme events?*
 - *What adaptation measures can be carried out for affected communities to cope with increasing flood risk and what is the impact of flood events on properties and livelihoods?*
- Aim:
 - To assess current and future flood risk for the Yallahs River, Jamaica
- Methods:
 - Analysis of measured rainfall
 - Climate model conditioned on rainfall
 - Models of catchment hydrology and flood hydraulics
- Part of the larger project: *Impact of Climate Change on Flooding on inland flooding in Jamaica, present and future scenarios. Risk and adaptation measures for vulnerable communities.*
 - Funded by Climate and Development Knowledge Network (CDKN)/ Caribsave
 - Project is also assessing the Orange River in west Jamaica (Negril)



Study site: Yallahs River



Upland catchment in south-east Jamaica, draining the Blue Mountains.

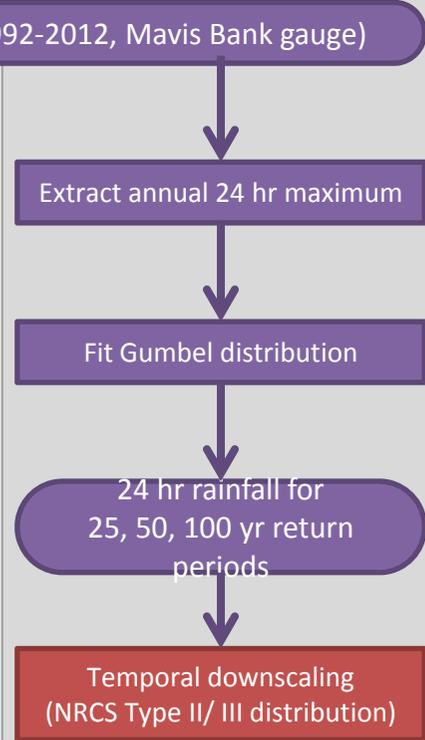
Major riverine flooding associated with Hurricane Gustav (28 August 2008).

Flood analysis method summary

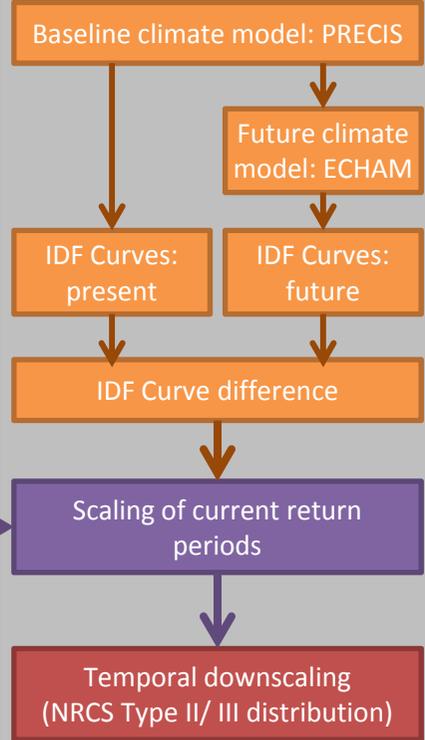
1. Past flood analysis



2. Current flood risk

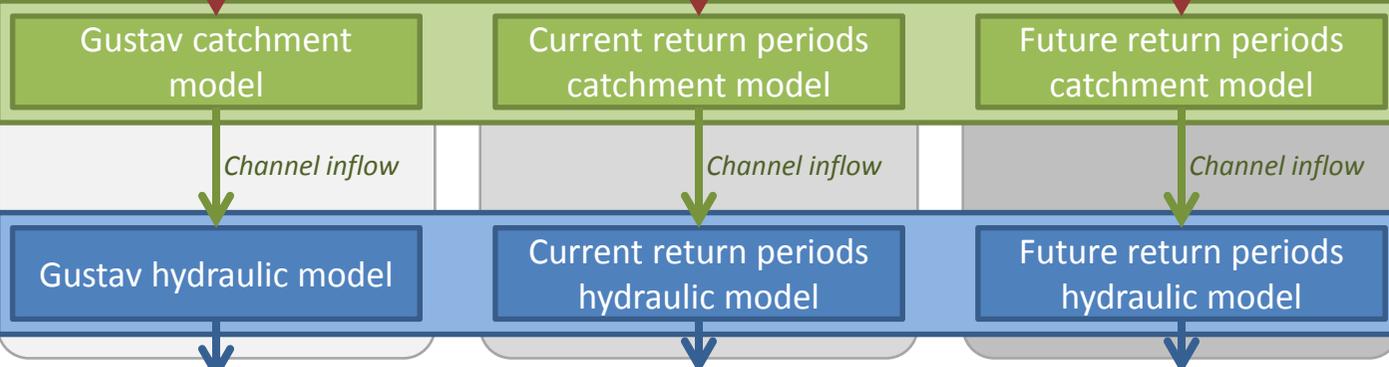


3. Future flood risk



Topography
River network
Land use/ cover
Water balance

Floodplain topography
Channel geometry



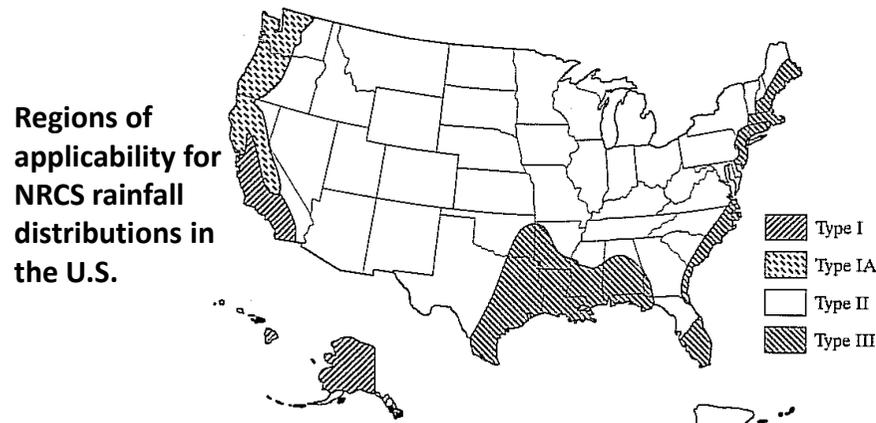
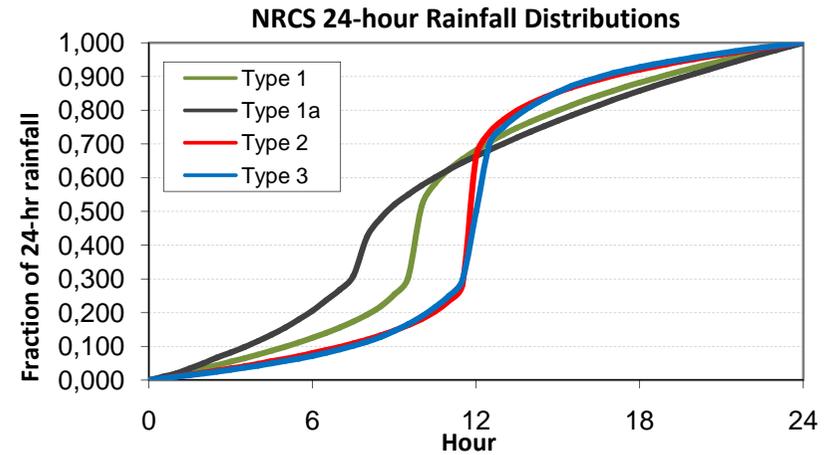
Inundation extents, depths and flood wave timings



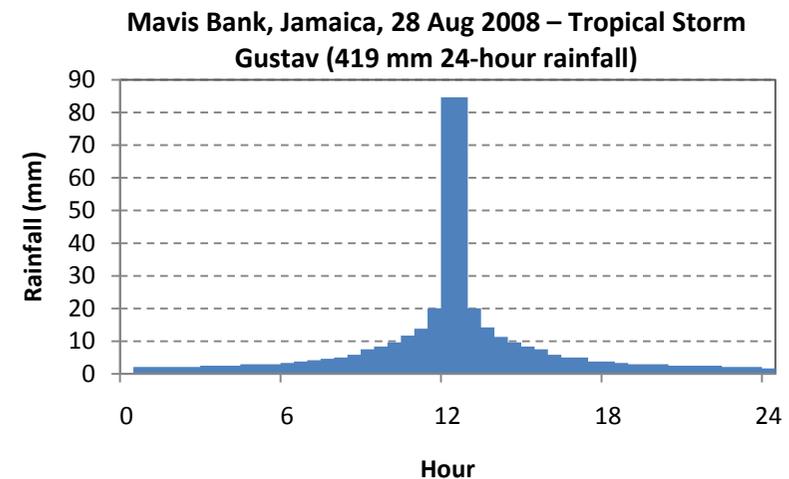
Methods: Temporal downscaling of rainfall



- Temporal downscaling necessary since we have 24-hour rainfall data
 - Using data directly would not represent peak flow during short-duration extreme events
- NRCS Method (National Resources Conservation Service - USDA) – Type-II
- Simple temporal transformation of 24-hour rainfall



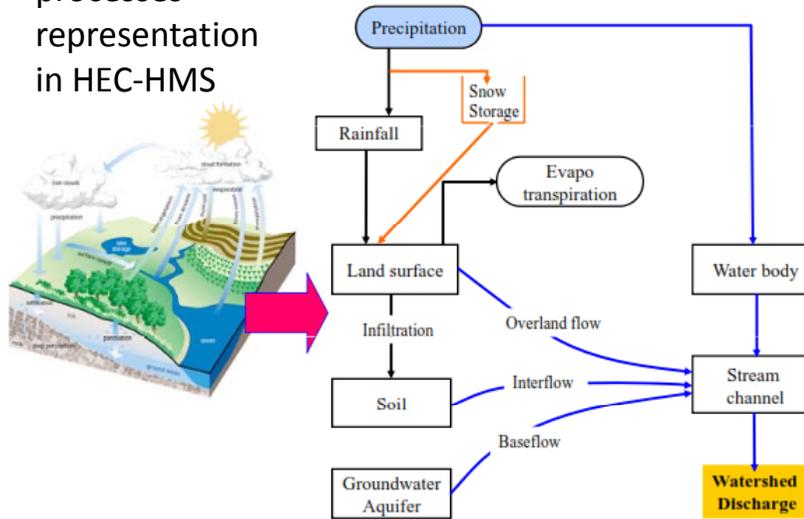
Wurbs & James (2002), *Water Resource Engineering*, Prentice-Hall



Methods: HEC-HMS



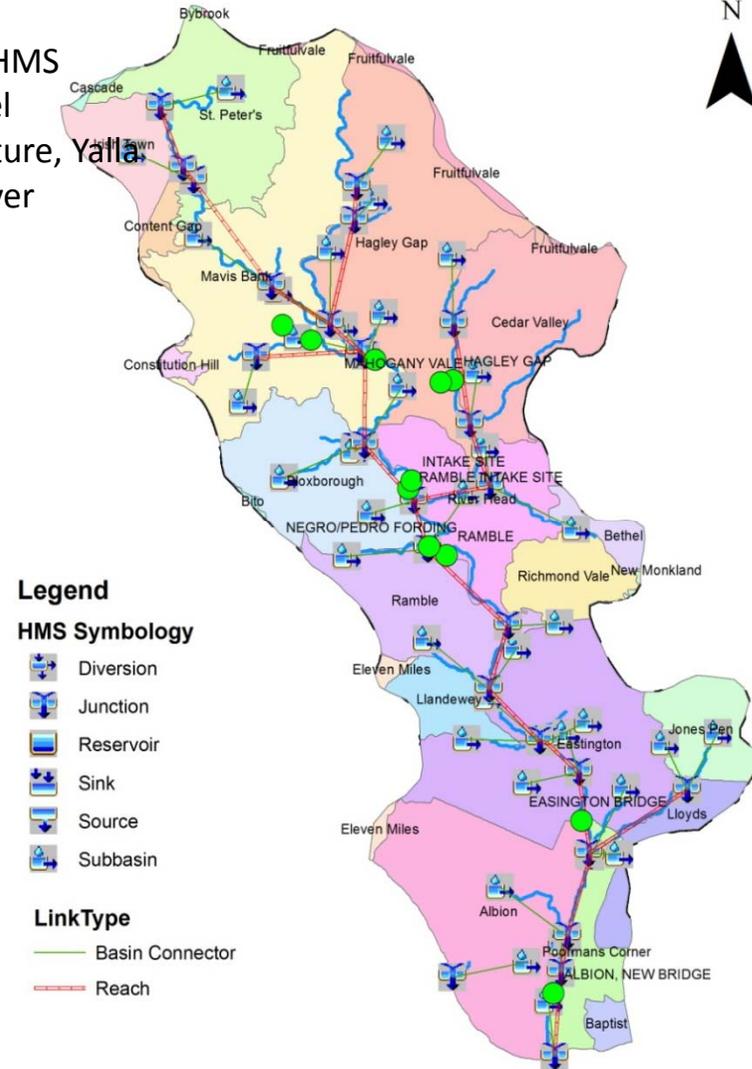
Hydrologic processes representation in HEC-HMS



1. • METEROLOGICAL MODEL
• Climatological Data
2. • BASIN MODEL
• Connectivity and Element Data
3. • CONTROL SPECIFICATIONS
• Simulation Duration & Time Steps

SCS loss method/ basin lag used;
Muskingham flood wave routing

HEC-HMS model structure, Yallahs River

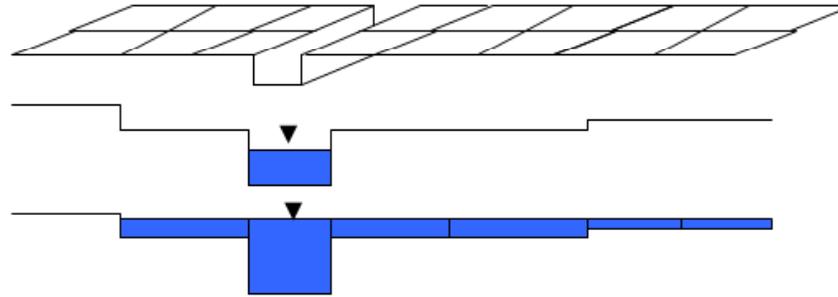


Methods: LISFLOOD-FP



Hybrid 1D/2D model

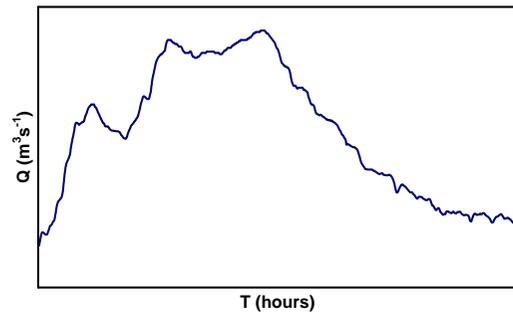
- Based on raster DEM
- 1D model in the channel
- Once bankfull depth is exceeded flow on the floodplain is calculated in 2D.



Model discretization of floodplain and channel topography

In-channel flow routed using a 1D wave equation

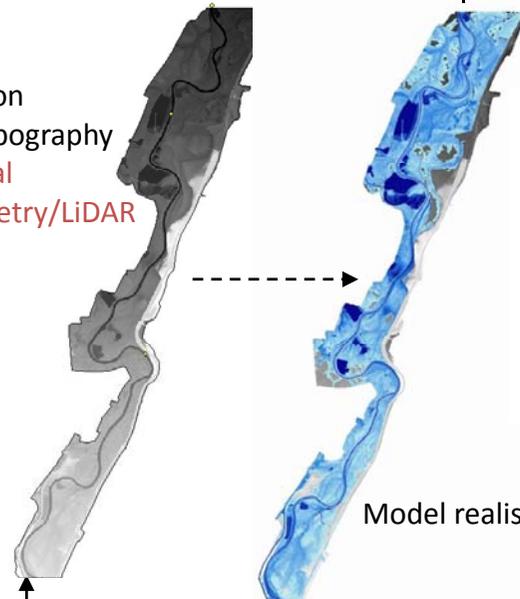
Once bankfull depth is exceeded water can flow laterally over adjacent low lying floodplains according to topography and free surface gradient



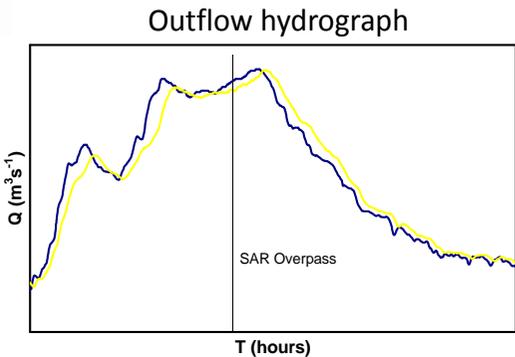
Inflow hydrograph (QT)

Source: Gauging station records or hydrological model output (e.g. HEC-HMS)

High resolution floodplain topography
Source: Digital photogrammetry/LiDAR



Model realisation

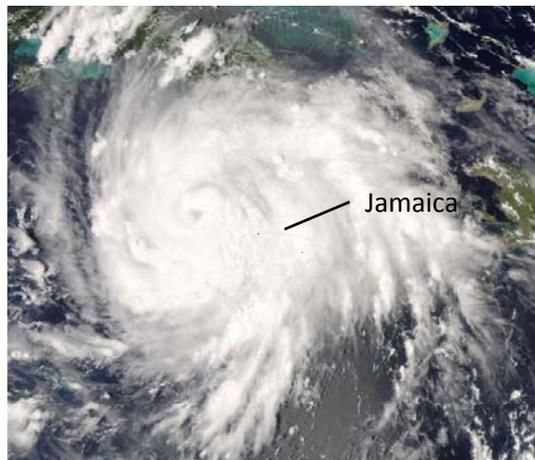
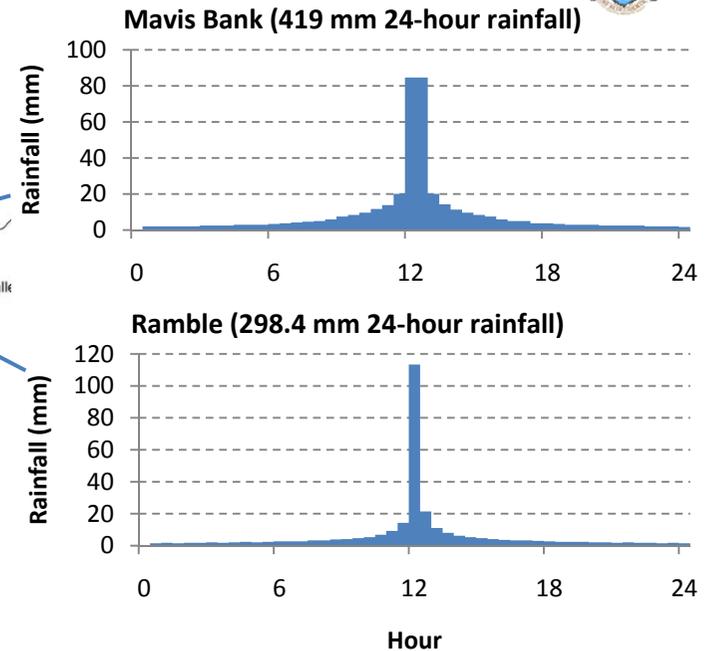
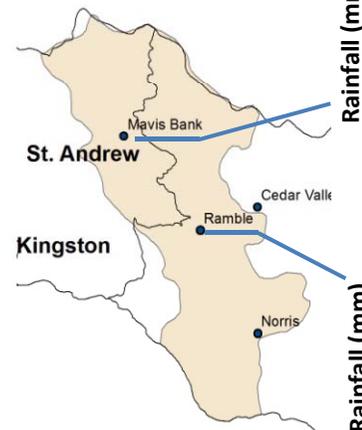


Outflow hydrograph

1. Past flood analysis: Tropical Storm Gustav



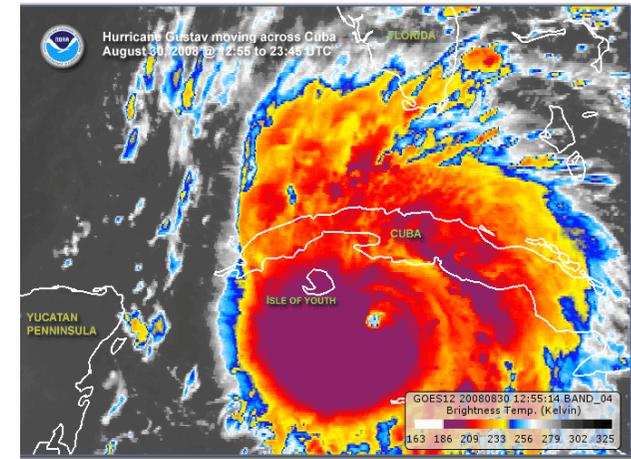
- Landfall in Jamaica 28 August 2008
- Major impact (US \$210 M), including flooding in Yallahs
- 24-hr data for Mavis Bank and Ramble gauges
- NRCS Type II method used to generate 15-minute rainfall
- Flows generated from rainfall using HEC-HMS



http://en.wikipedia.org/wiki/File:Gustav_29_August_2008.jpg

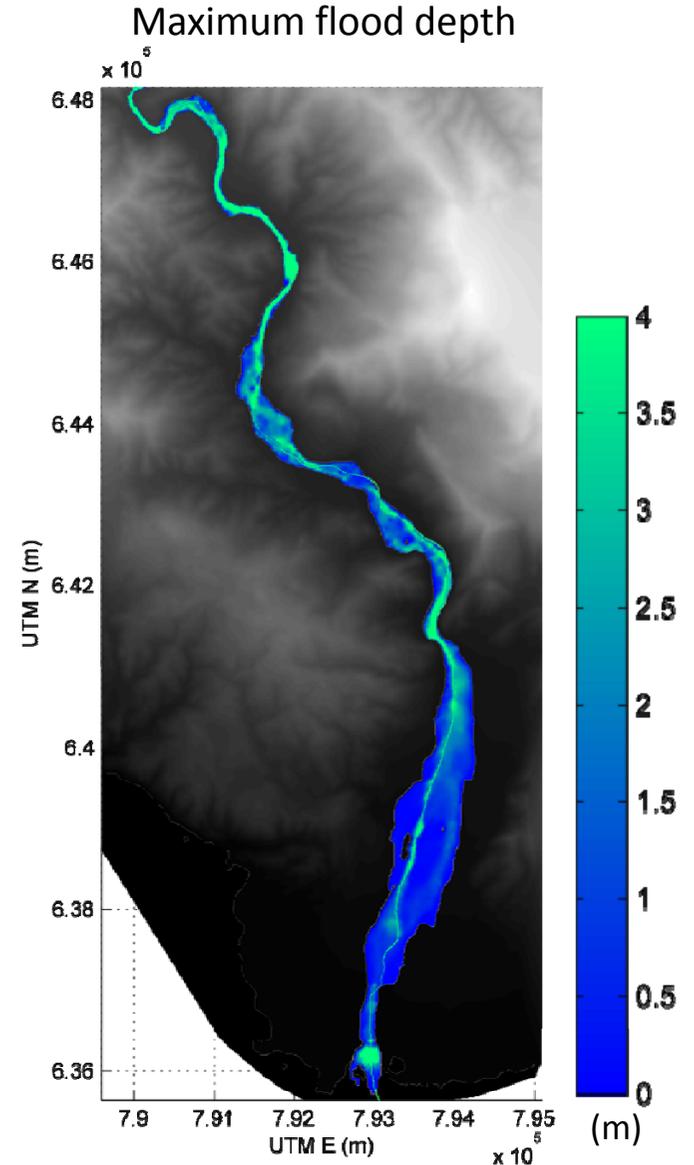
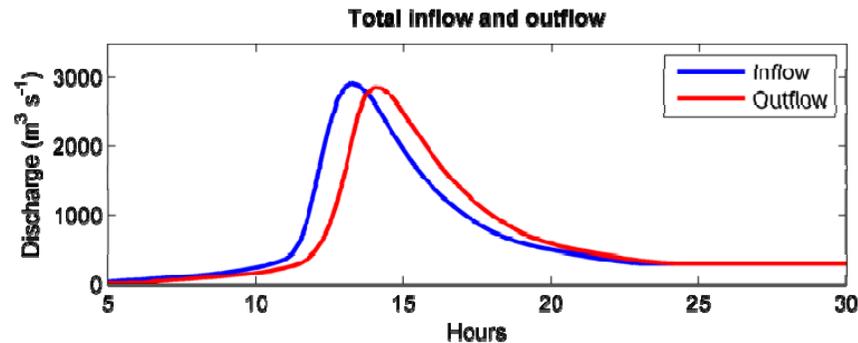
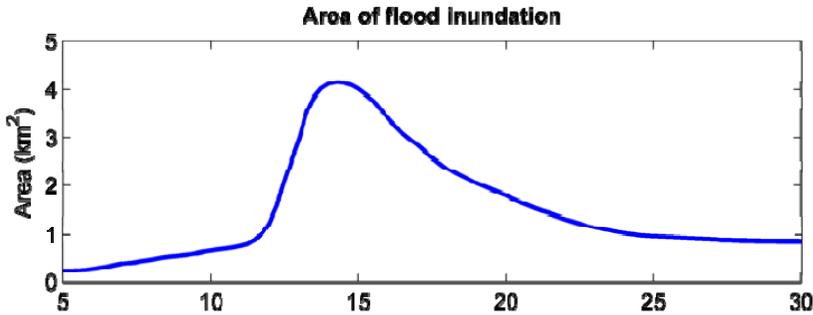
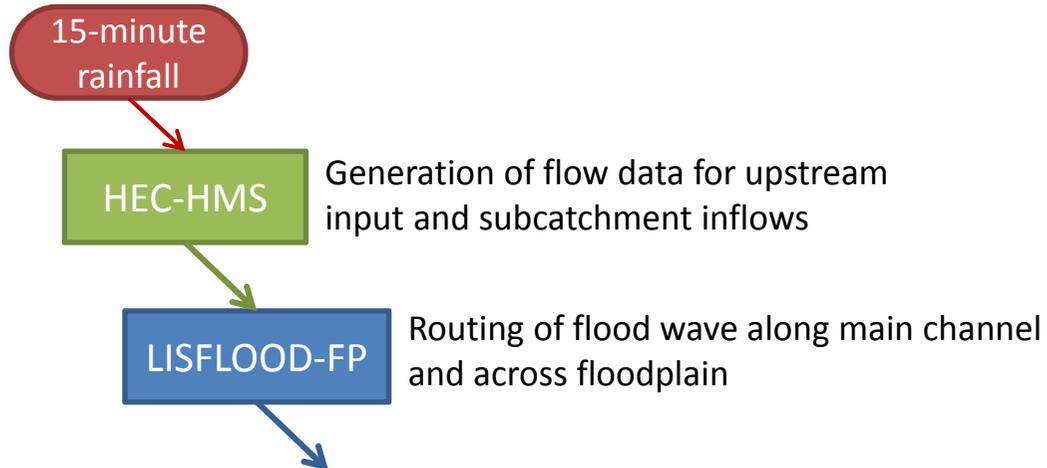


http://en.wikipedia.org/wiki/File:Gustav_2008_track.png



<http://en.wikipedia.org/wiki/File:GustavCuba.gif>

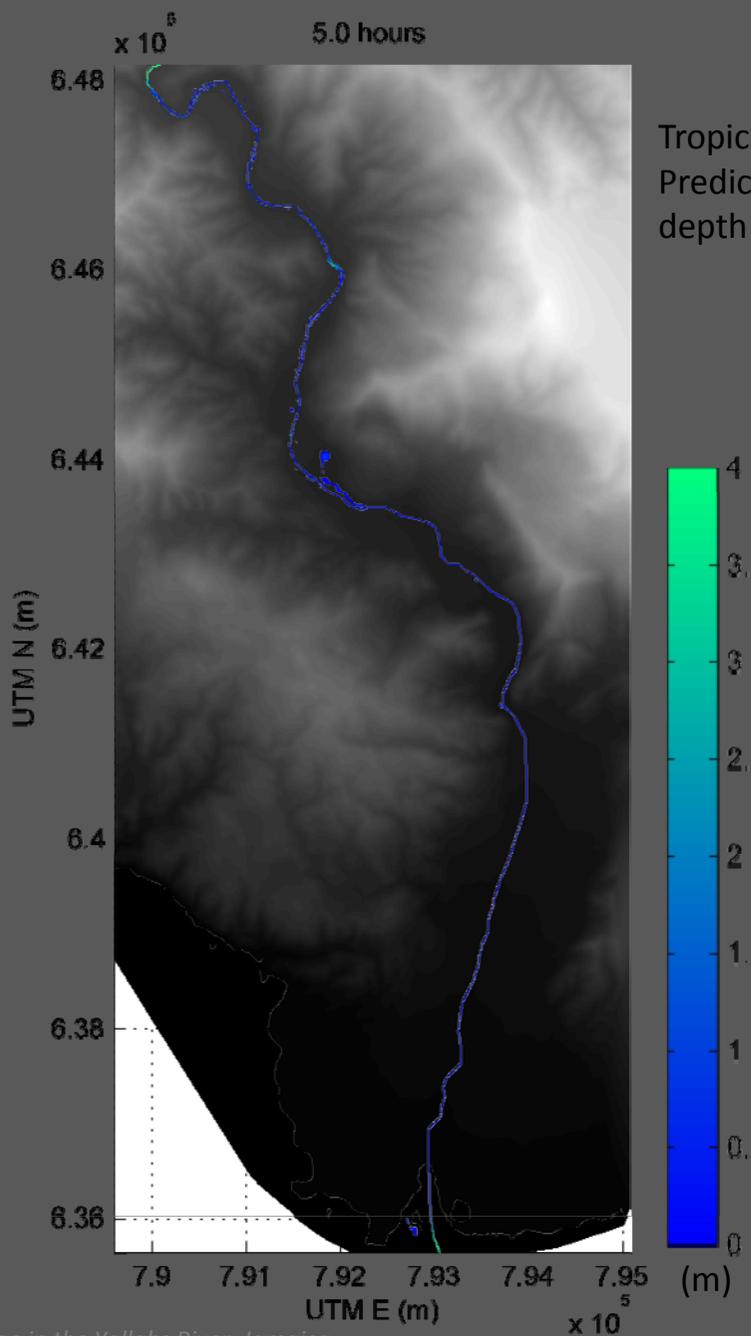
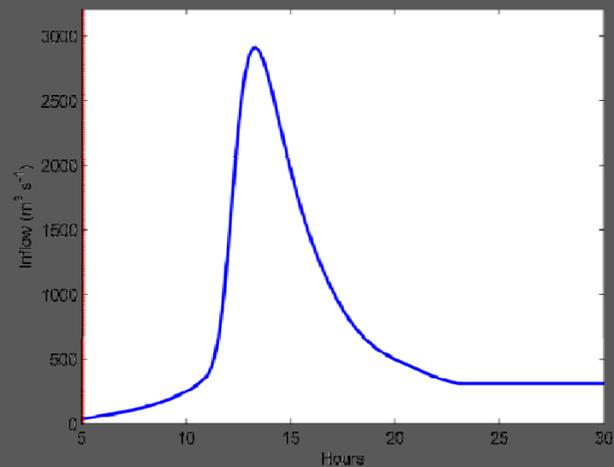
1. Tropical Storm Gustav: Results



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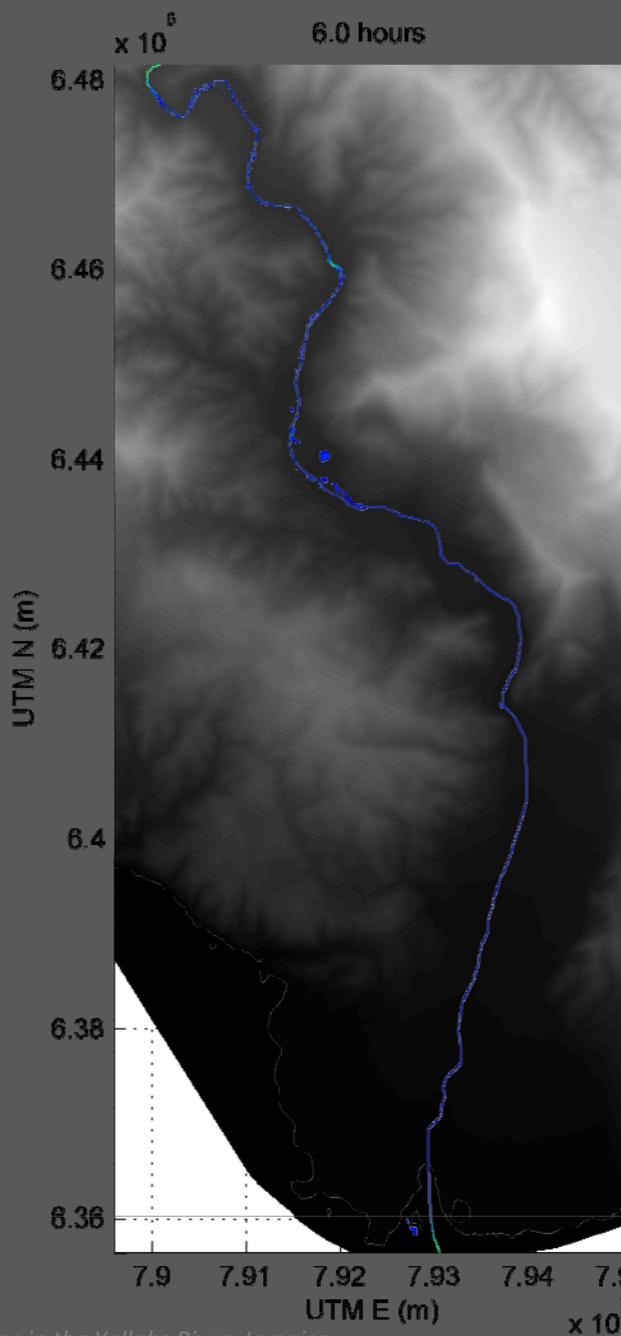
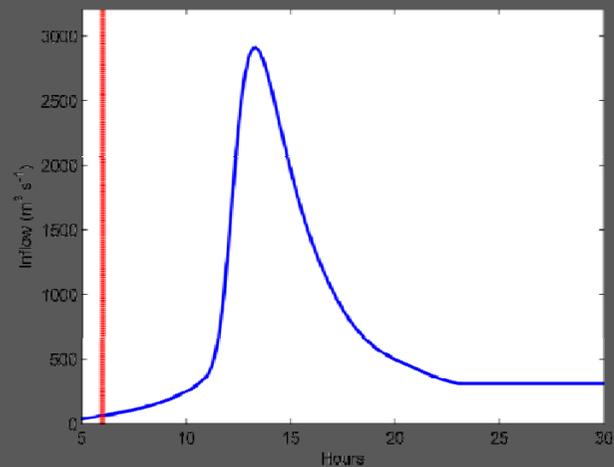


Tropical Storm Gustav: Prediction of flood extent and depth over time



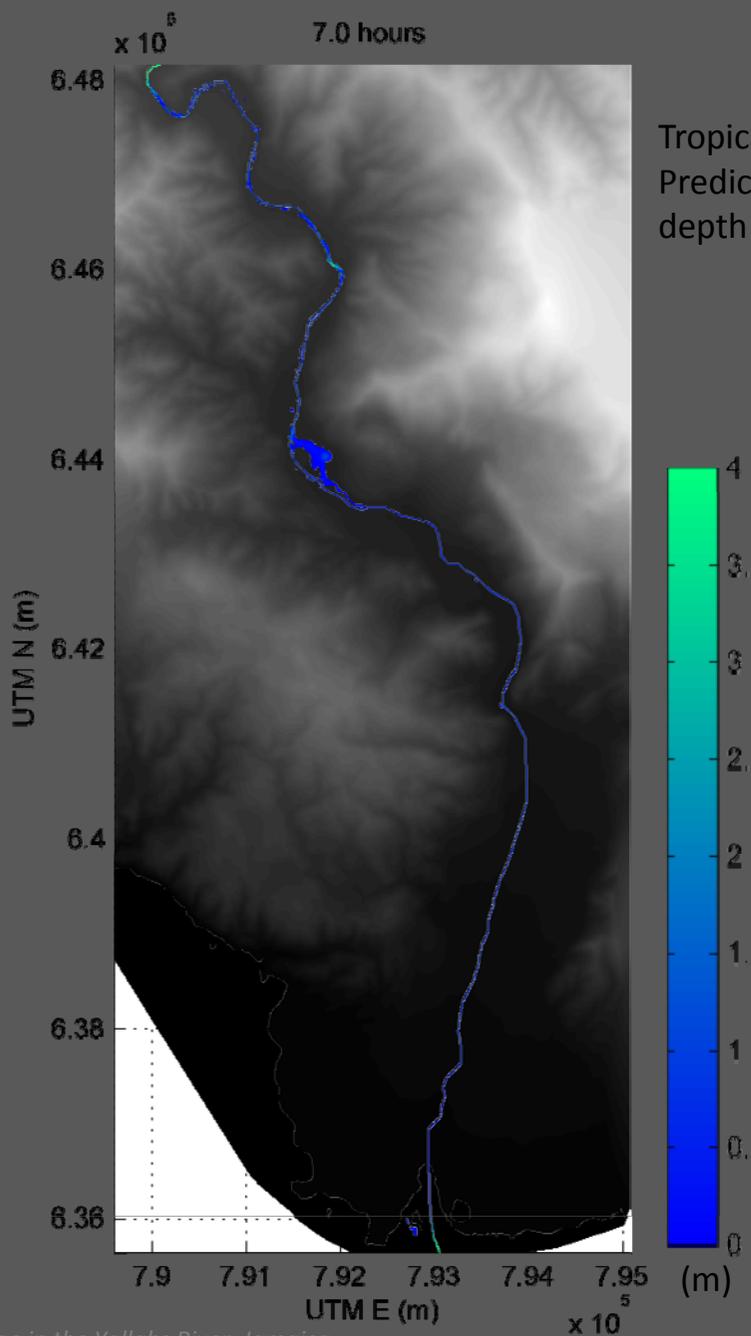
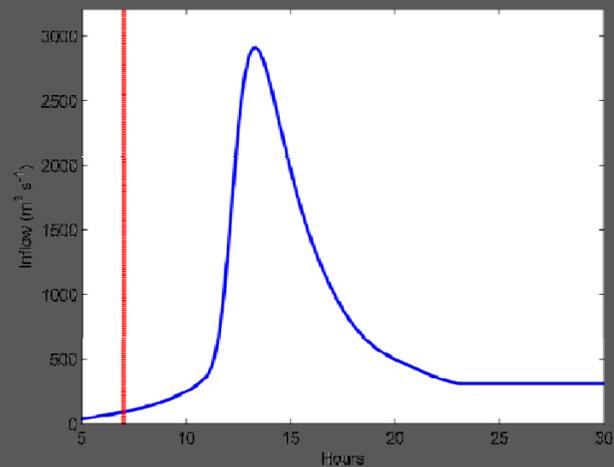


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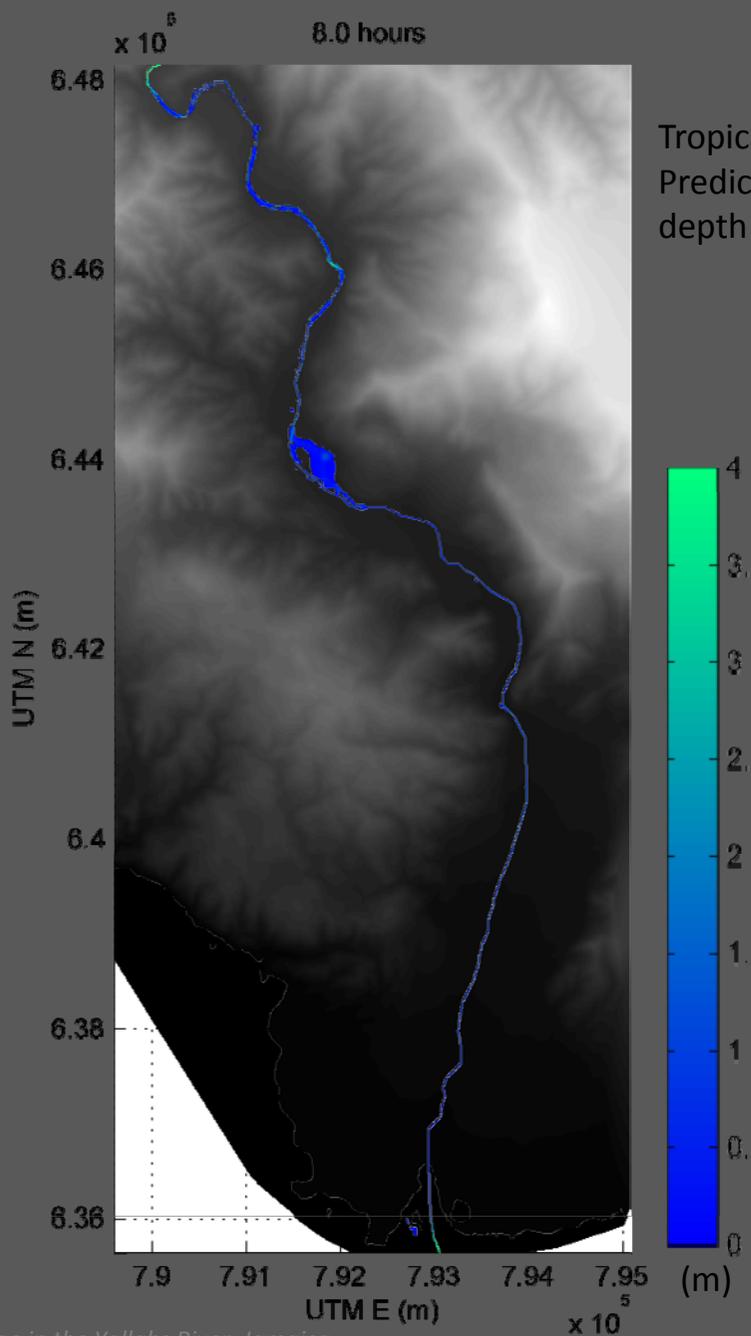
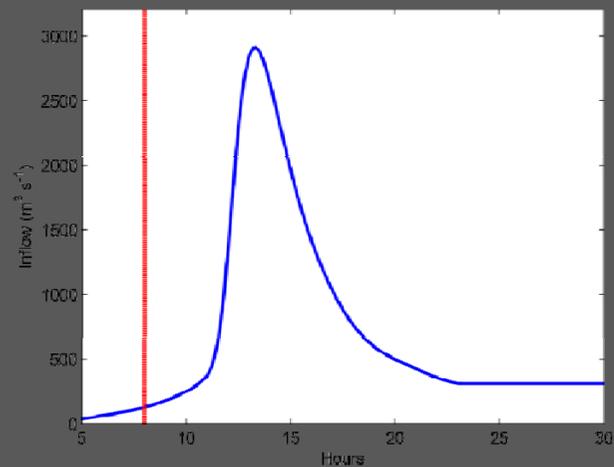


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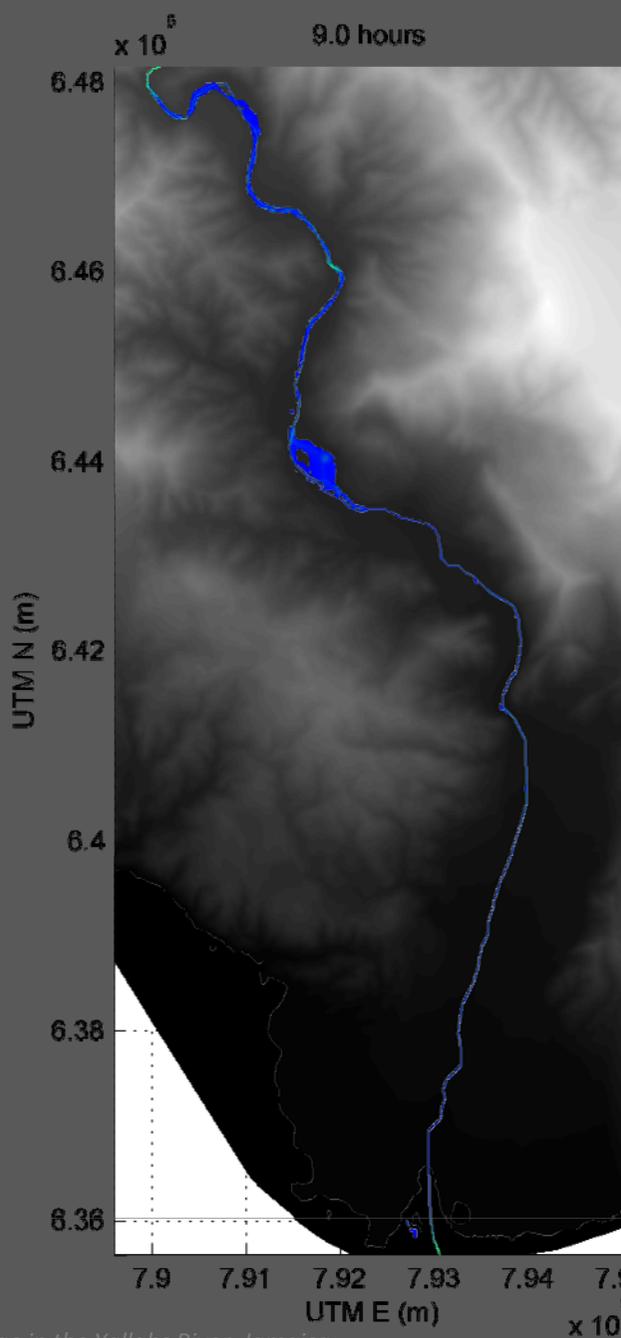
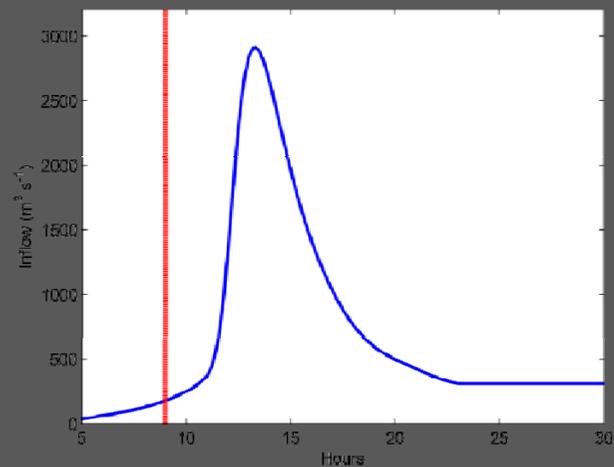


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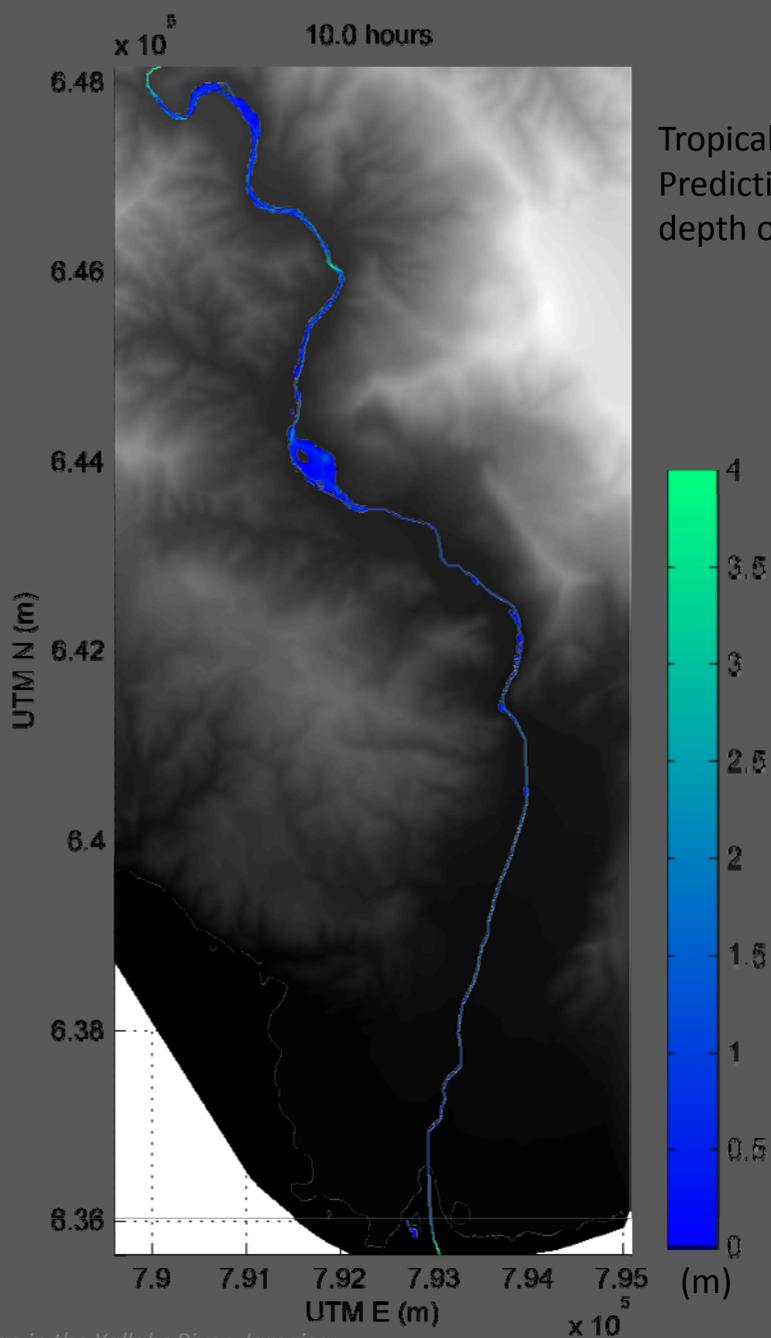
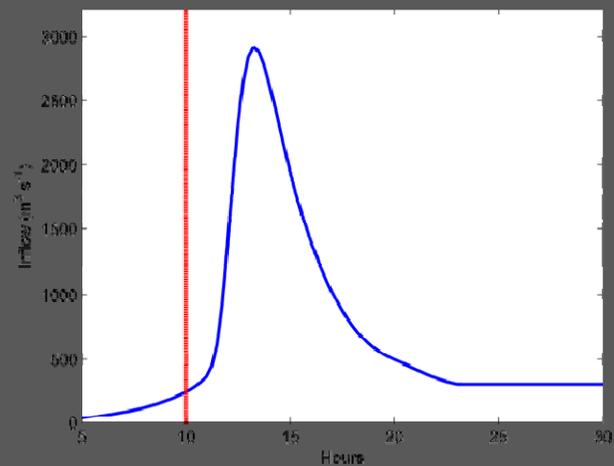


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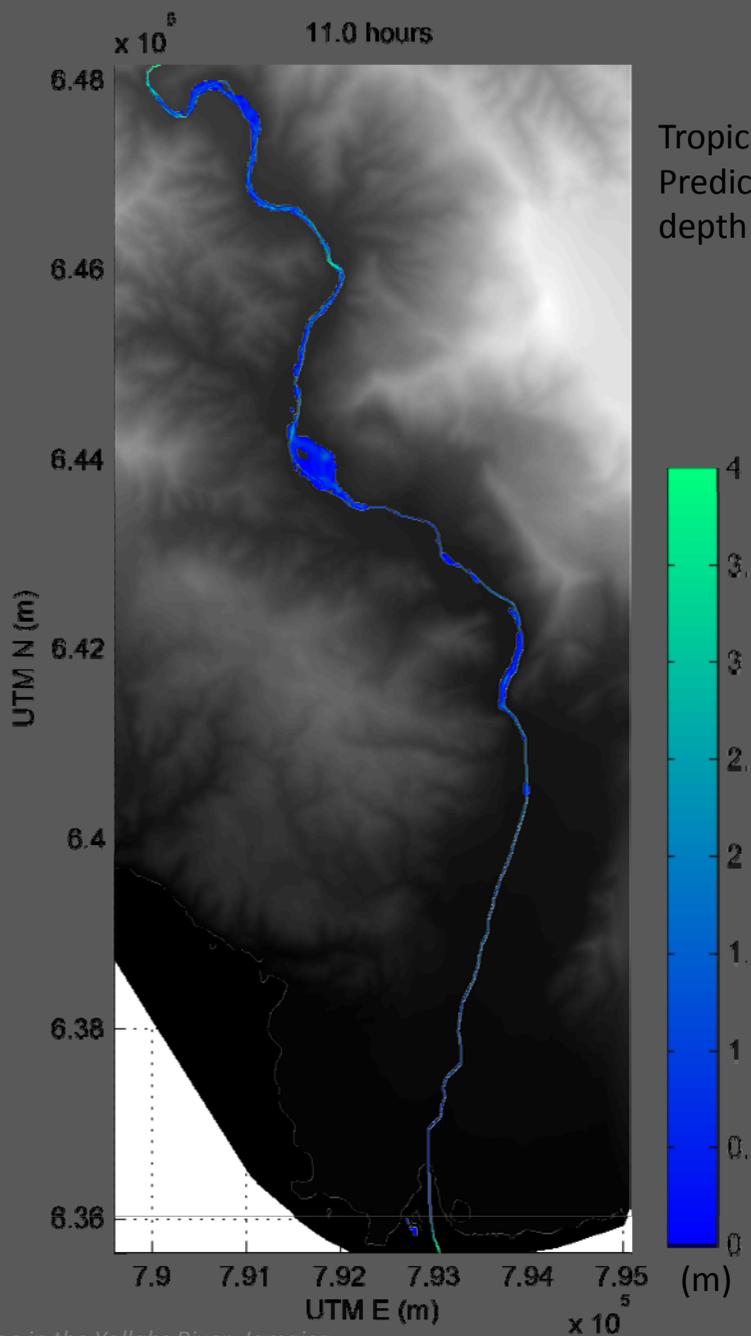
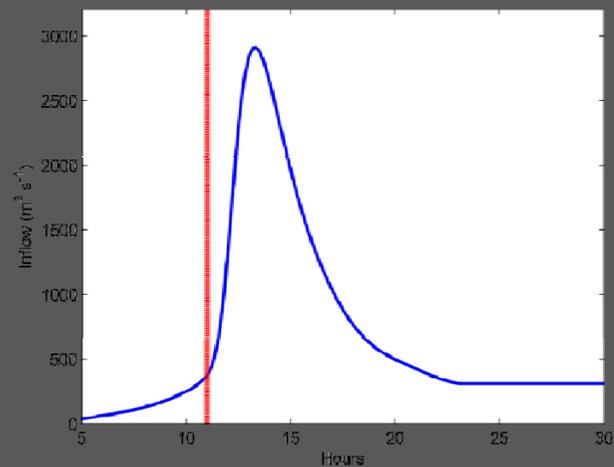


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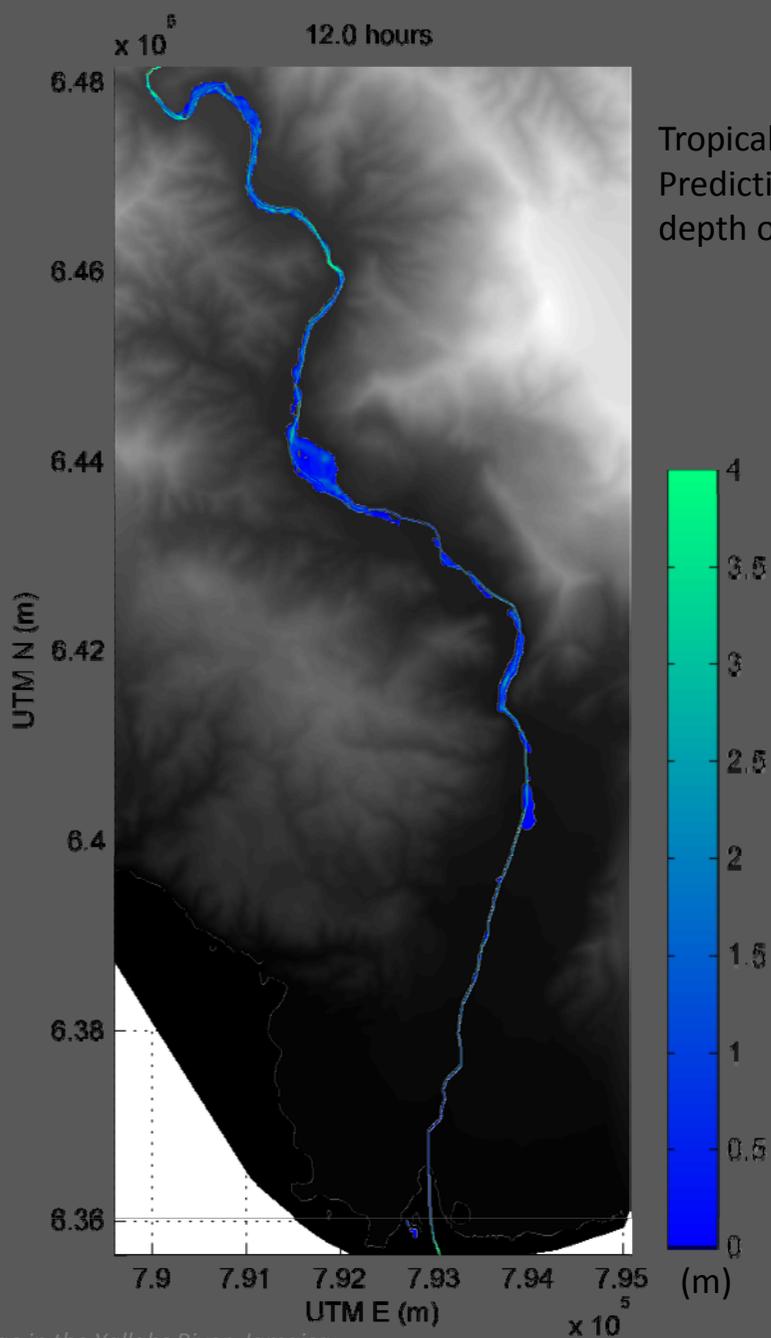
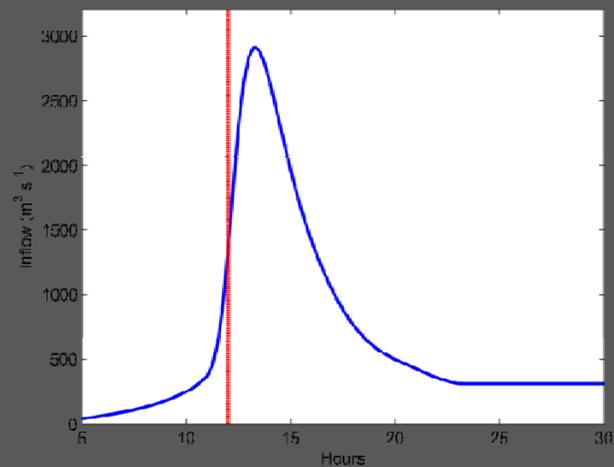


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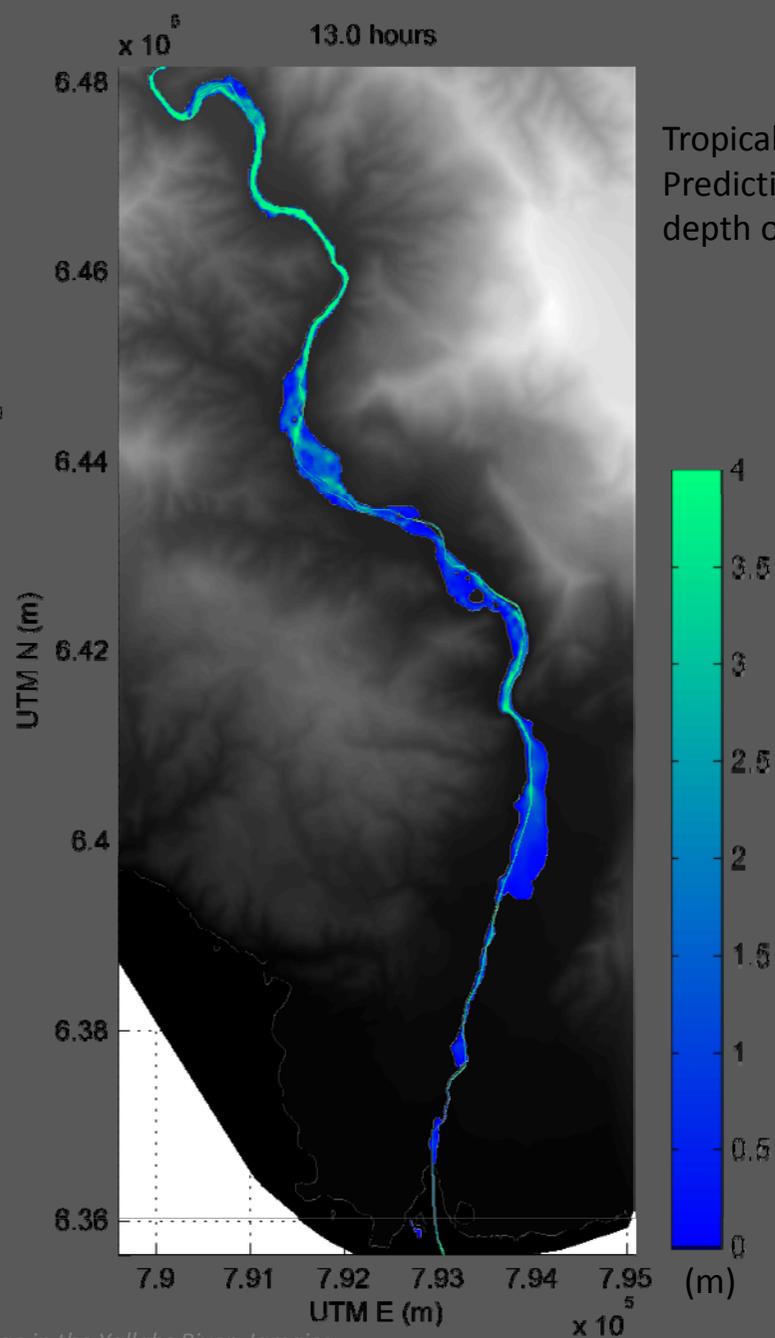
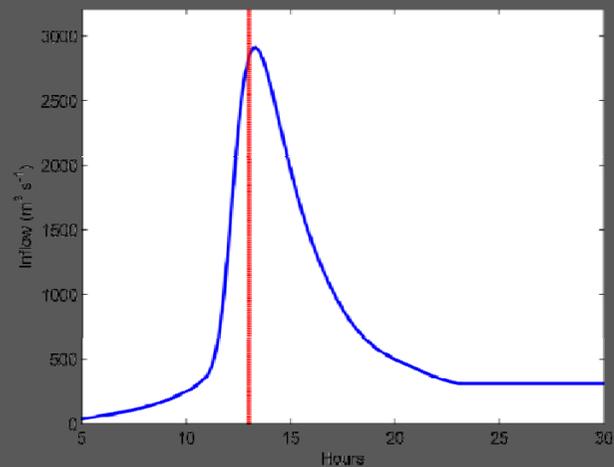


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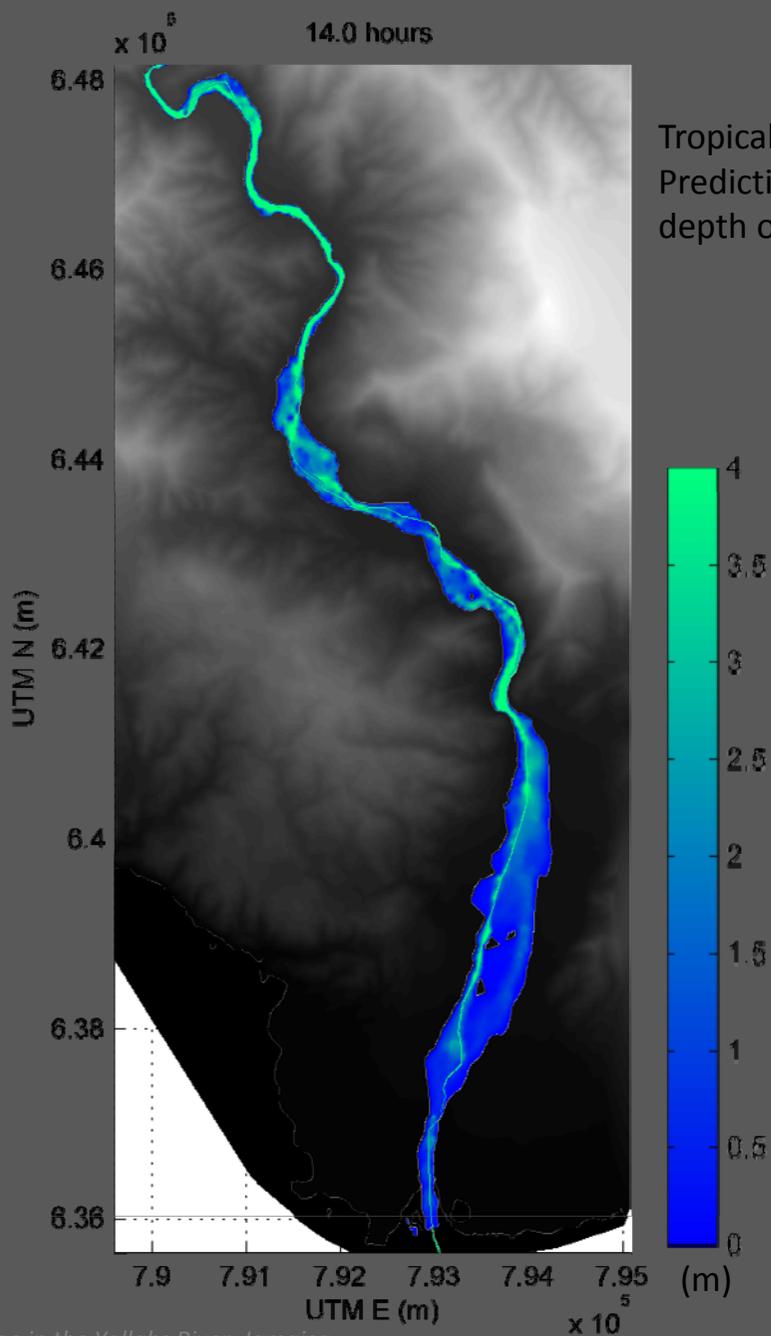
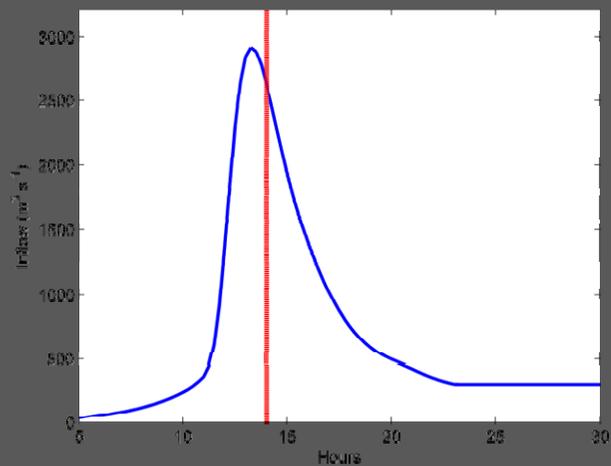


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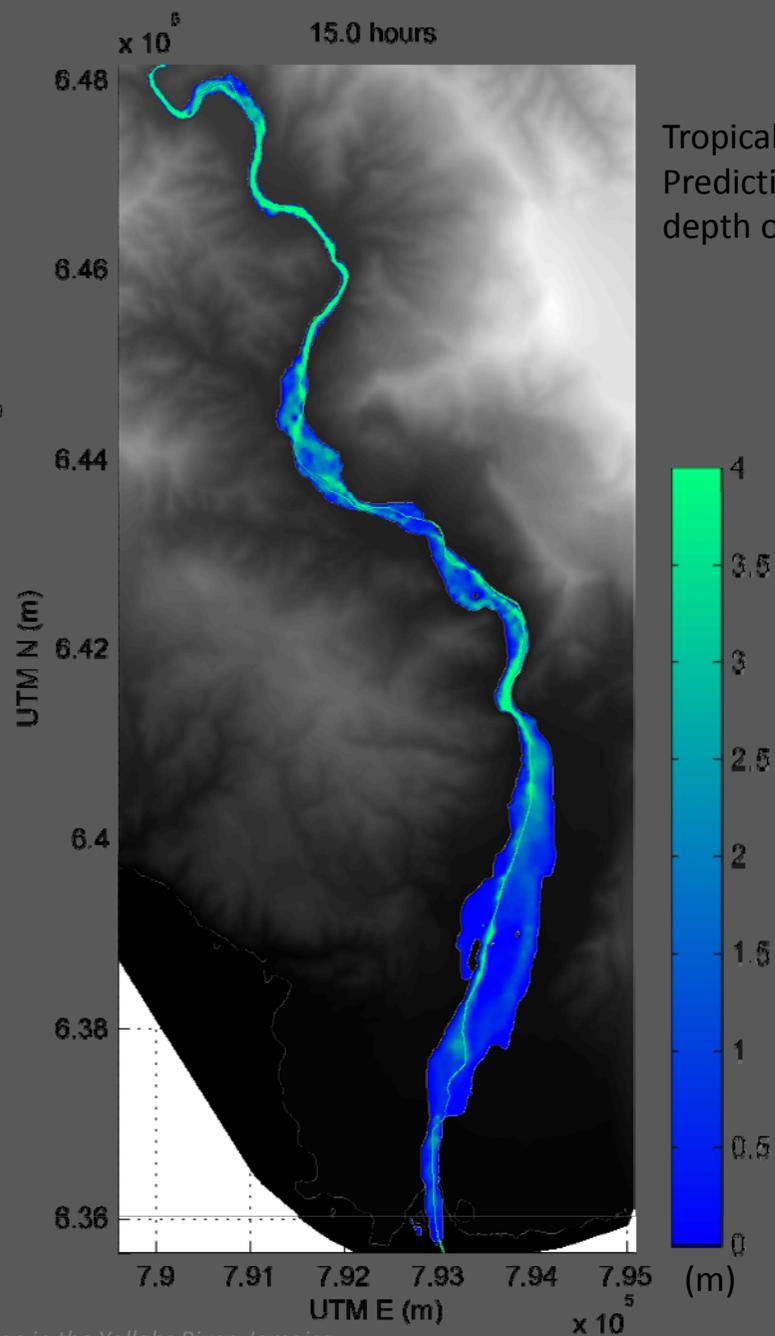
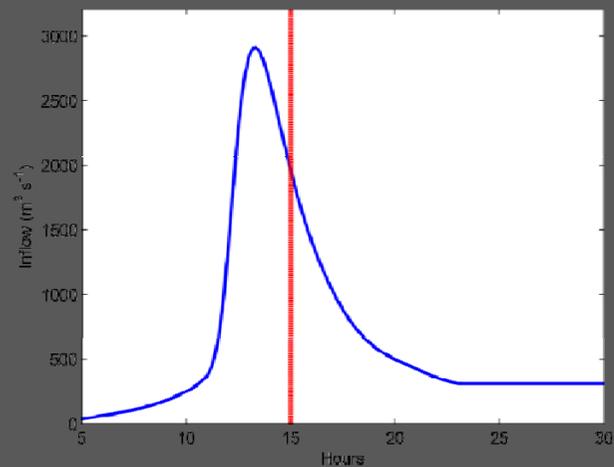


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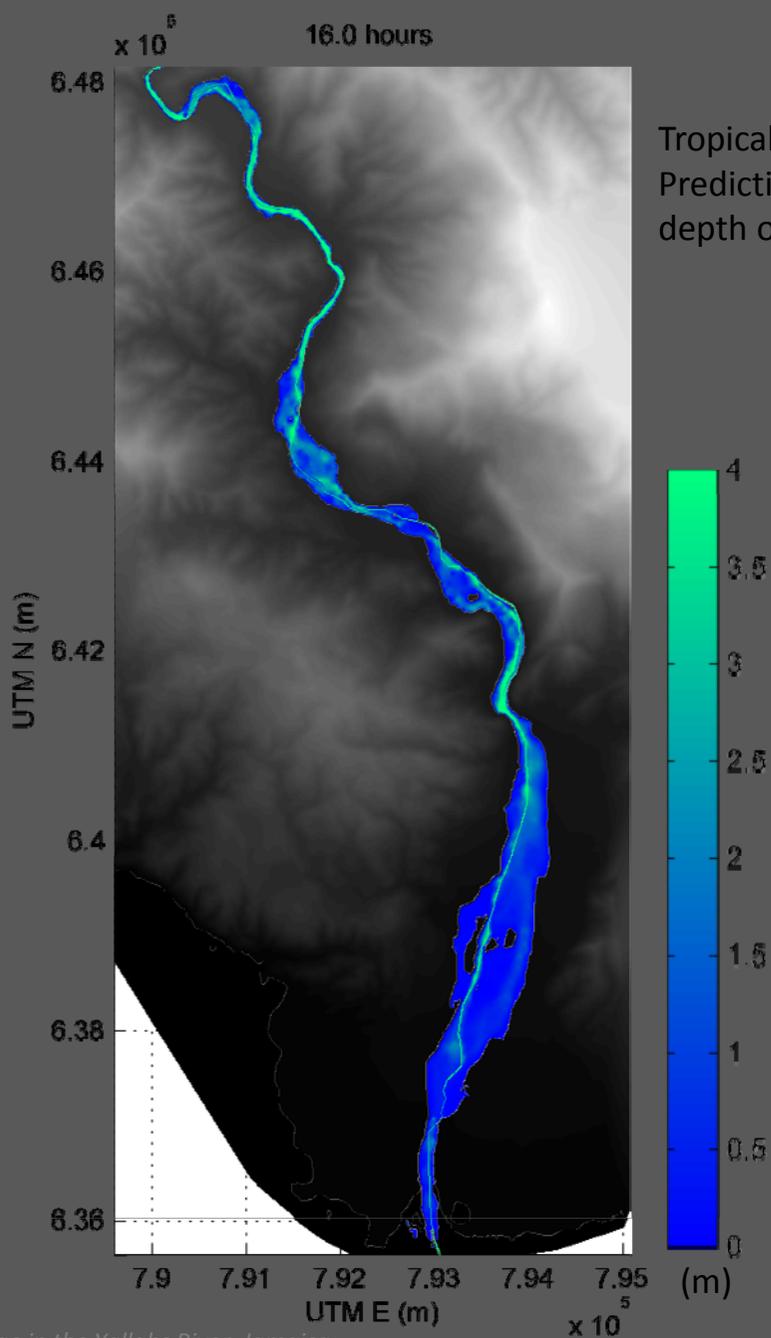
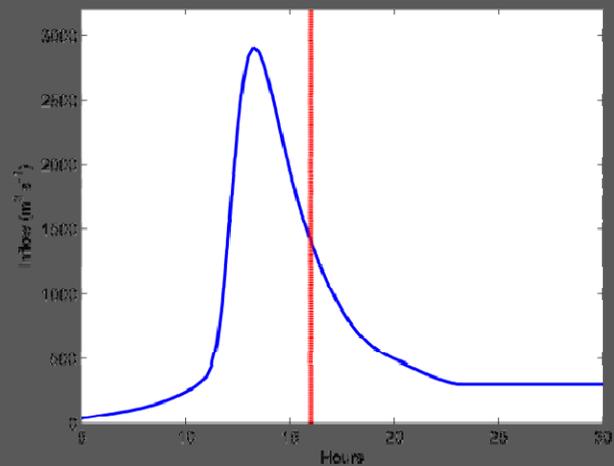


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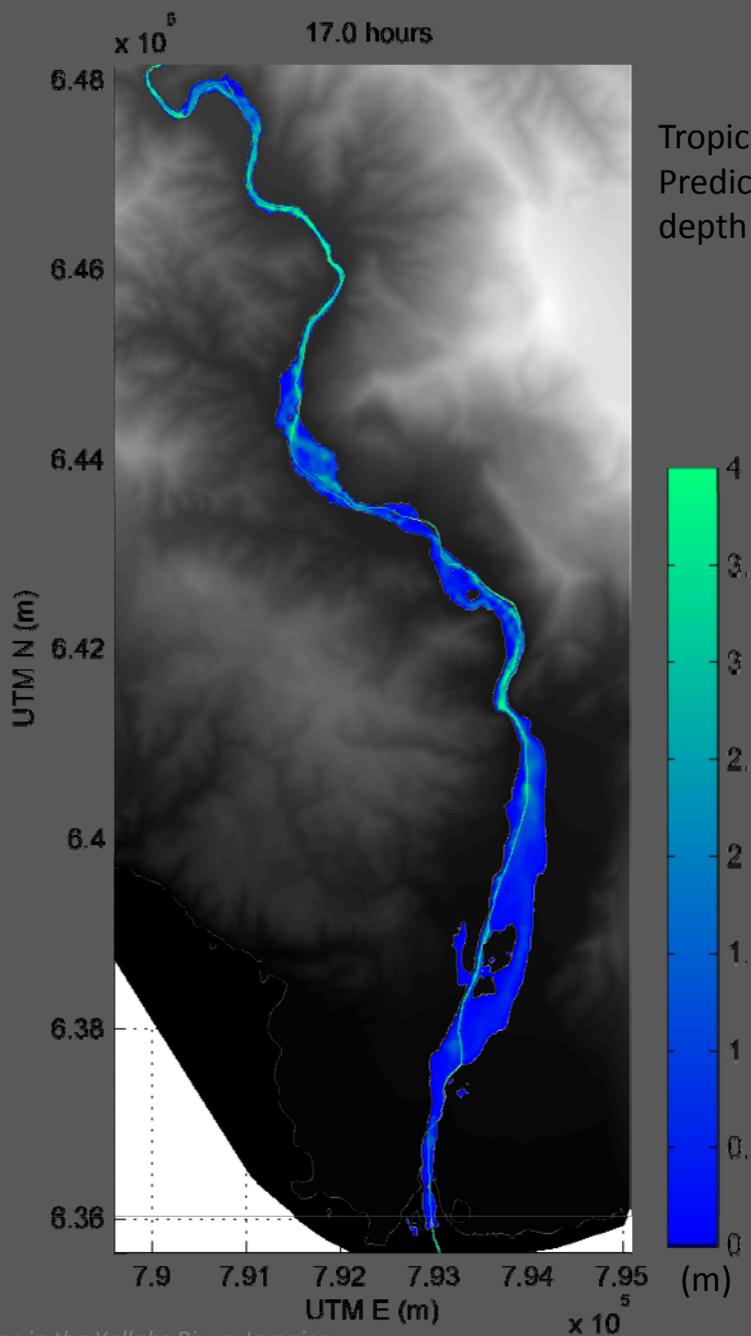
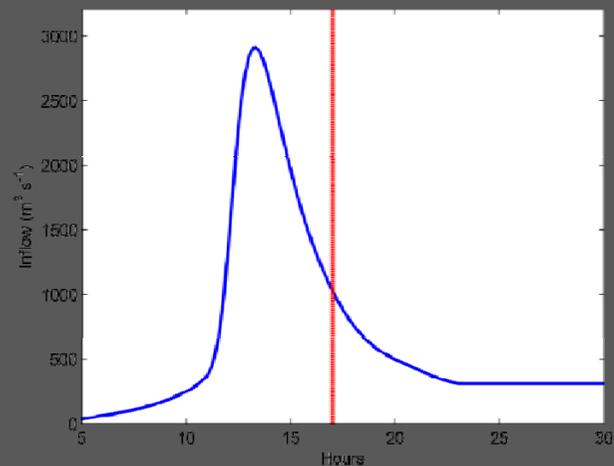


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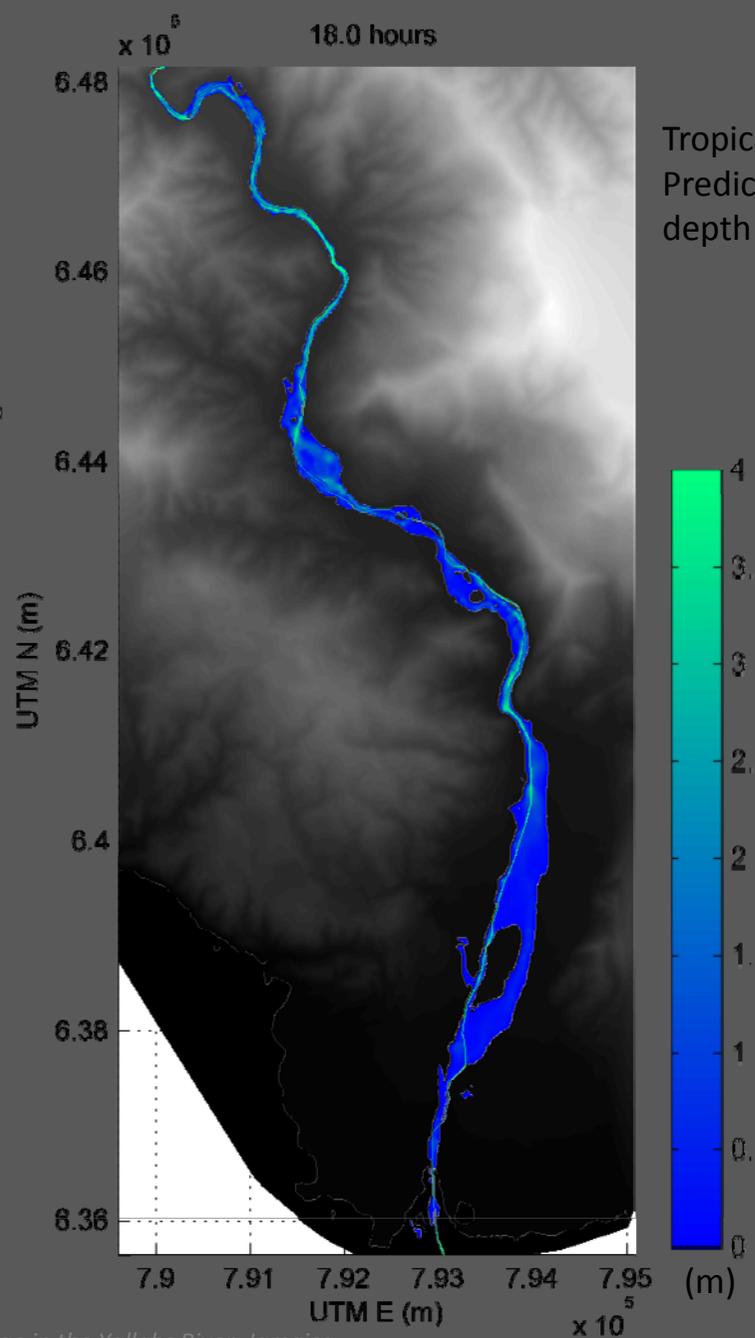
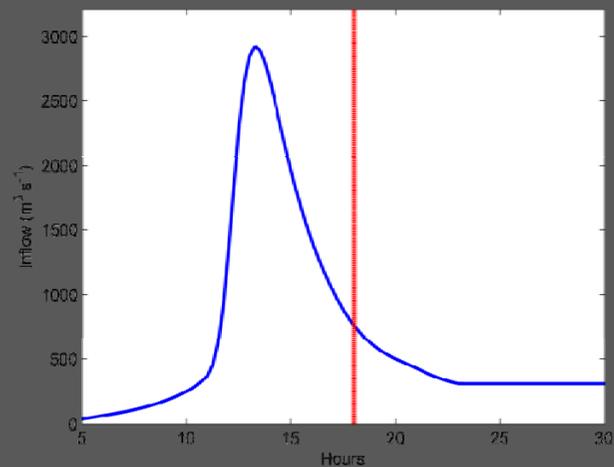


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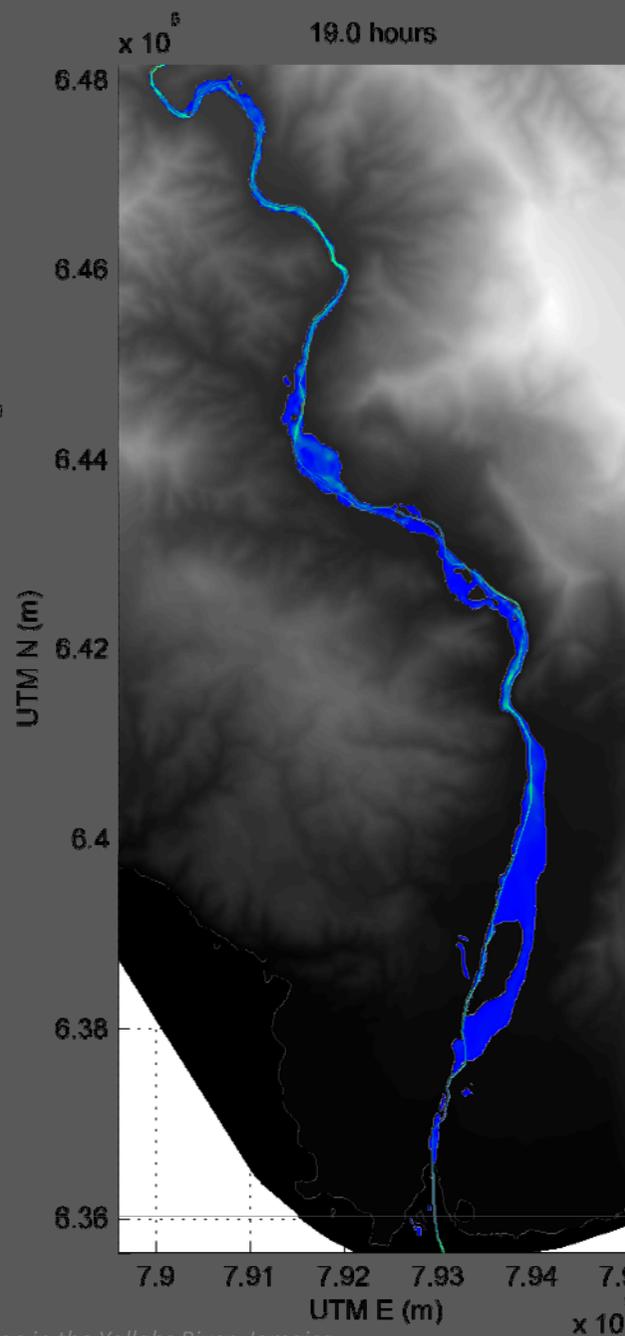
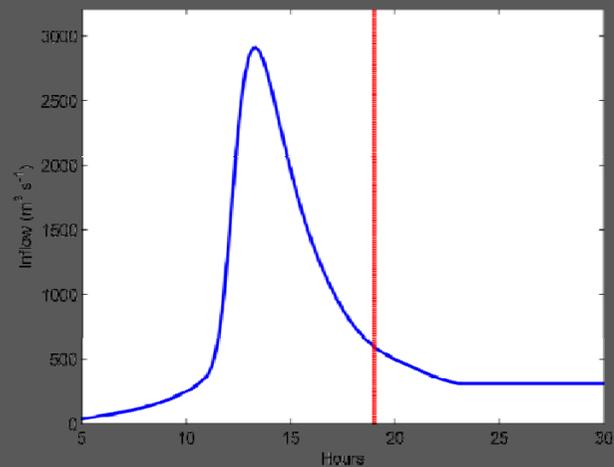


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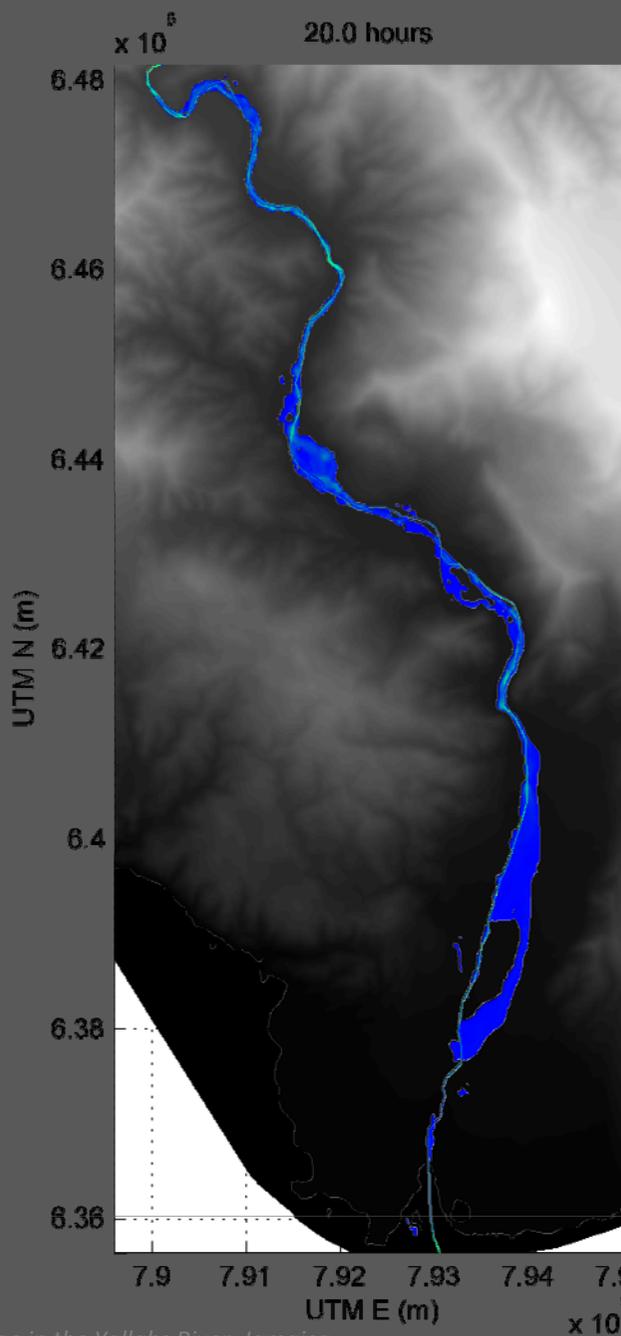
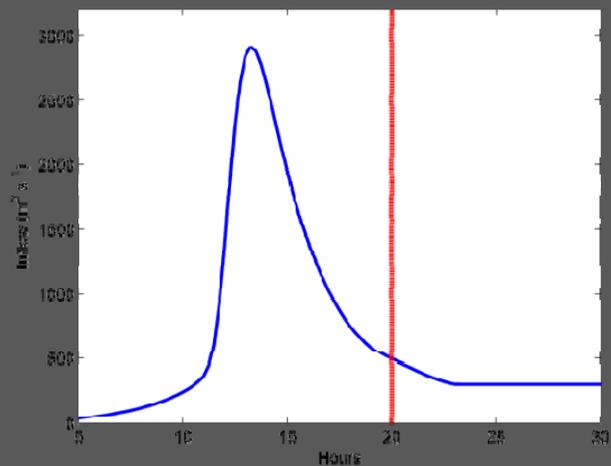


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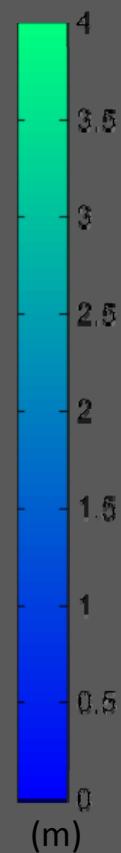
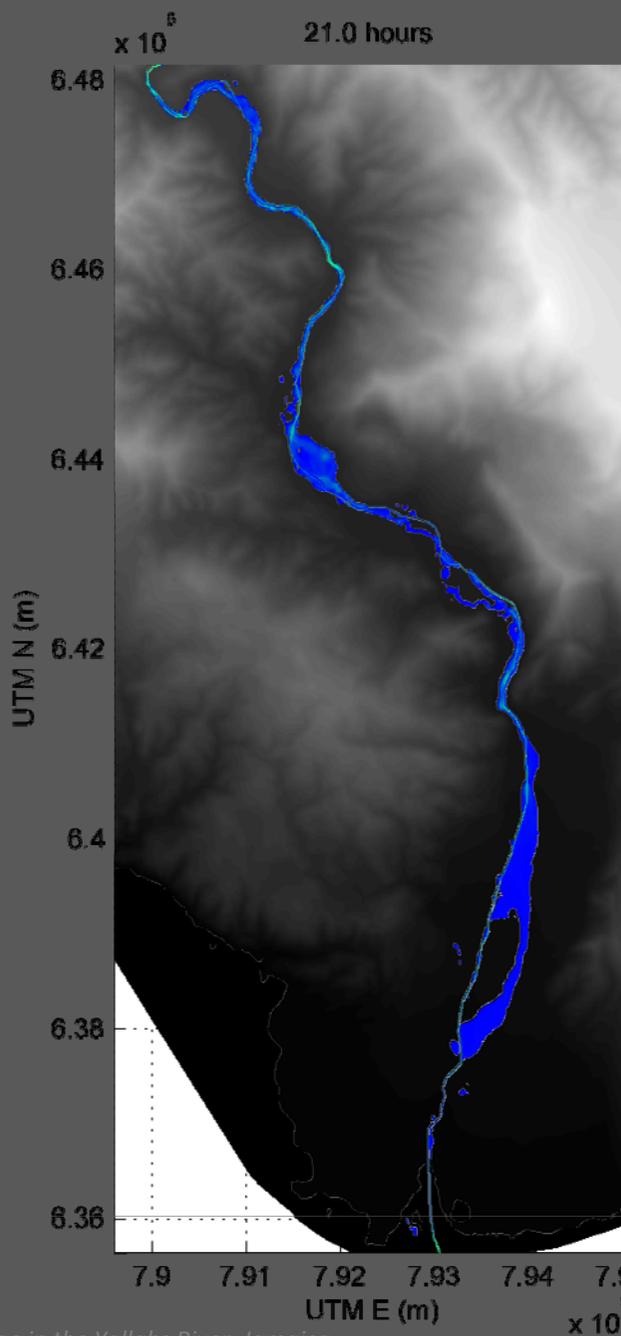
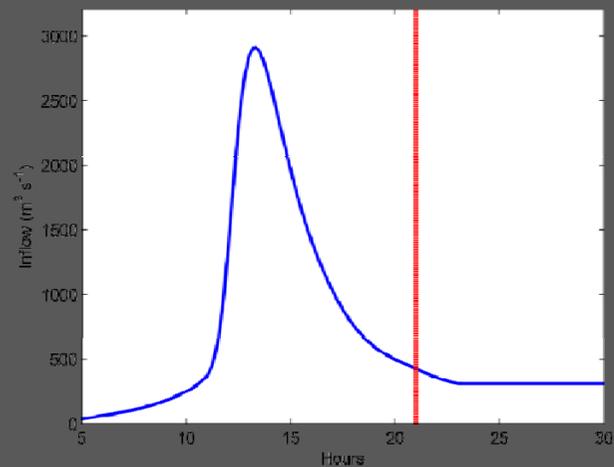


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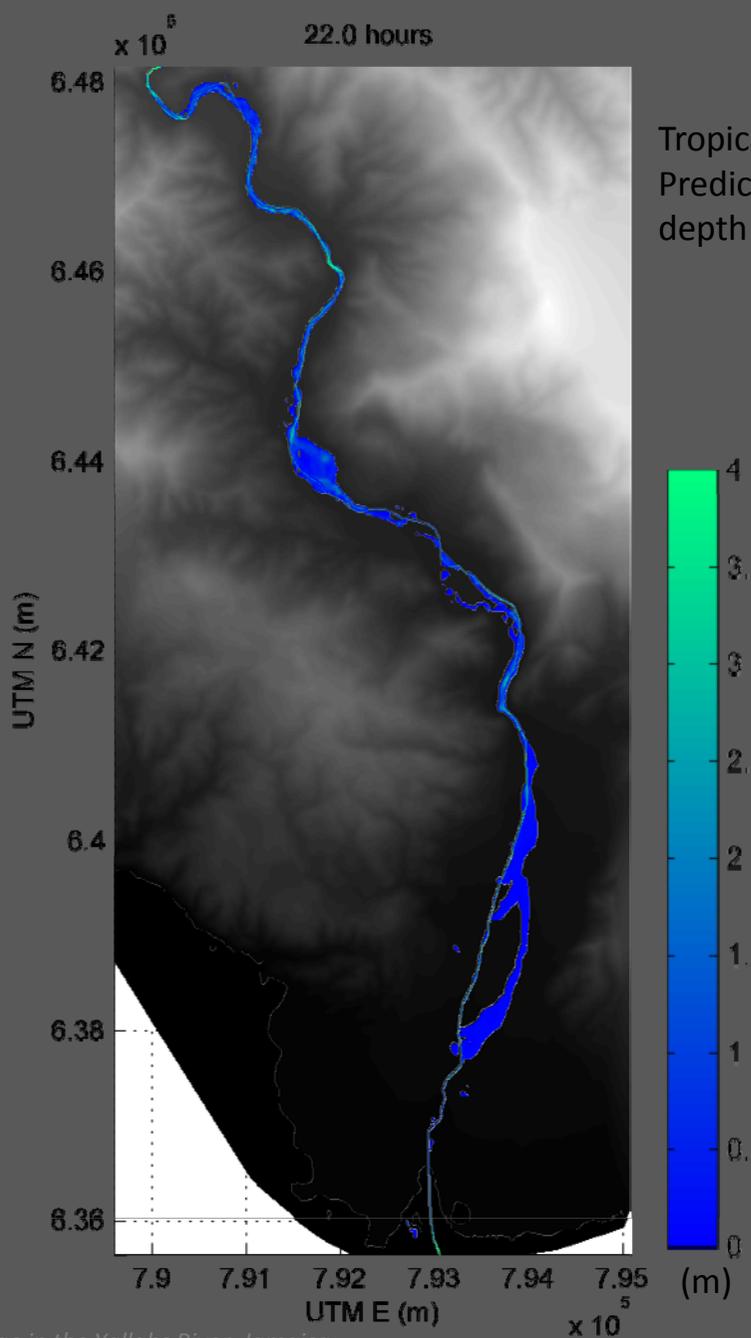
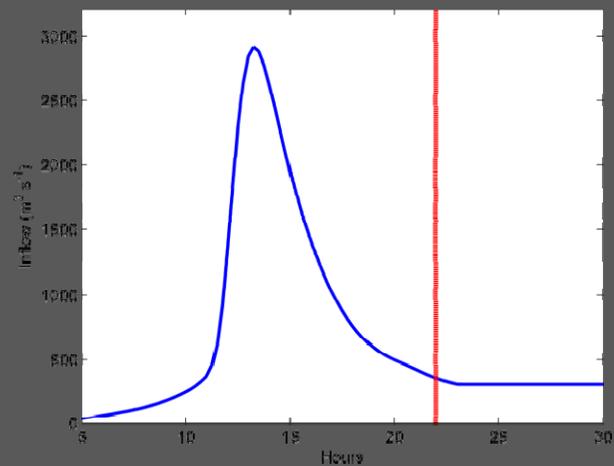


Tropical Storm Gustav: Prediction of flood extent and depth over time



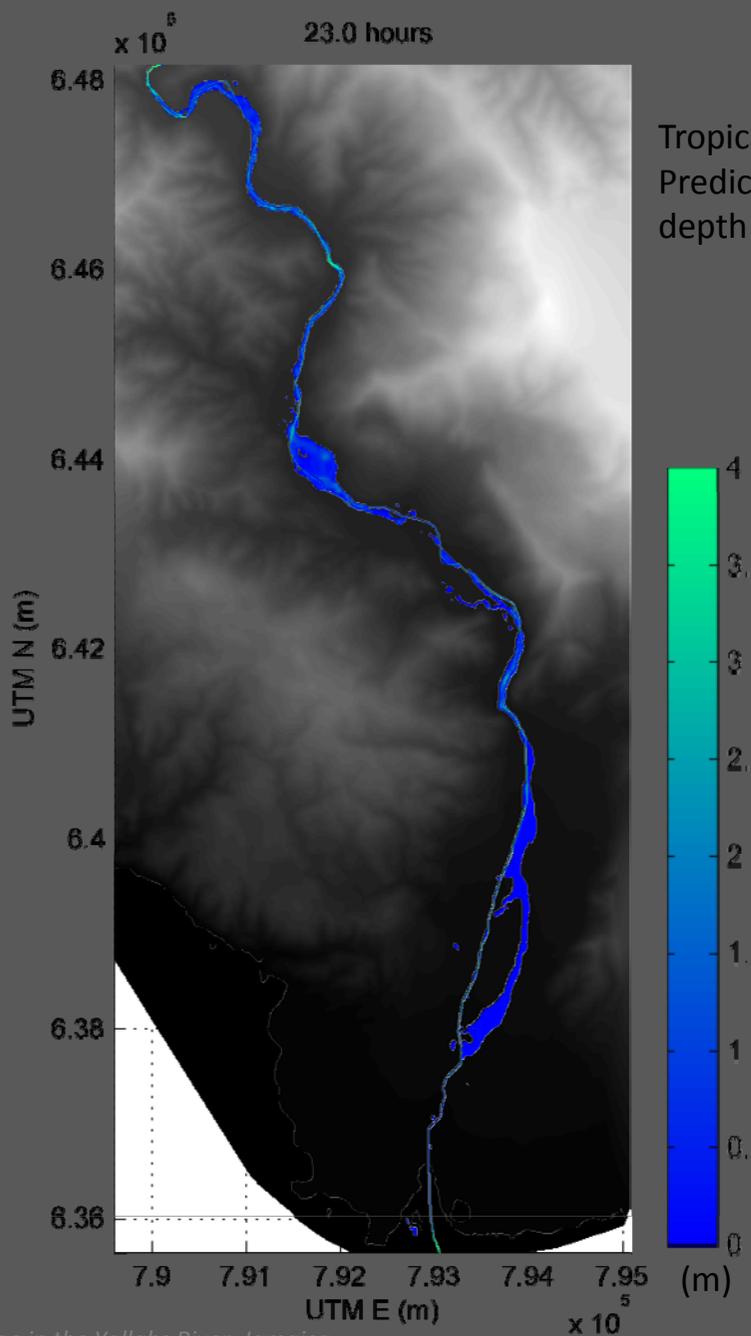
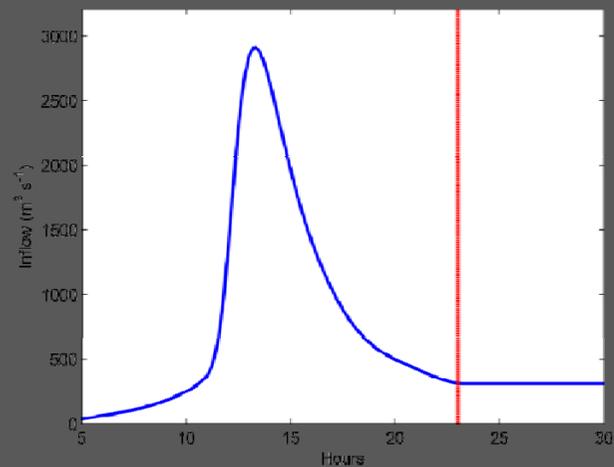


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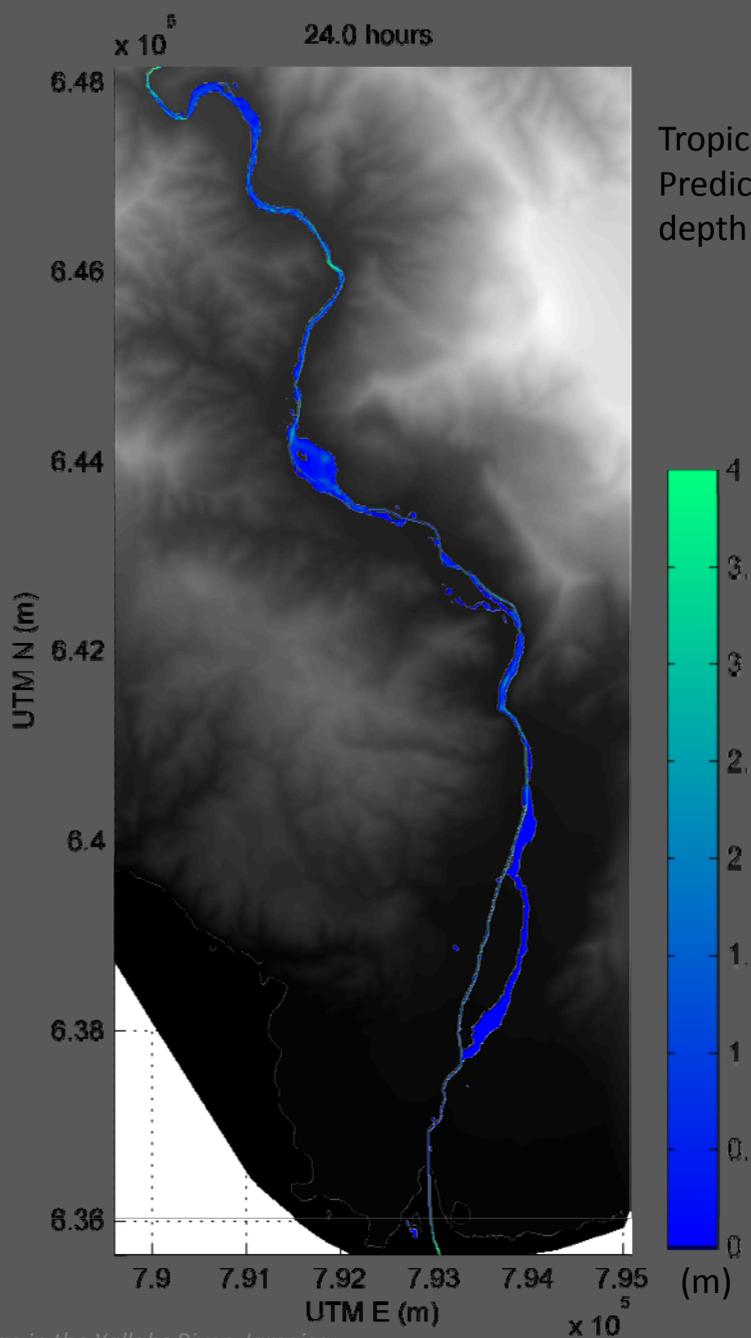
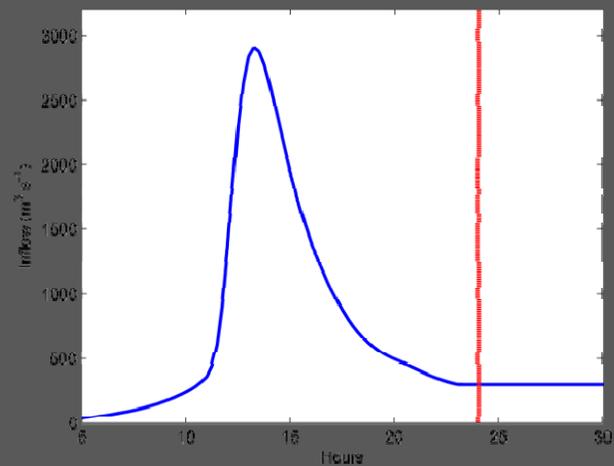


Tropical Storm Gustav: Prediction of flood extent and depth over time





Tropical Storm Gustav: Prediction of flood extent and depth over time





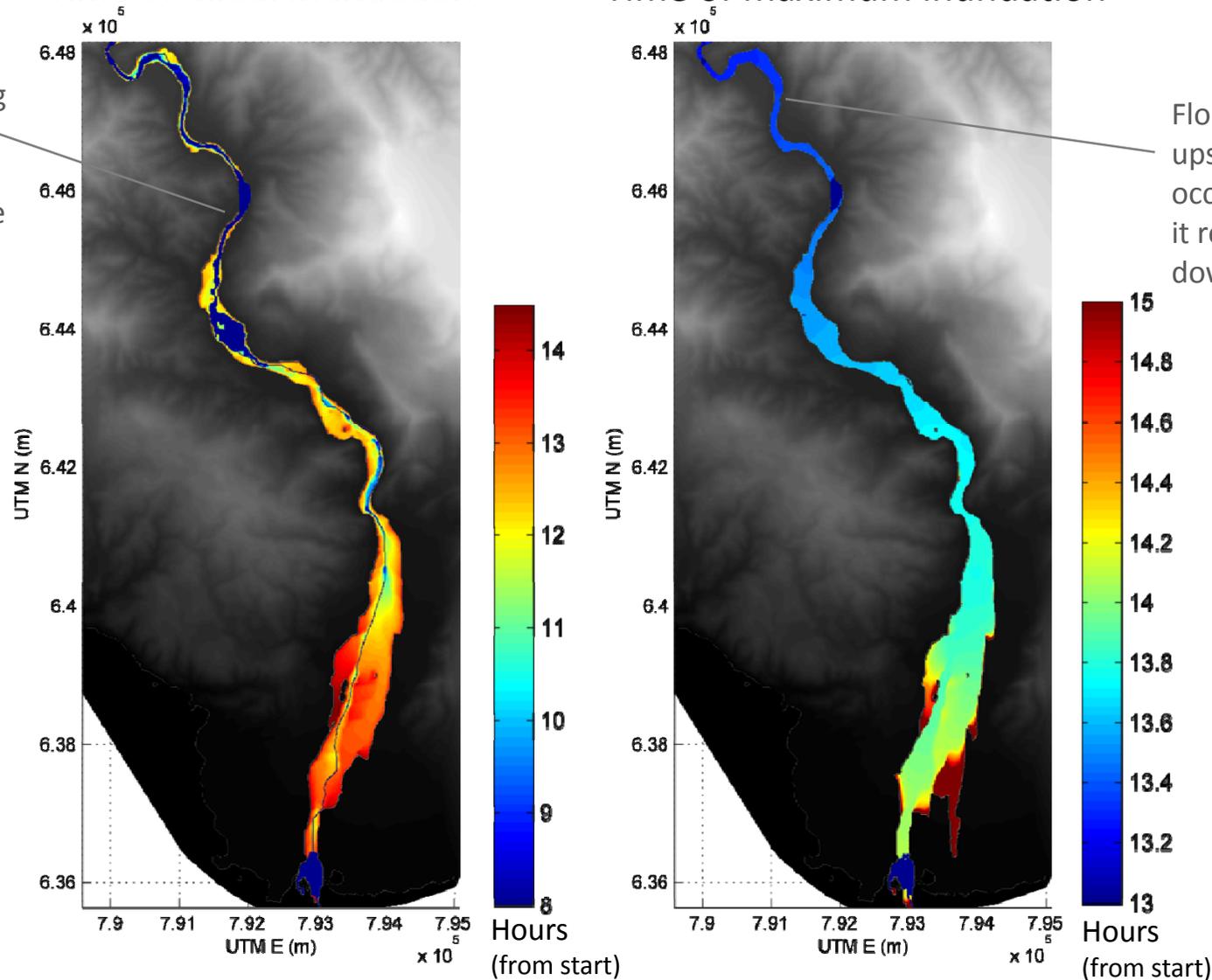
1. Tropical Storm Gustav: Results

Time of initial inundation

Time of maximum inundation

Early flooding in narrow section of valley (before flood peak)

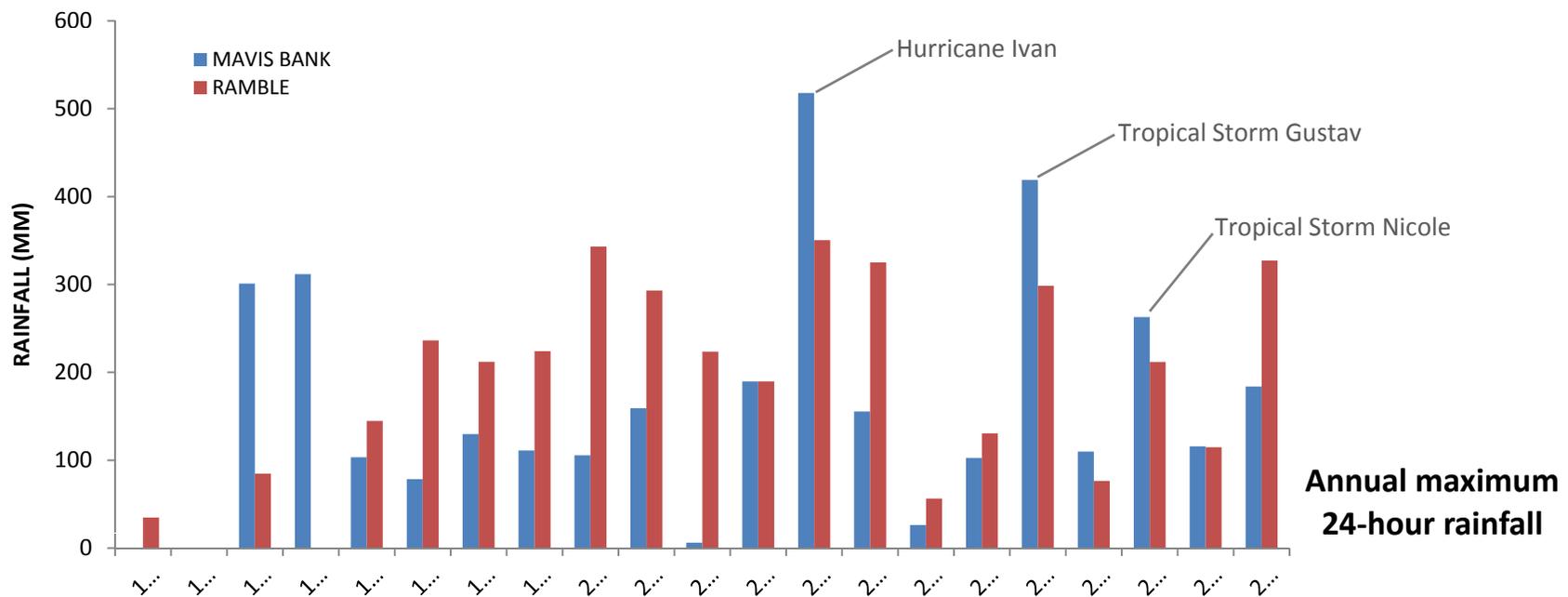
Flood peak upstream occurred ~1 hour it reached downstream



2. Estimation of current flood risk



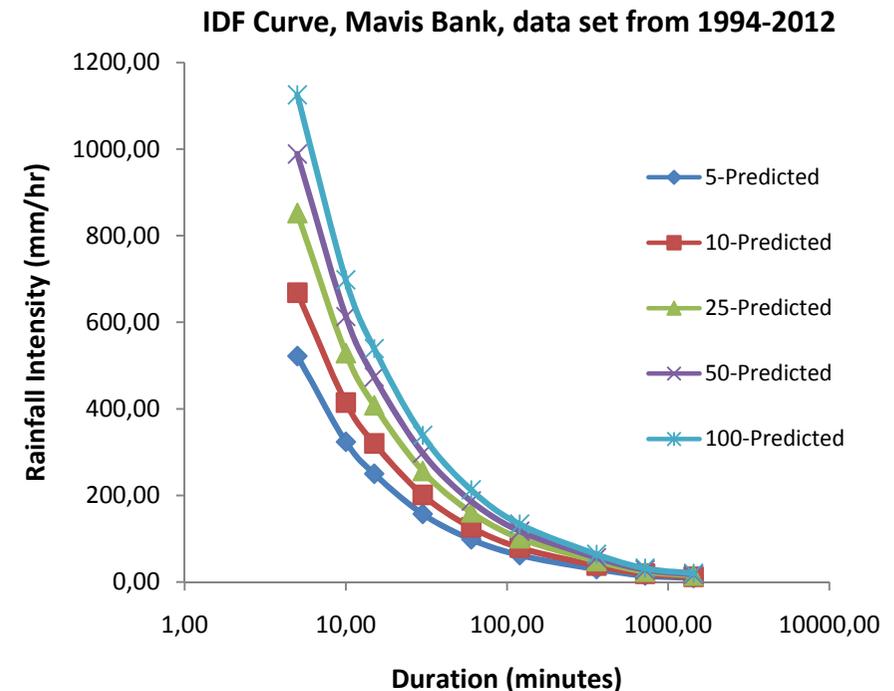
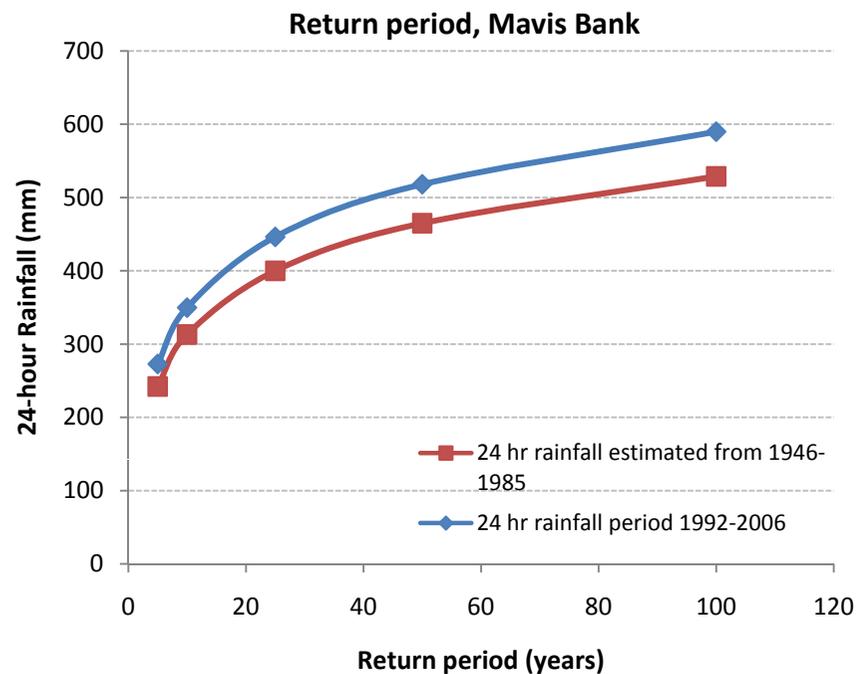
- Daily data (24-hour) obtained for 1992-2012 from Jamaica Met Service for Mavis Bank and Ramble
 - Data prior to 1992 unavailable due to loss of records in fire
 - Some historical data (1922-1966) obtained from “Jamaica Weather Reports” from NOAA central library (http://docs.lib.noaa.gov/rescue/data_rescue_jamaica.html)
 - Annual maximum extracted:





2. Estimation of current flood risk

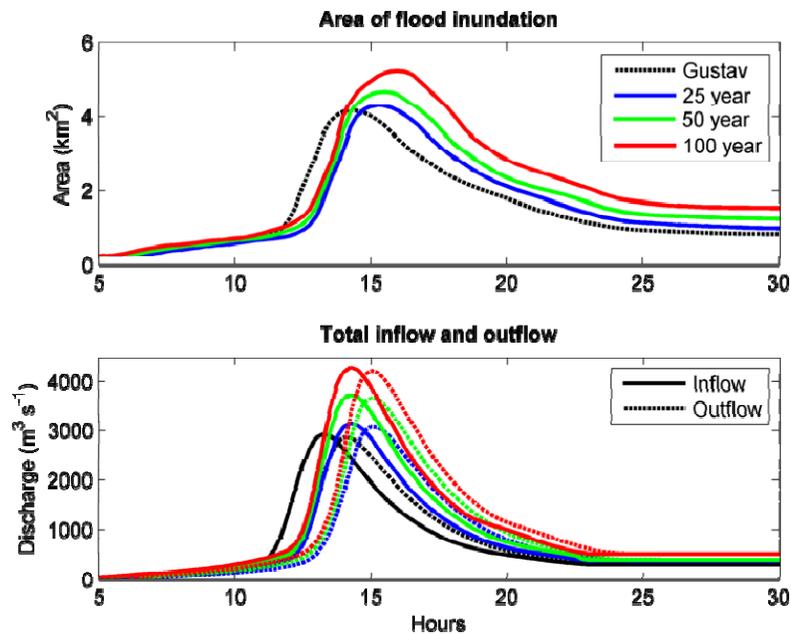
- Return periods calculated for 24-hour rainfall
- 24-hour maximum temporally downscaled using NRCS Type-II rainfall
 - IDF curves generated for return period calculations



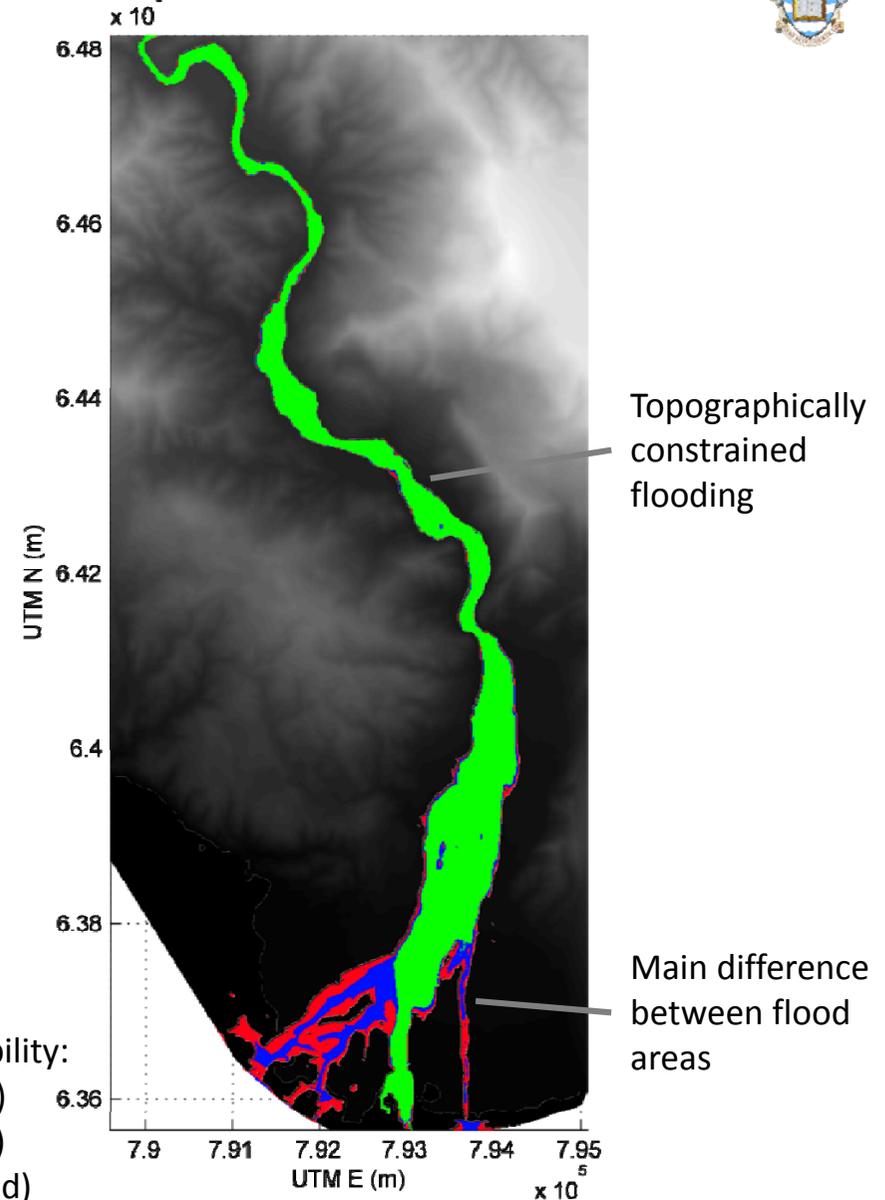
2. Estimation of current flood risk: results



- HEC-HMS run for 25, 50 and 100 year rainfall events
- Flows from HEC-HMS routed through the LISFLOOD-FP model to predict inundation extents and depths



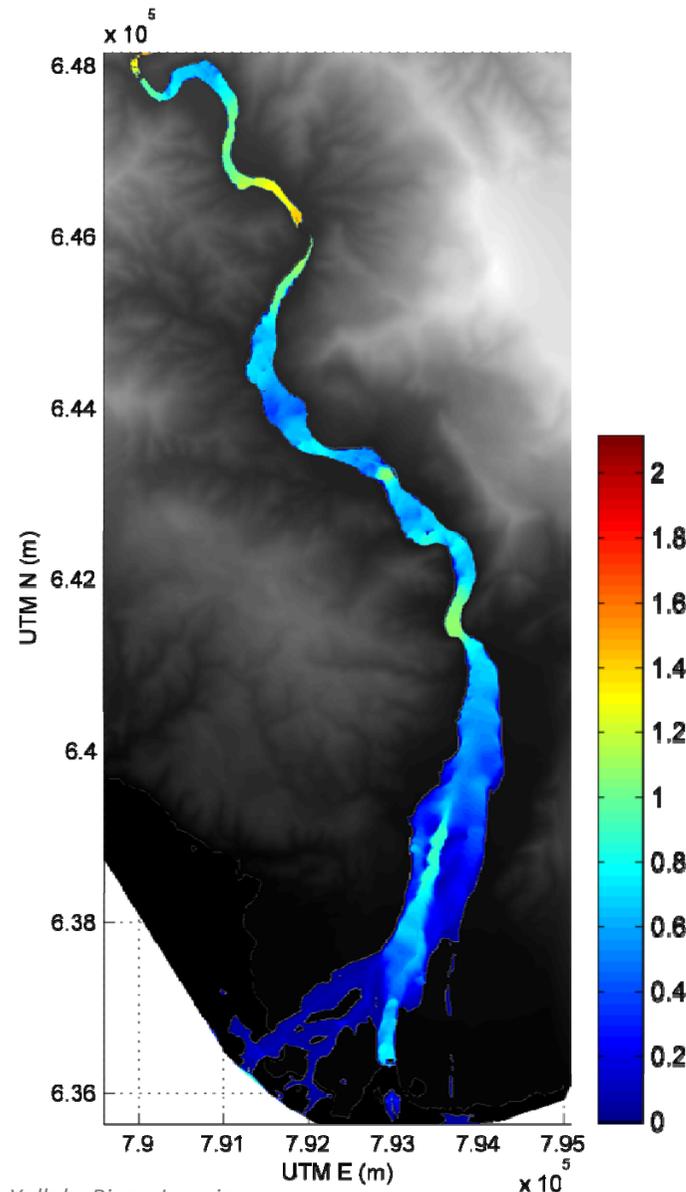
Right: Map of exceedance probability:
 Green: 4% (25 year return period)
 Blue: 2% (50 year return period)
 Red: 1% (100 year return period)



2. Estimation of current flood risk: results

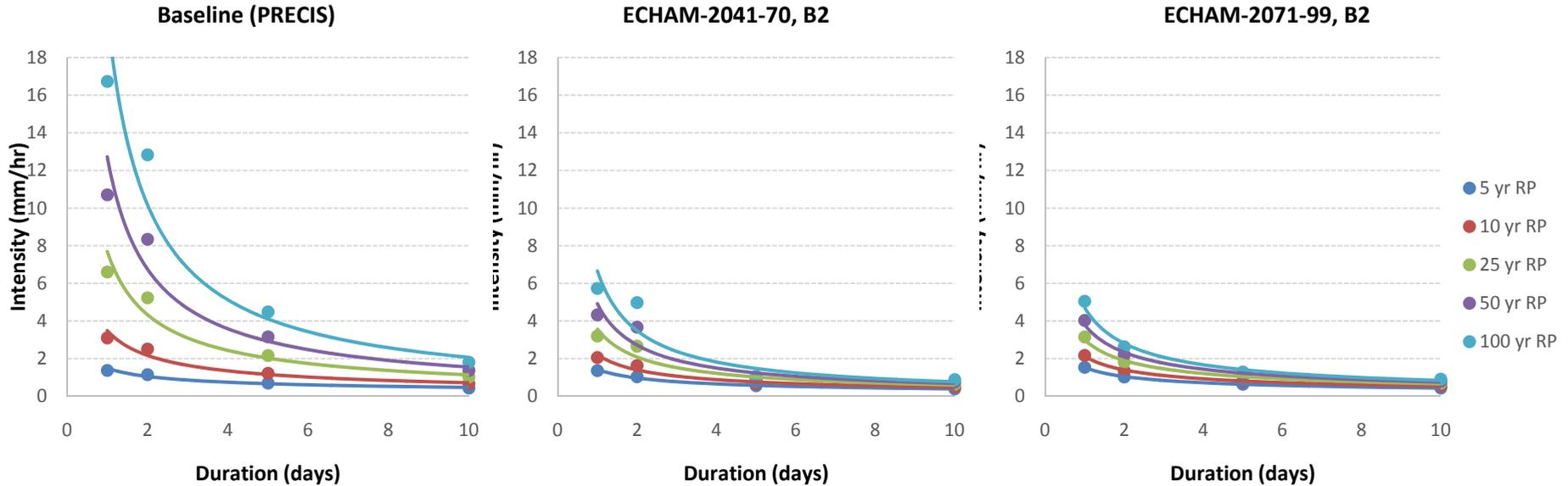


Depth difference:
100-year event maximum
depth minus 25-year
event maximum depth.

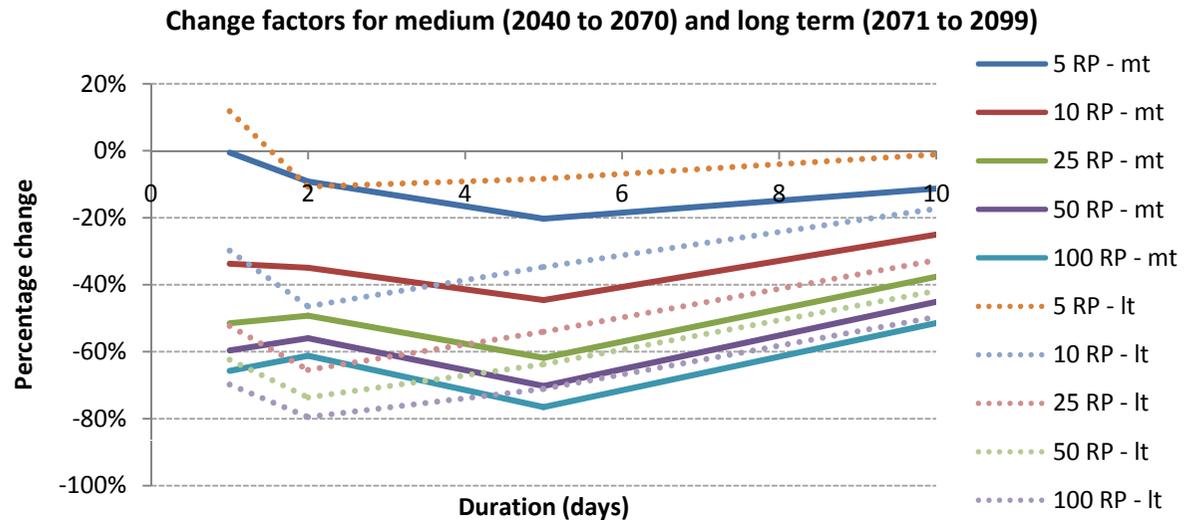


Although the flood
extents are
similar, water depths
are up to 2 m higher
on the floodplain
during a 100-year
event

3. Estimation of future flood risk



- Percentage difference between baseline climate (PRECIS) and future climates (ECHAM) calculated for rainfall events down to 24-hour

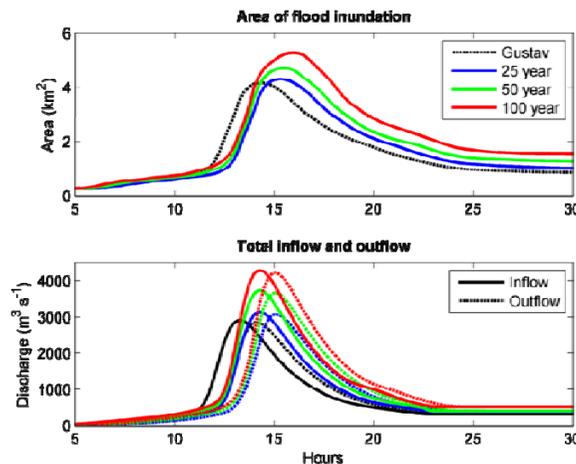


3. Estimation of future flood risk: results

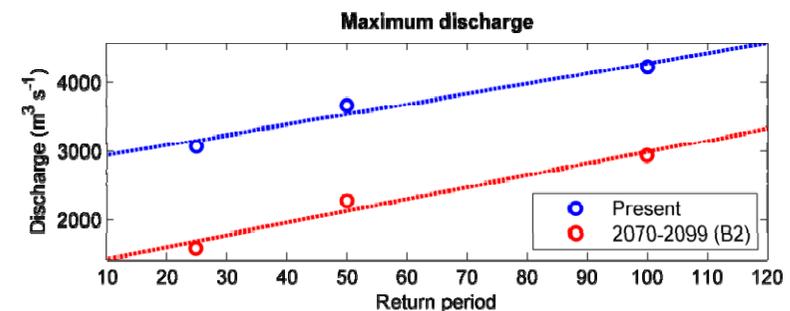
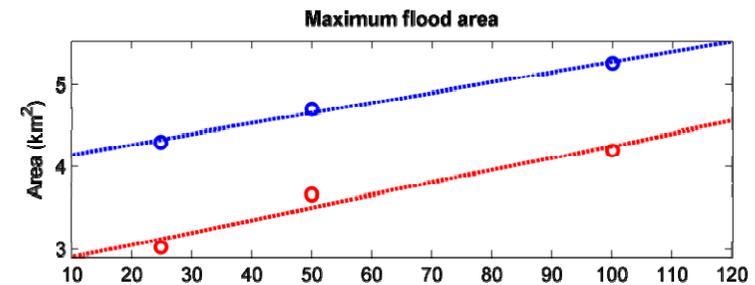
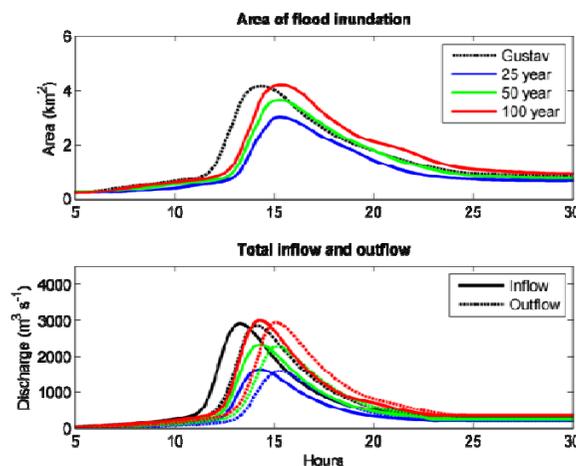


- 25, 50 and 100 year rainfall scaled by change factor from ECHAM and temporally downscaled using NRCS
- HEC-HMS run for future return periods and flows routed through the LISFLOOD-FP model to predict inundation extents and depths

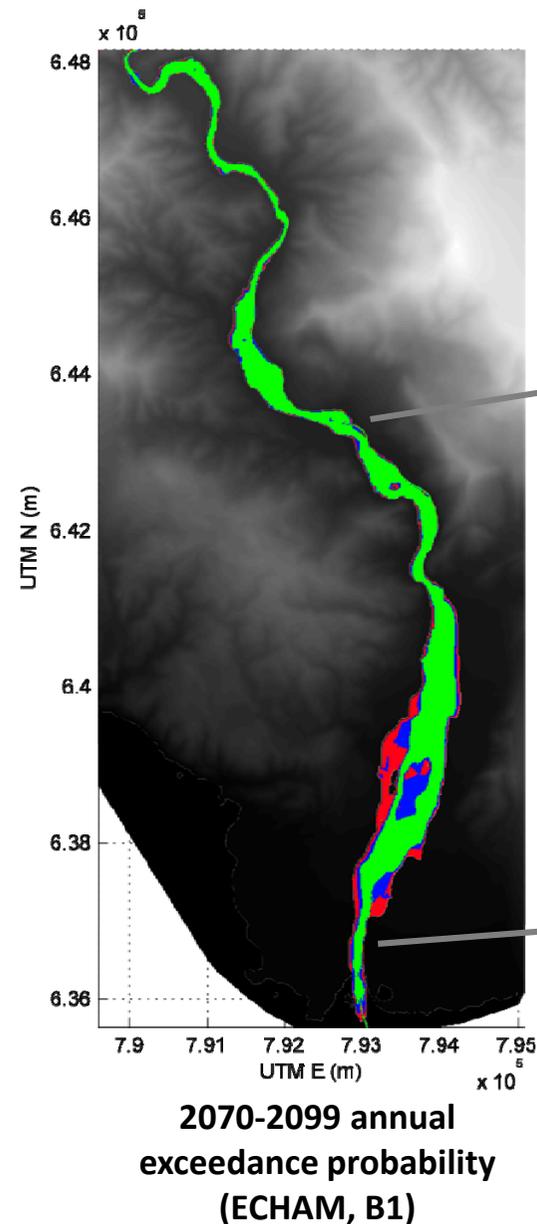
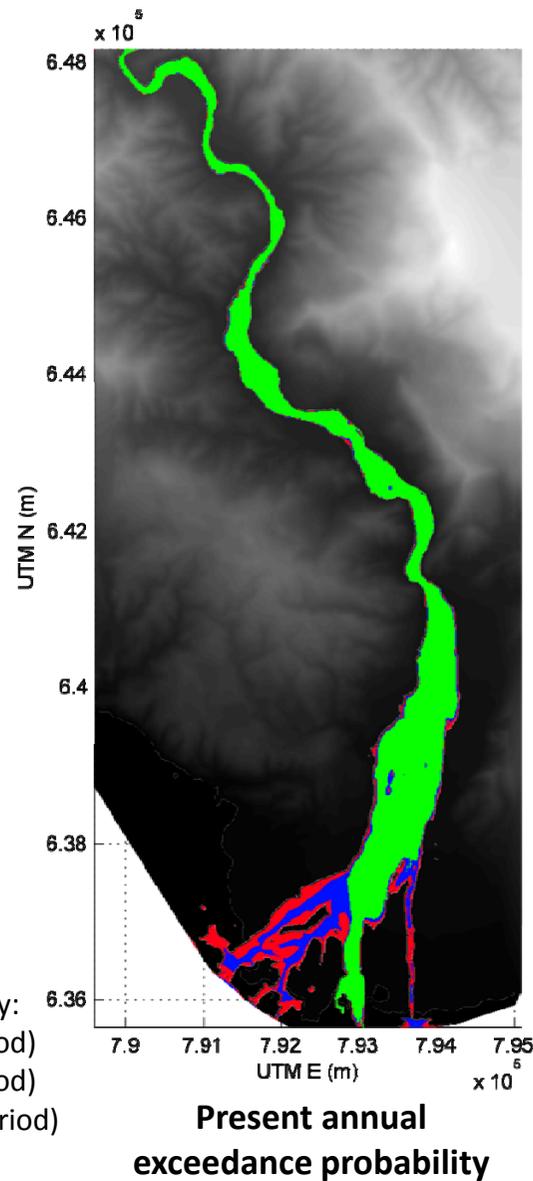
Present return periods
(analysis of gauge data)



Future return periods
(ECHAM, 2070-2099, B2)



3. Estimation of future flood risk: results



Maps of exceedance probability:
 Green: 4% (25 year return period)
 Blue: 2% (50 year return period)
 Red: 1% (100 year return period)

Summary 1



- Flood inundation predicted for Yallahs River using HEC-HMS and LISFLOOD-FP models
 - Past major event (Tropical Storm Gustav)
 - Current 25, 50 and 100-year events
 - 24-hour rainfall temporally downscaled using NRCS method
- Future return periods predicted using percentage changes between baseline climate (PRECIS) and future climates (ECHAM)
 - Future 25, 50 and 100-year events
 - Climate projections suggest a decline in future flood frequency... although inundation extend in valley does not reduce substantially

Summary 2



- More work required:
 - Scale issues are a major problem:
 - How well does the NCRS temporal downscaling of 24-hour rainfall represent actual rainfall intensities?
 - How well do climate models pick up extreme rainfall events? Both spatial and temporal averaging is present
 - Are extreme rainfall events likely to decline as suggested?
 - Further work required in model analysis:
 - Additional climate models
 - Validation of past event predictions for HEC-HMS/LISFLOOD-FP



Thank you Questions?

Thanks to the workshop organisers:



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