WCRP Conference for Latin America and the Caribbean:
Developing, linking and applying climate knowledge
March 17-21, 2014, Montevideo, Uruguay

Flood Risk and Climate Change in Negril, Jamaica

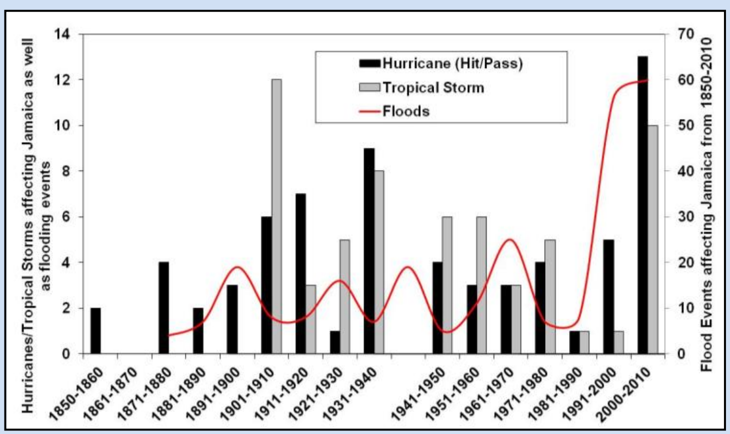
An assessment of combined terrestrial and coastal flood risk driven by projections of future climate

Matthew Wilson[1], Arpita Mandal[2], Michael Taylor[3], Christopher Burgess[3], Jayaka Campbell[3] and Tannecia Stepphenson[3]

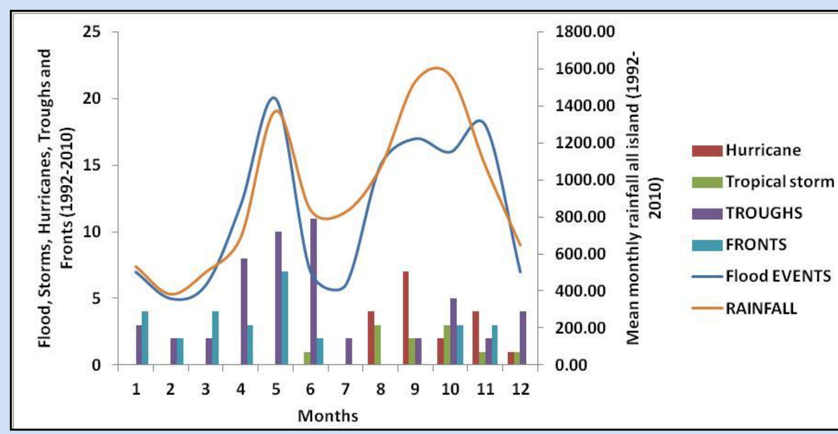
1. Department of Geography, University of the West Indies, St. Augustine, Trinidad & Tobago
2. Department of Geography and Geology, University of the West Indies, Mona, Jamaica
3. Climate Studies Group, Department of Physics, University of the West Indies, Mona, Jamaica

Introduction: Jamaica

- Flooding a major natural hazard affecting Jamaica.
- Located in the Atlantic Hurricane belt
  - Exposed to severe flooding from high intensity rains associated with tropical storms and hurricanes.



Increase in flooding and extreme events from in the last decade



Temporal relation of floods , rainfall and other events.

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 Orange and South Negril Rivers, Jamaica

- Methods:
  - Analysis of measured rainfall
  - Climate model conditioned on rainfall
  - Models of catchment hydrology and flood hydraulics

- Part of a 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 Yallahs River in east Jamaica (see poster by Mandall et al.)

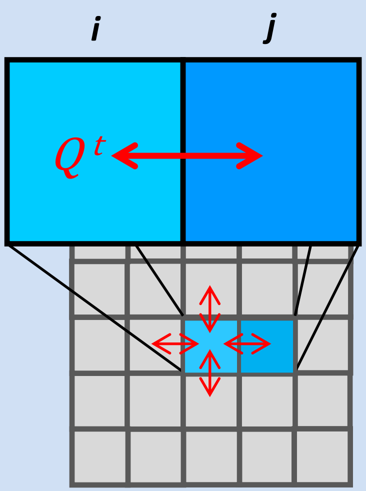
Climate & Development Knowledge Network

Study site/ model development

Orange/ South Negril Rivers:

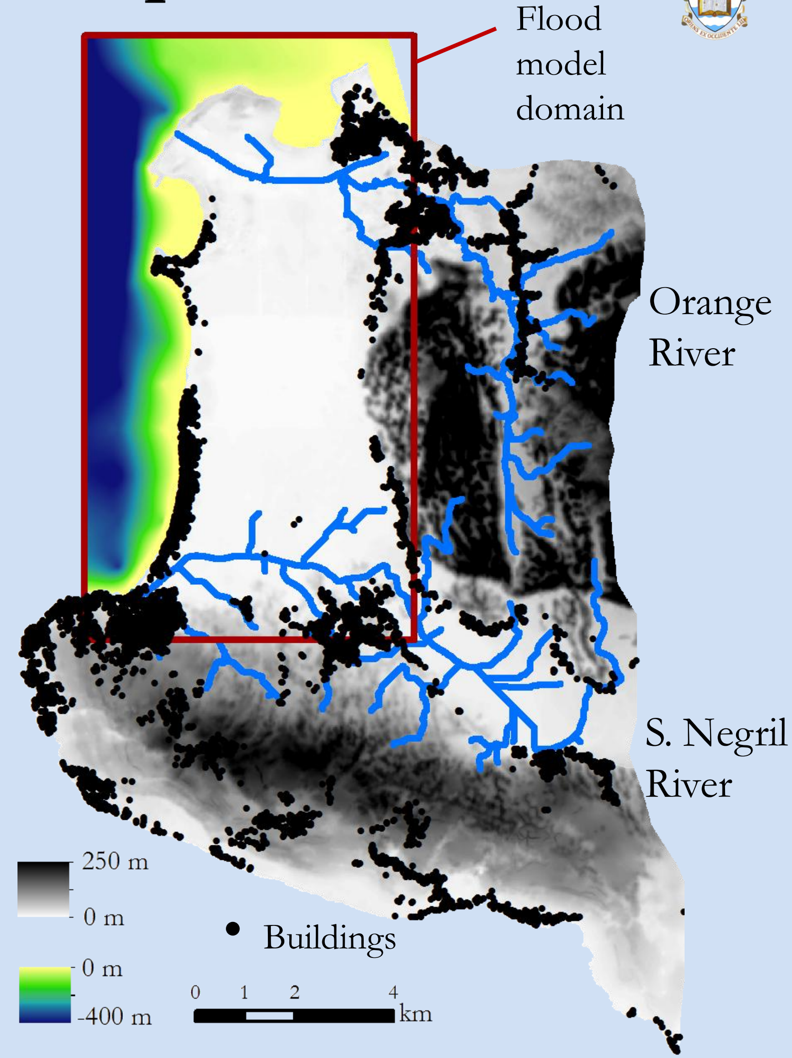
- Low lying twin catchments in west Jamaica.
- Important center of tourism.
- Exposed to storm surge and flood risk associated with storms and hurricanes.

Flood model: LISFLOOD-FP:



- 2D inundation model based on Cartesian grid (inertial formulation used)
- Orange/ S. Negril catchment flow inputs from HEC-HMS models
- Rain direct to the floodplain

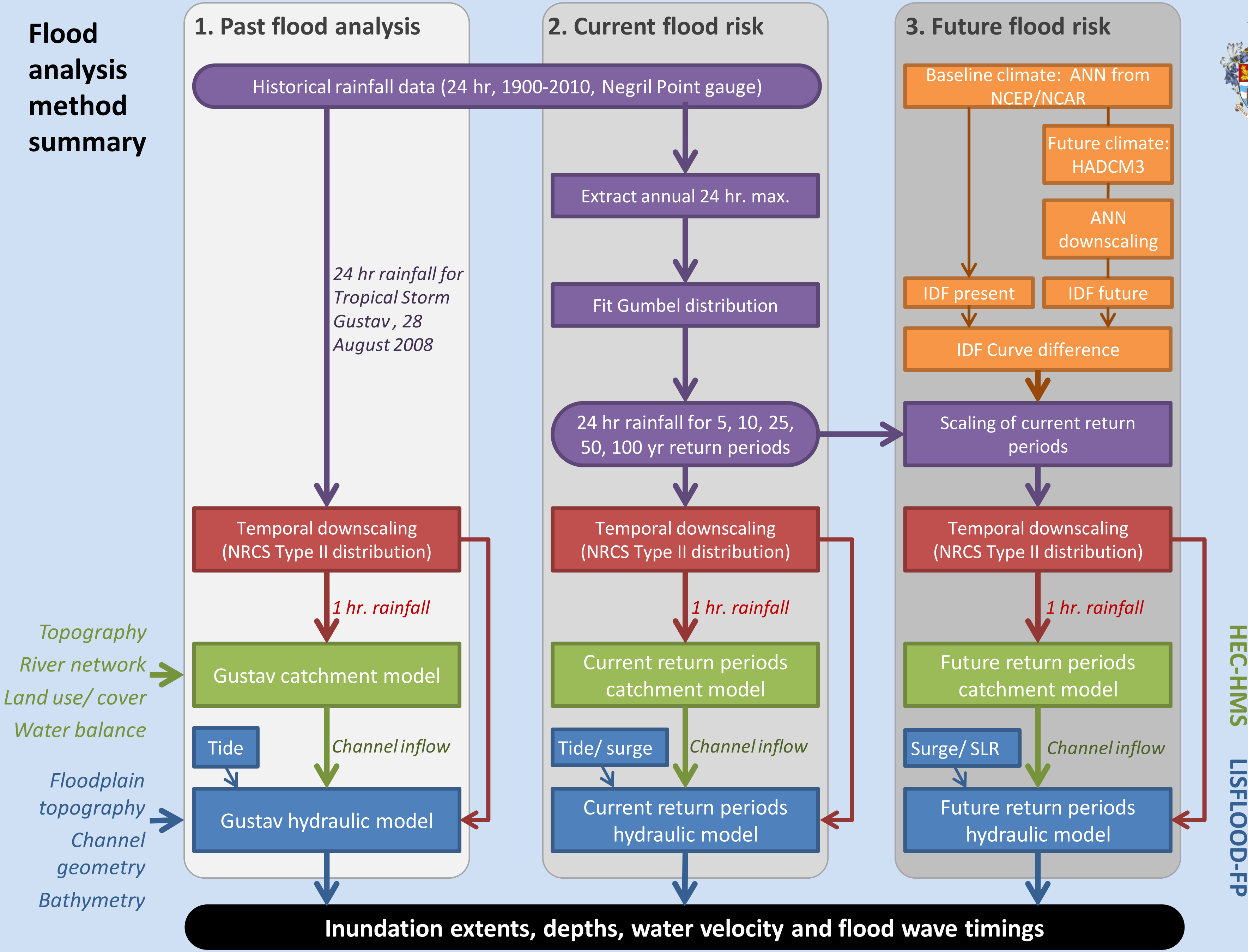
$$Q^t = \frac{q^t - g h^t_{\mathrm{flow}} \Delta t \dfrac{\Delta\left(h^t + z\right)}{\Delta x}}{\left(1 + g h^t_{\mathrm{flow}} \Delta t n^2 \left|q^{t-\Delta t}\right| / \left(h^t_{\mathrm{flow}}\right)^{10/3}\right)} \Delta x$$



Topography: 6 m horizontal and 1 m vertical resolution Digital Elevation Model (DEM) from stereo phogrammetry (Mona Geoinformatix Institute)

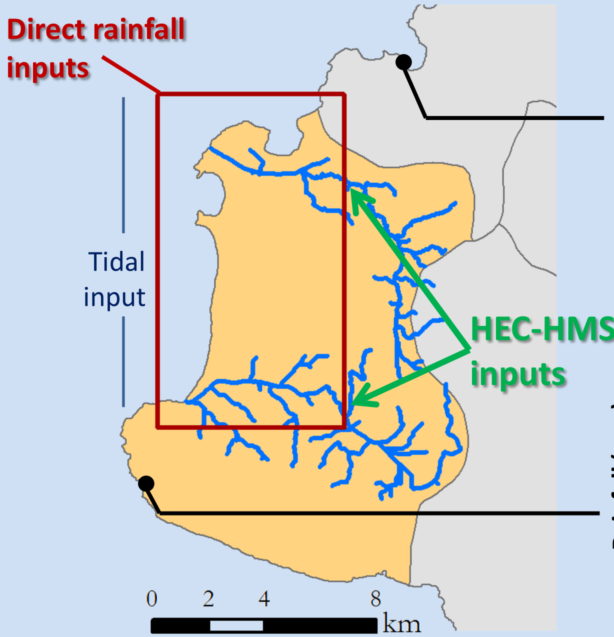
Bathymetry: Interpolated from GEBCO data

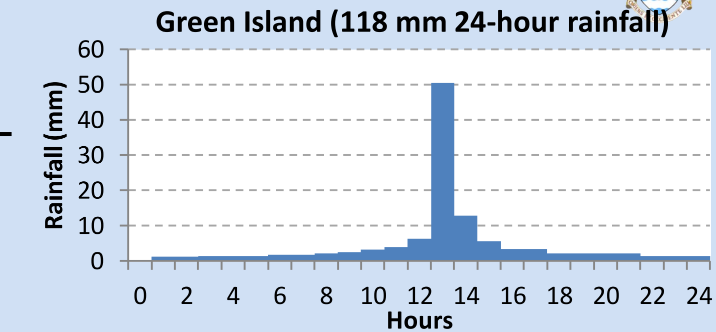
Flood analysis method summary

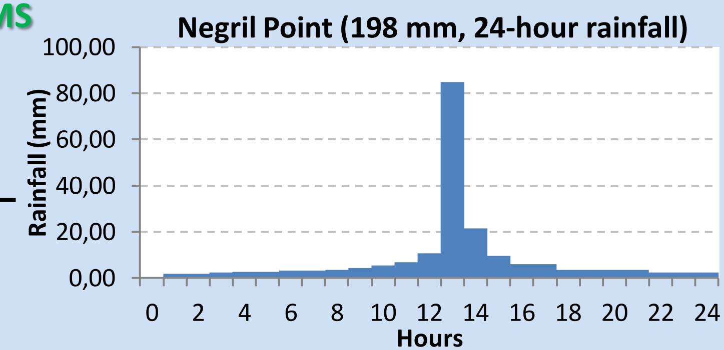


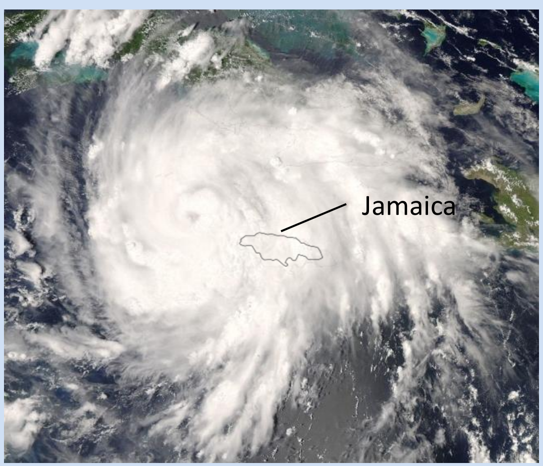
1. Past flood analysis: Tropical Storm Gustav

- Landfall in Jamaica 28 August 2008
- Major impact (US $210 M)
- 24-hr data for Negril Point and Green Island gauges
- National Resources Conservation Services (NRCS) Type II method used to generate 1-hr rainfall
- Flows generated from rainfall using HEC-HMS
- Inundation modelled using LISFLOOD-FP



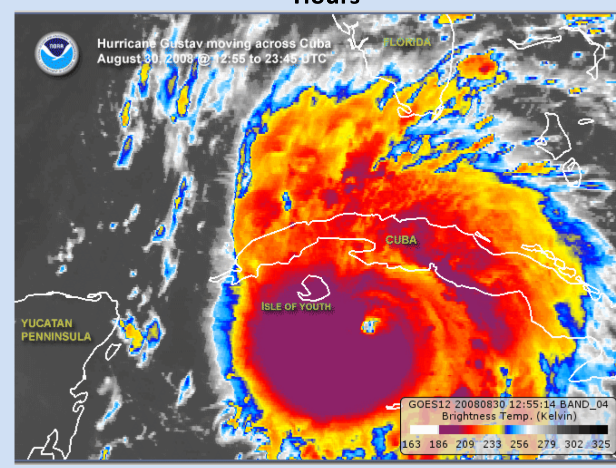






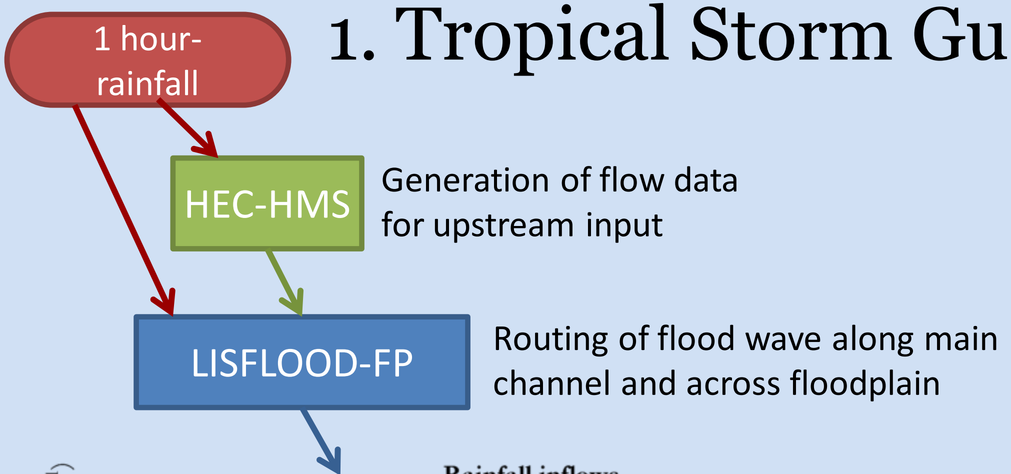
http://en.wikipedia.org/wiki/File:Gustav_29_August_2008.jpg

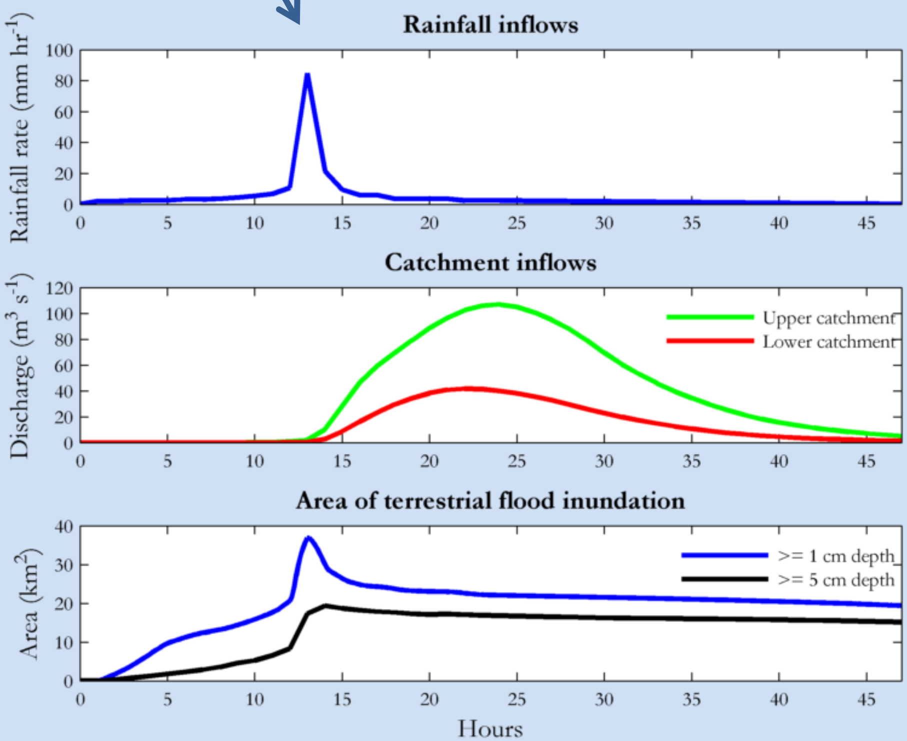
http://en.wikipedia.org/wiki/File:Gustav_2008_track.png



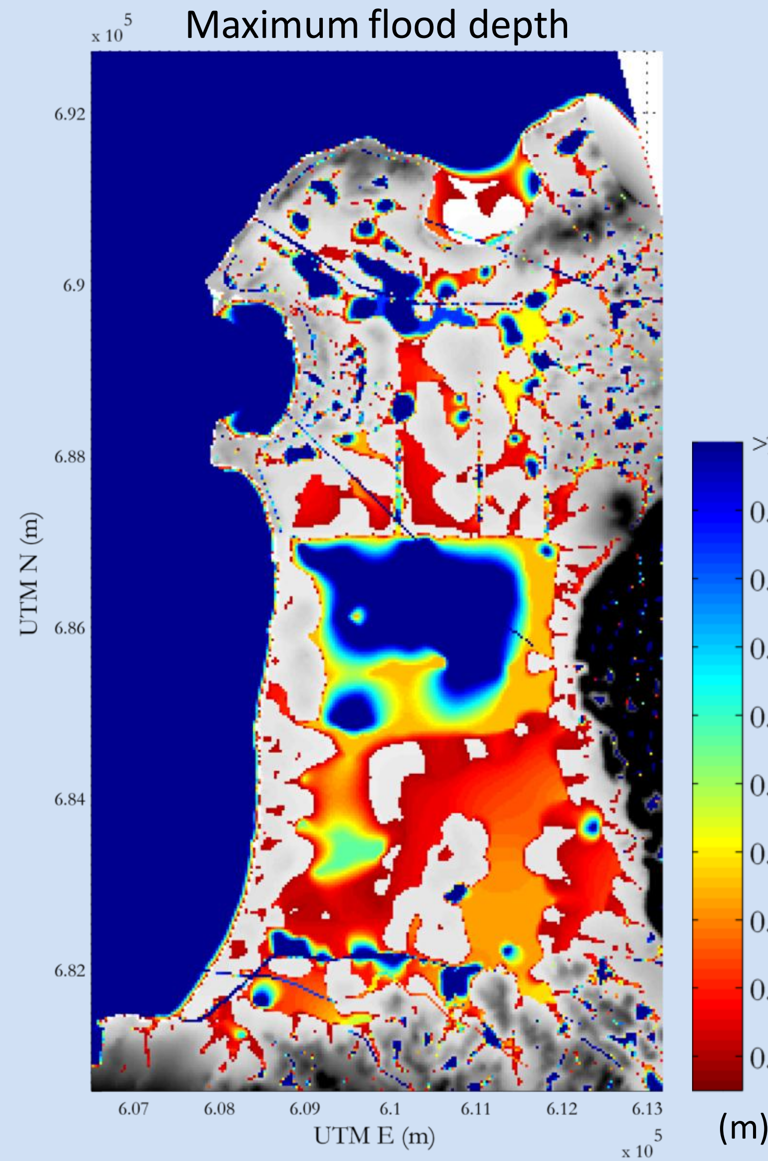
http://en.wikipedia.org/wiki/File:GustavCuba.gif

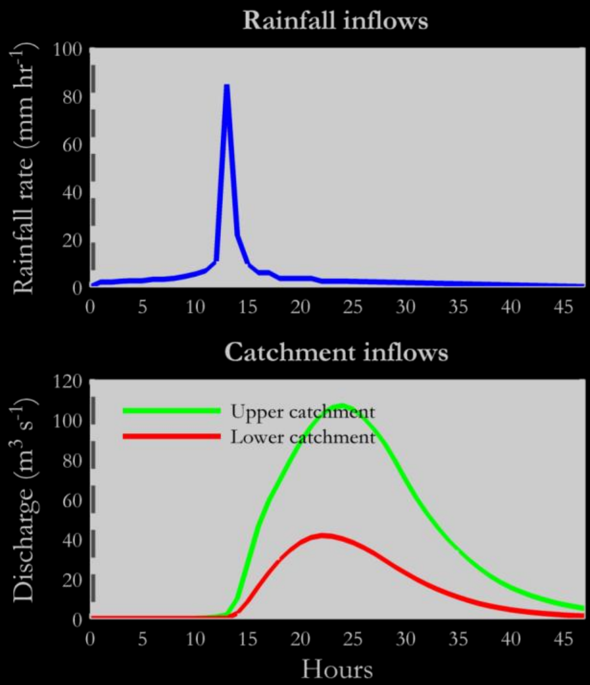
1. Tropical Storm Gustav: Results

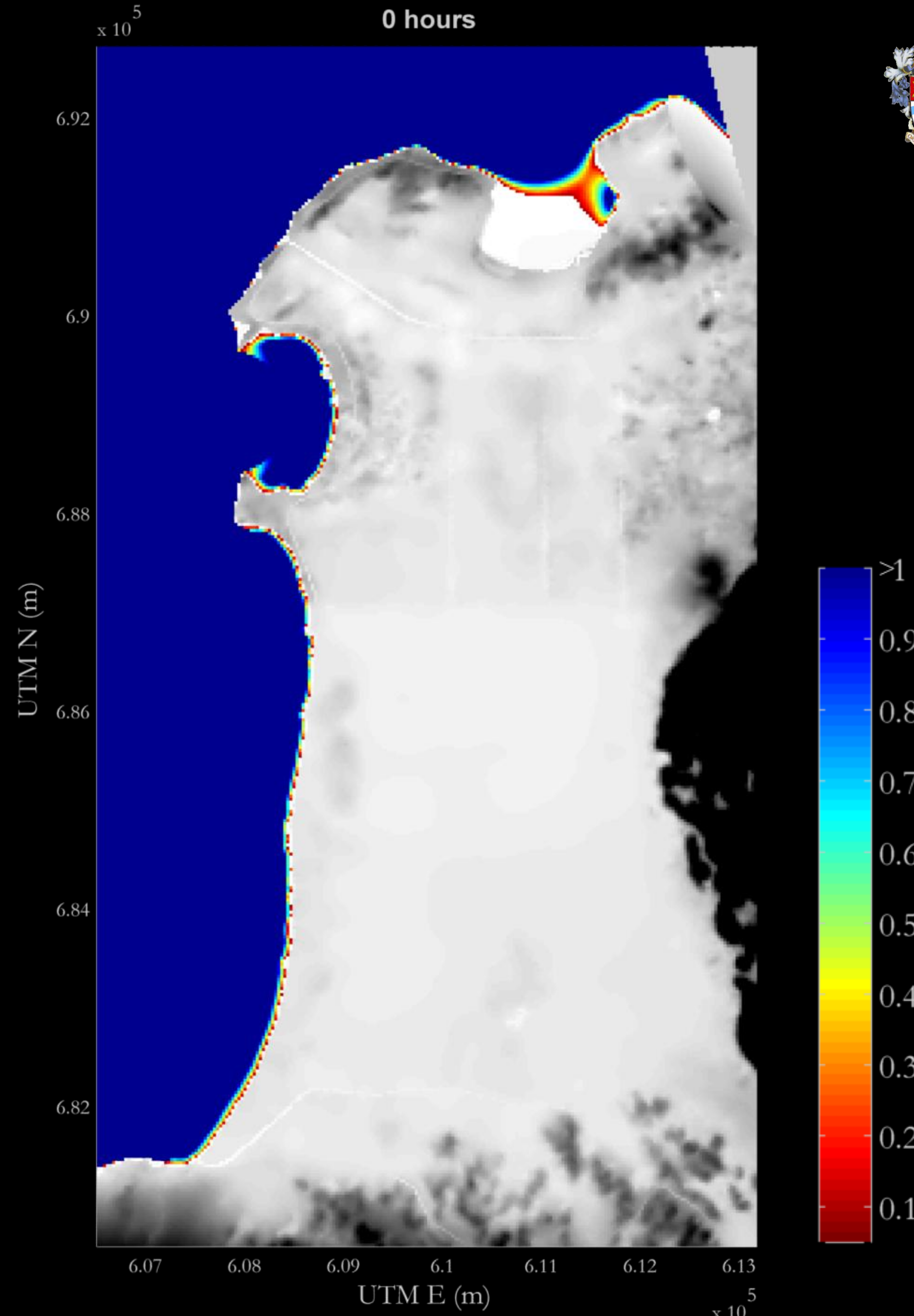




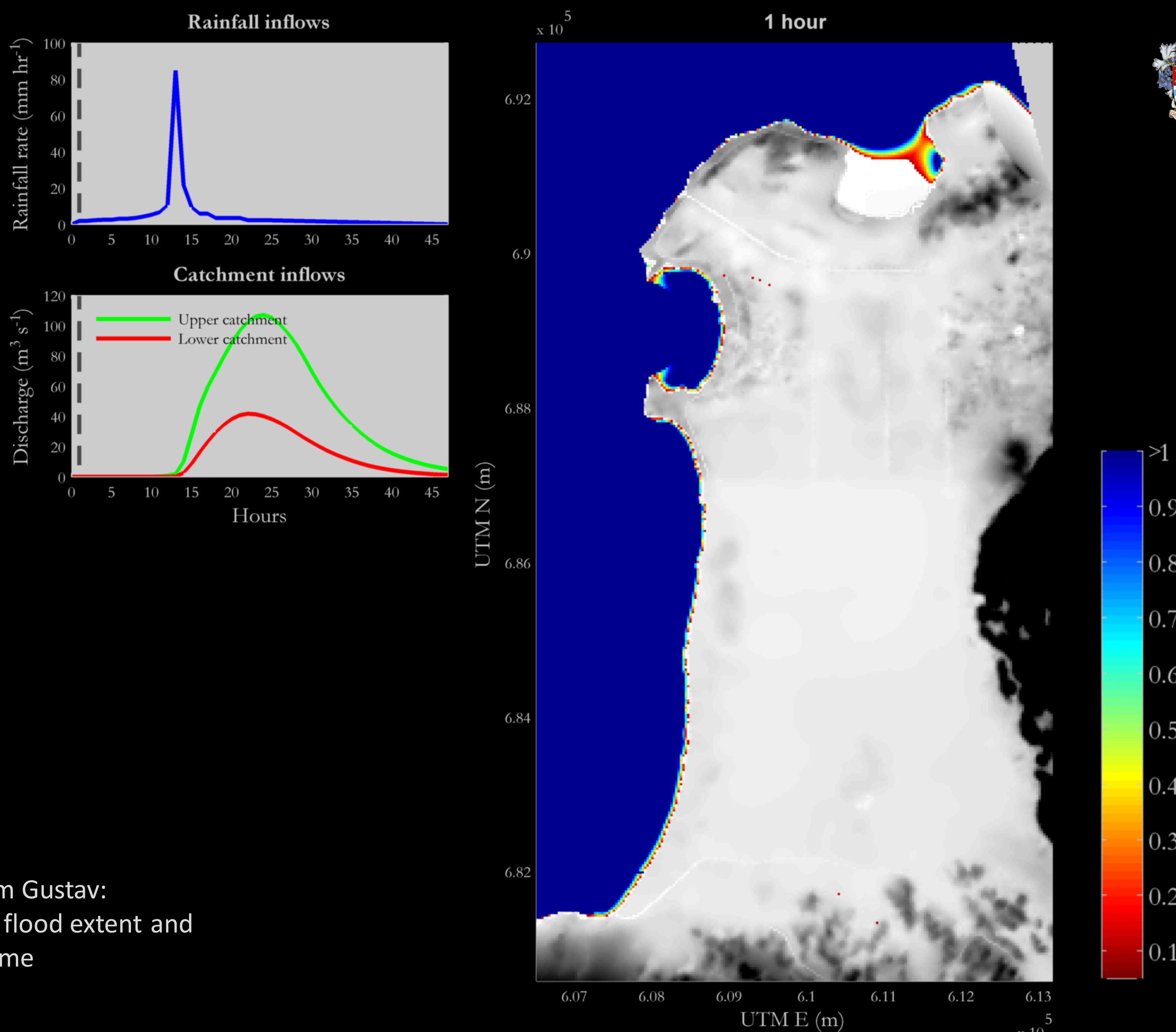
(no storm-surge included)



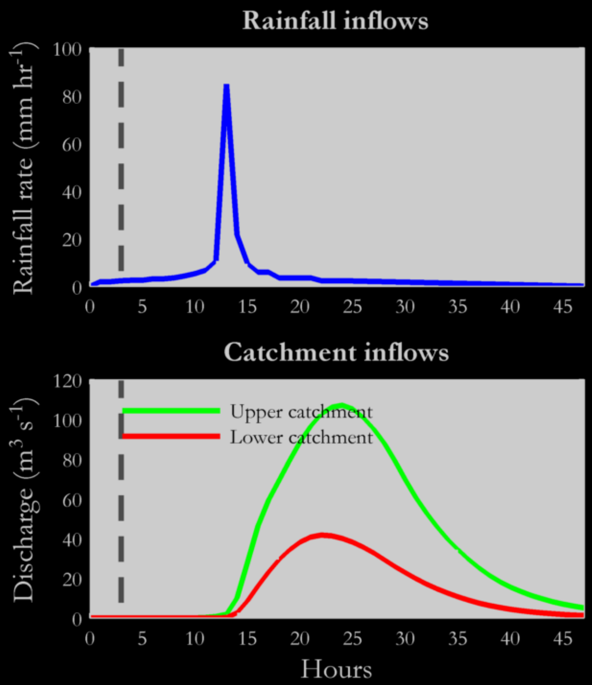


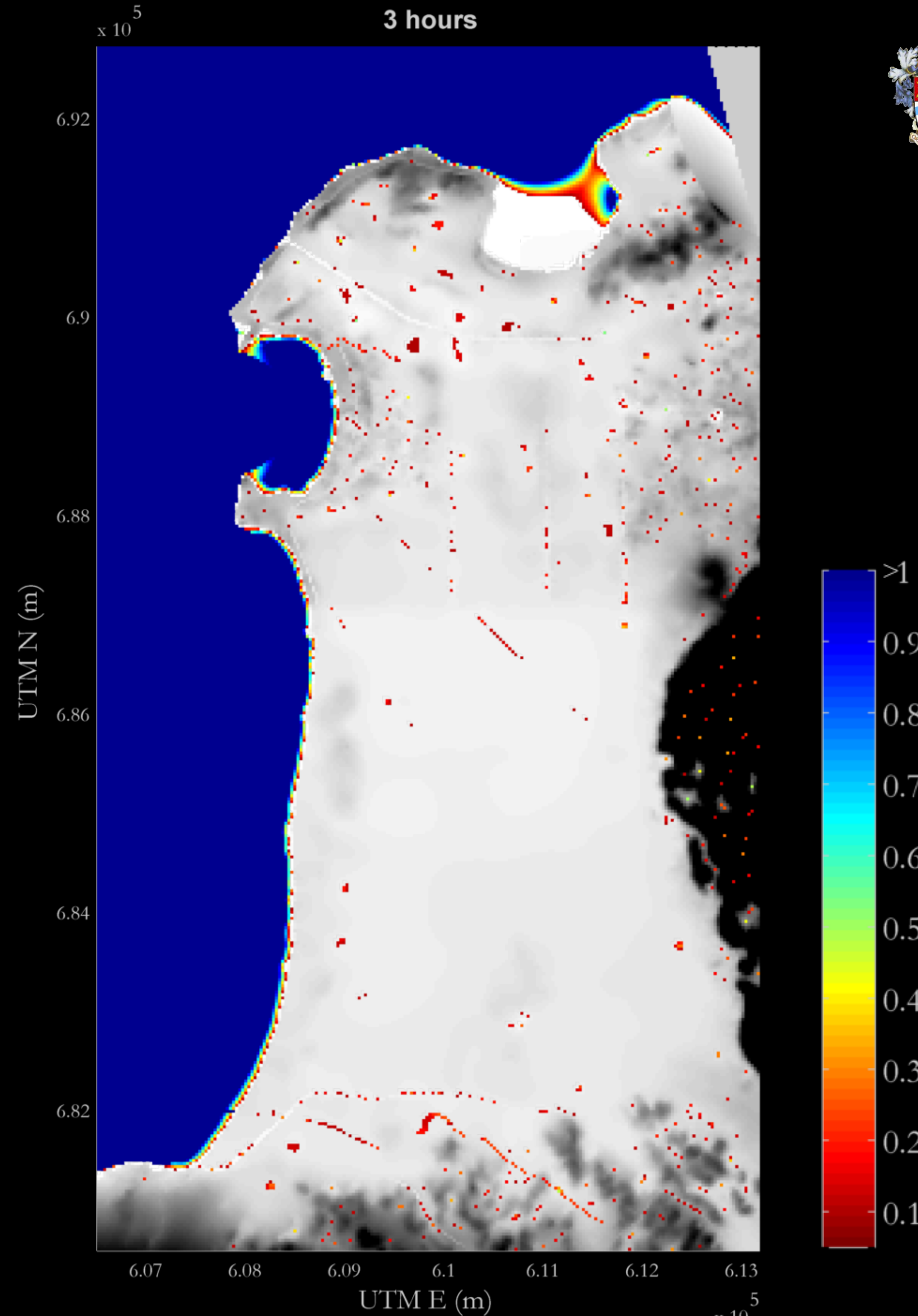


Tropical Storm Gustav:
Prediction of flood extent and depth over time

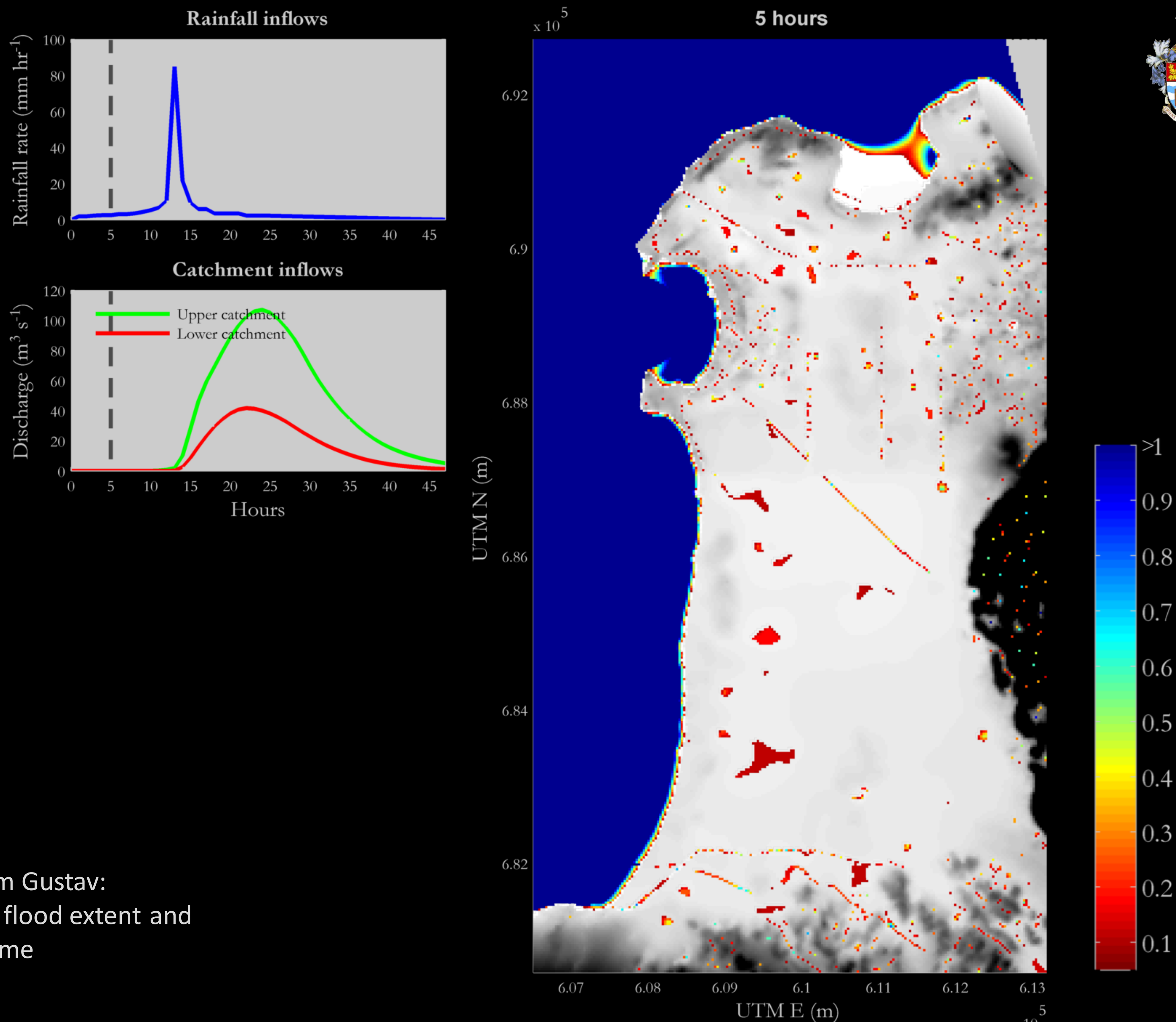


Tropical Storm Gustav:
Prediction of flood extent and depth over time

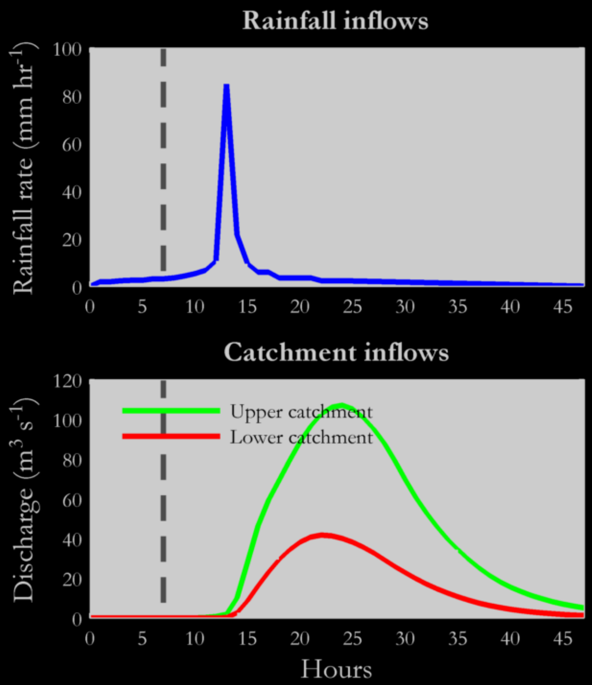


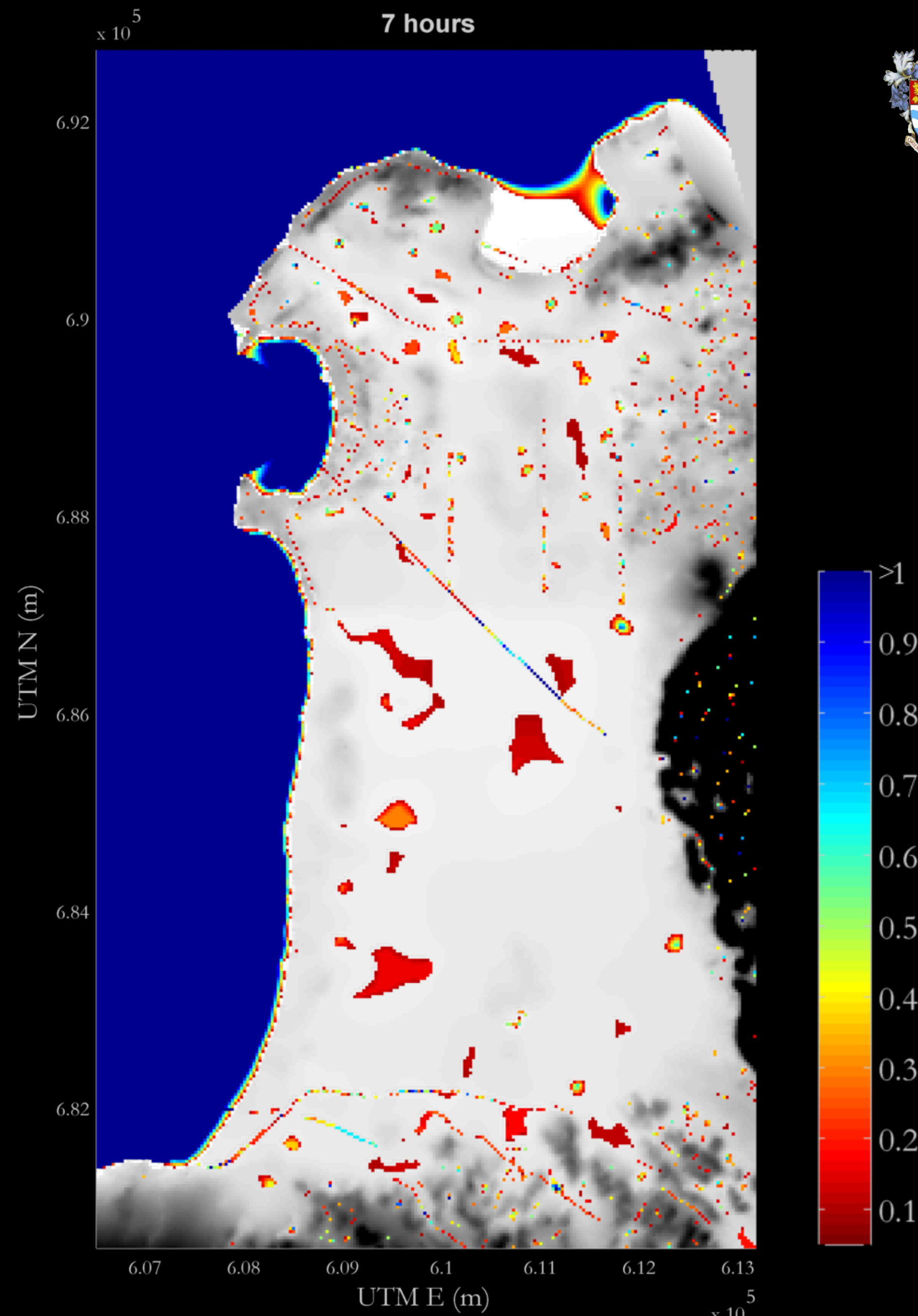


Tropical Storm Gustav:
Prediction of flood extent and depth over time

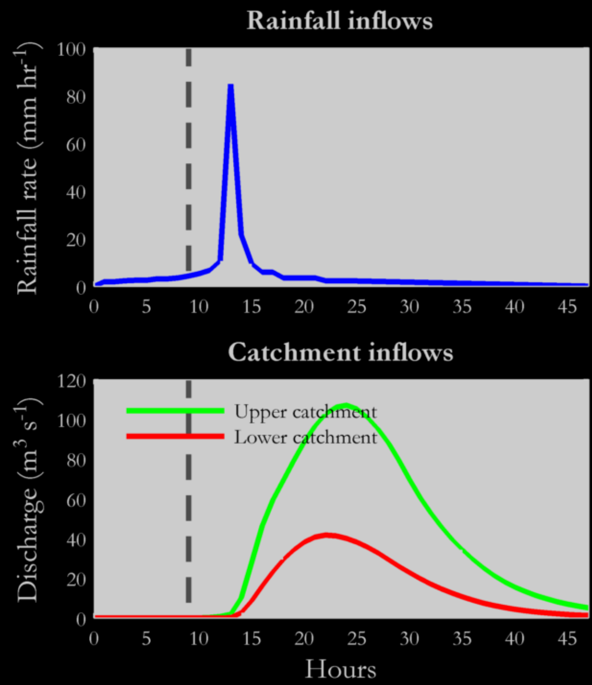


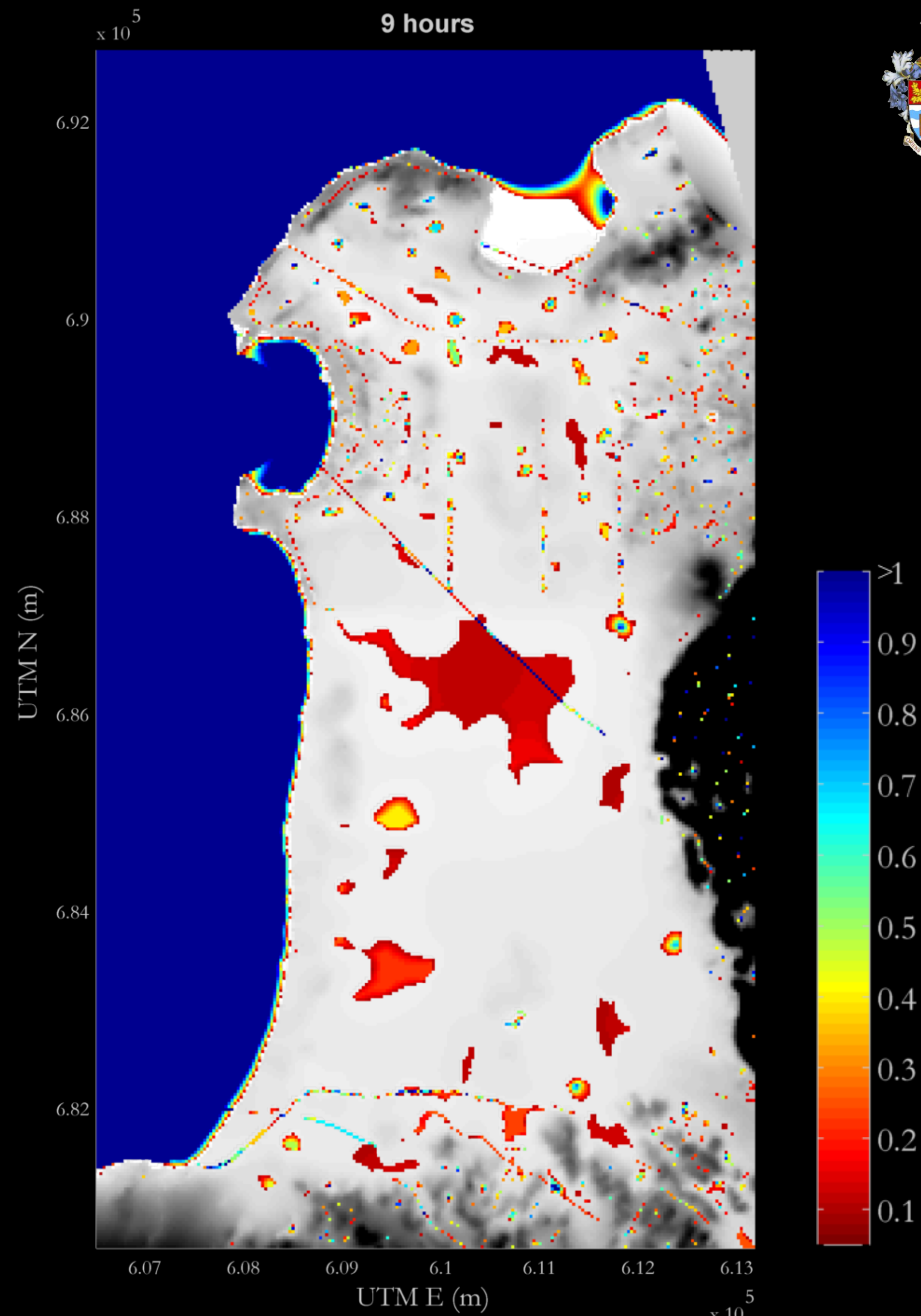
Tropical Storm Gustav:
Prediction of flood extent and depth over time



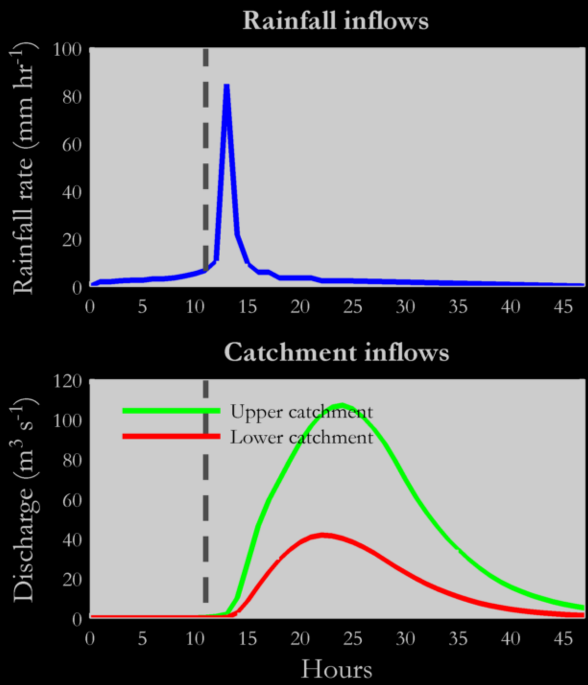


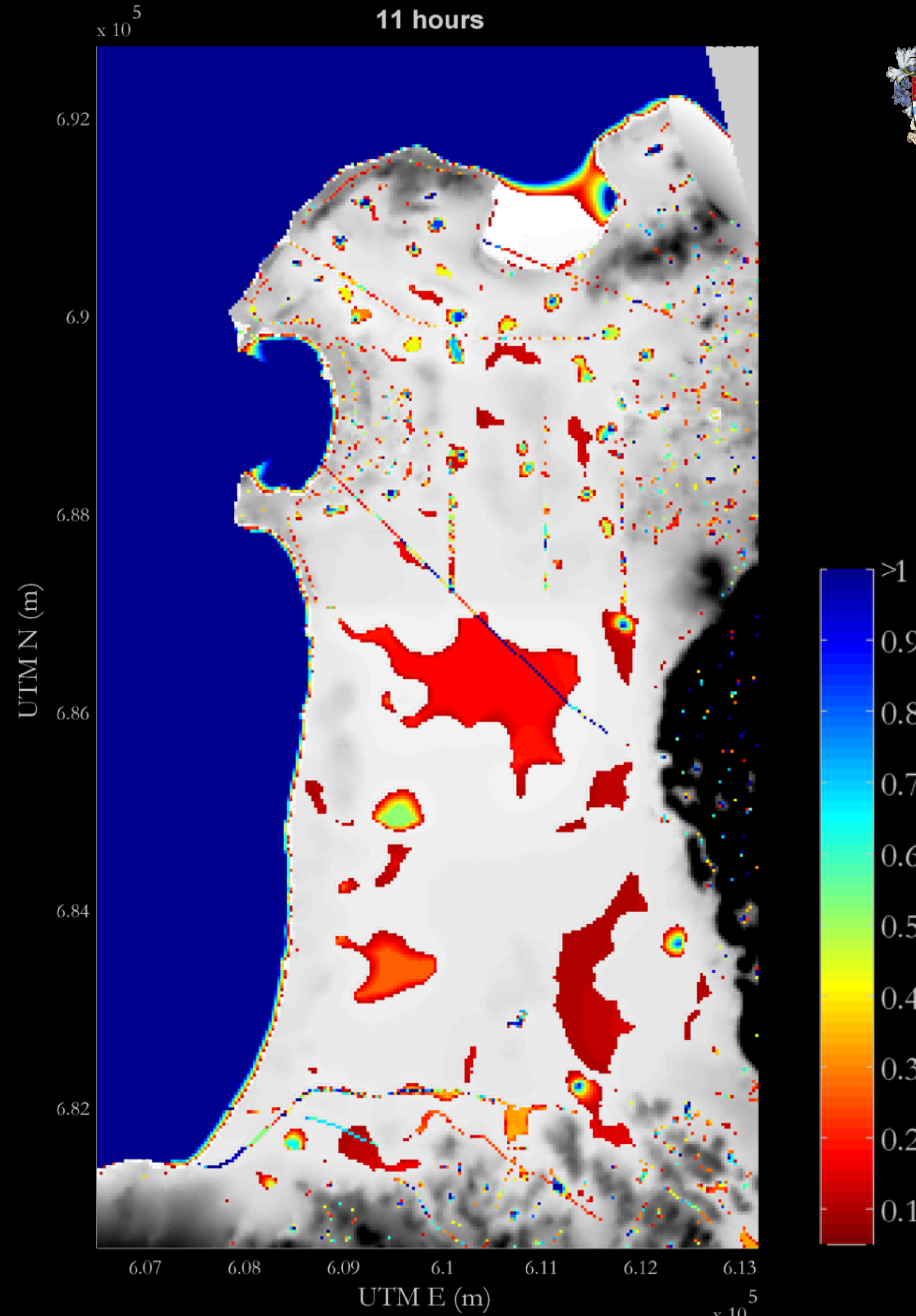
Tropical Storm Gustav:
Prediction of flood extent and
depth over time





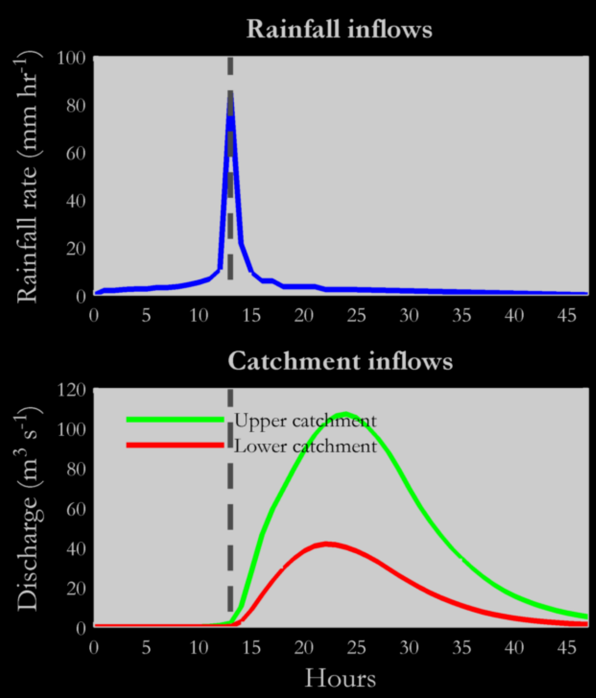
Tropical Storm Gustav:
Prediction of flood extent and depth over time

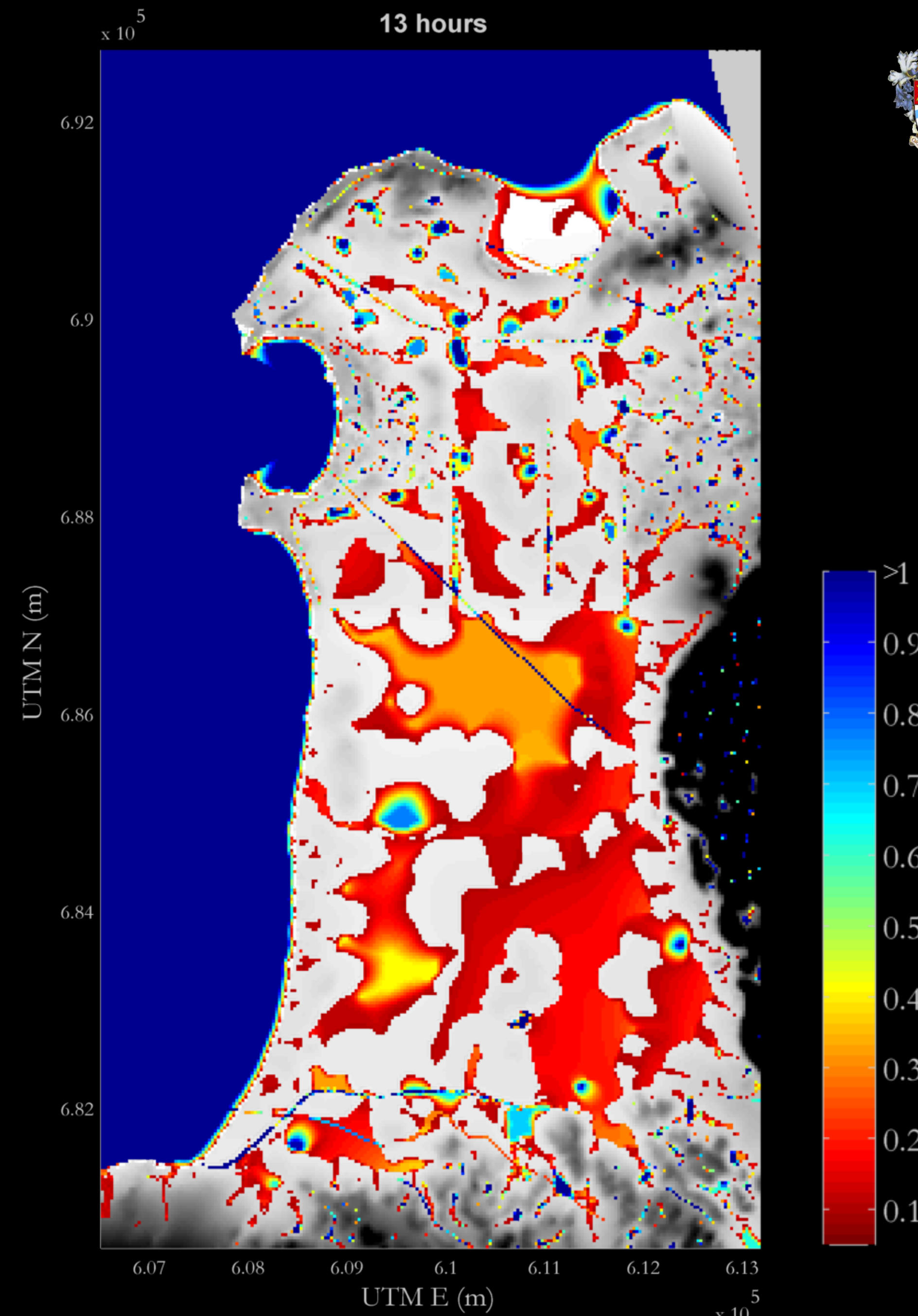




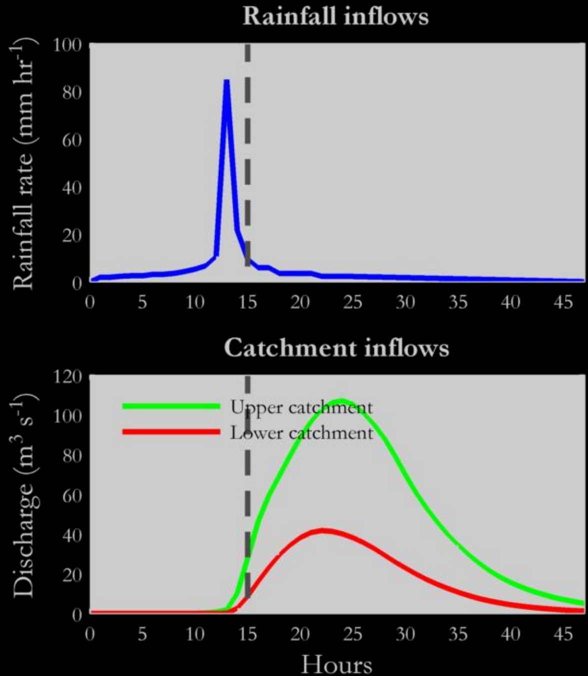
Tropical Storm Gustav:
Prediction of flood extent and depth over time

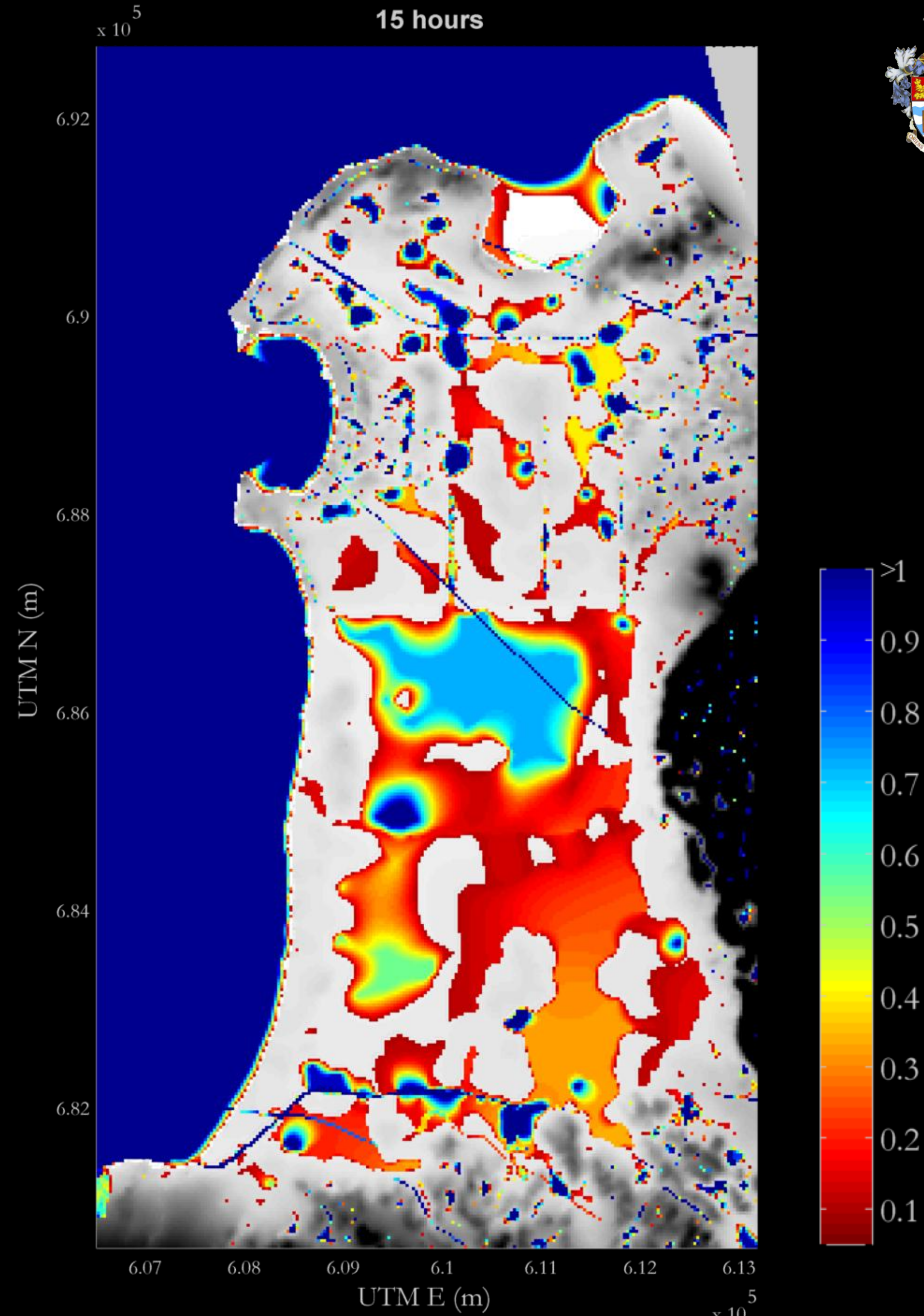
Wilson et al., *Flood Risk and Climate Change in Negril, Jamaica*, WCRP Conference for Latin America and the Caribbean, March 17-21, 2014, Montevideo, Uruguay



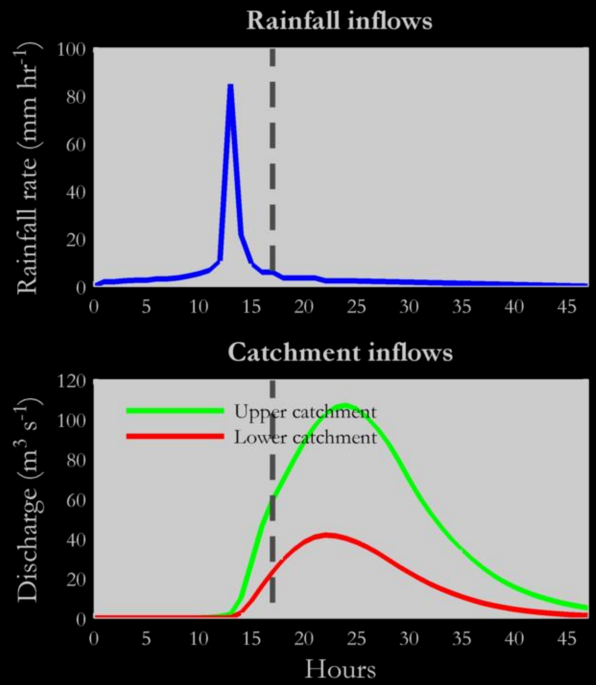


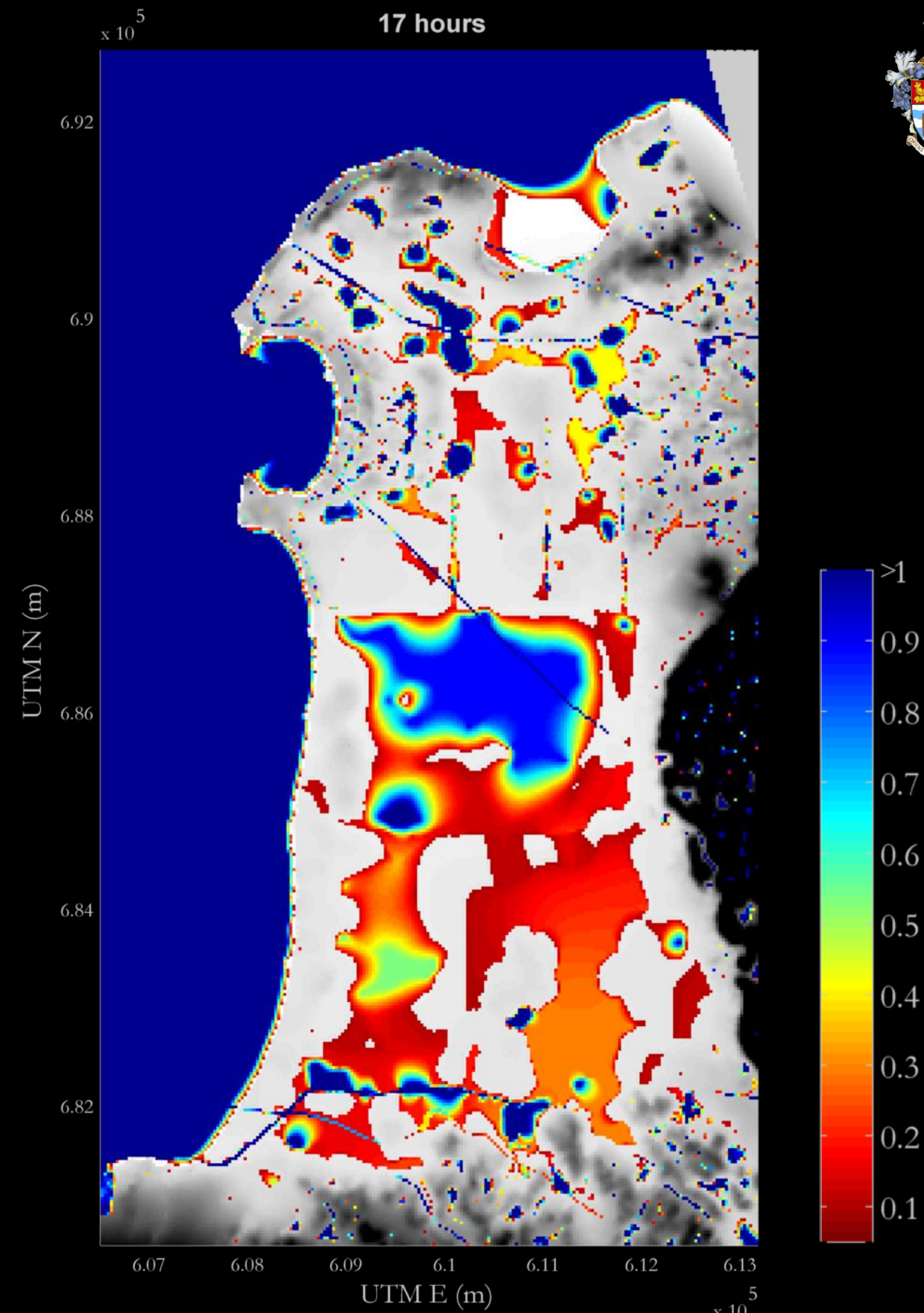
Tropical Storm Gustav:
Prediction of flood extent and depth over time



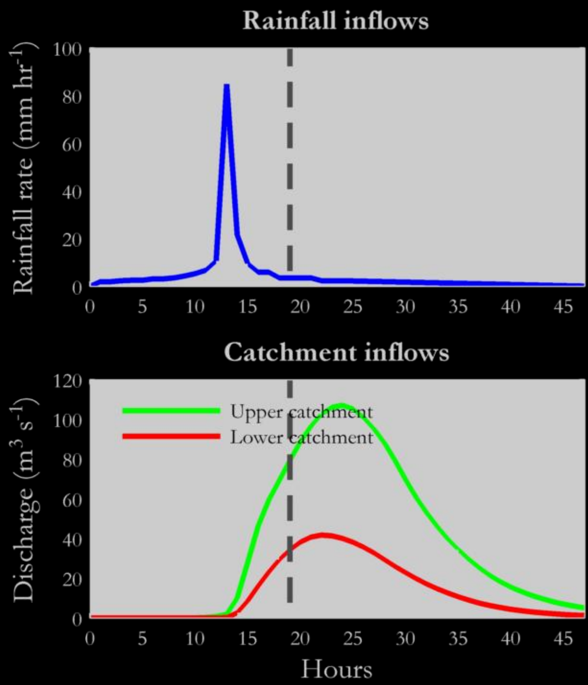


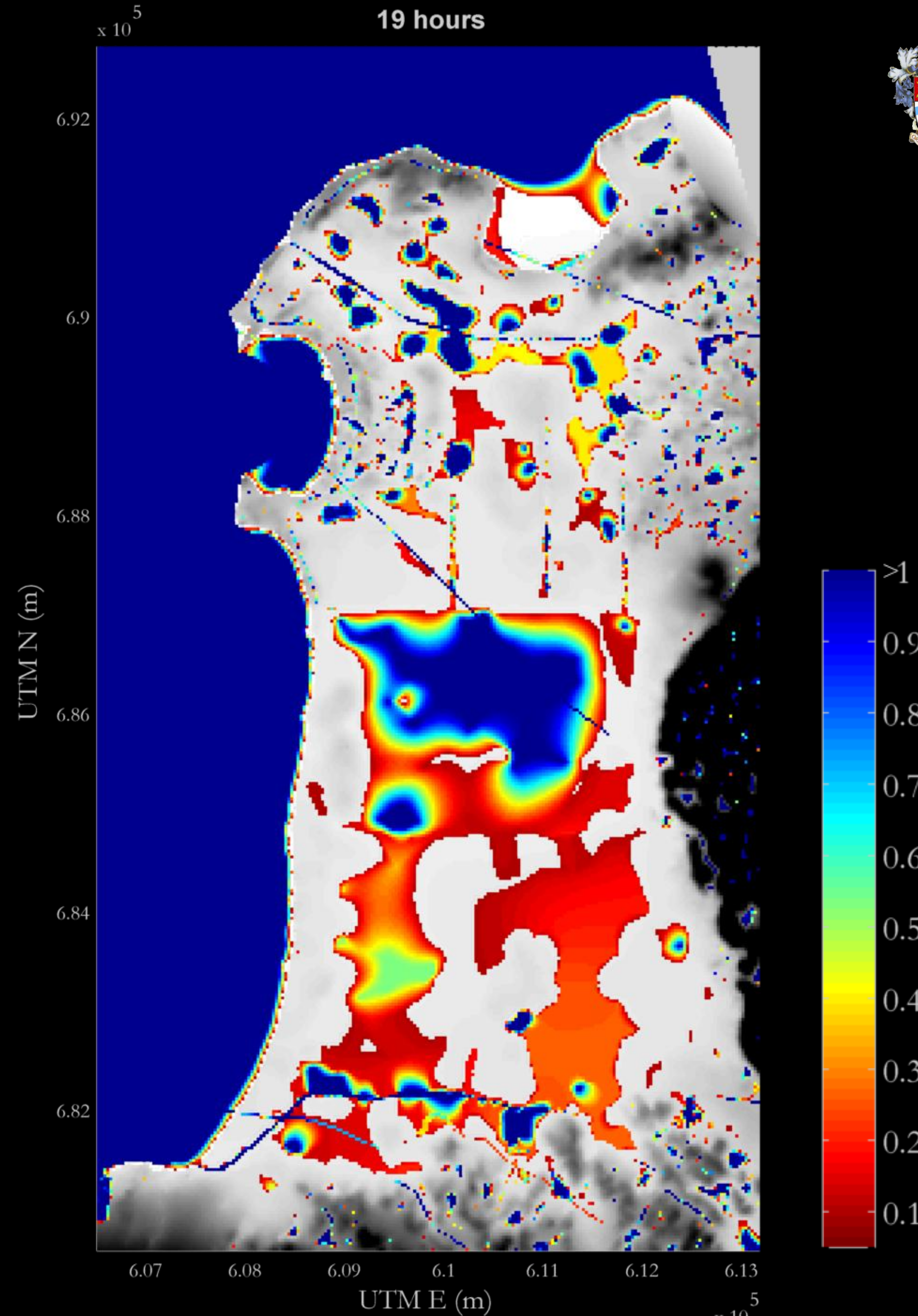
Tropical Storm Gustav:
Prediction of flood extent and depth over time



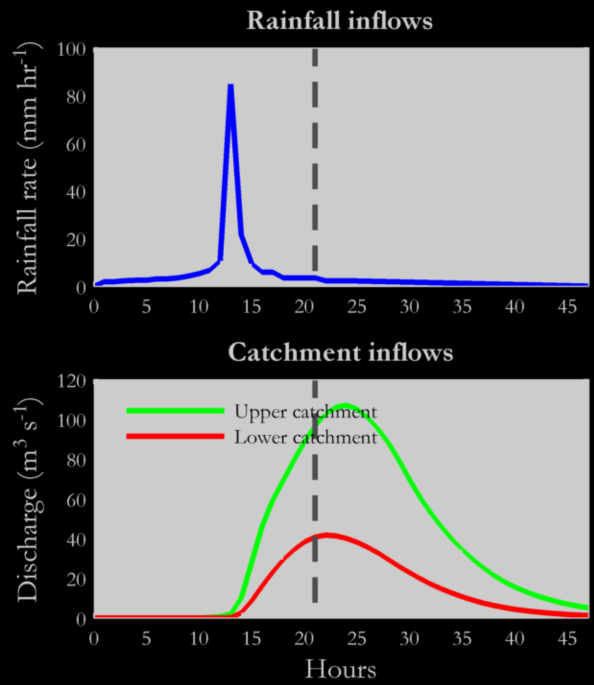


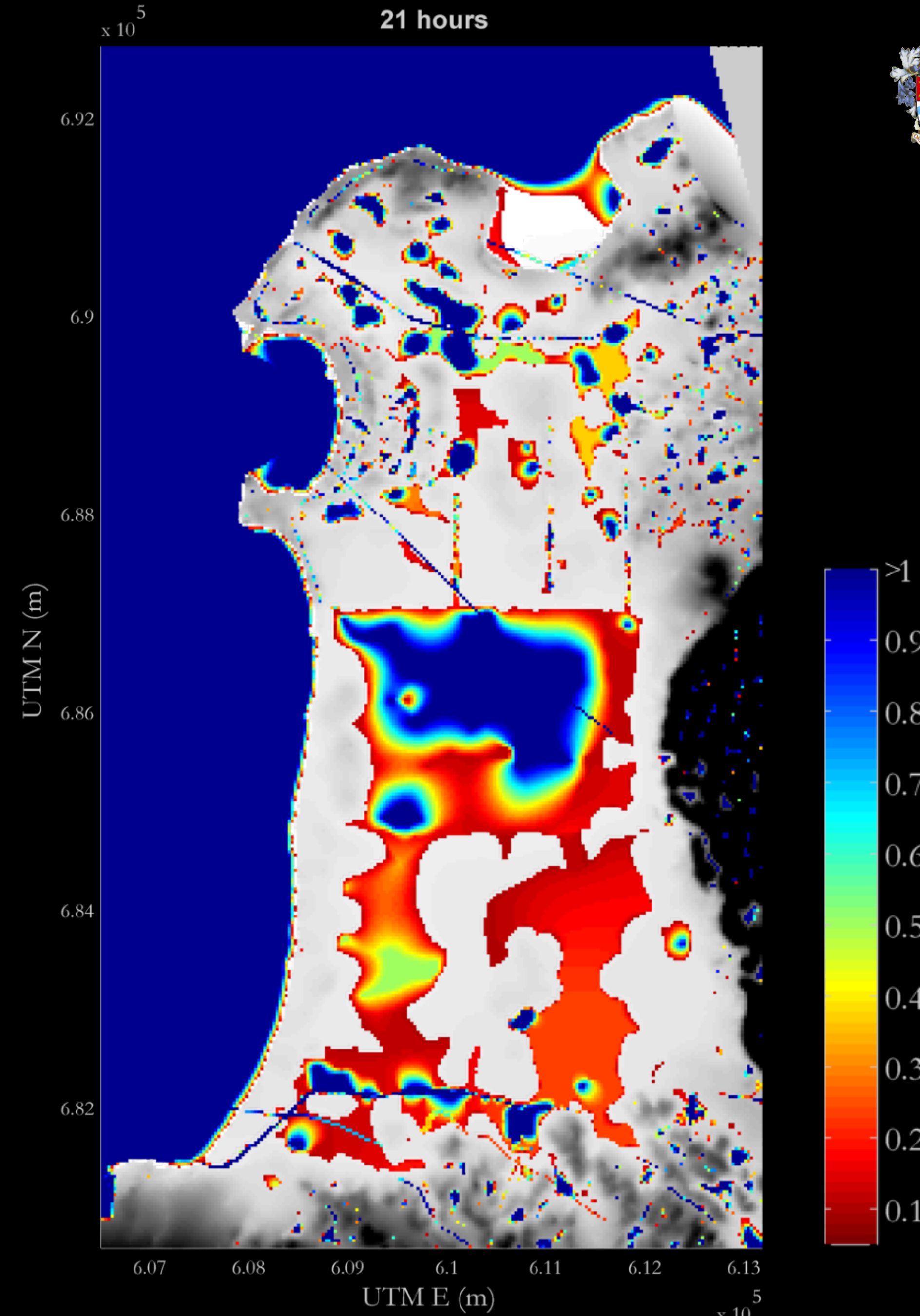
Tropical Storm Gustav:
Prediction of flood extent and depth over time



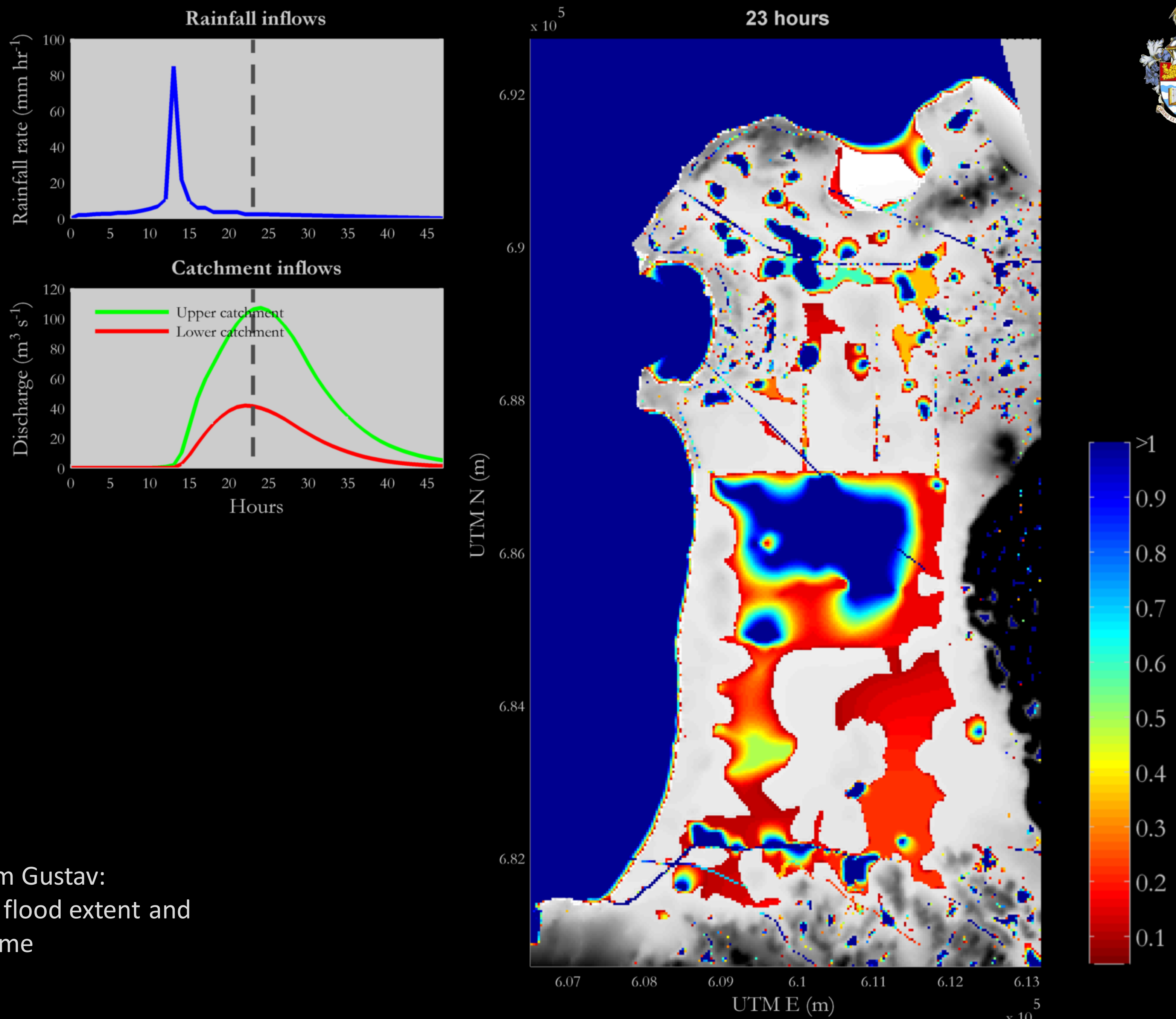


Tropical Storm Gustav:
Prediction of flood extent and depth over time



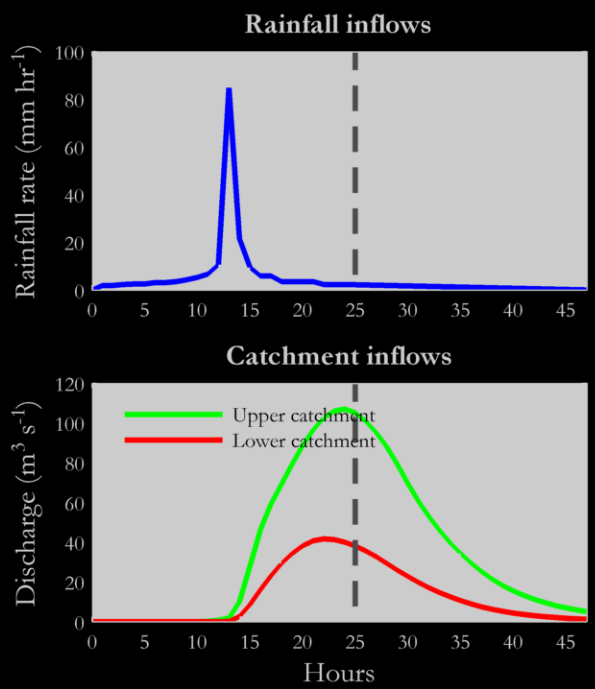


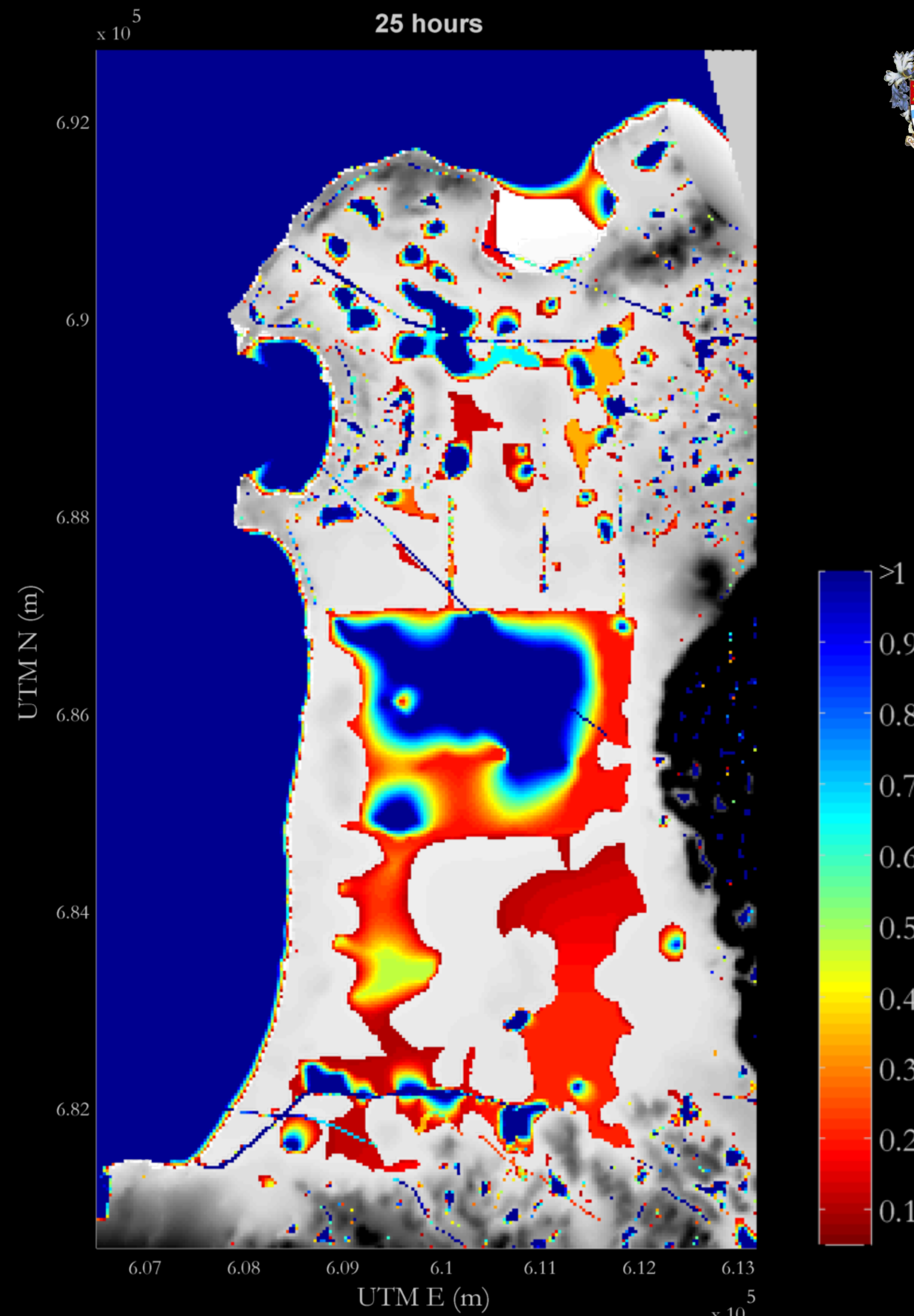
Tropical Storm Gustav:
Prediction of flood extent and depth over time



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

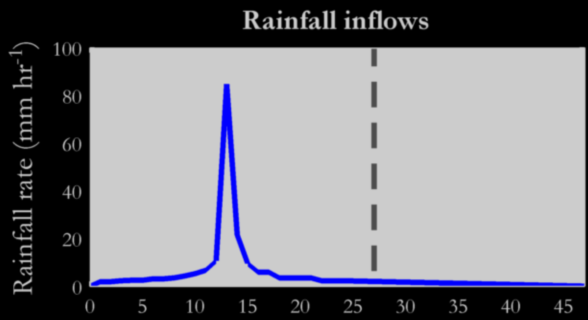
Wilson et al., *Flood Risk and Climate Change in Negril, Jamaica*, WCRP Conference for Latin America and the Caribbean, March 17-21, 2014, Montevideo, Uruguay

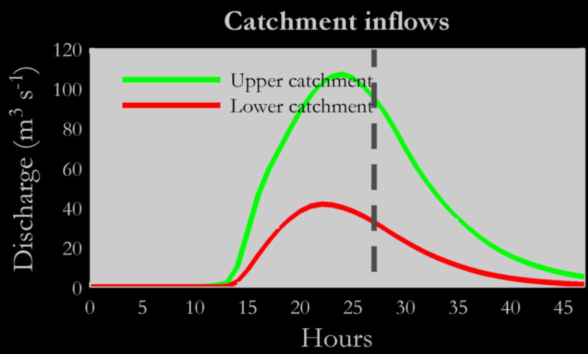


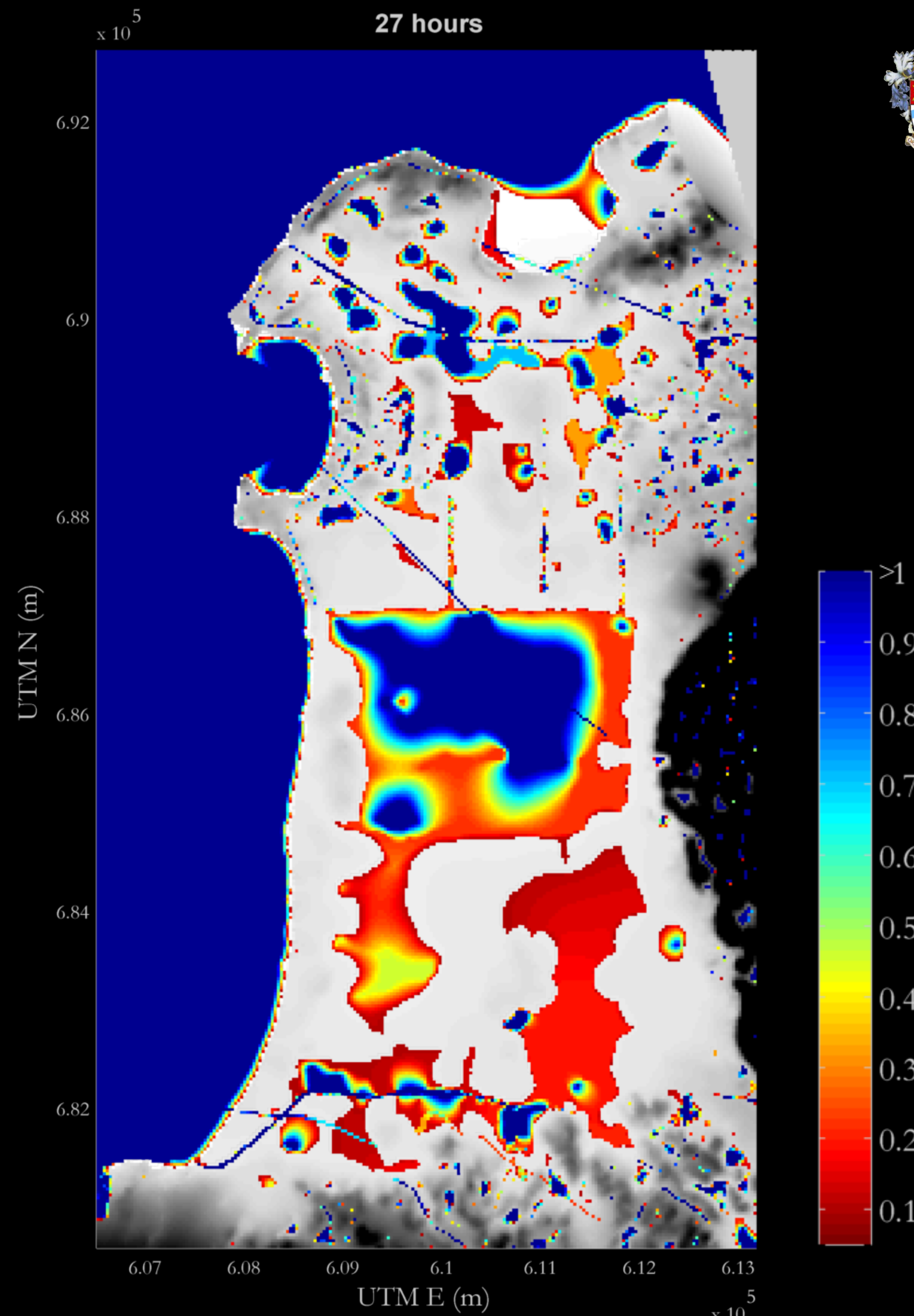


Tropical Storm Gustav:
Prediction of flood extent and depth over time

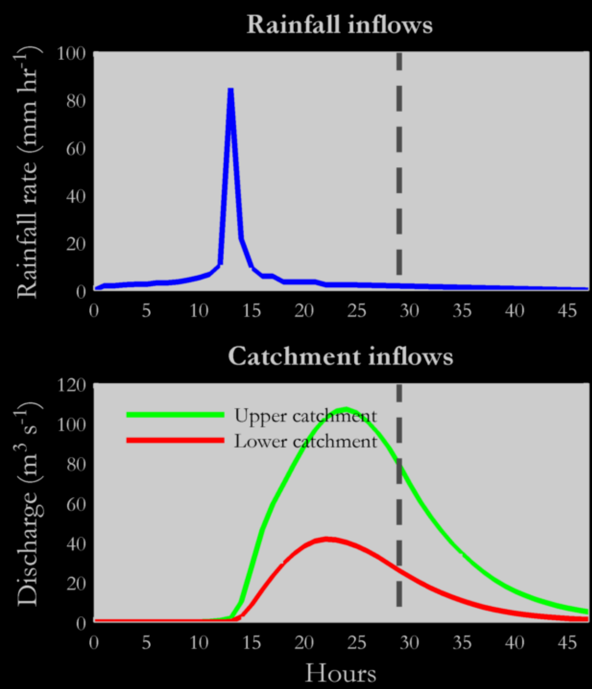
Wilson et al., *Flood Risk and Climate Change in Negril, Jamaica*, WCRP Conference for Latin America and the Caribbean, March 17-21, 2014, Montevideo, Uruguay

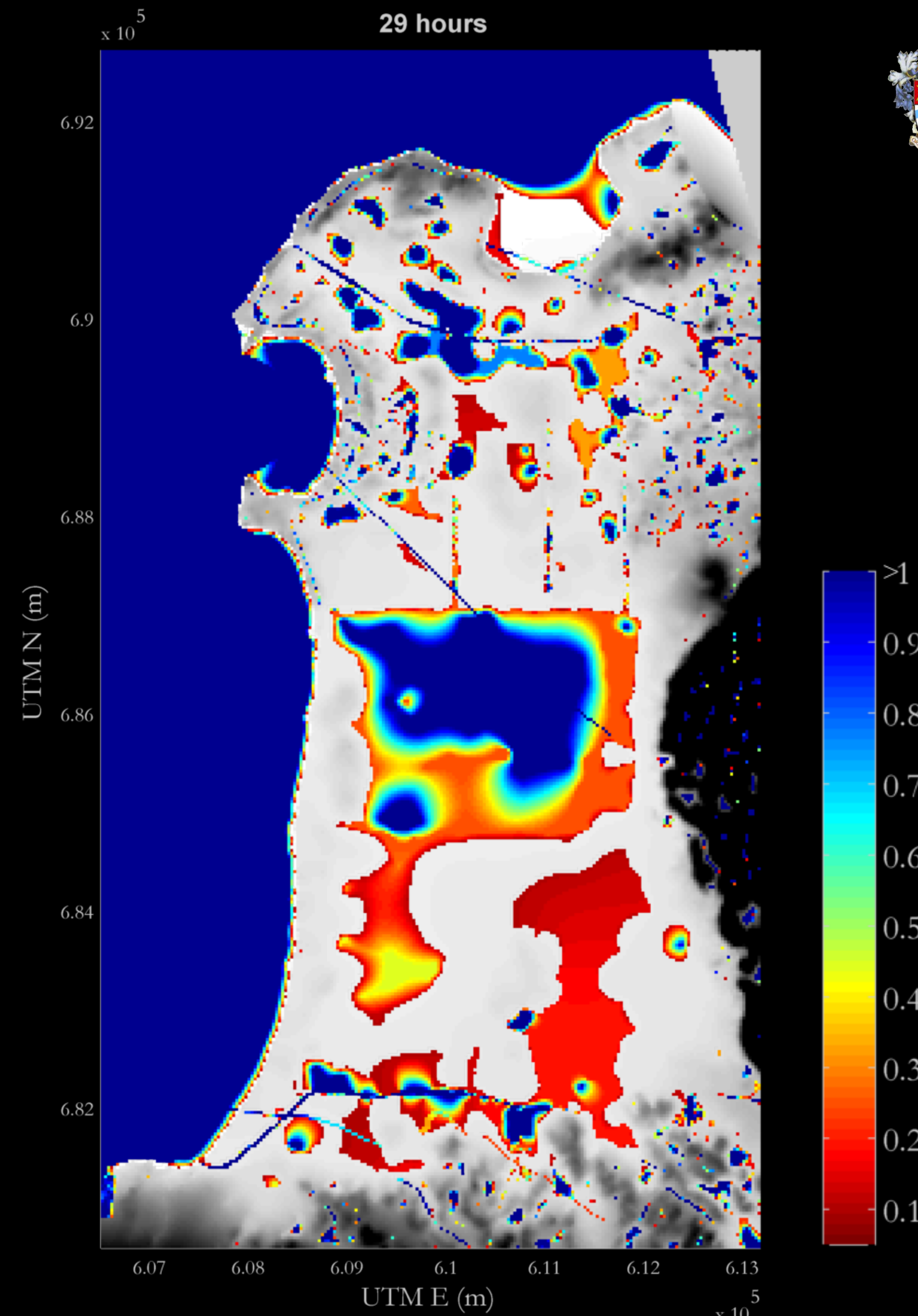






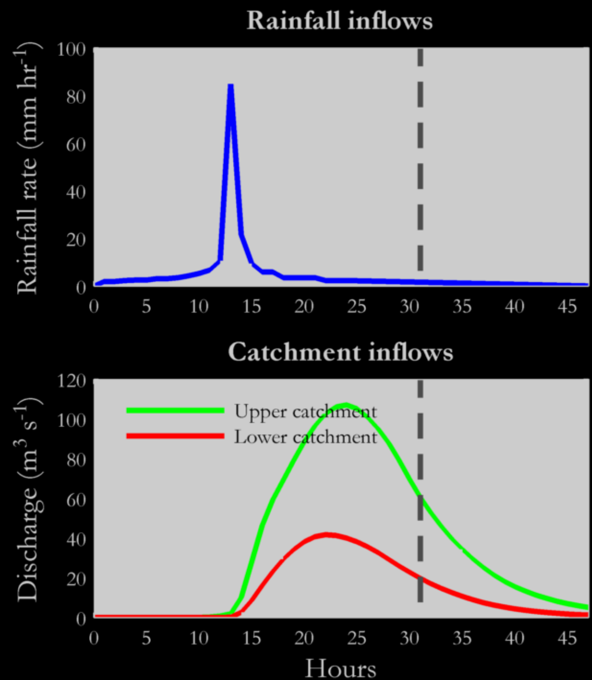
Tropical Storm Gustav:
Prediction of flood extent and
depth over time

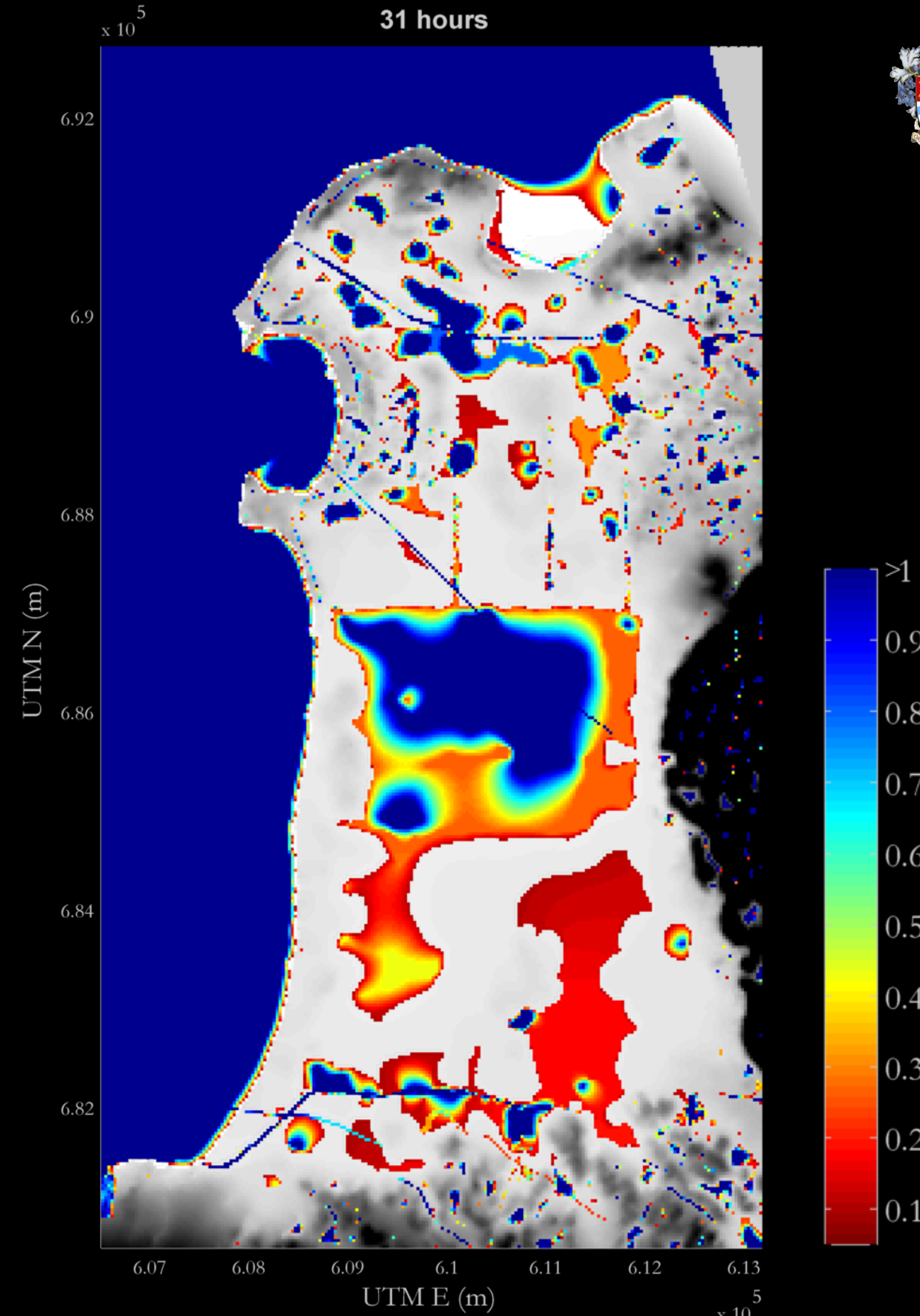




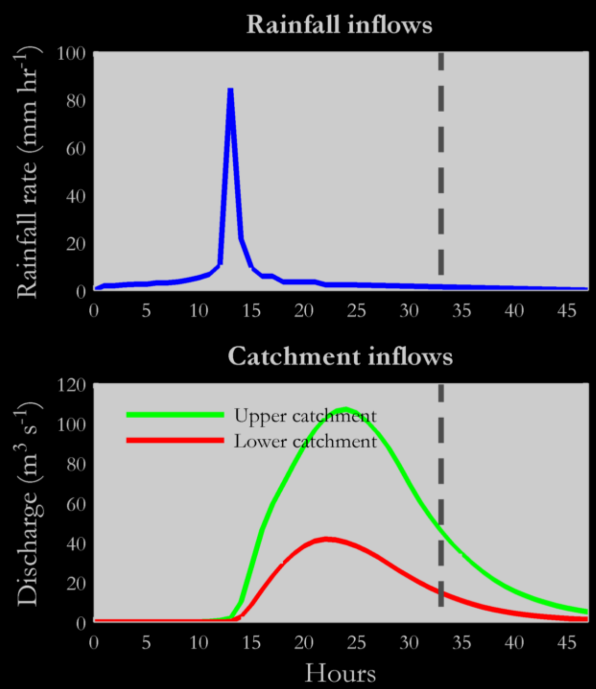
Tropical Storm Gustav:
Prediction of flood extent and depth over time

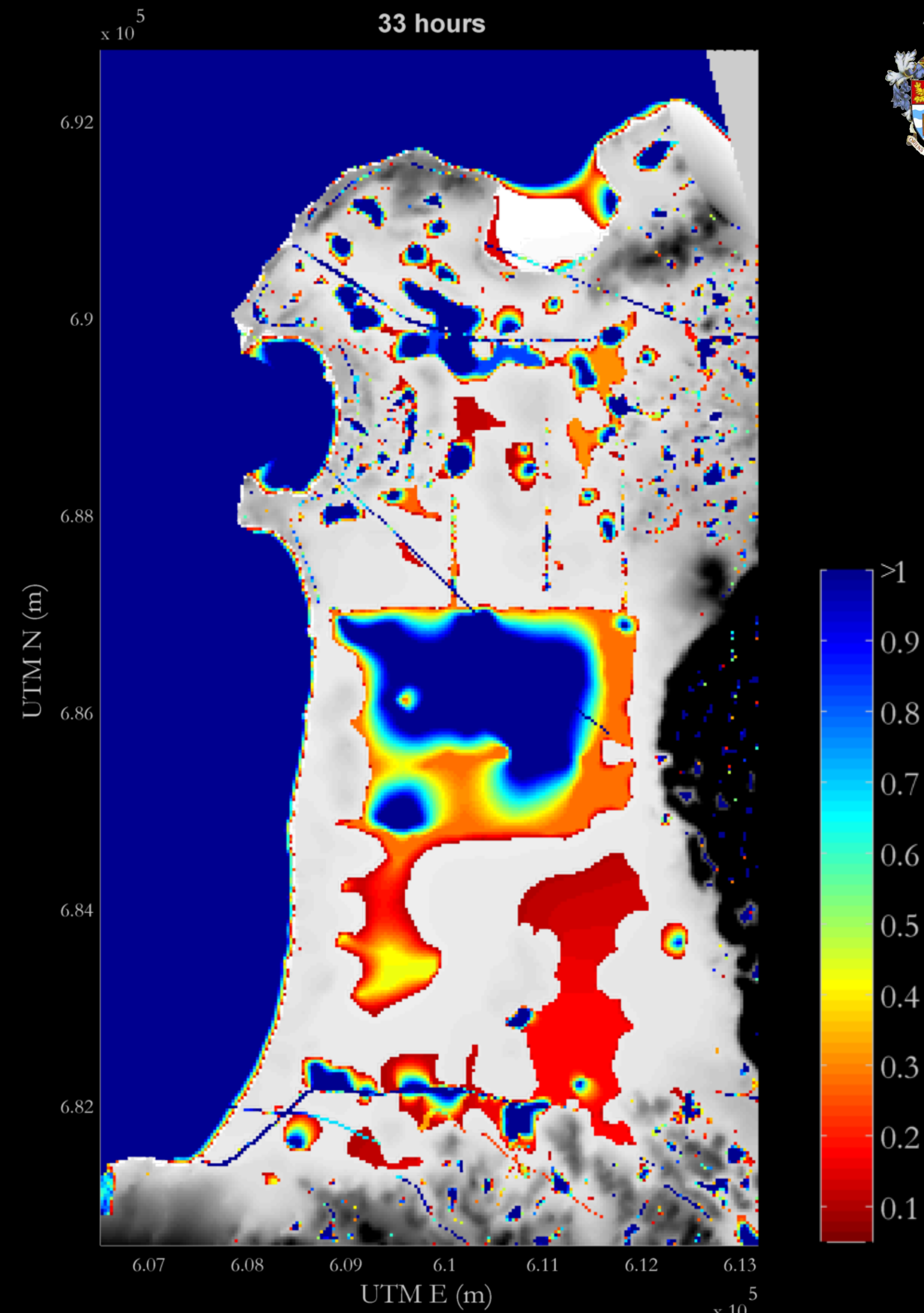
Wilson et al., *Flood Risk and Climate Change in Negril, Jamaica* , WCRP Conference for Latin America and the Caribbean, March 17-21, 2014, Montevideo, Uruguay



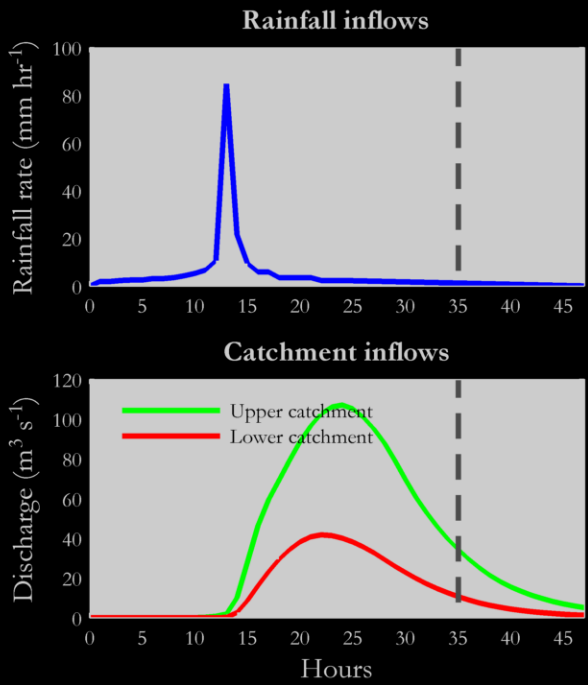


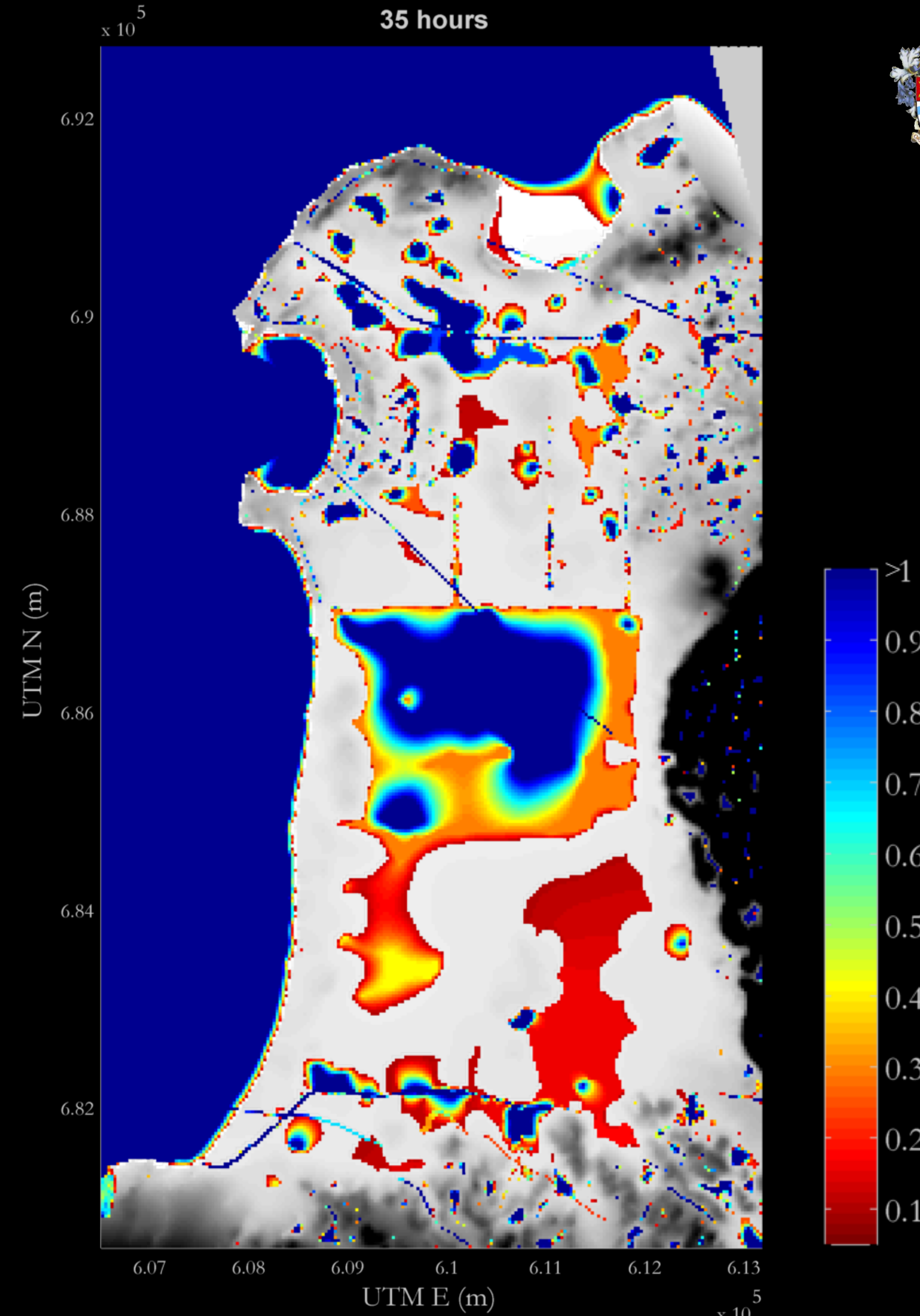
Tropical Storm Gustav:
Prediction of flood extent and depth over time





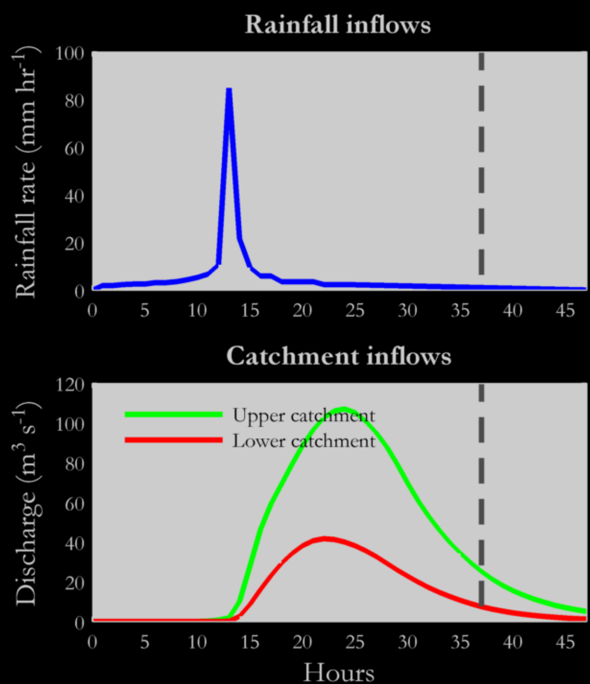
Tropical Storm Gustav:
Prediction of flood extent and depth over time

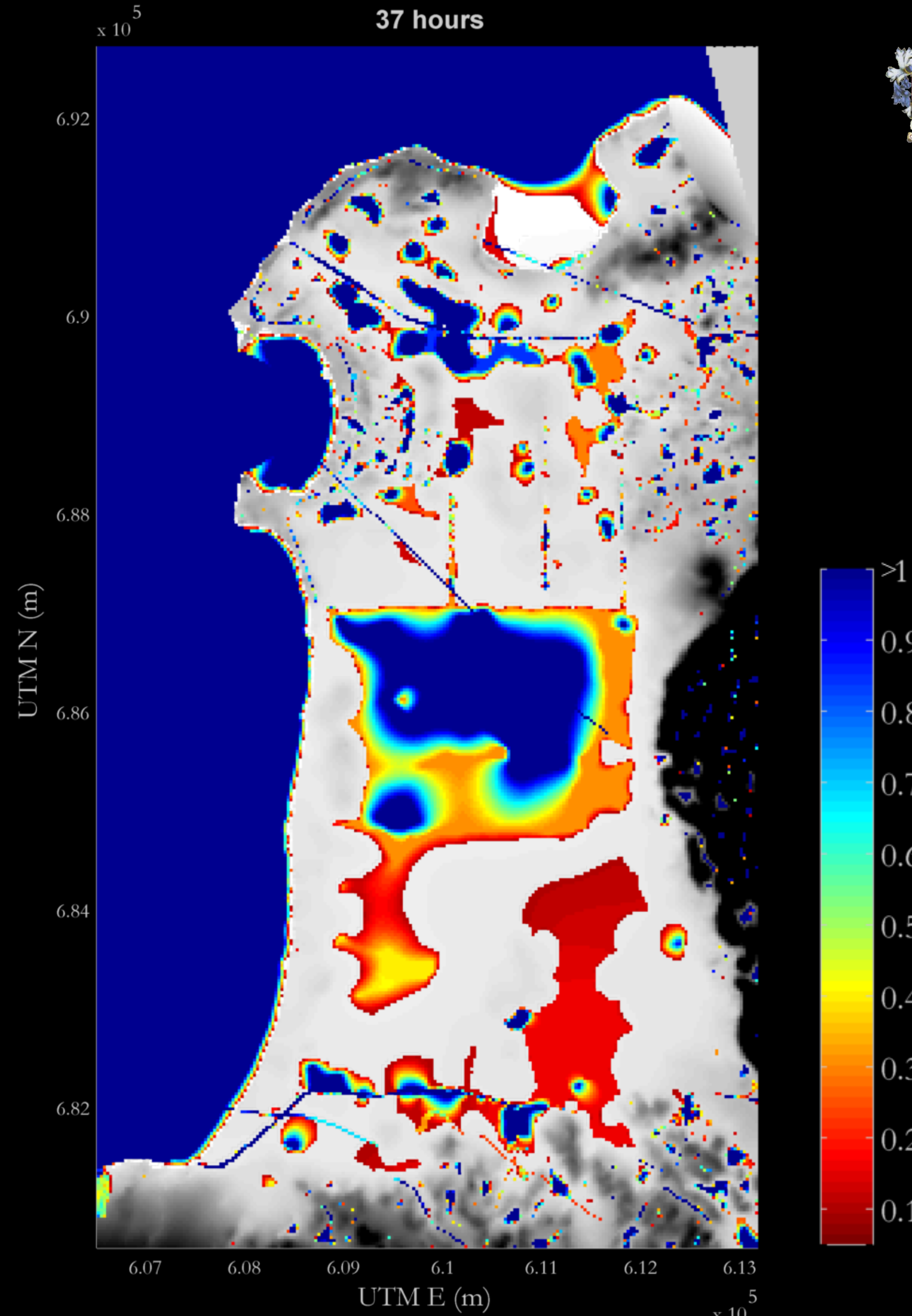




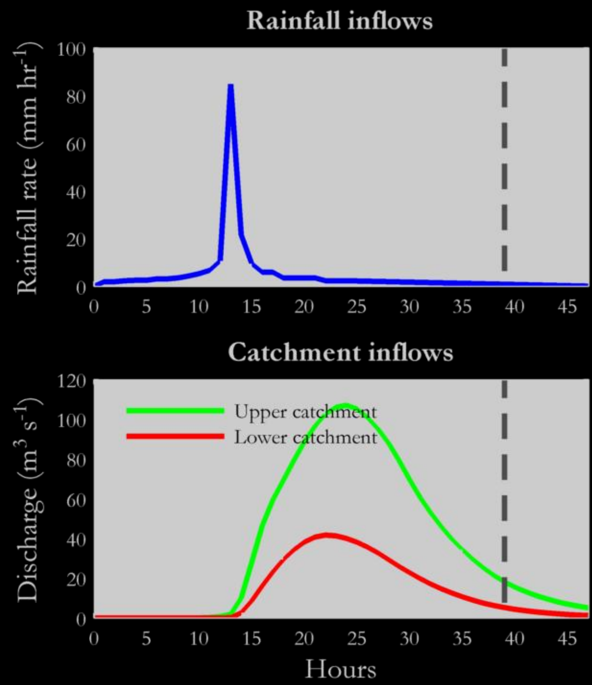
Tropical Storm Gustav:
Prediction of flood extent and depth over time

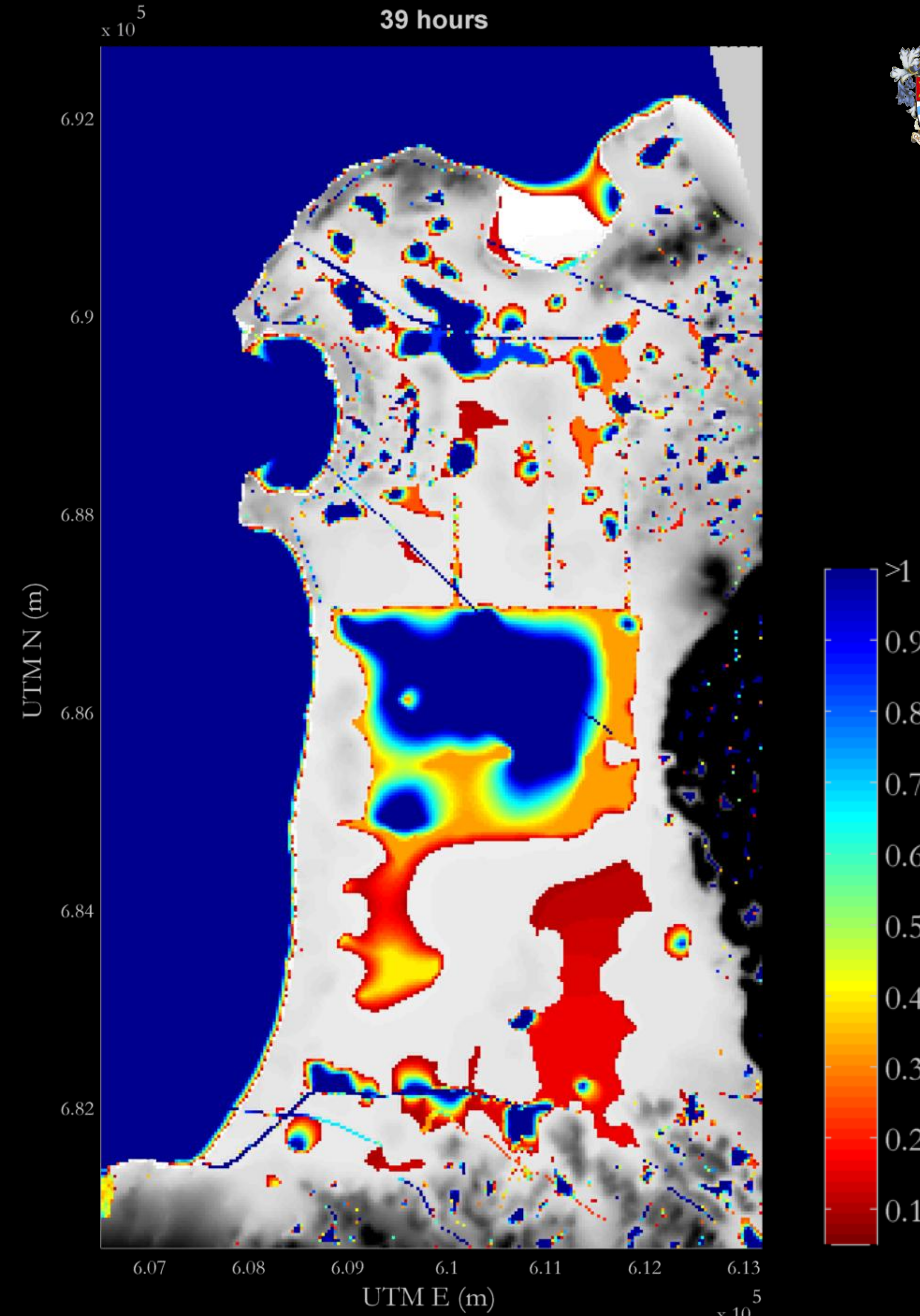
Wilson et al., *Flood Risk and Climate Change in Negril, Jamaica*, WCRP Conference for Latin America and the Caribbean, March 17-21, 2014, Montevideo, Uruguay





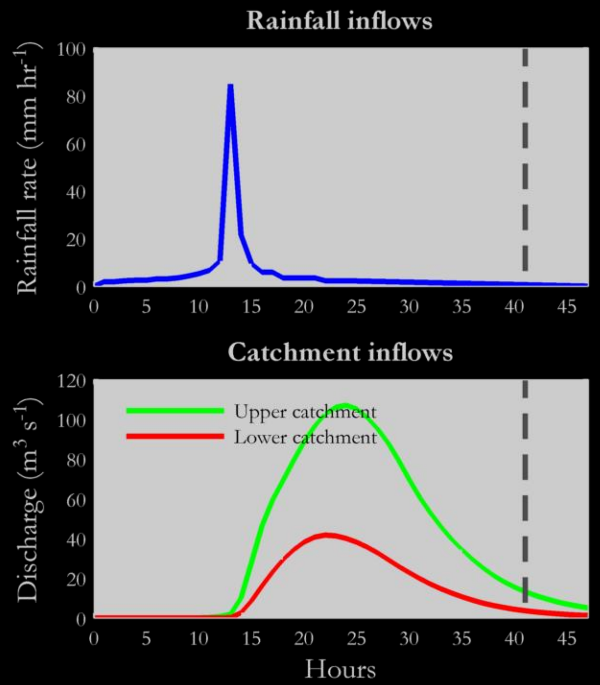
Tropical Storm Gustav:
Prediction of flood extent and
depth over time

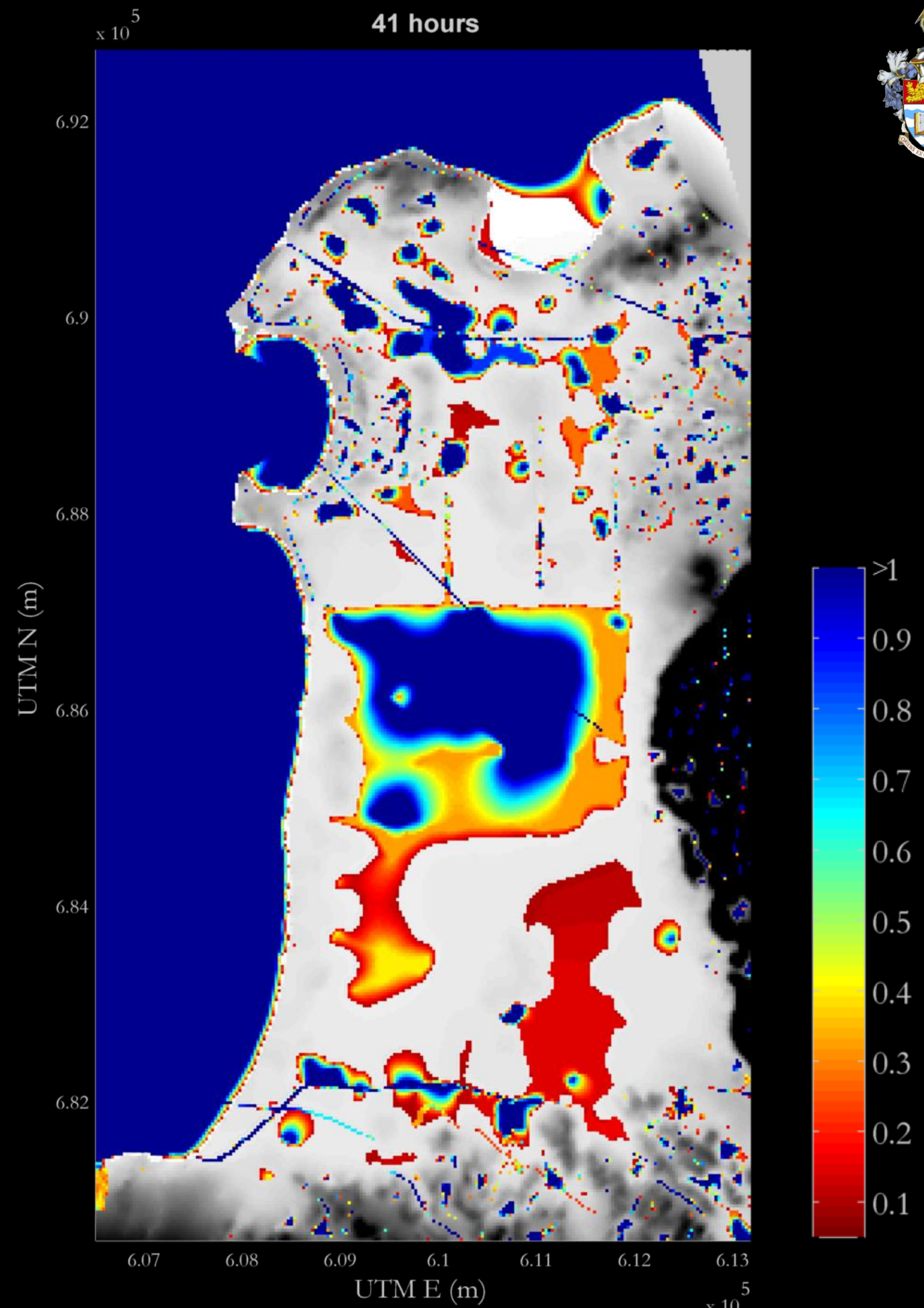




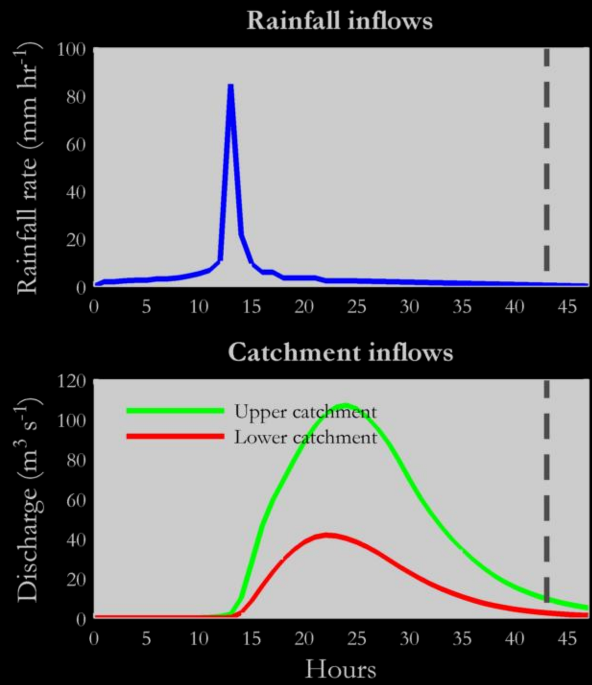
Tropical Storm Gustav:
Prediction of flood extent and depth over time

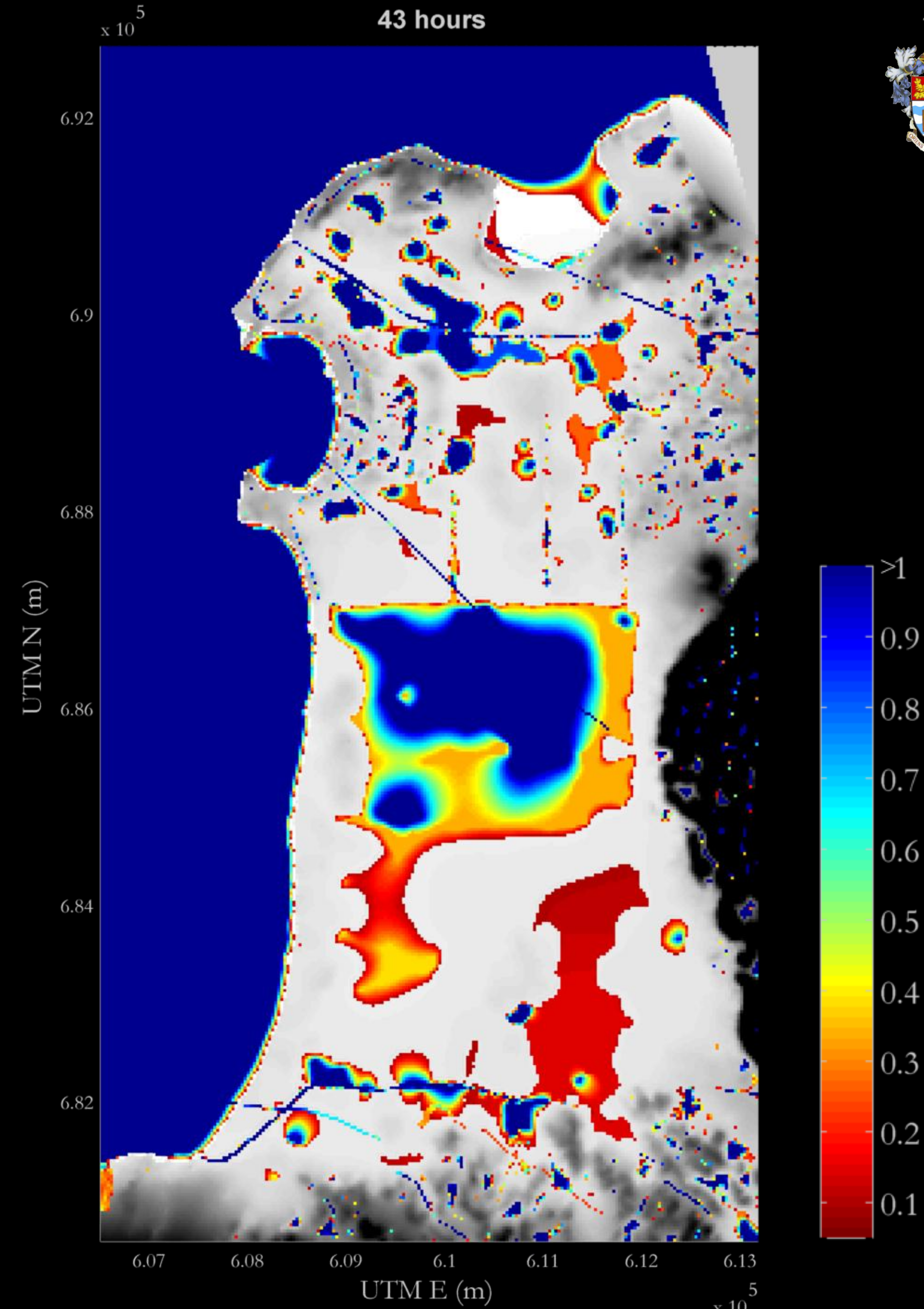
Wilson et al., *Flood Risk and Climate Change in Negril, Jamaica*, WCRP Conference for Latin America and the Caribbean, March 17-21, 2014, Montevideo, Uruguay



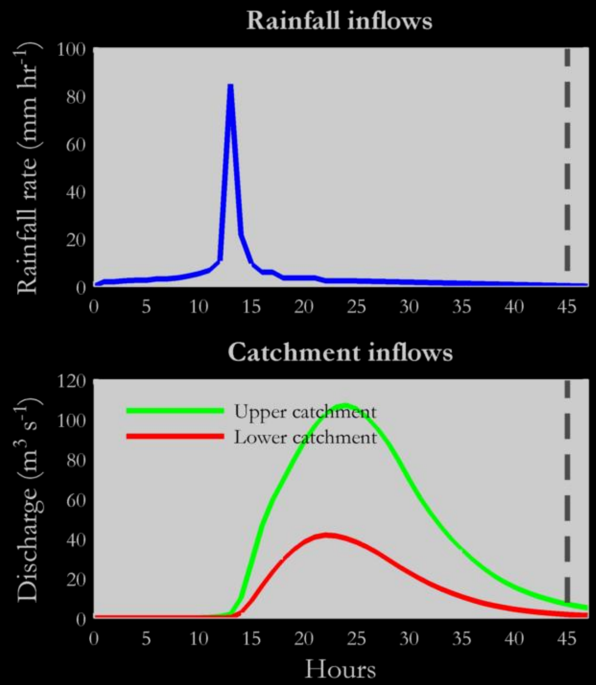


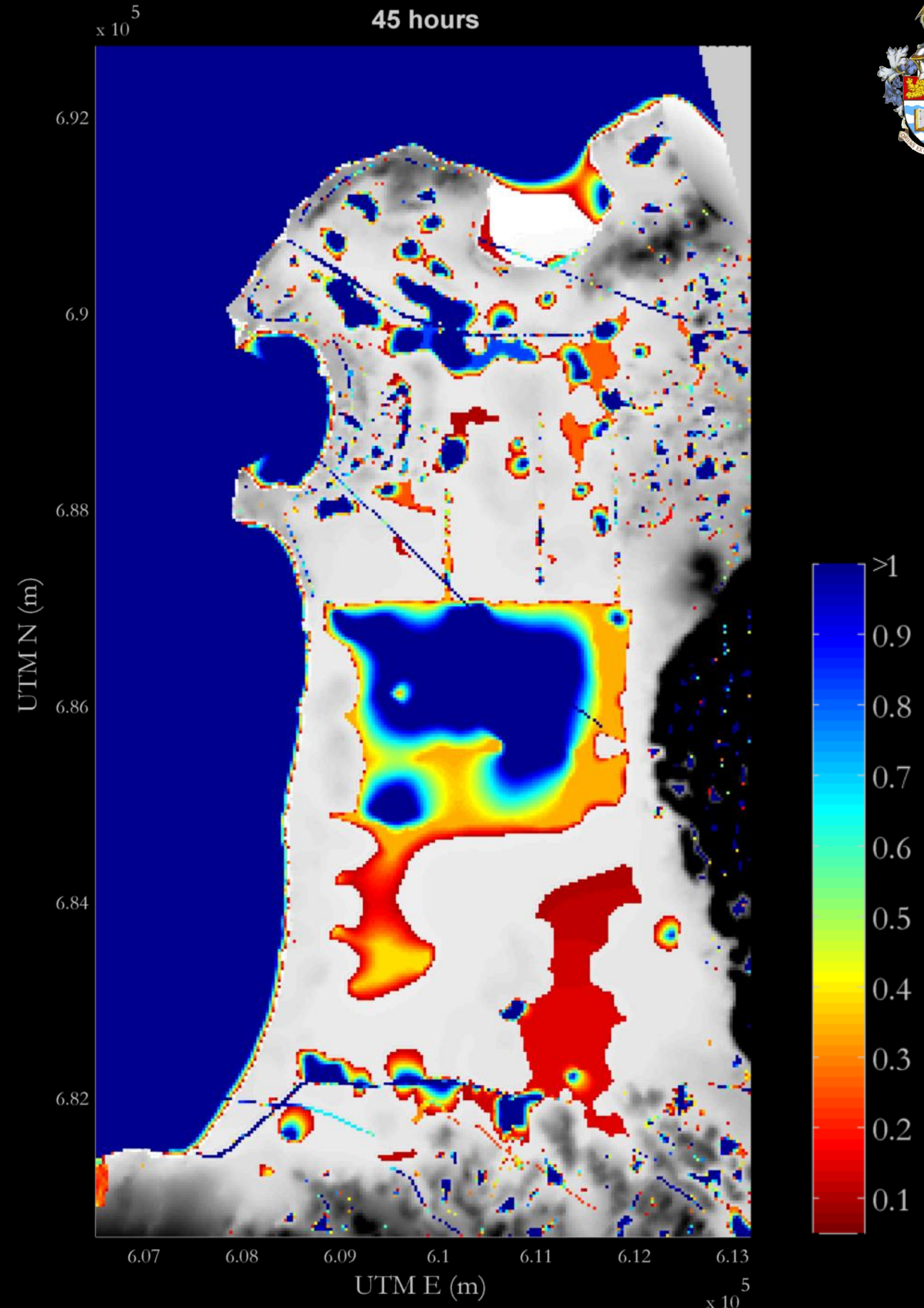
Tropical Storm Gustav:
Prediction of flood extent and depth over time





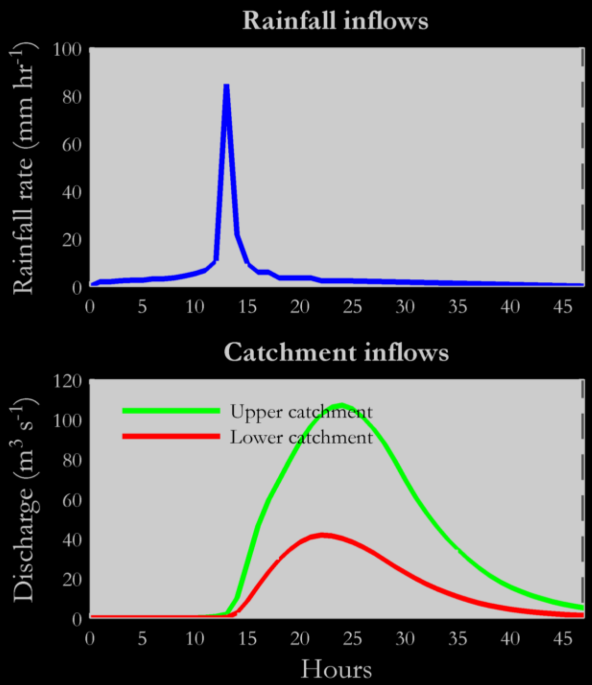
Tropical Storm Gustav:
Prediction of flood extent and depth over time

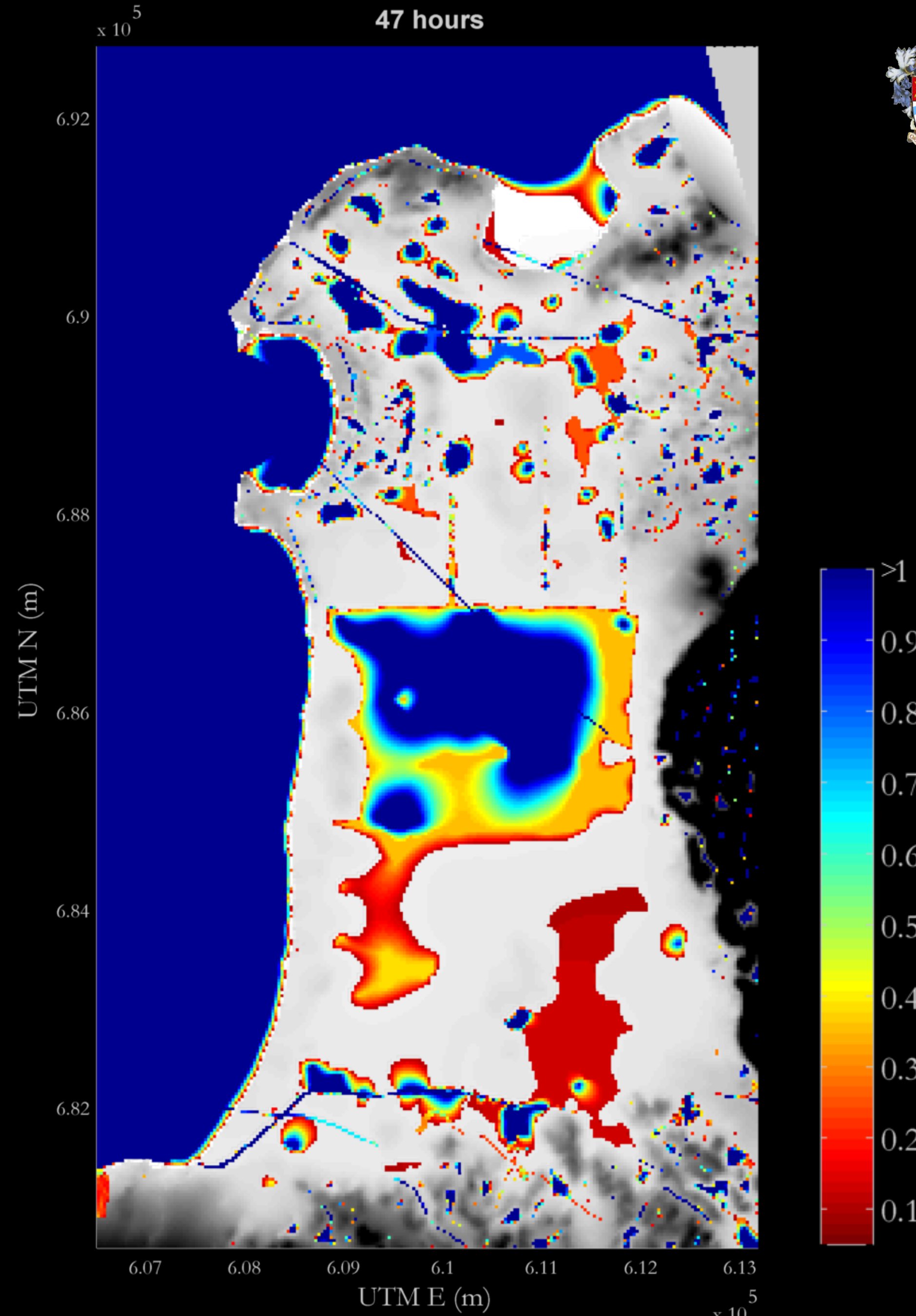




Tropical Storm Gustav:
Prediction of flood extent and depth over time

Wilson et al., *Flood Risk and Climate Change in Negril, Jamaica*, WCRP Conference for Latin America and the Caribbean, March 17-21, 2014, Montevideo, Uruguay



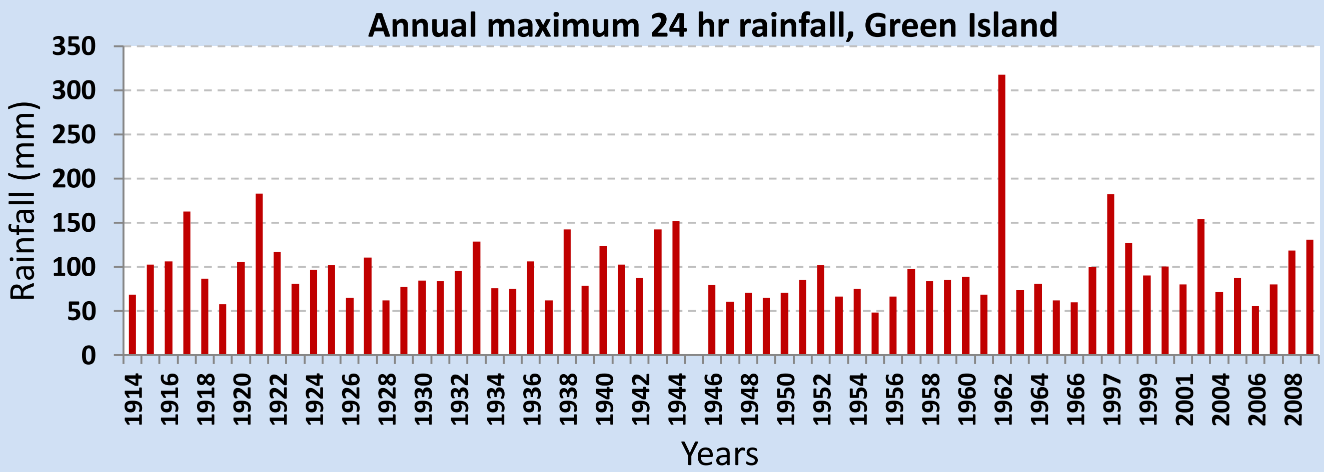


Tropical Storm Gustav:
Prediction of flood extent and depth over time

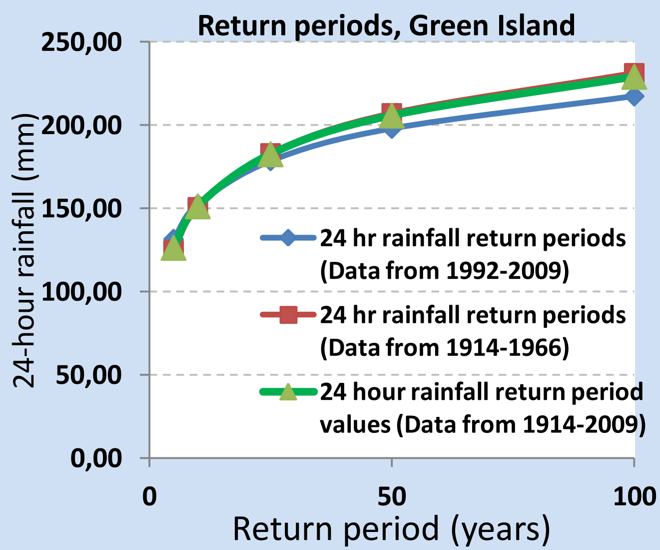
2. Estimation of current flood risk

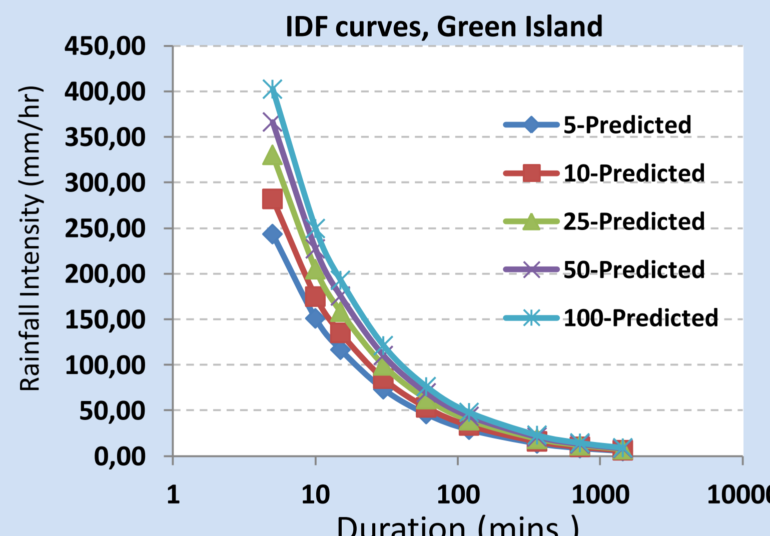
- Daily data (24-hour) obtained for 1900-1966, 1992-2010 (Negril Point) and 1914-1966, 1992-2009 (Green Island) from Jamaica Meteorological Service

Annual maximum extracted:



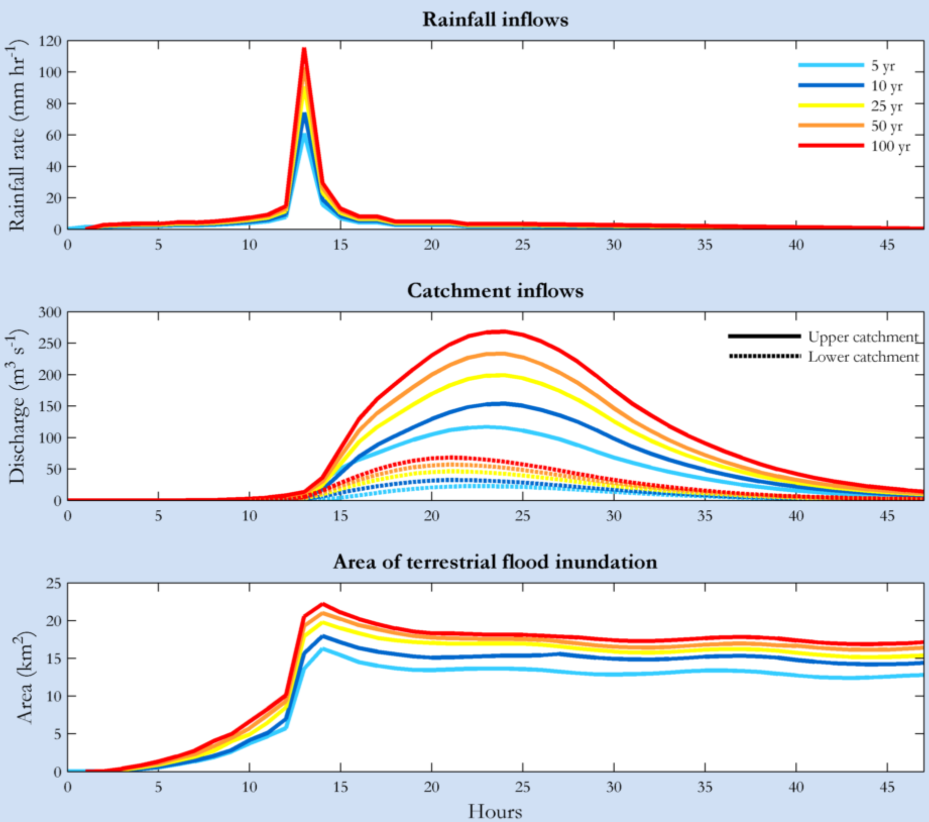
IDF curves and rainfall return periods calculated:

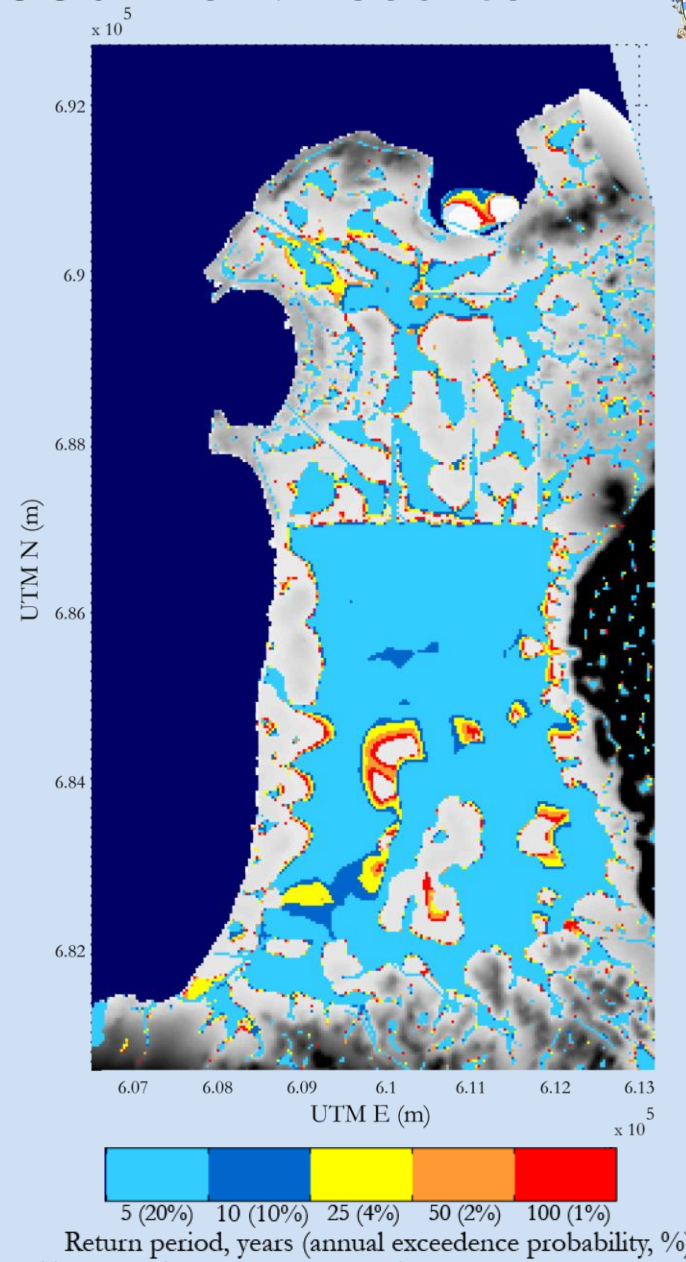




2. Estimation of current flood risk: results

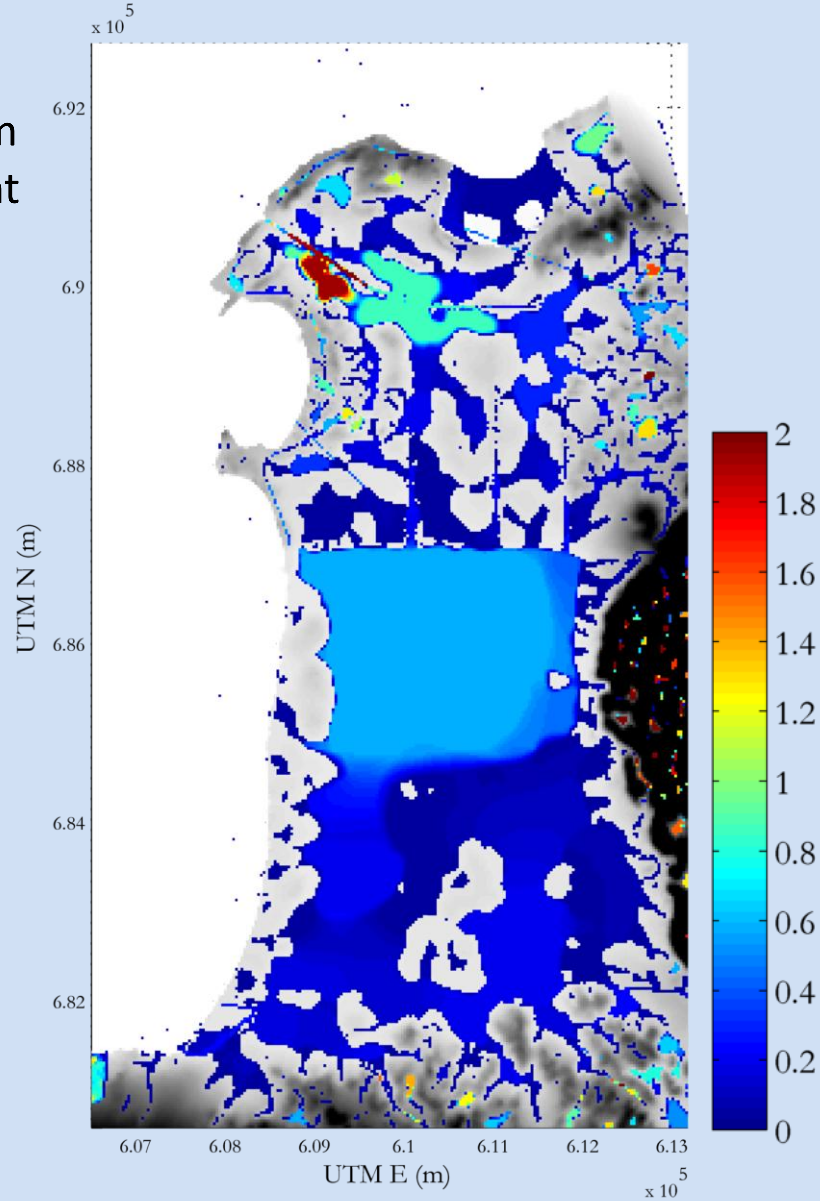
- HEC-HMS run for 5, 10, 25, 50 and 100 year rainfall
- Flows from HEC-HMS and rainfall routed through LISFLOOD-FP to predict inundation extents/depths





2. Estimation of current flood risk: results

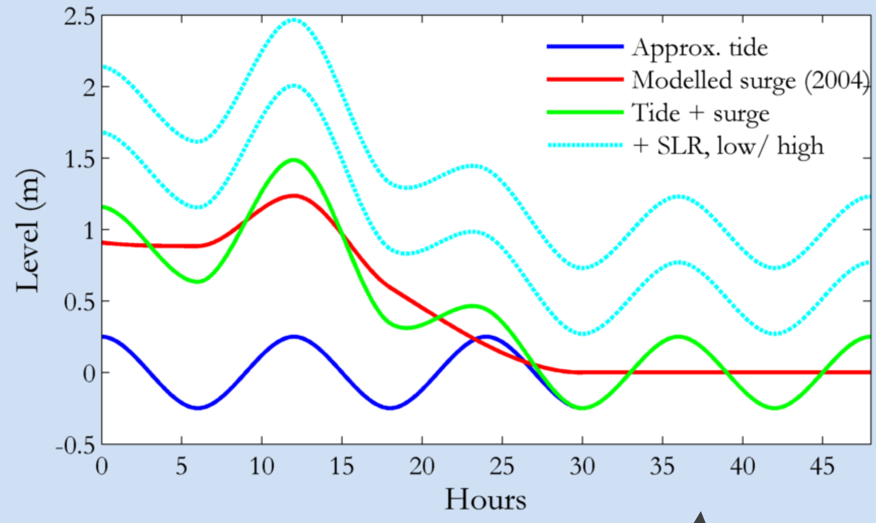
Depth difference:
100-year event maximum depth minus 5-year event maximum depth.

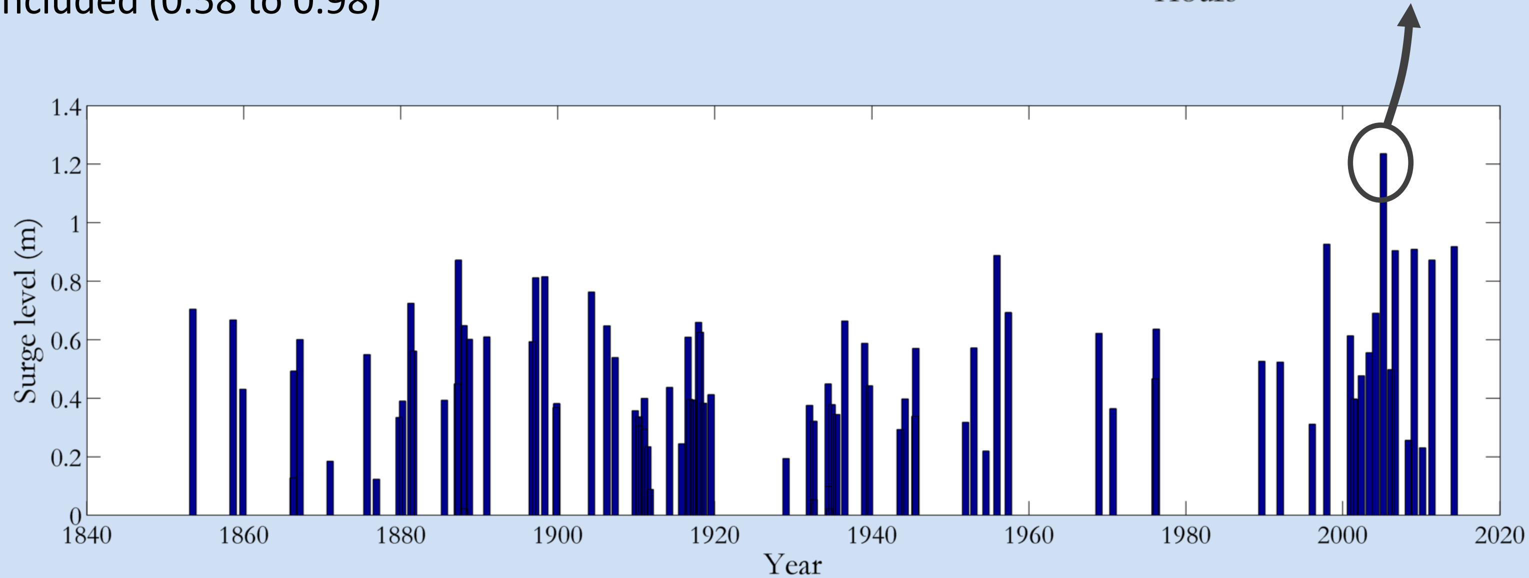


Although the flood extents are similar, water depths are up to 2 m higher on the floodplain during a 100-year event

3. Storm surge effects

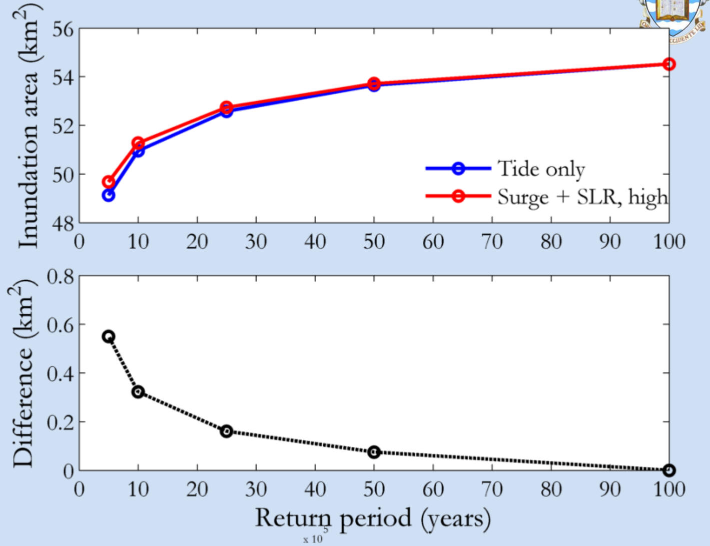
- Initial assessment of storm surge effects on terrestrial inundation
- Based on ~160 year hindcast model from 1852-2012, 6-hourly intervals.
  - 86 surge events: mean 0.49 m, standard deviation 0.23 m
  - Maximum of 1.24 m selected
  - Approx. tide (+/- 0.25 m) added, high tide conincinding with surge peak
  - IPCC AR5 global average SLR range included (0.58 to 0.98)

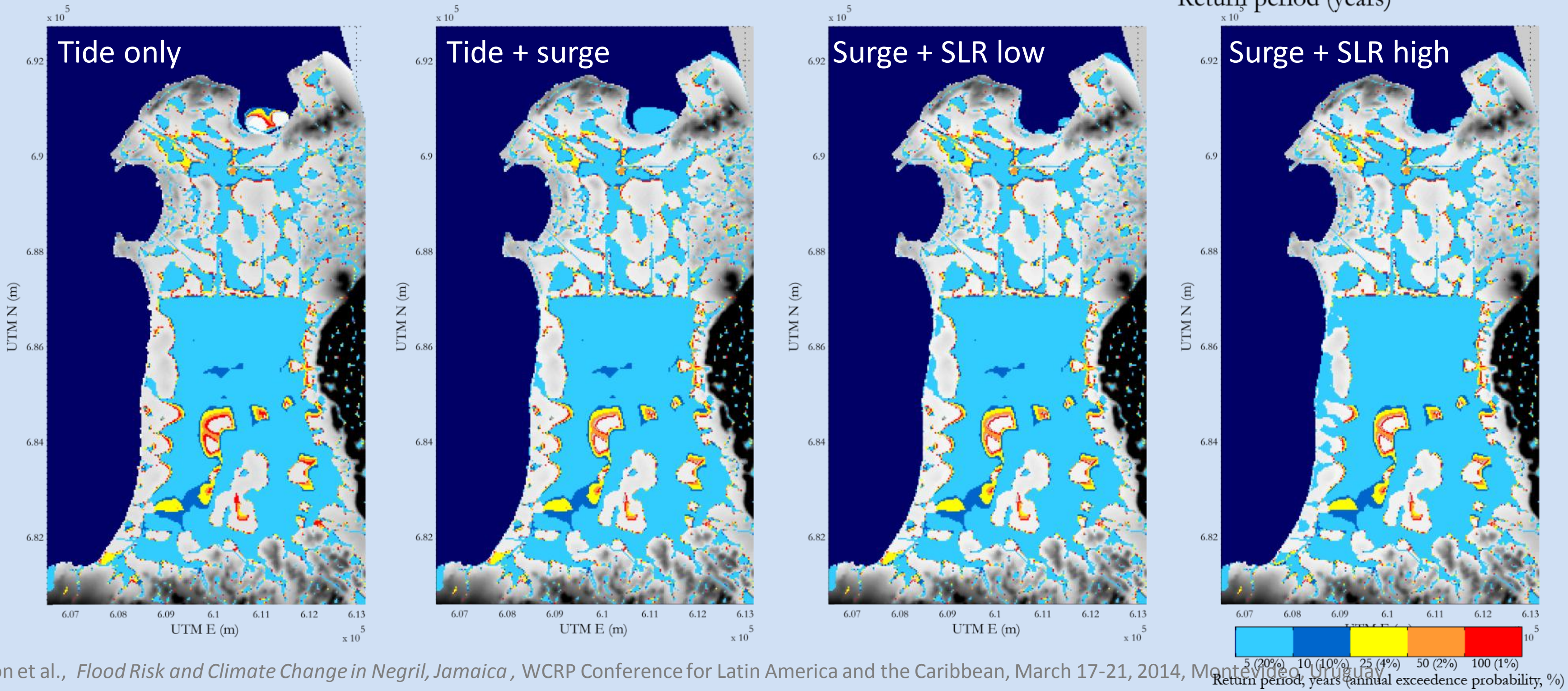




3. Storm surge effects: results

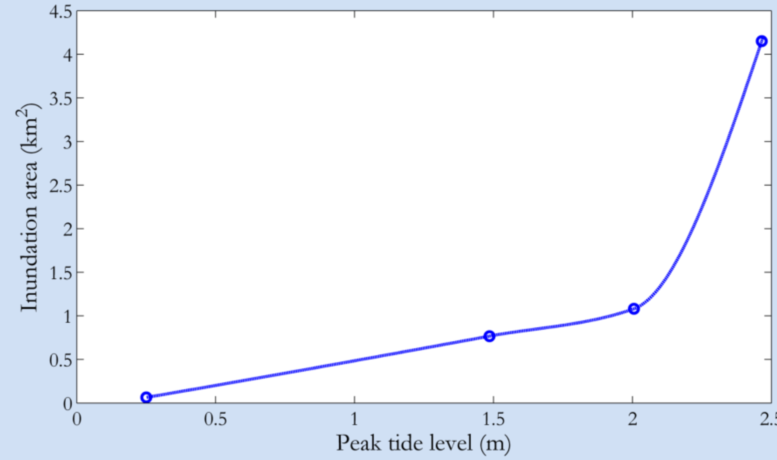
- Only small differences caused by surge/ SLR on terrestrial inundation probabilities
  - At 5-year return period, inundated area increased by ~0.6 km^2 under surge/ SLR (high)

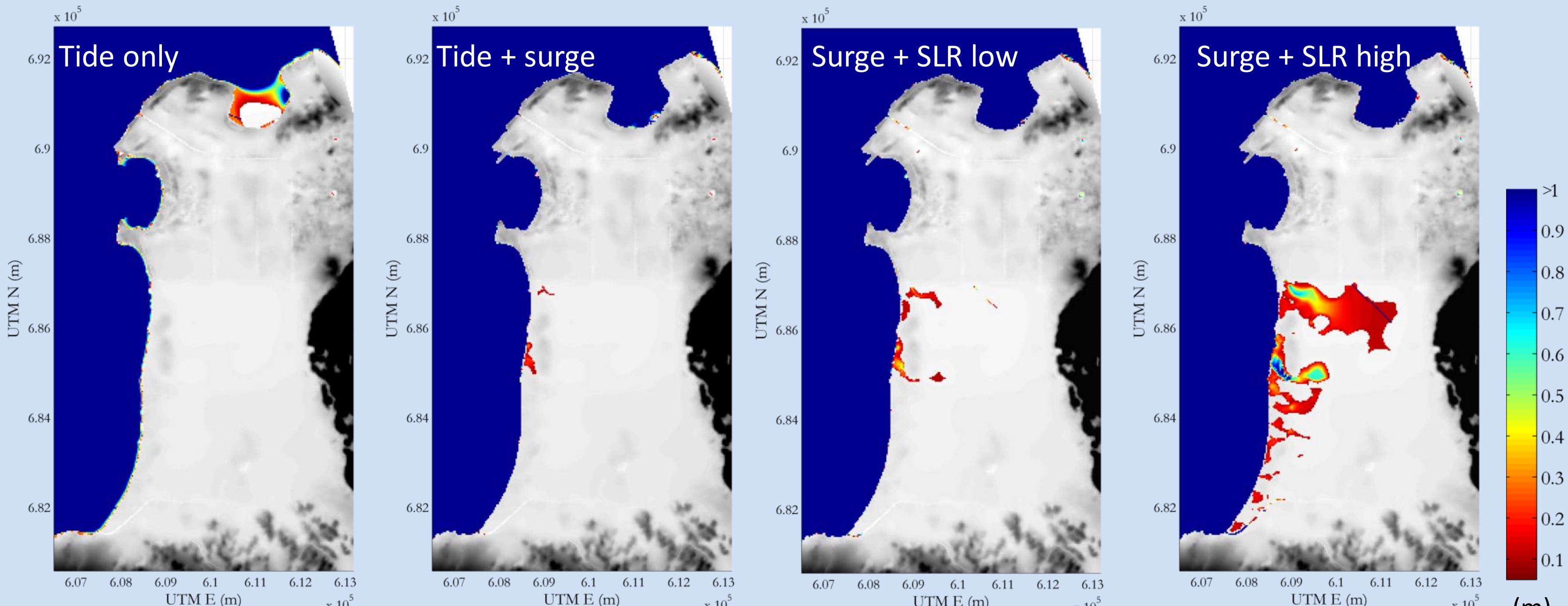




3. Storm surge effects: results

- Inundated area dominated by direct rainfall to floodplain
  - With no rain, surge + SLR (high) inundation area was ~4 km^2

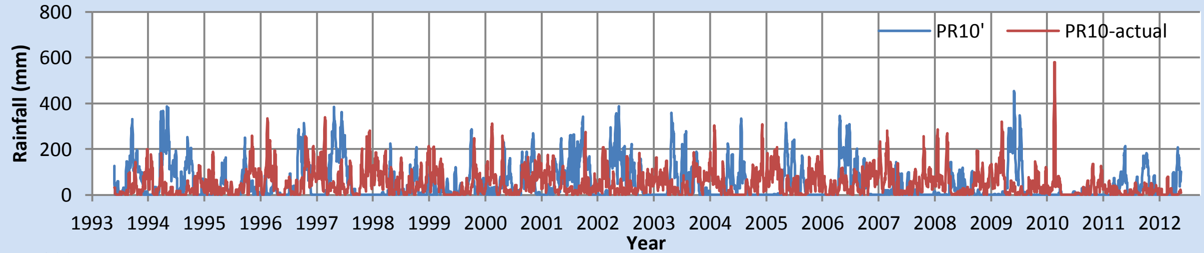




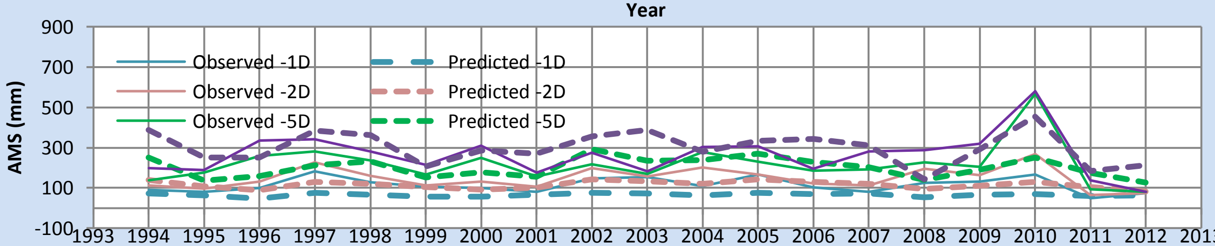
4. Estimation of future flood risk

- Calibration: station data aggregated from daily to 2, 5 and 10 days for 1993 to 2012. Artificial Neural Network (ANN) developed between NCEP/NCAR and station data.
- Present climate: NCEP/NCAR ANN reanalysis for the period 1950 to 2012
- Future climate model: HADCM3, SRES A2 for the period 2070 to 2100, downscaled using ANN
- IDF from Annual Maximum Series (AMS) for present and future period using L-Moments parameter estimation of the Weibull distribution

Station data and predictions for precipitation time series for Green Island 1993 to 2012

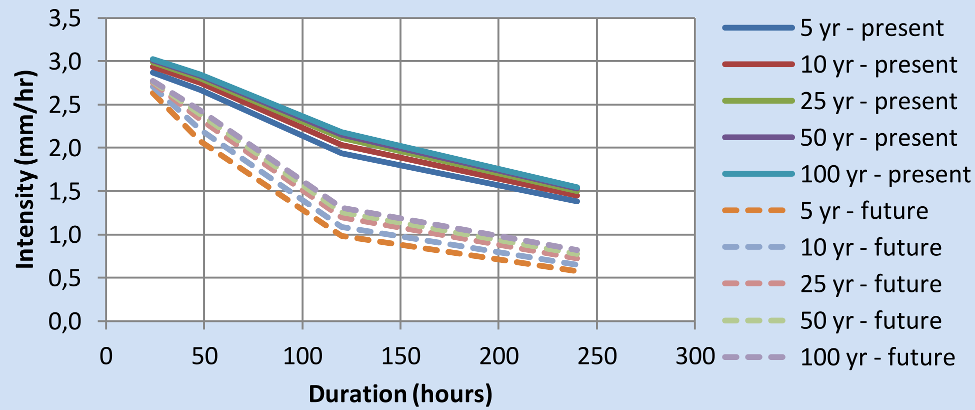


AMS Green Island



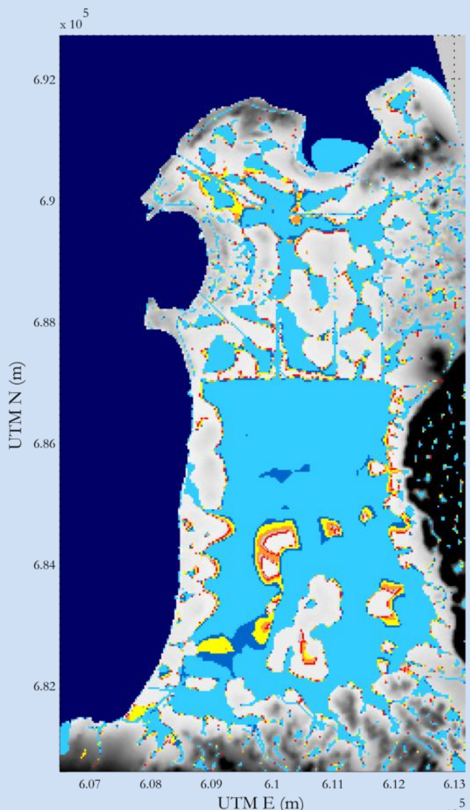
IDF curves for Green Island for present climate (1950 to 2012) and future climate (2070 to 2100, SRES A2).

Change factor for 24 hr rainfall ~0.92. Statistical downscaling from grid box of 50 by 50 km using Artificial Neural Network method (ANN)

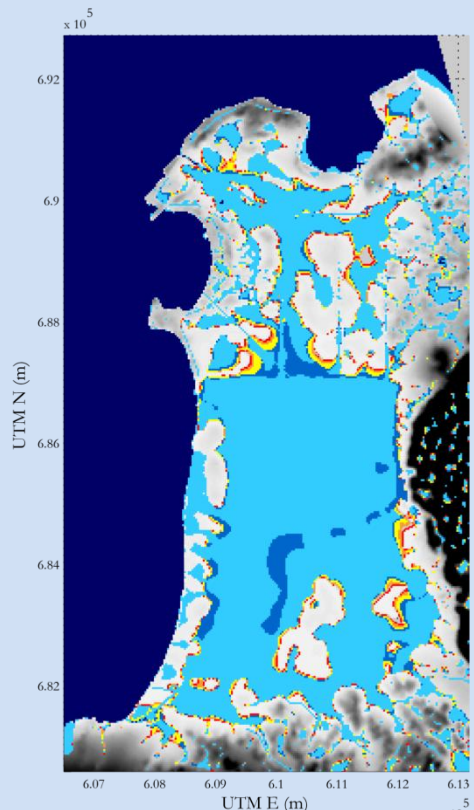


4. Estimation of future flood risk: results

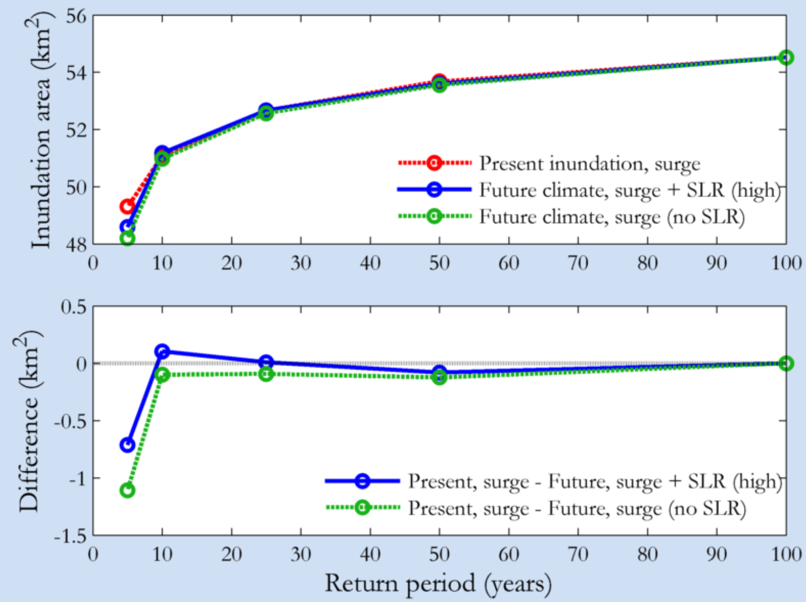
- 5,10, 25, 50 and 100 year rainfall scaled by change factor (0.92) and temporally downscaled using NRCS
- HEC-HMS run for future return periods and flows routed through the LISFLOOD-FP model to predict inundation extents and depths
- At 5-year return period, small decrease (~1 km^2) in area at risk of inundation
  - SLR dampens this reduced risk. Risk slightly increases at the 10-year level.

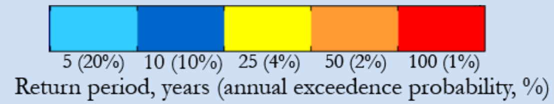


Present annual exceedance probability, surge



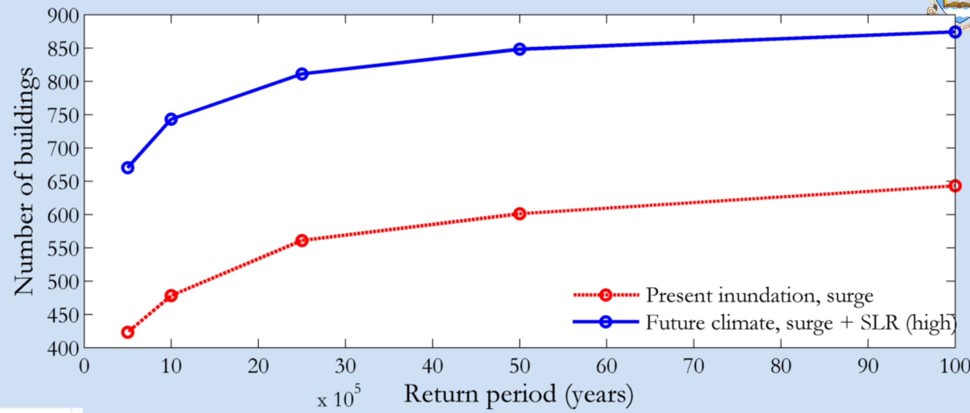
Future annual exceedance probability, surge/ SLR (high)

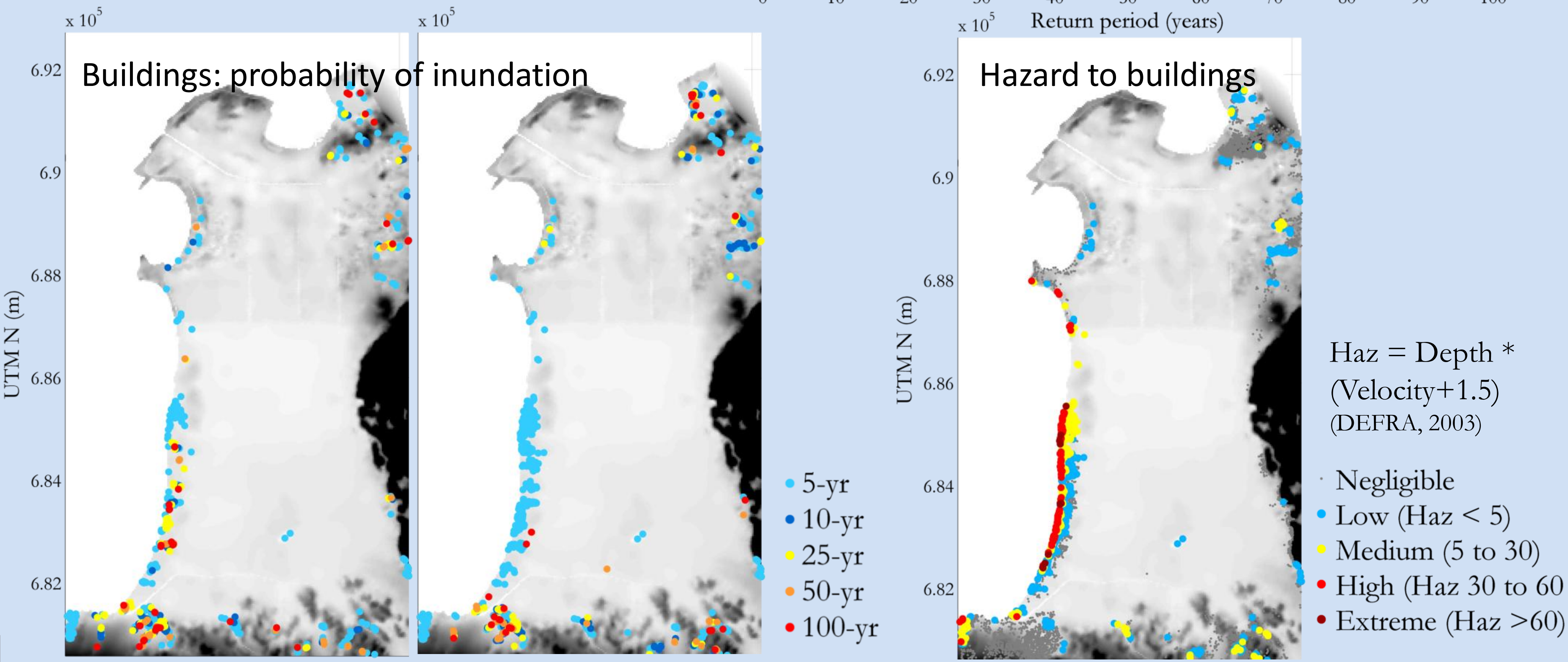




4. Estimation of future flood risk: results

- Buildings at risk: substantially more affected in future rainfall/ sea-level rise scenario
- Greatest hazard for buildings is along the coast





Present annual exceedance probability, surge

Future annual exceedance probability, surge/ SLR (high)

Future 100-yr, surge + SLR (high)

Summary 1

- Flood inundation predicted for Orange/ South Negril Rivers using HEC-HMS and LISFLOOD-FP models
  - Past major event (Tropical Storm Gustav, 2008)
  - Current 5, 10, 25, 50 and 100-year events
  - 24-hour rainfall temporally downscaled using NRCS method
  - Initial assessment of storm surge impacts

- Future return periods predicted using percentage changes between baseline climate (NCEP/NCAR, ANN) and future climate (HADCM3 – SRES A2, ANN)
  - Future 5, 10, 25, 50 and 100-year events
  - Initial assessment of sea-level rise/ storm surge impacts
  - Climate projection suggests a decline in future flood rainfall, although inundation extent does not reduce substantially
  - Buildings at risk increase, largely due to sea-level rise

Summary 2

- 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 (development of PRECIS for baseline/ future climate)
    - Improvements needed to DEM, bathymetry and storm surge/ SLR scenarios
    - Validation of past event predictions for HEC-HMS/LISFLOOD-FP
    - Stochastic sensitivity analysis to find thresholds for vulnerability

Gracias!

Questions?

Acknowledgements:

Research funding – CDKN and Caribsave

Meteorological Service of Jamaica, Water Resources Authority Jamaica, Mona Geoinformatix Inst , UWI MONA, CEAC Solutions Ltd, Jamaica.

Anuradha Maharaj (M.Phil candidate, UWI Mona) assisted with hydrological model development