Modelling coastal flood risk in the data poor Bay of Bengal region

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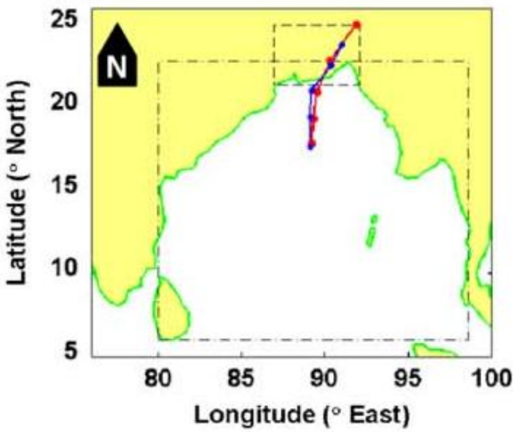

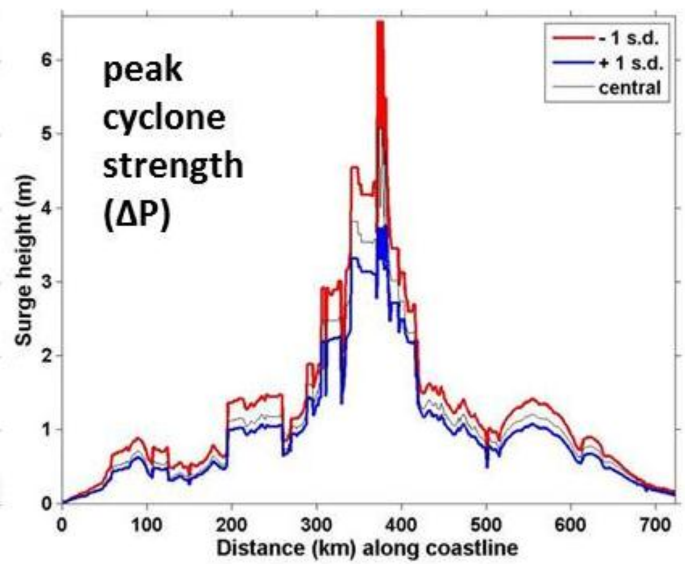

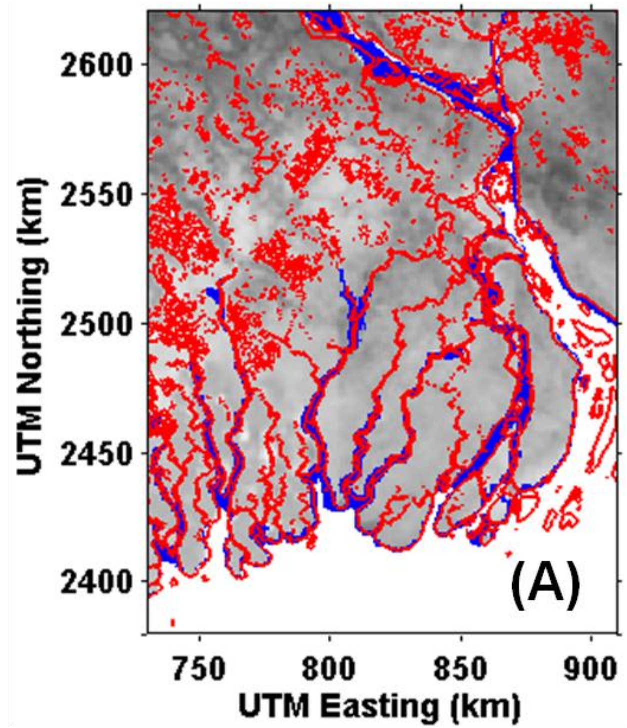

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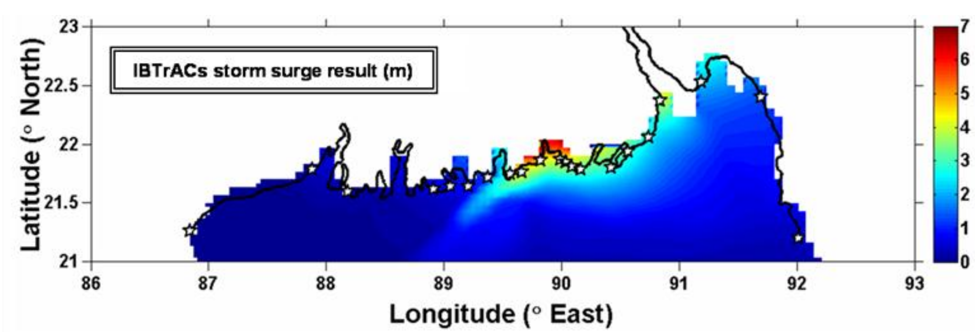
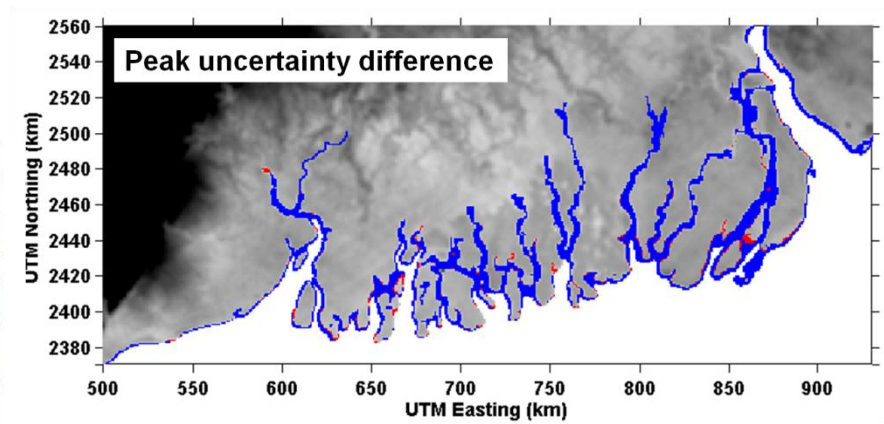
Summary

- A computationally light, region-scale, LISFLOOD-FP inundation model built from SRTM data (http://srtm.csi.cgiar.org).
- Forced with an idealised 1 in 50 year cyclone similar to the 2007 Sidr event using the IIT-D storm surge model.
- Sensitivity test of some major flood hazard uncertainties performed.





Motivation

To reduce future cyclone flood fatalities in Bay of Bengal:

(1) Consider climate change implications (e.g. SLR);

(2) Accurately estimate flood risk to mitigate future risk;

(3) Correctly predict inundation in real-time as part of an early warning system.

public perception to flood risk

"Understanding the uncertainty is essential because unrealistic expectations of accuracy can result in the misinterpretations of flood risk" (e.g. Hall and Solomatine, 2008).

Thus, what are the uncertainties in Bay of Bengal flood risk?

Some uncertainties within inundation modelling flood risk …

- **Water-level forcing uncertainties:**

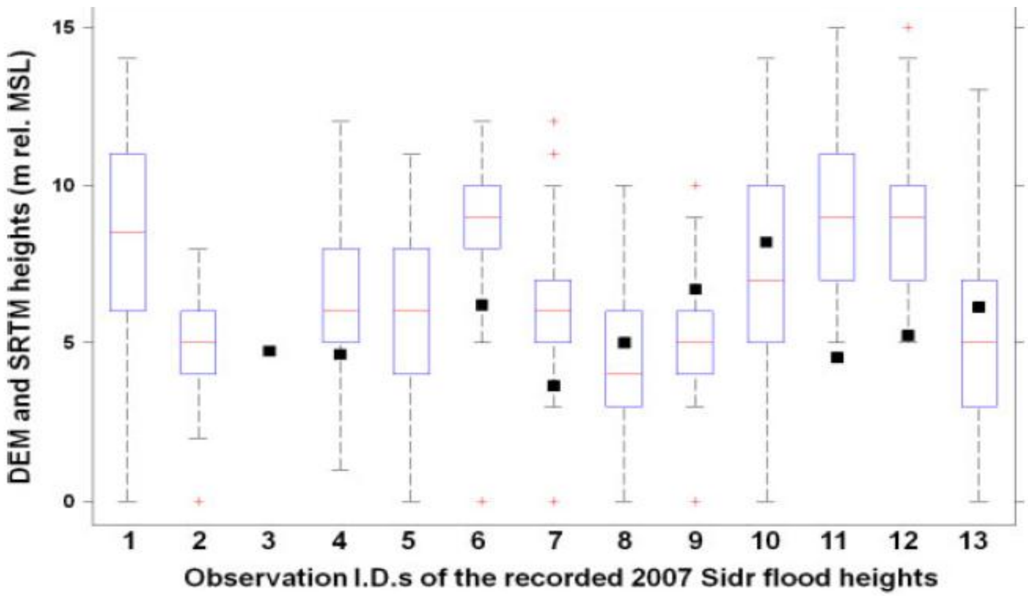
Few tide gauges available for extreme water-level estimation.

- **Intra-inundation model uncertainties:**

High quality topographic data unavailable (e.g. LiDAR).

- **Early warning system:**

Ensemble approach to forecast uncertainties?



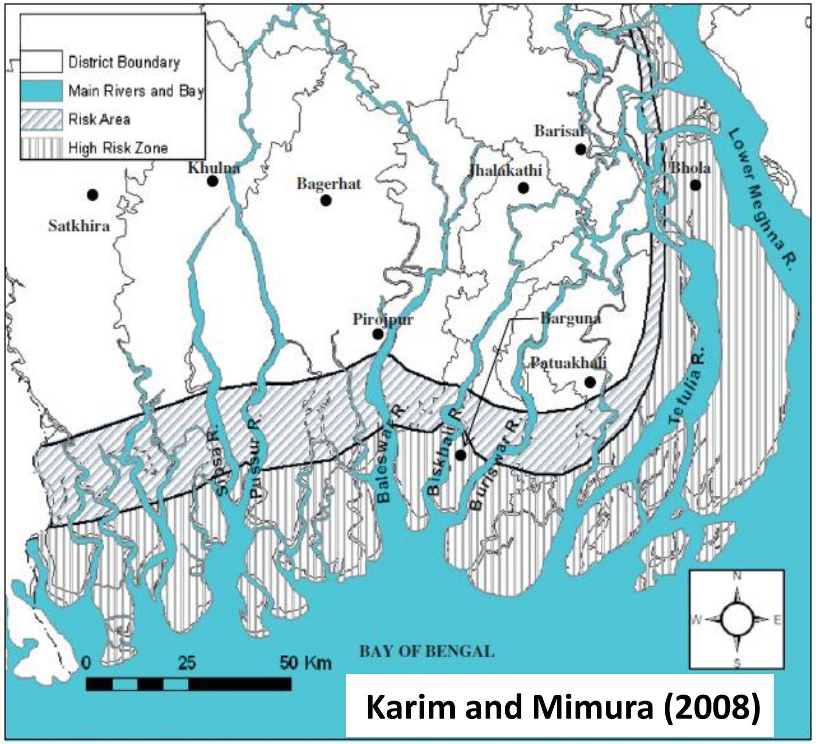
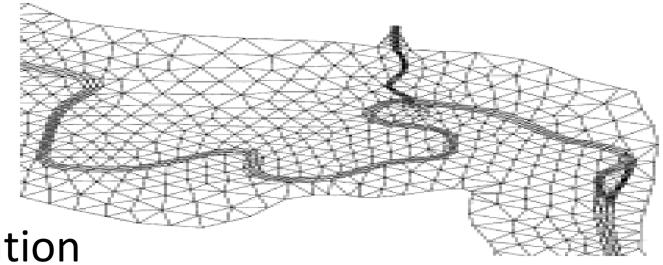


Fig. 5. Flood risk map corresponds to a typical projected climate (Scenario V: 2 °C temperature rise and 0.3 m SLR).

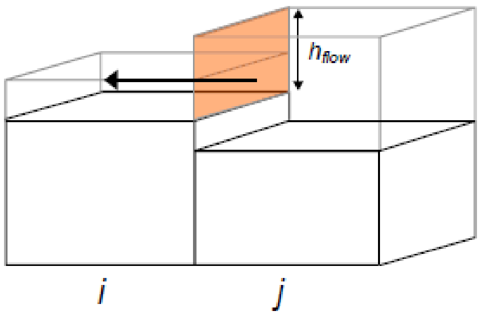
Regional Inundation modelling

Accurate prediction of inundation extent is at the heart of a flood risk estimate, and many models exist:



SHALLOW WATER EQUATION MODELS: (e.g. TELEMAC)

Full hydrodynamic models incur significant penalties at resolution useful to flood hazard predictions (Bates et al., 2005).



FLOOD STORAGE MODELING APPROACH: (e.g. LISFLOOD)

Computationally much faster, allowing multiple fine resolution simulations to be made as part of a probabilistic approach to quantifying uncertainty (e.g. Purvis et al., 2008).

How complex does an inundation model have to be?

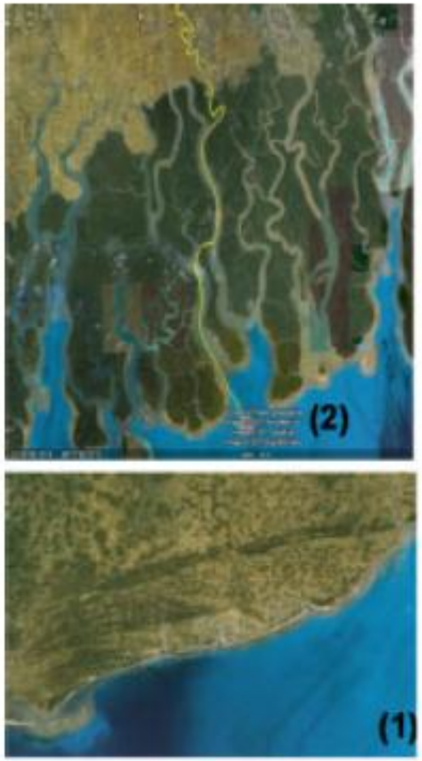
Are multiple fine resolution simulations necessary to resolve flood risk as part of a probabilistic approach?

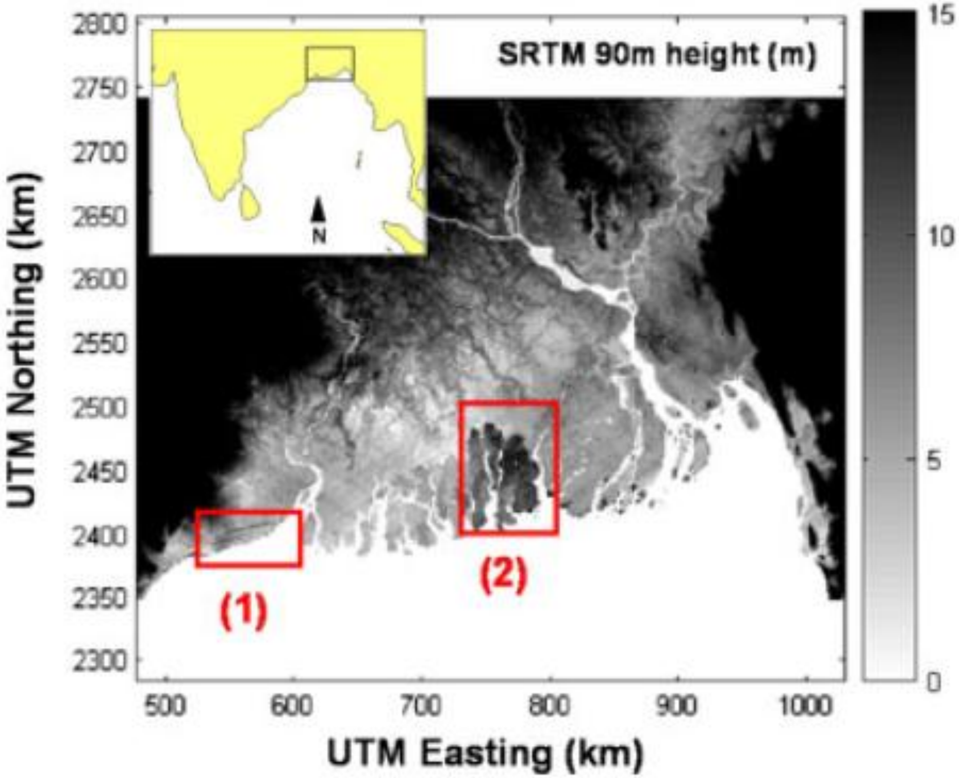
What is the magnitude of uncertainty in coastal flood risk?

Intra-modelling uncertainties in data poor regions: SRTM data

Topography accuracy and model resolution

We use the freely available Shuttle Radar Topography Mission (SRTM) data (http://srtm.csi.cgiar.org) is used to make a DEM.

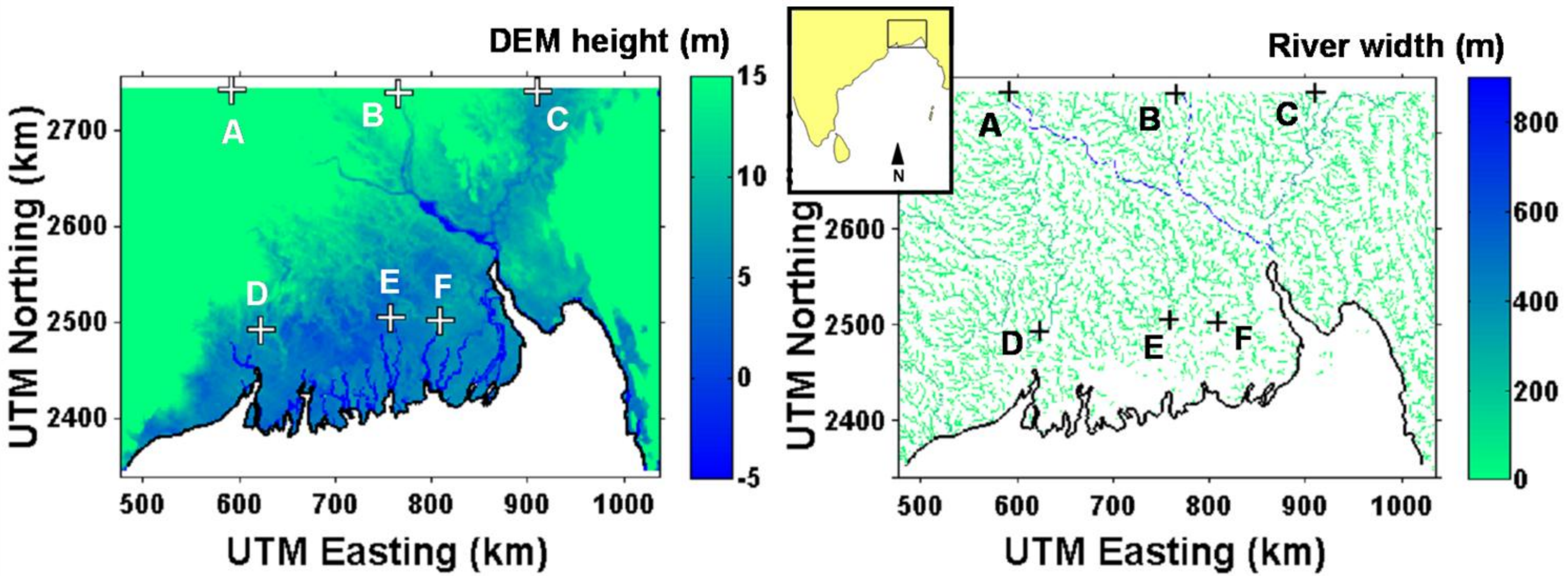




Vegetation a problem, but these effects were removed using a land-use map (www.landcover.org).

Spatial noise (thus artificial roughness) is another problem, and removed by averaging the 90m SRTM data to a 900m DEM grid.

Northern Bay of Bengal LISFLOOD-FP inundation model

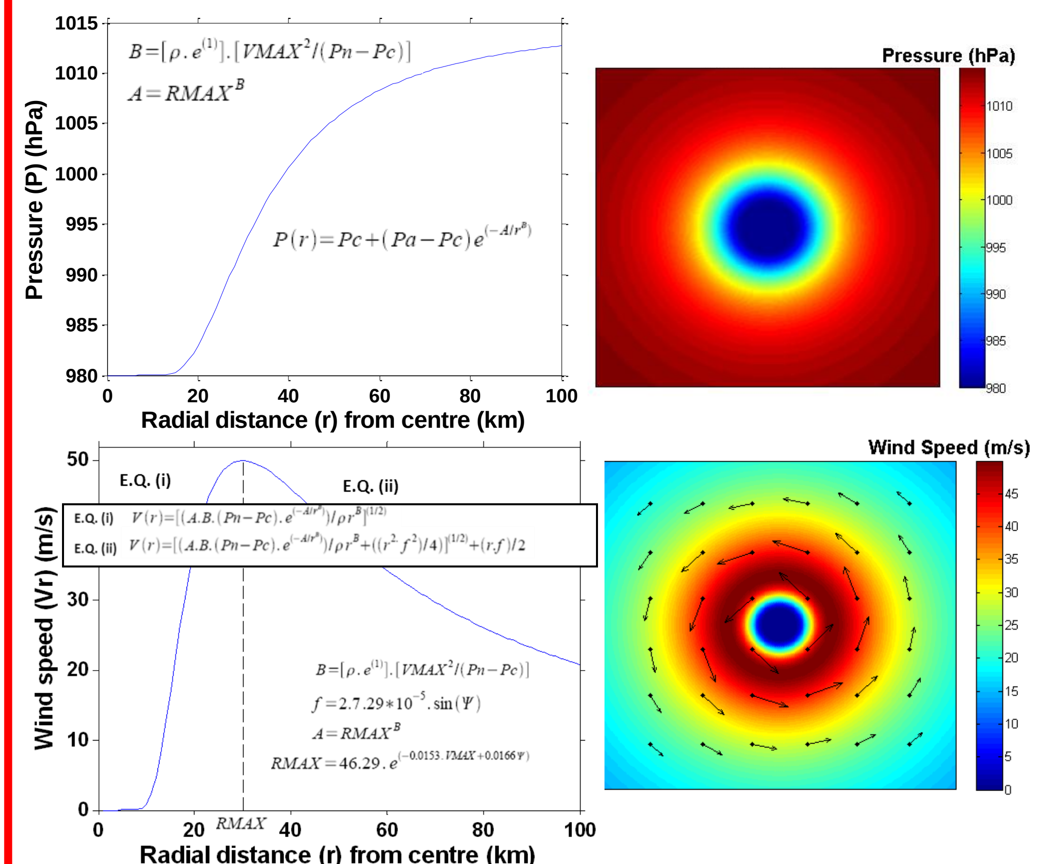


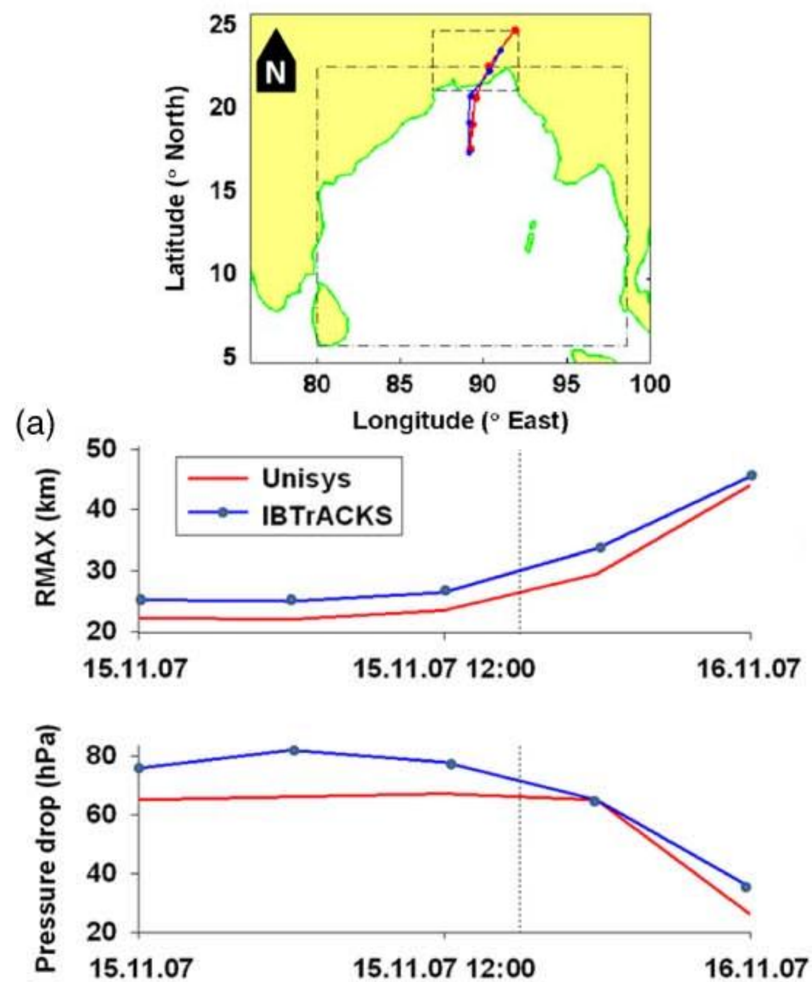
- 900m resolution LISFLOOD-FP inundation model from SRTM data
- Six river flows included (A to F).
- River channels simulated as a sub-grid routine (Neal et al. 2012), using Hydrosheds data (http://hydrosheds.cr.usgs.gov).
- River and estuarine bathymetry estimated during model calibration (see Lewis et al., 2012)

Validation: The 2007 Cyclone Sidr storm surge

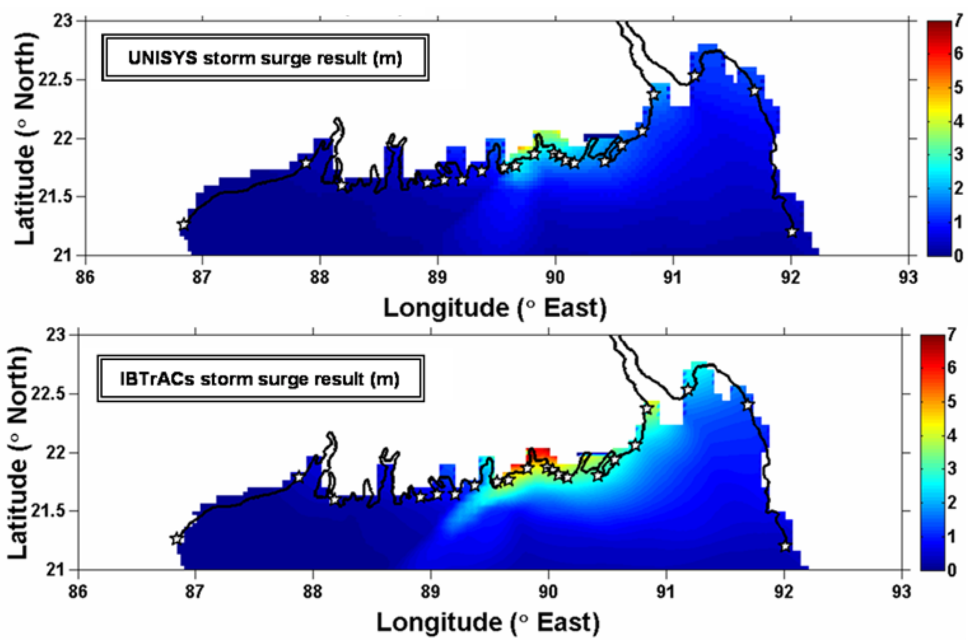
Cyclone parameters from two databases were input into an idealised cyclone model and the IIT-D Bay of Bengal storm surge model (e.g. Dube et al., 2009), and used to hind-cast 2007 Sidr storm surge .

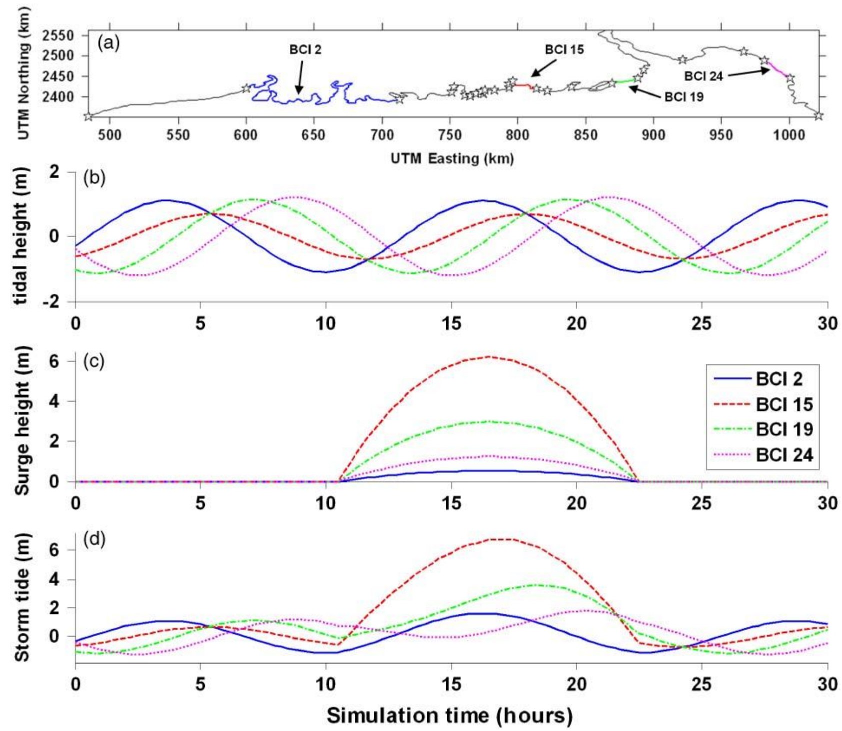
Idealised cyclone model (e.g. Jelesnianski & Taylor, 1973)

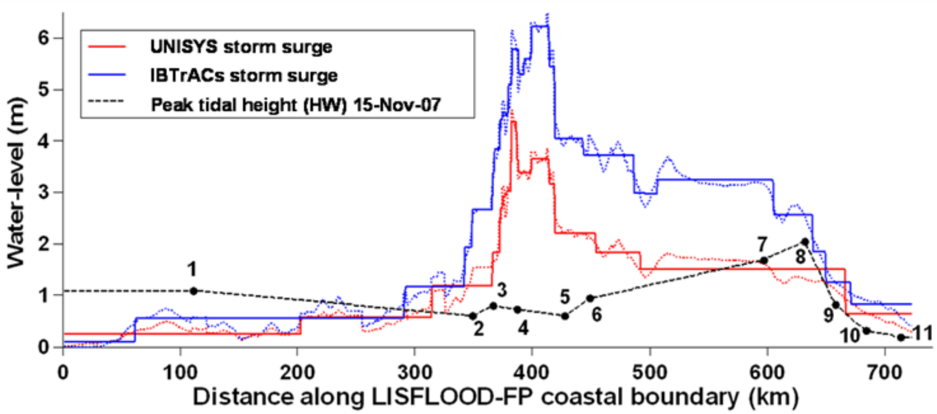




Validation of LISFLOOD-FP model to the 2007 Cyclone Sidr event







Tides are linearly added to the estimated storm surge time-series, and used to force the LISFLOOD-FP model along the coastline

How well did the LISFLOOD-FP model do?

Well, considering the uncertainty within the SRTM data at 900m resolution…

	Cyclone database	
	Unisys	IBTrACs
Simulated flood area (km²)	8,379	10,035
Overall RMSE (13 observations)	2.13m	1.89m
Flood area agreement	41%	43%

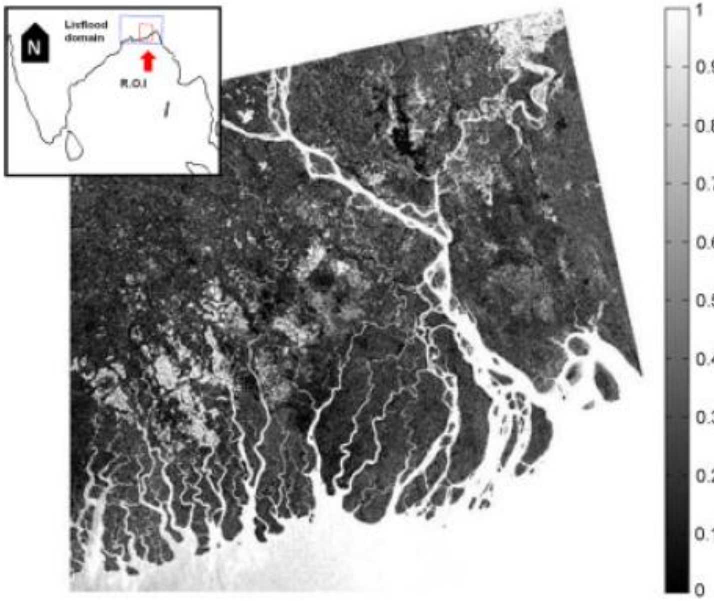
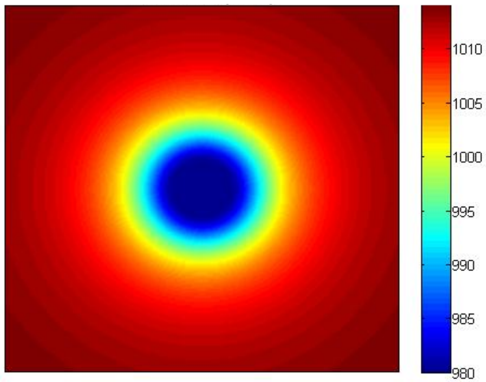


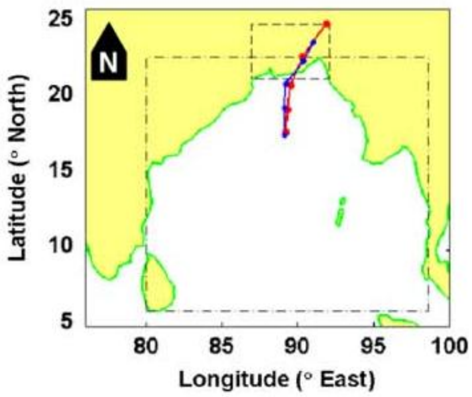
Figure 6. Synthetic Aperture Radar (SAR) map of 19 November 2007, showing wet state probability (0 to 1) for each pixel (see text for more explanation) for the region of interest (ROI) of the 2007

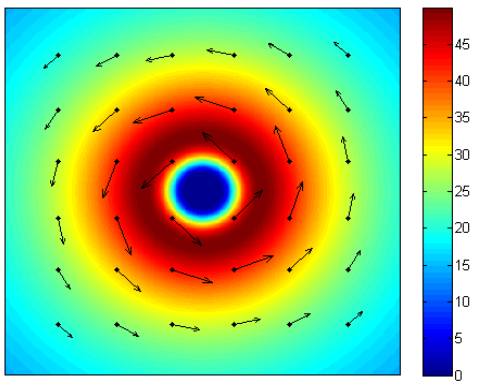
- Simulated flood level errors (RMSE) are the same order of magnitude as water-level uncertainty for the 2007 Cyclone Sidr event.
- SRTM data may be useful for flood risk managers, especially if better processing techniques are employed.
- Storm tide (extreme water-level estimate) uncertainty maybe much greater than topographic uncertainty

Bangladesh Extreme Water-Level estimation

- No “quality” tide gauge records in Bangladesh, so extreme water-level estimates made using a freely available cyclone parameter database (e.g. IBTrACs) and a storm surge model;
- Several methods exist to simulate the extreme storm surge
- The latest method uses a Joint Probability technique (see Irish et al., 2011; Toro et al., 2010), which statistically combines multiple extreme storm parameter frequency distributions of (see Resio et al. 2009):
  1. **central pressure,**
  2. **storm size (RMAX),**
  3. **angle of attack,**
  4. **storm speed (mvspeed),**
  5. **landfall location.**



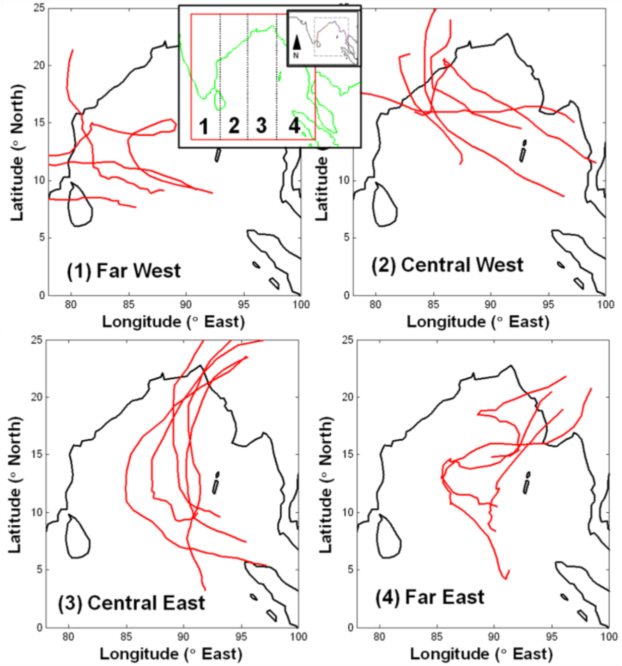


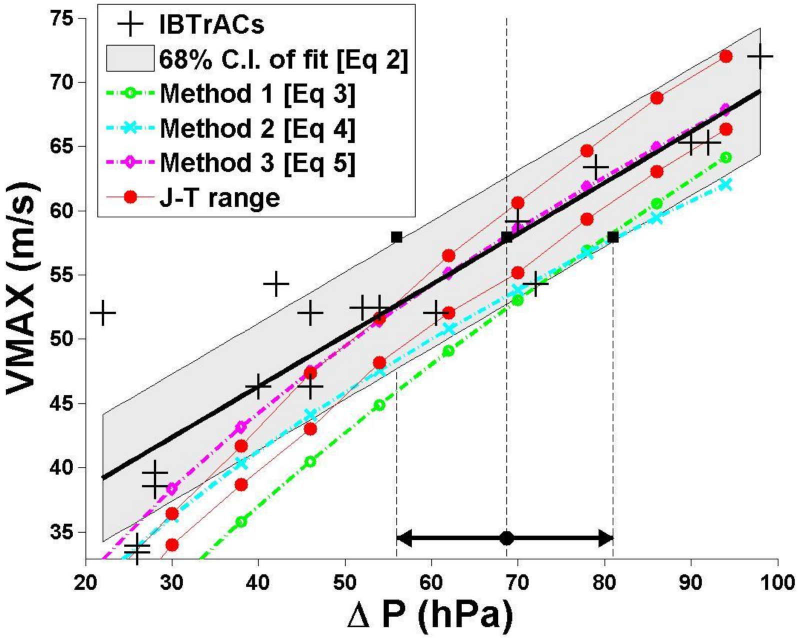


What is the magnitude of uncertainty with forcing water-levels of inundation models?

Given DEM uncertainty, do we need such a complex approach to EWL estimation?

The natural variability of the observed wind-pressure cyclone relationship



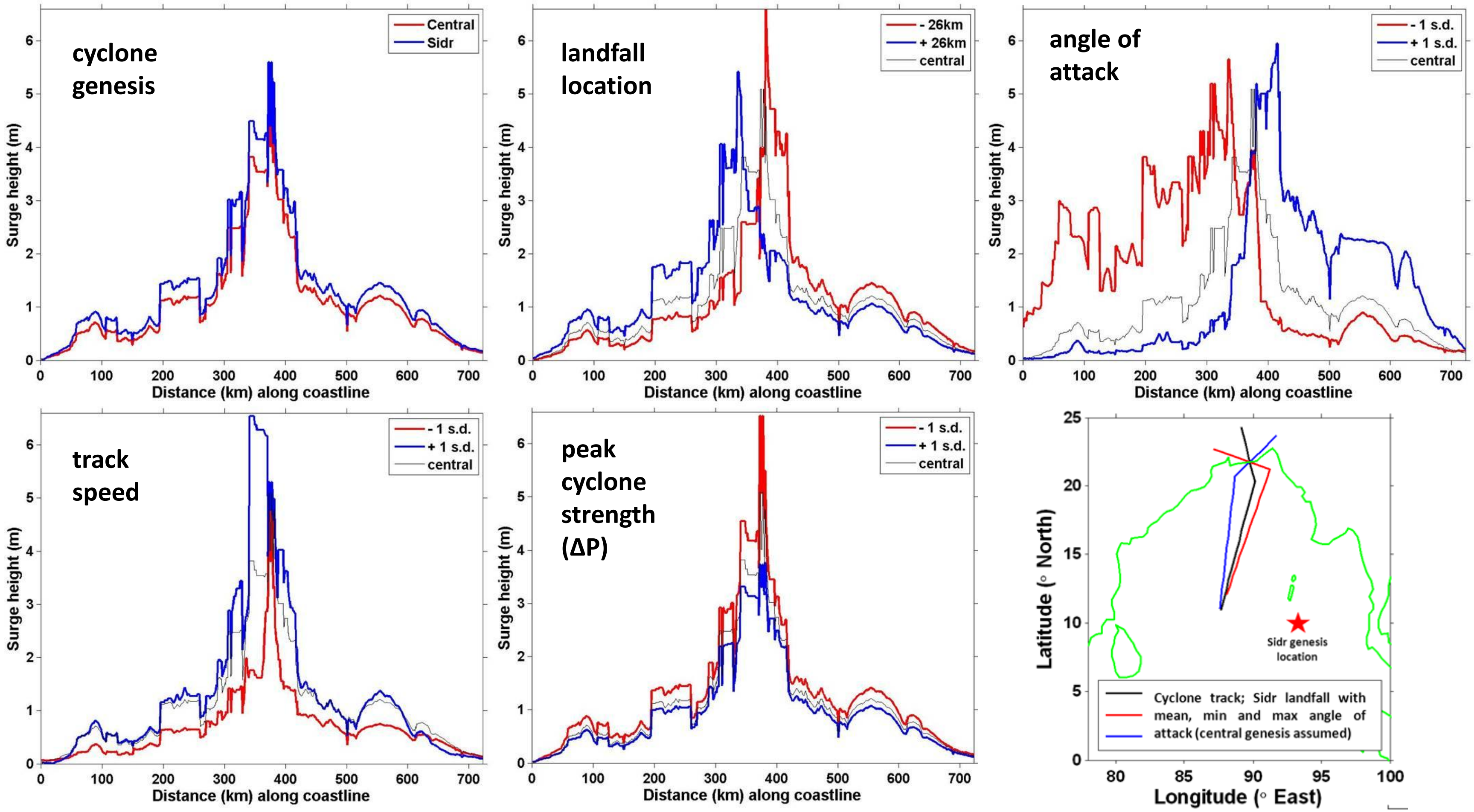


What will the other 4 cyclone parameters be if a 1:50year ΔP cyclone occurred?

- Spatial uniformity of cyclone parameters found in Bay of Bengal; so natural variability within all of the 18 cyclone events analysed;
- Variability within the wind-pressure relationship (also compared to 3 wind-pressure estimation methods);
- Cannot propagate the wind speed uncertainty into the IID-T model, however we try to represent this uncertainty with central pressure based on a "1 in 50 year" cyclone event (68.7hPa) based on the 2007 Sidr track;

Storm surge uncertainty of 1 in 50 year cyclone event

Estimated 1:50year cyclone parameter	mean	minimum scenario	maximum scenario
VMAX (m/s)	57.93	52.98	62.88
ΔP (hPa)	69	56	81
track speed (m/s)	3.8	2.8	4.8
angle of attack	347°N	291°N	43°N

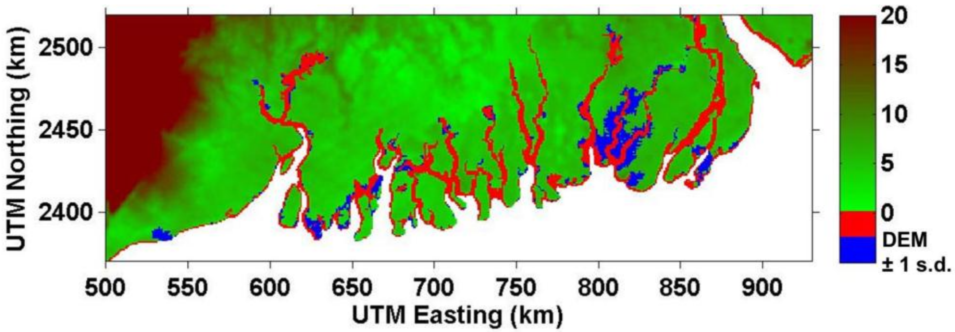


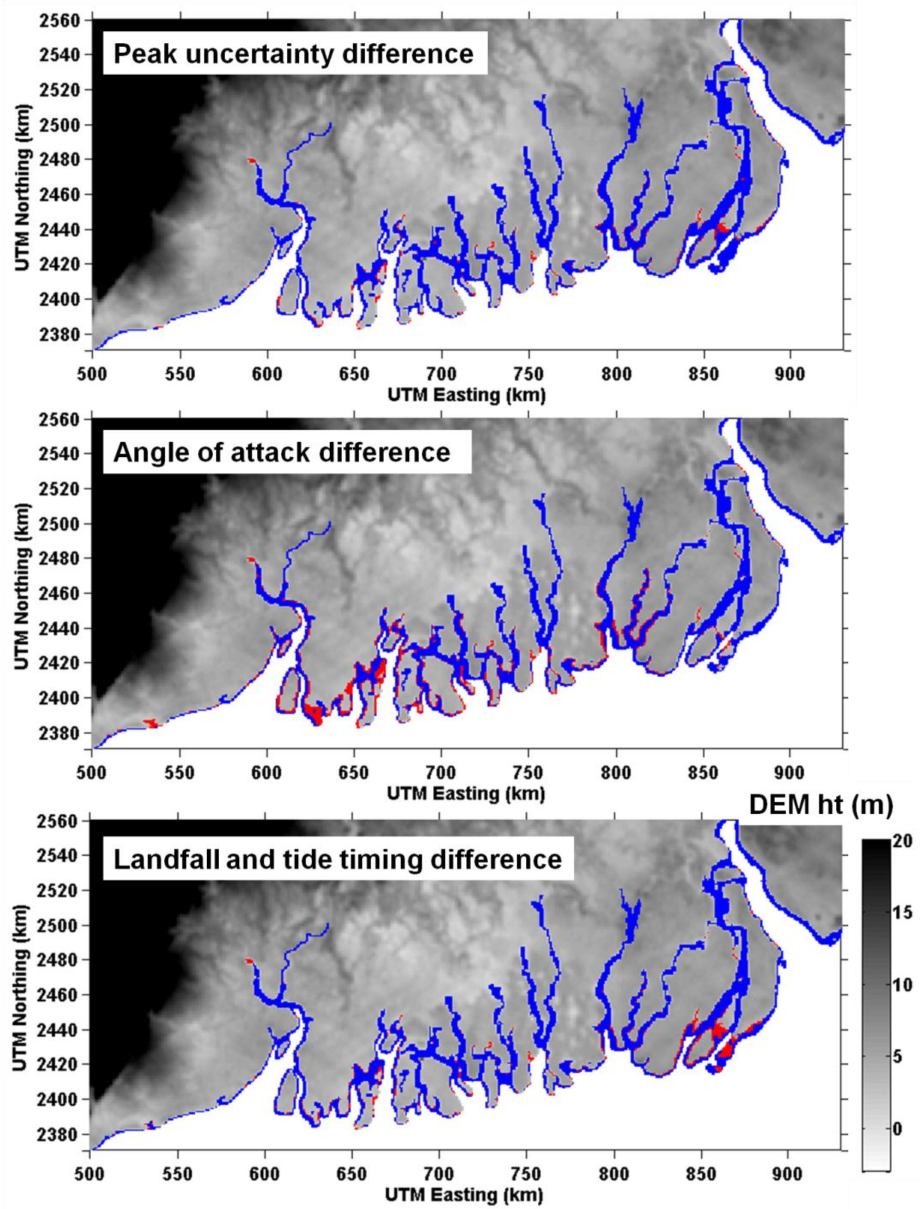
Results

1 in 50yr cyclone *Sidr* type event:

- ΔP uncertainty = **279 km²**
- Timing (maximum surge height at low water or high water) = **441 km²**
- Angle of attack = **1179 km²**
- DEM uncertainty = **1416 km²**

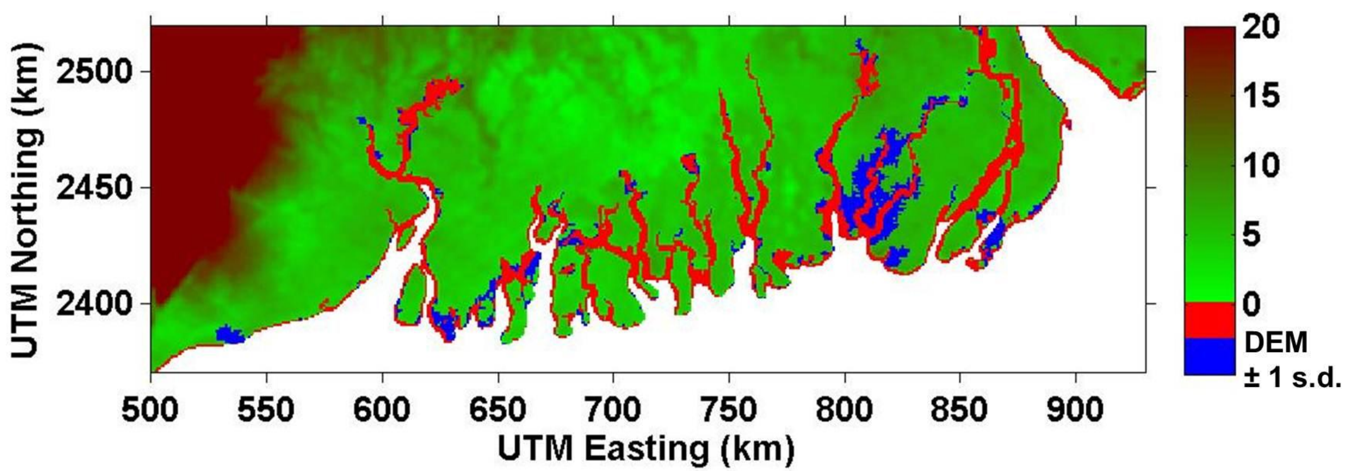
So inundation extent appears very sensitive to total storm tide & cyclone track uncertainty





Conclusions

- Cyclone track uncertainty important to resolve within predictions of coastal inundation
- Joint Probability Method techniques of EWL are required to improve extreme water-level uncertainty in this region.
- Freely available topography products, such as SRTM, can be useful in DEM construction.
- Considering this uncertainty, full shallow water equation models maybe over-specified to simulate inundation in "data poor regions"



Future work

What about waves?

Tide-surge interaction?

Climate changes?

Changes to land use?