



GHIRAF: closing the gap between global models and locally-actionable information

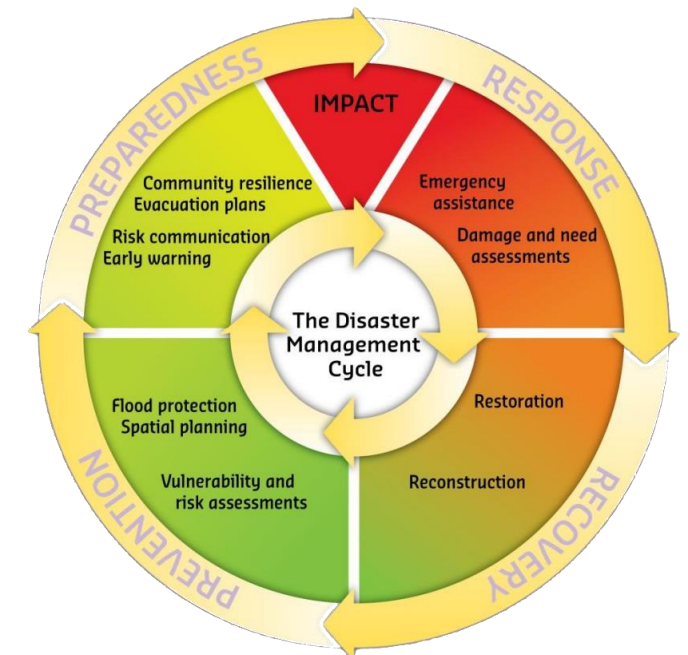
Robert McCall, Ferdinand Diermanse, Daniel Twigt, Ellen Quataert, Floortje Roelvink

Introduction

- Sea level rise, climate change and ongoing development in hazard-prone deltaic and coastal environments are leading to increasing impacts of extreme weather events
- Rapid assessment of the impacts and risks of extreme events is required to reduce disaster risk through:
 - Disaster preparation and response, e.g., impact-based cyclone early warning systems
 - Disaster prevention, e.g., scoping / prioritization of climate adaptation investments



Flooding in Bangkok © Dreamstime



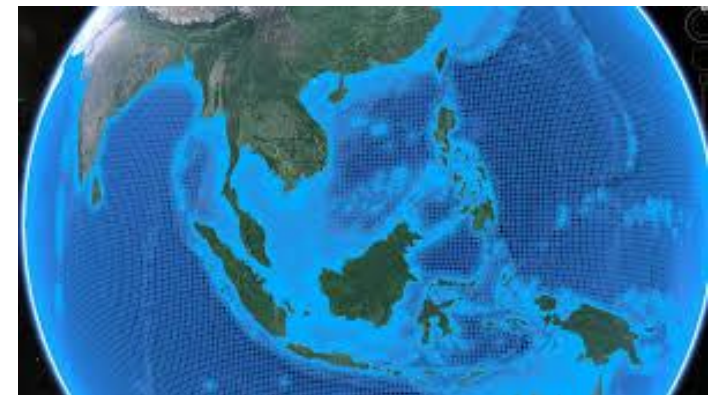
Disaster Management Cycle

Introduction

- Technical developments are starting to make rapid disaster risk assessment possible around the globe:
 - Increasing availability of remotely sensed (e.g., satellite, airborne LiDAR/SfM) data on the bio-physical system.
 - Growth of open-access geospatial data on receptors (e.g., OpenStreetMap).
 - Improvements in IT (e.g., faster software, cloud-based computing) removing computational time as a barrier.
- However, current global modelling efforts are typically still too coarse to aid decision-making at a local level.



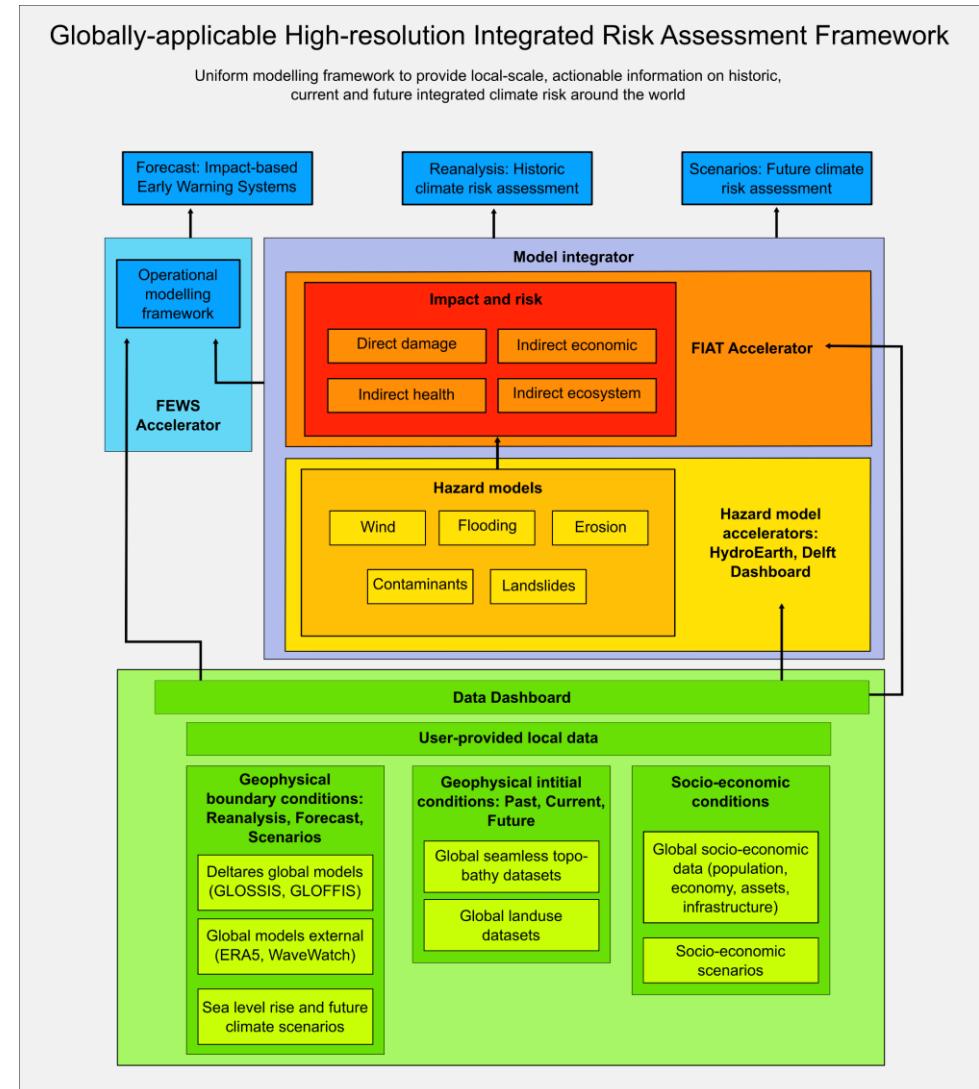
ICESat-2 © NASA



Deltares Global Storm Surge Information System

GHIRAF

- There is a need to bridge the gap between “global” simulations and locally-actionable information
- We have started the development of generalized framework to support rapid impact and risk assessment at local scale: GHIRAF (Globally-applicable High-resolution Integrated Risk Assessment Framework)
- Framework comprises
 - Provision of **global datasets** (or local, where applicable)
 - Quick / automated **hazard** and (indirect) **impact** model generation and **integration**
 - Automated **operational modelling** and impact/risk **analysis and visualization** tools
- Focus on high-resolution multi-hazards and impacts during extreme weather events



Objective

- Examine current ability of GHIRAF to rapidly simulate the impact of an extreme weather event
 - How accurate, how rapid?
 - Serves as baseline for future GHIRAF developments
- Identify sources of error and uncertainty
- Analysis by means of case study of Hurricane Florence (Sep. 2018) impact in New Hanover and Brunswick counties, NC, USA.
 - Location of landfall of Category 1 hurricane
 - Area subjected to storm surge and intense rainfall
 - Reported estimate of damages in Wilmington (New Hannover County) \$220M.
 - State-wide damages estimated \$17–22B.



Hurricane Florence (NOAA/STAR)



Flooding in Wilmington, NC. (JIM LO SCALZO / EPA)

Method

- Rapidly simulate Hurricane Florence as though it had just hit the US coast (preparedness and response phase)
- Use publicly-available datasets
- Use model accelerator tools to reduce time required to set-up models (minutes–hours), at the expense of accuracy
- Vary model input and processes to examine uncertainties
- Compare model predictions of flood extent and damages to observations and reports



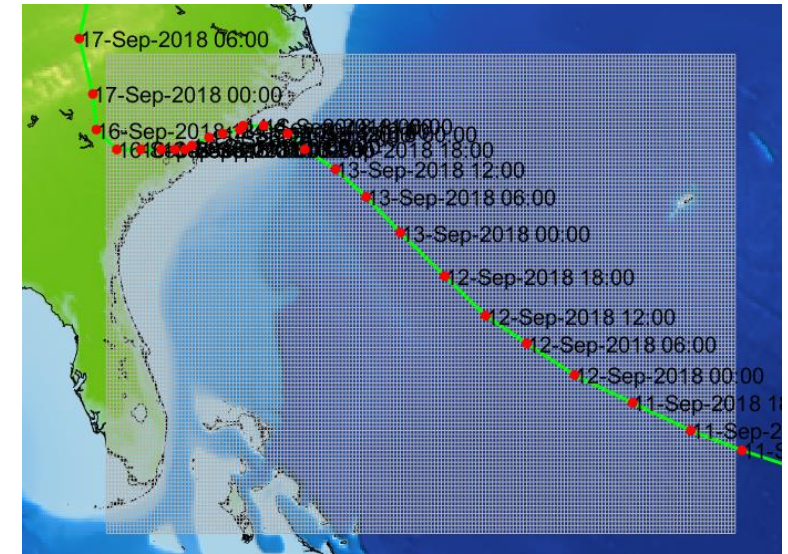
Hurricane Florence (NOAA/STAR)



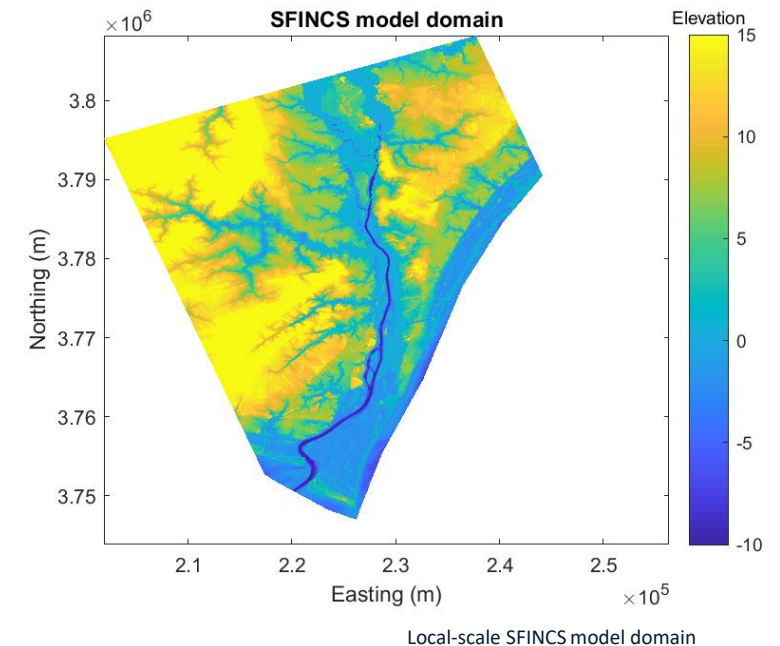
Flooding in Wilmington, NC. (JIM LO SCALZO / EPA)

Model train

- A train of hydrodynamic models is set up to simulate Hurricane Florence:
 - Large-scale Delft3D FLOW and WAVE model
 - Cross-shore transect XBeach nearshore models
 - High-resolution (25m) SFINCS coastal flood model
 - Models run using public bathymetric datasets and hurricane track information
 - See slides at end for more detail
- Impacts of combined marine and pluvial flooding are computed using the Delft-FIAT flood impact assessment tool
 - Model run using public exposure and vulnerability data
 - See slides at end for more detail



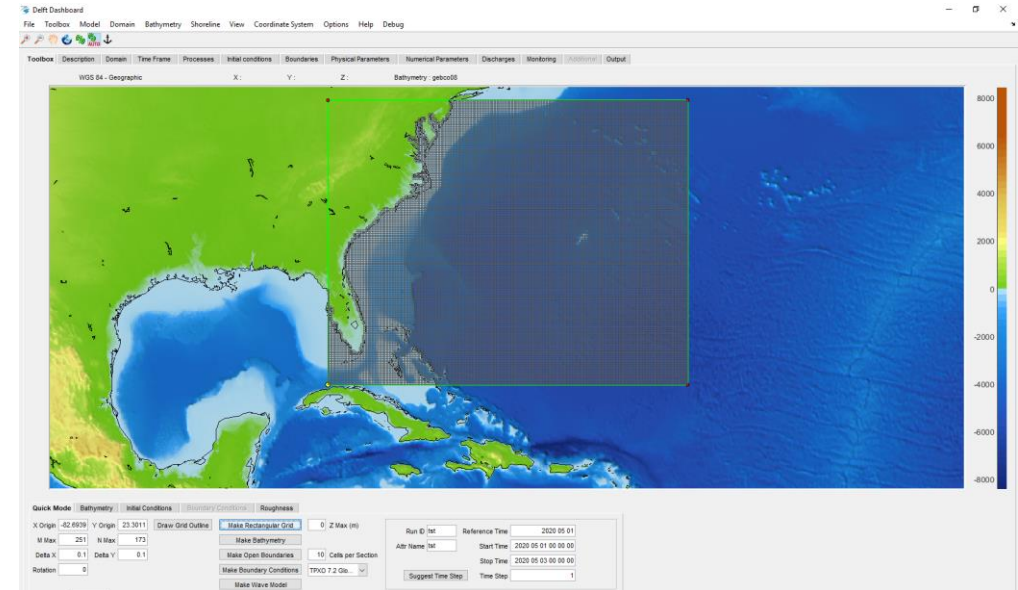
Large-scale Delft3D model grid and track of Hurricane Florence



Local-scale SFINCS model domain

Model set-up accelerators

- Model accelerators in current GHIRAF framework help to substantially reduce model set-up time
 - Hydrodynamic models (Delft3D, XBeach and SFINCS) are set up within hours using Delft Dashboard model accelerator¹.
 - A simple Delft-FIAT impact model is set up within minutes using the flood depth predictions of the SFINCS model.

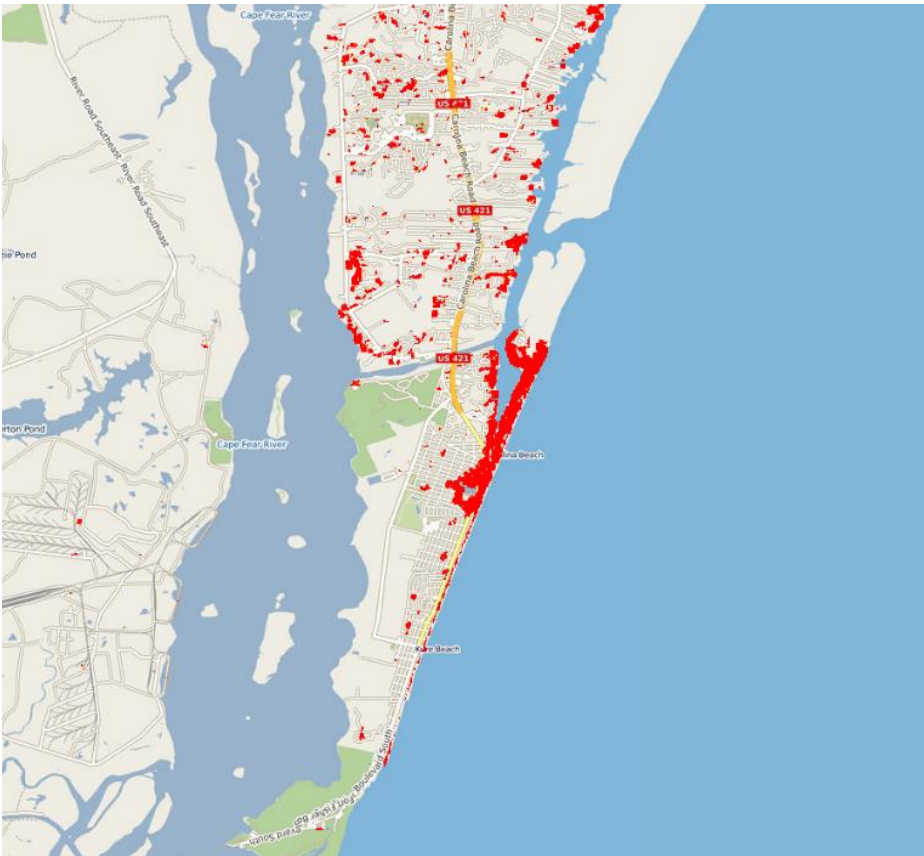


Delft Dashboard accelerator to aid rapid set-up of hydrodynamic models

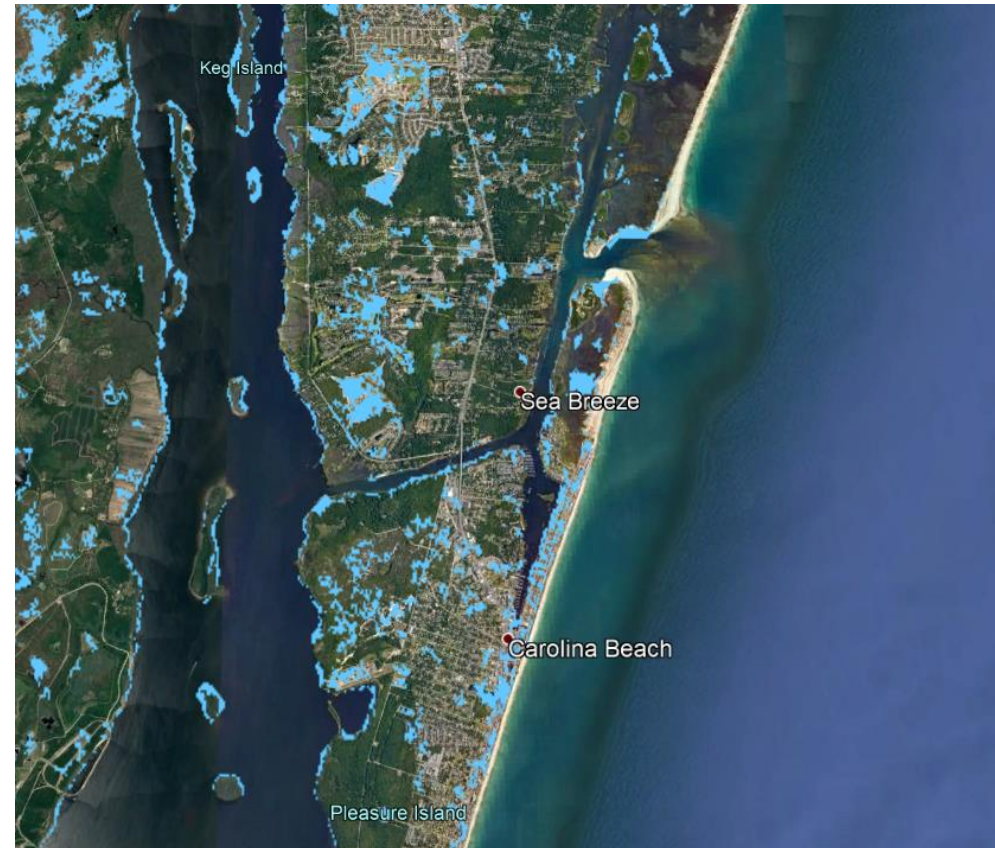
¹ van Ormondt, M., Nederhoff, K. and van Dongeren, A., 2020. Delft dashboard: a quick set-up tool for hydrodynamic models. *Journal of Hydroinformatics*. <https://doi.org/10.2166/hydro.2020.092>

Results

- Areas of damage in the Delft-FIAT model compare reasonably well with NASA JPL ARIA proxy data of flood extent



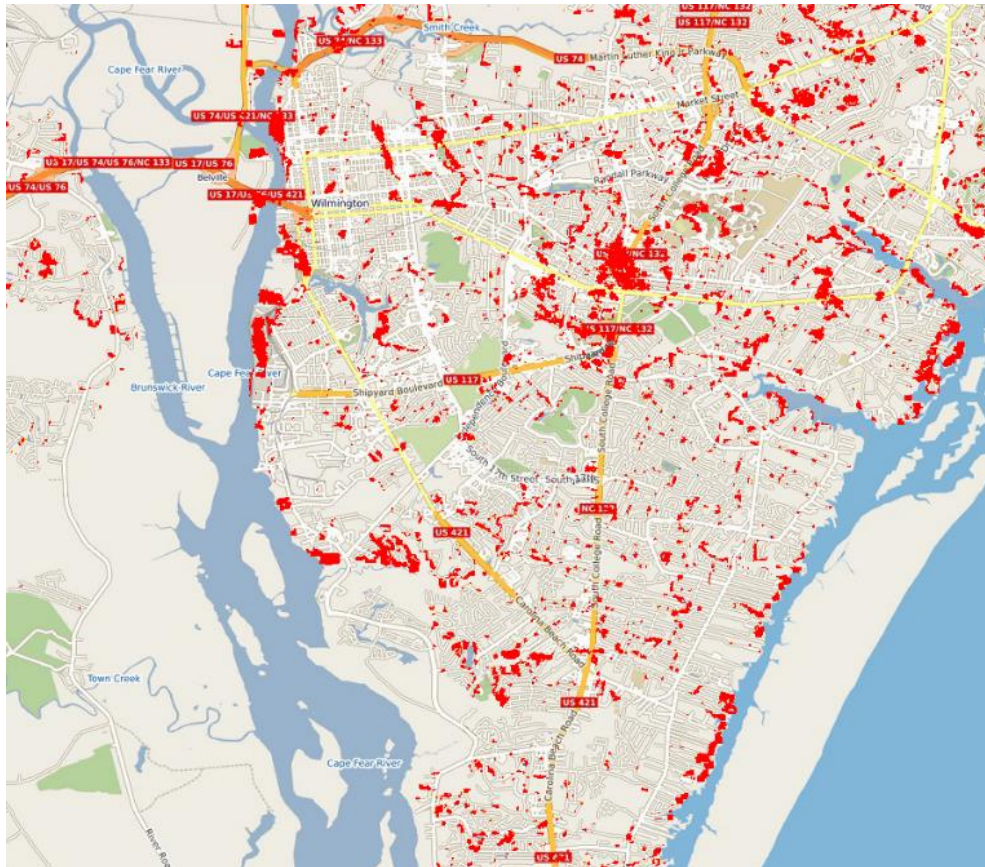
FIAT damage prediction



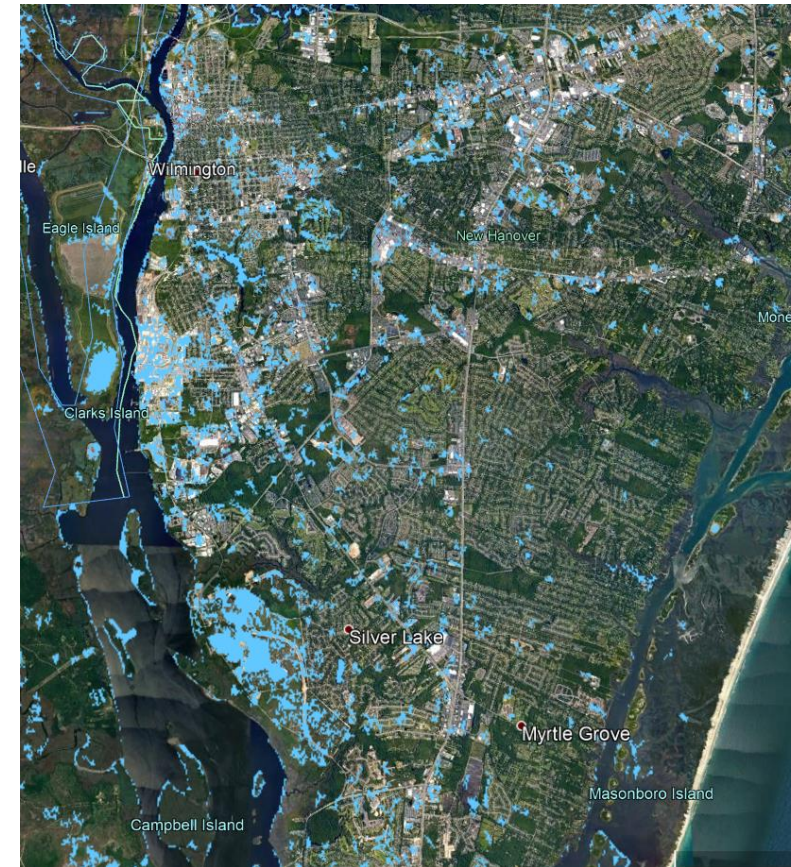
NASA JPL ARIA flood data

Results

- Areas of damage in the Delft-FIAT model compare reasonably well with NASA JPL ARIA proxy data of flood extent



FIAT damage prediction



NASA JPL ARIA flood data

Results

- Quantitative prediction of damage by model train is \$925M for New Hannover and Brunswick counties.
 - The predicted value is greater than estimate of damage to Wilmington alone (\$220M)
 - The predicted value is approximately 5% of the estimated state-wide damage (\$17–22B). Reported distribution of emergency federal funding (not equal to the total damage) given to these two counties relative to NC as a whole is approximately 10%.

Sensitivity

- Predictions of damage vary substantially for varying model input and processes
 - The range in damage between including and excluding pluvial flooding (damage \$262M) for this case study is almost factor 4. While inclusion of rainfall is obviously crucial to correctly model damage here, this difference also implies that assumptions regarding hydrology and infiltration capacity need to be assessed.
 - The range in damage between models run using local topographic and global SRTM data (damage \$1.8B) is a factor 2. Greater differences should be expected if more detailed local data are used.
 - Low-frequency wave effects (modelled in XBeach) contribute approximately \$140M to the total damage prediction of the model train. This contribution is substantial, but less than the relative contribution of rainfall and topographic data quality.
 - Post-landfall fluvial flooding from inland sources, as well as wind damage, were not included, but are known to have occurred in North Carolina.

Conclusions

- An analysis was made of the ability of the current GHIRAF framework to rapidly simulate the impact of Hurricane Florence in New Hanover and Brunswick counties, NC, USA.
- Using the model accelerators in GHIRAF allow a train of hydrodynamic and impact models to be set up for the case-study in hours, rather than days, by experienced modellers.
- Model damage predictions for the case study are of the correct order of magnitude, but have large uncertainty bands with factor 2–4 differences in predicted damage chiefly due to variations in model processes (here: pluvial flooding, but also wind damage elsewhere) and topographic data.
- Still plenty of ways to improve the framework and lots of development possible. Work in progress.

Future developments

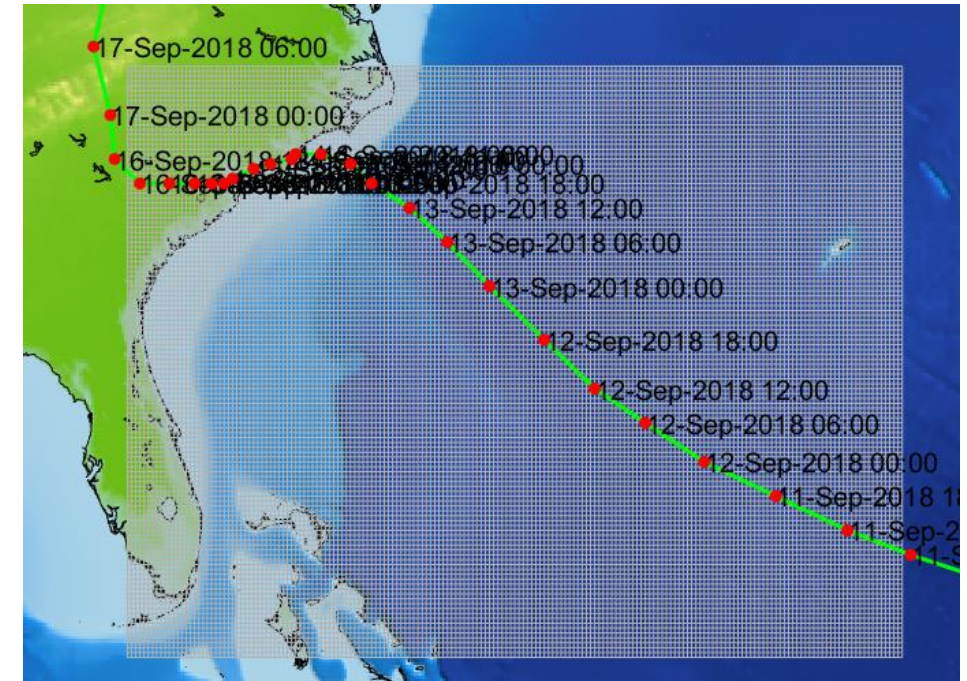
- Improve hazard and impact modelling
 - Model accelerators to rapidly couple hydrological models (fluvial flooding, better pluvial flooding)
 - Better topographic data worldwide (linking to latest satellite-derived data; data merging)
 - Including other receptors such as (critical) infrastructure
 - Inclusion of vulnerability to other hazards (wind, rain-induced landslides, etc.)
 - Inclusion of local exposure and vulnerability data where available
 - Computing indirect impacts
 - Much more validation!
- Make the framework even more rapid (seconds–minutes) with better automation
- All ideas welcome!



Extra: description of models

Models

- Large-scale Delft3D FLOW and WAVE model around the track of Hurricane Florence to provide nearshore (~20 m depth) surge and wave conditions
 - Set up using Delft Dashboard model accelerator¹
 - Model bathymetry derived from GEBCO_2019 Grid²
 - Hurricane wind field and rainfall boundary conditions estimated using TCWiSE³



Delft3D model grid and track of Hurricane Florence

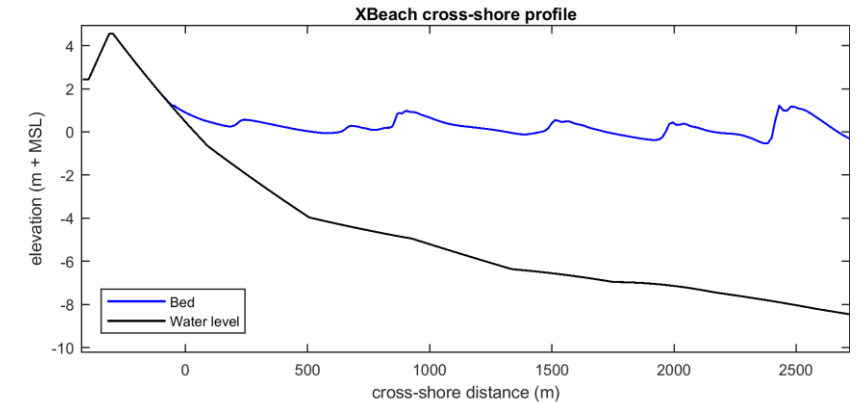
¹ van Ormondt, M., Nederhoff, K. and van Dongeren, A., 2020. Delft dashboard: a quick set-up tool for hydrodynamic models. *Journal of Hydroinformatics*. <https://doi.org/10.2166/hydro.2020.092>

² GEBCO Compilation Group, 2019. GEBCO 2019 Grid (doi:10.5285/836f016a-33be-6ddc-e053-6c86abc0788e)

³ Nederhoff, K., Giardino, A., van Ormondt, M. and Vatvani, D., 2019. Estimates of tropical cyclone geometry parameters based on best-track data. *Natural Hazards and Earth System Sciences*, 19(11), pp.2359-2370.

Models

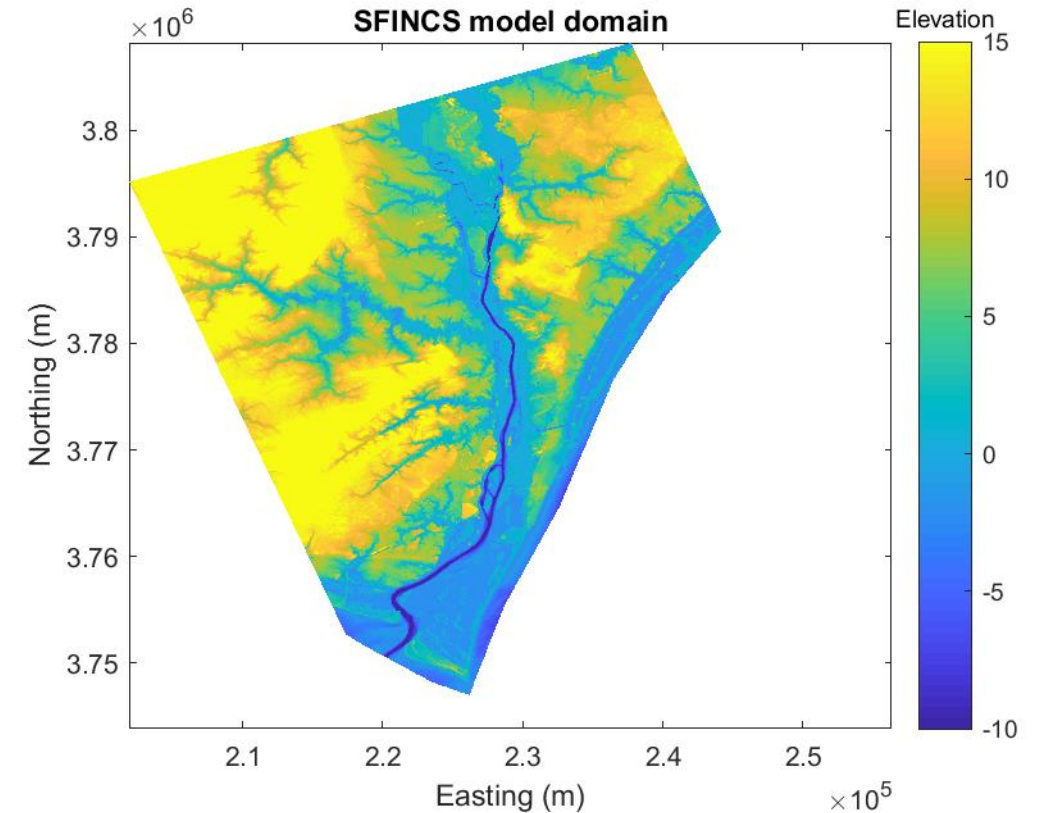
- XBeach cross-shore transect models to transfer Delft3D offshore surge and (infragravity) wave conditions to shallow water (~2 m depth)
- Set up every 10 km along the coast using Delft Dashboard model accelerator
- Model bathymetry derived from GEBCO_2019 Grid
- Boundary conditions derived from large-scale Delft3D model



Example of an XBeach cross-shore transect model

Models

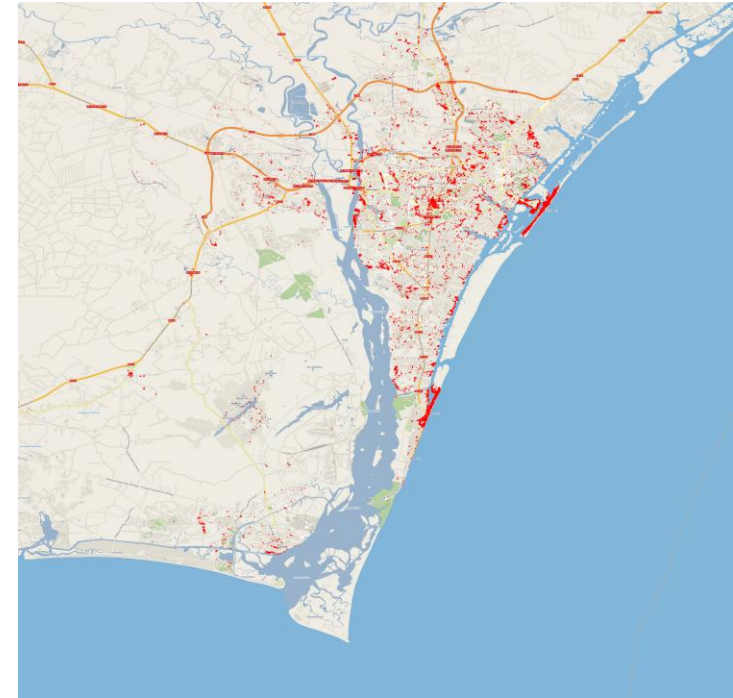
- SFINCS flood model used to simulate marine and pluvial flooding at high resolution (25 m) in the study area
 - Set up using Delft Dashboard model accelerator
 - Domain size ~40 x 40 km
 - Marine boundary conditions derived from XBeach transects and rainfall estimated using TCWiSE
 - Model bathymetry derived from USGS National Elevation Dataset (10m resolution) above sea level and NCEI U.S. Coastal Relief Model (90 m resolution) below sea level
 - For comparative purposes, the SFINCS model is also run using GEBCO_2019 bathymetric and SRTM topographic data.



SFINCS model domain and bed level

Models

- Delft-FIAT model used to simulate impact at the resolution of the SFINCS model (25 m) in the study area
 - Set up using FIAT model accelerator and maximum water depth computed by the SFINCS model
 - Exposure data derived from the World Settlement Footprint and Global Human Settlement datasets
 - Depth damage curves for the study area are derived from JRC data¹



Example of damage predicted by Delft-FIAT

¹ Huizinga, J., De Moel, H., Szewczyk, W., 2017. Global flood depth-damage functions. Methodology and the database with guidelines. JRC Technical Reports. European Commission