Deltares

Uncertainties in predicting barrier island morphodynamic response to hurricane impact

Influence of vegetation in XBeach

Ellen Quataert, Roel de Goede, Marlies van der Lugt, Ap van Dongeren

13 April 2023

NOPP

NOPP Hurricane Coastal Impacts

- Better understanding and predictive ability of hurricane impacts, to protect coastal communities
  - Flooding
  - Property destruction and infrastructure loss
  - Erosion and barrier island breaching

- 10 teams
  - Meteo forcing (COAMPS-TC)
  - DEMs and land use
  - In situ observations
  - Remote sensing
  - **Modelling**

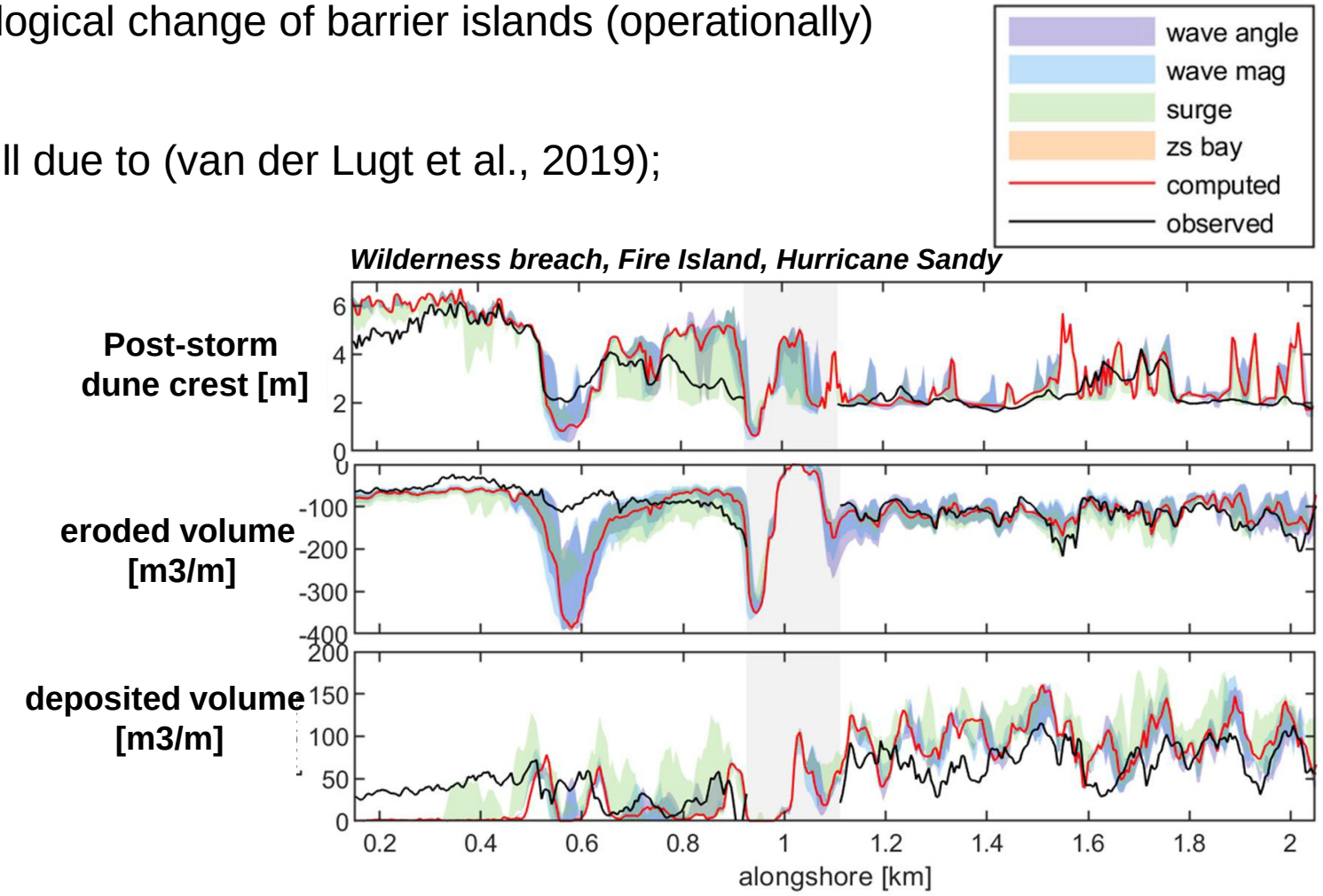
https://nopphurricane.sofarocean.com/

Deltares NOPP

Predicting hurricane impact on barrier islands

- Using XBeach to predict morphological change of barrier islands (operationally)

- Known uncertainties in model skill due to (van der Lugt et al., 2019);
  - forcing conditions

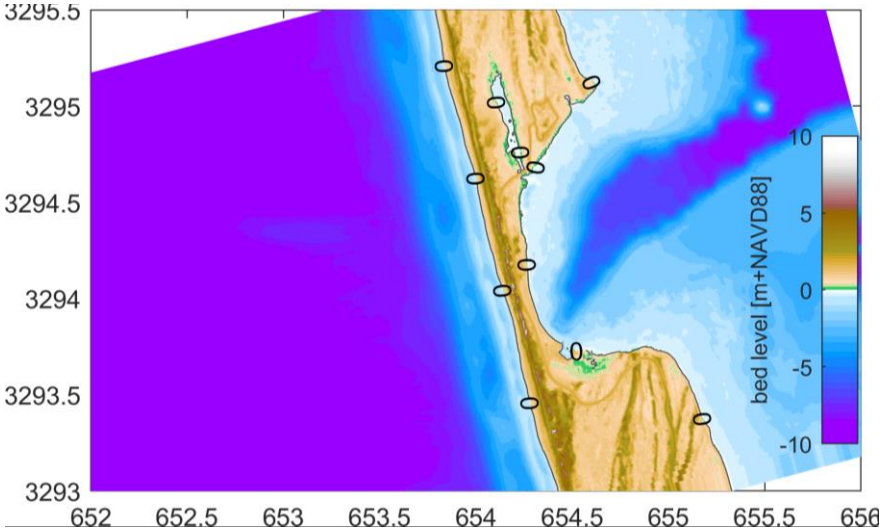


Van der Lugt, M., et al. (2019). Morphodynamic modeling of the response of two barrier islands to Atlantic hurricane forcing. https://doi.org/10.1016/j.ecss.2019.106404

Predicting hurricane impact on barrier islands

- Using XBeach to predict morphological change of barrier islands (operationally)

- Known uncertainties in model skill due to (van der Lugt et al., 2019);
  - forcing conditions
  - initial topo/bathymetry



Deltares NOPP

Van der Lugt, M., et al. (2019). Morphodynamic modeling of the response of two barrier islands to Atlantic hurricane forcing. https://doi.org/10.1016/j.ecss.2019.106404

Predicting hurricane impact on barrier islands

- Using XBeach to predict morphological change of barrier islands (operationally)

- Known uncertainties in model skill due to (van der Lugt et al., 2019);
  - forcing conditions
  - initial topo/bathymetry
  - parameterization of processes
    - sediment transport parameters
    - bed roughness by vegetation/land cover

- In this presentation: focus on uncertainties in XBeach predictive skill due to vegetation/land cover input and parameterization

Deltares

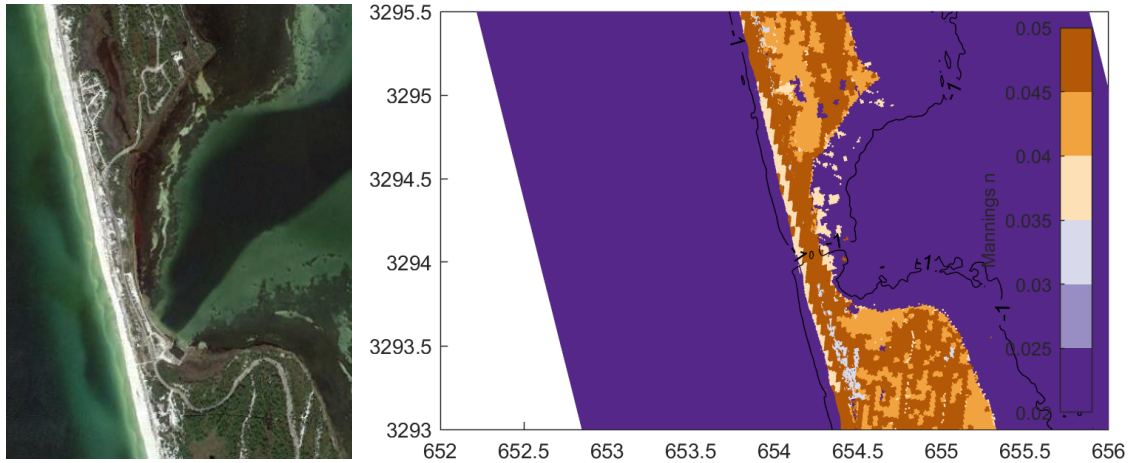
Van der Lugt, M., et al. (2019). Morphodynamic modeling of the response of two barrier islands to Atlantic hurricane forcing. https://doi.org/10.1016/j.ecss.2019.106404

Parameterization of bed roughness by vegetation

Vegetation plays a critical role in reducing overwash velocities, thereby retaining sediment on the subaerial dune.

Current approach in XBeach modelling:

1. Spatial variation of roughness
   - High resolution land-cover classification maps available
   - Convert Land Cover Classes to Manning's n roughness



Classification	NLCD class name	Manning's n
Sand	Open Water	0.02
Wetland Vegetation	Emergent Herbaceous Wetlands	0.045
Water	Open Water	0.02
Dune Grass	Grassland/Herbaceous	0.034
Woody Vegetation	Shrub/Scrub	0.05
Anthropogenic coverage	Developed – Low Intensity	0.05

Mattocks, C., Forbes, C., (2008). https://doi.org/10.1016/j.ocemod.2008.06.008.

Deltares NOPP

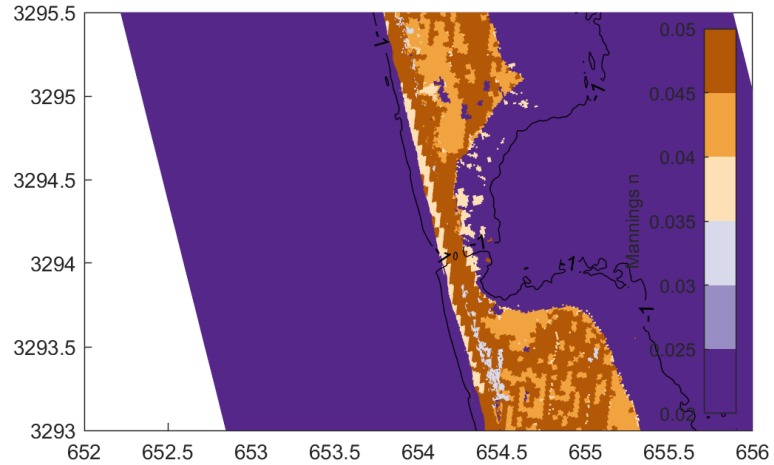
Parameterization of bed roughness by vegetation

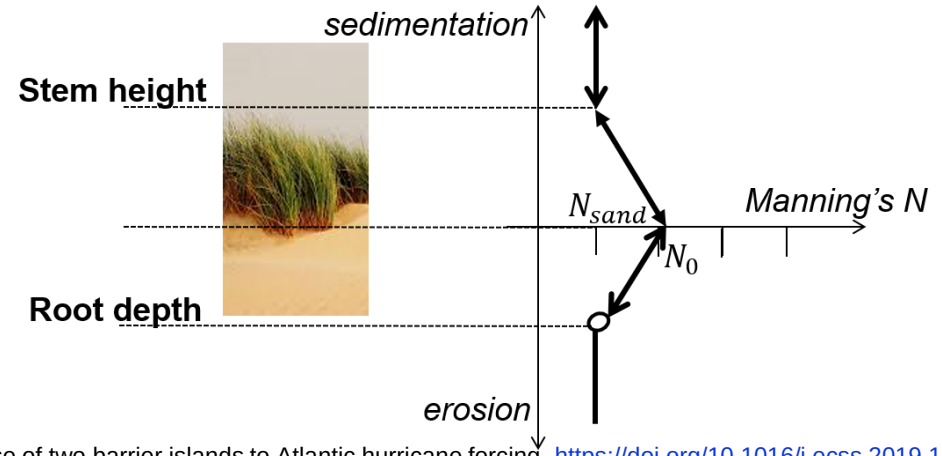
Vegetation plays a critical role in reducing overwash velocities, thereby retaining sediment on the subaerial dune.

Current approach in XBeach modelling:

1. Spatial variation of roughness
   - High resolution land-cover classification maps available
   - Convert Land Cover Classes to Manning's n roughness

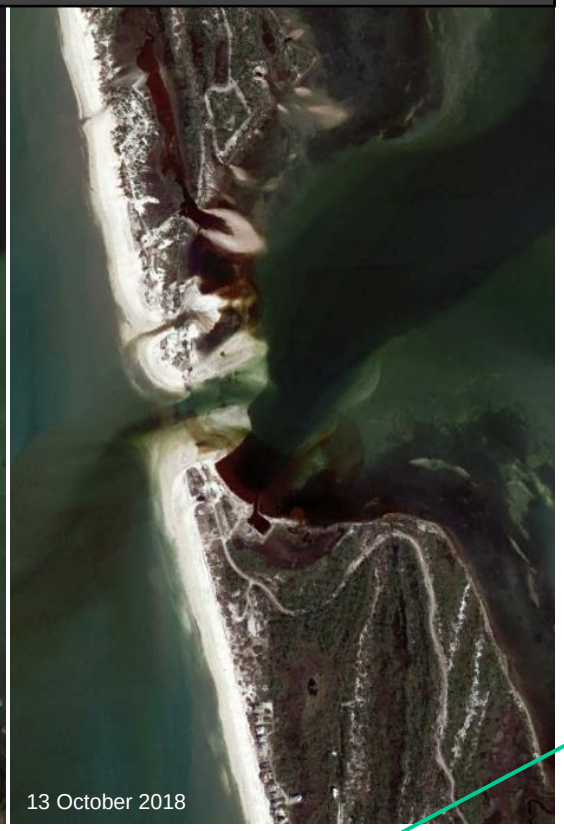
2. Temporal variation of roughness
   - Under extreme conditions vegetation washes away or is buried



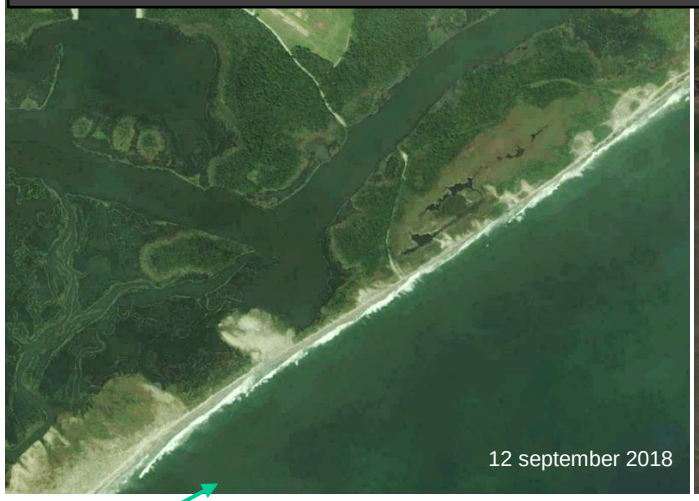


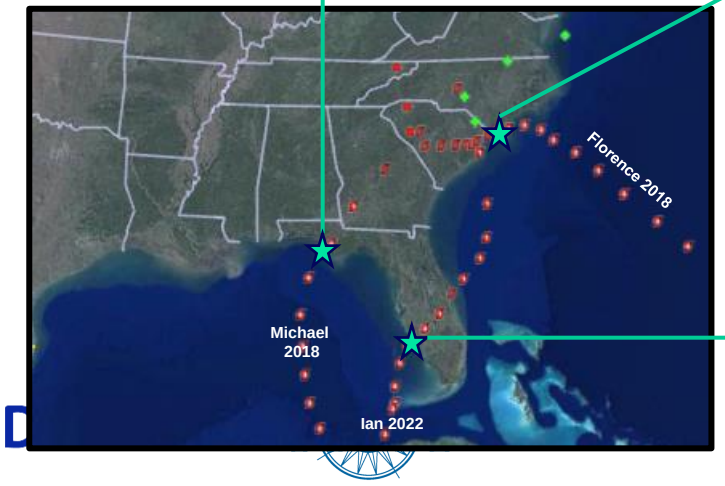
Van der Lugt, M., et al. (2019). Morphodynamic modeling of the response of two barrier islands to Atlantic hurricane forcing. https://doi.org/10.1016/j.ecss.2019.106404

Hurricane Michael



Hurricane Florence



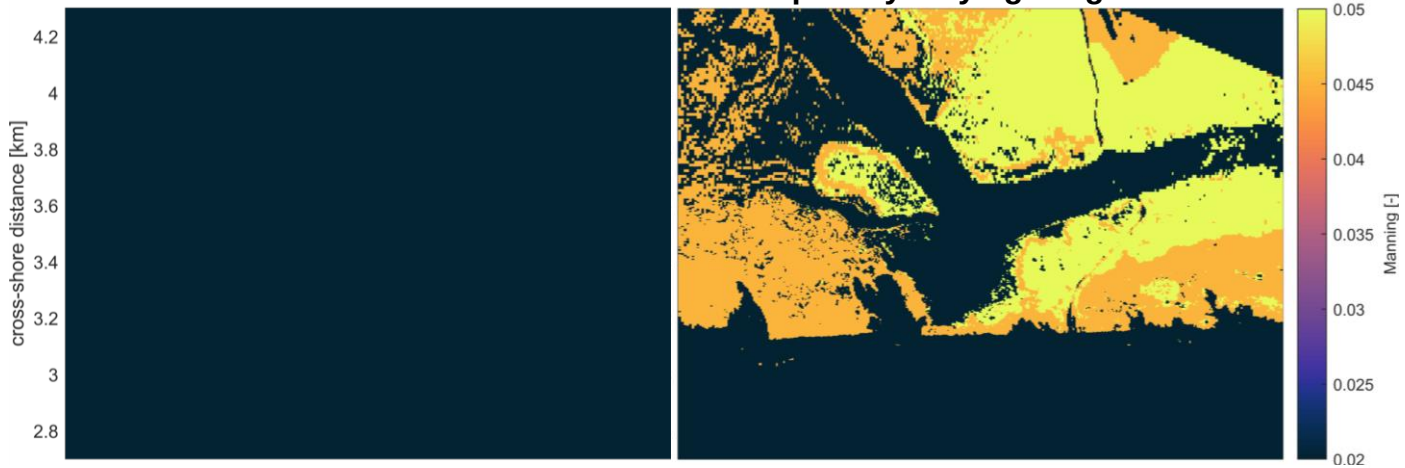


Hurricane Ian

Hurricane Florence

spatially uniform roughness n=0,02

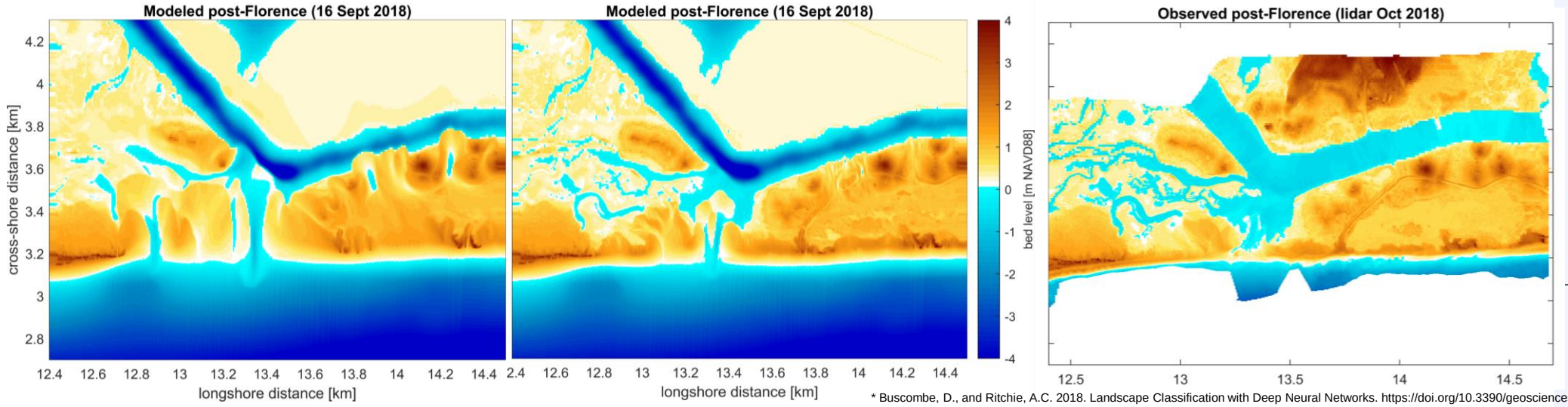
spatially varying roughness *



Modeled post-Florence (16 Sept 2018)

Modeled post-Florence (16 Sept 2018)

Observed post-Florence (lidar Oct 2018)



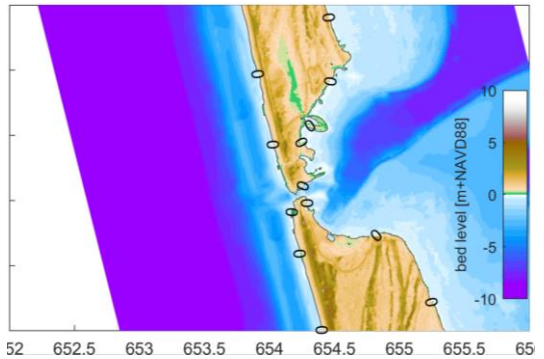
* Buscombe, D., and Ritchie, A.C. 2018. Landscape Classification with Deep Neural Networks. https://doi.org/10.3390/geosciences8070244

Deltares

Hurricane Michael

Breach at the St. Joseph Peninsula

Observed: post-storm

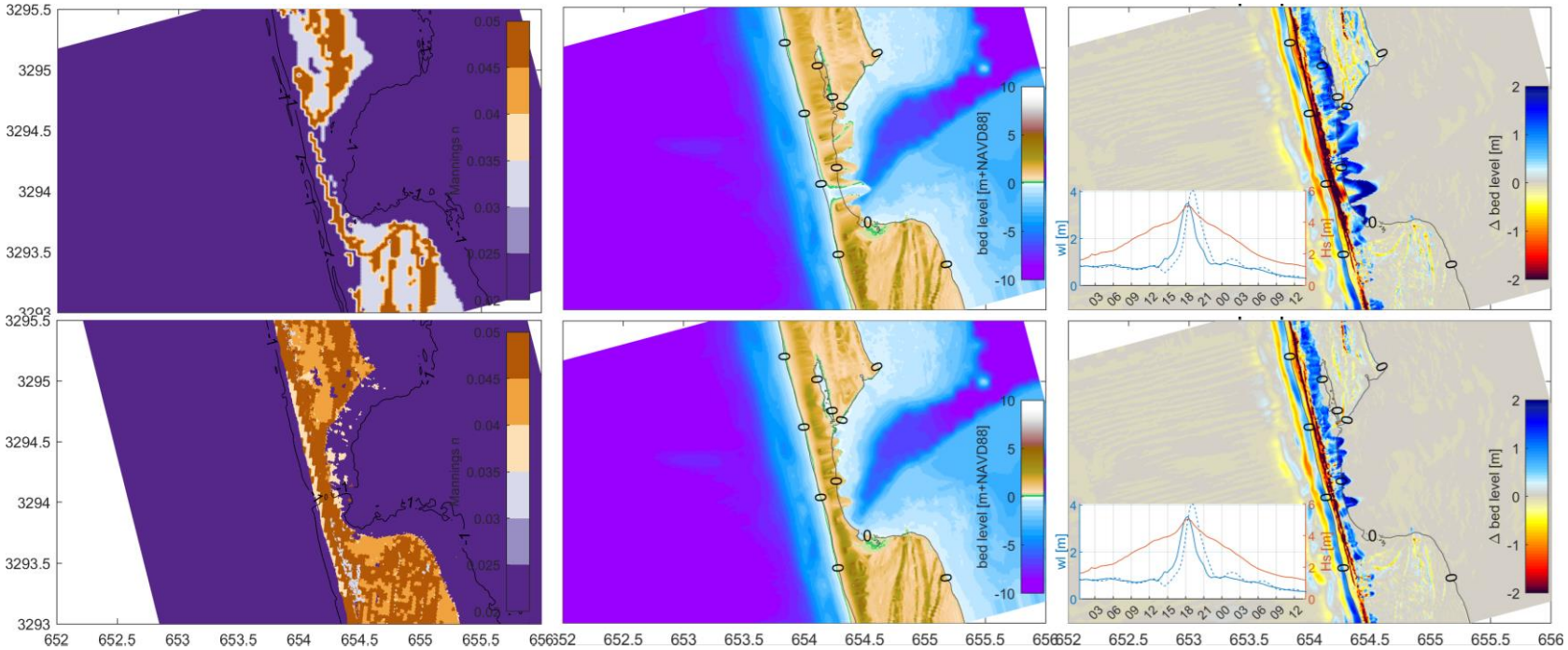


Modeled: post-storm

Modeled: sed-ero

Manning's n = 0.02 – 0.05
based on NLCD land cover data

Manning's n = 0.02 – 0.05
based on NOPP/C-CAP Fusion Product USGS

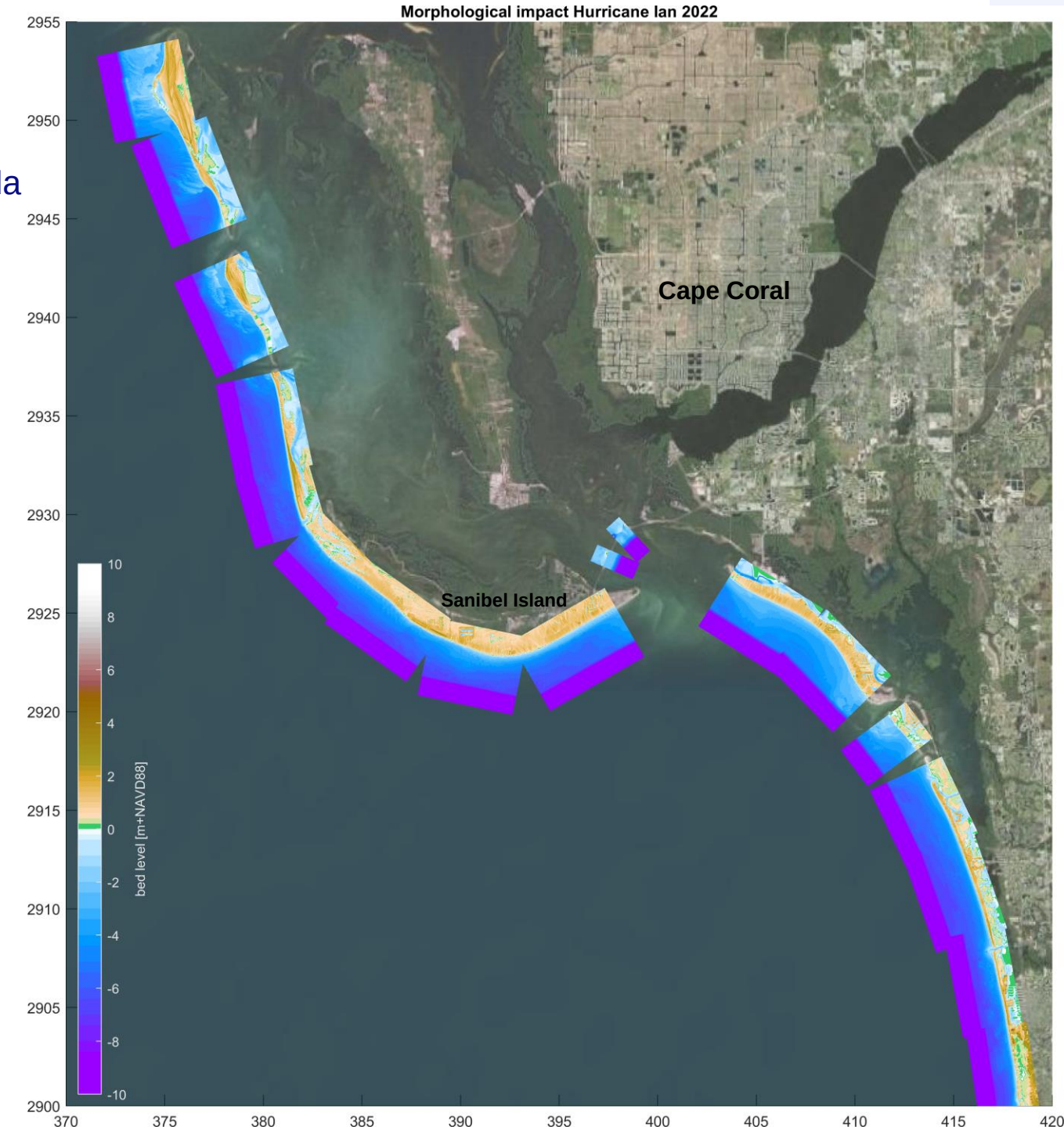


Deltares NOPP

Hurricane Ian

Operational forecast of morphological impact SW Florida

- ~230 XBeach models for the sandy GoM coast



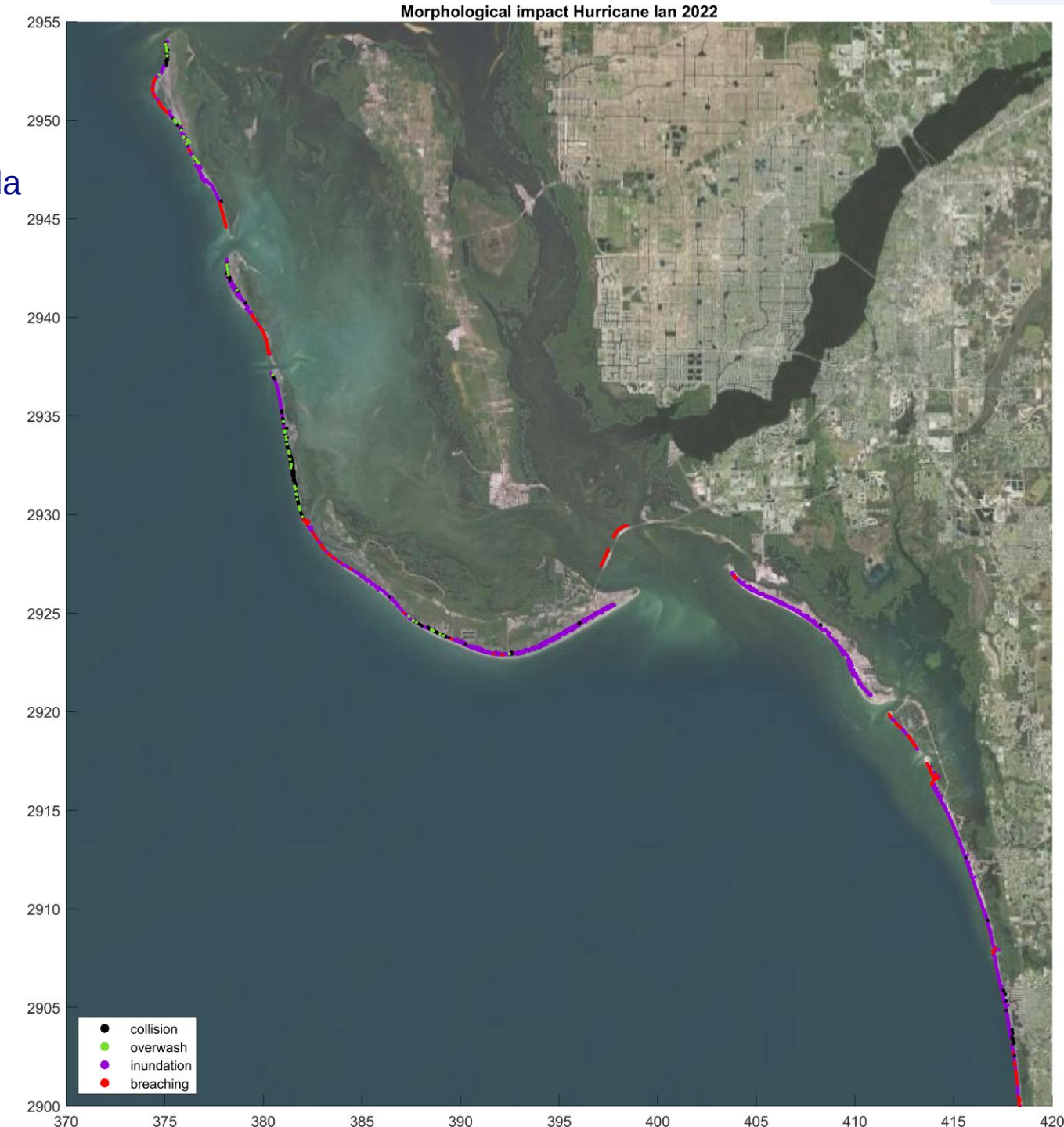
Deltares

NOPP

Hurricane Ian

Operational forecast of morphological impact SW Florida

- ~230 XBeach models for the sandy GoM coast
- Sallenger regimes to rapidly show morphological impact *



Deltares

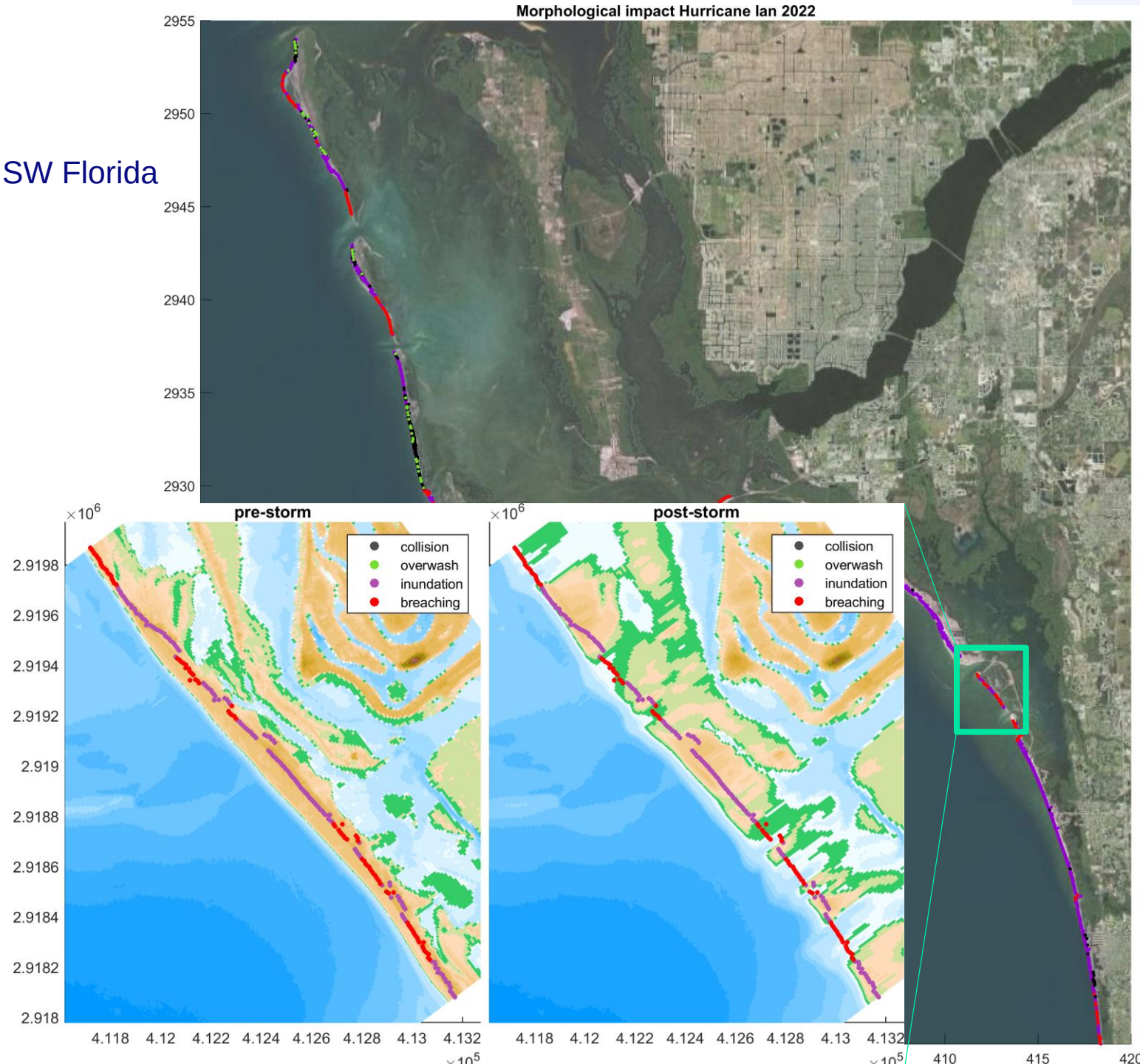
NOPP

* Stockdon, et al. (2012). National assessment of hurricane-induced coastal erosion hazards—Gulf Mexico: U.S.G.S Report

Hurricane Ian

Operational forecast of morphological impact SW Florida

- Zoomin on Lover's Key

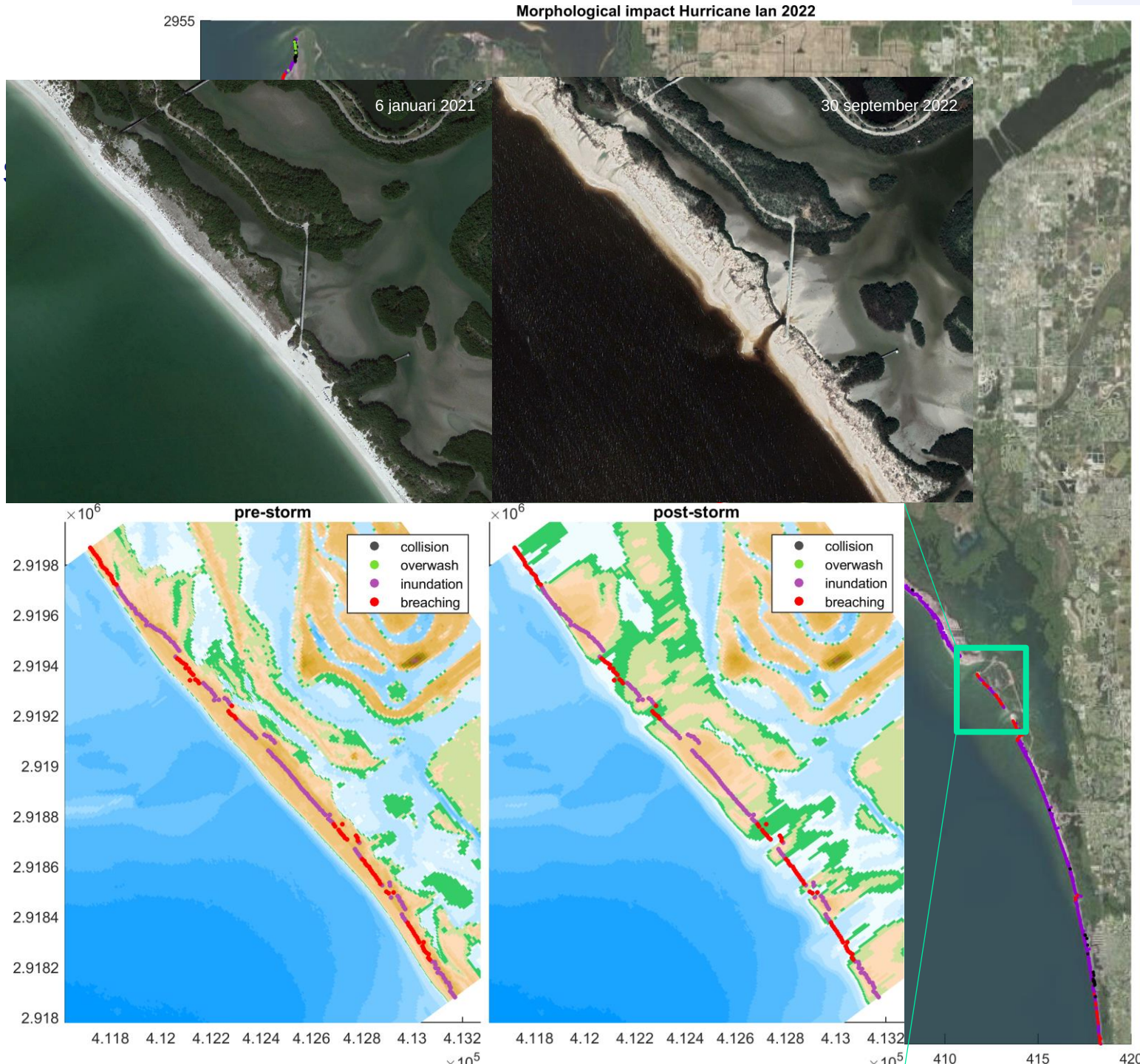


Hurricane Ian

Operational forecast of morphological impact

- Zoomin on Lover's Key
  - Breaching is predicted
  - But seem to be overestimating morphological impact

- We suspect this is due to the dynamic roughness
  - Breaches are formed when water is flowing from the bay to the ocean
  - Root depth in dynamic roughness is at the default 0.5m



Deltares

NOPP

Takeaways

- incorporation of high-resolution land cover-based bed roughness has led to improvements in XBeach model skill, for multiple cases

- However, still uncertainties:
  - specification of appropriate Manning's n values for different vegetation types remains subjective
  - temporal variation of roughness: root depth sensitivity
  - Importance of land cover resolution, spatial distribution may depend on the applied technique

Next steps and ongoing work:

- Data collected by NOPP-project teams will provide opportunity to validate and improve our (XBeach) model results

Deltares

Uncertainties in predicting barrier island morphodynamic response to hurricane impact

Influence of vegetation in XBeach

Ellen Quataert, Roel de Goede, Marlies van der Lugt, Ap van Dongeren

13 April 2023

NOPP