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UNESCO IHE DELFT

Wave effects in a rapid compound flood model

3rd International Workshop on Waves, Storm Surges, and Coastal Hazards, 2023

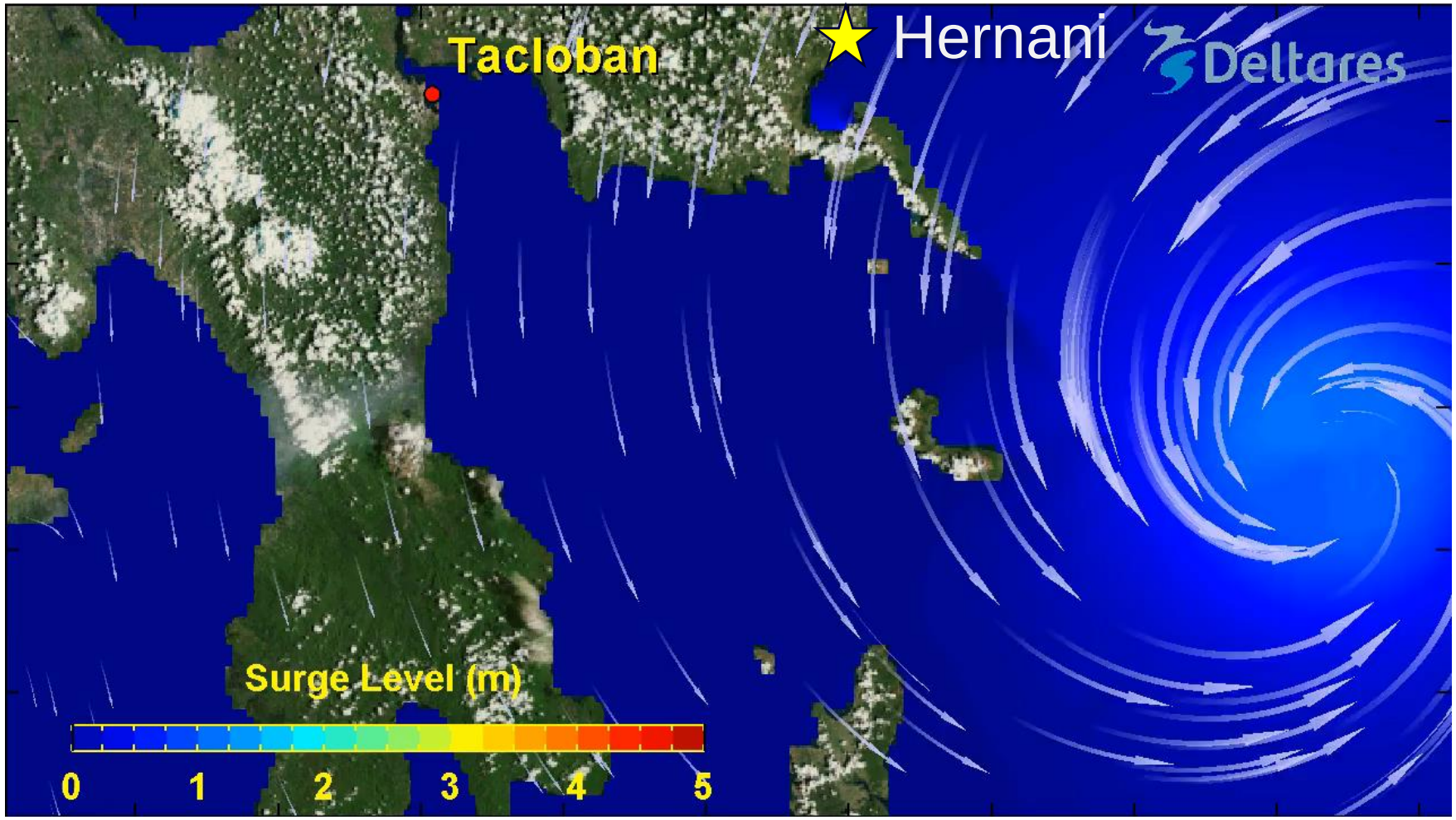
Maarten van Ormondt, Ap van Dongeren, Dano Roelvink

Why add wave effects?

Typhoon Haiyan 2013

Hernani, Eastern Samar, Philippines

Typhoon Haiyan (2013)
Storm surge



So, how to include waves in our forecasts?

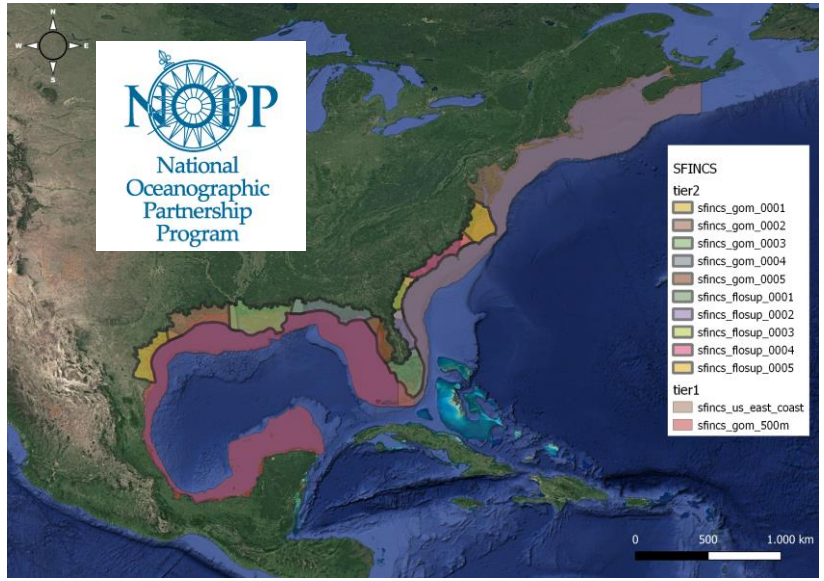
- Boussinesq, SWASH, Xbeach
- We need to cover large stretches of coast line
- We need to run ensemble forecasts
- Risk studies or for training machine learning systems
- 1D (empirical) run-up models - e.g. Stockdon (2006), Van Ormondt (2021)
  - Non-trivial to translate vertical run-up into horizontal flooding
  - Not accurate along complex coastlines

We're trying something new here:

- **Use SFINCS**
- **Couple it with SnapWave**
- **Add infragravity waves (see Tim's talk)**
- **Add wave paddles along the shoreline**

SFINCS: Super Fast Inundation of CoastS

- Open-source compound flood model (Leijnse et al., 2021)
- Linear Inertial Equations (Bates et al., 2010)
  - Storm surge and tide
  - Wave effects
  - Wind, rain and infiltration
  - River discharge
  - Sub-grid topography
  - Advection term
  - Structured or unstructured mesh (QuadTree)



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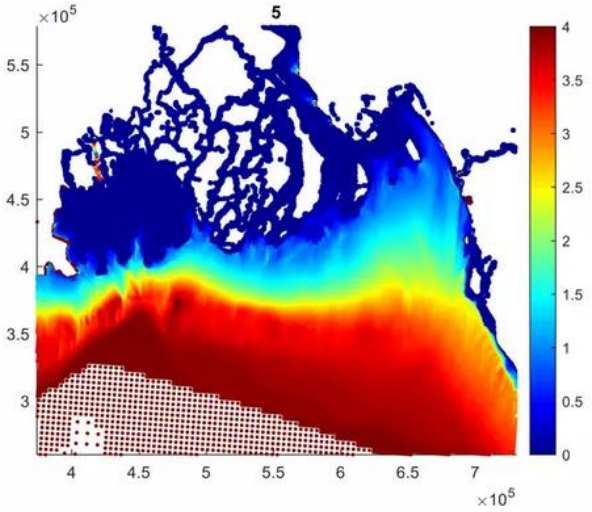
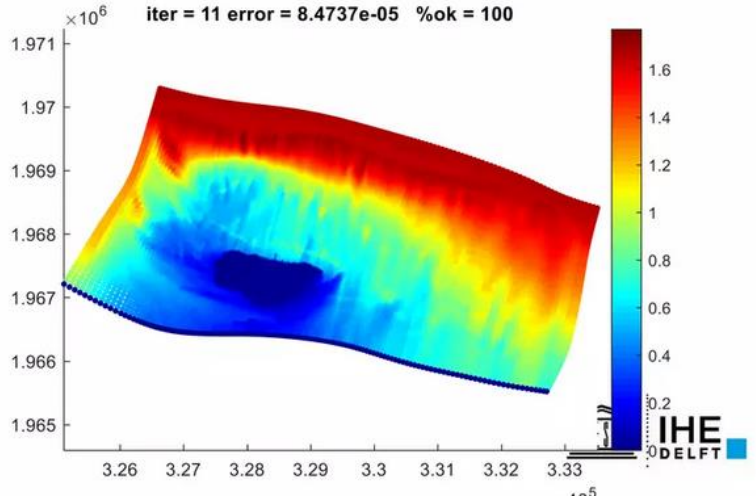
https://github.com/Deltares/SFINCS

SnapWave

- Developed by Dano Roelvink
- Solves wave-action equation with time-dependent forcing (also used in Xbeach-SB)
- Similar HISWA model (Holthuijsen et al., 1989)

- Unstructured grids
- Represents wave frequency spectrum by a single frequency
- Added infragravity waves





SFINCS – SnapWave coupling

- Straightforward (use the same mesh, SnapWave is incorporated in the SFINCS code)
- Provide boundary conditions (time series of Hm0, Tp, Wdir and Wspread)
- Coupling typically every ~15 minutes
- SFINCS -> SnapWave: water levels
- SnapWave -> SFINCS: Hm0, Hm0_IG, Fx, Fy

Hurricane Michael (2018)
Mexico Beach, Florida

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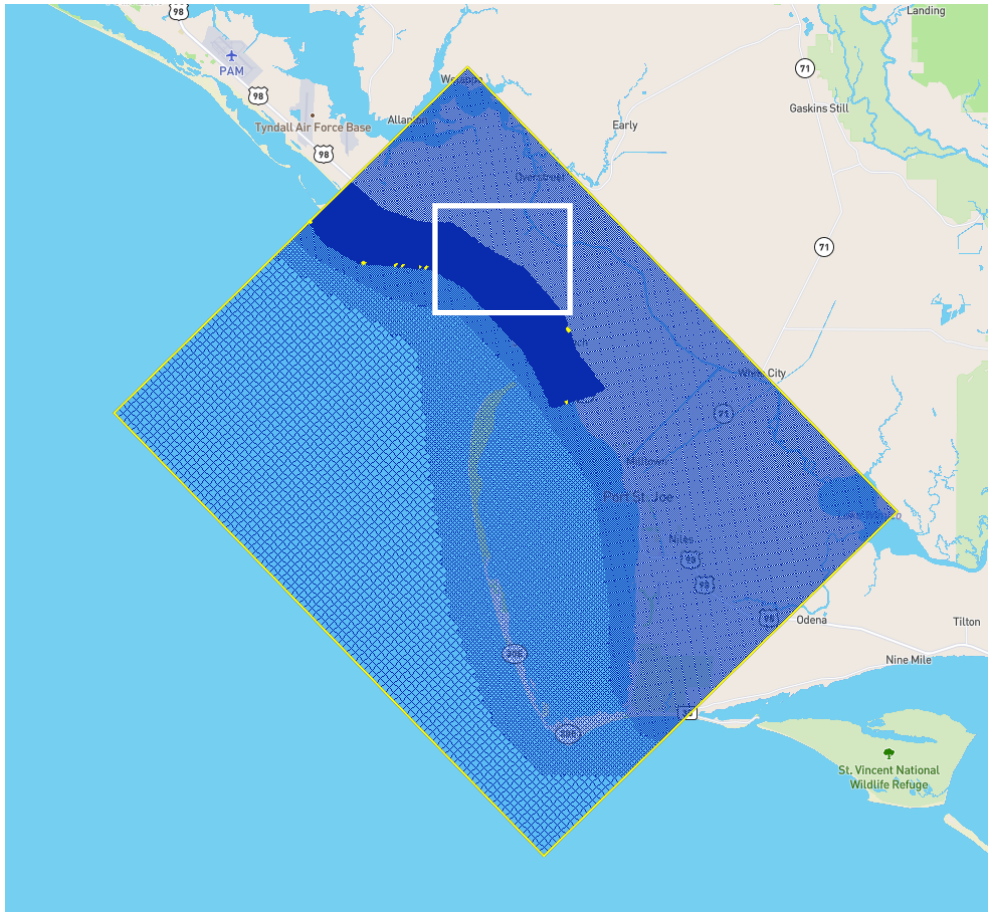
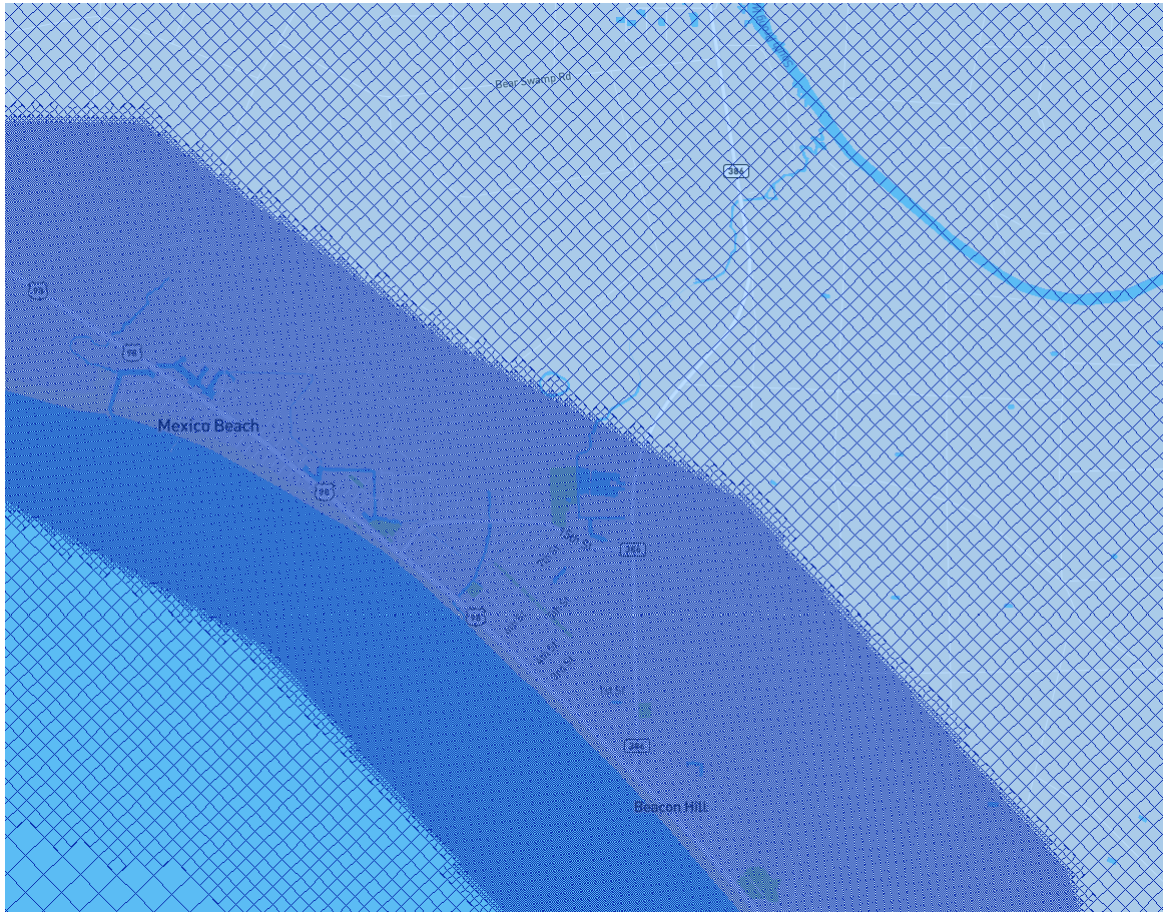
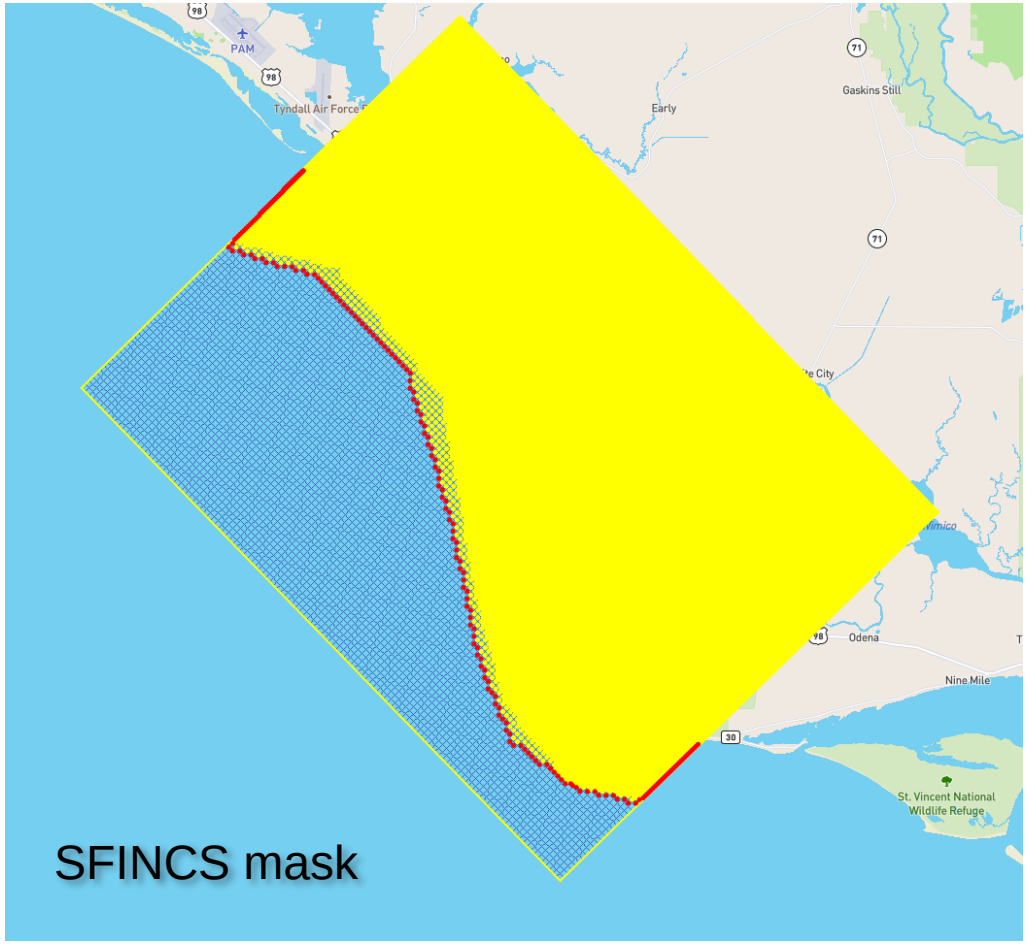
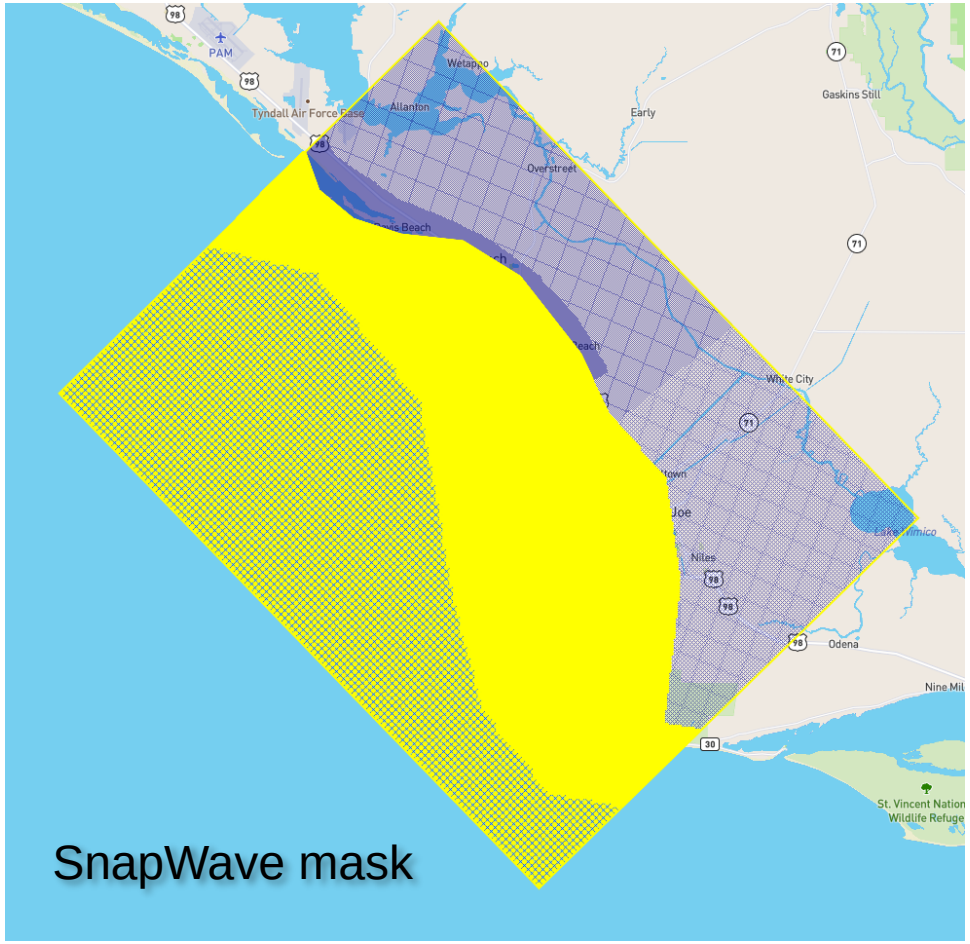
Hurricane Michael - Mexico Beach, Florida
SFINCS QuadTree mesh



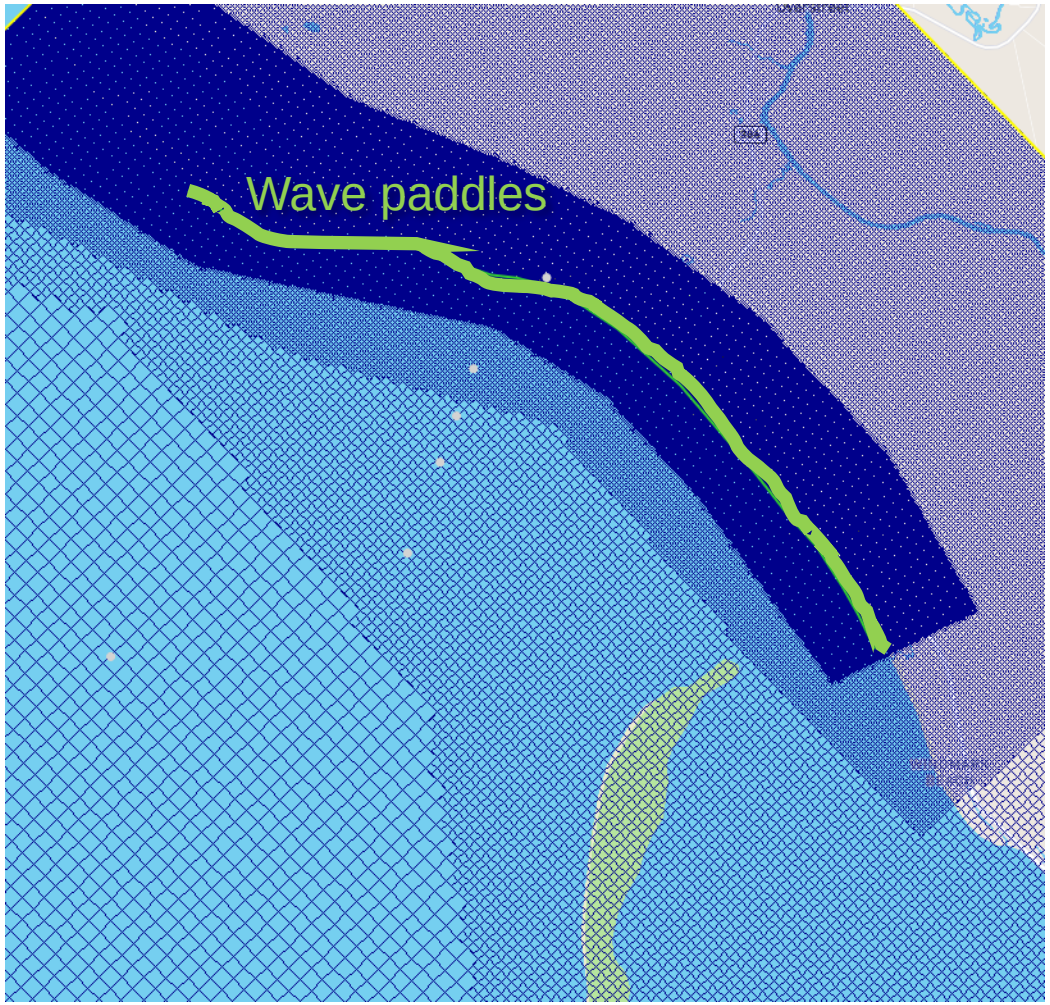


Hurricane Michael - Mexico Beach, Florida
SFINCS and SnapWave mask





Hurricane Michael - Mexico Beach, Florida
Wave paddles



Supply polyline(s) around the 2 m depth contour

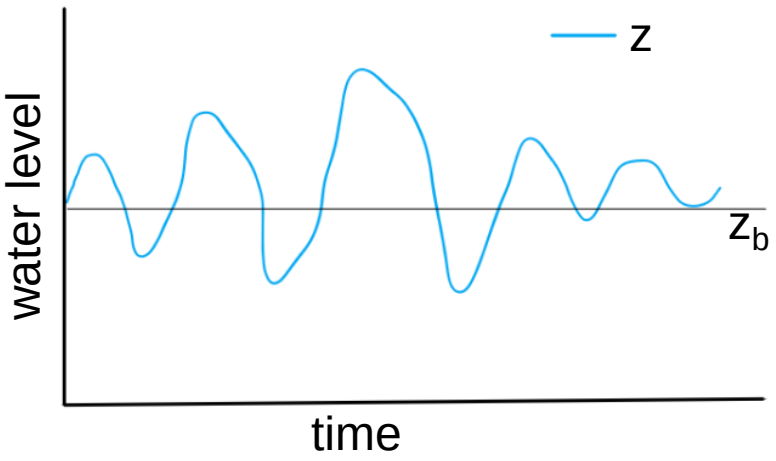
SFINCS will snap the polyline(s) to the mesh to generate individual wave paddles at u/v points

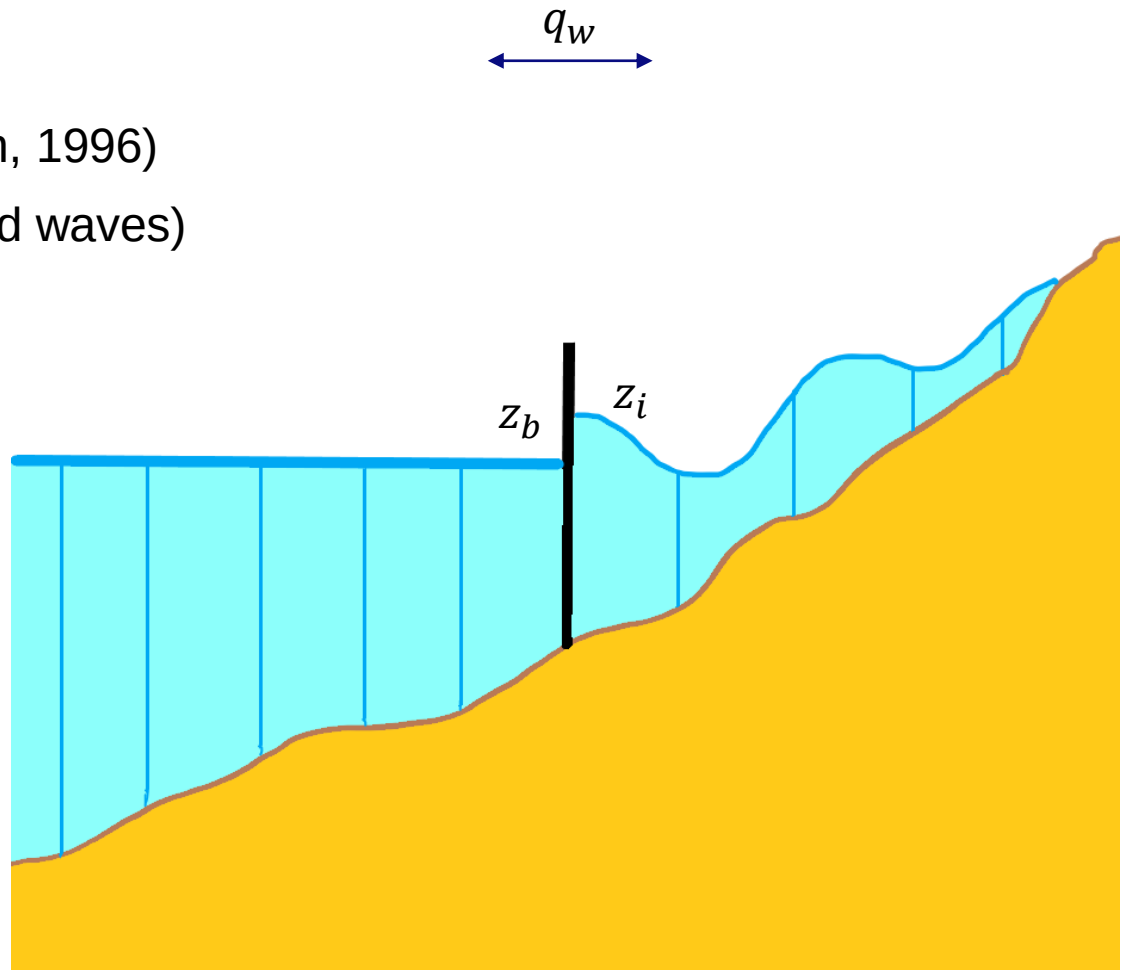
Wave paddles

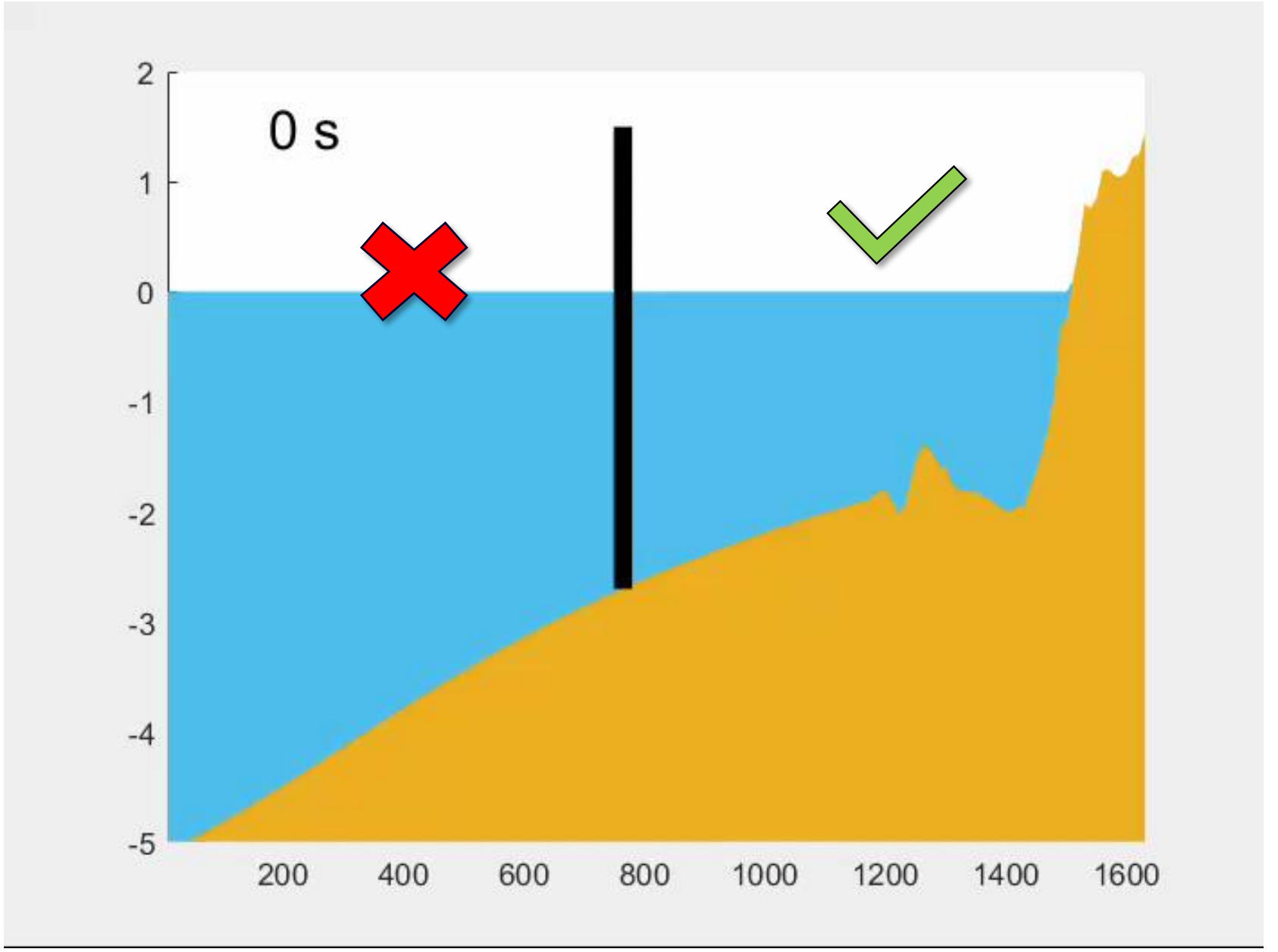
$$u_i = \sqrt{\frac{g}{h}}(z - z_b)$$

$$q_w = h\left(2u_i - \sqrt{\frac{g}{h}}(z_i - z_b)\right)$$

- Generate water level timeseries from wave height
- “Internal boundary condition”
- Taken from Xbeach (Van Dongeren, 1996)
- Weakly-reflective (absorbs reflected waves)



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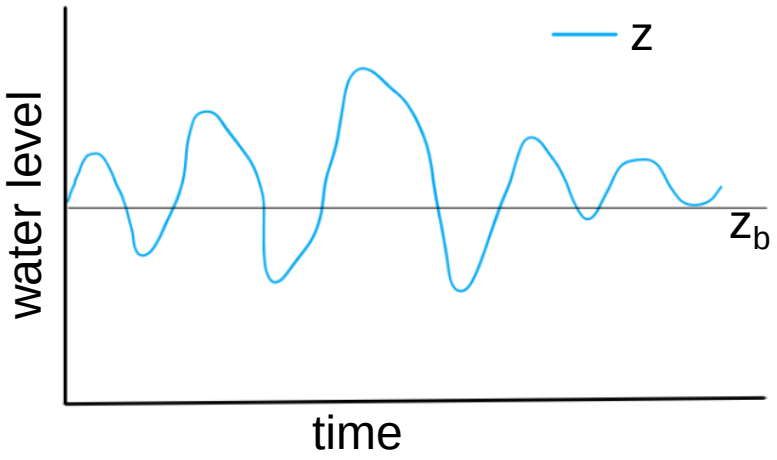
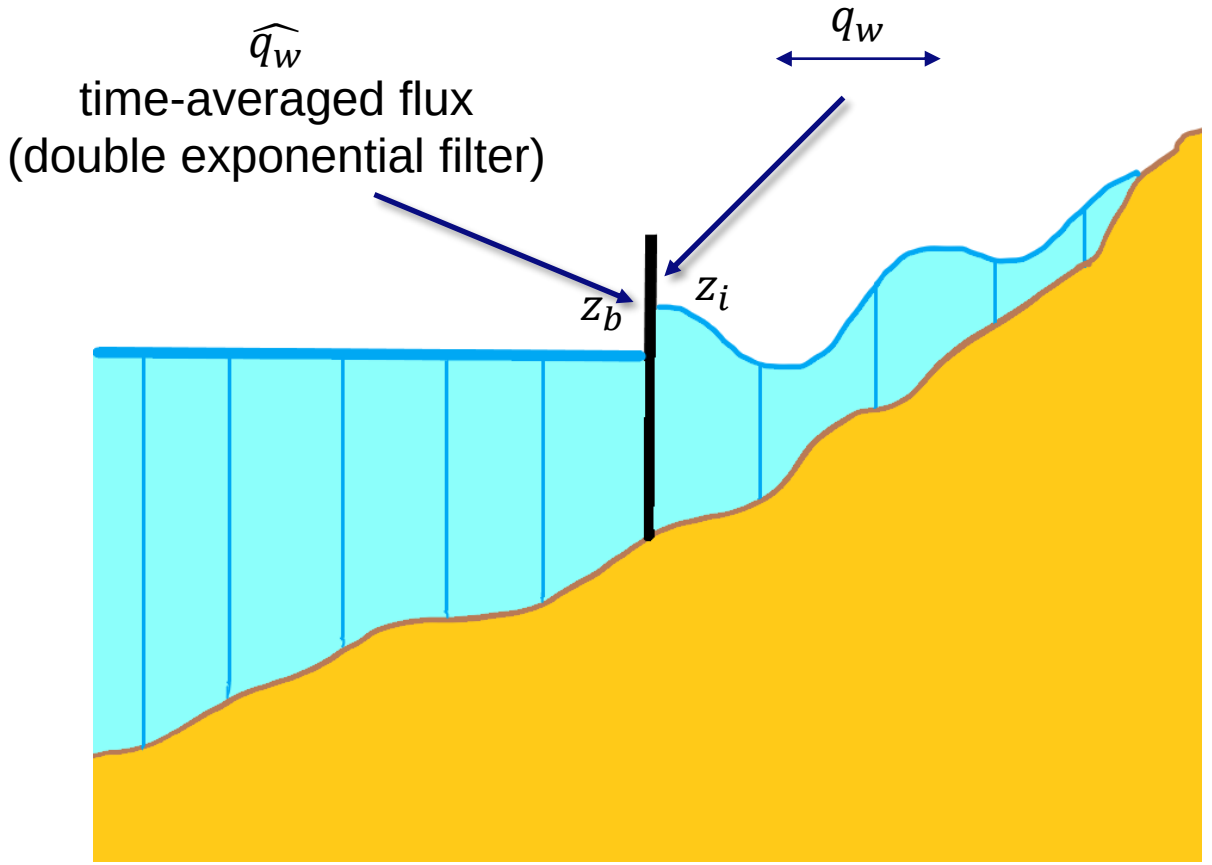
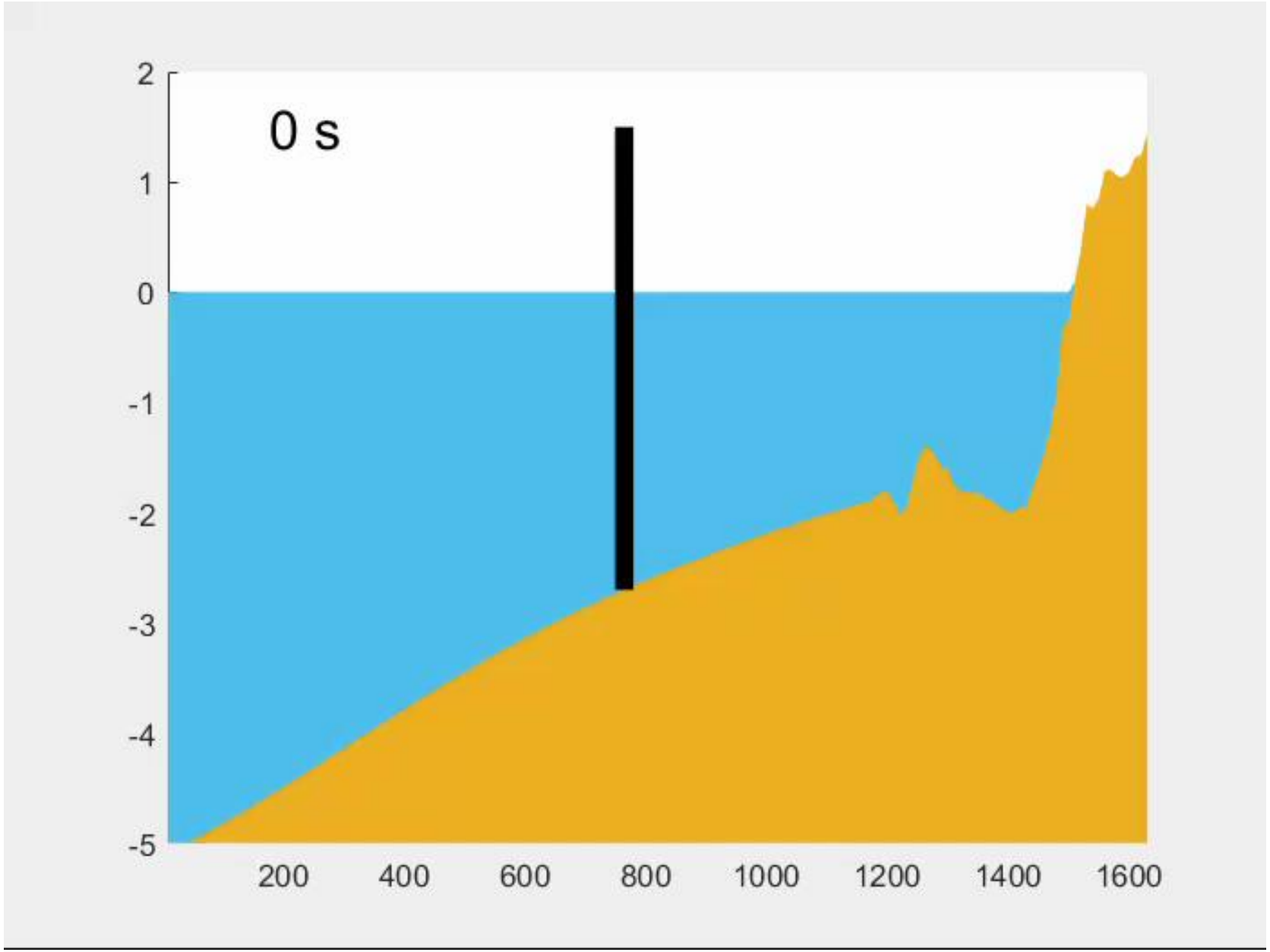
Wave paddles

$$u_i = \sqrt{\frac{g}{h}}(z - z_b)$$

$$q_w = h\left(2u_i - \sqrt{\frac{g}{h}}(z_i - z_b)\right)$$



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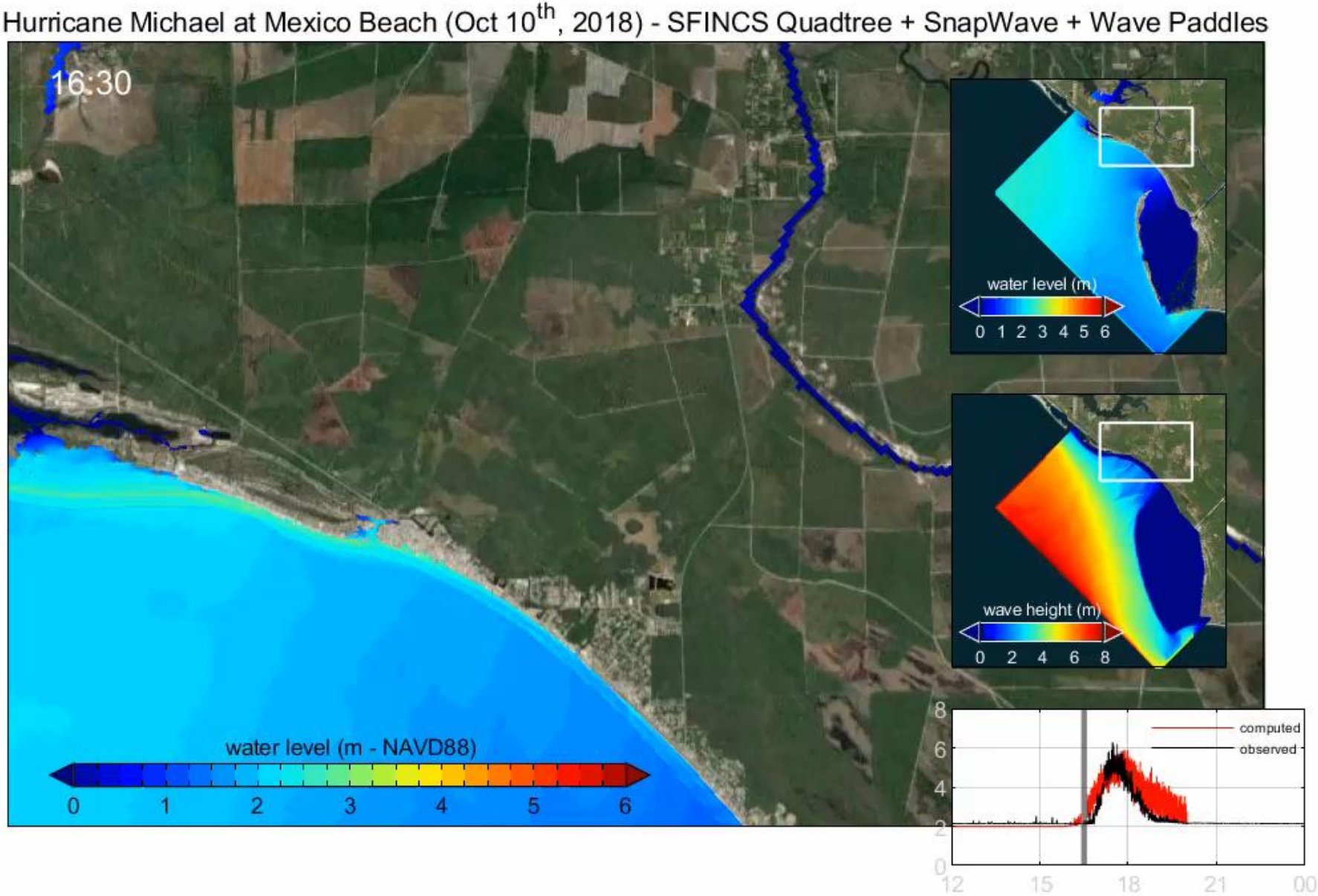
Hurricane Michael

Boundary conditions from large scale models (NOPP)



270,000 cells
1 day simulation
~ 90 seconds on i7 PC

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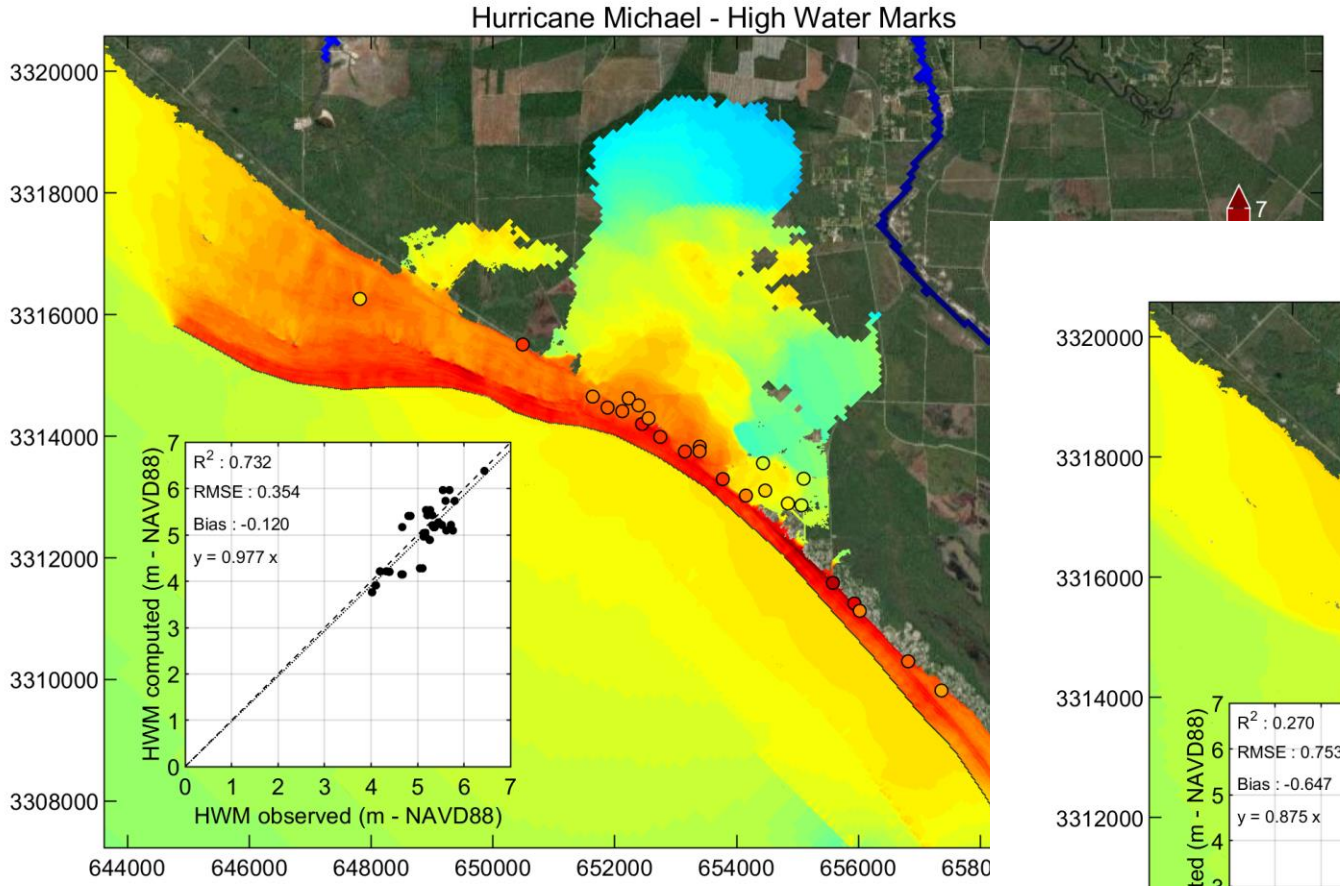
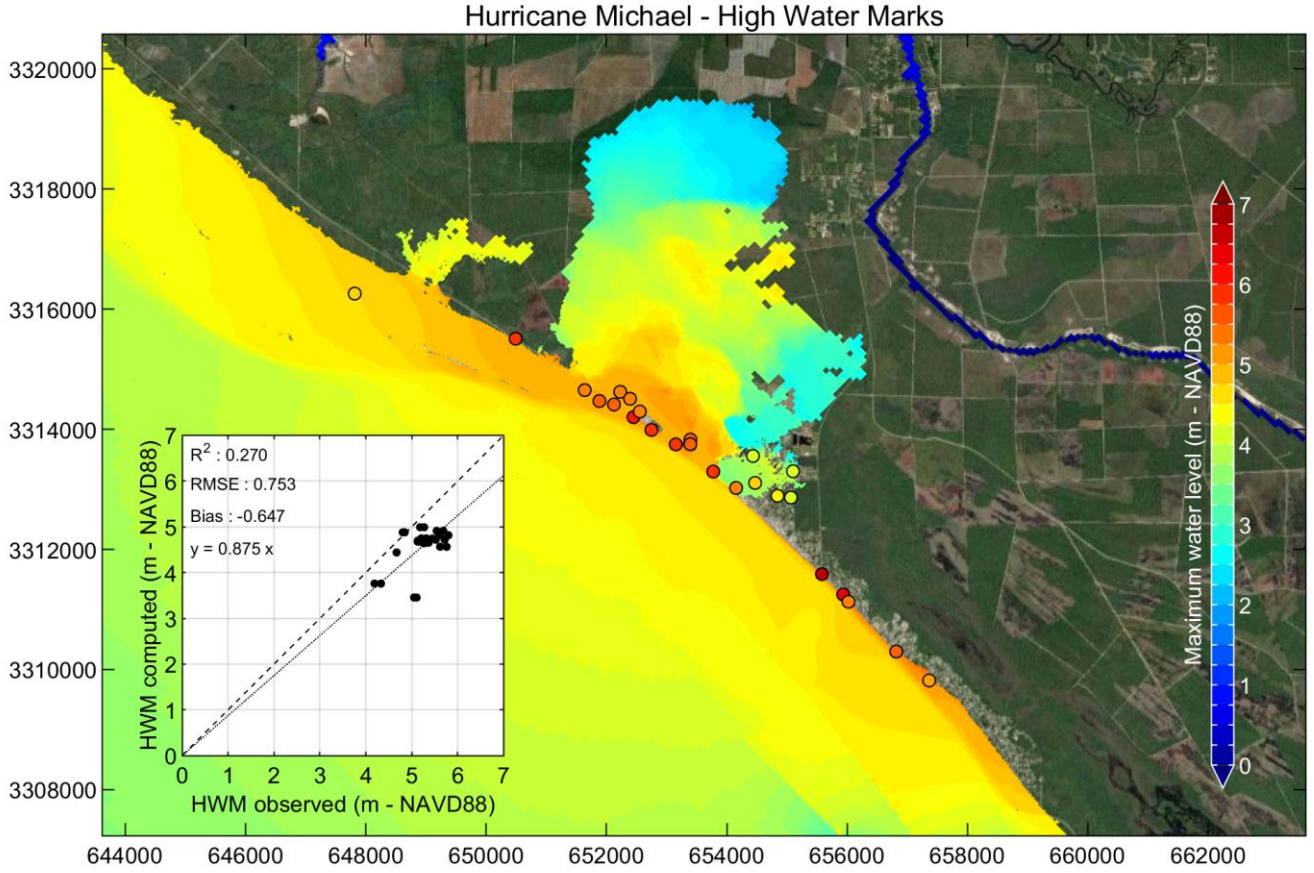
Comparison against USGS High Water Marks





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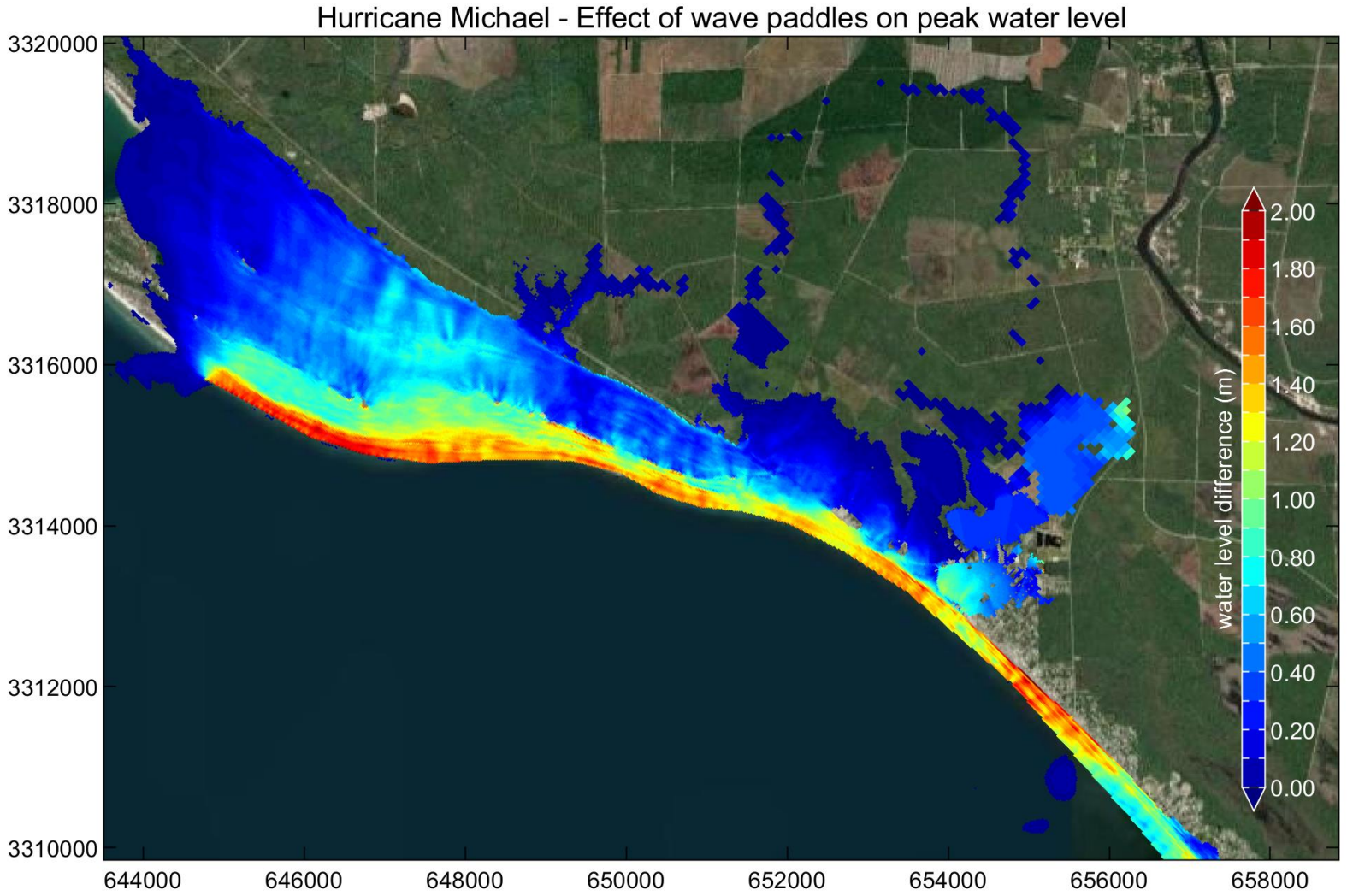
Effect of wave paddles

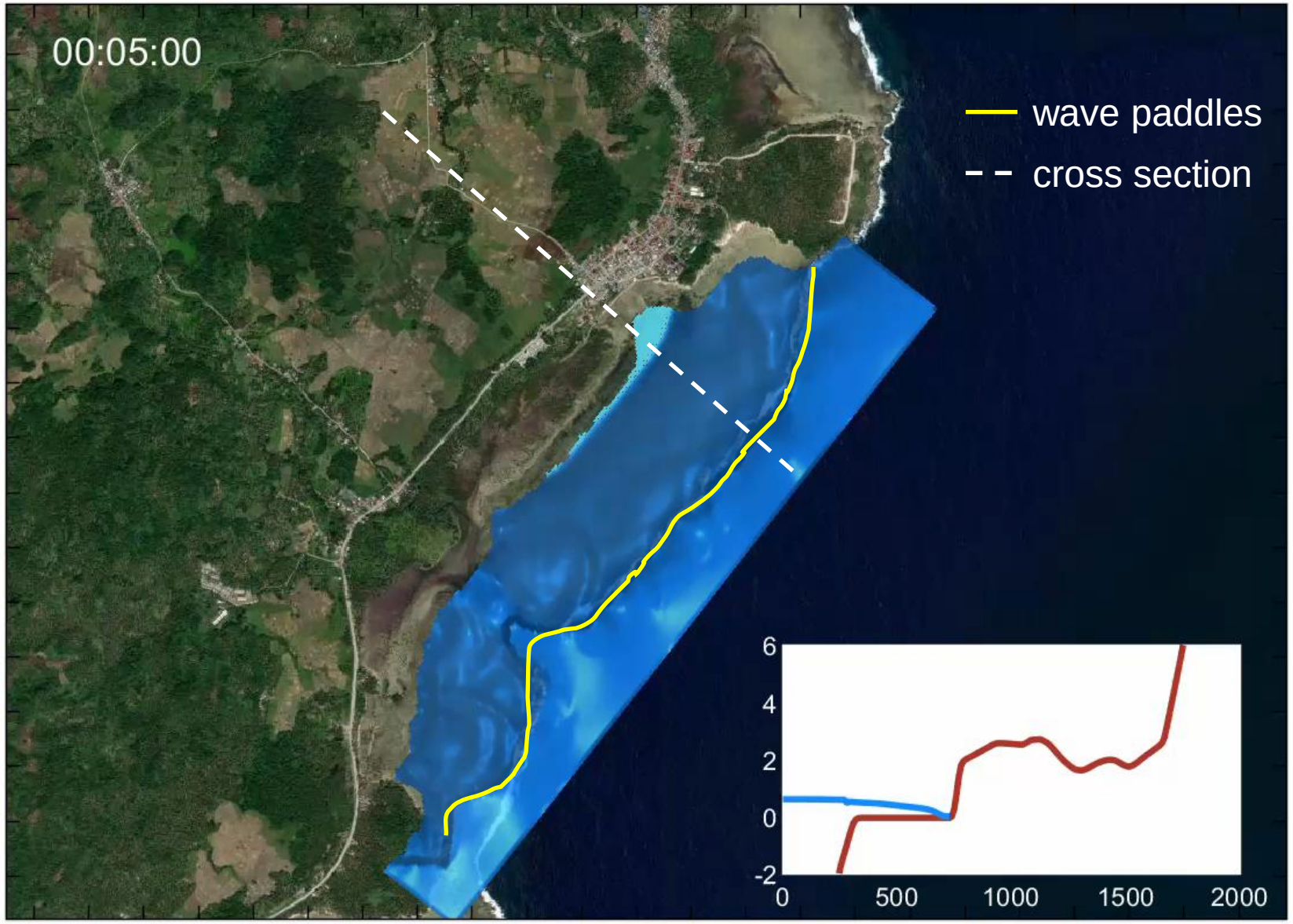


Typhoon Haiyan (2013) – Hernani, the Philippines

Hm0 = 16 m (SWAN)
Tp = 15 s

Tide + surge = 0.6 m (Delft3D)

57,000 cells
1 hour simulation
~10 seconds on i7 PC



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Conclusions

- Promising way to include wave set-up and IG run-up in fast compound flood model
- Still quite experimental
- Need some playing around to find optimal location of wave paddles
- Infragravity waves in SnapWave need further investigation (steep breaker zone, break point forcing)
- Work on more realistic alongshore variation of incoming wave signal (now long-crested)
- Include short waves as well

Question to the audience:

“What is a good metric for the destructive impact of Total Water Level and current velocity combined?”