An Operational Coastal Flood Forecasting and Hazard Mapping System for the Philippines

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1) Deltares

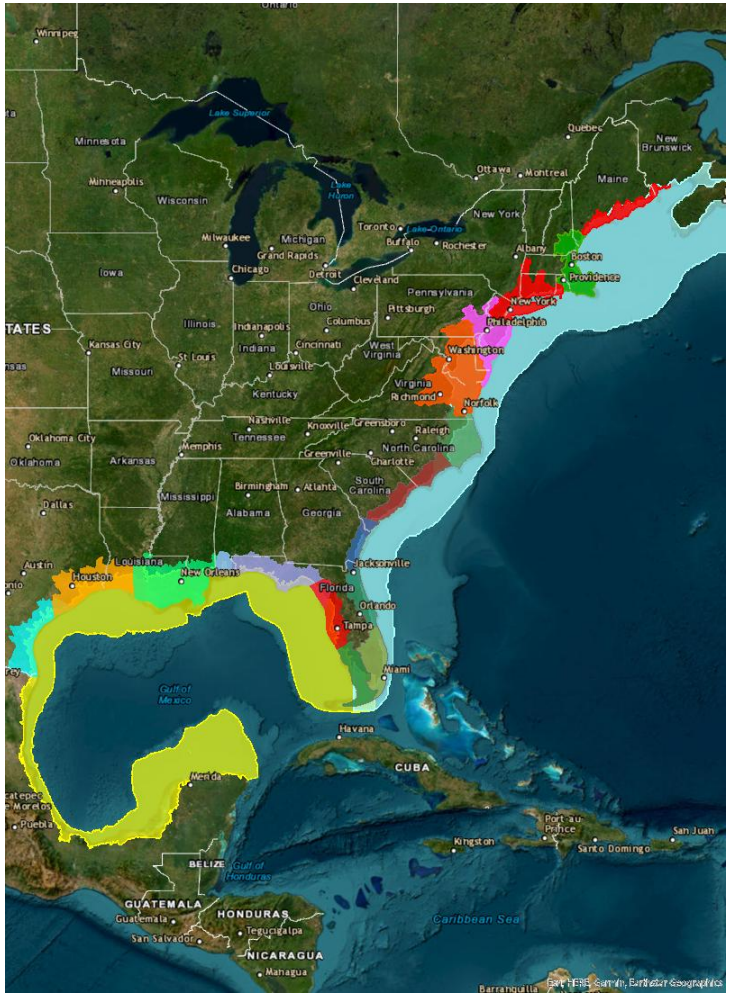
2) PAGASA

NOPP Hurricane Coastal Impacts (NHCI)

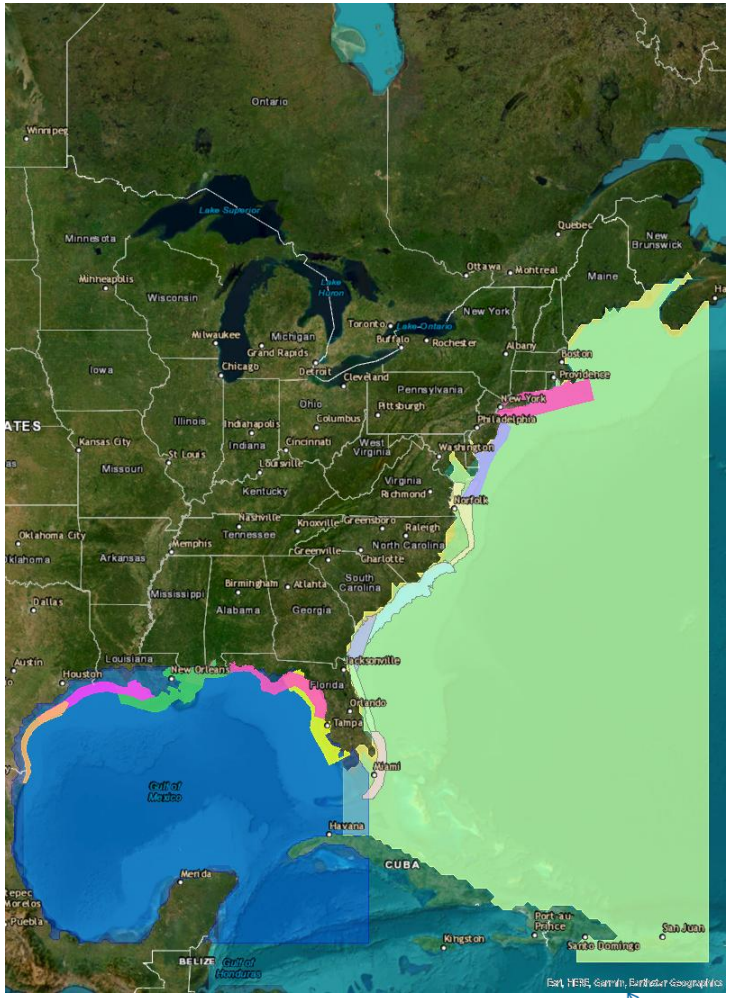
- Approach: model train of
  - Waves
  - Surge
  - Flooding
  - Morphological change
  - Damage

- SFINCS
  - Surge and tide
  - Coastal flooding
- HurryWave
  - Nearshore boundary conditions

SFINCS



HurryWave



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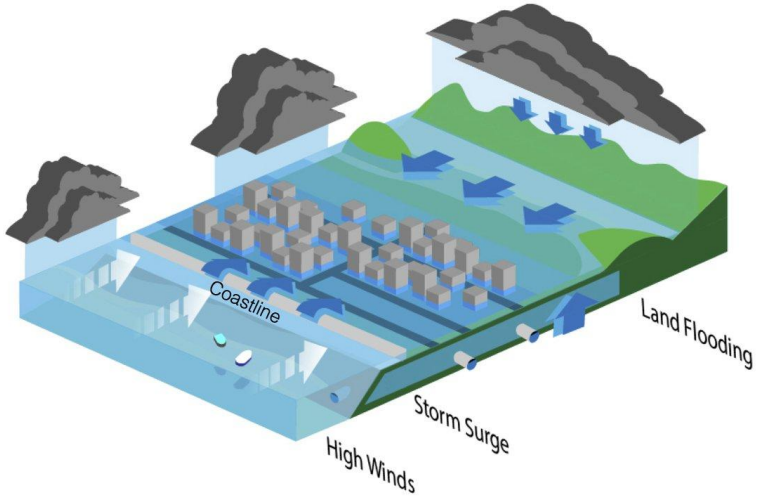
SFINCS: Super Fast Inundation of CoastS

- Open-source compound flood model
- Linear Inertial Equations (Bates et al., 2010)
  - Storm surge and tide
  - Wave effects (SnapWave)
  - Wind
  - Rainfall and infiltration
  - River discharge
  - Sub-grid topography
  - Quadtree refinement
  - CPU and GPU



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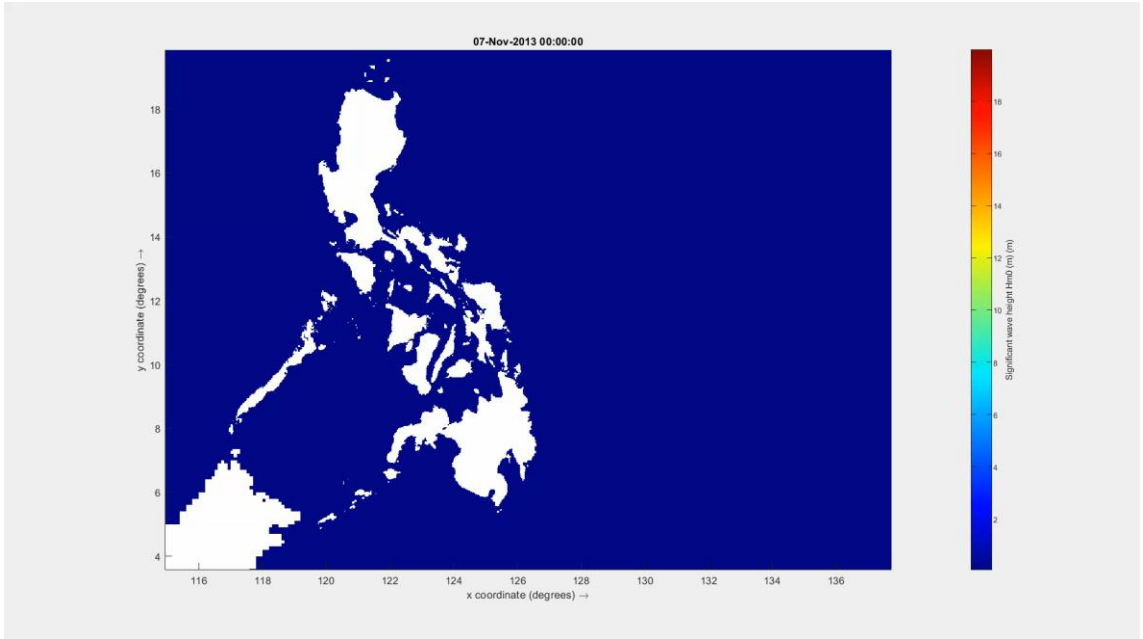
https://github.com/Deltares/SFINCS

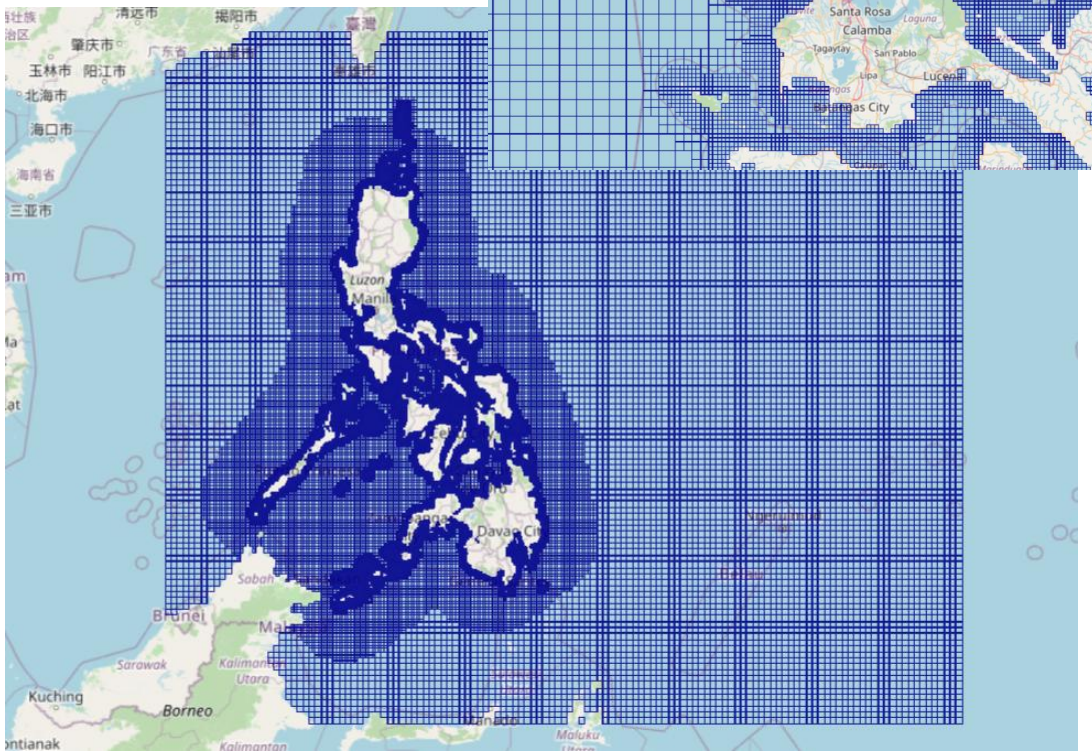
HurryWave

2.5 – 20 km grid (60,000 points)
2 days
36 directional bins
12 frequency bins

- 3rd generation spectral wave model (similar to SWAN and WAVEWATCH III)
- Simple numerical scheme
- > 2 orders of magnitude faster than SWAN
- Quadtree refinement
- Subgrid wave blocking

	Run time (s)
SWAN	3600
HurryWave (CPU)	120
HurryWave (GPU)	10





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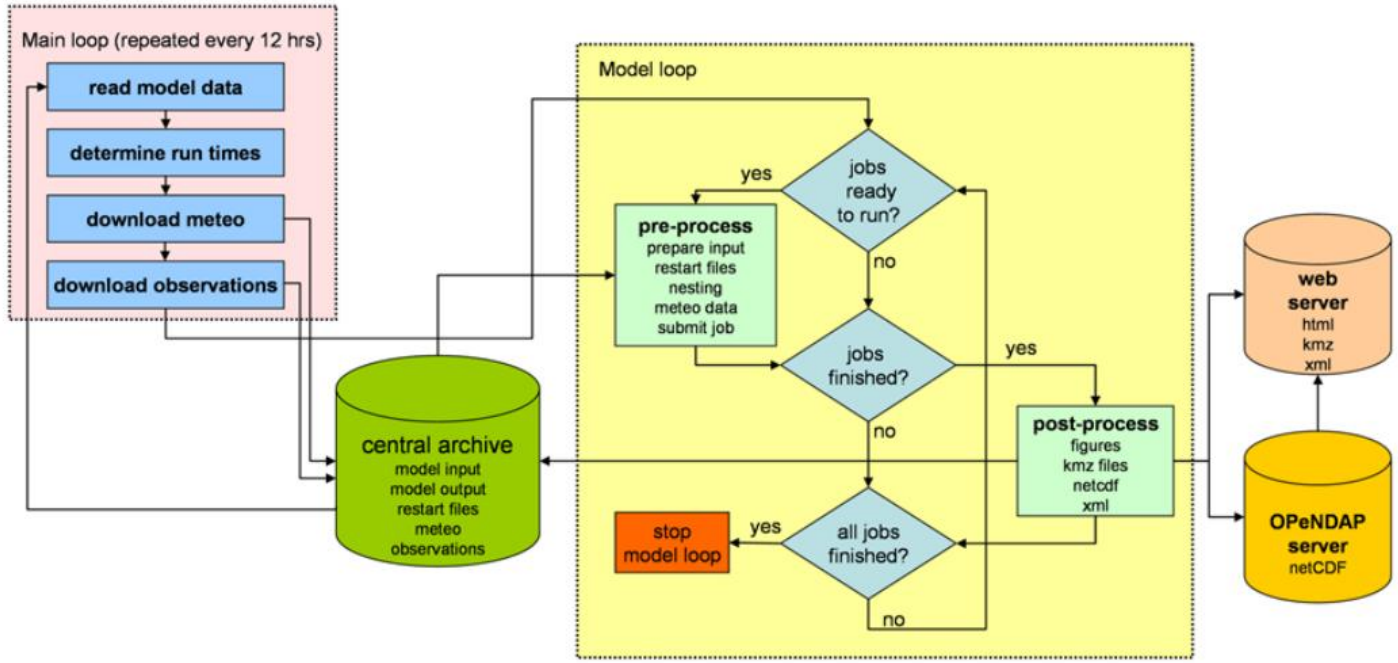
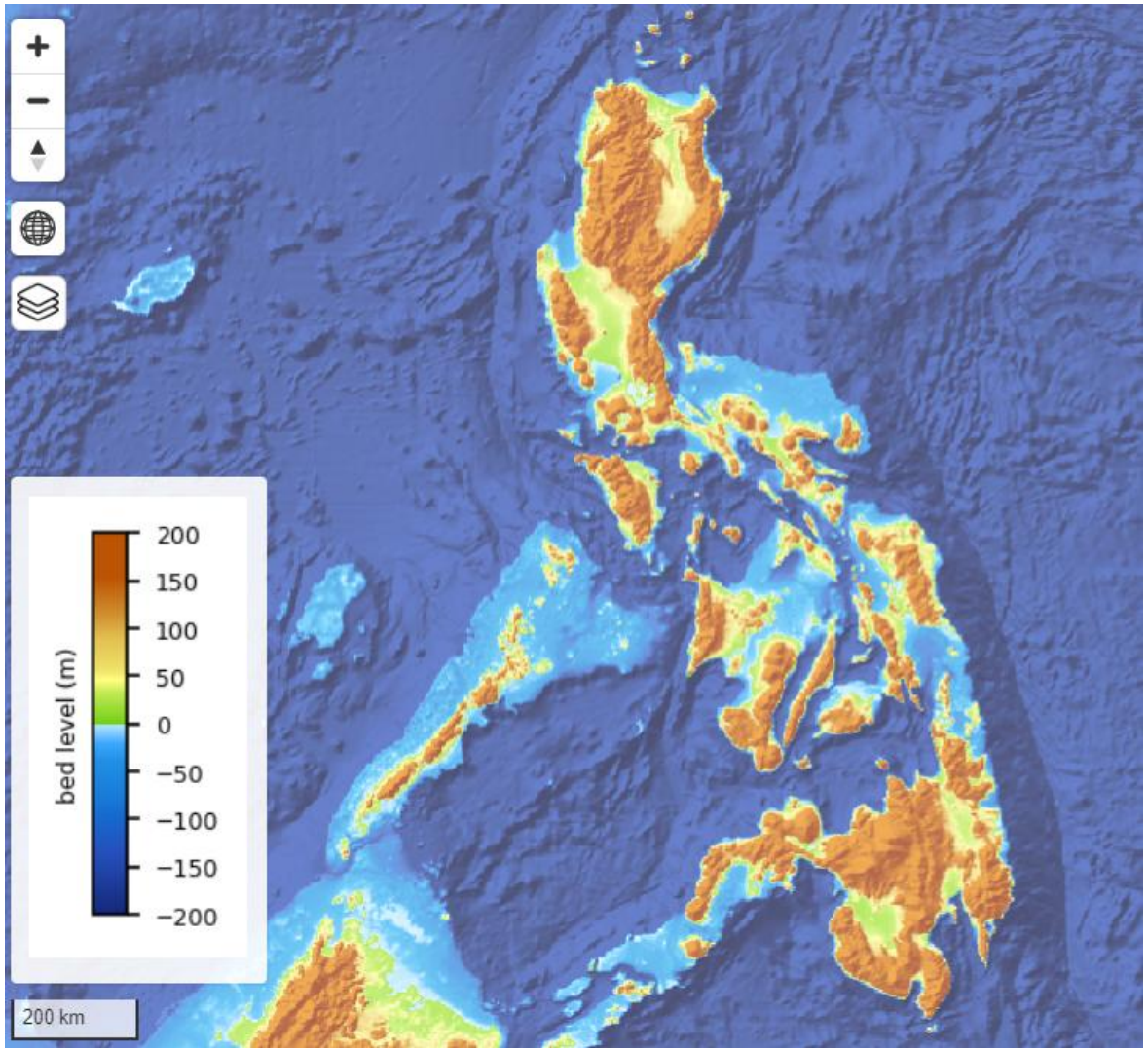
CoSMoS

- Barnard et al. (2014)
- Storm scenarios and operational forecasting

- Downloading meteo forcing
- Automated nesting of storm surge, wave, and flood models
- Generation of flood maps



The Philippines



- (Ensemble) forecasts of coastal flooding
- ECMWF meteo forcing
- Include rainfall

- Return period flood maps

- 35,000 km of coastline
- > 7000 islands
- ~20 typhoons per year

- Very irregular coastline:
  - Extremely steep
  - Shallow bays and shelves

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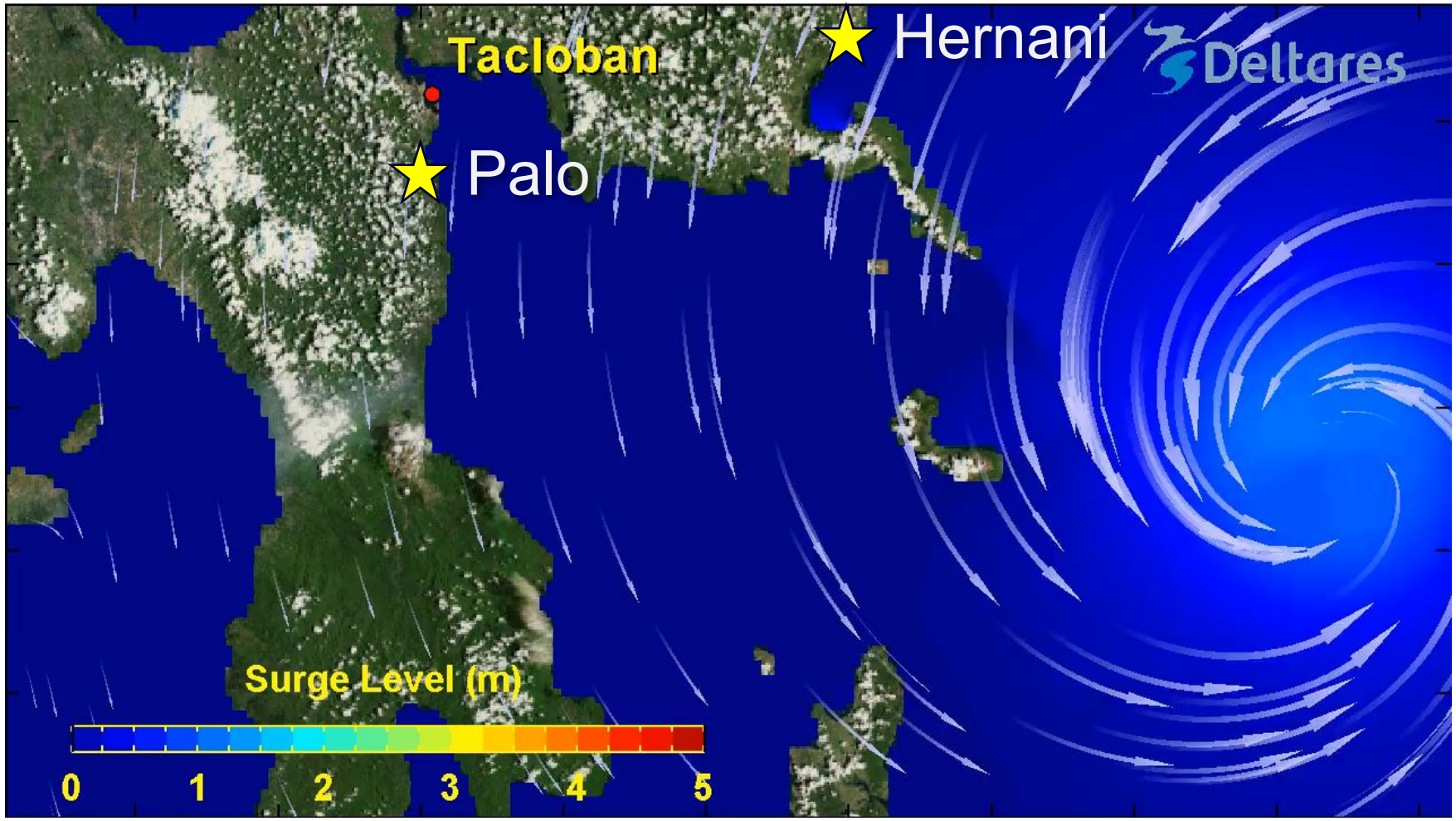
GREEN CLIMATE FUND

Typhoon Haiyan (2013)
Storm surge



Why waves are important

Typhoon Haiyan 2013

Hernani, Eastern Samar, Philippines

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Hurricane Michael (2018)
Mexico Beach, Florida

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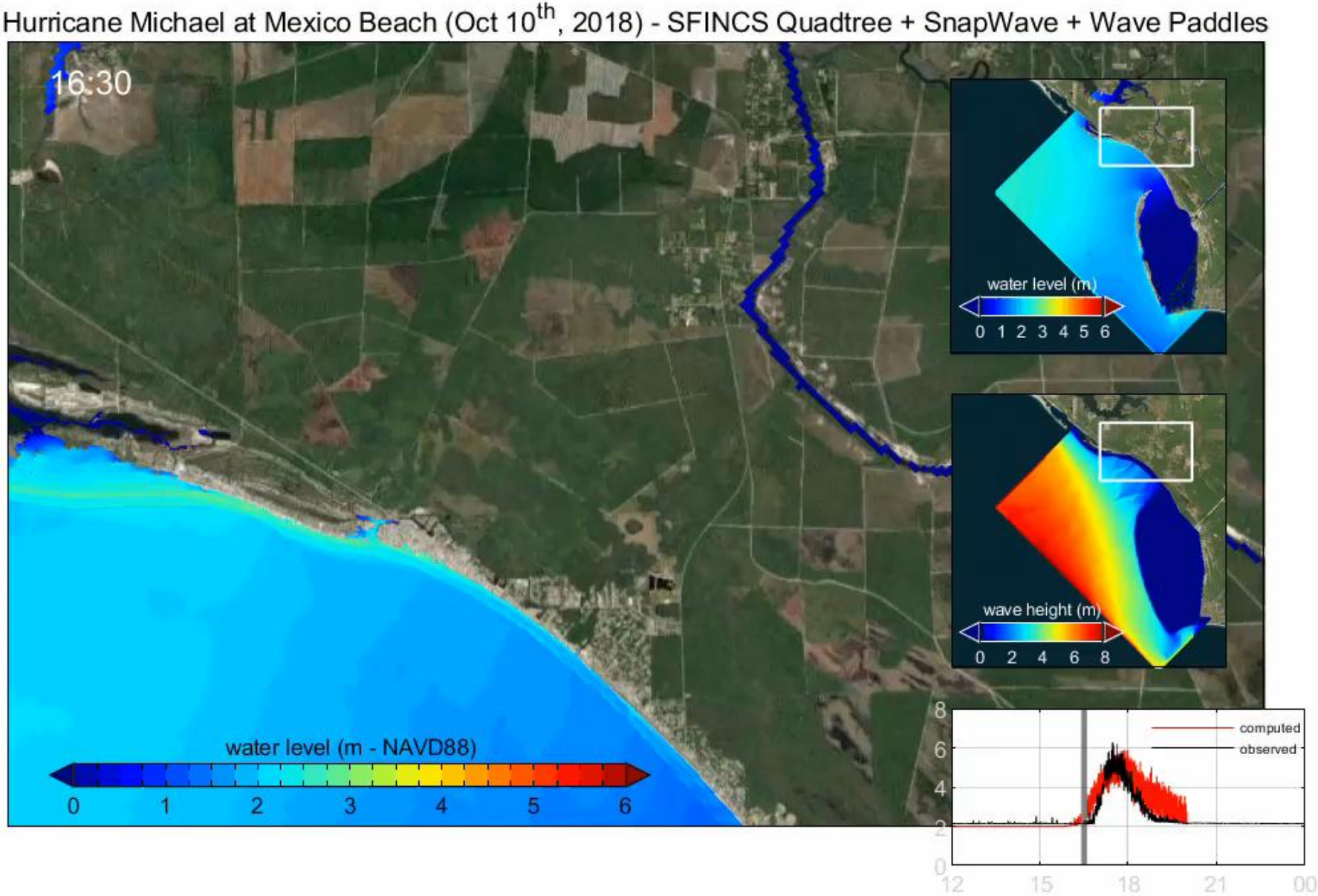
Hurricane Michael

Incident and IG waves computed SnapWave

Wave paddles in SFINCS

Boundary conditions from large scale models (NOPP)



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

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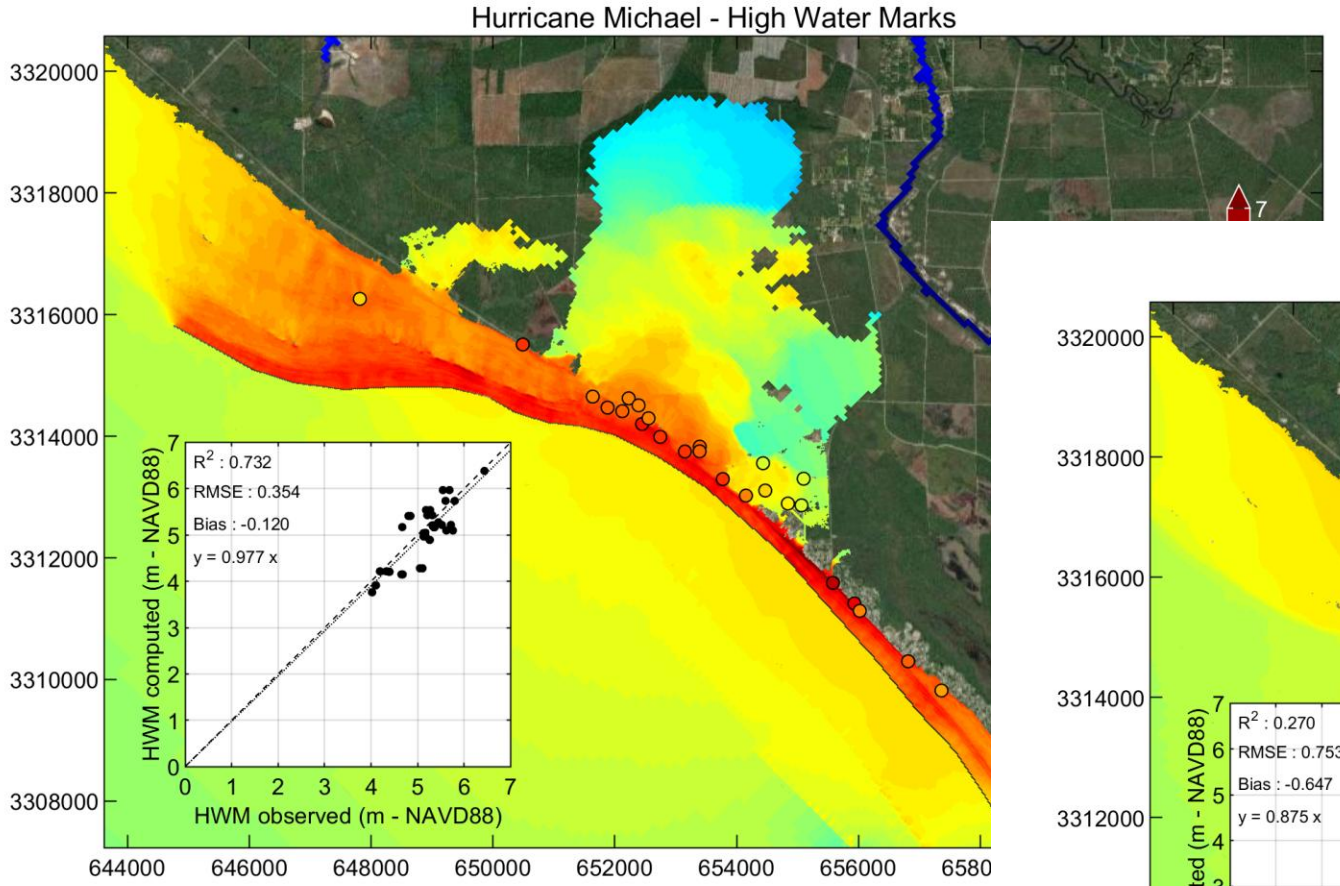
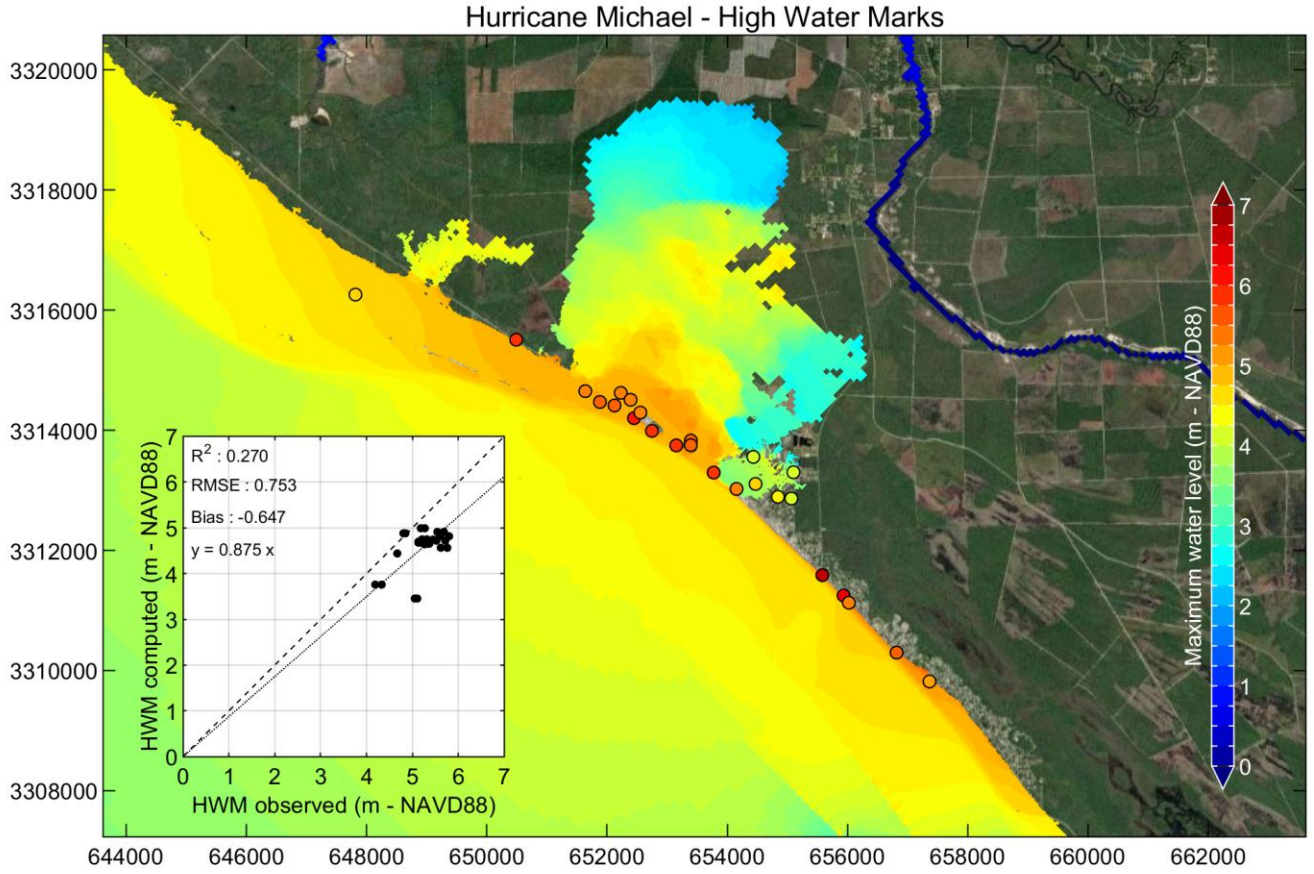
Comparison against USGS High Water Marks



without wave paddles



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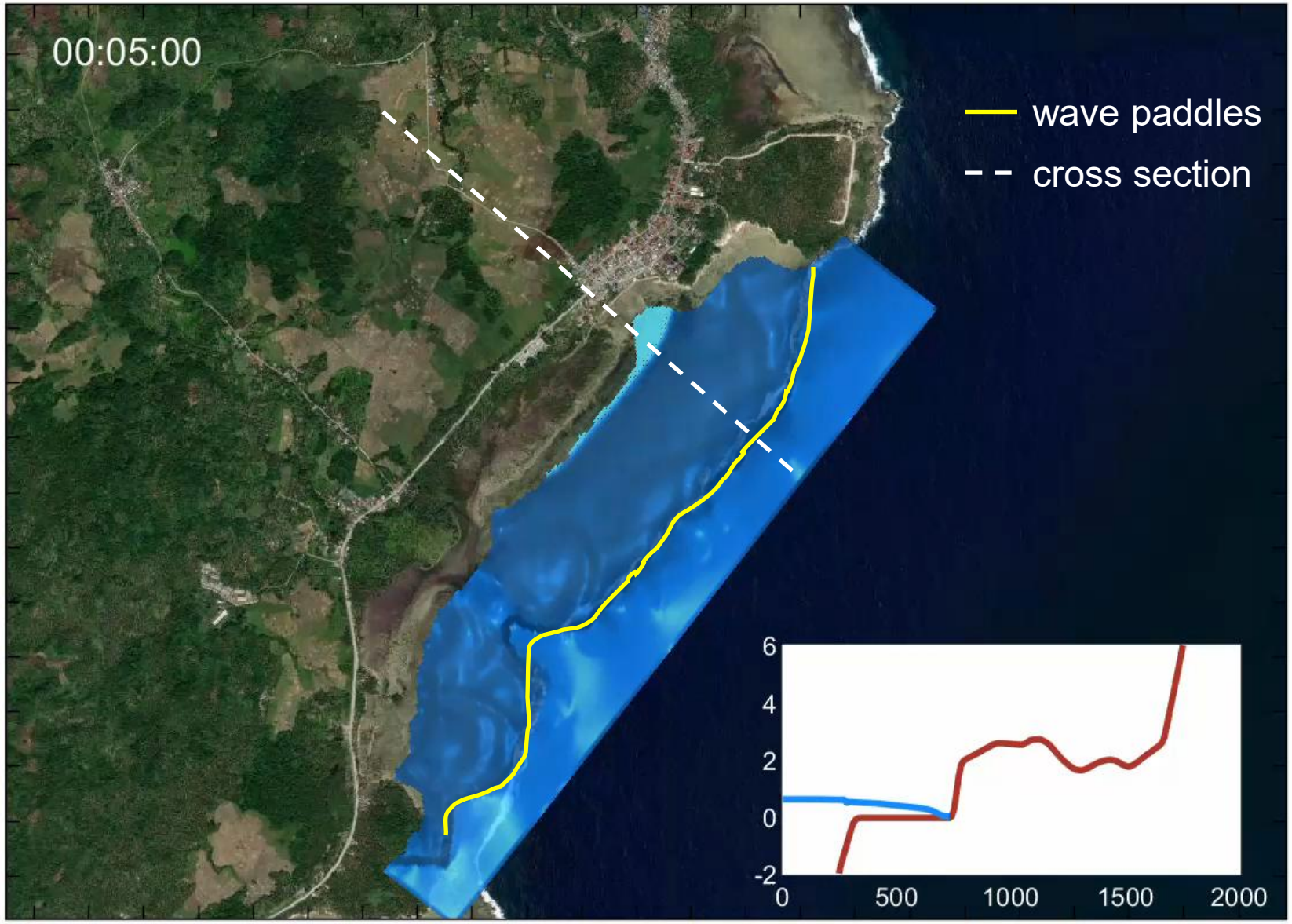
Typhoon Haiyan (2013) – Hernani, the Philippines

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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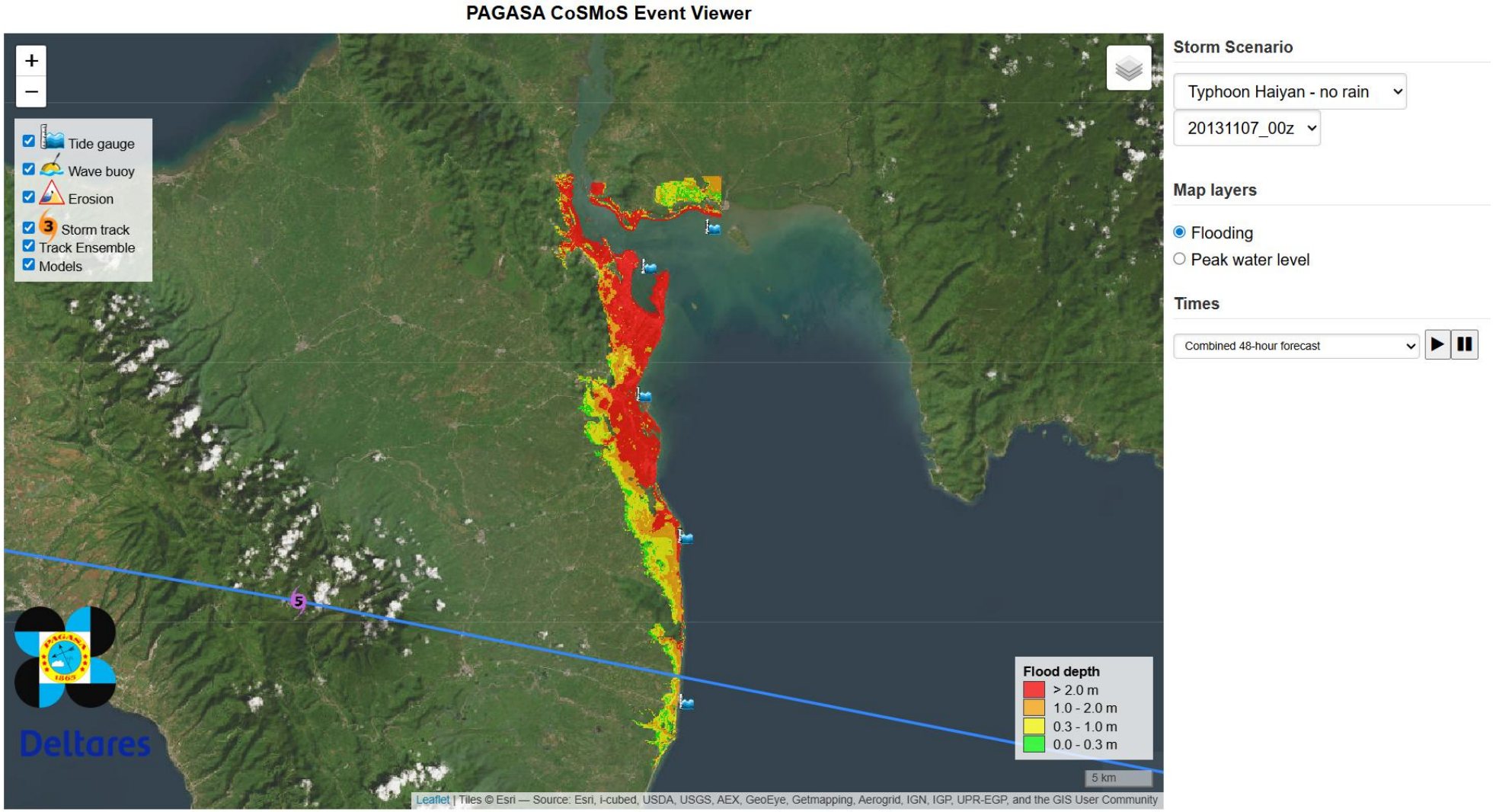
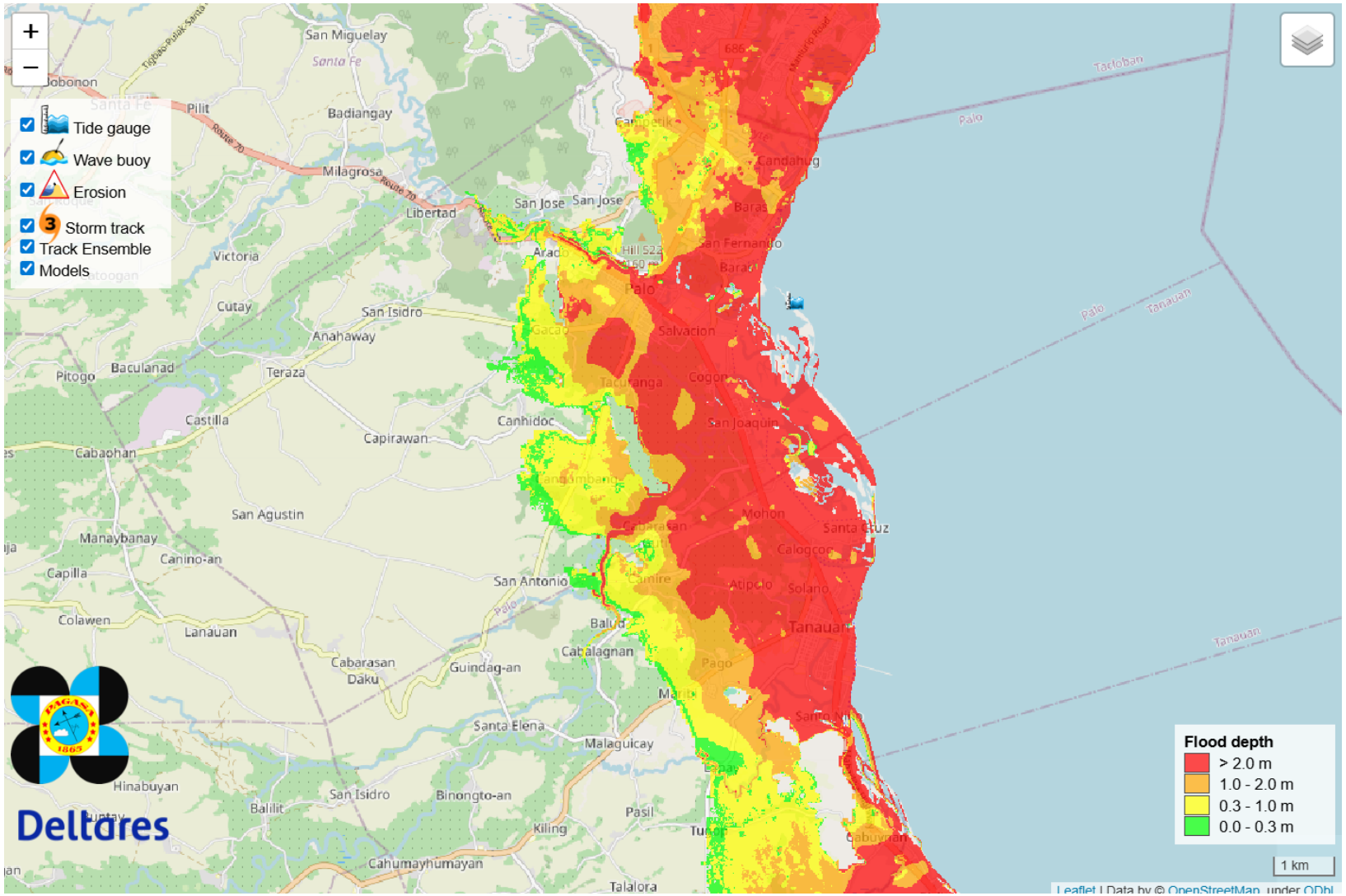
Hindcast - Typhoon Haiyan



Hindcast - Typhoon Haiyan

10 m resolution



Synthetic TC Data Development

***Dataset: JMA** 1951 – 2023 (72 years)*

1290
Historical TCs

Frequency = 17.9 TC / year

TCRM Model

Tropical Cyclone Risk Model (ver 1.0.2)

- *Developed by Geoscience Australia*
- *Stochastic and parametric model*

***Track Generator:** autoregressive process*

$$v(t) = \mu_v^i + \sigma_v^i \chi^i(t),$$
$$\chi^i(t) = \alpha_v^i \chi^i(t-1) + \phi_v^i \varepsilon,$$

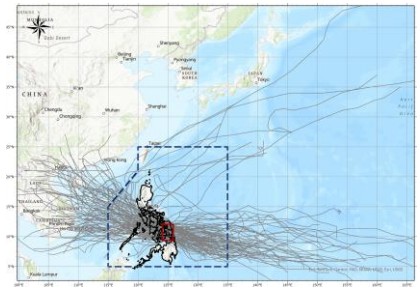
(Arthur, 2021)

165,508
Synthetic TCs

126
Historical TCs
(PALO)

Frequency = 1.75 TC / year

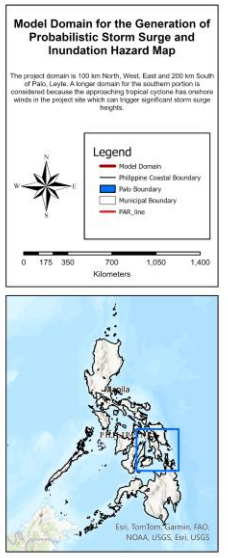
8,873
Synthetic TC **(PALO)**



***113 Tracks** is based on PAGASA Data*

COSMOS

Domain used to filter the synthetic tracks



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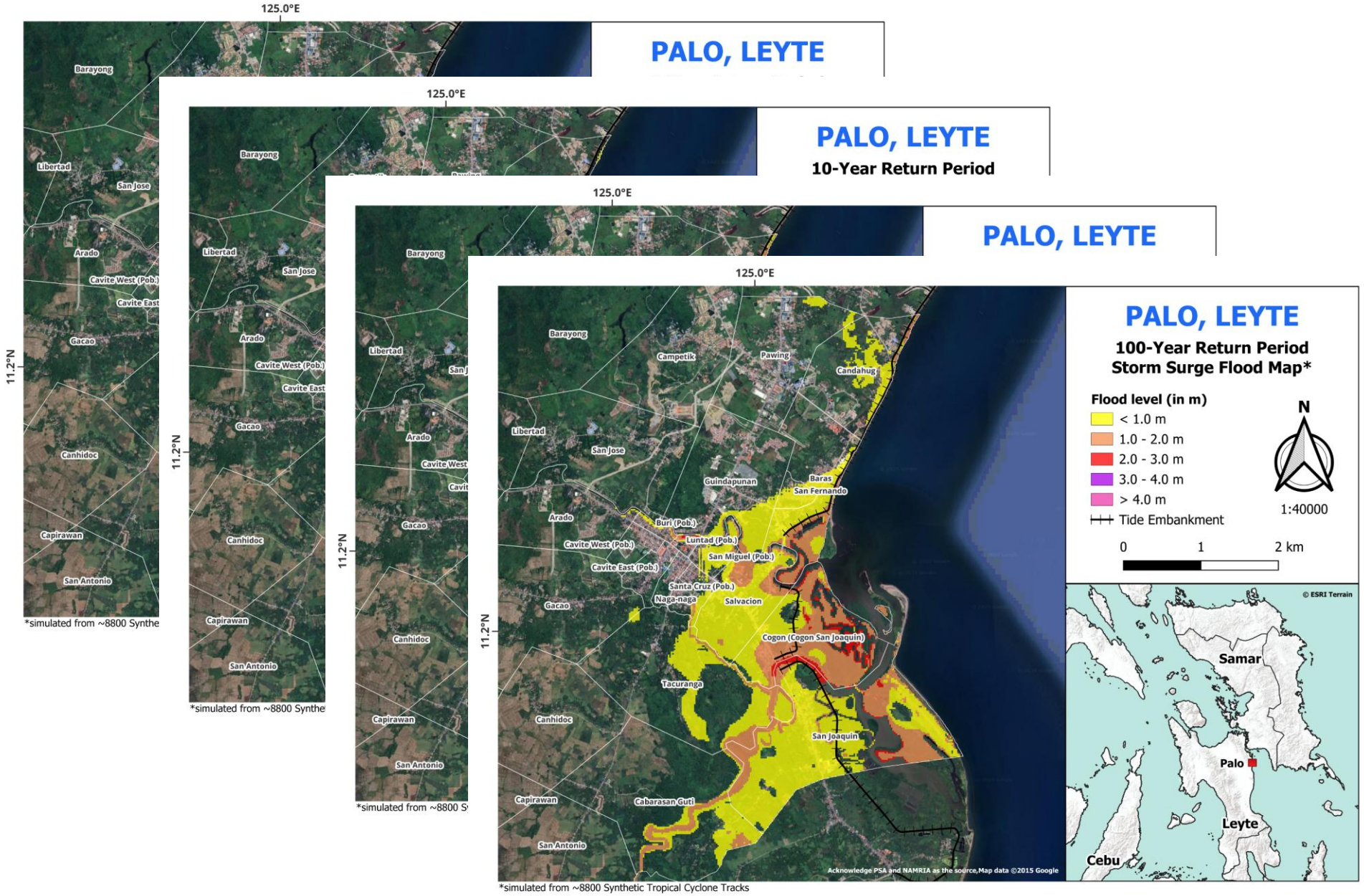
PALO, LEYTE
PALO, LEYTE
10-Year Return Period
PALO, LEYTE
PALO, LEYTE
100-Year Return Period
Storm Surge Flood Map*
Flood level (in m)
< 1.0 m
1.0 - 2.0 m
2.0 - 3.0 m
3.0 - 4.0 m
> 4.0 m
Tide Embankment
N
1:40000
0 1 2 km
125.0°E
11.2°N
Barayong
Libertad
San Jose
Arado
Cavite West (Pob.)
Cavite East
Gacao
Canhidoc
Capirawan
San Antonio
Campetik
Pawing
Candahug
Guindapunan
Baras
San Fernando
Buri (Pob.)
Luntad (Pob.)
San Miguel (Pob.)
Santa Cruz (Pob.)
Naga-naga
Salvacion
Cogon (Cogon San Joaquin)
Tacuranga
San Joaquin
Cabarasan Guti
Samar
Palo
Leyte
Cebu
© ESRI Terrain
Acknowledge PSA and NAMRIA as the source,Map data ©2015 Google
*simulated from ~8800 Synthetic Tropical Cyclone Tracks

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Conclusions

- Work in progress
- Framework is ready
- Deterministic forecasts are feasible on current hardware (GPU)
- Probabilistic (ensemble) forecasts may still be problematic
- Machine learning?