A New Mechanism for the Triggering of Turbidity Currents offshore Tropical River Deltas

Typhoon-Induced Megarips in-between River Deltas as Triggers of Turbidity Currents in Submarine Canyons

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Fig.1: Melor Typhoon on December 2015 near Samara Island, Philippines (https://en.wikipedia.org)
Fig.2: Megarip on December 2011 at Bateau Beach, New South Wales, Australia (http://www.earth.google.com)
Fig.3: Marine Turbidity Current (https://www.wired.com)

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Background

- Two studies in 2017 and 2018 linked **turbidity currents that displaced a submarine pipeline** offshore Philippines to the **landfall of intense typhoons nearby tropical river deltas**.

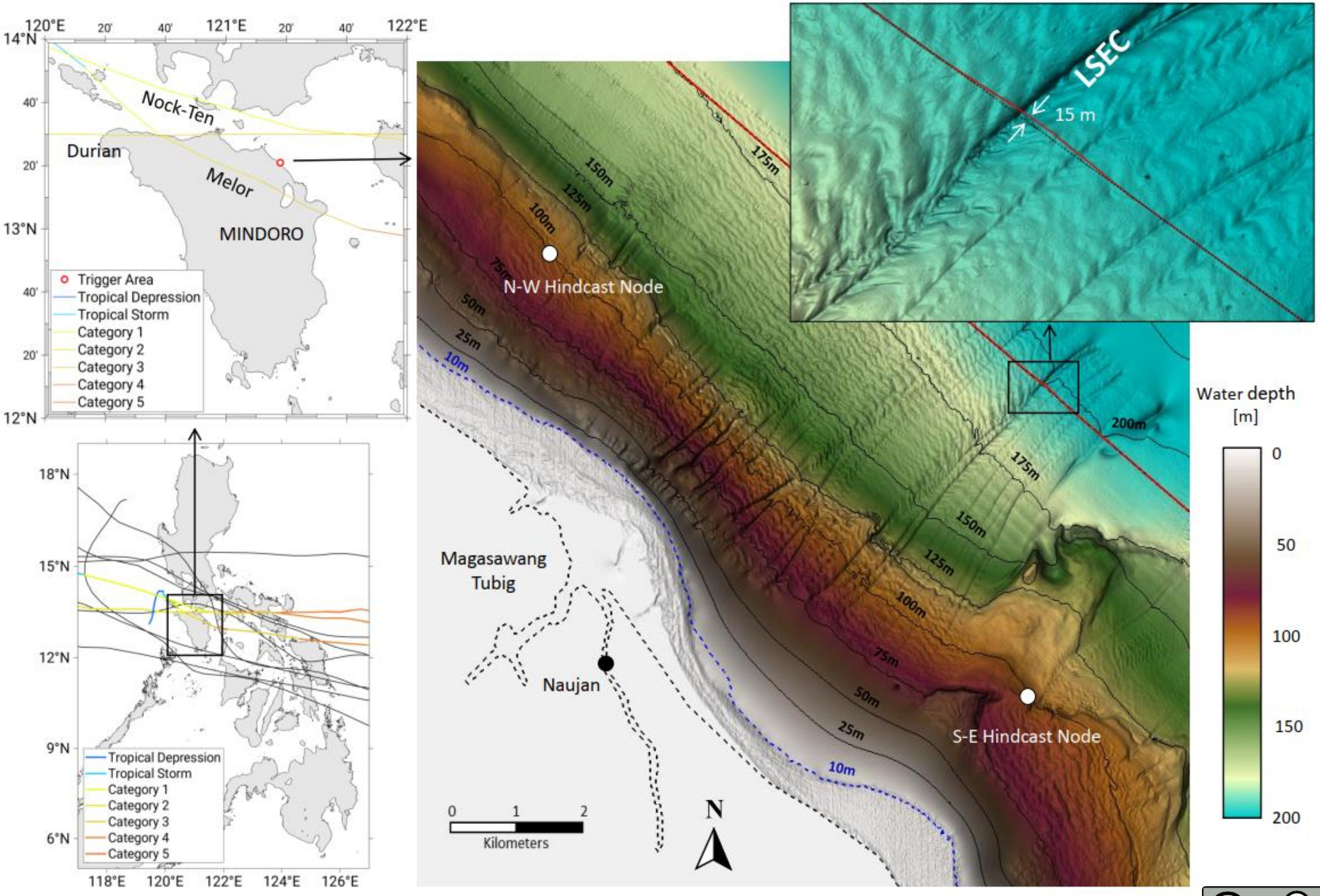
- We carried out a **2DV high-resolution application of the model Delft3D** to simulate the forcing of the nearshore environment nearby these deltas due to the most relevant typhoons of interest to better assess the local **interaction between typhoon-induced metocean conditions and river floods**.

- The model addresses winds, waves, surges, currents and river floods induced by these typhoons showing the **river plumes to be deflected alongshore by extreme surges and currents** and revealing the occurrence of a **megarip current in-between two neighbouring river deltas** flushing out water and sediment **towards the submarine canyon that crosses the pipeline where its shifting was recorded**.

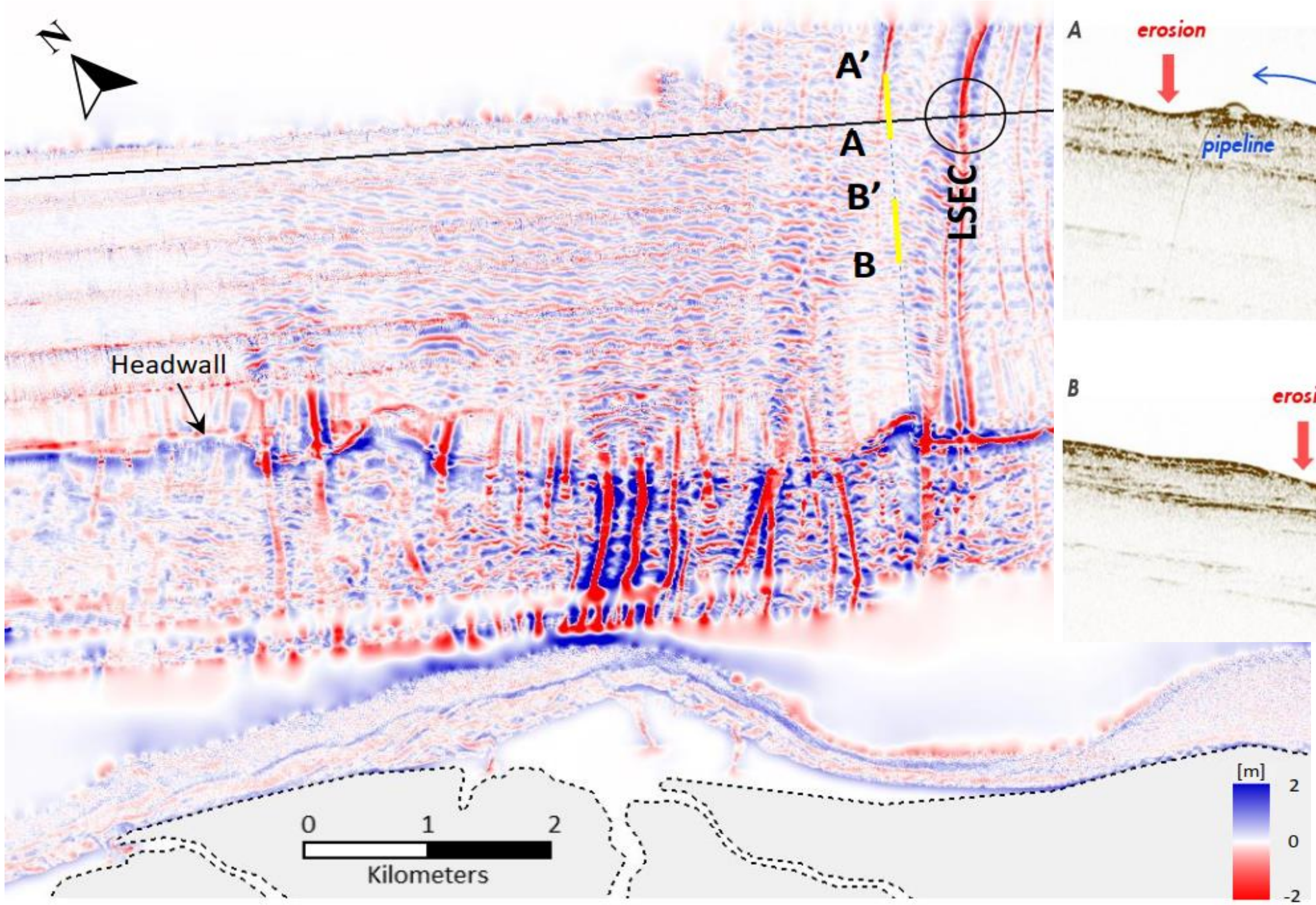
- The outcome of the 2DV modelling of the typhoon-induced coastal circulation were then used to inform a **3D model of the triggering of marine turbidity currents by means of the CFD code TCsolver**. This coupling disclosed the **typhoon-induced megarip current as the trigger of the turbidity current event**.

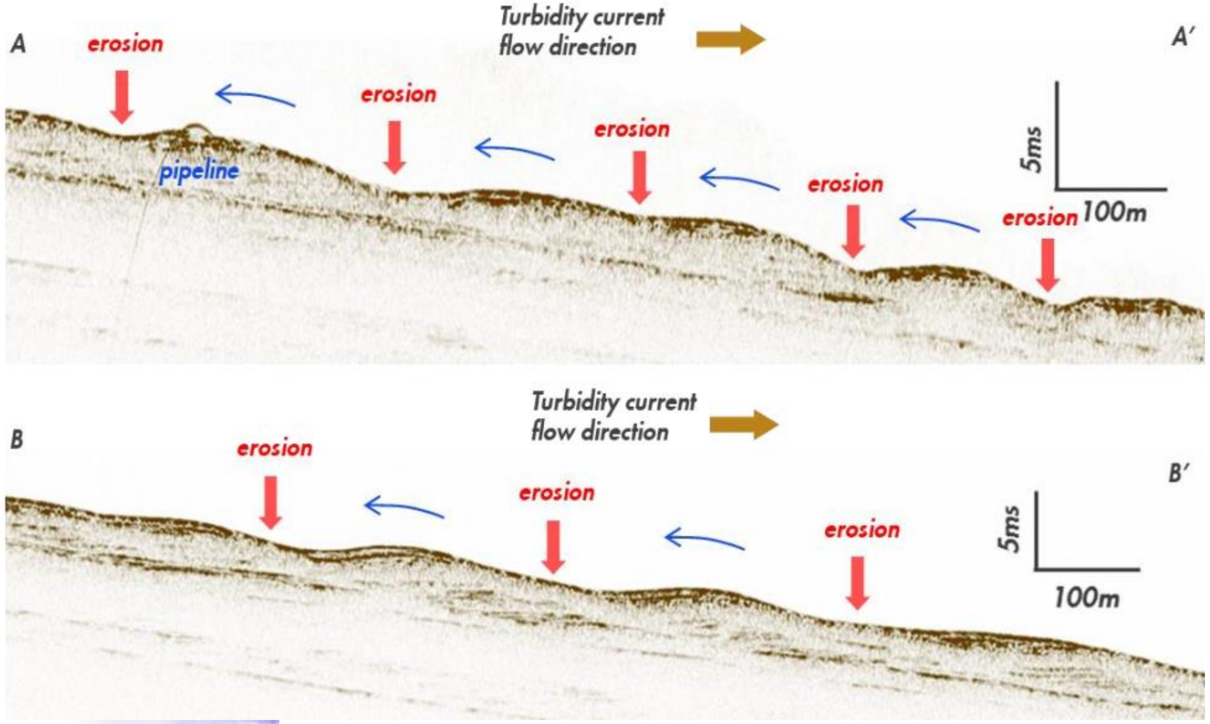
Study Area

Bathymetry map of the Magasawang-Tubig submarine canyon system. Insets indicate location of the trigger area, tracks of typhoons passing near Oriental Mindoro after the pipeline installation highlighting the most relevant typhoons with colors indicating the 1 to 5 rating based on the Saffir-Simpson Scale (IBTrACS, http://www.ncdc.noaa.gov) and details of the pipeline displacement. Black dashed line is the pipeline as built. Red continuous line is the pipeline now.



Turbidity Current Signatures

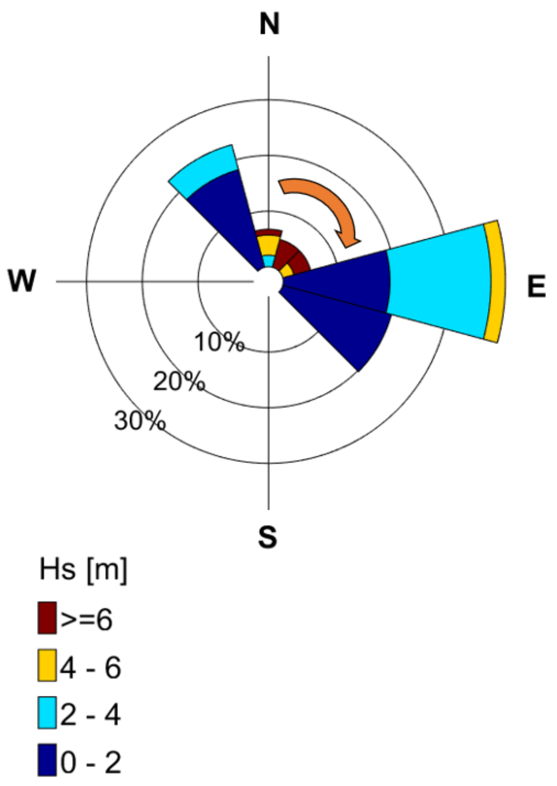


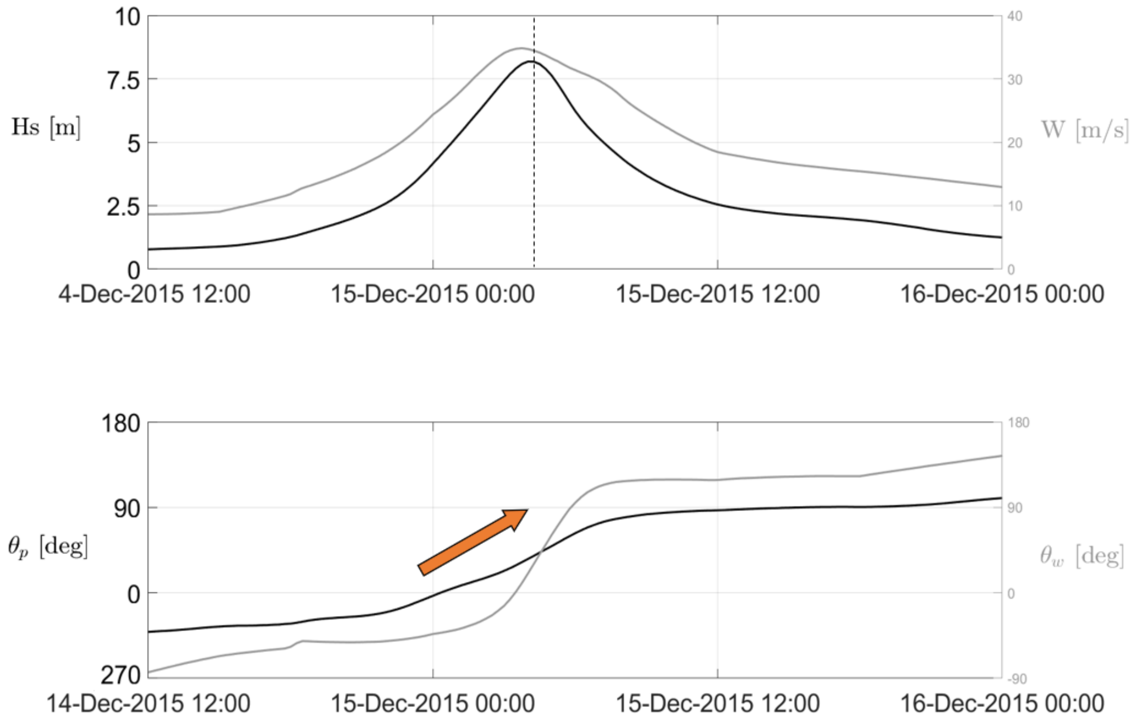


Two different downslope segments of sub-bottom profile data revealing the internal stratigraphy and the upstream migration pattern of the bedforms.

Map of the bedforms observed in the slope off the Magasawang-Tubig delta. Bedforms presence, location and orientation are indicated by subtracting from the bathymetry map a smoothed low-pass filtered version of it. Black continuous line marks the pipeline path. Black circle indicates the location of the pipeline displacement where it crosses the longest south-easternmost canyon (LSEC) of the Magasawang-Tubig submarine system.

Typhoon Melor as Trigger of the Turbidity Current Event





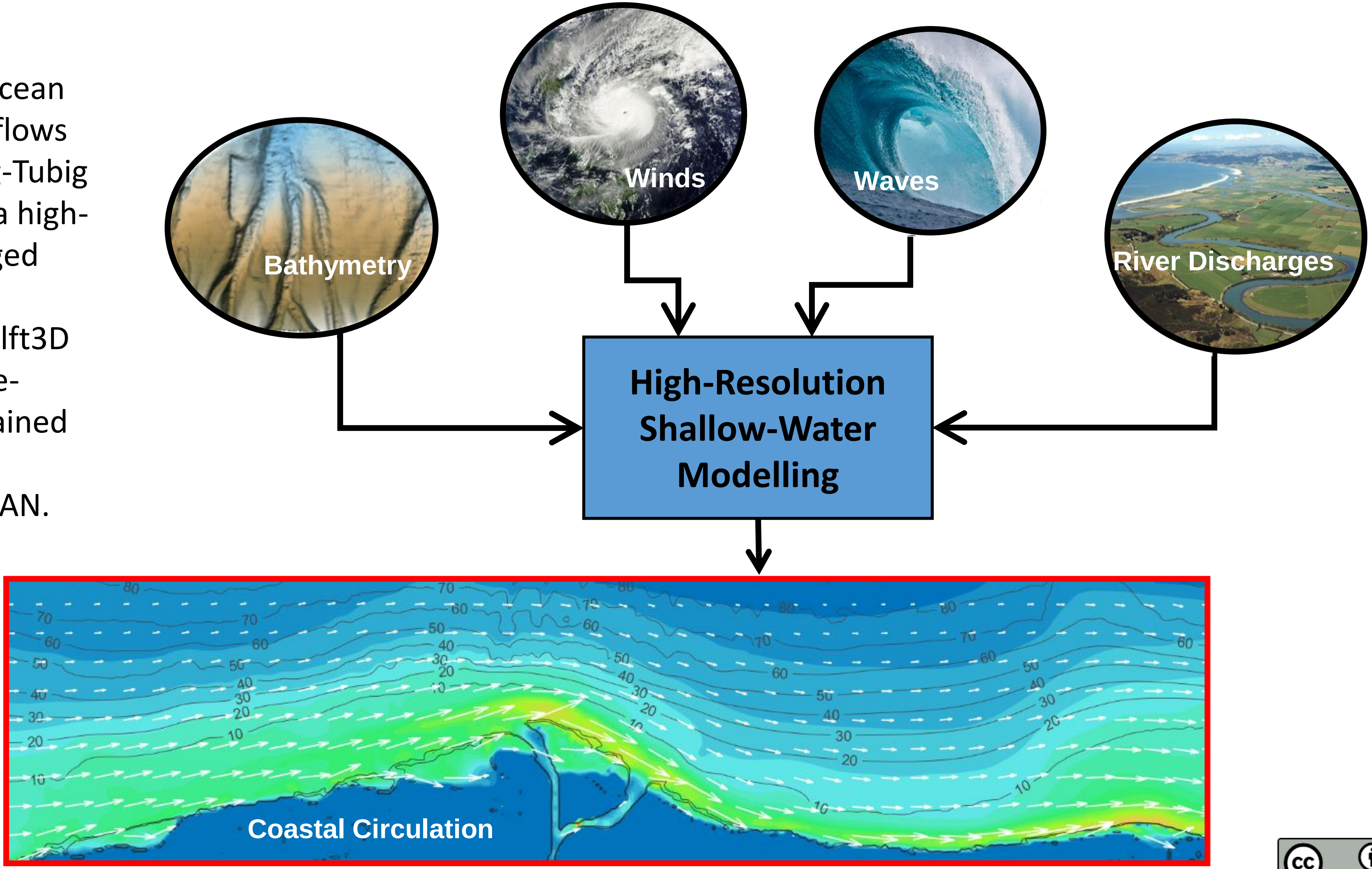
Melor typhoon passing over the eastern coast of Mindoro nearby the Magasawang-Tubig delta in December 2015.

A tropical cyclone reanalysis hindcast for Tayabas Bay was analyzed. Wave rose associated with the storm induced by Melor along with the time-series of wave heights Hs, wind speeds W, peak wave θp and wind direction θw extracted at the S-E hindcast node indicated in the study area map.

oceanweather inc.
Marine forecasts/hindcasts Research at the air-sea interface
ADCIRC SWAN Simulating WAves Nearshore

High-Resolution Shallow-Water Modelling of the Typhoon-Induced Coastal Circulation

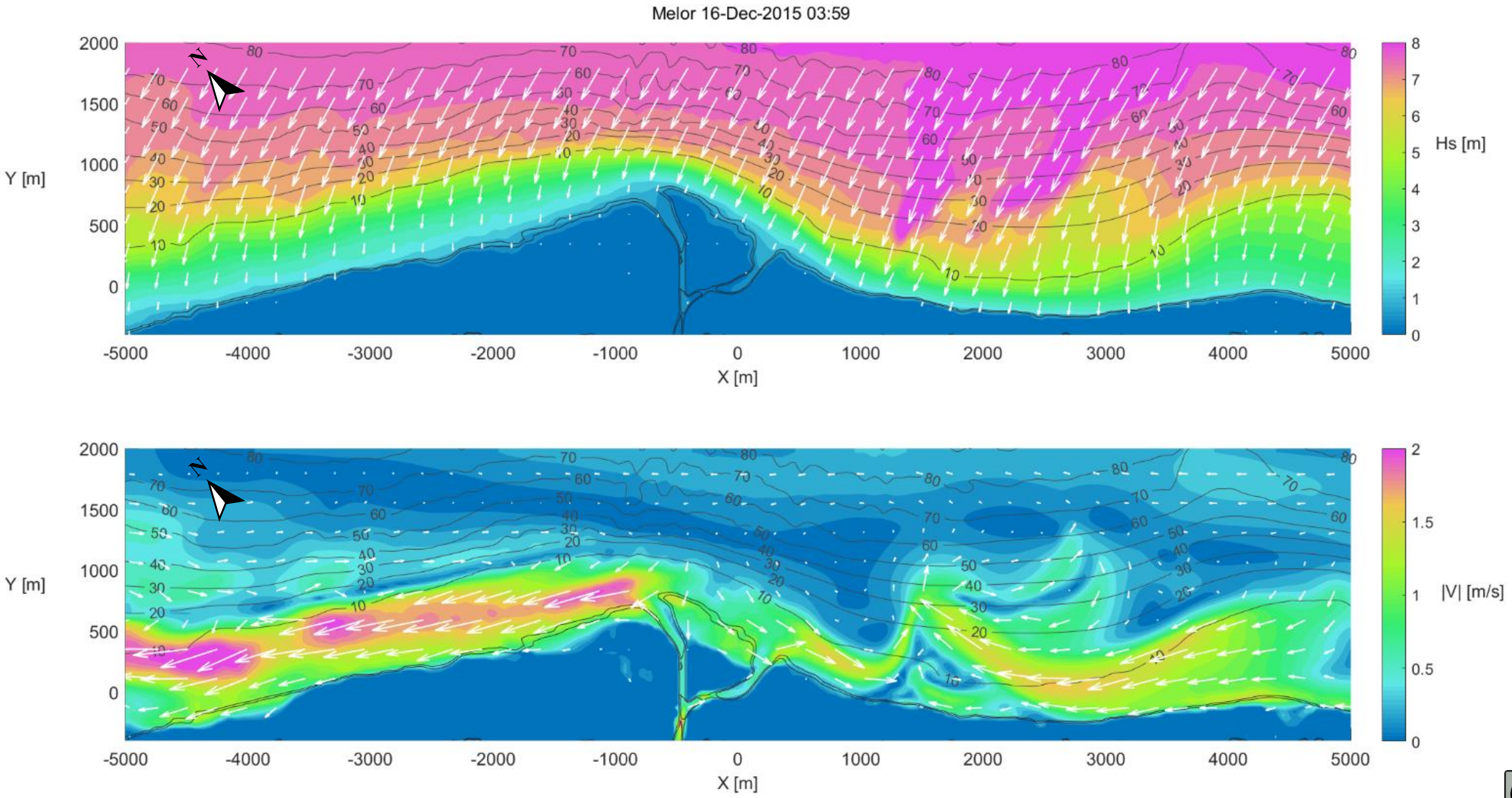
The interplay between typhoon-induced meteocean conditions and river outflows nearby the Magasawang-Tubig delta was addressed by a high-resolution, depth-averaged application of the hydrodynamic model Delft3D with superimposed wave-current interactions obtained by its coupling with the spectral wave model SWAN.



Deltares
Enabling Delta Life
Delft3D
SWAN
Simulating WAves Nearshore

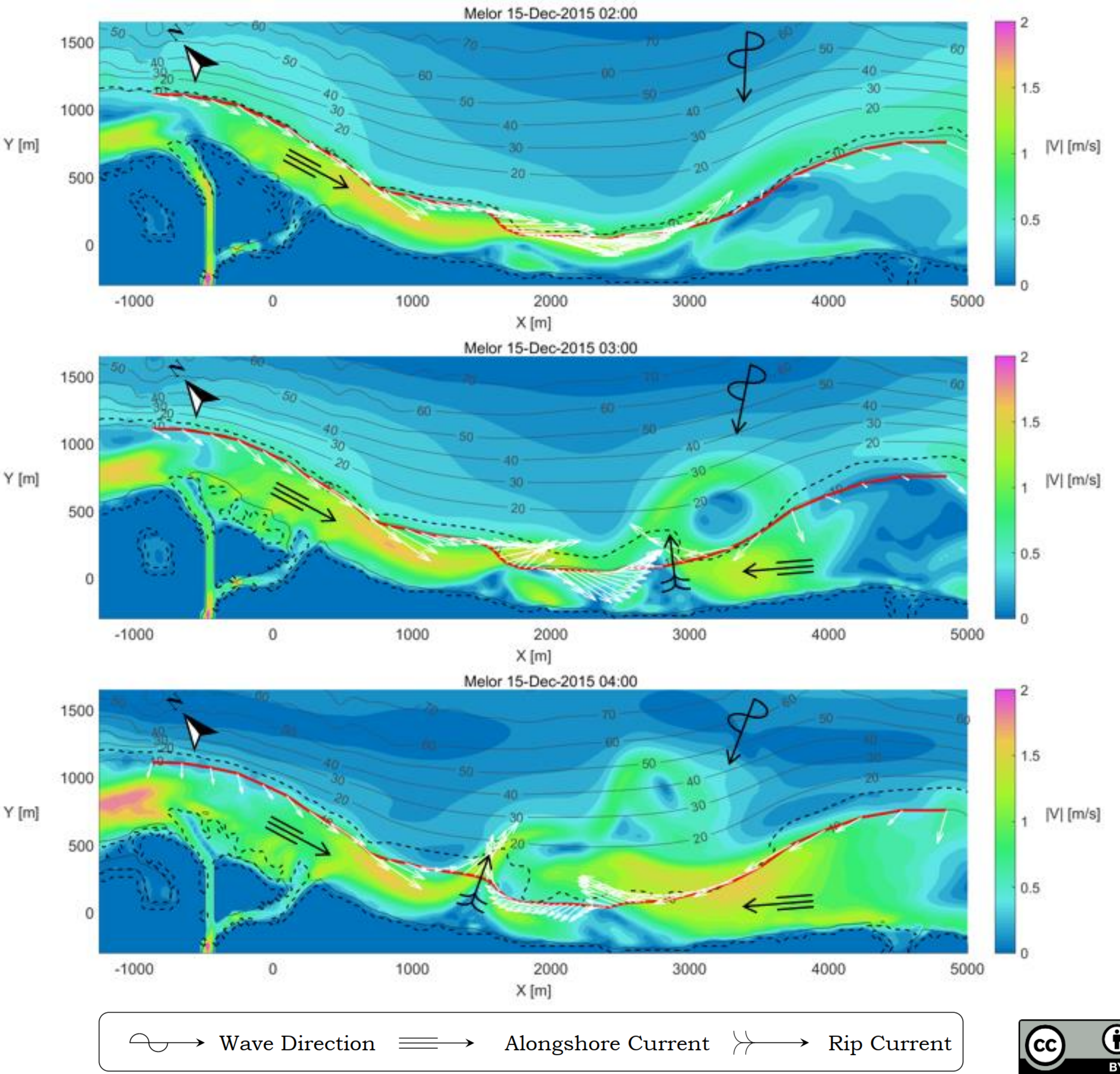
Typhoon-Induced Coastal Circulation

Snapshots of simulated (top) incoming wave and (bottom) flow conditions at the peak of the storm induced by Melor.



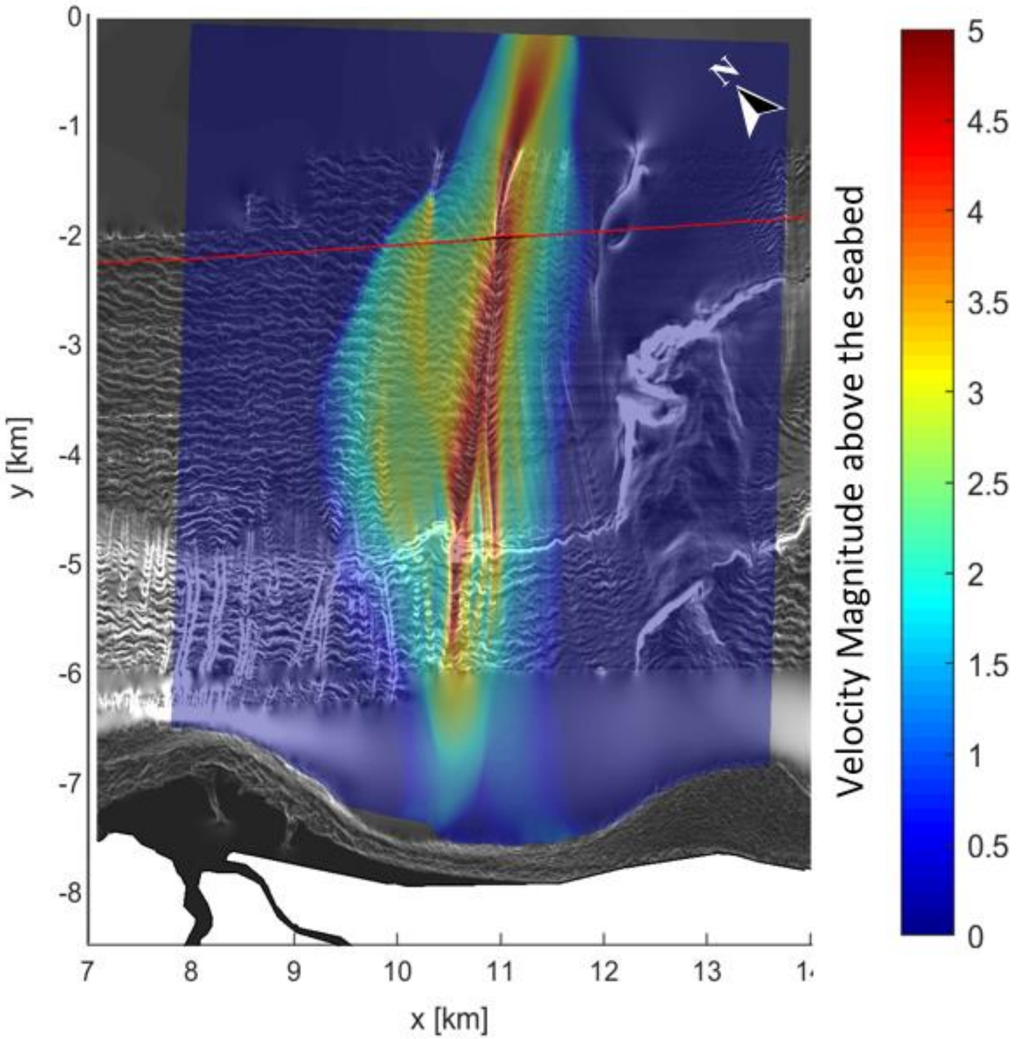
Megarip Time-Development

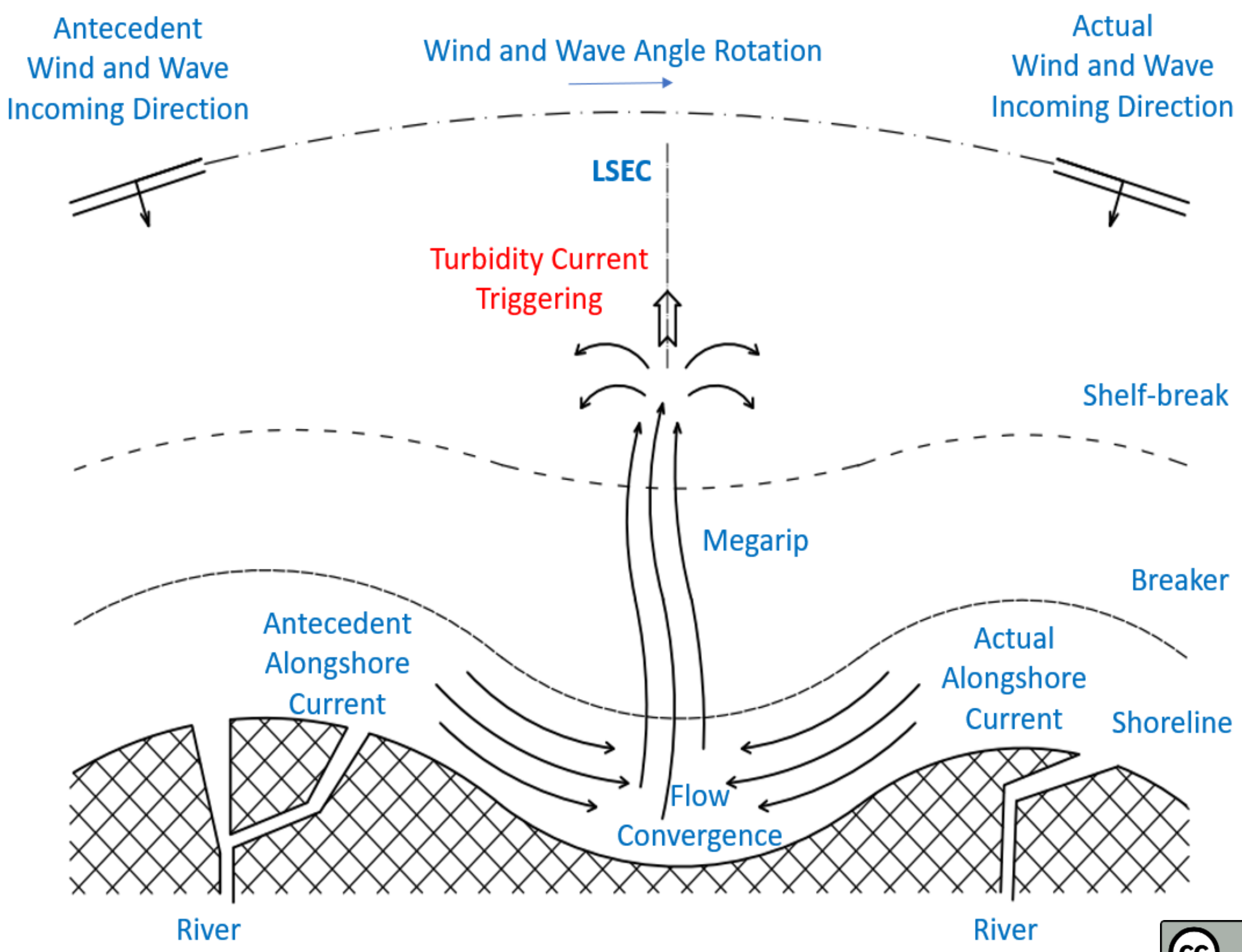
Hourly snapshots of simulated flow conditions during the peak of the Melor storm. Red line represents the onshore boundary of TCsolver. White arrows indicate extracted depth-averaged current directions to inform TCsolver. Dashed line is the contour of 1% breaking waves, representing the extension of the typhoon-induced surf-zone. Black arrows indicated incoming wave conditions, alongshore currents and megarip currents.



Megarip as Trigger of Turbidity Current

(Left) Simulated turbidity current induced by Melor. Black and red lines represent the position of the pipeline in the original design and in the current configuration. (Right) Schematic of the newly identified initiation mechanism for the triggering of the turbidity current in the longest south-easternmost canyon (LSEC) that caused the pipeline lateral displacement.





Concluding Remarks

- **Down-canyon turbidity currents** have been reported to be caused by **complex air-sea-land interactions**, including the alongshore pile up of water and its motion due to strong **onshore blowing winds**, high **surface waves**, **tidal currents**, **downwelling**, **internal waves** and **edge wave excitation resulting in canyon-oriented rip-current cells**. In line with these existing findings, our results reveal **a new initiation mechanism for turbidity currents in submarine canyons** in which the passage of a **typhoon** generates a sequence of opposing alongshore currents in an embayed zone between two protruding river deltas resulting into a **megarip current** directed towards an offshore canyon triggering an ignitive **turbidity current** that is inferred to have been responsible for the shifting of a seafloor pipeline.

- This newly identified turbidity current triggering **may have general application to worldwide submarine canyon systems** and thus extensive implications for both the **risk assessment of seafloor facilities** and the currents understanding of **sediment transport processes across continental margins** and their associated deep-sea deposits.

- Although in this study case the deltas play a critical role not only in supplying year-long sediment to the shelf but also in dictating the nearby shoreline concavity, the newly identified mechanism **may similarly apply to a wide range of morphologically different coastal regions**. Particularly, as rip currents are ubiquitous along energetic, rugged coastlines, a similar triggering mechanism of turbidity currents may occur offshore **embayed/concave shorelines**, **prominent headlands**, **pocket beaches**, even in the absence of any river outflow.

- Our modelling exercise paves the way for shedding light on the **initiation mechanisms responsible for the triggering of turbidity currents in coastal oceanic settings subject to extreme weather events** and for the formulation of realistic boundary conditions for their field-scale numerical simulation.

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Any QUESTIONS, COMMENTS or CRITICISMS ?