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Forecasting tropical cyclone surge for humanitarian relief

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Flood Early Warning Pilot

Purpose

- Monitor and provide early awareness to the UK Foreign, Commonwealth and Development Office (FCDO) of the risk of flooding from imminent tropical cyclones

Operation

- Produce a bulletin describing prediction of flooding and impact on local population and infrastructure.

- Response within one working day

Audience

- The bulletin is circulated to governments, local meteorological organisations and humanitarian decision-makers.

Flood Early Warning Pilot

Fluvial flooding

- Global Flood Awareness System (ECMWF, University of Reading, IFRC Climate Centre)

Coastal flooding from surge

- TELEMAC-2D (HR Wallingford)
- LISFLOOD-FP (Fathom)

Exposure analysis

- Impact on population and infrastructure (University of Bristol, Fathom)

14 responses 2019 to 2023

Event name (# bulletins)
Landfall date
Country location

Biparjoy (1)
15/06/23
Pakistan

Sitrang (1)
24/10/22
Bangladesh

Idai
15/03/19
Mozambique

Kenneth
25/04/19
Mozambique

Amphan
20/05/20
Bangladesh

Mocha (2)
14/05/23
Bangladesh/Myanmar

Ana (1)
26/01/22
Malawi

Iota
17/11/20
Nicaragua

Eloise
23/01/21
Mozambique

Gombe (2)
11/03/22
Mozambique

Cheneso (1)
19/01/23
Madagascar

Freddy (7)
24/02/23 & 11/03/23
Mozambique/Malawi/Zimbabwe

Batsirai (3)
05/02/22
Madagascar

Emnati (1)
22/02/22
Madagascar

4

Requirements for modelling of surge

- Cover areas at risk of TC surge that are of interest to FCDO
- Resolve wind & pressure fields, coastal bathymetry and shoreline
  - ~1km nearshore
- Include tide
- Runtime should be short – target of < 1 hour (36 cores)
- Regional hydrodynamic models
  - Bay of Bengal
  - Caribbean Sea
  - Mozambique Channel
  - Philippines
  - East coast Madagascar
  - Arabian Sea

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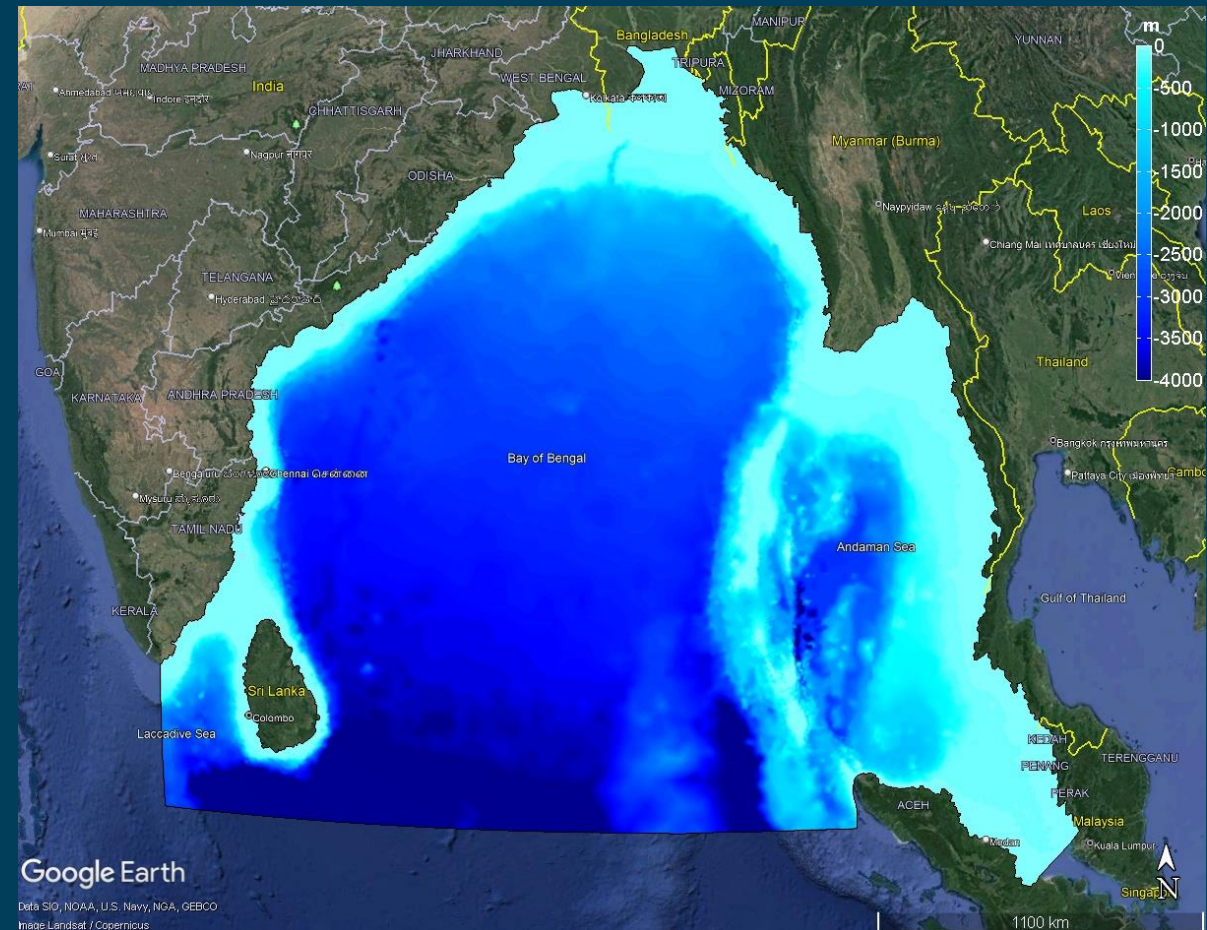
TELEMAC-2D hydrodynamic model

TELEMAC-2D has been used to hindcast TC surge and currents

Validated as part of previous projects:

- Australia

- Bangladesh

- The Bahamas

Include tide, wind and air pressure

Start from a basic level and incrementally improve methodology

Analysing warnings

Warnings issued by agencies provide forecast

- Position of centre of cyclone

- Maximum sustained wind speed

- Radii of wind speed thresholds

- Provided at 6 or 12 hour forecast times


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WTXS32 PGTW 220900
MSGID/GENADMIN/JOINT TYPHOON WRNCEN PEARL HARBOR HI//
SUBJ/TROPICAL CYCLONE 12S (ELOISE) WARNING NR 011//
RMKS/
1. TROPICAL CYCLONE 12S (ELOISE) WARNING NR 011
   03 ACTIVE TROPICAL CYCLONES IN SOUTHIO
   MAX SUSTAINED WINDS BASED ON ONE-MINUTE AVERAGE
   WIND RADII VALID OVER OPEN WATER ONLY
   ---
   WARNING POSITION:
   220600Z --- NEAR 18.8S 38.0E
      MOVEMENT PAST SIX HOURS - 255 DEGREES AT 15 KTS
      POSITION ACCURATE TO WITHIN 020 NM
      POSITION BASED ON CENTER LOCATED BY SATELLITE
   PRESENT WIND DISTRIBUTION:
   MAX SUSTAINED WINDS 065 KT, GUSTS 080 KT
   WIND RADII VALID OVER OPEN WATER ONLY
   RADIUS OF 064 KT WINDS - 025 NM NORTHEAST QUADRANT
                            025 NM SOUTHEAST QUADRANT
                            025 NM SOUTHWEST QUADRANT
                            025 NM NORTHWEST QUADRANT
   RADIUS OF 050 KT WINDS - 040 NM NORTHEAST QUADRANT
                            040 NM SOUTHEAST QUADRANT
                            040 NM SOUTHWEST QUADRANT
                            040 NM NORTHWEST QUADRANT
   RADIUS OF 034 KT WINDS - 110 NM NORTHEAST QUADRANT
                            100 NM SOUTHEAST QUADRANT
                            090 NM SOUTHWEST QUADRANT
                            110 NM NORTHWEST QUADRANT
   REPEAT POSIT: 18.8S 38.0E
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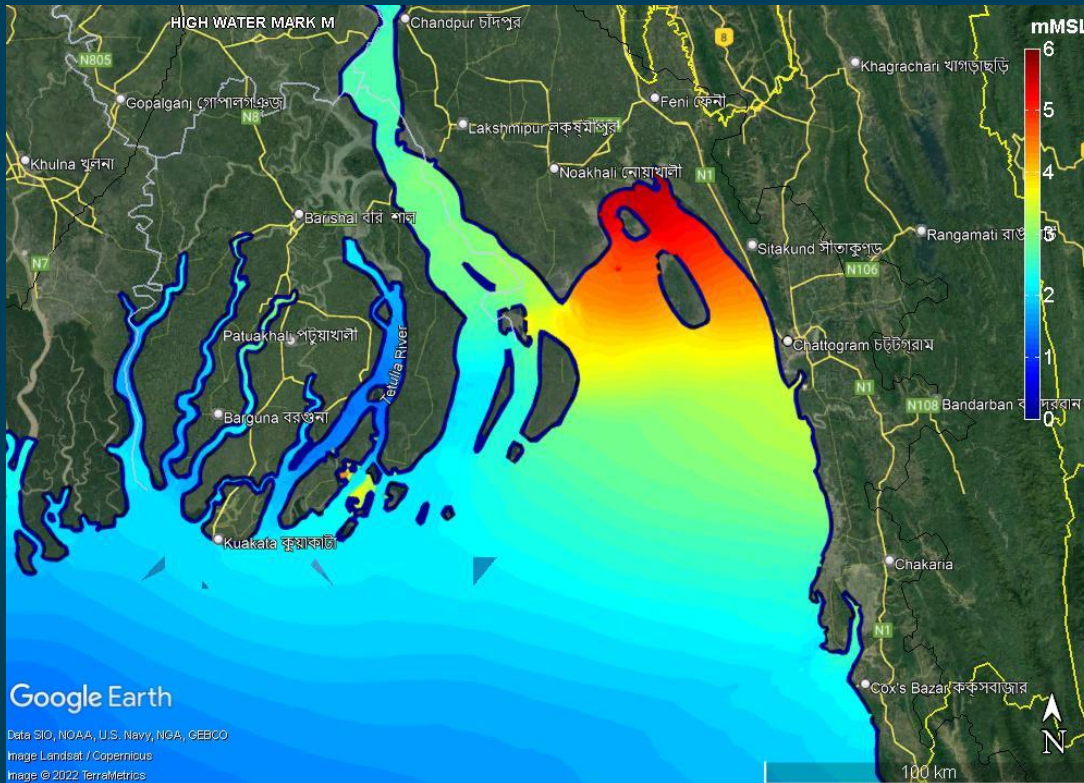
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Wind field set up – Cyclone Mocha
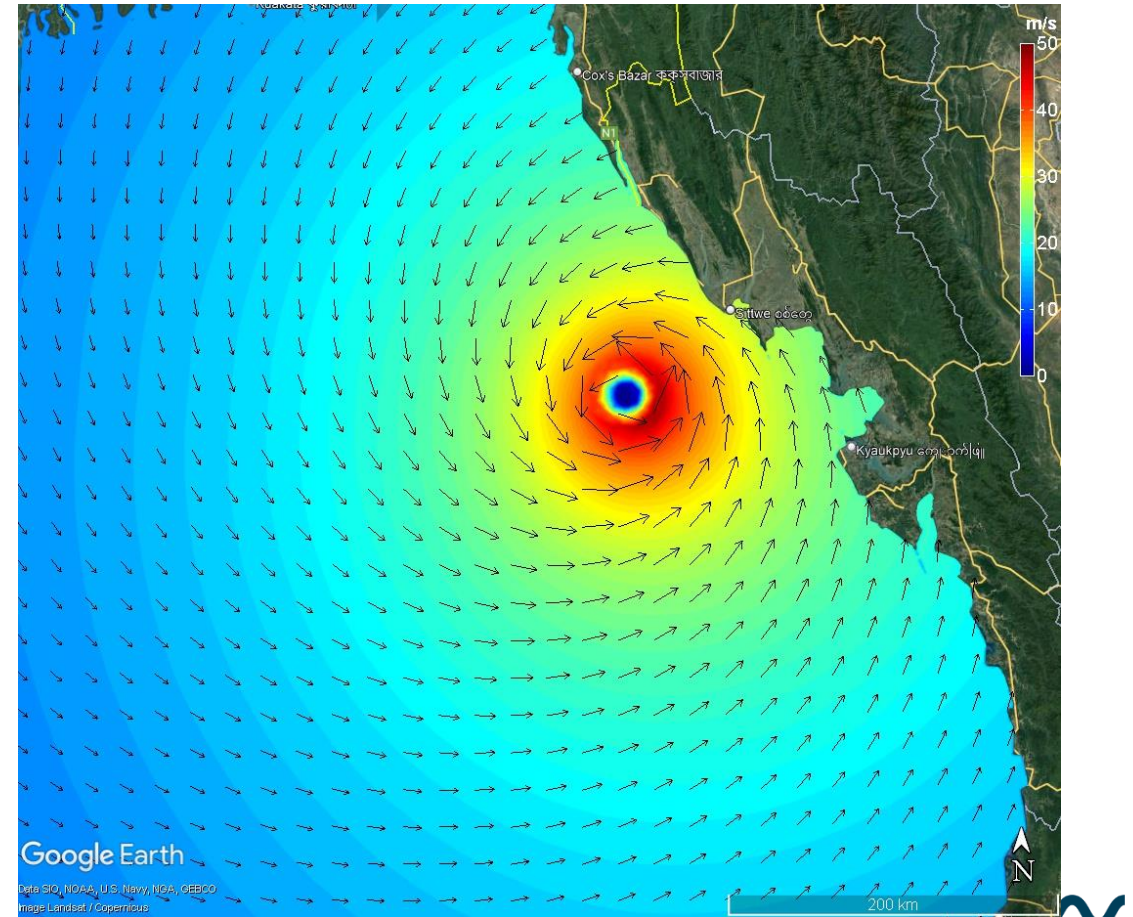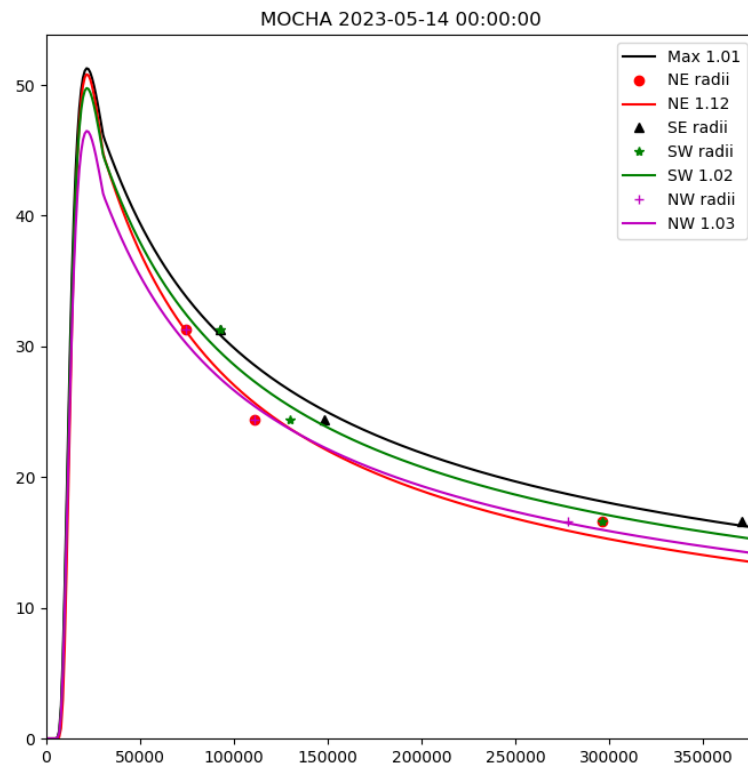
Cyclone Mocha – Myanmar May 2023
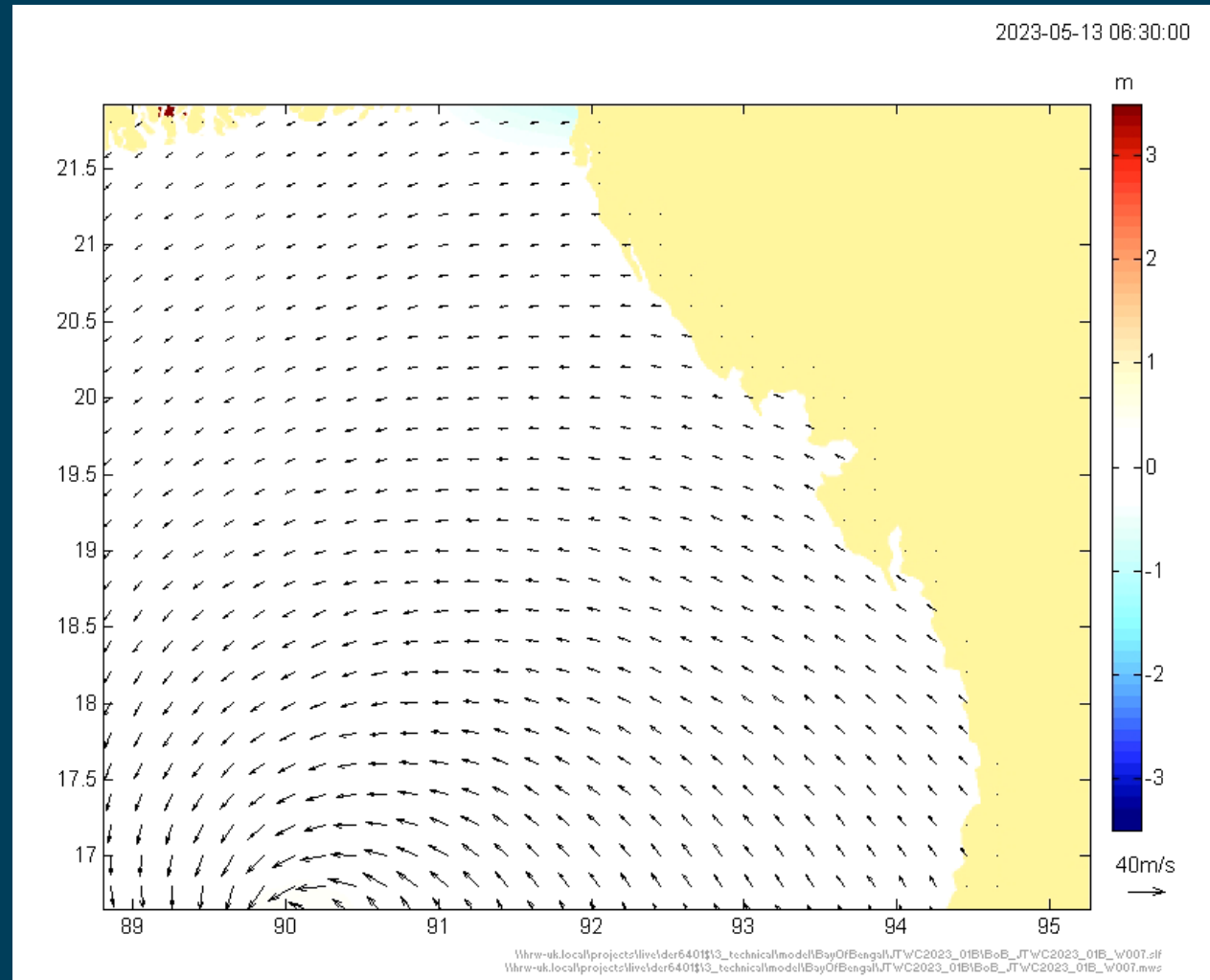
Cyclone Sitrang – October 2022

Water level peak

- Forecast: 7.6mCD
- Observed (BN):   7.3mCD

Deterministic and probabilistic approaches

Deterministic approach

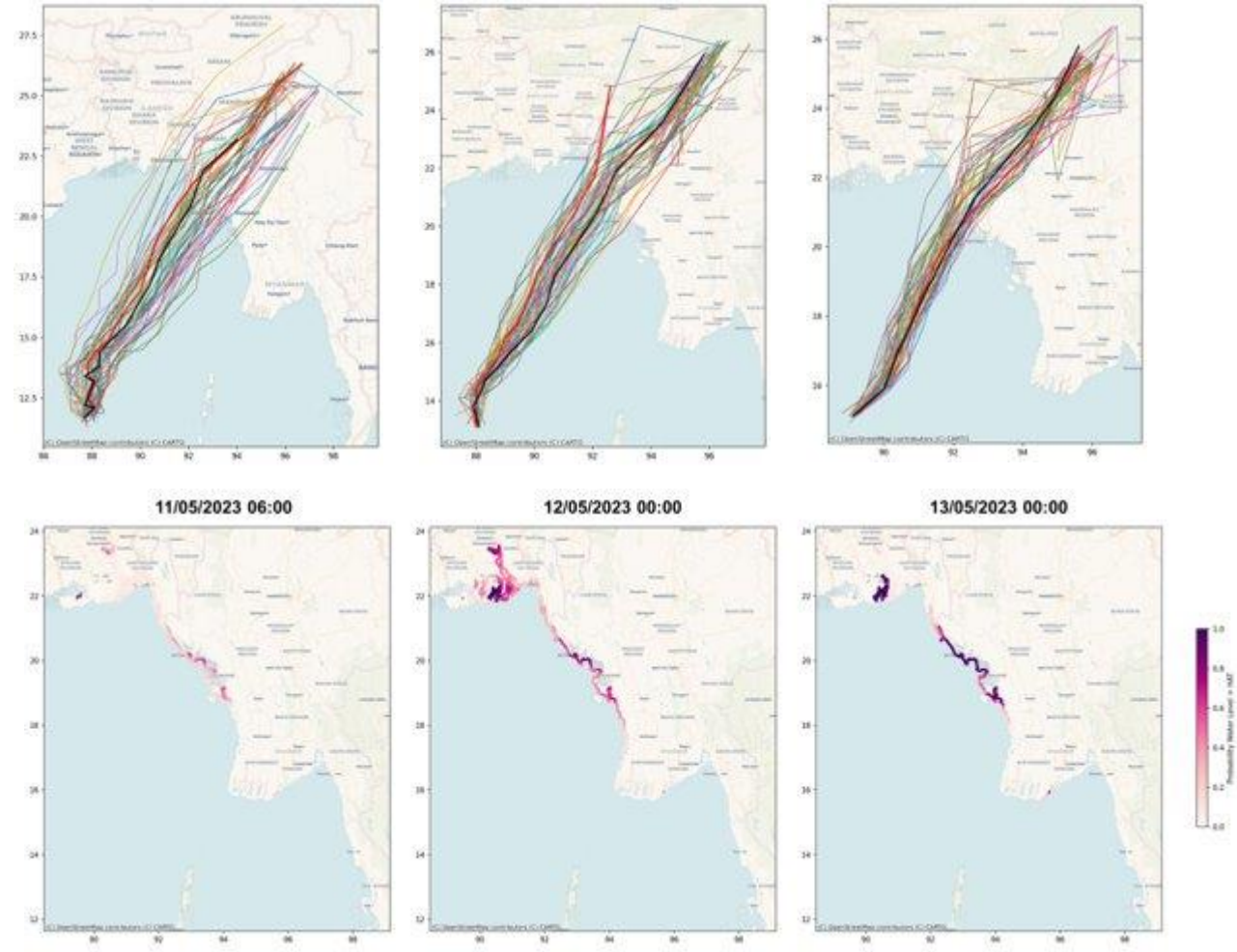- Used forecasts from 2 or 3 organisations (RSMC/JTWC/ECMWF)

Long lead time forecasts

- Large uncertainty
- Limited value

Complex locations (e.g. Philippines)

- Small change in cyclone track or intensity $\Rightarrow$ large change in predicted surge

Investigating a probabilistic approach with ensemble tracks

Reflections

Despite assumptions and simplifications, warnings have been well received

- Prediction of no coastal flooding is valuable

- Any advance warning is useful

    - Where is flooding most likely?

    - Indication of severity

Presentation of predictions

- Concise and clear

- Understandable

- Simple explanation of uncertainties

- Expert interpretation is vital

Incremental improvement is valuable

Open TELEMAC-MASCARET

Open source suite of models

http://www.opentelemac.org/

TELEMAC-2D

2D free-surface flow model

Depth-averaged model

Solves the Shallow Water equations
- Bed elevation, free-surface level, u and v velocity components

Flows in rivers, estuaries and seas
- For navigation studies, sediment modelling and effluent discharge simulations
- Assessment of available tidal energy sites
- Impact of coastal/waterfront developments
- Flushing assessments of marinas, harbours and canals
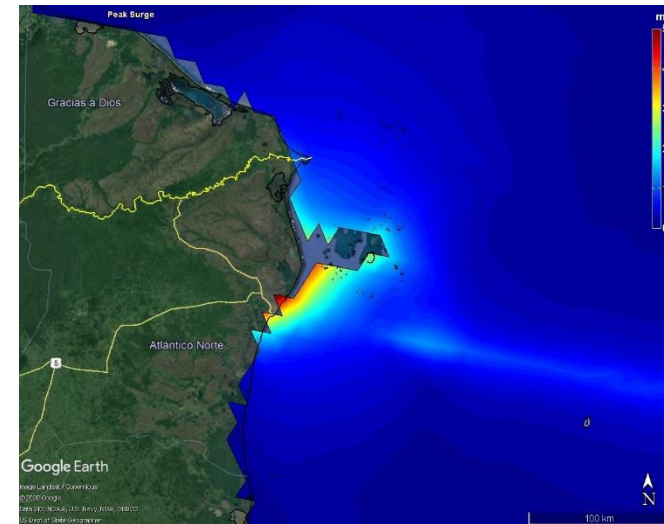- Flooding risk to storm surge, rainfall or tsunami events

Hurricane Iota

Hurricane Iota

- Made landfall on east coast of Nicaragua on 17th November 2020
- Category 4 hurricane at landfall

TELEMAC-2D Modelling

- Used The Earth by TELEMAC[1]
- Coarse model – useful for identifying location of surge
- Regular mesh and bathymetric errors (GEBCO)

[1]S. Bourban, M Turnbull, A. J. Cooper, "The Earth by TELEMAC" Proceedings of the XXIVth TELEMAC-MASCARET User Conference, Graz, Austria, pp1-8, 2017.
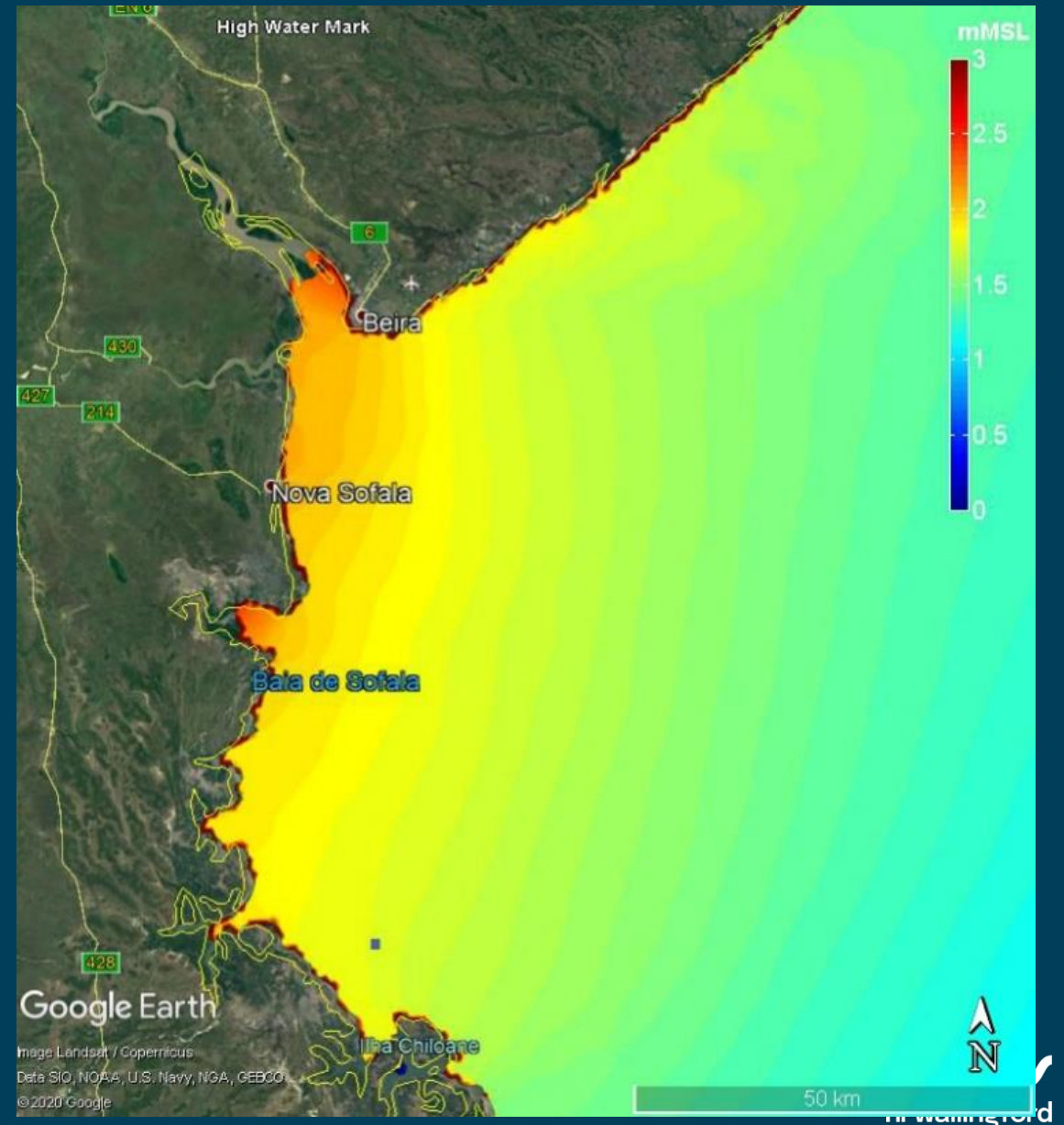
Cyclone Eloise

Cyclone Eloise
- Landfall near Beira in Mozambique on 22nd January 2021
- Category 2 at landfall

TELEMAC-2D Modelling
- Dedicated model of Mozambique Channel
- Includes tide
- 2.5m surge forecast coinciding with neap tide
- Total water level forecast to be less than MHWS

Typhoon Rai

Typhoon Rai

- Philippines 16th December 2021
- Category 5
- Tracked across Visayan Islands, central Philippines

TELEMAC-2D Modelling

- Dedicated model covering Philippines
- 2D structure of wind fields important
- Tide difficult to model
- Resultant surge *very* sensitive to track