MODELING OF TSUNAMIS AND TROPICAL CYCLONES CONTRIBUTIONS TO HAZARD ASSESSMENT AND DISASTER MANAGEMENT

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HUMAN and THE SEA

HUMAN HAS ALWAYS BEEN INTERACTED WITH THE COAST AND THE SEA.

BECAUSE WATER IS THE SOURCE of LIFE

FOR THOUSANDS OF YEARS, A LARGE PORTION OF THE WORLD'S POPULATION HAS MADE THEIR HOME ALONG OR NEAR THE COAST

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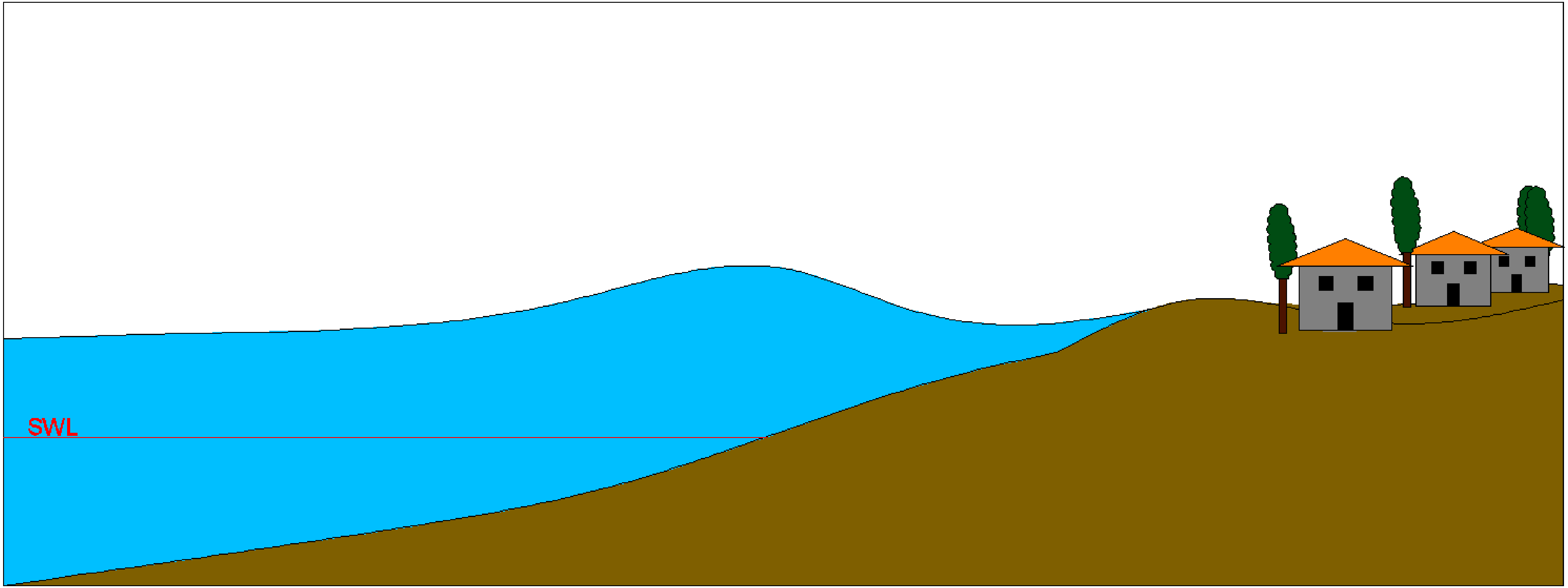
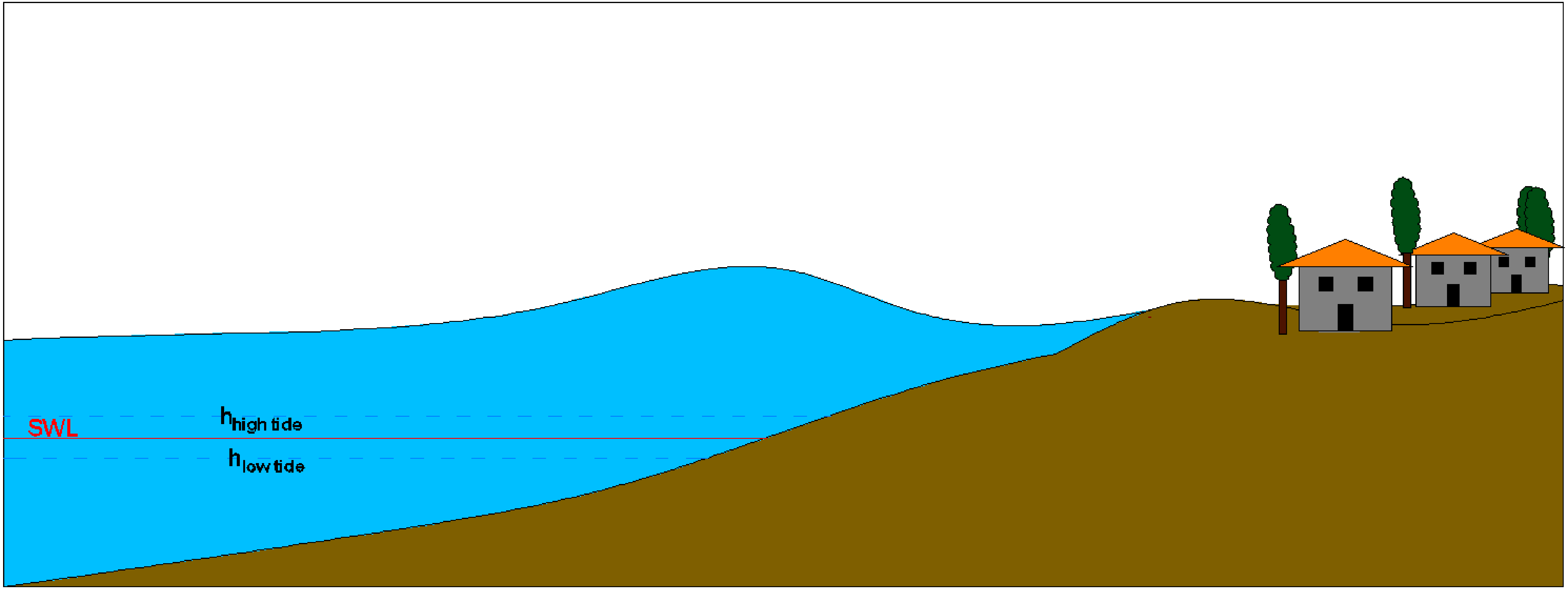
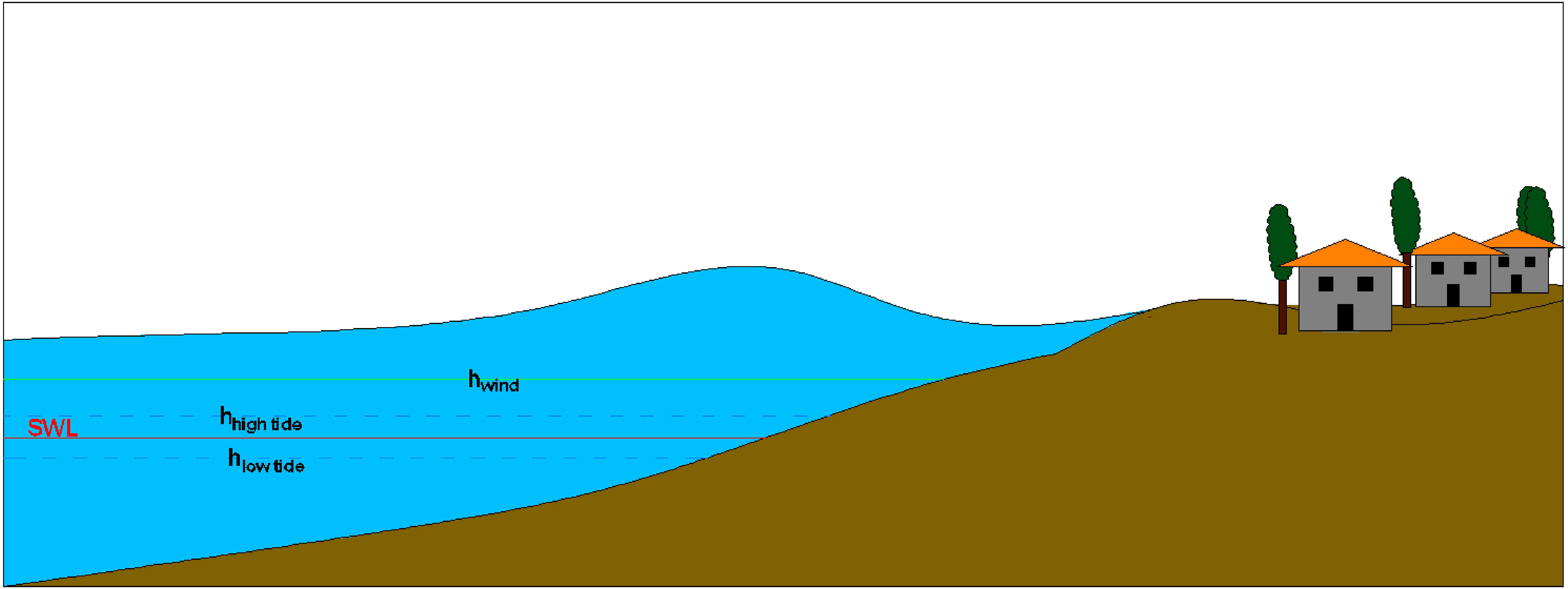
SOCIETAL SOLUTIONS AND MITIGATION STRATEGIES

Hydrological Hazards

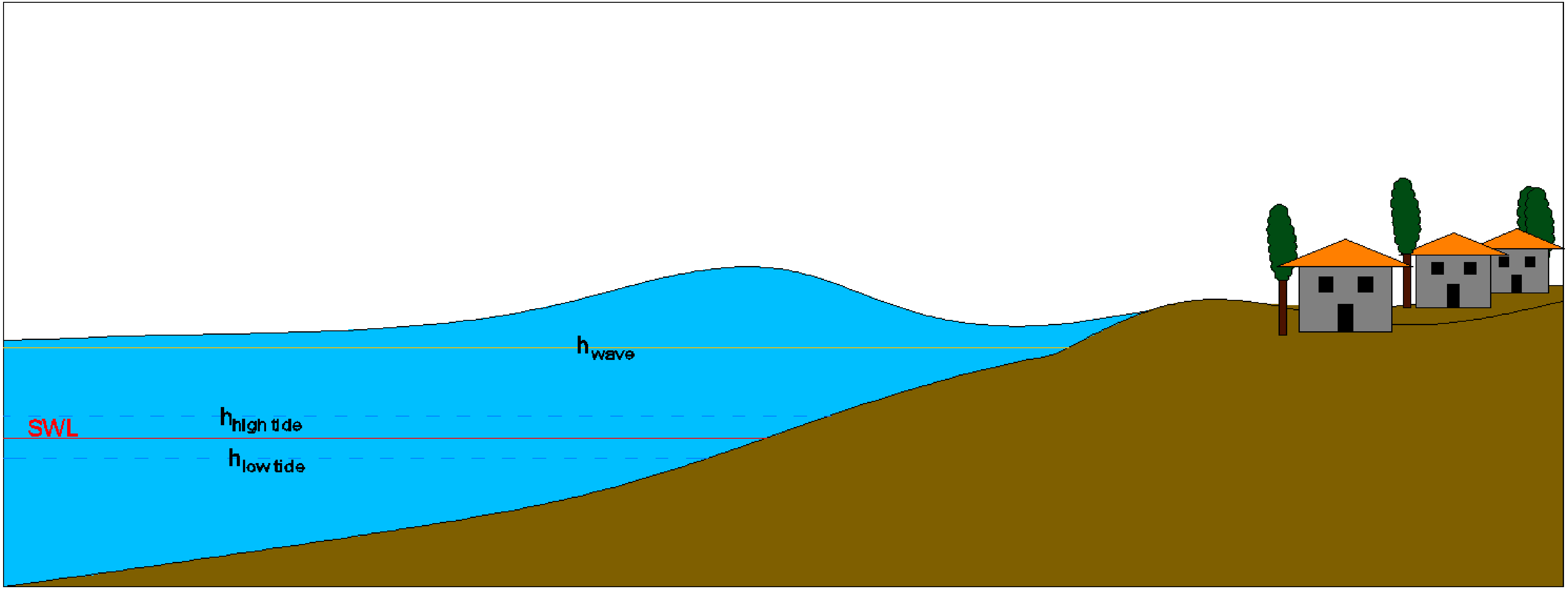
- Earthquakes
- Tsunami
- Tropical Cyclones, Hurricanes, Typhoons
- Storm and Storm Surge, Tornadoes
- Tides
- Sea Level Rise
- Swell
- Seiches and Resonance
- Freak Waves


SWL

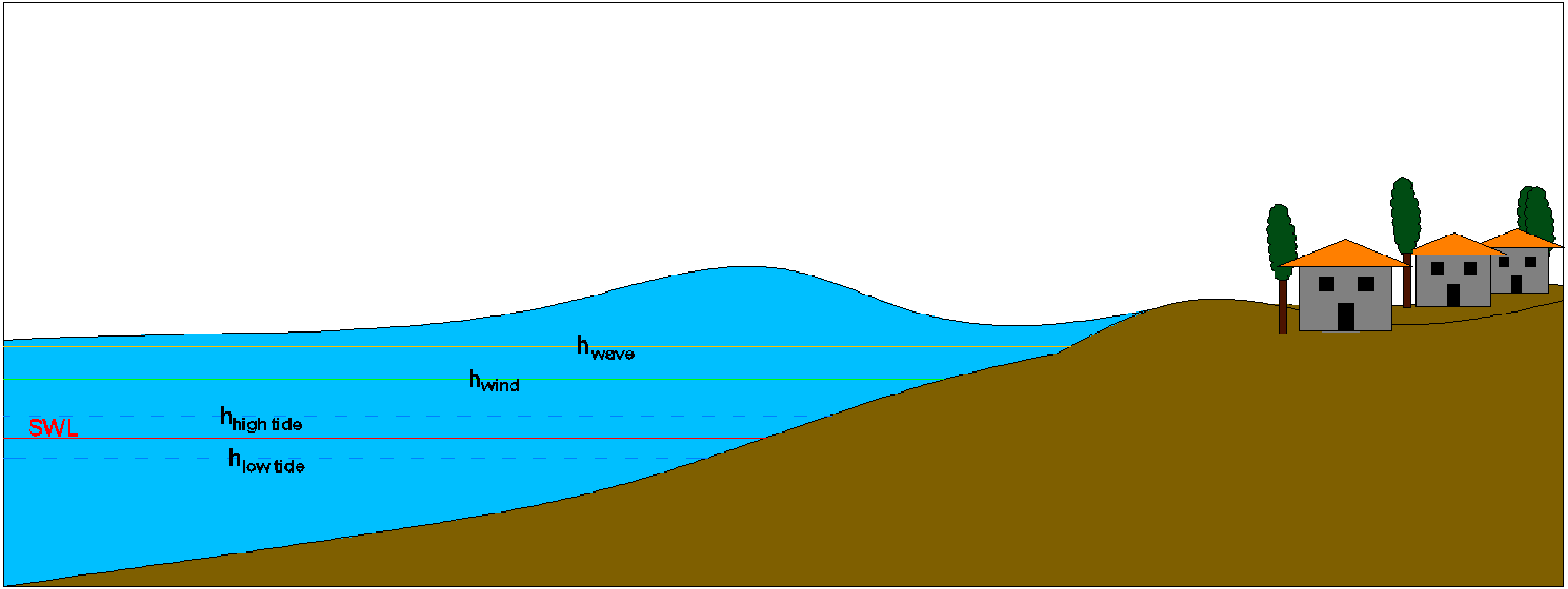

SWL
$h_{high\ tide}$
$h_{low\ tide}$



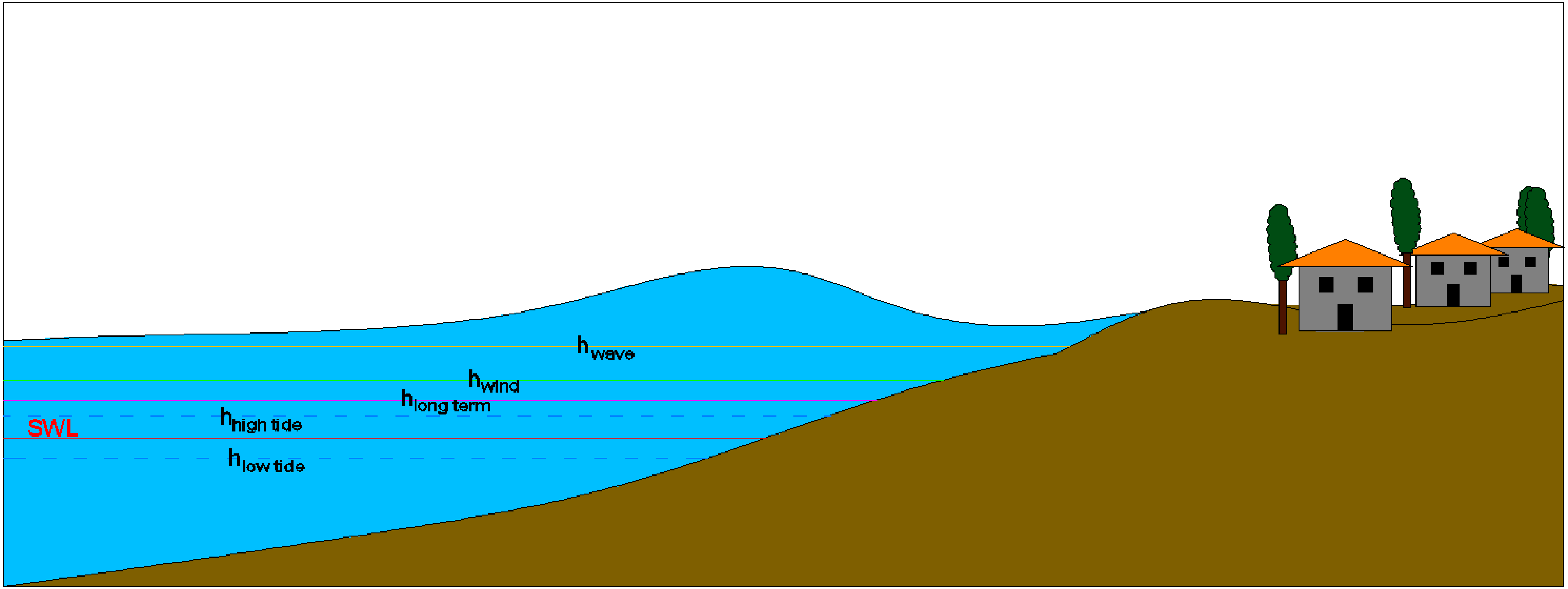
h_{wind}
$h_{high\ tide}$
SWL
$h_{low\ tide}$



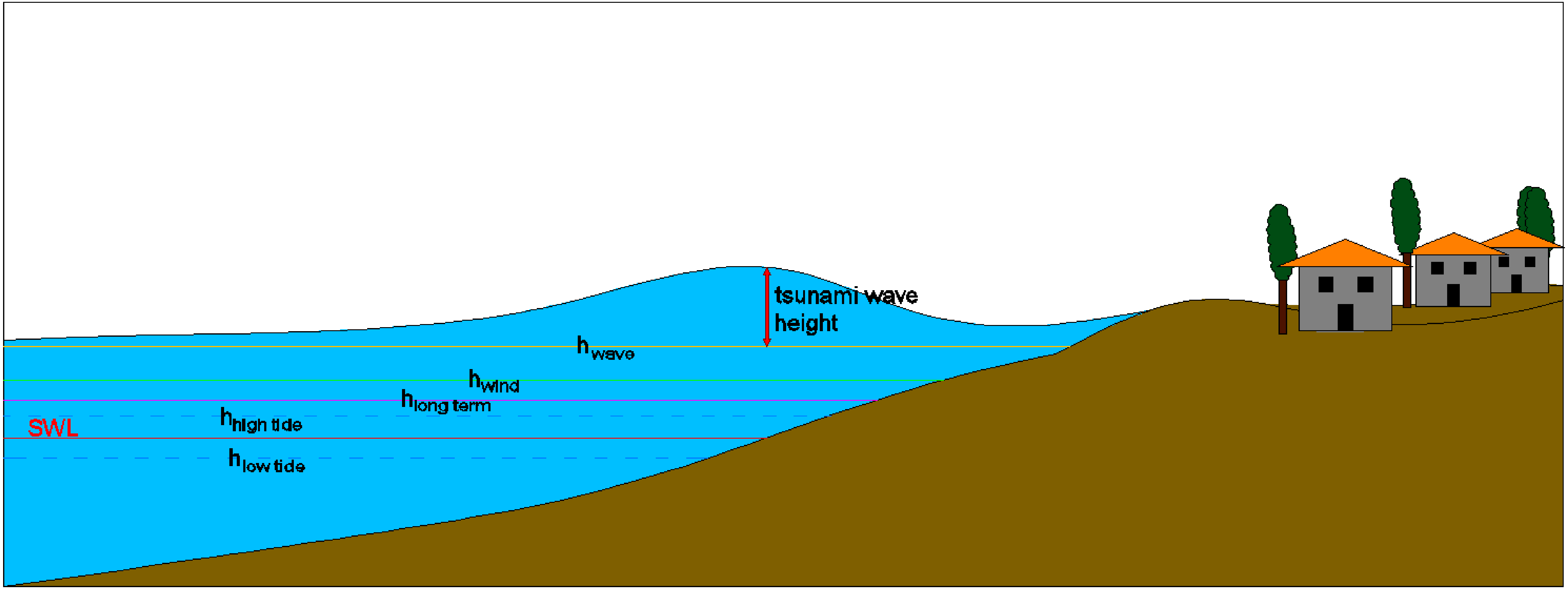
h wave
SWL
h high tide
h low tide

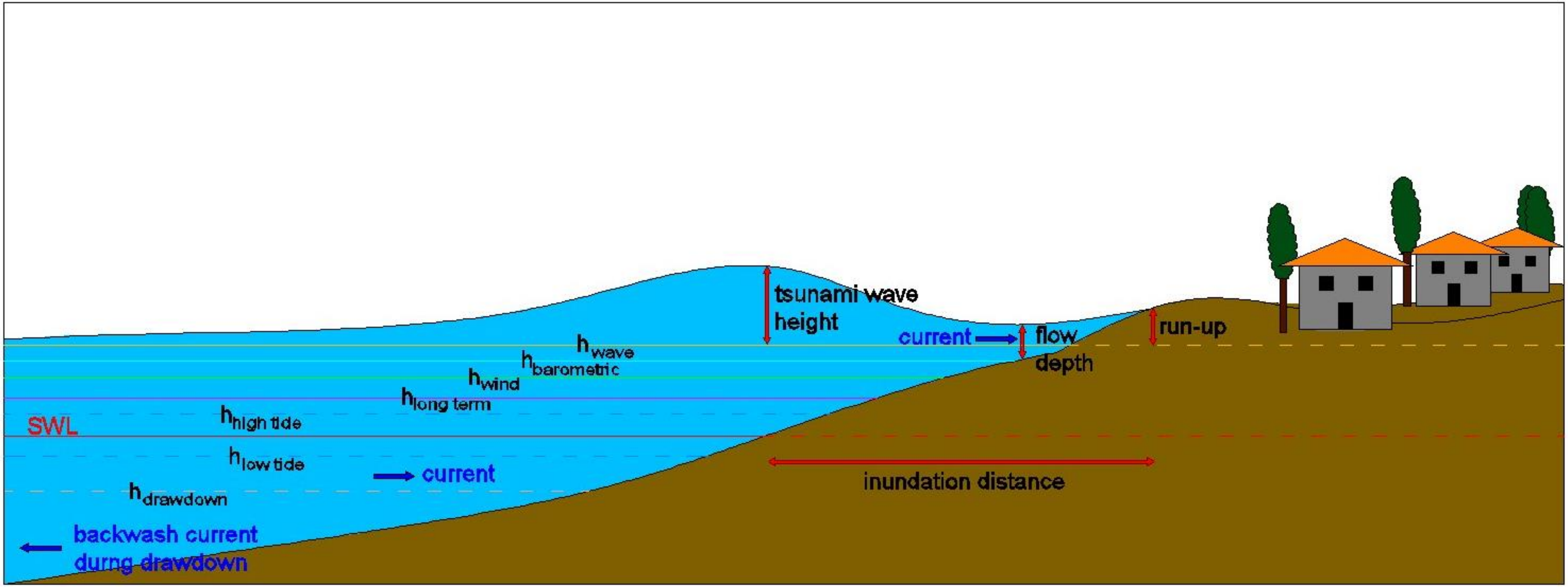


h_wave
h_wind
SWL
h_high tide
h_low tide



h_{wave}
h_{wind}
$h_{long\ term}$
$h_{high\ tide}$
SWL
$h_{low\ tide}$


tsunami wave
height
h_{wave}
h_{wind}
$h_{long\ term}$
SWL
$h_{high\ tide}$
$h_{low\ tide}$


tsunami wave height
current
flow depth
run-up
h wave
h barometric
h wind
h long term
h high tide
SWL
h low tide
current
inundation distance
h drawdown
backwash current durng drawdown

Hydrological Hazards

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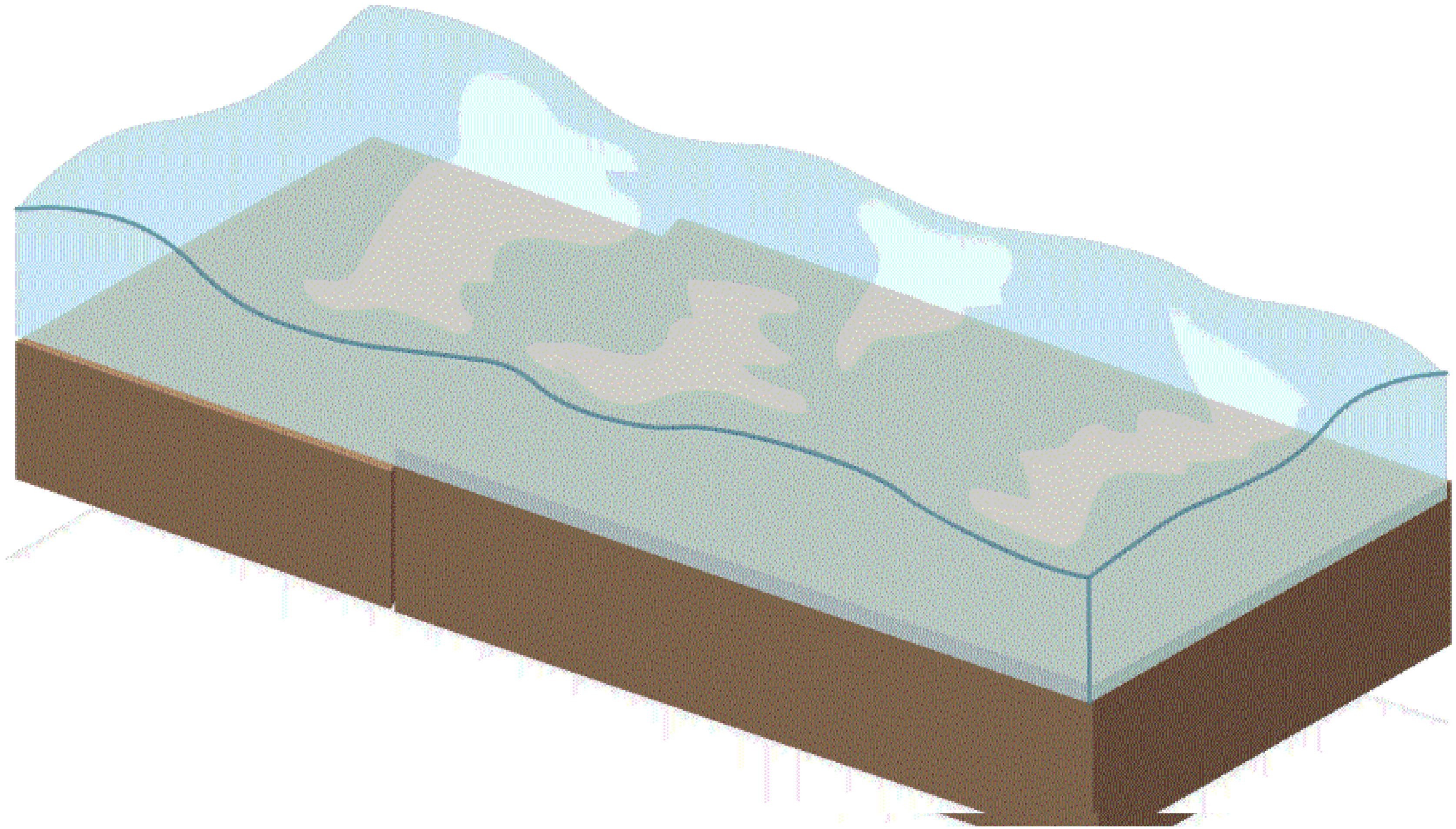
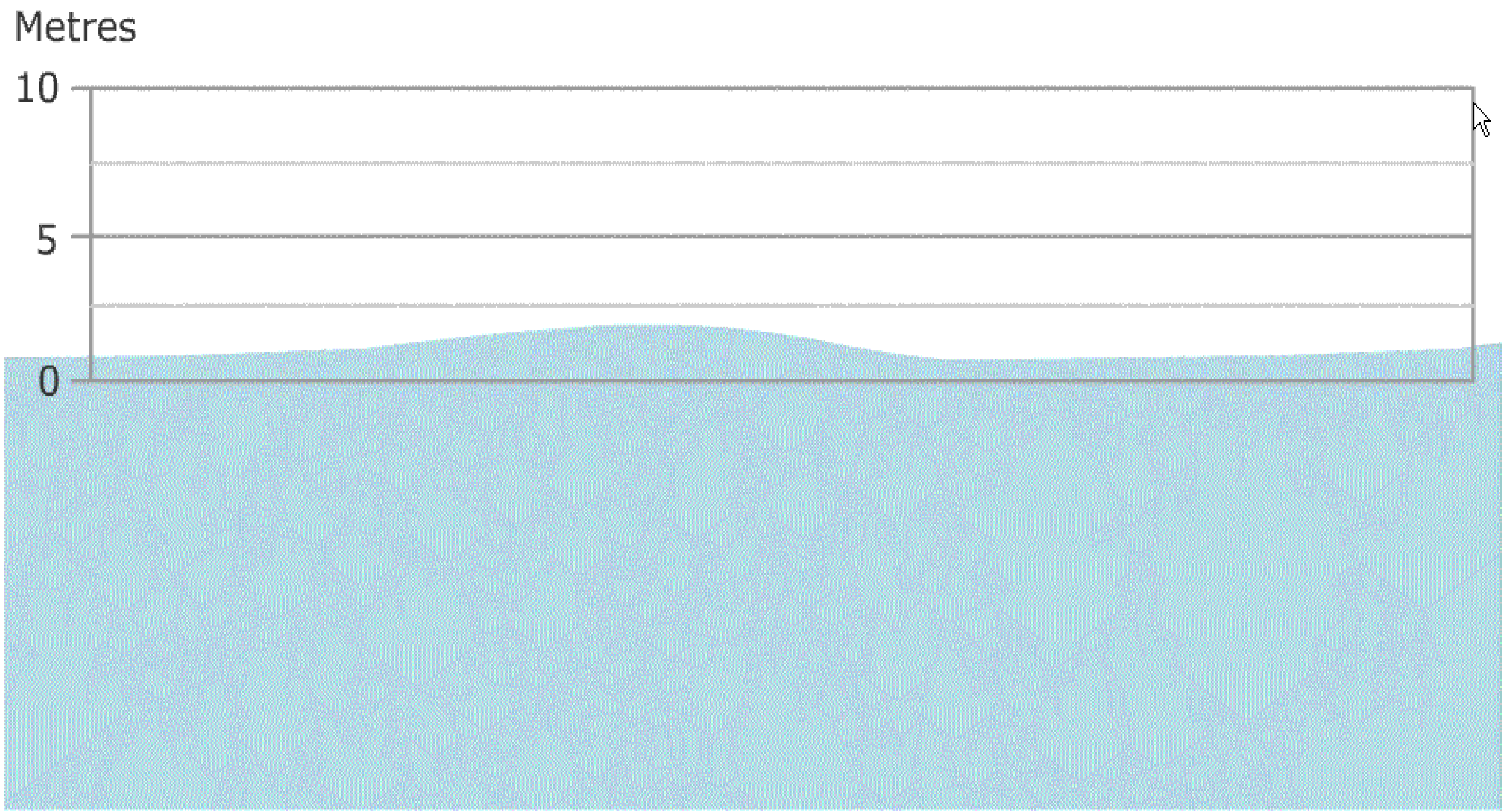
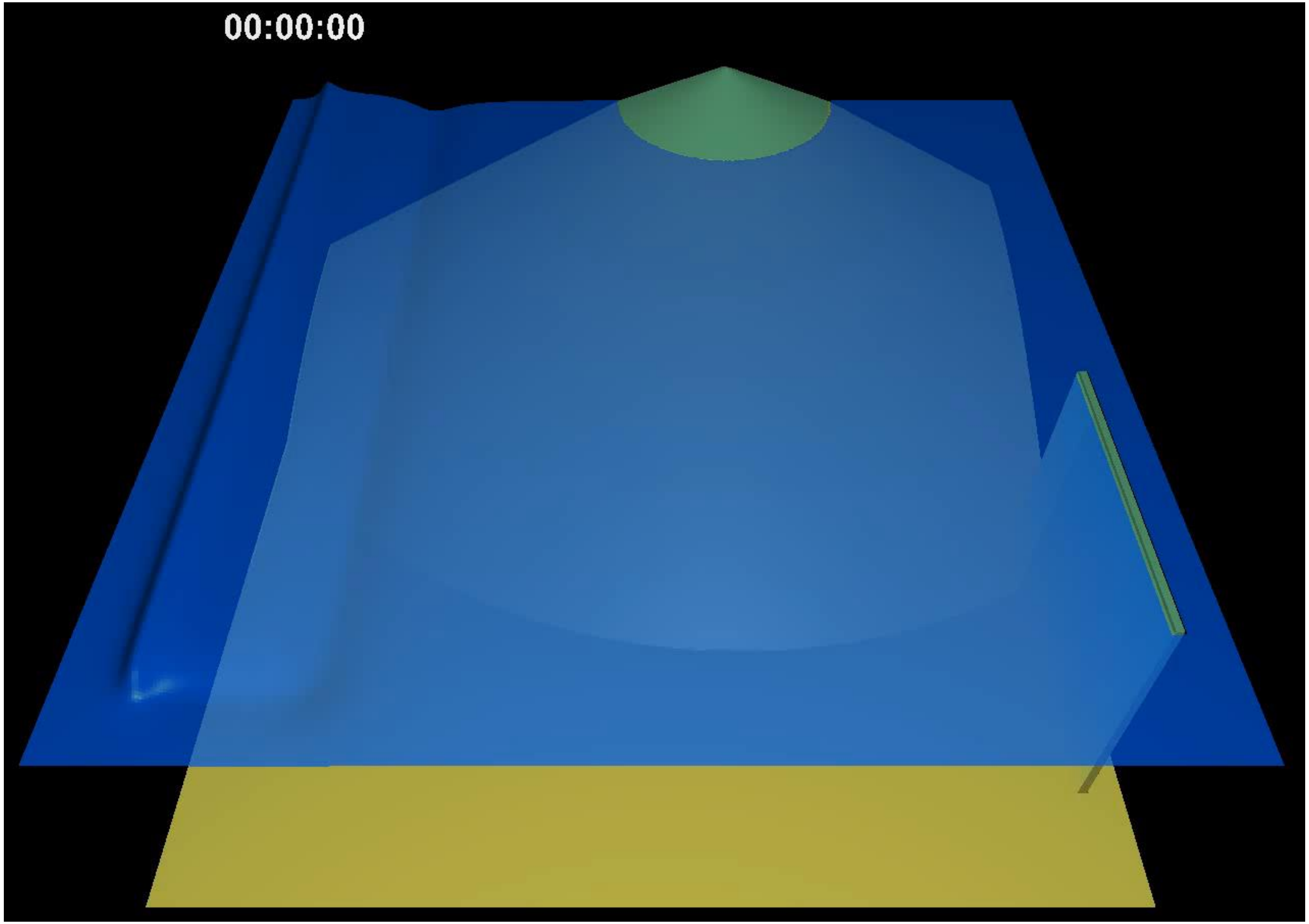
The tsunami formed when energy from the earthquake vertically jolted the seabed by several metres, displacing hundreds of cubic kilometres of water.



In deep water the tsunami moved at up to 800km/h (500mph). When it reached shallow water near coastal areas, the tsunami slowed but increased in height.

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Specific Terms (nearshore-inundation parameters):

Run-up: Vertical height a wave reaches above a reference sea level as it washes ashore.

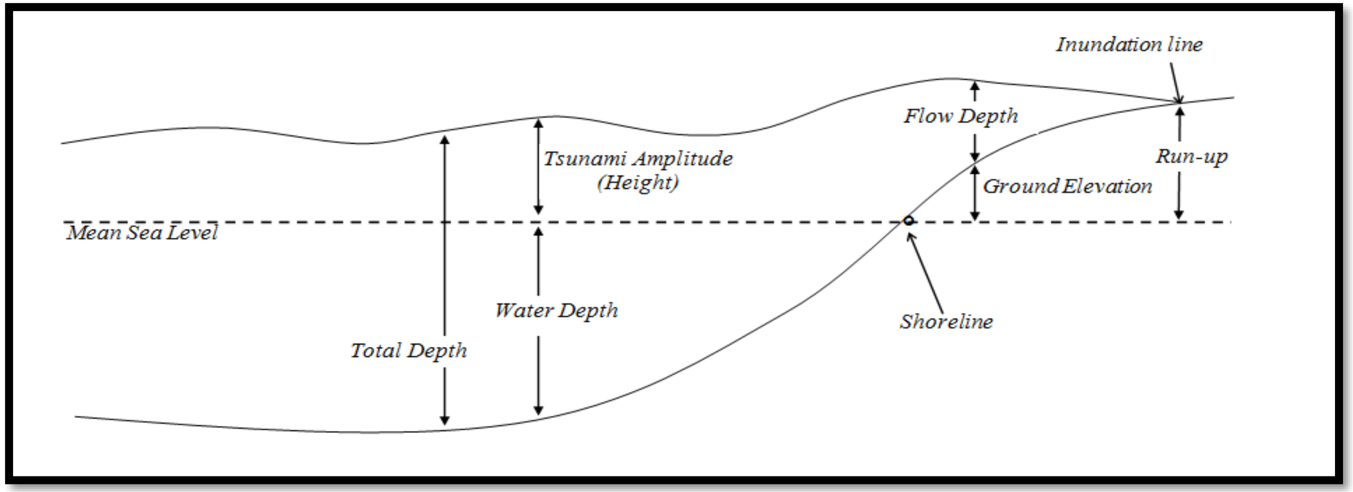
Wave height: Vertical measurement of the wave before it reaches shore.

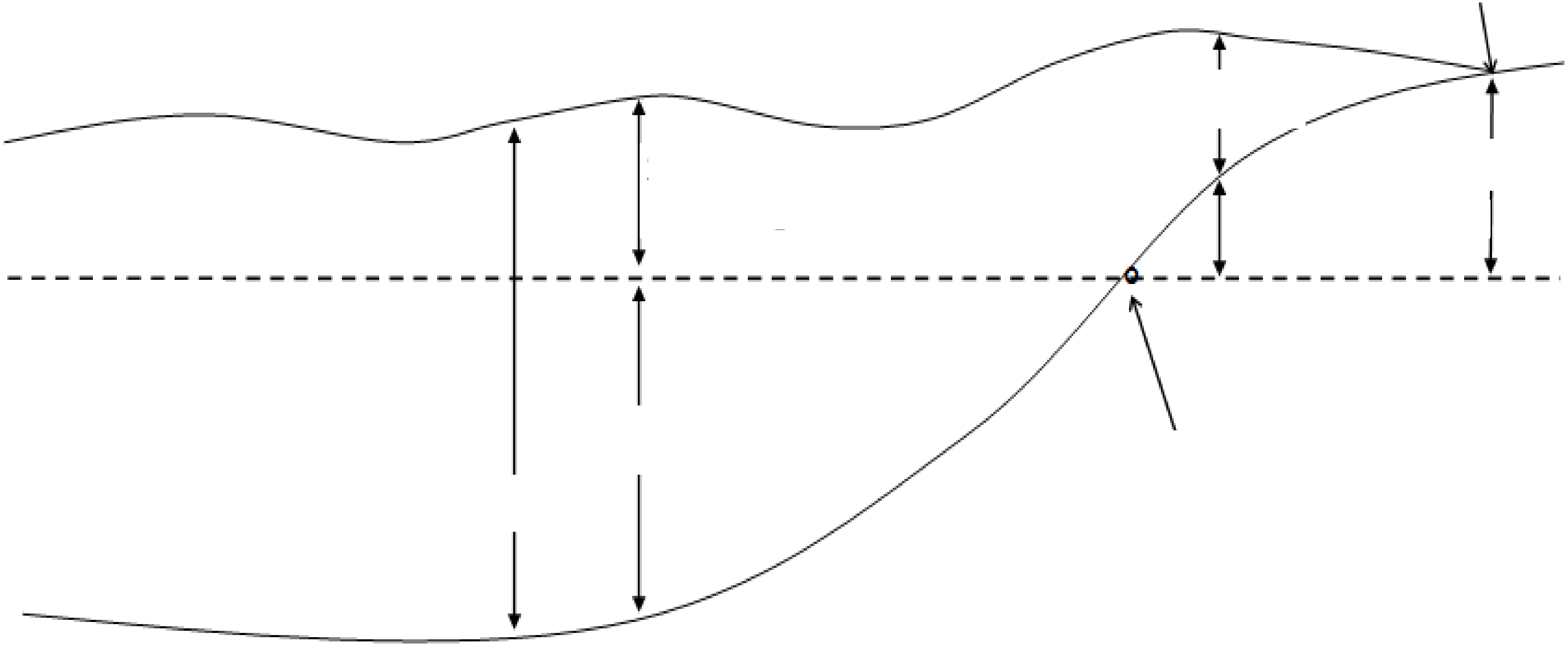
Flow Depth: Depth of the flow in inundation zone

Current velocity: Velocity of flow in inundation zone

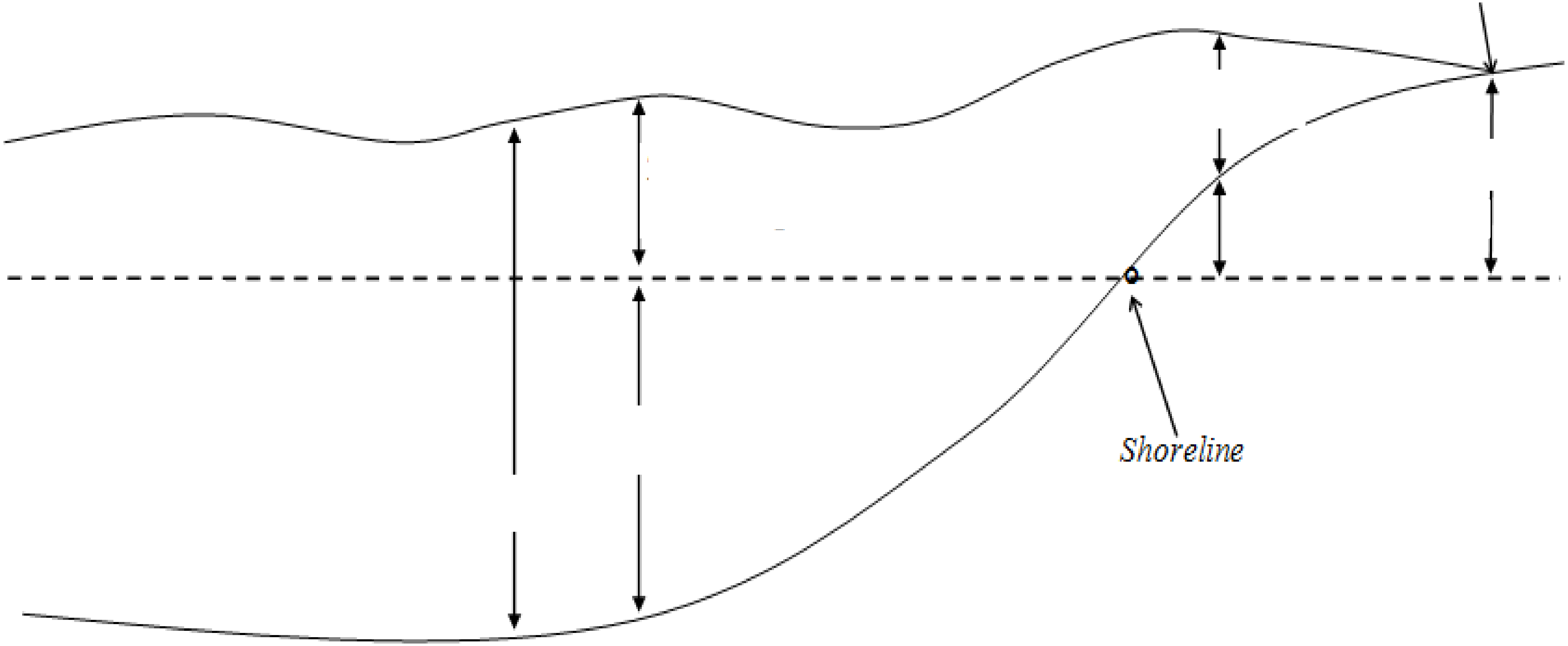
Inundation distance: Horizontal distance a tsunami reaches landward from shoreline.

Maximum negative Amplitude: The maximum level of sea level subsidence.





CROSS SECTIONAL VIEW OF INUNDATION AND NEARSHORE TSUNAMI AND TROPICAL CYCLONE PARAMETERS



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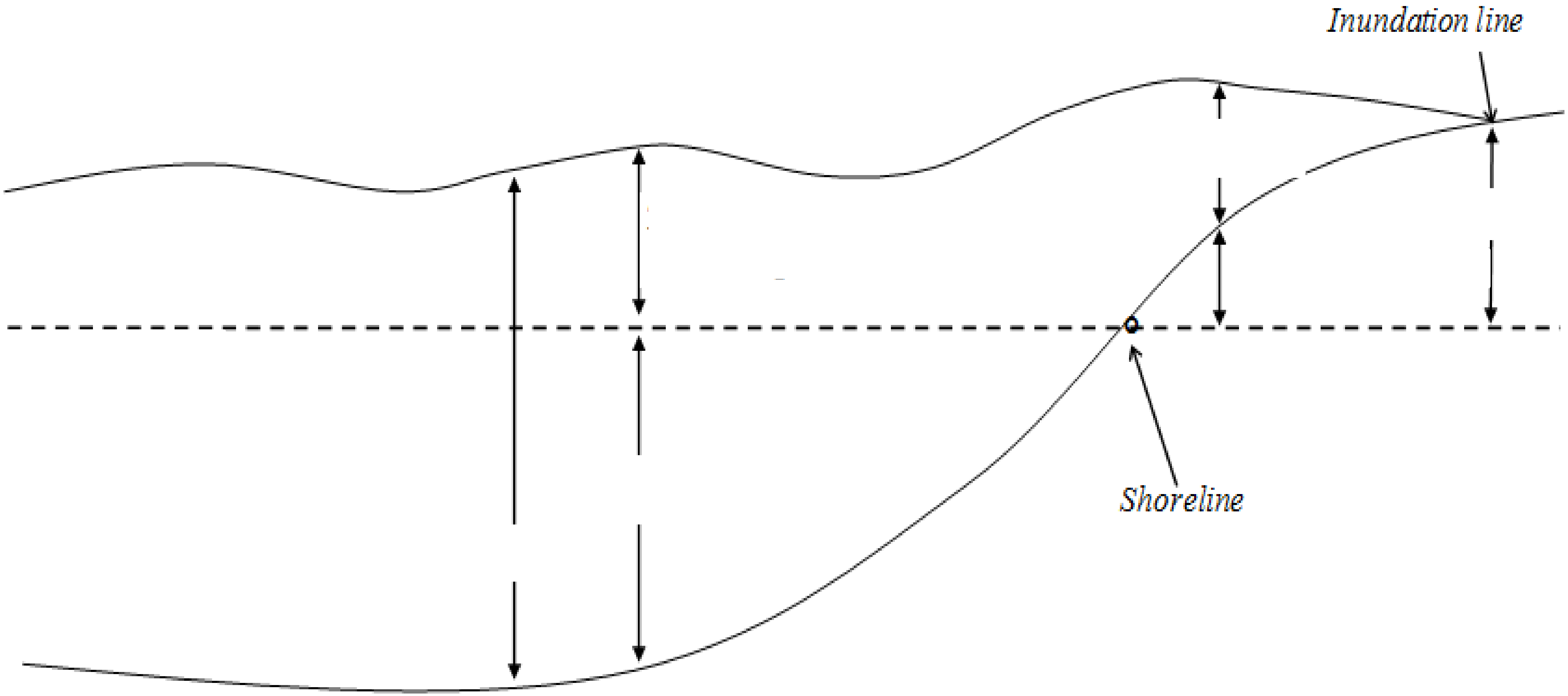

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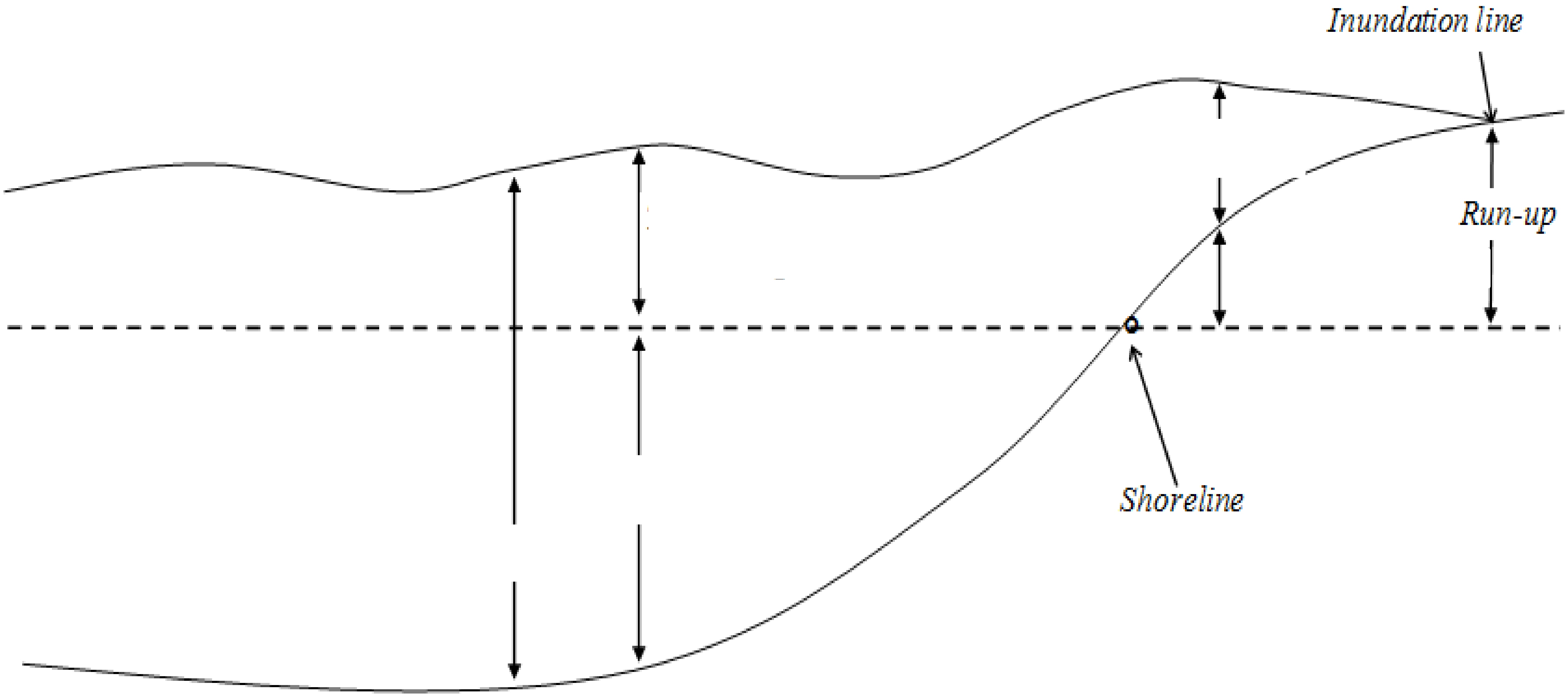

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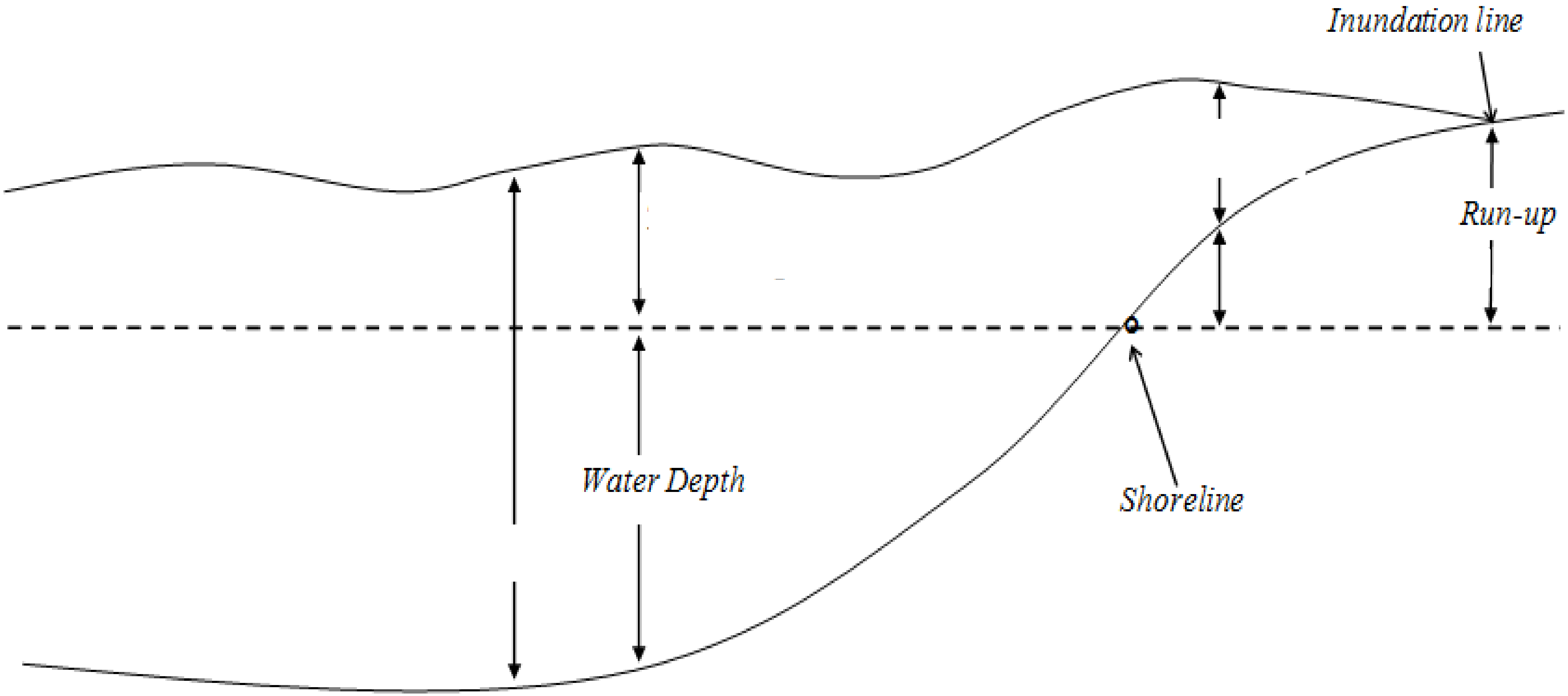
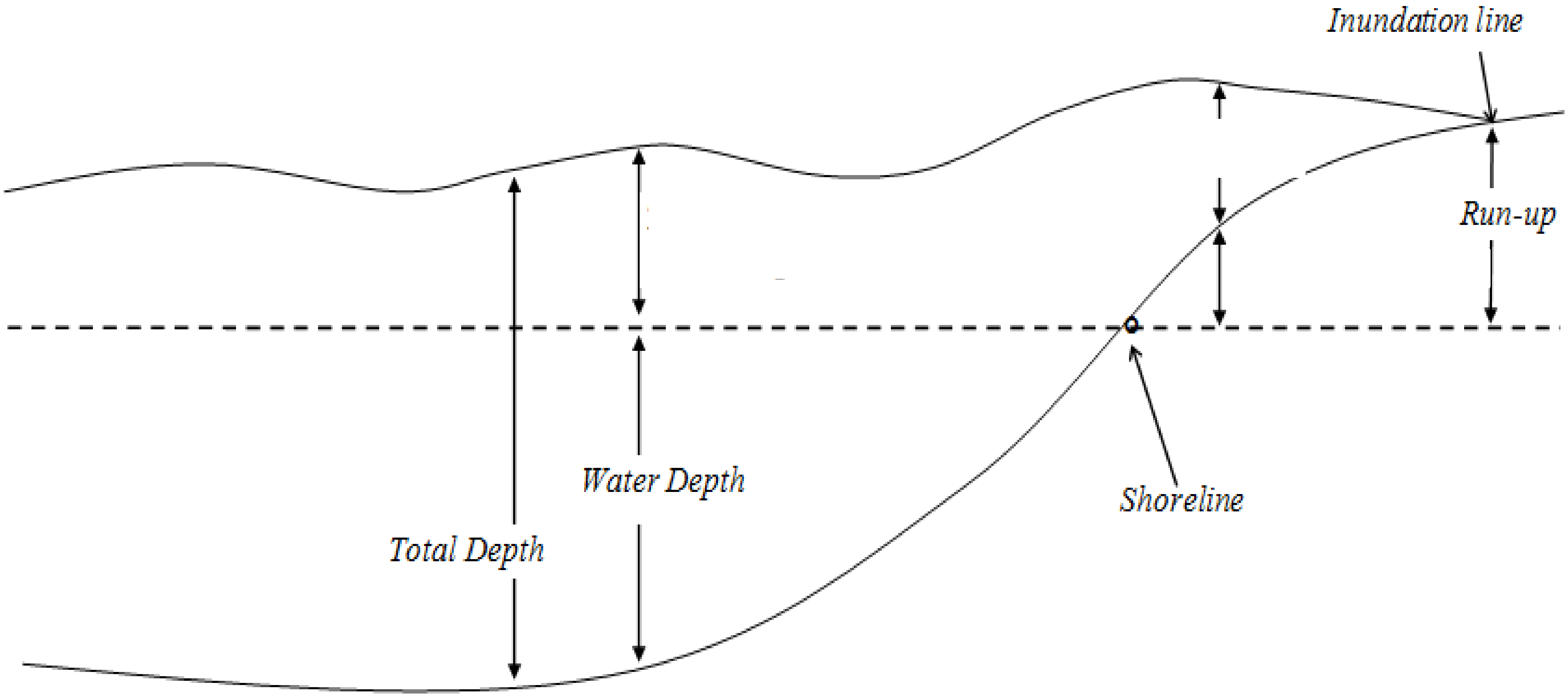


CROSS SECTIONAL VIEW OF INUNDATION AND NEARSHORE TSUNAMI AND TROPICAL CYCLONE PARAMETERS



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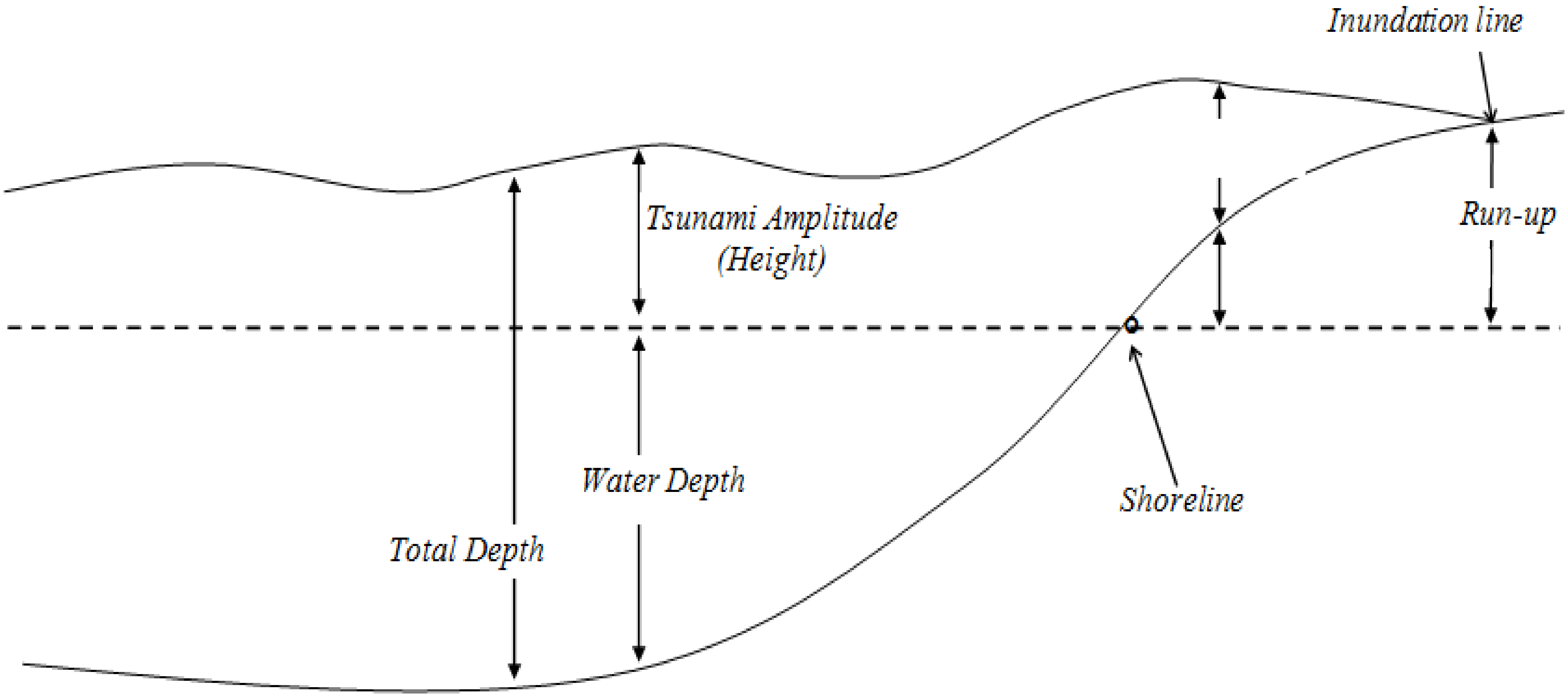

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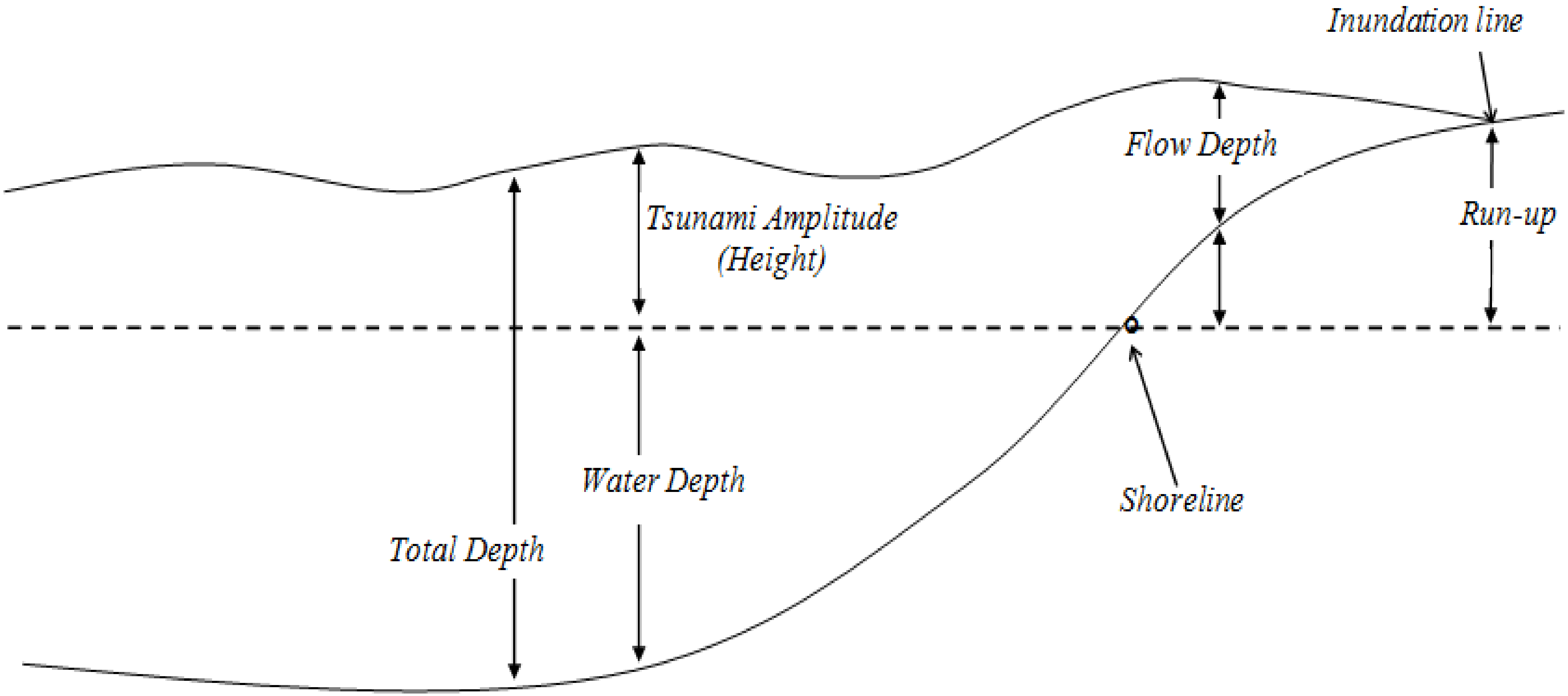

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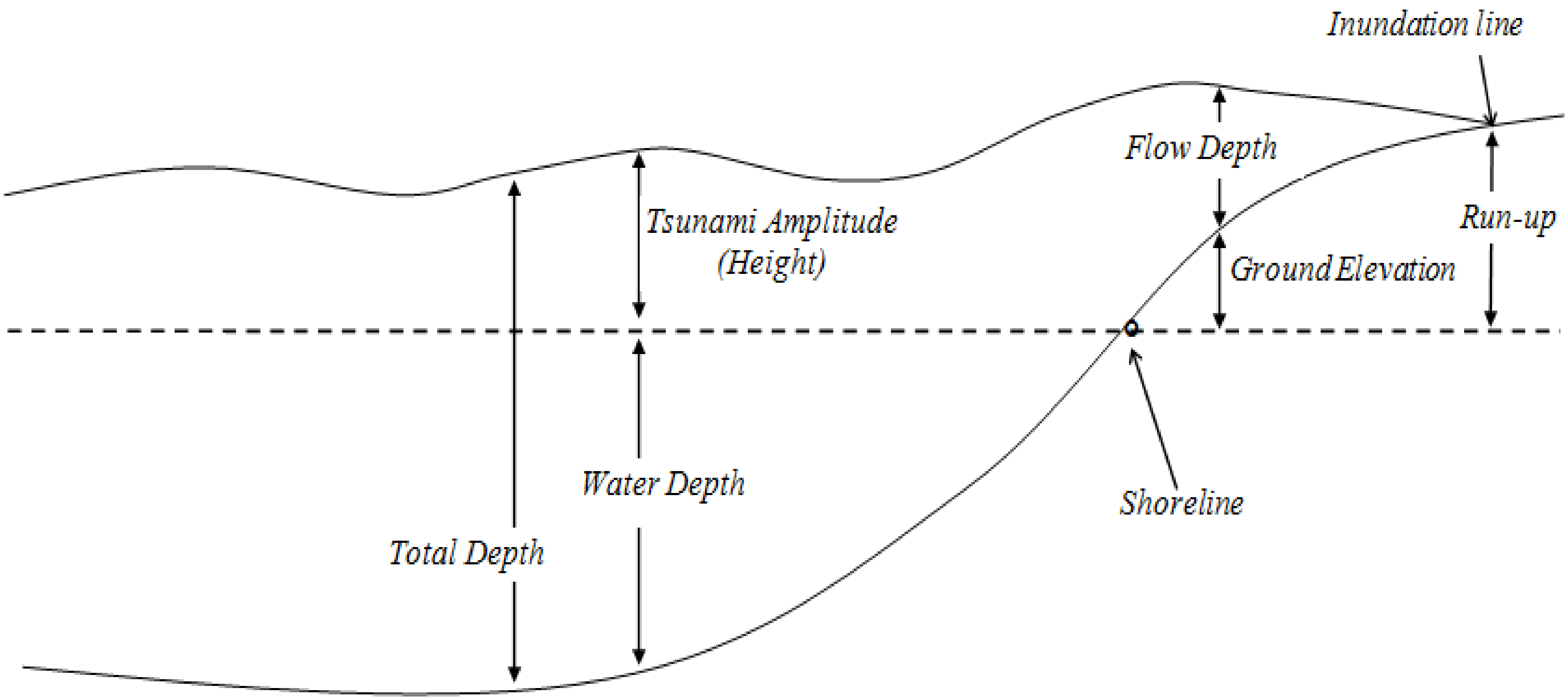

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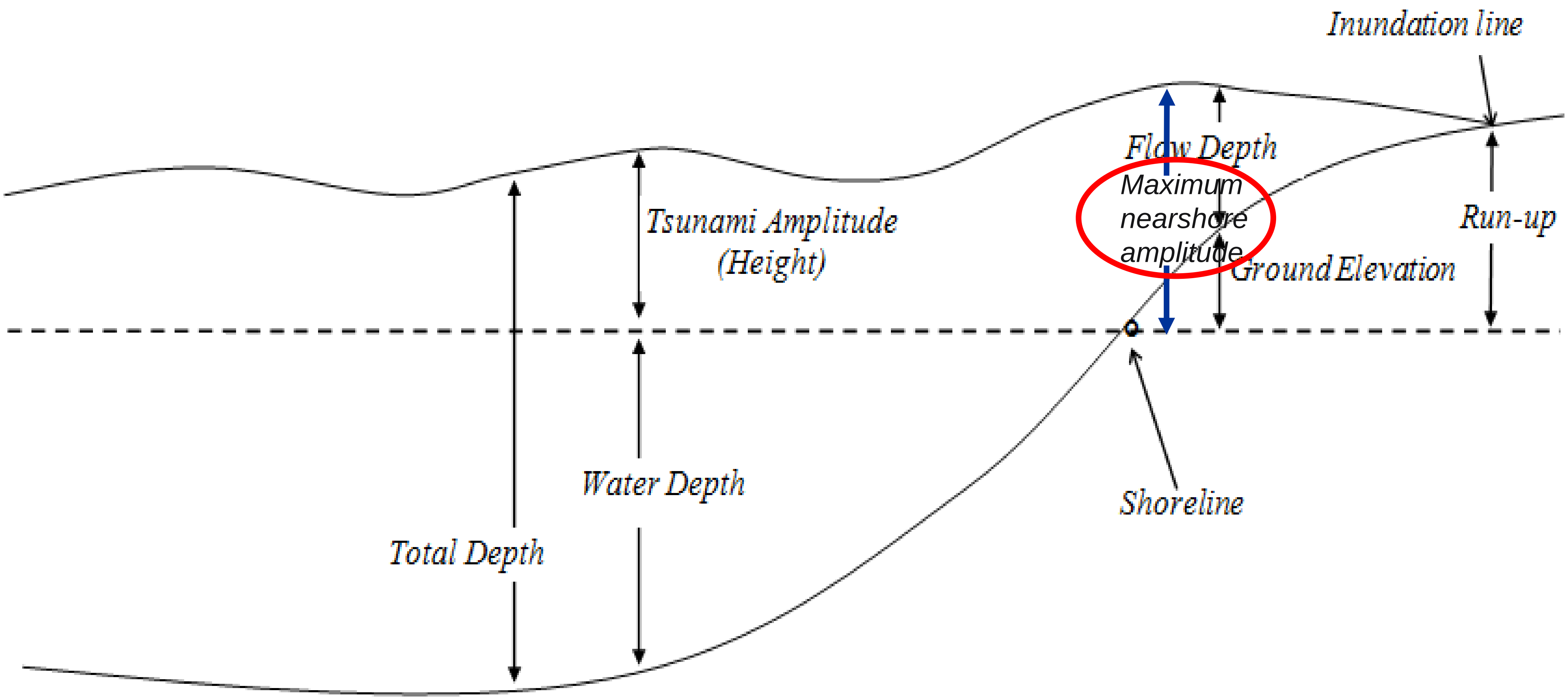

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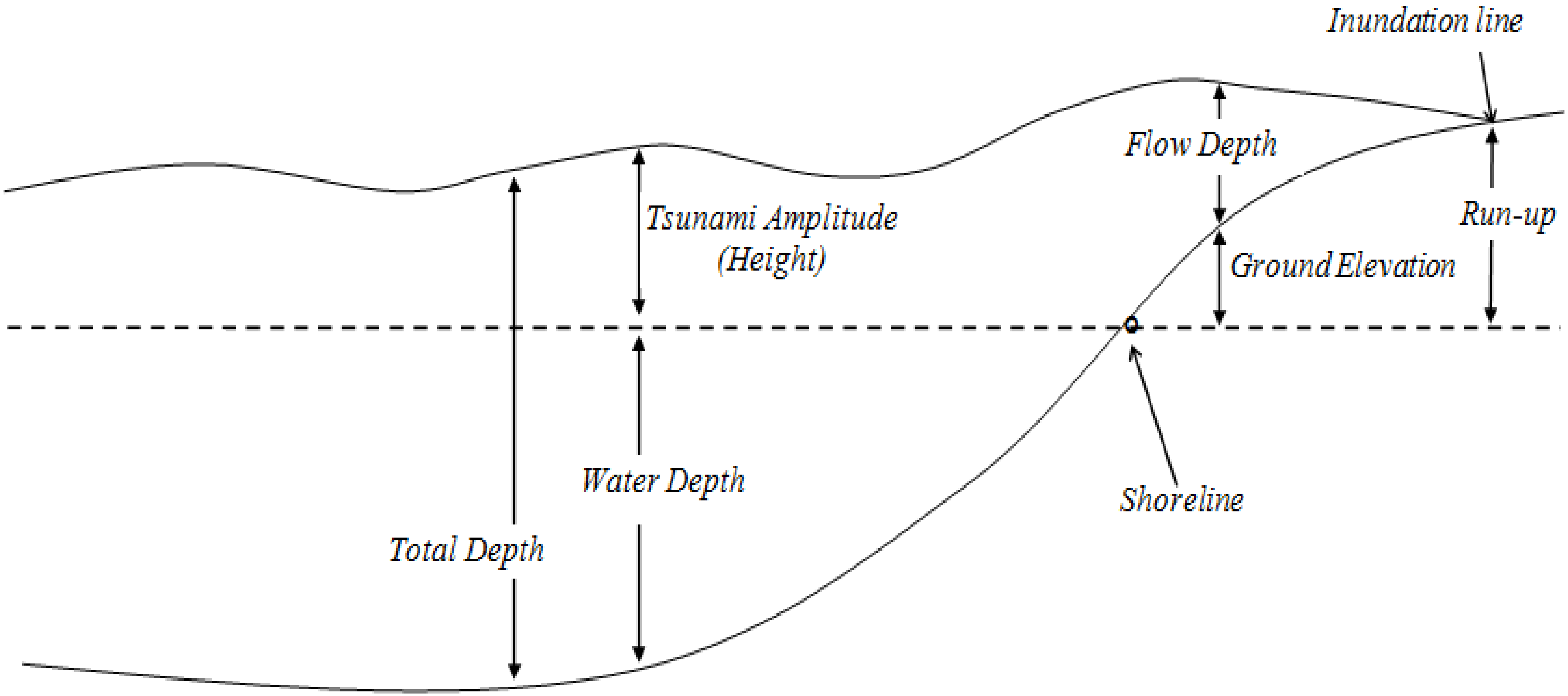

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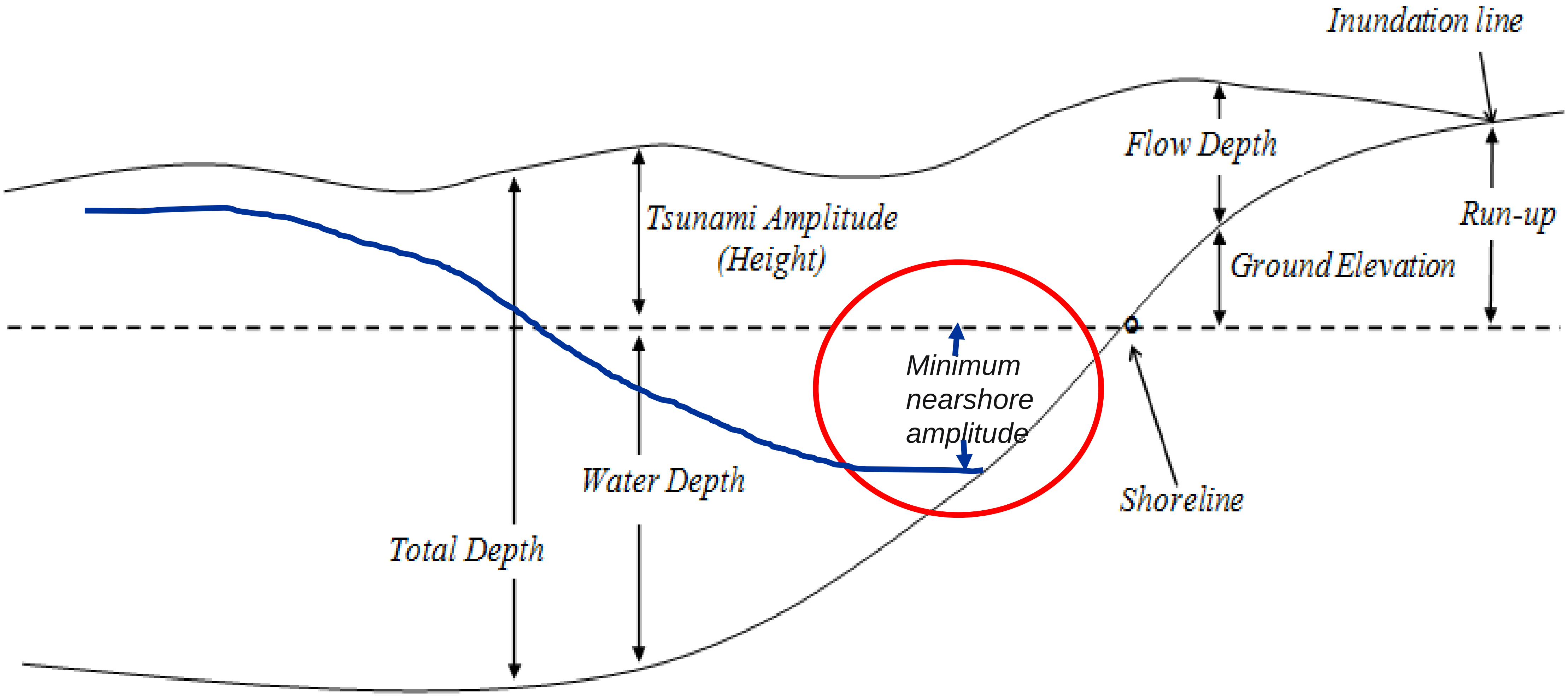

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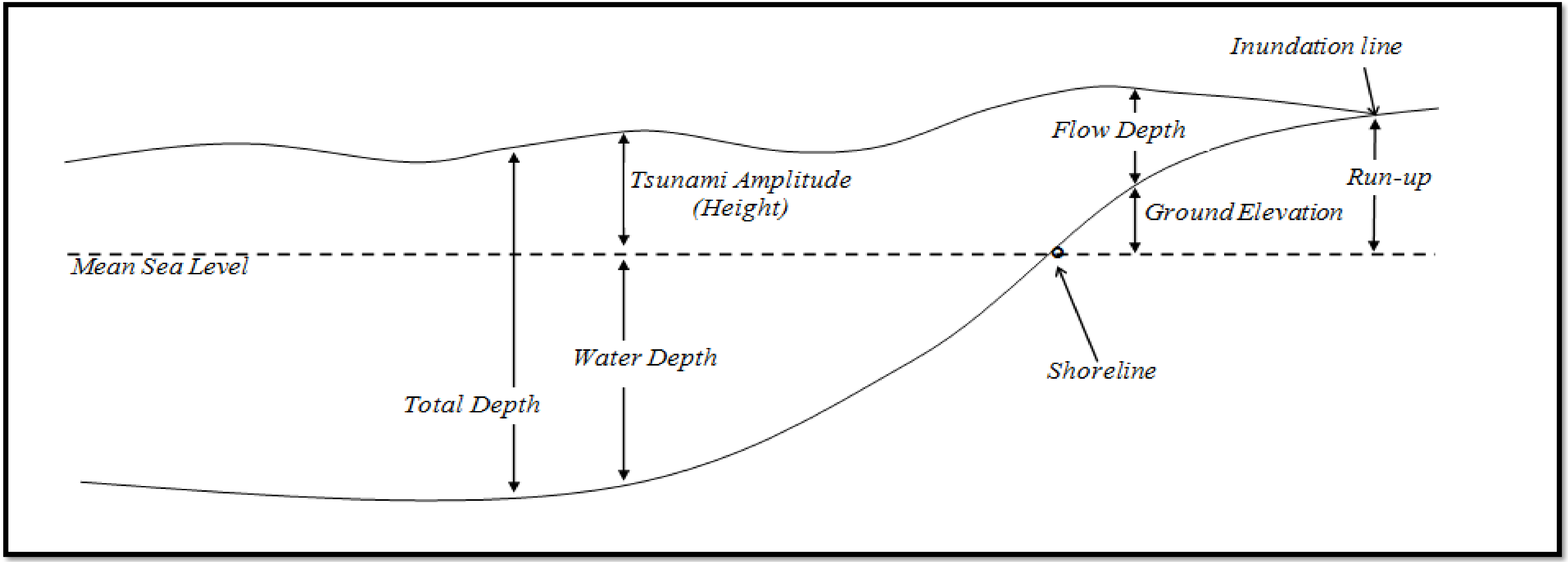
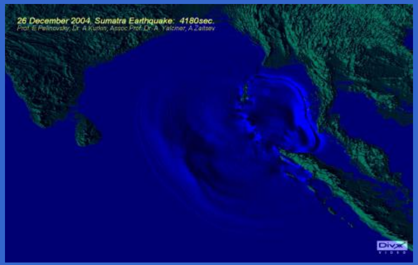
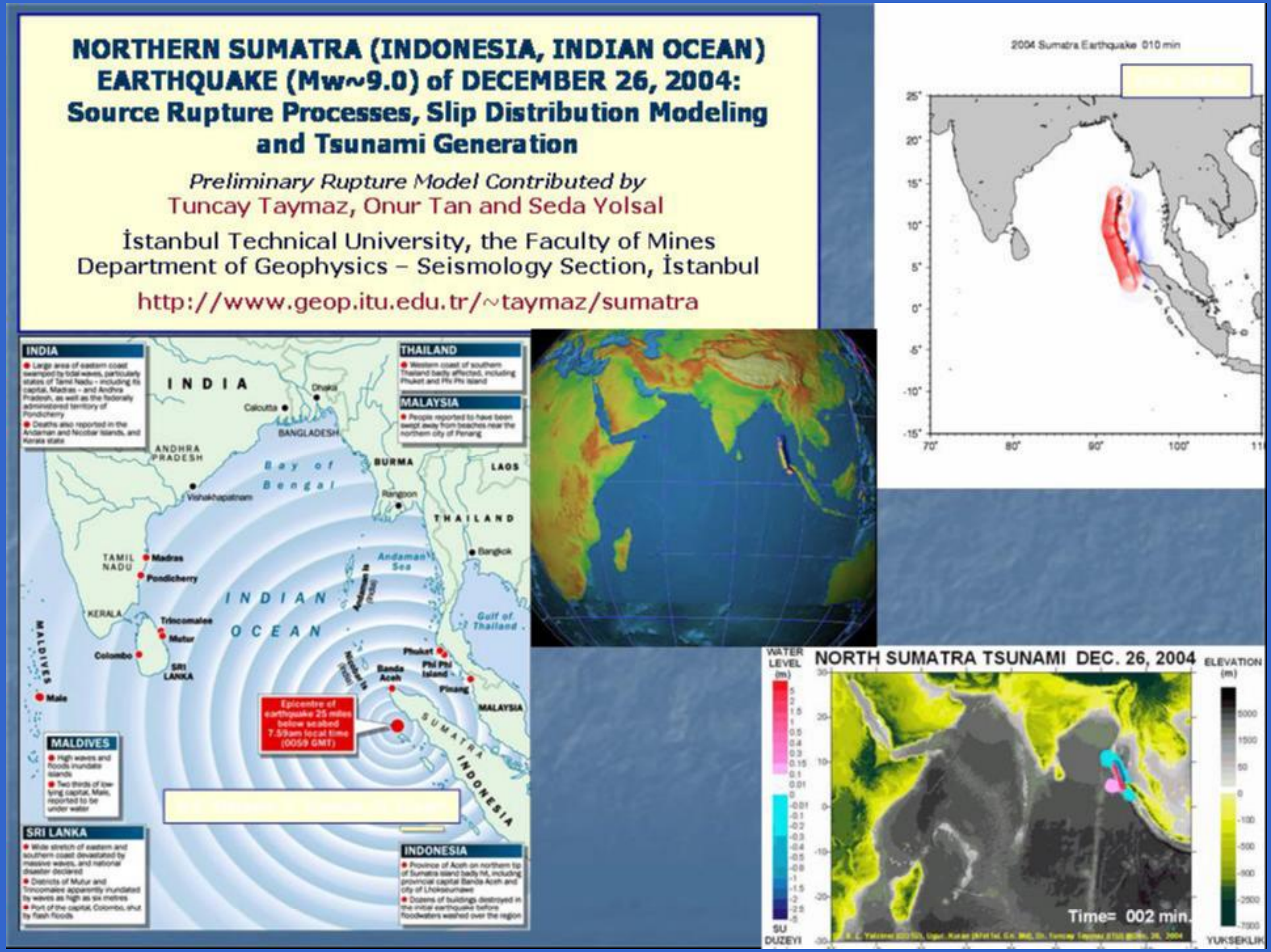


Inundation line
Flow Depth
Tsunami Amplitude (Height)
Run-up
Ground Elevation
Mean Sea Level
Water Depth
Shoreline
Total Depth



BEFORE

AFTER



DATE MARK

December 26, 2004

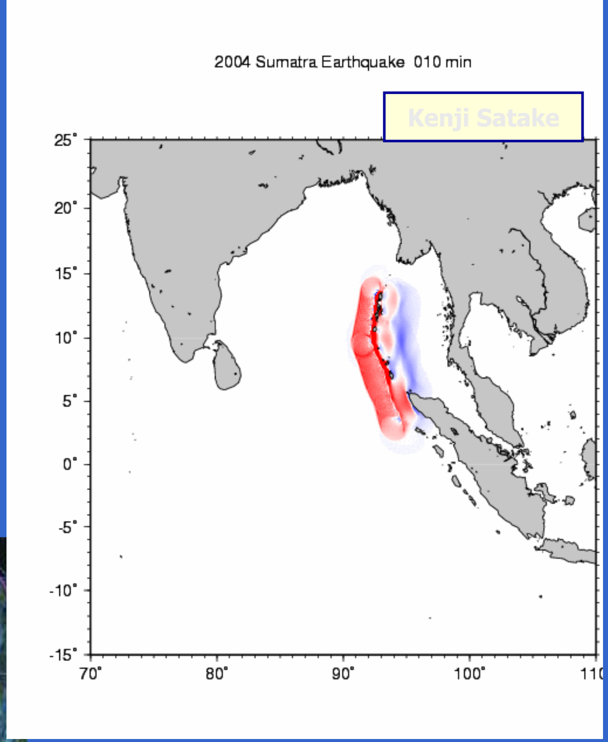
NORTHERN SUMATRA (INDONESIA, INDIAN OCEAN) EARTHQUAKE (Mw~9.0) of DECEMBER 26, 2004: Source Rupture Processes, Slip Distribution Modeling and Tsunami Generation

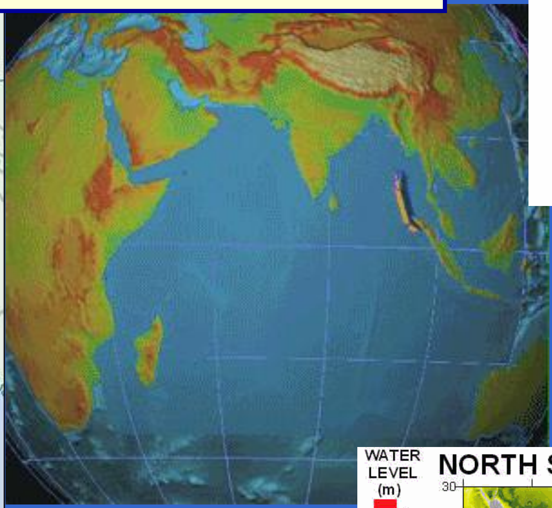
Preliminary Rupture Model Contributed by

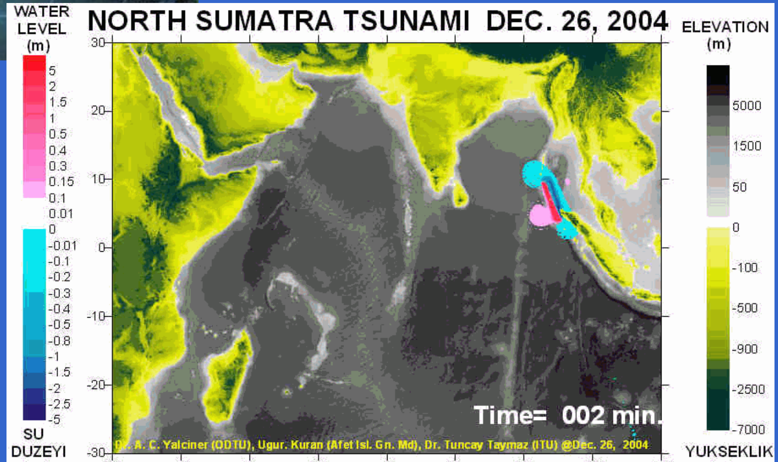
Tuncay Taymaz, Onur Tan and Seda Yolsal

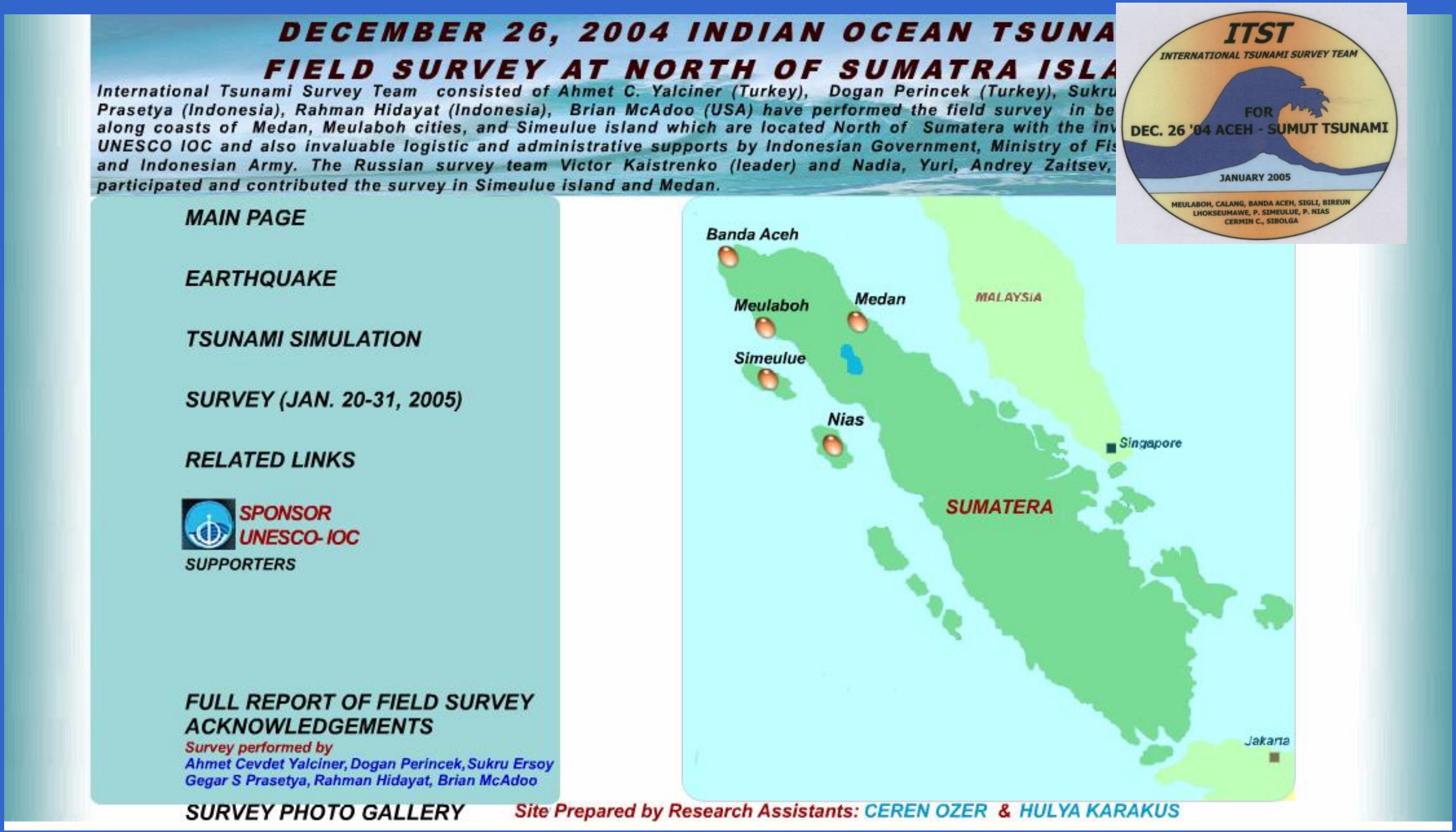
İstanbul Technical University, the Faculty of Mines
Department of Geophysics – Seismology Section, İstanbul

http://www.geop.itu.edu.tr/~taymaz/sumatra









UNESCO IOC POST TSUNAMI FIELD SURVEY SUMATRA

January 15-30, 2005 Medan, Simeulue and Meulaboh

http://yalciner.ce.metu.edu.tr/sumatra/survey


04º 07.740” N 96º 07.738” E

Meulaboh Port and Coastal Structures after tsunami


04º 07.740” N 96º 07.738” E

December 26, 2004 Indian Ocean Tsunami

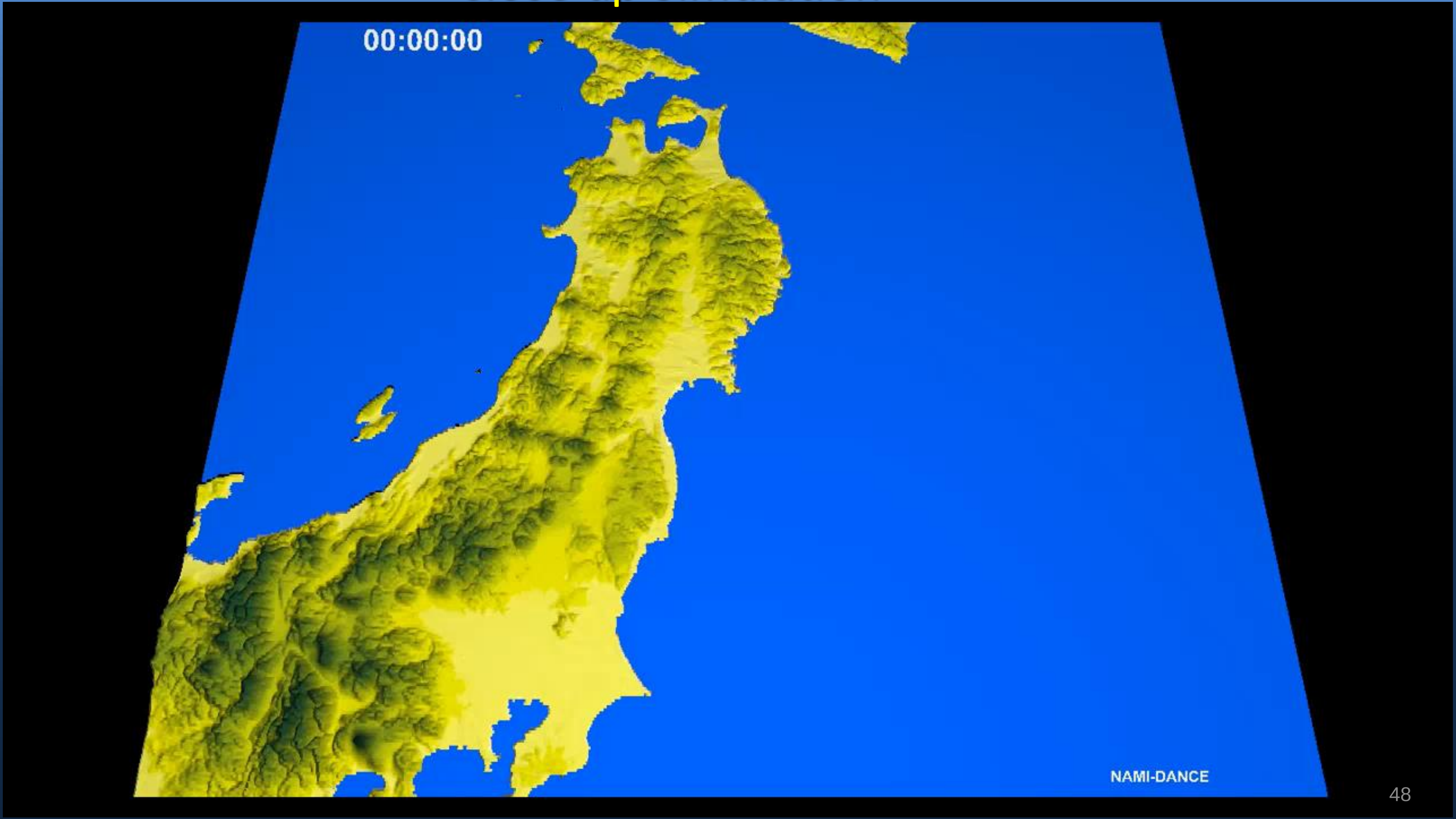
Prof.E.Pelinovsky;Dr.A.Kurkin;A.Zaitsev;Assoc.Prof.Dr.A.Yalciner; : 0sec.

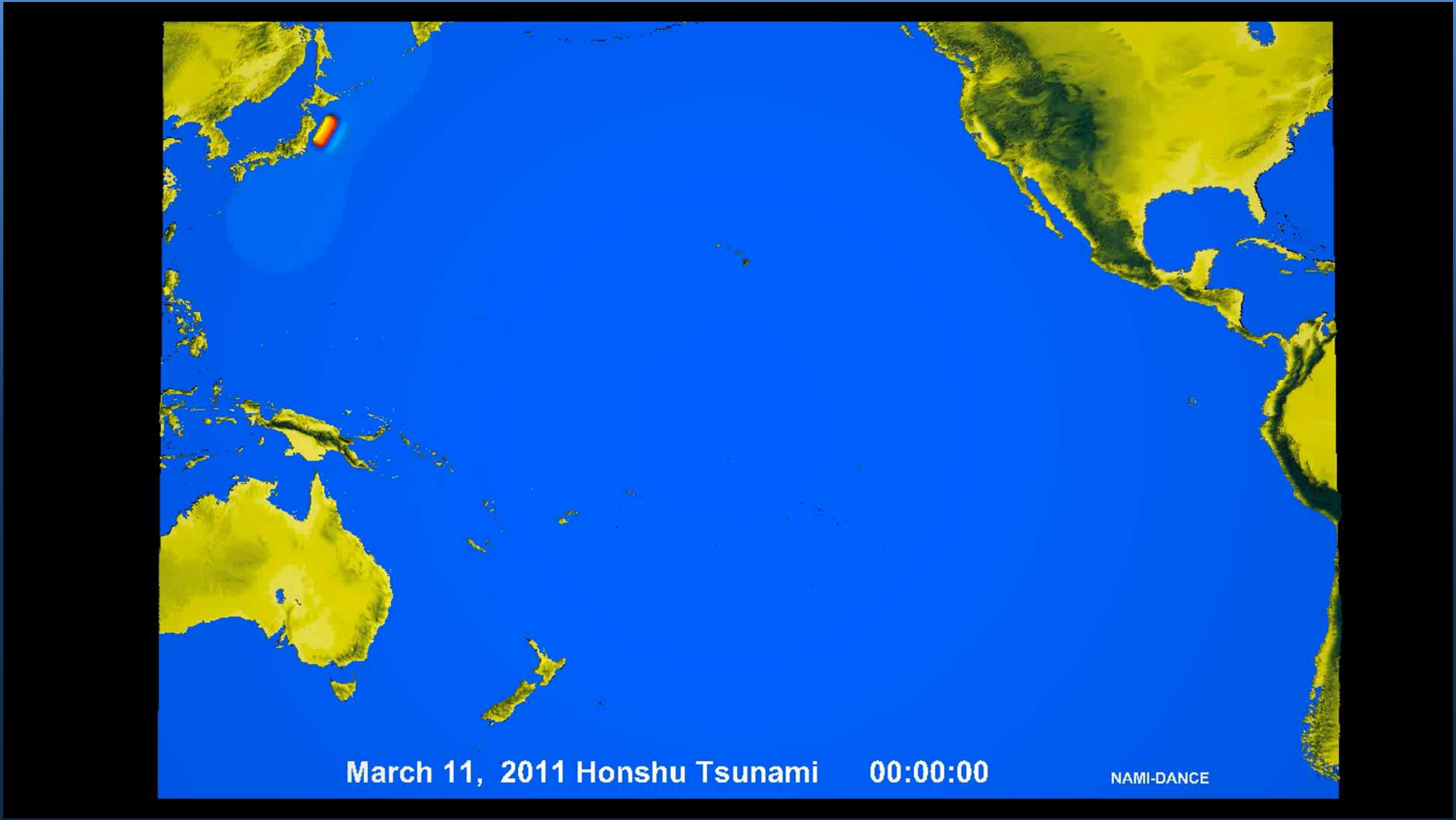
MEGA TSUNAMIS IN JAPAN

- 869 JOGAN TSUNAMI
- 1611 KEICHO TSUNAMI
- 1896 MEIJI TSUNAMI
- 1933 SHOWA TSUNAMI
- 1960 SHIZUKAWA TSUNAMI (CHILE EARTHQUAKE)

- 2011 GREAT EAST JAPAN EARTHQUAKE AND TSUNAMI

Close up Simulation




March 11, 2011 Honshu Tsunami
00:00:00
NAMI-DANCE

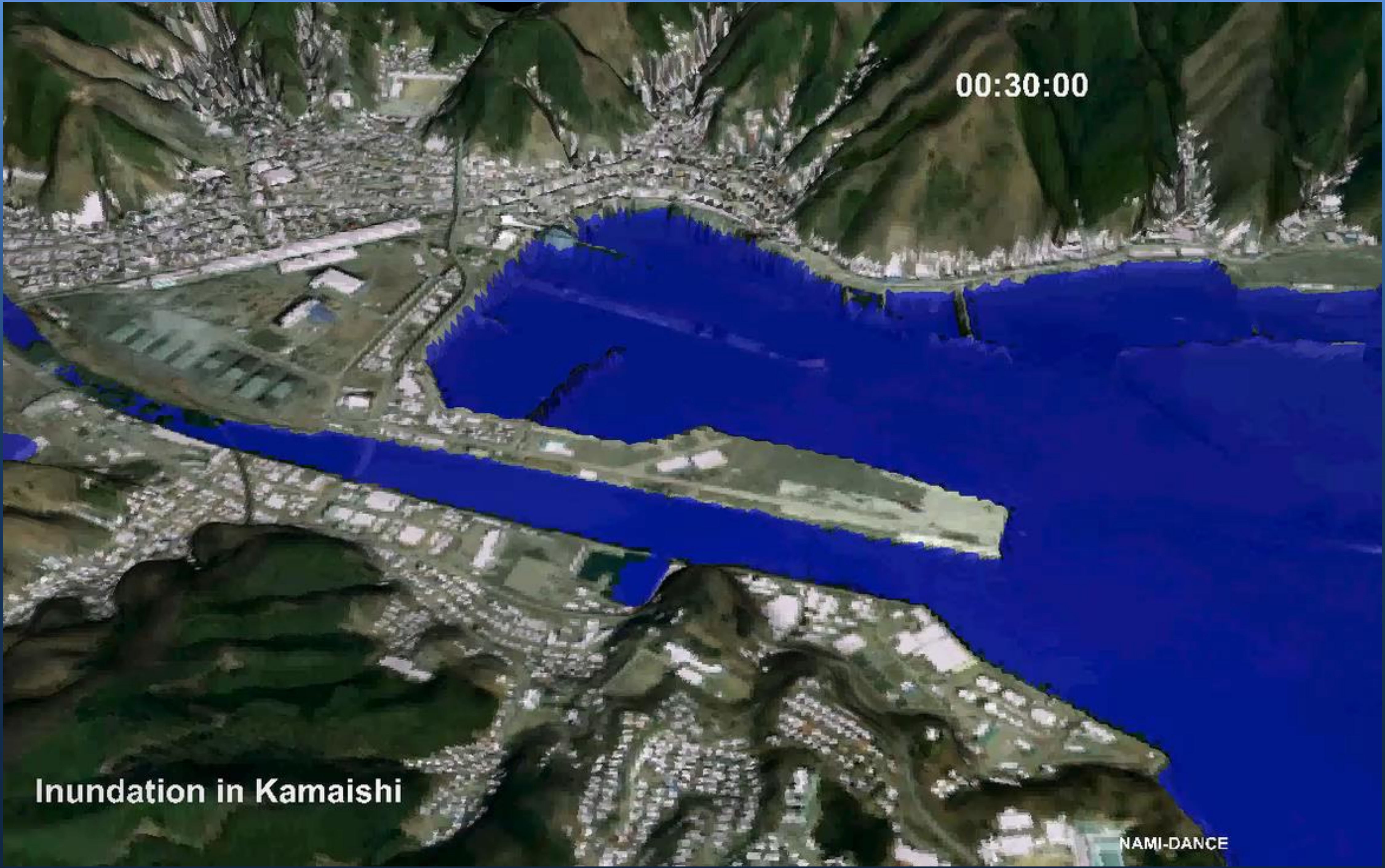
ARAHAMA-SENDAI


BBC
ANN


MIYAKO


BBC
ANN

KAMAISHI

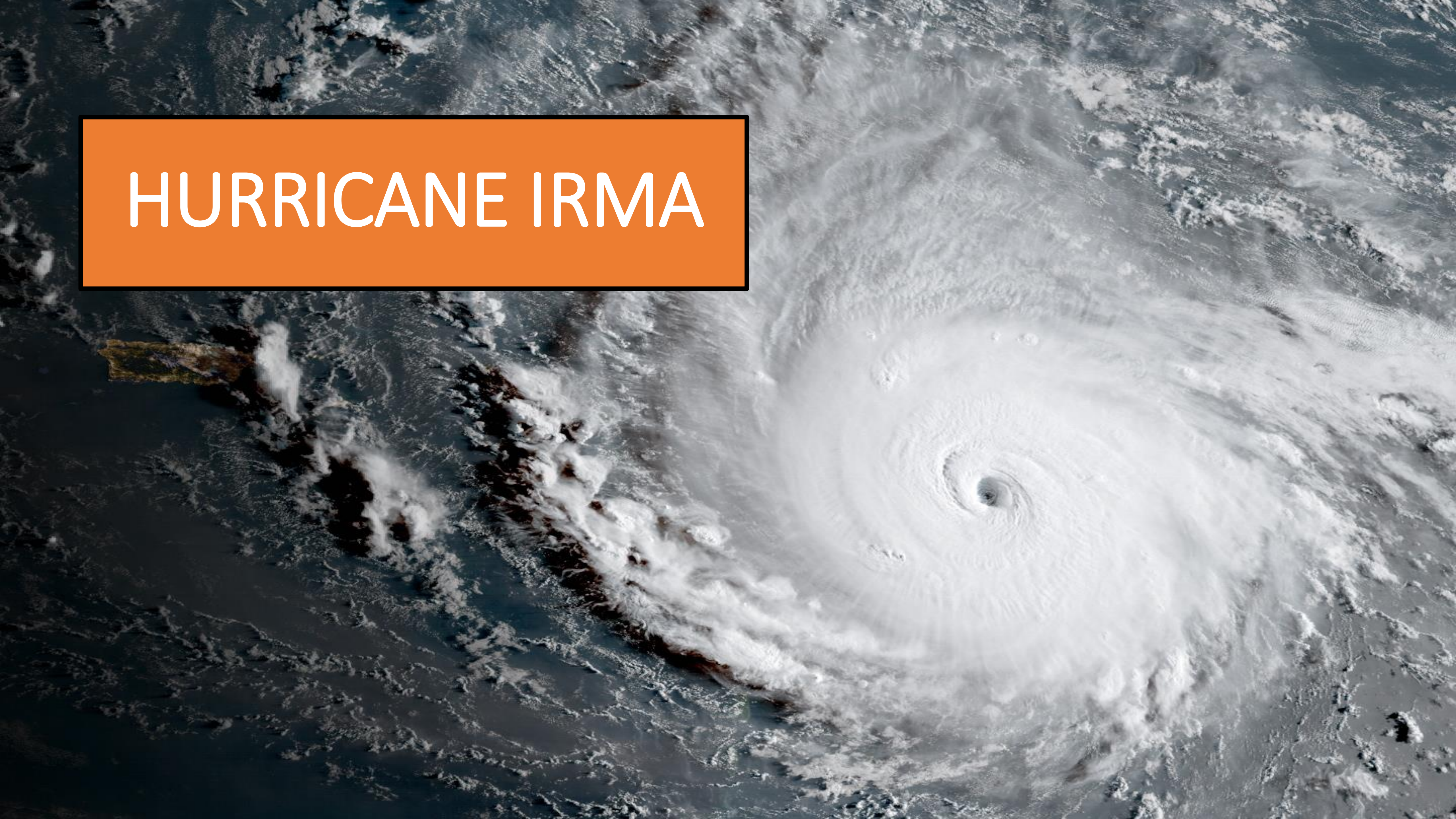

00:30:00
Inundation in Kamaishi
NAMI-DANCE

GENERAL EVALUATION FROM THE PERSPECTIVE OF STRUCTURAL PERFORMANCE
2011 GREAT EAST JAPAN TSUNAMI

- Narrow long bays
- Along rivers
- Coastal Forestation
- Marine Vessels
- Tsunami Breakwaters
- Tsunami Walls along the Coastlines

- Wooden Structures
- Concrete Structures
- Bridges
- Scouring
- Berthing Places

HURRICANE IRMA AND MARIA

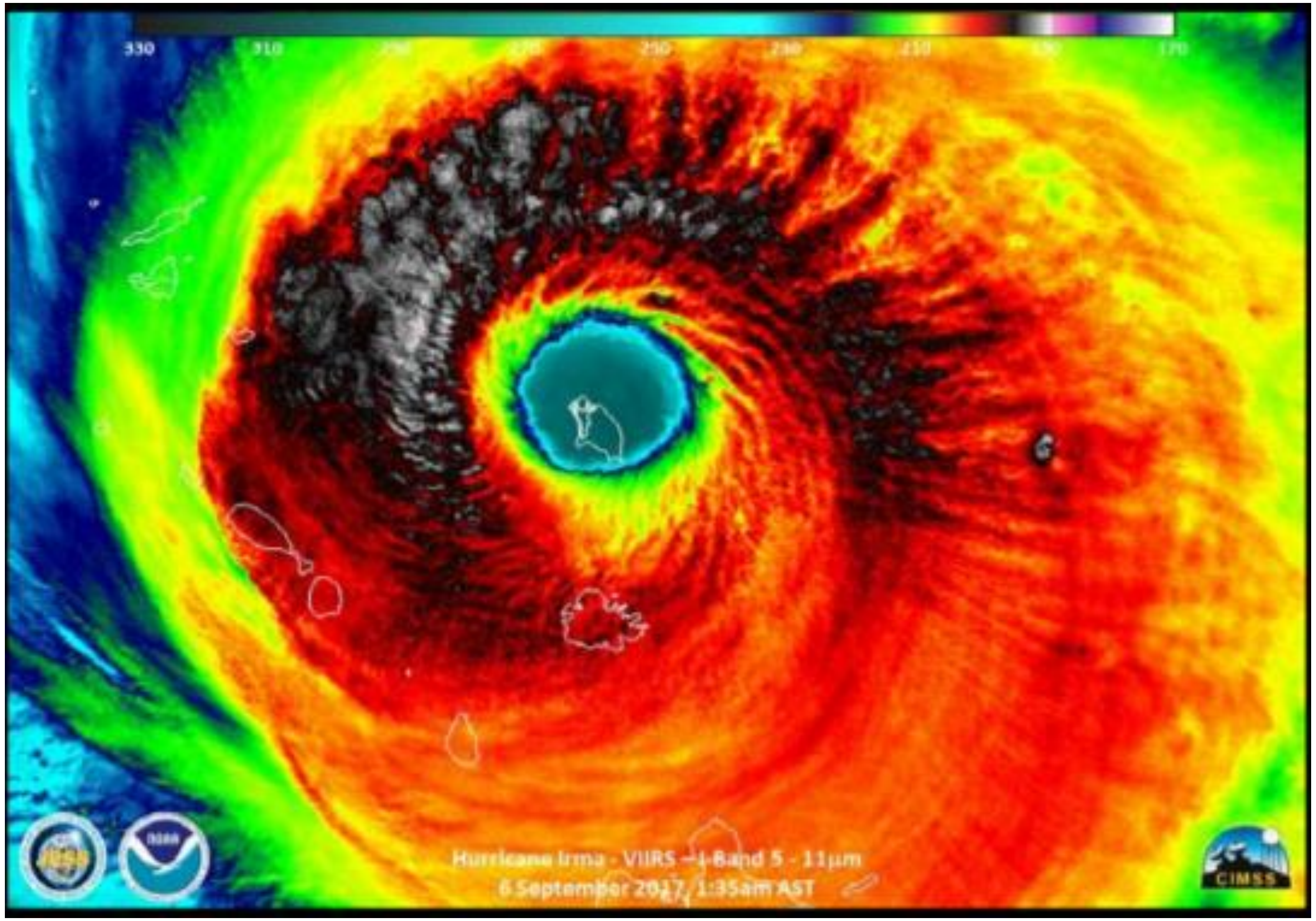

HURRICANE IRMA

HURRICANE IRMA

30 August–12 September 2017

The catastrophic hurricane made **seven landfalls**, four of which occurred as a **category 5** hurricane across the northern Caribbean Islands.

Irma caused widespread devastation across the affected areas and was one of the strongest and costliest hurricanes on record in the Atlantic basin.

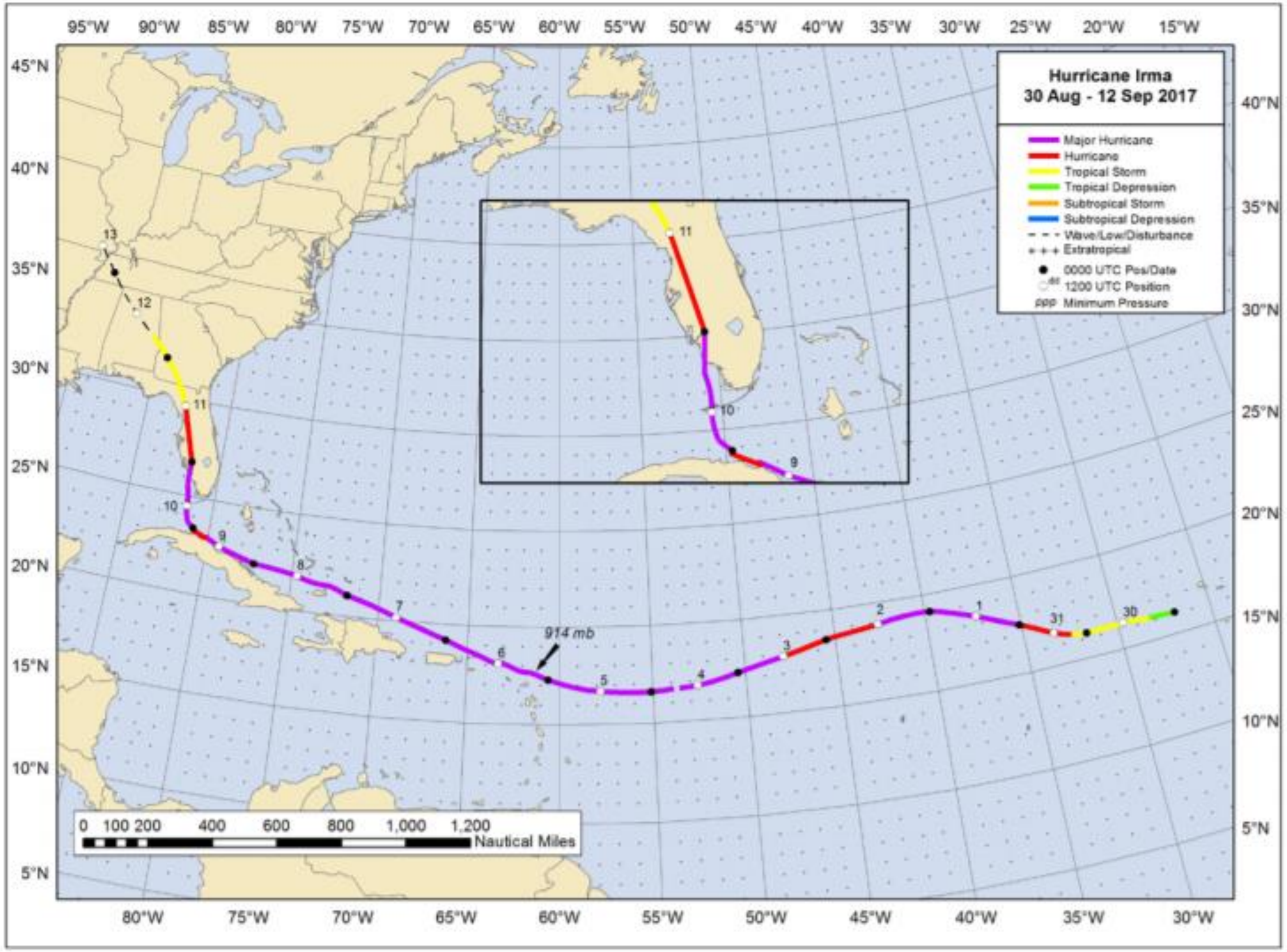


VIIRS satellite image of hurricane Irma when it was at its peak intensity and made landfall on Barbuda at 0535 UTC, 6 September.

John P. Cangialosi, Andrew S. Latto, and Robbie Berg ,"HURRICANE IRMA", National Hurricane Center, 30 June 2018.
Richard J. Pasch, Andrew B. Penny, and Robbie Berg,"HURRICANE MARIA", National Hurricane Center, 10 April 2018.

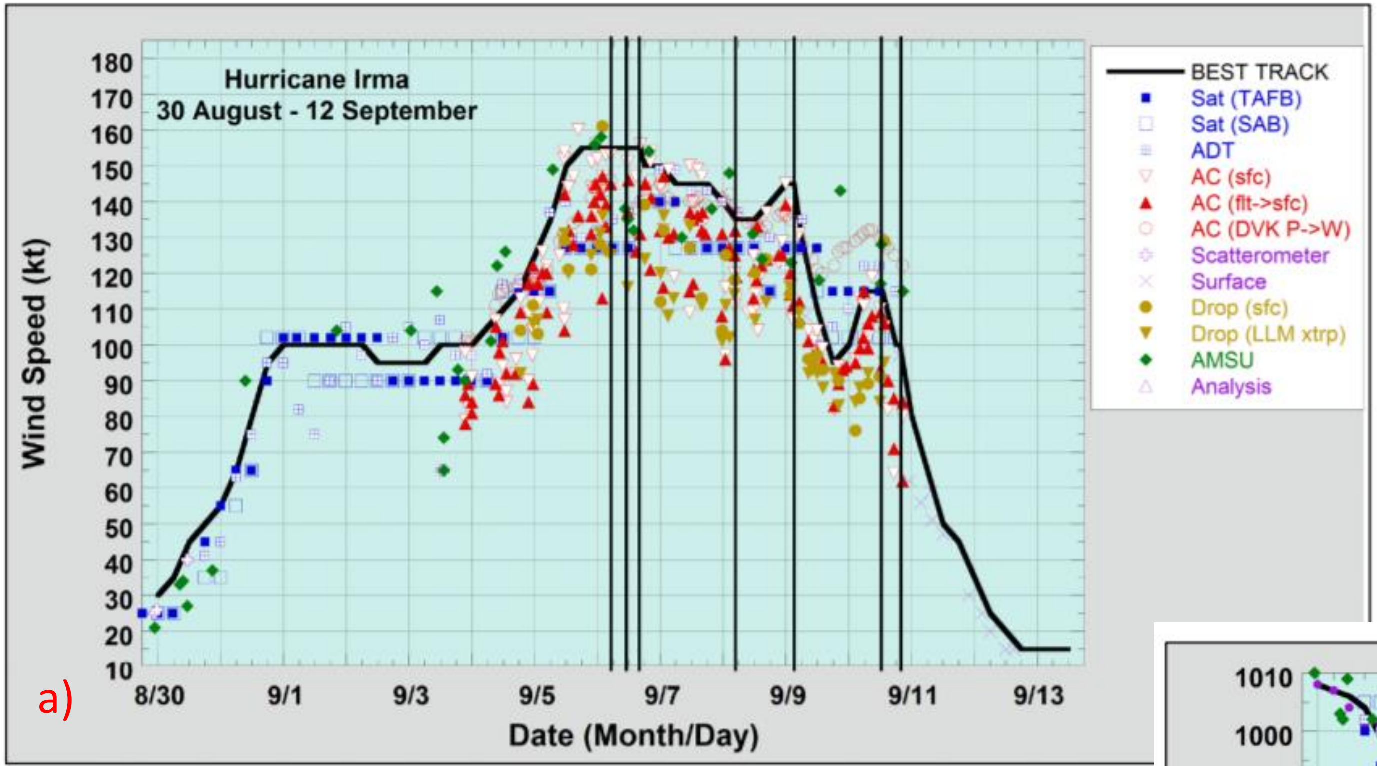
HURRICANE IRMA

Irma originated from a tropical wave that departed the west coast of Africa on 27 August 2017.



Best track positions for Hurricane Irma, 30 August–12 September 2017

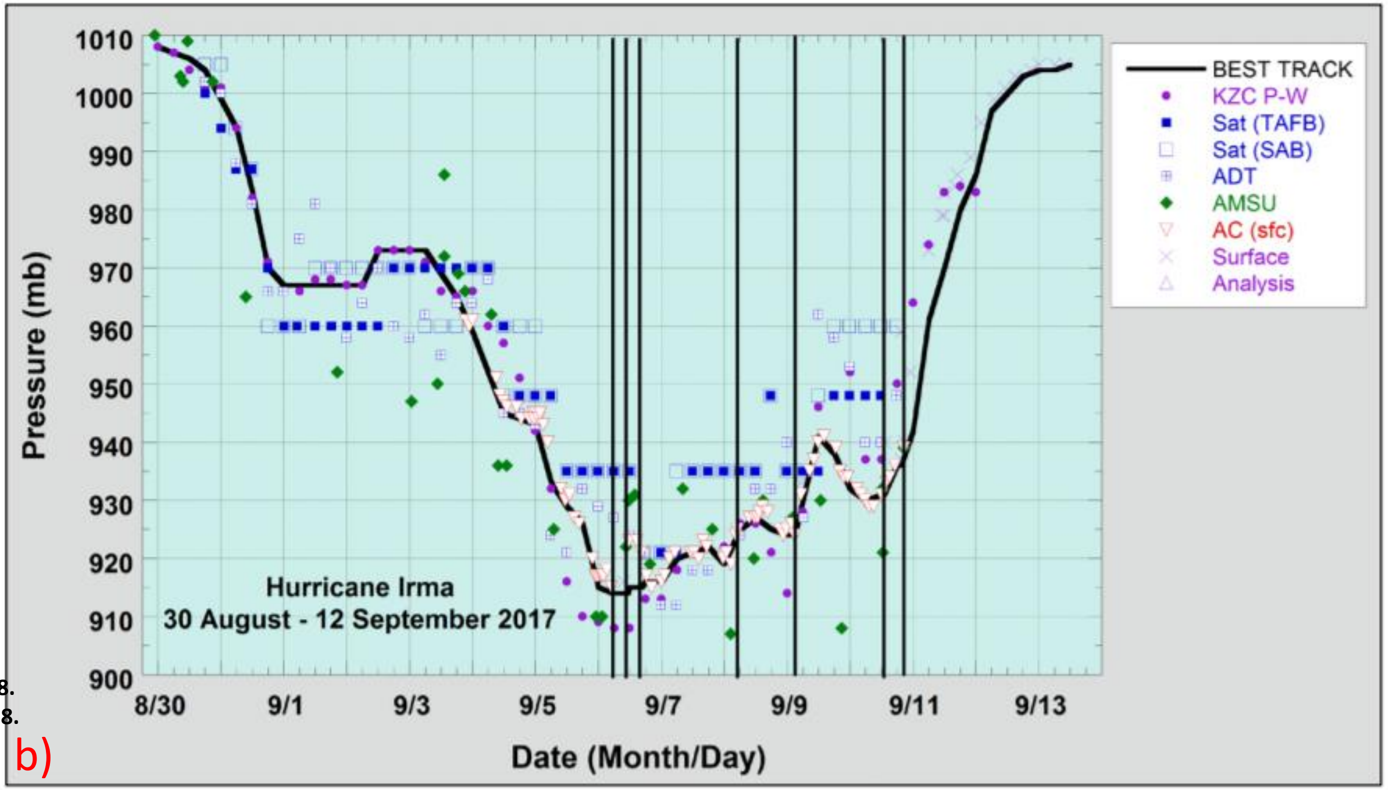
John P. Cangialosi, Andrew S. Latto, and Robbie Berg ,"HURRICANE IRMA", National Hurricane Center, 30 June 2018.
Richard J. Pasch, Andrew B. Penny, and Robbie Berg,"HURRICANE MARIA", National Hurricane Center, 10 April 2018.



Irma’s estimated **peak intensity of 155 kt** from **5 September to 6 September** is based on a blend of multiple SFMR surface wind estimates and flight-level winds observed by the Air Force Reserve and NOAA Hurricane Hunters during that time period.

a) Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Irma, 30 August–12 September 2017.

b) Selected pressure observations and best track minimum central pressure curve for Hurricane Irma, 30 August–12 September 2017.



John P. Cangialosi, Andrew S. Latto, and Robbie Berg ,“HURRICANE IRMA”, National Hurricane Center, 30 June 2018.
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Damage Caused By Hurricane Irma Across The Caribbean Islands

Damage Caused by Hurricane Irma Across Florida

Irma caused **47 direct deaths** as a result of its strong winds, heavy rains, and high surf **across the Caribbean Islands and the southeastern United States**. The majority of the causalities were in the Caribbean Islands, where Irma's winds were the strongest.

Eleven direct deaths were reported combined in Saint Martin and Saint Barthelemy, 9 in Cuba, 4 in Sint Maarten, 4 in the British Virgin Islands, 3 in the U.S. Virgin Islands, 3 in Barbuda, 1 in Barbados, 1 in Haiti, and 1 in Anguilla.

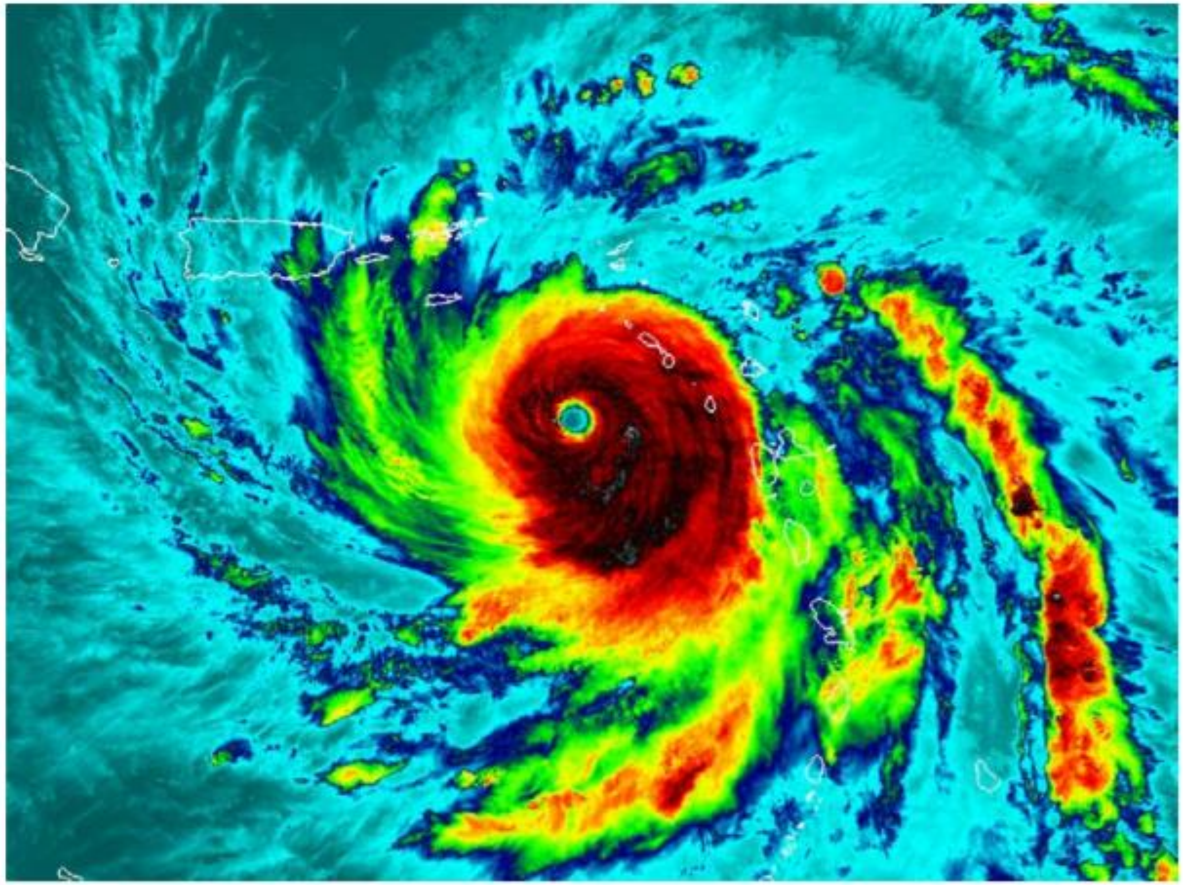
John P. Cangialosi, Andrew S. Latto, and Robbie Berg ,"HURRICANE IRMA", National Hurricane Center, 30 June 2018.
Richard J. Pasch, Andrew B. Penny, and Robbie Berg,"HURRICANE MARIA", National Hurricane Center, 10 April 2018.


HURRICANE MARIA

HURRICANE MARIA

16–30 September 2017

- Maria was a very severe Cape Verde Hurricane that ravaged the island of Dominica at category 5 (on the Saffir-Simpson Hurricane Wind Scale) intensity, and later devastated Puerto Rico as a high-end category 4 hurricane.
- It also inflicted serious damage on some of the other islands of the northeastern Caribbean Sea.
- Maria is the third costliest hurricane in United States history.

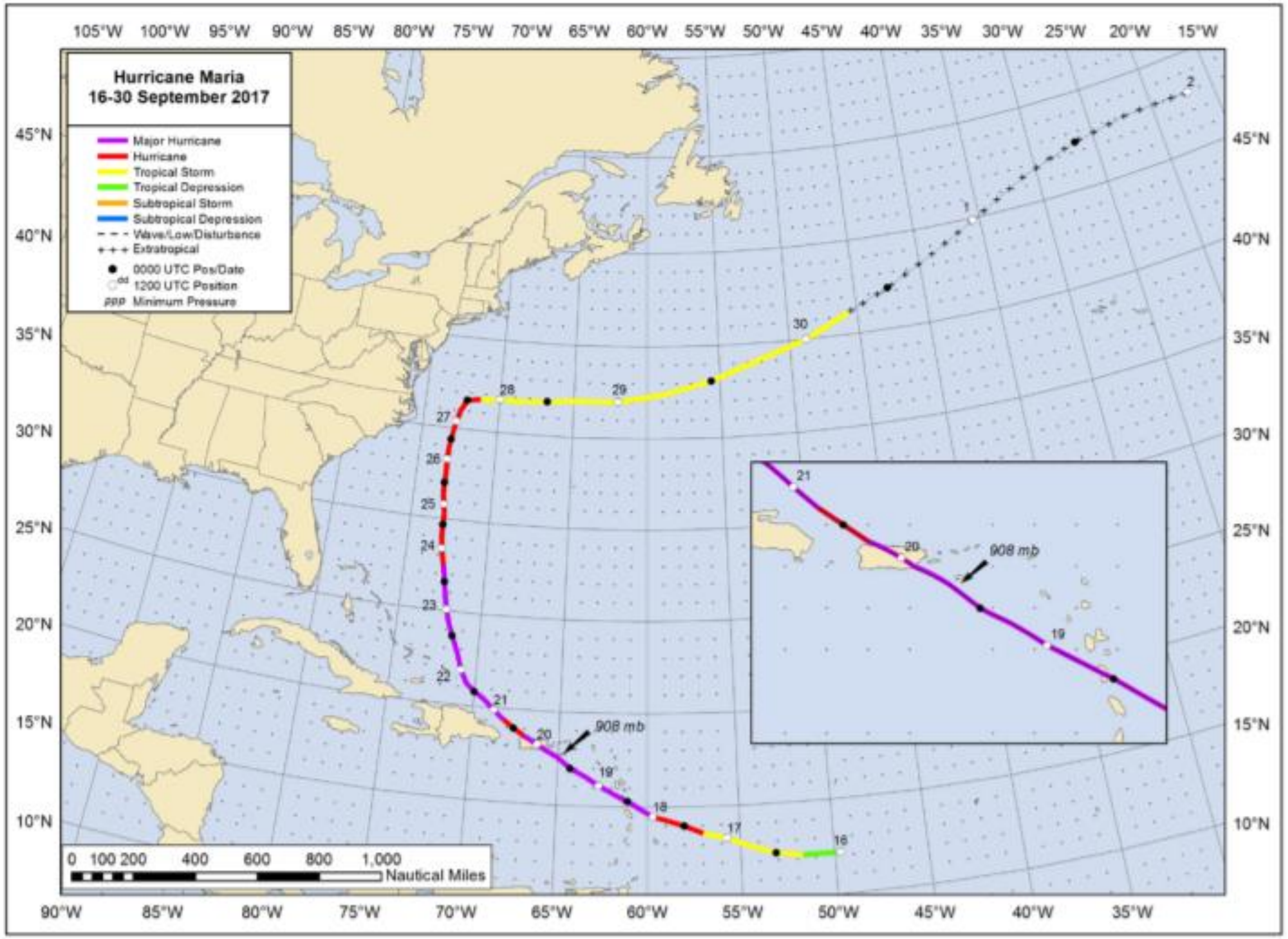


VIIRS satellite image of hurricane maria nearing peak intensity at 1942 UTC, 19 september 2017. Image Courtesy of UW-CIMSS.

John P. Cangialosi, Andrew S. Latto, and Robbie Berg ,"HURRICANE IRMA", National Hurricane Center, 30 June 2018.
Richard J. Pasch, Andrew B. Penny, and Robbie Berg,"HURRICANE MARIA", National Hurricane Center, 10 April 2018.

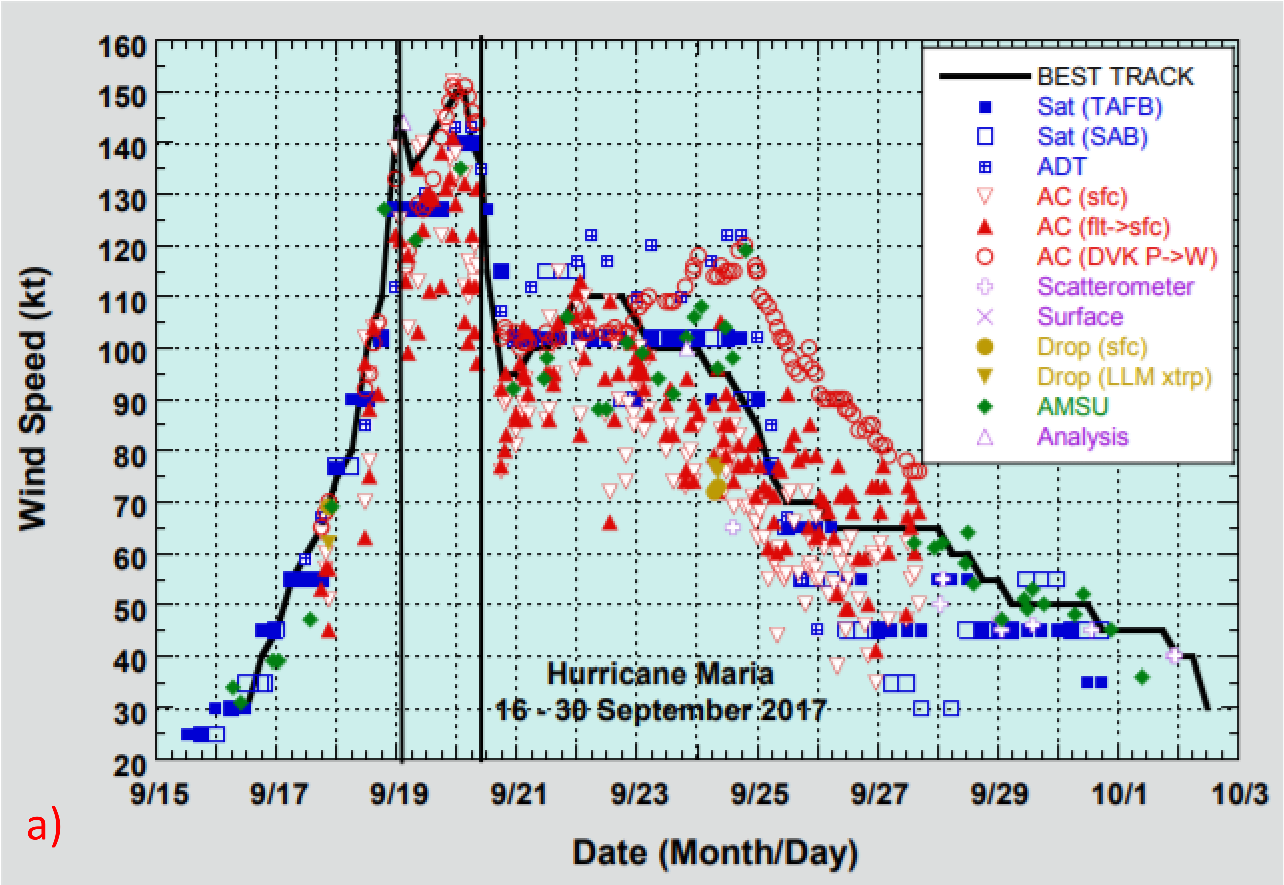
HURRICANE MARIA

Maria originated from a well-defined tropical wave that departed the west coast of Africa on 12 September



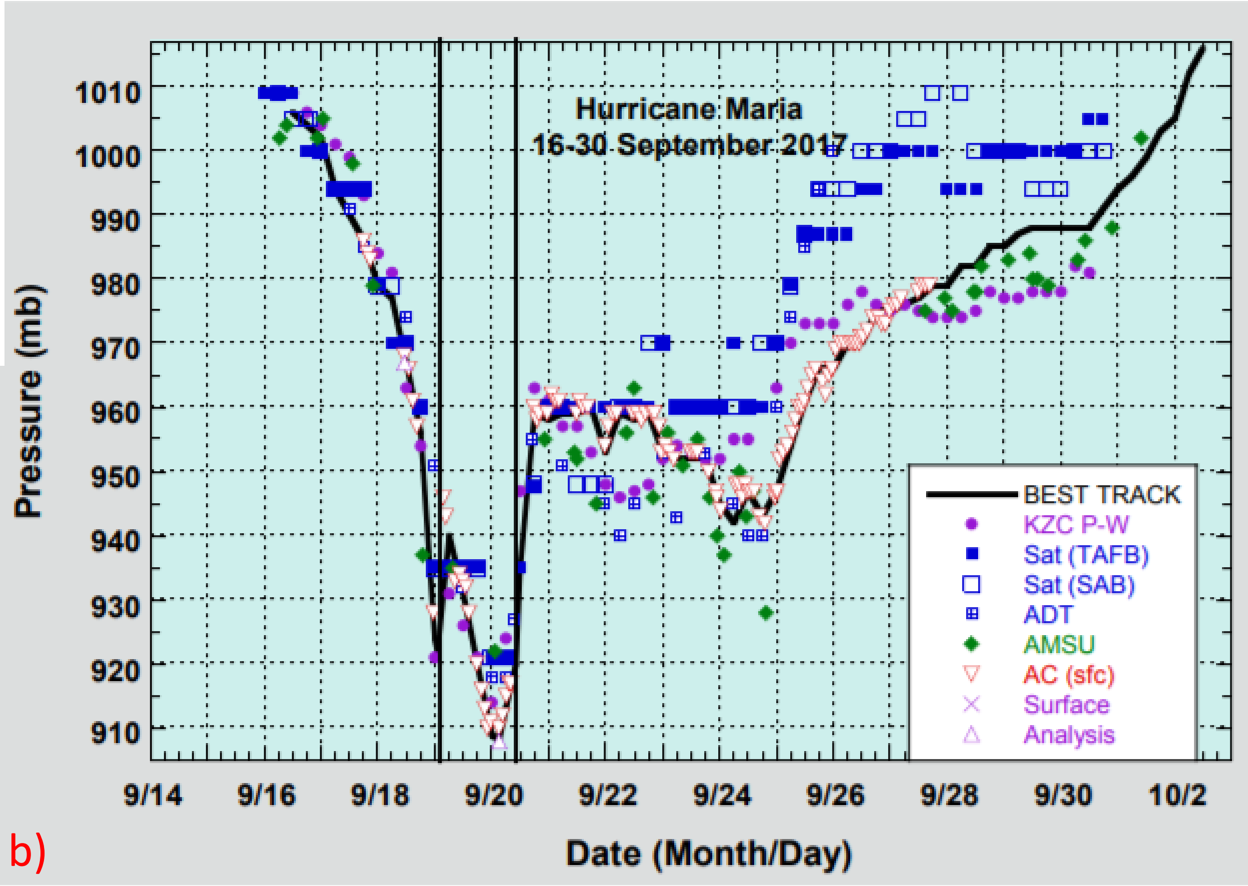
Best track positions for Hurricane Maria, 16–30 September 2017. Track during the extratropical stage is partially based on analyses from the NOAA Ocean Prediction Center.

John P. Cangialosi, Andrew S. Latto, and Robbie Berg ,"HURRICANE IRMA", National Hurricane Center, 30 June 2018.
Richard J. Pasch, Andrew B. Penny, and Robbie Berg,"HURRICANE MARIA", National Hurricane Center, 10 April 2018.



Maria's peak intensity of 150 kt is based on a blend of SFMR-observed surface winds of 152 kt and 700-mb flight-level winds of 157 kt.

Maria's 65-kt intensity increase over 24 h on 18 September makes it tied for the sixth-fastest intensifying hurricane in the Atlantic basin record.



a) Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Maria, 16–30 September 2017

b) Selected pressure observations and best track minimum central pressure curve for Hurricane Maria, 16–30 September 2017

John P. Cangialosi, Andrew S. Latto, and Robbie Berg ,"HURRICANE IRMA", National Hurricane Center, 30 June 2018.
Richard J. Pasch, Andrew B. Penny, and Robbie Berg,"HURRICANE MARIA", National Hurricane Center, 10 April 2018.

Damage by Cyclone Maria in Dominica.
Photo credits, clockwise from upper left: WIC News, responsibletravel.com, AFP/Getty Images, Tomás Ayuso/IRIN.

Damage by Cyclone Maria in Puerto Rico. Damage to St. Croix is shown in the lower right panel.
Photo credits, clockwise from upper left: U.S. Air Force, VOA News, Reuters/Jonathan Drake, Hector Retamal/AFP/Getty Images.

Maria caused 31 direct deaths **in Dominica** with **34 missing**. **In Guadeloupe**, **two direct fatalities are attributed to Maria**: one person died from a falling tree, and another was swept out to sea. **In Puerto Rico**, the death toll is **highly uncertain** and the **official number stands at 65**, which includes an unknown number of indirect deaths. It should be noted that hundreds of additional indirect deaths in Puerto Rico may eventually be attributed to Maria’s aftermath pending the results of an official government review.

John P. Cangialosi, Andrew S. Latto, and Robbie Berg ,“HURRICANE IRMA”, National Hurricane Center, 30 June 2018.
Richard J. Pasch, Andrew B. Penny, and Robbie Berg,“HURRICANE MARIA”, National Hurricane Center, 10 April 2018.

- Tsunamis and Tropical Cyclones are two of the major important marine hazards, which may cause extensive loss of life and property.

- Numerical modeling is one of the most efficient tools for the assessment of these types of disasters, understanding the related risks and development of mitigation measures.

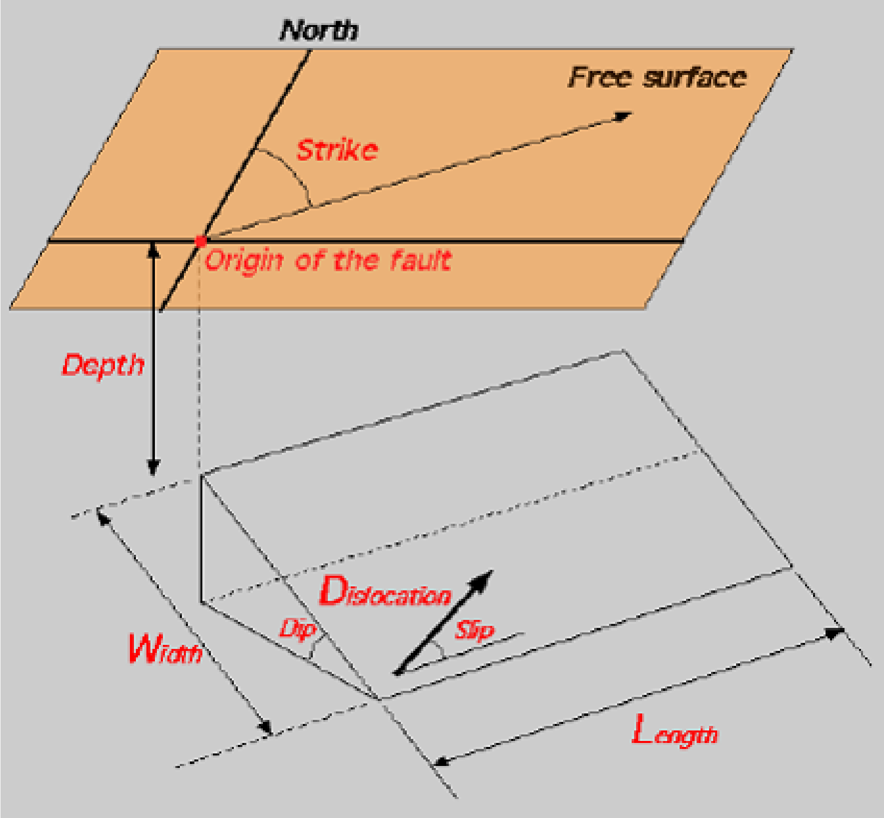
Forcing for Tsunamis and Cyclones

Phenomena causing long wave generation are transferring the energy gained by some outer forcing by;

- Tide
- Tsunami (earthquake, underwater landslides, volcanos)
- Atmospheric pressure disturbances (temporal-spatial)
- Wind Fields (temporal-spatial)

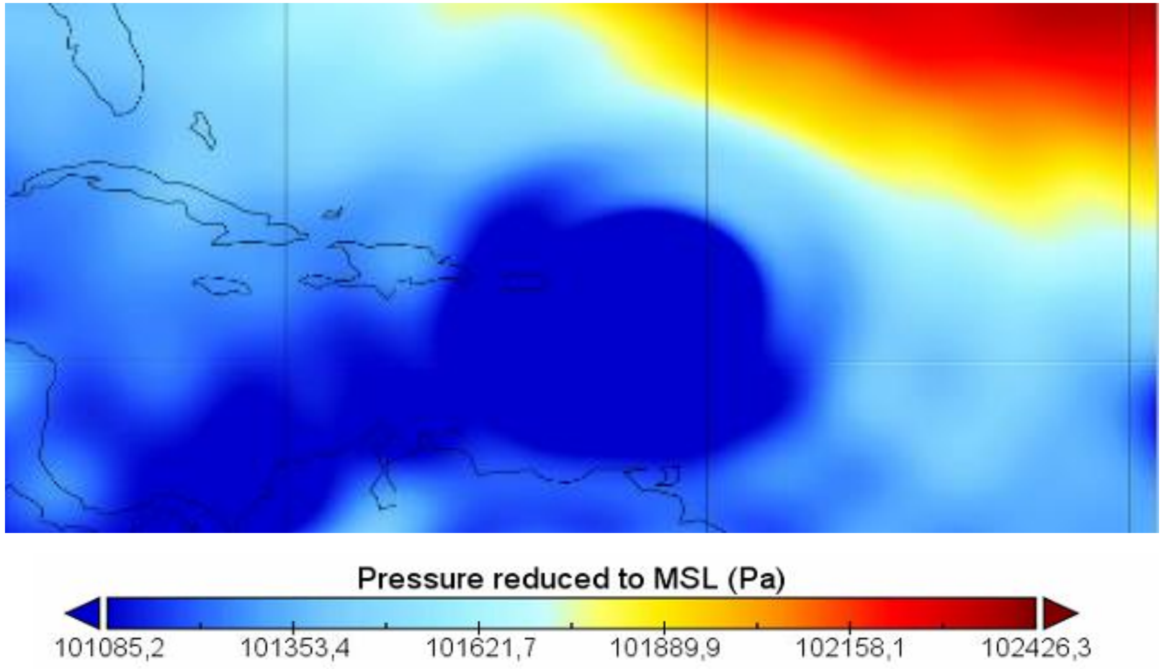
Seismic source model for tsunamis

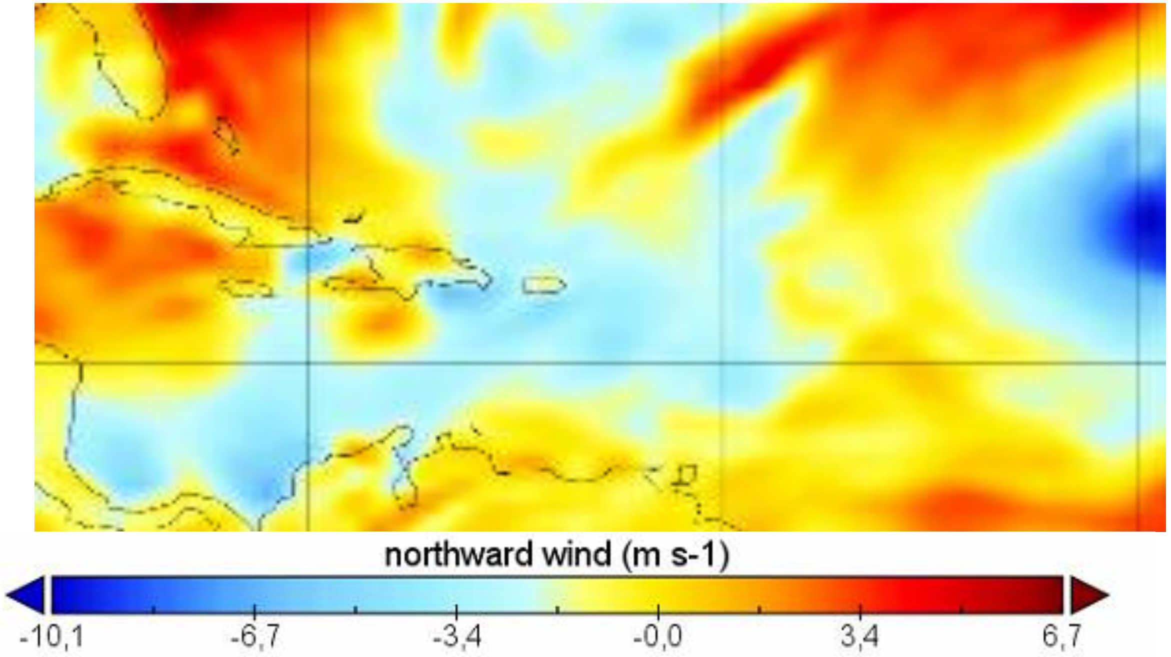
- For a sub-sea earthquake, the rupture typically has durations less than a minute, which is considered instantaneous compare to tens of minutes period of tsunami wave, thus dynamic effect is neglected
- Initial wave profile is assumed to be identical to the vertical static displacement of the sea floor given by Manshinha and Smylie's (1971) model for inclined strike-slip and dip-slip faults
- Typical fault parameters:
  - Epicenter location (lat., long.)
  - Rupture duration, τ
  - Strike angle, θ
  - Dip angle, λ
  - Rake angle (Slip), δ
  - Focal Depth, D
  - Length, L
  - Width, W
  - Slip Displacement or Dislocation, Δ
- Tsunami wave length ~ 2W

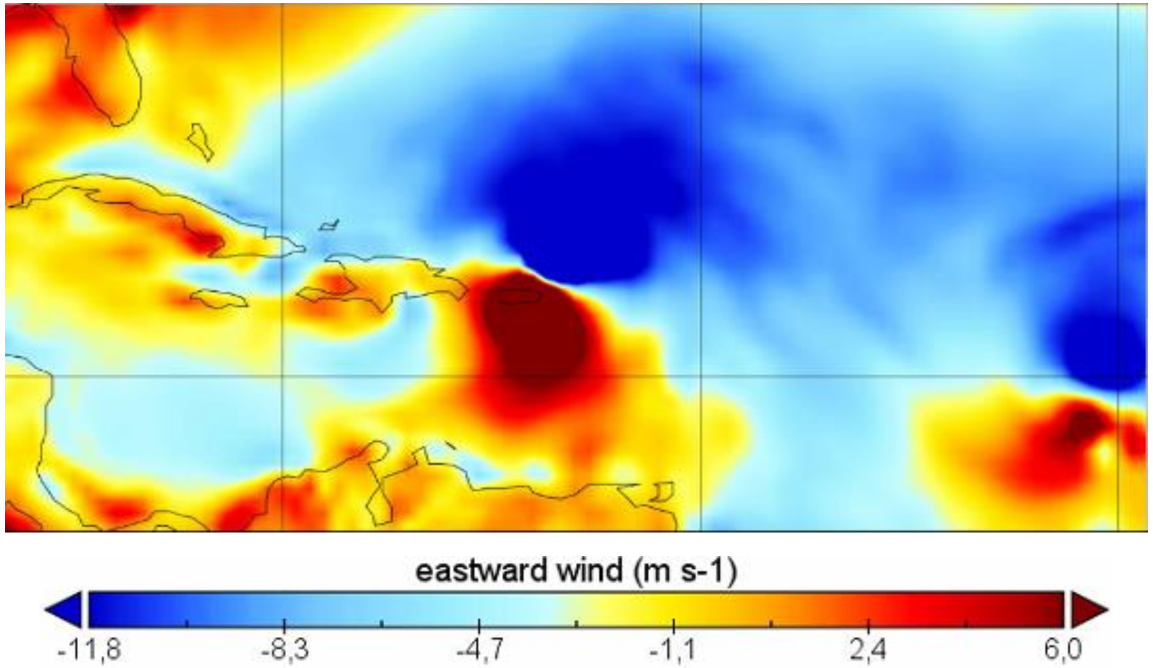


Source model for Tropical Cyclones

Atmospheric pressure
eastward wind
northward wind data







MODELING OF TSUNAMIS AND TROPICAL CYCLONES

PREPROCESSING

- ***STUDY AREA***

According to

- Earthquake and tsunami potential
- Cyclone trajectory

- Coastal Communities
- Social and economic importance
- Superstructure and infrastructure
- Critical Structures

MODELING OF TSUNAMIS AND TROPICAL CYCLONES

PREPROCESSING

DATA ACQUISITION AND PROCESSING

- the raw satellite data of the study area is collected from the available sources
- the collected data is analyzed and eliminated
- Digitize and process the available data

- ***BATHYMETRY and TOPOGRAPHY***
- the required resolution
- bathymetric and topographic database
- Numerical gauge points

MODELING OF TSUNAMIS AND TROPICAL CYCLONES

PREPROCESSING

SOURCE (TSUNAMI)

- Possible tsunami sources (seismic or non-seismic)

the source file is created by implementing:

- Rupture parameters (fault length, fault width, dip angle, etc.)
- Mass movements (submarine or subaerial)
- Volcano activities

SOURCE (TROPICAL CYCLONE)

- Atmospheric Presure
- Wind fields

MODELING OF TSUNAMIS AND TROPICAL CYCLONES

PROCESSING

SIMULATION (TSUNAMI AND TORPICAL CYCLONE)

- Use initial and boundary conditions, friction, tide etc.
- Compute all wave parameters (water elevations, current velocities, discharge fluxes, wave arrival times and max./min. free surface levels …)
- Simulation duration, output file time interval and friction coefficient are all inputted in this step

MODELING OF TSUNAMIS AND TROPICAL CYCLONES

POST-PROCESSING

SIMULATION (TSUNAMI AND TORPICAL CYCLONE)

- Evaluate the results of each simulation including inputs, and outputs (maximum positive amplitude of the wave, current, inundation, flow depth, arrival time, inundation distance, time histories of water level at selected locations) computed in the simulation

- Visualize the results, 1D, 2D Figures, inundation mapping, 3d animations, etc.

MODELING OF TSUNAMIS AND TROPICAL CYCLONES

$$\frac{\partial \eta}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0..........(Eq.1)$$

$$\frac{\partial M}{\partial t} + \frac{\partial}{\partial x}\left(\frac{M^2}{D}\right) + \frac{\partial}{\partial y}\left(\frac{MN}{D}\right) + gD\frac{\partial \eta}{\partial x} + \frac{\tau_x}{\rho_w} + \frac{D}{\rho_w}\frac{\partial P_{atm}}{\partial x} - \frac{\rho_{air} C_D}{\rho_w} U_{w10}\sqrt{U^2{}_{w10} + V^2{}_{w10}} = 0..........(Eq.2)$$

$$\frac{\partial N}{\partial t} + \frac{\partial}{\partial x}\left(\frac{MN}{D}\right) + \frac{\partial}{\partial y}\left(\frac{N^2}{D}\right) + gD\frac{\partial \eta}{\partial y} + \frac{\tau_y}{\rho_w} + \frac{D}{\rho_w}\frac{\partial P_{atm}}{\partial y} - \frac{\rho_{air} C_D}{\rho_w} V_{w10}\sqrt{U^2{}_{w10} + V^2{}_{w10}} = 0........(Eq.3)$$

P_{atm} $in\ Pascal$

U_{w10}, V_{w10} $are\ wind\ velocities\ at\ 10m\ elevation\ on\ the\ sea\ surface\ in\ W-E\ and\ S-N\ directions$ in m/sec

C_D is wind drag coefficient

$C_D = (0.75 + 0.067U_{w10})*10^{-3}$ $for U_{w10} <= 26m/\sec$ Garrat, 1977

$C_D = 2.18*10^{-3}$ $for U_{w10} > 26m/\sec$ Powell et al., 2003

Note: CD values depend on instantaneous wind velocity and are different in x and y directions at any time

MODELING OF TSUNAMIS AND TROPICAL CYCLONES

$$\frac{\partial \eta}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0..........(Eq.1)$$

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{D}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{D}\right)+gD\frac{\partial \eta}{\partial x}+\frac{\tau_x}{\rho_w}+\frac{D}{\rho_w}\frac{\partial P_{atm}}{\partial x}-\frac{\rho_{air}C_D}{\rho_w}U_{w10}\sqrt{U^2{}_{w10}+V^2{}_{w10}}=0..........(Eq.2)$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left(\frac{MN}{D}\right)+\frac{\partial}{\partial y}\left(\frac{N^2}{D}\right)+gD\frac{\partial \eta}{\partial y}+\frac{\tau_y}{\rho_w}+\frac{D}{\rho_w}\frac{\partial P_{atm}}{\partial y}-\frac{\rho_{air}C_D}{\rho_w}V_{w10}\sqrt{U^2{}_{w10}+V^2{}_{w10}}=0........(Eq.3)$$

P_{atm} *in Pascal*

U_{w10}, V_{w10} *are wind velocities at 10m elevation on the sea surface in* $W-E$ *and* $S-N$ *directions* in m/sec

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MODELING OF TSUNAMIS AND TROPICAL CYCLONES

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$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left(\frac{MN}{D}\right)+\frac{\partial}{\partial y}\left(\frac{N^2}{D}\right)+gD\frac{\partial \eta}{\partial y}+\frac{\tau_y}{\rho_w}+\frac{D}{\rho_w}\frac{\partial P_{atm}}{\partial y}-\frac{\rho_{air}C_D}{\rho_w}V_{w10}\sqrt{U^2{}_{w10}+V^2{}_{w10}}=0........(Eq.3)$$

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U_{w10}, V_{w10} $are\ wind\ velocities\ at\ 10m\ elevation\ on\ the\ sea\ surface\ in$ $W-E\ and\ S-N\ directions$ in m/sec

$$C_D=(0.75+0.067U_{w10})*10^{-3} \qquad for U_{w10}<=26m/\sec$$ Garrat, 1977

C_D is wind drag coefficient

$$C_D=2.18*10^{-3} \qquad for U_{w10}>26m/\sec$$ Powell et al., 2003

Note: CD values depend on instantaneous wind velocity and are different in x and y directions at any time

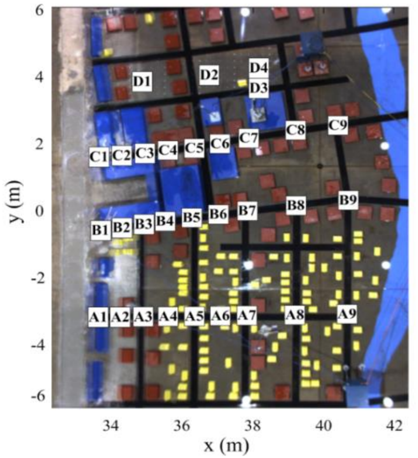
$$\frac{\tau_x}{\rho} = \frac{n^2}{D^{7/3}} M \sqrt{M^2 + N^2}$$

$$\frac{\tau_y}{\rho} = \frac{n^2}{D^{7/3}} N \sqrt{M^2 + N^2}$$

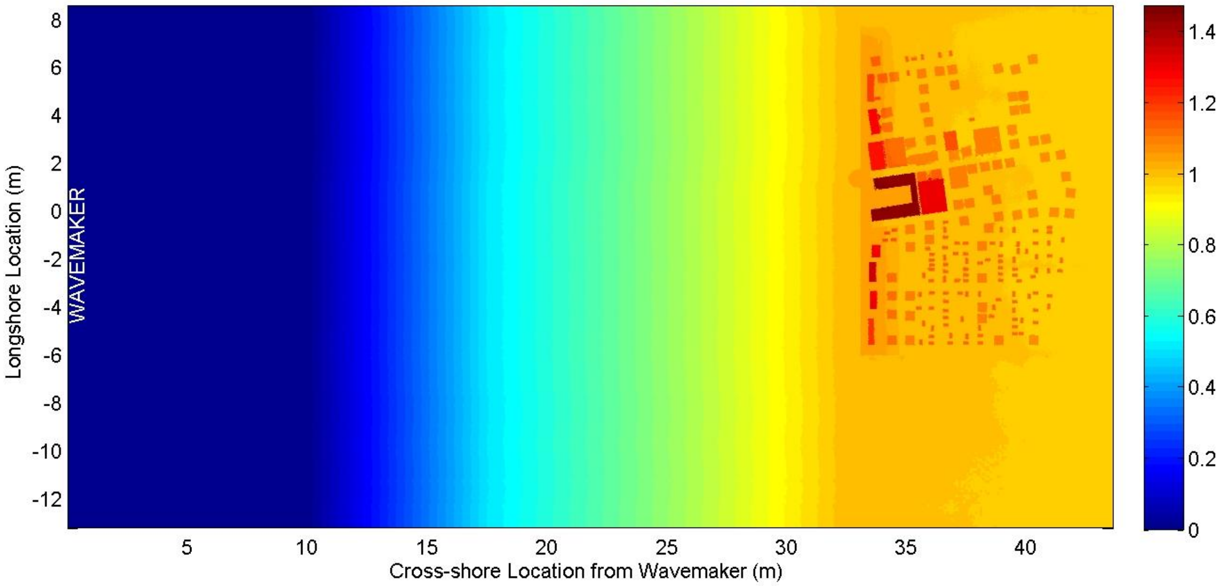
Powell, M. D., Murillo, S., Dodge, P., Uhlhorn, E., Gamache, J., Cardone, V., et al. (2010). Reconstruction of Hurricane Katrina's wind fields for storm surge and wave hindcasting. Ocean Engineering, 37, 26-36.

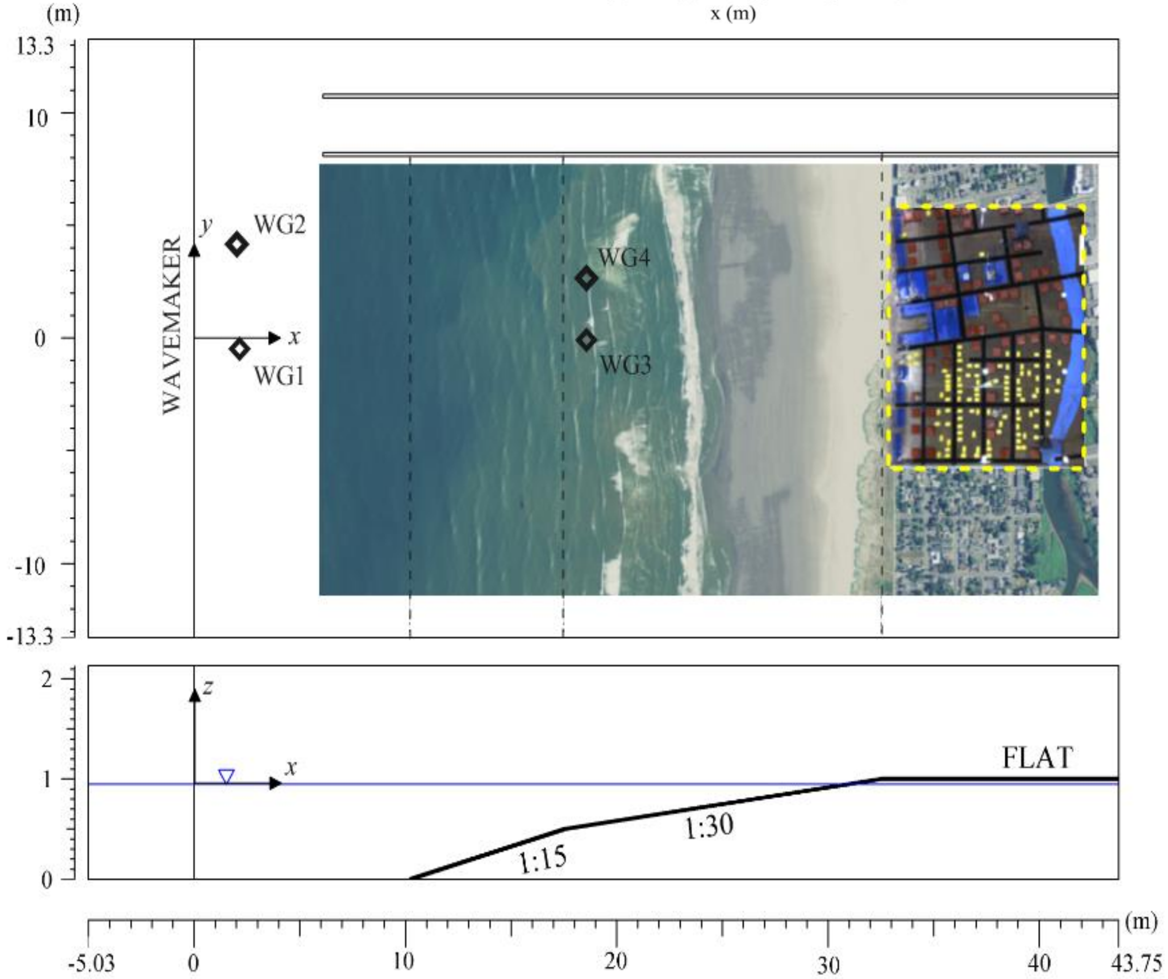
BM#4 – Bathymetry, Gauges

Benchmarking



- For this benchmark, we will compare free surface, velocity, and momentum flux information recorded throughout the tank.





resolution: 0.1 m
Maximum Water Depth : 0.97m
Simulation time step: 0.0005 sec
Manning Coeff: 0.01

BM#4

NTHMP Current Workshop (Lynett et al., 2017)

VALIDATION

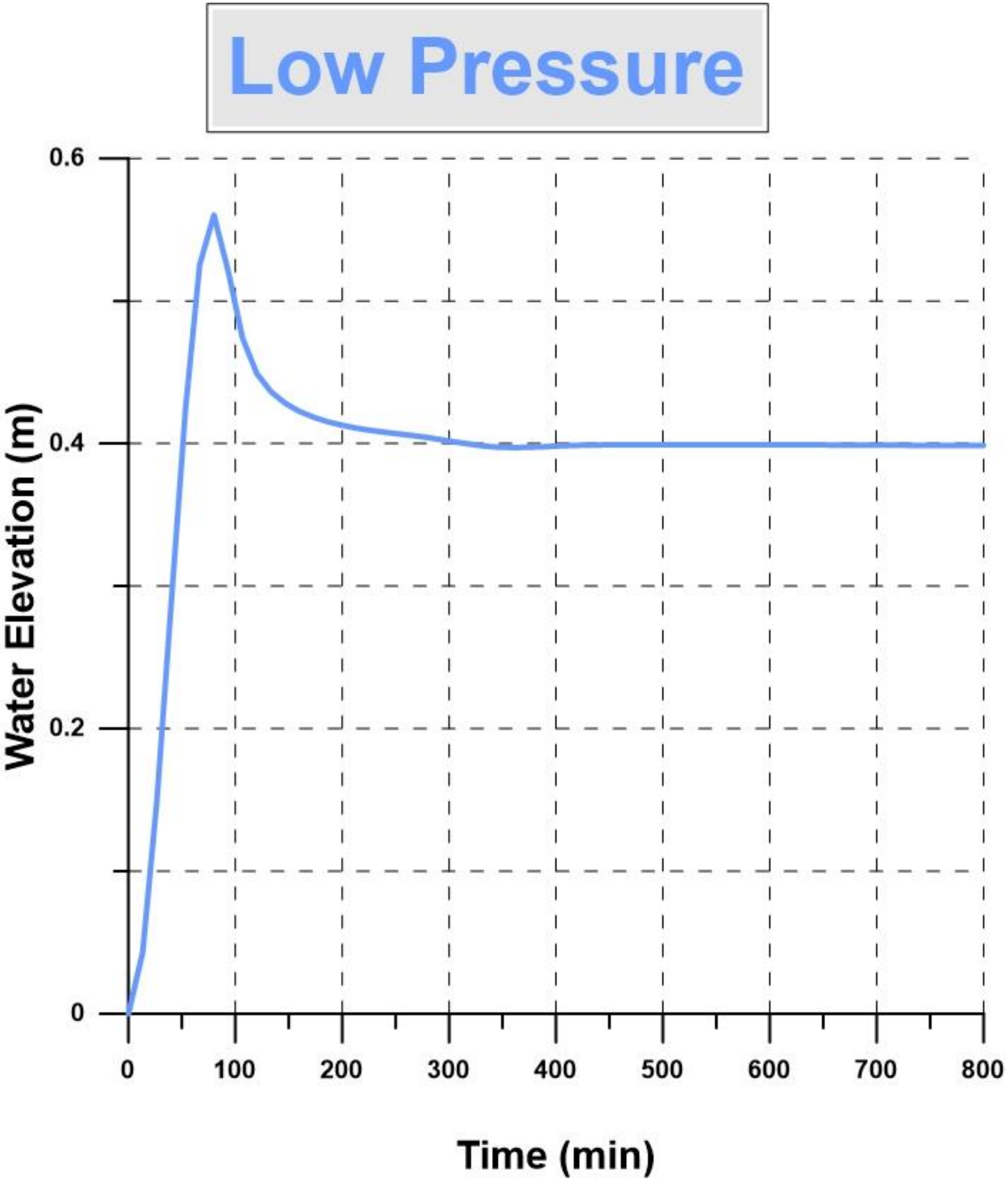
Bathymetry: 2756x804

2500m grid size

1000m depth flat bathymetry

Pressure: 973 mbar at the center

Outside Pressure: 1013 mbar



VALIDATION

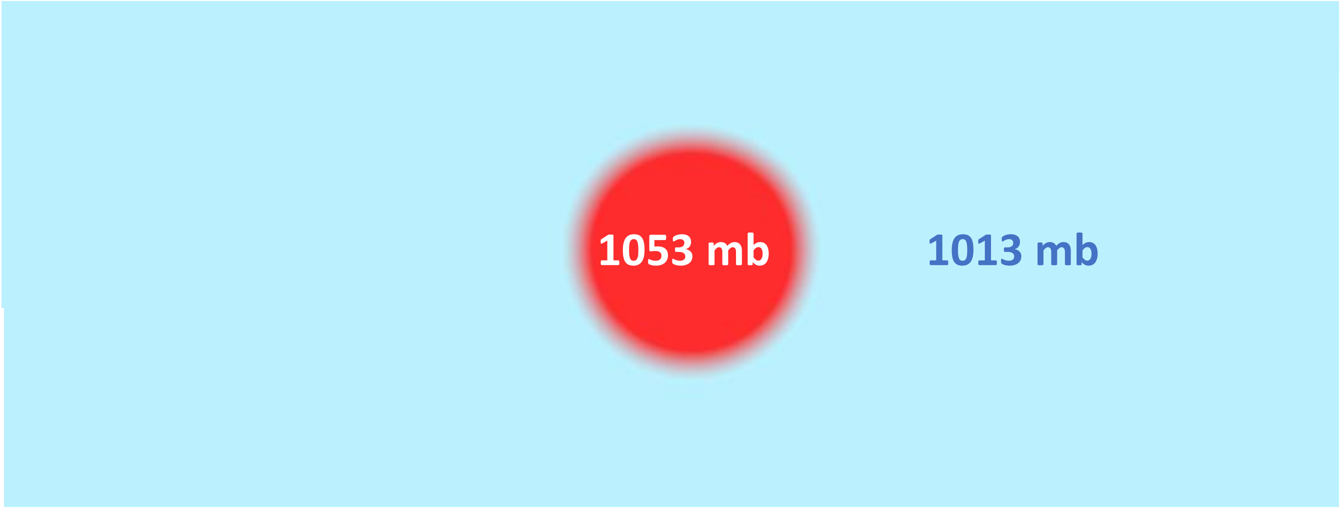
Bathymetry: 2756x804

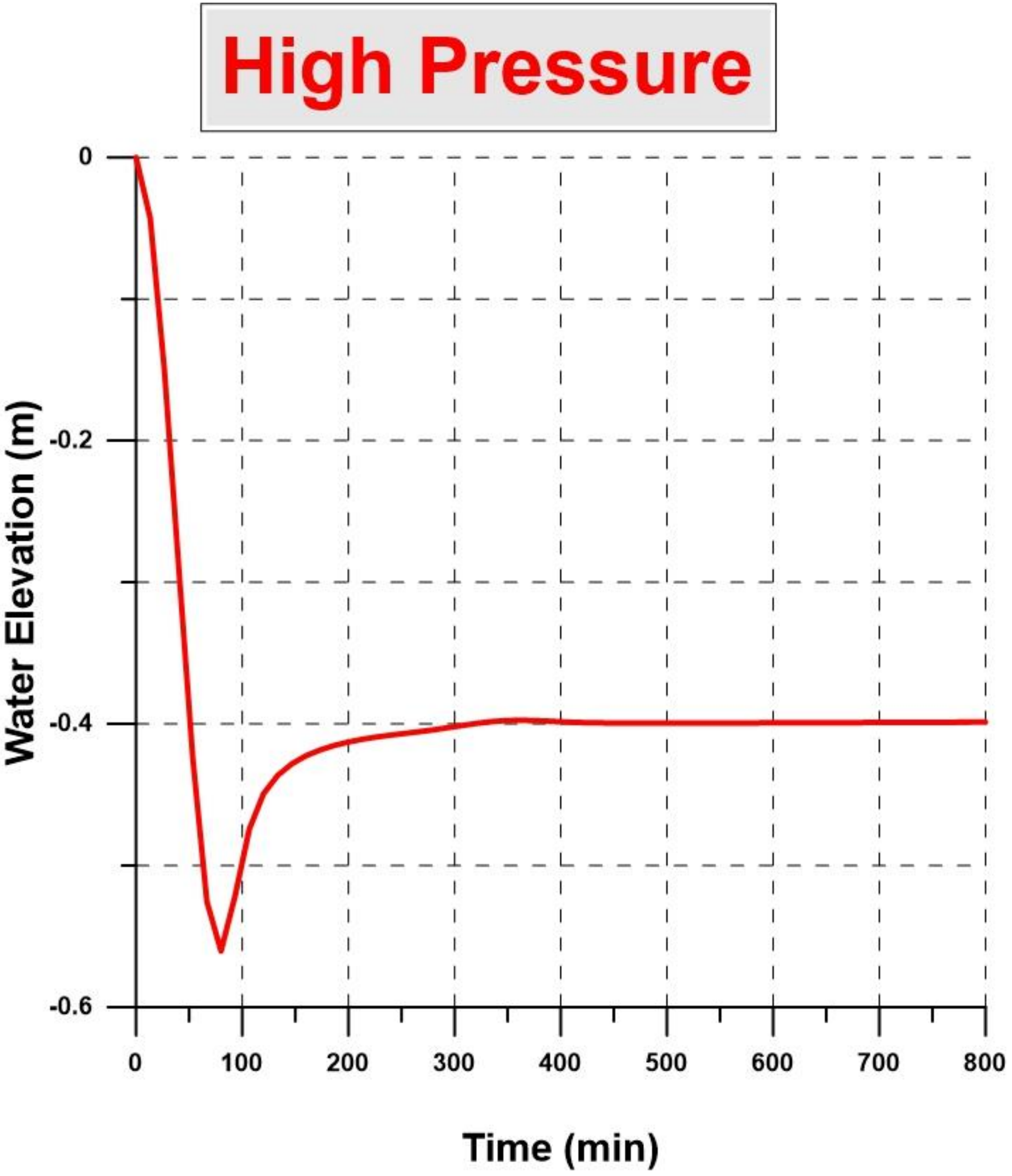
2500m grid size

1000m depth flat bathymetry

Pressure: 1053 mbar at the center

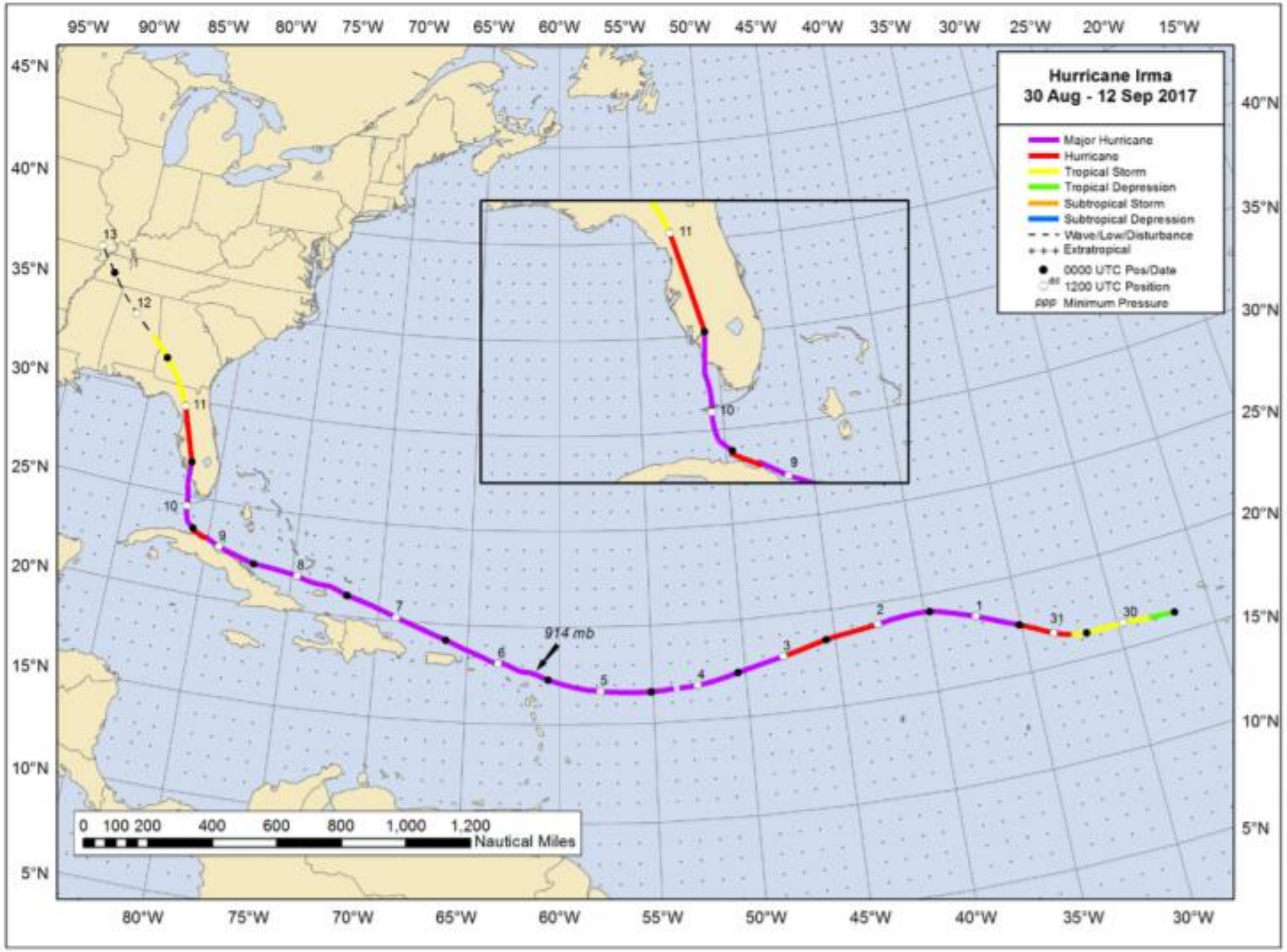
Outside Pressure 1013 mbar





MODELING OF HURRICANE IRMA

Irma originated from a tropical wave that departed the west coast of Africa on 27 August.



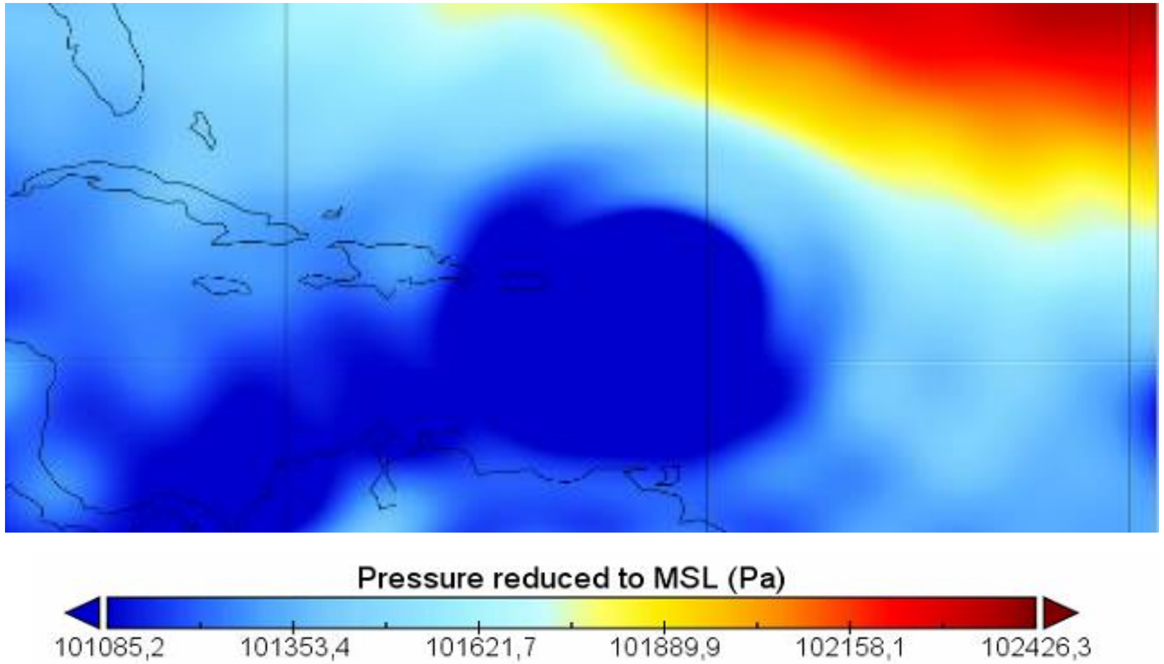
Best track positions for Hurricane Irma, 30 August–12 September 2017, (National Hurricane Center, Hurricane Irma Report, 2017)

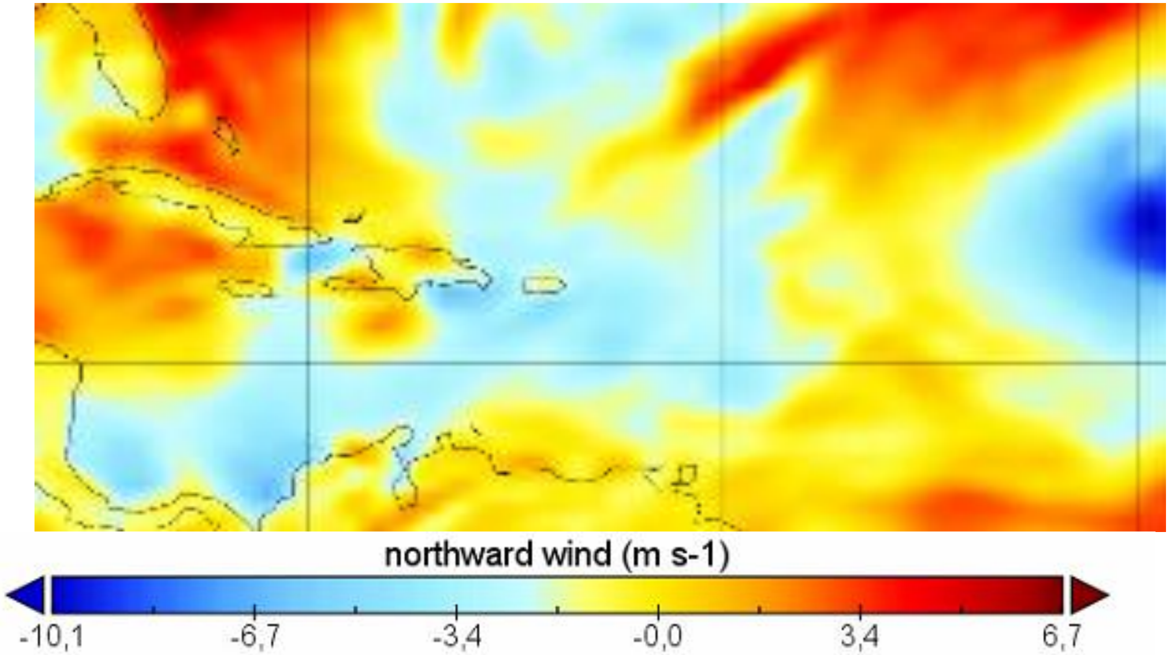
Numerical Modeling of IRMA

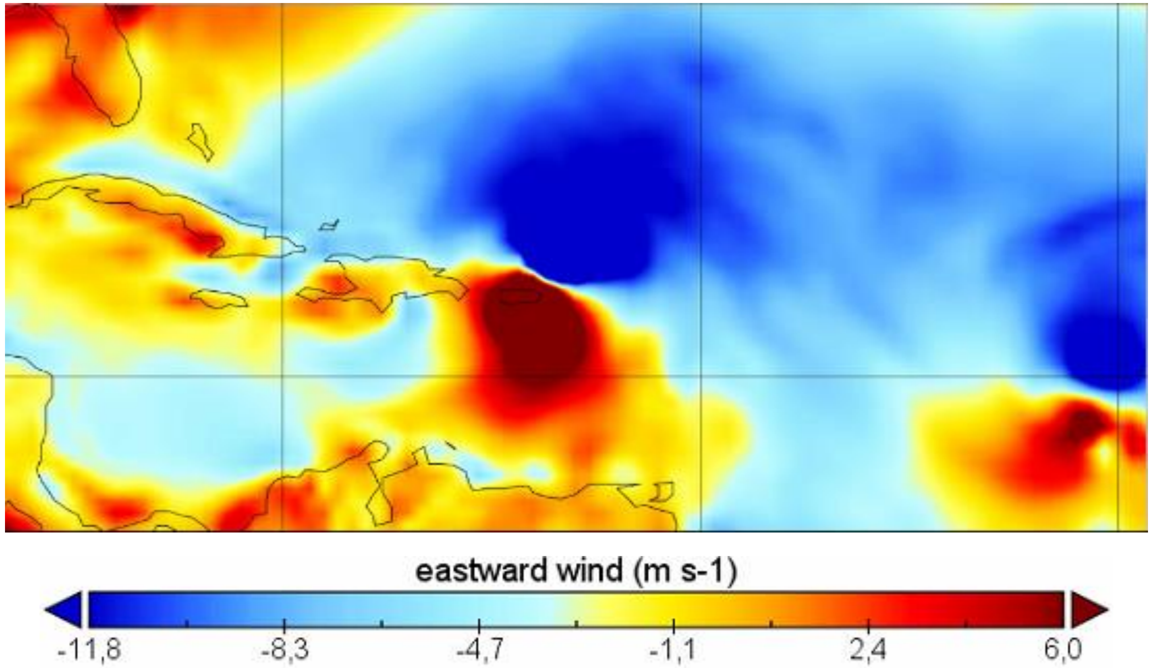
Bathymetry	Grid Size (m)	Corner Coordinates			
Coarse Bathymetry	900	292E	315E	9.8N	22N
Nested Bathymetry	200	296.5 E	299.5E	13.5N	18.7N

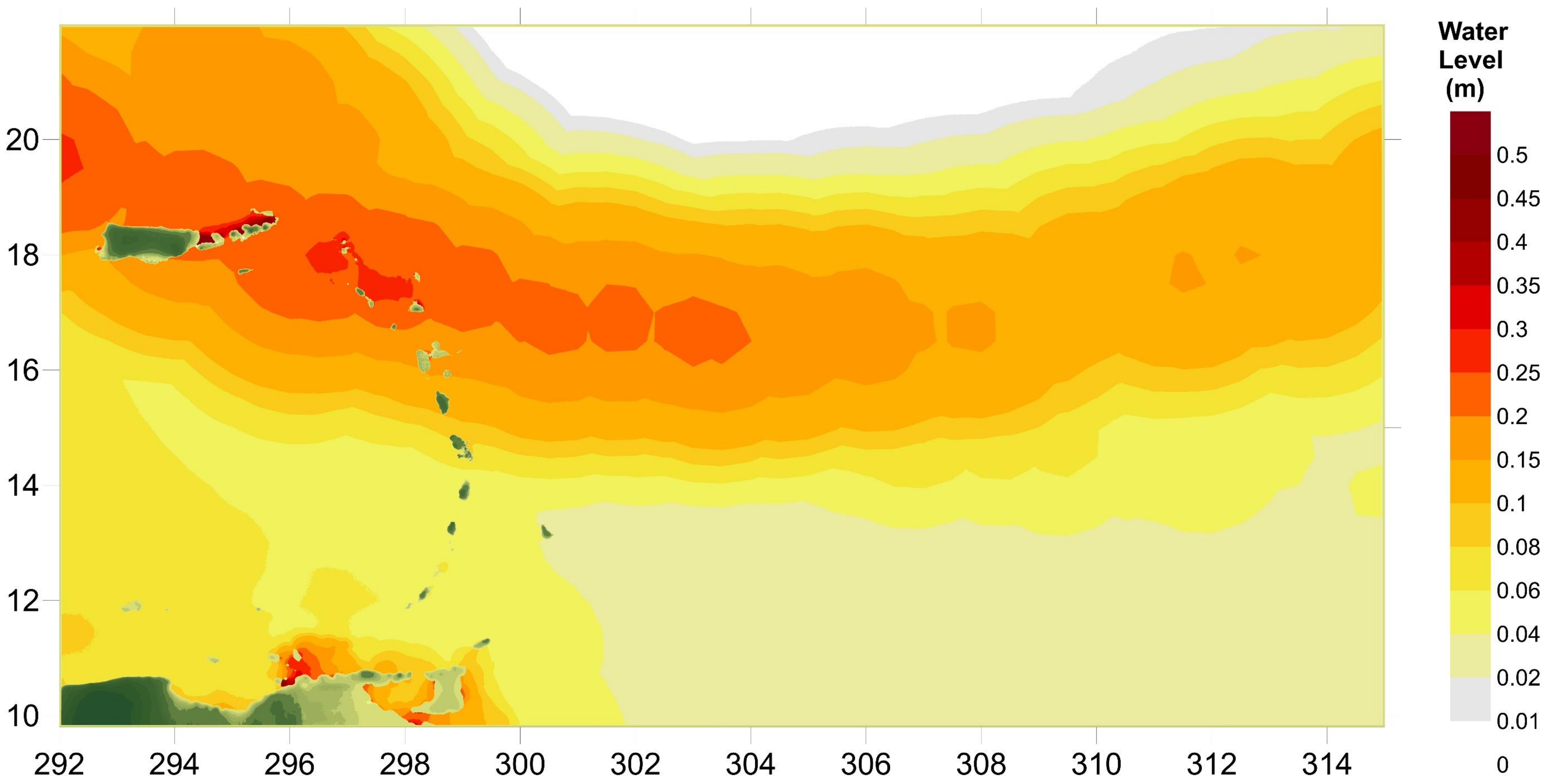
Run Time: 02.09.2017-11.09.2017

The atmospheric pressure, eastward wind and northward wind data of Hurricane Irma taken from CFSR on September 06, 2017 at 05:00 UTC.

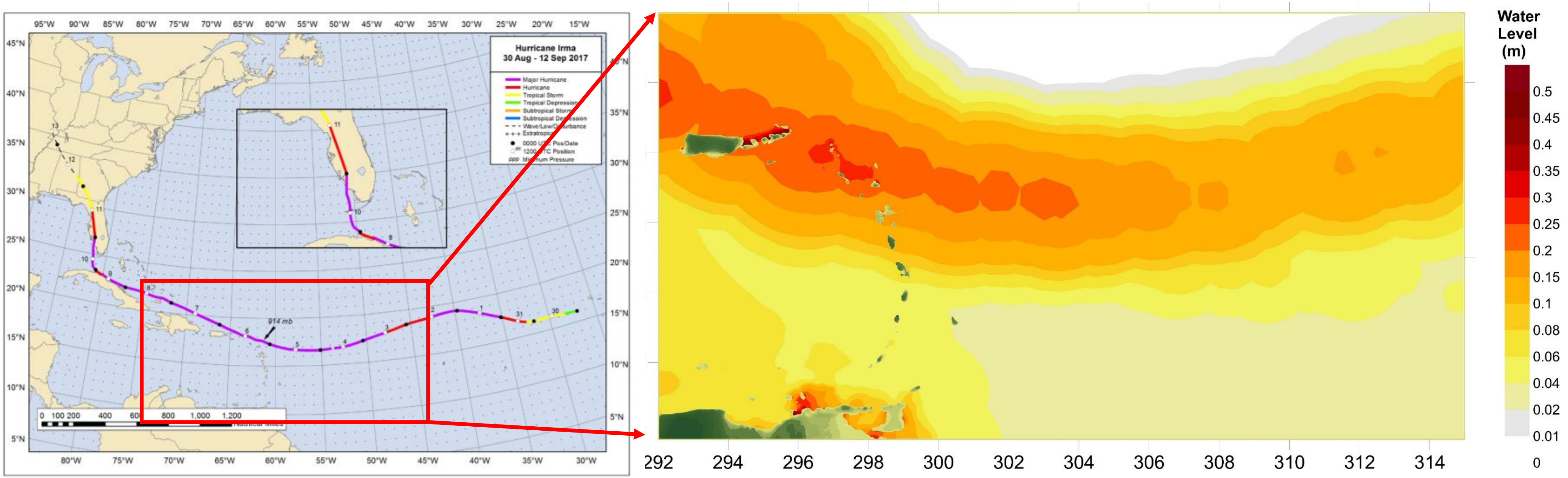




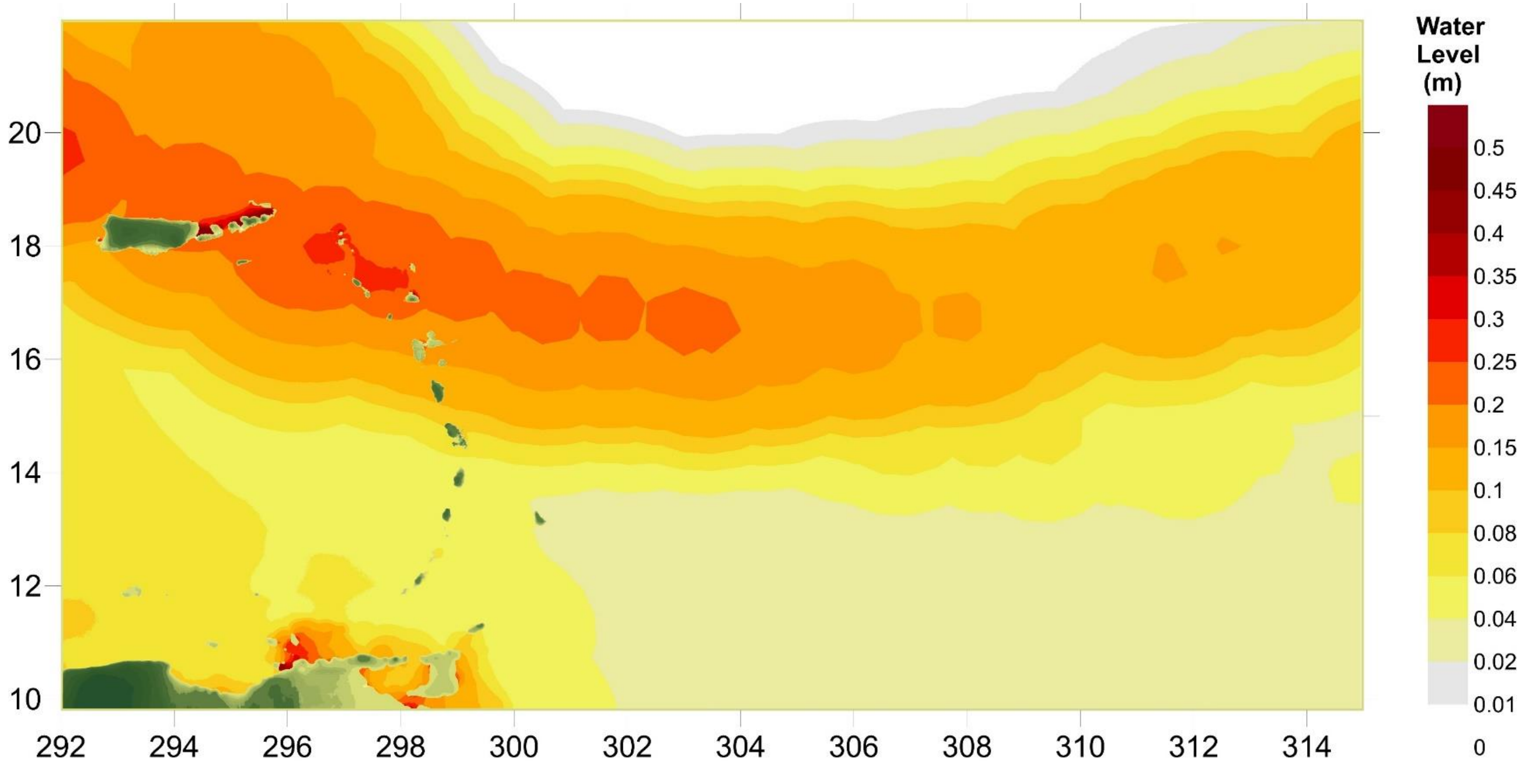




Distribution of maximum water level due to atmospheric pressure and wind during IRMA

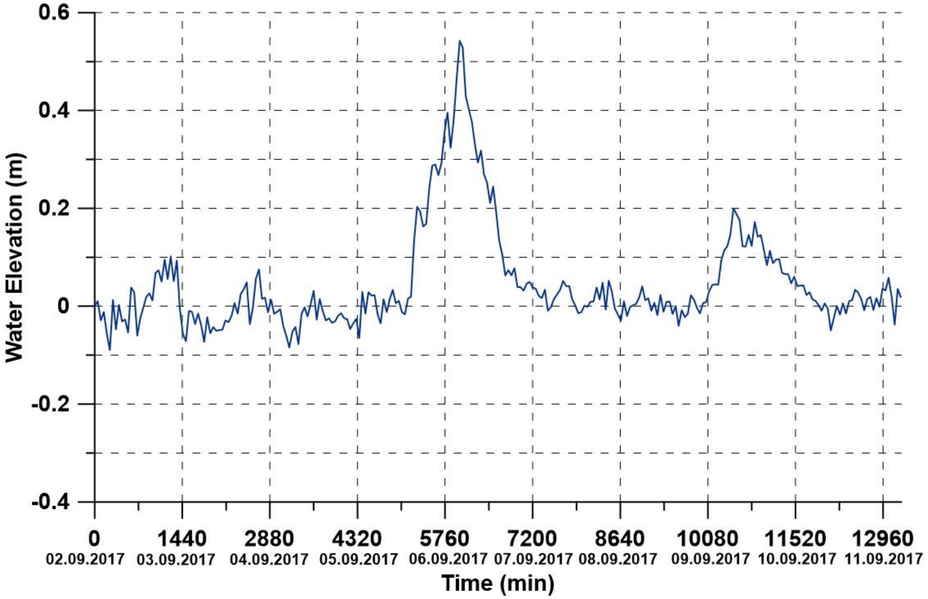


Distribution of maximum water level due to atmospheric pressure and wind during IRMA

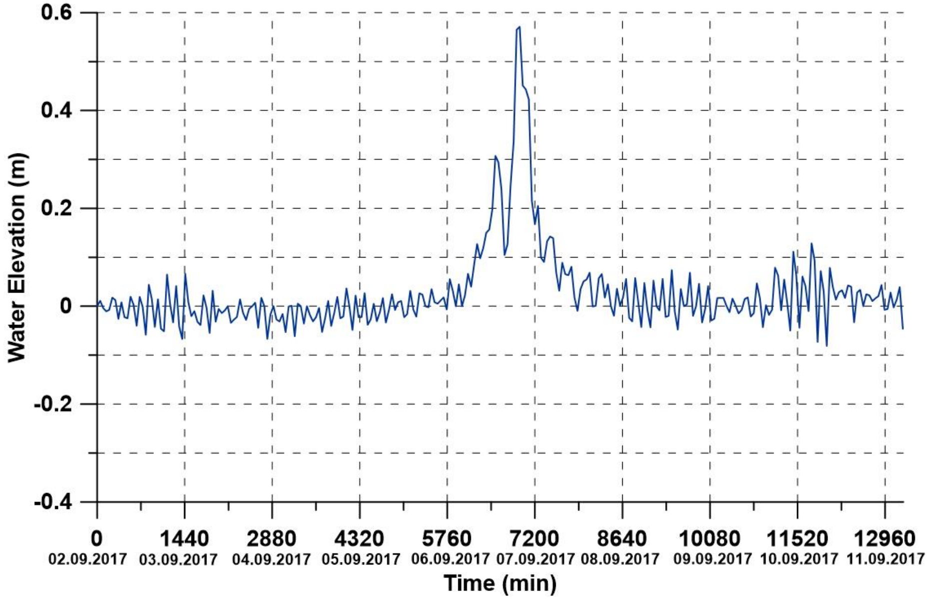


Distribution of maximum water level due to atmospheric pressure and wind during IRMA

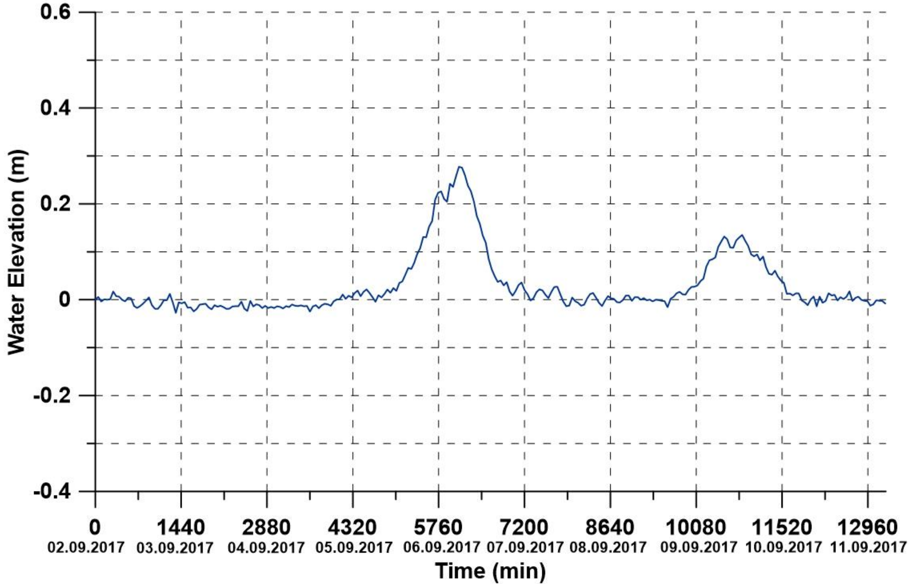
Antigua



Vieques

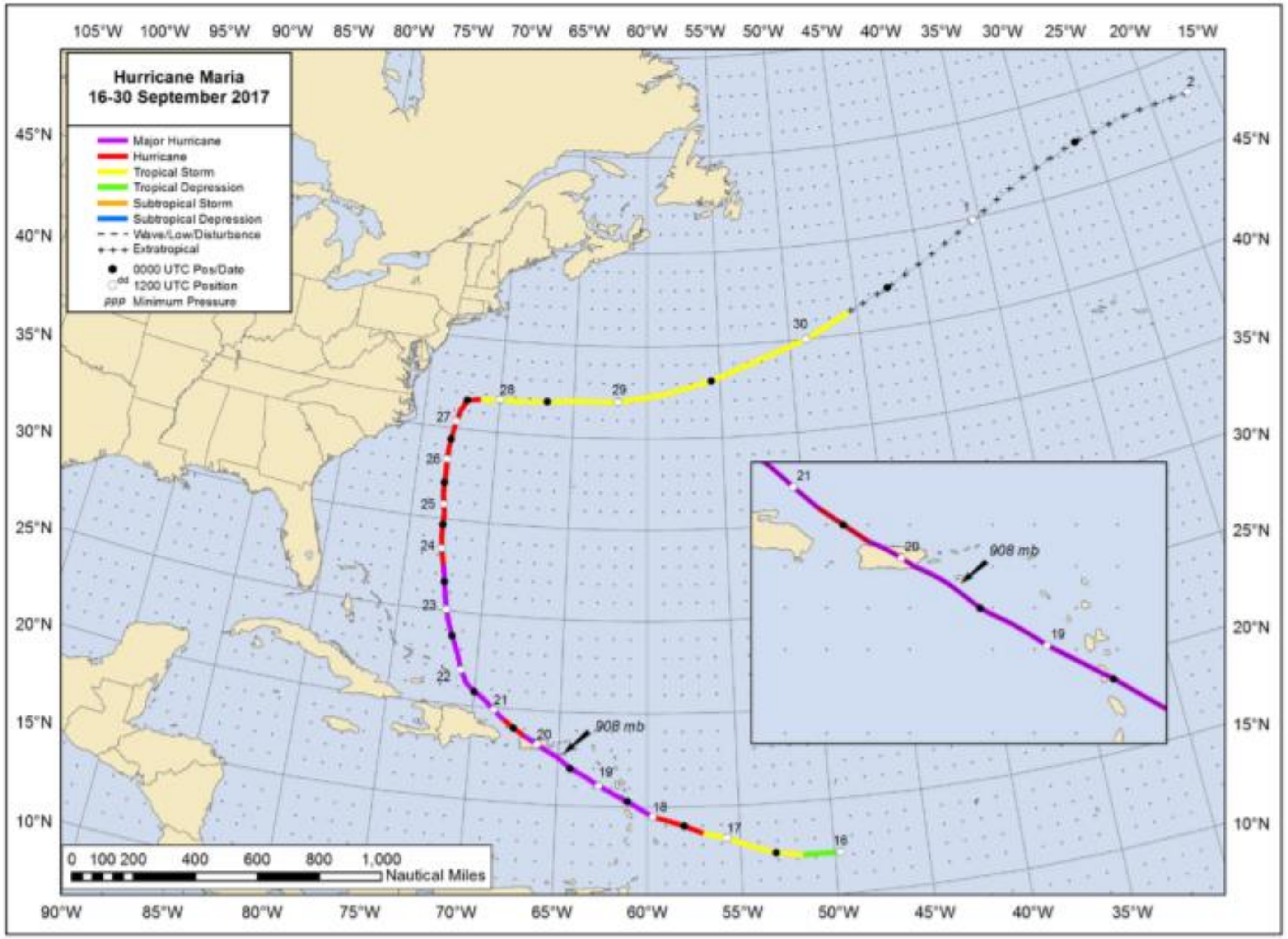


Barbuda



MODELING OF HURRICANE MARIA

Maria originated from a well-defined tropical wave that departed the west coast of Africa on 12 September

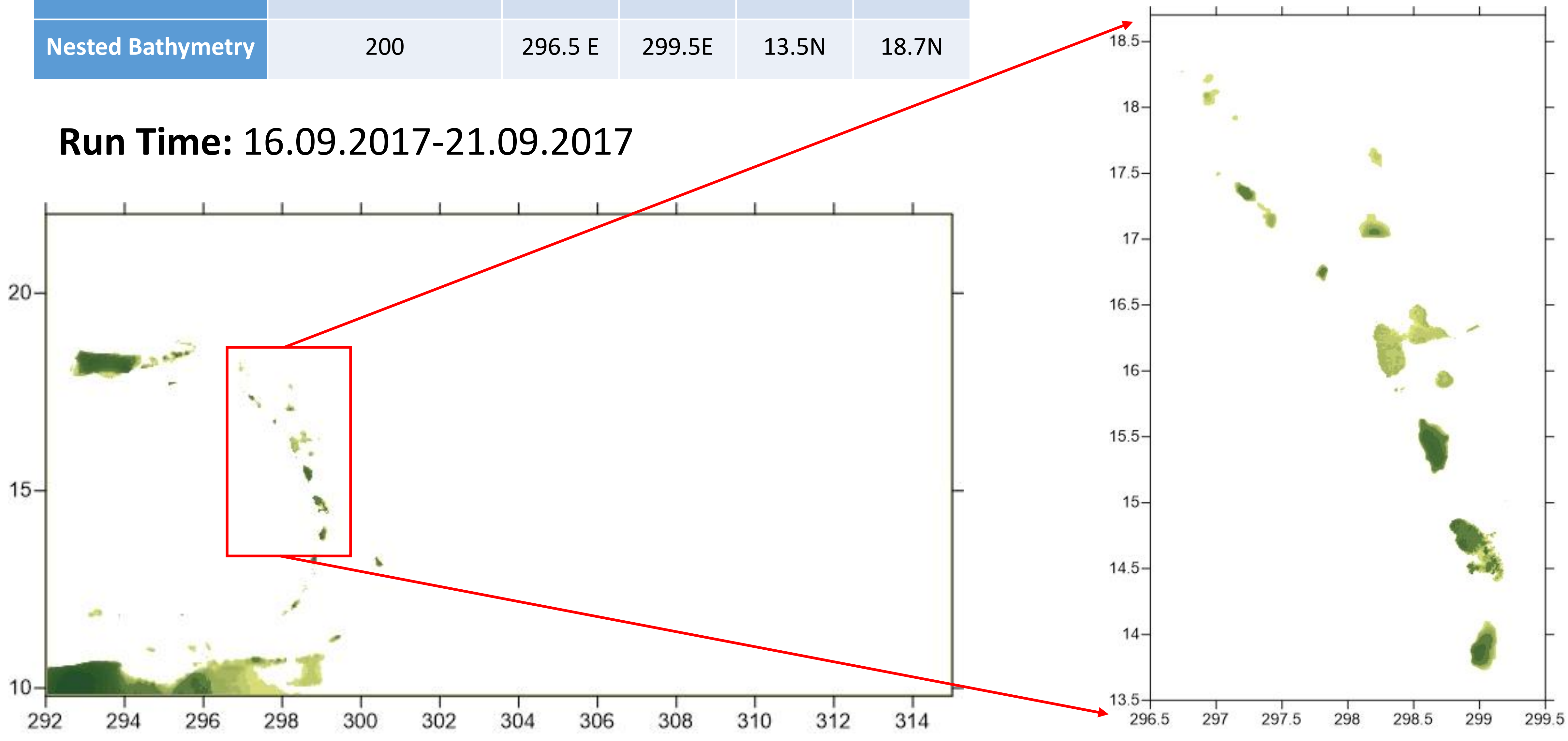


Best track positions for Hurricane Maria, 16–30 September 2017. Track during the extratropical stage is partially based on analyses from the NOAA Ocean Prediction Center National Hurricane Center, Hurricane Irma Report, 2017.

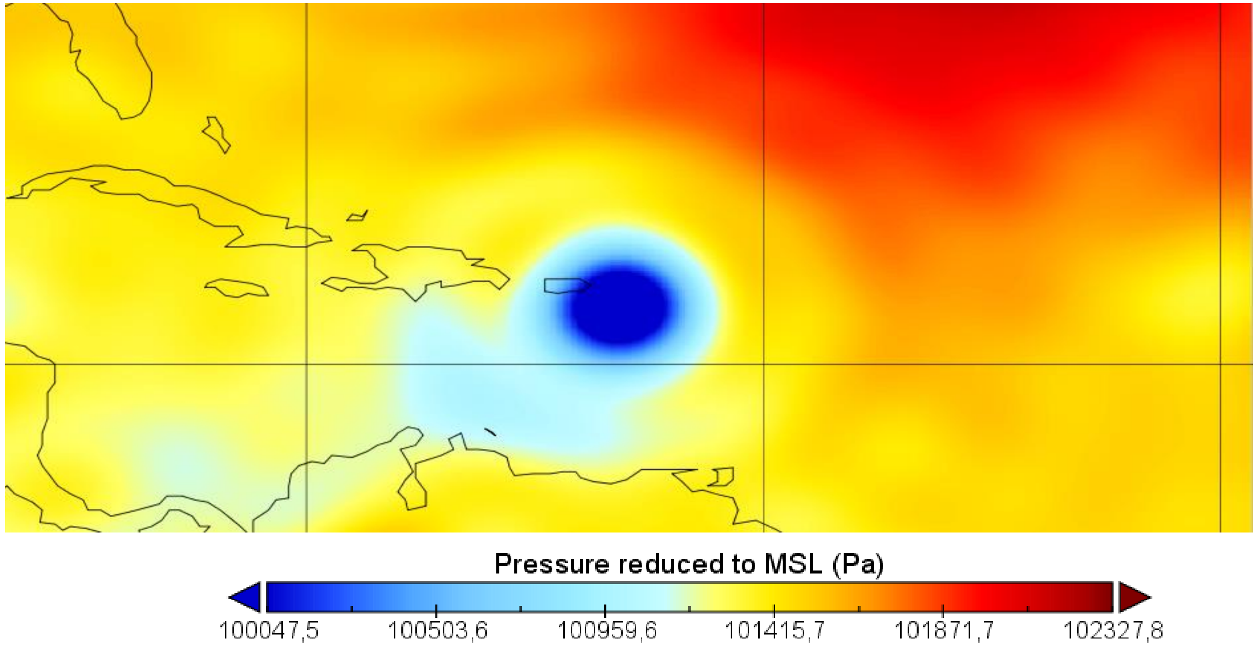
Numerical Modeling of MARIA

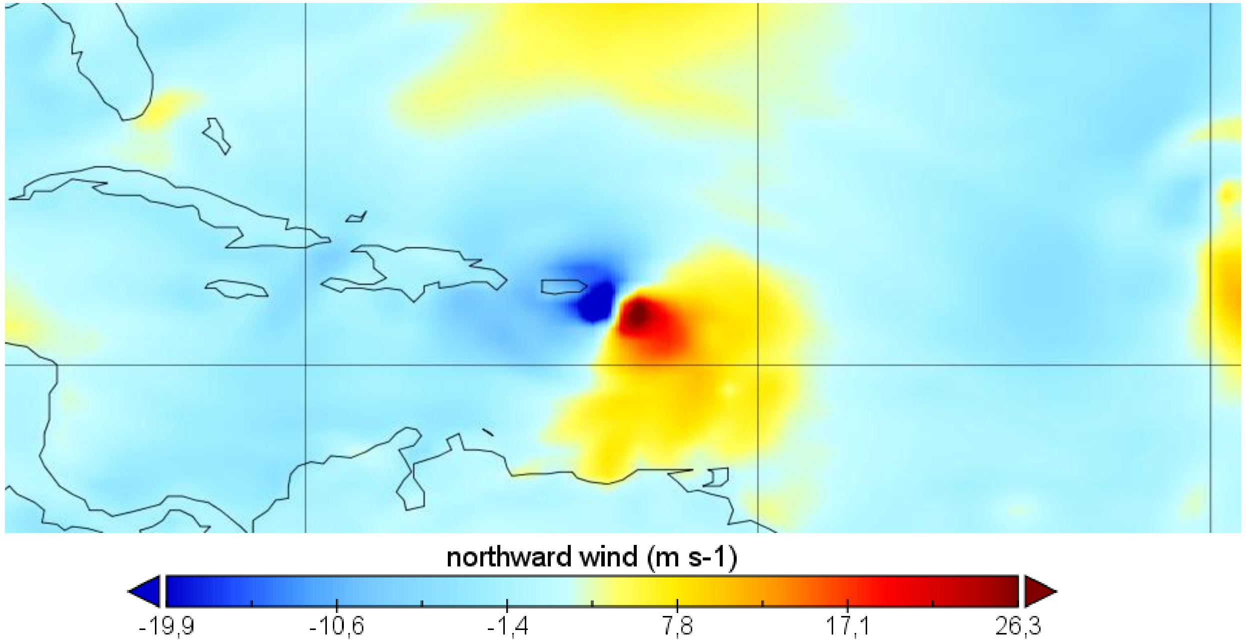
Bathymetry	Grid Size (m)	Corner Coordinates			
Coarse Bathymetry	900	292E	315E	9.8N	22N
Nested Bathymetry	200	296.5 E	299.5E	13.5N	18.7N

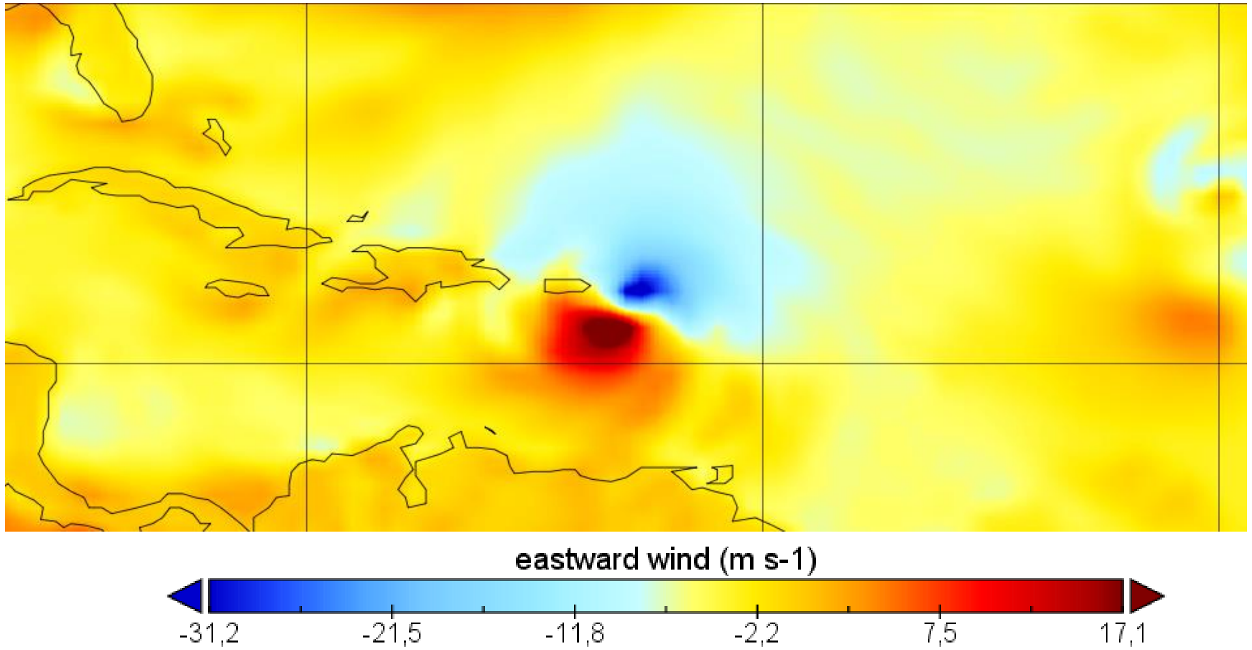
Run Time: 16.09.2017-21.09.2017

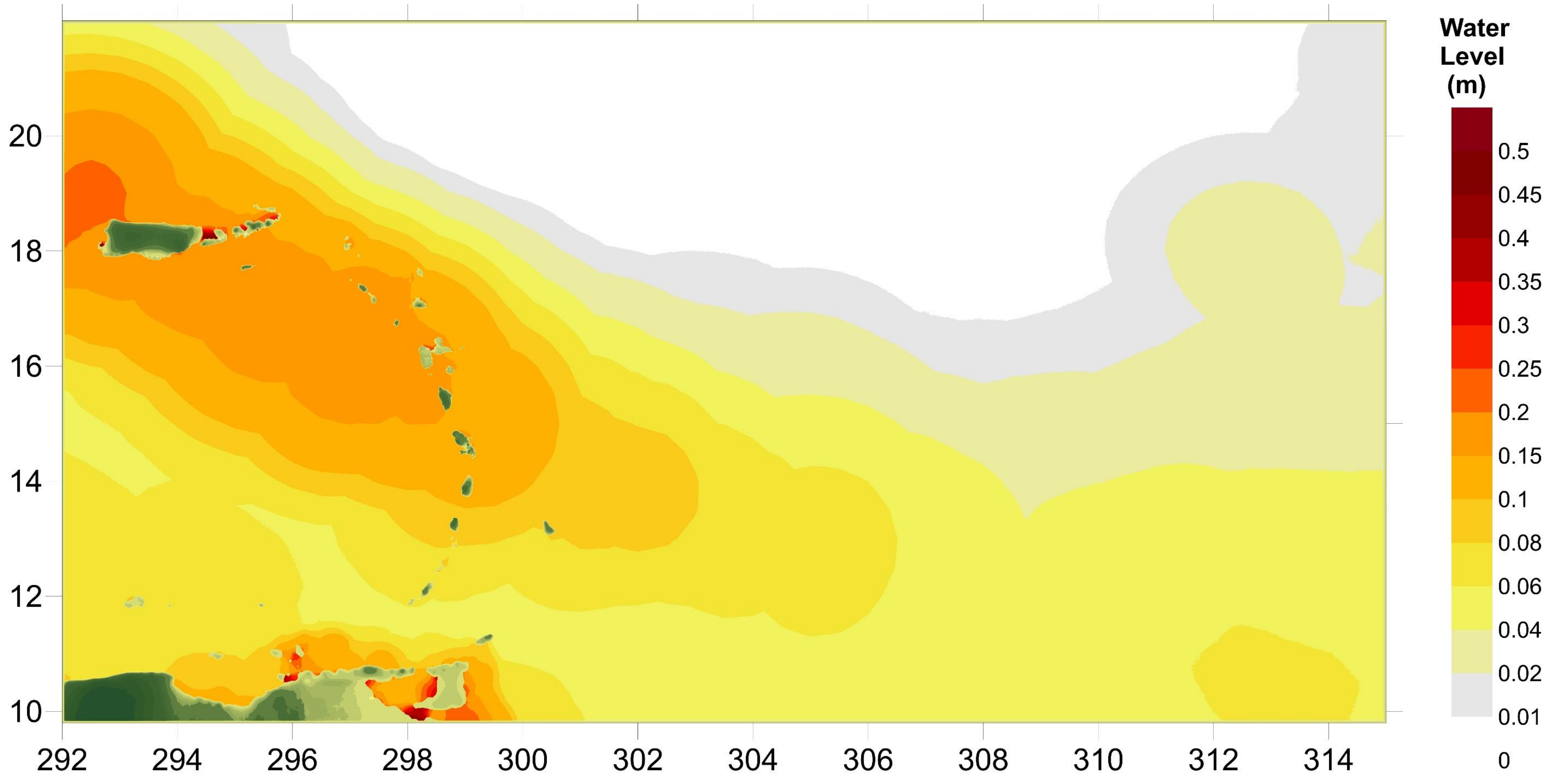


The atmospheric pressure, eastward wind and northward wind data of Hurricane Irma taken from CFSR on September 20, 2017 at 03:00 UTC.

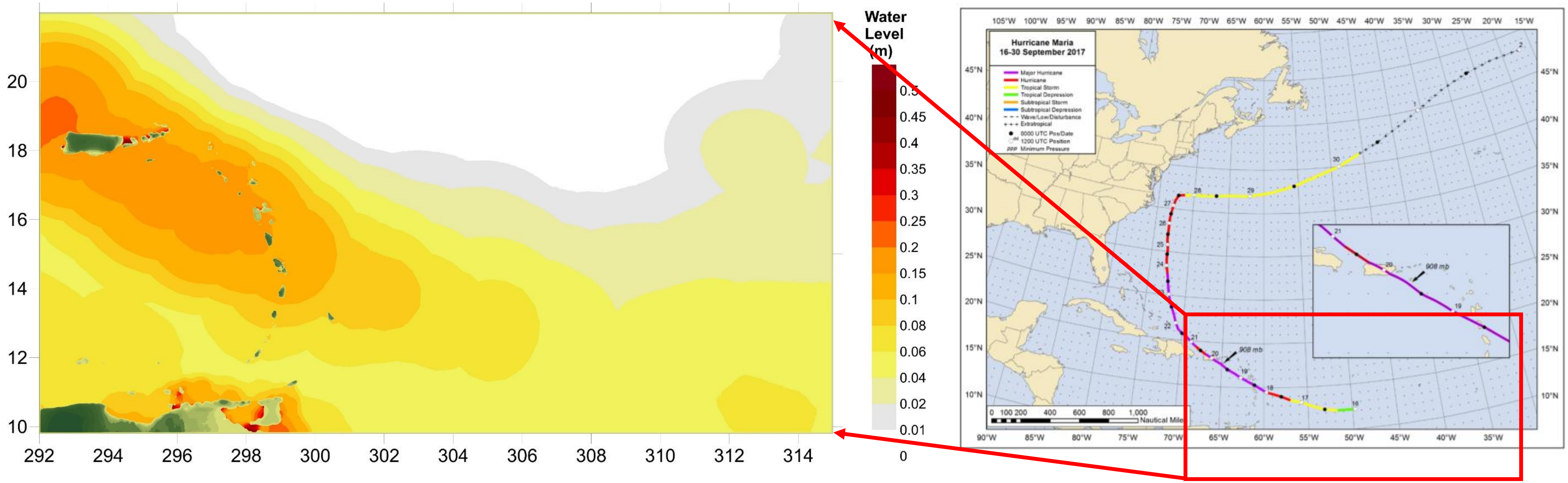




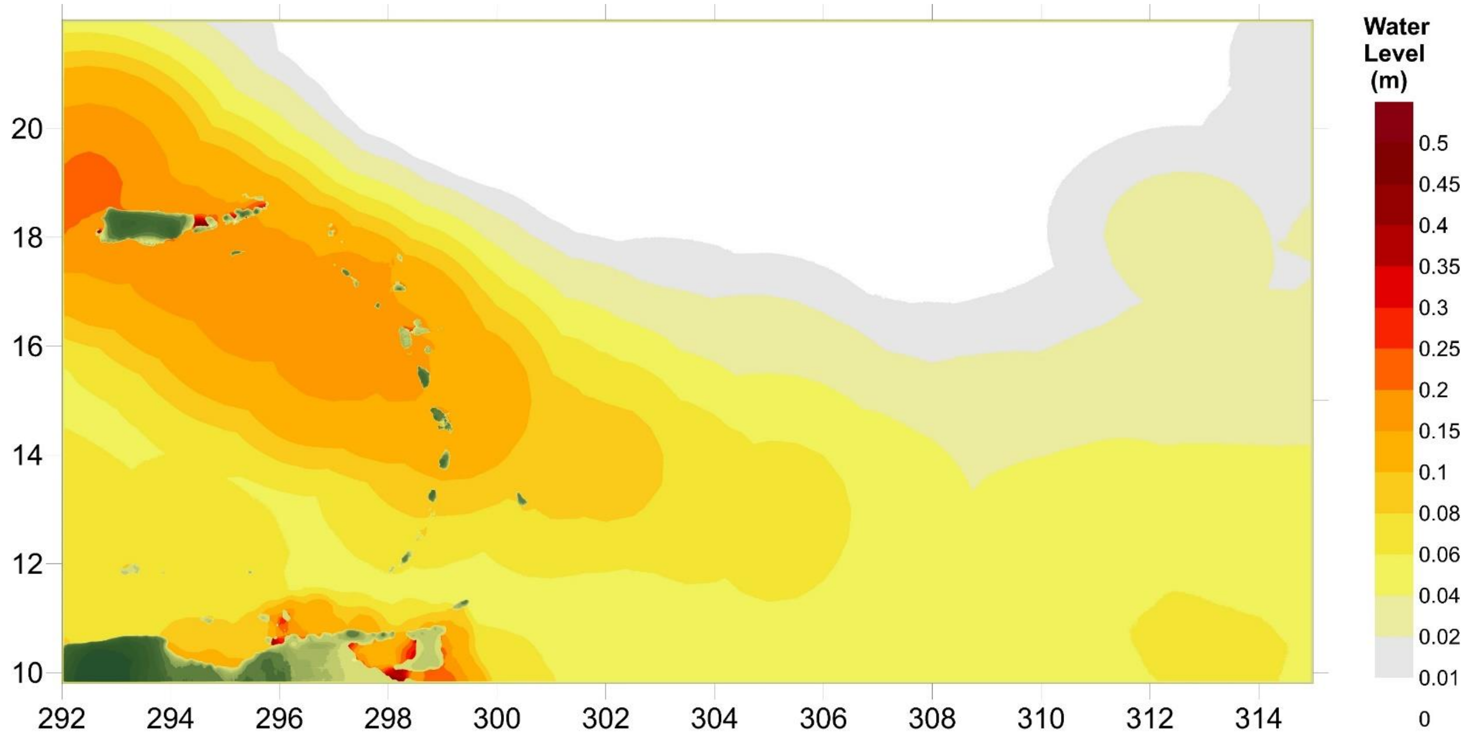


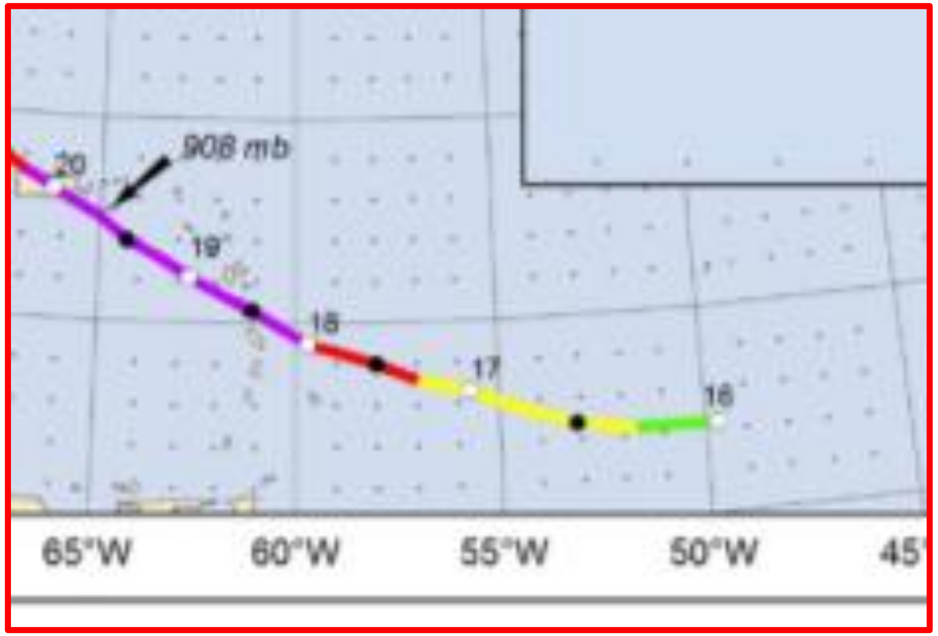


Distribution of maximum water level due to atmospheric pressure and wind during MARIA

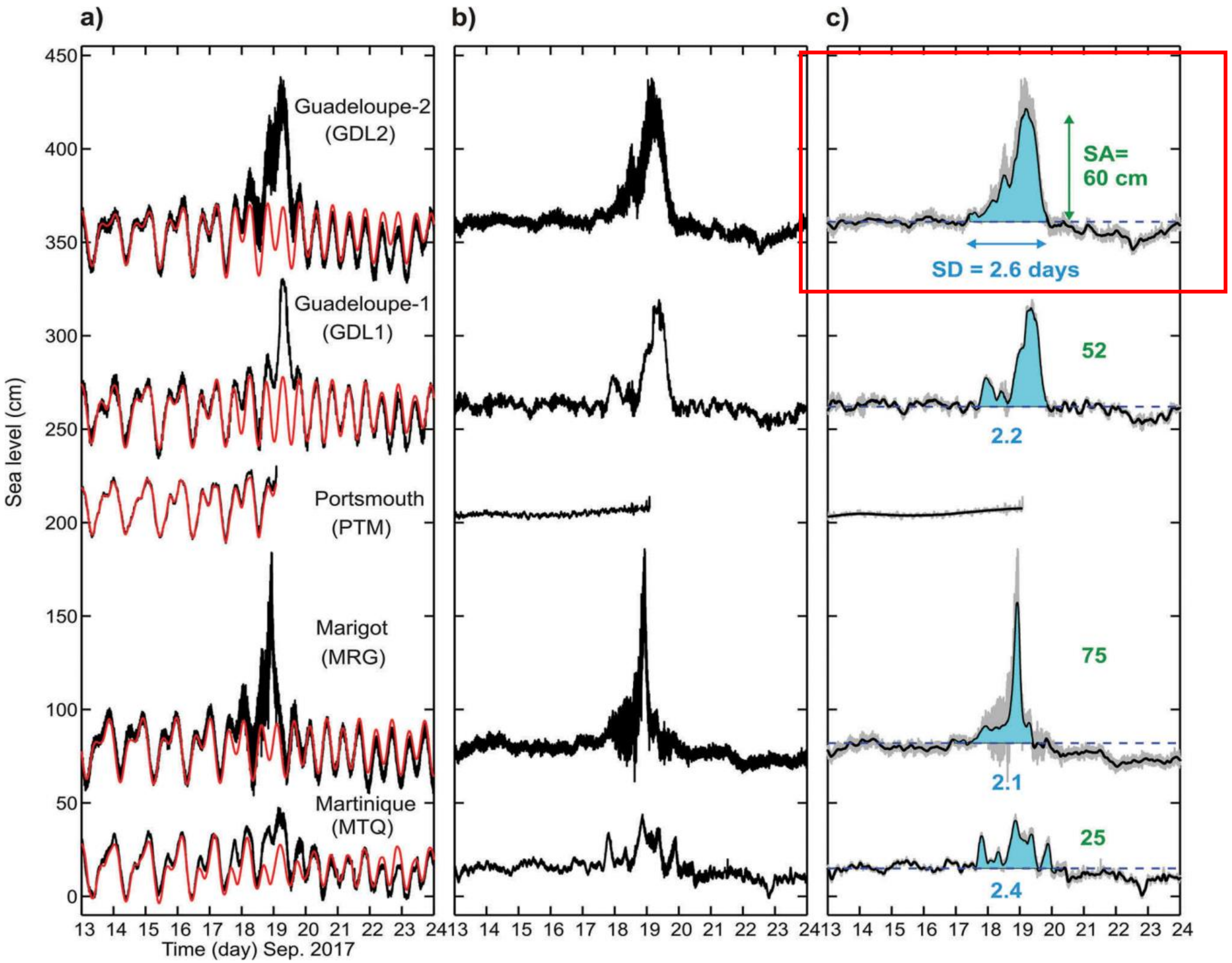


Distribution of maximum water level due to atmospheric pressure and wind during MARIA



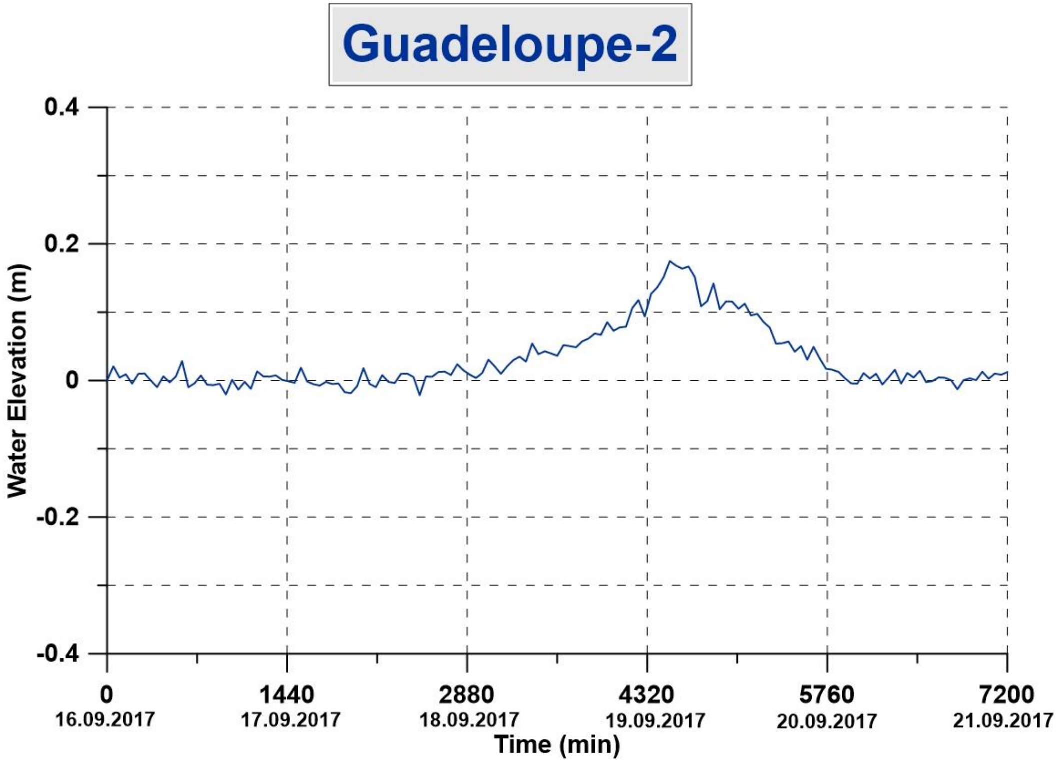


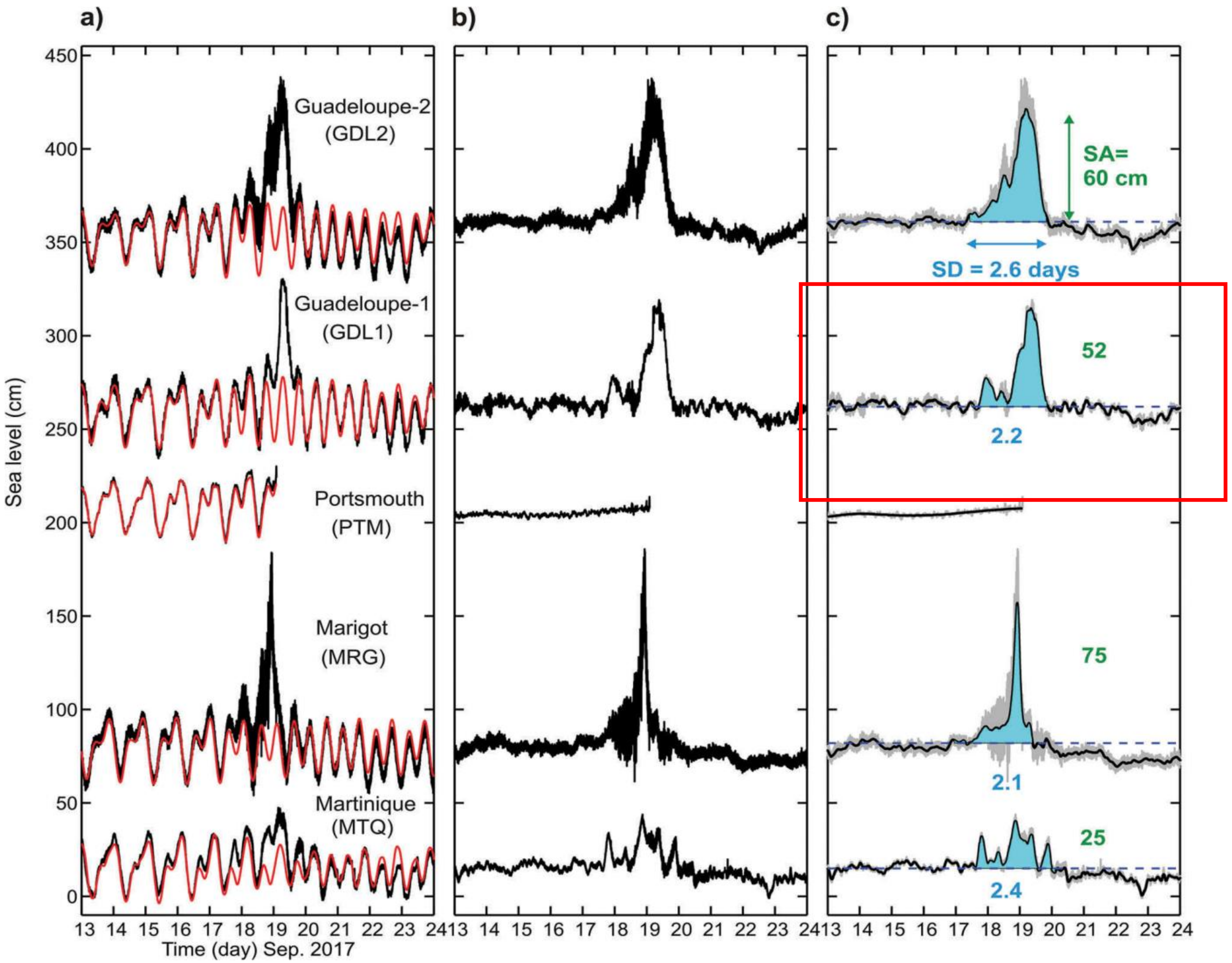
Distribution of maximum water level due to atmospheric pressure and wind during MARIA

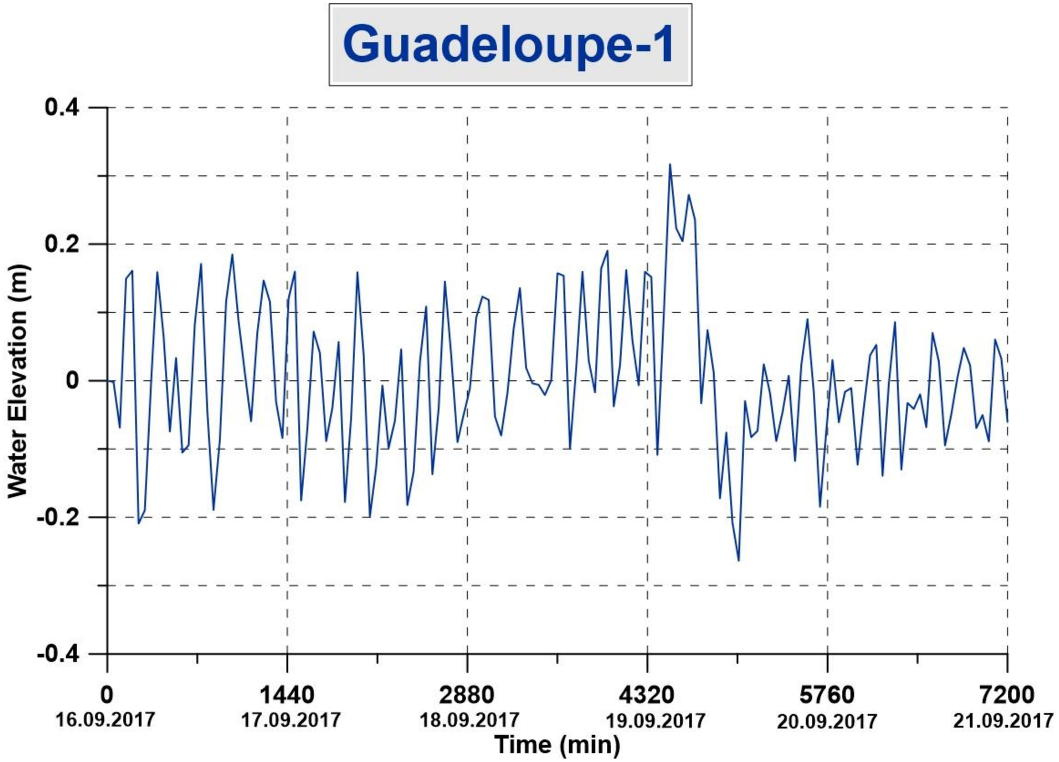


(Heidarzadeh et. al.,2018)

(a) The original tide gauge records
(b) The de-tided tide gauge waveforms
(c) The one-hour averaged waveforms representing the storm surge amplitudes







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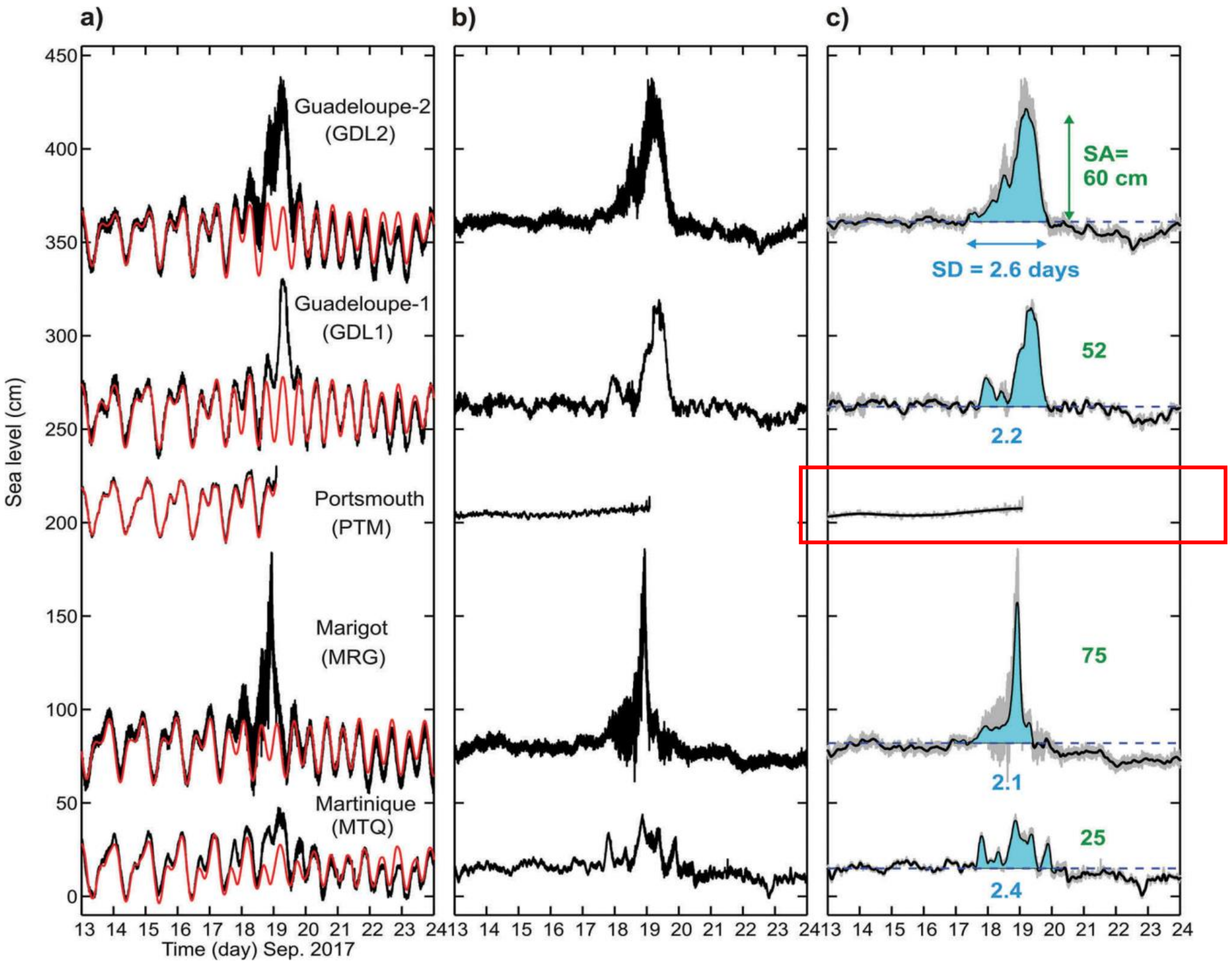

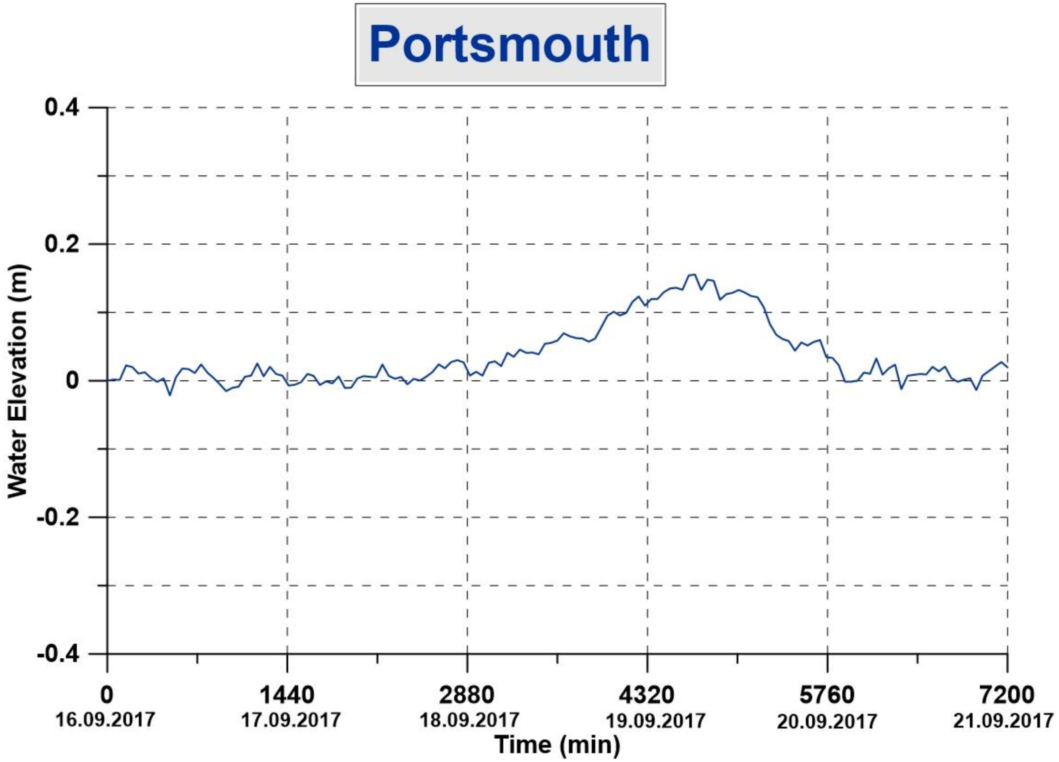

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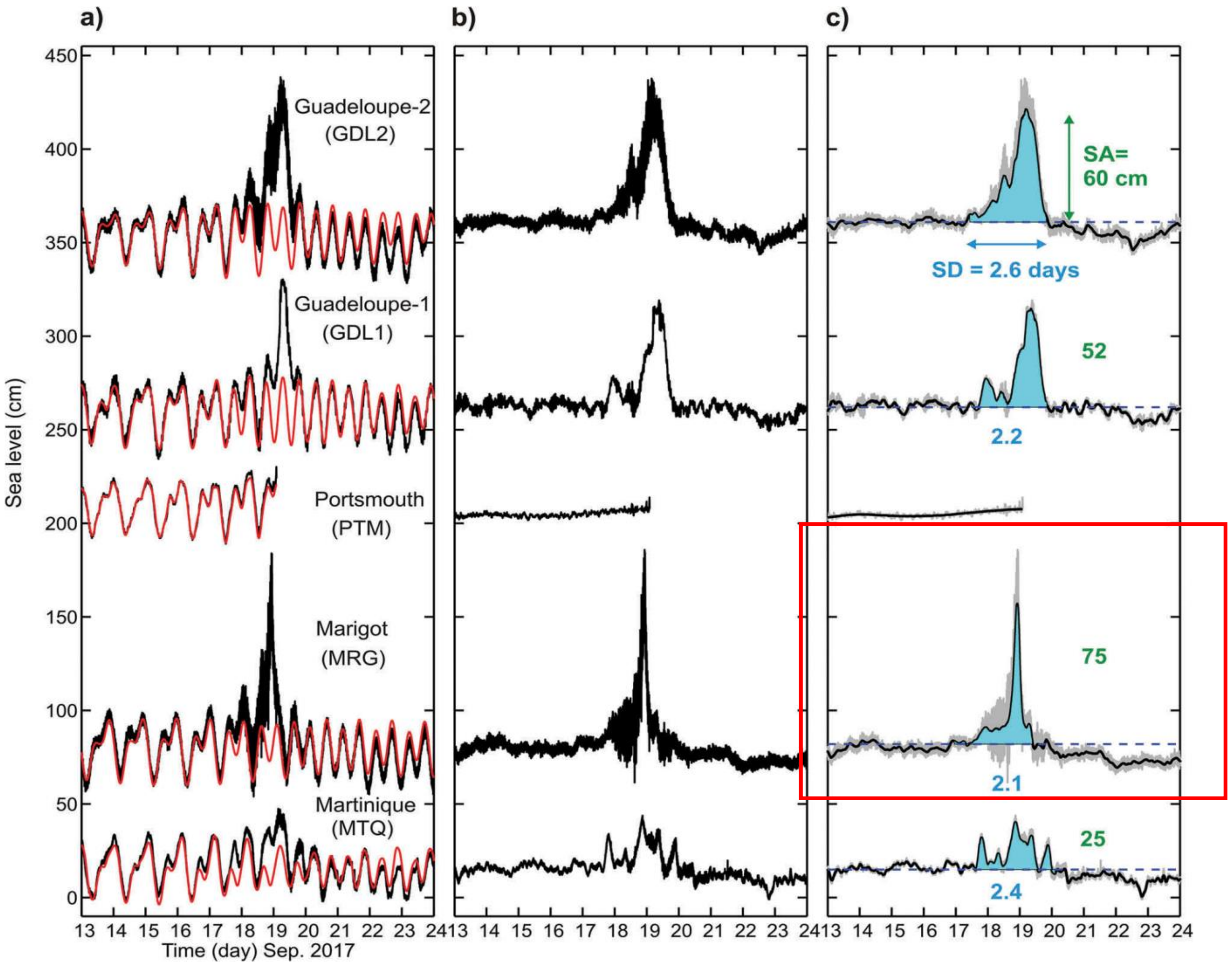

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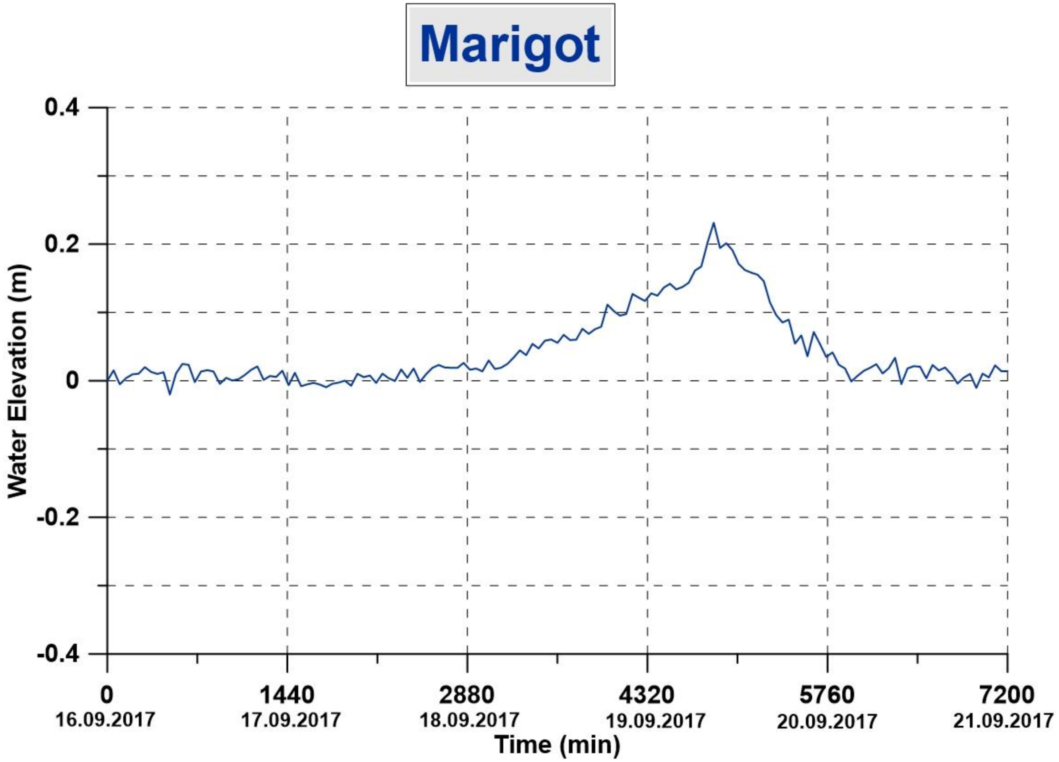

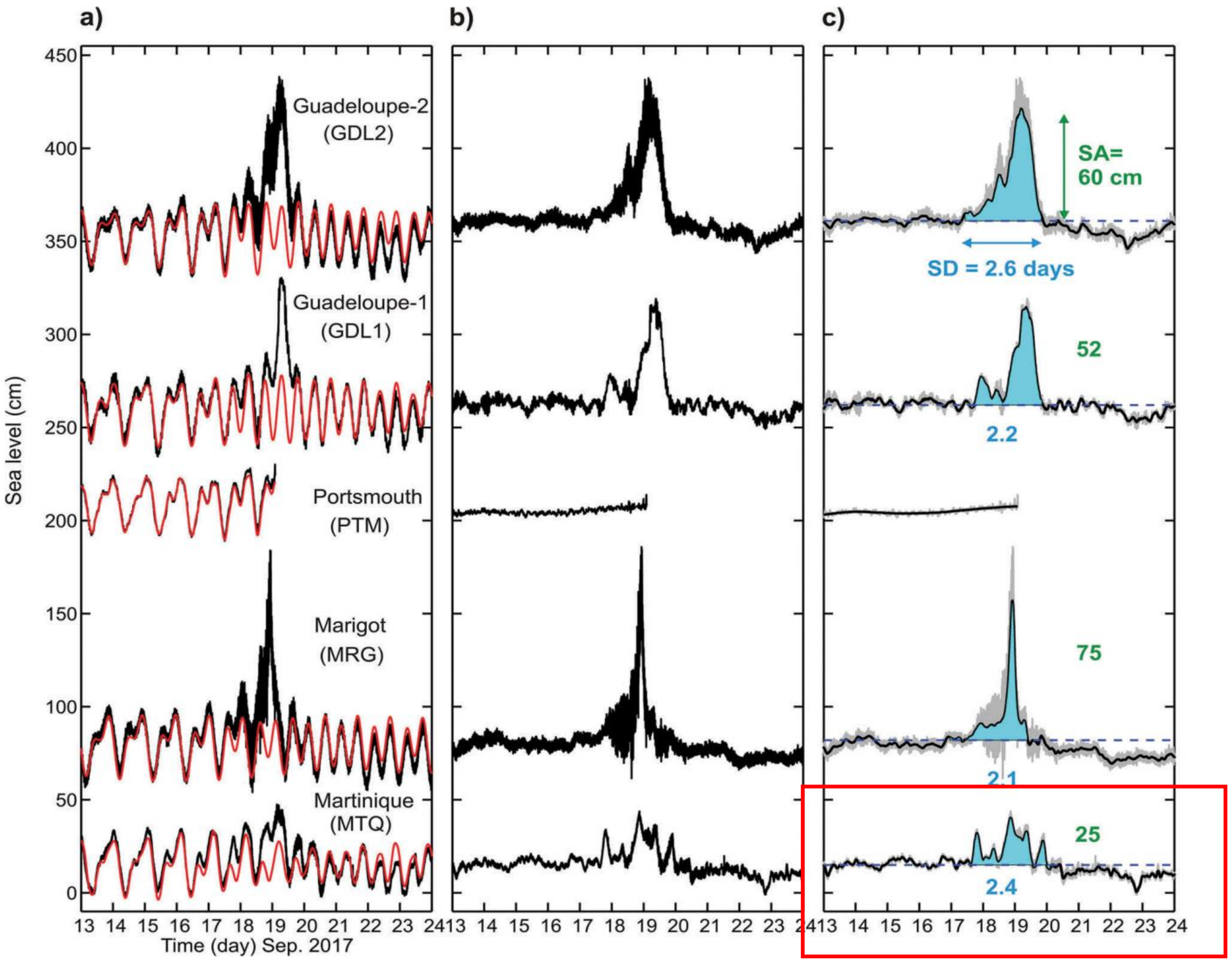

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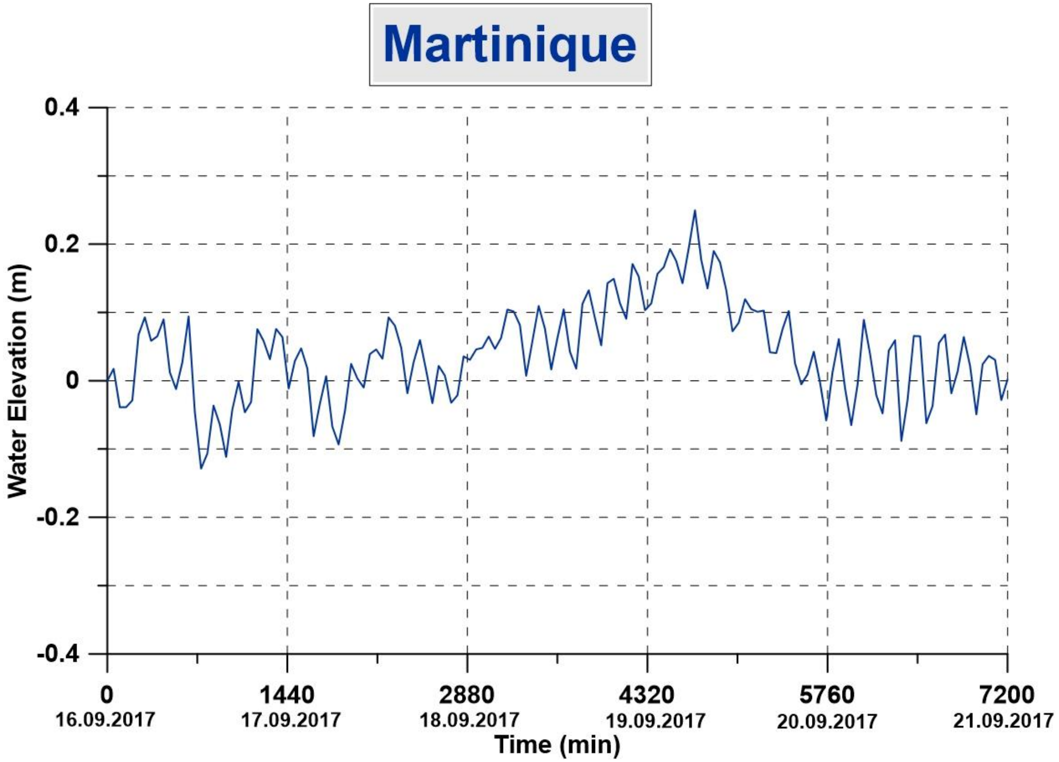
(c) The one-hour averaged waveforms representing the storm surge amplitudes



A CASE STUDY FOR TSUNAMI MODELING AND HAZARD ASSESSMENT

Complete Tsunami Hazard Assessment, Vulnerability and Risk Analysis for the Marmara Coast of Istanbul Metropolitan Area and Istanbul Metropolitan Municipality Tsunami Action Planning

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MIDDLE EAST TECHNICAL UNIVERSITY

İSTANBUL BÜYÜKŞEHİR BELEDİYESİ

PHASES

“Updating of Istanbul’s Tsunami Hazard and Vulnerability Analyses”

PHASE 1:

STAGE 1) Development of high resolution Digital Elevation Model (DEM) data enhanced by including buildings

STAGE 2) Computation of hazard levels for each 17 coastal districts w.r.t NAF sourced 14 different co-seismic and 3 submarine landslide areas with the use of NAMI DANCE GPU software

STAGE 3) Vulnerability analysis by using the MeTHuVA (METU Metropolitan Tsunami Human Vulnerability Assessment) Method (Tufekci et al., 2018) that covers human vulnerability assessment with GIS-based multi criteria decision analysis (MCDA)

PHASE 2:

Tsunami Action Plan

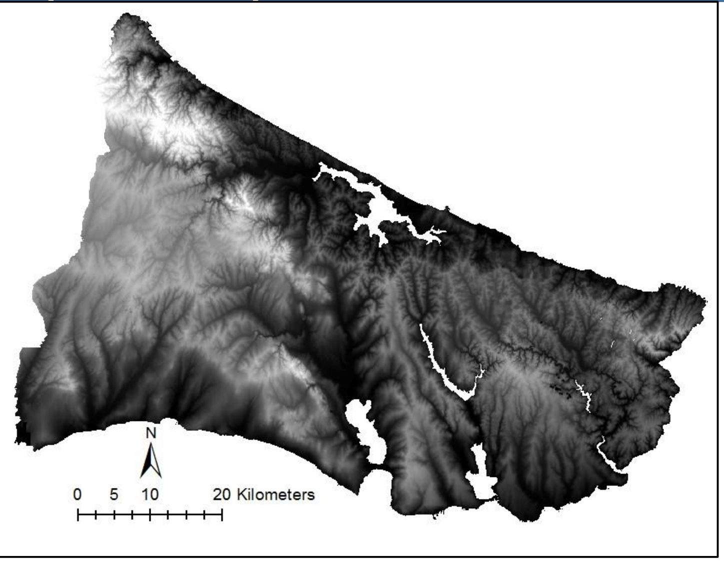
Structural measures

Nonstructural Measures

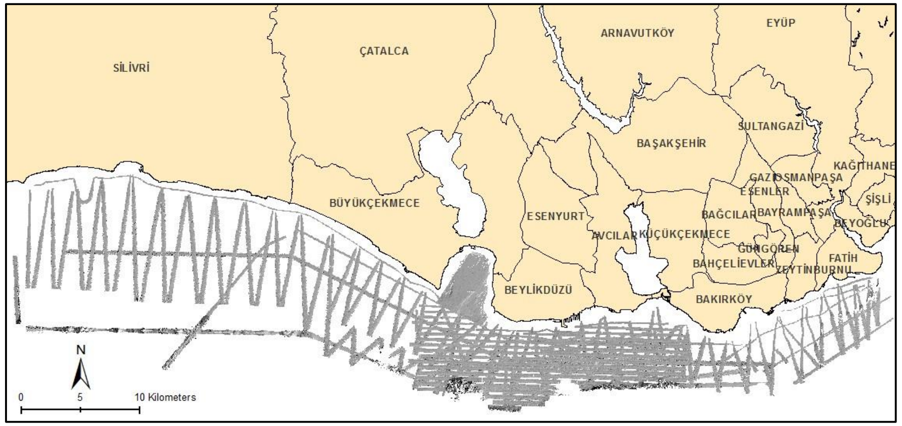
39 districts of Istanbul Metropolitan Municipality

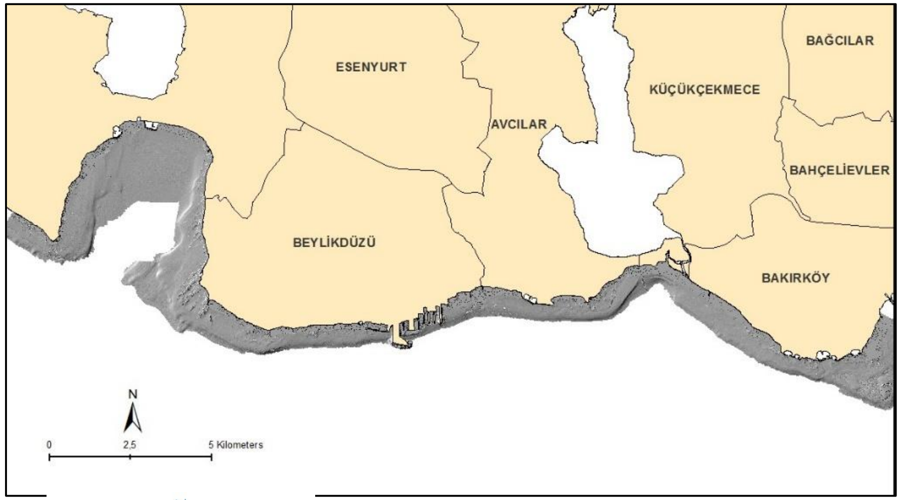
17 of 39 are along Marmara or Bosphorus Coast

STAGE 1: Development of high resolution Digital Elevation Model (DEM) data



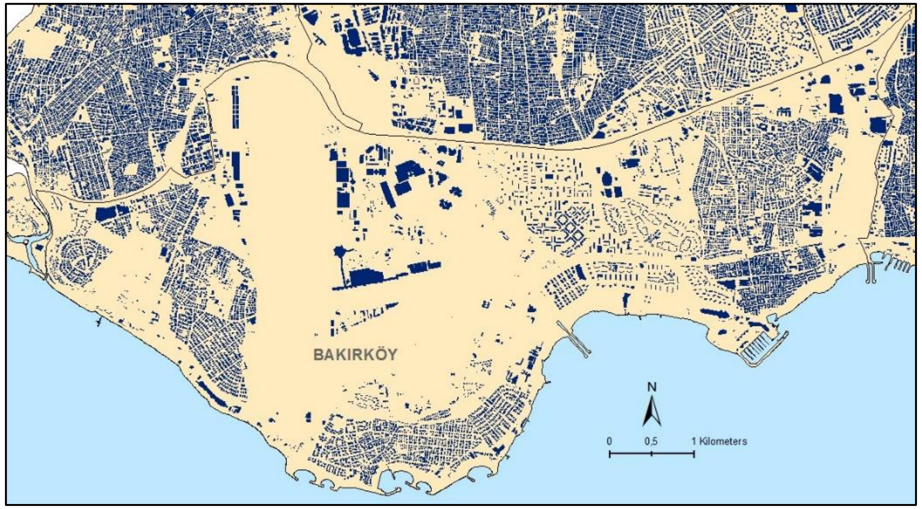
1m resolution LIDAR based DEM data





High re **netrical data for 7-8 km offshore**

Roads database



Buildings database

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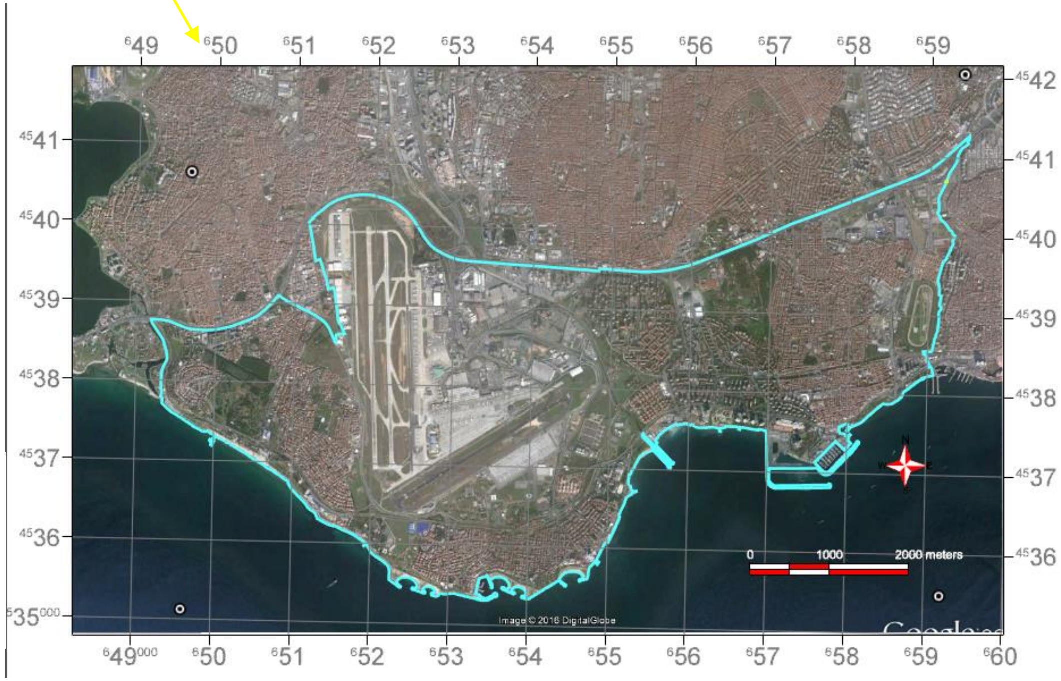
Example Application Area: Bakırköy district, İstanbul



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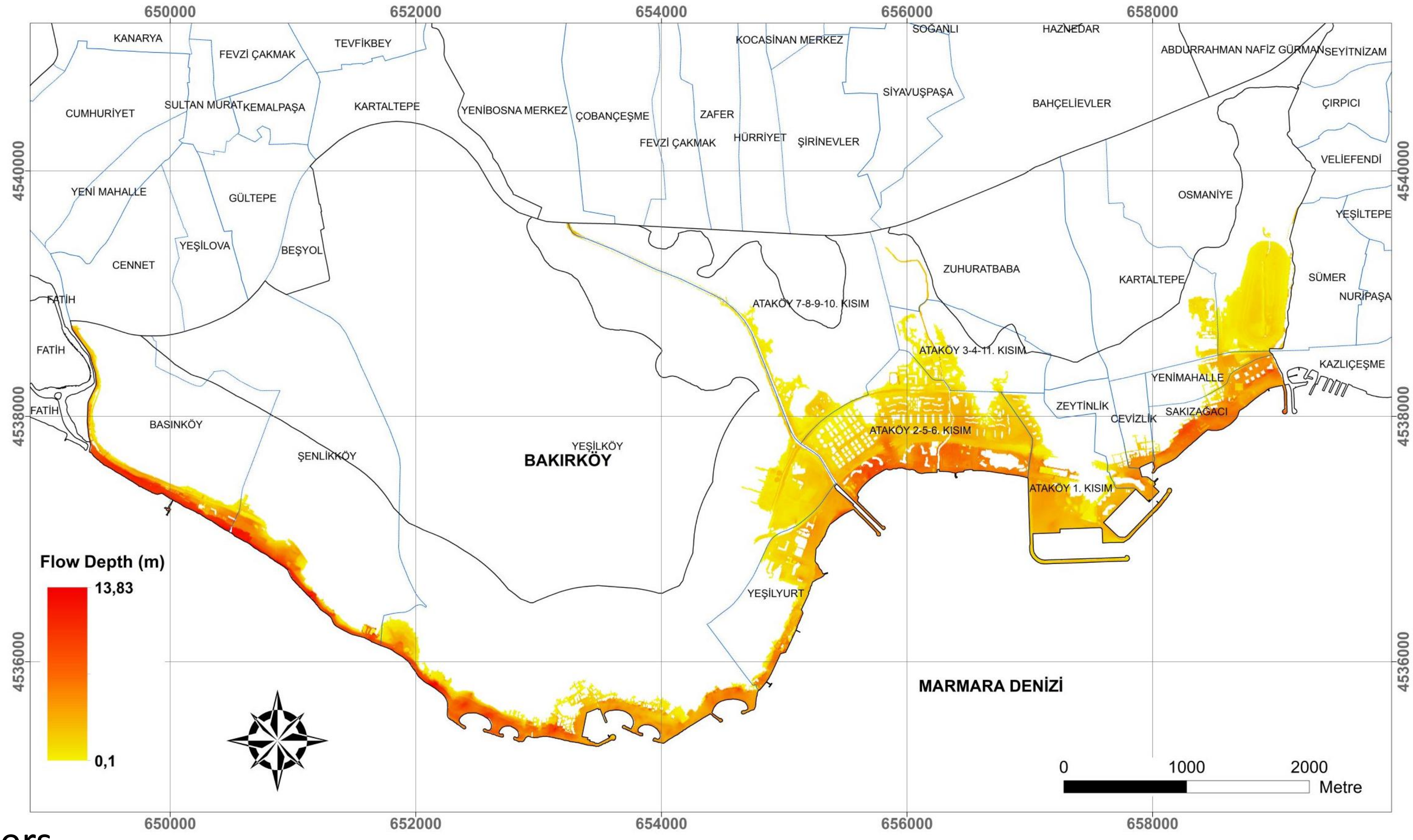
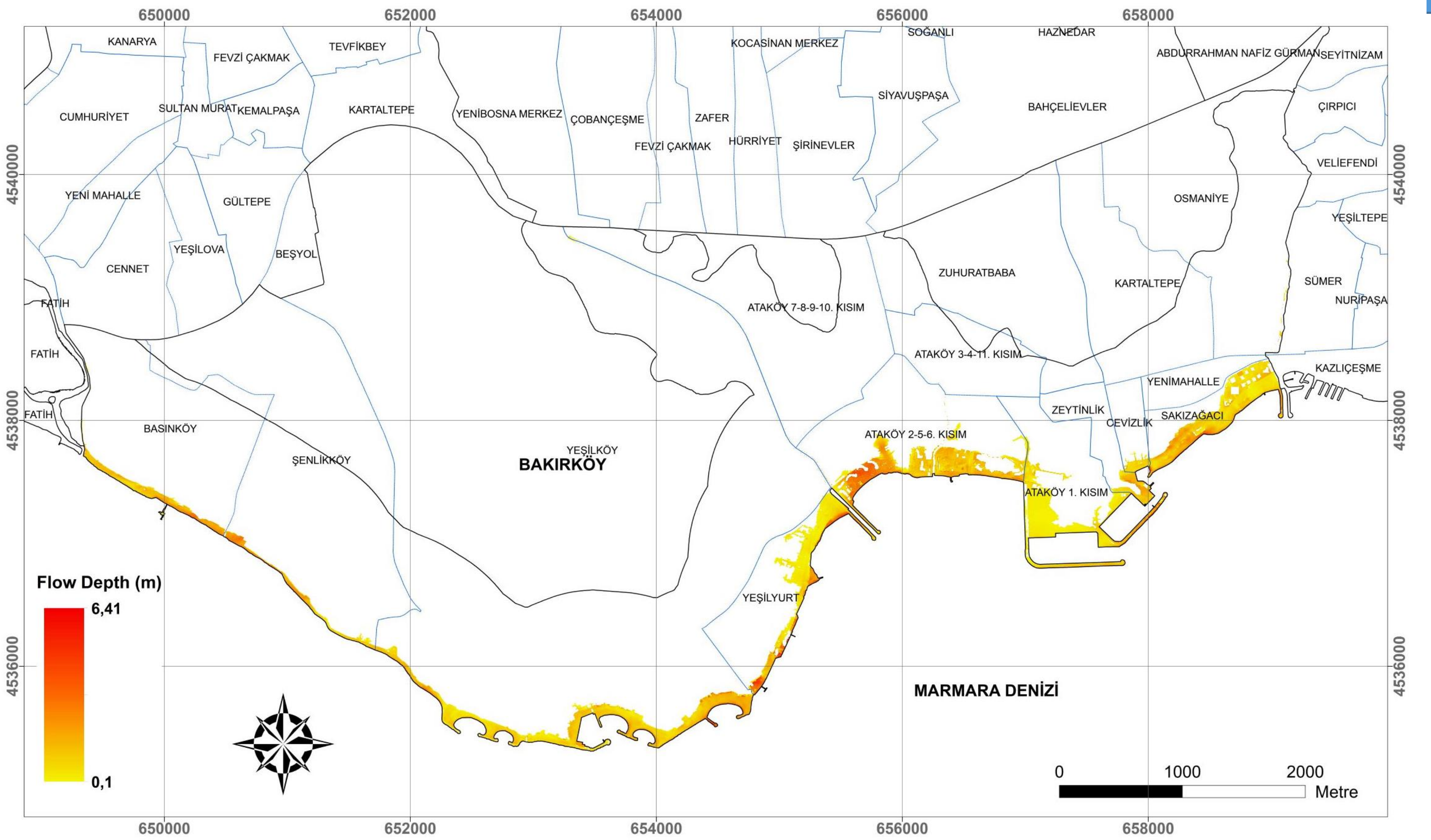
TSUNAMI HAZARD ANALYSIS – HAZARD MAP - LANDSLIDE SOURCE BAKIRKOY DISTRICT EXAMPLE



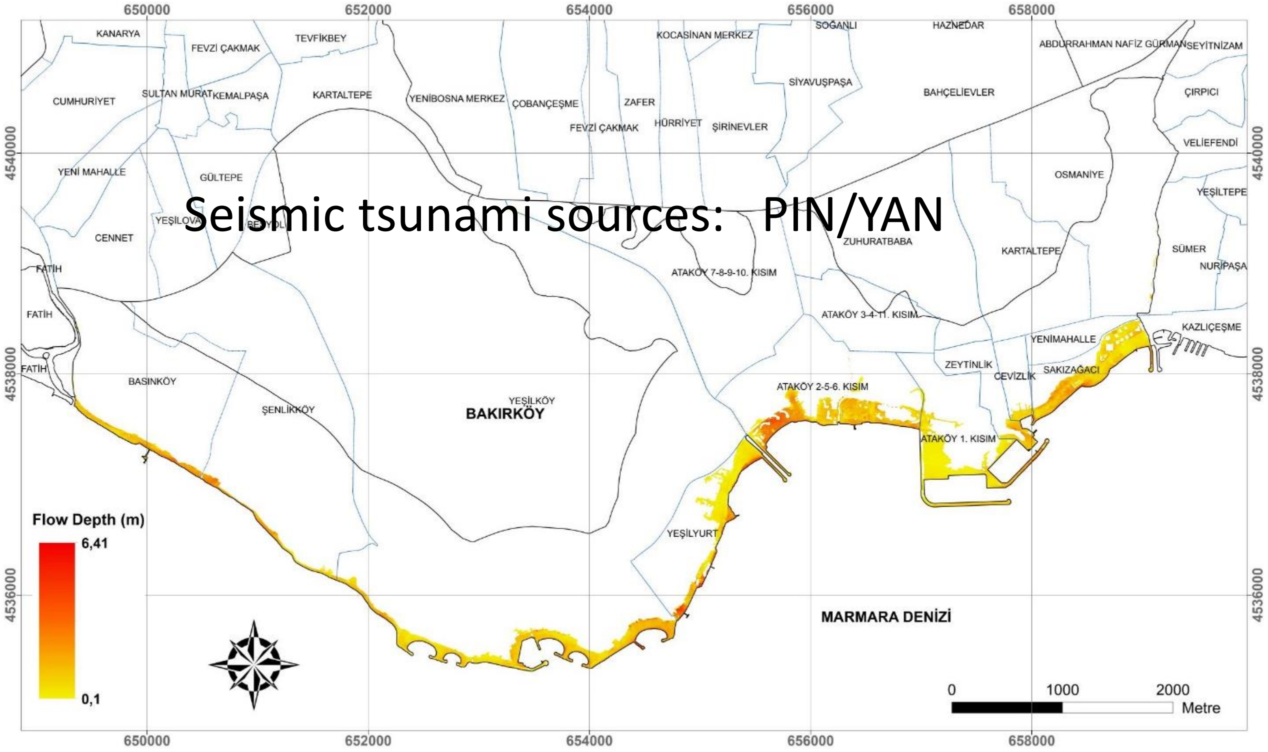
- Tsunami Source LSBC
- Maximum flow 13,80 meters
- Maximum inundation distance reached 1200 meters.

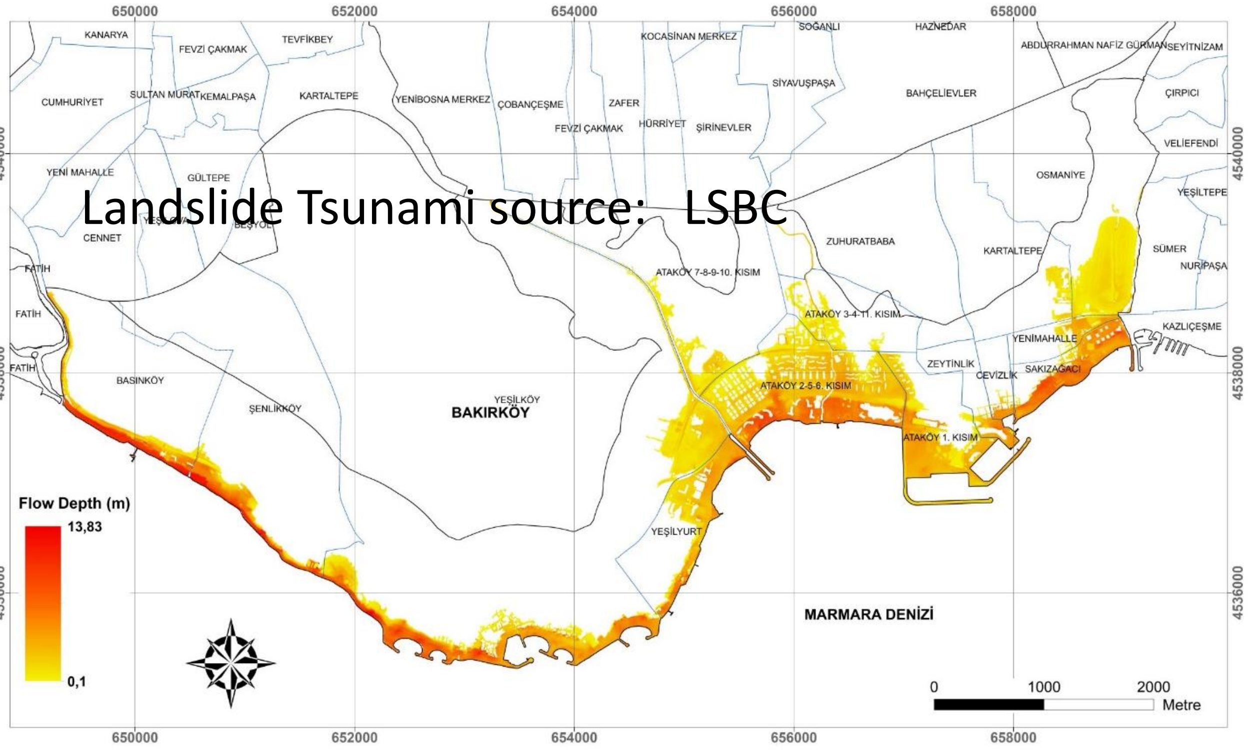
TSUNAMI HAZARD ANALYSIS – HAZARD MAP - SEISMIC SOURCES BAKIRKOY DISTRICT EXAMPLE

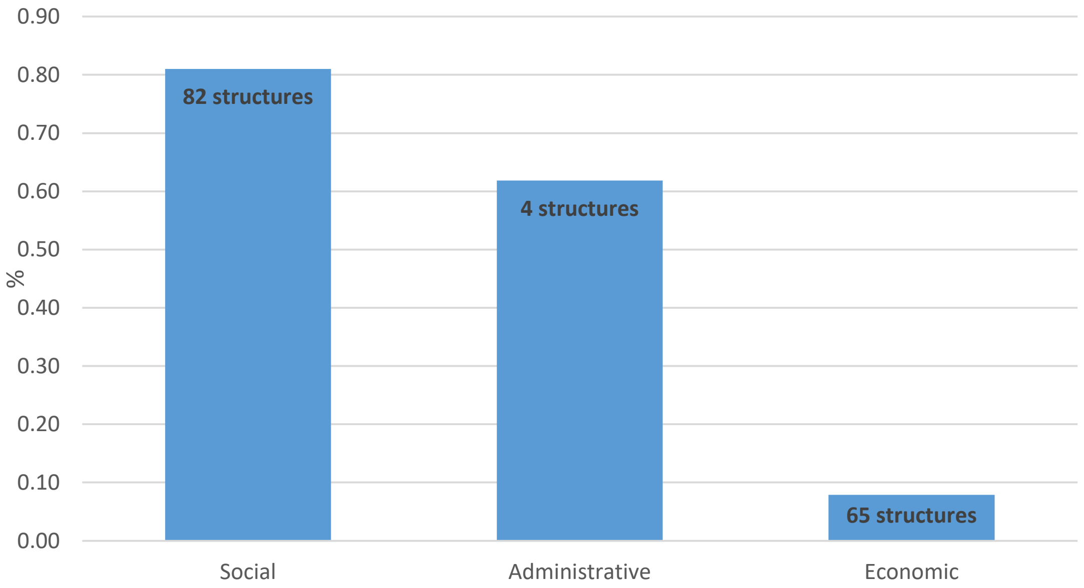


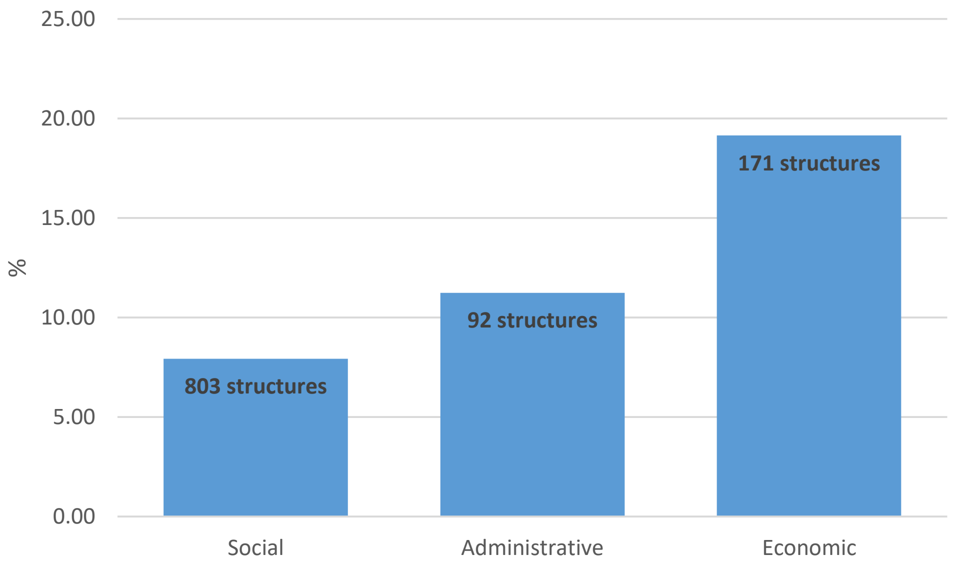
- Tsunami Source PIN/YAN
- Maximum flow depth 6.40 meters
- Maximum inundation distance reached 360 meters.

a)
b)
c)
Yeşil
TSUNAMİ BİLGİLENDİRMESİ VE TAHLİYE YOLLARI
İSTANBUL BÜYÜKŞEHİR BELEDİYESİ


Seismic tsunami sources: PIN/YAN
Flow Depth (m)
6,41
0,1
BAKIRKÖY
MARMARA DENİZİ
0
1000
2000
Metre
650000
652000
654000
656000
658000
4536000
4538000
4540000

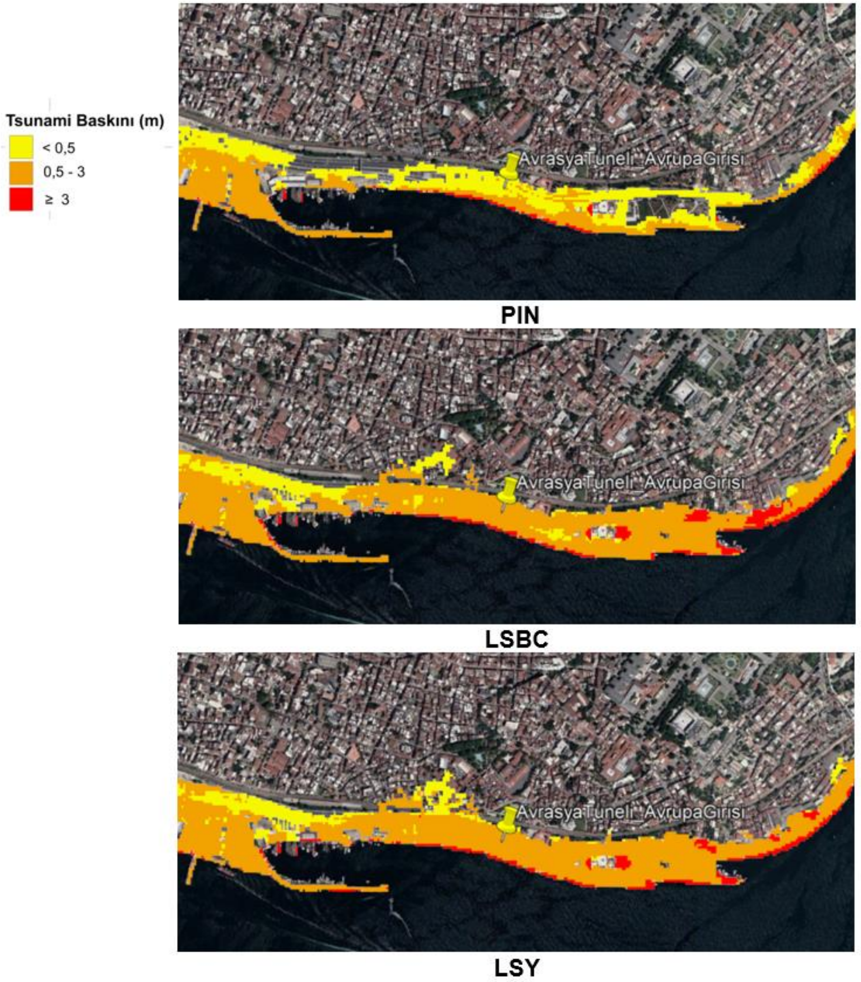

Landslide Tsunami source: LSBC
Flow Depth (m)
13,83
0,1
BAKIRKÖY
MARMARA DENİZİ
0
1000
2000
Metre
650000
652000
654000
656000
658000
4536000
4538000
4540000


%
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
82 structures
4 structures
65 structures
Social
Administrative
Economic


%
0.00
5.00
10.00
15.00
20.00
25.00
803 structures
92 structures
171 structures
Social
Administrative
Economic

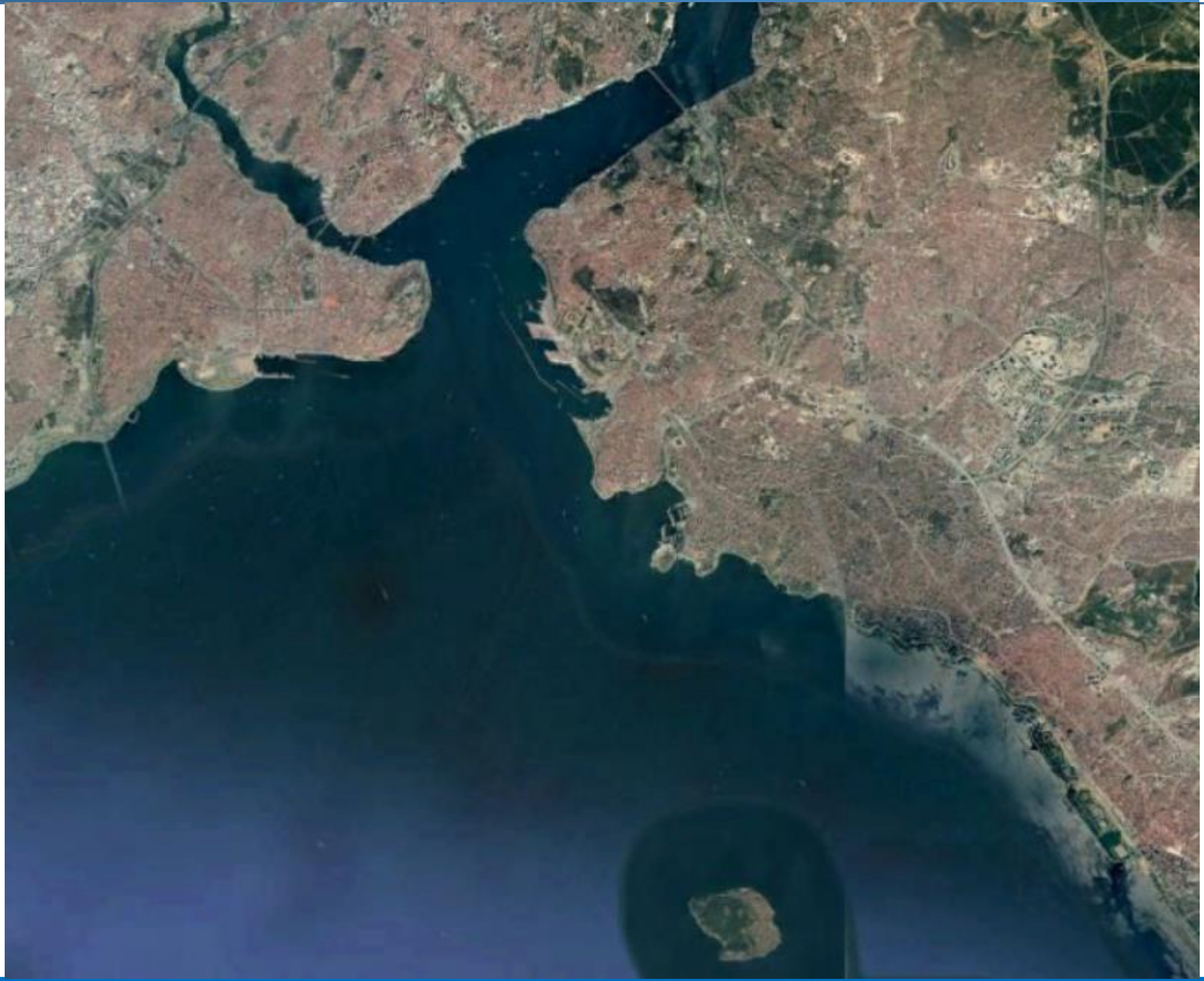
Şekil 10.6 Marmaray Üsküdar İstasyonu su baskını

Şekil 10.7 Marmaray Ayrılık Çeşmesi İstasyonu su baskını

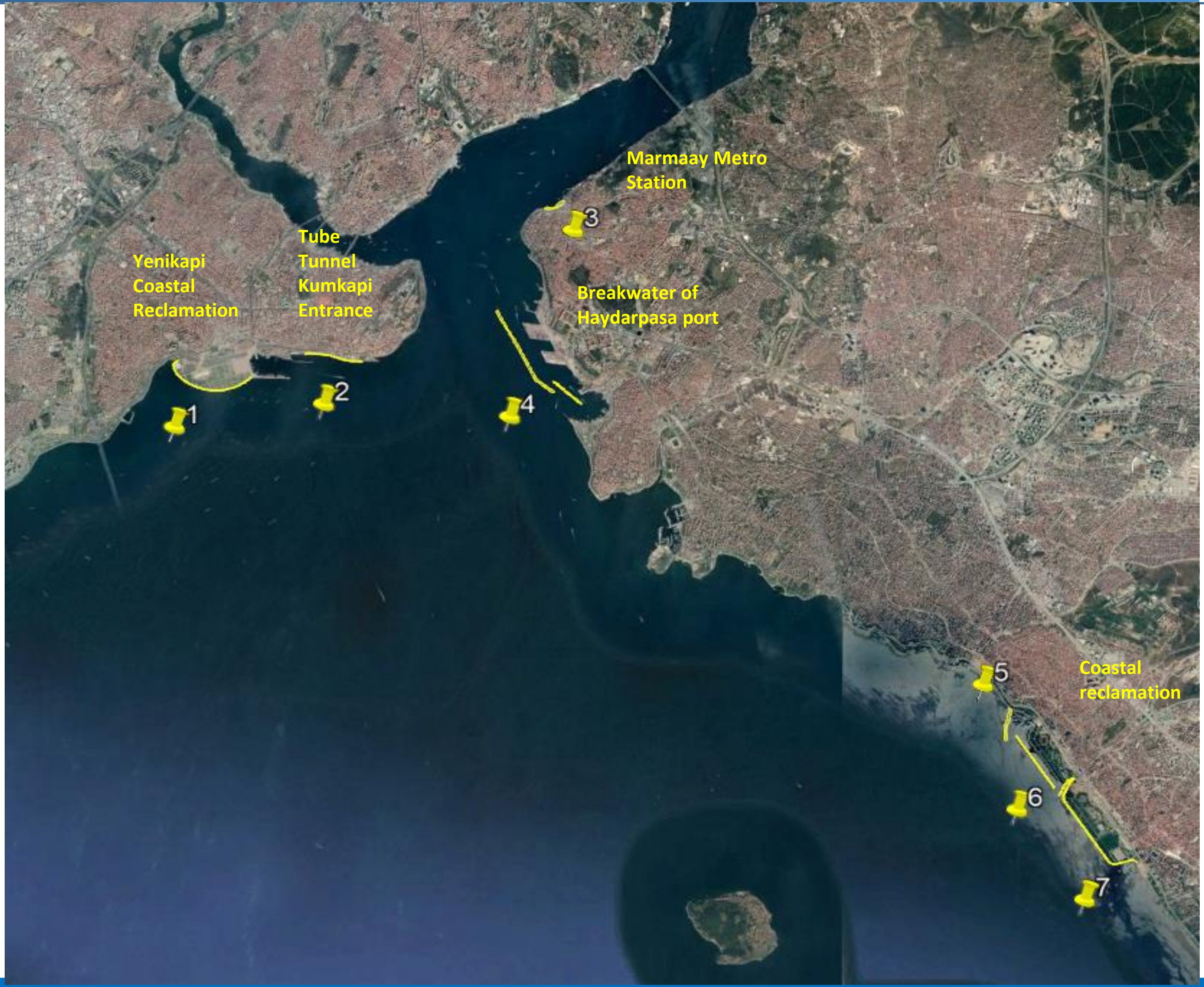


Şekil 10.8 Avrasya Tüneli Avrupa Girişi su baskını

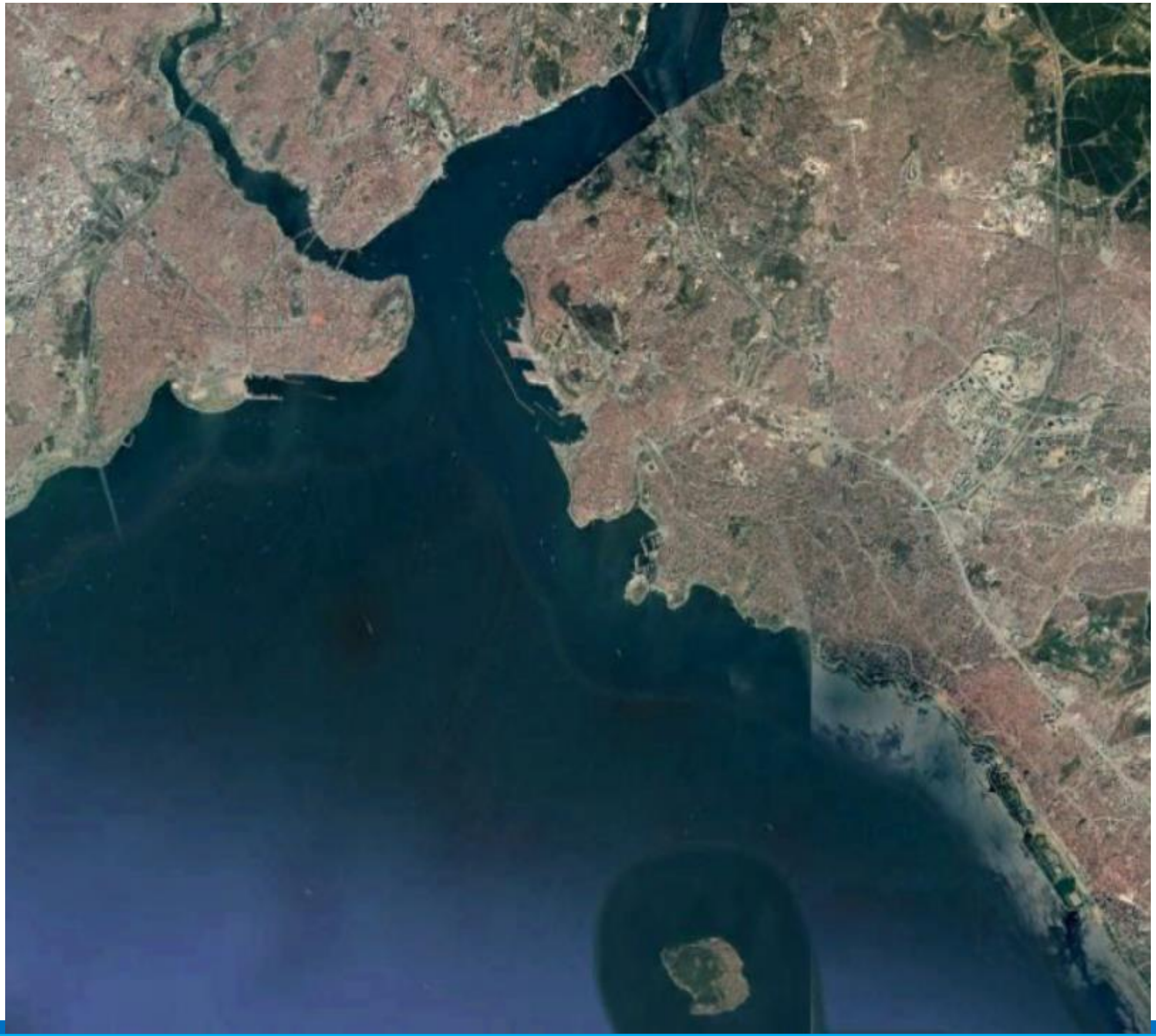
Structural Measures

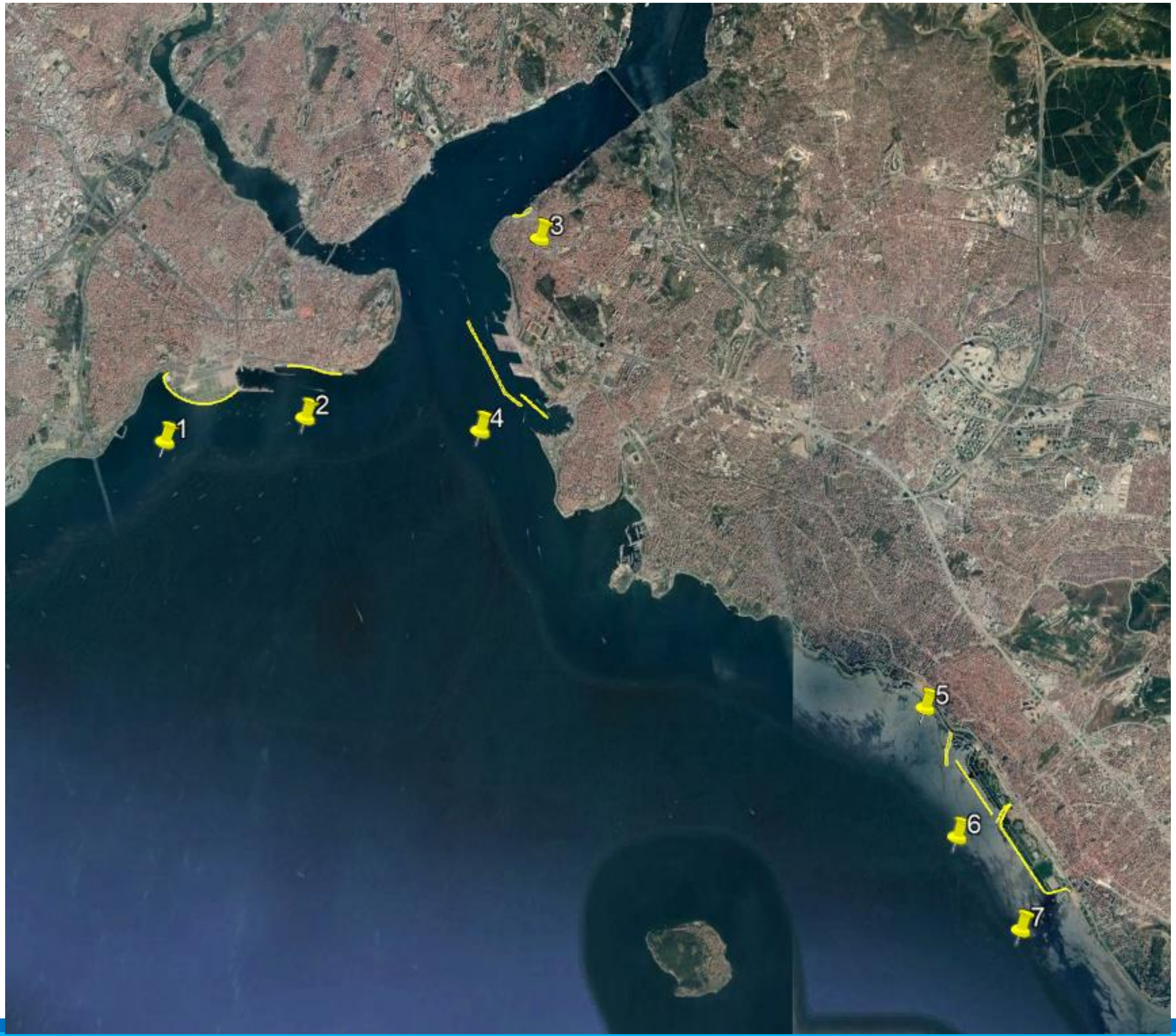


Structural Measures



Structural Measures

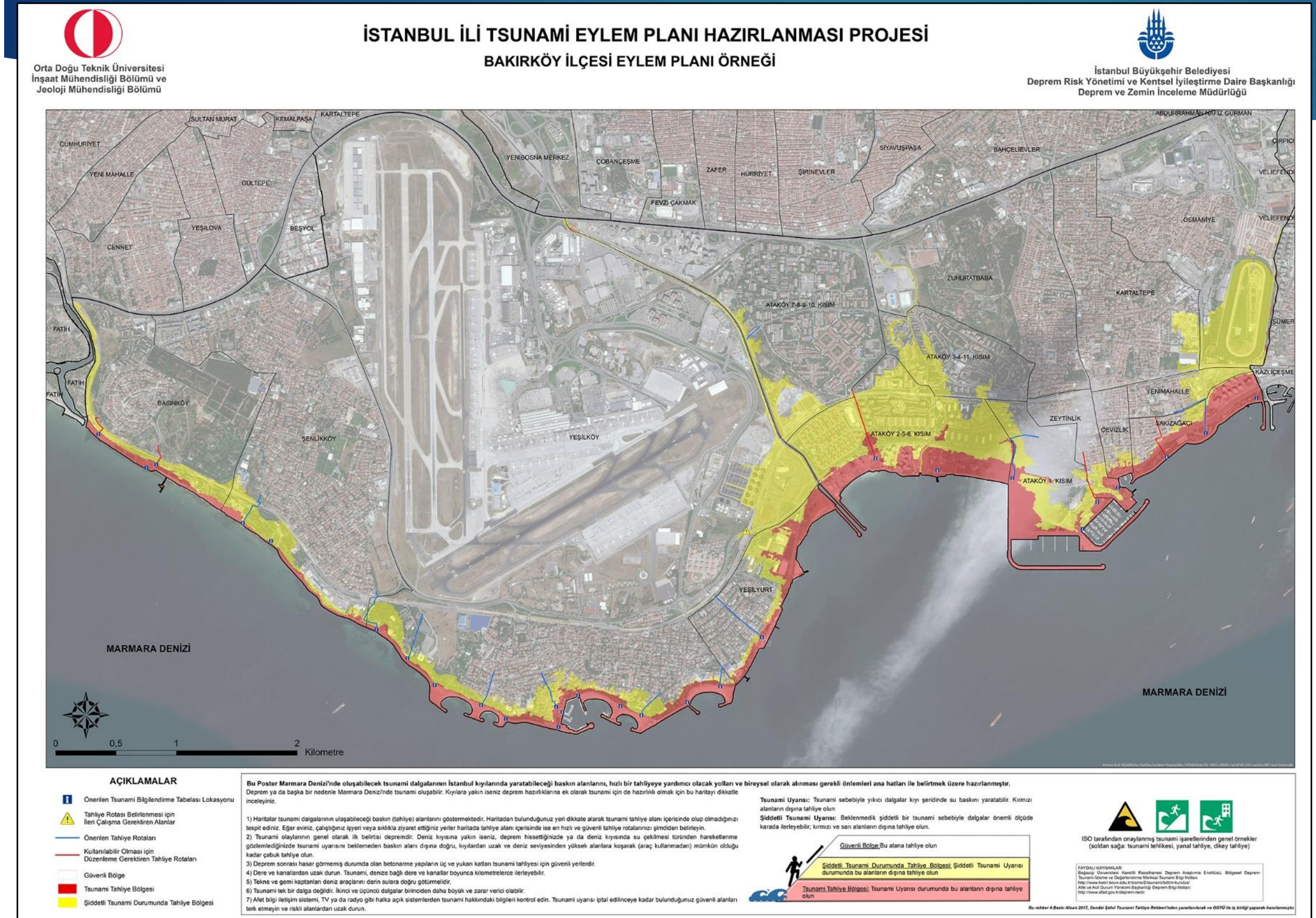




Non Structural Measures

- Conducting educational activities to increase tsunami awareness and preparedness
- By increasing tsunami awareness at personal level, increase of «n» parameter in MeTHuVA
- Evaluation of risk by change of parameter «n» MeTHuVA
- Planning and organization of regular Tsunami Drills with participation of stakeholders
- Preparation of «Tsunami Evacuation Guide»

ISTANBUL METROPOLITAN MUNICIPALITY TSUNAMI ACTION PLAN – BAKIRKOY DISTRICT EXAMPLE

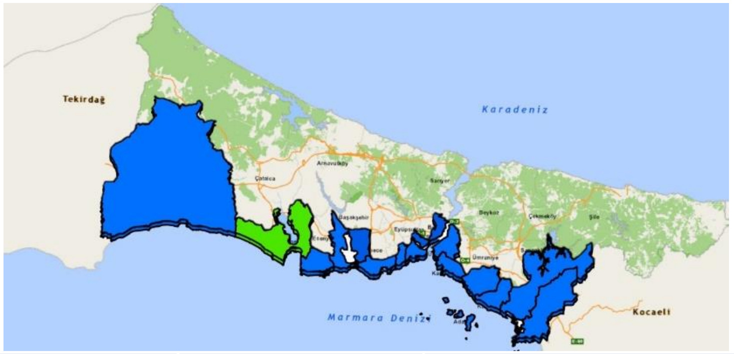


Hazard Zone Maps, Warning Signs and Evacuation Routes for 17 Districts of Istanbul

ISTANBUL METROPOLITAN MUNICIPALITY TSUNAMI ACTION PLAN – BUYUKCEKMECE DISTRICT EXAMPLE EVACUATION SIGNS

Achievements in Istanbul

KANDİLLİ OBSERVATORY AND EARTHQUAKE RESEARCH INSTITUTE 1868



DISTRICT	NUMBER OF EVACUATION ROUTES	NUMBER OF INFORMATION PANELS	NUMBER OF SECURE AREA SIGNS	NUMBER OF EVACUATION ROUTE SIGNS
ADALAR	24	26	24	37
AVCILAR	8	14	8	6
BAKIRKÖY	14	17	14	32
BEŞİKTAŞ	8	18	8	17
BEYLİKDÜZÜ	10	11	10	15
BEYOĞLU	12	16	12	24
FATİH	15	37	15	36
KADIKÖY	22	27	22	35
KARTAL	8	5	8	19
KÜÇÜKÇEKMECE	2	15	2	5
MALTEPE	6	9	6	9
PENDİK	6	12	6	13
SİLİVRİ	33	50	35	55
TUZLA	12	11	12	27
ÜSKÜDAR	9	14	9	18
ZEYTİNBURNU	3	6	3	9

Progress in Istanbul

Dr. Öcal NECMİOĞLU

b)

c)

Curtesy Istanbul Metropolitan Municipality

REMARKS

- MARINE EXTREME EVENTS COASTAL DISASTERS
- TSUNAMIS AND TROPICAL CYCLONES
- HAZARD ASSESSMENT AND DISASTER MANAGEMENT
- STRUCTURAL AND SOCIETAL PREPAREDNESS
- AWARENESS
- PREPAREDNESS
- RESILIENCE
- MITIGATION

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
ODTÜ

UNESCO
United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission

TÜBİTAK

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1911

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Birleşmiş Milletler Eğitim, Bilim ve Kültür Kurumu
UNESCO Türkiye Millî Komisyonu
2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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ÇEŞME BELEDİYESİ

SEFERİHISAR BELEDİYESİ
cittaslow

KOCAELİ ÜNİVERSİTESİ
1992

TMMOB
İNŞAAT MÜHENDİSLERİ ODASI

European Commission

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IPMA
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ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

FCT
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Kneissl touristik
Studien Erlebnis Reisen

KOTA PALU
SULAWESI TENGAH

UNESCO
United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
Indian Ocean Tsunami Information Centre
International Tsunami Information Center
Coordinating Ministry for Maritime Affairs
RISTEKDIKTI
LIPI
BMKG
BPPT
IATSI

THANKS FOR YOUR ATTENTION

Prof. Dr. Ahmet Cevdet Yalçıner
Gözde Güney Doğan Bingol
Andrey Zaytsev
Bora Yalciner
Efim Pelinovsky
Bilge Karakütük

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Safety Standards DS417 – Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations (under revision by integrating and refining Safety Standards NS-G-3.4 Meteorological Events in Site Evaluation for Nuclear Power Plants and Safety Standards NS-G-3.5 Flood Hazard for Nuclear Power Plants on Coastal and River Sites).

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