LANDSLIDE TSUNAMI GENERATION (3D) and PROPAGATION (2D)

By:
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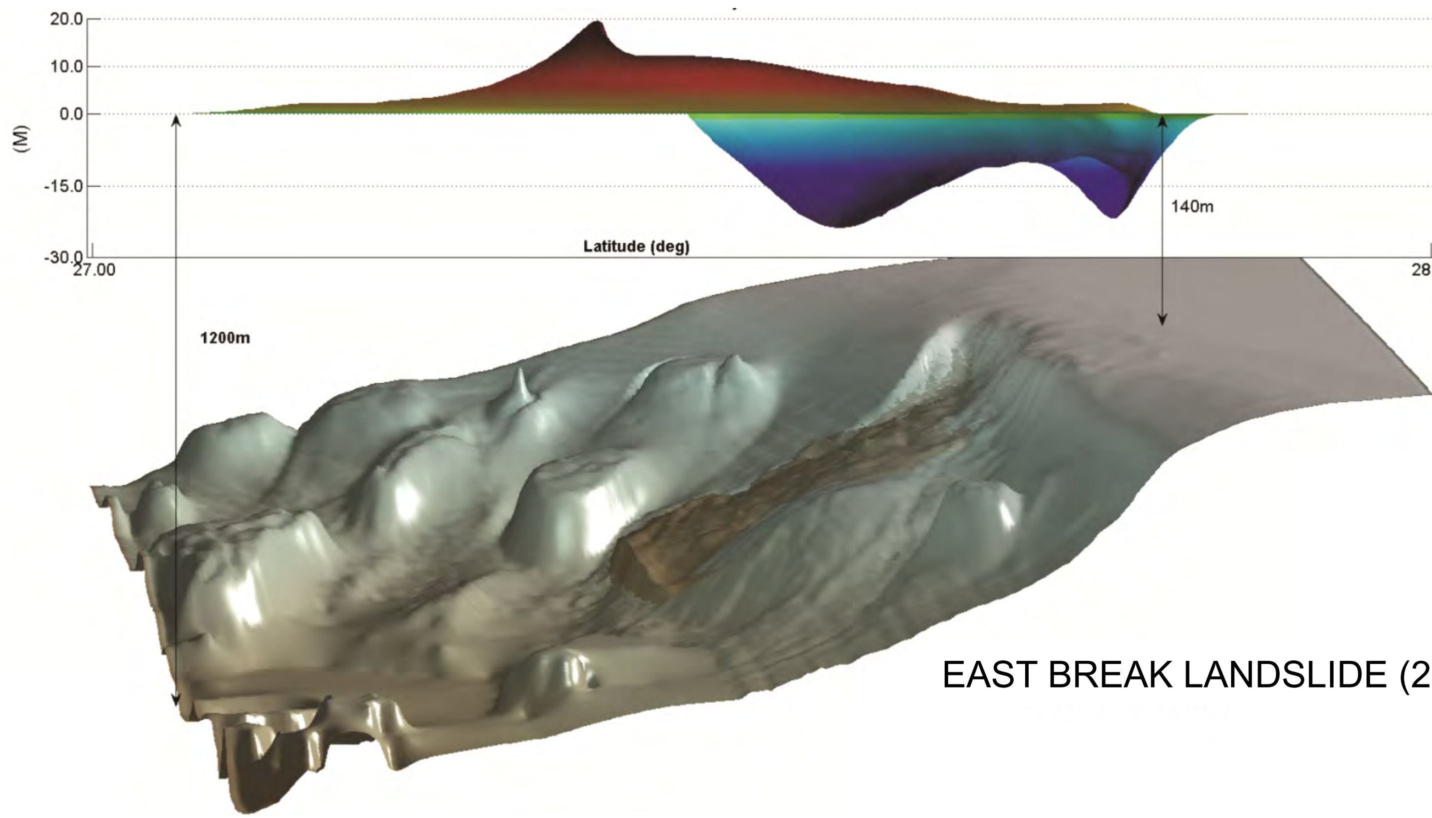
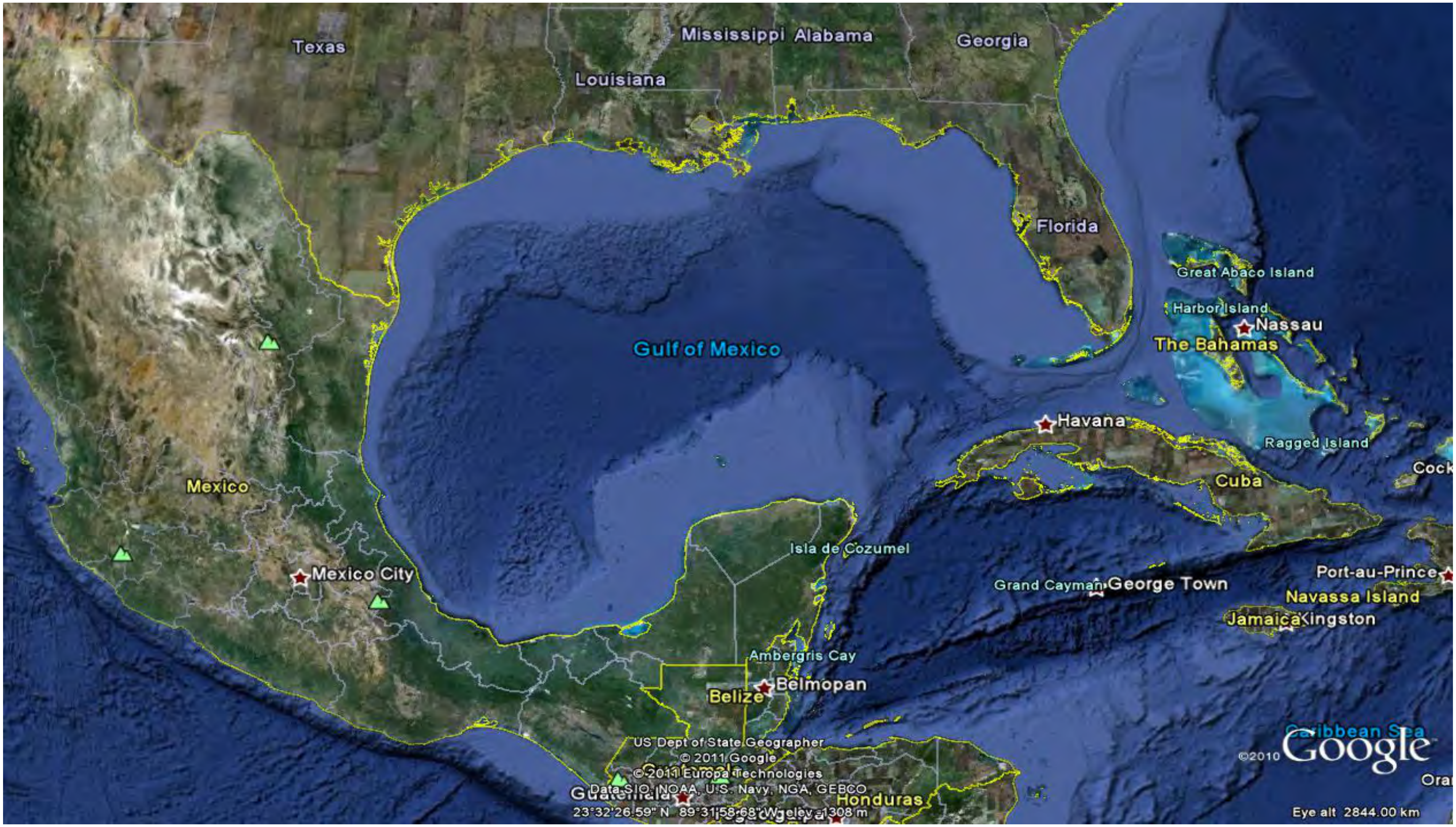
Texas A&M University at Galveston



EAST BREAK LANDSLIDE (26Km^3)

Woods Hole, Aug, 2011

TSUNAMI HAZARD IN the GOM



National Tsunami Hazard Mitigation Program
Construction of tsunami inundation maps in the Gulf of Mexico.

SCOPE

The goal of this project is to establish a systematic production of tsunami inundation maps along the US coast of the GOM aimed to provide guidance to state emergency managers and optimize real-time tsunami warnings to communities on the GOM coastline.

So far the construction of tsunami maps is based on identified past events of local submarine landslides and other hypothetical local landslide sources. It is planned in the near future to implement a probabilistic approach (proposal about to be submitted to the NTHMP).

INTRODUCTION

For practical tsunami application (construction of inundation maps) in the GOM two numerical models are used:

TSUNAMI3D & NEOWAVE

TSUNAMI3D (**3D** **T**sunami **S**olution **U**sing a **N**avier-Stokes **A**lgorithm with **M**ultiple **I**nterfaces).

NEOWAVE (**N**on-hydrostatic **E**volution of **O**cean **WAVE**).

INTRODUCTION

For practical tsunami application (construction of inundation maps) in the GOM two numerical models are used:

1. The landslide generation (tsunami source) is taken by the 3D Navier-Stokes model developed by the University of Alaska Fairbanks (UAF) and Texas A&M University at Galveston (TAMUG) dubbed TSUNAMI3D for **T**sunami **S**olution **U**sing **N**avier-Stokes **A**lgorithm with **M**ultiple **I**nterfaces.

2. The tsunami wave propagation and inundation is carried out by the 2D non-hydrostatic/hydrostatic model developed by the University of Alaska Fairbanks (UAF) and the University of Hawaii (UH), NEOWAVE for **N**on-hydrostatic **E**volution of **O**cean **WAVE**.

Using Stelling, Casulli and Zijlema 2003 approach.

INTRODUCTION

TSUNAMI3D:

Tsunami **S**olution **U**sing **N**avier-Stokes **A**lgorithm with **M**ultiple **I**nterfaces.

- Solves transient fluid flow with free surface boundaries
- Concept of the fractional VOF.
- Eulerian mesh of rectangular cells having variable sizes
- Bathymetry or objects are defined by blocking out fully or partially any desired combination of cells in the mesh.
- Finite difference approximation of the Navier-Stokes and the continuity equations.
- Used for calculations involving two incompressible fluids separated by a sharp or no-sharp interface.
- The hydrodynamic (nonhydrostatic) pressure field is solved using the incomplete Choleski conjugated gradient method.

INTRODUCTION

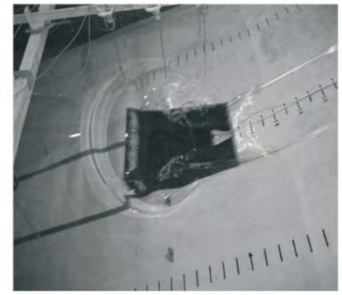
TSUNAMI3D FEATURES:

Tsunami **S**olution **U**sing **N**avier-Stokes **A**lgorithm with **M**ultiple **I**nterfaces.

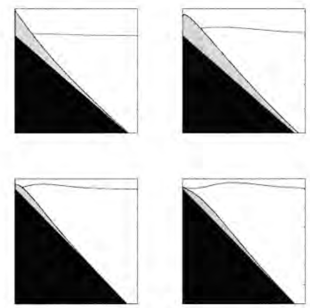
- Algorithm for tracking to account for the horizontal distortion with respect of the vertical scale which is proper in the construction of efficient 3D grids for tsunami simulations.
- The pressure term is split in two components, hydrostatic and non-hydrostatic. faster convergence? & to discern non-hydrostatic effects of the hydrostatic
- Moving or deformable objects capability
- Subaerial/subsea landslide including simplified soil rheology
- Complex vertical or lateral bottom deformation.
- TSUNAMI3D : FORTRAN and MATLAB (post-processing)
- Usually a 3D simulation: requires a large amount of computer memory and CPU wall time to obtain the solution. Subroutines, uses OPENMP & PETSC-MPI library to solve the pressure field.

MODEL VALIDATION
1.Lab Experiments
2.Analytical Sol.
3. Commercial Package Comparison

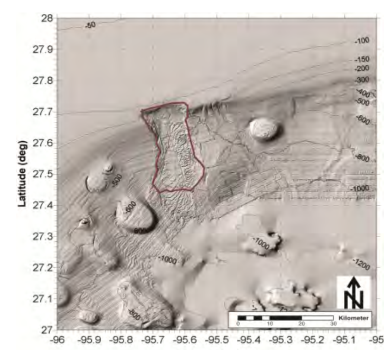
1. Tsunami generation and runup due to 3D landslide



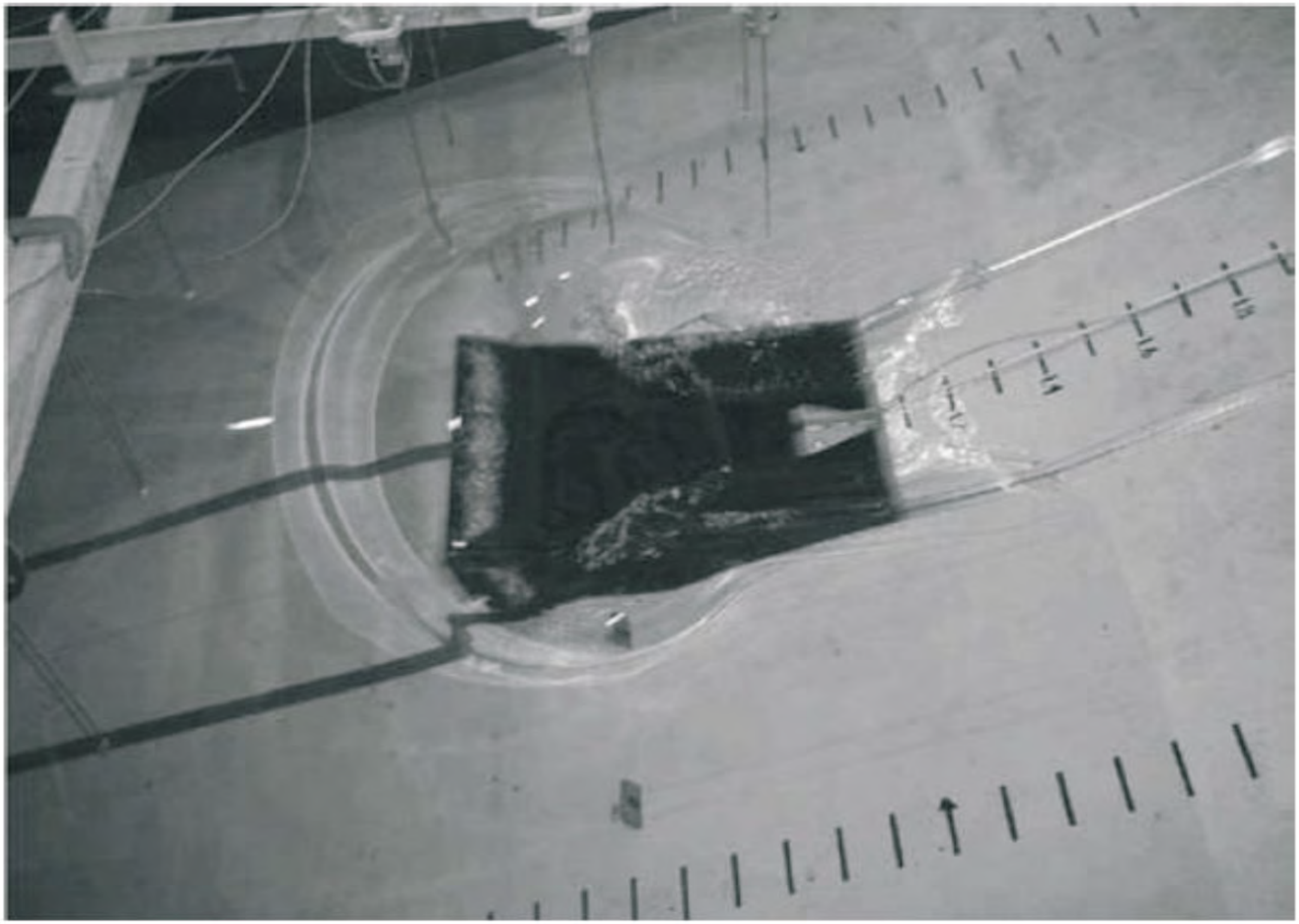
2. Tsunami generation and runup due to 2D landslide

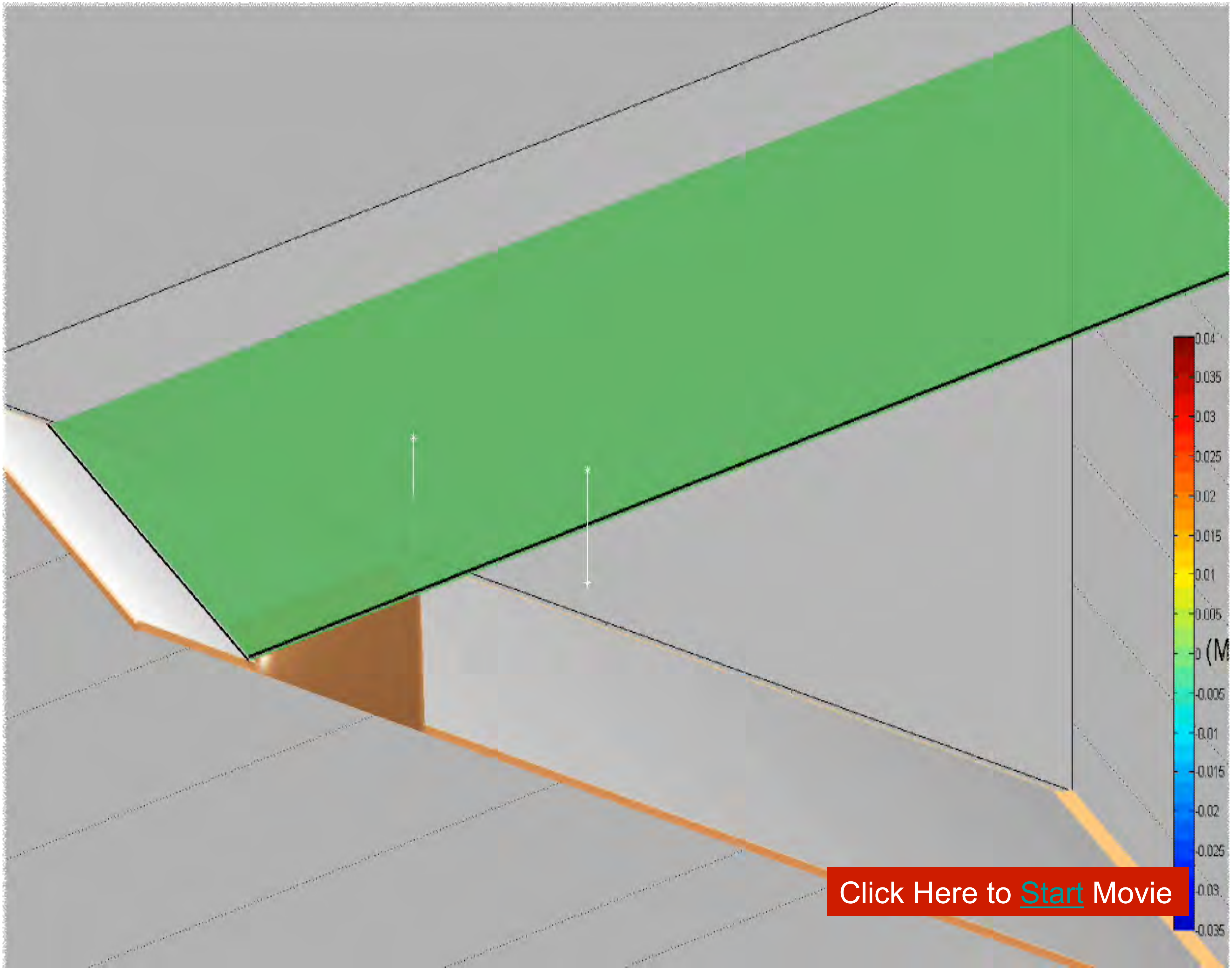


3. Practical 2D numerical simulation comparison with a commercial package

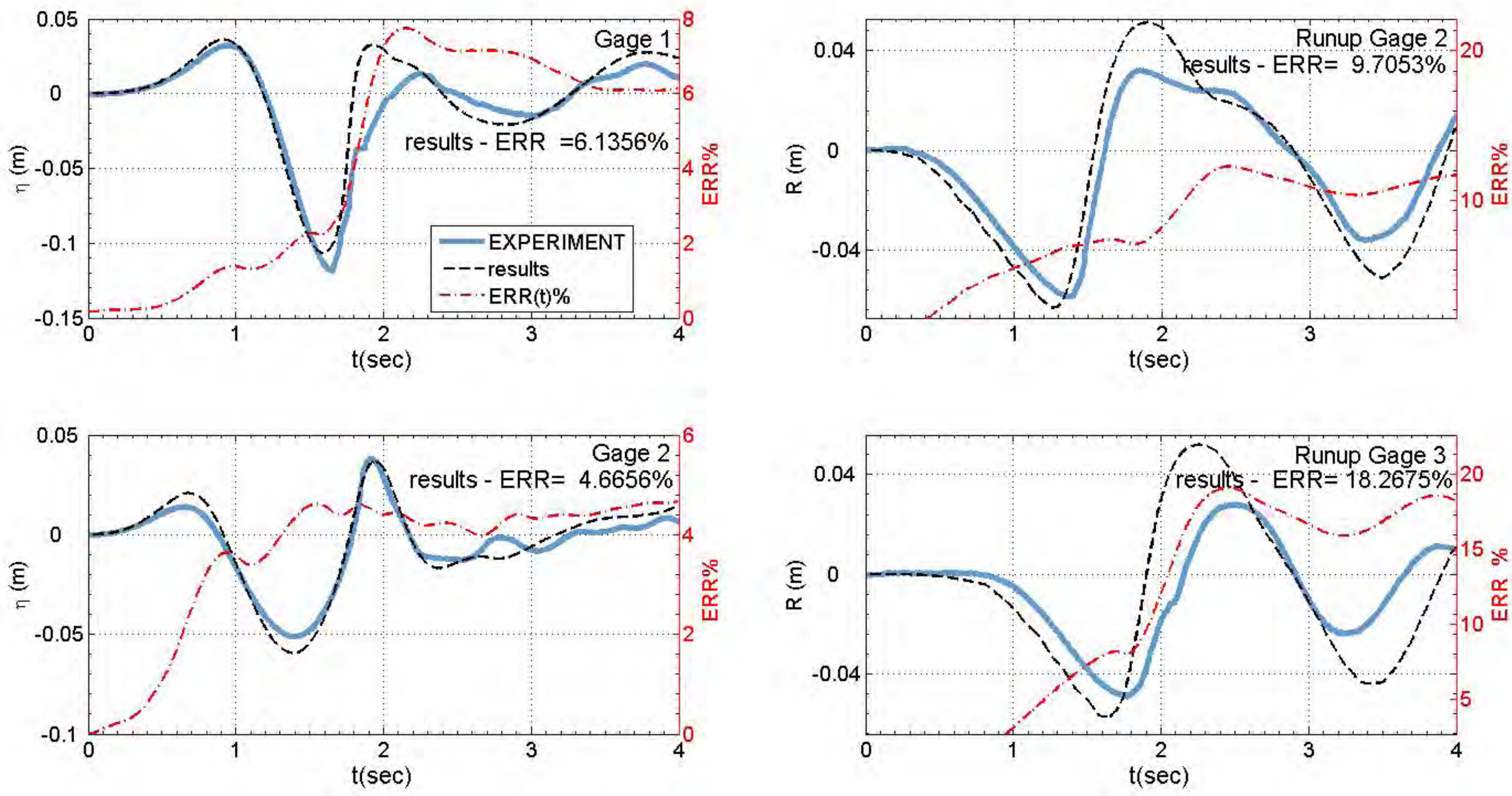


MODEL VALIDATION
1.Tsunami Generation and Runup due to 3D Landslide

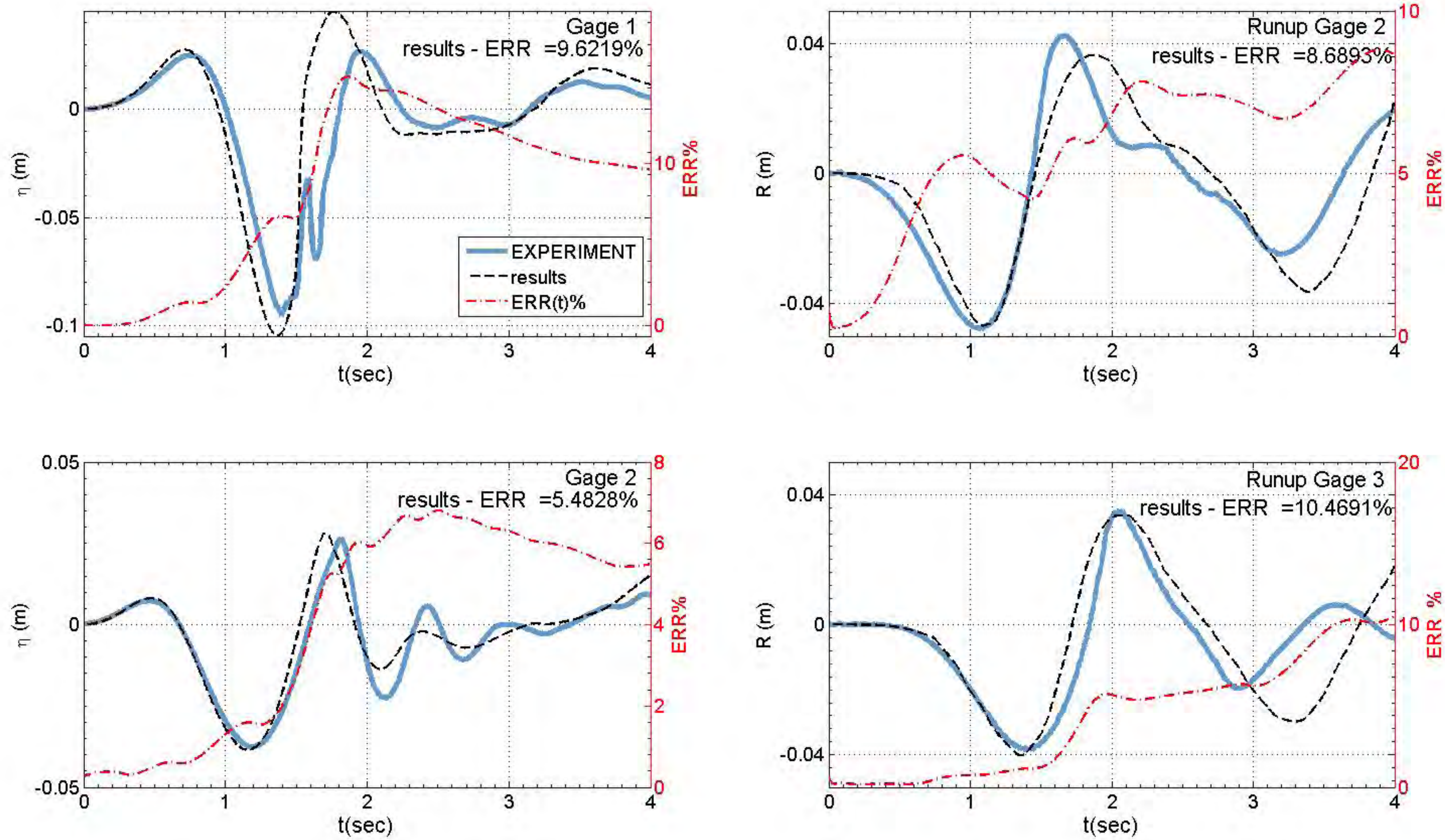



0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0 (M
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
-0.035
Click Here to Start Movie

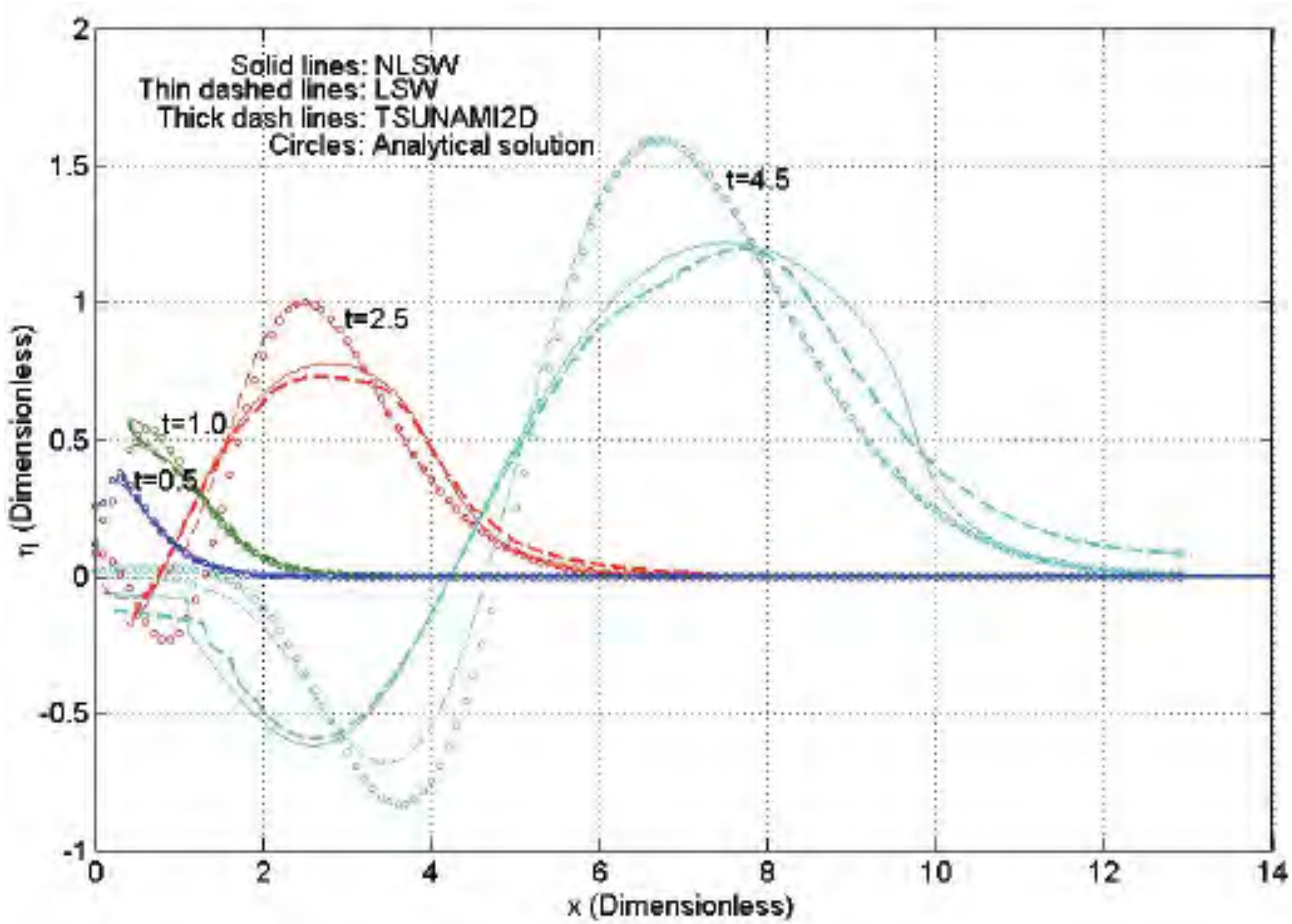
Tsunami generation and runup due to 3D landslide
Experiment [illegible]=0.025m



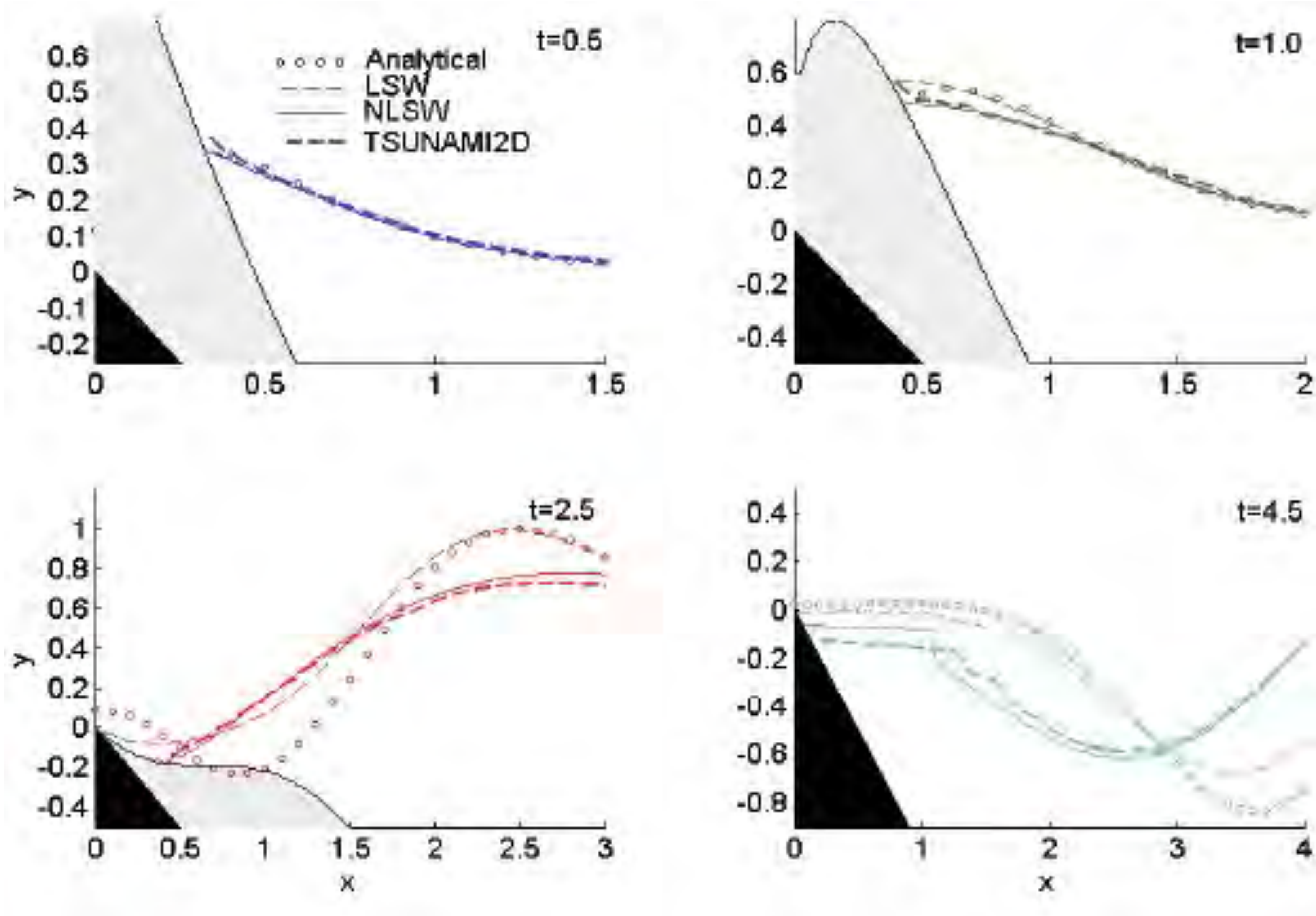
Tsunami generation and runup due to 3D landslide
Experiment [illegible]=0.10m



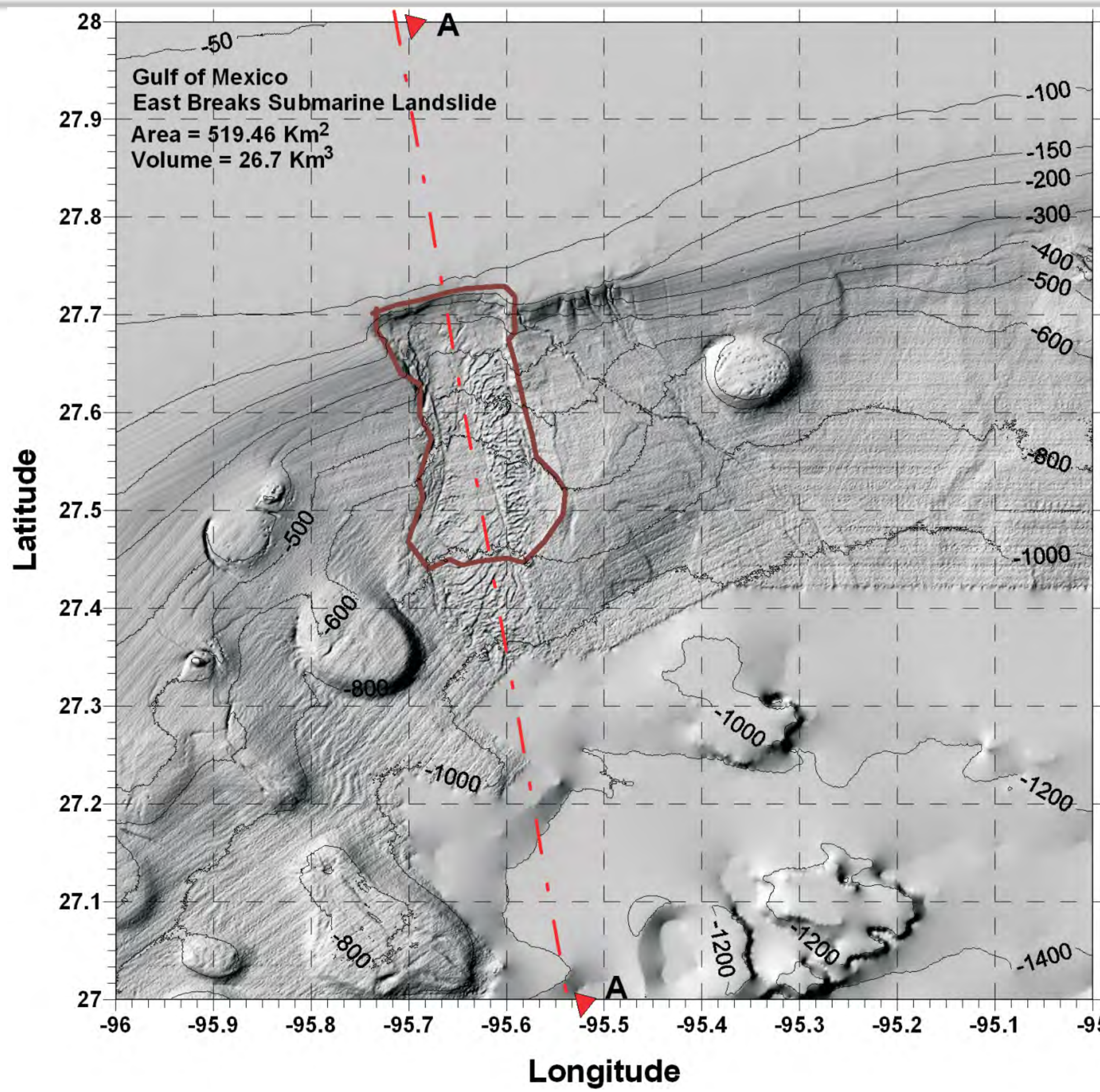
MODEL VALIDATION
2.Tsunami generation and runup due to 2D landslide



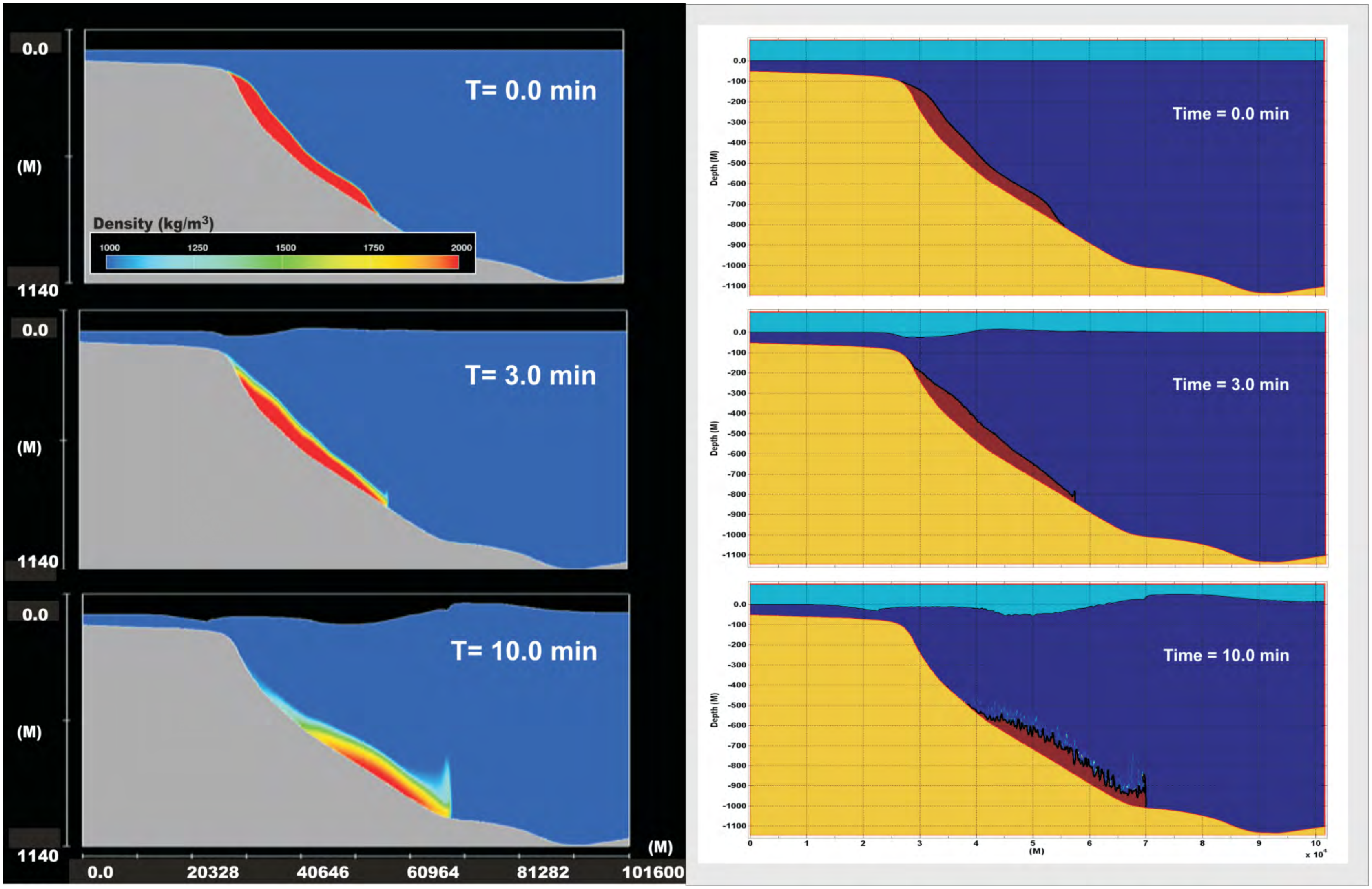
MODEL VALIDATION
2. Tsunami generation and runup due to 2D landslide



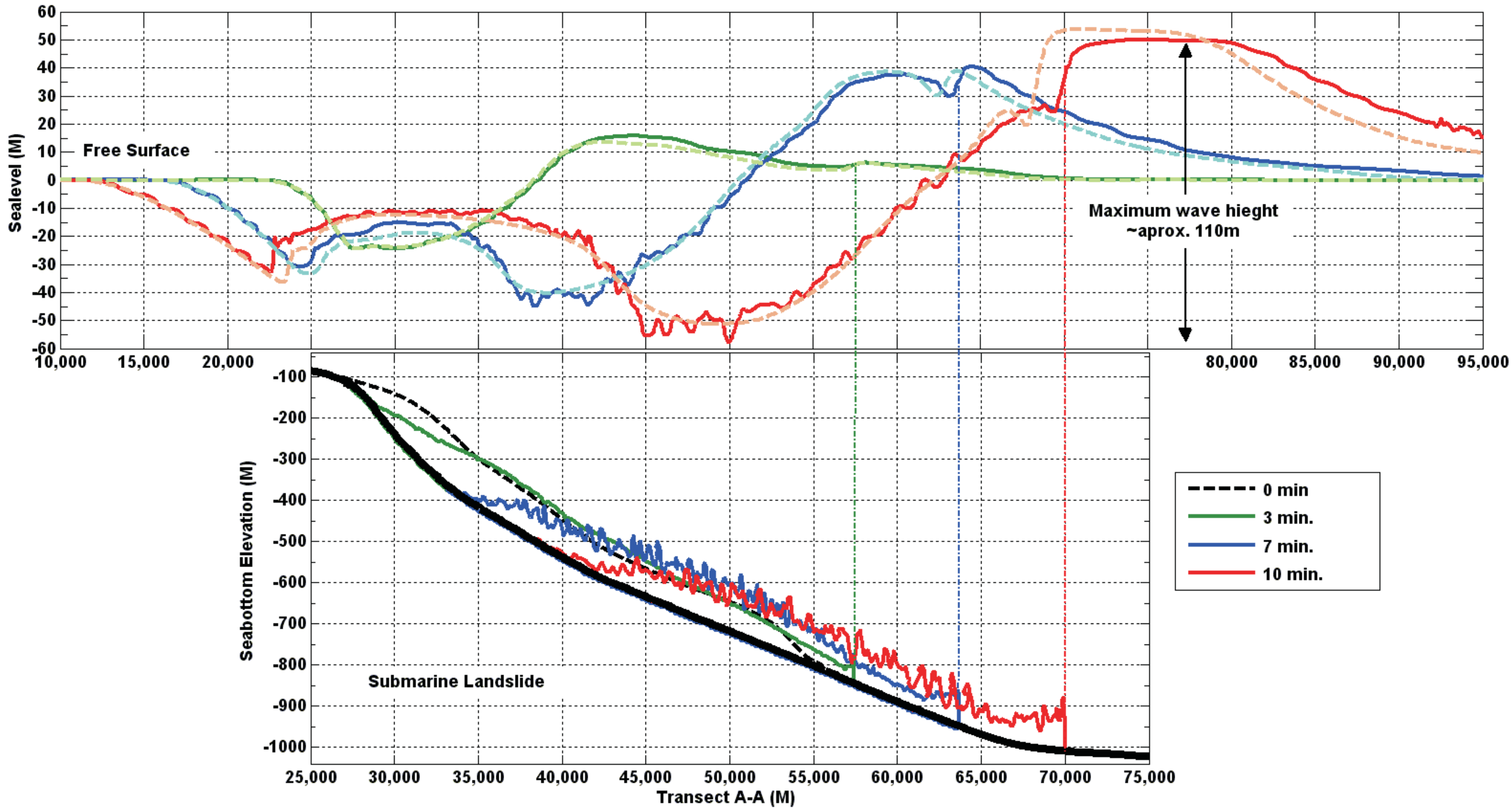
Practical 2D numerical simulation comparison with COMERCIAL PACKAGE



Tsunami generation and runup due to 2D landslide



Tsunami generation and runup due to 2D landslide

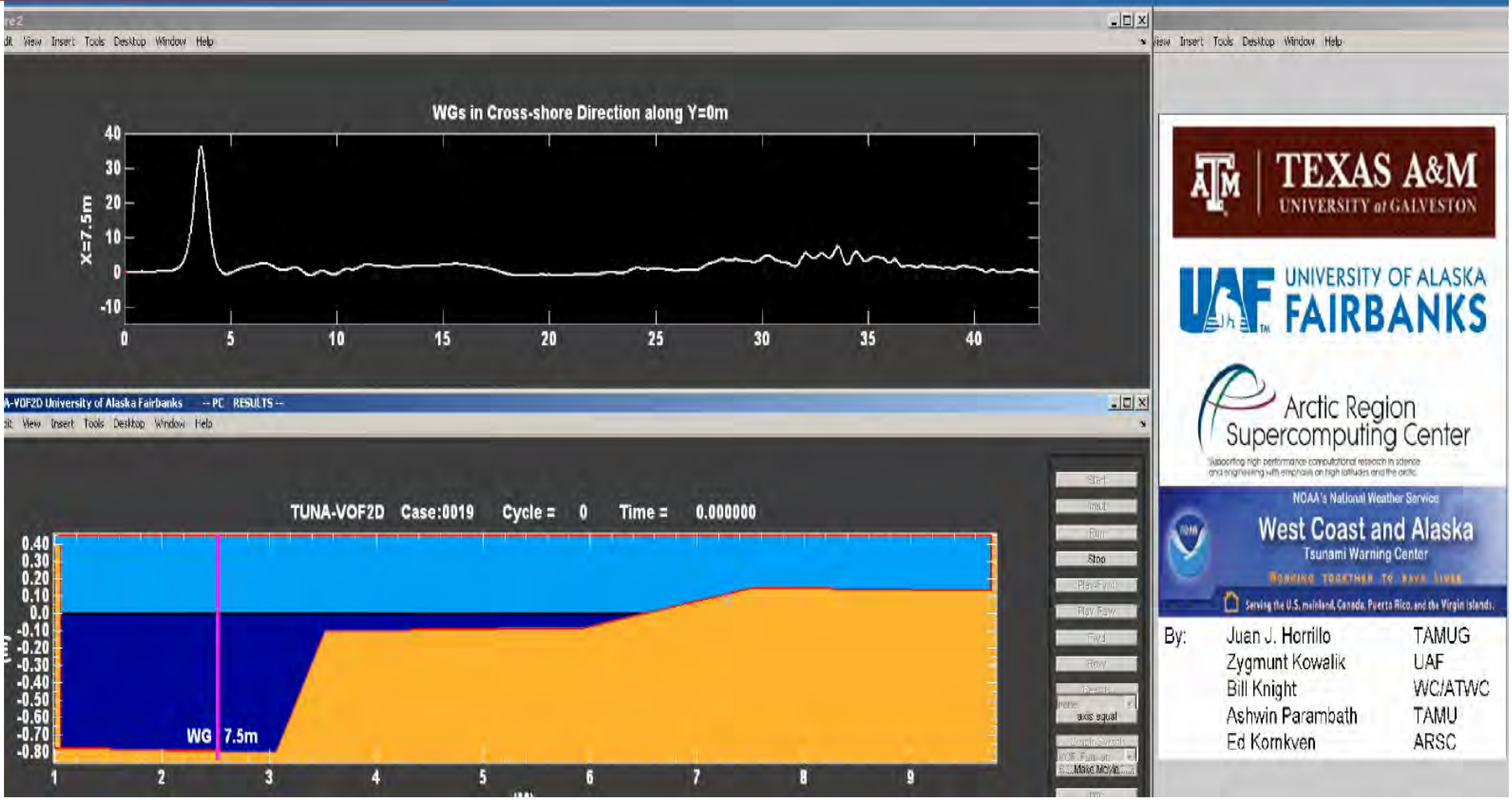


CURRENT VALIDATION WORKS and ADDITIONAL MODEL VALIDATION LITUYA BAY CASE

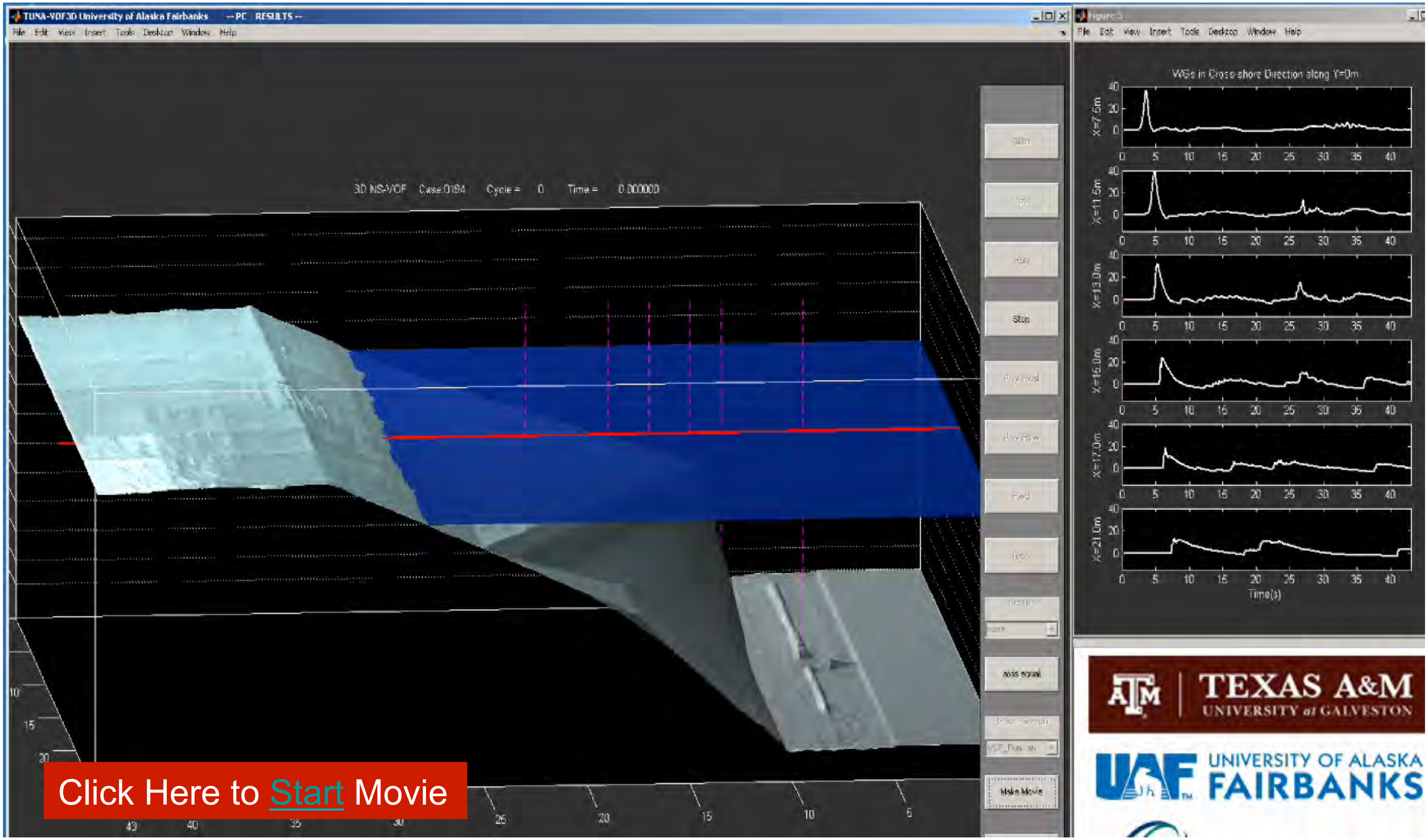
Click Here to Start Movie

OREGON STATE UNIVERSITY BP (Pat Lynett) 2009

Click Here to Start Movie



OREGON STATE UNIVERSITY BP (Pat Lynett) 2009



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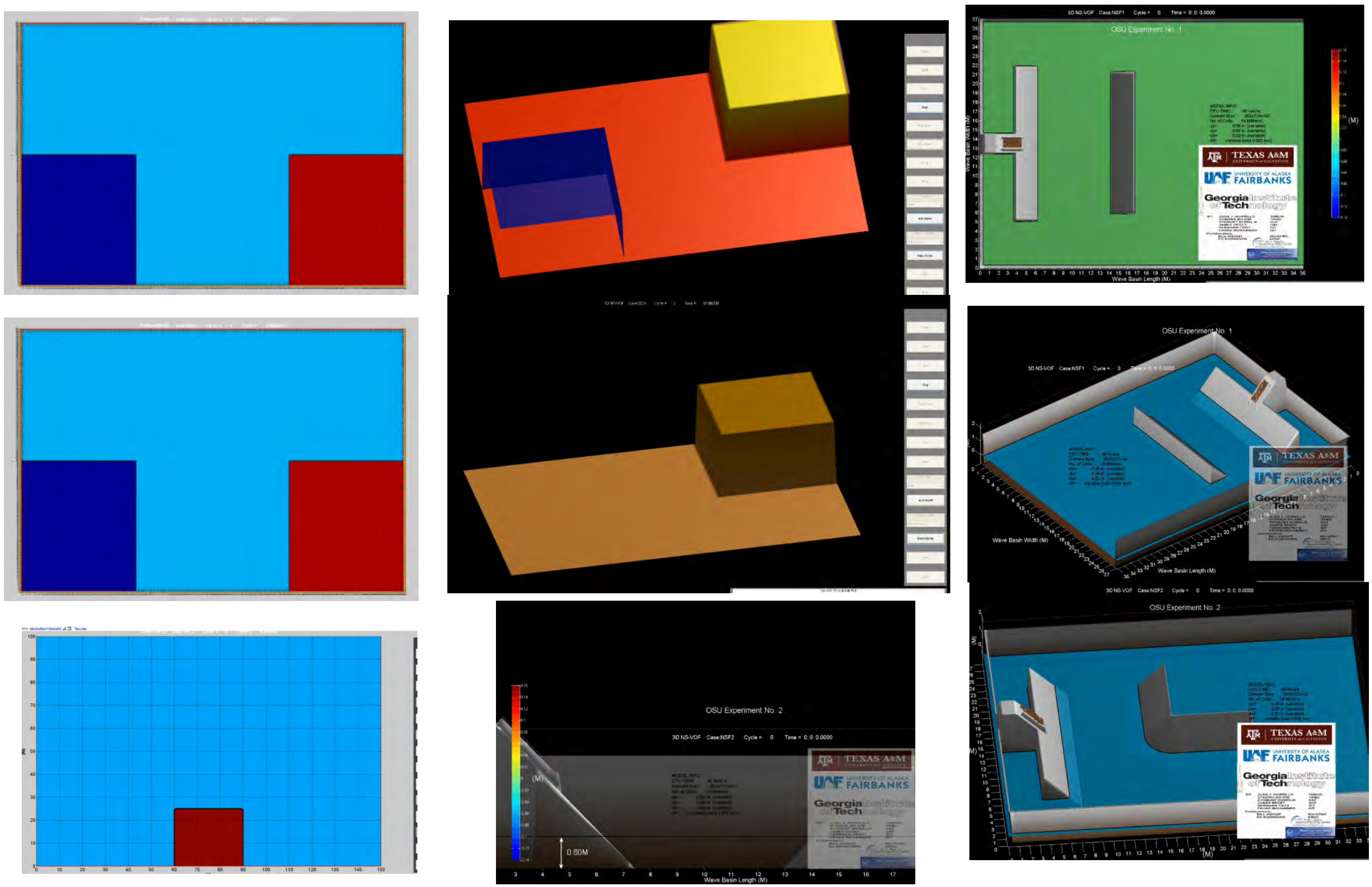
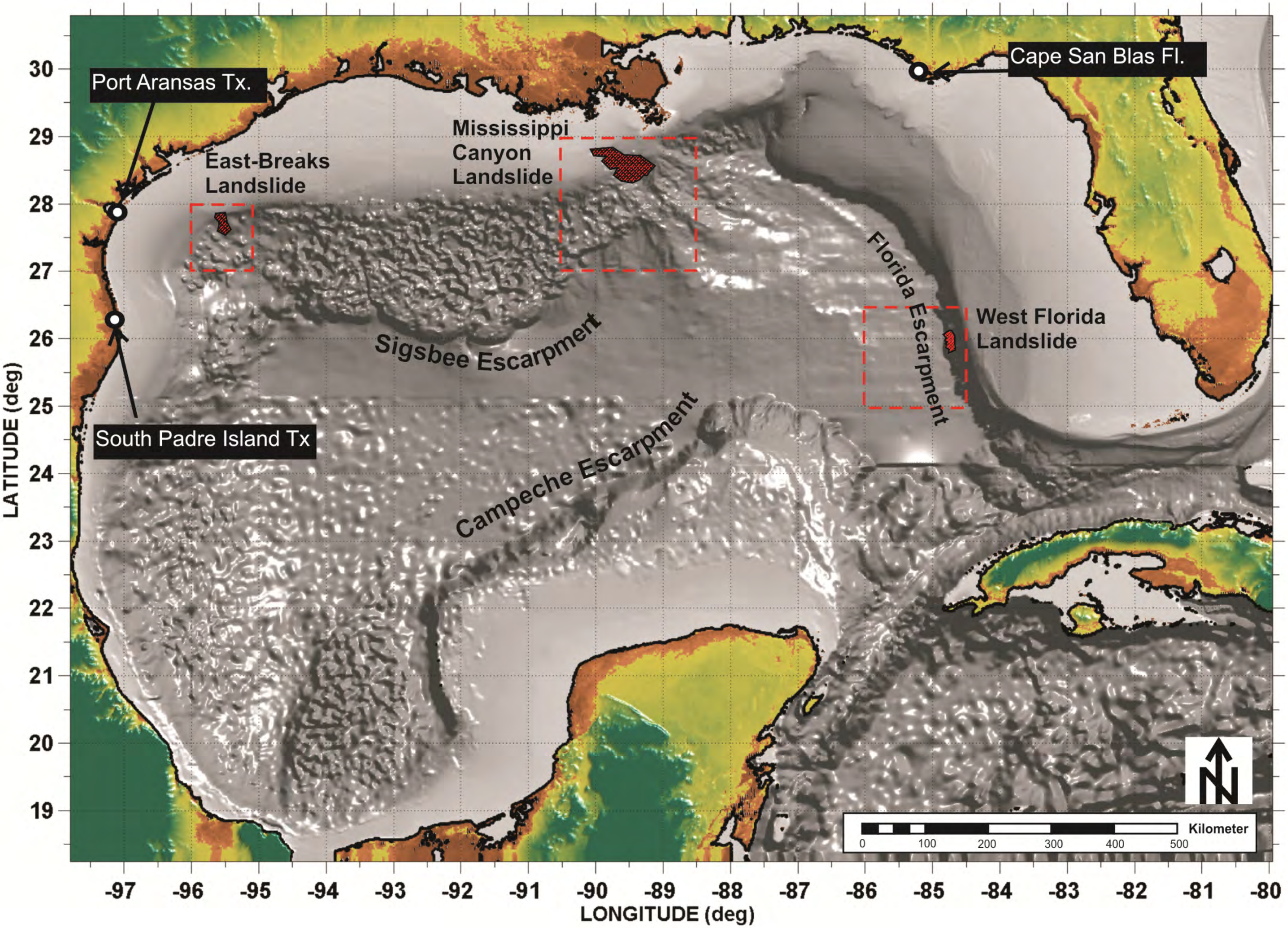
M A S E
Maritime Systems Engineering

NOAA

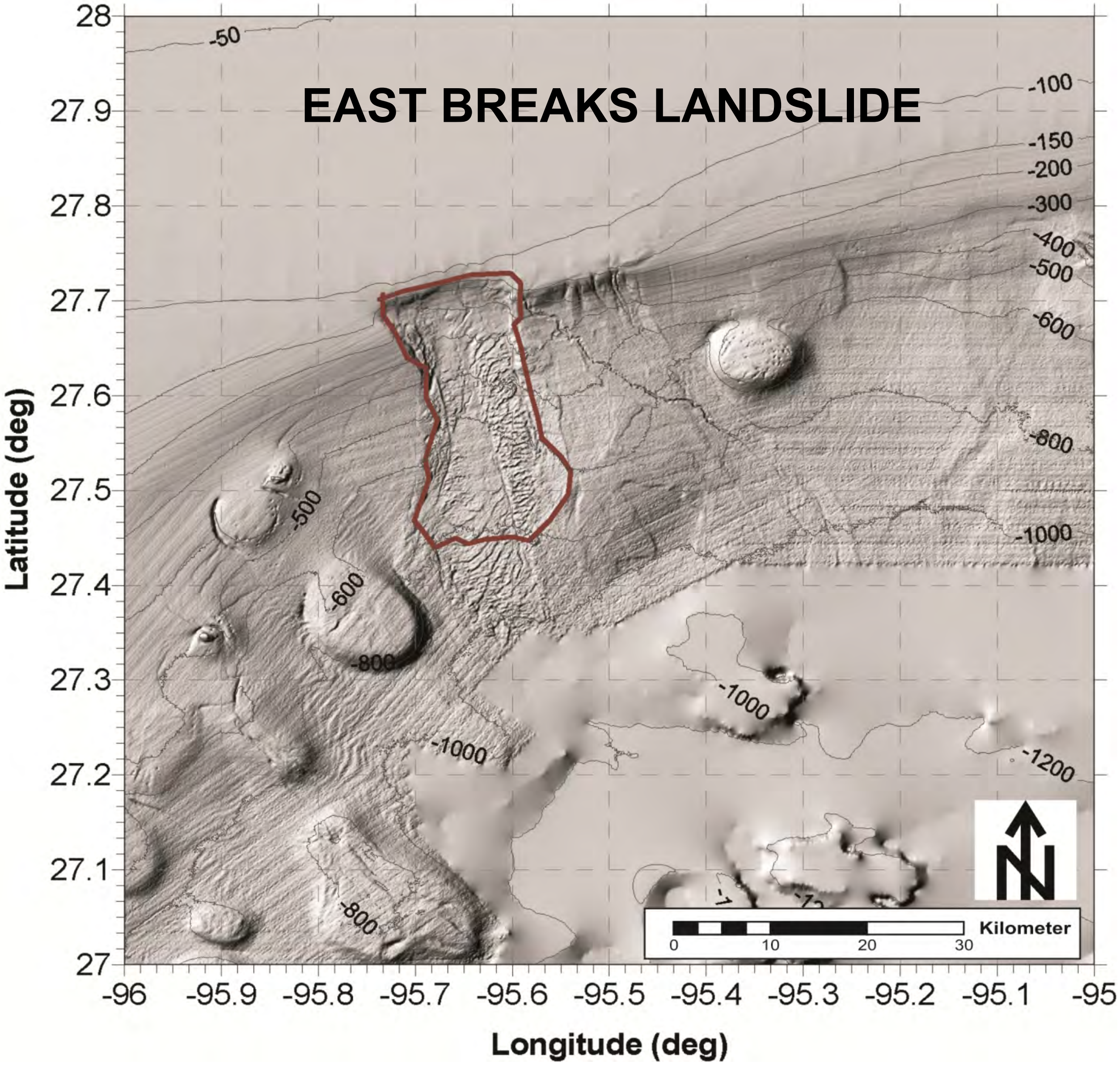
SIMPLE MODEL RHEOLOGY TEST



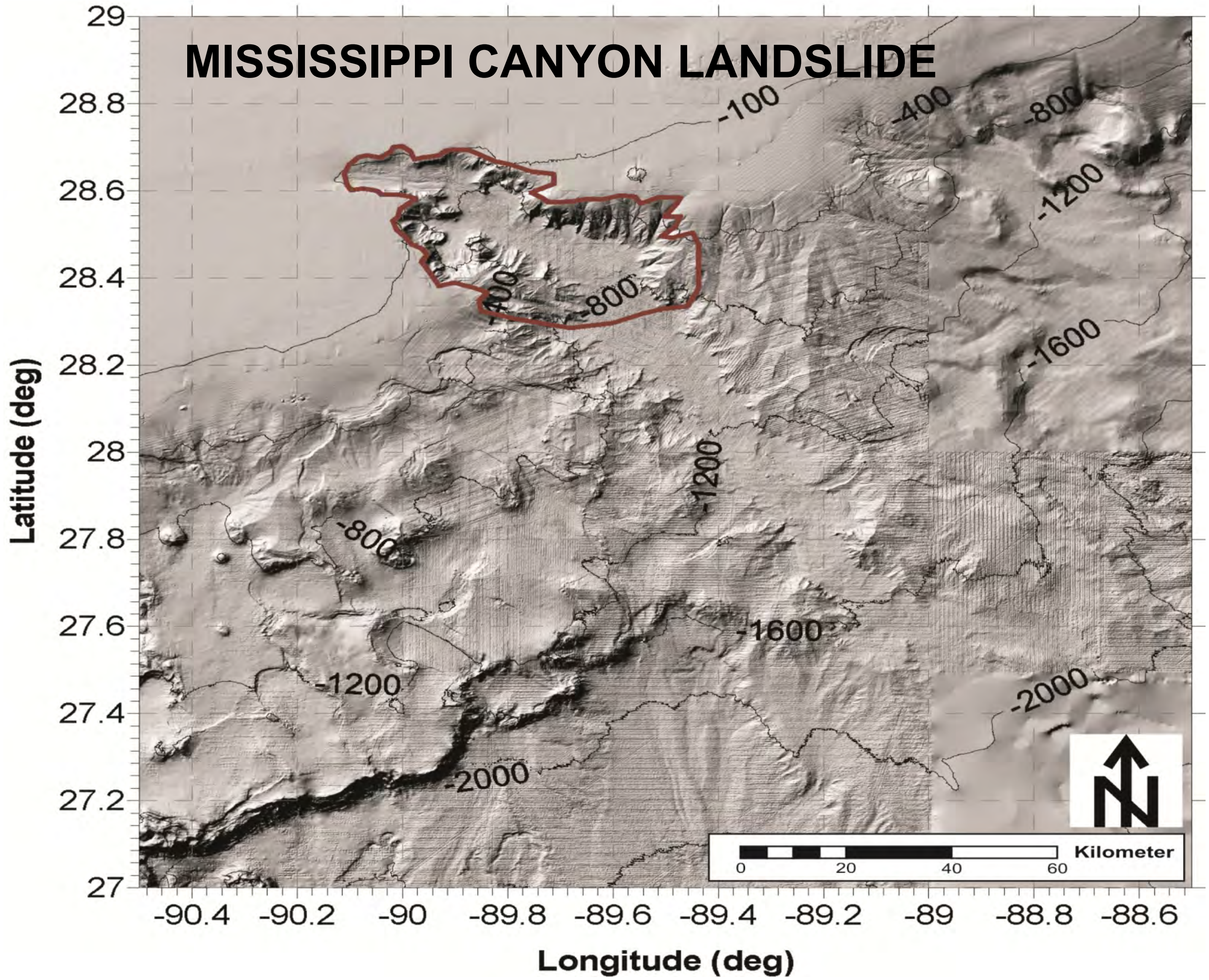
GOM - CONSTRUCTION OF TSUNAMI INUNDATION MAPS-



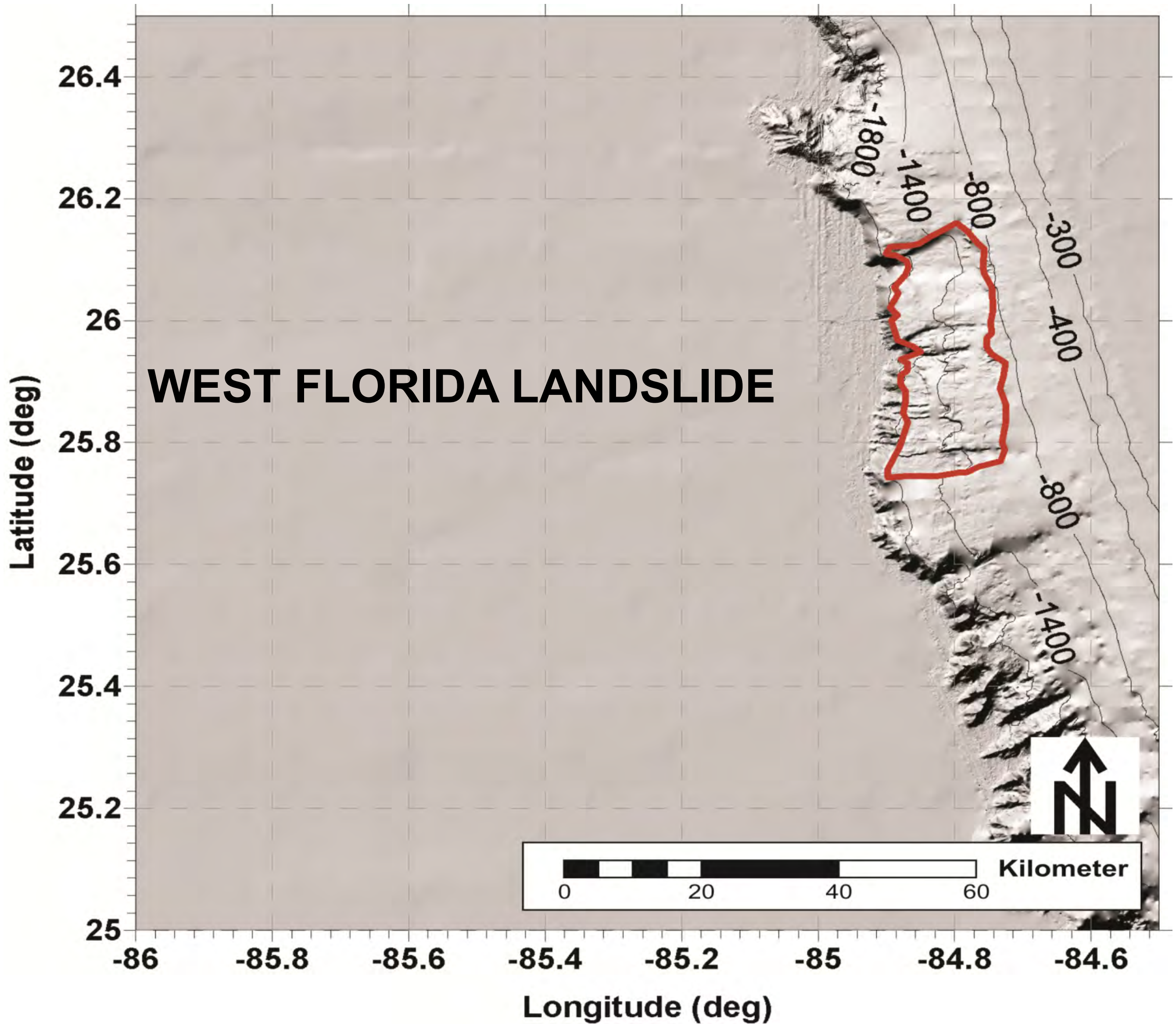
Port Aransas Tx.
Cape San Blas Fl.
Mississippi
Canyon
Landslide
East-Breaks
Landslide
Florida Escarpment
West Florida
Landslide
Sigsbee Escarpment
South Padre Island Tx
Campeche Escarpment
N
Kilometer
0
100
200
300
400
500
30
29
28
27
26
25
24
23
22
21
20
19
LATITUDE (deg)
-97
-96
-95
-94
-93
-92
-91
-90
-89
-88
-87
-86
-85
-84
-83
-82
-81
-80
LONGITUDE (deg)



East-Breaks submarine landslide location,
excavation limits and surrounding bathymetry (in meters).

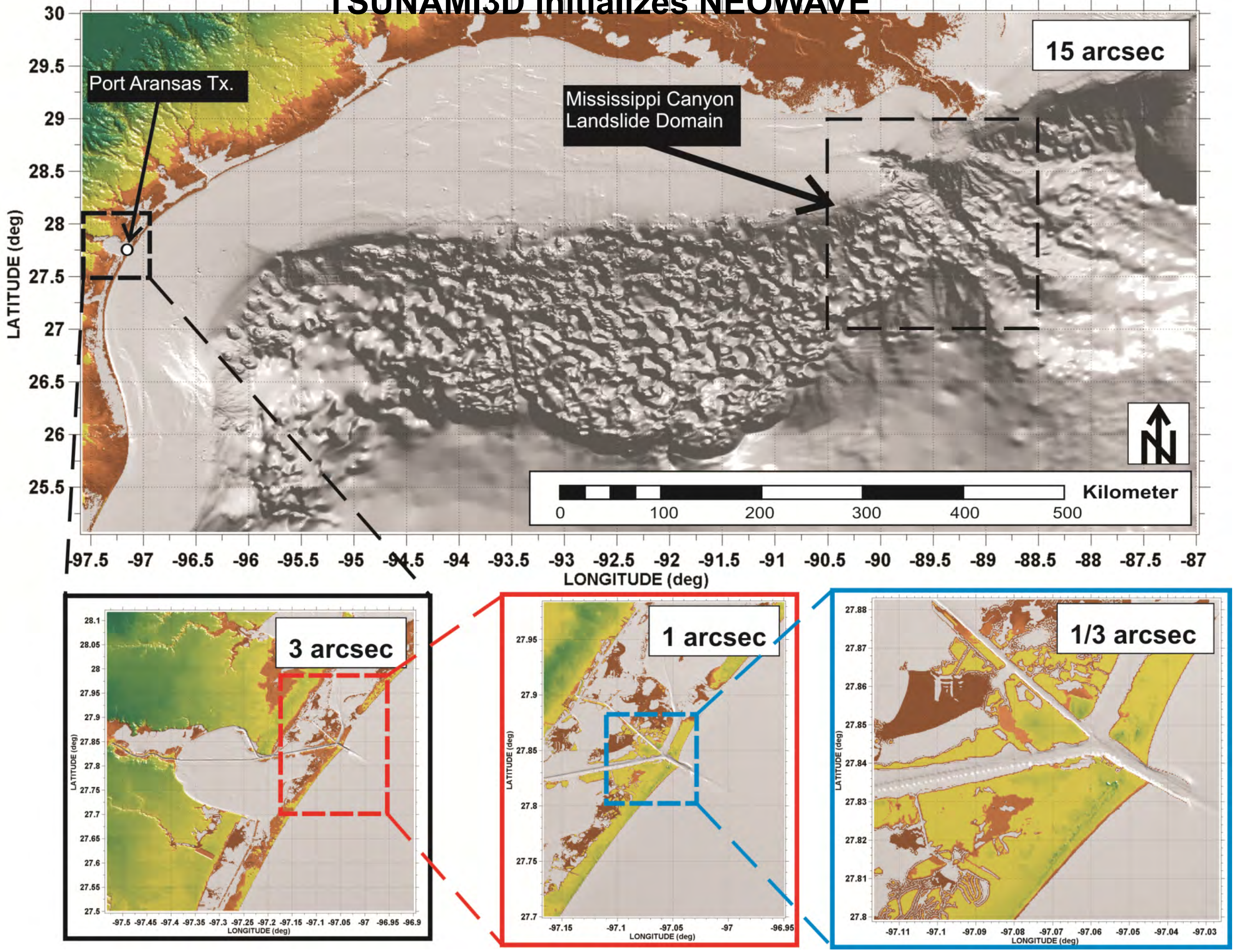


Mississippi Canyon submarine landslide, excavation limits and surrounding bathymetry (in meters).



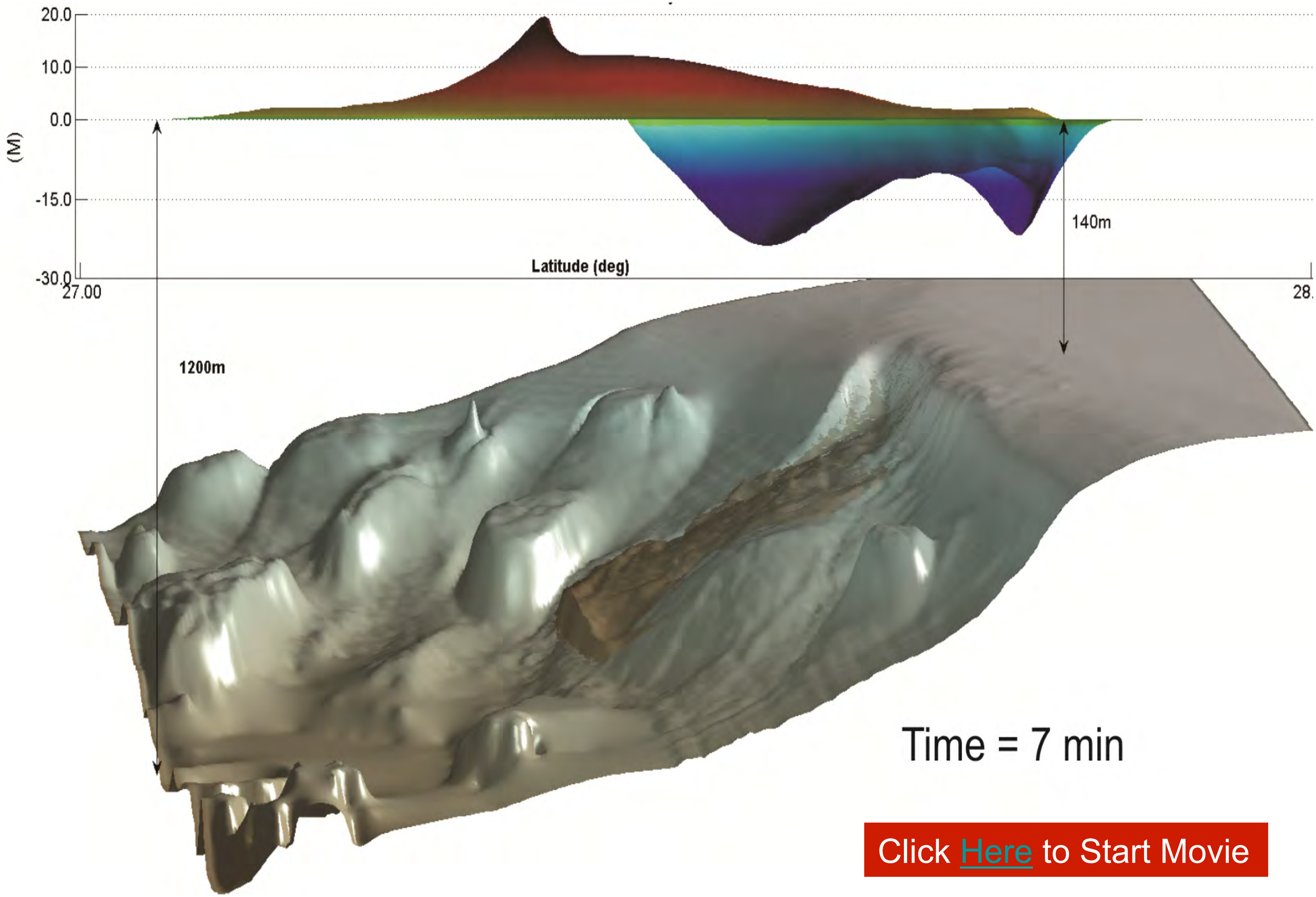
West Florida submarine landslide location,
excavation limits and surrounding bathymetry (in meters).

TYPICAL MODEL OPERATION
TSUNAMI3D initializes NEOWAVE



EAST BREAKS LANDSLIDE CASE

EAST BREAKS LANDSLIDE MOVIE (SIDE)



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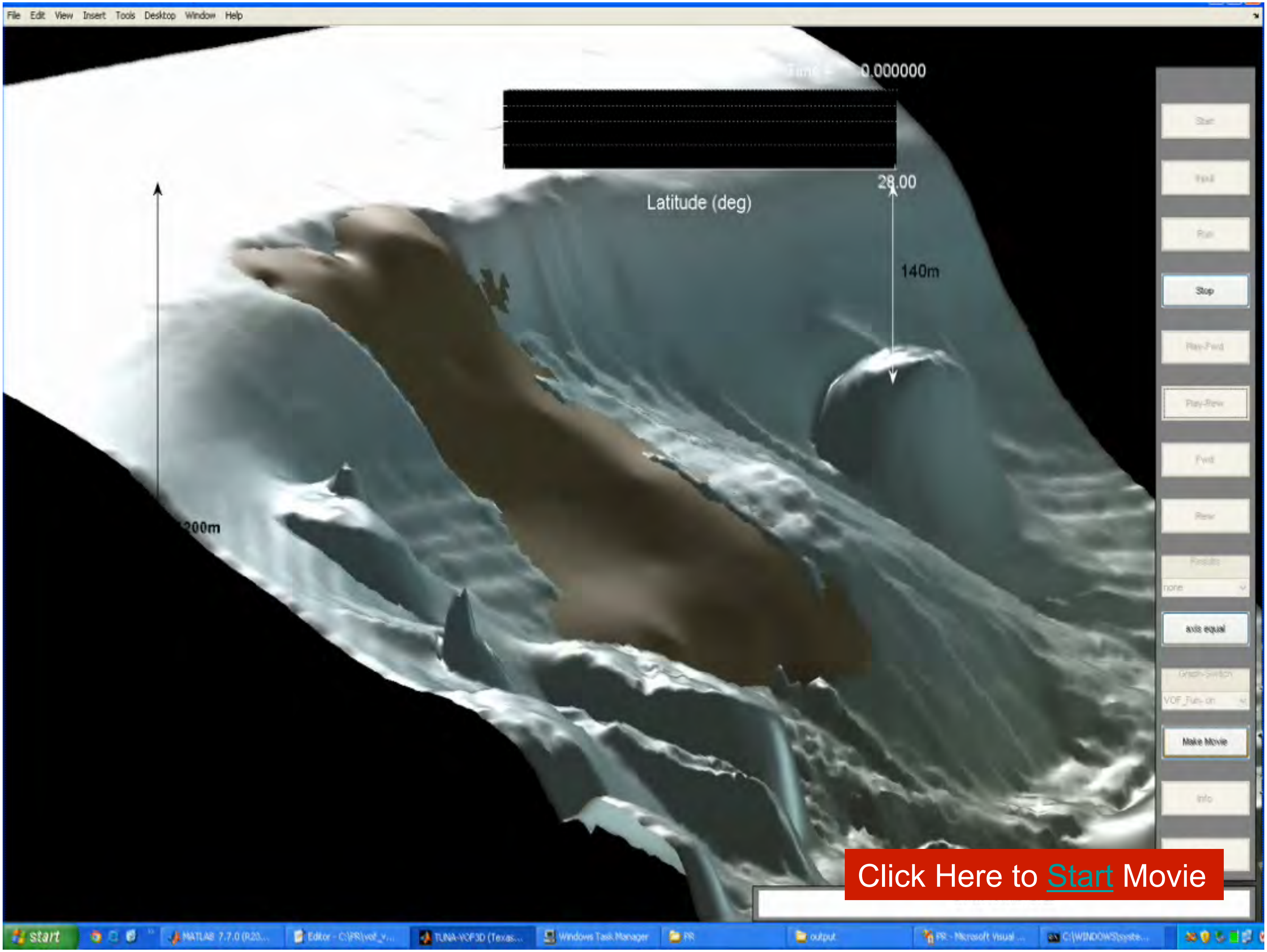
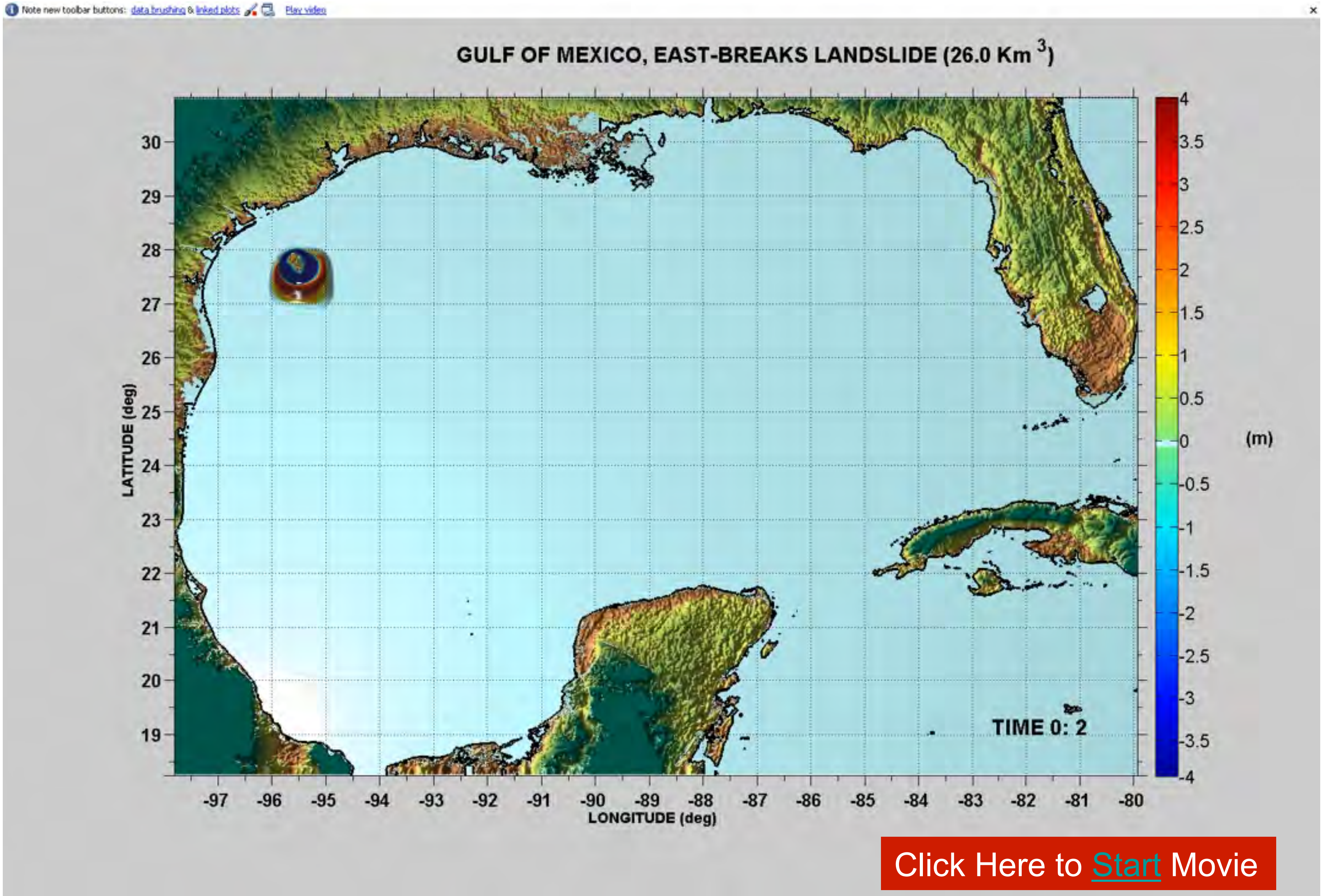
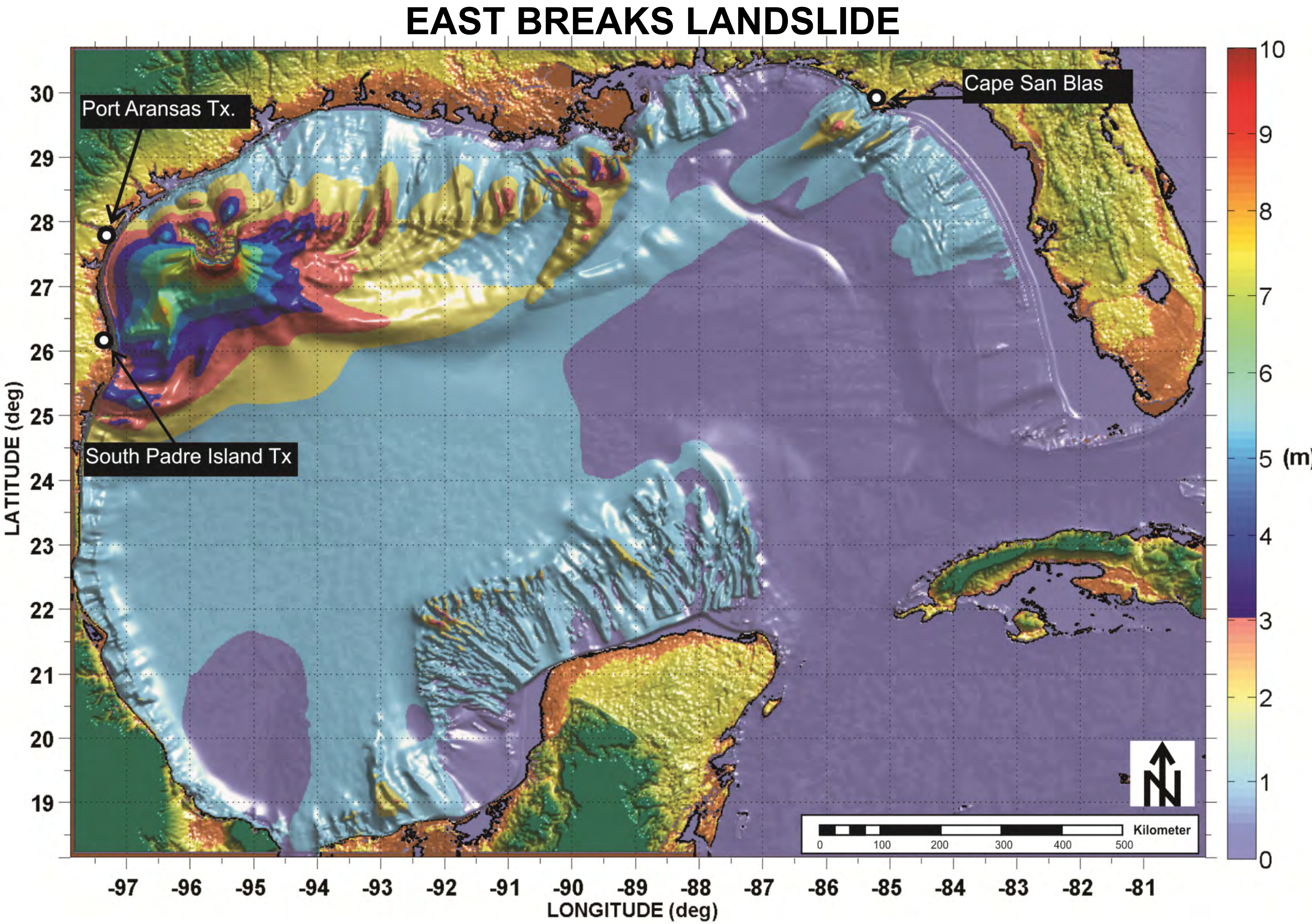
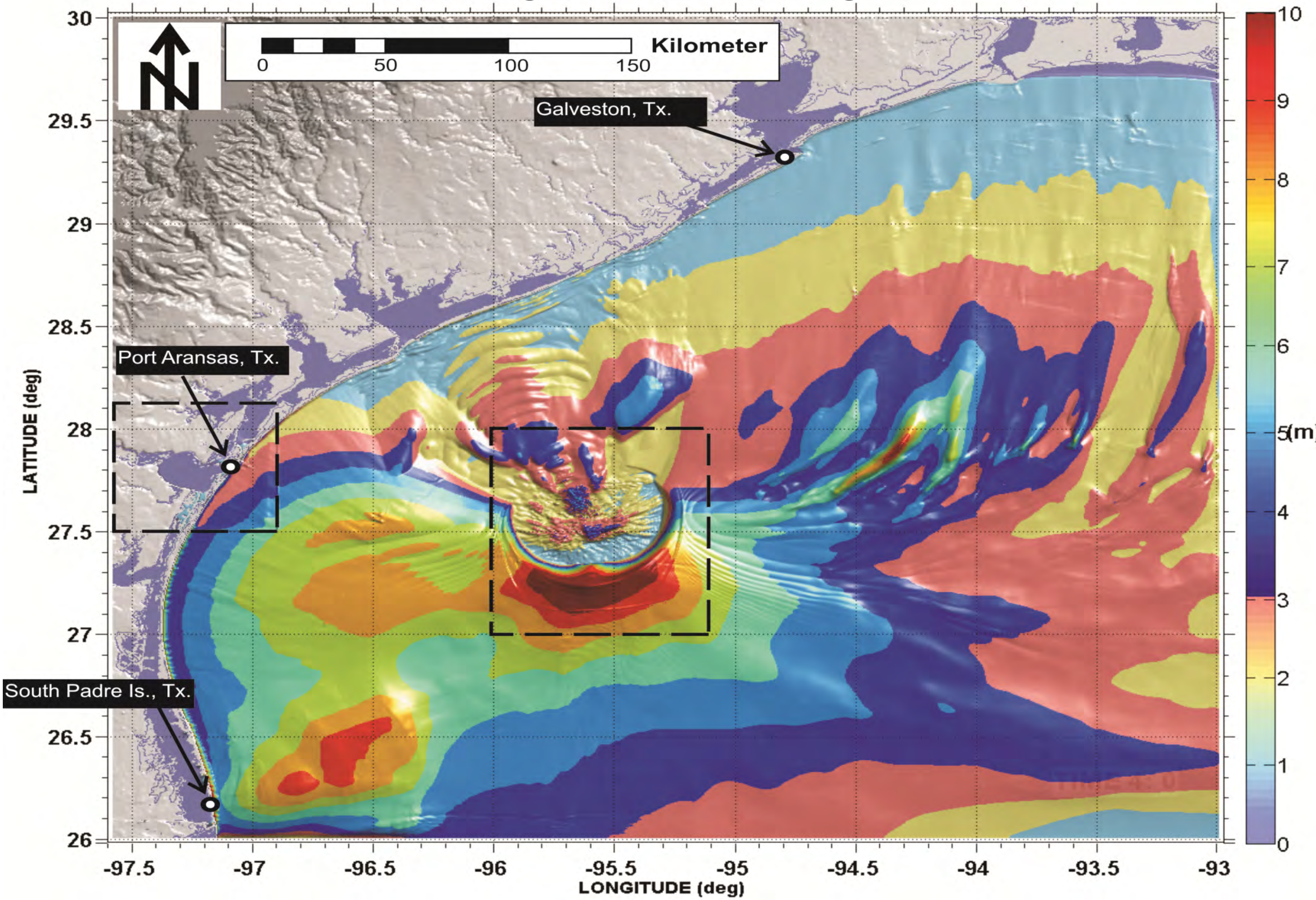


Click Here to Start Movie

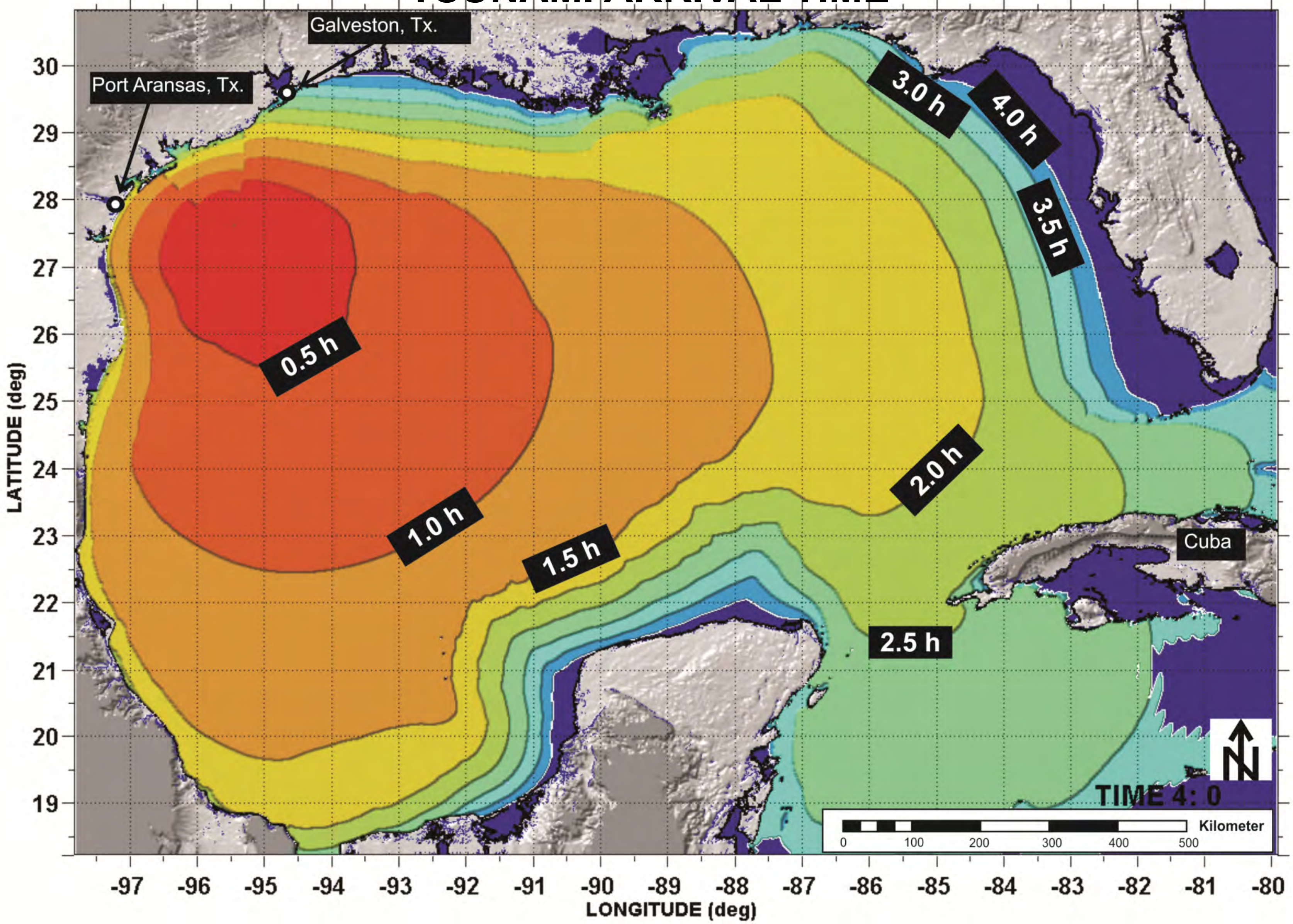

Note new toolbar buttons: data brushing & linked plots
Play video
GULF OF MEXICO, EAST-BREAKS LANDSLIDE (26.0 Km 3)
LATITUDE (deg)
30
29
28
27
26
25
24
23
22
21
20
19
-97
-96
-95
-94
-93
-92
-91
-90
-89
-88
-87
-86
-85
-84
-83
-82
-81
-80
LONGITUDE (deg)
TIME 0: 2
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
(m)
Click Here to Start Movie


EAST BREAKS LANDSLIDE
Port Aransas Tx.
Cape San Blas
South Padre Island Tx
LATITUDE (deg)
LONGITUDE (deg)
(m)
Kilometer
0
100
200
300
400
500
N

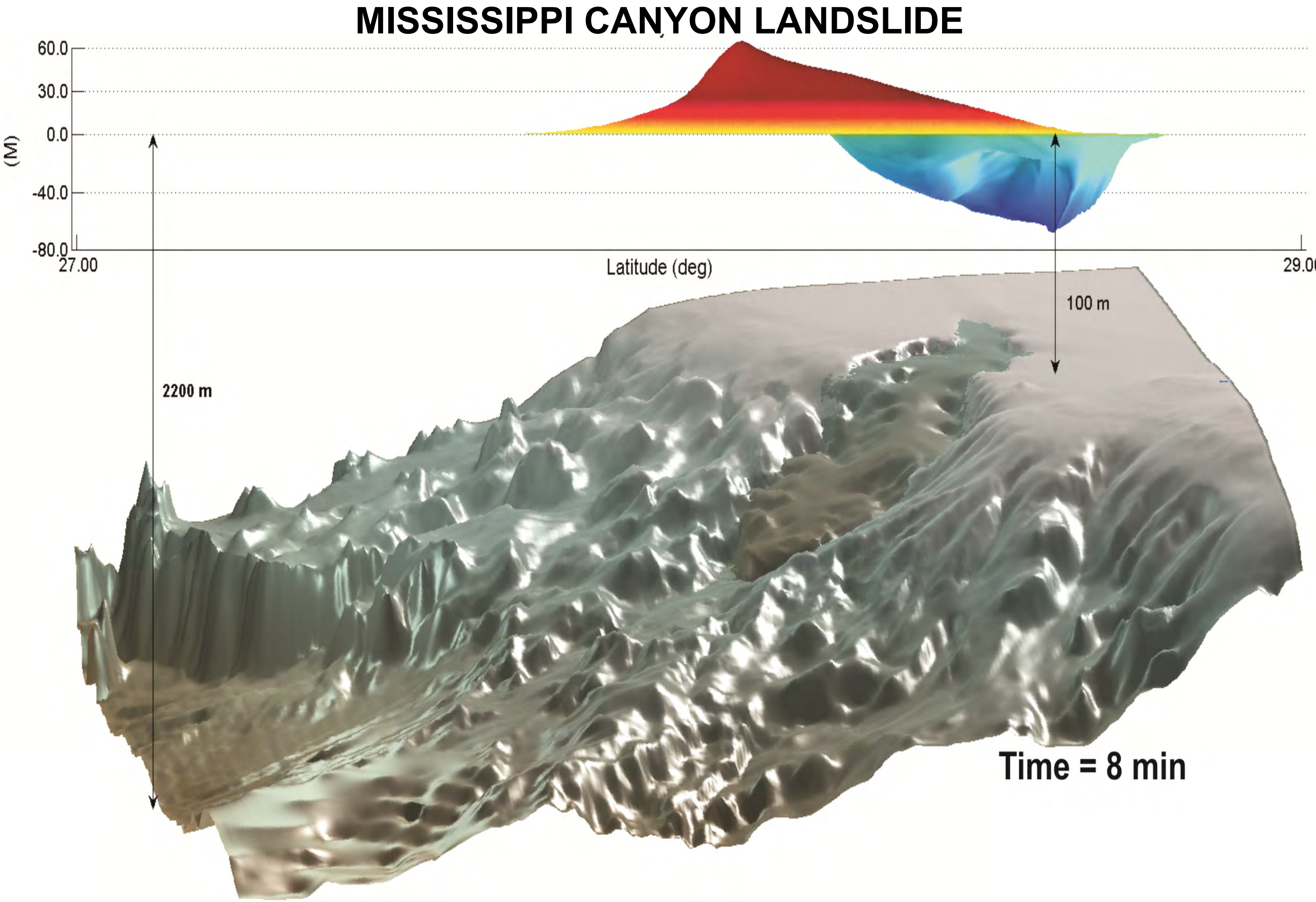
EAST BREAKS LANDSLIDE - ZOOM UP - MAXIMUM WAVE AMPLITUDE



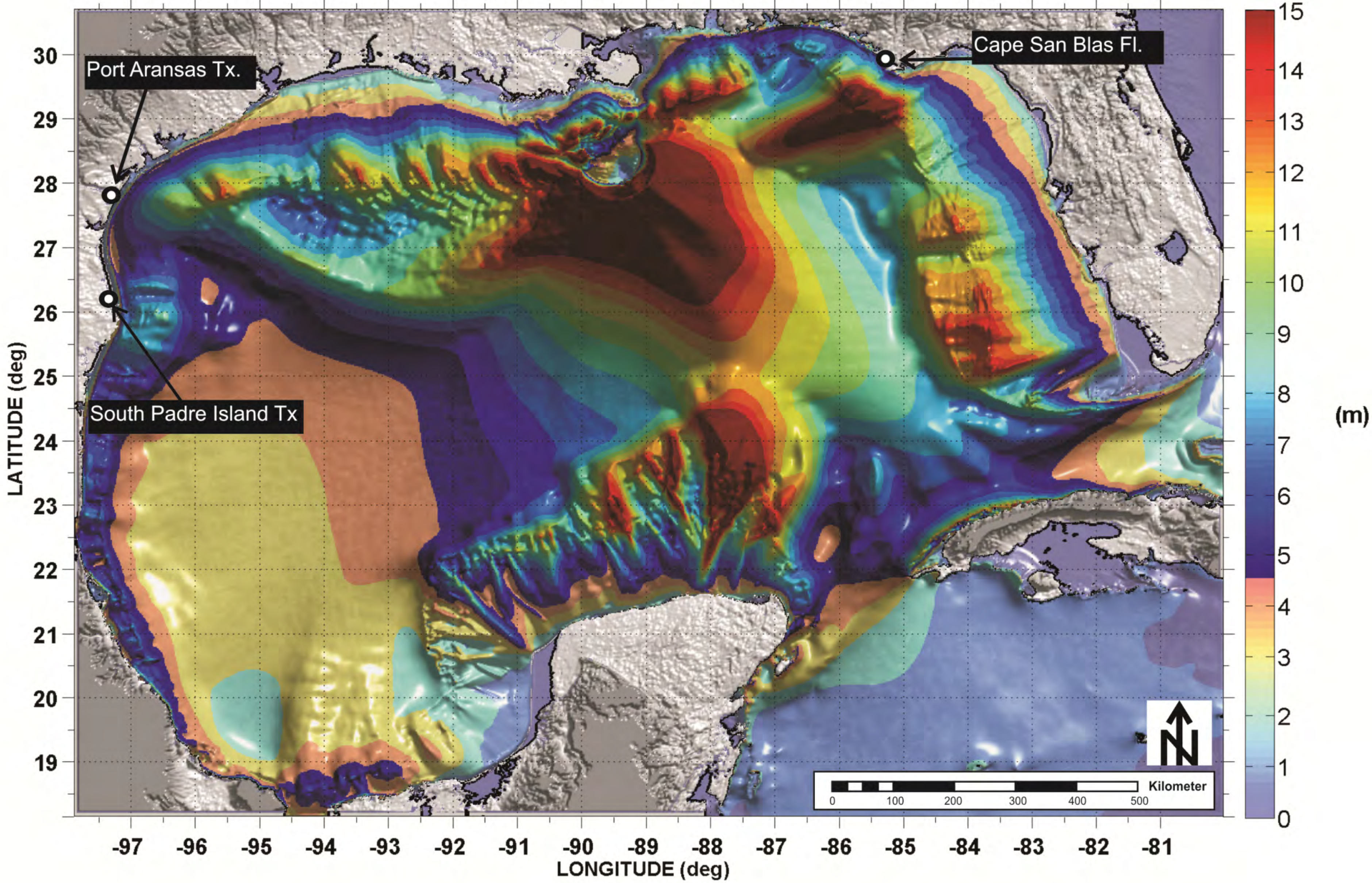
EAST BREAKS LANDSLIDE TSUNAMI ARRIVAL TIME



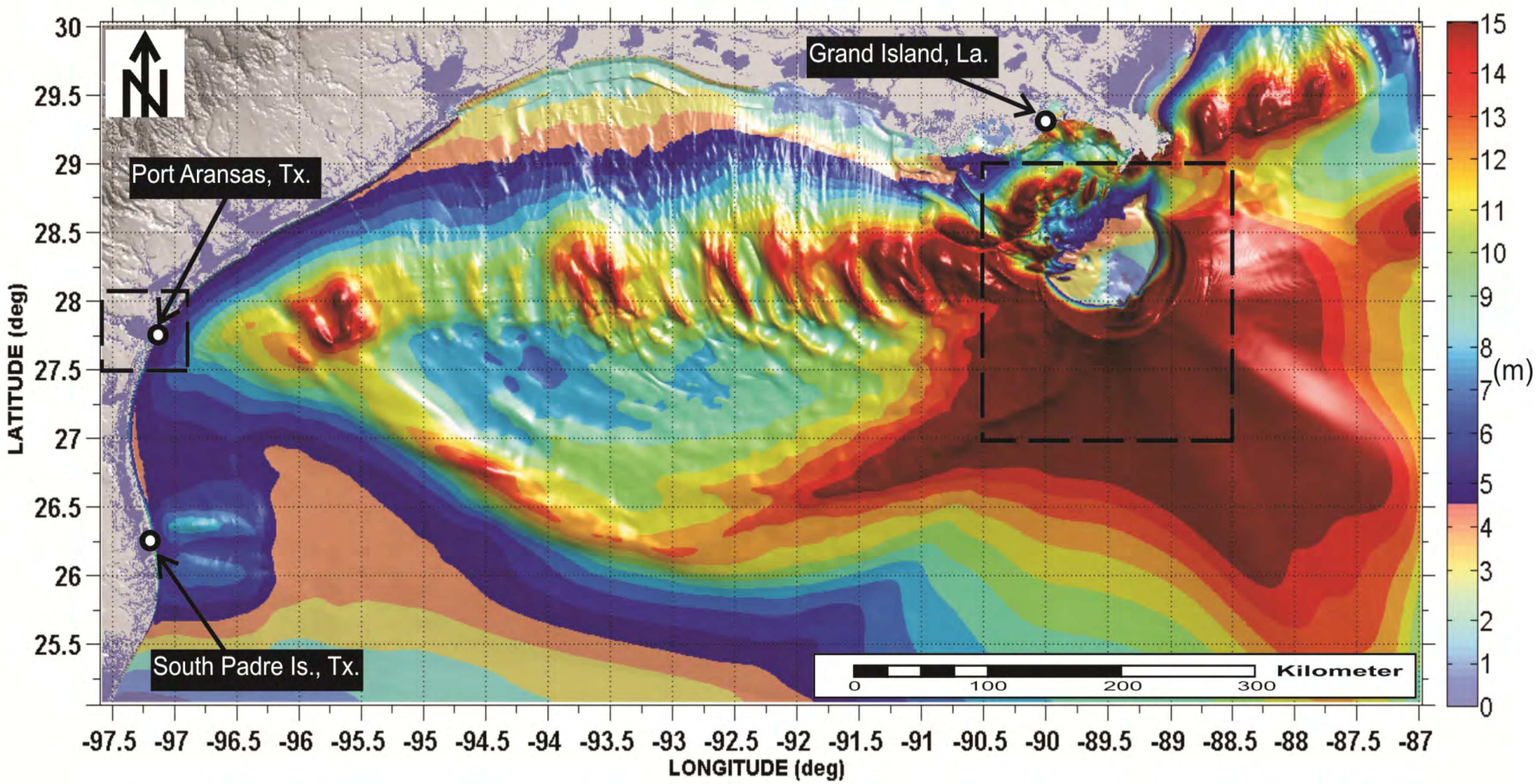
MISSISSIPPI CANYON LANDSLIDE CASE


MISSISSIPPI CANYON LANDSLIDE
60.0
30.0
0.0
(M)
-40.0
-80.0
27.00
Latitude (deg)
29.00
100 m
2200 m
Time = 8 min

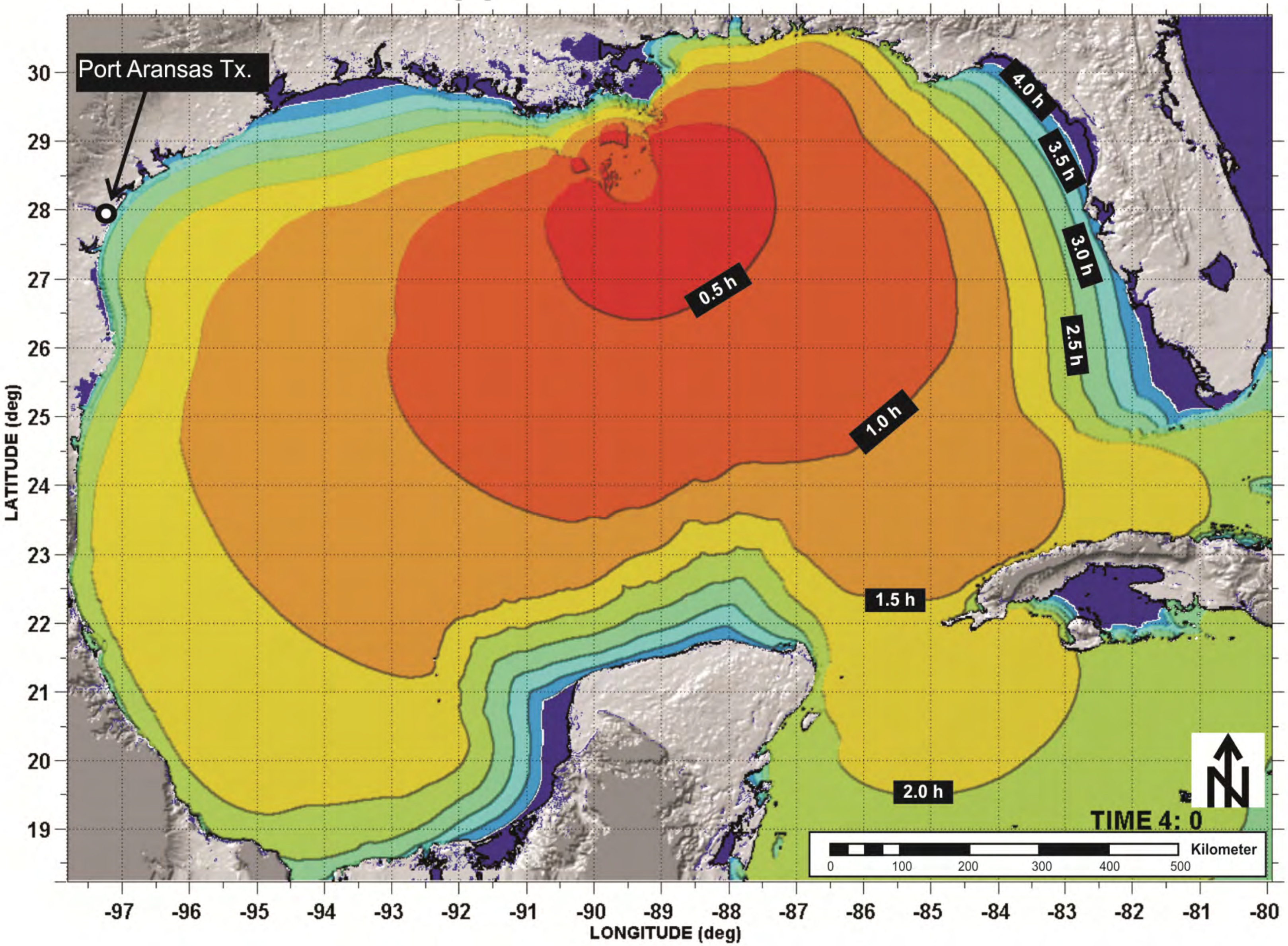
MISSISSIPPI CANYON LANDSLIDE
MAXIMUM WAVE AMPLITUDE



MISSISSIPPI CANYON LANDSLIDE - ZOOM UP - MAXIMUM WAVE AMPLITUDE



- MISSISSIPPI CANYON LANDSLIDE -
TSUNAMI ARRIVAL TIME



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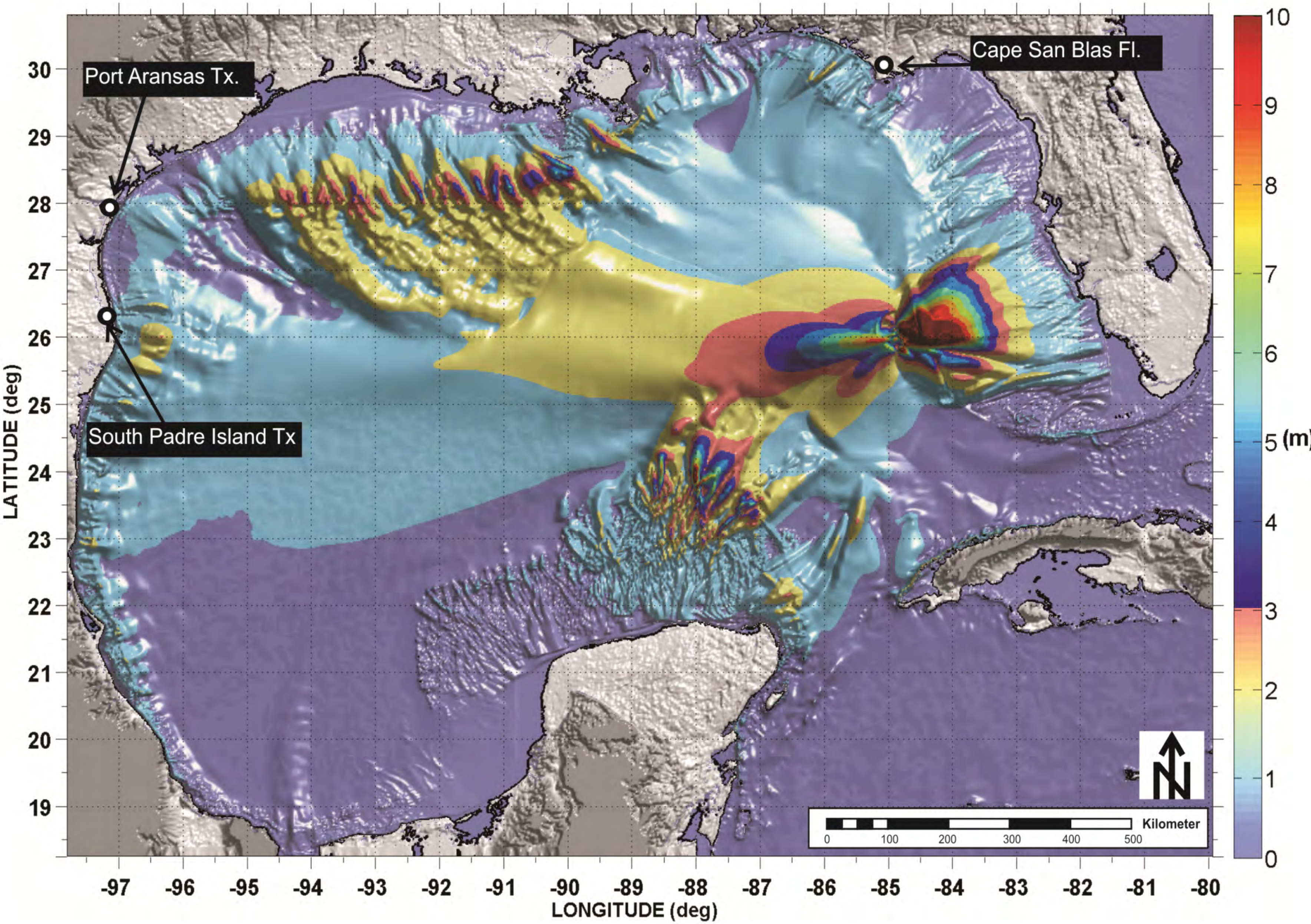
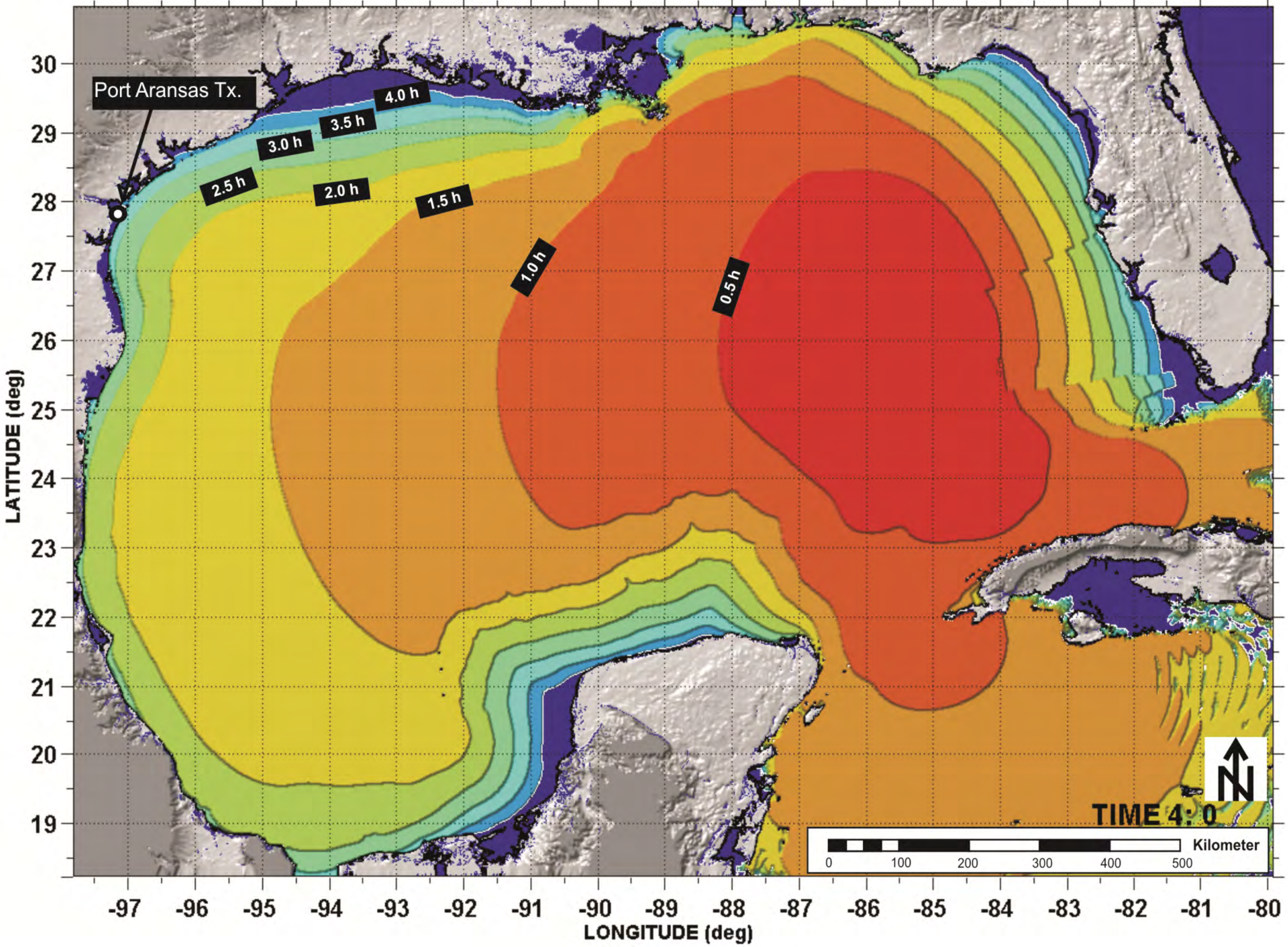
WEST FLORIDA LANDSLIDE CASE

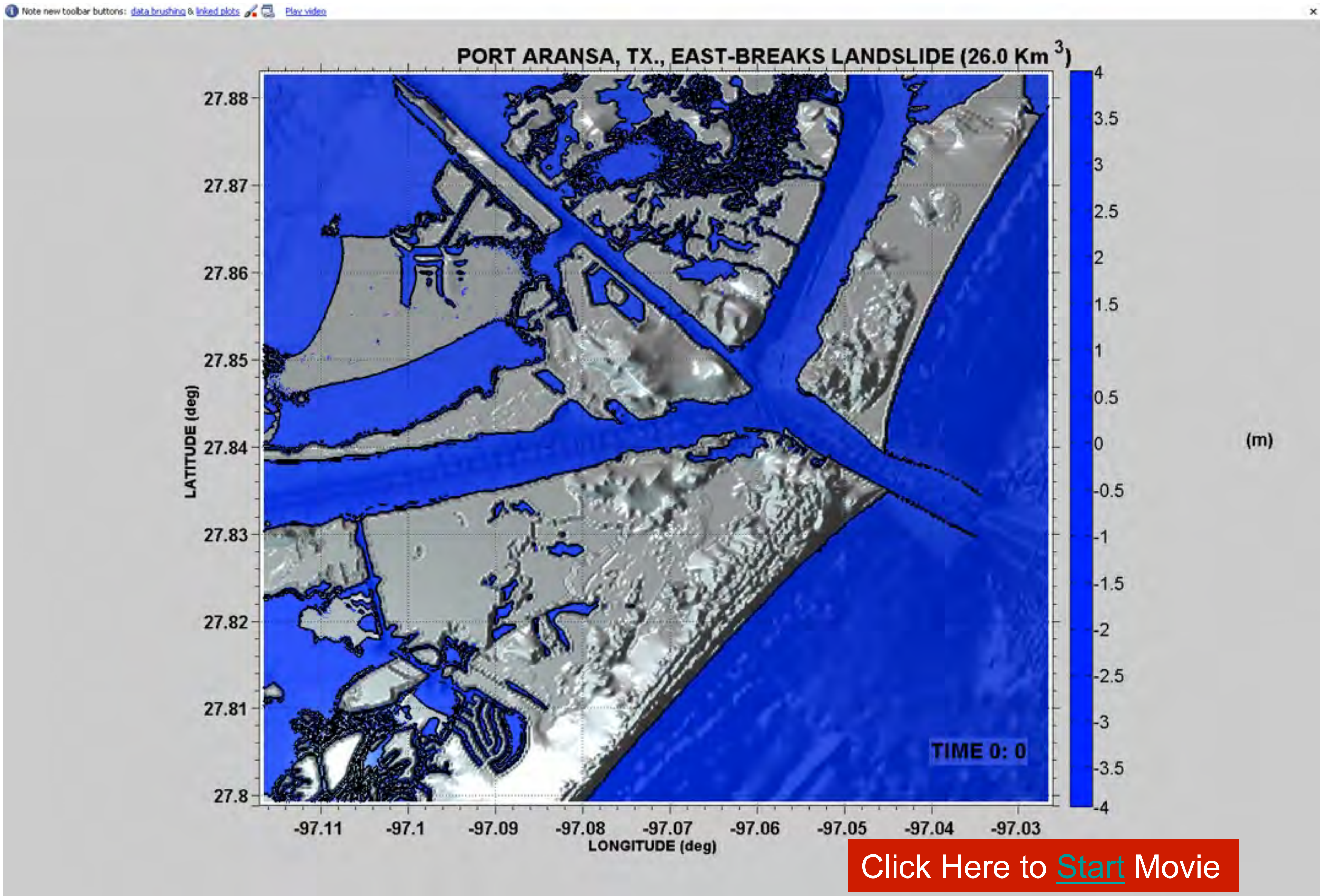
WEST FLORIDA LANDSLIDE
MAXIMUM WAVE AMPLITUDE



- WEST FLORIDA LANDSLIDE -
ARRIVAL TIME

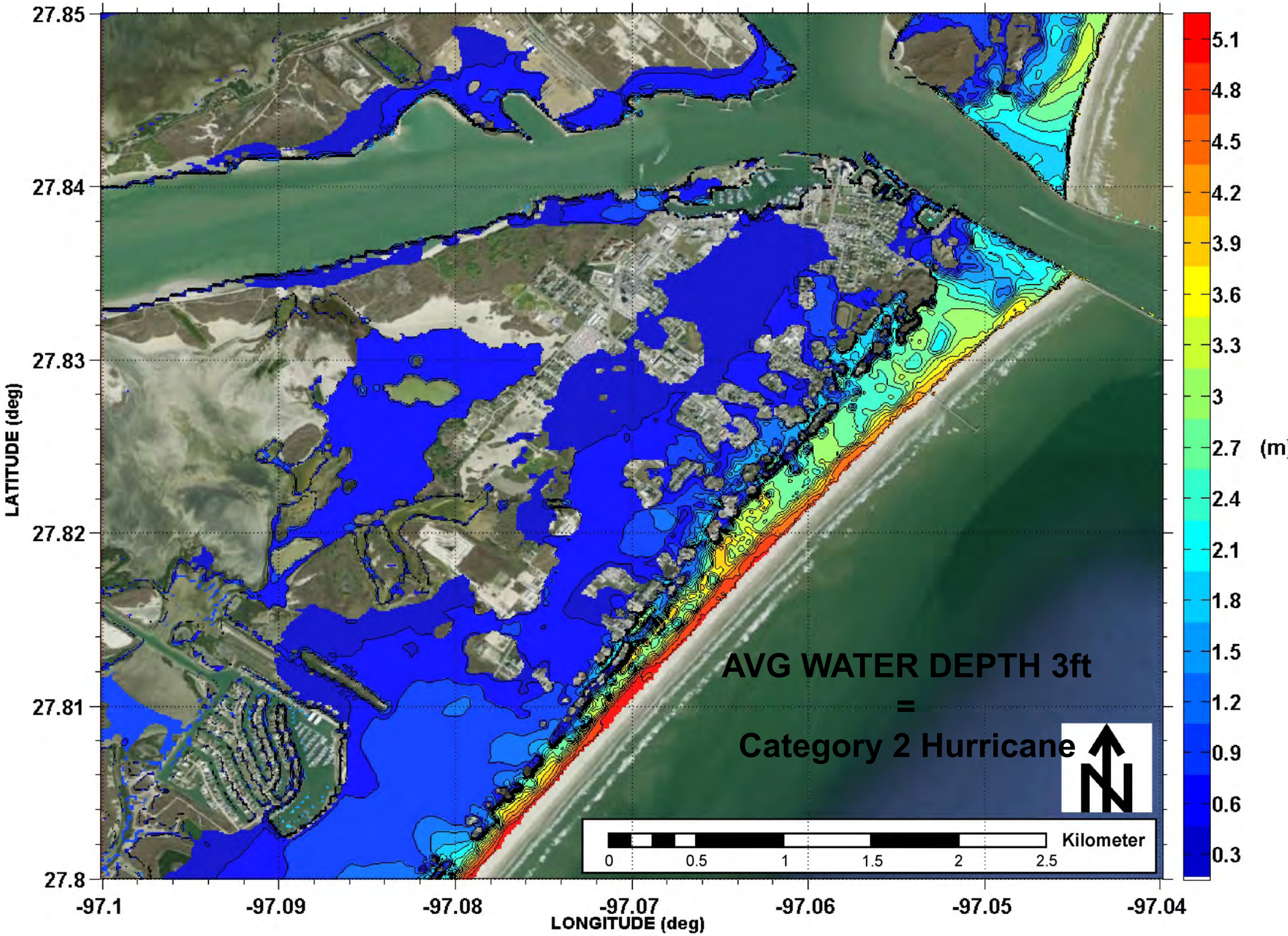


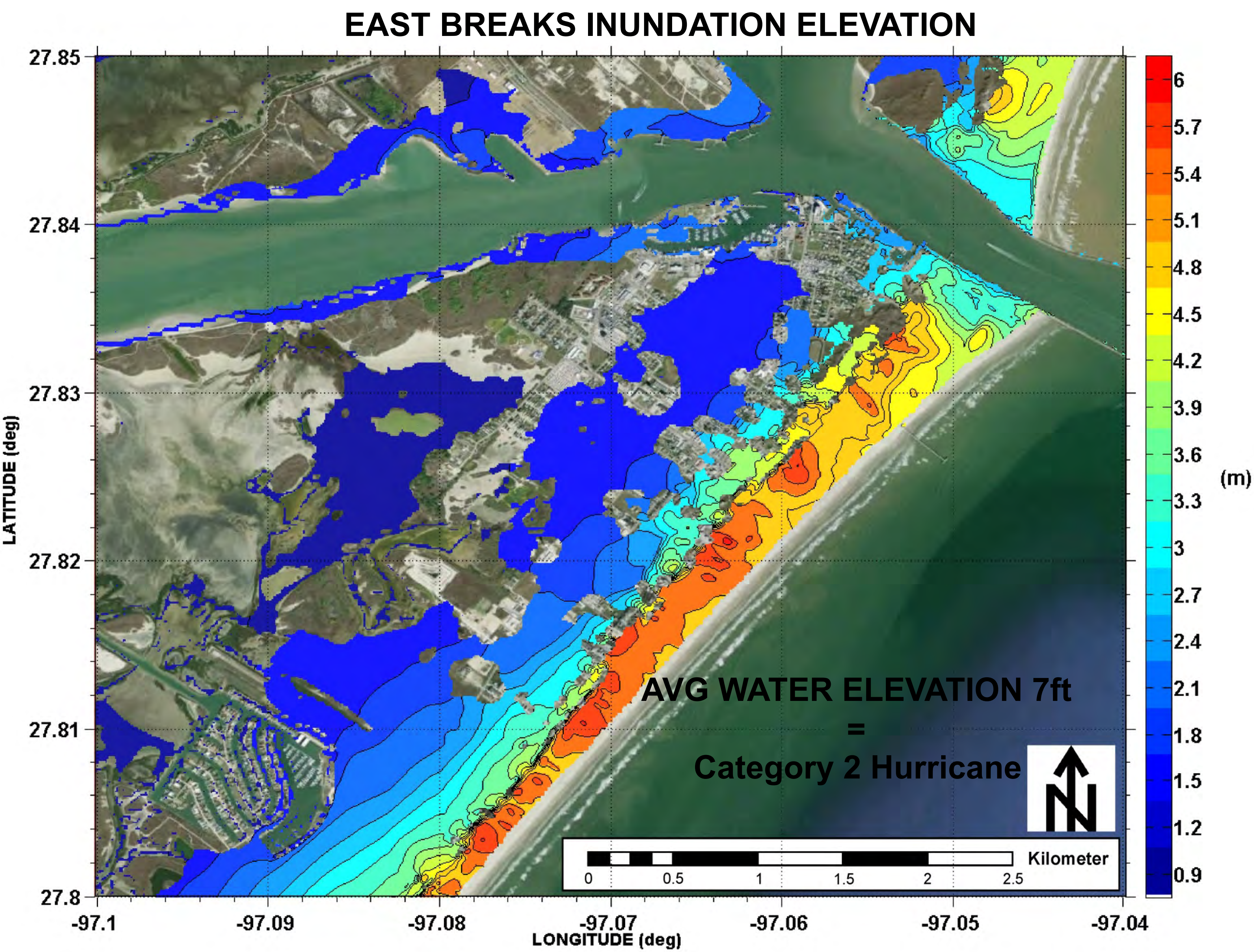
EAST BREAKS LANDSLIDE INUNDATION RESULTS

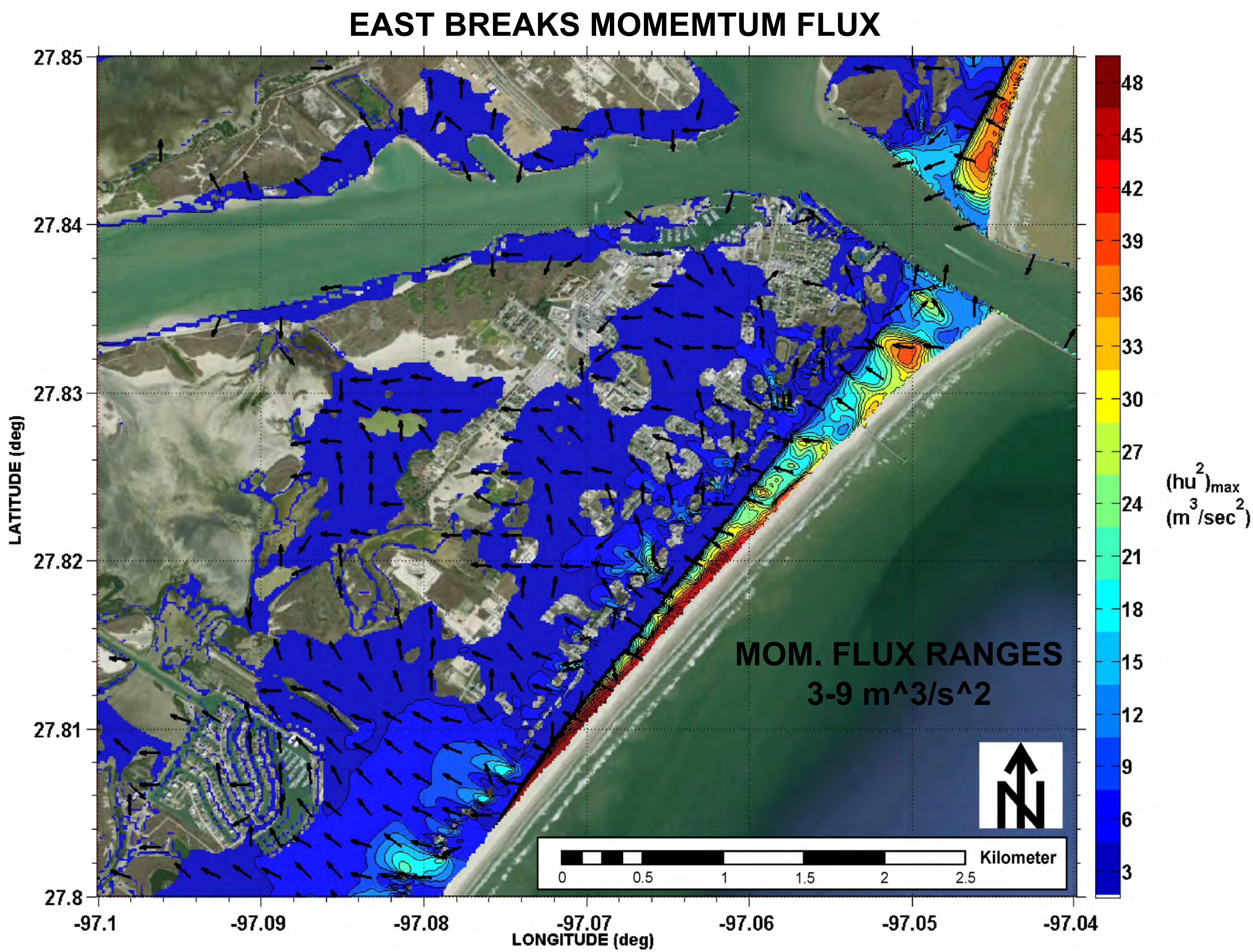


Click Here to Start Movie

EAST BREAKS INUNDATION DEPTH



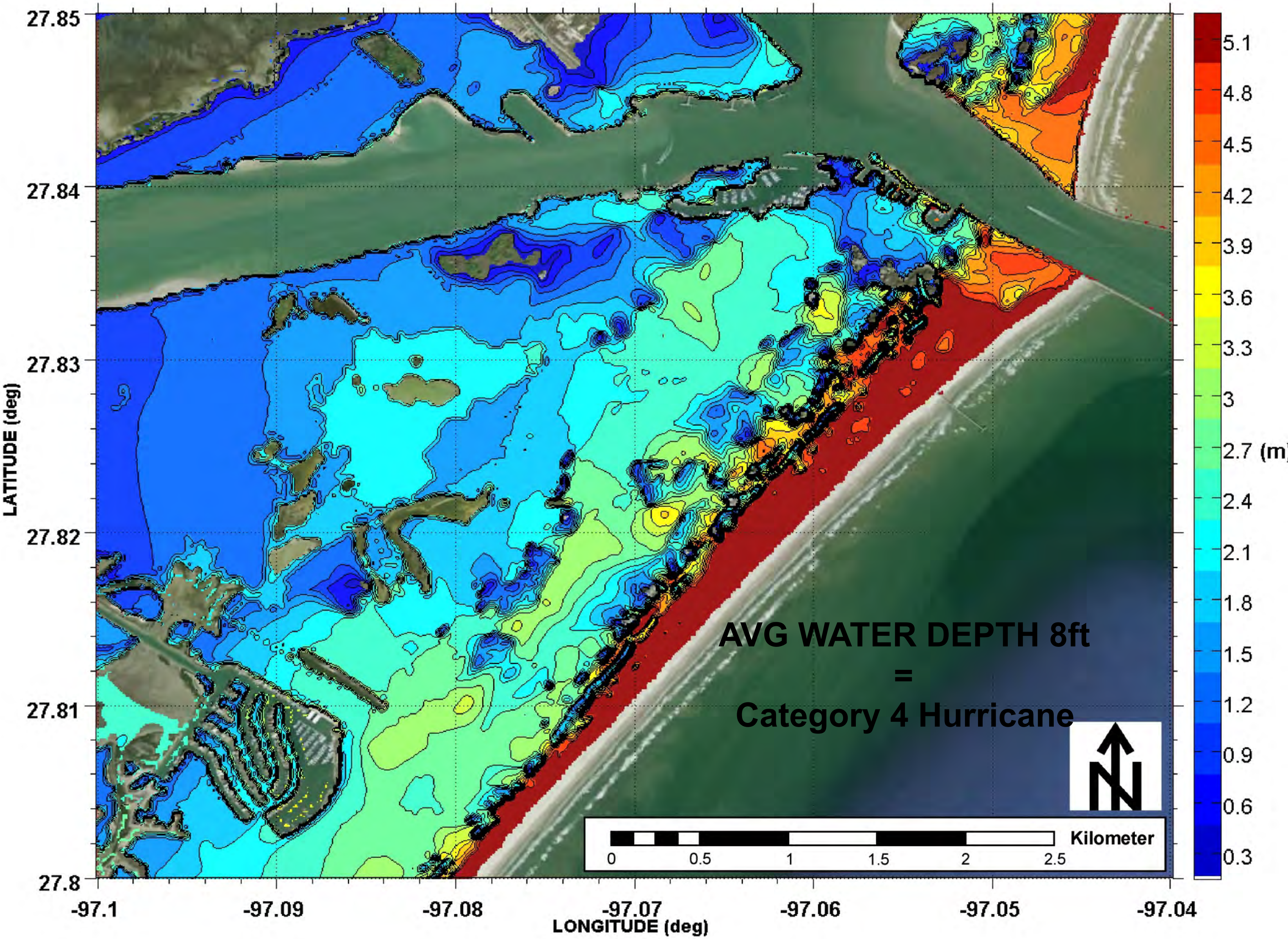

EAST BREAKS INUNDATION ELEVATION
27.85
27.84
27.83
27.82
27.81
27.8
LATITUDE (deg)
-97.1
-97.09
-97.08
-97.07
-97.06
-97.05
-97.04
LONGITUDE (deg)
6
5.7
5.4
5.1
4.8
4.5
4.2
3.9
3.6
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
(m)
AVG WATER ELEVATION 7ft
=
Category 2 Hurricane
N
0
0.5
1
1.5
2
2.5
Kilometer



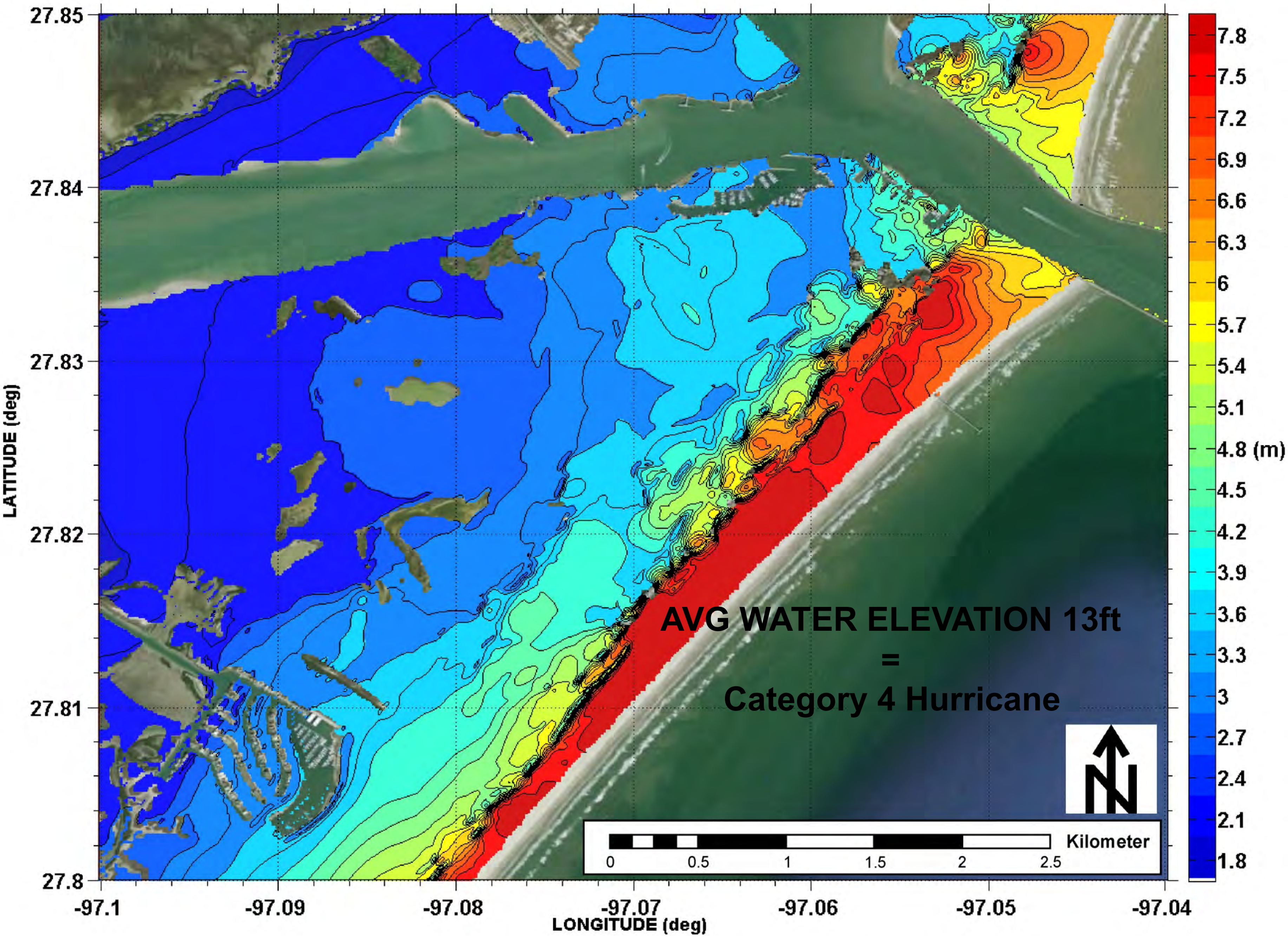
EAST BREAKS MOMEMTUM FLUX
LATITUDE (deg)
27.85
27.84
27.83
27.82
27.81
27.8
LONGITUDE (deg)
-97.1
-97.09
-97.08
-97.07
-97.06
-97.05
-97.04
MOM. FLUX RANGES
3-9 m^3/s^2
N
Kilometer
0
0.5
1
1.5
2
2.5
$(hu^2)_{max}$
(m^3/sec^2)
48
45
42
39
36
33
30
27
24
21
18
15
12
9
6
3

MISSISSIPPI CANYON LANDSLIDE INUNDATION RESULTS

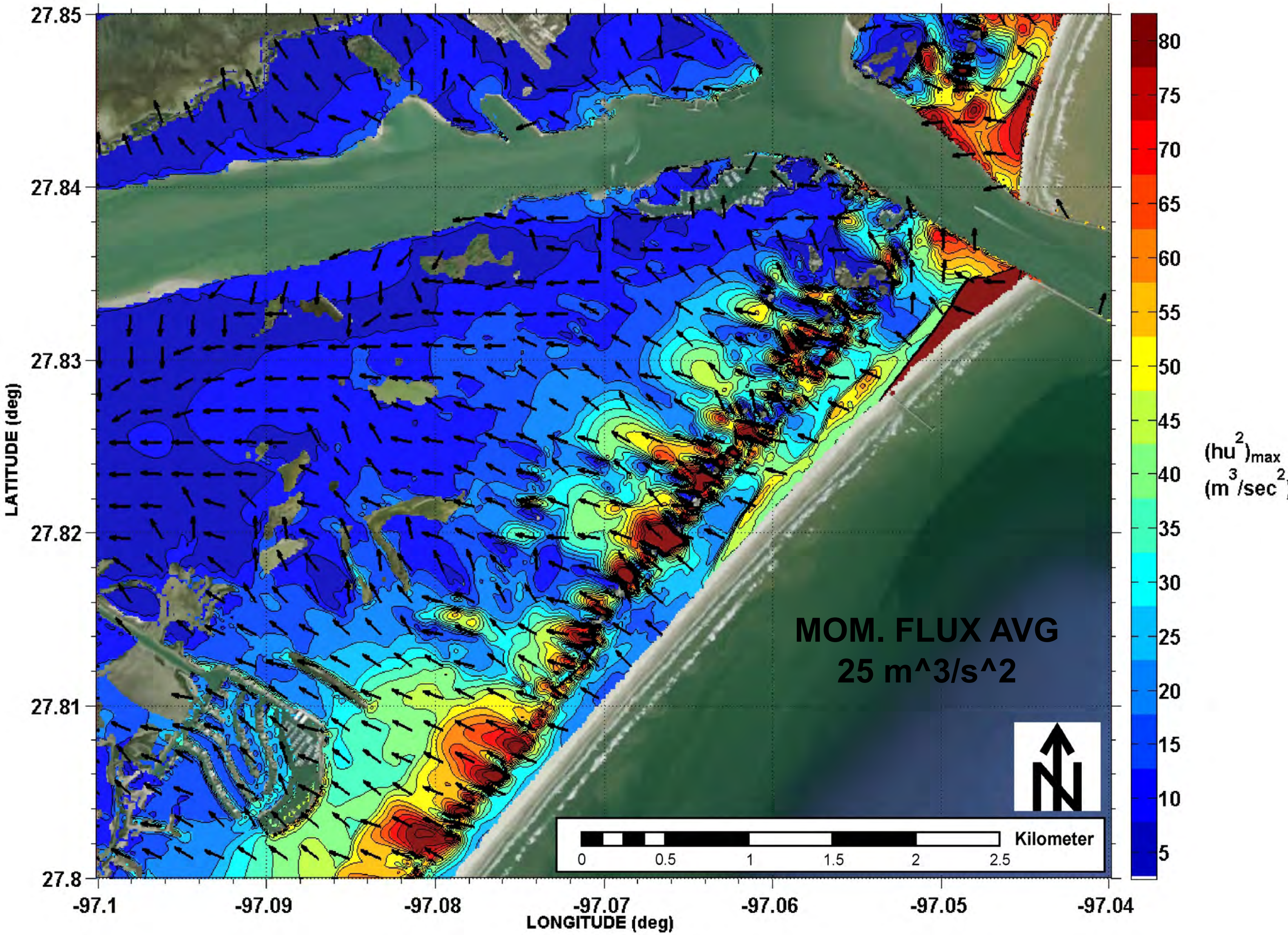
MISSISSIPPI CANYON INUNDATION DEPTH



MISSISSIPPI CANYON INUNDATION ELEVATION



MISSISSIPPI CANYON MOMEMTUM FLUX



CONCLUSIONS

These landslide scenarios have the potential to cause severe flooding and damage to the GOM coastal communities and oil infrastructure. Such landslide sources can flood Port Aransas with an:

Avg. water elevation of 7 - 13ft (2.1 - 3.9m)
Avg. water depth of 3 - 8ft (0.9 - 2.4m)

In term of flooding the tsunamis generated by these landslide are comparable to storm surges originated **by hurricanes of category 2 to 4**.

National Tsunami Hazard Mitigation Program
Construction of tsunami inundation maps in the Gulf of Mexico

Table 1. Maximum Water Elevation for hurricane of a given category in Port Aransas TX.

Hurricane Category	Maximum Water Elevation Range (ft)	Numerical Model Result
1	4.3-4.9	
2	7.3-7.6	East-Breaks
3	9.6-10.3	
4	13-13.2	Mississippi Canyon
5	16.3-16.6	

By Thomas LeBlanc

CONCLUSIONS

Tsunami energy focusing is identified in several regions along the GOM coastline

Regions most impacted are:

1- southern tip of South Padre Island, TX.,
2- Grand Island, LA,
3- Fort Walton Beach-to-Cape San Blas, FL,
4- Tamaulipas, Mexico.

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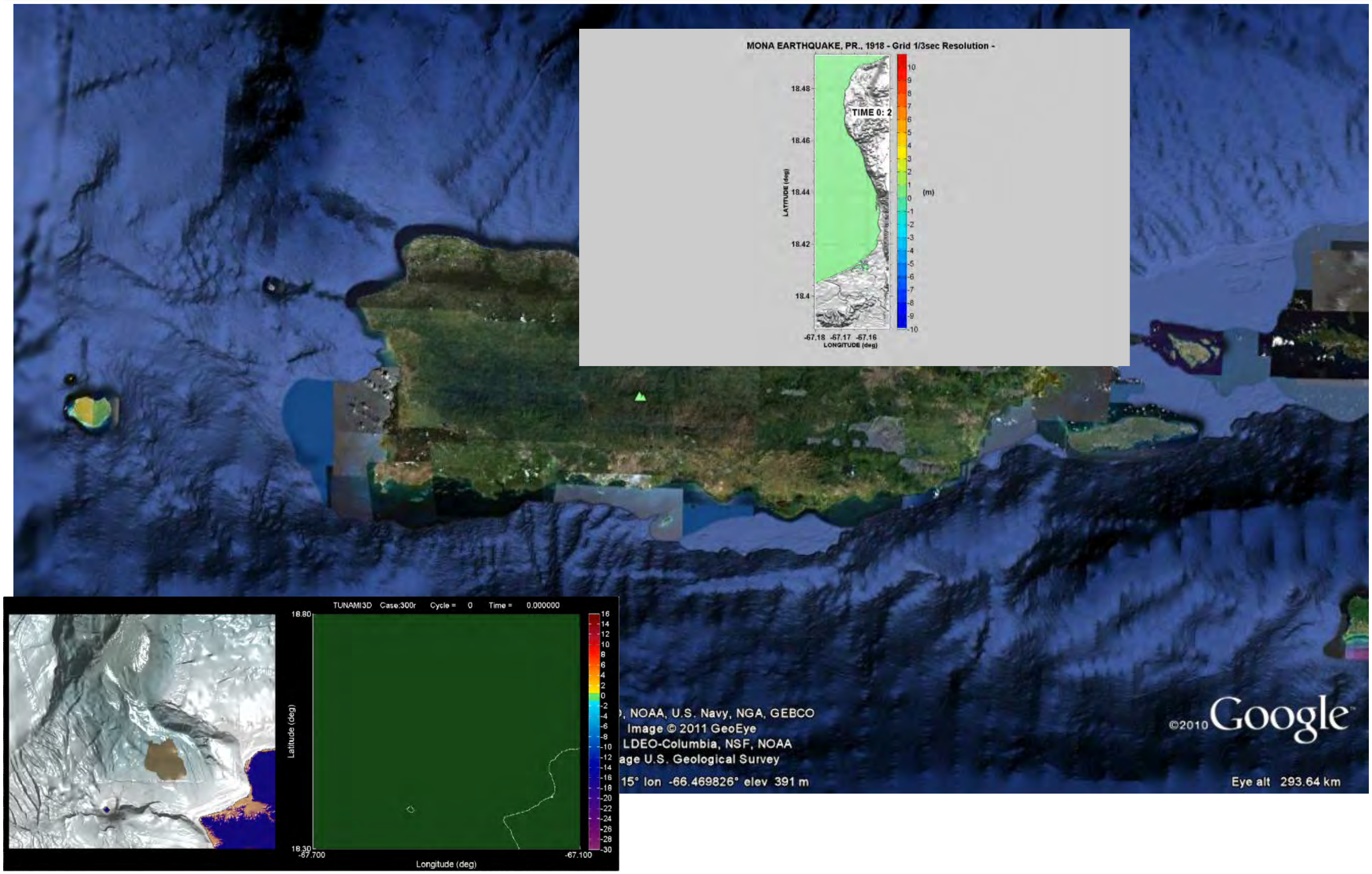
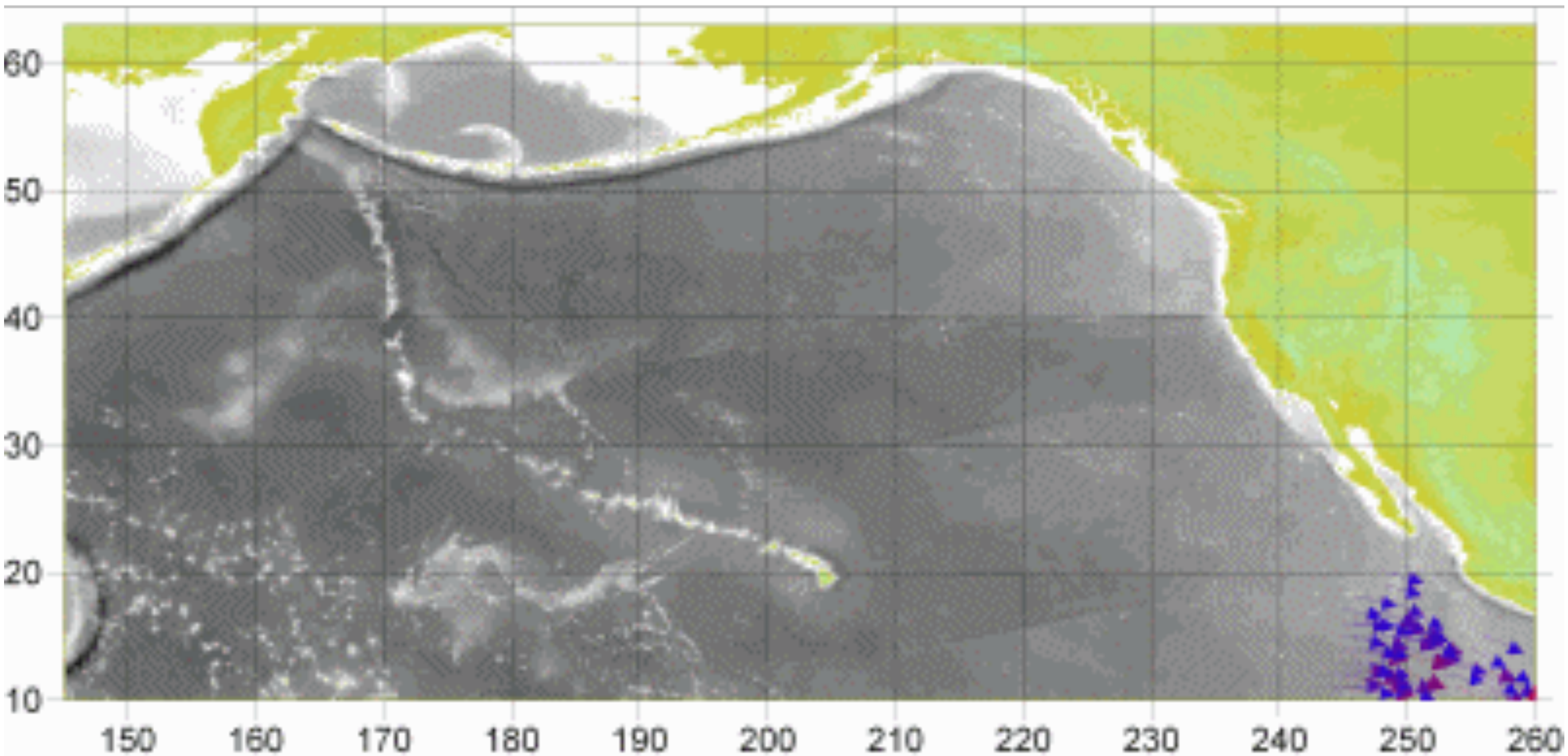
PUERTO RICO -MONA 1918 EARTHQUAKE- SUBSEA LANDSLIDE ?



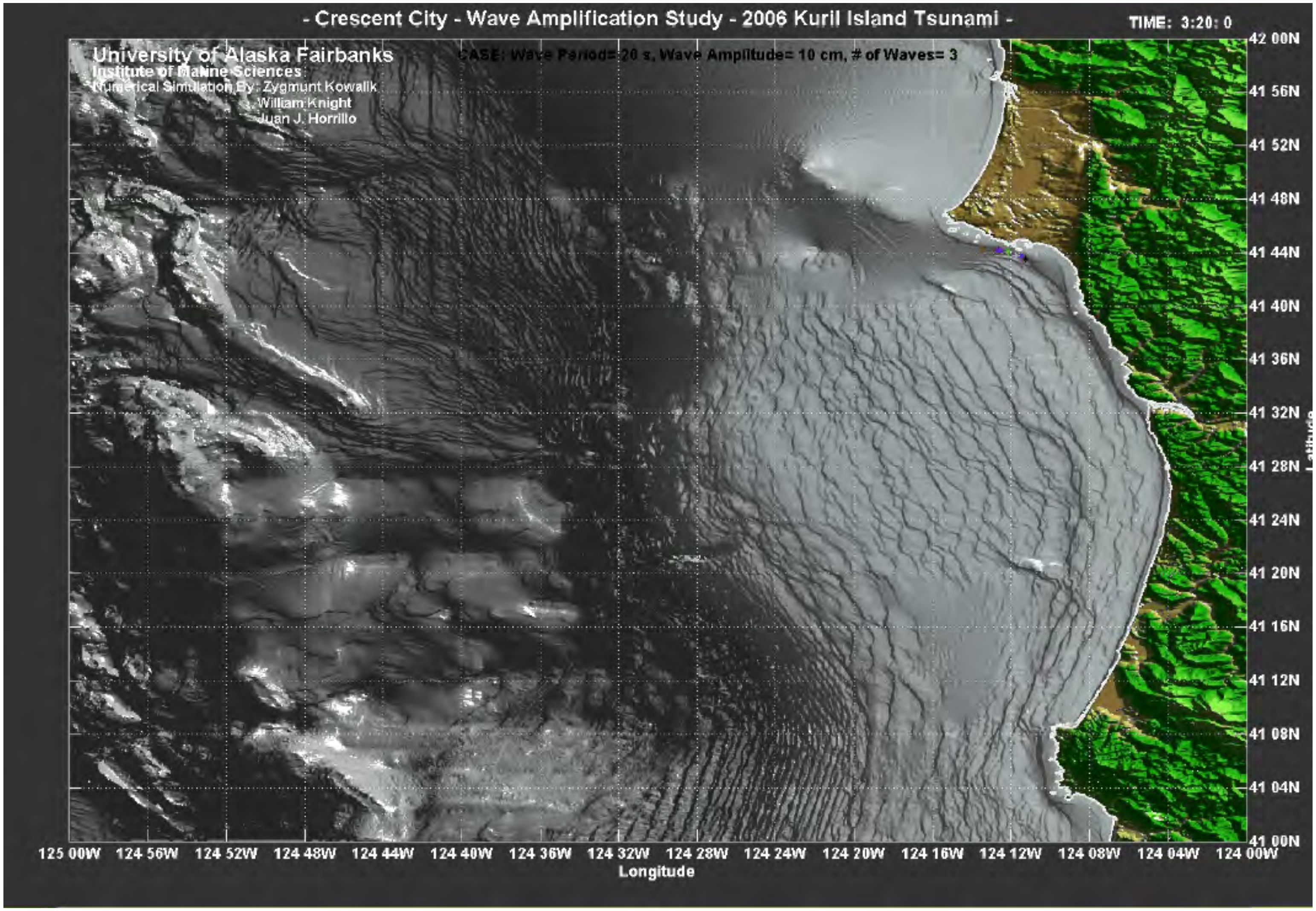
Probabilistic Approach
Late Tsunami Arrival and Tsunami Energy Focusing due to Distant Secondary Sources



By: Bill Knight

Probabilistic Approach

LOCAL AMPLIFICATION DUE TO the INMEDIATE CONTINENTAL SHELF



Probabilistic Approach
Landslide Tsunami Propagation Model
Nonhydrostatic vs. Hydrostatic