

# Multiscale Simulation of Erosion and Breaching of Barrier Islands: Coupling XBeach and ADCIRC

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ASBPA Coastal Conference, 22-25 Oct 2019



# Inlet Creation

## Isabel Inlet (2003)



# Preliminaries

## Goals and Objectives

### Goals:

1. Better understand the storm-induced erosion of barrier islands
2. Develop ways to represent that erosion in predictive models on large domains

### Objectives:

1. Develop a high-resolution hindcast of inlet creation in a barrier island system
2. Explore the sensitivity of erosion predictions to the quality of input data
3. Implement a two-way coupling of small-scale erosion to larger-scale flooding

## Preliminaries

### Inlet- and Region-Scale Models

How can we represent the full effects of Isabel Inlet?

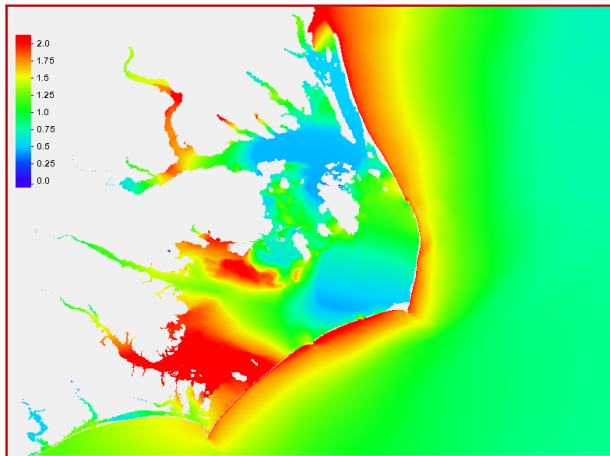
- Need circulation models on larger domains
  - Bring in winds, waves, storm surge
  - Typically solve the shallow-water equations with a static ground surface
  - We will use ADCIRC
- Also need erosion models on smaller domains
  - Typically consider both hydro- and morphodynamics
  - Employed on domains of only a few kilometers
  - We will use XBeach



## ADCIRC+XBeach

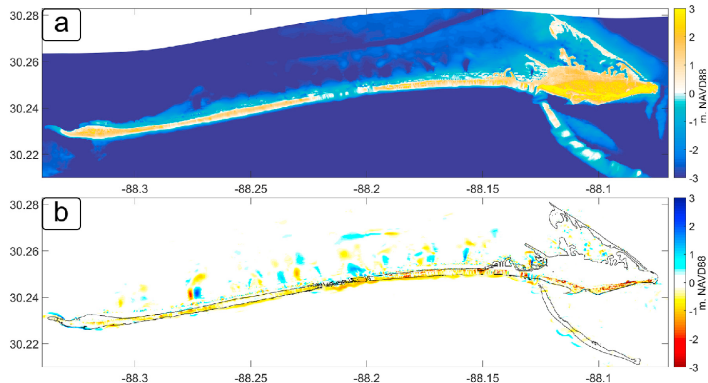
### ADvanced CIRCulation (ADCIRC)

- Flooding and storm surge modeling tool
- Finite-element model
- Flexible unstructured mesh
- Bathymetry and topography are fixed / constant
- No consideration of beach erosion, dune breaching, etc.



## ADCIRC+XBeach eXtreme Beach (XBeach)

- Open-source model developed in the Netherlands
- Capable of simulating hydrodynamic and morphodynamic processes
- Applied typically at beach scales (a few kilometers)



Passeri et al. (2018)

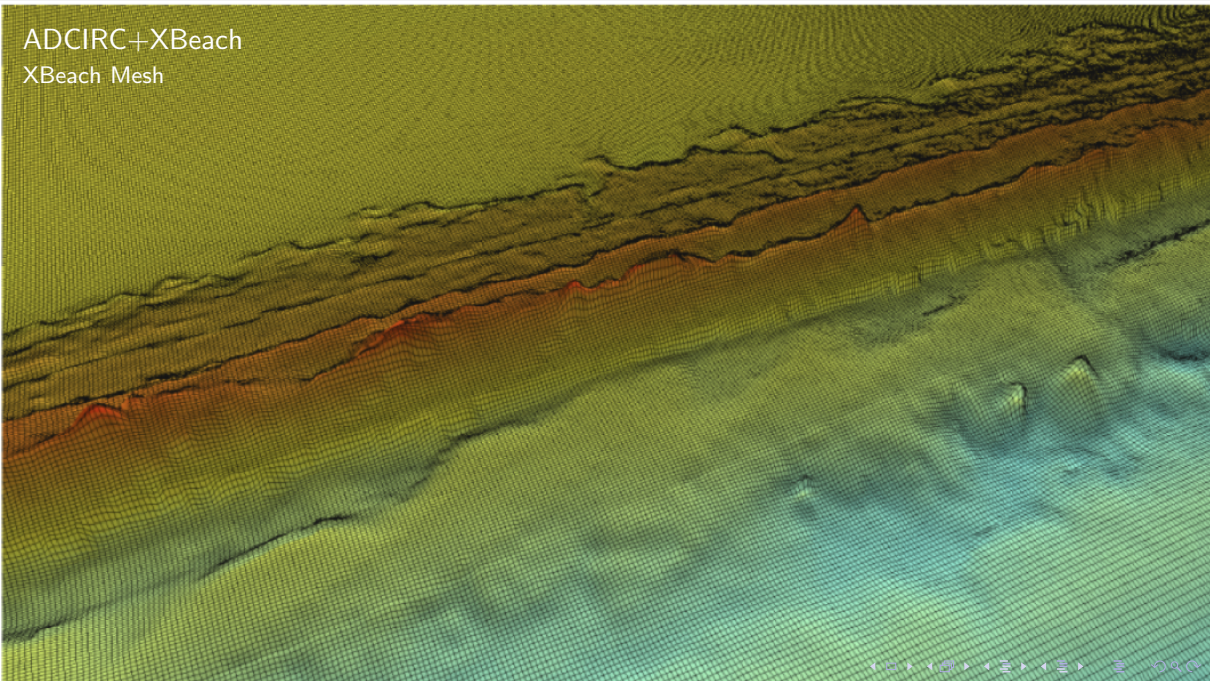
ADCIRC+XBeach

Aerial Photo of Hatteras Island



ADCIRC+XBeach  
ADCIRC Mesh

ADCIRC+XBeach  
XBeach Mesh



# Inlet Creation

## Numerical Experiments

We used a combination of XBeach and ADCIRC modeling:

- **Idealized Domain** – Uniform geometry, smooth hydrodynamic forcing
  - XBeach:
    - Can we initiate the inlet formation?
    - Can we control the location of the inlet?
- **Isabel Inlet** – Real geometry, real hydrodynamic and atmospheric forcing
  - XBeach:
    - How much of a 'seed' is necessary?
    - Instead of calibration factors, can we use bed friction?
  - ADCIRC:
    - Can we use the erosion timing from XBeach to inform the variation of the bathymetry in ADCIRC?

# Idealized Domain

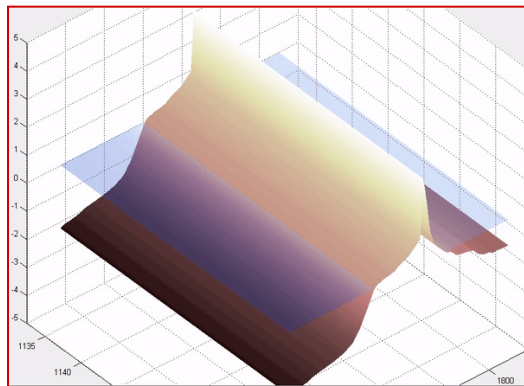
## Summary of earlier tests

We tried different setups:

- Resolution
- Forcing
- XBeach input parameters
- Presence of an initial channel

Findings:

- XBeach has a tendency to widen the breach, instead of deepening it
- How can we initiate the formation of a true inlet?
- How can we utilize sub-surface geological information?





## Idealized Domain

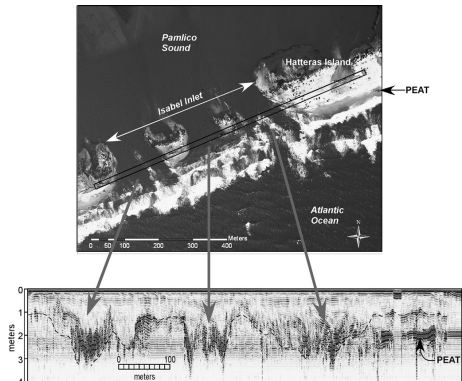
### Use of Non-Erodible Layer

So we added a non-erodible layer:

- Specified as a second ground surface as input to XBeach
- Erosion is computed until the ground surface is lowered to the non-erodible layer
- Then erosion is stopped

Used first on the idealized domain:

- Allowed erosion in the channel
- Prevent erosion in the beaches and dunes



Mallinson et al. (2010)



## Idealized Domain

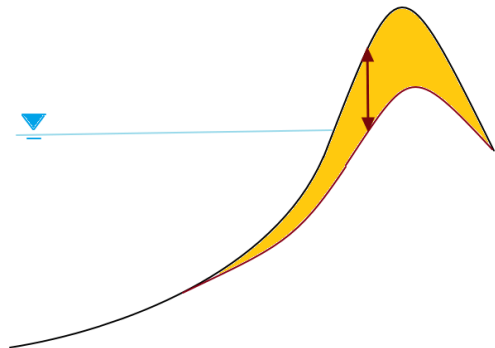
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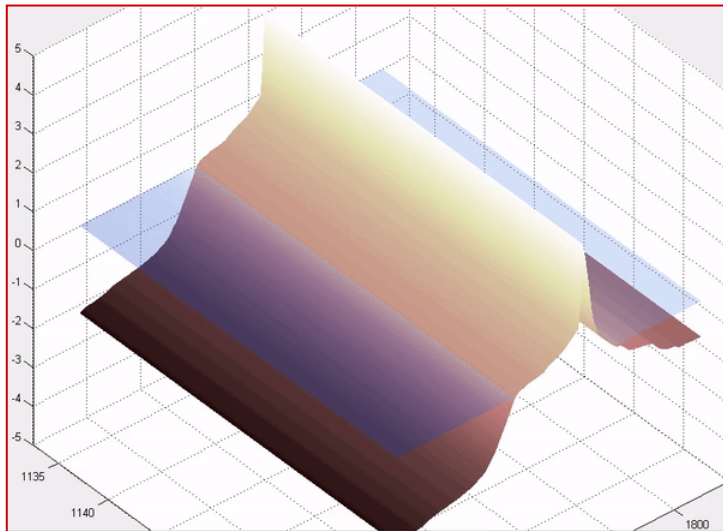
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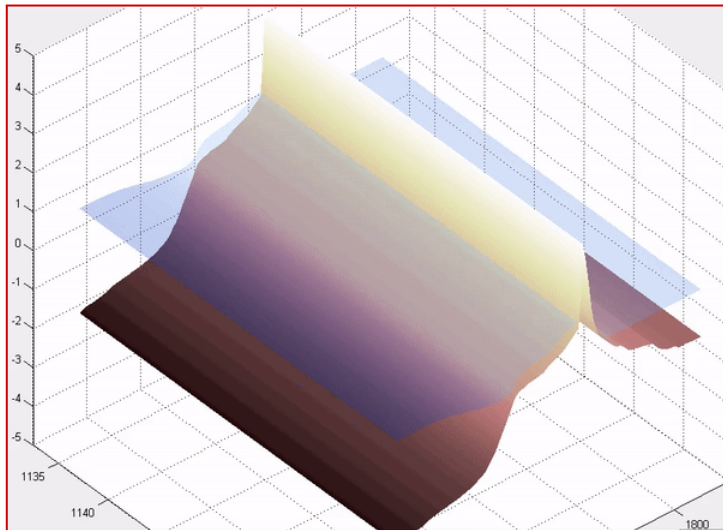
## Idealized Domain

Inlet is Created ... without an Initial Cut



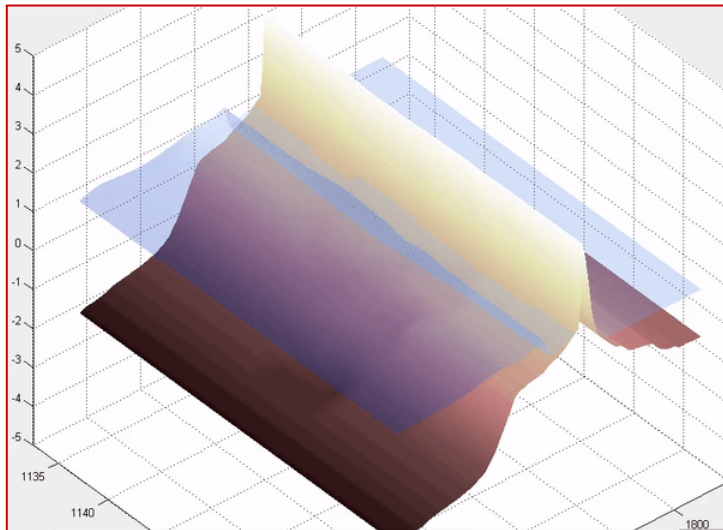
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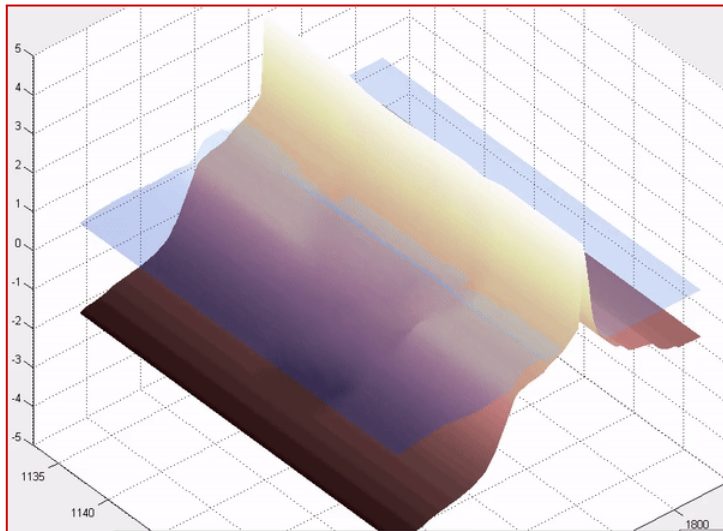
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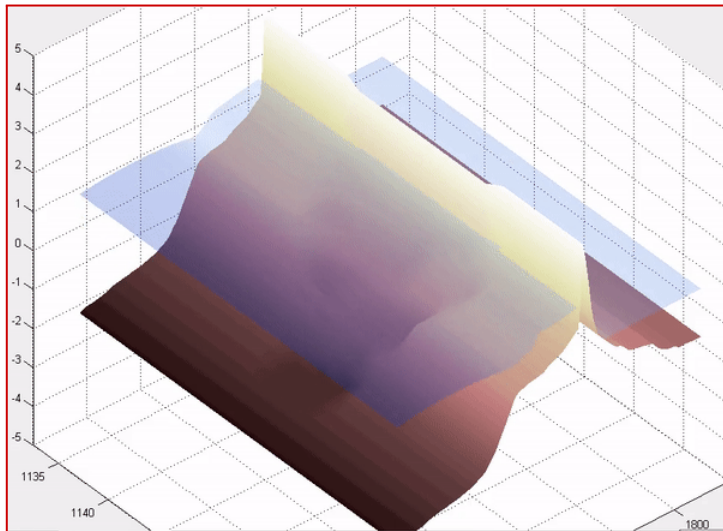
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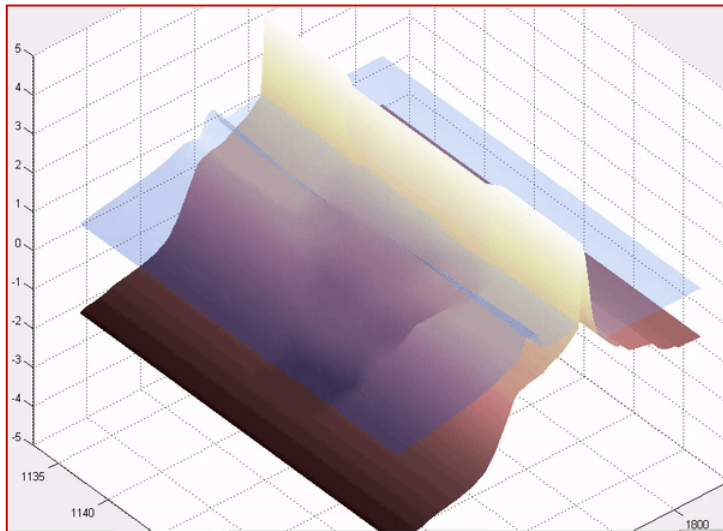
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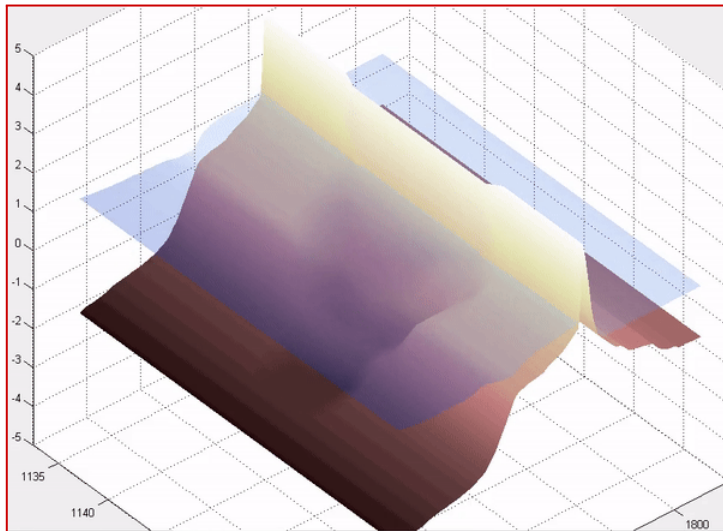
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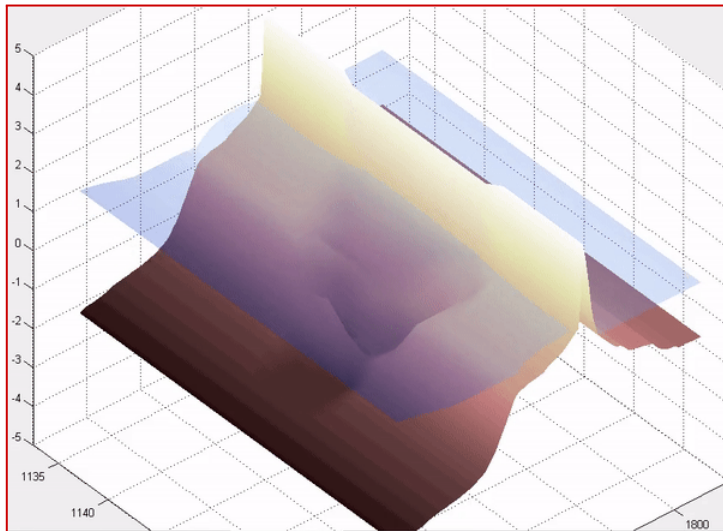
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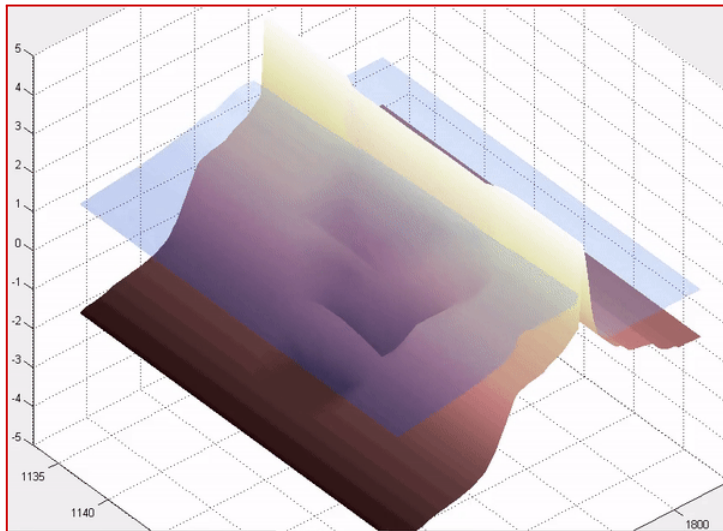
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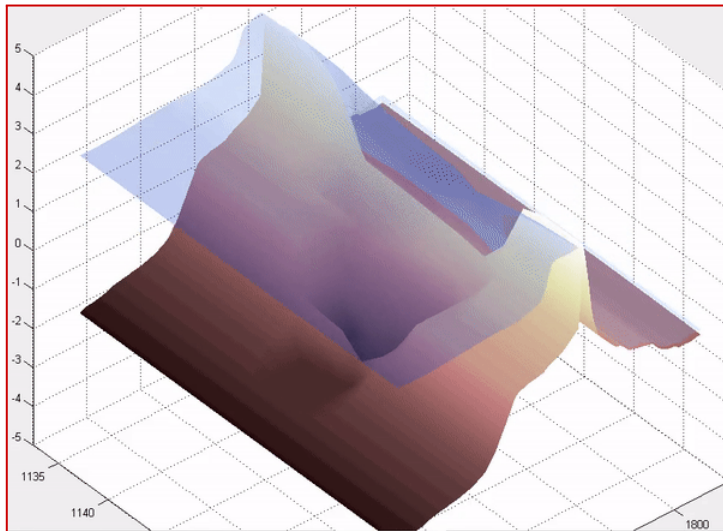
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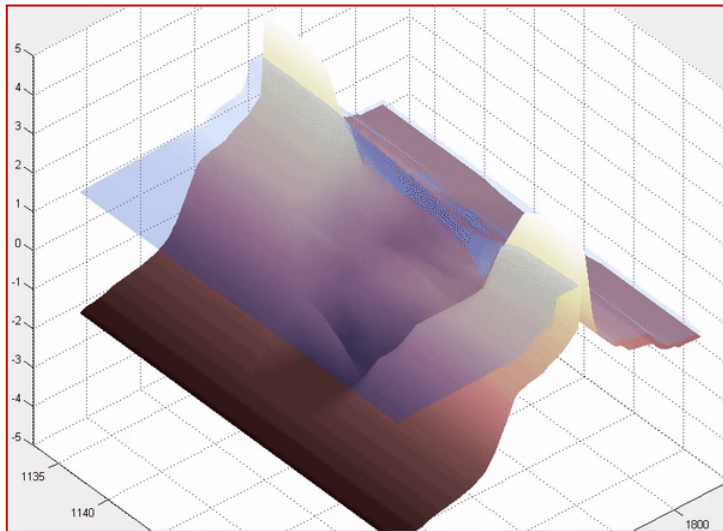
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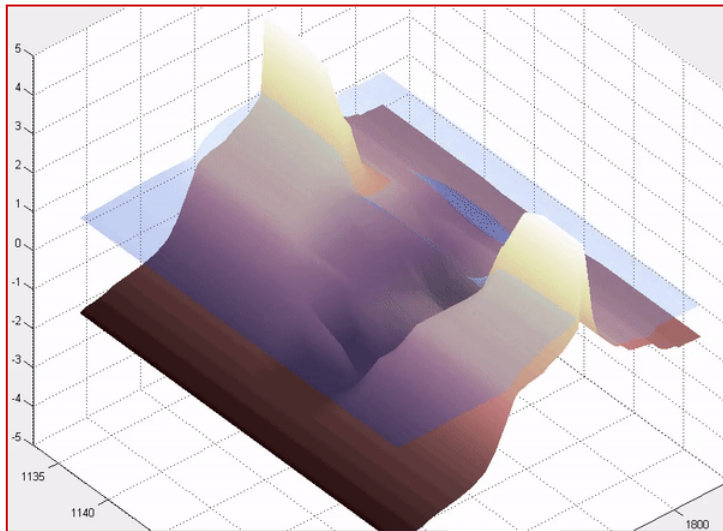
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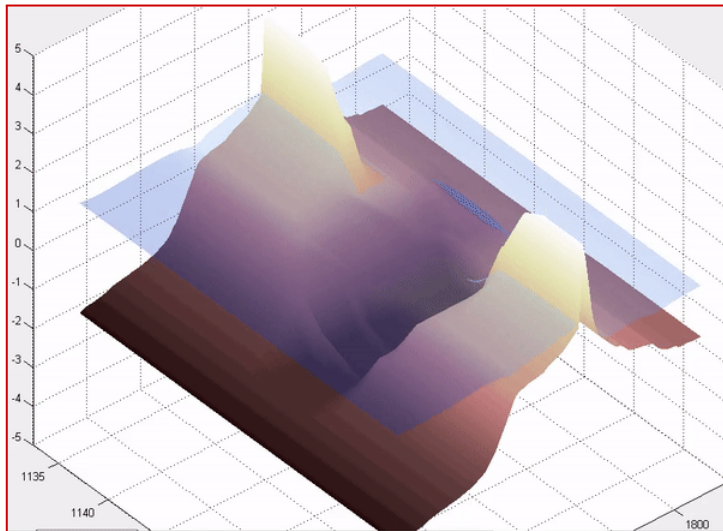
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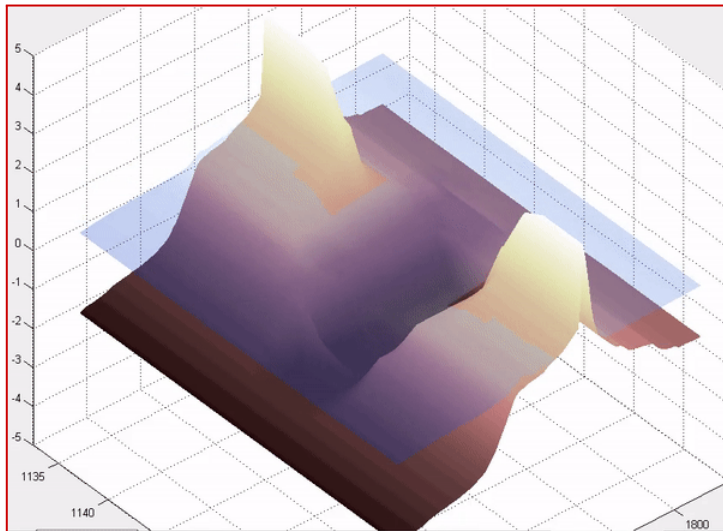
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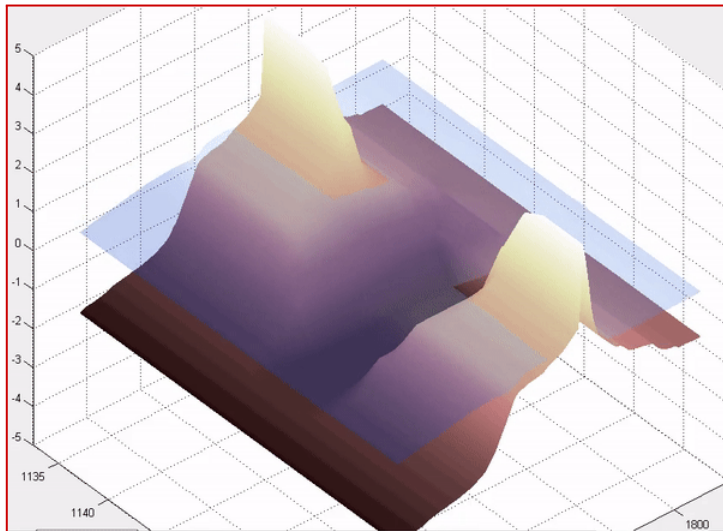
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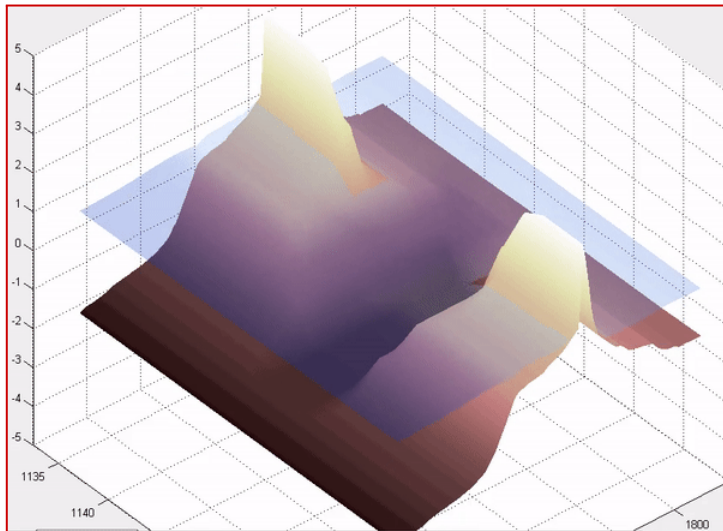
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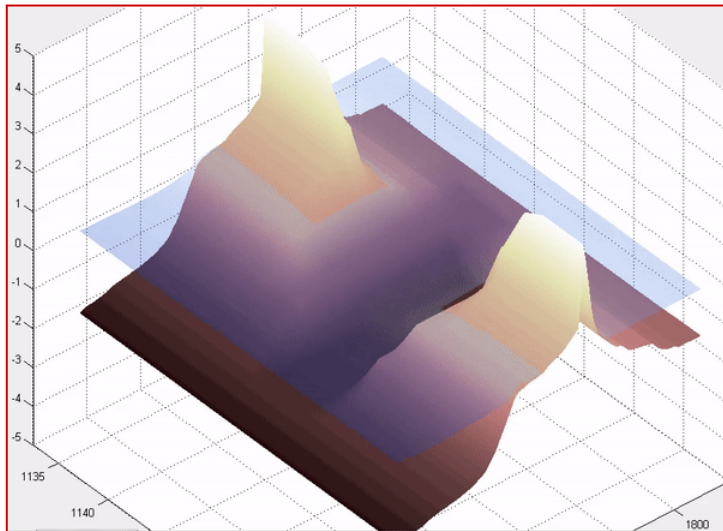
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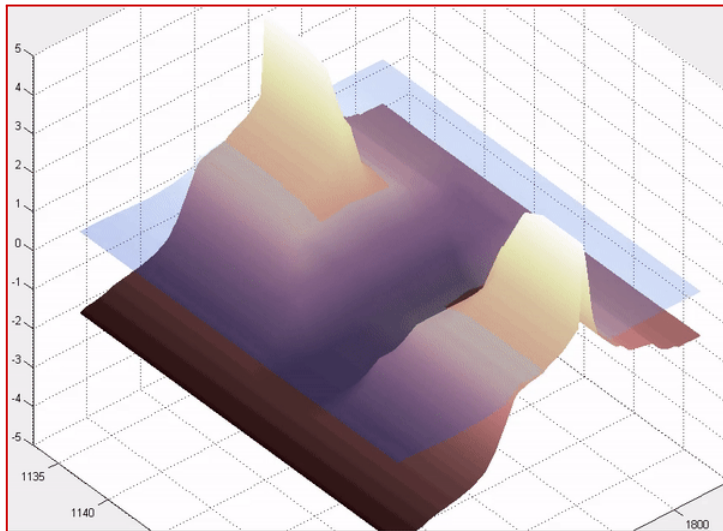
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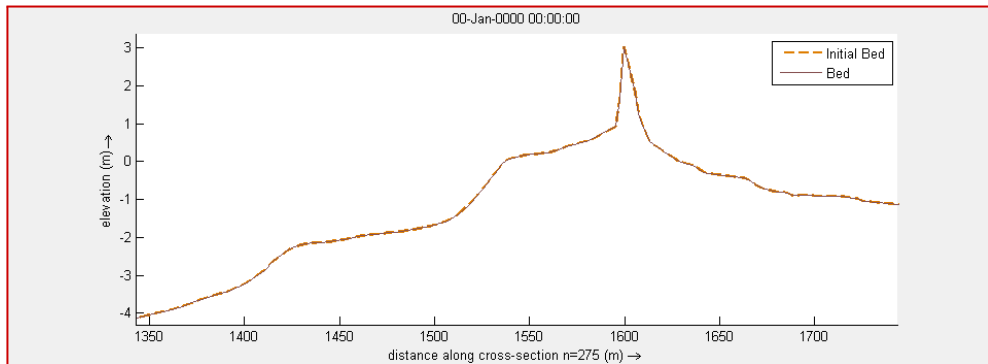


## Idealized Domain

### Success of Inlet Creation

Now we can erode a full channel:

- Without any initial seed, the full beach and dune are removed
- Animation of ground surface at centerline of channel:

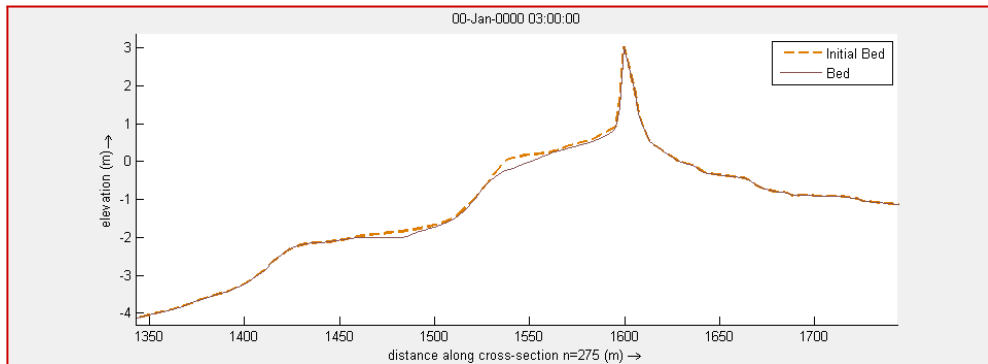


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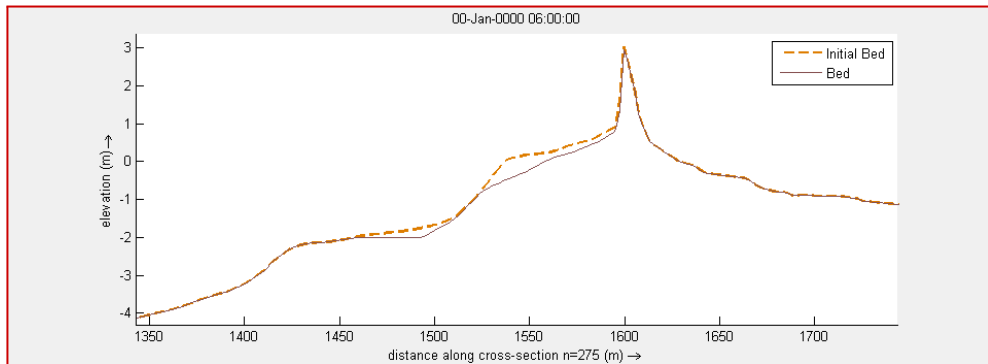


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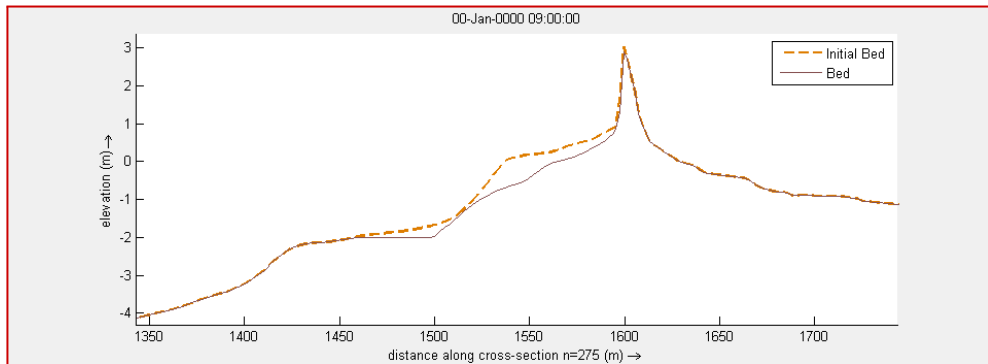


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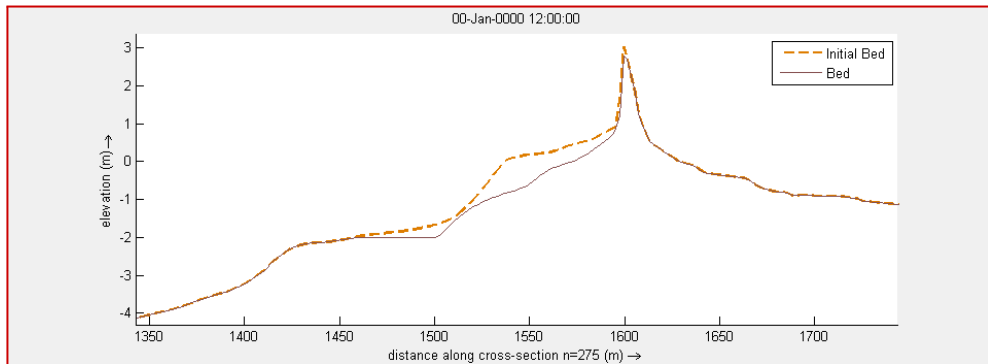


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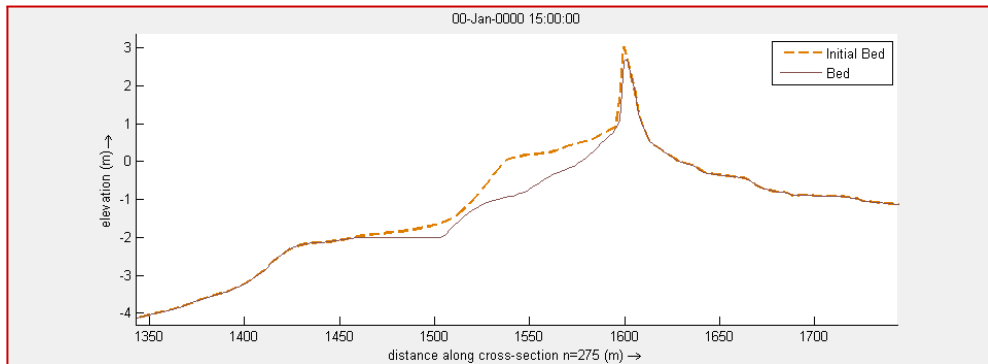


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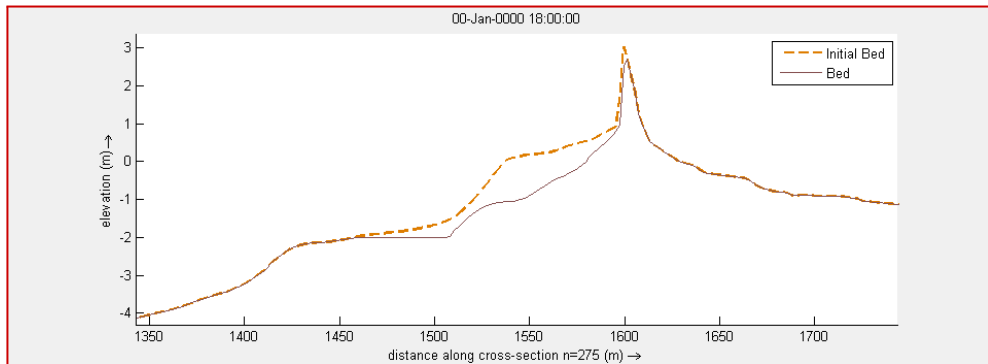


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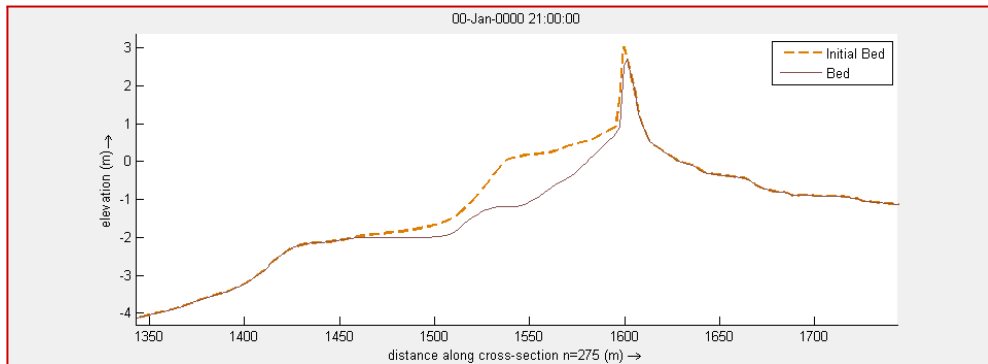


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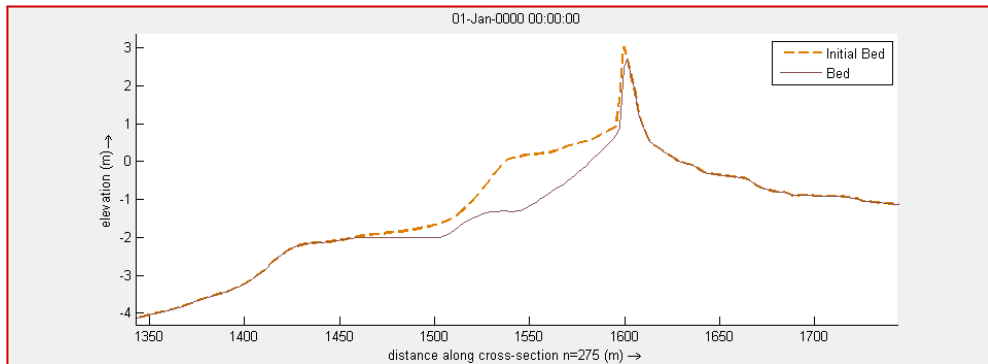


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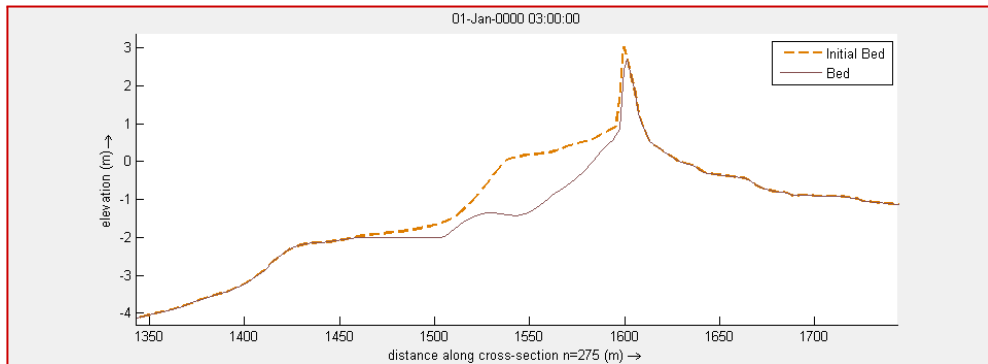


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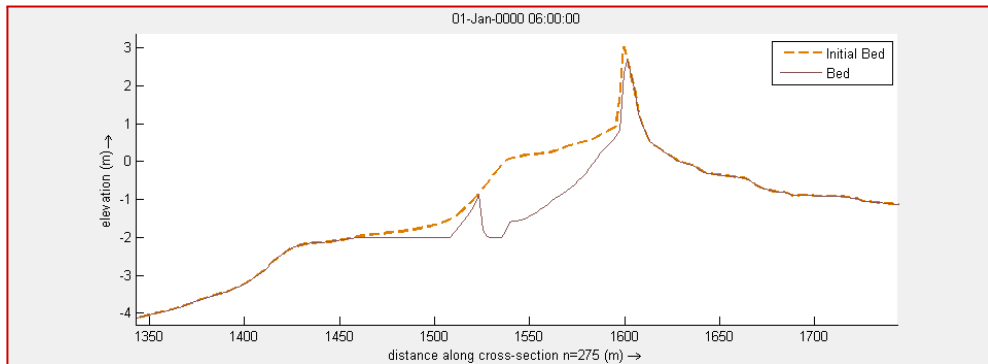


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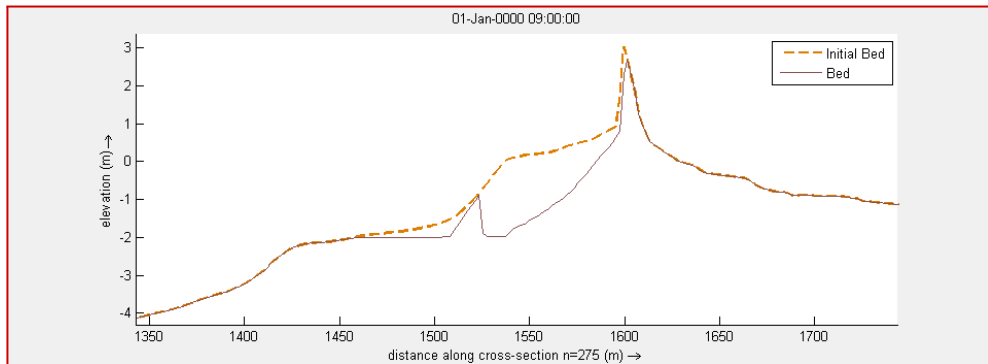


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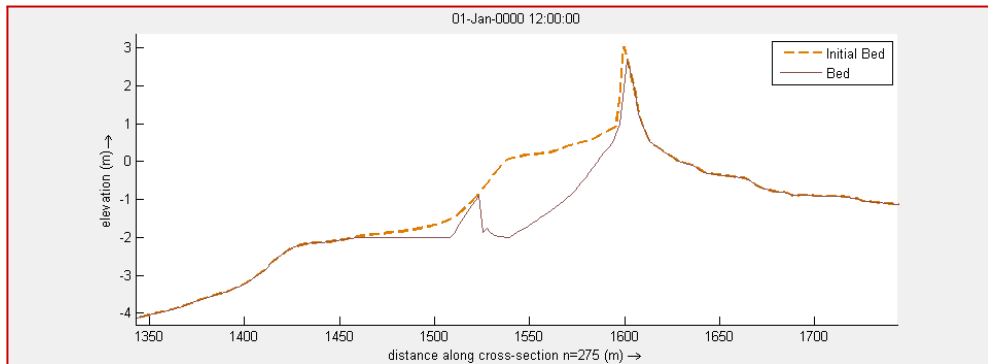


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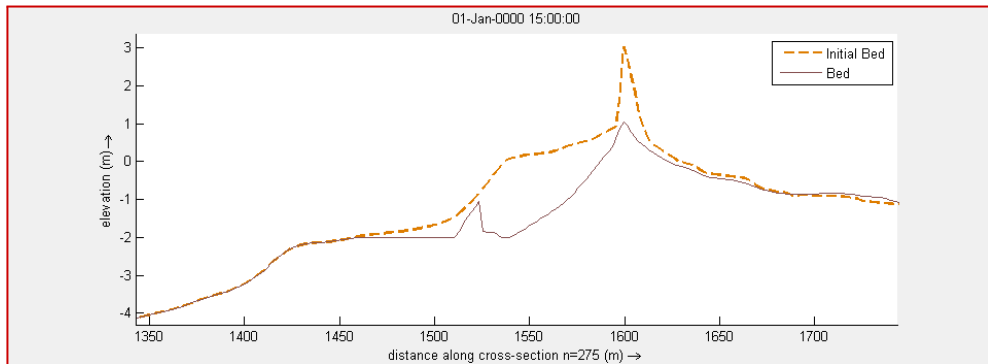


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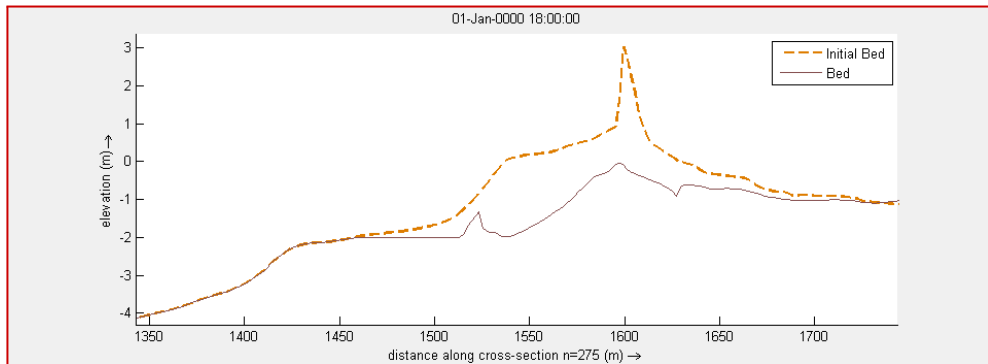


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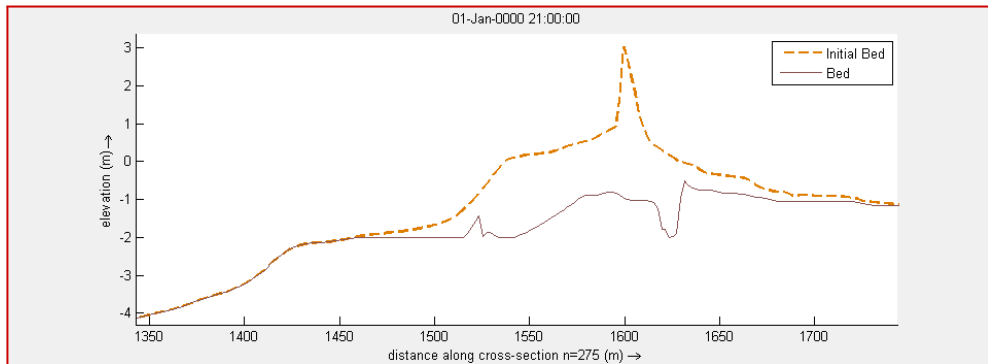


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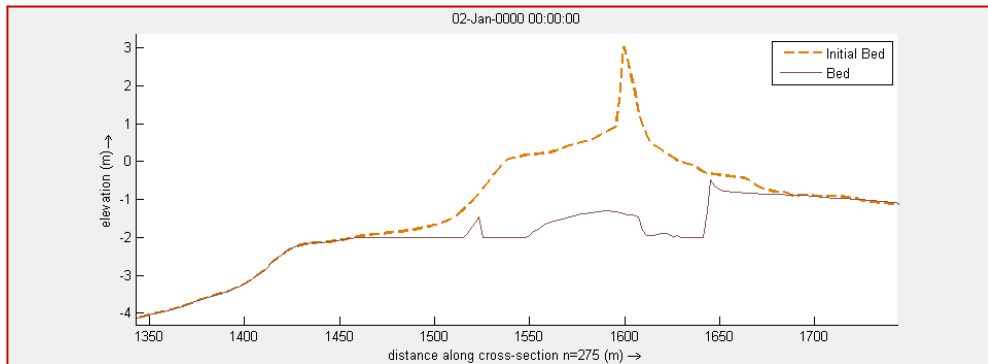


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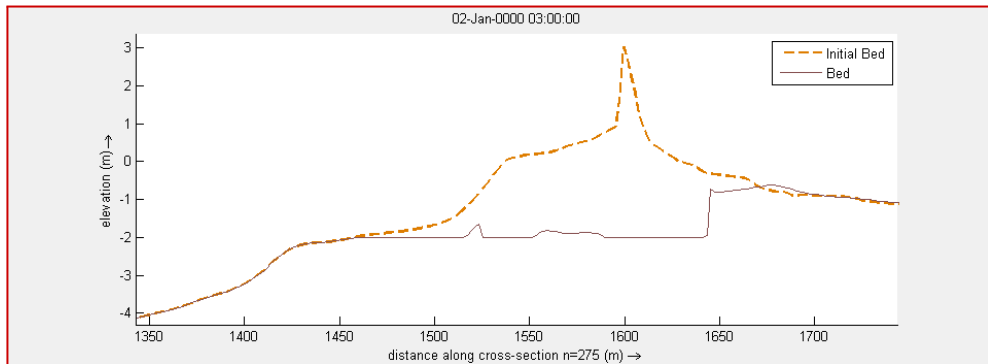


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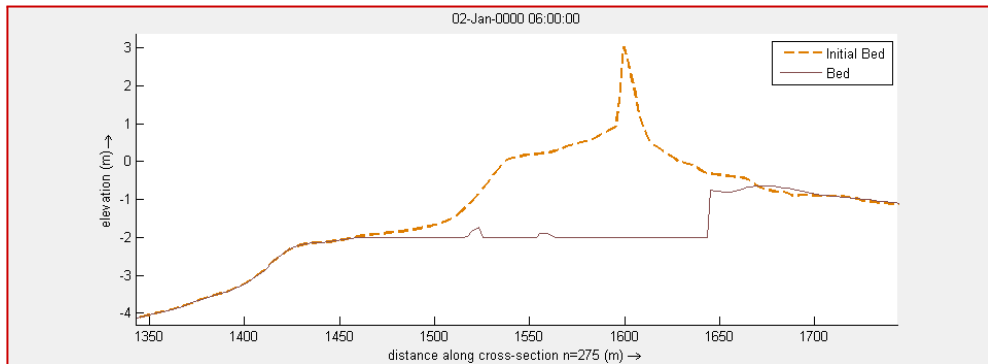


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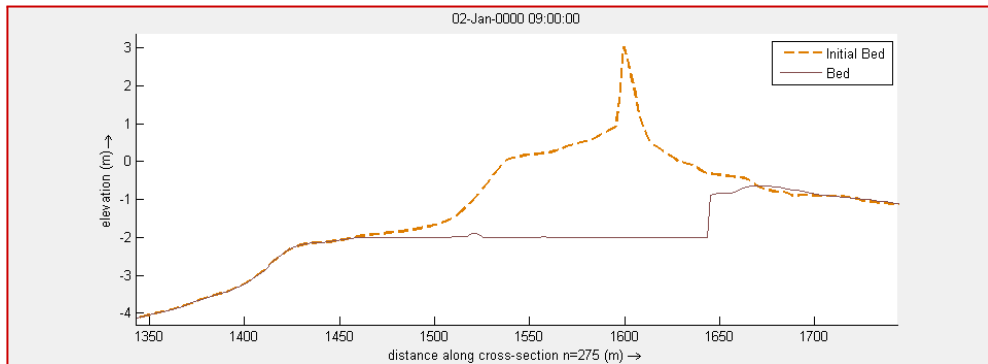


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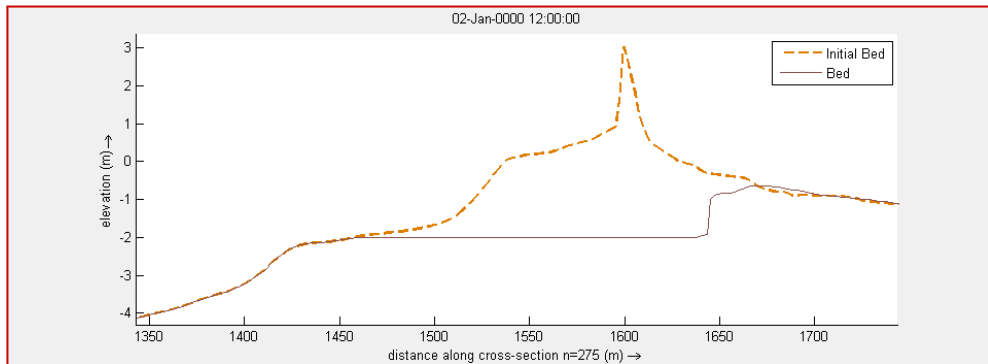


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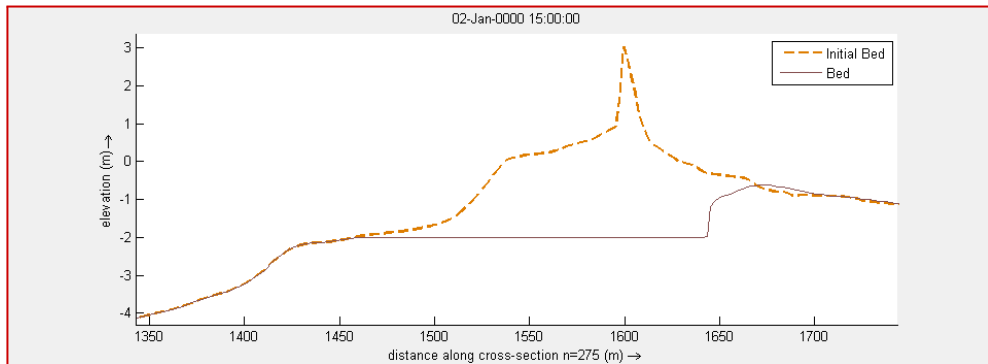


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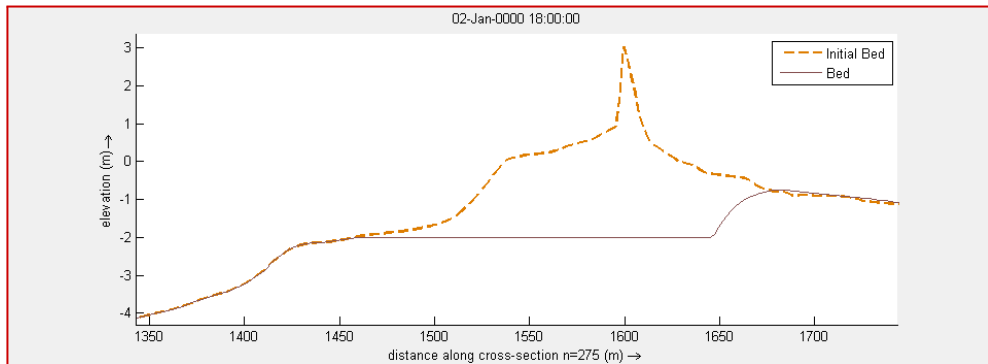


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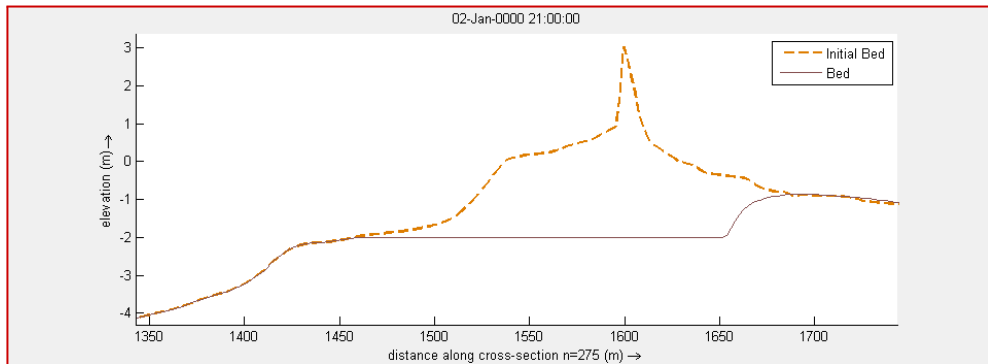


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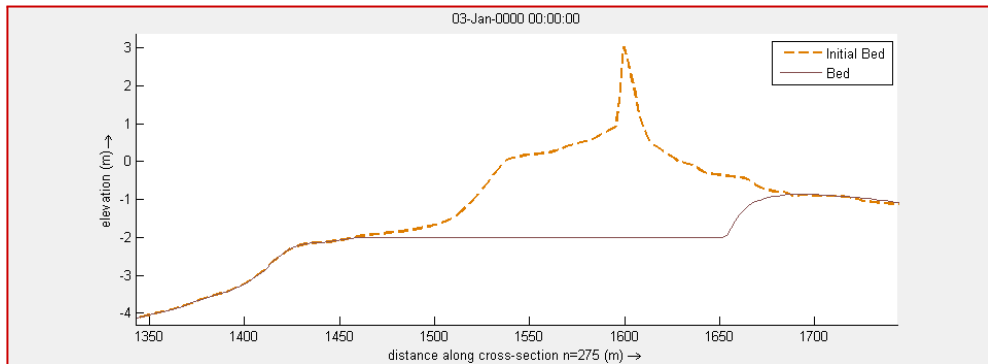


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Isabel Inlet

Pre-Storm Ground Surface



6 m

0 m

Isabel Inlet

Post-Storm Ground Surface



## Isabel Inlet XBeach Grid

### *Domain Size:*

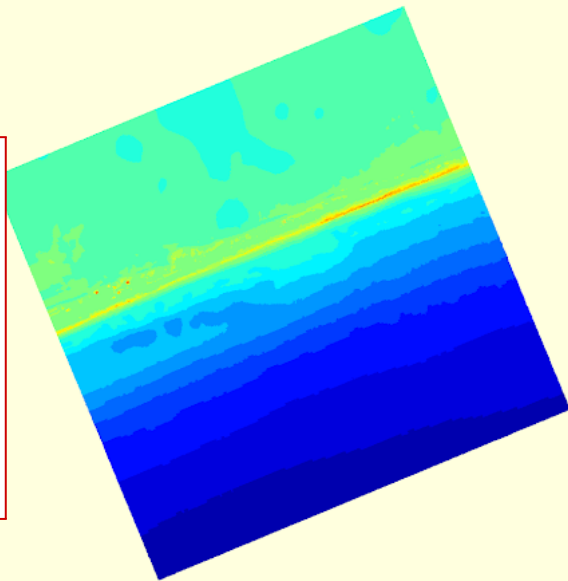
- 2.2 km  $\times$  2.2 km

### *Resolution:*

- Alongshore: 2 to 5 m
- Cross-shore: 2 to 15 m

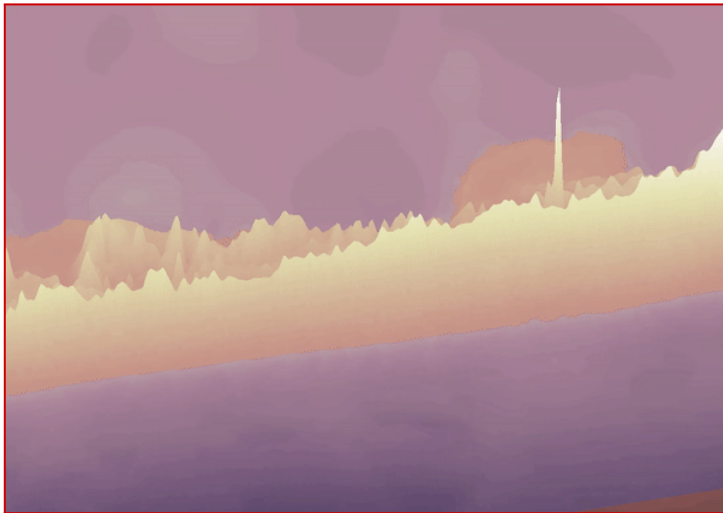
### *Layers:*

- Pre-storm: bathy/topo
- Post-storm: non-erodible



# Isabel Inlet

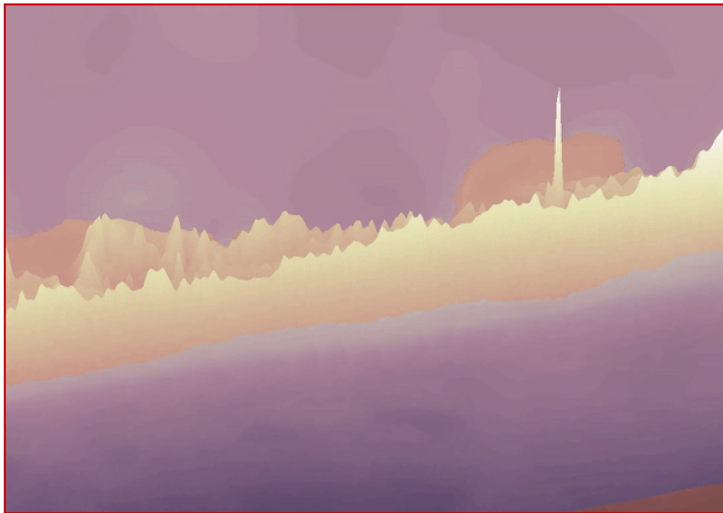
## XBeach Hindcast of Inlet Creation





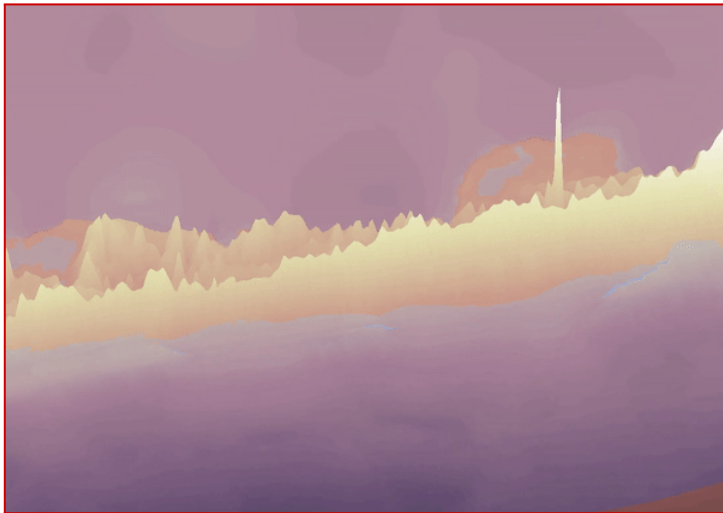
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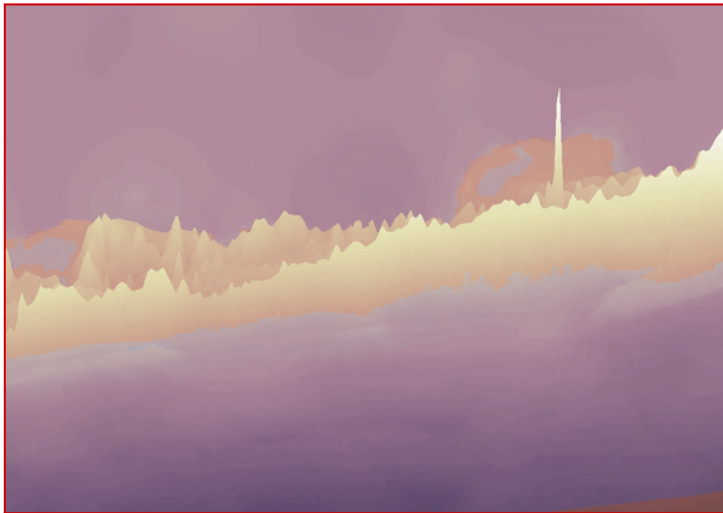
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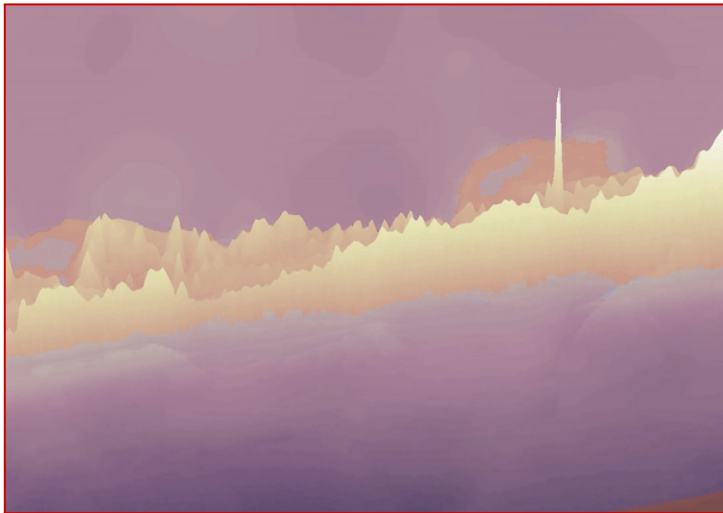
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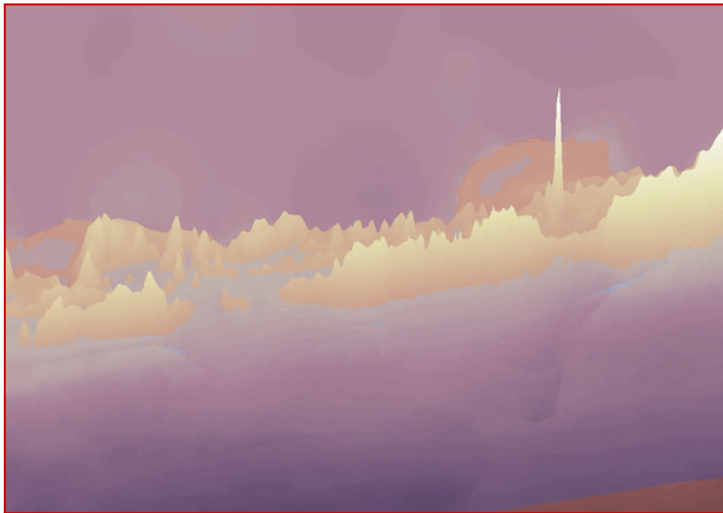
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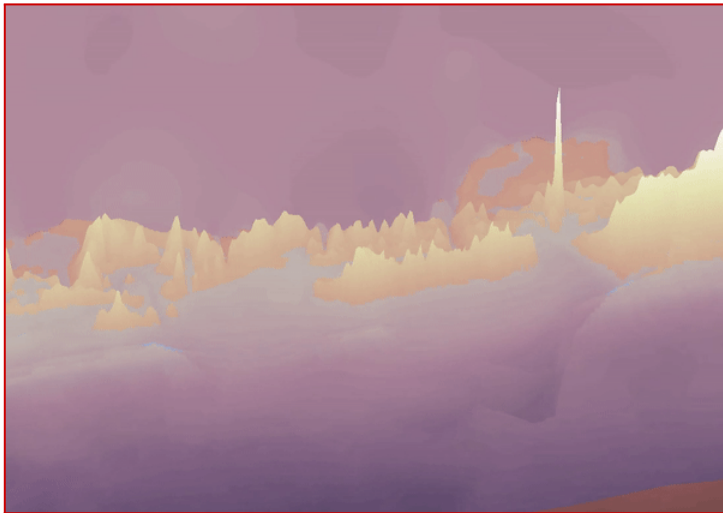
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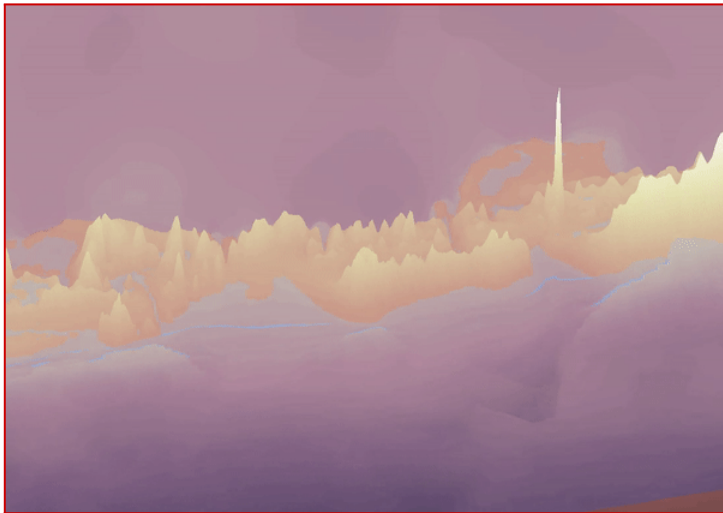
Isabel Inlet

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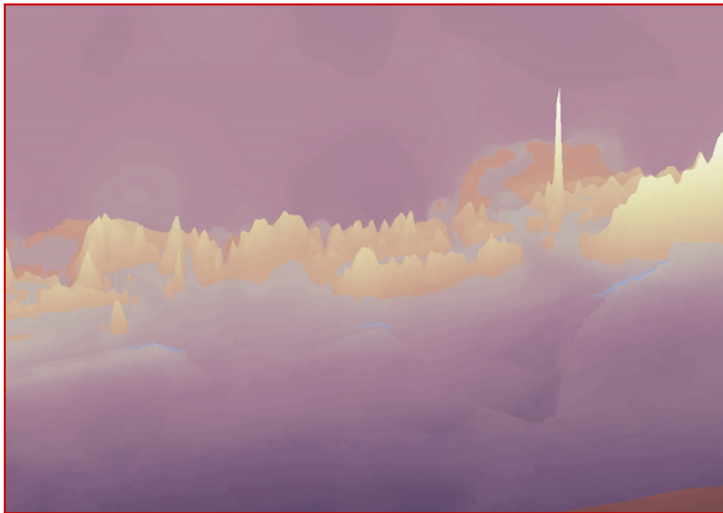
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Isabel Inlet

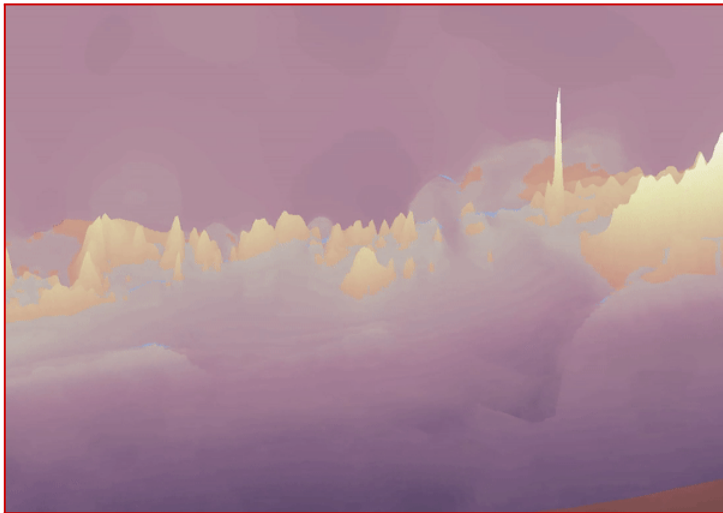
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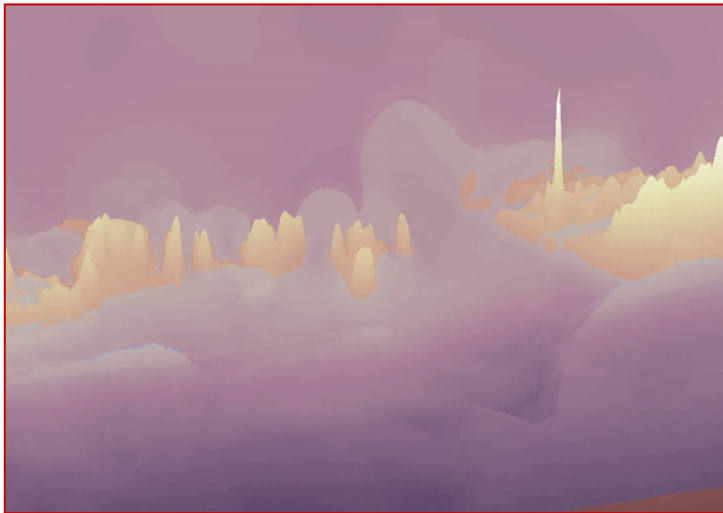
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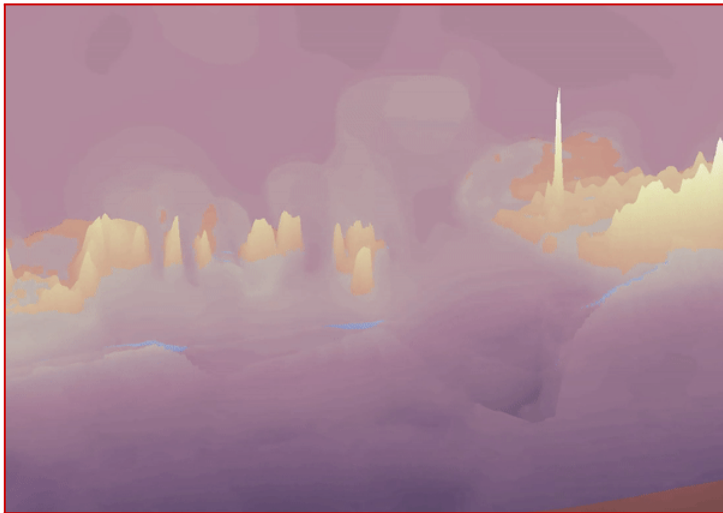
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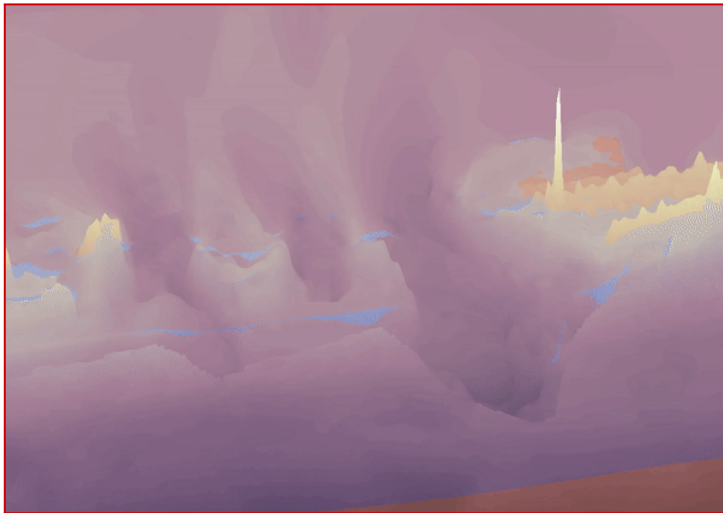
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## XBeach Hindcast of Inlet Creation



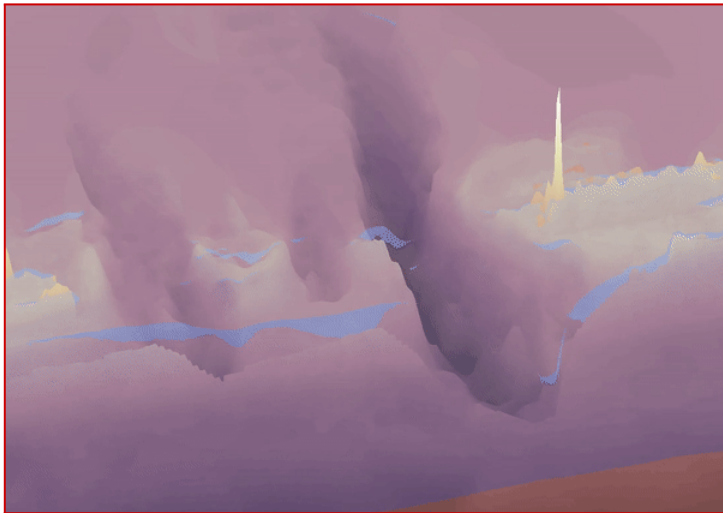
Isabel Inlet

XBeach Hindcast of Inlet Creation



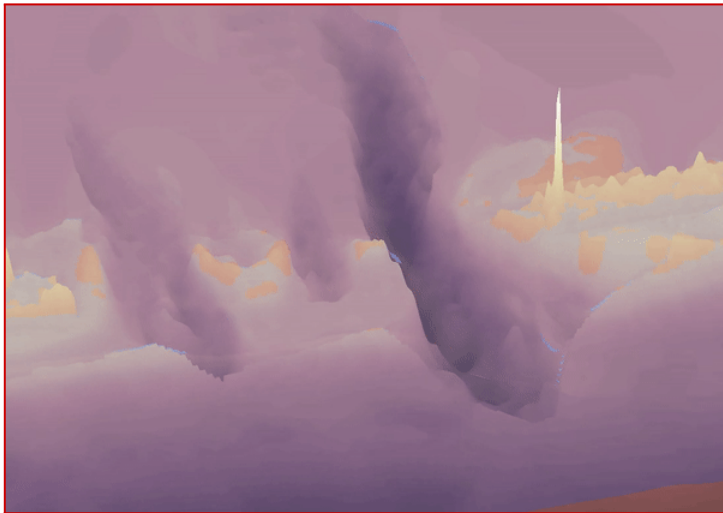
Isabel Inlet

XBeach Hindcast of Inlet Creation



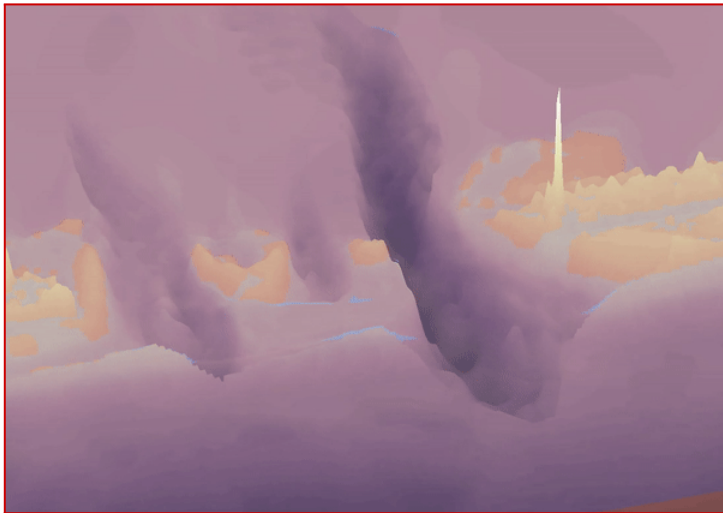
# Isabel Inlet

## XBeach Hindcast of Inlet Creation



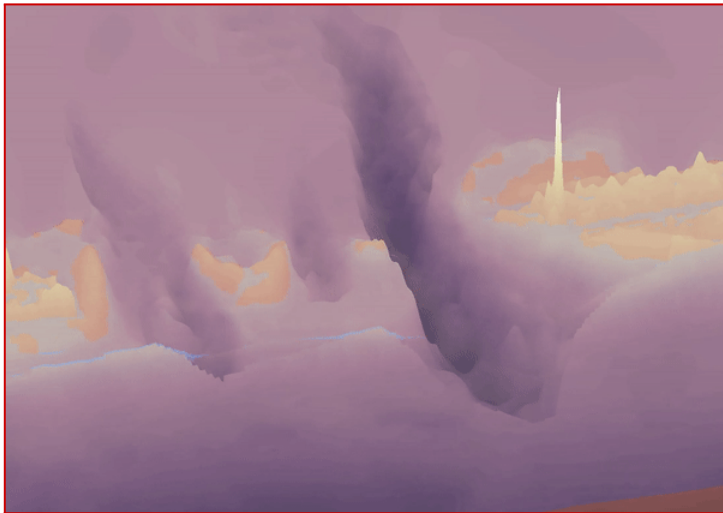
Isabel Inlet

XBeach Hindcast of Inlet Creation



Isabel Inlet

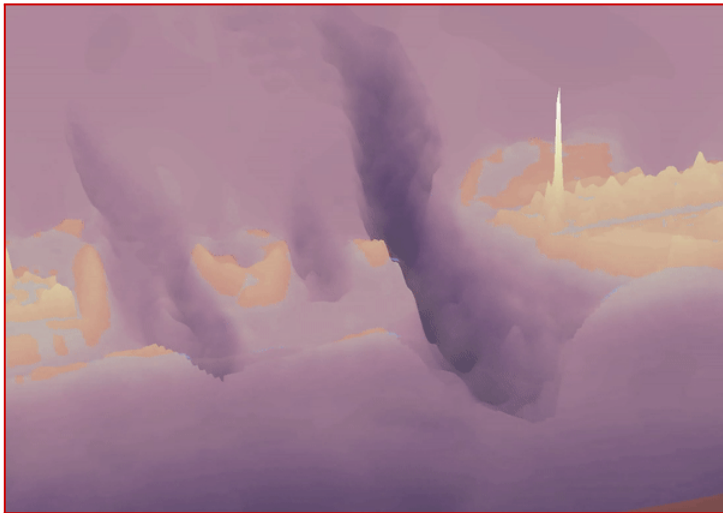
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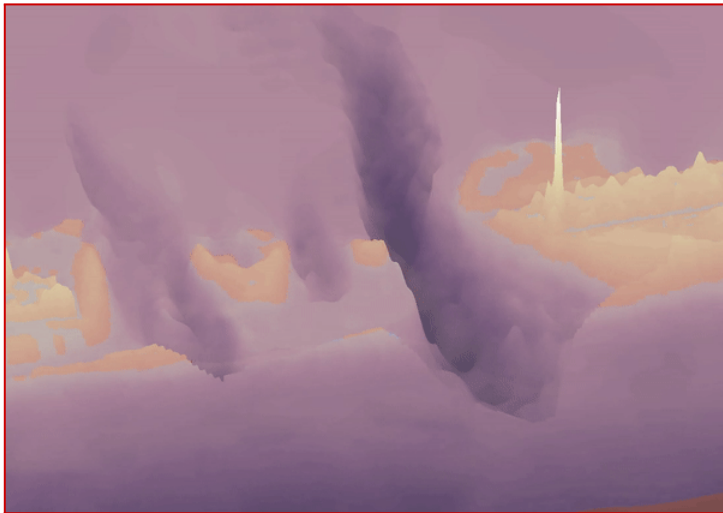
Isabel Inlet

XBeach Hindcast of Inlet Creation



# Isabel Inlet

## XBeach Hindcast of Inlet Creation



## Isabel Inlet

### XBeach Hindcast of Inlet Creation

#### Modeling the breach formation with XBeach

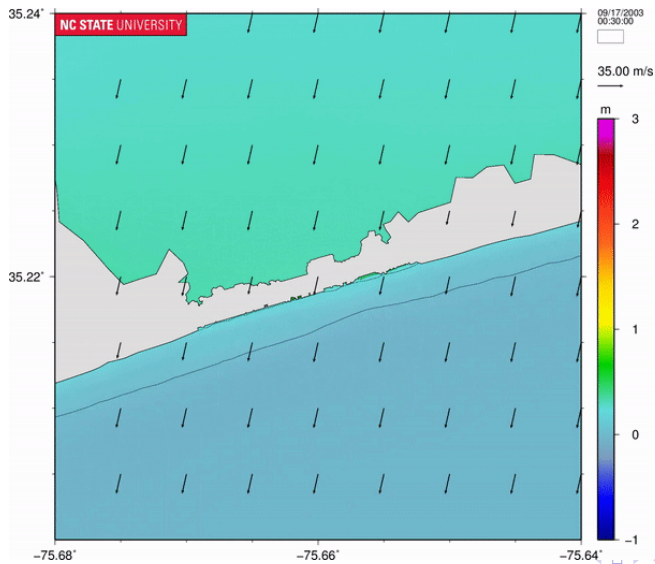
- Using non-erodible layer
- Timing of erosion
- More work with XBeach to represent sediment layers and spatially varying bed friction

#### Updating the ground surface in ADCIRC

- Include morphodynamic in large scale model
- Study the impacts on water level

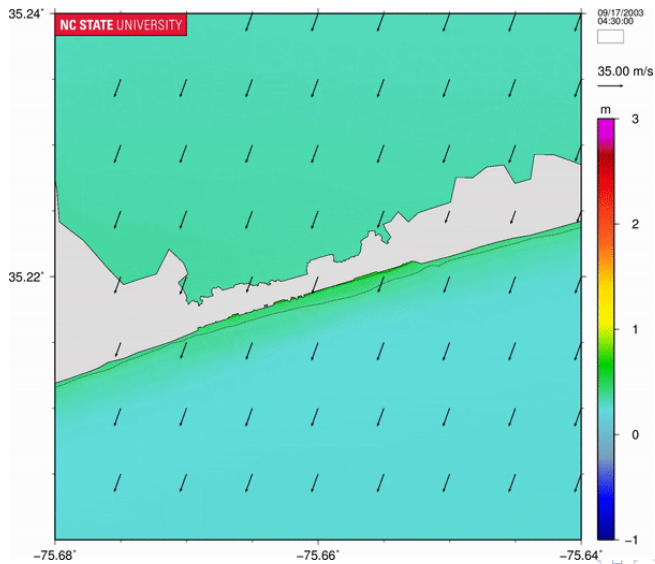
# Isabel Inlet

## Existing Capability with Static Ground Surface



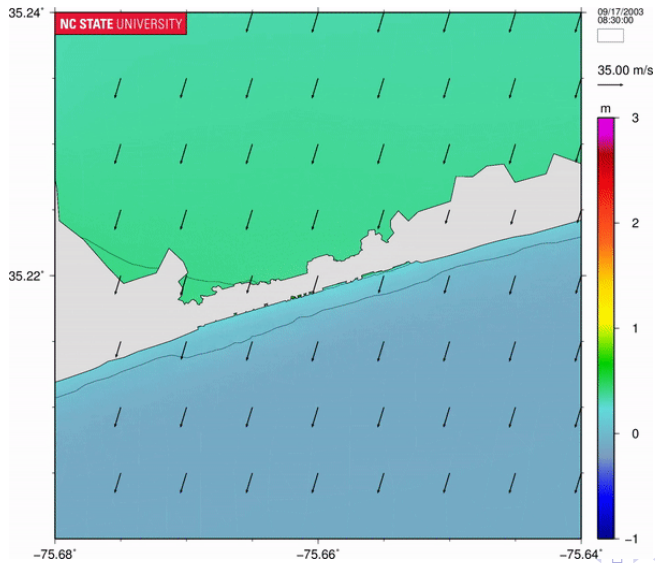
# Isabel Inlet

## Existing Capability with Static Ground Surface

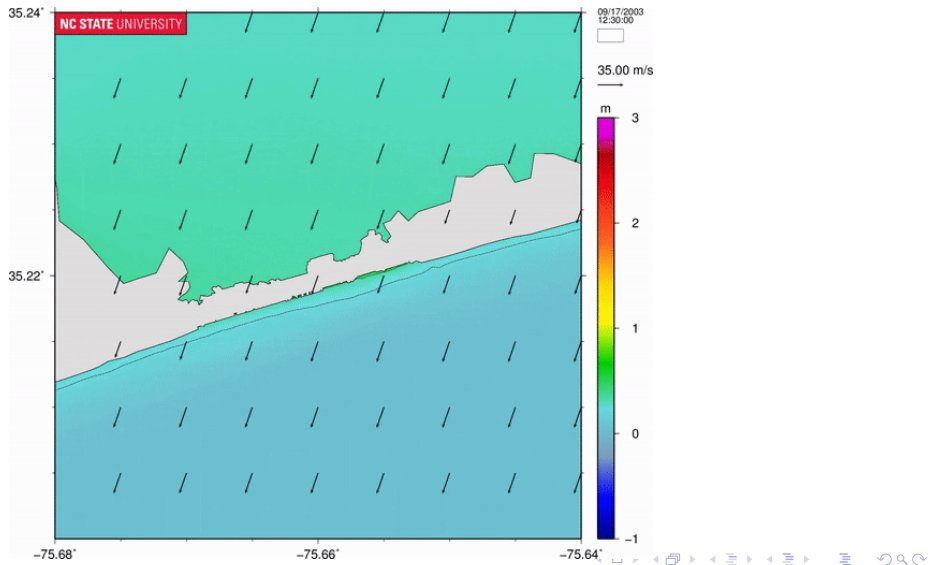


# Isabel Inlet

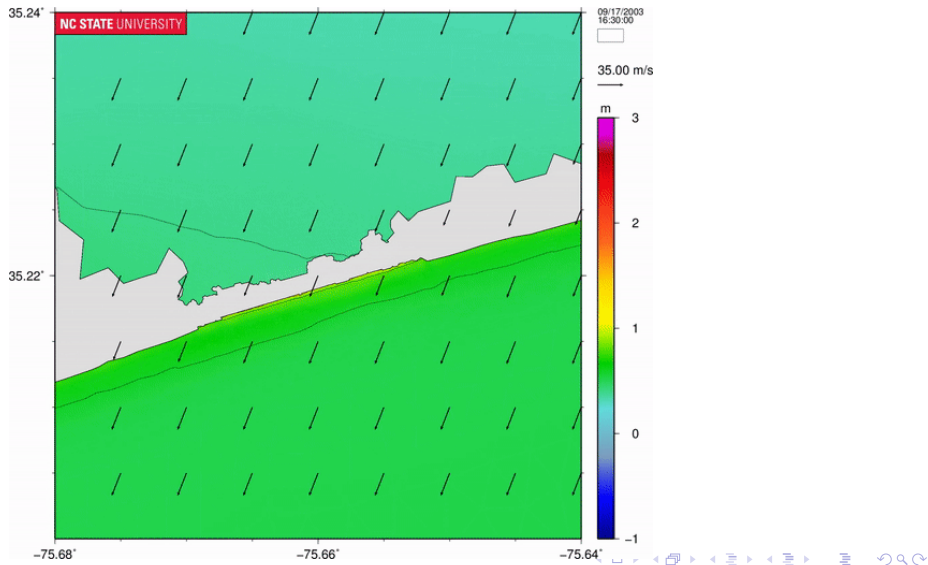
## Existing Capability with Static Ground Surface



## Existing Capability with Static Ground Surface

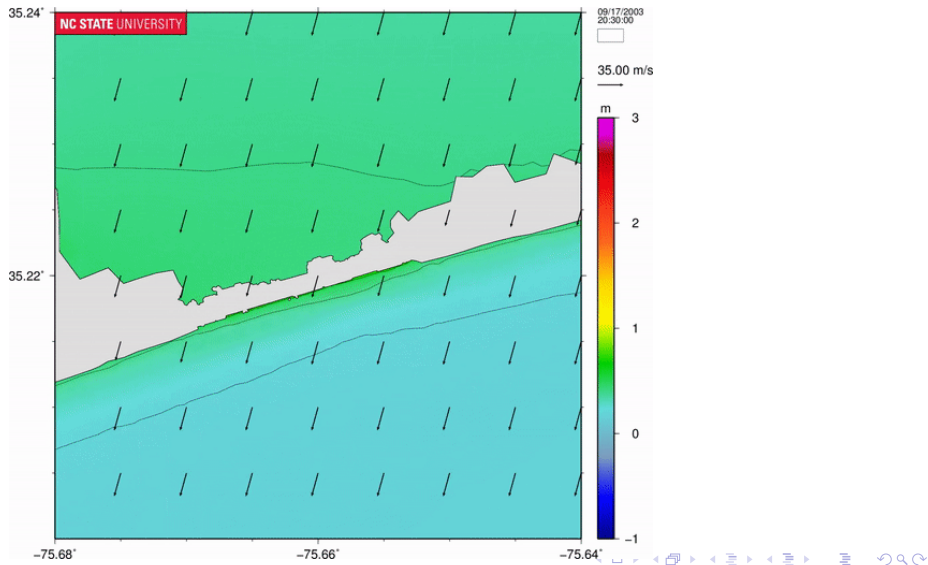


## Existing Capability with Static Ground Surface



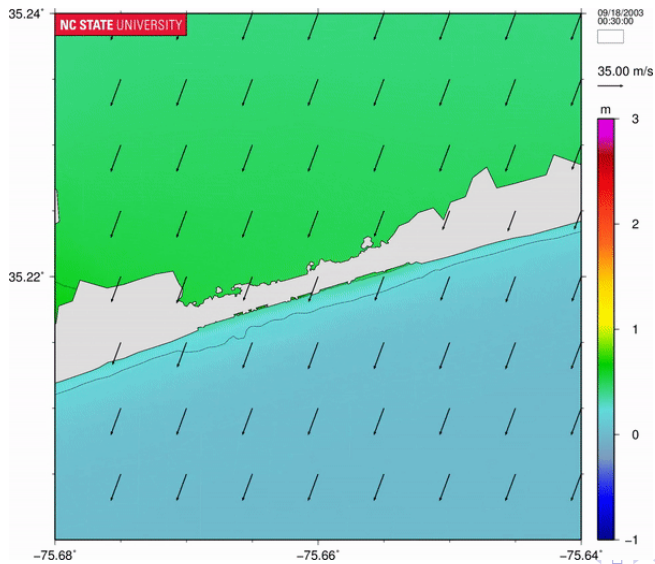


## Existing Capability with Static Ground Surface



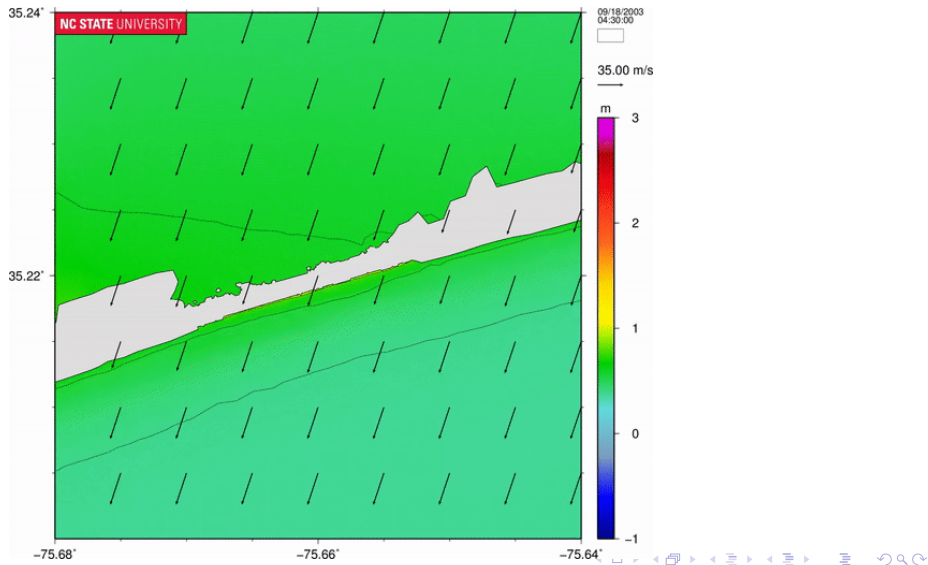
# Isabel Inlet

## Existing Capability with Static Ground Surface



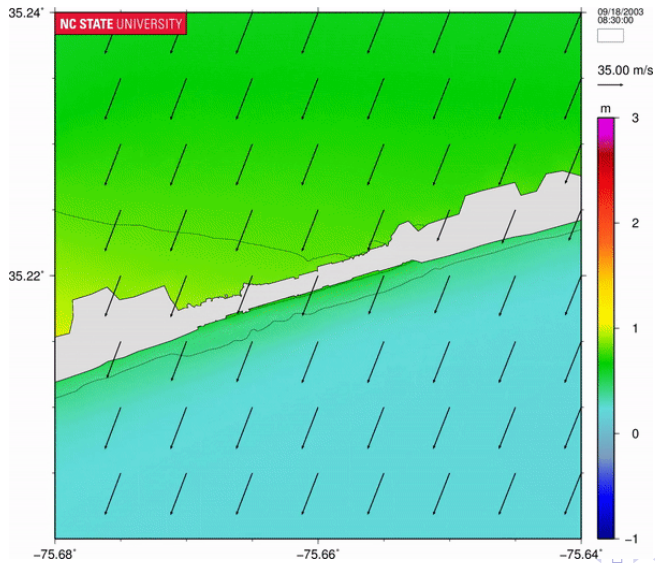
# Isabel Inlet

## Existing Capability with Static Ground Surface



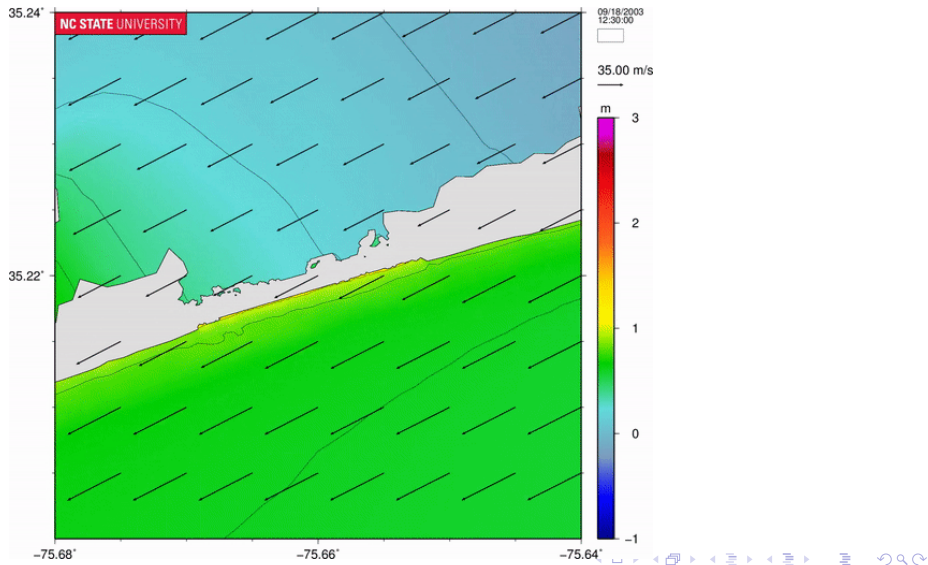
# Isabel Inlet

## Existing Capability with Static Ground Surface



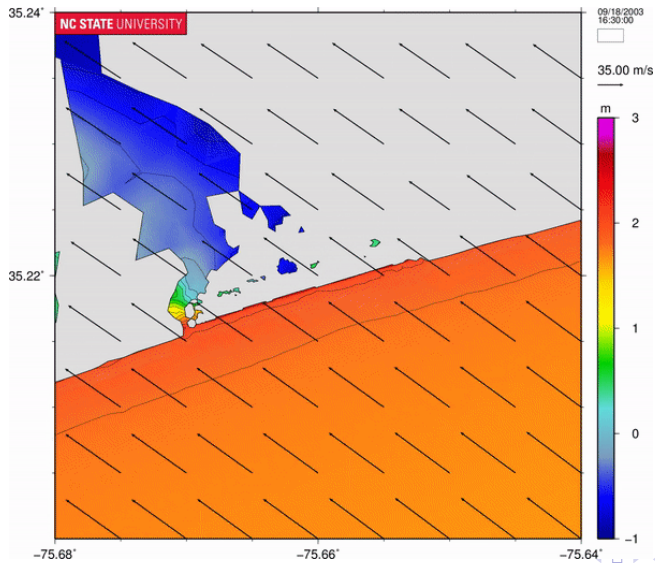
# Isabel Inlet

## Existing Capability with Static Ground Surface



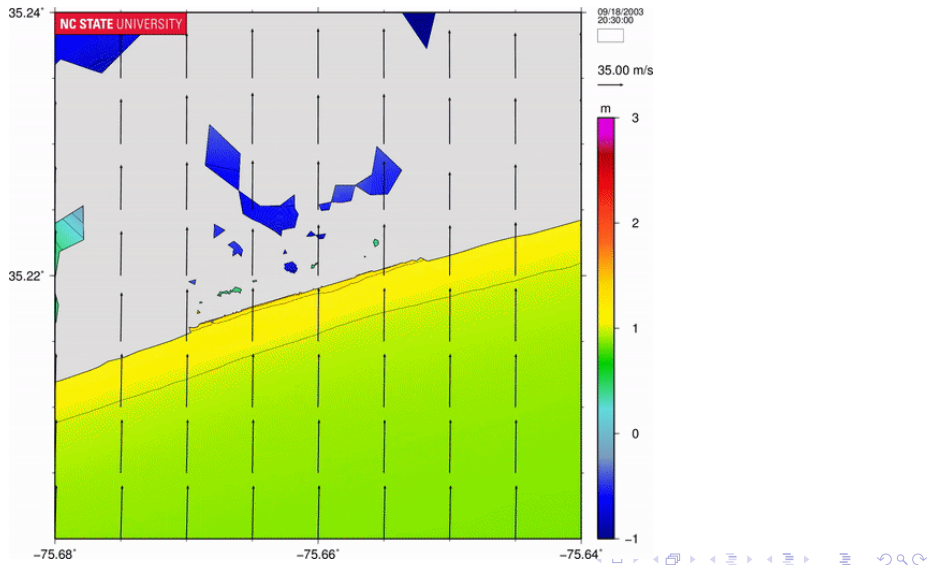
# Isabel Inlet

## Existing Capability with Static Ground Surface



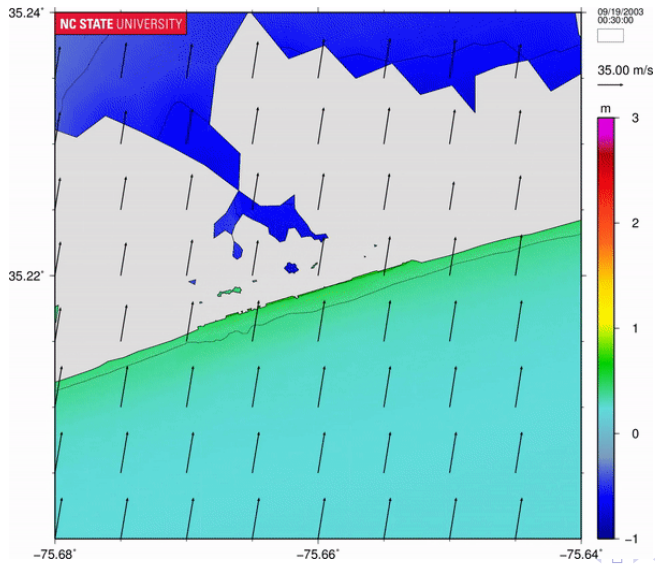
# Isabel Inlet

## Existing Capability with Static Ground Surface



# Isabel Inlet

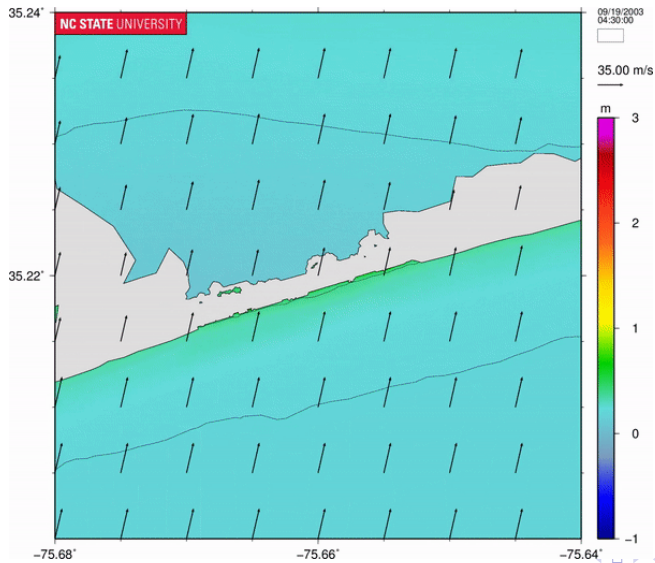
## Existing Capability with Static Ground Surface





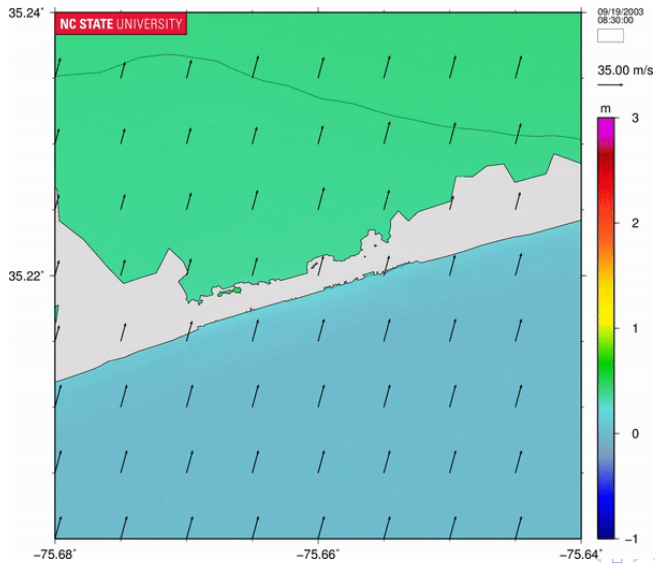
# Isabel Inlet

## Existing Capability with Static Ground Surface



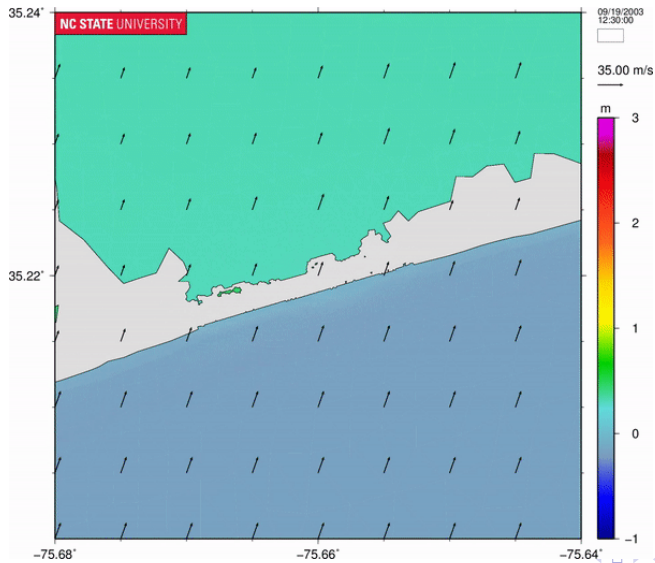
# Isabel Inlet

## Existing Capability with Static Ground Surface



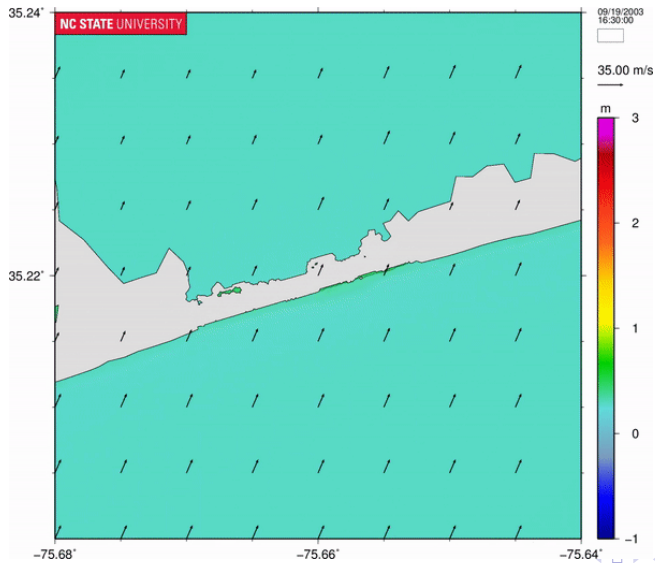
# Isabel Inlet

## Existing Capability with Static Ground Surface



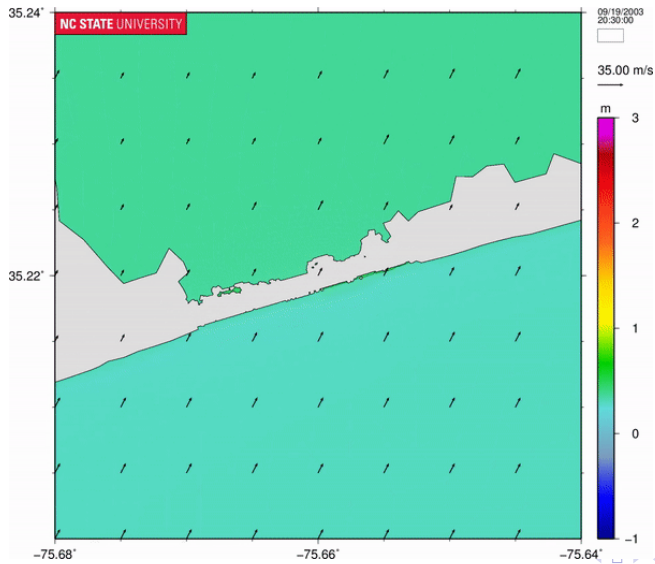
# Isabel Inlet

## Existing Capability with Static Ground Surface



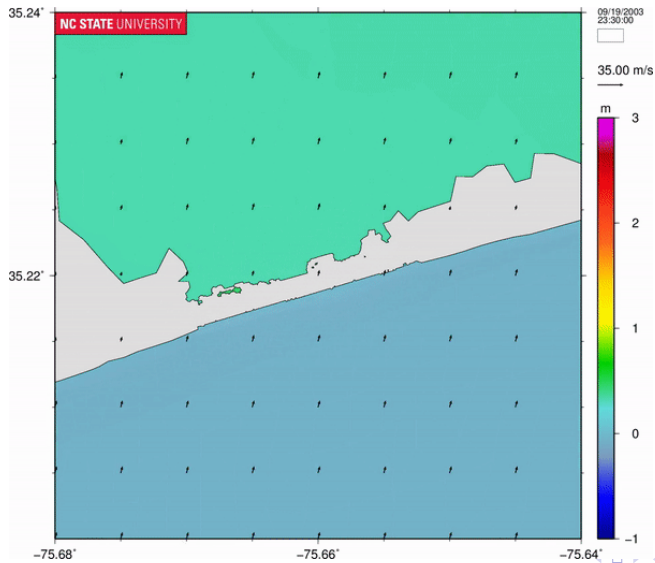
# Isabel Inlet

## Existing Capability with Static Ground Surface



# Isabel Inlet

## Existing Capability with Static Ground Surface

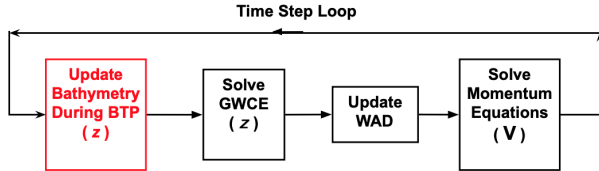


## Isabel Inlet

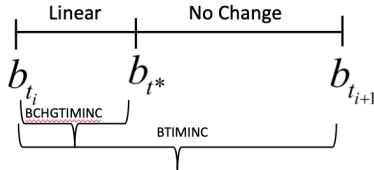
### Time-Varying Bathymetry in ADCIRC

Dr. Chris Massey (USACE) added capability for time-varying bathymetry:

- Occurs at start of time step:

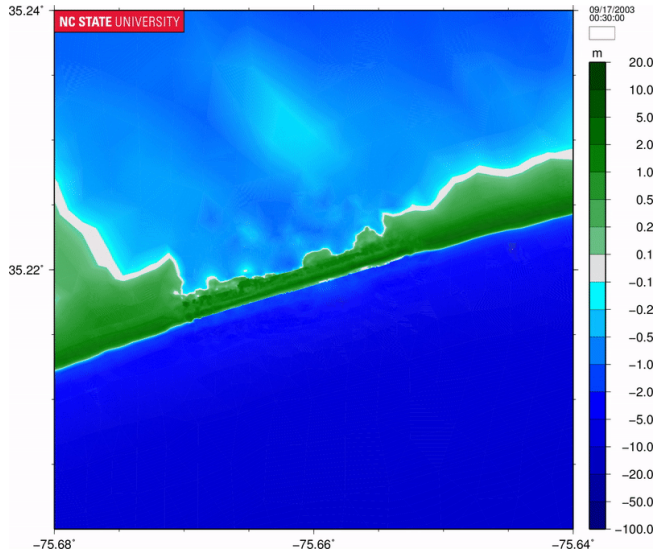


- Control over timing during simulation:



# Isabel Inlet

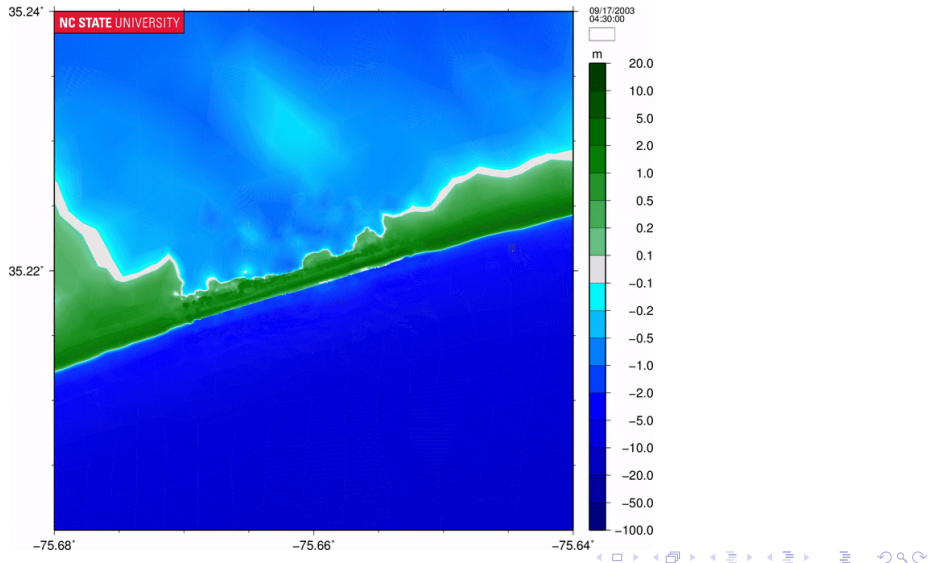
## Erosion over 1 Day





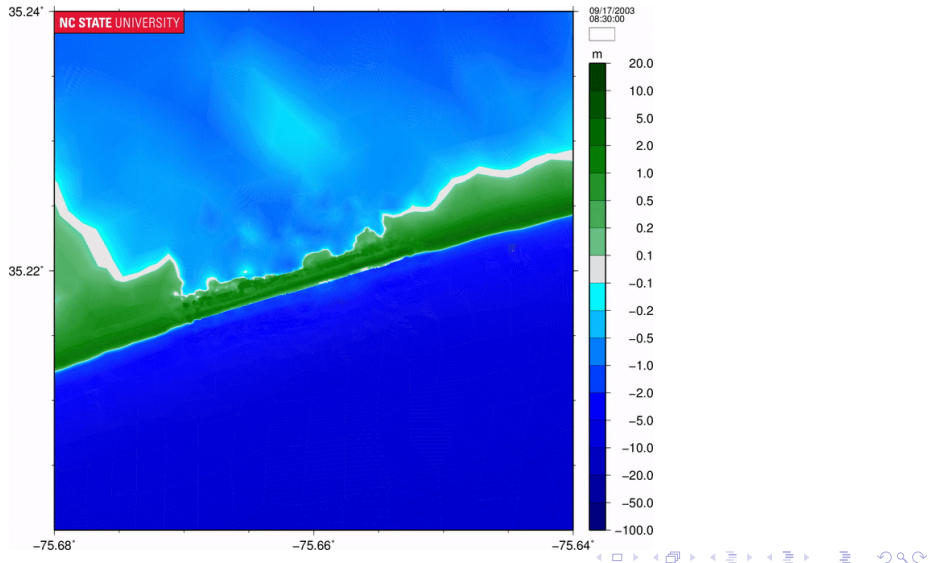
# Isabel Inlet

## Erosion over 1 Day



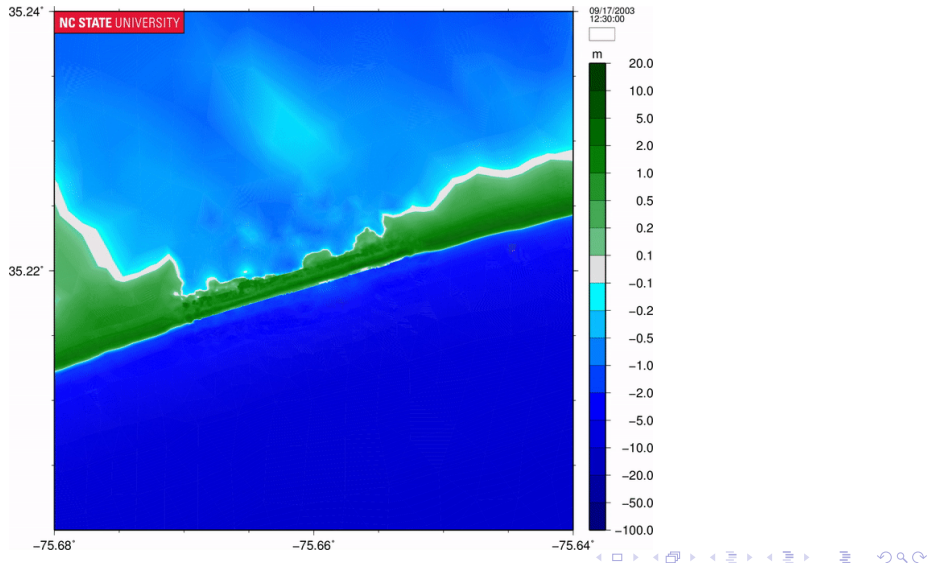
# Isabel Inlet

## Erosion over 1 Day



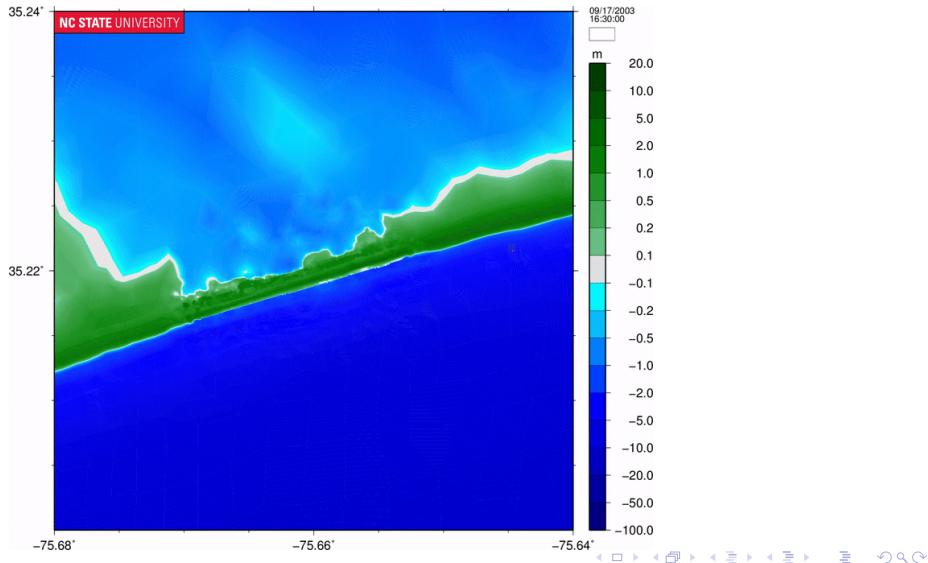
# Isabel Inlet

## Erosion over 1 Day



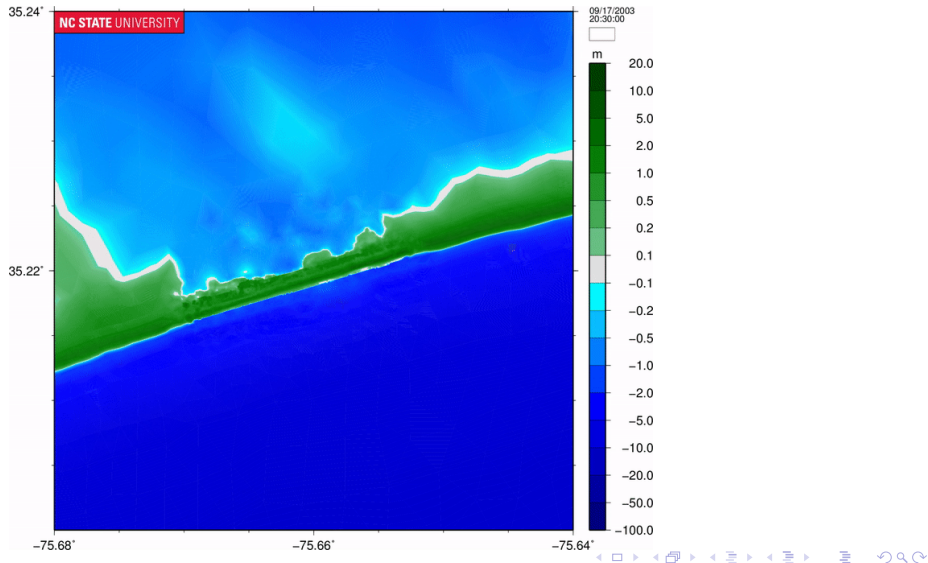
# Isabel Inlet

## Erosion over 1 Day



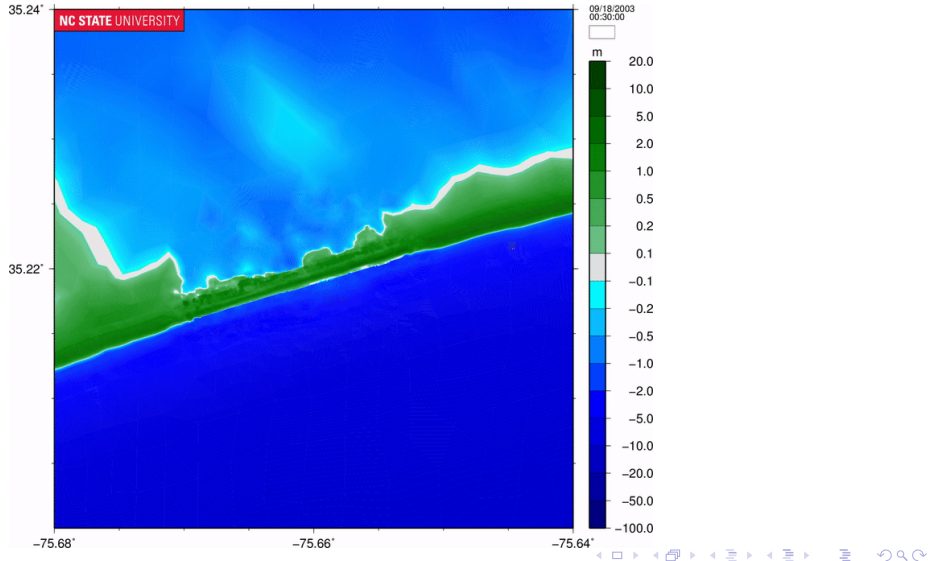
# Isabel Inlet

## Erosion over 1 Day



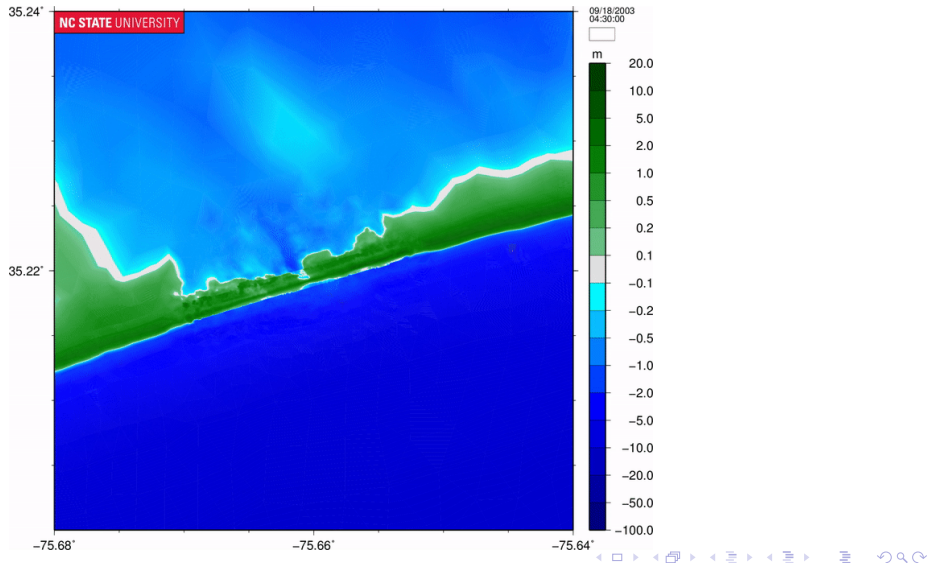
# Isabel Inlet

## Erosion over 1 Day



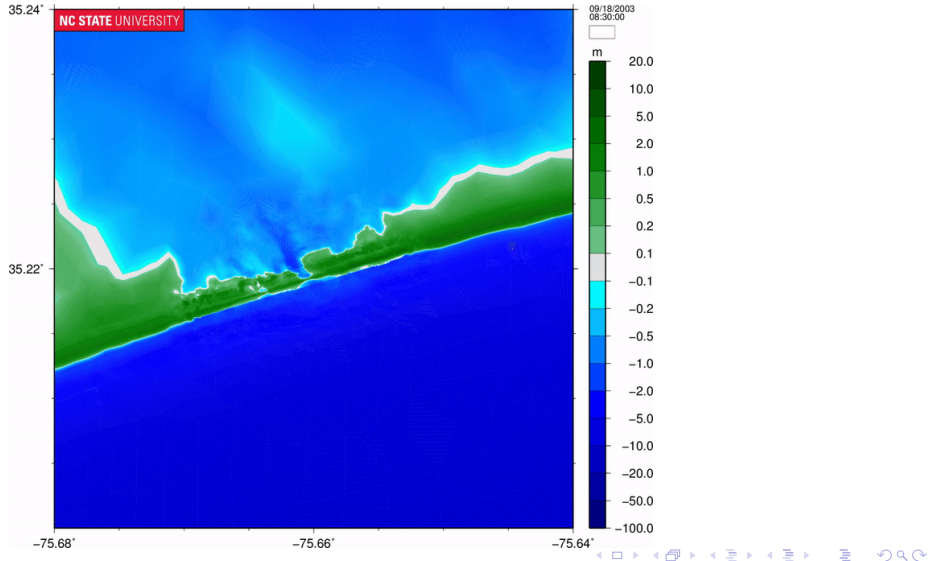
# Isabel Inlet

## Erosion over 1 Day



# Isabel Inlet

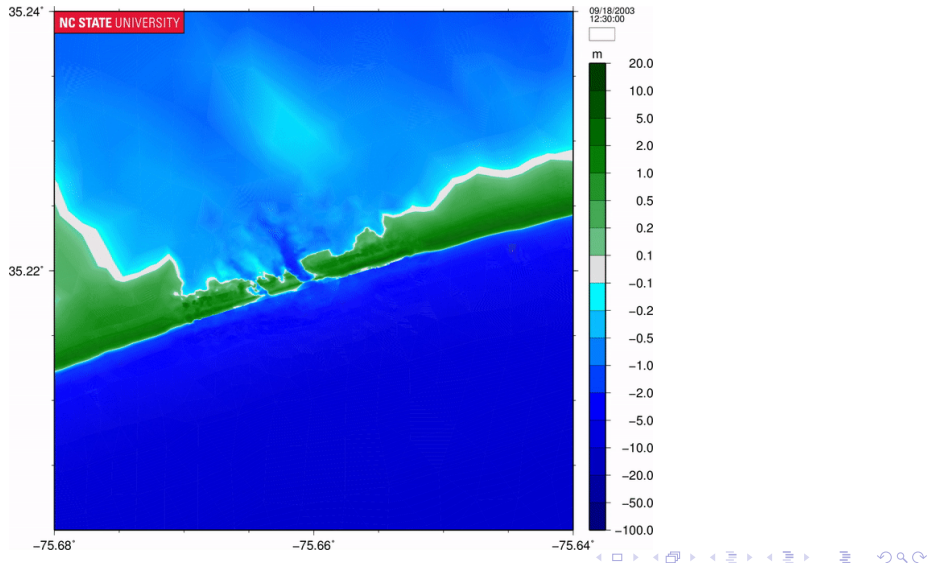
## Erosion over 1 Day





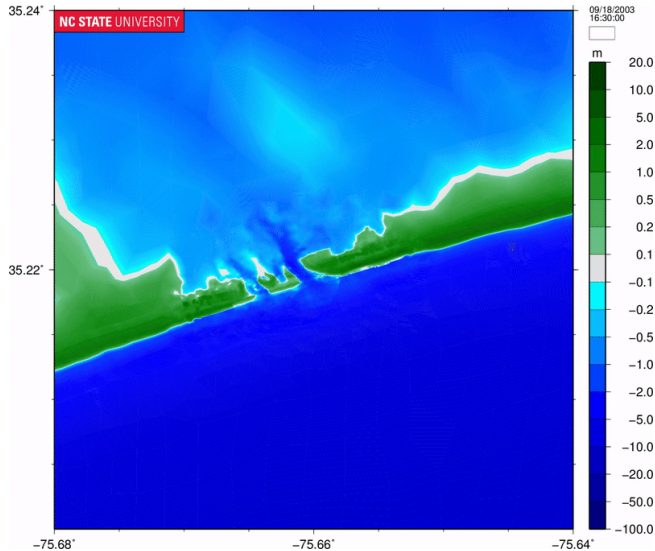
# Isabel Inlet

## Erosion over 1 Day



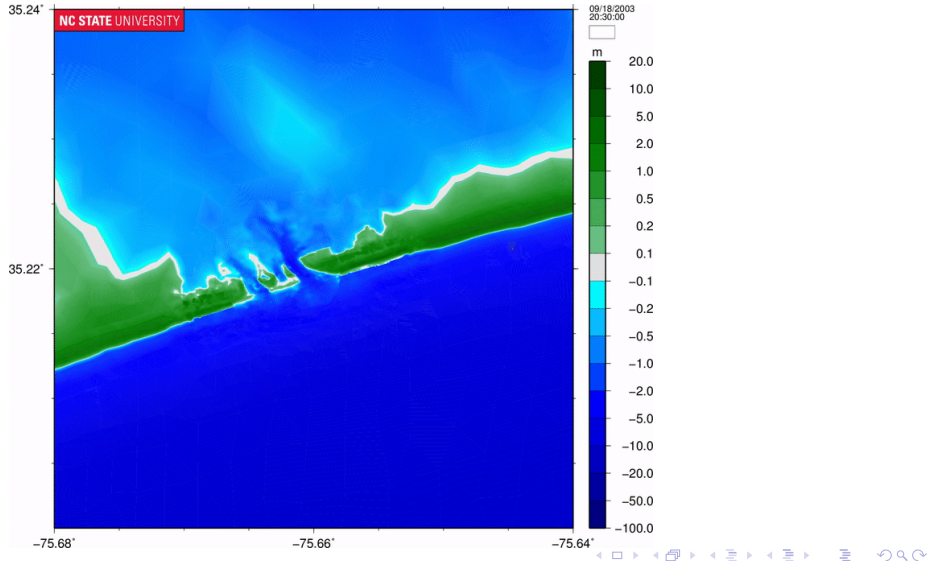
# Isabel Inlet

## Erosion over 1 Day



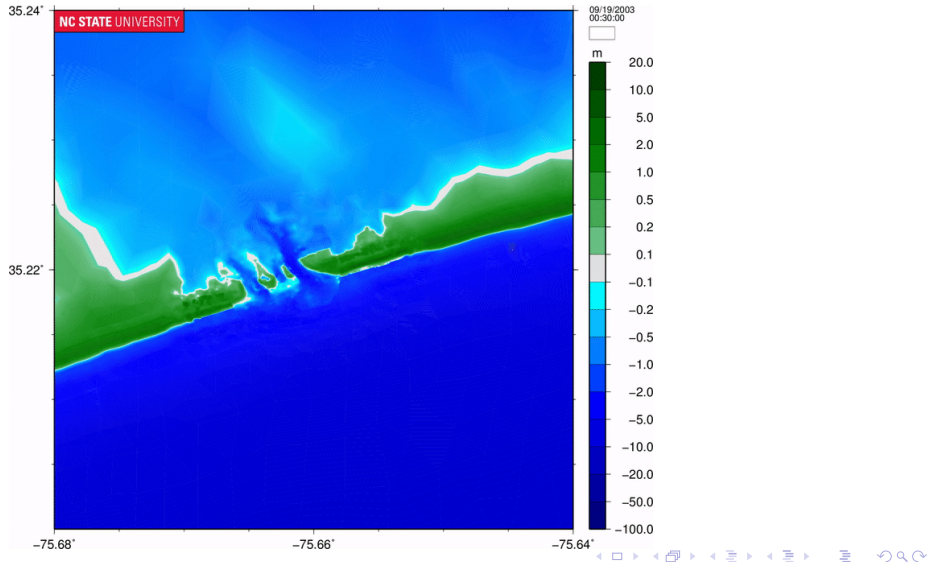
# Isabel Inlet

## Erosion over 1 Day



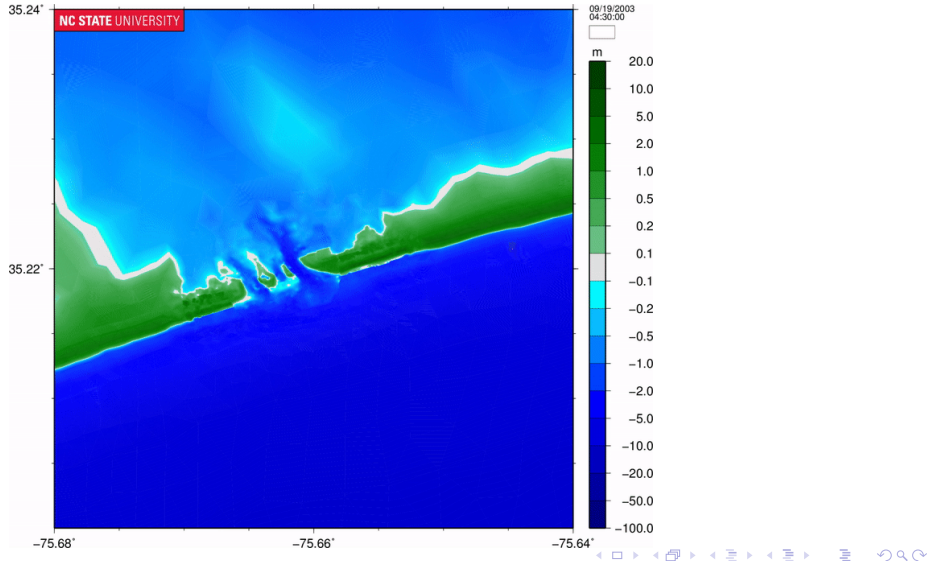
# Isabel Inlet

## Erosion over 1 Day



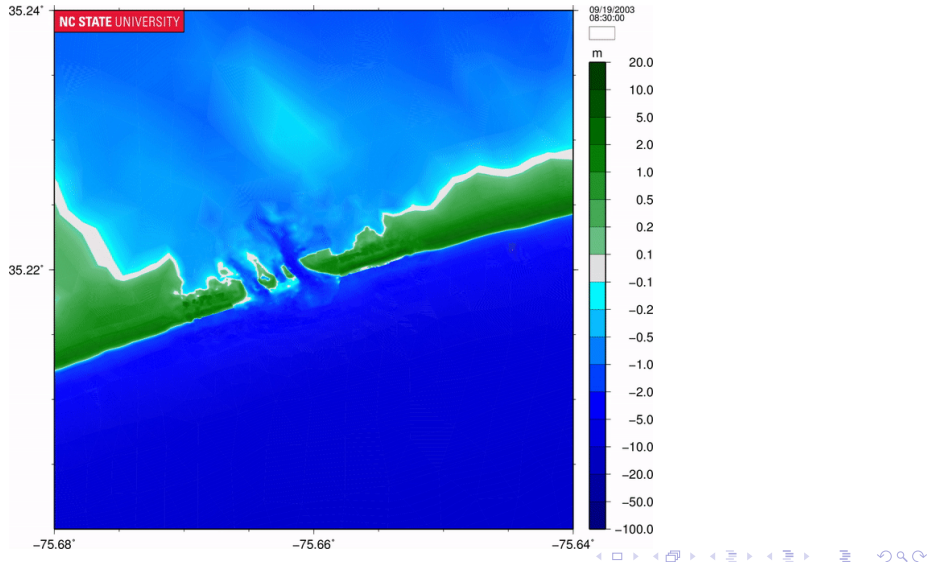
# Isabel Inlet

## Erosion over 1 Day



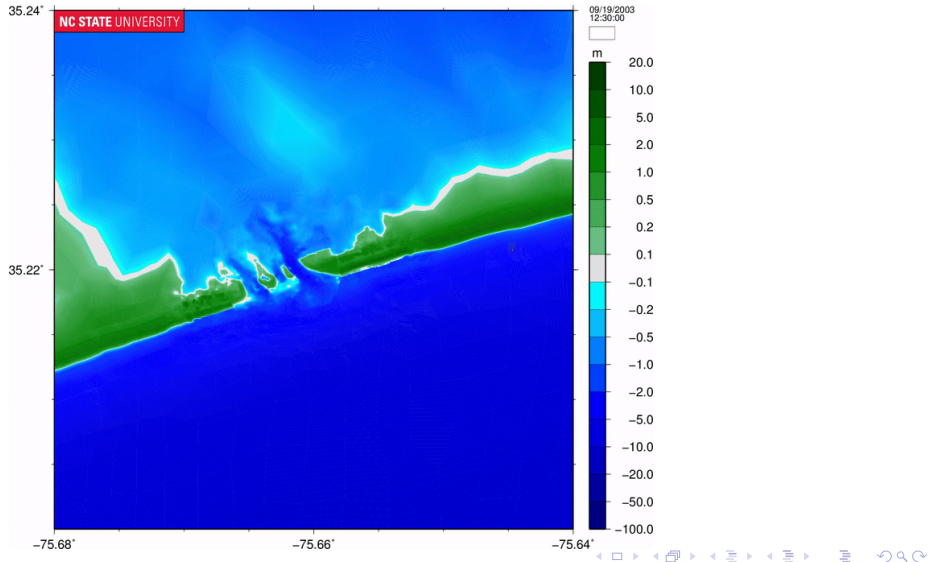
# Isabel Inlet

## Erosion over 1 Day



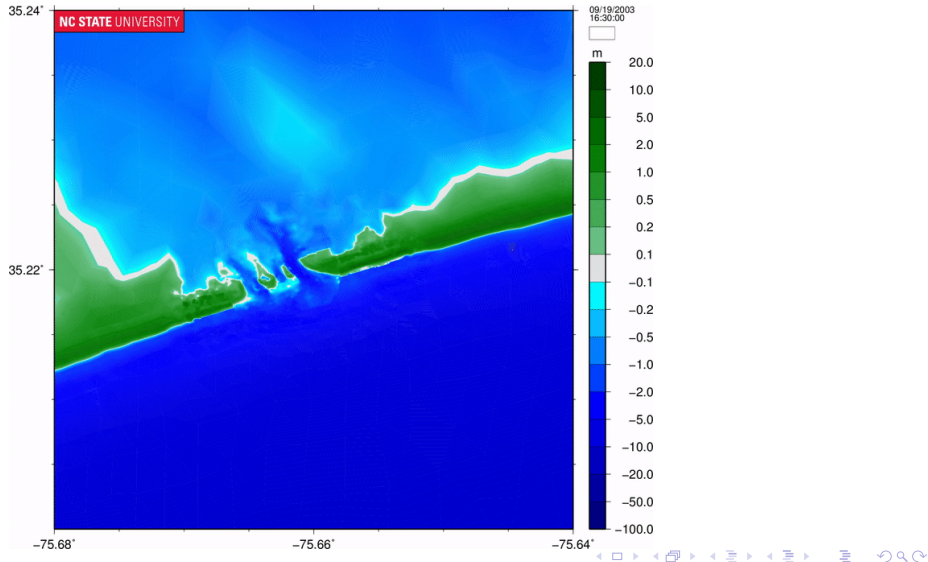
# Isabel Inlet

## Erosion over 1 Day



# Isabel Inlet

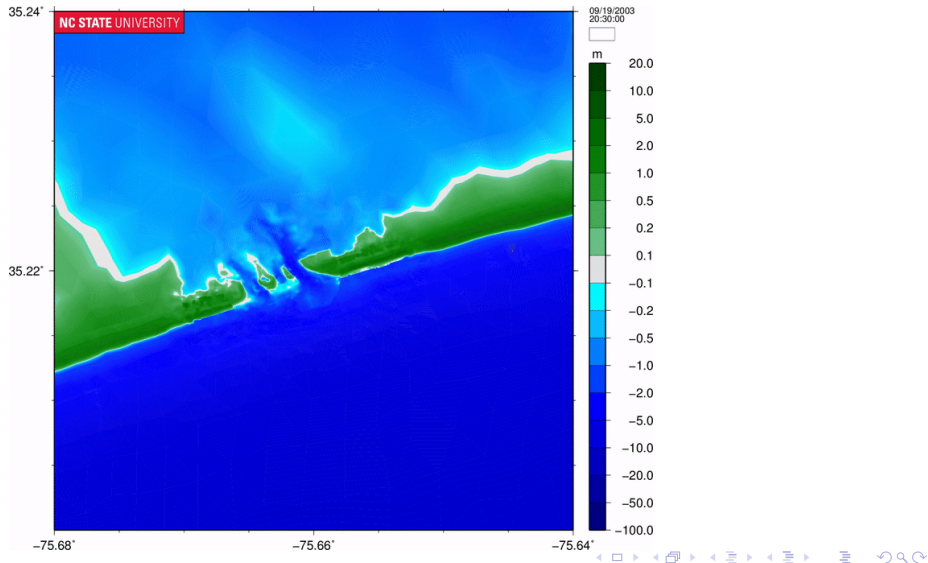
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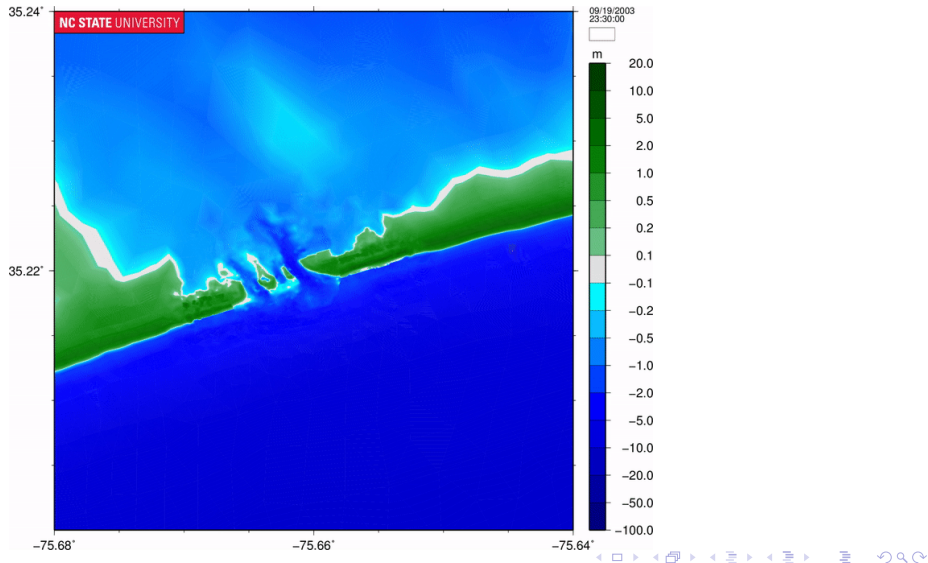
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## Erosion over 1 Day

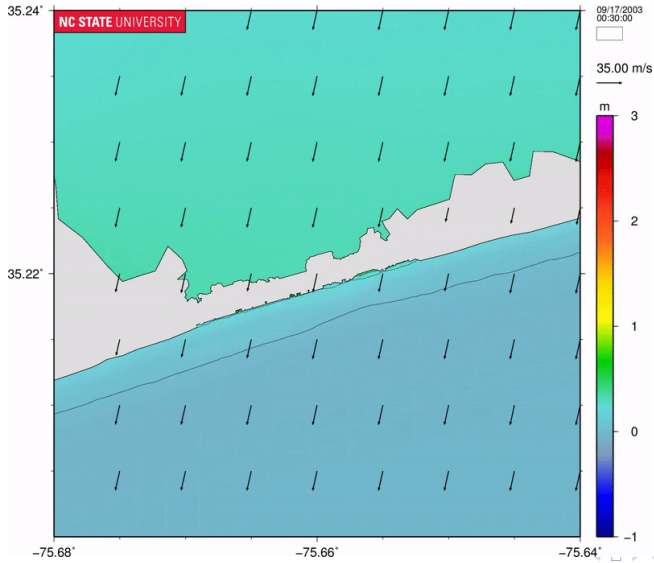


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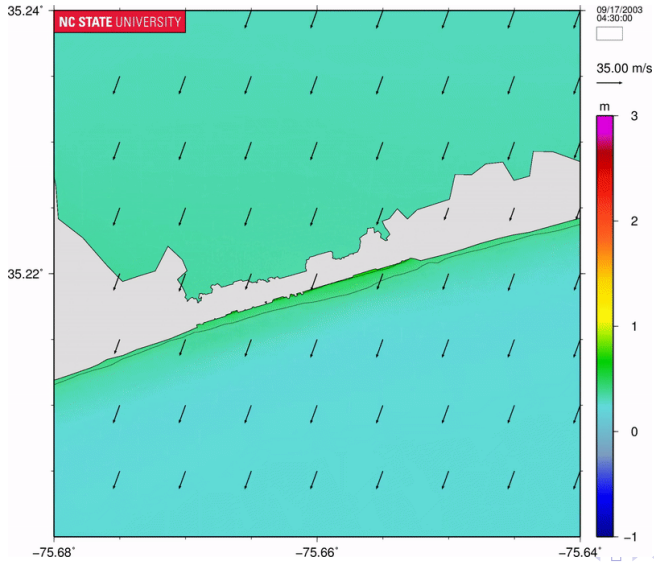
## Erosion over 1 Day



## Erosion over 1 Day

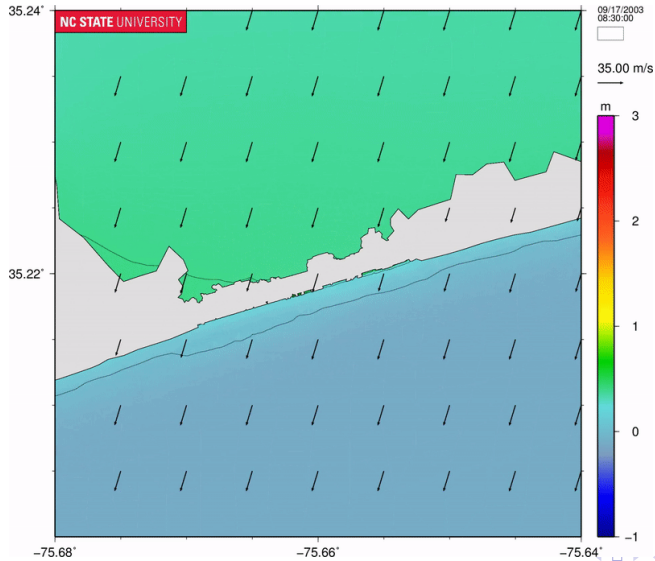


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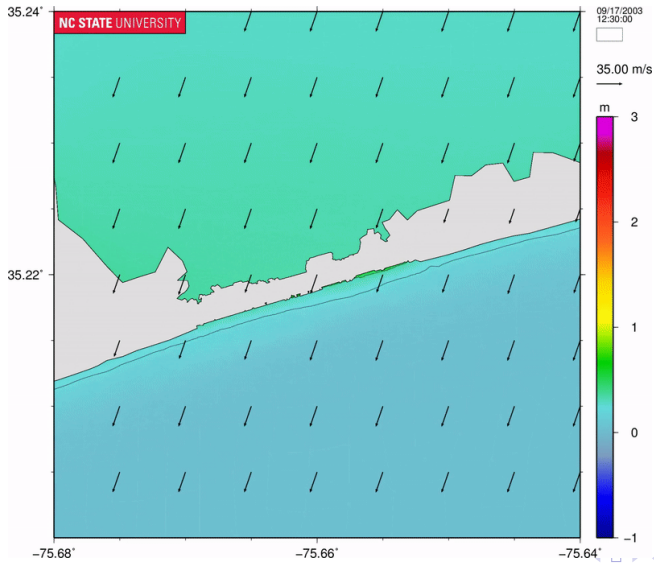


## Isabel Inlet

### Erosion over 1 Day

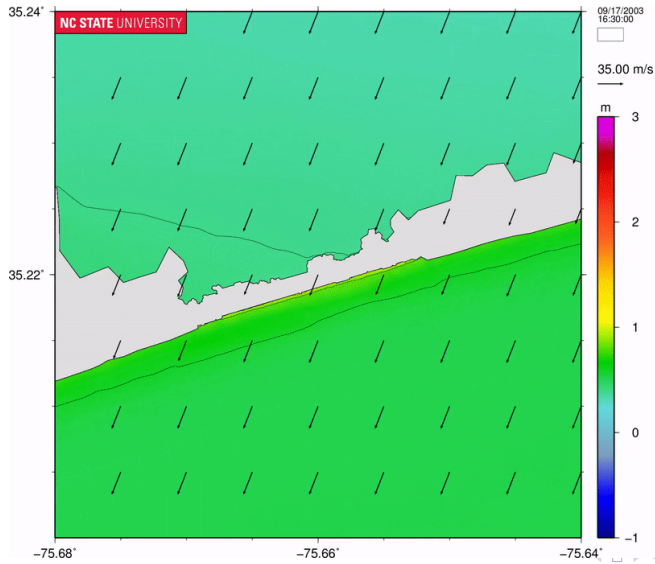


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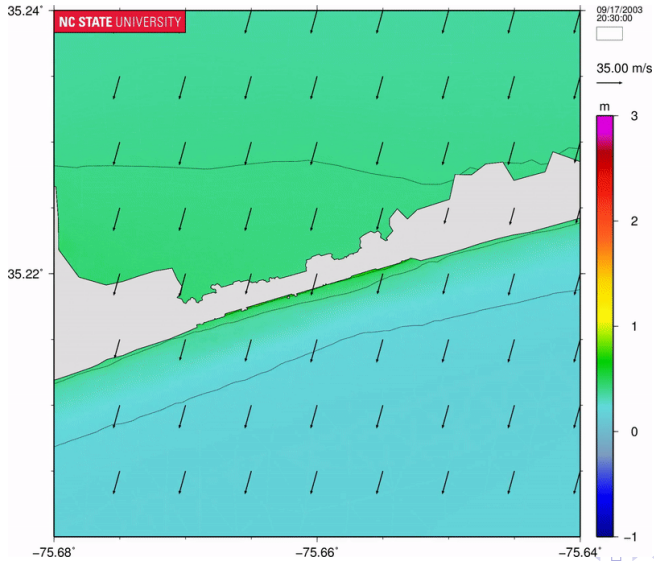


## Isabel Inlet

### Erosion over 1 Day



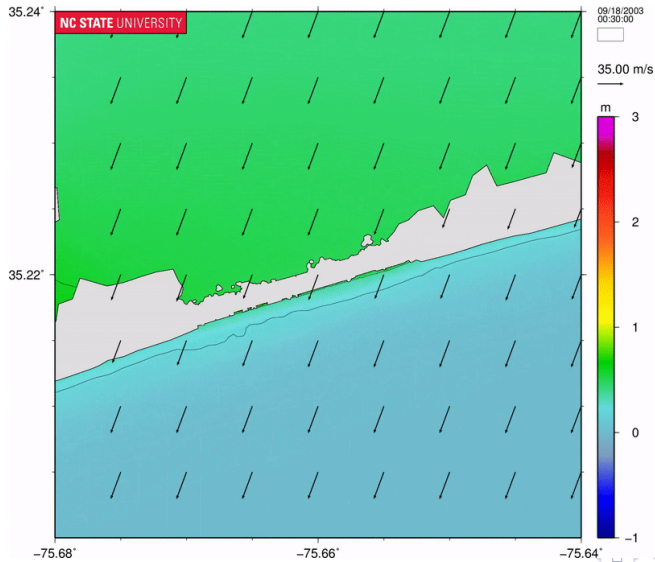
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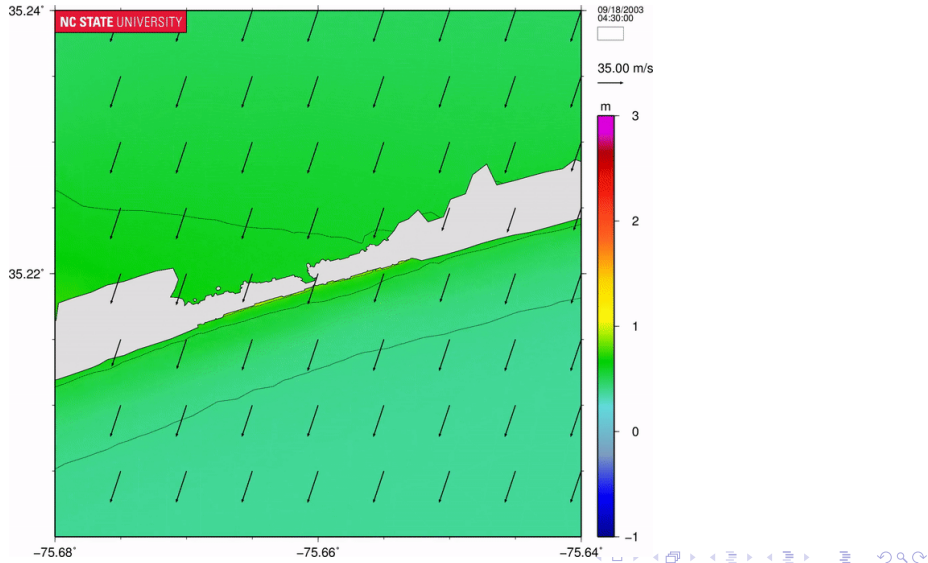
# Isabel Inlet

## Erosion over 1 Day



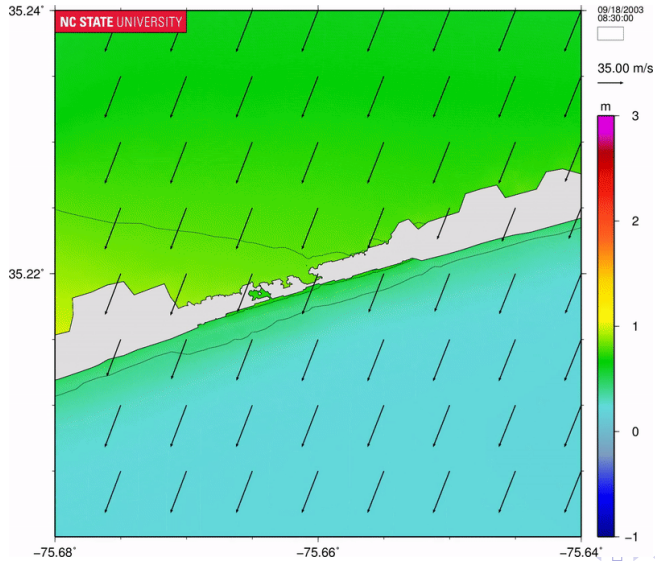
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### Erosion over 1 Day



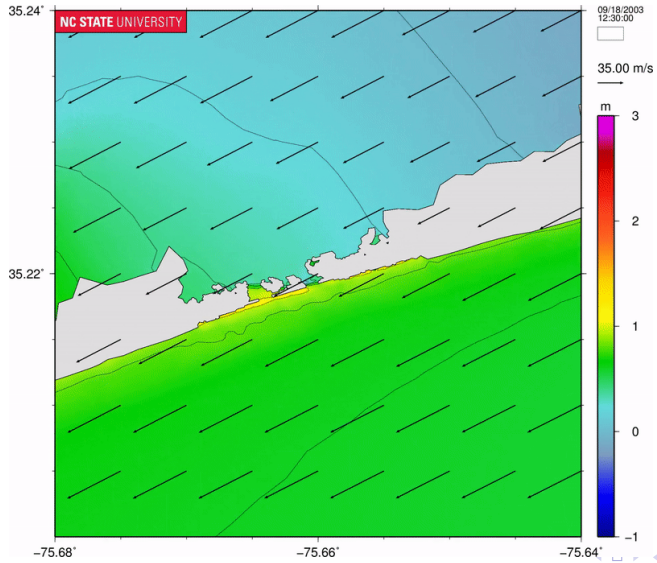
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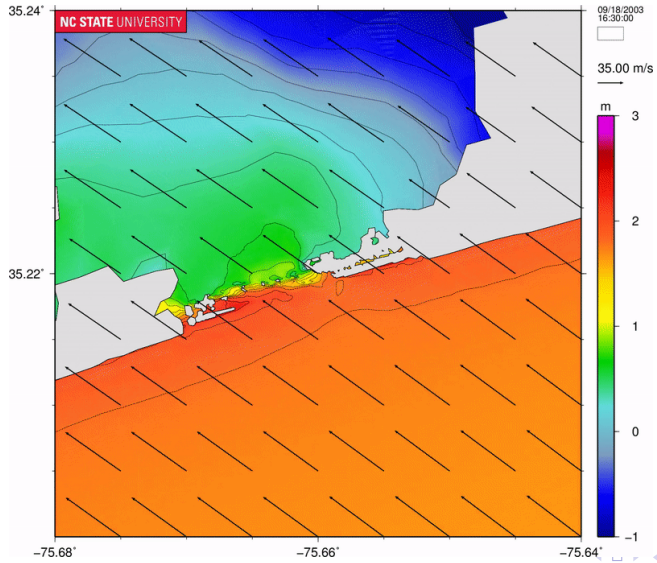


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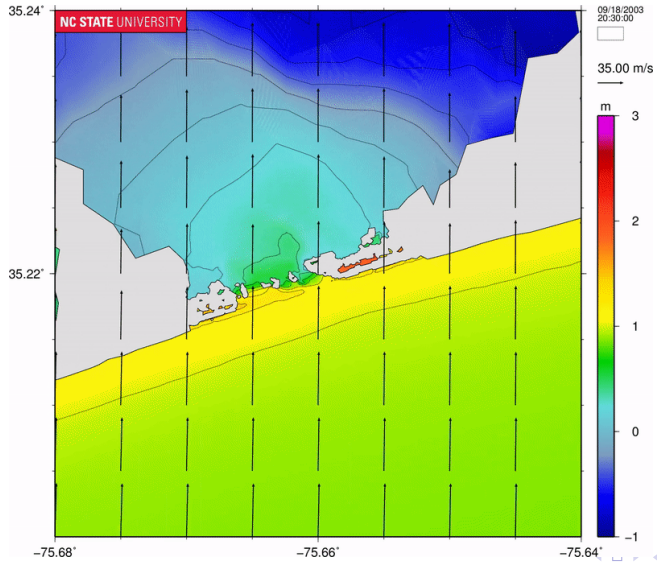
### Erosion over 1 Day



## Erosion over 1 Day

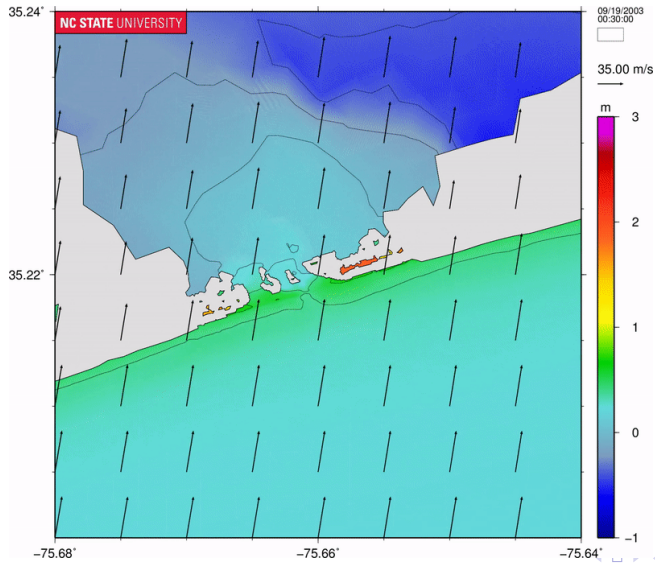


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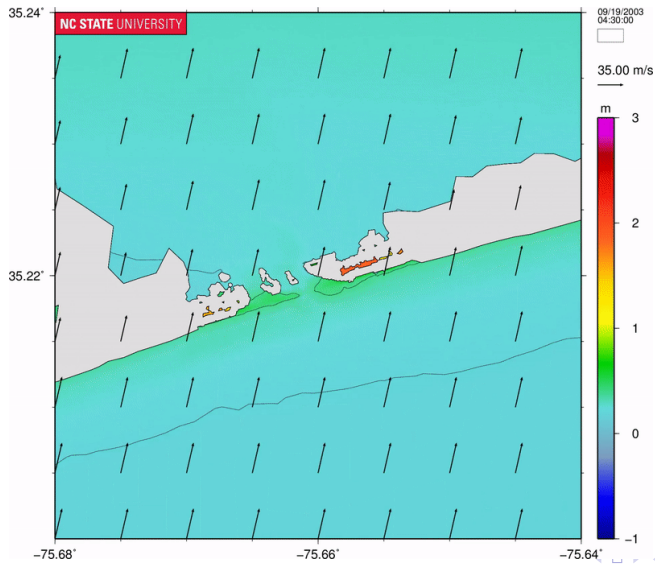
# Isabel Inlet

## Erosion over 1 Day



# Isabel Inlet

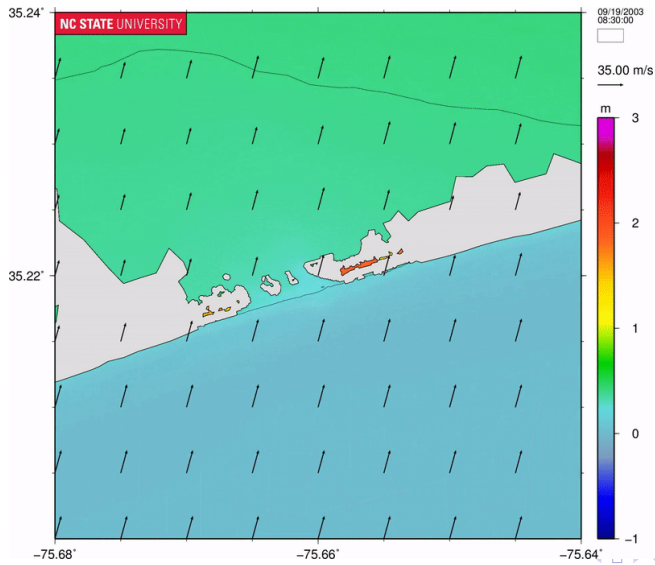
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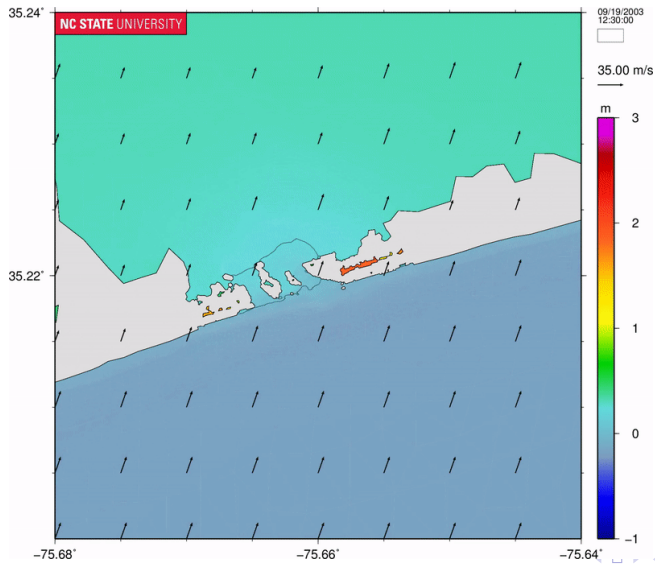
# Isabel Inlet

## Erosion over 1 Day



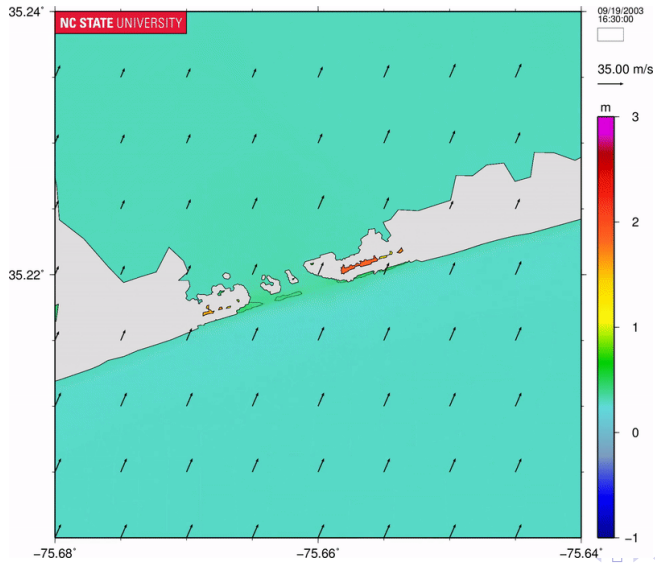
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## Erosion over 1 Day



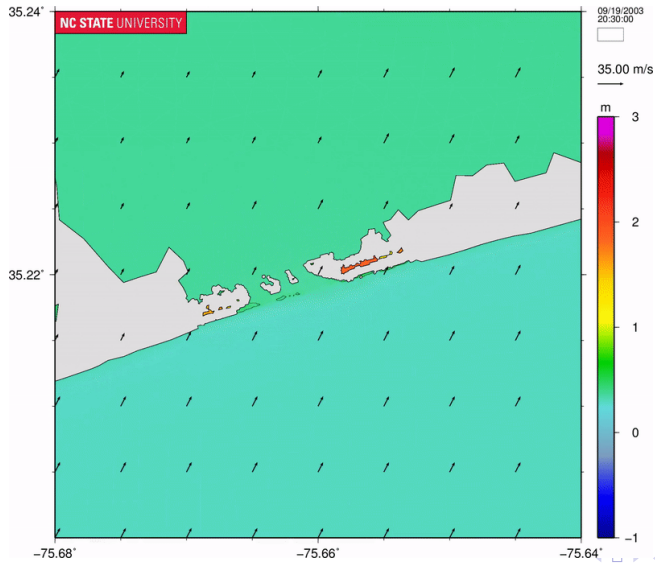
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## Erosion over 1 Day



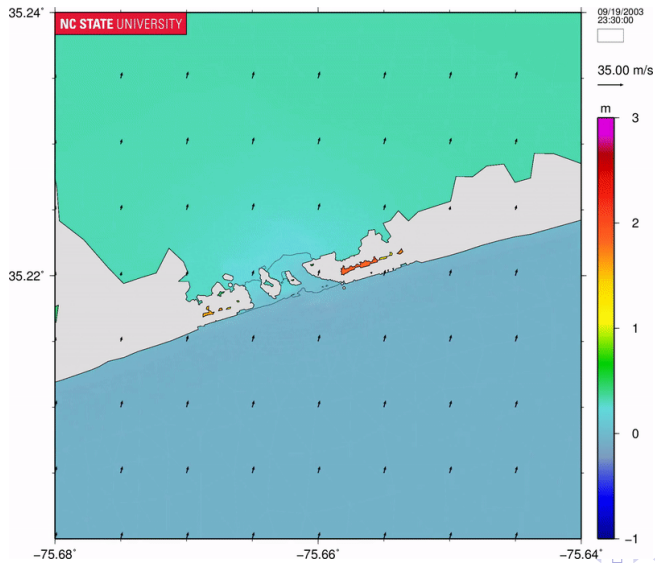
# Isabel Inlet

## Erosion over 1 Day



# Isabel Inlet

## Erosion over 1 Day



# Summary and Future Work

## Coupling of Inlet-Scale Erosion and Region-Scale Flooding Predictions

### Objectives:

1. High-resolution hindcast of inlet creation in a barrier island system
  - XBeach, using non-erodible layer
  - ADCIRC, using time-varying bathymetry
2. Explore the sensitivity of erosion predictions to the quality of input data
  - Still unable to initiate a deep channel in a desired location
  - Need a non-erodible layer
  - Sediment layers, varying bed friction
3. Two-way coupling of small-scale erosion to larger-scale flooding
  - Waves and water levels to XBeach, erosion timing to ADCIRC
  - Significant flows over and through the Isabel Inlet

