# Storm surge with GeoClaw

## Hurricane flooding simulation using Python and Fortran

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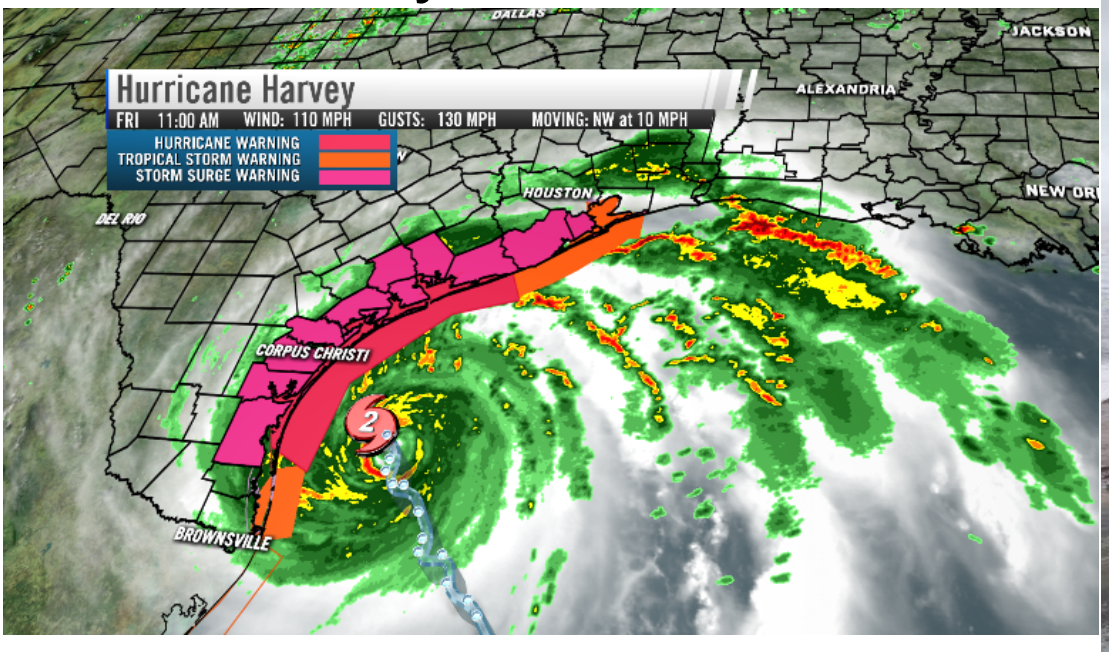
# 2017 Hurricane season

## Hurricane Harvey

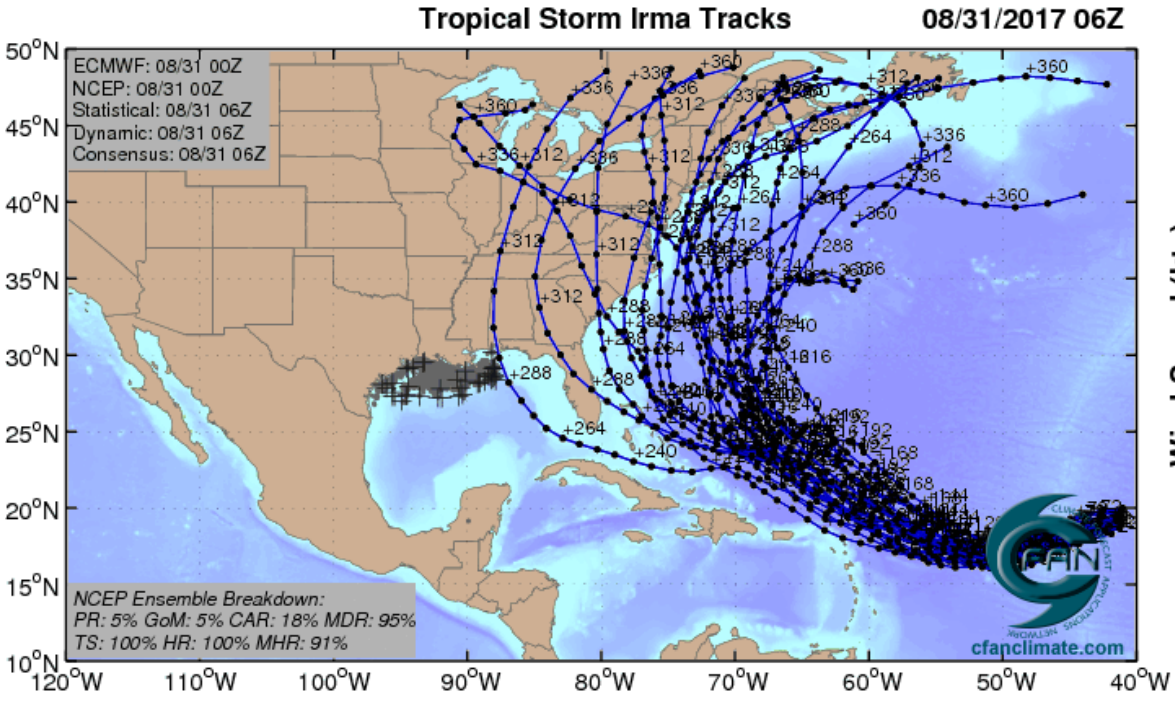


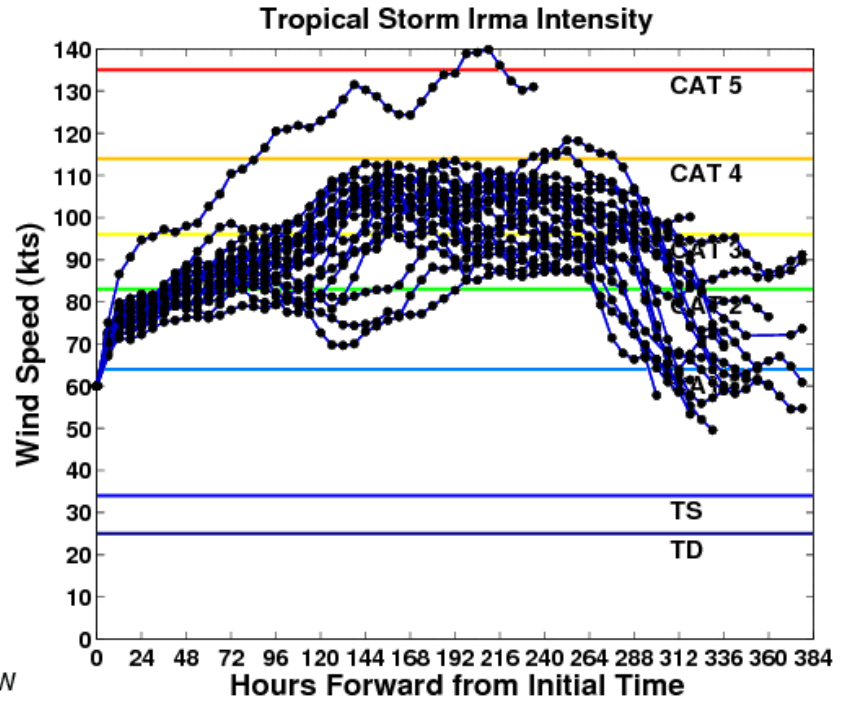

Texas (Houston)
Aug 25, 2017 (130 mph winds)
1.8m (6 ft) max surge height
71 deaths, $70 billion in damages

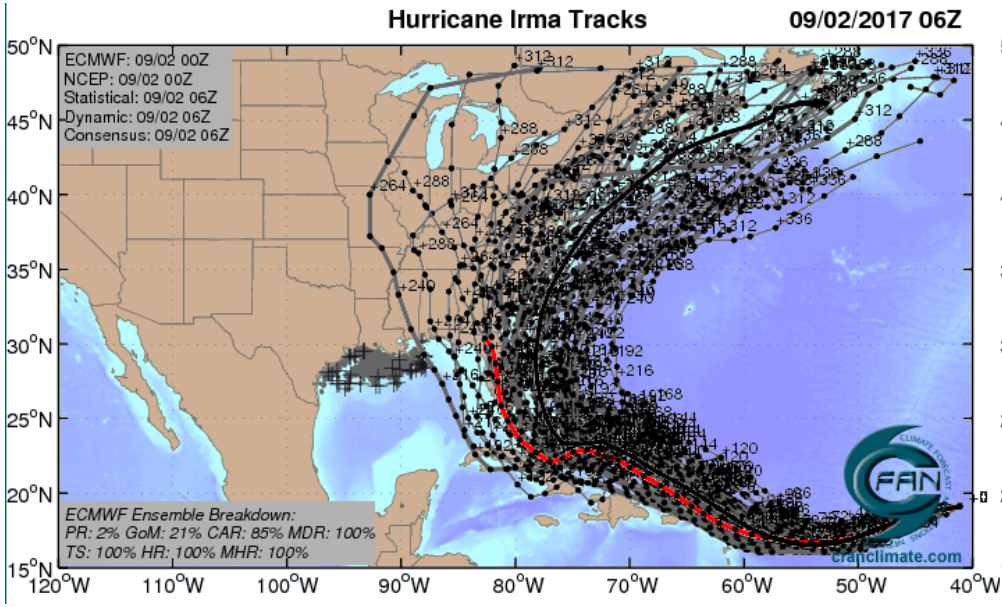
## Hurricane Irma

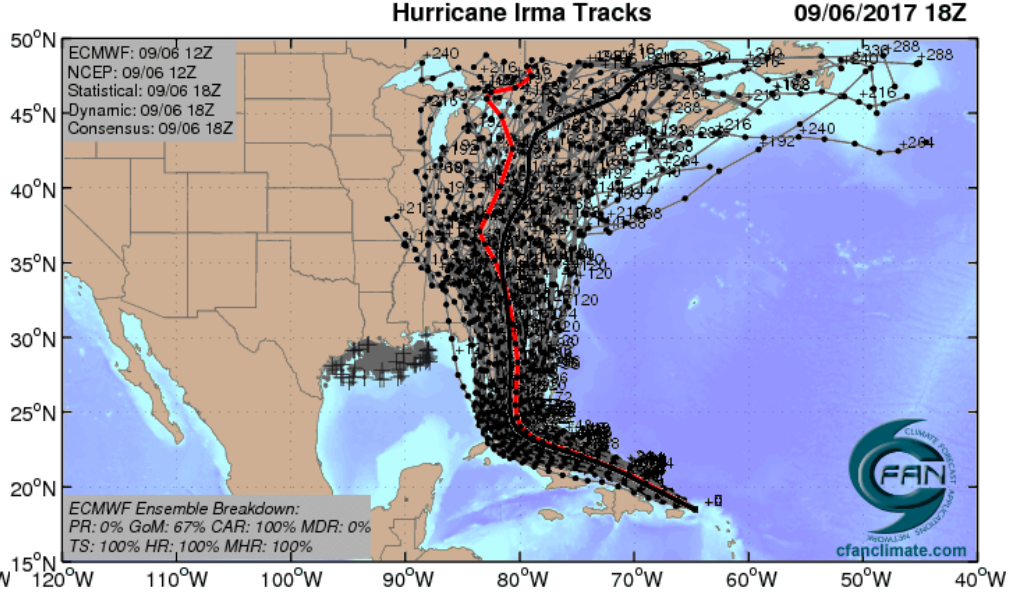
Carribbean, Florida, South Carolina
Sept 6, 2017 (185 mph winds)
3m (10 ft) surge height
81 deaths, $60 billion in damages

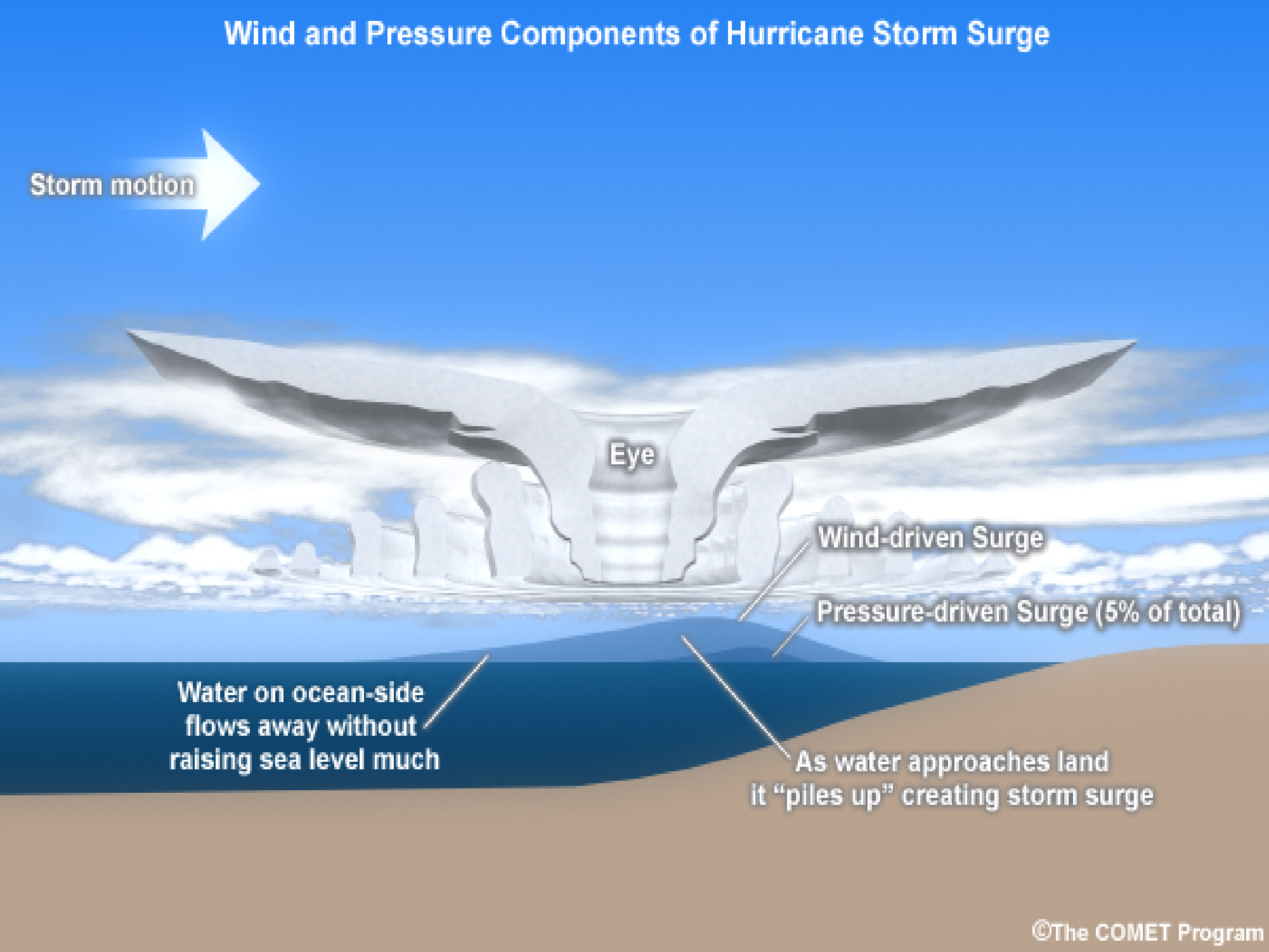
# Hurricane track forecasting




Wind and Pressure Components of Hurricane Storm Surge
Storm motion
Eye
Wind-driven Surge
Pressure-driven Surge (5% of total)
Water on ocean-side
flows away without
raising sea level much
As water approaches land
it "piles up" creating storm surge
©The COMET Program

# Governing eqns: Nonlinear shallow water eqns

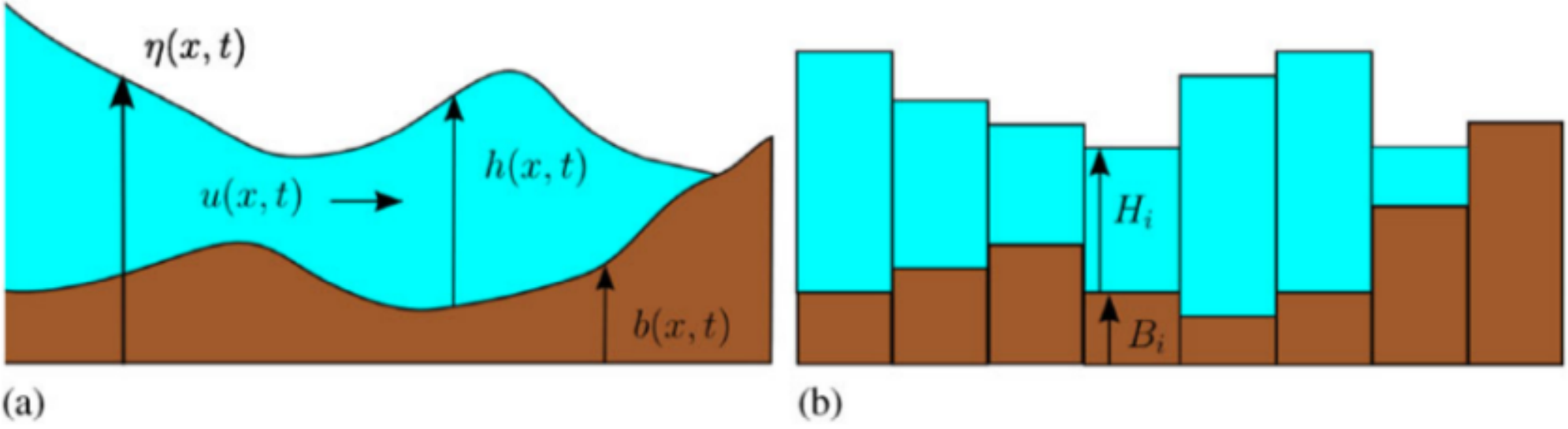
Water height $h$, depth averaged velocity $(u, v)$

$$\frac{\partial}{\partial t}h + \frac{\partial}{\partial x}(hu) + \frac{\partial}{\partial y}(hv) = 0,$$

$$\frac{\partial}{\partial t}(hu) + \frac{\partial}{\partial x}\left(hu^2 + \frac{1}{2}gh^2\right) + \frac{\partial}{\partial y}(huv) = -gh\frac{\partial b}{\partial x} + S_x,$$

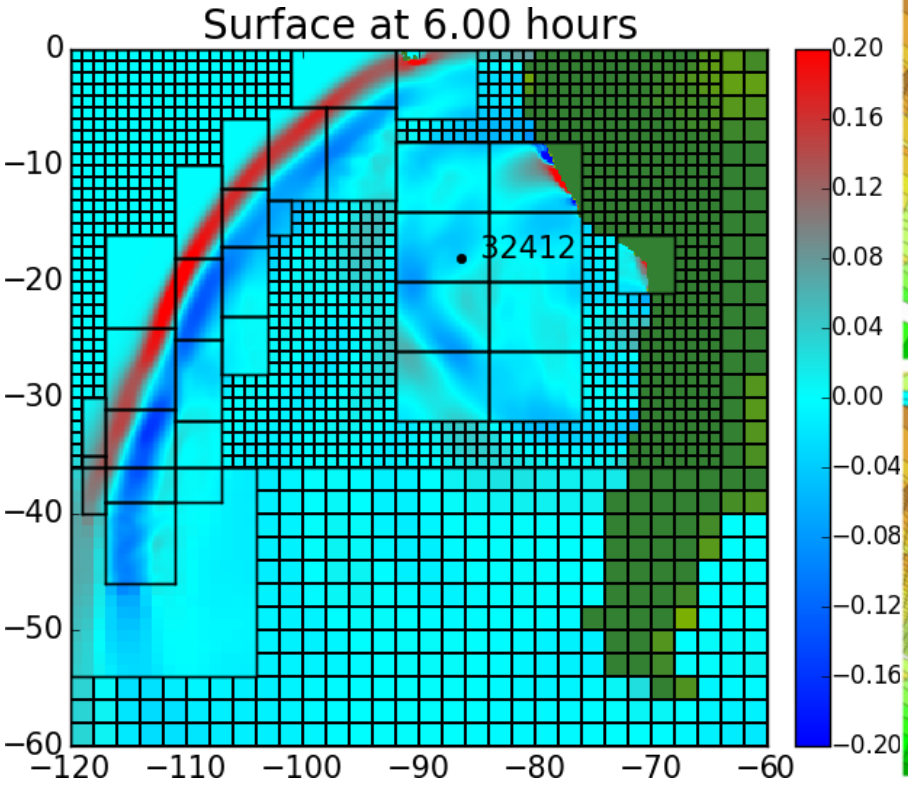
$$\frac{\partial}{\partial t}(hv) + \frac{\partial}{\partial x}(huv) + \frac{\partial}{\partial y}\left(hv^2 + \frac{1}{2}gh^2\right) = -gh\frac{\partial b}{\partial y} + S_y.$$

Source terms: wind stress, surface pressure, bottom friction, Coriolis

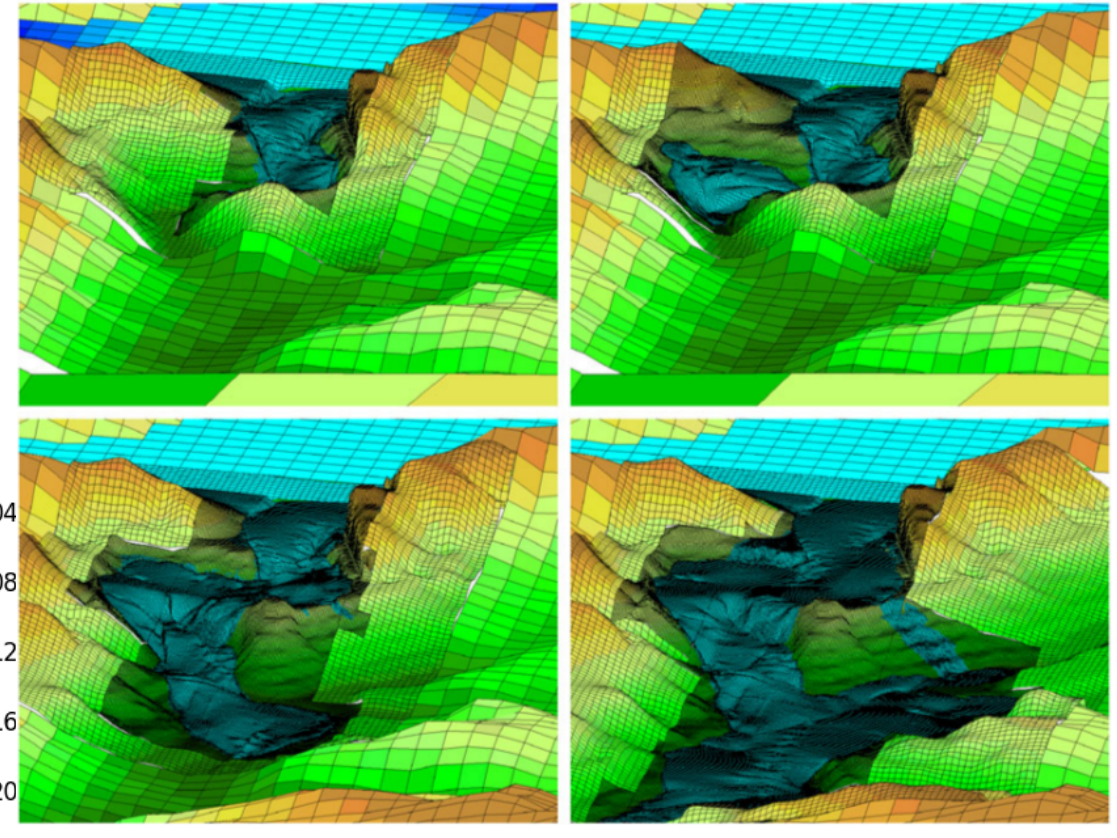


# Numerical solver - GeoClaw

- **GEO**physical **C**onservation **LAW** (Berger, George, LeVeque, Mandli, 2010)
- Finite volume solver for NSWE with adaptive mesh refinement
- Part of Clawpack: `github.com/clawpack/clawpack`




Application to 2010 Chile tsunami



Malpasset dam break

## Hurricane Harvey datasets

Spatial dimensions:

- Domain 300,000 km x 200,000 km
- Gridsize 25km - 500m

Hurricane data:

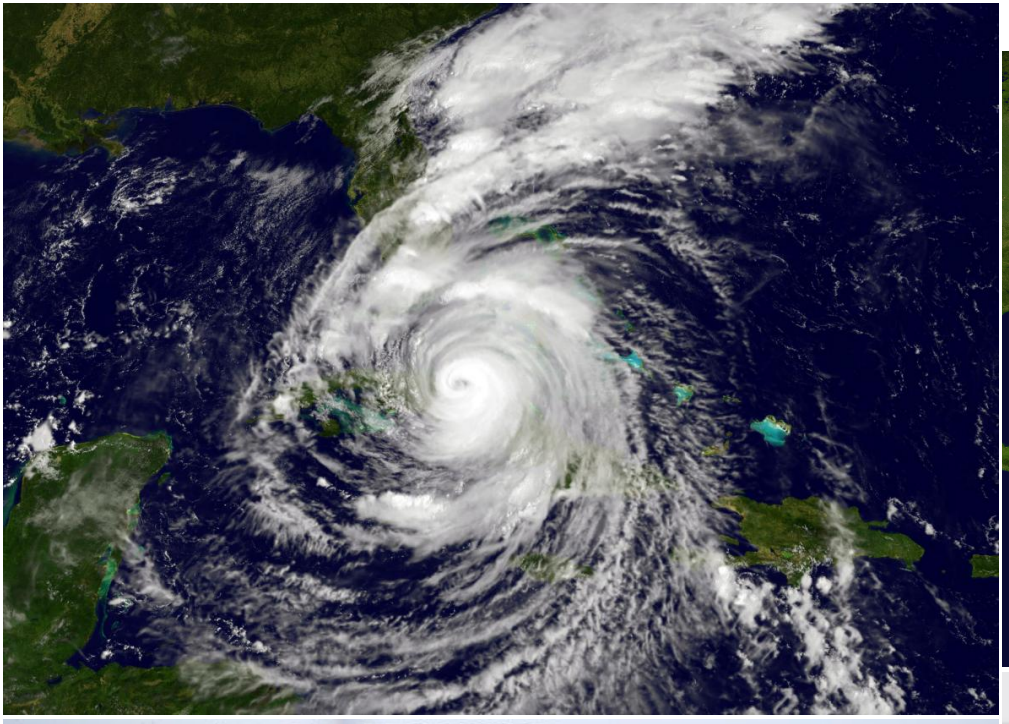
- National Hurricane Center "best track" parametric record
- Converted to wind field via Holland model

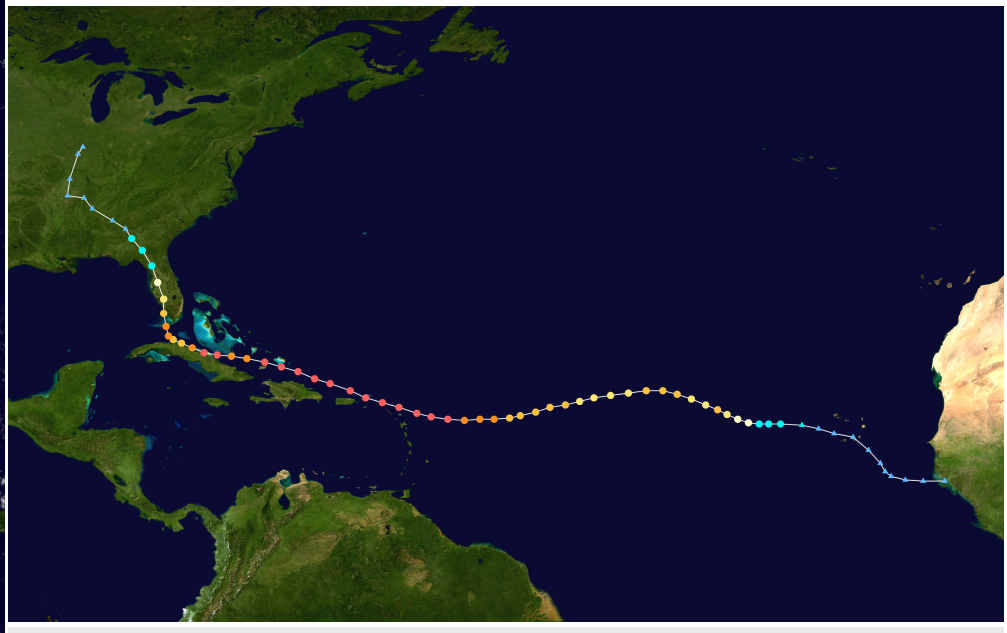
Topography + ocean bathymetry:

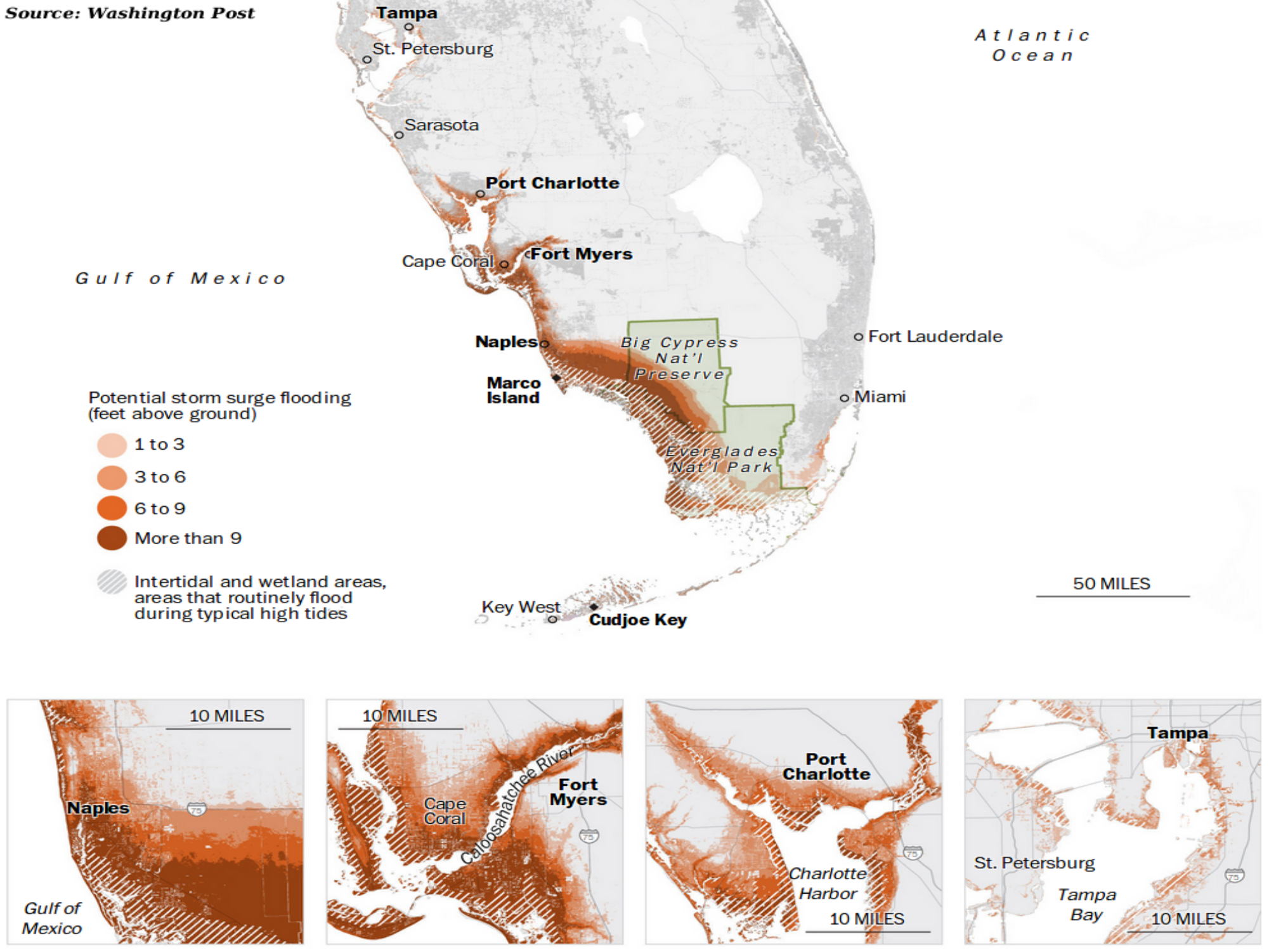
- ETOPO (1 arc-min, 160 km)
- SRTM15_plus (15 arc-sec, 40 km)
- Available through NOAA ERDDAP

[show animation]

# Hurricane Irma - a little weird






Source: Washington Post
Tampa
St. Petersburg
Sarasota
Port Charlotte
Cape Coral
Fort Myers
Gulf of Mexico
Atlantic Ocean
Naples
Big Cypress Nat'l Preserve
Fort Lauderdale
Marco Island
Miami
Everglades Nat'l Park
Key West
Cudjoe Key
Potential storm surge flooding (feet above ground)
1 to 3
3 to 6
6 to 9
More than 9
Intertidal and wetland areas, areas that routinely flood during typical high tides
50 MILES
10 MILES
Naples
Gulf of Mexico
10 MILES
Cape Coral
Caloosahatchee River
Fort Myers
10 MILES
Port Charlotte
Charlotte Harbor
10 MILES
Tampa
St. Petersburg
Tampa Bay
10 MILES

**Summary:**

- Storm surge is a major hazard for hurricane-prone coastlines
- GeoClaw is a low-cost tool for estimating storm surge
- Open source science is awesome!

**Further info:**

GeoClaw and Clawpack

- `github.com/clawpack/clawpack`
- `www.clawpack.org`

Source code for this talk:

- `marckjerland.com`
- `marc.kjerland@gmail.com`

# Thank you!