U.S. FLOOD MODELING

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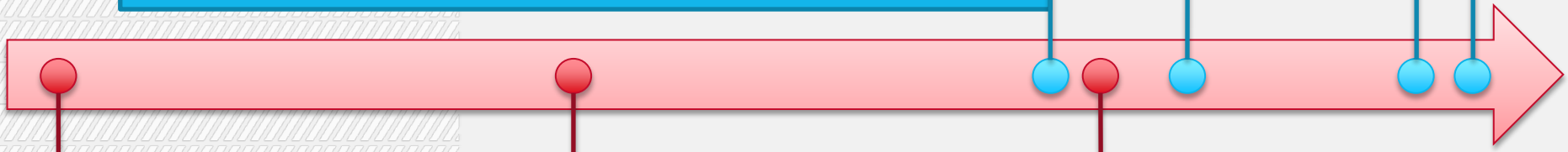
RMS™


Where have we been?
Where are we now?
What's changed?
What's coming?

US FLOOD TIMELINE



August 2005
Hurricane Katrina
$16.3 Bn NFIP loss

September 2008
Hurricane Ike
$2.7 Bn NFIP loss

June 2012
Biggert-Waters NFIP Reform Act signed into law

October 2012
Hurricane Sandy
$7.8 Bn NFIP loss

January 2014
***Partial* delay** of Biggert-Waters

July 2013
MTA Cat Bond is first ever **Cat Bond** for storm surge

March 2014
***Comprehensive* delay** of Biggert-Waters

NFIP: TOP 15 LOSSES

Flood risk in U.S. is dominated by coastal flood

14 of top 15 NFIP claims related to Tropical Storms and Hurricanes

Over half of total NFIP payout (since program began in 1978) from just two years – 2005 and 2012 – driven by coastal flood loss

Event	Year	Claims
Hurricane Katrina	**2005**	$16.3B
Hurricane Sandy	**2012**	$7.8B
Hurricane Ike	2008	$2.7B
Hurricane Ivan	2004	$1.6B
Hurricane Irene	2011	$1.3B
Tropical Storm Alison	2001	$1.1B
Louisiana Flood	1995	$585M
Tropical Storm Isaac	**2012**	$531M
Hurricane Isabel	2003	$493M
Hurricane Rita	**2005**	$472M
Hurricane Floyd	1999	$462M
Tropical Storm Lee	2011	$445M
Hurricane Opal	1995	$406M
Hurricane Hugo	1989	$376M
Hurricane Wilma	**2005**	$365M

NFIP: LOSS HISTORY

Flood risk in U.S. is dominated by coastal flood

Source	Total NFIP Claims in $Bn (1978-present)	Contribution to total (%)
Flooding from hurricanes and tropical storms	36.5	**87%**
Non-tropical cyclone-related flooding	5.7	13%
TOTAL	42.2	100%

complex processes

model full lifecycle

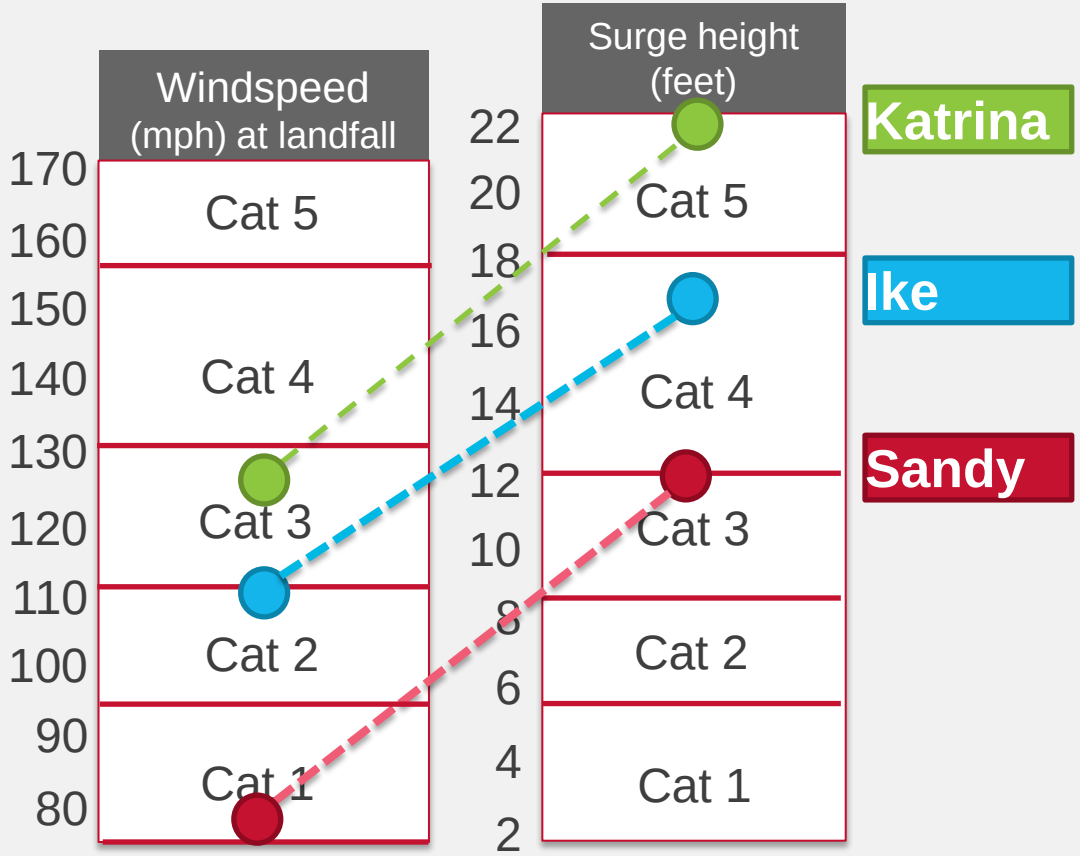
high resolution

IT'S NOT JUST LANDFALL CHARACTERISTICS THAT MATTER

Cannot assume 1:1 relationship between wind and surge severity at landfall

Storm surge impacts can be more severe than indicated by landfall characteristics

- Sandy (2012)
- Ike (2008)
- Katrina (2005)



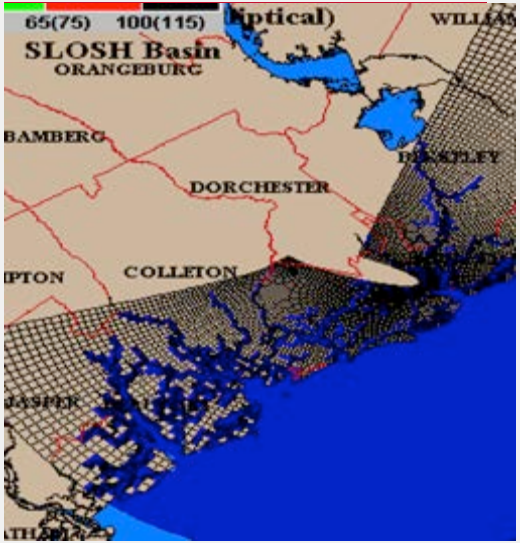
DIFFERENT APPROACHES TO STORM SURGE MODELING

Empirical Models

- Lack of observations to train on across all regions
- Doesn't account for surge development over life of storm
- Difficult to deal with complex coast-lines, bays, and barrier islands

SLOSH

- (Sea, Lake, and Overland Surge from Hurricane)
- **Operational** focus, widely used for disaster planning
- Not certified for FEMA flood modeling studies
- Grid resolution decreases away from central point



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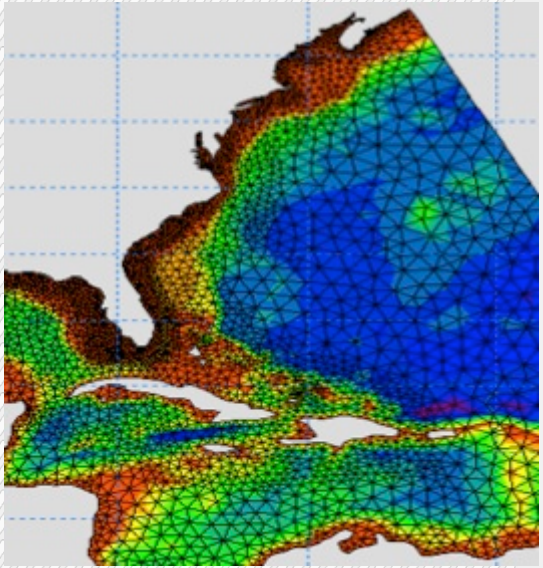
Hydrodynamic Models

- Physics-based calculation of time-stepping storm surge
- Considered best practice for FEMA flood modeling studies
- Can control grid resolution – put fine resolution grid cells where they're needed most

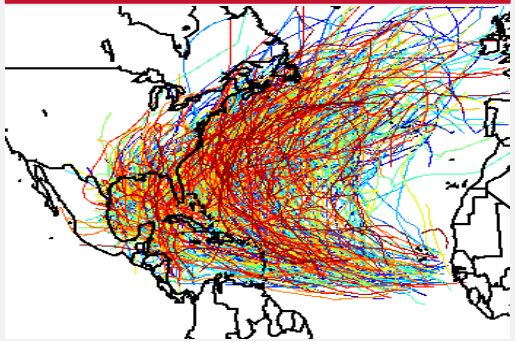
NUMERICAL APPROACH: SUPERCOMPUTING RESOURCES REQUIRED…



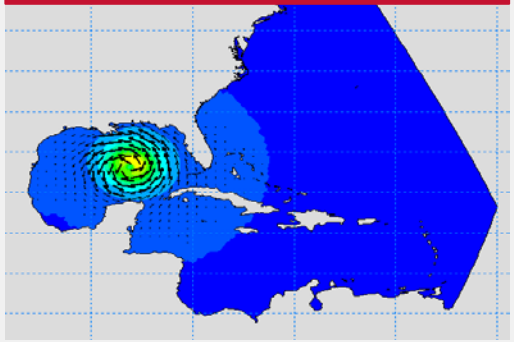
Required **500 CPUs** and **60 terabytes** of disk-space to generate RMS North Atlantic Hurricane Model storm surge stochastic set

RMS SURGE MODELING: NESTED MESH FRAMEWORK

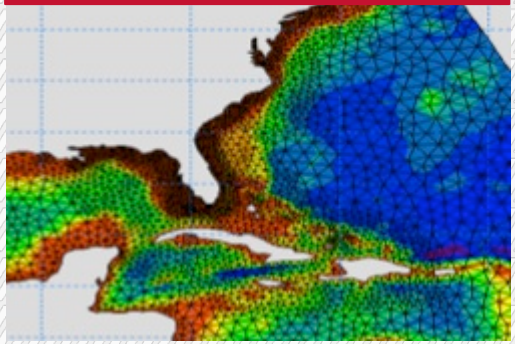
TRACK SET



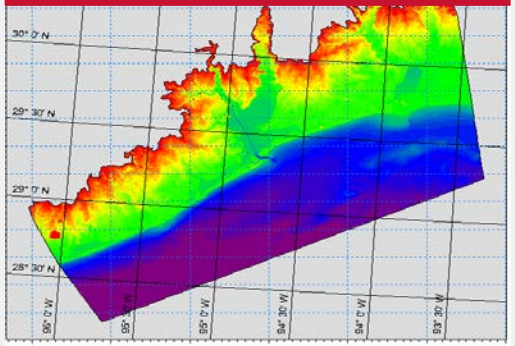
WIND FIELD



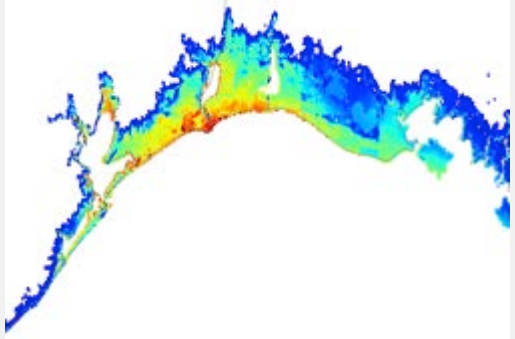
REGIONAL MESH



LOCAL MESH



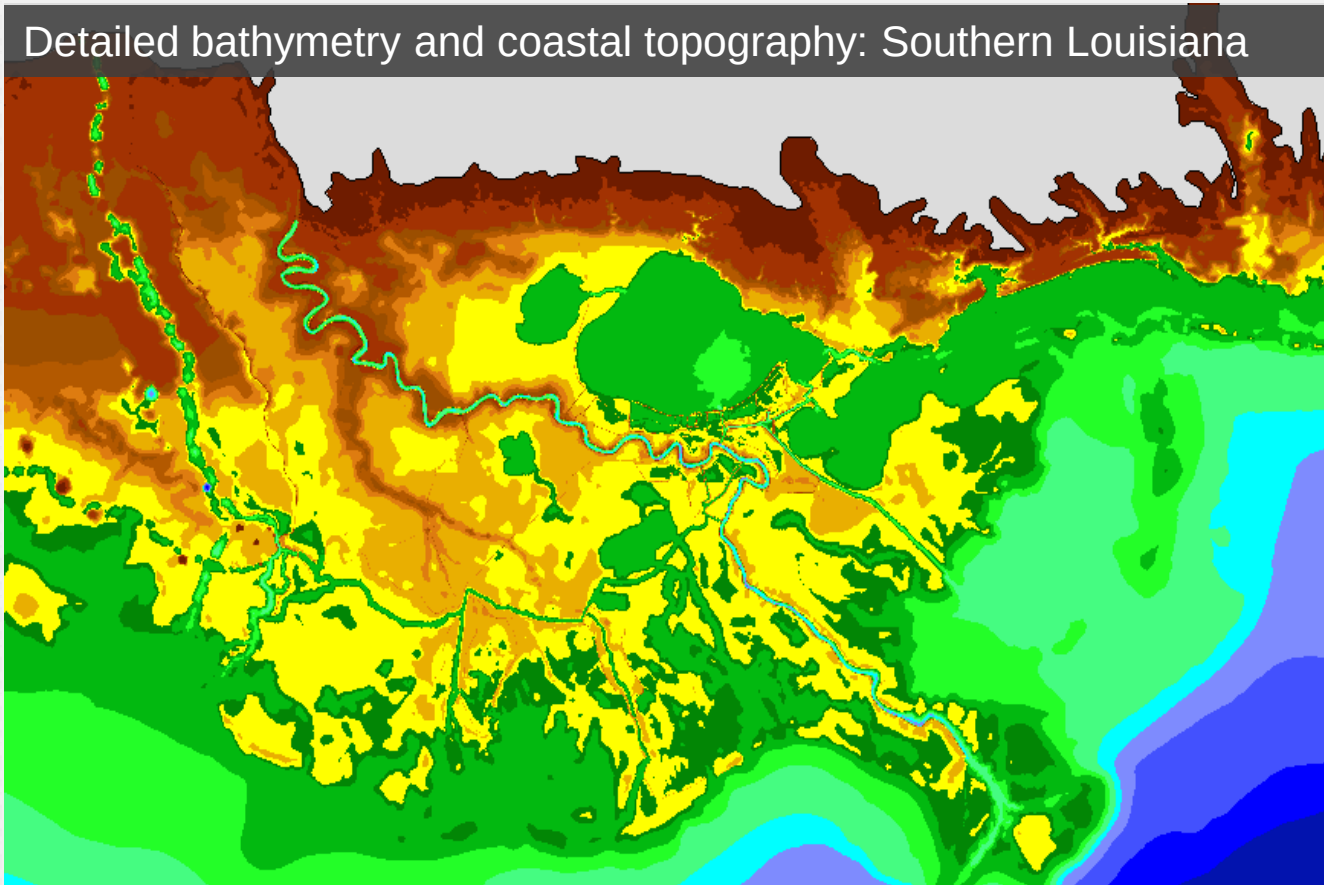
FLOOD DEPTHS



HIGH RESOLUTION COASTAL FLOOD MODELING

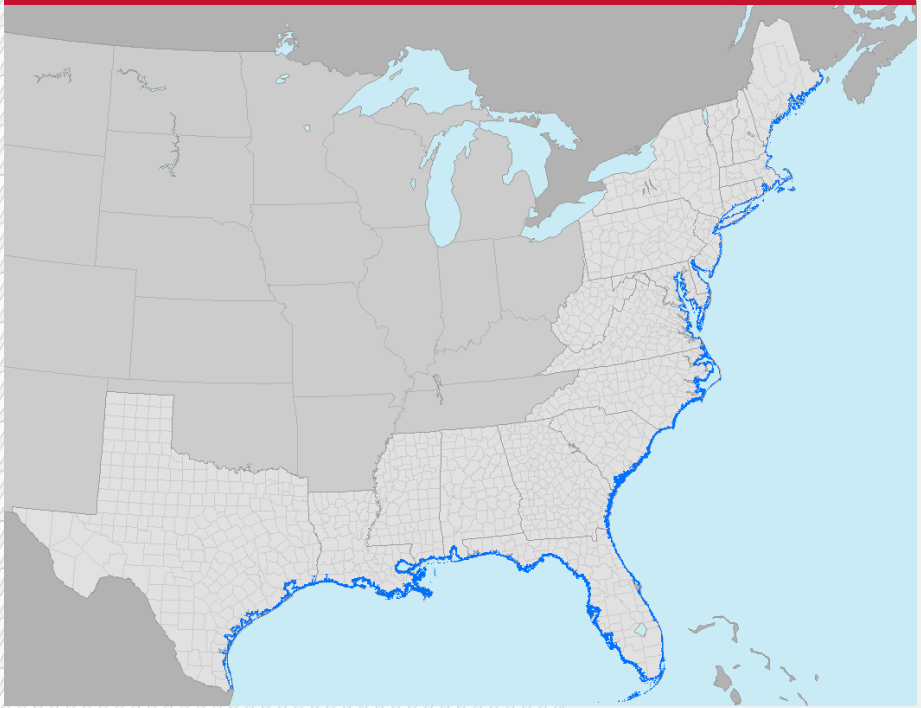
- Very high resolution input data
- Ability to model complex flows of water in and out of **bays** and **harbors**
- Manage and underwrite coastal flood risk with confidence, down to the **local level**

Detailed bathymetry and coastal topography: Southern Louisiana



ABLE TO MODEL REALISTIC COASTAL FLOODING

Previous model extent (parametric model)



Current model extent (full hydrodynamic model)

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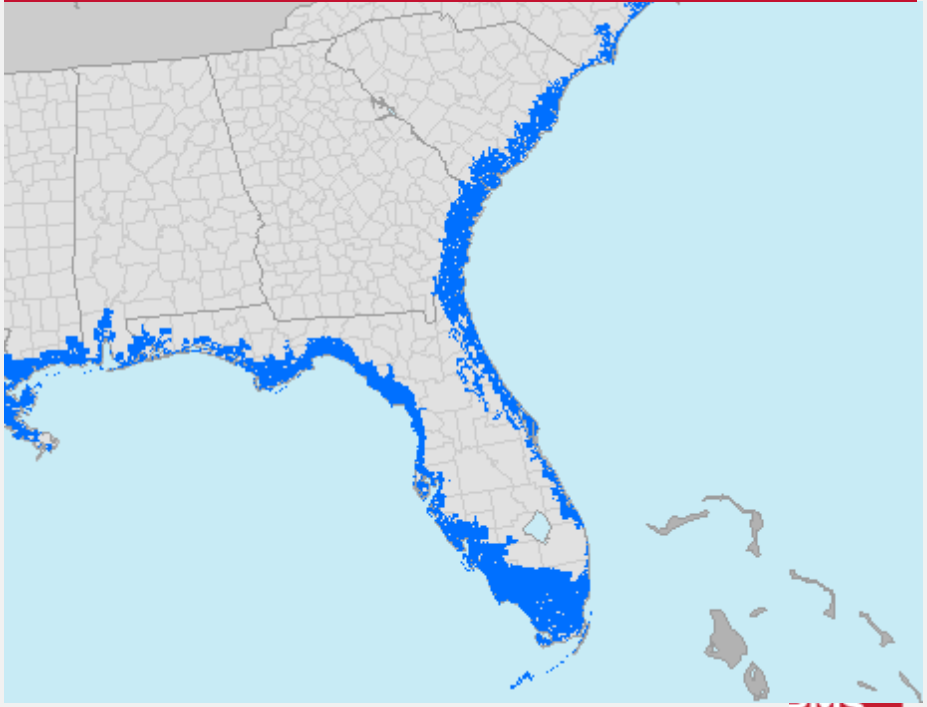
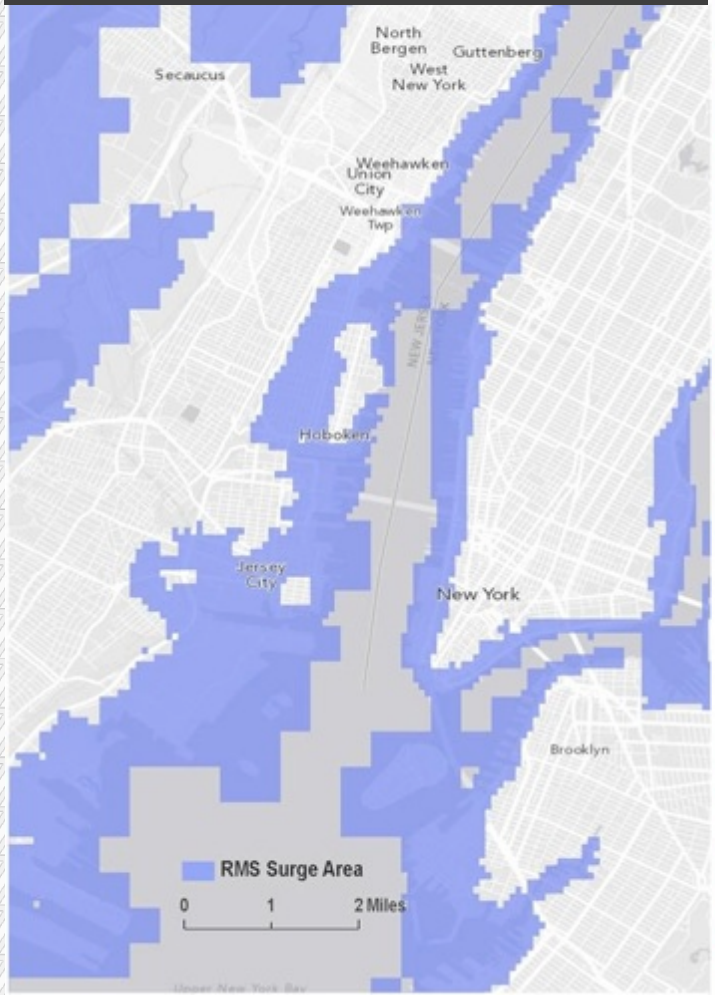


WELL VALIDATED DURING SANDY

- RMS model as good as best data developed by FEMA

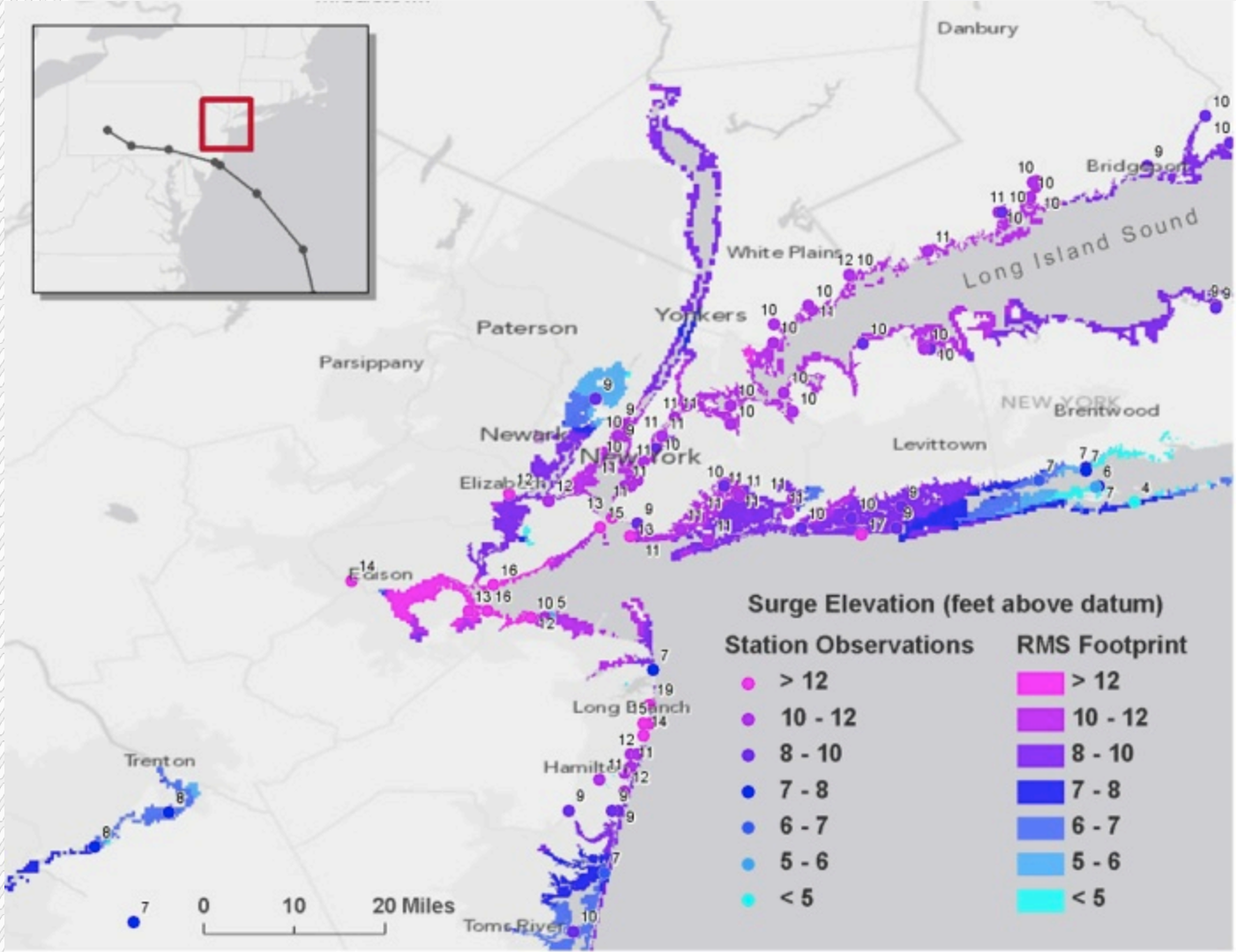
RMS Storm Surge Model



FEMA Flood Extent

WELL VALIDATED DURING SANDY

- Verified against over 200 independent flood observations



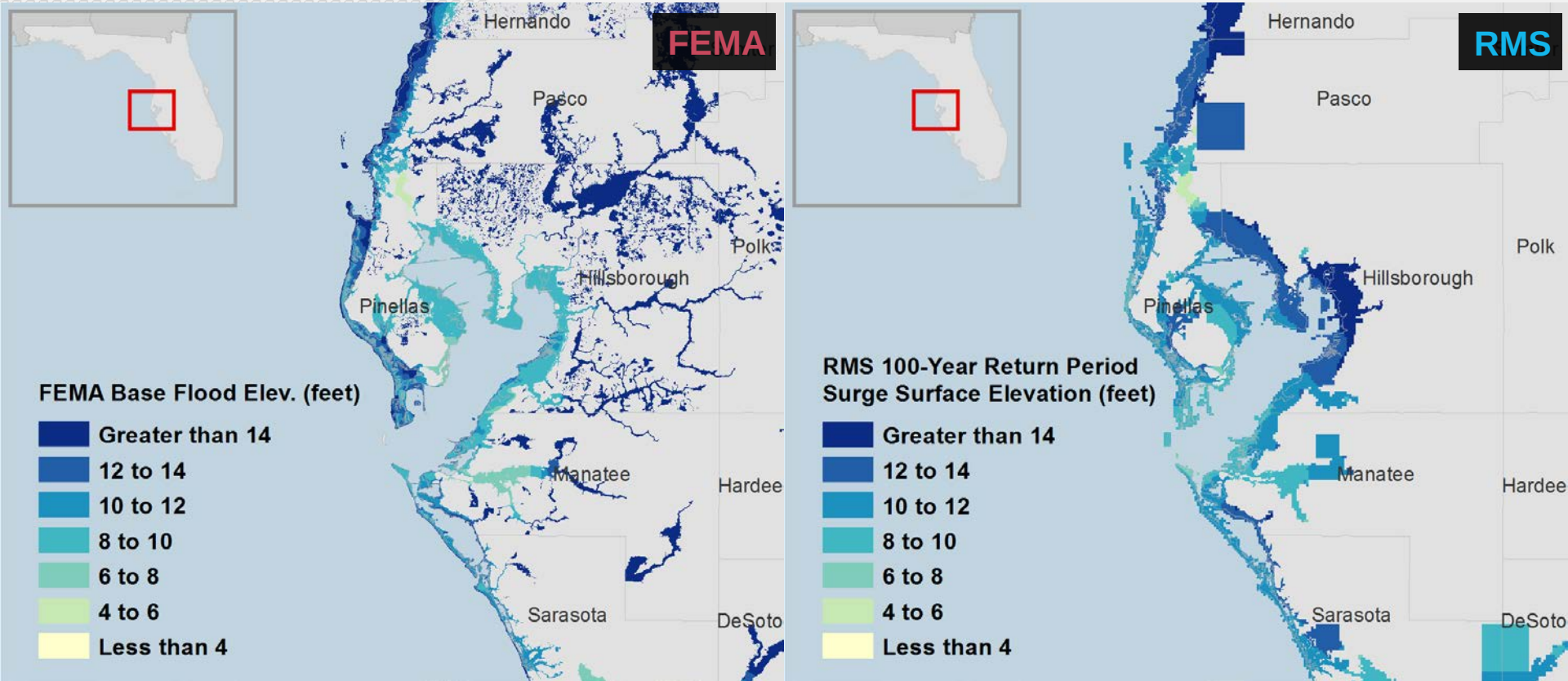
LESSONS LEARNED FROM SANDY

- High-value contents in basements within central business district took many by surprise
- Highlighted gaps in data capture, limited exposure information


where does this leave us now?
High quality, well-verified model for driver of U.S. flood loss
Viable alternate view of risk from FEMA for coastal flood, available now

COASTAL FLOOD VIEW ALREADY AVAILABLE

100-YEAR FLOOD ELEVATION: FEMA VERSUS RMS



Completing the U.S. Flood solution

GOAL:

Develop modeling solution covering all sources of flooding in US

- ❑ Tropical Cyclone Surge
- ❑ Tropical Cyclone Precipitation
- ❑ Non-Tropical Cyclone Precipitation

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- ✓ Tropical Cyclone Surge
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Suite of US Flood products:

- ✓ Storm Surge within Hurricane Model
- ❑ US Flood Hazard Data Product
- ❑ US Flood HD Model

coming soon!

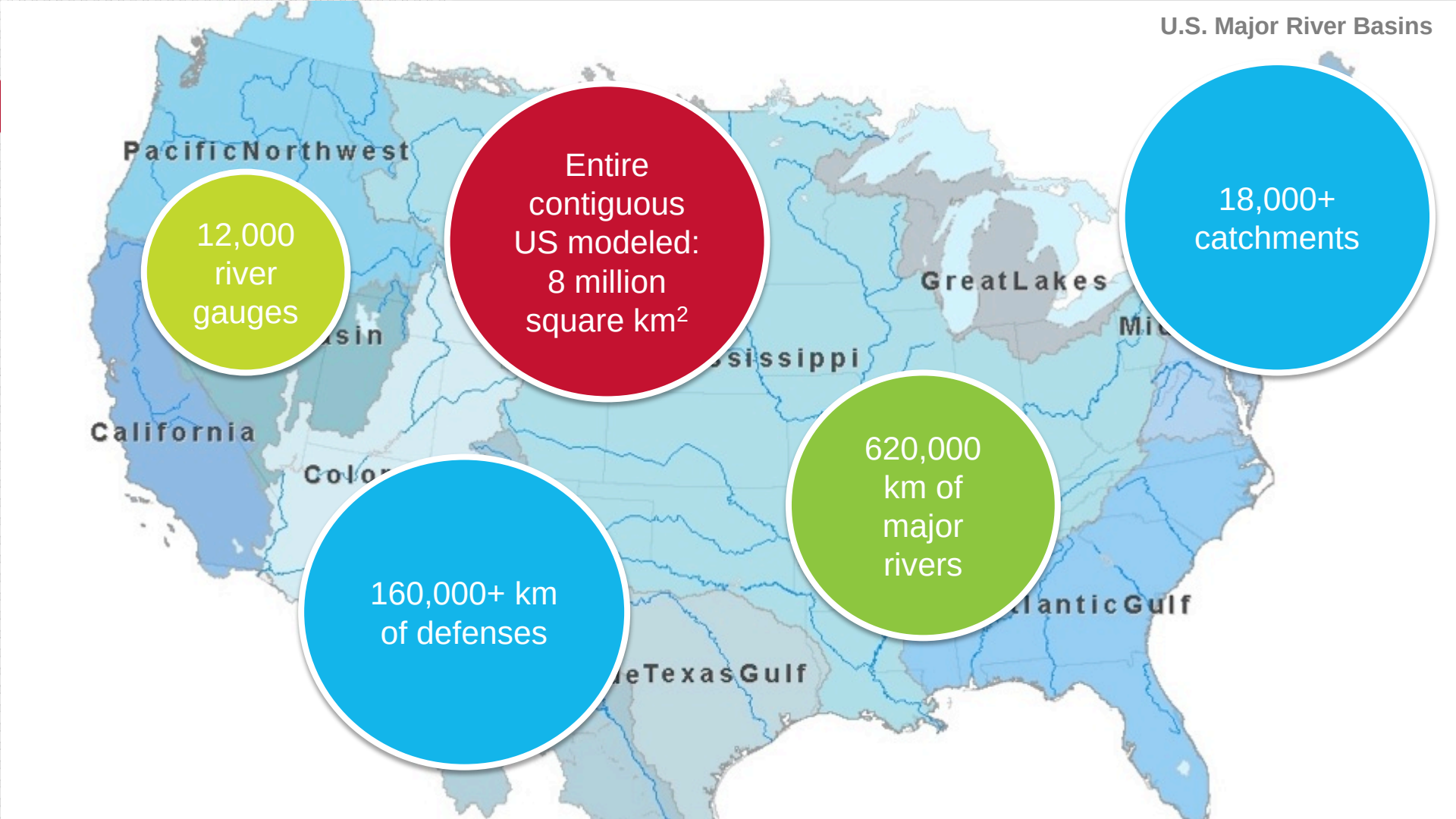
New US Inland Flood model

precipitation-driven, all sources

on- and off-floodplain flooding

antecedent conditions

delivered on RMS(one)


U.S. Major River Basins
PacificNorthwest
GreatLakes
California
12,000 river gauges
Entire contiguous US modeled: 8 million square km²
18,000+ catchments
620,000 km of major rivers
160,000+ km of defenses

LARGEST MODEL EVER BUILT

Number of grid cells in
US **Storm Surge** Model

32 Mn

Number of grid cells in
US **Inland Flood** Model

5.7 Bn

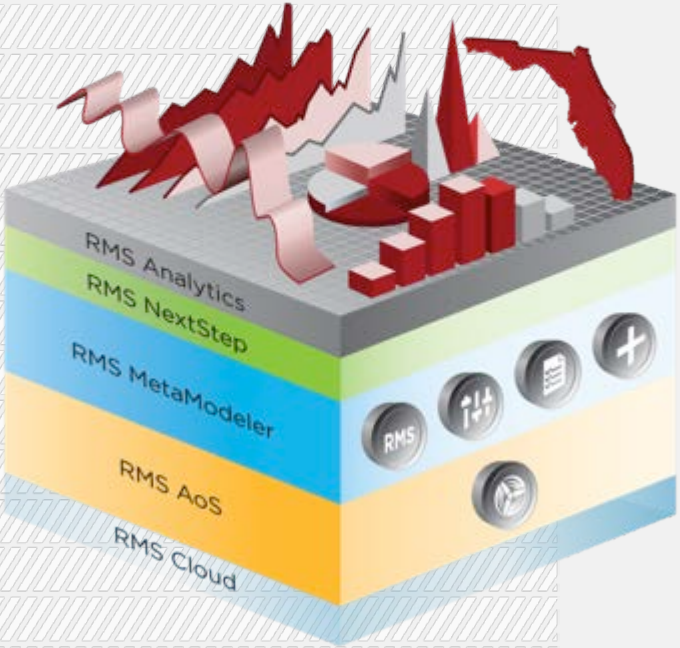
WHY NOW?

Not computationally possible previously

We’re able to do it now because:

- Migrated heavy processing from conventional CPUs to GPUs – gain of over 200x
- RMS(one) reduces storage need for client

BUILDING MODELS IN RMS(ONE)

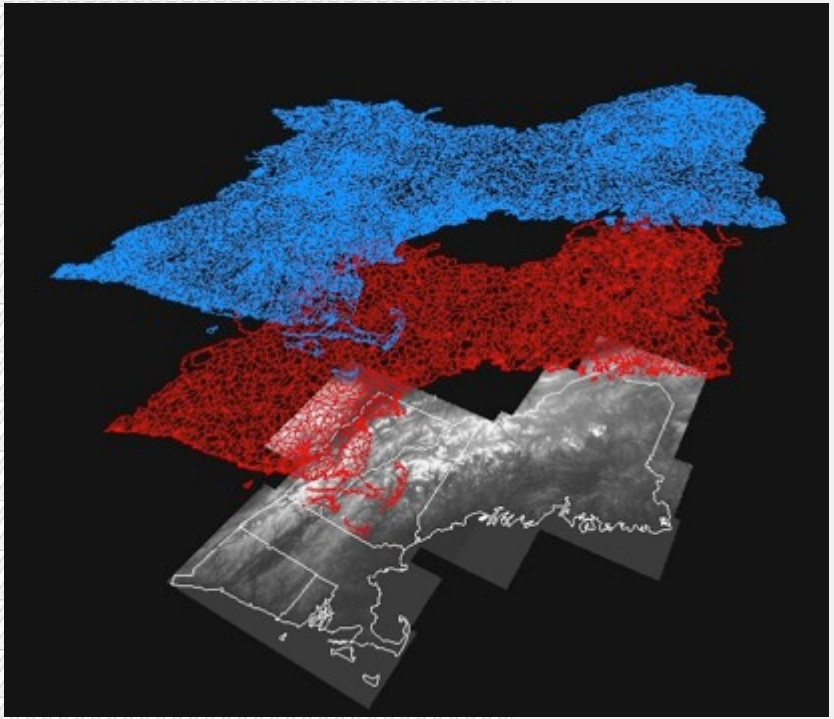


- **HD Simulation**: Allows for continuous simulation of events
  - Similar meteorological events can lead to very different hazard & loss events
    - **Antecedent conditions** strongly influence the severity of a flood
  - Able to capture clustering and correlation

- New financial model enabled by **Contract Definition Language** (CDL)
  - Properly model hours clause and complex flood policy terms

- Performance offered by the **Cloud**

HIGH QUALITY INPUT DATA

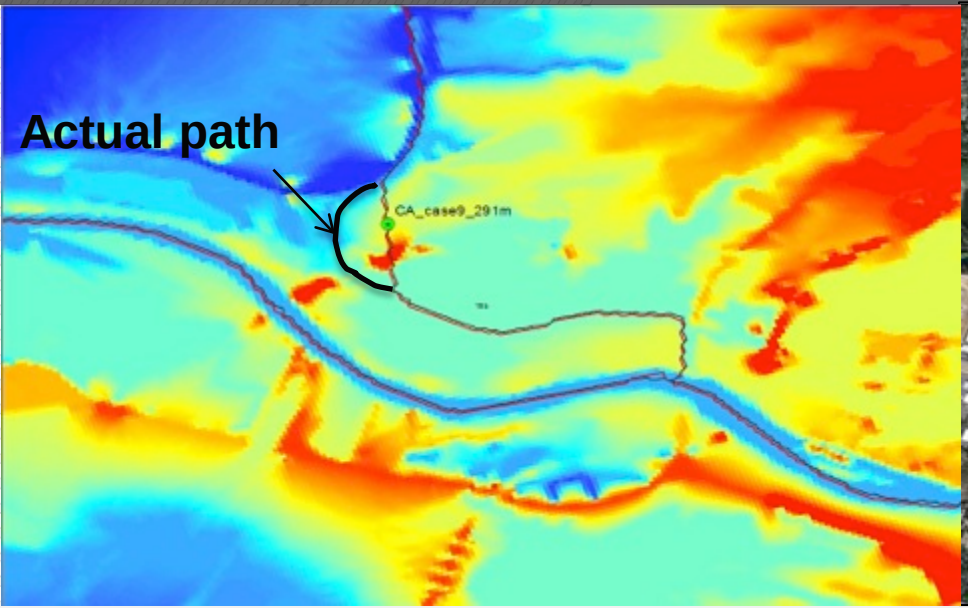


High-Quality, High-Resolution Geospatial Data is critical to flood modeling

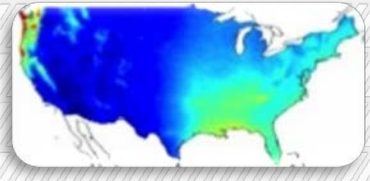
- Source resolution for elevation data improves quickly
- Using latest enhanced version of National Hydrography Dataset (NHD): **NHDPlusV2**
- RMS spent several person-years on QA of data layers
  - Fed findings back to **NHDPlus** data providers to help improve their product

EXAMPLE QA TASK

By comparing with Google Earth, corrected misplaced river segment in elevation dataset



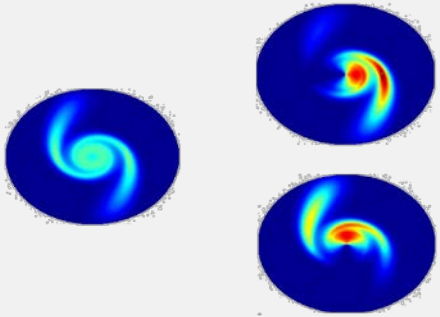
HAZARD SIMULATION APPROACH



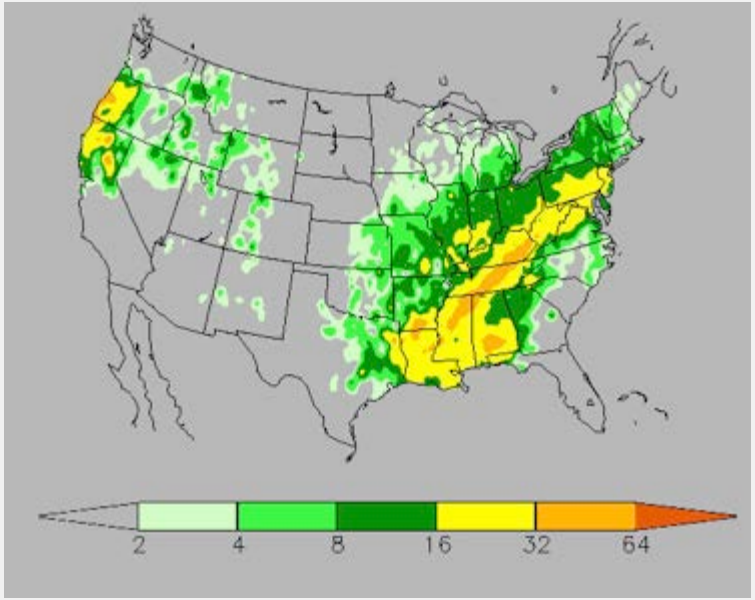
Precipitation

Simulate the source of the flooding: tropical cyclone and non-tropical cyclone

Tropical Cyclone Precipitation

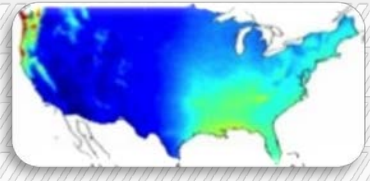


Non-Tropical Cyclone Precipitation



Source: cpc.ncep.noaa.gov

HAZARD SIMULATION APPROACH



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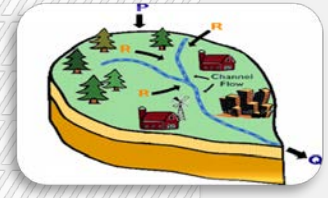


Rainfall Runoff

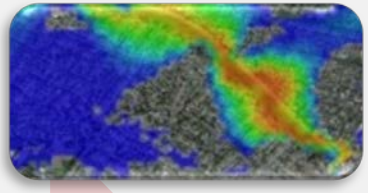
Understand how rainfall enters the water systems

Routing

Propagate the water through major and minor river systems

Defense

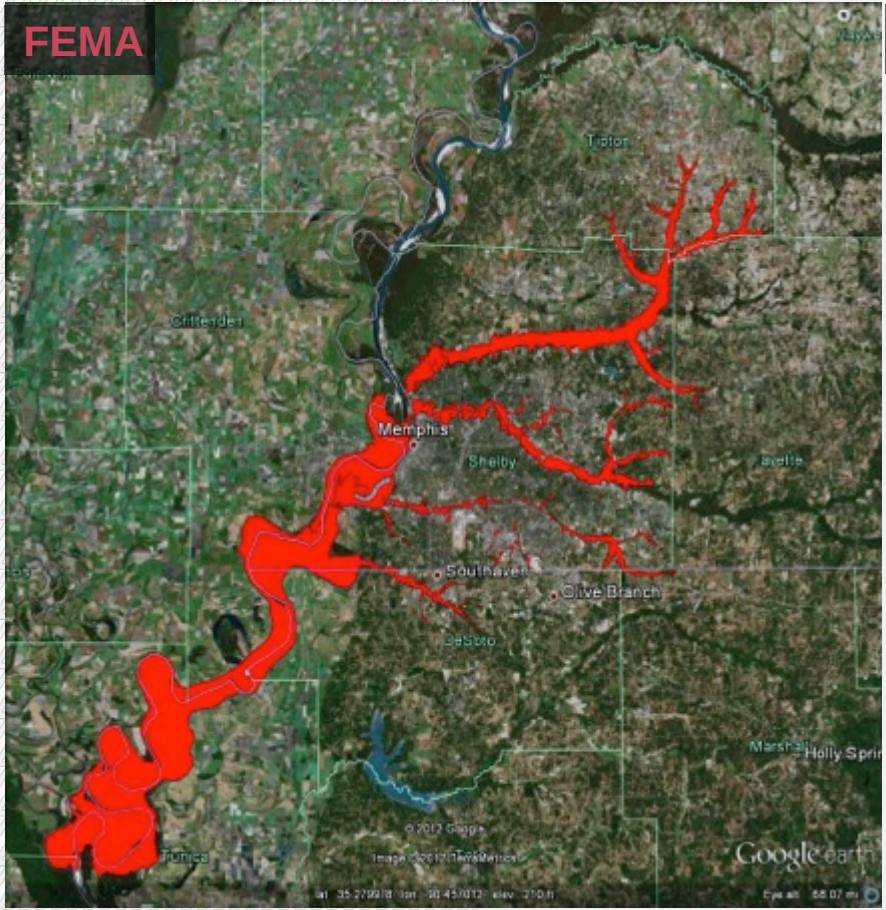
Account for mitigation measures and possibility of flood defense failures

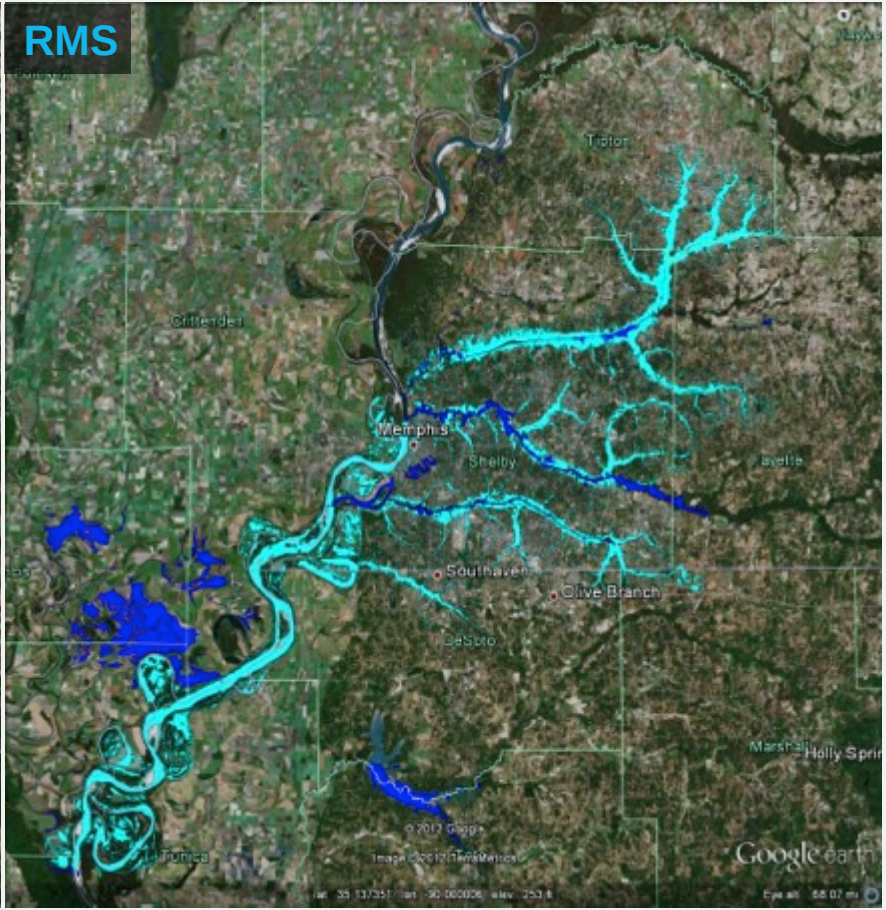


Inundation

Form a footprint of saturation and flooding

Comparison of 100 year model hazard with FEMA maps - Memphis, TN



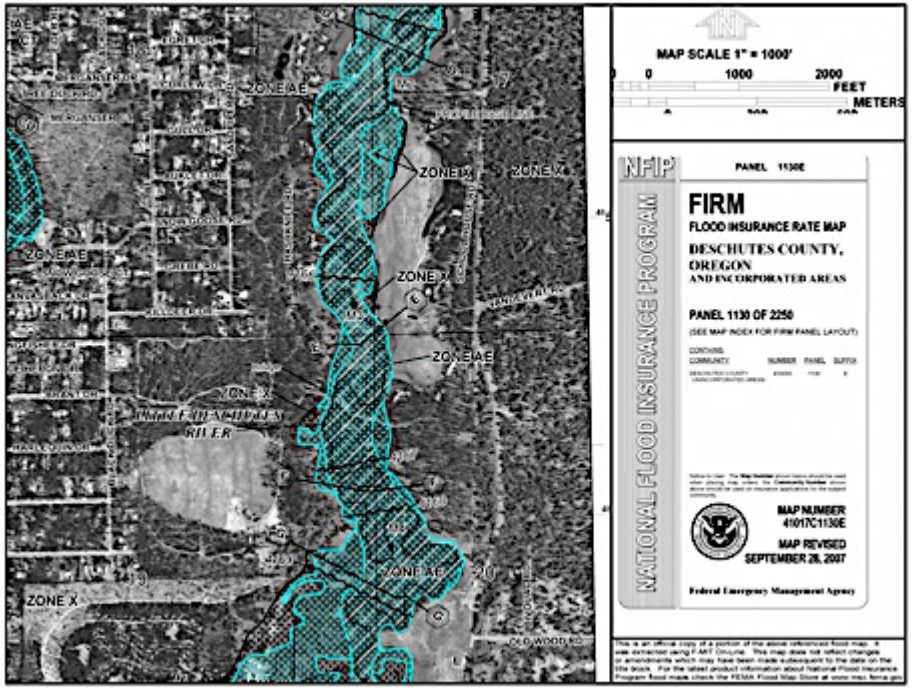


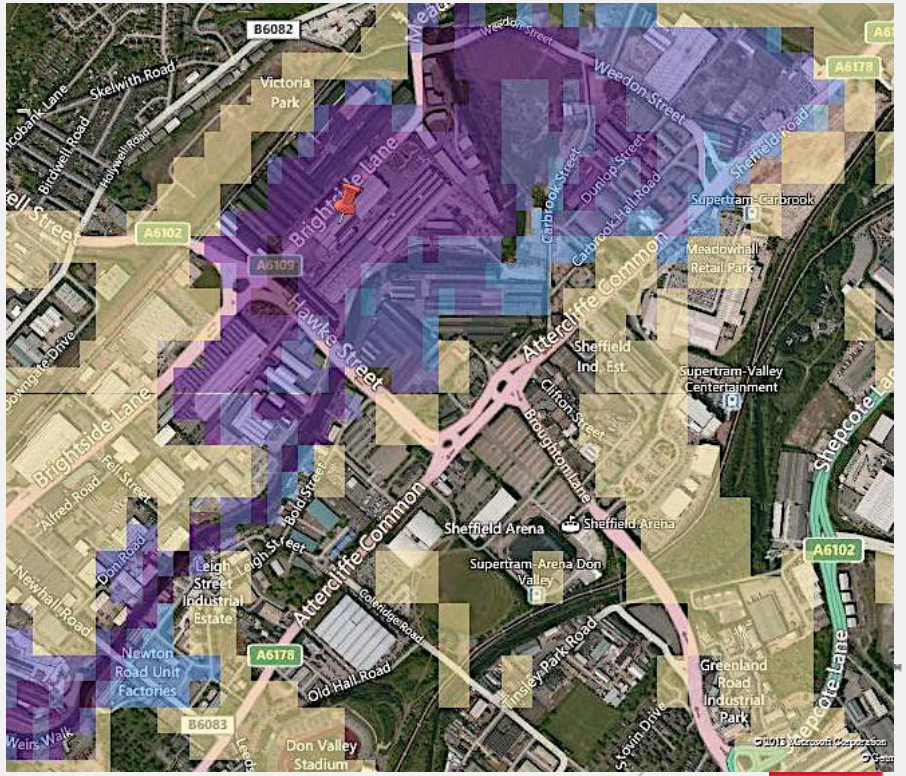
RMS FLOOD HAZARD DATA PRODUCT

Coming soon!

- Coverage: 48 states & District of Columbia
- All sources of flooding:
  - Coastal flooding from storm surge
  - Tropical cyclone precipitation
  - Non-tropical cyclone precipitation
- Return periods:
  - Multiple return periods, 20 years to 1000 years
  - Catchments by hydrological regions
- RMS(one) functionality:
  - Location-level underwriting, flood zone lookup frequency and severity with return period and flood depth
  - Accumulation management
  - Flood hazard visualization

RMS VS. FEMA: COMPARABLE BUT DIFFERENT





RMS VS. FEMA: COMPARABLE BUT DIFFERENT

Return Period (years)	FEMA FIRMs		RMS Hazard Data Product	
	Flood Extent	*Flood Elevation*	*Flood Extent*	*Flood Elevation*
20			✓	✓
50			✓	✓
100	✓	✓ (BFEs)	✓	✓
250			✓	✓
500	✓		✓	✓
1000			✓	✓

RMS VS. FEMA: COMPARABLE BUT DIFFERENT

Component	FEMA FIRMs	RMS Hazard Data Product
Mapping methodology	Varies by region	Consistent for entire lower 48 states
Geospatial data vintage (e.g., elevation)	Varies by region	Current
Update frequency	Varies by region, sometimes > 20 years	Can incorporate changes quickly
Correlation with other perils	n/a	Uses same event set as RMS North Atlantic Hurricane model


NFIP reform will happen, eventually
Can the private market take on more of the US flood risk?
Where have we been?
Where are we now?
What's changed?
What's coming?
Modeling tools already exist…
…and more are coming