Evolution of Flood Modeling: Is the U.S. Ready?
AIR Inland Flood Model for the US

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Agenda

- Defining flood events
- Why is AIR developing a US Flood Model?
- History of flood modeling at AIR
- AIR’s approach to modeling flood risk for the US

Defining Floods Events

- A **flood** is an overflow of an expanse of water that submerges land
- Floods can take many different forms
  - Coastal flooding/storm surge is caused by wind driven seas inundating low lying areas
  - **Inland flooding** is caused when a combination of precipitation and snow melt overtop river banks
  - Tsunami flooding results from ocean waves produced by earthquakes or underwater landslides

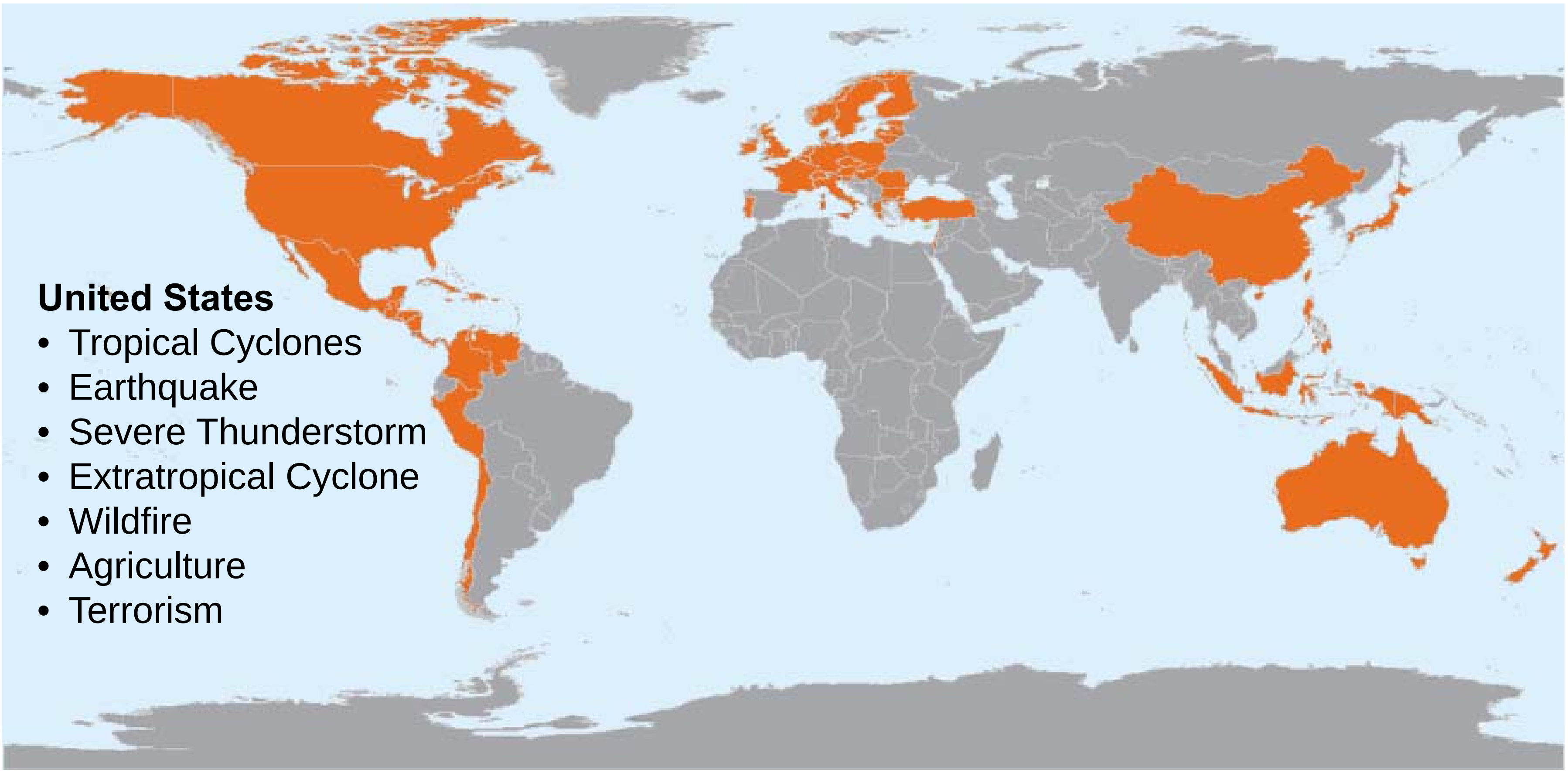


Why Is AIR Developing a US Flood Model?

- ✓ Have the most complete set of modeling capabilities to commercial carriers in the industry
- Floods are one of the most costly natural disasters in the US, causing an average of **$5 billion** in damages each year*
- In the US, about **3,800** towns and cities (of more than 2,500 inhabitants) are on floodplains*
- Despite the advances in flood science and hazard reduction policies, damage from flooding continues to escalate
- *FEMA is doing a good job with Flood Insurance Rate Maps; flood mapping is part of the risk analysis but not the entire story. We would like to provide a portfolio analysis tool and the full EP curve.*

**Source: "Large Floods in the United States Where They Happen and Why", USGS*

AIR Catastrophe Models Provide Global Catastrophe Coverage



United States

- Tropical Cyclones
- Earthquake
- Severe Thunderstorm
- Extratropical Cyclone
- Wildfire
- Agriculture
- Terrorism

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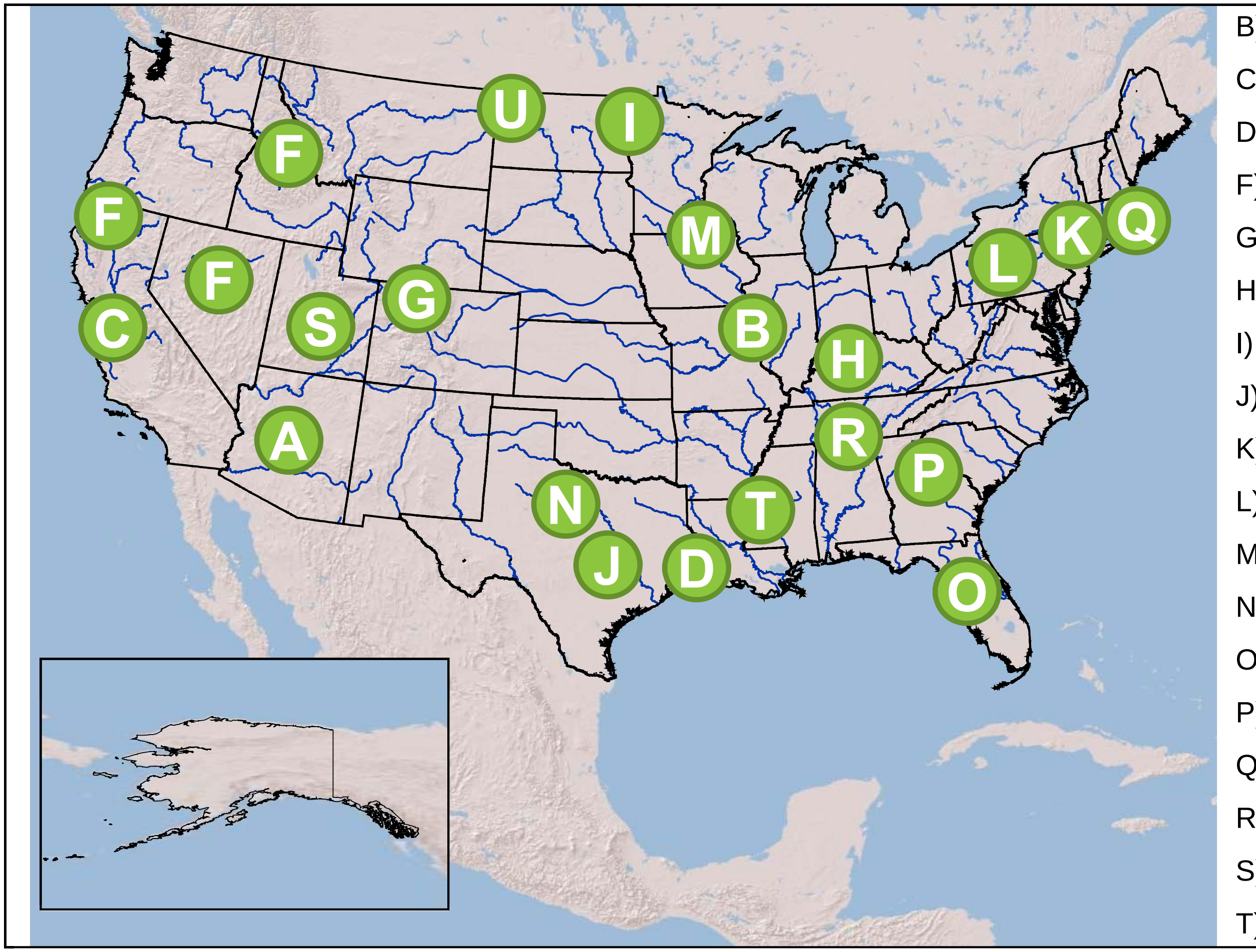
Extreme Riverine Flood Events in the US from 1993-to Present



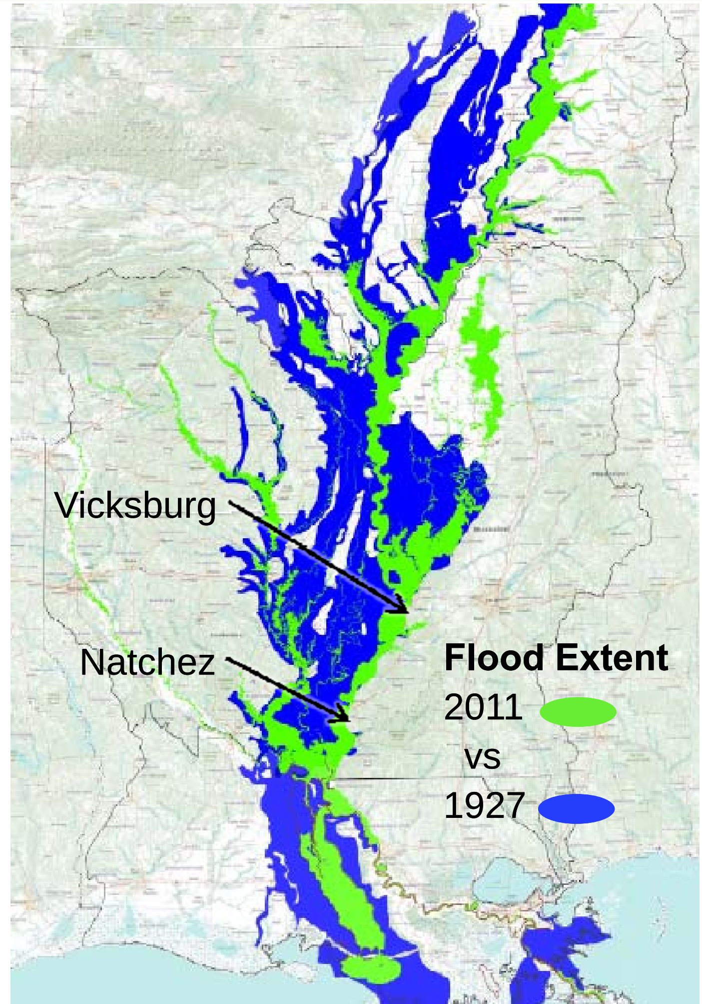
A) Gila, Salt and Santa Cruz Rivers, 1993 ($400M)
B) The Great Flood, of 1993 ($25B)
C) California Flood, 1995 ($3B)
D) Golf Coast Flooding , 1995 ($5.5B)
F) Pacific Northwest, 1996-97 ($6B)
G) Colorado Flood, 1997 ($500M)
H) Ohio Floods, 1997 ($500M)
I) Red River Flood, 1997 ($2B)
J) Texas Flood, 1998 ($1.3B)
K) Mid Atlantic Flood, 2005 ($30M)
L) Northeast Flood, 2006 ($1B)
M) Midwest Flooding, 2008 ($15B)
N) Texas Flood, 2009 ($166M)
O) Florida,2009 ($55M)
P) Southeast Floods, 2009 ($500M)
Q) Rhode Island Flooding, 2010 ($1.5B)
R) Tennessee Flooding, 2010 ($2.3B)
S) Utah Flood, 2010 ($1M)
T) Lower Mississippi River Flood, 2011 ($7.5B)
U) North Dakota Flood , 2011 ($2B)

Source: National Weather Service

The 2011 Mississippi River Flood Is a Reminder of the Flood Risk in the United States

- Peak streamflow 66,000 m^3s^{-1} (100 – 300 year return period)
- Record stream gage heights in Natchez and Vicksburg, MS
- Large portion of economic loss due to deliberate flooding by Army Corps
- Continuing improvements to flood defenses and Corps intervention prevented greater disaster

Event Name	Month-Year	Total Economic Loss (USD- Event Year)
The Great Flood	Spring 1993	25,000,000,000
Mid West Flooding	June 2008	15,000,000,000
Mississippi River	**Spring 2011**	**7,500,000,000**
Pacific Norwest	1996-97	6,000,000,000
California Flood	January 1995	3,000,000,000
Tennesse Flooding	May 2010	2,300,000,000
Southern New England Flood	March 2010	1,500,000,000



Source: Mississippi Valley Division, U.S. Army Corps of Engineers

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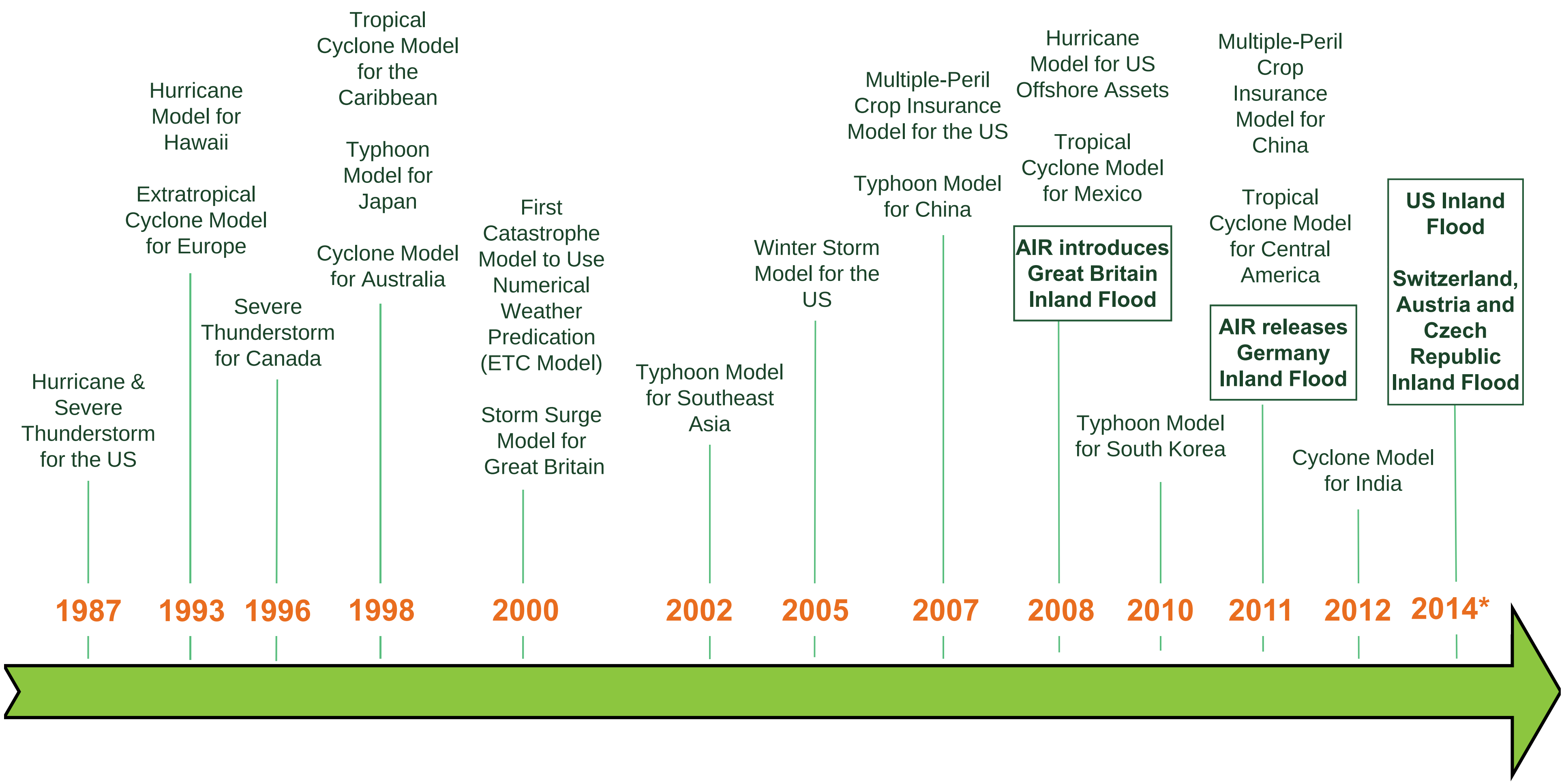
AIR Has a Long History of Flood Modeling, But More Recently Is Releasing Explicit Inland Flood Models



Top Ten Insured Fresh Water Floods Since 1993

Country	Date	Insured Losses (M USD) At 2011 prices
Thailand	Jul-Nov 2011	12,000
Germany & *Czech Republic*	Aug 2002	2,900
United Kingdom	Jun 2007	2,700
Switzerland	Aug 2005	2,400
Australia	Jan 2011	2,300
Poland & *Czech Republic*	Jul-Aug 1997	2,200
Australia	Dec 2010	2,100
United Kingdom	Jul 2007	2,000
United States	Apr 1993	1,900
United States	Jun - Aug 1993	1,600

Source: Swiss Re 2012

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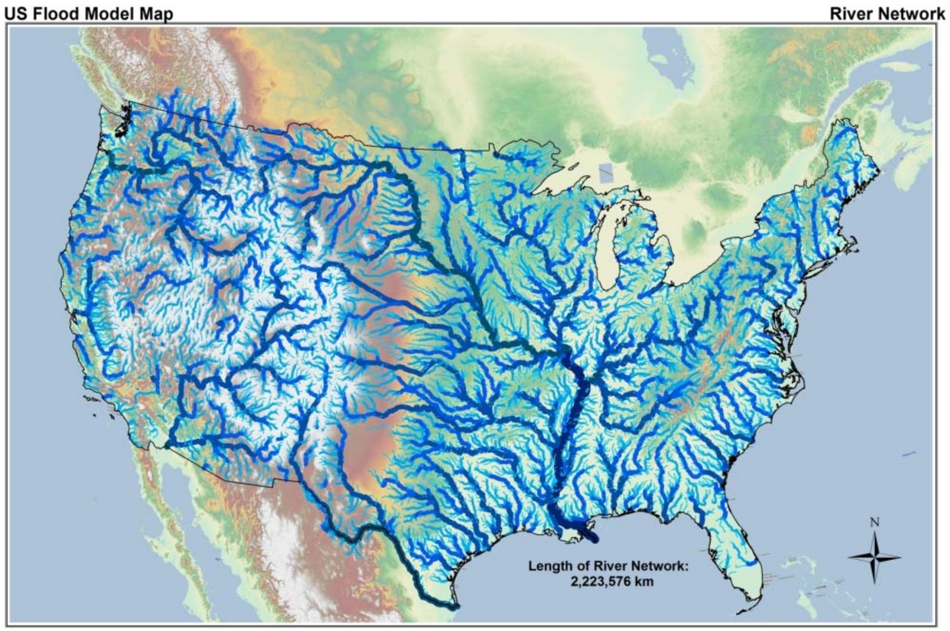
Overview of the AIR Inland Flood Model for the US

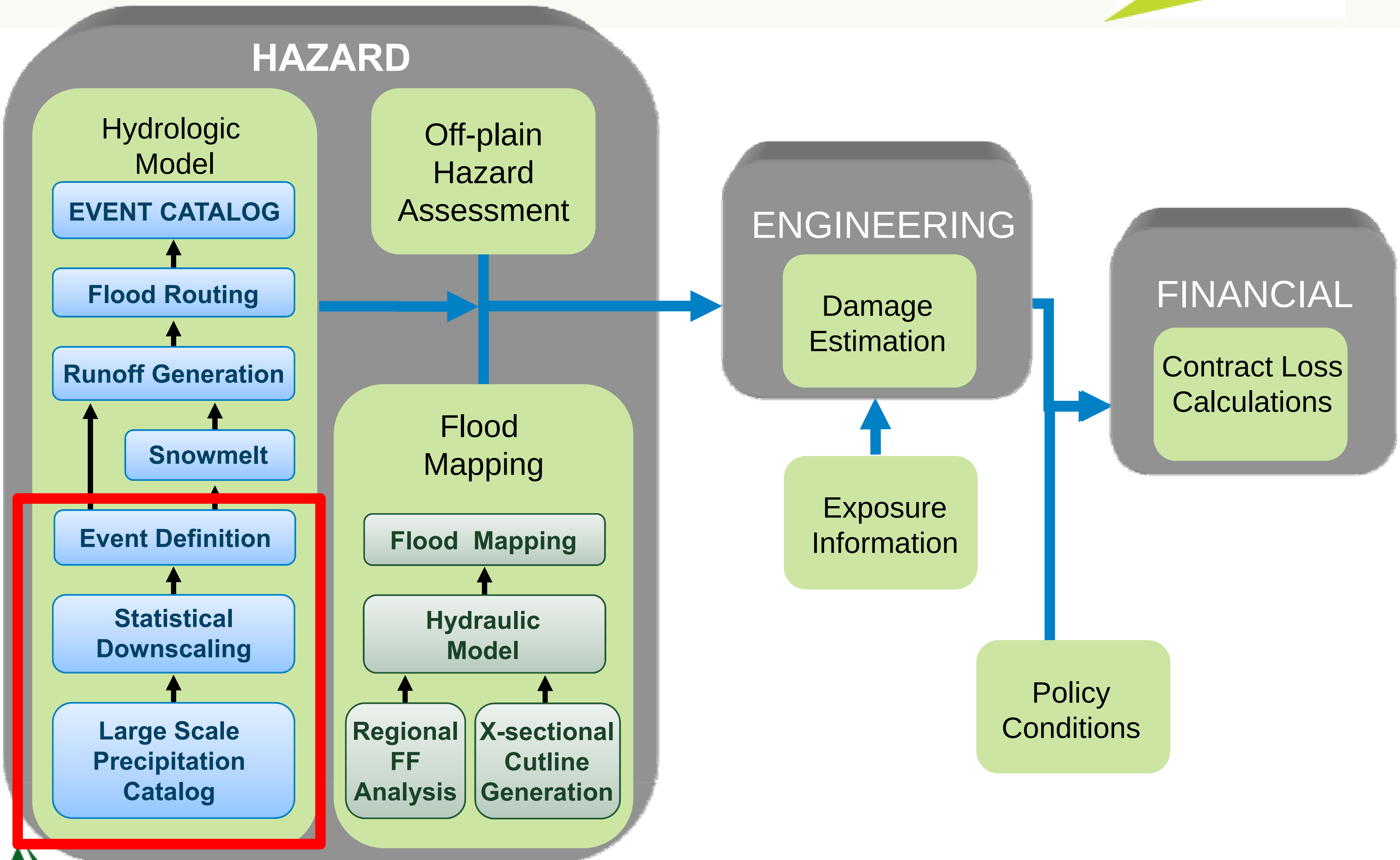
- The AIR Inland Flood Model for the US is a **fully stochastic, event-based** flood model, designed for portfolio risk management
- The model covers the effects of precipitation-induced flooding to properties, for both **on- and off-floodplain** locations
- The model captures all of the complexities inherent in a flood generation process, such as the space-time patterns of rainfall, topography, soil type, snowmelt, and man-made flood defenses
- For the purposes of local intensity and loss estimation, the model features a **physically-based hydraulic modeling** of detailed river networks

Hydraulic Model for US Flood Covers More Than 2,000,000 Kilometers of River Network



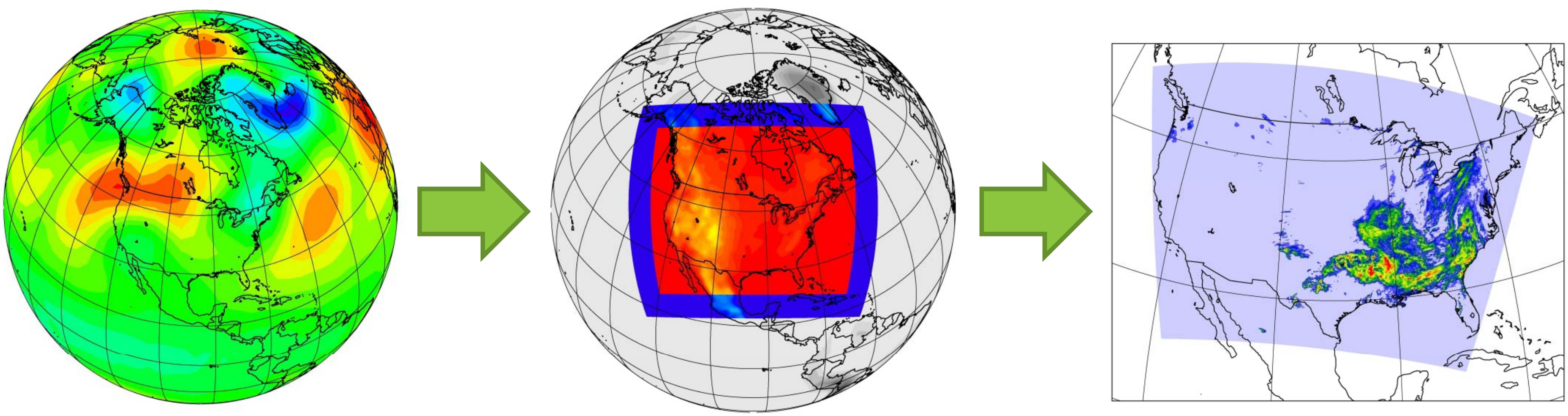
- 18 hydrologic regions
- 7,600,000 km^2 of drainage area
- 2,230,000 km of total streams
- Every stream draining 10 sq. km or more
- About 4,000 rated river gauges used for calibration
- Over 4,000,000 river cross-sections, roughly spaced every 500 m
- 30-m NED DTM used for flood depth estimation

Model Framework Must Incorporate Hydrologic and Hydraulic Components to Realistically Simulate Floods

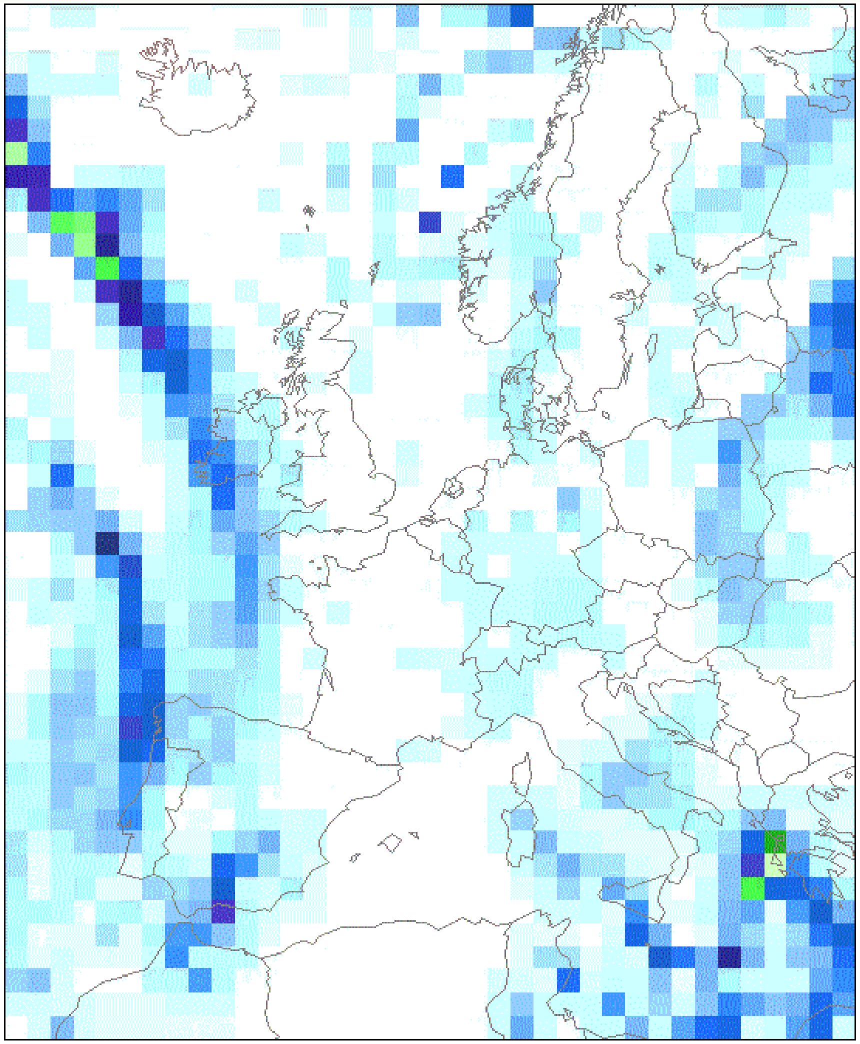


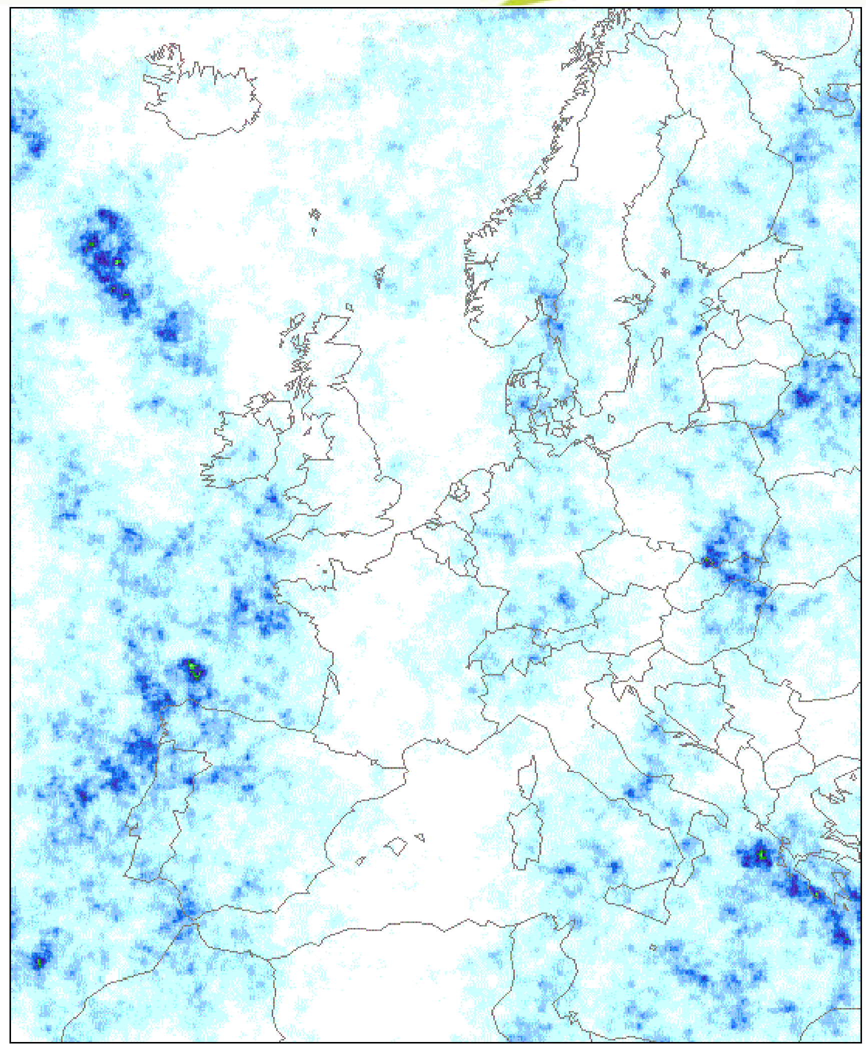
AIR's Innovative Solution to Large Scale Precipitation Simulation: Coupling GCM and NWP Models

1. Couple Global Circulation Models (GCM) at global scale with a mesoscale Numerical Weather Prediction (NWP) models at regional scale to provide coherent large-scale patterns
2. Employ sophisticated downscaling techniques to realistically simulate small scale features
3. Utilize "quantile mapping" to preserve local rainfall statistics



AIR's Advanced Downscaling Approach Yields Realistic Looking Precipitation Patterns





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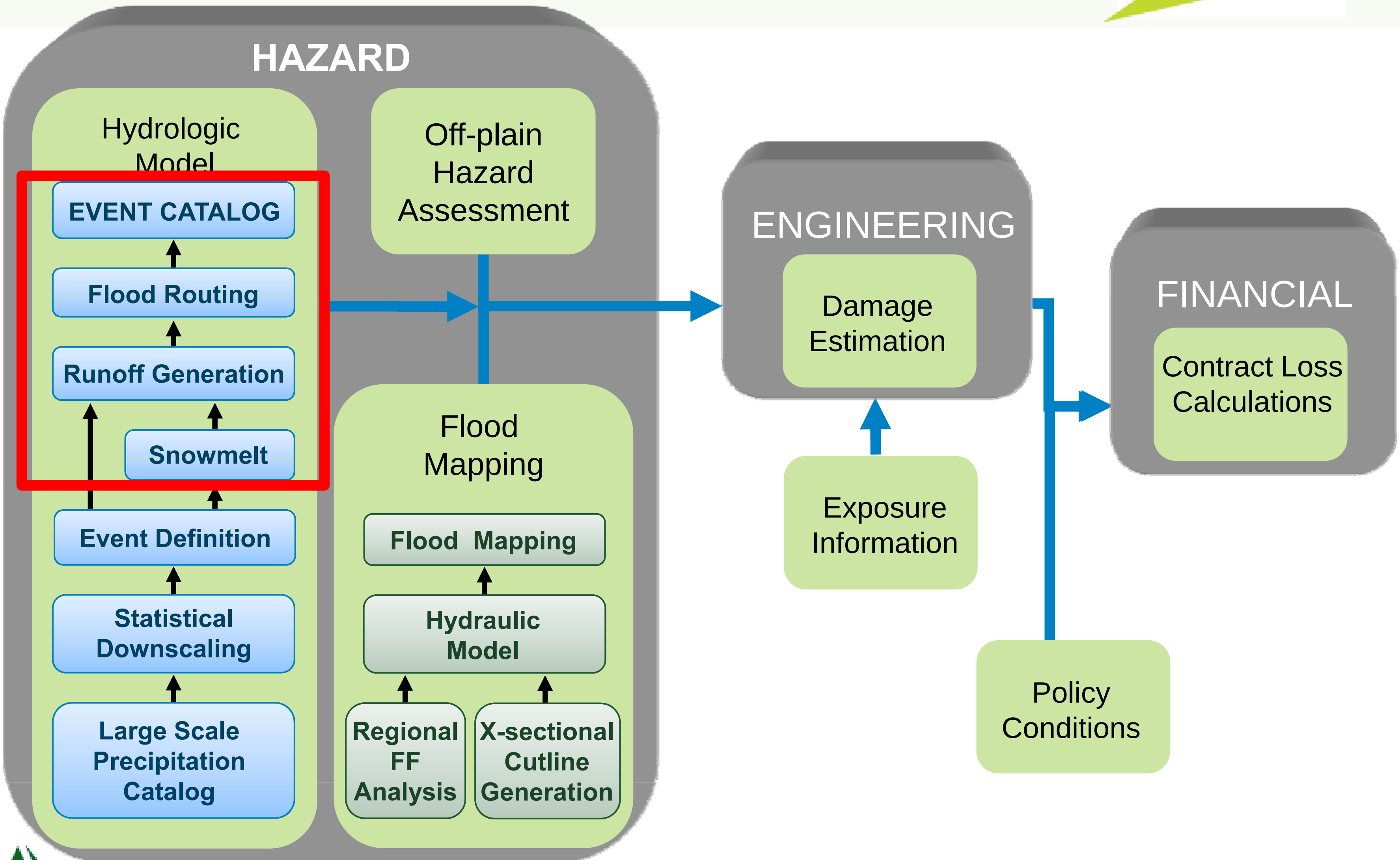
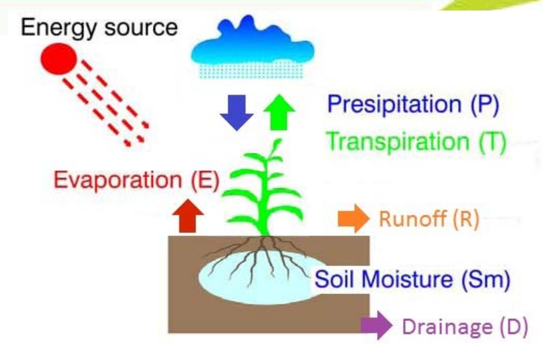
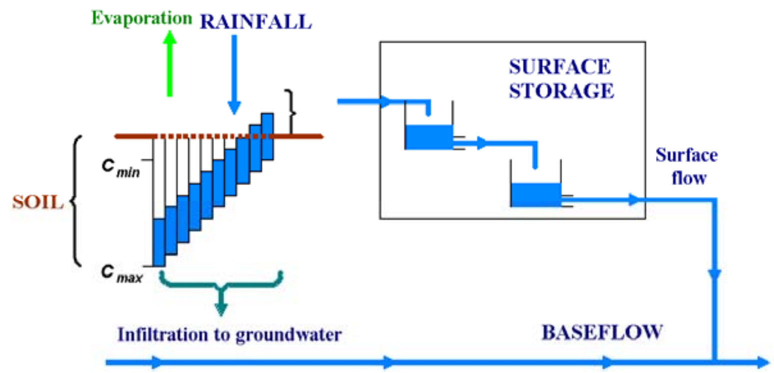


AIR Uses a Well Established Approach for Its Runoff Generation Module

- A **continuous water balance** accounts for the antecedent conditions at the beginning of each storm
- Incorporates a **nonlinear runoff generation** approach to better account for soil saturation over time
- The model accounts for the effect of **snowmelt** on both the runoff amount and the soil saturation





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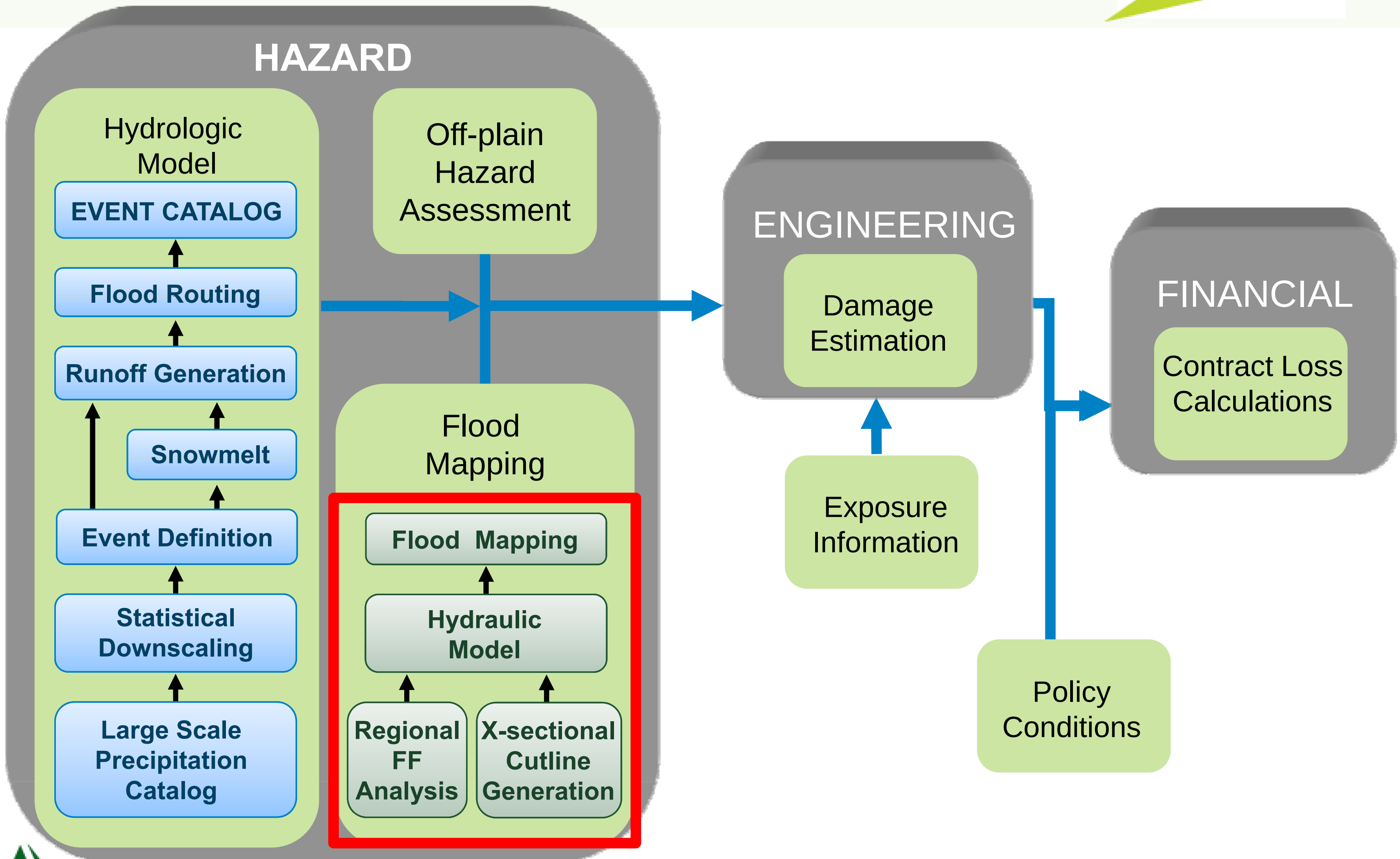
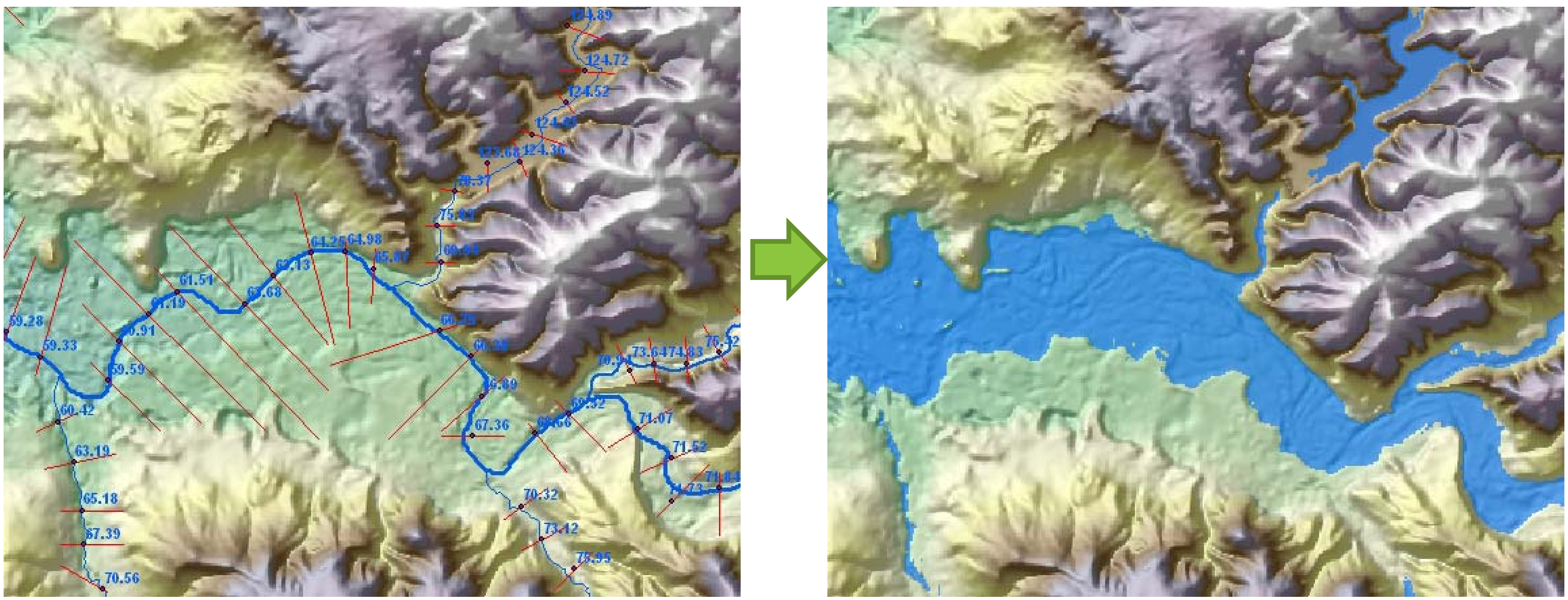
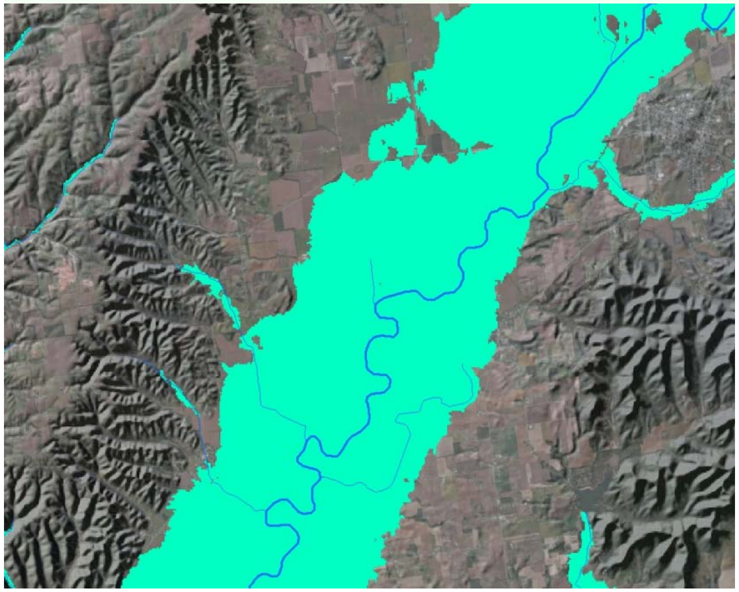


Flood Mapping Is Used to Determine Flood Extent Based on Hydraulic Model Results

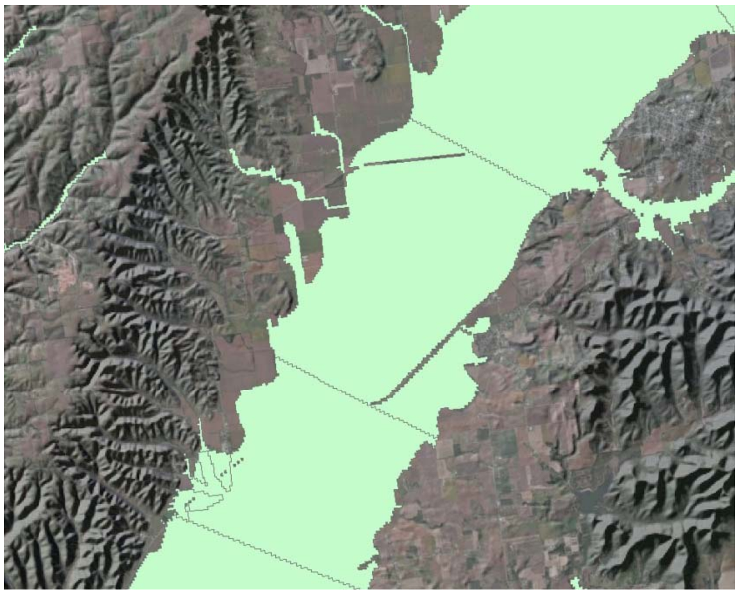
- The combination of hydraulic model with flood mapping provides a realistic flood extent
- 20 flood extent layers (2 to 10,000 year return period) are used to account for the hazard more accurately



Extent of Modeled Floods Validated with Government Produced Flood Maps Where Data Are Available

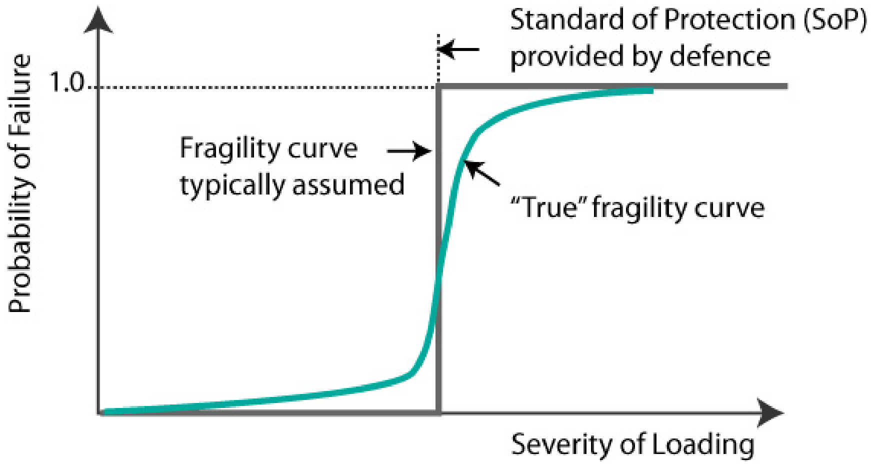


Extent of 100-year flood
(AIR model)



Extent of 100-year flood
(FIRM)

AIR Takes a Probabilistic Approach to Modeling Flood Defenses



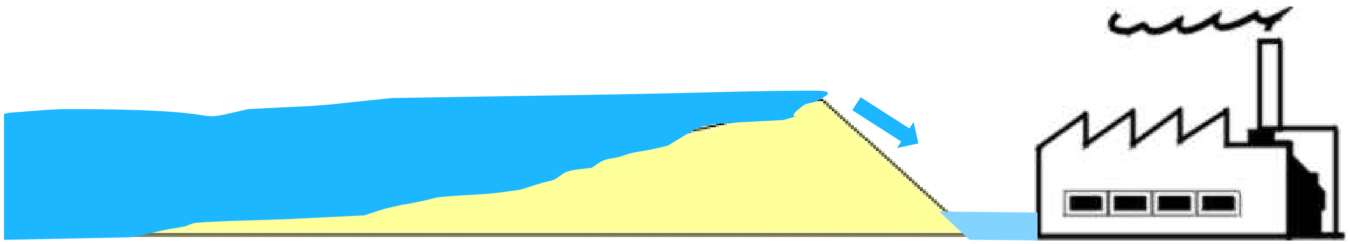
Fragility Curve

- Levee features (FEMA and USACE)
- Protected areas from USACE's (National Levee Database)
- National Flood Hazard Layer maps (FEMA)
- National Hydrologic Dataset (NHD) has some levee data
- Topographic Maps (USGS)
- Some states have levee data (CA, FL, IA, WA, AR, etc…)

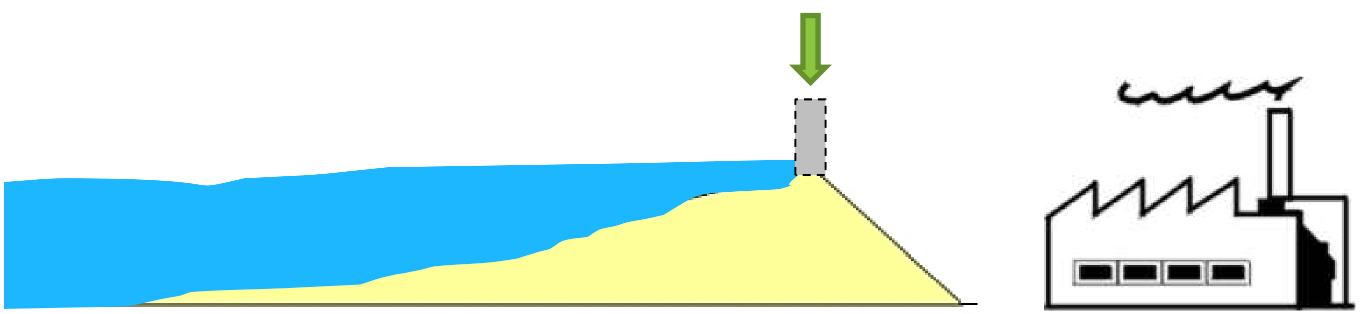
Users Can Enter a Secondary Modifier That Specifies Customized Flood Protection

The Secondary Modifier **Custom Flood Protection** enables users to set up site specific custom flood protection and mobile defenses.

Without Custom Flood Protection: Levee Overflow



Custom Flood Protection (SoP = Default SoP + additional 50 years return period)



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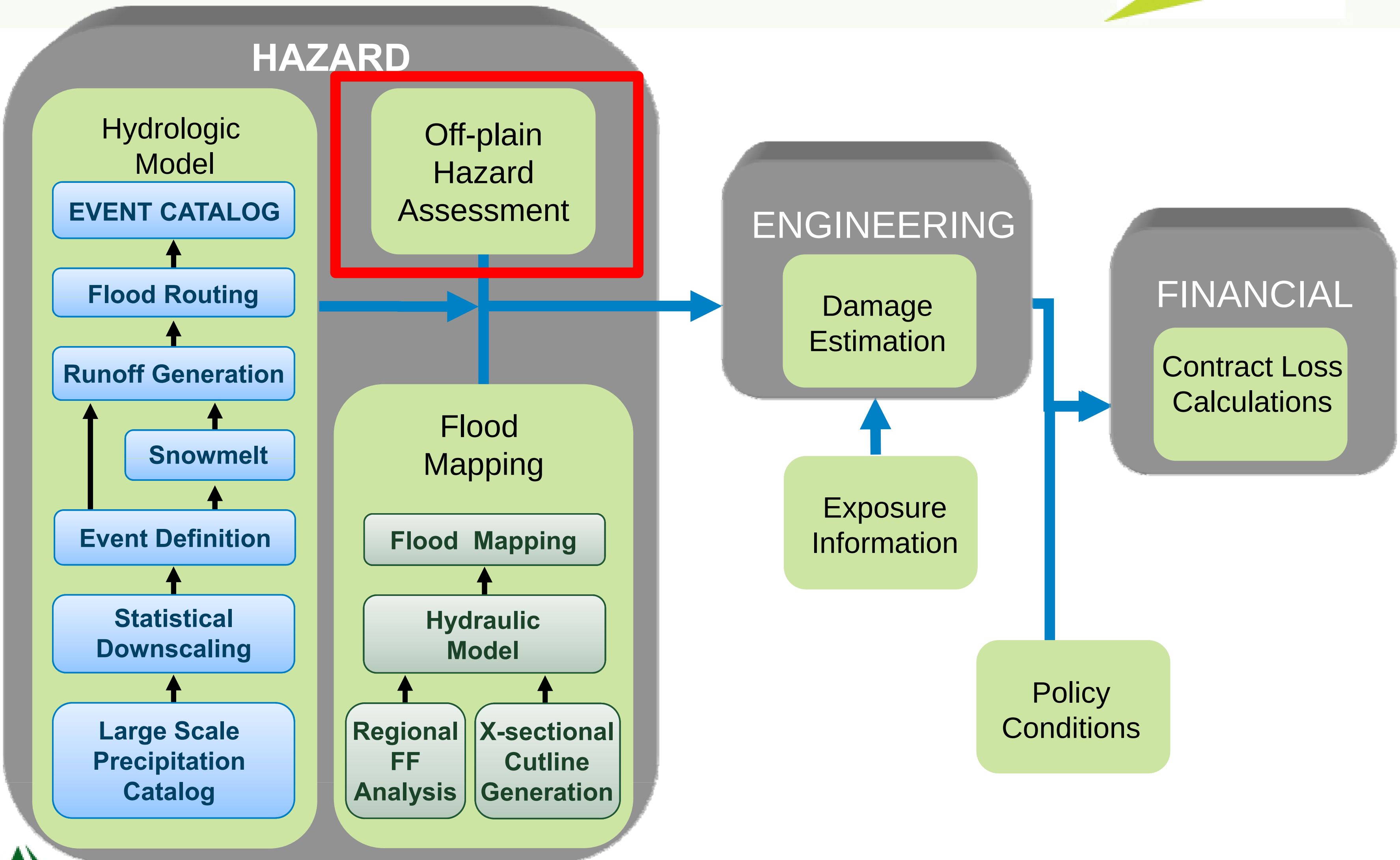
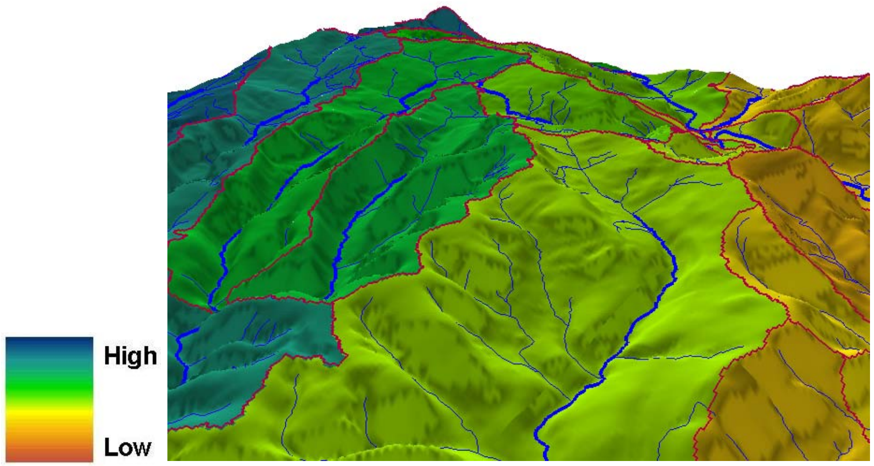
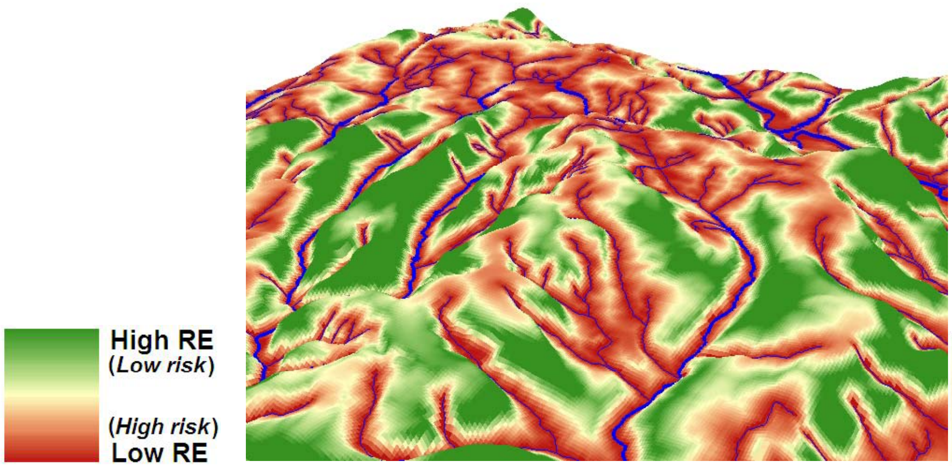


Relative Runoff Combined with Relative Elevation and Population Used to Assess the Off-Floodplain Risk

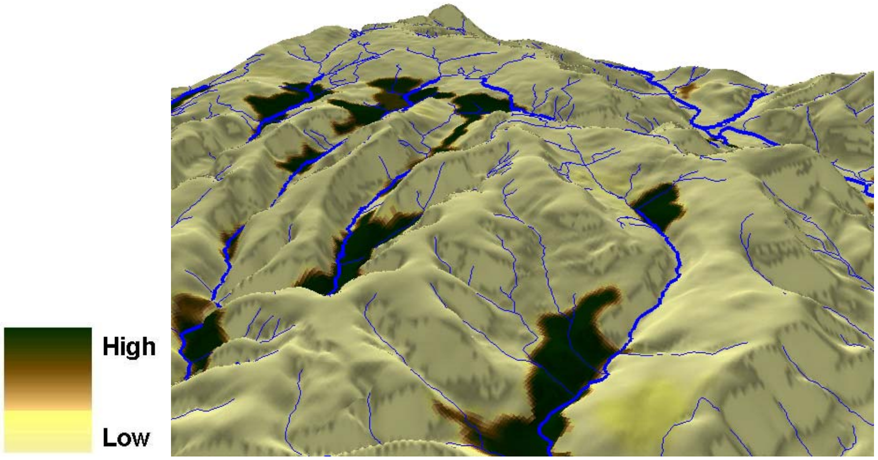
Relative Runoff



Relative Elevation



Population density



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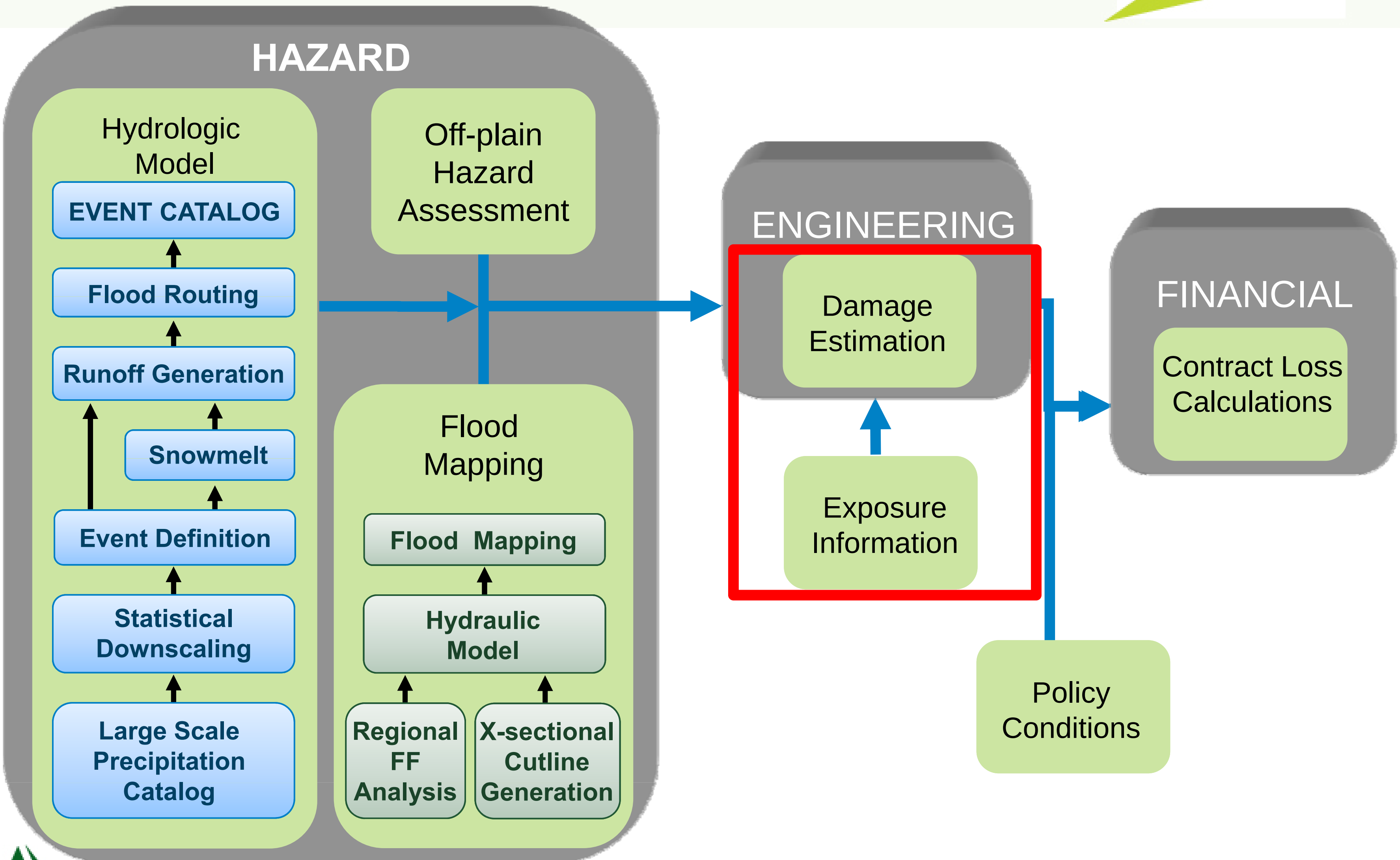


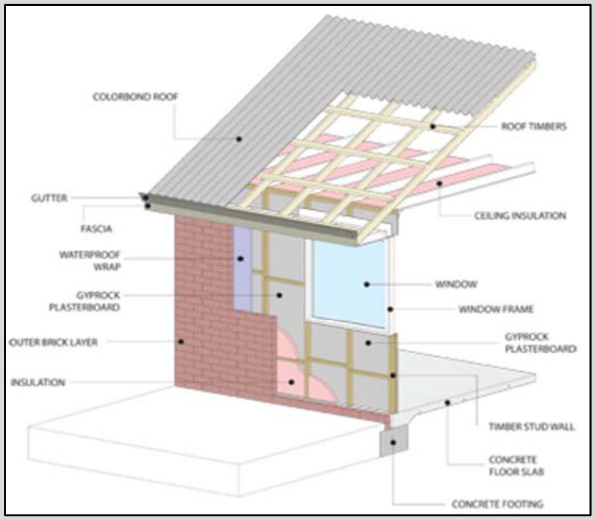
Vulnerability Assessment Framework Account for Flood Damage Resistance of Building Components

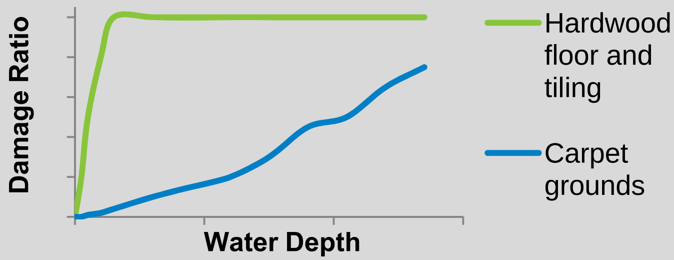
Construction

Material | **Structural System**



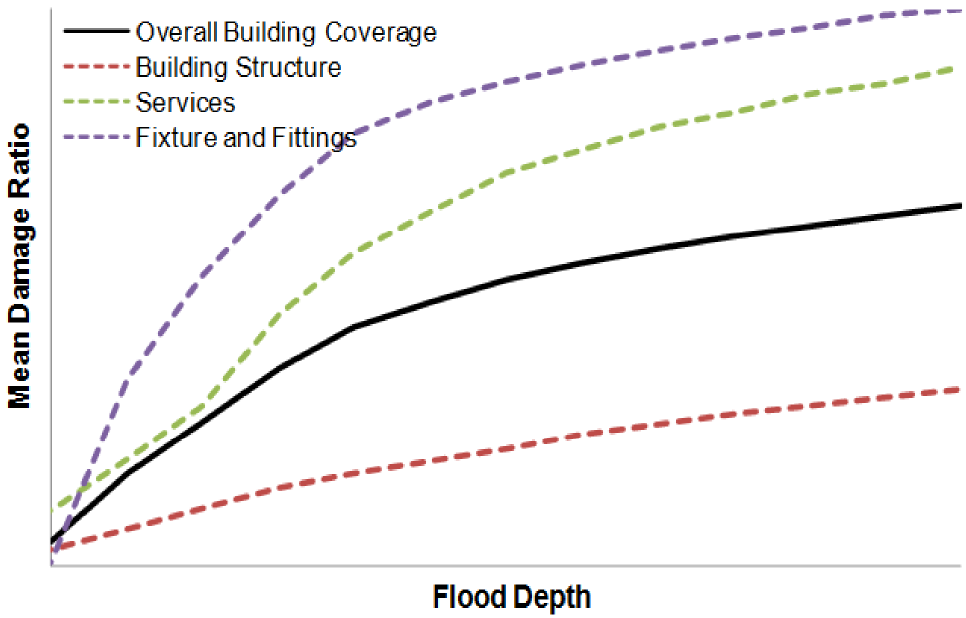

Building Components & Flood Resistance





Damage Functions Use a Component-Based Approach

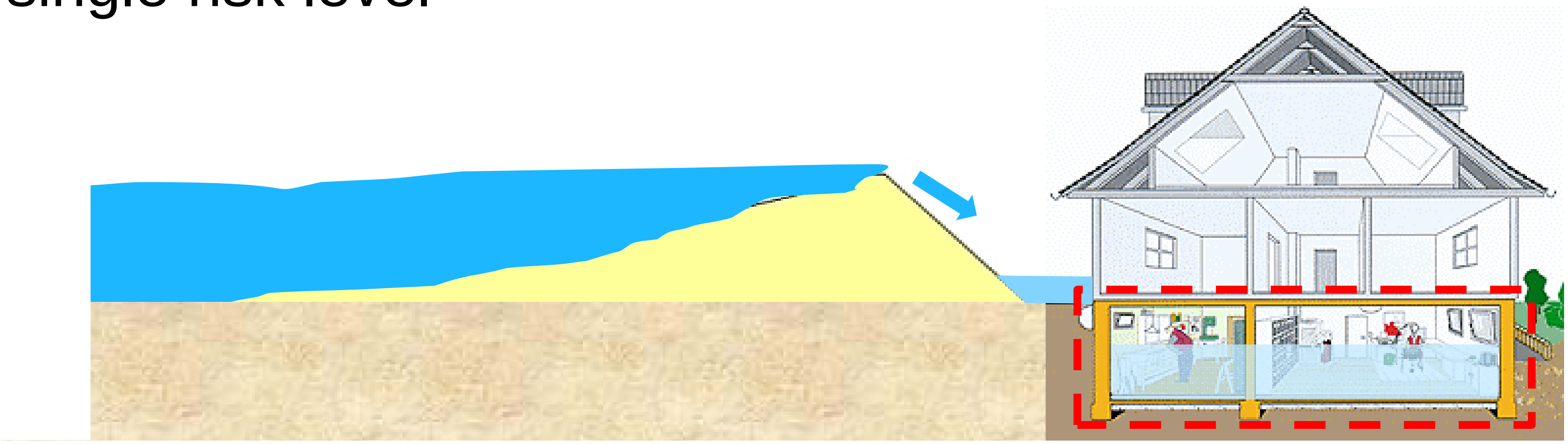
- Damage functions uses an assembly-based approach to estimate the mean building and contents damage
- Building is divided into key flood vulnerable components and items
- Each component vulnerability is aggregated using component cost breakdown to determine the overall building vulnerability

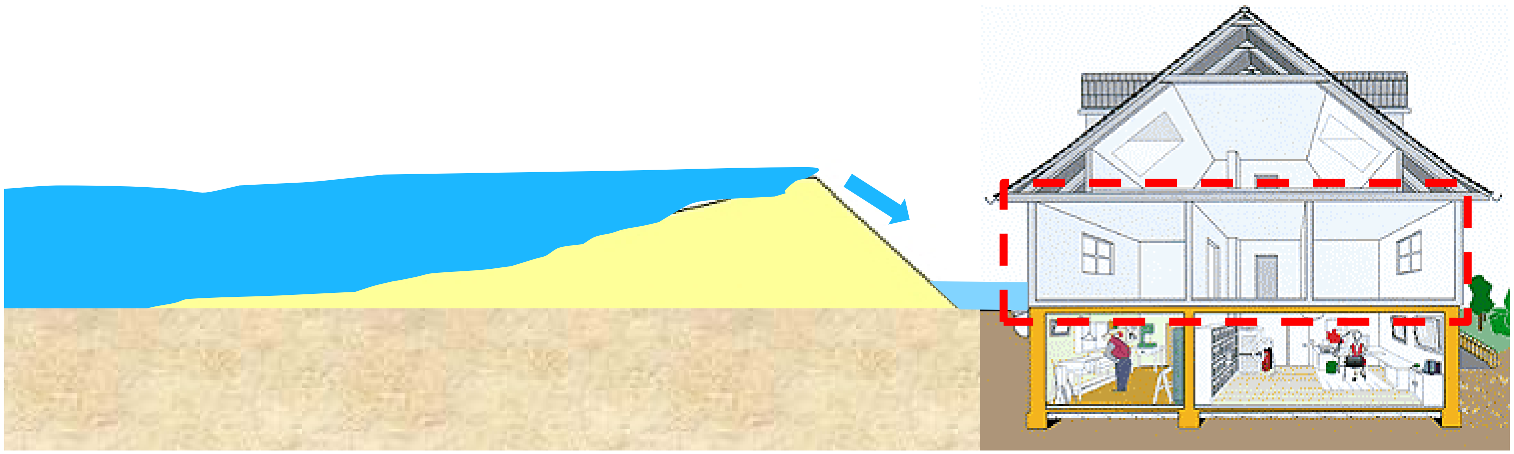


Building and Component Damage Functions for a Retail Shop

AIR Software Allows Loss Potential of Various Floors of the Building to Be Assessed

Secondary Modifier **Floor of Interest** can be entered at a single risk level

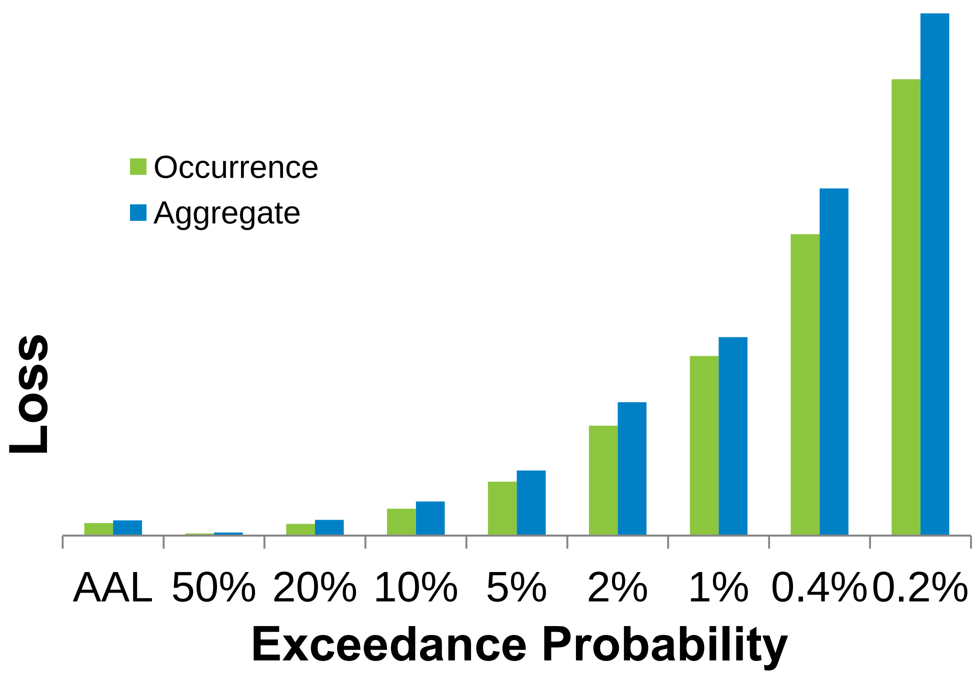




AIR Offers Model Outputs in a Variety Formats

Uniform Loss Cost Map Shows Risk Is Concentrated in River Basins Throughout the Country

AIR's Model Results Include Aggregate and Occurrence Loss Distributions



Summary

- AIR uses a Global Circulation Model (GCM) coupled with a regional Numerical Weather Prediction (NWP) model to provide a better representation of precipitation over large areas
- An advanced stochastic downscaling technique introduces statistically-robust and visually-realistic perturbations at fine scales
- Soil saturation and snowmelt modules provide a realistic representation of the associated runoff generation
- An advanced physically-based flood mapping approach applies detailed local terrain to more precisely estimate local flood depths
- The AIR flood model separately accounts for losses on- and off-floodplain
- AIR Vulnerability module uses local building characteristics, engineering research and claims analysis in building robust damage functions

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CELEBRATING 25 YEARS OF CATASTROPHE MODELING