CL-9: Flood – Australia and Other International Exposures

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Agenda

- Defining flood events
- Evolution of modeling floods around the world
- Innovative approach to modeling inland flood risk

Defining Floods Events

- A **flood** is an overflow of an expanse of water that submerges land
- Floods can take many different forms
  - Coastal flooding 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

Floods Can Claim Thousands of Lives Especially in Unprepared Regions

Location	Date	Event	Death toll
China	1931	1931 China floods	2,500,000–3,700,000
China	1887	1887 Yellow River (Huang He) flood	900,000–2,000,000
China	1938	1938 Yellow River (Huang He) flood	500,000–700,000
China	1975	Banqiao Dam failure, result of Typhoon Nina. Approximately 86,000 people died from flooding and another 145,000 died during subsequent disease.	231,000
Indonesia	2004	Indian Ocean tsunami	230,000
China	1935	1935 Yangtze river flood	145,000
Netherlands	1530	St. Felix's Flood, storm surge	100,000+
North Vietnam	1971	Hanoi and Red River Delta flood	100,000
China	1911	1911 Yangtze river flood	100,000

Source: Wikipedia: "Flood"

Floods Can Also Result in Billions of Dollars of Losses: Top 10 Economic Losses Since 2000

Location	Date	Event	Death Toll	Losses (M USD)	Area (km^2)
U.S.	2005	Hurricane Katrina overtops levies in New Orleans, LA	1,053	60,000	50,000
Central Europe	2002	Heavy rains flood the Danube and inundate areas in Czech Republic, Germany & Austria	55	20,000	252,000
U.K.	2007	A series of storms inundates much of the western U.K.	7	6,500	24,000
U.S.	2005	Hurricane Rita causes coastal flooding in LA and TX	0	6,000	33,000
U.K.	2000	A series of storms causes rivers to break their banks throughout the southern U.K	0	5,900	5,300
Iran	2001	Extreme rainfall caused severe flooding in southern Iran	6	5,000	500
Mexico	2007	Heavy rainfall caused extensive flooding of the states of Tabasco and Chiapas	19	5,000	36,000
China	2007	Heavy rains cause severe flooding in southern China	600	4,250	1,916,000
India	2005	Rain from monsoon floods areas around Mumbai	987	3,500	35,000
SE Asia	2006	Rain resulting from Typhoon Billis floods areas of Taiwan, China, and the Philippine	629	2,238	612,000

Source: Dartmouth Flood Observatory

On January 13th and 14th, 2011 Southern Queensland, Australia Experienced Major Flooding

- 30,000 properties in the Queensland city of Brisbane have been flooded
- Flood waters reached a peak of 4.46m (14.6ft), almost 1 m less than the record 1974 floods

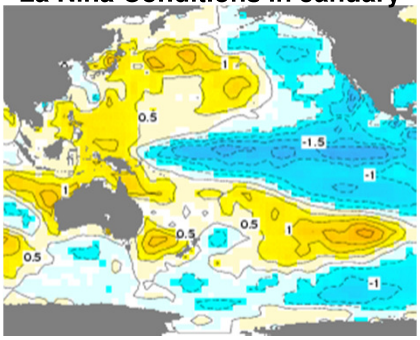
Flooding in Brisbane's Suburbs

Flooding in Rockhampton

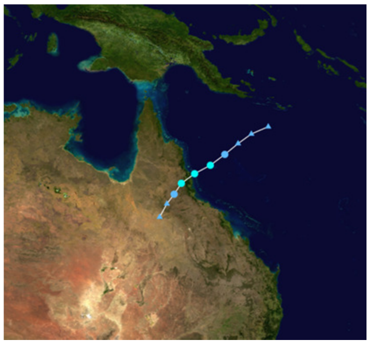
Heavy Rains Are a Result of a La Nina Weather Pattern in the Pacific

- The floods were a result of heavy rainfall caused by Tropical Cyclone Tasha that combined with a trough during the peak of a La Niña event

La Nina Conditions in January



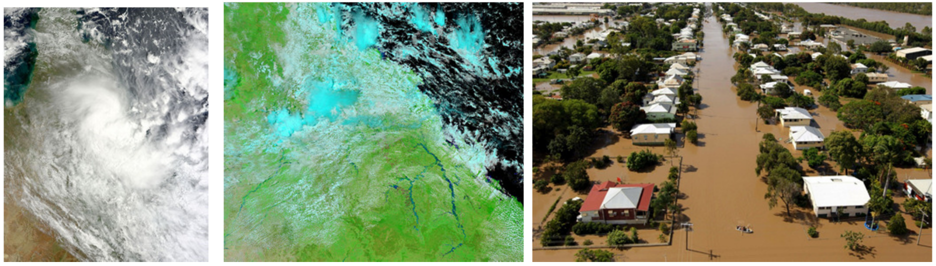
Tropical Cyclone Tasha's Track



Source: IRI

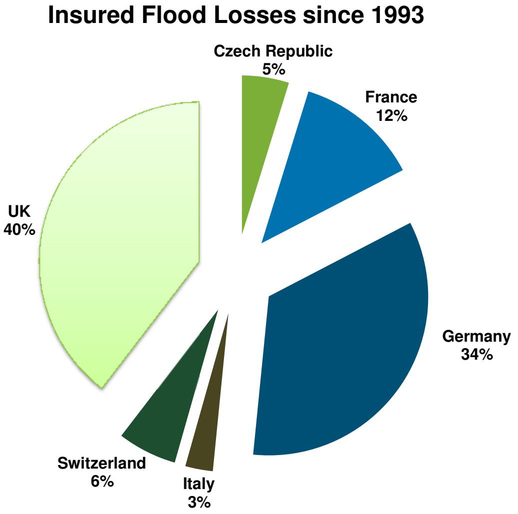
Heavy Rainfall from Tasha Caused Rivers in the Area to Overtop Their Banks, Flooding Many Towns

- Tasha made landfall between Cairns and Innisfail with only 45mph winds but featured torrential rains

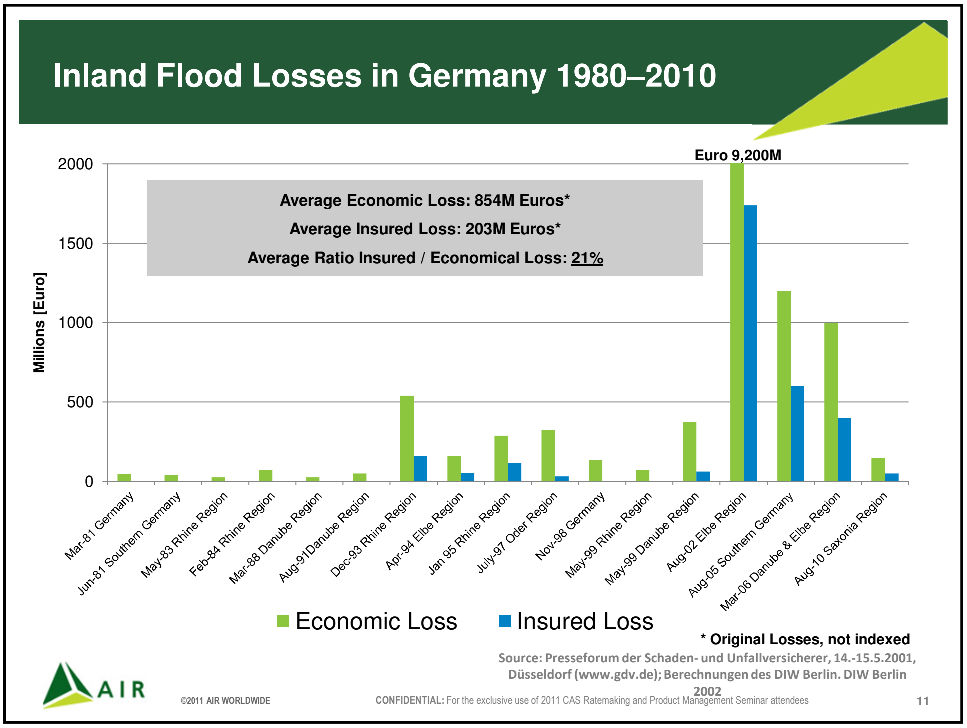


- The floods are expected to cost the Australian economy more than $10 billion AUD
- In figures released at the end of January 2011, the Insurance Council of Australia calculated that 38,460 individual claims were lodged with insurers which were worth $1.51 billion AUD

The U.K. and Germany Dominate Insured Flood Losses in Europe



Source: Munich Re



Inland Flood Losses in Germany 1980–2010

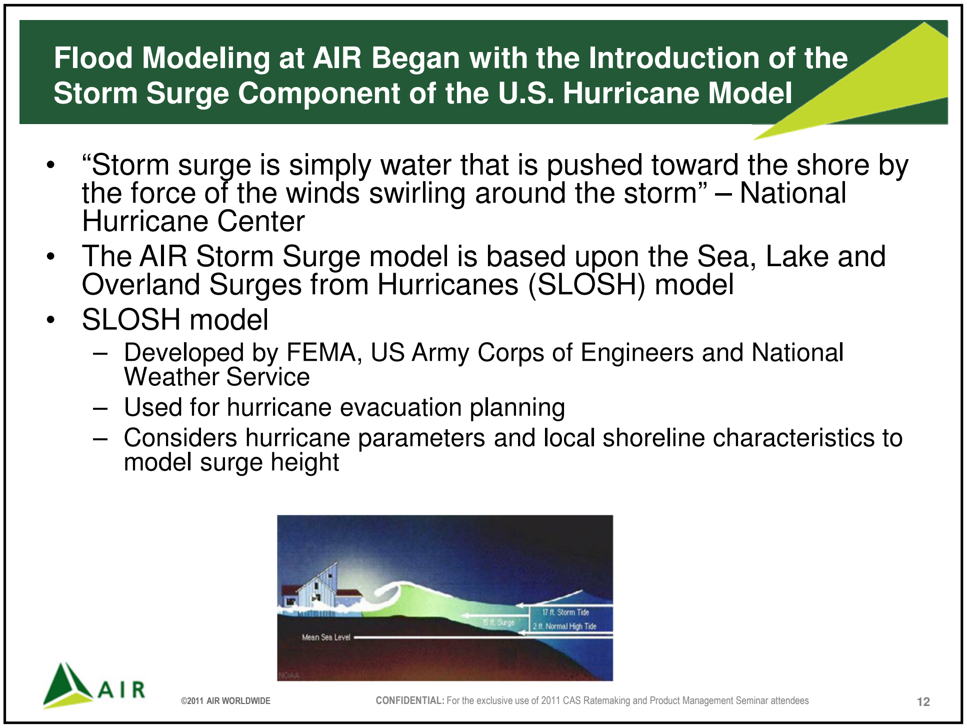
Average Economic Loss: 854M Euros*

Average Insured Loss: 203M Euros*

Average Ratio Insured / Economical Loss: 21%

*** Original Losses, not indexed**

Source: Presseforum der Schaden- und Unfallversicherer, 14.-15.5.2001, Düsseldorf (www.gdv.de); Berechnungen des DIW Berlin. DIW Berlin 2002



Flood Modeling at AIR Began with the Introduction of the Storm Surge Component of the U.S. Hurricane Model

- “Storm surge is simply water that is pushed toward the shore by the force of the winds swirling around the storm” – National Hurricane Center
- The AIR Storm Surge model is based upon the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model
- SLOSH model
  - Developed by FEMA, US Army Corps of Engineers and National Weather Service
  - Used for hurricane evacuation planning
  - Considers hurricane parameters and local shoreline characteristics to model surge height

Storm Surge Must Be Accounted for Because It Can Have a Large Financial Impact

- Storm surge poses challenges for insureds, insurers and reinsurers since many policies may cover wind but not surge damage
- Difficult to identify which losses occur purely from surge as opposed to wind
- Hurricane Ike modeled losses were perceived as too low in some cases
- The AIR model allows users to obtain an informed view of their storm surge risk and address these challenges

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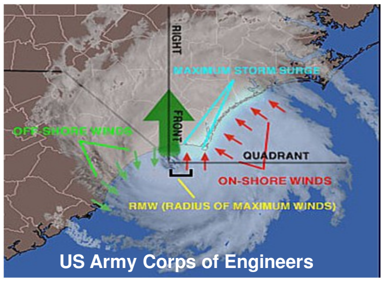
Probabilistic Storm Surge Models for the U.S. and U.K. Incorporate Both Storm and Surge-Specific Parameters

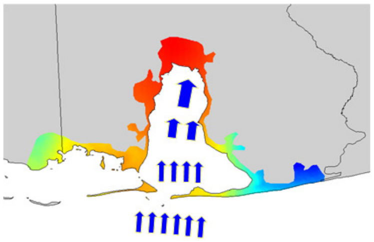
- Storm surge is a sub-peril which does not occur in the absence of hurricanes or extra tropical cyclones
- The storm surge model relies on the primary meteorological variables, including central pressure, forward speed and storm track angle at landfall
- In addition to these meteorological variables, the model incorporates detailed databases of
  - Coastal elevation
  - Coastline orientation
  - Tide height
  - Bathymetry
  - Storm duration and timing relative to tides
  - Sea defences
  - Waves



US Army Corps of Engineers

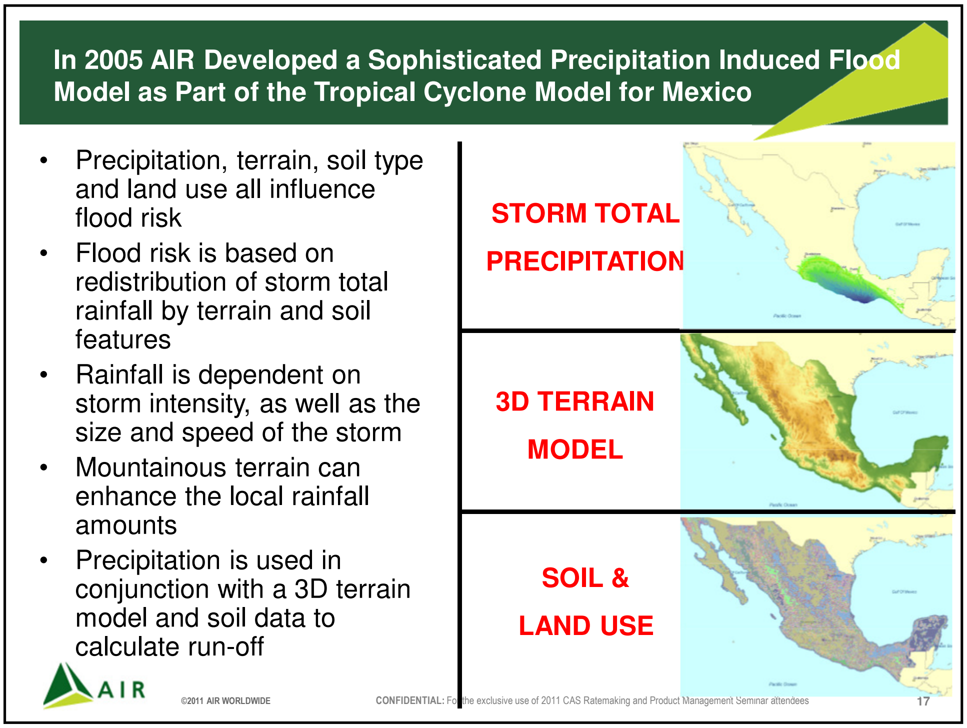
Interaction Between Storm Surge and Local Terrain

- Waves come ashore and attenuate based on the terrain type encountered
- Each attenuation function accounts for the friction factor different terrain types impart on the waves
- Flatter terrain imparts less friction and rougher terrain imparts more friction
- Wave heights may also be amplified because a larger volume of water is forced into a smaller area
- Bay amplification factors are used to capture unique features



Modeling Precipitation Induced Flood Introduces Additional Challenges

- Realistically simulating rainfall patterns over large areas while preserving rainfall distributions at each location
- Transforming the rainfall into runoff while accounting for antecedent conditions
- Accurately modeling local conditions including terrain's physical properties and possible snow melt
- Propagating the excess runoff downstream along the river network
- Differentiating flood damage from damage caused by other perils
- Accounting for the unique insurance terms surrounding flood losses
- Floods can result from conditions other than rainfall including storm surge and tsunamis



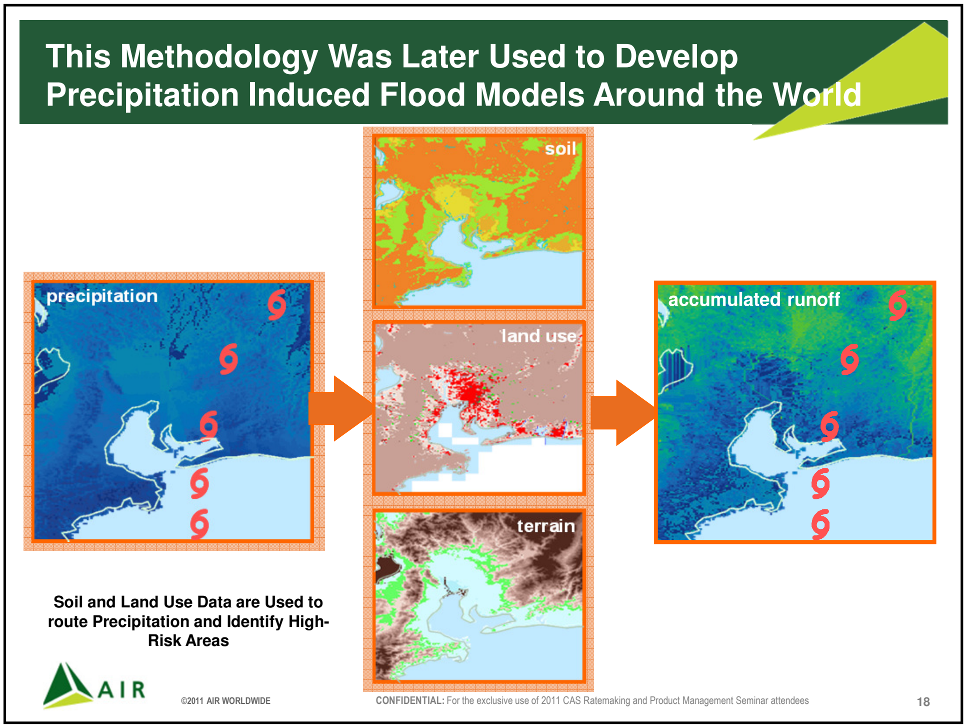
In 2005 AIR Developed a Sophisticated Precipitation Induced Flood Model as Part of the Tropical Cyclone Model for Mexico

- Precipitation, terrain, soil type and land use all influence flood risk
- Flood risk is based on redistribution of storm total rainfall by terrain and soil features
- Rainfall is dependent on storm intensity, as well as the size and speed of the storm
- Mountainous terrain can enhance the local rainfall amounts
- Precipitation is used in conjunction with a 3D terrain model and soil data to calculate run-off

STORM TOTAL PRECIPITATION

3D TERRAIN MODEL

SOIL & LAND USE

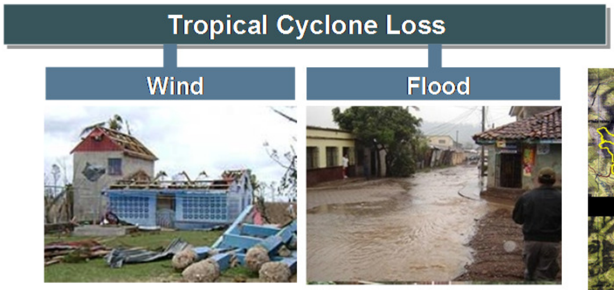


This Methodology Was Later Used to Develop Precipitation Induced Flood Models Around the World

Soil and Land Use Data are Used to route Precipitation and Identify High-Risk Areas

Wind and Precipitation Induced Flood are Accounted for in Regions where Both are Covered Perils

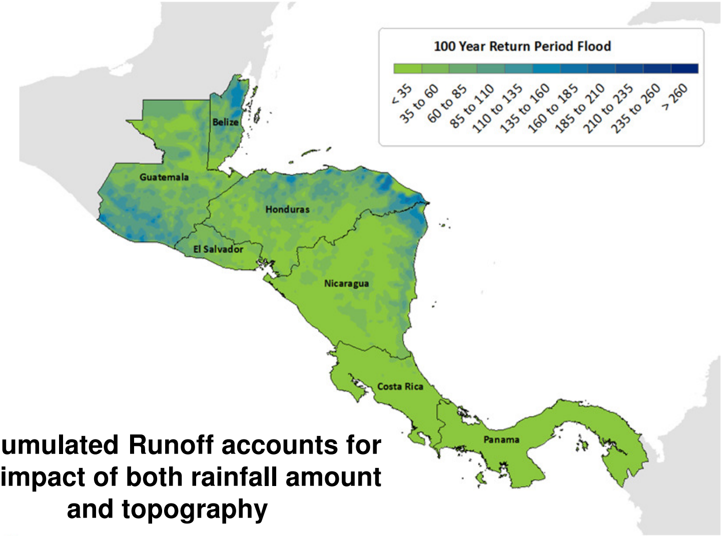
- Tropical cyclone models for Mexico, the Caribbean, Central America, China, Japan and South Korea all include both wind and flood components
- Flooding is highly impacted by duration of storm
- Landslides are implicitly captured in AIR's models


Tropical Cyclone Loss
Wind
Flood

Landslides from Mitch 1998

These Models Capture the Way Rainfall Risk Exists Throughout a Region…

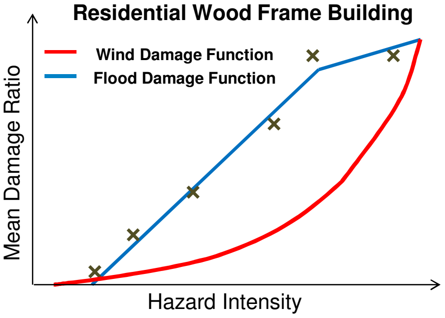
…And Use Accumulated Runoff to Captures Flood Risk

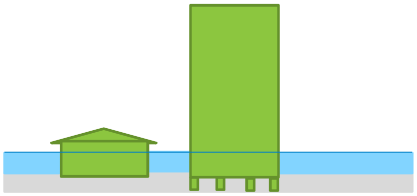


Accumulated Runoff accounts for the impact of both rainfall amount and topography

Flood Damage Is Fundamentally Different from Wind Damage

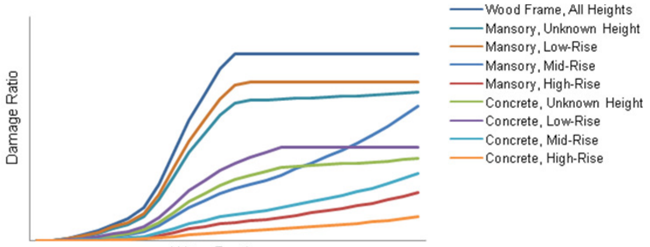
- Research results from local authorities and detailed claims data used to develop flood damage functions separately from wind damage functions
- Mean damage ratio for low-rise buildings is much higher than ratio for high-rise buildings because more of the exposure lies below the water line





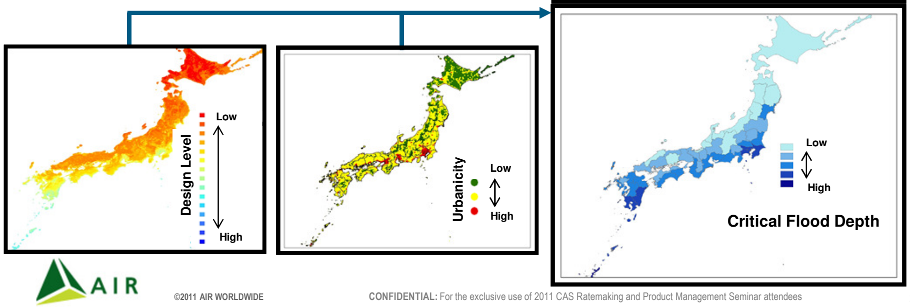
AIR Has Damage Functions for a Variety of Construction and Occupancy Combinations

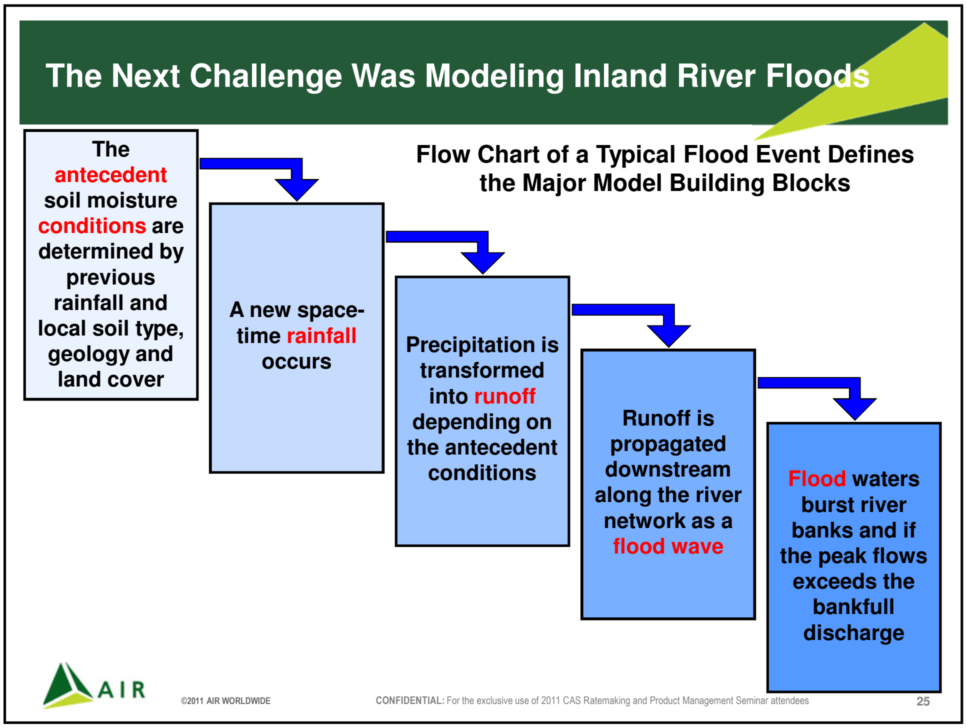
- Building and contents have separate vulnerability functions
- Damage increases as water height increases
- Relative flood damage to the overall structure decreases as structure height increases
- Damage is capped so that combined wind and flood damage does not exceed 100% of the replacement value



Where Applicable, AIR's Models Account for the Affect of Flood Defense Systems

- Japan is investing heavily to reduce flood risk
- Mitigation plan is for 50 mm/hr rain
- Present capacity varies regionally, based on urbanicity





The Next Challenge Was Modeling Inland River Floods

Flow Chart of a Typical Flood Event Defines the Major Model Building Blocks

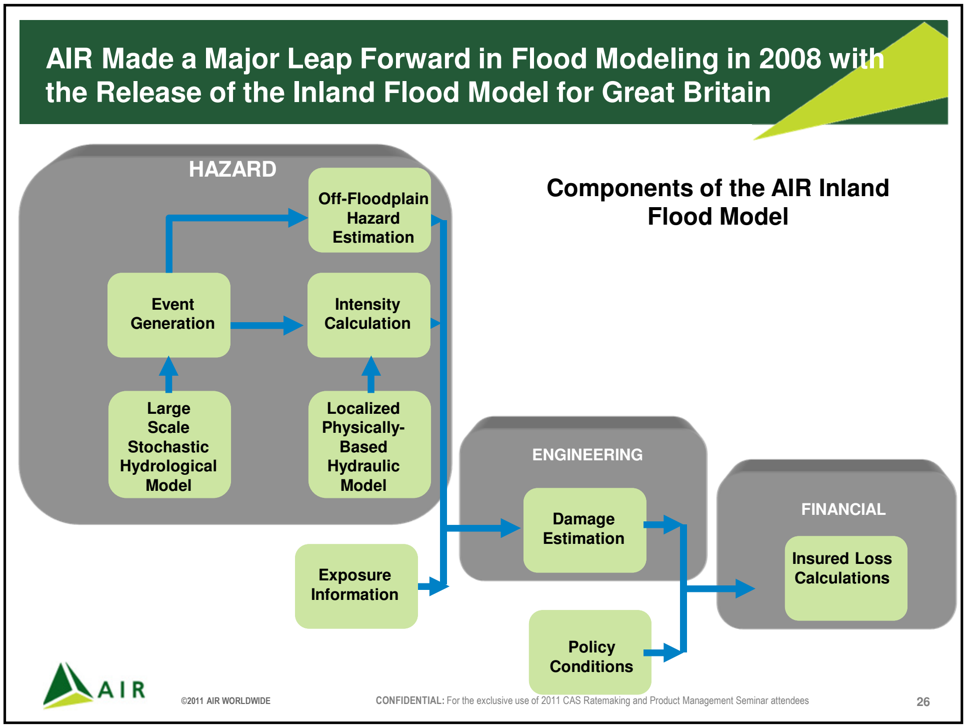
The antecedent soil moisture conditions are determined by previous rainfall and local soil type, geology and land cover

A new space-time rainfall occurs

Precipitation is transformed into runoff depending on the antecedent conditions

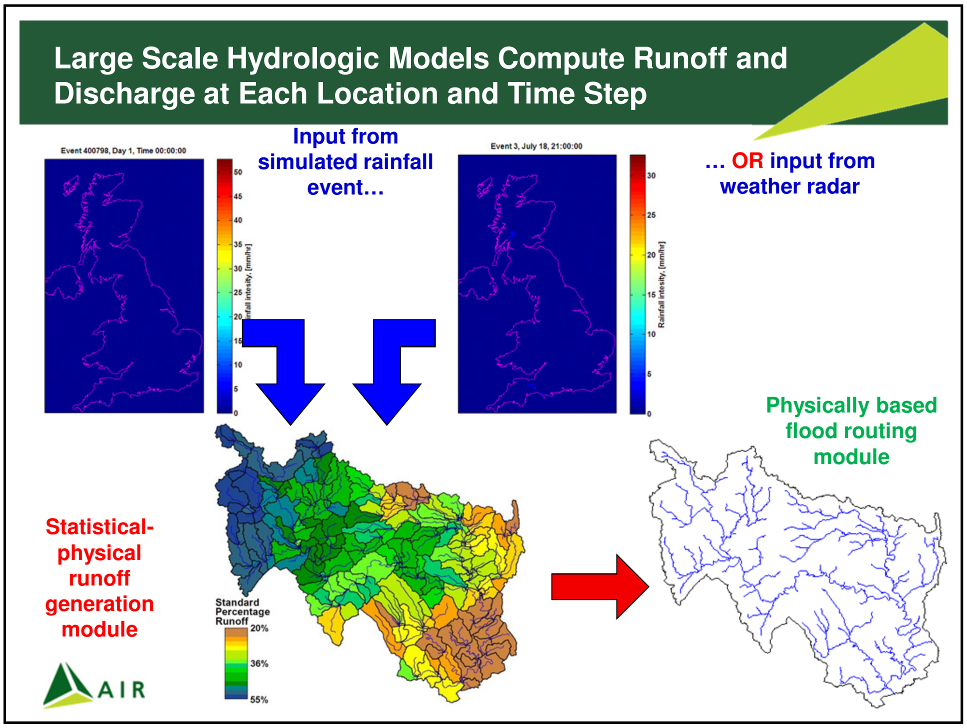
Runoff is propagated downstream along the river network as a flood wave

Flood waters burst river banks and if the peak flows exceeds the bankfull discharge



AIR Made a Major Leap Forward in Flood Modeling in 2008 with the Release of the Inland Flood Model for Great Britain

Components of the AIR Inland Flood Model



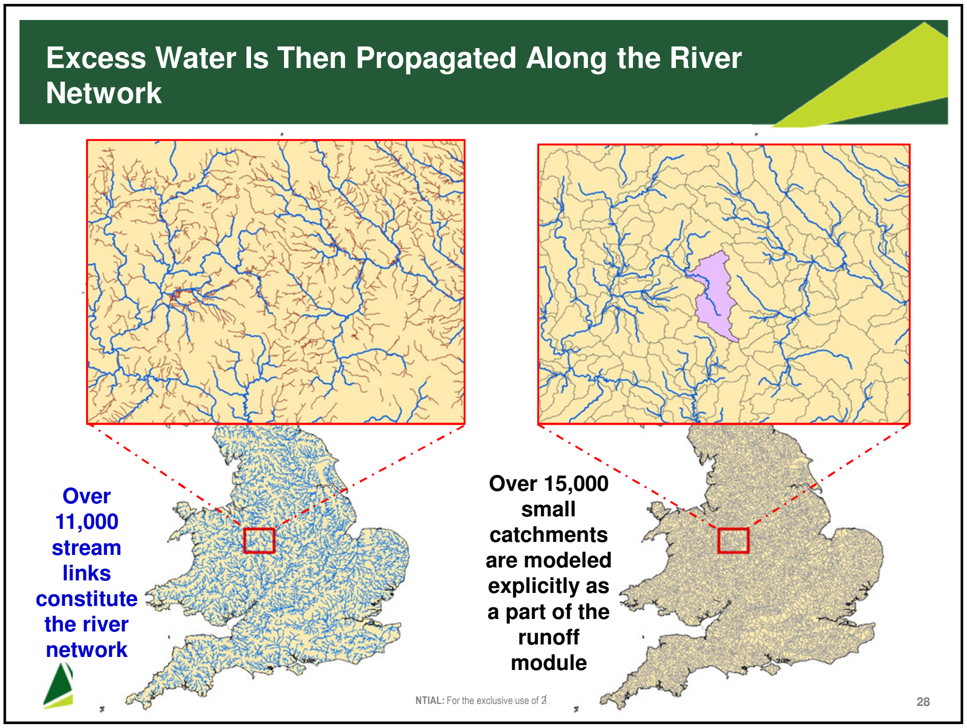
Large Scale Hydrologic Models Compute Runoff and Discharge at Each Location and Time Step

Input from simulated rainfall event…

… OR input from weather radar

Statistical-physical runoff generation module

Physically based flood routing module



Excess Water Is Then Propagated Along the River Network

Over 11,000 stream links constitute the river network

Over 15,000 small catchments are modeled explicitly as a part of the runoff module

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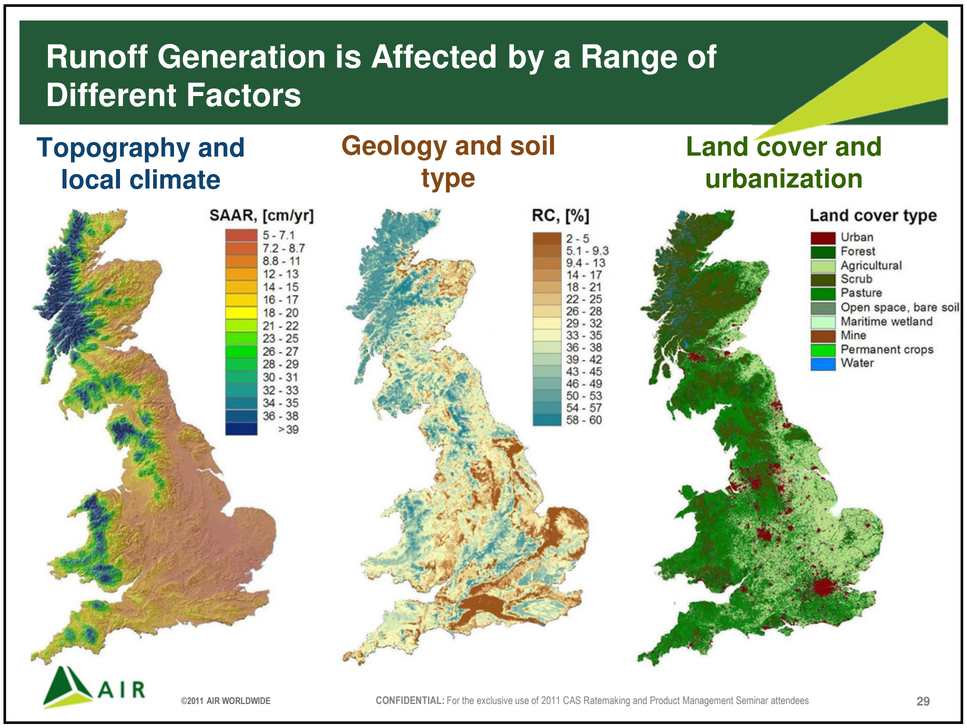

Runoff Generation is Affected by a Range of Different Factors

Topography and local climate

Geology and soil type

Land cover and urbanization

AIR

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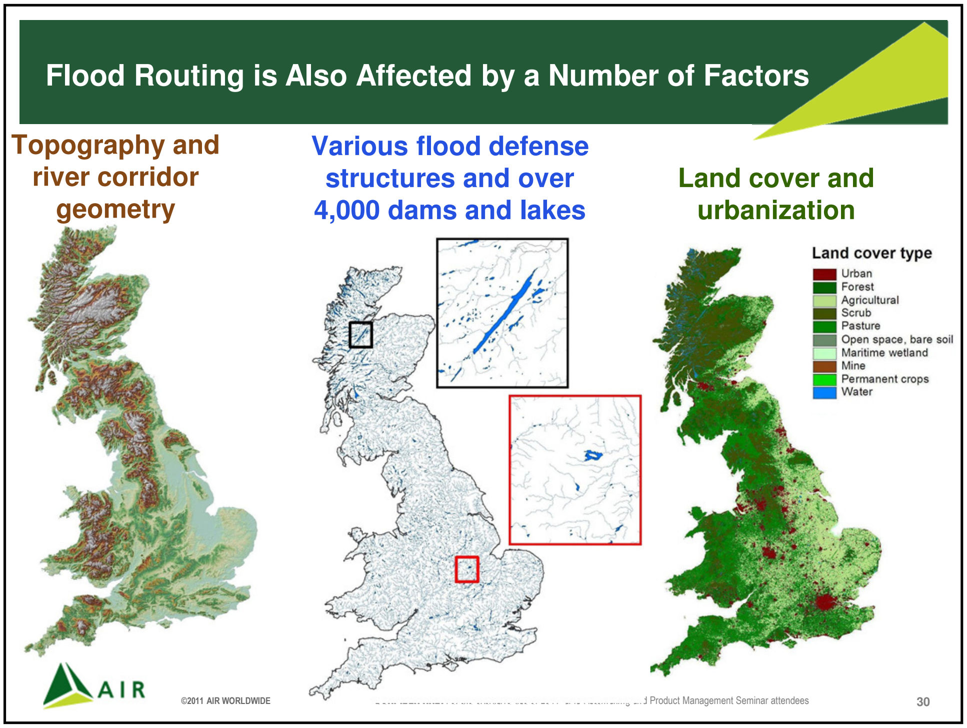

Flood Routing is Also Affected by a Number of Factors

Topography and river corridor geometry

Various flood defense structures and over 4,000 dams and lakes

Land cover and urbanization

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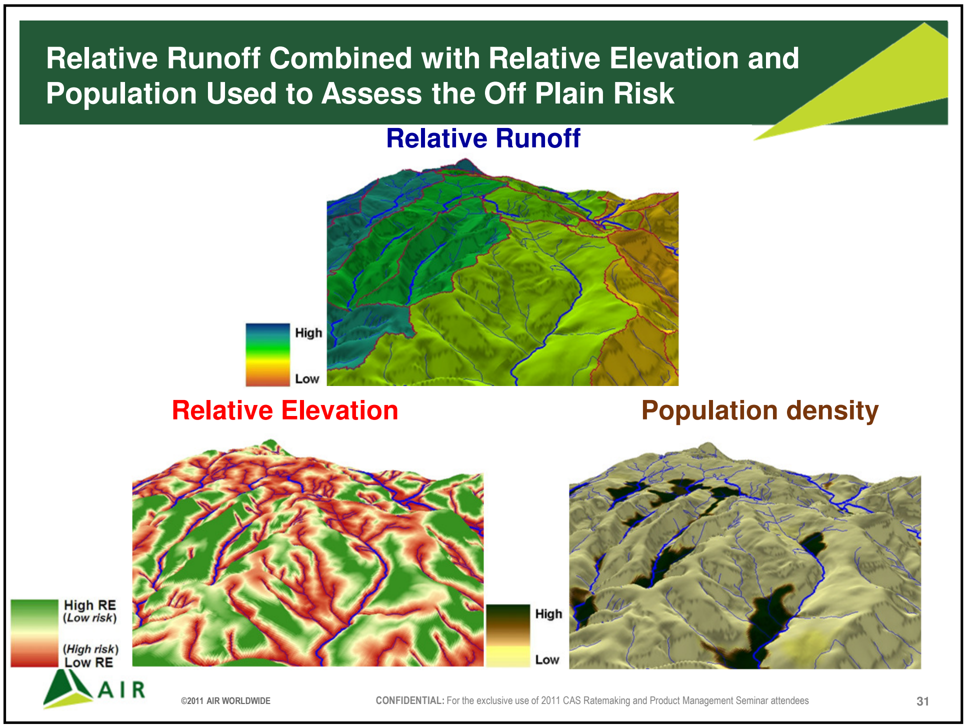
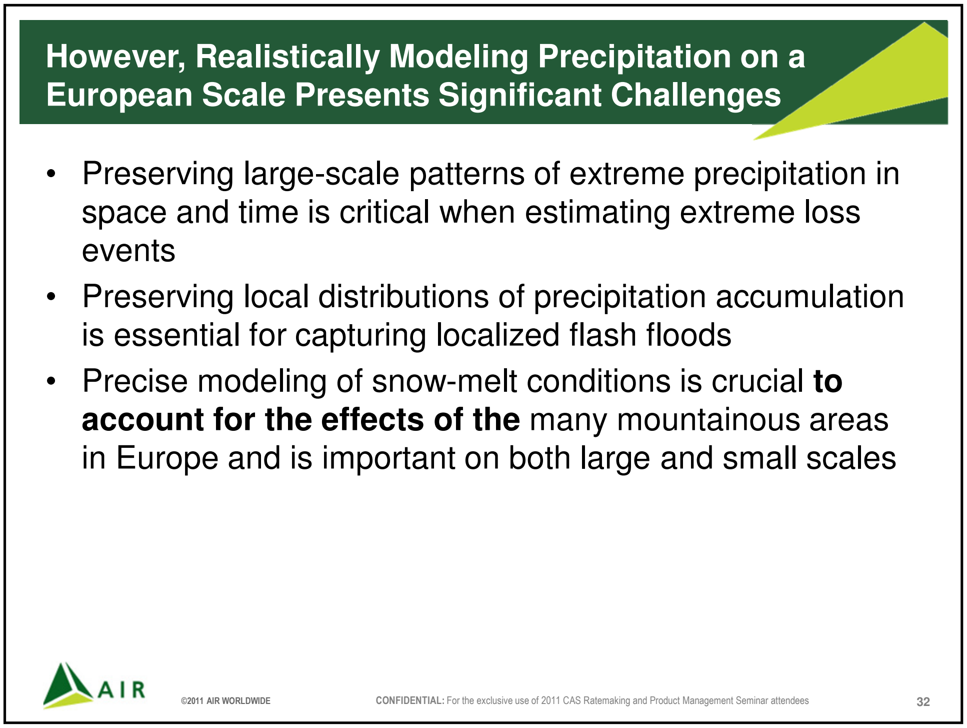
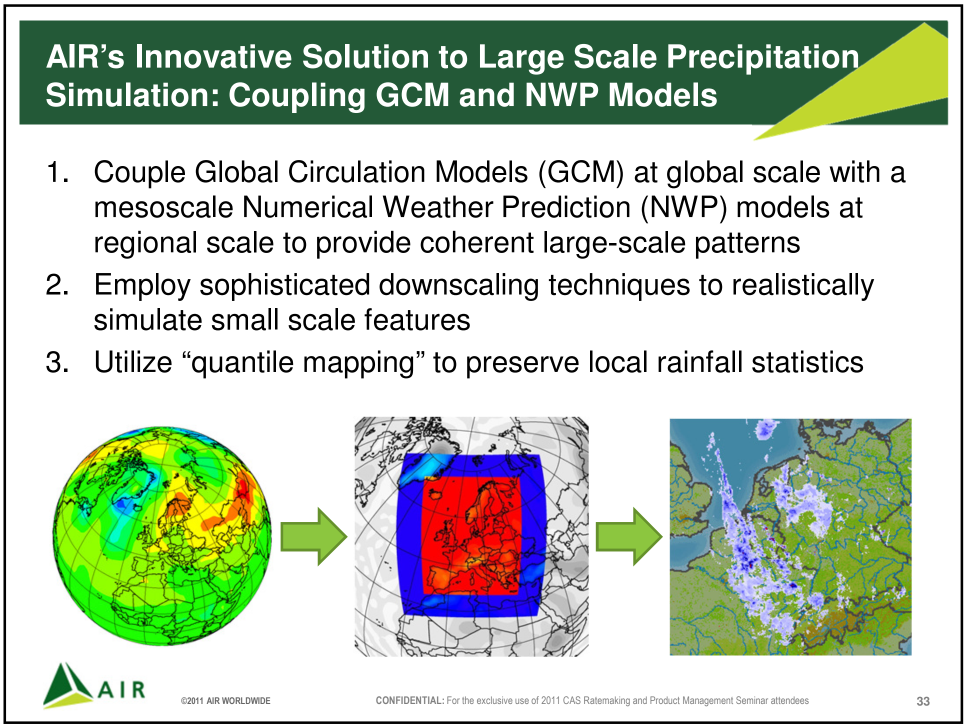


Relative Runoff Combined with Relative Elevation and Population Used to Assess the Off Plain Risk



However, Realistically Modeling Precipitation on a European Scale Presents Significant Challenges

- Preserving large-scale patterns of extreme precipitation in space and time is critical when estimating extreme loss events
- Preserving local distributions of precipitation accumulation is essential for capturing localized flash floods
- Precise modeling of snow-melt conditions is crucial **to account for the effects of the** many mountainous areas in Europe and is important on both large and small scales



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

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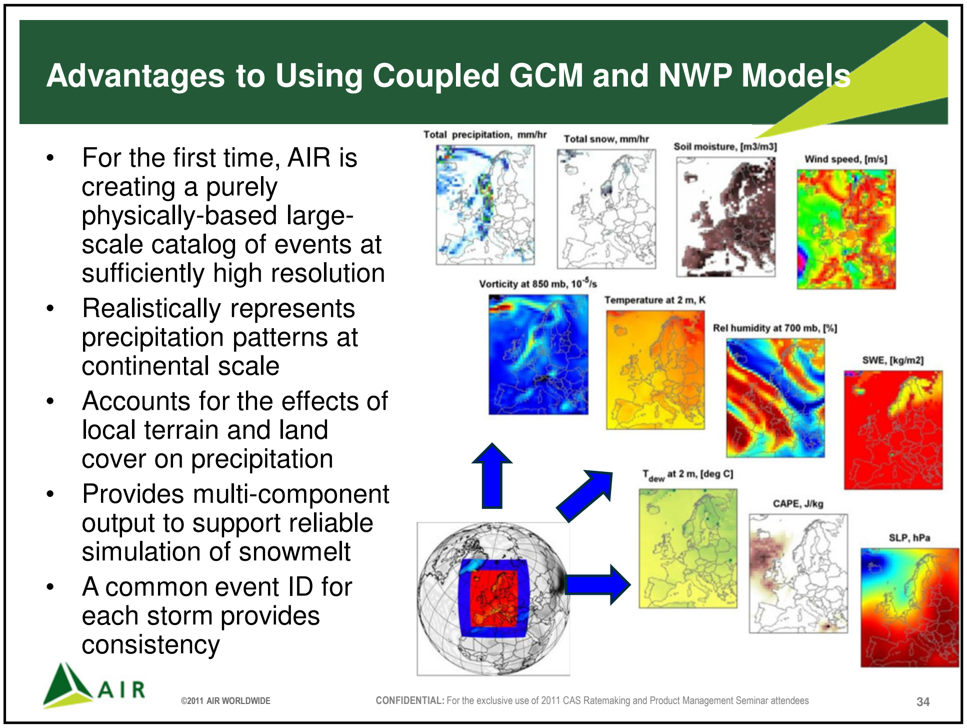
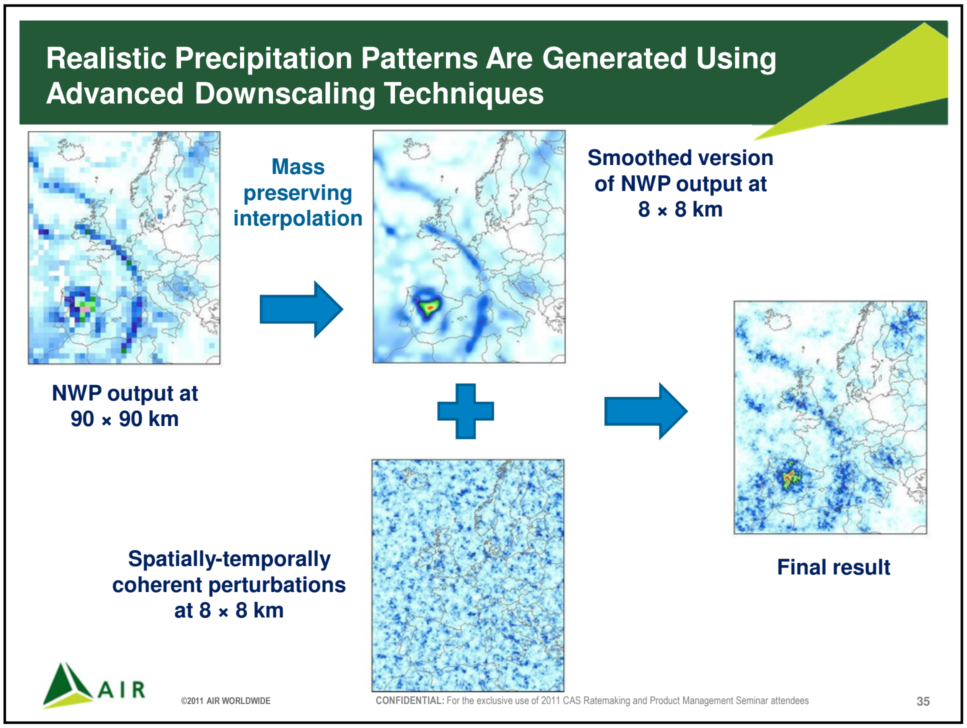


Advantages to Using Coupled GCM and NWP Models

- For the first time, AIR is creating a purely physically-based large-scale catalog of events at sufficiently high resolution
- Realistically represents precipitation patterns at continental scale
- Accounts for the effects of local terrain and land cover on precipitation
- Provides multi-component output to support reliable simulation of snowmelt
- A common event ID for each storm provides consistency



Realistic Precipitation Patterns Are Generated Using Advanced Downscaling Techniques

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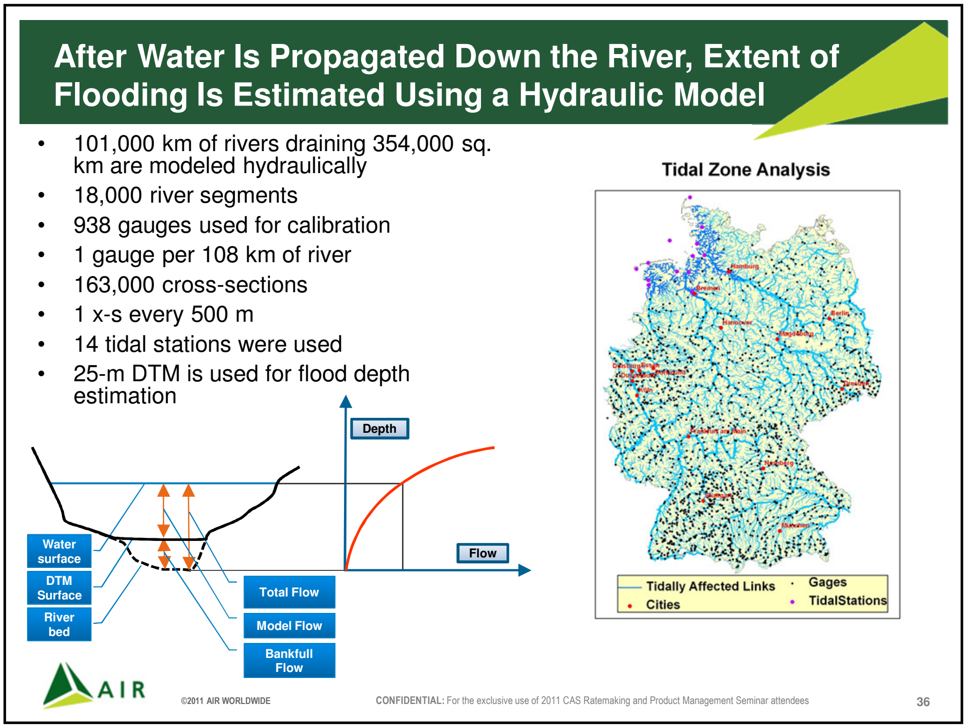
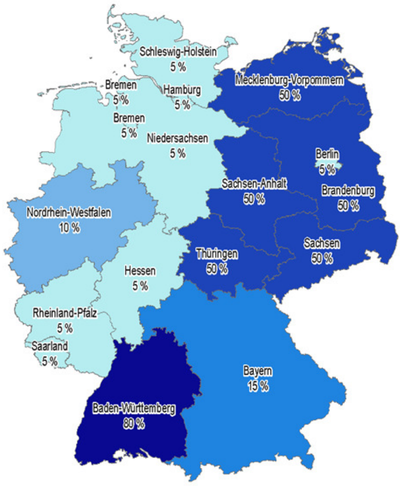


After Water Is Propagated Down the River, Extent of Flooding Is Estimated Using a Hydraulic Model

- 101,000 km of rivers draining 354,000 sq. km are modeled hydraulically
- 18,000 river segments
- 938 gauges used for calibration
- 1 gauge per 108 km of river
- 163,000 cross-sections
- 1 x-s every 500 m
- 14 tidal stations were used
- 25-m DTM is used for flood depth estimation

Insurance Terms Covering Flood Vary Across Different Regions

- In Germany, for example:
  - Flood risk is covered by **non-obligatory** extended elementary risk policies
  - Residential take-up rate in Germany is about 25% (with regional variations) → Tendency: Increasing.
  - Commercial / Industry take-up rate is higher at about 40%
  - Market generally uses standard policy conditions, deductibles, and limits
  - Reinsurance market generally applies a 504 hours clause captured in AIR's CLASIC/2

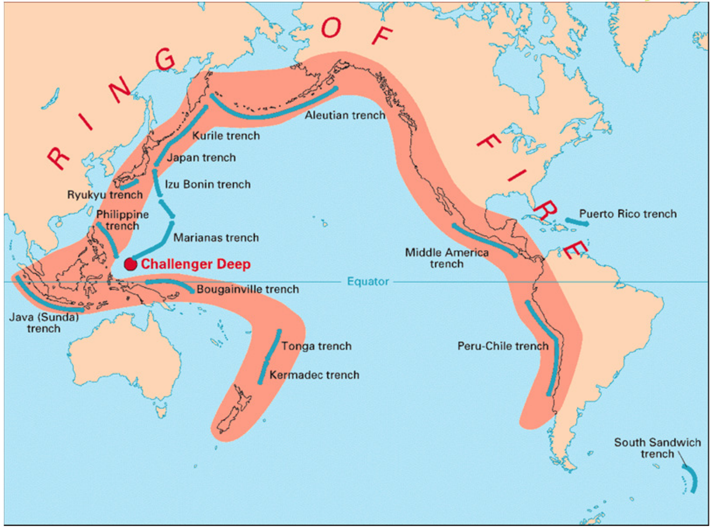


AIR Residential Take-up Rate Assumptions based on publications of the GDV figures (www.gdv.de)

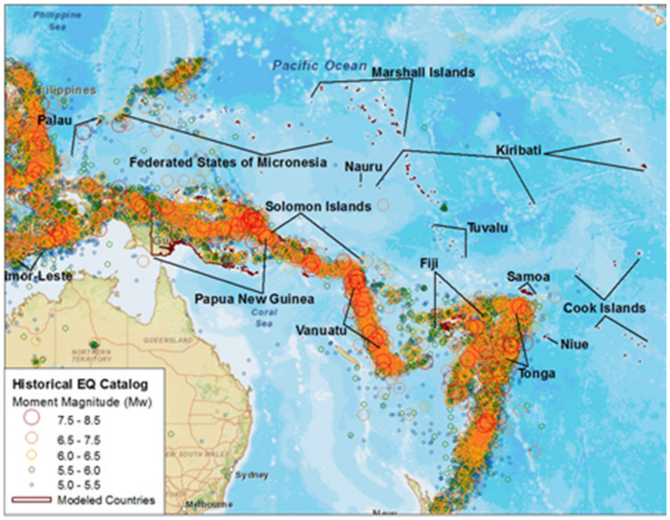
Tsunamis

- Tsunamis are caused when a large offshore earthquake that raises the sea floor
- Eighty percent of earthquakes occur on the sea floor, and most of them occur along plate boundaries, such as those in the South Pacific Region or around Japan
- For major faults in the Pacific, a fault slip map was estimated, describing the amount and direction of slip that occurs for the subduction zone
- Armed with the slip map, the orientation of the fault and the bathymetry of the seafloor in the region, the tsunami module produces wave height and velocity in the ocean and at the coastline

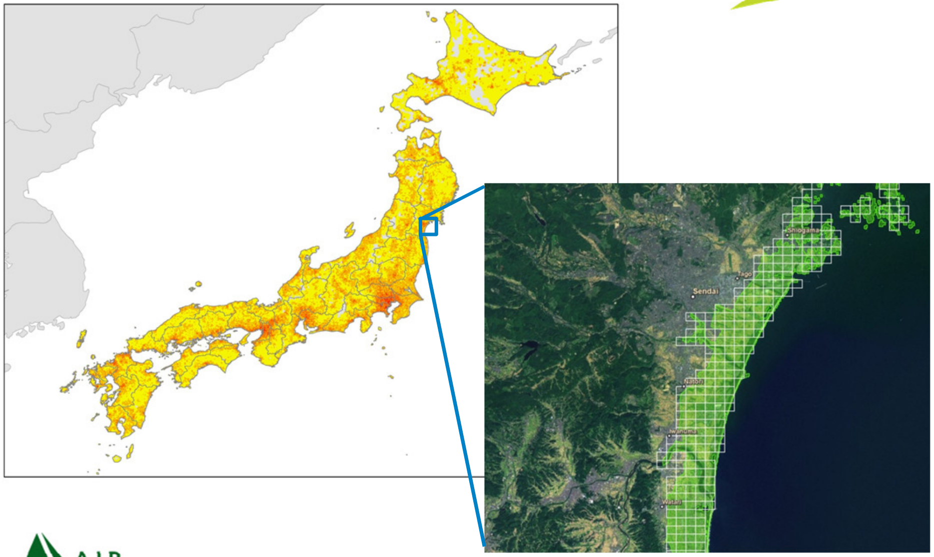
Regions Bordering Either Side of the Pacific Ocean Are Subject to Flood Risk from Tsunamis



Tsunami Models for the South Pacific Islands Are Critical Because Many of the Smaller Islands Can be Completely Inundated



High Resolution Industry Exposure Databases Allowed AIR to Calculate Damage Resulting from the Tsunami



Summary

- There are unique challenges that must be overcome when modeling each different type of flooding
- Flood modeling is not new, rather it has undergone several stages of evolution over time
- The peril of flood is receiving increased attention from many both within and outside of the catastrophe modeling community
- The AIR Flood Model for Germany embodies the state-of the-art in simulating inland river flooding