

# The New Inland Flood Model and Updated Typhoon Model for Japan

*Marc Marcella, Ph.D.*

*Yang “Gabby” Gao, Ph.D.*

*Ruilong Li, Ph.D.*



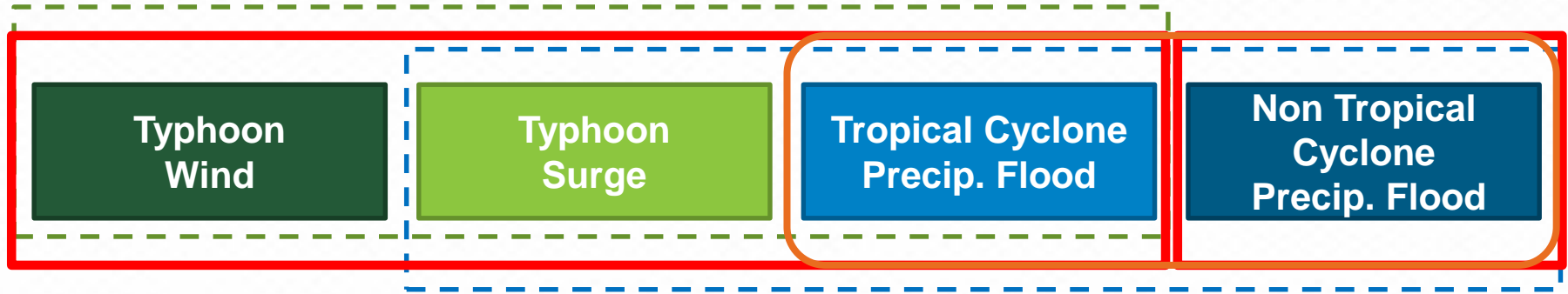
# Agenda

---

- Modeling Flood Hazard for Japan
- Modeling Flood Vulnerability for Japan
- Updates to the AIR Typhoon Model for Japan

# Modeling Precipitation in Touchstone

## Japan Typhoon Model



## Japan Inland Flood Model

- **SOLUTIONS in Touchstone®:**
  - Two models in Touchstone
    - AIR Typhoon Model for Japan: wind, surge, tropical cyclone precipitation flood
    - AIR Inland Flood Model for Japan: non tropical cyclone precipitation flood

# Modeling Flood Hazard for Japan



# Flood Model Components

A detailed topographic map of the Windermere area, showing contour lines, roads, and geographical features. The map is color-coded with various shades of brown, green, and blue to represent different elevations and water bodies.

**GEOPROCESSING**

A photograph of a mountain landscape under a dark, stormy sky. The mountains are covered in green vegetation, and the sky is filled with heavy, dark clouds, suggesting an approaching storm.

**PRECIPITATION**

A photograph of a river flowing through a mountainous landscape. The water is turbulent and white with foam, indicating a fast flow. The surrounding mountains are steep and rocky, with some green vegetation on the slopes.

**HYDROLOGY**

An aerial photograph of a flooded area. A large body of water has inundated a landscape, with a narrow strip of land or road visible in the center. The water is a murky brown color, and the surrounding areas are green and brown.

**HYDRAULICS**

A photograph of a two-story house that is partially submerged in floodwater. The water is a murky brown color, and the house is surrounded by trees and other vegetation. A person is standing in the water in front of the house, looking towards the camera.

**VULNERABILITY**



# Flooding in Japan

Flood peril is a significant risk for Japan

- 50% of population and 75% of assets located in a floodplain
- Major evacuations, loss of life, and billions in damage

**Aso, Kyushu - 2012**

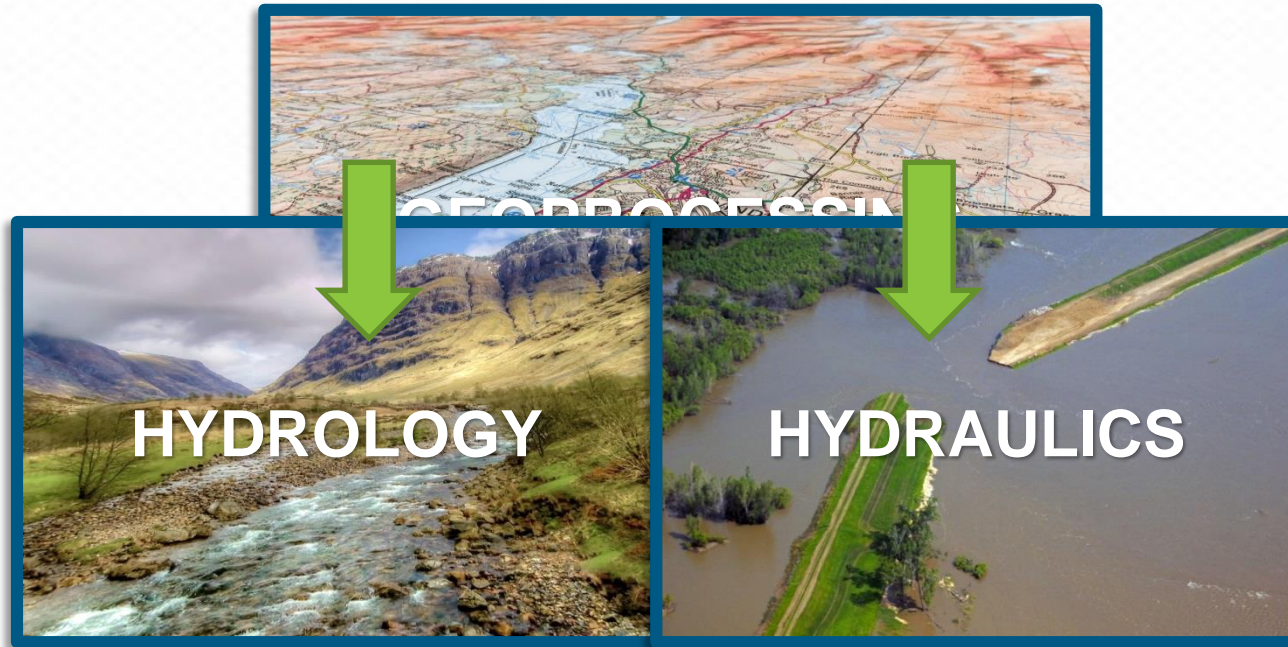


**Koshigaya, Honshu - 2015**



# Geoprocessing

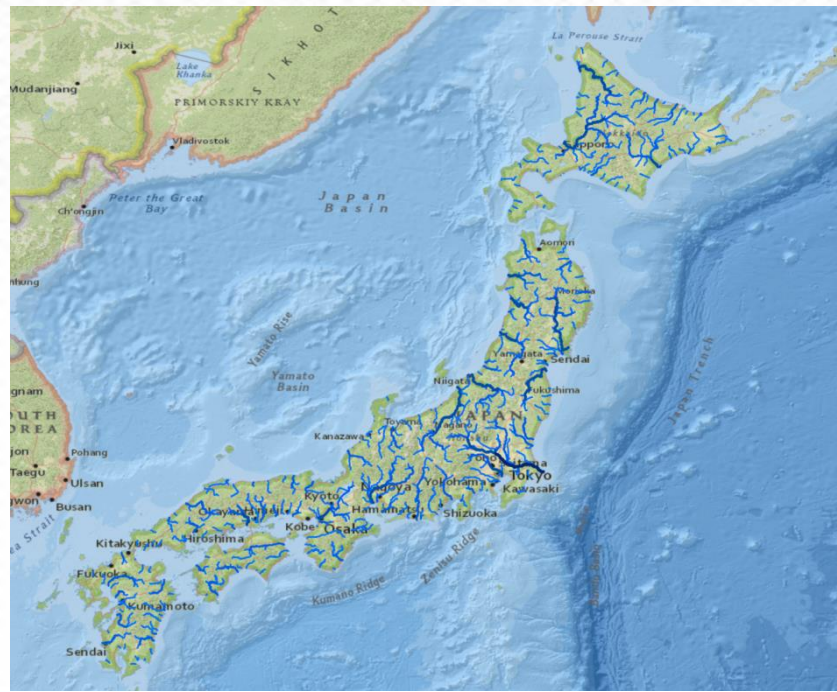
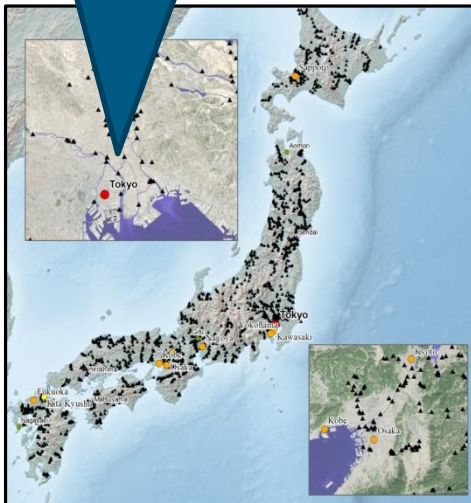
---






17,425  
river  
segments

~1,000  
streamflow  
gauge stations



**338,000 km<sup>2</sup>**  
modeled

~1,100  
dams & Reservoirs



103,000 km  
total stream  
length



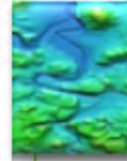
20,263  
catchments



# Geoprocessing Data Layers



**Model Boundary:**  
Country Border



**Digital Terrain Model (DTM):**  
Provided by MLIT



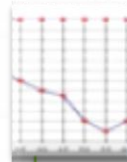
**River Network:**  
Derived from DTM



**Unit Catchments:**  
From DTM & River Networks



**Catchment Properties:**  
Land Use: JAXA, MODIS, AIR , Impervious Surface: NOAA & Soil: MLIT



**Cross Sections:**  
MLIT & DTM River Network



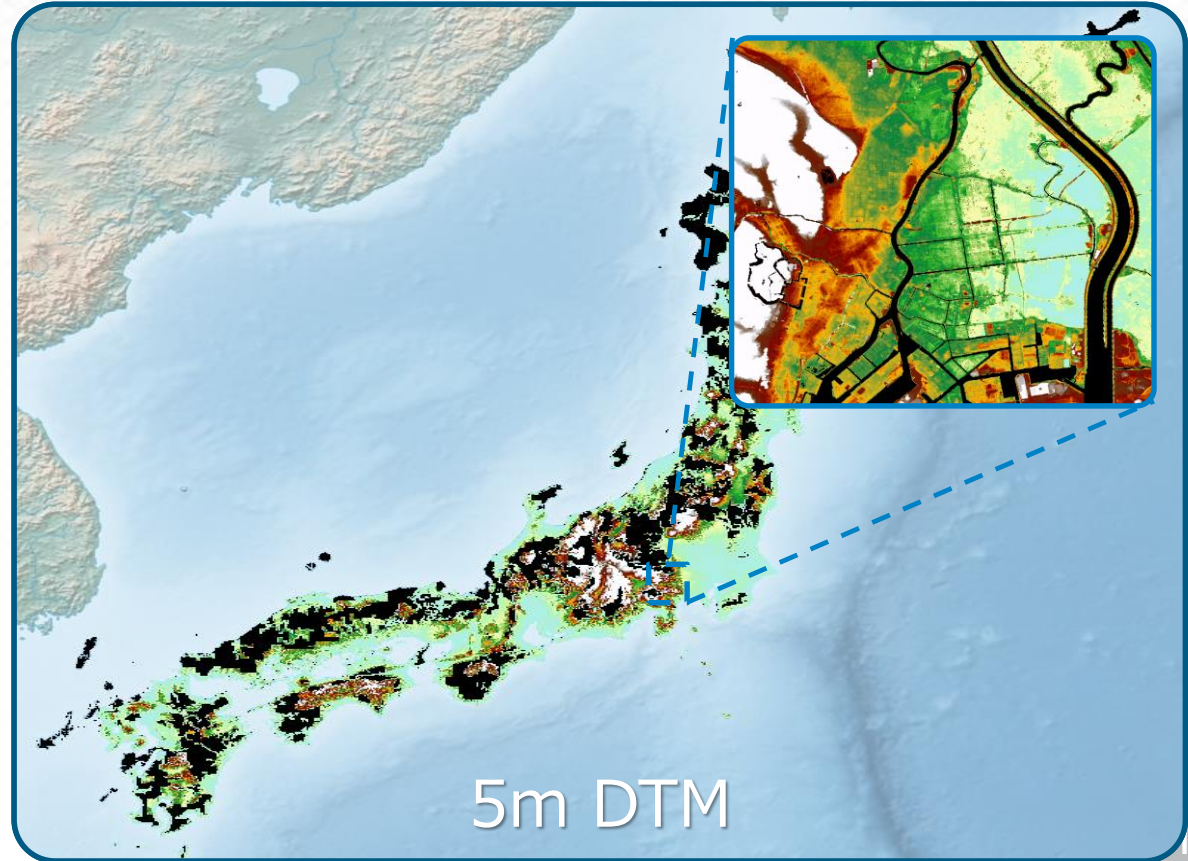
**Flood Defenses:**  
DTM & River Network



**Dams & Reservoirs:**  
MLIT, iCold, GRAND & SRTM

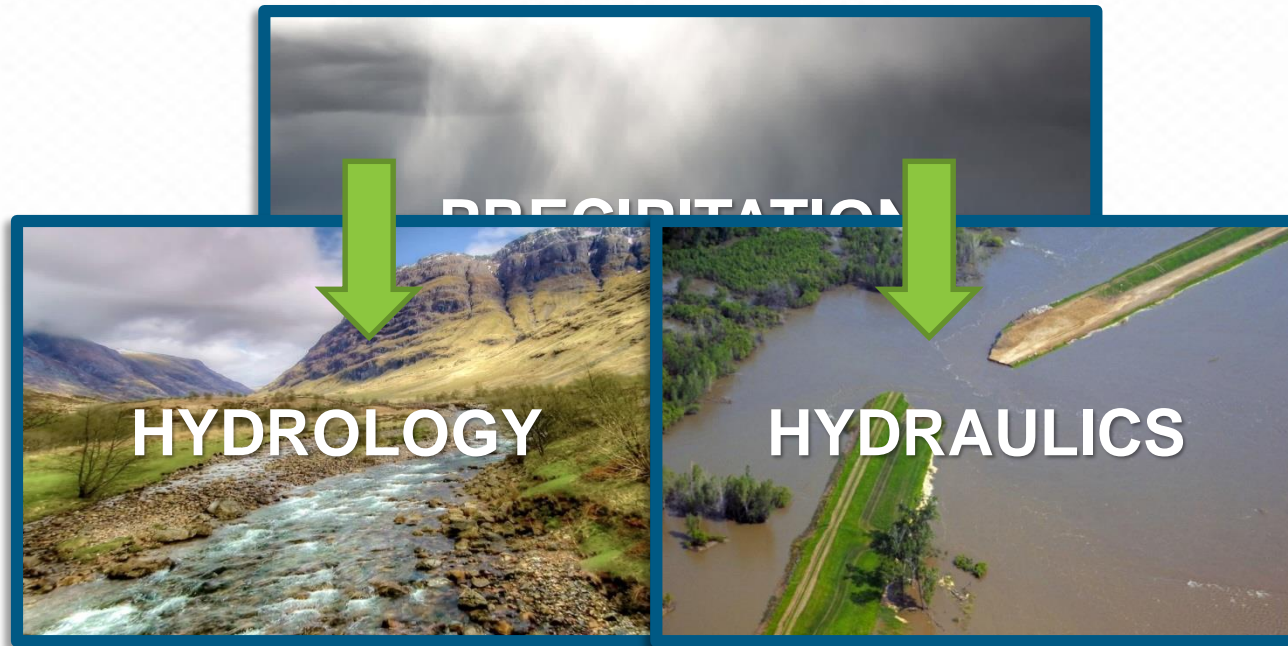
# Japan Digital Terrain Model Availability

- 5m DTM covers 60% of Japan
- Most major cities and rivers included
- 10m DTM used to supplement remaining area



# Precipitation Generation

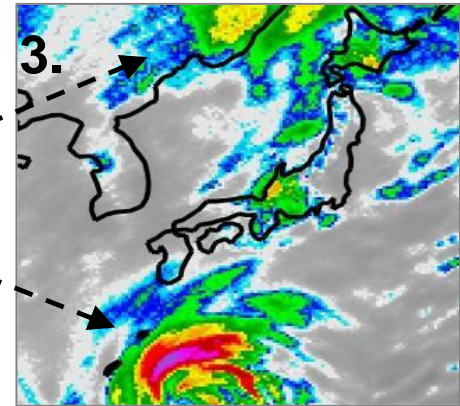
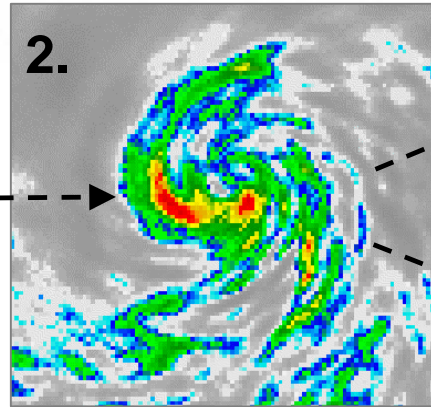
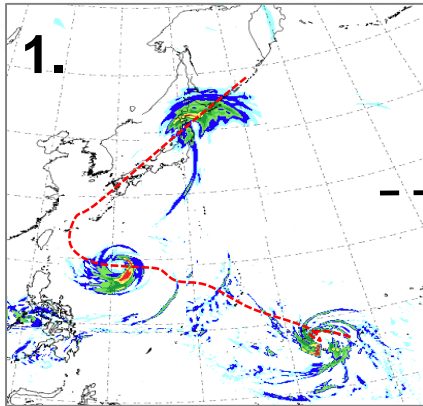
---





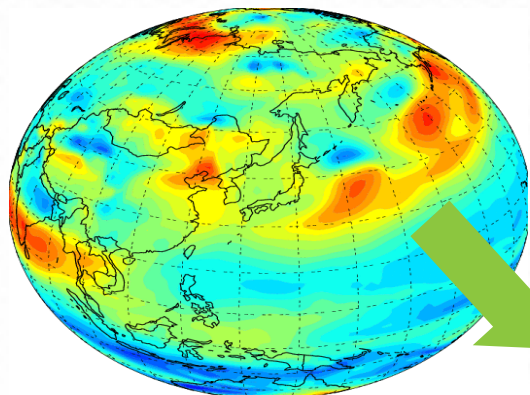
# Overview of Steps for Simulating Precipitation

1. Numerical modeling of historical TC events and non TC rainfall
2. Stochastic simulations of precipitation learning from numerically modeled precipitation
3. Blending of non TC and TC precipitation.



# Step 1: Numerical Modeling

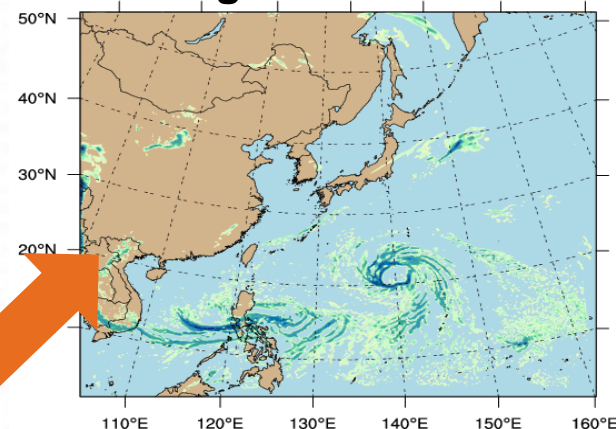
## Coarse-Resolution Global Model



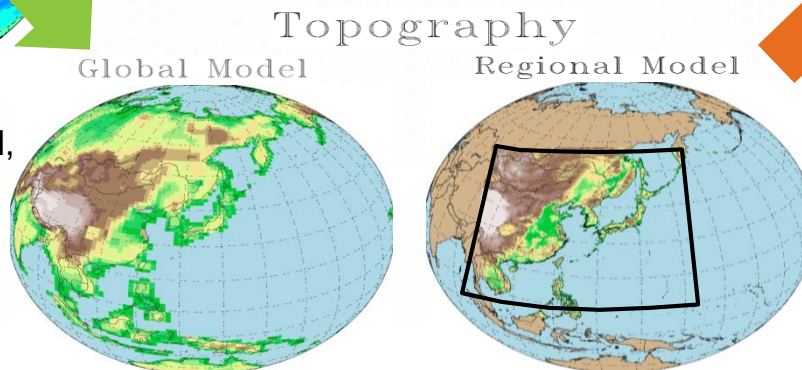
General Circulation Model,  
Reanalysis Data



## Fine-Resolution Regional Model



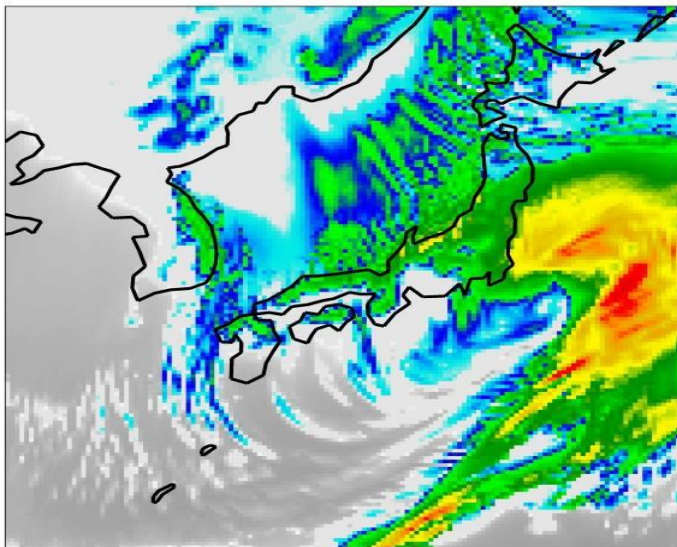
Numerical Weather Prediction  
Model



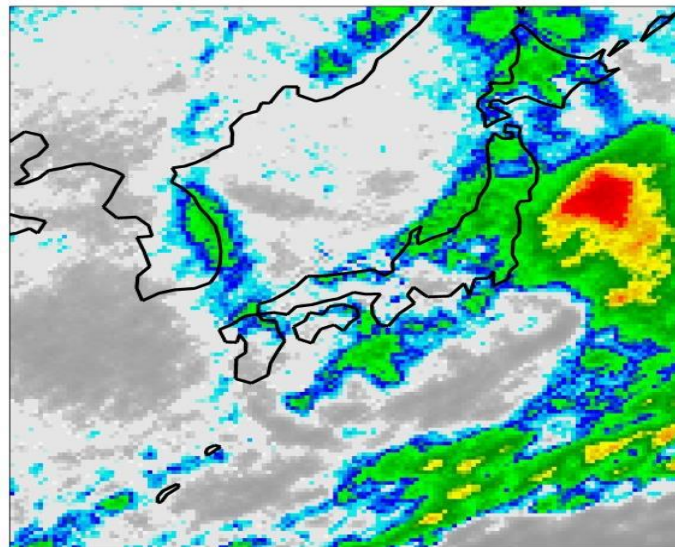
Regional Domain Selection for Numerical Weather  
Prediction (fine resolution)

## Step 2: Stochastic Simulation of Non TC Precipitation

**Numerical Weather Prediction Model**



**Stochastic Simulation Output**



Statistically robust perturbation of precipitation patterns



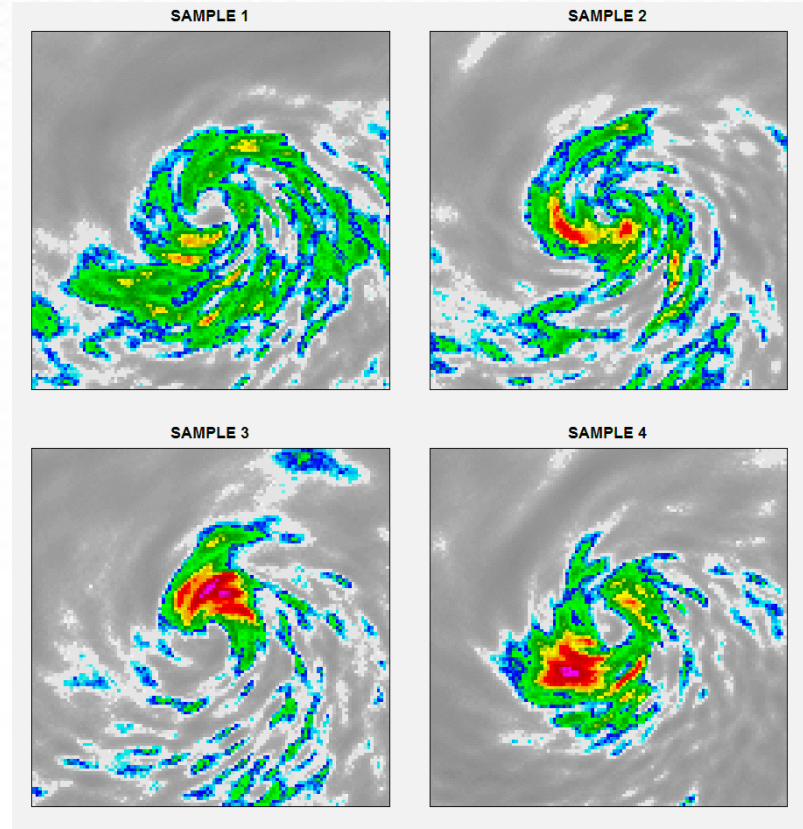
## Step 2: Stochastic Simulation of TC Precipitation

Group models in bundles representing different stages during a typical TC life cycle:

1. Central pressure
2. Storm evolution time (genesis, dissipation, etc.)

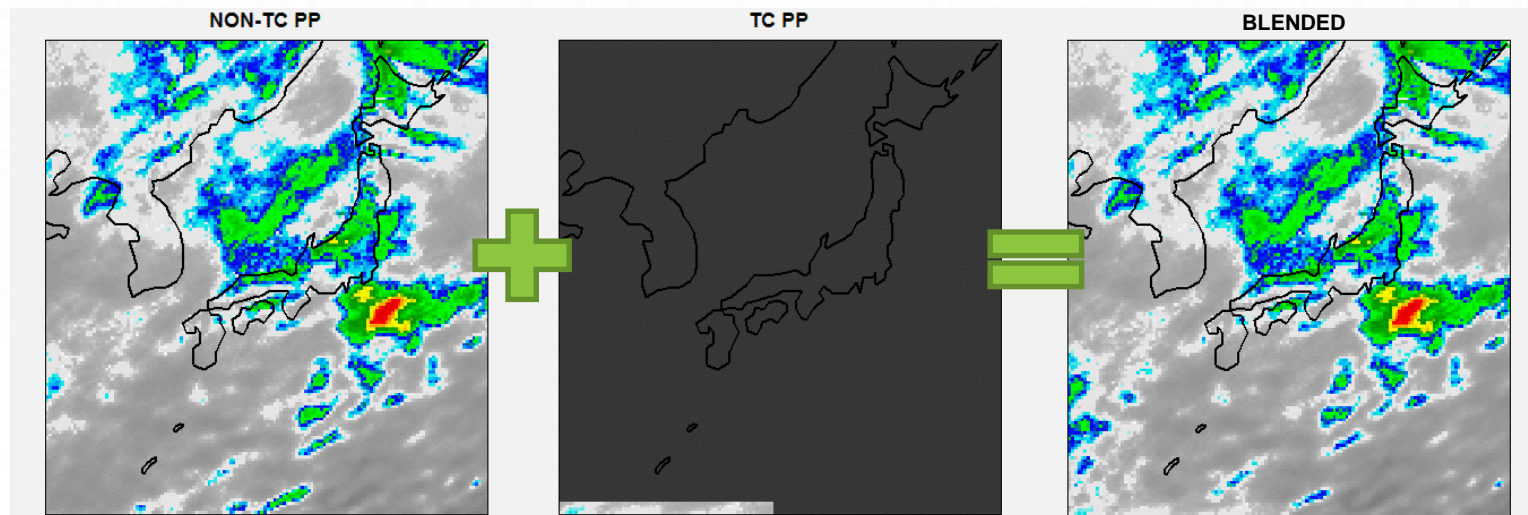
At simulation stage, draw samples from distinct models according to stochastic tracks:

1. Central pressure value
2. Time within storm cycle of stochastically simulated Japan catalog track



## Step 3: Blending Non TC and TC Precipitation

Tropical cyclone simulations are blended into the non tropical cyclone rainfall simulation



# Hydrology Model



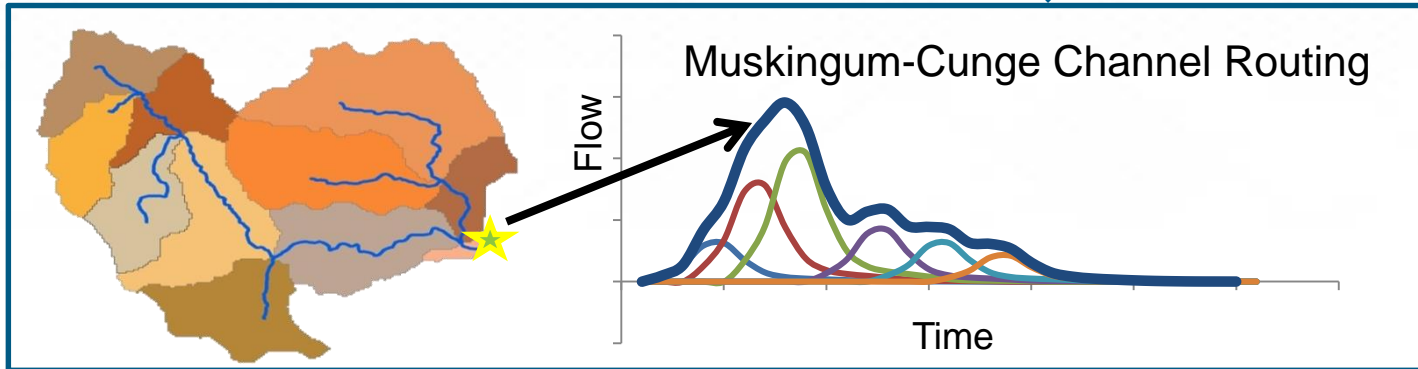
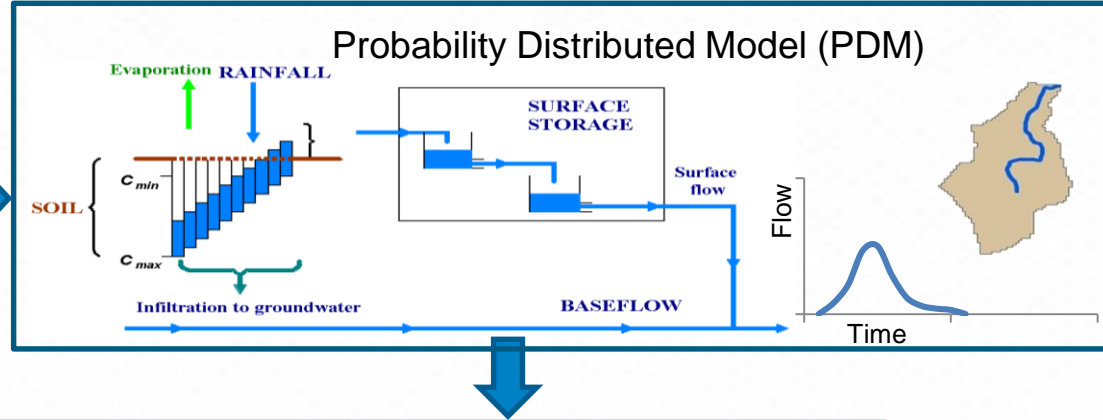
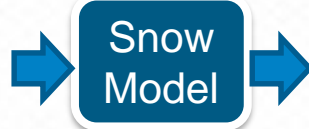


## Hydrologic Model: Transforming Precipitation to Flow

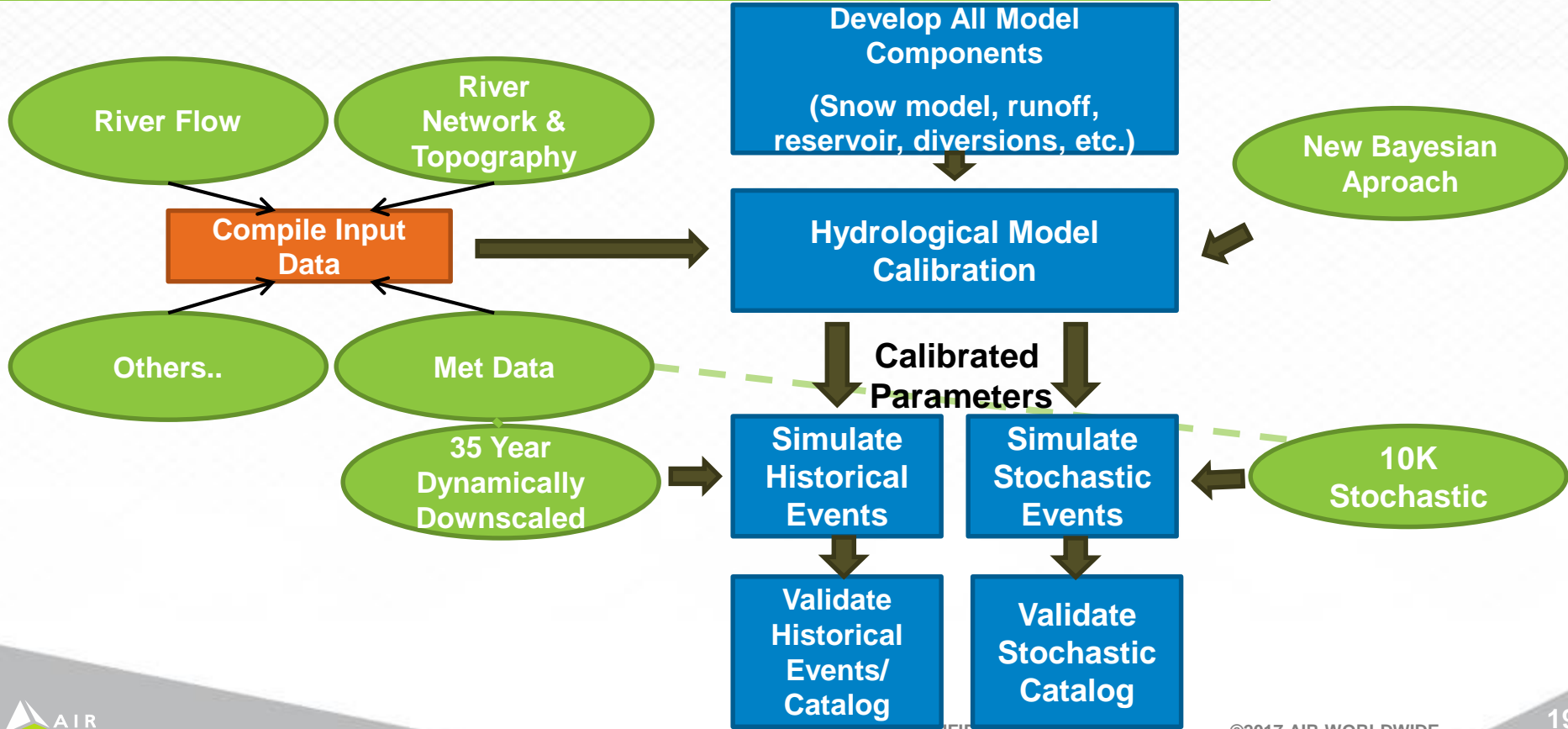
## Precipitation



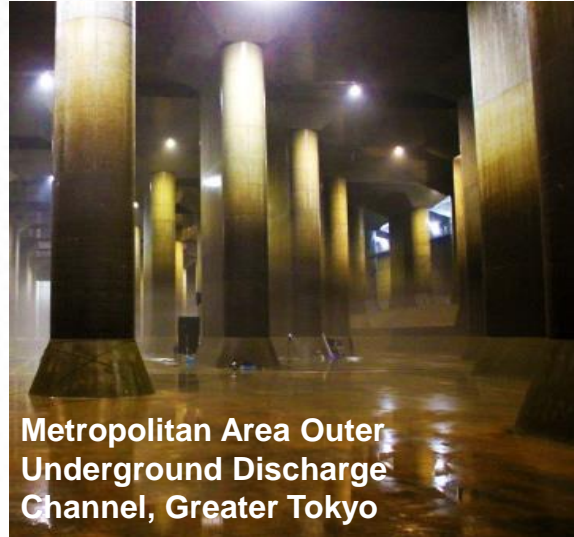
# Runoff and Flow Generation



# Hydrologic Modeling Stages



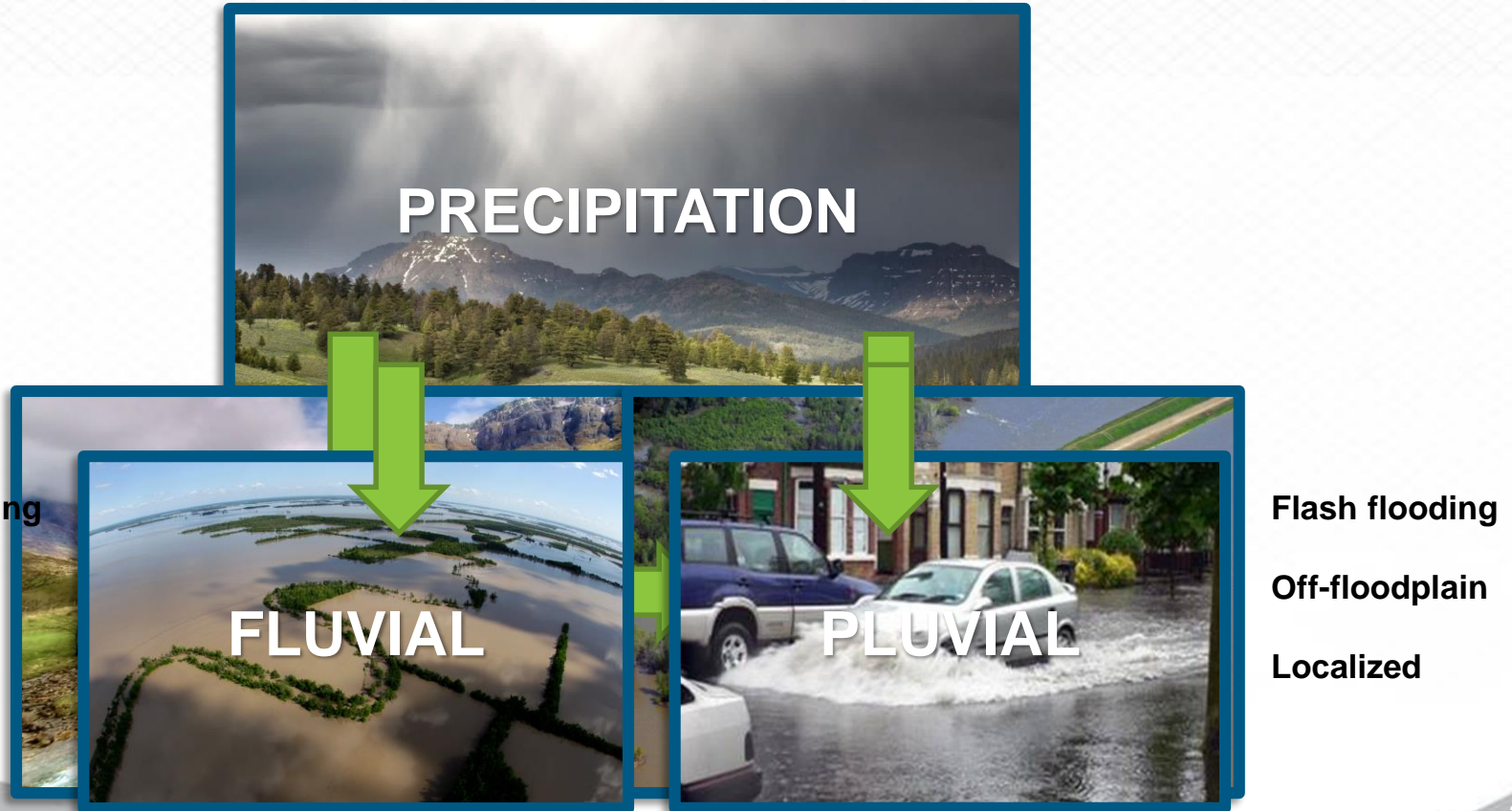
# Reservoirs, Dams, and Diversions



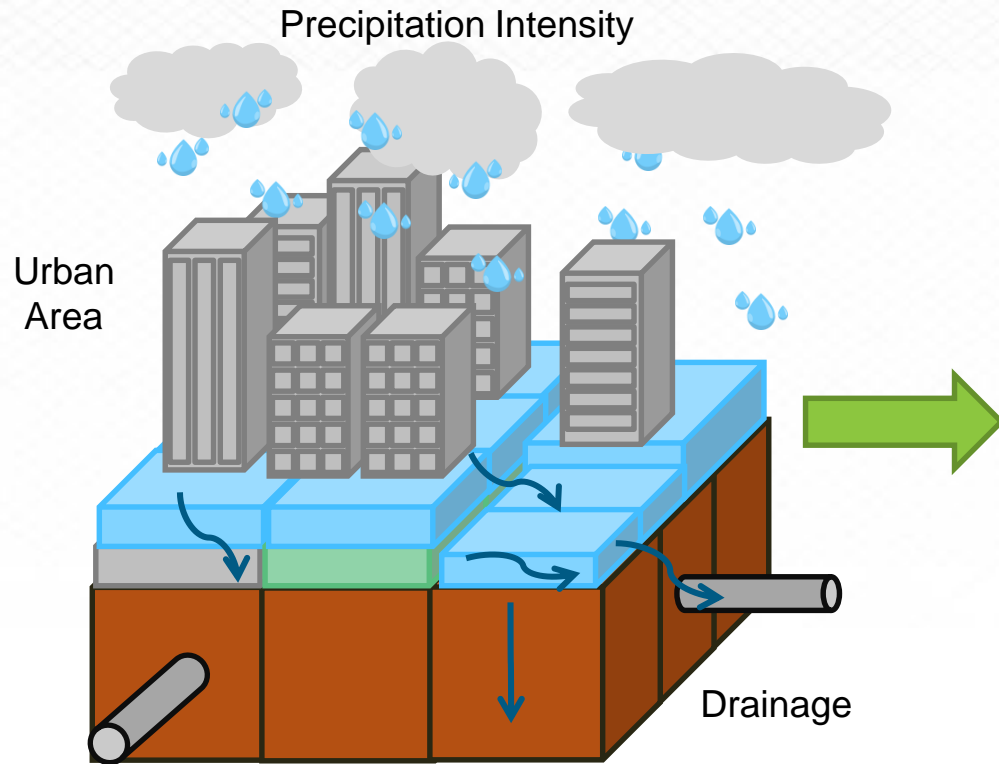
- Reservoirs/dams significantly attenuate the flows downstream
- The operation rules (reservoir rule curves) determine the desired reservoir stage at any given time



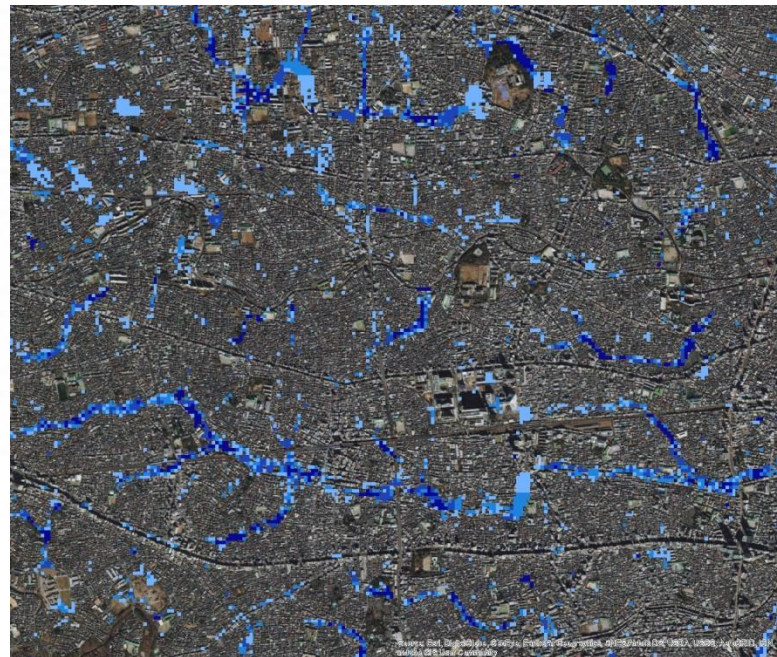
# Hydraulics Model



# Pluvial: New Off-Plain Flood Model

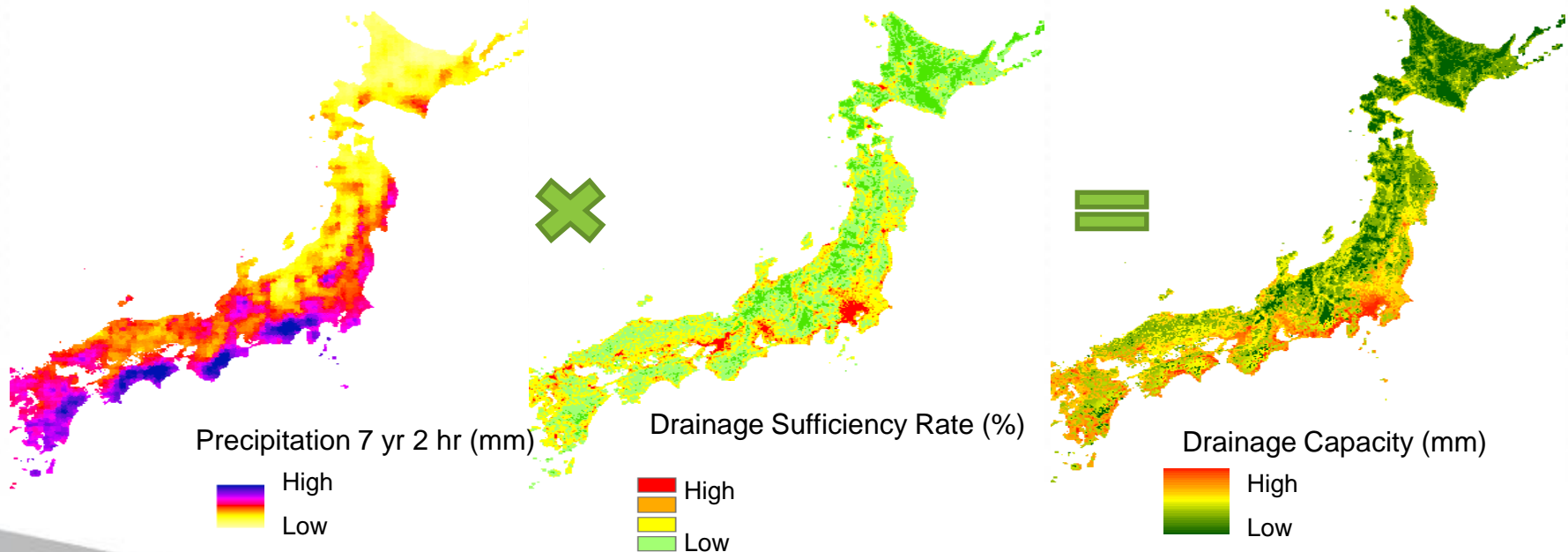


2D Pluvial Model Schematic



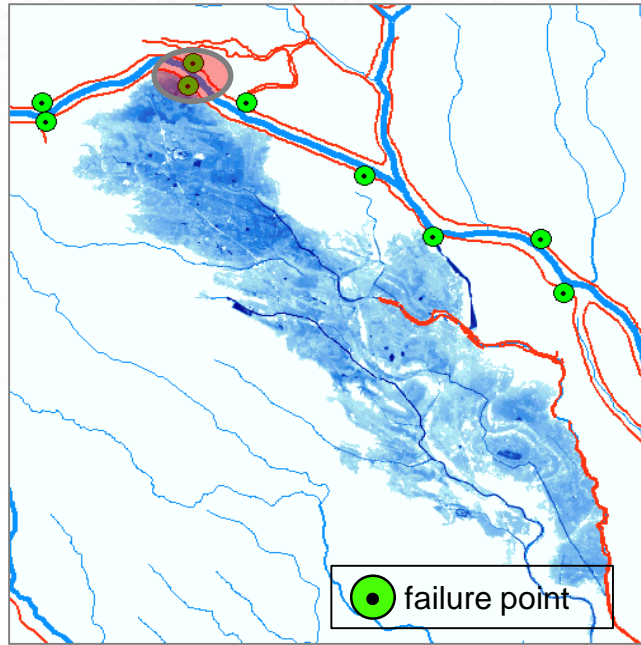
# Pluvial Flood Model: Storm Drainage Capacity in Urbanized Areas

Drainage sufficiency rate and design precipitation are used to estimate storm drainage capacity

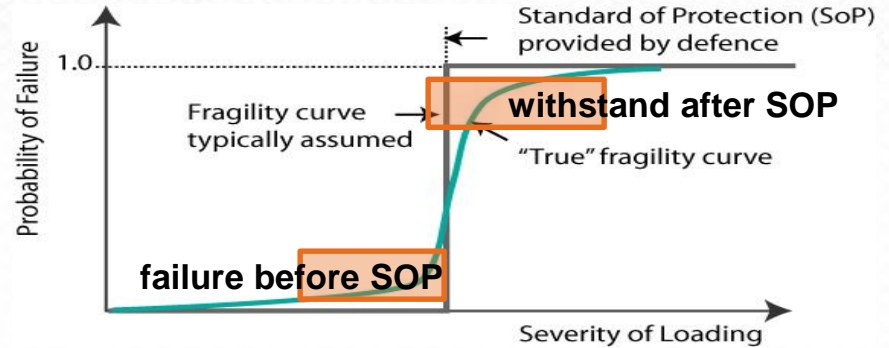




# Fluvial: Explicit Two-Dimensional Modeling



Wide floodplains modeled more effectively, with a more-robust approach and more-complex conditions

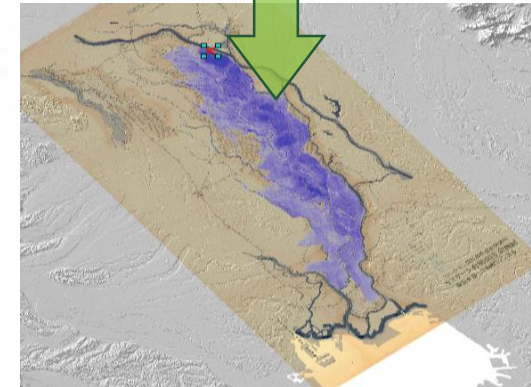
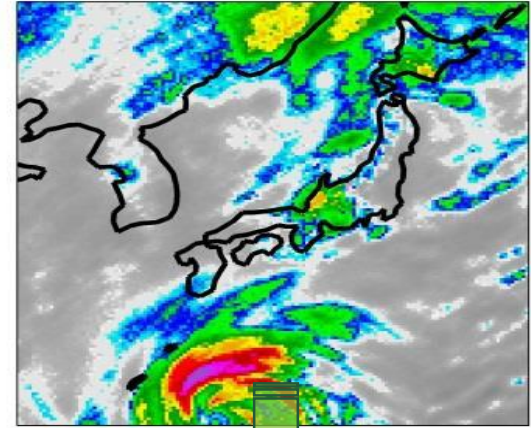


Flood defense failures are dynamically simulated with one-sided failure possible



# Summary of Advancements

- Unified view of hazard, including tropical cyclone and non tropical cyclone rainfall
- New, improved approach to hydrologic model calibration, as well as detailed reservoir representation
- New physically based off-plain flood model explicitly simulates pluvial flooding
- Explicit modeling of certain failure points, including one-sided flood defense failure

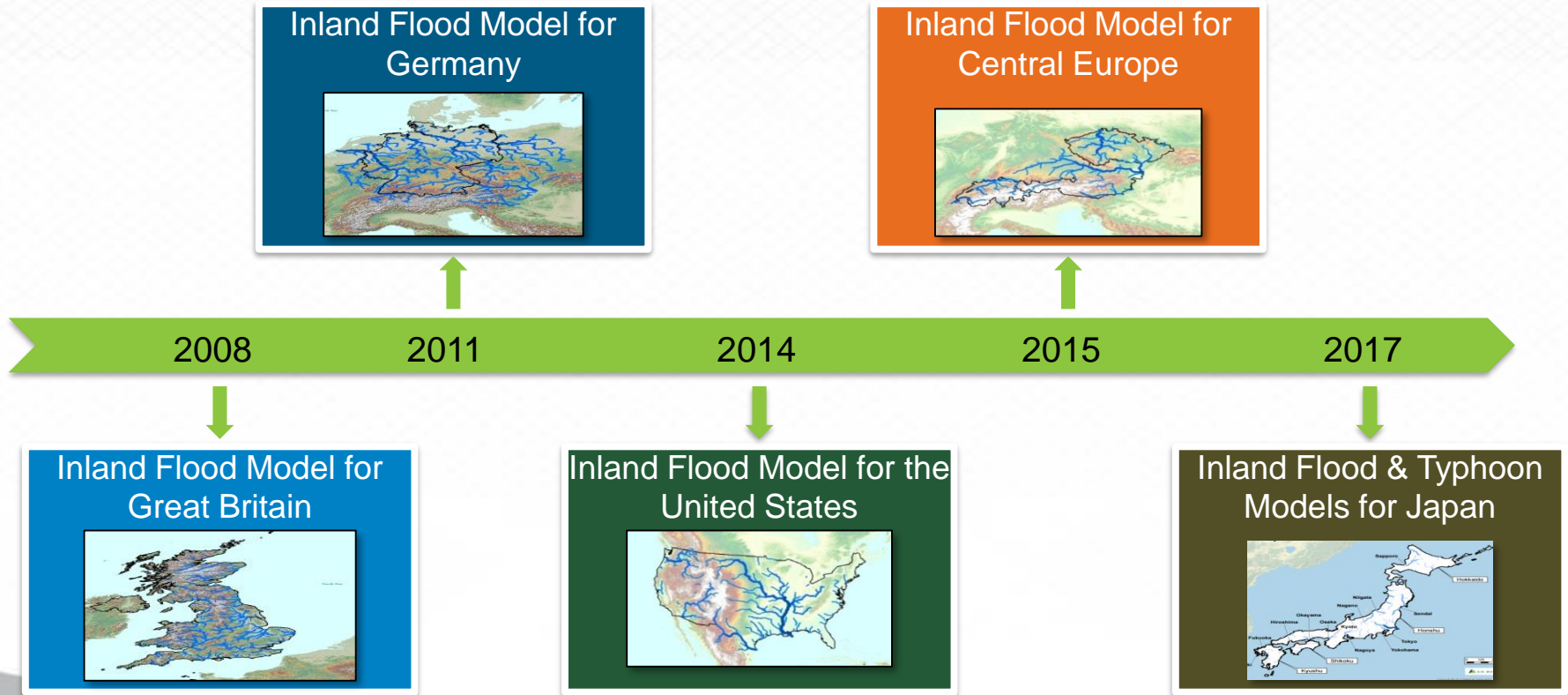


# Modeling Flood Vulnerability for Japan

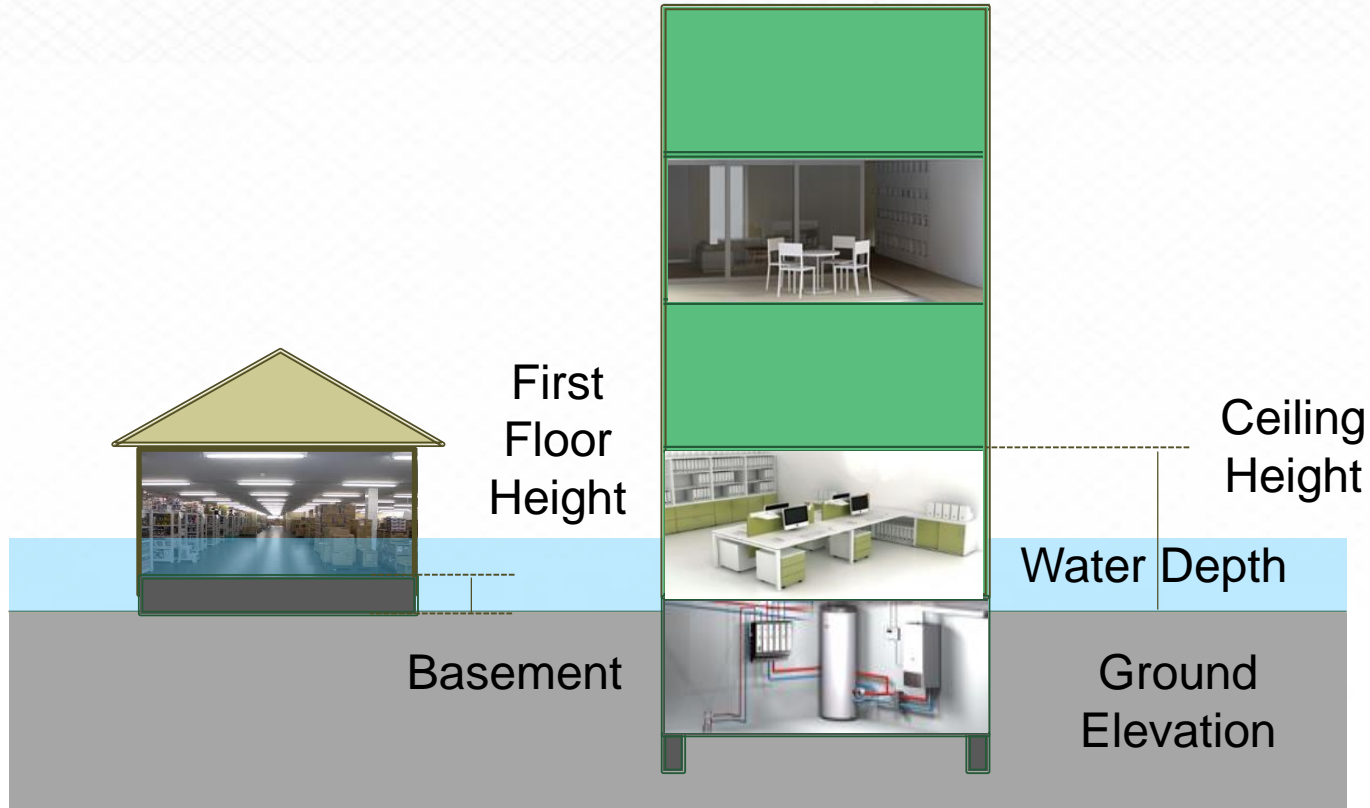




# AIR's Inland Flood Modeling Experience



# Vulnerability Modeling Framework: Overview of Risk Features and Modeling Approach



# Vulnerability Modeling Framework: Overview of Risk Features and Modeling Approach





# Primary Risk Features Supported in Japan

## Conventional Occupancy, Construction, Height, and Coverage



- Composite Construction Class (Fire Codes)
- Low Rise: 1-, 2-, and 3-Story
- Unknown at Prefecture level

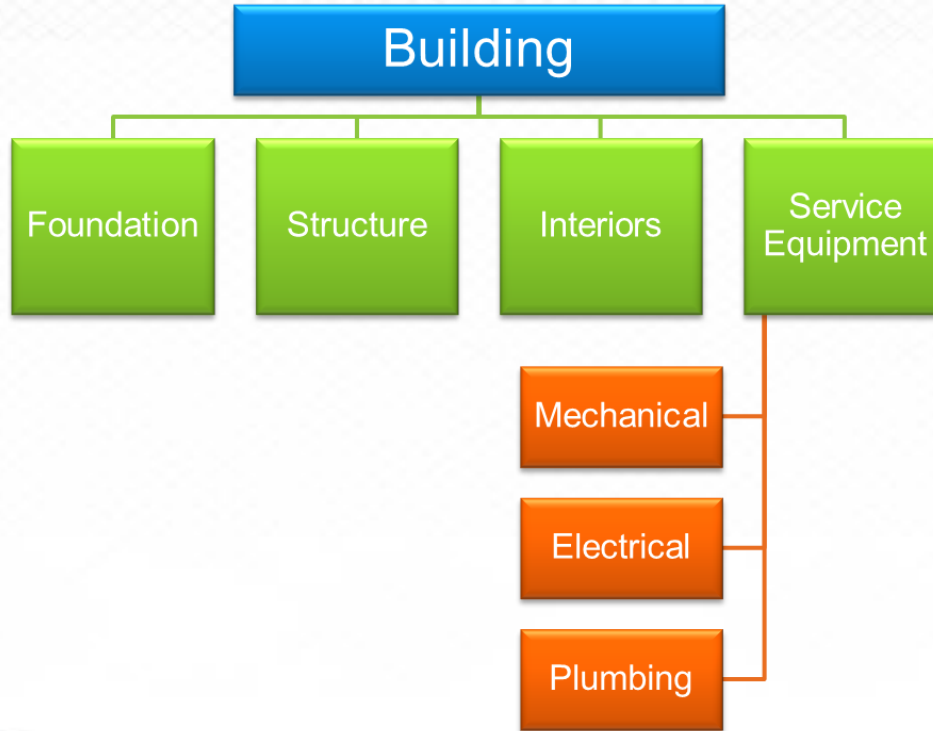
# Special Properties Supported in Japan Inland Flood Modeling

## Marine, Inland Transit, Builder's Risk, and Railway



~147,000 unique  
damage functions

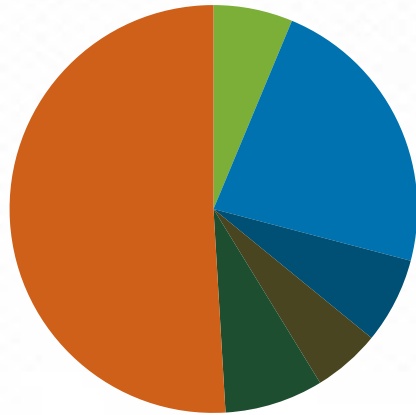
# Vulnerability: Component-Level Approach to Developing Damage Functions



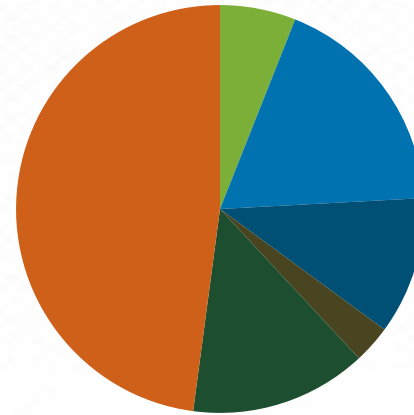
- Buildings are divided into 6 components, which total 100% of replacement value
- Component-level damage functions (DFs) are then combined in proportion to their contribution to the overall replacement value



# Vulnerability: Component-Level Approach to Developing Damage Functions



U.S. Single-Family Home:  
Wood Building

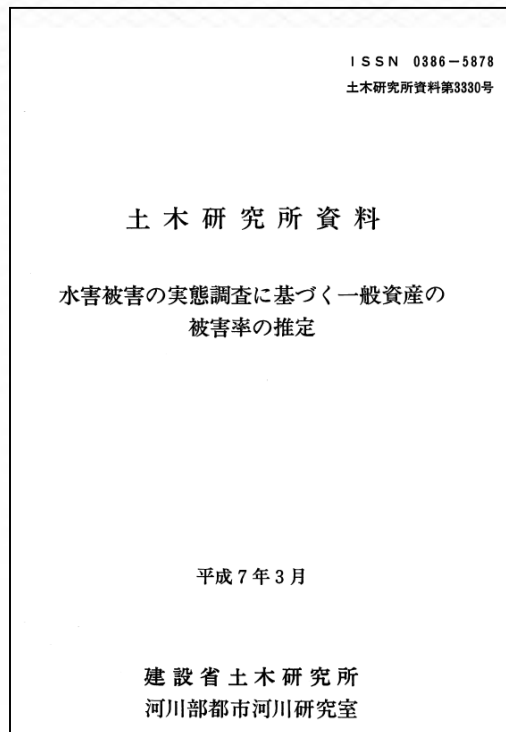


Japan Single-Family Home:  
Wood Building

- Electrical
- Interior
- Foundation
- Mechanical
- Plumbing
- Structures

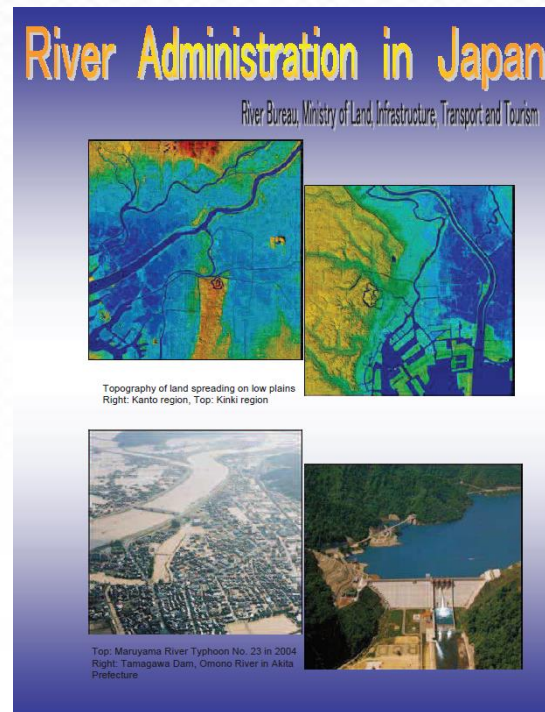


# Data Sources for Vulnerability Model Development



Japanese & Global Publications

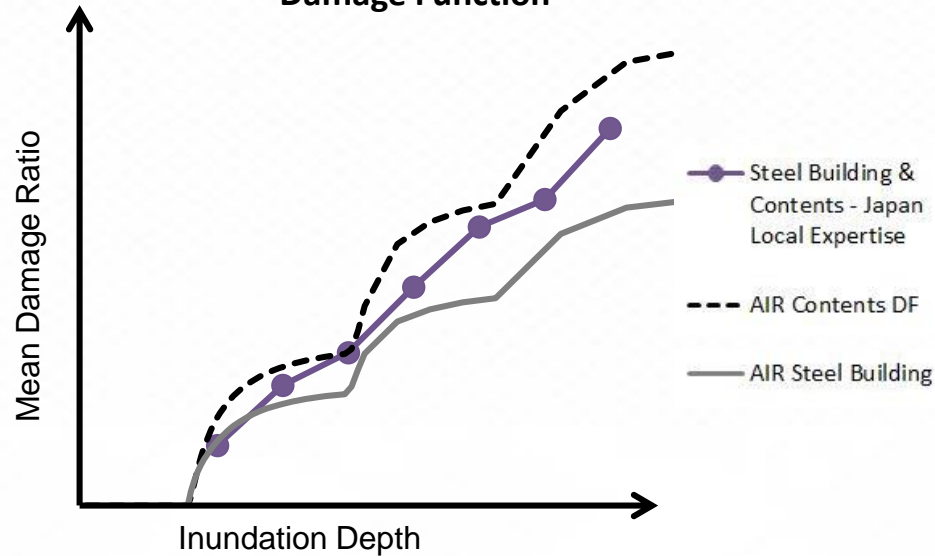
- ✓ Construction Research Institute Monthly Price Index
- ✓ Japan Survey and Inter-Risk Research Institute
- ✓ Japanese Architecture Disaster Prevention Association



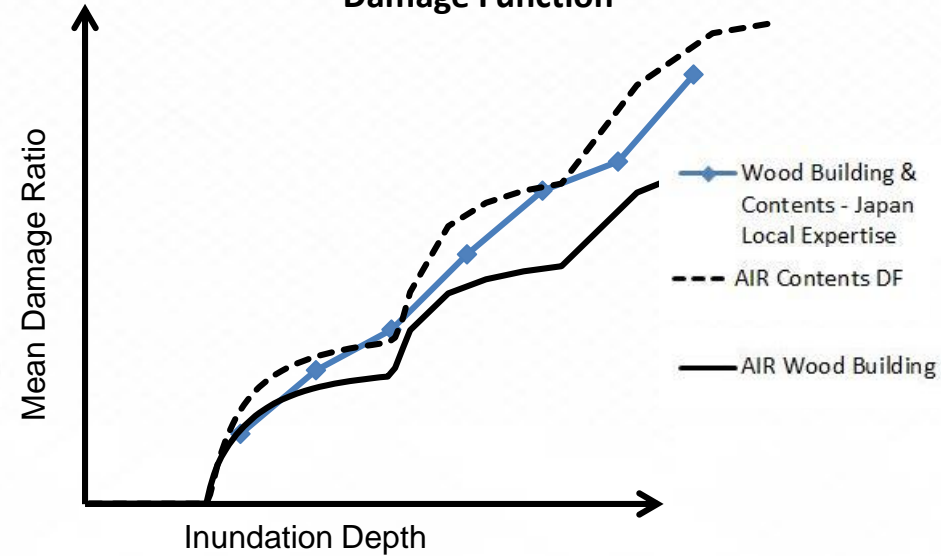
Ministry of Land, Infrastructure and Transport Water Management (MLIT)

# Component-Based Damage Functions Evaluation

Single-Family 3-Story Home: Steel  
Damage Function



Single-Family 3-Story Home: Wood  
Damage Function



# Benchmarking Loss Sources for Loss Validation

- MLIT National Flood Database
- Industry reports and research publications about major historical events losses

www.e-stat.go.jp/SG1/estat/GL02100104.do?gaid=GL02100102&toacd=00600590

**e-Stat** 政府統計の総合窓口

home : Contact Us : help : English : Character enlargement / speech

統計データを探す 地図や図表で見る 調査項目を調べる 統計サイト検索・リンク集 ログイン

Top page > Find statistical data > Provided statistics list

**Provided statistics list**

Please click on the name of the offering statistics you want to see.

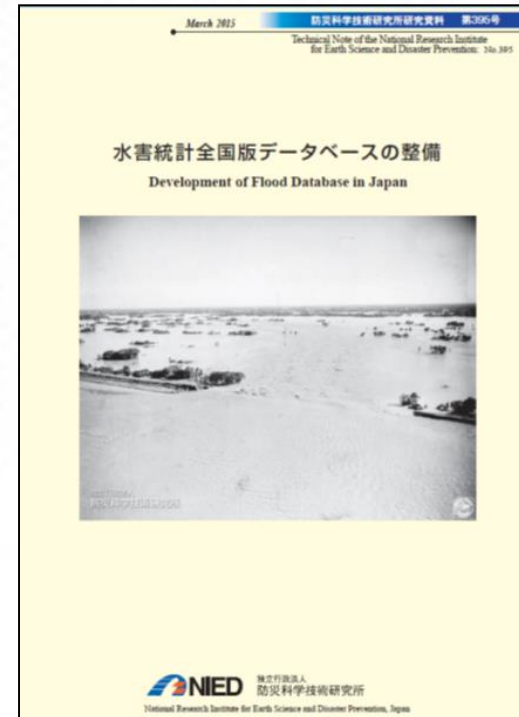
Provided statistic name
<a href="#">Flood damage statistics survey in Heisei 20</a>
<a href="#">Flood statistics survey in Heisei 20</a>
<a href="#">Flood statistics survey in Heisei 24</a>
<a href="#">Flood Damage Statistics Survey in Heisei 23</a>
<a href="#">Flood damage statistics survey in 2010 ("Public public works facility flood disaster statistics survey" was integrated into "flood disaster statistics survey" from 2010)</a>
<a href="#">Flood statistics survey in 2009</a>
<a href="#">Flood statistics survey in 2008</a>
<a href="#">Flood statistics survey in 2007</a>
<a href="#">Flood statistics survey in 2006</a>

GL 0210000104 [To the top of this page](#)

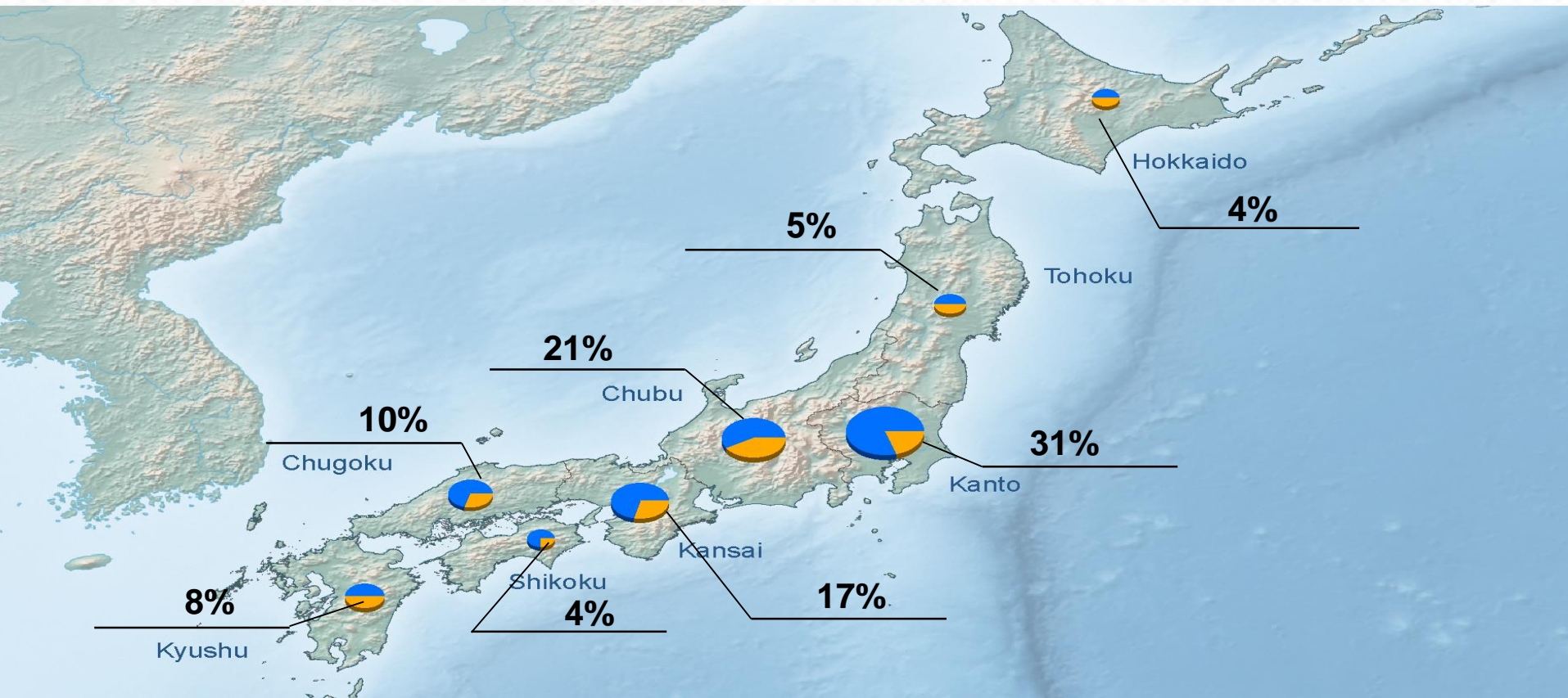
[about this website](#) [Getting Started](#) [Handling of personal information](#) [site map](#)

This website is developed mainly by the Ministry of [Internal Affairs and Communications statistics bureau](#) under the participation of each ministry and other ministries, and the statistical center of [independent administrative agency corporation](#) conducts [operation management](#).

Copyright (C) 2011 Ministry of Internal Affairs and Communications Statistics Bureau All rights reserved.

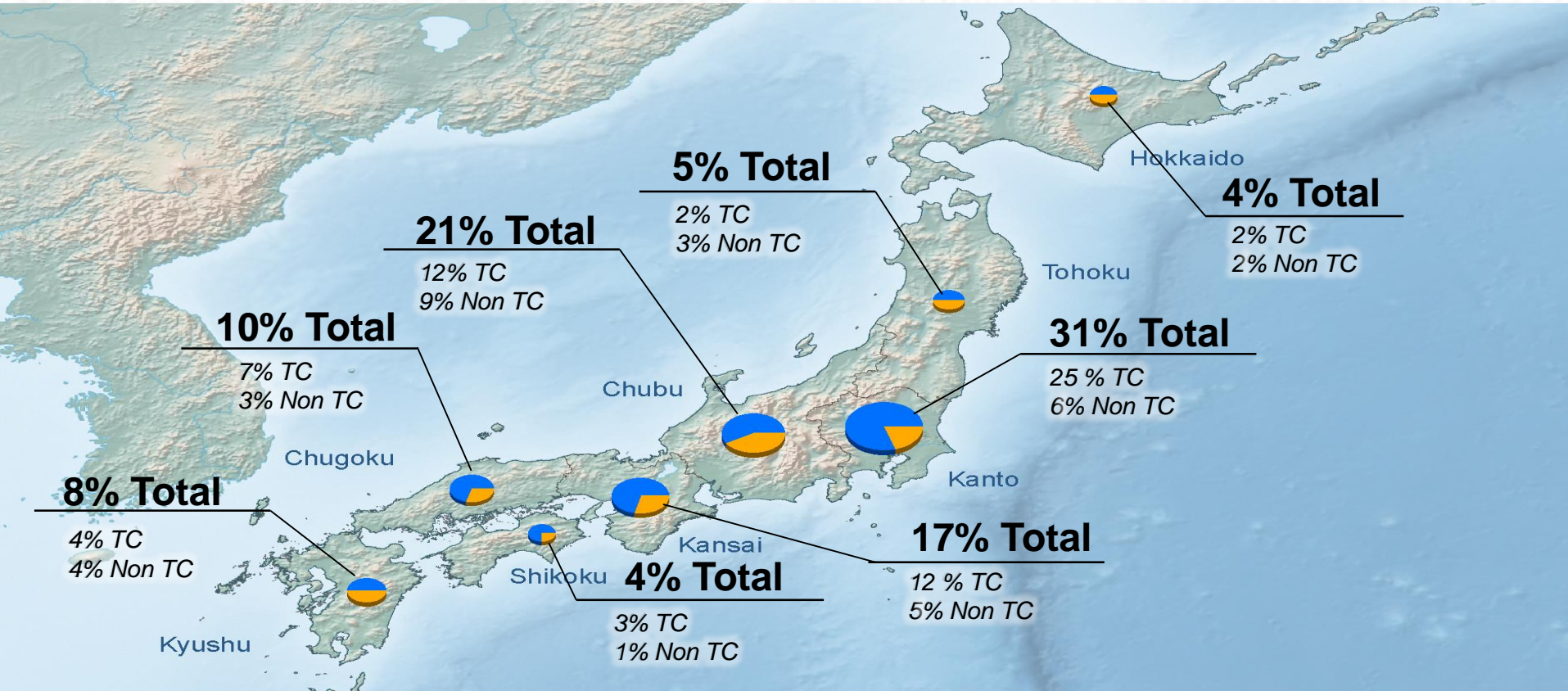


# Regional Distribution of Total Flood Risk





# Regional Distribution of Flood Risk for TC and Non TC Flood



# Updates to the AIR Typhoon Model for Japan



# Updates to the Typhoon Model for Japan

Updated the IED and enhanced building and time element damage function (supported old fire codes)

Introduced new IED and enhanced building damage function (supports new fire codes)

Introduce new IED, new flood module, and updated wind and surge modules

2002

2007

2010

2012

2015

2017

Released the first AIR Typhoon Model for Japan

Became part of the Northwest Pacific Basinwide Typhoon Model, introduced flood module, and supported more LOBs (marine, inland transit, railway, etc.)

Introduced physically based storm surge module and minor wind vulnerability update

# New Data Used to Evaluate the Model

AIR has collected detailed claims and loss information from 2001 to 2015



Typhoon Etau

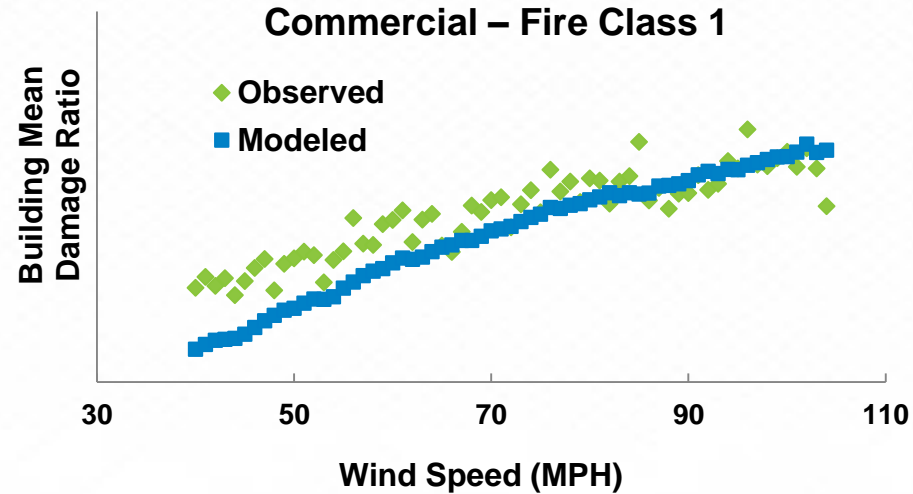
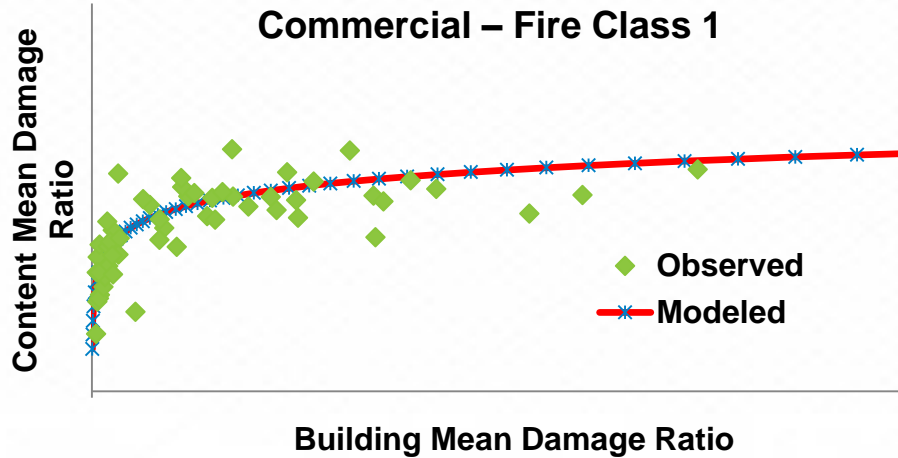


Typhoon Tokage

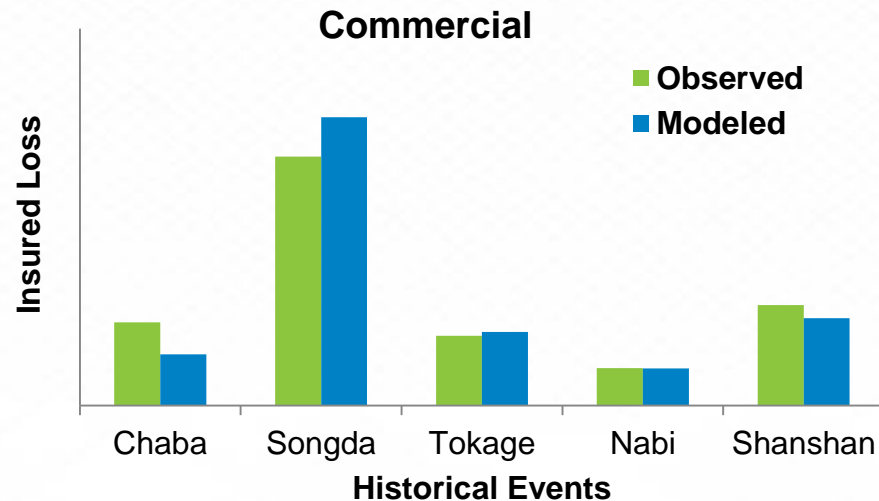
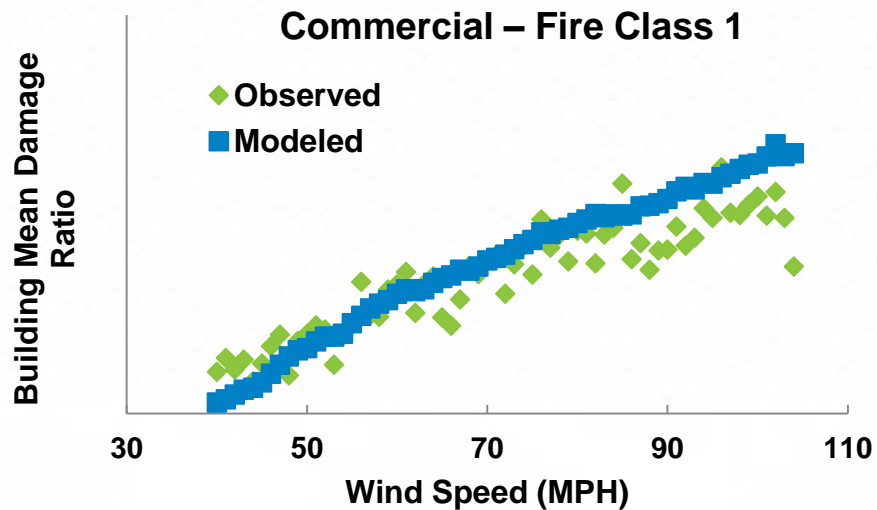




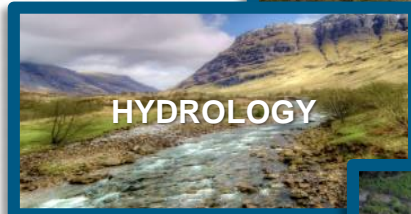
# Typhoon Wind: Re-Evaluating the Damage Function



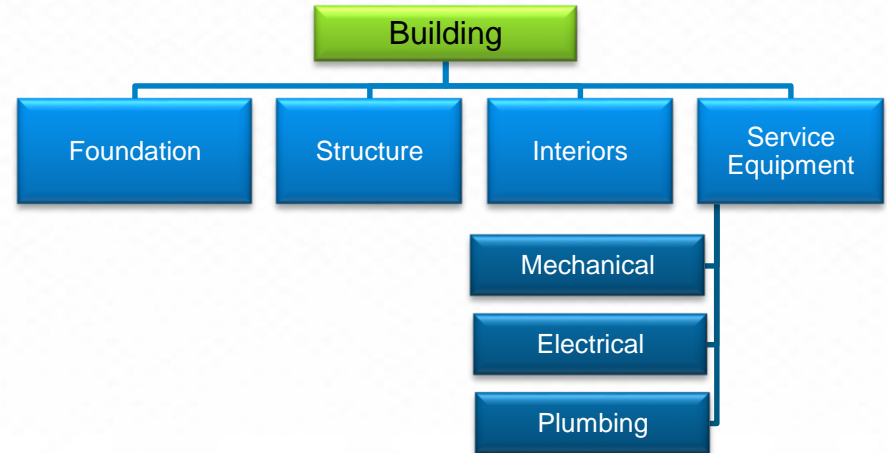
# Typhoon Wind: Positive Validation of the Updated Wind Component



# Enhanced Flood Hazard and Vulnerability Module



Flood Hazard



Flood Vulnerability

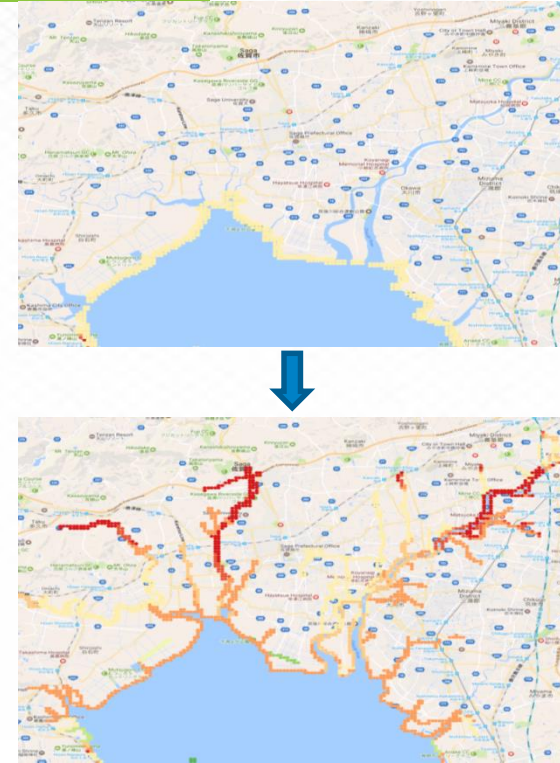
# Enhanced Storm Surge Hazard and Vulnerability Module

## Storm Surge Hazard

- Updated the coastal levee system in Hiroshima and Saga
- Increased the storm surge resolution from 250 meters to 25 meters

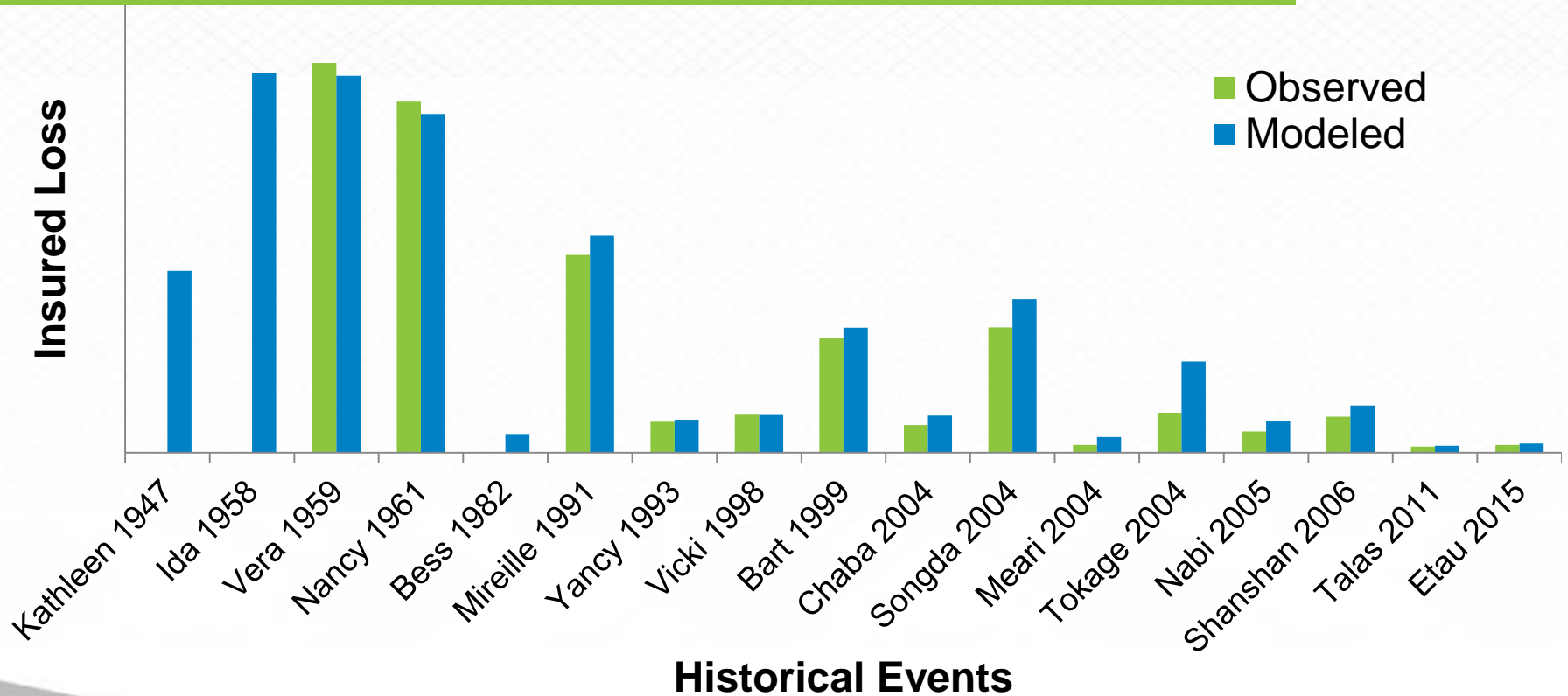
## Storm Surge Vulnerability

- Used the component level methodology
- Supported the same secondary features as flood



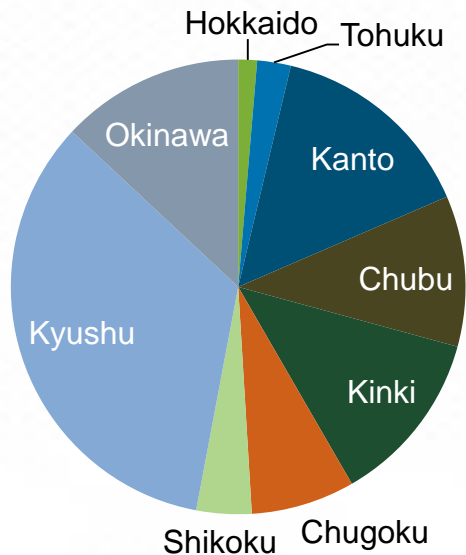


# Updated Validation for Historical Events

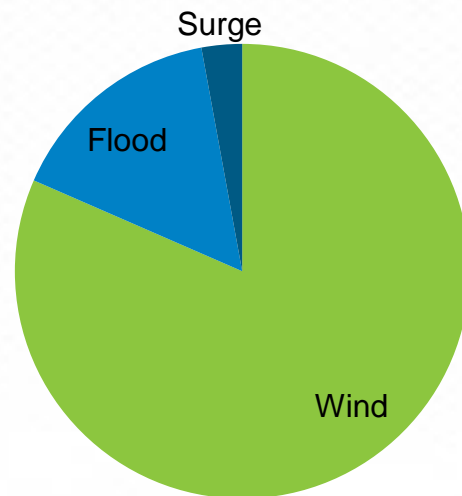


# AAL Contribution by Region and Sub-Perils

## AAL Distribution by Region



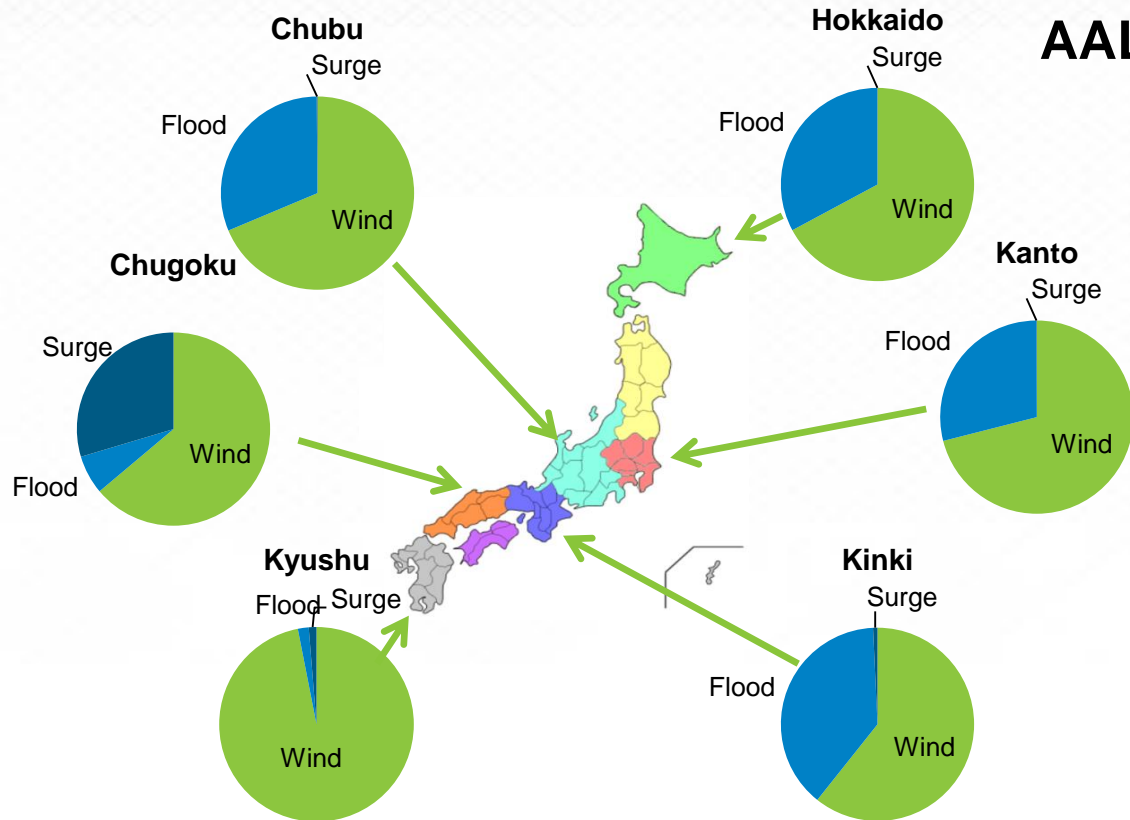
## AAL Distribution by Sub-Perils



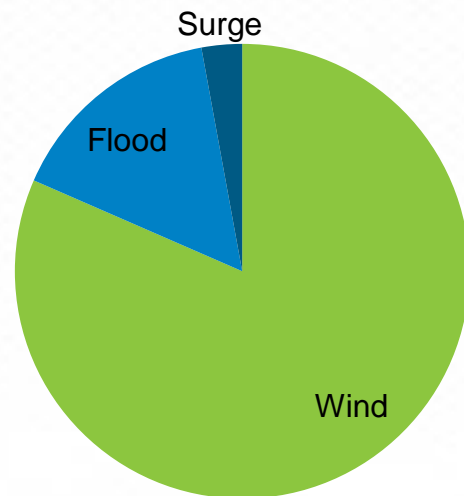
Typhoon risk in Japan is mainly in the southern region, including Kyushu, Okinawa, Chugoku, Kanto, etc.

# AAL Contribution by Region and Sub-Perils

## AAL Contribution by Sub-Peril for Key Regions



## AAL Distribution by Sub-Perils



# In the New AIR Model, Typhoon Risk Varies by Region and Sub-Perils in Japan

Region	Total	Wind	Flood	Surge
Japan	Small	Small	Large	Medium
Hokkaido	Small	Small	Medium	Small
Tohoku	Medium	Small	Large	Large
Kanto	Medium	Small	Large	Medium
Chubu	Small	Medium	Medium	Large
Kansai	Small	Medium	Small	Large
Chugoku	Small	Small	Large	Medium
Shikoku	Medium	Small	Medium	Large
Kyushu	Small	Small	Large	Medium
Okinawa	Medium	Medium	Large	Small

Category	Absolute Change %
Small	<10%
Medium	10%-50%
Large	>50%





## Closing Remarks

---

- Introducing a new model for floods from non tropical cyclones and enhancing flood module in typhoon model
- Flood model validates well against observed data from MLIT and other sources
- Updated typhoon model
- AIR provides a comprehensive view of risk in Japan

**Thank you!**

