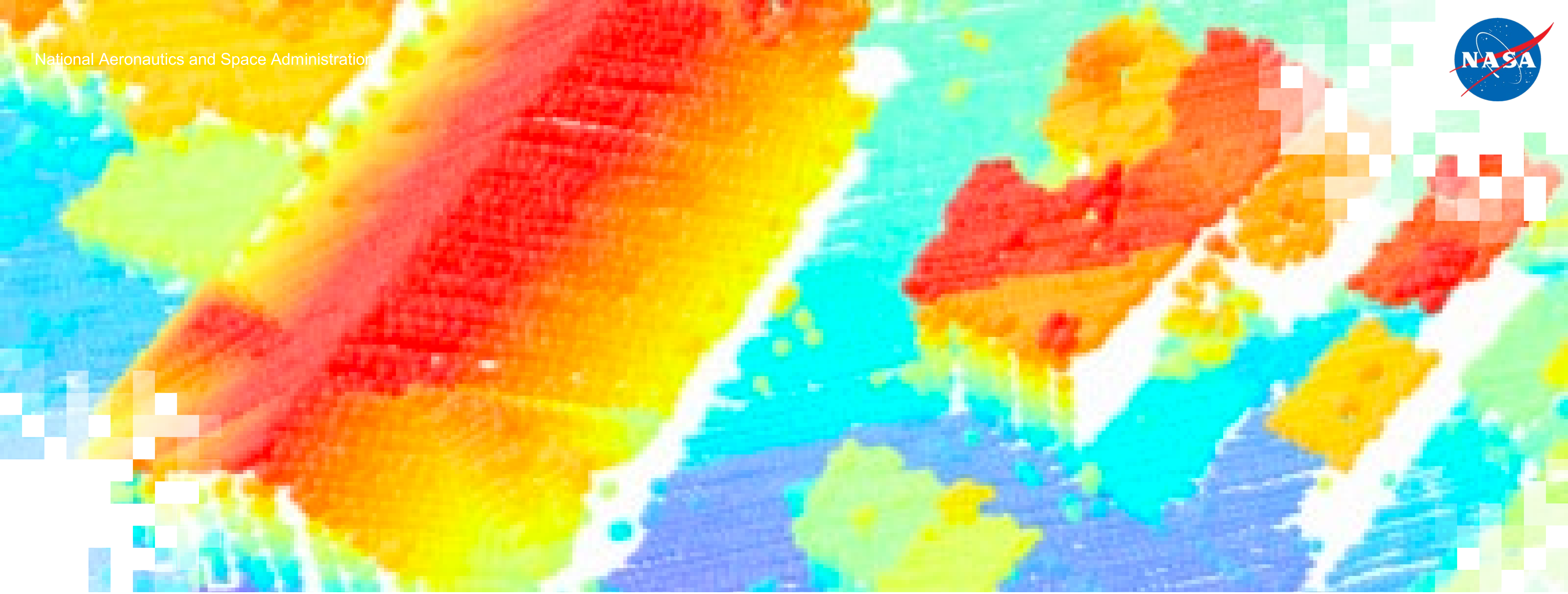
National Aeronautics and Space Administration

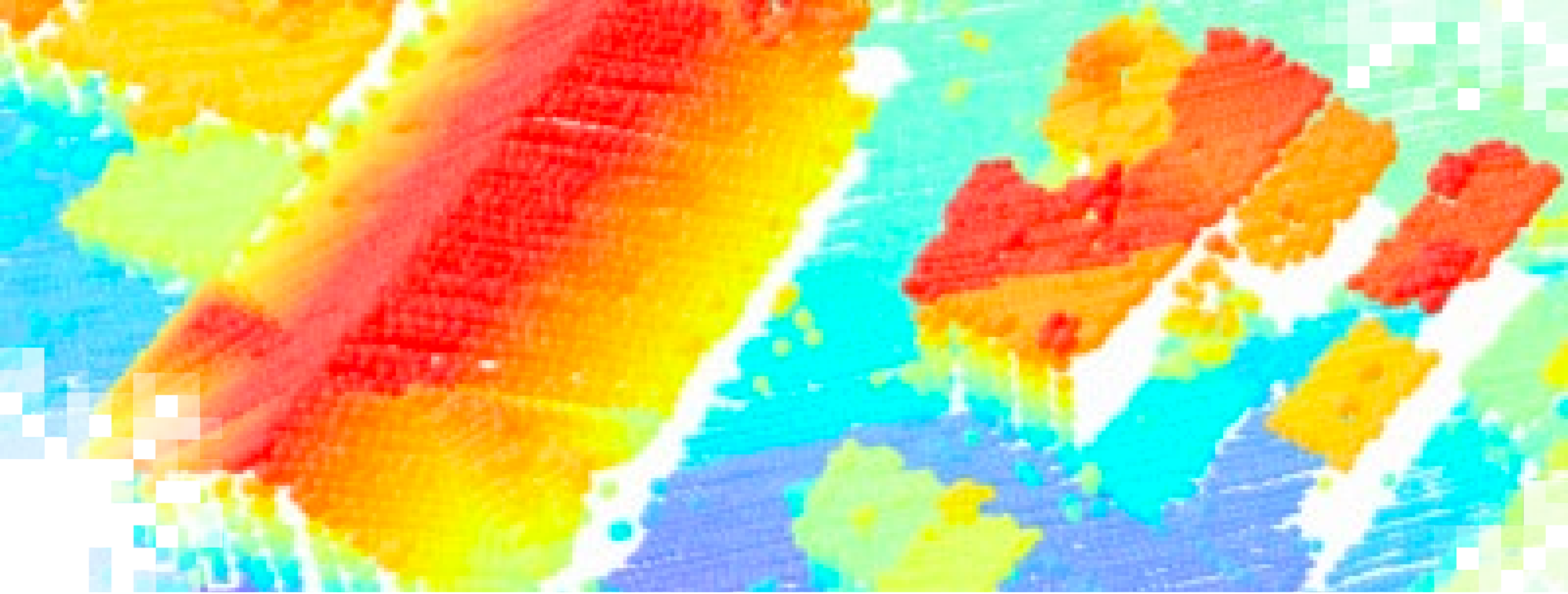


Transforming Earth Observation (EO) Data into Building Infrastructure Data Sets for Disaster Risk Modeling

Part 3: Assessing Utility and Communicating Uncertainty

Michael Eguchi (ImageCat), Paul Amyx (ImageCat), Charles Huyck (ImageCat) &
Marina T. Mendoza (ImageCat)

October 10, 2023



Transforming Earth Observation (EO) Data into Building Infrastructure Data Sets for Disaster Risk Modeling

Overview

Why is Climate Risk Assessment Important?

- Even with drastic reduction in carbon emissions, short and medium-term impacts are inevitable
- Climate change impacts and risks are becoming increasingly complex and more difficult to manage (IPCC AR6, 2022).
- Climate change impacts on human infrastructure are not well understood and vary drastically by location
- Understanding community-specific risks to climate change is critical to evaluating adaptation strategies

"You can't stop the waves, but you can learn to surf." - Jon Kabat-Zinn

Credit: Scott Pena

Training Outline

Part 1

Development of Regional Exposure Data with EO

October 03, 2023

10:00-12:00 EDT (UTC-4)

Part 2

Development of Site-Specific Exposure Data with EO

October 05, 2023

10:00-12:00 EDT (UTC-4)

Part 3

Assessing Utility and Communicating Uncertainty

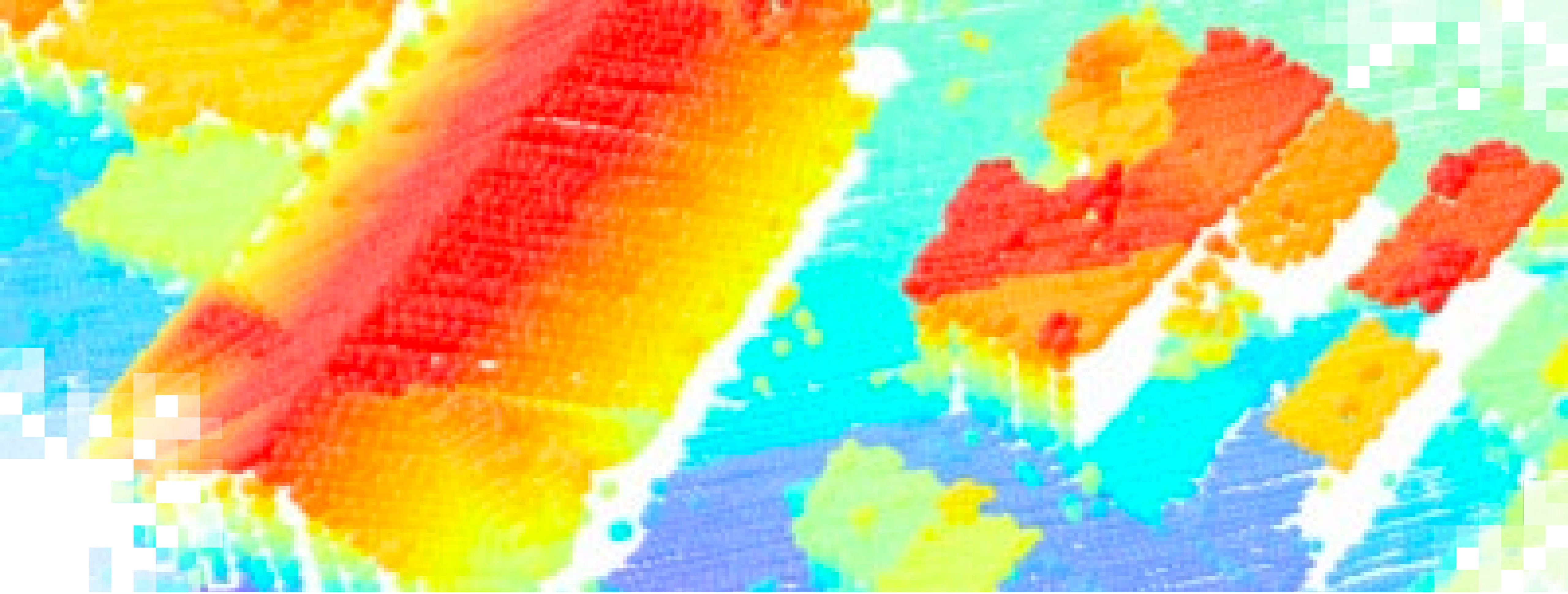
October 10, 2023

10:00-12:00 EDT (UTC-4)

Homework

Opens October 10 – Due October 24 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment before the given due date.



Transforming Earth Observation (EO) Data into Building Infrastructure Data Sets for Disaster Risk Modeling

Part 3: Assessing Utility and Communicating Uncertainty

Part 3 Objectives

By the end of Part 3, participants will be able to:

- Evaluate the appropriate use of modeled building exposure data to a given community
- Apply strategies to identify and address equity and bias considerations
- Apply approaches to validate building data with imagery for regional datasets
- Document your exposure development process through metadata so that others can understand the process used, the limitations, and how to update if necessary.

Part 3 – Trainers

Charles Huyck

Executive Vice President

ImageCat

Paul Amyx

Senior Programmer

ImageCat

Marina Mendoza

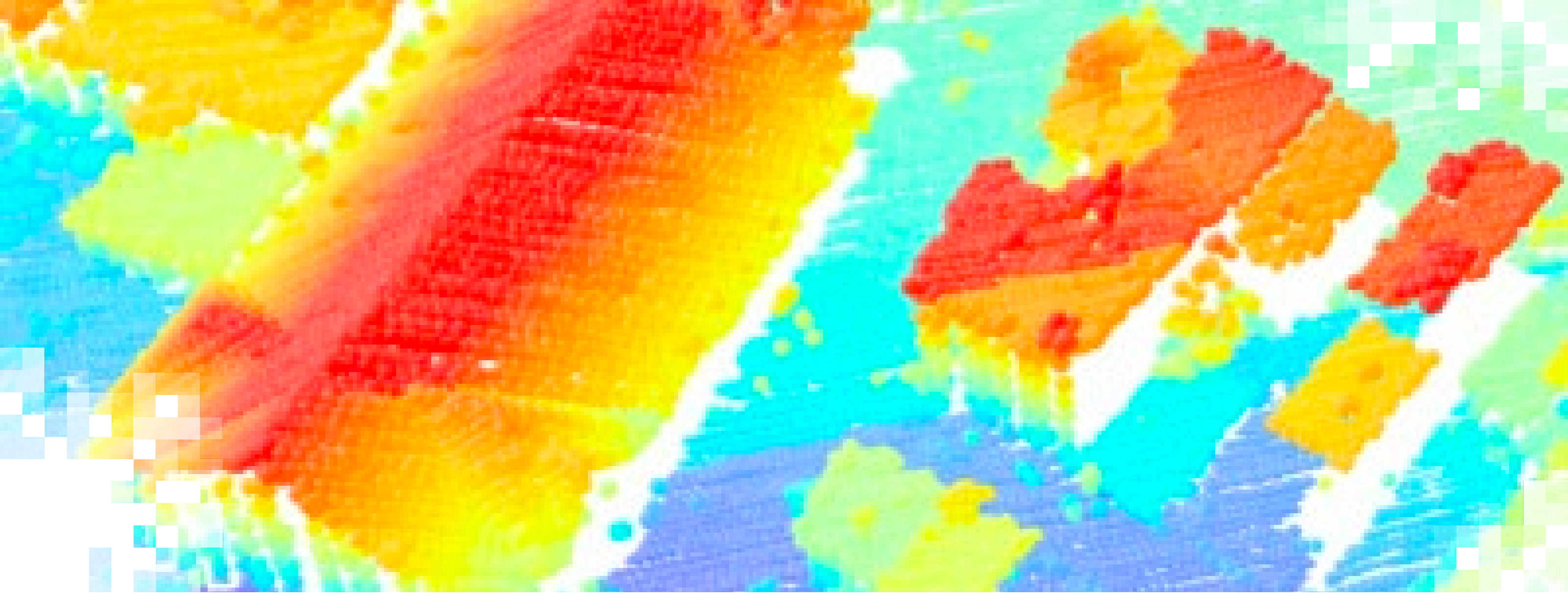
Project Engineer

ImageCat

Michael Eguchi

Project Engineer

ImageCat



Part 3:

How to check exposure data and ensure fit for purpose

Objective

- Overview of levels of exposure data
- Pre-event
  - How can the data assist in mitigation strategies?
  - How can the data further building safety through code adoption/enhancement or risk management?
  - Implications to insurance/reinsurance?
- Post-event
  - How can the data be used for post-disaster response?
- Limitations
  - How should the data NOT be used?

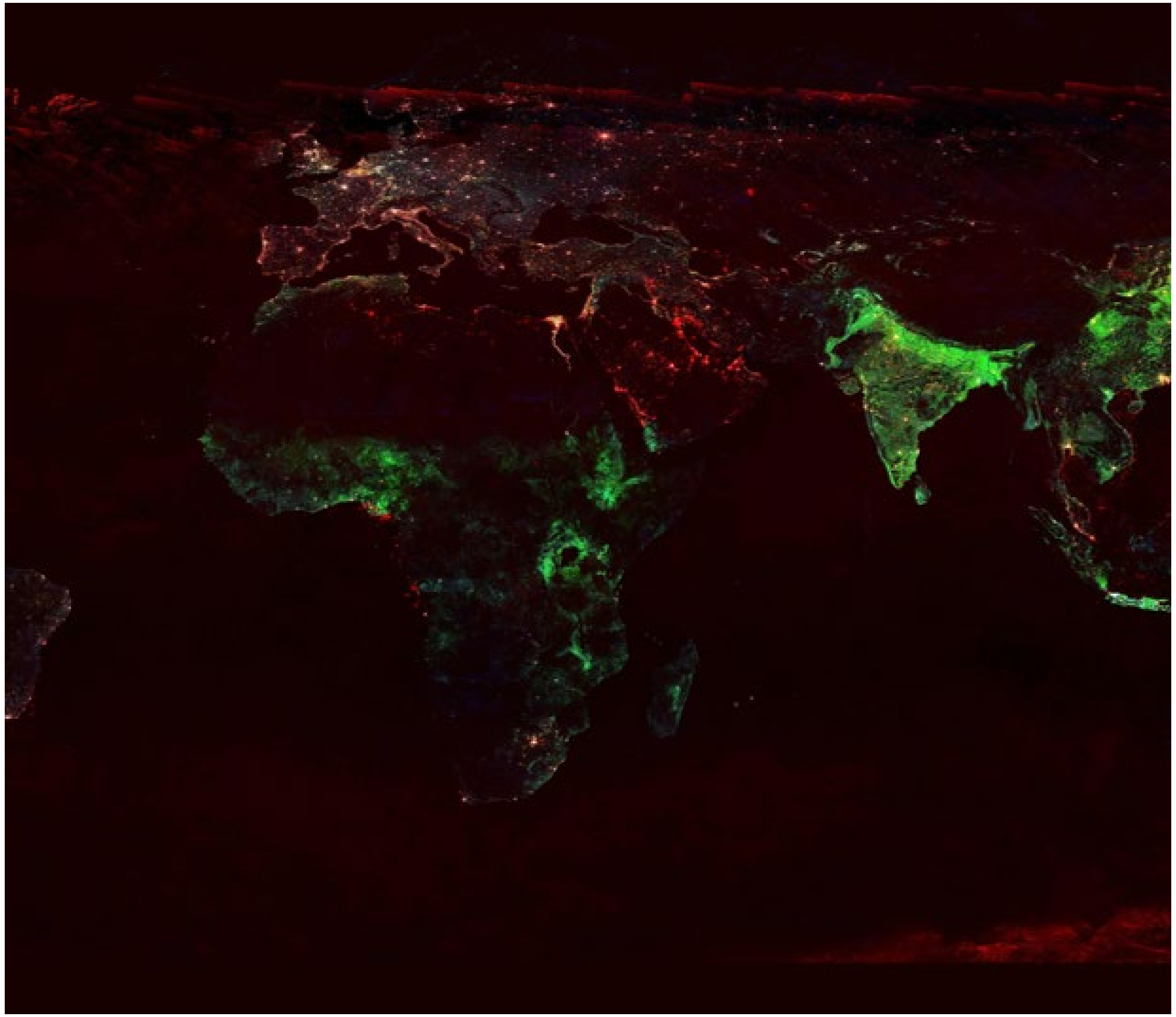
Level 1 Global Data - Overview

Description

- Rely on best available global datasets, but can be continental or regional
- Country-specific information is minimal while proxy countries are often be used
- Global population data sets used as primary source, with very rough mapping schemes typically broken out by rural and urban regions

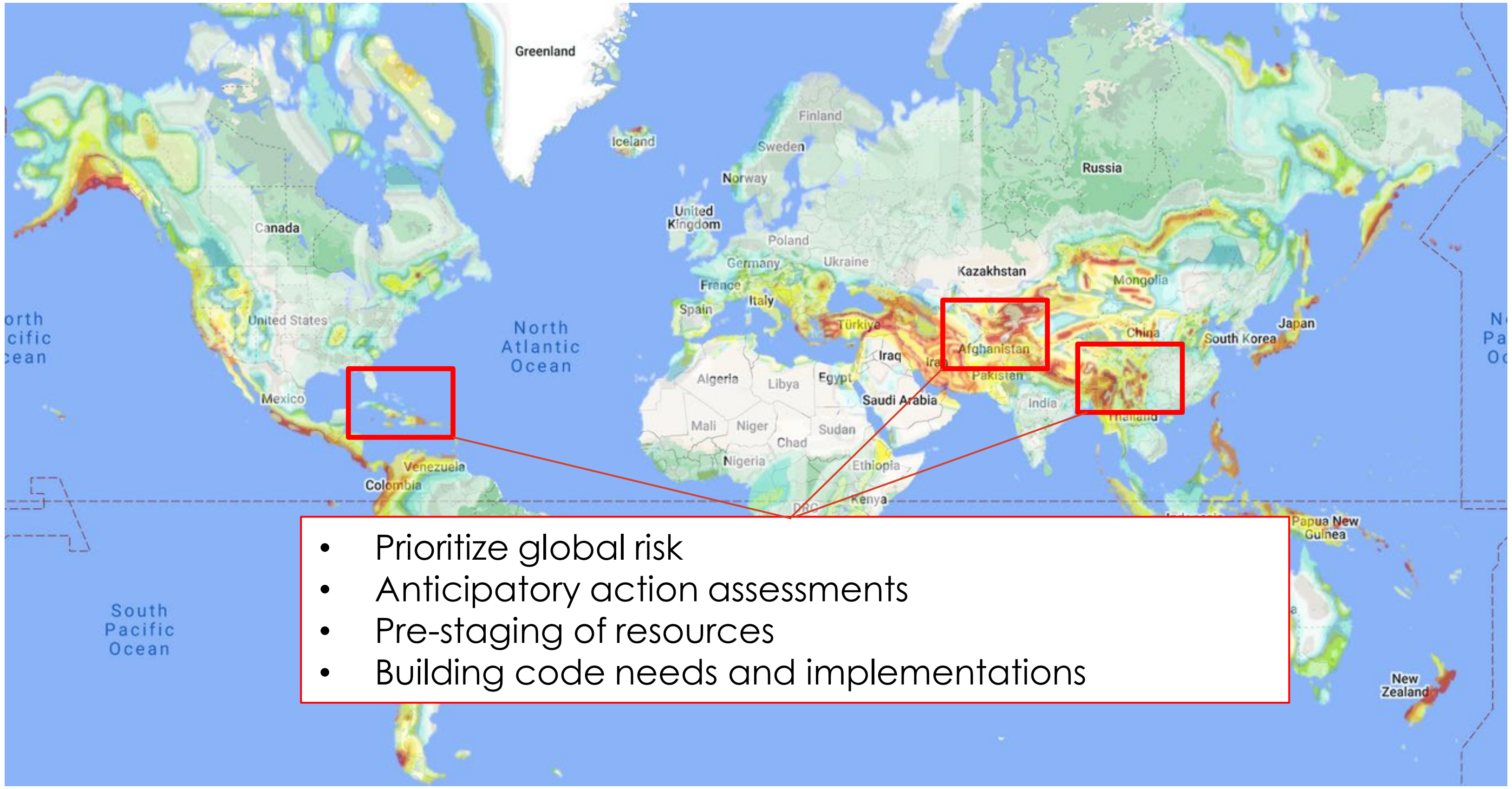
Data Available

- High level building descriptors



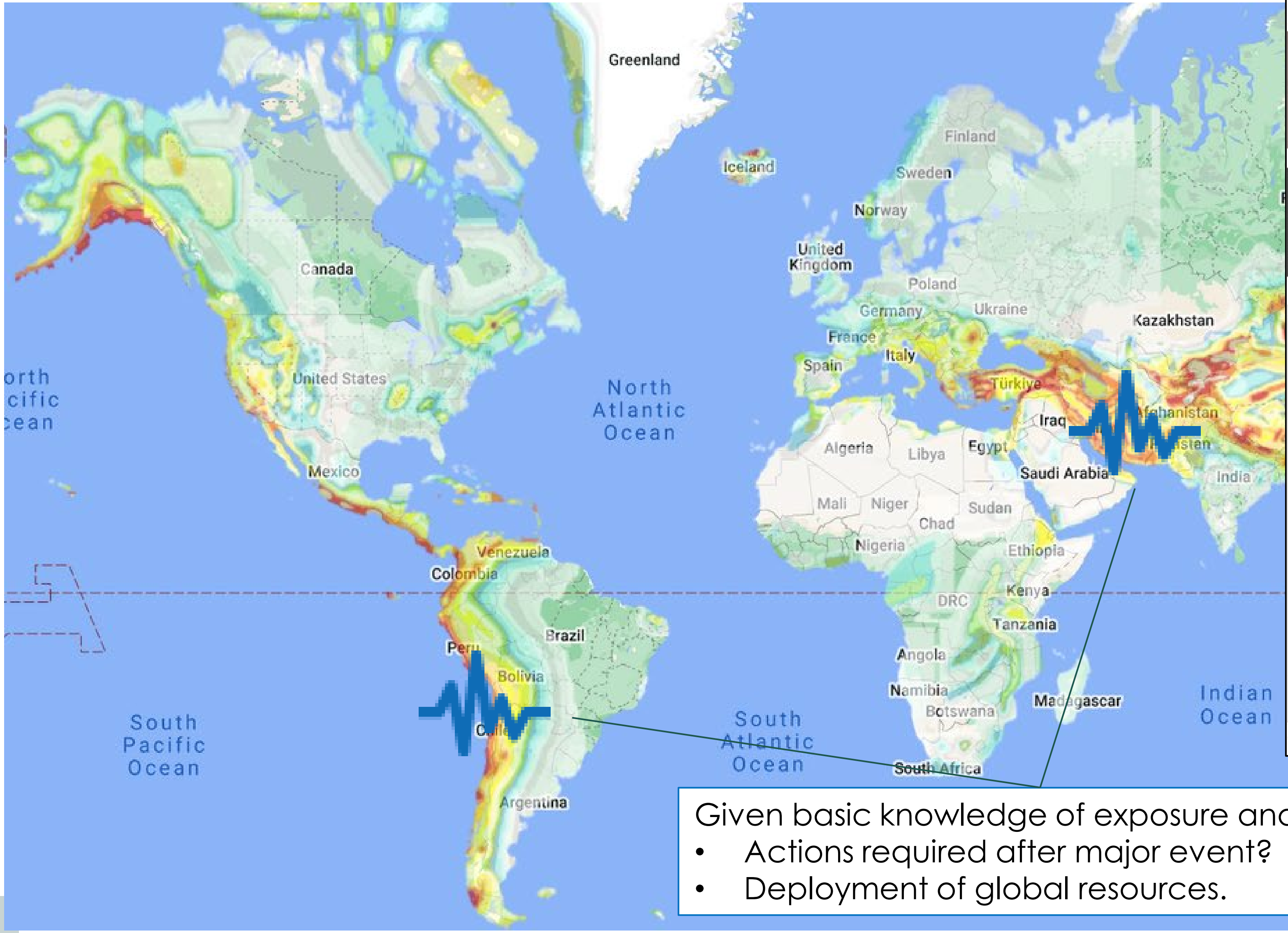
Level 1 Global Data – Mitigation and Preparation

- Broad-scale prioritization of further study
- Development of international risk indices
- Insurance and Reinsurance
  - Risk Diversification
  - Climate Change / ESG risk assessment



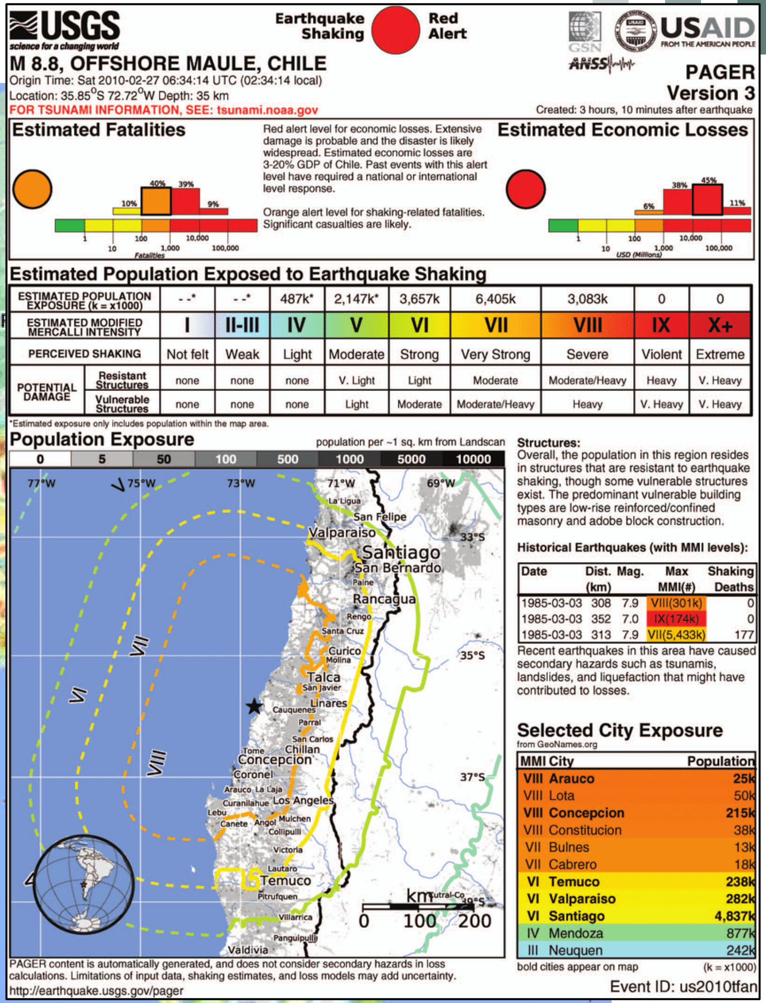
- Prioritize global risk
- Anticipatory action assessments
- Pre-staging of resources
- Building code needs and implementations

Level 1 Global Data – Post-Disaster Response



Given basic knowledge of exposure and risk

- Actions required after major event?
- Deployment of global resources.



USGS science for a changing world

Earthquake Shaking 🔴 **Red Alert**

USAID FROM THE AMERICAN PEOPLE

GSN ANSS

PAGER Version 3

M 8.8, OFFSHORE MAULE, CHILE

Origin Time: Sat 2010-02-27 06:34:14 UTC (02:34:14 local)

Location: 35.85°S 72.72°W Depth: 35 km

FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

Created: 3 hours, 10 minutes after earthquake

Estimated Fatalities

Estimated Economic Losses

Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 3-20% GDP of Chile. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	- -*	487k*	2,147k*	3,657k	6,405k	3,083k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landscan

0	5	50	100	500	1000	5000	10000

PAGER content is automatically generated, and does not consider secondary hazards in loss calculations. Limitations of input data, shaking estimates, and loss models may add uncertainty.

http://earthquake.usgs.gov/pager

Structures:

Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist. The predominant vulnerable building types are low-rise reinforced/confined masonry and adobe block construction.

Historical Earthquakes (with MMI levels):

Date	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1985-03-03	308	7.9	VIII(301k)	0
1985-03-03	352	7.0	IX(174k)	0
1985-03-03	313	7.9	VII(5,433k)	177

Recent earthquakes in this area have caused secondary hazards such as tsunamis, landslides, and liquefaction that might have contributed to losses.

Selected City Exposure

from GeoNames.org

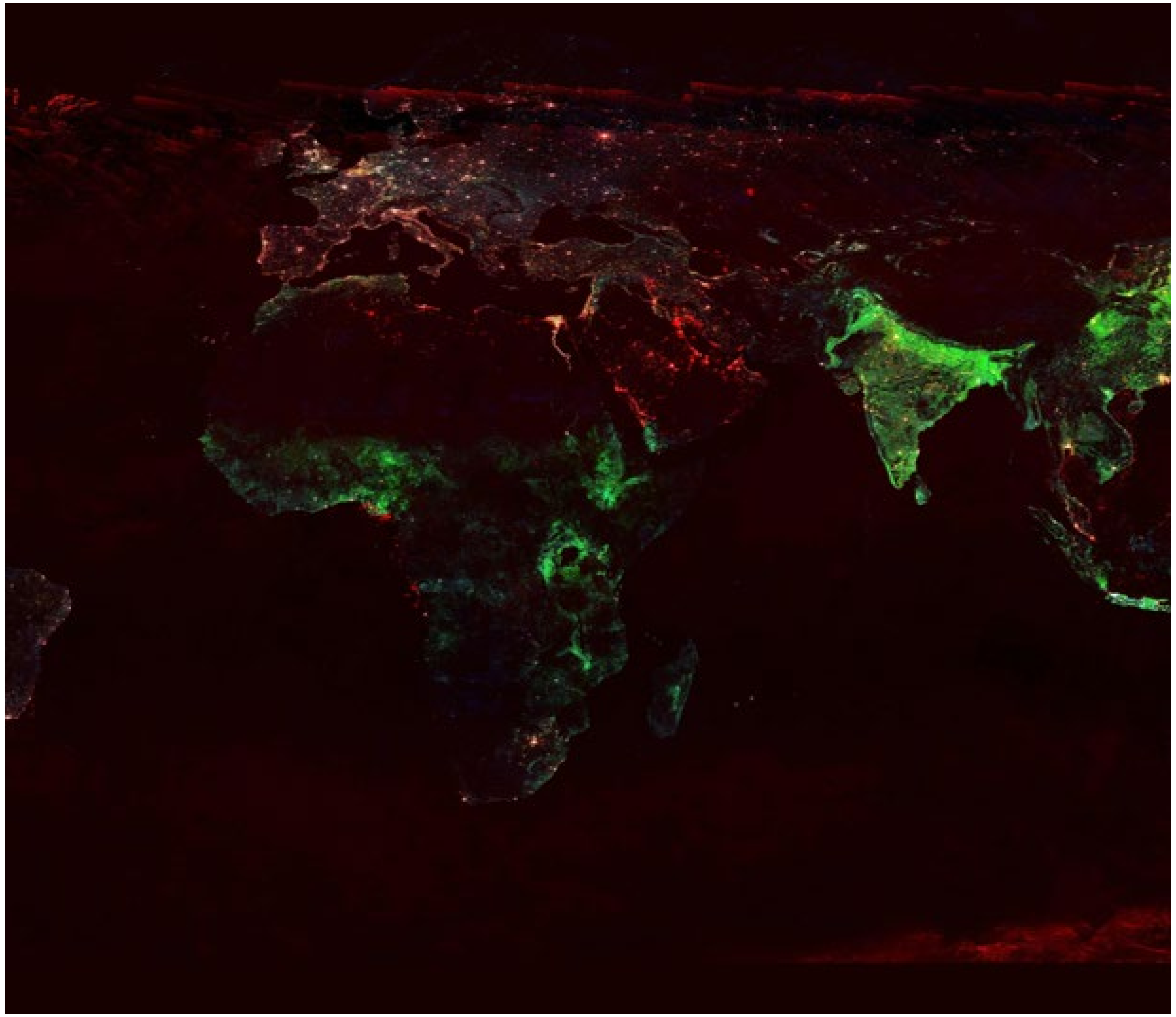
MMI	City	Population
VIII	**Arauco**	**25k**
VIII	Lota	50k
VIII	**Concepcion**	**215k**
VIII	Constitucion	38k
VII	Bulnes	13k
VII	Cabrero	18k
VI	**Temuco**	**238k**
VI	**Valparaiso**	**282k**
VI	**Santiago**	**4,837k**
IV	Mendoza	877k
III	Neuquen	242k

bold cities appear on map (k = x1000)

Event ID: us2010tfan

Level 1 Global Data - Limitations

- Very high-level exposure data
- Metadata and accuracy will vary based on underlying source
- Proxy countries may be used so reliability of data is questioned
- Generally trying to capture residential development
- Not to be used for region or building specific reconnaissance post-event



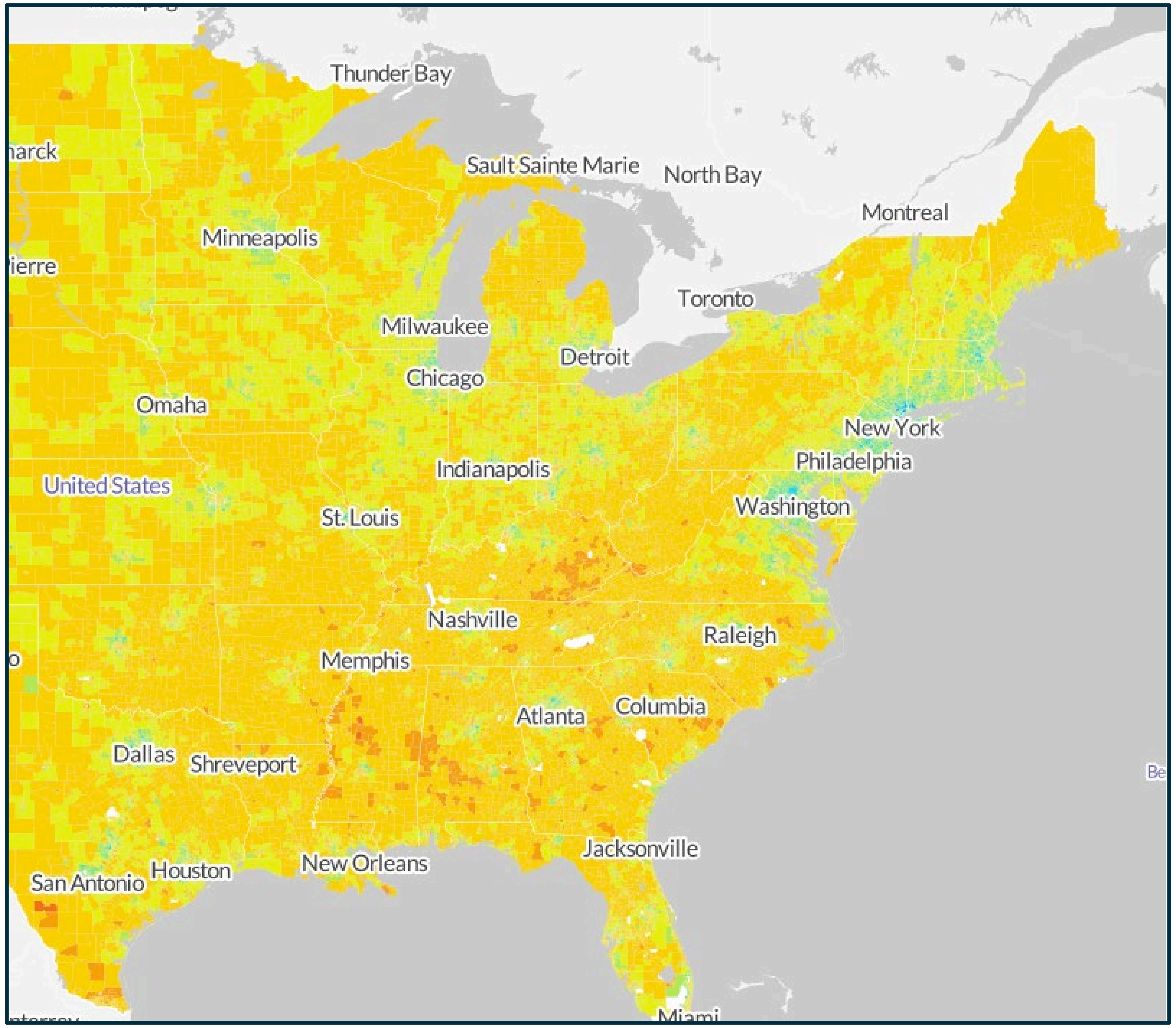
Level 2 Overview – Country Level Exposure

Description

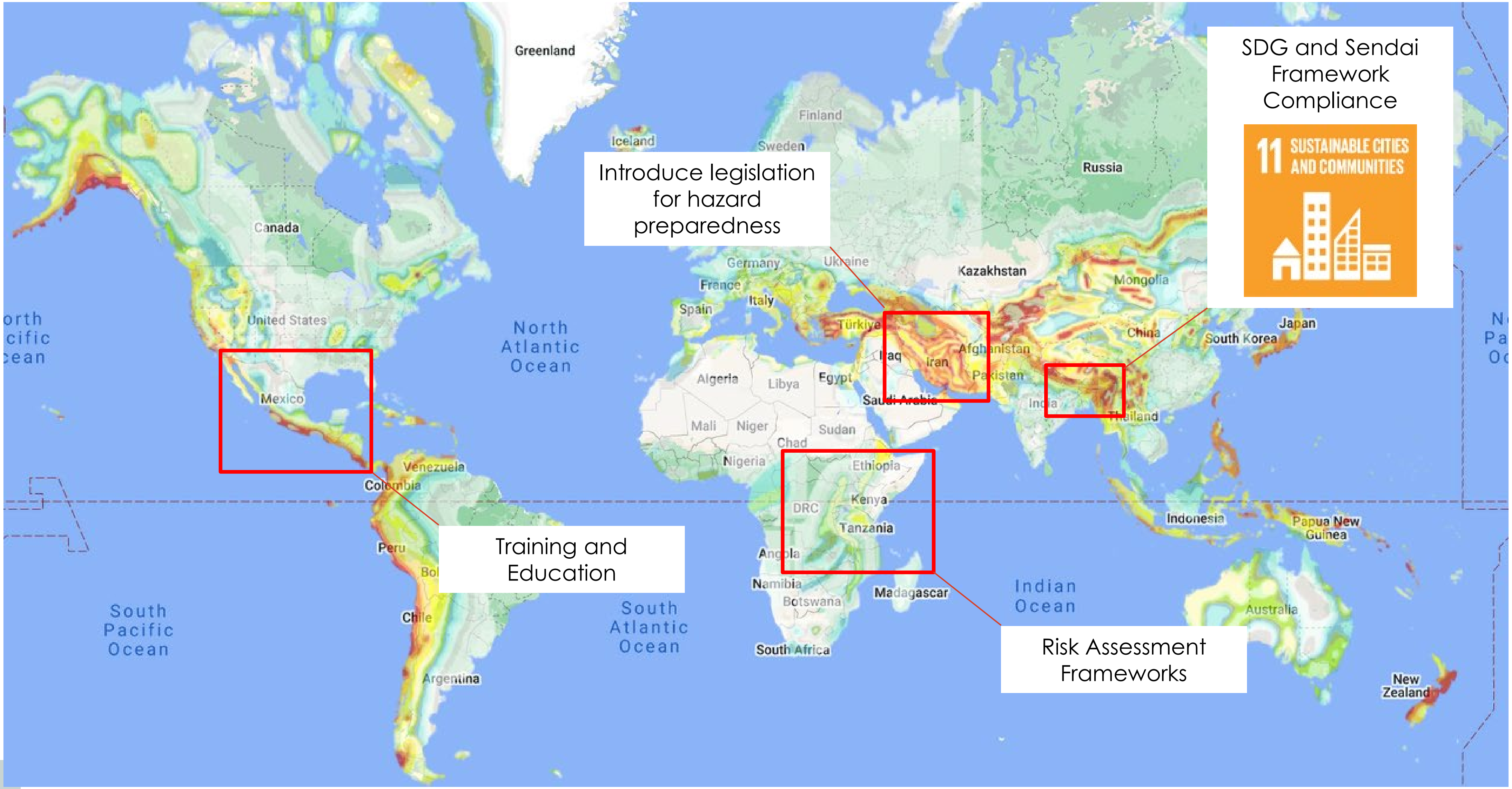
- Exposure data has been collected and reviewed at a national level (e.g. HAZUS)

Data Available

- General country-wide structural/material type distributions
- Census data
  - Household Size
  - Building replacement cost per square meter/foot



Level 2 – Mitigation and Preparation



Introduce legislation for hazard preparedness

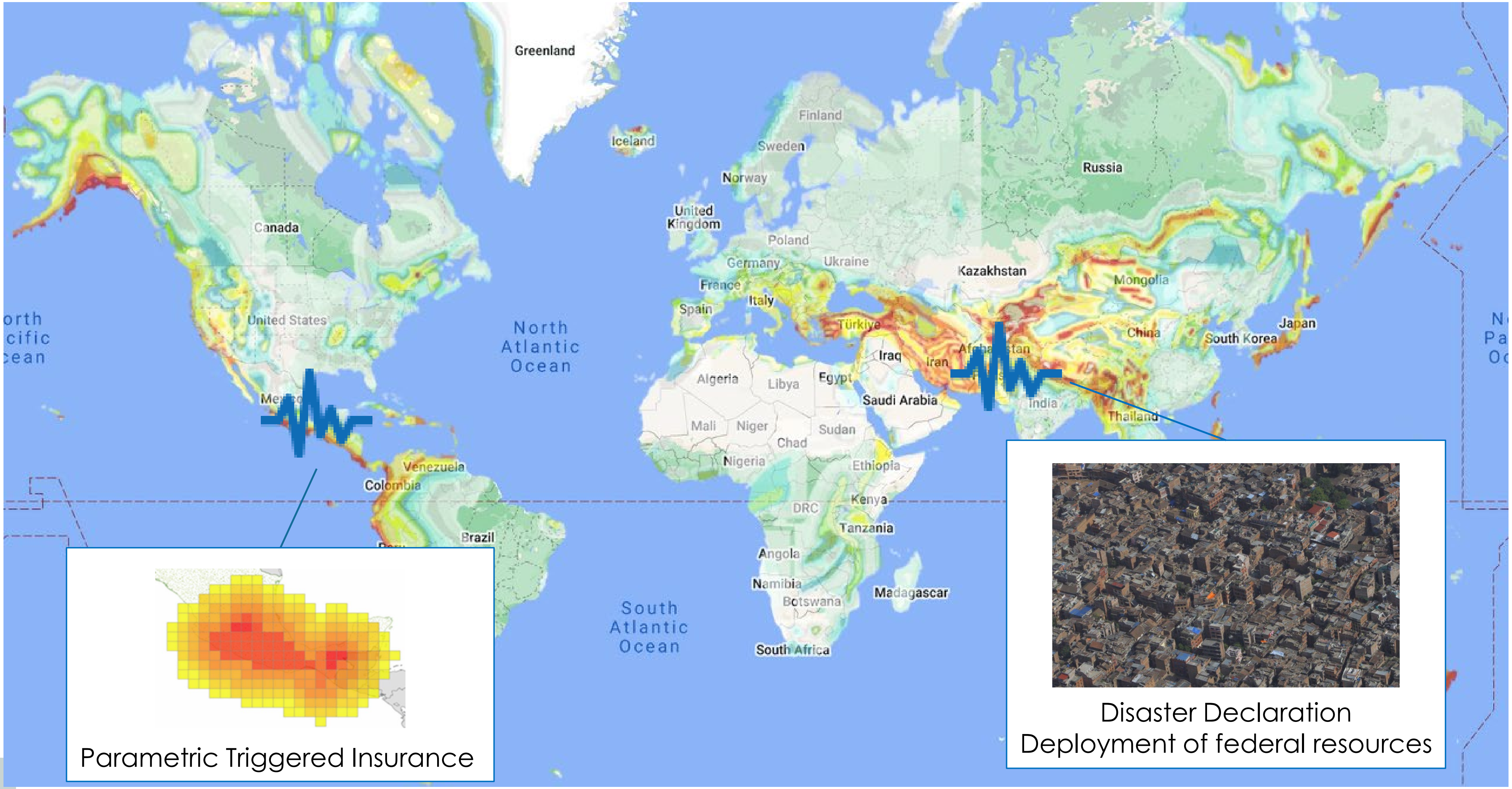
SDG and Sendai Framework Compliance

11 SUSTAINABLE CITIES AND COMMUNITIES

Training and Education

Risk Assessment Frameworks

Level 2 – Post-Disaster Response

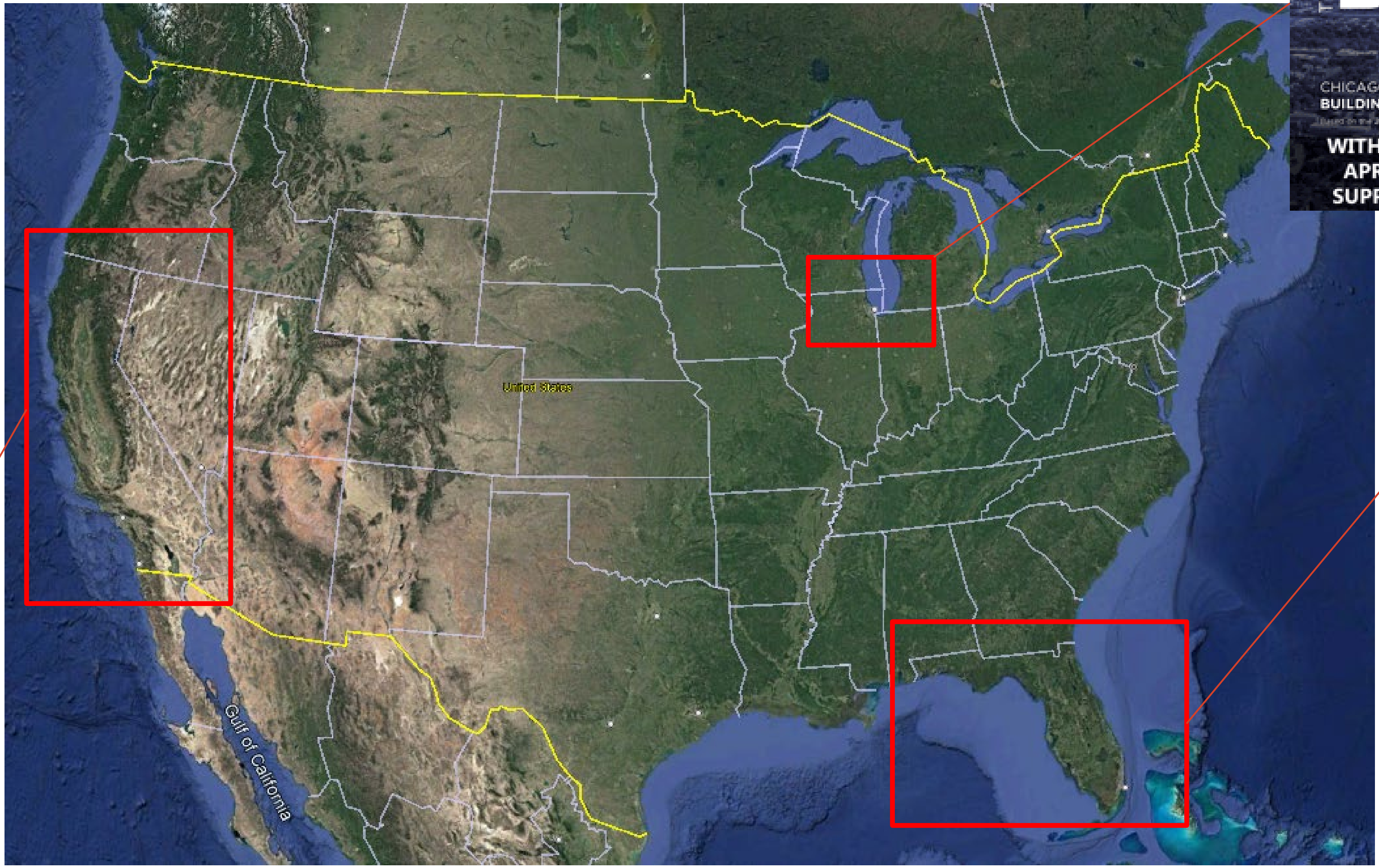


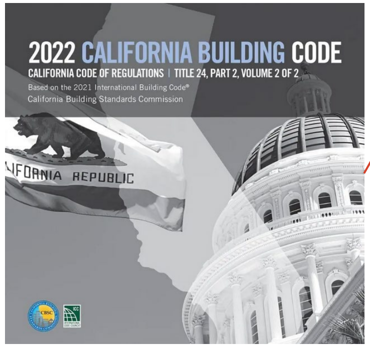
Parametric Triggered Insurance

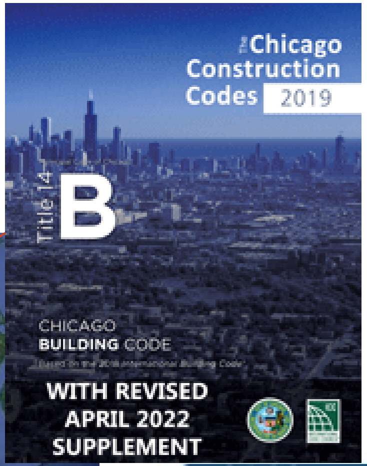
Disaster Declaration
Deployment of federal resources

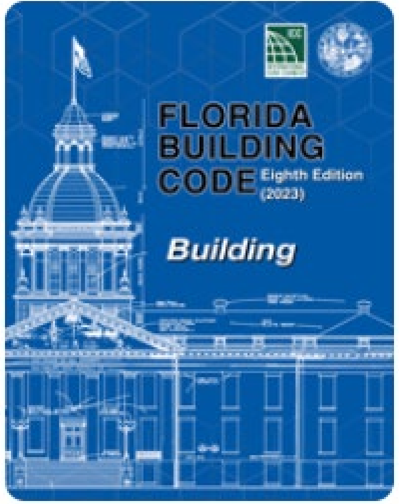
Level 2 Limitations

- No account for variations in regional building exposure




2022 CALIFORNIA BUILDING CODE
CALIFORNIA CODE OF REGULATIONS | TITLE 24, PART 2, VOLUME 2 OF 2
Based on the 2021 International Building Code®
California Building Standards Commission


Chicago Construction Codes 2019
Title 14 B
CHICAGO BUILDING CODE
WITH REVISED APRIL 2022 SUPPLEMENT


FLORIDA BUILDING CODE Eighth Edition (2023)
Building

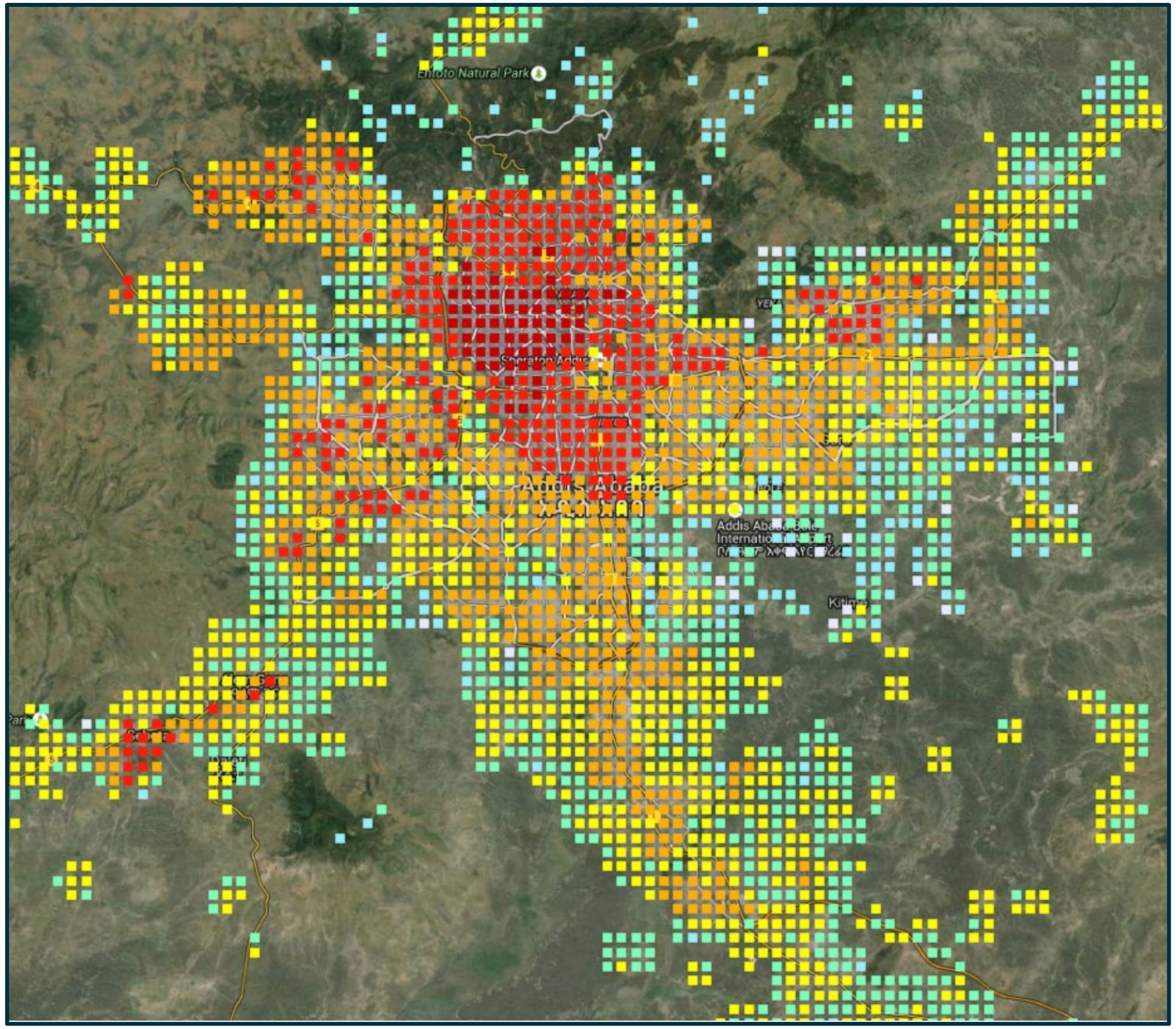
Level 3 Overview – Data Improvement / Sub-National Scale

Description

- Subdividing the country to reflect unique development patterns
  - Review of literature and imagery to develop region specific mapping schemes
- Identifying major urban areas and enhancing building attributes

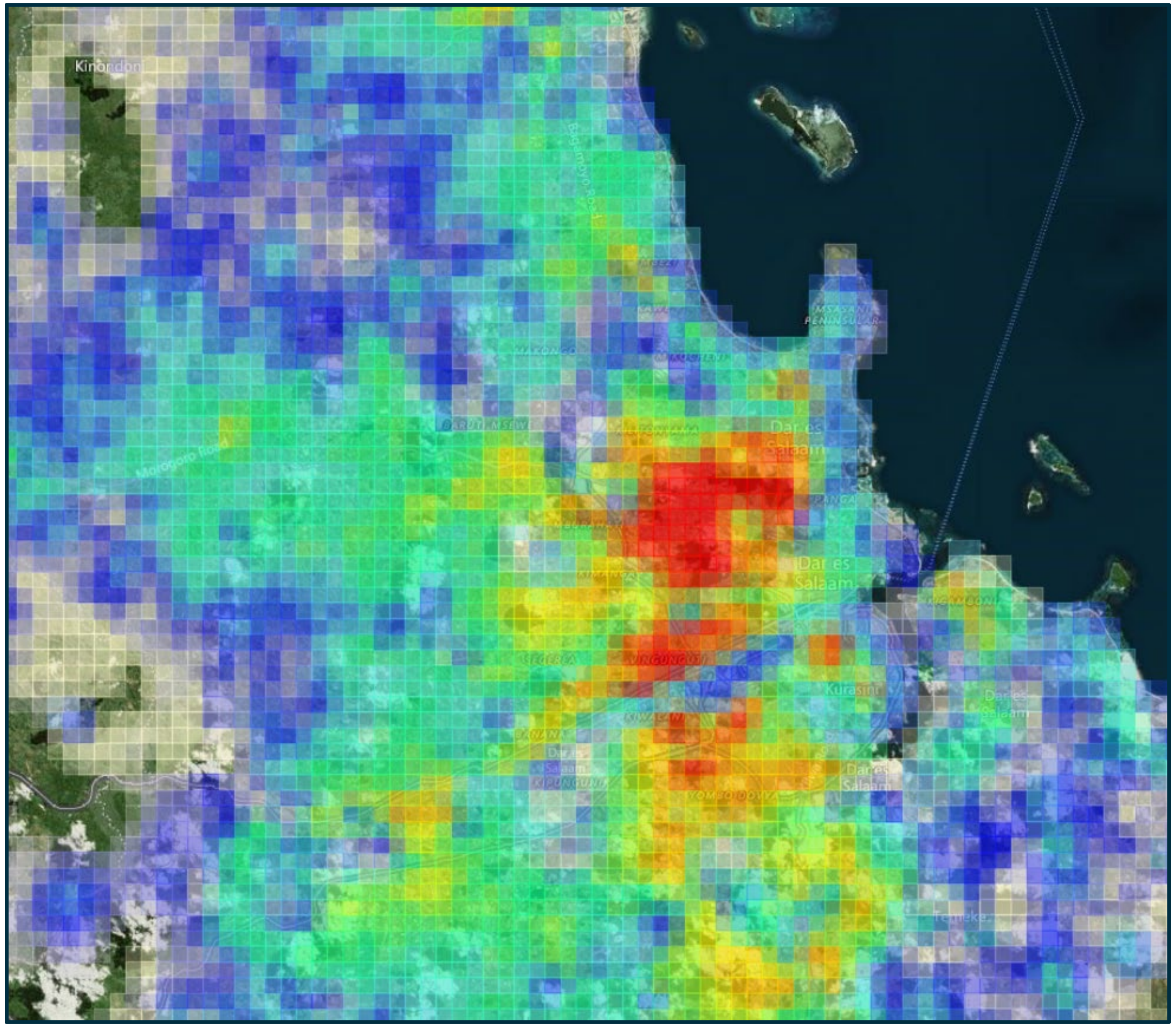
Data Available

- Mapping schemes at development pattern resolution



Level 4 Overview – Aggregated Building Specific Data

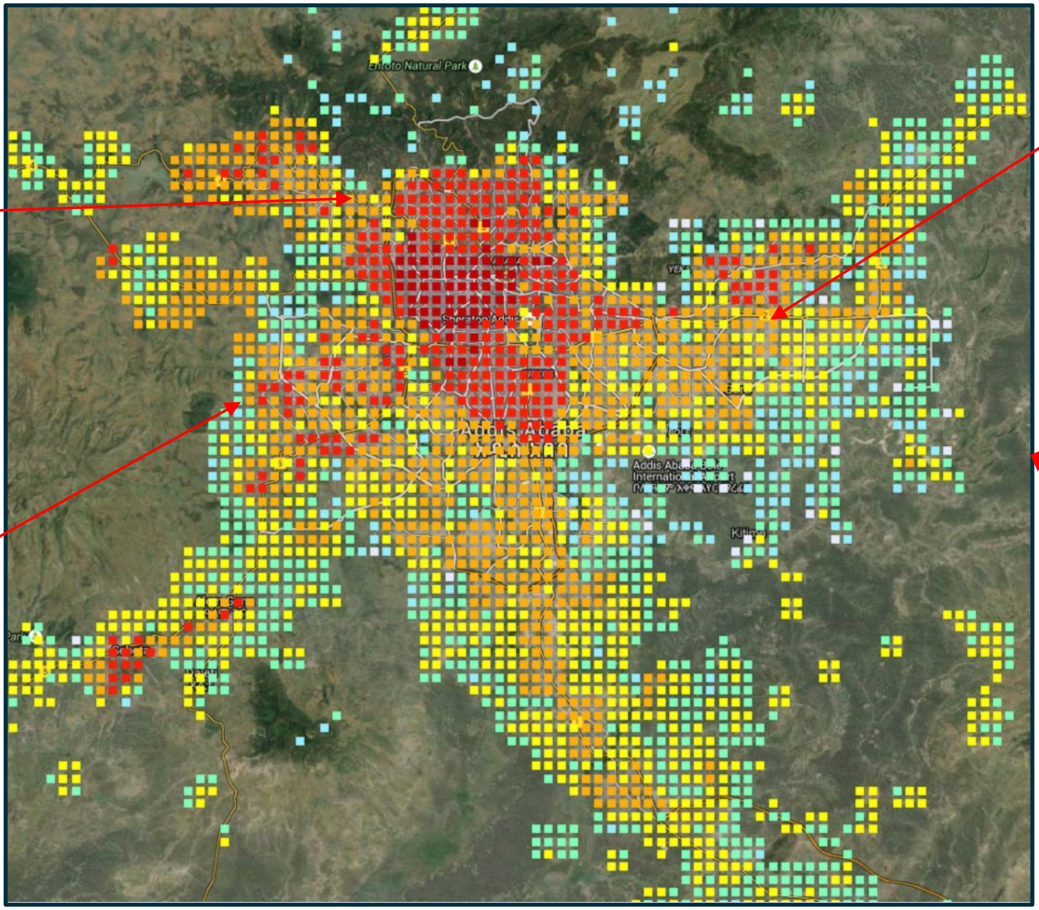
- Uses building data (OSM, building footprints, tax assessor, etc.) and aggregates up to polygonal level
- By aggregating, inferred data such as structural/occupancy, height distribution and other fields will not be mistaken for point-specific data
- May need to fill in the blanks for structural information at the aggregate level
  - Best guess given known data
    - Height
    - Occupancy
    - Age
- Aggregate up to avoid false precision.



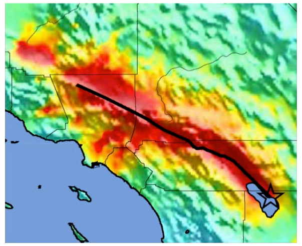
Level 3/4 – Mitigation and Preparedness

Assess building stock and infrastructure at a localized level

Examine Equity Concerns



Buy-out programs or mitigation programs



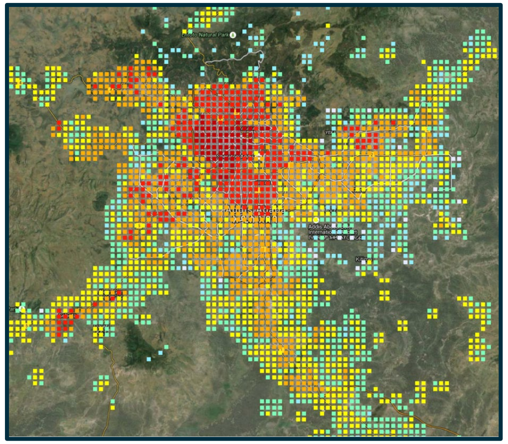
Scenarios for hazard planning

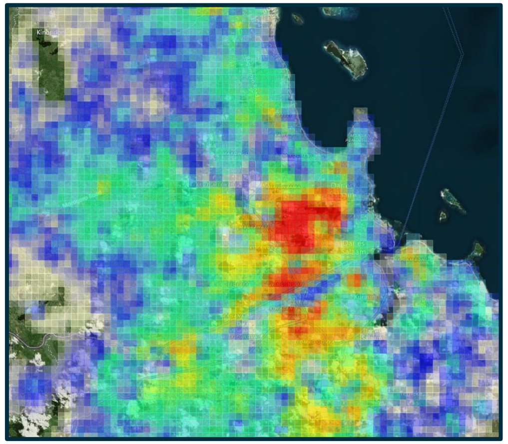
LOCAL HAZARD

MITIGATION PLAN

Disaster response and hazard mitigation plans

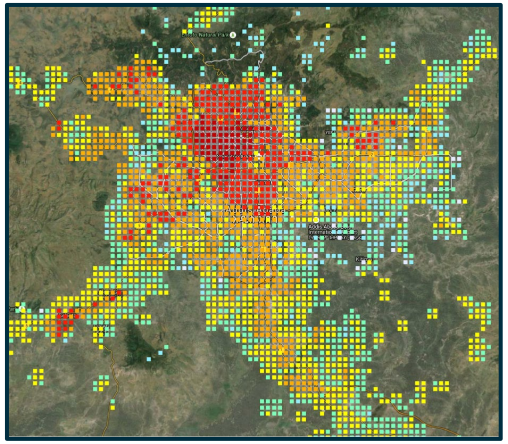
Level 3/4 – Post-Event

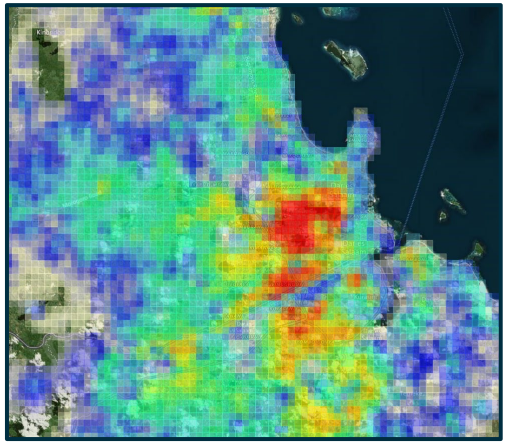




- Search and rescue missions
- Which region to focus on building reconnaissance
- Where to allocate personnel and equipment
- Where emergency shelters and aid should be focused
- Coordination, collaboration efforts and mutual aid

Level 3/4 Limitations

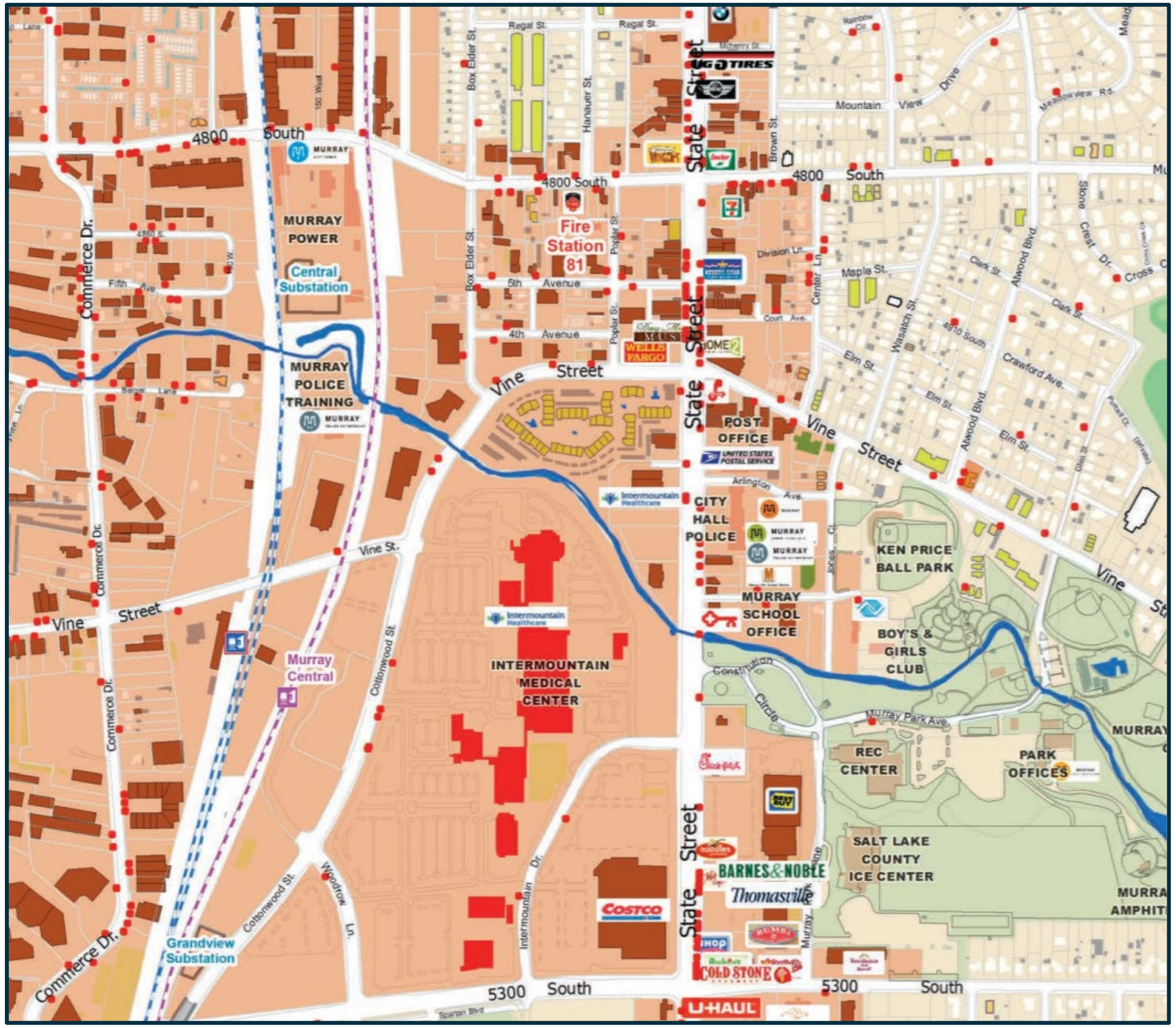




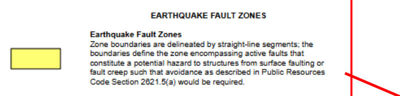
- Better understanding of the built-up environment, however not to be used for site-specific analyses or individual building tagging post-event
- Caveat: with good quality point data in Level 4 analyses, building specific data can be used to identify key facilities for further study. E.g. school, hospitals, emergency operations, pre-retrofit residential, etc.
- Level 4: Loss of geographic precision

Level 5 Overview

- Site-specific data, as with Level 4, but running it at building level.
- Optimal when you have enough data to make an assessment at site specific
- Site location precision is necessary for analyses e.g. flood, landslide, tsunami, etc.



Level 5 – Mitigation and Preparedness



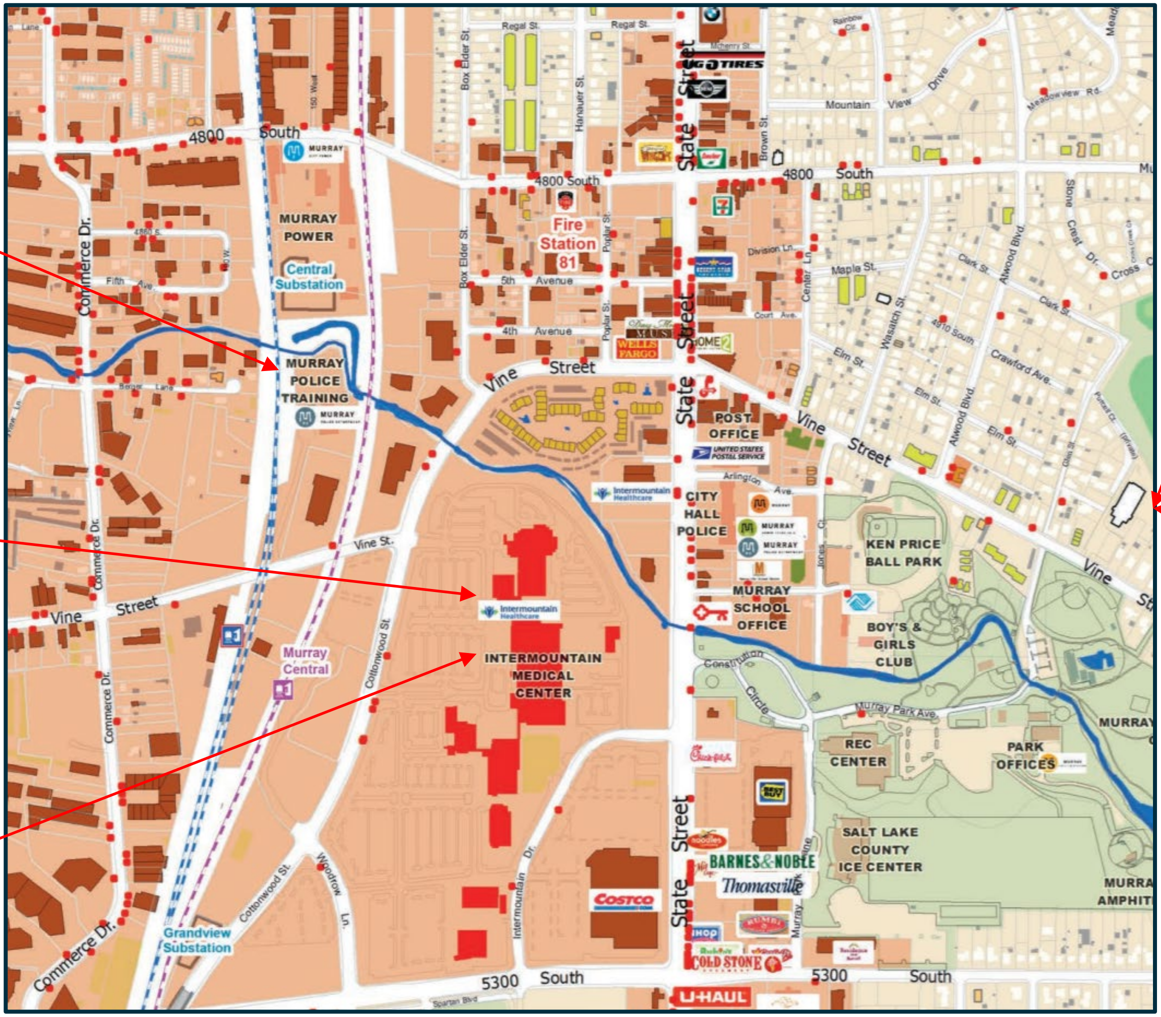
EARTHQUAKE FAULT ZONES

🟨 **Earthquake Fault Zones**
Zone boundaries are delineated by straight-line segments; the boundaries define the zone encompassing active faults that constitute a potential hazard to structures from surface faulting or fault creep such that avoidance as described in Public Resources Code Section 2621.5(a) would be required.

Site-specific hazards

Prioritize Engineering Review

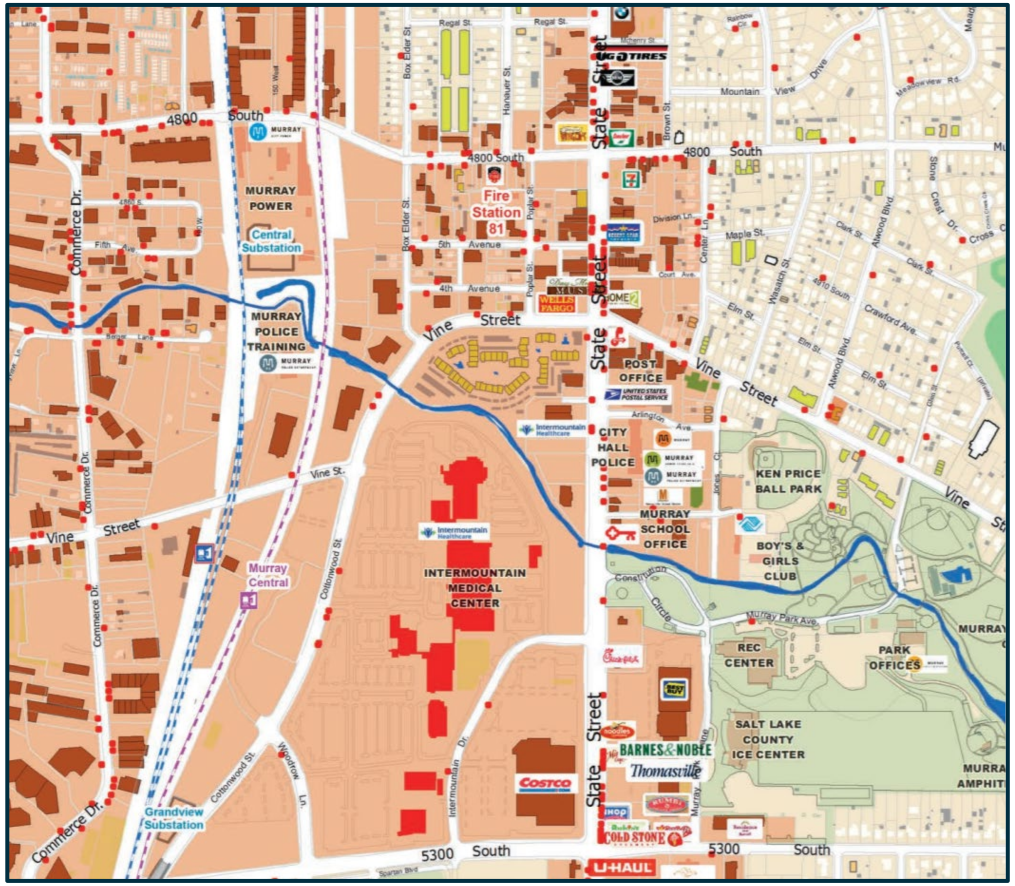
Life safety/essential facilities



Buyout / Managed Retreat

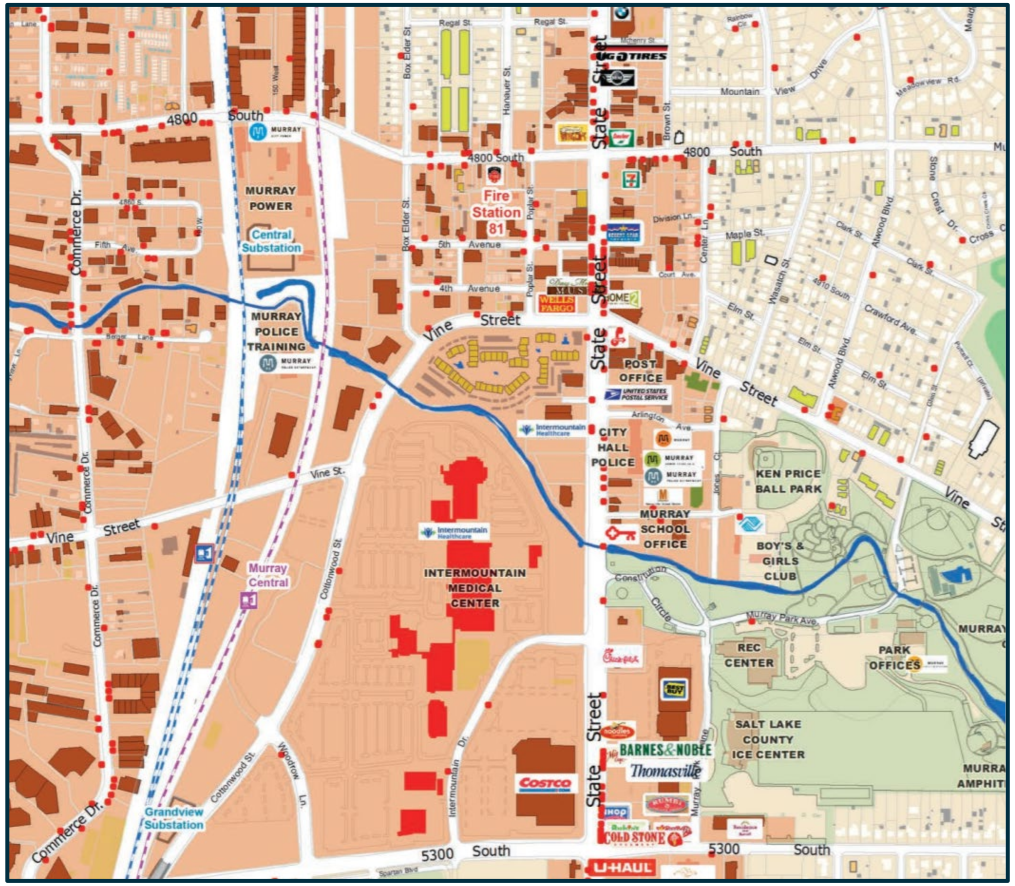
Retrofit or Mitigation Strategies

Level 5 – Post-Event



- Site review and safety
- Restoration of business operations

Level 5 Limitations



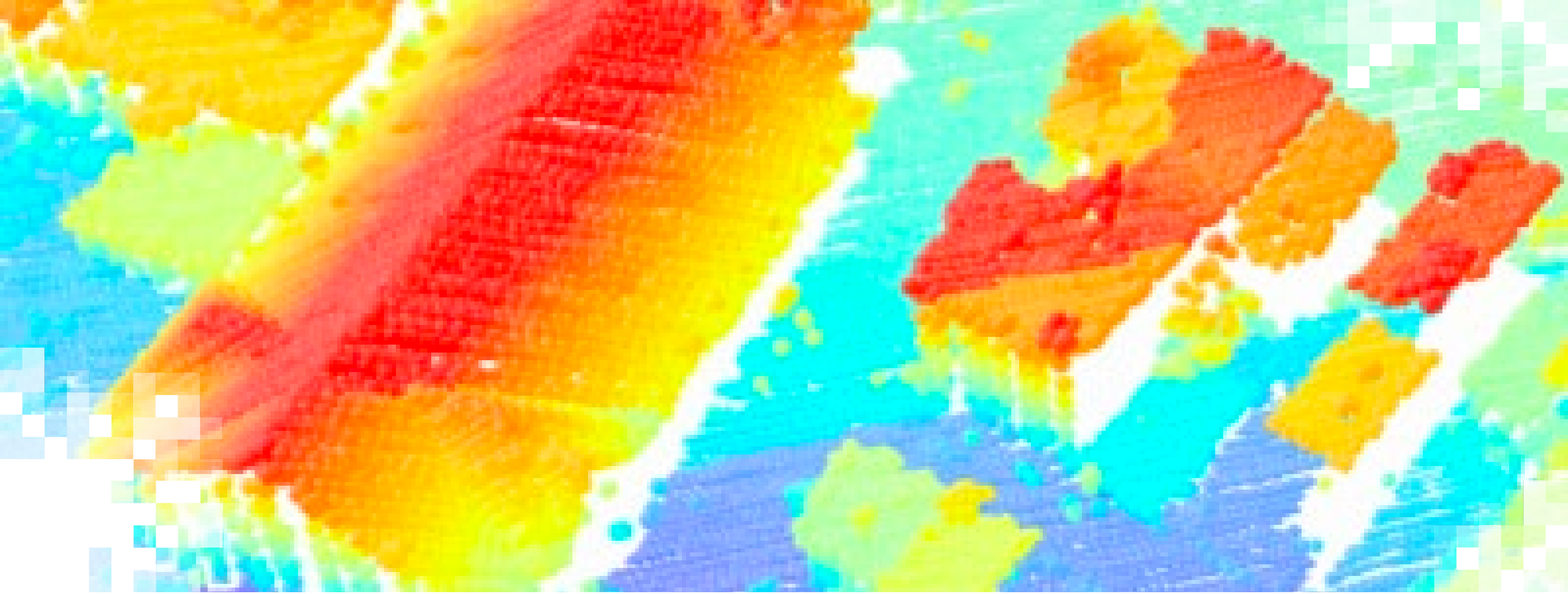
- Building characteristics only as accurate as the source provided
  – Where or who does the base data come from?
    - Insurance
    - Engineering team
    - Field survey
    - Other

Overview: What is the appropriate use?

	International (L1)	National (L2)	Local/City (L3/L4)	Campus/Portfolio (L5)	Site-Specific-ENGINEERING REVIEW
Building codes	Establish international Codes	Code adoption and enforcement prioritization	Code adoption and Enforcement	Risk management	Engineering review/enforcement
Mitigation, including divestment	SDGs, Sendai Framework, international resource prioritization Anticipatory action assessment Prestaging resources	SDGs, Sendai Framework Compliance Legislation Establish risk assessment frameworks Training and education	Assess infrastructure and building stock Examine equity concerns Buy-out programs or mitigation programs Scenarios Disaster response and hazard mitigation plans Early warning systems	Life-safety/essential facilities Assess feasibility of low-cost solutions Prioritize Engineering Review Retrofit / mitigation strategy Managed retreat Real estate investment strategy	Building-level adjustments Hazard disclosure Building-level risk predictions
Post-Disaster Response	Deployment of International aid Anticipatory action Search and rescue teams.	Disaster declaration Deployment of federal resources	Search and rescue Allocation of personnel and equipment Emergency shelter and aid Building tagging Coordination and collaboration Mutual aid	Site review and safety Restoration of business operations	Damage Assessment
Insurance and Reinsurance	ESG Need handle of CC. Reinsurer trying to track hazard Risk diversification	Parametric triggered insurance	Government insurance	Portfolio Analysis Average annualized loss	Probable maximum loss (PML) Average annualized loss

Conclusion

- Assess the needs and level of effort required for the analysis
- Each level has their own advantages and disadvantages that should be acknowledged by the user
- Understand the source and collection of data
  - Who collected it and how reliable can it conservatively be?
- Never make building specific decisions or assessments, such as red tagging
  - Pre and post-event assessments need to be performed through engineering review



Developing and Understanding Metadata

What is the….?

- Spatial resolution
- Source of the data
- Replacement cost
- Data vintage
- And why is this point in the river?

A Language for the Science of Exposure Development

- **Illuminate the process** - Develop robust methods of representing exposure assumptions with respect to vintage, progeny, resolution, and limitations- particularly when fusing multiple datasets collected over a considerable period of time.

- **Acknowledge the uncertainty** - Establish methods of characterizing the uncertainty of exposure datasets through the incorporation of modeling techniques. It is particularly important that end users understand uncertainties in key factors such as location, the taxonomy, and replacement cost before data use.

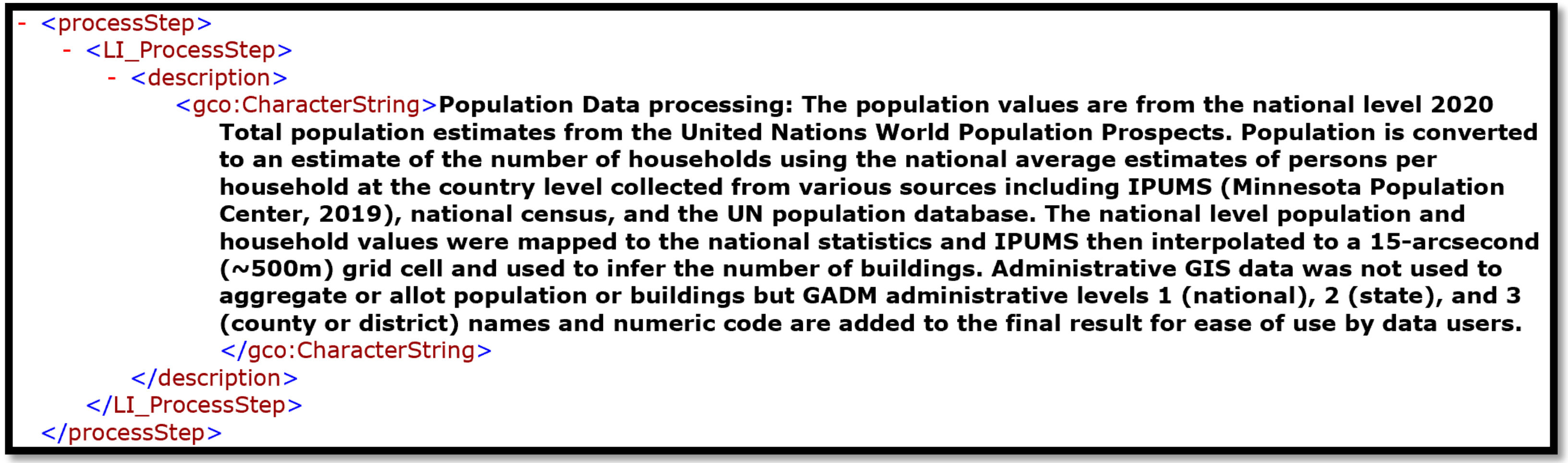
Why is Metadata Important for the Creator of Exposure Data?

- Track exact steps used to produce the data so that when it's time for an updated version with better sources, can determine which steps need adjustment and which can be replicated as written
- It's often not the same people or organization that will be updating it
- Can update the dataset without commissioning a whole new study

What Useful Things Can You Find in the Metadata?

- Mapping Scheme and Development Pattern definitions
- Detailed country-specific source data information and references
- Detailed country-specific processing steps
- Replacement Cost information
- Data field descriptions
- Limitations
- Contact information

<xml />



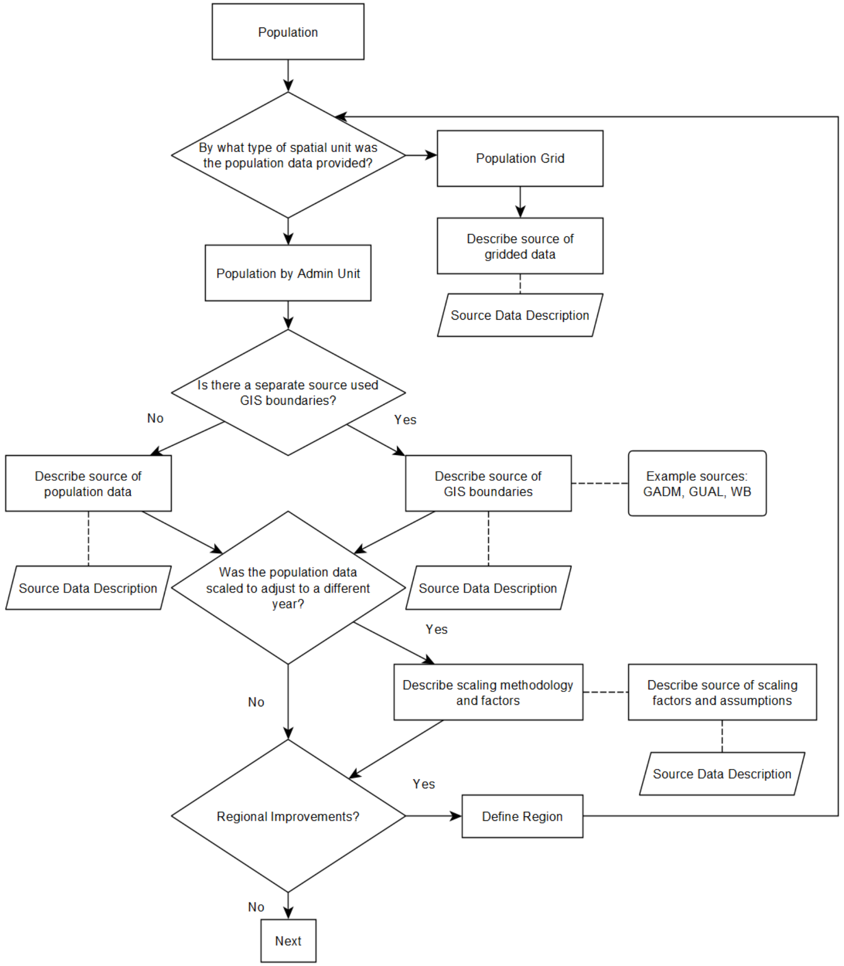
```
- <processStep>
  - <LI_ProcessStep>
    - <description>
        <gco:CharacterString>Population Data processing: The population values are from the national level 2020
          Total population estimates from the United Nations World Population Prospects. Population is converted
          to an estimate of the number of households using the national average estimates of persons per
          household at the country level collected from various sources including IPUMS (Minnesota Population
          Center, 2019), national census, and the UN population database. The national level population and
          household values were mapped to the national statistics and IPUMS then interpolated to a 15-arcsecond
          (~500m) grid cell and used to infer the number of buildings. Administrative GIS data was not used to
          aggregate or allot population or buildings but GADM administrative levels 1 (national), 2 (state), and 3
          (county or district) names and numeric code are added to the final result for ease of use by data users.
          </gco:CharacterString>
      </description>
    </LI_ProcessStep>
  </processStep>
```

Determining What to Include in Metadata

- How do we know what information is important?
- How can we cut through the complexity of gathering this information?

Flowcharts!

Tools to help you determine what information should be captured.



Population

By what type of spatial unit was the population data provided?

Population Grid

Describe source of gridded data

Source Data Description

Population by Admin Unit

Is there a separate source used GIS boundaries?

No

Yes

Describe source of population data

Source Data Description

Describe source of GIS boundaries

Example sources: GADM, GUAL, WB

Source Data Description

Was the population data scaled to adjust to a different year?

Yes

Describe scaling methodology and factors

Describe source of scaling factors and assumptions

Source Data Description

No

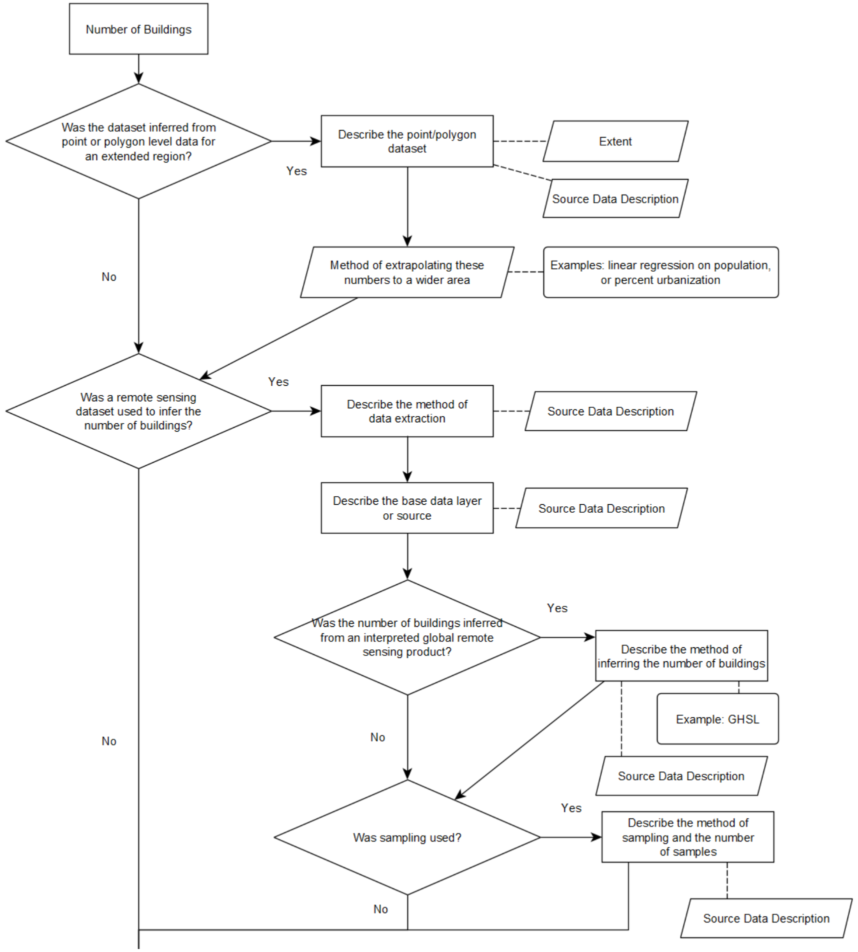
Regional Improvements?

Yes

Define Region

No

Next



Number of Buildings

Was the dataset inferred from point or polygon level data for an extended region?

Yes

Describe the point/polygon dataset

Extent

Source Data Description

Method of extrapolating these numbers to a wider area

Examples: linear regression on population, or percent urbanization

No

Was a remote sensing dataset used to infer the number of buildings?

Yes

Describe the method of data extraction

Source Data Description

Describe the base data layer or source

Source Data Description

Was the number of buildings inferred from an interpreted global remote sensing product?

Yes

Describe the method of inferring the number of buildings

Example: GHSL

Source Data Description

No

No

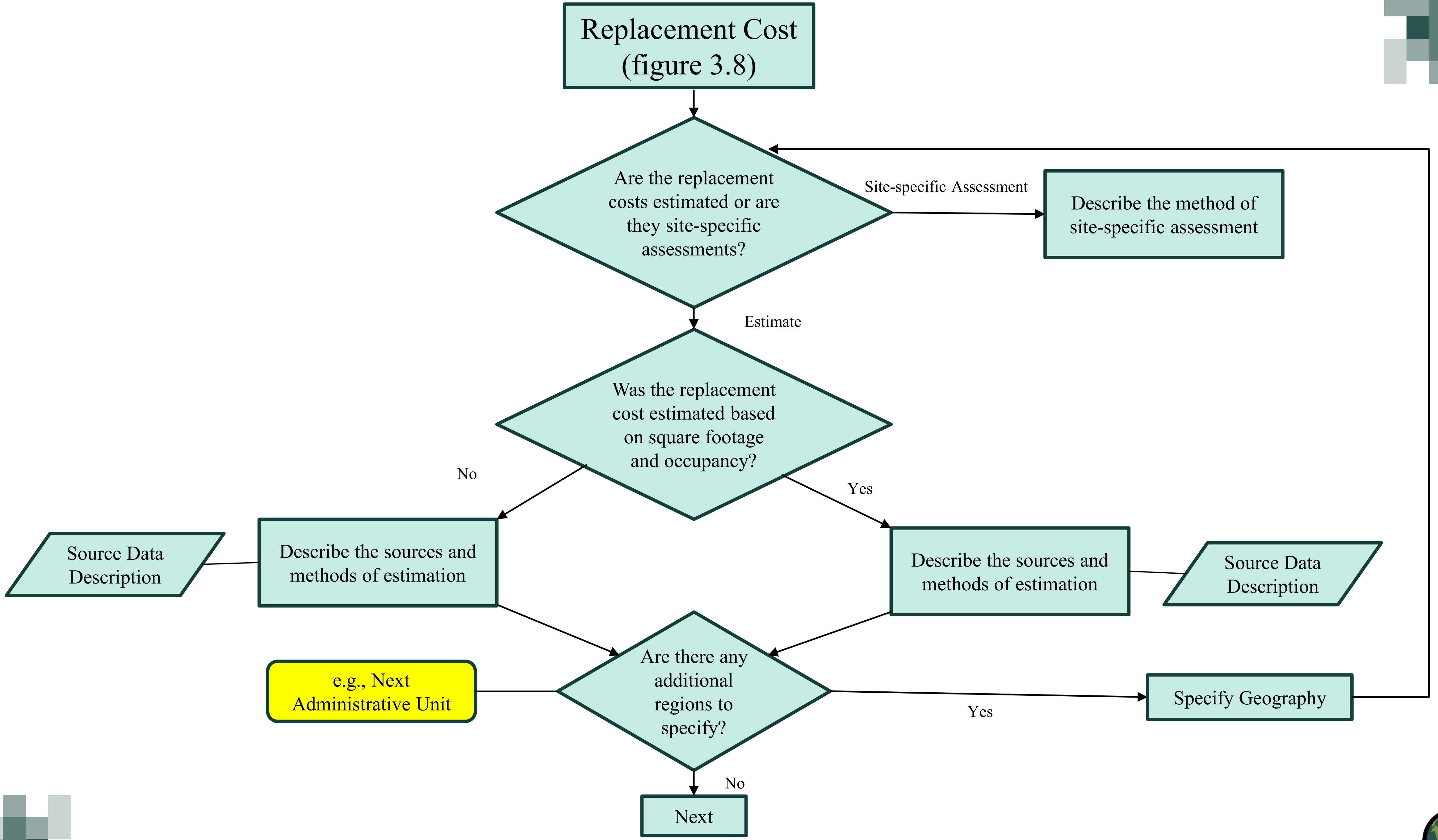
Was sampling used?

Yes

Describe the method of sampling and the number of samples

Source Data Description

No



Replacement Cost (figure 3.8)

Are the replacement costs estimated or are they site-specific assessments?

Site-specific Assessment

Describe the method of site-specific assessment

Estimate

Was the replacement cost estimated based on square footage and occupancy?

No

Yes

Source Data Description

Describe the sources and methods of estimation

Describe the sources and methods of estimation

Source Data Description

e.g., Next Administrative Unit

Are there any additional regions to specify?

Yes

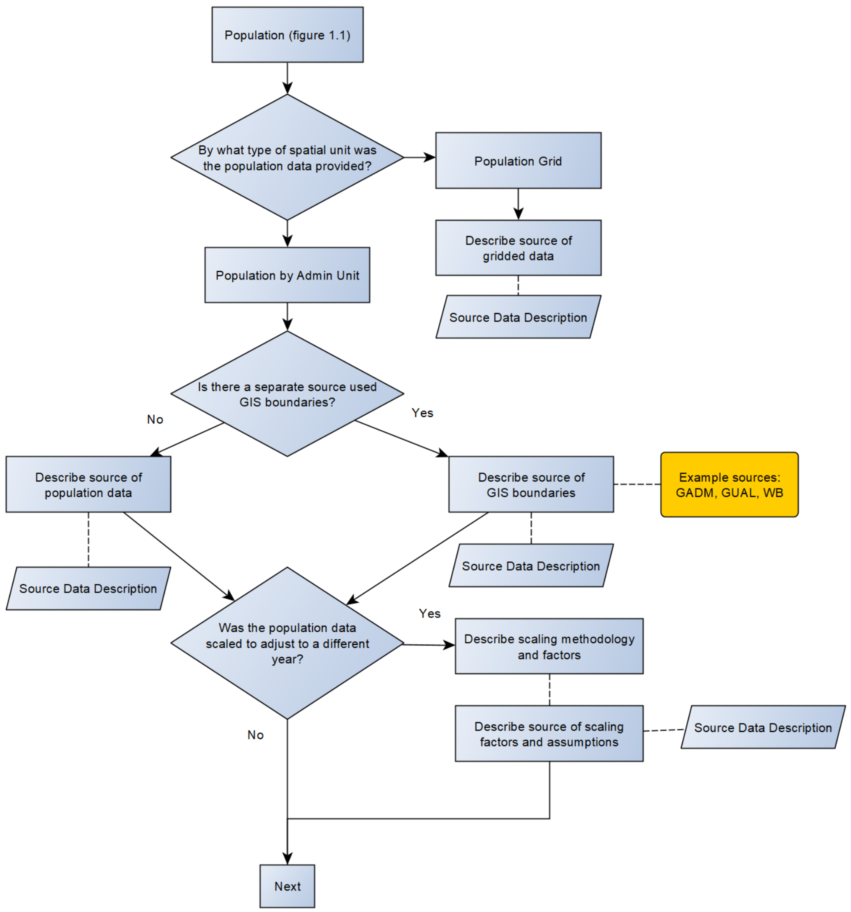
Specify Geography

No

Next

Example Flowcharts for Different Exposure Levels

Exposure Level 1 – Population Flowchart



Population (figure 1.1)

By what type of spatial unit was the population data provided?

Population Grid

Describe source of gridded data

Source Data Description

Population by Admin Unit

Is there a separate source used GIS boundaries?

No

Yes

Describe source of population data

Source Data Description

Describe source of GIS boundaries

Example sources: GADM, GUAL, WB

Source Data Description

Was the population data scaled to adjust to a different year?

Yes

Describe scaling methodology and factors

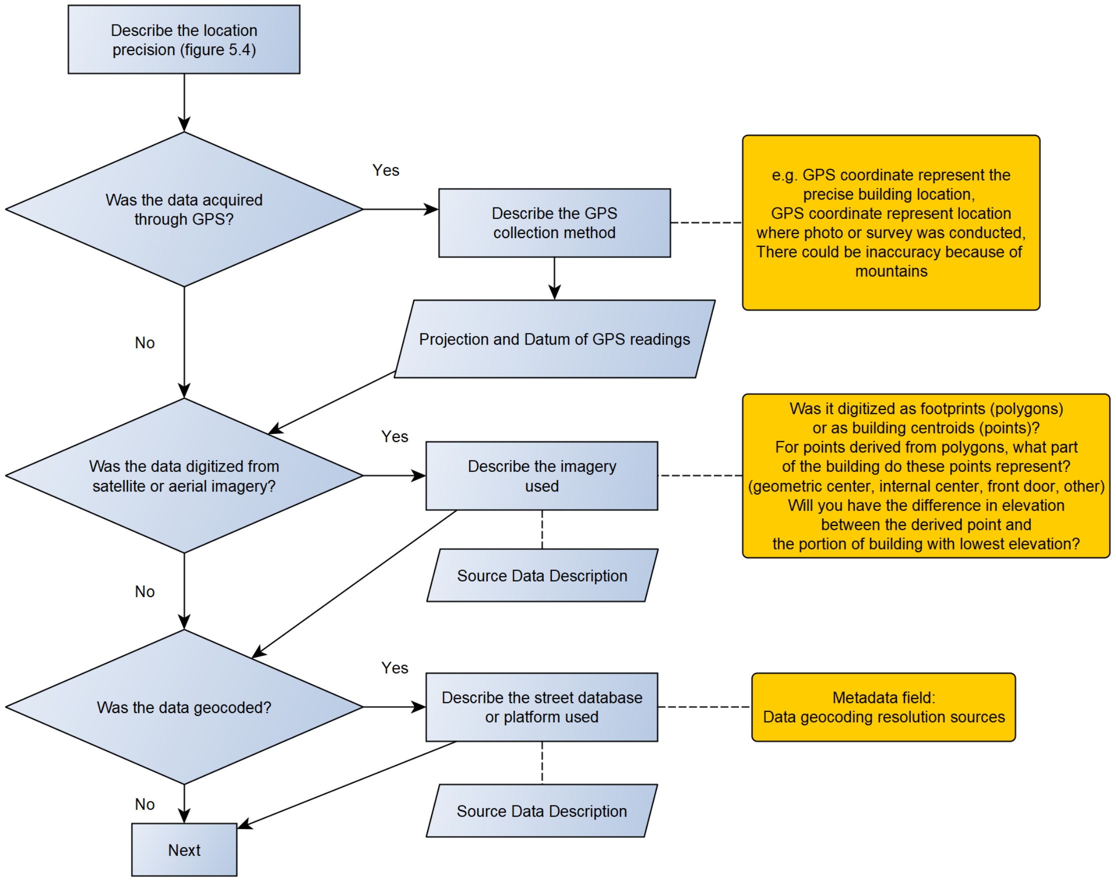
Describe source of scaling factors and assumptions

Source Data Description

No

Next

Exposure Level 5 – Location Precision Flowchart



Describe the location precision (figure 5.4)

Was the data acquired through GPS?

Yes

Describe the GPS collection method

e.g. GPS coordinate represent the precise building location, GPS coordinate represent location where photo or survey was conducted, There could be inaccuracy because of mountains

Projection and Datum of GPS readings

No

Was the data digitized from satellite or aerial imagery?

Yes

Describe the imagery used

Was it digitized as footprints (polygons) or as building centroids (points)? For points derived from polygons, what part of the building do these points represent? (geometric center, internal center, front door, other) Will you have the difference in elevation between the derived point and the portion of building with lowest elevation?

Source Data Description

No

Was the data geocoded?

Yes

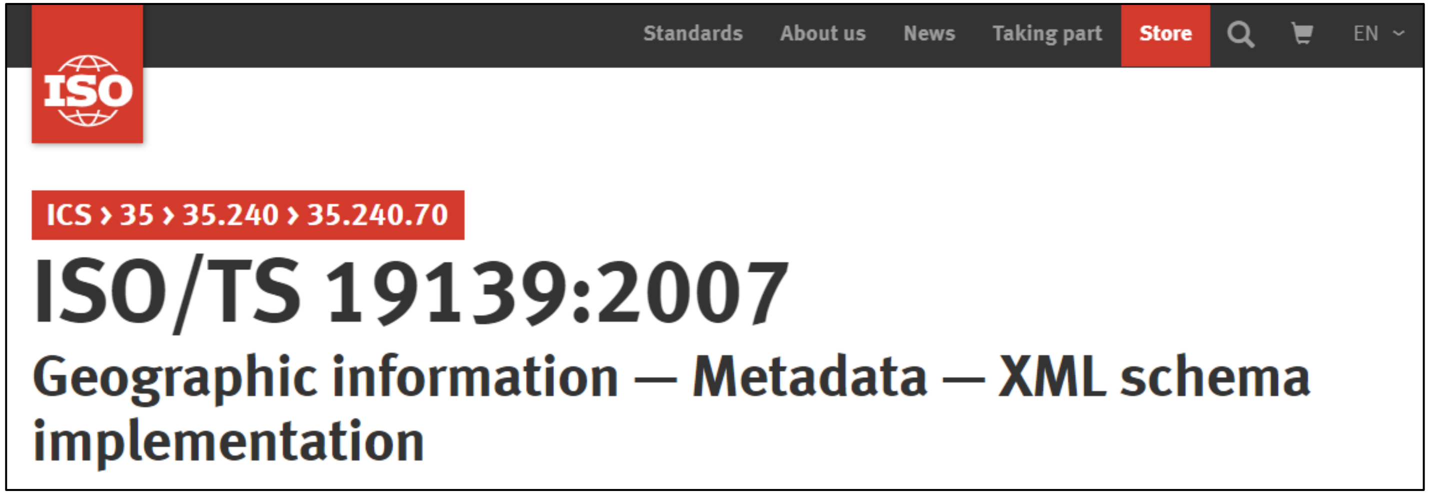
Describe the street database or platform used

Metadata field: Data geocoding resolution sources

Source Data Description

No

Next



ICS › 35 › 35.240 › 35.240.70

ISO/TS 19139:2007

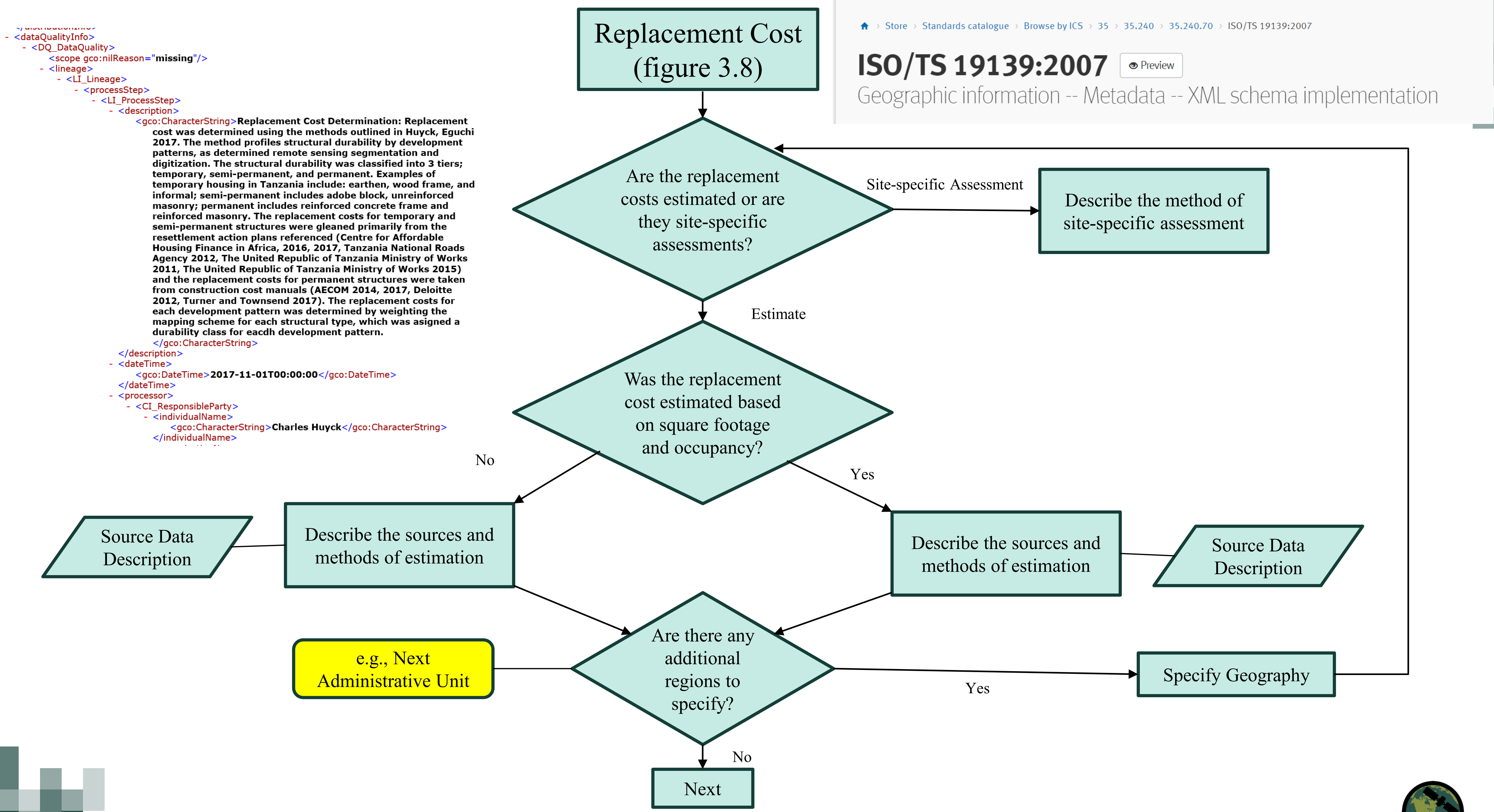
Geographic information — Metadata — XML schema implementation

+

ICS › 35 › 35.240 › 35.240.70

ISO 19110:2005

Geographic information — Methodology for feature cataloguing



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      - <LI_Lineage>
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                  cost was determined using the methods outlined in Huyck, Eguchi
                  2017. The method profiles structural durability by development
                  patterns, as determined remote sensing segmentation and
                  digitization. The structural durability was classified into 3 tiers;
                  temporary, semi-permanent, and permanent. Examples of
                  temporary housing in Tanzania include: earthen, wood frame, and
                  informal; semi-permanent includes adobe block, unreinforced
                  masonry; permanent includes reinforced concrete frame and
                  reinforced masonry. The replacement costs for temporary and
                  semi-permanent structures were gleaned primarily from the
                  resettlement action plans referenced (Centre for Affordable
                  Housing Finance in Africa, 2016, 2017, Tanzania National Roads
                  Agency 2012, The United Republic of Tanzania Ministry of Works
                  2011, The United Republic of Tanzania Ministry of Works 2015)
                  and the replacement costs for permanent structures were taken
                  from construction cost manuals (AECOM 2014, 2017, Deloitte
                  2012, Turner and Townsend 2017). The replacement costs for
                  each development pattern was determined by weighting the
                  mapping scheme for each structural type, which was asigned a
                  durability class for eacdh development pattern.
                  </gco:CharacterString>
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              </dateTime>
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                - <individualName>
                    <gco:CharacterString>Charles Huyck</gco:CharacterString>
                  </individualName>
```

ISO/TS 19139:2007

Geographic information -- Metadata -- XML schema implementation

Replacement Cost (figure 3.8)

Are the replacement costs estimated or are they site-specific assessments?

Site-specific Assessment

Describe the method of site-specific assessment

Estimate

Was the replacement cost estimated based on square footage and occupancy?

No

Yes

Source Data Description

Describe the sources and methods of estimation

Describe the sources and methods of estimation

Source Data Description

e.g., Next Administrative Unit

Are there any additional regions to specify?

Yes

Specify Geography

No

Next

Creating the Metadata Documents

Use ArcCatalog to develop the metadata

ICS › 35 › 35.240 › 35.240.70

ISO/TS 19139:2007

Geographic information — Metadata — XML schema implementation

Can export as both ISO-19139 and ESRI Native Metadata Format, to reach the widest audience

Creating the Metadata Documents

- ArcGIS format
  - Default XML format used by ArcGIS
  - Other metadata formats can be derived from this
  - De facto industry standard – but it is proprietary
- ISO-19139
  - International standard compatible with many typical GIS software tools
  - Non-proprietary
  - Expected to gain in popularity
- ISO-19110 (component of ISO-19139)
  - Also called the "Feature Catalog", stores metadata for specific fields of the GIS dataset
  - Designed to be used along with the ISO-19139 metadata file
  - In future revisions, this information will be embedded within ISO-19139

Creating the Metadata Documents

- ArcGIS will create metadata related to a dataset by default – This can be edited through the ArcGIS metadata editor or ArcCatalog
- To initialize the metadata for use with the ISO formats, the metadata should be set to use the ISO-19139 template.
  - See the ArcGIS site for more information
- ArcGIS will automatically save to its proprietary format
- To create the ISO-19139 XML file, export from ArcGIS to ISO-19139 format
- To create the ISO-19110 XML file, there is currently a convoluted process
  - Export the metadata in FGDC CSDGM XML format (an intermediate format)
  - Download the NOAA FGDC-to-ISO XSLT transform file for ISO-19110
  - Use an XSLT processing tool to combine the FGDC XML file with the NOAA XSLT file, producing an ISO-19110 XML file
  - **In the future these steps will hopefully not be needed!**

Metadata Sections of Note

- **Lineage Section**
  - Designated for tracking the input databases, data manipulation procedures or methodologies, and data processing. Data processing can give insight as to how a new survey was conducted, how various input data sets are fused or improved upon, and how various modelling or statistical methods are performed.
  - Contains multiple “Process Steps” to describe each exercise undertaken to develop the final dataset.
- **Report Section**
  - Evaluation of the quality of the input data, processing methods, final data set quality review, and results summaries. The data evaluation consists of a quantitative or qualitative assessment.
  - Contains multiple “Reports” to describe each evaluation undertaken to develop the final dataset.

Resources for Creating Exposure Metadata

- Exposure Metadata Flowcharts
  - Supplementary document containing the flowcharts that have been created for each exposure data level (1 through 5)
  - Includes discussion about the type of information that should be collected for each segment
- METEOR: Exposure data classification, metadata population and confidence assessment
  - Appendix A includes details for mapping information into the ISO-19139 metadata structure, the ISO-19110 metadata structure, and optional linkable tables
- METEOR: Bridge to commercial CAT model
  - Section 3 includes an example of the metadata fields that were generated for actual Level 1 exposure data created for the METEOR project
- METEOR Exposure Data
  - Includes ISO-19139 metadata that can be used as reference

Flowchart Example – Nepal Level 3 Exposure Development

- The following slides will go through a truncated set of the Level-3 flowcharts used for gathering data to develop the Level-3 building exposure for Nepal. The flowchart sections shown will include:
  - Building Height
  - Structural Distribution
  - Number of Buildings

Datasets Used to Develop the Nepal Building Exposure

1. Breiman, L. Random Forests. Machine Learning 45, 5–32 (2001).
2. Breiman, L., Friedman, J.H., Olshen, R., and Stone, C.J. (1984). Classification and Regression Tree. Wadsworth & Brooks/Cole Advanced Books & Software, Pacific California
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4. Center for International Earth Science Information Network - CIESIN - Columbia University, International Food Policy Research Institute - IFPRI, The World Bank, and Centro Internacional de Agricultura Tropical – CIAT. (2011). Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Urban Extents Grid [raster, map, map service]. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). Retrieved from https://sedac.ciesin.columbia.edu/data/set/grump-v1-urban-extents
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10. Department of Urban Development and Building Construction. (1994, 2003, 2015). Nepal National Building Codes [PDF files]. Retrieved from https://www.dudbc.gov.np/buildingcode
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13. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/jrc-ghsl-ghs_built_ldsmt_globe_r2015b
14. Facebook Connectivity Lab and Center for International Earth Science Information Network - CIESIN - Columbia University. 2016. High Resolution Settlement Layer (HRSL). Source imagery for HRSL © 2016 DigitalGlobe.
15. GoogleEarth. (n.d.) Nepal [map]. Available at https://www.google.com/earth/
16. ImageCat, Inc. (2019). OSM building footprint data aggregation to 3-arcsecond raster grid [dataset]. Unpublished.
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19. Jaiswal, K., Wald, D., & Porter, K. (2010). A global building inventory for earthquake loss estimation and risk management. Earthquake Spectra, 26(3), 731-748.
20. Kathmandu Living Labs (KLL). (2019). In-situ structural building type, height, and footprint area sampling polygons of Nepal [dataset]. Provided by Humanitarian OpenStreetMap Team.
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25. Nepal, C. B. S. (2012)-1. National population and housing census 2011 [National Report]. Gov't of Nepal, Natl Plan Comm Secr Cent Bureau Stat, 1, 1-278
26. Nepal, C. B. S. (2012)-2. Village Development Committee GIS data [dataset]. Provided by the National Society for Earthquake Technology – Nepal (NSET).
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30. Pesaresi, M., Ehrilch, D., Florczyk, A.J., Freire, S., Julea, A., Kemper, T., Soille, P. and Syrris, V. (2015): GHS built-up grid, derived from Landsat, multitemporal (1975, 1990, 2000, 2014)
31. Porter K., Hu, Z., Huyck, C. and Bevington, J. (2014), User guide: Field sampling strategies for estimating building inventories, GEM Technical Report 2014-02 V1.0.0, 42 pp., GEM Foundation, Pavia, Italy, doi: 10.13117/GEM.DATA-CAPTURE.TR2014.02.
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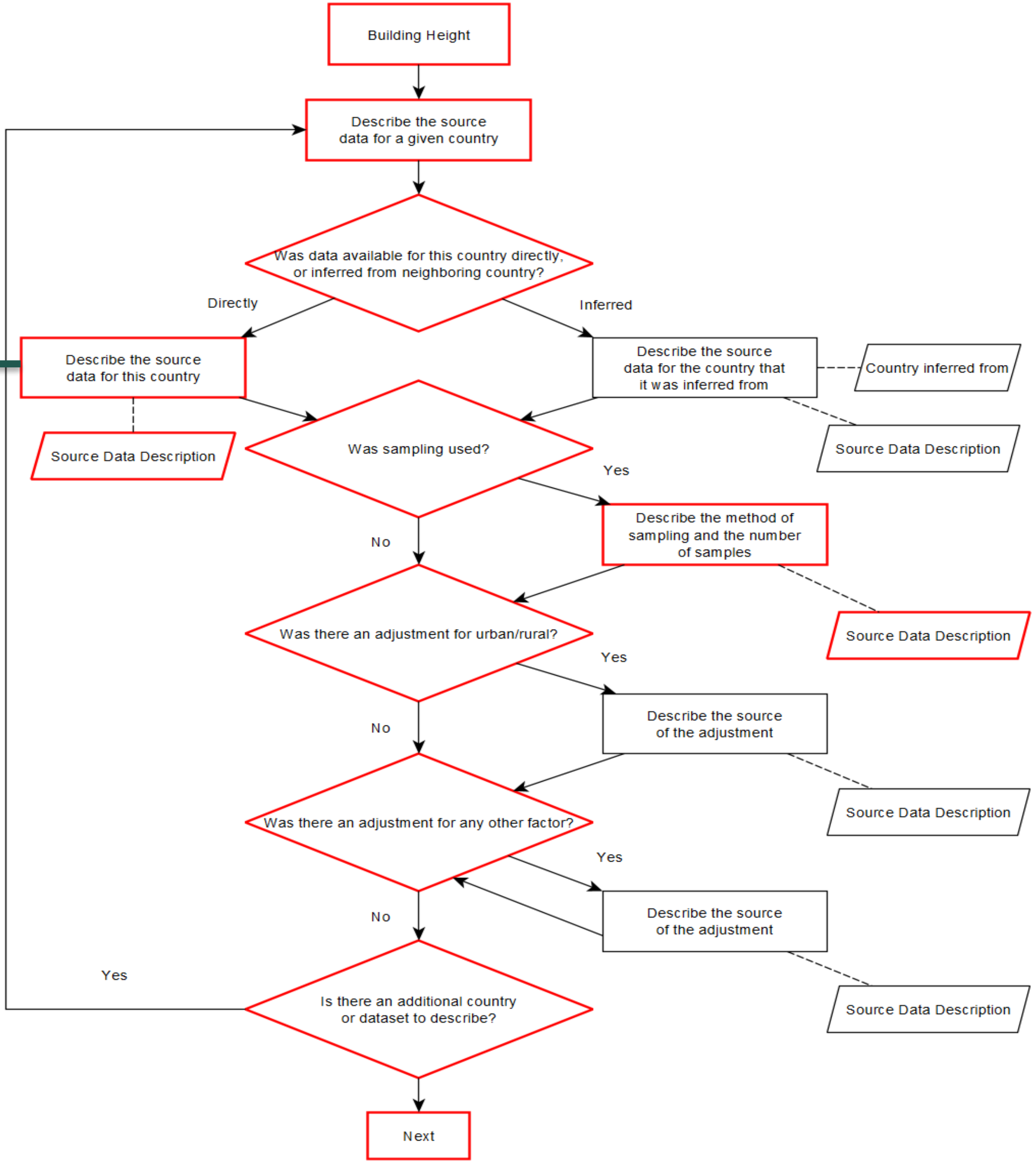
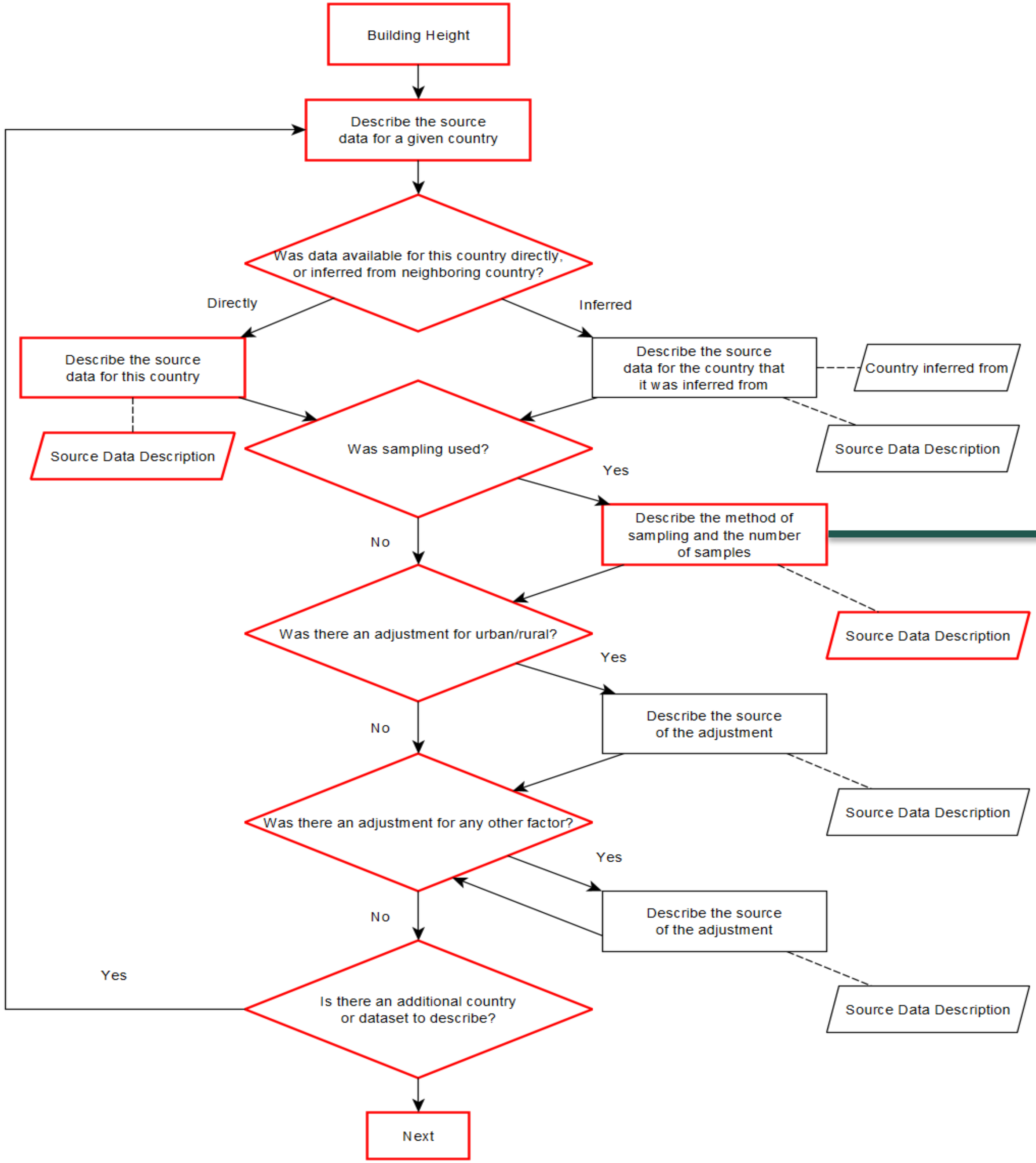
34. World Housing Encyclopedia, http://www.world-housing.net
35. WorldPop(1) (www.worldpop.org - School of Geography and Environmental Science, University of Southampton; Department of Geography and Geosciences, University of Louisville; Departement de Geographie, Universite de Namur) and Center for International Earth Science Information Network (CIESIN), Columbia University (2018). The spatial distribution of population in 2020, Nepal. From the Global High-Resolution Population Denominators Project - Funded by The Bill and Melinda Gates Foundation (OPP1134076).
36. Yamazaki, D., Trigg, M. A., & Ikeshima, D. (2015). Development of a global~ 90 m water body map using multi-temporal Landsat images. Remote Sensing of Environment, 171, 337-351.
37. Yogeshwar, K.P., Bothara, J.K. and Upadhyay, B.K. (2002). Housing Report-Traditional oval-shaped rural house. Nepal. World Housing Encyclopedia–an Encyclopedia of Housing Construction in Seismically Active Area of the World Retrieved at http://www.world-housing.net/WHEReports/wh100081.pdf

Building Height

There are two sources for the building height values - IPUMS and the field survey data collected by HOTOSM (Humanitarian OpenStreetMap Team, 2019).

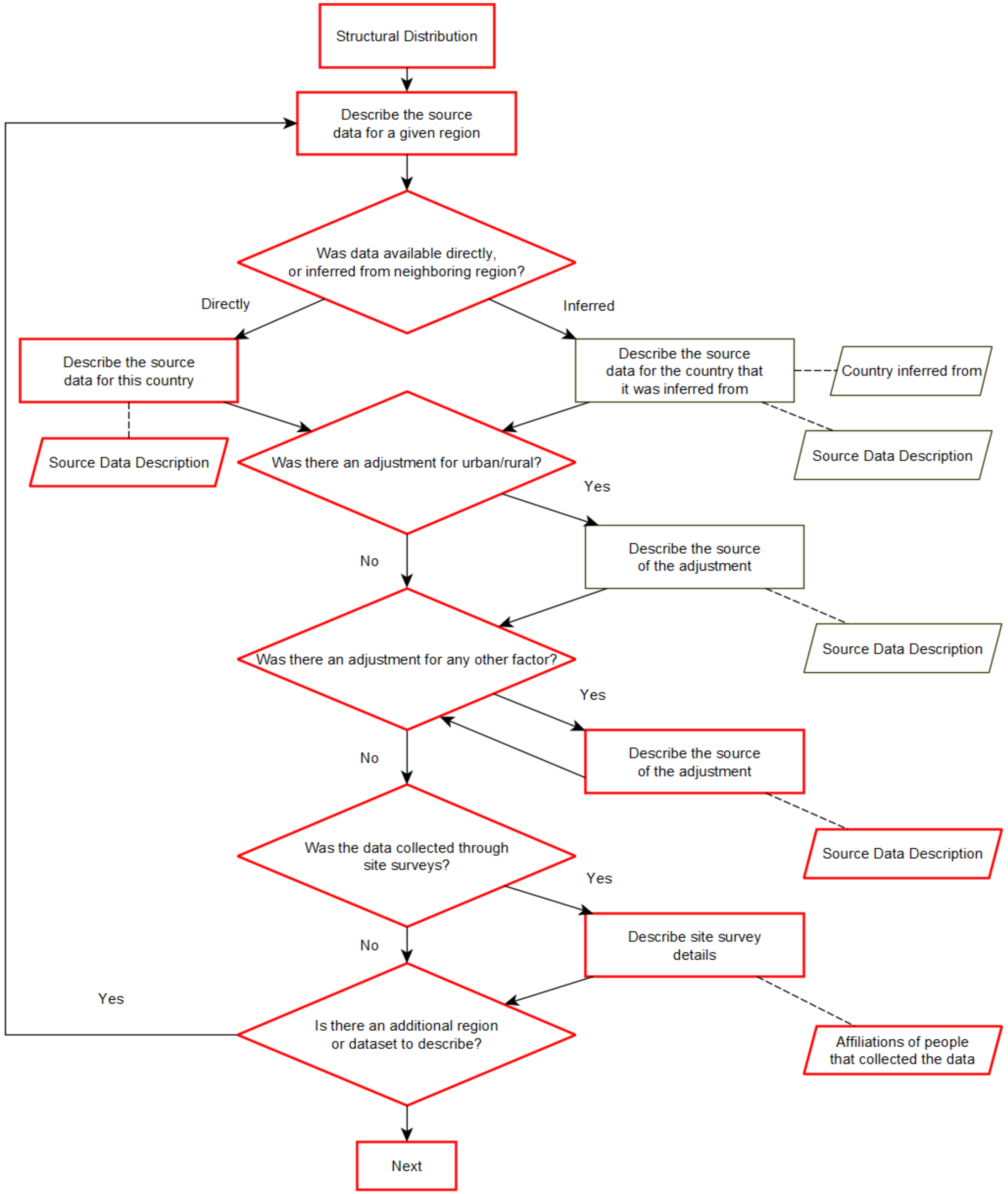


Building Height



Data collected by the HOT field team is used to characterize the height distribution in urban areas. In rural areas, the distribution of buildings by administrative level-2 was used to characterize the building stock, as gleaned from IPUMS data. Building height varies throughout the country depending on terrain, but the buildings are primarily low rise.

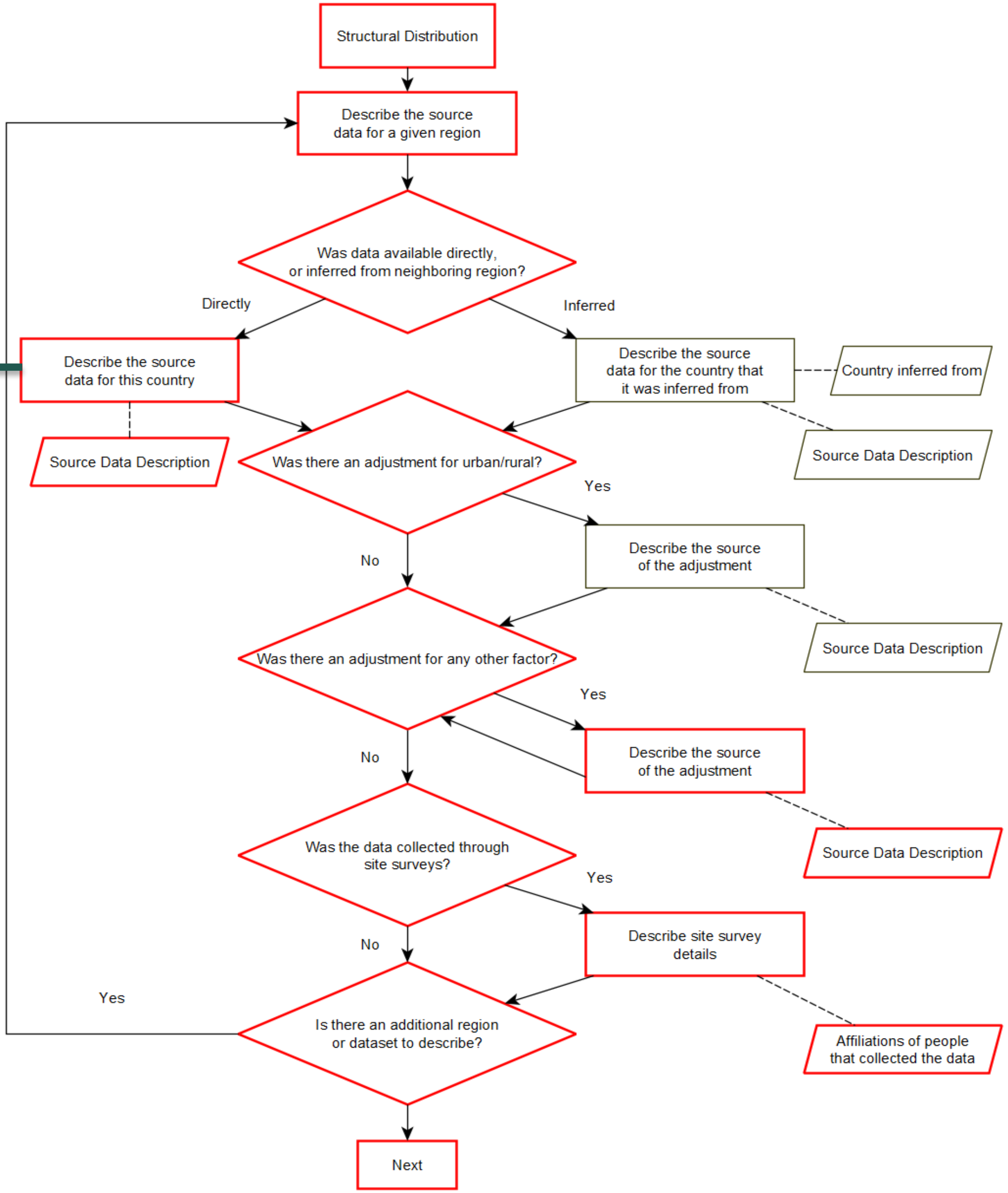
Structural Distribution



Structural Distribution

Estimates of structural distributions, or mapping schemes, was two-fold. First, a structural engineer conducts a web reconnaissance of any available data regarding both typical construction materials and methodologies within the region, as well as any data inferring structural distribution within the country. Sources such as the World Housing Encyclopedia [WHE], Prompt Assessment of Global Earthquakes for Response [PAGER] (Wald, et al. 2008), and Global Earthquake Model [GEM] (Brzev et al., 2013) were reviewed to identify all known structural types within the country. These preliminary types were validated through the Nepal National Building Code and Google StreetView survey.

After the web reconnaissance the structural engineer begins to formulate the mapping scheme by development pattern. Using the 2011 Nepal VDC-level census data the rural development pattern was assigned a mapping scheme using the building wall material type and number of household value. The building height values for UFB-1 and UFB-5 within the rural development pattern zones were obtained from Integrated Public Use Microdata Series (or IPUMS) data set. Based on discussion with Sharad Wagle, a Nepali Structural Engineer, cement mortar was assumed for those unreinforced masonry structures 5 stories or greater. The increased durability and bonding strength (in comparison to mud mortar) required for multi-story buildings was the logic behind such decisions. For low-rise, rural regions, mud mortar assumed as the bonding agent. For the remaining non-rural development patterns, the field survey data collected by HOTOSM was used to establish the mapping scheme for each of those development pattern types.



Structural Distribution

There was no urban-rural adjustment factor however Kathmandu Living Labs conducted a building survey for HOTOSM. The field team implemented a stratified sampling strategy and used a Bayesian updating approach. (Porter, et al. 2014). The survey data provided the structural mapping scheme for each development pattern.

Structural Distribution

Describe the source data for a given region

Was data available directly, or inferred from neighboring region?

Directly

Describe the source data for this country

Source Data Description

Inferred

Describe the source data for the country that it was inferred from

Country inferred from

Source Data Description

Was there an adjustment for urban/rural?

Yes

Describe the source of the adjustment

Source Data Description

No

Was there an adjustment for any other factor?

Yes

Describe the source of the adjustment

Source Data Description

No

Was the data collected through site surveys?

Yes

Describe site survey details

Affiliations of people that collected the data

No

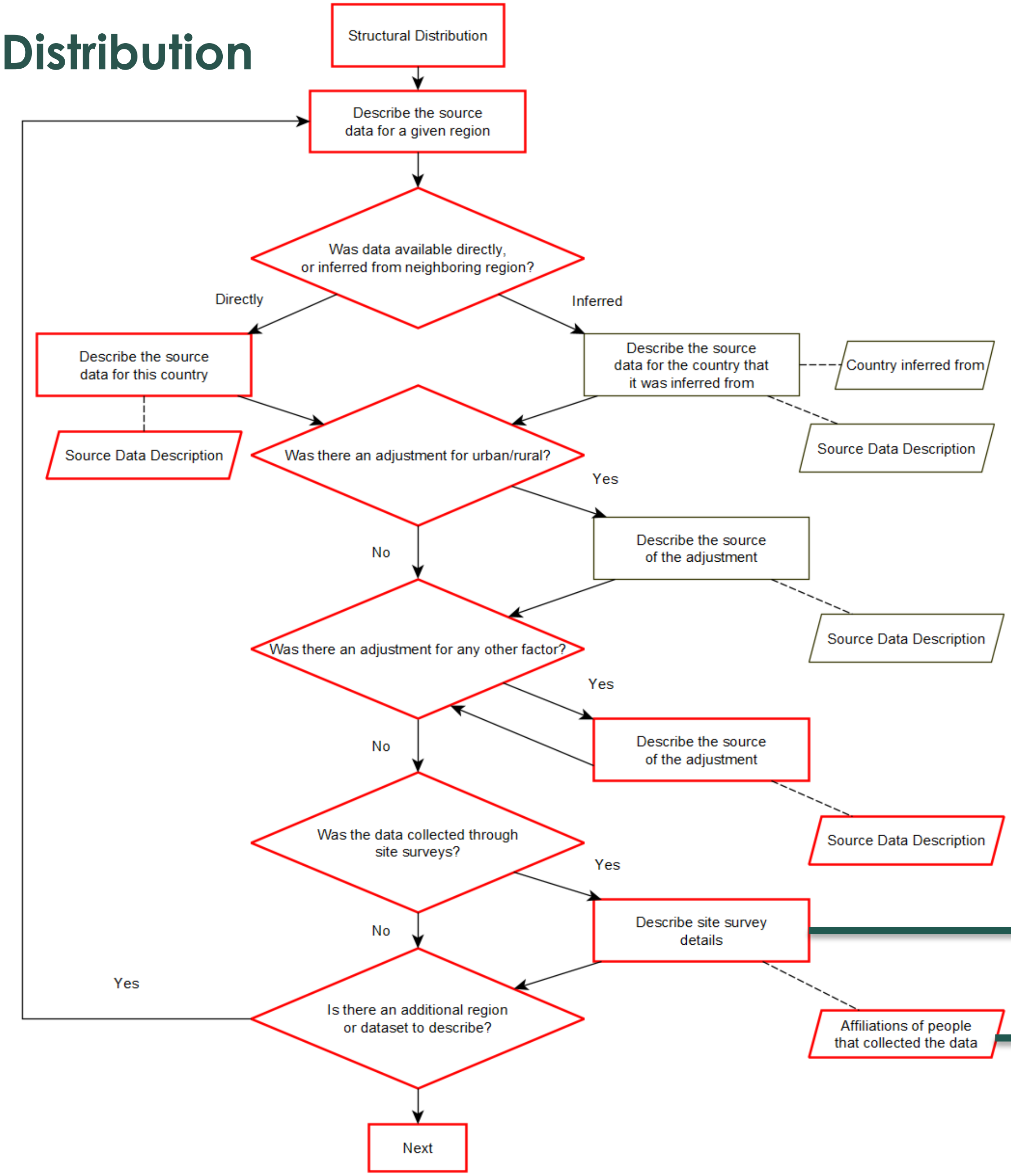
Is there an additional region or dataset to describe?

Yes

Next

Kathmandu Living Labs (KLL). (2019). In-situ structural building type, height, and footprint area sampling polygons of Nepal [dataset]. Provided by Humanitarian OpenStreetMap Team.

Structural Distribution



Structural Distribution

Describe the source data for a given region

Was data available directly, or inferred from neighboring region?

Directly

Inferred

Describe the source data for this country

Source Data Description

Describe the source data for the country that it was inferred from

Country inferred from

Source Data Description

Was there an adjustment for urban/rural?

Yes

Describe the source of the adjustment

Source Data Description

No

Was there an adjustment for any other factor?

Yes

Describe the source of the adjustment

Source Data Description

No

Was the data collected through site surveys?

Yes

Describe site survey details

Affiliations of people that collected the data

No

Is there an additional region or dataset to describe?

Yes

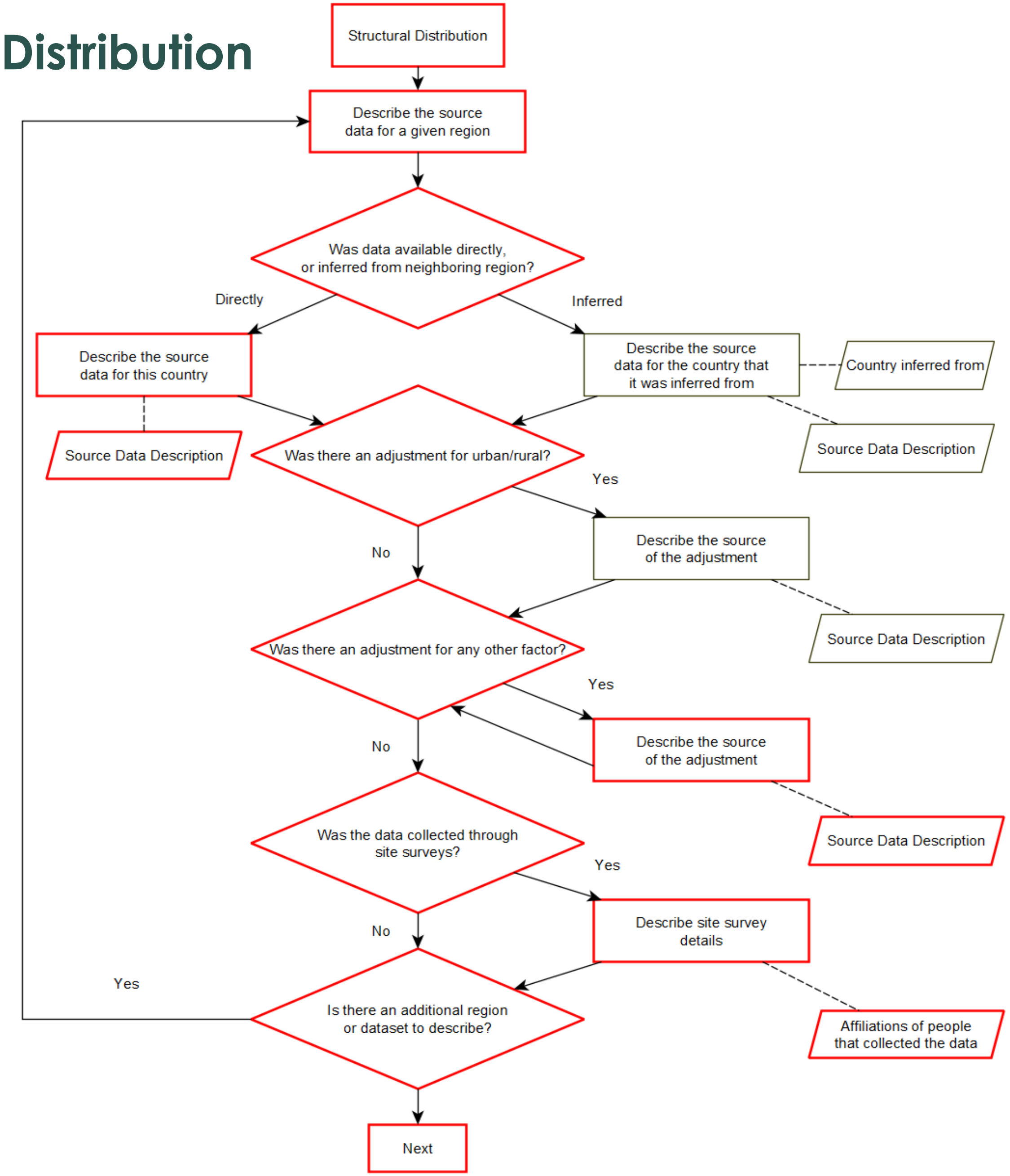
Next

GEM Class	DP1	DP2	DP3	DP4	DP5	DP6	DP7
MUR+ADO/HBET:1,3	1%	-	-	-	-	-	-
MUR+ADO/HBET:4,7	-	-	-	-	-	-	-
CR/LFINF+DNO/HBET:1,3	49%	37%	14%	28%	8%	17%	19%
CR/LFINF+DNO/HBET:4,7	22%	35%	56%	23%	4%	45%	22%
CR/LFINF+DNO/HBET:8,20	-	1%	3%	-	-	8%	1%
MATO/LN	-	-	-	2%	23%	-	-
S/LFM	-	-	-	-	-	-	-
S/LFBR	-	-	-	-	-	-	-
S/LO	2%	1%	-	9%	-	-	1%
S/LFINF	2%	-	-	3%	-	3%	1%
MUR+CL99/HBET:1,2	16%	13%	5%	30%	54%	14%	32%
MUR+CL99/HBET:3,5	7%	13%	21%	5%	-	13%	22%
W	-	-	-	-	6%	-	1%
W+WWD	1%	-	-	-	6%	-	-

The HOTOSM building survey data was verified by a local in-country engineer (Sharad Wagle) and in-house engineer (Michael Eguchi). All of the mapping schemes are then mapped to the PAGER standard structural types. These structure types are overlaid with the manually delineated development pattern sample polygons to create a refined mapping scheme. A final round of sanity checking is conducted by ImageCat engineers.

Sharad Wagle (NSET) and Michael Eguchi (ImageCat)

Structural Distribution



Structural Distribution

Describe the source data for a given region

Was data available directly, or inferred from neighboring region?

Directly

Inferred

Describe the source data for this country

Source Data Description

Describe the source data for the country that it was inferred from

Country inferred from

Source Data Description

Was there an adjustment for urban/rural?

Yes

No

Describe the source of the adjustment

Source Data Description

Was there an adjustment for any other factor?

Yes

No

Describe the source of the adjustment

Source Data Description

Was the data collected through site surveys?

Yes

No

Describe site survey details

Affiliations of people that collected the data

Is there an additional region or dataset to describe?

Yes

Next

Development patterns are patterns of construction in a given country that typify the building structure development and density as much as possible. They sometimes correspond with land use, but not always. The development patterns are determined by a structural engineer working with GIS analysts to conduct a web reconnaissance exercise using Google Earth, and structural distribution web searches to characterize the urbanity density and development patterns for each country. For Nepal, the ImageCat engineer characterized 8 development pattern types:

Development Pattern 1: Rural development found outside of city boundaries and is typically associated with agricultural development. The regions typically consist of small, remote villages with single roads in and out. Buildings are typically spaced far apart and are almost exclusively 1 to 2 stories. Local materials and construction practices are generally used and performed in these areas.

Development Pattern 2: This development pattern reflects areas typically dominated by single family residential structures. Commercial properties, such as local markets, are present, however residential structures are the primary occupancy. The built-up area is denser than rural class 1, however open land (yards, vacant lots, etc.) are present and can be observed via satellite imagery. All structures are low-rise, with most in the 1 to 2 story range.

Development Pattern 3: This development pattern is representative of regions with dense residential and commercial development. Apartments are typically located above first floor commercial properties. Structures are predominantly low to mid-rise, with an occasional high-rise structure located within the development pattern. Buildings are tightly spaced.

Development Pattern 4: This development pattern is typically associated with extremely dense, informal settlements. They are usually found within boundaries of large cities and are typically comprised of very small (<100 m^2) standalone structures with little to no space between adjacent buildings. The settlement is unplanned, therefore there is no organization to the configuration of building layouts. Almost all structures are 1-story and are typically erected using cheap and accessible local materials.

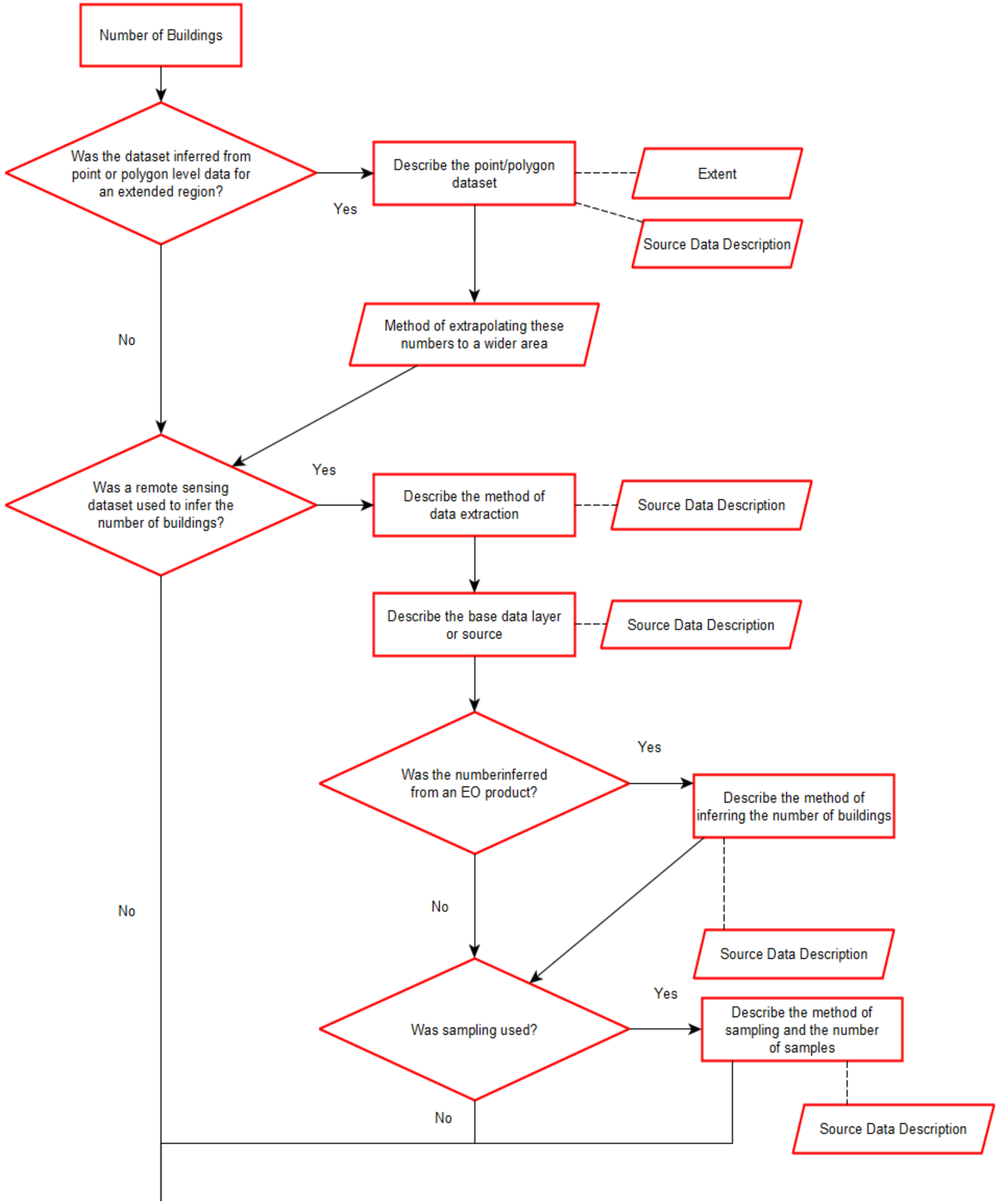
Development Pattern 5: Development pattern 5 is characterized by urban areas predominantly occupied by low to mid-rise residential and commercial structures. An occasional high-rise apartment or office building may be present. These developments are typically found near or around major city centers. Buildings are tightly spaced and are fairly regular in shape.

Development Pattern 6: This development pattern is the central business district of urban areas within the major cities. The region is occupied by low to high-rise apartments and commercial offices. Most structures are under 7-stories, however high-rise (8+ stories) can be found within the region. Building footprints are larger than most non-industrial development patterns. This development pattern will be found only in major cities and along the major, paved roads.

Development Pattern 7: This development pattern is characterized by areas dominated by ports, mining or industrial activities. Structures are typically closely spaced and regular in shape. A majority of buildings within these regions are warehouses, rectangular shape and single story. Smaller low-rise, office and commercial structures can also be found on site.

Development Pattern 8: This development pattern is typically located within the urban region and is comprised of large developments, such as universities. The built-up environment is typically comprised of low to mid-rise structures with large building footprints.

Number of Buildings



Number of Buildings

Was the dataset inferred from point or polygon level data for an extended region?

Yes

Describe the point/polygon dataset

Extent

Source Data Description

Method of extrapolating these numbers to a wider area

No

Was a remote sensing dataset used to infer the number of buildings?

Yes

Describe the method of data extraction

Source Data Description

Describe the base data layer or source

Source Data Description

Was the numberinferred from an EO product?

Yes

Describe the method of inferring the number of buildings

Source Data Description

No

Was sampling used?

Yes

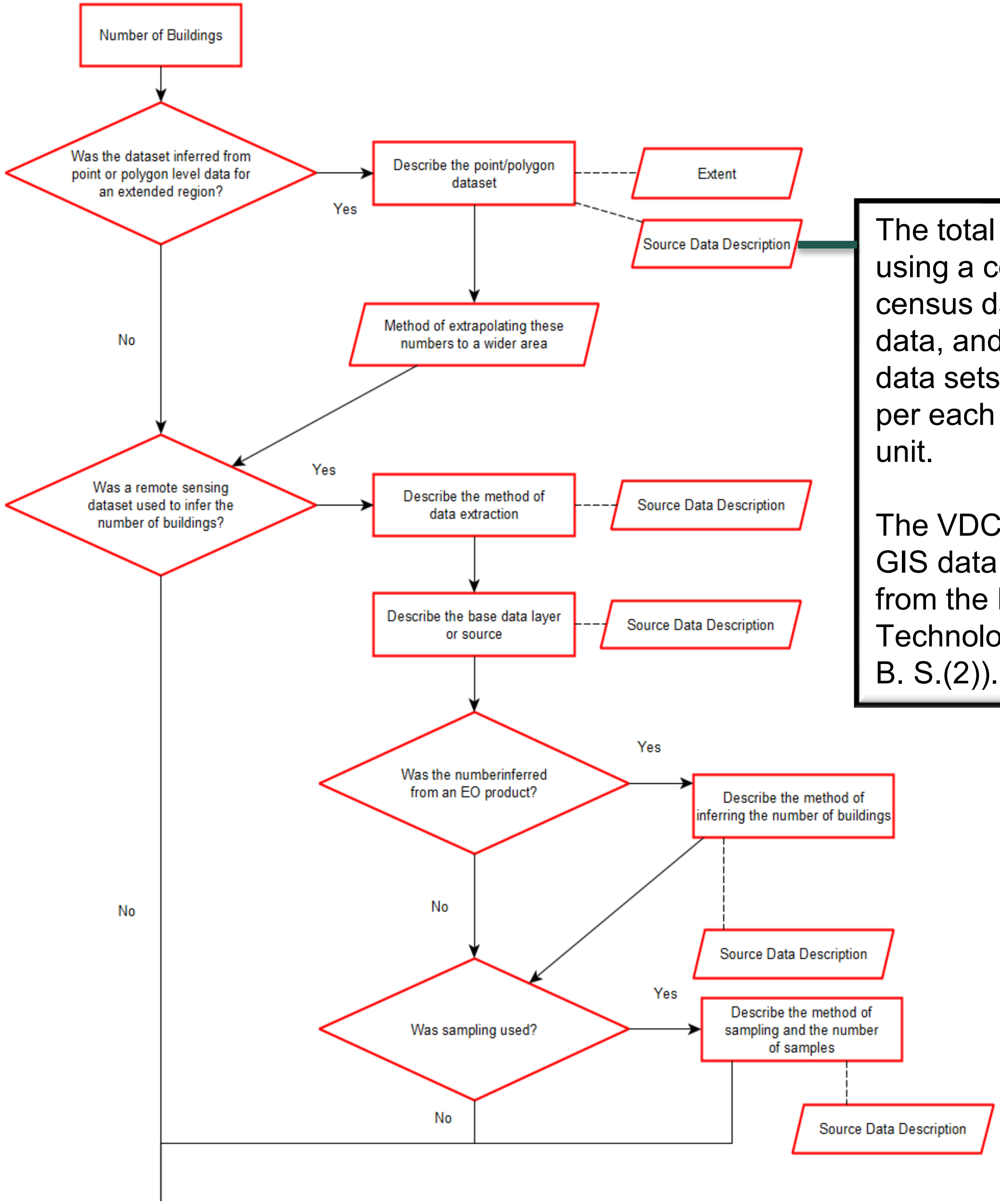
Describe the method of sampling and the number of samples

Source Data Description

No

No

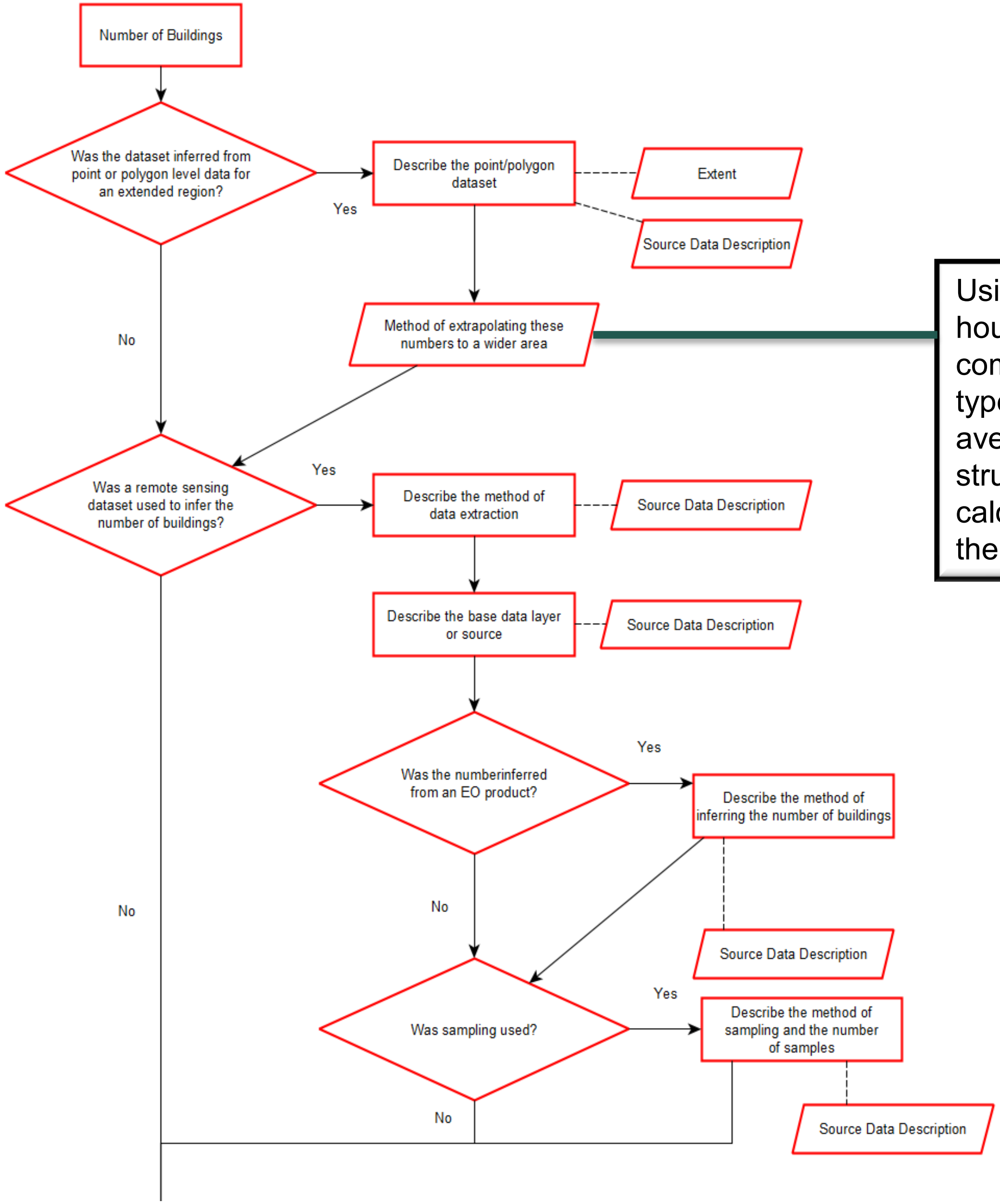
Number of Buildings



The total number of buildings was inferred using a combination of IPUMS, VDC census data, OpenStreetMap survey data, and aggregated OSM building raster data sets to estimate average household per each building type per VDC census unit.

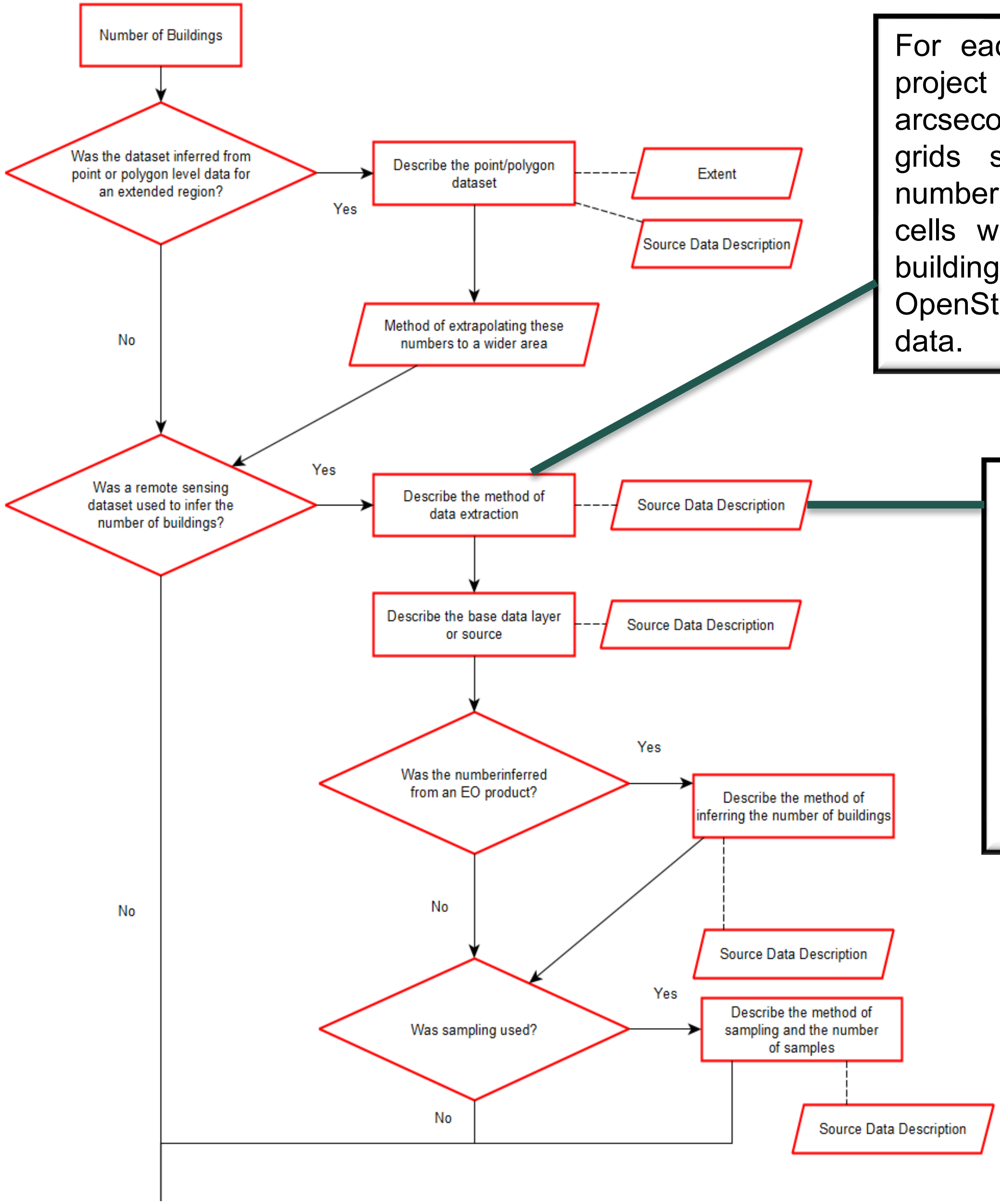
The VDC-level census spreadsheets and GIS data were provided by Sharad Wagle from the National Society for Earthquake Technology (NSET) in Nepal (Nepal, C. B. S.(2)).

Number of Buildings



Using the Nepal census count of household per village development committee (VDC) by wall material type a relationship between the average total building area using structural type was created to calculate total number of buildings for the rural zones.

Number of Buildings


Number of Buildings

Was the dataset inferred from point or polygon level data for an extended region?

Yes

Describe the point/polygon dataset

Extent

Source Data Description

Method of extrapolating these numbers to a wider area

No

Was a remote sensing dataset used to infer the number of buildings?

Yes

Describe the method of data extraction

Source Data Description

Describe the base data layer or source

Source Data Description

Was the numberinferred from an EO product?

Yes

Describe the method of inferring the number of buildings

Source Data Description

No

No

Was sampling used?

Yes

Describe the method of sampling and the number of samples

Source Data Description

No

For each development pattern, a project analyst reviewed 15-arcsecond (approximately 500m) grids selected using a random number generator and identified cells where at least 90% of the buildings were represented in the OpenStreetMap building footprint data.

Global Urban Footprint (GUF); DLR 2016.

V. Syrris, C. Corbane, M. Pesaresi and P. Soille, "Mosaicking Copernicus Sentinel-1 Data at Global Scale," in *IEEE Transactions on Big Data*. doi: 10.1109/TBDATA.2018.2846265 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8428406&isnumber=7153538

Number of Buildings

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Describe the method of inferring the number of buildings

Source Data Description

No

Was sampling used?

Yes

Describe the method of sampling and the number of samples

Source Data Description

No

These selected grids were used to train a regression model using the 3-arcsecond Sentinel-1 SAR mosaic with dual polarization bands, the Facebook Connectivity Lab & CIESIN High Resolution Settlement Layer, (Facebook Connectivity Lab & Center for International Earth Science Information Network [CIESIN], 2016), and the Global Urban Footprint (GUF) from DLR (DLR Earth Observation Center.

Development patterns samples and building count sample through satellite imagery reconnaissance.

Nepal.GoogleEarth, 2018. Map OpenStreetMap contributors. (2018) Geogabrik Public Server [nepal-latest-free.shp]. Retrieved from https://download.geofabrik.de/asia/nepal.html

Number of Buildings

In addition, the model was constrained using OpenStreetMap building footprints with an area between 10 - 5,000 meters square to create an aggregated 3-arcsecond grid OSM building count raster (Humanitarian OpenStreetMap Team, 2019; ImageCat, 2019) as a minimum value.

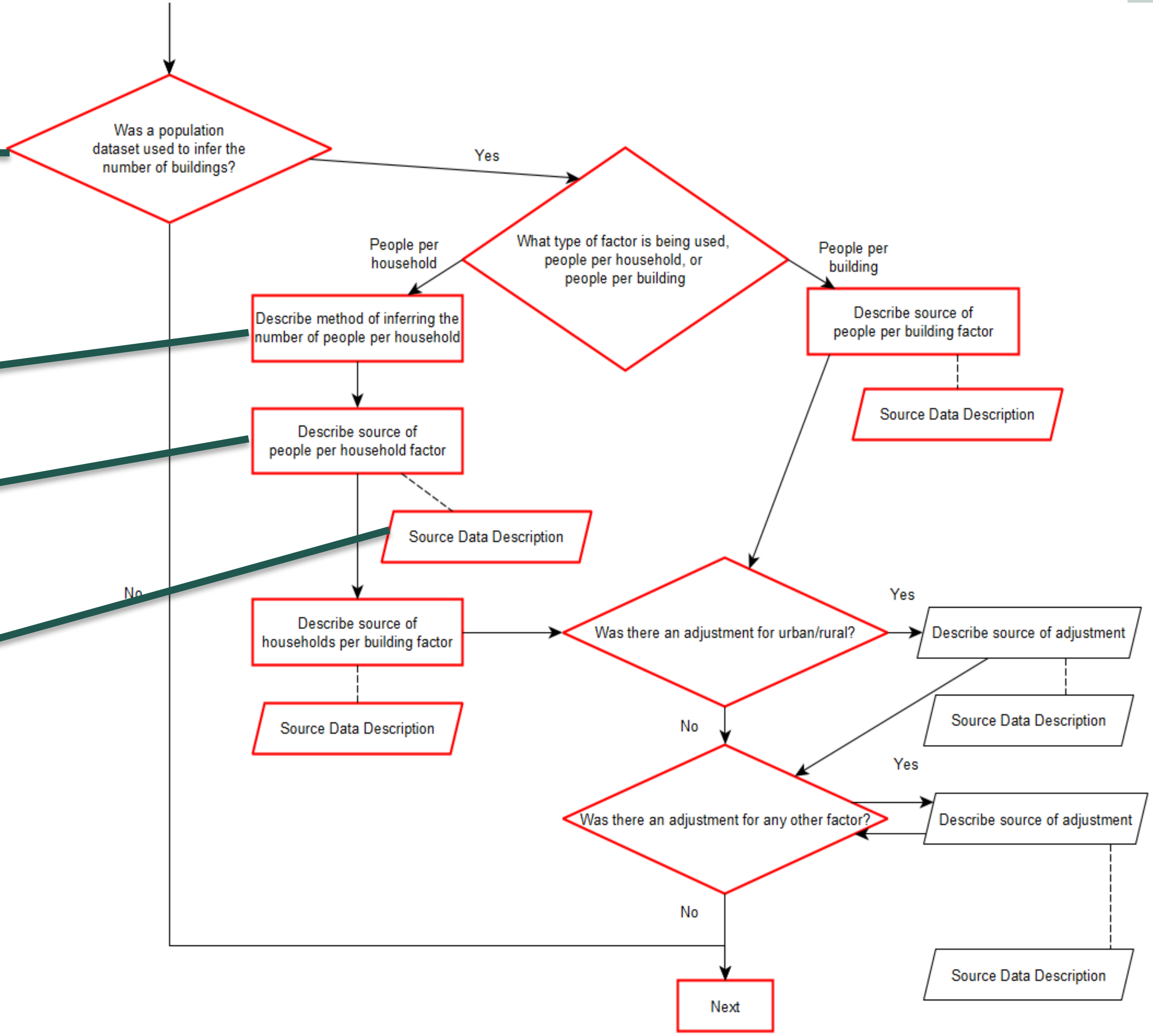
Provided directly in census data at the VDC level

The VDC GIS data was provided by Sharad Wagle from NSET.

Nepal, C. B. S. (2011). National Population Census 2011-Nepal [dataset]. Provided by IPUMS International.

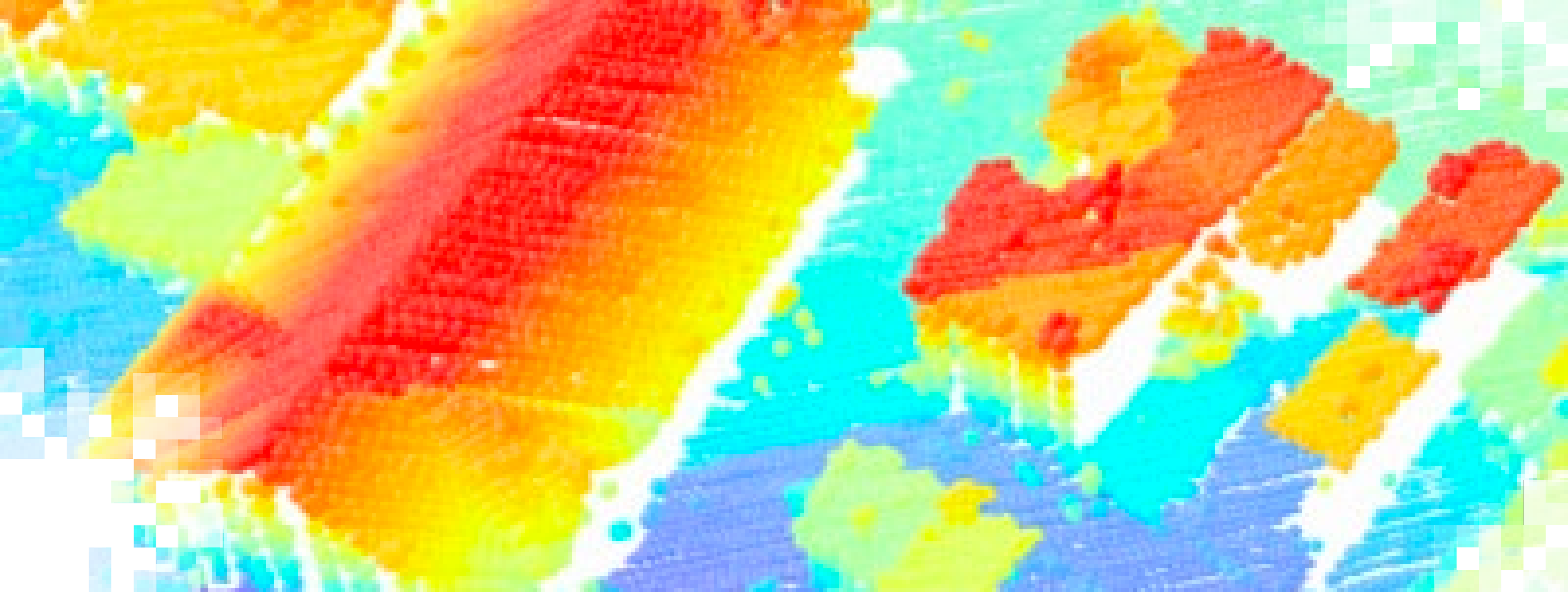
Nepal, C. B. S. (2012)-1. National population and housing census 2011 [National Report]. Gov't of Nepal, Natl Plan Comm Secr Cent Bureau Stat, 1, 1-278

Nepal, C. B. S. (2012)-2. Village Development Committee GIS data [dataset]. Provided by the National Society for Earthquake Technology – Nepal (NSET).



More Examples

- To see a continuation of this flowchart example for Nepal, please view this presentation (available from the METEOR training materials for Nepal).
- For more examples of actual metadata documents that have been produced for the METEOR project, see the METEOR Exposure Data site.



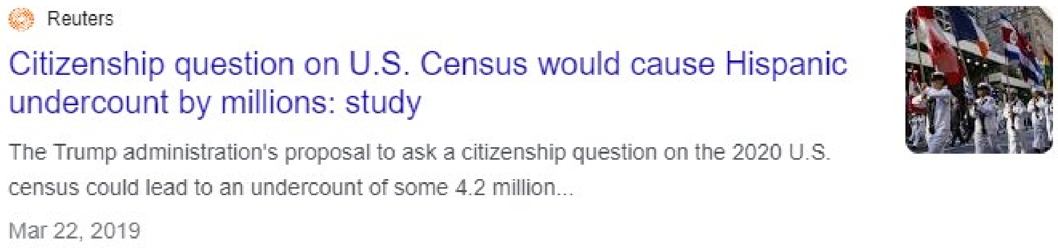
Equity and Bias Considerations

Overview of Equity and Bias Issues

- We are on the side of justice, right?
- Not necessarily
  - Economic perspective
  - History
  - Bias
  - Data feeds into a larger decision-making framework

Bias in the Exposure Data

- Unhoused, undocumented, and nomadic people more difficult to find (or easy to ignore).
- Mass migration due to conflict, other factors- are missed.
- Informal housing and BIPOC, ethnic minorities ignored or undercounted.
- Some census data is just old.

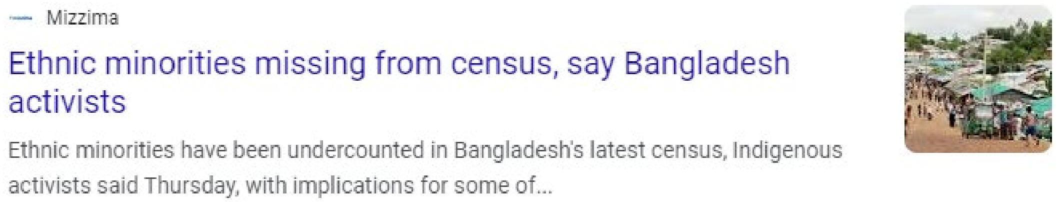


Reuters

Citizenship question on U.S. Census would cause Hispanic undercount by millions: study

The Trump administration's proposal to ask a citizenship question on the 2020 U.S. census could lead to an undercount of some 4.2 million...

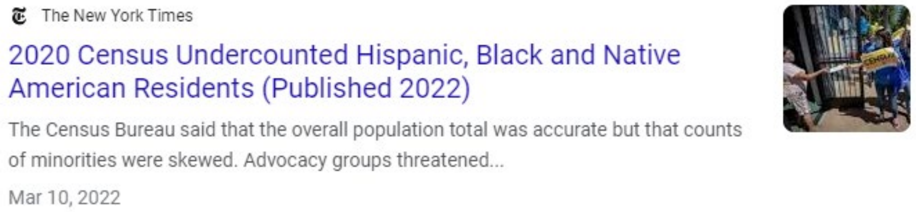
Mar 22, 2019



Mizzima

Ethnic minorities missing from census, say Bangladesh activists

Ethnic minorities have been undercounted in Bangladesh's latest census, Indigenous activists said Thursday, with implications for some of...



The New York Times

2020 Census Undercounted Hispanic, Black and Native American Residents (Published 2022)

The Census Bureau said that the overall population total was accurate but that counts of minorities were skewed. Advocacy groups threatened...

Mar 10, 2022

WBAY

Milwaukee challenge says 2020 census undercounted minorities

The city of Milwaukee has joined the ranks of other major cities challenging their 2020 census figures, claiming the once-a-decade U.S. head...

Dec 20, 2022

Nikkei Asia

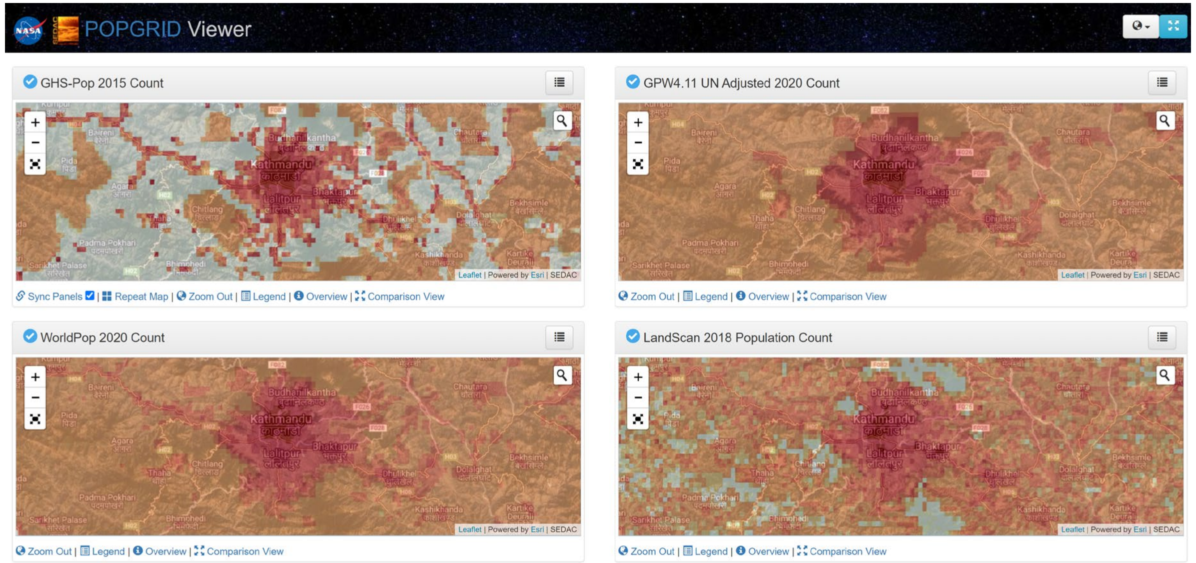
Pakistan census sparks accusations of manipulation

ISLAMABAD -- Pakistan's outgoing government is taking criticism for allegedly using the recent national census to delay elections for its...

4 weeks ago

Bias in the Exposure Data

- Data is extrapolated from tracts to grids using different assumptions.
- Building footprints more difficult to extract in some rural environments
  - Under tree canopies
  - In mountainous terrain
  - Biased training data
- Data is better where people pay more attention (more assets).



Adam Smith’s Dystopian Hand

- Those with less power and resources gravitate to higher risk areas (typically).
- Less power means less ability to impact social change.
- Risk analysis may feed into this process.
- When land is reclaimed, important to pay attention to the displaced.
- In some countries, it may mean keep quiet or you’ll be cleared out.

Real person

Lives here

An Accountant’s Perspective

- Risk modeling tools
  - Descend from sophisticated actuarial tools (CAT models)
  - Moved over to FEMA in the 90s,
  - Are a template for international tools
- This means:
  - Money over people (we tried)
  - Buildings over systems
    - Math is hard
    - Data is sparse
  - Vulnerability focused on engineered construction in developed countries

How much does it cost to build this hut?

Does it matter?

An Accountant’s Perspective

- Focus on Annualized Losses
  - Annualized losses don’t adequately assess the big ones!
  - Less frequent, high-impact events can overwhelm communities- cascading impacts
  - Regions with frequent impact are often better prepared

How do we price disruption?

Benefit Cost Analysis Does Not Help Society Answer the Question of "Who"

- Wealthy and highly populated cities have better risk consultants.
- Rural and less wealthy areas do not have the expertise.
- Wealthier constituents have more political leverage.
- The equations favor conditions where higher-value property is protected.
- Homeowners over renters
- The equations themselves don't care if the recipients are billionaires.

"Federal Emergency Management Agency spent disproportionate amounts of money elevating homes in communities that are wealthy or overwhelmingly white"

Source: https://www.politico.com/news/2022/06/16/fema-flood-program-civil-rights-00037261

An Accountant’s Perspective

- Benefit cost analysis-BCA is not designed to address a shifting climate
  - BCA provides a quantitative basis for evaluating investment options. By discounting future benefits, you effectively are comparing the benefit with investing the initial cost with a return that is equivalent to the discount rate. (I wish I would have put the money in the bank)
  - Not suitable for the unique condition where benefits accrue substantially in the future. (Wish I’d paid for the mitigation- or retreated)

Climate change is shifting storm patterns, reducing the frequency of lower-category storms and increasing the occurrence of more destructive Category 4 and 5 storms

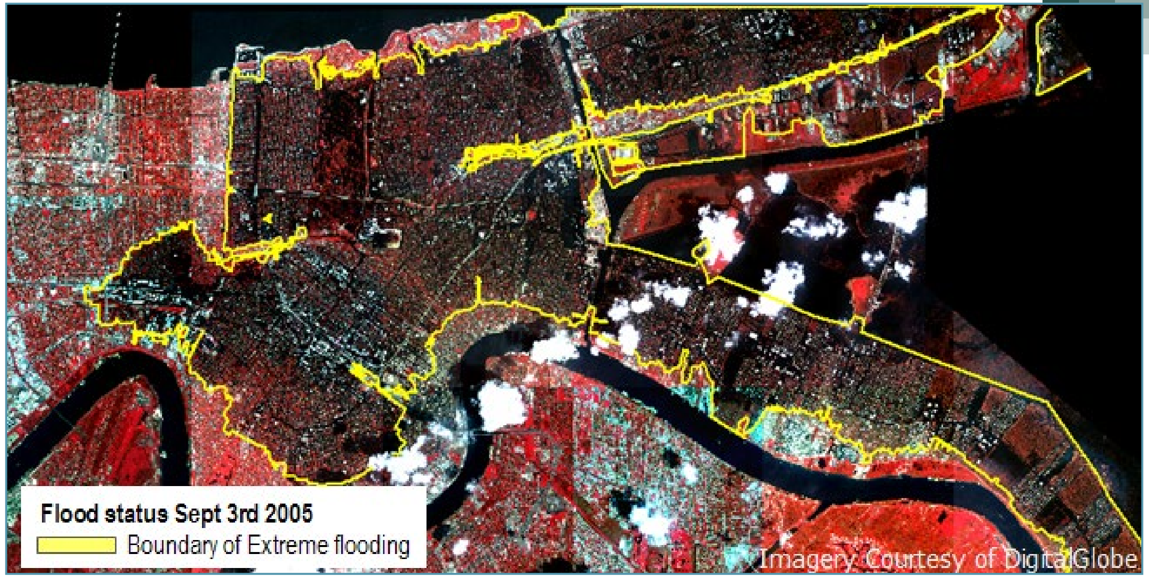
- ESG indices show reduced risk!

Stranded Asset

An Accountant's Perspective

Focus on individual properties, not communities

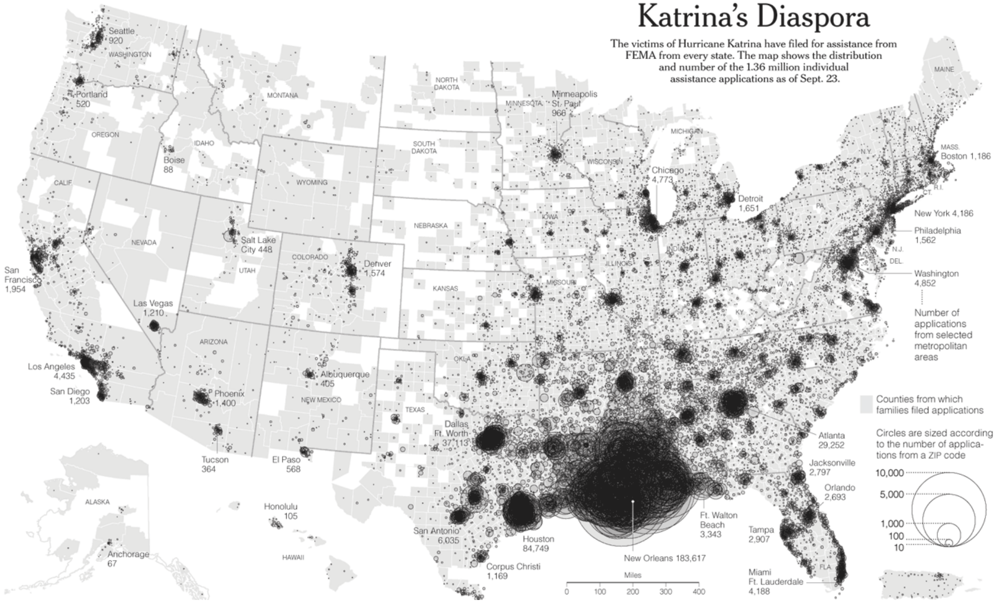
- Mitigation has synergy, difficult to capture
- Vulnerable populations may not align with the site-specific risk
- Identifying risk requires a comprehensive view of the entire community
- Example: Hurricane Katrina's risk from breached levees had distant impacts.


Flood status Sept 3rd 2005

🟨 Boundary of Extreme flooding

Imagery Courtesy of DigitalGlobe

9th Ward needed the levee strengthened, not raised structures


Katrina's Diaspora

The victims of Hurricane Katrina have filed for assistance from FEMA from every state. The map shows the distribution and number of the 1.36 million individual assistance applications as of Sept. 23.

Geographic Precision is Not Accuracy

- Exposure data that is not based on engineering reports should not be used or publicized at the building level.
- False precision leads to inappropriate decisions that impact people’s lives.
- In GIS, more accuracy always seems better- but we need a more holistic perspective.

Portland NAACP joins fight over city’s earthquake warning

The group says the policy will reinforce gentrification in Portland's historically black neighborhoods.

https://www.oregonlive.com

A Conundrum

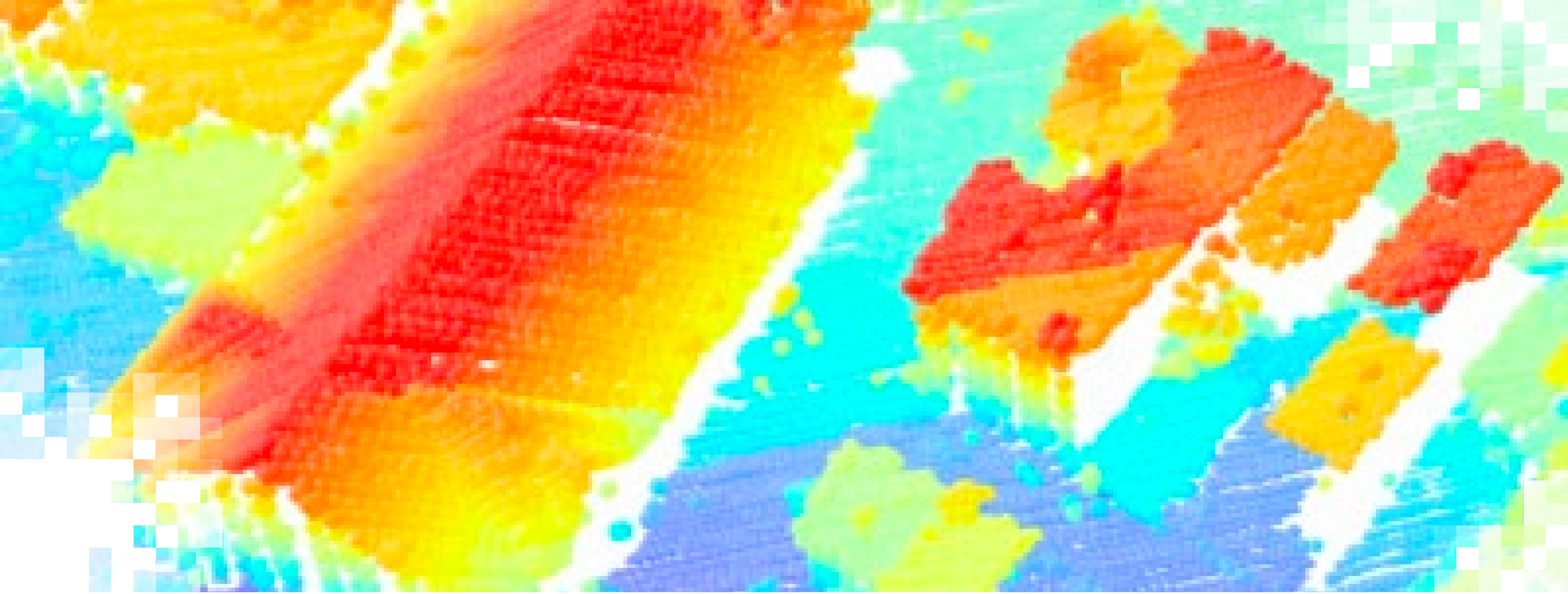
- Exposure data is essential to understanding risk.
- Exposure data can be used for nefarious purposes in totalitarian regimes.
- Exposure data, lifeline data, can be repurposed for terrorism, conflict.

“Informal” to “no lateral force-resisting system”

So, What Can You Do?

- Contribute to more sophisticated research in the area
- Encourage transparency (but not always openness)
- Protect privacy
- Acknowledge uncertainty
- Aggregate
- Speak up
- Find the accidents waiting to happen

What questions are we trying to answer?



Case Study: Assessing Climate Change Impacts with Building Exposure Data in Antigua and Barbuda

National Adaptation Plans (UNFCCC)

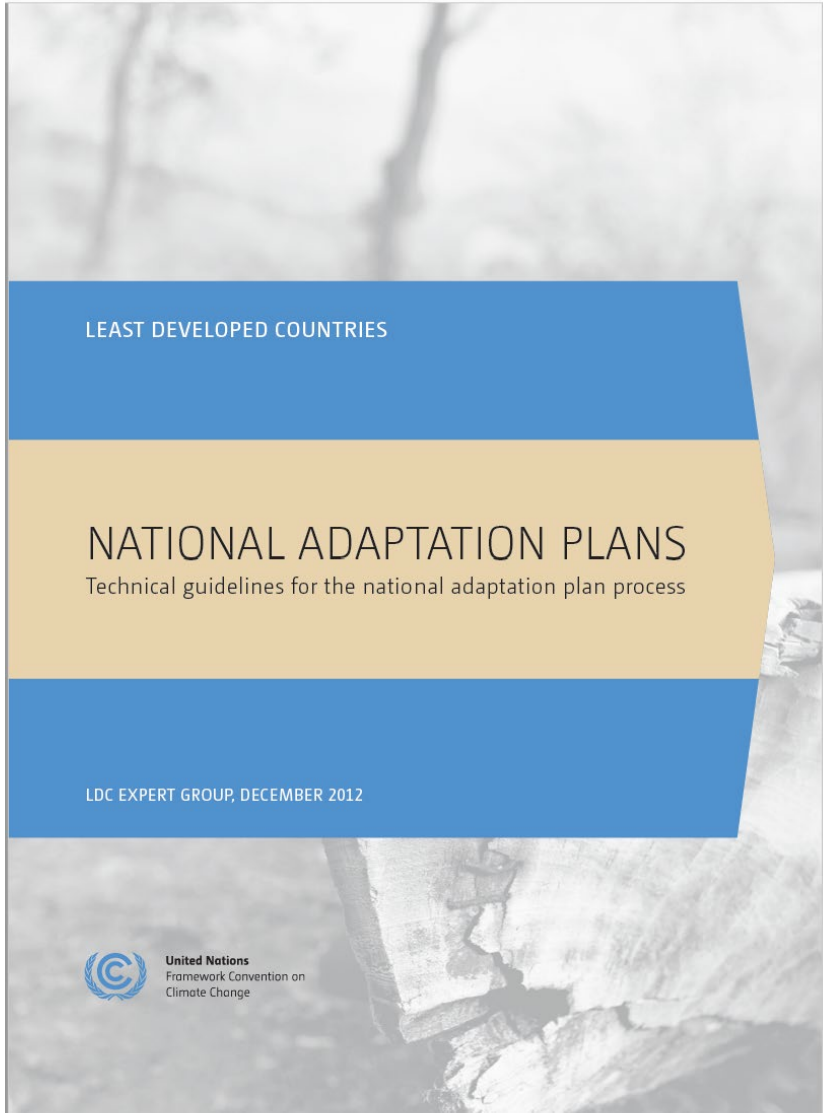
The objectives of the national adaptation plan process are:

(a) To reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience;

(b) To facilitate the integration of climate change adaptation (…) into relevant new and existing policies, programmes and activities…

United Nations Framework
Convention on Climate Change

Technical guidelines for the NAP



LEAST DEVELOPED COUNTRIES

NATIONAL ADAPTATION PLANS

Technical guidelines for the national adaptation plan process

LDC EXPERT GROUP, DECEMBER 2012

United Nations
Framework Convention on
Climate Change

The NAP Process

1. Analyze current climate and future climate change scenarios and risks
2. Assess climate vulnerabilities
3. Identify adaptation options
4. Review and appraise adaptation options

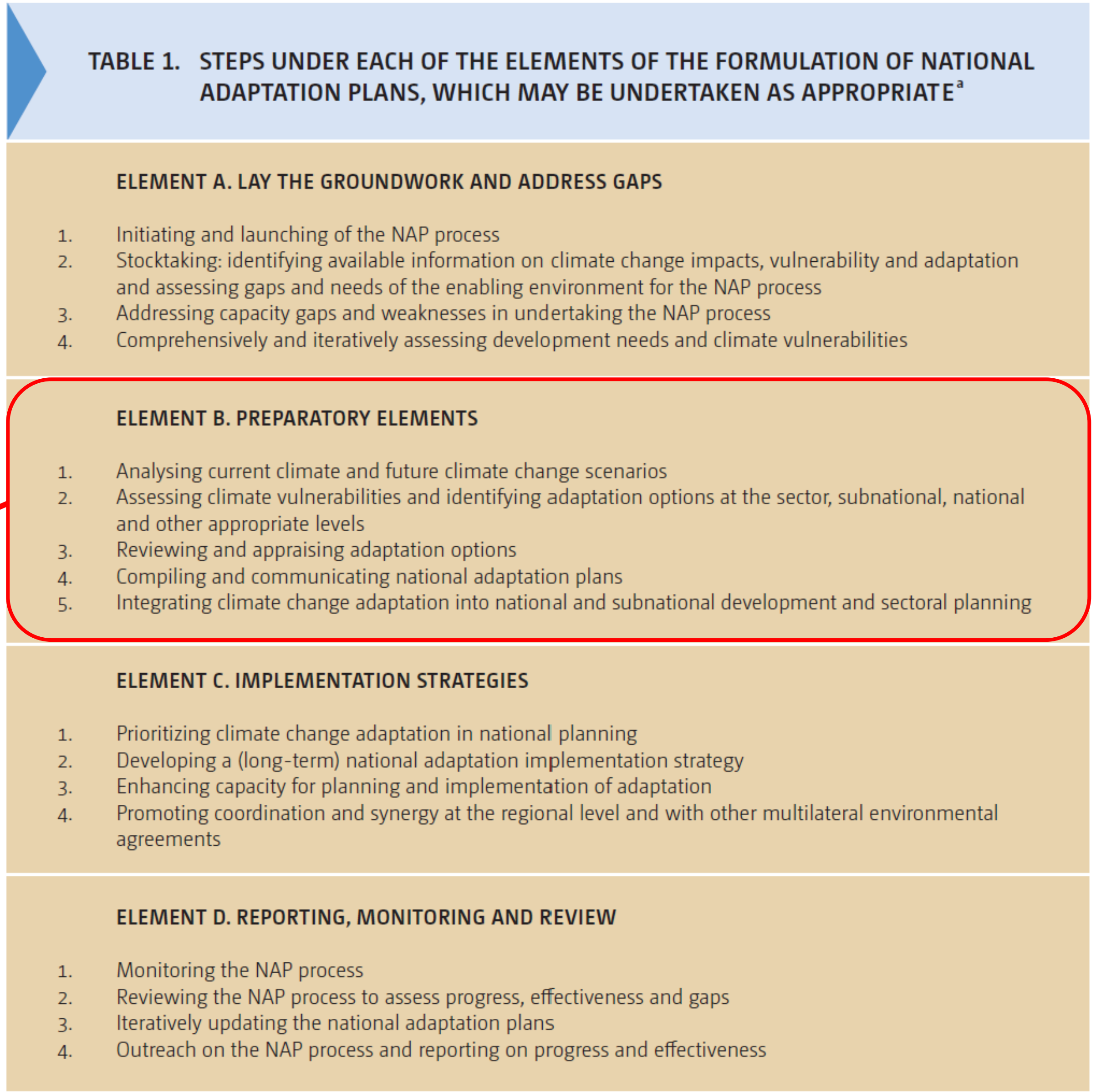


TABLE 1. STEPS UNDER EACH OF THE ELEMENTS OF THE FORMULATION OF NATIONAL ADAPTATION PLANS, WHICH MAY BE UNDERTAKEN AS APPROPRIATE[a]

ELEMENT A. LAY THE GROUNDWORK AND ADDRESS GAPS

1. Initiating and launching of the NAP process
2. Stocktaking: identifying available information on climate change impacts, vulnerability and adaptation and assessing gaps and needs of the enabling environment for the NAP process
3. Addressing capacity gaps and weaknesses in undertaking the NAP process
4. Comprehensively and iteratively assessing development needs and climate vulnerabilities

ELEMENT B. PREPARATORY ELEMENTS

1. Analysing current climate and future climate change scenarios
2. Assessing climate vulnerabilities and identifying adaptation options at the sector, subnational, national and other appropriate levels
3. Reviewing and appraising adaptation options
4. Compiling and communicating national adaptation plans
5. Integrating climate change adaptation into national and subnational development and sectoral planning

ELEMENT C. IMPLEMENTATION STRATEGIES

1. Prioritizing climate change adaptation in national planning
2. Developing a (long-term) national adaptation implementation strategy
3. Enhancing capacity for planning and implementation of adaptation
4. Promoting coordination and synergy at the regional level and with other multilateral environmental agreements

ELEMENT D. REPORTING, MONITORING AND REVIEW

1. Monitoring the NAP process
2. Reviewing the NAP process to assess progress, effectiveness and gaps
3. Iteratively updating the national adaptation plans
4. Outreach on the NAP process and reporting on progress and effectiveness

[Technical guidelines for the NAP]

1. Analyze Current Climate and Future Climate Change Scenarios and Risks

Climate Change Risk Modelling Project for Antigua and Barbuda

The Department of Environment (DOE) provided Leadership and Strategic Direction

Set New Standards for Climate Risk Modeling and Adaptation Planning

Participatory Process helped guide the development of the Final Results

Achieved International Standard of Excellence through Technical Implementation

World Renowned Consortium with expertise in Climate Risk led by ImageCat

1 Year Project

CLIMATE SCENARIOS ADDRESSED

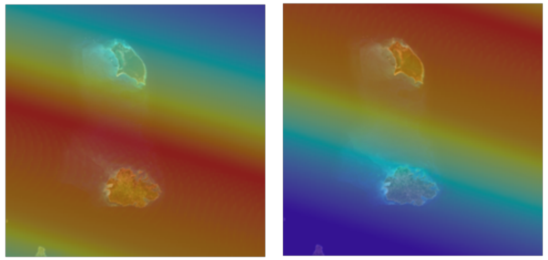
4.5 RCP Stabilization

8.5 RCP High Emissions

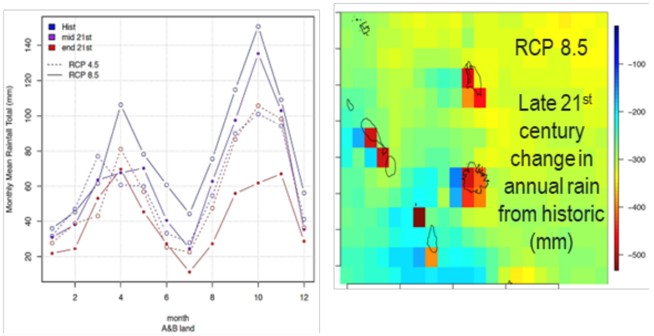
HAZARDS

Hazards considered:

- Tropical Cyclone - Wind and Surge
- Extreme Temperature
- Extreme Rainfall
- Sea Level Rise



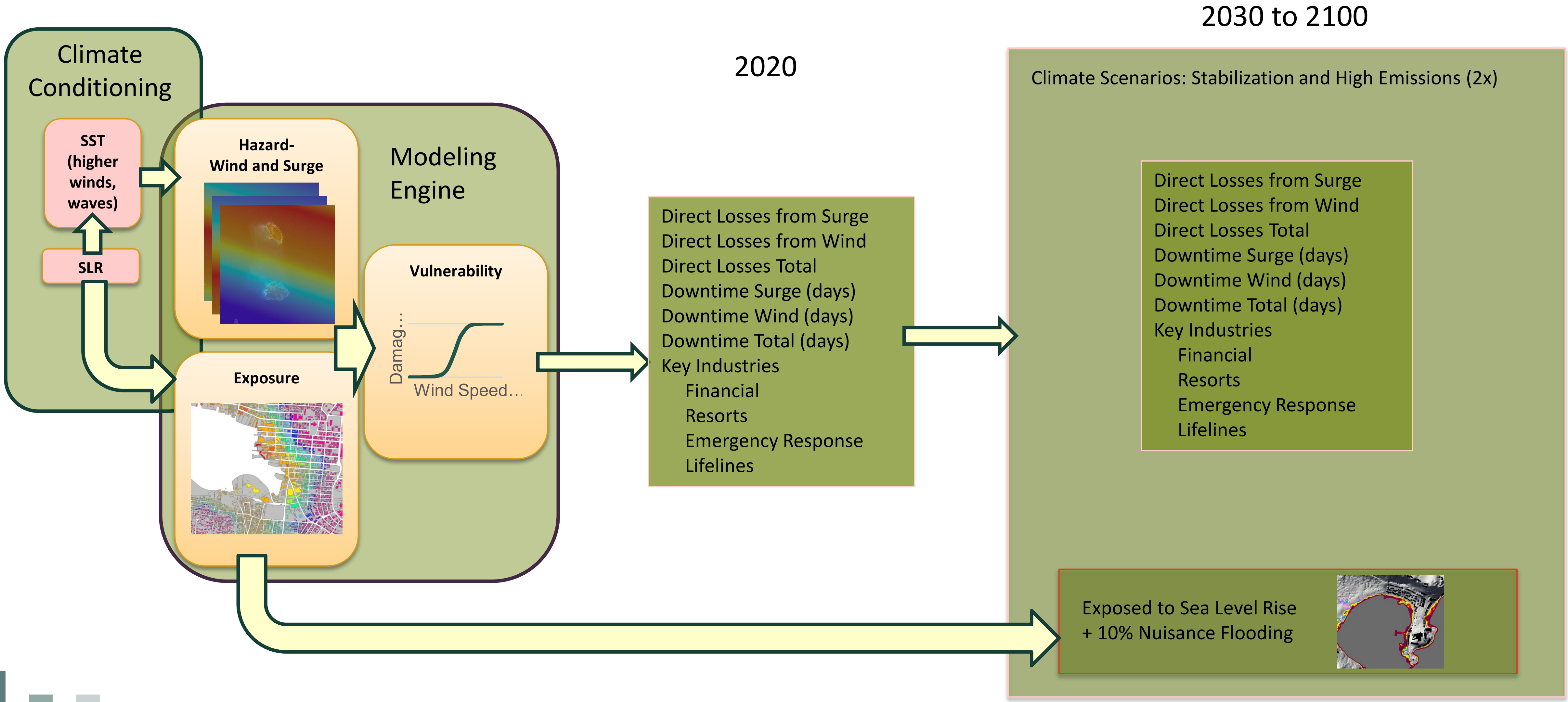
Stochastic Wind Field Model
3-second gust at 10-meters elevation in open terrain (m/s)



Regional Climate Model Rainfall Projections driven by HadGEM2-ES
(1 of 3 downscaled Global Climate Models)

12 km downscaled climate data from the UK Met Office was a key component in the climate change risk modeling process

Climate Change Risk Modeling



Climate Scenarios: Stabilization and High Emissions (2x)

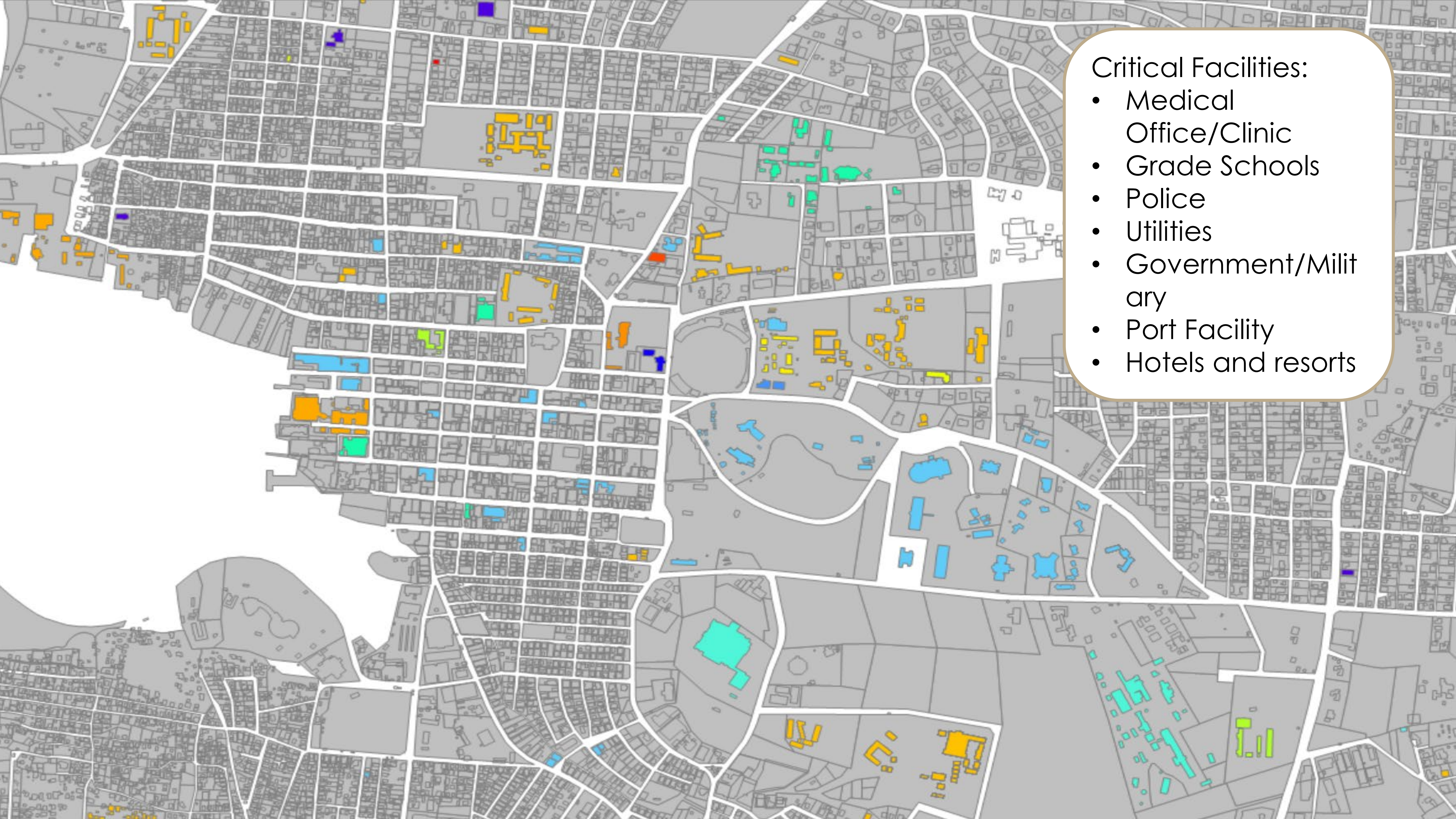
- Direct Losses from Surge
- Direct Losses from Wind
- Direct Losses Total
- Downtime Surge (days)
- Downtime Wind (days)
- Downtime Total (days)
- Key Industries
  - Financial
  - Resorts
  - Emergency Response
  - Lifelines

Exposed to Sea Level Rise + 10% Nuisance Flooding

Building Exposure Development

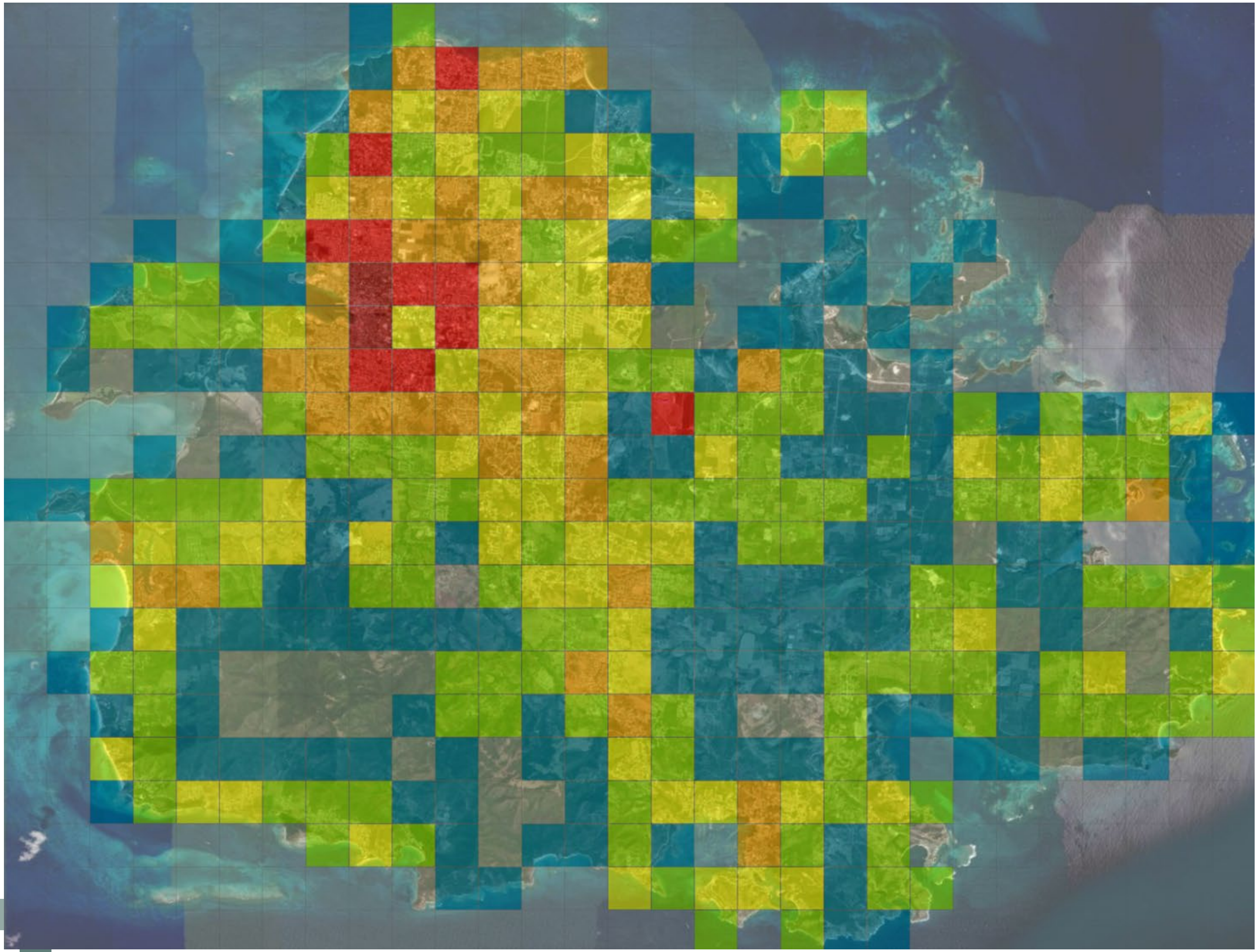
- ~98 GIS layers
- LIDAR data
- Building footprints
- Valuation from parcel level data
- Essential facilities- several places
- Utility datasets

Use detailed elevation data- Digital Surface-Terrain to yield height-then stories

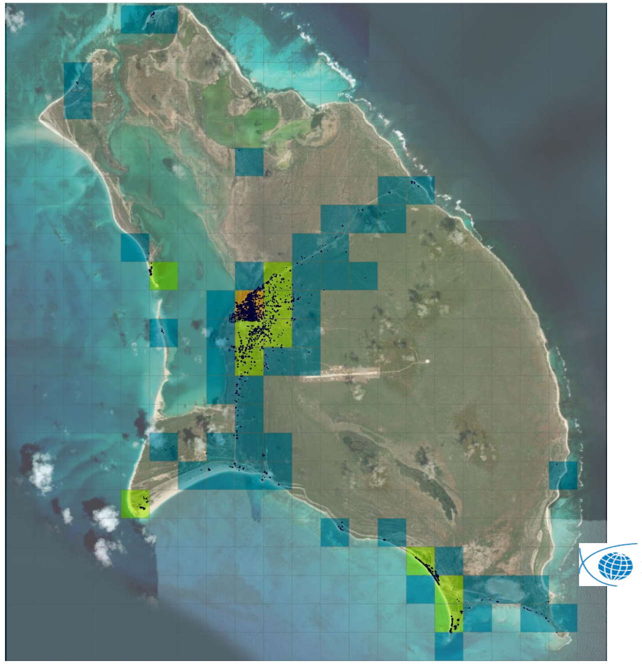


Critical Facilities:
- Medical Office/Clinic
- Grade Schools
- Police
- Utilities
- Government/Military
- Port Facility
- Hotels and resorts

Building Exposure



Parish	Number of Buildings	Total Building Area (Sq.Feet)	Total Replacement Cost (USD)
Saint George	6468	11,836,548	$1,138,239,173
Saint John	34748	48,419,388	$4,594,454,640
Saint Mary	6449	8,586,452	$853,092,079
Saint Paul	7419	9,460,809	$989,763,100
Saint Peter	4158	4,563,539	$442,813,969
Saint Philip	3711	6,384,213	$780,192,246
Barbuda	1463	1,895,324	$196,563,273

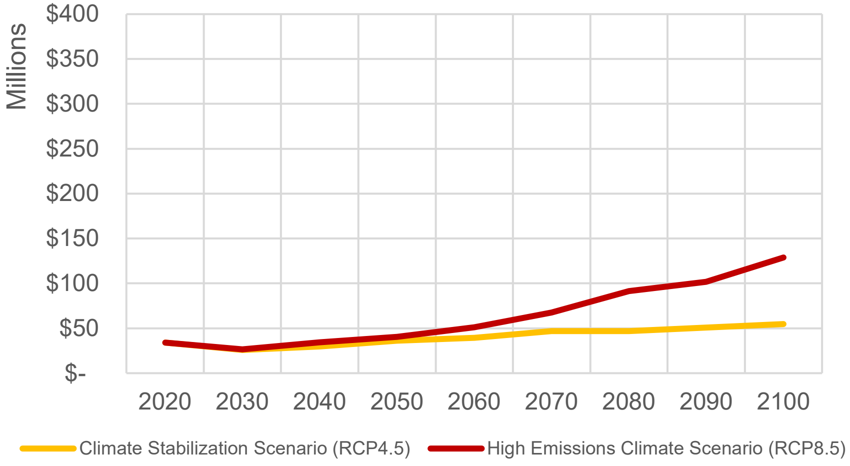


Replacement Cost (in Million USD)

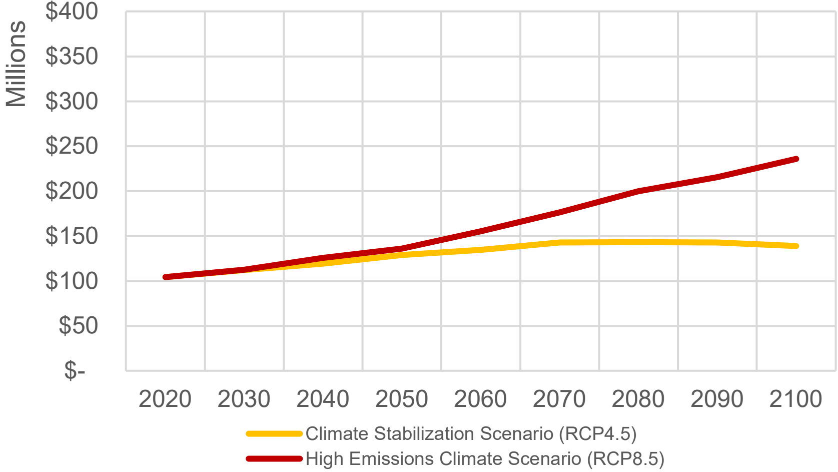
- ⬜ 0
- 🟦 0 - 5
- 🟩 5 - 25
- 🟨 25 - 50
- 🟧 50 - 100
- 🟥 100- 200
- 🟥 +200

Average Annual Loss

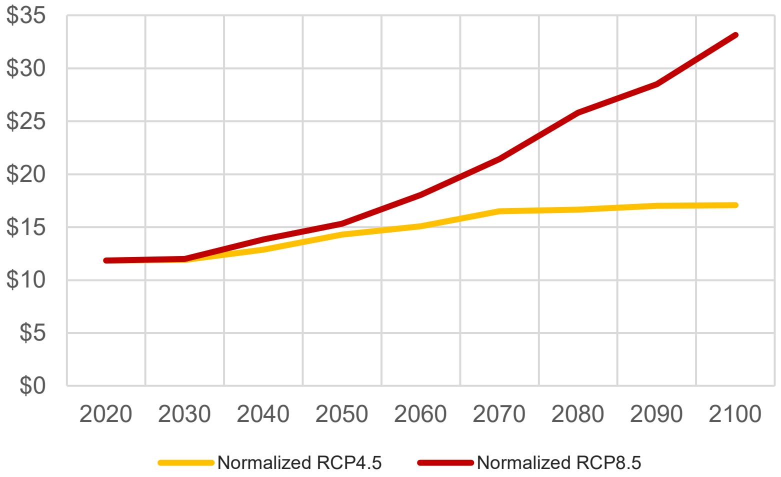
Future Anticipated Probable Losses from Building Damage based on Storm Surge in Average Annual Loss (AAL)

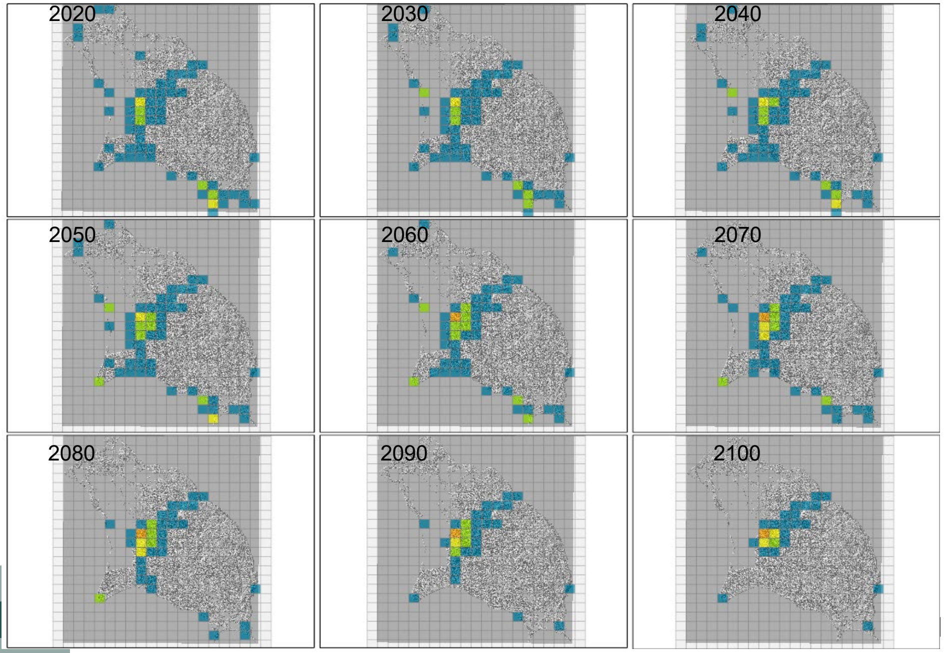


Future Anticipated Probable Losses from Building Damage based on Storm Wind in Average Annual Loss (AAL)



Future Anticipated Probable Losses from Building Damage based on Storm Surge in Average Annual Loss (Per 1K Exposed)





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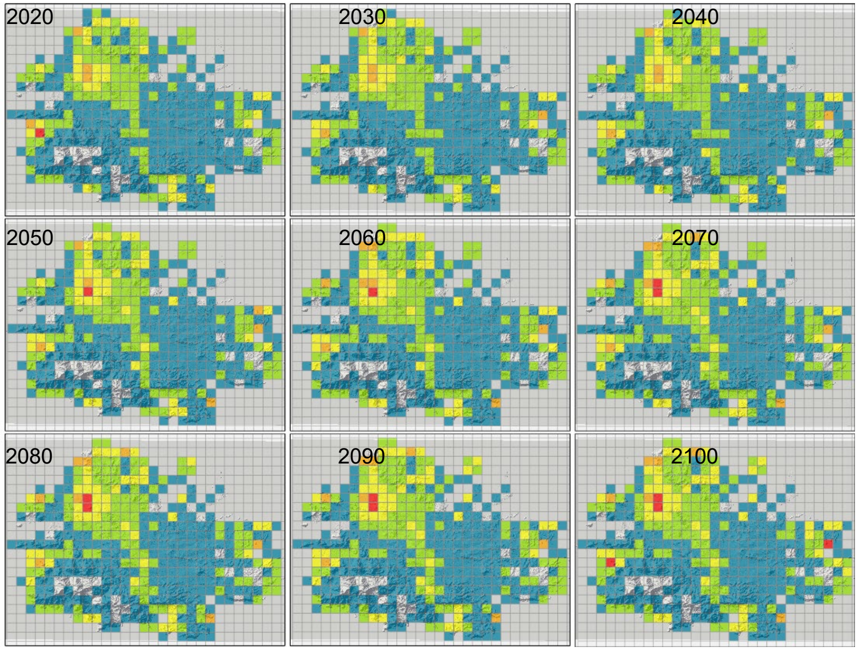


Loss in Millions (USD)

- ⬜ 0
- 🟦 0.0 - 0.25
- 🟩 0.25 - 1.0
- 🟨 1.0 - 2.5
- 🟧 2.5 - 5.0
- 🟥 5.0 - 15.0
- 🟥 +15

ImageCat

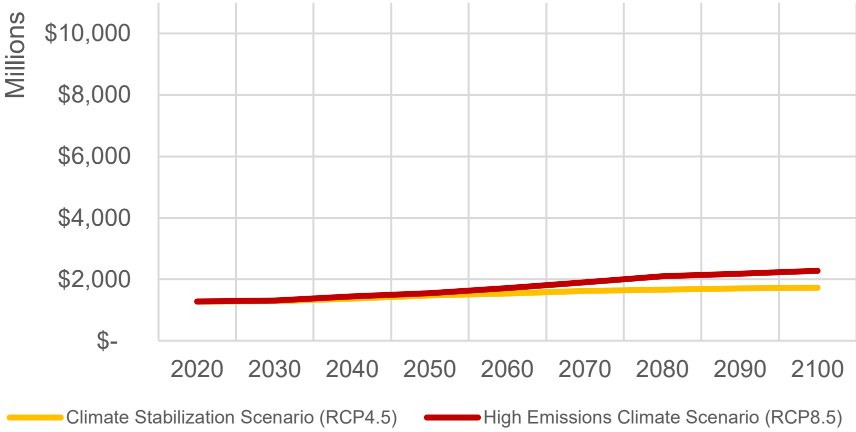
KINETIC

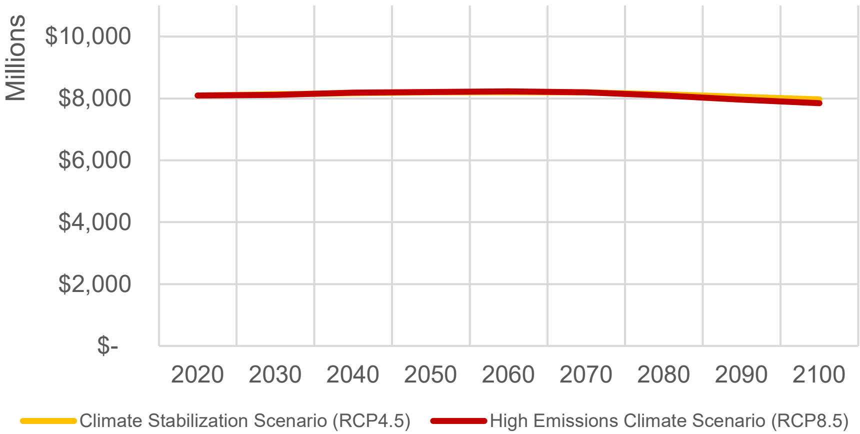
SCRIPPS INSTITUTION OF OCEANOGRAPHY

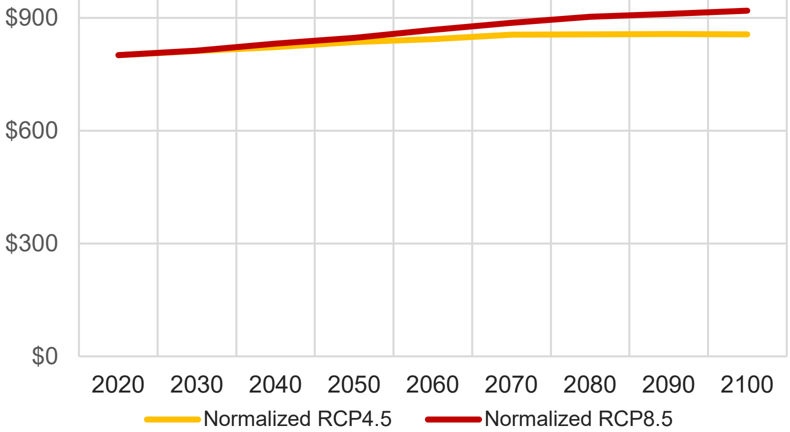
Willis Towers Watson

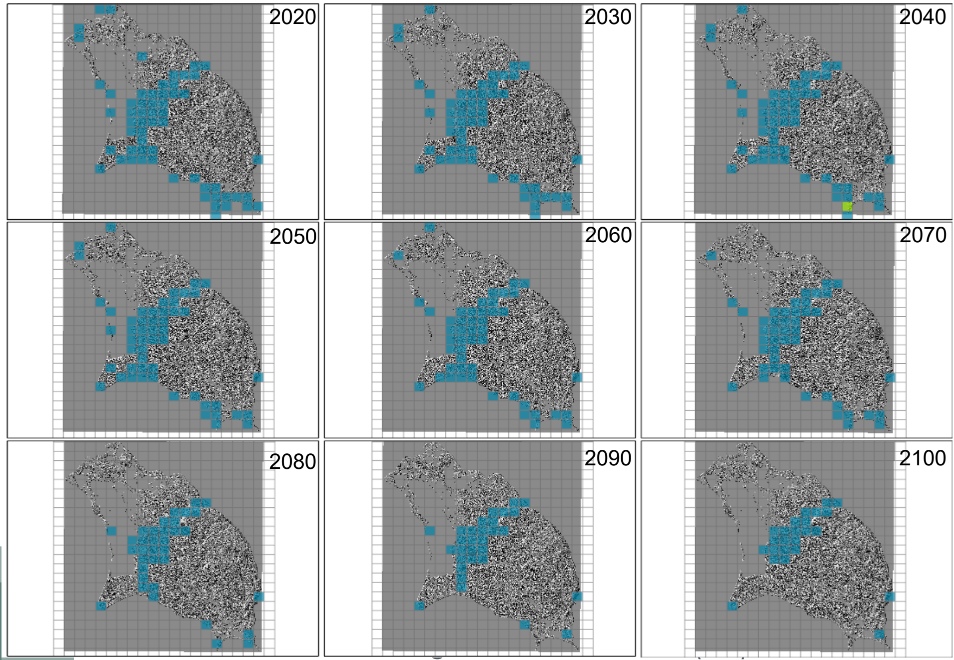
Met Office

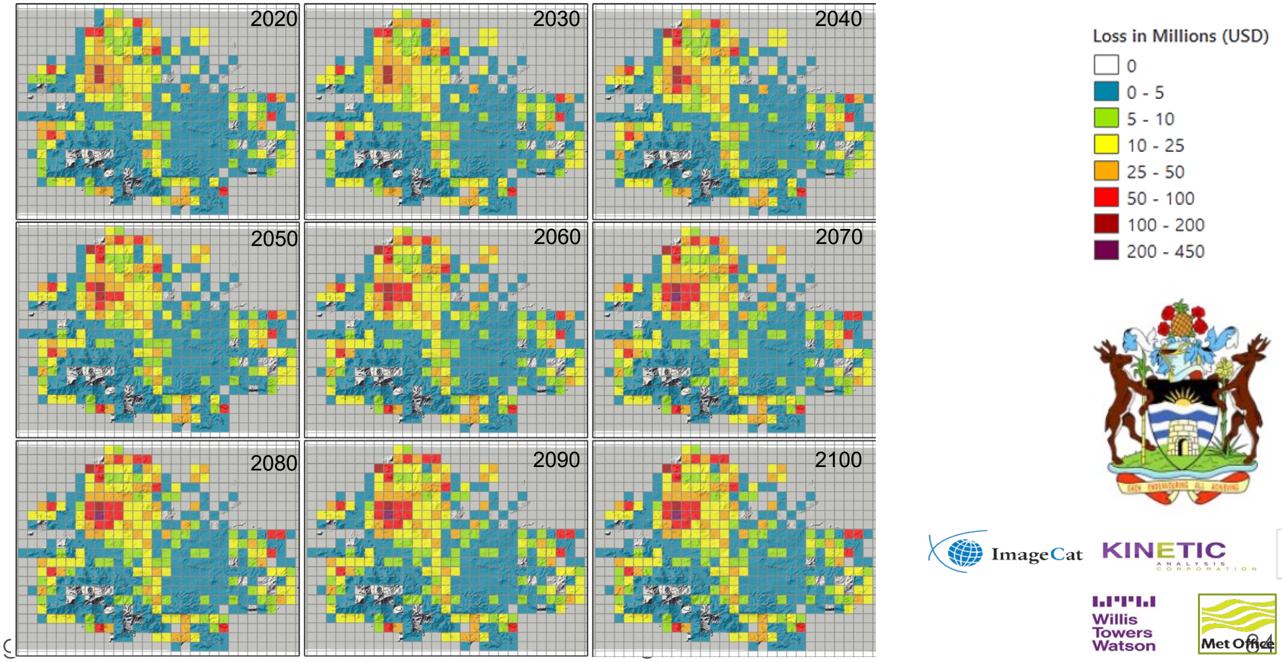
100-Year Event


Future Anticipated Probable Losses from Building Damage based on Storm Surge in a 100-year Event (1%-chance)

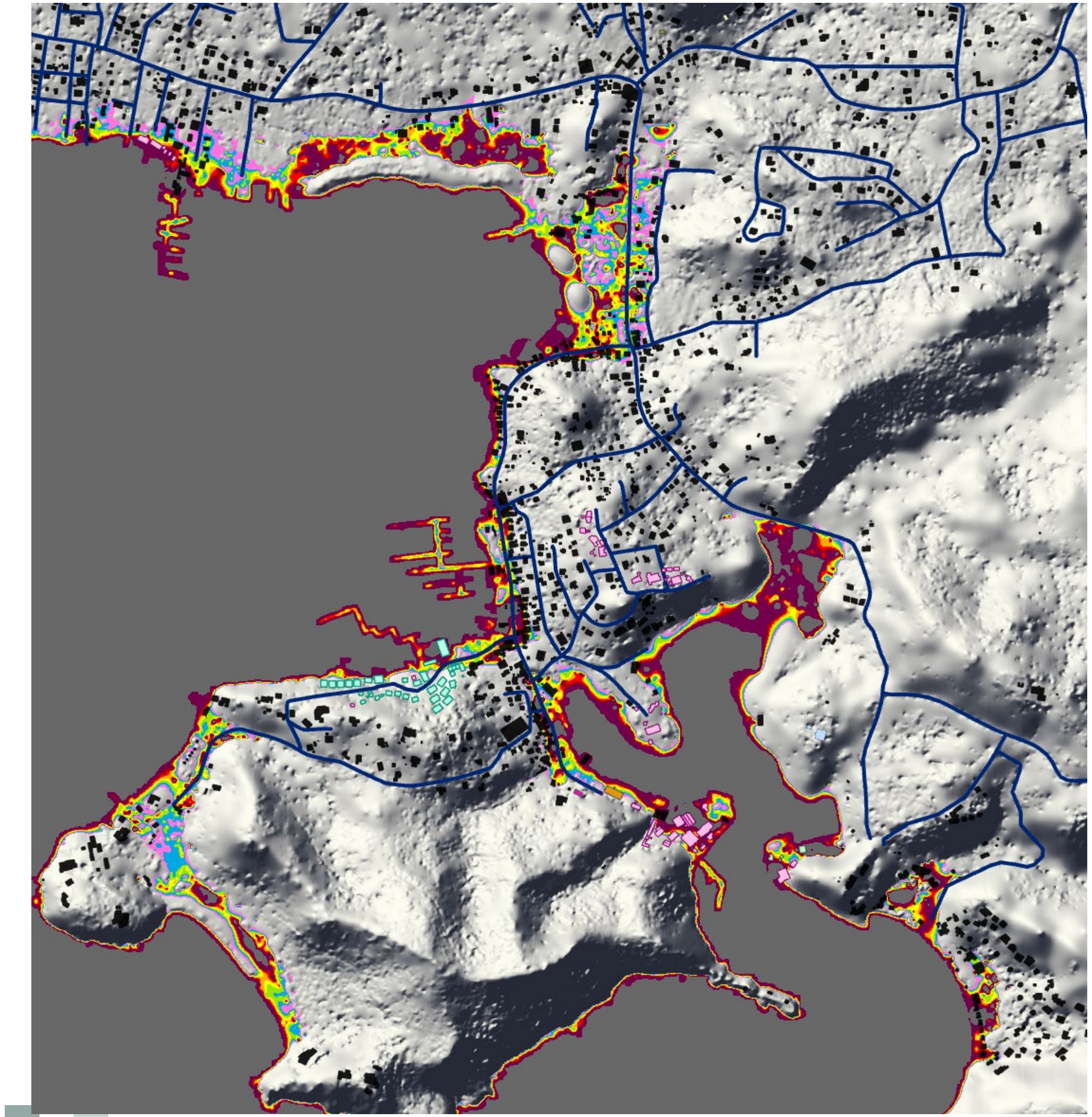

Future Anticipated Probable Losses from Building Damage based on Storm Wind in a 100-year Event (1%-chance)

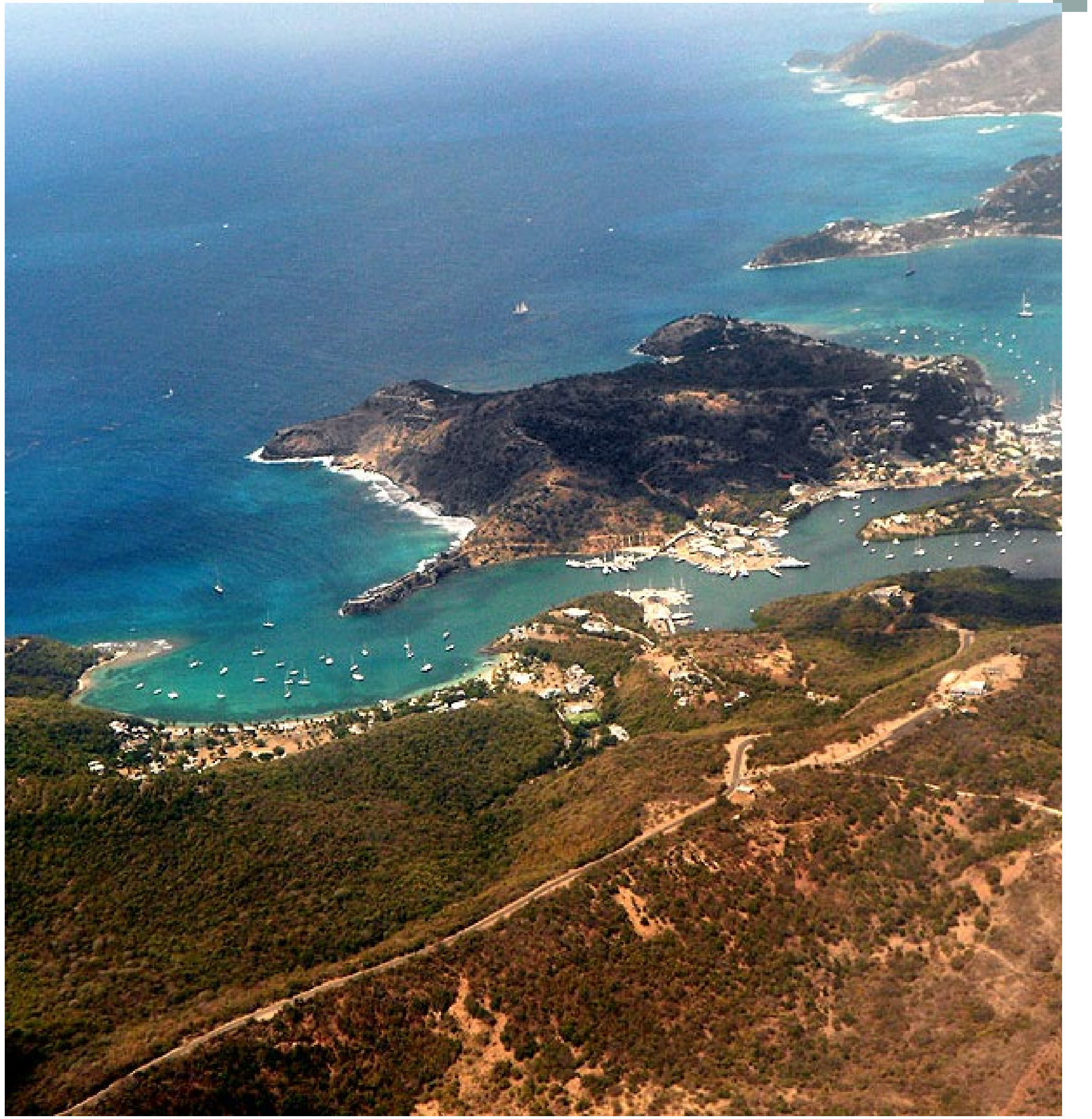

Future Anticipated Probable Losses from Building Damage based on Storm Surge in a 1%-Event (Per 1K Exposed)

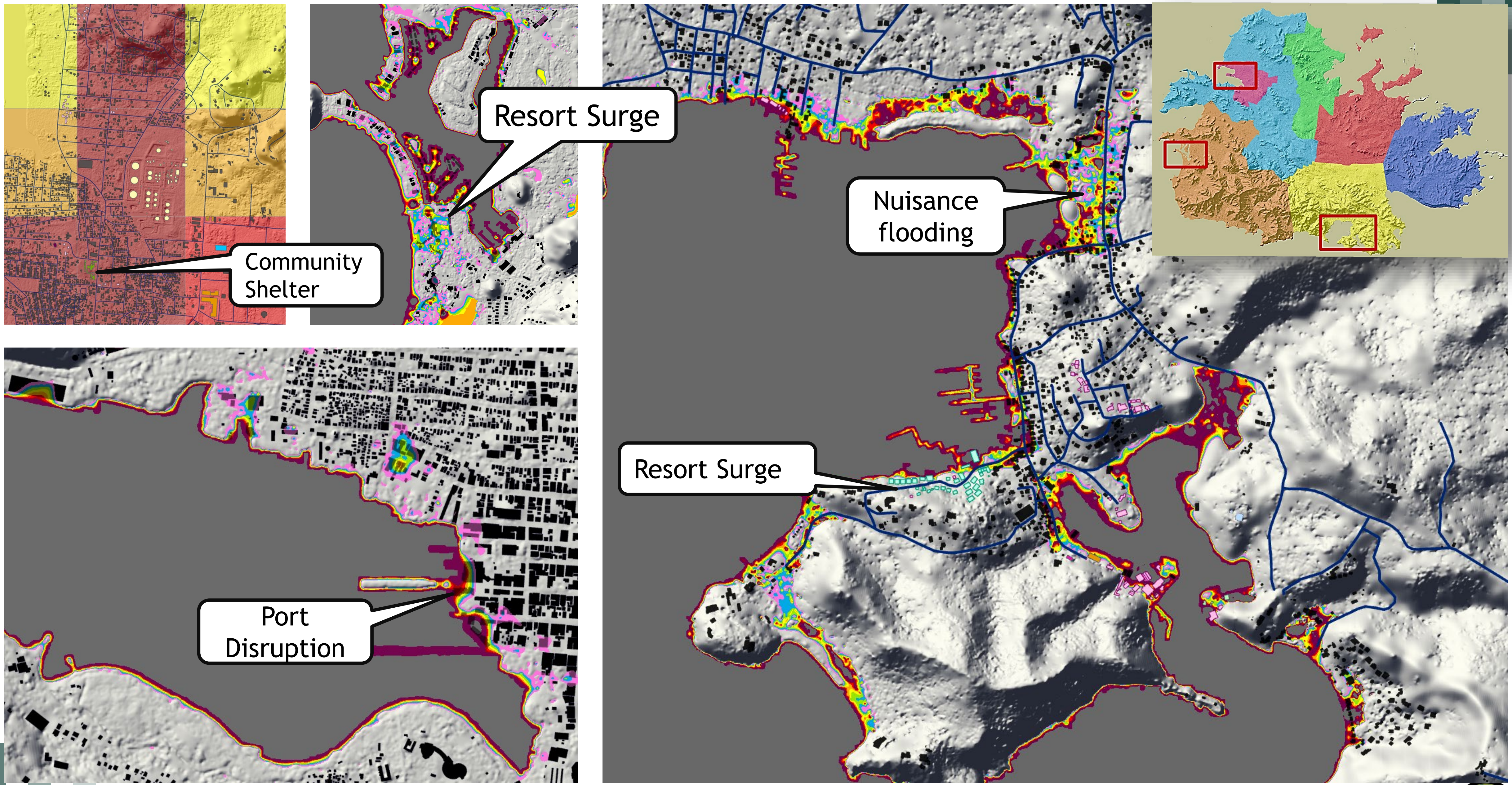




ImageCat KINETIC Scripps Institution of Oceanography Willis Towers Watson Met Office

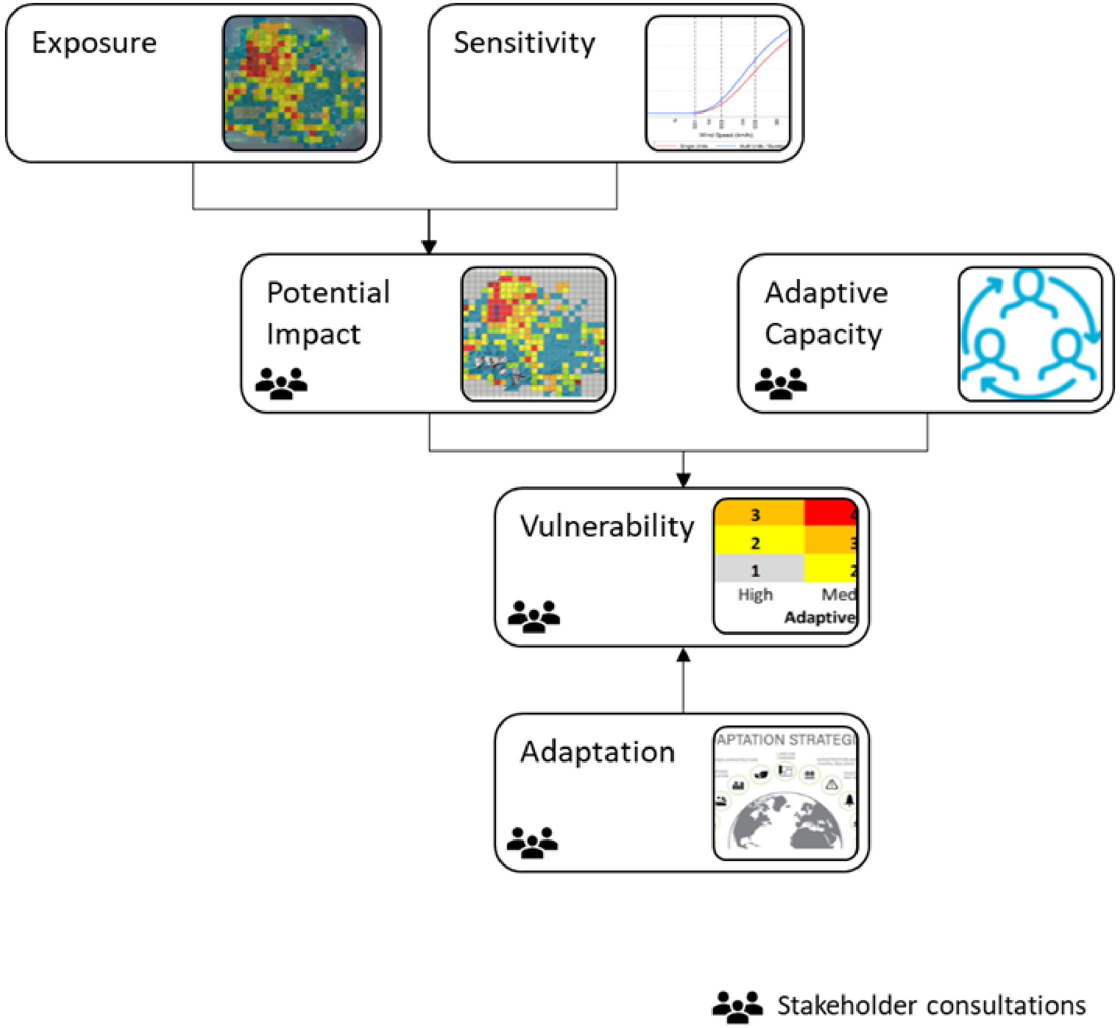





Community Shelter
Resort Surge
Nuisance flooding
Resort Surge
Port Disruption

2. Assess Climate Vulnerabilities

- **Vulnerability**: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity.
- **Adaptive capacity**: The ability of a system to adjust to climate change in order to moderate potential damages, to take advantage of opportunities or to cope with the consequences.
- **Exposure**: The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to climate hazards.
- **Sensitivity**: The degree to which a species, natural system, or community, government, and other associated systems would be affected by exposure to a changing climate.
- **Potential Impact**: Potential negative effects on a system, population, or asset based on its exposure and sensitivity to a climate hazard.



Exposure

Sensitivity

Potential Impact

Adaptive Capacity

Vulnerability

Adaptation

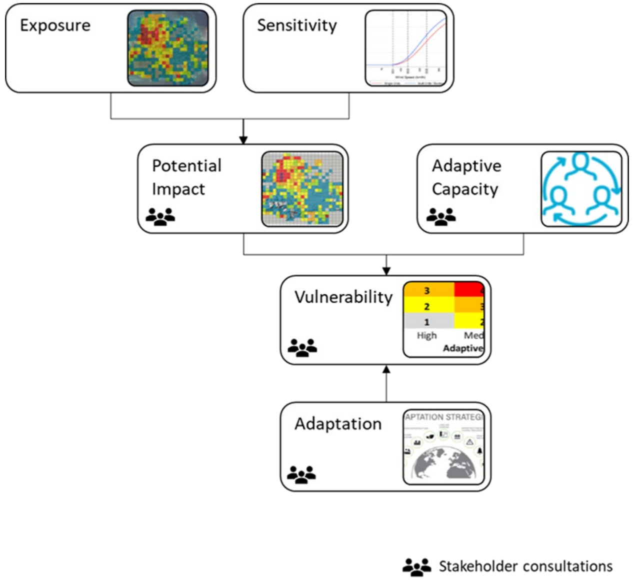
Stakeholder consultations

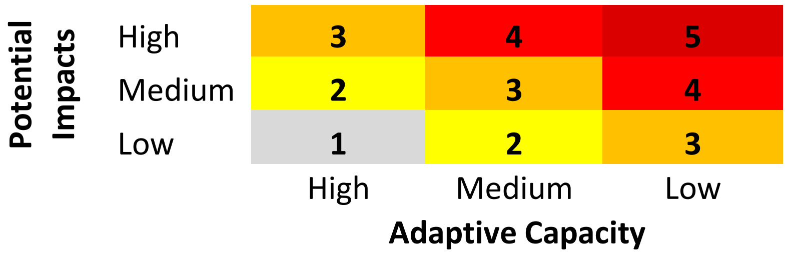
UNFCCC Glossary
California Adaptation Planning Guide

Vulnerability Scoring

Score	Potential Impact	Adaptive Capacity
Low	Impact is unlikely based on projected climate hazards; would result in minor consequences to the sector.	The population, organization (business) or asset lacks capacity to manage climate impact; major changes would be required.
Medium	Impact is somewhat likely based on projected climate hazards; would result in some consequences to the sector.	The population, organization (business) or asset has some capacity to manage climate impact; some changes would be required.
High	Impact is highly likely based on projected climate hazards; would result in substantial consequences to the sector.	The population, organization (business) or asset has high capacity to manage climate impact; minimal to no changes are required.

California Adaptation Planning Guide





Potential Impacts

High	3	4	5
Medium	2	3	4
Low	1	2	3
	High	Medium	Low

Adaptive Capacity

Data Sources

Risk Modelling

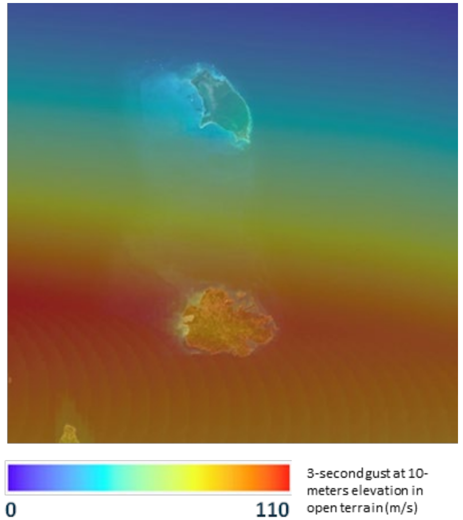
Stakeholder Consultations

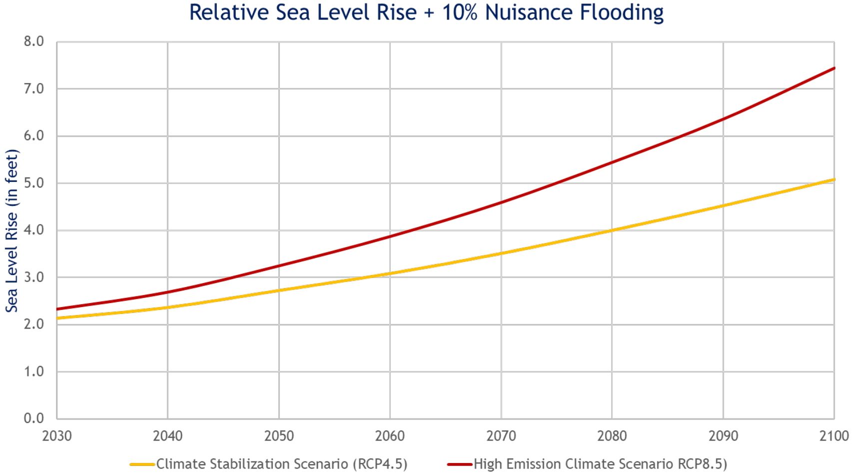
Reports on Past Events

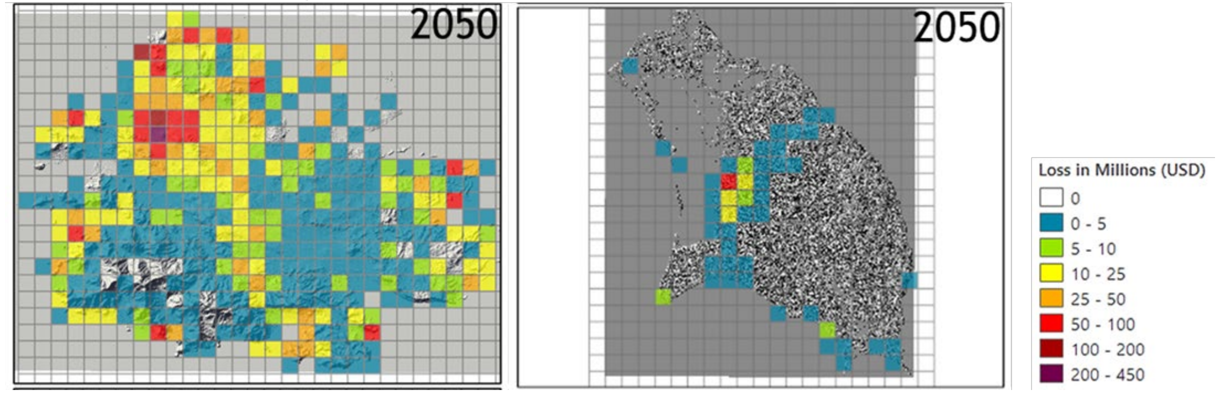
Climate Hazards

Climate Projections

- Severe wind and higher surge
- Rising sea levels
- Extreme heat
- Drought






100-year Event RCP8.5 Total

Vulnerability: Thematic Areas

Buildings

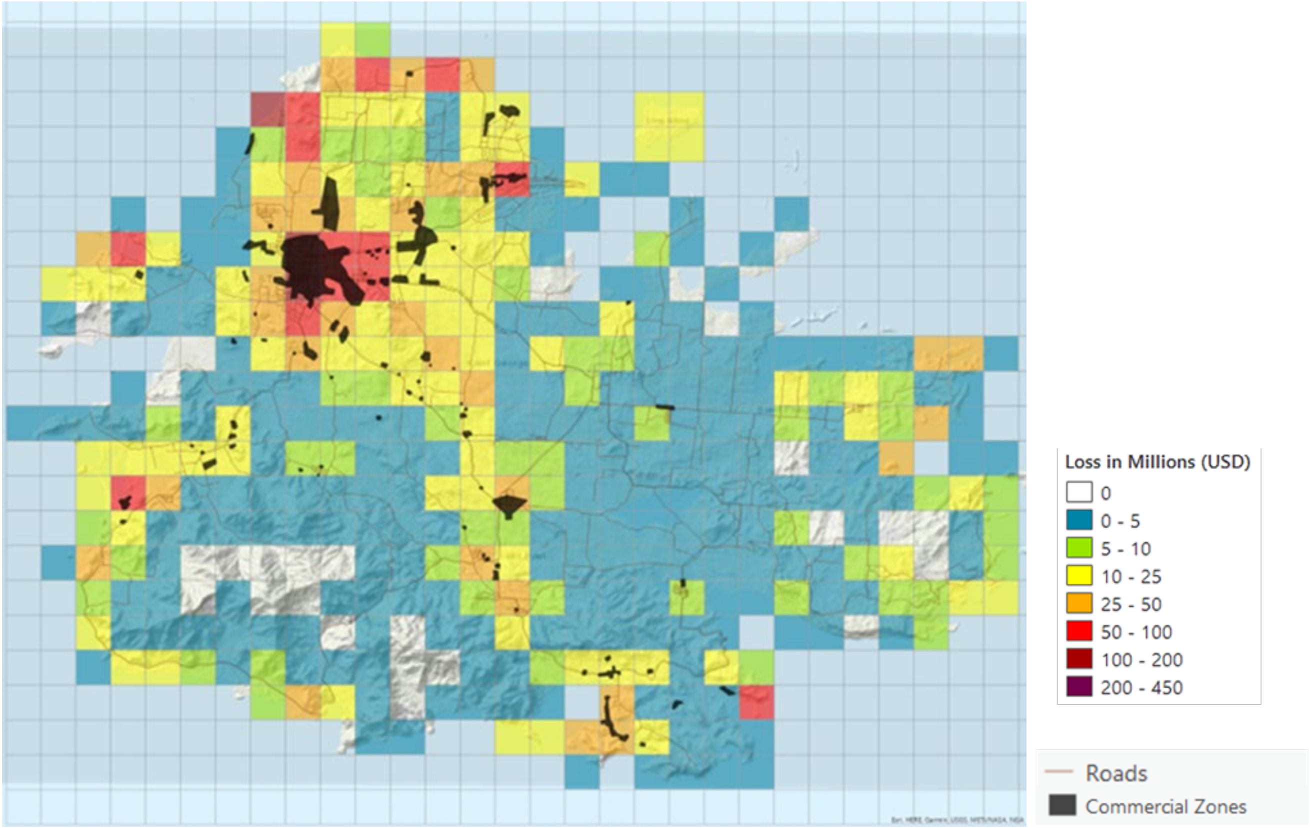
Lifeline / Critical Infrastructure

Supply Chain

Economic

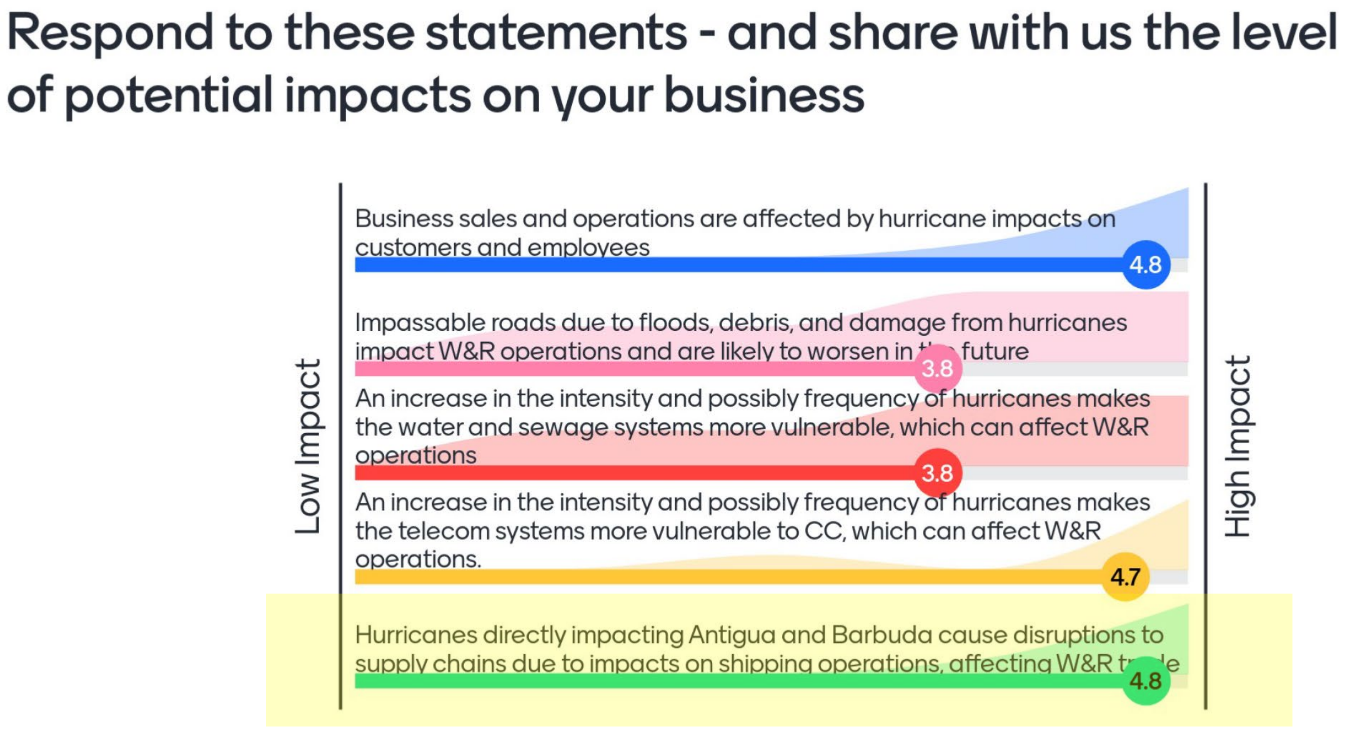
Hurricane Vulnerability Example

Hazard	Thematic Area	Vulnerability Description	Vulnerability Score
Hurricane	Buildings	Certain commercial buildings in Antigua and Barbuda are likely to be damaged by wind from hurricanes and impacts are projected to become more severe by 2050.	5



Supply Chain Vulnerability Examples

Hazard	Thematic Area	Vulnerability Description	Vulnerability Score
Hurricane	Supply Chain	Hurricanes directly impacting Antigua and Barbuda cause disruptions to supply chains due to impacts on shipping operations affecting trade. Hurricanes impacting overseas suppliers cause disruptions to supply chains.	5
Sea Level Rise	Supply Chain	Rising sea levels and frequent flooding increases the vulnerability of ports in Antigua and Barbuda. The risk of disruption to port operations is expected to increase in the medium term.	4



Respond to these statements - and share with us the level of potential impacts on your business

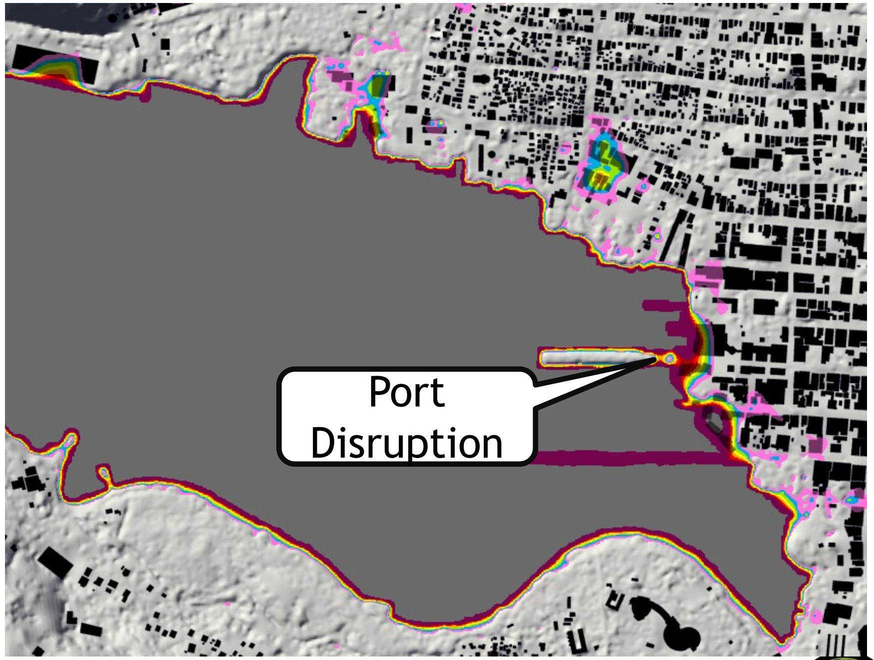
Business sales and operations are affected by hurricane impacts on customers and employees 4.8

Impassable roads due to floods, debris, and damage from hurricanes impact W&R operations and are likely to worsen in the future 3.8

An increase in the intensity and possibly frequency of hurricanes makes the water and sewage systems more vulnerable, which can affect W&R operations 3.8

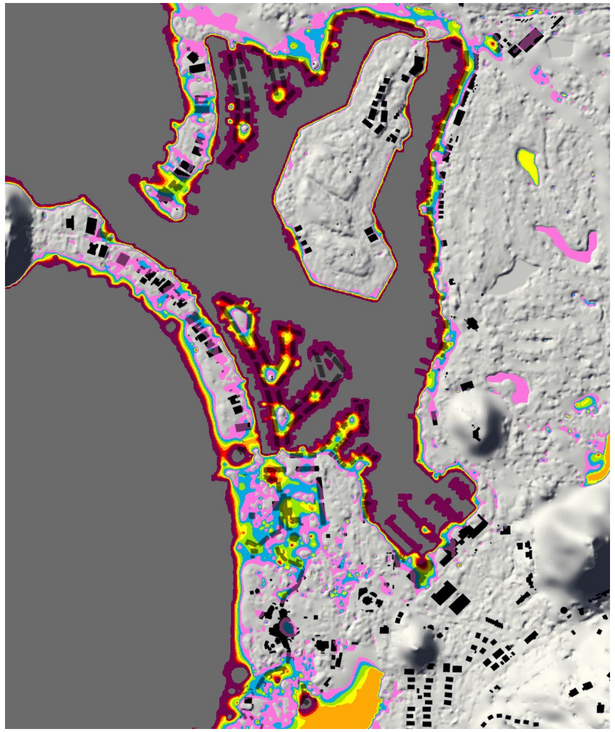
An increase in the intensity and possibly frequency of hurricanes makes the telecom systems more vulnerable to CC, which can affect W&R operations. 4.7

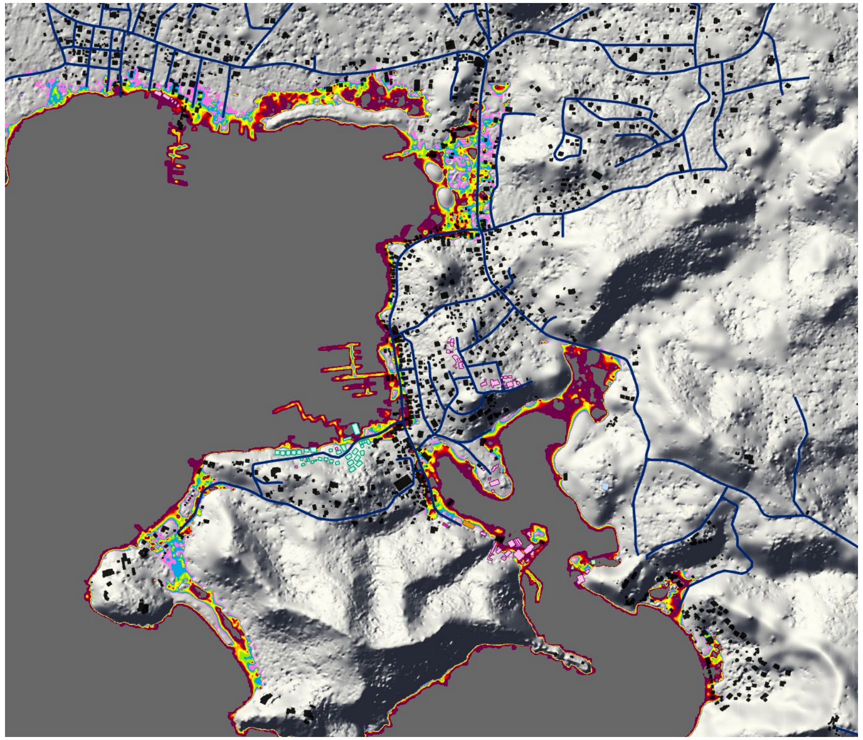
Hurricanes directly impacting Antigua and Barbuda cause disruptions to supply chains due to impacts on shipping operations, affecting W&R trade 4.8



Sea Level Rise Vulnerability Examples

Hazard	Thematic Area	Vulnerability Description	Vulnerability Score
Sea Level Rise	Economic	Under sea level rise projections, beach will be lost to sea and erosion is expected to accelerate. This phenomenon directly affects the profitability of the tourism sector and may indirectly affect commercial businesses.	5
Sea Level Rise	Lifeline / Critical Infrastructure	Some areas may become completely inaccessible during coastal flood events due to flooded or damaged roads, which will be progressively exacerbated through time due to climate change.	2





3. Identify Adaptation Actions: 4 Key Areas

Adaptation Actions: 4 Key Areas

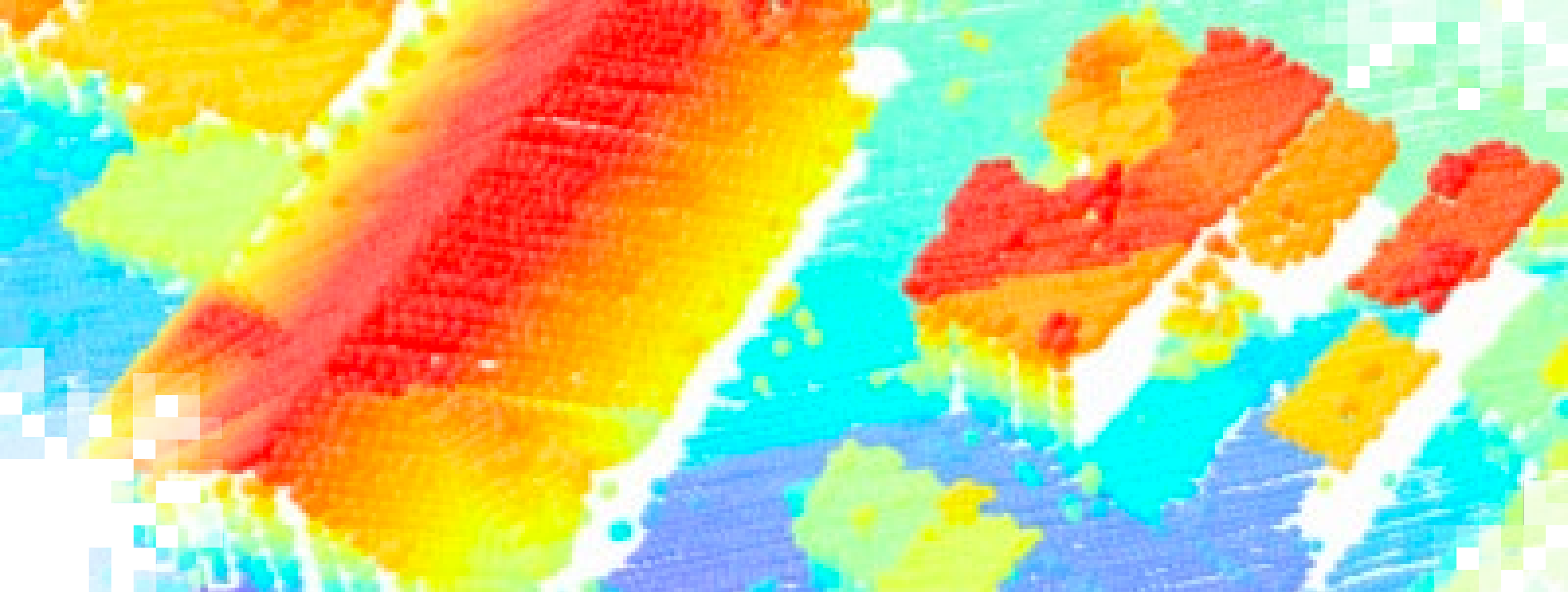
Physical Adaptation and Policy Planning	Climate-Proofing Buildings
Financing and Financial Instruments for Adaptation	Training, Capacity Building, Knowledge Transfer for Climate Adaptation & Business Continuity Planning

3. & 4. Identify and Review Adaptation Actions (Examples)

Area	Action	Co-benefit	Cost	Timeframe
Physical Adaptation and Policy	Building code implementation and enforcement	Yes	$$$	Medium-Long
	Building retrofit programs	Yes	$$$	Medium
	Building elevated structures	Yes	$$	Medium-Long
	Zoning / land use planning	Yes	$$$$	Long
	Encouraging and incentivizing the use of pervious and climate-smart surfaces in new development	Yes	$$	Short
Climate-proofing buildings	Use hurricane shutters and other impact resistance coverings for openings	Yes	$	Short
	Install roof-to-wall anchorage via hurricane straps and improved nailing of roofs	Yes	$	Short
	Increase presence of cool roofs and cool walls	Yes	$$	Medium
	Use water membranes to prevent roof leakage	Yes	$	Short
	Install barriers to keep flood waters out of building	Yes	$	Short

3. & 4. Identify and Review Adaptation Actions (Examples)

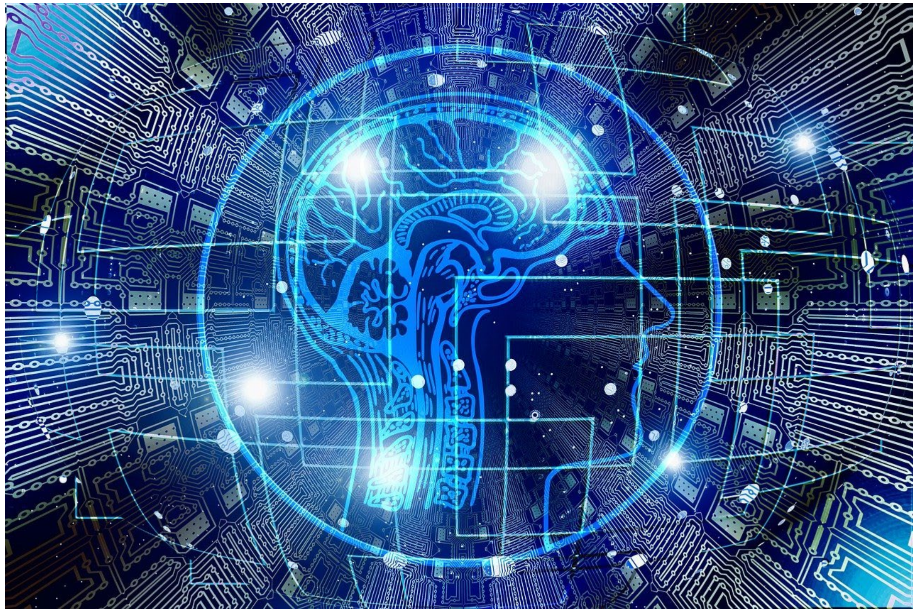
Area	Action	Co-benefit	Cost	Timeframe
Financing and Financial Instruments	Work with the insurance sector or other developmental organizations to introduce climate change-related microinsurance schemes	Yes, but limited	$$$	Medium
	Improve access to finance after disasters for MSMEs, utilizing business assets and accounts as bank account collateral	Yes	$$$	Medium
	Support the collaborative development of solutions to address the insurability gap by working with the government and other insurance programs in the region	Yes	$$$	Medium-Long
	Strengthen dialogue between insurers and policymakers around Build Back Better	Yes, depends on stakeholder engagement	$$	Short
	Provide access to climate-proofing financing, rebates, and incentives for building owners	Yes	$$	Medium
Training, Capacity Building and Knowledge Transfer	Have an emergency plan with business continuity, considering climate change effects	Yes	$	Short
	Develop and deliver education and training resources to equip MSMEs with an understanding of climate projections and climate risk in their business	Yes	$	Short
	Increase access to business-related emergency preparedness and mitigation resources	Yes	$	Short
	Supply Chain Management: Identifying alternative suppliers, off-site inventory of goods, stress testing and scenario planning	Yes	$$$	Medium
	Create a compendium of climate change adaptation practices	Yes	$	Short



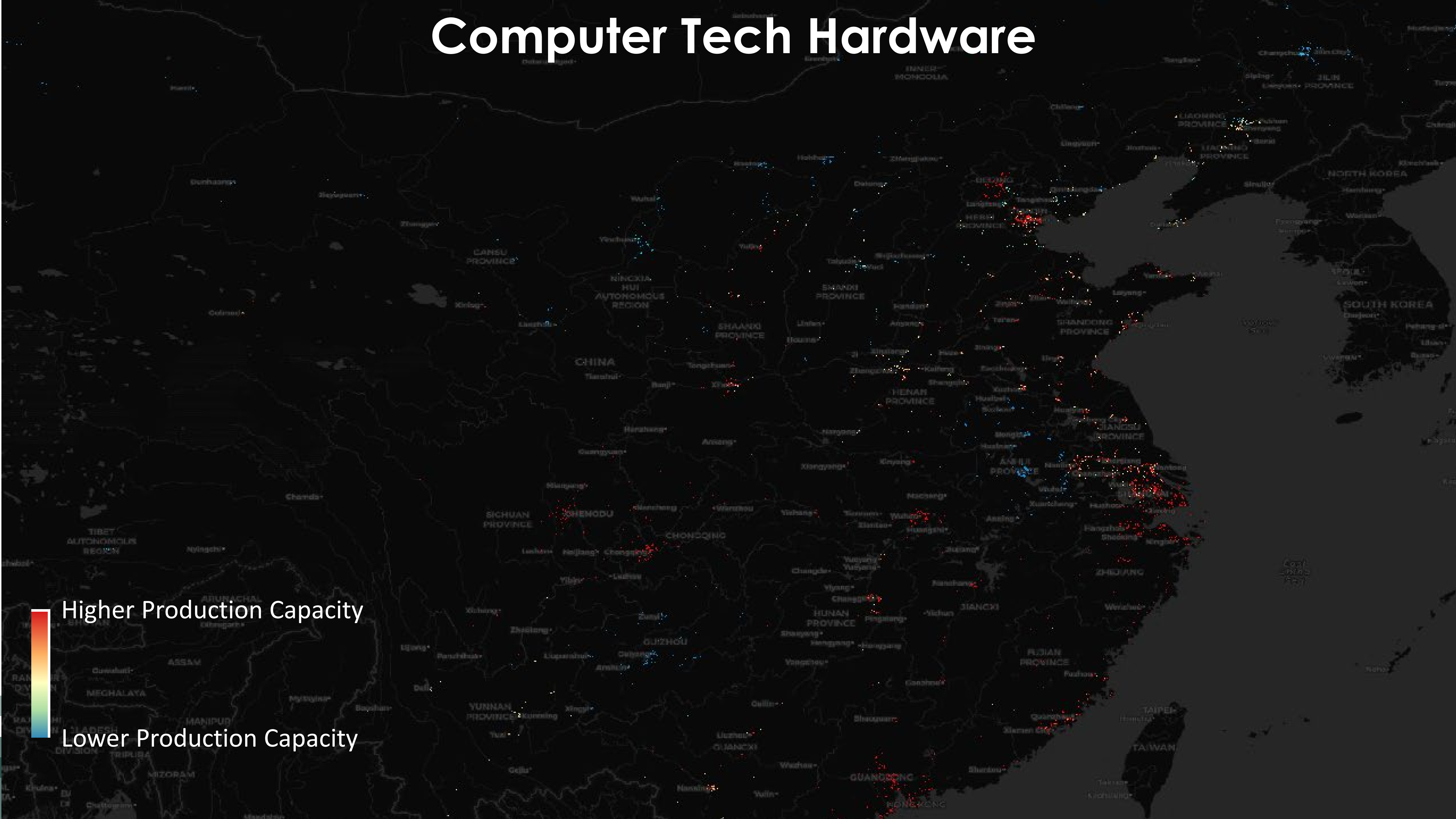
Closing Thoughts, Future Directions

Future Directions

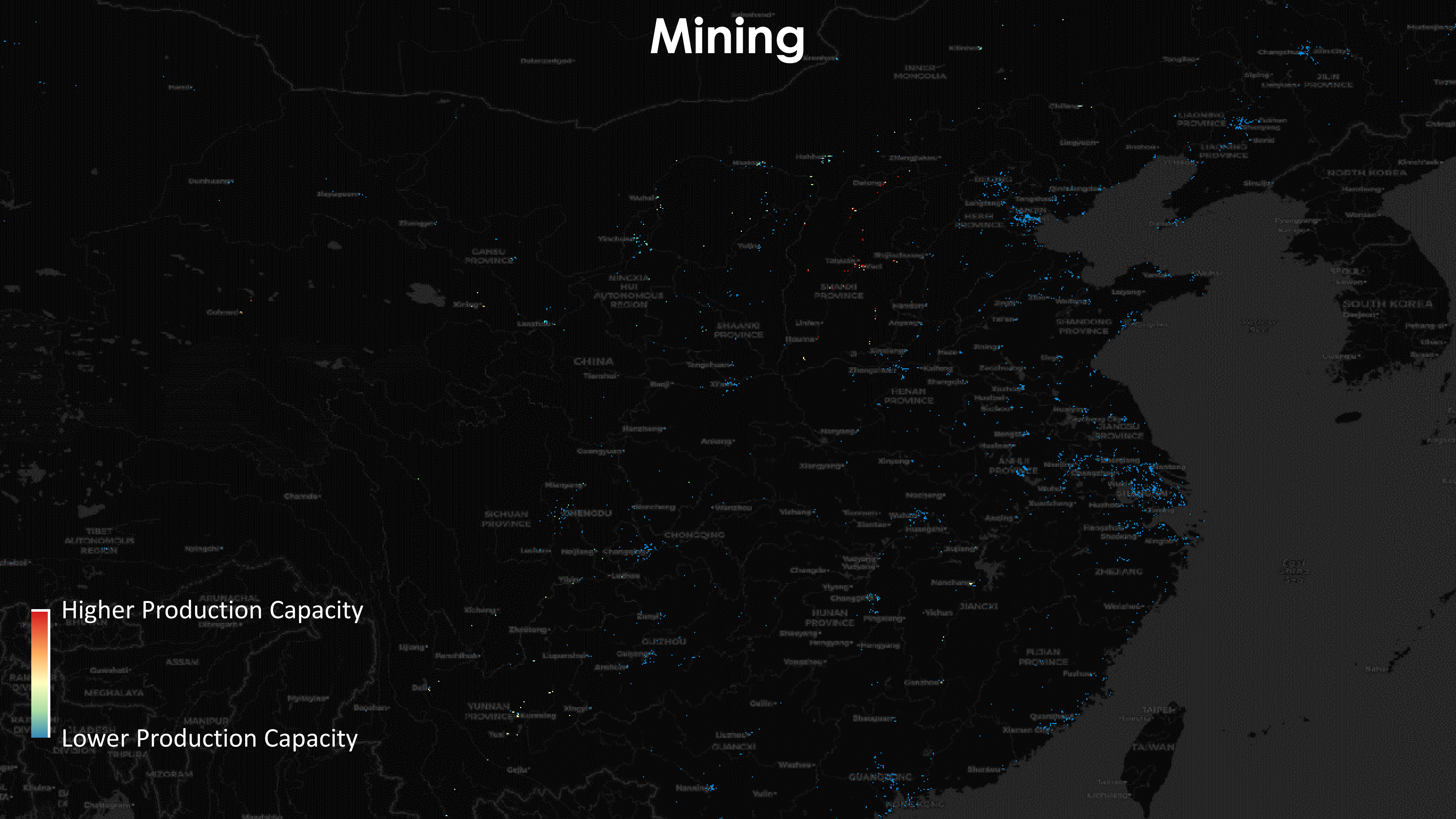
- More AI in exposure development
- More detailed in situ data:
  - Streetview, UAVs…



Computer Tech Hardware

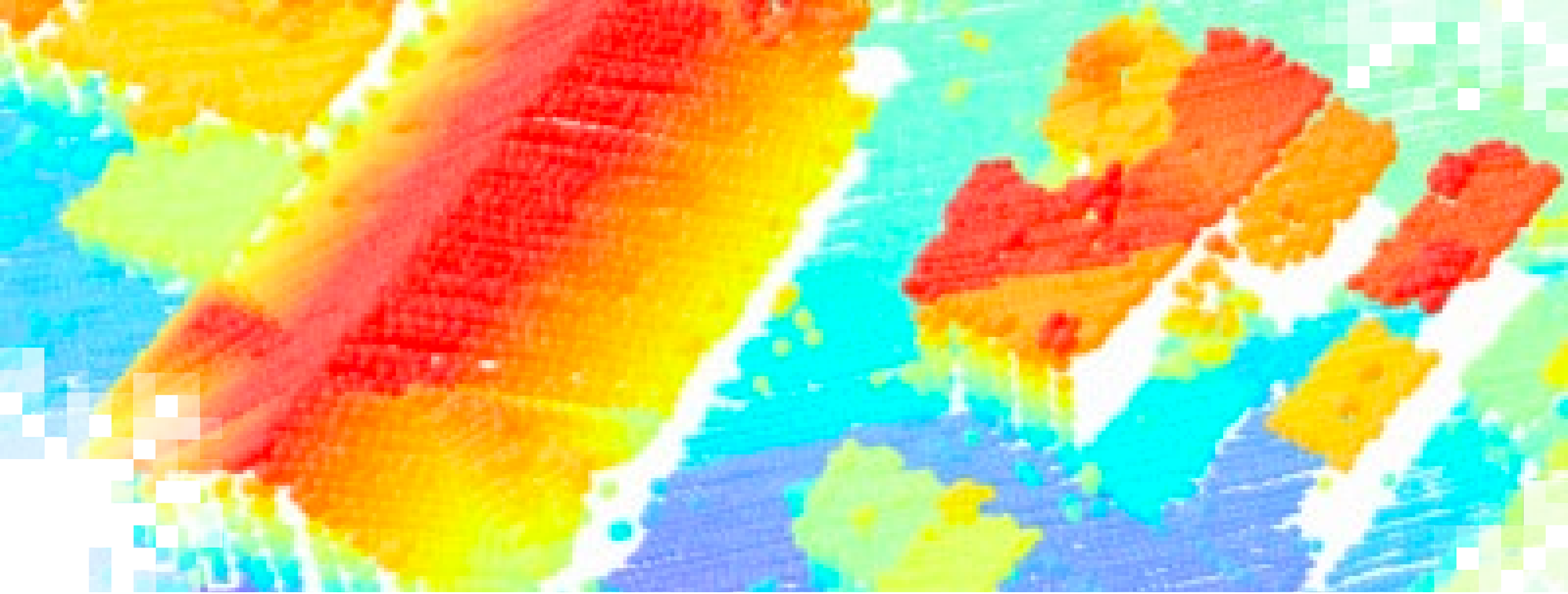


Mining


Higher Production Capacity
Lower Production Capacity
INNER MONGOLIA
GANSU PROVINCE
NINGXIA HUI AUTONOMOUS REGION
SHAANXI PROVINCE
SHANXI PROVINCE
HEBEI PROVINCE
BEIJING
TIANJIN
LIAONING PROVINCE
JILIN PROVINCE
NORTH KOREA
SOUTH KOREA
SHANDONG PROVINCE
HENAN PROVINCE
JIANGSU PROVINCE
ANHUI PROVINCE
SHANGHAI
ZHEJIANG
JIANGXI
HUNAN PROVINCE
FUJIAN PROVINCE
CHINA
SICHUAN PROVINCE
CHENGDU
CHONGQING
GUIZHOU
YUNNAN PROVINCE
GUANGXI
GUANGDONG
HONG KONG
TAIWAN
TIBET AUTONOMOUS REGION
ARUNACHAL PRADESH
ASSAM
MEGHALAYA
MANIPUR
TRIPURA
MIZORAM

Warnings ⚠

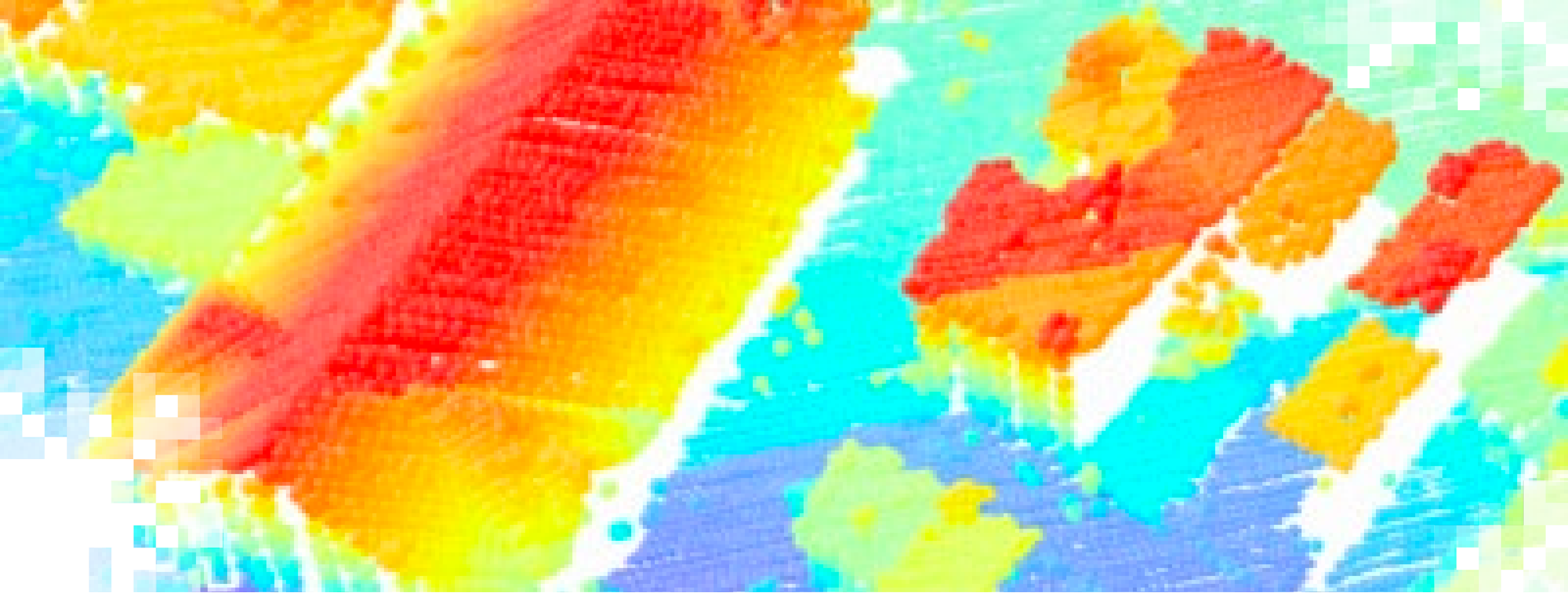
- AI can introduce more bias
- The use of detailed in situ data can aggravate privacy and security concerns



Part 3:
Summary

Summary

- What is exposure data, and how is it used in the loss estimation process?
- The basic process of developing exposure data
- Structural mapping scheme development and building sampling
- Case Study: walkthrough of building exposure data for Tunisia



Transforming Earth Observation (EO) Data into Building Infrastructure Data Sets for Disaster Risk Modeling

Summary

Training Summary

Part 1: Development of Regional Exposure Data with Earth Observations

- What is exposure data, and how is it used in the loss estimation process?
- The basic process of developing exposure data
- Structural mapping scheme development and building sampling
- Case Study: walkthrough of building exposure data for Tunisia

Part 2: Development of Site-specific Exposure Data with Earth Observations

- Developing a building-level exposure data set for HAZUS Flood Study in New York
- Using Earth Observations to develop a building structures dataset
- Case study: Sampling from streetview to characterize vulnerability

Part 3: Assessing Utility and Communicating Uncertainty

- Exposure data best practices
- Developing and understanding metadata
- Equity and bias considerations
- Case study: Assessing climate change impacts with building exposure data in Antigua and Barbuda

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 10/10/2023
  - Access from the [training webpage]
  - Answers must be submitted via Google Forms
  - **Due by 24/10/2023**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

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Robert Chen, Director of Center for International Earth Science Information Network (CIESIN)

Carolynne Hultquist, University of Canterbury

Yuri Gorokhovich, Professor, Earth and Environmental Sciences, City University of New York (Lehman College)

APPLIED REMOTE SENSING TRAINING PROGRAM

TRAIN - EMPOWER - ADVANCE

Thank You!