RUTGERS

Center for Advanced Infrastructure and Transportation

Mobile Hybrid LiDAR & Infrared Sensing for Natural Gas Pipeline Monitoring

Presentation for SOGO Meeting

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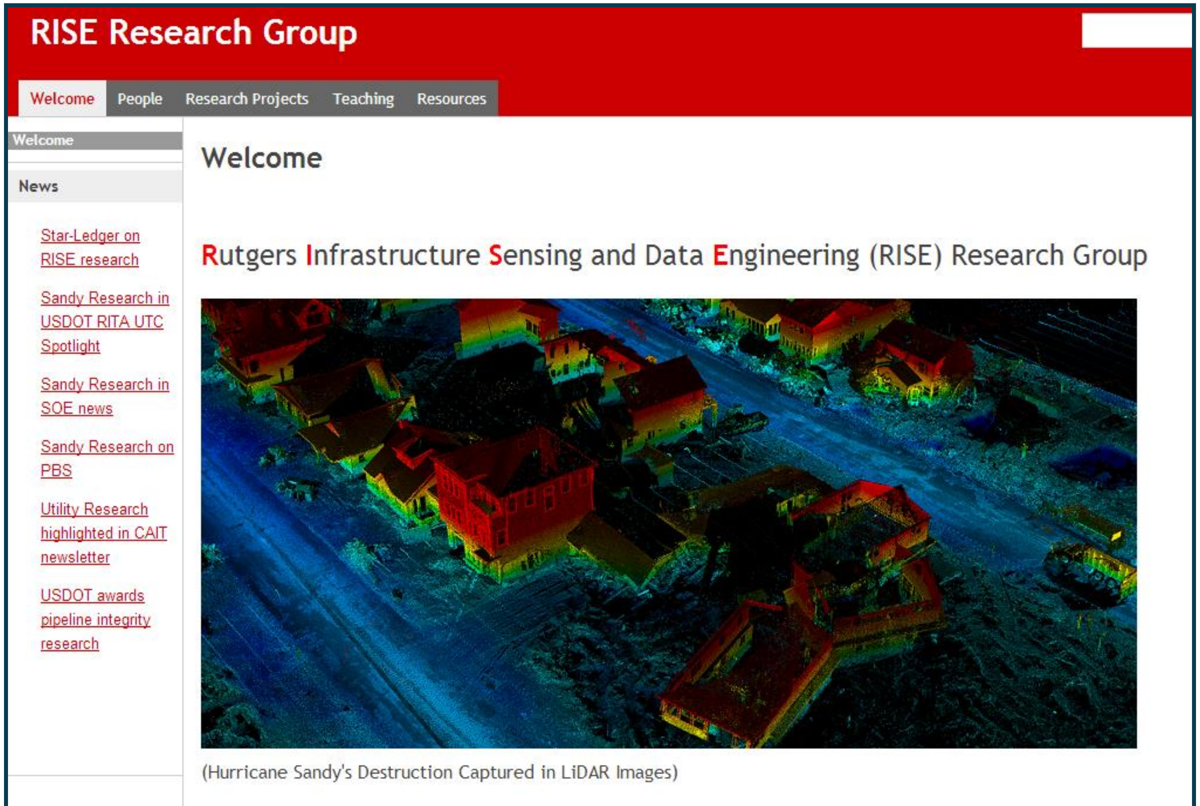
Gas Technology Institute

CAIT is a U.S. Department of Transportation University Transportation Center



Relevant Research Themes:
- Community Resilience and Disaster Preparedness
- Critical Infrastructure Protection
- Green Buildings and Energy Efficiency

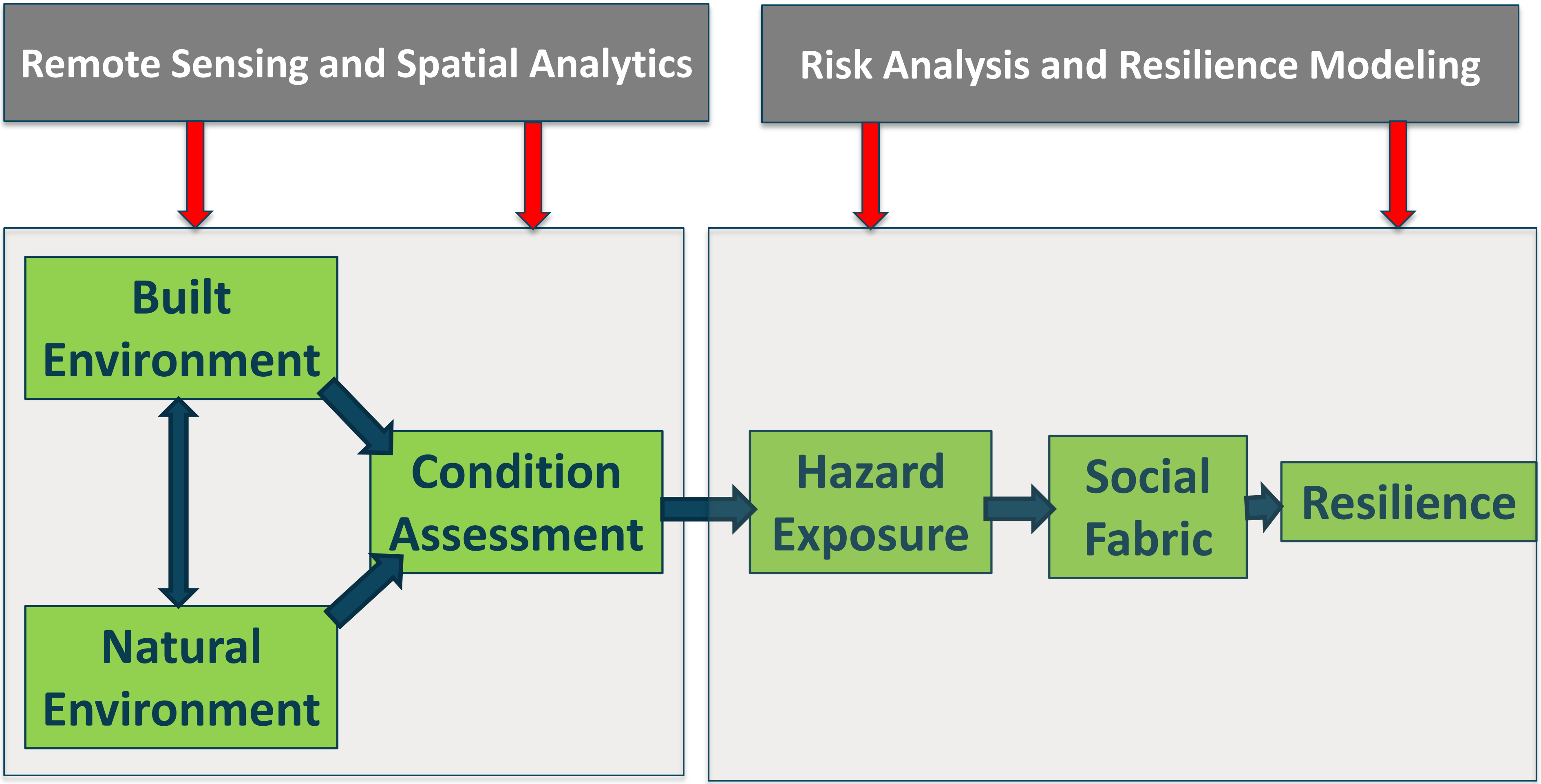
Research Focus:
- Sensing and Big Data Analytics
- Statistical Learning and Risk Analysis
- Simulation and Visualization

Group Member:
- 5 Ph.D. Students
- 6 Master Students
- 2 Undergraduate
- 1 Post-Doc

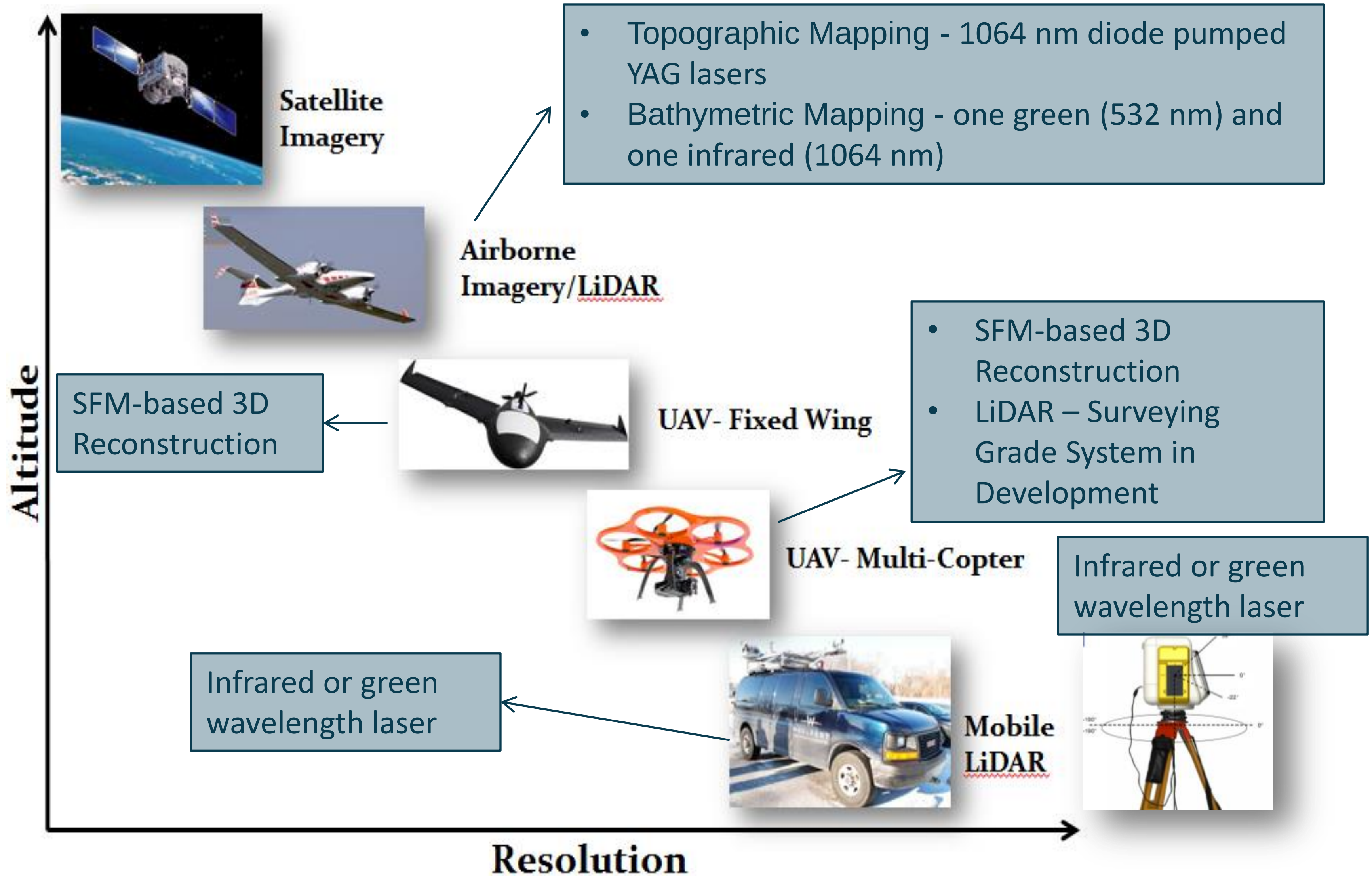
Collaboration Centers
- Center for Advanced Infrastructure & Transportation
- Center for Green Building
- DHS Center of Excellence CCICADA

Funding Agency:
- US DOT
- US HUD
- NJ DOT
- Port Authority
- NJBPU
- NJDEP
- Bentley Co.

A Framework for Energy Infrastructure Resilience

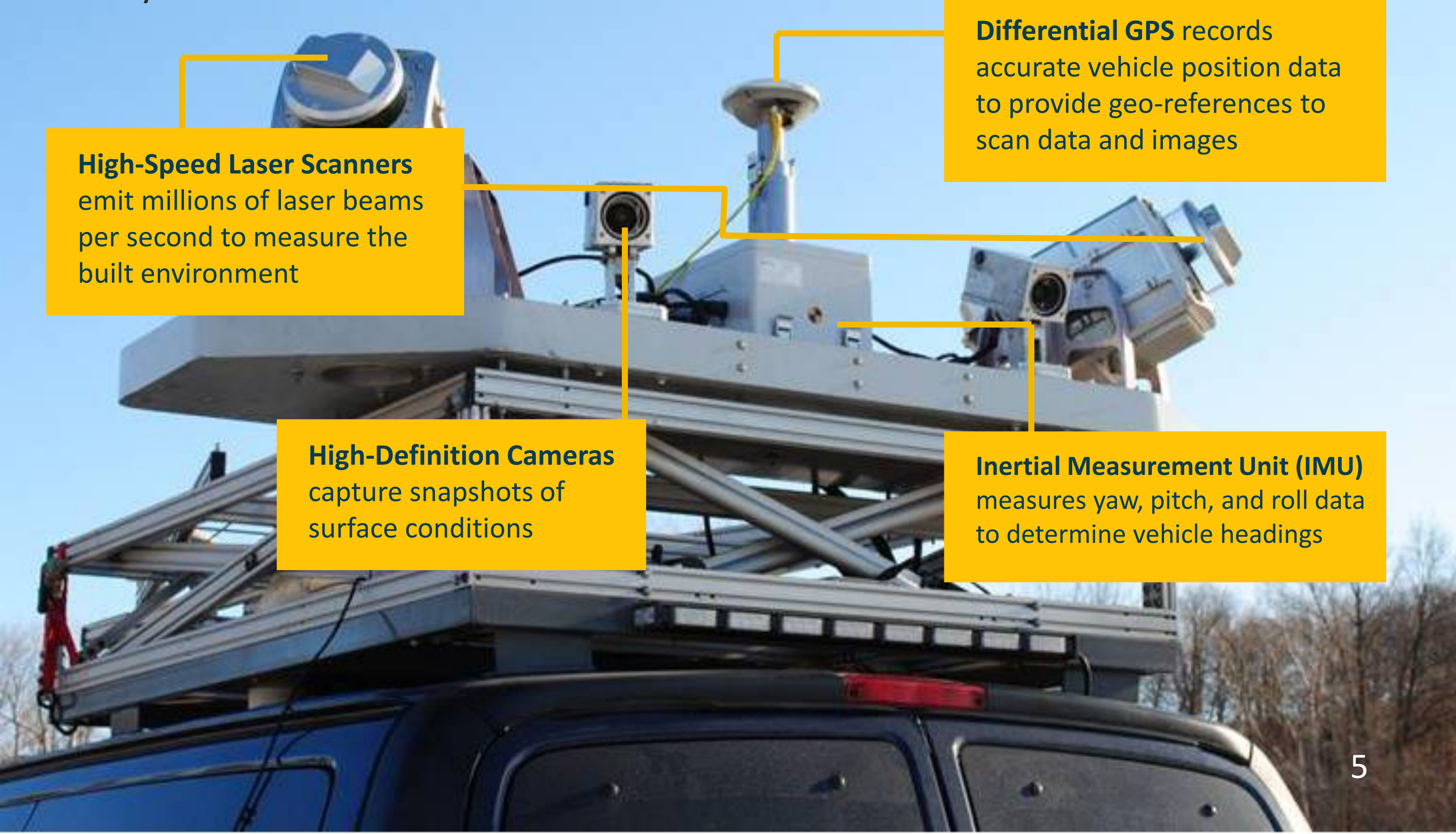


Spatial Sensing Technologies for Infrastructure Mapping

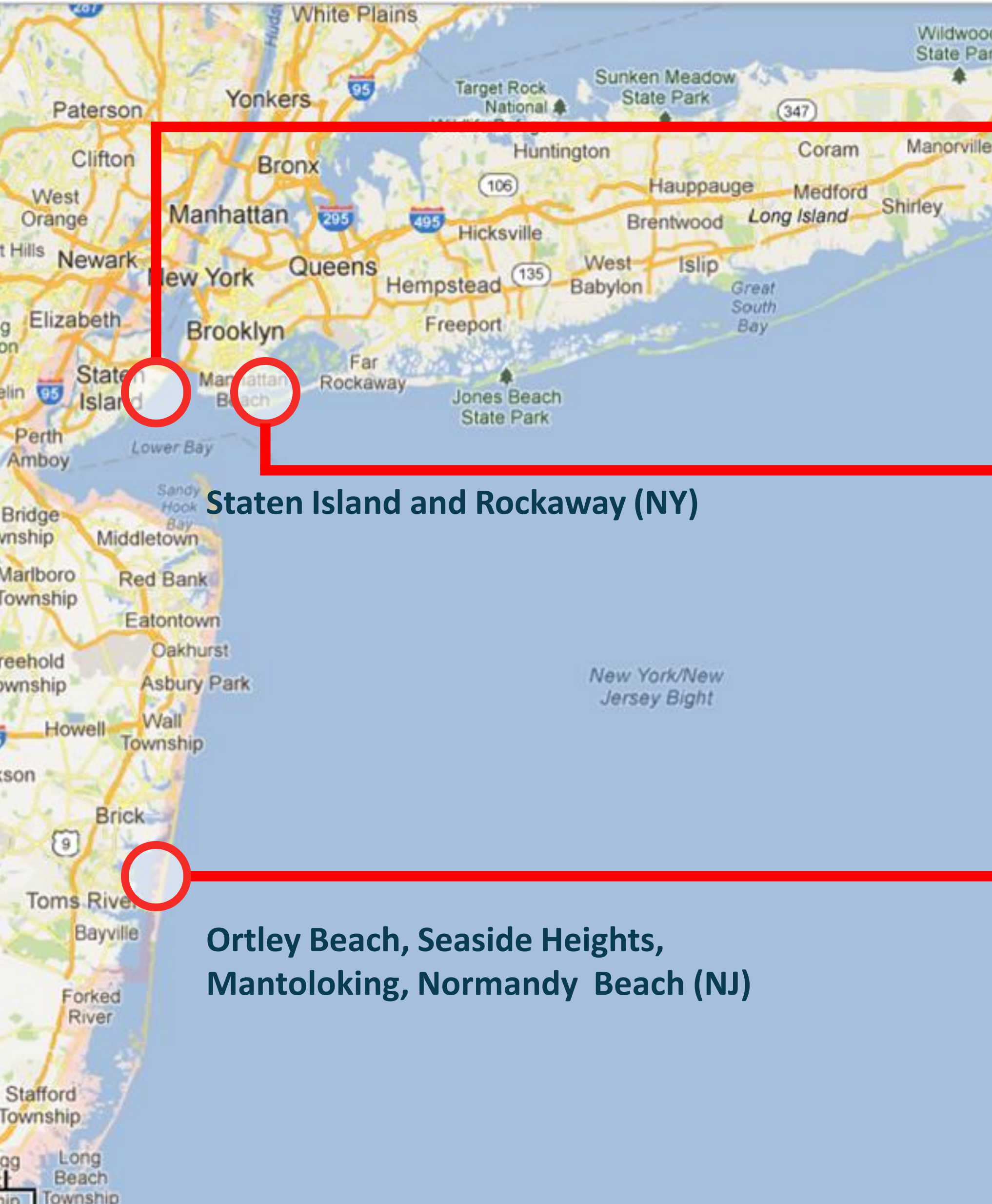


Mobile LiDAR (Light Detection and Ranging)

Mobile LiDAR features a combination of tools to create 3D "virtual reality" models of surface conditions.



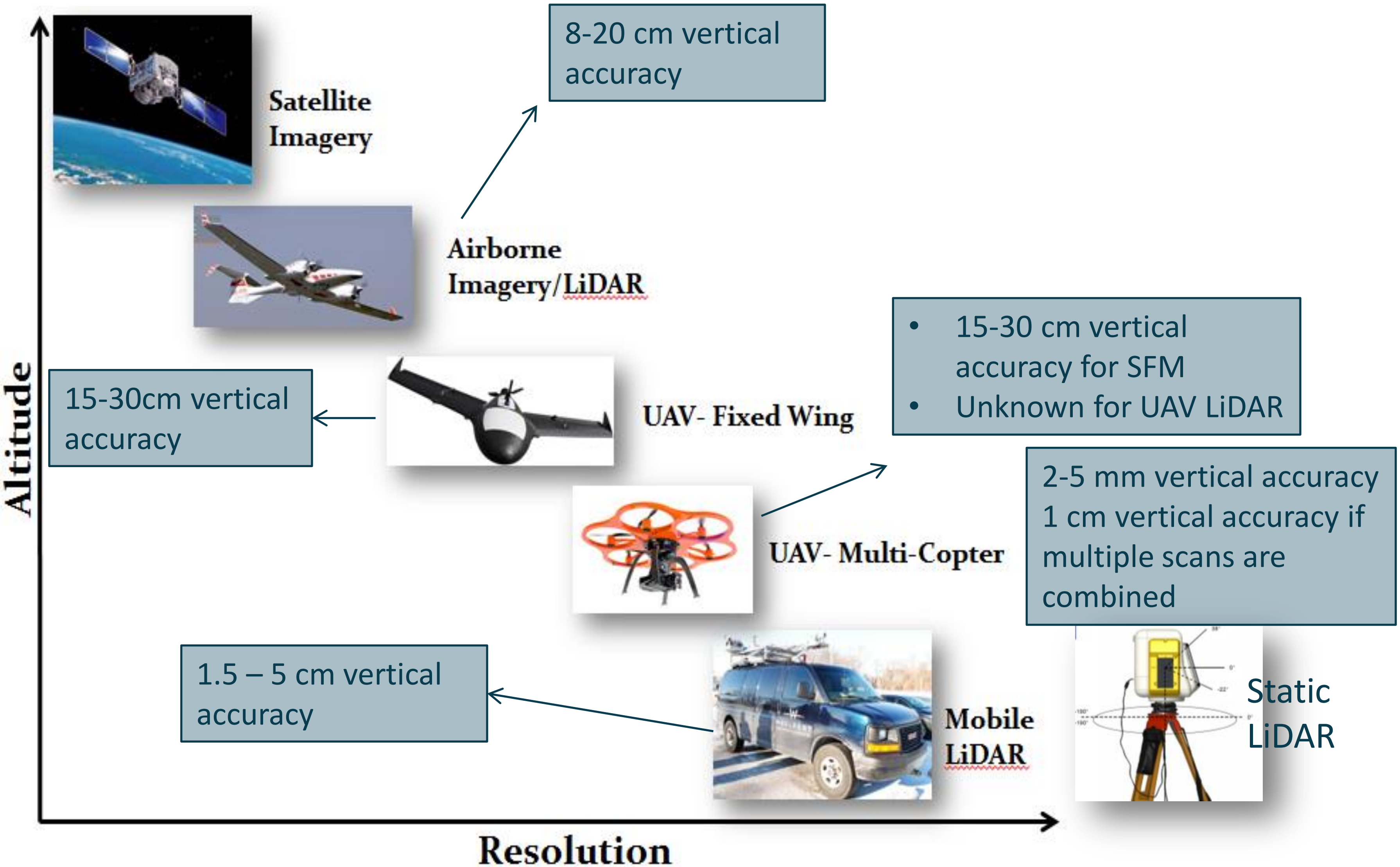
Post-Sandy Mobile LiDAR Study



Staten Island and Rockaway (NY)

Ortley Beach, Seaside Heights, Mantoloking, Normandy Beach (NJ)

Spatial Sensing Technologies for Disaster Response

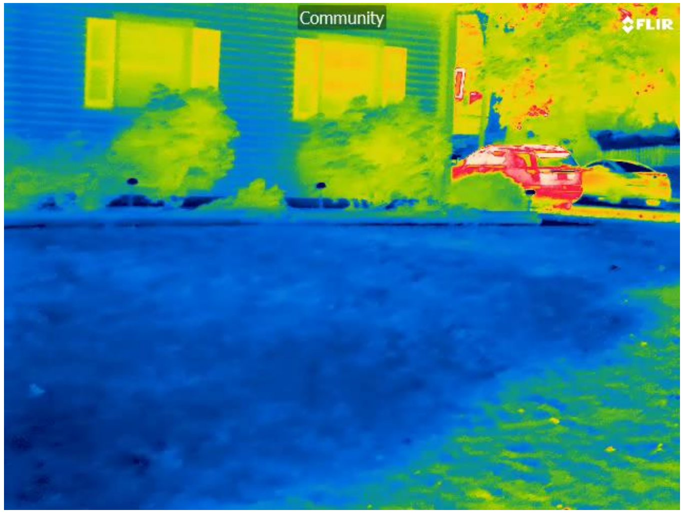


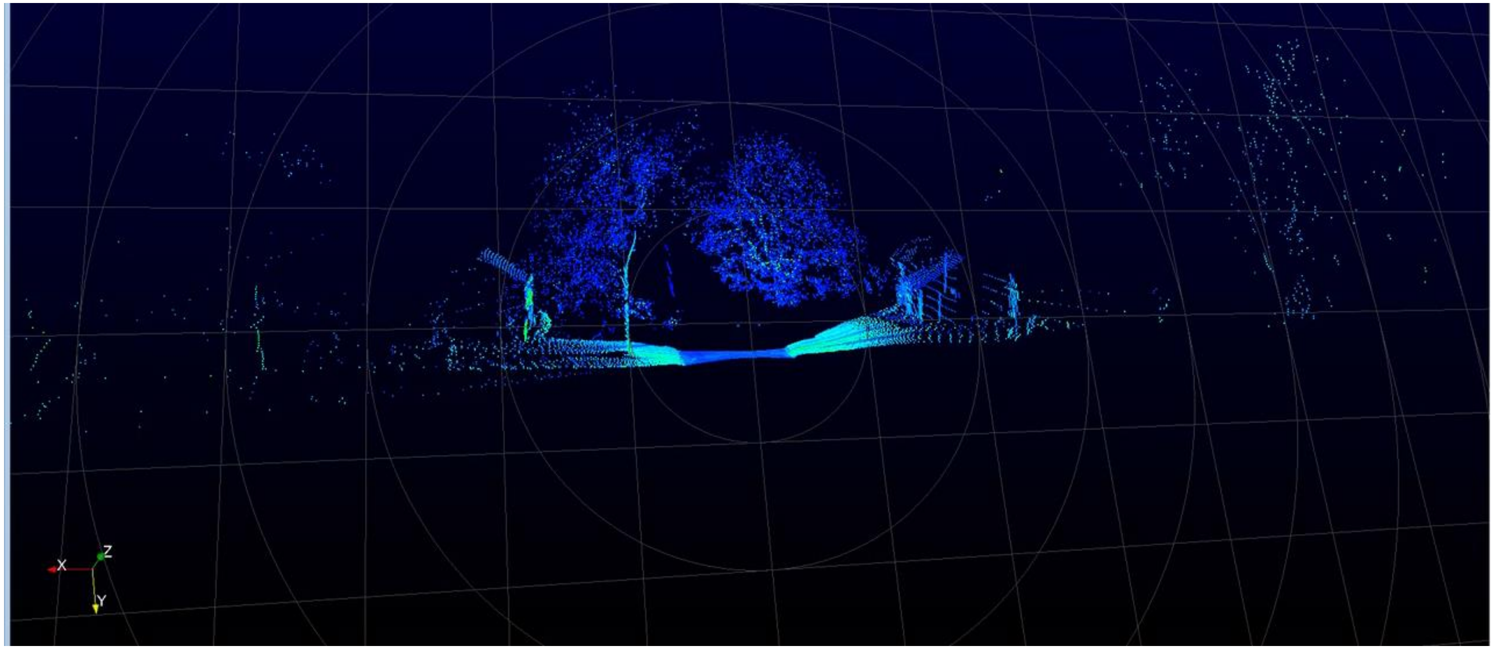
Spatial Sensing Technologies for Post-Disaster Mapping

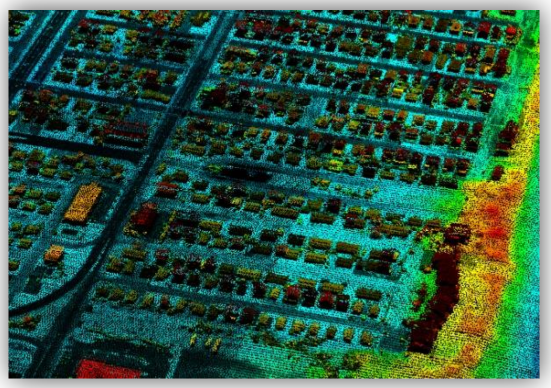
	Wide Area Mapping	Terrain Change Detection	Infrastructure and Building Displacement	Structural Deformation & Assessment	Accessibility Concern
Airborne LiDAR	x	x			Air Traffic/ Cloud Coverage
SFM-based 3D Reconstruction	x	x			Air Traffic/ Cloud Coverage
Mobile LiDAR	x	x	x	x	Ground Accessibility
Static LiDAR		x	x	x	Ground Accessibility
UAV LiDAR*	x	x	x	x	FAA Regulation

* The state of UAV LiDAR is very dynamic and in flux.

A Hybrid Mobile LiDAR and Infrared System



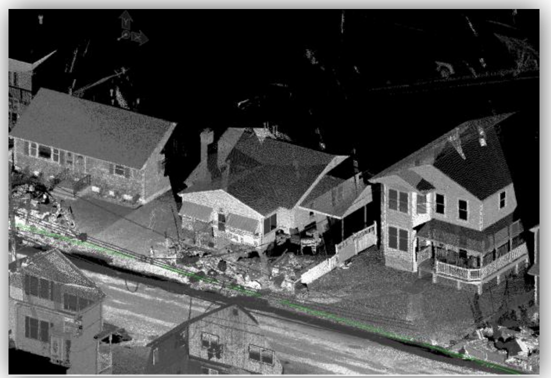




Airborne LiDAR

Google Earth Street View

Images from Ground Survey



Mobile LiDAR

Spatial Data Integration

- Data in Transit vs. Data at Rest
- Agencies/Academics/Crowd Sourcing
- Big Data Characteristics: Volume, Variety, Velocity, and Veracity

Images on the Internet

Aerial Imagery

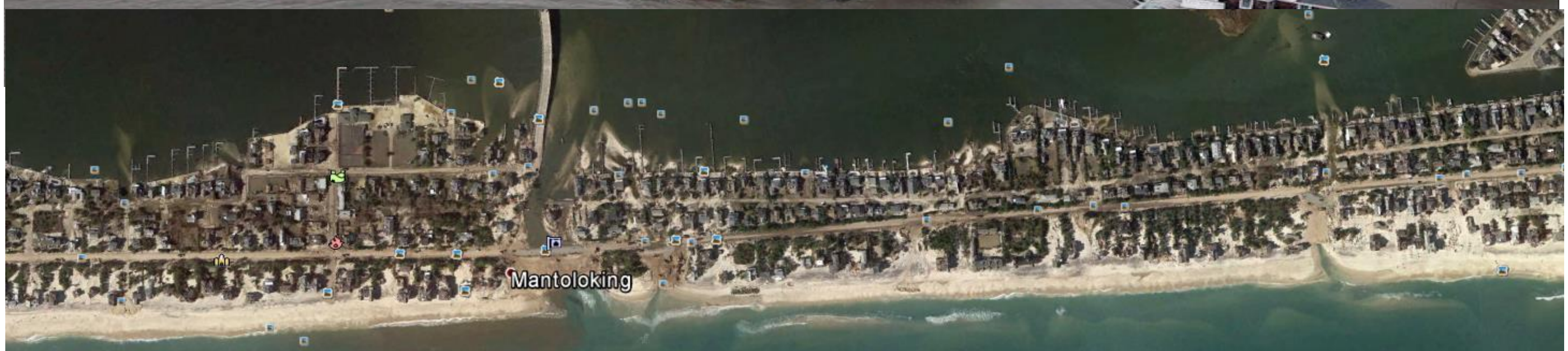
Volunteer Generated Information (VGI)

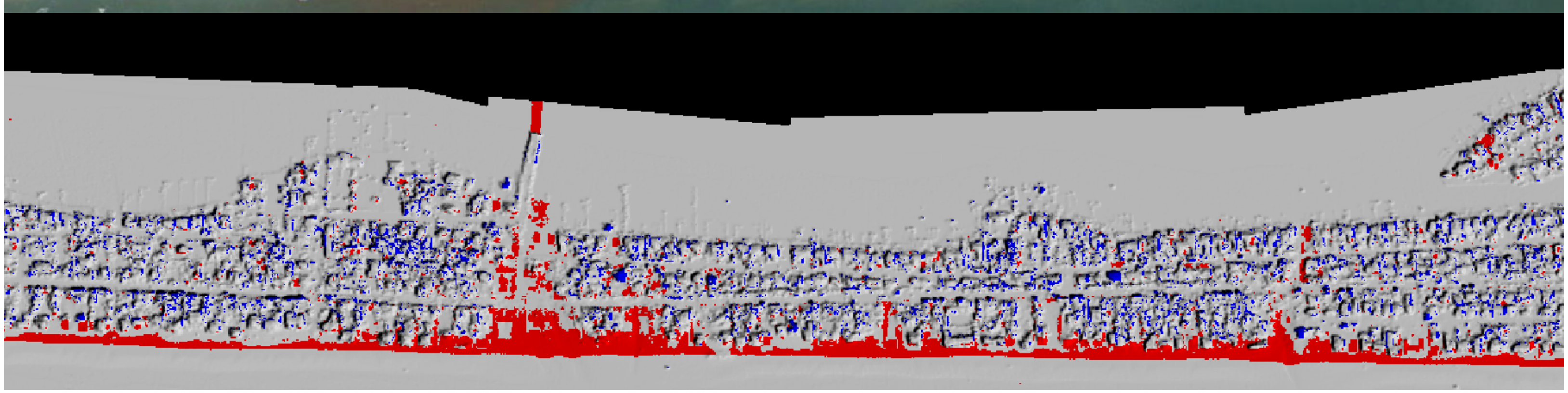
Images from Other Survey Teams

Spatial Data Accuracy

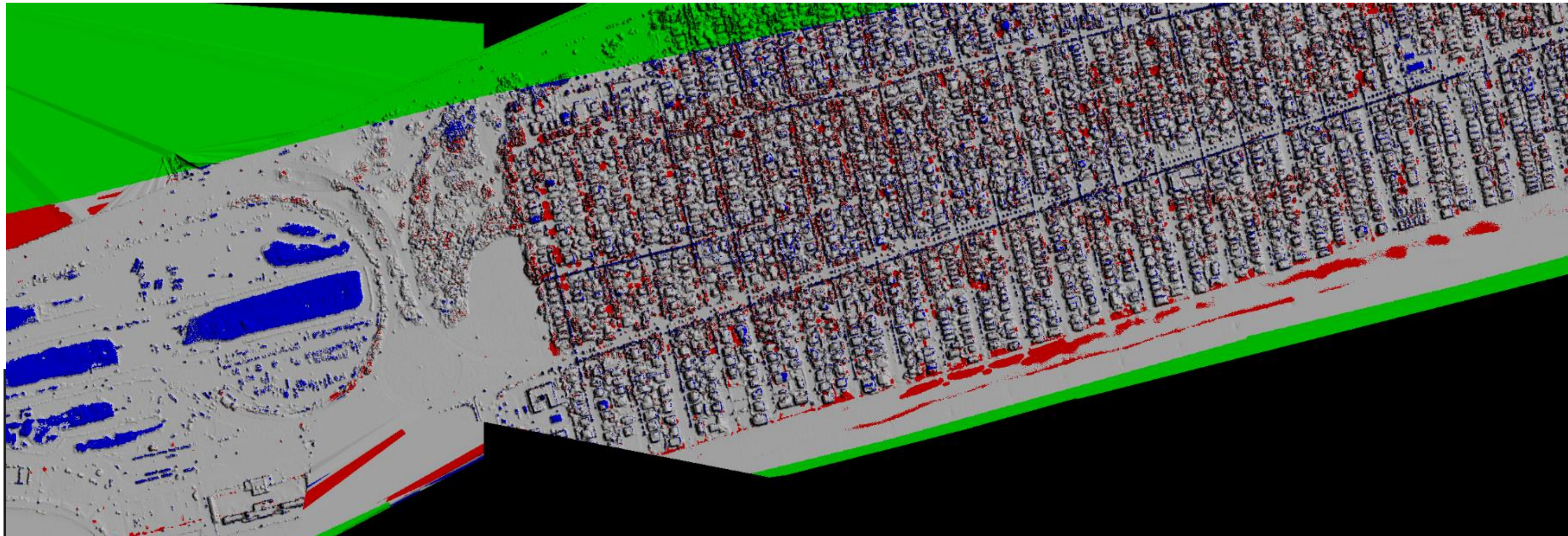
	Density (/m2)	Vertical Accuracy	Year
NJ State LiDAR (Pre-Sandy)	1-4 points	36.6 cm	2006&2010
USGS EARL-B (Post Sandy)	1-2 points	20 cm	2012
USACE LiDAR (Post-Sandy)	1-4 points	8.2cm	2012
NYC LiDAR (Pre-Sandy)	1-2 points	20 cm	2010
Mobile LiDAR (Post-Sandy)	1000 - 8000 points	5 cm	2012
SFM Reconstruction (Post-Sandy)	500-2000 points	20 cm	2012

Mantoloking, New Jersey

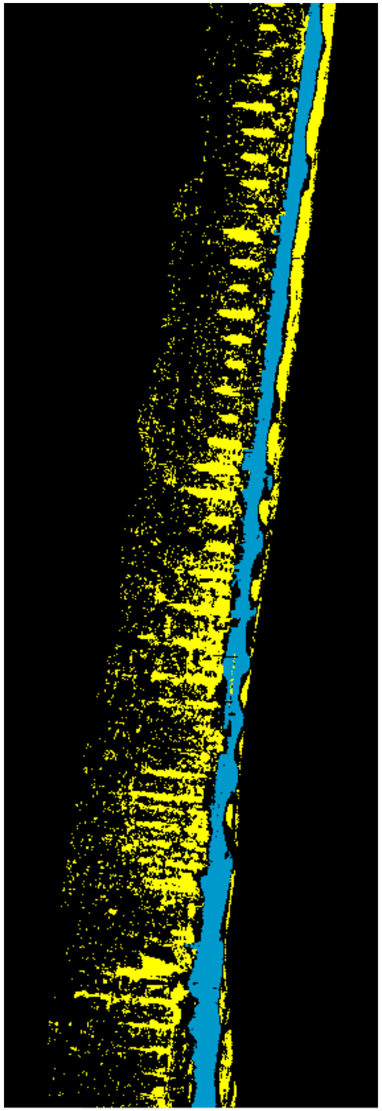


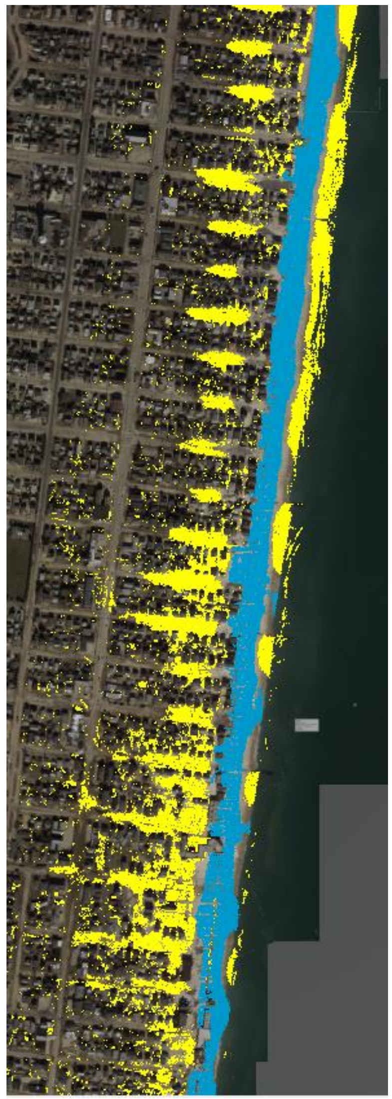


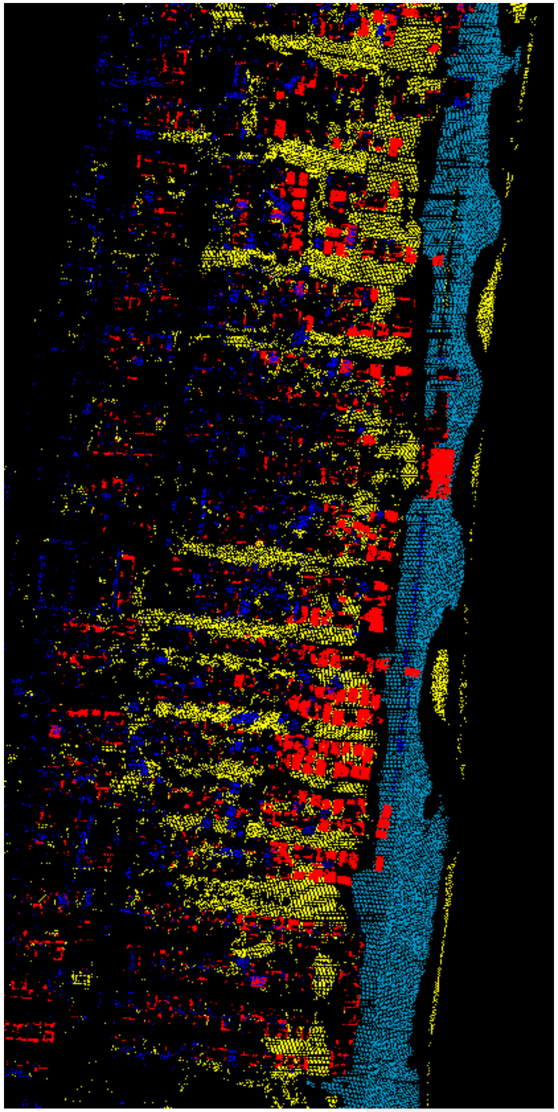
Rockaway, NYC



Post-Disaster Response Planning- Debris Field and Flow at Ortley Beach

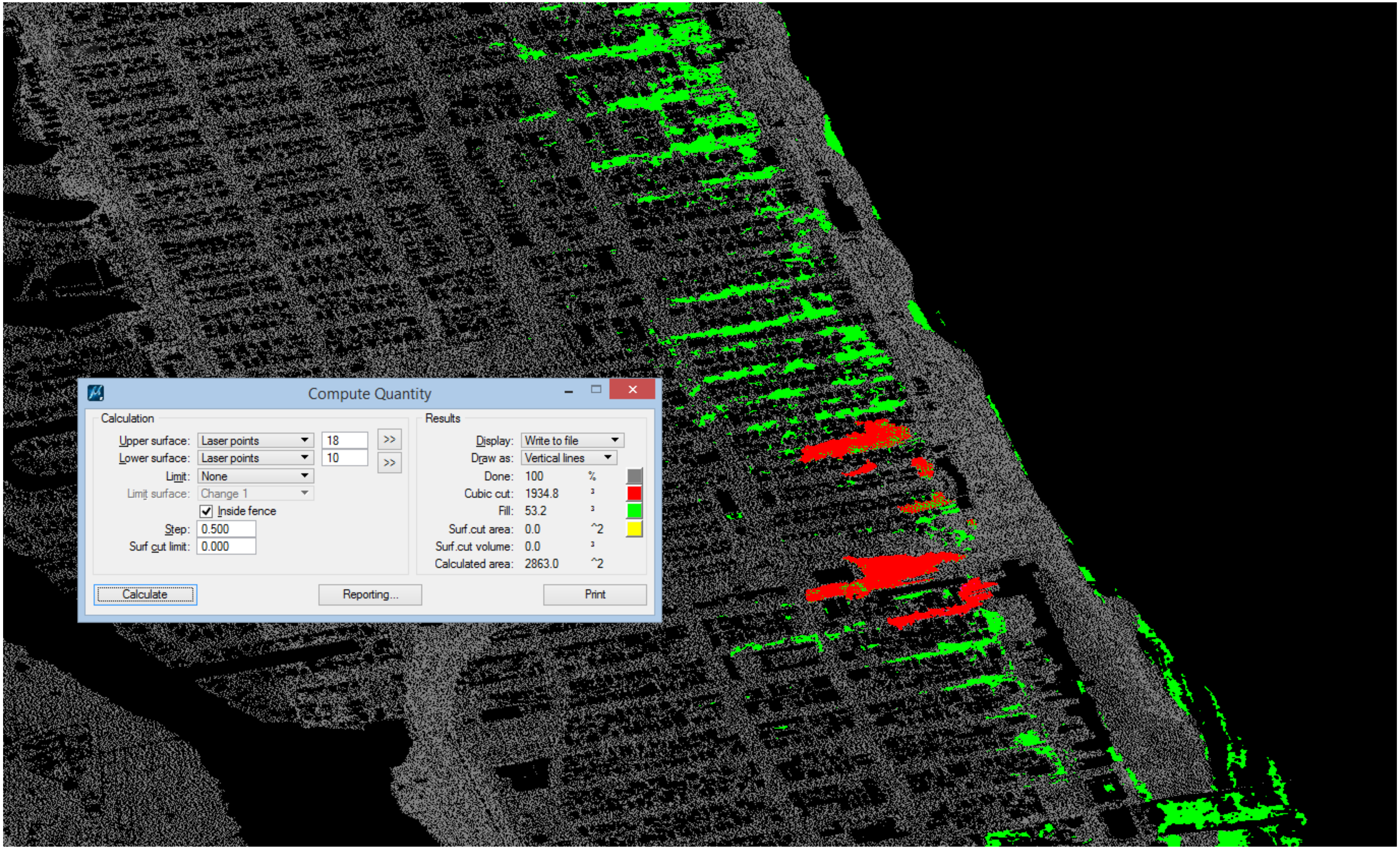






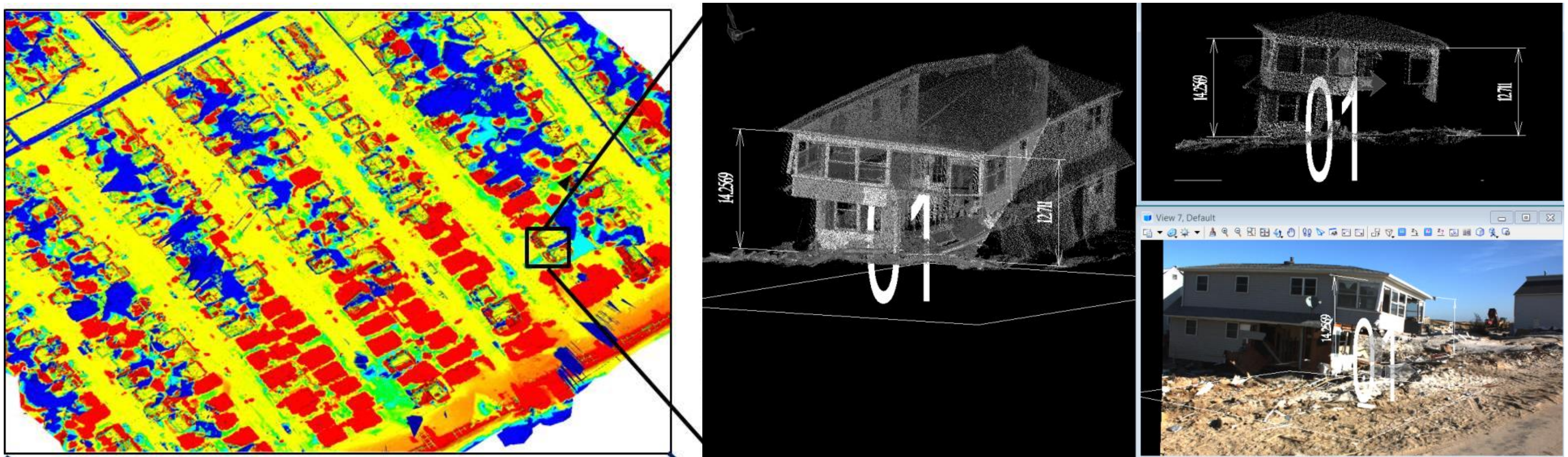
- **Yellow:** Sand Debris
- **Cyan:** Erode Dunes
- **Red:** Destroyed Buildings
- **Blue:** Building Debris or Changes

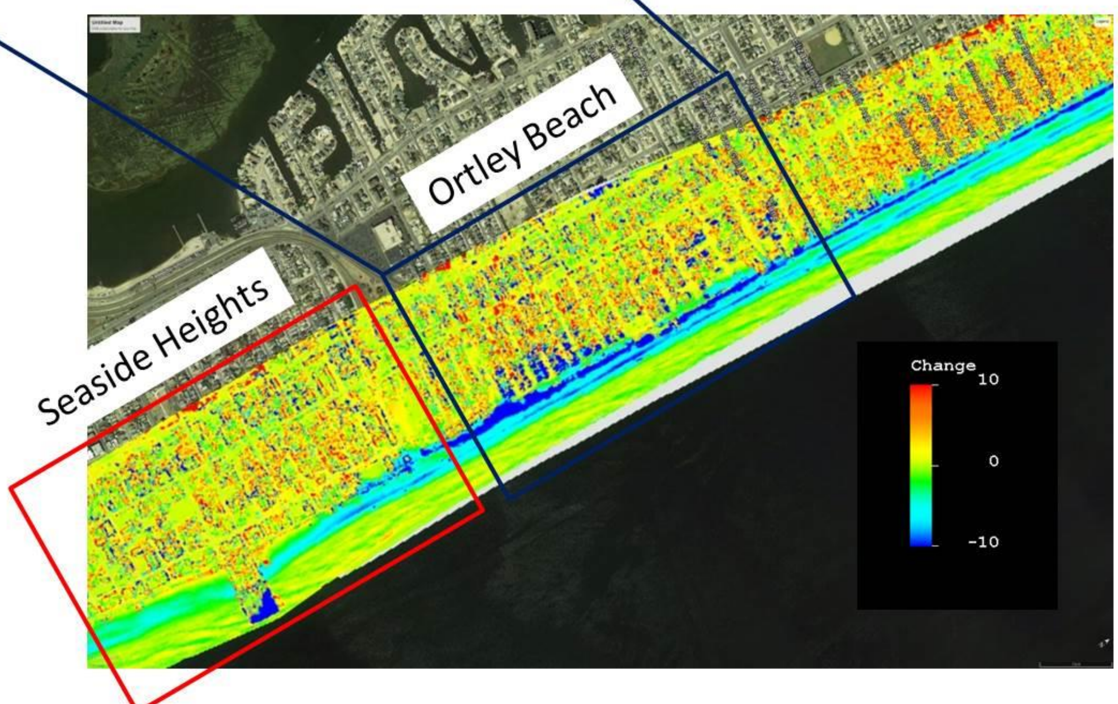
Quantify Debris Field and Flow



Building Displacement

Multi-Scale Damage Assessment

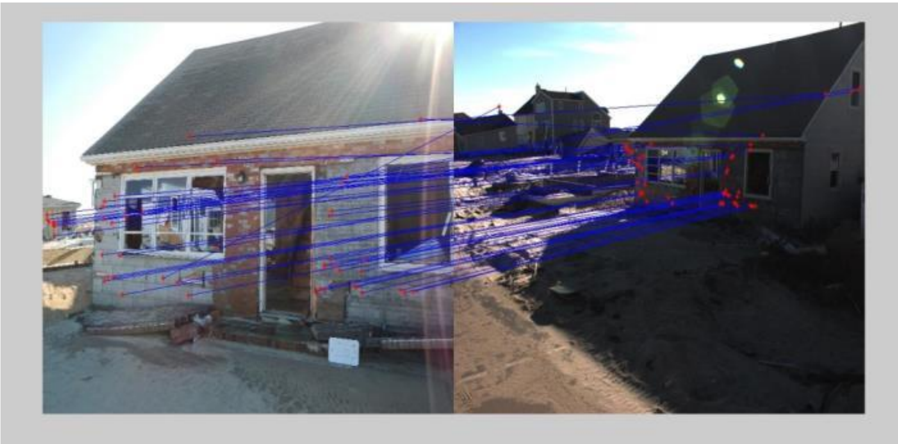


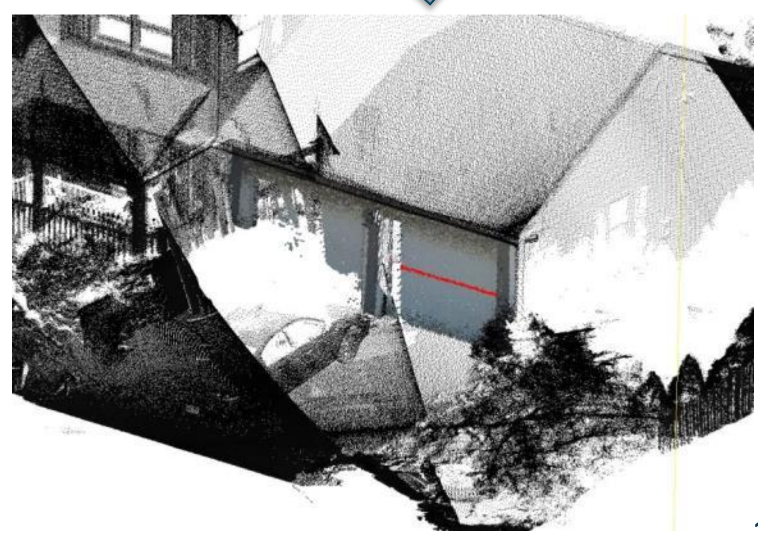


Airborne LiDAR
Mobile LiDAR
Street Level Imagery

Collaborator: Manish Parashar
Rutgers, Computer Science

Crowd-Sourced Storm Surge Height Estimation





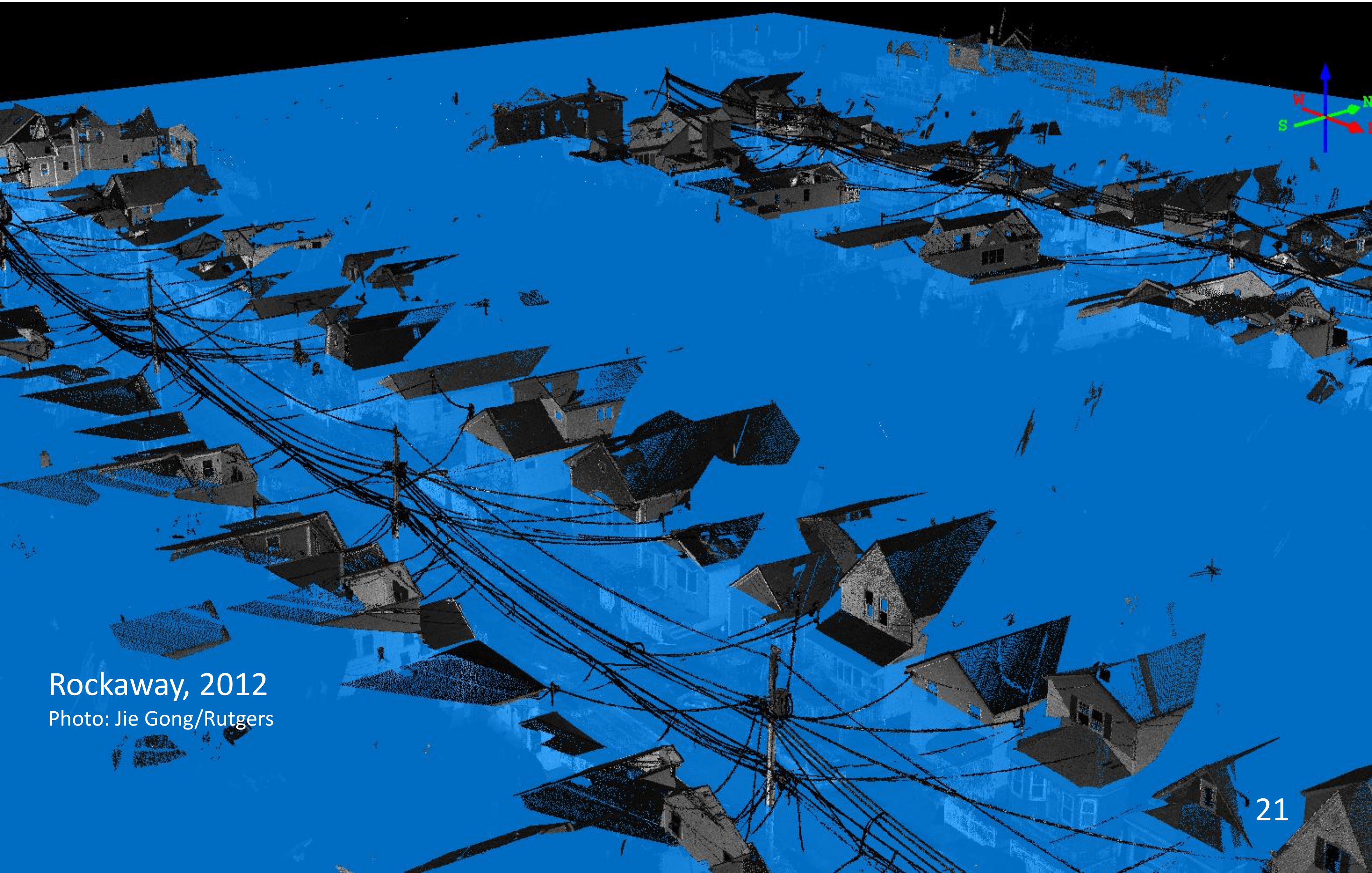
Recreate Water Level During Event

Ortley Beach, 2012
Photo: Jie Gong/Rutgers

Flooding Scenario: Crossbay Avenue, Rockaway, NY

Rockaway, 2012
Photo: Jie Gong/Rutgers

Risk Visualization for Crossbay Avenue
1% EL 16 Feet



Rockaway, 2012
Photo: Jie Gong/Rutgers

Risk Analysis of Post-Disaster Area [with GIS Mapping]

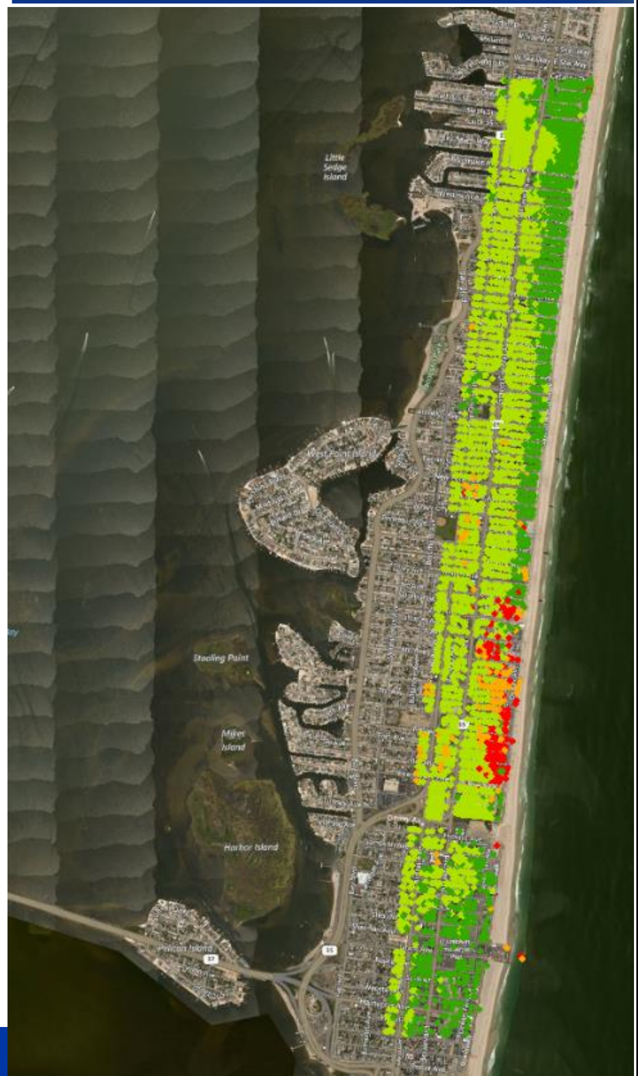
1. Select post-disaster area for risk analysis.
2. Level-1 Data: Buildings, above-surface movement, and flooding.

   [Use Lidar & other GIS data (FEMA)]
3. Level-2 Data: Detailed above-surface soil Displacement & water level.

   [Use Lidar & other GIS data (FEMA)]
4. Level-3 Analysis: Soil Displacement & water level at gas distribution Lines (Mains and services).

1. Select Post-Disaster Area [Example: Sample Data at NJ, after Sandy]

Level-1 Data: Buildings Movement [FEMA DATA]



- Affected
- Minor
- Major
- Destroyed

FEMA DAMAGE CLASSIFICATION		VISIBLE IMAGERY BASED CLASSIFICATION				
DAMAGE LEVEL	OBSERVED DAMAGE	Roof Covering	Roof Diaphragm	Collapsed Walls	Other Considerations	
Affected	Generally superficial damage to solid structures (loss of tiles or roof shingles); some mobile homes and light structures damaged or displaced.	Up to 20%	None	None	Gutters and/or awning; loss of vinyl or metal siding	
Minor	Solid structures sustain exterior damage (e.g., missing roofs or roof segments); some mobile homes and light structures are destroyed, many are damaged or displaced.	>20%	Up to 20%	None	Collapse of chimney; garage doors collapse inward; failure of porch or carport Mobile homes could be partially off foundation	137,369
Major	Wind: Some solid structures are destroyed; most sustain exterior and interior damage (roofs missing, interior walls exposed); most mobile homes and light structures are destroyed.	-	>20%	Some exterior walls are collapsed.	Mobile home could be completely off foundation – if appears to be repairable.	21,981
	Storm Surge: Extensive structural damage and/or partial collapse due to surge effects. Partial collapse of exterior bearing walls.			Some exterior walls are collapsed		
Destroyed	Wind: Most solid and all light or mobile home structures destroyed.	-	-	Majority of the exterior walls are collapsed.	-	841
	Storm Surge: The structure has been completely destroyed or washed away by surge effects.	-	-	Majority of the exterior walls are collapsed		

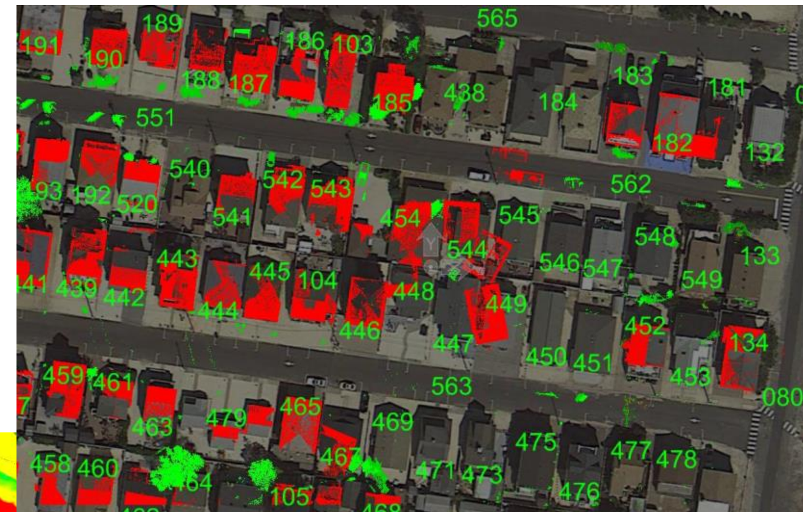
Level-2: Buildings Movement

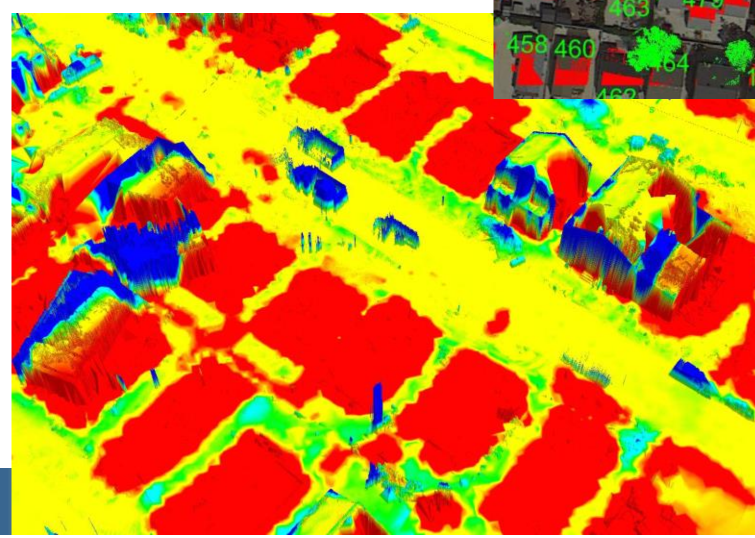
- Affected
- Minor
- Major
- Destroyed

Level-2 Data: Buildings Movement, [LiDAR Data]

LiDAR Spatial Analysis Can Provide:

- Digital Surface Model (DSM)
- Digital Terrain Model (DTM)
- Digital Elevation Model (DEM)
- Triangulated Irregular Network (TIN)
- Break line
- Contours
- Vector Drawings
    - Buildings,
    - Roads,
    - Power lines.

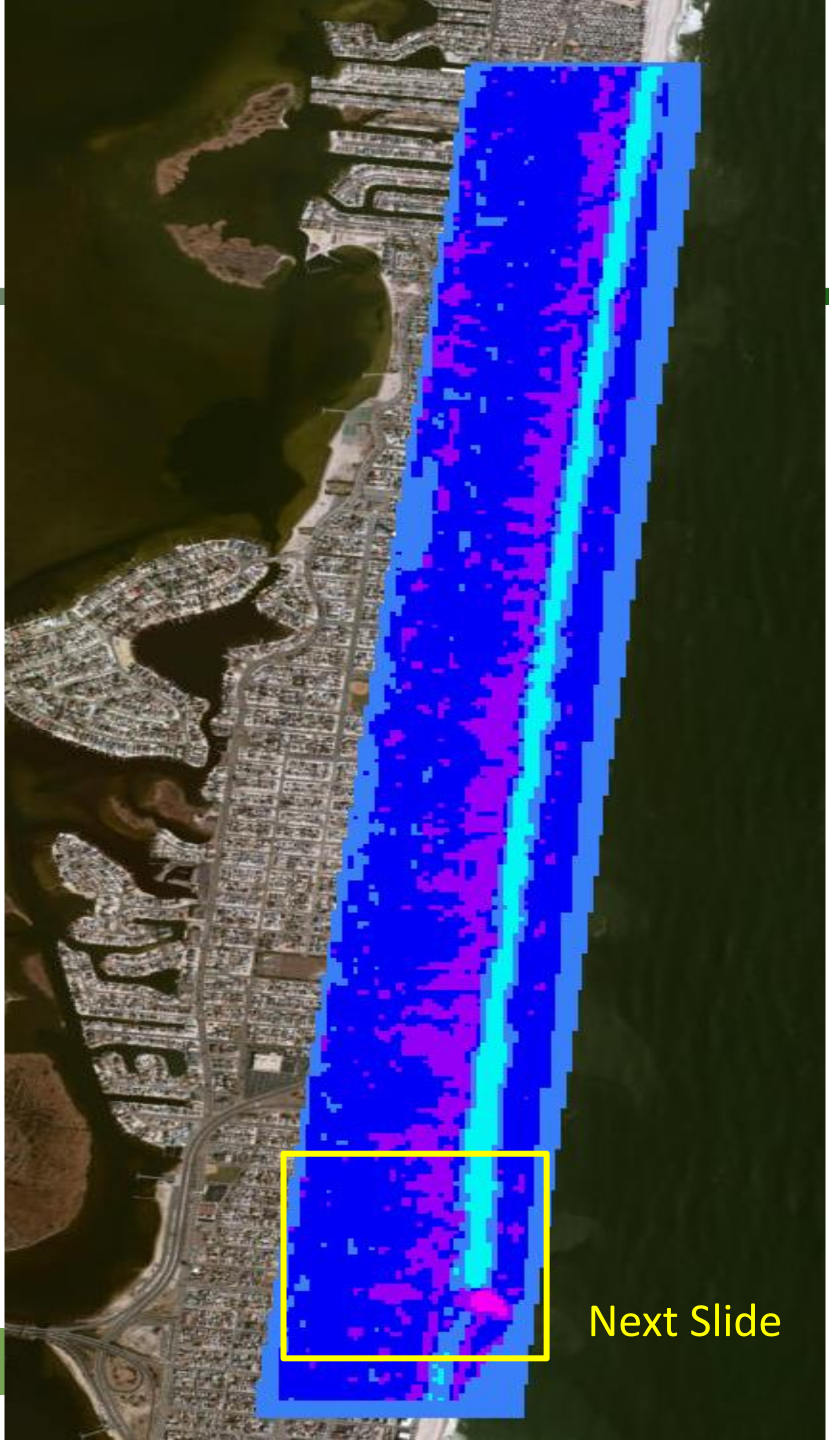




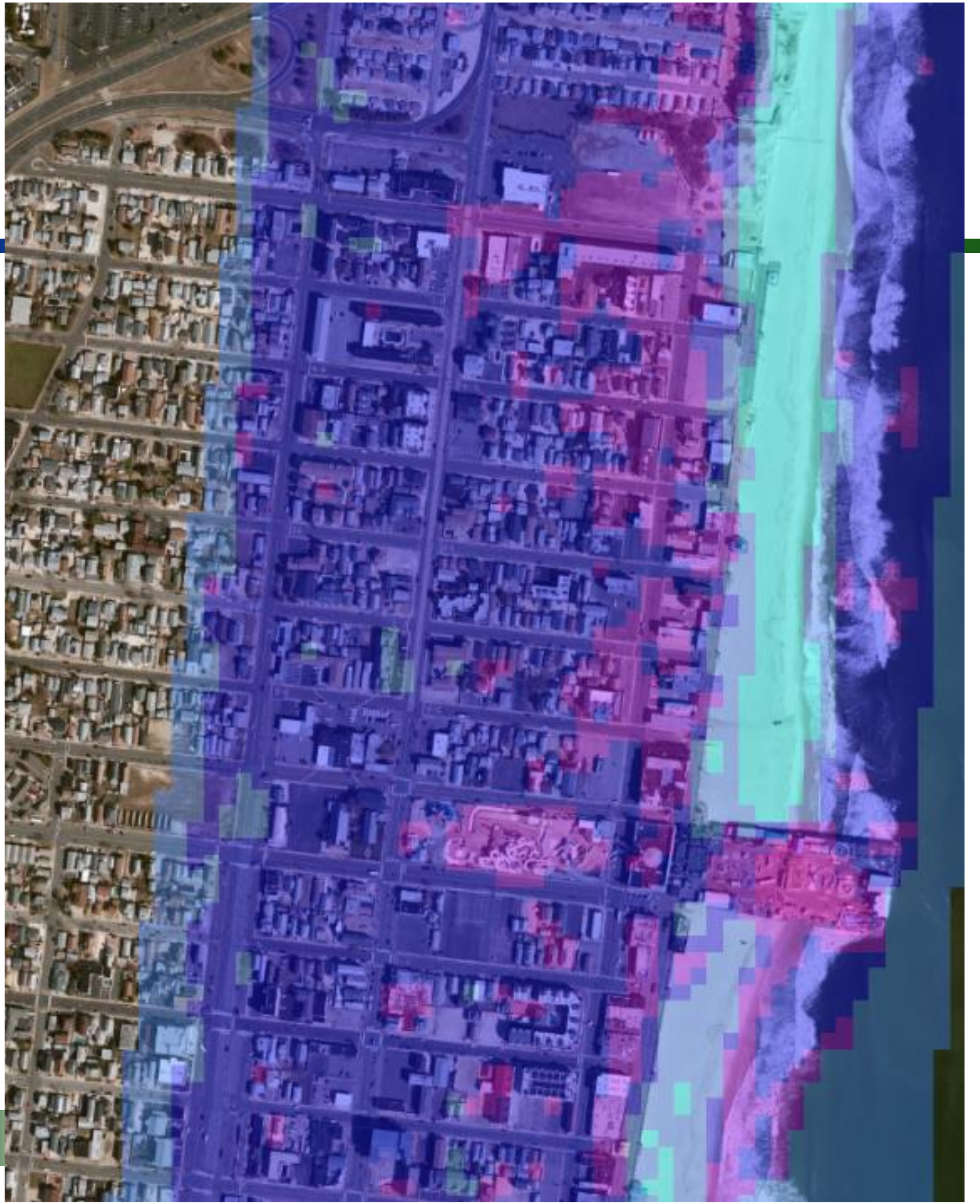
Level-1 Data: Soil Movement, [LiDAR DATA]

Mean Change of Soil Elevation [Before & After Sandy]

- -4.8 – -1.0 ft
- -1.0 – 0.10
- 0.10 – 0.55
- 0.55 – 2.50
- 2.50 – 6.00



Level-2 Data: Soil Movement, [LiDAR]



Data Tabulated in 50-ft Grids

Mean Change of Soil Elevation [Before & After Sandy]

- -4.8 – -1.0 ft
- -1.0 – 0.10
- 0.10 – 0.55
- 0.55 – 2.50
- 2.50 – 6.00

Level-1 Data: Flooding, [FEMA DATA]

Flood Levels After Sandy

- 0.0 – 1.00 ft
- 1.00 – 2.55
- 2.55 – 3.80
- 3.80 – 6.00

Level-2 Data: Water Level, [FEMA]

Flood Levels After Sandy

- 0.0 – 1.00 ft
- 1.00 – 2.55
- 2.55 – 3.80
- 3.80 – 6.00

Level-3 Risk Analysis: Soil Movement and Water Level at Distribution Lines

Note: The distribution lines in the figure does not represent an actual system and it is made for illustration only.

Level 3 Risk Analysis: Quantify Earth Movement and Water Table.

Table

SoilChange

PeakSeaLVL	BelowWater	PostZ	FID_GRID	PreZ	ZDifference
2.1336	-0.37975	1.75385	71	1.685293	0.068556
2.1336	-0.384662	1.748938	72	1.684558	0.06438
2.1336	-0.380286	1.753314	73	1.675209	0.078105
2.1336	-0.359902	1.773698	74	1.630488	0.14321
2.1336	-0.339451	1.794149	75	1.637051	0.157098
2.1336	-0.324807	1.808793	76	1.670995	0.137798
2.1336	-0.223636	1.909964	77	1.780052	0.129913
2.1336	-0.135806	1.997794	78	1.897202	0.100592
2.1336	-0.063536	2.070064	79	2.001032	0.069032
2.1336	0.014354	2.147954	80	1.998357	0.149598
2.1336	0.014529	2.148129	81	1.953615	0.194514
2.1336	0.050543	2.184143	82	1.976818	0.207325
2.1336	0.045084	2.178684	83	1.976818	0.201867
2.1336	0.023328	2.156928	84	1.976818	0.18011
2.1336	-0.080888	2.052712	85	2.033223	0.019489
2.1336	-0.14251	1.99109	86	1.98029	0.0108
2.1336	-0.148838	1.984762	87	1.923227	0.061534
2.1336	-0.106819	2.026781	88	1.923227	0.103554
2.1336	-0.056524	2.077076	89	1.966519	0.110557
2.1336	0.007493	2.141093	90	2.016519	0.124574
2.1336	0.024806	2.158406	91	2.009406	0.148999
2.1336	0.016102	2.149702	92	1.962505	0.187197
2.1336	0.055673	2.189273	93	1.973244	0.216029
2.1336	0.060481	2.194081	94	1.968977	0.225104
2.1336	0.051139	2.184739	95	1.997983	0.186756
2.1336	-0.00881	2.12479	96	2.019719	0.105071
2.1336	-0.080395	2.053205	97	2.031827	0.021379
2.1336	-0.050443	2.083157	98	2.016686	0.066471
2.1336	-0.063481	2.070119	99	1.982602	0.087517
2.1336	-0.081687	2.051913	100	1.982602	0.069311

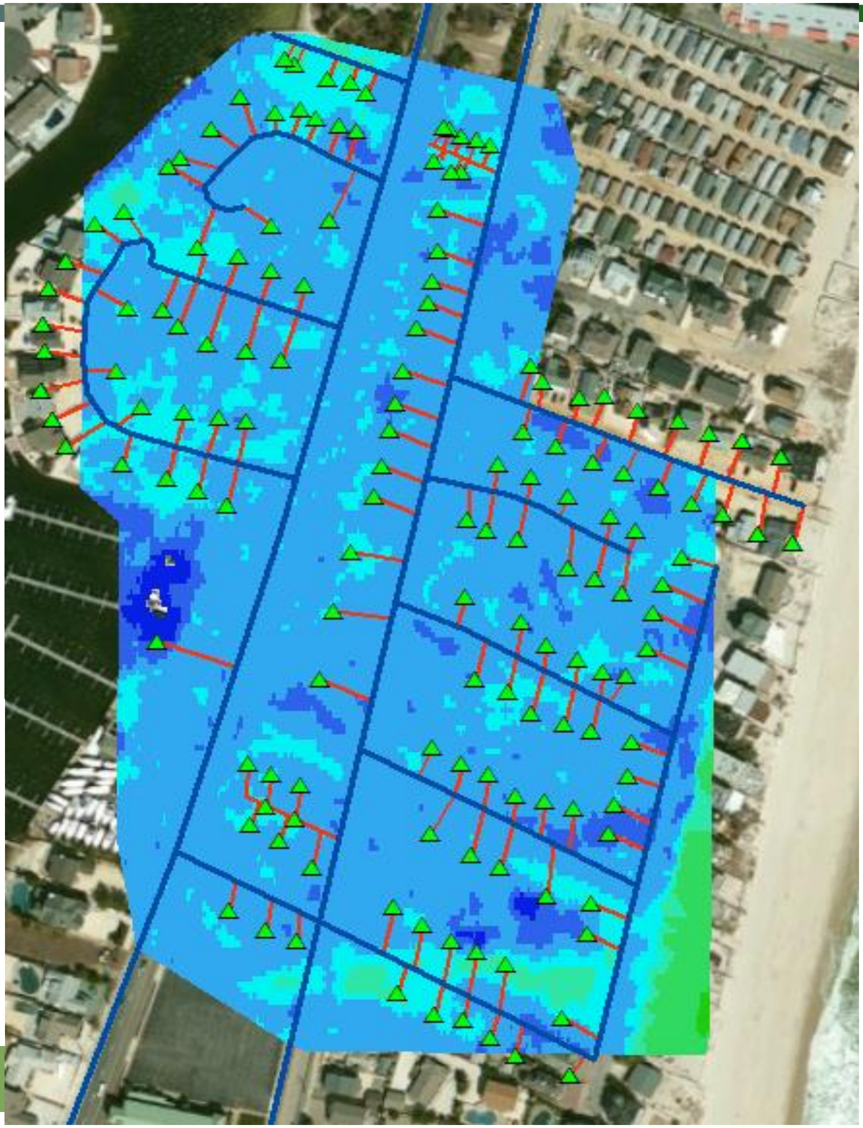
Note: We don't need to calculate earth movement & Water table at all the 50-ft grids.

We'll focus only on the grids where mains, service lines exist.

Level-3 Risk Analysis: Soil Movement and Water Level at Distribution Lines

Spatial Changes in soil elevation before and after Sandy.

[Note: Z in this figure is in meters]



SoilChange

ZDifference
-5.25 - -4.00
-3.99 - -1.00
-0.99 - -0.50
-0.49 - 0
0.01 - 0.50
0.51 - 1.00
1.01 - 1.75

Level-3 Risk Analysis: Soil Movement and Water Level at Distribution Lines

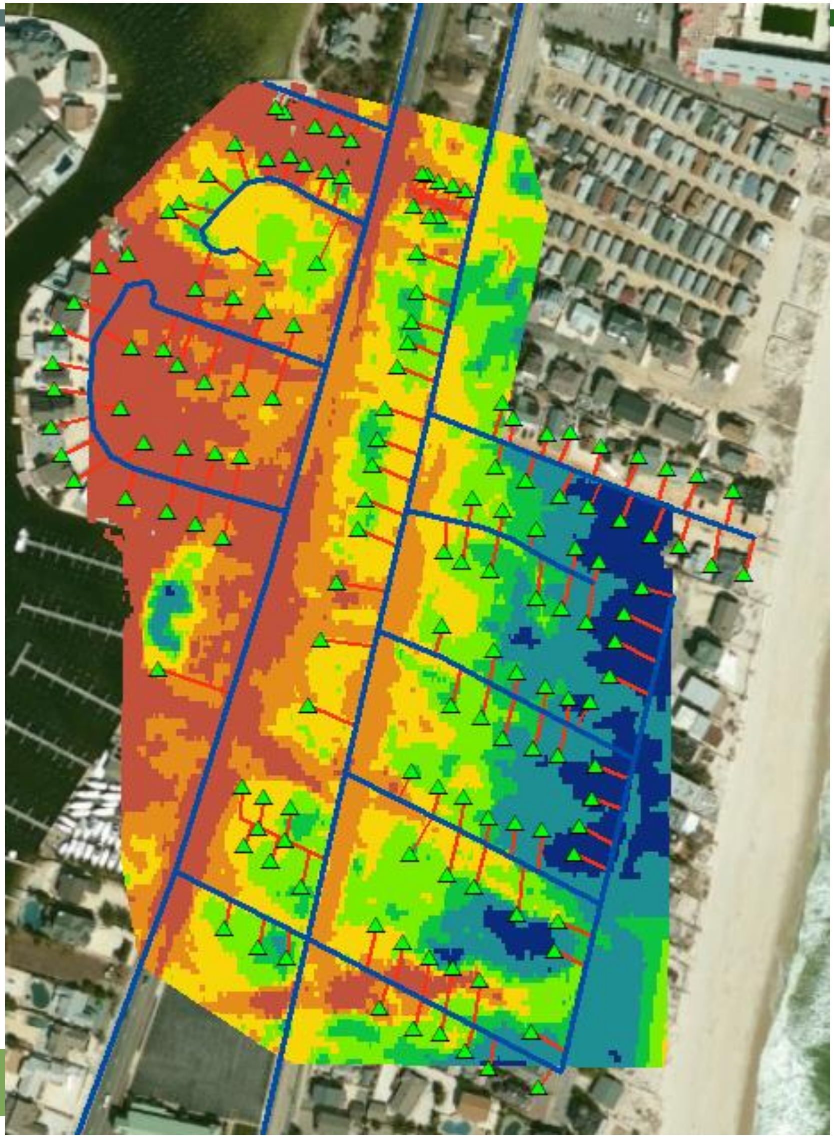
Spatial Changes in water table before and after Sandy.

[Note: Levels in this figure are in meters]

WaterLevel

BelowWater

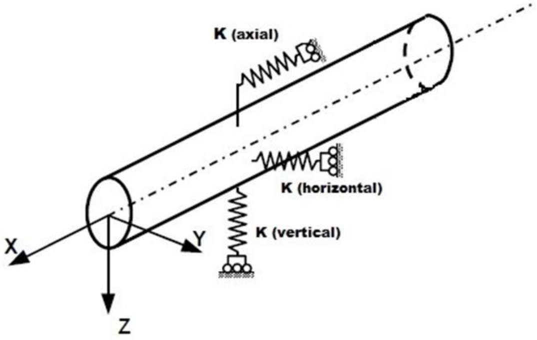
- -1.49 - -0.75
- -0.74 - -0.50
- -0.49 - -0.25
- -0.249 - 0
- 0.1 - 0.25
- 0.26 - 0.75
- 0.76 - 1.75



Level-3 Risk Analysis: Soil Movement and Water Level at Distribution Lines

Deformations and strains in the pipe are modeled under to the following natural forces threats:

1. Vertical soil movement and settlement,
2. Horizontal soil movement and landslides,
3. Debris and horizontal forces on aboveground facilities
4. Flooding.



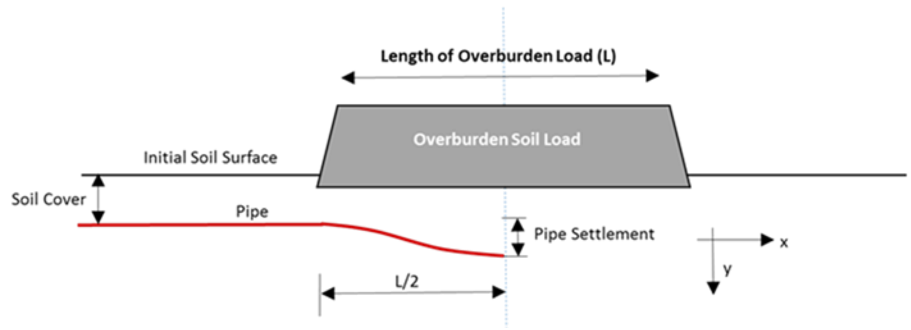
Level-3 Risk Analysis: Soil Movement and Water Level at Distribution Lines

Deformations and strains in the pipelines due to soil movement are modeled using the Finite Element Program PIPLIN. The program is a special purpose commercially available program for stress and deformation analysis of pipelines.

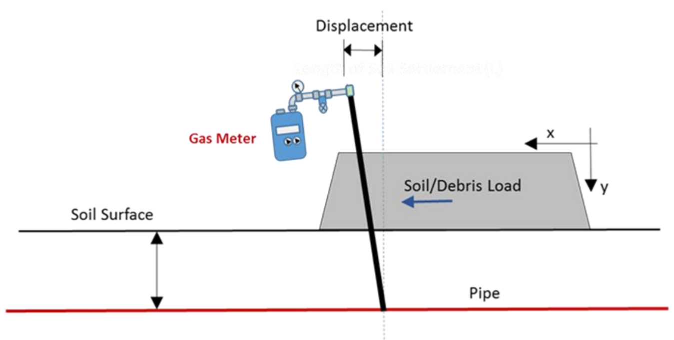
Parameters	Range of Parameters for gas distribution lines
Pipe Type	Steel Mains (grades A and X40), Plastic mains and services (PE, Aldyl-A), and Cast iron Mains
Pipe Size	Plastic: ¾-6 inch Steel: 1-4 inch Cast Iron: 4-12 inch
Soil Type	Loose sand Dense sand Clay
Length of moving soil section	60-120 feet
Vert. & Horiz. soil movement	1-4 ft soil movement

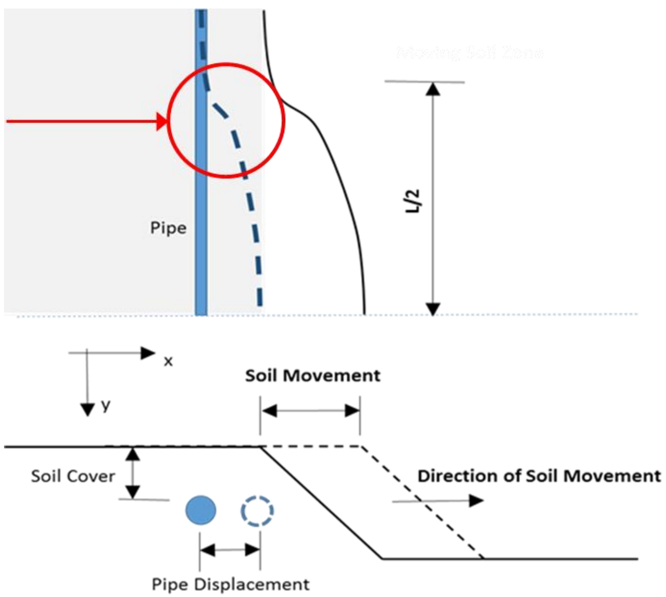
Level-3 Risk Analysis: Soil Movement and Water Level at Distribution Lines

Vertical Displacement



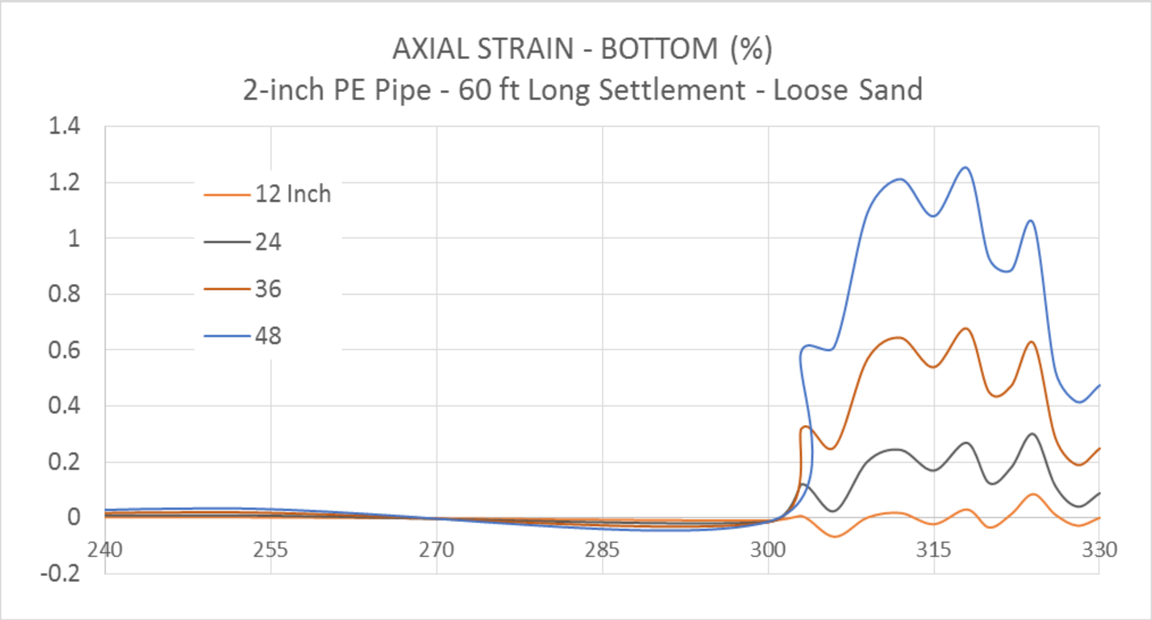
Aboveground Displacement



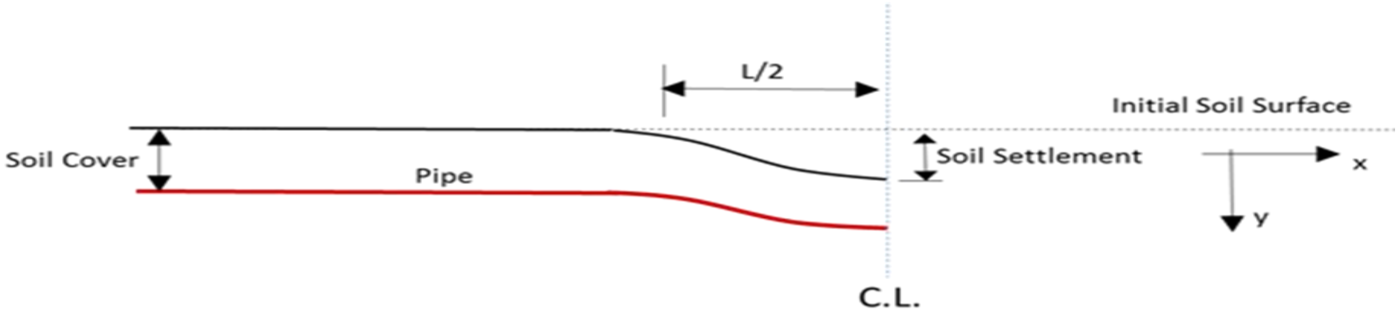


Horizontal Displacement

Level-3 Risk Analysis: Soil Movement and Water Level at Distribution Lines



PE Deformation Due to Vertical Soil Movement



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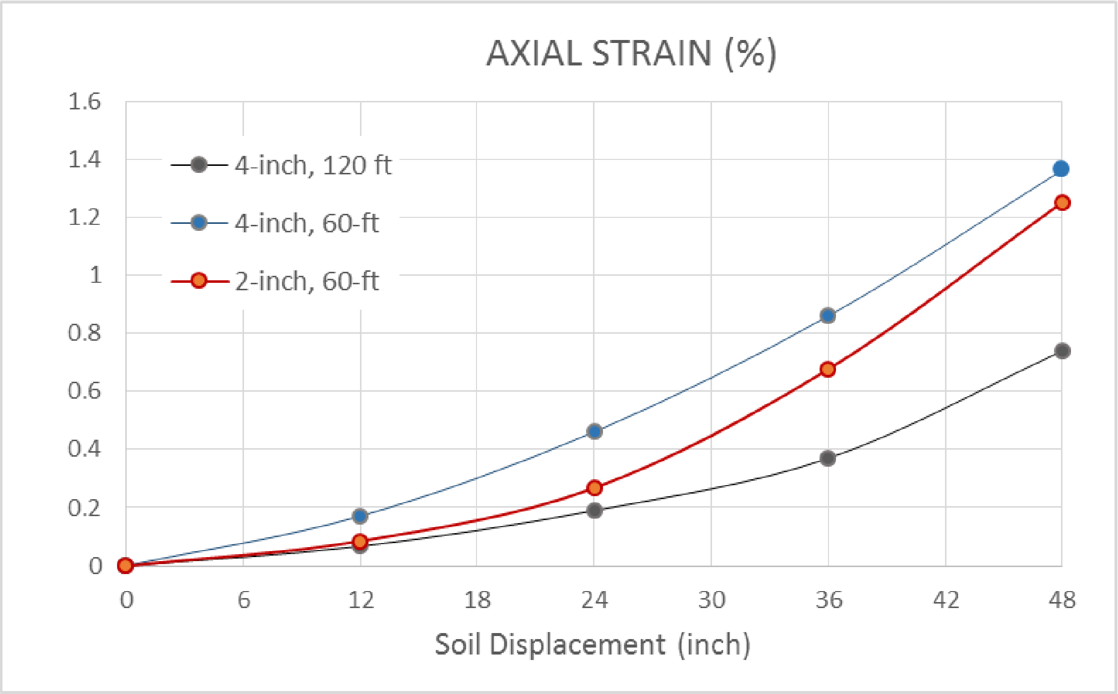
Level-3 Risk Analysis: Soil Movement and Water Level at Distribution Lines

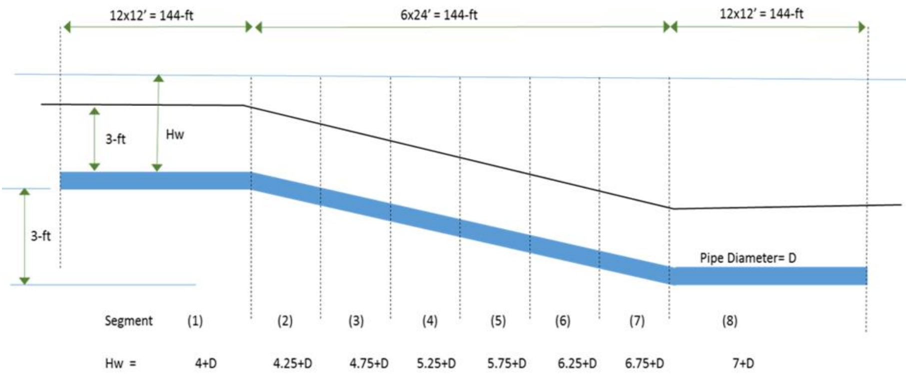
PE Deformation Due to Vertical Soil Movement



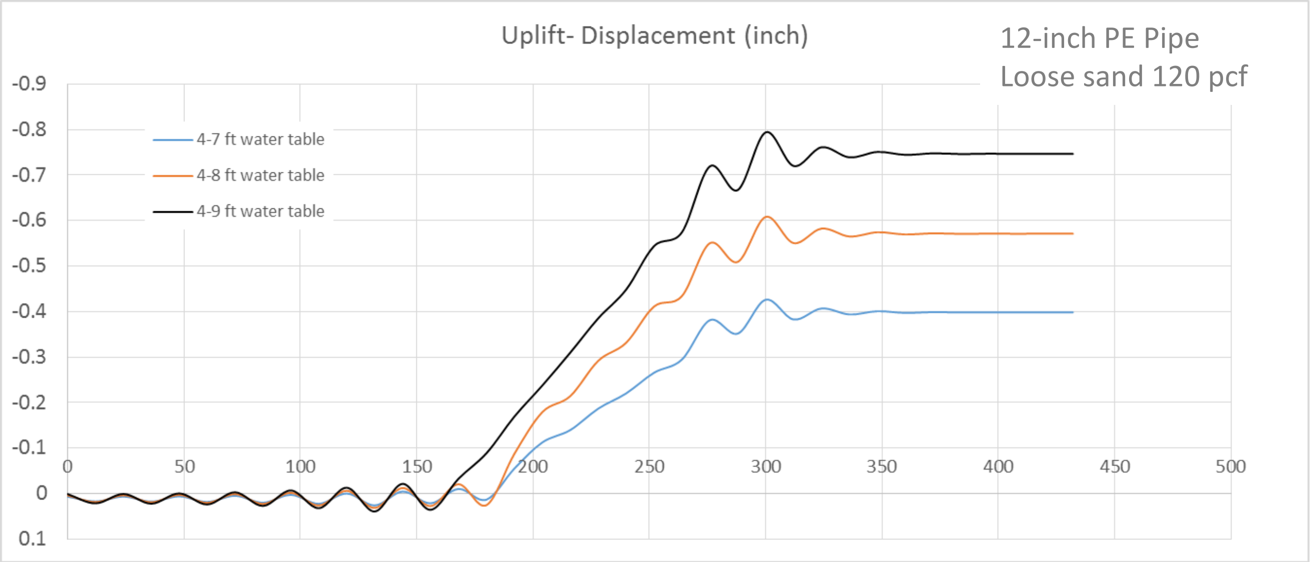
2 – 4 inch PE Pipe

Loose Sand – Settlement Length 60 -120 ft

Level-3 Risk Analysis: Soil Movement and Water Level at Distribution Lines



Pipe Uplift Due to Flooding



Questions?