The cost of floods: how rising waters will reshape our lives and our economy

M. Tedesco

Columbia University, NASA GISS and Sant'Anna School of Advanced Studies

February 5th, 2021
Outline

• Current state of climate and global temperatures
• General introduction on impacts of climate on economical and financial sectors
• Floods and sea level rise: Greenland, Antarctica and warming up the oceans
• Not just sea level rise: the compounding effect of storm surges, SLR, rain and other extreme events
• Examples of previous impacts of floods on economic and financial sectors
• Results from our current and previous projects
• Issues and recommendations
My Journey

1999 ME
Electrical Engineering
(Microwaves)
My Journey

1999 ME Electrical Engineering (Microwaves)

2002 PhD, Physics (Electromagnetic waves and snow particles)
My Journey

1999 ME Electrical Engineering (Microwaves)

2002 PhD, Physics (Electromagnetic waves and snow particles)

2003 - 2008 NASA GSFC (operational algorithms for snow)
My Journey

1999 ME Electrical Engineering (Microwaves)

2002 PhD, Physics (Electromagnetic waves and snow particles)

2003 - 2008 NASA GSFC (operational algorithms for snow)

2007 NASA GSFC (algorithms for melting of Greenland from satellites)
My Journey

1999 ME Electrical Engineering (Microwaves)

2002 PhD, Physics (Electromagnetic waves and snow particles)

2003 - 2008 NASA GSFC (operational algorithms for snow)

2007 NASA GSFC (algorithms for melting of Greenland from satellites)

2008 - 2013 CCNY, Ass. Prof (fieldwork in Greenland, Antarctica and models for melting)
My Journey

1999 ME Electrical Engineering (Microwaves)

2002 PhD, Physics (Electromagnetic waves and snow particles)

2003 - 2008 NASA GSFC (operational algorithms for snow)

2007 NASA GSFC (algorithms for melting of Greenland from satellites)

2008 - 2013 CCNY, Ass. Prof (fieldwork in Greenland, Antarctica and models for melting)

2013 - 2015 NSF Program manager (Polar, cyberinfrastructure)
My Journey

1999 ME Electrical Engineering (Microwaves)

2002 PhD, Physics
(Electromagnetic waves and snow particles)

2003 - 2008 NASA GSFC
(operational algorithms for snow)

2007 NASA GSFC
(algorithms for melting of Greenland from satellites)

2008 - 2013 CCNY, Ass. Prof
(fieldwork in Greenland, Antarctica and models for melting)

2013 - 2015 NSF Program manager
(Polar, cyberinfrastructure)

2015 - now Columbia/NASA
Socio-economic impacts of floods + Arctic atmosphere and global changes

NOW
Surface temperatures have been increasing since 1880s with the recent years breaking records, year after year.

Source: NASA GISS
For the first time in the history of the Global Risks Perception Survey, environmental concerns dominate the top long-term risks by likelihood among members of the World Economic Forum’s multistakeholder community; three of the top five risks by impact are also environmental.

Global Risk Report 2020, World Economic Forum
.. LET US TAKE A QUICK STEP BACK AND LET US LOOK AT DRIVERS FOR FLOODS ...
The ocean is not a bathtub

SLR is different in different places
Where does the heat go?

Ocean 93.4%

Atmosphere 2.3%
Continents 2.1%
Glaciers and ice caps 0.9%
Arctic sea ice 0.8%
Greenland Ice Sheet 0.2%
Antarctic Ice Sheet 0.2%
The ocean is not a bathtub

22 years SLR anomaly

Nerem et al., 2018
GMSL from satellites show a rate of $\sim 3 \pm 0.4$ mm/yr and an acceleration of $0.084 \pm 0.025$ mm/yr$^2$. 

... and it is accelerating.
Relative contribution to SLR

Current
- Thermal expansion: 53%
- Greenland: 21%
- Glaciers: 21%
- ANT: 5%

Future (Bus. As usual)
- Thermal expansion: 31%
- Greenland: 37%
- Glaciers: 11%
- ANT: 21%

Source: Mengel et al., PNAS, 2016
Sea level not only increasing but accelerating
Sea level in the past was much higher than today, despite similar CO2 and temperatures levels. Sea level could rise between 6 and 15 m (18 and 40 feet) based on historical data.
Factors driving floods, not just sea level rise!

- Coastal erosion
- Extreme events (rain)
- High tides
- Stronger and more frequent storms
- Sea level rise
- Hurricanes

The combination of the factors above is already creating storm surges of several feet (see Florence hurricane test case study next slides).
Estimated $600 billion/yr loss by 2100

Cost: 1.2% GDP per °C warming

Hsiang et al., 2017
$300 billion loss in 2017

U.S. 2017 Billion-Dollar Weather and Climate Disasters

North Dakota, South Dakota, and Montana Drought Spring–Fall 2017

Western Wildfires, California Firestorm Summer–Fall 2017

California Flooding February 8–22

Colorado Hail Storm and Central Severe Weather May 8–11

Midwest Severe Weather June 12–16

Midwest Severe Weather June 27–29

South/Southeast Severe Weather March 26–28

Midwest Tornado Outbreak March 6–8

Central/Southeast Tornado Outbreak February 28–March 1

Missouri and Arkansas Flooding and Central Severe Weather April 25–May 7

Southeast Freeze March 14–16

Southern Tornado Outbreak and Western Storms January 20–22

Minnesota Hail Storm and Upper Midwest Severe Weather June 9–11

Hurricane Harvey August 25–31

Hurricane Irma September 6–12

Hurricane Maria September 19–21

This map denotes the approximate location for each of the 16 billion-dollar weather and climate disasters that impacted the United States during 2017.
2020 tied with 2017 and 2011

U.S. 2020 Billion-Dollar Weather and Climate Disasters

Western Wildfires, California, Oregon, Washington Firestorms Fall 2020

Western / Central Drought and Heatwave Summer-Fall 2020

Central and Eastern Severe Weather May 3–5

Southern Severe Weather April 21–23

South Texas Hail Storms May 27

Central Severe Weather - Derecho August 10

North Central and Ohio Valley Hail Storms and Severe Weather April 7–8

Midwest and Ohio Valley Severe Weather March 27–28

Tennessee Tornadoes and Southeast Severe Weather March 2–4

South, East and Northeast Severe Weather Feb 5–7

South, Central and Eastern Severe Weather May 20–23

Southeast Tornadoes and Northern Storms and Flooding Jan 10–12

Hurricane Laura August 27–28

Southeast and Eastern Tornado Outbreak April 12–13

Hurricane Sally September 15–17

Hurricane Isaias August 3–4
Flooding is a CURRENT socio-economic threat

The number of events related to flood with more than 1 Billion dollar impact over the recent decade has been considerably increasing with respect to the previous decade

https://www.ncdc.noaa.gov/billions/mapping/
Not only in the US …

Natural disasters caused overall losses of US$ 210bn
Relevant natural catastrophe loss events worldwide 2020
Impacts of climate change on real estate investment trusts (REITs): an example

- 35 percent of REITs properties globally are currently exposed to climate hazards

- Of these, 17 percent of properties are exposed to inland flood risk, 6 percent to sea level rise and coastal floods, and 12 percent to hurricanes or typhoons.

- U.S. markets most exposed to sea level rise include New York, San Francisco, Miami, Fort Lauderdale, and Boston.

- 37 Japanese REITs have their entire portfolio exposed to the highest risk for typhoon globally, representing $264.5 billion at risk in properties in Tokyo and other Japanese cities.

The Thailand 2011 flood on two stocks ...

10/14/11: WDC plant flooded. STX plant not flooded.
Some outstanding issues we have identified …

- Lack of consistent metrics and spread of tools
- What is the role of man-built infrastructure on the exposure (e.g., number of buildings, location, etc.) vs. the physical one?
- Satellite data is great but what about “temporal” coverage?
- Linking socio-economic vulnerability with climate impacts
- Access and acquisition of financial data (e.g., property values, rentals, managers portfolios)
- Lack of inter- and trans-disciplinary collaboration to “converge” towards common goals and actions
Some outstanding issues we have identified …

- Lack of consistent metrics and spread of tools
- What is the role of man-built infrastructure on the exposure (e.g., number of buildings, location, etc.) vs. the physical one?
- Satellite data is great but what about “temporal” coverage?
- Linking socio-economic vulnerability with climate impacts
- Access and acquisition of financial data (e.g., property values, rentals, managers portfolios)
- Lack of inter- and trans-disciplinary collaboration to “converge” towards common goals and actions
What is the role of man-built infrastructure on the exposure (e.g., number of buildings, location, etc.) vs. the physical one?

Test case # 1: Exposure of properties to Hurricane Florence (2018) based on urbanization rate
The “Bull-eye” expanding effect

Map of inundated areas estimated by FEMA (red) and through the Sentinel1 radar images (blue). The inset in the top left corner shows the footprint of the several radar images to create the composite water extent map.

Distribution of properties and the Hurricane Florence when it landed

Property data provided by ATTOM ®

Tedesco et al., NHESS, 2019

Formed: August 31, 2018
Dissipated: September 18, 2018
Highest winds: 1-minute sustained: 150 mph (240 km/h)
Lowest pressure: 937 mbar (27.67 inHg)
Fatalities: 24 direct, 30 indirect
Damage: $24.23 billion (2018 USD)
Areas affected: West Africa, Cape Verde, Bermuda, East Coast of the United States (especially The Carolinas, Atlantic Canada)
Exposure and urbanization

Estimated property value (in 2018 US Billion$) exposed to the flooding generated by Florence based on the distribution of properties

Tedesco et al., NHESS, 2019
Estimated property value (in 2018 US Billion$) exposed to the flooding generated by Florence based on the distribution of properties

Tedesco et al., NHESS, 2019
Estimated property value (in 2018 US Billion$) exposed to the flooding generated by Florence based on the distribution of properties.

Tedesco et al., NHESS, 2019
Estimated property value (in 2018 US Billion$) exposed to the flooding generated by Florence based on the distribution of properties

Tedesco et al., NHESS, 2019
Estimated property value (in 2018 US Billion$) exposed to the flooding generated by Florence based on the distribution of properties.

Tedesco et al., NHESS, 2019
Addressing “coverage” issue of satellites …

Test case # 2: Using passive microwave data for filling spatio-temporal gaps
Satellite coverage (spatial and temporal)

- Satellites can provide crucial information for floods management and mapping but limitations exist due to clouds or repeat time
- Despite recent advances in satellite data availability and technology, limitations still exist
  1. Optical Data limited by passing time and clouds
  2. Radar data limited by narrow spatial coverage and repeat time

Passive microwave data can help in this regard

  1. Longer satellite data record (since 1979)
  2. Global daily coverage (99.9 % coverage daily)
  3. No impact by clouds and small impact by rain
  4. Can see “through” vegetation and other “obstacles”
  5. Highly sensitive to water
Passive microwave has been historically delivered at coarse spatial resolution (e.g., tens of Km).

This has made difficult its use in flood mapping and services.
PMW spatial resolution

Passive microwave has been historically delivered at coarse spatial resolution (e.g., tens of Km)

This has made difficult its use in flood mapping and services

We have addressed this issue by employing a spatially enhanced product
KHARTOUM, 23 AUGUST 2019 - Heavy rains and floods across Sudan have affected over 190,000 people in 15 different states in the country including Khartoum. 60 people were reportedly killed in affected areas.
Sudan flood of August 2019

**Signal C/M 37GHz H-pol**

- **37H-207th day of the year**
- **37H-225th day of the year**
- **37H-246th day of the year**

*Flood*
Application to 2005 Bangladesh flood

Optical image
Inundated area = 9777 Km$^2$

Passive microwave data can “see” through clouds
Linking socio-economic vulnerability with climate impacts

Test case # 3: Climate gentrification and floods in Florida
CG is based on a simple proposition: climate change impacts arguably make some property more or less valuable by virtue of its capacity to accommodate a certain density of human settlement and its associated infrastructure.

The implication is that the price volatility associated with rent seeking, speculative investment, or superior purchasing power is either a primary or a partial driver of the patterns of urban development that lead to displacement (and sometimes entrenchment) of existing populations consistent with conventional framings of gentrification.
The little River/Little Haiti case

Little Haiti residents forced from home again as climate change upends Miami real estate

Miami Little Haiti Landlord-Developer Evicting Tenants From Complex It Wants Redeveloped

Little River/Little Haiti case

By THE DAILY ACT   Monday, April 11, 2023

Little Haiti residents forced from home again as climate change upends Miami real estate

Watch CBSN Live
Police car drives through crowd in Tacoma, Washington, leaving two people injured
President Biden reviews travel ban as new COVID strains emerge
Video of baby carrots South Korea Zun goes viral with more than 4 million views
Dr. Fauci says COVID variants complicating response; Dr. Blount speaks on working with Trump’s White House
Chiefs and Buccaneers to square off in Super Bowl LV

Follow Us:

Latest From ‘60 Minutes’
ICYMI: A look back at Sunday’s ‘60 Minutes’

Miami Little Haiti Landlord-Developer Evicting Tenants From Complex It Wants Redeveloped

SPV Realty is within its right to have filed a 29-plaintiff suit at its Design Place apartments amid the pandemic as the state moratorium was lifted. But residents and a nonprofit law firm say the suit to evict struggling tenants doesn’t match the company’s promise to accommodate residents at its proposed Latetstone Ridge project.

By LITTLE HAITI   December 23, 2020 at 07:48 PM

A rendering of the proposed Latetstone Ridge project that would rise on 22.5 acres on the southwest...
## A Climate gentrification/flood tool

<table>
<thead>
<tr>
<th>Name</th>
<th>Variables</th>
<th>Sector</th>
<th>Spatial</th>
<th>Temporal</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rental Price</td>
<td>Price</td>
<td>Real Estate</td>
<td>Zip Code</td>
<td>2014 – 2020</td>
<td>Zillow</td>
</tr>
<tr>
<td>Demographics and socio-economic data</td>
<td>Poverty, unemployment, PCI, minority, etc.</td>
<td>Socio-Economic Exposure</td>
<td>Census tract</td>
<td>2010 - 2018</td>
<td>CDC</td>
</tr>
<tr>
<td>Evictions</td>
<td>- Number of requested and performed evictions</td>
<td>Real Estate</td>
<td>Census tract</td>
<td>2010 - 2018</td>
<td>Evictionlab.org</td>
</tr>
<tr>
<td></td>
<td>- Demographics and ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of rental</td>
<td>Percentage of rental properties in the area</td>
<td>Real Estate</td>
<td>Census tract</td>
<td>2014 - 2018</td>
<td>County</td>
</tr>
<tr>
<td>National Risk Index (NRI)</td>
<td>- Risk Exposure to Riverine and Coastal flooding</td>
<td>Exposure Socio-Economic</td>
<td>Census tract</td>
<td>2014 - 2018</td>
<td>FEMA</td>
</tr>
<tr>
<td>Seal Level Rise</td>
<td>Projection of inundated areas for different SLR scenarios</td>
<td>Exposure</td>
<td>Shapefile</td>
<td>N/A (1 ft through 10 ft)</td>
<td>FEMA</td>
</tr>
<tr>
<td>Opportunity Zones</td>
<td>Boundaries of areas designated as Opportunity Zones</td>
<td>Real Estate/Exposure</td>
<td>Census tract</td>
<td>2017</td>
<td>HUD</td>
</tr>
</tbody>
</table>

A tool to identify and address drivers of climate gentrification associated with floods and real estate market (specifically rent in this case)
Little River / Little Haiti is properly identified by the tool as exposed to GC associated with rent increase exceeding national average.
Little River / Little Haiti is properly identified by the tool as exposed to GC associated with rent increase exceeding national average.

High percentage of people living below poverty level

LOW PCI (e.g., between 5k and 10k US$/year)

High concentration of African-American

Low Education
Gentrification between 2014 and 2018

Reduction of percentage of people below poverty level and in number of people with only high school diploma
Total evictions

High number of evictions in Little River

Low number of evictions in Biscayne
Total evictions

High number of evictions in Little River (gentrifying area) vs an almost absent number of evictions for the contiguous area (non gentrifying)

Cumulative evictions between 2014 and 2018

Low number of evictions in Biscayne
The house sale market supports GC process

- Average prices for home sales begins increasing in Little Haiti in 2014, where we identify the gentrification process starting

- House prices skyrocketed in the gentrifying region.

- This did not happen in the contiguous area, where gentrification is not occurring.
Some final thoughts …

• Floods are currently impacting many sectors of the financial, social and economic systems and this will increase in the future.

• Remote sensing technologies can provide data at daily (or sub-daily) temporal scales globally, paving the way to service-oriented products through the merging with models, in-situ data and machine learning technologies.

• Properly quantifying the role of urbanization on exposure is key to plan future cities accordingly.

• Socially vulnerable people are already impacted by floods in direct and indirect ways and quantitative information is crucial for, for example, advocacy groups.

• Inter-disciplinary and cross-disciplinary collaborations are crucial for the necessary “convergence” toward implementation of solutions for local communities or governments for undertaking proper measures towards increasing resiliency and developing adaptation measures (please contact me if you are interested in being involved in an ongoing effort in this regard).
Thank you!

mtedesco@ldeo.columbia.edu
Or
cryocity@gmail.com
@cryocity