WHAT IS THE VALUE OF MANGROVES IN REDUCING THE COST OF STORM SURGES?

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BACKGROUND & MOTIVATION

Who is **RMS?**

- RMS produces models used to quantify & manage catastrophe risk
- Work with most major global insurers and reinsurers
- $2 trillion worth of insurance and capital markets transactions based on RMS risk models

Which **natural hazards** does RMS model?

- Earthquakes, winter/tropical/convective storms, inland floods, […]
- RMS clients (insurers/reinsurers) use our models to **estimate their annual losses** & other risk metrics from these perils
- Here, we focus on **tropical cyclone-driven storm surge flooding**

How do mangroves come into this?

We & our partners(*) wanted to ask the question:

Can we put a price on the risk reduction benefit of mangroves?

In other words, can we answer questions like:

- When a storm hits, how much do mangroves protect properties behind them from coastal flooding?
- Is any benefit significant in economic terms?
- What is the $ value of avoided annual losses (on average) due to mangroves being present?

And ultimately:

- **Should (re-)insurers care whether the properties they insure are “protected” by mangroves?**

(*) This study was carried out in collaboration with our partners at University of California Santa Cruz & The Nature Conservancy

Are mangroves important for storm surge risk reduction?

Mangroves can attenuate storm surge propagation inland by dissipating energy

- But depends on many factors, e.g. storm duration, severity, mangrove extent & quality (cf. Zhang et al. 2012; Montgomery et al. 2019)
- Various studies have estimated physical and/or economic impact of mangroves in specific locations

- Our aim: to estimate **physical & economic impact** of mangroves over
  - **a) Large space-scale** (100s-100km)
  - **b) Full spectrum of *all possible* TC-storm surge events** which could hypothetically hit that region

(we need to consider *all* possible storms which could affect the region, and their frequency, if we want to calculate average annual losses, rather than simply estimate losses from a few specific storms from history)

Are mangroves important for storm surge risk reduction?

For this study we focus on Southern Florida (USA)

Mangrove extent shown in dark green
Base layer: Google Satellite

This region has:
- extensive mangrove forests,
- high concentration of properties,
- and high frequency of damaging storms

Some recent storms to have impacted the area include:
- Andrew (1992)
- Charley (2004)
- Wilma (2005)
- Irma (2017)

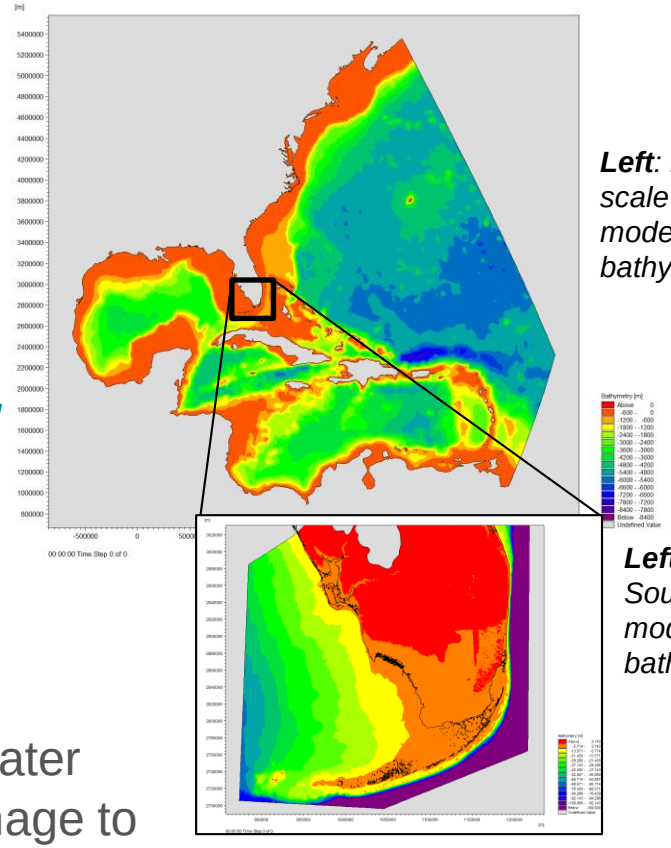
Our Tropical Cyclone (TC) storm surge **catastrophe modelling** framework

1) Generate set of **1,000s of synthetic TCs** designed to span the range of the physically possible in FL

2) Simulate **surge + tide propagation during each event** over all area affected
   - Depth-integrated hydrodynamic model spanning Western Atlantic & Gulf of Mexico
   - Nested high-resolution models simulate propagation close to shore & onto land

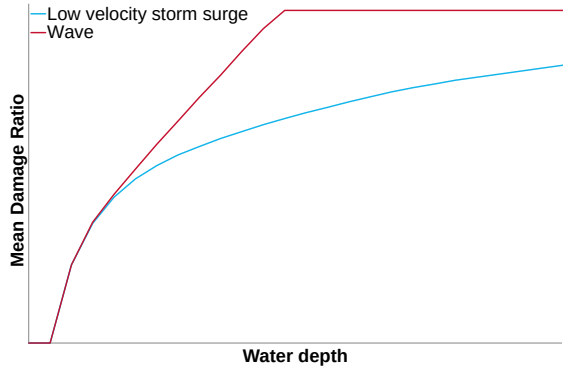
3) Apply **vulnerability functions** to translate water depth at property locations into physical damage to property, expressed as % of value

4) Financial model translates property damage into **economic loss to insurer**
   - Can calculate **average annual loss** (**AAL**) from all TC events
   - And many other risk metrics – e.g. probability of exceeding $X loss/year



***Left**: RMS large-scale surge model bathymetry*

***Left**: RMS South-FL nested model bathymetry*



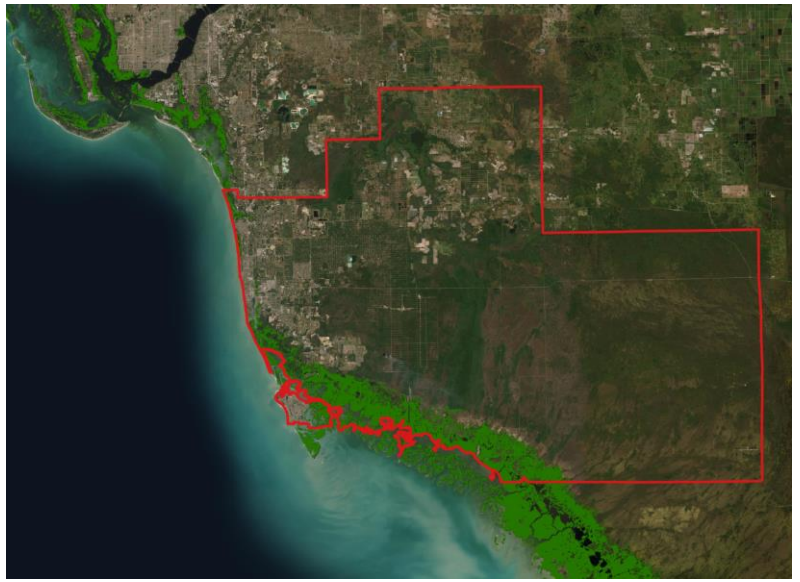
***Above**: Sample storm surge vuln. functions for locations experiencing low-velocity & high-velocity wave action*

Our study:

Impact of mangroves on AAL in Collier County

- **Aim**: quantify the impact of existing mangrove forests on Average Annual Losses (AAL) from TC-storm surges

- **Where**: we focus on Collier County, Florida
  - Contains extensive mangroves
  - High total insured property value
  - Significant modelled TC surge risk



Collier County, FL
Green overlay: mangrove extent

- **How**: scenario-based modelling
  - Simulate the disappearance of all mangrove forests in the county using hydrodynamic modelling
  - Calculate AAL to all insured properties(*) in Collier county considering "present-day" and "no-mangroves" scenarios
  - Quantify the change in AAL between caused by removal of all mangroves
    (cf. Appendix #1 for more info on methodology)

(*) AAL is calculated using RMS's Industry Exposure Database (IED) – an RMS model database estimating the location & characteristics of all insured properties in the USA

Results:

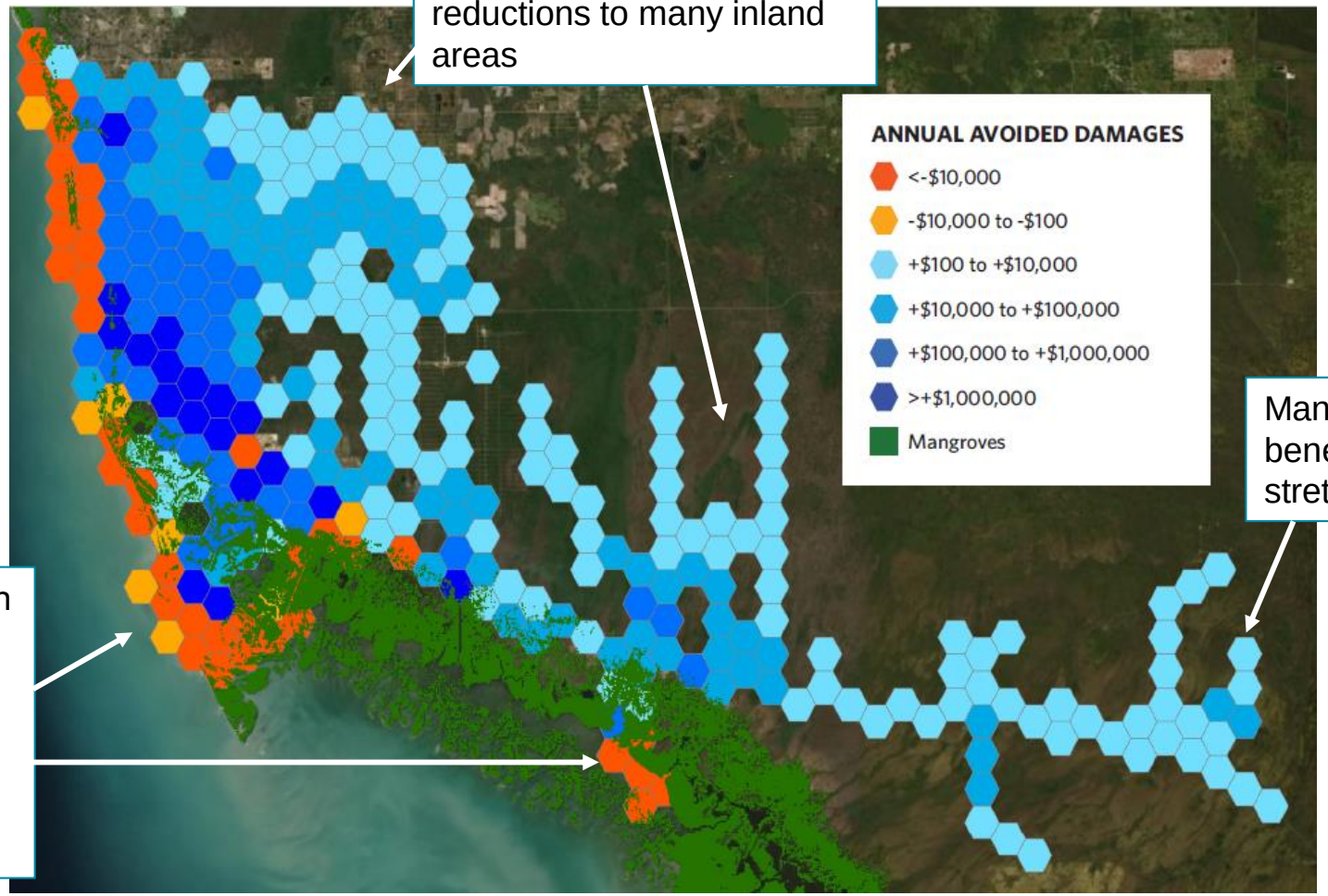
Impact of mangroves on AAL in Collier County

- **Overall, mangroves reduced county-wide AAL by 12%**
- **High geographical heterogeneity** (cf. next slide) – mangrove presence increases losses to many high-value properties constructed seaward of mangroves
  - Considering only properties located behind mangroves, **mangrove presence reduces AAL by 26%**
  - **Average benefit of $540/hectare per year** across these properties

Results:

Impact of mangroves on AAL in Collier County – geographical heterogeneity

Mangroves along the coast offer v significant AAL reductions to many inland areas



Mangrove benefits can stretch far inland

… but mangroves can cause also losses to increase in areas seaward of forests - eg. developments built on pre-existing coastal mangroves

Note: hexagons are only shown for areas where change in annual avoided damages is >$100

Map shows the effect of mangrove presence on Average Annual Losses (AAL)

- **Blues**: mangrove presence causes **lower losses** in these areas
- **Red**: mangroves cause **higher losses** here
- **Green** overlay shows the extent of mangrove forests

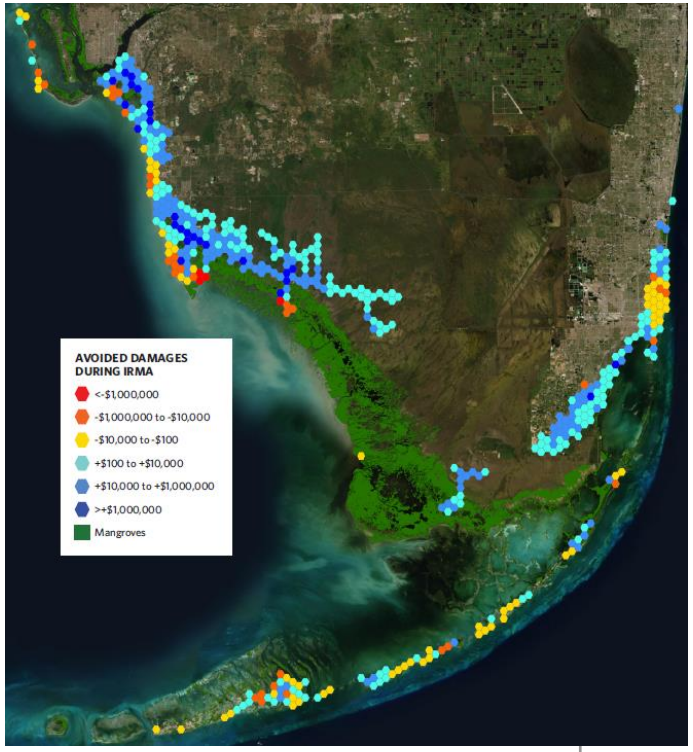
Base-map from ©ArcGIS Online

Extra case study: Hurricane Irma

As a case study, we also simulated **Hurricane Irma** considering a total loss of mangroves in FL:

- Removal of mangroves would cause total property loss estimate from Irma to **increase** by between $700 Million and $1.5 Billion
- Again, we see high geographical heterogeneity:
  - Coastal mangroves are estimated to have **protected many properties inland of them** from damage
  - But properties built **seaward of mangrove forests** may have seen a negative impact
- This work is still ongoing & **results shown are preliminary**

Map showing difference in modelled Irma coastal flood damages, to all properties, between the with-mangrove and no-mangrove scenarios



Conclusions

- We used a **catastrophe modelling approach** to estimate the effect of Florida's mangroves on storm surge risk to properties
- We estimate that coastal mangroves are causing a **significant reduction in flooding risk** to properties behind them in Collier County, FL
  - Properties located behind coastal mangroves can **receive significant economic benefits**, in terms of avoided flood damages
  - Benefits can extend to properties located far inland
- … but the effect is **spatially heterogeneous;** notably properties built seaward of mangroves are potentially at higher risk
  - Developers would be wise to account for surrounding land use when siting new developments
- We estimate that mangroves saved hundreds of millions of dollars in damages during Hurricane Irma (2017)

Further reading:
(references on next slide)

Narayan et al. (2017)

A similar study into the value of salt marshes in reducing surge risk in North-East USA

Estimated marshes avoided ~$600M damages during Hurricane Sandy

Narayan et al. (2019)

Contains results from the mangroves study described in these slides

Thank you for reading all the way to the end!

All questions or comments are very welcome!

EGU Session chat: Thursday 7 May from 16:15 to 18:00 CEST (15:15 to 17:00 BST)

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Appendix 1:

A quick note on calculating the “no-mangroves” scenario AAL

- Rerunning the hydrodynamic model for every synthetic storm event in our catalogue which hits Collier County is computationally very expensive
- Instead, we select a subset of 100 events which are representative of the complete distribution of storms for the region
  - The subset recreates the original County-wide AAL with an error <0.05%
  - Other metrics are also reproduced with low errors – e.g. the contribution to the total AAL from events whose Return Period is lower than 100yrs has an error of <0.1%
  - Note that errors will increase as you focus on smaller geographic units, but are acceptable down to sub-ZIP-level
- The hydrodynamic model was rerun for these 100 events, with areas covered by present-day mangroves considered to have lower surface roughness to simulate their disappearance
- The AALs of the “no-mangroves” scenario was then compared to the “present-day” AAL to obtain the results shown in the preceding slides
- More information can be found in Narayan et al (2019) Technical Appendix: http://www.conservationgateway.org/SiteAssets/Pages/floridamangroves/Mangrove_Report_Technical_Apprendix_FINAL.pdf

ABOUT RMS

RMS is the world's leading provider of products, services, and expertise for the quantification and management of catastrophe risk. More than 400 leading insurers, reinsurers, trading companies, and other financial institutions rely on RMS models to quantify, manage, and transfer risk. As an established provider of risk modeling to companies across all market segments, RMS provides solutions that can be trusted as reliable benchmarks for strategic pricing, risk management, and risk transfer decisions.