Climate informed catastrophe models - building and selling science

My 20+ year journey through the cat modeling industry

Dag Lohmann, 2026

KatRisk

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What I will talk about

- What are catastrophe models? Answer: The only tool capable to make decisions about extreme events
- A quick story how we started
  - Founding Team (full team at katrisk.com/About) – the skills needed
  - Timing, Financing, Planning, Good and Bad Choices, Luck (R in 64 Bit, GPU & Super Computing Grant)
- Products
  - From flood maps to correlated weather probabilistic models
  - Expanding the product line
- Science
  - Model science (Frequency, Severity, Correlation) & Vulnerability
  - Climate Variability & Climate Change
- Platform
  - Simulation (what's important, what not to do, shortcuts, intellectual property vs. making everything open)
  - Data formats (exposure, output, log files, exposure conversion)
  - Programming languages (everybody at KatRisk uses R, but we need speed for simulations)
  - Financial Model
- Funny things we did – thinking we would be on to something

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Background

13+ years older

KatRisk was a 100% employee / founder owned catastrophe modeling company formed in 2012.
We sold the company in 2023 to TA.

We service clients largely in the insurance industry

- Four of the largest 5 worldwide reinsurance brokers
- Four of the top five worldwide non-life reinsurers
- Four of the top 15 worldwide property insurers
- The U.S. Federal Emergency Management Agency (FEMA)
- The Philippines Government (Flood Model on OASIS)
- The Canadian Government
- Close to 100 clients total

About Dag (h-index = 32)
Ph.D. in Hamburg (Germany) 1996
Princeton Postdoc
NOAA/NCEP/EMC 1999 – 2004
RMS 2004 – 2012
KatRisk CEO 2012 – 2024, now adviser

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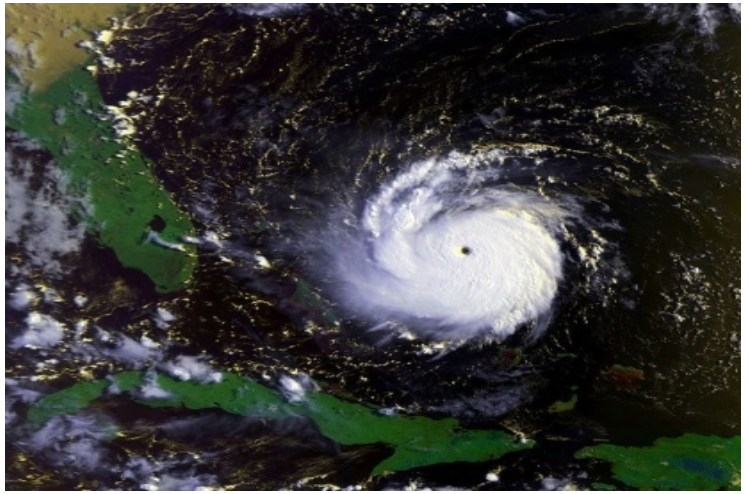
History of Catastrophe Models



- AIR (1987) and RMS (Stanford, 1988) founded
  - Build first EQ and hurricane models
- 1992: Hurricane Andrew
  - $16B insured losses
  - 11 insolvencies
- 1994: Northridge Earthquake
  - $12B insured losses
- 1996: First cat bonds, Rating Agencies require cat loss information
- 2001/2002: WTC and first terrorism model
- 2005: Hurricane Katrina
  - $40B insured losses
  - 0 insolvencies

Timeline and Milestones

I know…..
a bad slide

July 2012: Start
Guy, Stefan, Dag

July 2012: Buy Computers
Sandy Bridge
GPUs

2012: R Shiny

2013: first TC Wind Models

2013: R 64 Bit

2013: Vulnerability Wind / Flood

2013-2017: Global flood maps + SS on AWS

Spring 2016: Start to hire

Spring 2017: SpatialKat TC Wind + SS

2014-2015: R Simulation Prototypes

Dec 2012: SST & Precip Model

May 2014: US 10m maps
Location Loss

May 2013: First flood maps,
Titan GPU Grant
Plan for models
and first client

Aug 2017: SK Wind,SS,IF

Aug 2017: Harvey

July 2018: 1st FEMA Cat Bond

2017 - 2023: Financial Model
Exposure Conversion
More Vulnerability

2020: EU Flood Model

2019-2023: FEMA Cat Bonds

2020: Global TC Wind Model

2019: Location APIs

2018: climate change

2022: OASIS Philippines

May 2022: Forecast

Aug 2022: GeoKat

Mar 2023: Australia TC/SS/IF

March 2023: CMIP6 CC

Oct 2023: Sold to TA

2024: Severe Storm

2025: Wildfire & TBA

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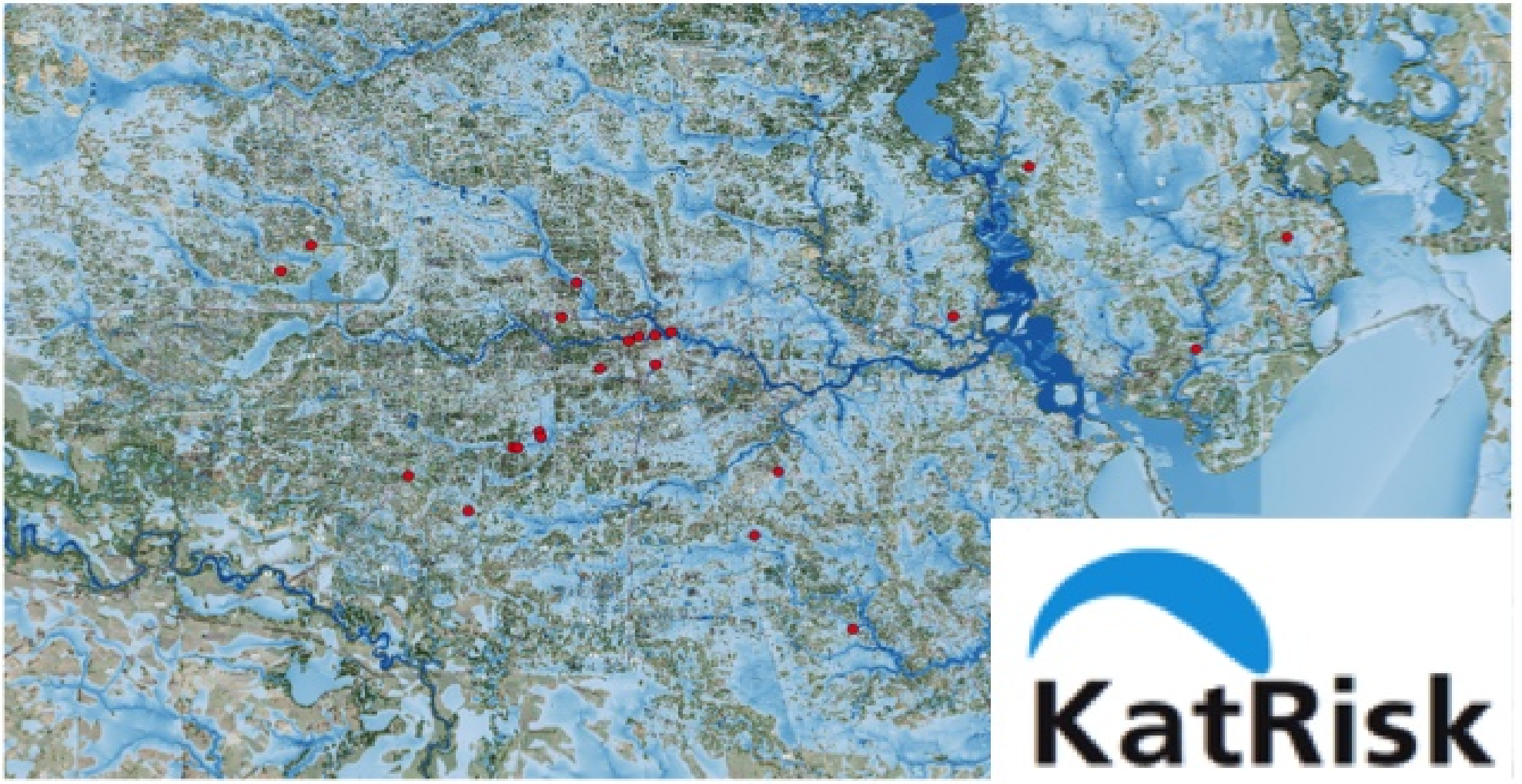
Event Footprints = Loss producing hazard (Harvey)

- Loss estimates based on KatRisk footprints
- 8.8 million point IED in Texas
  - $45 Billion GU Inland Flood Loss
  - Large demand surge (1.4?) + wind and storm surge (~$2 Billion) + other areas

    ~ $80 Billion

Houston Area Overview



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What's now and in the future?

Peril / Time	Core Cat Model Cat Response	1 - 10 day Forecast	Climate Variability / Seasonal Forecast	Climate Change (2025 - 2100)
Flood	50k yr stochastic Observations	KatGFS Return period forecast (Obs + NWP based)	Global SST driven (VARMA model)	Change in local frequency / severity
TC Wind + Storm Surge	50k yr stochastic Observations	Observed and forecast track / track ensemble	SST teleconnections (ENSO, Atlantic SST) from global SST model	Change in local severity Change in sea level
Severe Storm	50k yr stochastic Observations	Public data Event Set Conditioning	Trans-Niño index (TNI)	Change in local frequency/severity
WildFire	50k yr stochastic Observations	Public data Event Set Conditioning	Precipitation driven from Flood model	Change in size / frequency

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Thoughts on climate and cat models

Topic	Climate and NWP Models	Catastrophe Models
Time Horizon	real-time to centuries	This year to next 5 years
Techniques used	Fluid mechanics on grids As physically based as possible	Stochastic representation of key processes Fluid mechanics on grids
Number of ensembles	1 to 1k	10k to 1000k for extreme events in time horizon
Coverage	Regional to global	Regional to continental
Spatial resolution	1km to 500km	10m to 10km
Good at	Slow varying variables (temperature, sea level rise) Physical feedback in system	Low bias (calibrated to reality) Extreme events Calculates financial impact
Bad at	Extreme events (especially coarse climate models – e.g. hard time to reflect cyclones)	Cross peril and country correlations Complex interactions
Availability / Price	Open source / free Complicated and expensive to run	Commercial black box / expensive / easy to run

What are Catastrophe Models doing?

- Three basic business processes:
  - Underwriting
  - Portfolio Management
  - Risk Transfer
- Underwriting needs information about local risk at the location level and its surrounding area
- Portfolio Management needs information about correlation between locations and aggregation of risks
- Risk Transfer relates to finding the right price for risk when passing risk to another party

What is at the heart of catastrophe models?

- Frequency
  - How often does a hazard of a certain type strike in each individual location?
  - Good example of this are FEMA flood maps
- Severity
  - Given that you have a hazard, how severe is it?
  - A good example are our KatRisk flood maps
- Correlation
  - What are the correlations of frequency and severity between any two locations?
  - Since the correlation structure is quite complex, we normally resort to a location / event loss table

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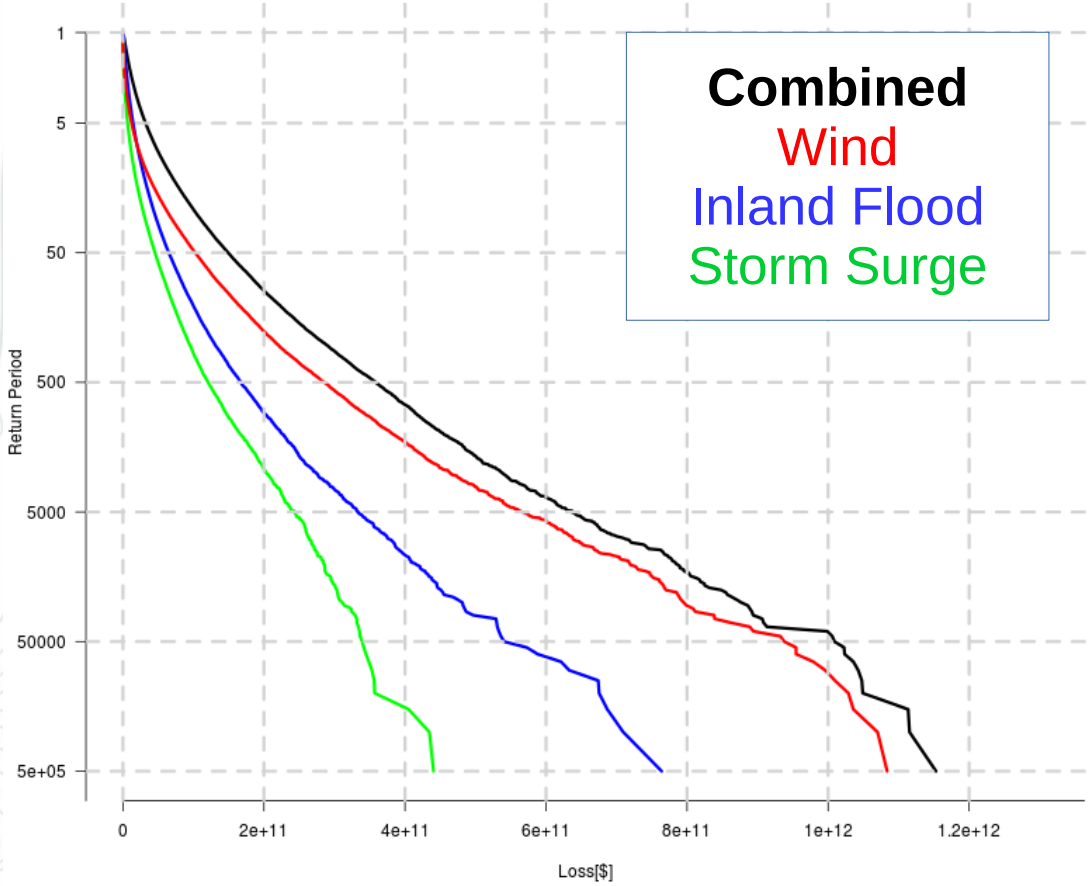
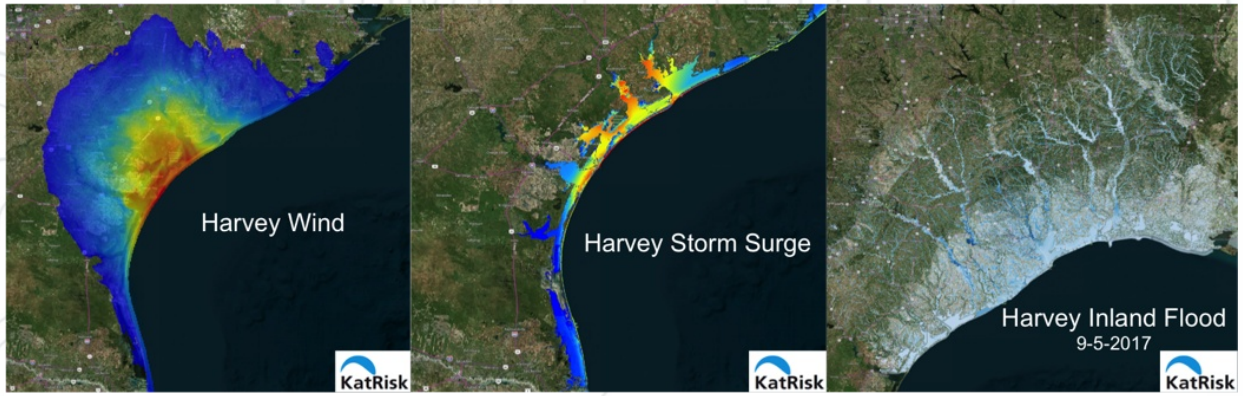
Risk Models – Event Footprints

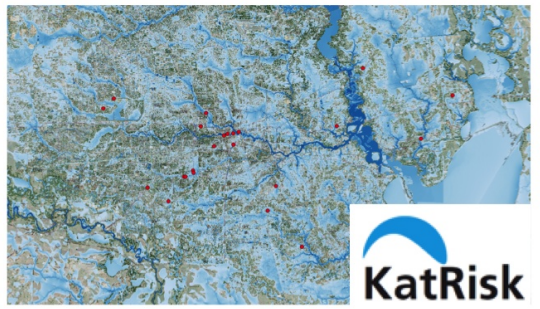
USA all perils (TC, IF, SS): Combined Analysis: Three LOBs,
10 samples, average vulnerability, no climate change
Minutes to run for 1 Million sample locations (25 cores)
30x faster than any other platform



Harvey Event Response
Rapid hazard and loss response based on forecasts and observations



Houston Area Overview



Downtown Area

Provided for all major storms and floods
in SoloKat, SpatialKat, TIF

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The event loss / damage ratio table

Event \ location	Loc 1	Loc 2	Loc 3	Loc 4
Event 1	0%	1%	3%	5%
Event 2	3%	0%	2%	8%
Event 3	1%	3%	0%	0%
Event 4	0%	4%	6%	3%
Event 5	2%	2%	1%	0%

- The event loss table contains
  - For each event the damage ratio (or mean damage ratio) or loss per location
  - If there is uncertainty (or some distribution) around the mean, then this doesn't change the conclusion, although one must make assumptions about the correlation of the uncertainty and do sampling.
  - Whether one starts off a year loss table or event loss table doesn't matter
- This table can be split into two different data sets

  1) An event correlation table

  2) A marginal loss distribution for each location

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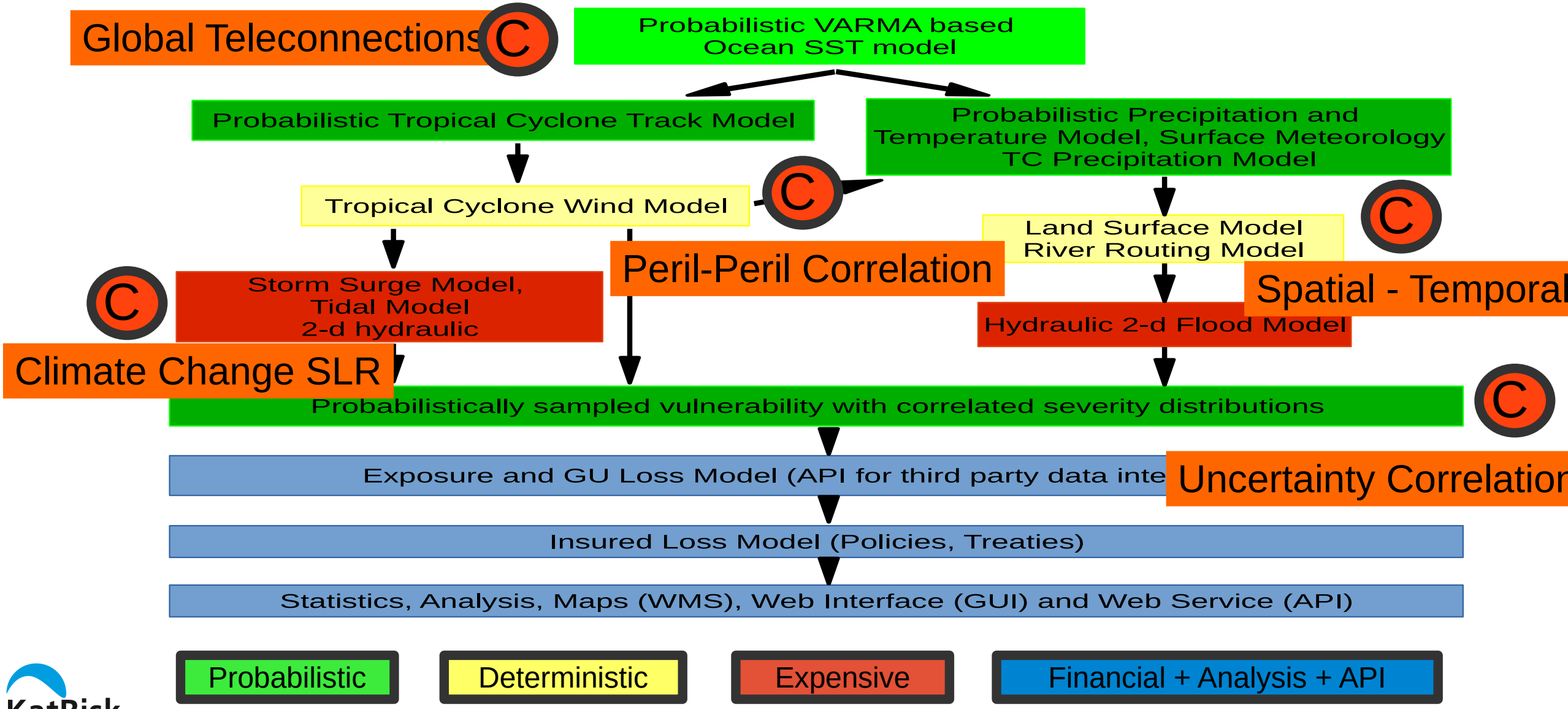
Teleconnections and Peril – Peril Correlation



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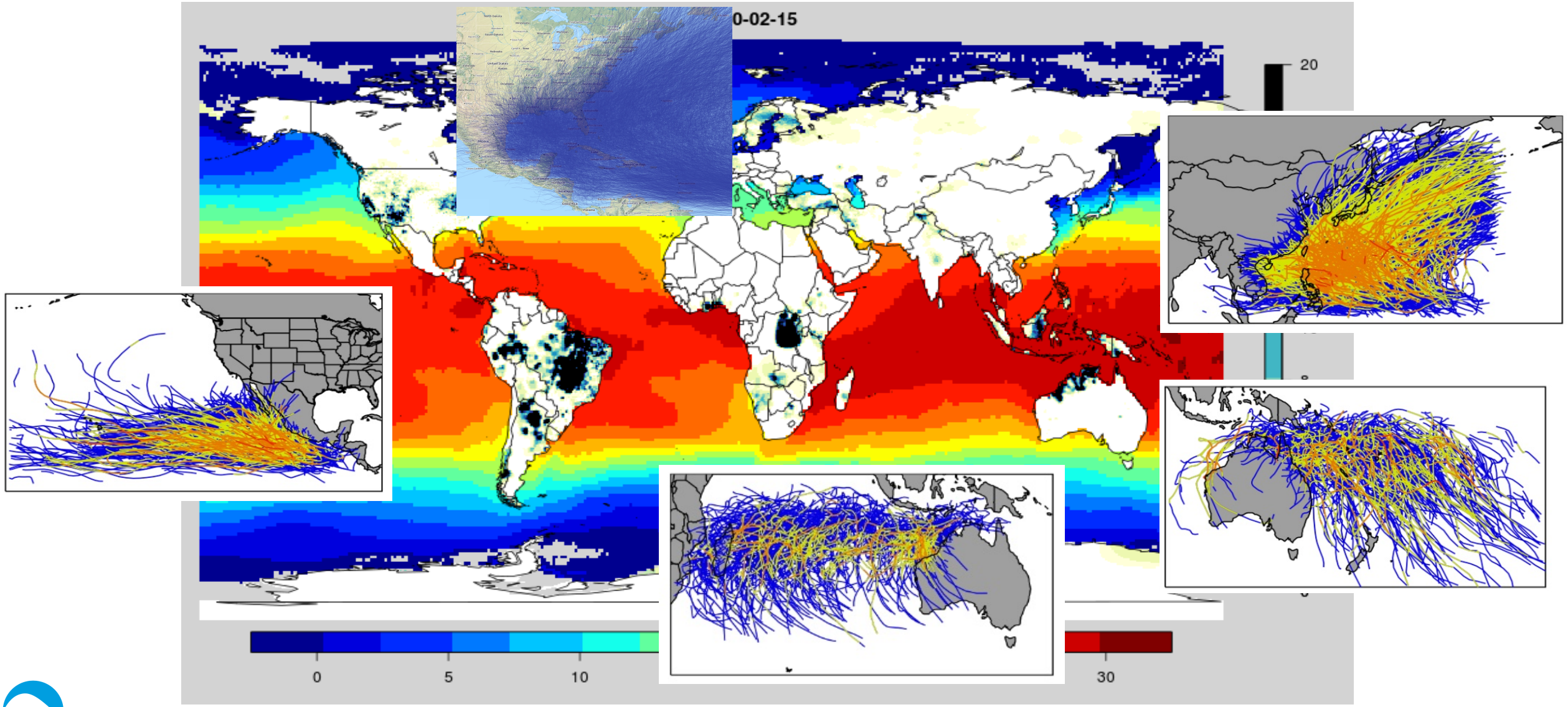
Climate Conditioned TC / Storm Surge / Flood Models



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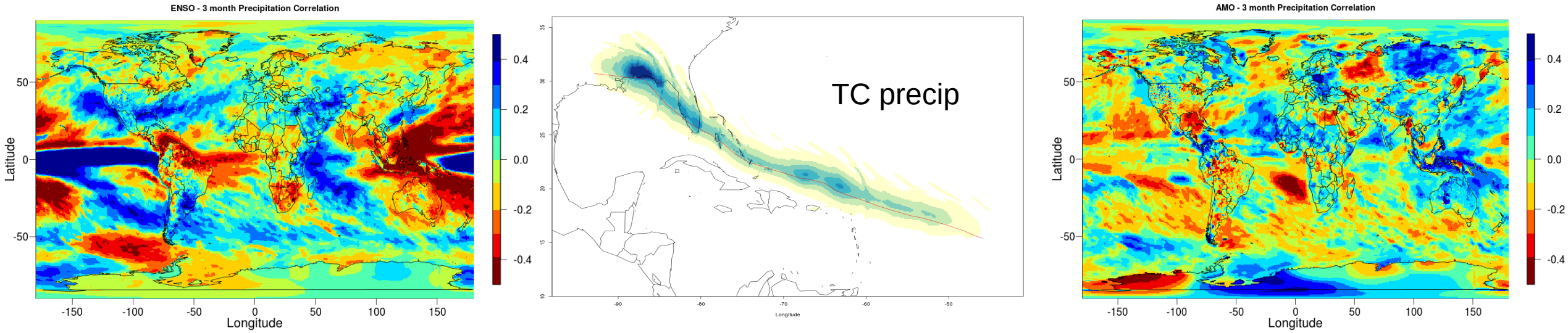
Flood Global Correlations with TCs

- Impact of teleconnections on global precipitation
  - Combine TC and non-TC precip
  - Base hurricane model and global precipitation model on same data set of global SST expressing natural variability and global correlations
  - **Correlate events between perils and continents based on SST**



ENSO

Three month lag anomaly correlation with PCAs

AMO

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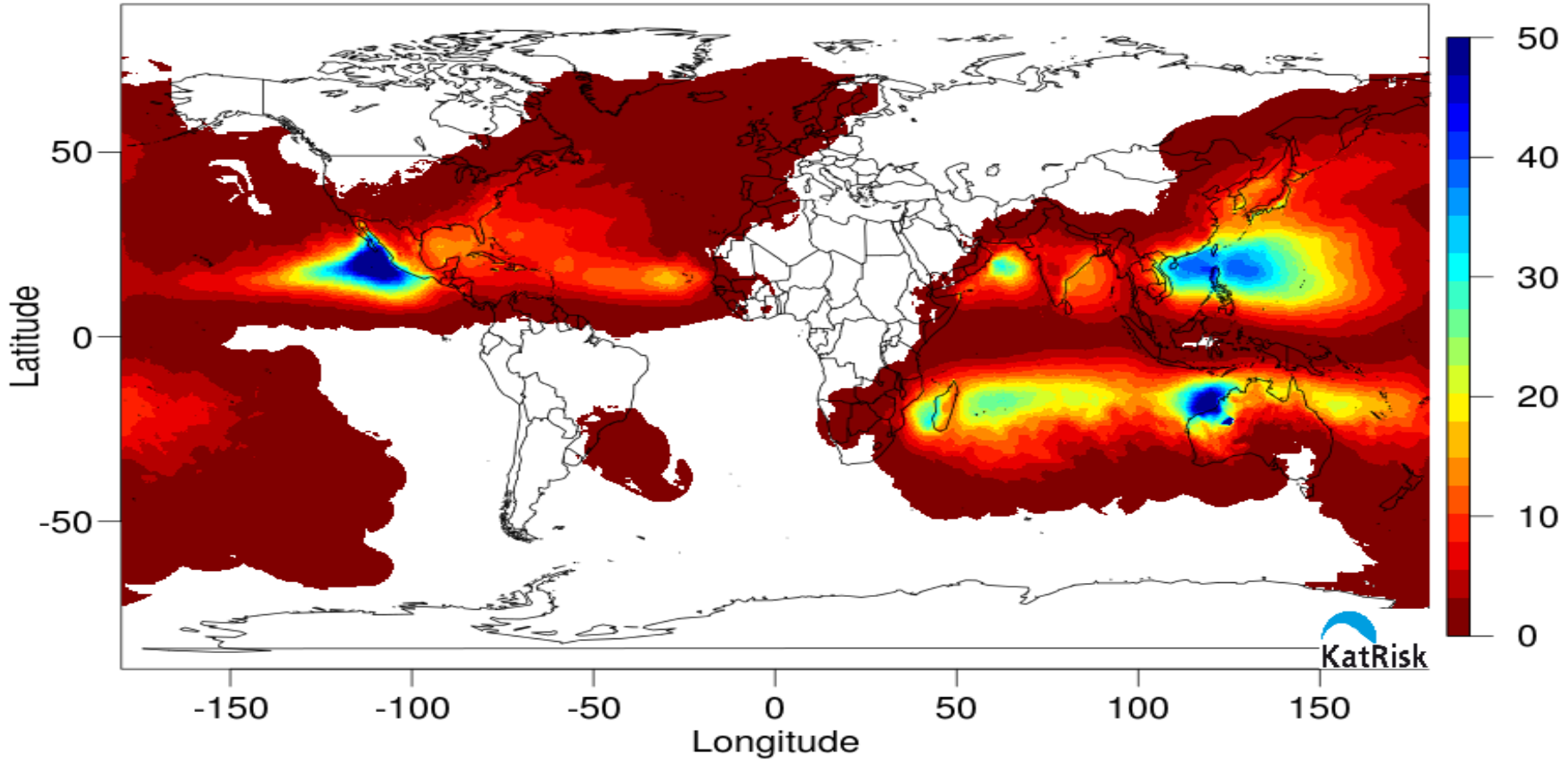
Fraction of Tropical Cyclone Rain [%]

- Tropical cyclones create a large fraction of the total precipitation amount in some parts of the world



Globally Correlated Cat Models

UNDERSTANDING CURRENT RISK

The opportunity	The goal	The questions
Provide the ability to quantify risk globally correlated for all weather perils based on simulations of global sea surface temperature.	Allow customers to accurately price and manage weather and climate risks globally with better representation of clustering.	Will this work? How important is this for clients? By working on this, there's other work we won't do!

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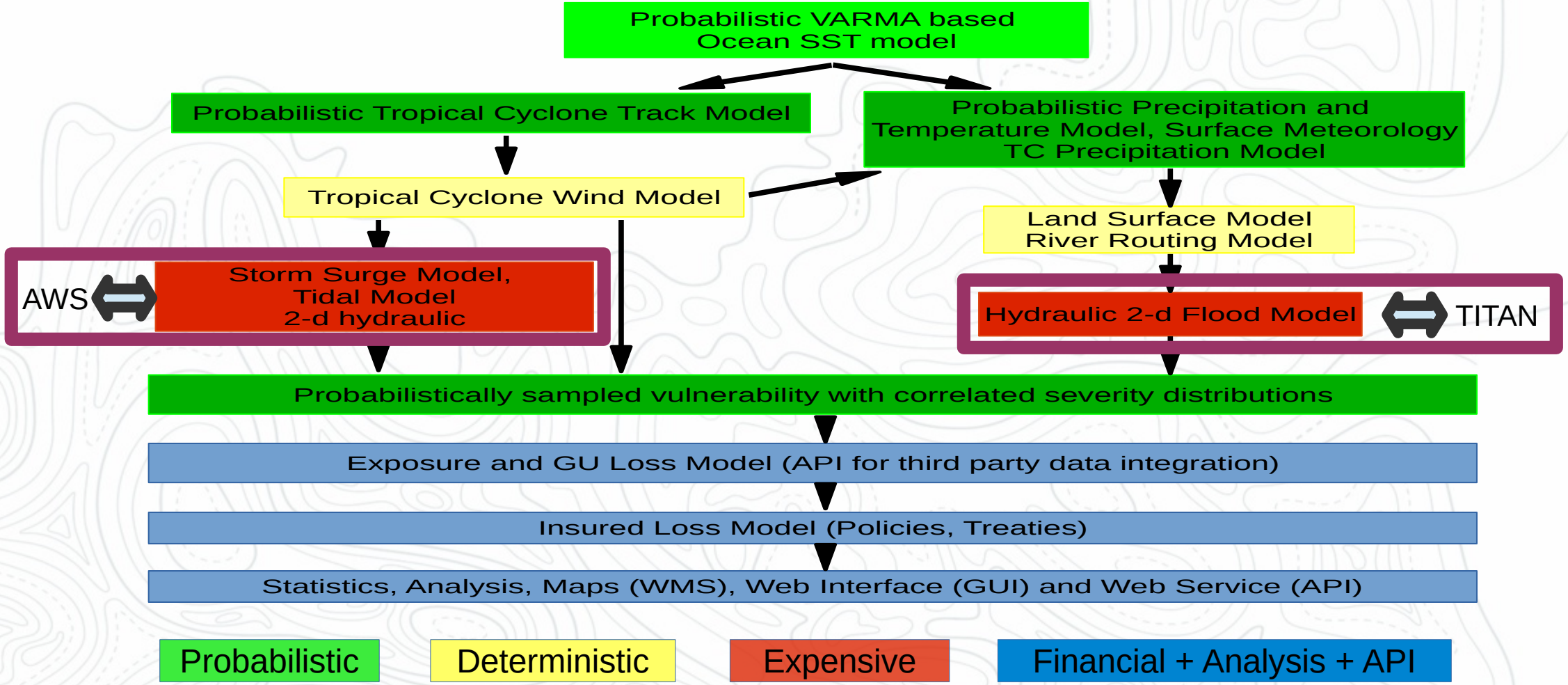
The Foundation: SST Correlation

We showed this 10 years ago at RAA 2016. All models since then fit into the same framework
We can compute any co-variate for models we want to release, e.g. TNI for US Hail model



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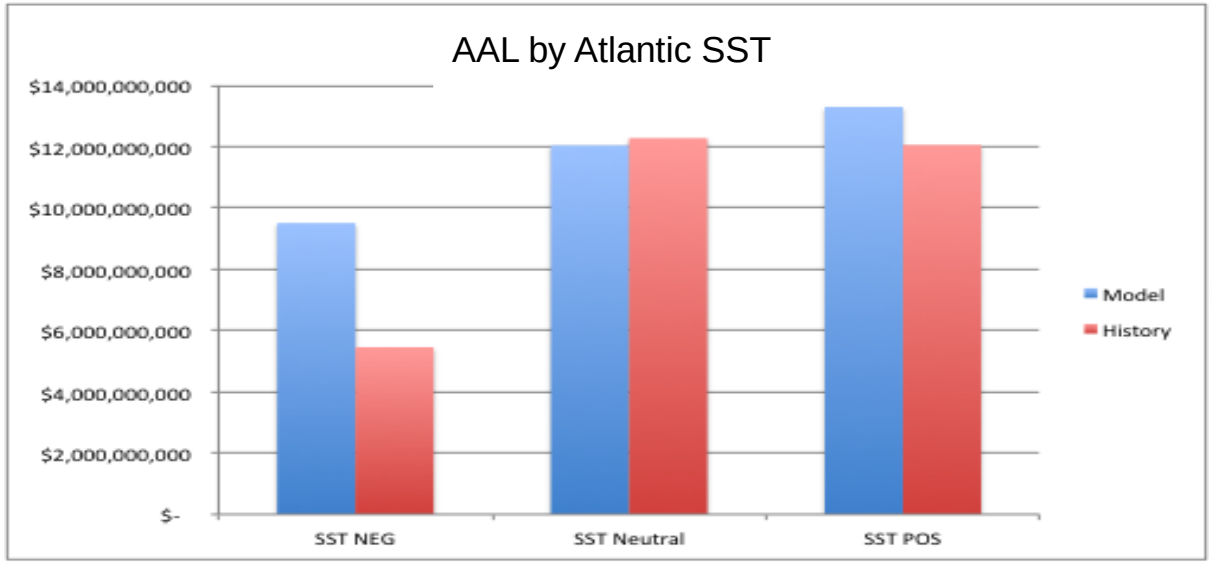
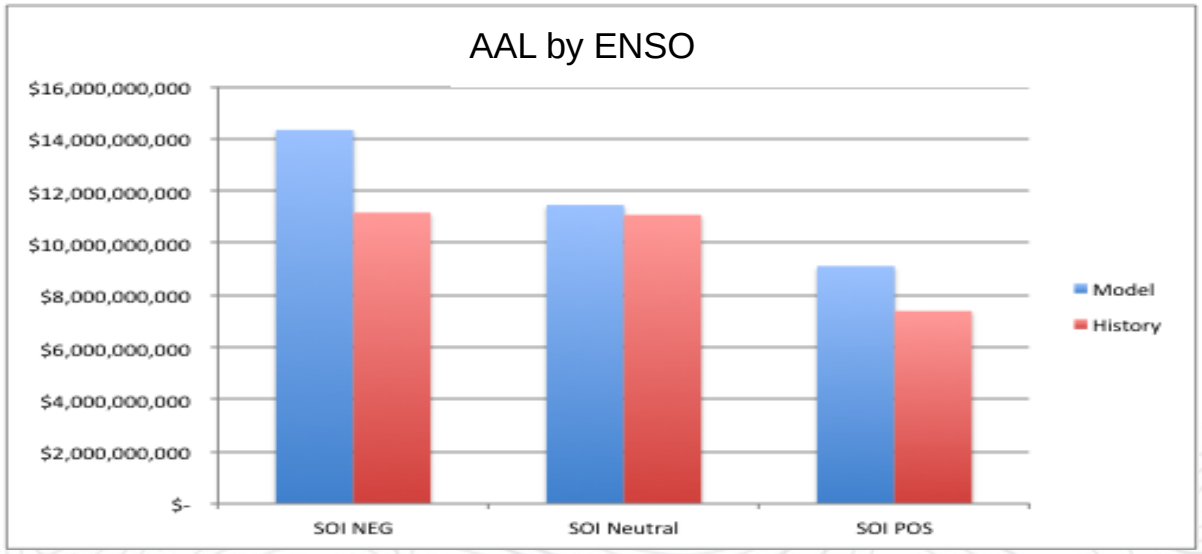
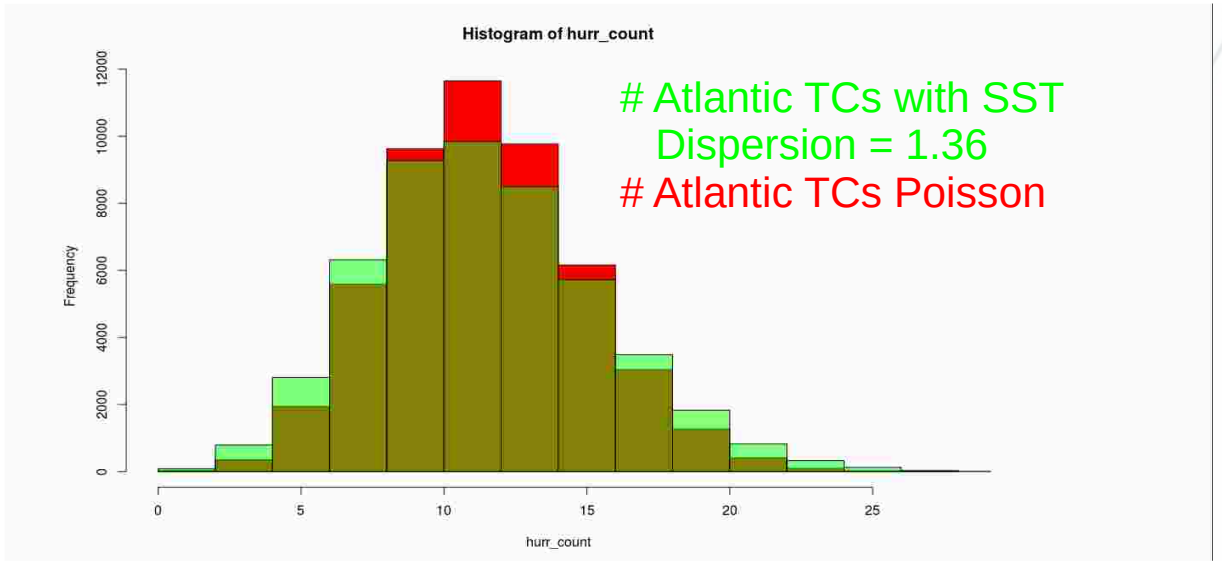
USA AAL by Atlantic SST and ENSO





Another important point: Can climate variability help us with thinking about climate change?

Introduction of SST leads to clustering



Hurricane losses dependency on Atlantic SST Anomaly and ENSO

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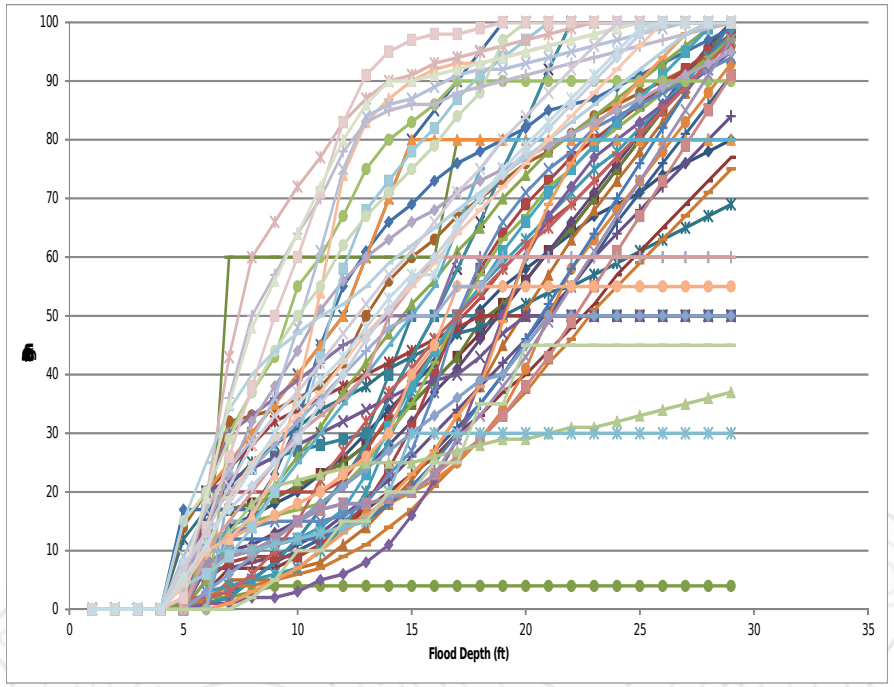
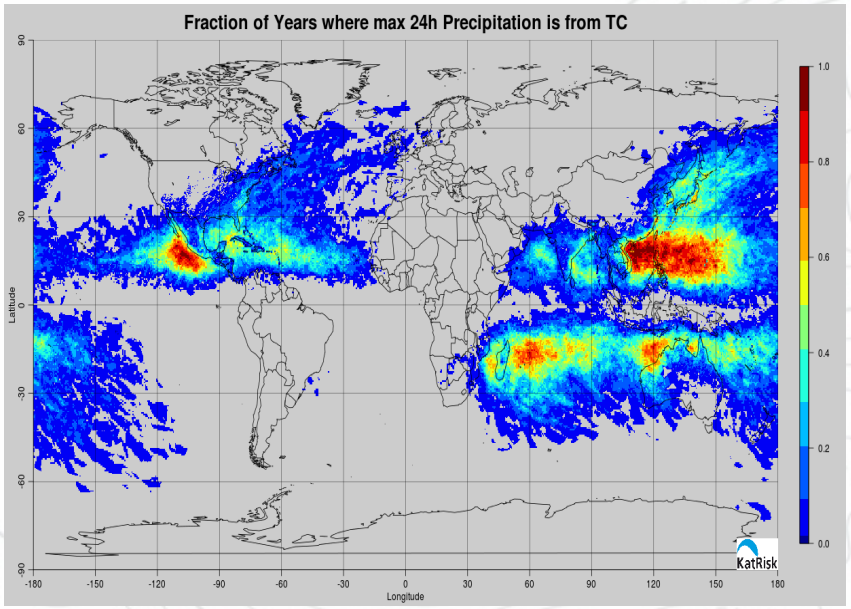
Some random figures from the past

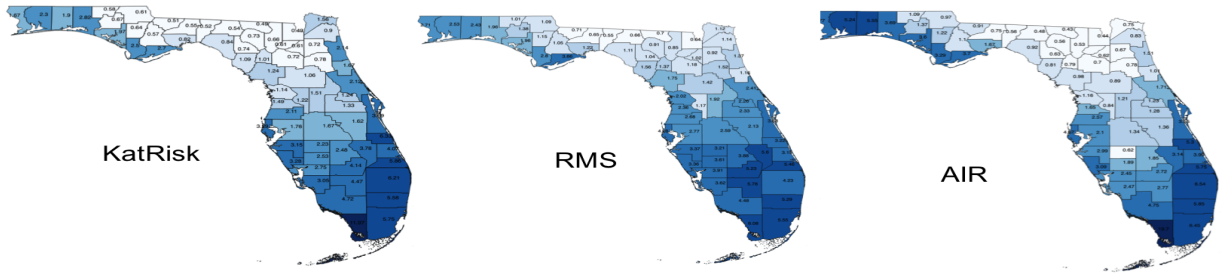




Procedure: for each year count whether the max precipitation is from a tropical cyclone

Asking data whether to start specific research projects turned out to be the right path.

At least our vulnerability functions have axis one can identify – but we plotted so many… in the end we gave our clients the complete spreadsheets



Should we do it or not? Masonry Loss Costs by county: Based on exposure specified by the Florida Commission on Hurricane Loss Projection Methodology. US vs. THEM!

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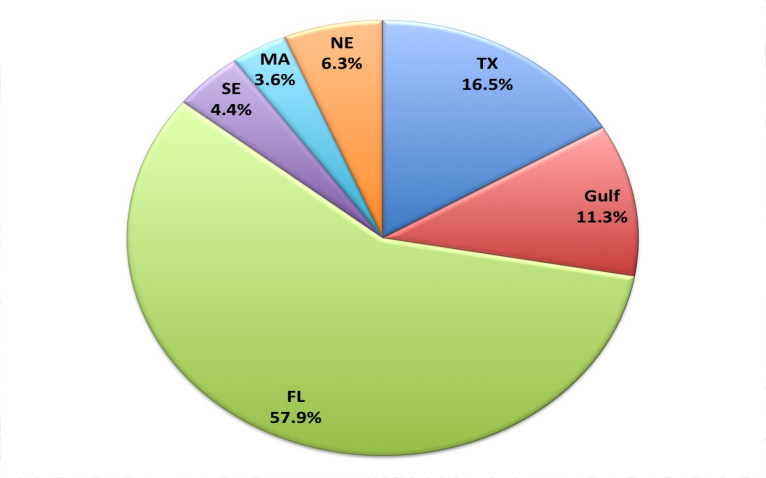
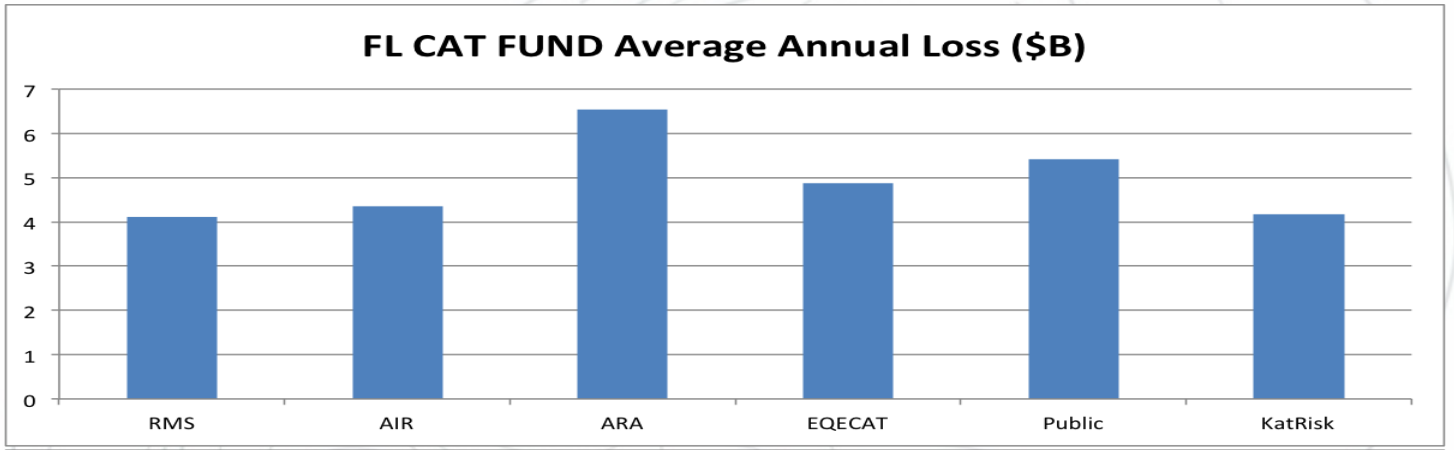
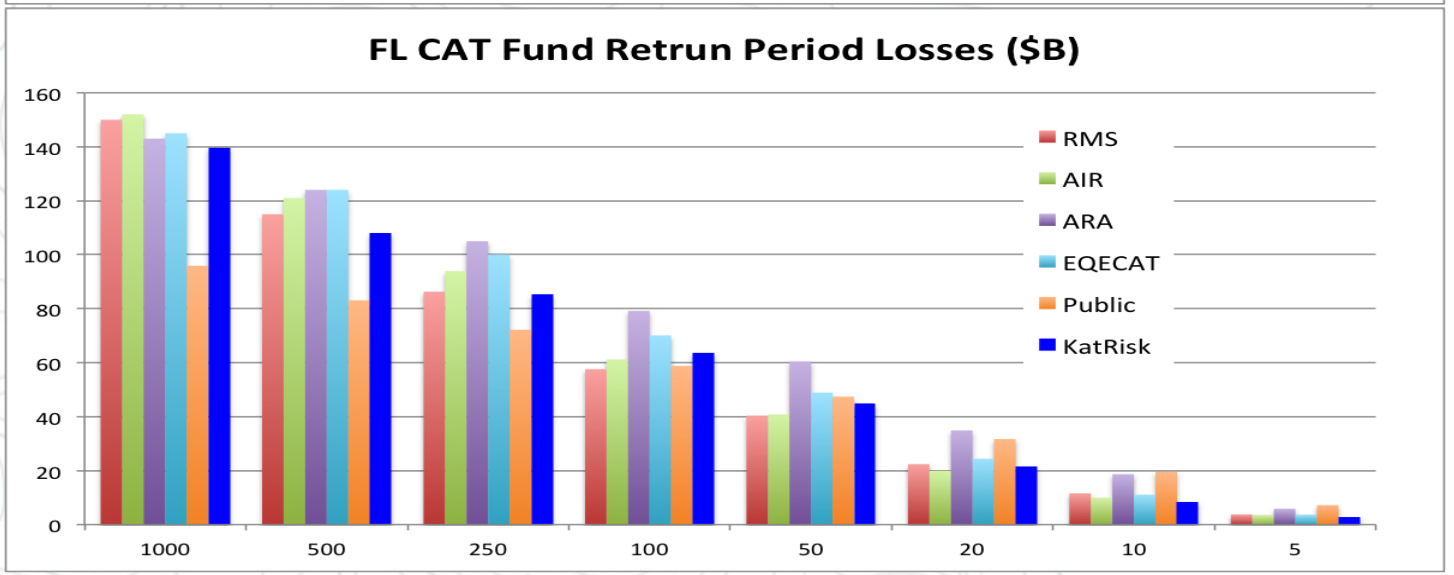
Our V1 US Hurricane Results 2014/15

- Total AAL using our industry exposure is $12.1 B
- The model has also been run against the Florida CAT Fund exposure set used in the submittal process to the Florida Hurricane Commission



Geographic Distribution of AAL





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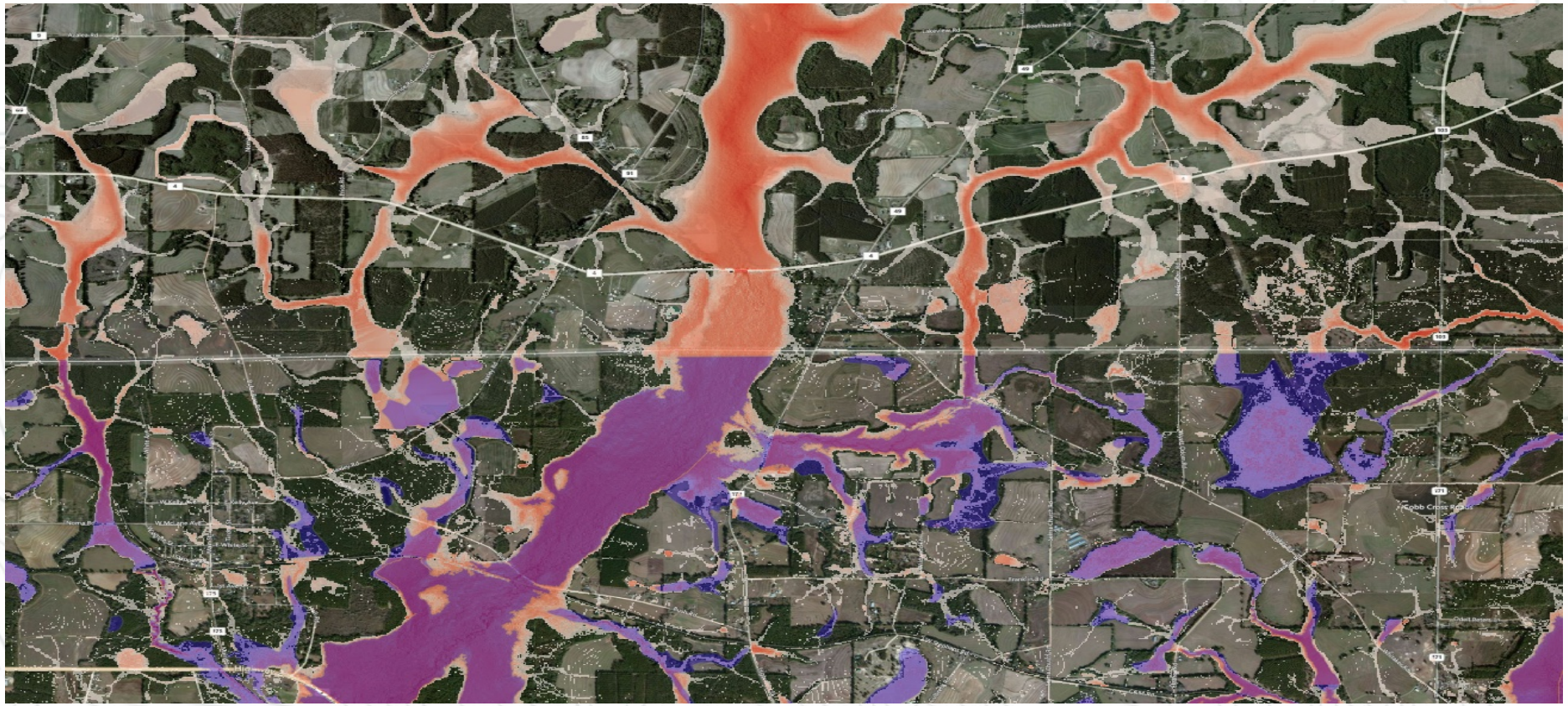
2014 – we started to like our flood maps

Red = KatRisk only, no FEMA

White = Katrisk only, low flood depth



Purple = FEMA and KatRisk overlap

Blue = FEMA > KatRisk

KatRisk

Things we need help with: KatGFS

UNDERSTANDING NEAR-TERM RISK

The opportunity	The goal	The questions
Provide the ability to quantify potential risks in a given area to inland flood events occurring in the near term (+/- 10 days) based on forecast data.	Allow customers to better prepare for potential flood events.	What parts of your organization would have to be involved? What is the information you need? (e.g. simplified view, moratorium areas, etc)

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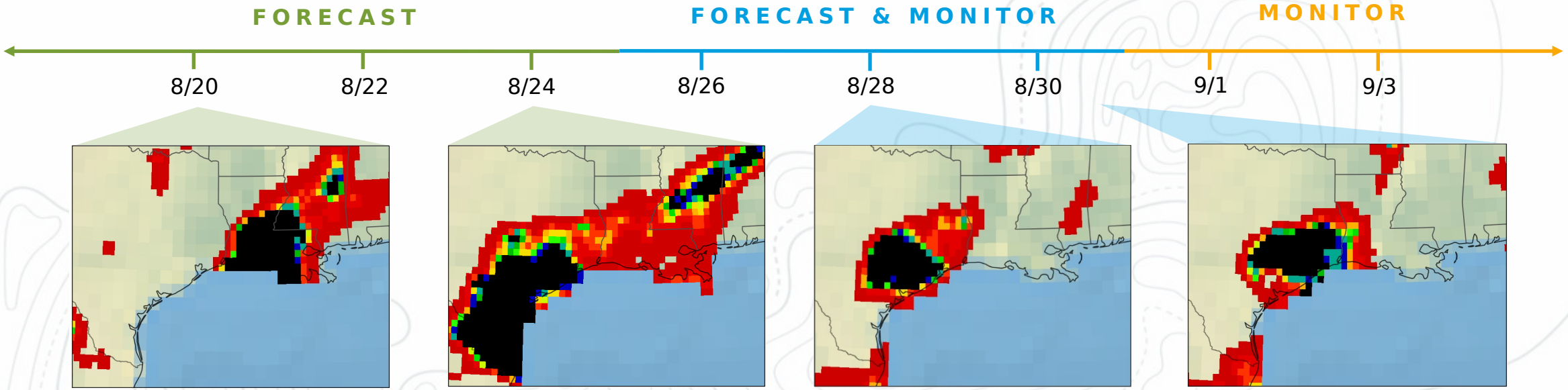
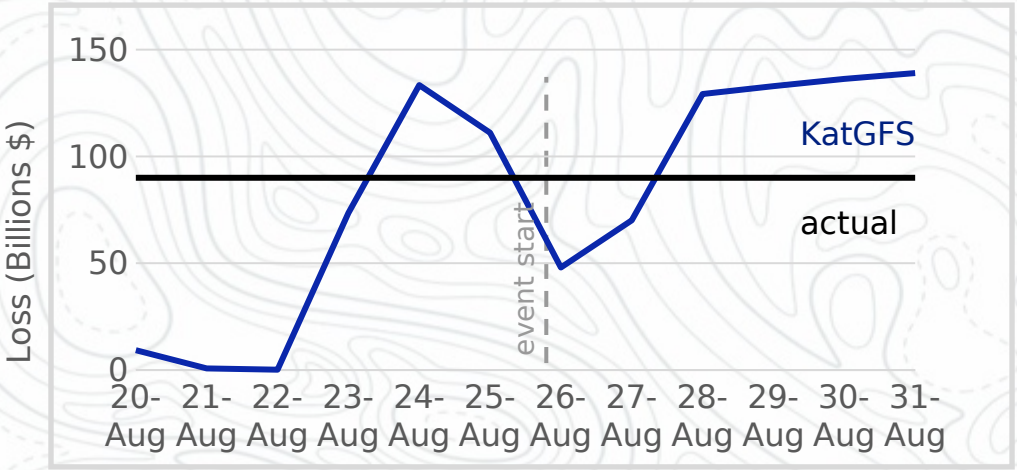
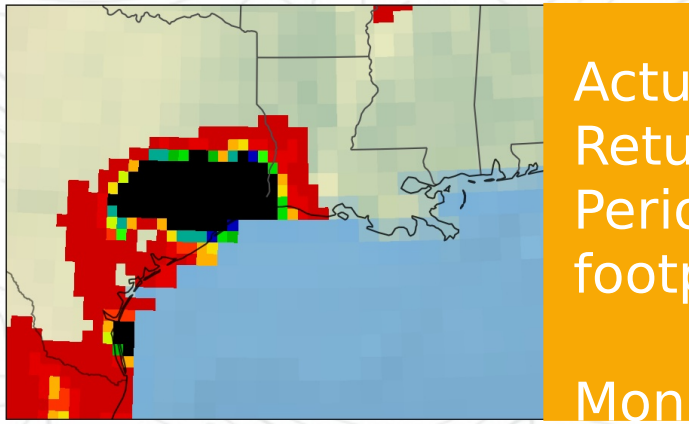
Hurricane Harvey

90TH PERCENTILE

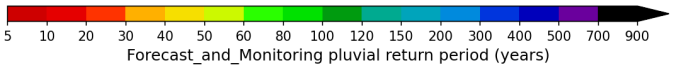






Actual Return Period footprint

Monitor8/31



Losses from 80th percentile

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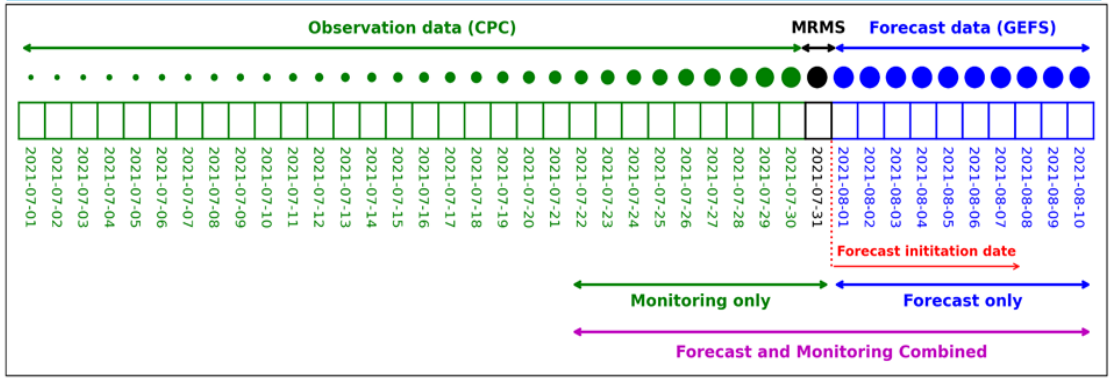
Enterprise Software – KatGFS

Realtime Forecasting System (Global – Inland Flood)

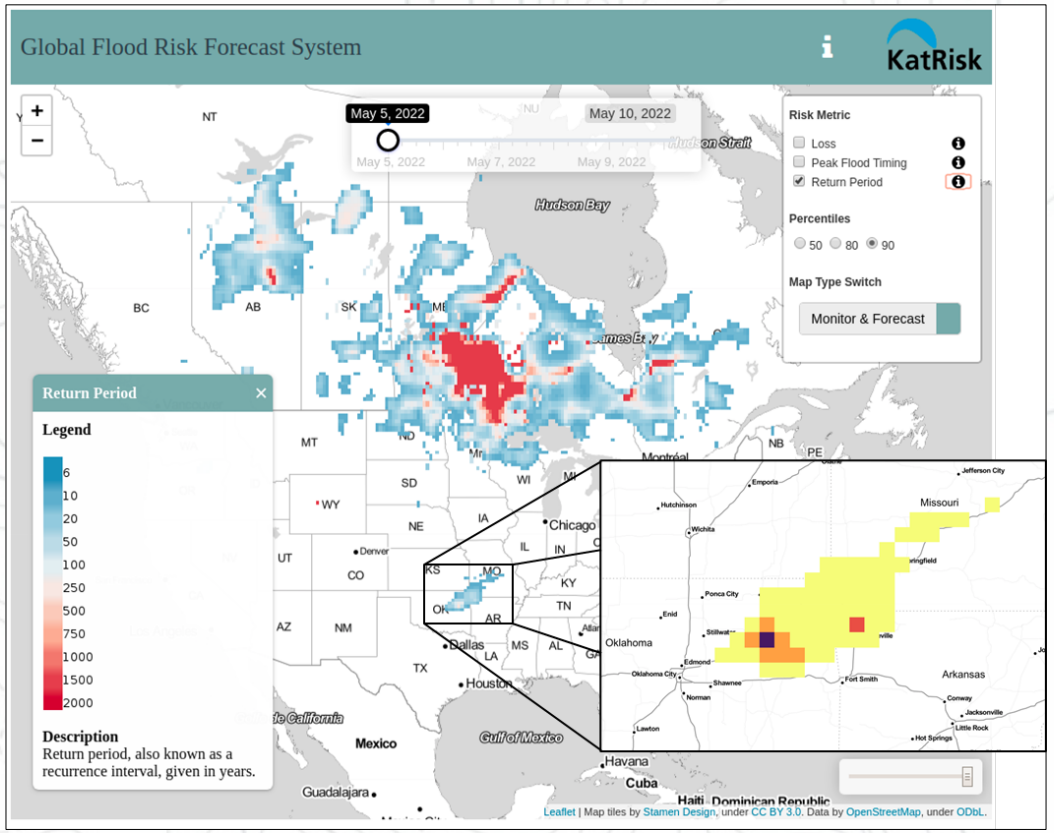
1. Compute forecast and event flood return periods for ensemble members



2. Use APIs in SpatialKat to compute range of event losses by location

3. Repeat for each forecast assemble; generate loss reports for each client exposure send automated email reports

Free version available at https://floodriskforecast.com/



KatGFS
Generate daily forecasts (return period, loss, and timing)

Speed Optimized
Cached tiles

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Climate Variability and Forecast

UNDERSTANDING MEDIUM-TERM RISK

The opportunity

Provide the ability to quantify potential risks in a given area for all perils based on the inherent memory in the climate system

The goal

Allow customers to better quantify moving targets of risk metrics (tVaR, AAL, etc.) on monthly to annual time scales

The questions

Given that some risk metrics vary by +- 20% based on climate variability, I would expect more questions from our clients on how to use it.

UCAR: Climate variability is the way aspects of climate (such as temperature and precipitation) differ from an average. Climate variability occurs dueA to natural and sometimes periodic changes in the circulation of the air and ocean, volcanic eruptions, and other factors.

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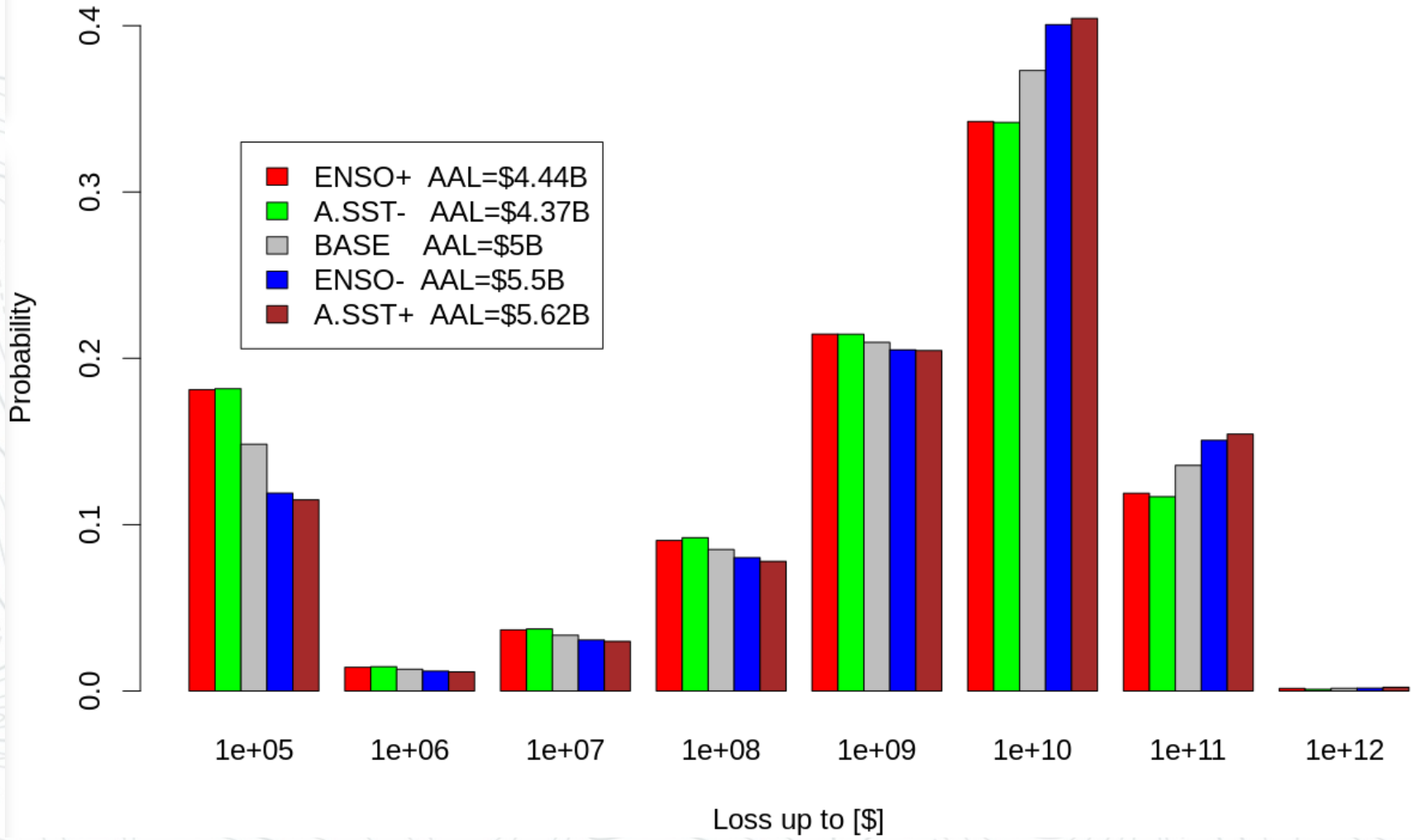
Losses & climate variability

Climate variability has an impact on losses
Example US Storm Surge based on ENSO and Atlantic SST



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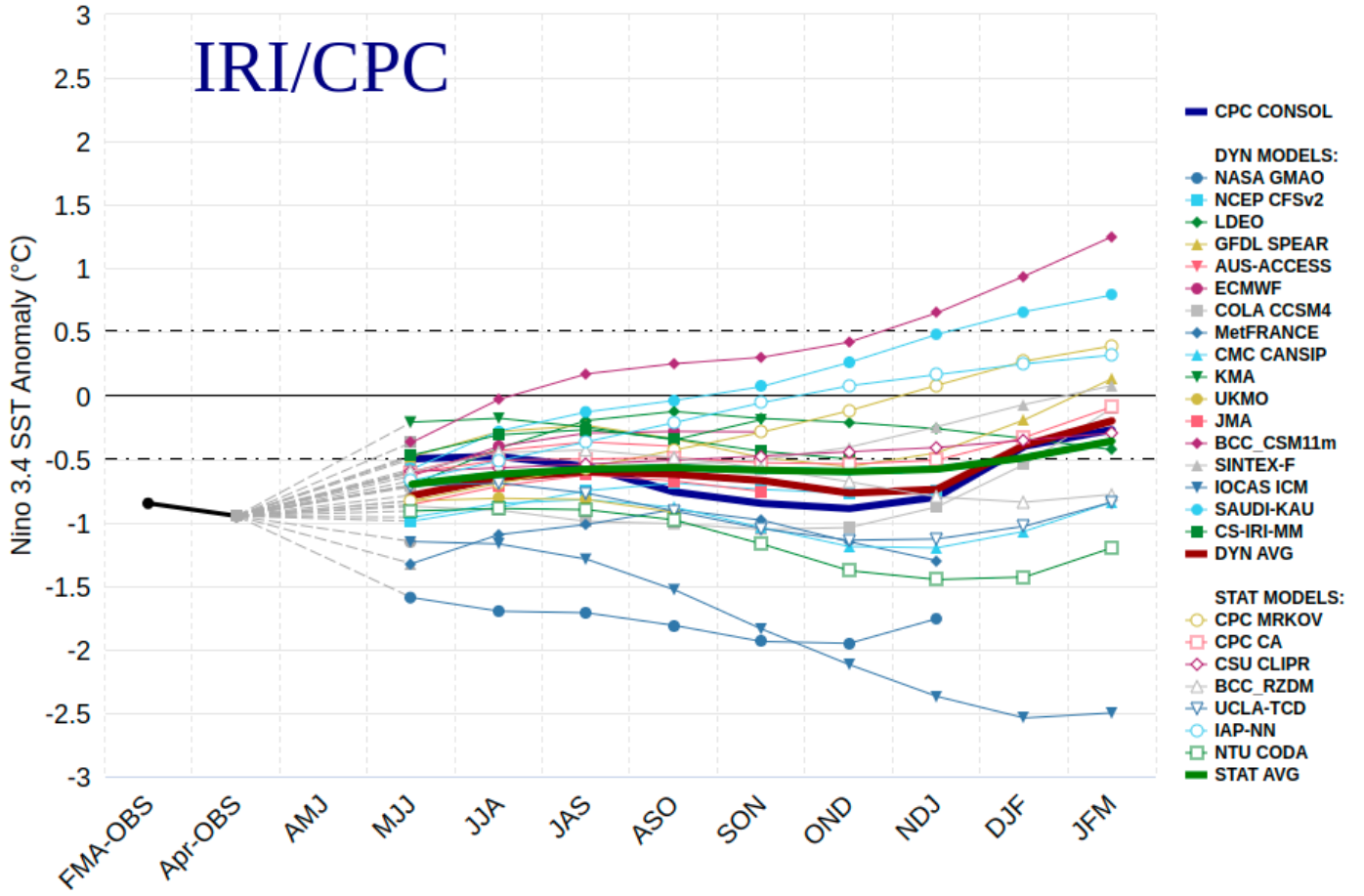
Using variability to forecast risk

Method 1: Use KatRisk provided SST / Indices
Use either persistence (shown) or SST model

Method 2: Use public SST / Index forecasting
Pick your own distribution



ENSO Forecast May 2022

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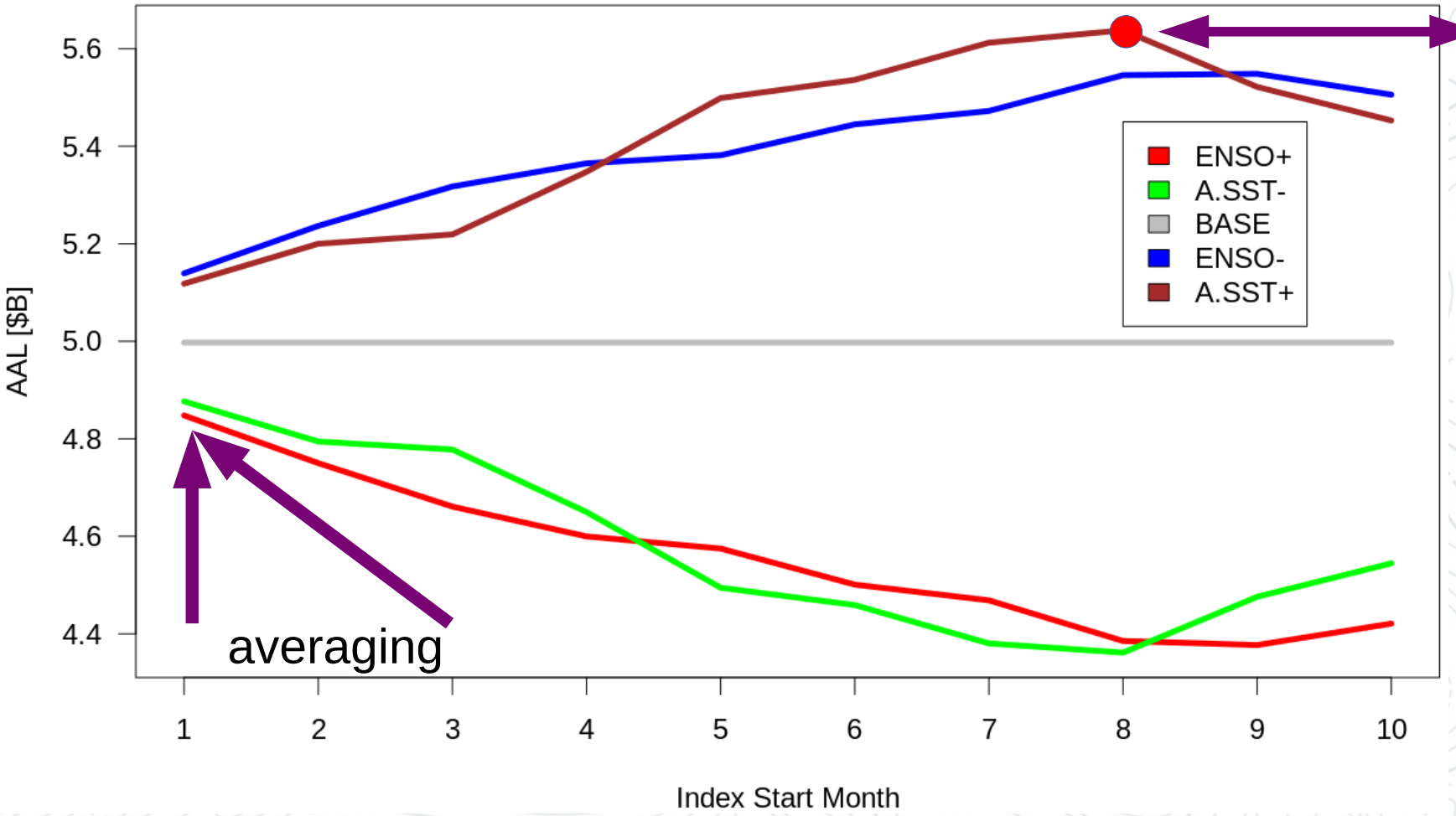
Main result: AAL(variability)

Investigate changes in AAL based on teleconnections (+- 20% impact)



Atlantic SST Warm Catalog

Interval from Jan to March is stored as January result (average index)

Results show the impact new knowledge has on conditioning losses based on just SST

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Climate Change

UNDERSTANDING LONG-TERM RISK

The opportunity	The goal	The questions
Provide the ability to quantify risk in a given area from potential impacts of climate change for all perils.	Allow customers to better prepare for potential long term changes in risk given a non-stationary climate.	What is the right way to do this? Is an approximate answer better than no answer? If we don't provide some answer, who will?

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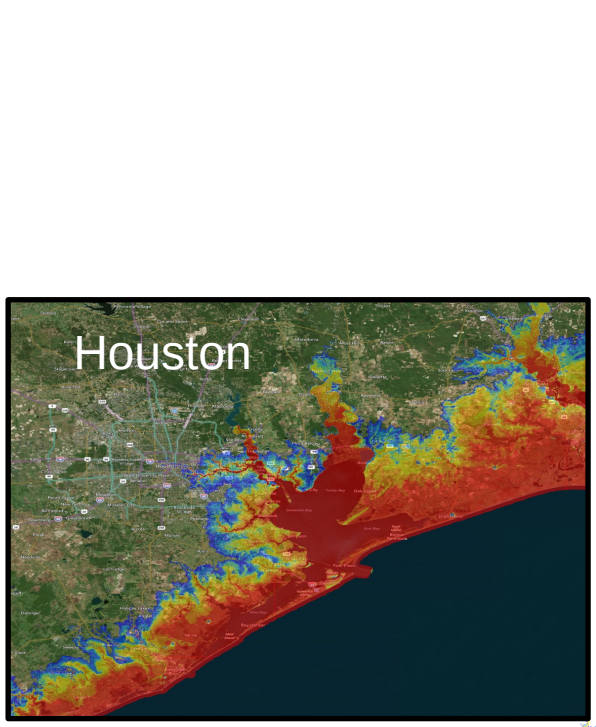
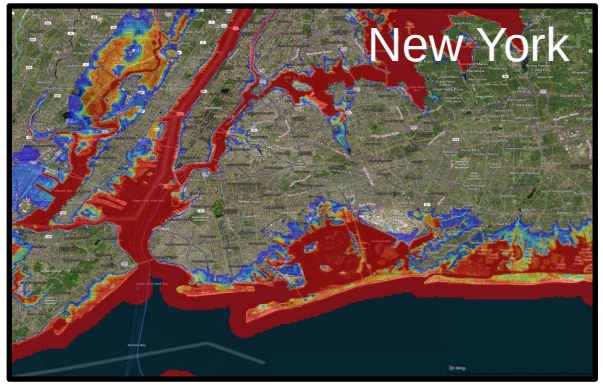
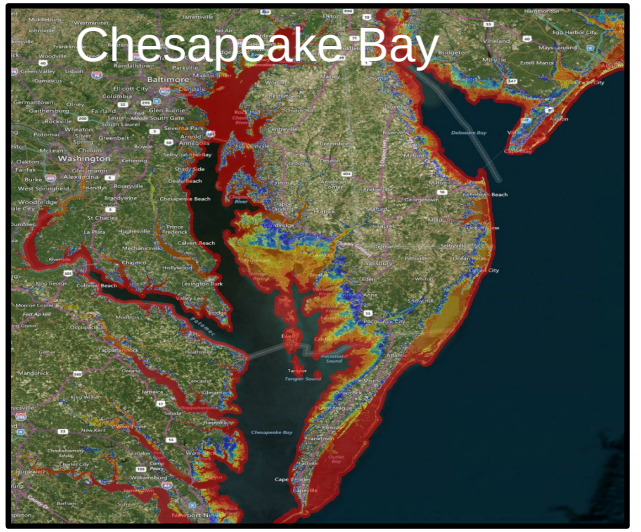
Storm Surge Modeling

- Storm surge has been analyzed for 50,000 years of hurricane tracks

Images show KatRisk Score (1-10)







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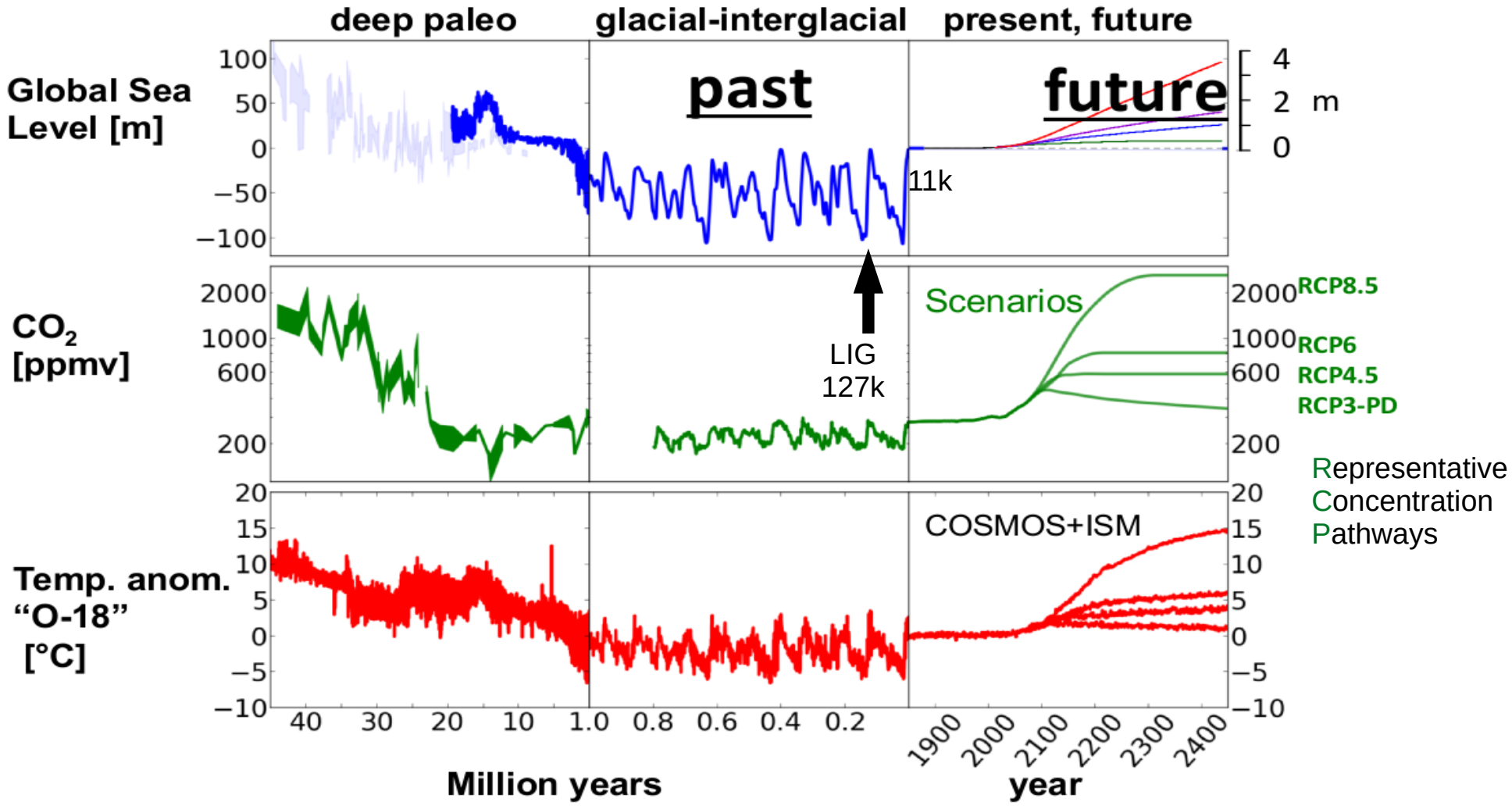
Short Story about Sea Levels and SLR

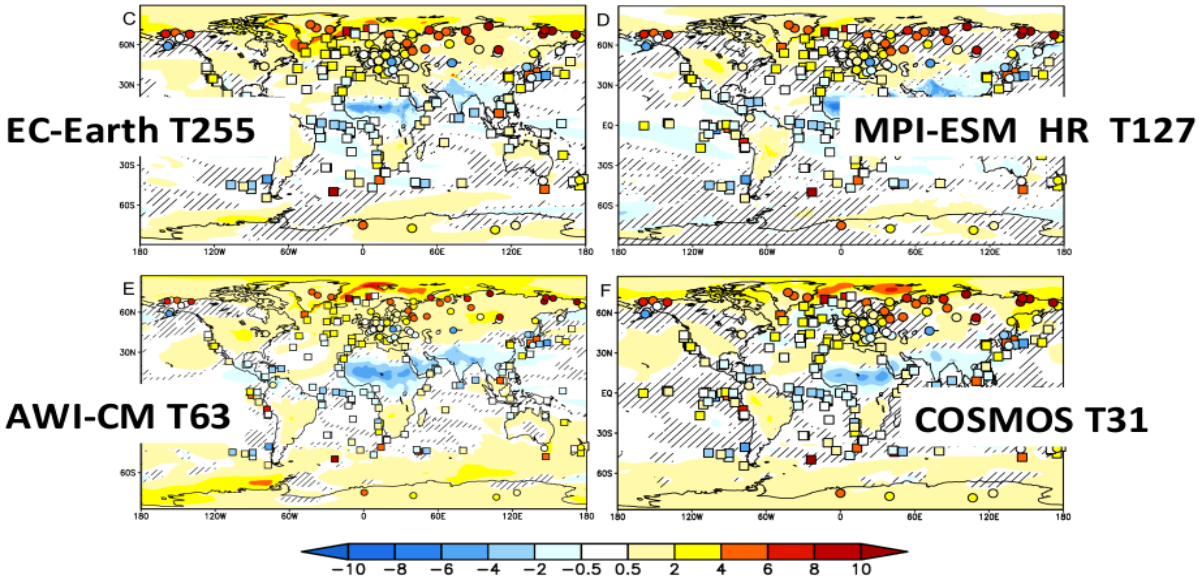


(Kominz et al., 2008; Pagani et al., 2009; Kramer et al., 2011; Crowley & Kim 1995, Gierz et al., 2016)

Sea Level Rise Puzzle

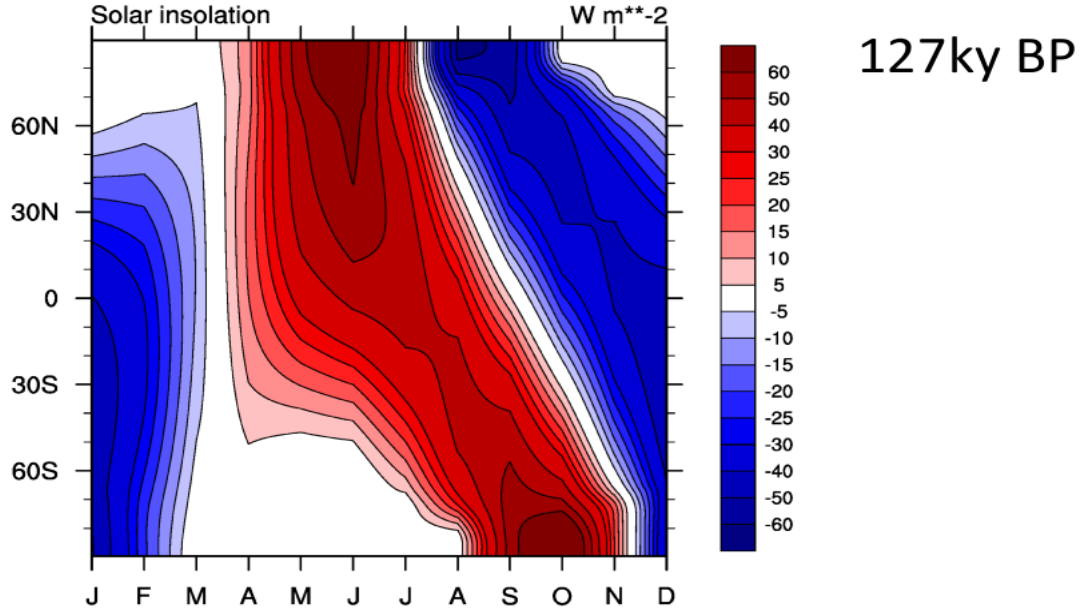
- During Last Inter-Glacial (LIG) exposed fossil reef indicate **5m - 9m higher sea level** (Dutton & Lambeck, 2012, Dutton et al., 2015)
- LIG with Sea Surface Temperature Southern Hemisphere + **1 - 3°C warmer** (Capron et. al. 2014)

Annual mean surface temperature anomaly with peak LIG



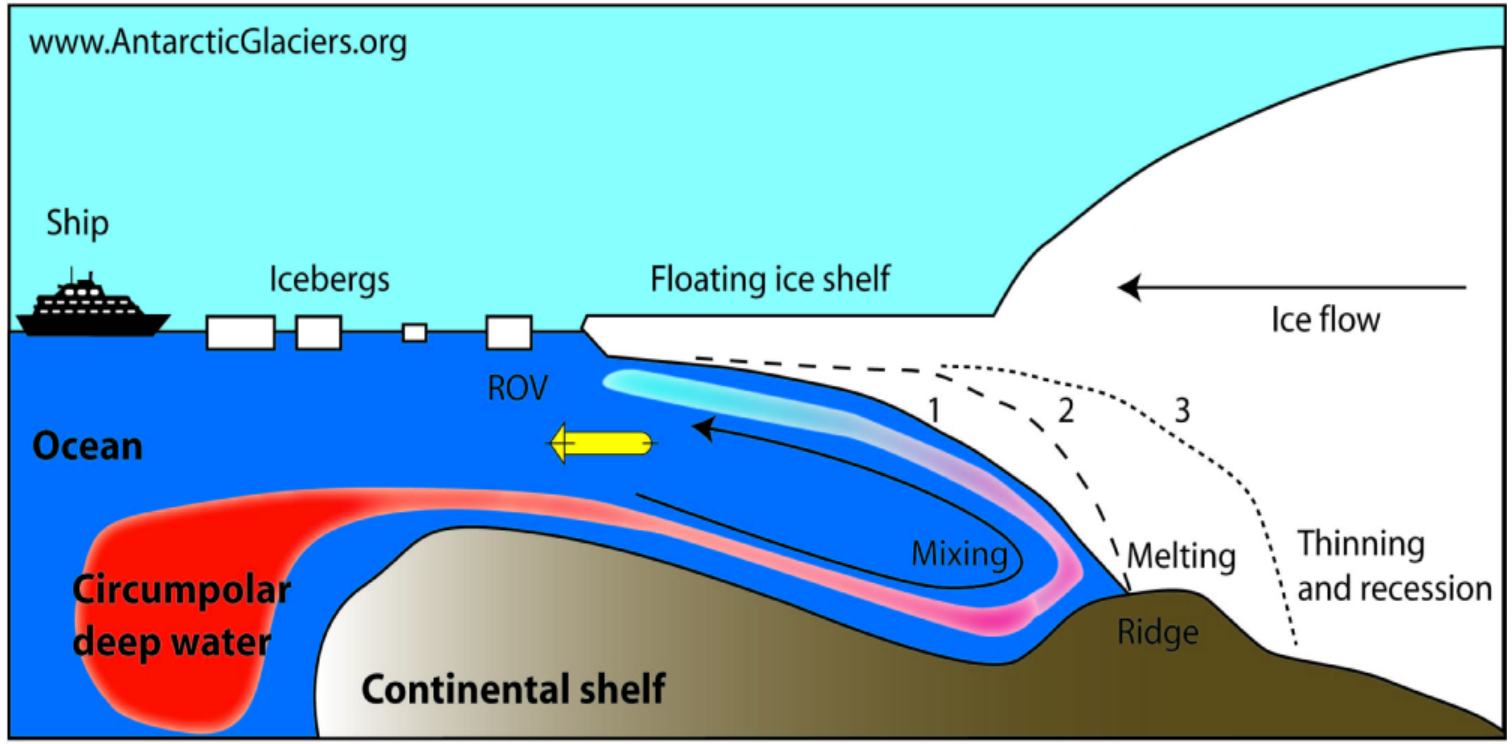
Data: Turney & Jones, 2010

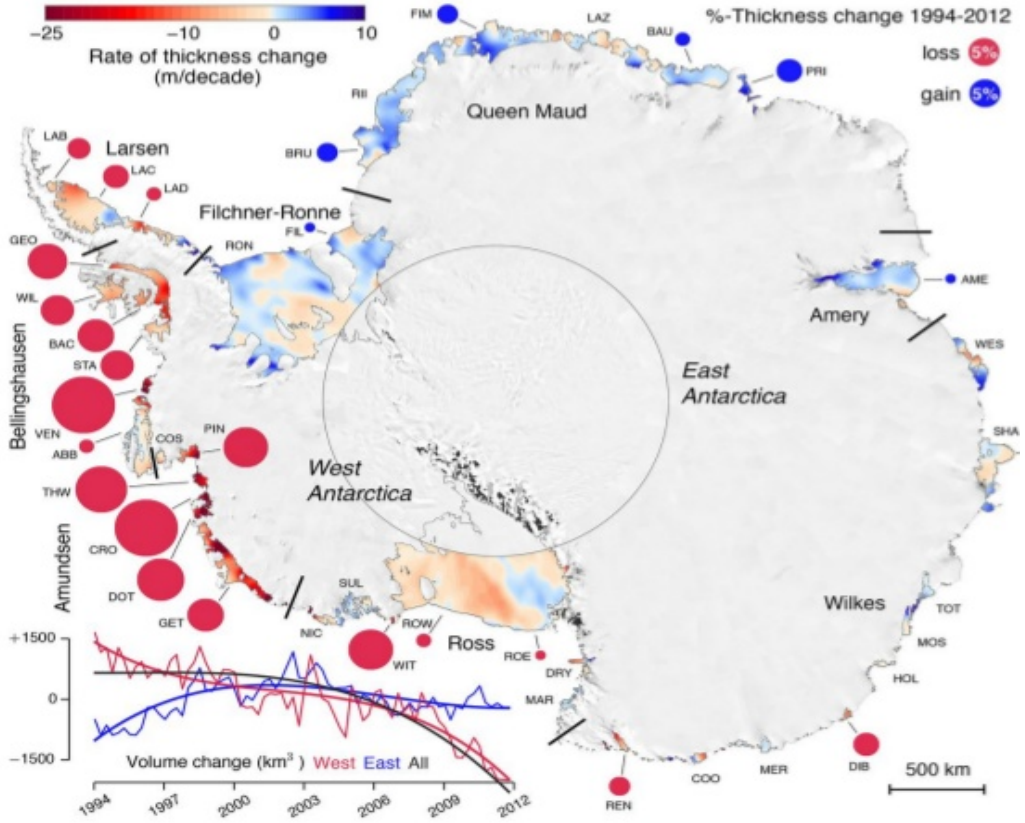
Warming at high latitudes (especially boreal spring/summer, austral autum)



Melting West Antarctic Ice Sheet from below

- Last Interglacial: Climate Models and paleo-climate data are consistent
- Antarctic Ice Sheet: Marine ice sheet instability -> Sea level rise
- Threshold ~2°C based on paleo-climate studies





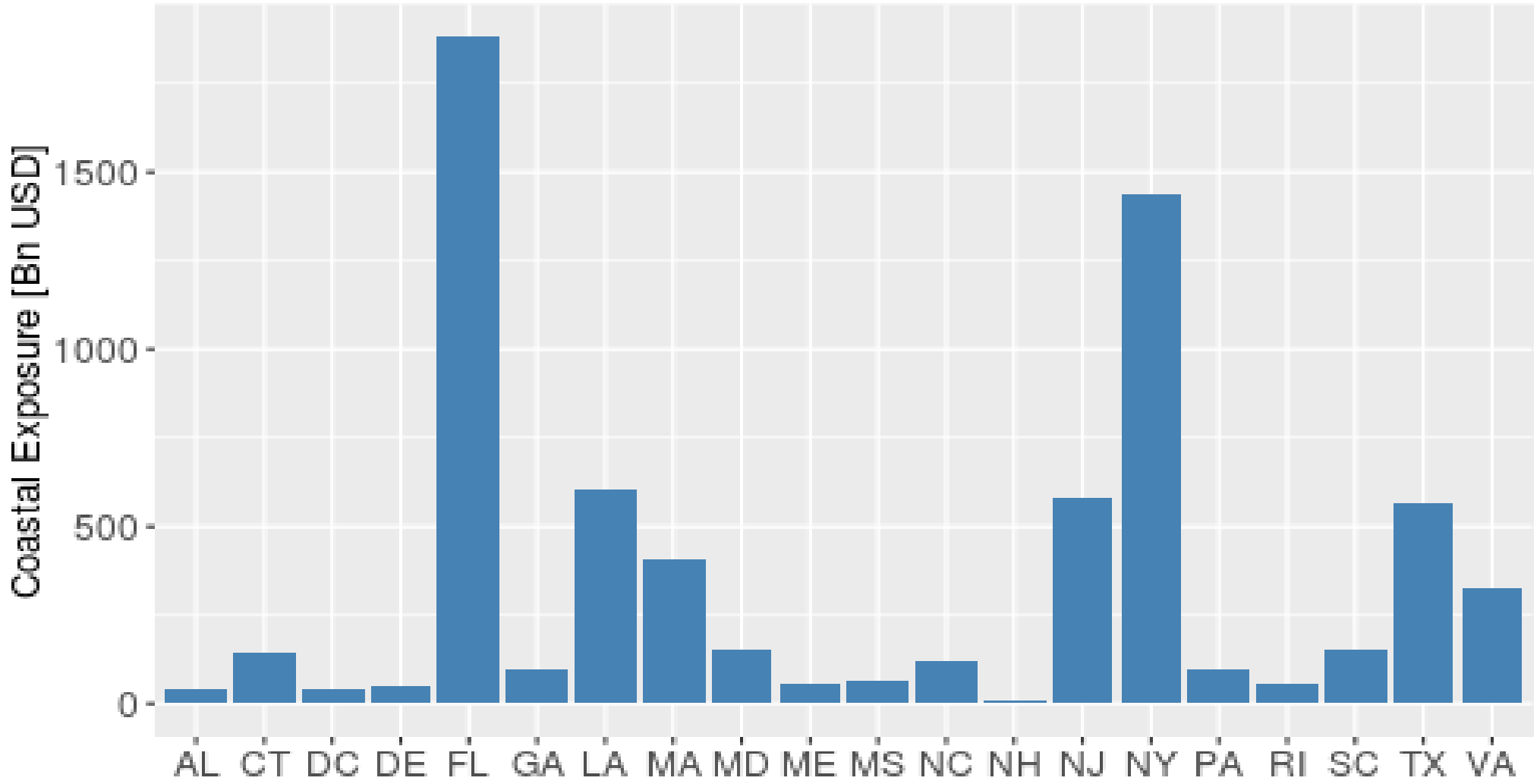
Fernando S. Paolo et al. Science 2015

KatRisk Surge Climate Change Study

- Compares USA surge losses with current conditions and 30 cm sea level rise
  - Current speed of SLR is about 2.8 to 3.6 mm/year (could speed up), and was about 1.8 mm/year in the 20th century
- Use high resolution exposure of $6.88 trillion along the coasts results summarized on 200m gridded resolution
- Buildings, contents, time element and appurtenant structures modeled
- Ground-up AAL increased from $5.0 billion to $6.9 billion, implying an increase of about $60 million per centimeter SLR, or currently about $20 million per year (although the increase is not linear), equal to 0.4% of the AAL – but also with potential to accelerate.

KatRisk

Exposure By State



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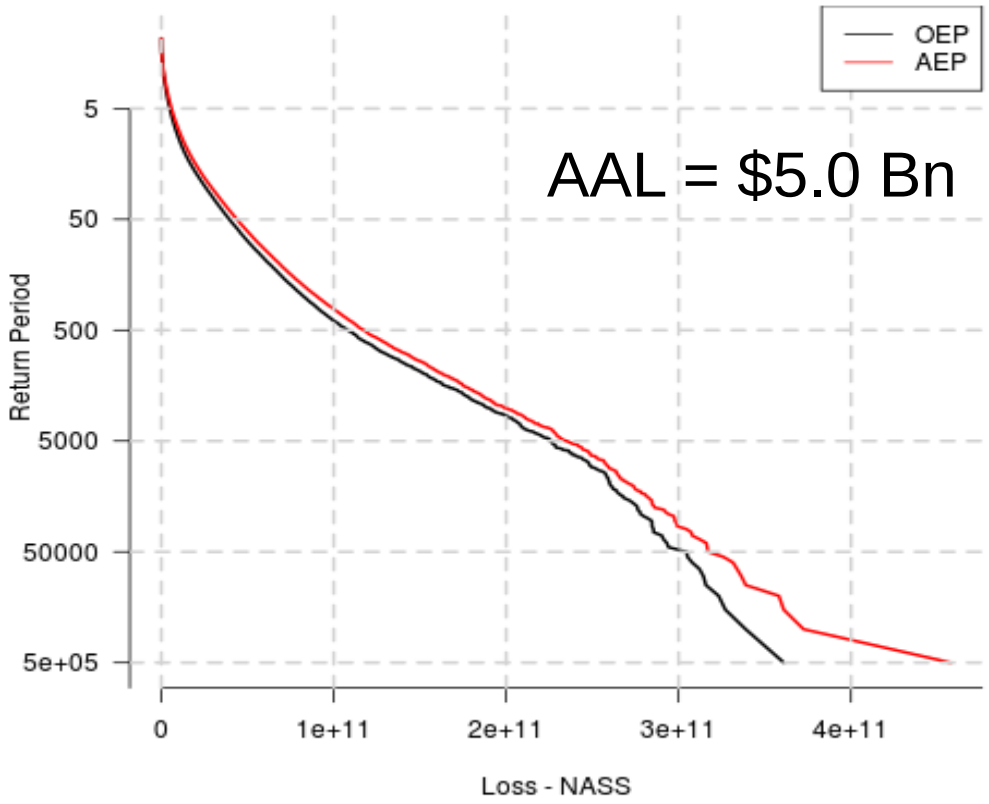
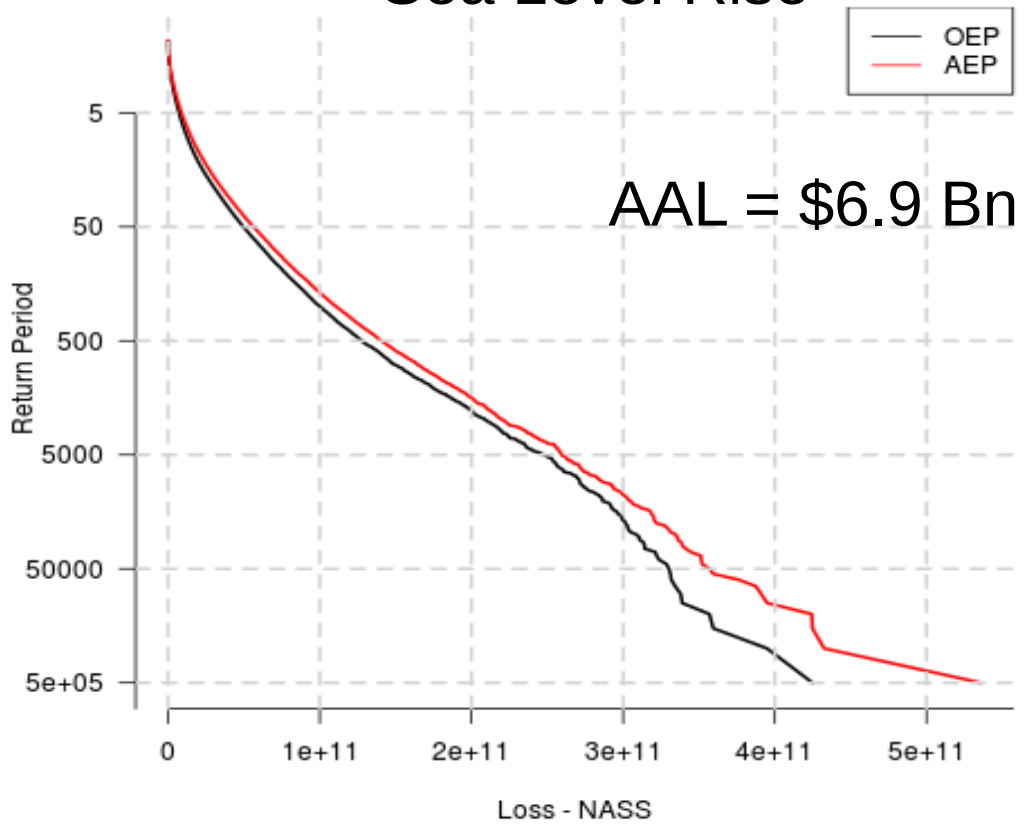
EP curves base and SLR (30cm)

BASE



Sea Level Rise



Loss / RP	2	5	10	20	50	100	200	500	1000
BASE [$billion]	0.65	4.8	10.8	20.9	39.5	56.4	92.2	108	141
SLR [$billion]	1.0	7.1	15.2	27.6	49.6	69.6	75.9	128	161

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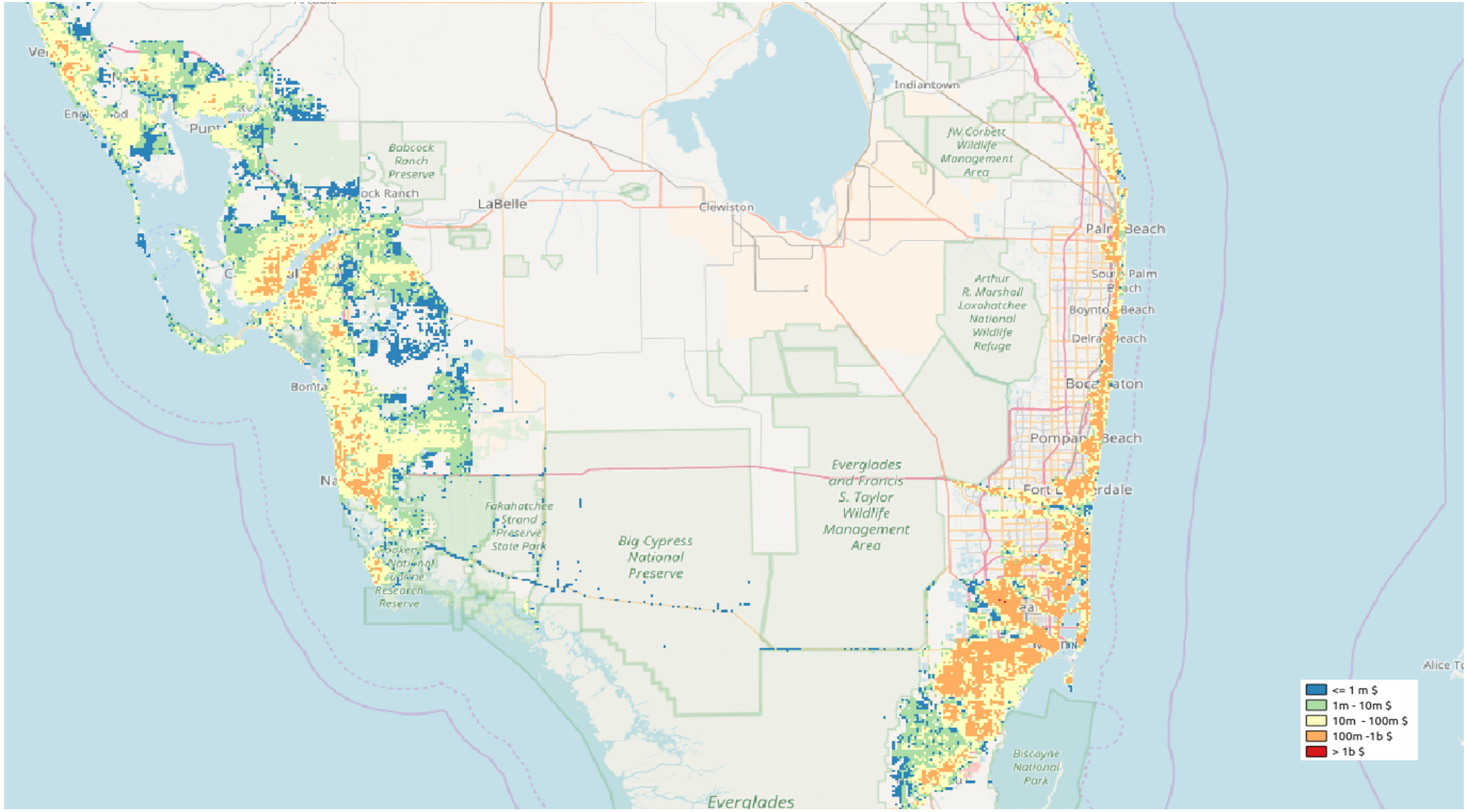
Southern Florida Exposure



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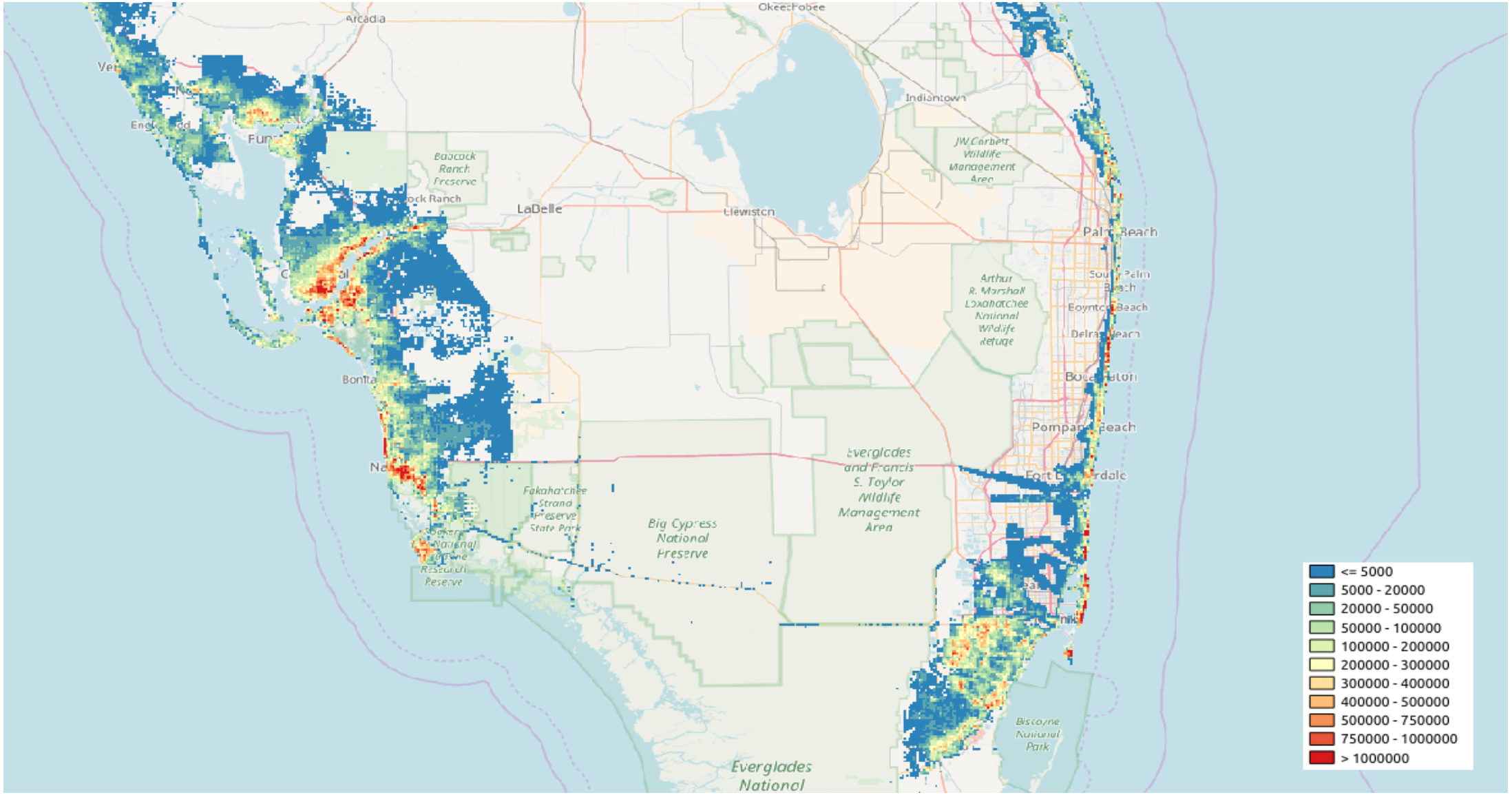
Southern Florida AAL base



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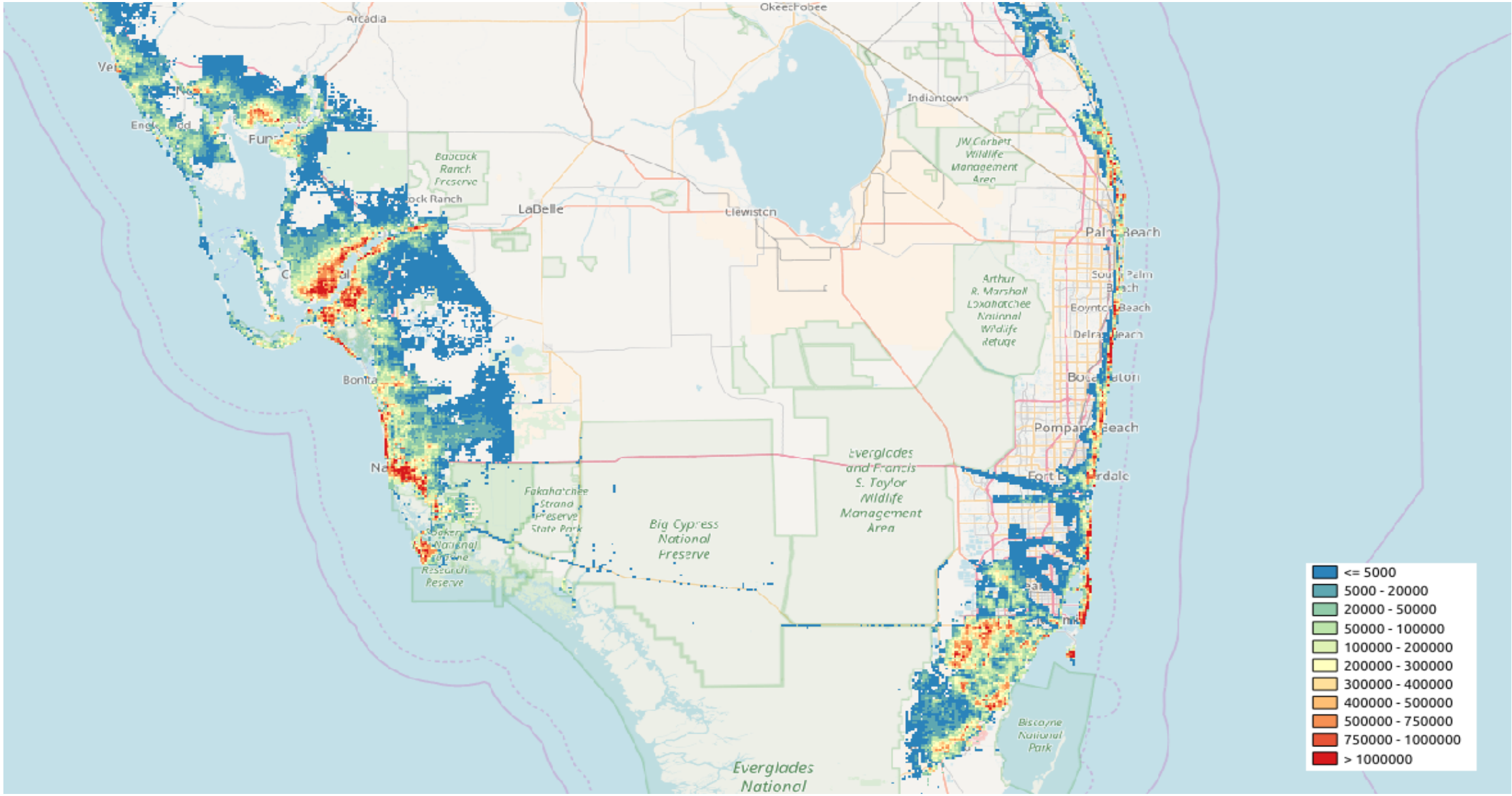
Southern Florida AAL SLR



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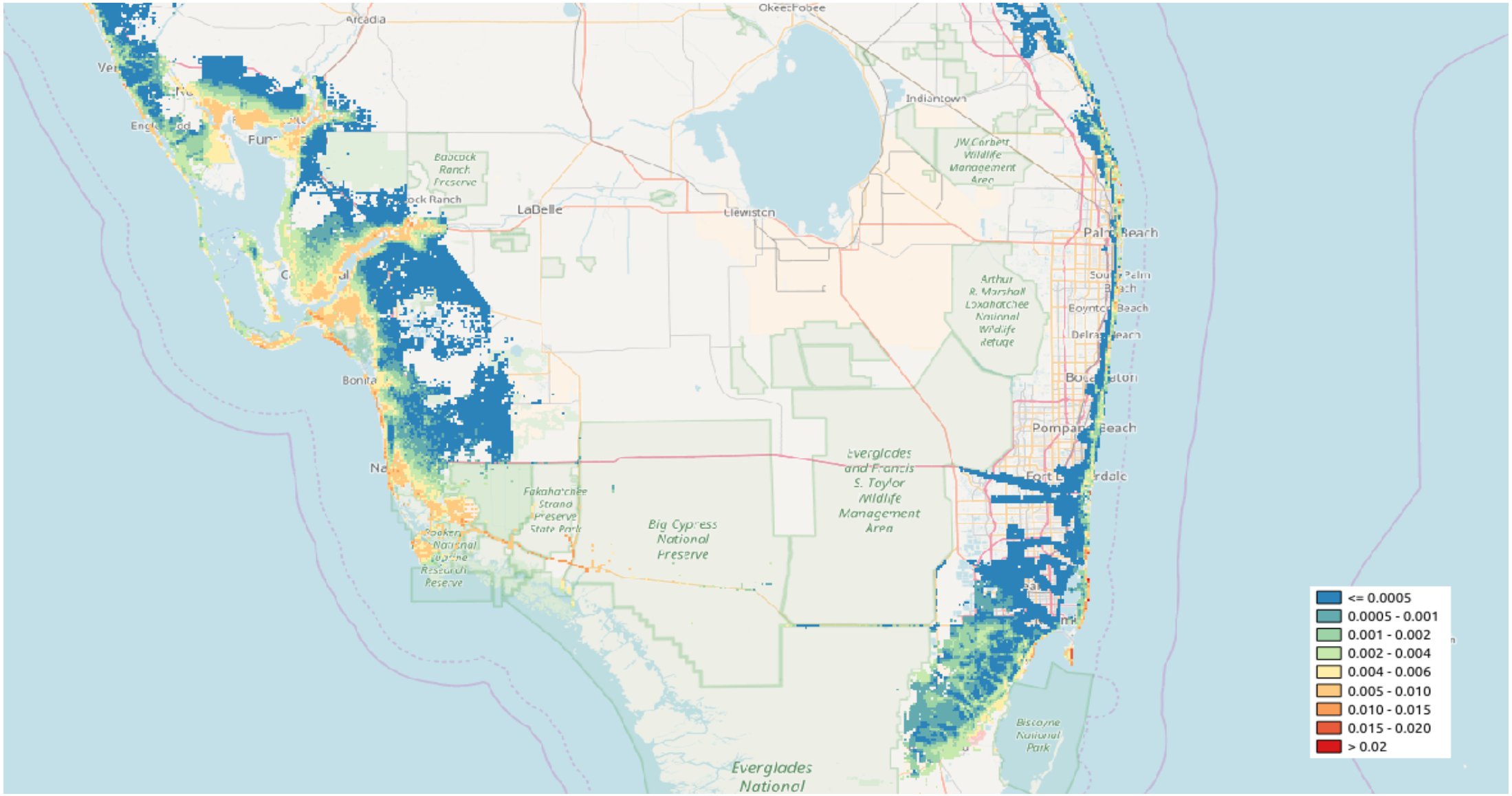
Southern Florida Loss Ratio base



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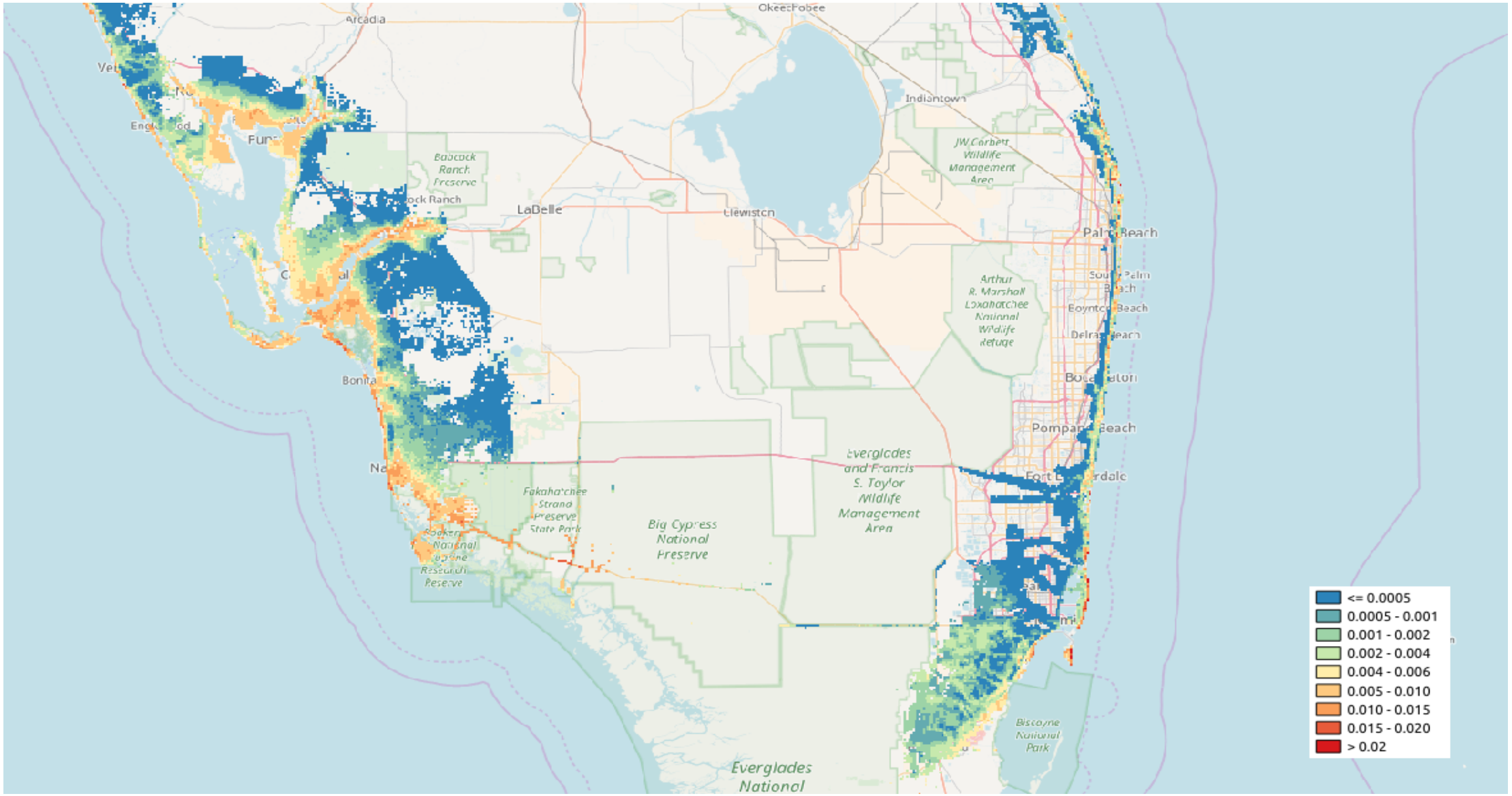
Southern Florida Loss Ratio SLR



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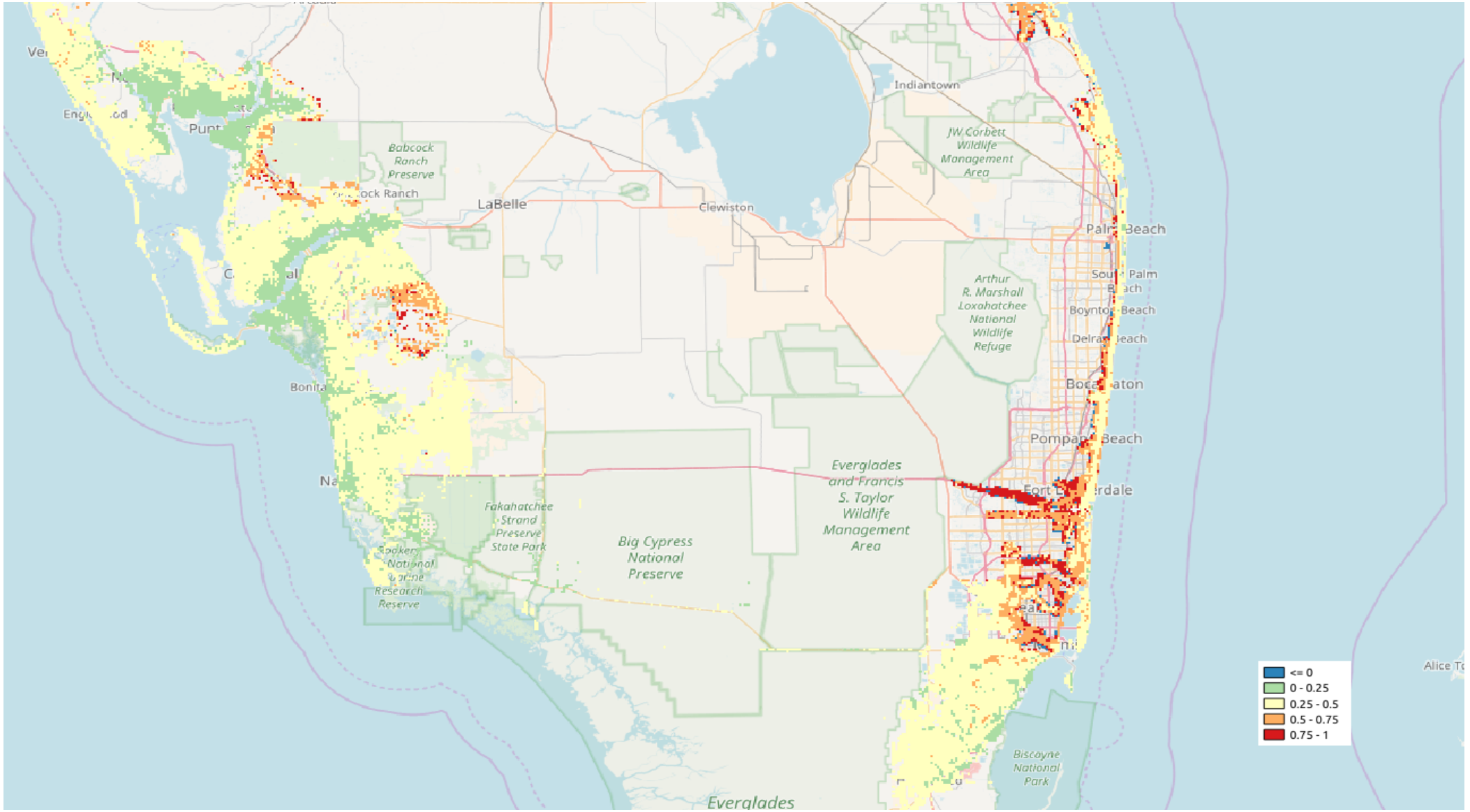
Southern Florida change (SLR – base)/SLR



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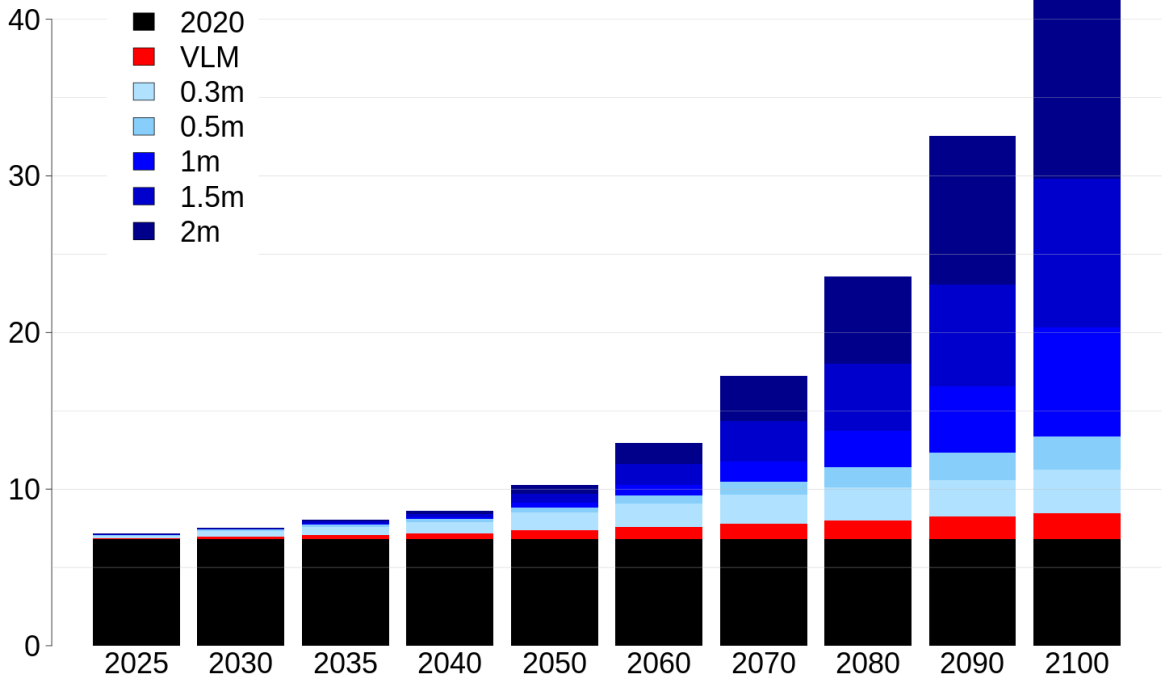
US Economic Loss from SLR

- US economic loss based on new NOAA sea level rise scenarios (Feb. 2022)
- Significantly different from previous NOAA SLR
- KatRisk implemented and tested.
  Recommendation: replace current NOAA scenarios with new 2022 ones
  - More realistic vertical land movement
  - More realistic SLR values

https://www.soa.org/globalassets/assets/files/resources/research-report/2020/soa-flood-report.pdf

US Economic Storm Surge losses based on NOAA 2022 Medium scenarios



Difference OLD and NEW NOAA Scenarios

2100 GMSL Rise	Scenario	Year									
		2025	2030	2035	2040	2050	2060	2070	2080	2090	2100
0.3	LOW	1.2%	2.3%	3.8%	5.4%	9.3%	12.9%	16.8%	19.8%	22.8%	27.7%
0.3	MED	1.2%	2.5%	3.6%	4.7%	6.5%	8.1%	9.1%	10.1%	10.6%	13.2%
0.3	HIGH	0.9%	2.0%	2.7%	3.5%	4.7%	5.1%	4.9%	4.2%	3.7%	5.8%
0.5	LOW	0.9%	1.9%	3.0%	4.3%	7.1%	9.9%	12.8%	16.3%	19.9%	24.0%
0.5	MED	1.3%	2.4%	3.5%	4.7%	7.0%	9.2%	11.6%	14.3%	16.9%	20.6%
0.5	HIGH	1.1%	2.0%	3.4%	4.3%	6.6%	8.4%	10.5%	13.3%	15.9%	20.0%
1	LOW	-0.2%	-0.3%	-0.3%	-0.4%	-1.0%	-1.8%	-2.2%	-1.3%	1.7%	3.8%
1	MED	-0.3%	-0.7%	-0.7%	-0.7%	-1.5%	-3.0%	-3.6%	-2.6%	0.1%	5.1%
1	HIGH	-0.5%	-0.9%	-0.7%	-0.2%	-0.4%	-2.0%	-2.6%	-1.9%	-1.5%	3.0%
1.5	LOW	-0.9%	-1.9%	-2.9%	-4.0%	-7.5%	-9.7%	-11.7%	-11.8%	-12.6%	-15.3%
1.5	MED	-1.6%	-3.2%	-3.9%	-5.0%	-7.9%	-9.6%	-10.0%	-10.5%	-10.9%	-11.6%
1.5	HIGH	-1.1%	-2.0%	-1.9%	-1.7%	-2.0%	-3.8%	-5.2%	-6.0%	-9.3%	-12.0%
2	LOW	-4.2%	-8.0%	-11.2%	-14.3%	-19.7%	-23.3%	-26.2%	-28.6%	-28.4%	-29.2%
2	MED	-3.0%	-6.2%	-8.6%	-11.0%	-16.5%	-19.9%	-20.7%	-21.0%	-22.3%	-24.8%
2	HIGH	-2.3%	-4.4%	-5.3%	-6.1%	-8.2%	-10.9%	-12.8%	-14.5%	-16.3%	-18.4%

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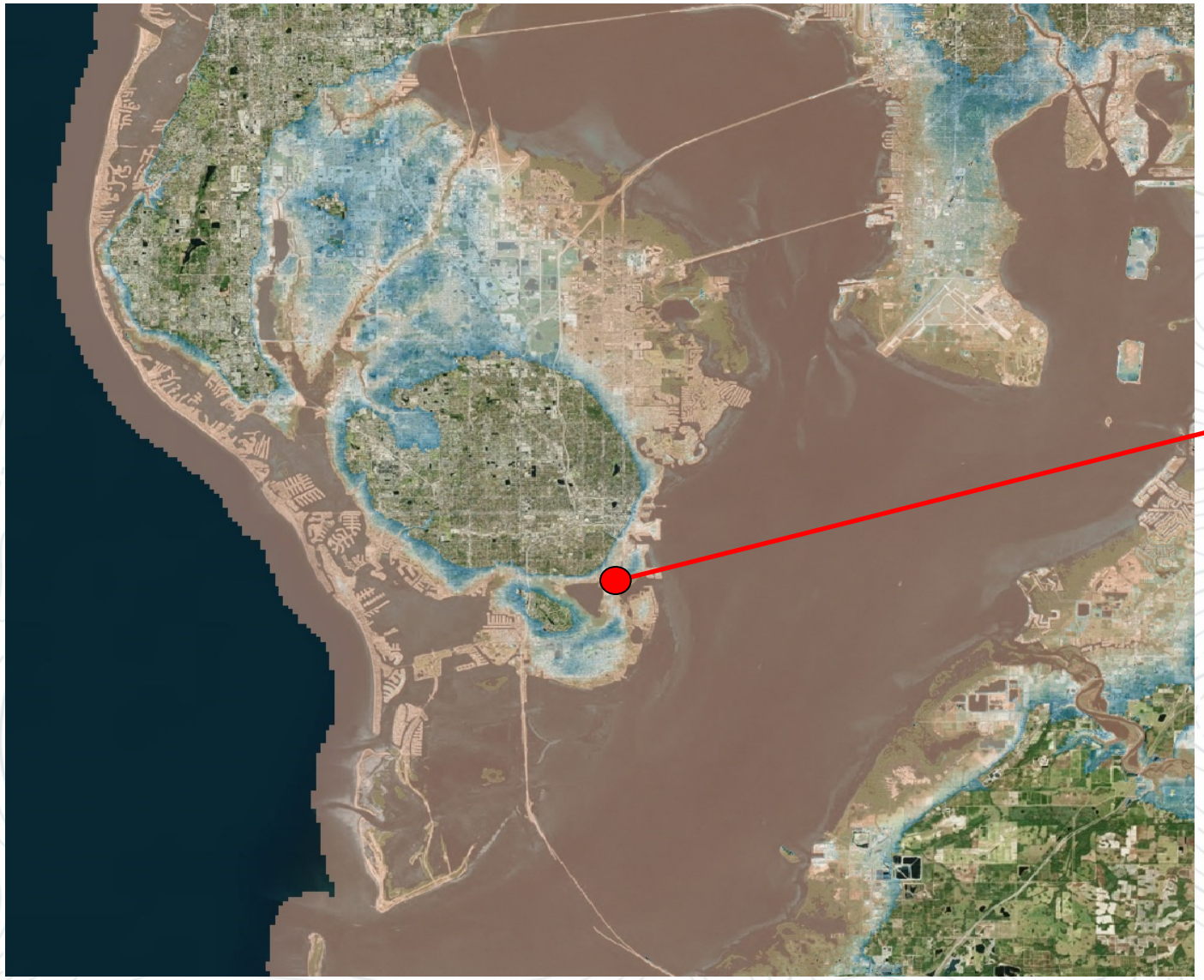
Tampa Bay Climate Change



Change in Relative Score and AAL by Year		
Scenario	Relative Score	Uniform Exposure AAL per $1m
Base	66	976
2025	67	1,006
2030	67	1,051
2035	68	1,080
2040	70	1,234
2050	71	1,471
2060	73	1,807
2070	75	2,187
2080	79	2,850
2090	82	3,632
2100	85	**4,580**

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Platform Development

DIFFICULT CHOICES IN AN EMERGING ECOSYSTEM

The opportunity

Develop a multi-peril cat modeling engine that is faster than anything else out there
Use our knowledge of math, sampling, data structures, hardware and coding to excite people

The goal

Use fastest compiled code (C++) for engine
Use code everybody at KatRisk uses for GUI (R Shiny)
Make it fast within one machine
Use identical code deployed or hosted on multiple OS

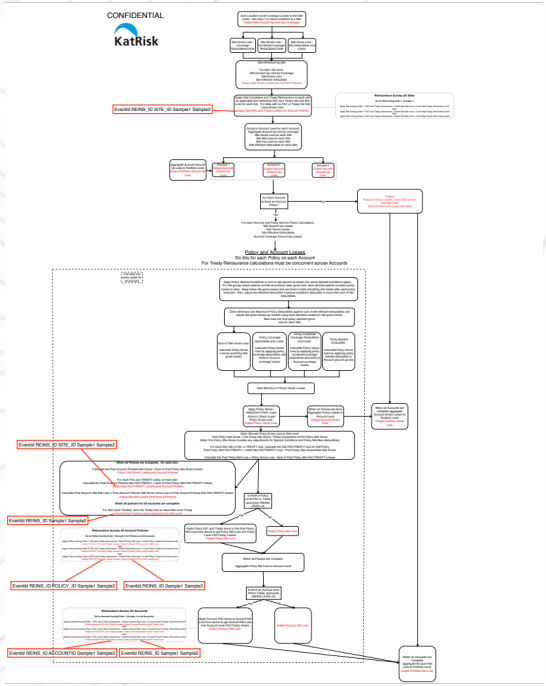
The questions

Why are we not building on OASIS?
How will computers look like within the next 10 years?
Do we need a real platform or just model execution?
Will clients accept another platform?

Platform Development

Had to make a decision in 2016 whether to go with OASIS, another party or develop our own. Here are the criteria we used:

I) Independence vs. potential rejection from clients
II) Sampling and math – need to have coherent risk measures
III) Intellectual property vs. Open Source
IV) Speed and simplicity
V) Need to understand everything about the financial model



Data formats (exposure, output, log files, exposure conversion)

- Started with the first version of OASIS exposure files
- That developed as our financial model complexity grew
- Now one of the easier to use and convert to and from data formats
- In hindsight should have made our development open source (maybe) to get even broader adoption. Hard to say in hindsight

Summary: We are happy with all major decisions

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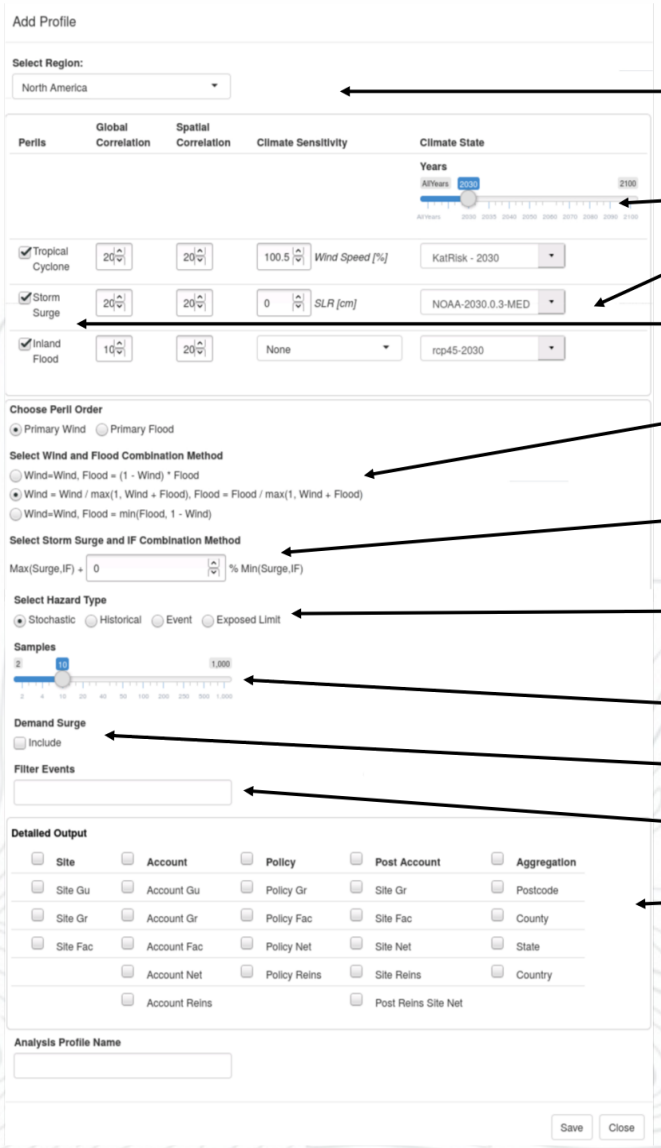
Analysis Settings Options / FM



Analysis region

Climate sensitivity options

Perils to include and correlation between locations

If running an analysis including wind and flood, how the losses are combined

If running an analysis including storm surge and inland flood, how the losses are combined

Type of analysis: stochastic, historical, event (event response), exposed limit

Number of samples

Include demand surge or not

Event filter list

Detailed by event loss options

- ❑ Settings per GUI or API
- ❑ FM also as standalone FMKat

Choices:

- Climate scenario or climate sensitivity
- Keep current flood defenses or change over time
- Multiple perils at the same time or single peril
- Expose everything

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Funny Things We Did

UNDERSTANDING THINGS A LITTLE LATER

The opportunity	The goal	The questions
Provide people with the opportunity to have a good laugh	Didn’t really plan this, but we really thought some of these were good (if not great) ideas	Are we still doing this? Why are we still doing this?

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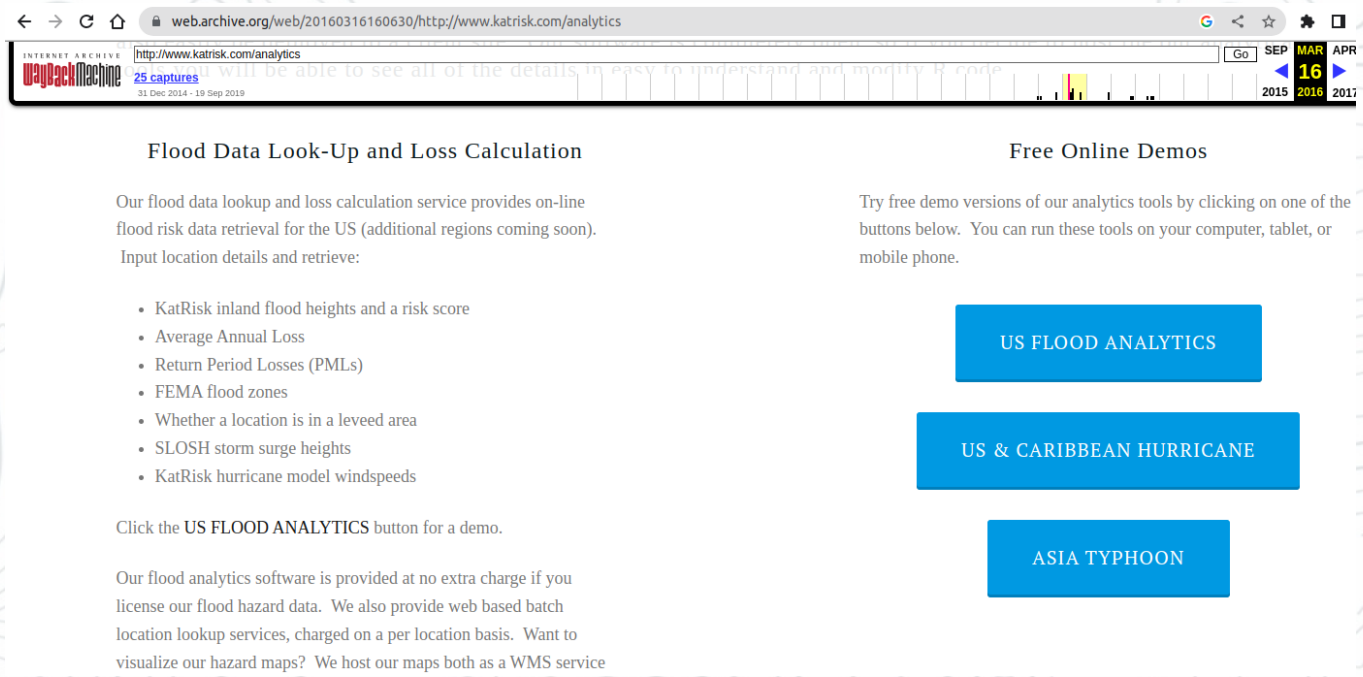
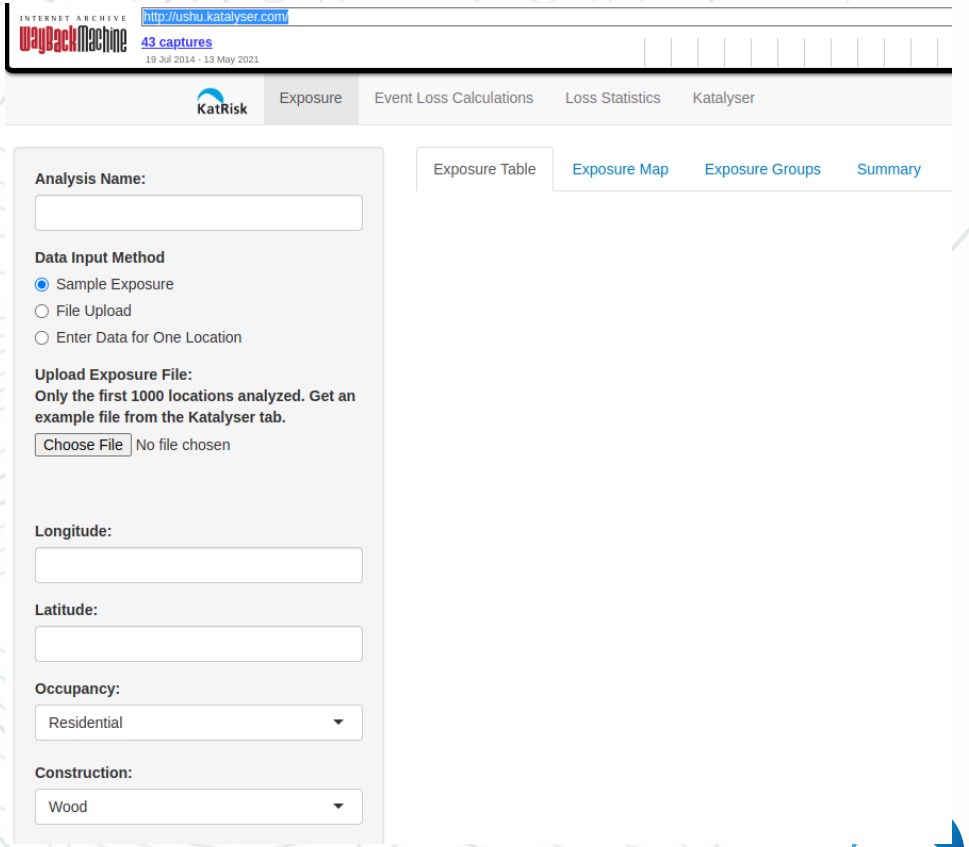
Open everything up? Really?

In 2015 we thought the R prototype of our loss models was great. We hosted it for free – only to discover that our flood maps were being harvested from all around the globe, but mainly from India. We had to stop within a month. You can see our website evolving in the WayBack machine.





The really stupid stuff I keep to myself, e.g. crashing Titan's queuing system.

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THE END

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