AMERICAN ACADEMY of ACTUARIES

Connecting the Insurance Industry and Academia on Catastrophe and Climate Modeling Webinar Series

April 17, 2023

Welcome from the American Academy of Actuaries on behalf of the Academy, NOAA and NSF

Ken Kasner, MAAA, FCAS
Co-Vice Chairperson
of the Academy's
Climate Change Joint Committee

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Panelists and Agenda

Welcoming Remarks	Ken Kasner, MAAA, FCAS; American Academy of Actuaries
Panel Overview	Mark Bove, CPCU, CCRMP, ARe; MunichRe America
1	Panelist 1, Charles Jackson, PhD; Verisk
2	Panelist 2, Eric Robinson, PhD; Aon
3	Panelist 3, Michael Young, PE; RMS
Audience Questions and Dialogue	Mark Bove, CPCU, CCRMP, ARe; MunichRe America

Goals and Intentions

- Focus on:
  **the state of the science
  **model inputs
  **resolution,
  **uncertainty
- Perspectives of cat modelers (today) and climate modelers (on May 15th)
- Specific Goals:
  **Enable stakeholders to incorporate NOAA's climate data into their decision-making
  **Encourage academic cat and climate modelers to submit proposals to NSF later this year
  **Support the Academy's on-going efforts to examine climate change and climate risk

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Overview of the Panel

Mark Bove, CPCU, CCRMP, ARe
Meteorologist & SVP Natural Catastrophe Solutions
RD-Specialty-Inno/Tech
Munich Reinsurance America, Inc.

Catastrophe Risk Models
Definition

Munich RE

- Computer programs that estimate the potential financial impact to one or more insured risks from a given peril, such as tropical cyclones.
- Cat models are highly granular, bottom-up models that use large, pre-compiled stochastic event sets to calculate financial losses to insurance contracts based upon (1) event intensity at each insured risk, (2) the physical characteristics of each insured risk, and (3) the terms of the insurance policy of each insured risk.
- Catastrophe risk models rely on the Law of Large Numbers to produce statistically stable financial and statistical outputs, such as pure premium (the amount of premium needed annually to “break even” with respect to a given peril over an infinite time period) and loss exceedance probability distributions (likelihood that financial losses will exceed *x* dollars in a given year).

Source: Munich Re

Catastrophe Risk Models
Simple Model Flowchart

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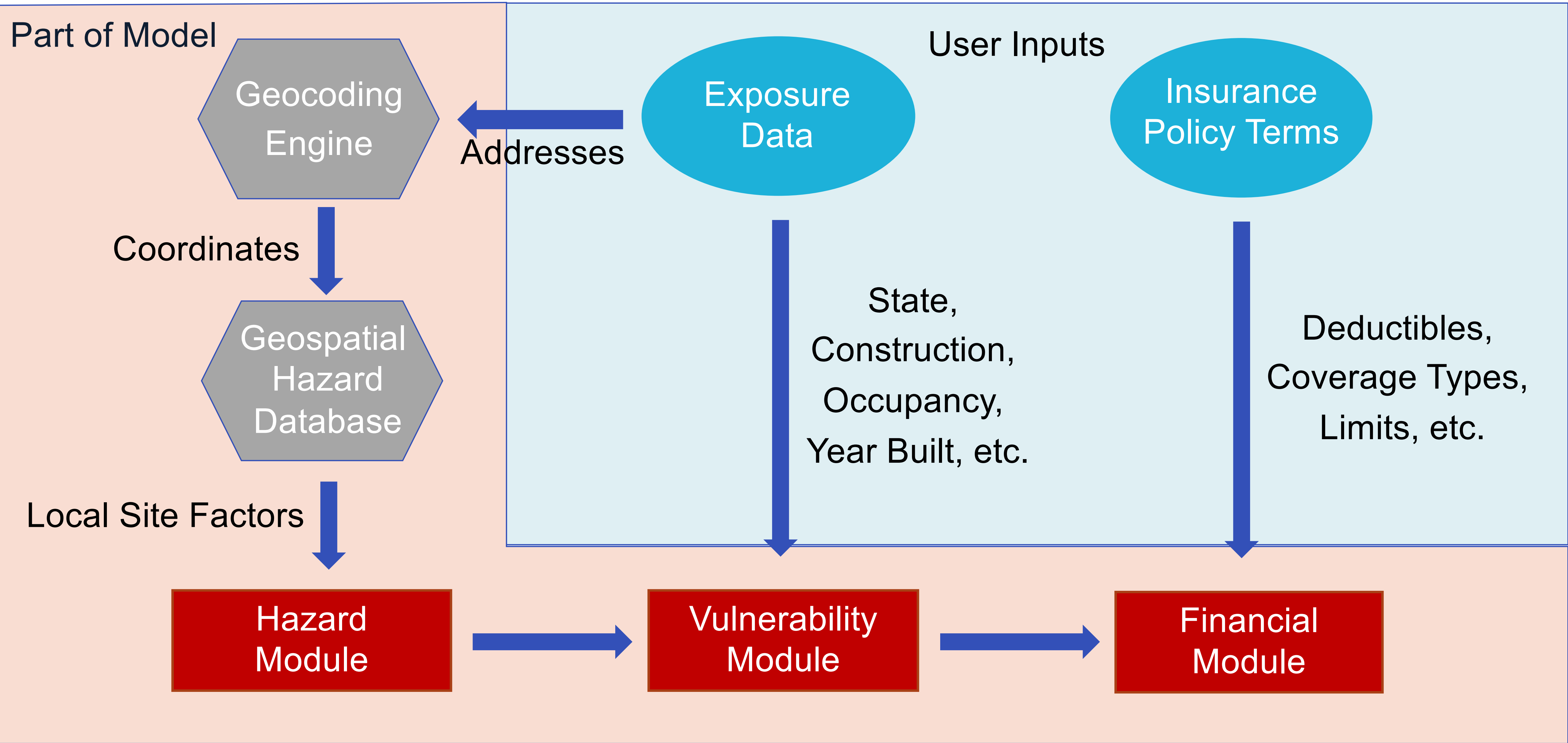

Catastrophe Risk Models
Creating a Stochastic Event Set for Atlantic Hurricane

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- All cat modelers use HURDAT2 / Best Track data as the first-order source in calibrating the frequency & severity of landfalling tropical cyclone (TC) events in the Atlantic. It is also used to extract TC parameters for statistical modeling.

- **Event Tree:** Modelling a range of hurricane parameters (different combinations of intensity, landfall angle, R_{max}, etc.) at thousands of pre-defined points along the U.S. coastline, without regard to overall basin behavior, except for landfall rates.

- **Basin Simulation:** Modelling entire Atlantic Basin to recreate realistic hurricane event sets using tens of thousands of model iterations (years). Can be done with either numerical weather prediction (NWP) or statistical models. Historical landfall frequency/severity relationships along coastal segments ("gates") must be closely approximated by the model.

- **TC Windfield:** Several different equations or mathematical approximations can be used to simulate a hurricane wind field. Examples include NWP models, Gradient Wind Equation, Holland B Parameter, and Rankine Vortex. Max 3-sec gust typically used to related wind intensity to damage, duration of wind may also be considered.

- **TC Storm Surge:** Due to complexity of modeling coastal flooding, NWP is typically used for storm surge footprints (SLOSH, MIKE, etc.), forced by the stochastic event's wind field.

Florida Commission on Hurricane Loss Projection Methodology:
https://fchlpm.sbafla.com/model-submissions/hurricane-model-submissions/?year=2019

Incorporating Climate Change into Cat Risk Models

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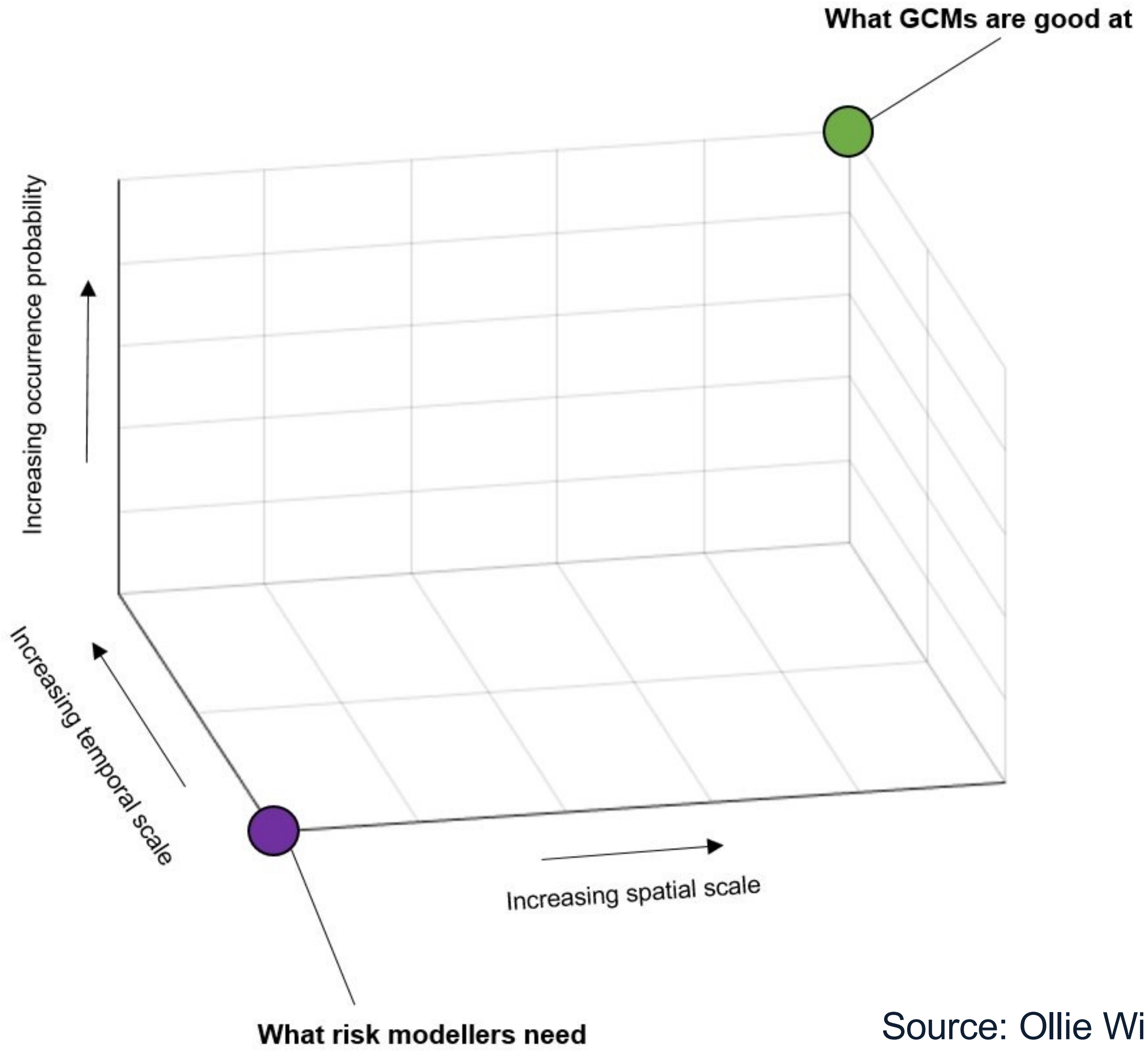
The insurance industry is most concerned about:

- The next 12 months: Typical length of insurance contract
- The next 5 years: Business strategy & planning
- 20-30 years from now: Regulatory reporting to Gov'ts, etc.

What climate data are most useful to insurers?

- Attribution science: Climate change is implicitly included in every new year of loss and hazard data. Can we distinguish the extant climate signal from natural variability and noise?
- Changes in peril tail risk & shifts in the overall probability distributions at regional spatial scales (or better).
- Measuring uncertainty around the above.

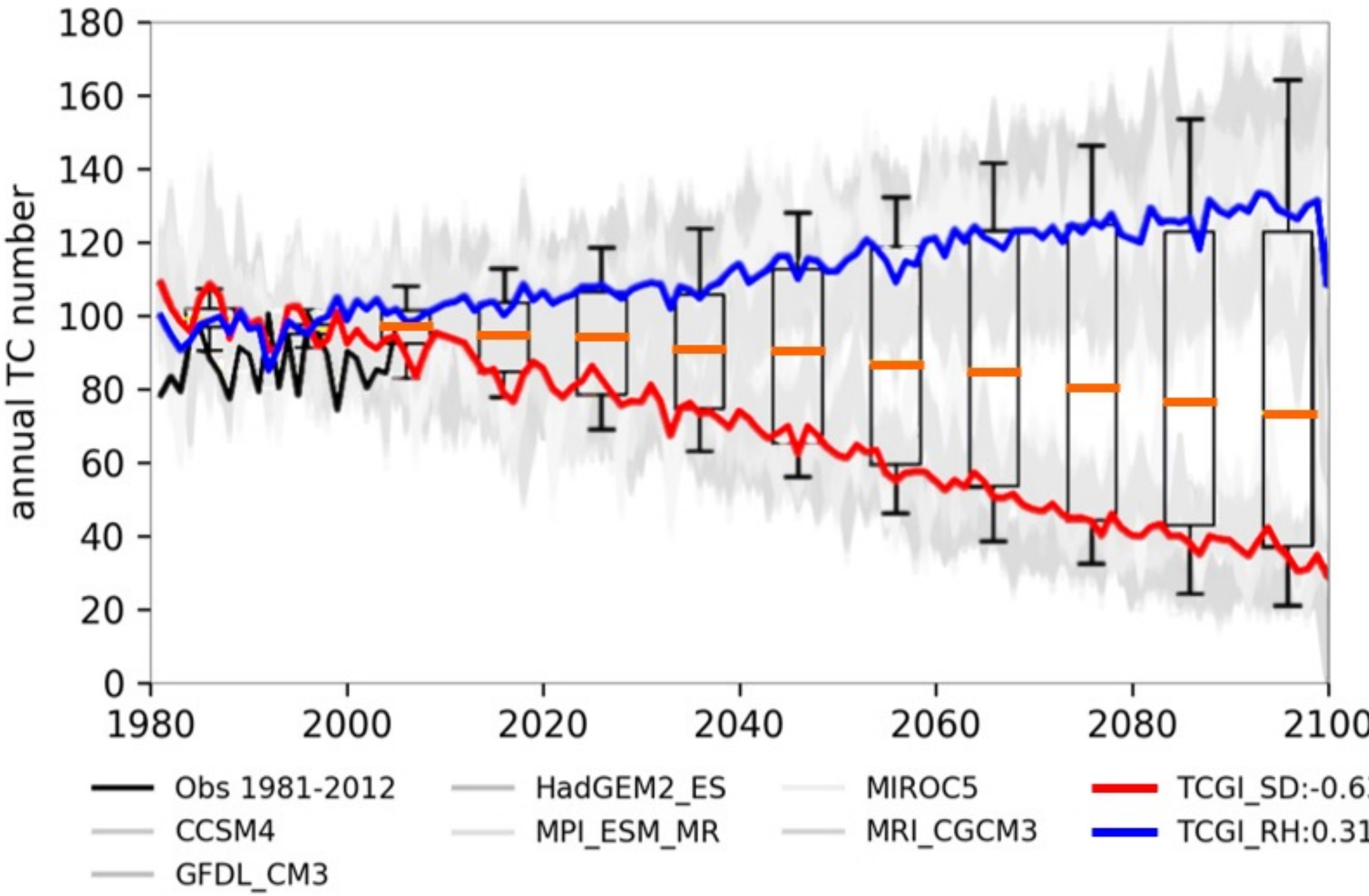


Source: Ollie Wing

Munich RE

Unanswered science questions:

- Impact of climate on global TC frequency.
- Understanding the drivers of the 1970-94 Atlantic TC drought.
- Impact of anthropogenic warming on natural climate variability, esp. ENSO & its teleconnections.
- How important are global correlations in cat modeling? Do we need global, all-peril meteorological cat models?



Source: J. Climate, Lee et. Al (2020)

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Catastrophe Models 1

Charles Jackson, PhD
Director of Atmospheric Perils Modeling
Verisk

Shared research goals between the climate and catastrophe modeling communities

Charles Jackson, Director of Atmospheric Perils Modeling

4/17/2023

Shared research goals between the climate and catastrophe modeling communities

Outline:

I. It’s not what you may be thinking

II. One good science question

III. Obstacles and opportunities

I. It’s not what you may be thinking

- Catastrophe models represent possible losses that could happen next year.
- Losses are sensitive to peril characteristics including damaging **area**, **intensity**, and **frequency**.

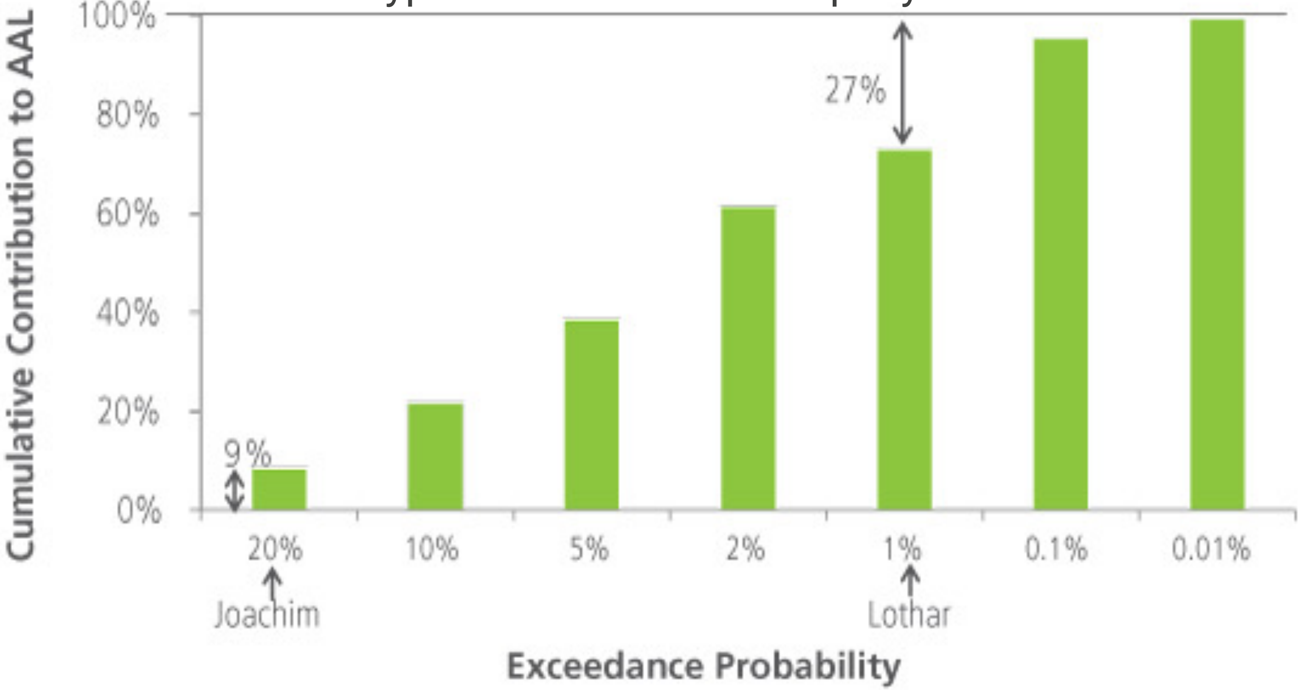
Cat Model ⇆ Claims Experience

Catastrophe models are designed to estimate frequency of losses from observed and possible extreme events.

- Average Annual Loss (AAL) is the mean of a highly skewed probability distribution.
- 9% of AAL comes from high frequency, low severity events (< 5-year return period).
- 27% of AAL comes from the tail (>100-year return period).

With only ~30 years of loss data, we lack good information about the exceedance probabilities for events with return periods greater than 5-10 years.

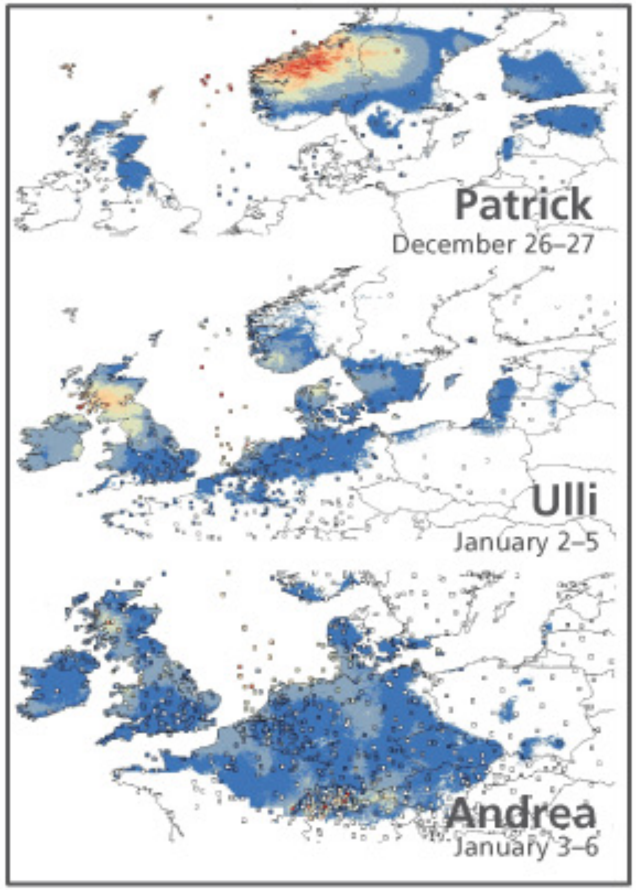
Exceedance Probability for Average Annual Loss of a hypothetical French company to ETC storms

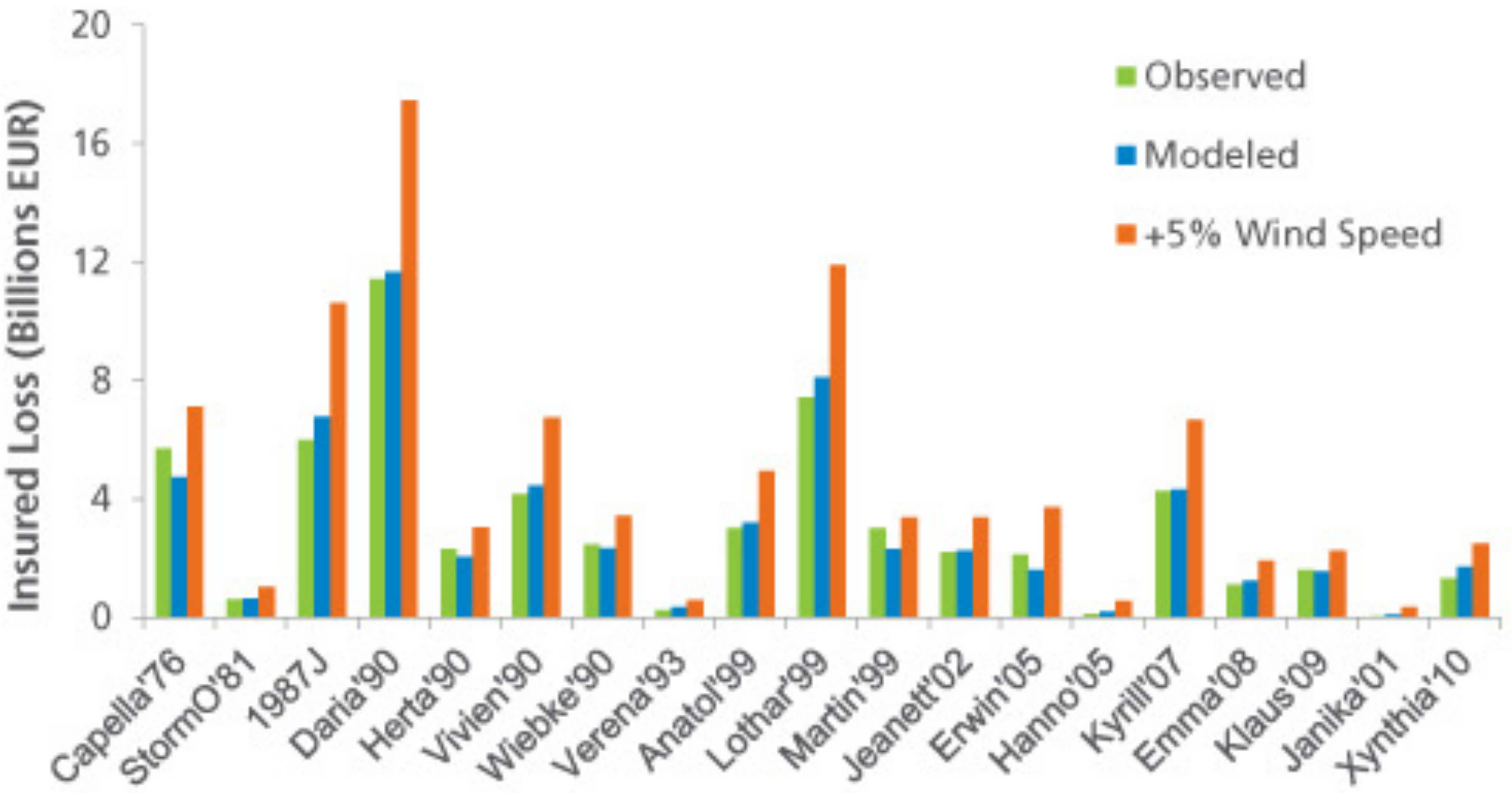


https://www.air-worldwide.com/publications/air-currents/2012/European-Windstorm-Models--Questions-You-Should-Ask/

Losses are a highly non-linear function of peril characteristics.

Maximum wind for a cluster of storms in 2011/12





https://www.air-worldwide.com/publications/air-currents/2012/European-Windstorm-Models--Questions-You-Should-Ask/

Local Intensity Estimation: ETC Daria

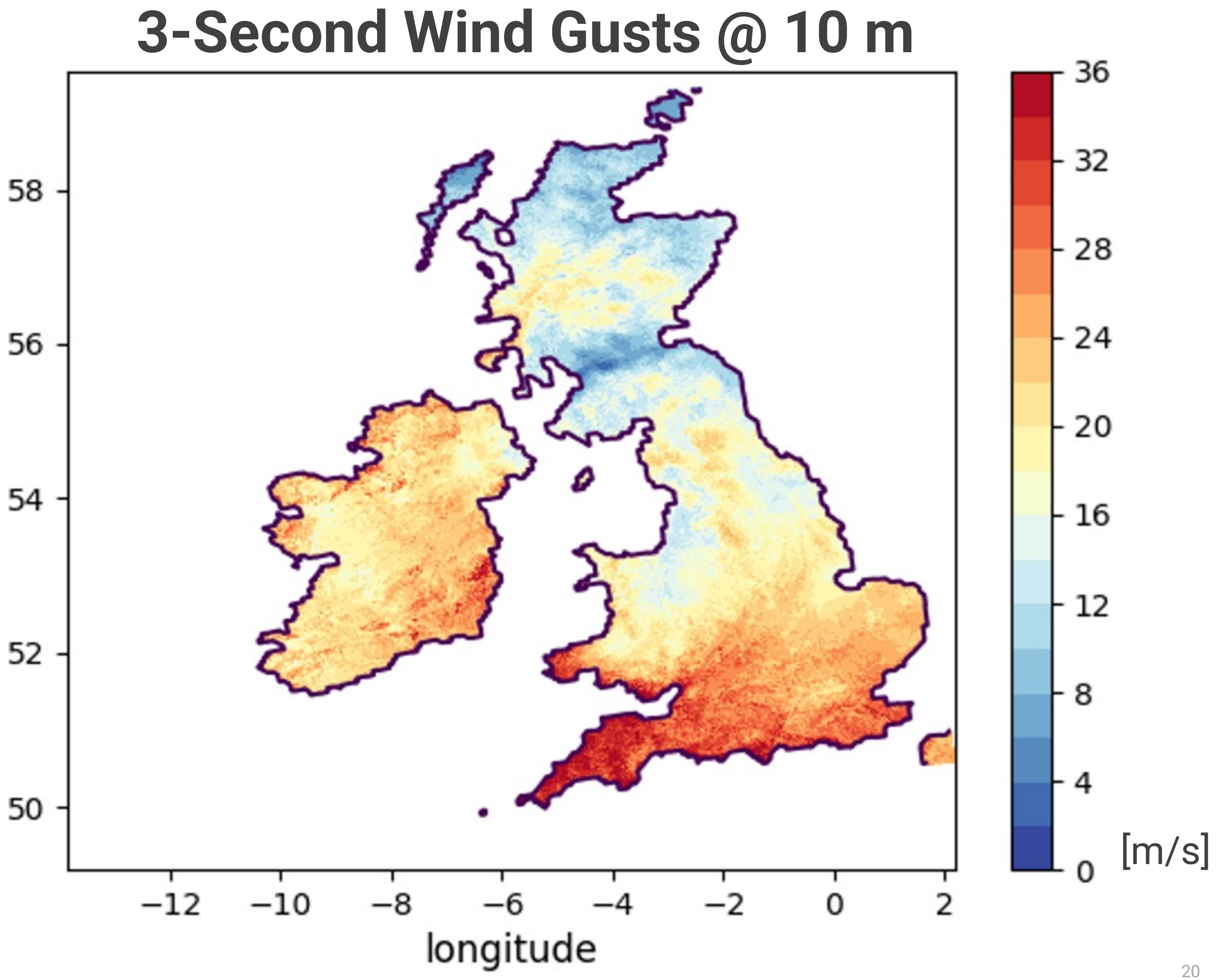
January 25, 1990, at 12 am

Typical cat model development:

- Perturb 50-year history of storms using numerical weather prediction and statistical modeling.

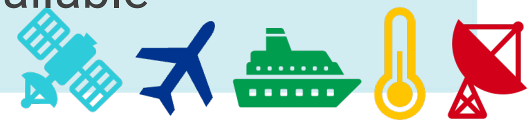
Next generation cat model (@Verisk):

- Uses Deep Learning tools and reanalysis products to debias and downscale climate model output.



Accounting for Climate Change

Strategy 1 — Calibrate models against latest available observations.



Adjust model intensities toward observations

Strategy 2 — Subsample catalog years to capture changes in frequency, intensity, and location.

Inventory

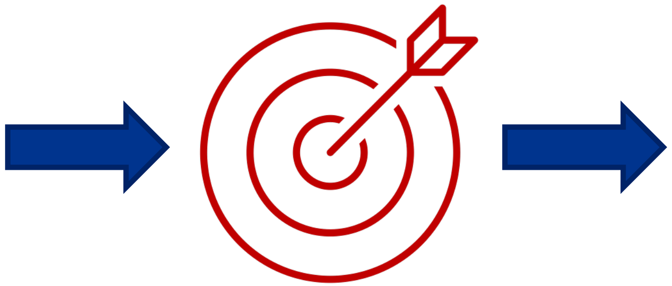
Climate Change Projections

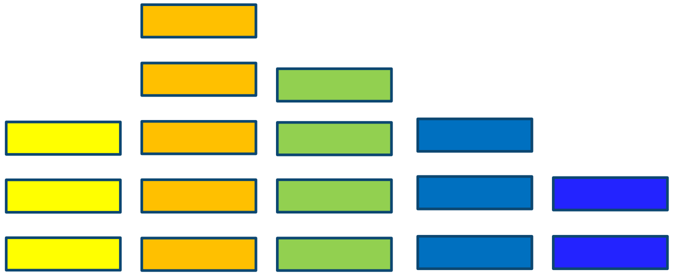
Conditioned Catalog

Existing Catalog

New catalog

Low severity High severity





Low severity High severity

Shared research goals between the climate and catastrophe modeling communities

Outline:

I. It’s not what you may be thinking

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What explains changes in US tornado counts?

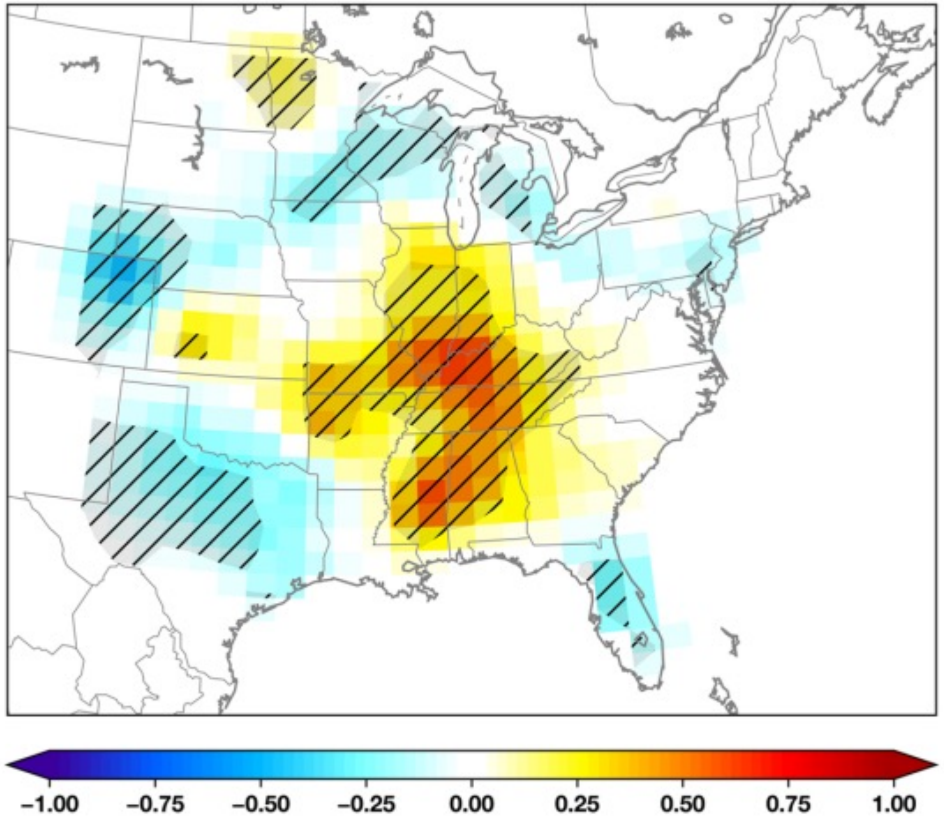
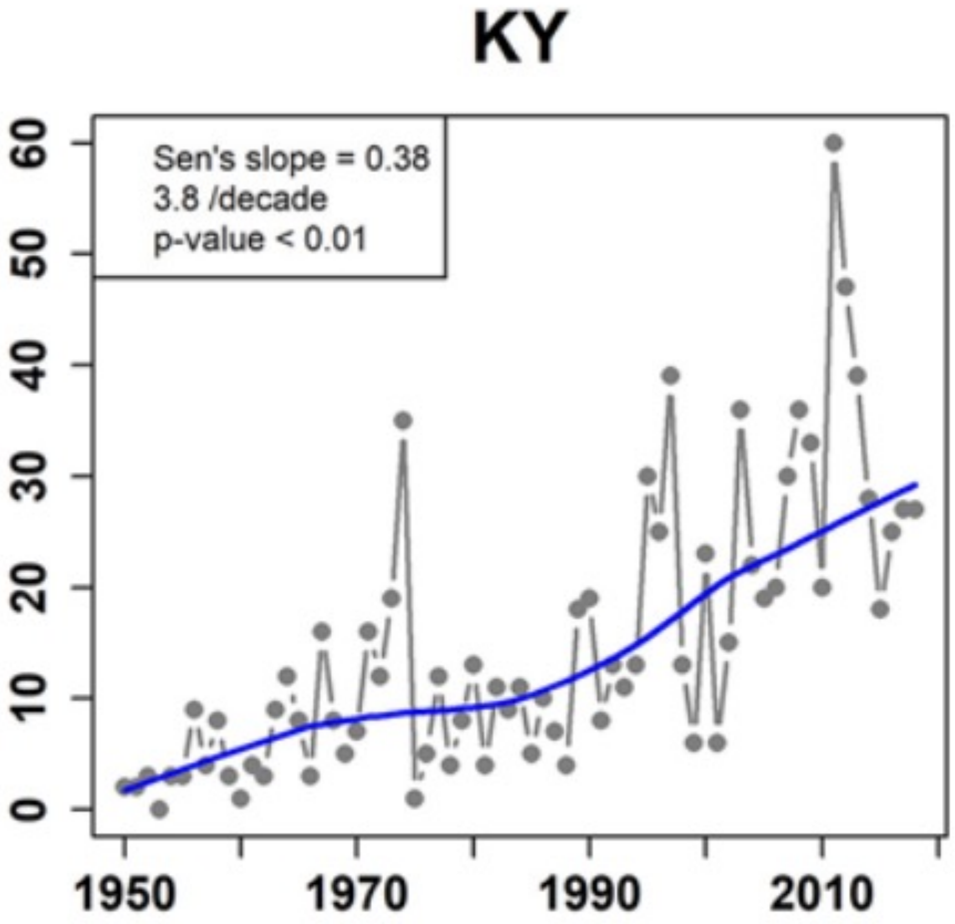


Fig. 5 Theil-Sen slope analysis of 1979–2017 annual gridded tornado reports. *p* values are hatched at values ≤ 0.05 significance using Kendall's τ statistic. Slope units are reports per year * 10^{-1}

Gensini and Brooks (2018)



Nouri et al. (2021)

Why these observations seem problematic for catastrophe modeling:

- CMIP5 ensemble shows that environmental predictors for the number of days with severe thunderstorm environments (NDSEV) should increase the most in the spring. From 1980 to 2020, spring NDSEV was only expected to increase by 10% (Diffenbaugh et al., 2013).

- Observed changes in tornado counts is dramatic. For instance, in Kentucky EF 1+ counts increase by 600% since 1980.

- **Are environmental predictors of severe thunderstorm perils robust predictors of potential loss characteristics (area, intensity, and frequency)?**

Shared research goals between the climate and catastrophe modeling communities

Outline:

I. It's not what you may be thinking

II. One good science question

III. Obstacles and opportunities

“Please address these questions”

What are the major obstacles to improvements in cat modeling?

- Lack of radar observations of peril characteristics (area, intensity, frequency) and storm report data, particularly outside the US.

“Please address these questions”

What changes in climate models would improve cat modeling generally?

- Ability to resolve effects of mesoscale processes on peril characteristics.
- Develop high resolution fingerprints of the effects of anthropogenic forcing to interpret the predictable component of observed changes in station data.

“Please address these questions”

What changes in climate models would improve cat modeling for specific perils?

- For severe thunderstorm perils (hail, straight-line wind, and tornados), develop new strategies for predicting peril characteristics from environmental data.

Catastrophe Models 2

Eric Robinson, PhD
Director, Global SCS Lead
Impact Forecasting
Aon

Using Climate Data in Catastrophe Models

04/17/2023

Usage Falls into 2 Categories: Direct and Indirect

Indirect Applications

- Data are used as a background field from which statistical models of the hazard are created
- May utilize “observations”, numerical models, or a mix of both
- Example: Using CAPE and Shear from Reanalysis to guide placement of Severe Convective Storms

Direct Applications

- Data or model output is used directly as a way of generating the hazard component of the model
- Example: Simulation of ETCs over Europe extracted from 1000-year simulation of current climate

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Difficulties with Indirect Applications

- **Indirect can also mean "incomplete"**
  - Catastrophe models often require more detailed information than can be gleaned reliably from "proxies"
    - Tornado length/width/intensity and how this relates to environmental conditions
    - Radius of maximum winds for Tropical Cyclones
    - Snow-to-Liquid Ratio, Snow vs. Freezing Rain
- **Indirect can sometimes be in conflict**
  - Various environmental parameters can be in conflict
    - CAPE vs. Shear vs. CIN
    - Drought results in drier fuel, but also significantly less growth of fuels (but only in some pyromes)
- **Indirect often depends on invariance**
  - Statistical models very often rely on stationarity, which is rarely true when it comes to environmental conditions over shorter periods of time
  - "Past performance is not a guarantee of future returns…"

Difficulties with Direct Applications

- **Direct applications can heavily rely on resolution**
  - Perils have varying needs when it comes to resolution, making direct applications very resource intensive
    - ETCs vs. Supercells vs. Tornadoes vs. Hailstones
    - Urban versus Rural locations
- **Direct applications often require downscaling, which may or may not be sufficient for proper risk assessment**
  - Dynamic downscaling is exponentially expensive: We often need 10s-100s of thousands of years
  - Statistical downscaling is faster, but may miss interactions that happen on small scales
    - Example: Downstream storms initiated by a convective outflow
  - Not all variables are straight-forward to downscale
    - Cloud Cover
- **Parameterizations are unavoidable, and have varying degrees of "goodness"**
  - Land surface interactions and changes
  - Microphysics
  - Turbulence

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Applications of Future Climate Suffer from Additional Problems

- **Greater uncertainty requires examining many models**
  - Differences in resolution, variable availability, output frequency, etc., can make comparison difficult
    - Also dramatically increase processing time and complexity
  - Different models are more credible for certain phenomena than others, but this isn't always clear

- **Model independence can be difficult to determine**
  - For example, some models share the same dynamical core which can cause them to form "families" of solutions which are not truly independent

- **The mean can be meaningless…**
  - Focusing purely on changes in the mean is not always helpful, especially when:
    - The "mean" falls outside of the envelope of deterministic outcomes (e.g., the mean of two equal but opposite trends is no trend at all)
    - The response of the mean is not equal to the mean of the responses (e.g., the damage from the mean wind speed is not equal to the mean damage of the constituent wind speeds)

Some Suggestion for Future/Continued Work

Proxy to Property

What can large-scale environmental conditions tell us about small-scale details?

Conflict to Congruence

What additional information do we need to resolve conflicting climate signals?

Persistent or Passing?

How do we identify relationships that are the result of the fundamental underlying physics?

Develop Deft Downscaling

Are there more efficient ways to achieve downscaled results? ClimateGPT anyone?

Time for a Tree?

Time for a “model family tree”? How do we decide when models are different enough?

Diagnose the Distribution

Move past the mean! How does the distribution of variables change? On different temporal and spatial scales?

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2

Some Thoughts on Public-Private Partnerships

Public-Private Partnerships Require a Joint Understanding

Academic and industry priorities are not always aligned

Research takes time, but investment demands results

Publish or Perish vs. Playing it Close to the Chest

In the end… It’s a business… and businesses require ROI

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Some Suggestions when Starting a New Public-Private Partnership

List out explicit deliverables and timelines

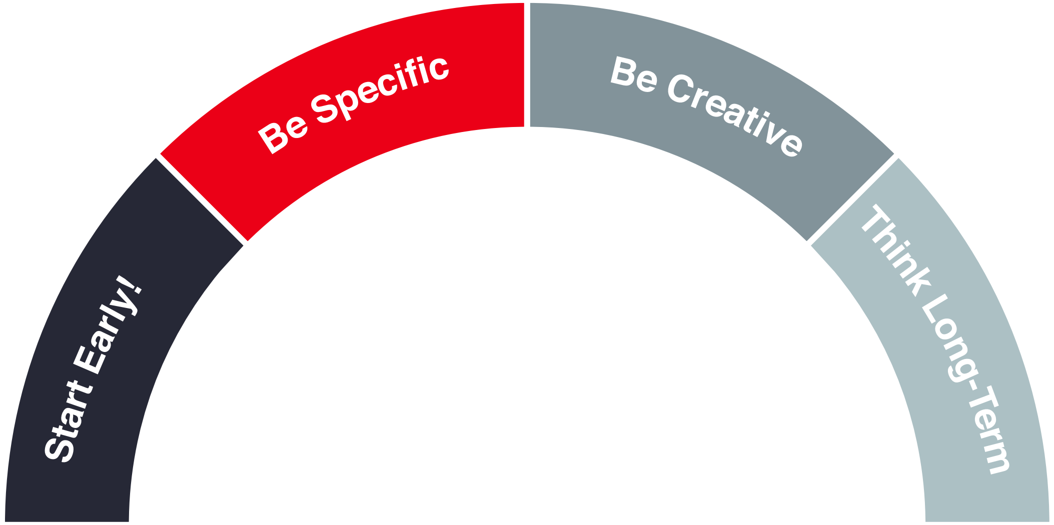
Ensures that everyone gets what they need, when the need it. Explain the different use cases for the deliverables to ensure adequacy of project scope and proper use of research. Be sensitive to academic timelines and department funding practices.

Approach difficult topics with creativity

Most private companies are going to want commercial use of the project outputs with limited restrictions and some level of exclusivity. How can this be arranged but still allow for dissemination of the research for peer-review and advancement of the field?

Contract negotiations take time

A minimum of six months if you expect back and forth between legal departments, possibly longer if there are multiple institutions involved. Cover usage, dissemination, publication, publicity, ownership, costs, timelines. Never underestimate the ability of legal negotiations to take 10x longer than you think is "necessary"



The best collaborations are partnerships

- Don't limit your thinking to just the task at hand… if it goes well, can you create an enduring partnership?
- Projects get easier with time and familiarity, continuing partnership has a much better ROI

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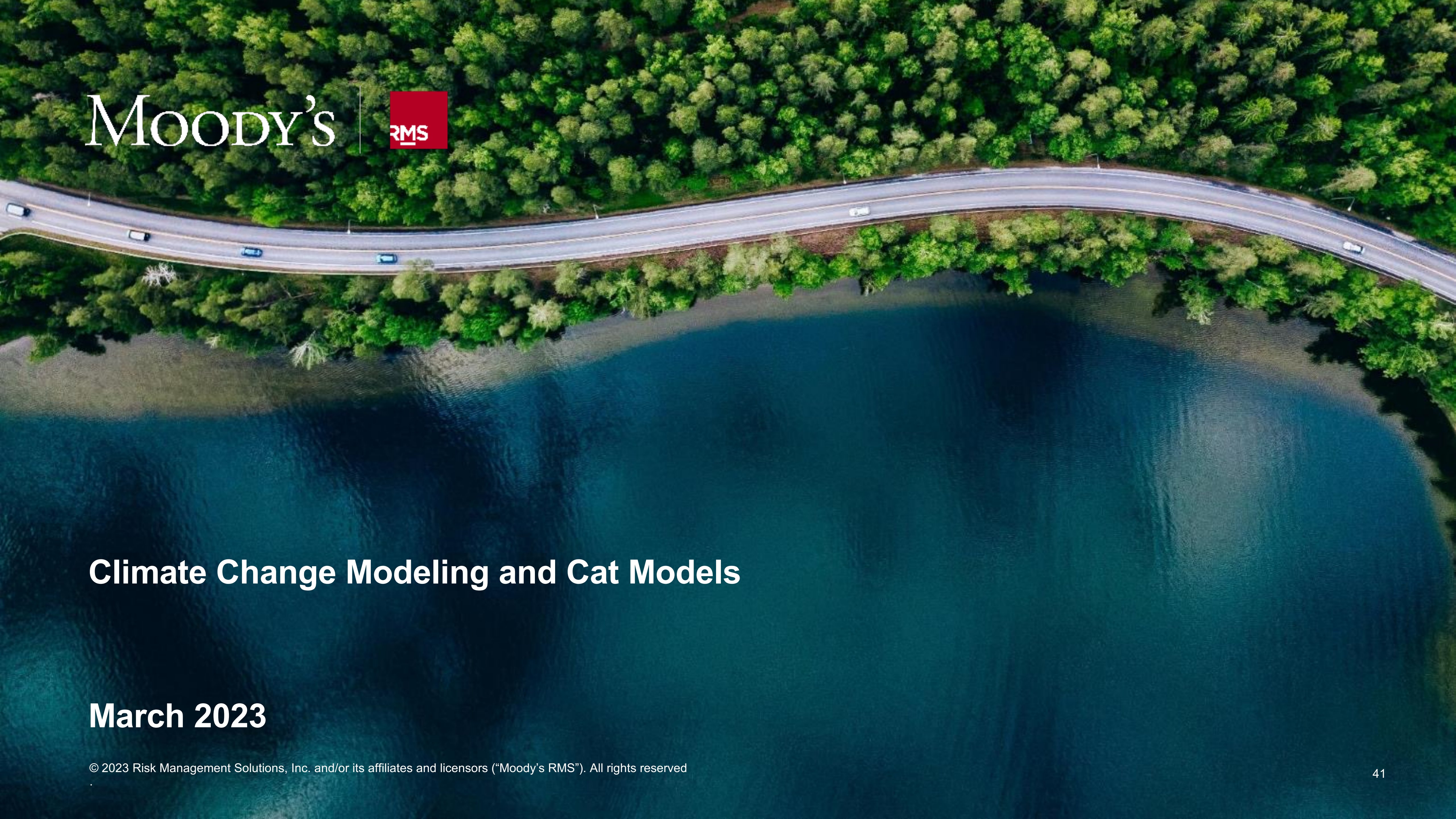
Catastrophe Models 3

Michael Young, PE
Vice-President, Product Management
RMS



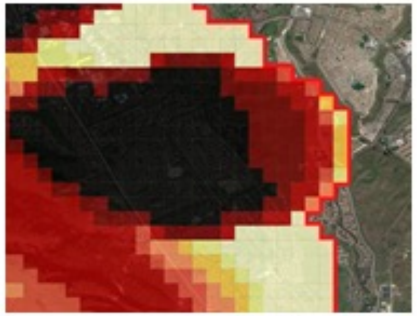
Climate Change Modeling and Cat Models

March 2023

Catastrophe Modeling FRAMEWORK

Stochastic Event Catalogue

Simulate wildfire scenarios for 50,000 versions of next year



Assess Hazard

Quantify spatial extent & intensity of heat, ember, smoke hazards using physical science models

Apply Exposure

Apply replacement value of properties at risk for structure, contents, and business interruption

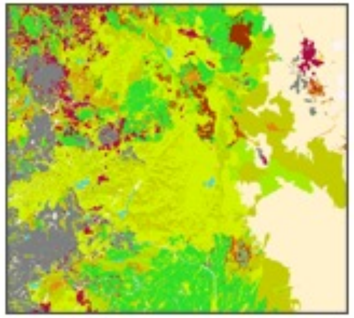
Calculate Damage

Estimate damage for different vulnerability classes based on material, height, occupancy, year built & mitigation measures

Quantify Financial Loss

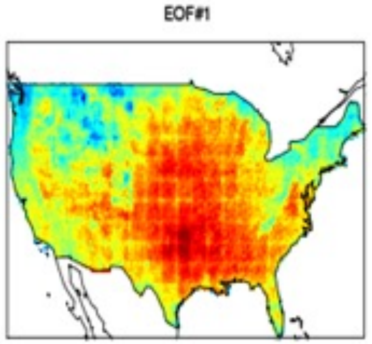
Apply insurance terms & conditions to estimate loss to policy holder, insurer, reinsurer

WILDFIRE HAZARD MODELING FRAMEWORK



Topography
Surface Fuels
Canopy Fuels
Forest Fuels

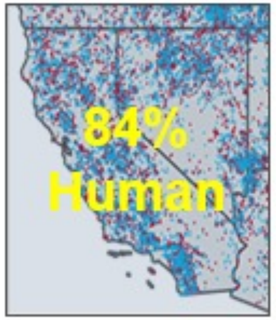
Dist. to Vegetation



50,000-year Extreme Weather Simulations

50,000-year Extreme Wind Simulations

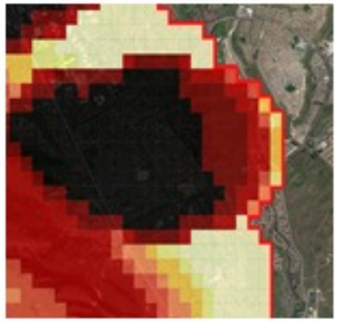
Climate Change "So-Far"



Simulate Ignitions considering urbanization patterns

Minimum Travel Time Algorithm
=
Realistic fire durations

Explicit Ember Transport Modeling



Structure to Structure Spread
=
Next Coffey Park

Smoke Footprints:

Emission and Transport models

Up to 20% of loss

FIRE WEATHER SIMULATIONS

35 Years North American Land Data Assimilation System (NLDAS-2)

↓

Generate Principal Components of fire weather index patterns

↓

Generate synthetic ENSO index time series

↓

Generate synthetic anomalies time series using Monte Carlo sampling of PCA linked to ENSO time series

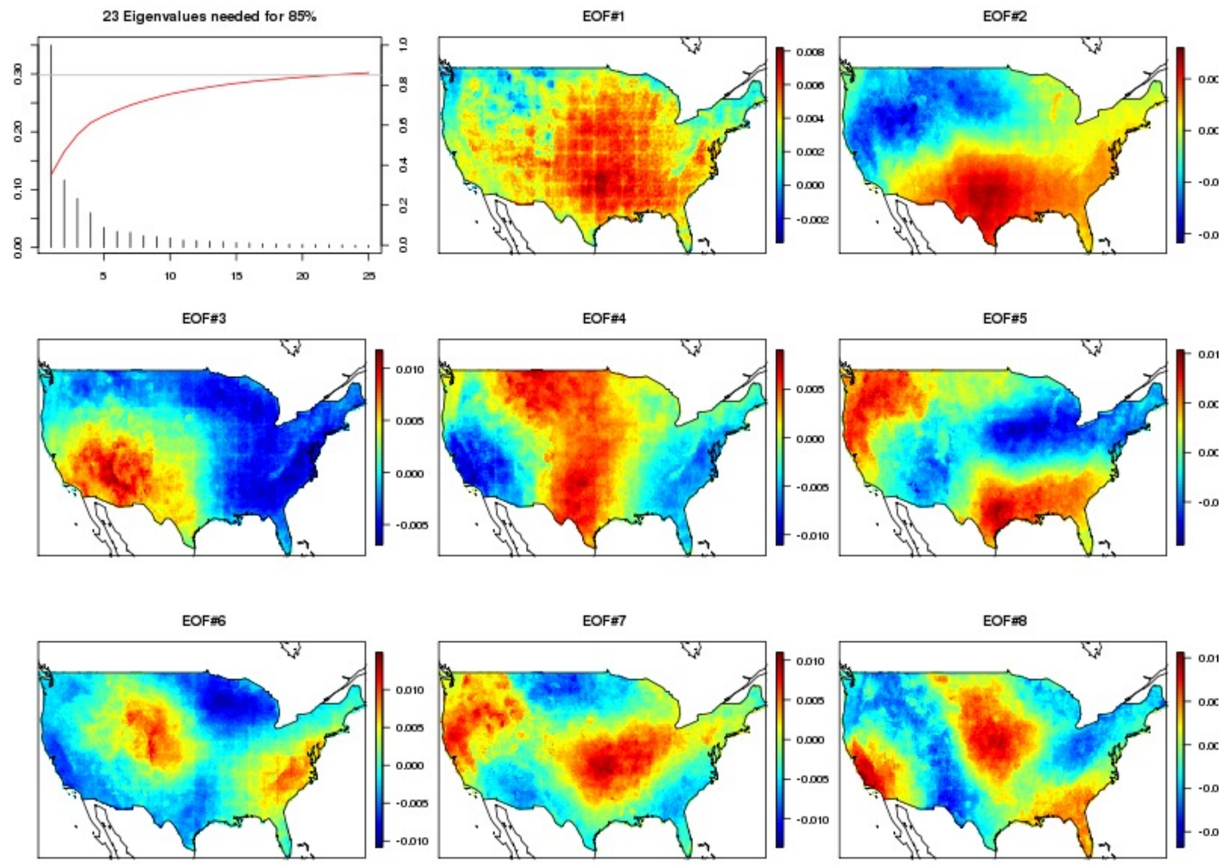
↓

Create monthly fire weather index applying anomalies to long term mean

↓

Temporally disaggregate monthly fire weather index to daily time series for 50,000 years

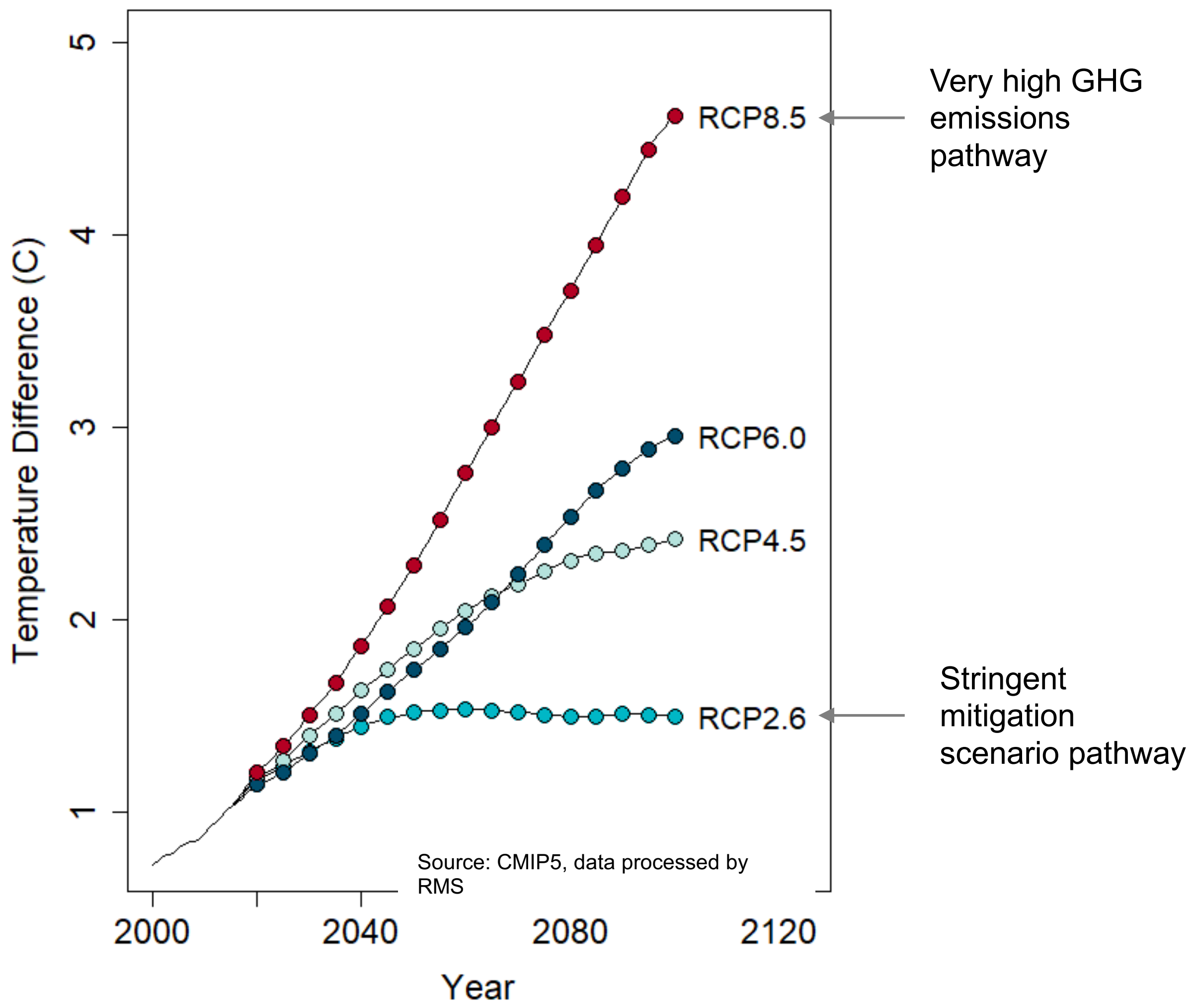
Principal Component Analysis (PCA) to capture spatiotemporal patterns



Full Range of RCPs and Time Horizons

- Representative Concentration Pathways (RCPs) are different IPCC pathways which describe future greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use
- RCPs are pathways not snapshots – the rate of climate change varies:
  - By time along each RCP
  - Between RCPs
- RMS climate change models include:
  - RCP2.6, RCP4.5, RCP6.0, RCP8.5
  - From 2020-2100 in 5 year intervals
  - Total of 68 RCP/Time Horizon conditioned views

Global Mean Surface Temperature (GMST) Relative to Pre-Industrial Levels



IPCC: Intergovernmental Panel on Climate Change | CMIP: Coupled Model Intercomparison Project

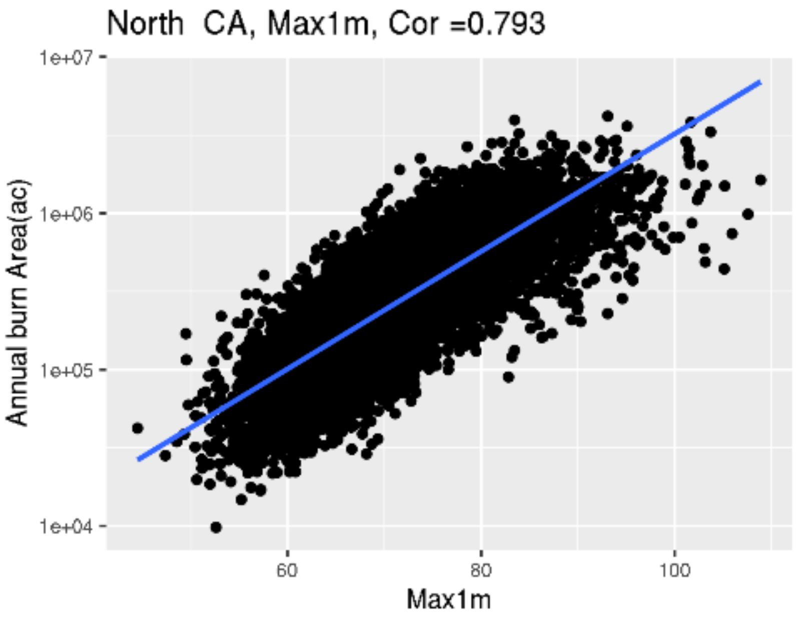
What Peril parameters are affected by Climate Change?

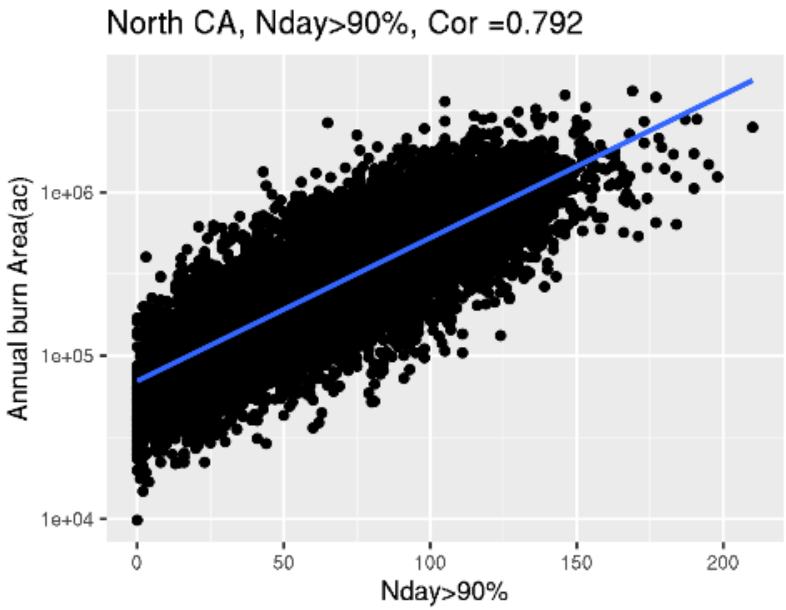
- Changes in Temperature and evaporation
  - Increased evapotranspiration of wet and dry fuel load
  - Earlier snowpack melt
- Changes in humidity and rainfall
  - Atmosphere holds more water vapor – 21% more verses 1951-1980 baseline
- Changes in wind
  - Warming may affect circulation patterns, wind seasonality, wind speeds/direction
  - GCM not well calibrated and validated on this aspect.
  - Relationship not clear
- Changes in length of fire season
- Other factors such as fuel type, ignition, exposure, vulnerability, fire spread (wind), PSPS, urban conflagration changed as a function of ERC changes (but not explicitly)

What's the right ERC-G metric?

Our objective is to pick ERC derived risk metrics that correlate with burned area & $ loss:

- **Nday90**: yearly number of days with ERC-G > 90 percentile of reference data, used often in the literature (Goss et al., 2020 and Abatzoglou et al 2020)
- **Max1m**: yearly maximum 1-month ERCG





The chosen metrics for conditioning should, when changed, alter risk profiles for re/insurance applications

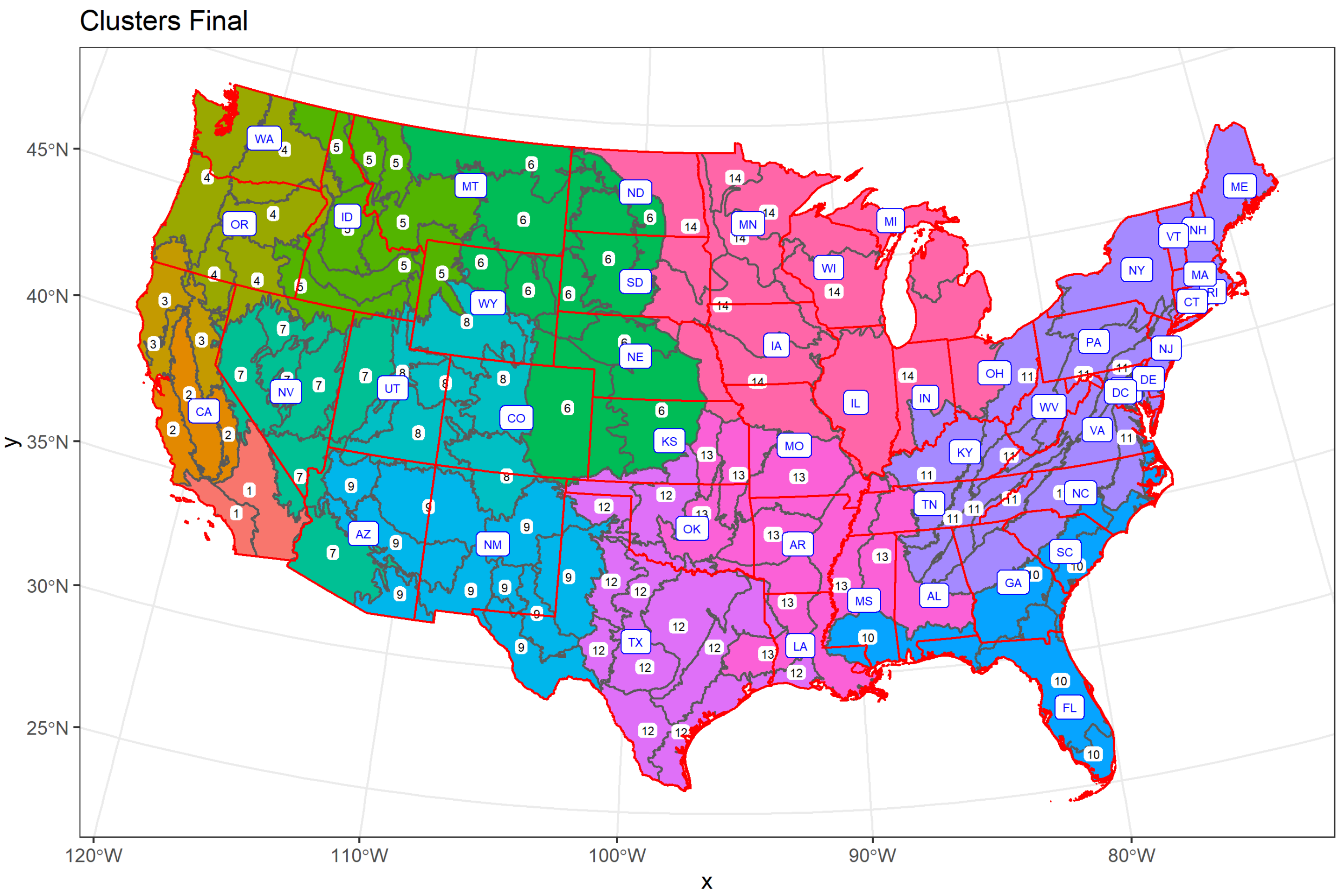
Region definition

- Aggregated ERCG index from the stochastic model and climate model data to 14 regions (considering both physical and $ factors)

- 'Dimension reduction' useful for two reasons:

- Avoid computational issues related to 'curse of dimensionality' (http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=7EB55EC5C863B4EBD16F4AAC079709A9?doi=10.1.1.64.5084&rep=rep1&type=pdf)

- Climate model signals are highly uncertain, and therefore high-resolution targets are not justified. Our approach is to use aggregated targets, and use the core cat model to understand relative risks at granular resolutions (since a great deal is invested in the core cat model)



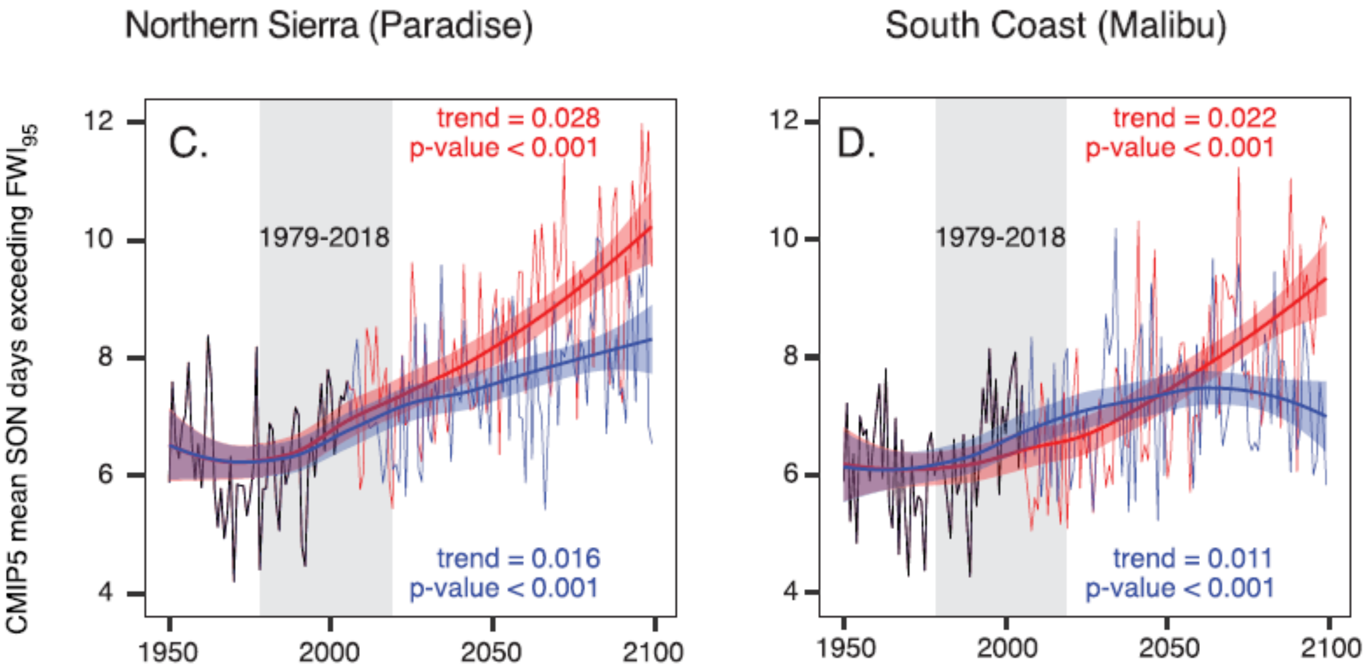
Consistent With Existing Literature

RMS analysis of global climate model data (18 GCM)
RMS analysis is consistent with the published literature

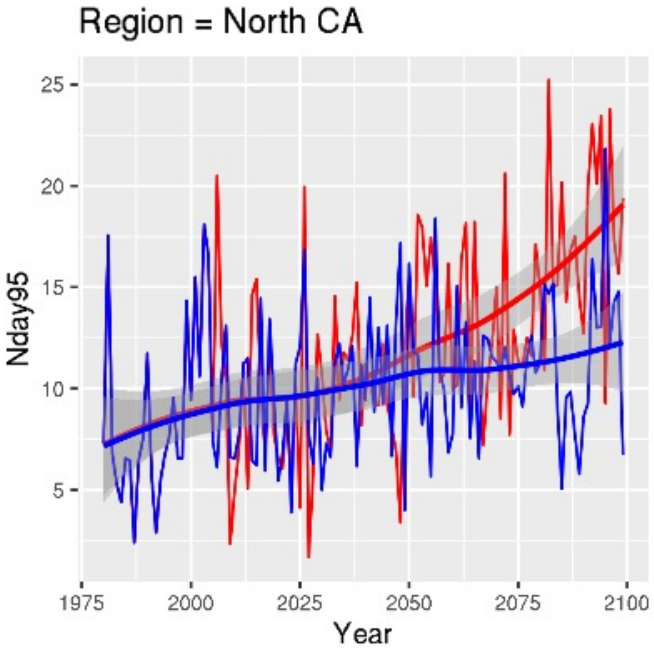
Working with
Dr. John Abatzoglou

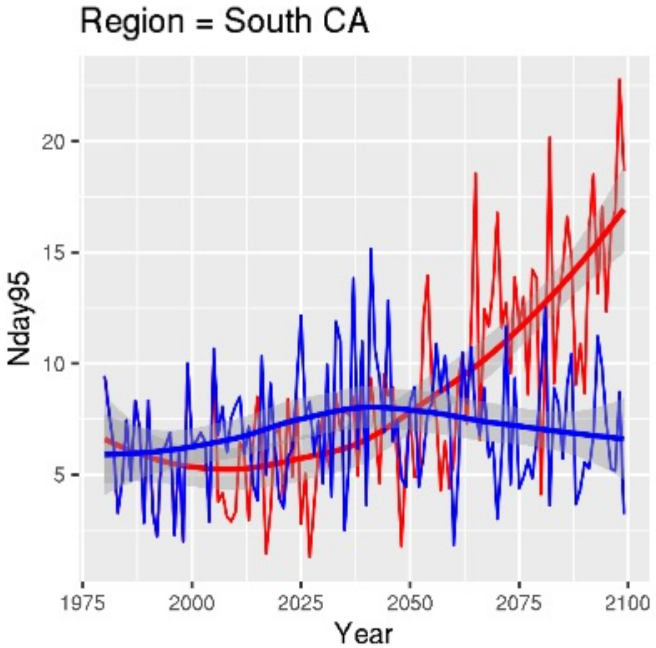
Fire weather: Temperature, humidity, and precipitation

Goss et al. 2020



RMS





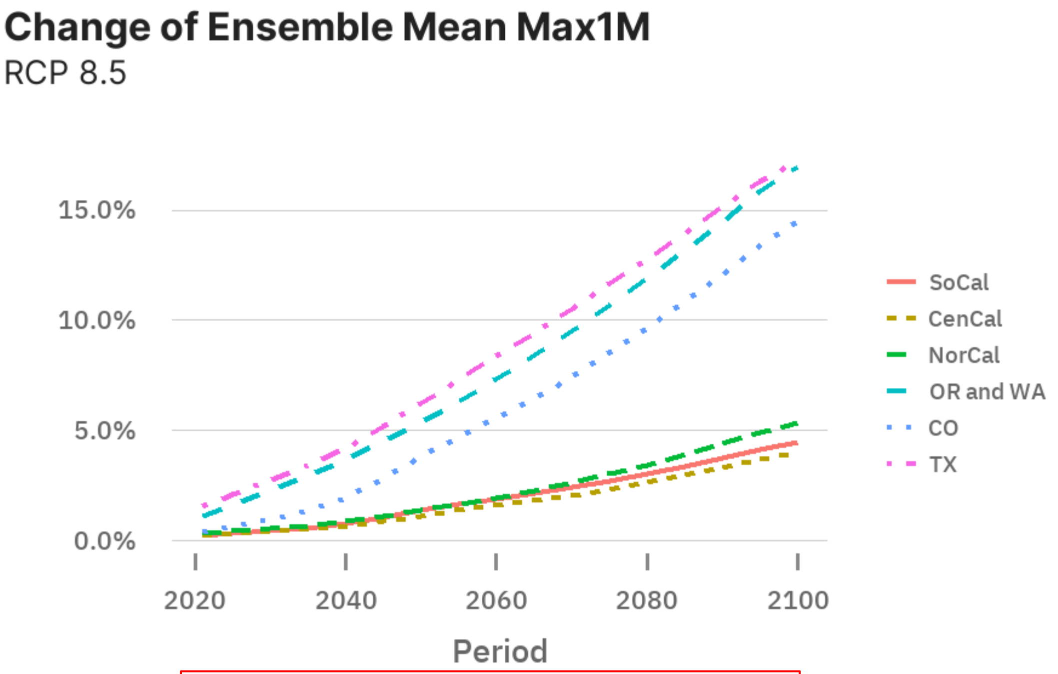
Blue: RCP4.5
Red: RCP8.5

U.S. Wildfire: Fire Weather Index Conditioning

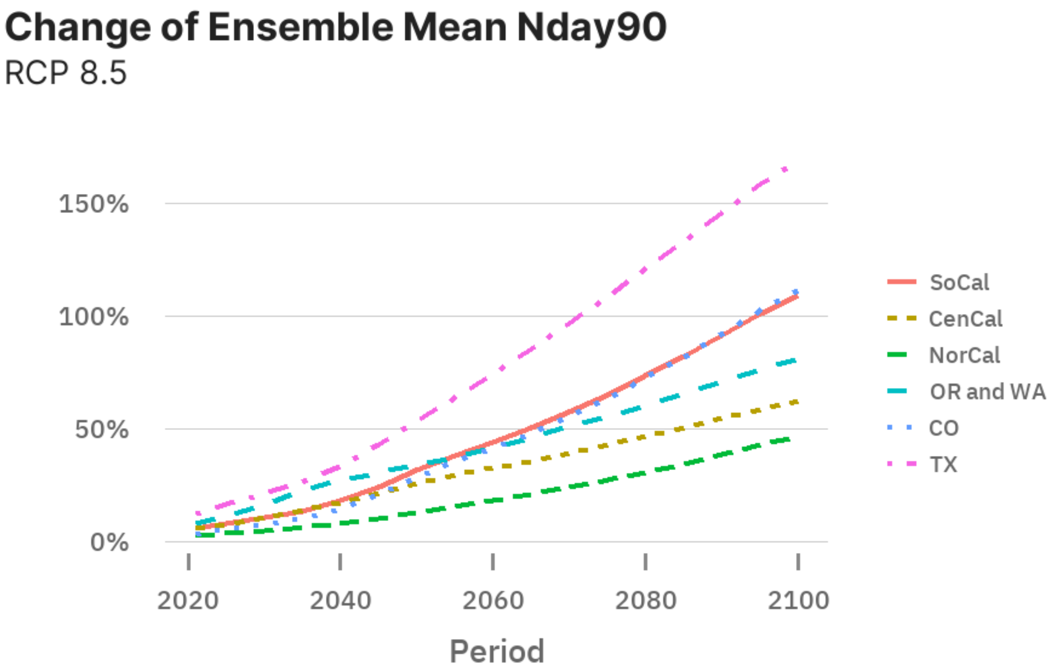
Conditioned Variables

Energy Release Component – fuel class G (ERC-G)
(fire weather index capturing fuel moisture, temperature, precipitation, and humidity)

Yearly maximum 1-month ERC-G	Yearly number of days > 90th percentile of reference ERC-G



Max change > 15%



Max change > 150%

Source: data from MACAV2-METDATA, processed by RMS

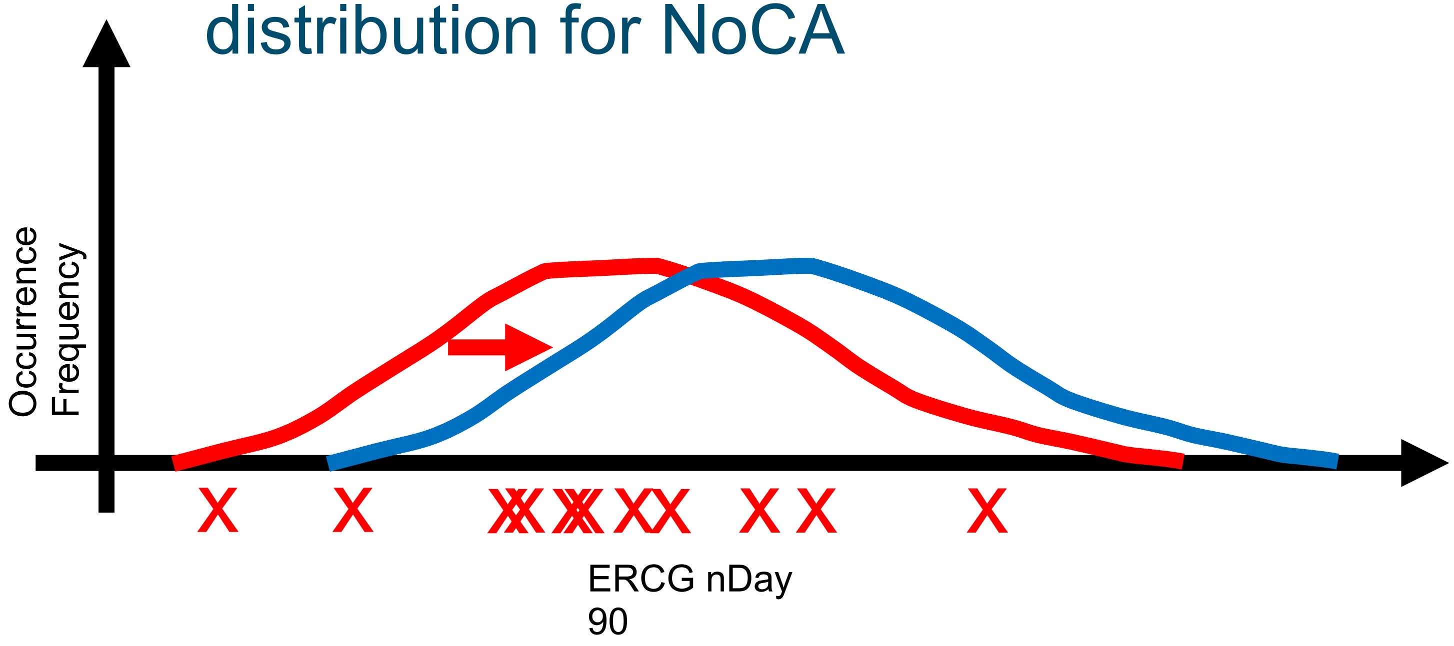
Model conditioning concept

- Take the distribution of ERCG (e.g. Nday90) in the existing model (**red**)
- Construct a target distribution using insights from the MACA data (**blue**)
- Adjust frequencies of years which make up the existing model distribution (**X**’s) to shift model distribution to match the blue target curve
- Multidimensional problem: perform conditioning across the 14 regions and 2 ERCG metrics

➢ **Single conditioned weight for each model year**

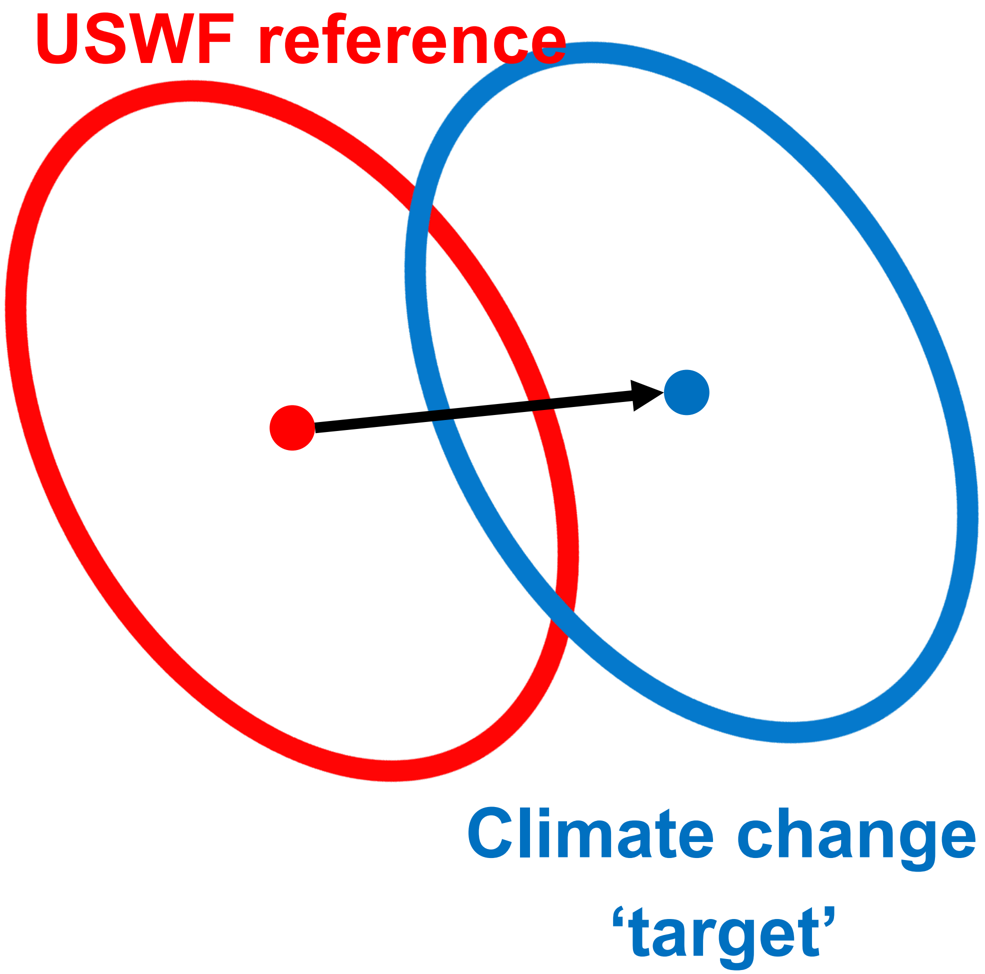
- Repeat for each RCP and Time Horizon

Schematic: ERCG nDay90 distribution for NoCA



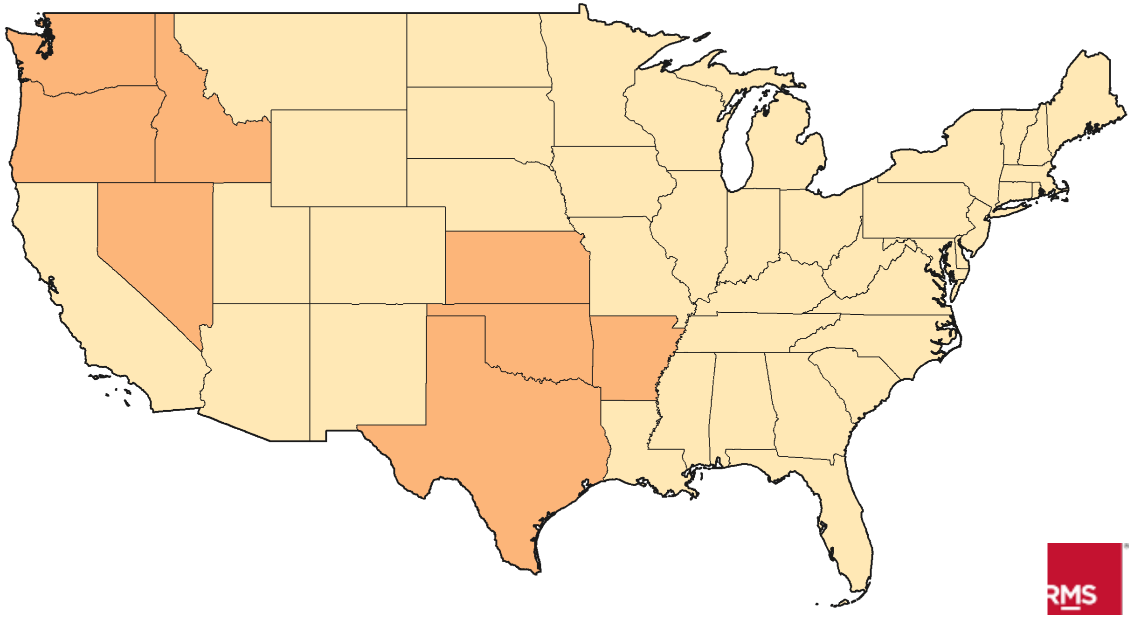
Model conditioning concept for a given RCP and time-slice

- For each region algorithm shifts the distribution from the **reference model** to the climate change model (in a user-friendly way)
- Optimization algorithm enables weighting regions
- Target has no change in volatility
- Target has same correlation structure

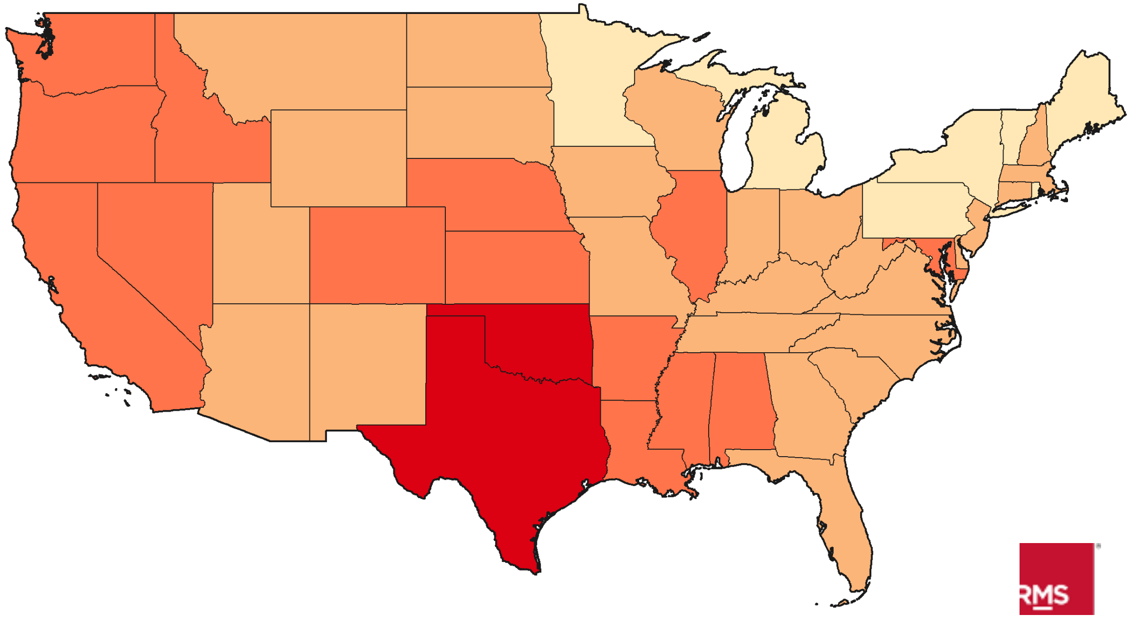


U.S. Wildfire Climate Change Risk

RCP2.6



RCP8.5



Percentage Change in Average Annual Loss: 2050 vs. Present Day

Challenges with working with GCMs

1. Currency of data – align with baseline today
2. Biases
3. Resolution
4. Volatility / Uncertainty

Thank you.

Dialogue

Please enter your questions in the Q & A engagement tool on your screen

Recording Available

This webinar has been recorded and is accessible on the website on the QR Code below

Thank You

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