Hurricane Fed: The New Climate Stress Test for Banks

Metamodel.blog/R. Saravanan

1 Hurricane Fed: The New Climate Stress Test for Banks

The Fed's new hurricane-based risk assessment is well-intentioned but poorly formulated. Since future hurricane probabilities are hard to predict, a simple storyline approach would have been better.

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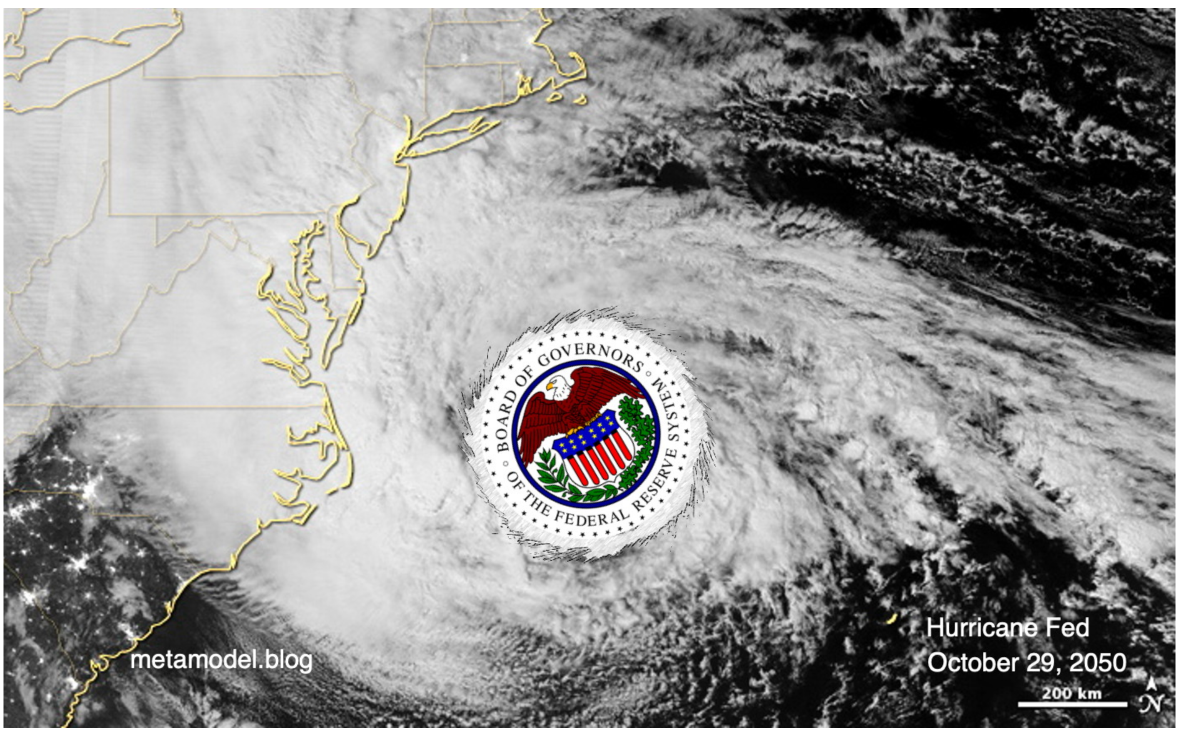

Recently, the US Federal Reserve ("Fed") issued guidance for a pilot exercise on how the six largest US banks should analyze their exposure to climate risk.[1] The Fed calls the study exploratory and says the results will have no capital implications. Nevertheless, this exercise is essentially a climate stress test—like the financial stress tests to check whether banks have enough capital to survive economic shocks. Other central banks around the world are taking similar steps. Climate change can lead to increased

[1] Explaining the Fed's climate test (EEnews.net)

economic risk. Planning to deal with this risk, taking into account all the uncertainties, is prudent for the Fed and other central banks to advocate.

The Fed proposes a probabilistic assessment of the risk of an extreme hurricane event making landfall in the Northeast US in 2050 under two different carbon emission scenarios: a medium emission scenario, RCP4.5 and a high-emission scenario, known as RCP8.5. This sounds straightforward at the surface, but when you dig deeper the proposed assessment turns out to be quite complicated, involving many assumptions.

Predicting future climate and economic conditions requires using complicated models and scenarios. However, this doesn't mean that risk assessment needs to be framed in a convoluted fashion. When we ask bankers (and other lay people) to test for climate risk, it would be best provide guidance in the simplest terms possible. The Fed's risk estimation exercise fails the stress test of simplicity. As explained later in this article, a better way for banks to assess climate risk would be to use a simple "storyline approach" with a few well-defined assumptions about future climate change.

1.1 Problems with the Fed's guidance

In January 2023, the Fed issued instruction for the *Pilot Climate Scenario Analysis Exercise*[2], which asks the banks to assess physical climate risk in the following manner:

> [F]or the iterations of the common shock component, participants should estimate the impact of a hurricane event(s) within the Northeast region with the following characteristics:
>
> 1. Climate conditions broadly consistent with possible future climate conditions in 2050 as characterized by the SSP2-4.5 (or RCP 4.5) pathways with a 100-year return period loss…
> 2. Climate conditions broadly consistent with possible future climate conditions in 2050 as characterized by the SSP5-8.5 (or RCP 8.5) pathways with a 200-year return period loss…
> 3. Climate conditions broadly consistent with possible future climate conditions in 2050 as characterized by the SSP5-8.5 (or RCP 8.5) pathways with a 200-year return period loss…
>
> To estimate the impact of the hurricane event(s) in 2050 across the three iterations above, participants may need to make additional assumptions around the state of climate and the related chronic physical features in 2050, including, but not limited to, an increase in surface temperatures, sea level rise, and precipitation levels.

Taken at face value, this sounds like the right approach. The Fed's reasoning appears to rest on the following chain of assumptions: *(i) risk assessments should be based on probabilities; (ii) extreme weather is expected to worsen with climate change; (iii) considering climate in a specific region rather than global average climate makes the assessment relevant to the US; (iv) decadal timescales are more important for financial risk than centennial timescales; and (v) different emission scenarios allow us to span the range of policy responses.*

Most people's intuition about climate change is based on the popular discourse on climate change, which often focuses on the global average temperature increasing

[2] Pilot Climate Scenario Analysis Exercise (FederalReserve.gov)

over centuries. There is a clear separation of the global warming signal on centennial timescales as predicted by climate models for different emission scenarios—the globe will be much warmer under RCP8.5 than RCP4.5 by the year 2100. There is always random noise associated with unpredictable ("stochastic") variations associated with weather, but it is relatively small when temperature is averaged globally, because of cancellations amongst regional variations.[3]

However, nobody lives in "global-average-land"! While global warming thresholds of 1.5 (or 2.0)°C dominate newspaper headlines, what will affect your life is the warming in the region you live in. In the middle latitudes, the regional greenhouse gas warming signal remains roughly the same as the global warming signal, but the random noise will be a lot stronger, because the cancellation benefit of global averaging is lost. That makes it much harder to discern the regional warming signal. If we are interested in short-term warming (by year 2050, say), the warming signal becomes even weaker whereas the noise amplitude remains the same (Figure 1).

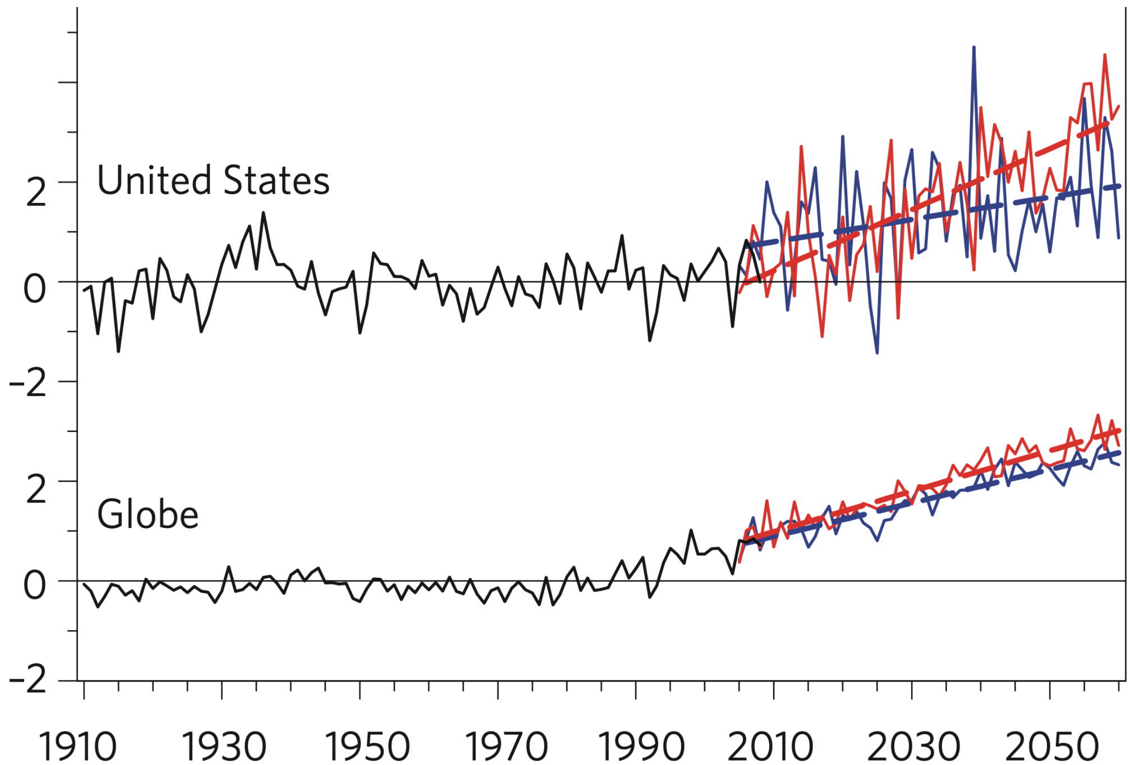

Figure 1 *Temperature change averaged over the globe and over the contiguous United States in observations until 2008 (black) and for a single emission scenario (A1B; similar to RCP6.0) until 2060, for the weather realization with the largest (red) and smallest (blue) future trends. The smaller the averaging region, the larger the random noise due to weather.* [Adapted from Figure 2b of Deser et al., 2020][4]

The popular discourse on climate change also leaves the impression that just because we have models that predict future global warming, we can compute precise probabilities of all future extreme events like heat waves, heavy rainfall or hurricanes. Climate

[3] What to expect when you're expecting a better climate model, Fig. 3 (Metamodel.blog)

[4] Communication of the role of natural variability in future North American climate (C. Deser et al., 2012; Nature Climate Change)

models simulate different phenomena with differing degrees of realism. Large-scale warming patterns and heat waves are simulated better than small-scale rainfall events. Uncertainties associated with different climate models make it hard to estimate precise future probabilities of regional extreme rainfall, for example (Figure 2).

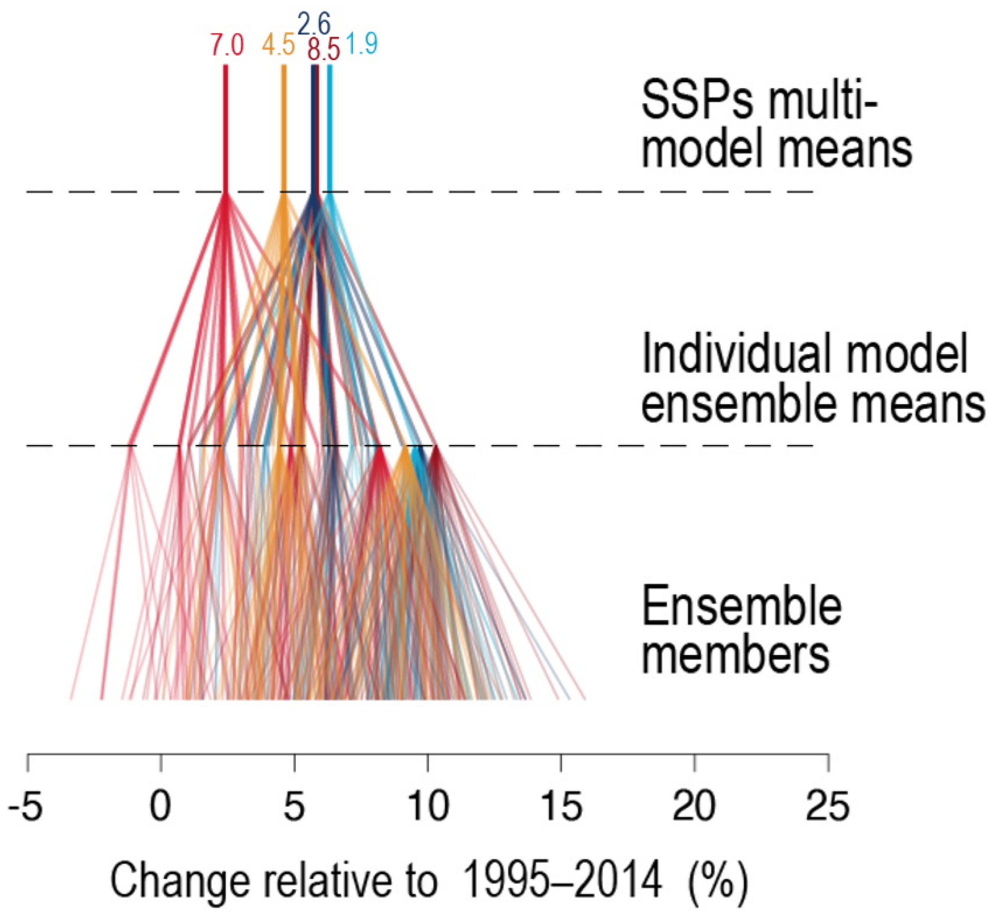

Figure 2 *Cascading uncertainties in IPCC model projections of East Asia summer (June-August) rainfall for multiple emission scenarios (SSP 1.9, 2.6, 4.5, 7.0, 8.5) for years 2041-2060. Top row shows average for each SSP; next row shows the average for individual models; bottom row shows the rainfall for each individual realization of weather in each model (representing the random variability). It is hard to distinguish between emission scenarios 4.5 and 8.5 when looking at the spread of simulated rainfall in the year 2050. Interestingly, the lowest emission scenario, 1.9, shows the largest rainfall changes in the near term due to the effect of aerosols in that scenario.* [Adapted from Figure 1.15 of IPCC AR6 WG1 report][5]

With the above caveats in mind, we focus on weak links in the chain of assumptions (i)—(v) that underlie Fed's guidance.

(i) *Risk assessments should be based on probabilities*. By specifying numeric probabil-

[5] IPCC AR6 WG1 report, Chapter 1: Framing, Context and Methods, p.198

ities (e.g., 100-year return period loss), the Fed aims to make the risk assessment precise. That would work if we knew the precise probabilities of hurricanes making landfall in the Northeast US in the year 2050. But we don't. Our current global climate models have too coarse spatial resolution to estimate the precise probability of future hurricane landfalling events. The current horizontal grid of climate models is at best about 50kmX50km—not enough to resolve the eyewall of a hurricane. Making additional assumptions and using simpler/regional models, we can come up with numbers for future hurricane probabilities, but the answers will be sensitive to the assumptions.[6]

(ii) *Extreme weather is expected to worsen with climate change*. This statement is generally true, but the devil is in the details. Large-scale weather extremes like heat waves will uniformly get worse but the picture is more complicated for hurricanes because they involve small-scale moist processes. According to our current scientific understanding, the strength of hurricanes and the associated rainfall are expected to increase but their total number may actually decrease (Figure 3). The strongest hurricanes are expected to get even stronger and may increase in number. If the total number of hurricanes does not increase, it implies that weaker hurricanes, such as Category 1 or 2, will decrease in number.

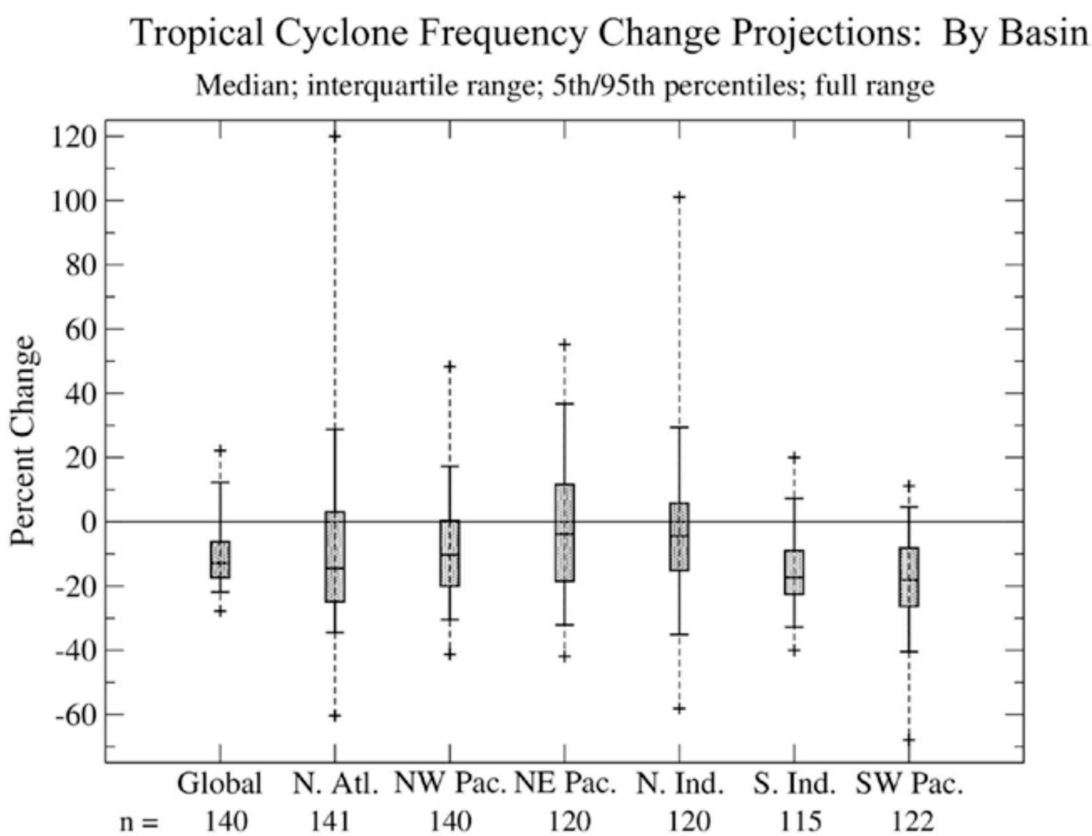

Figure 3 *Projected changes in the frequency of tropical cyclones (known as hurricanes in the North Atlantic) for each ocean basin for 2°C of additional global warming*

[6] IPCC AR6 WG1 report, Chapter 11: Weather and Climate Extreme Events in a Changing Climate, p.1588

compared to current conditions. Hurricane frequency in the North Atlantic is projected to decline about 15% on the average, but the uncertainty range is huge! [Adapted from Fig. 1b of Knutson et al., 2020][7]

The Fed's choice to focus on an extreme hurricane affecting the Northeast US is presumably motivated by an actual natural disaster, Hurricane Sandy, that wreaked havoc in that region in October 2012, killing hundreds of people and inflicting many tens of billions of dollars in damage.[8] But Sandy was not very strong, as hurricanes go; it barely reached a peak intensity of Category 3 and made landfall as a Category 1 storm. Bankers may be surprised to learn that climate change might actually make weak storms like Sandy rarer in the future.

Of course, a stronger hurricane than Sandy could impact the Northeast in the near future. Such a rare event could happen purely by chance, even in the absence of additional warming between now and 2050. Future global warming could be responsible for amplifying the storm, but the distinction between different emission scenarios may not be very discernible by the year 2050.

(iii) *Considering climate in a specific region rather than global average climate makes the assessment relevant to the US*. Yes, but the regional focus also greatly increases the strength of random (stochastic) noise as discussed earlier. To probabilistically assess regional climate change for a small area like the Northeast US, we would need a large ensemble of climate model simulations to quantify the random noise[9] — something the Fed's guidance fails to note.

(iv) *Decadal timescales are more relevant for financial risk than centennial timescales*. True, but focusing on shorter timescales means the global warming will be weaker and less sensitive to the scenario being considered. Coupled with the much larger amplitude of random variability, as noted in the (iii) discussion, there may be no point in trying to distinguish between the signals of RCP8.5 vs. RCP4.5 by 2050, as the Fed recommends.

(v) *Different emission scenarios allow us to span the range of policy responses*. Yes, but it would become a moot issue with the lower signal-to-noise ratio, as noted in the discussion of points (iii) and (iv) above.

The Fed's guidance may sound well-defined and numerically precise on the surface, but it isn't quite so. The numerical precision of the specified return period loss becomes irrelevant if our estimates of the probability of the physical hazard, i.e., future landfalling hurricanes, are themselves imprecise. Since banks are free to make numerous additional assumptions needed to estimate the physical hazard, the guidance is poorly formulated. Even seemingly small errors in these assumptions can lead to big errors in the estimation of tail risk of the physical hazard.[10] The uncertainties associated with the assumptions can be lost in translation, leading to faux precision in the final risk assessment.

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[7] Tropical cyclones and climate change assessment part II: projected response to anthropogenic warming. (T. Knutson et al., 2019; Bulletin of the American Meteorological Society)

[8] Sandy and Its Impacts (NYC.gov)

[9] Strange weather in the multiverse of climate (Metamodel.blog)

[10] The perils of predicting perils: (mis)calculating wet-bulb temperature (Metamodel.blog)

1.2 The super-Sandy storyline

Since climate risk is real and important, is there is a better way to assess its impact on the banking sector? One that does not involve hard-to-compute probabilities and a multitude of assumptions? Instead of hiring consultants to make many small assumptions involving a cascade of models that we can't keep track of, can't we just make a few big assumptions? Wouldn't it be more transparent if we are upfront about the uncertainties?

An alternative, and simpler, way to frame the risk assessment is to start with a known extreme event, say Hurricane Sandy that affected the Northeast US in 2012, and ask how a stronger version of this storm occurring in the near future would affect bank finances. Such an approach, often referred to as a "storyline", is better suited to describing future high-impact low-likelihood events whose probabilities are hard to quantify.[11]

Scientific research shows that global warming amplifies the water cycle, meaning that extreme storms like Sandy can become more intense as the atmosphere becomes moister. One can assess the financial risks of a stronger "super-Sandy" hurricane, say 10% stronger than Sandy, making landfall in the Northeast US. Such an assessment should also include estimates of higher sea-levels by the year 2050, which would amplify the coastal impacts.

The storyline framing possesses several advantages. It sidesteps the contentious issue of whether the high-emission RCP8.5 scenario—required by the Fed—is even a plausible future.[12] According to the latest international climate assessment from the IPCC, recent trends in the energy sector mean that the likelihood of the RCP8.5 scenario is low. The storyline framing focuses on the narrower question of whether a super-Sandy storm impacting the Northeast US by 2050 is a plausible event. The combination of climate change and random variability can make such an event plausible. (If need be, we can consider different plausible strengths of super-Sandy to span the range of physical risk.)

The current Fed proposal allows the use of *a la carte* assumptions to assess climate risk. Banks may end up making different modeling assumptions. A smorgasbord of assumptions will mean that comparing risk assessments from different banks will be like comparing apples to oranges. A simpler alternative is to assess financial impacts using a well-defined storyline with fewer assumptions. That can provide a clearer picture of the climate risk faced by banks.

Keep it simple, Fed!

(*Top image shows a NASA satellite view of Hurricane Sandy approaching the Northeast US on October 29, 2012, with the Federal Reserve logo in the eye of the storm.*)

1.3 Comments

Note: For updated comments, see the original blog post and the anouncement tweet.

- *Stephen Jewson*:
  Hello, I'd quite like to respond to this blog, in the spirit of debate, from the point of view of a climate risk modeller. What's the best way for me to do that? I'm not sure this little box is quite the best way to do that. What do you suggest? Can I write an article that you could post on your blog?

[11] Storylines: an alternative approach to representing uncertainty in physical aspects of climate change (T.G. Shepherd et al., 2018; Climatic Change)

[12] Emissions – the 'business as usual' story is misleading (Z. Hausfather and G.P. Peters, 2020; Nature)

- *R Saravanan*:
  Sure, you are welcome to post a guest «rebuttal» article on this blog.

- *Stephen Jewson*:
  But long story short, multiple models already exist that can be used to answer the Fed's questions. They've been built by climate scientists like you and me, and, by and large, deal with all the issues you raise in your post, plus a whole load of other relevant issues. They avoid over-precision by propagating and communicating uncertainty and allowing sensitivity tests i.e., in the normal way.
  Many folk in the financial industry have these models at their fingertips already. Their answers to the Fed's questions, which they could calculate any time they want, would be based on simulations of 1000s of possible storms that might hit NY, including their wind, flood and surge damage, all adjusted for distributions of possible climate change. Boiling all of that down to just 1 event, when they already have the whole distribution, would throw away an enormous amount of information about risk. It'd be a bit like reducing all of climate modelling to one ensemble member from one climate model.
  Are the models perfect? Of course not. They are a work in progress, just like everything else. Even after 50 years (the first journal paper on probabilistic hurricane risk modelling was published in 1972) it's a rapidly evolving field, especially because of climate change. Different models by different groups have different strengths and weaknesses. We can pick holes here and there, and propose improvements, and more transparency would be good. But for questions like the questions the Fed are asking, the current models do a reasonable job (I would say). 2100 would be much harder. Tornado-hail would be much harder .
  If there are particular technical points you are interested in, let me know. E.g., you mention the Knutson et al (2020) paper. If you're interested in how the results from that paper are post-processed for use in risk models, and propagated thru into loss estimates, while still preserving the uncertainty, I can send you links to several peer-reviewed papers on that.
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  - *R Saravanan*:
    Simulation of hurricanes in global climate models is still highly «dodgy», to borrow a British expression. The quantitative results are research-grade, but not yet application grade (and may not be for a while). A new generation of global models could yield different research results, invalidating any prior application of the results to risk assessment. (The storyline approach avoids this built-in obsolescence by making the uncertainties explicit, not hidden.) I know that there are models that simulate 1000s of possible storms. But the answers they provide vary with the assumptions used to build them. End users are often not aware of this and end up treating the results with more precision than is deserved. Yes, we can propagate uncertainties, but what is the point of propagating huge uncertainties of the kind shown in Knutson et al. 2020/Fig. 3 of this post? The numbers may well be different in future peer-reviewed papers Knutson et al., 2024. or 2028. Peer-reviewed means that the published model results are the best research estimates at the time of publication. It does not guarantee stationarity of the statistics that is needed for true risk estimation. That's because the quantified uncertainty does not consider the unquantified structural model uncertainty. Actually, I like it that the Fed chose to focus on a single event, rather than 1000s of events simulated by assumptive models, where different groups may make different assumptions. The problem is that the Fed chose to define that 1 event using a «return loss period» which adds

the damage function uncertainty to the hurricane probability estimation uncertainty. You argue that by focusing on 1 event, we are throwing out information about risk. I would argue that the information thrown is not actuarial risk, but guesstimates.
Ultimately, I think our disagreement is philosophical. Is precise (actuarial) risk assessment possible for poorly simulated phenomena like hurricanes in 2050? Conventional risk assessment assumes it is possible, storylines don't.

∗ *Stephen Jewson*:
One thing you and I totally agree on: that over-interpretation of approximate and uncertain results is a bad thing, whatever the topic.
I see risk assessments as being more like weather forecasts: they start with low signal and large uncertainty, and then gradually improve. So I'm not sure I'd ever use words like "precise" or "true risk". I would say that risk assessments are just what we can deduce, right now, based on the information available. More subjective Bayesian than objective frequentist. The best way to avoid a shock, with both, is to start watching them early on, and track them as they develop. We start weather forecasts as soon as there's a signal…and it seems that there's a signal in the climate projections for 2050, albeit small and uncertain.
I wonder what you'd think about hurricane risk estimates for 2023: they are also extremely uncertain…not that much less uncertain than the estimates for 2050, in fact, if you factor in all the sources of uncertainty. But we've got to make quantitative risk assessments, because people need them for quantitative decisions.
Apart from everything else, we've learnt a huge amount about hurricanes and climate change by making these risk assessments. Not about hurricane physics, but about how to count and measure hurricanes, what information we need from climate models, and how to process it. It took me 2 years to figure out how to extract the right information from the Knutson et al. projections, and there were some big surprises. Next time (Knutson et al. (2024), as you say) hopefully it'll take a couple of weeks, given that learning. The sooner we start providing risk assessments to users, the sooner they can start their own learning curve.
Makes me laugh that we are citing Tom's paper that he hasn't even written yet. Should we tell him? Does that count as a proper citation? Watch out or you might start a citogenesis process.
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∗ *R Saravanan*:
This has been a useful discussion. Thanks for the LinkedIn post with the quick (and useful) hurricane analysis. I would use that analysis, but in a somewhat different way. One thing I wasn't very specific about in my blog post is how to construct the storyline. I simply threw out a round number like 10% stronger for super-Sandy. One could consider a range of super-Sandy storms, say 5%, 10%, and 15% stronger, perhaps, to span a range. The way to pick the range would be to consider analyses like yours and others (but purely for physical risk) to choose some plausible numbers. Once we pick the storyline, we don't need to go back to conventional risk analysis. Knutson et al (2024/2028) might just move the needle of plausibility in the storyline dial.
The problem with the Fed's guidance is that it lets banks pick different ways to estimate risk and conflates physical risk with damages. As you

note in your comment, subjective Bayesian estimates could yield different numbers for risk. Each bank may effectively be using a different storyline hidden in their methodology, making it difficult to compare the final stress test results.

There's a big difference between hurricane risk analysis for 2023 and 2050. We know what the regional background state will be in 2023, but there is much greater uncertainty about the background state for 2050. Regional climate prediction is hard. This will greatly amplify the uncertainty. Different subjective analyses may give very different results. If your results for 2050 differ greatly from that of company X or Y, which one should we trust? On what basis?

- *R Saravanan*:
  Found a LinkedIn post discussing similar issues. It has some additional references to recent activity on storylines and narratives.
  Why climate models struggle with acute physical risks
  https://www.manifestclimate.com/blog/why-clim…
- *R Saravanan*:
  Another relevant reference: Acute climate risks in the financial system: examining the utility of climate model projections
  https://iopscience.iop.org/article/10.1088/2752-5295/ac856f#references
  We strongly encourage a review of existing top-down approaches before they develop into de facto standards and note that existing approaches that use a 'bottom-up' strategy (e.g. catastrophe modelling and storylines) are more likely to enable a robust assessment of material risk.
- *Stephen Jewson*:
  Just to prove that hurricane risk modelling is a real thing, I spent the morning actually running some numbers for NY hurricane risk in 2050. I've posted the results on my Linkedin page, along with all the scientific journal citations to the methodologies I'm using. Comments welcome.
  - *R Saravanan*:
    Link to Steve Jewson's post: https://www.linkedin.com/posts/steve-jewson-p…