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Using Information and Ideas to Transform Public Policy

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An Assessment of the New Hampshire Coastal Risk and Hazards Commission Report

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Among the many drivers of unsound public policy in this day and age, perhaps the most odious is the alarmism over changes in climate that are supposedly driven by human activity. Time and again, we have seen costly, unjustified, and economically destructive public policy implemented in the name of climate protection, proclaiming that humanity can and should micromanage the earth's climate, the largest and most complex system mankind will ever encounter. The justification for these costly actions is based on flimsy evidence, exaggerated claims, and a profound ignorance of the natural evolution and cycles of our climate systems. National, state, and local governments have all acted to impose damaging regulatory regimes, costly mandates, and harsh anti-development initiatives in the name of climate change, and New Hampshire has not been immune to the consequences.

On November 30, 2016, the New Hampshire Coastal Risk and Hazard Commission ("NHCRHC") released its final report (http://www.nhcrhc.org/wp-content/uploads/2016-CRHC-final-report.pdf). This report is 124 pages of alarmist hand wringing, with a litany of recommendations that would expand government and strangle development in the Seacoast area. The apparent goal of the authors is to prod state legislators, bureaucrats and local officials to institutionalize acceptance of anthropogenic global warming (AGW) in state law and state regulations, based on the premise that sea level rise (SLR) threatens our Seacoast in an unprecedented fashion. The unstated result of these actions would be to cede control from local towns to the state, impose huge barriers to development and undermine the economy in the region.

Unfortunately, there is not enough critical analysis and skepticism of the basis for the fears outlined in the report. The result is a document heavy on fearful scenarios, calls to action and demands for spending.

This paper is an attempt to put much of the science in its proper context, educate the reader with real data, raise the types of questions that should have been raised by the NHCRHC, consider the nature of the actual risks involved, and question whether the recommendations are really what the state, the region, and local communities need at this time.

The Science

Let's start with the science. This is the foundation supporting all the concerns, recommendations and additional spending.

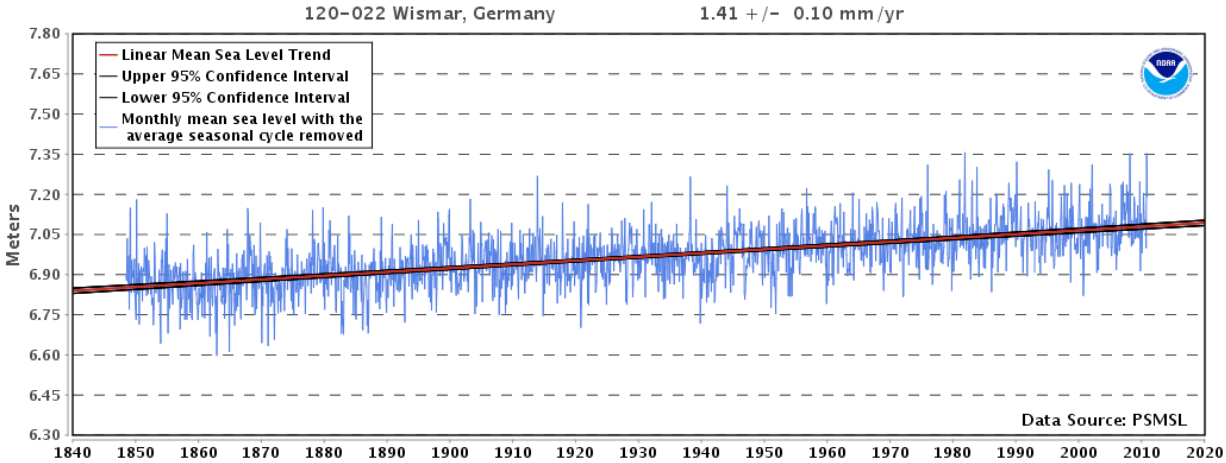
The "Understanding What We Are Facing" section of the NHCRHC report outlines the findings of the Commission's Science and Technical Advisory Panel. This list of findings are the critical underpinnings for all the resultant recommendations. These findings include:

- Global and regional sea levels have been rising for decades, though not uniformly.
- Using mean sea level in 1992 as a starting point, New Hampshire sea levels are expected to rise between 0.6 and 2.0 feet by 2050 and between 1.6 and 6.6 feet by 2100.
- Today's extreme storm surge events will have a significantly greater inundation extent and destructive impact due to higher sea levels.
- It is likely that coastal storms will be more severe as a result of warmer oceans and other changes in climate systems, but at the time of the STAP report publication, the research continues to be uncertain about whether storm frequency will change in the future.
- Annual precipitation is expected to increase by as much as 20 percent by the end of the 21st century as compared to the late 20th century, and extreme precipitation events are projected to increase in frequency and in the amount of precipitation produced.

These finding themselves are a combination of factual data ("Global and regional sea levels have been rising for decades . . ."), conjecture and unsubstantiated fear. We will use these findings as the starting point of our analysis.

Sea Level Rise

Taking the initial findings individually, it is impossible to disagree with the first point. Global sea levels have been rising for centuries. This is well documented and undeniable. In fact, the longer running sea level data, which includes places like Wismar, Germany, clearly shows the steady rise in sea level. As can be seen in Figure 1, there has been long term sea level rise of 1.41 mm/year (+/-0.10 mm/yr) at this location. While this single location is not indicative of the entire global sea level change, when we look at a variety of long term records from around the globe, we see a regular and steady rise in sea level.



This should not come as a surprise to anyone. As the earth has come out of the most recent Little Ice Age (typically recognized as the period from around 1300AD to about 1850AD) and experienced warming, two major factors led to sea level rise. First, the warming of the ocean caused thermal expansion (warm water has a slightly larger volume than cooler water), and second, the increase in meltwater from land based glaciers and ice including parts of Greenland and Antarctica increases the volume of water in the oceans. These natural processes began almost 200 years ago, and it has driven the cycle we see indicated in the Wismar data.

Where the NHCRHC seems to leap to conclusions is in its second finding. Starting with the historical data, it is extremely difficult to equate the long term trends we see globally and locally with a conclusion that "New Hampshire sea levels are expected to rise between 0.6 and 2.0 feet by 2050 and between 1.6 and 6.6 feet by 2100". Again, looking at the Wismar data, we find that the long term trend is 1.41 mm/year (+/-0.10 mm/yr), equivalent to 0.056 inches/year (+/-0.004in/yr). That projects to only 1.87 inches (0.16 feet) by 2050 and 4.63 inches (0.39 feet) by 2100. This historic trend indicates a substantially lower level of sea level rise than even the lowest estimate by the NHCRHC.

The Permanent Service for Mean Sea Level Data (PSMSL) was established in 1933 and has been responsible for the collection, publication, analysis and interpretation of sea level data from the global network of tide gauges. Looking at additional long term sea level data from around the globe using the PSMSL site reveals similar trends as to what we see in the Wismar data. Here is a brief list of some of the longest running data sets in the PSMSL database:

- Dan Helder, Netherlands (1865-2015) – 1.56 mm/yr
- Trieste, Italy (1875-2015) – 1.71 mm/yr
- Honolulu, Hawaii (1905-2015) – 1.49 mm/yr
- Sydney, Australia (1886-1993) – 0.61 mm/yr
- Perth, Australia (1897-2015) – 1.93 mm/yr
- Balboa, Panama (1908-2015) – 1.46 mm/yr
- San Francisco, CA (1908-2015) – 1.38 mm/yr
- Buenos Aires, Argentina (1910-1987) – 1.80 mm/yr

All of these are long dated data sets and all show a long-term sea level rise trend that is a fraction of the trend used by NHCRHC to baseline its analysis. With this type of global data set it is very difficult to see how the Commission can justify its decision to use such a high sea level

rise assumption for even its lowest SLR scenario.

The IPCC and Sea Level Rise

The NHCRHC report does acknowledge that "current greenhouse gas concentrations and current or accelerated emissions rates will continue to influence sea levels in the future." This implies that what we are seeing today is an acceleration in sea level rise that justifies using assumptions far greater than the actual long term global sea level rise trends.

The Commission report includes a very brief section on the actual science underpinning the analysis, risk assessment and recommendations. Chapter 3, "Understanding what we are facing", is only three pages long in the 124 page report, and directly cites very little science. The chapter includes endnotes which reference three studies that focus on sea level rise, but all three reports are not scientific references themselves. They are merely another series of reports raising the alarm on sea level rise in New Hampshire. These reports are:

1) The New Hampshire Coastal Risk Hazards Commission Science and Technical Advisory Panel (STAP) report "Sea Level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire (2014)
2) Rockingham Planning Commission "Tide to Storms": Assessing Risk and Vulnerability to Sea-Level Rise and Storm Surge" (2015)
3) New Hampshire Climate Change Policy Task Force "New Hampshire Climate Action Plan" (2009)

As can be seen, the first document is the analysis done by a subgroup of the Commission itself. The three documents provide no scientific analysis directly, but merely reference several other compendia of science as justification for the assumptions used in the analysis. The critical references that these three reports fall back on are the Intergovernmental Panel on Climate Change (IPCC) reports and summaries for policymakers and the US National Climate Assessment Report (NCAR). The STAP report also reviewed the 2012 National Research Council report on sea level rise.

In turn the IPCC and NCAR reports actually reference scientific research. This is the science on which the NHCRHC ultimately is basing its projections and recommendations.

A thorough look through the information provided in these reports and the underlying scientific papers raises series questions about the "choice" the STAP and the NHCRHC made with respect to the science. While it is not expected that local commissions are performing original scientific study themselves, as members of a body that will be analyzing risks and making policy recommendations to decision makers, it is incumbent that they make prudent and justifiable evaluation of the science underlying the reference documents. It is this critical function that seems to have been ignored.

So what do the IPCC reports and other scientific studies indicate with respect to SLR?

On page 13 of the most recent IPCC report "Climate Change 2014 – Synthesis Report" reads:

> Global mean sea level rise will continue during the 21st century, *very likely* at a faster rate than observed from 1971 to 2010. For the period 2081–2100 relative to 1986–2005, the rise will *likely* be in the ranges of 0.26 to 0.55 m for RCP2.6, and of 0.45 to 0.82 m for RCP8.5 (*medium confidence*)10

It should be noted that Footnote 10 is very relevant in understanding the implications and risk of the RCP8.5 scenario. It reads as follows

> [10] Based on current understanding (from observations, physical understanding and modelling), only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the likely range during the 21st century. There is medium confidence that this additional contribution would not exceed several tenths of a meter of sea level rise during the 21st century.

In fact, this is the chart that accompanies the Summary for Policymakers report indicating the range of scenarios in graphic form:

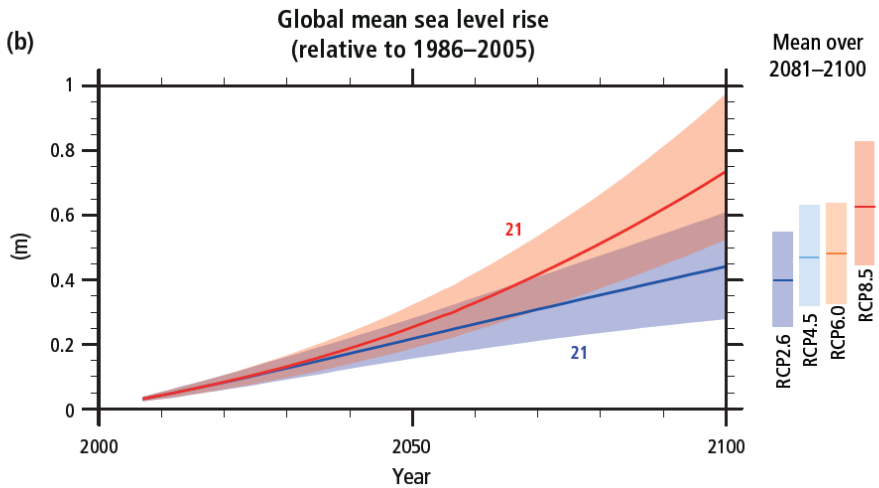


Figure SPM.6 | Global average surface temperature change **(a)** and global mean sea level rise[10] **(b)** from 2006 to 2100 as determined by multi-model simulations. All changes are relative to 1986–2005. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as coloured vertical bars at the right hand side of each panel. The number of Coupled Model Intercomparison Project Phase 5 (CMIP5) models used to calculate the multi-model mean is indicated. *{2.2, Figure 2.1}*

This figure shows that the IPCC modeling indicates that even under its most severe model (RCP 8.5) result in SLR of under 1.0 m (39.4 inches) by 2100. The report language also indicates that even the "collapse of marine-based sectors of the Antarctic ice sheet" would only add another "several tenths of a meter of sea level rise". This equate to a sea level rise in 2100 of about 40 inches (0.82 m + 0.20 m = 1.02 m) even under an Antarctic sea ice collapse occurring in a scenario greater than their highest temperature model.

The following table outlines the expected SLR for the range of scenarios by the IPCC. As can be seen, the highest level of projected SLR even under their most extreme scenario is a range of 0.45 to 0.82 meters. Given that the IPCC modeling is cited by the NHCRHC report, it is baffling how they came to the conclusion that "expected" SLR by 2100 would be up to 6.6 feet (over 2 meters), almost triple the high end of the "likely range" determined by the IPCC.

Table 2.1 | Projected change in global mean surface temperature and global mean sea level rise for the mid- and late 21st century, relative to the 1986–2005 period. *{WGI Table SPM.2, 12.4.1, 13.5.1, Table 12.2, Table 13.5}*

		2046–2065		2081–2100	
	Scenario	Mean	*Likely* range [c]	Mean	*Likely* range [c]
Global Mean Surface Temperature Change (°C) [a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	Mean	*Likely* range [d]	Mean	*Likely* range [d]
Global Mean Sea Level Rise (m) [b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

The Question of SLR Acceleration

Much of the justification for the most extreme SLR scenarios in both the IPCC and the NCAR studies is based on the idea that while sea level rise for the past 100 years has averaged only 1.7 mm/yr, some data indicates that the rate of SLR is accelerating to much higher levels. As noted above, much of the PSMSL data does not show this type of acceleration, but there are some signals that SLR is accelerating. This is noted in the IPCC reports as indicated here:

IPCC (2015) Summary for Policy Makers 2.2

> It is *virtually certain* that global mean sea level rise will continue for many centuries beyond 2100, with the amount of rise dependent on future emissions. The threshold for the loss of the Greenland ice sheet over a millennium or more, and an associated sea level rise of up to 7 m, is greater than about 1°C (*low confidence*) but less than about 4°C (*medium confidence*) of global warming with respect to pre-industrial temperatures. Abrupt and irreversible ice loss from the Antarctic ice sheet is possible, but current evidence and understanding is insufficient to make a quantitative assessment. *{2.4}*
>
> It is *very likely* that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm/yr between 1901 and 2010 and 3.2 [2.8 to 3.6] mm/yr between 1993 and 2010. Tide gauge and satellite altimeter data are consistent regarding the higher rate during the latter period. It is *likely* that similarly high rates occurred between 1920 and 1950. *{WGI SPM B.4, 3.7, 13.2} [emphasis added]*

What the IPCC has done in the 2015 report is different from what its assessments in prior reports. In prior reports there was a larger emphasis on the tide gauge data and their historical record which pointed towards using the long term average of 1.7 mm/yr for the SLR in its projections. In the 2015 IPCC report, based on recent scientific publications, the decision was made to focus on altimeter data for assessing the rate of SLR at 3.2 mm/yr. It should be noted that despite the fact that a similar higher rate was detected for periods well before anthropogenic warming took place and then slowed down, the assumption is made that the current accelerated rate is driven by AGW and will continue in the future at gradually increasing levels.

There are several problems that are generally recognized with the IPCC decision to rely on the altimeter data in making a substantial adjustment in the recent sea level trends and the supposed acceleration. Most important, the altimeter data spans only about 20 years. This

makes it virtually impossible to separate the secular (long term) trends in sea level rise from any natural climate influences that take place on longer time scales. While the IPCC justifies this by using tide gauge data over the 20 year period to verify its values, by relying on only 20 years of tide gauge data they commit the same type of error. Using such short time frames to assess a change in longer term trends is not typically done for this reason as any multi-decadal influence would be difficult to discern.

In fact, climate variability on decadal and longer time scales has been well documented as contributing to sea level trends. [Feng et al 2004; Woodsworth et al 2011; Sturges and Douglas 2011; Chambers et al 2012; Meyssignac et al 2012]. This is a factor that the IPCC appears to have discounted in its decision to rely on the shorter time frame altimeter data and dramatically accelerate sea level rise estimates over the past 20 years. In fact, while many studies are cited noting this issue, the IPCC determined "Only the time series from Church and White (2011) extends to 2010, so it is used in the assessment of sea level rise." This was despite that many of the studies reviewed comparable length of time series but only extended through 2009 (Meyssignac 2012), through 2008 (Ray and Douglas 2011) and through 2002 (Jevrejeva 2008).

As an example of how large an impact this can have, a recent University of Colorado study (Hamlington et al 2013) examined problems with the altimetry based assumptions on sea level trends and compared a more robust analysis with the Church et al (2011) study, which is one of the several studies that challenged the IPCC conclusions with respect to sea level trends. In that work, Hamlington indicates that there is a strong relationship between the pattern of sea level rise and the Pacific Decadal Oscillation (PDO). It was calculated that over the past 20 years, as the PDO shifted from positive to negative phases, it contributed 0.49 mm/yr +/- 0.25 mm/yr to the global mean sea level (GMSL). This adjustment accounts for almost half of the acceleration in sea level trend that the IPCC is assuming in its latest report.

The issues raised by Hamlington are also echoed in the best practices of other government agencies. In reviewing the actual report by the science task force, one has to wonder why they did not raise questions about the IPCC data. In fact, the NHCRHC STAP report on page 12 states:

> In general, the Army Corps of Engineers and National Oceanic and Atmospheric Administration recommend against using data records shorter than 40 years when determining sea level trends, for the following reasons:
>
> 1) A 19-year period is used by the Army Corps of Engineers and National Oceanic and Atmospheric Administration to describe tidal cycles around the world (a 19-year period allows us to include the 18.6 year period for the regression of the lunar nodes). At least two full cycles are generally needed to determine a reasonable trend.
>
> 2) There are very long period oscillations in the large ocean basins that, in some instances, are multiple decades in length. A 40-year period of record allows an accounting for the variations in sea-surface height that are associated with these multi-decadal oscillations.
>
> 3) Analyses by the National Oceanic and Atmospheric Administration and in the Army Corps of Engineers sea level guidance indicate the standard error of the estimate of the sea-level rise trend decreases significantly with periods of record longer than 40 years.

So despite the guidance from NOAA and the ACoE on using data (and presumably projections

based on data) that is shorter than 40 years of duration, and quoting those concerns directly in its own report, the NHCRHC ignored best scientific practice and chose to use projections based on the IPCC Church and White acceleration of sea level rise data covering 1993-2010.

So what does this brief analysis of the science indicate? It is universally accepted that the long term trend of sea level rise over the 20th Century is 1.7 mm/yr. Long term tide gauge data show that to be the case and even the IPCC reports all accept this as the past 100 year trend. The two open ended questions have thus become "Has the recent sea level rise accelerated in the past 20 years?" and "Given the possible reasons for any acceleration, how high will sea levels be (on average) by the year 2100?"

Given the recent work on the recent sea level trends that have focused on removing longer term natural decadal variability from short term data, the current rate of sea level rise of 3.2 mm/yr sea level the IPCC assumes may be much lower, around 2.7 mm/yr or possibly lower. Again, the IPCC hinted at this when in its Summary for Policy Makers (2015) (Section 2.2) it indicated:

> It is *very likely* that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm/yr between 1901 and 2010 and 3.2 [2.8 to 3.6] mm/yr between 1993 and 2010. Tide gauge and satellite altimeter data are consistent regarding the higher rate during the latter period. <u>It is *likely* that similarly high rates occurred between 1920 and 1950.</u> *{WGI SPM B.4, 3.7, 13.2} [emphasis added]*

Yet instead of pointing out these uncertainties, in the final report draft they choose to bury the numerous peer reviewed studies that determined a material effect on the rate of acceleration of sea level rise and quantified that value, and instead based their conclusions almost solely on the Church and White study. This had the effect of dramatically increasing the likely current rate of sea level rise to a much higher level.

The follow-on effect of this is significant. If we are not actually seeing as dramatic an acceleration in sea level rise over the past 20 years as the report presumes, then it is very likely that the current projections of sea level rise over the next 85 years are greatly exaggerated. Any objective and robust analysis of the science and the data would conclude the IPCC likely scenarios are the high end of probable SLR by the year 2050 and year 2100.

<u>The NHCRHC Chooses NCA</u>

It appears that at some point the NHCRHC science task force made a decision to not only accept the IPCC inflated projections for future sea levels (ignoring much of the current science on sea level trends), but they then doubled down and choose to use data that was well above the IPCC numbers.

	20th Century Trend	IPCC (Current Trend)	Adjusted for Multi Decadal Variabiltiy	IPCC RCP 2.6	IPCC RCP 8.5	NHCRHC Low	NHCRHC High
GMSL Rise	1.7 mm/yr	3.2 mm/yr	2.7 mm/yr				
By 2050	2.27 in		3.61 in	6.69 in - 12.60 in	8.66 in - 14.96 in	7.2 in	19.2 in
By 2100	5.62 in		8.93 in	10.24 in - 21.65 in	17.71 in - 32.28 in	19.2 in	79.2 in

Even after ignoring the sound practices recommended by NOAA and the ACoE, the NHCRHC determined to go beyond the IPCC exaggerated projections and use the US National Climate

Assessment (NCA) projections as the basis for the impact studies. Unfortunately the NHCRHC did not analyze the underlying assumptions that the NCA used when it made its high, intermediate and low scenarios. For example, as stated in the NHCRHC science task force report:

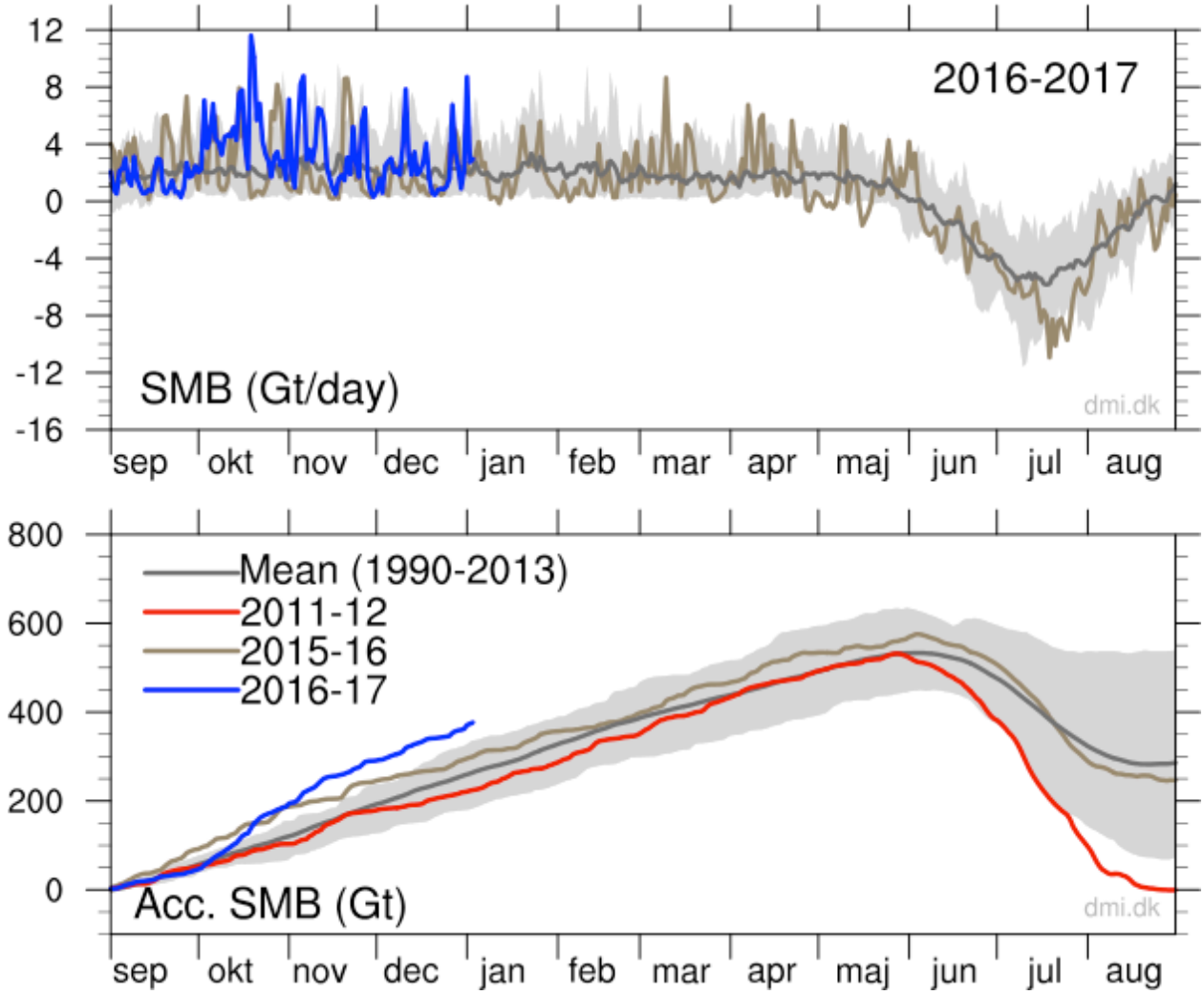
> The *Highest Scenario* (6.6 feet by 2100) is based on estimated ocean warming from the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC 2007) <u>combined with a calculation of the maximum possible contribution to sea level from the glacier and ice sheet loss</u>. *[emphasis added]*

This is a significant problem in that even the IPCC (2015) report acknowledges that:

> It is *virtually certain* that global mean sea level rise will continue for many centuries beyond 2100, with the amount of rise dependent on future emissions**. The threshold for the loss of the Greenland ice sheet over a <u>millennium or more</u>**, and an associated sea level rise of up to 7 m, is greater than about 1°C (*low confidence*) but less than about 4°C (*medium confidence*) of global warming with respect to pre-industrial temperatures. **Abrupt and irreversible ice loss from the Antarctic ice sheet is possible, but current evidence and understanding is insufficient to make a quantitative assessment.** *{2.4} [emphasis added]*

Even a reader without a strong scientific background can see that the NCA is using entirely unrealistic projections (even to the IPCC) to justify a clearly alarmist scenario for SLR. Unfortunately for readers of the NHCRHC report, fully understanding how exaggerated a scenario this is requires extensive backtracking through the endnotes, references and report citations to understand what claims are being made, and how unrealistic those claims are. Of course, there is truly no limit to the potential for SLR. We could see a rise of several hundred feet as was seen in records from 15,000 years ago, but what is important is understanding why we might see particular SLR scenarios and the probability of those scenarios coming true.

As a matter of reference, it is important to examine at least the near term trends in the Greenland ice sheet to evaluate whether a rapid (less than 100 year) event is likely to take place, or whether the IPCC estimates of over a millennium is more likely. Here is a graph from the Danish Meteorological Institute (DMI) which tracks Greenland ice mass levels.

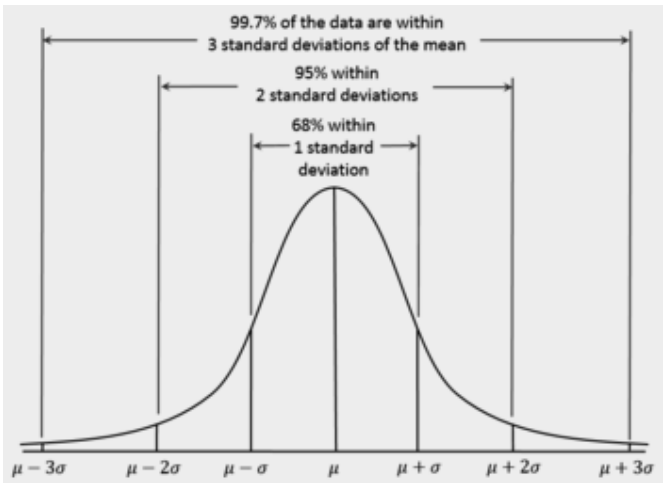


As can be seen in the lower graph, while years like 2011-2012 have shown indications of greater than average ice loss, more recent years (and this year in particular) have shown extensive mass gains vs the mean changes. This is what we would expect in a natural system – some years showing mass loss and some showing gains. Overall the mass loss for Greenland has been averaging 200 gigatons of ice per year, which equates to about 0.1% of ice mass loss per decade. That means on current trends (and that assumes the short term trend is the long term trend which as shown above is not usually a very good assumption) by the year 2100 Greenland will lose about 1% of its ice mass. Contrast this with the assumption the NHCRHC chose to accept which requires a massive loss of ice sheets over a brief (84 year) time period which current data and trends do not support in any way.

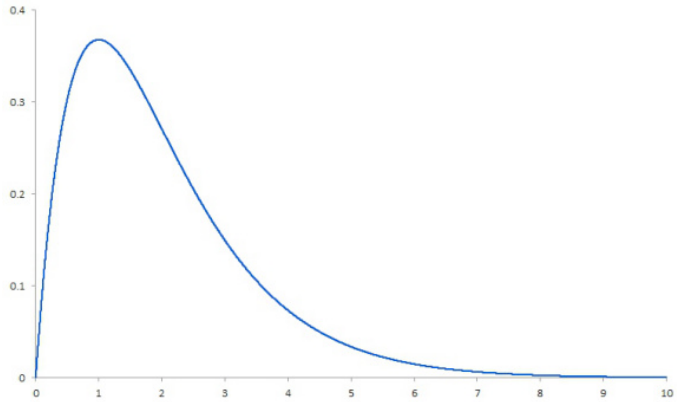
Proper Assessment of Probabilistic Events

The IPCC does not have ANY projections through the year 2100 which assumes a loss of the Greenland Ice Sheet and the Antarctic Ice Sheet. In fact, as they state, those assumptions only exist on time scales of "a millennium or more", yet the NCA and the NHCRHC are basing their worst case scenarios on that happening in 84 years.

The NHCRHC does state in its STAP report that "In planning for a future condition a relatively narrow range of numbers is the most useful, yet if we want relative certainty that the estimate will be right, we have to accept a wide range, which is much harder to plan for." It is absolutely the case that understanding the range of projections is very important for decision makers. Where the NHCRHC makes a critical mistake is in presenting its range of potential without providing the readers with some assessments of the likelihood of the various outcomes. As noted above, and as indicated by the IPCC itself, "the threshold for the loss of the Greenland Ice Sheet over a millennium or more… " is not a high confidence projection. Given the statement that this type of collapse would likely to take a millennium or more makes the potential for 6.6 feet of sea level rise in the next 84 years virtually certain to NOT occur. By not quantifying any type of probability or likelihood of the various scenarios in the report, the NHCRHC presents its information in a way that implies the distribution of scenarios is a normal distribution (i.e. typical Bell Curve) centered around the 3.9 feet of sea level rise by 2100.



Given the historical trends for sea level, the problems with the assumption of accelerated sea level rise, and the long time periods expected for any possible Antarctic and Greenland ice sheet collapse to occur (which are the basis for the intermediate and high scenarios) the probability density function should not look like a bell curve. Instead it should look like a curve that is positively skewed. Here is an example of a skewed distribution curve.



By introducing probabilities based on a curve like this, the report would better inform decision makers that while extreme situations are *possible* they are extremely unlikely to occur. Given the

historical trends, the concerns over the assumption of sustained acceleration in SLR and the use of scenarios which require 1000 years of glacier/ice melt, it is irresponsible for the NHCRHC to not better inform the readers with a better presentation of probable outcomes. Consider that readers and decision makers may have a much different perspective on the need for particular action or the timing of a particular action if they knew that the scenarios provided by the NHCRHC might have a less than 1% chance (authors estimate) of occurring, while historical rates of SLR or even the higher current trend of SLR might encompass 85% of likelihood.

It is critical for sound public policy making that the specific scenarios are properly identified in order to understand potential impacts, but it is even more important to indicate the probability of those scenarios. The NHCRHC failed on this measure.

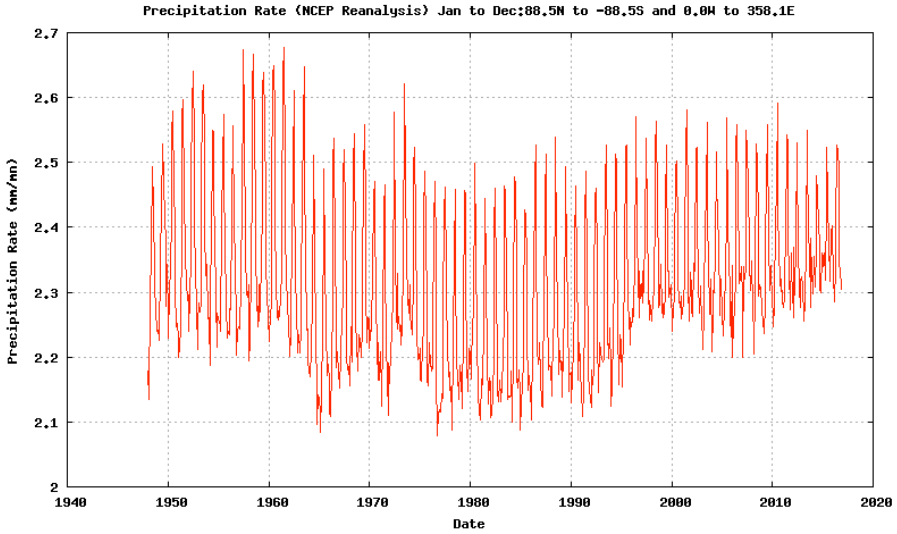
Rainfall Events

In addition to SLR concerns, the report highlights a concern over more extreme rainfall events in the Seacoast area. As stated in the initial findings:

- Annual precipitation is expected to increase by as much as 20 percent by the end of the 21st century compared to the late 20th century, and extreme precipitation events are projected to increase in frequency and in the amount of precipitation produced.

In the NHCRHC report, the only rainfall study directly referenced was the "Trends in Extreme Precipitation for the Northeast United States 1948-2007" by Spierre and Wake (2010). Based on the 1948-2007 rainfall data analyzed in the study, the trend is towards more extreme precipitation events in the region, with the assumed risk of greater flooding associated with these events.

I credit Drs. Spierre and Wake for their identification of what may be a pattern of increasing rainfall. Given that the world has been warming since the 1850s, the trend of average rainfall per event may be increasing naturally in that a warmer world should be a wetter world. Warm air can hold more water vapor and should translate (all other things being equal) to more precipitation. When looking at global trends we do see an increase in the precipitation rate since the late 1970s, but this is still below the highs we see in the 1950s, as indicated in the NCEP Renanalysis graph below.



Climate scientists still have little understanding about cloud formation, the relationship between temperature and precipitation and the causes of increased/decreased precipitation rates, so projecting how our ever-changing climate will drive future precipitation is speculative at best. We can see that patterns of natural variability do occur even though we do not necessarily understand the cause and effect at this time, and while providing hypotheses is useful, relying on those hypotheses for setting public policy is not prudent.

That being understood, there are many outstanding questions about the Spierre/Wake study that should be noted. These includes:

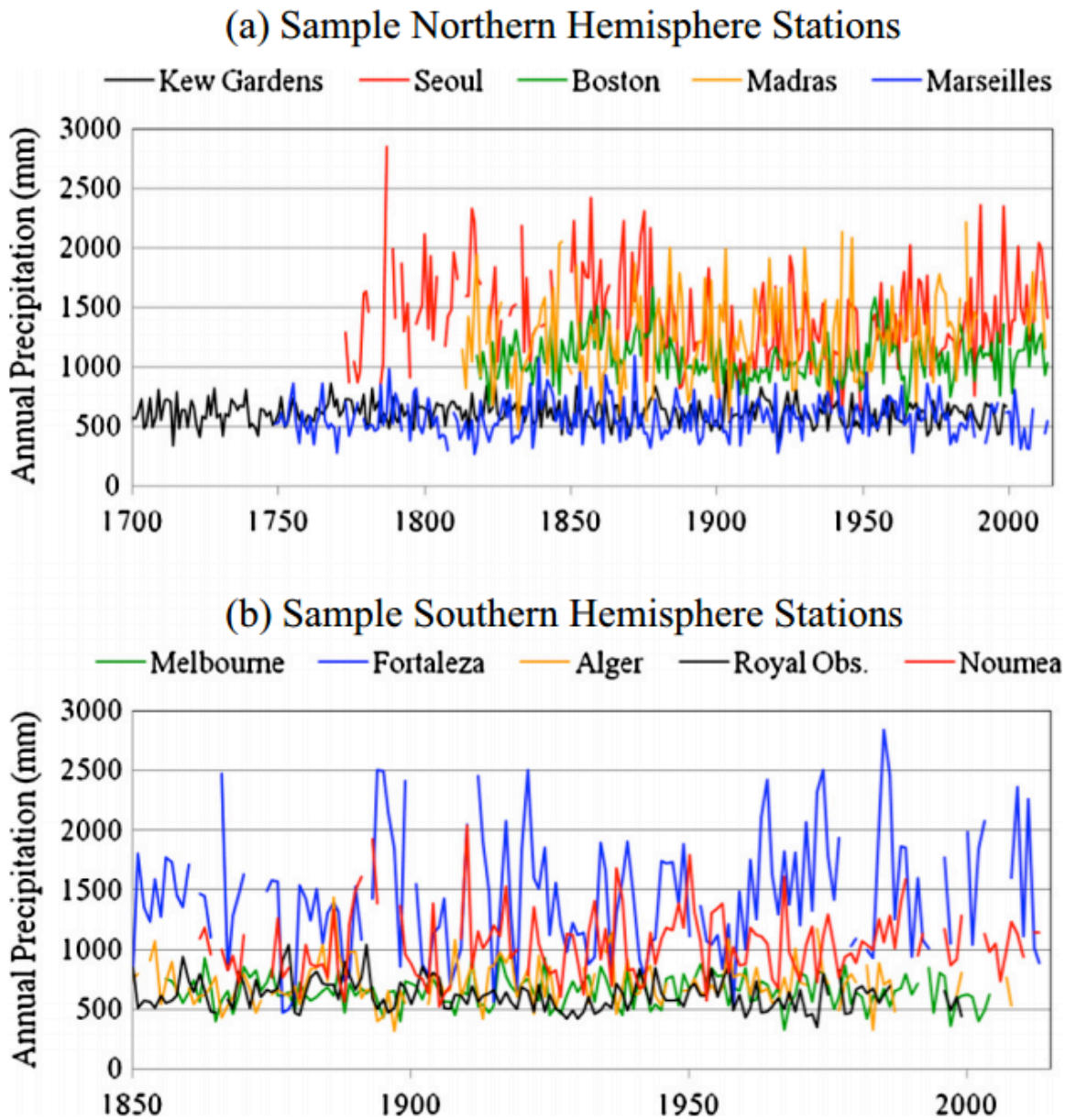
1. The decadal trend analysis is based on 51 year time windows. Given the data set itself only extends back 60 years, this only allows for 10 data sets to determine the trend. Clearly the statistical analysis indicates significance in the trend (i.e. statistically significant p-values), but given the standard deviation of the mean, none of the values are outside of a range of what could be called natural variability (i.e. a 2 STDEV range).
2. Looking at the regional average trends in Table 4, the margin of error for many of the definitions of extreme precipitation for the region makes definitive conclusions about these trends difficult to justify. For example, for events 1 inch or greater, the century long trend has been 0.16 events/decade +/- 0.20 events while the more recent trend is 0.26 +/- 0.07. Given these margins of error, it is difficult to have a high level of confidence in this trend (regardless of statistical significance).
3. Large precipitation events for this region are driven by hurricanes and Nor'easters. In fact a cursory look at the top 20 rainfall events for Durham, NH (see below) indicates that 9 of those events are directly related to hurricanes. Is the pattern of large precipitation events more related to hurricane paths and based on longer term cycles (i.e. hurricane frequency) as opposed to a steady trend of general precipitation that can be projected into the future?
4. If the change in precipitation is taking place, is it related to large natural climate cycles? For example, are the frequency of events or intensity of events related to the Atlantic Multidecadal Oscillation (AMO) and its long-term cycle, much as the PDO may be having substantial impact on global SLR?
5. The IPCC in its 2012 Special Report on Extremes directly states that long term trends in tropical and extra tropical storms, flood loss and other disaster losses CANNOT be attributed to anthropogenic climate change. (IPCC Special Report on Extremes Chapter 4.5.3.3). The point here is that if these types of precipitation events cannot be linked to anthropogenic climate change, we cannot rely on the climate models and their forecasts to determine what to expect for flooding, precipitation and storm activity in the year 2050 or 2100.

In 2015 the Journal of Hydrology published an analysis done by W.A. van Wijngaarden and A. Syed titled "Changes in annual precipitation over the Earth's land mass excluding Antarctica from the 18th century to 2013" which was a very extensive review of the historic rainfall data on a global basis. The study looked at nearly 1000 stations located in 114 countries. Each station had at least 100 years of observations resulting in a dataset comprising over 1½ million monthly precipitation amounts.

The study looked at precipitation changes on six continents, across different latitudes and examined trends for low, moderate and high precipitation rates. The results of the study were

that "most trends exhibited no clear precipitation change."

As seen in the following graphs from the paper, a visual look at several of the Northern Hemisphere stations (note that Boston is included here) and the Southern Hemisphere stations shows no substantial long term trends in precipitation. Just as importantly, even while some stations show short term increases in precipitation, in the context of the longer term lack of trend, those short term (25-50 years) changes appear to be part of natural cycles. This very well may be what we are seeing in the Spierre/Wake data – a shorter term change that is part of a longer term natural cycle which is obscured by the relatively short duration of the data sets used.

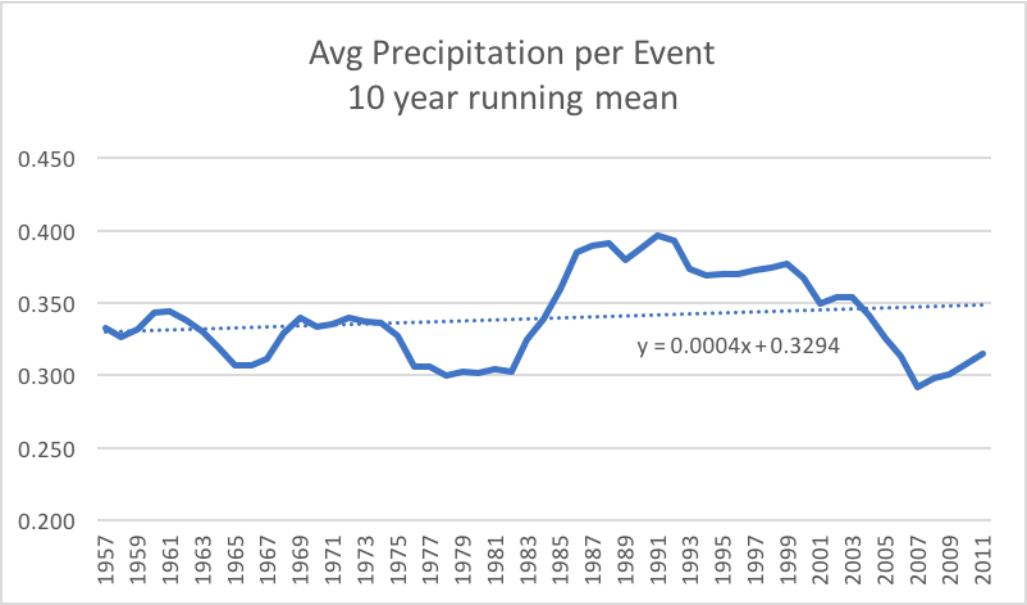


I believe that the Spierre/Wake paper raises questions about our regional weather that should be further investigated. I encourage further analysis, but instead of focusing on anthropogenic global warming and the projections of the climate models, it is important for our region to

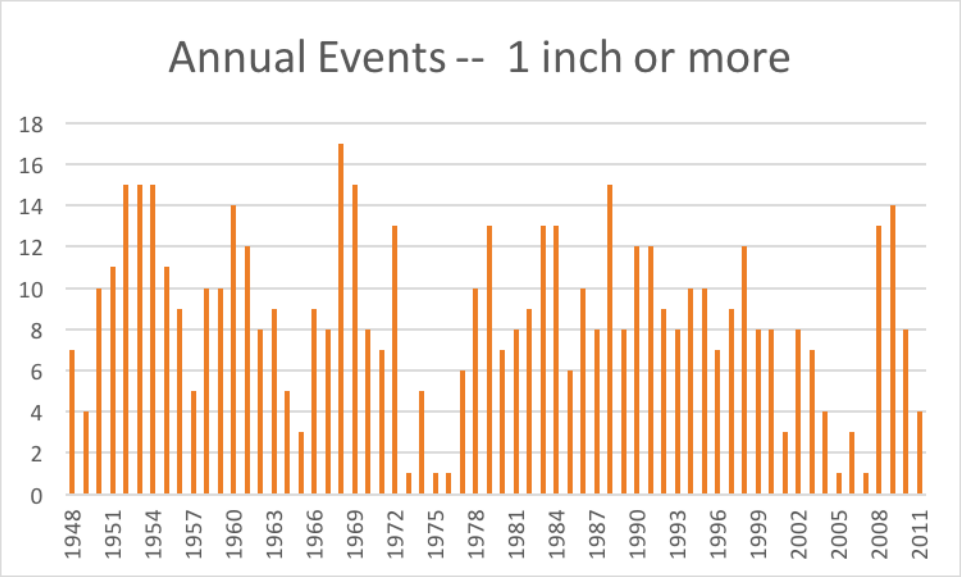
understand the relationship of our precipitation patterns with climate systems like the AMO. This could provide our decision makers with an understanding of the true nature of precipitation cycles and how to think about infrastructure in relation to these very important climate influences.

Given the questions raised by the Spierre/Wake paper, I reviewed the NCDC precipitation data for Durham. NH. This covers the years 1948-2011. The NCDC data for years after 2011 is sporadic and cannot be reliably used at this time. I compiled the data to provide a daily rainfall total and looked at the overall trends of this data over the time period. While this is a single station and any indications of the data should be recognized as a single point, this is also the only station that covers the region of Seacoast New Hampshire in the NCDC database and should be considered as the "best" individual indicator of our regions trends.

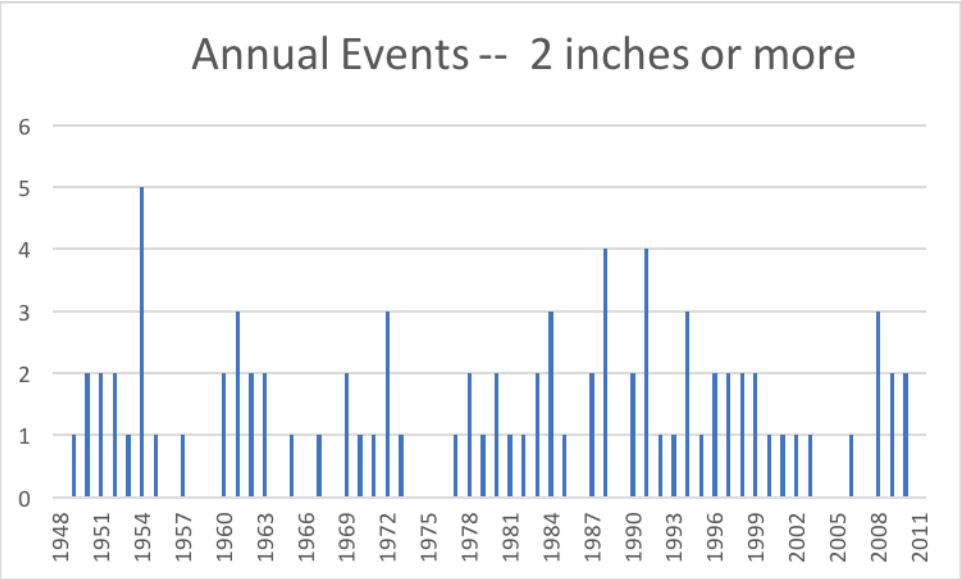
First, I looked at the total number of days of precipitation. I was surprised to see that the overall trend since 1948 is down from about 120 days per year (5 year average) in the 1950s to around 80 days per year in the past decade. I then looked at the average precipitation per rain event over the time period. Again, surprisingly, the trend was not what I expected. Given that the world has been warming since the 1850s, I expected that the trend of average rainfall per event would be increasing given 1) a warmer world is a wetter world as warm air can hold more water vapor and should translate (all other things being equal) to more precipitation and 2) with fewer events per year I would expect each event to precipitate greater amounts. In fact the average precipitation per event has been remarkably stable over the past 60 years at 0.338 inches per event with a standard deviation of 0.03 inches (10 year running mean) with a flat trend over the time period.



Given these surprising trends (or lack of trends) I looked at the occurrence of 1-inch and 2-inch rain events for every year since 1948. Again, my expectation after reading the NHCRHC report is that the overall trend for the Seacoast area in general (and Durham in particular) was that I would see a greater frequency of these large precipitation events. In fact, though, there is no such trend. Here is the chart of annual 1 inch events in Durham, NH.



There is no discernable trend in this data indicating that we are seeing a greater frequency of large rain events. Looking at the graph of events of 2-inches of more yields a similar result:



Again, there is no trend indicated in this data that would point towards more "extreme" rain for the Seacoast region of New Hampshire.

Without claiming any greater scientific knowledge, even a cursory look by the NHCRHC at the publicly available data and more comprehensive global studies of precipitation may have given them a better and more judicious assessment of what is going on with respect to precipitation in the region. While there may be short term trends occurring, immediately accepting that the trend is going to continue far into the future and then making assumptions based on this trend is not good science. Not putting the short-term trends in the context of larger precipitation patterns is another major shortfall in the NHCRHC report.

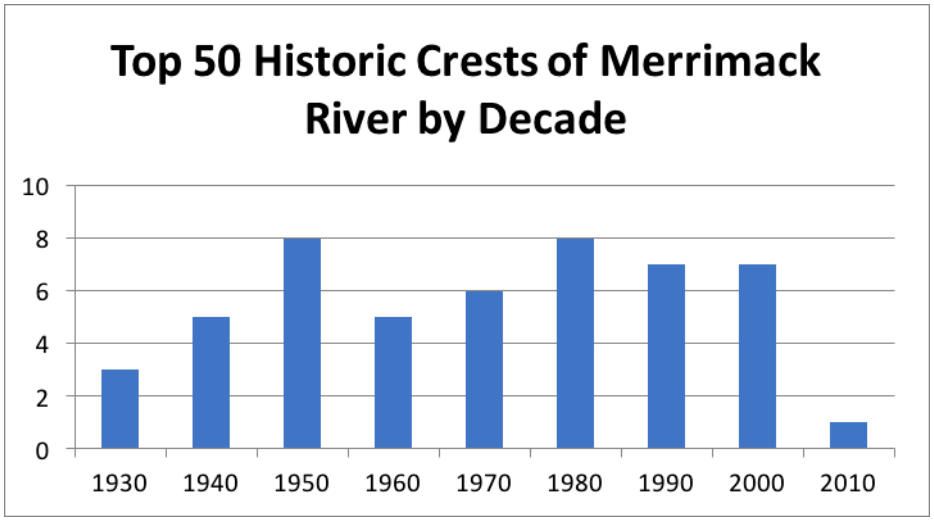
Given this basic analysis of the most relevant rainfall data set for the Seacoast region, it is difficult to justify a projection of increased flooding risk due to rainfall.

Flood Risk

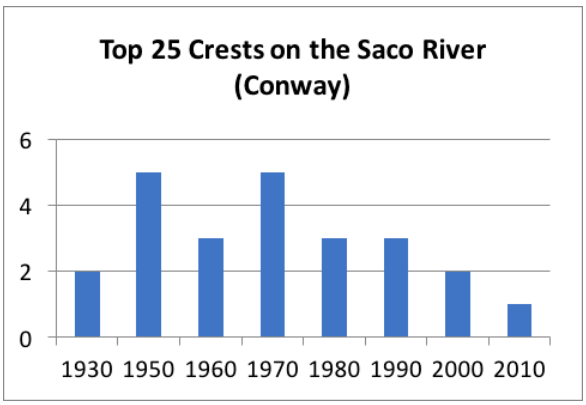
So perhaps the risk of flooding can be accounted for due to land use changes? There is a much larger area of impermeable surfaces today than existed 50 or 100 years ago. This would increase the risk of large runoff occurring in a short period of time, potentially overwhelming existing rivers and streams and creating a larger risk of flooding. Of course, some of this increased risk can be mitigated by the improved storm water systems that have been implemented over the past several decades, but most of these systems are located in the larger communities and may have limited impact in more rural areas.

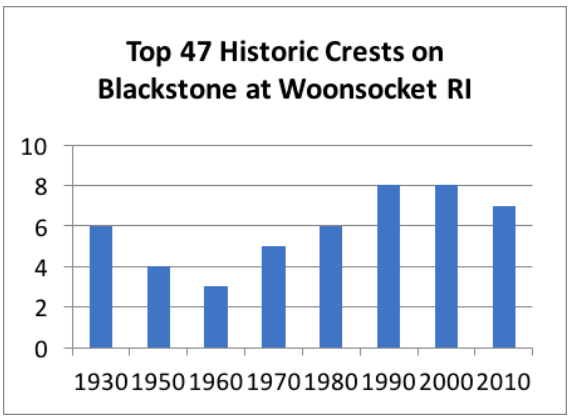
In order to assess if there are any longer term trends for flood risk in New Hampshire, I reviewed the available data for the major rivers in the state and the region that have long term records maintained by the National Weather Service (NWS) Advanced Hydrologic Prediction division. They maintain the stream gauges for the major rivers and streams in the United States. For each location the NWS also provides a list of the historic crests at that location.

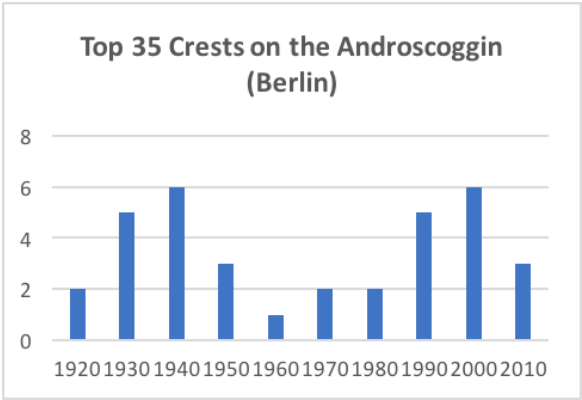
I reviewed data for the Merrimack River, the Lamprey River, the Saco River, the Androscoggin River, the White River, the Connecticut River, the Blackstone River and the Contoocook River. For each gauge, I reviewed the list of the historic crests at each location and then looked at how many historic crests took place for each decade going back to the 1930s. For example, when you plot the top 50 crests for the Merrimack River at Goffs Falls by decade, we see the following:

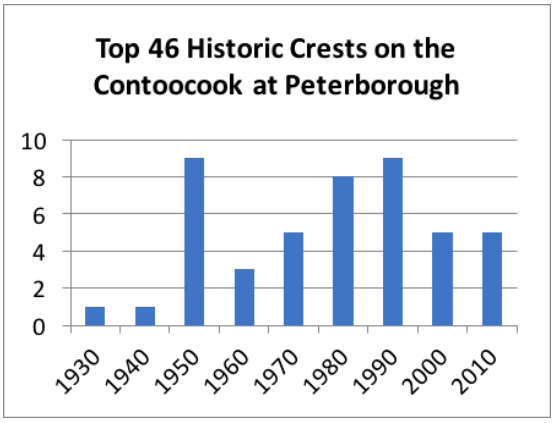


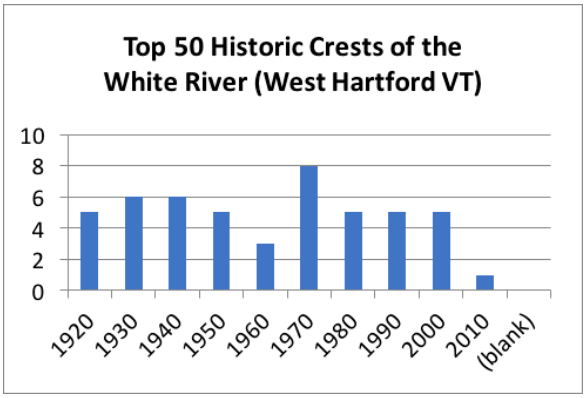
The 2010-2019 decade is obviously incomplete at this point, but more than half the decade has passed and been documented. Yet thus far we have only one flood event this decade in the top 50 events over the past 85 years. As we saw in the precipitation data for Durham, there doesn't appear to be any real increase in flooding events at this location. In fact, the two largest flooding events, by a huge margin, occurred in 1936 and in 1938. The other rivers in the region have a similar look to them. Note that there is also one flood event in 1919 not included in this data for the White River.

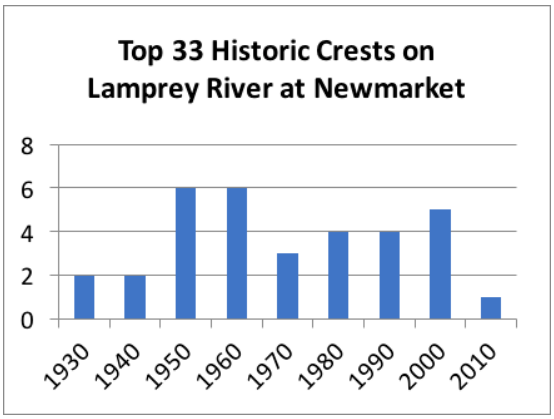


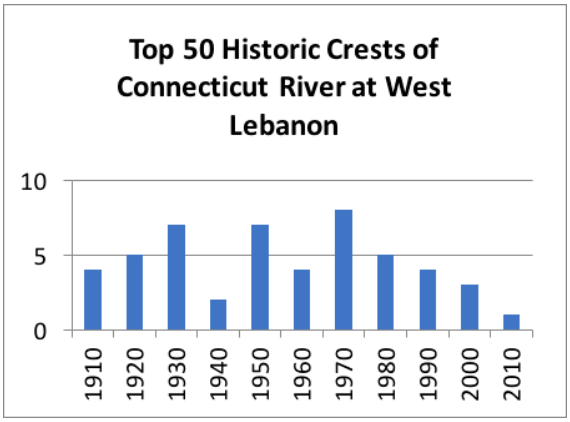












Note that the data for the one river located in the Seacoast Region, the Lamprey River in

Newmarket, shows no significant uptick in the number of historic crests in the past nine decades. While there certainly was substantial flooding in the back-to-back years of 2006 and 2007 and this raised flooding concerns in the area, the overall trend for major crest events appears to be no more or less frequent than what was seen in the 1950s or 1960s.

While this is certainly a general analysis of basic data, and our study here is by no means a scientific analysis of rainfall or flooding trends for the region, this data does in fact raise questions as to the level of certainty that the NHCRHC assumed for flooding for the region over the next 85 years. Global precipitation rates do not appear to be trending any higher than historical norms. State level data indicates that precipitation, at least when looking at the Durham data, shows almost no change in trend for total precipitation over the course of a year, average precipitation per event, number of 1-inch or greater rainfall events or the number of 2-inch or greater rainfall events. In addition, when looking at the historic crest data for rivers all around the state, we again see no discernable trend as to the frequency of flooding per decade over the past 80+ years.

Given this basic analysis, it is very difficult to understand how the NHCRHC and the STAP did not either adjust some of the general assumptions around projected rainfall/flooding or make clear that the historical trends for regional rainfall and flooding do not point towards greater risks of extreme events.

NHCRHC Report Does a Disservice to Science

Taken as a whole, the NHCRHC has done a disservice in that the group appears not to have done its own analysis of the underlying science that supports accelerated sea level rise. As discussed here, basic review of the underlying questions on SLR, rainfall and flooding certainly makes it clear that the extreme NCAR assumptions appear alarmist. The group also made the decision to mostly ignore the long term historic trends of precipitation and flooding in the region and assume a much higher probability of "extreme" rain events and the ensuing flooding impacts. The group apparently did not look at available global data sets on precipitation and precipitation rates in determining how to assess future projections. They choose to present the most extreme scenarios to decision makers as the base cases, and provided no substantial historical context and the fact that many of the overall rain, flooding and SLR trends have not substantially changed over the past 85 years. Finally, they presented the scenarios in a way that implies much higher probabilities than what the underlying science acknowledges as likely.

The end result of the NHCRHC embedding their unrealistic projections as potential scenarios is that the next aspect of their report dealing with the potential impacts is seriously called into question.

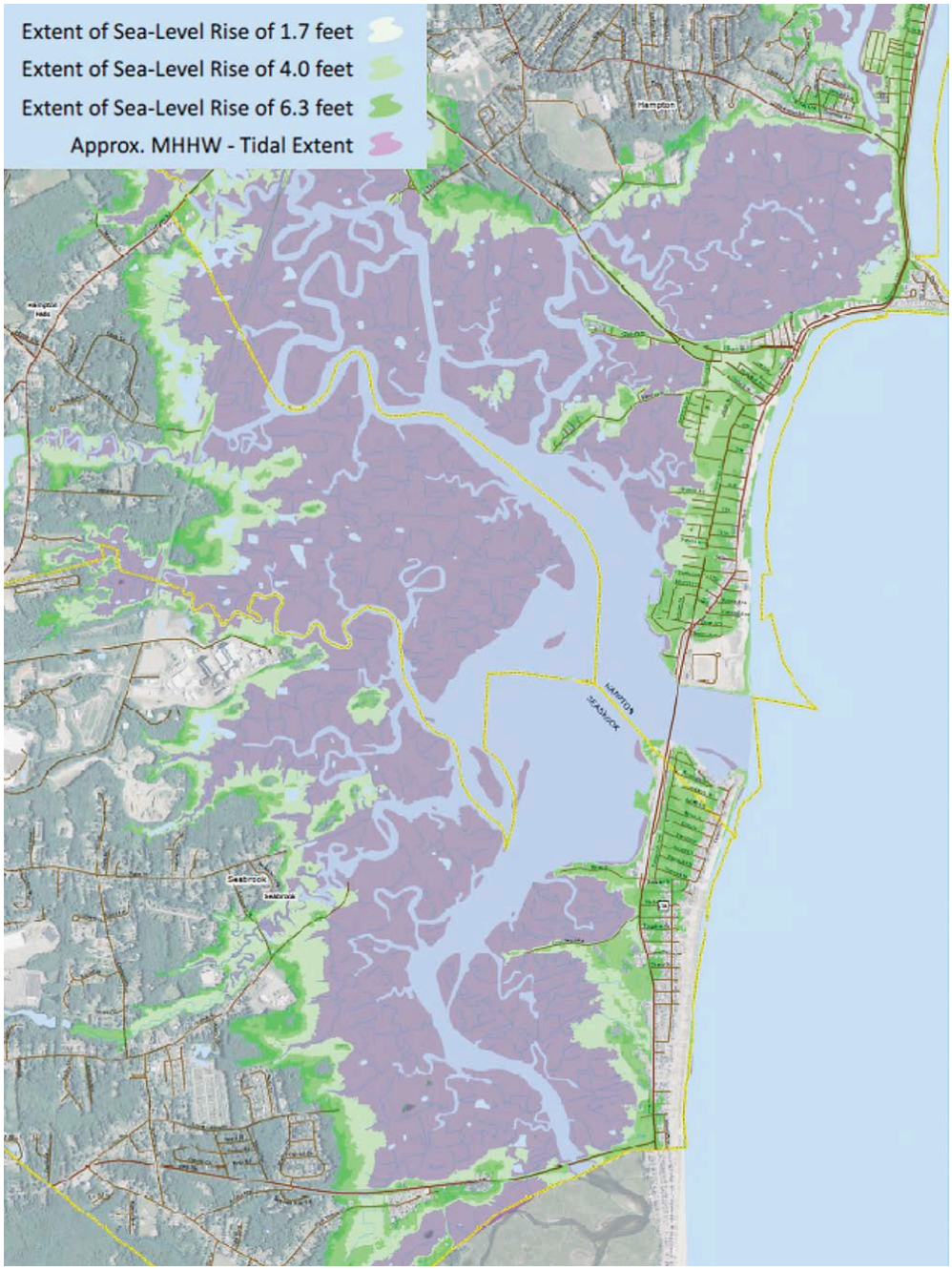
Exaggerated Science = Exaggerated Impacts

The NHCRHC decision to embrace the most alarming scenarios and their questionable underlying science has dramatic effects on the assessment of the potential impact from sea level rise. As anyone who has lived in the Seacoast area of New Hampshire knows, over the past 350 years of development in the region our cities and towns have been very capable of managing the historic pattern of sea level rise. Portsmouth has continued to be a vibrant port city despite the very large tidal shifts that occur up and down the Piscataqua River. Hampton and Seabrook

continue to be popular tourist destinations in the summer, while maintaining their beaches and boardwalks. Homeowners up and down our coasts and along the bays, inlets and rivers have all maintained their properties even as we have had up to 8 inches of sea level rise over that time period (350 years *1.7 mm/yr).

With the extreme solutions presented in the NHCRHC report, the authors project an extremely dire future for some of these areas without ever indicating what are the more likely scenarios of sea level rise. For example, on page 13 of the report we are presented with this illustration of impact:

FIGURE 5. Illustration of the extent of flooding from three sea-level rise scenarios in the Hampton-Seabrook estuary. *Source: RPC (2015)*



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This presentation implies that even under the "low" scenario, large portions of Hampton and Seabrook will be underwater by 2100. Under the "medium" scenario, most of Hampton Beach south of Great Boars Head will be uninhabitable.

While this possible future could occur, given the exaggerated extent of the science used to underpin these projections and the lack of any indication as to the probabilities of these scenarios, one is left with an impression that drastically exaggerates the likely impacts. If a reader had been shown the same graphic, but with a projection of the historic trend of sea level rise, and informed that this is the more likely outcome, and was then shown the figure above, the reader would take away an entirely different (and more accurate) representation of the real risks. If informed that the 1.7 foot sea level projection has a probability of occurring that is less than 1% (authors estimate), and that the 6.3 foot projection is a fraction of that likelihood, the impact of the graphic would become far less concerning.

Looking at the infrastructure to be impacted in the Great Bay Municipalities, again the use of exaggerated sea level rise has alarmist effects that are not put into proper context. On page 18 of the NHCRHC report we see this table.

TABLE 2. Summary of flood impacts from sea-level rise and storm surge* scenarios for the ten Great Bay municipalities**
Source: NHDES et al. (In-Progress).

Sea-Level Rise (SLR) Scenarios	1.7 feet SLR	4.0 feet SLR	6.3 feet SLR	1.7 feet SLR + Storm Surge	4.0 feet SLR + Storm Surge	6.3 feet SLR + Storm Surge
Upland*** (acres)	914	83	2,309	1,894	2,604	3,343
BUILT LANDSCAPE						
Infrastructure (# of sites)	4	23	115	69	167	304
Critical Facilities (# of sites)	0	0	1	0	1	4
Roadways – Local (miles)	0	1	3	2	4	5
Roadways – State (miles)	0	0	1	1	2	4
Transportation Assets (# of sites)	46	46	49	47	52	57
100-year floodplain (acres)	739	1,234	1,355	1,316	1,397	1,461
NATURAL RESOURCES						
Freshwater Wetlands (acres)	59	182	259	222	306	413
Tidal Wetlands (acres)	754	834	851	845	855	860
Conserved Lands (acres)	304	610	928	758	1,026	1,277
Land Protection Priorities (acres)	625	1,040	1,474	1,244	1,610	1,978
Critical Wildlife Habitat (acres)	721	1,204	1,723	1,447	1,895	2,357

* Storm surge = 100-year (one-percent-annual-chance) flood event.
** The ten Great Bay municipalities include Dover, Durham, Exeter, Greenland, Madbury, Newfields, Newington, Newmarket, Rollinsford, and Stratham.
*** Upland refers to land above mean higher high water (highest tidal extent). The ten Great Bay municipalities have approximately 86,210 acres of upland.

Considering just the left hand column, we can see that there are only 4 infrastructure sites that are at risk under the 1.7 foot SLR scenario, and no critical facilities or roadways threatened. When you look at the 6.3 foot SLR column the numbers of infrastructure goes up to 115, although the numbers of critical facilities and roadways still are still in the low single digits. Recall that the *high end* scenario in the IPCC RCP 8.5 report was 1.5 to 2.7 feet.

Again, we are making an assumption, but it is likely that under a historical average SLR scenario, there would be no infrastructure under threat, no critical facilities, no roadways, and even the number of transportation assets would be significantly under the 46 indicated in the

1.7 foot scenario. It is also likely that the number of acres which would be impacted would be much less than the figures indicated. Given this potential for radically lower assets and acreage at risk, it is a disservice that readers are not provided a better perspective on the real probabilistic adjusted risks.

It would have been very helpful, and a more realistic projection of future possibilities, if the NHCRHC had included a column of the infrastructure and acreage at risk under the long term historic SLR scenario of 1.7 mm/yr.

There is no questioning that our seacoast infrastructure will face risks from weather events. We will see Nor'easters, blizzards, ice storms and other events occur. These events will impact electrical grids, pipelines, roads, telecommunications and other important systems that are important. But looking at even the lowest of the unrealistic projections by the NHCRHC, the development of the seacoast area -- including our waste water treatment plants, our roads, our critical infrastructure and our homes -- is not under serious threat from sea level rise.

NHCRHC Recommended Actions

The final sections of the NHCRHC report outline recommended steps and actions that can and should be taken by local and state officials. The recommendations are not specific regarding towns or assets, but are general strategies that can be employed.

The recommendations are presented in three sections – Science, Assessments/Implementation and Legislation. Each section has specific recommendations and action steps associated with them. It should be noted that the Legislative recommendations are a restatement of the steps in the other sections that directly reference legislative actions.

In the Science section, the first recommendation is to legislatively authorize a state agency to convene a Science and Technology Advisory Panel. This is expected as most reports like this one typically advocate for additional governmental bodies to engage and buy in to the agenda promoted by the study. In this case, the authors would like a permanent STAP that can continuously receive state funding support so it can update the data and regularly put our reports like this one. Needless to say, given the incomplete scientific assessment performed by the NHCRHC STAP, along with the decision to promote the most alarmist scenarios out there, legislators should be very cautious about making this type of panel a funded and permanent one.

The other four Science recommendations and action steps push for more agency actions and funding for more studies, more data, more awareness and more applied research on coastal risks in New Hampshire. This is not to say that having a better understanding of risks is not a worthwhile endeavor, but the track record of the past several years of funding these types of studies at the state, regional and planning levels is not very good. All the past funding appears to be concentrated on an alarmist viewpoint and not addressing many of the questions that exist regarding the true nature of SLR and flood risks. Given this very biased and one-sided approach to what should be an objective process, legislators should be extremely cautious of taking the actions recommended.

For the Assessment and Implementation sections, there are 30 recommendations with nearly 100 specific actions. As expected, nearly all of these request more funding. There are funding requests for more assessments, funding requests for state agency review of statutes, funding for review of building codes, funding to make facilities more resilient, funding to acquire property

at higher elevations, and so on.

Just as significant though, is a very direct request to use the findings of this report, and any future state STAP reports, and incorporate them into development standards, land use policies and planning at the state, regional and local levels. They want to REQUIRE state agencies to implement these risk assessments into how they plan, operate and impose rules on local authorities. They want to "encourage" municipalities to adopt even larger buffers and setbacks on properties. The want to "reduce existing inconsistencies" between municipal and state plans, building plans and design codes. They want to establish special districts, tax credits and revolving loan funds to discourage development in vulnerable areas. They want to "improve" consumer protection disclosure of properties vulnerable to coastal flooding. They want to cordon off huge tracts of land from any development by expanding the floodplain definitions well beyond the traditional 100 year flood standards.

The macro implications of these recommendations would be to bring economic development in huge areas of the Seacoast to a screeching halt.

This report seeks to divert millions of scarce government dollars to maintaining the alarmist machine. In a fiscal environment where available state funding is limited, where exploding health care costs are draining budgets, where our red list of bridges and roads gets longer, where the needs for improving our children's education options grows larger, where we need to take care of the most needy -- it makes no sense to give these types of alarmist driven recommendations a priority in state and local funding.

This report seeks to impose state rules on local planning, zoning and building codes, taking away local control. Do legislators really want to take additional steps to hand over more power, authority and control to state agencies and regulatory bureaucracies, and further reduce the power of local government to decide what is best for their citizens? Do the people of Portsmouth want a state agency to determine that Strawberry Bank needs to be relocated when it decides that its current location is at risk? Do they want a state building code for more resilient facilities to determine how portions of the historic areas in the South End have to be revised?

This report will put the property values of thousands of homeowners at risk – immediate risk, not "possible", "future", "potential" risk. The recommendation of greater "disclosure" of flooding and SLR risk could have dramatic impacts on property values. How many homeowners in Rye, or Hampton Beach, or Portsmouth or New Castle believe that they should be informing potential buyers that their property could be underwater in 84 years – assuming of course that an event projected to take place over 1000 years or more in fact occurs in the next few decades? Such a disclosure may or may not have a large impact on sale prices, but such a disclosure is sure to have only one direction on home values. Down.

It is unfortunate that state resources, time and money have gone to an effort that clearly is using alarmist scenarios to create a sense of risk that is far more extreme than what is likely to occur. It is worse that this effort then uses the fear of disaster to attempt to drive an agenda that usurps local control, stops development in its tracks, seeks tens of millions (if not hundreds of millions) of dollars of funding, and threatens the region's land values. Based on this analysis, state officials, bureaucrats and local decision makers would be wise to put this study in a desk drawer and let it collect dust instead of using it to justify unnecessary and costly actions.

Recommendations to Decision Makers

Reports that properly evaluate and assess risks are important for decision makers. It is imperative that legislators and policy makers have access to information so that they can make informed decisions. But just as imperative to having access to information is ensuring that the information that is provided properly represents the magnitude and probabilities of the threats.

This is where the NHCRHC report fails.

Instead of basing its analysis and recommendations on extreme projections of sea level rise, a more prudent and justifiable report would have presented the scenarios in their proper context. For instance, the highest likelihood scenario would likely be the continuation of historic sea level rise at 1.7 mm/yr +/- 0.2 mm/yr. Consideration of even two standard deviations (95% of the historical distribution) should be considered as the range with the highest confidence levels. Even the current trend assumption of 3.2 mm/yr (without adjusting for the long term trends due to natural cycles) has much higher probabilities than what the NHCRHC report uses. Recognizing that even the NHCRHC "low scenario" is three to four times larger than the historical trend would place the report's scenarios far to the right on a probability distribution graph. The "high scenarios" should have a probability of a fraction of a fraction of a fraction of a percent.

Projecting the subsequent potential sea level rise based on these assumptions dramatically alters the perception of the likely impacts, as well as the urgency of the recommendations. Granted, it does not convey the type of alarm which many of the participants in the NHCRHC process want to convey, but it does properly put the science and the projections of sea level rise in prudent and proper context. It is only in this context can decision makers properly assess the conclusions and take the proper actions to address the potential future.

As the report notes, representatives of the NHCRHC have already passed legislation last session to start the implementation of some of the recommendations, which occurred before the report was even drafted. This includes SB374 and SB452 from 2016 that empower DES to update the science every five years and requires state agencies to determine if any changes are necessary to enable appropriate state and local actions to prepare for projected coastal flood risks. Additionally, SB452 requires state agencies involved in planning, siting, and design of state-funded structures and facilities, public works projects, and transportation projects, as well as land acquisition and management, and other environmental activities in the coastal and Great Bay regions to reference the 2014 STAP Report, as updated, for guidance on all potentially affected activities.

The implications of this type of legislation is to institutionalize alarmist assessments and begin the process of pushing its recommendations down to the regional and local level. Combined with the ongoing efforts to establish "climate adaptation coordinators" in state agencies, the effect of this report, even before it was finished, is to push an agenda instead of properly understand the science.

As an example of the potential costs to the citizens of the region, as if on cue, the City of Portsmouth is now considering spending $10 to $12 million to protect Prescott Park from sea level rise. Presumably this funding would come from either the taxpayers of Portsmouth or public donations – funding that could go to more immediate needs like improving educational programs for the children in Portsmouth, building a new parking garage, or to help pay for the new wastewater system on Pierce Island. Take this potential drain of public money and multiply it by 100 or more. That is the real threat to the Seacoast region, not sea level rise.

Legislators, state leaders, local administrators and elected officials in the Seacoast must raise the questions outlined here when confronted with requests to implement the NHCRHC recommendations. It is imprudent policy to take actions such as these and commit millions of taxpayer dollars based on unrealistic assumptions and unknown assessments of risk probabilities. The NHCRHC report is an unfortunate result of an alarmist agenda instead of a prudent evaluation of our Seacoast region's true risks.

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