Risk can be thought of as the product of consequences and likelihood: what can happen, and the odds of it happening. With regards to hurricanes, we are facing the following three risks in the coming decades. The first risk is associated with the continuing increase in population and wealth in vulnerable coastal regions. The second risk is from increased North Atlantic hurricane activity. The third risk that we are facing is the potential loss of key elements of the hurricane observing system.

NEXT

This figure shows a plot of the total number of North Atlantic tropical cyclones since 1851, in blue. There is debate among scientists over the quality of the historical data record, and the data from the satellite era is certainly the most reliable. But what the data shows is an overall correlation with tropical Atlantic sea surface temperature. We see that coldest period around 1920 is associated with lowest number of tropical cyclones and the warmest period (since 1995) is associated with the largest number of tropical cyclones.

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This figure shows the distribution of North Atlantic tropical cyclone intensity since 1970. What we see is that the number of major hurricanes, and particularly category 4 hurricanes, has increased particularly since 1995. Unfortunately hurricane intensity data isn’t reliable prior to 1970.

NEXT

So is this increase in hurricane activity caused by natural variability, or global warming? If we look again at the historical record of North Atlantic tropical cyclones, some scientists see an apparent signal from the Atlantic Multidecadal Oscillation, which is nominally a 70 year cycle. The peak of the current warm phase which began in the mid 1990s, and the elevated hurricane activity, might be expected to occur around 2020. Other scientists interpret this data to reflect global warming, comparing the recent active period in the blue square with the previous active period in the 1950’s and find a substantial increase that they attribute to global warming. Regardless of the differing opinions on the cause of the recent increase in hurricane activity, scientists on both sides of the debate agree that we can expect the level of Atlantic hurricane activity to remain high in the coming decades.

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This slide summarizes a simple statistical projection of North Atlantic hurricane activity for the year 2025, that accounts for both natural variability and global warming, using results from the historical data record and climate models. In 2025, we assume that tropical sea surface temperatures will have increased by 1^{o}F owing to global warming, and that we are near the peak of the warm phase of the Atlantic Multidecadal Oscillation. For reference, the long-term average number of tropical cyclones per year has been 10, and the average since 1995 is 14. Estimates for the annual number of tropical cyclones ca. 2025 range on the low side of 14 (essentially the same number we have now) to 20, if you combine the effects of the oscillation and global warming. This analysis implies between 3-4 category 4 and 5 hurricanes per year. The combination of natural variability and global warming has the potential to produce hurricane activity in the coming decades that is unprecedented in the historical record.

Does this projection constitute a certainty? No! This projection does encapsulate the risk we are facing from hurricanes based upon the best available knowledge, accounting for the uncertainty associated with the different perspectives of scientists studying this issue. To summarize we are facing an elevated risk from hurricanes in the coming decades, which is compounded by projected increases in population and wealth in vulnerable coastal regions.

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Now for issue of “flying blind”. In the previous decade, there was a substantial investment in NASA research satellites. Several of these satellites have turned out to be extremely useful for understanding and forecasting hurricanes.

The satellite altimeter has proven to be useful not only for determining global sea level, but also for determining upper ocean heat content. The diagram on the left shows the sea surface temperature in the Gulf of Mexico during the intensification of Hurricane Katrina. The entire Gulf is seen to be warm, with surface temperatures reaching almost 90 degrees Fahrenheit. Looking at the figure on the left, Hurricane Katrina underwent rapid intensification when it reached the deep layer of warm water in the Gulf

Loop Current. Hurricane Rita showed a similar rapid intensification over this deep layer of warm water.

In 2013, with the expected demised of the Jason-2 satellite, we are facing complete loss of the altimetry capability. There are no planned satellite altimeters after 2013. We will be flying blind in terms of observations of upper ocean heat content from satellite, not to mention global sea level determination from satellite. As an alternative, we can improve our vision with the proposed Wide Swath Altimeter mission, which was cancelled two years ago.

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The Quikscat scatterometer has been at the center of a recent controversy. This figure illustrates the impact of Quikscat winds on weather analyses during hurricane season. These two maps are from September 1999, during the period when Quikscat data was just becoming available. The map on the left shows the ocean surface wind speeds and direction obtained from a conventional weather analysis. On the right we see the weather analysis including the Quikscat data. The weather analysis without Quikscat completely misses tropical storm Harvey that was developing in the Gulf of Mexico and made landfall 2 days later.

Quikscat is already past its expected lifetime, and almost certainly will not continue operating after 2009. We can substantially improve our vision with the extended ocean surface vector wind mission that will provide much higher resolution measurements and more accurate measurements particularly in conditions of heavy rain.

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Reconnaissance aircraft have provided critical information for the last several decades for predicting hurricane tracks. It is not an either/or situation, the reconnaissance aircraft provide critical information that is complementary to that provided by satellites. Unmanned aerial vehicles, or UAVs, that are being used by the military in Iraq, have substantial potential to extend our capability of observing hurricanes. The advantages of UAVs are their extended range and duration, far longer than a manned aircraft can fly, elimination of safety concerns for the crew, and the ability to fly into portions of the storm that are too dangerous for manned aircraft. In 2005, this capability was demonstrated when the Aerosonde, a small UAV weighing about 30 lbs, flew into hurricane Ophelia and coordinated with the Hurricane Hunter aircraft. Small UAVs like the Aerosonde are relatively inexpensive and are semi disposable: if an aircraft is lost flying into a dangerous situation, valuable information can be obtained at the cost of a relatively inexpensive asset.

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To make rational decisions about continued and enhanced investment in the observing system, I would argue that we need observing system assessment and valuation studies. There are three elements to such a valuation study. The first element is to assess the societal value of improved track and intensity forecasts. Such an assessment needs to consider not only the economics, but also safety issues and various political issues. The second element is relatively simple to assess: the cost of the proposed observing system. The third element, assessing the impact of the observing system on the forecast, is complex. It takes time and research to figure out how to effectively use a new observing system in a forecast. Much of this research is done by universities, and forecasters are relatively conservative in adopting new technologies in their operational forecasts. I would argue that even though the Quikscat satellite was launched in 1999, the data may not yet be used optimally in the forecasts. Given the large societal value of accurate hurricane forecasts, I very much doubt that it makes any sense to diminish our present observing capability. Rather, we need to look forward to developing the next generation, improved observing capability to help us address the coming risks associated with hurricanes.

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So in closing I would like to return to the issue of risk. There are two general strategies that we can use to manage the risk of hurricanes. The first strategy is the status quo, cross our fingers, and hope for the best. The second strategy is a pre-emptive strike on hurricanes. Such a strategy would include a comprehensive risk assessment of our coastal cities, development of adaptation strategies and improvements to hurricane forecasts, which require an improved observing system and research to improve our understanding hurricanes. I suspect that any valuation studies would find that the pre-emptive strike strategy involves an investment that is a fraction of the damage from one major landfalling hurricane strike.