

TROPICAL CYCLONES AND CLIMATE CHANGE ASSESSMENT

Part I: Detection and Attribution

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PREVIOUS ASSESSMENT SUMMARY.

Previous global assessments of this topic include Knutson et al. (2010), which was a WMO task team report, and the IPCC Fifth Assessment Report (AR5) assessment (Bindoff et al. 2013). Some key aspects of the IPCC AR5 assessment on TC activity are reproduced here for reference and comparison to the current assessment.

Regarding attribution of past TC changes, IPCC AR5 (Bindoff et al. 2013) concluded, “Globally, there is low confidence in any long-term increases in tropical cyclone activity (section 2.6.3) and we assess that there is low confidence in attributing global changes to any particular cause. In the North Atlantic region there is medium confidence that a reduction in aerosol forcing over the North Atlantic has contributed at least in part to the observed increase in tropical cyclone activity since the 1970s. There remains substantial disagreement on the relative importance of internal variability, GHG [greenhouse gas] forcing and aerosols

for this observed trend. It remains uncertain whether past changes in tropical cyclone activity are outside the range of natural internal variability.”

AUTHOR RESPONSES TO ELICITATION ON CONFIDENCE/LIKELIHOOD LEVELS.

Table ES1 provides a full list of elicitation responses from each individual author for the specific detection and attribution statements listed.

REFERENCES

- Bindoff, N. L., and Coauthors, 2013: Detection and attribution of climate change: From global to regional. *Climate Change 2013: The Physical Science Basis*, T. F. Stocker et al., Eds., Cambridge University Press, 867–952.
- Knutson, T. R., and Coauthors, 2010: Tropical cyclones and climate change. *Nat. Geosci.*, **3**, 157–163, <https://doi.org/10.1038/ngeo779>.

TABLE ESI. Author elicitation responses to detection and attribution statements.

S. Camargo	J. Chan	K. Emanuel	C.-H. Ho	T. Knutson	J. Kossin	Mohapatra	M. Satoh	M. Sugi	K. Walsh	L. Wu
Perspective: Type I error avoidance										
The estimated contribution of decreased anthropogenic aerosol forcing to the increased Atlantic TC frequency since the 1970s is large and positive and is highly unusual (e.g., $p < 0.05$) compared to natural variability.										
low to medium confidence	low confidence	medium to high confidence	low confidence	low confidence	medium confidence	low confidence	low confidence	low confidence	low confidence	low to medium confidence
Observed poleward migration of latitude of maximum intensity in the northwest Pacific basin is highly unusual (e.g., $p < 0.05$; statistically distinguishable) compared with expected natural variability.										
low to medium confidence	low to medium confidence	medium to high confidence	low to medium confidence	low to medium confidence	medium to high confidence	low to medium confidence				
Anthropogenic forcing has contributed to the observed poleward migration of the latitude of maximum intensity in the northwest Pacific basin.										
low to medium confidence	low confidence	medium confidence	low confidence	low confidence	medium confidence	low confidence	low confidence	medium confidence	low confidence	low to medium confidence
There has been a detectable decrease (highly unusual compared to natural variability; e.g., $p < 0.05$) in the global-scale propagation speed of TCs since 1949.										
low to medium confidence	low confidence	medium confidence	low confidence	low confidence	medium confidence	low confidence	low confidence	medium confidence	low confidence	low to medium confidence
Anthropogenic forcing has contributed to the observed decrease in the global-scale propagation speed of TCs since 1949.										
low confidence	low confidence	medium confidence	low confidence	low confidence	medium confidence	low confidence	low confidence	medium confidence	low confidence	low to medium confidence
List any other observed multidecadal- to century-scale change in TC activity that is highly unusual (e.g., $p < 0.05$; statistically distinguishable) compared with expected natural variability (from a type I error avoidance perspective), and provide confidence level.										
none	none	none	none	none	none	none	none	none	none	none

TABLE ESI. Continued. For the type II error avoidance, each substatement is prefaced by “The balance of evidence suggests...” and “Detectable” refers to “unusual compared to natural variability, e.g., $p < 0.1$.”

S. Camargo	J. Chan	K. Emanuel	C.-H. Ho	T. Knutson	J. Kossin	Mohapatra	M. Sato	M. Sugii	K. Walsh	L. Wu
Perspective: Type II error avoidance										
Detectable increase in North Atlantic TC activity since the 1970s; and anthropogenic forcing (reduced aerosol forcing) has contributed to this increase.										
no and yes	no and no	yes and yes	no and no	no and yes	no and yes	no and no	no and no	no and no	no and no	no and yes
Observed poleward migration of latitude of maximum intensity in the northwest Pacific basin is detectable; and anthropogenic forcing has contributed to the observed poleward migration of the latitude of maximum intensity in the northwest Pacific basin.										
yes and yes	yes and no	yes and yes	yes and yes	yes and yes	yes and yes	yes and no	yes and yes	yes and yes	yes and yes	yes and yes
Detectable increase in TC intensity over the Arabian Sea (premonsoon) 1979–2010; and anthropogenic forcing has contributed to this increase.										
no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no
Detectable increase in the frequency of extremely severe cyclonic storms over the Arabian Sea (postmonsoon) over 1998–2015; and anthropogenic forcing has contributed to this increase.										
yes and yes	yes and no	yes and yes	yes and yes	yes and yes	yes and yes	yes and no	yes and yes	yes and yes	yes and no	yes and yes
Detectable increase in the global proportion of TCs reaching category 4 or 5 intensity in recent decades; and anthropogenic forcing has contributed to this increase.										
yes and yes	yes and no	yes and yes	yes and yes	yes and yes	yes and yes	yes and no	yes and yes	yes and yes	yes and no	yes and yes
Detectable increase in the global average intensity of strongest (hurricane intensity) TCs since the early 1980s; and anthropogenic forcing has contributed to this increase of global average intensity of strongest (hurricane intensity) TCs.										
yes and yes	no and no	yes and yes	yes and yes	yes and yes	yes and yes	yes and no	yes and yes	yes and yes	yes and no	yes and yes
Detectable multidecadal increase in TC occurrence near Hawaii; and anthropogenic forcing contributed to the recent unusually active TC season near Hawaii in 2014.										
no and yes	no and no	no and no	no and no	no and yes	no and yes	no and no	no and yes	no and yes	no and no	no and yes
Detectable increase in TC occurrence activity in the western North Pacific in recent decades; and anthropogenic forcing contributed to the recent unusually active TC season, including the record-setting (1984–2015) TC intensity, in the western North Pacific in 2015.										
no and yes	no and no	no and yes	no and yes	no and yes	no and yes	no and no	no and yes	no and yes	no and no	no and yes
Detectable increase in the intensity of Hurricane Sandy-like storms in the Atlantic in recent decades; and anthropogenic forcing contributed to the intensity of Hurricane (Superstorm) Sandy in 2012.										
no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no

TABLE ESI. Continued.

S. Camargo	J. Chan	K. Emanuel	C.-H. Ho	T. Knutson	J. Kossin	Mohapatra	M. Sato	M. Sugii	K. Walsh	L. Wu
Detectable increase in the intensity of Haiyan-like supertyphoons in the western North Pacific in recent decades; and anthropogenic forcing contributed to the intensity of Supertyphoon Haiyan in 2013.										
no and yes	no and no	yes and no	yes and yes	no and no	no and yes	no and no	no and yes	no and yes	no and no	no and no
Detectable long-term increase in the occurrence of Hurricane Harvey-like extreme precipitation events in the Texas region (U.S.); and anthropogenic forcing has contributed to increased frequency of Hurricane Harvey-like precipitation events in the Texas region.										
yes and yes	yes and yes	yes and yes	yes and yes	yes and yes	yes and yes	yes and yes	yes and yes	yes and yes	yes and yes	yes and yes
Detectable increase in the frequency of moderately large U.S. surge events since 1923 as documented by the index of Grinsted et al. (which strongly filters out sea level rise influences); and anthropogenic forcing has contributed to this increase.										
no and no	yes and yes	yes and yes	no and no							
Detectable decrease in the global-scale propagation speed of TCs since 1949; and anthropogenic forcing has contributed to this decrease.										
yes and no	no and no	yes and yes	yes and no	yes and no	yes and no	no and no	no and no	yes and no	yes and no	yes and no
Detectable decrease in severe landfalling TCs in eastern Australia since the late 1800s; and balance of evidence suggests anthropogenic forcing has contributed to this decrease.										
yes and no	yes and no	yes and no	no and no	yes and no	yes and no	no and no	yes and no	yes and no	yes and no	yes and no
Detectable decrease in U.S. landfalling-hurricane frequency since the late 1800s; and anthropogenic forcing has contributed to this decrease.										
no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no
Detectable increase in global major-hurricane-landfall frequency in recent decades; and anthropogenic forcing has contributed to this increase.										
no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no	no and no
Detectable decrease in TC frequency in the southeastern part of the western North Pacific (1992–2011); and anthropogenic forcing (changes in aerosol emissions) has contributed to this decrease.										
no and yes	no and no	no and yes	no and no	no and yes	no and yes	no and yes				
Detectable multidecadal increase in TC occurrence near Hawaii and in the eastern and central Pacific Ocean basins; and anthropogenic forcing contributed to the recent unusually active TC seasons near Hawaii in 2014 and 2015 and in the eastern and central Pacific Ocean in 2015.										
no and yes	no and no	no and yes								