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Supplement

Tropical Cyclones and Climate Change Assessment

Part II: Projected Response to Anthropogenic Warming

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Process used to develop the assessment

The process used to develop the assessment was as follows. A seven-member assessment task team was selected by the WMO's Working Group on Tropical Meteorology Research within the World Weather Research Programme. In addition, four authors (Chan, Emanuel, Kossin, and Sugi) from the previous assessment (Knutson et al. 2010) agreed to participate as additional authors on the new assessment. The full author team developed the assessment and deliberated on its content via email, with no in-person meetings. Because unanimous agreement could not be reached on some important issues, the opinions (confidence levels) of each individual author were elicited for a specific set of agreed-upon statements, as in Part I (Knutson et al. 2019). The distribution of author opinion from this elicitation is summarized in the main text (and detailed in Table ES5). Author elicitation responses were not anonymous and were distributed among all authors once available. Authors were permitted to alter their own elicitation table responses at any time up until final acceptance of the manuscript.

Previous assessment summary of TCS and climate change

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

For TC projections, Christensen et al. (2013) concluded, "Based on process understanding and agreement in 21st century projections, it is likely that the global frequency of occurrence of TCs will either decrease or remain essentially unchanged, concurrent with a likely increase in both global mean TC maximum wind speed and precipitation rates. The future influence of climate change on TCs is likely to vary by region, but the specific characteristics of the changes are not yet well quantified and there is low confidence in region-specific projections of frequency and intensity. However, better process understanding and model agreement in specific regions provide medium confidence that precipitation will be more extreme near the centres of TCs making landfall in North and Central America; East Africa; West, East, South and Southeast Asia as well as in Australia and many Pacific islands. Improvements in model resolution and downscaling techniques increase confidence in projections of intense storms, and the frequency of the most intense storms will more likely than not increase substantially in some basins."

Evaluation of future projections of TC-relevant environmental parameters

The reliability of future projections of the large-scale environment that affect TCs is a broad problem of climate science. Since IPCC AR5 presented assessments of confidence in model projections for a number of key environmental variables of relevance to TC activity and its impacts (IPCC 2013; Collins et al. 2013), the reader is referred to that report for more detailed assessment of these, since the focus of our assessment is more narrowly on TC projections, rather than the related environmental parameters. In this supplemental material, we provide a summary for some of the more relevant TC-related environmental variables.

The most confident projection and detection/attribution statements in IPCC AR5 were generally for temperature and closely related variables, such as atmospheric moisture content and sea level rise. For example, Collins et al. conclude that global mean temperatures will continue to rise over the twenty-first century for high (unabated) emission scenarios, with a *likely* warming range of 2.6°–4.8°C for the RCP8.5 scenario. They do not make as confident a projection statement about spatial details of surface warming, such as the relative SST warming of different tropical basins. They note that a consistent enhanced equatorial Pacific warming pattern (distinct from El Niño–like warming) is seen in model projections, although estimates of even observed (twentieth century) trends in equatorial Pacific mean SST and the Walker Circulation remain uncertain (e.g., Vecchi et al. 2006; Deser et al. 2010; Solomon and Newman 2012). IPCC (2013) concludes that there is only *low confidence* in any specific projected change in El Niño–Southern Oscillation. An enhanced warming of the upper tropical troposphere relative to the surface is *likely* but with *medium confidence* according to Collins et al., which is a climate change detail that appears very relevant for TC intensity change in a warming climate (e.g., Tuleya et al. 2016).

IPCC assessments have been very confident about future increases in water vapor in a warmer climate. For example, in IPCC AR4, Randall et al. (2007) state, “In the planetary boundary layer, humidity is controlled by strong coupling with the surface, and a broad-scale quasi-unchanged [relative humidity] response [to climate warming] is uncontroversial.” A quasi-unchanged relative humidity response implies higher water vapor content as the air temperature increases. Related to this highly confident increase in moisture, IPCC AR5 projects that “over wet tropical regions, extreme precipitation events will *very likely* be more intense and more frequent in a warmer world” (Collins et al. 2013). Concerning sea level rise, according to IPCC AR5, global mean sea level rise will continue through the twenty-first century, and it is *very likely* that the rate of sea level rise will exceed the rate observed during 1971–2010 (IPCC 2013), although the amount of rise expected at various locations remains uncertain (IPCC 2013; Garner et al. 2017).

Atmospheric circulation change projections are generally even less confident than the temperature projections. For example, Collins et al. (2013) conclude: “In the tropics, the Hadley and Walker Circulations are *likely* to slow down. Poleward shifts in the mid-latitude jets of about 1°–2° latitude are *likely* at the end of the twenty-first century under RCP8.5 in both hemispheres (*medium confidence*), with weaker shifts in the Northern Hemisphere. In austral summer, the additional influence of stratospheric ozone recovery in the Southern Hemisphere opposes changes due to GHGs there, though the net response varies strongly across models and scenarios ... The Hadley Cell is *likely* to widen, which translates to broader tropical regions...” IPCC AR5 did not provide confidence statements on whether certain regional changes in circulation would occur, such as changes in steering flows or vertical wind shear that could alter TC tracks, genesis, or intensity.

In summary, the large-scale TC-relevant environmental changes where IPCC AR5 has most confidence in future projections include surface temperatures (warming), atmospheric temperatures (warming), atmospheric moisture content (increasing), and sea level rise (increasing). Projections of changes in tropical and subtropical circulation features and regional patterns of SST change are in general less confident. These findings have important implications for confidence in TC projections.

Recommended metrics for future studies

As a step toward future progress in this topic area, we recommend that more standardized TC spatial occurrence metrics be used in future studies to facilitate comparison between studies and to facilitate constructing multimodel and/or multistudy ensemble findings.

Basic information. Model name/source, model resolution, forcing scenario, years of integrations, description of ocean coupling used. Cite methodology used for TC detection.

TC metrics. Provide a number or value in control run or present-day simulation, percentage change in climate change experiment (except as noted below); report these for globe, NH, SH, and each of the six following basins:

Basin definitions.
North Atlantic: 0°–90°N, ~265°–360°E*
Northeast Pacific: 0°–90°N, 180°–~265°E*
Northwest Pacific: 0°–90°N, 100°–180°E
North Indian: 0°–90°N, 30°–100°E
South Indian: 90°S–0°, 20°–135°E
Southwest Pacific: 90°S–0°, 135°–295°E
South Atlantic: 90°S–0°, South America to Africa
*The North Atlantic–northeast Pacific boundary is on a diagonal tracing a path through Mexico and Central America.

List of recommended metrics.
1) Frequency (categories 0–5 combined)
2) Intense TC frequency (categories 4–5 combined)

3) Lifetime maximum TC intensity (10-m near-surface wind speed)
4) Lifetime maximum TC intensity (percentage change in pressure fall, which is the difference between central pressure and an environmental pressure; note that the method used for estimating the environmental pressure should be consistent for the present-day and warm climate storms)
5) Proportion of all TCs (categories 0–5) that are very intense (categories 4–5)
6) Accumulated cyclone energy (ACE)
7) Power dissipation index (PDI)
8) TC precipitation rate (averaged within 100, 300, and 500 km of storm center)
9) TC size (radius of hurricane force wind; radius of 12 m s^{-1} wind)
10) TC propagation speed (while storm is classified as a TC)
11) TC duration (time classified as a TC)
12) Surge damage potential (Powell and Reinhold 2007)
13) Latitude of maximum intensity (in degrees latitude, not percentage change)

Further recommendations. We have noted in this assessment the difficulties in obtaining a clear consensus in projected TC track and occurrence, and the sensitivity of such projections for future patterns of SST change. To help address this issue, encourage coordinated AGCM experiments using the same SST and climate forcing change across models (e.g., CMIP5 ensemble mean) and coupled GCM experiments nudged to the same future SST change. This will facilitate quantification of at least the component of uncertainty in TC projections associated with the simulated TC response to a common SST change pattern.

Supplemental projections tables

Detailed information on TC projections, as summarized in this report, is presented in Tables ES1–ES4, where projections are provided for different cyclone domains, including the globe (all basins), by hemisphere, and for six individual TC basins. In the tables, decreases are depicted by blue text, increases by red text, and bold numbers denote statistically significant results as reported by the original authors. In some cases, highly idealized experiments are included in the table, such as 2×CO_2 change only (with no change in SST) or uniform +2-K increase in SST only, with no change in CO_2 content. These are flagged by using green text, indicating that they will not be included in the summary figures alongside more realistic projection types.

To create our summary projection figures (Figs. 1–4), we use published results from a substantial number of available modeling studies to inform our estimates. The separate studies and projection details are provided in Tables ES1–ES4 and accompanying references. The “raw projections” from individual studies shown in Tables ES1–ES4 provide a traceable account of published results we used to develop our projection summaries and assessment statements, although we needed to use judgment and some subjectivity in combining information from the multiple available studies into summary ranges or other summary information for various TC metrics, as discussed in the main text.

Table ES1 for TC (categories 0–5) frequency of occurrence shows that, at the global scale, the vast majority of separate projection estimates from the various studies are blue, showing the dominant tendency for current models to project a decrease in overall TC frequency as the climate warms. Twenty-two out of 27 studies report that global TC frequency decreases in greenhouse warming scenarios, while five studies project an increase or mixed changes in global TC frequency. Among these five studies, one study (Emanuel 2013) finds an increase in global TC frequency using a statistical downscaling framework—in one of five CMIP3 models (A1B scenario) and in all six CMIP5 models (RCP8.5 scenario). Some other studies that examined CMIP5 model results find mixed changes in global TC frequency. Camargo (2013) finds increased global frequency in 6 of 12 CMIP5 models (RCP4.5 and RCP8.5 scenarios), while Murakami et al. (2014) finds increased global frequency upon downscaling 3 of 11 climate models (RCP8.5 scenario), but in 0 of 11 CMIP5 models (RCP4.5 scenario). Tory et al. (2013) also examined CMIP5 model results with an alternative detection scheme and finds a decrease in global TC frequency in all eight CMIP5 models (RCP8.5 scenario). It should be noted that different studies find different (opposite sign) TC frequency changes for the same CMIP5 model in some cases [e.g., for CCSM4, an 8% decrease in Tory et al. (2013) but an 8% increase in Murakami et al. (2014); and for MPI-ESM-LR, a 15% increase in Camargo et al. (2013) but a 15% decrease in Murakami et al. (2014)]. This indicates that there are uncertainties in TC detection algorithms, particularly for tropical storm strength storms and for low-resolution models. Therefore, projection results for tropical storms from such models have some degree of uncertainty. Another model resolution-related issue was found in Wehner et al. (2015) who simulated increased TC global frequency but only after degrading their global model resolution from a 25-km grid (which has decreased global frequency) to a 100-km grid. On the other hand, a recent study by Bhatia et al. (2018) projects an increase in global TC frequency using a global coupled model with a 25-km-grid atmosphere (RCP4.5 scenario), in contrast to a decrease in global TC frequency projected by all other relatively high-resolution dynamical models that we are currently aware of.

Table ES2 presents projections of the frequency of intense (categories 4–5) TCs. Owing to concern about model resolution and intensity, the entries in Table ES2 are generally organized with higher-resolution models located toward the top of the table and lower-resolution models toward the bottom. In some cases, results from dynamical models have been statistically downscaled in an effort to achieve a more realistic distribution of TC intensities. Table ES2 shows that, in contrast to overall TC frequency (Table ES1), for the intense TCs an increased frequency at the global scale is projected, at least for the case of higher-resolution models. Specifically, an increase in the global frequency of higher-intensity TCs under climate warming was reported in eight of nine dynamical modeling studies using models with grid spacing of 28 km or finer and also for Emanuel's (2013) empirical–statistical downscaling study. For these relatively higher-resolution models, the category 4+ range is often being explicitly modeled, at least in terms of maximum near-surface windspeeds of the modeled storms. In contrast, future intense TC frequency projections are much more mixed for lower-resolution models, as shown by the results from the models with relatively coarser resolution (e.g., grid spacing of 50 km and larger) in Table ES2.

Table ES3 presents the TC intensity projections from published studies. In the table, the higher-resolution model results are grouped toward the top of the table and the lower-resolution model results, in which we have relatively less confidence, are grouped toward the bottom. The 15 global estimates included in Fig. 3a are all positive, with a mean increase of about 5% and a range from +1% to +10%. According to the modeled intensity projections details in Table ES3, average intensity at the global scale is projected to increase in all eight of the eight studies that used dynamics models with grid spacing of 60 km or finer, and also in the Emanuel et al. (2008) study with a statistical–dynamical framework. Thus, at least the relatively higher-resolution models agree on an increase in global averaged TC intensity, in contrast to their general agreement on a *decrease* in global frequency as discussed earlier (Fig. 1). A few much coarser grid dynamical modeling studies (grid spacing of over 100 km) that project no change in TC intensity with climate warming are included in Table ES3, but these are not included in the summary Fig. 3.

Table ES4 shows that the projected TC rainfall rate for all TC basins combined increases with climate warming in all 16 of 16 available model estimates (summarized from eight studies in which quantitative projections of a rainfall-rate metric were reported). As shown in Table ES4, projections of this metric are positive even in most individual basin assessments, with only a few exceptions for some individual basin cases. The negative changes occasionally projected for individual basins have been interpreted as related to a model simulation having lower SST warming rates within that basin compared to the warming in other parts of the tropics (e.g., Knutson et al. 2015). The median of the 16 quantitative global estimates is 14% for a 2°C global warming.

Summary of projected TC track and occurrence map changes

Here we present a narrative summary of projected TC track and occurrence changes from a number of publications. Owing to the difficulty in quantitatively combining results from different studies into a common distribution, here the changes are summarized in a narrative form. These summaries are organized roughly into several broad categories representing broadly similar change features seen across multiple studies.

A feature seen in a number of projection studies is a shift in TC activity in the northwest Pacific basin from the South China Sea region to the East China Sea region. For example, this is projected under future climate change forcing experiments by selected subsets of CMIP3 and CMIP5 models (Wang et al. 2011; Wang and Wu 2015; Kossin et al. 2016). There is, however, a considerable range of results across different projection studies for such a change, with results being sensitive to the particular set of climate models used for these projections. Among other TC–climate studies projecting an eastward shift in TC tracks in the western North Pacific are the following: Yokoi and Takayabu (2009) report an eastward shift in TC genesis locations as projected by CMIP5 models under the IPCC A1B scenario. Murakami et al. (2011) project an eastward shift in western North Pacific TC tracks using a 20-km-mesh AGCM. Both of the above studies infer that the projected eastward shift is related to a projected eastward shift in the monsoon trough due to the dynamical atmospheric response to an SST warming pattern that is greater in the eastern Pacific than in the western Pacific (i.e., an El Niño–like change pattern). Yokoi et al. (2012) report that an eastward shift in TC tracks in the basin is projected by the CMIP5 models. Using a regional model downscaling technique, Lok and Chan (2017) project a poleward shift of TC activity in the western North Pacific, leading to fewer landfalling TCs in South China, but higher projected intensities for the TCs making landfall there.

Another common feature in several published TC track/occurrence projections is an increase in TC activity in the central Pacific and near Hawaii. Murakami et al. (2013a) project a significant increase in TC tracks near Hawaii using 20-km-mesh high-resolution AGCM. Yoshida et al. (2017) also project a poleward expansion of TC activity in the northeast Pacific including near Hawaii along with some poleward expansion in the far eastern North Atlantic; decreased occurrence is projected elsewhere. Li et al. (2010) analyzed the GFDL HiRAM2.1 and ECHAM5 T319 models (IPCC AR4, A1B scenario) and found that both models projected increased TC genesis frequency in the north central Pacific but decreased TC genesis frequency elsewhere in the North Pacific. Zhang et al. (2017), analyzing projections for the North Pacific based on the Emanuel (2013) framework, project increased TC occurrence over most of the North Pacific, but especially in the central North Pacific. Other studies projecting increased TC frequency in the central North Pacific include Knutson et al. (2015), Murakami et al. (2017a), and Bhatia et al. (2018).

A number of other features are seen in published TC track/occurrence projections. Roberts et al. (2015) project a poleward expansion in the northeast Pacific and in the eastern part of the northwest Pacific basin, along with a slight increase in the north Indian Ocean, and decreases elsewhere. Kim et al. (2014) find in a 2×CO_2 experiment decreased occurrence in most regions, but with slight increases near Hawaii and in the eastern southwest Pacific. Manganello et al. (2014) focused on the northwest Pacific only, and project a poleward expansion of TC occurrence (A1B scenario time slice) using a 16-km-grid global model time slice experiment, but did not simulate such a change using a 125-km-grid version of the model. Sugi et al. (2017) project essentially no significant expansion of overall tropical storm occurrence. Wehner et al. (2015) project a poleward expansion of TC occurrence in their 2×CO_2 and +2-K uniform SST warming timeslice experiments using a ~25-km-grid global model. Park et al. (2017) project a decrease in TC occurrence over the North Atlantic (Gulf of Mexico) but an increase over the northwest Pacific (particularly near Korea and Japan). Yamada et al. (2017), using a 14-km-grid global nonhydrostatic model, project decreased TC occurrence in the eastern North Pacific, but generally only small (nonsignificant) changes elsewhere in the tropics. Two TC projection studies showing an eastward shift in TC tracks in the North Atlantic include Murakami and Wang (2010) and Colbert et al. (2013).

Regarding behavior of very intense TCs, four studies provide global maps of projected changes in geographical distribution of very intense (categories 4–5 or category 5) TC occurrence that have some broadly similar characteristics over several basins (Murakami et al. 2012b, Fig. 12; Knutson et al. 2015, Fig. 9; Sugi et al. 2017, Fig. 3; and Yoshida et al. 2017, Fig. 2f). According to each of these studies, the occurrence frequency of categories 4–5 TCs will increase in northern part of the tropical North Pacific TC basins but decrease in the southwestern part of the northwest Pacific, in the South Pacific and in the south Indian Ocean near Australia. On the other hand, Bhatia et al. (2018) project that the occurrence of category 3–5 TCs will increase in most TC regions, although areas with the most pronounced statistical significance include the Atlantic, western North Pacific, central and eastern North Pacific, and the southwest Pacific, including near northeast Australia. Also, Ogata et al. (2016) commented that the increase in categories 4–5 occurrence frequency in the northern part of the western North Pacific reported by Sugi et al. (2017) could be overestimated due to lack in air–sea interaction in their model simulations.

Author responses to elicitation on confidence levels

See Table ES5.

Table ES1. Projections of tropical storm frequency. Projected change in frequency of tropical storms in warm climate runs relative to control run in percent. Red and blue numbers/text denote projected increases and decreases, respectively. Boldface text denotes where a statistical significance test was reported that showed significance. Black values denote no change. Green text denotes changes based on SST-increase-only or 2×CO$_2$-only idealized experiments. The frequency projections from Emanuel et al. (2008) have been computed slightly differently from those shown in Fig. 8 of the original paper in order to facilitate intercomparison with projection results from other studies. Additional data from Roberts et al. (2015) are via M. Roberts (2017, personal communication). Type of ocean coupling for the study is indicated by the following model/type: [1] no ocean coupling (e.g., specified sea surface temperatures or statistical downscaling of tropical cyclones; [2] fully coupled ocean experiment; or [3] hybrid type, with uncoupled atmospheric model for storm genesis, but with ocean coupling for the dynamical or statistical–dynamical downscaling step. Basin abbreviations: Atlantic, Atl.; Pacific, Pac.; Indian, Ind.

Reference	Model/Type	Resolution	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Sugi et al. 2002	JMA Timeslice [1]	T106 L21 (~120 km)	10 yr 1×CO$_2$, 2×CO$_2$	**−34**	**−28**	**−39**	**+61**	**−66**	−67	+9	**−57**	**−31**
McDonald et al. 2005	HadAM3 Timeslice [1]	N144 L30 (~100 km)	15 yr IS95a 1979–94 2082–97	**−6**	−3	**−10**	**−30**	**−30**	**+80**	**+42**	+10	**−18**
Hasegawa and Emori 2005	CCSR/NIES/FRCAGCM timeslice [1]	T106 L56 (~120 km)	5 × 20 yr at 1×CO$_2$ 7 × 20 yr at 2×CO$_2$					−4				
Yoshimura et al. 2006	JMA Timeslice [1]	T106 L21 (~120 km)	10 yr 1×CO$_2$, 2×CO$_2$	**−15**								
Oouchi et al. 2006	MRI/JMA Timeslice [1]	TL959 L60 (~20 km)	10 yr A1B 1982–93 2080–99	**−30**	**−28**	**−32**	**+34**	**−38**	**−34**	**−52**	**−28**	**−43**
Chauvin et al. 2006	ARPEGE Climat Timeslice [1]	~50 km	Downscale CNRM B2				**+18**					
			Downscale Hadley A2				**−25**					
Stowasser et al. 2007	IPRC Regional [1]		Downscale NCAR CCSM2, 6xCO$_2$					+19				
Bengtsson et al. 2007	ECHAM5 timeslice [1]	T213 (~60 km)	2071–2100, A1B		−13		−8	−20	+4	−26		
Bengtsson et al. 2007	ECHAM5 timeslice [1]	T319 (~40 km)	2071–2100, A1B		−19		−13	−28	+7	−51		
Leslie et al. 2007	OU-CGCM with high-res. window [2]	Up to 50 km	2000–50 control and IS92a (6 members)									~0
Emanuel et al. 2008	Statistical–deterministic [3]	—	Downscale 7 CMIP3 mods.: A1B, 2180–2200 Average over 7 models	−7	+2	−13	+4	+6	−5	−7	−12	−15
Knutson et al. 2008	GFDL Zetac regional [1]	18 km	Downscale CMIP3 ens. A1B, 2080–2100				−27					
Gualdi et al. 2008	SINTEX-G coupled model [2]	T106 (~120 km)	30-yr 1×CO$_2$, 2×CO$_2$,	**−16** (2×)			−14	−20	−3	−13	−14	**−22**
			4×CO$_2$	**44** (4×)								
Semmler et al. 2008	Rossby Centre regional model [1]	28 km	16 yr control and A2, 2085–2100				−13					
Zhao et al. 2009	GFDL HIRAM timeslice [1]	50 km	Downscale A1B:									
			CMIP3 *n* = 18 ens.	**−20**	**−14**	**−32**	**−39**	**−29**	+15	−2	**−30**	**−32**
			GFDL CM2.1	**−20**	**−14**	**−33**	−5	−5	**−23**	**−43**	**−33**	**−31**
			HadCM3	**−11**	+5	**−42**	**−62**	**−12**	**+61**	−2	**−41**	**−42**
			ECHAM5	**−20**	**−17**	**−27**	−1	**−52**	**+35**	−25	**−13**	**−48**

				Basin								
Reference	**Model/Type**	**Resolution**	**Experiment**	**Global**	**NH**	**SH**	**N Atl.**	**NW Pac.**	**NE Pac.**	**N Ind.**	**S. Ind.**	**SW Pac.**
Sugi et al. 2009	JMA/MRI global AGCM timeslice [1]		Downscale A1B:									
		20 km	MRI CGCM2.3	**–29**	**–31**	**–27**	+22	**–36**	**–39**	**–39**	**–28**	**–22**
		20 km	MRI CGCM2.3	**–25**	**–25**	**–25**	+23	**–29**	**–30**	–29	**–25**	**–27**
		20 km	MIROC-H	**–27**	**–15**	**–42**	–18	**+28**	**–50**	+32	**–24**	**–90**
		20 km	CMIP3 *n* = 18 ens.	**–20**	**–21**	**–19**	+5	**–26**	**–25**	–15	–5	**–42**
		60 km	MRI CGCM2.3	**–20**	**–21**	**–17**	**+58**	**–36**	**–31**	–12	**–22**	–8
		60 km	MIROC-H	–6	0	**–16**	+6	**+64**	**–42**	**+79**	+10	**–69**
		60 km	CMIP3 *n* = 18 ens.	**–21**	**–19**	**–25**	+4	–14	**–33**	+33	–18	**–36**
		60 km	CSIRO	**–22**	**–29**	–11	**–37**	+13	**–49**	–7	**–22**	+10
Yokoi and Takayabu 2009	CMIP3 ensemble [2]	various	A1B (2081–2100)					–1				
Emanuel et al. 2010	Statistical–deterministic [3]	—	Timeslice using CMIP3 A1B SST change, 1990–2090, NICAM model 14 km		+45 (global but Jun–Oct only)							
Yamada et al. 2010	NICAM timeslice [1]	14 km	Timeslice using CMIP3 A1B SST change, 1990–2090		–35 (global but Jun–Oct only)		–80	0	0	–77		
Li et al. 2010	ECHAM5 Timeslice [1]	40 km	A1B change (2080–2009)					**–31**	**+65**			
Murakami et al. 2010a	JMA/MRI global AGCM timeslice [1]	V3.1 20 km	Downscale A1B:CMIP3 *n* = 18 ens.				+5					
Murakami et al. 2010b	JMA/MRI global AGCM timeslice [1]	V3.1	Downscale A1B:CMIP3 *n* = 18 ens.									
		20 km		**–16**	**–16**	**–16**	+6	**–27**	–15	–12	–5	**–35**
		60 km		**–19**	**–19**	**–19**	+4	–12	**–30**	+18	–9	**–34**
		120 km		**–29**	**–22**	**–43**	**–14**	**–26**	**–25**	–3	**–33**	**–63**
		180 km		–1.2	+9	**–15**	**+57**	**–19**	+17	+22	**–17**	–14
Murakami et al. 2011	JMA/MRI global AGCM timeslice [1]	V3.1 20 km	Downscale A1B:CMIP3 *n* = 18 ens.					**–23**				
Murakami et al. 2012a	JMA/MRI global AGCM timeslice [1]	V3.2 60 km	Downscale A1B:									
			YS, CMIP3 ens.	**–27**	**–27**	**–27**	**–44**	**–33**	–11	–16	**–29**	**–31**
			YS, Cluster 1	**–25**	**–25**	**–27**	–24	**–32**	**–30**	+19	**–24**	**–37**
			YS, Cluster 2	**–28**	**–30**	**–26**	–23	**–42**	–9	–21	**–20**	**–42**
			YS, Cluster 3	**–14**	–3	**–35**	**–31**	–2	+6	+1	**–46**	**–25**
			KF, CMIP3 ens.	**–20**	**–24**	**–16**	**–39**	**–28**	–3	**–42**	**–24**	–11
			KF, Cluster 1	**–20**	**–27**	**–10**	**–40**	**–33**	–15	**–28**	**–20**	–6
			KF, Cluster 2	**–21**	**–28**	**–12**	–21	**–44**	+5	**–50**	–10	**–24**
			KF, Cluster 3	**–14**	**–12**	**–15**	**–53**	–8	+17	**–48**	**–26**	–6
			AS, CMIP3 ens.	**–20**	–11	**–33**	+1	–19	–22	+1	**–31**	**–43**
			AS, Cluster 1	**–22**	**–22**	**–24**	–27	–19	**–42**	**–20**	**–25**	**–27**
			AS, Cluster 2	**–13**	**–11**	**–17**	+28	**–32**	+24	–5	–2	**–44**
			AS, Cluster 3	**–14**	0	**–32**	–24	+8	+15	–15	**–48**	–11

Reference	Model/Type	Resolution	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Villarini et al. 2011	Statistical downscale of CMIP3 models [1]	—	24 CMIP3 model mean and ±1σ range; A1B scenario, twenty-first-century trend				basin: −10 ± 29% U.S. land: −3 ± 26%					
Lavender and Walsh 2011	CSIRO CCAM regional model nested in a suite of GCMs [1]	15 km	A2 1990, 2090									
			GFDL CM2.1									−38
			MPI ECHAM5									−33
			CSIRO Mk3.5									−27
Yokoi et al. 2012	CMIP5 ensemble [2]	Various	RCP4.5 (2061–2100):									
			CNRM-CM5					−5				
			CSIRO-Mk3.6.0					**+19**				
			HadGEM2-CC					**+10**				
			INM-CM4					**+15**				
			MIROC5					**−23**				
			MPI-ESM-LR					**+7**				
			MRI-CGCM3					**+4**				
Murakami et al. 2013b	JMA/MRI global AGCM timeslice [1]	V3.2 60 km	As in Murakami et al. (2012a), but using different criteria for TC detection							−2		
Murakami et al. 2012b	JMA/MRI global AGCM timeslice [1]	V3.1 20 km	Downscale CMIP3 multimodel ens. A1B change (2075–99 minus control)	**−23**	**−20**	**−25**	+8	**−27**	**−24**	−14	−10	**−45**
		V3.2 20 km		**−15**	**−14**	**−18**	**−29**	**−23**	+1	−2	**−23**	−15
		V3.1 60 km		**−23**	**−23**	**−24**	−2	−20	**−32**	+21	**−15**	**−39**
		V3.2 60 km		**−24**	**−23**	**−25**	**−39**	**−28**	−10	−14	**−24**	**−27**
Villarini and Vecchi 2012	Statistical downscale of CMIP5 models [1]	—	17 CMIP5 models Mean and (min/max range)									
			RCP2.6				+4 (−17, 32)					
			RCP4.5				+4 (−30, 57)					
			RCP8.5 (late twenty-first century)				+2 (−49, 45)					
Knutson et al. 2013	GFDL Zetac regional [1]	18 km	Downscale (yr 2081–2100)									
			CMIP3 ens. A1B				**−27**					
			CMIP5 ens. RCP4.5				**−23**					
			GFDL CM2.1 A1B				−9					
			MPI A1B				**−38**					
			HadCM3 A1B				**−52**					
			MRI A1B				−25					

Reference	Model/Type	Resolution	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Knutson et al. 2013, continued			GFDL CM2.0 A1B				+8					
			HadGEM1 A1B				**−62**					
			MIROC hi A1B				**−33**					
			CCMS3 A1B				−28					
			INGV A1B				−22					
			MIROC med A1B				**−43**					
Emanuel 2013	Statistical–dynamical downscaling [3]	—	Downscale A1B/CMIP3 (1981–2000 vs 2181–2200):									
			CCSM3	−3								
			CM2.0	−13								
			ECHAM5	−11								
			MIROC3.2	−12								
			MRI-CGCM	+2								
			RCP8.5 CMIP5:									
			CCSM4	+11			+30	+14	−18	+48	+33	−2
			GFDL CM3	+41			+222	+44	+60	+42	+24	+7
			HADGEM2	+22			+27	+35	+58	+57	+14	−12
			MPI-ESM-MR	+29			+26	+25	+72	+26	+11	+11
			MIROC5	+38			+55	+33	+34	+187	+37	+6
			MRI-CGCM3	+13			+38	+23	+27	+71	+25	−11
			Ensemble mean:	+25			+48	+28	+37	+75	+24	−1.5
			Periods: 1981–2000, 2081–2100									
Mori et al. 2013	Model:											
	MIROC ensemble	—	—					**−14**				
	MIROC3m	T42	CMIP3 A1B					**−10**				
	MIROC4h	T213	CMIP5 RCP4.5					**−15**				
	MIROC5	T85	CMIP5 RCP2.6					**−11**				
	MIROC5	T85	CMIP5 RCP4.5					**−17**				
	MIROC5	T85	CMIP5 RCP6.0					**−12**				
	MIROC5	T85	CMIP5 RCP8.5					**−12**				
	Type: global CGCM [2]		Periods: 1979–2007, 2016–35									
Camargo 2013	Global CGCMs [2]											
	CMIP5 Model:		RCP4.5(2071–2100 minus 1971–2000									
	CSIRO			**−25**								

Reference	Model/Type	Resolution	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Camargo 2013, continued	GFDL-CM3			**–20**								
	GFDL-ESM2M			+1								
	MIROC5			**–25**								
	MPI			**+11**								
	MRI			**+11**								
	CSIRO		RCP8.5(2071–2100 minus 1971–2000	**–27**								
	GFDL-CM3			**–29**								
	GFDL-ESM2M			+9								
	MIROC5			**–26**								
	MPI			**+15**								
	MRI			**+32**								
Tory et al. 2013	Alternative detection method for climate model TCs [1]	—	CNRM-CM5	–8.9	–7.9	–10	+2.9	**–15**	–3.5	+6.2	–18	–3.3
			CCSR4	**–8.4**	**–6.9**	**–11**	**–60**	0.0	0.0	**–20**	–11	–11
			CSIRO-Mk3.6.0	**–11**	+2.3	**–33**	–25	–0.7	**+19**	+11	**–42**	–4.3
			GFDL-CM3	**–28**	**–25**	**–31**	–27	**–30**	–20	**–24**	**–34**	**–20**
			GFDL-ESM2M	–6.8	+3.9	**–22**	**+79**	+3.7	–11	–8.3	**–19**	**–28**
			GFDL-ESM2G	**–9.3**	–5.5	**–16**	**+40**	**–17**	+5.6	–6.3	**–13**	**–27**
			BCC-CSM1.1	**–12**	**–8.3**	**–16**	–24	–4.6	–13	–3.7	–12	**–18**
			MIROC5	**–23**	**–18**	**–30**	–12	**–31**	**–25**	**+23**	**–32**	**–27**
			CMIP5/RCP8.5 Periods: (1970–2000 vs 2070–2100									
Murakami et al. 2014	Model: MRI											
	AGCM3.1(AS)	20 km × 20 km	Timeslice using CMIP3 A1B multi model ens. mean SST change (2075–99 minus 1979–2003	**–16**			+6	**–27**	–15	–12	–5	**–35**
	AGCM3.1(AS)	60 km × 60 km		**–19**			+4	–12	**–31**	+18	–9	**–34**
	AGCM3.1(AS)	120 km × 120 km		**–29**			–14	**–26**	**–25**	–3	**–33**	**–63**
	AGCM3.1(AS)	200 km × 200 km		–1			**+56**	**–19**	**+17**	+22	**–17**	**–14**
	AGCM3.2(YS)	20 km × 20 km		**–17**			**–21**	**–19**	–4	–11	**–24**	**–30**
	AGCM3.2(YS)	60 km × 60 km		**–25**			**–45**	**–30**	–13	–16	**–25**	**–25**
	AGCM3.2(YS)	200 km × 200 km		**–23**			**–37**	**–23**	**–25**	–16	**–31**	**–20**
	AGCM3.2(KF)	60 km × 60 km		**–18**			**–29**	**–24**	–6	**–31**	**–24**	–5
	AGCM3.2(AS)	60 km × 60 km		**–17**			–13	–13	–18	+1	**–24**	**–32**
	AGCM3.3(YS)	60 km × 60 km		–0			**–25**	+8	**+65**	+9	**–26**	–8
	Type: global (AGCM) [1]											
	Model:		CMIP5 RCP4.5									
	CCSM4	130 km × 100 km		**–7**			–27	+9	–7	–4	**–15**	–12
	CMCC-CM	80 km × 80 km		**–5**			–13	–1	**+28**	+3	**–21**	–19

Reference	Model/Type	Resolution	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Murakami et al. 2014, continued	CNRM-CM5	150 km × 150 km		**−10**			**−21**	**−11**	−1	**−24**	**−12**	**−8**
	CSIRO Mk3.6.0	200 km × 200 km		**−16**			**−46**	+4	**−26**	**+21**	**−36**	**−19**
	HadGEM2-CC	200 km × 130 km		**−16**			−16	−2	+16	+21	**−30**	**−31**
	HadGEM2-ES	200 km × 130 km		**−16**			−19	**−15**	**+27**	−6	**−27**	**−26**
	MIROC5	150 km × 150 km		**−23**			−14	**−33**	**−27**	−4	**−22**	**−30**
	MPI-ESM-LR	200 km × 200 km		**−7**			**−28**	−5	+7	−2	−9	−8
	MPI-ESM-MR	200 km × 200 km		−3			**−30**	−2	**+31**	−14	**−14**	+10
	MRI-CGCM3	120 km × 120 km		−2			+14	+7	+13	+10	**−16**	−3
	BCC_CSN1.1	120 km × 120 km		−1			+15	+2	+1	−11	−6	+7
	Type: global (CGCM) [2]											
	Model:		CMIP5 RCP8.5									
	CCSM4	130 km × 100 km		**+8**			**−46**	+12	**+39**	−2	−1	−14
	CMCC-CM	80 km × 80 km		**+34**			+1.8	**+30**	**+102**	**+97**	**−15**	**+17**
	CNRM-CM5	150 km × 150 km		**−20**			−14	**−26**	**−14**	**−29**	**−22**	**−14**
	CSIRO Mk3.6.0	200 km × 200 km		**−22**			**−56**	−5	−1	+2	**−47**	−12
	HadGEM2-CC	200 km × 130 km		**−36**			**−41**	**−19**	−9	+2	**−52**	**−47**
	HadGEM2-ES	200 km × 130 km		**−40**			−23	**−26**	**−15**	**−36**	**−57**	**−50**
	MIROC5	150 km × 150 km		**−32**			−13	**−47**	**−35**	0	**−37**	**−35**
	MPI-ESM-LR	200 km × 200 km		**−15**			**−55**	**−12**	**+22**	**−28**	**−27**	**−16**
	MPI-ESM-MR	200 km × 200 km		**−13**			**−49**	**−16**	**+31**	**−37**	**−24**	+2
	MRI-CGCM3	120 km × 120 km		−2			+32	+2	**+23**	**+29**	**−24**	+6
	BCC_CSN1.1	120 km × 120 km		**+6**			−6	**+11**	+5	+13	−7	**+12**
	Type: global (CGCM) [2]		Periods: 1979–2003, 2075–99									
Manganello et al. 2014	Model: IFS Type: global (AGCM) [1]	T1279(16 km)	Timeslice using CMIP3 A1B CCSM3.0 ens. mean SST change (2065–75 minus 1965–75					−4 (NW Pac. but May–Nov only)				
		T159(125 km)	Periods:1960–2007, 2070–2117					+2 (NW Pac. but May–Nov only)				
Scoccimarro et al. 2014	Model:		Clim. SST (1982–2005) with									
	HiRAM2.2 Type: global (AGCM) [1]	50 km	2×CO$_2$ only	−10								
			SST + 2 K only	+16								
			2×CO$_2$ and SST + 2 K	−9								
			Periods: 10 yr									
	ECHAM5 Type: global (AGCM) [1]	T159(~80 km)	2×CO$_2$ only	−3								
			SST + 2 K only	−10								
			2×CO$_2$ and SST + 2 K	−11								
			Periods: 10 yr									

				Basin								
Reference	Model/Type	Resolution	Experiment	Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Kim et al. 2014	Model: GFDL CM2.5 Type: global coupled climate model [2]	50 km (atm.); 25 km (ocean)	2×CO$_2$ vs control (fully coupled) 50-yr periods	**−19**			**−30**	**−16**	**−16**	**−13**	**−24**	**−19**
Wu et al. 2014	Model: GFDL Zetac Type: regional [1]	18 km	Downscale CMIP3 A1B multi-model ens. Periods: 1980–2006, 2080–99					−6.8				
Walsh 2015	Model: GFDL Zetac Type: regional [1]	18 km	Downscale CMIP3 A1B multi model ens. Periods: 1981–2000, 2080–99									−26 (SW Pac. but Jan–Mar only
Wehner et al. 2015	Model: CAM5.1 Type: global (AGCM) [1]	25 km	Clim. SST (early 1990s) with									
			2×CO$_2$ only	−17								
			SST + 2 K only	−4								
			2×CO$_2$ and SST + 2 K	−18								
			Periods: 13 yr									
		100 km	Clim. SST (early 1990s) with									
			2×CO$_2$ only	−12								
			SST + 2 K only	+33								
			2×CO$_2$ and SST + 2 K	+18								
			Periods: 23 yr									
Knutson et al. 2015	Model: GFDL HiRAM (global AGCM) [1]	50 km	Timeslice using CMIP5 RCP4.5 Late twenty-first century vs 1982–2005 climatological SST	**−16**			−9	**−35**	**+16**	+20	**−26**	**−37**
Roberts et al. 2015	Model: HadGEM3 Type: global (AGCM) [1]	N96: 130 km	Timeslice using CMIP5 RCP8.5 HadGEM2-ES SST change (2090–2110 minus 1990–2010 Periods: 1985–2011, 2100s	−29	−12	−48	−59	−20	+14	−13	−65	−38
		N216: 60 km		−24	−4.6	−47	−54	−19	+22	−5.9	−56	−47
		N512: 25 km		−21	−1.2	−45	−65	−9.9	+24	+25	−54	−40
Sugi et al. 2017	JMA/MRI global AGCM3 CMIP3 Timeslice 25 years [1]		Control (1979–2003) vs A1B (2075–99)									
		60 km, AGCM3.1	AS-convection CMIP3 ens SST									
			$N = 1$	−24	−23	−24	−1	−20	−33	+17	−14	−41
			$N = 2$	−24	−26	−19	−7	−19	−37	+22	−6	−39
			$N = 3$	−27	−29	−23	−16	−33	−31	−28	−11	−43
			AS-convection CSIRO SST									
			$N = 1$	−26	−33	−13	−36	+7	−50	−23	−22	+3
			$N = 2$	−28	−33	−16	−37	−1	−47	−10	−20	−9
			$N = 3$	−26	−29	−19	−40	−7	−36	−41	−22	−14

Reference	Model/Type	Resolution	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Sugi et al. 2017, continued			AS-convection MIROC hi SST									
			N = 1	−14	−8	−25	+13	+57	−43	+45	+3	−71
			N = 2	−18	−16	−24	−9	+43	−47	+62	+5	−73
			N = 3	−19	−18	−23	−32	+29	−40	+16	+7	−76
			AS-convection MRI SST									
			N = 1	−21	−23	−18	+37	−31	−31	−23	−21	−14
			N = 2	−23	−31	−8	+30	−46	−38	−10	−4	−14
			N = 3	−27	−35	−10	+9	−58	−35	−33	−11	−7
		60 km, AGCM3.2	YS-convection CMIP3 ens. SST									
			N = 1	−24	−23	−25	−38	−27	−12	−16	−24	−26
			N = 2	−23	−23	−21	−23	−33	−4	−13	−18	−26
			N = 3	−19	−19	−18	−37	−16	−22	−5	−19	−18
			N = 4	−24	−21	−30	−23	−23	−14	−20	−27	−35
			YS-convection									
			CMIP3, cluster 1	−23	−22	−25	−21	−25	−31	+12	−21	−30
			CMIP3, cluster 2	−25	−25	−25	−20	−34	−10	−21	−19	−35
			CMIP3, cluster 3	−12	−2	−32	−27	+1	+2	−2	−40	−18
			KF-convection									
			CMIP3 ens. SST	−20	−21	−18	−34	−25	−1	−34	−23	−11
			CMIP3, cluster 1	−20	−25	−13	−36	−30	−13	−17	−20	−4
			CMIP3, cluster 2	−21	−25	−15	−18	−36	+2	−47	−10	−23
			CMIP3, cluster 3	−13	−11	−17	−45	−4	+14	−46	−25	−5
			AS-convection									
			CMIP3 ens. SST	−17	−9	−29	−3	−10	−30	+1	−25	−38
			CMIP3, cluster 1	−20	−19	−21	−29	−12	−45	−18	−20	−24
			CMIP3, cluster 2	−11	−9	−14	+20	−21	+18	−4	−1	−38
			CMIP3, cluster 3	−12	0	−29	−23	+11	−4	−13	−38	−13
		20 km, AGCM3.1	AS-convection									
			CMIP3 ens SST	−22	−20	−24	+11	−24	−25	−22	−8	−46
		20 km, AGCM3.2	YS-convection									
			CMIP3 ens SST	−15	−13	−18	−30	−21	+3	−9	−19	−17
Bacmeister et al. 2018	Model: CAM5 Type: global AGCM [1]	28 km	Bias-corrected CAM5 coupled model SSTs: RCP8.5 (2070–90 vs 1985–2005)	−19			−42					
Kossin et al. 2016	Model: Emanuel type: statistical–dynamical downscaling [3]		CMIP5 RCP8.5 (2006–35 vs 2070–99)					+22				

Reference	Model/Type	Resolution	Experiment	Basin Global	 NH	 SH	 N Atl.	 NW Pac.	 NE Pac.	 N Ind.	 S. Ind.	 SW Pac.
Ogata et al. 2016	Atm. Model: MRI-AGCM3.2H Ocean Model: MRI.COM3 Type [1] vs [2]	60 km grid Atm. Model	CMIP5 RCP8.5 (2075–99 vs 1979–2003)									
			Coupled: [2]	−33	−32	−36	−30	−43	−19	−8.1	−32	−44
			Atm. Only: [1]	−34	−31	−40	−28	−44	−26	22	−39	−44
Tsou et al. 2016	Atm. Model: HiRAM Type: global AGCM [1]	20 km	CMIP5 RCP8.5 (2075–99 vs 1979–2003)					−54				
Park et al. 2017	Statistical downscale of CMIP5 models [1]	—	22 CMIP5 models Mean (and quartiles RCP8.5 (late twenty-first century				**−15**	**+28**				
Yamada et al. 2017	NICAM Type: global (AGCM) [1]	14 km	Timeslice using CMIP3 A1B ens. mean SST change (2075–99 minus 1979–2003)	**−23**	**−24**	**−21**	**−41**	**−11**	**−40**	−13	**−38**	3
Yoshida et al. 2017	JMA/MRI global AGCM Timeslice 60 years Ensemble 90 members Statistical downscale for TC intensity [1]	V3.2 60 km	RCP8.5 late twenty-first century									
			CMIP5 6-model ensemble (*n* = 90 min/max)	**−33** (−43, −27)	**−29** (−38, −17)	**−41** (−60, −23)	**−23** (−59, 52)	**−42** (−78, −23)	−4 (−45, 40)	**−20** (−46, 3)	**−44** (−64, −25)	**−40** (−79, −13)
			CCSM4 (*n* = 15 min/max)	**−33** (−35, −30)	**−34** (−38, −31)	**−29** (−34, −23)	**−48** (−59, −37)	**−37** (−44, −33)	**−33** (−45, −26)	−8 (−17, 2)	**−32** (−41, −25)	**−28** (−35, −18)
			GFDL-CM3 (*n* = 15 min/max)	**−31** (−34, −28)	**−26** (−30, −23)	**−40** (−45, −36)	−9 (−25, 6)	**−37** (−43, −32)	**−14** (−21, −2)	**−18** (−29, −3)	**−41** (−49, −34)	**−42** (−53, −33)
			HadGEM2-AO (*n* = 15 min/max)	**−32** (−35, −29)	**−22** (−26, −17)	**−52** (−57, −46)	**−42** (−49, −36)	**−31** (−38, −23)	+5 (−14, 21)	−8 (−16, 3)	**−58** (−64, −53)	**−43** (−50, −29)
			MIROC5 (*n* = 15 min/max)	**−41** (−43, −39)	**−33** (−36, −31)	**−55** (−60, −50)	**+41** (25, 52)	**−74** (−78, −71)	**+29** (15, 40)	**−38** (−46, −31)	**−44** (−52, −36)	**−74** (−79, −70)
			MPI-ESM-MR (*n* = 15 min/max)	**−31** (−34, −28)	**−29** (−32, −26)	**−34** (−40, −28)	**−45** (−57, −37)	**−43** (−47, −38)	**+15** (3, 24)	**−31** (−36, −22)	**−39** (−48, −32)	**−29** (−41, −23)
			MRI-CGCM3 (*n* = 15 min/max)	**−32** (−35, −27)	**−29** (−34, −23)	**−38** (−44, −33)	**−37** (−47, −27)	**−30** (−34, −24)	**−27** (−35, −16)	**−14** (−32, −1)	**−49** (−57, −43)	**−24** (−37, −13)
Zhang and Wang 2017	Model: Modified WRF Type: regional climate model (RCM) [1]	20 km	RCP4.5 (2080–99 minus 1989–2010)					0				−34
			RCP8.5 (2080–99 minus 1979–2010)					**−16**				−60
Murakami et al. 2017a	Model: FLOR Type: global (CGCM) [2]	50 km	RCP4.5 (2021–40 minus 1941 Control)						+9			
Murakami et al. 2017b	Model:HiFLORType: global (CGCM) [2]	25 km	2015 Control minus 1860 Control (historical warming)							0 (Arabian Sea)		
Choi et al. 2017	Statistical downscale of CFSv2 free runs [1]	—	NCEP CFS decadal runs (2016–30 minus 2002–15)				−12					
Lok and Chan 2017	Downscale of HadGEM2-ES into RegCM3 [1]	RegCM3: 50 km	RCP 8.5 (2090s vs 2000)					−23%				
Wehner et al. 2018	Model: CAM5.3 Type: global (AGCM) [1]	28 km	+2 K global warming; RCP2.6 Forcing changes 60 simulated yrs	−10	−6	−19	−9	−6	−8	−29	−18	−23

Reference	Model/Type	Resolution	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Bhatia et al. 2018	Model: HiFLOR Type: global (CGCM) [2]	25 km	RCP4.5 (2081–2100) vs.(1986–2005)	**+9**			**+23**	**+6**	**+23**	**–12**		

Table ES2. Projections of intense TC frequency. Projected change in frequency of intense tropical cyclones (i.e., more intense than tropical storms—see table) in warm climate runs relative to control run in percent. The rows of reported results are ordered from top to bottom generally in order of decreasing model horizontal resolution. The section at the bottom of the table lists the percentage change in the proportion of category 0–5 storms that become very intense at some point in their lifetime (i.e., category 4–5 intensity or as noted). Red and blue numbers/text denote projected increases and decreases, respectively. Boldface text denotes where a statistical significance test was reported that showed significance. Black values denote no change. Green text denotes changes based on SST-increase-only or 2×CO$_2$-only idealized experiments. Type of ocean coupling for the study is indicated by the following model/type: [1] no ocean coupling (e.g., specified sea surface temperatures or statistical downscaling of tropical cyclones; [2] fully coupled ocean experiment; or [3] hybrid type, with uncoupled atmospheric model for storm genesis, but with ocean coupling for the dynamical or statistical–dynamical downscaling step.

Reference	Model/Type	Resolution: high to low	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Emanuel 2013	Statistical–dynamical downscaling [3]	—	Downscale RCP8.5 CMIP5:	# Cat 4–5:			# Cat 4–5:	# Cat 4–5	# Cat 4–5:	# Cat 4–5:	# Cat 4–5:	# Cat 4–5:
			CCSM4	+13			+123	+20	–17	+126	+68	–19
			GFDL CM3	+78			+1290	+60	+140	+116	+134	+16
			HADGEM2	+33			+51	+60	+106	+109	+33	–9
			MPI-ESM-MR	+51			+78	+33	+166	+62	+38	+11
			MIROC5	+98			+217	+68	+138	+600	+119	+39
			MRI-CGCM3	+31			+67	+39	+75	+84	+112	–2
			Ensemble Mean:	+50			+108	+45	+103	+181	+76	+4
			Periods: 1981–2000, 2081–2100									
Knutson et al. 2015	Model: GFDL HiRAM (global AGCM) downscaled into GFDL Hurricane model w/ocean coupling [3]	6 km	Timeslice using CMIP5 RCP4.5 Late twenty-first century vs 1982–2005 climatological SST	# Cat 4–5:			# Cat 4–5:	# Cat 4–5:	# Cat 4–5:	# Cat 4–5:	# Cat 4–5:	# Cat 4–5:
				+28			+42	–7	**+338**	+200	+64	**–58**
				Cat 4–5 days:			Cat 4–5 days:	Cat 4–5 days:	Cat 4–5 days:	Cat 4–5 days:	Cat 4–5 days:	Cat 4–5 days:
				+35			+175	+10	**+478**	**+405**	+55	**–53**
Bender et al. 2010	GFDL Zetac (18 km atmospheric model), downscaled into GFDL Hurricane model with ocean coupling [3]	9 km	Downscale TCs from regional model (A1B) 18-mod ensemble; 2081–2100 minus 2001–20: (range over 4 indiv. models)				# Cat 4–5: **+100** (–66 to +138)					

Reference	Model/Type	Resolution: high to low	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Knutson et al. 2013	GFDL Zetac (18 km atmospheric model), downscaled into GFDL Hurricane model with ocean coupling [3]	9 km	Downscale TCs (2081–2100)				# Cat 4–5:					
			CMIP3 ens. A1B				**+87**					
			CMIP5 ens RCP4.5				+39					
			GFDL CM2.1 A1B				**+116**					
			MPI A1B				+21					
			HadCM3 A1B				–53					
			MRI A1B				**+110**					
			GFDL CM2.0 A1B				**+211**					
			HadGEM1 A1B				–100					
			MIROC hi A1B				–42					
			CCMS3 A1B				+26					
			INGV A1B				+47					
			MIROC med A1B				–32					
Yamada et al. 2017	NICAM Type: global (AGCM) [1]	14 km	Timeslice using CMIP3 A1B multi model ens. mean SST change (2075–99 minus 1979–2003) Periods: 1979–2008, 2075–2104	#<944 hPa **+7**	#<944 hPa +1	#<944 hPa +20	#<944 hPa –50	#<944 hPa +18	#<944 hPa **–100**	#<944 hPa –61	#<944 hPa +8	#<944 hPa +43
Manganello et al. 2014	IFS Type: global (AGCM) [1]	T1279 (~16 km)	Timeslice using CMIP3 A1B CCSM3.0 ens. mean SST change (2065–75 minus 1965–75) Periods:1960–2007, 2070–2117					# Cat 3–5 **+70%** (NW Pac. but May–Nov only)				
Knutson et al. 2008	GFDL Zetac regional [1]	18 km	Downscale CMIP3 ens. A1B, 2080–2100				+140% (12 vs 5) # with $V_{sfc} > 45$ m s^{-1}					
Murakami et al. 2012b	JMA/MRI global AGCM timeslice [1]	V3.2 20 km	Downscale CMIP3 multimodel ens. A1B change (2075–99 minus control)	**# Cat 4–5:**								
				+4	+9	–7	+15	–4	**+179**	+35	**+45**	**–54**
				# Cat. 5:								
				+56	**+60**	+43	**+287**	**+45**	Incr from 0	+100	**+261**	**–61**
Tsou et al. 2016	Atm. Model: HiRAM Type: global AGCM [1]	20 km	CMIP5 RCP8.5 (2075–99 vs 1979–2003)					# Cat 4–5: +400				
Oouchi et al. 2006	MRI/JMA Timeslice [1]	TL959 L60 (~20 km)	10 yr A1B 1982–93 vs 2080–99	**Signif. Increase, # V_{850} of 55–60 m s^{-1}**								
Bhatia et al. 2018	Model: HiFLOR Type: global (CGCM) [2]	25 km	RCP4.5 (2081–2100) vs.(1986–2005)	**# Cat 4:**								
				+28			+73	+1	+163	+129		
				# Cat 5:								
				+85			+136	+80	+200	+133		

Reference	Model/Type	Resolution: high to low	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Sugi et al. 2017	JMA/MRI global AGCM3 CMIP3 Timeslice 25 years [1]		Control (1979–2003) vs. A1B (2075–99)	**# Cat 4–5:**								
		60 km, AGCM3.1	AS-convection CMIP3 ens SST									
			N = 1	–2	–1	–5	+15	0	–11	–14	+13	–50
			N = 2	–5	–6	+2	+13	–14	–13	+71	+24	–47
			N = 3	–29	–32	–23	–14	–26	–39	–38	–7	–41
			AS-convection CSIRO SST									
			N = 1	–25	–35	+11	–30	+8	–78	–86	–25	+106
			N = 2	–26	–33	+13	–44	–3	–48	–71	+19	0
			N = 3	–23	–36	+19	–39	–8	–56	–63	–2	+43
			AS-convection MIROC hi SST									
			N = 1	+44	+47	+33	+53	+115	–19	–29	+60	–39
			N = 2	+20	+13	+52	+3	+73	–27	+14	+110	–74
			N = 3	+12	+12	+11	+14	+83	–42	–13	+79	–65
			AS-convection MRI SST									
			N = 1	–4	–6	+3	+51	–17	–24	–57	–15	+50
			N = 2	–8	–11	+3	+51	–37	–23	+43	+7	–5
			N = 3	–30	–35	–16	+46	–45	–47	–25	–26	–5
		60 km, AGCM3.2	YS-convection CMIP3 ens. SST									
			N = 1	–26	–24	–31	–63	–30	+17	+33	–33	–25
			N = 2	–13	–12	–14	–14	–17	+22	–17	–7	–38
			N = 3	+10	+11	+6	–11	+8	+11	+122	+2	+16
			N = 4	+5	+4	+6	–7	0	+46	–25	+16	–17
			YS-convection									
			CMIP3, cluster 1	–16	–18	–10	–6	–29	–13	+133	+8	–45
			CMIP3, cluster 2	–5	–9	+8	+31	–31	+70	+67	+18	–10
			CMIP3, cluster 3	+10	+24	–36	+19	+30	–26	+56	–56	+5
			KF-convection									
			CMIP3 ens. SST	–6	–10	+4	–22	–19	+23	+7	+9	–6
			CMIP3, cluster 1	–23	–29	–10	–52	–39	+20	–29	+3	–39
			CMIP3, cluster 2	–5	–19	+29	–15	–36	+41	–36	+38	+10
			CMIP3, cluster 3	+10	+12	+7	–30	+13	+48	–29	+19	–19
			AS-convection									
			CMIP3 ens. SST	–4	0	–13	+24	+1	–47	+45	0	–39

Reference	Model/Type	Resolution: high to low	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Sugi et al. 2017, continued			CMIP3, cluster 1	–16	–14	–22	–47	–4	–65	+28	–3	–61
			CMIP3, cluster 2	+1	+5	–10	+18	–10	+12	+53	+14	–56
			CMIP3, cluster 3	+4	+17	–24	–24	+26	+4	+15	–20	–32
		20 km, AGCM3.1	AS-convection									
			CMIP3 ens SST	+13	+5	+25	+50	–14	+26	–22	+43	–17
		20 km, AGCM3.2	YS-convection									
			CMIP3 ens SST	–5	+1	–20	–31	–13	+50	+38	+6	–66
Murakami et al. 2017b	Model: HiFLOR Type: global (CGCM) [2]	25 km	2015 Control minus 1860 Control (historical warming)							#>46 m s^{-1}: **+60** (Arabian Sea)		
Murakami et al. 2018	Model: HiFLOR Type: global (CGCM) [2]	25 km					# Cat 3–5:					
			RCP4.5 (2081–2100) vs.(1986–2005)				**+66**					
			RCP8.5 (2081–2100) vs.(1986–2005)				**+83**					
Bacmeister et al. 2018	Model: CAM5 Type: global [1]	28 km	Bias-corrected CAM5 coupled model SSTs: RCP8.5 (2070–90 vs 1985–2005)	**#Cat 4–5:** +200				#Cat 4–5: +282			#Cat 4–5: +224	#Cat 4–5: +317
Wehner et al. 2018	Model: CAM5.3 Type: global (AGCM) [1]	28 km	+2 K global warming; RCP2.6	**#Cat4–5:**								
			Forcing changes 60 simulated yrs	+27	+30	+19	+28	+17	+52	–62	+32	–23
Walsh et al. 2004	CSIRO DARLAM regional model [1]	30 km	IS92a; 2061–90 minus 1961–90									+26% $P < 970$ mb
Bengtsson et al. 2007	ECHAM5 timeslice [1]	T319 (~40 km)	2071–2100, A1B		+42%, #>50 m s^{-1}							
Zhao and Held 2010	GFDL HIRAM timeslice with statistical refinement of intensity [1]	50 km	Downscale A1B:				#Cat 3–5					
			CMIP3 n = 7 ens.				–13					
			GFDL CM2.0				+9					
			GFDL CM2.1				+5					
			HadCM3				–28					
			HadGem1				–53					
			ECHAM5				+24					
			MRI_CGCM2.3				0					
			MIROC High				–27					
Zhao and Held 2012	GFDL HIRAM timeslice [1]	50 km	Downscale A1B:	#>33 m s^{-1}	#>33 m s^{-1}	#>33 m s^{-1}	#>33 m s^{-1}	#>33 m s^{-1}	#>33 m s^{-1}	#>33 m s^{-1}	#>33 m s^{-1}	#>33 m s^{-1}
			CMIP3 n = 18 ens.	**–15**	**–16**	**–13**	**–20**	**–30**	+14	+6	–11	–14
			GFDL CM2.0	–6	–1	**–21**	+16	**–19**	**+30**	+20	–14	**–30**
			GFDL CM2.1	**–11**	–5	**–26**	–4	+9	**–34**	–31	**–30**	–19
			HadCM3	+6	**+17**	**–26**	**–51**	–11	**+121**	+39	**–20**	**–35**
			HadGem1	**–11**	–3	**–31**	**–84**	**–29**	**+115**	–35	**–46**	–9
			ECHAM5	**–14**	**–13**	**–16**	**+25**	**–49**	**+58**	–21	+9	**–56**
			CCCMA	**–22**	**–24**	–16	**–42**	**–37**	+17	–21	–2	**–37**

Reference	Model/Type	Resolution: high to low	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Zhao and Held 2012, continued			MRI_CGCM2.3	**−16**	**−18**	−10	+20	**−33**	−3	−12	−12	−7
			MIROC High	−5	−6	−4	**−31**	**−17**	**+44**	−40	+16	**−34**
Kim et al. 2014	Model: GFDL CM2.5 Type: global coupled climate model [2]	50 km (atm.); 25 km (ocean)	2×CO$_2$ vs control (fully coupled) 50-yr periods	#>33 m s^{-1}			#>33 m s^{-1}	#>33 m s^{-1}	#> 33 m s^{-1}	#>33 m s^{-1}	#>33 m s^{-1}	#>33 m s^{-1}
				−9.2			−25	−7.6	+17	0	**−23**	−16
Leslie et al. 2007	OU-CGCM with high-res. window [2]	Up to 50 km	2000 to 2050 control and IS92a (6 members)									+100% #>30 m s^{-1} by 2050
Bengtsson et al. 2007	ECHAM5 timeslice [1]	T213 (~60 km)	2071–2100, A1B		#>50 m s^{-1}, +32%							
Yoshida et al. 2017	JMA/MRI global AGCM Timeslice 60 years Ensemble 90 members	V3.2 60 km	RCP8.5 late twenty-first century:	#Cat 4–5	#Cat 4–5	#Cat 4–5	#Cat 4–5	#Cat 4–5	#Cat 4–5	#Cat 4–5	#Cat 4–5	#Cat 4–5
			CMIP5 6-model ensemble (*n* = 90 min/max)	**−13** (−33, 6)	**−7** (−36, 13)	**−28** (−66, 11)	+20 (−69, 275)	**−26** (−81, 13)	**+88** (−62, 307)	−1 (−49, 75)	**−23** (−62, 31)	**−37** (−97, 37)
	Statistical downscale for TC intensity [1]		CCSM4 (*n* = 15 min/max)	**−18** (−28, −9)	**−23** (−36, −17)	−7 (−24, 11)	**−44** (−83, −17)	**−22** (−35, −8)	−32 (−62, 6)	+4 (−32, 41)	+7 (−8, 31)	**−32** (−58, −16)
			GFDL-CM3 (*n* = 15 min/max)	**−10** (−17, −2)	−4 (−14, 6)	**−25** (−37, −13)	**+40** (0, 114)	**−20** (−33, −8)	**+72** (40, 105)	−24 (−61, 7)	−15 (−37, 16)	**−43** (−66, −8)
			HadGEM2-AO (*n* = 15 min/max)	**−12** (−20, −5)	+2 (−8, 12)	**−48** (−56, −37)	−23 (−61, 18)	−13 (−21, 3)	**+106** (44, 163)	+15 (−49, 58)	**−48** (−62, −34)	**−49** (−64, −36)
			MIROC5 (*n* = 15 min/max)	**−23** (−33, −14)	**−10** (−23, −1)	**−55** (−66, −37)	**+216** (175, 275)	**−76** (−81, −67)	**+223** (163, 307)	−14 (−38, 18)	**−37** (−49, −19)	**−89** (−97, −72)
			MPI-ESM-MR (*n* = 15 min/max)	**−13** (−22, −5)	−9 (−20, 3)	**−21** (−37, −8)	−44 (−69, 35)	**−30** (−40, −20)	**+146** (95, 190)	−11 (−32, 13)	**−17** (−32, −1)	−27 (−50, 4)
			MRI-CGCM3 (*n* = 15 min/max)	−2 (−8, 6)	+3 (−10, 13)	**−12** (−39, 0)	−22 (−48, 26)	+2 (−8, 13)	+10 (−32, 40)	+25 (−10, 75)	**−27** (−55, −11)	+15 (−10, 37)
Ogata et al. 2016	Atm. Model: MRI-AGCM3.2H Ocean Model: MRI.COM3 [1] vs [2]	60 km grid Atm. Model ~55 to 110 km grid Ocean model	CMIP5 RCP8.5 (2075–99 vs 1979–2003)	# Cat 3–5	# Cat 3–5:	# Cat 3–5:	# Cat 3–5:	# Cat 3–5:	# Cat 3–5:	# Cat 3–5:	# Cat 3–5:	# Cat 3–5:
			Coupled mod.[2]	+20	+13	+44	+14	+9.1	+100	0.0	+125	0.0
			Atm. Only [1]	−25	−7.3	−48	−29	−19	+200	+150	−43	−60
McDonald et al. 2005	HadAM3 Timeslice [1]	N144 L30 (~100 km)	15 yr IS95a 1979–94 vs 2082–97	Increase In # strong TCs (vort > 24–30 × 10^{-5} s^{-1})								
Sugi et al. 2002	JMA Timeslice [1]	T106 L21 (~120 km)	10 yr 1×CO$_2$, 2×CO$_2$	~0 # >40 m s^{-1}								
Gualdi et al. 2008	SINTEX-G coupled model [2]	T106 (~120 km)	30 yr 1×CO$_2$, 2×CO$_2$, 4×CO$_2$	~0								
Hasegawa and Emori 2007	CCSR/NIES/FRC coupled model [2]	T106 L56 (~120 km)	20 yr control vs +1% yr^{-1} CO$_2$ (yr 61–80)	Rel. freq. of Pc < 985 mb +21 coupled +59 uncoupled								
Yoshimura et al. 2006	JMA Timeslice [1]	T106 L21 (~120 km)	10 yr 1×CO$_2$, 2×CO$_2$	Mixed changes: # > 25 m s^{-1}								

Reference	Model/Type	Resolution: high to low	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Wang and Wu. 2012	CMIP5 downscaling; statistical–dynamical model [1]	—	A1B (2065–99 minus 1965–99)					#Cat 4–5 +66				
Change in the proportion of Cat 4–5 storms vs Cat 0–5 storms in percent												
Emanuel 2013	Statistical–dynamical downscaling [3]	—	Downscale RCP8.5 CMIP5:	**# Cat 4–5/** **# Cat 0–5:**								
			CCSM4	+2								
			GFDL CM3	+26								
			HADGEM2	+9								
			MPI-ESM-MR	+17								
			MIROC5	+43								
			MRI-CGCM3	+16								
			Ensemble Mean:	+20								
			Periods: 1981–2000, 2081–2100									
Knutson et al. 2015	Model: GFDL Hi-RAM (global AGCM) downscaled into GFDL Hurricane model w/ocean coupling [3]	6 km	Timeslice using CMIP5 RCP4.5 Late twenty-first century vs 1982–2005 climatological SST	# Cat 4–5/ # Cat 0–5: **+52**								
Yamada et al. 2017	NICAM	14 km	Timeslice using CMIP3 A1B multi model ens. mean SST change (2075–99 minus 1979–2003)	**#<944 hPa/**								
	Type: global (AGCM) [1]		Periods: 1979–2008, 2075–2104	**#Cat 0–5** **+39**								
Murakami et al. 2012b	JMA/MRI global AGCM timeslice [1]	V3.2 20 km	Downscale CMIP3 multimodel ens. A1B change (2075–99 minus control)	**# Cat 4–5/** # Cat 0–5: +22								
Bhatia et al. 2018	Model: HiFLOR Type: global (CGCM) [2]	25 km	RCP4.5 (2081–2100) vs.(1986–2005)	**# Cat 4–5/** **# Cat 0–5** +17%								
Wehner et al. 2018	Model: CAM5.3 Type: global (AGCM) [1]	28 km	+2 K global warming; RCP2.6 Forcing changes 60 simulated yrs	**# Cat4–5/** **# Cat 0–5:** +41%								
Sugi et al. 2017	JMA/MRI global AGCM3 CMIP3 Timeslice 25 years [1]		Control (1979–2003) vs. A1B (2075–99)	**# Cat 4–5/** # Cat 0–5:								
		60 km, AGCM3.1	AS-convection CMIP3 ens SST									
			N = 1	+28	+29	+26	+16	+25	+32	–27	+32	–16
			N = 2	+25	+27	+25	+22	+5	+38	+41	+32	–13
			N = 3	–3	–3	0	+2	+10	–12	–13	+5	+5

Reference	Model/Type	Resolution: high to low	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Sugi et al. 2017, continued			AS-convection CSIRO SST									
			N = 1	+2	–3	+26	+10	+2	–57	–81	–4	+99
			N = 2	+3	0	+34	–12	–3	–2	–68	+48	+10
			N = 3	+4	–10	+47	0	–1	–32	–36	+25	+67
			AS-convection MIROC hi SST									
			N = 1	+67	+60	+77	+35	+37	+41	–51	+56	+108
			N = 2	+47	+34	+100	+13	+21	+39	–29	+99	–2
			N = 3	+38	+36	+44	+68	+41	–3	–25	+66	+46
			AS-convection MRI SST									
			N = 1	+22	+22	+26	+10	+20	+10	–44	+8	+75
			N = 2	+20	+29	+12	+16	+16	+24	+58	+12	+10
			N = 3	–5	0	–8	+35	+32	–18	+11	–17	+2
		60 km, AGCM3.2	YS-convection CMIP3 ens. SST									
			N = 1	–2	–1	–7	–40	–5	+33	+59	–12	+1
			N = 2	+13	+14	+9	+11	+24	+26	–4	+14	–16
			N = 3	+35	+38	+29	+43	+28	+42	+134	+25	+41
			N = 4	+38	+32	+52	+22	+31	+71	–6	+59	+28
			YS-convection									
			CMIP3, cluster 1	+9	+5	+19	+19	–5	+26	+109	+37	–22
			CMIP3, cluster 2	+27	+21	+45	+64	+4	+88	+111	+45	+39
			CMIP3, cluster 3	+25	+27	–6	+64	+29	–28	+60	–27	+28
			KF-convection									
			CMIP3 ens. SST	+17	+14	+26	+19	+7	+24	+62	+41	+5
			CMIP3, cluster 1	–4	–5	+4	–24	–12	+39	–14	+29	–36
			CMIP3, cluster 2	+21	+9	+53	+3	0	+39	+21	+54	+42
			CMIP3, cluster 3	+27	+25	+29	+28	+17	+30	+33	+59	–15
			AS-convection									
			CMIP3 ens. SST	+16	+10	+23	+27	+13	–24	+44	+33	–2
			CMIP3, cluster 1	+4	+6	–2	–25	+9	–36	+56	+21	–49
			CMIP3, cluster 2	+13	+15	+5	–2	+15	–6	+59	+15	–29
			CMIP3, cluster 3	+19	+17	+7	–1	+14	+8	+32	+28	–22
		20 km, AGCM3.1	AS-convection									
			CMIP3 ens SST	+44	+32	+63	+35	+14	+69	0	+54	+54
		20 km, AGCM3.2	YS-convection									
			CMIP3 ens SST	+12	+17	–1	–2	+9	+46	+52	+32	–59

Reference	Model/Type	Resolution: high to low	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Tsou et al. 2016	Atm. Model: HiRAM Type: global AGCM [1]	20 km	CMIP5 RCP8.5 (2075–99 vs 1979–2003)					# Cat 4–5/ # Cat 0–5 +990				
Bacmeister et al. 2018	Model: CAM5 Type: global [1]	28 km	Bias-corrected CAM5 coupled model SSTs: RCP8.5 (2070–90 vs 1985–2005)	**# Cat 4–5/** **# Cat 0–5** +270								
Yoshida et al. 2017	JMA/MRI global AGCM Timeslice 60 years Ensemble 90 members Statistical downscale for TC intensity [1]	V3.2 60 km	RCP8.5 late twenty-first century:	**#Cat 4–5 /** **# Cat 0–5**								
			CMIP5 6-model ensemble (*n* = 90)	+30								
			CCSM4 (*n* = 15)	+22								
			GFDL-CM3 (*n* = 15)	+30								
			HadGEM2-AO (*n* = 15)	+29								
			MIROC5 (*n* = 15 min/max)	+31								
			MPI-ESM-MR (*n* = 15 min/max)	+26								
			MRI-CGCM3 (*n* = 15 min/max)	+42								
Ogata et al. 2016	Atm. Model: MRI-AGCM3.2H Ocean Model: MRI.COM3 [1] vs [2]	60 km grid atm. model ~55 to 110 km grid ocean model	CMIP5 RCP8.5 (2075–99 vs 1979–2003)	**# Cat 3–5/** # Cat 0–5								
			Coupled mod.[2]	+79								
			Atm. only [1]	+14								

Table ES3. Tropical cyclone intensity change projections (percentage change in maximum wind speed or central pressure fall, except as noted in the table). The dynamical model projections are ordered from top to bottom in order of decreasing model horizontal resolution. Red and blue colors denote increases and decreases, respectively. Boldface values denote statistically significant changes. Black values denote no change. Green text denotes changes based on SST-increase-only or 2×CO$_2$-only idealized experiments. Pairs of numbers in parentheses denote ranges obtained using different models as input to a downscaling model or theory. The potential intensity change projections from Emanuel et al. (2008), Knutson and Tuleya (2004), and Vecchi and Soden (2007) and pressure fall changes from Yamada et al. (2017) in the table include some unpublished supplemental results (personal communication from the authors) such as results for individual basins, ranges of results across models, and results for additional or modified calculations that are adapted from the original papers but have been modified in order to facilitate intercomparison of methods and projection results from different studies. In some cases, ACE or PDI changes are reported, which depend on intensity, frequency, and lifetime. Type of ocean coupling for the study is indicated by the following model/type: [1] no ocean coupling (e.g., specified sea surface temperatures or statistical downscaling of tropical cyclones); [2] fully coupled ocean experiment; or [3] hybrid type, with uncoupled atmospheric model for storm genesis, but with ocean coupling for the dynamical or statistical–dynamical downscaling step.

Reference	Model/Type	Resolution/ Metric type (high to low resolution)	Climate Change scenario	Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Dynamical or Stat/Dyn. Model Projections Max wind speed % change								**Avg (low ,high)**				
Emanuel et al. 2008	Stat./dyn. model [3]	Max Wind speed (%)	CMIP3 7-model A1B (2181–2200 minus 1981–2000)	+1.7	+3.1	+0.2	+2.0	+4.1	−0.1	+0.2	+0.5	−0.8
Tsuboki et al. 2015	CReSS regional model downscale of 30 strongest typhoons in MRI-AGCM3.1 present and warm climates [3]	2 km; Average max wind speed (%)	CMIP3 18-model ens. A1B (2074–87 minus 1979–93)					+15.1				
Hill and Lackmann 2011	WRF regional model downscale of CMIP3 environments (idealized simulations) [1]	2 km; Square root of Central Pressure Deficit	Downscale CMIP3 ens.									
			A1B (2090–99)				+5.1					
			A2 (2090–99)				+8.1					
			B2 (2090–99)				+4.6					
Kanada et al. 2013	NHM2 nonhydrostatic regional atm. model	2 km grid; Max. azmuthial avg 10 m wind speed	RCP8.5 (2075–99 vs 1979–2003)]				+8.7					
Gutmann et al. 2018	WRF regional model downscale of 22 hurricane cases [1]	4 km grid model; Avg. Max. surface wind speed change along track (%)	RCP8.5 19-model CMIP5 ensemble environmental change and Greenhouse gas change				+6.3					
Patricola and Wehner 2018	WRF regional model v. 3.8.1 nested in CAM5.1 atm. Model forced with CMIP5 ens. boundary conditions [1]	4.5 km grid Maximum wind speed change (%)	RCPx 1980–2000 vs 2081–2100 10-member ensembles of 1 to 9 cases per basin									
			RCP4.5				+5.9	+5.8	−0.35		+7.8	+12
			RCP6.0				+7.6	+4.6	−3.4		+8	+14
			RCP8.5				+10.5	+12	+4.0		+15	+20

Reference	Model/Type	Resolution/ Metric type (high to low resolution)	Climate Change scenario	Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Kanada et al. 2017	Four nonhydrostatic regional models [1]	5 km grids % change in Sq Root of central pressure fall. Assume envir press $p =$ 1013.26 mb	CMIP5 ens. RCP8.5 (1979–2003 vs 2075–99)									
			CReSS					+11				
			JMANJM					+10				
			MM5					+16				
			WRF v. 3.3.1					+11				
			WRF with synthetic vortex					+3.9				
Knutson et al. 2015	Model: GFDL HiRAM (global AGCM) downscaled into GFDL Hurricane model with ocean coupling [3]	6 km; Max Wind speed change (%) for hurricanes	Timeslice using CMIP5 RCP4.5 Late twenty-first century vs 1982–2005 climatological SST	**+4.1**			**+4.5**	**+5.5**	**+7.8**	+1.6	**+3.3**	−3.1
Bender et al. 2010	GFDL Zetac (18 km atmospheric model), downscaled into GFDL Hurricane model with ocean coupling [3]	9 km; Max Wind speed (%)	Downscale TCs from regional model 18-mod ensemble: CMIP3 A1B; yrs 2081–2100 minus 2001–20				+0.7 (trop. storms) +6 (hurricanes)					
Knutson et al. 2013	GFDL Zetac (18 km atmospheric model), downscaled into GFDL Hurricane model with ocean coupling [3]	9 km; Max Wind speed change (%) for hurricanes	Downscale TCs (2081–2100)									
			CMIP3 ens. A1B				**+6.1**					
			CMIP5 ens RCP4.5				**+4.0**					
			GFDL CM2.1 A1B				**+8.6**					
			MPI A1B				**+4.2**					
			HadCM3 A1B				+2.0					
			MRI A1B				**+9.2**					
			GFDL CM2.0 A1B				**+11**					
			HadGEM1 A1B				−2.7					
			MIROC hi A1B				+2.9					
			CCMS3 A1B				**+5.3**					
			INGV A1B				+5.9					
			MIROC med A1B				+2.9					

Reference	Model/Type	Resolution/ Metric type (high to low resolution)	Climate Change scenario	Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Knutson and Tuleya 2004	GFDL Hurricane Model [1]	9 km grid inner nest; Max Wind speed (%) Pressure fall (%)	CMIP2+ +1% yr^{-1} CO$_2$ 80-yr trend				+5.5 (1.5, 8.1) +13 (3.2, 22)	+5.4 (3.3, 6.7) +14 (8.0, 17)	+6.6 (1.1, 10.1) +15 (3.6, 25)			
Yamada et al. 2017	NICAM Type: global (AGCM) [1]	14 km Lifetime Max: sqrt of pressure fall. Red/blue indicate increase/ decrease in intensity.	Timeslice using CMIP3 A1B multi model ens. mean SST change (2075–99 minus 1979–2003) Periods: 1979–2008, 2075–2104	**+2.8**	+2.1	**+4.3**	−1.0	+3.2	**−6**	**−5.4**	**+7**	+2.2
Lavender and Walsh 2011	CCAM regional model nested in a suite of GCMs [1]	15 km Max winds	A2 1990, 2090									+5% to +10%
Manganello et al. 2014	IFS Type: global (AGCM) [1]	T1279 (~16 km) Max wind	Timeslice using CMIP3 A1B CCSM3.0 ens. mean SST change (2065–75 minus 1965–75) Periods:1960–2007, 2070–2117					**+12**				
Knutson et al. 2001	GFDL Hurricane Model [3]	18 km grid w./ ocean coupling; Max Wind speed (%)	GFDL R30 downscale, +1% yr^{-1} CO$_2$ yr 71–120 avg	+6								
Knutson et al. 2008	GFDL Zetac regional [1]	18 km; Max Wind speed (%)	Downscale CMIP3 ens. A1B, 2080–2100				+2.9					

Reference	Model/Type	Resolution/ Metric type (high to low resolution)	Climate Change scenario	Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Knutson et al. 2013	GFDL Zetac regional [1]	18 km;	Downscale TCs									
		Max Wind speed (%) of hurricanes	(2081–2100)									
			CMIP3 ens. A1B				**+2.0**					
			CMIP5 ens Rcp45				**+2.2**					
			Gfdl CM2.1 A1B				**+2.8**					
			MPI A1B				+3.6					
			HadCM3 A1B				+0.9					
			MRI A1B				+4.0					
			Gfdl CM2.0 A1B				**+3.6**					
			HadGEM1 A1B				+1.5					
			MIROC hi A1B				+2.3					
			CCMS3 A1B				+3.8					
			INGV A1B				+2.0					
			MIROC med A1B				+2.1					
Wu et al. 2014	Model: Zetac Type: regional [1]	18 km	Downscale CMIP3 A1B multi model ens. Periods: 1980–2006, 2080–99					+2.6				
Tsou et al. 2016	Atm. Model: HiRAM Type: global AGCM [1]	20 km	CMIP5 RCP8.5 (2075–99 vs 1979–2003)					+14				
Murakami et al. 2012b	JMA/MRI global AGCM timeslice [1]	V3.1 20 km	Downscale CMIP3 multimodel ens. A1B change (2075–99 minus control)	**+13**	**+12**	**+14**	+2	**+16**	**+13**	+8	**+15**	**+7**
		V3.2 20 km		**+3**	**+5**	–1	**+9**	**+6**	**+6**	+5	**+7**	**–10**
		Avg. lifetime max winds										
Murakami et al. 2012b	JMA/MRI global AGCM timeslice [1]	V3.1 20 km	Downscale CMIP3 multimodel ens. A1B change (2075–99 minus control)	**+11**	**+12**	**+10**	**+5**	**+18**	**+12**	**+5**	**+10**	**+8**
		V3.2 20 km;		**+4**	**+6**	0	**+10**	**+7**	**+6**	**+7**	**+7**	**–10**
		Avg. max winds over lifetime of all TCs										
Oouchi et al. 2006	MRI/JMA Timeslice [1]	TL959 L60 (~20 km) Avg. lifetime max wind speed	10 yr A1B 1982–93 vs 2080–99	+11	+8.5	+14	+11	+4.2	+0.6	–13	+17	–2.0
Oouchi et al. 2006	MRI/JMA Timeslice [1]	TL959 L60 (~20 km) Avg. annual max winds	10 yr A1B 1982–93 vs 2080–99	+14	+16	+6.9	+20	–2.0	–5.0	–17	+8.2	–23

Reference	Model/Type	Resolution/ Metric type (high to low resolution)	Climate Change scenario	Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Semmler et al. 2008	Rossby Centre regional model [1]	28 km; Max winds	16 yr control and A2, 2085–2100				+4					
Wehner et al. 2015	Model: CAM5.1	25 km	Clim. SST (early 1990s) with									
	Type: global (AGCM) [1]	Avg. 10 highest max wind	$2\times CO_2$ only	−2								
			SST + 2 K only	+10								
			$2\times CO_2$&SST + 2 K	+7								
			Periods: 13 yr									
Chauvin et al. 2006	ARPEGE Climat	~50 km	Downscale									
	Timeslice [1]	Max winds	- CNRM B2				~0					
			- Hadley A2				~0					
Kim et al. 2014	Model: GFDL CM2.5 Type: global coupled climate model [2]	50 km (atm.); 25 km (ocean)	$2\times CO_2$ vs control (fully coupled) 50-yr periods	+2.7			+4.3	+2.5	+4.6	+3.2	+2.0	+1.5
Yoshida et al. 2017	J JMA/MRI global AGCM	V3.2	RCP8.5 late twenty-first century									
	Timeslice 60 years Ensemble 90 members	60 km Max Wind	CMIP5 6-model ensemble (*n* = 90 min/max)	+9 (4, 13)	+10 (4, 13)	+6 (−4, 13)	+8 (−9, 25)	+8 (−5, 15)	+15 (1, 27)	+9 (2, 22)	+9 (−1, 16)	0 (−19, 17)
	Statistical downscale for TC intensity [1]		CCSM4 (n = 15 min/max)	+7 (4, 9)	+7 (4, 9)	+7 (5, 10)	+3 (−3, 9)	+8 (5, 11)	+7 (1, 13)	+8 (3, 12)	+12 (9, 16)	−1 (−4, 5)
			GFDL-CM3 (*n* = 15 min/max)	+9 (8, 11)	+10 (9, 11)	+6 (2, 9)	+12 (6, 20)	+10 (9, 12)	+17 (13, 22)	+4 (0, 8)	+10 (5, 16)	−1 (−7, 7)
			HadGEM2-AO (*n* = 15 min/max)	+8 (6, 10)	+9 (7, 11)	+2 (−3, 6)	+6 (−2, 18)	+8 (6, 11)	+15 (8, 20)	+11 (3, 17)	+6 (−1, 10)	−1 (−6, 3)
			MIROC5 (*n* = 15 min/max)	+9 (7, 12)	+10 (7, 13)	+1 (−4, 6)	+21 (19, 25)	−1 (−5, 5)	+22 (18, 27)	+13 (6, 22)	+6 (0, 13)	−14 (−19, −4)
			MPI-ESM-MR (*n* = 15 min/max)	+9 (7, 12)	+10 (7, 12)	+8 (5, 11)	+1 (−9, 18)	+9 (5, 11)	+18 (15, 22)	+9 (2, 14)	+11 (8, 15)	+4 (1, 11)
			MRI-CGCM3 (*n* = 15 min/max)	+12 (10, 13)	+12 (10, 13)	+10 (6, 13)	+6 (0, 14)	+13 (11, 15)	+13 (10, 18)	+12 (4, 8)	+10 (2, 15)	+10 (4, 17)
Sugi et al. 2002	JMA Timeslice [1]	T106 L21 (~120 km) Max winds	10 yr $1\times CO_2$, $2\times CO_2$	~0								
Gualdi et al. 2008	SINTEX-G coupled model [2]	T106 (~120 km); Max winds	30 yr $1\times CO_2$, $2\times CO_2$, $4\times CO_2$	~0								

Reference	Model/Type	Resolution/ Metric type (high to low resolution)	Climate Change scenario	Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Hasegawa and Emori 2005	CCSR/NIES/FRC AGCM timeslice [1]	T106 L56 (~120 km) Max winds	5 × 20 yr at 1×$\mathrm{CO_2}$ 7 × 20 yr at 2×$\mathrm{CO_2}$					Decrease				
Yoshimura et al. 2006	JMA Timeslice [1]	T106 L21 (~120 km) Max winds	10 yr 1×$\mathrm{CO_2}$, 2×$\mathrm{CO_2}$	~0								
Hasegawa and Emori 2007	CCSR/NICS/FRC Coupled GCM [2]	T106 L56 (~120 km) Max winds	20 yr control Vs +1% yr^{-1} $\mathrm{CO_2}$ (yr 61–80)	~0 for Pc < 985 mb								
Wang and Wu 2012	CMIP5 downscaling – statistical/dyn model [1]	various	A1B (2065–99 minus 1965–99)						**+14**			
Potential intensity theory projections of intensity % Change								**Avg (low, high)**				
Vecchi and Soden 2007	Emanuel PI, reversible w/diss. heating [1]	Max Wind speed (%)	CMIP3 18-model A1B (100 yr trend)	+2.6	+2.7	+2.4	+0.05 (−8.0, 4.6)	+2.9 (−3.1, 13)	+3.5 (−6.4, 16)	+4.4 (−3.3, 16)	+3.7 (−7.6, 17)	+0.99 (−8.6, 8.6)
Knutson and Tuleya 2004	Potential Intensity Emanuel, reversible [1]	Pressure fall (%)	CMIP2+ +1% yr^{-1} $\mathrm{CO_2}$ 80-yr trend				+2.6 (−5.6, 13)	+7.0 (−1.0, 20)	+5.4 (−5.0, 22)			
Knutson and Tuleya 2004	Potential Intensity, Emanuel, pseudoadiabatic [1]	Pressure fall (%)	CMIP2+ +1% yr^{-1} $\mathrm{CO_2}$ 80-yr trend				+6.0 (1.6, 13)	+8.5 (2.8, 25)	+8.2 (−3.3, 28)			
Knutson and Tuleya 2004	Potential Intensity, Holland [1]	Pressure fall (%)	CMIP2+ +1% yr^{-1} $\mathrm{CO_2}$ 80-yr trend				+12 (−4.0, 29)	+17 (9.4, 31)	+16 (3.4, 43)			
Yu et al. 2010	Emanuel PI modified by vertical wind shear [1]	Max Wind speed (%)	CMIP3 18 model ensemble 1% yr^{-1} $\mathrm{CO_2}$, 70-yr trend				−0.1 to +2.3	+2.3	+2.4	+3.3	+3.4	+1.0
Wehner et al. 2015	Emanuel PI reversible Model: CAM5.1 Type: global (AGCM) [1]	Max Wind speed (%)	Clim. SST (early 1990s) 2×$\mathrm{CO_2}$ only SST + 2 K only 2×$\mathrm{CO_2}$&SST + 2 K Periods: 13 yr	 −1 +6 +5								
ACE or PDI % change using Dynamical or Stat/Dyn. Models												
Emanuel et al. 2010	Stat./Dyn. Model [1]	Power Dissipation Index (%)	Timeslice using CMIP3 A1B ens. SST change, 1990–2090, and NICAM model 14 km fields		+65% in PDI (global but Jun–Oct only)							

Reference	Model/Type	Resolution/ Metric type (high to low resolution)	Climate Change scenario	Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Knutson et al. 2015	Model: GFDL HiRAM (global AGCM) downscaled into GFDL Hurricane model with ocean coupling [3]	6 km; ACE or Power Dissipation Index	Timeslice using CMIP5 RCP4.5 Late twenty-first century vs 1982–2005 climatological SST	−13 (ACE) **−10** (PDI)			−10 (ACE) −3 (PDI)	**−27** (ACE) **−23** (PDI)	**+44** (ACE) **+53** (PDI)	+23 (ACE) +29 (PDI)	**−29** (ACE) **−27** (PDI)	**−42** (ACE) **−44** (PDI)
Yamada et al. 2010	NICAM GCM timeslice [1]	14 km Metric: ACE (Accum. Cyclone Energy)	Timeslice using CMIP3 A1B ens, SST change, 1990–2090		−14 (ACE) (global but Jun–Oct only)		−88 (ACE)	+17 (ACE)	+65 (ACE)	−86 (ACE)	−14 (ACE)	
Manganello et al. 2014	IFS Type: global (AGCM) timeslice [1]	T1279 (~16 km) PDI	Timeslice using CMIP3 A1B CCSM3.0 ens. mean SST change (2065–75 minus 1965–75) Periods:1960–2007, 2070–2117					**+51** (PDI)				
Sun et al. 2017	WRF v. 3.3 global AGCM [Table S.5] [1]	~20 km	+2 K SST-only expt. ; 10-member ensemble (May–October season)				+220 (PDI)	+30 (PDI)				
Stowasser et al. 2007	IPRC Regional Model [1]	~50 km PDI	Downscale NCAR CCSM2, 6xCO$_2$					+50 in PDI,; incr. intensity				
Wu et al. 2014	Model: Zetac Type: regional [1]	18 km	Downscale CMIP3 A1B multimodel ens. Periods: 1980–2006, 2080–99					−0.5 (ACE)				
Kim et al. 2014	Model: GFDL CM2.5 Type: global coupled climate model [2]	50 km (atm.); 25 km (ocean)	2×CO$_2$ vs control (fully coupled) 50-yr periods	−3.5 (PDI)			−11 (PDI)	−4.6 (PDI)	−7.1 (PDI)	+3.4 (PDI)	−12 (PDI)	−7.6 (PDI)
Villarini and Vecchi 2013	Statistical downscale of CMIP5 models [1]	—	17 CMIP5 models Mean and (min/max range) RCP2.6 RCP4.5 RCP8.5 (late twenty-first century)				PDI: **+34** (−1, 126) **+57** (−21, 270) **+110** (−23, 320)					

Reference	Model/Type	Resolution/ Metric type (high to low resolution)	Climate Change scenario	Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Emanuel 2013	Statistical–dynamical model [3]	PDI	Downscale									
			CCSM3 A1B	+5								
			CM2.0 A1B	+2								
			ECHAM5 A1B	+4								
			MIROC3.2 A1B	+8								
			MRI-CGCM2.3.2a A1B	+22								
			Periods: 1981–2000, 2181–2200									
			CCSM4 RCP8.5	+8								
			CM3 RCP8.5	+72								
			HADGEM2-ES RCP8.5	+31								
			MPI-ESM-MR RCP8.5	+57								
			MIROC5 RCP8.5	+80								
			MRI-CGCM3 RCP8.5	+26								
			Periods: 1981–2000, 2081–2200									

Table ES4. TC-related precipitation projected changes (%) for the late twenty-first century (relative to the present day). Results from Gualdi et al. (2008) are from the original paper and personal communication with the authors (2009, 2010). Red and blue colors denote increases and decreases, respectively. Boldface values denote statistically significant changes. Rows with *R* refer to the averaging radius around the storm center used for the precipitation calculation. Type of ocean coupling for the study is indicated by the following model⁄type: [1] no ocean coupling (e.g., specified sea surface temperatures or statistical downscaling of tropical cyclones; [2] fully coupled ocean experiment; or [3] hybrid type, with uncoupled atmospheric model for storm genesis, but with ocean coupling for the dynamical or statistical–dynamical downscaling step.

Reference	Model/Type	Resolution/ averaging radius (*R*)	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Knutson and Tuleya 2004	GFDL Hurricane Model (idealized) [1]	9 km inner nest *R* = 100 km	CMIP2+ +1% yr^{-1} CO_2 80-yr trend		+22 (Atlantic, NE Pacific, NW Pacific only)							
Hasegawa and Emori 2005	CCSR/NIES/FRC AGCM timeslice [1]	T106 L56 (~120 km) *R* = 1000 km	5 × 20 yr at $1\times CO_2$ 7 × 20 yr at $2\times CO_2$					+8.4 (all TC periods)				
Yoshimura et al. 2006	JMA GSM8911 Timeslice [1]	T106 L21 (~120 km) *R* = 300 km All TC periods	10 yr $1\times CO_2$, $2\times CO_2$	+10 Arakawa–Schubert +15 Kuo								
Chauvin et al. 2006	ARPEGE Climat Timeslice [1]	~50 km; *R* = n/a	Downscale CNRM B2 Downscale Hadley A2				Substantial increase					
Bengtsson et al. 2007	ECHAM5 timeslice [1]	T213 (~60 km); *R* = 550 km. Accum. Along path	2071–2100, A1B	+30 (TC > 33 m s^{-1} intensity)	+21 (all TCs)							
Knutson et al. 2008	GFDL Zetac regional (All hurricane periods) [1]	18 km;	Downscale CMIP3 ens. A1B, 2080–2100									
		R = 50 km					+37					
		R = 100 km					+23					
		R = 400 km					+10					
Gualdi et al. 2008	SINTEX-G coupled model [2]	T106 (~120 km)	30 yr $1\times CO_2$, $2\times CO_2$									
	All TC Periods			+6.1 (*R* = 100 km) +2.8 (*R* = 400 km)								
	Time of Max. winds			+11 (*R* = 100 km) +4.9 (*R* = 400 km)								

Reference	Model/Type	Resolution/ averaging radius (*R*)	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Hill and Lackmann 2011	WRF regional model downscale of CMIP3 environments (idealized simulations) [1]	2 km; R = 100 km	Downscale CMIP3 ens.									
			A1B (2090–99)				+19					
			A2 (2090–99)				+13					
			B2 (2090–99)				+11					
Knutson et al. 2013	GFDL Zetac regional/ GFDL hurricane model; (All TC periods) [3]	18 km/9 km; R = 100 km	Downscale TCs (2081–2100)				Zetac/Hurr. Model					
			CMIP3 ens. A1B				**+19**/**+22**					
			CMIP5 ens: RCP 4.5				**+13**/**+19**					
			GFDL CM2.1 A1B				**+22**/**+28**					
			MPI A1B				**+24**/**+33**					
			HadCM3 A1B				+12/+8.2					
			MRI A1B				**+28**/**+24**					
			GFDL CM2.0 A1B				**+26**/**+34**					
			HadGEM1 A1B				+11/–4.3					
			MIROC hi A1B				**+22**/**+14**					
			NCAR CCMS3 A1B				**+23**/**+29**					
			INGV A1B				**+19**/**+26**					
			MIROC med A1B				**+22**/**+12**					
Kim et al. 2014	Model: GFDL CM2.5 Type: global coupled climate model [2]	50 km (atm.); 25 km (ocean)	$2\times\mathrm{CO_2}$ vs control (fully coupled) 50-yr periods	**+12** (R = 150 km) **+11** (R = 450 km)								
Villarini et al. 2014	Models:											
	GFDL HiRAM	50 km	20 yrs	+12	+13	+9	–12	+17	+17	+18	+5.8	+13
	CMCC	75 km	10 yrs	+13	+17	+4.5	+11	+15	+24	+21	–1.4	+5.3
	CAM5	25 km	9 yrs	+17	+16	+18	+8.5	+3.7	+28	+19	+26	+11
	AGCMs with specified SSTs and $\mathrm{CO_2}$ levels [1]	Avg. rain rate within 5° radius, 10% rainiest storms	$2\times\mathrm{CO_2}$ and +2 K SST increase combined									
Tsuboki et al. 2015	CReSS regional model downscale of 30 strongest typhoons in MRI-AGCM3.1 present and warm climates [3]	2 km; Average rain rate with 100 km radius	CMIP3 18-model ens. A1B (2074–87 minus 1979–93)					+25				

Reference	Model/Type	Resolution/ averaging radius (*R*)	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Knutson et al. 2015	Model: GFDL HiRAM (global AGCM) downscaled into GFDL Hurricane model with ocean coupling [3]	6 km; Radius around storm center (*R*) = 100 km	Timeslice using CMIP5 RCP4.5 Late twenty-first century vs 1982–2005 climatological SST	+13			+21	+16	+14	+13	+11	+3.5
Wright et al. 2015	Model: GFDL Zetac regional model [1]	18 km Median rain rate over storm lifetime	Timeslice:				Ocean; Land					
			CMIP3/A1B Late (2090 minus 2010)				+19; +10 (R = 150 km) +15; +21 (R = 500 km)					
			CMIP5 RCP4.5 Early (2025 minus 1995)				+10; +11 (R = 150 km) +10; +14 (R = 500 km)					
			CMIP5 RCP4.5 Late (2090 minus 1995)				+13; +5 (R = 150 km) +7; +4 (R = 500 km)					
Bacmeister et al. 2018	Model: CAM5 Type: global [1]	28 km	Bias-corrected CAM5 coupled model SSTs: RCP8.5 (2070–90 vs 1985–2005)	Increase freq. of intense TC rainfall								
Yamada et al. 2017	NICAM Timeslice [1]	14 km;	Timeslice using CMIP3 A1B multi model ens. mean SST change (2075–99 minus 1979–2003) Periods: 1979–2008, 2075–2104	Global +11.8 (time of min sea level press.)								
Tsou et al. 2016	Atm. Model: HiRAM Type: global AGCM [1]	20 km; Max precip within 200 km of center at max TC intensity	CMIP5 RCP8.5 (2075–99 vs 1979–2003)					+54				

Reference	Model/Type	Resolution/ averaging radius (*R*)	Experiment	Basin								
				Global	NH	SH	N Atl.	NW Pac.	NE Pac.	N Ind.	S. Ind.	SW Pac.
Yoshida et al. 2017	JMA/MRI global AGCM Timeslice 60 years Ensemble 90 members [1]	V3.2 60 km Radius around storm center: 200 km	RCP8.5 late twenty-first century									
			CMIP5 6-mod. ensemble (*n* = 90 min/max)	**+28** (8, 45)	**+28** (3, 49)	**+29** (5, 47)	**+24** (–23, 67)	**+32** (7, 48)	**+47** (1, 76)	**+30** (12, 53)	**+39** (15, 62)	**+13** (–28, 44)
			CCSM4 (*n* = 15 min/max)	**+30** (24, 36)	**+27** (19, 35)	**+36** (29, 44)	+6 (–23, 29)	**+29** (20, 36)	**+15** (1, 29)	**+23** (12, 35)	**+49** (40, 62)	**+18** (7, 29)
			GFDL-CM3 (*n* = 15 min/max)	**+32** (27, 35)	**+33** (28, 37)	**+29** (21, 35)	**+39** (26, 67)	**+38** (33, 42)	**+55** (43, 75)	**+24** (13, 32)	**+42** (28, 58)	+11 (–5, 29)
			HadGEM2-AO (*n* = 15 min/max)	**+28** (23, 33)	**+30** (27, 37)	**+21** (11, 32)	+8 (–10, 35)	**+30** (24, 37)	**+58** (43, 68)	**+28** (12, 44)	**+32** (16, 47)	+10 (–8, 22)
			MIROC5 (*n* = 15 min/max)	**+13** (8, 19)	**+11** (3, 14)	**+19** (5, 34)	**+51** (36, 65)	**+19** (7, 36)	**+62** (49, 76)	**+38** (24, 53)	**+30** (15, 49)	–12 (–28, 10)
			MPI-ESM-MR (*n* = 15 min/max)	**+27** (23, 33)	**+26** (20, 31)	**+30** (21, 40)	+13 (–17, 45)	**+31** (22, 38)	**+54** (42, 67)	**+32** (17, 40)	**+41** (34, 54)	**+16** (7, 24)
			MRI-CGCM3 (*n* = 15 min/max)	**+40** (37, 45)	**+42** (39, 49)	**+37** (24, 47)	**+28** (11, 41)	**+44** (39, 48)	**+39** (29, 60)	**+35** (25, 52)	**+42** (25, 58)	**+33** (19, 44)
Wehner et al. 2015	Model: CAM5.1 Type: global (AGCM) [1]	25 km Avg. of max. precip. Rates for each storm	Clim. SST (early 1990s) 2×CO_2&SST + 2 K Periods: 13 yr	**(+14%, +24%)**								
Gutmann et al. 2018	WRF regional model downscale of 22 hurricane cases [1]	4 km grid model; Avg. Max. precip. rate along track (%)	RCP8.5 19-model CMIP5 ensemble environmental change and Greenhouse gas change				+24					
Patricola and Wehner 2018	WRF regional model v. 3.8.1 nested in CAM5.1 atm. model forced with CMIP5 ens. boundary conditions [1]	4.5 km grid Precip rate change (%)	RCPx 1980–2000 vs 2081–2100. 10-member ensembles of 1 to 9 cases per basin.				Region: 5° × 5°					
			RCP4.5				+7.6	+12	+5.8		+20	+16
			RCP6.0				+11	+12	+4.9		+17	+23
			RCP8.5				+13	+31	+15		+42	+35
							1.5° × 1.5°					
			RCP4.5				+20					
			RCP6.0				+25					
			RCP8.5				+32					

Table ES5. Author elicitation responses to TC projection statements. Responses for global metrics are color shaded, where red boxes indicate high confidence in a TC risk becoming greater, orange for medium-to-high confidence, purple for medium confidence, blue for medium-to-low confidence, and green for low confidence. For global TC frequency, these are reversed so that green indicates highest confidence in fewer TCs (high confidence in a relative lowering of TC frequency risk), while red indicates lowest confidence in fewer TCs (that TC frequency risk will decrease) and so forth.

Author:										
S. Camargo	**J. Chan**	**K. Emanuel**	**C.-H. Ho**	**T. Knutson**	**J. Kossin**	**Mohapatra**	**M. Satoh**	**M. Sugi**	**K. Walsh**	**L. Wu**
Projections for the late twenty-first century:										
Global average TC Precipitation rates of individual TCs will increase										
medium-to-high confidence, likely	medium to high confidence	high confidence, very likely	high confidence, very likely	medium-to-high confidence; likely	high confidence, very likely	medium-to-high confidence; likely	high confidence; very likely	high confidence; virtually certain	high confidence; virtually certain	medium-to-high, likely
Average TC Precipitation rates of individual TCs will increase in the North Atlantic basin										
medium-to-high confidence, likely	medium confidence	high confidence, very likely	medium-to-high confidence; likely	medium confidence; likely	medium, likely	medium confidence; likely	medium-to-high confidence, likely	high confidence; virtually certain	medium confidence; likely	medium, likely
Average TC Precipitation rates of individual TCs will increase in the NW Pacific basin										
medium confidence, likely	medium confidence	high confidence, very likely	medium-to-high confidence; likely	medium confidence; likely	medium confidence; likely	medium confidence; likely	medium-to-high confidence, likely	high confidence; virtually certain	medium confidence; likely	medium confidence, likely
Average TC Precipitation rates of individual TCs will increase in the NE Pacific basin										
low to medium confidence	low confidence	medium confidence	low confidence	low confidence	medium	medium confidence; likely	medium confidence	low confidence	low confidence	low to medium confidence
Average TC Precipitation rates of individual TCs will increase in the N. Indian basin										
low to medium confidence	low confidence	low to medium confidence	low confidence	low confidence	medium	medium confidence; likely	low confidence	low to medium	low confidence	low to medium confidence
Average TC Precipitation rates of individual TCs will increase in the S. Indian basin										
low confidence	low confidence	low to medium confidence	low confidence	low confidence	low-to-medium	medium confidence; likely	low confidence	low confidence	low confidence	low to medium confidence
Average TC Precipitation rates of individual TCs will increase in the SW Pacific basin										
medium confidence, likely	medium confidence	medium confidence; likely	medium confidence; likely	medium confidence;	medium, likely	medium confidence; likely	medium-to-high confidence, likely	high confidence; very likely	medium confidence;	medium, likely
Global average TC intensity (maximum surface winds) will increase										
medium-to-high confidence, likely	low to medium confidence	medium-to-high confidence; likely	medium-to-high confidence; likely	medium-to-high confidence; likely	medium-to-high confidence; likely	medium-to-high confidence; likely	high confidence; very likely	high confidence; virtually certain	high confidence; virtually certain	medium-to-high, likely
Average TC intensity (maximum surface winds) will increase in the N. Atlantic basin										
medium-to-high confidence, likely	medium to high confidence	medium-to-high confidence; likely	medium confidence; likely	medium confidence	medium-to-high confidence; likely	medium-to-high confidence; likely	medium confidence, likely	high confidence; very likely	medium confidence	medium-to-high confidence
Average TC intensity (maximum surface winds) will increase in NW Pacific basin										
medium-to-high confidence, likely	low to medium confidence	medium-to-high confidence; likely	medium confidence; likely	medium confidence	medium-to-high confidence; likely	medium-to-high confidence; likely	medium confidence, likely	high confidence; virtualy certain	medium confidence	medium-to high confidence
Average TC intensity (maximum surface winds) will increase in S. Indian basin										
medium confidence, likely	low to medium confidence	low-to-medium confidence; about as likely as not	medium confidence; likely	medium confidence	medium-to-high confidence; likely	medium confidence, likely	medium confidence, likely	high confidence; virtualy certain	medium confidence	medium confidence

Author:										
S. Camargo	**J. Chan**	**K. Emanuel**	**C.-H. Ho**	**T. Knutson**	**J. Kossin**	**Mohapatra**	**M. Satoh**	**M. Sugi**	**K. Walsh**	**L. Wu**
Average TC intensity (maximum surface winds) will increase in NE Pacific basin										
medium confidence, likely	low to medium confidence	medium-to-high confidence; likely	low-to-medium confidence; likely	low to medium confidence	medium-to-high confidence; likely	medium confidence, likely	medium confidence, likely	high confidence; very likely	low to medium confidence	medium confidence
Average TC intensity (maximum surface winds) will increase in N. Indian basin										
low confidence	low to medium confidence	low confidence	low confidence	low confidence	medium, more likely than not	low confidence	medium confidence, likely	medium-to high confidence; likely	low confidence	low confidence
Average TC intensity (maximum surface winds) will increase in SW Pacific basin										
low confidence	low to medium confidence	low confidence	low confidence	low confidence	medium-to-high confidence; likely	low confidence	medium confidence, likely	medium confidence; as likely as not	low confidence	low confidence
Global TC frequency (Cat 0–5) will decrease										
low-to-medium confidence; about as likely as not	medium to high confidence	low-to-medium confidence; about as likely as not	low-to-medium confidence; about as likely as not	low-to-medium confidence	low-to-medium confidence; about as likely as not	low-to-medium confidence; about as likely as not	medium-high confidence;very likely	medium-to-high confidence; very likely	medium confidence; very likely	low-to-medium
TC frequency (Cat 0–5) in the SW Pacific basin will decrease										
low confidence	low to medium confidence	low-to-medium confidence; about as likely as not	low confidence	low-to-medium confidence	low-to-medium confidence; about as likely as not	low to medium confidence	low-medium confidence, likely	medium-to-high confidence; very likely	medium confidence	low-to medium confidence
TC frequency (Cat 0–5) in the S. Indian basin will decrease										
low confidence	low to medium confidence	low-to-medium confidence; about as likely as not	low confidence	low-to-medium confidence	low-to-medium confidence; about as likely as not	low to medium confidence	low-medium confidence, likely	medium-to-high confidence; very likely	low-to-medium confidence	low-to-medium confidence
Latitude of at which TCs reach their maximum intensity in the western North Pacific will migrate poleward										
low-to-medium confidence	low confidence	medium-to-high confidence, likely	medium-to-high confidence, likely	low-to-medium confidence	medium to high, likely	medium confidence	medium confidence, likely	medium confidence	low-to-medium confidence	low-to-medium confidence
Global frequency of very intense (Cat 4–5) TCs will increase										
medium-to high confidence	medium confidence	high confidence; very likely	medium-to-high confidence, likely	low-to-medium confidence	medium-to high confidence, likely	low to medium confidence	medium-high confidence; likely	low confidence	low confidence	low confidence
Frequency of very intense (Cat 4–5) TCs will increase in S. Indian basin										
low-to-medium confidence	low to medium confidence	low-to-medium confidence; about as likely as not	low-to-medium confidence	low to medium confidence	medium-to high confidence, likely	low confidence	low confidence; about as likely as not	low confidence; about as likely as not	low confidence	low confidence
Global proportion of Cat 4–5 TCs will increase (ratio: Cat 4–5 frequency/Cat 0–5 frequency)										
medium to high confidence, likely	medium to high	high confidence; very likely	medium-to-high confidence, likely	medium-to-high confidence; likely	medium-to high confidence, likely	medium to high confidence, likely	medium-to-high confidence; very likely	high confidence; virtually certain	medium-to-high confidence; very likely	high confidence;very likely

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