

1 *Supplementary Material for “North American Climate in CMIP5 Experiments: Part*
2 *III: Assessment of 21st Century Projections” by Maloney et al.*
3

4 As mentioned in the main text, for some analyses, the number of models used was
5 significantly lower than that of the core set, or the RCP4.5 scenario was used rather than
6 RCP8.5. In these cases, while the results are still potentially enlightening, we have placed
7 the details of these analyses into this supplement section. These analyses moisture
8 transport, frost days, East Coast cyclone intensity, and diurnal temperature range changes,
9 as well as an analysis of tropical cyclone activity change using a downscaling technique
10 with a high-resolution model. Also provided in this supplement is a partitioning of
11 projected RCP8.5 temperature and precipitation changes on a regional detail, including a
12 more refined seasonal and model-by-model breakdown.

13

14 *a. Moisture fluxes*

15 Model projected differences in vertically integrated moisture transport (MT) to
16 500 hPa (vectors) and its divergence (contours) are shown in Figure S2 for five coupled
17 models, for RCP8.5 (2081-2100) minus historical (1981-2000) experiments. The MT is
18 well simulated in these models in historical simulations (Sheffield et al. 2013a). While
19 the number of models is too few to provide robust conclusions regarding changes in MT,
20 this analysis provides process level support for model agreement/disagreement in
21 precipitation projections. In summer, the models suggest an increased transport in both
22 (East coast and Great Plains) branches of moisture flow, with a poleward intensification
23 in the coastal branch associated with a poleward shift in moisture convergence on the
24 northwest flank of the Atlantic subtropical anticyclone and increased moisture divergence

25 to the south. The increased Great Plains flux is consistent with projected strengthening of
26 the Great Plains low-level jet, as described in more detail below. Three of the five models
27 show increased divergence in the northern plains during summer, and all show increased
28 divergence in the Pacific Northwest that is associated with stronger descending flow in
29 the North Pacific anticyclone, and where model agreement exists on precipitation
30 decrease (Figure 2).

31 In winter, the models indicate stronger MT from the Pacific into the Northwest,
32 but the latitude of the increased westerly transport is critical in determining whether
33 much of California is in a region of increased or decreased divergence. Agreement does
34 exist that increased southerly MT in the Atlantic sector is the source for stronger
35 convergence in the poleward shifted North Atlantic storm track, while the Gulf coast and
36 Florida would see increased divergence of moisture.

37

38 *b. Frost days*

39 Figure S3 shows the change in the number of frost days (FDs) simulated by 14
40 core models between 1979-2005 and 2071-2100. MEM changes of over 40 days occur in
41 the western third of NA from the US western mountains north through the Canadian
42 Rockies to Alaska, and between 20 to 30 days over the eastern two thirds of NA, with
43 less change in the southern U.S.. Most uncertainty exists among the model projections for
44 the West, with multimodel standard deviations of up to 8 days. The highest agreement is
45 in the Canadian Northern Territories. Some of the differences among models can be
46 explained by the historical biases in the models (Sheffield et al., 2013a), which may limit
47 or enhance future changes even if the projected shift in temperature is the same across

48 models. For example, CCSM4 has historically too few FDs in the central US, and
49 projects less of a decrease in this region in the future. The IPSL-CM5A-LR and CSIRO-
50 MK3-6-0 models project the largest decreases in FDs over the western U.S., but these
51 two models also have the largest over-estimation of historic FDs in this region. These
52 results indicate that bias correction of the modeled extreme values of this type can help
53 reduce the uncertainty in future projections.

54

55 *c. Diurnal temperature range*

56 One robust global climate change signal over the 20th Century was the
57 widespread decline of diurnal temperature range (DTR, $T_{\max}-T_{\min}$), especially in winter,
58 resulting from nighttime temperatures warming faster than daytime (Karl et al. 1993, Dai
59 et al 1999, Easterling et al 1997, and Vose et al 2005). Global T_{\min} increased by $0.20\text{ }^{\circ}\text{C}$
60 dec^{-1} while T_{\max} raised $0.14\text{ }^{\circ}\text{C}\text{ dec}^{-1}$ from 1950–2004, resulting in a DTR decrease of
61 $0.07\text{ }^{\circ}\text{C}$ (Vose et al., 2005). During the same period over North America, summer T_{\max}
62 and T_{\min} increased 0.07 and $0.12\text{ }^{\circ}\text{C}$, respectively, resulting in a $-0.05\text{ }^{\circ}\text{C}$ decrease in
63 DTR. A similar decrease ($-0.06\text{ }^{\circ}\text{C}$) occurred in winter. In RCP4.5, the core CMIP5
64 models of Table 1 project sharp decreases in wintertime DTR in the mid 21st Century,
65 most prominent in an east-west oriented band at northern latitudes where DTR decreases
66 by more than $0.2\text{ }^{\circ}\text{C}/\text{decade}$ (Figure S4). This decrease in DTR is largely due to
67 preferential increases in nighttime temperature. In the southern U.S. and Mexico, DTR is
68 projected to increase, although with larger uncertainty as indicated by the larger inter-
69 model variance. During summer, DTR is projected to slightly increase ($<0.15\text{ }^{\circ}\text{C}/\text{decade}$)
70 in the north central section of the U.S. In the southwestern U.S., the MEM DTR signal is

71 rather weak, which is also accompanied by larger variance among the models, likely due
72 to different treatments of local convection over complex terrain in each model. The
73 uncertainty in projected DTR trend is generally higher in the lower latitudes. If we view
74 the signal (DTR trend) to noise (inter-model variance) ratio as a simple measure of the
75 confidence in the model projections, the northern Rocky Mountain region has smallest
76 uncertainty in future projections.

77 It should be noted that the spatial pattern of DTR trend in the first half of the 21st
78 century here is surprisingly similar to that simulated for the second half of 20th century in
79 part 2 of this paper series (Sheffield et al., 2013b). Given that the same group of models
80 largely missed the observed decreasing DTR over a large part of the U.S. in the *historical*
81 experiment, caution should be exercised in interpreting largely positive DTR trends over
82 the U.S. during summer in coming decades.

83

84 *d. Extratropical cyclone intensity distribution*

85 A gradual reduction in the maximum intensity of cyclones occurs within the
86 dashed box region of Fig. 10a for the three future periods (Fig. S5); however, this
87 reduction is delayed around 990 hPa during the first two 30-year periods. By 2069-2098,
88 a 0.5 to 1.5 (5-10%) reduction in the number of cyclones is projected between the 960
89 and 1010 hPa pressure bins. In contrast, Colle et al. (2013) showed a 5-10% increase in
90 the number of 960-980 hPa cyclones along the U.S. East coast (not shown), as well as a
91 20-40% increase in more rapid deepening cyclones in this region.

92

93 *e) Tropical cyclone-like vortices in the eastern North Pacific and North Atlantic*

94 In the main text we only showed the tropical cyclone-like track density and
95 numbers for 5 models, although we analyzed a total of 14 CMIP5 models. A complete
96 analysis of the global TC activity in these 14 models is given in Camargo (2013). In order
97 to complement the results of the main section with this subset of models, here we show
98 the TC tracks of all 14 models in the historical and the RCP8.5 scenario (for the case of
99 the MPI model, RCP4.5 scenario as well) in Figures S6 and S7. As shown in Figs. S6 and
100 S7, most models have almost no TC activity in the Atlantic and eastern North Pacific
101 basin, even though in some cases they are active in the western North Pacific and
102 southern hemisphere (see Camargo 2013). The five chosen models in our subset are the
103 most active in these two basins, but even in these 5 models the number of models TCs in
104 these two basins are still much lower than the observed number.

105

106 *f. Tropical cyclone downscaling with a high resolution model*

107 To complement the analysis in Section 6b, we use a dynamical downscaling
108 approach in which a high resolution global atmospheric model (GFDL HIRAM; Zhao et
109 al. 2009; Zhao and Held 2012) is integrated and forced by CMIP3 and CMIP5 coupled
110 model projected SSTs and sea ice concentrations. Recent studies suggest that when
111 forced by the observed SSTs and sea-ice concentrations, a global atmospheric model with
112 a resolution ranging from 50km to 20km can accurately simulate many aspects of
113 hurricane frequency and its variability for the past few decades during which reliable
114 observations are available (e.g., Sugi et al. 2002; McDonald et al. 2005; Yoshimura et al.
115 2006; Oouchi et al. 2006; Bengtsson et al. 2007; Gualdi et al. 2008; LaRow et al. 2008;
116 Zhao et al. 2009).

117 We first generate a present-day control simulation by prescribing climatological
118 SSTs and sea-ice concentration (seasonally varying with no interannual variability) using
119 time-averaged (1982-2005) Hadley Center Global Sea Ice and Sea Surface Temperature
120 (HadISST) data (Rayner et al. 2003). For the CMIP3 global warming experiments, we
121 add the SST anomalies (also seasonally varying with no interannual variability) projected
122 by the coupled models to the climatological SSTs and double the CO₂ concentration. For
123 the CMIP5 high-resolution time-slice simulations with prescribed SSTs and sea-ice
124 concentrations, the specifications for both the present-day and the future projection
125 experiments also include interannual variability, and feature future SSTs from two GFDL
126 coupled models (ESM and CM3). The results from downscaling the GFDL CMIP5
127 projections include changes in both SST anomalies and different specifications for
128 greenhouse-gases and aerosols depending on the pathway used (Held et al 2013). The
129 storm detection and tracking algorithm we use in the analysis is described in Zhao et al.
130 (2009).

131 The GFDL C180HIRAM simulations with CMIP3 model forcing produce a large
132 inter-model spread (standard deviation of fractional changes ~ 0.35) in the N. Atlantic
133 hurricane frequency response to warming (Figure S8a). For example, the two Hadley
134 Center models produce the largest decrease while the ECHAM5 model generates a
135 modest increase of hurricanes. In contrast, the two GFDL CMIP5 models tend to
136 produce an increase especially in the near decade (2026-2035), and in the CM3
137 projections for RCP4.5. However, for RCP8.5, both the CM3 and ESM produce
138 insignificant change at the late 21st century.

139 Zhao and Held (2012) found that most of the inter-model spread in the N. Atlantic
140 hurricane frequency response among the CMIP3 models can be explained by a simple
141 relative SST (RSST) index defined as the tropical Atlantic SST minus tropical mean SST.
142 Under global warming scenarios the SST difference between the MDR and the other
143 tropical ocean basins varies from model to model with implications for hurricane activity
144 (Latif et al. 2007; Swanson 2008; Vecchi et al. 2008; Wang and Lee 2008; Xie et al.
145 2010). The RCP4.5 projections for both near decades and late 21st century from the CM3
146 and ESM models show consistent relationship between the N. Atlantic hurricane
147 frequency and the RSST (Figure S9a). However, the results from the two late 21st
148 century runs with RCP8.5 show a marked departure from the regression line associated
149 with the largest reduction (38% for CM3-2090-RCP8.5 and 25% for ESM-2090-RCP8.5)
150 in global mean hurricane frequency. This departure is most likely a result of the larger
151 direct effect of the atmospheric greenhouses-gases concentration (RCP8.5) that can
152 suppress global and regional TC/hurricane frequency and therefore shift the hurricane
153 frequency-RSST regression line downward (Held and Zhao 2011). In general, the CMIP5
154 downscaling results continue to suggest a large uncertainty in future projections of N.
155 Atlantic hurricane frequency, consistent with the analysis in Section 6a-c.

156 The GFDL CMIP5 downscaling results tend to produce a reduction in east Pacific
157 hurricanes (Figure S8b, S9b). A negative correlation generally exists between the
158 response of east Pacific and the north Atlantic hurricane frequency. When the fractional
159 changes are plotted against the east Pacific RSST index, we also see a strong correlation
160 between east Pacific hurricane frequency and east Pacific RSST. Again, the departure for
161 the two RCP8.5 models at the late 21st century supports that the global mean reduction

162 due to the direct effect of GHG tends to systematically move the regression line

163 downward.

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References

- 166 Bengtsson, L., K. Hodges, M. Esch, N. Keenlyside, L. Kornblueh, J.-J. Luo, and T.
167 Yamagata, 2007: How may tropical cyclones change in a warmer climate. *Tellus*,
168 **59A**, 539–561.
- 169 Colle, B.A., Z. Zhang, K. Lombardo, P. Liu, E. Chang, and M. Zhang, 2013: Historical
170 Evaluation and Future Prediction of Eastern North American and Western Atlantic
171 Extratropical Cyclones in the CMIP5 Models during the Cool Season. *J. Climate*, **26**,
172 6882–6903.
- 173 Camargo, S.J., 2013. Global and regional aspects of tropical cyclone activity in the
174 CMIP5 models. *J. Climate*, in press, doi: 10.1175/JCLI-D-12-00549.1.
- 175 Dai, A., K. E. Trenberth, and T. R. Karl, 1999: Effects of Clouds, Soil Moisture,
176 Precipitation, and Water Vapor on Diurnal Temperature Range. *J. Climate*, 12, 2451–
177 2473, doi: 10.1175/1520-0442(1999)0122.0.CO;2.
- 178 Easterling, D.R., B. Horton, P. D. Jones, T. C. Peterson, T. R. Karl, D. E. Parker, M. J.
179 Salinger, V. Razuvayev, N. Plummer, P. Jamason and C. K. Folland, 1997: Maximum
180 and Minimum Temperature Trends for the Globe. *Science*, **277**, 364-367. DOI:
181 10.1126/science.277.5324.364.
- 182 Gualdi, S., E. Scoccimarro, and A. Navarra, 2008: Changes in tropical cyclone activity
183 due to global warming: results from a high-resolution coupled general circulation
184 model. *J. Climate*, **21**, 5204–5228.
- 185 Held, I. M. and coauthors, 2013: High resolution AMIP simulation for CMIP5 using
186 GFDL’s HIRAM model. *J. Climate*, manuscript in preparation.

187 Held, I. and M. Zhao, 2011: The response of tropical cyclone statistics to an increase in
188 CO2 with fixed sea surface temperatures. *J. Climate*, **24**, 5353–5364.

189 Karl, T. R., and Coauthors, 1993: A New Perspective on Recent Global Warming:
190 Asymmetric Trends of Daily Maximum and Minimum Temperature. *Bull. Amer.*
191 *Meteor. Soc.*, **74**, 1007–1023.

192 Latif, M., N. Keenlyside, and J. Bader, 2007: Tropical sea surface temperature, vertical
193 wind shear, and hurricane development. *Geophys. Res. Lett.*, **34**,
194 doi:10.1029/2006GL027969.

195 LaRow, T., Y.-K. Lim, D. Shin, E. Chassignet, and S. Cocks, 2008: Atlantic basin
196 seasonal hurricane simulations. *J. Climate*, **21**, 3191–3206.

197 McDonald, R., D. Bleaken, D. Creswell, V. Pope, and C. Senior, 2005: Tropical
198 storms: representation and diagnosis in climate models and the impact of climate
199 change. *Clim. Dyn.*, **25**, 19–36.

200 Oouchi, K., J. Yoshimura, H. Yoshimura, R. Mizuta, S. Kusunoki, and A. Noda, 2006:
201 Tropical cyclone climatology in a global-warming climate as simulated in a 20 km
202 mesh global atmospheric model: Frequency and wind intensity analysis. *J. Meteor.*
203 *Soc. Japan*, **84**, 259–276.

204 Rayner, R., D. Parker, E. Horton, C. Folland, L. Alexander, and D. Rowel, 2003: Global
205 analyses of sea surface temperature, sea ice, and night marine air temperature since
206 the late nineteenth century. *J. Geophys. Res.*, **108**, D14,4407,doi:10.1029/2002JD002
207 670.

208 Sheffield, J., and others, 2013a: North American Climate in CMIP5 Experiments. Part I:
209 Evaluation of 20th Century Continental and Regional Climatology. *J. Climate*, **26**,
210 9209–9245.

211 Sheffield, J., and others, 2013b: North American Climate in CMIP5 Experiments. Part II:
212 Evaluation of 20th Century Intra-seasonal to Decadal Variability. *J. Climate*, **26**,
213 9247–9290.

214 Swanson, K. L., 2008: Nonlocality of Atlantic tropical cyclone intensities. *Geochem.*
215 *Geophys. Geosyst.*, **9**, Q04V01. doi:10.1029/2007GC001844.

216 Sugi, M., A. Noda, and N. Sato, 2002: Influence of the global warming 105 on tropical
217 cyclone climatology: An experiment with the JMA global model. *J. Meteor. Soc.*
218 *Japan*, **80**, 249–272.

219 Vecchi, G. A., K. Swanson, and B. Soden, 2008: Whither hurricane activity? *Science*,
220 **322**, 687-689.

221 Vose, R. S., D. R. Easterling, and B. Gleason (2005), Maximum and minimum
222 temperature trends for the globe: An update through 2004, *Geophys. Res. Lett.*, **32**,
223 L23822, doi:10.1029/2005GL024379.

224 Wang, C., and S.-K. Lee, 2008: Global warming and United States landfalling hurricanes.
225 *Geophys. Res. Lett.*, **35**, L02708. doi:10.1029/2007GL032396.

226 Xie, S.-P., C. Deser, G.A. Vecchi, J. Ma, H. Teng, and A.T. Wittenberg, 2010: Global
227 warming pattern formation: Sea surface temperature and rainfall. *J. Climate*, **23**, 966–
228 986.

229 Yoshimura, J., M. Sugi, and A. Noda, 2006: Influence of greenhouse warming on tropical
230 cyclone frequency. *J. Meteor. Soc. Japan*, **84**, 405–428.

231 Zhao, M., and I. M. Held, 2012: TC-Permitting GCM Simulations of Hurricane
232 Frequency Response to Sea Surface Temperature Anomalies Projected for the Late-
233 Twenty-First Century. *J. Climate*, **25**, 2995–3009.

234 Zhao, M., I. M. Held, S.-J. Lin, and G. A. Vecchi, 2009: Simulations of global hurricane
235 climatology, interannual variability, and response to global warming using a 50km
236 resolution GCM. *J. Climate*, **22**, 6653–6678.

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239 **Table S1:** RCP8.5, near surface air temperature change (2070 to 2099) - (1961 to 1990):
 240 Annual mean. Regions are defined in Figure 4, except conUS, which represents the lower
 241 48 U.S. states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| bcc-csm1-1 | 5.7 | 4.8 | 7.4 | 7.1 | 4.9 | 4.9 | 5.4 | 3.5 |
| CanESM2 | 7.1 | 6.0 | 8.9 | 9.0 | 6.3 | 6.0 | 6.6 | 5.3 |
| CCSM4 | 5.4 | 4.7 | 7.0 | 6.3 | 4.8 | 4.9 | 4.9 | 3.9 |
| CNRM-CM5 | 5.4 | 4.8 | 6.8 | 6.6 | 4.7 | 4.8 | 5.2 | 3.5 |
| CSIRO-Mk3-6-0 | 5.8 | 5.5 | 6.7 | 6.3 | 5.1 | 5.8 | 5.8 | 4.9 |
| GFDL-CM3 | 7.7 | 6.3 | 10.0 | 11.2 | 7.1 | 6.3 | 6.3 | 5.3 |
| GFDL-ESM2M | 4.0 | 3.8 | 4.3 | 4.7 | 4.0 | 3.8 | 3.6 | 3.5 |
| GISS-E2-R | 3.9 | 3.6 | 4.7 | 4.7 | 3.9 | 3.7 | 3.4 | 3.3 |
| HadGEM2-ES | 7.8 | 6.6 | 10.1 | 10.2 | 7.3 | 7.0 | 6.7 | 5.2 |
| inmcm4 | 4.1 | 3.7 | 5.0 | 5.0 | 3.5 | 3.8 | 3.9 | 3.2 |
| IPSL-CM5A-LR | 6.5 | 6.1 | 7.5 | 7.5 | 5.8 | 6.1 | 6.4 | 5.6 |
| MIROC5 | 6.8 | 5.6 | 8.5 | 9.9 | 6.0 | 6.2 | 5.6 | 4.2 |
| MIROC-ESM | 7.6 | 6.8 | 9.1 | 9.7 | 7.2 | 7.3 | 7.1 | 4.8 |
| MPI-ESM-LR | 5.8 | 5.0 | 7.7 | 6.9 | 5.1 | 5.2 | 5.2 | 4.6 |
| MRI-CGCM3 | 4.0 | 3.3 | 4.7 | 5.2 | 3.7 | 3.3 | 3.4 | 3.3 |
| NorESM1-M | 5.8 | 5.1 | 7.4 | 7.5 | 5.3 | 5.5 | 5.2 | 4.0 |
| MM | 5.8 | 5.1 | 7.2 | 7.4 | 5.3 | 5.3 | 5.3 | 4.3 |
| std | 1.4 | 1.1 | 1.8 | 2.1 | 1.2 | 1.2 | 1.2 | 0.8 |

243 **Table S2:** RCP8.5, near surface air temperature change (2070 to 2099) - (1961 to 1990):
 244 DJF mean. Regions are defined in Figure 4, except conUS, which represents the lower 48
 245 U.S. states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|------------|------------|-------------|-------------|------------|------------|------------|------------|
| bcc-csm1-1 | 7.6 | 4.7 | 11.6 | 12.5 | 5.4 | 5.0 | 6.3 | 2.7 |
| CanESM2 | 8.4 | 5.7 | 12.8 | 13.1 | 6.2 | 5.7 | 6.7 | 5.1 |
| CCSM4 | 6.4 | 4.7 | 9.5 | 9.3 | 5.0 | 5.0 | 5.1 | 3.7 |
| CNRM-CM5 | 7.3 | 5.7 | 10.6 | 10.7 | 6.0 | 6.0 | 6.1 | 3.5 |
| CSIRO-Mk3-6-0 | 7.0 | 5.3 | 9.7 | 9.6 | 5.4 | 6.2 | 5.8 | 4.5 |
| GFDL-CM3 | 8.3 | 4.8 | 13.7 | 14.7 | 6.5 | 4.8 | 5.2 | 4.3 |
| GFDL-ESM2M | 4.7 | 3.4 | 7.1 | 7.0 | 4.0 | 3.6 | 3.4 | 3.0 |
| GISS-E2-R | 4.0 | 3.0 | 6.0 | 5.6 | 4.2 | 3.1 | 2.6 | 2.9 |
| HadGEM2-ES | 9.5 | 6.9 | 14.2 | 14.6 | 7.8 | 8.0 | 6.9 | 5.0 |
| inmcm4 | 5.3 | 3.9 | 7.4 | 8.0 | 4.6 | 4.1 | 4.5 | 2.2 |
| IPSL-CM5A-LR | 7.1 | 5.9 | 9.2 | 9.8 | 5.8 | 6.1 | 6.4 | 4.7 |
| MIROC5 | 8.1 | 5.4 | 12.2 | 13.9 | 6.4 | 6.1 | 5.6 | 3.8 |
| MIROC-ESM | 8.8 | 6.7 | 12.3 | 12.6 | 7.8 | 7.3 | 7.5 | 4.3 |
| MPI-ESM-LR | 7.0 | 4.4 | 11.6 | 10.4 | 4.9 | 4.7 | 5.3 | 4.2 |
| MRI-CGCM3 | 4.8 | 3.2 | 6.4 | 8.1 | 4.3 | 3.2 | 3.4 | 3.0 |
| NorESM1-M | 6.4 | 5.0 | 7.9 | 10.4 | 5.8 | 5.5 | 4.6 | 3.8 |
| MM | 6.9 | 4.9 | 10.1 | 10.6 | 5.6 | 5.3 | 5.4 | 3.8 |
| std | 1.6 | 1.2 | 2.6 | 2.7 | 1.2 | 1.4 | 1.4 | 0.9 |

247 **Table S3:** RCP8.5, near-surface air temperature change (2070 to 2099) - (1961 to 1990):
 248 MAM mean. Regions are defined in Figure 4, except conUS, which represents the lower
 249 48 U.S. states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| bcc-csm1-1 | 4.5 | 4.1 | 5.4 | 5.0 | 4.2 | 4.0 | 4.2 | 3.9 |
| CanESM2 | 6.3 | 5.8 | 6.9 | 7.7 | 5.7 | 5.7 | 5.9 | 5.4 |
| CCSM4 | 4.7 | 4.3 | 5.7 | 5.2 | 4.5 | 4.5 | 4.2 | 4.1 |
| CNRM-CM5 | 4.5 | 4.0 | 5.9 | 5.0 | 3.7 | 3.5 | 4.5 | 3.7 |
| CSIRO-Mk3-6-0 | 4.8 | 4.9 | 5.3 | 4.3 | 4.9 | 5.1 | 4.5 | 5.1 |
| GFDL-CM3 | 7.2 | 5.6 | 9.2 | 10.8 | 6.7 | 5.5 | 5.7 | 5.2 |
| GFDL-ESM2M | 3.8 | 3.5 | 4.2 | 4.3 | 3.5 | 3.2 | 3.6 | 3.7 |
| GISS-E2-R | 3.7 | 3.7 | 4.2 | 3.9 | 3.8 | 3.8 | 3.2 | 3.5 |
| HadGEM2-ES | 7.3 | 5.4 | 11.2 | 10.3 | 6.1 | 5.2 | 5.6 | 5.2 |
| inmcm4 | 4.1 | 3.2 | 5.2 | 5.5 | 3.8 | 3.2 | 3.2 | 3.8 |
| IPSL-CM5A-LR | 5.6 | 5.3 | 7.1 | 5.3 | 4.8 | 5.2 | 5.6 | 5.5 |
| MIROC5 | 6.8 | 6.3 | 7.3 | 9.3 | 7.0 | 7.1 | 5.9 | 4.3 |
| MIROC-ESM | 7.8 | 6.9 | 8.8 | 10.1 | 7.8 | 7.3 | 7.2 | 5.1 |
| MPI-ESM-LR | 5.5 | 4.4 | 7.8 | 6.7 | 4.5 | 4.4 | 4.8 | 4.6 |
| MRI-CGCM3 | 3.2 | 2.8 | 3.7 | 3.8 | 3.0 | 2.5 | 2.6 | 3.6 |
| NorESM1-M | 5.3 | 4.8 | 6.7 | 6.5 | 4.8 | 5.1 | 4.8 | 4.3 |
| MM | 5.3 | 4.7 | 6.5 | 6.5 | 4.9 | 4.7 | 4.7 | 4.4 |
| std | 1.4 | 1.1 | 2.0 | 2.4 | 1.4 | 1.3 | 1.2 | 0.7 |

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252 **Table S4:** RCP8.5, near surface air temperature change (2070 to 2099) - (1961 to 1990):

253 JJA mean. Regions are defined in Figure 4, except conUS, which represents the lower 48

254 U.S. states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| bcc-csm1-1 | 4.8 | 5.3 | 4.6 | 4.2 | 5.1 | 5.2 | 5.6 | 4.0 |
| CanESM2 | 7.0 | 6.5 | 7.4 | 7.9 | 7.0 | 6.4 | 7.4 | 5.4 |
| CCSM4 | 5.0 | 5.1 | 5.5 | 4.5 | 5.0 | 5.1 | 5.6 | 3.9 |
| CNRM-CM5 | 4.6 | 4.8 | 4.3 | 4.7 | 4.3 | 4.7 | 5.2 | 3.5 |
| CSIRO-Mk3-6-0 | 5.3 | 6.3 | 3.9 | 4.2 | 5.5 | 6.3 | 6.5 | 5.2 |
| GFDL-CM3 | 8.0 | 7.7 | 8.3 | 10.2 | 8.2 | 7.7 | 7.5 | 6.0 |
| GFDL-ESM2M | 3.5 | 4.2 | 2.3 | 3.0 | 4.1 | 4.1 | 3.8 | 3.9 |
| GISS-E2-R | 3.9 | 4.2 | 3.6 | 4.3 | 3.7 | 4.0 | 4.2 | 3.2 |
| HadGEM2-ES | 6.9 | 7.2 | 6.2 | 6.9 | 7.7 | 7.4 | 7.6 | 5.2 |
| inmcm4 | 3.2 | 4.0 | 2.1 | 2.5 | 2.7 | 3.8 | 4.1 | 3.7 |
| IPSL-CM5A-LR | 6.6 | 6.8 | 6.2 | 7.0 | 6.1 | 6.7 | 7.0 | 6.3 |
| MIROC5 | 5.9 | 5.4 | 6.1 | 7.4 | 5.2 | 6.1 | 5.5 | 4.6 |
| MIROC-ESM | 7.0 | 7.1 | 7.3 | 7.7 | 6.5 | 7.7 | 7.2 | 5.3 |
| MPI-ESM-LR | 5.2 | 5.7 | 4.3 | 5.2 | 5.7 | 5.8 | 5.3 | 4.7 |
| MRI-CGCM3 | 3.4 | 3.8 | 2.5 | 3.3 | 3.6 | 3.8 | 3.7 | 3.6 |
| NorESM1-M | 5.7 | 5.3 | 6.7 | 5.9 | 5.3 | 5.7 | 5.9 | 4.0 |
| MM | 5.4 | 5.6 | 5.1 | 5.6 | 5.4 | 5.7 | 5.8 | 4.5 |
| std | 1.5 | 1.2 | 1.9 | 2.1 | 1.5 | 1.3 | 1.3 | 0.9 |

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256 **Table S5:** RCP8.5, near-surface air temperature change (2070 to 2099) - (1961 to 1990):
 257 SON mean. Regions are defined in Figure 4, except conUS, which represents the lower
 258 48 U.S. states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| bcc-csm1-1 | 5.8 | 5.1 | 8.0 | 6.7 | 5.1 | 5.4 | 5.4 | 3.6 |
| CanESM2 | 6.6 | 6.0 | 8.4 | 7.2 | 6.2 | 6.1 | 6.3 | 5.3 |
| CCSM4 | 5.3 | 4.7 | 7.3 | 6.2 | 4.8 | 5.0 | 4.8 | 3.8 |
| CNRM-CM5 | 5.1 | 4.7 | 6.6 | 5.9 | 4.8 | 4.9 | 4.9 | 3.5 |
| CSIRO-Mk3-6-0 | 6.2 | 5.7 | 8.0 | 6.8 | 4.7 | 5.7 | 6.3 | 4.9 |
| GFDL-CM3 | 7.4 | 6.9 | 9.0 | 9.2 | 7.1 | 7.0 | 6.5 | 5.7 |
| GFDL-ESM2M | 3.9 | 4.2 | 3.7 | 4.4 | 4.3 | 4.4 | 3.7 | 3.4 |
| GISS-E2-R | 4.0 | 3.7 | 5.0 | 4.9 | 3.8 | 3.8 | 3.4 | 3.5 |
| HadGEM2-ES | 7.5 | 7.1 | 8.7 | 8.9 | 7.7 | 7.4 | 6.8 | 5.3 |
| inmcm4 | 3.9 | 3.7 | 5.2 | 4.2 | 2.8 | 3.9 | 3.9 | 2.9 |
| IPSL-CM5A-LR | 6.8 | 6.5 | 7.6 | 7.8 | 6.5 | 6.5 | 6.5 | 5.7 |
| MIROC5 | 6.3 | 5.4 | 8.5 | 8.8 | 5.6 | 5.7 | 5.3 | 4.0 |
| MIROC-ESM | 6.8 | 6.6 | 7.9 | 8.2 | 6.8 | 7.1 | 6.3 | 4.5 |
| MPI-ESM-LR | 5.6 | 5.6 | 7.0 | 5.5 | 5.3 | 5.7 | 5.4 | 4.8 |
| MRI-CGCM3 | 4.4 | 3.6 | 6.2 | 5.8 | 3.7 | 3.5 | 3.9 | 3.1 |
| NorESM1-M | 6.0 | 5.3 | 8.3 | 7.3 | 5.1 | 5.7 | 5.3 | 4.0 |
| MM | 5.7 | 5.3 | 7.2 | 6.7 | 5.3 | 5.5 | 5.3 | 4.2 |
| std | 1.2 | 1.1 | 1.5 | 1.6 | 1.3 | 1.2 | 1.1 | 0.9 |

260 **Table S6:** RCP8.5, % precipitation change (2070 to 2099) - (1961 to 1990): Annual
 261 mean. Regions are defined in Figure 4, except conUS, which represents the lower 48 U.S.
 262 states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|------------|------------|-------------|-------------|-------------|------------|------------|--------------|
| CanESM2 | 15.9 | 12.1 | 41.4 | 28.7 | 11.1 | 7.7 | 22.6 | -17.8 |
| CCSM4 | 7.2 | 5.8 | 25.6 | 14.7 | 10.4 | 8.0 | 6.9 | -18.9 |
| CNRM-CM5 | 11.9 | 8.9 | 26.6 | 22.4 | 10.3 | 6.0 | 13.3 | -4.0 |
| CSIRO-Mk3-6-0 | 8.6 | 6.7 | 27.1 | 18.2 | 17.0 | 7.0 | 5.9 | -18.5 |
| GFDL-CM3 | 17.7 | 9.0 | 51.8 | 32.9 | 16.8 | 14.5 | 11.1 | -5.2 |
| GFDL-ESM2M | 9.4 | 2.7 | 18.4 | 19.2 | 8.1 | 4.8 | 4.2 | 6.3 |
| GISS-E2-R | 5.1 | 4.2 | 15.5 | 13.9 | 14.6 | 9.3 | -0.3 | -11.5 |
| HadGEM2-ES | 10.7 | 5.2 | 33.9 | 26.6 | 10.0 | 9.6 | 2.1 | -11.6 |
| inmcm4 | 4.6 | -0.6 | 24.9 | 16.7 | 4.1 | 1.0 | 4.9 | -27.6 |
| IPSL-CM5A-LR | 4.6 | -3.5 | 24.4 | 19.7 | 6.1 | -6.5 | 3.5 | -38.2 |
| MIROC5 | 8.0 | 0.6 | 23.7 | 26.3 | 12.6 | -3.0 | 4.3 | -6.7 |
| MIROC-ESM | 14.2 | 2.8 | 36.4 | 32.4 | 7.0 | 4.4 | 8.3 | 1.1 |
| MPI-ESM-LR | 10.0 | 4.8 | 33.5 | 23.5 | 13.7 | 7.7 | 4.3 | -14.3 |
| MRI-CGCM3 | 11.7 | 7.7 | 28.1 | 28.1 | 14.5 | 8.8 | 7.5 | -4.0 |
| NorESM1-M | 6.4 | 1.6 | 25.6 | 20.5 | 14.0 | 2.0 | 5.6 | -25.1 |
| MM | 9.7 | 4.5 | 29.1 | 22.9 | 11.4 | 5.4 | 6.9 | -13.1 |
| std | 4.0 | 4.1 | 9.1 | 6.1 | 3.9 | 5.3 | 5.5 | 11.7 |

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266 **Table S7:** RCP8.5, % precipitation change (2070 to 2099) - (1961 to 1990): DJF mean.
 267 Regions are defined in Figure 4, except conUS, which represents the lower 48 U.S. states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|
| CanESM2 | 26.3 | 22.2 | 45.1 | 51.7 | 24.0 | 19.4 | 28.2 | -30.4 |
| CCSM4 | 14.4 | 14.4 | 29.3 | 31.5 | 18.0 | 18.2 | 17.3 | -31.7 |
| CNRM-CM5 | 17.6 | 15.6 | 30.3 | 40.3 | 17.7 | 6.8 | 22.8 | -20.6 |
| CSIRO-Mk3-6-0 | 12.6 | 3.3 | 40.6 | 34.7 | 9.5 | -5.1 | 17.9 | -34.1 |
| GFDL-CM3 | 27.0 | 20.1 | 61.3 | 60.1 | 37.9 | 27.7 | 14.9 | -11.7 |
| GFDL-ESM2M | 14.2 | 8.3 | 39.7 | 36.0 | 14.2 | 12.2 | 10.7 | -16.9 |
| GISS-E2-R | 9.2 | 10.1 | 11.9 | 18.9 | 31.0 | 17.2 | 1.4 | -12.9 |
| HadGEM2-ES | 25.5 | 22.4 | 52.9 | 66.1 | 26.2 | 28.5 | 11.6 | -8.8 |
| inmcm4 | 8.4 | 6.5 | 13.3 | 22.9 | 6.0 | 4.9 | 18.7 | -31.3 |
| IPSL-CM5A-LR | 11.3 | 2.5 | 24.4 | 49.7 | 11.0 | -12.2 | 21.4 | -55.3 |
| MIROC5 | 12.1 | 3.1 | 27.5 | 43.9 | 16.2 | 3.4 | 6.4 | -18.2 |
| MIROC-ESM | 19.3 | 3.2 | 45.8 | 54.6 | 13.5 | 12.3 | 8.0 | -9.5 |
| MPI-ESM-LR | 16.3 | 10.5 | 50.9 | 37.8 | 22.2 | 11.9 | 10.1 | -26.3 |
| MRI-CGCM3 | 11.9 | 13.4 | 12.8 | 38.2 | 21.8 | 10.1 | 15.6 | -29.7 |
| NorESM1-M | 10.4 | 1.6 | 28.3 | 41.8 | 17.1 | 13.2 | 6.0 | -33.3 |
| MM | 15.8 | 10.5 | 34.3 | 41.9 | 19.1 | 11.2 | 14.1 | -24.7 |
| std | 6.2 | 7.3 | 15.3 | 13.0 | 8.4 | 10.9 | 7.2 | 12.4 |

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271 **Table S8:** RCP8.5, % precipitation change (2070 to 2099) - (1961 to 1990): MAM mean.

272 Regions are defined in Figure 4, except conUS, which represents the lower 48 U.S. states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|-------------|------------|-------------|-------------|-------------|-------------|------------|--------------|
| CanESM2 | 19.2 | 5.8 | 53.6 | 46.1 | 18.6 | 3.6 | 20.3 | -10.7 |
| CCSM4 | 7.9 | 5.9 | 22.1 | 17.5 | 9.6 | 12.4 | 4.2 | -16.1 |
| CNRM-CM5 | 13.2 | 9.2 | 30.0 | 27.1 | 13.7 | 7.8 | 13.6 | -4.2 |
| CSIRO-Mk3-6-0 | 16.4 | 13.4 | 30.2 | 23.6 | 22.0 | 20.2 | 5.7 | -10.7 |
| GFDL-CM3 | 23.5 | 16.1 | 43.9 | 53.5 | 26.0 | 23.1 | 19.6 | -23.7 |
| GFDL-ESM2M | 8.8 | 7.2 | 13.4 | 17.5 | 13.0 | 11.1 | 7.5 | -25.7 |
| GISS-E2-R | 6.7 | 7.6 | 11.5 | 10.8 | 18.0 | 12.7 | 3.6 | -22.1 |
| HadGEM2-ES | 17.8 | 12.8 | 51.4 | 36.8 | 22.7 | 21.5 | 4.1 | -17.3 |
| inmcm4 | 10.7 | 7.9 | 27.4 | 24.8 | 13.3 | 13.8 | 8.5 | -35.4 |
| IPSL-CM5A-LR | 1.5 | -2.9 | 10.4 | 9.0 | 8.2 | -8.0 | 0.1 | -50.7 |
| MIROC5 | 14.0 | 5.9 | 33.7 | 33.5 | 15.6 | 5.3 | 13.7 | -2.7 |
| MIROC-ESM | 20.6 | 13.1 | 33.6 | 41.7 | 16.9 | 19.5 | 14.2 | -2.7 |
| MPI-ESM-LR | 9.9 | 6.2 | 34.9 | 27.8 | 16.4 | 11.2 | 6.3 | -40.4 |
| MRI-CGCM3 | 14.2 | 10.0 | 32.8 | 44.6 | 18.0 | 14.4 | 9.0 | -20.8 |
| NorESM1-M | 9.7 | 7.0 | 24.6 | 18.2 | 18.5 | 16.9 | 5.2 | -25.1 |
| MM | 12.9 | 8.3 | 30.2 | 28.8 | 16.7 | 12.4 | 9.0 | -20.5 |
| std | 5.9 | 4.5 | 13.0 | 13.5 | 4.8 | 8.0 | 6.0 | 13.9 |

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275 **Table S9:** RCP8.5, % precipitation change (2070 to 2099) - (1961 to 1990): JJA mean.
 276 Regions are defined in Figure 4, except conUS, which represents the lower 48 U.S. states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|------------|-------------|-------------|-------------|------------|-------------|-------------|--------------|
| CanESM2 | 2.7 | 8.7 | 26.4 | 6.2 | -1.4 | -3.3 | 17.8 | -22.6 |
| CCSM4 | -2.2 | -3.8 | 22.3 | 2.8 | 6.8 | -5.7 | -8.9 | -24.8 |
| CNRM-CM5 | 5.9 | 2.7 | 24.4 | 12.3 | 4.7 | 1.7 | 2.8 | -6.7 |
| CSIRO-Mk3-6-0 | -0.3 | 2.7 | 16.0 | 7.9 | 17.7 | 4.7 | -13.5 | -17.7 |
| GFDL-CM3 | 9.2 | 0.8 | 55.1 | 12.5 | 5.4 | 7.4 | 4.2 | -12.1 |
| GFDL-ESM2M | 3.0 | -2.0 | 9.7 | 9.2 | 1.8 | 0.7 | -3.2 | 1.9 |
| GISS-E2-R | -0.1 | -4.7 | 17.1 | 12.3 | 0.6 | 2.5 | -9.7 | -6.8 |
| HadGEM2-ES | -9.6 | -20.2 | 14.6 | 3.1 | -10.3 | -23.9 | -19.0 | -25.8 |
| inmcm4 | 0.1 | -7.8 | 32.4 | 14.2 | 4.2 | -8.3 | -10.1 | -30.1 |
| IPSL-CM5A-LR | -4.5 | -11.3 | 21.8 | 2.9 | 1.2 | -10.6 | -14.2 | -37.8 |
| MIROC5 | -2.1 | -5.3 | 11.5 | 12.3 | 6.3 | -13.8 | -6.1 | -15.0 |
| MIROC-ESM | 3.3 | -10.0 | 29.9 | 18.8 | -3.3 | -16.7 | -0.9 | -11.3 |
| MPI-ESM-LR | 0.2 | -1.9 | 18.1 | 9.2 | 3.2 | 2.3 | -6.0 | -16.2 |
| MRI-CGCM3 | 10.5 | 3.3 | 37.2 | 23.4 | 6.2 | 7.2 | 2.3 | 2.5 |
| NorESM1-M | -0.2 | -3.0 | 20.0 | 9.3 | 10.4 | -12.0 | 2.7 | -26.1 |
| MM | 1.1 | -3.5 | 23.8 | 10.4 | 3.6 | -4.5 | -4.1 | -16.6 |
| std | 5.1 | 7.1 | 11.6 | 5.8 | 6.3 | 9.4 | 9.3 | 11.5 |

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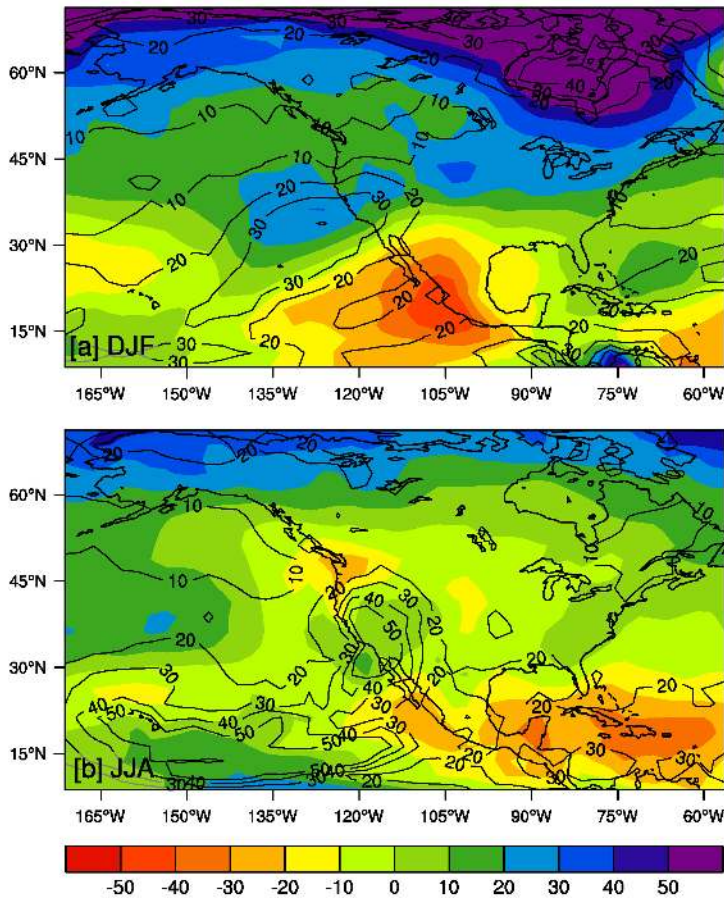
279 **Table S10:** RCP8.5, % precipitation change (2070 to 2099) - (1961 to 1990): SON mean.
 280 Regions are defined in Figure 4, except conUS, which represents the lower 48 U.S. states.

| Model Name | NA | conUS | ALA | NEC | ENA | CNA | WNA | CAM |
|---------------|-------------|------------|-------------|-------------|------------|------------|------------|-------------|
| CanESM2 | 18.7 | 11.4 | 54.7 | 29.1 | 2.9 | 12.6 | 21.9 | -7.4 |
| CCSM4 | 10.7 | 8.6 | 28.5 | 16.4 | 9.1 | 15.3 | 9.3 | -6.9 |
| CNRM-CM5 | 13.9 | 9.3 | 25.4 | 22.9 | 7.1 | 7.6 | 14.2 | 5.5 |
| CSIRO-Mk3-6-0 | 9.3 | 5.5 | 32.3 | 17.3 | 18.0 | 1.0 | 10.1 | -16.3 |
| GFDL-CM3 | 15.6 | -0.8 | 47.1 | 32.5 | 1.2 | 1.0 | 6.0 | 12.5 |
| GFDL-ESM2M | 13.9 | -2.0 | 23.1 | 24.8 | 4.4 | -4.3 | 2.2 | 28.3 |
| GISS-E2-R | 6.9 | 6.6 | 19.1 | 15.2 | 16.3 | 9.9 | 4.7 | -10.3 |
| HadGEM2-ES | 17.2 | 4.9 | 45.5 | 31.4 | 5.1 | 8.5 | 9.2 | 11.7 |
| inmcm4 | 0.1 | -13.0 | 24.0 | 10.4 | -8.2 | -14.4 | -0.7 | -18.6 |
| IPSL-CM5A-LR | 11.4 | -0.9 | 36.4 | 31.0 | 5.8 | 6.8 | 2.2 | -21.9 |
| MIROC5 | 11.9 | -0.6 | 31.9 | 27.6 | 14.6 | -4.8 | 4.3 | 6.3 |
| MIROC-ESM | 16.3 | 5.2 | 38.4 | 28.7 | 2.3 | 5.2 | 12.9 | 14.5 |
| MPI-ESM-LR | 17.4 | 5.4 | 42.7 | 30.3 | 16.5 | 7.3 | 4.7 | 8.2 |
| MRI-CGCM3 | 10.8 | 4.0 | 25.7 | 20.5 | 13.2 | 3.3 | 2.2 | 10.1 |
| NorESM1-M | 8.0 | 1.9 | 30.3 | 22.7 | 12.5 | 1.4 | 8.1 | -18.9 |
| MM | 12.1 | 3.0 | 33.7 | 24.1 | 8.1 | 3.8 | 7.4 | -0.2 |
| std | 4.9 | 6.0 | 10.2 | 6.9 | 7.2 | 7.6 | 5.8 | 15.1 |

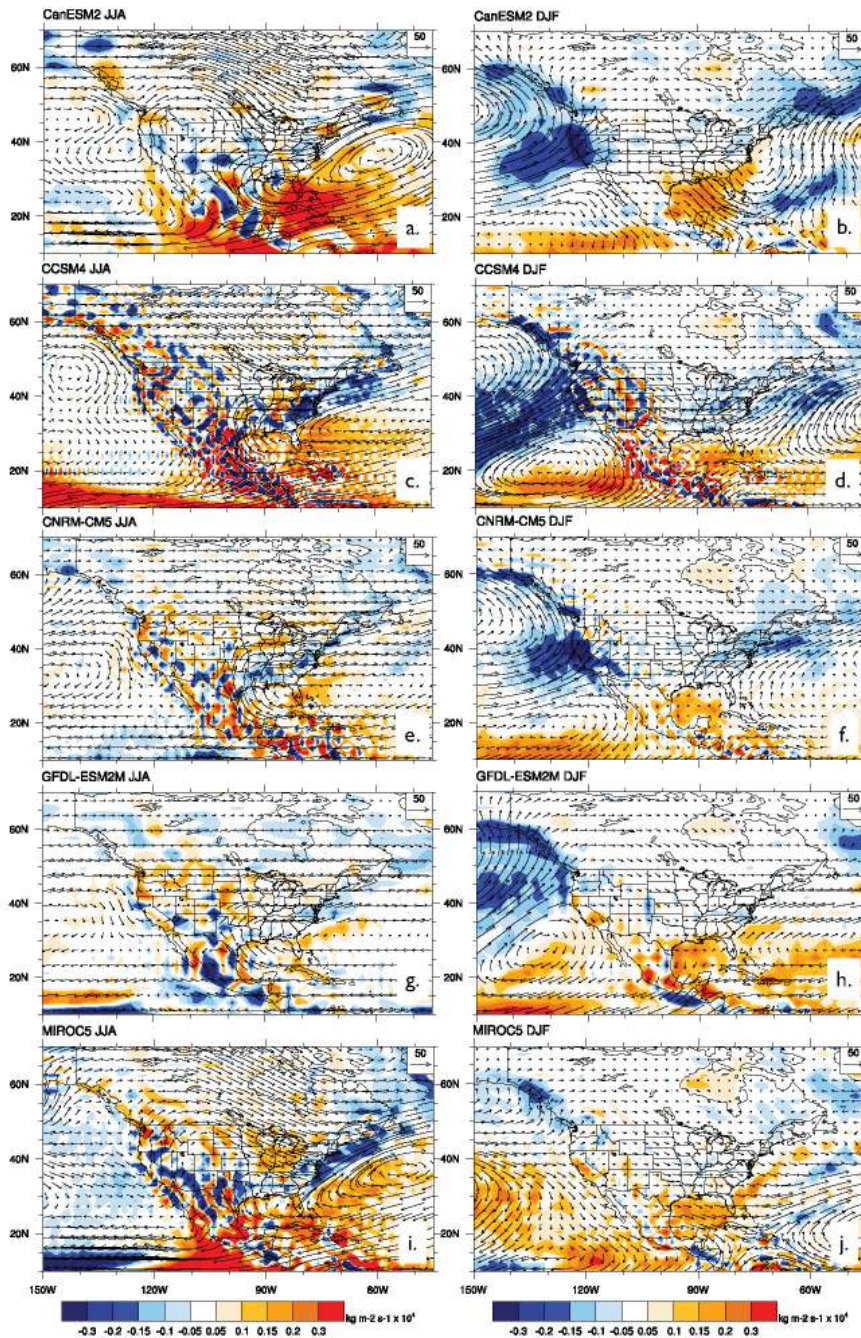
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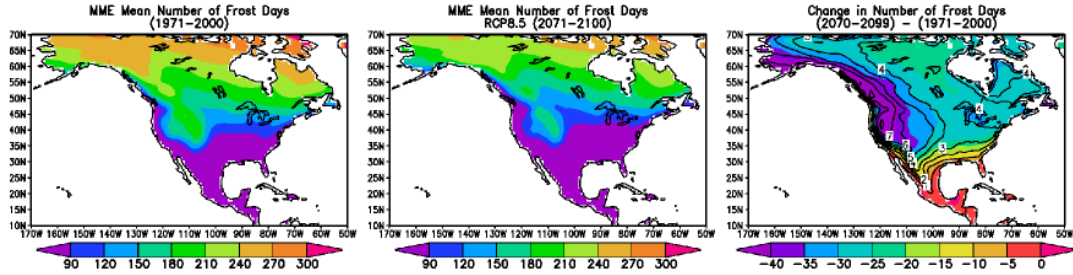


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 286 **Figure S1.** CMIP5 16 member MEM percentage precipitation change (colors) and
 287 standard deviation of percent precipitation change (contours) for RCP8.5 for 2070-
 288 2099 relative to 1901-1960 base period for December-February (DJF) and June-
 289 August (JJA). Models used: BCC-ESM-1, CanESM2, CCSM4, CNRM-CM5, CSIRO-Mk3-
 290 6-0, GFDL-CM3, GFDL-ESM2M, GISS-E2-R, HadGEM2-ES, INMCM4, IPSL-CM5A-LR,
 291 MIROC5, MIROC-ESM, MPI-ESM-LR, MRI-CGCM3, NORESM1-M.
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Figure S2. MEM difference in JJA (left) and DJF (right) moisture transport integrated vertically to 500 hPa (VIMT shown as vectors, Kg/ms), and moisture divergence (color contours, Kg/m²s x10⁴) computed from five coupled models for 2081-2100 from RCP8.5 minus 1981-2000 the historical experiments. The models used are CanESM2, CCSM4, CNRM-CM5, GFDL-ESM2M, and MIROC5, for which one realization of the required 6-hourly fields were available. This figure should be compared with the corresponding analysis from Sheffield et al. 2013a.

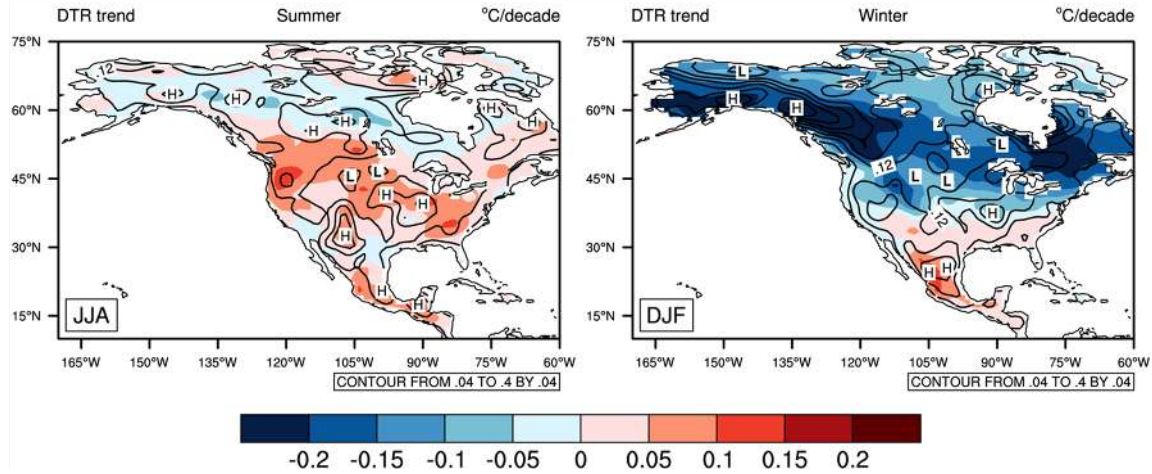


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Figure S3. Projected MEM changes in number of frost days (upper right) for 14 core CMIP5 models (BCC-CSM1-1, CanESM2, CCSM4, CSIRO-Mk3-6-0, GFDL-CM3, GFDL-ESM2M, HadGEM2-ES, INMCM4, IPSL-CM5A-LR, MIROC5, MIROC-ESM, MRI-CGCM3, MPI-ESM-LR, NorESM1-M; all single ensemble member r1i1p1) for RCP8.5. Multimodel standard deviations are also plotted in contours. Also shown in the center and left panels are the MEM frost days for the historical runs (1971-2000) and RCP8.5 (2071-2100). Changes are calculated as the difference between the mean for 2071-2100 and 1971-2000. Frost days are calculated as the annual number of days with T_{\min} less than 0°C (Frick et al., 2002). Values were calculated on the model grid, interpolated to 2.0° resolution and then averaged over 1979-2005 for the "historical" and 2071-2100 for the RCP8.5 scenario.

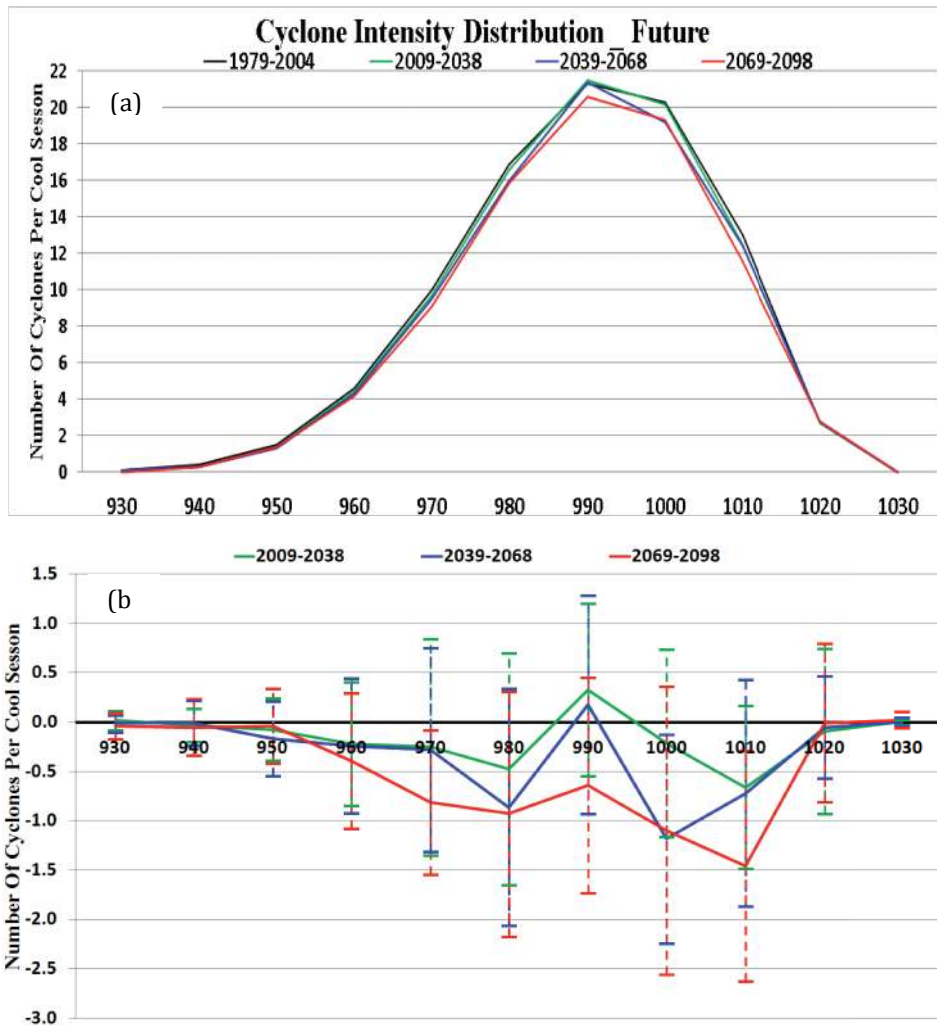
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Trend of Diurnal Temperature Range during 2006-2055



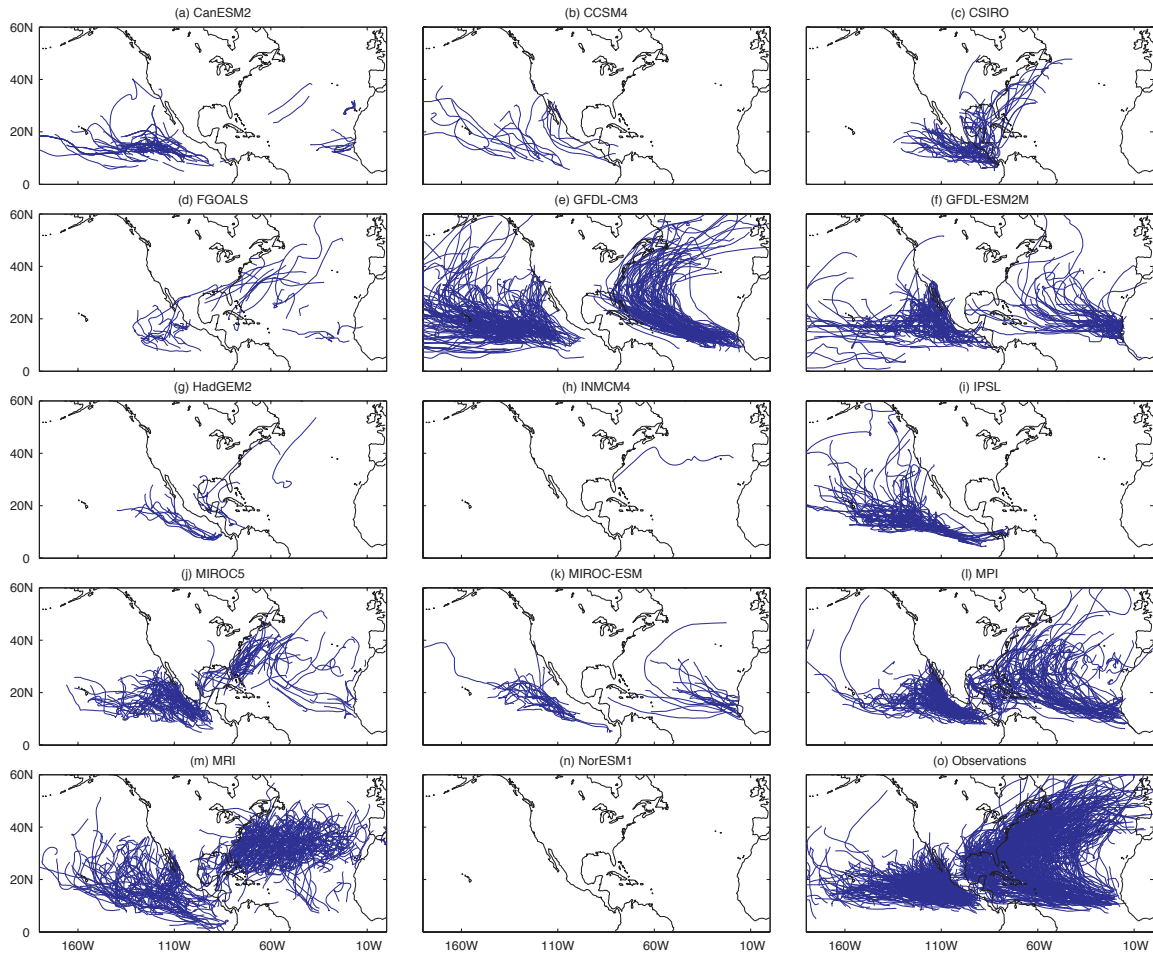
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Figure S4. Trend of diurnal temperature range ($T_{\max} - T_{\min}$) during 2006-2055 averaged among 16 core models' first member (r1irp1) in the RCP4.5 experiment. The contours are the inter-model standard deviation of the trend.



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Figure S5. (a) Number of cyclone central pressures at their maximum intensity for the 1979-2004 cool seasons within the dashed box region in Fig. 10a for a 10 hPa range centered every 10 hPa showing the mean historical (black), 2009-2038 (green), 2038-2068 (blue), and 2068-2098 (red) years for 15 CMIP5 models. (b) Same as (a) except the difference and standard deviation between three future periods and the historical 1979-2004 period.

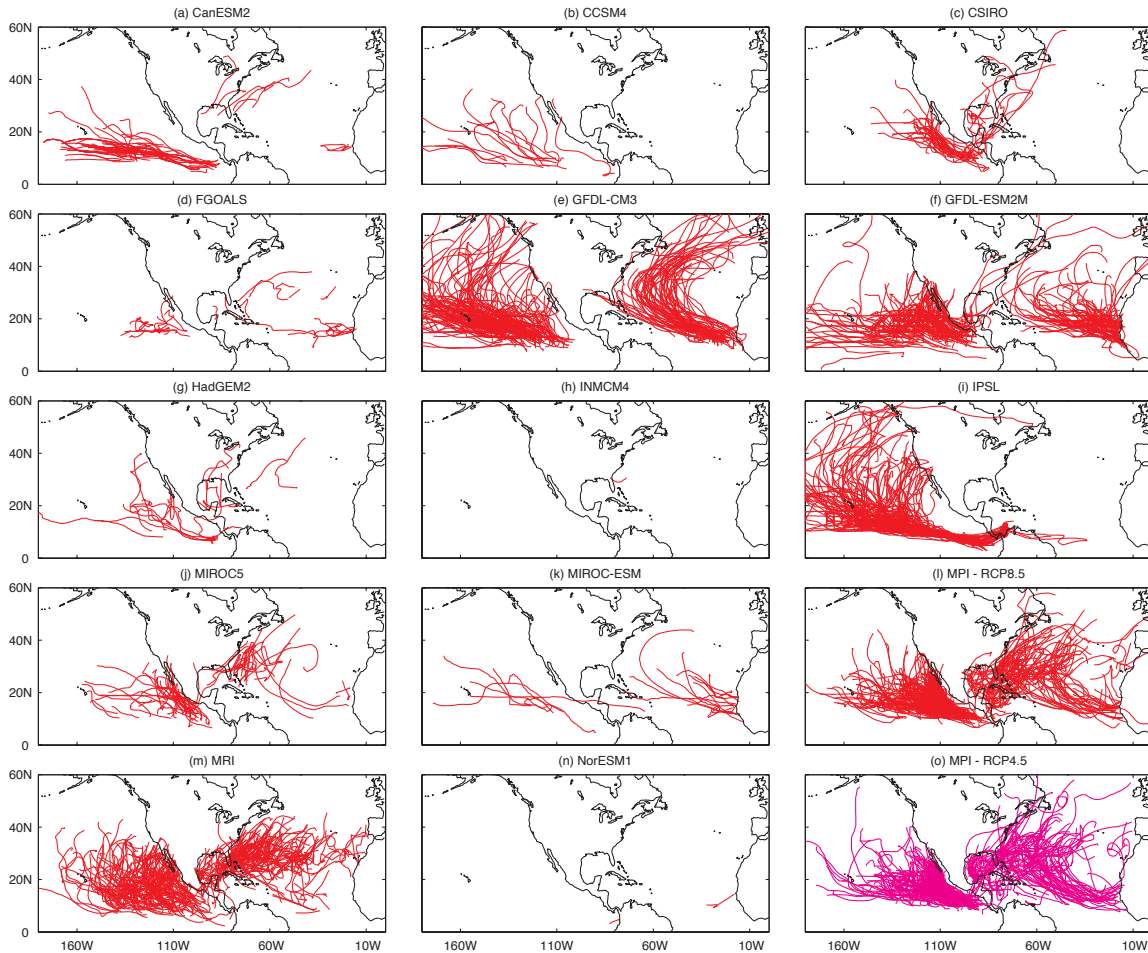


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358 **Figure S6:** Tracks of model tropical cyclones in 14 CMIP5 core models in the historical runs
 359 and in observations in the period 1951-2000 in the eastern north Pacific and north Atlantic
 360 basins.

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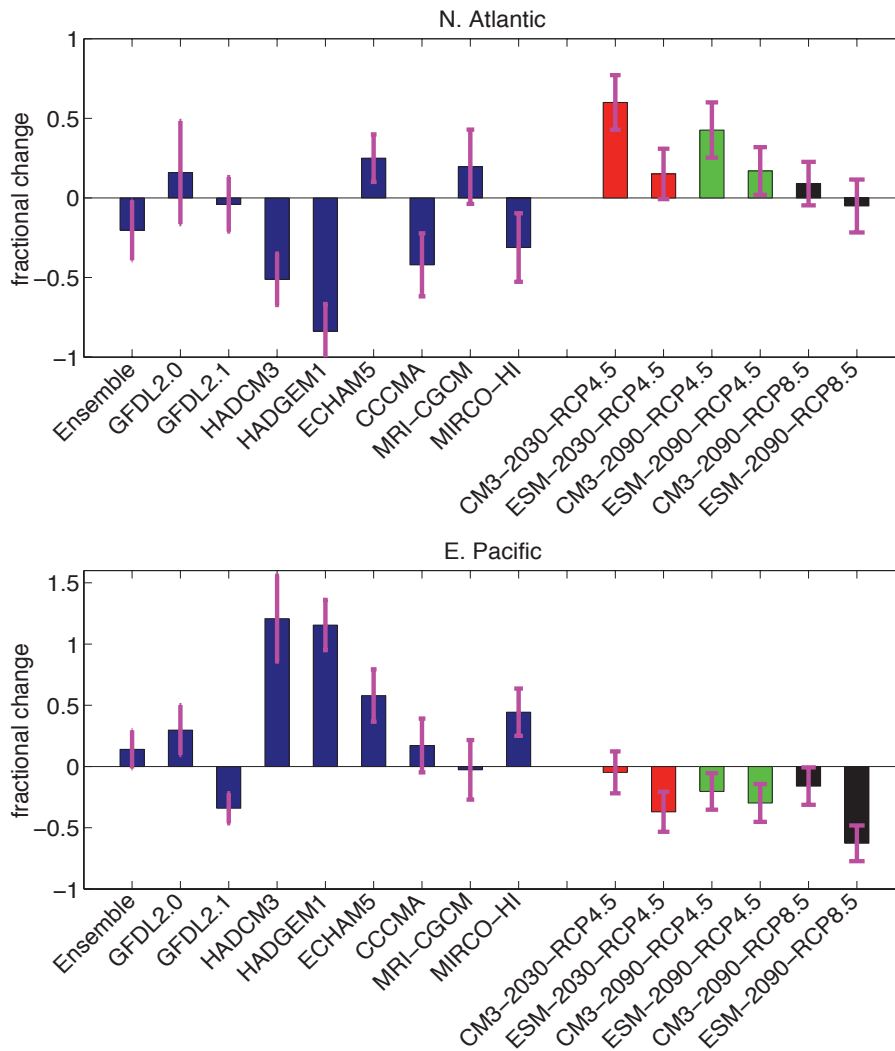


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364 **Figure S7:** Tracks of model tropical cyclones in 14 core CMIP5 models in the RCP8.5
 365 scenario in the period 2051-2100 in the eastern north Pacific and north Atlantic basins. In
 366 the case of the MPI model, the tracks for the RCP4.5 scenario are also shown.

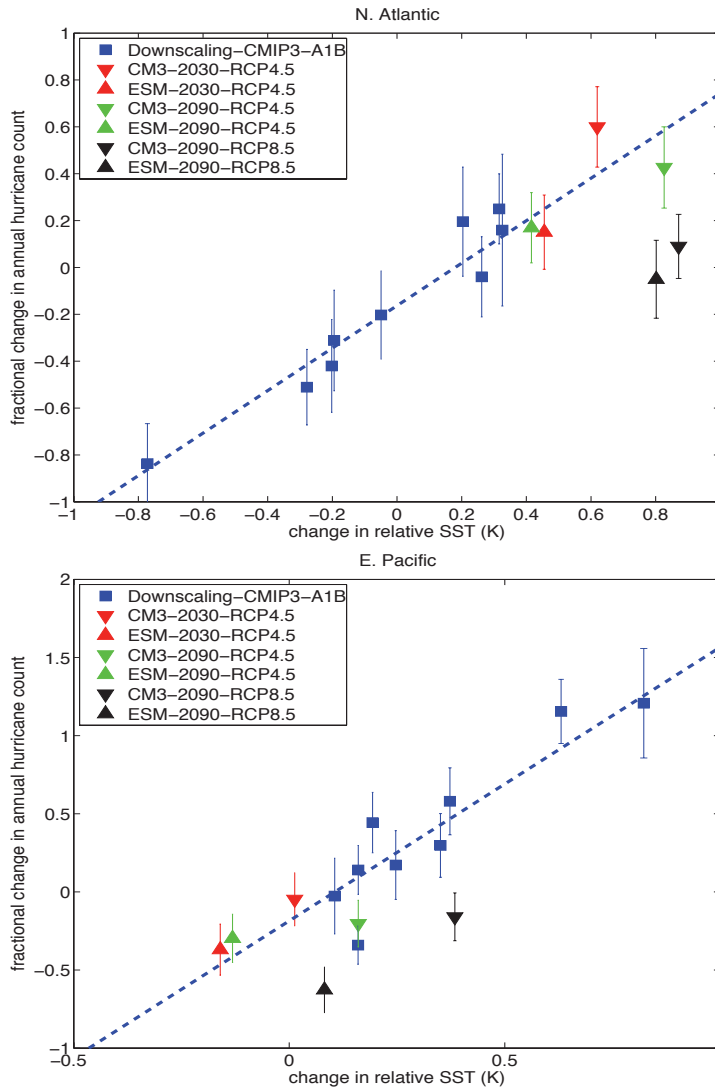
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370 **Figure S8.** a) Fractional change in N. Atlantic hurricanes frequency downscaled
 371 using the GFDL C180HIRAM. Blue bars show results using the CMIP3 models
 372 projected SST warming anomalies (and their ensemble mean) at the late 21st
 373 century (2080-2100 relative to 2000-2020) for the A1B scenario. The control
 374 experiment was integrated for 20 years while most of the warming experiments
 375 were carried out for 10 years due to constraints of computer time. Red, green and
 376 black bars show results using GFDL CMIP5 model (CM3 and ESM) projected SST
 377 warming anomalies (CM3-2030-RCP4.5 and ESM-2030-RCP4.5: 2026-2035
 378 averaged SST anomalies from CM3 and ESM RCP4.5 experiments with radiative
 379 gases at RCP4.5 2026-2035 values. CM3-2090-RCP4.5 and ESM-2090-RCP4.5: 2086-
 380 2095 averaged SST anomalies from CM3 and ESM RCP4.5 experiments with
 381 radiative gases at RCP4.5 2085-2095 values. CM3-2090-RCP8.5 and ESM-2090-
 382 RCP8.5: As in CM3-2090-RCP4.5 and ESM-2090-RCP4.5 experiments except using
 383 RCP8.5 model projected SST anomalies with

384 radiative gases at RCP8.5 2086-2095 values. The GFDL C180HIRAM present-day
385 experiments contain a 3-member ensemble simulation for the period of 1981 to
386 2008. The CMIP5 SST anomalies are computed relative to 1981-2008 average. b) As
387 in a) except for the E. Pacific.
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Figure S9. a) the fractional change in N. Atlantic hurricane frequency against changes in a relative SST index defined as the Atlantic Main Development Region (MDR) [80°W-20°W, 10°N-25°N] SST minus tropical mean [30S-30N] SST in ASO season. b) As in a) except for the E. Pacific, the E. Pacific Main Development Region is defined as [160°W-100°W, 7.5°N-15°N].