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## Supplemental Material

*Journal of Climate*

Future Changes in the Intensity and Duration of Marine Heat and Cold Waves: Insights from  
Coupled Model Initial-Condition Large Ensembles

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**Supplemental Materials**

**“Future changes in the Intensity and Duration of Marine Heat and Cold Waves:  
Insights from Coupled Model Initial-Condition Large Ensembles”**

Clara Deser<sup>1,\*</sup>, Adam S. Phillips<sup>1</sup>, Michael. A. Alexander<sup>2</sup>, Dillon J. Amaya<sup>2</sup>, Antonietta  
Capotondi<sup>2,3</sup>, Michael G. Jacox<sup>2,4,5</sup> and James D. Scott<sup>2,3</sup>

1 National Center for Atmospheric Research, Boulder CO

2 NOAA Physical Sciences Laboratory, Boulder CO

3 CIRES, University of Colorado, Boulder, CO

4 NOAA Southwest Fisheries Science Center, Monterey, CA

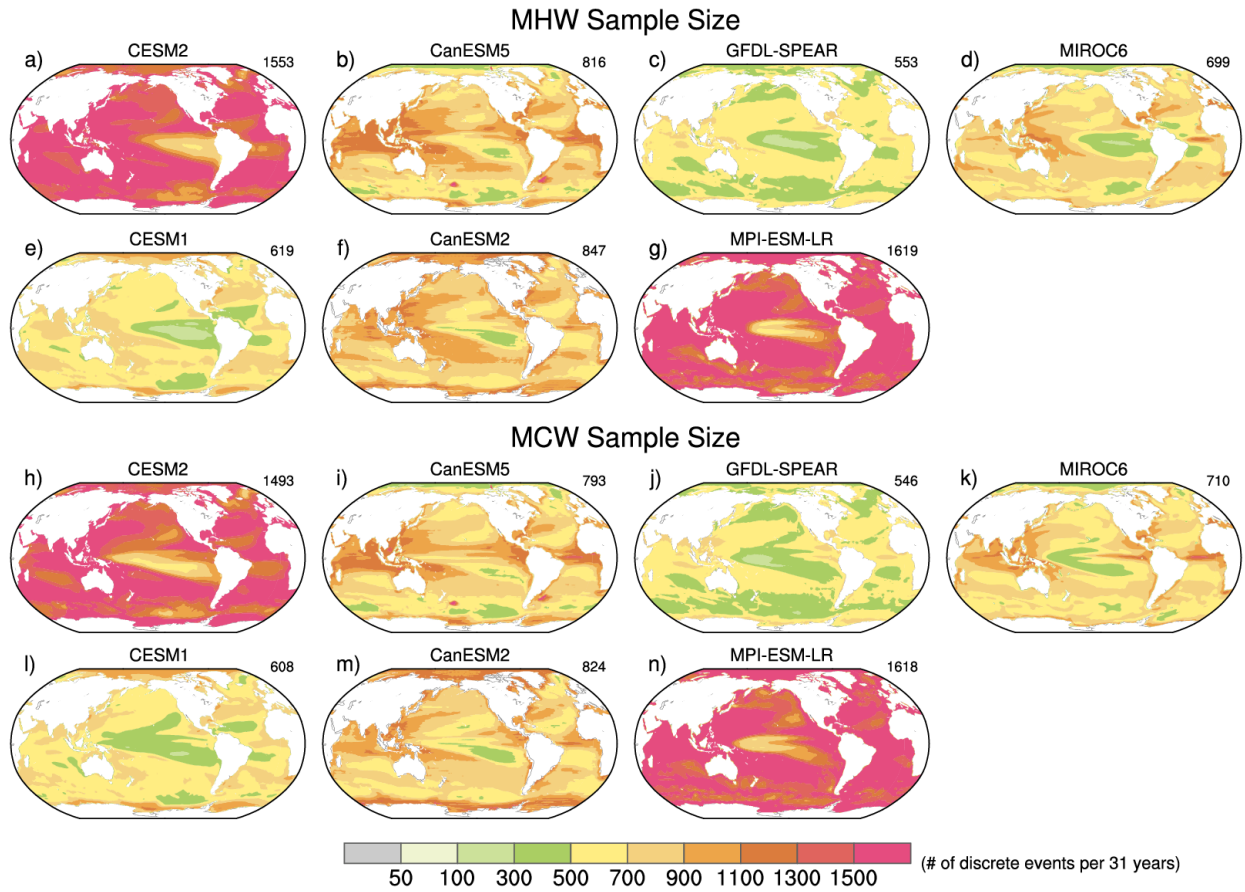
5 University of California Santa Cruz, Santa Cruz, CA

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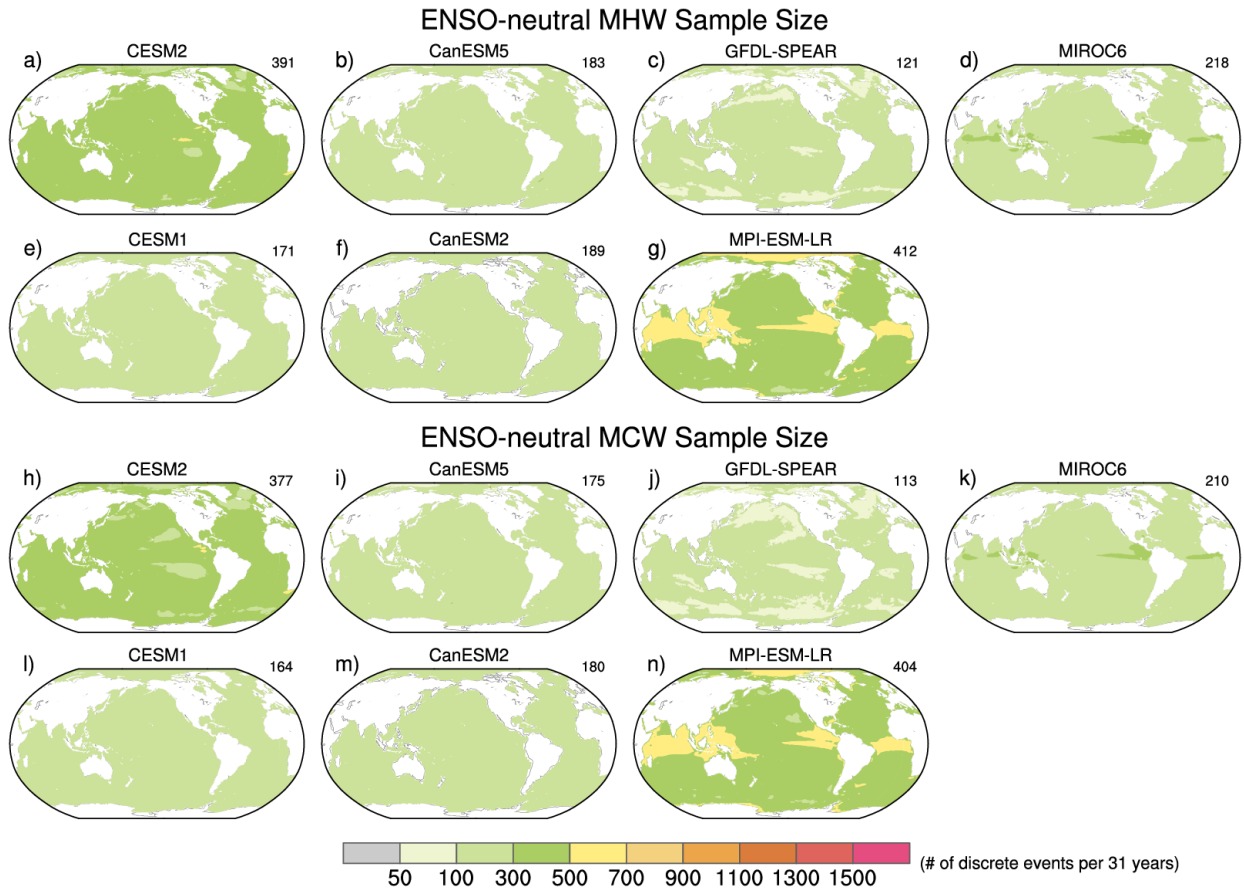
Revised October 8, 2023

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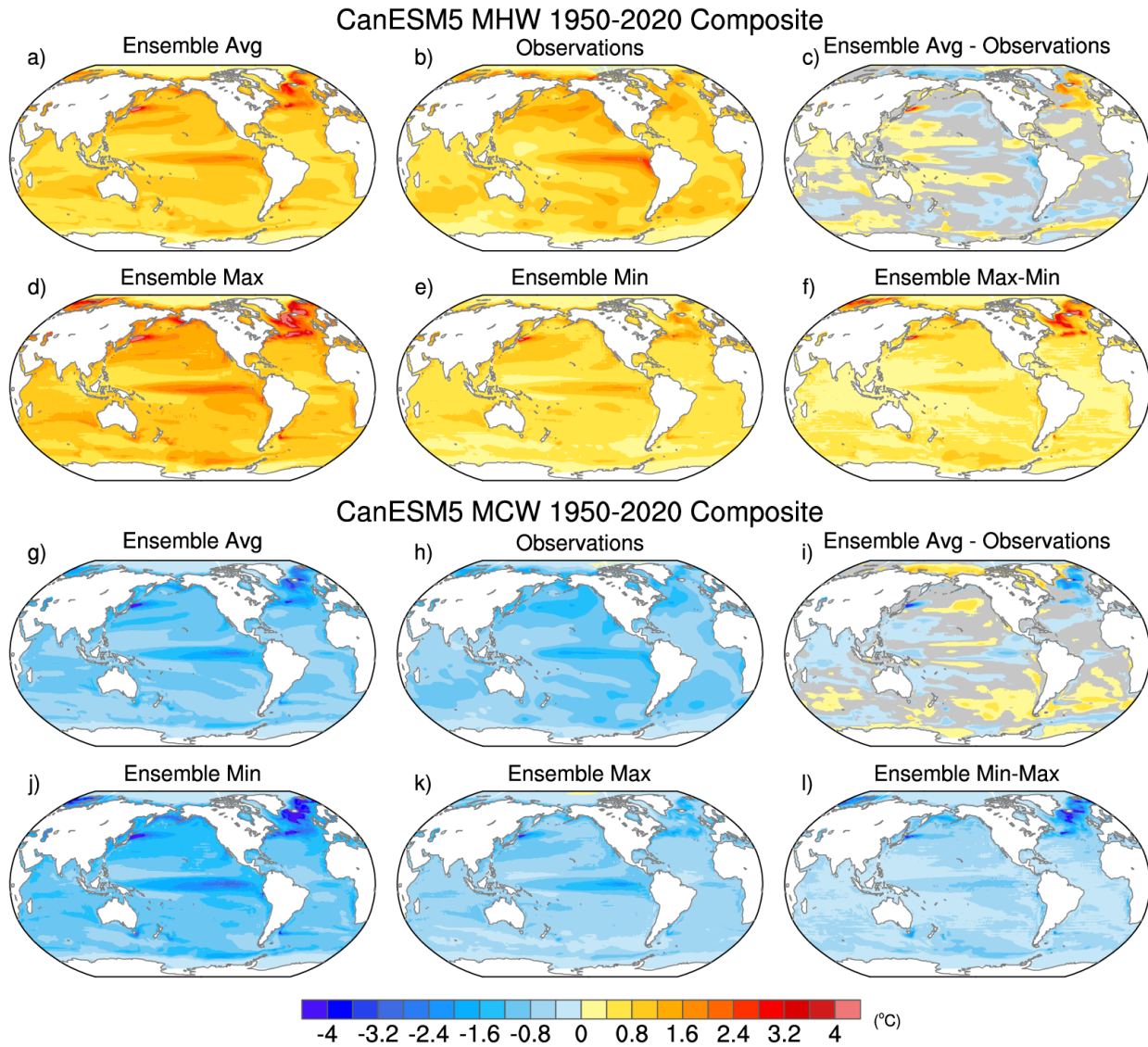
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**Figure S1.** Number of discrete MHW and MCW events per 31 years (average of 1970-2000, 2020-2050 and 2070-2100). (a,g) CESM2; (b,h) CanESM5; (c,i) GFDL-SPEAR; (d,j) MIROC6; (e,k) CESM1; (f,l) CanESM2; (g,o) MPI-ESM-LR. The number in the upper right of each panel denotes the average value over the global ocean.



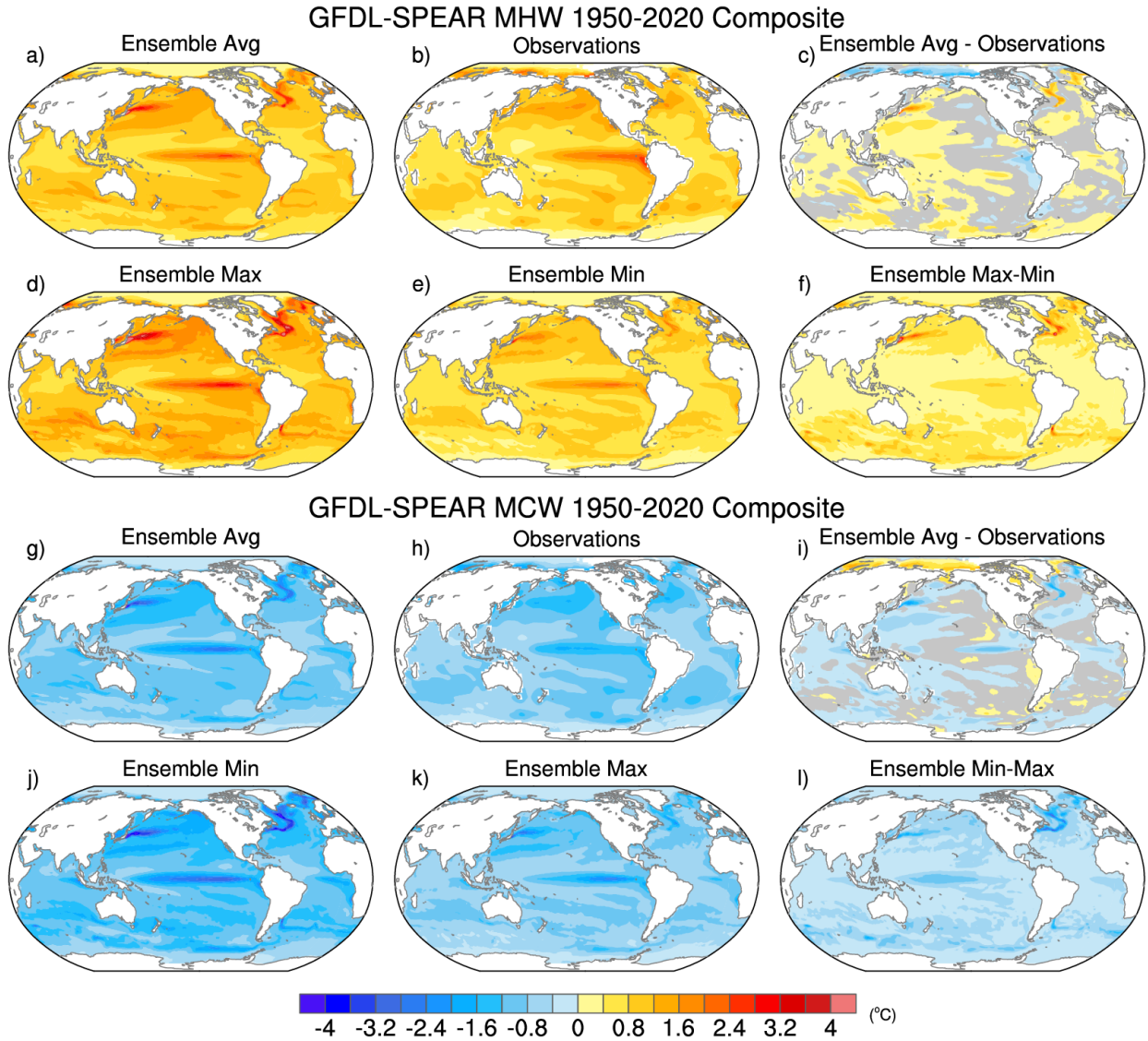
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**Figure S2.** As in Fig. S1 but for ENSO-neutral events.



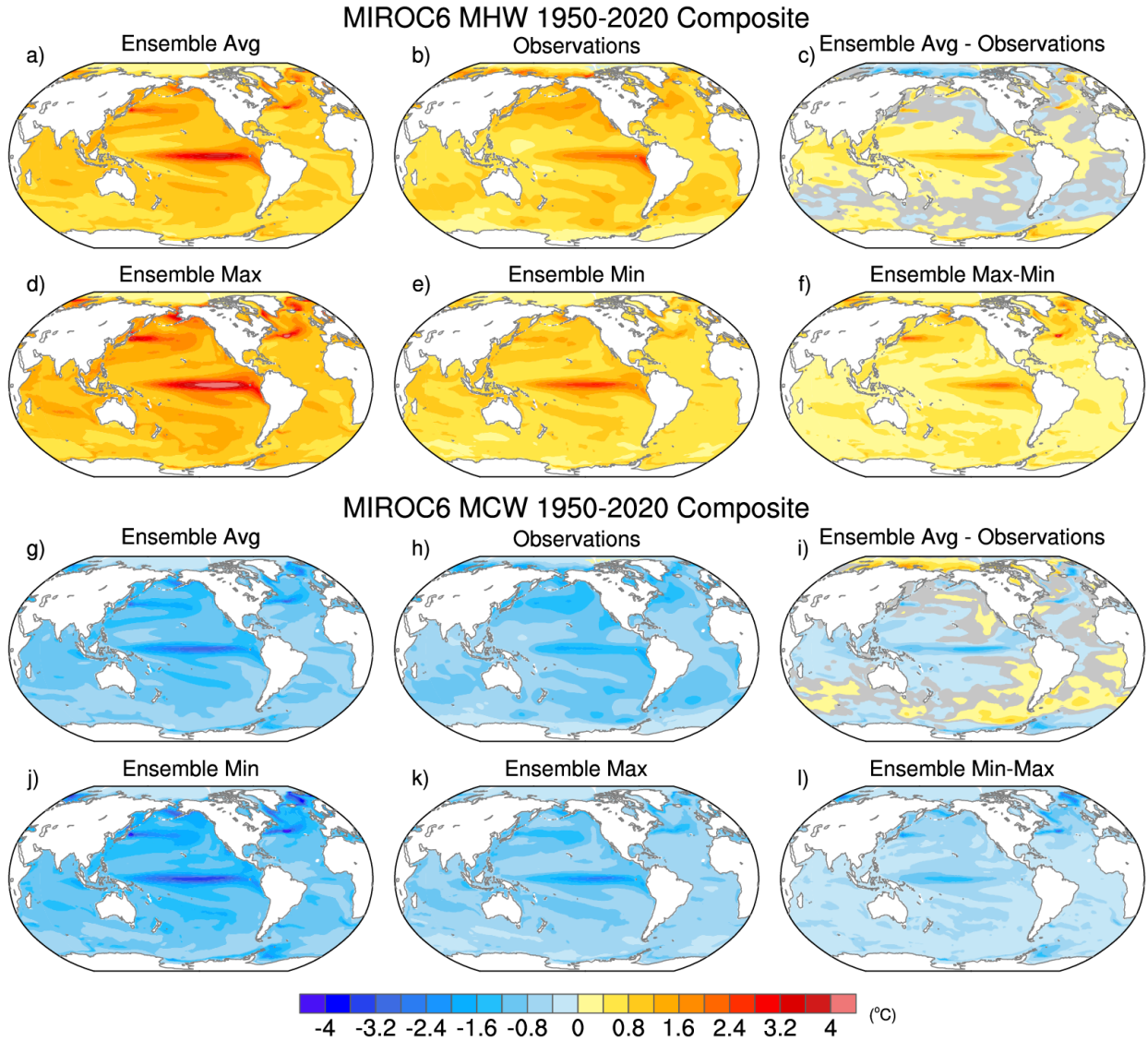
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**Figure S3.** Composite MHW and MCW intensity (°C) during 1950-2020 from the 50-member CanESM5 Large Ensemble and Observations. (a,g) Ensemble average; (b,h) Observations; (c,i) Ensemble average minus Observations; (d,j) Ensemble maximum; (e,k) Ensemble minimum; (f,l) Ensemble maximum minus minimum. Gray shading in (c,i) indicates that observations lie within the 5<sup>th</sup>-95<sup>th</sup> percentile range of the CanESM5 Large Ensemble.



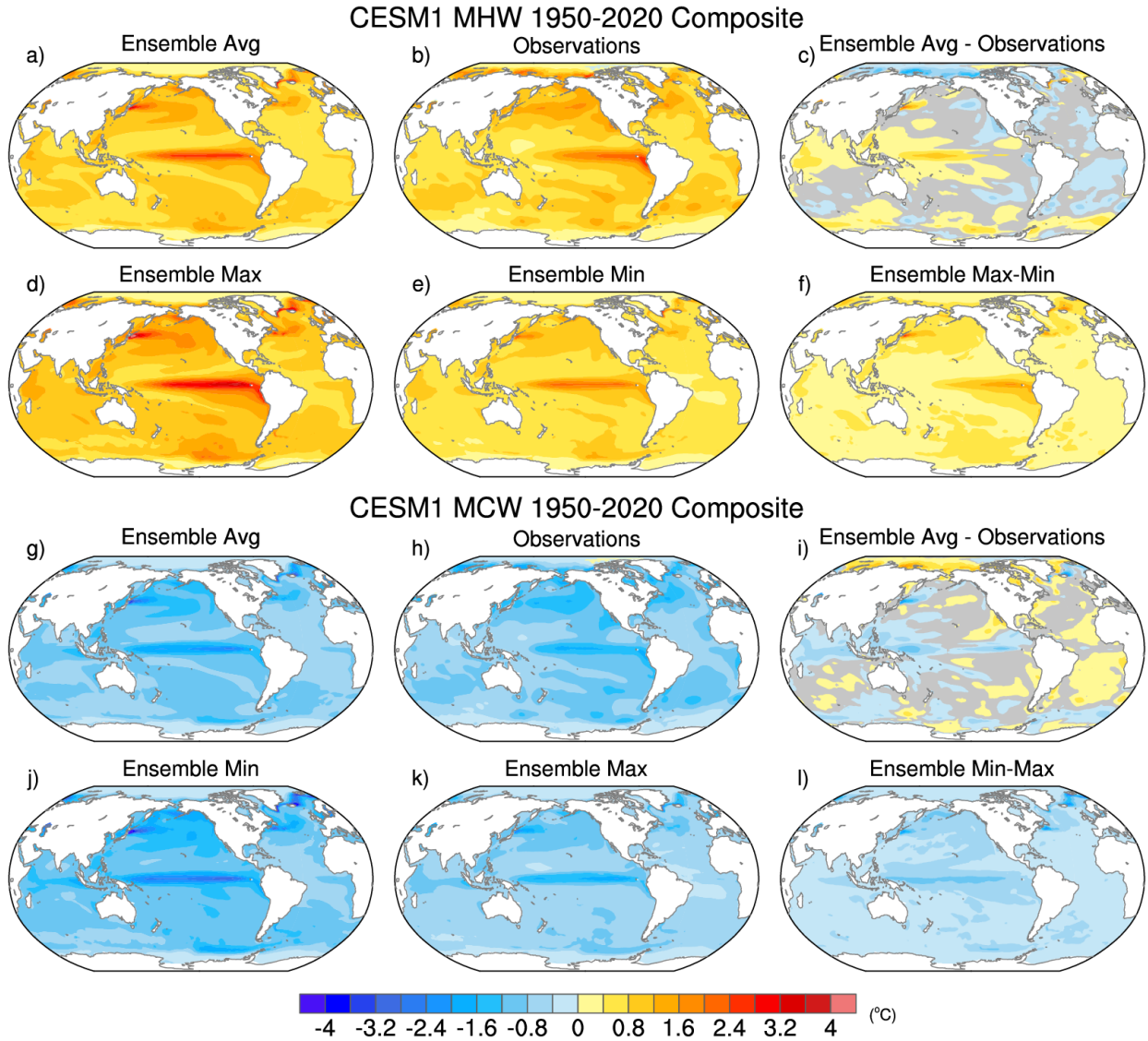
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**Figure S4.** As in Fig. S3 but for the 30-member GFDL-SPEAR Large Ensemble.



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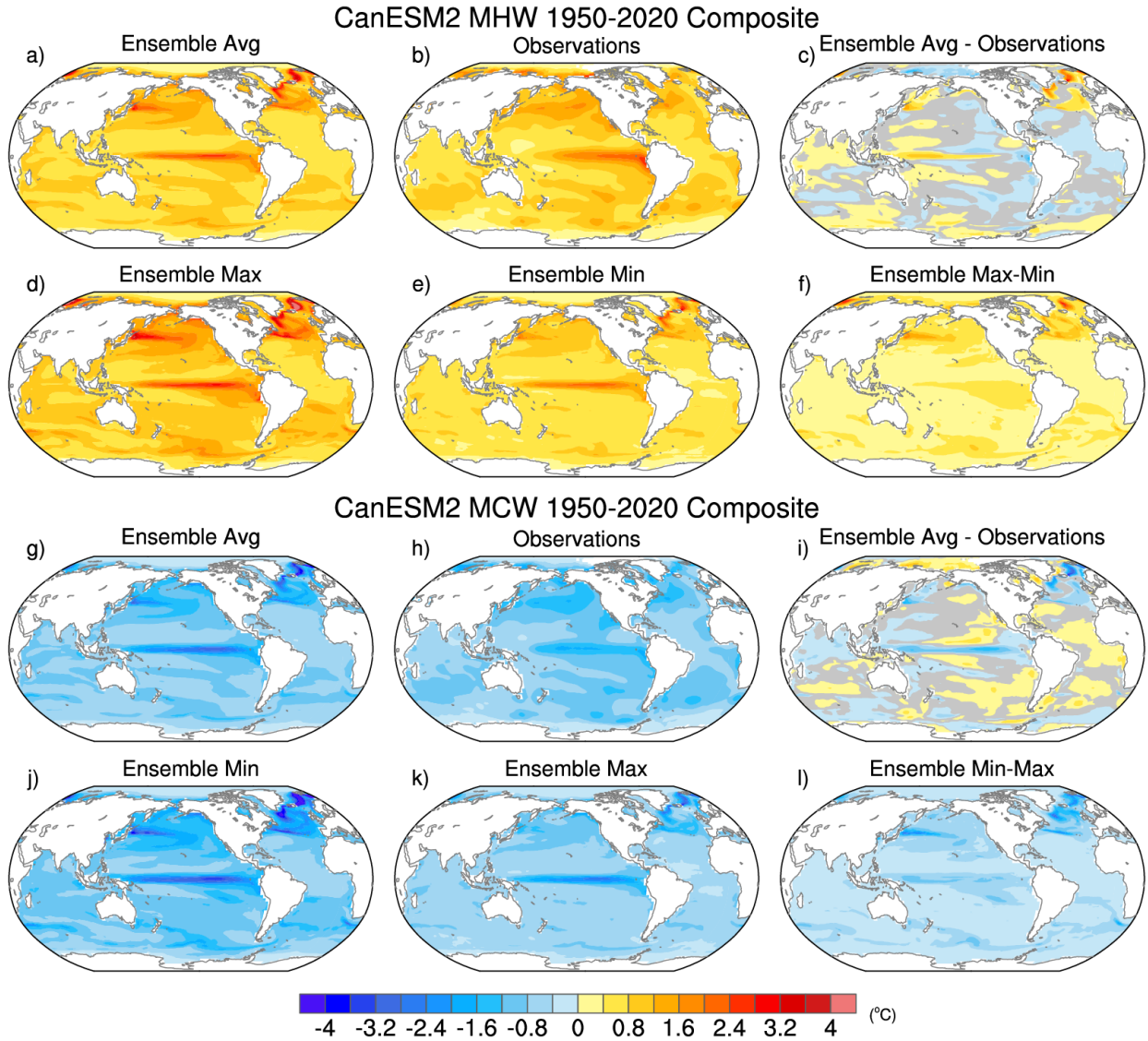
**Figure S5.** As in Fig. S3 but for the 50-member MIROC6 Large Ensemble.



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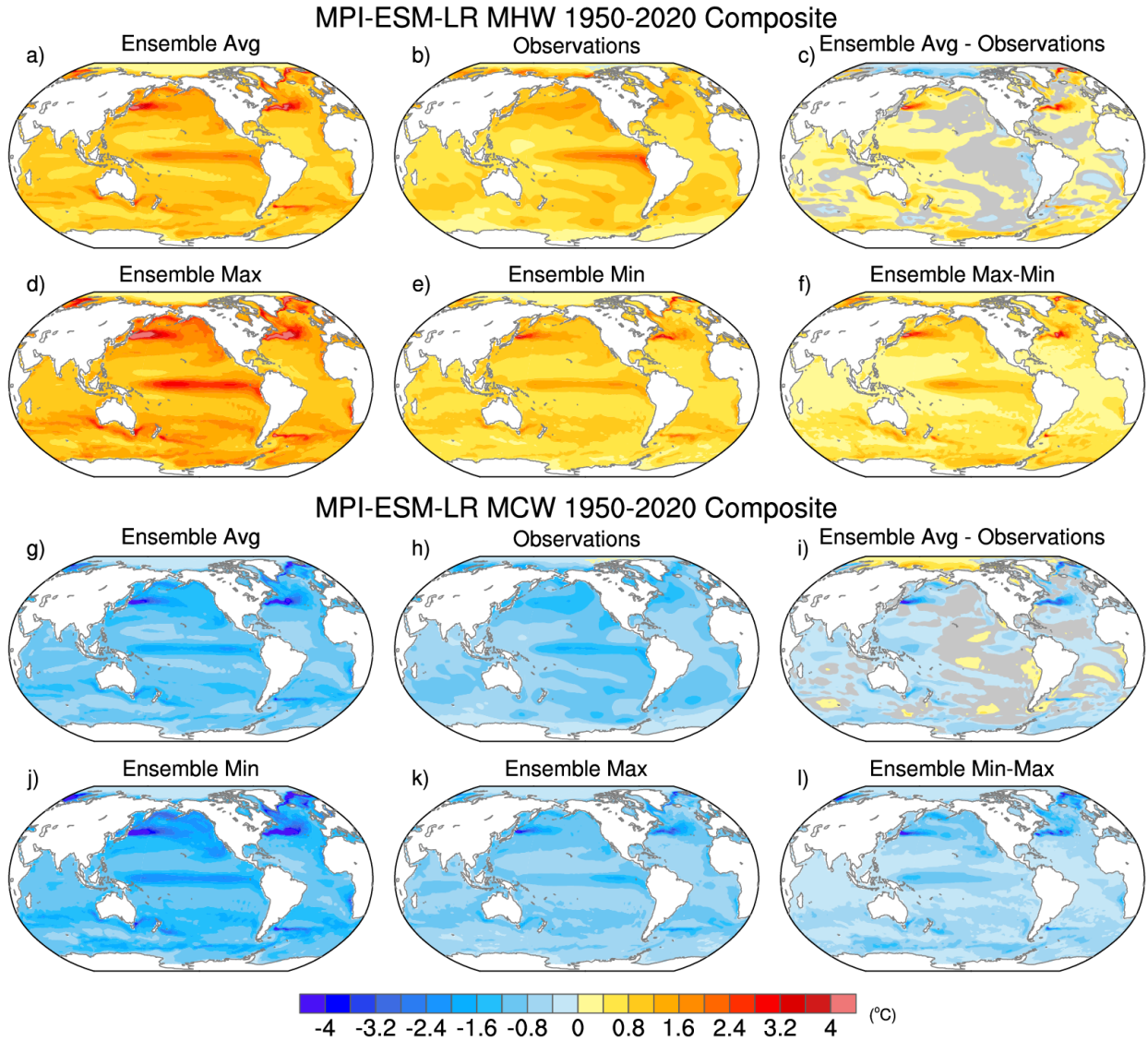
**Figure S6.** As in Fig. S3 but for the 40-member CESM1 Large Ensemble.





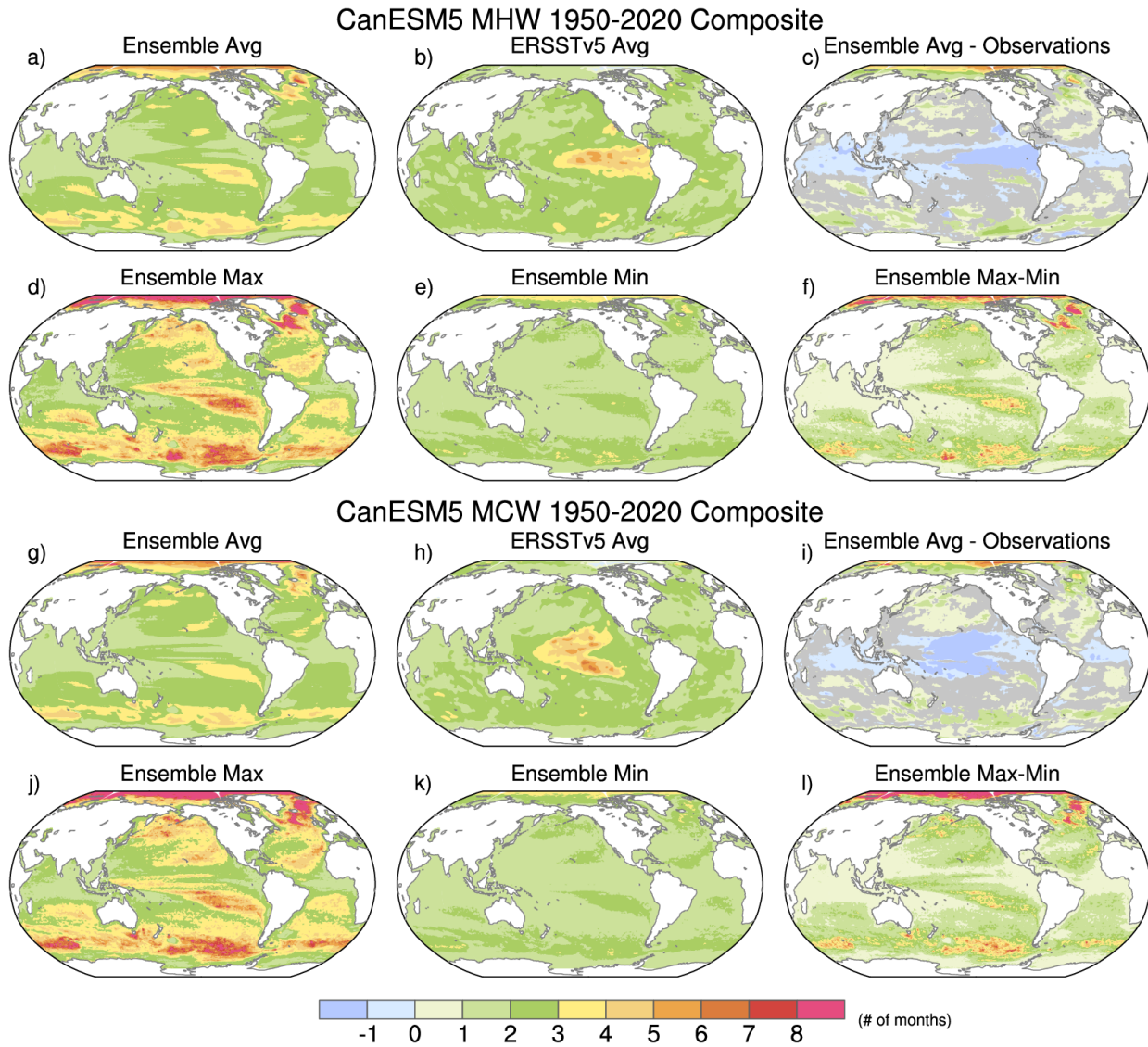
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**Figure S7.** As in Fig. S3 but for the 50-member CanESM2 Large Ensemble.



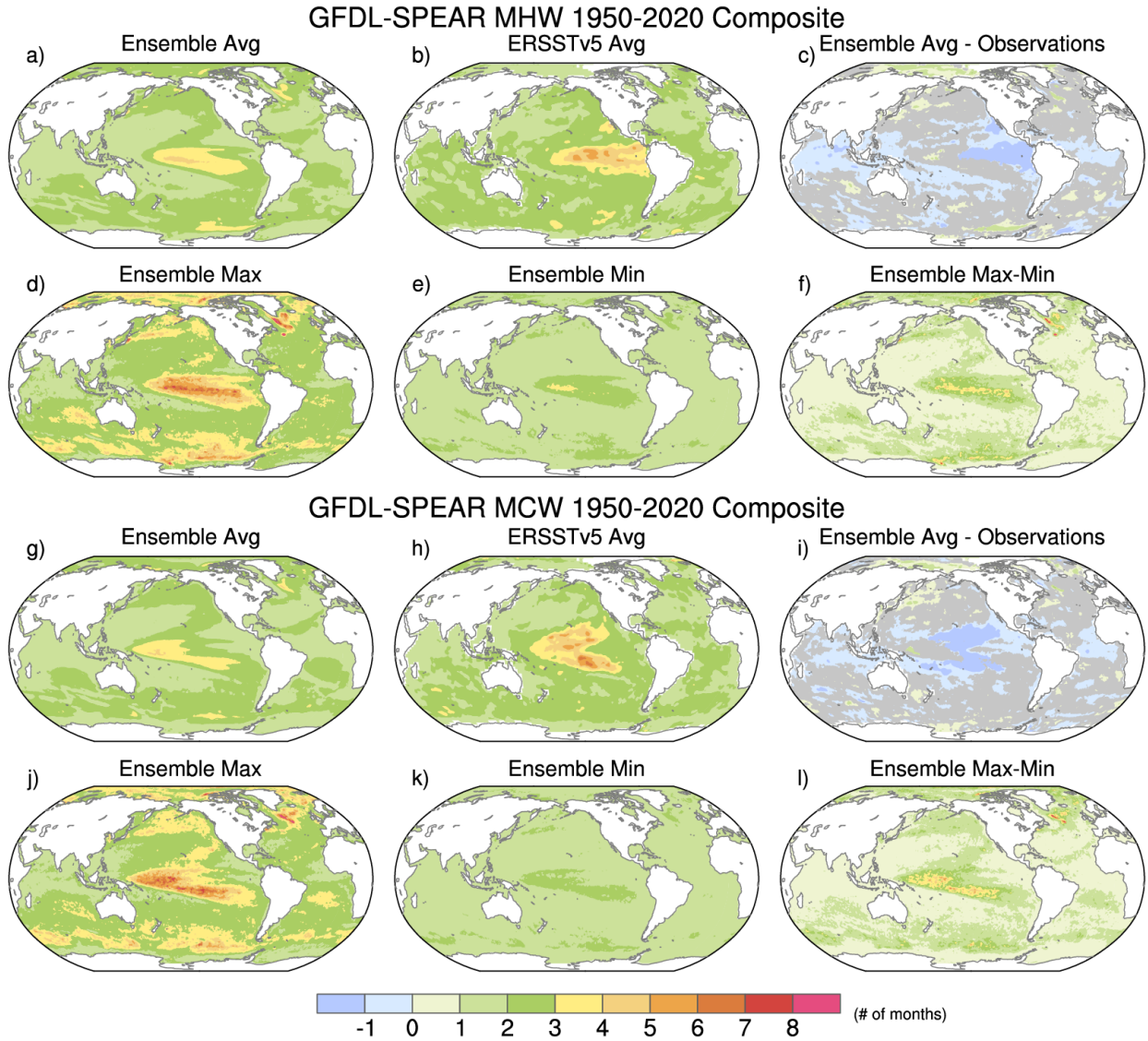
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**Figure S8.** As in Fig. S3 but for the 100-member MPI-ESM-LR Large Ensemble.



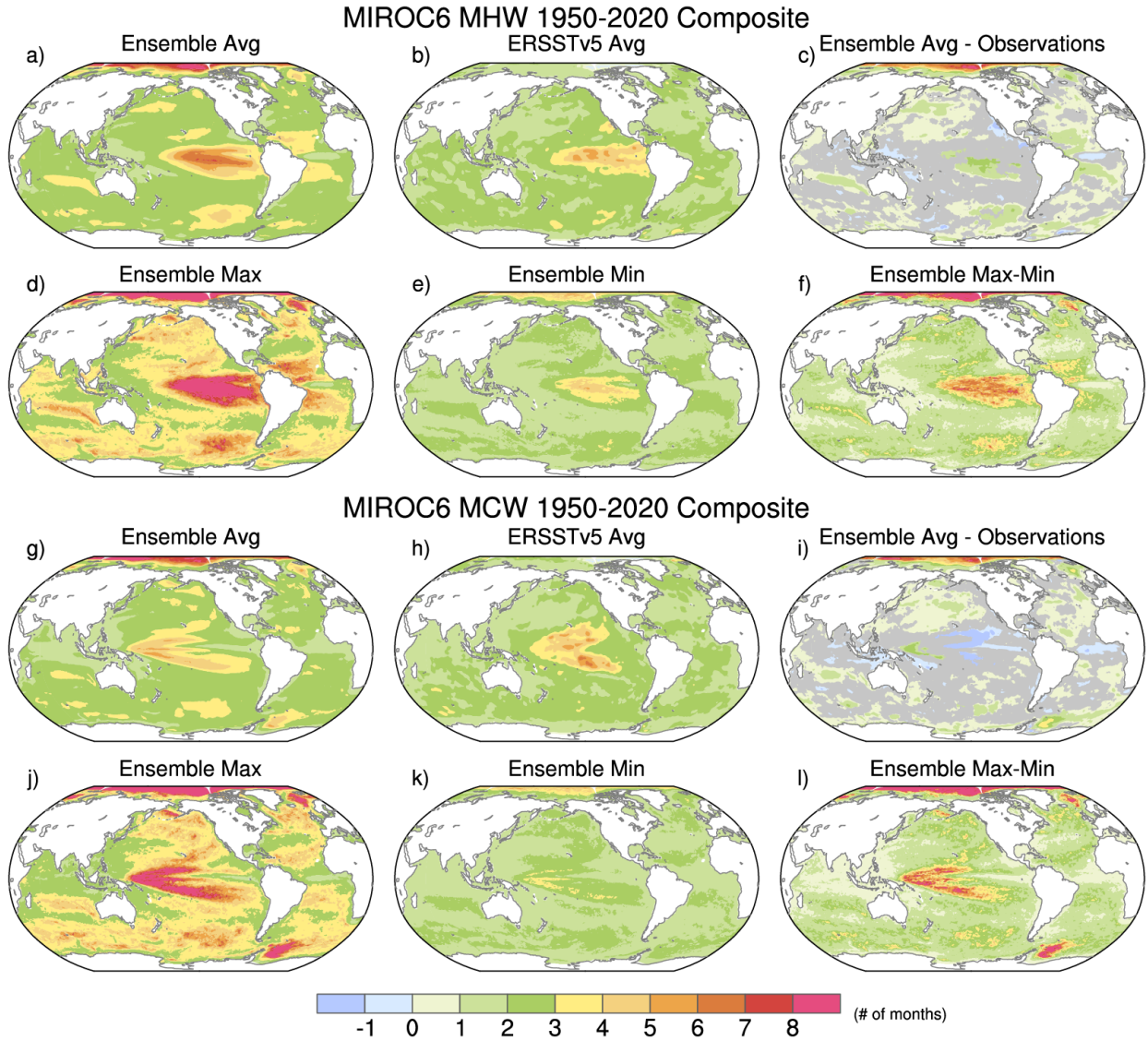
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**Figure S9.** Composite MHW and MCW duration (months) during 1950-2020 from the 50-member CanESM5 Large Ensemble and Observations. (a,g) Ensemble average; (b,h) Observations; (c,i) Ensemble average minus Observations; (d,j) Ensemble maximum; (e,k) Ensemble minimum; (f,l) Ensemble maximum minus minimum. Gray shading in (c,i) indicates that observations lie within the 5<sup>th</sup>-95<sup>th</sup> percentile range of the CanESM5 Large Ensemble.



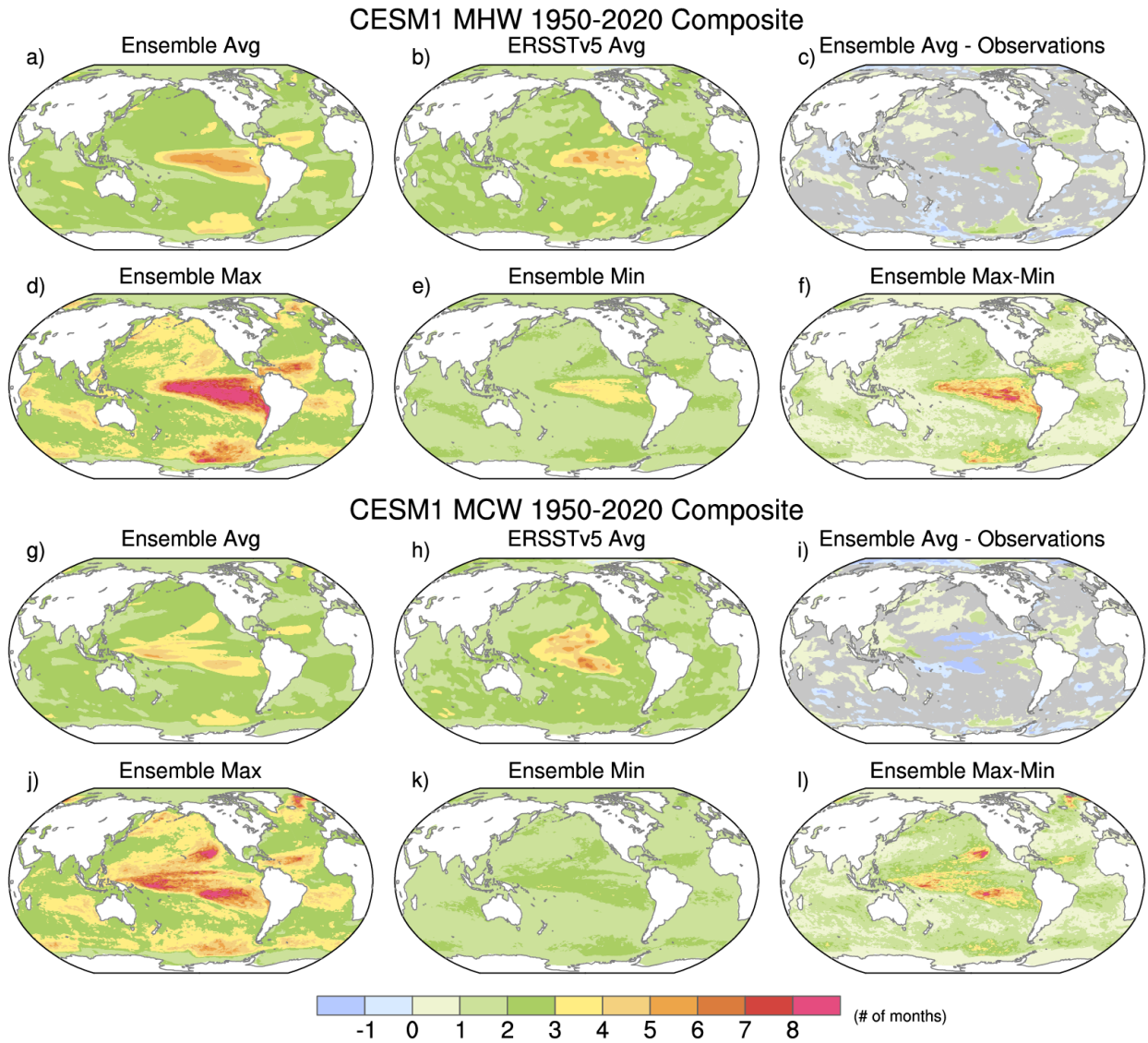
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**Figure S10.** As in Fig. S9 but for the 30-member GFDL-SPEAR Large Ensemble.



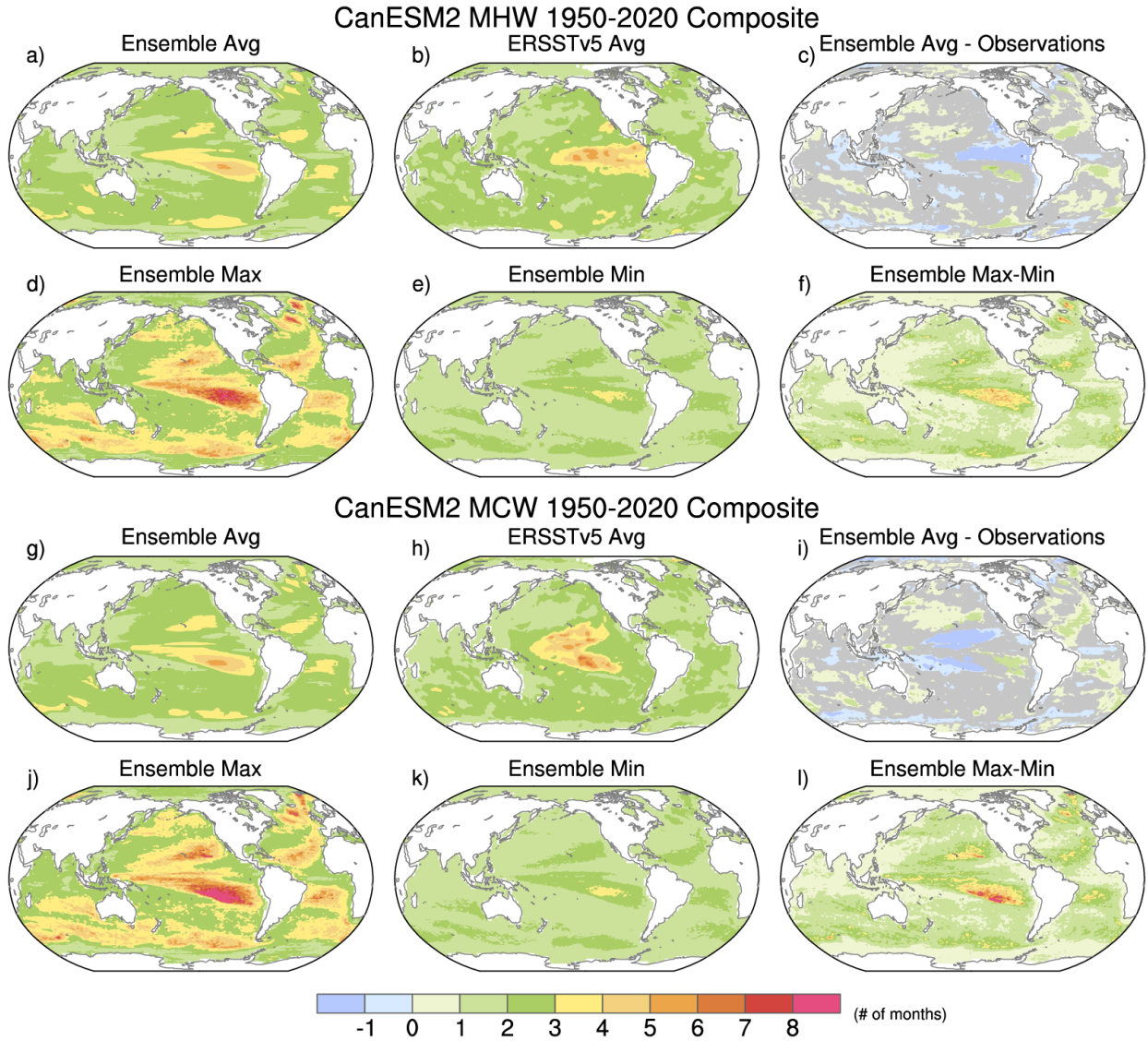
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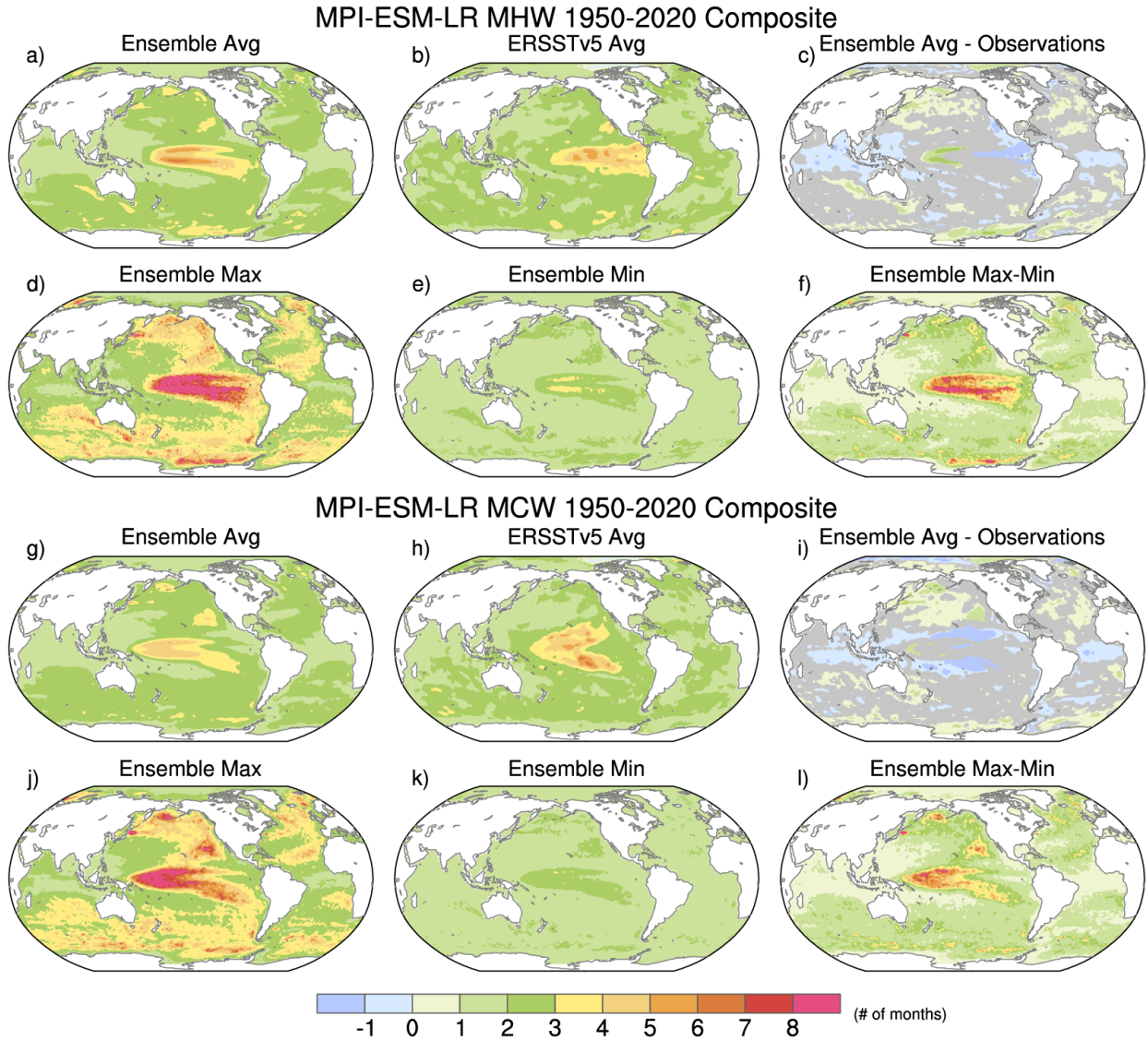
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**Figure S13.** As in Fig. S9 but for the 50-member CanESM2 Large Ensemble.

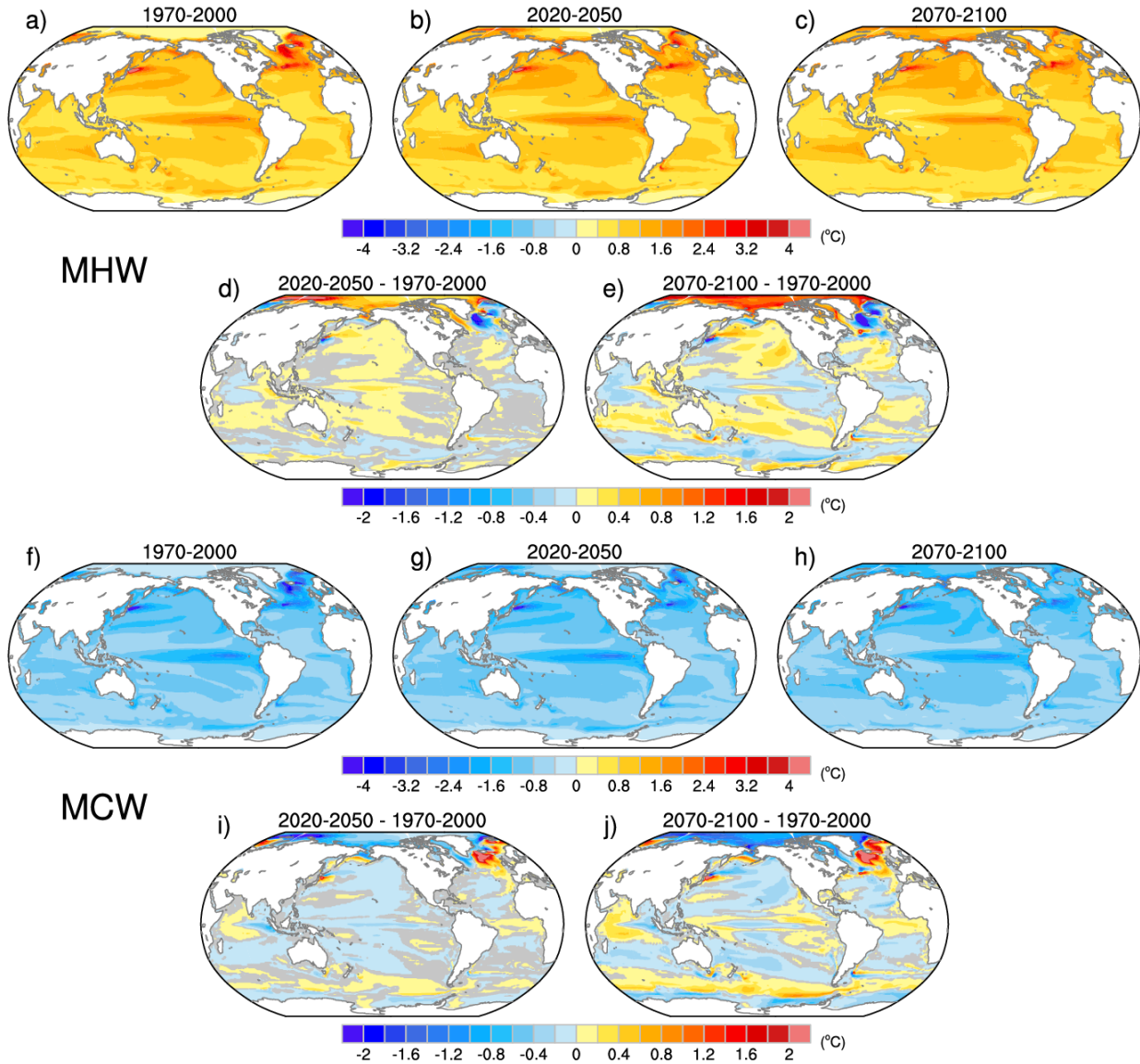


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**Figure S14.** As in Fig. S9 but for the 100-member MPI-ESM-LR Large Ensemble.



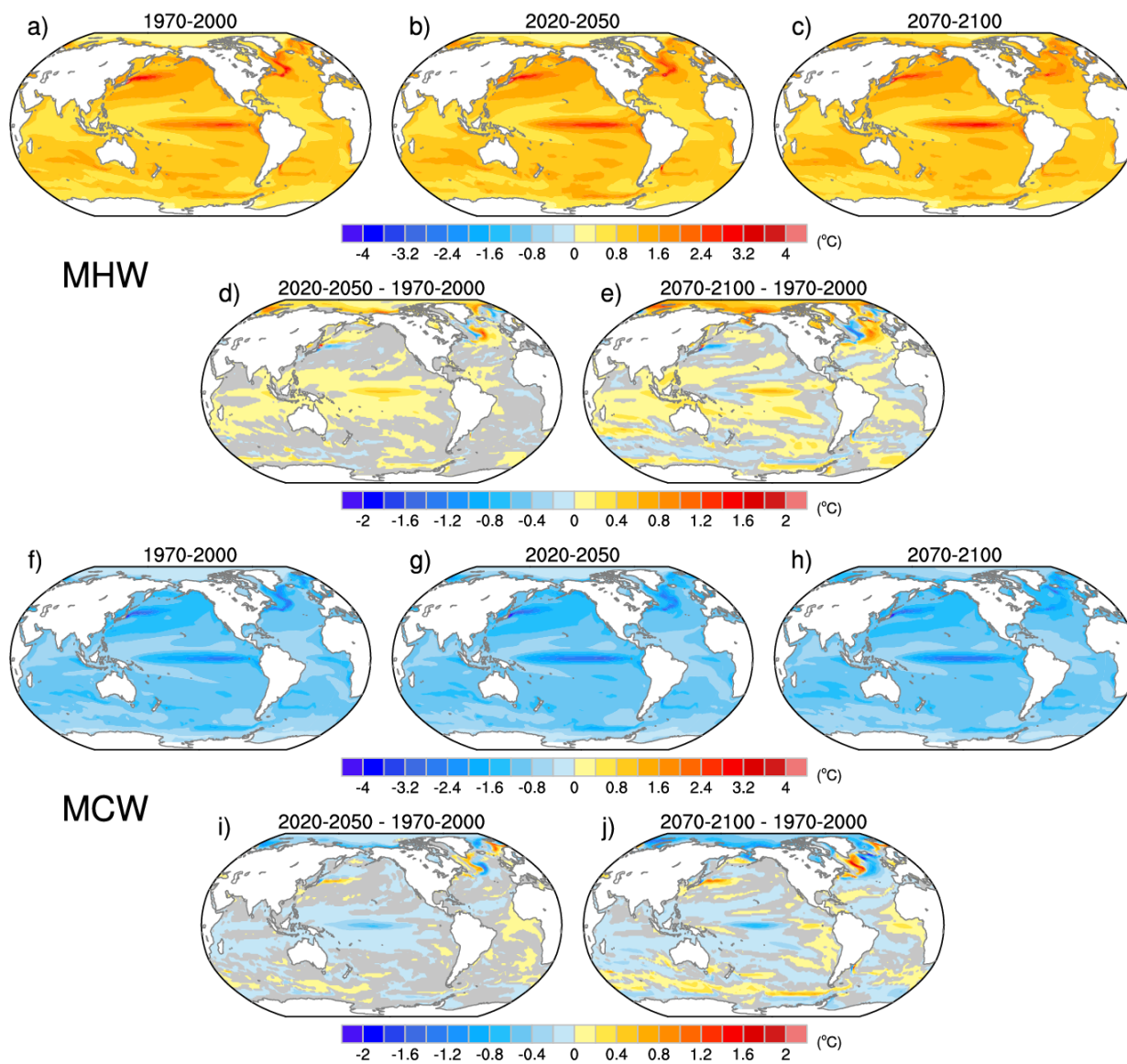
# CanESM5



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**Figure S15.** Composite MHW and MCW intensity (°C) from the 50-member CanESM5 Large Ensemble during (a,f) 1970-2000, (b,g) 2020-2050, (c,h) 2070-2100, and differences (d,i) 2020-2050 minus 1970-2000, and (e,j) 2070-2100 minus 1970-2000. Note that the color bar range is twice as large in a-c, f-h compared to d-e, i-j. Gray shading in d-e, i-j indicates that the differences are not statistically significant according to the False Discovery Rate applied to a 2-sided t-test at the 95% confidence level.

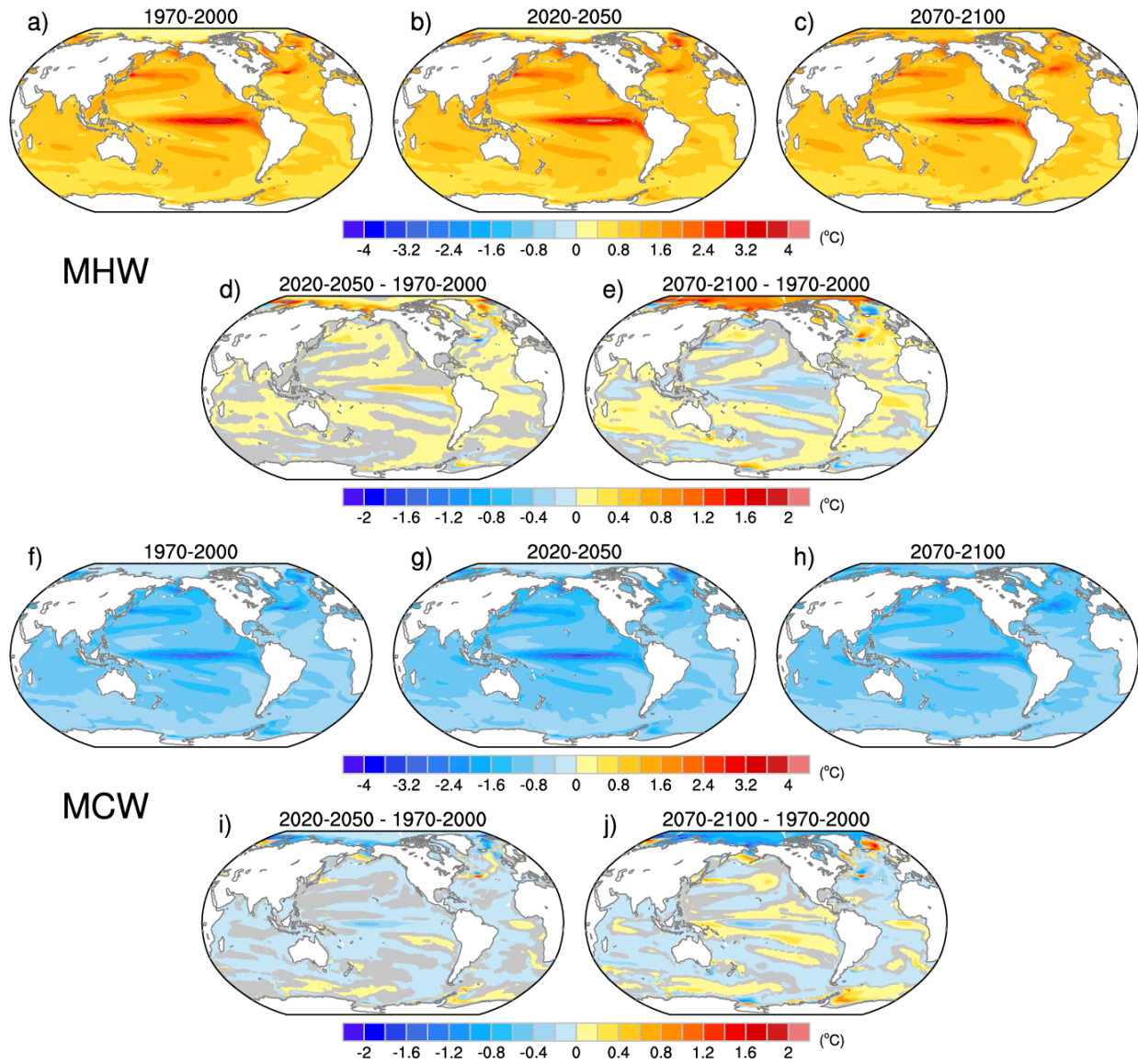
# GFDL-SPEAR



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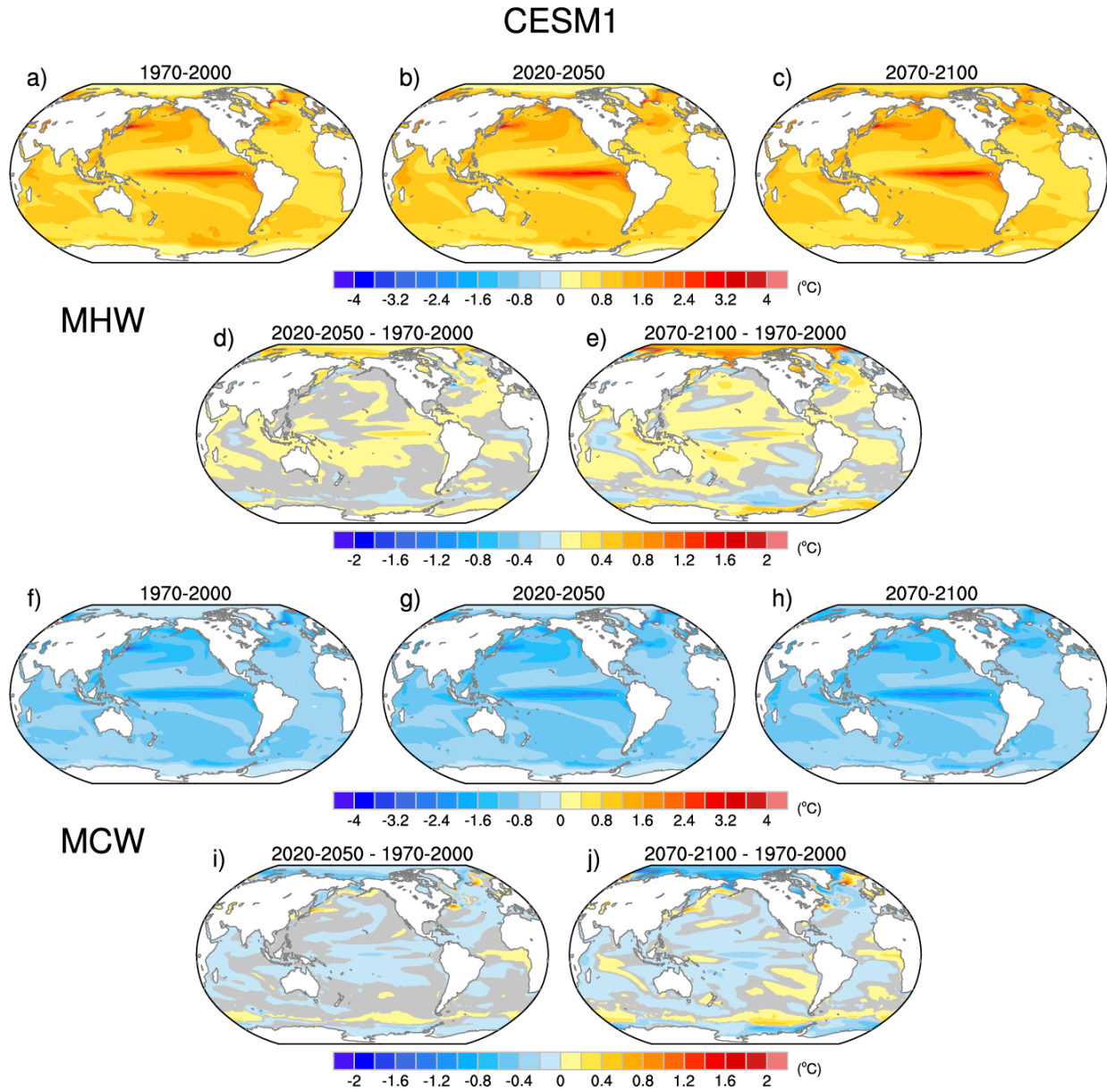
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# MIROC6



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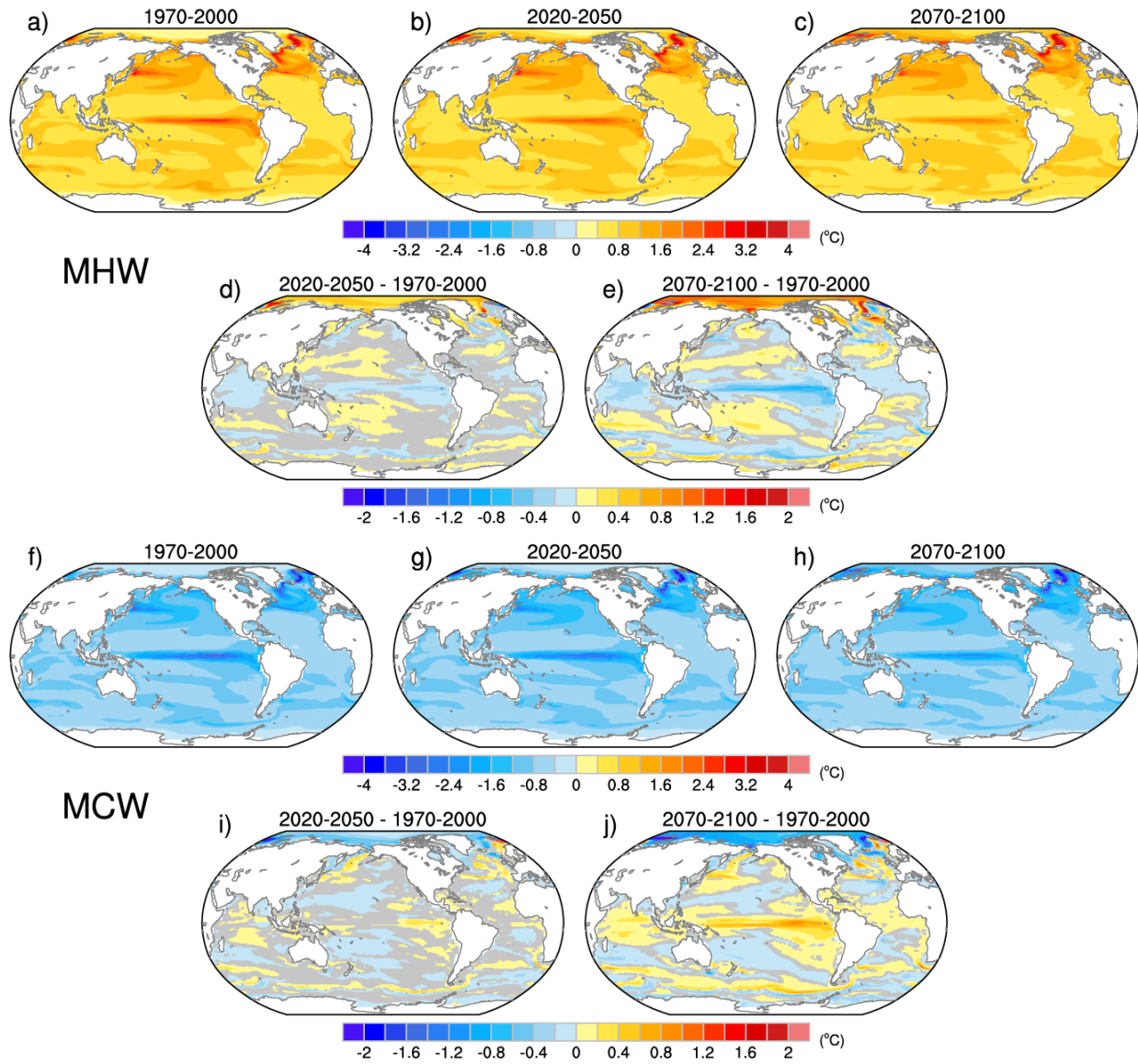
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**Figure S18.** As in Fig. S15 but for the 40-member CESM1 Large Ensemble.

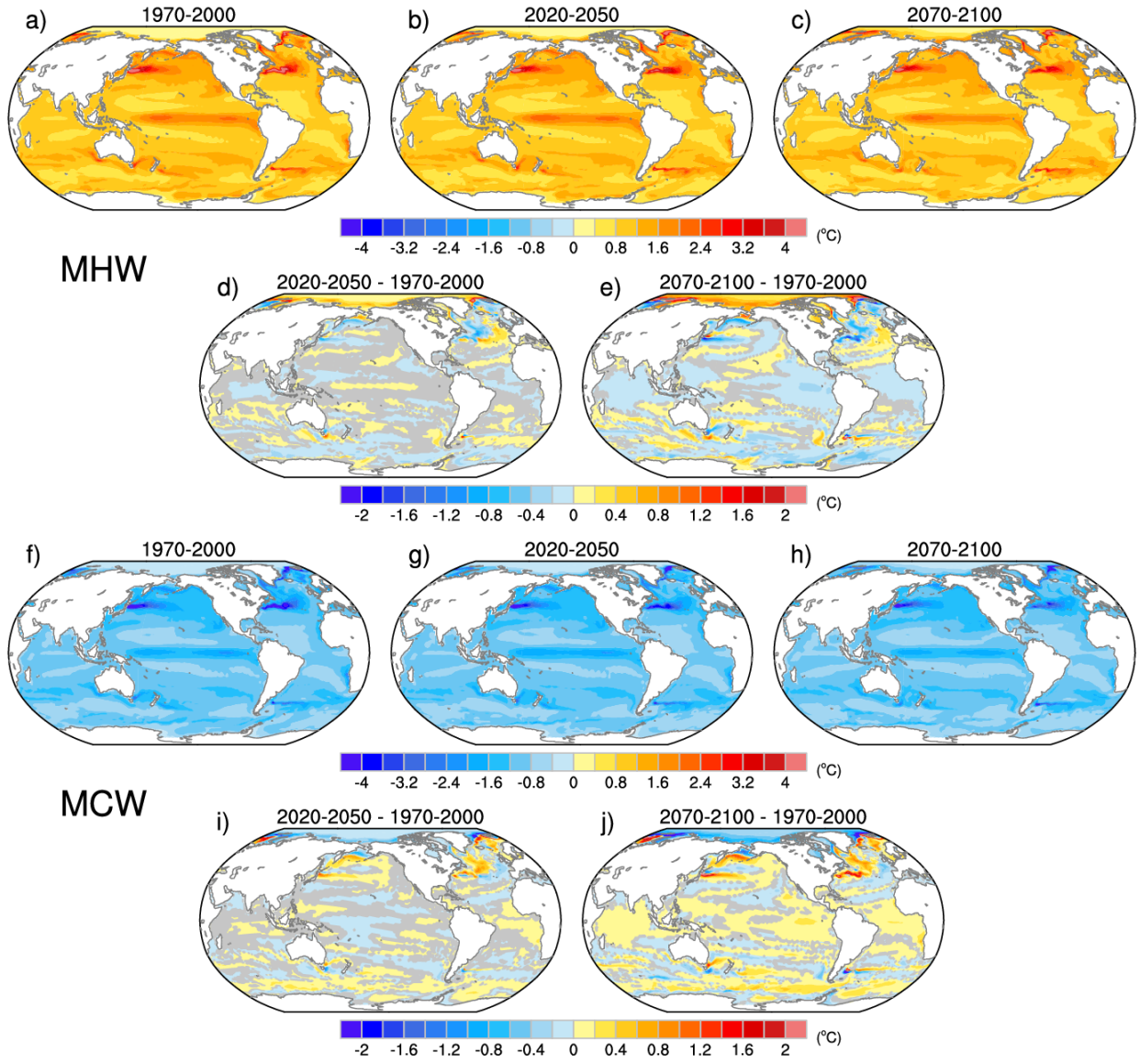
# CanESM2



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**Figure S19.** As in Fig. S15 but for the 50-member CanESM2 Large Ensemble.

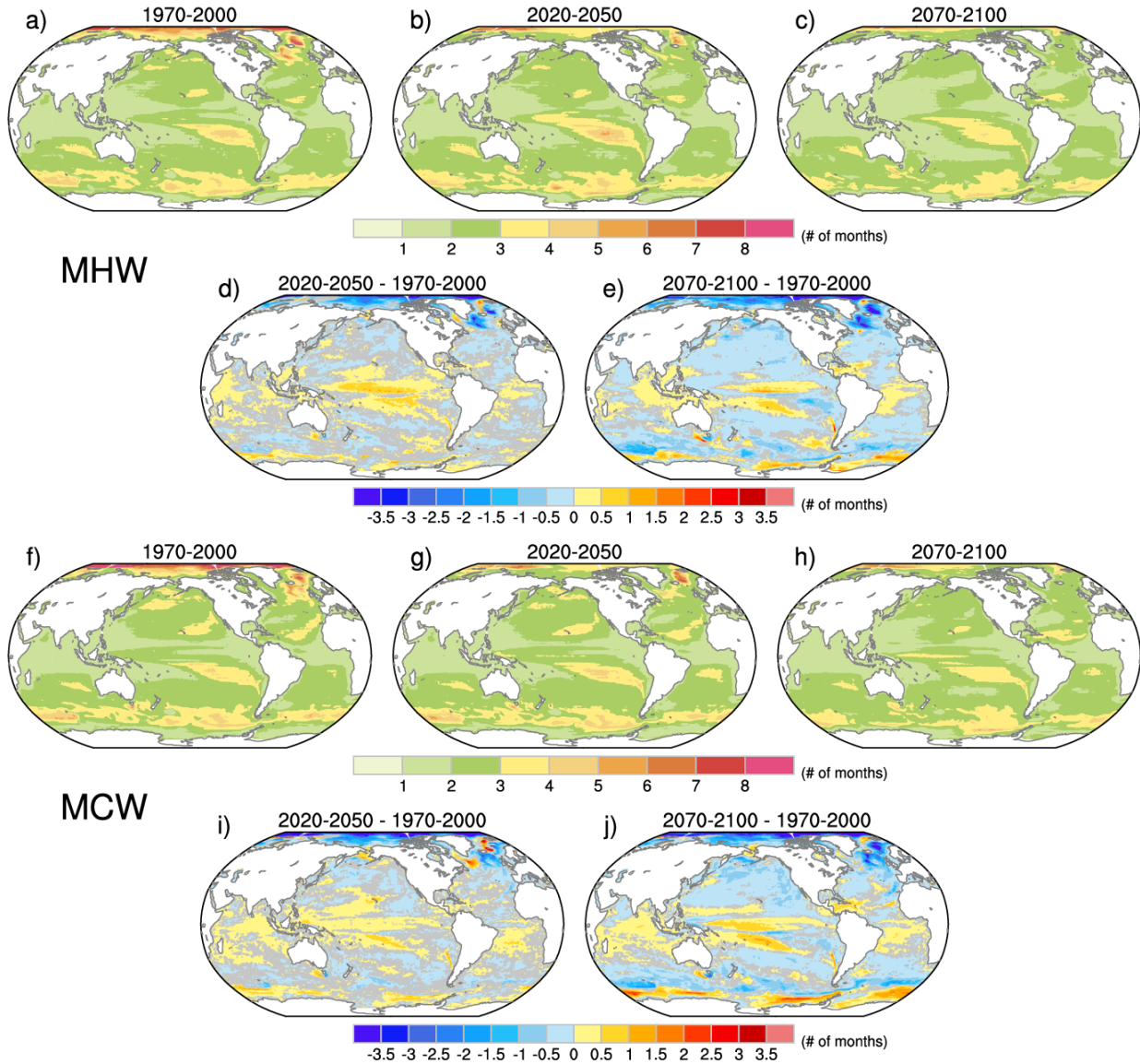
# MPI-ESM-LR



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**Figure S20.** As in Fig. S15 but for the 100-member MPI-ESM-LR Large Ensemble.

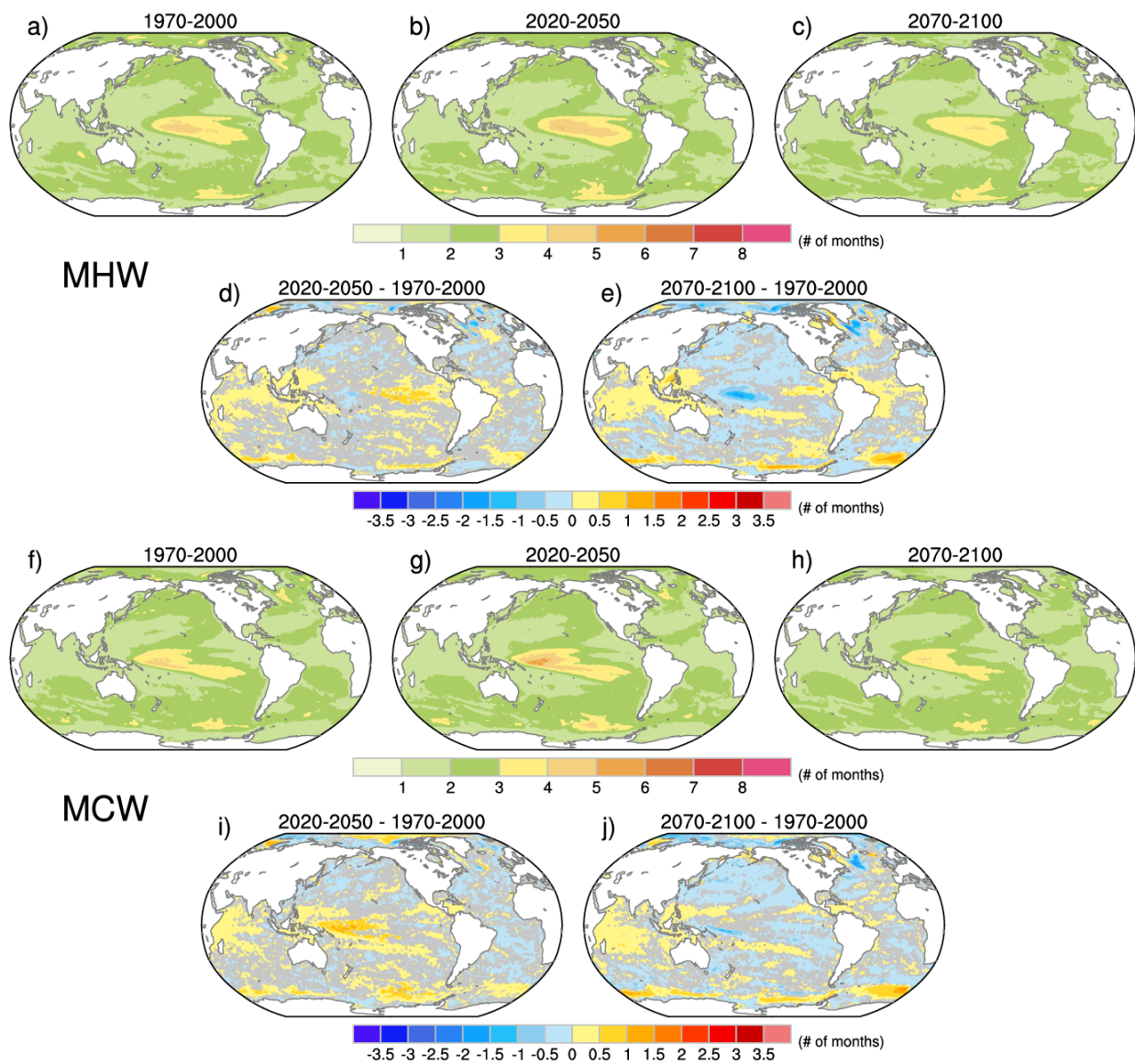
# CanESM5



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**Figure S21.** Composite MHW and MCW duration (months) from the 50-member CanESM5 Large Ensemble during (a,f) 1970-2000, (b,g) 2020-2050, (c,h) 2070-2100, and differences (d,i) 2020-2050 minus 1970-2000, and (e,j) 2070-2100 minus 1970-2000. Note that the color bar range is twice as large in a-c, f-h compared to d-e, i-j. Gray shading in d-e, i-j indicates that the differences are not statistically significant according to the False Discovery Rate applied to a 2-sided t-test at the 95% confidence level.

# GFDL-SPEAR

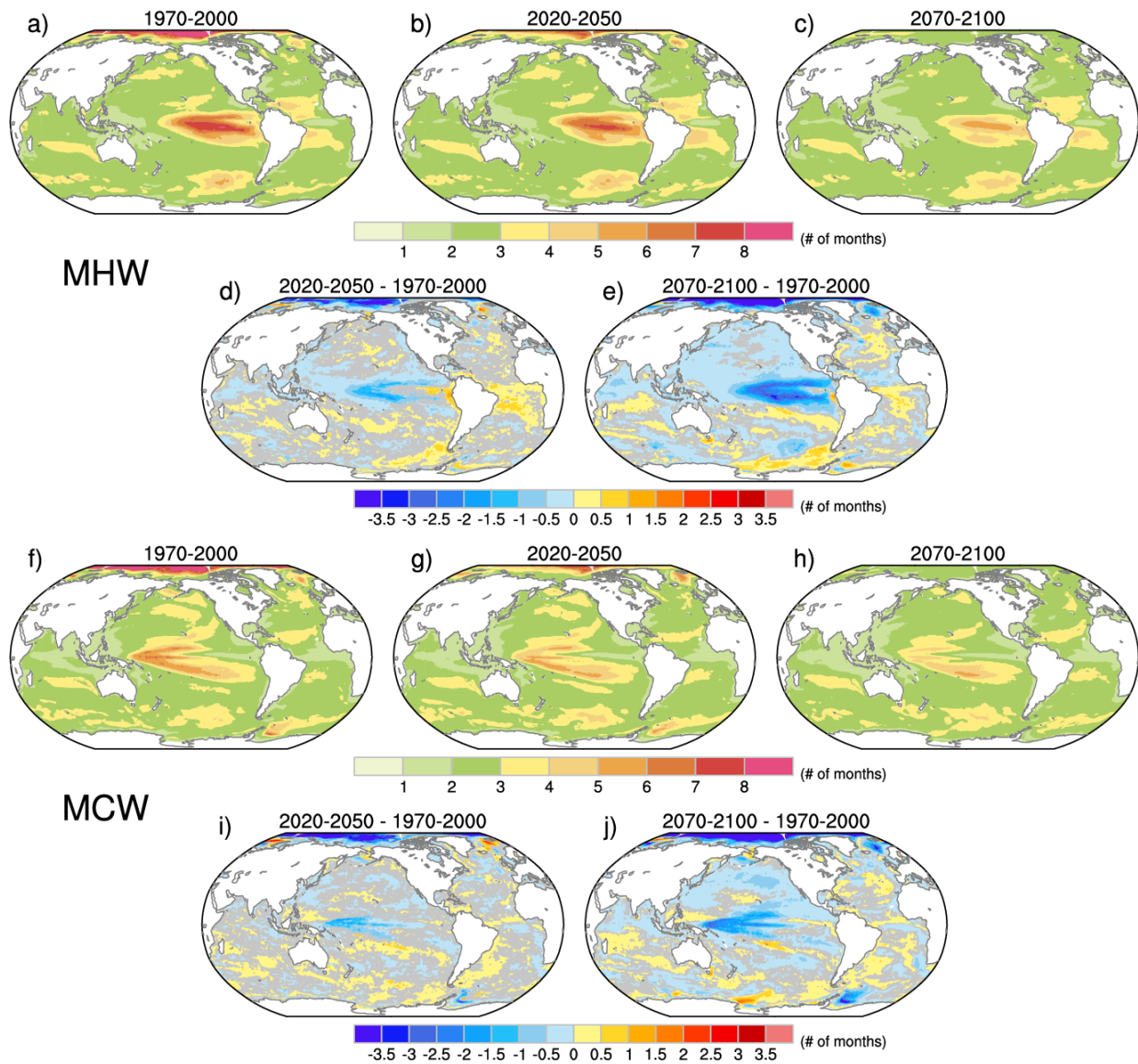


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**Figure S22.** As in Fig. S21 but for the 30-member GFDL-SPEAR Large Ensemble.

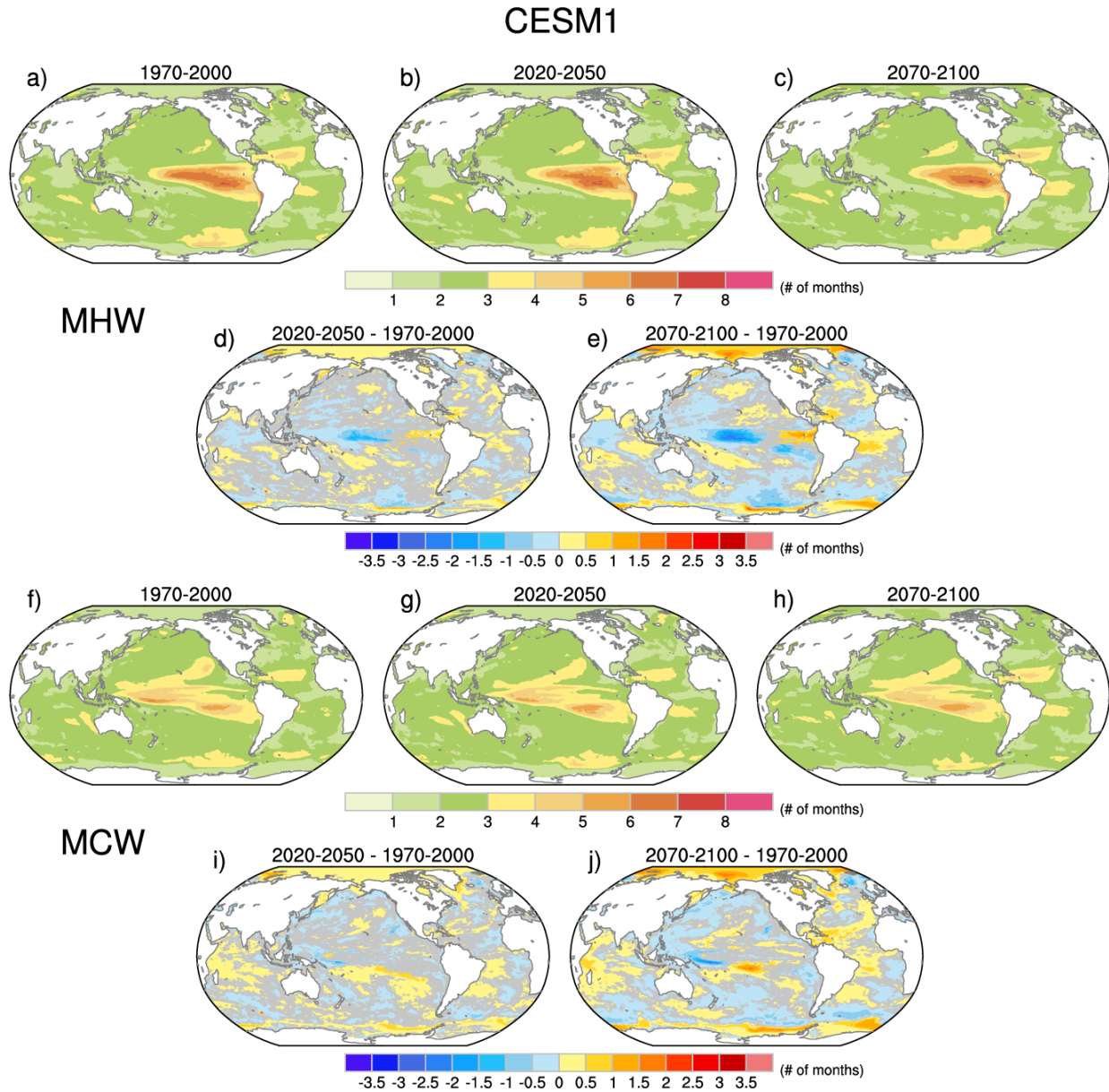


# MIROC6



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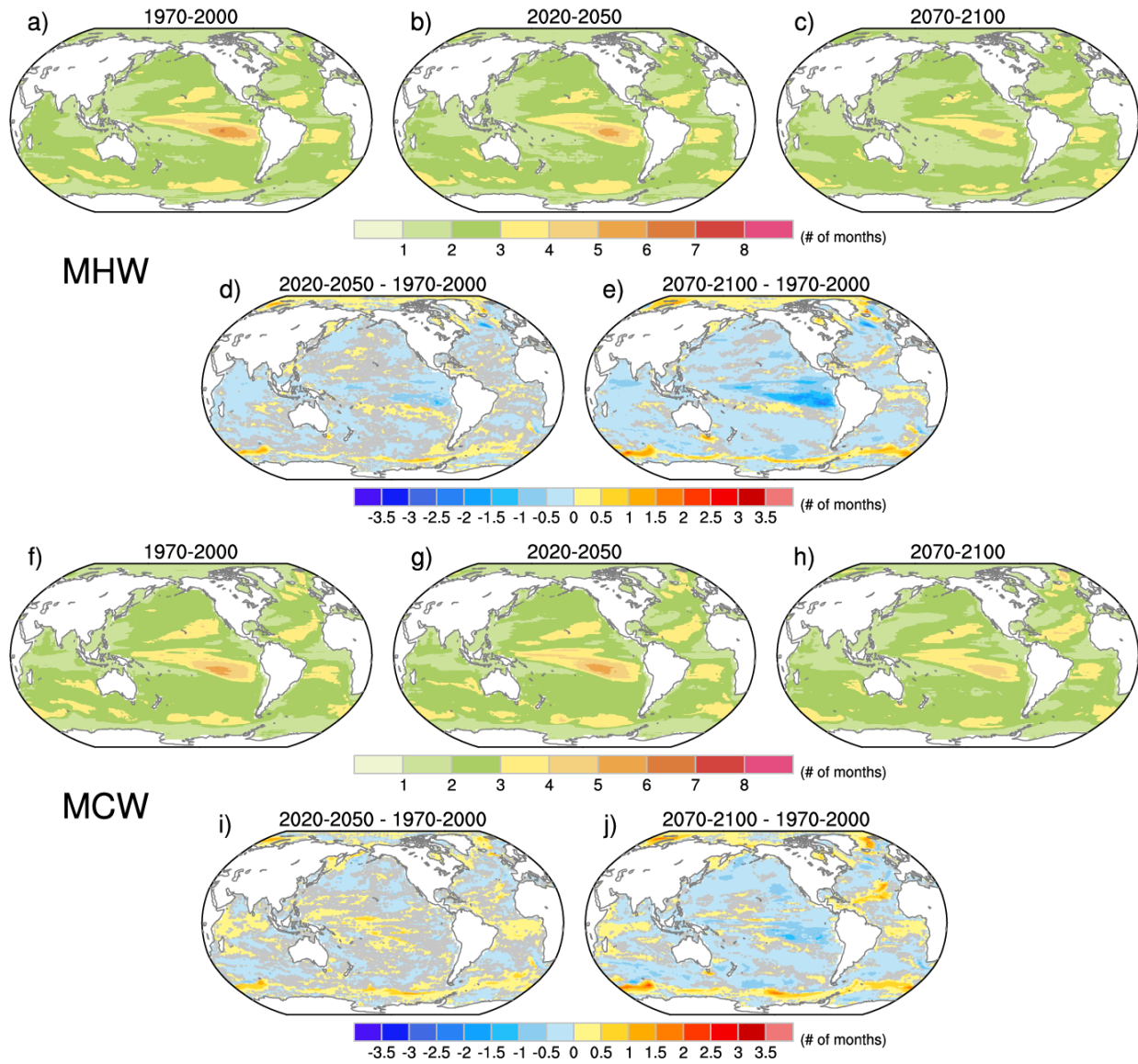
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**Figure S24.** As in Fig. S21 but for the 40-member CESM1 Large Ensemble.

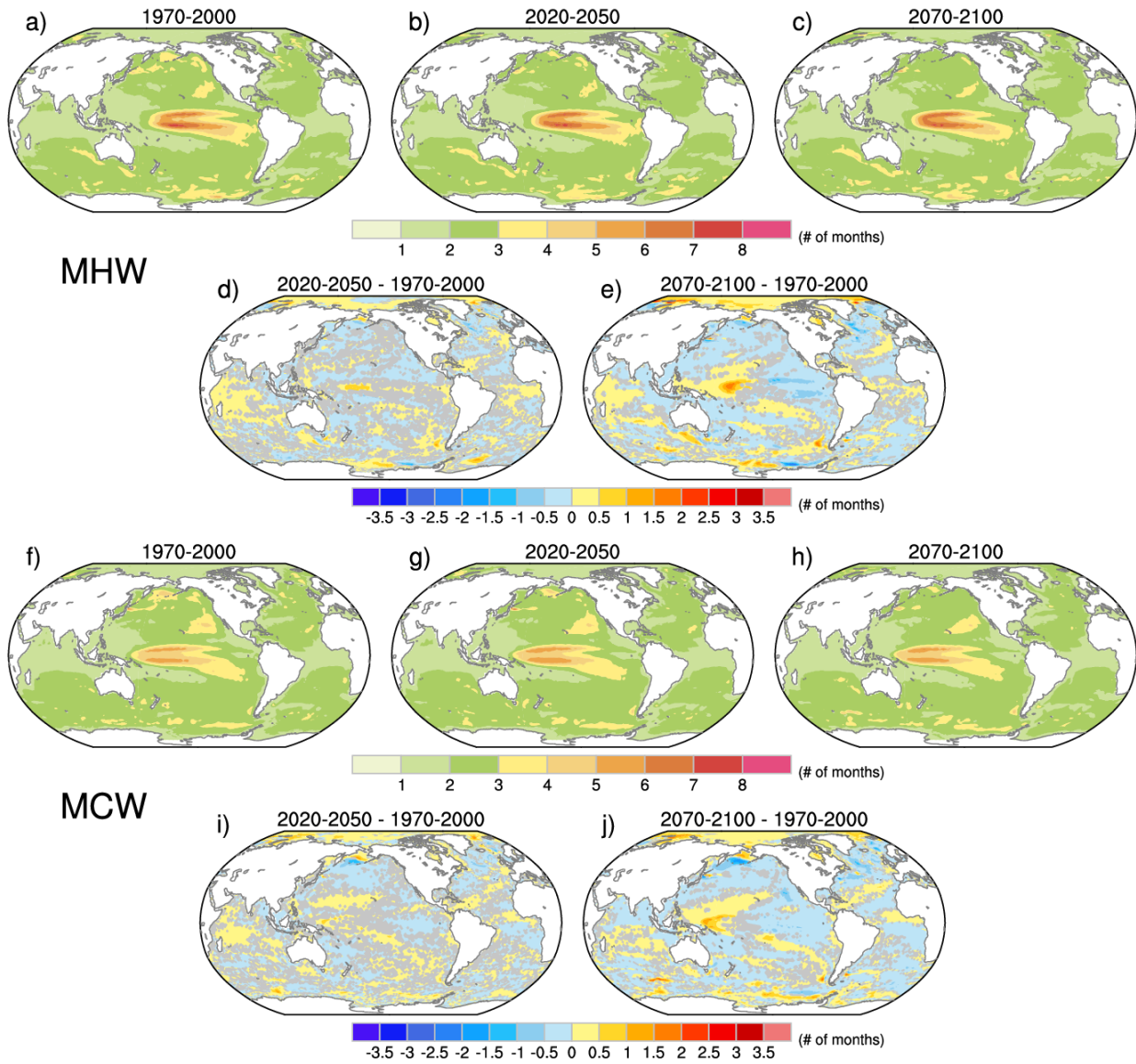
# CanESM2



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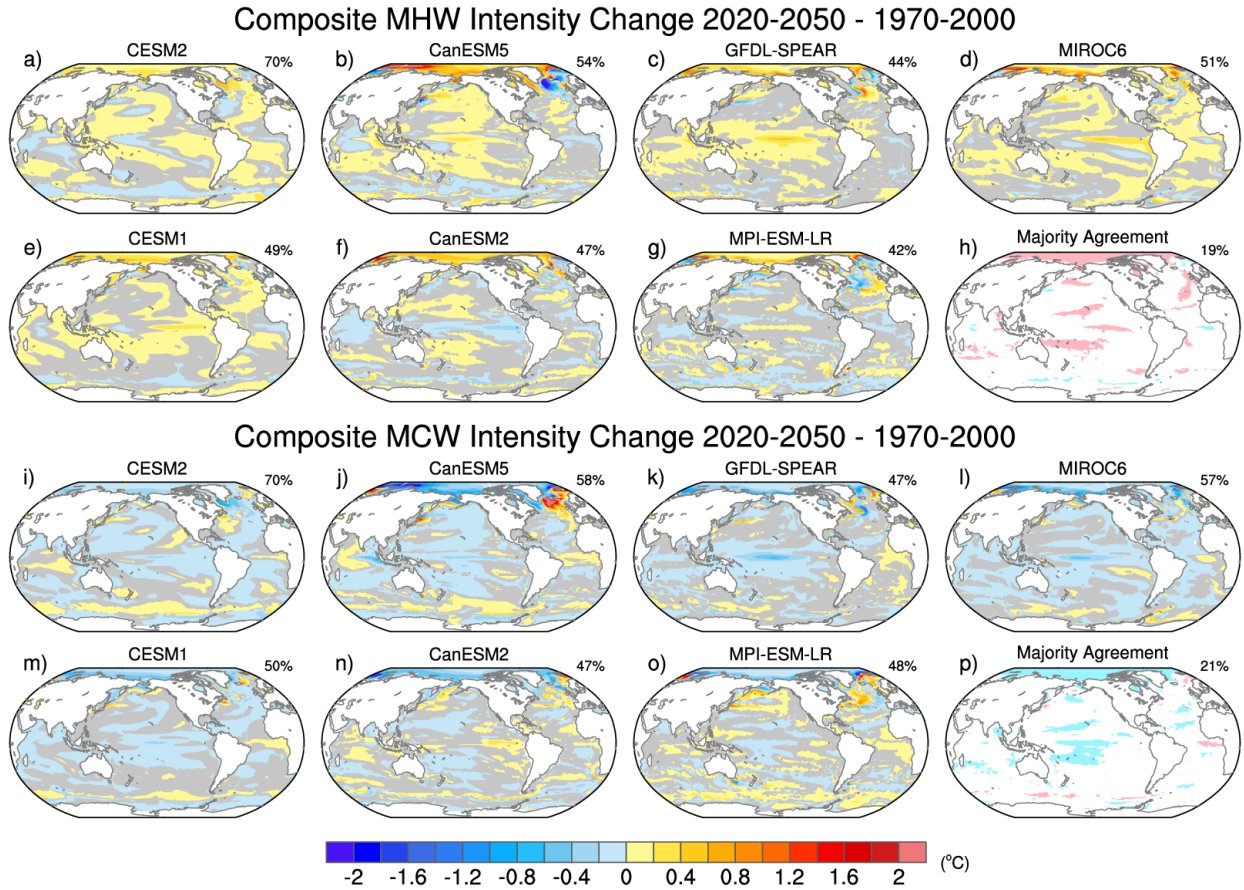
**Figure S25.** As in Fig. S21 but for the 50-member CanESM2 Large Ensemble.

# MPI-ESM-LR



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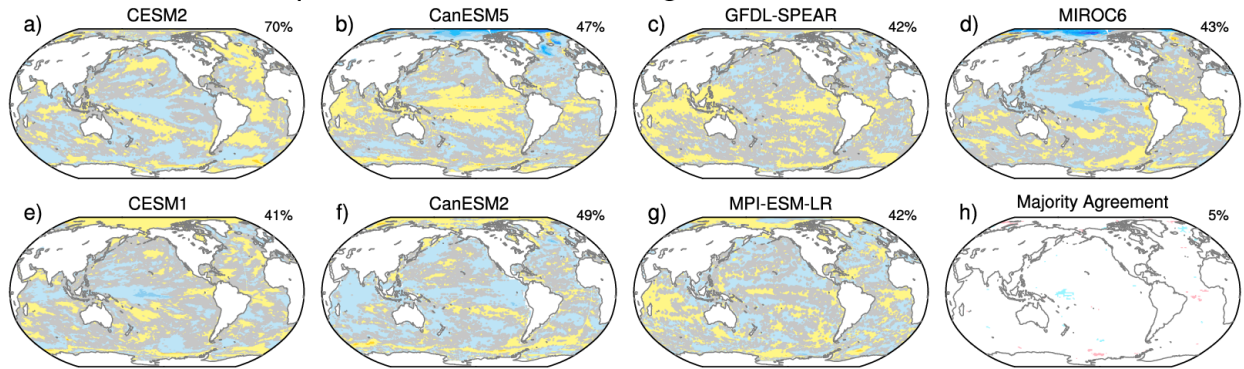
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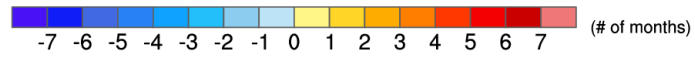
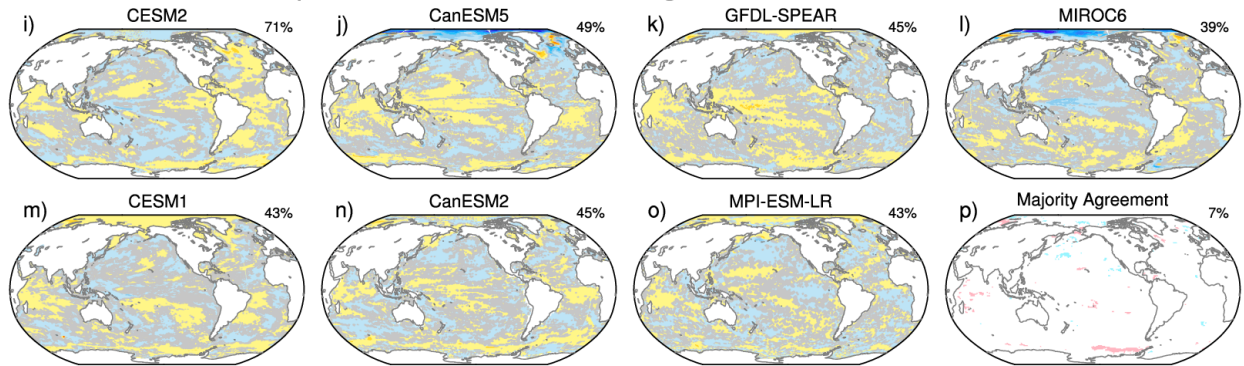
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**Figure S27.** Composite MHW and MCW intensity (°C) differences between 2020-2050 and 1970-2000 for the ensemble-mean of each model Large Ensemble: (a,h) CESM2; (b,i) CanESM5; (c,j) GFDL-SPEAR; (d,k) MIROC6; (e,l) CESM1; (f,m) CanESM2; (g,n) MPI-ESM-LR. Gray shading indicates that the differences are not statistically significant according to the False Discovery Rate applied to a 2-sided t-test at the 95% confidence level. The number in the upper right of each panel denotes the fractional area (%) of significant differences (e.g., non-gray areas). Shading in panels (h,p) show locations where at least two-thirds of the models show statistically significant values (pink for positive and blue for negative); the number in the upper right denotes the fractional area (%) of the pink and blue shading.

Composite MHW Duration Change 2020-2050 - 1970-2000



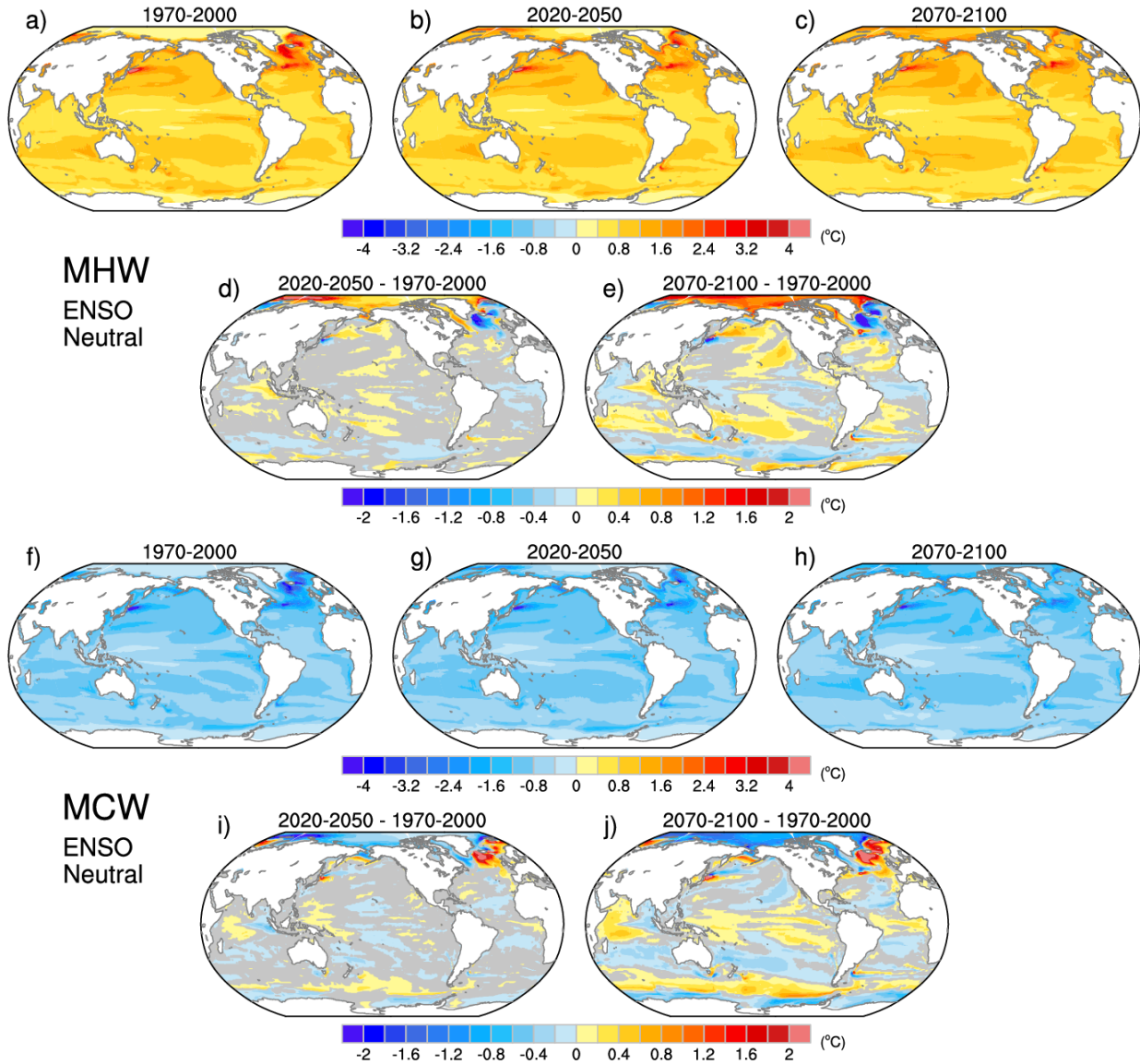
Composite MCW Duration Change 2020-2050 - 1970-2000



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**Figure S28.** As in Fig. S27 but for composite MHW and MCW duration (months).

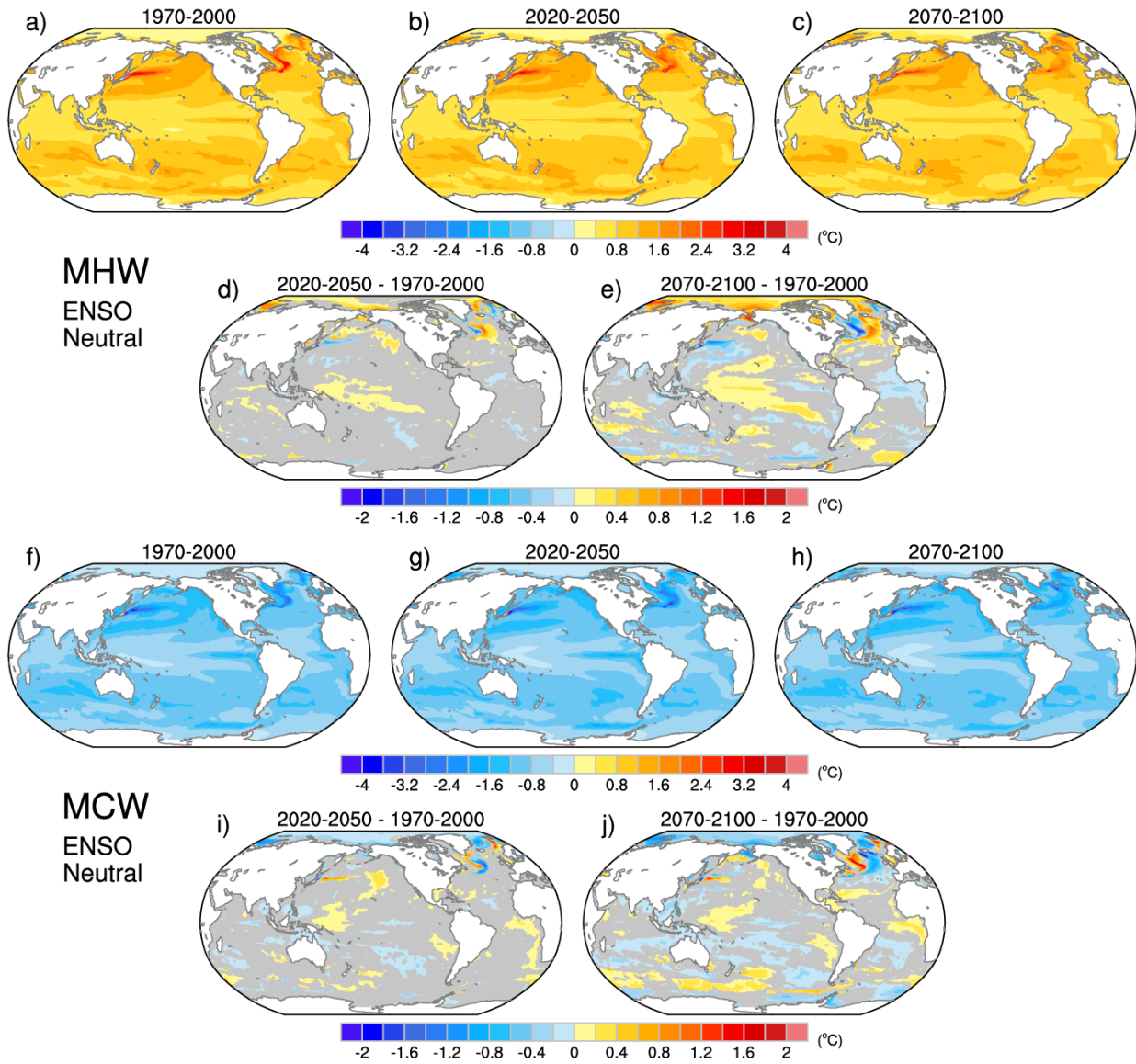
## CanESM5



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**Figure S29.** Composite ENSO-neutral MHW and MCW intensity ( $^{\circ}\text{C}$ ) from the 50-member CanESM5 Large Ensemble during (a,f) 1970-2000, (b,g) 2020-2050, (c,h) 2070-2100, and differences (d,i) 2020-2050 minus 1970-2000, and (e,j) 2070-2100 minus 1970-2000. Note that the color bar range is twice as large in a-c, f-h compared to d-e, i-j. Gray shading in d-e, i-j indicates that the differences are not statistically significant according to the False Discovery Rate applied to a 2-sided t-test at the 95% confidence level.

# GFDL-SPEAR

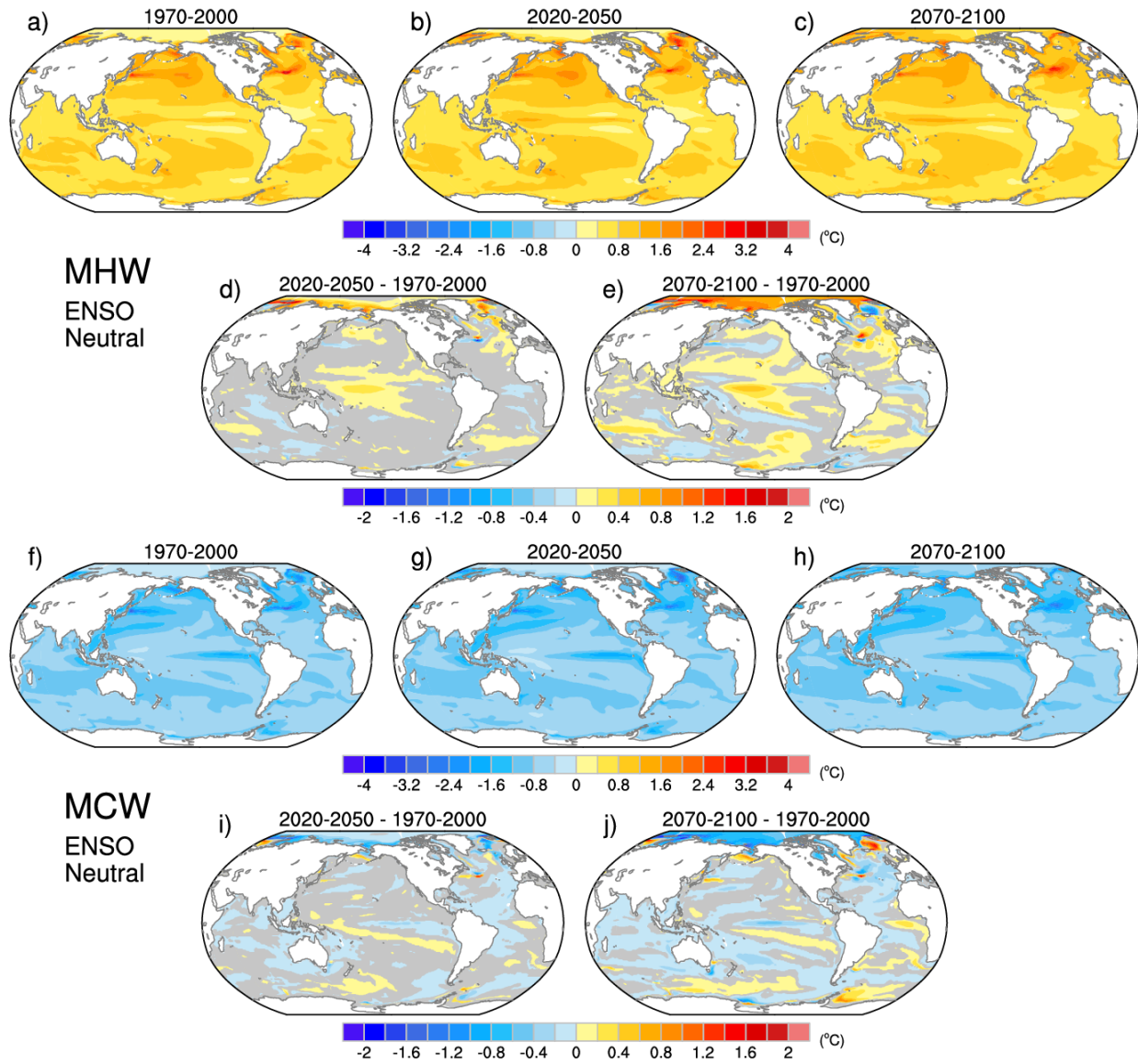


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**Figure S30.** As in Fig. S29 but for the 30-member GFDL-SPEAR Large Ensemble.



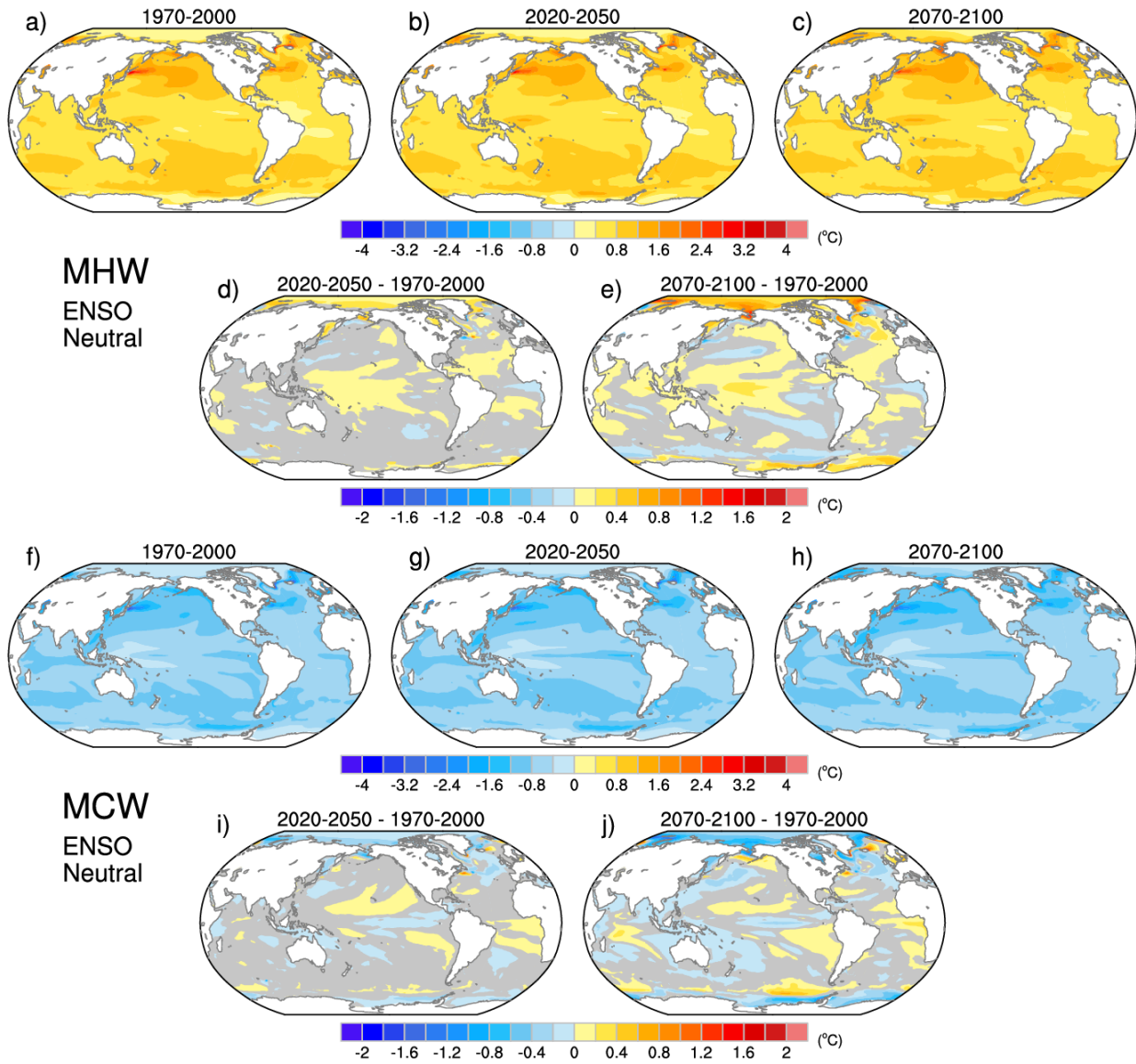
# MIROC6



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**Figure S31.** As in Fig. S29 but for the 50-member MIROC6 Large Ensemble.

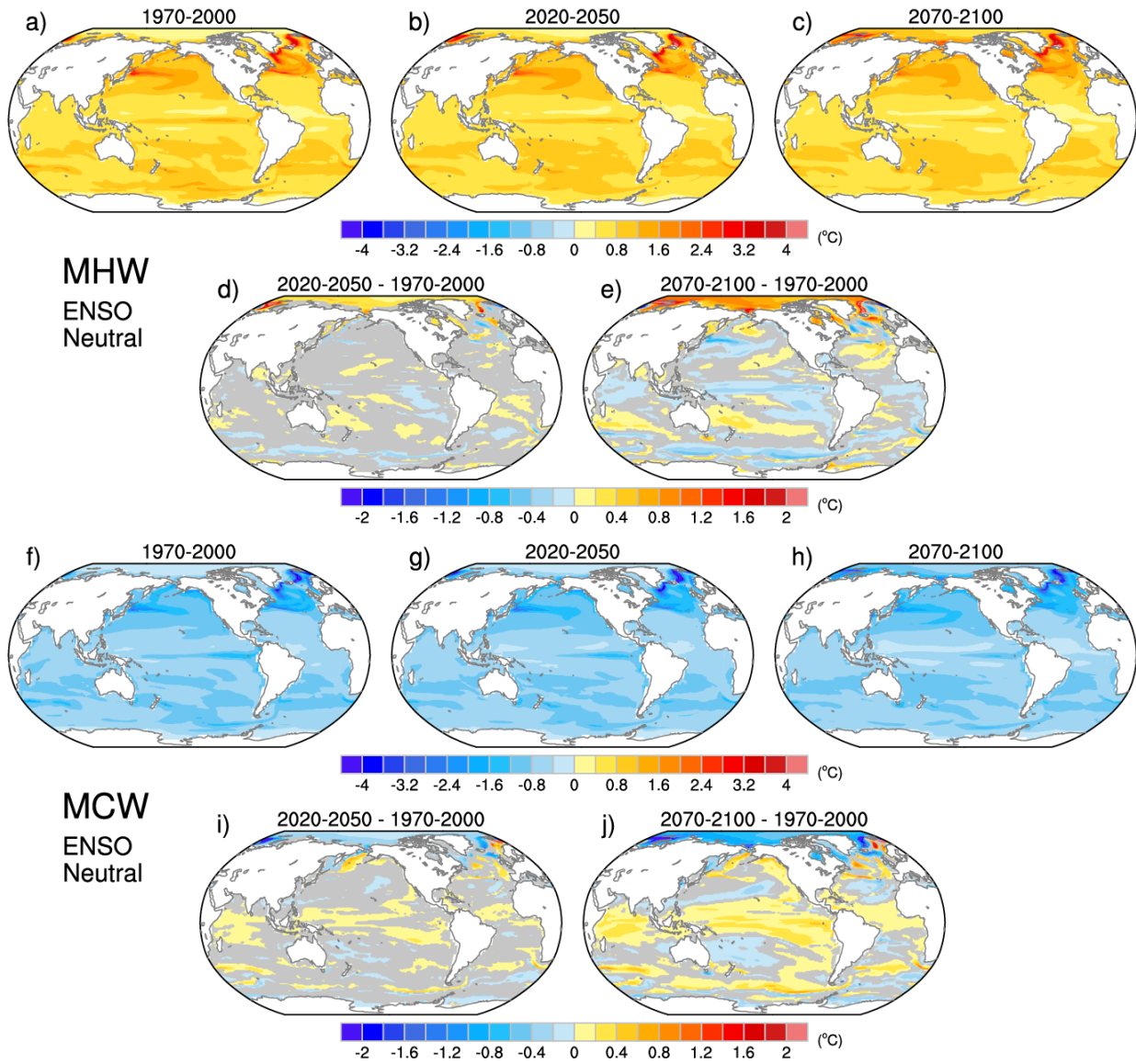
# CESM1



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**Figure S32.** As in Fig. S29 but for the 40-member CESM1 Large Ensemble.

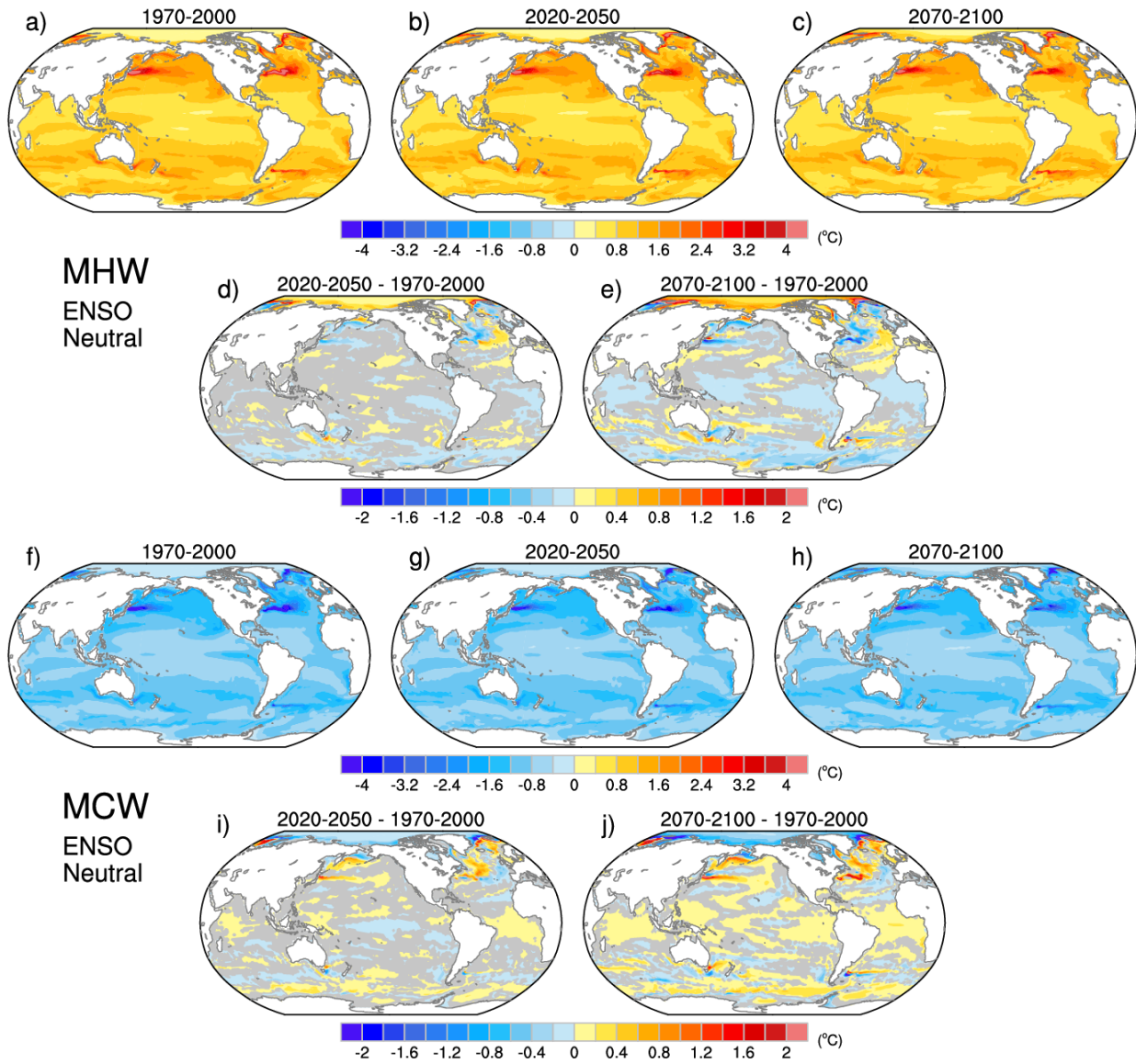
# CanESM2



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**Figure S33.** As in Fig. S29 but for the 50-member CanESM2 Large Ensemble.

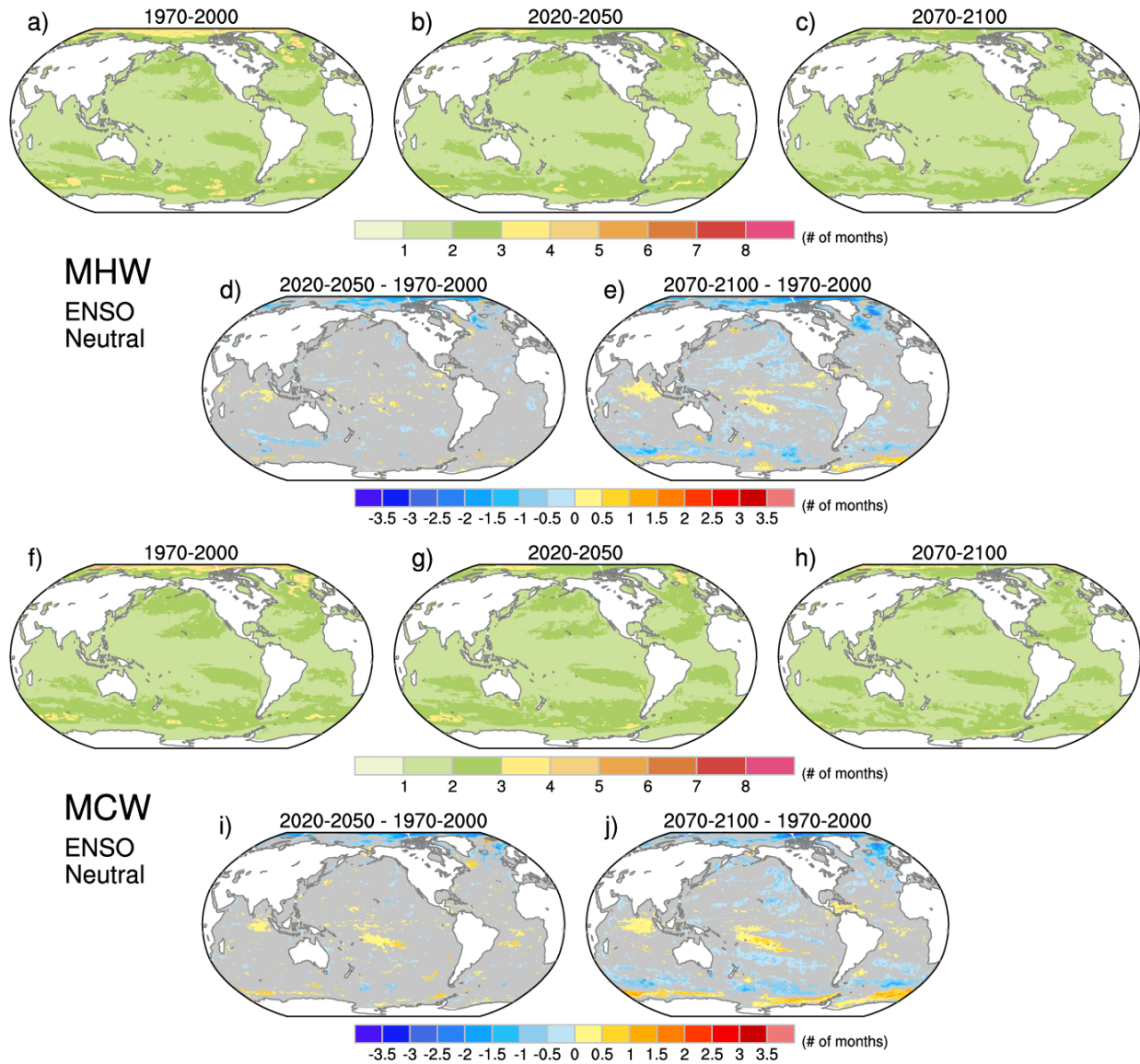
# MPI-ESM-LR



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**Figure S34.** As in Fig. S29 but for the 100-member MPI-ESM-LR Large Ensemble.

## CanESM5

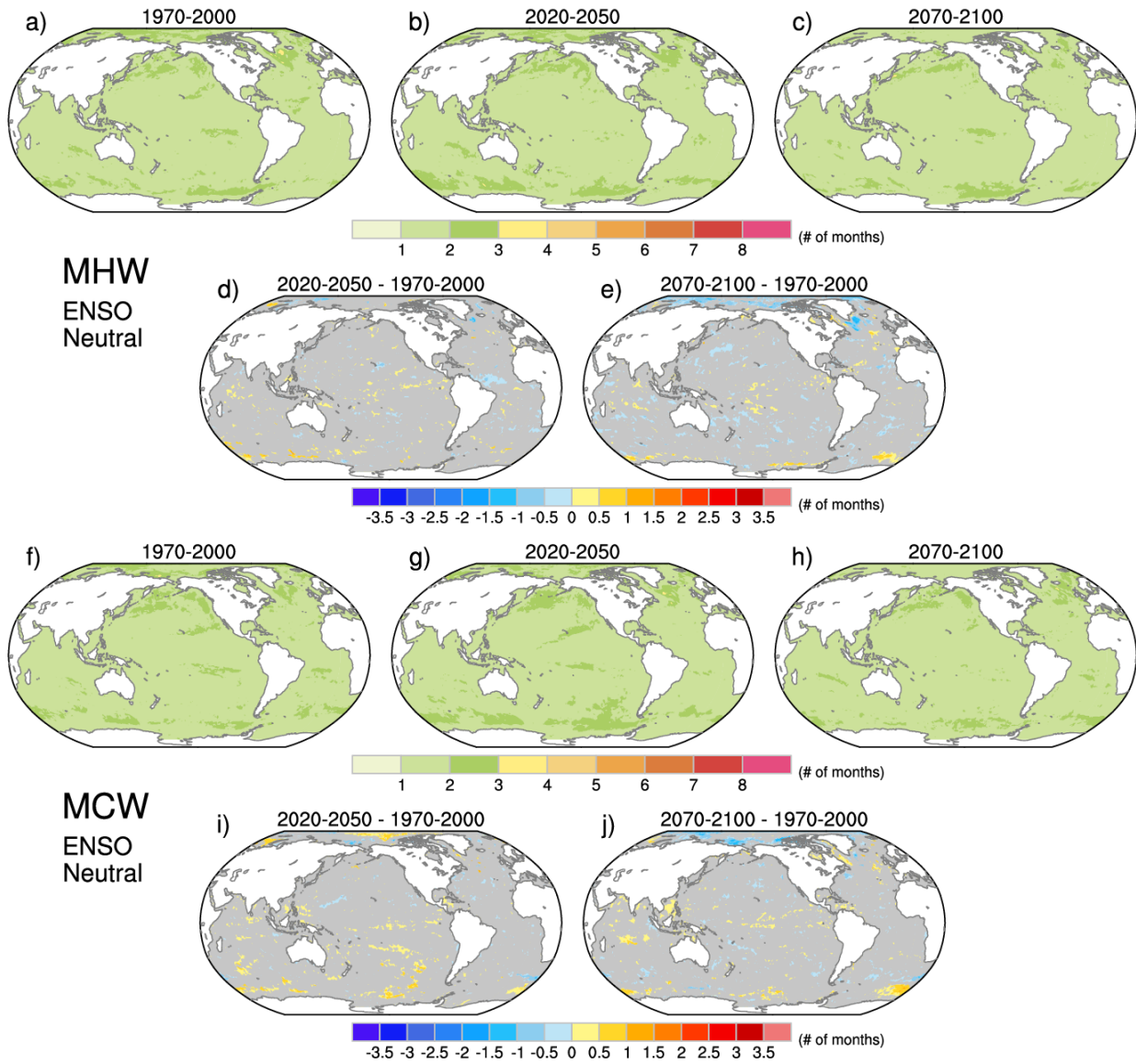


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196 **Figure S35.** Composite ENSO-neutral MHW and MCW duration (months) from the 50-member  
 197 CanESM5 Large Ensemble during (a,f) 1970-2000, (b,g) 2020-2050, (c,h) 2070-2100, and  
 198 differences (d,i) 2020-2050 minus 1970-2000, and (e,j) 2070-2100 minus 1970-2000. Note that  
 199 the color bar range is twice as large in a-c, f-h compared to d-e, i-j. Gray shading in d-e, i-j indicates  
 200 that the differences are not statistically significant according to the False Discovery Rate applied  
 201 to a 2-sided t-test at the 95% confidence level.  
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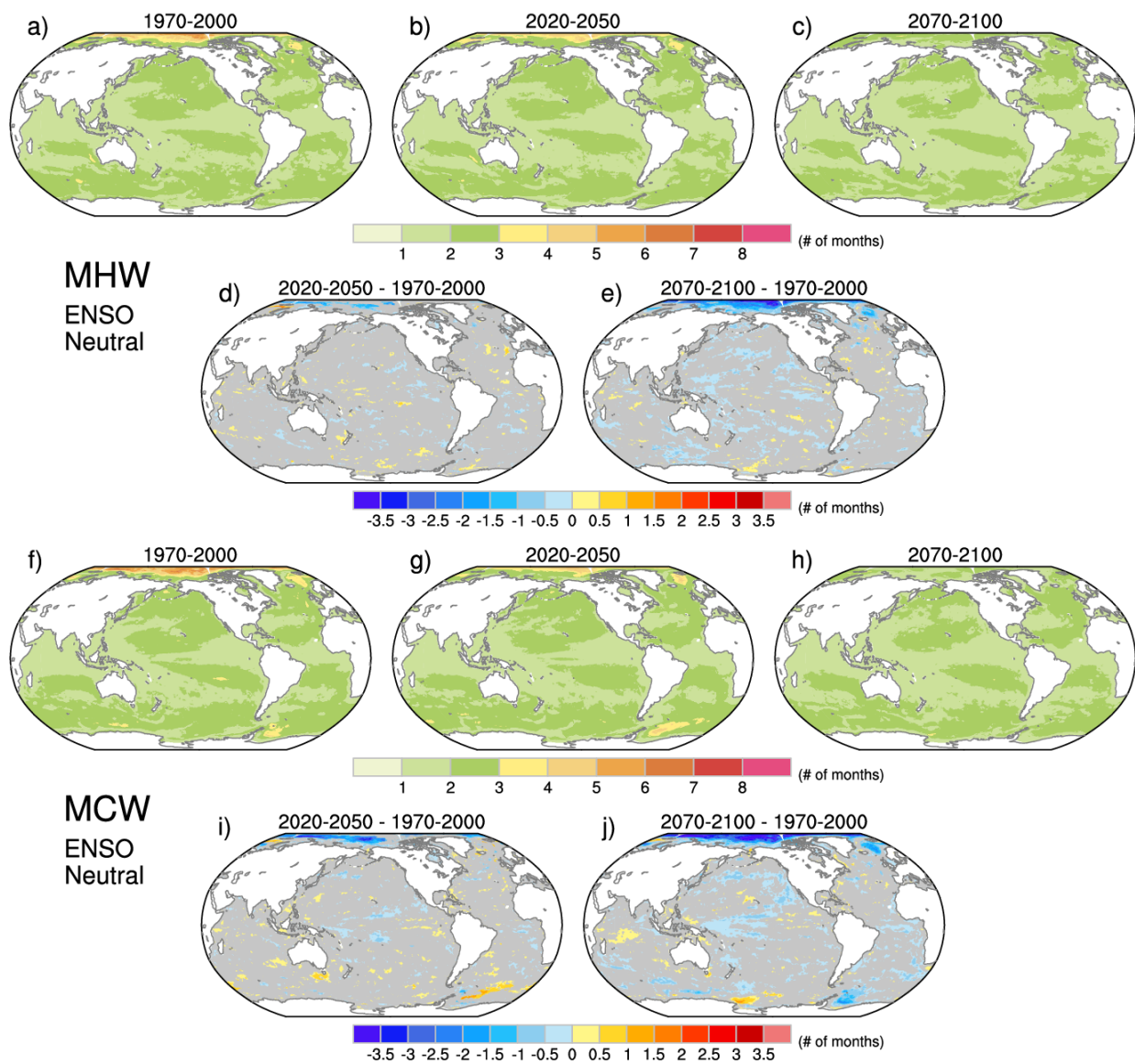
# GFDL-SPEAR



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**Figure S36.** As in Fig. S35 but for the 30-member GFDL-SPEAR Large Ensemble.

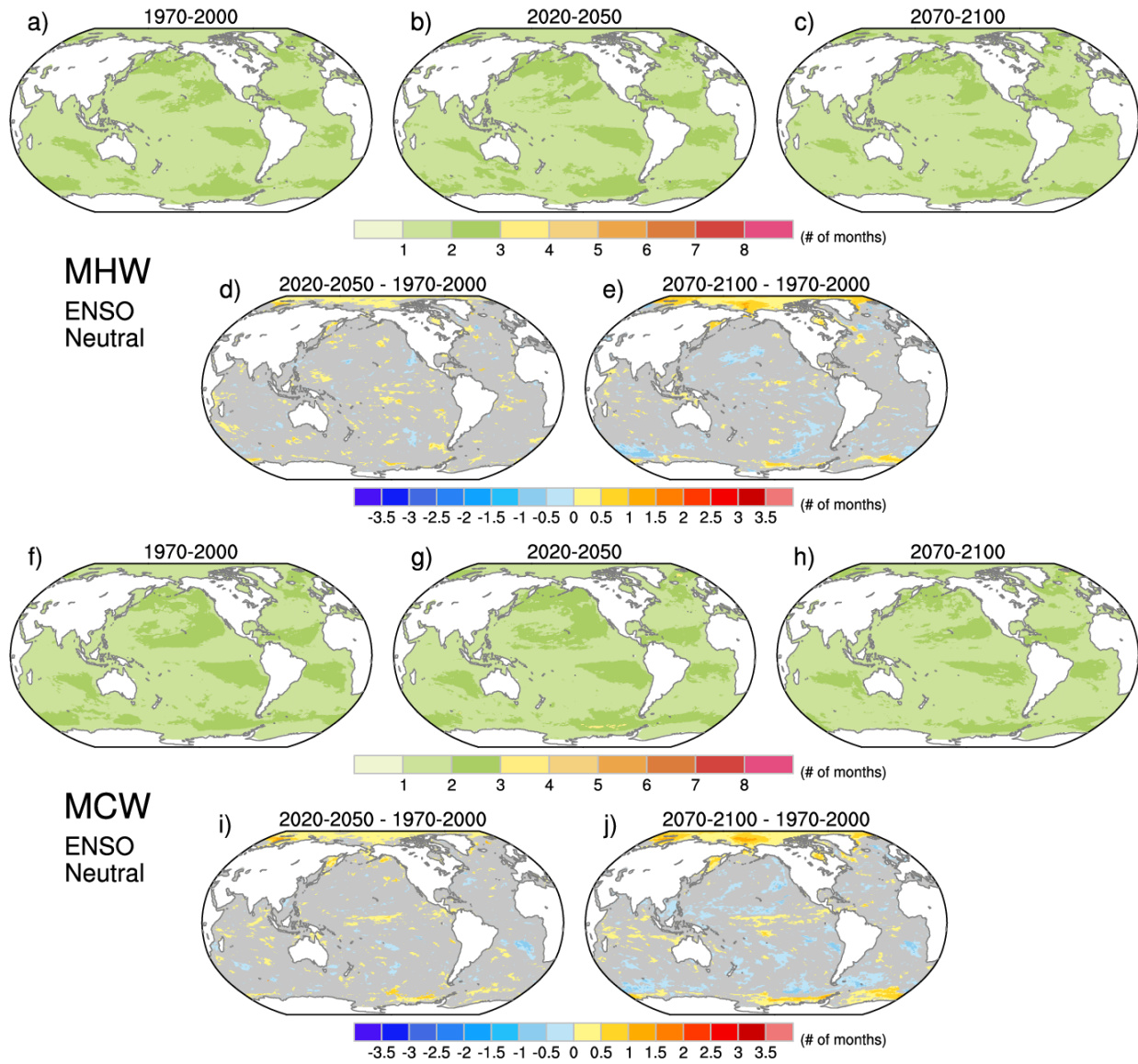
# MIROC6



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**Figure S37.** As in Fig. S35 but for the 50-member MIROC6 Large Ensemble.

# CESM1

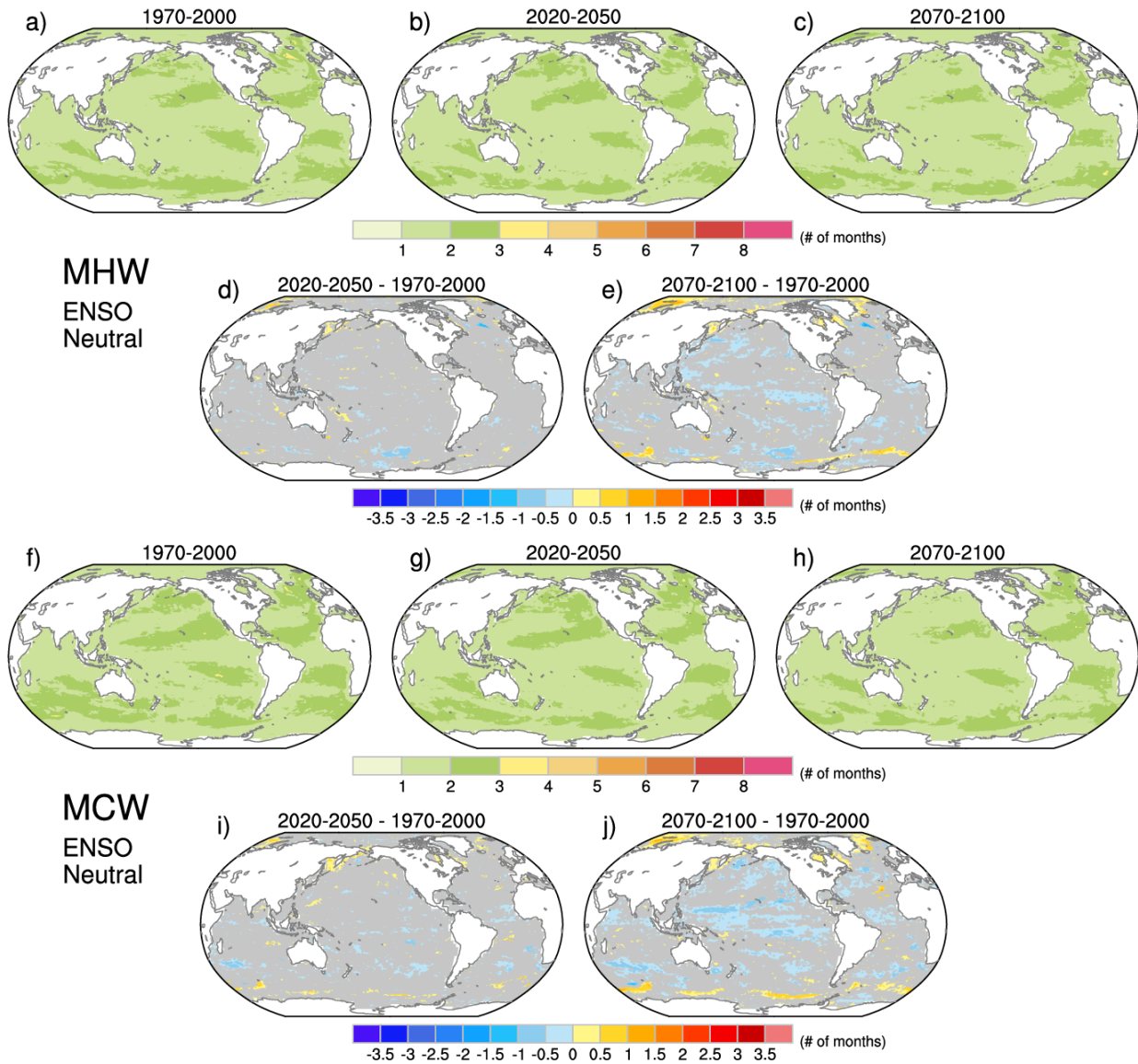


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**Figure S38.** As in Fig. S35 but for the 40-member CESM1 Large Ensemble.



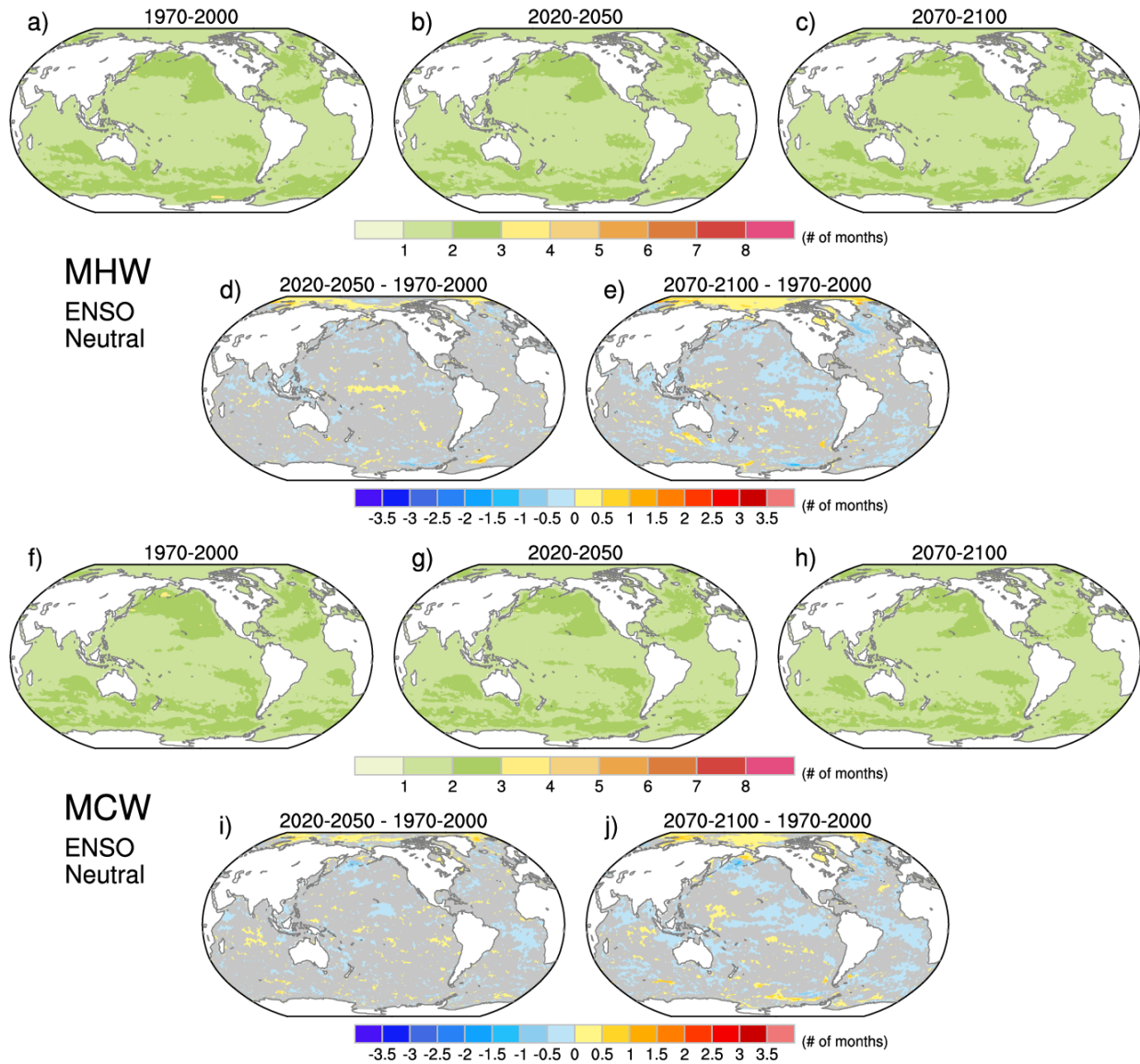
# CanESM2



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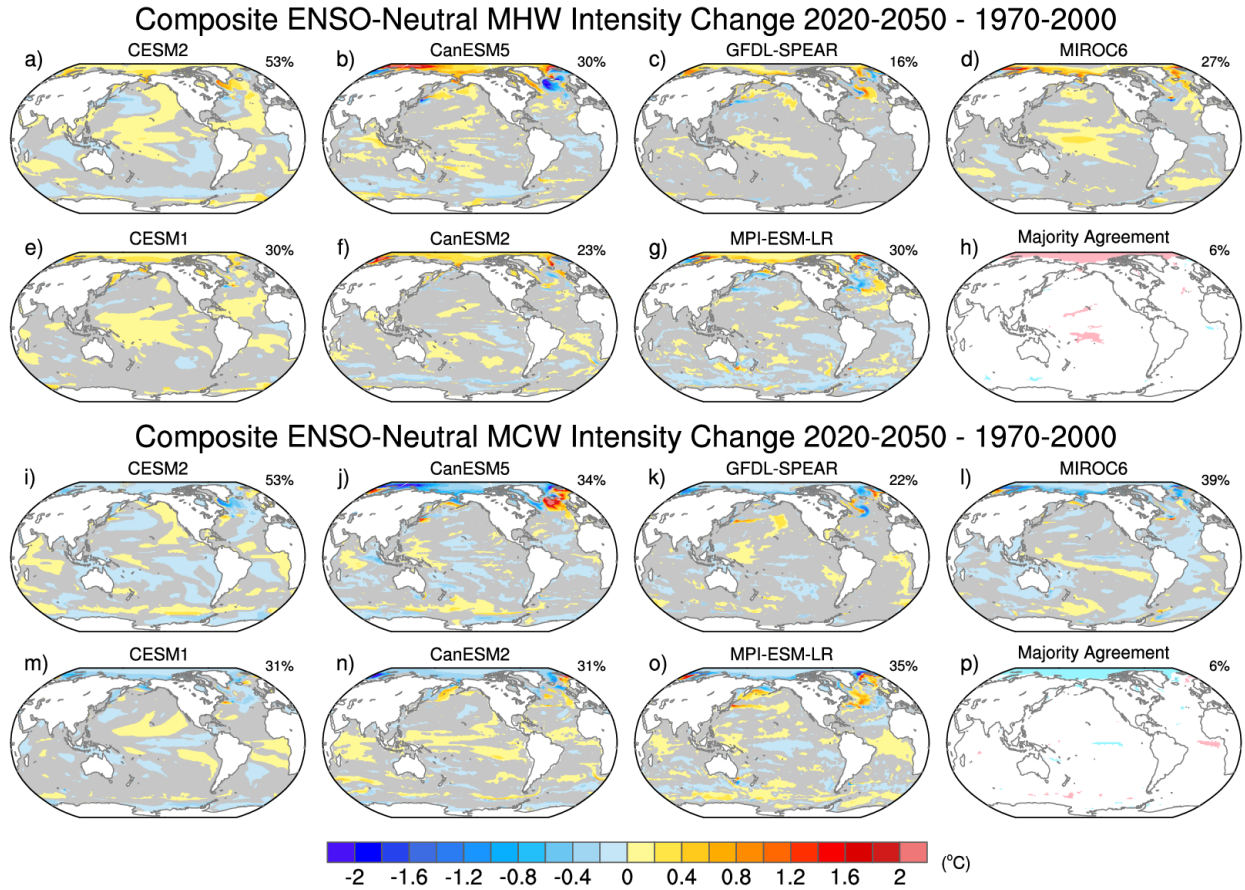
**Figure S39.** As in Fig. S35 but for the 50-member CanESM2 Large Ensemble.

# MPI-ESM-LR



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**Figure S40.** As in Fig. S35 but for the 100-member MPI-ESM-LR Large Ensemble.

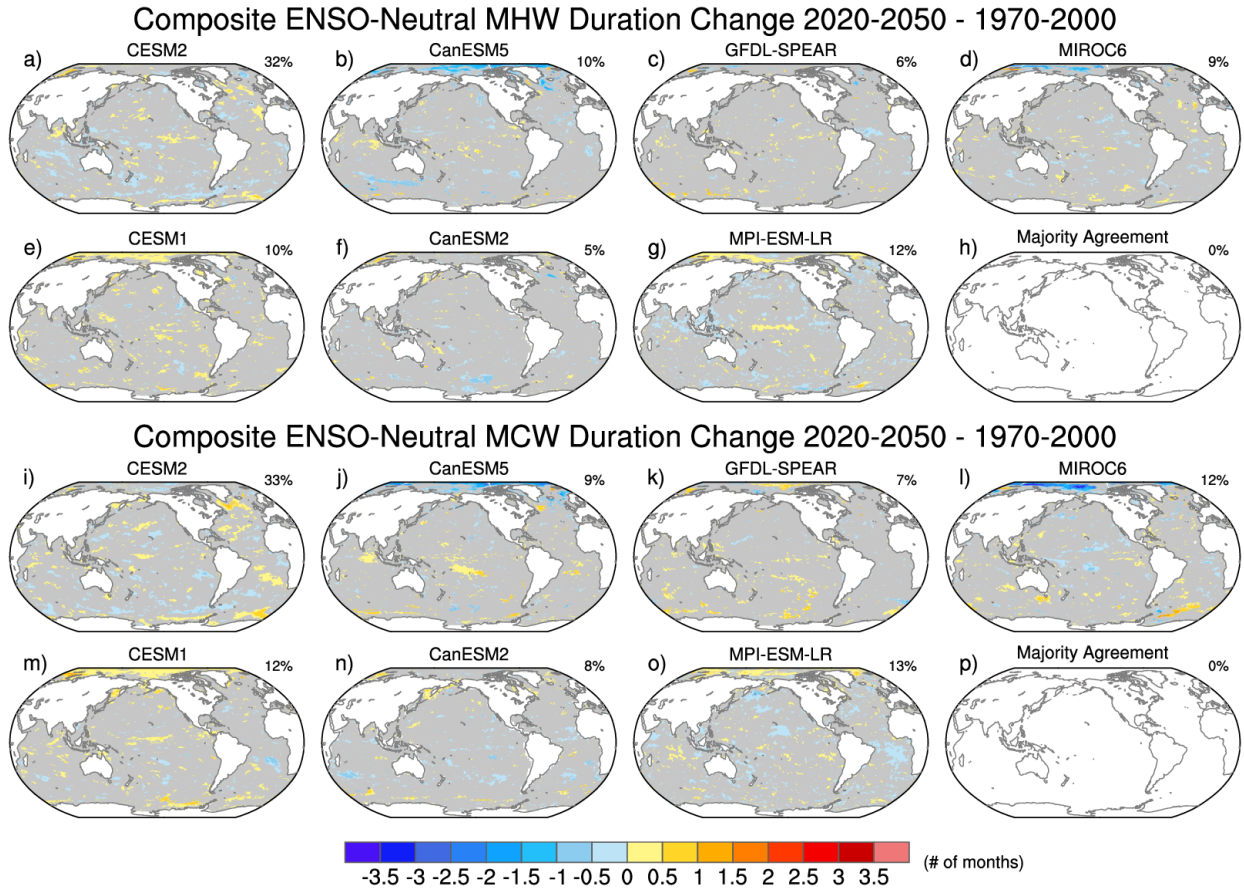


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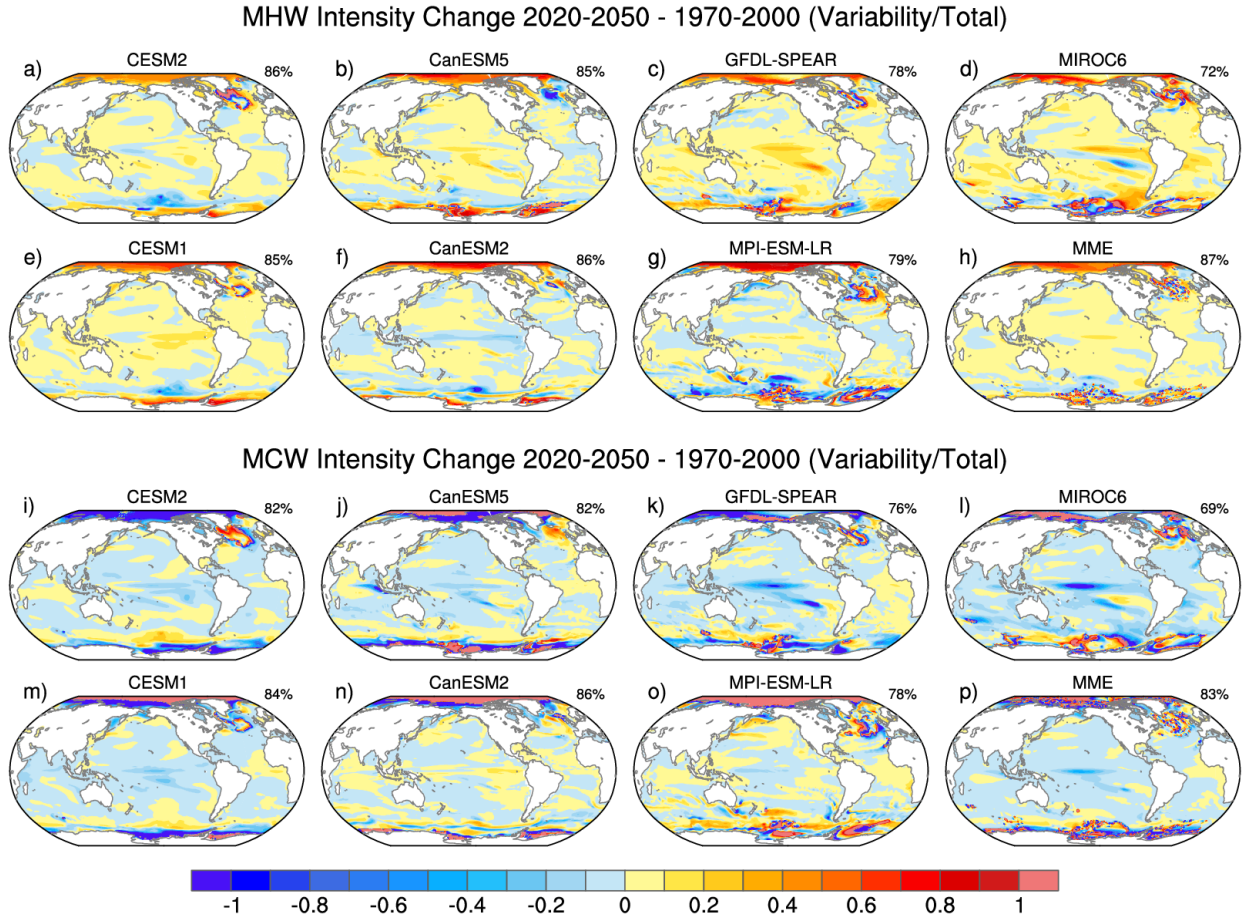
225 **Figure S41.** Composite ENSO-neutral MHW and MCW intensity (°C) differences between  
 226 2020-2050 and 1970-2000 for the ensemble-mean of each model Large Ensemble: (a,h) CESM2;  
 227 (b,i) CanESM5; (c,j) GFDL-SPEAR; (d,k) MIROC6; (e,l) CESM1; (f,m) CanESM2; (g,n) MPI-  
 228 ESM-LR. Gray shading indicates that the differences are not statistically significant according to  
 229 the False Discovery Rate applied to a 2-sided t-test at the 95% confidence level. The number in  
 230 the upper right of each panel denotes the fractional area (%) of significant differences (e.g., non-  
 231 gray areas). Shading in panels (h,p) show locations where at least two-thirds of the models show  
 232 statistically significant values (pink for positive and blue for negative); the number in the upper  
 233 right denotes the fractional area (%) of the pink and blue shading.

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**Figure S42.** As in Fig. S41 but for duration (months).



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**Figure S43.** Ratio of mid-century changes (2020-2050 minus 1970-2000) in MHW and MCW composite intensity due to changes in variability divided by that due to changes in variability-plus-mean state for: (a,h) CESM2; (b,i) CanESM5; (c,j) GFDL-SPEAR; (d,k) MIROC6; (e,l) CESM1; (f,m) CanESM2; (g,n) MPI-ESM-LR. Panels h,p show the multi-model ensemble (MME) average. The number in the upper right of each panel denotes the fractional area (%) of values within the range -0.1 to +0.1.