

How will the intensity and duration of marine heat waves and cold waves change in the future?

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How will the intensity and duration of marine heat waves and cold waves change in the future?

- 1) Background warming
- 2) Changes in variability

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2) Changes in variability 

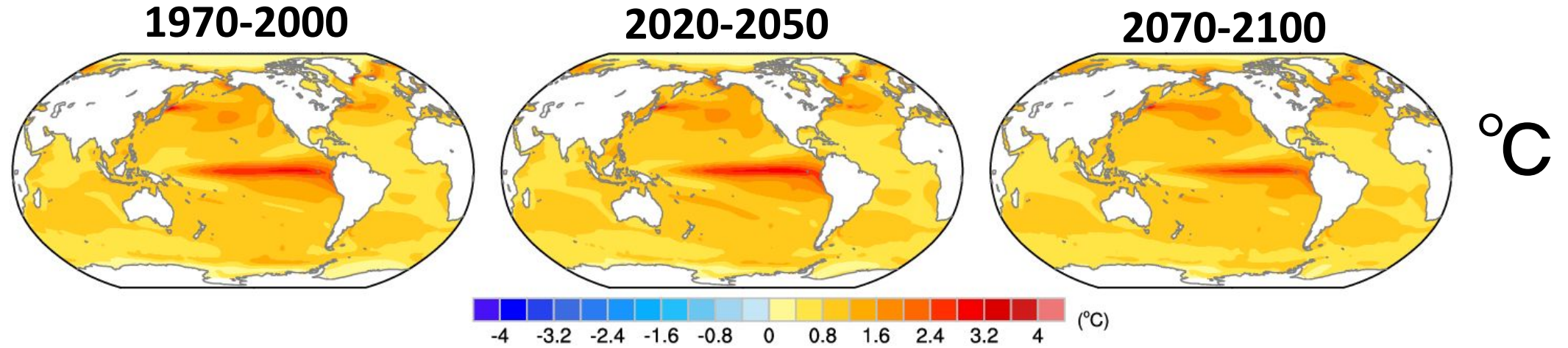
7 Initial-Condition Large Ensembles (1970-2100)

4 CMIP6 models and 3 CMIP5 models (30-100 members each)

Procedure at each grid box (monthly SST):

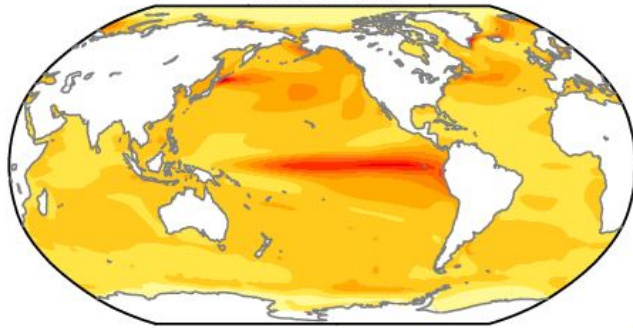
- 1) Remove background warming by subtracting the ensemble mean from each member at each time step: $iSST(t)$.
- 2) Pool together $iSST(t)$ from all members and identify seasonally-varying 10th and 90th % thresholds for 1970-2000, 2020-2050 and 2070-2100 (thresholds computed for each period separately).
- 3) Define a Marine Heat Wave (MHW) when $iSST > 90^{\text{th}}$ % and a Marine Cold Wave (MCW) when $iSST < 10^{\text{th}}$ %.
- 4) Form MHW and MCW composites of intensity ($^{\circ}\text{C}$) and duration (months) for each time period.
(3720 samples in each period for a 100-member ensemble)

Marine Heat Wave Intensity (100-member CESM2 Large Ensemble)

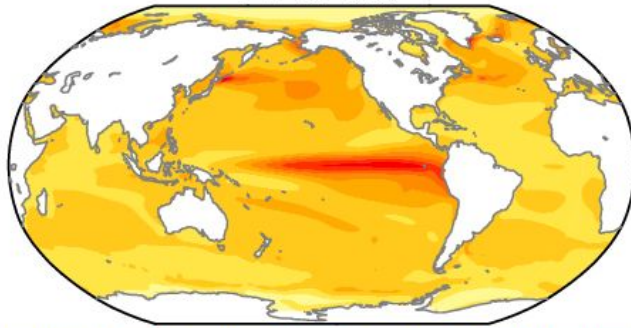


Marine Heat Wave Intensity (100-member CESM2 Large Ensemble)

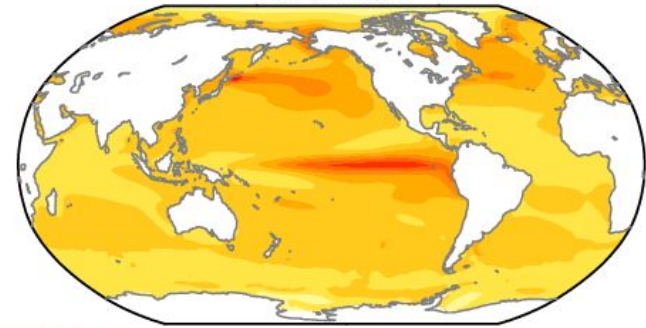
1970-2000



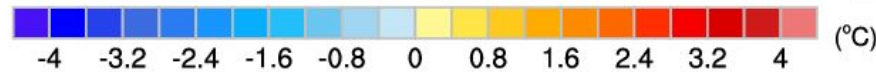
2020-2050



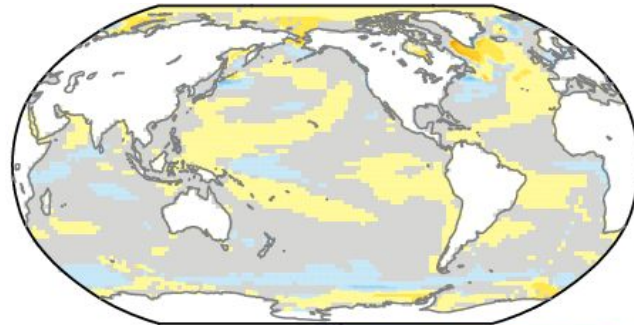
2070-2100



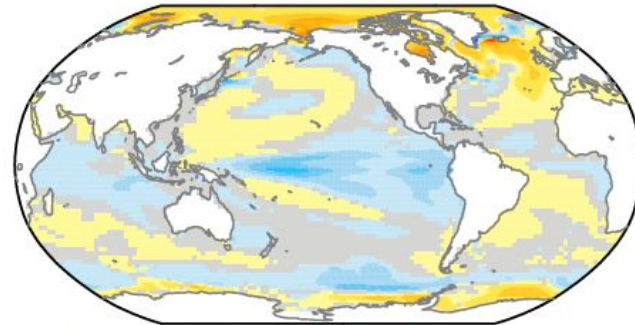
°C



2020-2050



2070-2100



Difference relative
to 1970-2000

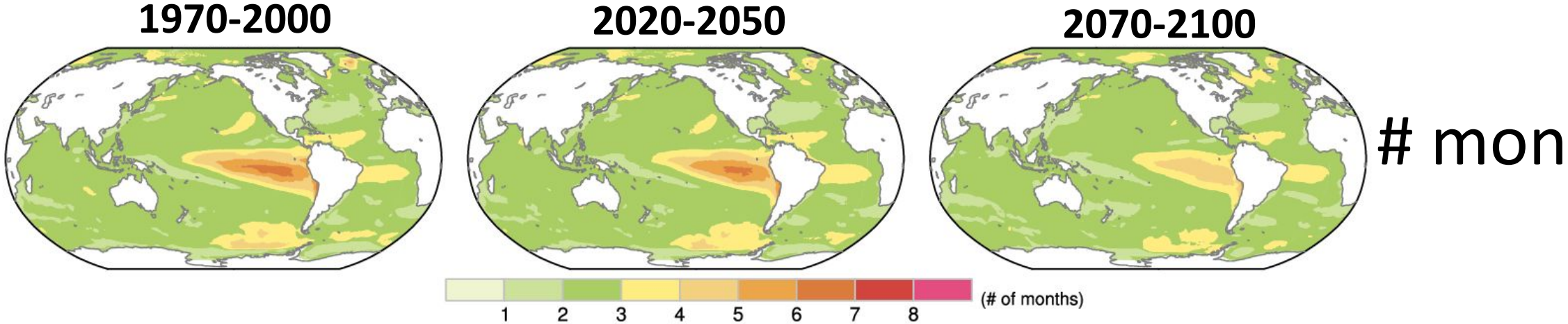
More intense
Less intense



Gray shading: change is insignificant

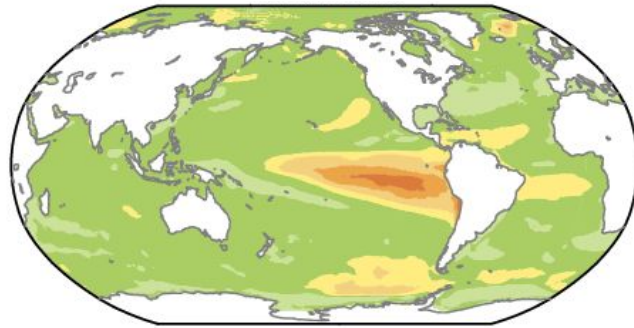
(False Discovery Rate test applied to the t-test at the 5% confidence level)

Marine Heat Wave Duration (100-member CESM2 Large Ensemble)

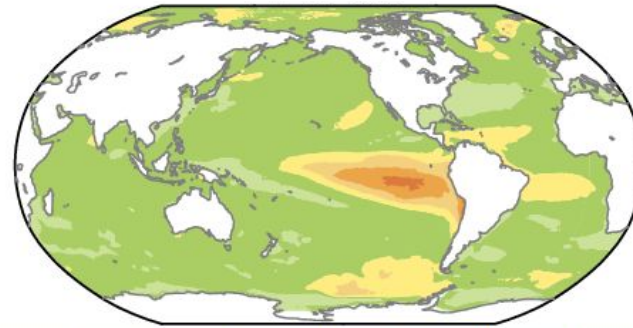


Marine Heat Wave Duration (100-member CESM2 Large Ensemble)

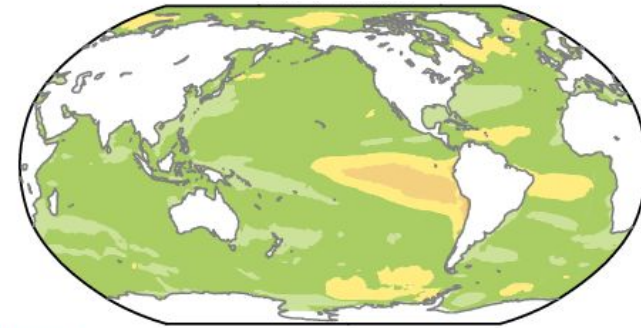
1970-2000



2020-2050



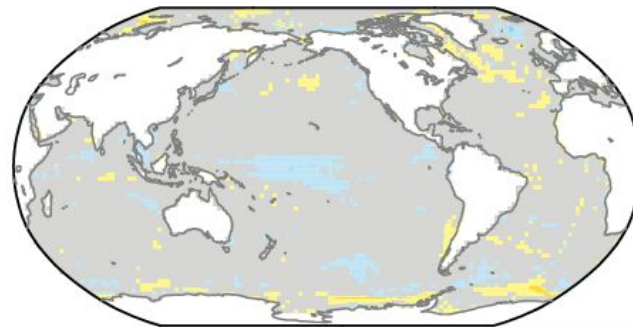
2070-2100



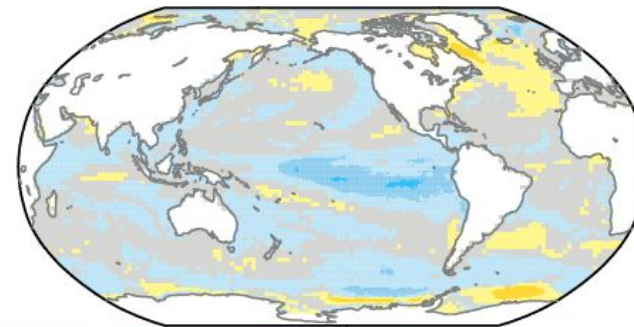
mon



2020-2050



2070-2100



Difference relative
to 1970-2000

Longer
Shorter



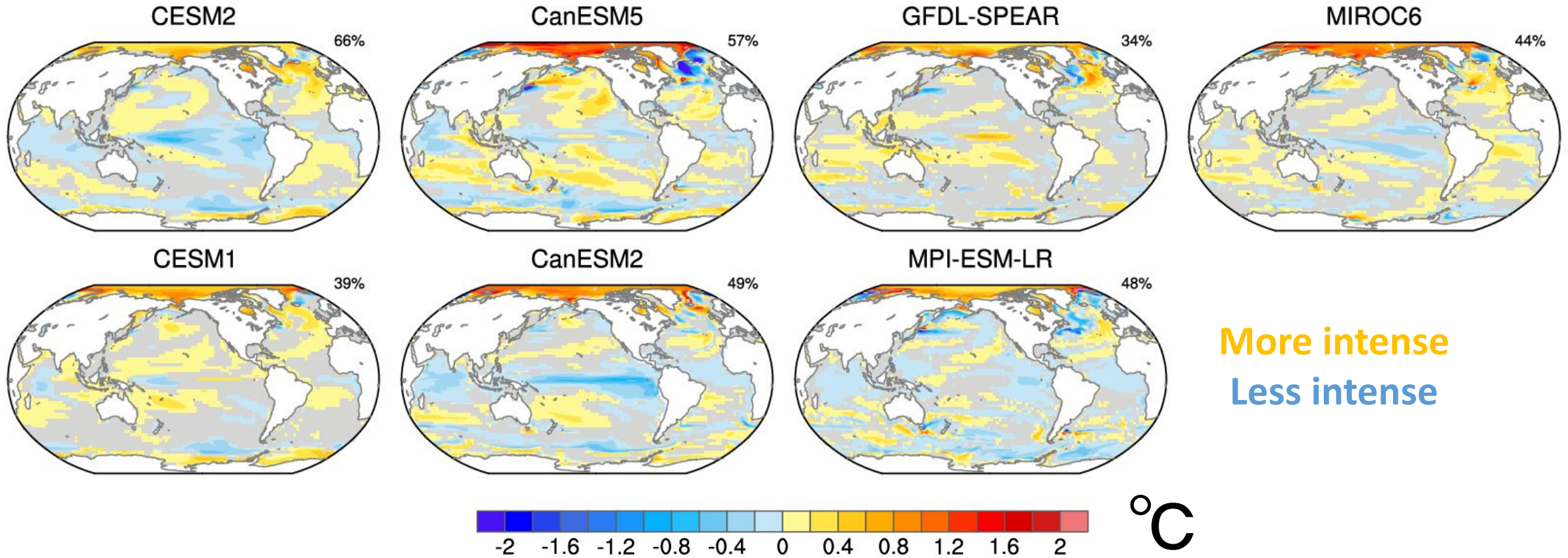
Gray shading: change is insignificant

(False Discovery Rate test applied to the t-test at the 5% confidence level)

Inter-model Comparison

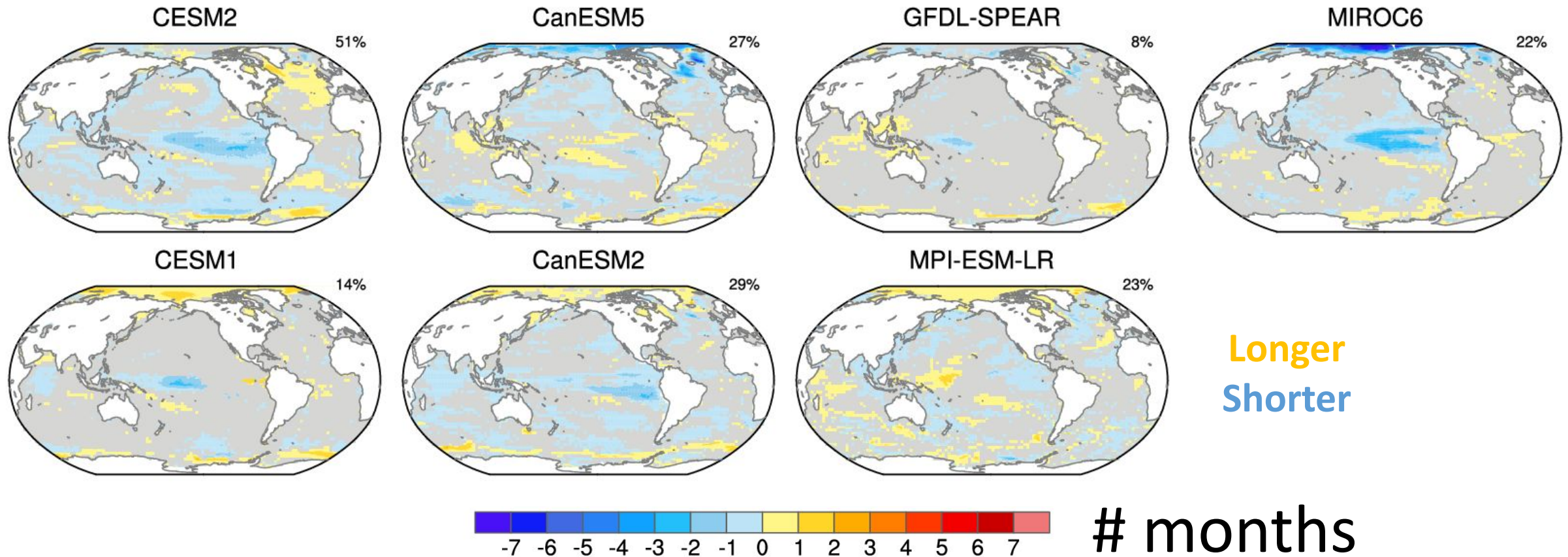
Future Changes
(2070-2100 minus 1970-2000)

Marine Heat Wave Intensity Changes: 2070-2100 minus 1970-2000



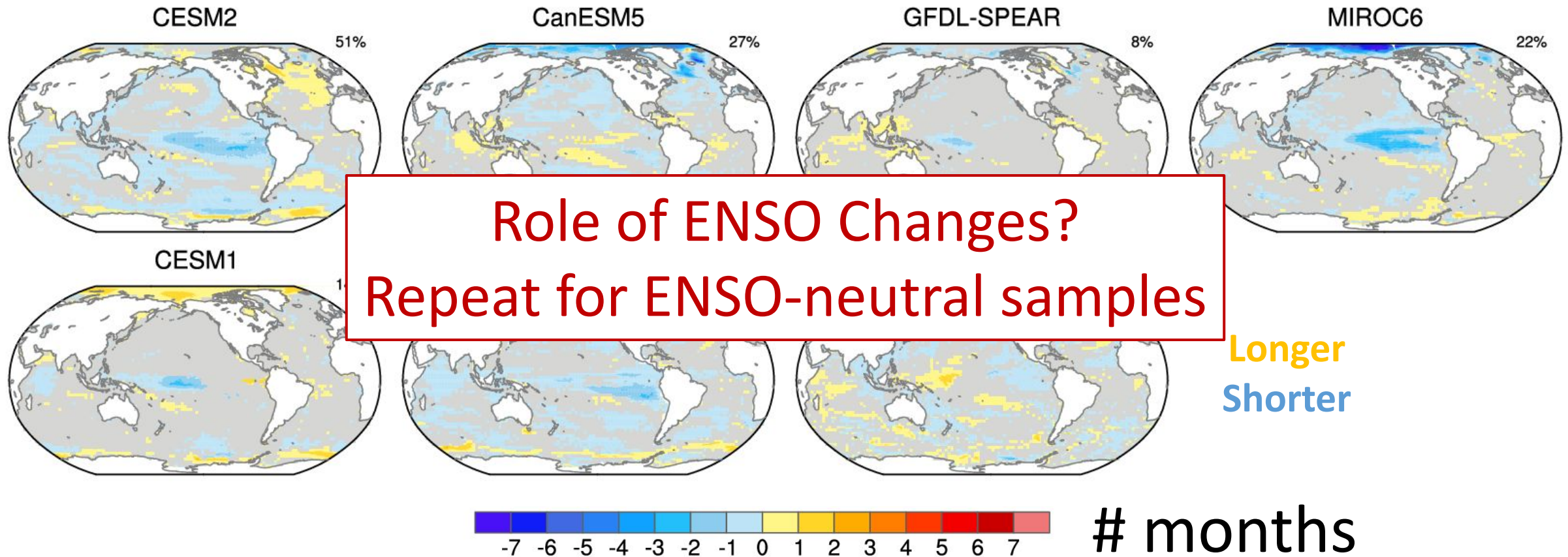
Gray shading: change is insignificant
(False Discovery Rate test applied to the t-test at the 5% confidence level)

Marine Heat Wave Duration Changes: 2070-2100 minus 1970-2000



Gray shading: change is insignificant
(False Discovery Rate test applied to the t-test at the 5% confidence level)

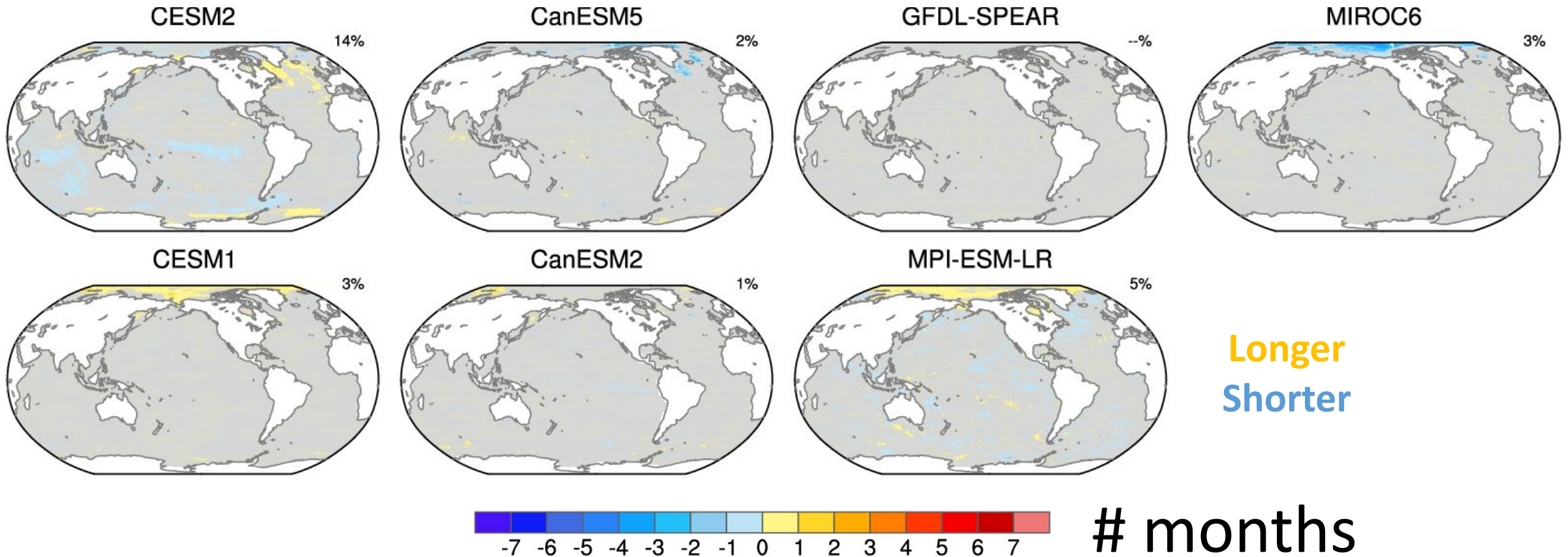
Marine Heat Wave Duration Changes: 2070-2100 minus 1970-2000



Gray shading: change is insignificant
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Marine Heat Wave Duration Changes: 2070-2100 minus 1970-2000

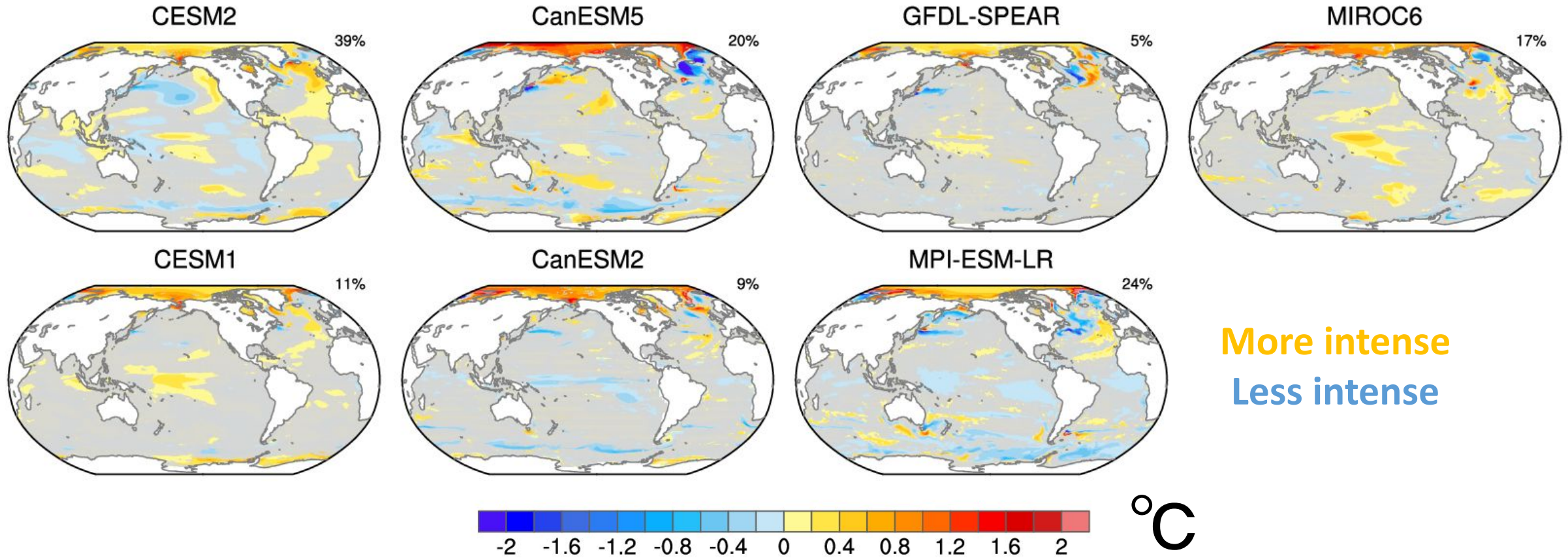
ENSO-neutral samples



Gray shading: change is insignificant
(False Discovery Rate test applied to the t-test at the 5% confidence level)

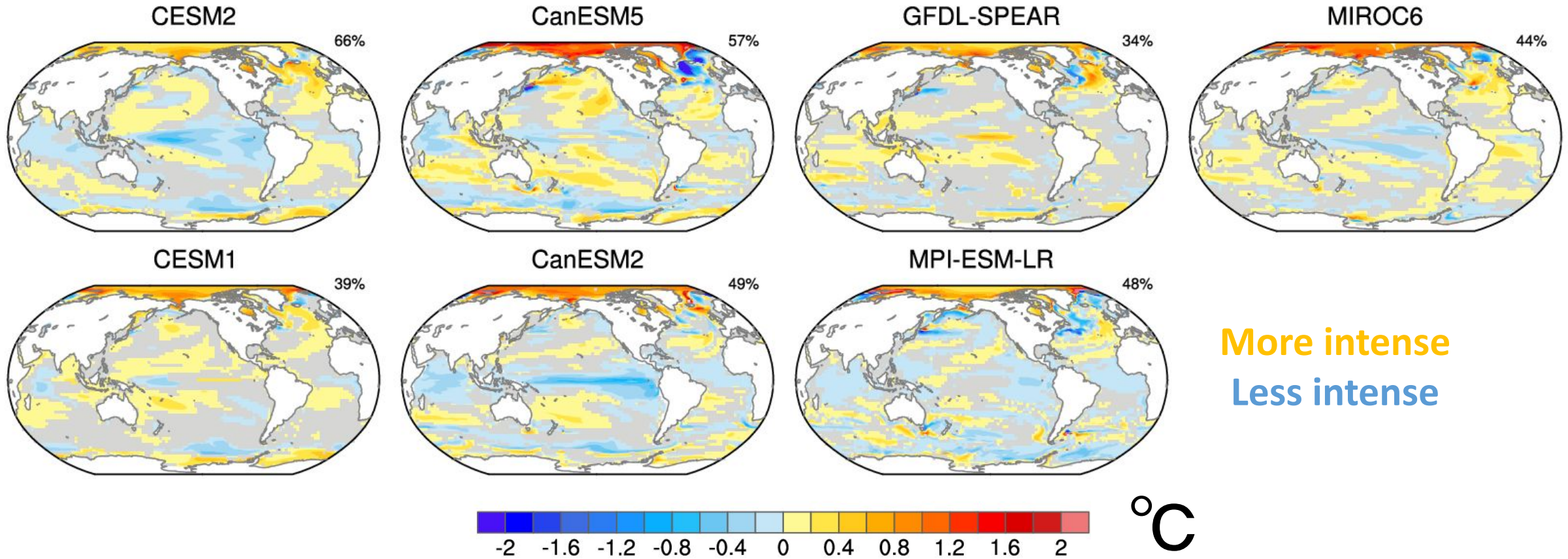
Marine Heat Wave Intensity Changes: 2070-2100 minus 1970-2000

ENSO-neutral samples



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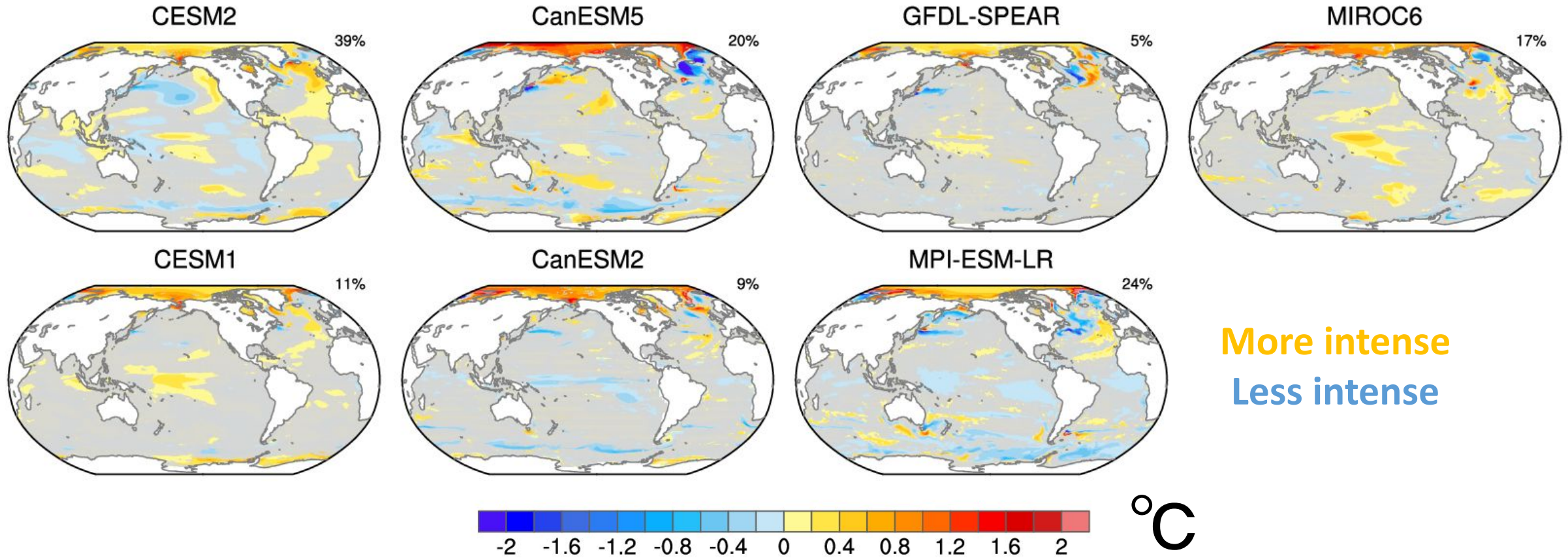
Marine Heat Wave Intensity Changes: 2070-2100 minus 1970-2000



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(False Discovery Rate test applied to the t-test at the 5% confidence level)

Marine Heat Wave Intensity Changes: 2070-2100 minus 1970-2000

ENSO-neutral samples



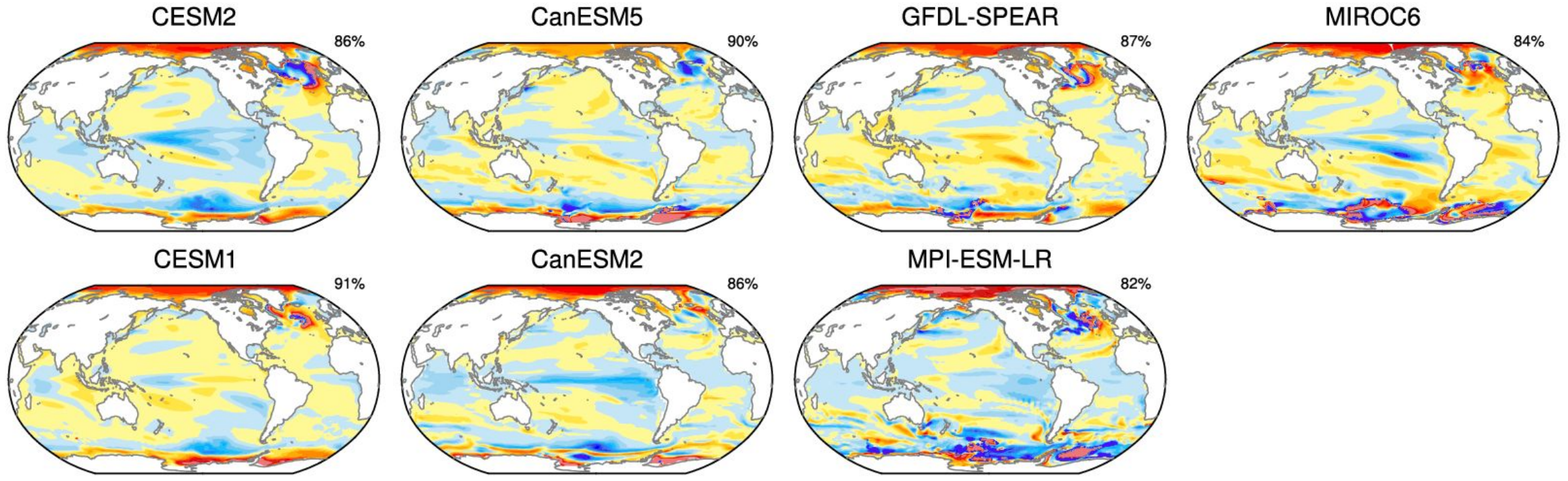
Gray shading: change is insignificant
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Conclusions

- 1) Initial-condition Large Ensembles provide a robust way to quantify future changes in marine heat (and cold) waves arising from changes in variability.
- 2) *In general*, changes in variability are projected to lead to more intense MHWs in the extra-tropics and less intense MHWs in the tropics, and to shorten their duration (except in the Arctic). Similar conclusions hold for MCWs.
- 3) Changes in ENSO account for almost all of the changes in duration and most of the changes in intensity (outside of the Arctic and North Atlantic) noted above.
- 4) Projected changes in variability generally contribute < 10% of the total (background warming + variability) change in MHW intensity except in polar regions.

Marine Heat Wave Intensity Changes: 2070-2100 minus 1970-2000

Internal / (Internal + Mean State)



± 10%