Future hydrographic state of the Scotian Shelf and Gulf of Maine from 23 CMIP6 Models

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2023

Canadian Technical Report of Hydrography and Ocean Sciences 358

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Cat. No. Fs97-18/358E-PDF ISBN 978-0-660-49551-4 ISSN 1488-5417

Correct citation for this publication:

Wang, Z., DeTracey, B., Maniar, A., Greenan, B., Gilbert, D. and Brickman, D., Future hydrographic state of the Scotian Shelf and Gulf of Maine from 23 CMIP6 models. Can. Tech. Rep. Hydrogr. Ocean. Sci. 358: vi + 104 p.

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This report investigates hydrographic changes on the Scotian Shelf and in the Gulf of Maine using 23 CMIP6 earth system models and two future scenarios (SSP245 and SSP370). For each model we first evaluate performance using HadISST1 data and ship-based measurements of bottom temperature. Next, we evaluated seasonality of SST based on forecasts from each CMIP6 model under both climate scenarios. Overall trends of the SST, SSS, SSH, BT and BS for the 2020-2049 period are investigated. In addition, changes of the aforementioned quantities, relative to a historical 1995-2014 period, are calculated for two future periods, 2030-2049 and 2040-2049.

RÉSUMÉ

Wang, Z., DeTracey, B., Maniar, A., Greenan, B., Gilbert, D. and Brickman, D., Future hydrographic state of the Scotian Shelf and Gulf of Maine from 23 CMIP6 models. Can. Tech. Rep. Hydrogr. Ocean. Sci. 358: vi + 104 p.

Le présent rapport examine les changements hydrographiques sur le plateau néo-écossais et dans le golfe du Maine au moyen de 23 modèles de la CMIP6 et 2 scénarios futurs (SSP245 et SSP370). Pour chaque modèle, nous évaluons d'abord les performances en utilisant l'ensemble de données HadISST1 et des mesures de la température du fond effectuées à bord de navires. Nous avons ensuite évalué les tendances saisonnières de la température de la surface de la mer en fonction des prévisions de chaque modèle de la CMIP6 selon les deux scénarios climatiques. On a étudié les tendances générales de la température, de la salinité et de la hauteur de la surface de la mer ainsi que la température et la salinité du fond pour la période de 2020 à 2049. En outre, les variations des quantités susmentionnées, comparativement à la période de 1995 à 2014, sont calculées pour deux périodes futures, soit de 2030 à 2049 et de 2040 à 2049.

1 Introduction

The Scotian Shelf (SS) and Gulf of Maine (GoM) are in the confluent zone of the North Atlantic's subtropical and subpolar gyres and are subject to influences from both the Gulf Stream (GS) and the Labrador Current (LC ; Loder et al., 1998). Changes in these two currents are likely to have significant impacts on the oceanographic characteristics of the SS and GoM. Indeed, recent periods of significant bottom temperature warming on SS have originated from the interaction between these two currents, at the tip of the Grand Bank (GB) (Brickman et al. 2018). Hydrographic conditions in the SS and GoM underpin many of the macro-ecological processes of each region (e.g., Jeffery et al. 2018, Stanley et al. 2018) and changes to these conditions can have significant and measurable impacts on the ecosystem function and ultimately the distribution of biological diversity. For example, Wang et al. (2020) demonstrate that changes in surface and bottom temperatures in the SS and GoM influence the diving behavior of porbeagle sharks; Greenan et al. (2019) utilize the close link between environment (mainly temperature) and lobster distribution to model how the regional fisheries will be influenced by changing oceanographic conditions associated with climate change. The influence of these changes can be profound (i.e., Pershing et al. 2015) and it is therefore essential that knowledge of possible future hydrographic conditions be developed and integrated into both fisheries' planning and management.

The Coupled Model Inter-comparison Project (CMIP), organized under the auspices of the World Climate Research Programme's Working Group on Coupled Modelling, kicked off two decades ago as a comparison of a few early global coupled climate models performing experiments using atmosphere models coupled to a dynamic ocean, a simple land surface, and thermodynamic sea ice (Meehl et al., 1997). CMIP has evolved over six phases into a major international multi-model research activity (Meehl et al., 2000, 2007; Taylor et al., 2012), which has not only opened a new page in climate science research but has also become the core of national and international assessments of climate change. The goals of the Paris Agreement (PA) negotiated in December of 2015 are to keep global warming below 2.0°C, relative to the start of the Industrial Era, and pursue efforts to limit global warming to 1.5°C. However, local climate change can differ greatly from the mean global change, and therefore it is imperative that regional patterns of oceanographic change be investigated so that the influence of any future climate on local ecological function can be better projected. Earth System Models (ESMs) project future temperature change using various evolutions of greenhouse gases, and determine the likelihood of achieving the goals of the PA. Many ESMs have participated in the current on-going sixth phase of CMIP (CMIP6) to quantify how the models represent different aspects of climate change (Eyring et al., 2016). Having reliable and accurate projections of future temperature is critical to achieving the goals of the PA. However, Chapter 11 of IPCC's Fifth Assessment Report states that some ESMs participating in phase five of CMIP (CMIP5; Taylor et al., 2012) evolved from parent models with tendencies to over-estimate 21st century increases in global mean surface temperature (Kirtman et al., 2013).

Due to the heavy computational, storage and bandwidth costs of ESMs (which continue to be developed by adding new or upgrading component systems, e.g., bio-geochemical models), resolutions of CMIP ESMs are generally coarse, which raises challenges for resolving the LC and GS and presents an even greater challenge to resolve the interaction between these currents at the tip of the GB. Loder et al. (2013) reported the climate change projections for the Northwest Atlantic from 6 CMIP5 models for two scenarios (RCP4.5 and RCP8.5). They identified some key failures of these models to resolve detailed structural attributes of several important ocean and ice features, raising concerns of the applicability of these projections to SS and GoM under future climate change scenarios. CMIP6 is the latest modeling effort for simulating and projecting various aspects of climate change. Much of the ESM output has been archived, is freely accessible online and can be used to calculate equilibrium climate sensitivity and forecast future hydrographic change, based on emissions scenarios from several Shared Socio-economic Pathways (SSPs). In addition, some CMIP6 models have eddy permitting spatial resolutions not possible in prior CMIPs, which may better position these models to resolve important regional oceanographic features. CMIP6 ESMs provide a valuable base for investigating the future state of the hydrography for SS and GoM, and verifying how well they represent the hydrography of these two regions.

In this project, we will analyze projections from CMIP6 ESMs for SS and GoM and provide information on the possible future states of these waters, focused on changes in sea surface temperature and salinity (SST, SSS), sea surface height (SSH) , and bottom temperature and salinity (BT, BS). We also attempt to evaluate performance of CMIP6 ESMs using model outputs matched to historical observations. To provide geographically detailed information on the hydrographic changes for the SS, we divide it into three subareas denoting the Eastern (ESS), Central (CSS) and Western (WSS) Scotian Shelf (Figure 1 and summarized in Table 1).

NOTE: For brevity and intelligibility, all future use of the terms “ESM” and “model” refer specifically to the ESM ocean model component, unless explicitly stated otherwise.

2 Data Sources and Methodology

2.1 CMIP6 ESM selection and time series processing

For this report, our goal was to select as many CMIP6 ESMs as possible, and investigate the projected changes of SS and GoM hydrologies. Choosing CMIP6 ESMs is not straight forward, subject to both data availability and adherence of data publishers to CMIP6 publishing standards. CMIP6 is a work in progress, with errors continually fed by data users back to data publishers, who may push corrected datasets to the Earth System Grid Federation (ESGF; ESGF, 2014) if the required corrections are deemed feasible. ESM choice is also dictated by the time and resource constraints of one’s research proposal. Our choice of 23 ESMs should be regarded with these caveats in mind and would best be considered as “random”. All downloaded CMIP6 data was current as of 2021-04-03. A brief summary of the selected ESMs may be found in Table 2. The variables downloaded were monthly mean ocean potential temperature (ESGF variable_id: *thetao*), ocean salinity (*so*) and sea surface height (*zos*). The typical ocean layer vertical resolution of each ESM is shown in Figure 2.

CMIP6 variables for top/bottom potential temperature/salinity (ESGF variable_id: *tos, tob, sos, sob*) are not used. Instead, the top and bottom ocean layers are used for consistency with ESMs that did not provide these variables. (Anecdotally, irregularities were observed with these 4 variables that cast doubt upon their reliability). Some ESMs have an extra bottom layer to include the effects of deep abyssal flow; these were *not* used as the bottom layer. ESM datasets are processed predominantly using Climate Data Operators (CDO; Schulzweida, 2020) with a dash of NetCDF Operators (Zender, 2008). CDO's first order conservative remapping operator *remapcon* (aka *gencon*/*remap*) is used to calculate area weighted averages of each variable/subarea pair, producing the time series used in this report. CDO weights by the areal intersection between a subarea and a given ESM's ocean grid cells, normalizing the weights by their sum. Table 3 summarizes, for each ESM/subarea pair, the total number of ESM data points contributing to the subarea mean value. It also tabulates the area weighted mean ESM ocean grid cell area (ESGF variable_id: *areacello*) and the area weighted mean ESM ocean model depth (ESGF variable_id: *deptho*) and standard deviation (STD).

Data from 23 CMIP6 simulations for the period 1955-2049 are analyzed; 1955 to 2014 is the period of historical simulation, 2015 to 2049 is the period of projected simulation. In this report, we selected two SSP scenarios: SSP245 and SSP370. This report investigates five oceanographic variables: sea surface temperature (SST), sea surface salinity (SSS), sea surface height (SSH), sea bottom temperature (BT), and sea bottom salinity (BS). We calculate trend for each variable over thirty-year groups representing a historical period (1985-2014) and a projected period (2020-2049). Projected changes of bi-decadal means (2030-2049) and of decadal means (2040-2049), relative to a historical bi-decadal mean (1995-2014) are calculated to provide information on the hydrographic changes for the 4 subareas (Figure 1). To provide detailed information about future seasonality of SST, the mean seasonality for the 2030-2049 period is calculated, and changes between this projected seasonality and the historical mean seasonality for the 1995-2014 period are investigated. To evaluate ESM performance, reanalysis SST and ship survey BT are compared with the historical simulations. The correlation between reanalysis product/observations and historical simulations is used to evaluate ESM performance, along with time series differences and trends. We need to mention that any conclusions on ESM performance reflect only what is evaluated within our chosen subareas, and this cannot be used as a refection of the overall performance of each ESM. We interpret differences in ESM performance based on publicly accessible and somewhat basic information about each model. Hence biased, even problematic, judgement is unavoidable. There are a variety of causes that may lead to differing model solutions, e.g., resolution (horizontal and vertical), parameterizations, numerical approaches, etc., and details on many of these are not simply quantified or comparable.

The nominal ESM resolutions vary from ~25 km to ~250 km (Table 1), with the mean ocean grid cell area within models ranging from ~180 km^2 to ~11000 km^2 (Table 2). All selected ESMs are finite difference except for AWI-CM-1-1-MR, a finite element model with high shelf resolution and lower resolutions for open ocean. The ocean top layer thicknesses vary greatly, from 1 m to 12 m (Table 2; Fig.2). Many of the ESMs use variable volume schemes and/or have mixed vertical coordinate schemes. NorESM2-LM uses near-isopycnic interior layers and variable density layers in the surface well-mixed boundary layer.

The ocean model nominal resolutions provided by CMIP6 may be misleading. For example, AWI-CM-1-1-MR has a reported nominal resolution of ~25 km ($\sqrt{625\ km^2}$), but over our subareas the average local resolution is closer to 6 km ($\frac{\sqrt{3}}{4}\sqrt{\sim 180\ km^2}$). Assuming a square grid cell, MPI-ESM1-2-HR and CNRM-CM6-1-HR have local resolutions of ~12 km and ~20 km. AWI-CM-1-1-MR and MPI-ESM1-2-HR are eddy resolving, CNRM-CM6-1-HR is eddy permitting.

NOTE: Issues processing the bottom values from MRI-ESM2-0 were not resolved in time to include BT/BS from this ESM in our analysis.

2.2 HadISST1

HadISST1 (Hadley Centre Sea Ice and Sea Surface Temperature; Met Office Hadley Centre observations datasets; Rayner et al., 2003) is the United Kingdom Met Office's Hadley Centre Interpolated SST dataset, with 1° x 1° resolution extending back to 1870. Met Office starts with data from their Marine Data Bank (MDB) which from 1982 onwards includes data received through the Global Telecommunications System. Monthly median COADS SST is used to fill in missing MDB data for 1871-1995. HadISST1 is constructed using optimal interpolation, followed by blending quality-improved observations to restore local detail. SST near sea ice is estimated using statistical relationships between SST and sea ice concentration.

2.3 Sea bottom temperature DFO July Research Vessel surveys

Since 1999, the Atlantic Zone Monitoring Program (AZMP) of Fisheries and Oceans Canada (DFO) conducts regular surveys along standard sections and stations in order to help understand physical and biological processes in the Atlantic Canada region, which collectively provide a significant database of measurements, predominately temperature and salinity. The broadest spatial temperature and salinity coverage on SS is obtained during the annual DFO Research Vessel (RV) summer trawl survey, which covers SS from Cabot Strait to the Bay of Fundy. The deep-water boundary of the survey is marked roughly by the 200 m isobath along the shelf break at the Laurentian Channel, at the outer SS, and at the Northeast Channel into GoM towards the Bay of Fundy. The RV survey, which takes about one month to complete (nominally July), typically contains about 175 CTD stations, and has been performed on an annual basis since 1970. The temperatures from the survey are interpolated onto a 0.2° x 0.2° latitude-longitude grid at standard depths and at near bottom (Brickman et al., 2018). The near bottom temperatures are used in this report to examine the performance of each ESM in representing bottom temperature. GoM is not covered by this dataset.

3 Validation

In this section we validate CMIP6 ESM surface and bottom temperatures.

3.1 Sea Surface Temperature (SST)

Here we investigate the temporal variability of SST for all CMIP6 ESMs, all subareas. To measure ESM performance, we compare the mean SST from HadISST1 with the 23 ESM SST time series for each subarea, focusing on seasonal representation and temporal variations for the 1955-2014 period.

3.1.1 Seasonal cycle

To provide an indication of the extent to which the seasonal cycles of SST in the historical CMIP6 simulations agree with the reanalysis product, Figure 3 compares bi-decadal monthly means for the 1995-2014 period, from all ESMs and HadISST1, over each subarea. There is a wide range of differences. Although some ESMs appear to be in reasonable agreement with HadISST1, a large number of the models show significant differences. To quantify the difference, we calculate the annual mean absolute difference (*Er*) between the respective bi-decadal monthly mean time series.

$$Er = \frac{1}{12} \sum_{month=1}^{month=12} |cmip6_{month} - Hadisst_{month}| \qquad (1)$$

Table 4 shows the calculated differences using Equation (1) and indicates the “top 5” models with minimal errors and with maximal errors. The differences range from 0.24°C (CSS/AWI-CM-1-1-MR) to 7.45°C (WSS/TaiESM1). WSS has the greatest differences from HadISST1 for almost all ESMs, ESS and CSS have relatively small differences. AWI-CM-1-1-MR, CNRM-CM6-1, CNRM-CM6-1-HR and MPI-ESM1-2-HR all have lower errors for at least 3 of the 4 subareas. MPI-ESM1-2-HR is the only ESM with low errors for all subareas. ACCESS-ESM1-5, CESM2, CESM2-WACCM, GISS-E2-1-G, and TaiESM1 have larger errors.

3.1.2 Annual mean time series 1955-2014

Figure 4 shows the comparison between each CMIP6 ESM and HadISST1. Not surprisingly, the differences are generally large, but some ESMs have smaller differences.

Annual mean time series for CMIP6 ESMs and HadISST1 are compared by calculating diagnostic measures: mean absolute error (Er; Eq. 2) for the 60 year period 1955-2014; correlation coefficients (Cr) between ESM annual mean time series and HadISST1; trend (Tr) of each annual mean time series (Table 5).

$$Er = \frac{1}{60} \sum_{year=1955}^{year=2014} \left|cmip6_{year} - HadISST_{year}\right| \qquad (2)$$

ESM performance varies significantly and is neither consistent across measures (Er, Cr, Tr) nor across subareas. We rank the top and bottom 5 within each column (subarea/measure pair). Both CAMS-CSM1-0 and CNRM-CM6-1-HR demonstrate reasonable agreement with HadISST1. Interestingly, CESM2 and CESM2-WACCM show large Er across all subareas, but their performance for Cr and Tr are among the top 5. For Cr and Tr, ACCESS-CM2 ranks in the bottom 5 for all subareas except GoM.

3.2 Sea Bottom Temperature (BT)

Here we investigate the temporal variability of BT for all but one CMIP6 ESM (MRI-ESM2-0; see Sec. 2.2), and all but one subarea (GoM; see Sec. 2.3). To measure ESM performance we compare ESM time series to the July RV survey data for the ESS, CSS and WSS subareas, over the period 1970-2014.

We found that the differences between CMIP6 ESMs and observations are large, which is not surprising considering the sources of the two datasets, particularly the source of the RV survey data (Figure 5). Comparing a monthly mean (CMIP6) with instantaneous in-situ data taken over a month in early to mid-summer (JAS) can be problematic (Brickman et al. 2018).

CMIP6 ESMs are validated against the RV survey data using the same three measures (Er, Cr, Tr) as for SST, except that the time period is 1970-2014 and Er is defined by:

$$Er = \frac{1}{45} \sum_{year=1970}^{year=2014} \left| cmip6(July)_{year} - RV(July)_{year} \right| \quad (3)$$

ESM performance varies significantly and is neither consistent across measures (Er, Cr, Tr) nor across subareas. Again, we ranked the top and bottom 5 within each subarea/measure pair. From this ranking we show that CNRM-ESM2-1, MPI-ESM1-2-LR and NorESM2-LM demonstrate better agreement with observations for the 3 subareas (Table 6). Interestingly, the models with higher resolutions (AWI-CM-1-1-MR, CNRM-CM6-1-HR, MPI-ESM1-2-HR) do not show consistent performance across subareas and MPI-ESM1-2-HR performs relatively poorly in subareas ESS and CSS. Among the high-resolution models CNRM-CM6-1-HR appears to perform best.

4 Projections

In this section we summarize the CMIP6 ESM projections for SST, SSS, SSH, BT and BS for the SSP245 and SSP370 future scenarios, all subareas.

4.1 Sea Surface Temperature (SST)

In this section we summarize the CMIP6 SST projections, including future seasonality as well as trends and changes in climatology.

4.1.1 Seasonality 2030-2049

To investigate the seasonality changes for each model, two bi-decadal periods, 1995-2014 and 2030-2049, are selected. The historical simulations for the 1995-2014 bi-decade are averaged to create historical monthly climatologies, and for the 2030-2049 bi-decade to create projected monthly climatologies for SSP245 and SSP370 (Fig. 6; Fig. 7). There is a wide range between ESMs, for each month, each subarea and each scenario. Changes between projected monthly climatologies and corresponding historical monthly climatologies are calculated for SSP245 and SSP370 (Fig. 8; Fig. 9).

Figures 10 and 11 show the ranges of the predicted SST changes in seasonality for scenarios SSP245 and SSP370. The largest predicted range is approximately 4°C. The ESM ensemble mean change in SST, however, is in the 1 to 1.5°C range. The “top 5” models from Table 4 have, in general, changes in seasonality well below the mean values for both scenarios.

4.1.2 Annual and seasonal mean time series 1955-2049

Figures 12 to 34 show the 1955-2049 time series of the annual, winter (JFM), spring (AMJ), summer (JAS), and fall (OND) subarea means for each ESM. These figures show the change in each model over a 95-year period created by concatenating historical and projected time series. Bi-decadal means for 1995-2014 (historical) and 2030-2049 (projected) overlay each time series.

In general, the results from each subarea are different, some of them indicating large differences within an ESM.

4.1.3 Trends

In this section, 30-year trends for historical (1985-2014) and projected (2020-2049; SSP245 and SSP370) periods are compared. The trends are calculated for mean annual and seasonal (winter (JFM), spring (AMJ), summer (JAS), fall (OND)) time series. We will not discuss trend results for individual ESMs, instead focusing our assessment as anensemble of all ESM trends, following approaches commonly used used in climate studies.

4.1.3.1 Annual means

Most of the 30-year trends have a range of ~1°C/decade, with GoM/SSP370 having the minimum range (Fig. 35). Some ESMs predict negative (cooling) trends, however, the number of ESMs with negative trends is very small (Fig. 36), suggesting negative trends are unlikely.

Table 7 lists the annual trends of the historical (1985-2014) and projected (2020-2049; SSP245 and SSP370) periods for all subareas and ESMs. ESS has, in general, the greatest historical trend (0.44°C/decade) of all subareas. Its projected trends are smaller with SSP370 having a smaller trend (0.30°C/decade) than SSP245 (0.36°C/decade). CSS has the second strongest historical trend (0.39°C/decade). Again, its projections are smaller with SSP370 (0.30°C/decade) less than SSP245 (0.35°C/decade). However, WSS and GoM have projected trends larger than their historical values (0.30°C/decade; 0.33°C/decade). For WSS, SSP245 (0.30°C/decade) is marginally less than SSP370 (0.32°C/decade). For GoM SSP245 and SSP370 are near identical (0.35°C/decade; 0.34°C/decade).

4.1.3.2 Winter means

Most of the winter trends have ranges greater than 1°C/decade (Fig. 37). The smallest range is for GoM/ SSP245. Some ESMs predict negative (cooling) trends, however, the number of models with negative trends is very small (Fig. 38), suggesting negative trends are unlikely.

Table 8 lists the winter trends. ESS has, in general, the greatest historical trend (0.37°C/decade) of all subareas. Its projected trends are smaller with SSP370 having a smaller trend (0.22°C/decade) than SSP245 (0.32°C/decade). CSS has the second strongest historical trend (0.32°C/decade). Again, its projections are smaller with SSP370 (0.24°C/decade) less than SSP245 (0.32°C/decade; equal to historical). However, WSS and GoM have projected trends larger than their historical values (0.23°C/decade; 0.25°C/decade). For WSS and GoM, SSP245 (0.31°C/decade; 0.34°C/decade) is greater than SSP370 (0.26°C/decade; 0.29°C/decade).

4.1.3.3 Spring means

Most of the spring trends have ranges greater than 1°C/decade (Fig. 39). The smallest range is for GoM/SSP245. Some ESMs predict negative (cooling) trends, however, the number of models with negative trends is very small (Fig. 40), suggesting negative trends are unlikely.

Table 9 lists the spring trends. ESS and CSS have the largest historical trends (both 0.42°C/decade). Both subareas' projected trends are less than their historical trends with SSP245 (0.32^{o}C/decade; 0.33^{o}C/decade) greater than SSP370 (0.24^{o}C/decade; 0.23^{o}C/decade). For WSS and GoM, the historical trends (both 0.42°C/decade) are smaller than the projections for SSP245

(0.31°C/decade; 0.32°C/decade) and SSP370 (0.22°C/decade; 0.30°C/decade). GoM has the greatest trend for SSP370 of all subareas.

4.1.3.4 Summer means

Most of the summer trends have ranges greater than 1°C/decade (Fig. 41). The smallest range is for CSS/SSP245. Some ESMs predict negative (cooling) trends, however, the number of models with negative trends is very small (Fig. 42), suggesting negative trends are unlikely.

Table 10 lists the summer trends. ESS has the largest historical trend (0.56°C/decade). Its projected trends are smaller with SSP245 (0.40°C/decade) marginally less than SSP370 (0.41°C/decade). CSS has the second largest historical trend (0.49°C/decade). Its projected trends are smaller with SSP245 (0.40°C/decade) marginally greater than SSP370 (0.39°C/decade). WSS has a historical trend (0.42°C/decade) slightly greater than projections (0.38°C/decade SSP245; 0.40°C/decade SSP370). GoM (0.43°C/decade historical; 0.40°C/decade SSP 245) has the largest trend for SSP370 (0.44°C/decade) of all subareas and is the only subarea for which SSP370 has the maximum trend.

4.1.3.5 Fall means

Most of the fall trends have a range of ~1°C/decade (Fig. 43). WSS/SSP370 has the largest range (~1.6°C/decade). Some ESMs predict negative (cooling) trends, however, the number of models with negative trends is very small (Fig. 44), suggesting negative trends are unlikely.

Table 11 lists the fall trends. ESS has the largest historical trend (0.40°C/decade). Its projected trends are smaller with SSP245 (0.34°C/decade) greater than SSP370 (0.32°C/decade). CSS has the second largest historical trend (0.32°C/decade). Its projected trends (0.34°C/decade SSP245; 0.32°C/decade SSP370) are not smaller than its historical trend. WSS and GoM have projected trends larger than their historical (0.22°C/decade; 0.31°C/decade) values. For WSS, SSP245 and SSP370 have similar values (0.31°C/decade). This is also true of GoM (0.34°C/decade).

4.1.4 Changes

In this section, projected changes are investigated by comparing historical (1995-2014) bi-decadal annual and seasonal means against two future periods, 2030-2049 (bi-decadal) and 2040-2049 (decadal). The focus is again on the ESM ensemble means of all 23 model solutions.

4.1.4.1 Annual means

Table 12 lists the annual SST changes relative to the historical bi-decadal climatology for 1995-2014. For all subareas under both scenarios the changes for the 2030-2049 period are between 1.3 to 1.4°C, and 1.5 to 1.6°C for the 2040-2049 period.

4.1.4.2 Winter means

Table 13 lists the winter (JFM) SST changes relative to the historical bi-decadal climatology for 1995-2014. For all subareas under both scenarios the changes for the 2030-2049 period are between 1.2 to 1.3°C, and 1.3 to 1.5°C for the 2040-2049 period.

4.1.4.3 Spring means
Table 14 lists the spring (AMJ) SST changes relative to the historical bi-decadal climatology for 1995-2014. For all subareas under both scenarios the changes for the 2030-2049 period are between 1.1 to 1.4°C, and 1.2-1.5°C for the 2040-2049 period.

4.1.4.4 Summer means
Table 15 lists the summer (JAS) SST changes relative to the historical bi-decadal climatology for 1995-2014. For all subareas under both scenarios, the changes for the 2030-2049 period are between 1.5 to 1.6°C, and 1.7 to 1.8°C for the 2040-2049 period.

4.1.4.5 Fall means
Table 16 lists the fall (OND) SST changes relative to the historical bi-decadal climatology for 1995-2014. For all subareas under both scenarios, the SST changes for the 2030-2049 period are between 1.3 to 1.4°C, and 1.5 to 1.7°C for the 2040-2049 period.

4.2 Sea Surface Salinity (SSS)
In this section we summarize the CMIP6 SSS projections, including trends and changes in climatology.

4.2.1 Annual mean time series 1955-2049
Figures 45(a-e) show the 1955-2049 time series of the annual subarea means for each ESM. These figures show the change in each model over a 95 year period created by concatenating historical and projected time series. Bi-decadal means for 1995-2014 (historical) and 2030-2049 (projected) overlay each time series. In general, the results from each subarea are different, some of them indicating large differences within an ESM.

4.2.2 Trends
In this section, 30 year trends for historical (1985-2014) and projected (2020-2049; SSP245 and SSP370) periods are compared. The trends are calculated for mean annual time series. We will not discuss trend results for individual ESMs, instead focusing on the ensemble means of all ESM trends since ensemble statistics are often used in climate studies.

4.2.2.1 Annual means
Most of the 30 year trends have ranges of ~0.6 PSU/decade, with CSS/SSP370 having the maximum range of ~0.91 PSU/decade (Fig. 46). Some ESMs predict negative (freshening) trends, however, a small number of ESMs predict increasing salinity (Fig. 47). The average trend is less than -0.1 PSU/decade. The smallest trend is -0.03 PSU/decade (GoM/SSP370).

Table 17 lists the annual trends of the historical (1985-2014) and projected (2020-2049; SSP245 and SSP370) periods for all subareas and ESMs. ESS is the only subarea with an increasing historical trend (0.03 PSU/decade). Its projected trends are the freshest of all subarea/scenario pairs (-0.08 PSU/decade SSP245; -0.10 PSU/decade SSP370). CSS has a neutral historical trend (0.00 PSU/decade) and freshening projected trends (-0.05 PSU/decade SSP245; -0.09 PSU/decade SSP370). WSS has a freshening historical trend and projected freshening trends with SSP370 marginally greater than SSP245 (-0.06 PSU/decade SSP245; -0.07 PSU/decade SSP370). GoM has a weak freshening historical trend (-0.01 PSU/decade) and is the only subarea for which SSP245 is larger than SSP370 (-0.05 PSU/decade; -0.03 PSU/decade SSP370).

4.2.3 Changes

In this section, projected changes are investigated by comparing historical (1995-2014) bi-decadal annual and seasonal means against two future periods, 2030-2049 (bi-decadal) and 2040-2049 (decadal). The focus is again on the ESM ensemble means of all 23 model solutions.

4.2.3.1 Annual means

Table 18 lists the annual SSS changes relative to the historical bi-decadal climatology for 1995-2014. All projected changes are negative (freshening), except for the mostly neutral changes for GoM. There is small spatial negative trend in the projected changes, progressing ~-0.1 PSU per subarea from west to east (-0.0 PSU GoM; -0.1 PSU WSS; -0.2 PSU CSS, -0.3 PSU ESS).

4.3 Sea Surface Height (SSH)

In this section we summarize the CMIP6 SSH projections, including trends and changes in climatology.

4.3.1 Annual mean time series 1955-2049

Figures 48(a-e) show the 1955-2049 time series of the annual subarea means for each ESM. These figures show the change in each model over a 95 year period created by concatenating historical and projected time series. Bi-decadal means for 1995-2014 (historical) and 2030-2049 (projected) overlay each time series. In general, most ESM have small differences between subareas, however, several ESMs have relatively large subarea differences. The high-resolution ESMs (AWI-CM-1-1-MR, MPI-ESM1-2-HR, CNRM-CM6-1-HR; see end of Sec. 2.1) generally have a much tighter range of SSH across all subareas than lower resolution ESMs.

4.3.2 Trends

In this section, 30-year trends for historical (1985-2014) and projected (2020-2049; SSP245 and SSP370) periods are compared. The trends are calculated from mean annual time series. We will not discuss trend results for individual ESMs, instead focusing on the ensemble means of all ESM trends since ensemble statistics are often used in climate studies.

4.3.2.1 Annual means

Most of the 30-year trends have ranges of ~0.07 m/decade for SSP245 and ~0.09 m/decade for SSP370 (Fig. 49). Most ESMs (Fig. 50) project positive trends (rising sea level), however, a small number of ESMs project weak negative trends (falling sea level). GoM is the only subarea with any negative trends for SSP245. All subareas have a small number of negative trends for SSP370. The average trends for SSP245 and SSP370 are ~0.03 m/decade and ~0.02 m/decade.

Table 19 lists the annual trends of the historical (1985-2014) and projected (2020-2049; SSP245 and SSP370) periods for all subareas and ESMs. The ensemble mean trends are serendipitously near identical for all subareas and experiments (0.01 m/decade historical; 0.03 m/decade SSP245; 0.02 m/decade SSP370). Projections have larger trends than historical, with SSP245 greater than SSP370.

4.3.3 Changes

In this section, projected changes are investigated by comparing historical (1995-2014) bi-decadal annual and seasonal means against two future periods, 2030-2049 (bi-decadal) and 2040-2049 (decadal). The focus is again on the ESM ensemble means of all 23 model solutions.

4.3.3.1 Annual means

Table 20 lists the annual SSH changes relative to the historical bi-decadal climatology for 1995-2014. The bi-decadal changes for SSP245 and SSP370 are near identical for all subareas. SSP245 trends are either 0.01 m greater than SSP370 (ESS, WSS, GoM) or equal (CSS). The projected mean sea level rise for all subareas and projections are 0.085 m (bi-decadal) and 0.10 m (decadal).

4.4 Sea Bottom Temperature (BT)

In this section we summarize the CMIP6 BT projections, including trends and changes in climatology. Remember that ESM MRI-ESM2-0 is *not* included (see end of Sec. 2.1).

4.4.1 Annual mean time series 1955-2049

Figures 51(a-e) show the 1955-2049 time series of the annual subarea means for each ESM. These figures show the change in each model over a 95-year period created by concatenating historical and projected time series. Bi-decadal means for 1995-2014 (historical) and 2030-2049 (projected) overlay each time series. In general, the results from each subarea are different, some of them indicating large differences within an ESM.

4.4.2 Trends

In this section, 30 year trends for historical (1985-2014) and projected (2020-2049; SSP245 and SSP370) periods are compared. The trends are calculated for mean annual time series. We will not discuss trend results for individual ESMs, instead focusing on the ensemble means of all ESM trends since ensemble statistics are often used in climate studies.

4.4.2.1 Annual means

There is a wide spread in the ranges of the 30 year trends. SSP370 has larger ranges than SSP245 (Fig. 52). The ranges for each SSP generally increase by subarea from west to east (GoM, WSS, CSS, ESS). A large number of ESMs project positive trends (warming), however, a small number of ESMs project a decrease in bottom temperatures (Fig. 53). The averaged trends for all subareas, both projections, are between 0.2 to 0.4°C/decade.

Table 21 lists the annual trends of the historical (1985-2014) and projected (2020-2049; SSP245 and SSP370) periods for all subareas and ESMs. All trends are positive (warming). ESS has the largest trends of all subareas. SSP245 trends are greater than SSP370 trends for all subareas. The largest trend is ESS/SSP245 (0.38°C/decade), the smallest is WSS/SSP370 (0.28°C/decade).

4.4.3 Changes

In this section, projected changes are investigated by comparing historical (1995-2014) bi-decadal annual and seasonal means against two future periods, 2030-2049 (bi-decadal) and 2040-2049 (decadal). The focus is again on the ESM ensemble means of 22 model solutions.

4.4.3.1 Annual means

Table 22 lists the annual BT changes relative to the historical bi-decadal climatology for 1995-2014. All changes are positive (warming). ESS has the largest changes of all subareas, CSS the smallest. For bi-decadal projections the difference between SSP245 and SSP370 is less than 0.1°C for all subareas except WSS.

4.5 Sea Bottom Salinity (BS)

In this section we summarize the CMIP6 BS projections , including trends and changes in climatology. Remember that ESM MRI-ESM2-0 is *not* included (see end of Sec. 2.1).

4.5.1 Annual mean time series 1955-2049

Figures 54(a-e) show the 1955-2049 time series of the annual subarea means for each ESM. These figures show the change in each model over a 95-year period created by concatenating historical and projected time series. Bi-decadal means for 1995-2014 (historical) and 2030-2049 (projected) overlay each time series. In general, the results differ significantly between subareas, however, some ESMs have more consistent values.

4.5.2 Trends

In this section, 30 year trends for historical (1985-2014) and projected (2020-2049; both SSP245 and SSP370) periods are compared. The trends are calculated for mean annual time series. We will not discuss trend results for individual ESMs, instead focusing on the ensemble means of all ESM trends since ensemble statistics are often used in climate studies.

4.5.2.1 Annual means

There is a wide spread in the ranges of the 30-year trends. SSP370 has much larger ranges than SSP245 (Fig. 55). The ranges for SSP370 generally increase by subarea from west to east (GoM, WSS, CSS, ESS). The ranges for SSP245 are similar between subareas. The distribution of trends (Fig. 56) shows no clear indication of positive or negative trends. The averaged trends for all subareas, both projections, are ~0.0 PSU/decade.

Table 23 lists the annual BS changes relative to the historical bi-decadal climatology for 1995-2014. The historical trends for the three SS subareas are positive (freshening) and small, and for GoM marginally negative. SSP370 has slightly positive trends for all subareas. SSP245 has slightly negative trends for SS subareas and a slightly positive trend for GoM.

4.5.3 Changes

In this section, projected changes are investigated by comparing historical (1995-2014), bi-decadal, annual and seasonal means against two future periods, 2030-2049 (bi-decadal) and 2040-2049 (decadal). The focus is again on the ESM ensemble means of 22 model solutions.

4.5.3.1 Annual means

Table 24 lists the annual BS changes relative to the historical bi-decadal climatology for 1995-2014. All projected changes are positive. The magnitude of changes follow a negative trend from west to east (GoM, WSS, CSS, ESS). GoM decadal change ranges from 0.6 to 0.8 PSU, bi-decadal change from 0.6 to 0.8 PSU. ESS decadal change ranges from 0.1 to 0.2 PSU, bi-decadal change is 0.0 PSU.

5 Summary

This report investigates future hydrographic changes using 23 CMIP6 ESMs for SST, SSS, and SSH, and 22 for BT and BS.

This report attempts to evaluate the performance of the investigated CMIP6 ESMs using HadISST1 data and ship survey data. This report finds that the three ESMs with relatively high resolutions over the 4 subareas (AWI-CM-1-1-MR, CNRM-CM6-1-HR, MPI-ESM1-2-HR) compare more favorably with HadISST1 data with respect to SST seasonality. Use of high resolution ocean models can reduce SST errors on the shallow shelves.

In terms of representing long term variability of SST, CAMS-CSM1-0 and CNRM-CM6-1-HR have reasonable agreement with HadISST1. In addition, CESM2 and CESM2-WACCM demonstrate good performance on correlation (Cr) and trend (Tr), but not the difference (Er). Better prediction of SST on the shelves cannot be granted solely by the application of higher model resolutions.

With respect to BT, ESM agreement with observed data was not encouraging. CNRM-ESM2-1, NorESM2-LM and MPI-ESM1-2-LR appear to agree better than other ESMs, and CNRM-CM6-1-HR agrees better than the other two high-resolution models. Model resolution does not appear to be a clear factor impacting model performance for BT.

NOTE: The summarized results below are applicable to all subareas and both future scenarios unless explicitly stated otherwise. Additionally, all quantities refer to ESM ensemble mean values unless explicitly stated otherwise.

5.1 SST projections

(1) Regarding the future seasonality of SST, this report finds that the changes in SST ranges are 4°C or greater. Mean seasonality change, however, is in the 1 to 1.5°C range. The "top 5" models have, in general, changes in seasonality well below the mean values for both future scenarios

(2) Regarding SST trends for 2020-2049, the annual means have trends from 0.30 to 0.36°C/decade (SSP245), and 0.30 to 0.34°C /decade (SSP370). The winter means have trends 0.31 to 0.34°C /decade (SSP245), and 0.22 to 0.29°C /decade (SSP370). The spring means have trends 0.31 to 0.33°C /decade (SSP245), and 0.22 to 0.30°C/decade (SSP370). The summer means have trends 0.38 to 0.40°C/decade (SSP245), and 0.39 to 0.44°C/decade (SSP370). The fall means have trends 0.31 to 0.34°C/decade (SSP245), and 0.31 to 0.34°C/decade (SSP370). The greatest trends are projected for the summer season.

(3) Regarding SST changes relative to the historical 1995-2014 period, annual mean SST changes are 1.3 to 1.4°C for 2030-2049, and 1.5 to 1.6°C for 2040-2049. The changes in winter means are 1.2 to 1.3°C (2030-2049) and 1.3 to 1.5°C (2040-2049). The changes in spring means are 1.1 to 1.4°C (2030-2049) and 1.2 to 1.5°C (2040-2049). The changes in summer means are 1.5 to 1.6°C (2030-2049) and 1.7 to 1.8°C (2040-2049). The changes in fall means are 1.3 to 1.4°C (2030-2049) and 1.5 to 1.7°C (2040-2049).

5.2 SSS projections

(1) Regarding SSS trends for 2020-2049, annual means have trends from -0.05 to -0.08 PSU/decade for SSP245, and -0.03 to -0.10 PSU/decade for SSP370.
(2) Regarding SSS changes relative to the historical 1995-2014 period, mean SSS changes are -0.0 to -0.3 PSU (2030-2049) and 0.0 to -0.3 PSU (2040 -2049).

5.3 SSH projections

(1) Regarding SSH trends for 2020-2049, annual means have a trend of 0.03 m/decade for SSP245, and 0.02 m/decade for SSP370.
(2) Regarding SSH changes relative to the historical 1995-2014 period, mean SSH change for 2030-2049 is 0.09 m (SSP245) and 0.08 m (SSP370). For 2040-2049 the changes are 0.09 m (SSP245) and 0.12 m (SSP370).

5.4 BT projections

(1) Regarding BT trends for 2020-2049, annual means have trends from 0.2 to 0.4°C/decade.
(2) Regarding BT changes relative to the historical 1995-2014 period, the changes are 1.1 to 1.4°C (2030-2049) and 1.2 to 1.7°C (2040-2049).

5.5 BS projections

(1) Regarding BS trends for 2020-2049, the annual mean trends are close to 0.0 PSU/decade.
(2) Regarding BS changes relative to the historical 1995-2014 period, the changes are 0.00 to 0.08 PSU (2030-2049) and 0.01 to 0.10 PSU (2040-2049).

Acknowledgements

This work is supported by DFO's ACCASP program. BIO colleagues, Drs. Ryan Stanley and Li Zhai provided helpful comments on an early version of the report. Z.W. would like to thank Dr. John Loder for his support and sharing of useful knowledge for this work.

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Tables

Table 1. Summary of report subareas. STD: standard deviation.

Subarea	Label	Area (10^3 km^2)	Area weighted mean ETOPO1 depth (m)	Area weighted STD ETOPO1 depth (m)
Gulf of Maine	GoM	162	116	72
Western Scotian Shelf	WSS	24	108	37
Central Scotian Shelf	CSS	31	140	50
Eastern Scotian Shelf	ESS	81	100	50

Table 2. Summary of the 23 CMIP6 ESMs selected for this report. M: modelled component; S: specified component; BGC: bio-geochemical.

			Ocean				Atmosphere			Land
Earth system model name	ESGF source_id	ESGF institute_id	Nominal resolution (km)	# Vertical layers	Top layer max. thickness (m)	BGC	Nominal resolution (km)	Chemistry	Aerosol	Land ice
ACCESS-CM2	ACCESS-CM2	CSIRO-ARCCSS	100	50	10	-	250	-	M	-
ACCESS-ESM1.5	ACCESS-ESM1-5	CSIRO	100	50	10	M	250	-	M	-
AWI-CM 1.1 MR	AWI-CM-1-1-MR	AWI	25	46	5	-	100	-	-	-
CAMS-CSM 1.0	CAMS-CSM1-0	CAMS	100	50	10	-	100	-	-	-
CanESM5	CanESM5	CCCma	100	45	6	M	500	M	M	S
CanESM5-CanOE	CanESM5-CanOE	CCCma	100	45	6	M	500	M	M	S
CESM2	CESM2	NCAR	100	60	10	M	100	M	M	M
CESM2-WACCM	CESM2-WACCM	NCAR	100	60	10	M	100	M	M	M
CMCC-CM2-SR5	CMCC-CM2-SR5	CMCC	100	50	1	M	100	-	M	-
CNRM-CM6-1	CNRM-CM6-1	CNRM-CERFACS	100	75	1	-	250	M	S	-
CNRM-CM6-1-HR	CNRM-CM6-1-HR	CNRM-CERFACS	25	75	1	-	100	M	S	-
CNRM-ESM2-1	CNRM-ESM2-1	CNRM-CERFACS	100	75	1	M	250	M	M	-
EC-Earth3	EC-Earth3	EC-Earth-Consortium	100	75	1	-	100	-	-	-
GISS-E2.1G	GISS-E2-1-G	NASA-GISS	100	40	10	-	250	-	-	-
IPSL-CM6A-LR	IPSL-CM6A-LR	IPSL	100	75	2	M	250	-	-	-
MIROC-ES2L	MIROC-ES2L	MIROC	100	63	2	M	500	-	M	-
MIROC6	MIROC6	MIROC	100	63	2	-	250	-	M	-
MPI-ESM1.2-HR	MPI-ESM1-2-HR	MPI-M, DWD, DKRZ	50	40	12	M	100	-	S	-
MPI-ESM1.2-LR	MPI-ESM1-2-LR	MPI-M, AWI, DKRZ	250	40	12	M	250	-	S	-
MRI-ESM2.0	MRI-ESM2-0	MRI	100	61	2	M	100	M	M	-
NorESM2-LM	NorESM2-LM	NCC	100	70	2	M	250	M	M	M
TaiESM 1.0	TaiESM1	AS-RCEC	100	60	10	-	100	M	M	-
UKESM1.0-LL	UKESM1-0-LL	MOHC, NERC, NIMS-KMA, NIWA	100	75	1	M	250	M	M	-

Table 3. Number of ESM data points contributing to each subarea mean; mean ocean grid cell surface area (i.e. resolution); mean and STD of ocean model depth. All quantities are area weighted except "Number of points". An ESGF source_id truncated with an asterisk indicates ESMs with identical grids e.g. ACCESS = ACCESS-CM2 | ACCESS-ESM1-5*

CMIP6 ESM (ESGF source_id)	**Subarea**	**Number of points**	**Area weighted mean ocean grid cell area(km²)**	**Area weighted mean ocean model depth(m)**	**Area weighted STD ocean model depth(m)**
ACCESS*	GOM	27	8369	110	159
	WSS	6	8121	158	249
	CSS	5	7954	119	28
	ESS	19	7677	162	277
AWI-CM-1-1-MR	GOM	1048	180	116	72
	WSS	171	179	108	36
	CSS	214	182	136	47
	ESS	587	165	98	48
CanESM5*	GOM	35	6297	150	274
	WSS	9	6197	143	155
	CSS	10	6129	235	301
	ESS	23	6015	140	210
CAMS-CSM1-0	GOM	26	9087	123	253
	WSS	7	8948	224	318
	CSS	6	8846	191	426
	ESS	18	8706	169	259
CESM2*	GOM	52	4334	199	237
	WSS	10	4194	248	209
	CSS	13	4098	222	195
	ESS	37	3958	234	229
CMCC-CM2-SR5	GOM	35	6297	143	262
	WSS	9	6197	137	151
	CSS	10	6129	223	296
	ESS	23	6015	131	200
CNRM-CM6-1	GOM	35	6297	146	269
	WSS	9	6197	139	150
	CSS	10	6129	225	295
	ESS	23	6015	135	207
CNRM-CM6-1-HR	GOM	450	392	112	72
	WSS	82	386	103	64
	CSS	100	381	142	51
	ESS	255	375	103	69

EC-Earth3	GOM	35	6297	151	275
	WSS	9	6197	144	155
	CSS	10	6129	239	301
	ESS	23	6015	140	210
GISS-E2-1-G	GOM	21	11465	186	283
	WSS	4	11292	287	375
	CSS	8	11156	222	351
	ESS	16	10976	241	298
IPSL-CM6A-LR	GOM	35	6297	151	275
	WSS	9	6197	144	155
	CSS	10	6129	239	301
	ESS	23	6015	140	210
MIROC*	GOM	25	7649	275	298
	WSS	6	7452	302	307
	CSS	5	7327	298	239
	ESS	18	7111	330	328
MPI-ESM1-2-HR	GOM	146	1348	129	120
	WSS	26	1431	127	119
	CSS	30	1473	167	98
	ESS	67	1538	134	105
MPI-ESM1-2-LR	GOM	31	6983	147	149
	WSS	8	6362	149	128
	CSS	10	5986	148	95
	ESS	23	5470	147	159
MRI-ESM2-0	GOM	54	4418	188	232
	WSS	14	4102	232	212
	CSS	14	4130	204	182
	ESS	32	4073	215	225
TaiESM1	GOM	52	4335	200	238
	WSS	10	4194	248	210
	CSS	13	4098	222	195
	ESS	37	3958	235	230
UKESM1-0-LL	GOM	35	6297	150	274
	WSS	9	6197	143	155
	CSS	10	6129	234	301
	ESS	23	6015	139	209

Table 4. The annual mean seasonal differences in SST between CMIP6 ESMs and HadISST1. Black bold: top 5 with minimal differences; Red bold: top 5 with maximal differences. Units are degrees Celsius.

CMIP6 ESM	ESS	CSS	WSS	GOM
ACCESS-CM2	2.13	2.09	2.15	1.95

ACCESS-ESM1-5	***3.87***	***4.97***	***5.49***	***4.42***
AWI-CM-1-1-MR	***0.65***	***0.24***	***1.20***	1.49
CAMS-CSM1-0	1.86	1.74	2.39	1.83
CanESM5	1.71	1.48	3.16	2.54
CanESM5-CanOE	1.71	1.48	3.16	2.54
CESM2	***3.95***	***6.33***	***7.21***	***5.92***
CESM2-WACCM	***4.09***	***6.43***	***7.28***	***6.08***
CMCC-CM2-SR5	1.52	2.09	3.98	3.84
CNRM-CM6-1	***0.38***	***0.70***	***1.15***	1.39
CNRM-CM6-1-HR	1.23	***1.10***	***1.18***	***0.98***
CNRM-ESM2-1	1.02	1.10	1.89	2.49
EC-Earth3	***0.83***	1.23	2.94	2.84
GISS-E2-1-G	***3.20***	***3.84***	***4.70***	***4.79***
IPSL-CM6A-LR	1.01	1.14	1.77	2.06
MIROC6	1.76	1.91	2.57	2.81
MIROC-ES2L	1.72	***1.06***	1.41	***1.18***
MPI-ESM1-2-HR	***0.82***	***0.93***	***0.63***	***0.89***
MPI-ESM1-2-LR	2.28	2.09	1.93	1.25
MRI-ESM2-0	1.53	1.29	***1.03***	***1.16***
NorESM2-LM	***0.71***	1.54	3.17	3.50
TaiESM1	***3.60***	***6.41***	***7.45***	***6.56***
UKESM1-0-LL	1.73	1.73	1.35	***0.96***

Table 5. The mean absolute error (Er), correlation coefficients (Cr) between CMIP6 ESMs and HadISST1 data, and trends (Tr) for all time series, all calculated from time series of annual means, 1955-2014. Black bold: top 5 with minimal differences; Red: top 5 with maximal differences; Underlined: confidence level < 95%; Blue in brackets (in Tr title cell): trend values for HadISST1.

	ESS			CSS			WSS			GOM		
CMIP6 ESM	**Er**	**Cr**	**Tr** (0.28)	**Er**	**Cr**	**Tr** (0.34)	**Er**	**Cr**	**Tr** (0.35)	**Er**	**Cr**	**Tr** (0.24)
ACCESS-CM2	0.77	0.23	0.14	1.64	-0.05	0.06	2.39	-0.07	0.03	1.33	0.26	0.10
ACCESS-ESM1-5	3.58	**0.49**	**0.27**	5.10	0.43	0.20	5.73	0.41	0.15	4.26	0.27	0.18
AWI-CM-1-1-MR	**0.62**	0.47	0.15	**0.65**	0.34	0.15	**1.03**	0.36	0.14	**0.78**	0.21	0.18
CAMS-CSM1-0	**0.57**	**0.57**	**0.30**	1.23	**0.52**	**0.30**	2.55	**0.46**	**0.29**	1.71	0.40	**0.24**
CanESM5	0.97	0.26	0.21	1.54	0.27	0.21	3.47	0.22	0.19	2.40	0.33	0.25
CanESM5-CanOE	0.97	0.26	0.21	1.54	0.27	0.21	3.47	0.22	0.19	2.40	0.33	0.25
CESM2	3.68	**0.50**	**0.25**	6.19	**0.47**	**0.26**	7.20	**0.53**	**0.26**	5.78	**0.57**	**0.25**
CESM2-WACCM	3.63	**0.55**	**0.31**	6.22	**0.48**	**0.28**	7.26	**0.47**	**0.26**	5.87	**0.42**	0.26
CMCC-CM2-SR5	1.13	0.28	0.17	2.38	0.30	0.19	4.27	0.22	0.22	3.71	0.30	**0.24**
CNRM-CM6-1	**0.65**	0.37	0.17	**0.76**	0.24	0.13	1.41	-0.04	0.05	1.63	-0.10	0.05

CNRM-CM6-1-HR	1.11	**0.55**	0.21	**1.02**	0.44	**0.24**	**1.09**	0.41	**0.23**	**0.91**	0.36	**0.24**
CNRM-ESM2-1	1.16	0.42	0.24	1.33	0.36	0.23	2.35	0.22	0.16	2.61	0.26	0.17
EC-Earth3	0.78	0.34	**0.24**	1.21	0.26	0.22	3.15	0.24	0.19	2.75	0.41	0.20
GISS-E2-1-G	**3.17**	0.21	0.13	4.36	0.27	0.15	5.15	0.26	0.16	4.90	0.30	0.16
IPSL-CM6A-LR	**0.60**	0.47	0.19	**0.72**	**0.48**	0.18	2.19	0.36	0.14	2.18	0.36	0.15
MIROC6	1.17	0.48	0.23	1.89	**0.48**	**0.25**	2.55	**0.50**	**0.27**	2.52	**0.50**	0.28
MIROC-ES2L	1.31	0.19	0.10	1.35	0.19	0.11	1.85	0.25	0.13	1.28	0.26	0.17
MPI-ESM1-2-HR	0.80	0.12	0.17	1.02	0.11	0.16	**1.01**	0.10	0.16	**0.78**	-0.01	0.11
MPI-ESM1-2-LR	2.15	0.41	0.20	1.94	0.43	0.21	1.75	0.27	0.18	**1.00**	0.08	0.19
MRI-ESM2-0	0.88	0.33	0.19	**0.74**	0.27	0.17	**1.16**	0.21	0.15	1.11	0.03	0.12
NorESM2-LM	**0.56**	0.47	0.20	1.76	0.39	0.21	3.42	0.35	0.21	3.43	**0.41**	0.22
TaiESM1	3.44	0.47	0.37	6.37	0.45	**0.37**	7.54	**0.53**	**0.30**	6.45	**0.61**	**0.25**
UKESM1-0-LL	1.69	0.35	0.14	1.51	0.16	0.07	**1.18**	0.04	0.01	**0.88**	0.26	0.15

Table 6. The mean absolute error (Er), correlation coefficients (Cr) between CMIP6 ESMs and RV data, and trends (Tr) for all time series, 1970-2014. Black bold: top 5 with minimal differences; Red: top 5 with maximal differences; Underlined: confidence level < 90%; Blue in brackets (in Tr title cell): trend values for and RV July survey data.

CMIP6 ESM	ESS			CSS			WSS		
	Er	Cr	Tr (-0.03)	Er	Cr	Tr (-0.01)	Er	Cr	Tr (0.09)
ACCESS-CM2	3.49	-0.01	0.33	**1.56**	-0.11	0.29	**1.47**	0.05	0.31
ACCESS-ESM1-5	6.85	-0.13	0.33	5.77	-0.09	0.16	5.51	-0.03	0.18
AWI-CM-1-1-MR	1.93	**0.15**	0.41	2.19	-0.08	0.33	**1.18**	0.12	0.39
CAMS-CSM1-0	3.63	-0.10	0.38	1.63	-0.08	0.26	2.56	0.02	0.22
CanESM5	5.71	-0.19	0.16	4.64	**0.11**	0.22	5.01	0.15	0.22
CanESM5-CanOE	5.71	-0.19	0.16	4.64	**0.11**	0.22	5.01	0.15	0.22
CESM2	4.83	-0.12	0.49	2.71	-0.08	0.40	2.91	0.14	0.40
CESM2-WACCM	4.54	-0.03	0.57	2.59	-0.06	0.48	2.81	**0.21**	0.44
CMCC-CM2-SR5	4.07	-0.15	**0.03**	2.90	-0.33	0.10	4.43	-0.23	0.24
CNRM-CM6-1	**1.10**	0.02	-0.22	**1.58**	-0.12	-0.30	**1.15**	-0.07	-0.32
CNRM-CM6-1-HR	**0.90**	**0.05**	0.30	**1.63**	-0.08	0.56	2.07	-0.01	0.51
CNRM-ESM2-1	**1.41**	-0.07	**-0.10**	**0.90**	**0.12**	**-0.00**	**1.14**	**0.22**	0.01
EC-Earth3	7.30	-0.08	**-0.08**	5.44	0.01	**0.05**	5.26	0.03	**0.10**
GISS-E2-1-G	4.09	-0.26	0.11	2.40	-0.25	0.13	2.23	-0.14	**0.15**
IPSL-CM6A-LR	5.18	-0.06	-0.18	3.79	0.05	**-0.05**	4.39	**0.17**	**0.06**
MIROC6	6.02	-0.00	0.28	4.09	**0.07**	0.20	3.56	0.17	0.19
MIROC-ES2L	5.20	**0.15**	**0.10**	3.14	-0.15	0.15	2.67	0.03	**0.14**
MPI-ESM1-2-HR	5.07	-0.04	0.41	3.48	-0.09	0.32	2.11	-0.02	0.34
MPI-ESM1-2-LR	**1.03**	**0.25**	0.18	**1.31**	0.04	0.23	**1.21**	-0.03	0.24

NorESM2-LM	**0.73**	**0.04**	**0.07**	2.09	-0.01	**0.05**	2.27	**0.28**	**0.06**
TaiESM1	3.93	0.03	0.41	2.77	**0.15**	0.25	2.85	**0.34**	0.23
UKESM1-0-LL	3.01	0.02	-0.23	1.93	-0.04	**-0.11**	2.93	-0.06	0.00

Table 7. Trends of SST annual means, each CMIP6 ESM, each subarea, for the periods 1985-2014 (Hist) and 2020-2049 (SSP245 and SSP370). Underlined numbers indicate trends with a confidence level less than 95%. Units are °C/decade.

CMIP6 ESM	**ESS**			**CSS**			**WSS**			**GOM**		
	Hist	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**
ACCESS-CM2	0.45	0.52	0.78	0.37	0.49	0.55	0.23	0.39	0.41	0.16	0.36	0.32
ACCESS-ESM1-5	0.51	0.40	-0.17	0.37	0.35	-0.25	0.31	0.31	-0.19	0.34	0.28	-0.06
AWI-CM-1-1-MR	0.46	0.49	0.70	0.37	0.49	0.77	0.42	0.54	0.77	0.40	0.42	0.78
CAMS-CSM1-0	0.34	0.24	0.02	0.28	0.20	-0.03	0.18	0.15	-0.05	0.24	0.23	0.10
CanESM5	0.33	0.35	0.61	0.31	0.41	0.64	0.20	0.35	0.63	0.34	0.40	0.62
CanESM5-CanOE	0.33	0.35	0.61	0.31	0.41	0.64	0.20	0.35	0.63	0.34	0.40	0.62
CESM2	0.95	0.91	-0.20	0.82	0.96	-0.22	0.59	0.85	0.09	0.42	0.69	0.15
CESM2-WACCM	1.17	0.74	0.16	0.96	0.75	0.18	0.72	0.69	0.29	0.55	0.62	0.37
CMCC-CM2-SR5	0.12	0.66	0.63	0.16	0.56	0.67	0.14	0.47	0.64	0.35	0.44	0.65
CNRM-CM6-1	0.32	0.22	0.04	0.12	0.25	0.05	-0.25	0.25	-0.14	-0.22	0.28	-0.02
CNRM-CM6-1-HR	0.32	0.36	0.40	0.32	0.31	0.39	0.32	0.30	0.42	0.34	0.34	0.41
CNRM-ESM2-1	0.30	0.02	0.01	0.24	-0.02	-0.03	0.13	-0.25	-0.13	0.27	-0.18	-0.06
EC-Earth3	0.55	0.55	0.26	0.54	0.56	0.37	0.50	0.53	0.30	0.56	0.39	0.30
GISS-E2-1-G	-0.01	0.10	0.02	0.13	0.17	0.04	0.22	0.26	0.09	0.29	0.34	0.30
IPSL-CM6A-LR	0.14	0.34	0.81	0.15	0.51	0.75	0.09	0.45	0.85	0.17	0.37	0.78
MIROC6	0.58	0.28	0.33	0.57	0.23	0.36	0.54	0.18	0.32	0.48	0.16	0.37
MIROC-ES2L	0.14	0.58	0.25	0.07	0.60	0.26	0.08	0.57	0.29	0.07	0.50	0.31
MPI-ESM1-2-HR	0.53	0.10	-0.09	0.63	0.06	-0.05	0.68	0.02	-0.01	0.63	0.08	0.26
MPI-ESM1-2-LR	0.32	0.20	0.39	0.29	0.31	0.42	0.10	0.38	0.39	0.03	0.38	0.38
MRI-ESM2-0	0.47	0.21	0.28	0.54	0.31	0.40	0.66	0.54	0.59	0.79	0.79	0.60
NorESM2-LM	0.47	0.15	0.15	0.42	0.13	0.17	0.42	0.22	0.24	0.49	0.29	0.25
TaiESM1	0.72	-0.07	0.27	0.71	0.00	0.29	0.61	0.20	0.28	0.52	0.30	0.24
UKESM1-0-LL	0.57	0.20	0.52	0.26	-0.09	0.43	-0.12	-0.22	0.26	0.09	0.17	0.37
Ensemble mean	**0.44**	**0.36**	**0.30**	**0.39**	**0.35**	**0.30**	**0.30**	**0.30**	**0.32**	**0.33**	**0.35**	**0.34**

Table 8. Trends of SST winter (JFM) means, each CMIP6 ESM, each subarea, for the periods 1985-2014 (Hist) and 2020-2049 (SSP245 and SSP370). Underlined numbers indicate trends with a confidence level less than 95%. Units are °C/decade.

CMIP6 ESM	**ESS**			**CSS**			**WSS**			**GOM**		
	Hist	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**
ACCESS-CM2	0.48	0.50	0.58	0.36	0.46	0.39	0.22	0.38	0.29	0.22	0.25	0.12

ACCESS-ESM1-5	0.38	0.37	-0.28	0.21	0.41	-0.43	0.22	0.37	-0.33	0.26	0.36	0.02
AWI-CM-1-1-MR	0.31	0.37	0.87	0.19	0.43	0.87	0.29	0.50	0.94	0.15	0.26	0.84
CAMS-CSM1-0	0.22	0.29	-0.04	0.10	0.16	-0.07	0.04	0.02	-0.11	0.20	0.19	0.08
CanESM5	0.23	0.33	0.34	0.12	0.22	0.37	-0.08	0.18	0.46	0.15	0.43	0.41
CanESM5-CanOE	0.23	0.33	0.34	0.12	0.22	0.37	-0.08	0.18	0.46	0.15	0.43	0.41
CESM2	1.07	0.98	-0.16	0.87	0.95	0.00	0.66	0.88	0.12	0.47	0.77	0.15
CESM2-WACCM	1.21	0.81	0.18	0.91	0.79	0.28	0.72	0.79	0.32	0.53	0.78	0.34
CMCC-CM2-SR5	-0.05	0.62	0.43	0.21	0.65	0.47	0.12	0.50	0.47	0.30	0.30	0.54
CNRM-CM6-1	0.05	0.23	-0.17	-0.20	0.23	-0.29	-0.53	0.12	-0.53	-0.52	0.26	-0.30
CNRM-CM6-1-HR	0.36	0.36	0.24	0.36	0.27	0.21	0.39	0.30	0.20	0.40	0.13	0.29
CNRM-ESM2-1	0.30	0.05	0.04	0.27	0.09	0.03	0.09	-0.07	-0.14	0.18	-0.06	0.09
EC-Earth3	0.21	0.37	0.16	0.37	0.46	0.36	0.34	0.47	0.36	0.44	0.40	0.37
GISS-E2-1-G	-0.00	0.14	0.10	0.09	0.23	0.20	0.12	0.30	0.22	0.20	0.37	0.19
IPSL-CM6A-LR	0.22	0.37	0.77	0.17	0.47	0.78	-0.06	0.31	0.16	-0.02	0.41	0.80
MIROC6	0.63	0.26	0.42	0.58	0.10	0.43	0.55	0.04	0.40	0.48	0.12	0.43
MIROC-ES2L	0.13	0.65	0.14	0.05	0.68	0.22	0.07	0.58	0.27	0.03	0.58	0.27
MPI-ESM1-2-HR	0.45	-0.02	-0.30	0.61	-0.03	-0.28	0.70	0.01	-0.10	0.73	0.07	0.16
MPI-ESM1-2-LR	0.34	-0.02	0.28	0.22	0.15	0.20	0.01	0.33	0.16	-0.17	0.38	0.17
MRI-ESM2-0	0.42	0.29	0.23	0.54	0.42	0.33	0.70	0.68	0.51	0.73	0.78	0.56
NorESM2-LM	0.40	0.26	0.16	0.38	0.26	0.24	0.38	0.39	0.33	0.49	0.30	0.28
TaiESM1	0.61	-0.10	0.28	0.65	0.07	0.33	0.55	0.28	0.31	0.44	0.38	0.22
UKESM1-0-LL	0.38	-0.14	0.32	0.20	-0.38	0.53	-0.08	-0.43	0.50	-0.00	-0.02	0.24
Ensemble mean	**0.37**	**0.32**	**0.22**	**0.32**	**0.32**	**0.24**	**0.23**	**0.31**	**0.26**	**0.25**	**0.34**	**0.29**

Table 9. Trends of SST spring (AMJ) means, each CMIP6 ESM, each subarea, for the periods 1985-2014 (Hist) and 2020-2049 (SSP245 and SSP370). Underlined numbers indicate trends with a confidence level less than 95%. Units are °C/decade.

CMIP6 ESM	ESS			CSS			WSS			GOM		
	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370
ACCESS-CM2	0.43	0.37	0.81	0.40	0.40	0.64	0.34	0.36	0.49	0.11	0.34	0.35
ACCESS-ESM1-5	0.53	0.41	-0.29	0.44	0.32	-0.46	0.30	0.32	-0.39	0.29	0.22	-0.15
AWI-CM-1-1-MR	0.46	0.58	0.71	0.32	0.64	0.73	0.31	0.68	0.75	0.44	0.48	0.79
CAMS-CSM1-0	0.31	0.26	0.06	0.23	0.20	0.02	0.12	0.21	0.00	0.19	0.17	0.22
CanESM5	0.28	0.23	0.52	0.37	0.36	0.53	0.23	0.17	0.46	0.38	0.22	0.51
CanESM5-CanOE	0.28	0.23	0.52	0.37	0.36	0.53	0.23	0.17	0.46	0.38	0.22	0.51
CESM2	0.87	0.90	-0.23	0.90	1.06	-0.52	0.58	0.92	-0.28	0.37	0.71	-0.05
CESM2-WACCM	1.22	0.64	0.02	1.08	0.76	-0.09	0.76	0.69	0.09	0.53	0.65	0.29
CMCC-CM2-SR5	0.06	0.67	0.60	0.25	0.52	0.68	0.22	0.43	0.76	0.36	0.46	0.70
CNRM-CM6-1	0.48	0.20	-0.10	0.39	0.19	-0.03	0.28	0.27	-0.25	-0.06	0.32	-0.08
CNRM-CM6-1-HR	0.39	0.53	0.40	0.38	0.49	0.39	0.32	0.48	0.44	0.33	0.52	0.40
CNRM-ESM2-1	0.07	-0.02	-0.05	0.11	0.07	-0.06	0.18	-0.02	-0.11	0.23	-0.18	-0.12

EC-Earth3	0.52	0.64	0.29	0.62	0.60	0.37	0.60	0.56	0.22	0.48	0.41	0.16
GISS-E2-1-G	-0.08	0.15	-0.01	0.04	0.21	0.01	0.17	0.26	0.06	0.25	0.30	0.03
IPSL-CM6A-LR	-0.08	0.40	0.82	0.01	0.51	0.84	0.01	0.44	1.01	0.14	0.27	0.92
MIROC6	0.62	0.23	0.27	0.63	0.21	0.26	0.61	0.16	0.26	0.59	0.07	0.29
MIROC-ES2L	0.15	0.59	0.28	0.08	0.64	0.31	0.10	0.66	0.36	0.12	0.58	0.45
MPI-ESM1-2-HR	0.57	0.15	-0.20	0.67	0.07	-0.13	0.71	0.08	-0.19	0.61	0.14	0.16
MPI-ESM1-2-LR	0.48	0.10	0.32	0.51	0.14	0.38	0.34	0.15	0.32	0.19	0.17	0.32
MRI-ESM2-0	0.46	0.08	0.32	0.54	0.20	0.36	0.60	0.33	0.42	0.82	0.79	0.68
NorESM2-LM	0.41	0.14	0.01	0.34	0.10	0.03	0.32	0.19	0.05	0.37	0.32	0.10
TaiESM1	0.73	-0.16	0.14	0.88	-0.34	0.12	0.73	-0.09	0.09	0.56	0.12	0.12
UKESM1-0-LL	0.56	0.14	0.39	0.17	-0.13	0.34	-0.16	-0.40	0.15	0.04	0.05	0.30
Ensemble mean	**0.42**	**0.32**	**0.24**	**0.42**	**0.33**	**0.23**	**0.34**	**0.31**	**0.22**	**0.34**	**0.32**	**0.30**

Table 10. Trends of SST summer (JAS) means, each CMIP6 ESM, each subarea, for the periods 1985-2014 (Hist) and 2020-2049 (SSP245 and SSP370). Underlined numbers indicate trends with a confidence level less than 95%. Units are °C/decade.

CMIP6 ESM	**ESS**			**CSS**			**WSS**			**GOM**		
	Hist	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**
ACCESS-CM2	0.56	0.63	0.91	0.49	0.68	0.68	0.22	0.51	0.49	0.21	0.50	0.48
ACCESS-ESM1-5	0.64	0.42	-0.13	0.50	0.36	-0.10	0.41	0.31	-0.01	0.40	0.28	-0.13
AWI-CM-1-1-MR	0.64	0.60	0.71	0.49	0.47	0.80	0.58	0.49	0.77	0.61	0.56	0.85
CAMS-CSM1-0	0.47	0.18	0.05	0.50	0.23	-0.01	0.39	0.25	-0.02	0.36	0.35	0.08
CanESM5	0.51	0.46	0.91	0.51	0.55	0.94	0.45	0.53	0.91	0.55	0.49	0.94
CanESM5-CanOE	0.51	0.46	0.91	0.51	0.55	0.94	0.45	0.53	0.91	0.55	0.49	0.94
CESM2	1.02	0.88	-0.16	0.85	0.90	-0.27	0.63	0.77	0.06	0.47	0.61	0.30
CESM2-WACCM	1.11	0.77	0.19	0.98	0.74	0.20	0.77	0.62	0.38	0.63	0.48	0.50
CMCC-CM2-SR5	0.35	0.67	0.96	0.27	0.54	0.94	0.26	0.48	0.89	0.45	0.52	0.76
CNRM-CM6-1	0.39	0.28	0.47	0.23	0.27	0.55	0.02	0.28	0.45	-0.04	0.25	0.37
CNRM-CM6-1-HR	0.27	0.35	0.63	0.30	0.32	0.67	0.29	0.29	0.72	0.31	0.51	0.68
CNRM-ESM2-1	0.37	-0.01	0.04	0.32	0.01	0.03	0.28	-0.16	-0.05	0.28	-0.21	-0.00
EC-Earth3	1.08	0.70	0.33	0.88	0.66	0.31	0.75	0.58	0.26	0.78	0.41	0.24
GISS-E2-1-G	0.06	-0.20	-0.03	0.27	0.24	-0.09	0.37	0.36	-0.05	0.38	0.47	0.12
IPSL-CM6A-LR	0.56	0.38	0.82	0.53	0.44	0.61	0.56	0.45	0.65	0.52	0.34	0.56
MIROC6	0.53	0.33	0.28	0.56	0.26	0.41	0.51	0.25	0.35	0.44	0.20	0.39
MIROC-ES2L	0.10	0.62	0.21	0.06	0.61	0.17	0.09	0.60	0.14	0.10	0.50	0.18
MPI-ESM1-2-HR	0.57	0.22	0.22	0.59	0.25	0.22	0.59	0.14	0.19	0.58	0.15	0.42
MPI-ESM1-2-LR	0.48	0.28	0.57	0.47	0.42	0.60	0.32	0.43	0.61	0.26	0.32	0.56
MRI-ESM2-0	0.47	0.26	0.30	0.48	0.33	0.43	0.58	0.49	0.64	0.83	0.89	0.70
NorESM2-LM	0.65	0.13	0.23	0.60	0.11	0.24	0.59	0.19	0.27	0.57	0.28	0.29
TaiESM1	0.75	0.02	0.32	0.66	0.12	0.36	0.58	0.29	0.36	0.55	0.35	0.32
UKESM1-0-LL	0.70	0.52	0.70	0.29	0.10	0.39	-0.05	0.05	0.24	0.29	0.42	0.60

Ensemble mean	**0.56**	**0.40**	**0.41**	**0.49**	**0.40**	**0.39**	**0.42**	**0.38**	**0.40**	**0.43**	**0.40**	**0.44**

Table 11. Trends of SST fall (OND) means, each CMIP6 ESM, each subarea, for the periods 1985-2014 (Hist) and 2020-2049 (SSP245 and SSP370). Underlined numbers indicate trends with a confidence level less than 95%. Units are °C/decade.

CMIP6 ESM	**ESS**			**CSS**			**WSS**			**GOM**		
	Hist	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**
ACCESS-CM2	0.33	0.60	0.81	0.23	0.43	0.48	0.13	0.30	0.40	0.21	0.34	0.33
ACCESS-ESM1-5	0.51	0.40	0.03	0.36	0.29	-0.02	0.33	0.22	-0.06	0.43	0.28	0.02
AWI-CM-1-1-MR	0.41	0.45	0.52	0.49	0.44	0.67	0.51	0.49	0.60	0.41	0.37	0.65
CAMS-CSM1-0	0.34	0.25	0.02	0.28	0.23	-0.06	0.17	0.13	-0.05	0.21	0.20	0.01
CanESM5	0.30	0.37	0.69	0.25	0.50	0.73	0.21	0.51	0.69	0.27	0.46	0.62
CanESM5-CanOE	0.30	0.37	0.69	0.25	0.50	0.73	0.21	0.51	0.69	0.27	0.46	0.62
CESM2	0.84	0.89	-0.25	0.65	0.90	-0.10	0.49	0.81	0.13	0.37	0.67	0.21
CESM2-WACCM	1.16	0.75	0.26	0.87	0.72	0.32	0.64	0.64	0.36	0.50	0.55	0.35
CMCC-CM2-SR5	0.11	0.69	0.54	0.00	0.62	0.58	-0.05	0.48	0.45	0.27	0.46	0.62
CNRM-CM6-1	0.37	0.18	-0.02	0.05	0.30	-0.01	-0.76	0.31	-0.25	-0.24	0.27	-0.08
CNRM-CM6-1-HR	0.27	0.22	0.32	0.25	0.15	0.30	0.25	0.13	0.31	0.32	0.21	0.28
CNRM-ESM2-1	0.45	0.07	0.02	0.24	-0.25	-0.13	-0.02	-0.74	-0.21	0.37	-0.26	-0.19
EC-Earth3	0.39	0.46	0.25	0.29	0.52	0.43	0.32	0.50	0.39	0.56	0.33	0.43
GISS-E2-1-G	-0.02	-0.09	0.01	0.14	0.00	0.06	0.22	0.10	0.15	0.32	0.21	0.24
IPSL-CM6A-LR	-0.15	0.32	0.83	-0.12	0.63	0.77	-0.15	0.61	0.81	0.03	0.44	0.83
MIROC6	0.53	0.31	0.32	0.50	0.33	0.35	0.49	0.27	0.29	0.42	0.24	0.36
MIROC-ES2L	0.18	0.48	0.34	0.09	0.46	0.36	0.06	0.45	0.36	0.02	0.32	0.36
MPI-ESM1-2-HR	0.53	0.05	-0.07	0.63	-0.03	0.01	0.73	-0.12	0.06	0.62	-0.03	0.29
MPI-ESM1-2-LR	-0.02	0.45	0.39	-0.04	0.53	0.51	-0.30	0.60	0.48	-0.16	0.64	0.46
MRI-ESM2-0	0.52	0.19	0.27	0.60	0.30	0.49	0.77	0.66	0.79	0.77	0.70	0.45
NorESM2-LM	0.44	0.06	0.18	0.38	0.07	0.19	0.39	0.12	0.29	0.51	0.25	0.33
TaiESM1	0.77	-0.04	0.35	0.66	0.18	0.35	0.58	0.31	0.34	0.52	0.36	0.29
UKESM1-0-LL	0.65	0.27	0.67	0.37	0.04	0.45	-0.22	-0.11	0.15	0.05	0.24	0.34
Ensemble mean	**0.40**	**0.34**	**0.31**	**0.32**	**0.34**	**0.32**	**0.22**	**0.31**	**0.31**	**0.31**	**0.34**	**0.34**

Table 12. Projected bi-decadal (bd:2030-2049) and decadal (de: 2040-2049) annual mean changes of SST relative to 1995-2014 period for SSP245 (s2) and SSP370 (s3). Units are degrees Celsius.

CMIP6 ESM	**ESS**				**CSS**				**WSS**				**GOM**			
	bd s2	**bd s3**	**de s2**	**de s3**	**bd s2**	**bd s3**	**de s2**	**de s3**	**bd s2**	**bd s3**	**de s2**	**de s3**	**bd s2**	**bd s3**	**de s2**	**de s3**
ACCESS-CM2	1.6	1.9	1.9	2.2	1.1	1.4	1.2	1.5	0.8	1.2	0.9	1.1	1.2	1.5	1.2	1.5
ACCESS-ESM1-5	1.2	0.7	1.3	0.9	1.2	0.6	1.3	0.6	1.3	0.6	1.4	0.7	1.4	0.9	1.5	1.0
AWI-CM-1-1-MR	2.0	2.0	2.6	2.5	1.8	2.0	2.4	2.6	1.9	2.0	2.5	2.6	1.8	2.0	2.3	2.6

CAMS-CSM1-0	0.2	0.5	0.5	0.8	0.1	0.5	0.3	0.7	0.1	0.5	0.2	0.7	0.3	0.6	0.4	0.8
CanESM5	2.5	3.0	2.6	3.5	2.6	3.0	2.6	3.5	2.5	2.8	2.5	3.4	2.4	2.6	2.5	3.0
CanESM5-CanOE	2.5	3.0	2.6	3.5	2.6	3.0	2.6	3.5	2.5	2.8	2.5	3.4	2.4	2.6	2.5	3.0
CESM2	0.9	0.1	1.3	0.3	0.8	-0.0	1.2	0.1	1.0	0.3	1.3	0.5	1.2	0.7	1.5	0.9
CESM2-WACCM	1.3	0.6	1.7	0.5	1.1	0.6	1.5	0.6	1.1	0.8	1.5	0.9	1.1	0.9	1.5	1.1
CMCC-CM2-SR5	1.0	1.2	1.6	1.5	1.0	1.4	1.5	1.7	0.9	1.4	1.3	1.7	0.7	1.2	1.0	1.6
CNRM-CM6-1	1.0	0.5	1.0	0.7	1.1	0.7	1.2	1.0	1.4	0.8	1.6	1.1	1.6	1.2	1.7	1.4
CNRM-CM6-1-HR	1.0	0.9	1.2	1.2	0.7	0.7	1.0	1.0	0.7	0.8	1.1	1.1	0.7	0.9	1.2	1.1
CNRM-ESM2-1	0.8	0.6	0.6	0.5	0.8	0.6	0.5	0.5	0.7	0.8	0.4	0.7	1.0	0.9	0.6	1.0
EC-Earth3	1.7	1.6	2.2	1.8	1.5	1.6	2.0	1.9	1.1	1.4	1.7	1.6	1.4	1.7	1.7	1.8
GISS-E2-1-G	0.8	0.7	0.6	0.5	0.9	0.7	1.0	0.3	1.1	0.7	1.1	0.4	1.1	0.7	1.2	0.5
IPSL-CM6A-LR	1.5	1.5	1.8	2.0	1.4	1.3	1.7	1.8	1.5	1.3	1.7	1.9	1.5	1.3	1.7	1.9
MIROC6	1.1	0.9	1.2	1.1	0.9	0.9	1.0	1.1	0.9	0.9	0.9	1.1	0.8	1.0	0.8	1.3
MIROC-ES2L	1.9	1.4	2.3	1.3	1.8	1.4	2.5	1.4	1.7	1.4	2.4	1.4	1.6	1.4	2.2	1.4
MPI-ESM1-2-HR	0.9	0.7	1.0	0.5	1.1	0.8	1.0	0.6	0.9	0.7	0.9	0.5	1.2	1.1	1.1	1.1
MPI-ESM1-2-LR	1.1	1.0	1.3	1.3	1.3	0.9	1.5	1.3	1.5	0.9	1.8	1.3	1.4	1.0	1.6	1.3
MRI-ESM2-0	1.4	1.4	1.4	1.6	1.6	1.6	1.5	2.0	1.8	1.9	1.8	2.3	2.0	2.0	2.1	2.4
NorESM2-LM	1.8	1.7	2.3	1.7	2.5	1.6	1.9	1.6	1.6	1.6	1.8	1.6	1.4	1.6	1.7	1.6
TaiESM1	1.1	2.2	1.2	2.2	0.9	1.7	0.9	1.8	0.9	1.5	1.0	1.5	1.0	1.2	1.1	1.3
UKESM1-0-LL	2.3	2.8	2.5	2.0	2.2	3.0	2.3	3.1	2.0	3.0	2.2	2.9	2.2	2.8	2.4	2.8
Ensemble mean	**1.4**	**1.3**	**1.6**	**1.5**	**1.3**	**1.3**	**1.5**	**1.5**	**1.3**	**1.3**	**1.5**	**1.5**	**1.4**	**1.4**	**1.5**	**1.6**

Table 13. Projected bi-decadal (bd:2030-2049) and decadal (de: 2040-2049) winter (JFM) mean changes of the SST relative to 1995-2014 period for SSP245 (s2) and SSP370 (s3). Units are degrees Celsius.

CMIP6 ESM	**ESS**				**CSS**				**WSS**				**GOM**			
	bd s2	**bd s3**	**de s2**	**de s3**	**bd s2**	**bd s3**	**de s2**	**de s3**	**bd s2**	**bd s3**	**de s2**	**de s3**	**bd s2**	**bd s3**	**de s2**	**de s3**
ACCESS-CM2	1.3	1.5	1.3	1.7	0.7	0.9	0.5	0.9	0.2	0.5	0.1	0.4	1.1	1.3	0.9	1.1
ACCESS-ESM1-5	0.9	0.4	0.9	0.6	1.1	0.3	1.2	0.2	1.2	0.3	1.3	0.3	1.5	0.8	1.5	1.0
AWI-CM-1-1-MR	2.0	2.1	2.5	2.7	1.7	1.9	2.3	2.4	1.9	2.0	2.5	2.7	1.8	2.0	2.0	2.5
CAMS-CSM1-0	0.0	0.4	0.3	0.7	-0.0	0.4	0.0	0.7	-0.0	0.3	-0.2	0.5	0.0	0.4	0.0	0.6
CanESM5	2.3	2.8	2.4	3.2	2.5	3.1	2.3	3.6	2.5	2.8	2.3	3.5	2.2	2.3	2.3	2.7
CanESM5-CanOE	2.3	2.8	2.4	3.2	2.5	3.1	2.3	3.6	2.5	2.8	2.3	3.5	2.2	2.3	2.3	2.7
CESM2	1.0	0.1	1.5	0.4	1.0	0.2	1.5	0.5	1.2	0.5	1.6	0.7	1.2	0.7	1.6	0.8
CESM2-WACCM	1.4	0.6	2.0	0.5	1.3	0.7	1.8	0.7	1.3	0.8	1.8	0.9	1.1	0.7	1.6	0.9
CMCC-CM2-SR5	0.9	1.2	1.5	1.3	1.0	1.4	1.7	1.7	1.9	1.4	1.5	1.5	0.8	1.3	1.1	1.6
CNRM-CM6-1	0.8	0.3	1.1	0.3	1.2	0.6	1.4	0.5	1.6	0.9	1.8	0.7	1.9	1.2	2.0	1.3
CNRM-CM6-1-HR	1.1	0.9	1.2	1.2	0.6	0.6	0.9	0.8	0.7	0.6	0.9	0.8	0.2	0.5	0.6	0.6
CNRM-ESM2-1	1.0	0.5	0.6	0.3	1.0	0.6	0.6	0.4	1.1	0.6	0.5	0.3	1.1	1.0	0.6	0.9
EC-Earth3	1.6	1.3	2.0	1.5	1.7	1.2	2.0	1.7	1.5	1.2	1.8	1.6	1.3	1.6	1.6	1.8
GISS-E2-1-G	0.8	0.8	1.0	0.5	1.0	0.9	1.1	0.8	1.0	0.9	1.2	0.8	0.9	0.6	1.1	0.5

IPSL-CM6A-LR	1.0	0.9	1.2	1.3	0.9	0.7	1.0	1.2	0.7	0.5	0.9	1.4	1.5	1.3	1.7	1.8
MIROC6	0.9	0.5	1.1	0.7	0.7	0.5	0.7	0.8	0.6	0.6	0.5	0.9	0.7	0.9	0.6	1.3
MIROC-ES2L	1.9	1.3	2.3	1.2	1.9	1.4	2.6	1.4	1.8	1.5	2.5	1.5	1.7	1.5	2.4	1.6
MPI-ESM1-2-HR	0.8	0.5	0.8	0.0	1.0	0.6	0.9	0.1	1.1	0.7	0.9	0.2	1.4	1.1	1.2	0.9
MPI-ESM1-2-LR	0.9	0.9	0.9	1.2	1.2	0.9	1.3	1.2	1.3	0.8	1.6	1.2	1.4	0.8	1.8	1.2
MRI-ESM2-0	1.4	1.2	1.4	1.4	1.6	1.4	1.5	1.7	1.8	1.7	1.8	2.0	1.9	1.8	2.1	2.2
NorESM2-LM	1.6	1.5	2.2	1.6	1.5	1.4	1.9	1.6	1.7	1.6	1.9	1.5	1.3	1.4	1.6	1.4
TaiESM1	1.5	2.7	1.7	2.8	1.2	2.1	1.4	2.2	1.1	1.6	1.4	1.8	0.9	1.1	1.3	1.3
UKESM1-0-LL	1.6	2.3	1.7	2.5	1.4	2.6	2.6	2.6	1.2	2.7	1.6	2.5	1.6	2.4	1.8	2.3
Ensemble mean	**1.3**	**1.2**	**1.5**	**1.3**	**1.2**	**1.2**	**1.4**	**1.4**	**1.2**	**1.2**	**1.4**	**1.4**	**1.3**	**1.3**	**1.5**	**1.4**

Table 14. Projected bi-decadal (bd:2030-2049) and decadal (de: 2040-2049) spring mean changes of the SST relative to 1995-2014 period for SSP245 (s2) and SSP370 (s3). Units are degrees Celsius.

CMIP6 ESM	**ESS**				**CSS**				**WSS**				**GOM**			
	bd s2	**bd s3**	**de s2**	**de s3**	**bd s2**	**bd s3**	**de s2**	**de s3**	**bd s2**	**bd s3**	**de s2**	**de s3**	**bd s2**	**bd s3**	**de s2**	**de s3**
ACCESS-CM2	1.5	1.9	1.7	2.3	1.1	1.4	1.3	1.6	0.6	0.9	0.7	0.9	1.0	1.4	0.9	1.3
ACCESS-ESM1-5	1.1	0.6	1.3	0.7	0.8	0.1	1.1	0.1	1.1	0.3	1.3	0.2	1.4	0.8	1.5	0.9
AWI-CM-1-1-MR	2.2	1.9	2.8	2.6	2.0	1.9	2.8	2.6	2.1	1.9	2.8	2.6	2.0	2.0	2.5	2.7
CAMS-CSM1-0	0.2	0.6	0.6	1.0	0.1	0.6	0.3	0.8	0.1	0.5	0.2	0.7	0.3	0.7	0.4	0.9
CanESM5	2.3	2.8	2.4	3.3	2.3	2.8	2.4	3.1	2.2	2.6	2.1	3.0	2.1	2.4	2.2	2.6
CanESM5-CanOE	2.3	2.8	2.4	3.3	2.3	2.8	2.4	3.1	2.2	2.6	2.1	3.0	2.1	2.4	2.2	2.6
CESM2	0.9	-0.0	1.4	0.1	0.6	-0.6	1.0	-0.6	0.6	-0.3	1.0	-0.2	1.0	0.4	1.3	0.5
CESM2-WACCM	1.3	0.4	1.8	0.1	1.1	0.4	1.7	0.1	1.2	0.7	1.7	0.7	1.4	1.1	1.8	1.2
CMCC-CM2-SR5	1.1	1.2	1.6	1.3	0.9	1.2	1.4	1.5	0.8	1.4	1.3	1.7	0.7	1.3	0.9	1.6
CNRM-CM6-1	0.9	0.4	0.8	0.7	1.0	0.5	0.9	0.9	0.9	0.3	1.1	0.5	1.5	1.0	1.6	1.3
CNRM-CM6-1-HR	0.9	1.0	1.2	1.2	0.7	0.9	1.2	1.0	0.8	1.0	1.3	1.2	0.8	1.1	1.5	1.3
CNRM-ESM2-1	0.7	0.5	0.3	0.3	0.6	0.5	0.3	0.3	0.6	0.4	0.2	0.2	0.9	0.9	0.4	0.9
EC-Earth3	1.5	1.6	2.1	1.8	1.1	1.4	1.6	1.4	0.6	0.9	1.3	0.8	1.3	1.8	1.6	1.8
GISS-E2-1-G	0.8	0.6	0.8	0.3	0.9	0.5	0.9	0.3	1.0	0.5	1.0	0.2	1.1	0.4	1.1	0.1
IPSL-CM6A-LR	1.5	1.7	1.7	2.2	1.3	1.3	1.6	1.8	1.3	1.1	1.5	1.8	1.1	1.3	1.4	2.0
MIROC6	0.9	0.9	1.1	1.0	0.9	0.9	1.1	1.1	0.9	0.9	1.0	1.1	0.8	1.0	0.9	1.2
MIROC-ES2L	1.8	1.3	2.3	1.3	1.9	1.4	2.5	1.4	1.9	1.5	2.6	1.5	1.7	1.5	2.3	1.6
MPI-ESM1-2-HR	0.8	0.6	0.9	0.2	1.0	0.7	0.9	0.3	0.7	0.4	0.8	0.1	1.2	1.0	1.3	0.9
MPI-ESM1-2-LR	1.0	0.9	1.2	1.3	1.2	1.0	1.3	1.2	1.3	1.0	1.4	1.2	1.5	1.2	1.7	1.4
MRI-ESM2-0	1.1	1.3	1.1	1.6	1.2	1.6	1.2	1.8	1.4	1.7	1.3	2.0	1.8	2.1	1.9	2.5
NorESM2-LM	2.0	1.8	2.7	1.6	1.6	1.7	2.3	1.5	1.6	1.7	2.2	1.5	1.7	1.9	2.2	1.6
TaiESM1	0.8	1.7	0.9	1.8	0.2	1.5	0.1	1.5	0.4	1.2	0.3	1.3	0.7	1.1	0.7	1.2
UKESM1-0-LL	2.3	3.0	2.5	3.0	1.9	3.0	2.1	3.0	1.5	2.7	1.6	2.5	1.9	2.6	2.1	2.6
Ensemble mean	**1.3**	**1.3**	**1.5**	**1.4**	**1.2**	**1.2**	**1.4**	**1.3**	**1.1**	**1.1**	**1.3**	**1.2**	**1.3**	**1.4**	**1.5**	**1.5**

Table 15. Projected bi-decadal (bd:2030-2049) and decadal (de: 2040-2049) summer (JAS) mean changes of the SST relative to 1995-2014 period for SSP245 (s2) and SSP370 (s3). Units are degrees Celcius.

CMIP6 ESM	ESS				CSS				WSS				GOM			
	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3
ACCESS-CM2	2.0	2.2	2.4	2.5	1.7	1.9	2.0	2.0	1.4	1.7	1.6	1.6	1.5	1.8	1.5	1.8
ACCESS-ESM1-5	1.5	1.0	1.8	1.2	1.5	0.9	1.8	1.0	1.7	1.2	1.8	1.3	1.5	1.0	1.6	1.1
AWI-CM-1-1-MR	2.2	2.2	2.8	2.7	1.9	2.4	2.5	3.0	2.1	2.4	2.6	3.1	1.9	2.2	2.5	2.9
CAMS-CSM1-0	0.5	0.5	0.9	0.7	0.3	0.5	0.6	0.6	0.3	0.5	0.5	0.6	0.5	0.6	0.8	0.7
CanESM5	3.0	3.5	3.0	4.0	2.9	3.2	3.0	3.7	2.9	3.1	2.9	3.6	2.8	3.1	3.0	3.5
CanESM5-CanOE	3.0	3.5	3.0	4.0	2.9	3.2	3.0	3.7	2.9	3.1	2.9	3.6	2.8	3.1	3.0	3.5
CESM2	0.7	0.1	1.1	0.1	0.5	-0.2	0.8	-0.2	0.9	0.3	1.1	0.5	1.3	0.9	1.5	1.1
CESM2-WACCM	1.2	0.6	1.5	0.6	0.9	0.6	1.2	0.6	0.9	0.9	1.2	1.0	1.0	1.0	1.2	1.3
CMCC-CM2-SR5	1.2	1.3	1.6	1.9	1.1	1.5	1.4	2.1	1.0	1.4	1.2	1.9	0.9	1.2	1.1	1.8
CNRM-CM6-1	1.1	0.8	1.1	1.9	1.3	1.2	1.4	1.7	1.3	1.1	1.5	1.6	1.3	1.2	1.5	1.6
CNRM-CM6-1-HR	1.0	1.0	1.2	1.4	0.7	0.9	1.0	1.3	0.8	1.1	1.2	1.6	1.1	1.3	1.6	1.7
CNRM-ESM2-1	0.7	0.6	0.7	0.7	0.7	0.6	0.7	0.7	0.7	0.6	0.7	0.9	0.8	0.8	0.7	1.1
EC-Earth3	1.9	2.1	2.5	2.2	1.7	1.9	2.2	2.1	1.3	1.9	1.9	2.0	1.6	1.7	1.8	1.9
GISS-E2-1-G	1.0	0.5	1.0	2.2	1.0	0.4	1.0	-0.2	1.2	0.5	1.2	0.0	1.4	0.9	1.4	0.6
IPSL-CM6A-LR	2.0	1.8	2.4	2.2	1.5	1.3	2.0	1.6	1.6	1.4	1.9	1.7	1.4	1.2	1.7	1.6
MIROC6	1.5	1.4	1.6	1.6	1.1	1.4	1.3	1.6	1.1	1.3	1.2	1.6	1.0	1.3	1.1	1.6
MIROC-ES2L	2.0	1.5	2.6	1.4	1.8	1.4	2.4	1.3	1.6	1.3	2.2	1.2	1.6	1.2	2.0	1.2
MPI-ESM1-2-HR	1.3	1.0	1.2	1.0	1.4	1.1	1.3	1.1	1.1	1.0	1.0	1.1	1.1	1.2	1.1	1.5
MPI-ESM1-2-LR	1.1	1.1	1.5	1.4	1.5	1.1	1.8	1.5	1.7	1.3	1.9	1.6	1.4	1.3	1.5	1.6
MRI-ESM2-0	1.7	1.8	1.8	2.0	2.0	2.0	2.0	2.4	2.1	2.2	2.0	2.7	2.3	2.3	2.5	2.7
NorESM2-LM	1.8	2.1	2.1	1.8	1.4	1.7	1.6	1.6	1.4	1.7	1.7	1.6	1.4	1.6	1.6	1.6
TaiESM1	0.9	1.7	0.9	1.9	0.9	1.6	0.9	1.7	1.1	1.5	1.2	1.6	1.1	1.4	1.2	1.5
UKESM1-0-LL	3.2	3.3	3.3	3.6	3.0	3.6	3.0	3.7	3.0	3.5	3.1	3.5	3.0	3.4	3.2	3.6
Ensemble mean	**1.6**	**1.6**	**1.8**	**1.8**	**1.5**	**1.5**	**1.7**	**1.7**	**1.5**	**1.5**	**1.7**	**1.7**	**1.5**	**1.6**	**1.7**	**1.8**

Table 16. Projected bi-decadal (bd:2030-2049) and decadal (de: 2040-2049) fall (OND) mean changes of the SST relative to 1995-2014 period for the SSP245 (s2) and SSP370 (s3). Units are degrees Celsius.

CMIP6 model	ESS				CSS				WSS				GOM			
	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3
ACCESS-CM2	1.6	1.9	2.0	2.2	1.0	1.5	1.2	1.5	0.9	1.5	1.0	1.4	1.3	1.7	1.4	1.7
ACCESS-ESM1-5	1.3	0.9	1.3	1.1	1.4	0.9	1.4	0.9	1.3	0.7	1.2	0.9	1.4	0.9	1.3	0.9
AWI-CM-1-1-MR	1.8	1.8	2.4	2.1	1.6	1.8	2.1	2.3	1.6	1.7	2.2	2.2	1.7	1.9	2.2	2.3
CAMS-CSM1-0	0.1	0.5	0.5	0.9	0.1	0.5	0.3	0.8	0.1	0.6	1.0	0.8	0.3	0.6	0.4	0.9
CanESM5	2.5	2.9	2.6	3.4	2.7	2.8	2.7	3.4	2.7	2.6	2.7	3.3	2.5	2.6	2.5	3.0
CanESM5-CanOE	2.5	2.9	2.6	3.4	2.7	2.8	2.7	3.4	2.7	2.6	2.7	3.3	2.5	2.6	2.5	3.0

CESM2	1.2	0.4	1.3	0.4	1.2	0.4	1.4	0.6	1.5	0.8	1.6	1.1	1.5	1.0	1.6	1.2
CESM2-WACCM	1.2	0.7	1.5	0.7	1.1	0.8	1.5	0.9	1.1	0.9	1.5	1.1	1.0	0.8	1.4	1.1
CMCC-CM2-SR5	1.0	1.3	1.5	1.5	0.9	1.6	1.5	1.7	0.8	1.6	1.2	1.5	0.6	1.2	1.0	1.4
CNRM-CM6-1	1.0	0.5	1.1	0.6	1.1	0.5	1.2	0.8	1.9	1.1	2.2	1.5	1.7	1.2	1.8	1.4
CNRM-CM6-1-HR	0.9	0.7	1.1	1.1	0.6	0.5	0.9	0.8	0.6	0.5	0.9	0.8	0.5	0.6	1.0	0.7
CNRM-ESM2-1	0.9	0.8	0.6	0.7	1.0	0.9	0.5	0.7	1.2	1.6	0.3	1.5	1.0	1.0	0.5	1.0
EC-Earth3	1.5	1.5	2.0	1.7	1.4	1.9	2.2	2.2	1.1	1.8	1.7	2.0	1.4	1.5	1.7	1.7
GISS-E2-1-G	0.7	0.6	0.7	0.2	0.9	0.8	0.9	0.3	1.1	0.9	1.1	0.6	1.1	1.0	1.2	0.8
IPSL-CM6A-LR	1.6	1.7	1.8	2.3	2.1	2.0	2.3	2.6	2.3	2.1	2.4	2.9	1.8	1.6	1.9	2.2
MIROC6	1.1	0.8	1.2	0.9	0.9	0.8	1.0	1.0	0.8	0.8	0.9	1.0	0.8	0.9	0.8	1.2
MIROC-ES2L	1.8	1.4	2.2	1.5	1.7	1.4	2.3	1.5	1.6	1.4	2.3	1.5	1.4	1.3	2.1	1.4
MPI-ESM1-2-HR	0.9	0.8	0.9	0.6	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	1.0	1.0	0.9	1.2
MPI-ESM1-2-LR	1.4	0.9	1.6	1.3	1.2	0.7	1.6	1.3	1.6	0.6	2.0	1.3	1.3	0.6	1.6	1.1
MRI-ESM2-0	1.4	1.3	1.3	1.6	1.6	1.6	1.5	2.1	2.0	2.0	2.0	2.6	2.1	1.9	1.0	1.2
NorESM2-LM	1.8	1.5	2.1	1.7	1.4	1.4	1.6	1.6	1.5	1.5	1.6	1.7	1.3	1.4	1.5	1.6
TaiESM1	1.3	2.3	1.2	2.3	1.2	1.7	1.1	1.8	1.2	1.5	1.2	1.5	1.0	1.2	1.0	1.2
UKESM1-0-LL	2.3	2.5	2.4	3.0	2.4	2.9	2.6	3.2	2.4	3.0	2.5	3.2	2.5	2.7	2.7	2.8
Ensemble mean	**1.4**	**1.3**	**1.6**	**1.5**	**1.3**	**1.3**	**1.5**	**1.6**	**1.4**	**1.4**	**1.6**	**1.7**	**1.4**	**1.4**	**1.5**	**1.6**

Table 17. Trends of SSS annual means, each CMIP6 ESM, each subarea, for the periods 1985-2014 (Hist) and 2020-2049 (SSP245 and SSP370). Underlined numbers indicate trends with a confidence level less than 95%. Units are PSU/decade.

CMIP6 model	ESS			CSS			WSS			GOM		
	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370
ACCESS-CM2	0.31	-0.00	-0.13	0.14	-0.08	-0.08	0.05	-0.11	0.18	0.01	-0.10	-0.22
ACCESS-ESM1-5	0.05	-0.11	-0.49	0.03	0.04	-0.60	0.01	0.05	-0.41	0.01	-0.00	-0.06
AWI-CM-1-1-MR	0.10	0.11	0.18	0.06	0.27	0.31	0.09	0.27	0.26	0.23	0.31	0.32
CAMS-CSM1-0	0.06	-0.03	-0.04	0.06	-0.10	-0.10	-0.01	-0.14	-0.14	0.01	-0.18	-0.10
CanESM5	-0.11	-0.20	-0.12	-0.17	-0.15	-0.10	-0.25	-0.17	-0.04	-0.19	-0.13	-0.02
CanESM5-CanOE	-0.11	-0.20	-0.12	-0.17	-0.15	-0.10	-0.25	-0.17	-0.04	-0.19	-0.13	-0.02
CESM2	0.24	0.16	-0.39	0.21	0.22	-0.28	0.11	0.17	-0.10	0.10	0.12	-0.10
CESM2-WACCM	0.28	0.19	-0.16	0.24	0.20	-0.05	0.16	0.16	-0.06	0.19	0.16	0.09
CMCC-CM2-SR5	-0.19	0.02	-0.04	-0.21	0.09	-0.03	-0.26	0.02	-0.03	-0.22	0.04	-0.03
CNRM-CM6-1	0.04	-0.15	-0.11	-0.03	-0.17	-0.11	-0.20	-0.19	-0.24	-0.25	-0.17	-0.29
CNRM-CM6-1-HR	-0.12	-0.1	-0.1	-0.12	-0.14	-0.15	-0.11	-0.20	-0.16	-0.01	-0.25	-0.10
CNRM-ESM2-1	0.04	-0.21	-0.19	-0.03	-0.24	-0.25	-0.07	-0.36	-0.30	0.02	-0.39	-0.25
EC-Earth3	0.02	-0.35	-0.12	-0.07	-0.21	-0.03	-0.07	-0.13	-0.05	-0.03	-0.12	-0.10
GISS-E2-1-G	-0.04	-0.05	-0.16	0.01	0.00	-0.07	0.04	0.04	-0.00	0.06	0.07	0.04
IPSL-CM6A-LR	-0.11	-0.14	-0.23	-0.16	-0.09	-0.29	-0.21	-0.08	-0.13	-0.25	-0.11	-0.05
MIROC6	0.03	-0.08	0.03	0.06	-0.17	-0.02	0.06	-0.25	-0.02	-0.00	-0.26	-0.05
MIROC-ES2L	-0.10	-0.17	-0.14	-0.13	-0.10	-0.14	-0.12	-0.12	-0.11	-0.14	-0.20	-0.10

MPI-ESM1-2-HR	0.08	-0.06	-0.06	0.16	-0.08	-0.07	0.20	-0.12	-0.05	0.31	-0.07	-0.01
MPI-ESM1-2-LR	0.08	-0.02	0.11	0.11	-0.07	0.06	0.03	-0.03	0.04	-0.09	0.01	0.02
MRI-ESM2-0	0.09	0.07	-0.07	0.15	0.08	-0.01	0.23	0.18	0.09	0.33	0.29	0.11
NorESM2-LM	-0.08	0.03	0.03	-0.09	0.01	0.02	-0.07	0.05	0.06	-0.01	0.11	0.14
TaiESM1	0.14	-0.33	0.03	0.14	-0.17	0.06	0.07	-0.01	0.07	0.04	0.03	0.08
UKESM1-0-LL	-0.01	-0.01	-0.14	-0.05	-0.09	-0.11	-0.32	-0.25	-0.22	-0.20	-0.07	-0.10
Ensemble mean	**0.03**	**-0.08**	**-0.10**	**0.00**	**-0.05**	**-0.09**	**-0.04**	**-0.06**	**-0.07**	**-0.01**	**-0.05**	**-0.03**

Table 18. Projected bi-decadal (bd:2030-2049) and decadal (de: 2040-2049) annual mean changes of SSS relative to 1995-2014 period for SSP245 (s2) and SSP370 (s3). Units are PSU.

CMIP6 ESM	ESS				CSS				WSS				GOM			
	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3
ACCESS-CM2	-1.0	-1.0	-1.2	-1.1	-1.0	-1.0	-1.4	-1.3	-0.9	-0.9	-1.3	-1.3	-0.4	-0.4	-0.8	-0.7
ACCESS-ESM1-5	-1.1	-1.3	-1.1	-1.6	-0.8	-1.2	-0.5	-1.6	-0.3	-0.7	-0.1	-1.0	0.0	-0.0	0.0	-0.1
AWI-CM-1-1-MR	0.2	0.1	0.4	0.4	0.3	0.3	0.6	0.7	0.3	0.3	0.6	0.6	0.5	0.4	0.8	0.9
CAMS-CSM1-0	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3	-0.2	-0.3	-0.3	-0.5	-0.2	-0.2	-0.2	-0.4	-0.2
CanESM5	-0.2	-0.1	-0.2	-0.1	0.1	0.2	0.1	0.3	0.2	0.3	0.2	0.6	0.2	0.2	0.2	0.5
CanESM5-CanOE	-0.2	-0.1	-0.2	-0.1	0.1	0.2	0.1	0.3	0.2	0.3	0.2	0.6	0.2	0.2	0.2	0.5
CESM2	-0.2	-0.5	-0.1	-0.6	-0.0	-0.4	0.1	-0.4	0.1	-0.1	0.2	-0.1	0.1	-0.0	0.1	-0.0
CESM2-WACCM	-0.1	-0.2	0.2	-0.4	0.2	0.0	0.3	-0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.2
CMCC-CM2-SR5	-0.2	-0.2	-0.2	-0.3	-0.1	-0.0	-0.0	-0.1	-0.0	0.1	0.0	-0.1	-0.0	0.1	0.0	-0.0
CNRM-CM6-1	-0.4	-0.4	-0.4	-0.5	-0.3	-0.4	-0.4	-0.5	-0.2	-0.3	-0.2	-0.4	0.1	-0.1	0.0	-0.2
CNRM-CM6-1-HR	-0.0	-0.0	-0.3	-0.1	-0.2	-0.2	-0.4	-0.3	-0.3	-0.3	-0.5	-0.4	-0.5	-0.3	-0.5	-0.5
CNRM-ESM2-1	-0.5	-0.4	-0.5	-0.4	-0.6	-0.4	-0.6	-0.4	-0.5	-0.3	-0.7	-0.3	-0.5	-0.2	-0.7	-0.2
EC-Earth3	-0.5	-0.4	-0.7	-0.4	-0.5	-0.2	-0.5	-0.1	-0.7	-0.3	-0.6	-0.3	-0.5	-0.2	-0.4	-0.3
GISS-E2-1-G	-0.1	-0.2	-0.2	-0.4	0.0	-0.0	0.0	-0.2	0.1	0.1	0.1	-0.0	0.1	0.1	0.2	0.1
IPSL-CM6A-LR	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.2	-0.4	-0.2	-0.4	-0.2	-0.2	-0.1	-0.3	-0.0	-0.1
MIROC6	-0.3	-0.1	-0.3	-0.1	-0.3	-0.1	-0.4	-0.2	-0.3	-0.1	-0.5	-0.1	-0.3	0.2	-0.5	0.2
MIROC-ES2L	-0.4	-0.3	-0.6	-0.3	-0.2	-0.2	-0.3	-0.2	-0.3	-0.1	-0.3	-0.1	-0.4	-0.2	-0.4	-0.2
MPI-ESM1-2-HR	-0.3	-0.3	-0.5	-0.4	-0.2	-0.3	-0.5	-0.4	-0.3	-0.4	-0.6	-0.5	-0.1	-0.3	-0.4	-0.4
MPI-ESM1-2-LR	-0.2	-0.1	-0.2	-0.2	-0.2	-0.1	-0.3	-0.3	-0.1	-0.2	-0.1	-0.3	-0.0	-0.2	-0.0	-0.3
MRI-ESM2-0	0.0	-0.1	0.0	-0.2	0.1	0.0	0.0	-0.0	0.2	0.2	0.2	0.2	0.4	0.3	0.4	0.3
NorESM2-LM	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.3	0.2	0.5	0.4	0.5	0.3
TaiESM1	-0.2	0.5	-0.3	0.4	0.0	0.4	-0.1	0.4	0.1	0.3	0.1	0.3	0.2	0.2	0.2	0.3
UKESM1-0-LL	-0.6	-0.4	-0.7	-0.4	-0.5	-0.2	-0.6	-0.1	-0.6	-0.2	-0.7	-0.2	-0.4	-0.1	-0.4	-0.1
Ensemble mean	**-0.3**	**-0.3**	**-0.3**	**-0.3**	**-0.2**	**-0.2**	**-0.2**	**-0.2**	**-0.1**	**-0.1**	**-0.2**	**-0.1**	**-0.0**	**-0.0**	**-0.1**	**0.0**

Table 19. Trends of SSH annual means, each CMIP6 ESM, each subarea, for the periods 1985-2014 (Hist) and 2020-2049 (SSP245 and SSP370). Underlined numbers indicate trends with a confidence level less than 95%. Units are metres per decade.

CMIP6 model	ESS			CSS			WSS			GOM		
	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370
ACCESS-CM2	-0.00	0.03	0.03	-0.00	0.03	0.03	-0.00	0.03	0.03	-0.00	0.03	0.03
ACCESS-ESM1-5	-0.01	0.01	0.03	-0.01	0.01	0.03	-0.00	0.01	0.02	-0.00	0.01	0.01
AWI-CM-1-1-MR	-0.01	0.01	0.00	-0.01	0.00	0.00	-0.01	0.00	0.01	-0.01	-0.00	0.00
CAMS-CSM1-0	0.01	0.02	-0.00	0.01	0.02	-0.00	0.01	0.02	-0.00	0.01	0.02	-0.00
CanESM5	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.03	0.01
CanESM5-CanOE	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.03	0.01
CESM2	0.03	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.02	0.04	0.04	0.03
CESM2-WACCM	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.02	0.03	0.01
CMCC-CM2-SR5	0.03	0.01	-0.02	0.02	0.00	-0.02	0.03	0.00	-0.02	0.03	0.00	-0.02
CNRM-CM6-1	0.01	0.04	0.04	0.01	0.04	0.03	0.02	0.04	0.04	0.02	0.04	0.04
CNRM-CM6-1-HR	0.01	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.03
CNRM-ESM2-1	-0.00	0.05	0.05	-0.00	0.05	0.05	-0.00	0.05	0.05	-0.00	0.06	0.05
EC-Earth3	-0.01	0.04	0.03	-0.01	0.04	0.03	-0.01	0.04	0.03	-0.01	0.04	0.03
GISS-E2-1-G	0.03	0.07	0.07	0.02	0.07	0.06	0.02	0.07	0.06	0.03	0.07	0.06
IPSL-CM6A-LR	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.04	0.03	0.01
MIROC6	0.01	0.04	0.03	0.01	0.04	0.02	0.01	0.05	0.02	0.02	0.05	0.02
MIROC-ES2L	0.02	0.04	0.03	0.02	0..03	0.03	0.02	0.04	0.03	0.02	0.04	0.02
MPI-ESM1-2-HR	0.00	0.02	0.02	0.00	0.02	0.02	-0.00	0.02	0.02	-0.00	0.02	0.02
MPI-ESM1-2-LR	0.02	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.01
MRI-ESM2-0	0.01	0.03	0.03	0.00	0.03	0.3	0.00	0.03	0.03	-0.00	0.03	0.03
NorESM2-LM	0.03	0.06	0.04	0.03	0.06	0.04	0.03	0.06	0.04	0.03	0.06	0.04
TaiESM1	0.02	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
UKESM1-0-LL	0.00	0.02	0.03	0.00	0.02	0.02	0.01	0.03	0.02	0.00	0.02	0.02
Ensemble mean	0.01	0.03	0.02	0.01	0.03	0.02	0.01	0.03	0.02	0.01	0.03	0.02

Table 20. Projected bi-decadal (bd:2030-2049) and decadal (de: 2040-2049) annual mean changes of SSH relative to 1995-2014 period for SSP245 (s2) and SSP370 (s3). Units are metres.

CMIP6 ESM	ESS				CSS				WSS				GOM			
	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3
ACCESS-CM2	**0.10**	**0.09**	**0.12**	**0.11**	**0.10**	**0.09**	**0.12**	**0.12**	**0.10**	**0.9**	**0.12**	**0.13**	**0.09**	**0.08**	**0.11**	**0.11**
ACCESS-ESM1-5	**0.06**	**0.11**	**0.07**	**0.13**	**0.05**	**0.10**	**0.06**	**0.13**	**0.04**	**0.09**	**0.04**	**0.11**	**0.02**	**0.06**	**0.04**	**0.07**
AWI-CM-1-1-MR	**0.01**	**0.03**	**0.02**	**0.02**	**0.01**	**0.03**	**0.02**	**0.02**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**	**0.03**	**0.01**	**0.01**
CAMS-CSM1-0	**-0.00**	**-0.00**	**0.02**	**0.00**	**-0.00**	**0.00**	**0.03**	**0.00**	**-0.01**	**-0.00**	**0.03**	**0.00**	**-0.01**	**-0.00**	**0.03**	**0.00**
CanESM5	**0.07**	**0.0**	**0.08**	**0.07**	**0.06**	**0.06**	**0.07**	**0.06**	**0.06**	**0.06**	**0.07**	**0.05**	**0.06**	**0.06**	**0.06**	**0.04**
CanESM5-CanOE	**0.07**	**0.07**	**0.08**	**0.07**	**0.06**	**0.06**	**0.07**	**0.06**	**0.06**	**0.06**	**0.07**	**0.05**	**0.06**	**0.06**	**0.06**	**0.04**
CESM2	**0.12**	**0.09**	**0.13**	**0.11**	**0.11**	**0.08**	**0.13**	**0.10**	**0.11**	**0.08**	**0.13**	**0.09**	**0.11**	**0.08**	**0.13**	**0.10**

CESM2-WACCM	**0.12**	**0.10**	**0.13**	**0.11**	**0.11**	**0.09**	**0.13**	**0.10**	**0.11**	**0.08**	**0.13**	**0.09**	**0.11**	**0.09**	**0.13**	**0.10**
CMCC-CM2-SR5	**0.03**	**-0.00**	**0.03**	**-0.00**	**0.03**	**-0.00**	**0.02**	**-0.00**	**0.02**	**-0.01**	**0.02**	**-0.01**	**0.02**	**-0.01**	**0.02**	**-0.01**
CNRM-CM6-1	**0.13**	**0.14**	**0.15**	**0.16**	**0.13**	**0.14**	**0.15**	**0.15**	**0.13**	**0.14**	**0.15**	**0.16**	**0.12**	**0.14**	**0.15**	**0.15**
CNRM-CM6-1-HR	**0.03**	**0.04**	**0.04**	**0.06**	**0.03**	**0.04**	**0.05**	**0.07**	**0.04**	**0.05**	**0.05**	**0.07**	**0.05**	**0.06**	**0.06**	**0.09**
CNRM-ESM2-1	**0.14**	**0.11**	**0.15**	**0.13**	**0.14**	**0.11**	**0.15**	**0.13**	**0.14**	**0.11**	**0.15**	**0.13**	**0.14**	**0.11**	**0.15**	**0.12**
EC-Earth3	**0.06**	**0.04**	**0.09**	**0.05**	**0.06**	**0.04**	**0.08**	**0.04**	**0.06**	**0.04**	**0.08**	**0.04**	**0.06**	**0.03**	**0.08**	**0.04**
GISS-E2-1-G	**0.22**	**0.22**	**0.27**	**0.25**	**0.22**	**0.21**	**0.26**	**0.24**	**0.22**	**0.21**	**0.26**	**0.23**	**0.22**	**0.20**	**0.26**	**0.23**
IPSL-CM6A-LR	**0.09**	**0.08**	**0.09**	**0.08**	**0.09**	**0.07**	**0.08**	**0.08**	**0.09**	**0.07**	**0.08**	**0.07**	**0.08**	**0.07**	**0.08**	**0.06**
MIROC6	**0.07**	**0.04**	**0.10**	**0.06**	**0.07**	**0.04**	**0.10**	**0.06**	**0.07**	**0.04**	**0.10**	**0.06**	**0.07**	**0.03**	**0.10**	**0.05**
MIROC-ES2L	**0.10**	**0.09**	**0.12**	**0.10**	**0.10**	**0.09**	**0.12**	**0.09**	**0.10**	**0.09**	**0.12**	**0.09**	**0.11**	**0.09**	**0.13**	**0.10**
MPI-ESM1-2-HR	**0.09**	**0.09**	**0.11**	**0.09**	**0.09**	**0.09**	**0.11**	**0.10**	**0.09**	**0.09**	**0.11**	**0.10**	**0.09**	**0.09**	**0.11**	**0.10**
MPI-ESM1-2-LR	**0.06**	**0.05**	**0.07**	**0.06**	**0.06**	**0.06**	**0.07**	**0.06**	**0.06**	**0.06**	**0.07**	**0.06**	**0.06**	**0.05**	**0.07**	**0.06**
MRI-ESM2-0	**0.10**	**0.08**	**0.12**	**0.11**	**0.09**	**0.08**	**0.12**	**0.10**	**0.09**	**0.08**	**0.11**	**0.10**	**0.08**	**0.07**	**0.11**	**0.10**
NorESM2-LM	**0.22**	**0.17**	**0.25**	**0.20**	**0.21**	**0.17**	**0.25**	**0.20**	**0.21**	**0.17**	**0.24**	**0.20**	**0.20**	**0.17**	**0.23**	**0.20**
TaiESM1	**0.11**	**0.10**	**0.14**	**0.12**	**0.11**	**0.10**	**0.13**	**0.12**	**0.10**	**0.10**	**0.13**	**0.12**	**0.10**	**0.10**	**0.13**	**0.12**
UKESM1-0-LL	**0.11**	**0.08**	**0.12**	**0.10**	**0.11**	**0.07**	**0.12**	**0.08**	**0.11**	**0.07**	**0.12**	**0.08**	**0.11**	**0.07**	**0.12**	**0.08**
Ensemble mean	**0.09**	**0.08**	**0.11**	**0.10**	**0.09**	**0.08**	**0.12**	**0.12**	**0.09**	**0.08**	**0.10**	**0.09**	**0.09**	**0.08**	**0.10**	**0.09**

Table 21. Trends of BT annual means, each CMIP6 ESM, each subarea, for the periods 1985-2014 (Hist) and 2020-2049 (SSP245 and SSP370). Underlined numbers indicate trends with a confidence level less than 95%. Units are °C/decade.

CMIP6 ESM	**ESS**			**CSS**			**WSS**			**GOM**		
	Hist	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**	**Hist**	**SSP 245**	**SSP 370**
ACCESS-CM2	0.41	0.45	0.67	0.24	0.35	0.43	0.21	0.31	0.33	0.16	0.32	0.28
ACCESS-ESM1-5	0.36	0.38	-0.25	0.20	0.29	-0.27	0.21	0.27	-0.21	0.29	0.28	-0.06
AWI-CM-1-1-MR	0.58	0.37	1.26	0.05	0.39	1.24	0.24	0.38	1.08	0.29	0.35	0.86
CAMS-CSM1-0	0.09	0.29	-0.02	0.12	0.28	-0.09	0.09	0.19	-0.09	0.11	0.17	0.06
CanESM5	0.13	0.38	0.59	0.18	0.42	0.52	0.26	0.44	0.45	0.29	0.41	0.55
CanESM5-CanOE	0.13	0.38	0.59	0.18	0.42	0.52	0.26	0.44	0.45	0.29	0.41	0.55
CESM2	0.85	0.80	0.34	0.57	0.75	0.26	0.55	0.78	0.27	0.39	0.67	0.36
CESM2-WACCM	0.83	0.56	0.43	0.66	0.59	0.35	0.54	0.61	0.38	0.35	0.67	0.41
CMCC-CM2-SR5	-0.18	0.54	0.23	-0.01	0.21	0.30	0.19	0.19	0.40	0.40	0.20	0.56
CNRM-CM6-1	-0.21	0.38	-0.28	-0.50	0.38	-0.25	-0.64	0.43	-0.26	-0.43	0.32	0.05
CNRM-CM6-1-HR	0.37	-0.02	0.18	0.45	-0.36	0.12	-0.46	-0.23	0.15	0.42	-0.05	0.26
CNRM-ESM2-1	-0.00	0.48	0.43	-0.20	0.35	0.28	-0.13	0.26	0.24	0.15	0.24	0.27
EC-Earth3	-0.09	0.92	0.39	0.17	0.64	0.30	0.22	0.59	0.32	0.29	0.45	0.25
GISS-E2-1-G	0.04	0.26	0.33	0.07	0.21	0.19	0.10	0.29	0.15	0.21	0.32	0.13
IPSL-CM6A-LR	-0.20	0.63	1.30	-0.08	0.53	1.15	0.15	0.34	0.88	0.51	0.43	0.69
MIROC6	0.38	0.51	0.54	0.34	0.51	0.43	0.35	0.46	0.42	0.35	0.46	0.40
MIROC-ES2L	0.25	0.49	0.38	0.29	0.50	0.45	0.25	0.48	0.43	0.23	0.70	0.57
MPI-ESM1-2-HR	1.02	-0.14	-0.40	0.81	-0.11	-0.14	0.90	-0.16	-0.18	0.25	0.10	0.13

MPI-ESM1-2-LR	0.04	0.03	0.24	-0.21	0.24	0.05	-0.33	0.56	0.16	-0.13	0.68	0.30
NorESM2-LM	0.14	0.29	0.23	0.11	0.12	0.15	0.09	0.17	0.17	0.19	0.13	0.18
TaiESM1	0.66	0.36	0.39	0.41	0.30	0.34	0.39	0.31	0.46	0.36	0.34	0.34
UKESM1-0-LL	-0.08	-0.04	0.29	-0.52	-0.42	0.08	-0.53	-0.24	0.06	-0.08	0.13	0.23
Ensemble mean	**0.25**	**0.38**	**0.36**	**0.15**	**0.30**	**0.29**	**0.17**	**0.31**	**0.28**	**0.22**	**0.35**	**0.33**

Table 22. Projected bi-decadal (bd:2030-2049) and decadal (de: 2040-2049) annual mean changes of BT relative to 1995-2014 period for SSP245 (s2) and SSP370 (s3). Units are degrees Celsius.

CMIP6 ESM	ESS				CSS				WSS				GOM			
	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3
ACCESS-CM2	1.1	1.3	1.2	1.6	0.6	0.9	0.7	1.0	0.4	0.8	0.5	0.7	1.1	1.4	1.0	1.3
ACCESS-ESM1-5	0.8	0.4	1.0	0.5	1.0	0.5	1.2	0.5	1.1	0.5	1.2	0.5	1.4	0.8	1.4	0.9
AWI-CM-1-1-MR	2.9	2.9	3.5	3.6	2.1	2.5	2.5	2.8	2.0	2.3	2.5	2.6	1.6	1.8	1.9	2.2
CAMS-CSM1-0	-0.0	0.4	0.2	0.8	-0.0	0.5	0.1	0.7	0.0	0.5	0.1	0.6	0.1	0.5	0.1	0.7
CanESM5	2.0	2.5	2.2	3.2	1.7	1.7	1.7	2.2	1.7	1.8	1.7	2.1	1.9	2.0	2.0	2.4
CanESM5-CanOE	2.0	2.5	2.2	3.2	1.7	1.7	1.7	2.2	1.7	1.8	1.7	2.1	1.9	2.0	2.0	2.4
CESM2	1.5	0.9	1.8	1.2	1.2	0.7	1.6	1.0	1.4	0.9	1.8	1.1	1.5	1.1	1.9	1.4
CESM2-WACCM	1.9	1.3	2.2	1.5	1.5	0.9	1.8	1.0	1.6	1.1	2.0	1.4	1.5	1.1	1.9	1.3
CMCC-CM2-SR5	1.3	1.3	1.9	1.2	1.1	1.7	1.6	1.6	1.0	1.4	1.3	1.5	0.8	1.1	1.0	1.6
CNRM-CM6-1	1.7	1.1	2.2	1.2	1.8	1.2	2.3	1.4	2.0	1.4	2.4	1.6	1.8	1.5	2.0	1.8
CNRM-CM6-1-HR	0.1	0.3	0.3	0.4	-1.4	-1.0	-1.0	-1.1	-1.0	-0.7	-0.6	-0.8	-0.8	-0.5	-0.2	-0.5
CNRM-ESM2-1	1.7	1.2	1.6	1.1	1.6	1.0	1.2	0.9	1.9	1.3	1.3	1.1	1.4	1.2	1.1	1.2
EC-Earth3	1.2	1.5	2.0	1.5	1.0	1.3	1.5	1.2	1.2	1.4	1.8	1.4	1.7	1.6	2.0	1.6
GISS-E2-1-G	0.9	1.1	1.2	1.2	0.8	0.8	0.9	0.7	0.8	0.7	1.0	0.6	0.8	0.5	1.0	0.4
IPSL-CM6A-LR	2.0	1.6	2.4	2.7	1.8	1.4	1.9	2.2	1.7	1.4	1.5	1.8	1.1	0.9	1.0	1.1
MIROC6	1.1	0.9	1.3	1.1	1.1	0.8	1.3	1.1	1.0	0.9	1.3	1.1	1.1	0.9	1.4	1.2
MIROC-ES2L	1.3	1.2	1.8	1.2	1.3	1.2	1.7	1.3	1.3	1.2	1.6	1.3	1.6	1.5	2.1	1.6
MPI-ESM1-2-HR	0.9	0.7	0.6	0.0	1.2	1.2	0.9	0.8	1.0	1.0	0.6	0.5	1.0	1.5	1.3	1.4
MPI-ESM1-2-LR	0.9	0.8	1.1	1.1	0.9	0.4	1.4	0.7	1.1	0.2	1.8	0.7	1.3	1.0	1.8	1.6
NorESM2-LM	1.2	0.9	1.3	1.0	0.7	0.6	0.8	0.7	0.8	0.7	0.9	0.8	0.8	0.7	0.9	0.9
TaiESM1	2.4	2.6	2.7	2.9	1.3	1.6	1.5	1.8	1.4	1.7	1.6	1.9	1.1	1.3	1.4	1.4
UKESM1-0-LL	2.2	2.8	2.5	2.8	1.6	2.4	1.7	2.3	1.9	2.4	1.9	2.3	2.0	2.0	2.1	1.9
Ensemble mean	**1.4**	**1.4**	**1.7**	**1.6**	**1.1**	**1.1**	**1.3**	**1.2**	**1.2**	**1.1**	**1.4**	**1.2**	**1.2**	**1.2**	**1.4**	**1.4**

Table 23. Trends of BS annual means, each CMIP6 ESM, each subarea, for the periods 1985-2014 (Hist) and 2020-2049 (SSP245 and SSP370). Underlined numbers indicate trends with a confidence level less than 95%. Units are PSU/decade.

CMIP6 model	ESS			CSS			WSS			GOM		
	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370	Hist	SSP 245	SSP 370

ACCESS-CM2	0.28	-0.11	0.05	0.07	-0.02	-0.07	0.05	-0.06	-0.12	0.02	-0.09	-0.20
ACCESS-ESM1-5	0.05	-0.05	-0.48	0.02	0.05	-0.36	0.02	0.05	-0.31	0.01	-0.00	-0.05
AWI-CM-1-1-MR	0.17	-0.00	0.24	0.04	0.04	0.21	0.10	0.05	0.19	0.13	0.11	0.17
CAMS-CSM1-0	0.01	-0.01	-0.05	0.00	-0.03	-0.08	-0.01	-0.05	0.19	-0.02	-0.15	-0.07
CanESM5	-0.08	-0.05	0.07	-0.03	-0.00	0.09	-0.03	-0.01	0.07	-0.12	-0.03	0.07
CanESM5-CanOE	-0.08	-0.05	0.07	-0.03	-0.00	0.09	-0.03	-0.01	0.07	-0.12	-0.03	0.07
CESM2	0.15	0.13	-0.01	0.12	0.14	-0.03	0.08	0.13	0.01	0.06	0.11	0.01
CESM2-WACCM	0.14	0.10	0.05	0.14	0.12	0.04	0.10	0.10	0.07	0.08	0.10	0.07
CMCC-CM2-SR5	-0.17	0.07	-0.03	-0.11	0.01	0.02	-0.05	0.01	0.05	-0.10	0.02	0.02
CNRM-CM6-1	-0.03	-0.05	-0.17	-0.09	-0.04	-0.15	-0.12	-0.03	-0.16	-0.18	-0.07	-0.10
CNRM-CM6-1-HR	-0.00	-0.02	-0.04	0.05	-0.12	-0.05	0.05	-0.07	-0.06	0.04	-0.10	-0.05
CNRM-ESM2-1	0.01	-0.04	-0.03	-0.04	-0.04	-0.05	-0.02	-0.05	-0.07	0.00	-0.14	-0.10
EC-Earth3	-0.10	0.11	-0.02	-0.02	0.08	-0.01	-0.02	0.06	-0.02	-0.02	-0.03	-0.05
GISS-E2-1-G	-0.00	0.02	0.02	0.01	0.03	0.01	0.02	0.05	0.02	0.04	0.06	0.03
IPSL-CM6A-LR	-0.15	0.06	0.25	-0.11	0.06	0.23	-0.07	0.01	0.17	-0.01	0.00	0.09
MIROC6	0.05	0.04	0.09	0.05	0.06	0.06	0.04	0.04	0.06	0.03	0.03	0.06
MIROC-ES2L	0.04	0.05	0.08	0.06	0.06	0.10	0.03	0.04	0.08	0.01	0.09	0.13
MPI-ESM1-2-HR	0.23	-0.07	-0.16	0.20	-0.07	-0.12	0.23	-0.09	-0.13	0.13	-0.03	-0.02
MPI-ESM1-2-LR	-0.10	-0.08	-0.06	-0.12	-0.04	-0.08	-0.15	0.06	-0.03	-0.09	0.08	0.03
NorESM2-LM	0.02	0.05	0.03	0.02	0.02	0.02	0.01	0.03	0.03	0.02	0.02	0.03
TaiESM1	0.08	0.01	0.06	0.06	-0.01	0.06	0.05	0.01	0.08	0.05	0.02	0.09
UKESM1-0-LL	-0.03	-0.03	0.00	-0.11	-0.15	-0.02	-0.12	-0.10	-0.02	-0.05	0.04	0.02
Ensemble mean	**0.02**	**-0.00**	**0.00**	**0.01**	**-0.00**	**0.01**	**0.01**	**-0.00**	**0.01**	**-0.00**	**0.01**	**0.00**

Table 24 Projected bi-decadal (bd:2030-2049) and decadal (de: 2040-2049) annual mean changes of SSS relative to 1995-2014 period for SSP245 (s2) and SSP370 (s3). Units are PSU.

CMIP6 ESM	ESS				CSS				WSS				GOM			
	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3	bd s2	bd s3	de s2	de s3
ACCESS-CM2	-0.96	-0.89	-1.17	-0.95	-0.57	-0.60	-0.83	-0.81	-0.64	-0.63	-0.91	-0.90	-0.38	-0.32	-0.71	-0.61
ACCESS-ESM1-5	-1.03	-1.22	-0.93	-1.51	-0.38	-0.66	-0.24	-0.91	-0.19	-0.50	-0.07	-0.72	0.04	-0.03	0.03	-0.07
AWI-CM-1-1-MR	0.52	0.45	0.56	0.67	0.31	0.37	0.36	0.47	0.34	0.37	0.42	0.51	0.31	0.29	0.41	0.50
CAMS-CSM1-0	-0.16	-0.10	-0.17	-0.03	-0.16	-0.80	-0.23	-0.05	-0.12	-0.04	-0.21	-0.02	-0.13	-0.10	-0.32	-0.06
CanESM5	0.07	0.24	0.13	0.42	0.12	0.15	0.12	0.33	0.13	0.18	0.12	0.34	0.22	0.30	0.27	0.64
CanESM5-CanOE	0.07	0.24	0.13	0.42	0.12	0.15	0.12	0.33	0.13	0.18	0.12	0.34	0.22	0.30	0.27	0.64
CESM2	0.17	0.06	0.23	0.08	0.14	0.03	0.21	0.03	0.18	0.10	0.24	0.10	0.17	0.11	0.22	0.11
CESM2-WACCM	0.26	0.17	0.31	0.18	0.22	0.14	0.29	0.14	0.24	0.21	0.30	0.25	0.21	0.18	0.27	0.23
CMCC-CM2-SR5	0.16	0.15	0.25	0.05	0.19	0.36	0.31	0.29	0.19	0.26	0.23	0.22	0.05	0.10	0.10	0.06
CNRM-CM6-1	-0.04	-0.13	0.04	-0.15	0.05	-0.08	0.11	-0.07	0.10	-0.02	0.15	-0.02	0.20	0.12	0.15	0.11
CNRM-CM6-1-HR	0.14	0.12	0.06	0.09	-0.29	-0.20	-0.26	-0.29	-0.17	-0.12	-0.15	-0.20	-0.30	-0.24	-0.25	-0.35
CNRM-ESM2-1	-0.08	-0.08	-0.13	-0.12	-0.06	-0.12	-0.16	-0.15	0.03	-0.03	-0.09	-0.08	-0.10	0.05	-0.21	0.08

EC-Earth3	0.06	0.10	0.16	0.07	0.09	0.14	0.14	0.10	0.08	0.14	0.17	0.10	0.01	0.09	0.00	0.05
GISS-E2-1-G	0.07	0.11	0.09	0.07	0.08	0.11	0.11	0.07	0.11	0.12	0.13	0.08	0.11	0.11	0.15	0.08
IPSL-CM6A-LR	0.15	0.02	0.23	0.28	0.17	0.05	0.20	0.25	0.15	0.07	0.12	0.17	-0.01	-0.06	0.01	-0.01
MIROC6	0.15	0.15	0.15	0.16	0.16	0.13	0.18	0.16	0.16	0.15	0.17	0.17	0.20	0.17	0.21	0.20
MIROC-ES2L	0.11	0.12	0.20	0.14	0.13	0.16	0.22	0.17	0.12	0.15	0.17	0.17	0.14	0.20	0.24	0.22
MPI-ESM1-2-HR	-0.02	-0.07	-0.17	-0.27	0.10	0.06	-0.02	-0.07	-0.01	-0.40	-0.18	-0.19	-0.03	0.02	-01.0	-0.04
MPI-ESM1-2-LR	-0.08	-0.08	-0.08	-0.06	-0.04	-0.12	0.02	-0.09	0.04	-0.17	0.12	-0.12	0.09	0.03	0.16	0.14
NorESM2-LM	0.19	0.13	0.22	0.15	0.12	0.10	0.13	0.12	0.13	0.11	0.15	0.13	0.10	0.09	0.12	0.11
TaiESM1	0.31	0.41	0.33	0.43	0.15	0.27	0.15	0.28	0.16	0.26	0.17	0.28	0.16	0.22	0.17	0.25
UKESM1-0-LL	0.00	0.16	0.05	0.16	0.01	0.24	0.02	0.20	0.09	0.28	0.08	0.24	0.05	0.12	0.09	0.10
Ensemble mean	0.00	0.00	0.02	0.01	0.03	0.03	0.04	0.02	0.05	0.05	0.06	0.04	0.06	0.08	0.06	0.10

Figures

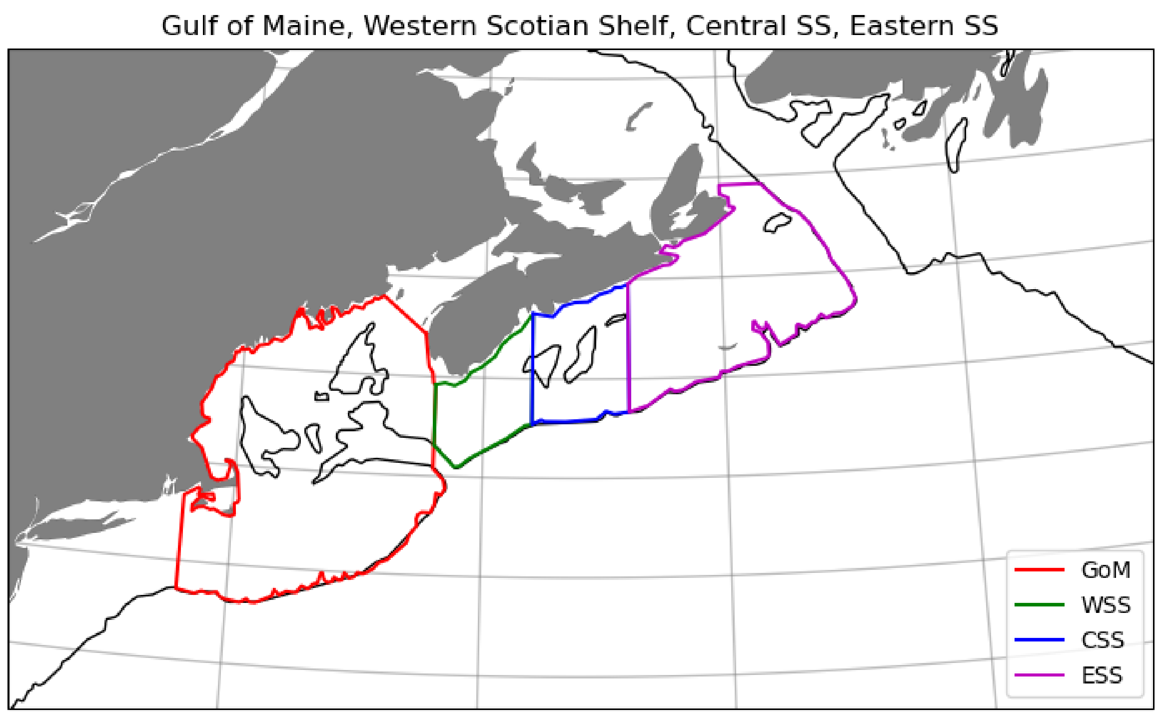
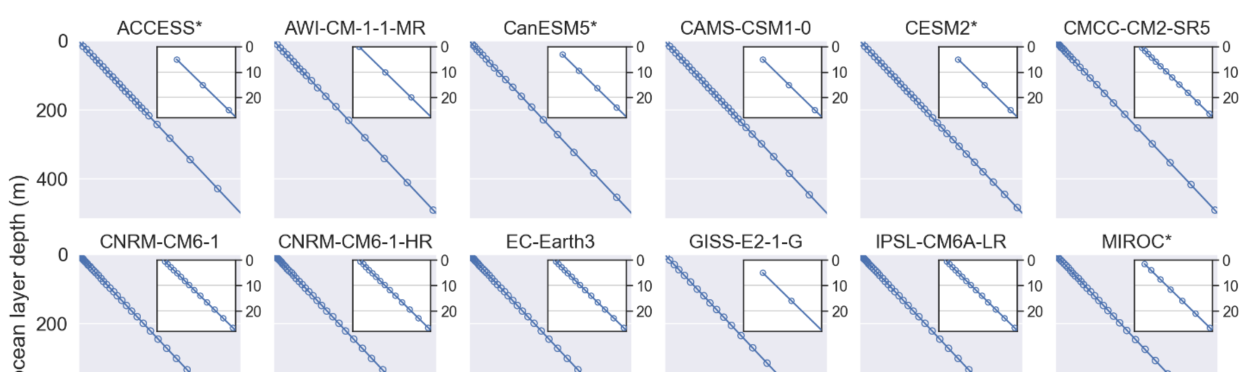


Figure 1. Map of research subareas. Magenta: eastern Scotian Shelf (ESS); Blue: central Scotian Shelf (CSS); Green: western Scotian Shelf (WSS); Red: Gulf of Maine (GoM); Black: 200m isobath (Natural Earth Bathymetry i.e. contoured from SRTM Plus).



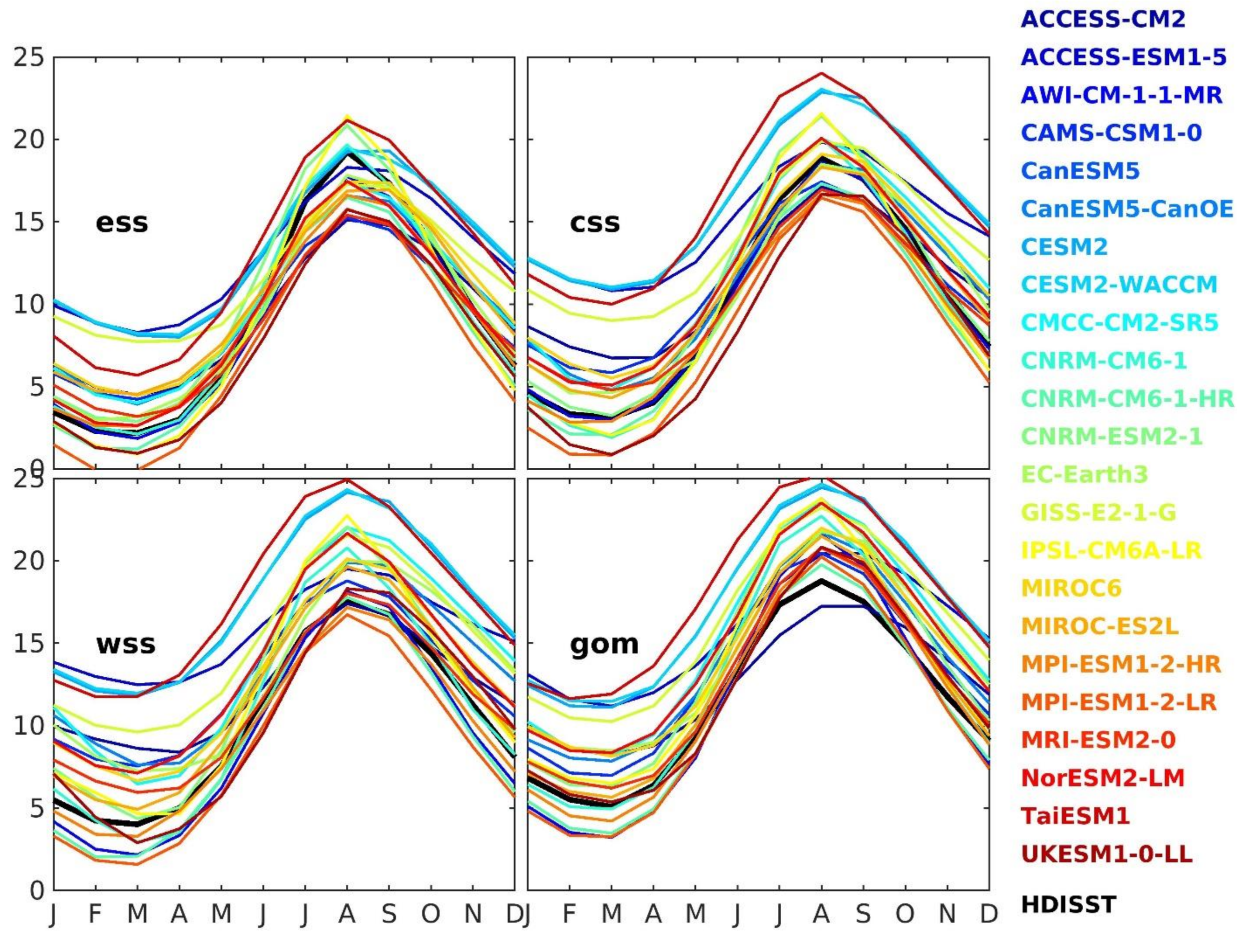


Figure 3. Climatological seasonal cycles from CMIP6 ESMs and HadISST1 data for the 1995-2014 period. The color of each ESM name matches the line color. The seasonality from HadISST1 is in black. Units are degrees Celsius.

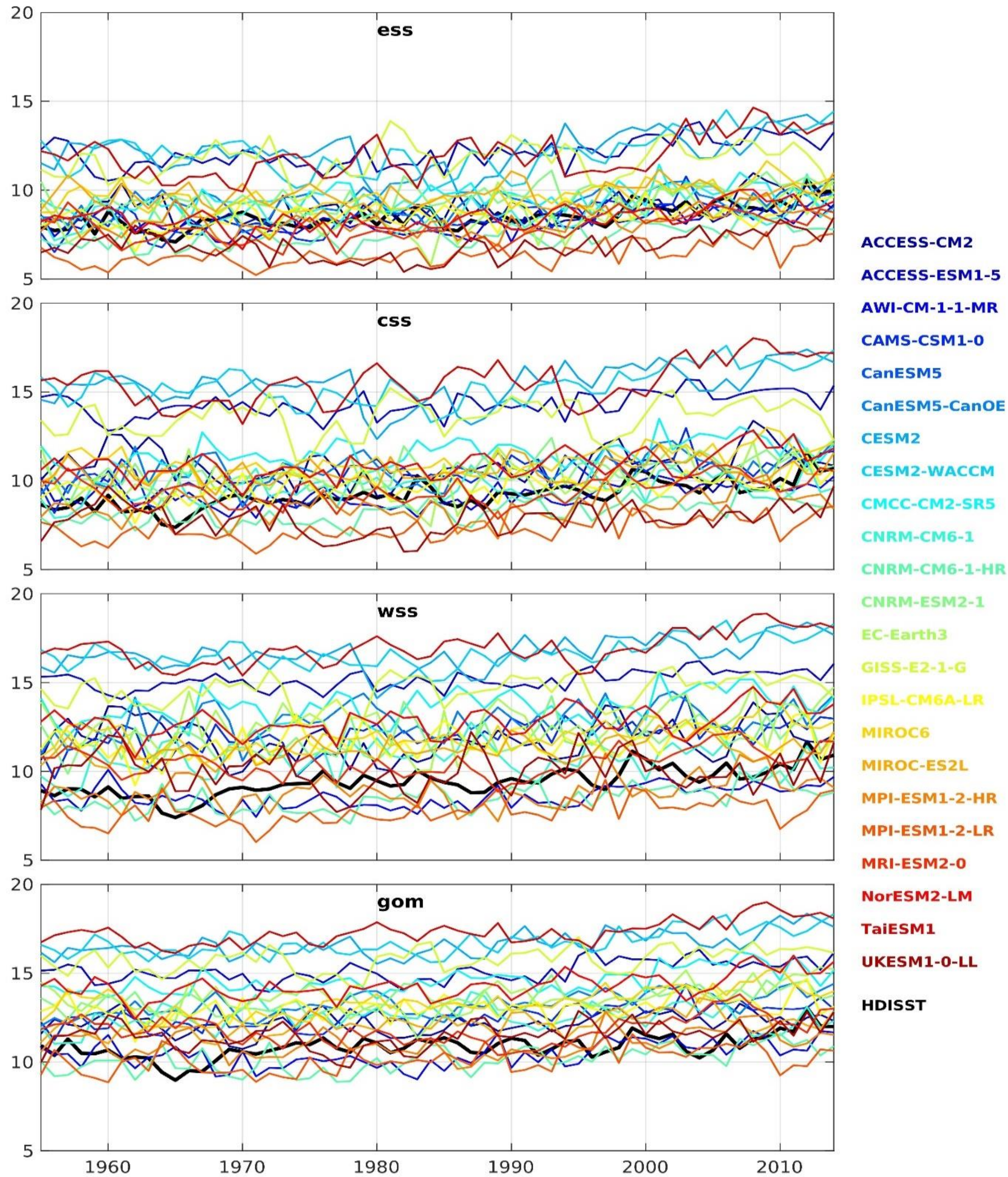


Figure 4. SST subarea time series for CMIP6 ESMs and HadISST1 data, 1955-2014. The color of each ESM name matches the line color. The heavy black line is HadISST1. Units are degrees Celsius.

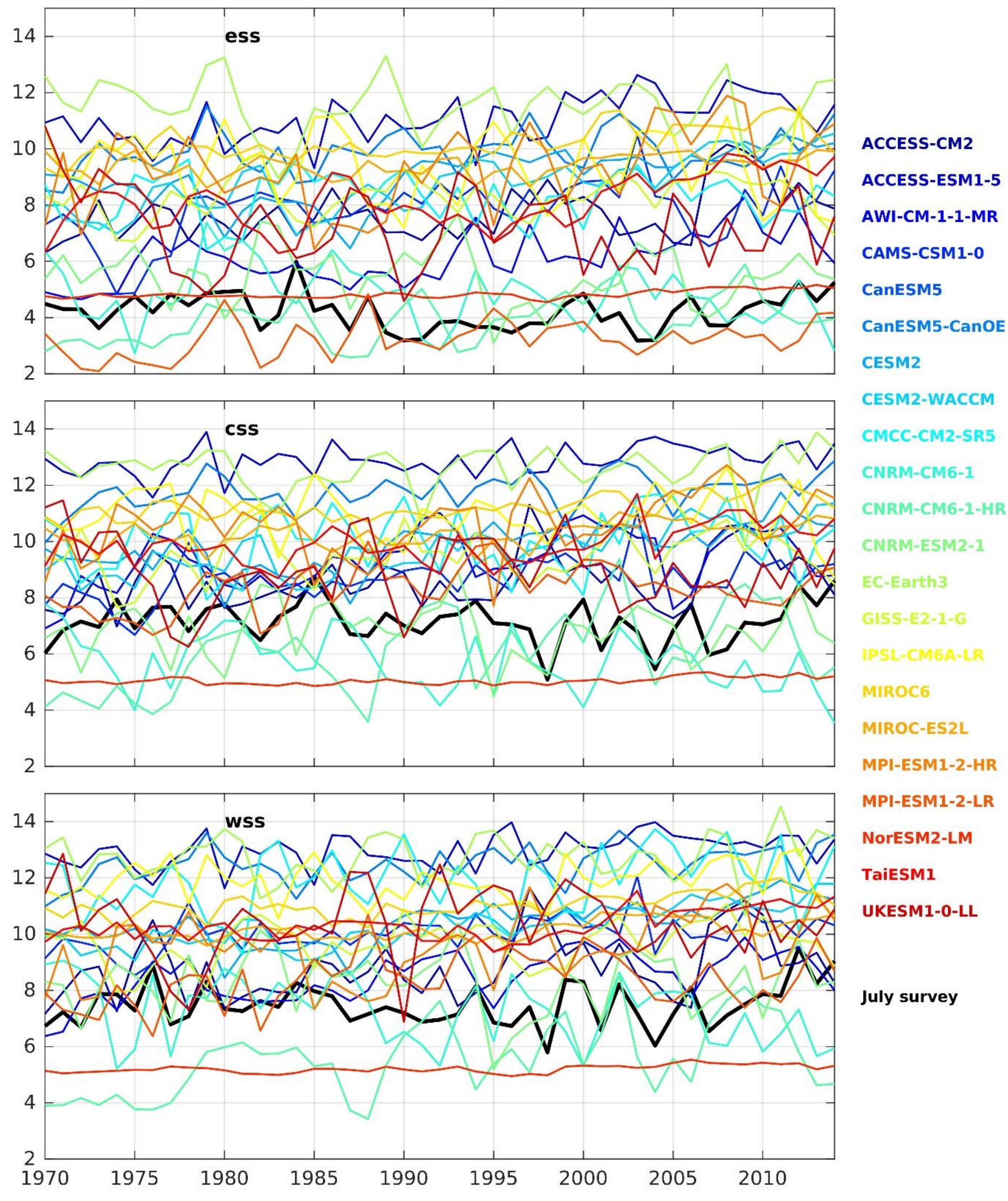


Figure 5. Time series of the BT from ship surveys and the 22 CMIP6 models for the period of 1970-2014.

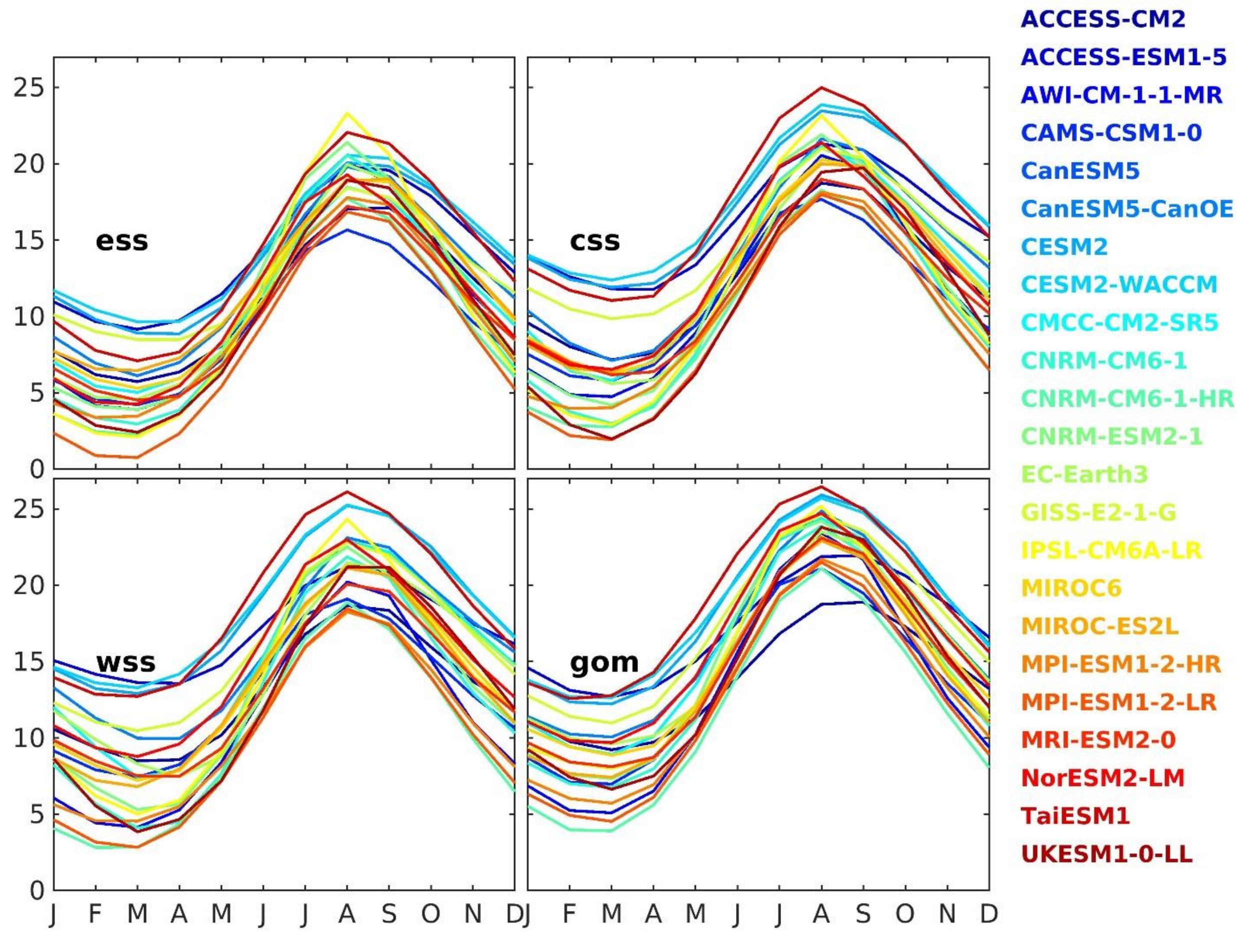


Figure 6. Projected seasonal cycles of SST for each subarea, each CMIP6 ESM, scenario SSP245. The color of each ESM name matches the line color. Units are degrees Celsius.

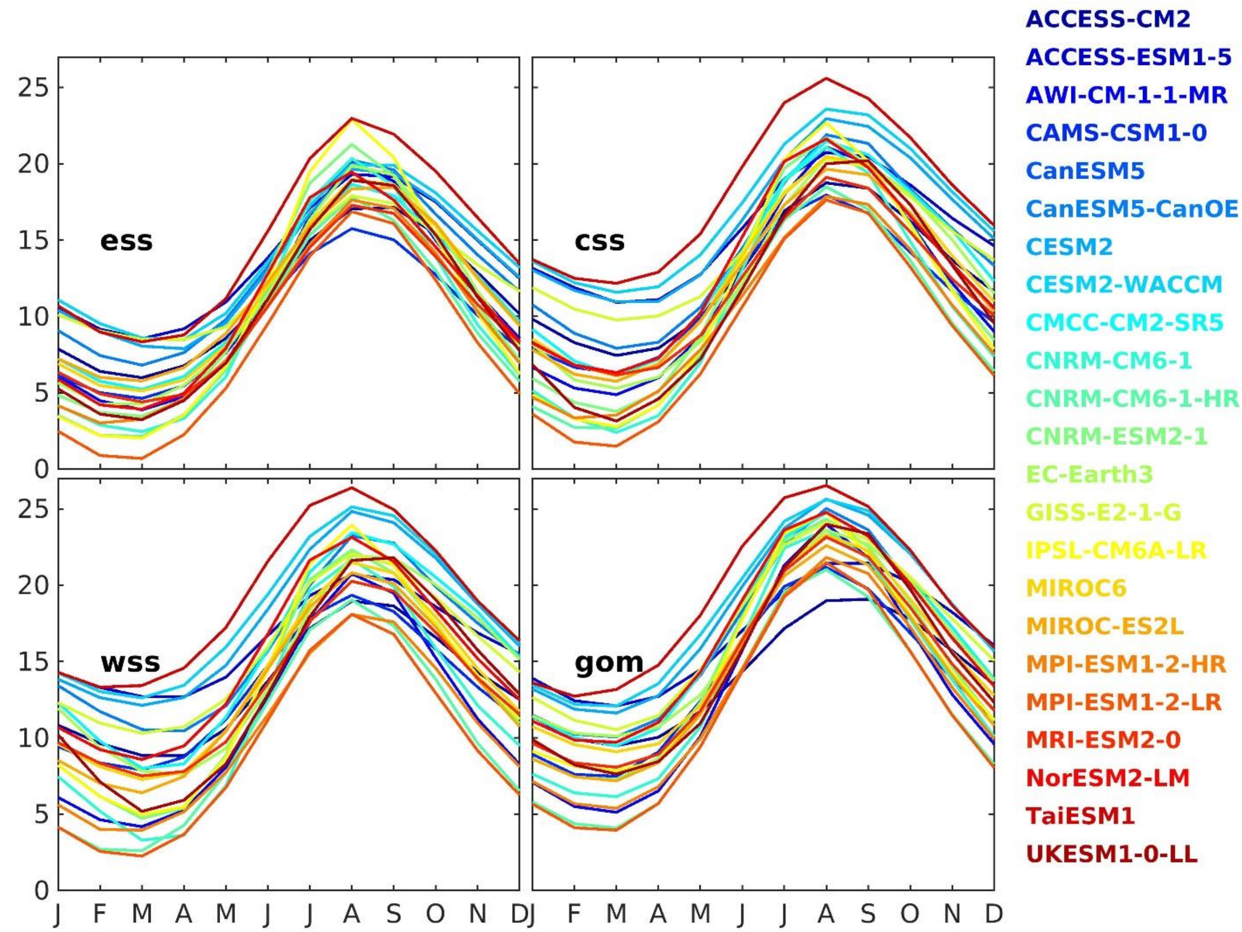


Figure 7. Projected seasonal cycles of SST of each subarea, each CMIP6 ESM, scenario SSP370. The color of each ESM name matches the line color. Units are degrees Celsius.

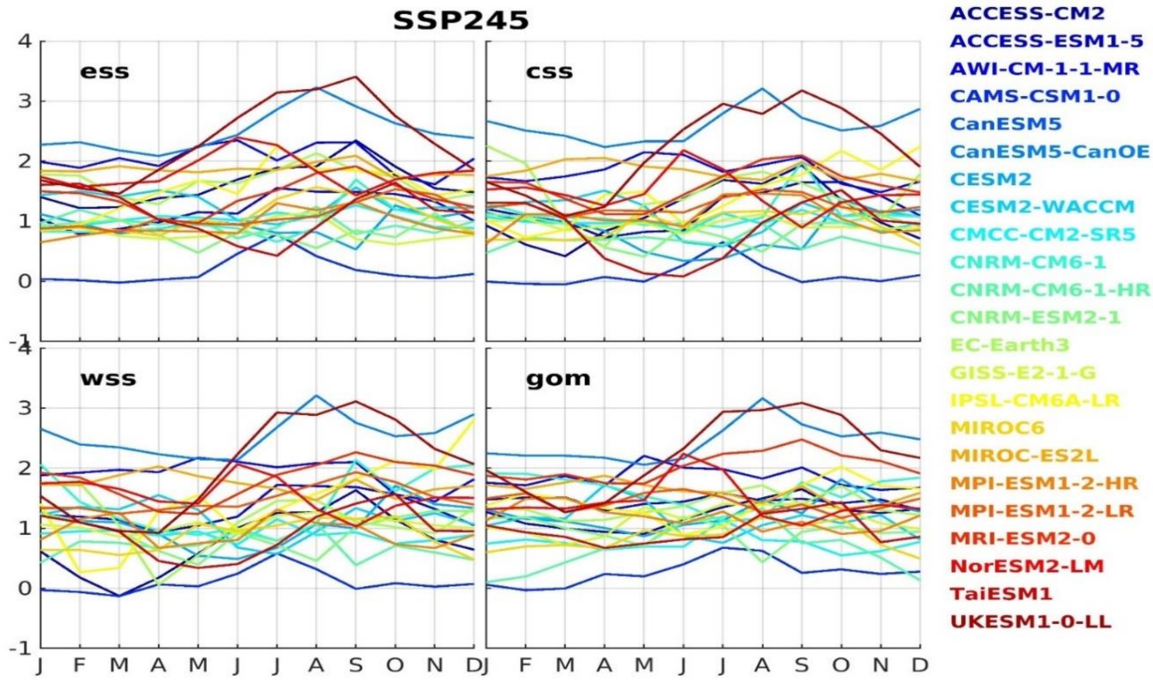


Figure 8. Changes in SST seasonality between 2030-2049 and 1995-2014, for each CMIP6 ESM and each subarea, scenario SSP245. The color of each ESM name matches the line color. Units are degrees Celsius.

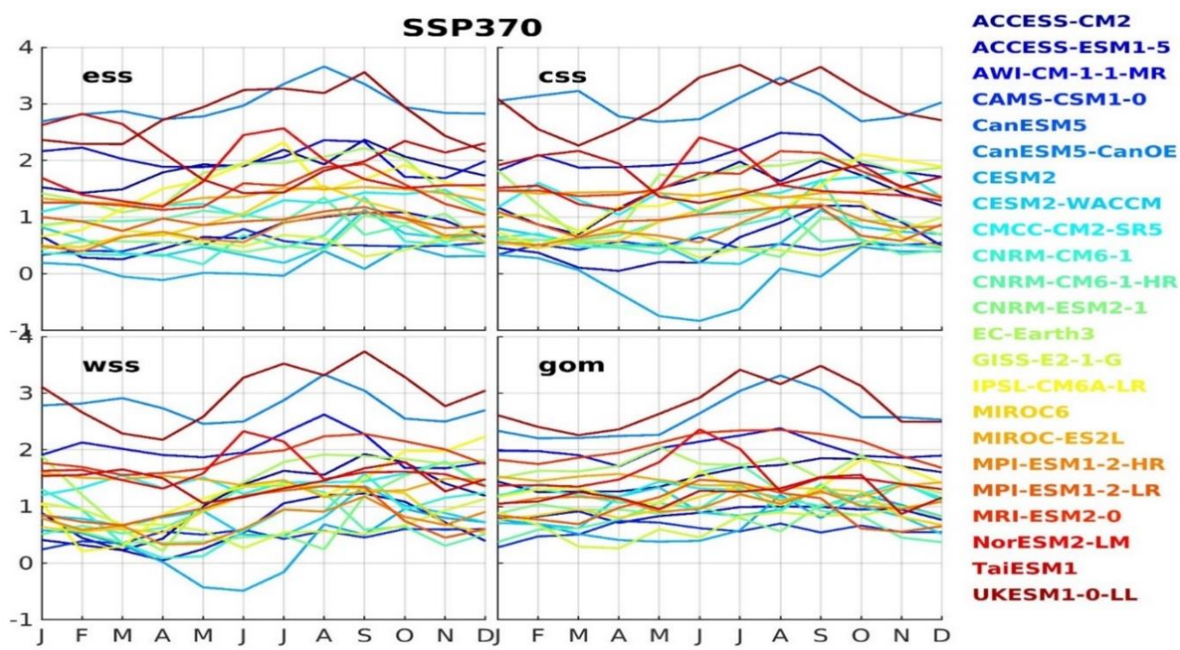


Figure 9. Changes in SST seasonality between 2030-2049 and 1995-2014, for each CMIP6 ESM and each subarea, scenario SSP370. The color of each ESM name matches the line color. Units are degrees Celsius.

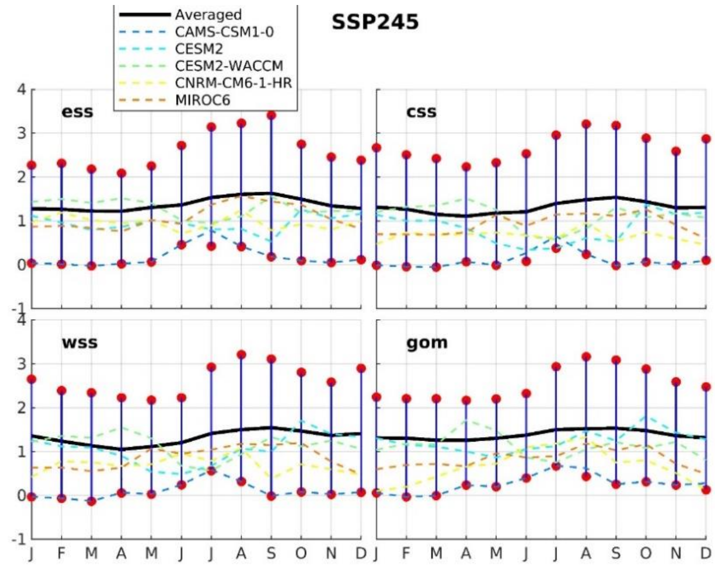


Figure 10. Predicted range of monthly SST change, considering all ESMs (vertical bars with red circle at each end); ESM ensemble mean monthly SST change (thick black lines); SST changes of the "top 5" ESMs (dashed lines). Scenario: SSP245. Units are degrees Celsius.

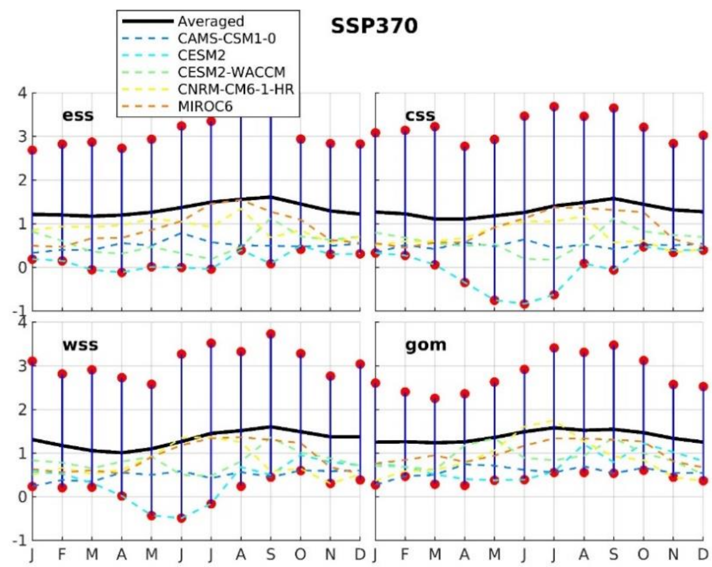


Figure 11. Predicted range of monthly SST change, considering all ESMs (vertical bars with red circle at each end); ESM ensemble mean monthly SST change (thick black lines); SST changes of the "top 5" ESMs (dashed lines). Scenario: SSP370. Units are degrees Celsius.

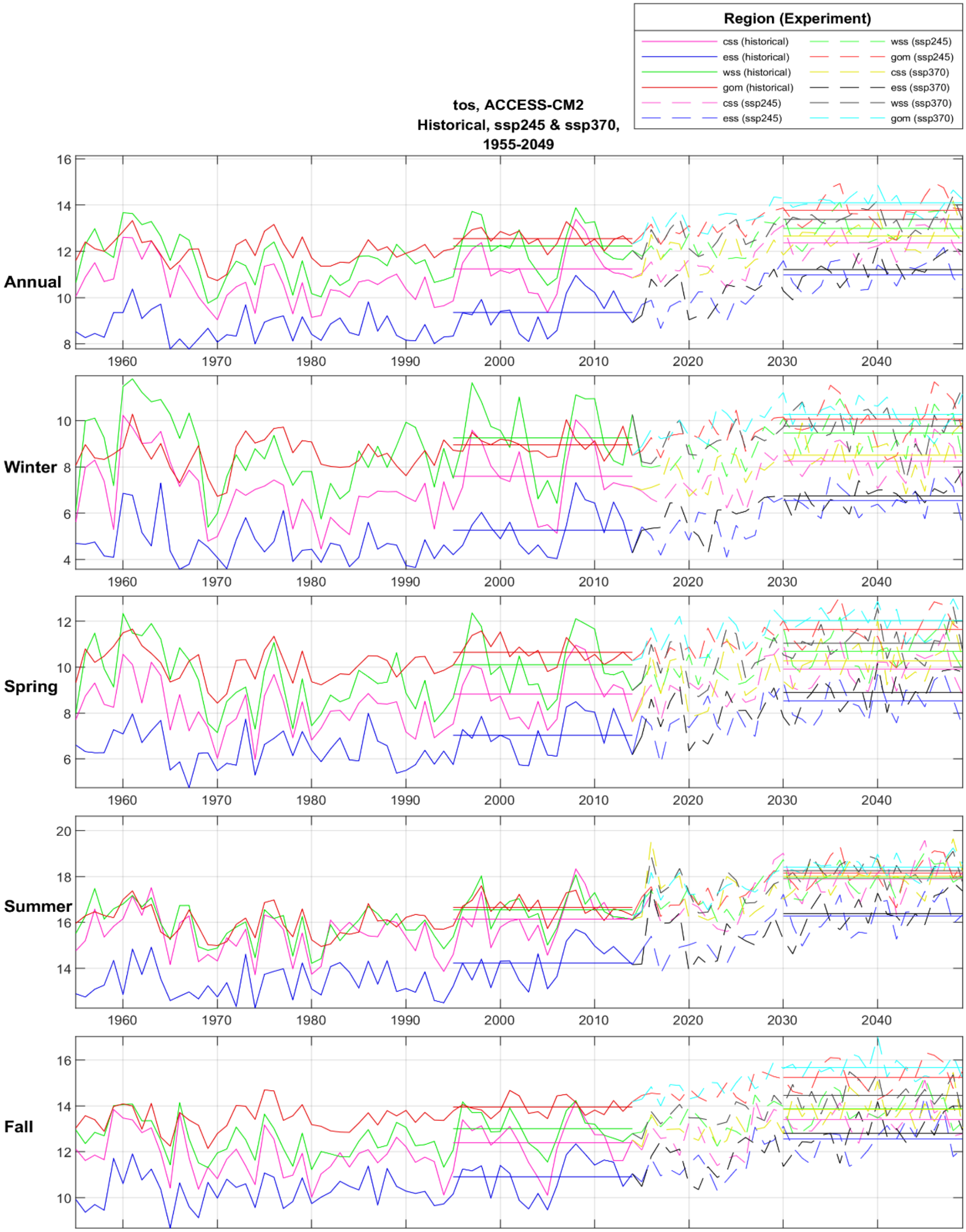


Figure 12. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: ACCESS-CM2. Units are degrees Celsius.

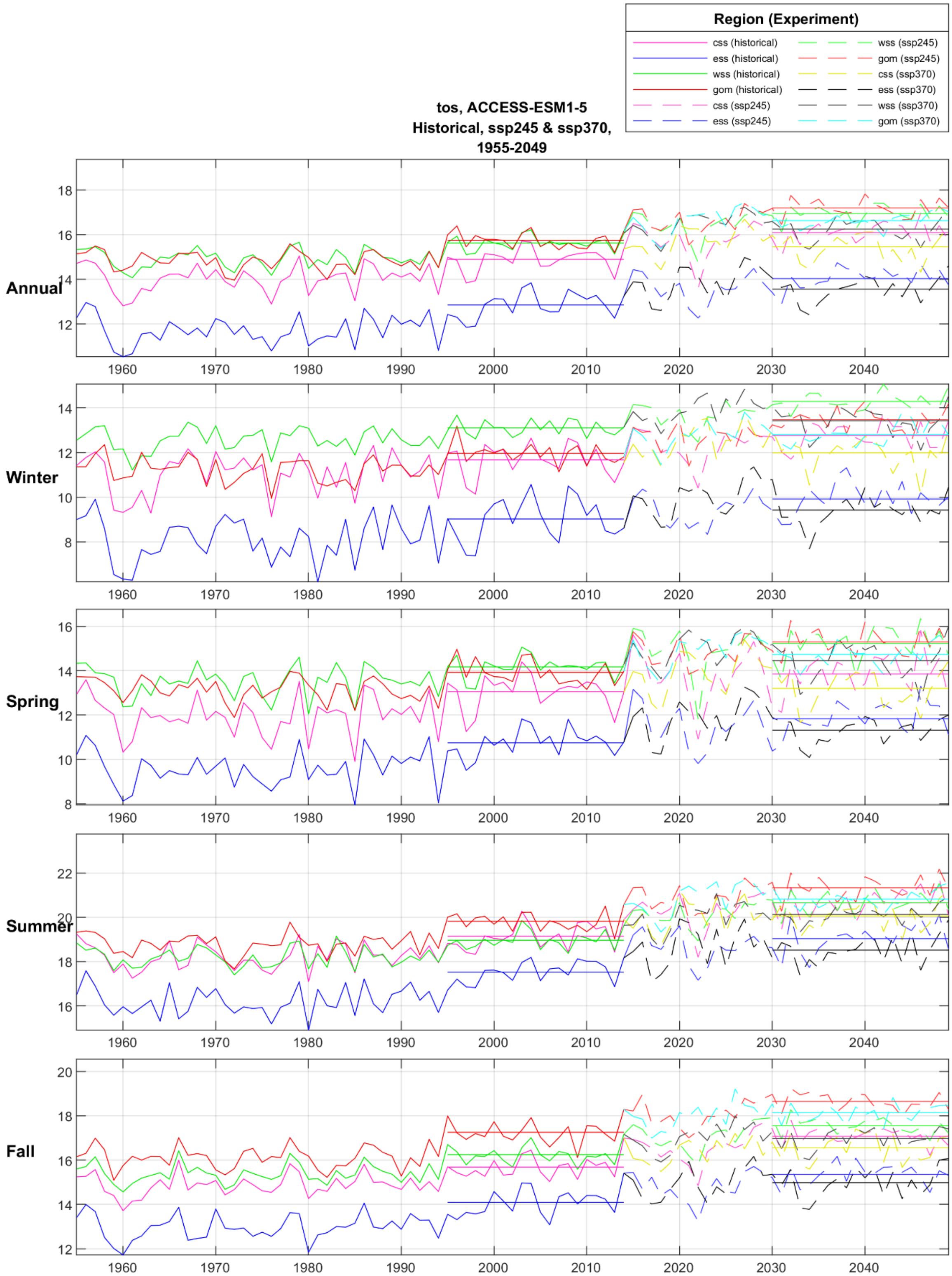


Figure 13. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: ACCESS-ESM1-5. Units are degrees Celsius.

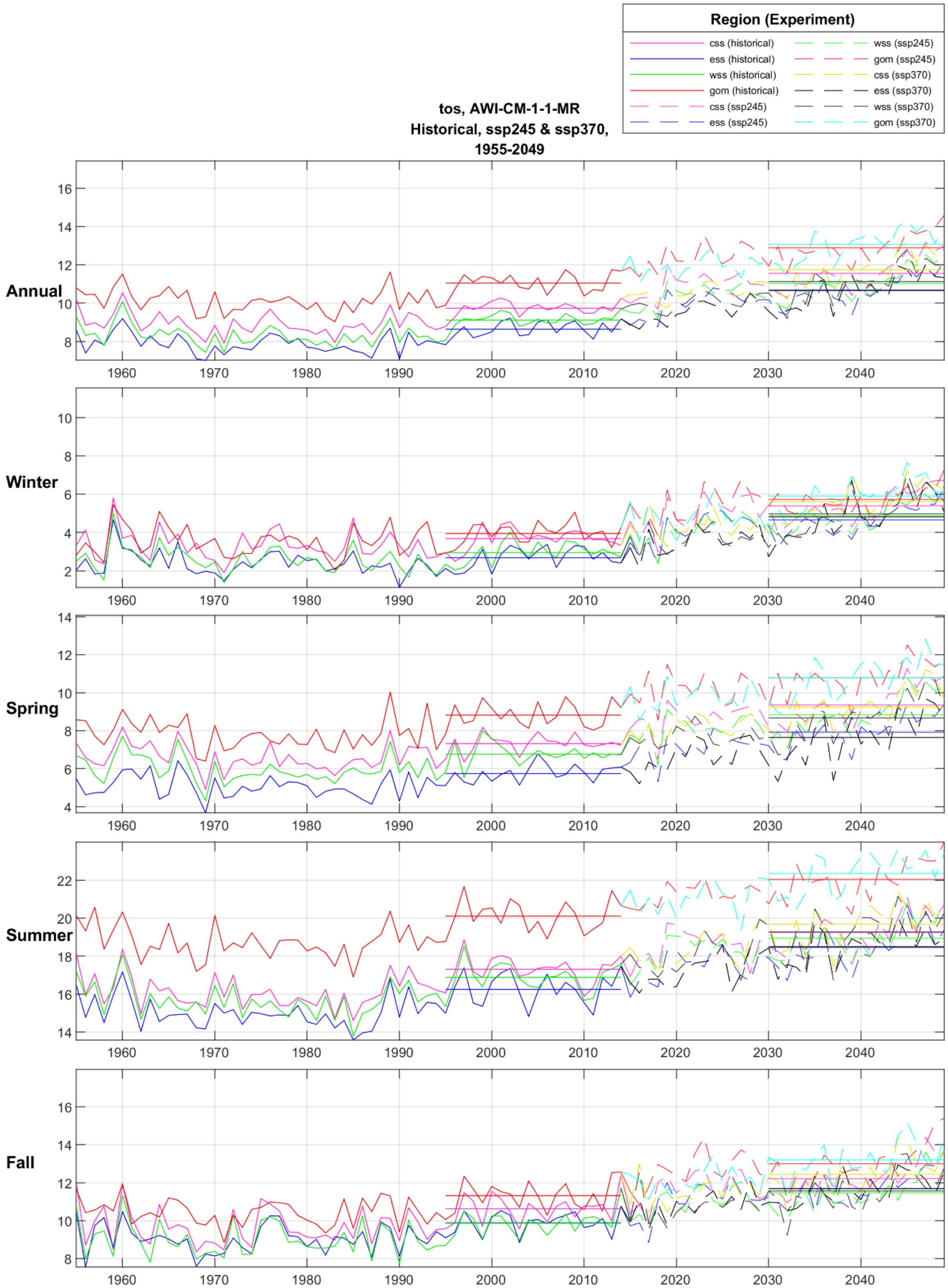


Figure 14. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: AWI-CM-1-1-MR. Units are degrees Celsius.

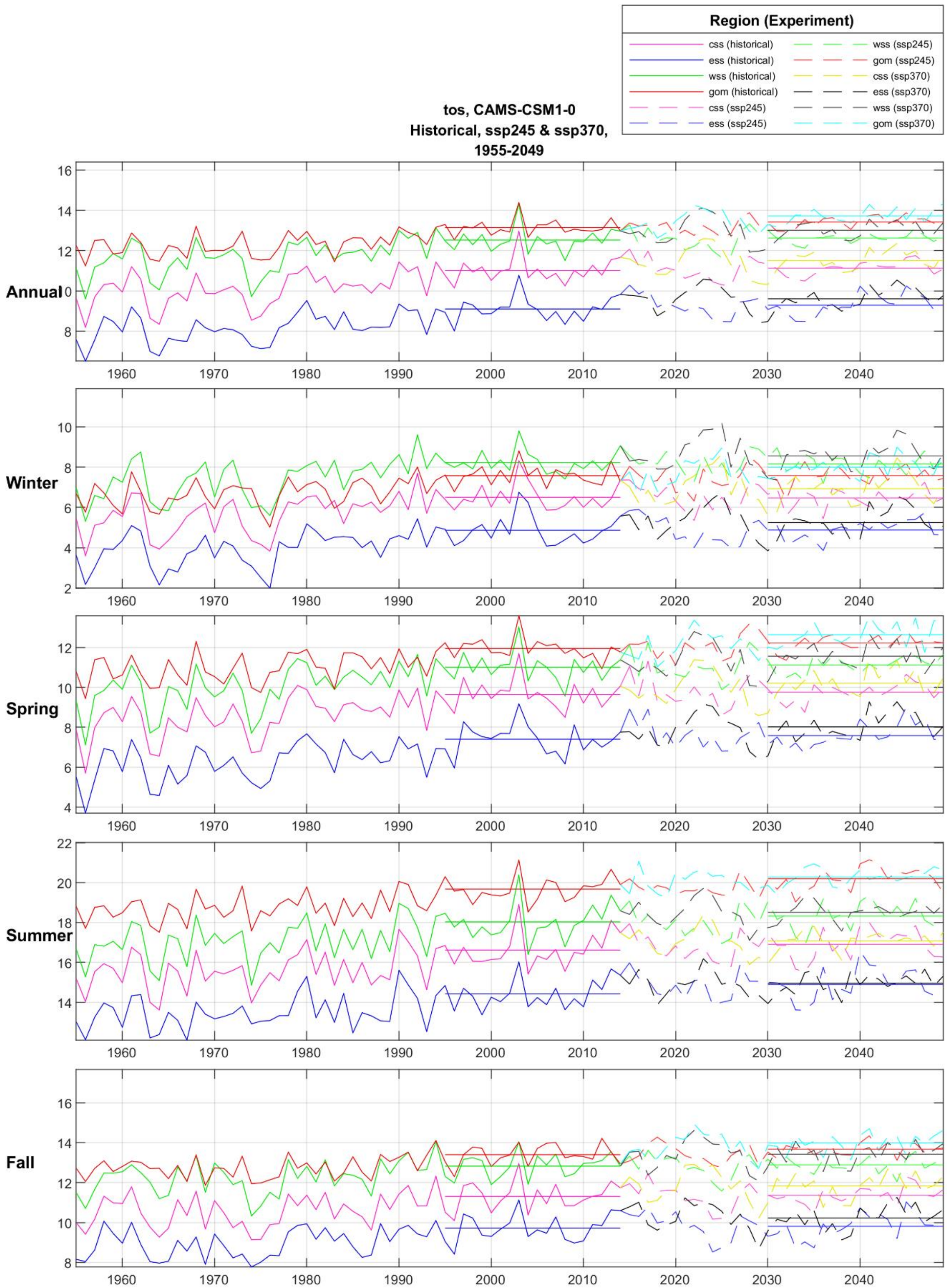


Figure 15. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: CAMS-CSM1-0. Units are degrees Celsius.

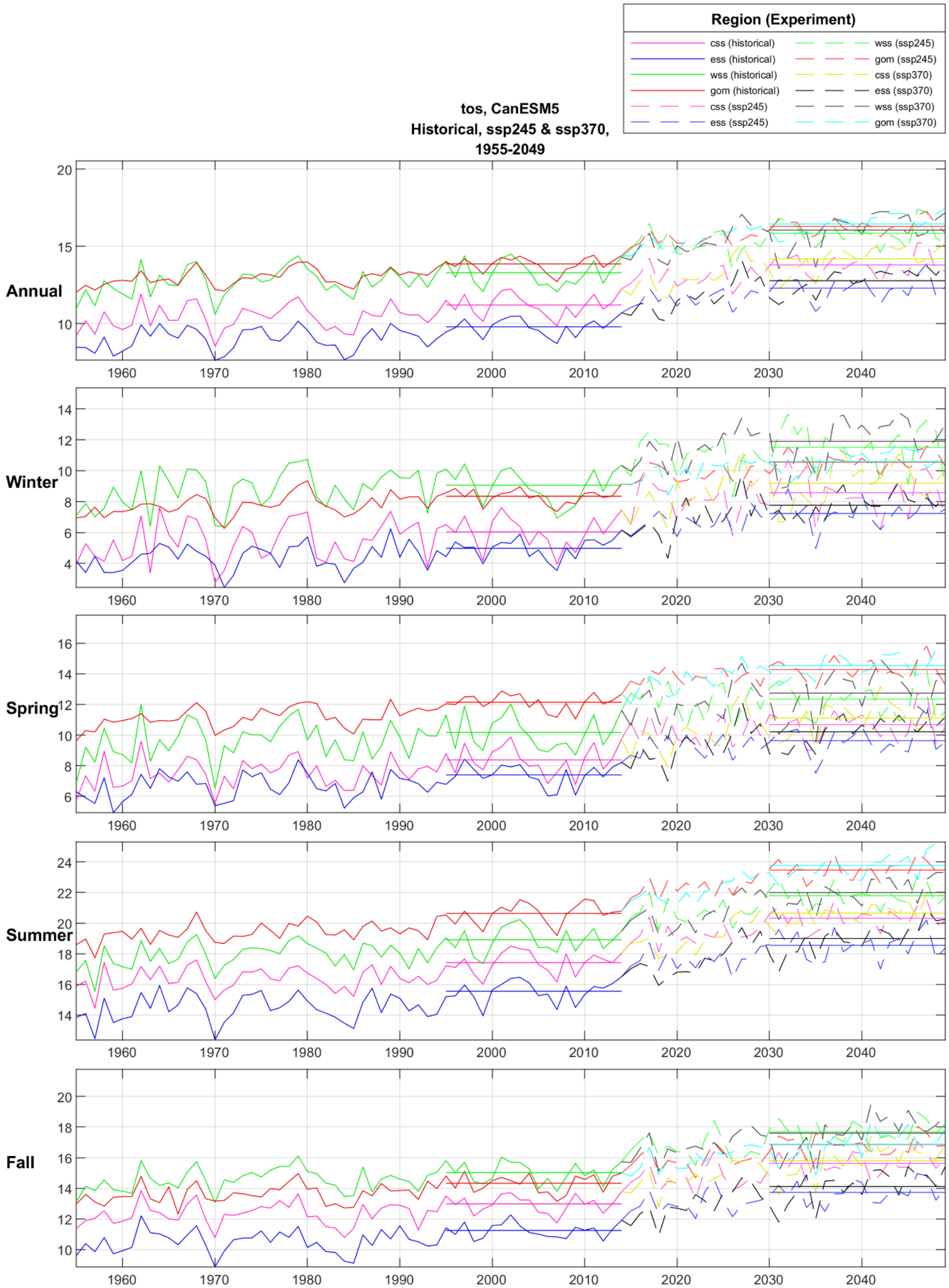


Figure 16. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: CanESM5. Units are degrees Celsius.

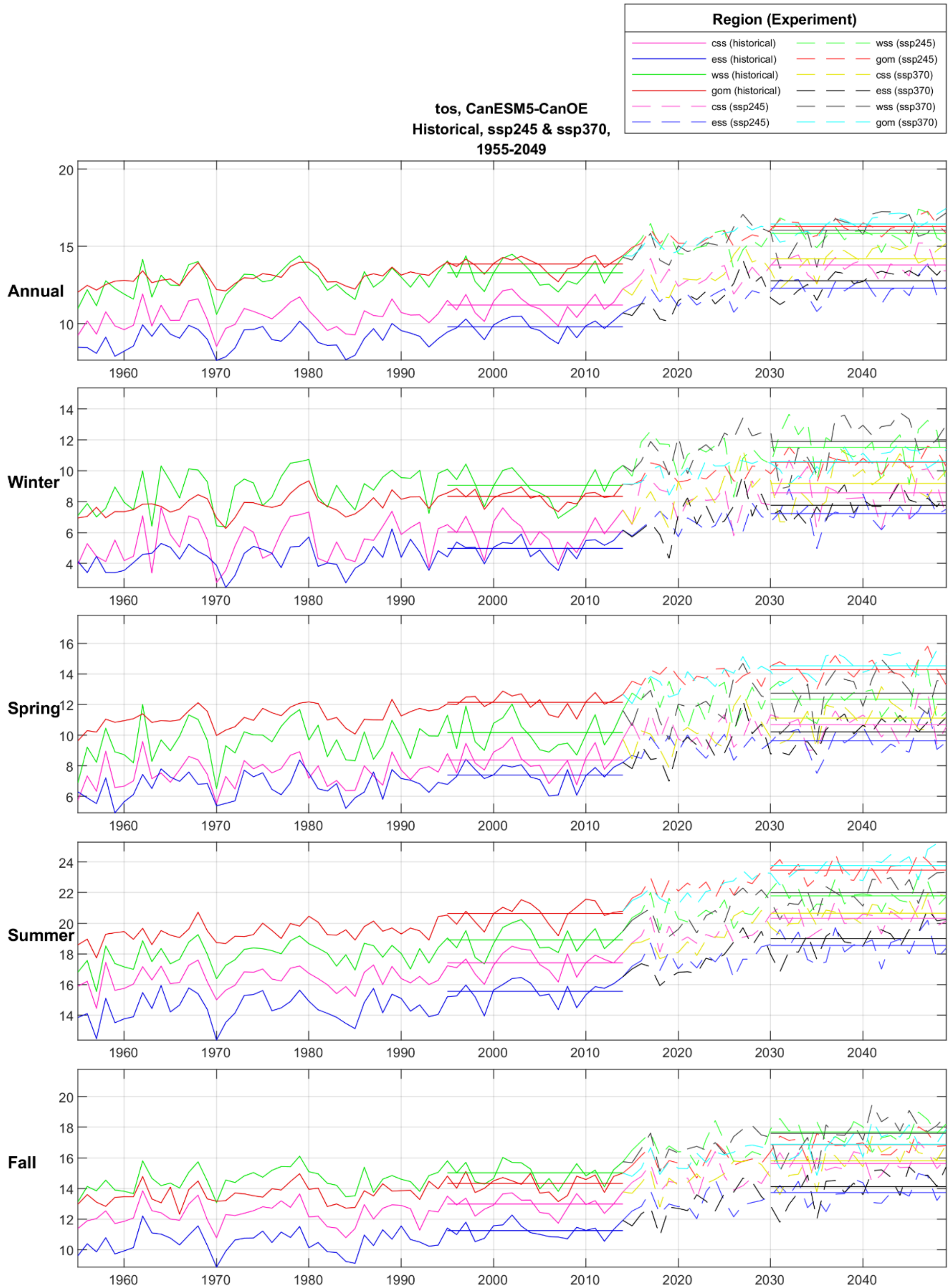


Figure 17. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: CanESM5-CanOE. Units are degrees Celsius.

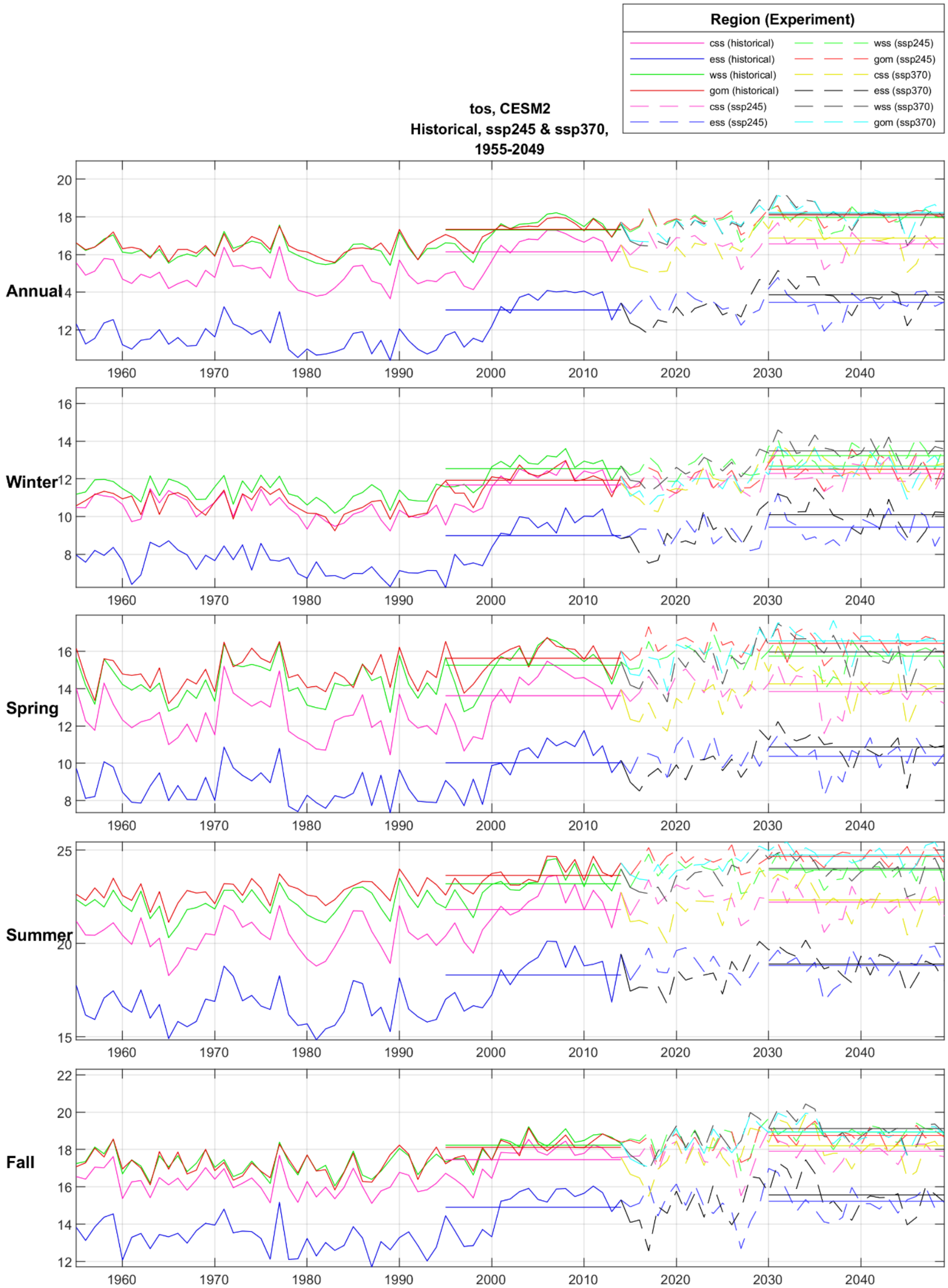


Figure 18. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: CESM2. Units are degrees Celsius.

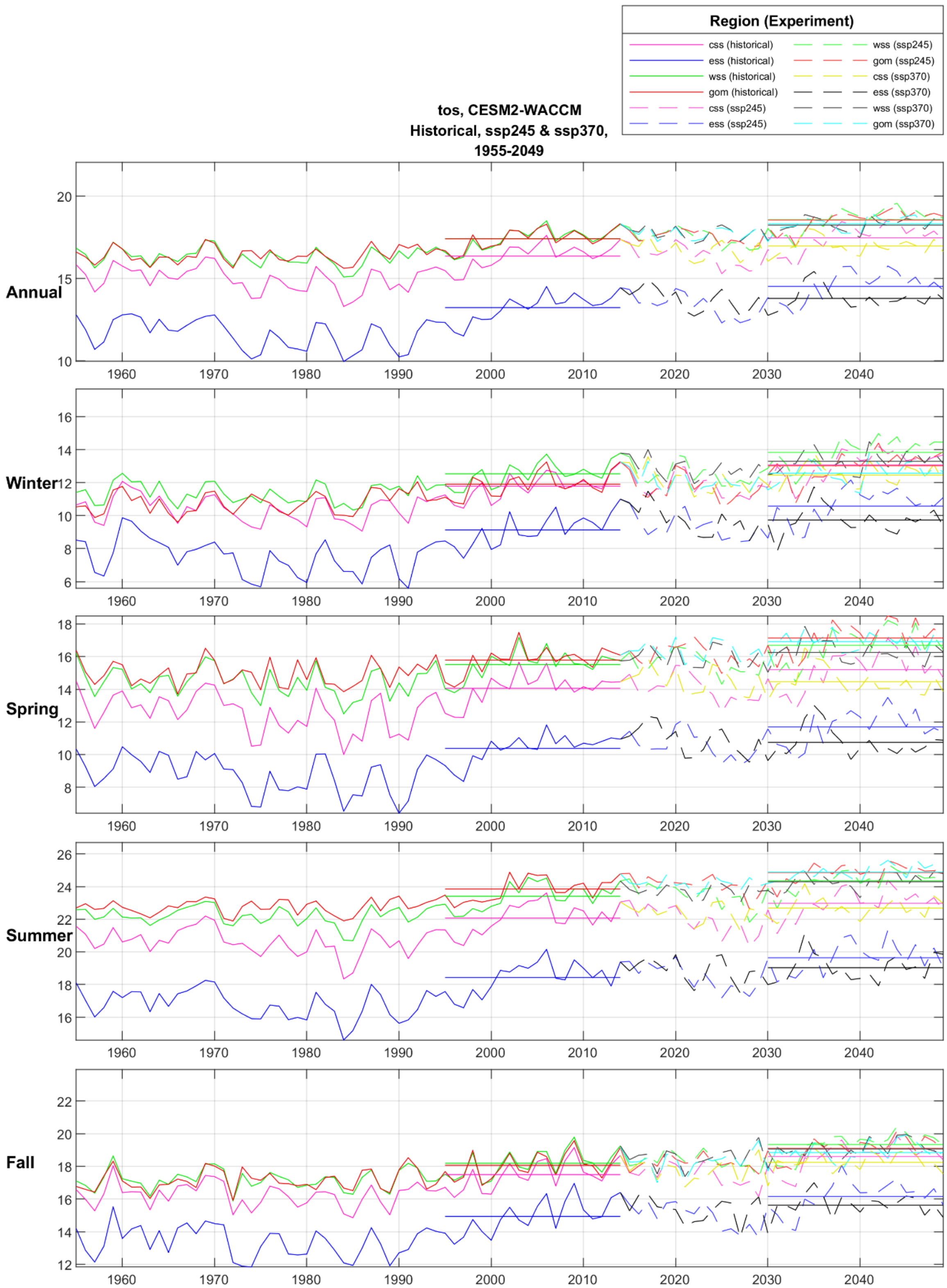


Figure 19. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: CESM2-WACCM. Units are degrees Celsius.

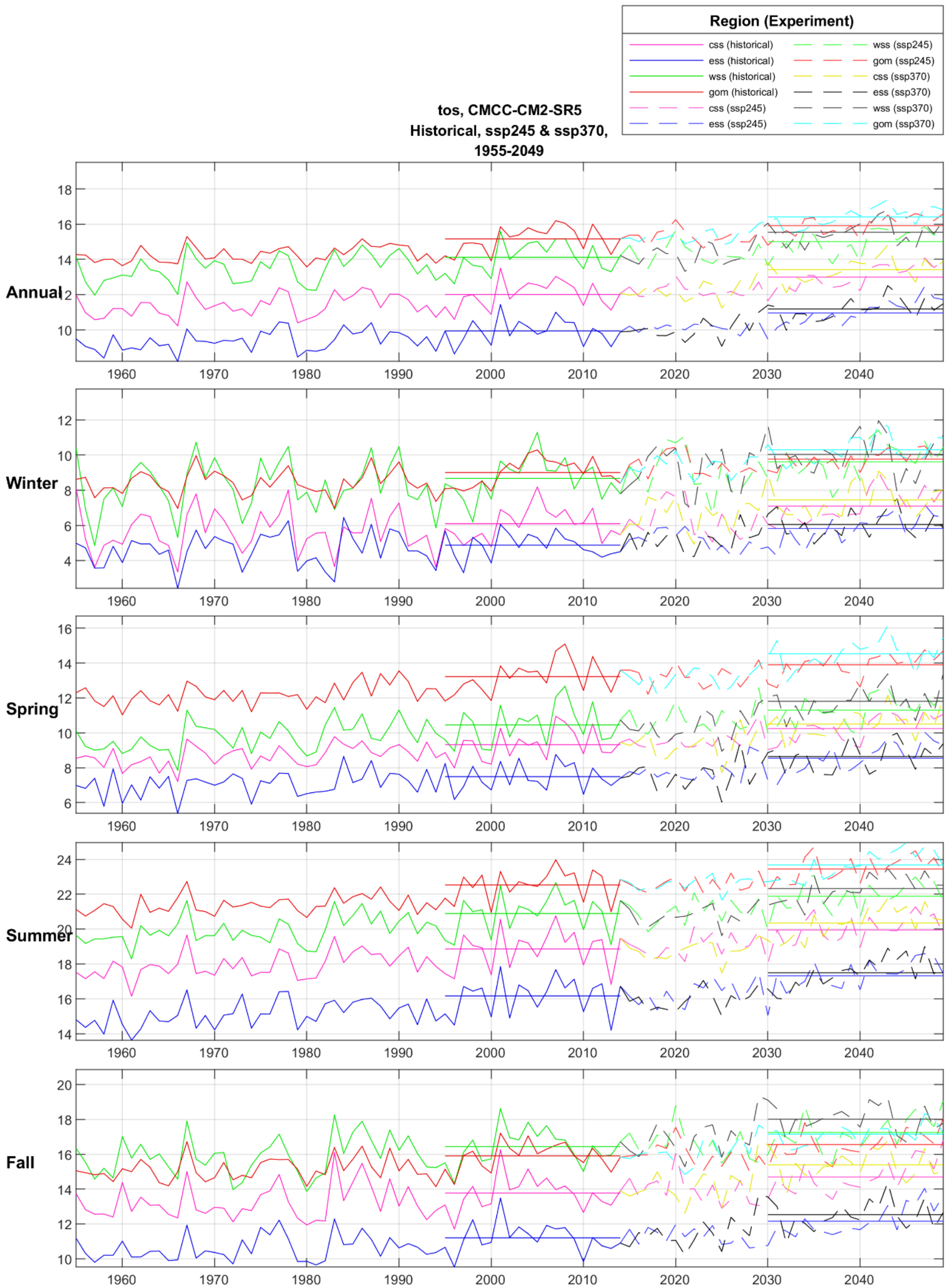


Figure 20. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: CMCC-CM2-SR5. Units are degrees Celsius.

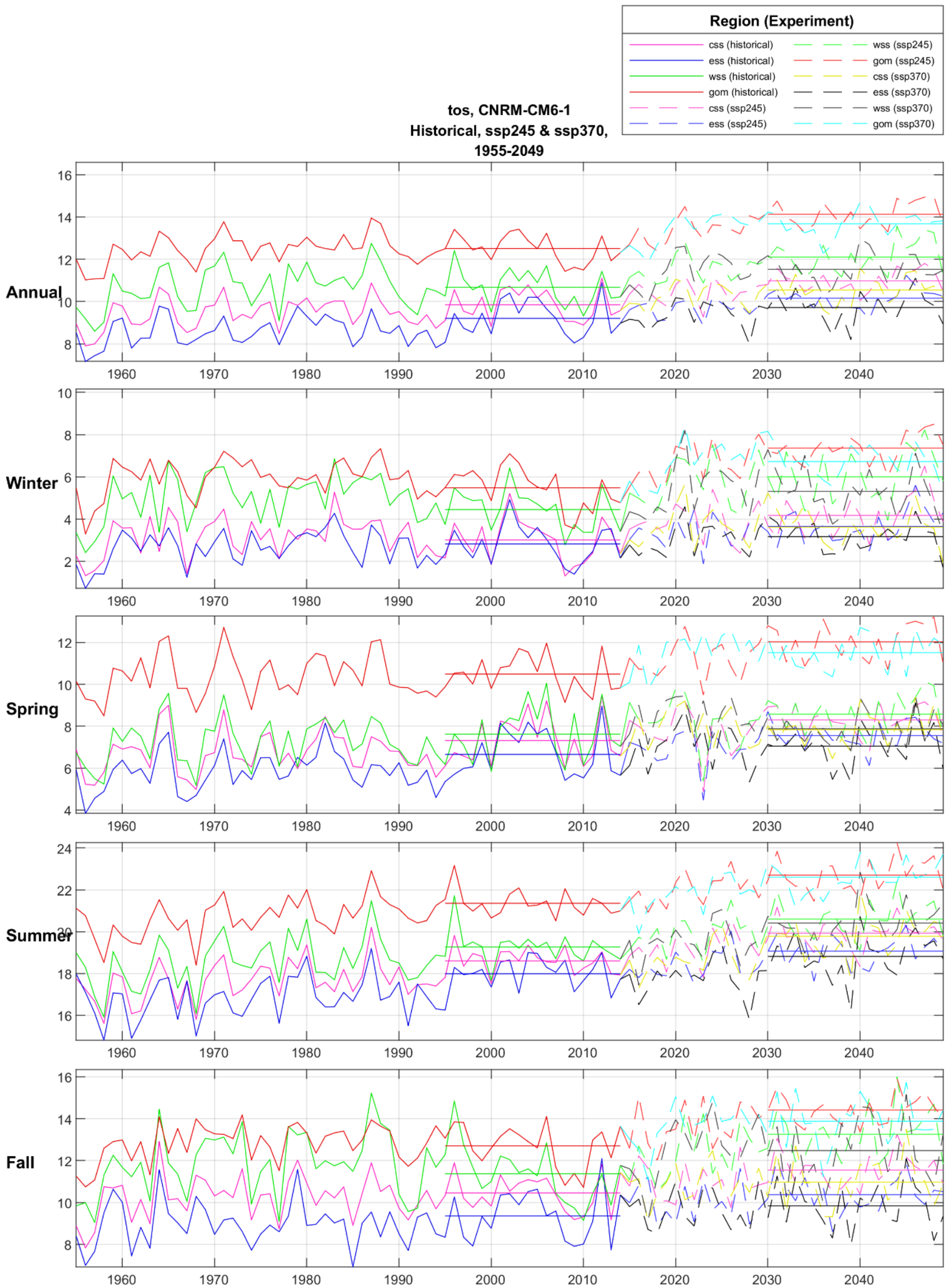


Figure 21. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: CNRM-CM6-1. Units are degrees Celsius.

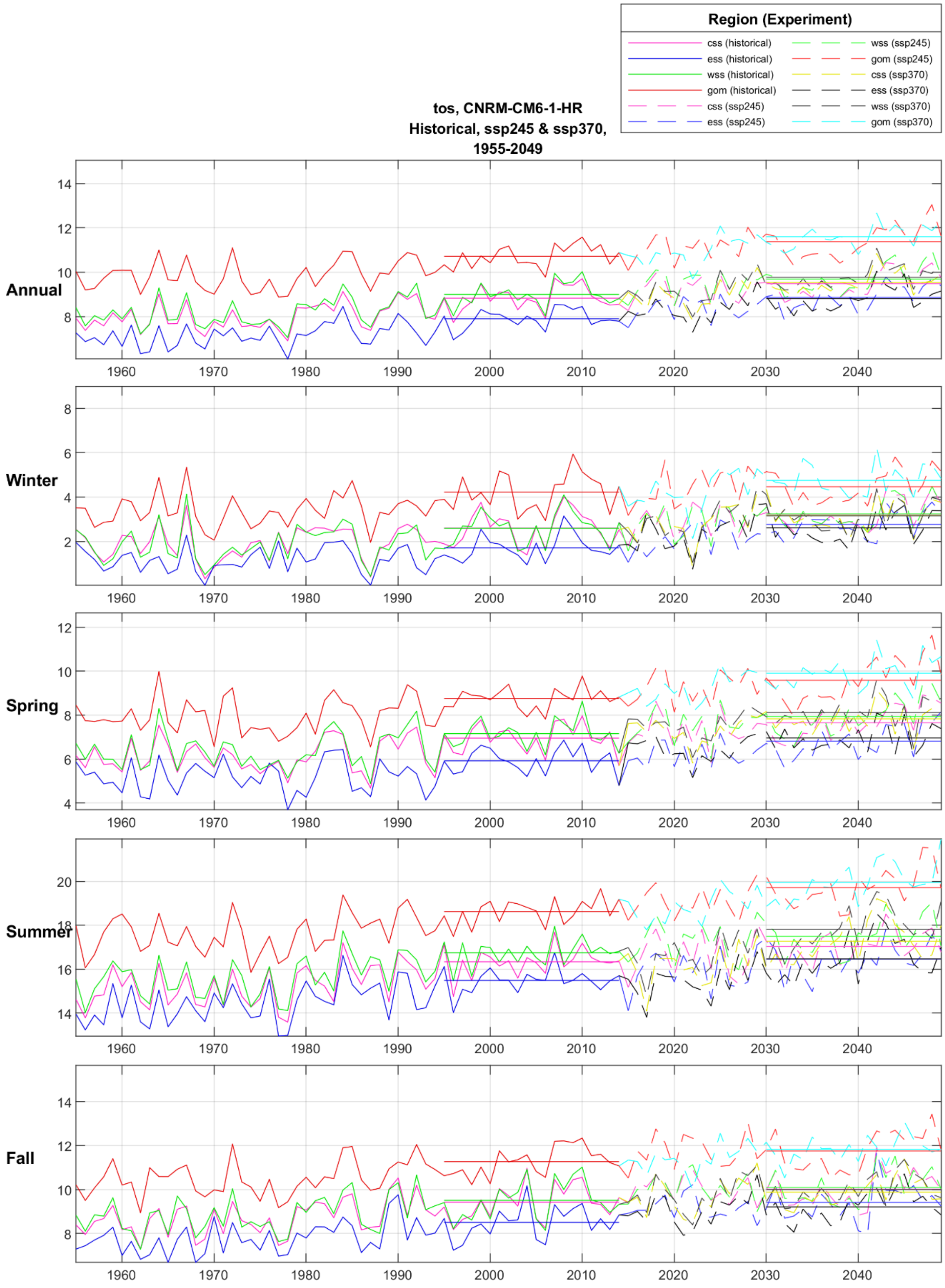


Figure 22. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: CNRM-CM6-1-HR. Units are degrees Celsius.

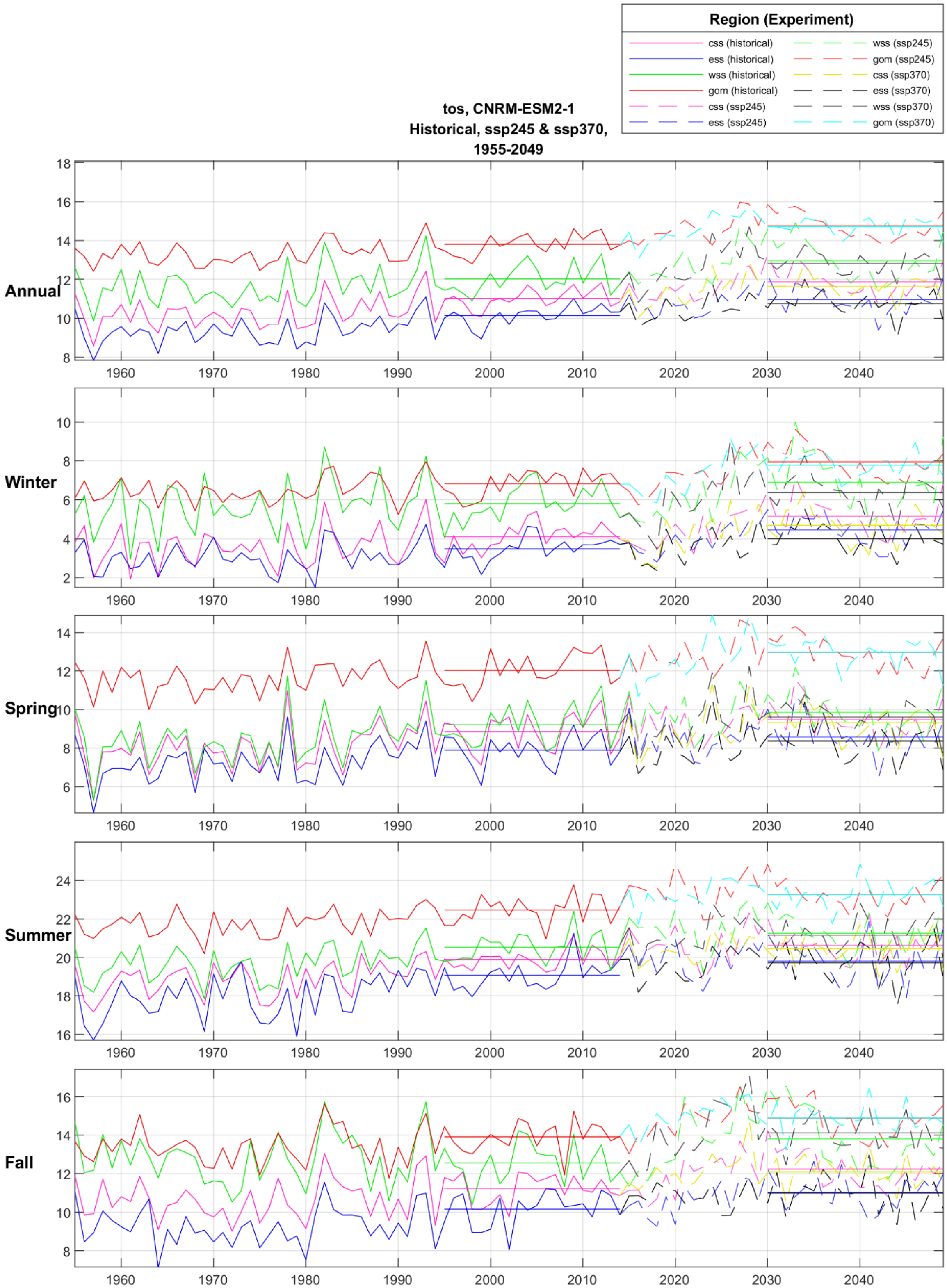


Figure 23. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: CNRM-ESM2-1. Units are degrees Celsius.

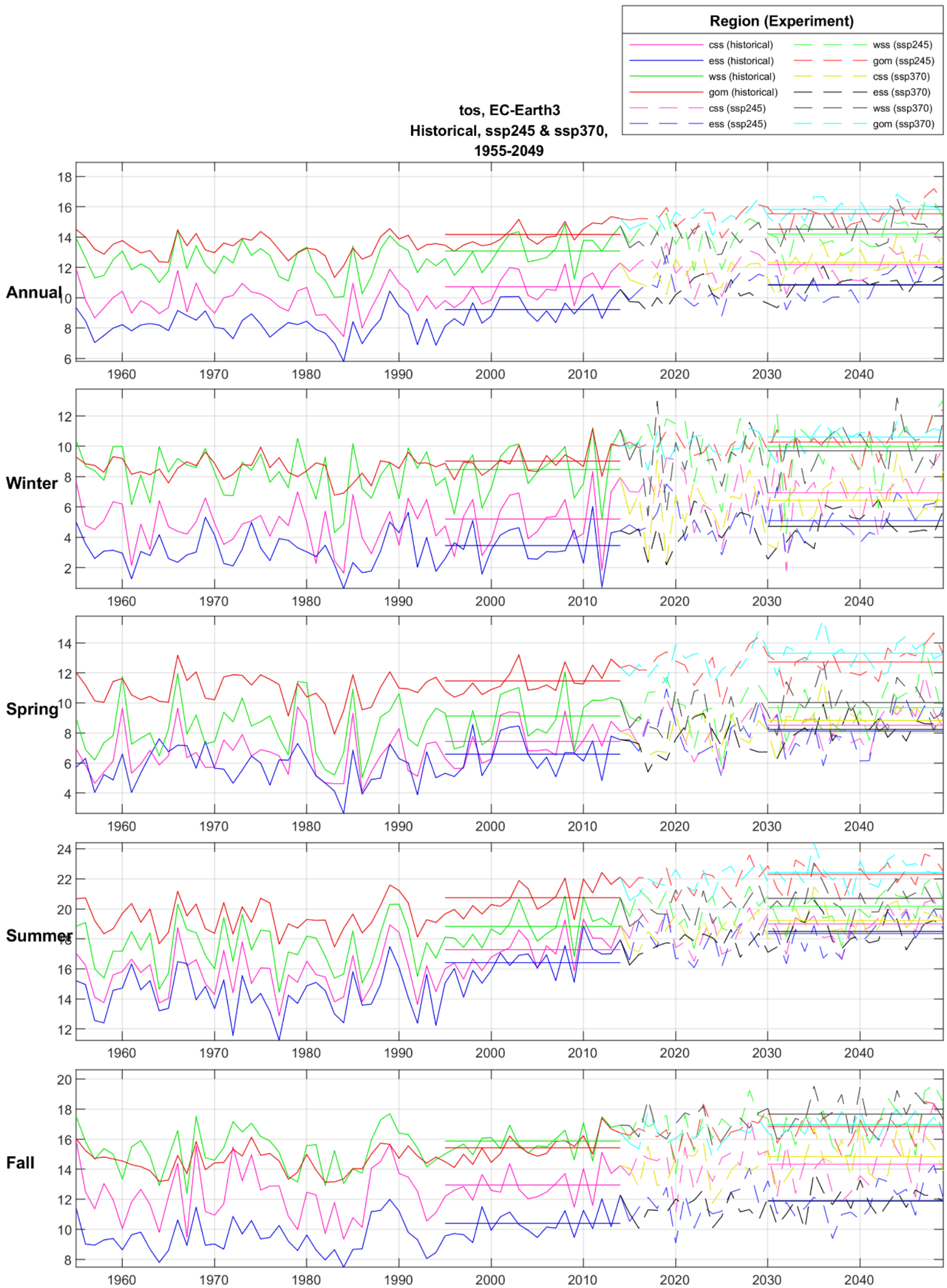


Figure 24. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: EC-Earth3. Units are degrees Celsius.

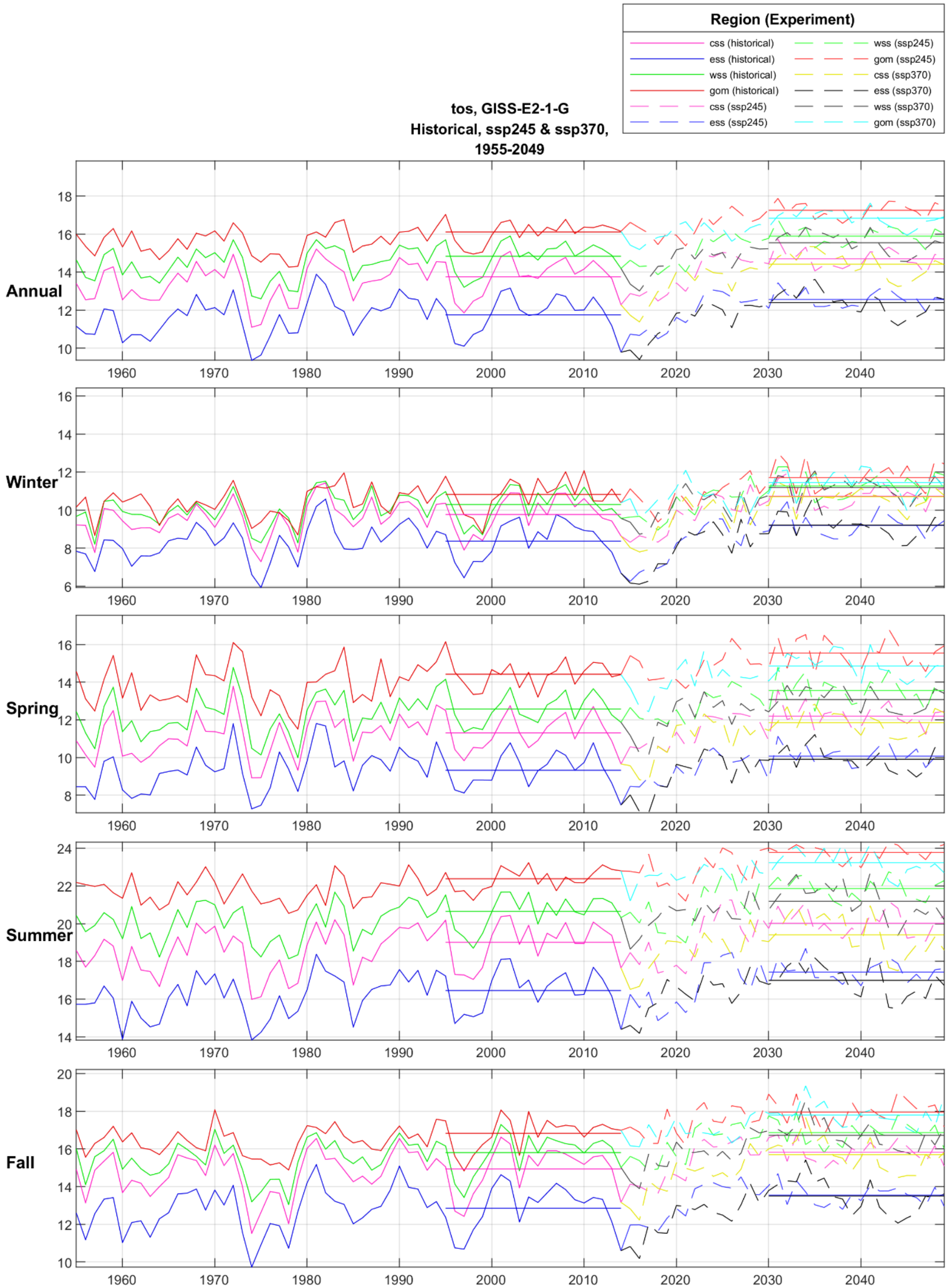


Figure 25. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: GISS-E2-1-G. Units are degrees Celsius.

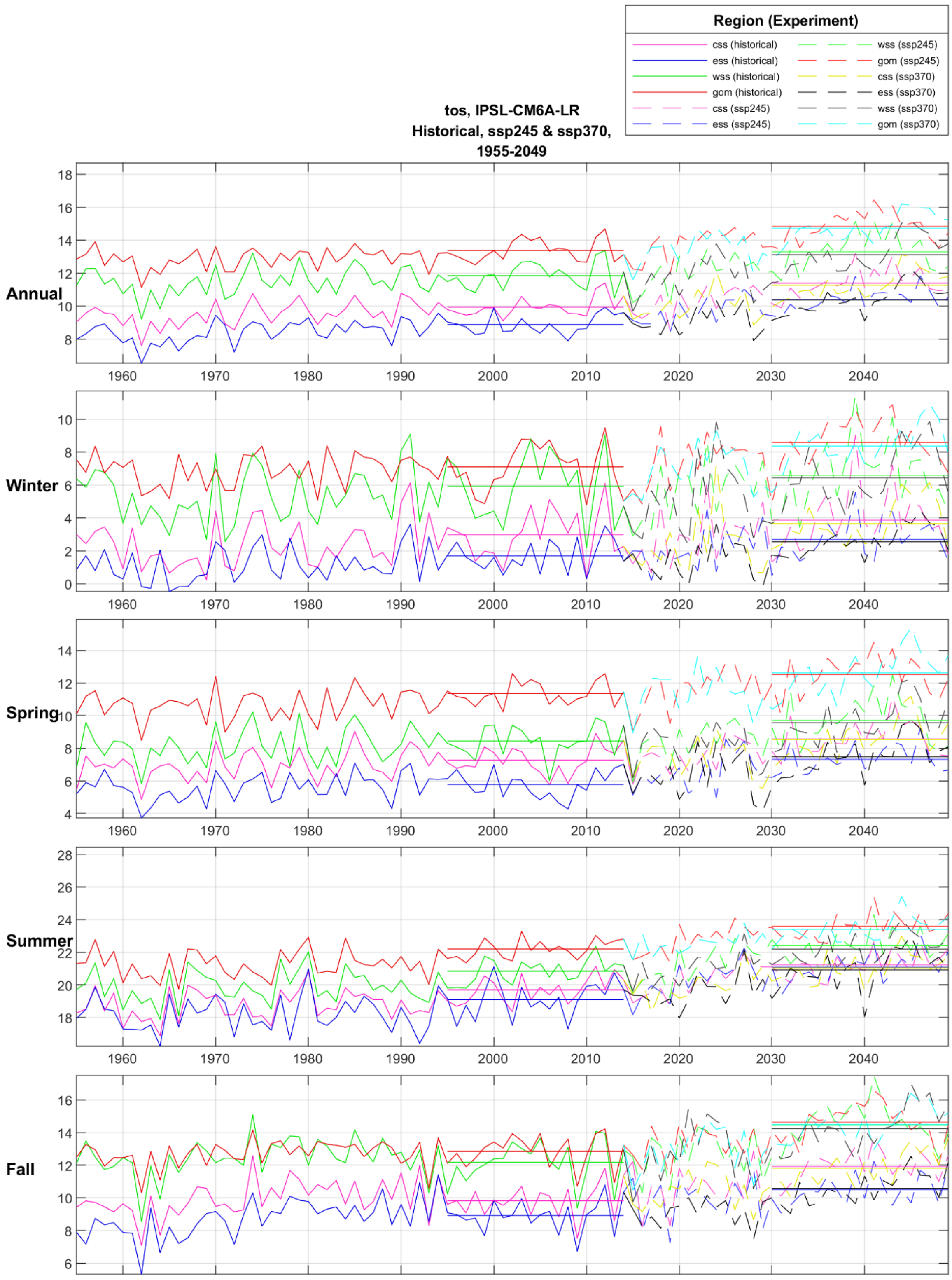


Figure 26. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model:IPSL-CM6A-LR. Units are degrees Celsius.

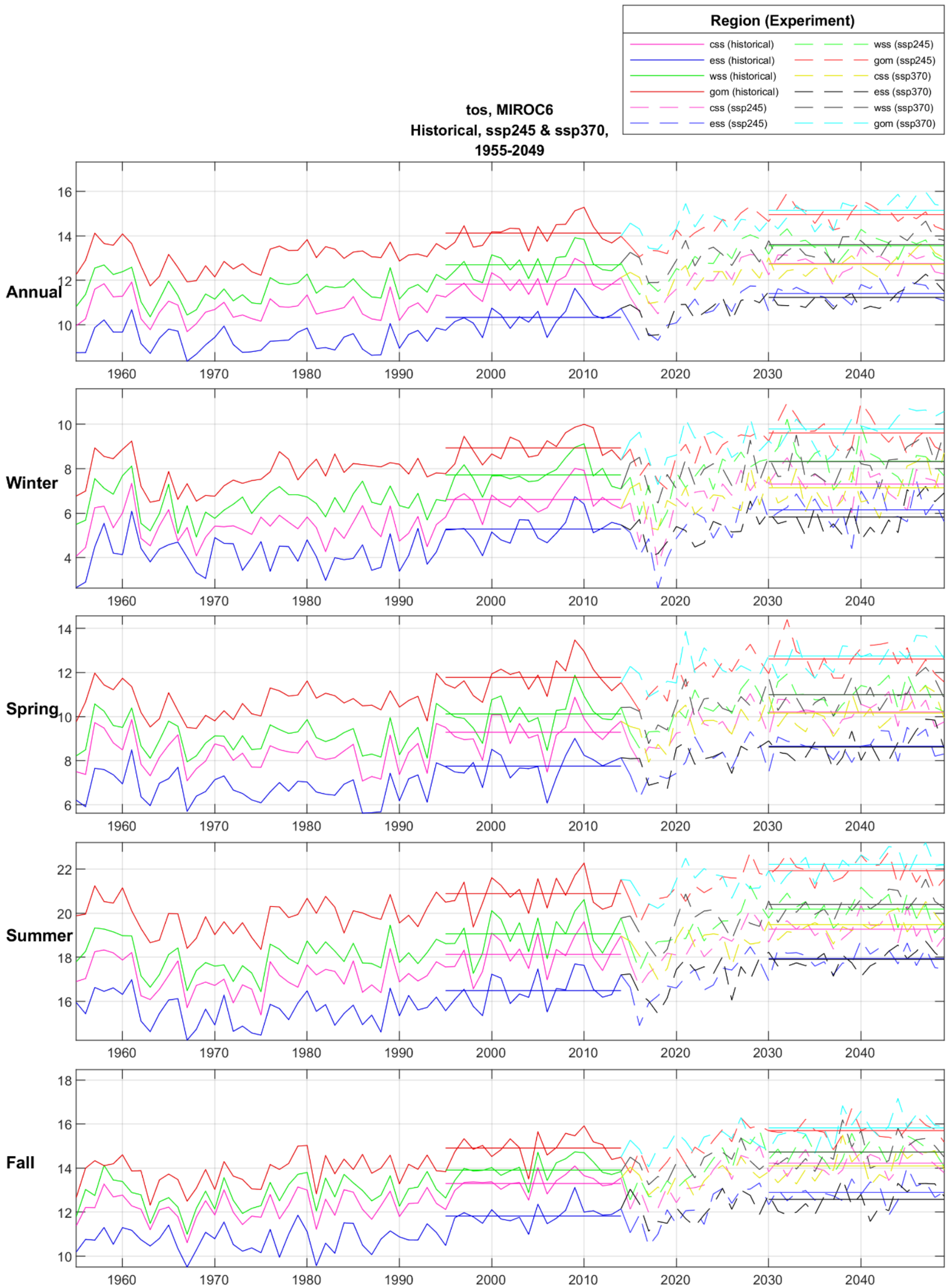


Figure 27. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: MIROC6. Units are degrees Celsius.

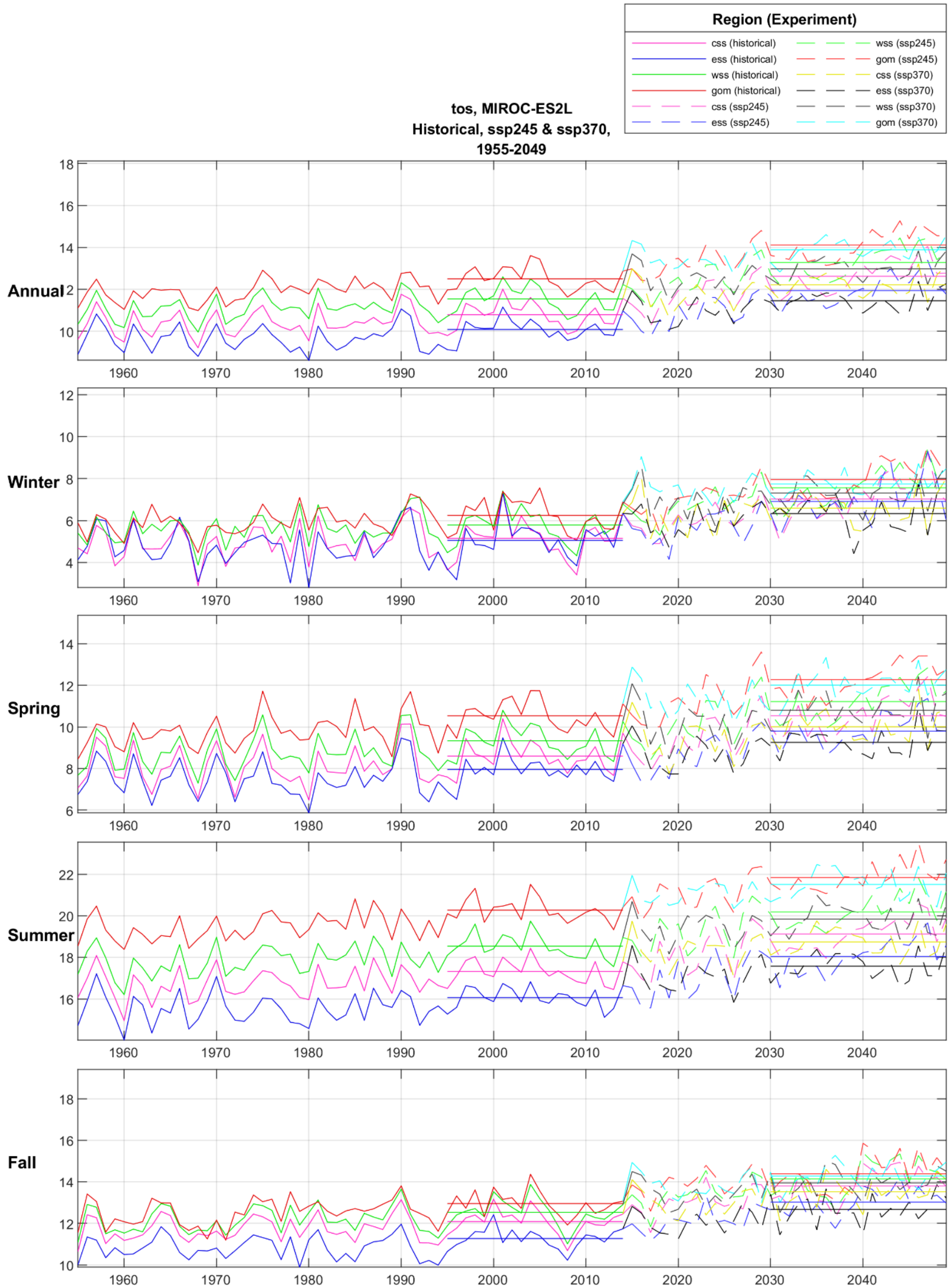


Figure 28. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: MIROC-ESL2. Units are degrees Celsius.

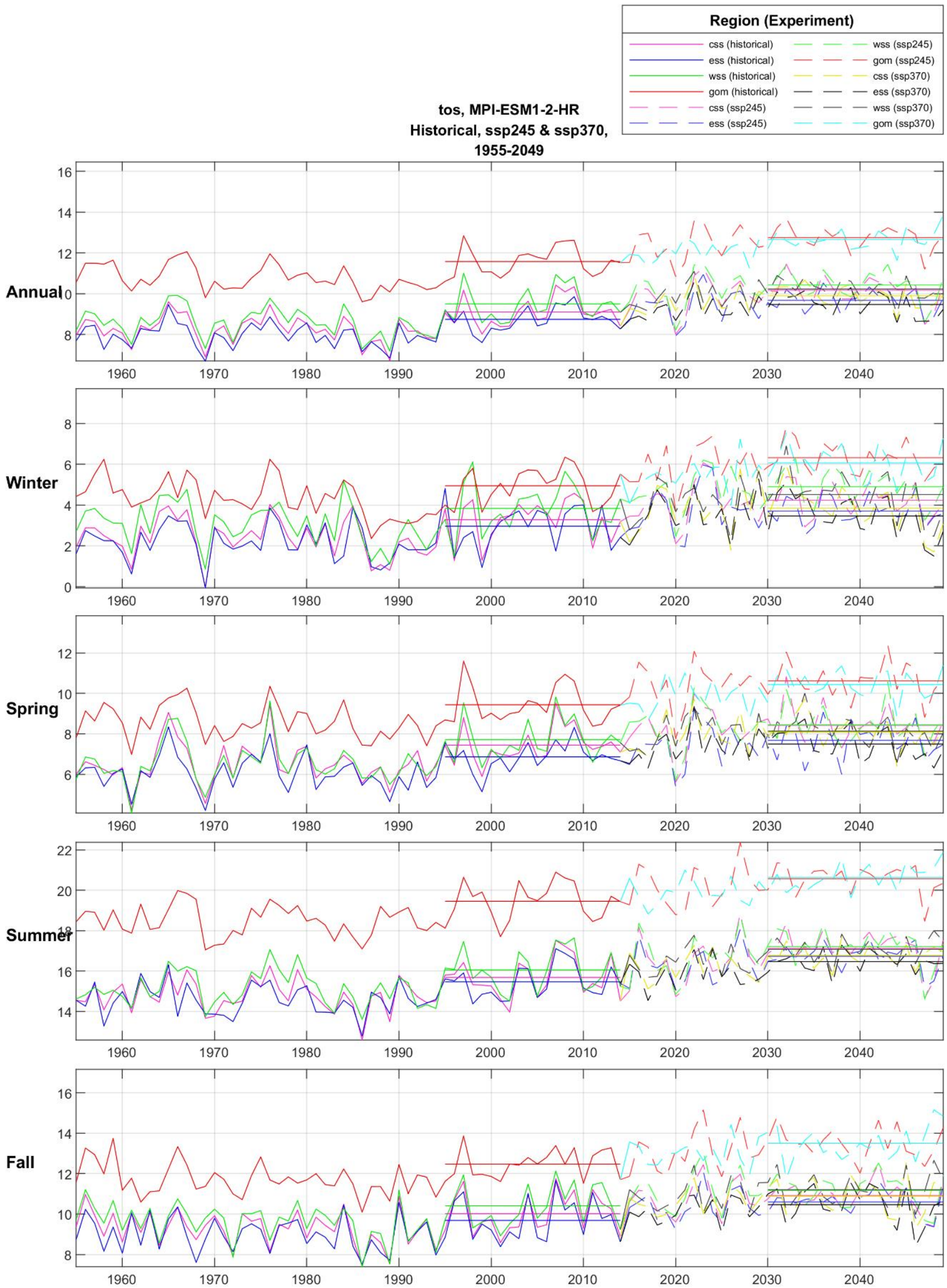


Figure 29. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: MPI-ESM1-2-HR. Units are degrees Celsius.

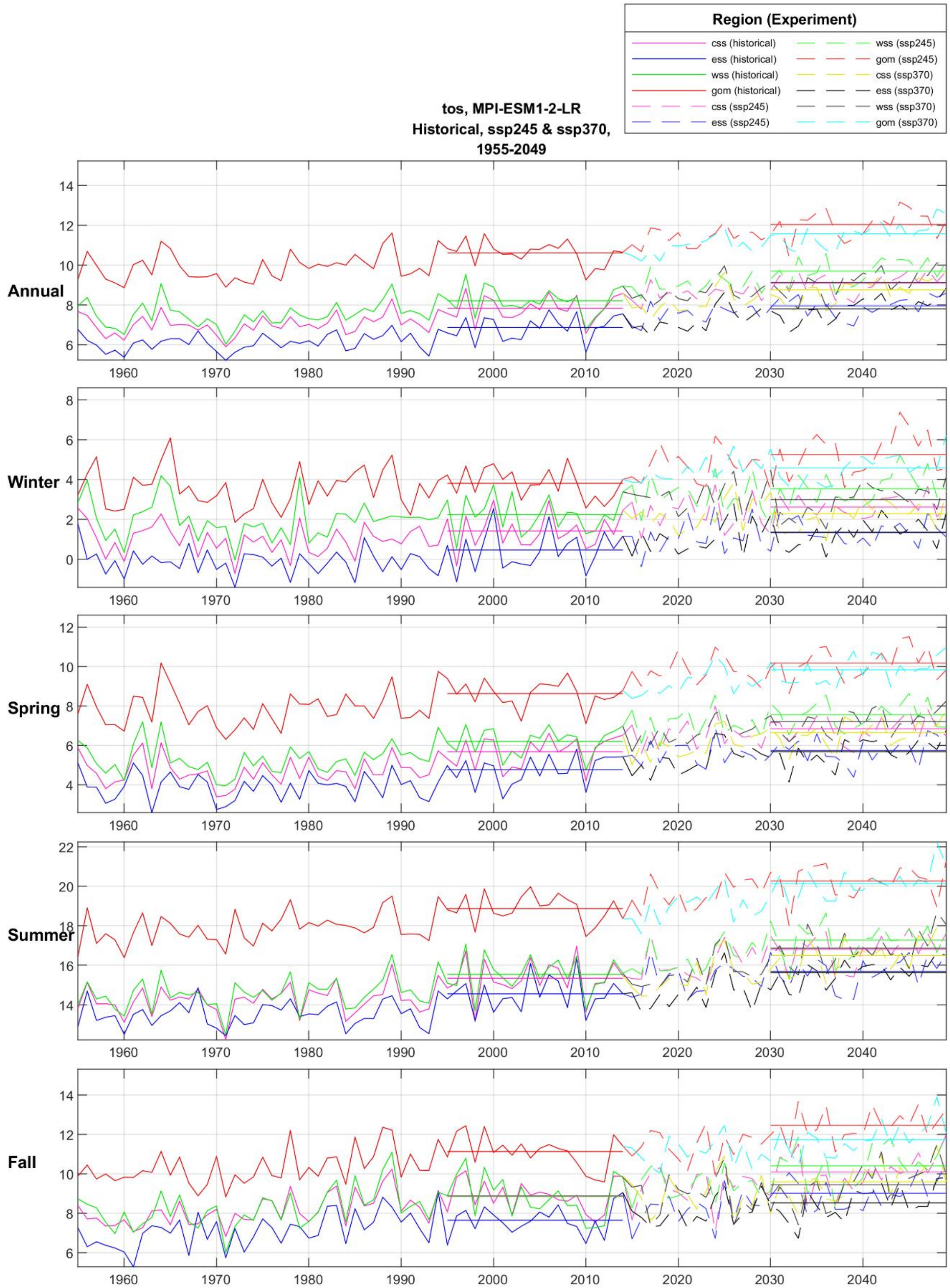


Figure 30. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: MPI-ESM1-2-LR. Units are degrees Celsius.

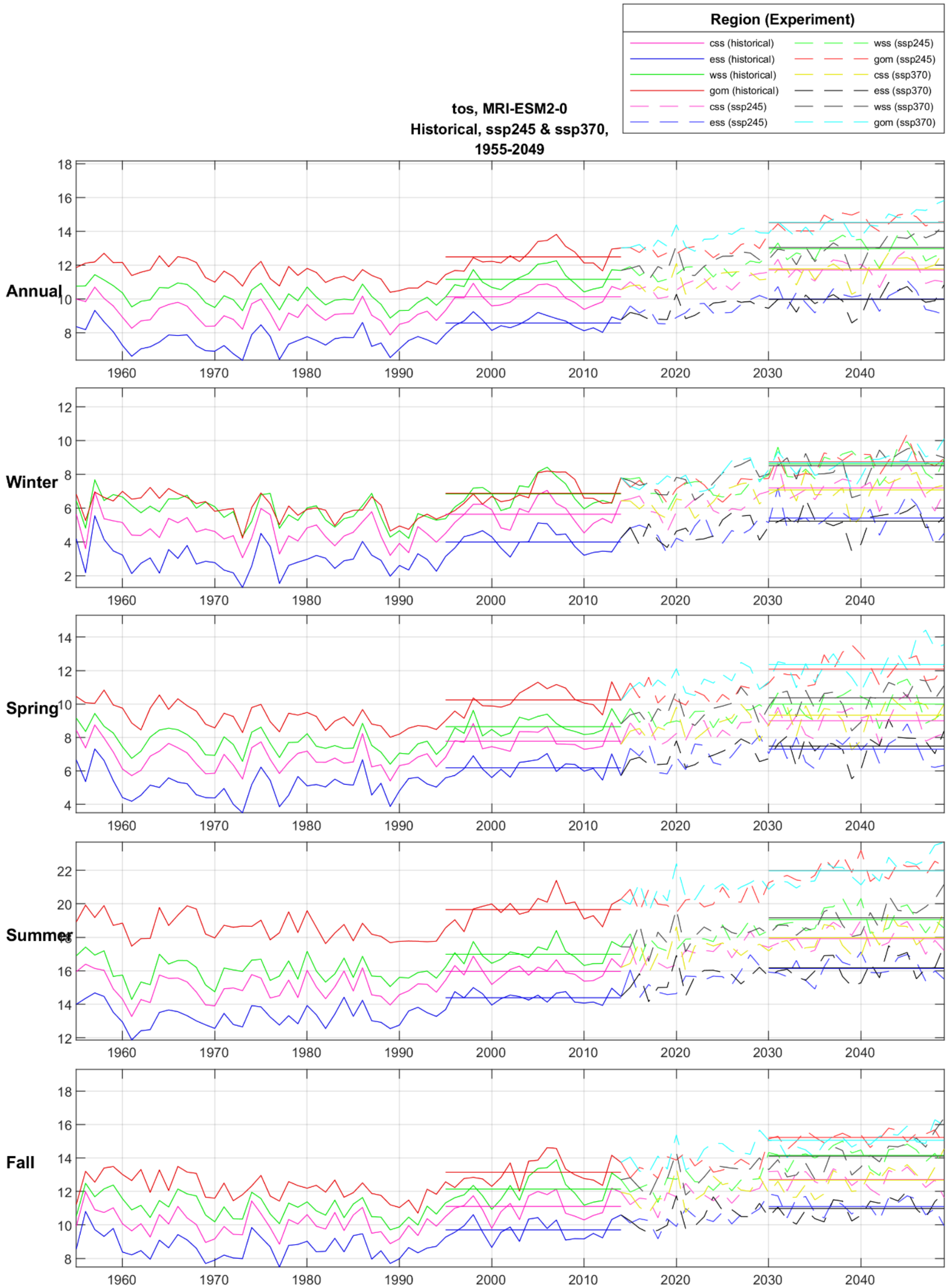


Figure 31. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: MRI-ESM2-0. Units are degrees Celsius.

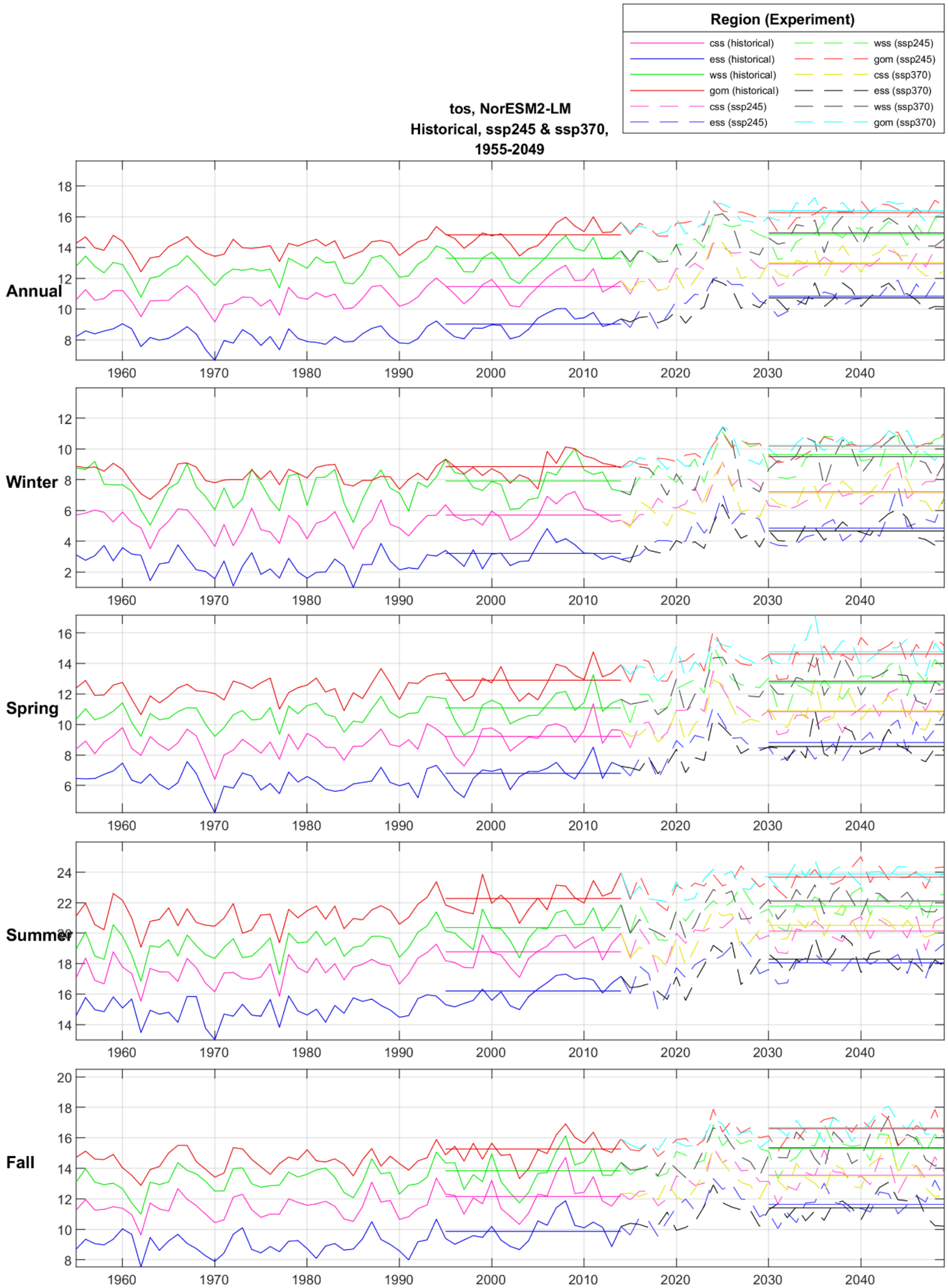


Figure 32. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: NorESM2-LM. Units are degrees Celsius.

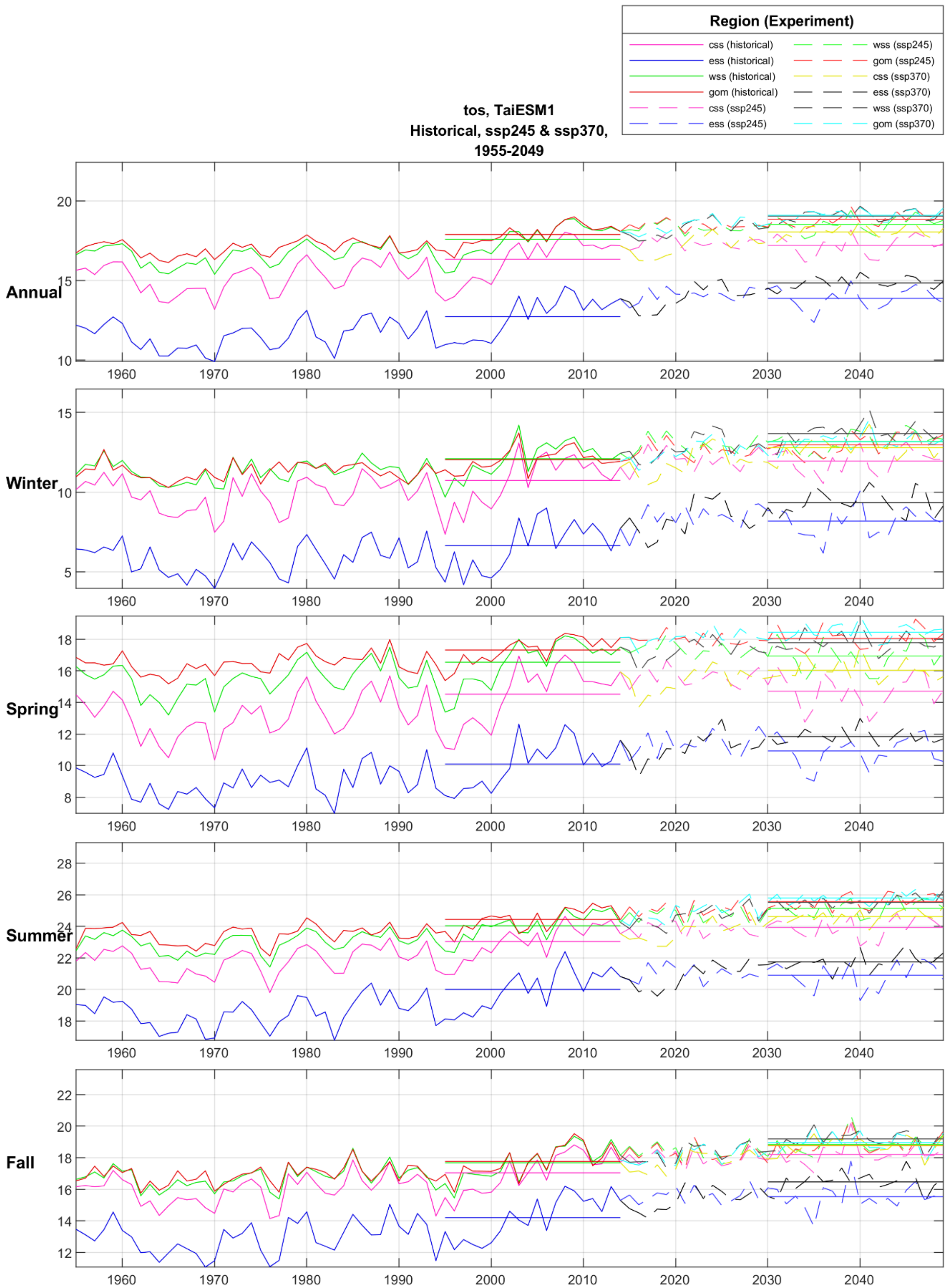


Figure 33. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: TaiESM1. Units are degrees Celsius.

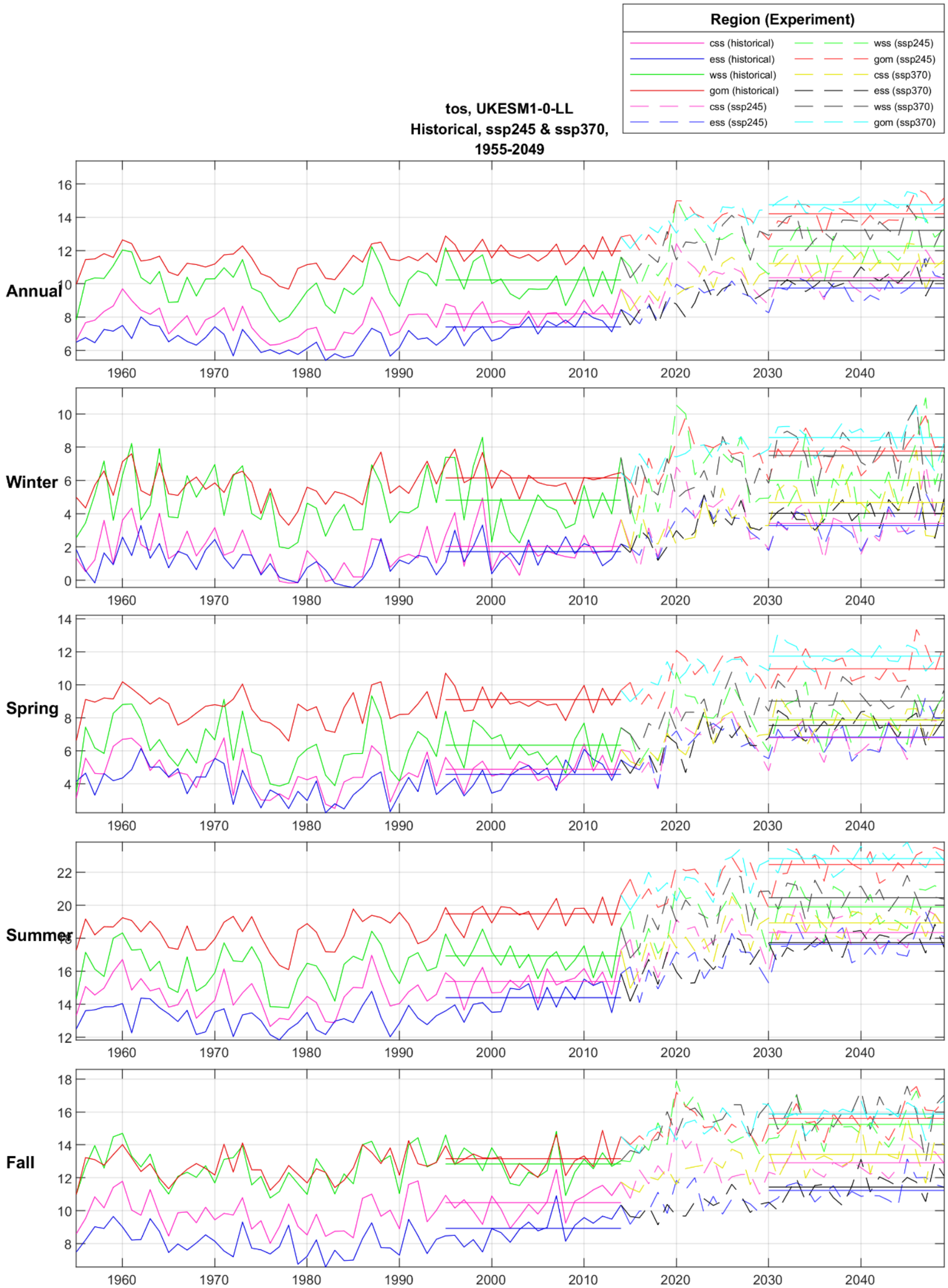


Figure 34. Annual and seasonal mean SST time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Model: UKESM1-0-LL. Units are degrees Celsius.

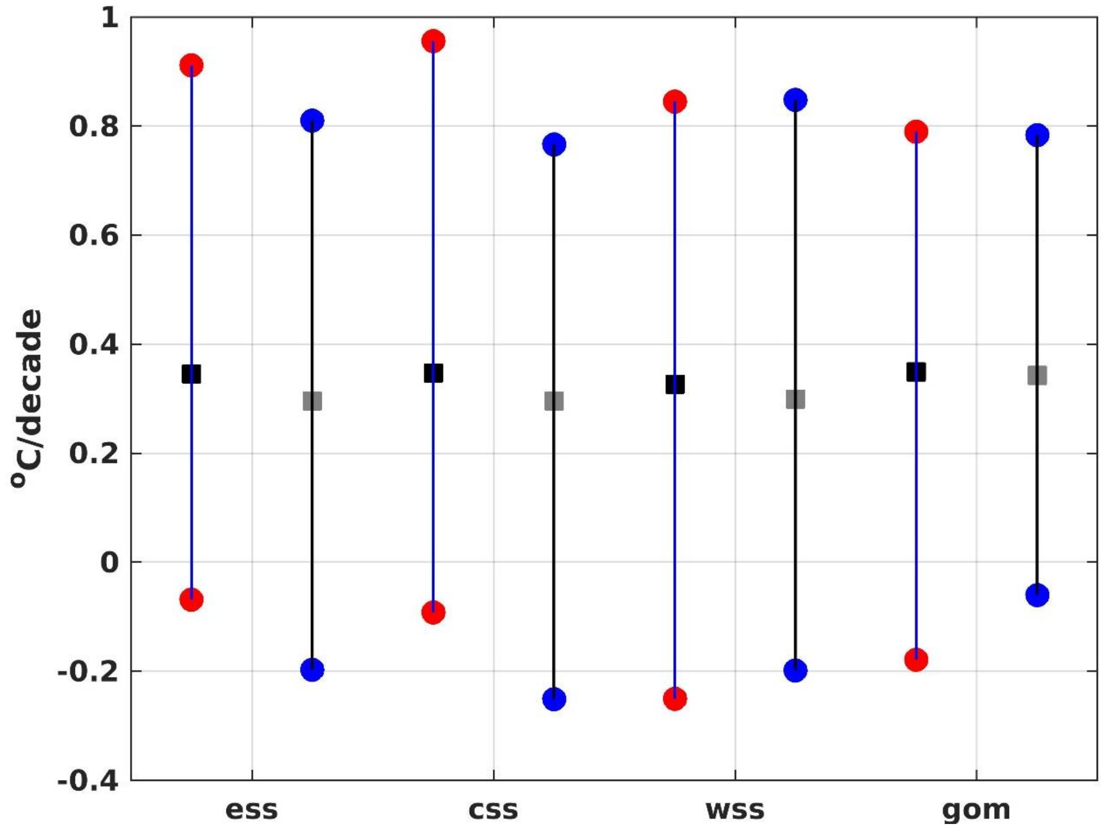


Figure 35. SST annual means: range and mean projected trend of all ESMs, all subareas. SSP245: Blue line with red circle at each end, circles indicate maximum and minimum trends from those models, and the black square is the averaged trend. SSP370: Black line with blue circle at each end, circles indicate maximum and minimum trends from all ESMs, and the grey square is the averaged trend.

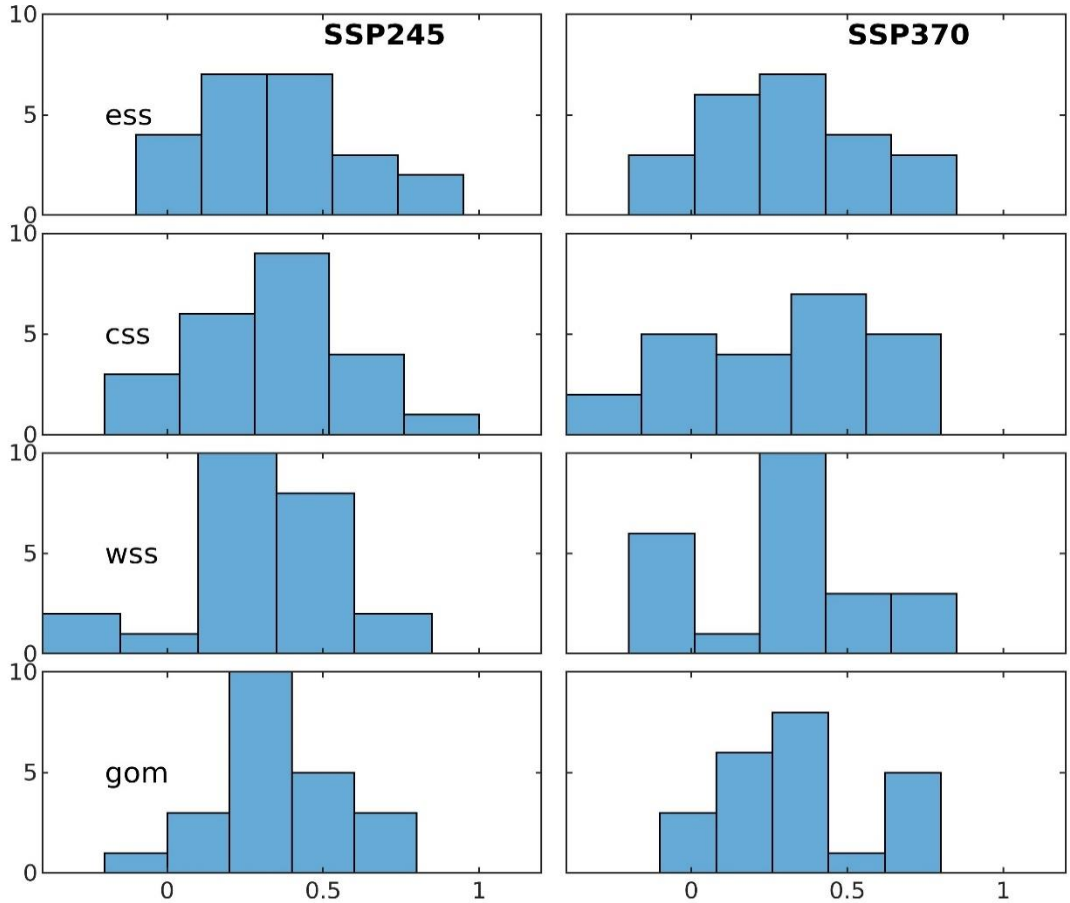


Figure 36. SST annual means: histograms of projected trends from all ESMs, each subarea, each SSP. Abscissa units are °C/decade.

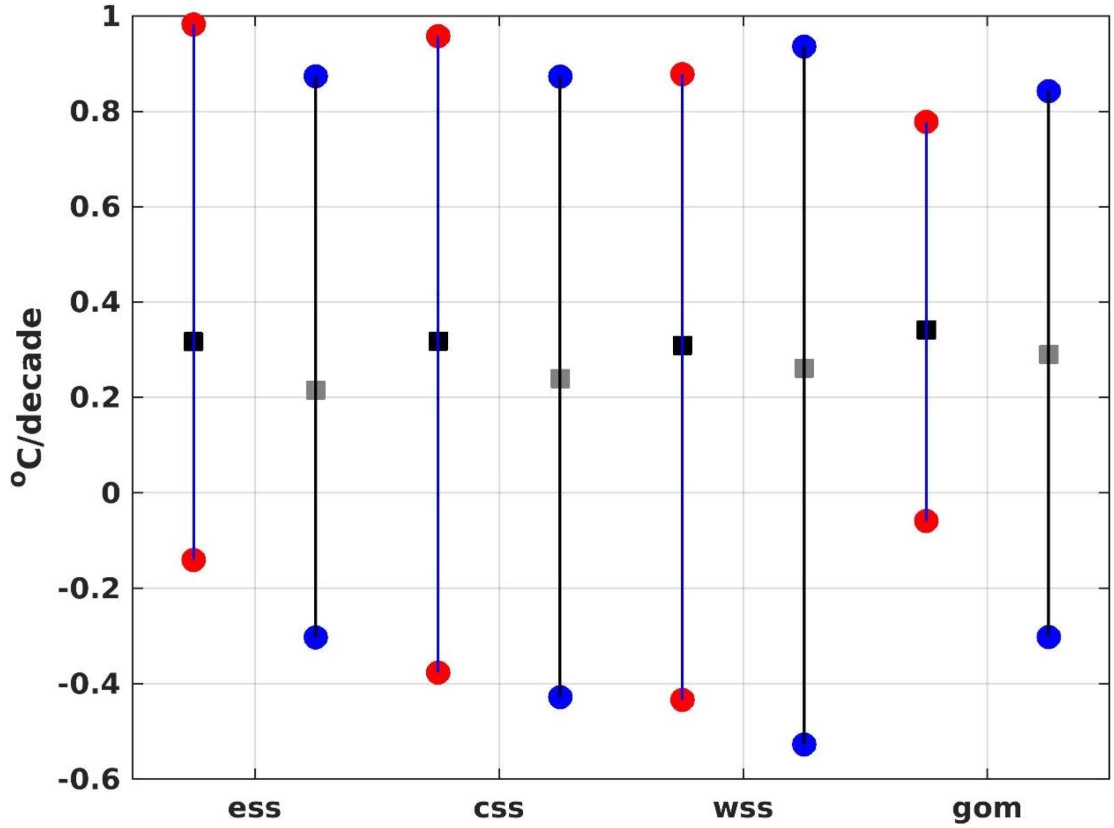


Figure 37. SST winter (JFM) means: range and mean projected trend of all ESMs, all subareas. SSP245: Blue line with red circle at each end, circles indicate maximum and minimum trends from those models, and the black square is the averaged trend. SSP370: Black line with blue circle at each end, circles indicate maximum and minimum trends from all ESMs, and the grey square is the averaged trend.

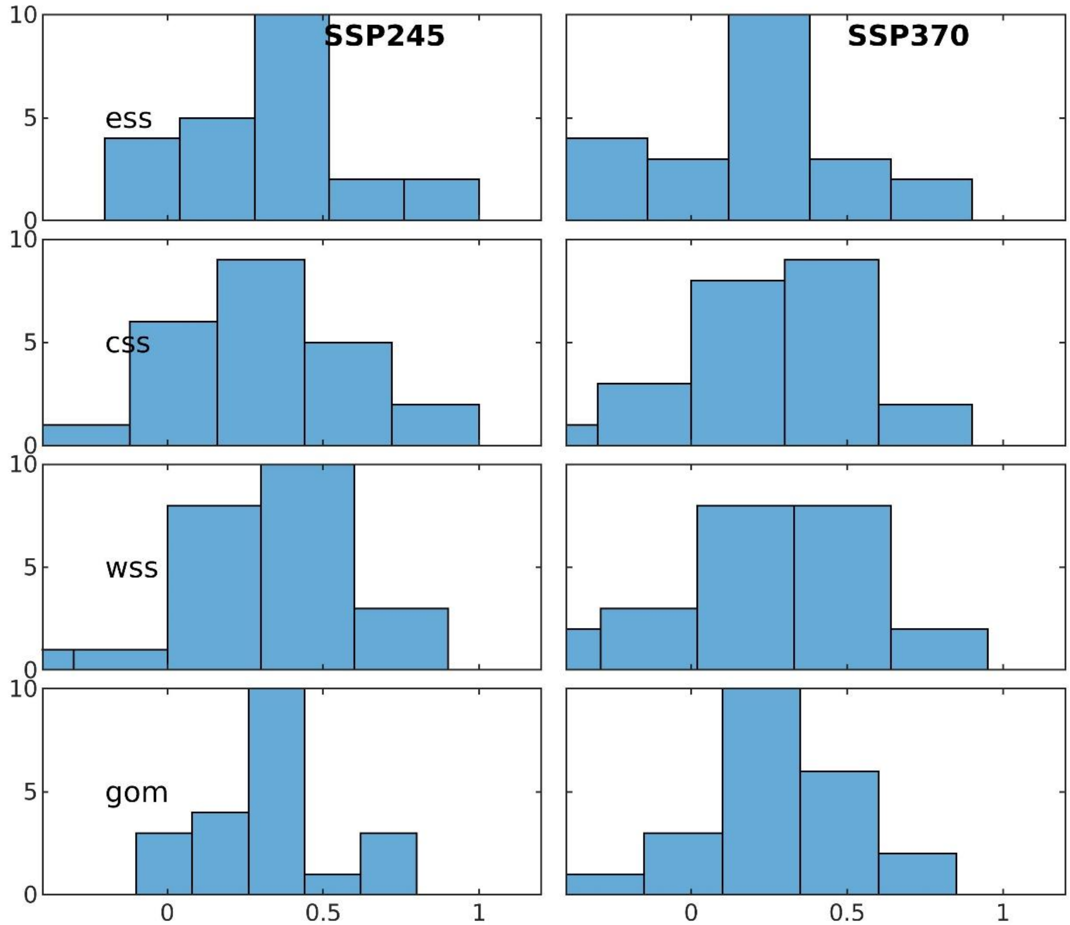


Figure 38. SST winter (JFM) means: histograms of projected trends from all ESMs, each subarea, each SSP. Abscissa units are °C/decade.

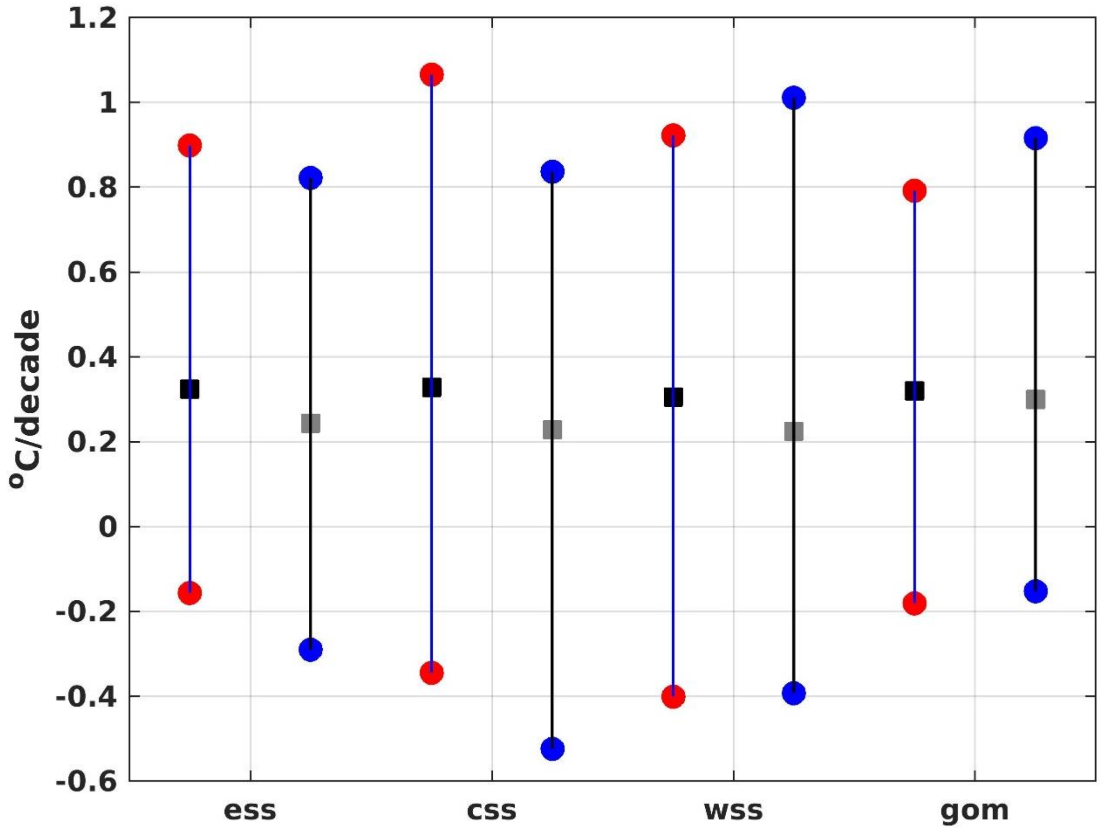


Figure 39. SST spring (AMJ) means: range and mean projected trend of all ESMs, all subareas. SSP245: Blue line with red circle at each end, circles indicate maximum and minimum trends from those models, and the black square is the averaged trend. SSP370: Black line with blue circle at each end, circles indicate maximum and minimum trends from all ESMs, and the grey square is the averaged trend.

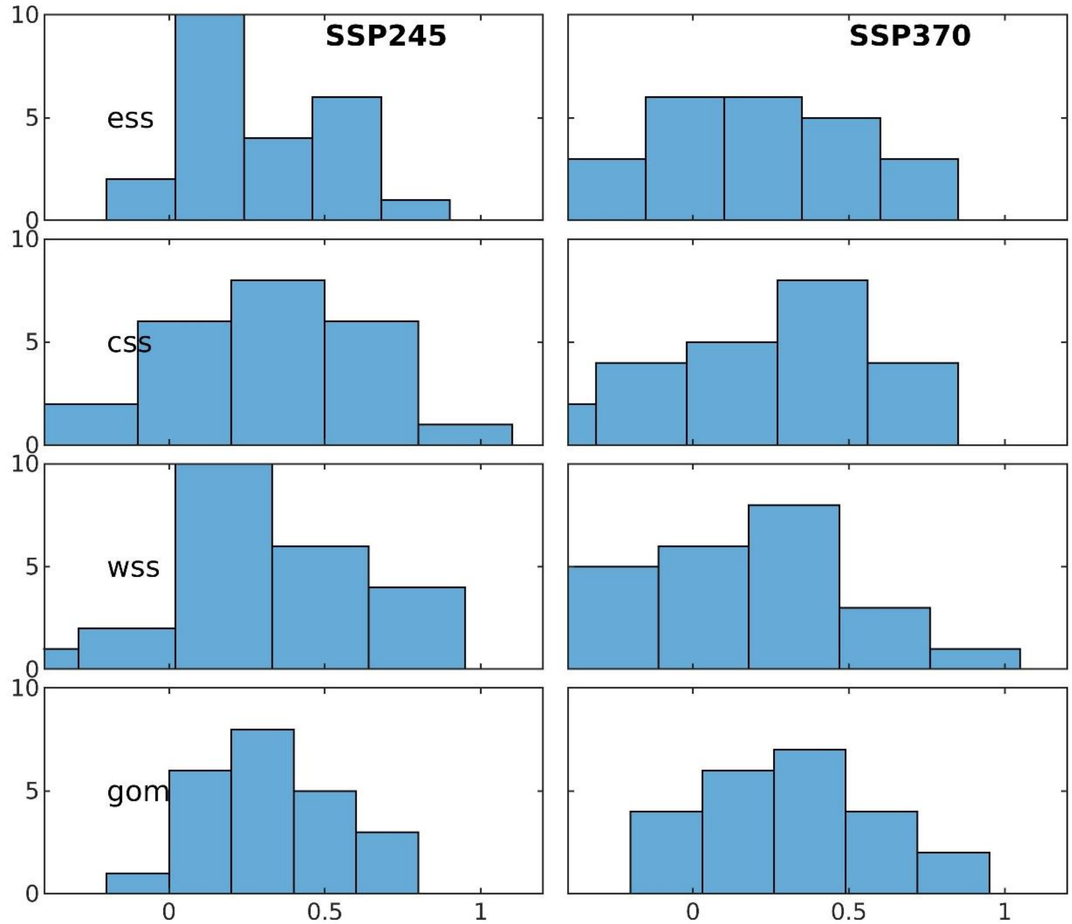


Figure 40. SST spring (AMJ) means: histograms of projected trends from all ESMs, each subarea, each SSP. Abscissa units are °C/decade.

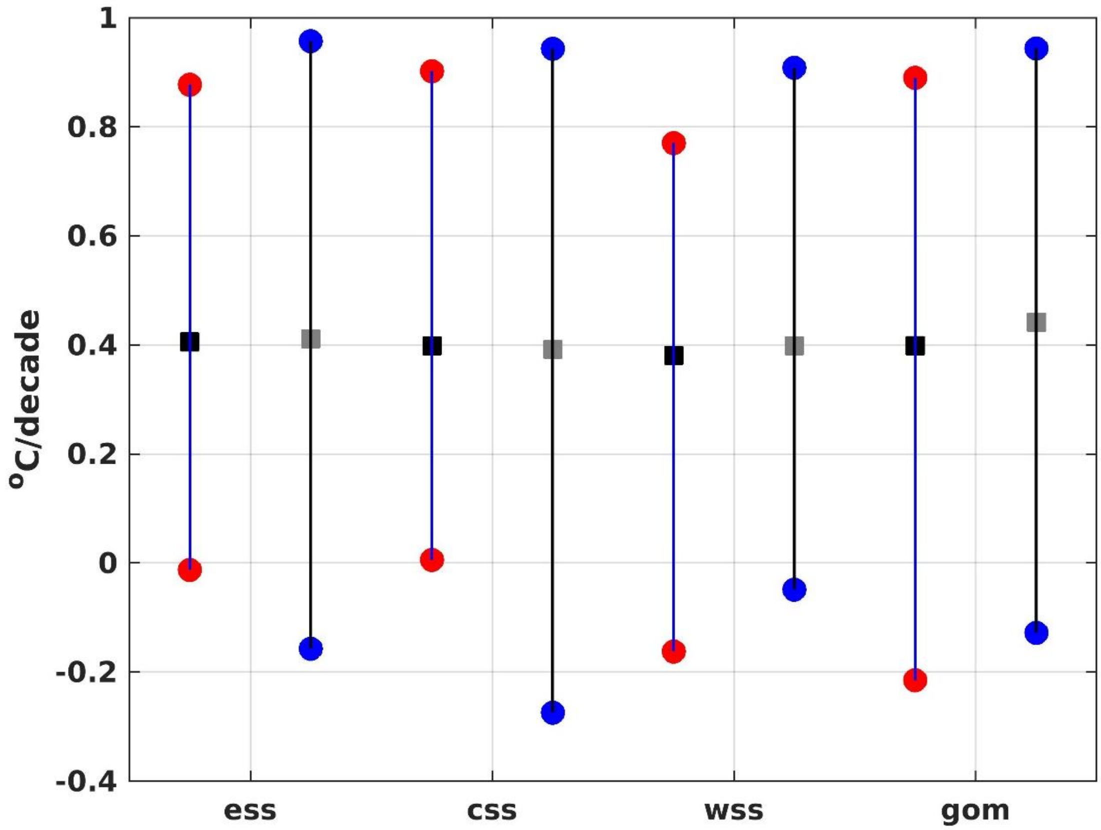


Figure 41. SST summer (JAS) means: range and mean projected trend of all ESMs, all subareas. SSP245: Blue line with red circle at each end, circles indicate maximum and minimum trends from those models, and the black square is the averaged trend. SSP370: Black line with blue circle at each end, circles indicate maximum and minimum trends from all ESMs, and the grey square is the averaged trend.

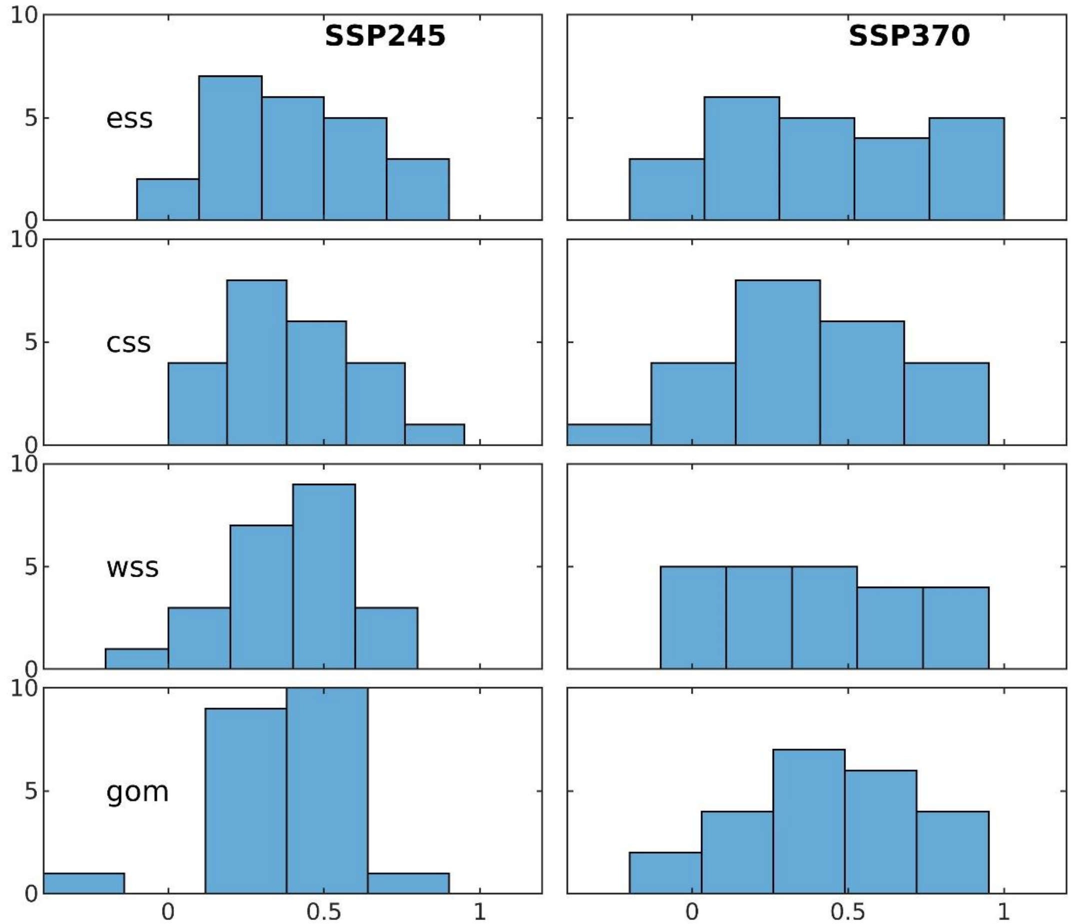


Figure 42. SST summer (JAS) means: histograms of projected trends from all ESMs, each subarea, each SSP. Abscissa units are °C/decade.

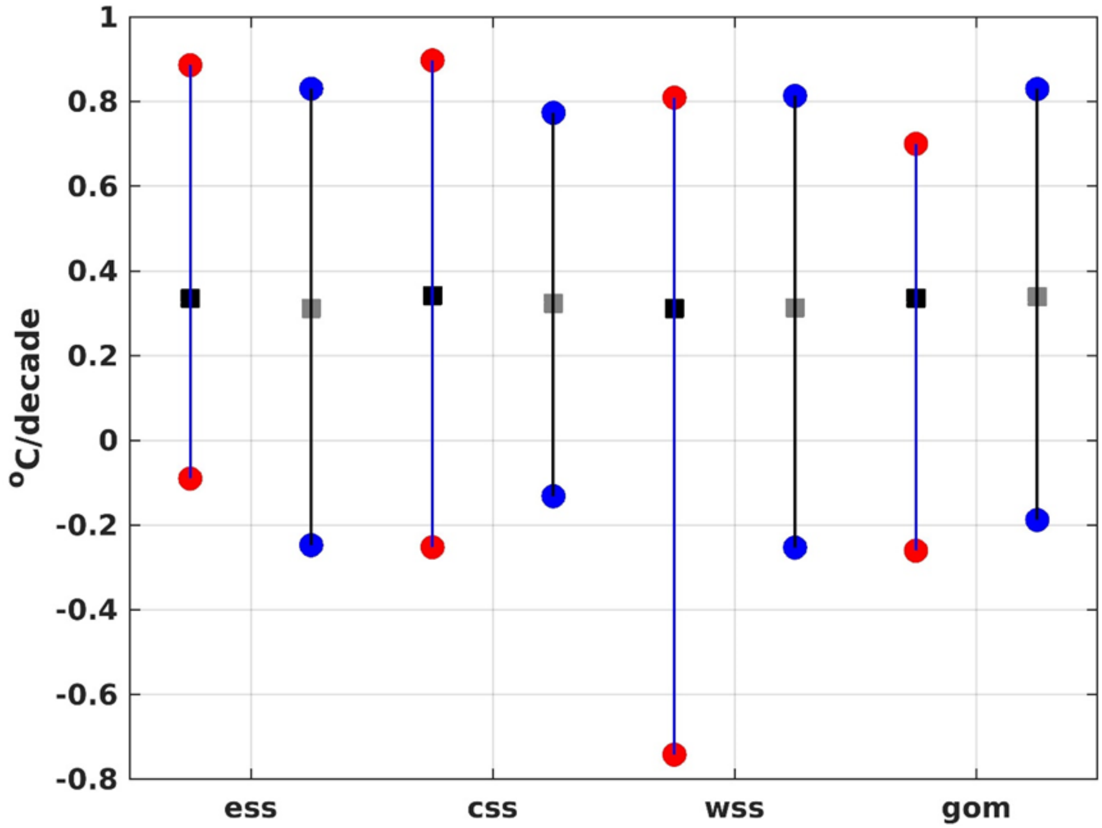


Figure 43. SST fall (OND) means: range and mean projected trend of all ESMs, all subareas. SSP245: Blue line with red circle at each end, circles indicate maximum and minimum trends from those models, and the black square is the averaged trend. SSP370: Black line with blue circle at each end, circles indicate maximum and minimum trends from all ESMs, and the grey square is the averaged trend.

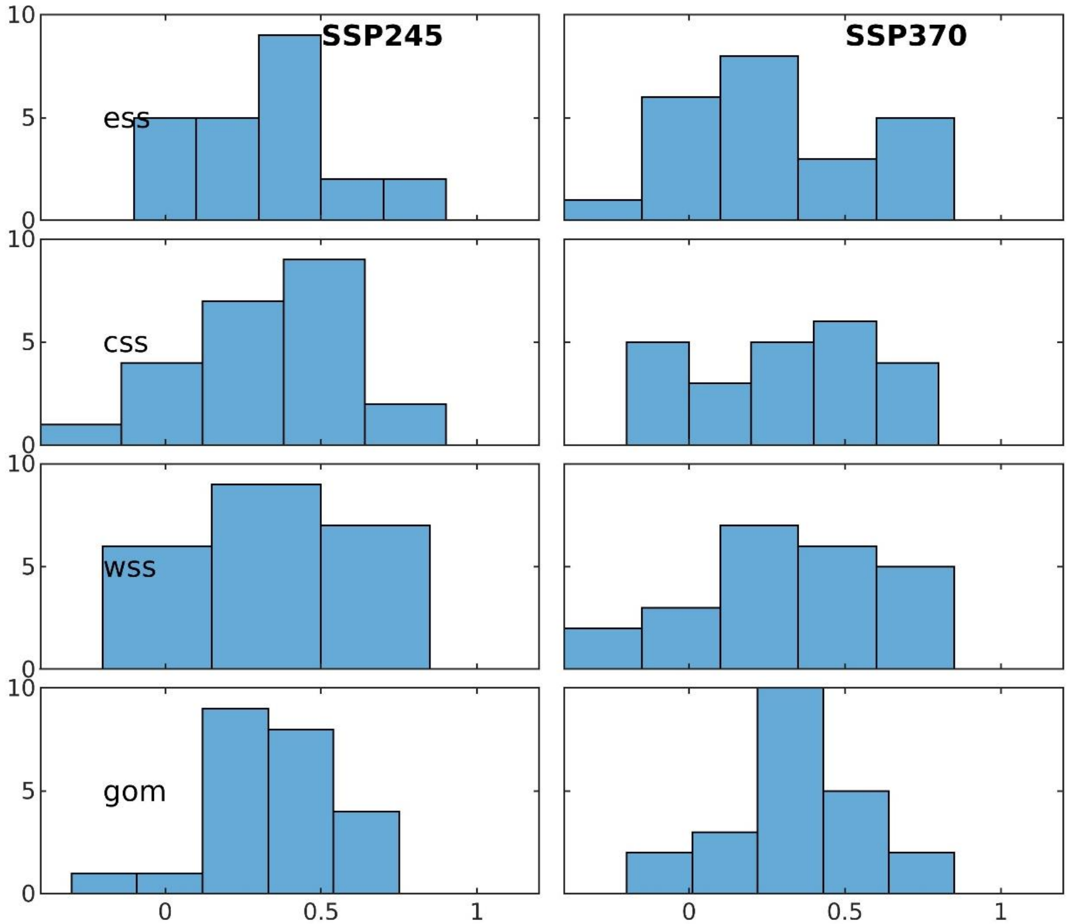
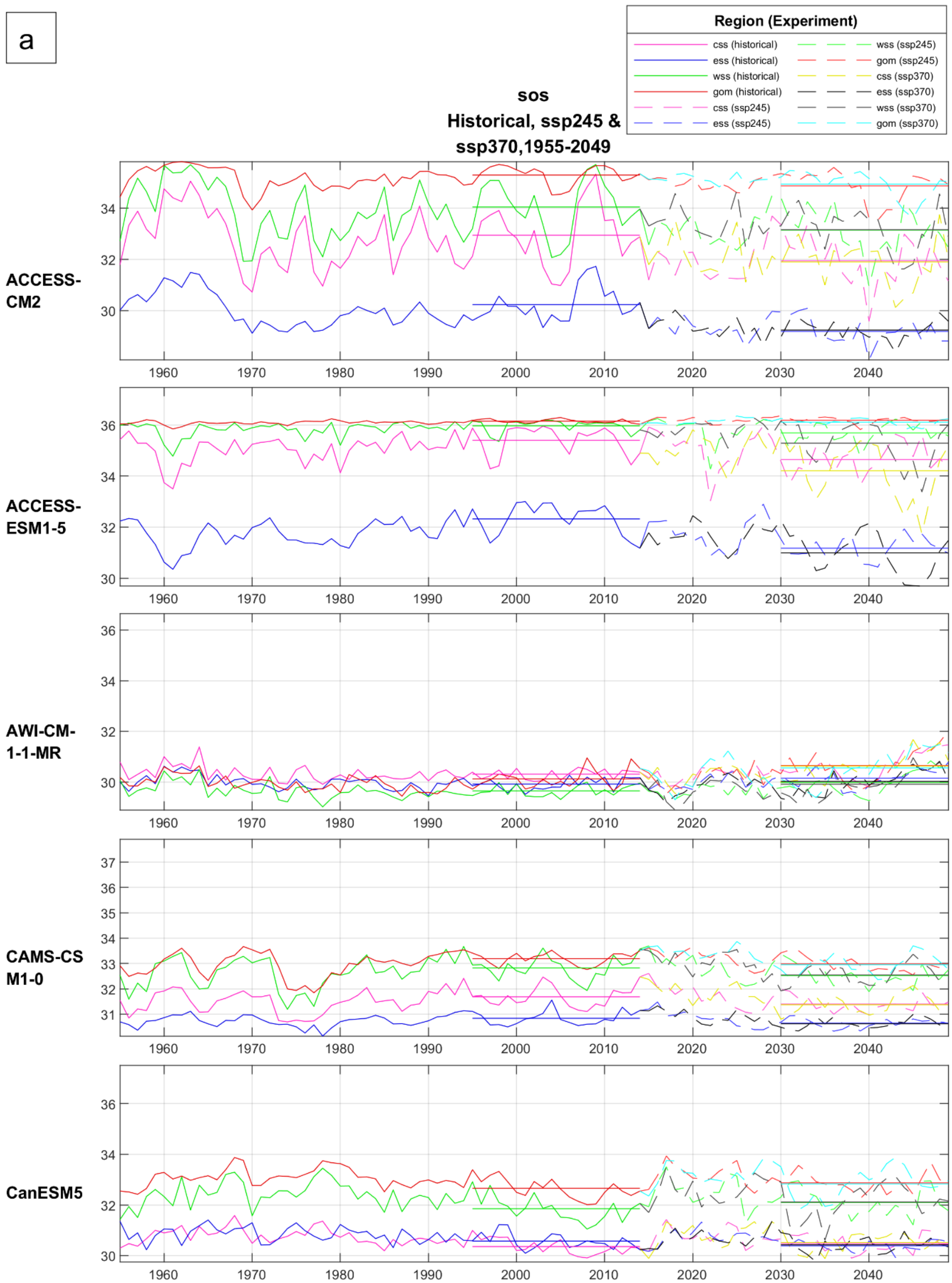


Figure 44. SST fall (OND) means: histograms of projected trends from all ESMs, each subarea, each SSP. Abscissa units are °C/decade.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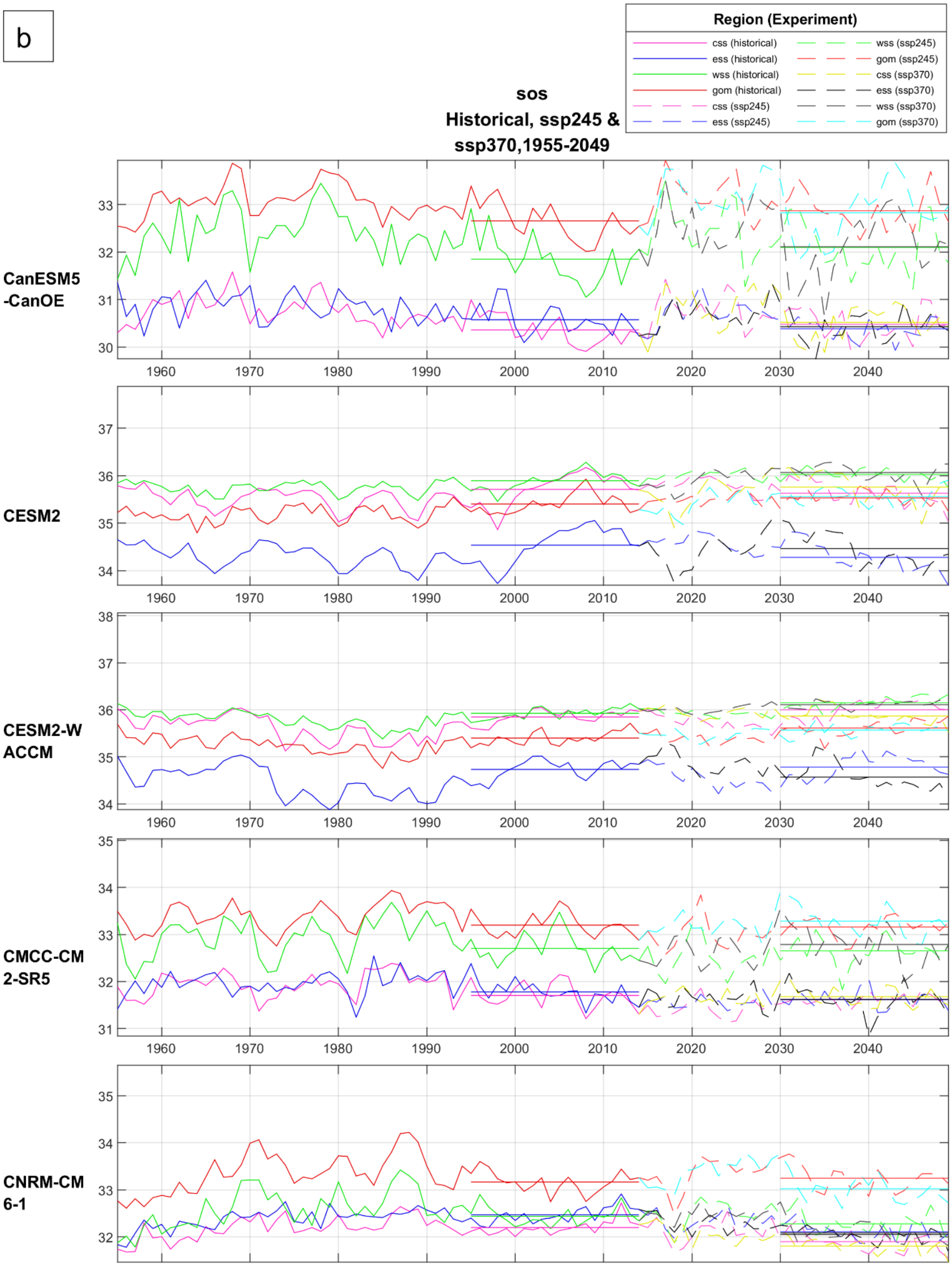
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Historical, ssp245 & ssp370,1955-2049
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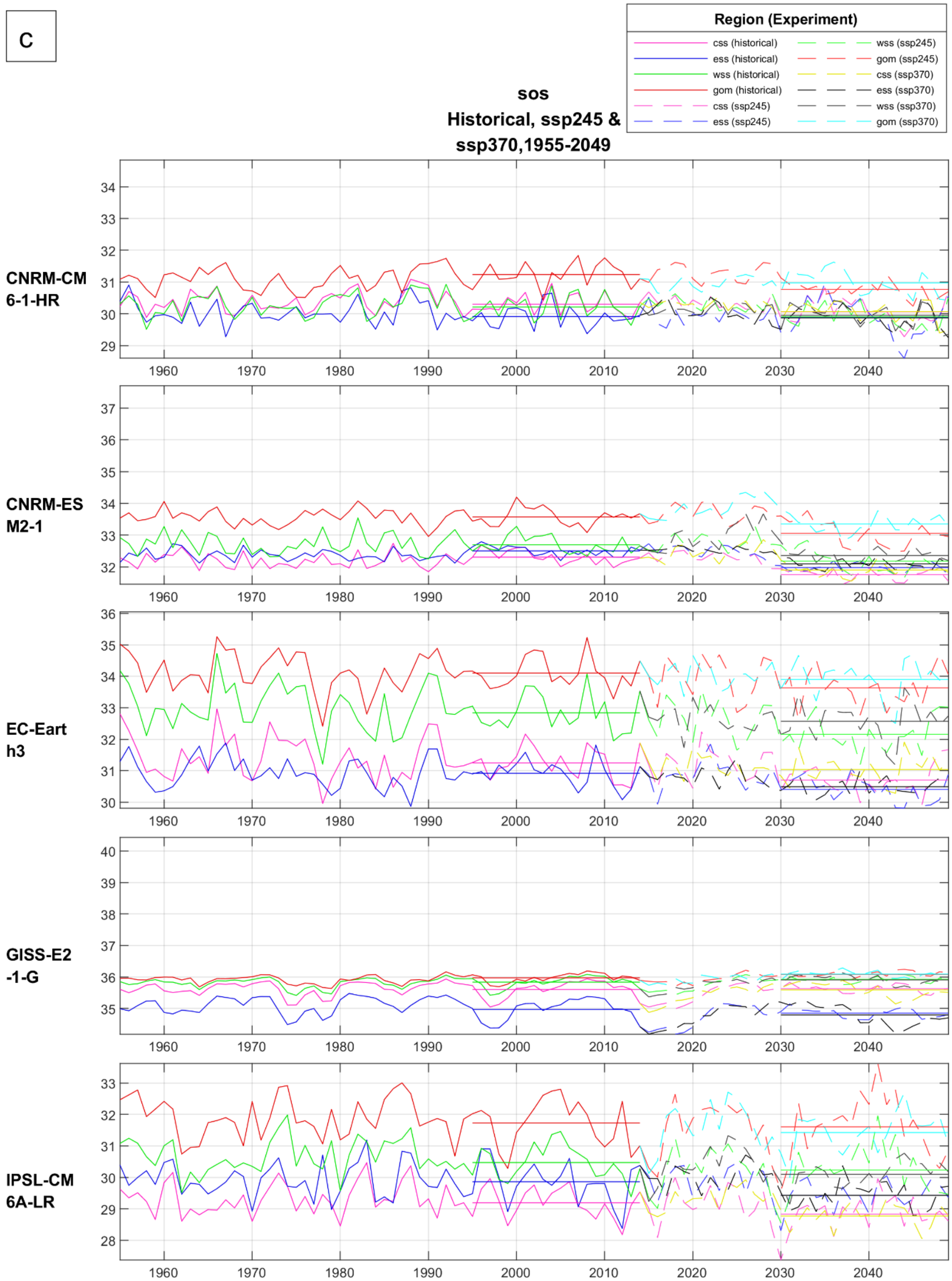

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Historical, ssp245 & ssp370,1955-2049
CNRM-CM 6-1-HR
CNRM-ES M2-1
EC-Earth3
GISS-E2-1-G
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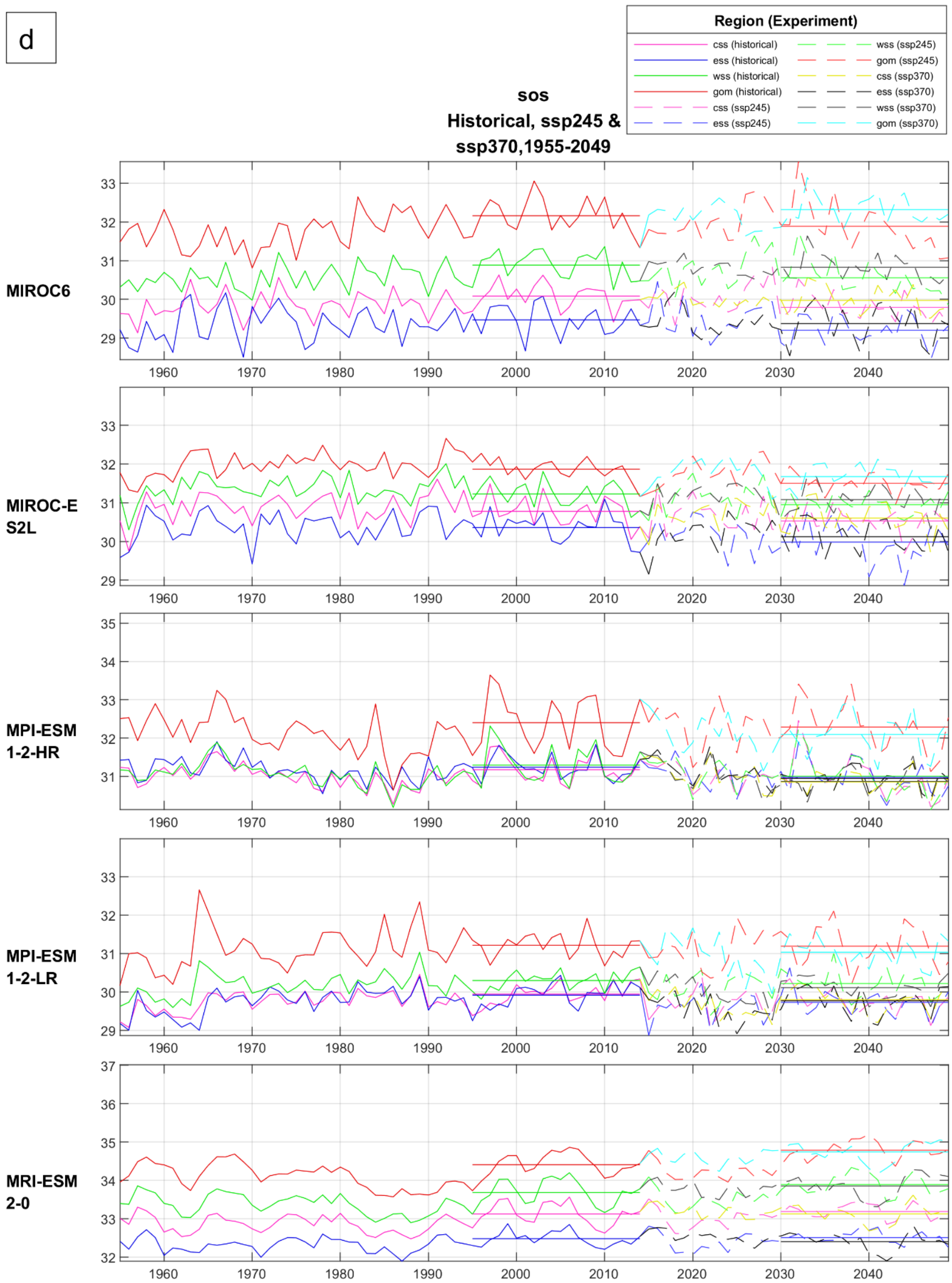
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Historical, ssp245 & ssp370,1955-2049
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MRI-ESM 2-0
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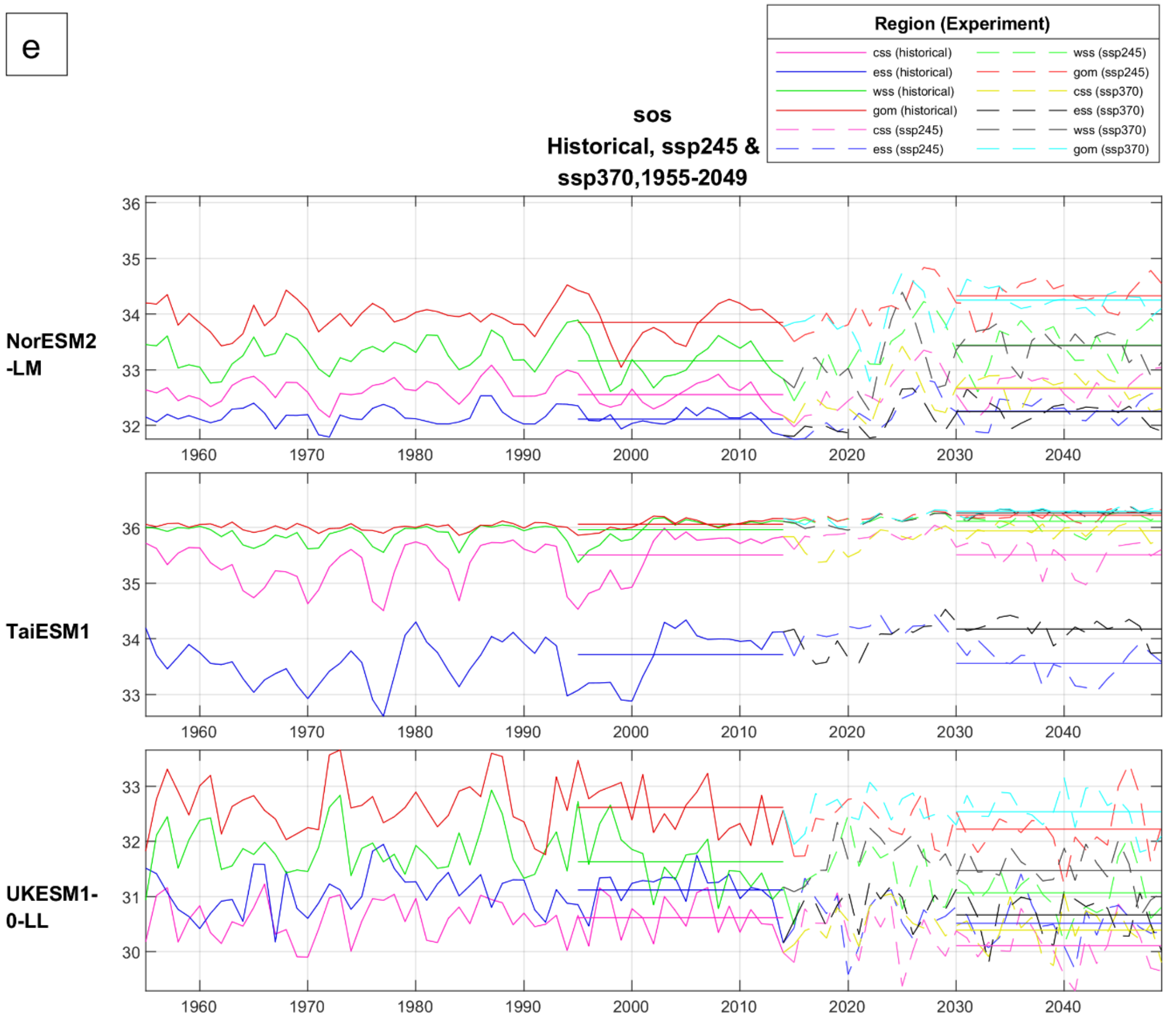


Figure 45 (a-e). Annual mean SSS time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Units are PSU.

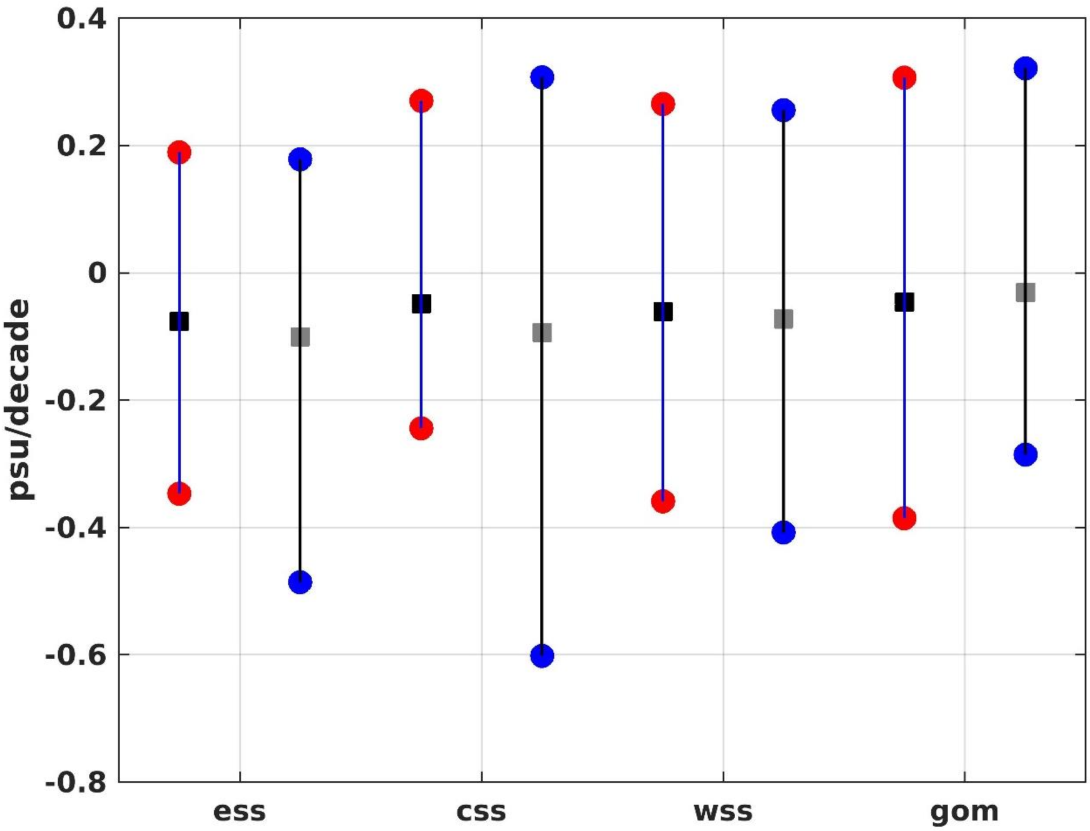


Figure 46. SSS annual means: range and mean projected trend of all ESMs, all subareas. SSP245: Blue line with red circle at each end, circles indicate maximum and minimum trends from those models, and the black square is the averaged trend. SSP370: Black line with blue circle at each end, circles indicate maximum and minimum trends from all ESMs, and the grey square is the averaged trend.

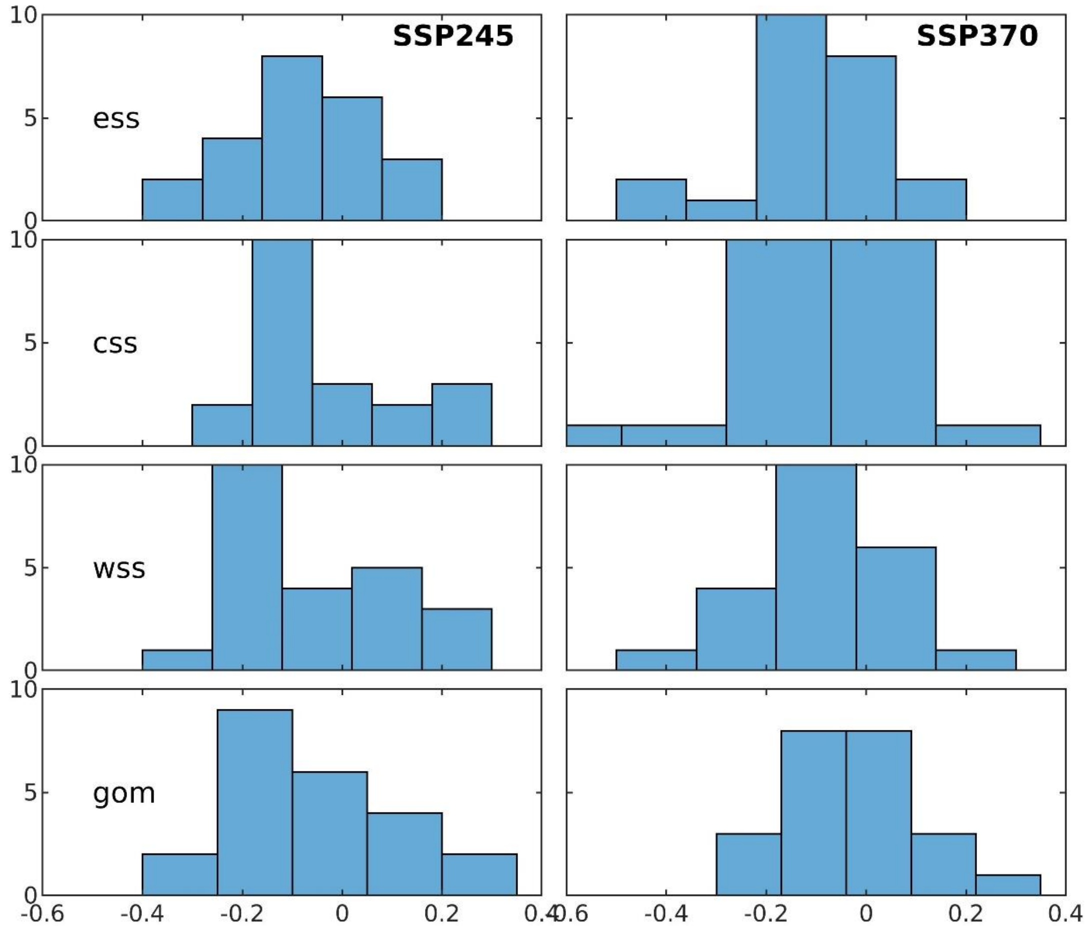
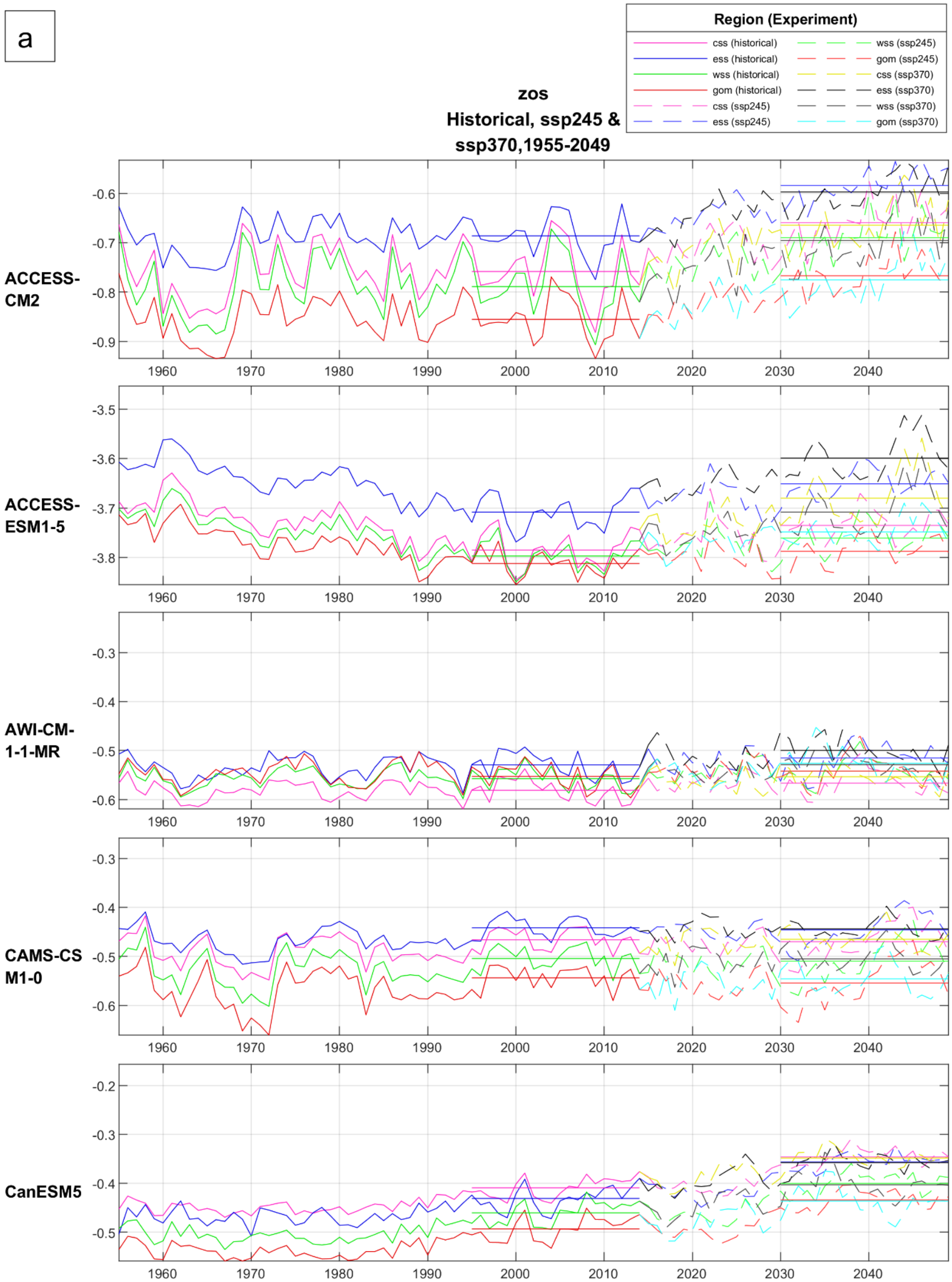


Figure 47. SSS annual means: histograms of projected trends from all ESMs, each subarea, each SSP. Abscissa units are PSU/decade.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Historical, ssp245 &
ssp370,1955-2049
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ACCESS-CM2
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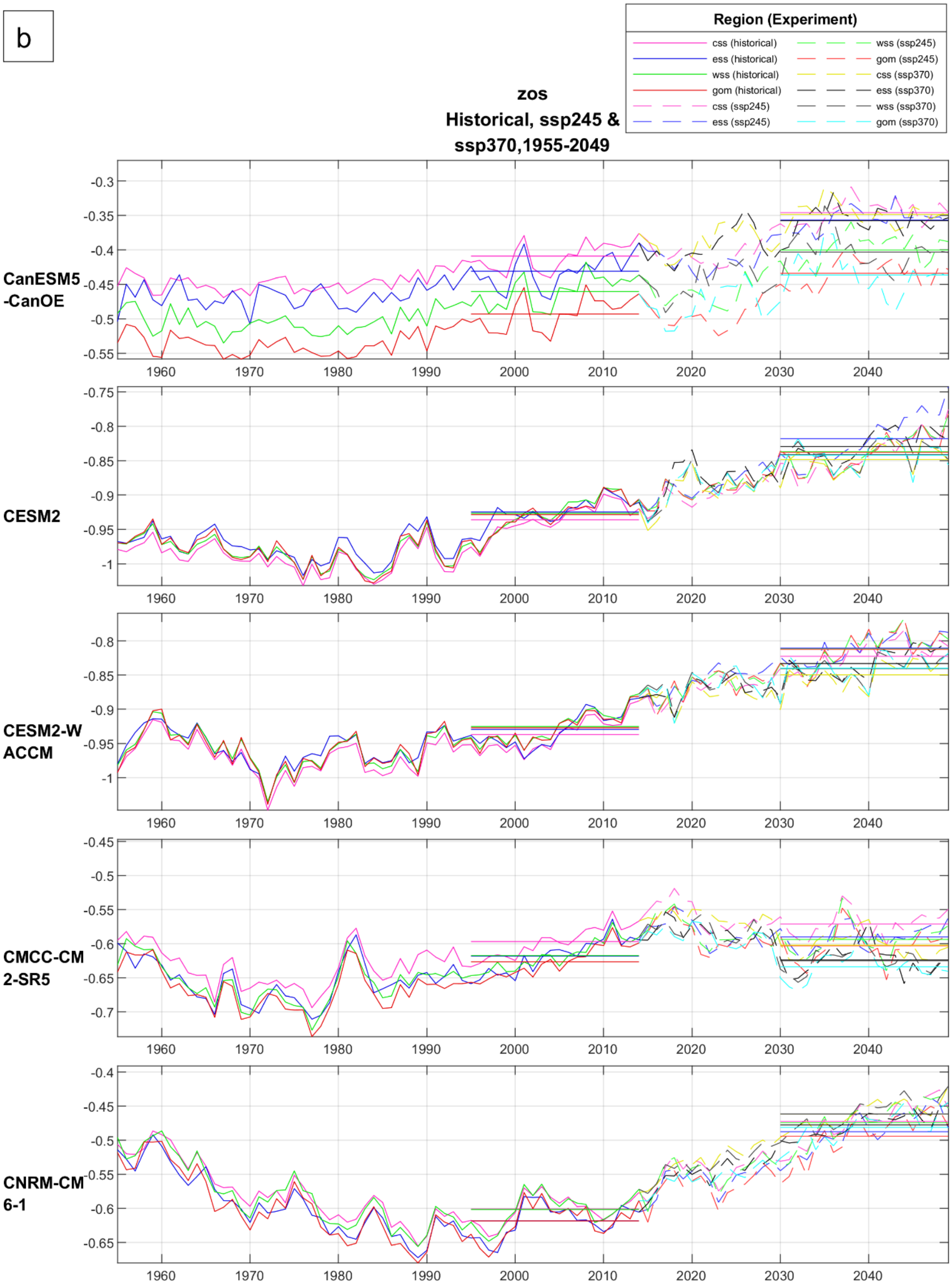
AWI-CM-1-1-MR
CAMS-CSM1-0
CanESM5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Historical, ssp245 & ssp370,1955-2049
CanESM5-CanOE
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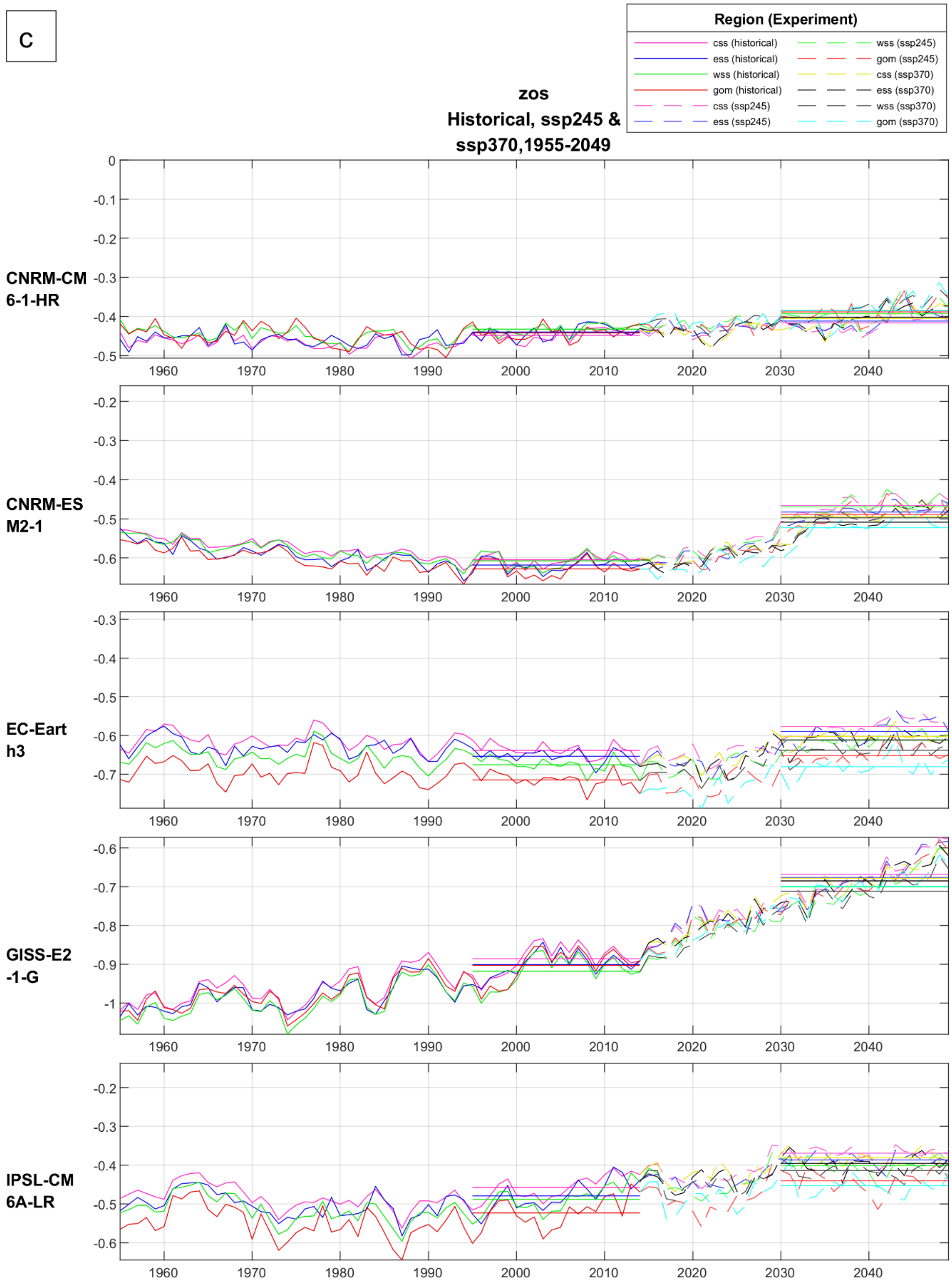

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Historical, ssp245 & ssp370,1955-2049
CNRM-CM 6-1-HR
CNRM-ES M2-1
EC-Earth3
GISS-E2-1-G
IPSL-CM 6A-LR
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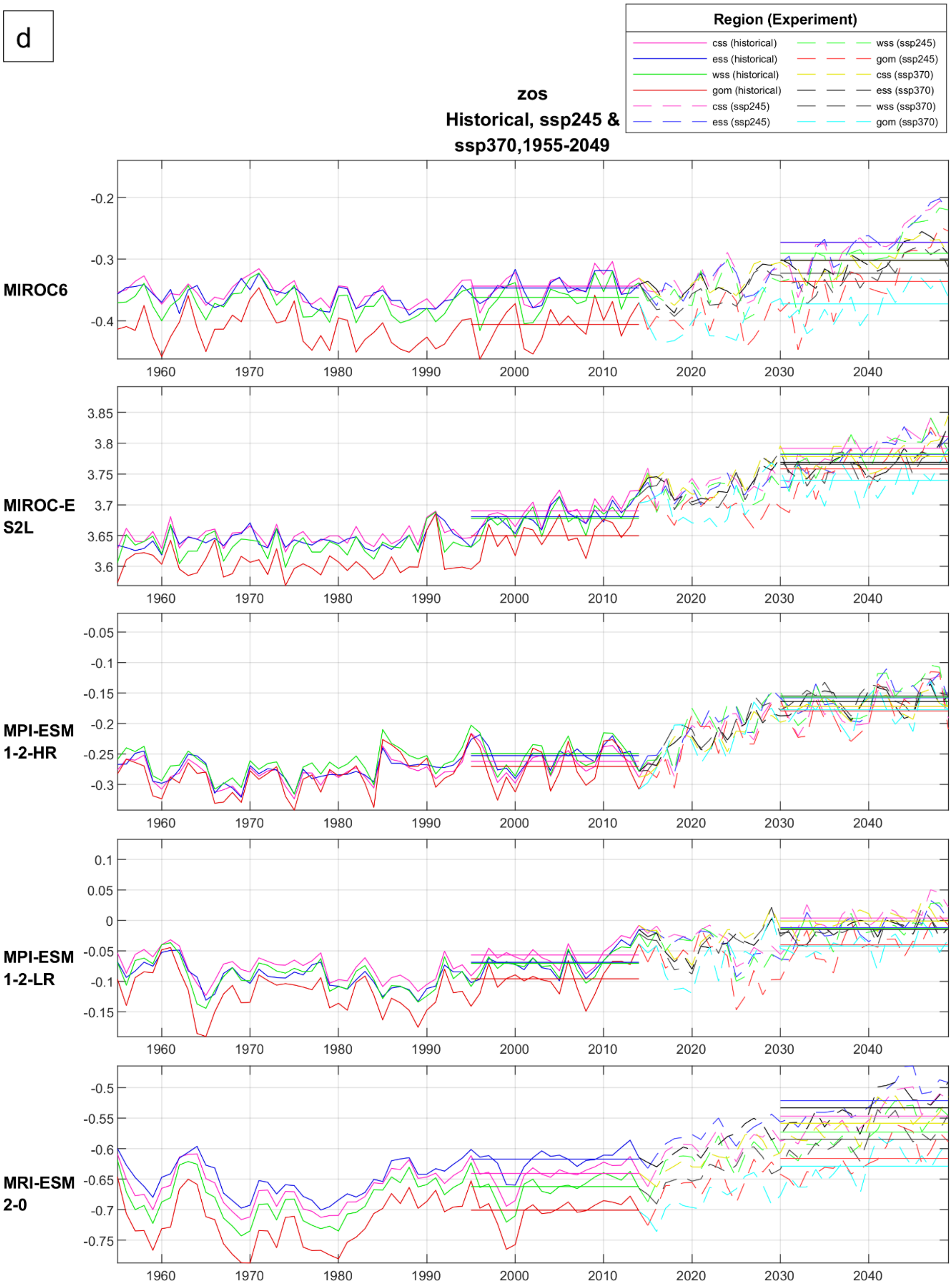
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Historical, ssp245 & ssp370,1955-2049
MIROC6
MIROC-ES2L
MPI-ESM 1-2-HR
MPI-ESM 1-2-LR
MRI-ESM 2-0
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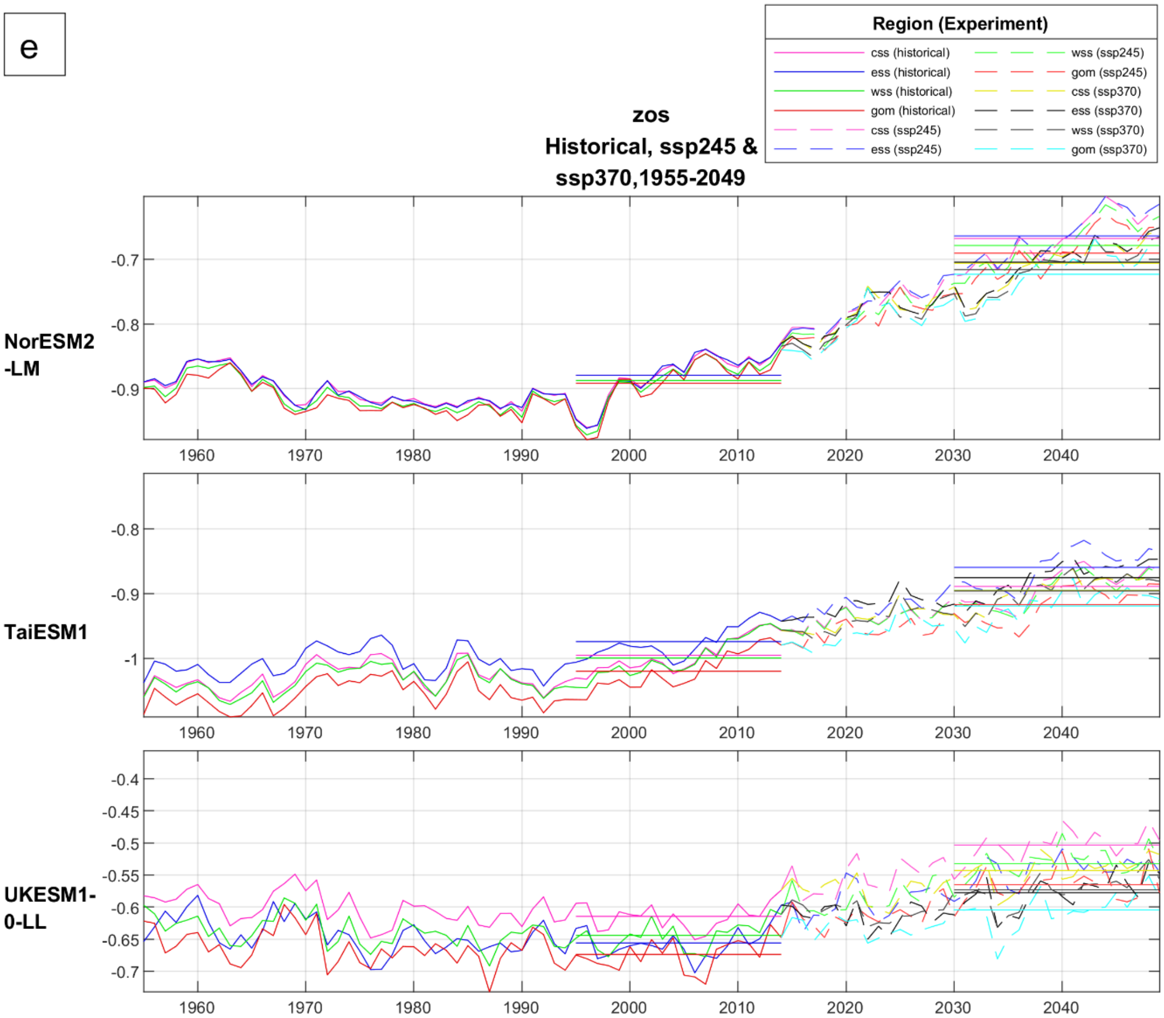


Figure 48 (a-e). Annual mean SSH time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Units are metres.

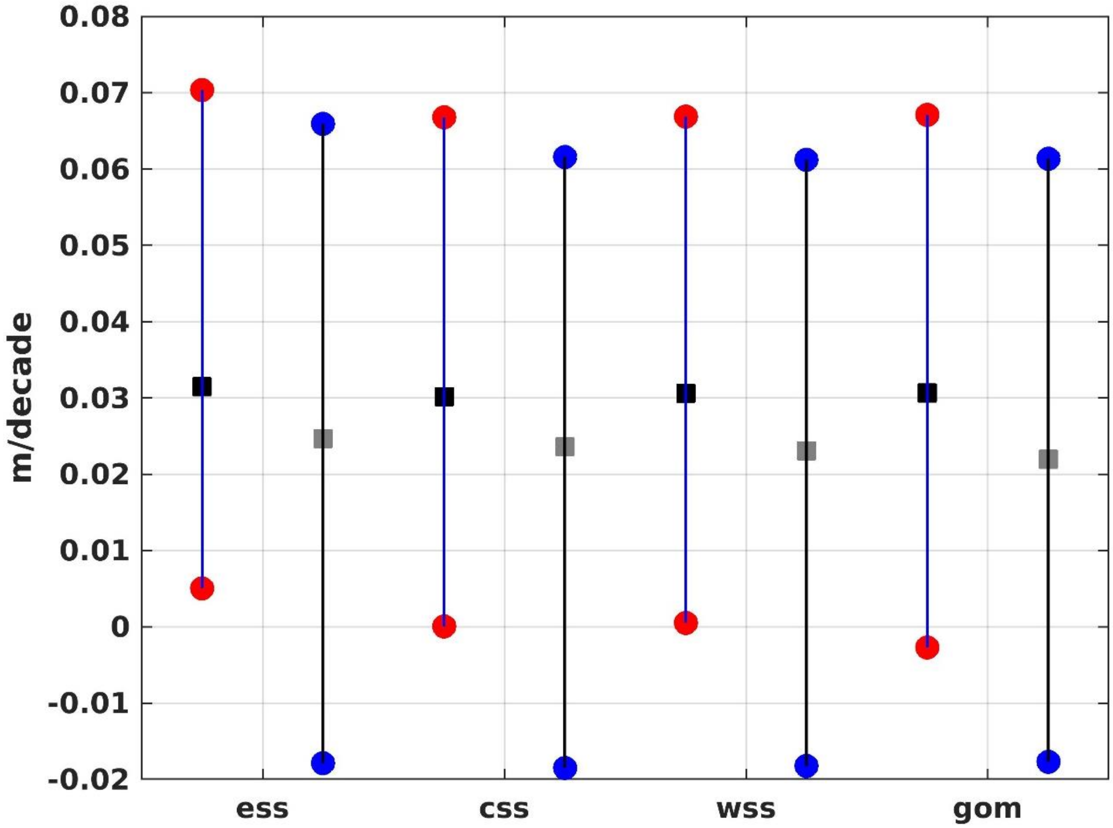


Figure 49. SSH annual means: range and mean projected trend of all ESMs, all subareas. SSP245: Blue line with red circle at each end, circles indicate maximum and minimum trends from those models, and the black square is the averaged trend. SSP370: Black line with blue circle at each end, circles indicate maximum and minimum trends from all ESMs, and the grey square is the averaged trend.

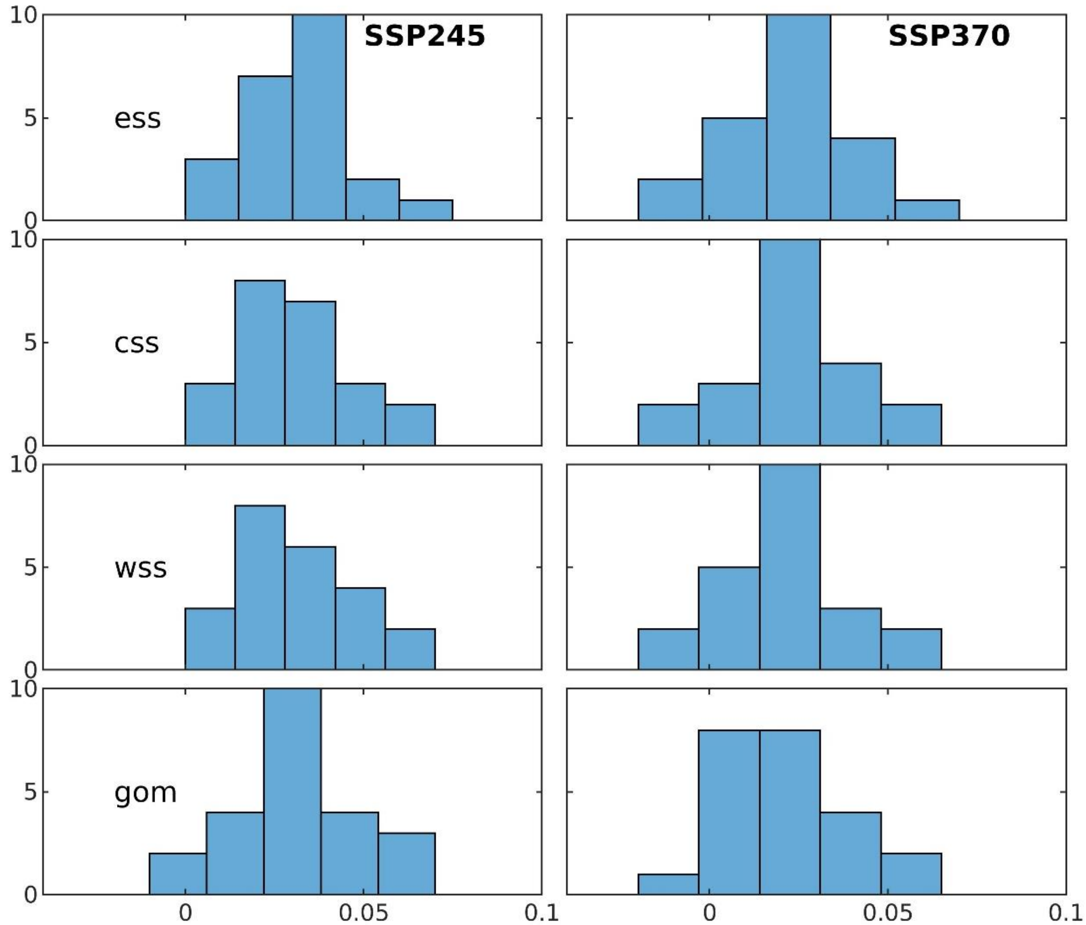
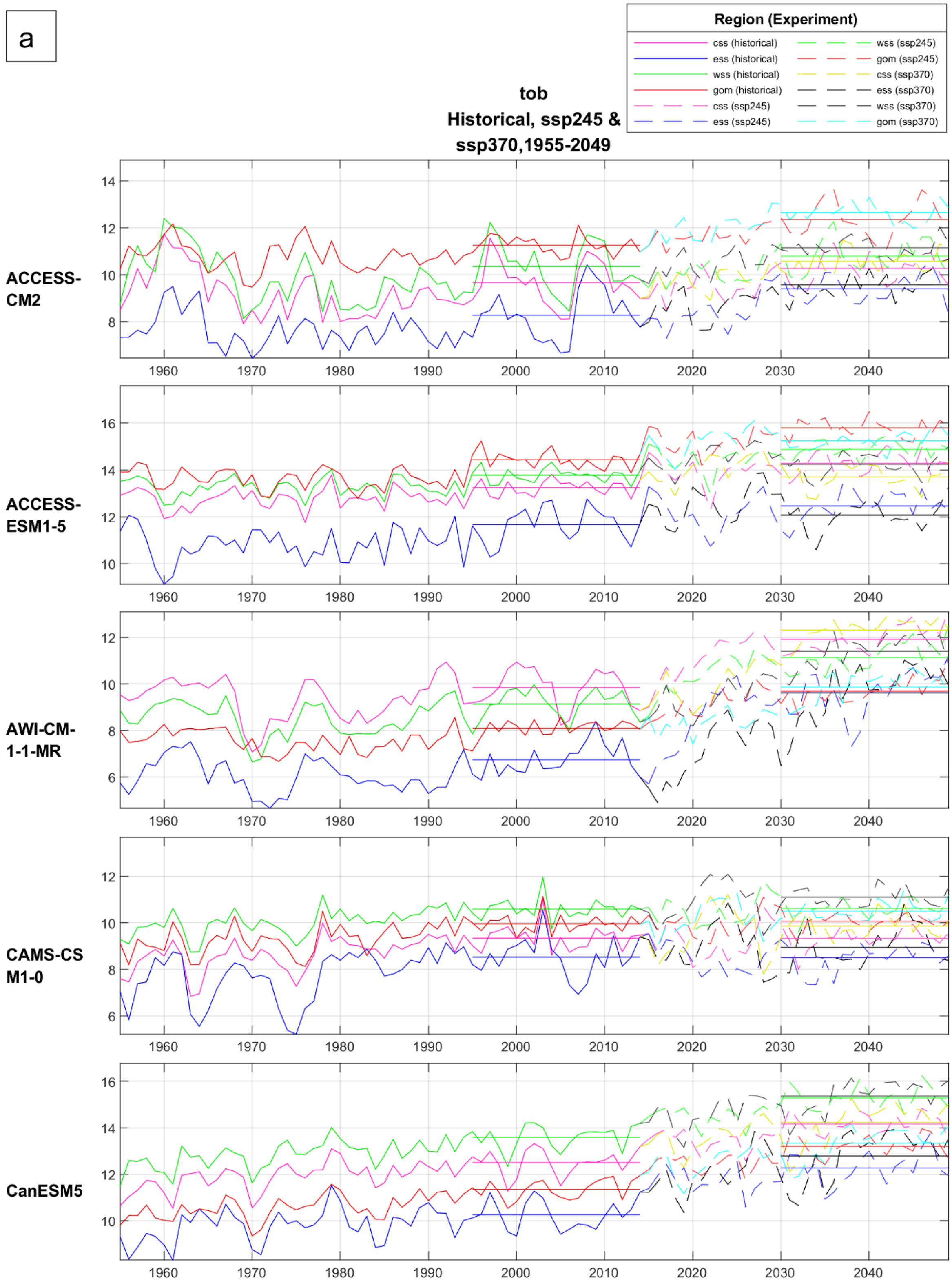


Figure 50. SSH annual means: histograms of projected trends from all ESMs, each subarea, each SSP. Abscissa units are m/decade.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Historical, ssp245 & ssp370,1955-2049
ACCESS-CM2
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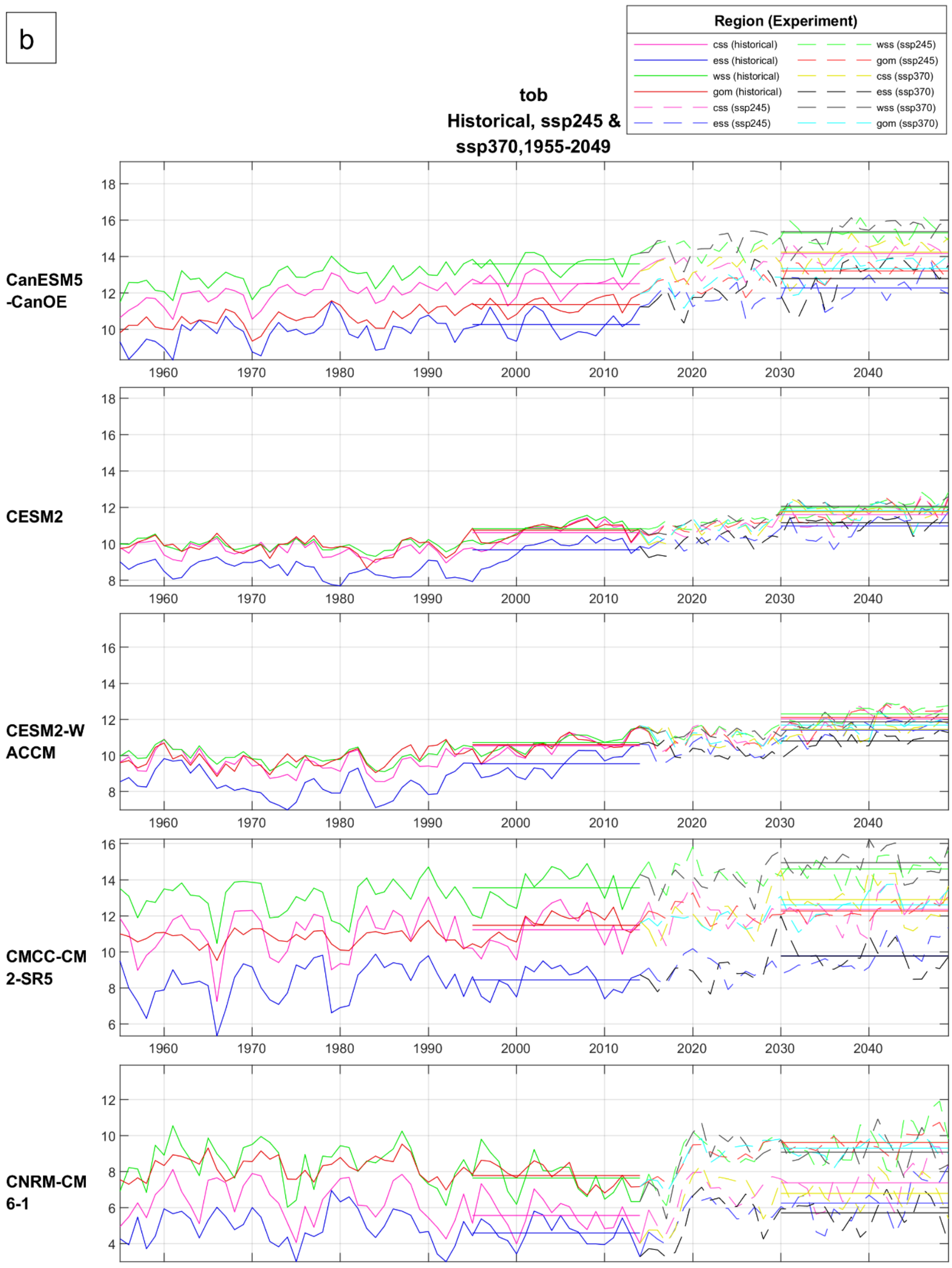

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Historical, ssp245 & ssp370,1955-2049
CanESM5 -CanOE
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CESM2-W ACCM
CMCC-CM 2-SR5
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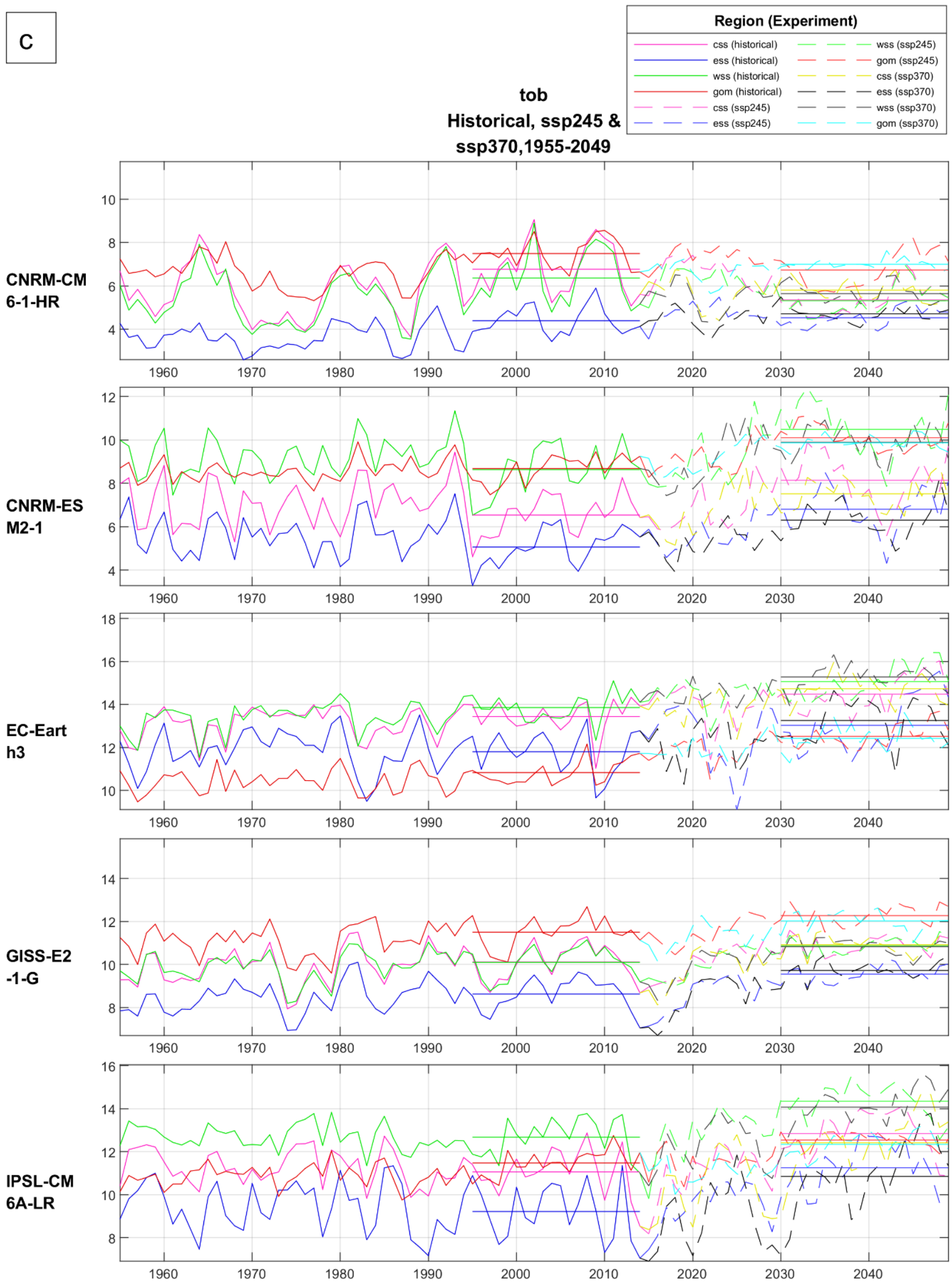

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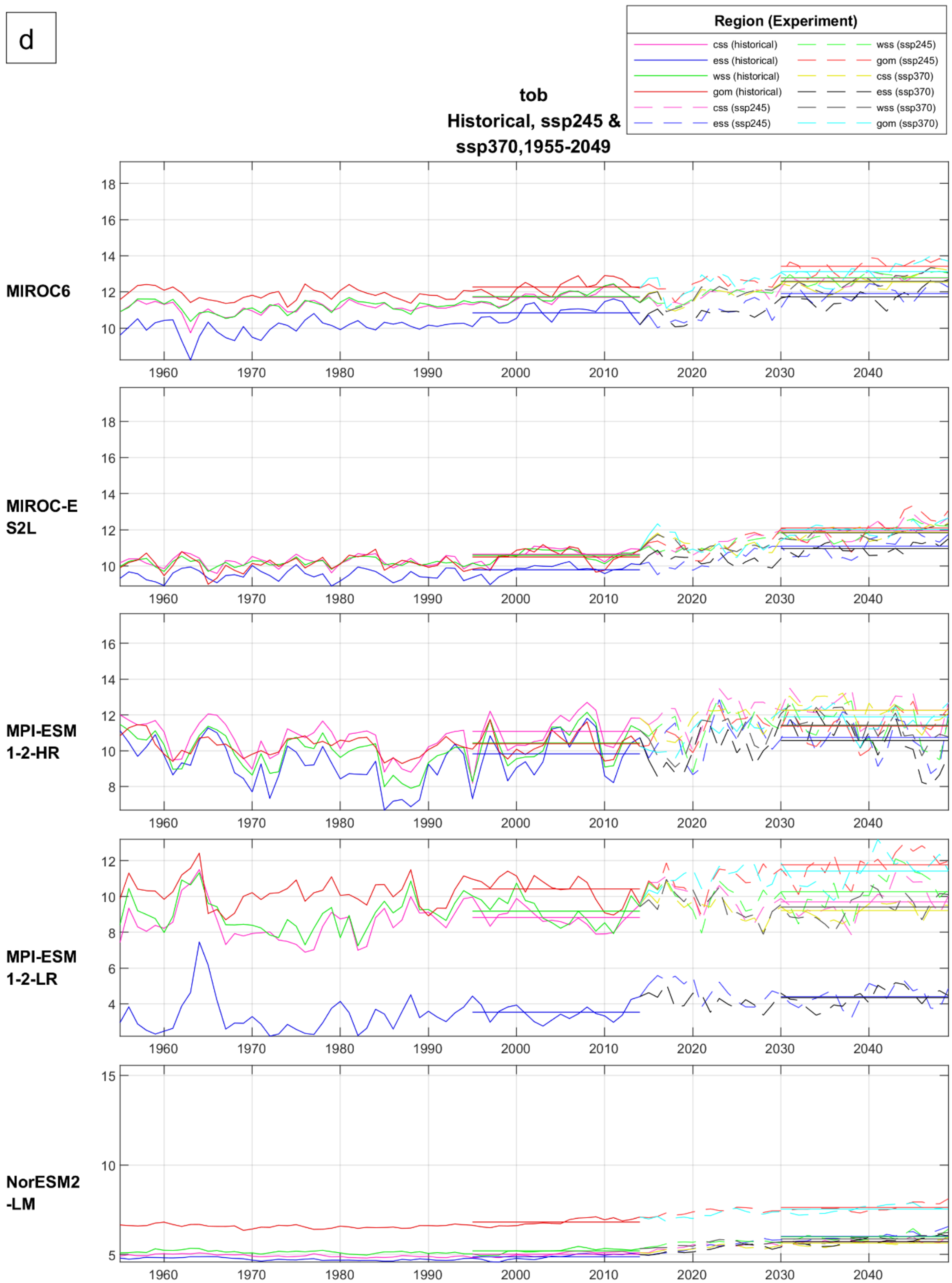
Historical, ssp245 & ssp370,1955-2049
CNRM-CM 6-1-HR
CNRM-ES M2-1
EC-Earth3
GISS-E2-1-G
IPSL-CM 6A-LR
1960 1970 1980 1990 2000 2010 2020 2030 2040


d
Region (Experiment)
css (historical)
ess (historical)
wss (historical)
gom (historical)
css (ssp245)
ess (ssp245)
wss (ssp245)
gom (ssp245)
css (ssp370)
ess (ssp370)
wss (ssp370)
gom (ssp370)
tob
Historical, ssp245 & ssp370,1955-2049
MIROC6
MIROC-ES2L
MPI-ESM 1-2-HR
MPI-ESM 1-2-LR
NorESM2-LM
1960
1970
1980
1990
2000
2010
2020
2030
2040

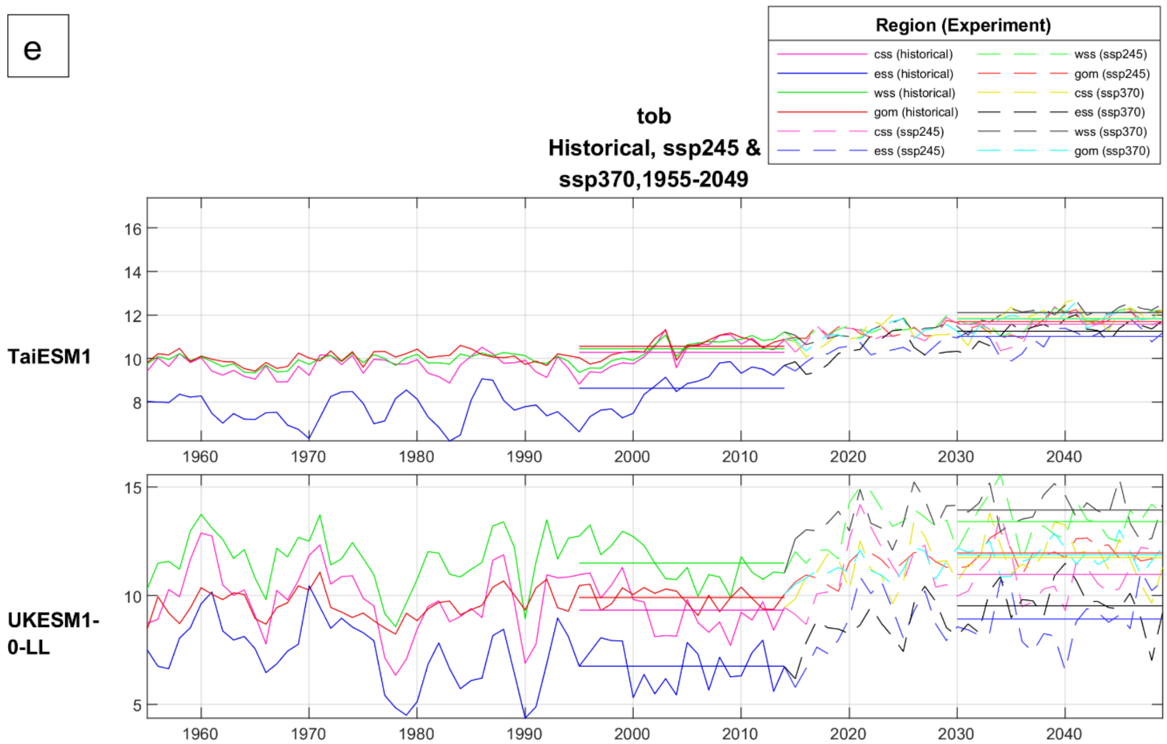


Figure 51 (a-e). Annual mean BT time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Units are degrees Celsius

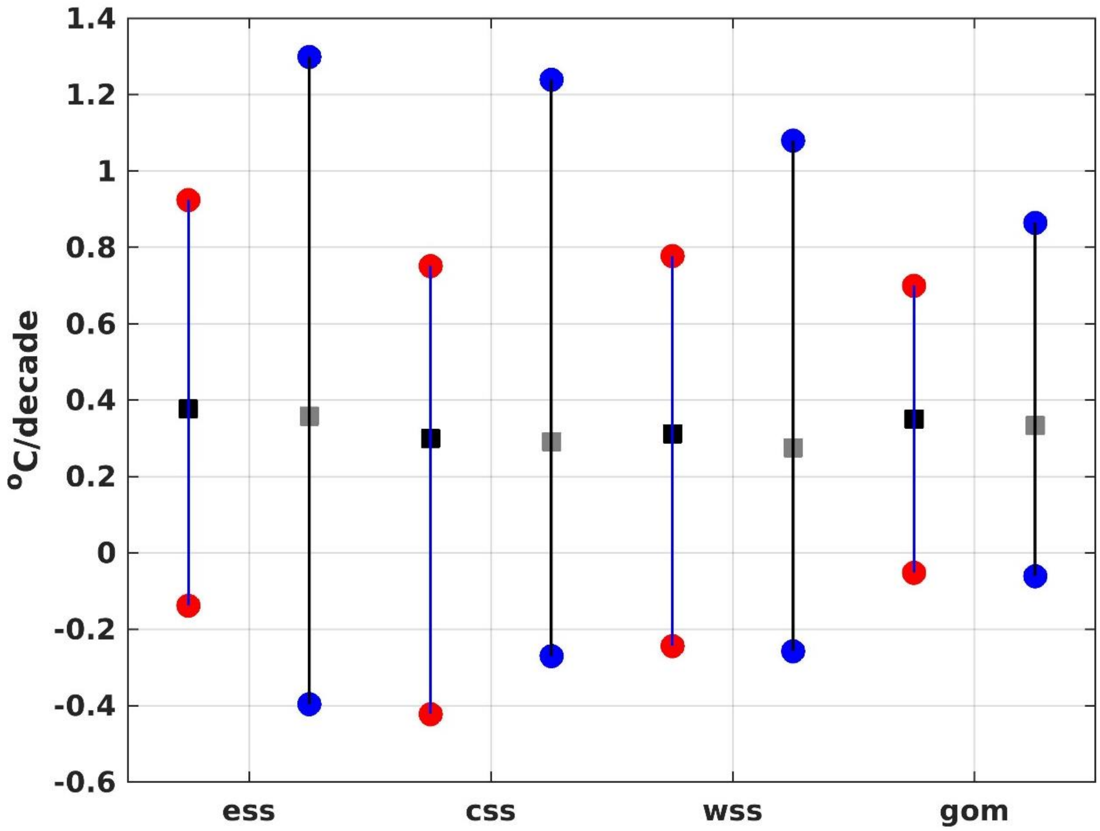


Figure 52. BT annual means: range and mean projected trend of all ESMs, all subareas. SSP245: Blue line with red circle at each end, circles indicate maximum and minimum trends from those models, and the black square is the averaged trend. SSP370: Black line with blue circle at each end, circles indicate maximum and minimum trends from all ESMs, and the grey square is the averaged trend.

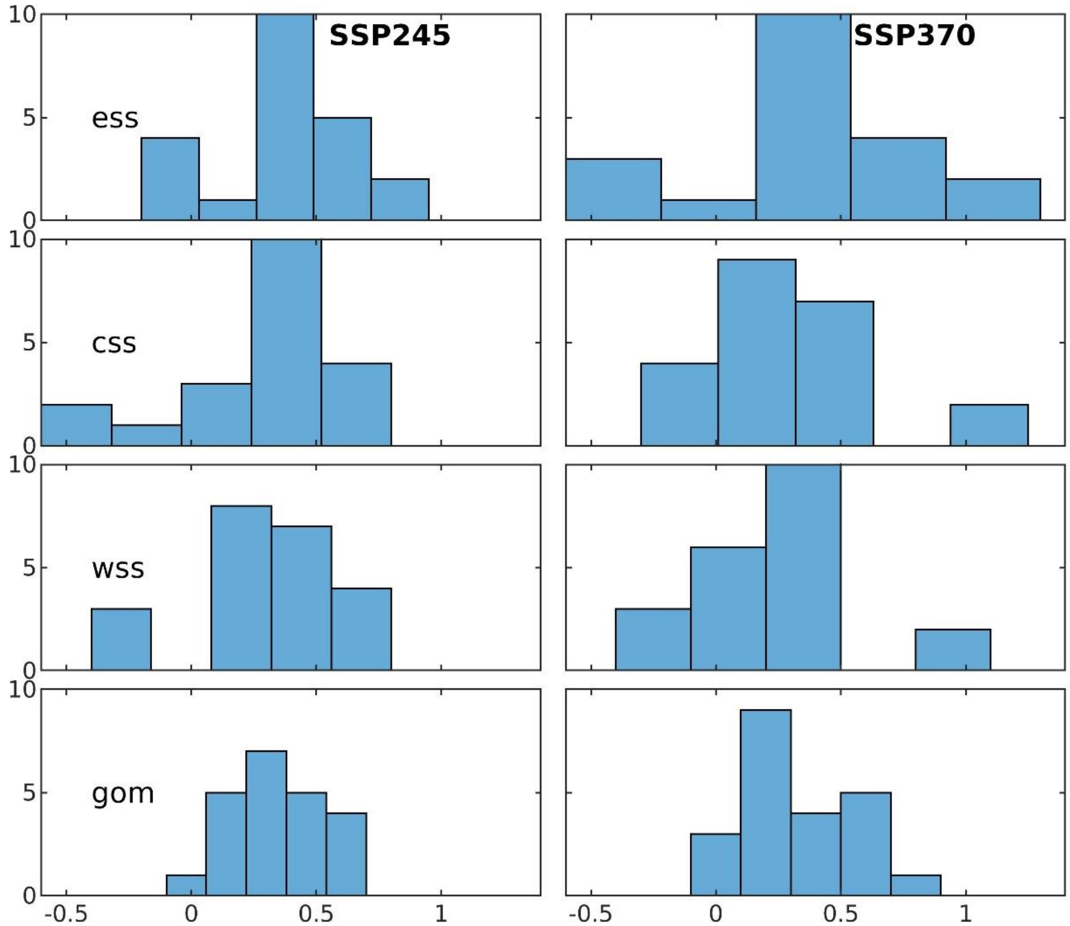
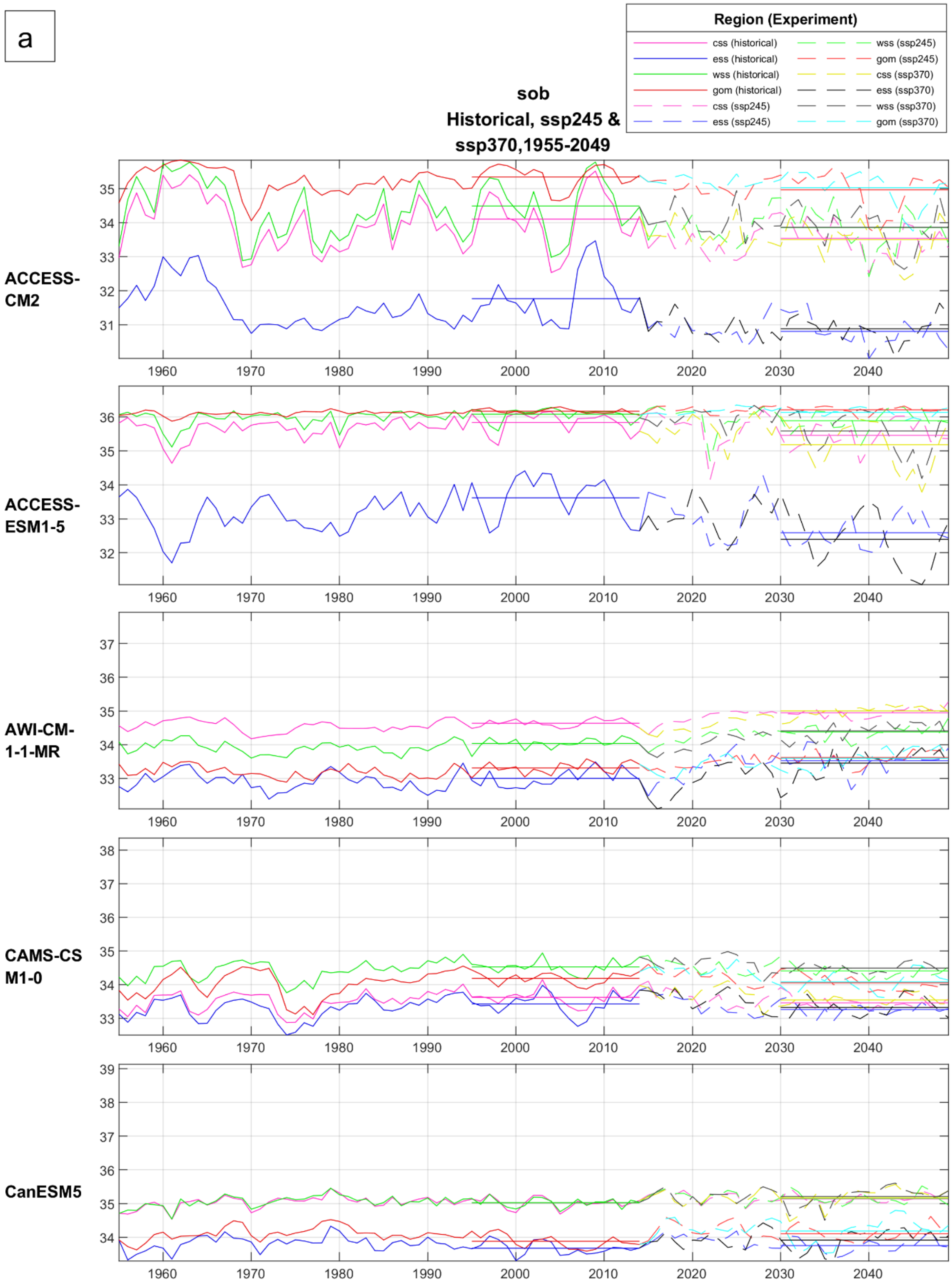
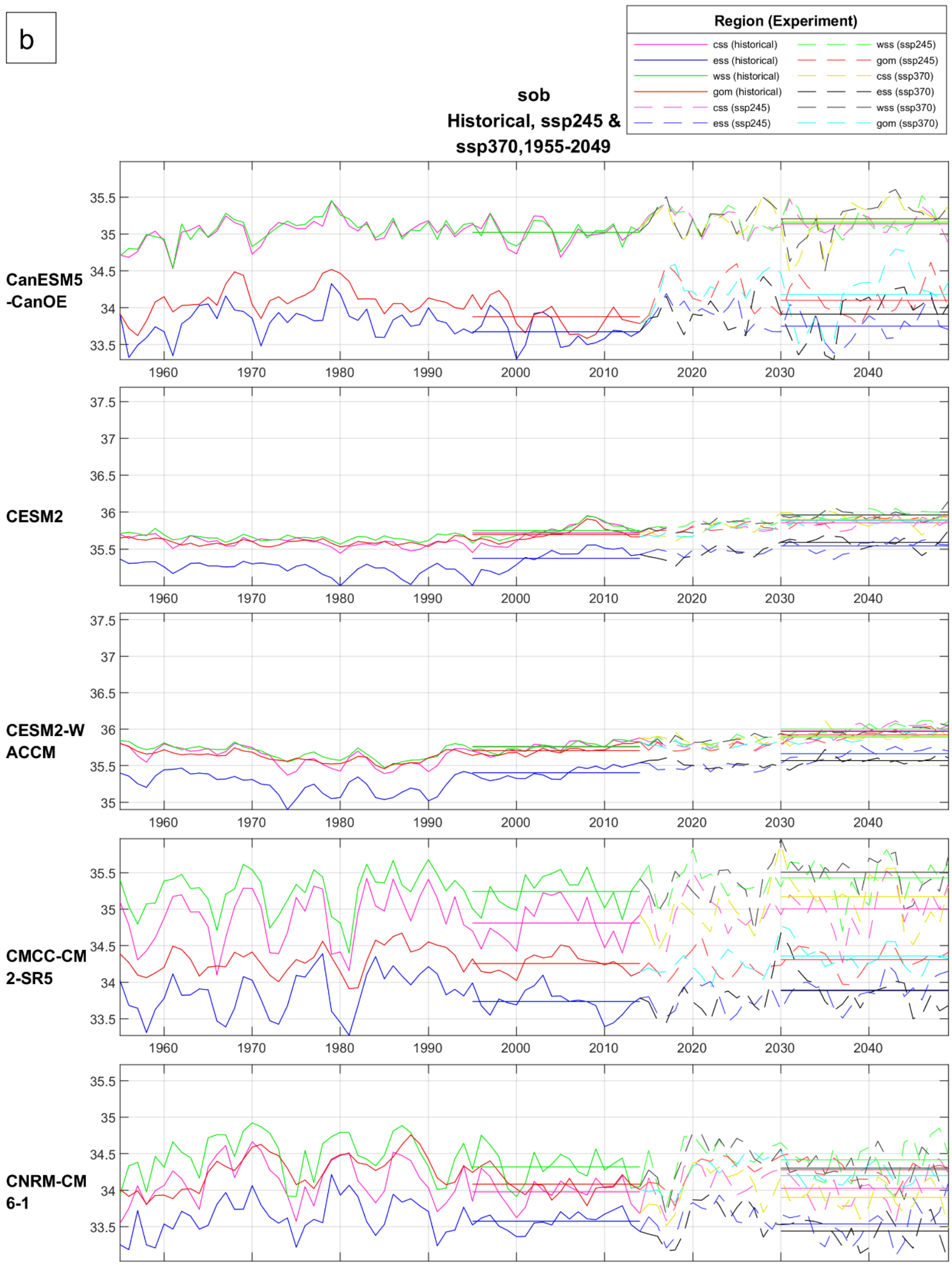
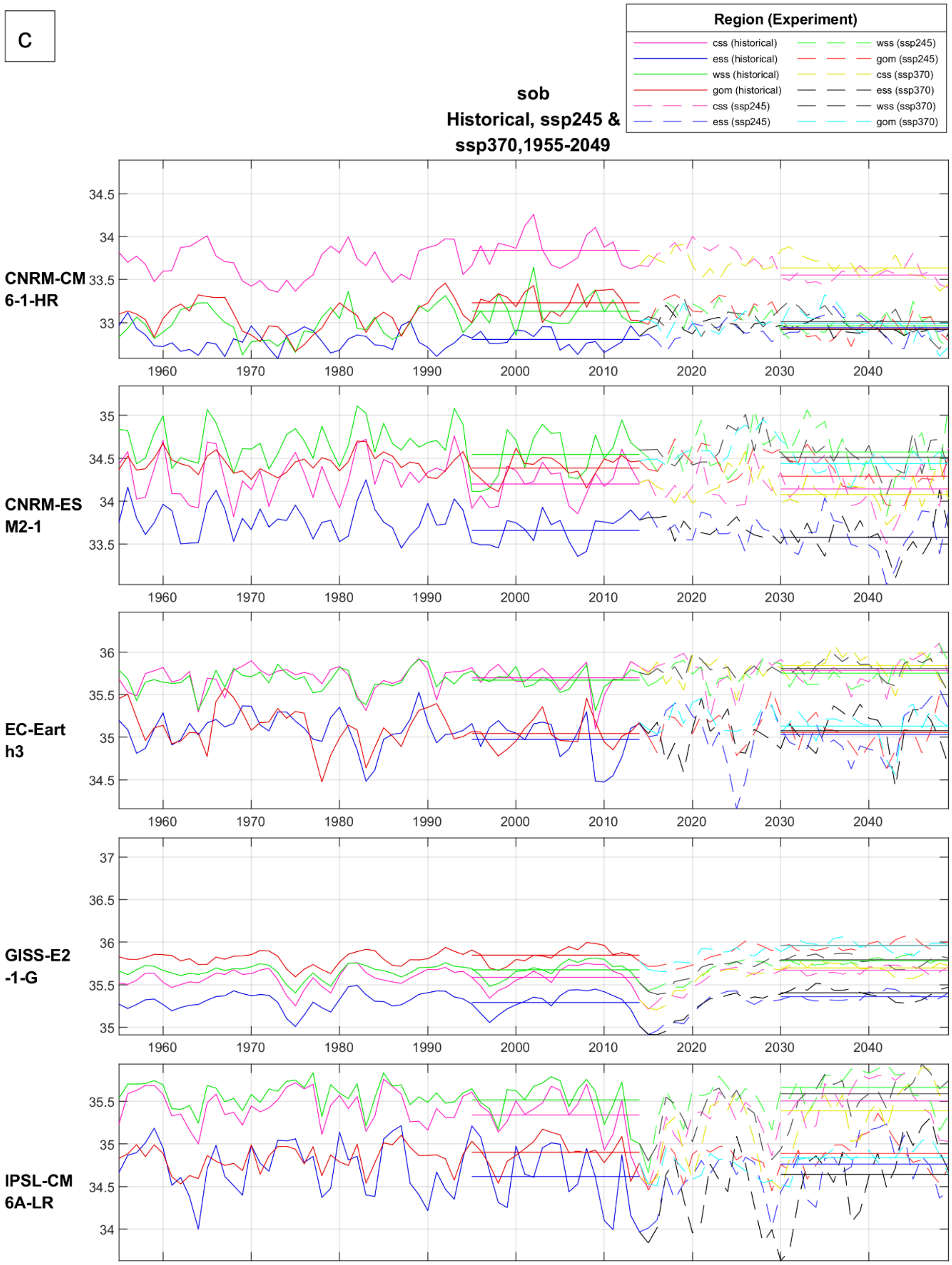


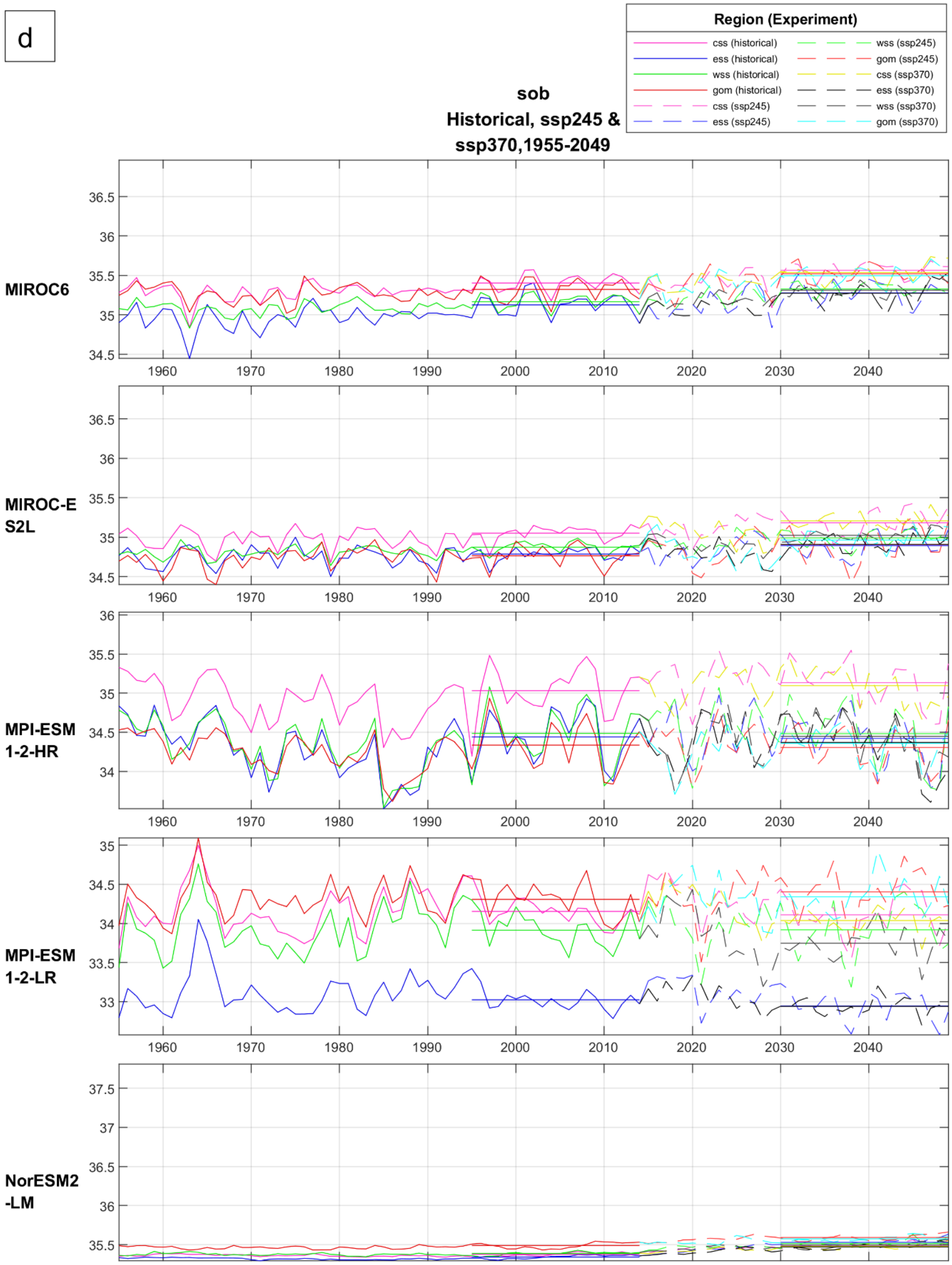
Figure 53. BT annual means: histograms of projected trends from all ESMs, each subarea, each SSP. Abscissa units are degrees Celsius.


a
Region (Experiment)
css (historical)
ess (historical)
wss (historical)
gom (historical)
css (ssp245)
ess (ssp245)
wss (ssp245)
gom (ssp245)
css (ssp370)
ess (ssp370)
wss (ssp370)
gom (ssp370)
sob
Historical, ssp245 & ssp370,1955-2049
ACCESS-CM2
ACCESS-ESM1-5
AWI-CM-1-1-MR
CAMS-CSM1-0
CanESM5
1960
1970
1980
1990
2000
2010
2020
2030
2040



b
Region (Experiment)
css (historical)
ess (historical)
wss (historical)
gom (historical)
css (ssp245)
ess (ssp245)
wss (ssp245)
gom (ssp245)
css (ssp370)
ess (ssp370)
wss (ssp370)
gom (ssp370)
sob
Historical, ssp245 & ssp370,1955-2049
CanESM5-CanOE
CESM2
CESM2-WACCM
CMCC-CM2-SR5
CNRM-CM6-1
1960
1970
1980
1990
2000
2010
2020
2030
2040


c
Region (Experiment)
css (historical)
ess (historical)
wss (historical)
gom (historical)
css (ssp245)
ess (ssp245)
wss (ssp245)
gom (ssp245)
css (ssp370)
ess (ssp370)
wss (ssp370)
gom (ssp370)
sob
Historical, ssp245 & ssp370,1955-2049
CNRM-CM 6-1-HR
CNRM-ES M2-1
EC-Eart h3
GISS-E2 -1-G
IPSL-CM 6A-LR
1960
1970
1980
1990
2000
2010
2020
2030
2040


d
Region (Experiment)
css (historical)
ess (historical)
wss (historical)
gom (historical)
css (ssp245)
ess (ssp245)
wss (ssp245)
gom (ssp245)
css (ssp370)
ess (ssp370)
wss (ssp370)
gom (ssp370)
sob
Historical, ssp245 & ssp370,1955-2049
MIROC6
MIROC-ES2L
MPI-ESM 1-2-HR
MPI-ESM 1-2-LR
NorESM2-LM
1960
1970
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e

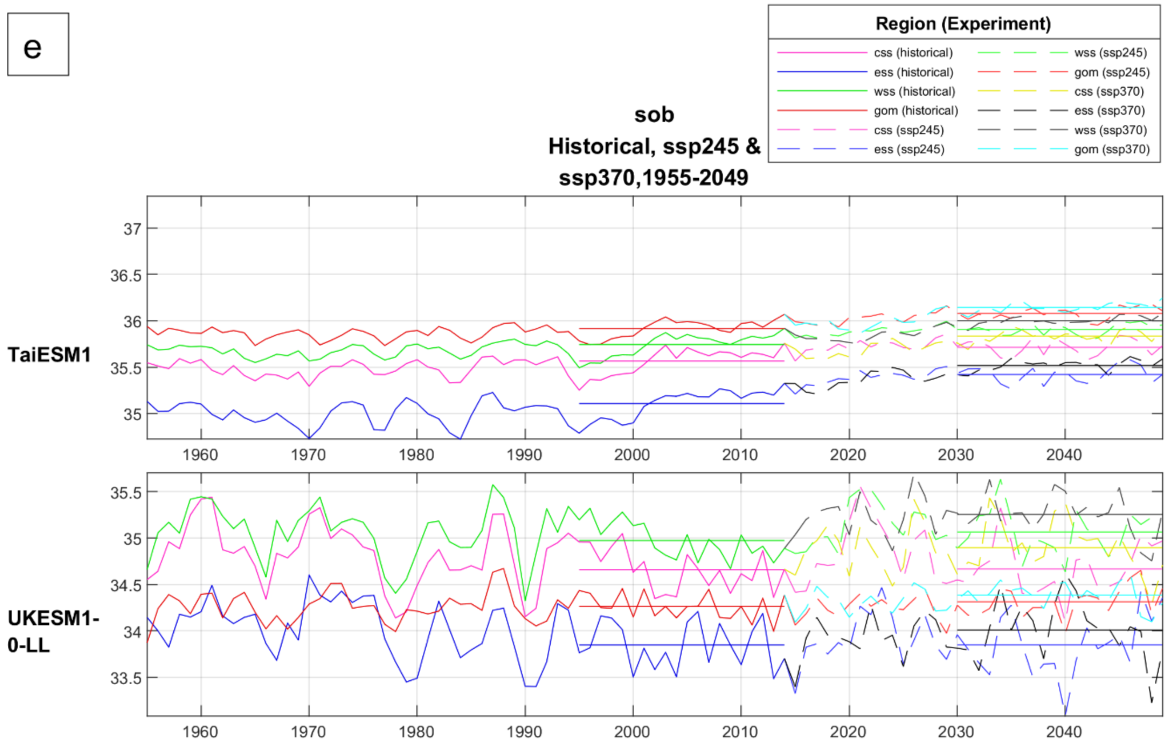

Figure 54 (a-e). Annual seasonal mean BS time series for 1955-2049, all subareas. The horizontal line segments indicate the bi-decadal means for the period spanned. Scenarios: SSP245, SSP370. Units are PSU.

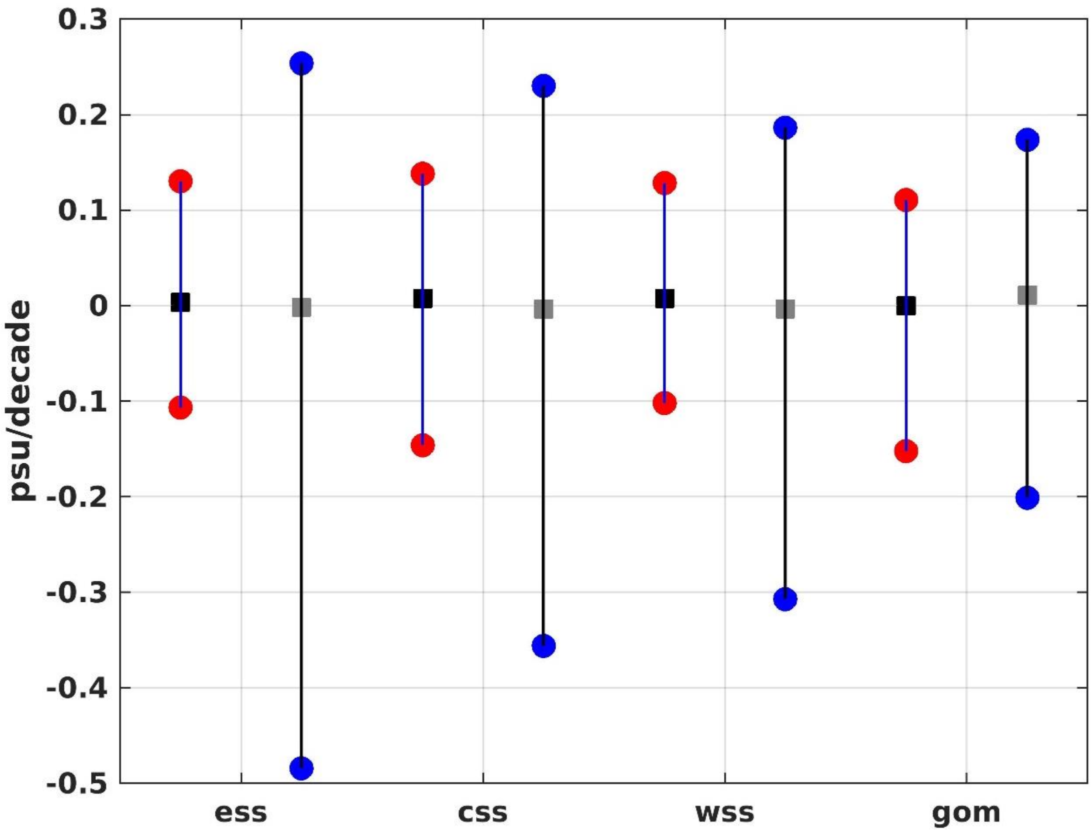

Figure 55. BS annual means: range and mean projected trend of all ESMs, all subareas. SSP245: Blue line with red circle at each end, circles indicate maximum and minimum trends from those models, and the black square is the averaged trend. SSP370: Black line with blue circle at each end, circles indicate maximum and minimum trends from all ESMs, and the grey square is the averaged trend.

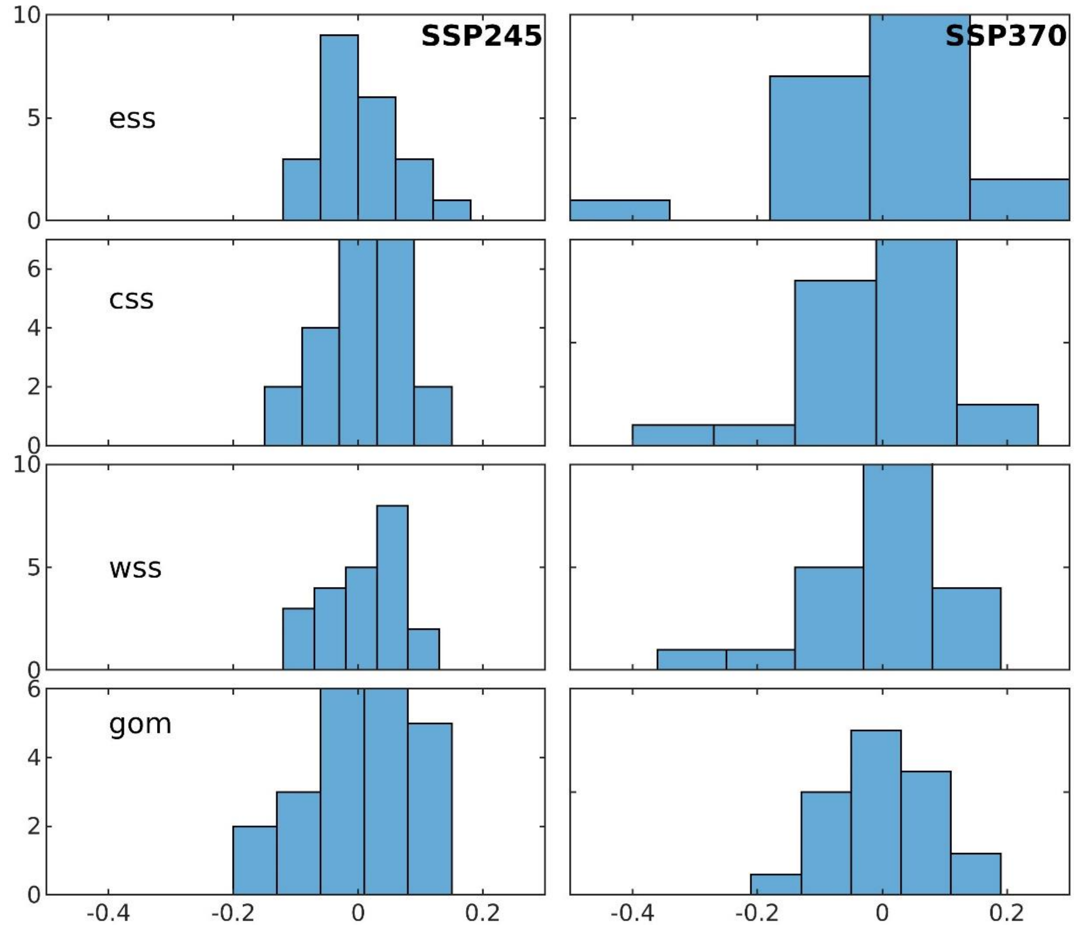

Figure 56. BS annual means: histograms of projected trends from all ESMs, each subarea, each SSP. Abscissa units are PSU.

Appendix A: CMIP6 ESM Citations

SOURCE_ID	INSTITUTION_ID	EXPERIMENT_ID	DOI	Data Reference
ACCESS-CM2	CSIRO-ARCCSS	historical	https://doi.org/10.22033/ESGF/CMIP6.4271	Martin Dix et al. [2019].
ACCESS-CM2	CSIRO-ARCCSS	ssp245	https://doi.org/10.22033/ESGF/CMIP6.4321	Martin Dix et al. [2019].
ACCESS-CM2	CSIRO-ARCCSS	ssp370	https://doi.org/10.22033/ESGF/CMIP6.4323	Martin Dix et al. [2019].
ACCESS-ESM1-5	CSIRO	historical	https://doi.org/10.22033/ESGF/CMIP6.4272	Tilo Ziehn et al. [2019].
ACCESS-ESM1-5	CSIRO	ssp245	https://doi.org/10.22033/ESGF/CMIP6.4322	Tilo Ziehn et al. [2019].
ACCESS-ESM1-5	CSIRO	ssp370	https://doi.org/10.22033/ESGF/CMIP6.4324	Tilo Ziehn et al. [2019].
AWI-CM-1-1-MR	AWI	historical	https://doi.org/10.22033/ESGF/CMIP6.2686	Tido Semmler et al. [2018].
AWI-CM-1-1-MR	AWI	ssp245	https://doi.org/10.22033/ESGF/CMIP6.2800	Tido Semmler et al. [2018].
AWI-CM-1-1-MR	AWI	ssp370	https://doi.org/10.22033/ESGF/CMIP6.2803	Tido Semmler et al. [2019].

CAMS-CSM1-0	**CAMS**	**historical**	**https://doi.org/10.22033/ESGF/CMIP6.9754**	**Xinyao Rong [2019].**
CAMS-CSM1-0	**CAMS**	**ssp245**	**https://doi.org/10.22033/ESGF/CMIP6.11047**	**Xinyao Rong [2019].**
CAMS-CSM1-0	**CAMS**	**ssp370**	**https://doi.org/10.22033/ESGF/CMIP6.11048**	**Xinyao Rong [2019].**
CanESM5	**CCCma**	**historical**	**https://doi.org/10.22033/ESGF/CMIP6.3610**	**Neil Cameron Swart et al. [2019].**
CanESM5	**CCCma**	**ssp245**	**https://doi.org/10.22033/ESGF/CMIP6.3685**	**Neil Cameron Swart et al. [2019].**
CanESM5	**CCCma**	**ssp370**	**https://doi.org/10.22033/ESGF/CMIP6.3690**	**Neil Cameron Swart et al. [2019].**
CanESM5-CanOE	**CCCma**	**historical**	**https://doi.org/10.22033/ESGF/CMIP6.10260**	**Neil Cameron Swart et al. [2019].**
CanESM5-CanOE	**CCCma**	**ssp245**	**https://doi.org/10.22033/ESGF/CMIP6.10270**	**Neil Cameron Swart et al. [2019].**
CanESM5-CanOE	**CCCma**	**ssp370**	**https://doi.org/10.22033/ESGF/CMIP6.10271**	**Neil Cameron Swart et al. [2019].**
CESM2	**NCAR**	**historical**	**https://doi.org/10.22033/ESGF/CMIP6.7627**	**Gokhan Danabasoglu et al. [2019].**
CESM2	**NCAR**	**ssp245**	**https://doi.org/10.22033/ESGF/CMIP6.7748**	**Gokhan Danabasoglu et al. [2019].**
CESM2	**NCAR**	**ssp370**	**https://doi.org/10.22033/ESGF/CMIP6.7753**	**Gokhan Danabasoglu et al. [2019].**
CESM2-WACCM	**NCAR**	**historical**	**https://doi.org/10.22033/ESGF/CMIP6.10071**	**Gokhan Danabasoglu et al. [2019].**
CESM2-WACCM	**NCAR**	**ssp245**	**https://doi.org/10.22033/ESGF/CMIP6.10101**	**Gokhan Danabasoglu et al. [2019].**
CESM2-WACCM	**NCAR**	**ssp370**	**https://doi.org/10.22033/ESGF/CMIP6.10102**	**Gokhan Danabasoglu et al. [2019].**
CMCC-CM2-SR5	**CMCC**	**historical**	**https://doi.org/10.22033/ESGF/CMIP6.3825**	**Tomas Lovato & Daniele Peano [2020].**
CMCC-CM2-SR5	**CMCC**	**ssp245**	**https://doi.org/10.22033/ESGF/CMIP6.3889**	**Tomas Lovato & Daniele Peano [2020].**
CMCC-CM2-SR5	**CMCC**	**ssp370**	**https://doi.org/10.22033/ESGF/CMIP6.3890**	**Tomas Lovato & Daniele Peano [2020].**
CNRM-CM6-1	**CNRM-CERFACS**	**historical**	**https://doi.org/10.22033/ESGF/CMIP6.4066**	**Aurore Voldoire [2018].**
CNRM-CM6-1	**CNRM-CERFACS**	**ssp245**	**https://doi.org/10.22033/ESGF/CMIP6.4189**	**Aurore Voldoire [2019].**
CNRM-CM6-1	**CNRM-CERFACS**	**ssp370**	**https://doi.org/10.22033/ESGF/CMIP6.4197**	**Aurore Voldoire [2019].**
CNRM-CM6-1-HR	**CNRM-CERFACS**	**historical**	**https://doi.org/10.22033/ESGF/CMIP6.4067**	**Aurore Voldoire [2019].**
CNRM-CM6-1-HR	**CNRM-CERFACS**	**ssp245**	**https://doi.org/10.22033/ESGF/CMIP6.4190**	**Aurore Voldoire [2019].**
CNRM-CM6-1-HR	**CNRM-CERFACS**	**ssp370**	**https://doi.org/10.22033/ESGF/CMIP6.4198**	**Aurore Voldoire [2020].**

SOURCE_ID	INSTITUTION_ID	EXPERIMENT_ID	DOI	Data Reference
CNRM-ESM2-1	CNRM-CERFACS	historical	https://doi.org/10.22033/ESGF/CMIP6.4068	Roland Seferian [2018].
CNRM-ESM2-1	CNRM-CERFACS	ssp245	https://doi.org/10.22033/ESGF/CMIP6.4191	Aurore Voldoire [2019].
CNRM-ESM2-1	CNRM-CERFACS	ssp370	https://doi.org/10.22033/ESGF/CMIP6.4199	Aurore Voldoire [2019].
EC-Earth3	EC-Earth-Consortium	historical	https://doi.org/10.22033/ESGF/CMIP6.4700	EC-Earth [2019].
EC-Earth3	EC-Earth-Consortium	ssp245	https://doi.org/10.22033/ESGF/CMIP6.4880	EC-Earth [2019].
EC-Earth3	EC-Earth-Consortium	ssp370	https://doi.org/10.22033/ESGF/CMIP6.4884	EC-Earth [2019].
GISS-E2-1-G	NASA-GISS	historical	https://doi.org/10.22033/ESGF/CMIP6.7127	NASA/GISS[2018].
GISS-E2-1-G	NASA-GISS	ssp245	https://doi.org/10.22033/ESGF/CMIP6.7415	NASA/GISS[2020].
GISS-E2-1-G	NASA-GISS	ssp370	https://doi.org/10.22033/ESGF/CMIP6.7426	NASA/GISS[2020].
IPSL-CM6A-LR	IPSL	historical	https://doi.org/10.22033/ESGF/CMIP6.5195	Olivier Boucher et al. [2018].
IPSL-CM6A-LR	IPSL	ssp245	https://doi.org/10.22033/ESGF/CMIP6.5264	Olivier Boucher et al. [2019].
IPSL-CM6A-LR	IPSL	ssp370	https://doi.org/10.22033/ESGF/CMIP6.5265	Olivier Boucher et al. [2019].
MIROC-ES2L	MIROC	historical	https://doi.org/10.22033/ESGF/CMIP6.5602	Tomohiro Hajima et al. [2019].
MIROC-ES2L	MIROC	ssp245	https://doi.org/10.22033/ESGF/CMIP6.5745	Kaoru Tachiiri et al. [2019].
MIROC-ES2L	MIROC	ssp370	https://doi.org/10.22033/ESGF/CMIP6.5751	Kaoru Tachiiri et al. [2019].
MIROC6	MIROC	historical	https://doi.org/10.22033/ESGF/CMIP6.5603	Hiroaki Tatebe et al. [2018].
MIROC6	MIROC	ssp245	https://doi.org/10.22033/ESGF/CMIP6.5746	Hideo Shiogama et al. [2019].
MIROC6	MIROC	ssp370	https://doi.org/10.22033/ESGF/CMIP6.5752	Hideo Shiogama et al. [2019].
MPI-ESM1-2-HR	MPI-M	historical	https://doi.org/10.22033/ESGF/CMIP6.6594	Johann Jungclaus et al. [2019].
MPI-ESM1-2-HR	DKRZ	ssp245	https://doi.org/10.22033/ESGF/CMIP6.4398	Martin Schupfner et al. [2019].
MPI-ESM1-2-HR	DKRZ	ssp370	https://doi.org/10.22033/ESGF/CMIP6.4399	Martin Schupfner et al. [2019].
MPI-ESM1-2-LR	MPI-M	historical	https://doi.org/10.22033/ESGF/CMIP6.6595	Karl-Hermann Wieners et al. [2019].
MPI-ESM1-2-LR	MPI-M	ssp245	https://doi.org/10.22033/ESGF/CMIP6.6693	Karl-Hermann Wieners et al. [2019].
MPI-ESM1-2-LR	MPI-M	ssp370	https://doi.org/10.22033/ESGF/CMIP6.6695	Karl-Hermann Wieners et al. [2019].
MRI-ESM2-0	MRI	historical	https://doi.org/10.22033/ESGF/CMIP6.6842	Seiji Yukimoto et al. [2019].
MRI-ESM2-0	MRI	ssp245	https://doi.org/10.22033/ESGF/CMIP6.6910	Seiji Yukimoto et al. [2019].
MRI-ESM2-0	MRI	ssp370	https://doi.org/10.22033/ESGF/CMIP6.6915	Seiji Yukimoto et al. [2019].
TaiESM1	AS-RCEC	historical	https://doi.org/10.22033/ESGF/CMIP6.9755	Wei-Liang Lee et al. [2020].
TaiESM1	AS-RCEC	ssp245	https://doi.org/10.22033/ESGF/CMIP6.9808	Wei-Liang Lee et al. [2020].
TaiESM1	AS-RCEC	ssp370	https://doi.org/10.22033/ESGF/CMIP6.9809	Wei-Liang Lee et al. [2020].
UKESM1-0-LL	MOHC	historical	https://doi.org/10.22033/ESGF/CMIP6.6113	Yongming Tang et al. [2019].
UKESM1-0-LL	NIMS-KMA	historical	https://doi.org/10.22033/ESGF/CMIP6.8379	Young-Hwa Byun et al. [2020].
UKESM1-0-LL	MOHC	ssp245	https://doi.org/10.22033/ESGF/CMIP6.6339	Peter Good et al. [2019].
UKESM1-0-LL	NIMS-KMA	ssp245	https://doi.org/10.22033/ESGF/CMIP6.8436	Sungbo Shim et al. [2020].
UKESM1-0-LL	NIMS-KMA	ssp370	https://doi.org/10.22033/ESGF/CMIP6.8438	Sungbo Shim et al. [2021].
UKESM1-0-LL	MOHC	ssp370	https://doi.org/10.22033/ESGF/CMIP6.6347	Peter Good et al. [2019].