TSSM

Technical Summary
Supplementary Material

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TS.SM.1 Notes and Technical Details on Observed Global Surface Temperature Figures in the Summary for Policymakers – Figure SPM.1

Data and programming code (IDL) used to create Summary for Policymakers and Technical Summary figures originating from Sections 2.4 and 2.5 of Chapter 2 can be obtained from the IPCC WGI AR5 website www.climatechange2013.org.

TS.SM.1.1 Annual and Decadal Global Surface Temperature Anomalies – Figure SPM.1a

Global Mean Surface Temperature (GMST) anomalies as provided by the dataset producers are given normalized relative to a 1961–1990 climatology from the latest version (as at 15 March 2013) of three combined Land-Surface Air Temperature (LSAT) and Sea Surface Temperature (SST) datasets. These combined datasets and the corresponding colours used in Figure SPM.1a are:

HadCRUT4 (version 4.1.1.0) – black
NASA GISS – blue
NCDC MLOST (version 3.5.2) – orange.

An overview of methodological diversity between these three temperature datasets is provided in Table 2.SM.6 of the Supplementary Material to Chapter 2, and full comprehensive details on the construction process for these datasets are provided in the references cited in this table. For time-series of LSAT only, and SST only, the reader is referred to Figure TS.1.

For the decadal anomalies, 90% confidence intervals are shown for the HadCRUT4 dataset (based on Morice et al., 2012).

TS.SM.1.2 Maps of Observed Changes in Surface Temperature – Figure SPM.1b

Maps of observed changes in surface temperature are based on trends calculated from the 3 datasets listed above for the period 1901–2012. See the Supplementary Material of Chapter 2 for a detailed description of the methodology used for trend and uncertainty calculations (Section 2.SM.3.3). Trends have been calculated only for those grid boxes with greater than 70% complete records and more than 20% data availability in the first and last 10% of the time period. White areas indicate incomplete or missing data. Black plus signs (+) indicate grid boxes where trends are significant at the 2-tailed 10% significance level (i.e., a trend of zero lies outside the 90% confidence interval).

The Technical Summary provides maps for all 3 datasets (Figure TS.2), while the Summary for Policymakers provides a map based on NCDC MLOST only (Figure SPM.1b).

TS.SM.2 Notes and Technical Details on Observed Change in Precipitation Over Land Figures in the Summary for Policymakers – Figure SPM.2

Data and programming code (IDL) used to create Summary for Policymakers and Technical Summary figures originating from Sections 2.4 and 2.5 of Chapter 2 can be obtained from the IPCC WGI AR5 website www.climatechange2013.org.

TS.SM.2.1 Map of Observed Changes in Precipitation Over Land – Figure SPM.2

Maps of observed changes in annual precipitation over land show trends calculated from 3 datasets:

CRU TS 3.10.01 (updated from Mitchell and Jones, 2005)
GHCN V2 (updated through 2011; Vose et al., 1992)
GPCC V6 (Becker et al., 2013)

Trends in annual precipitation are expressed per decade, and are calculated for the time periods 1901–2010 and 1951–2010. See the Supplementary Material of Chapter 2 for a detailed description of the methodology used for trend and uncertainty calculations (Section 2.SM.3.3). Trends have been calculated only for those grid boxes with greater than 70% complete records and more than 20% data availability in first and last 10% of the time period. White areas indicate incomplete or missing data. Black plus signs (+) indicate grid boxes where trends are significant at the 2-tailed 10% significance level (i.e., a trend of zero lies outside the 90% confidence interval).

The Technical Summary provides maps for all 3 datasets (TS TFE.1, Figure 2), while the Summary for Policymakers provides a map based on GPCC only (Figure SPM.2).

TS.SM.3 Notes and Technical Details on Observed Indicators of a Changing Global Climate Figures for the Summary for Policymakers – Figure SPM.3

This material documents the provenance of the data and plotting procedures that were used to create Figure SPM.3 in the IPCC WGI Fifth Assessment Report. This figure is closely derived from Figure TS.1 and FAQ 2.1, Figure 2 (see Chapter 2 Supplementary Material Section 2.SM.5), but includes fewer observed indicators. In addition, Figure SPM.3 includes an estimate of uncertainty for those datasets where this is available and has been assessed, illustrated with shading. Figure SPM.3 includes datasets and parameters assessed in Chapters 3 (ocean heat content, sea level), and 4 (snow cover, sea ice).

TS.SM.3.1 Northern Hemisphere Spring Snow Cover – Figure SPM.3a

TS.SM.3.1.1 Datasets

Green: Northern Hemisphere annual March-April average snow-cover extent based on an updated series from Brown and Robinson (2011), 1922–2012.

Shaded uncertainty estimate indicated by the 95% confidence interval.

TS.SM.3.1.2 Plotting Techniques

Annual values are plotted.

TS.SM.3.2 Arctic Summer Sea Ice Extent – Figure SPM.3b

All datasets provide Arctic annual July-August-September average sea ice extent.

Green: Updated from Walsh and Chapman (2001). Annual values are from 1900–1978.

Blue: Hadley Centre Sea Ice and Sea Surface Temperature dataset (HadISST1.2) (Rayner et al., 2003). Annual values are from 1900–1939 and 1953–2012. Values are excluded for the period 1940–1952 because the available data showed no change. It was a period when *in situ* data were very sparse and the gaps were filled in for completeness with climatology. For this assessment, this was not considered sufficiently robust and therefore the data during the period were excluded from the time series.

Red: Bootstrap algorithm (SBA) applied to data from the Scanning Multichannel Microwave Radiometer (SMMR) (updated from Comiso and Nishio, 2008). Annual values are from 1979–2012.

Black: NASA Team algorithm (NT1) applied to data from the Special Sensor Microwave/Imager (SSM/I) (Cavalieri et al., 1984) – updated in Cavalieri and Parkinson (2012) and Parkinson and Cavalieri (2012). Annual values are from 1979–2011.

Yellow: Bootstrap algorithm (ABA) applied to data from the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) (updated from Comiso and Nishio, 2008). Annual values are from 2002–2011.

Orange: Revised NASA Team algorithm (NT2) applied to data from the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) (updated from Markus and Cavalieri, 2000). Annual values are from 2002–2011.

Uncertainty estimates for each data point in the plots have been calculated based on the interannual variability of the ice extents. The systematic errors are not considered because they are generally unknown and are expected to be approximately constant from one year to another and would not change the results of trend analyses significantly. The interannual variability of the extent and actual area of the sea ice cover during the satellite era (since 1979) can be quantified accurately because of global coverage at good temporal resolution and the high contrast in the signature of ice free and ice covered oceans. The uncertainty (shaded range) that is shown is 1 standard deviation of the more than 30 years of satellite data, assuming a Gaussian distribution. The standard deviation is calculated after the data have been linearly detrended.

For the pre-satellite data (pre 1979), the true interannual variability is not known because available data are sparse and limited to only a few locations. Based on the expected quality of the Walsh and Chapman (2001) data and because of the lack of a better procedure, we use 1.75 standard deviations for the period 1880 to 1952 when data were sparse and 1.5 standard deviation for the period 1953 to 1978 when significantly more data were available. For the HadISST1.2 data set, which includes both pre- and post-satellite data (Rayner et al., 2003), we use 1 standard deviation for the entire period since 1900, calculated after the data has been linearly detrended.

TS.SM.3.2.2 Plotting Techniques

Annual values are plotted.

TS.SM.3.3 Global Average Upper Ocean Heat Content – Figure SPM.3c

TS.SM.3.3.1 Datasets

All datasets provide global annual upper-ocean (0 to 700 m depth) heat content anomalies.

Blue: Updated from Palmer et al. (2007). Annual values are from 1950–2011.

Green: Updated from Domingues et al. (2008). Annual values, smoothed with a 3-year running mean, are from 1950–2011.

Yellow: Updated from Ishii and Kimoto (2009). Annual values are from 1950–2011.

Orange: Updated from Smith and Murphy (2007). Annual values are from 1950–2010.

Black: Updated from Levitus et al. (2012). Annual values are from 1955–2011.

Uncertainty estimates are as reported in the cited publications. These are one standard error of the mean, except for Levitus et al. (2012) which provide one standard deviation. No uncertainty estimate is available for Smith and Murphy (2007).

TS.SM.3.3.2 Plotting Techniques

The published ocean heat content anomaly datasets are relative to different climatological reference periods. Therefore, the datasets have been aligned in Figure SPM.3c for the period 2006–2010, five years that are well measured by Argo, and then plotted relative to the resulting mean of all curves for 1970, a time when the increasing availability of annual data from XBTs causes the uncertainty estimates to reduce considerably. Specifically the alignment procedure for Figure SPM.3c involved the following steps:

Obtain all five upper ocean heat content anomaly time series.

1. Recognize that all the time-series values are annual values, centered on the middle of calendar years.
2. Find the average value of each time series for the years 2006–2010.
3. Subtract the average 2006–2010 value for each time series from that specific time-series.
4. Find the value of each time series for the year 1970.
5. Average these five values from the year 1970.
6. Subtract this 1970 average value from all of the time-series.

TS.SM.3.4 Global Average Sea Level – Figure SPM.3d

TS.SM.3.4.1 Datasets

Black: Church and White (2011) tide gauge reconstruction. Annual values are from 1900–2009.

Yellow: Jevrejeva et al. (2008) tide gauge reconstruction. Annual values are from 1900–2002.

Green: Ray and Douglas (2011) tide gauge reconstruction. Annual values are from 1900–2007.

Red: Nerem et al. (2010) satellite altimetry. A 1-year moving average boxcar filter has been applied to give annual values from 1993–2009.

Shaded uncertainty estimates are one standard error as reported in the cited publications. The one standard error on the 1-year averaged altimetry data (Nerem et al., 2010) is estimated at ±1 mm, and thus considerably smaller than for all other datasets.

TS.SM.3.4.2 Plotting Techniques

The published Global Mean Sea Level (GMSL) datasets use arbitrary and different reference periods where they start from zero. Furthermore, the altimetry data begins only in 1993. Therefore, the datasets have been aligned in Figure SPM.3d to a common reference period of time using the following steps:

1. The longest running record (Church and White, 2011) is taken as the reference to which all other datasets are aligned.
2. GMSL from Church and White (2011) is calculated relative to the average for the period 1900–1905, and the resulting value for the year 1993 (127 mm) is identified.
3. All other records are then adjusted to give the same value of 127 mm in 1993 (i.e., for each dataset the offset required to give 127 mm in 1993 is applied to all annual values in that dataset).

TS.SM.4 Notes and Technical Details on Observed Changes in the Global Carbon Cycle Figures in the Summary for Policymakers – Figure SPM.4

TS.SM.4.1 Atmospheric Concentrations of Carbon Dioxide – Figure SPM.4a

The top panel of Figure TS.5, and panel (a) of Figure SPM.4 show time series of atmospheric concentrations of carbon dioxide (CO_2). CO_2 concentrations are expressed as a mole fraction in dry air, micromol/mol, abbreviated as ppm. Time series are shown for the Mauna Loa Observatory (red in Figure SPM.4a), and South Pole (black in Figure SPM.4a). Data were accessed from the following sources (active at the time of publication):

1. Mauna Loa Observatory
   ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_mm_mlo.txt.

Monthly averages are plotted from March 1958 to August 2012. For further details on the measurements see Keeling et al. (1976a) and Thoning et al. (1989).

2. South Pole
   http://scrippsco2.ucsd.edu/data/flask_co2_and_isotopic/monthly_co2/monthly_spo.csv

Monthly averages are plotted from June 1957 to February 2012. For further details on the measurements see Keeling et al. (1976b; 2001).

TS.SM.4.2 Ocean Surface Carbon Dioxide and *In Situ* pH – Figure SPM.4b

The top panel of Figure TS.5, and panel (b) of Figure SPM.4 show time series of observed partial pressure of dissolved CO_2 (pCO_2 given in µatm) at the ocean surface, together with time series of ocean surface *in situ* pH (total scale). All ocean time series are plotted as 12-month running means (6 months before to 6 months after the sample date) for each 6-month period centered on 1 January and 2 July of each year. Data for both pCO_2 and *in situ* pH were measured at the following stations and obtained from the following sources (active at the time of publication):

1. Hawaii Ocean Time-Series program (HOT) from the station ALOHA (updated from, Dore et al., 2009)
   http://hahana.soest.hawaii.edu/hot/products/HOT_surface_CO2.txt

Shown as light green and light blue time series in Figure SPM.4b, for *in situ* pH and pCO_2 respectably. Data were plotted for the period 1988–2011.

Further technical details regarding the data are available from the readme file: http://hahana.soest.hawaii.edu/hot/products/HOT_surface_CO2_readme.pdf.

2. Bermuda Atlantic Time-Series Study (BATS): http://bats.bios.edu/bats_form_bottle.html

Shown as green and blue time series in Figure SPM.4b, for *in situ* pH and pCO_2, respectively, but not shown in Figure TS.5. Data were plotted for the period 1991 – 2011.

Measured dissolved inorganic carbon (DIC) and total alkalinity (TA) at *in situ* temperature were used to calculate pH on the total scale as well as pCO_2 in µatm.

Further technical details are described in Bates (2007).

3. European Station for Time series in the Ocean (ESTOC; see González-Dávila and Santana-Casiano, 2009): http://cdiac.ornl.gov/ftp/oceans/ESTOC_data

Shown as dark green and dark blue time series in Figure SPM.4b, for *in situ* pH and pCO_2, respectively, but not shown in Figure TS.5. Data were plotted for the period 1996–2009.

Further technical details regarding the data are available from González-Dávila (2010).

Note that the data for Figure SPM.4 (and Figure TS.5) provided at the external sources cited above may be subject to revision based on recalibration, and other quality control procedures conducted over time by the data providers.

TS.SM.5 Notes and Technical Details on Radiative Forcing Estimates Figure in the Summary for Policy Makers – Figure SPM.5

This material documents the underlying traceability for values that were used to create Figure SPM.5 in the IPCC WG1 Fifth Assessment Report. This figure is closely related to Figures TS.6 and TS.7 and Chapter 8, Figures 8.14 to 8.18. The reader is therefore referred to the Supplementary Material of Chapter 8 for detailed information on methods and sources used to estimate forcing values.

Figure SPM.5 (and Figure TS.7) plots Radiative Forcing (RF) estimates in 2011 relative to 1750 and aggregated uncertainties for the main drivers of climate change. This figure is different from similar figures shown in previous IPCC report SPMs (though an analogous figure was shown in Chapter 2 of AR4) as it evaluates the RF based on the emissions rather than the concentration changes. An emitted compound changes the atmospheric concentration of the same substance but may also impact that of other atmospheric constituents through chemistry processes.

Values are global average RF, partitioned according to the emitted compounds or processes that result in a combination of drivers. In calculations of RF for well-mixed greenhouse gases and aerosols in this report, physical variables, except for the ocean and sea ice, are allowed to respond to perturbations with rapid adjustments. The resulting forcing is called Effective Radiative Forcing (ERF) in the underlying report. For all drivers other than well-mixed greenhouse gases and aerosols, rapid adjustments are less well characterized and assumed to be small, and thus the traditional RF is used.

The 'level of confidence' given in Figure SPM.5 is based on Table 8.5.

For the main emitted compounds of CO_2, CH_4, Halocarbons, N_2O, CO, NMVOC and NO_x, the underlying values, their sources, and uncertainties can be found in the Chapter 8 Supplementary Material, Tables 8.SM.6 and 8.SM.7.

The value of –0.27 W m^{-2} for aerosols and precursors shown in Figure SPM.5 results from –0.35 W m^{-2} from RFari (Table 8.6) with the addition of 0.04 W m^{-2} from BC-on-snow and the subtraction of the small nitrate contribution from NO_x of –0.04 W m^{-2} (Table 8.SM.6).

The value of –0.55 W m^{-2} for cloud adjustments due to aerosols given in Figure SPM.5 results from the combination of ERFaci –0.45 [–1.2 to 0.0] W m^{-2} and rapid adjustment of ari –0.1 [–0.3 to +0.1] W m^{-2} as reported in Figure TS.7. Detailed information can be found in Chapter 8 and the Chapter 8 Supplementary Material, Table 8.SM.6.

The values for albedo changes due to land use and changes in solar irradiance come from Table 8.6 of Chapter 8.

Total anthropogenic RF relative to 1750 is based on values given in Table 8.6 (for 2011) and Figure 8.18 (values for 1950 and 1980 given in the caption).

TS.SM.6 Notes and Technical Details on Comparison of Observed and Simulated Climate Change Figures for the Summary for Policymakers – Figure SPM.6

Figure SPM.6 and the related Figure TS.12 are reduced versions of Figure 10.21 in Chapter 10. The reader is therefore referred to the detailed description of the main components of Figure 10.21 for datasets and methods used (see the Chapter 10 Supplementary Material, Section 10.SM.1). Here, mainly the differences of Figure SPM.6 and TS.12 from Figure 10.21 are listed.

Figures SPM.6 and TS.12 show time series of decadal average, plotted on a common axis and at the centre of each decade. The decadal averages are taken from the annual time series that Figure 10.21 is based on. Figure TS.12 features the multi-model mean as dark blue and dark red line, while Figure SPM.6 only features the 5–95% confidence interval. Note that the precipitation plot from Figure 10.21 are not included in the Technical Summary and SPM versions of this figure.

TS.SM.6.1 Continental Temperatures

The same model simulations and observational data sets are used as for Figure 10.21. Continental land areas are based on the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) defined regions (IPCC, 2012) shown pictorially in the bottom right most panel of Figure 10.7. Temperature anomalies in Figure SPM.6 are with respect to 1880–1919 (except for Antarctica where anomalies are relative to 1950–2010).

TS.SM.6.2 Ocean Heat Content

The same model simulations and observational data sets are used as for Figure 10.21.

TS.SM.6.3 Sea Ice

The same model simulations and observational data sets are used as for Figure 10.21.

TS.SM.6.4 Data Quality

For land and ocean surface temperatures panels, solid lines indicate where data spatial coverage of areas being examined is above 50% coverage and dashed lines where coverage is below 50%. For example, data coverage of Antarctica never goes above 50% of the land area of the continent. For ocean heat content and sea-ice panels, the solid line is where the coverage of data is good and higher in quality, and the dashed line is where the data coverage is only adequate, based respectively on the spatial coverage and instrument type and on the presence of satellite measurements.

TS.SM.7 Notes and Technical Details on CMIP5 Simulated Time Series Figures in the Summary for Policymakers – Figure SPM.7

This material documents the provenance of the data and plotting procedures that were used to create Figure SPM.7, based on Climate Model Intercomparison Project Phase 5 (CMIP5) model results as of March, 2013. This figure is closely derived from Figures 12.5 and TS.15 (global average surface temperature), 12.28 and TS.17 (sea ice), 6.28 and TS.20a (ocean surface pH), but includes fewer model scenarios. The reader is referred to the Technical Summary and the Chapters 12 and 6 where all RCP scenarios are given for the respective quantity.

TS.SM.7.1 Global Average Surface Temperature Change (Figure SPM.7a) and Global Ocean Surface pH (Figure SPM.7c)

Step 1 – Analyzed simulations
The simulations considered are annual or monthly mean fields from different model simulations carried out as part of the CMIP5 project (when applicable the variable name as given in the CMIP5 archive is indicated in square brackets). The time series between 1850 and 2005 originate from the historical simulations. The two time series of the future projections are from RCP2.6 and RCP8.5. The box plots showing the change at the end of the century additionally use RCP4.5 end RCP6.0. Table TS.SM.1 lists the models and ensemble simulations used for panels (a) and panel (c). Only one ensemble simulation per model is used. All models are weighted equally except for sea ice (panel (b)) where a subset of models is considered.

Step 2a – Interpolation
For panel (a), the monthly temperature fields [tas] are re-gridded to a 2.5° × 2.5° grid using bilinear interpolation. No special treatment is used at the land-sea border.

For panel (c), the monthly temperature [tos] and salinity [sos] fields are first averaged to yield annual means. Then, annual-mean temperature, salinity, dissolved inorganic carbon [dissic] and alkalinity [talk] fields are re-gridded to a 1° × 1° using bilinear interpolation. For the model MIROC-ESM-CHEM the upper-most layers of the 3-dimensional fields of monthly sea water potential temperature [thetao] and monthly sea water salinity [so] are used.

Step 2b – Derivation of pH
For each model, surface pH was computed from simulated DIC, alkalinity, temperature, and salinity. Before computation each simulated input field was corrected for its decadal mean bias relative to modern observations, using the approach of Orr et al. (2005) and Orr (2011). That is, pH was computed after first removing from each model field, the average difference between the model mean during 1989–1998

Table TS.SM.1 | Models and ensembles used for panels (a) and (c).

Model	Ensemble Member	Historical	RCP2.6	RCP4.5	RCP6.0	RCP8.5
ACCESS1.0	r1i1p1	(a)		(a)		(a)
ACCESS1.3	r1i1p1	(a)		(a)		(a)
BCC-CSM1.1	r1i1p1	(a)	(a)	(a)	(a)	(a)
BCC-CSM1.1(m)	r1i1p1	(a)	(a)	(a)	(a)	
BNU-ESM	r1i1p1	(a)	(a)	(a)		(a)
CanESM2	r1i1p1	(a) (c)	(a) (c)	(a) (c)		(a) (c)
CCSM4	r1i1p1	(a)	(a)	(a)	(a)	(a)
CESM1(BGC)	r1i1p1	(a)		(a)		(a)
CESM1(CAM5)	r1i1p1	(a)	(a)	(a)	(a)	(a)
CMCC-CM	r1i1p1	(a)		(a)		(a)
CMCC-CMS	r1i1p1	(a)		(a)		(a)
CNRM-CM5	r1i1p1	(a)		(a)		(a)
CSIRO-Mk3.6.0	r1i1p1	(a)	(a)	(a)	(a)	(a)
EC-EARTH	r8i1p1	(a)	(a)	(a)		(a)

(continued on next page)

Table TS.SM.1 (continued)

Model	Ensemble Member	Historical	RCP2.6	RCP4.5	RCP6.0	RCP8.5
FGOALS-g2	r1i1p1	(a)	(a)	(a)		(a)
FIO-ESM	r1i1p1	(a)	(a)	(a)	(a)	(a)
GFDL-CM3	r1i1p1	(a)	(a)	(a)	(a)	(a)
GFDL-ESM2G	r1i1p1	(a) (c)	(a) (c)	(a) (c)	(a) (c)	(a) (c)
GFDL-ESM2M	r1i1p1	(a) (c)	(a) (c)	(a) (c)	(a) (c)	(a) (c)
GISS-E2-H	r1i1p1	(a)	(a)	(a)	(a)	(a)
GISS-E2-H	r1i1p2	(a)	(a)	(a)	(a)	(a)
GISS-E2-H	r1i1p3	(a)	(a)	(a)	(a)	(a)
GISS-E2-H-CC	r1i1p1	(a)		(a)		
GISS-E2-R	r1i1p1	(a)	(a)	(a)	(a)	(a)
GISS-E2-R	r1i1p2	(a)	(a)	(a)	(a)	(a)
GISS-E2-R	r1i1p3	(a)	(a)	(a)	(a)	(a)
GISS-E2-R-CC	r1i1p1	(a)		(a)		
HadGEM2-AO	r1i1p1	(a)	(a)	(a)	(a)	(a)
HadGEM2-CC	r1i1p1	(a) (c)		(a) (c)		(a)
HadGEM2-ES	r2i1p1	(a)	(a)	(a)	(a)	(a)
INM-CM4	r1i1p1	(a)		(a)		(a)
IPSL-CM5A-LR	r1i1p1	(a) (c)	(a) (c)	(a) (c)	(a) (c)	(a) (c)
IPSL-CM5A-MR	r1i1p1	(a) (c)	(a) (c)	(a) (c)	(a)	(a) (c)
IPSL-CM5B-LR	r1i1p1	(a) (c)		(a)		(a) (c)
MIROC5	r1i1p1	(a)	(a)	(a)	(a)	(a)
MIROC-ESM	r1i1p1	(a) (c)	(a) (c)	(a) (c)	(a)	(a) (c)
MIROC-ESM-CHEM	r1i1p1	(a) (c)	(a) (c)	(a) (c)	(a) (c)	(a) (c)
MPI-ESM-LR	r1i1p1	(a) (c)	(a) (c)	(a) (c)		(a) (c)
MPI-ESM-MR	r1i1p1	(a) (c)	(a) (c)	(a) (c)		(a) (c)
MRI-CGCM3	r1i1p1	(a)	(a)	(a)	(a)	(a)
NorESM1-M	r1i1p1	(a)	(a)	(a)	(a)	(a)
NorESM1-ME	r1i1p1	(a) (c)	(a)	(a) (c)	(a)	(a)

and the observational reference. For observed fields, the GLODAP gridded data product (Key et al., 2004) for DIC and alkalinity along with the 2009 World Ocean Atlas climatology for temperature, salinity, and concentrations of phosphate and silica (Locarnini et al., 2010; Antonov et al., 2010; Garcia et al., 2010) were used. Changes to the concentrations of phosphate and silica were assumed to be zero, because not all models provided those variables. pH was computed using routines based on the standard OCMIP carbonate chemistry adapted for earlier studies (Orr, 2011) to compute all carbonate system variables and use recommended constants from the Guide to Best Practices for Ocean CO_2 Measurements (Dickson et al., 2007).

Step 3 – Global and annual mean

The monthly (temperature) or annual (pH) surface fields are averaged (weighted by the cosine of the latitude) to obtain the global mean values. The monthly global mean temperature values are averaged to annual means.

Step 4 – Reference period

The average from 1986 to 2005 of the annual means for each model is computed and is subtracted from the respective model time series to obtain the corresponding temperature anomalies.

Step 5 – Mean and standard deviation

The mean and standard deviation over all the models is calculated. For the time period after 2006 all the possible models that are listed in Table TS.SM.1 are used. If a model provided several RCPs based on the same historical simulation, that historical simulation is counted only once.

Step 6 – Uncertainty estimates

First, for each model the average from 2081 to 2100 is computed from the above mentioned time series. Then, in a second step, the multi-model average and standard deviation over all model averages are calculated. The *likely* ranges on the right of the figure show the mean plus/minus 1.64 times the standard deviation across the model averages. The shading on the time series indicates the mean value plus/minus 1.64 times the standard deviation across the models for each year.

Step 7 – Graphical display

To close the multi-model mean time series at the year 2005 when the historical simulation ends and the RCP begins, the value at year 2005 is assigned to belong to both the historical time series and also to the corresponding RCP.

TS.SM.7.2 Northern Hemisphere September Sea Ice Extent – Figure SPM.7b

Step 1 – Analyzed simulations

Table TS.SM.2 provides the model and RIP ensemble member included from each RCP to create the multi-model mean time series of the NH September sea ice extent [sic] shown in Figure SPM.7b. In most cases, the first ensemble member (r1i1p1) was used. A selection algorithm produces a subset of models that most closely match observations, and is detailed below. The corresponding historical ensemble member is catenated with the respective RCP scenario ensemble member to create a continuous time series from 1850–2100.

Step 2 – Time series of NH September sea ice extent

Using the sea ice concentration field, a mask of the sea ice concentration >15% for each month of data for the Northern Hemisphere was created. For each month, the sea ice extent is the sum of the area of the ocean [areacello] times the ocean fraction [sftof] times the mask of sic >15% at each grid point. The time series are computed on the original model grids, which is usually the ocean grid. In some cases,

Table TS.SM.2 | Models and ensemble members used.

Model	Ensemble Member	RCP2.6	Historical/RCP4.5	RCP6.0	RCP8.5
ACCESS1.0	r1i1p1		x		x
ACCESS1.3	r1i1p1		x		x
BCC-CSM1.1	r1i1p1	x	x	x	x
BCC-CSM1.1(m)	r1i1p1	x	x	x	x
BNU-ESM	r1i1p1	x	x		x
CanESM2	r1i1p1	x	x		x
CCSM4	r1i1p1	x	x	x	x
CESM1(BGC)	r1i1p1		x		x
CESM1(CAM5)	r1i1p1	x	x	x	x
CESM1(WACCM)	r2i1p1	x	x		x
CMCC-CM	r1i1p1		x		x
CMCC-CMS	r1i1p1		x		x
CNRM-CM5	r1i1p1	x	x		x
CSIRO-Mk3.6.0	r1i1p1	x	x	x	x
EC-EARTH	r1i1p1		x		x
	r8i1p1	x			
FGOALS-g2	r1i1p1	x	x		x
FIO-ESM	r1i1p1	x	x	x	x
GFDL-CM3	r1i1p1	x	x	x	x
GFDL-ESM2G	r1i1p1	x	x	x	x
GFDL-ESM2M	r1i1p1	x	x	x	x
GISS-E2-H	r1i1p1	x	x	x	x
GISS-E2-H-CC	r1i1p1		x		
GISS-E2-R	r1i1p1	x	x	x	x
GISS-E2-R-CC	r1i1p1		x		
HadGEM2-AO	r1i1p1	x	x	x	x
HadGEM2-CC	r1i1p1		x		x
HadGEM2-ES	r2i1p1	x	x	x	x
INM-CM4	r1i1p1		x		x
IPSL-CM5A-LR	r1i1p1	x	x	x	x
IPSL-CM5A-MR	r1i1p1	x	x	x	x
IPSL-CM5B-LR	r1i1p1		x		x
MIROC5	r1i1p1	x	x	x	x
MIROC-ESM	r1i1p1	x	x	x	x
MIROC-ESM-CHEM	r1i1p1	x	x	x	x
MPI-ESM-LR	r1i1p1	x	x		x
MPI-ESM-MR	r1i1p1	x	x		x
MRI-CGCM3	r1i1p1	x	x	x	x
NorESM1-M	r1i1p1	x	x	x	x
NorESM1-ME	r1i1p1	x	x	x	x

sea ice concentration is on the atmospheric grid. In cases where the grid area was not available for regular grids, a regular lat-lon grid was constructed based on the grid dimensions following

areacello=((dlat*2π/360)*R_earth) .* ((dlon*2 π/360).*(R_earth*-cos(LAT))),

with R_earth being the radius of Earth (6,371,000 m), dlat and dlon being the differentials in lat/lon in each dimension, and LAT being the latitude in radians.

If the ocean fraction was unavailable, it was assumed that the ocean fraction was 1 where the sea ice concentration was greater than 0%.

Step 3 – Create multi-model mean time series
The multi-model mean time series of sea ice extent is computed across all model members in Table TS.SM.2. A five-year running mean is applied to this time series. This is plotted as the dotted line in the figure. Some time series start later than 1850 or end earlier than 2100, and these are treated as missing values for those years.

Step 4 – Select models that most closely match observations
The selection process is done in a series of steps which compare the models to observed/reanalyzed data. This selection process is based on the underlying assessment of Chapter 12 and referenced therein. The method proposed by Massonnet et al. (2012) is applied here to the full set of models that provided sea ice output fields to the CMIP5 database. For the model selection, all available ensemble members are used for all of the models that provide simulations for Historical and RCP4.5. These ensemble members are listed in Table TS.SM.3.

Four diagnostics from the models are compared to the same quantities in observations or reanalyses. The diagnostics are: (a) September Arctic sea ice extent (1986–2005), (b) Annual mean Arctic sea ice volume (1986–2005), (c) Amplitude of the seasonal cycle of Arctic sea ice extent (1986–2005), and (d) Trend in September Arctic sea ice extent (1979–2012). Computation of each diagnostic is described and then the method for comparison is described below.

Step 4a – Computation of diagnostic quantities
(a) Sea ice extent is computed for each model ensemble member as outlined above to get the total area where sea ice concentration is >15%. For each ensemble member, an average September sea ice extent is then computed for the years 1986–2005. Observations for sea ice extent use the monthly mean sea ice extents from Comiso and Nishio (2008, updated 2012). The observations were computed in the same way as in the models (i.e., these are the monthly mean extents computed from the observed monthly mean sea ice concentration).

(b) Sea ice volume is computed as the sum of the sea ice thickness field [sit] times the ocean area [areacello] times the ocean fraction [sftof], since the sea ice thickness is given as thickness averaged over the entire ocean grid cell. Caveats for the grids are the same as discussed in Step 2 above. The time series of monthly sea ice volume for each ensemble member is then annually averaged for the period 1986–2005. The bias-adjusted PIOMAS (Pan-Arctic Ice-Ocean Modelling and Assimilation System) reanalysis data (Schweiger et al., 2011) is used to provide estimates for sea ice volume for comparison to the models.

(c) The amplitude of the seasonal cycle of Arctic sea ice extent is computed for each model from a climatology of monthly sea ice extent for 1986–2005. The amplitude is the difference between the maximum (March) and minimum (September) sea ice extent for each model ensemble member. Amplitude of seasonal cycle for observations are computed in the same way from Comiso and Nishio (2008, updated 2012).

(d) The linear trend in September sea ice extent is computed for the period 1979–2012. Again observations are taken from Comiso and Nishio (2008, updated 2012).

Step 4b – Estimation of natural variability for model ensembles
For models with multiple ensemble members, a standard deviation is computed for each of the diagnostics for each ensemble member. Then the mean of all the standard deviations is computed, and using this value, a ±2 standard deviation interval is constructed around the ensemble mean or single realization of each diagnostic for each model.

Step 4c – Model selection - Comparison of modeled diagnostics to observed/reanalyzed diagnostic
For each of the observed/reanalyzed diagnostics, a ±–20% interval is constructed around the mean value for the given period. A model is retained in the selection if, for each diagnostic, either the ±2 standard deviation around the model ensemble mean diagnostic overlaps the ±20% interval around the observed/reanalysed value of the diagnostic OR at least one ensemble member from that model gives a value for the diagnostic that falls within ±20% of the observed/reanalysed data. A model is selected only if all four diagnostic values meet this criterion.

Results of the selection
The model diagnostics are calculated using RCP4.5 which has the largest number of models. Five models are selected by this process: ACCESS1.0, ACCESS1.3, GFDL-CM3, IPSL-CM5A-MR, MPI-ESM-MR, and all five models have simulations for both RCP8.5 and RCP4.5. For RCP2.6 only three of this subset have simulations (GFDL-CM3, IPSL-CM5A-MR, MPI-ESM-MR), and for RCP6.0, only two models have simulations (GFDL-CM3, IPSL-CM5A-MR).

Step 5 – Time series of sea ice extent for the selected models
The multi-model mean time series of September sea ice extent is calculated for the selected models. The solid line shows the multi-model mean smoothed with a five-year running mean, and the shading represents the minimum and maximum range of the selected model time series, also smoothed by the same five year running mean.

The shaded bars on the right are the multi-model mean and the mean of the maximum and minimum range for the selected models for the period 2081–2100.

Table TS.SM.3 | Models and ensembles used for model selection, RCP4.5.

Model	Ensemble Member RCP4.5
ACCESS1.0	r1i1p1
ACCESS1.3	r1i1p1
BCC-CSM1.1	r1i1p1
BCC-CSM1.1(m)	r1i1p1
BNU-ESM	r1i1p1
CanESM2	r1i1p1 r2i1p1 r3i1p1 r4i1p1 r5i1p1
CCSM4	r1i1p1 r2i1p1 r3i1p1 r4i1p1 r5i1p1 r6i1p1
CESM1(BGC)	r1i1p1
CESM1(CAM5)	r1i1p1 r2i1p1 r3i1p1
CESM1(WACCM)	r2i1p1
CMCC-CM	r1i1p1
CMCC-CMS	r1i1p1
CNRM-CM5	r1i1p1
CSIRO-Mk3.6.0	r1i1p1 r2i1p1 r3i1p1 r4i1p1 r5i1p1 r6i1p1 r7i1p1 r8i1p1 r9i1p1 10i1p1
EC-EARTH	r1i1p1 r2i1p1 r3i1p1 r6i1p1 r7i1p1 r8i1p1 r9i1p1 10i1p1 11i1p1 12i1p1 13i1p1 14i1p1
FGOALS-g2	r1i1p1
FIO-ESM	r1i1p1 r2i1p1 r3i1p1
GFDL-CM3	r1i1p1 r3i1p1 r5i1p1
GFDL-ESM2G	r1i1p1
GFDL-ESM2M	r1i1p1
GISS-E2-H	r1i1p1 r2i1p1 r3i1p1 r4i1p1 r5i1p1
GISS-E2-H-CC	r1i1p1
GISS-E2-R	r1i1p1 r2i1p1 r3i1p1 r4i1p1 r5i1p1 r6i1p1
GISS-E2-R-CC	r1i1p1
HadGEM2-AO	r1i1p1
HadGEM2-CC	r1i1p1
HadGEM2-ES	r2i1p1 r3i1p1 r4i1p1
INM-CM4	r1i1p1
IPSL-CM5A-LR	r1i1p1 r2i1p1 r3i1p1 r4i1p1
IPSL-CM5A-MR	r1i1p1
IPSL-CM5B-LR	r1i1p1
MIROC5	r1i1p1 r2i1p1 r3i1p1
MIROC-ESM	r1i1p1
MIROC-ESM-CHEM	r1i1p1
MPI-ESM-LR	r1i1p1 r2i1p1 r3i1p1
MPI-ESM-MR	r1i1p1 r2i1p1 r3i1p1
MRI-CGCM3	r1i1p1
NorESM1-M	r1i1p1
NorESM1-ME	r1i1p1

TS.SM.8 Notes and Technical Details on Maps Showing CMIP5 Results in the Summary for Policymakers – Figure SPM.8

This material documents the provenance of the data and plotting procedures that were used to create Figure SPM.8, based on CMIP5 model results as of March, 2013. This figure is closely derived from Figures 12.11 and TS.15 (global average surface temperature), TS.16 (precipitation), 12.29 and TS.17 (sea ice), 6.28 and TS.20b (ocean surface pH), but includes fewer model scenarios. The reader is referred to the Technical Summary or the Chapters 12 and 6 where all RCP scenarios are given for the respective quantity.

TS.SM.8.1 Change in Average Surface Temperature (Figure SPM.8a) and Change in Average Precipitation (Figure SPM.8b)

Step 1 – Analyzed simulations

The simulations considered are monthly mean fields of surface temperature [tas] and precipitation [pr] from different model simulations carried out as part of the CMIP5 project (when applicable the variable name as given in the CMIP5 archive is indicated in square brackets). Table TS.SM.4 lists the models and ensemble members used for these panels. Only one ensemble member per model is used.

Step 2 – Interpolation

In a first step the monthly fields are re-gridded to a 2.5° × 2.5° grid using bilinear interpolation. No special treatment is used at the land-sea border.

Step 3 – Annual average and period

The monthly mean values are averaged to annual means. Then in a second step the time mean is computed over the 20-year period of interest.

Table TS.SM.4 | Models and ensemble members used.

Model	Ensemble Member	RCP2.6	Historical/RCP4.5	RCP6.0	RCP8.5
ACCESS1.0	r1i1p1		x		x
ACCESS1.3	r1i1p1		x		x
BCC-CSM1.1	r1i1p1	x	x	x	x
BCC-CSM1.1(m)	r1i1p1	x	x	x	
BNU-ESM	r1i1p1	x	x		x
CanESM2	r1i1p1	x	x		x
CCSM4	r1i1p1	x	x	x	x
CESM1(BGC)	r1i1p1		x		x
CESM1(CAM5)	r1i1p1	x	x	x	x
CMCC-CM	r1i1p1		x		x
CMCC-CMS	r1i1p1		x		x
CNRM-CM5	r1i1p1		x		x
CSIRO-Mk3.6.0	r1i1p1	x	x	x	x
EC-EARTH	r8i1p1	x	x		x
FGOALS-g2	r1i1p1	x	x		x
FIO-ESM	r1i1p1	x	x	x	x
GFDL-CM3	r1i1p1	x	x	x	x
GFDL-ESM2G	r1i1p1	x	x	x	x
GFDL-ESM2M	r1i1p1		x	x	x
GISS-E2-H	r1i1p1	x	x	x	x
GISS-E2-H	r1i1p2	x	x	x	x
GISS-E2-H	r1i1p3	x	x	x	x
GISS-E2-H-CC	r1i1p1		x		
GISS-E2-R	r1i1p1	x	x	x	x
GISS-E2-R	r1i1p2	x	x	x	x
GISS-E2-R	r1i1p3	x	x	x	x
GISS-E2-R-CC	r1i1p1		x		
HadGEM2-AO	r1i1p1	x	x	x	x
HadGEM2-CC	r1i1p1		x		x
HadGEM2-ES	r2i1p1	x	x	x	x
INM-CM4	r1i1p1		x		x
IPSL-CM5A-LR	r1i1p1	x	x	x	x
IPSL-CM5A-MR	r1i1p1	x	x	x	x
IPSL-CM5B-LR	r1i1p1		x		x
MIROC5	r1i1p1	x	x	x	x
MIROC-ESM	r1i1p1	x	x	x	x
MIROC-ESM-CHEM	r1i1p1	x	x	x	x
MPI-ESM-LR	r1i1p1	x	x		x
MPI-ESM-MR	r1i1p1	x	x		x
MRI-CGCM3	r1i1p1	x	x	x	x
NorESM1-M	r1i1p1	x	x	x	x
NorESM1-ME	r1i1p1	x	x	x	x

Step 4 – Time average and anomalies
The average from 1986 to 2005 of the annual means for each model is computed as the reference value and the annual mean from 2081 to 2100 are computed as the future period for the two RCPs. For each model the reference value is then subtracted from the future period value.

Step 5 – Calculation of the significance

Step 5a – Natural variability
To compute the natural variability all the models that provide more than 500 years of pre-industrial control simulation [piControl] are used. A list of these models is given in Table TS.SM.5. For each model the first 100 years are discarded to minimize problems with model initialization. Re-gridding and calculation of annual means is done as described in steps 2 and 3. The control runs are divided into 20-year non-overlapping periods. If the available data are not a multiple of 20-year the remaining years after the last 20-year period are not used in the calculation.

Averages over the 20-year periods are computed for every grid point. A quadratic trend is subtracted from this time series of 20-year averaged periods to remove potential model drift at each grid point. Finally for each model the standard deviation is computed over the different 20-year periods and for each grid point.

To obtain the final value of the natural variability the median of the standard deviations of the different models is multiplied with the square root of 2 (the natural variability characterizes the typical difference between two 20-year periods, rather than the difference of one period from the long-term mean, the former being larger than the latter by the square root of two).

Table TS.SM.5 | Models and ensemble members from the piControl experiments used for the calculation of the natural variability.

Model	Ensemble Member
ACCESS1.0	r1i1p1
ACCESS1.3	r1i1p1
BCC-CSM1.1	r1i1p1
BNU-ESM	r1i1p1
CanESM2	r1i1p1
CCSM4	r1i1p1
CESM1(BGC)	r1i1p1
CMCC-CMS	r1i1p1
CNRM-CM5	r1i1p1
CSIRO-Mk3-6-0	r1i1p1
FGOALS-g2	r1i1p1
FIO-ESM	r1i1p1
GFDL-CM3	r1i1p1
GFDL-ESM2G	r1i1p1
GFDL-ESM2M	r1i1p1
GISS-E2-H	r1i1p2
GISS-E2-H	r1i1p3
GISS-E2-R	r1i1p2
GISS-E2-R	r1i1p3
INM-CM4	r1i1p1
IPSL-CM5A-LR	r1i1p1
MIROC5	r1i1p1
MIROC-ESM	r1i1p1
MPI-ESM-LR	r1i1p1
MPI-ESM-MR	r1i1p1
MPI-ESM-P	r1i1p1
MRI-CGCM3	r1i1p1
NorESM1-M	r1i1p1

Step 5b – Testing for significance
For each model the projected change is taken relative to its reference period and then the multi-model average at every grid point is computed. In a second step, at each grid point the number of models with positive and negative change are counted.

If more than 90% of the models agree on the sign of the change and the multi-model mean change is larger than 2 times the natural variability (as defined above) this grid point is said to be significant and robust across models.

Step 5c – Check for non-significance
Again, for each model the projected change is taken relative to the reference period and then the multi-model average at every grid point is computed.

If the multi-model mean change at one grid point is less than the natural variability (as defined above) the value is said to be non-significant.

Step 6 – Graphical display
For each model the projected change is taken relative to the reference period and then the multi-model average at every grid point is computed. The locations that are significant and robust (as described in step 5b) are marked by small black dots and the locations that are non-significant (as described in step 5c) are marked by hatching.

For panel b, all calculations are performed as absolute changes. To show the relative changes, the multi-model mean precipitation change is divided by the multi-model mean of the reference period.

TS.SM.8.2 Northern Hemisphere September Sea Ice Extent (Figure SPM.8c)

Step 1 – Analyzed simulations and subset of models
The simulations analyzed here are the same as those listed for Figure SPM.7b. The subset of models are the same that are selected for Figure SPM.7b outlined in the following Step 4. Only one ensemble member from each model is used to create these figures.

Step 2 – Computation of mean sea ice concentration
For each model ensemble member, the mean sea ice concentration [sic] is calculated for the two periods, 1986–2005 and 2081–2100, on the native model grid (see also recipe for Figure SPM.7b).

Step 3 – Regrid sea ice concentration to common grid
SOSIE (http://sosie.sourceforge.net/) is used to regrid the mean sea ice concentration to a common 1° × 1° grid, applying the bilinear

interpolation scheme (SOSIE: cmethod = 'bilin'). Further, the regridded sea ice concentrations are 'drowned' across the land-sea boundary to eliminate low-biased interpolated values in the area of land-sea transition (SOSIE: ldrown = T). With this approach, interpolation artifacts can occur throughout the Canadian Archipelago, since each model represents this area quite differently. Comparison of individual models on their native grid allows to identify and mask such areas. Note that, for these reasons the interpolated sea ice concentrations shall not be used for quantitative interpretation, but only for visualization purposes. For visualization the MATLAB land-ocean mask is overlaid.

Step 4 – Calculate multi-model mean sea ice concentration
For each RCP, RCP2.6 and RCP8.5, and each period, 1986–2005 and 2081–2100, the mean sea ice concentration is calculated in each grid cell on the common grid. The same is done for the subset of models for each period. For RCP2.6 this subset is GFDL-CM3, IPSL-CM5A-MR, MPI-ESM-MR. For RCP8.5 this subset is ACCESS1.0, ACCESS1.3, GFDL-CM3, IPSL-CM5A-MR, MPI-ESM-MR.

Step 5 – Contour the multi-model mean sea ice concentration of 15%
The multi-model mean sea ice concentration is contoured at 15% according to the following:

1986–2005: multi-model mean all models: white line
1986–2005: subset models: light blue line
2081–2100: multi-model mean all models: white filled patch
2081–2100: subset models: light blue filled patch

Note for RCP8.5 there is no sea ice concentration >15% for the subset of models.

The decision was taken to contour the 15% contour of mean sea ice concentration to make this figure consistent with Figure 12.29, which shows a contour plot of the multi-model mean sea ice concentrations. It is also possible to make binary fields of sea ice concentration >15%, take the mean of those binary fields (for both 20 year averages and then in multi-model averages), and contour the 50% contour of the mean binary field as the mean sea ice extent. This option was not chosen here.

TS.SM.8.3 Change in Ocean Surface pH (Figure SPM.8d)

Step 1 – Analyzed simulations
The simulations considered are annual or monthly mean fields from different model simulations carried out as part of the CMIP5 project (when applicable the variable name as given in the CMIP5 archive is indicated in square brackets). Table TS.SM.6 lists the models and ensemble members used for these panels. Only one ensemble member per model is used.

Step 2a – Interpolation
In a first step, the monthly temperature [tos] and salinity [sos] fields are first averaged to yield annual means. For the model MIROC-ESM-CHEM the upper-most layer of the 3-dimensional fields of monthly sea water potential temperature [thetao] and monthly sea water salinity [so] are used. Then, annual-mean temperature, salinity, dissolved inorganic carbon [dissic] and alkalinity [talk] fields are re-gridded to a 1° × 1° using bilinear interpolation.

Step 2b – Derivation of pH
For each model, surface pH was computed from simulated DIC, alkalinity, temperature, and salinity. Before computation each simulated input field was corrected for its decadal mean bias relative to modern observations, using the approach used in Orr et al. (2005) and Orr (2011). That is, pH was computed after first removing from each model field, the average difference between the model mean during 1989–1998 and the observational reference. For observed fields, we used the GLODAP gridded data product (Key et al., 2004) for DIC and alkalinity along with the 2009 World Ocean Atlas climatology for temperature, salinity, and concentrations of phosphate and silica (Locarnini et al., 2010; Antonov et al., 2010; Garcia et al., 2010). Changes to the concentrations of phosphate and silica were assumed to be zero, because all models did not provide those variables. pH was computed using routines based on the standard OCMIP carbonate chemistry adapted for earlier studies (Orr, 2011) to compute all carbonate system variables and use recommended constants from the Guide to Best Practices for Ocean CO_2 Measurements (Dickson et al., 2007).

Step 3 – Average of 20-year period
The time mean is computed over the 20-year period of interest.

Table TS.SM.6 | Models and ensemble members used.

Model	Ensemble Member	Historical	RCP2.6	RCP4.5	RCP6.0	RCP8.5
CanESM2	r1i1p1	d	d	d		d
GFDL-ESM2G	r1i1p1	d	d	d	d	d
GFDL-ESM2M	r1i1p1	d	d	d	d	d
HadGEM2-CC	r1i1p1	d		d		d
IPSL-CM5A-LR	r1i1p1	d	d	d	d	d
IPSL-CM5A-MR	r1i1p1	d	d	d		d
IPSL-CM5B-LR	r1i1p1	d		d		d
MIROC-ESM	r1i1p1	d	d	d	d	d
MIROC-ESM-CHEM	r1i1p1	d	d	d	d	d
MPI-ESM-LR	r1i1p1	d	d	d		d
MPI-ESM-MR	r1i1p1	d	d	d		d
NorESM1-ME	r1i1p1	d		d		

Step 4 – Time average and anomalies
The average from 1986 to 2005 of the annual means for each model is computed as the reference value and the annual mean from 2081 to 2100 is computed as the future period for the two RCPs. For each model the reference value is then subtracted.

Step 5 – Graphical display
For each model the projected change is taken relative to the reference period and the multi-model mean at every grid point is computed.

TS.SM.9 Notes and Technical Details on the Sea Level Projection Figure for the Summary for Policymakers – Figure SPM.9

A full and comprehensive description of the methods used in the projections of global mean sea level for the 21st century is provided in the Supplementary Material to Chapter 13 (see Section 13.SM.1). Further plotting details used to produce Figure SPM.9, and the related Figure TS.22 are provided here.

TS.SM.9.1 Projected Global Mean Sea Level Rise

Projections are given from process-based models of global mean sea level rise relative to 1986–2005 for the four emissions scenarios RCP2.6, RCP4.5, RCP6.0 and RCP8.5.

The *likely* range for each RCP timeseries is delimited by the data in files rcpXX_sumlower and rcpXX_sumupper, while the median timeseries is the data in file rcpXX_summid, where 'XX' stands for the respective RCP scenario. These data files are available from the WGI AR5 website www.climatechange2013.org. The coloured vertical bars with horizontal lines for the four RCP scenarios indicate the *likely* ranges and medians for these scenarios as given in Table 13.5 of Chapter 13.

Note that in Figure SPM.9, projected time series are shown only for RCP2.6 and RCP8.5. Figure TS.22 include time series for all four RCP scenarios.

Projected contributions to sea level rise in 2081–2100 relative to 1986–2005 for the four RCP scenarios are provided in Figure TS.21.

TS.SM.10 Notes and Technical Details on the Summary for Policymakers Figure Plotting Global Mean Temperature Increase as a Function of Cumulative Total Global CO_2 Emissions – Figure SPM.10

Figure SPM.10 contains data from CO_2 only simulations and the RCP simulations. This figure is closely derived from TS TFE.8, Figure 1. CO_2 only simulations are represented by grey-shaded patches and thin black lines, RCP data by coloured lines and patches. CMIP5 results are taken from the archive as of March 15, 2013. Note that the thick black line represents the historical time period of the RCP runs.

TS.SM.10.1 Part A – CO_2 Only Runs

The thin black line represents the multi-model mean of the decadal averaged global-mean temperature response of the models listed in Table TS.SM.7 to a global 1% CO_2 only forcing increase as performed as part of CMIP5, as a function of the decadal averaged global-mean diagnosed carbon emissions.

The dark grey patch represents the 90% range surrounding the decadal averaged model response of the CMIP5 models listed in Table TS.SM.7 and is calculated as follows: Diagnosed carbon emissions and temperature response data of the above-defined CMIP5 models (computed as in Gillett et al., 2013) is scaled, respectively, by dividing by the standard deviation over all available decadal-averaged data points for a specific scenario. The 90% range is computed in polar coordinates. The radius stretches along the x-axis (cumulative emissions) and the angle is the one between the slope from (0, 0) to a respective scaled point (cumulative emissions, temperature anomaly) and the x-axis. For each scaled point the radius and angle are computed. A number of n (n = 20) segments are defined by regularly spaced steps along the maximum radius of all available decadal-averaged data points of a specific scenario (scaled as described earlier). From all points that fall within the boundaries of each respective radius segment, the 5th and 95th percentiles in terms of available angles is computed. These percentiles are then assigned to the radius corresponding to the middle of the current radius segment. Each of these mid-segment radii and its corresponding pair of angles are then transformed back to Cartesian coordinates. Finally, the 90% range is drawn by connecting all 5th and 95th percentile points of a specific scenario in a hull.

Table TS.SM.7 | Models that were included in the shown results of the CO2 only 1% increase CMIP5 runs (dark grey patch and thin black line).

Model	Ensemble Member
GFDL-ESM2G	r1i1p1
INM-CM4	r1i1p1
GFDL-ESM2M	r1i1p1
IPSL-CM5B-LR	r1i1p1
BCC-CSM1.1	r1i1p1
MPI-ESM-MR	r1i1p1
IPSL-CM5A-MR	r1i1p1
IPSL-CM5A-LR	r1i1p1
MPI-ESM-LR	r1i1p1
NorESM1-ME	r1i1p1
CESM1(BGC)	r1i1p1
HadGEM2-ES	r1i1p1
MIROC-ESM	r1i1p1
CanESM2	r1i1p1
BNU-ESM	r1i1p1

TS.SM.10.2 Part B – RCP Runs

Data of the RCP runs (coloured lines and patches) is prepared with the same methodology as the data for the CO_2 only runs as described in the previous section. Note that markers show decadal time steps, and that the labels in Figure SPM.10 (and TS TFE.8, Figure 1) denote the cumulative global carbon emissions from 1870 until (but not including) that year (i.e., label 2050 is placed next to the marker of the 2040–2049 decade). The 90% range is computed for n (n = 12) regularly spaced steps along the maximum radius available for each RCP (scaled as described earlier). Available Earth System Models (ESM) for the respective RCP are listed in Table TS.SM.8, available Earth System Models of Intermediate Complexity (EMIC) in Table TS.SM.9.

Following operations are carried out onto the data:

- Decadal means of global-mean temperature change are computed relative to the 1861–1880 base period.
- Emissions from the ESMs for the different scenarios are computed as in Jones et al. (2013).
- Land-use change emission estimated for each RCP are added to all EMICs, and to the ESMs that diagnose fossil-fuel emission only (see Table TS.SM.8). Land-use change emissions are obtained from http://www.pik-potsdam.de/~mmalte/rcps/ for each RCP, respectively. Note that the data for Figure SPM.10 provided at the external sources cited above may be subject to changes in the future by the owners. Furthermore, no guarantee is provided that the weblinks cited above remain active.
- Decadal-mean cumulative emissions are computed from cumulative carbon emissions relative to 1870.
- Each RCP range is drawn as long as data is available for all models or until temperatures have peaked. The encompassing range shown in Figure SPM.10 (and TS TFE.8, Figure 1) is constructed by connecting the outer last points of each single RCP range and is filled as long as data are available for all models for RCP8.5. Beyond this point, the range is illustratively extended by further progressing along the radius while keeping the angles fixed at those available at the last point with data from all models for RCP8.5. The fading out of the range is illustrative.

Table TS.SM.8 | Overview of RCP model runs available in the CMIP5 archive, as used in Figure SPM.10 (and TS TFE.8, Figure 1).

Model	Ensemble Member	RCP2.6	RCP4.5	RCP6.0	RCP8.5
BCC-CSM1.1	r1i1p1	x*	x*	x*	x*
CanESM2	r1i1p1	x	x		x
CESM1(BGC)	r1i1p1		x		x
GFDL-ESM2G	r1i1p1	x	x	x	x
GFDL-ESM2M	r1i1p1	x	x	x	x
HadGEM2-CC	r1i1p1		x		x
HadGEM2-ES	r2i1p1	x	x	x	x
INM-CM4	r1i1p1		x*		x*
IPSL-CM5A-LR	r1i1p1	x	x	x	x
IPSL-CM5A-MR	r1i1p1	x	x		x
IPSL-CM5B-LR	r1i1p1		x		x
MIROC-ESM	r1i1p1	x	x	x	x
MIROC-ESM-CHEM	r1i1p1	x	x	x	x
MPI-ESM-LR	r1i1p1	x	x		x
NorESM1-ME	r1i1p1	x	x	x	x

Notes:
* runs do not include explicit land-use change modelling. Models diagnose fossil-fuel and land-use change emissions jointly and therefore do not require adding land-use change emissions.

Table TS.SM.9 | Overview of EMIC RCP model runs from (Eby et al. 2013; Zickfeld et al. 2013), as used in Figure SPM.10 (and TS TFE.8, Figure 1). EMICs output is available from http://www.climate.uvic.ca/EMICAR5.

Model	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Bern3D	x	x	x	x
DCESS	x	x	x	x
GENIE	x	x	x	x
IGSM	x	x	x	x
UVic	x	x	x	x

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