Appendix 3.A:
Notes and Technical Details on Chapter 3 Figures

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3.A.1. Figure 3-1

Figure 3-1 provides the definition of the regions used for the computations in Figures 3-5 and 3-7, as well as for the assessments in Tables 3-2 and 3-3. The regions are all defined as polygons. Table 3.A-1 provides the coordinates (latitude, longitude) of the respective regions.

3.A.2. Figure 3-2

Figure 3-2 is reproduced from Zwiers et al. (2011). Graphical elements in the figure were modified to improve readability.

3.A.3. Figure 3-3

Figure 3-3 is adapted from Figure 3 of Orlowsky and Seneviratne (2011), using the Robinson map projection and modified color scales and stippling to improve readability.

3.A.4. Figure 3-4

Figure 3-4 is adapted from Figure 4 of Orlowsky and Seneviratne (2011), using the Robinson map projection and modified color scales and stippling to improve readability.

3.A.5 Figure 3-5

Figure 3-5 is based on Figure 9 of Kharin et al. (2007). The difference to the original figure is that Figure 3-5 uses aggregated values over the regions defined in Figure 3-1 of Chapter 3 (see Section 3.A.1) as well as for the global land regions (Steps 7 and 11 below), and that it considers additional scenarios (B1 and A2) as well as an additional time frame (2081-2100). Furthermore, it also provides analyses for the global land regions of changes in annual mean daily maximum temperature over the same time periods and for the same emission scenarios (Step 8 below).

Extreme value statistics are aggregated over land grid boxes only. The land area fraction on the 256x128 Gaussian grid is taken from the NCAR-CCSM3 model. A grid box is considered to be land if the land area fraction exceeds 25%. A grid box is assumed to be completely inside a region if its center is located inside of the region boundaries.

Analyzed Model Simulations

Step 1 – The analyzed simulations originate from the Coupled Model Intercomparison Project 3 Multi-Model Ensemble (CMIP3 MME, see Section 3.2.3.3). Daily maximum temperatures simulated by 12 Global Climate Models (GCMs) for the 20th century (20C3M simulations) for 1981-2000, and under the B1, A1B, and A2 forcing scenarios for the 2046-2065 and 2081-2100 periods have been used in the production of

Table 3.A-1 | Coordinates of corners of regions displayed in Figure 3-1.

Region Label and Number		Coordinates (Latitude [°], Longitude [°]) of Region Corners
ALA	1	(60.000N, 105.000W) (60.000N, 168.022W) (72.554N, 168.022W) (72.554N, 105.000W)
AMZ	7	(20.000S, 66.377W) (1.239S, 79.729W) (11.439N, 68.800W) (11.439N, 50.000W) (20.000S, 50.000W)
CAM	6	(11.439N, 68.800W) (1.239S, 79.729W) (28.566N, 118.323W) (28.566N, 90.315W)
CAS	20	(30.000N, 60.000E) (50.000N, 60.000E) (50.000N, 75.000E) (30.000N, 75.000E)
CEU	12	(45.000N, 10.000W) (48.000N, 10.000W) (61.320N, 40.000E) (45.000N, 40.000E)
CGI	2	(50.000N, 10.000W) (50.000N, 105.000W) (85.000N, 105.000W) (85.000N, 10.000W)
CNA	4	(50.000N, 85.000W) (28.566N, 85.000W) (28.566N, 105.000W) (50.000N, 105.000W)
EAF	16	(11.365S, 25.000E) (15.000N, 25.000E) (15.000N, 51.990E) (11.365S, 51.990E)
EAS	22	(20.000N, 100.000E) (50.000N, 100.000E) (50.000N, 145.000E) (20.000N, 145.000E)
ENA	5	(25.000N, 60.000W) (25.000N, 85.000W) (50.000N, 85.000W) (50.000N, 60.000W)
MED	13	(30.000N, 10.000W) (45.000N, 10.000W) (45.000N, 40.000E) (30.000N, 40.000E)
NAS	18	(50.000N, 40.000E) (70.000N, 40.000E) (70.000N, 180.000E) (50.000N, 180.000E)
NAU	25	(30.000S, 110.000E) (10.000S, 110.000E) (10.000S, 155.000E) (30.000S, 155.000E)
NEB	8	(20.000S, 34.000W) (20.000S, 50.000W) (0.000N, 50.000W) (0.000N, 34.000W)
NEU	11	(48.000N, 10.000W) (75.000N, 10.000W) (75.000N, 40.000E) (61.320N, 40.000E)
SAF	17	(35.000S, 10.000W) (11.365S, 10.000W) (11.365S, 51.990E) (35.000S, 51.990E)
SAH	14	(15.000N, 20.000W) (30.000N, 20.000W) (30.000N, 40.000E) (15.000N, 40.000E)
SAS	23	(5.000N, 60.000E) (30.000N, 60.000E) (30.000N, 100.000E) (20.000N, 100.000E) (20.000N, 95.000E) (5.000N, 95.000E)
SAU	26	(50.000S, 110.000E) (30.000S, 110.000E) (30.000S, 180.000E) (50.000S, 180.000E)
SSA	10	(20.000S, 39.376W) (56.704S, 39.376W) (56.704S, 67.348W) (50.000S, 72.141W) (20.000S, 66.377W)
SEA	24	(10.000S, 95.000E) (20.000N, 95.000E) (20.000N, 155.000E) (10.000S, 155.000E)
TIB	21	(30.000N, 75.000E) (50.000N, 75.000E) (50.000N, 100.000E) (30.000N, 100.000E)
WAF	15	(11.365S, 20.000W) (15.000N, 20.000W) (15.000N, 25.000E) (11.365S, 25.000E)
WAS	19	(15.000N, 40.000E) (50.000N, 40.000E) (50.000N, 60.000E) (15.000N, 60.000E)
WSA	9	(1.239S, 79.729W) (20.000S, 66.377W) (50.000S, 72.141W) (56.704S, 67.348W) (56.704S, 82.022W) (0.530N, 82.022W)
WNA	3	(28.566N, 105.000W) (28.566N, 130.000W) (60.000N, 130.000W) (60.000N, 105.000W)

Table 3.A-2 | List of CMIP3 GCMs and respective number of runs for each scenario used in Figure 3-5.

Model	20C3M	A1B	A2	B1
CGCM3.1(T47)	5	3	3	3
CGCM3.1(T63)	1	1	1	1
CNRM-CM3	1	1	1	1
ECHAM5/MPI-OM	1	1	1	1
ECHO-G	3	3	3	3
GFDL-CM2.0	1	1	1	1
GFDL-CM2.1	1	1	1	1
GISS-ER	1	1	1	1
INM-CM3.0	1	1	1	1
IPSL-CM4.0	2	1	1	1
MIROC3.2(medres)	3	3	3	3
MRI-CGCM2.3.2	5	5	5	5

Figure 3-5. Several models have multiple simulations for the same forcing scenario. Details are listed in Table 3.A-2.

Steps for Computation of Figure 3-5a

Step 2 – Extraction of annual extremes of daily maximum temperature
For each ensemble member and at every grid box of the model, the largest values of the daily maximum temperature for each model year are extracted from daily values. Thus, there is a sample of 20 values of annual maximum of daily maximum temperature at every grid box for each of the three 20-year periods.

Step 3 – Estimation of return values and L-moments
A Generalized Extreme Value (GEV) distribution is fitted to 20-year samples of annual temperature extremes using the method of L-moments as implemented in Kharin et al. (2005). A 20-year return value (RV20) is computed as the 95th quantile of the fitted GEV distribution.

Step 4 – Ensemble mean estimate
When multiple members of an ensemble are available from a model, the ensemble mean of the RV20s and the first three L-moments [L1, L2, and T3=L3/L2 (to be used in Step 7)], are obtained by averaging values estimated from individual ensemble members and are used to represent that model.

Step 5 – Interpolation to common grid
Different models have different spatial resolutions. The RV20s and the first three L-moments from the ensemble mean or the single model run (if only one simulation is available) from different models are interpolated onto a common 256x128 Gaussian grid using bi-linear interpolation.

Step 6 – Computation of regional changes in return values
The RV20 values on the common 256x128 Gaussian grid are averaged for different regions for every model, every forcing scenario, and each of the three periods. Projected regional changes in the 20-year return values around the 2050s and 2090s are obtained as the differences in the regional mean between 2046-2065 and 1981-2000, and between

2081-2100 and 1981-2000, respectively. The regional changes for different models are then summarized by a boxplot for each region, each future time period, and each forcing scenario. The multi-model median values shown in the boxes are the averages of the values from the 6th- and 7th-ranked models.

Step 7 – Computation of changes in return values over global land regions
The computation of the changes in 20-year return values for the global land regions ("Globe (Land only) / Δ 20-year return value") are also displayed in Figure 3-5a. These are computed in the same way as the regional changes (Step 6), but using all land grid points.

Step 8 – Computation of changes in annual mean daily maximum temperature over global land regions
Figure 3-5a also provides analyses of the changes in annual mean daily maximum temperature averaged over all land grid points over the periods 2046-2065 and 2081-2100, for the three scenarios, compared with the respective averages for 1981-2000 ("Globe (Land only), Δ mean").

Steps for Computation of Figure 3-5b

Step 9 – Estimation of return periods
The gridded values of the three L-moments (L1, L2, and T3=L3/L2) on the common 256x128 grid obtained from Step 5 are spatially smoothed by applying a 3x3 gridbox averaging filter twice. The spatially smoothed versions of 20-year return values in 1981-2000 and of the GEV parameters for the future periods are derived using the spatially smoothed L-moments for the corresponding time periods. Return periods for the late 20th-century 20-year return values are then derived for future time periods (2050s or 2090s) by first computing the probability of exceeding the 1981-2000 20-year return values using the estimated future GEV distributions for the respective periods, and then inverting the probability.

Step 10 – Computation of regional return periods
The median value of return periods in a region (that is, return periods

Table 3.A-3 | List of CMIP3 GCMs and respective number of runs used in Figure 3-7.

Model	20CM3	A1B	A2	B1
CGCM3.1(T47)	5	3	3	3
CGCM3.1(T63)	1	1	1	1
CNRM-CM3	1	1	1	1
ECHAM5/MPI-OM	1	1	1	1
ECHO-G	3	3	3	3
GFDL-CM2.0	1	1	1	1
GFDL-CM2.1	1	1	1	1
GISS-ER	1	1	1	1
INM-CM3.0	1	1	1	1
IPSL-CM4.0	2	1	1	1
MIROC3.2(medres)	2	3	3	3
MRI CGCM2.2.3	5	5	5	5
NCAR-CCSM3	6	7	5	4
NCAR-PCM	4	1	1	3

are larger than the median value in one half of the region, and are smaller than the median value in the other half) simulated by a model in a future time period is used to represent a regional estimate of return periods for that period from that model. The regional return periods for different models are then summarized by a boxplot for each region, each future time period, and each forcing scenario. The multi-model median values shown in the boxes are the averages of the values from the 6th- and 7th-ranked models.

Step 11 – Computation of return periods over global land regions
The computation of the median values of return periods for the global land regions ("Globe (Land only)") are also displayed in Figure 3-5b. These are computed in the same way as the regional return periods (Step 10), but using all land grid points.

3.A.6. Figure 3-6

Figure 3-6 is adapted from Figure 7 of Orlowsky and Seneviratne (2011), using the Robinson map projection and modified color scales and stippling to improve readability.

3.A.7. Figure 3-7

Analyzed Model Simulations

Figure 3-7 is based on Figure 13 from Kharin et al. (2007). It is produced in a similar way as Figure 3-5 (Section 3.A.5), but there is a difference in the number of models being used (14 in total, including two additional GCMs from NCAR), and the changes in return values are expressed as percentage changes. Furthermore, similarly as for Figure 3-5a analyses of changes in annual mean 24-hour (daily) precipitation averaged over global land regions, i.e., using all land grid points, are additionally provided in Figure 3-7a. Table 3.A-3 lists the GCMs used in the computation of Figure 3-7.

Steps for Computation of Figure 3-7a

Figure 3-7a is produced following Steps 1 to 6 for the preparation of Figure 3-5a, except that the box plots are based on the percentage changes relative to the 1981-2000 return values. That is, the regionally averaged changes in the 20-year return values in 2046-2065 or 2081-2100, relative to 1981-2000, are divided by the corresponding regionally averaged 20-year return values in 1981-2000 and multiplied by 100, and are then used to produce the box plot. The multi-model median values shown in the boxes are the averages of the values from the 7th- and 8th-ranked models. Similarly, as for Figure 3-5a, changes in 20-year return values are also provided for the global land regions (cf. Step 7 above). They are computed in the same way as the regional changes in 20-year return values, using all land grid points. Additionally, analyses of changes in annual mean 24-hour precipitation averaged over the global land regions, i.e., using all land grid points, are provided (cf. Step 8 above).

Steps for Computation of Figure 3-7b

Figure 3-7b is produced following Steps 9 to 11 for the preparation of Figure 3-5b, taking account of the different number of models used.

3.A.8. Figure 3-8

Figure 3-8 is adapted from Figures 3c-d and Figures 5c-d of McInnes et al. (2011), using the Robinson map projection with a modified palette to improve readability. Modelled meridional and zonal 10-m winds were obtained from the CMIP3 MME (see www-pcmdi.llnl.gov/ipcc/ standard_output.html#Table_A1a). Daily average winds were available from 19 models forced with the A1B emission scenario: BCCR-BCM2, CGCM3.1(T47), CGCM3.1(T63), CNRM-CM3, CSIRO-Mk3.0, CSIRO-Mk3.5, GFDL-CM2.0, GFDL-CM2.1, GISS-AOM, GISS-E_R, IAP-FGOALS-g1.0, INM-CM3.0, IPSL-CM4, MIROC3.2(hires), MIROC3.2(medres),

MIUB/ECHO-G, ECHAM4/INGV, ECHAM5/MPIOM, and MRI-CGCM2.3.2. For each model, a single simulation was used. This was run 1 in all models except for GFDL-CM2.0 and ECHAM5/MPIOM in which runs 2 and 4 were used, respectively. Two periods of the simulations were used: 1981 to 2000 (from the 20C3M simulations) and 2081 to 2100 from the A1B simulations (note that for some models daily data for the years 2000 and 2100 was not available, so quantities from the shorter period were instead evaluated).

Mean wind speed and 99th percentile wind speed (the threshold dividing the highest 1% of daily wind speeds from the remaining wind values) were calculated from the daily meridional and zonal 10-m wind components in each model and season over the 1981-2000 and 2081-2100 periods after interpolation to a common 2.5° resolution grid. Prepared figures show the multi-model average changes in 10-m mean and 99th percentile wind speeds for DJF and JJA for the period 2081 to 2100 relative to 1981 to 2000 (expressed as %) only where more than 66% of the models agree on the sign of the change. Black stippling indicates areas where more than 90% of the models agree on the sign of the change and red stippling indicates areas where more than 66% of models agree on a small change between ±2%.

3.A.9. Figure 3-10

Figure 3-10 is based on Figure 8 of Orlowsky and Seneviratne (2011). The differences to the original figure are that (1) the projected changes for the middle of the 21st century are additionally included in Figure 3-10 and (2) that the display was modified (Robinson map projection, modified color scale and stippling). Details on the computation of the figures are provided hereafter.

Steps for Computation of Figure 3-10 Left Panel (Consecutive Dry Days, CDD)

Step 1 – Analyzed simulations
The simulations originate from the CMIP3 MME (see Section 3.2.3.3). Daily precipitation amounts simulated by 17 GCMs for the 20th century (20C3M) for 1980-1999, and under the A2 forcing scenarios for the 2046-2065 and 2081-2100 time periods, have been used in the production of the left panel of Figure 3-10. Only the 20C3M runs with models that also computed respective A2 scenarios are used. Some models have multiple simulations for the same forcing scenario. Details are listed in Table 3.A-4.

Step 2 – Calculation of maximum consecutive dry days (CDD) on annual and seasonal time scales
A day is defined as a dry day for a model grid box if the amount of precipitation simulated by the model for that day and for that grid box is less than 1 mm. The number of consecutive dry days is defined as the number of days in a row during which every day is a dry day (i.e., daily precipitation amounts are less than 1 mm in every day during the period).

For the computation of the *annual* values (top two rows), the counting of consecutive dry days starts from the first day of the year if it is a dry day or the first dry day following it if the first day of the year is not a dry day. The counting of consecutive dry days stops when a wet day occurs or if the year ends. CDD, in this case the annual maximum number of consecutive dry days, is the maximum length of all consecutive dry days in the year.

For the computation of the *seasonal* values (bottom two rows), the counting of consecutive dry days starts from the first day of the season if it is a dry day or the first dry day following it if the first day of the

Table 3.A-4 | List of CMIP3 GCMs, number of runs used in Figure 3-10 left panel.

Model	20C3M/A2
BCCR-BCM2.0 [1]	1 (run1)
CGCM3.1-T47	3 (run1 run2 run3)
CNRM-CM3	1 (run1)
CSIRO Mk3.0	1 (run1)
CSIRO Mk3.5	1 (run1)
GFDL-CM2.0	1 (run1)
GFDL-CM2.1	1 (run2 for 20C3M, and run1 for A2)
GISS-ER [2]	1 (run1)
INGV-ECHAM4	1 (run1)
INM-CM3.0	1 (run1)
IPSL-CM4	1 (run1)
MIROC3.2-medres	2 (run1, run2)
ECHO-G	3 (run1, run2, run3)
ECHAM5/MPI-OM	1 (run1)
MRI-CGCM2.3.2	5 (run1, run2, run3, run4, run5)
NCAR CCSM3	3 (run1, run3, run5)
NCAR PCM1	1 (run1)

Notes: 1. For the A2 simulations some of the files have overlapping time steps. We use the following files: pr_A2_2046-2055.nc, pr_A2_2056-2065.nc and pr_A2_2081-2100.nc.
2. Precipitation for the years 1971-2000 was divided by 8, which removed a jump detected in the original data.

season is not a dry day. In the first year of the respective time periods, the counting for the December-January-February period starts in January. The counting of consecutive dry days stops when a wet day occurs or if the season ends. CDD, in this case the seasonal maximum number of consecutive dry days, is the maximum length of all consecutive dry days in the season.

Note that for GCMs featuring leap years, all February 29th data are removed prior to the analysis.

Step 3 – Estimation of changes in CDD for individual grid box

CDD values are averaged for three periods – 1980-1999, 2046-2065, 2081-2100, respectively – for each model simulation separately. The differences in the averages between 2046-2065 and 1980-1999, and between 2081-2100 and 1980-1999 represent projected changes around the middle and late 21st century. For the standardization of the changes, the average values of time series of CDD of the three periods are removed from the respective periods. The residuals from the three periods are pooled together to compute the standard deviation. The projected changes are then divided by the standard deviation to obtain a standardized change. If the standard deviation is less than or equal to 1E-10, the projected change is set to NA.

Step 4 – Interpolation to a common grid

Different GCMs have different resolutions. The standardized changes from different models are gridded using bi-linear interpolation to a common Gaussian grid at T42 truncation.

Step 5 – Changes in ensemble mean

If a GCM has more than one run (Table 3.A-4), the standardized changes from individual runs already interpolated to T42 resolution are averaged to represent that GCM. If at a given grid box at least one run has NA, then the average over the runs of that GCM is set to NA at this grid box. If a GCM has one run only, the result from that run is used. The multi-model ensemble mean change is the average from standardized changes of individual GCMs, with NA values from individual GCMs being excluded prior to the averaging.

Step 6 – Mapping

Only the multi-model ensemble mean values on land grid cells are mapped. The land/ocean mask is from the MIROC3.2-medres NetCDF description file. The multi-model ensemble mean is the average of the standardized changes on the common grid from every model. A value is considered as an outlier, and thus assigned an NA value, if it is 10 times of the median absolute deviation away from the median of the non-NA values. A grid box is colored if at least 12 out of 17 models (66%) have valid (i.e., non-NA) values for that box and agree on the sign of the projected changes; otherwise, the grid box is shaded in grey. The grid box is stippled if at least 16 out of the 17 GCMs have valid values and agree on the sign of projected changes.

Steps for Computation of Figure 3-10 Right Panel (Soil Moisture Anomalies, SMA)

Step 7 – Model simulations

The simulations originate from the CMIP3 MME (see Section 3.2.3.3). Monthly mean soil moisture simulated by 15 GCMs for the 20th century (20C3M) for 1980-1999, and under the A2 forcing scenario for the 2046-2065 and 2081-2100 time periods, have been used in the production of the right panel of Figure 3-10. Some models have multiple simulations for the same forcing scenario. Details are listed in Table 3.A-5.

Step 8 – Calculation of annual and seasonal mean values of soil moisture

Annual values of soil moisture are obtained by averaging the 12-monthly values of soil moisture within the year. Seasonal values for the seasons June-July-August and December-January-February are obtained by averaging 3-monthly values of soil moisture over these respective seasons. In the first year of the respective time periods, the averaging for the December-January-February period only comprises January and February.

Step 9 – Estimation of changes in soil moisture on annual and seasonal time scales (Soil Moisture Anomalies, SMA)

The above-described Step 3 is followed to compute standardized changes in units of standard deviation for the two considered periods (2046-2065 and 2081-2100) compared to 1980-1999. For 2046-2065, only differences for the annual values are displayed; for 2081-2100 differences for annual values and for the JJA and DJF seasons are displayed. The displayed analyses represent SMA of the future conditions compared to the late 20th-century conditions. If the standard deviation is less than or equal to 1E-10, this grid box is assigned an NA (not a value). Step 4 is followed to convert values of different spatial resolution onto a common Gaussian T42 grid. If any of the grid values used in the interpolation is NA, the resulting interpolated value is assigned an NA. Step 5 is followed to compute ensemble mean changes.

Step 10 – Mapping

Only the multi-model ensemble mean values on land grid boxes are mapped. The land/ocean mask is from the MIROC3.2-medres NetCDF description file. The multi-model ensemble mean is the average of the standardized changes on the common grid from every model, with NA values being excluded from the averaging. A value is considered as an outlier, and thus assigned an NA value, if it is 10 times of the median absolute deviation away from the median of the non-NA values. A grid box is colored if at least 10 out of the 15 GCMs have valid (i.e., non-NA) values for that box and agree on the sign of the projected changes; otherwise, the grid box is shaded in grey. The grid box is stippled if at least 14 out of the 15 GCMs have valid values and agree on the sign of projected changes.

Table 3.A-5 | List of CMIP3 GCMs, number of runs used in Figure 3-10 right panel.

Model	20C3M/A2
CGCM3.1 (T47)	5 (run1, run2, run3, run4, run5)
ECHO-G	3 (run1, run2, run3)
ECHAM5/MPI-OM [1]	3 (run1, run2, run3)
GFDL CM2.0	1 (run1)
GFDL CM2.1	1 (run1)
GISS-ER	1 (run1)
INGV-ECHAM4	1 (run1)
INM-CM3.0	1 (run1)
IPSL-CM4 [2]	1 (run1)
MIROC3.2-medres	3 (run1, run2, run3)
MRI-CGCM2.3.2	5 (run1, run2, run3, run4, run5)
NCAR CCSM3	3 (run1, run3, run5)
NCAR PCM1	4 (run1, run2, run3, run4)
UKMO-HadCM3	1 (run1)
UKMO-HadGEM1	1 (run1)

Notes: 1. The 20C3M simulations last until 2100, with unclear scenario forcing after 2000. For the 2046–2065 and the 2081–2100 periods, we use the files from the A2-simulations.
2. The time axis of the 20C3M simulation is corrupt and has been adjusted manually.

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