Description of Data Used in:

Human Influence on the Seasonal Cycle of Tropospheric Temperature

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1 Introduction

This document contains a description of the model and observational tropospheric temperature data analyzed in the 2018 Santer et al. *Science* paper (henceforth S18) entitled "Human Influence on the Seasonal Cycle of Tropospheric Temperature". All data analyzed in S18 are publicly available on the PCMDI website (http://www-pcmdi.llnl.gov).

1.1 File naming conventions

1.1.1 Observations

There are six `NetCDF` files containing satellite-based estimates of the monthly-mean temperature of the mid- to upper troposphere (TMT). The files names are as follows:

1. `tf1_RSS_v33jan17_20c3m_run1_mm_xy_fw_r0000_0000.nc`
2. `tf1_RSS_v40jan17_20c3m_run1_mm_xy_fw_r0000_0000.nc`
3. `tf1_STR_v30jan17_20c3m_run1_mm_xy_st_r0000_0000.nc`
4. `tf1_STR_v40jan17_20c3m_run1_mm_xy_st_r0000_0000.nc`
5. `tf1_UAH_v56jan17_20c3m_run1_mm_xy_jc_r0000_0000.nc`
6. `tf1_UAH_v60jan17_20c3m_run1_mm_xy_jc_r0000_0000.nc`

The string `tf1` denotes the variable of interest (TMT). In this case, TMT has been corrected for lower stratospheric cooling using latitudinally invariant regression coefficients (see Supplementary Material of S18). The strings `RSS`, `STR`, and `UAH` identify the research group that produced the data (Remote Sensing Systems, The Center for

Satellite Applications and Research, and the University of Alabama at Huntsville, respectively). The strings `v33`, `v40` (etc.) identify the dataset version number.* The string `20c3m_run1` indicates that only one realization of the observations is available. The strings `mm` and `xy` denote monthly-mean data on a longitude/latitude grid. The strings `fw`, `st`, and `jc` are not relevant here. Finally, the string `r0000_0000` indicates that the data are in Kelvin – i.e., no reference period was used for calculating monthly mean anomalies.

Each NetCDF file contains 456 months of corrected TMT data on a regular 2.5° × 2.5° grid with 144 longitude bands and 72 latitude bands. The first month of data is January 1979. The last month of data is December 2016.† The time is in "months since 1800", so the first month on each file (January 1979) has the time index `2148`.

1.1.2 Model control runs

There are 36 `NetCDF` files containing model estimates of monthly-mean, gridded TMT from pre-industrial control simulations. Model results are "synthetic" TMT, calculated using weighting functions relying on the local (grid-point) surface pressure, the surface temperature, and the atmospheric temperature at discrete pressure levels. As in the case of the satellite data, model TMT data were corrected for lower stratospheric cooling using latitudinally invariant regression coefficients. There is one `NetCDF` file for each of the 36 model pre-industrial control runs listed in Table 2 of this document.

Here are several examples of model file names:

*Each group provides the most recent version and the previous version of their datasets. The versions available are: 3.3 and 4.0 (RSS), 3.0 and 4.0 (STAR), and 5.6 and 6.0 (UAH).

†Data for all months of 2017 were not available at the time this study was performed; complete years are required for calculating the amplitude of the annual and semi-annual cycles of TMT.

1. tf1_can_esm2.piControl.r1i1p1.mo.nc
2. tf1_ccsm4.piControl.r1i1p1.mo.nc
3. tf1_gfdl_cm3.piControl.r1i1p1.mo.nc
4. tf1_giss_e2_h_p1.piControl.r1i1p1.mo.nc
5. tf1_giss_e2_h_p2.piControl.r1i1p2.mo.nc

As in the case of the satellite data, the string tf1 denotes the variable of interest (corrected TMT). The model name is encoded in the file name – e.g., can_esm2, ccsm4, gfdl_cm3, giss_e2_h_p1, and giss_e2_h_p2. Table 1 of this document lists the scientific institutions at which the models used here were developed. Note that the strings p1 and p2 denote different physics versions of the GISS-E2-H model. These different physics versions are also encoded in the so-called "ensemble member identifier" (r1i1p1, r1i1p2, etc). The piControl and mm strings indicate that synthetic TMT was calculated from model pre-industrial control runs, and that model output is in the form of monthly means. Synthetic TMT data are stored on the native model grid. The start date, end date, and length of each control run is given in Table 2 of this document.

1.1.3 Spliced HIST+8.5 runs

There are 49 NetCDF files containing model estimates of monthly-mean, gridded TMT from spliced historical+RCP8.5 simulations (HIST+8.5). There is one file for each of the 49 HIST+8.5 realizations. The realizations were performed with 37 different CMIP5 models. The models with multiple HIST+8.5 realizations are can_esm2, ccsm4, hadgem2_cc, hadgem2_es, ipsl_cm5a_lr, and mpi_esm_lr. Model results are "synthetic" TMT (see discussion of control run data). As in the case of the satel-

lite and control run data, model TMT data from the HIST+8.5 simulations were corrected for lower stratospheric cooling.

Here are several examples of model file names:

1. `tf1_can_esm2.hist_rcp85.r1i1p1.mo.nc`
2. `tf1_can_esm2.hist_rcp85.r2i1p1.mo.nc`
3. `tf1_can_esm2.hist_rcp85.r3i1p1.mo.nc`
4. `tf1_ccsm4.hist_rcp85.r1i1p1.mo.nc`
5. `tf1_gfdl_cm3.hist_rcp85.r1i1p1.mo.nc`

The string `tf1` denotes the variable of interest (corrected TMT). The model name is encoded in the file name – e.g., `can_esm2`, `ccsm4`, and `gfdl_cm3`. Note that the strings `r1`, `r2`, and `r3` identify three different realizations performed with the same model. The `hist_rcp85` and `mm` strings indicate that synthetic TMT was calculated from spliced historical plus RCP8.5 simulations, and that model output is in the form of monthly means. Synthetic TMT data are stored on the native model grid. The start date, end date, and length of each HIST+8.5 run is given in Table 3 of this document.

Table 1: CMIP5 models used in this study.

	Model	**Country**	**Modeling center**
1	ACCESS1.0	Australia	Commonwealth Scientific and Industrial Research Organization and Bureau of Meteorology
2	ACCESS1.3	Australia	Commonwealth Scientific and Industrial Research Organization and Bureau of Meteorology
3	BCC-CSM1.1	China	Beijing Climate Center, China Meteorological Administration
4	BCC-CSM1.1(m)	China	Beijing Climate Center, China Meteorological Administration
5	CanESM2	Canada	Canadian Centre for Climate Modelling and Analysis
6	CCSM4	USA	National Center for Atmospheric Research
7	CESM1-BGC	USA	National Science Foundation, U.S. Dept. of Energy, National Center for Atmospheric Research
8	CESM1-CAM5	USA	National Science Foundation, U.S. Dept. of Energy, National Center for Atmospheric Research
9	CMCC-CESM	Italy	Centro Euro-Mediterraneo per I Cambiamenti Climatici
10	CMCC-CM	Italy	Centro Euro-Mediterraneo per I Cambiamenti Climatici
11	CMCC-CMS	Italy	Centro Euro-Mediterraneo per I Cambiamenti Climatici
12	CSIRO-Mk3.6.0	Australia	Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence
13	EC-EARTH	Various	EC-EARTH consortium
14	FGOALS-g2	China	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University
15	FIO-ESM	China	The First Institute of Oceanography, SOA
16	GFDL-CM3	USA	NOAA Geophysical Fluid Dynamics Laboratory
17	GFDL-ESM2G	USA	NOAA Geophysical Fluid Dynamics Laboratory

Table 1: CMIP5 models used in this study (continued).

	Model	Country	Modeling center
18	GFDL-ESM2M	USA	NOAA Geophysical Fluid Dynamics Laboratory
19	GISS-E2-H (p1)	USA	NASA Goddard Institute for Space Studies
20	GISS-E2-H (p2)	USA	NASA Goddard Institute for Space Studies
21	GISS-E2-H (p3)	USA	NASA Goddard Institute for Space Studies
22	GISS-E2-R (p1)	USA	NASA Goddard Institute for Space Studies
23	GISS-E2-R (p2)	USA	NASA Goddard Institute for Space Studies
24	GISS-E2-R (p3)	USA	NASA Goddard Institute for Space Studies
25	HadGEM2-CC	UK	Met. Office Hadley Centre
26	HadGEM2-ES	UK	Met. Office Hadley Centre
27	INM-CM4	Russia	Institute for Numerical Mathematics
28	IPSL-CM5A-LR	France	Institut Pierre-Simon Laplace
29	IPSL-CM5A-MR	France	Institut Pierre-Simon Laplace
30	IPSL-CM5B-LR	France	Institut Pierre-Simon Laplace
31	MIROC5	Japan	Atmosphere and Ocean Research Institute (the University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
32	MIROC-ESM-CHEM	Japan	As for MIROC5
33	MIROC-ESM	Japan	As for MIROC5
34	MPI-ESM-LR	Germany	Max Planck Institute for Meteorology

Table 1: CMIP5 models used in this study (continued).

	Model	**Country**	**Modeling center**
35	MPI-ESM-MR	Germany	Max Planck Institute for Meteorology
36	MRI-CGCM3	Japan	Meteorological Research Institute
37	NorESM1-M	Norway	Norwegian Climate Centre
38	NorESM1-ME	Norway	Norwegian Climate Centre

Table 2: Start dates, end dates, and lengths (N_m, in months) of the 36 CMIP5 pre-industrial control runs used in this study. EM is the "ensemble member" identifier.*

	Model	EM	Start	End	N_m
1	ACCESS1.0	r1i1p1	300-01	799-12	6000
2	ACCESS1.3	r1i1p1	250-01	749-12	6000
3	BCC-CSM1.1	r1i1p1	1-01	500-12	6000
4	BCC-CSM1.1(m)	r1i1p1	1-01	400-12	4800
5	CanESM2	r1i1p1	2015-01	3010-12	11952
6	CCSM4	r1i1p1	800-01	1300-12	6012
7	CESM-BGC	r1i1p1	101-01	600-12	6000
8	CESM-CAM5	r1i1p1	1-01	319-12	3828
9	CMCC-CESM	r1i1p1	4324-01	4600-12	3324
10	CMCC-CM	r1i1p1	1550-01	1879-12	3960
11	CMCC-CMS	r1i1p1	3684-01	4183-12	6000
12	CSIRO-Mk3.6.0	r1i1p1	1651-01	2150-12	6000
13	FGOALS-g2	r1i1p1	201-01	900-12	8400
14	FIO-ESM	r1i1p1	401-01	1200-12	9600
15	GFDL-CM3	r1i1p1	1-01	500-12	6000
16	GFDL-ESM2G	r1i1p1	1-01	500-12	6000
17	GFDL-ESM2M	r1i1p1	1-01	500-12	6000
18	GISS-E2-H (p1)	r1i1p1	2410-01	2949-12	6480
19	GISS-E2-H (p2)	r1i1p2	2490-01	3020-12	6372
20	GISS-E2-H (p3)	r1i1p3	2490-01	3020-12	6372
21	GISS-E2-R (p1)	r1i1p1	3981-01	4530-12	6600
22	GISS-E2-R (p2)	r1i1p2	3590-01	4120-12	6372
23	HadGEM2-CC	r1i1p1	1859-12	2099-12	2881
24	HadGEM2-ES	r1i1p1	1859-12	2435-11	6912
25	INM-CM4	r1i1p1	1850-01	2349-12	6000
26	IPSL-CM5A-LR	r1i1p1	1800-01	2799-12	12000

Table 2 (continued): Information on the 36 CMIP5 pre-industrial control runs used in this study.

	Model	EM	Start	End	N_m
27	IPSL-CM5A-MR[§]	r1i1p1	1800-01	2068-12	3228
28	IPSL-CM5B-LR	r1i1p1	1830-01	2129-12	3600
29	MIROC5	r1i1p1	2000-01	2669-12	8040
30	MIROC-ESM-CHEM	r1i1p1	1846-01	2100-12	3060
31	MIROC-ESM	r1i1p1	1800-01	2330-12	6372
32	MPI-ESM-LR	r1i1p1	1850-01	2849-12	12000
33	MPI-ESM-MR	r1i1p1	1850-01	2849-12	12000
34	MRI-CGCM3	r1i1p1	1851-01	2350-12	6000
35	NorESM1-M	r1i1p1	700-01	1200-12	6012
36	NorESM1-ME	r1i1p1	901-01	1152-12	3024

[*]See http://cmip-pcmdi.llnl.gov/cmip5/documents.html for further details.

[§]The `IPSL-CM5A-MR` control run has a large discontinuity in year 2069. We therefore truncated the `IPSL-CM5A-MR` control run after December 2068.

Table 3: Basic information relating to the start dates, end dates, and lengths (N_m, in months) of the 37 CMIP5 historical and RCP8.5 simulations used in this study. EM is the "ensemble member" identifier*.

	Model	EM	Hist. Start	Hist. End	Hist. N_m	RCP8.5 Start	RCP8.5 End	RCP8.5 N_m
1	ACCESS1.0	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
2	ACCESS1.3	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
3	BCC-CSM1.1	r1i1p1	1850-01	2012-12	1956	2006-01	2300-12	3540
4	BCC-CSM1.1(m)	r1i1p1	1850-01	2012-12	1956	2006-01	2099-12	1128
5	CanESM2	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
6	CanESM2	r2i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
7	CanESM2	r3i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
8	CanESM2	r4i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
9	CanESM2	r5i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
10	CCSM4	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
11	CCSM4	r2i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
12	CCSM4	r3i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
13	CESM1-BGC	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
14	CESM1-CAM5	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
15	CMCC-CESM	r1i1p1	1850-01	2005-12	1872	2000-01	2095-12	1140
16	CMCC-CM	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
17	CMCC-CMS	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
18	CSIRO-Mk3.6.0	r10i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
19	EC-EARTH	r8i1p1	1850-01	2012-12	1956	2006-01	2100-12	1140
20	FGOALS-g2	r1i1p1	1850-01	2005-12	1872	2006-01	2101-12	1152
21	FIO-ESM	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
22	GFDL-CM3	r1i1p1	1860-01	2005-12	1752	2006-01	2100-12	1140
23	GFDL-ESM2G	r1i1p1	1861-01	2005-12	1740	2006-01	2100-12	1140
24	GFDL-ESM2M	r1i1p1	1861-01	2005-12	1740	2006-01	2100-12	1140

Table 3 (continued): Information on the 37 CMIP5 historical and RCP8.5 simulations used in this study.

	Model	EM	Hist. Start	Hist. End	Hist. (months)	RCP8.5 Start	RCP8.5 End	RCP8.5 (months)
25	GISS-E2-H (p1)	r1i1p1	1850-01	2005-12	1872	2006-01	2300-12	3540
26	GISS-E2-H (p3)	r1i1p3	1850-01	2005-12	1872	2006-01	2300-12	3540
27	GISS-E2-R (p1)	r1i1p1	1850-01	2005-12	1872	2006-01	2300-12	3540
28	GISS-E2-R (p2)	r1i1p2	1850-01	2005-12	1872	2006-01	2300-12	3540
29	GISS-E2-R (p3)	r1i1p3	1850-01	2005-12	1872	2006-01	2300-12	3540
30	HadGEM2-CC	r1i1p1	1859-12	2005-11	1752	2005-12	2099-12	1129
31	HadGEM2-CC	r2i1p1	1959-12	2005-12	553	2005-12	2099-12	1129
32	HadGEM2-CC	r3i1p1	1959-12	2005-12	553	2005-12	2099-12	1129
33	HadGEM2-ES	r1i1p1	1859-12	2005-11	1752	2005-12	2299-12	3529
34	HadGEM2-ES	r2i1p1	1859-12	2005-12	1753	2005-12	2100-11	1140
35	INM-CM4	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
36	IPSL-CM5A-LR	r1i1p1	1850-01	2005-12	1872	2006-01	2300-12	3540
37	IPSL-CM5A-LR	r2i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
38	IPSL-CM5A-MR	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
39	IPSL-CM5B-LR	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
40	MIROC5	r1i1p1	1850-01	2012-12	1956	2006-01	2100-12	1140
41	MIROC-ESM-CHEM	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
42	MIROC-ESM	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
43	MPI-ESM-LR	r1i1p1	1850-01	2005-12	1872	2006-01	2300-12	3540
44	MPI-ESM-LR	r2i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
45	MPI-ESM-LR	r3i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
46	MPI-ESM-MR	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
47	MRI-CGCM3	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
48	NorESM1-M	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140
49	NorESM1-ME	r1i1p1	1850-01	2005-12	1872	2006-01	2100-12	1140

*See http://cmip-pcmdi.llnl.gov/cmip5/documents.html for further details.