Historical GHG concentrations for CMIP6 Historical Runs (HISTGHGCONC v0.1)

M. Meinshausen, A. Nauels, 17th February 2015

1. OVERVIEW

Phase 6 of the Coupled Model Intercomparison Project (CMIP6) includes a Historical Simulation that serves as entry-check for other CMIP runs, spanning from 1850 to 2014. Depending on the model setup and emission species (short-lived, ozone, long-lived GHG), this historical simulation is driven by emissions and/or concentrations. Here, we provide an outline of a consolidated set of atmospheric concentration time series for the long-lived greenhouse-gases, including CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, several ODS, and NF_3 to serve as input for the CMIP6 Historical simulations. The first published dataset is planned for May/June 2015 to be submitted to the GMD special issue, with a final version ready before 1 Jan 2016. This dataset will serve as basis for concentration-driven historical CMIP6 runs, the estimation of inverse historical emissions and as starting point for smoothly transitioning into future ScenarioMIP experiments. Feedback on this initial description of the historical GHG concentrations and on some questions outline below is sought until 15th April 2015.

2. TIMELINE

17. February 2015: Release of data description (this note).

15. April 2015: Community to provide feedback on this outline for Historical GHG concentrations, and the intended datasets. The suggestion and provision of alternative datasets to be considered is much appreciated.

May/June 2015: The draft consolidated dataset will be submitted to Geophysical Model Development Special Issue.

Until 1 Jan 2015: In line with the timeline on slide 11 of the 16th Jan 2015 version of the CMIP6 Design and Organisation slide set and based on comments during the review process, the revised dataset will be submitted at the latest until 1 Jan 2015.

3. FEEDBACK

These datasets are meant to be by the community and for the community to support the historical CMIP6 experiments. Please provide feedback on the planned design of the historical GHG concentrations, data sources etc. to the primary points of contact for this data:

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Authors who contributed substantial amounts to the historical GHG concentration data, especially in cases where the data is not yet published elsewhere, are of course invited to be co-authors of this GMD article. Please notify the above contacts.

4. KEY CHARACTERISTICS

The historical GHG mixing ratios dataset used to extend the RCP dataset in 2011 combined a large variety of data from the community, including the Keeling MLP record, many NOAA ESRL GMD datasets (Montzka, Dlugokencky, Conway et al.) as well as WMO data (Velders, Daniel et al.). The RCP dataset provided annual and global average values for CO_2, CH_4, N_2O, C_2F_6, CF_4, HFC-125, HFC-134a, HFC-143a, HFC-23, SF_6, and took on board the WMO2009 dataset for another 16 ODS substances [see Table 1 in *Meinshausen et al.*, 2011].

This new community CMIP6 historical GHG dataset is meant to provide a suggested update of these historical GHG concentration datasets for the CMIP6 Historical runs. The key characteristics of this updated dataset shown in Table 1 below.

Table 1 - Key characteristics of CMIP6 historical GHG concentration dataset.

CMIP6 Historical GHG concentrations

Time-span:	1850 to 2014 (With optional backward extension to year 1010 for CO_2, CH_4 and N_2O)
Gases:	CO_2, CH_4, N_2O, C_2F_6, CF_4, HFC-125, HFC-134a, HFC-143a, HFC-23, SF_6, NF_3, and 16 ODS, namely: CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, CCl14, CH3CCl3, HCFC-22, HCFC-141b, HCFC-142b, Halon1211, Halon1202, Halon1301, Halon2404, CH_3Br, CH_3Cl
Time resolution	Annual averages. Value for 1850 is average mixing ratio from 1st Jan 1850 to 31 Dec 1850 (with optional extension to monthly values for CO_2, CH_4 back to Year 1010).
Spatial resolution:	Global averages (with optional extension to latitudinal resolution, interpolated to at 0.5° degree steps for CO_2, CH_4).

5. DATA SOURCES

The compilation of historical GHG concentration data series is only possible due to the generosity of many individuals and institutions in the community, who provide their data to CMIP6. The following table indicates the proposed data sources for CMIP6 (Table 2). For comparability with CMIP5 historical data runs, we indicate as well the differences to the CMIP5 version of historical GHG concentrations that have been used for the RCP process (Table 3).

Table 2: Proposed datasets for CMIP6 historical GHG concentrations

GHG	Period	Source	Description
CO2	1010-1832	Etheridge et al 1998b	75year smoothed
	1832-1958	Etheridge et al 1998b	20year smoothed
	1959-1981	Keeling and Whorf 2004	Keeling MLO minus 0.59ppm (mean delta between MLO and NOAA/ESRL/GMD 1982-1986 estimates, Conway et al 1994)
	1982-2014	Dlugokencky et al 2015	NOAA ESRL GMD ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_gl.txt
CH4	1010-1850	Etheridge et al 1998a	Law Dome Ice Core date
	1850-1983	Etheridge et al 1998a	taken from data compilation for NASA GISS model (http://data.giss.nasa.gov/modelforce/ghgases/Fig1B.ext.txt)
	1984-2003	Dlugokencky, private communication	NOAA ESRL GMD data
	2004-2013	WMO 2014	WDCGG based on Tsutsumi et al 2009, http://ds.data.jma.go.jp/gmd/wdcgg/pub/global/globalmean.html
N2O	1010-1850	Flueckiger et al 2002	smoothed with 300 year cut-off spline
	1850-1977	Machida et al 1995	from data compilation of NASA GISS model (ftp://ftp.cmdl.noaa.gov/hats/n2o/flasks)
	1978-2015	Elkins et al 2015	NOAA ESRL GMD ftp://ftp.cmdl.noaa.gov/hats/n2o/combined/HATS_global_N2O.txt
C2F6	1850-1900		assumed 0ppt
	1900-1940		linearly interpolated to zero levels in 1900
	1940-1972	Worton et al 2007	Fig 2, determined from firn air
	1973-1994	Muehle et al 2010	check: assumed pre-industrial background level of 0.1±0.02 ppt
	1995-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
CF4	1850-1922	Worton et al 2007, Deeds et al 2008	assumed pre-industrial mixing ratio of 35ppt
	1922-1940		constant rate of increase based on model results
	1940-1994	Worton et al 2007	Fig 2, determined from firn air
	1995-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
HFC-125	1850-1970		assumed 0ppt
	1970-1980		linearly interpolated to zero levels between 1970 and 1980
	1980-1994	WMO 2007	Figure 1-23
	1995-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
HFC-134a	1850-1990		assumed 0ppt
	1990-1993	extended Montzka et al 1996a/b	NOAA ESRL GMD data
	1994-2014	Montzka et al 2015	NOAA ESRL GMD monthly station data, ftp://ftp.cmdl.noaa.gov/data/hats/hfcs/hfc134a_GCMS_flask.txt
HFC-143a	1850-1970		assumed 0ppt
	1970-1978		linearly interpolated to zero levels in 1970
	1978-1996	Culbertson et al 2004	interpolated end-of-year values
	1997-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
HFC-23	1850-1930		assumed 0ppt
	1930-1960		Extension using average 1977–1987 growth rate of 8.7%/year
	1960-1995	Oram et al 1998	based on Gape Grim Air Archive
	1996-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
SF6	1850-1950		asssumed 0ppt
	1950-1960		linearly interpolated to zero levels in 1950
	1961-1993	Butler et al 1999, Geller et al 1997, Peters et al 2004	firn air, flask, and in-situ records from the NOAA/ESRL/GMD
	1994-2015	Elkins et al 2015	NOAA ESRL GMD monthly, ftp://ftp.cmdl.noaa.gov/hats/sf6/combined/HATS_global_SF6.txt
ODS	1850-1950		loosely based on AFEAS production data and consistent with 1950 values for default lifetimes, eg linear ramp up of 1938-1950 HCFC-22 emissions assumed to match 1950 concentration of 0.95 ppt
CFC-11	1950-1979	Daniel et al 2007	taken directly from WMO 2007 (Table 8-4) plus personal communication
CFC-12	1980-2013	WMO 2014	Figure 1-1, Table, 1-1, Table 5A-2
CFC-113			
CFC-114			
CFC-115			
CCl4			
CH3CCl3			
HCFC-CH322			
HCFC-141b			
HCFC-142b			
Halon1211			
Halon1202			
Halon1301			
Halon2402			
CH3Br			
CH3Cl			
NF3	1980-2011	Arnold et al 2013	extended in-situ record with air samples complementing lab data

Table 3: Overview of RCP historical GHG concentration datasets (left side) and potential dataset updates for the CMIP6 historical GHG concentrations (right)

RCP historical GHG concentrations				CMIP6 - selection of available dataset updates		
GHG	**Period**	**Source**	**Description**	**Period**	**Source**	**Description**
CO2	1010-1832	Etheridge et al 1998b	75year smoothed	1980-2014	Dlugokencky et al 2015	NOAA ESRL GMD ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_gl.txt
	1832-1958	Etheridge et al 1998b	20year smoothed			
	1959-1981	Keeling and Whorf 2004	Keeling MLO minus 0.59ppm (mean delta between MLO and NOAA/ESRL/GMD 1982-1986 estimates, Conway et al 1994)			
	1982-2008	Conway et al 1994	extended with NOAA global mean datapoints			
CH4	1010-1850	Etheridge et al 1998a	Law Dome Ice Core date	1983-2013	Dlugokencky et al 2014	NOAA ESRL GMD ftp://aftp.cmdl.noaa.gov/data/trace_gases/ch4/flask/surface/
	1850-1980	Etheridge et al 1998a	taken from data compilation for NASA GISS model (http://data.giss.nasa.gov/modelforce/ghgases/Fig1B.ext.txt)			Cape Grim, ftp://ftp.cmdl.noaa.gov/data/trace_gases/ch4/flask/surface/ch4_cgo_surface-flask_1_ccgg_month.txt
	1984-2003	Dlugokencky, private communication	NOAA ESRL GMD data	1984-2013	WMO 2014	WDCGG based on Tsutsumi et al 2009, http://ds.data.jma.go.jp/gmd/wdcgg/pub/global/globalmean.html
	2004-2008	Dlugokencky et al 2009	NOAA ESRL GMD flask data			
N2O	958-1850	Flueckiger et al 2002	smoothed with 300 year cut-off spline	1980-2013	WMO 2014	WDCGG based on Tsutsumi et al 2009, http://ds.data.jma.go.jp/gmd/wdcgg/pub/global/globalmean.html
	1850-1977	Machida et al 1995	from data compilation of NASA GISS model (ftp://ftp.cmdl.noaa.gov/hats/n2o/flasks)	1977-2015	Elkins et al 2015	NOAA ESRL GMD ftp://ftp.cmdl.noaa.gov/hats/n2o/combined/HATS_global_N2O.txt
	1978-1999		from data compilation of NASA GISS model, NOAA ESRL GMD flask data correction	1977-2015	Dutton et al 2015	NOAA ESRL GMD in-situ ftp://ftp.cmdl.noaa.gov/data/hats/n2o/insituGCs/CATS/global/insitu_global_N2O.txt
	2000-2008	Dutton et al 2009	from data compilation of NASA GISS model, NOAA ESRL GMD in-situ data			
C2F6	1900-1940		linearly interpolated to zero levels in 1900	1973-2010	Muehle et al 2010	check: assumed pre-industrial background level of 0.1±0.02 ppt
	1940-2001	Worton et al 2007	Fig 2, determined from firn air	1995-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
CF4	1900-1922	Worton et al 2007, Deeds et al 2008	assumed pre-industrial mixing ratio of 35ppt	1995-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
	1922-1940		constant rate of increase based on model results			
	1940-2003	Worton et al 2007	Fig 2, determined from firn air			
HFC-125	1900-1970		assumed 0ppt	1995-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
	1970-1980		linearly interpolated to zero levels between 1970 and 1980			
	1980-2004	WMO 2007	Figure 1-23			
HFC-134a	1930-1990		assumed 0ppt	1994-2014	Montzka et al 2015	NOAA ESRL GMD monthly station data, ftp://ftp.cmdl.noaa.gov/data/hats/hfcs/hfc134a_GCMS_flask.txt
	1990-2007	extended Montzka et al 1996a/b	NOAA ESRL GMD data			
HFC-143a	1930-1970		assumed 0ppt	1995-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
	1970-1978		linearly interpolated to zero levels in 1970			
	1978-1996	Culbertson et al 2004	interpolated end-of-year values			
	1996-2000		linear extrapolation to attain the average RCP value			
HFC-23	1930-1960		Extension using average 1977–1987 growth rate of 8.7%/year	1978-2010	Miller et al 2010	AGAGE network, Medusa3 and Medusa9
	1960-1995	Oram et al 1998	based on Gape Grim Air Archive	1995-2012	WMO 2014	Table 1-14, Figure 1-24, data from AGAGE network
	1996-2004	WMO 2007	Figure 1-23			
SF6	1930-1950		asssumed 0ppt	1994-2015	Elkins et al 2015	NOAA ESRL GMD monthly, ftp://ftp.cmdl.noaa.gov/hats/sf6/combined/HATS_global_SF6.txt
	1950-1960		linearly interpolated to zero levels in 1950			
	1961-2008	Butler et al 1999, Geller et al 1997, Peters et al 2004	firn air, flask, and in-situ records from the NOAA/ESRL/GMD			
ODS	1900-1950		loosely based on AFEAS production data and consistent with 1950 values for default lifetimes, eg linear ramp up of 1938 - 1950 HCFC-22 emissions assumed to match 1950 concentration of 0.95 ppt	1980-2013	WMO 2014	Figure 1-1, Table, 1-1, Table 5A-2, values for the beginning of the corresponding year
CFC-11	1951-2008	Daniel et al 2007	taken directly from WMO 2007, see Table 8-4	1992-2013	Montzka et al 2003, Muehle et al 2010	NOAA ESRL GMD ftp://ftp.cmdl.noaa.gov/hats/Total_Cl_Br/
CFC-12						
CFC-113						
CFC-114						
CFC-115						
CCl4						
CH3CCl3						
HCFC-CH322						
HCFC-141b						
HCFC-142b						
Halon1211						
Halon1202						
Halon1301						
Halon2402						
CH3Br						
CH3Cl						
NF3	NONE	NONE	NOT INCLUDED	1980-2011	Arnold et al 2013	air samples complementing lab data; extended in-situ record

6. DATA FORMAT

The data format for the consolidated dataset of historical GHG concentrations is proposed to be consistent with those of CMIP5, using a simple ASCII format given that the timeseries are going to be rather small (see RCP dataformats here: http://www.pik-potsdam.de/~mmalte/rcps/). The data is likely going to be stored on various CMIP6 repositories, and as well as supplementary material to the GMD article.

7. QUESTIONS TO THE COMMUNITY

In addition to comments on the datasources suggested above, we would welcome feedback on the following questions from you:

a) **Other/new gases?** Are there additional long-lived greenhouse gases (e.g. some fluorinated gases) for which concentration timeseries are desirable within the CMIP6 historical GHG dataset compilation?

b) **Time and spatial resolution?** Are annual and global average concentrations sufficient for, e.g., CO_2 and CH_4? If not, how should seasonality and e.g. latitudinal variation be captured and on the basis of which datasets? For which tasks would those historical fields likely be important?

c) **Extension back in time?** To enable potential 1000-year runs or spin-ups with realistic forcing of volcanic eruptions [*Gregory et al.*, 2013] and other gases, the CMIP6 historical GHG concentration datasets plans to provide CO_2, CH_4 and N_2O timeseries based on Etheridge et al., Flueckiger et al. etc. Would you suggest other datasets, even longer time horizons or a history for other gases to be part of the CMIP6 Historical GHG concentrations?

d) **How to aggregate fluorinated gases?** In order to enable ESMs to capture the aggregate radiative effect of fluorinated gases without representing all individual components, which aggregate equivalent concentration timeseries would be useful for the modelling groups? For CMIP5, we provided the aggregate of HFCs, PFCs, and SF_6 as a HFC134a equivalent concentration and all Ozone Depleting Substances as CFC-12 equivalent concentrations. We calculated equivalence concentration on the basis of radiative forcing efficiencies. Would modelling groups like to see changes from this practice or additional aggregations into other bins?

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