

The PRIMAP-hist national historical emissions time series (1850-2017) (v2.1, updated November 2019)

1 Recommended citation

Gütschow, J.; Jeffery, L.; Gieseke, R.; Günther, A. (2019): The PRIMAP-hist national historical emissions time series v2.1 (1850-2017). GFZ Data Services. <<https://doi.org/10.5880/pik.2019.018>>.

Gütschow, J.; Jeffery, L.; Gieseke, R.; Gebel, R.; Stevens, D.; Krapp, M.; Rocha, M. (2016): The PRIMAP-hist national historical emissions time series, Earth Syst. Sci. Data, 8, 571-603, <https://dx.doi.org/10.5194/essd-8-571-2016>

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3 Use of the dataset and full description

Before using the dataset, please read this document and the article describing the methodology, especially the section on uncertainties and the section on limitations of the method and use of the dataset.

Gütschow, J.; Jeffery, L.; Gieseke, R.; Gebel, R.; Stevens, D.; Krapp, M.; Rocha, M. (2016): The PRIMAP-hist national historical emissions time series, Earth Syst. Sci. Data, 8, 571-603, <https://dx.doi.org/10.5194/essd-8-571-2016>

Please notify us (johannes.guetschow@pik-potsdam.de) if you use the dataset so that we can keep track of how it is used and take that into consideration when updating and improving the dataset.

When using this dataset or one of its updates, please cite the DOI of the precise version of the dataset used and also the data description article which this dataset is supplement to (see above). Please consider also citing the relevant original sources when using the PRIMAP-hist dataset. See the full citations in the References section further below.

4 Support

If you encounter possible errors or other things that should be noted, please check our issue tracker at github.com/JGuetschow/PRIMAP-hist and report your findings there.

If you need support in using the dataset or have any other questions regarding the dataset, please contact johannes.guetschow@pik-potsdam.de.

5 Abstract

The PRIMAP-hist dataset combines several published datasets to create a comprehensive set of greenhouse gas emission pathways for every country and Kyoto gas, covering the years 1850 to 2017, and all UNFCCC (United Nations Framework Convention on Climate Change) member states as well as most non-UNFCCC territories. The data resolves the main IPCC (Intergovernmental Panel on Climate Change) 2006 categories. For CO₂, CH₄, and N₂O subsector data for Energy, Industrial Processes and Product Use (IPPU), and Agriculture is available. Due to data availability and methodological issues, version 2.1 of the PRIMAP-hist dataset does not include emissions from Land Use, Land-Use Change, and Forestry (LULUCF).

The PRIMAP-hist v2.1 dataset is an updated version of

Gütschow, J.; Jeffery, L.; Gieseke, R.; Gebel, R. (2017): The PRIMAP-hist national historical emissions time series v2.0 (1850-2016). GFZ Data Services. <<https://doi.org/10.5880/pik.2019.001>>.

The [Changelog](#) below indicates the most important changes. You can also check the issue tracker on github.com/JGuetschow/PRIMAP-hist for additional information on issues found after the release of the dataset.

6 Sources

Global CO₂ emissions from cement production v4 (Andrew 2019) [data](#), [paper](#) Andrew (2019)

BP Statistical Review of World Energy [website](#): British Petroleum (2019)

CDIAC [data](#): Boden et al. (2017)

EDGAR versions 4.2 and 4.2 FT2010: [EDGAR v4.2](#), [EDGAR v4.2 FT2010](#): JRC and PBL (2017), Olivier and Janssens-Maenhout (2012)

EDGAR version 4.3.2: [data](#), [paper](#): JRC and PBL (2011), Janssens-Maenhout et al. (2017)

EDGAR-HYDE 1.4 [data](#): Van Aardenne et al. (2001), Olivier and Berdowski (2001),

FAOSTAT database [data](#): Food and Agriculture Organization of the United Nations (2019)

RCP historical data [data](#), [paper](#): Meinshausen et al. (2011)

UNFCCC National Communications and National Inventory Reports for developing countries [website](#), [data](#): UNFCCC (2019c), Gieseke and Gütschow (2019)

UNFCCC Biennial Update Reports [website](#): UNFCCC (2019b)

UNFCCC Common Reporting Format (CRF) [website](#), [data](#): UNFCCC (2019a) UNFCCC (2018) (processed as described in Jeffery et al. (2018a)),

7 Files included in the dataset

PRIMAP-hist_v2.1_09-Nov-2019.csv: With numerical extrapolation of all time series to 2017.

PRIMAP-hist_no_extrapolation_v2.1_09-Nov-2019.csv: Without numerical extrapolation of missing values and not including the country groups mentioned in section [country].

8 Notes

- Emissions from international aviation and shipping are not included in the dataset.
- Emissions from Land Use, Land-Use Change, and Forestry (LULUCF) are not included in this dataset.

9 Data format description (columns)

9.1 “scenario”

- HISTCR: In this scenario country-reported data (CRF, BUR, UNFCCC) is prioritized over third-party data (CDIAC, FAO, Andrew, EDGAR, BP).
- HISTTP: In this scenario third-party data (CDIAC, FAO, Andrew, EDGAR, BP) is prioritized over country-reported data (CRF, BUR, UNFCCC)

9.2 “country”

ISO 3166 three-letter country codes or custom codes for groups:

Table 1: Additional “country” codes.

Code	Region description
EARTH	Aggregated emissions for all countries.
ANNEXI	Annex I Parties to the Convention
NONANNEXI	Non-Annex I Parties to the Convention
AOSIS	Alliance of Small Island States
BASIC	BASIC countries (Brazil, South Africa, India and China)
EU28	European Union
LDC	Least Developed Countries
UMBRELLA	Umbrella Group

9.3 “category”

IPCC (Intergovernmental Panel on Climate Change) 2006 categories for emissions. Some aggregate sectors have been added to the hierarchy. These begin with the prefix *IPCM* instead of *IPC*.

Table 2: Category descriptions using IPCC 2006 terminology.

Category code	Description
IPCM0EL	National Total excluding LULUCF
IPC1	Energy
IPC1A	Fuel Combustion Activities
IPC1B	Fugitive Emissions from Fuels
IPC1B1	Solid Fuels
IPC1B2	Oil and Natural Gas
IPC1B3	Other Emissions from Energy Production
IPC1C	Carbon Dioxide Transport and Storage (currently no data available)
IPC2	Industrial Processes and Product Use (IPPU)
IPC2A	Mineral Industry
IPC2B	Chemical Industry
IPC2C	Metal Industry
IPC2D	Non-Energy Products from Fuels and Solvent Use

Category code	Description
IPC2E	Electronics Industry (no data available as the category is only used for fluorinated gases which are only resolved at the level of category IPC2)
IPC2F	Product uses as Substitutes for Ozone Depleting Substances (no data available as the category is only used for fluorinated gases which are only resolved at the level of category IPC2)
IPC2G	Other Product Manufacture and Use
IPC2H	Other
IPCMAG	Agriculture, sum of IPC3A and IPCMAGELV
IPC3A	Livestock
IPCMAGELV	Agriculture excluding Livestock
IPC4	Waste
IPC5	Other

9.4 “entity”

Gas categories using global warming potentials (GWP) from either Second Assessment Report (SAR) or Fourth Assessment Report (AR4).

Table 3: Gas categories and underlying global warming potentials

Code	Description
CH ₄	Methane
CO ₂	Carbon Dioxide
N ₂ O	Nitrous Oxide
HFCS	Hydrofluorocarbons (SAR)
HFCSAR4	Hydrofluorocarbons (AR4)
PFCS	Perfluorocarbons (SAR)
PFCSAR4	Perfluorocarbons (AR4)
SF ₆	Sulfur Hexafluoride
NF ₃	Nitrogen Trifluoride
FGASES	Fluorinated Gases (SAR): HFCs, PFCs, SF ₆ , NF ₃
FGASESAR4	Fluorinated Gases (AR4): HFCs, PFCs, SF ₆ , NF ₃
KYOTOGHG	Kyoto greenhouse gases (SAR)
KYOTOGHGAR4	Kyoto greenhouse gases (AR4)

9.5 “unit”

Unit is either Gg or GgCO₂eq (CO₂-equivalent according to the global warming potential used).

9.6 Remaining columns

Years from 1850-2017.

10 Changelog

Throughout this section we use “CR” to refer to the country-reported data priority source and “TP” to refer to the third-party priority source.

10.1 v2.1 (November 2019)

The 2.1 release is a minor update of the v2.0 version. The methodology is unchanged, only the input sources have been updated where available. Additionally some bugs have been fixed.

10.1.1 Changes in PRIMAP-hist source creation

10.1.1.1 Data source prioritization

- Data from the third BUR reports have been included as first priority source for non-Annex I parties.

10.1.1.2 Sectors and gases

No changes

10.1.1.3 Composite source generation methodology

No changes

10.1.1.4 Special treatment of individual countries

- Andorra: In the Waste sector (IPC4) scaling of BUR data to EDGAR432 data gives huge emissions as BUR data are near zero in the scaling year 2012. We use linear extrapolation instead of BUR data.
- Namibia: In the mineral industry sector (IPC2A) scaling of CDIAC data to ANDREWv4 data gives huge emissions as CDIAC is near zero 2010 and before, while ANDREW is non-zero in 2011 and the following years. We use CDIAC data directly for 1994 to 1998.

10.1.2 Changes in data sources and preprocessing

10.1.2.1 Input source updates

- We have included Andrew Cement data (v4, Andrew (2019)), which replace v2 used in PRIMAP-hist v2.0.
- BP fossil CO₂ data have been updated to the 2019 release (British Petroleum (2019)), last used data year is 2017.
- Data from the Biennial Update Reports (BURs, UNFCCC (2019b)) have been updated. We have added the second BURs from Colombia, Indonesia, Mexico, Moldova, and Montenegro. We have also added the third BURs from Andorra and Namibia. Data from the third BURs of Chile and Brazil are (at least partly) included in the UNFCCC detailed data by party interface as their data used a mixture of IPCC 1996 and IPCC 2006 categories. Data from the South African third BUR are currently not included, as data detail is not sufficient and downscaling to gases did not provide results consistent with available national total individual gas time series. In total, countries included in our BUR data are
 - first BUR: Indonesia, Montenegro, Mongolia, Mauritania, and Togo
 - second BUR: Andorra, Argentina, Colombia, Indonesia, Macedonia, Mexico, Moldova, Montenegro, Namibia, and South Africa
 - third BUR: Andorra and Namibia
- CRF data have been updated to the 2019 release (UNFCCC (2019a), as of October 31. 2019) with the 2018 release used as backup for missing 2019 data. The last data year is now 2017 for all categories and gases.
- FAOSTAT data have been updated to include all data available by September 30th, 2019 (Food and Agriculture Organization of the United Nations (2019)). For all sectors and gases the last year is now 2017. The new FAO data shows significant changes in emissions estimates in the following sectors: IPC3C4 - direct N₂O from managed soils; IPC3C1AG - agricultural biomass burning.

- UNFCCC “Detailed Data by Party” has been updated to data available in August 1st, 2019 (Gieseke and Gütschow (2019)): Jamaica, Mali, and Yemen have been added to the source. Azerbaijan, Brazil, Chile, Malaysia, Mexico, Chad, United Arab Emirates, and Uruguay have extended and / or updated data.

10.1.2.2 Changes in preprocessing

- The EDGAR v4.3.2 data source contains some time series with only a single or very few data points. These have been removed as we do not use single data point time series. This has affected several countries, though only slightly as the time series with missing data are in sectors with low emissions.

10.1.3 Bug fixes

- In earlier versions of PRIMAP-hist, the FAO time series for savanna burning and burning of agricultural residues were mixed up. As they are summed for use in the PRIMAP-hist dataset, this does not directly influence the emissions. However, the savanna burning time series starts in 1990 only, and was extrapolated back to 1961 using EDGAR data, and thus in the older version we erroneously used data for burning of agricultural residues instead of data for savanna burning. This has been corrected in v2.1. Several countries, especially African countries, were affected by the change as visible in the [Noteworthy Changes](#) section.
- In the FAO data some time series are published in units of a gas and other in GgCO₂eq units. In consequence, the livestock (IPC3A) CH₄ TP time series in PRIMAP-hist v2.0 used a CO₂eq unit. As the global warming potential (GWP) used for the conversion is not stored with the data, this time series was not converted when aggregating the Kytoto GHG baskets. The original time series is in SAR GWPs (100 year GWP for CH₄: 21) while the AR4 value for CH₄ 100 year GWP is 25. Thus, IPC3A CH₄ was underestimated by a factor of $21/25 = 0.84$ in the AR4 Kyoto GHG time series. This has been fixed now and all data are now converted to native units before use in the PRIMAP-hist source. The bug has affected all countries in the TP time series (AR4 GWP Kyoto GHG time series only), but total emissions have only changed notably for those countries which have a high share of livestock emissions in total emissions. (issue #4 in the issue tracker)
- In the CRF data some countries report an unspecified mix of HFCs (PFCs). These can not be converted to different GWPs automatically as their mix is unknown. CRF data are reported in AR4 GWPs. Because there was no conversion to other GWPs the emissions reported as unspecified mix of HFCs (PFCs) were only included for AR4 GWPs. Only few countries report unspecified mixes and of these only Japan in quantities sufficient to noticeably affect total emissions (for recent years only).
- The BUR data have no common specifications of units, GWPs, etc used by all countries. Thus, time series presented in CO₂eq units can use different GWPs throughout the BUR data source. These time series were not in all cases converted to a common GWP leading to GWP conversion errors in PRIMAP-hist v2.0. This has been corrected in v2.1. Affected countries are Argentina and South Africa.
- For a few very small countries, which are included in reporting of larger countries for some sources there was a bug in downscaling of agricultural emissions leading to emissions time series dropping to 0 in 2013. This has been corrected. Affected countries are Monaco, San Marino, Vatican. (issue #3 in the issue tracker)

10.1.4 Known problems

No known problems. For problems that were found after the release of the dataset, please consult the issue tracker github.com/JGuetschow/PRIMAP-hist.

10.1.5 Noteworthy changes

Here, we list the most important changes in total and per sector / per gas emissions and their reasons. The changes due to bugs fixed and discussed in the [Bug fixes](#) section above are omitted here.

10.1.5.1 Notable changes in total Kyoto GHG emissions

- **Changes of 20-50% in cumulative emissions**
 - **Central African Republic:** changes in data before 1990 in CR and TP datasets. The changes originate from the extrapolation bugfix in agricultural biomass burning emissions.
 - **Colombia:** the inclusion of data from the second BUR has changed emissions in the CR time series in all sectors with largest changes in the agricultural sector. The TP time series has only small changes coming mostly from the IPC3A FAO GWP bug (AR4 GWP time series only).
 - **Democratic Republic of the Congo:** overall data changes in CR and TP datasets. The changes originate mostly from biomass burning emissions, where FAO data have changed. The extrapolation bugfix has also influenced pre-1990 emission estimates.
 - **Guinea:** overall data changes in CR and TP datasets. The changes originate mostly from biomass burning emissions, where FAO data have changed. The extrapolation bugfix has also influenced pre-1990 emission estimates.
 - **Guinea Bissau:** overall data changes in CR and TP datasets. The changes originate mostly from biomass burning emissions, where FAO data have changed. The extrapolation bugfix has also influenced pre-1990 emission estimates.
 - **Namibia:** changes mainly in the agricultural sectors. The changes originate from new BUR data and new FAO data including the extrapolation bugfix. Changes for the TP source are in the 10-20% range.
 - **South Sudan:** changes in the agricultural sectors. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical.
- **Changes of 10-20% in cumulative emissions**
 - **Angola:** changes in the agricultural sectors. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical.
 - **Botswana:** changes in the agricultural sectors. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical.
 - **Côte d'Ivoire:** changes in the agricultural sectors. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical.
 - **Republic of the Congo:** changes in the agricultural sectors excluding livestock. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical. The changes are smaller for the AR4 GWP time series as they partly cancel with changes introduced by the FAO IPC3A GWP bugfix.
 - **Mali:** changes in several categories for the CR dataset, as the addition of data for 2010 has enabled the use of the country-reported UNFCCC data in the PRIMAP-hist dataset. The TP dataset has changes in the agricultural sector originating from new FAO data including the extrapolation bugfix.
 - **Namibia:** the most important change comes from fixing a scaling bug in IPC2A (Mineral Industry) CO₂ emissions, which lead to an emissions peak in PRIMAP-hist v2.0. Further changes come from the inclusion of the third BUR (CR dataset) and FAO2019 (both datasets).
 - **Papua New Guinea:** changes in emissions estimates from the agricultural sector and from industrial processes (cement). In the agricultural sector, the main source of changes are direct N₂O emissions from managed soils (IPC3C4) from the FAO dataset. As there is no country-reported data, CR and TP datasets are identical.
 - **Russia:** strong downward correction of emissions from several sectors and gases in the CR source: CH₄, CO₂, and N₂O from fugitive emissions from oil and natural gas (IPC1B2), N₂O from livestock (IPC3A), CO₂ and N₂O from agricultural emissions excluding livestock (IPCMAGELV), CH₄ from waste (IPC4). The national inventory report mentions a change in emissions factors as the source of the changes.
 - **Togo:** changes in the agricultural sectors in the CR source. The changes originate from new FAO data including the bugfix. Changes in the TP source are smaller (5-10% range) as the estimates for agricultural emissions are higher in the CR source and FAO data are scaled to match these higher emissions.
 - **Tanzania:** changes in the agricultural sectors excluding livestock. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR

and TP datasets are identical.

10.1.5.2 Changes for individual categories / gases

Here, we group the changes by their cause and not by country, as several countries are affected in the same way. Not all changes that are large for a sector and gas combination are listed, because that sector and gas combination might not play a significant role in a country's total emissions.

- **FAO data update**

- The FAO data update mainly affected emissions excluding livestock. Livestock emissions are largely unchanged.
- Several countries are affected by a change in direct N₂O emissions from managed soils (IPC3C4):
 - * much higher emissions: Iceland (TP)
 - * higher emissions: Burundi (CR, TP), Gabon (CR, TP), UK (TP)
 - * lower emissions: Armenia (TP), Belize (CR, TP), Canada (TP), Ireland (TP), Malaysia (TP), Nepal (CR, TP), Oman (CR, TP)
 - * much lower emissions: Estonia (TP), Suriname (CR, TP)
 - * other changes: Bahrain (peaks removed, CR, TP), Trinidad and Tobago (peaks removed, CR, TP)
- The Update of biomass burning emissions (and the bugfix) affected several countries as well. A lot of them are already mentioned above. Additionally we have
 - * Australia (CH₄, N₂O: TP)
 - * Ghana (CH₄, N₂O: TP)
 - * Gambia (lower N₂O: CR, TP)
 - * Guyana (lower CH₄, N₂O: CR, TP)
 - * Indonesia (slightly lower CH₄, N₂O: CR, TP)
 - * Lesotho (CH₄, N₂O: CR, TP)
 - * Madagascar (CH₄, N₂O: TP)
 - * Mozambique (CH₄, N₂O: CR, TP)
 - * Paraguay (CH₄, N₂O: CR, TP)
 - * Sudan (CH₄, N₂O: CR, TP)
 - * Senegal: (CH₄, N₂O: CR, TP)
 - * Sierra Leone: (CH₄, N₂O: CR, TP)
 - * South Africa: (CH₄, N₂O: CR, TP)
 - * Zambia: (CH₄, N₂O: CR, TP)
 - * Zimbabwe: (CH₄, N₂O: CR, TP)
- Other changes
 - * Kuwait: new peaks in N₂O from IPCMAGELV
 - * Chad: different changes through new FAO data. The most important is a strong increase in emissions for the last years for livestock and direct soil N₂O. (CH₄, N₂O: CR, TP)

- **CRF data update**

- Cyprus: lower N₂O emissions in agriculture without livestock, but not relevant on national total Kyoto GHG level
- Iceland: much lower livestock N₂O emissions in CR source.
- Kazakhstan: Fugitive emissions from oil and natural gas (IPC1B2) are much higher in CRF 2019 than in the CRF data used fore PRIMAP-hist v2.0. (CR)
- Luxembourg: slight decrease in N₂O data from agriculture excluding livestock (CR)
- Romania: changed emission for several sectors and gases (CR)
- Turkey: changed emissions for several sectors and gases (CR)
- USA: N₂O emissions from energy corrected upwards (CR)

- **UNFCCC data update**

- Chile: the new F-gases UNFCCC data are much higher than EDGAR42 used before. There are no HFCs data in EDGAR, thus the TP source also shows higher F-gases emissions. N₂O data are lower. One problematic data point has been removed.
- United Arab Emirates: changed emission estimates for latest years
- Azerbaijan: drop in agricultural N₂O data in last years
- Uruguay: new data have changed emissions for several sectors and gases
- Yemen: newly available in UNFCCC (data detail not sufficient for all sectors). The PRIMAP-

hist time series show changes in several sectors and gases (CR).

- **BUR data update**

- Colombia: the new F-gases BUR data are much higher than EDGAR42 used before. No HFCs data in EDGAR, thus the TP source also shows higher F-gases emissions.
- Moldova: new BUR data replace UNFCCC data and lead to changes for several sectors and gases in the CR time series.
- Montenegro: new BUR2 data replace BUR1 data and lead to changes for several sectors and gases in the CR time series.

10.2 v2.0 (December 2018)

The v2.0 release comes with several important changes. The dataset now uses the sectors from the IPCC 2006 guidelines. It includes new and updated data sources (EDGAR v4.3.2, Andrew 2018 cement data, updated BUR, CRF and UNFCCC data, updated BP and FAO data). This release of PRIMAP-hist does not include LULUCF emissions. We also present two different data sets to highlight discrepancies between data from third-party assessments and data reported by countries. In the “country-reported priority” time series we prioritize country-reported data over third-party data. This is a direct continuation of earlier versions of PRIMAP-hist. These time series has the scenario code “HISTCR”. In the “third-party priority” time series we prioritize data from third-party assessments (e.g. by research institutes, international organizations, or private companies) over the third-party data. The scenario code is “HISTTP”. A new data description paper with detailed methodology description is currently under preparation.

10.2.1 Changes in PRIMAP-hist source creation

10.2.1.1 Data source prioritization

- Through the inclusion of new data sources, the source prioritization has changed a little. The “HISTCR” time series, which are the continuation of the previous PRIMAP-hist time series now use the following source prioritization: CRF 2018, CRF 2017, BUR, UNFCCC2018, Andrew2018, CDIAC 2017, FAO2018, EDGAR v4.3.2, EDGAR v4.2 (FT2010), BP2018.
- The new “HISTTP” time series use the same basic prioritization, but with the block of country-reported data sources (CRF, BUR, UNFCCC) at the end of the priority list.

10.2.1.2 Sectors and gases

The data source now uses the IPCC 2006 sectors. The sectors are listed in section [category] above. The new sectors bring some changes to the categorical resolution.

- In the agricultural sector we now distinguish between emissions from livestock (IPC3A) and agricultural emissions without livestock (IPCMAGELV). Because of the use of manure as fertilizer for crops, this split is not always exactly the same for all data sources. The extrapolation has also changed, as EDGAR-HYDE has individual data for livestock and agricultural emissions without livestock (for CH₄ and for N₂O we use the combined time series as the individual time series for agriculture without livestock are zero before 1940 for most regions).
- Subsector resolution for IPC1 and IPC2 is now available for all gases except the fluorinated gases, which lack this resolution in some input data sources.

The gas resolution has not been changed. Country- and sector-resolved data for individual HFCs and PFCs are still too scarce to create individual gas time series. However, NF₃ has been added to the time series but data are only available for a few countries.

10.2.1.3 Composite source generation methodology

- When only a few (less than 6) years are added to the time series by a lower priority source (for a specific country / gas / sector), the scaling is not carried out using regression values but the raw data of the time series and the lower priority source in the last year of the time series (first year in case of extension to the past). This method better accounts for short term trends, which are the information we want to obtain from the lower priority source if only a few years are added.

- The the scaling of lower priority time series to higher priority time series has been adjusted for category IPC1B2. Now a trend of 5 years is used instead of a trend of 15 years. This was necessary as several countries showed a steep increase in emissions in the first half of the 1970s, leading to very high starting points of the backwards extrapolation of EDGAR v4.3.2 data.
- The scaling of lower priority sources when filling gaps in higher priority sources has been changed as there were some problems when the lower priority source data showed strong fluctuations in the years of the gap, leading to different scaling factors for the right and the left boundary. Now small gaps (< 5 years), where the quotient of the left and right boundary scaling factors is larger than 2, are linearly interpolated instead of filling with scaled lower priority data.
- The bound on the scaling factor has been removed. Lower priority sources are now strictly used as growth rates.

10.2.1.4 Special treatment of individual countries

- South Sudan and Sudan now have individual data in most data sources. Thus, individual time series are created for the two countries instead of downscaling of a common time series after the source creation, as done before.

10.2.2 Changes in data sources and preprocessing

10.2.2.1 Input source updates

- We have included Andrew 2018 (v2) data on CO₂ emissions from cement to replace the CDIAC cement CO₂ emissions. We classify the dataset as third-party data, as it provides an overview over emissions from almost all countries. However, country-reported data (CRF) are also used to create the dataset.
- BP fossil CO₂ data have been updated to the 2018 release, last used data year is 2016.
- Data from the Biennial Update Reports (BURs) have been updated to include all BURs submitted until 1st September 2018 which use IPCC 2006 categories and contain sufficient data to be used in PRIMAP-hist. All data from countries which submitted their BURs in IPCC 1996 categories should be included in the UNFCCC “Detailed Data by Party” source. Countries included in our BUR data are
 - first BUR: Indonesia, Montenegro, Mongolia, Mauritania, Togo
 - second BUR: Andorra, Argentina, Macedonia, Namibia, South Africa
- CRF data have been updated to the 2018 release with the 2017 release used as backup for missing 2018 data. The last data year is now 2016 for all categories and gases
- EDGAR data have been updated to version v4.3.2. The new release shows significant differences in emissions estimates for some sectors and gases. Most prominent is a strong increase in estimates of fugitive emissions from oil and gas production. While this is a small contribution for most developed countries, it is a very important emissions source for oil exporting countries, especially when export of fossil fuels is the main economic sector. The change is justified in the EDGAR v4.3.2 description paper, see Janssens-Maenhout et al. (2017).
- FAOSTAT data have been updated to include all data available by September 2018. Changes in historical emissions are very limited. For most sectors and gases the last year is now 2016. There are some exceptions which need special processing which is explained in the following section.
- UNFCCC “Detailed Data by Party” has been updated to data available by September 2018 (no updates from the cited July version: Gieseke and Gütschow (2018)): several countries are included for the first time with sufficient data to be used in PRIMAP-hist. Some countries have updated and extended data. However, some time series seem to be constructed from data points that were calculated using different methodologies and therefore show large discrepancies. Other data show strong fluctuations or deviate strongly from third-party sources. In several cases we excluded data from use in PRIMAP-hist as we could not identify the source of the fluctuations and discrepancies. Details are presented in the section *Noteworthy Changes* below.

10.2.2.2 Changes in preprocessing

- In earlier versions of PRIMAP-hist, all input sources were extrapolated during sector and gas aggregation where individual subsectors or gases did not cover the full time frame. This has now been replaced by more specific extrapolations for the few cases where extrapolation is needed.
- All data sources not reported in IPCC 2006 sectors are converted to these sectors. These are: FAOSTAT, EDGAR v4.2, EDGAR v4.3.2, EDGAR-HYDE v1.4, RCP, and UNFCCC. BP, CDIAC, and Andrew cement data do not need a conversion as they only cover subsectors which are also present in the 2006 guidelines.
- FAOSTAT data covers the period 1961 to 2016 for most sectors and gases. However, there are a few exceptions that need special treatment:
 - For N₂O emissions from synthetic fertilizers, the resolved direct and indirect emissions miss 2016 data. We use the net emissions trend to extrapolate direct and indirect emissions. Direct and indirect emissions are mapped to different sectors in the IPCC 2006 categories and are thus needed for the whole time frame.
 - Data for agricultural waste burning are only available from 1990 onwards. In the PRIMAP-hist source creation agricultural waste burning emissions are included in the IPCMAGELV sector. For some countries emissions from this sector are a mayor contribution to the IPCAGELV sector. We thus extrapolate the FAO data with EDGAR v4.3.2 data for the same sector before aggregation of the IPCMAGELV sector.
 - Data for cultivation of organic soils are only available from 1990 onwards. As we have no alternative data source for this sector, we use a constant extrapolation. The data available in FAO are also a constant time series. Implicitly, the same was done in PRIMAP-hist v1.2 as the linear extrapolation of a constant function is a constant extrapolation
- In the BUR data, some tables contained unit errors or ambiguities that had to be corrected. Some countries provided the detailed category and gas information only for selected years and required downscaling to obtain time series usable in PRIMAP-hist
 - SF₆ data for Montenegro have been corrected as they were presented with a wrong unit in the BUR (The unit given is Gg while the data are actually in GgCO₂eq)
 - Indonesia data need downscaling of IPC1 and IPC2 data to subsectors for 2000 - 2011, where detailed 2012 data are used as downscaling key.
 - Mongolia data only resolve gases for 1990 and 2014 for all sectors. KYOTOGHG time series are provided for all sectors for 1990 - 2014. Some sectors only contain emissions from a certain gas and thus the Kyoto GHG time series can be used to construct an individual gas time series for these sectors. Other sectors need downscaling of Kyoto GHG time series to individual gases using the shares from 1990 and 2014 (linearly interpolated). These sectors are: IPC1 and subsectors and IPC4.
 - Argentina provides data for 1990 - 2014 with gas detail only for 2014. Thus, for all sectors Kyoto GHG data are downscaled to individual gas level using the 2014 shares.
- The UNFCCC “Detailed Data by Party” interface combines data from different country submissions. Sometimes these data have been prepared using different methodologies and guidelines and are inconsistent. When the sectors do not match the IPCC 1996 guidelines used by the interface, the time series are sometimes put into “other” categories. We thus have to remove data points and partial time series for several countries. In other cases we have to downscale data that are not available in the necessary categorical detail using detailed data available for individual years.
- Downscaling of Sudan data to Sudan and South Sudan is now carried out in the individual sources which do not yet contain data for the individual countries (e.g. EDGAR v4.2) or only resolve the individual countries for the time after the separation of Sudan e.g. (FAO, CDIAC).
- The downscaling of the groups for countries not individually resolved in the BP data has been improved. It now uses the trend of emissions shares from CDIAC rather than the shares themselves.

10.2.3 Further bug fixes

None.

10.2.4 Known problems

- The shorter regression period for category IPC1B2 extrapolation is only applied when extrapolating with EDGAR-HYDE data. However, EDGAR-HYDE data for N₂O in IPC1B2 starts in 1970, the

same year as EDGAR v4.3.2 data. Thus it is not used for extrapolation. In the extrapolation with RCP data the normal regression period is used and thus the starting point of the extrapolation is higher as there was a steep increase in fugitive emissions in the early 1970s.

- Data for the Pitcairn Islands has no CO₂. All data for the territory comes from EDGAR v4.2 and is very patchy. However, this is not very important as the Pitcairn Islands have only about 50 inhabitants.
- Tokelau CO₂ data are not extrapolated before 1890. Tokelau has no CO₂ IPC1A data and thus needs a special treatment for the CO₂ extrapolation. This will be added in a future version.
- The agricultural sectors (IPC3A, IPCMAG, IPCMAGELV) miss the last years for some countries. To add them in a manner consistent with the rest of the dataset, we use a linear extrapolation with a trend calculated from the last 15 years with data available. This bug will be corrected in the next release.

10.2.5 Noteworthy changes

We group the changes by their impact on cumulative IPCM0EL, Kyoto GHG emissions and present the reasons for these changes.

- Changes over 100% in cumulative emissions
 - Brunei Darussalam: EDGAR v4.3.2 shows strong changes compared with EDGAR v4.2 and other sources (especially CH₄). These changes come from fugitive emissions (IPC1B2, fugitive emissions from oil and natural gas).
- Changes between 50 and 100% in cumulative emissions
 - Republic of the Congo, Gabon, Libya, Nigeria, Oman, Qatar: All countries have large changes in fugitive emissions due to differences in EDGAR v4.3.2 vs. EDGAR v4.2. The main sector is IPC1B2, but other sectors are also affected (e.g., N₂O from fuel combustion activities (IPC1A), or for Oman emissions from industrial processes and product use (IPC2))
- Changes between 20 and 50% in cumulative emissions
 - Angola, Algeria, Cameroon, Iraq, Kuwait, Saudi Arabia: These countries are impacted by the change in fugitive emissions in the EDGAR data (IPC1B2, CH₄; for Cameroon also CO₂; for Iraq also N₂O from different sectors).
 - Armenia: UNFCCC data are now used. This has changed emissions estimates. Agricultural data from UNFCCC are subject to high fluctuations.
 - Bhutan: Changes in CH₄ and N₂O from new EDGAR data (IPC1 and subsectors) have reduced emissions estimates.
 - Democratic Republic of the Congo: There are changes for all three mayor gases. Changes in CO₂ and CH₄ from EDGAR v4.3.2, IPC1B2. Changes in N₂O from IPC5, which has also changed substantially from EDGAR v4.2 to EDGAR v4.3.2.
 - Equatorial Guinea: Changes come mainly from CH₄, a bit from N₂O. They originate from EDGAR v4.3.2, which is also used for CH₄ in IPCMAGELV.
 - Guyana: CH₄ extrapolation before 1960.
 - Lebanon: Changes in CH₄ and N₂O emissions from UNFCCC data. Changes before 1990 in CO₂, IPC1B2 from EDGAR v4.3.2 data.
 - Saint Lucia, Madagascar: UNFCCC data have been included, which differs from other sources. (For Saint Lucia especially for N₂O and CH₄).
 - Mauritania: Inclusion of BUR data changed emissions estimates. The main source of differences are: N₂O in IPC4 and IPCMAG, and CH₄ in IPC4.
 - Niger: Inclusion of UNFCCC data introduced changes for all sectors and gases. UNFCCC data are very scarce and fluctuating but somewhat in line with third-party sources and therefore kept.
 - Turks and Caicos Islands: Changes in emissions estimates of all three mayor gases due to EDGAR v4.3.2.
 - Chad: Changes mainly in emissions estimates of N₂O and CH₄ from EDGAR v4.3.2. UNFCCC data are only used for IPC4.
 - Tokelau: Changes in emissions estimates of N₂O and CH₄ from EDGAR v4.3.2.
 - Timor-Leste: Changes mainly in emissions estimates of CH₄ and smaller changes in CO₂ emissions, both from EDGAR v4.3.2.

- Saint Vincent and the Grenadines: UNFCCC data for agricultural CH₄ and N₂O are not used any more as they showed large fluctuations and step changes not in line with any other source.
- Changes between 10 and 20% in cumulative emissions
 - Djibouti: EDGAR v4.3.2 has changed emissions estimates of CH₄ and N₂O significantly.
 - Ecuador: CH₄ emissions estimates have changed for several sectors due to EDGAR v4.3.2.
 - Federated States of Micronesia: cumulative changes mainly from CO₂ (because downscaled BP data are available), but also strong peak changes for CH₄ and N₂O (from FAO, which had very low emission in the last data year in the last revision).
 - Georgia: We have removed UNFCCC CH₄ CAT1A data prior to 2000 because they were reported in CAT1A5 (other) and did not match the data for later years, which means that they were likely calculated using a different methodology than data submitted later.
 - Croatia: CH₄ data have changed as IPC3A data in CRF 2018 are significantly higher than in CRF 2017 which was used in PRIMAP-hist v1.2. CO₂ data before 1990 are higher, because the scaling of EDGAR to CRF is not bounded any more. PFCs data have changed, because the CRF data have a gap and the gap filling procedure was adapted.
 - Haiti: CH₄ emissions from IPC1B1 are much higher after 2004 due to EDGAR v4.3.2.
 - Iran: Changes come mainly from CH₄ in IPC1B2, originating from EDGAR v4.3.2. The EDGAR data also introduce changes in N₂O data for different sectors.
 - Kiribati: The changes come mainly from CH₄, where IPC4 has been added in EDGAR v4.3.2 and IPC3A, where UNFCCC data are now used. Other gases and sectors changed as well, also due to the inclusion of UNFCCC and EDGAR v4.3.2 data.
 - Mali, Senegal, Mozambique, Tanzania: CH₄ and N₂O have changed, mostly before 1990: this is due to a new method to extrapolate missing emissions from burning of agricultural residues. In v1.2, linear extrapolation was used, now we use growth rates from EDGAR v4.3.2 (see above).
 - Montenegro: The main change in emissions estimates comes from a modified scaling of EDGAR v4.2 PFCs data to the much higher country-reported data (BUR and UNFCCC).
 - Mongolia: The inclusion of BUR data have introduced changes in several sectors and gases.
 - Paraguay: Inclusion of UNFCCC data, which was not included in v1.2 has changed emissions, primarily N₂O, where IPCMAGELV is the dominant sector.
 - Sudan and South Sudan: There now are more independent data available for South Sudan, such that we need less downscaling based on economical data. This introduces some changes in emissions, especially for years after 2000. Furthermore, some input data have changed (FAO, EDGAR). The different extrapolation of missing FAO data have also impacted pre-1990 CH₄ and N₂O emissions especially for South Sudan.
 - Syria: Changes are mainly CH₄, IPC1B2 and originate from EDGAR v4.3.2 data. N₂O data have also changed, again because of changes in EDGAR data.
 - Togo: Emissions estimates for all gases have changed because of the inclusion of BUR data.
 - Yemen: CH₄ has changed post-1990 in sector IPC1B2. N₂O has also changed. Both changes come from EDGAR v4.3.2.
 - South Africa: Higher CH₄ emissions due to the inclusion of BUR data for the agricultural sector, which is much higher than third-party sources.

10.3 v1.2 (December 2017)

The v1.2 release uses new input data. CRF data have been updated to the 2017 and 2016 releases, CDIAC and BP data have been updated to their 2017 releases and the UNFCCC Non-Annex I data have been updated to the status of August 2017.

10.3.1 Changes in PRIMAP-hist source creation

- The method to fill gaps in time series has been changed. In v1.1, gaps in higher priority time series were linearly interpolated to enable the calculation of trends for the combination of time series from different data sources, even if the time series contained only few data points. This method can not be used any more as we now include UNFCCC data for China, which has data for only three years. Linear interpolation overestimates emissions in the late 1990s, where the Asian financial crisis lead to declining emissions (with a steep increase after the crisis). In v1.2, gaps are filled with data

from lower priority time series (where available) in the following way: the linear trend for the gap period is calculated both for the time series with the gap and the time series used to fill the gap. Then the deviation from the trend is calculated for the time series used to fill the gap. Scaling factors between the two time series are calculated for the left and right boundary of the gap. They are capped using the same bound as for the extension with lower priority time series (a factor of 3 (1/3)). The final time series to fill the gap is constructed as the sum of the linear trend of the higher priority time series and the scaled deviation from trend of the lower priority time series. The scaling uses a linear interpolation between the scaling at the left and right boundaries. This change affects all countries that have reported only a few years under UNFCCC2017B data, however, for most countries the differences are small. Details are presented in the *noteworthy changes* section.

- Changes in extrapolation trend calculations: in some cases the time span to calculate linear trends for the extrapolation starting points have changed.
 - LULUCF, CO₂, future extrapolation: FAOSTAT LULUCF data have a change in methodology in 2011 (inclusion of forest degradation and regrowth) leading to abrupt changes in estimates of emissions and removals. To avoid calculating an average over data calculated using different methodologies, we shorten the period to calculate the average to 4 years (2011 - 2014). The average is used to extrapolate data to 2015.
 - LULUCF, all gases: The trend used to calculate the starting point for extrapolations to the past is now calculated over 20 years instead of 30 years to avoid the use of different unharmonized data sources in the trend calculation.
 - BP data are only used to amend a single year to energy CO₂ time series. We therefore no longer use a trend calculation to determine the starting point for the extrapolation, but use the last data point of the higher priority source directly.
- Historical extrapolation for LULUCF, CH₄: until v1.1, we used EDGARHYDE data for the extrapolation. However, for some regions the EDGARHYDE data have non-zero emissions only between 1960 and 1985 - 1990, which is inconsistent with other sources. We therefore switched to RCP data, which is available on a level of 5 regions. As RCP data are defined starting in 1850, the linear interpolation for 1850 - 1890 is no longer necessary.

10.3.2 Changes in data sources and preprocessing

10.3.2.1 Input source updates

- CRF data have been updated to the 2017 release with the 2016 release used as backup for missing 2017 data.
 - The last data year is now 2015 for all categories and gases.
 - CRF data since 2015 follow the IPCC 2006 guidelines. Therefore, reported emissions have changed, especially for fugitive emissions and CH₄ and N₂O from agriculture and land use. See also Jeffery et al. (2018a) and Jeffery et al. (2018b).
- CDIAC fossil CO₂ data have been updated to the 2017 release, last data year is 2014.
- BP fossil CO₂ data have been updated to the 2017 release, last used data year is 2015.
- UNFCCC “Detailed Data by party” has been updated to August 2017: several countries are included for the first time with sufficient data to be used in PRIMAP-hist. Some countries have updated and extended data. However, some time series seem to be constructed from data points that were calculated using different methodologies and therefore show large discrepancies. Other data show strong fluctuations or deviate strongly from third-party sources. In several cases we excluded data from use in PRIMAP-hist, as we could not identify the source of the fluctuations and discrepancies. Details are presented in the *noteworthy changes* section.

10.3.2.2 Changes in preprocessing

- CRF 2016 and 2017 data are reported using new tables. The sectors in these tables are similar to but not exactly the IPCC 2006 sectors. The new reporting format makes a conversion to IPCC 1996 sector definitions used for PRIMAP-hist necessary. Depending on the reporting this is not perfectly possible for all countries. However, this mainly influences category 3, which has very small emissions. For details we refer to Jeffery et al. (2018a).

10.3.3 Further bug fixes

none

10.3.4 Known problems

- For Mauritius, the first data point for CH₄, category 6 (waste) in the UNFCCC2017 dataset is very low compared to the other data points. This influences the final dataset. As the low data point is in line with EDGAR data we do not remove it.
- There are no CH₄ and N₂O land use data for Egypt, Grenada, Haiti, and Singapore in PRIMAP-hist v1.1. The only available data source is FAO, which has only zero values in its current version and is thus not used for the PRIMAP-hist source.
- The (former) Netherlands Antilles are not included in the country mask used for Houghton (2008) downscaling, thus there are no Houghton (2008) based data.
- The country mask used in the downscaling of Houghton (2008) data treats Taiwan as a part of China and thus does not deliver data for Taiwan. As none of the data sources used for PRIMAP-hist has land use data for Taiwan, we have no option to downscale Taiwan from China.

10.3.5 Noteworthy changes

The noteworthy changes are grouped by dataset or processing which induced the change

- CRF (UNFCCC Annex I)
 - The new reporting guidelines introduce changes in emissions estimates for all countries which vary in strength and sectors affected. Countries with smaller changes are grouped, while for countries with larger changes or changes that are specific to a single country we explain the changes individually. For a more comprehensive discussion of the CRF 2017 data see Jeffery et al. (2018a).
 - Several countries exhibit changes in several sectors where relative changes are large for some sectors and gases but differences in economy-wide GHG emission estimates are small: Canada, Czech Republic, Germany, Denmark, Spain, France, Luxembourg, Netherlands, Norway, New Zealand, Poland, Slovakia, USA.
 - Several countries exhibit changes of emissions estimates which are mainly in the agricultural sector: Greece, Croatia, Hungary, Ireland, Liechtenstein, Lithuania, Latvia, Portugal, Slovenia, Sweden.
 - Australia: Total CH₄ emissions are much lower under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines used for CRF 2014 data, which is the basis of v1.1. The largest change is in the agricultural sector. N₂O emissions are much lower in CRF 2017 than in CRF 2014 as well.
 - Austria: Total CH₄ emissions are higher under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines. Total CO₂ emissions are almost unchanged, however, CAT1 emissions decreased significantly while CAT2 emissions increased. Total N₂O emissions are much lower.
 - Belgium: Total CH₄ emissions are higher under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines.
 - Bulgaria: Total CH₄ emissions are much lower in 1990 under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines. This leads to different historical emissions. Total N₂O emissions are much lower.
 - Belarus: Total CH₄ emissions are higher under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines. Total N₂O emissions are significantly lower.
 - Cyprus: Total CH₄ emissions are much lower under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines, especially for CAT6. This leads to different historical emissions. Total N₂O emissions are much lower as well where CAT4 is the main source.
 - Iceland: CH₄ from land use drastically increased under IPCC 2006 guidelines and significantly increased total emissions.
 - Kazakhstan: Changes due to changed data in the industrial processes sector.
 - Monaco: Energy CO₂ is lower in CRF 2017 than in CRF 2014

- Malta: Changes due to changed data in several sectors and gases.
- Russia: Increased emissions mostly due to higher non-CO₂ emissions from the energy sector.
- Turkey: Changes due to changed data, mainly in the waste and agricultural sectors.
- Ukraine: Lower emissions due to changed data in several sectors and gases
- UNFCCC2017B (UNFCCC for Non-Annex I)
 - for several countries UNFCCC data are available, which were not available for v1.1.
 - * Countries which now use UNFCCC data but show no strong changes in total emissions: Guatemala, Togo.
 - * Some countries have newly available UNFCCC data, however, the sector resolution is not sufficient to be used for CO₂ in categories 1 and 2: Albania, Egypt (CAT2 only), Chad.
 - * Countries with newly available UNFCCC data, where PRIMAP-hist total emissions are corrected downward significantly (individual sectors / gases / years can also show increased emissions): Albania, China (especially energy CO₂), Cuba, Ethiopia, India, Kenya, Niue, Saudi Arabia, Thailand.
 - * Countries with newly available UNFCCC data, where PRIMAP-hist emissions are corrected upward significantly (individual sectors / gases / years can also show decreased emissions): Morocco, Marshall Islands, Montenegro (post-1990), Malaysia, Saint Vincent and the Grenadines, Lebanon (CAT4).
 - Some countries have extended or modified data
 - * Extended and modified data: Brazil (total emissions corrected downward, but individual sectors / gases corrected upward), Mauritius (small changes), Kyrgyzstan (significant differences for most sectors and gases), Uzbekistan (small changes), Uruguay (lower emissions, mainly from CAT4 and CAT6).
 - * Extended data: Argentina (recent emissions corrected upward), Bosnia and Herzegovina (recent emissions corrected upward), Peru (no major changes), Singapore (much higher emissions in recent years).
 - We excluded some existing and new data. Some data might be included again in future versions of the PRIMAP-hist dataset if discrepancies to other sources and between years can be understood and the data verified.
 - * Belize: single years show emissions with a factor of 20-50 above the other years and EDGAR data for several sectors and gases. Data removed completely.
 - * Chile: We exclude the UNFCCC2017B data and only use BUR data as the UNFCCC data contains additional data points which do not fit the BUR data and presumably were generated using a different methodology than used for the BUR data. This impacts emissions estimates for several sectors and gases.
 - * Central African Republic: single year with emissions which strongly differ from other years (factor of ~100). Presumably using different methodology and from older National Communication. Removed completely, as remaining data only covers a period of 8 years.
 - * Dominica: single year with emissions which strongly differ from other years (factor of ~100). Presumably using different methodology and from older National Communication. Removed completely, as remaining data only covers a period of 6 years.
 - * Ecuador: factor ~100 discrepancies with EDGAR and FAO in CAT4, N₂O. Similar discrepancies in other sectors. As several years are affected, we remove data completely. Emissions are changed compared to v1.1.
 - * Ethiopia: UN data for CAT1(A4), CH₄, N₂O seem to contain a mistake as they are inconsistent with the preceding and following years and the figures in the national communication. The tables in the national communication (The Federal Democratic Republic Of Ethiopia: Ministry of Environment and Forest (2015)) contain the presumably erroneous data. We remove 1997 - 2004 for CAT1, CH₄ and N₂O.
 - * Jordan: single year with higher (factor 3) emissions in CAT6 (CH₄, N₂O) influencing the CATM0EL KYOTO GHG results. We remove UNFCCC data completely as only 2 data years remaining.
 - * Kenya: CAT4 N₂O data are almost 0 in 1994 compared to significant emissions in later years. Potentially using different methodology and from older National Communication. This strongly influences economy-wide emissions and is not in line with other sources. We remove 1994 data. This changes emissions compared to v1.1
 - * Kiribati: CAT4 N₂O data are very high for a few years and not in line with EDGAR and FAO. This strongly affects the CAT0 results. We remove UNFCCC data completely.

- * Kyrgyzstan: HFCs data seem to have a unit error. HFCs data are removed and EDGAR data are used.
- * Niger: scaling of CDIAC due to UNFCCC data are extreme, especially as based on only two data points. We completely remove UNFCCC data.
- * Paraguay: strong fluctuations for CH₄ and N₂O data (CAT4 and CAT6) which dominate the KYOTO GHG time series. We remove UNFCCC data completely.
- * Zimbabwe (ZWE): Energy CO₂ is much higher than other sources for one of the three available data points. We remove UNFCCC data completely as only 2 years remaining.
- CDIAC2017
 - Four countries have major adjustments of recent emissions:
 - * Afghanistan: emissions for energy CO₂ have been corrected downward. In the 2016 release, 2013 emissions were above 20 Mt while for the 2017 release they are roughly 10 Mt. BP data are in line CDIAC and extend the downward trend for 2015. Economy-wide Kyoto GHG emissions are corrected downward by about 1/3rd.
 - * Botswana: Emissions have strongly increased and are much higher than calculated in PRIMAP-hist v1.1. Consequently, 2014 emissions have changed from PRIMAP-hist v1.1 and 2015 emissions have increased further from 2014 emissions (based on BP2017 data).
 - * Mongolia: Emissions for energy CO₂ have been corrected downward. In the 2016 release, 2013 emissions were above 45 Mt while in the 2017 release they are roughly 20 Mt. BP data are in line with CDIAC and extend the downward trend for 2015. Economy-wide Kyoto GHG emissions are corrected downward by about 1/5th.
 - * Tonga: Emissions for 2013 are much lower than in CDIAC2016. This has significantly decreased 2013 and 2014 total emissions.
 - CDIAC emissions have changed for several small states, especially small island states, also for historical years. The changes differ in affected years and strength over countries. Some larger countries have been corrected as well. Affected countries are: Anguilla, Antigua and Barbuda, Belize, Cook Islands, Comoros, Cape Verde, Dominican Republic, Fiji, Federated States of Micronesia, Iran, Kiribati, Saint Kitts and Newis, Lesotho, Macao, Nigeria, Palau, People’s Democratic Republic of Korea, Singapore, Suriname, Seychelles, Turks and Caicos Islands, Trinidad and Tobago, Samoa, Yemen, Zimbabwe.
 - Additional historical years for Andorra lead to changes in extrapolation with EDGAR-HYDE data for energy CO₂.
 - CDIAC contains data for Tuvalu in the 2017 release. Former releases did not contain data for Tuvalu.
- Processing
 - Gap filling algorithm:
 - * Singapore: According to CDIAC data, energy CO₂ emissions were decreasing from 2011 to 2007. This was not visible in v1.1, as the gap between 2000 and 2010 in UNFCCC data was interpolated linearly and not filled with CDIAC trends as in v1.2.
 - * Other countries affected: Armenia, Azerbaijan, Colombia, Costa Rica, Dominican Republic, Peru, Peoples’ Democratic Republic of Korea, and Uruguay.

10.4 v1.1 (March 2017)

The v1.1 release contains mostly bug fixes. To keep the dataset up to date we also included some updated data sources. The methodology remained unchanged apart from the minor changes described below.

10.4.1 Changes in PRIMAP-hist source creation

- South Sudan now has individual data for some sectors. For these sectors, South Sudan is treated as any other country during the source creation, while time series for other sectors and gases are downscaled from Sudan data.
- Sources with scarce data points for several countries (BUR2015, UNFCCC2017) are now interpolated before the creation of the PRIMAP-hist dataset, such that the linear regression used to match lower priority data sources can be computed. Before, the last data point was used directly.

10.4.2 Changes in data sources and preprocessing

10.4.2.1 Input source updates

- FAOSTAT data have been updated to the January 2017 version.
 - The last data year is now 2014 for all categories except for forest land emissions where it is 2015. However, for the PRIMAP-hist dataset we use the aggregate land use time series which has 2014 as the last data point.
 - There are significant changes in historical emissions for several countries.
 - * Land use data for several countries are very different from the 2015 version of FAOSTAT data.
 - * Manure management CH₄ and N₂O emissions for a lot of (mostly developed) countries were adjusted down by a large margin. This is not a general adjustment though, as some countries' emissions were adjusted upward, while others remained unchanged.
 - * For some economies in transition, pre-1990 emissions are higher than in the 2015 FAOSTAT data.
- CDIAC fossil CO₂ data have been updated to the 2016 release.
- BP fossil CO₂ data have been updated to the 2016 release.
- UNFCCC “Detailed Data by Party” has been updated to January 2017
 - Data have not changed much compared to the version used for PRIMAP-hist v1.0.
 - For Kazakhstan, HFCs and PFCs data for the years 1990 and 1991 with very high emissions were removed from the UNFCCC data repository. In consequence Kazakhstan's historical (pre-1992) emissions for HFCs and PFCs are much lower in v1.1 than in v1.0.

10.4.2.2 Changes in processing

- FAOSTAT
 - In version 1.0 negative data were removed from the FAOSTAT dataset during processing. This has been fixed. It only affected land use CO₂. Where data were negative for part of the time series they were replaced by zero, while time series completely consisting of negative data were discarded such that Houghton data were used.
 - In v1.0, single subcategories were linearly extrapolated during category aggregation, such that time series for all categories covered the same time frame. When the linear extrapolation lead to emission estimates of these subcategories to increase backwards in time, the linear regression was replaced with a linear path to zero emissions in the first year with data (1961). In v1.1, this has been changed, such that in those cases a constant extrapolation is used instead of a linear extrapolation to zero. This affects emission estimates from “Field burning of agricultural residues” (IPCC 1996 category 4F) and to a lesser extent subsectors of the “Agricultural soils” sector (IPCC 1996 category 4D). CH₄ and N₂O emissions are affected. Only a few countries are affected by the change.
- CDIAC
 - A bug in the downscaling of regions to countries was fixed. This affected Indonesia (though not concerning the growth rates used in the PRIMAP-hist dataset, just the absolute values), Timor-Leste, Latvia and Estonia (cement only), and Palau prior to 1992.
 - Downscaling of Italy and San Marino as a region to individual countries now uses EDGAR emissions from appropriate sectors instead of GDP data.
- UNFCCC
 - A bug in the routine that read the csv files exported from the UNFCCC website lead to omitting the second block in the non-standard csv files. This bug has been fixed. Consequently, some countries now have one to three additional data points added at the end of the time series.
 - Data for Viet Nam and Peru are now contained in the UNFCCC dataset with enough data to meet our minimum requirements. UNFCCC data for these two countries are therefore included in PRIMAP-hist v1.1.

10.4.3 Further bug fixes

- In v1.0, a few countries were missing in the downscaled Houghton data. Some countries are still not available as they are missing in the country mask used to convert the gridded vegetation data to countries. For details see Section Known problems below.
- In some cases the Composite Source Generator removed the first or last data point of a time series. This bug has been fixed.

10.4.3.1 Known problems

- For Mauritius, the first data point for CH₄ for different sectors in the UNFCCC 2017 dataset is very low compared to the other data points. This influences the final dataset.
- For Micronesia, the last data point for CH₄ and N₂O from the agricultural sector (and all subsectors) is very low. This influences the final dataset.
- For Saint Kitts and Nevis, N₂O emissions from the agricultural sector in the last years are much higher than the rest of the data. This influences the final dataset.
- There are no CH₄ and N₂O land use data for Egypt, Grenada, Haiti, and Singapore in PRIMAP-hist v1.1. The only available data source is FAO, which has only zero values in its current version and is thus not used for the PRIMAP-hist source.
- The (former) Netherlands Antilles are not included in the country mask used for Houghton (2008) downscaling, thus there are no Houghton (2008) based data.
- The country mask used in the downscaling of Houghton (2008) data treats Taiwan as a part of China and thus does not deliver data for Taiwan. As none of the data sources used for PRIMAP-hist has land use data for Taiwan we have no option to downscale Taiwan from China.
- Due to the additional year in FAO (2014) some developed countries have very low land use CH₄ emissions in 2014 compared to the period with CRF data. This will be solved in the next revision of PRIMAP-hist where CRF 2015 and CRF 2016 will be used. A number of possible reasons account for the differences between FAO and CRF data, which likely differ between countries. Land-use CH₄ emissions are dominantly from biomass burning. The FAO (Food and Agriculture Organization of the United Nations (2016)) calculate non-CO₂ from biomass burning using the tier 1 methodology of IPCC 2006 guidelines (IPCC (2006)) and activity data from GFED4 (Giglio et al. (2017)). National inventories (CRF 2014) are often based on country specific emissions factors and data for burned areas. The national inventories may also exclude natural disturbances and have different definitions than FAO for managed land areas. Land use N₂O emissions are subject to similar differences in data.
- UNFCCC data for Ecuador (aggregate sectors and gases) are much higher than third-party data, but only covers a few years. The resulting time series are thus discontinuous.

10.4.4 Noteworthy changes

- Aruba: historical CO₂ emissions are lower than in v1.0 because CDIAC emissions have been adjusted downward for the years prior to 1998.
- Australia, Belize, Botswana, Guinea-Bissau, Namibia, Papua New Guinea, Zimbabwe, Mongolia: changes in CH₄ and/or N₂O emissions due to the change in extrapolation of FAO data for subsectors of the agricultural sector.
- Bosnia and Herzegovina: pre-1990 CDIAC data have changed, leading to higher pre-1990 CO₂ emissions in PRIMAP-hist.
- Eritrea: historical CO₂ emissions are higher than in v1.0 because CDIAC emissions have been adjusted upward for the years prior to 1998.
- Federated States of Micronesia and Saint Helena, Ascension, and Tristan da Cunha: emissions have increased due to an increase in FAO agricultural CH₄ and N₂O emissions.
- India: energy related CO₂ is lower starting in 1977 due to changes in CDIAC data.
- Palau, Timor-Leste: higher historical emissions due to the bugfix in CDIAC downscaling.
- Peru: the UNFCCC data that are now used as the first priority source differs from the third-party sources used in PRIMAP-histy v1.0.
- San Marino: changes in historical emissions due to the changed key data for downscaling of San Marino from Italy in CDIAC.

- Sudan, South Sudan: the availability of data for South Sudan changed the time series from the previous time series which, were based on downscaling using population data.
- Vanuatu had zero CO₂ emissions before 1960 in PRIMAP-hist v1.0 because CDIAC2015 had zero data for a few years before 1960. Now, the data are non-zero as these data points are not contained in CDIAC2016.
- For several countries, data for the last two years have changed, as additional data points from updated CDIAC, FAOSTAT, UNFCCC, and BP data replace extrapolated data.
- Land use data for the period of 1991 - 2014 have changed for several countries. The first reason is that we now use Houghton data for all years where they are available and not obtained through extrapolation (see Section 2.4.1 of the data description paper). The second reason is that the FAO data changed massively.

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