Supplementary information for Global nature run data with realistic high-resolution carbon weather for the year of the Paris Agreement

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Parameter	Parameter type	Parameter ID	Units
2 metre dewpoint temperature	single level (surface)	168.128	K
2 metre temperature	single level (surface)	167.128	K
10 metre U wind component	single level (surface)	165.128	m s^{-1}
10 metre V wind component	single level (surface)	166.128	m s^{-1}
Accumulated carbon dioxide ecosystem respiration (REC)&	single level (surface)	82.228	kg m^{-2}
Accumulated carbon dioxide Gross Primary Production (GPP)&	single level (surface)	81.228	kg m^{-2}
Anthropogenic emissions of carbon dioxide&	single level (surface)	69.210	kg $m^{-2}s^{-1}$
Boundary layer height	single level (surface)	159.128	m
Carbon dioxide^	model and pressure levels	61.210	kg kg^{-1}
Carbon dioxide column-mean molar fraction^^	single level (surface)	64.210	ppm
Carbon monoxide^	model and pressure levels	123.210	kg kg^{-1}
Charnock	single level (surface)	148.128	unitless
Convective available potential energy	single level (surface)	59.128	J kg^{-1}
Convective inhibition	single level (surface)	1.228	J kg^{-1}
Convective precipitation	single level (surface)	143.128	m
Convective rain rate	single level (surface)	218.228	kg m^{-2} s^{-1}
Convective snowfall rate water equivalent	single level (surface)	220.228	kg m^{-2} s^{-1}
Direct solar radiation	single level (surface)	47.128	J m^{-2}
Divergence	model and pressure levels	155.128	s^{-1}
Downward UV radiation at the surface	single level (surface)	57.128	J m^{-2}
Evaporation	single level (surface)	182.128	m of water equivalent
Flux of carbon dioxide ecosystem respiration (instantaneous REC)&	single level (surface)	85.228	kg m^{-2} s^{-1}
Flux of carbon dioxide Gross Primary Production (instantaneous GPP)&	single level (surface)	84.228	kg m^{-2} s^{-1}
Flux of carbon dioxide Net Ecosystem Exchange (instantaneous NEE)&	single level (surface)	83.228	kg m^{-2} s^{-1}
Forecast albedo	single level (surface)	243.128	(0-1)
GPP coefficient from Biogenic Flux Adjustment System (bias correction scaling factor for GPP)	single level (surface)	78.228	unitless
Geopotential*	model and pressure levels	129.128	m^2 s^{-2}
High cloud cover	single level (surface)	188.128	(0-1)
Instantaneous 10 metre wind gust	single level (surface)	29.228	m s^{-1}
Instantaneous moisture flux	single level (surface)	232.128	kg m^{-2} s^{-1}
Instantaneous surface sensible heat flux	single level (surface)	231.128	W m^{-2}
Land-sea mask	single level (surface)	172.128	(0-1)
Large scale rain rate	single level (surface)	219.228	kg m^{-2} s^{-1}
Large scale snowfall rate water equivalent	single level (surface)	221.228	kg m^{-2} s^{-1}
Large scale precipitation	single level (surface)	142.128	m
Logarithm (natural) of surface pressure.	model levels	152.128	**
Low cloud cover	single level (surface)	186.128	(0-1)
Mean sea level pressure	single level (surface)	151.128	Pa
Medium cloud cover	single level (surface)	187.128	(0-1)
Methane^	model and pressure levels	62.210	kg kg^{-1}
Methane column-mean molar fraction^^	single level (surface)	159.128	ppb
Methane loss rate due to Radical hydroxyl (OH)	model levels	71.210	s^{-1}
Methane surface fluxes (excluding biomass burning) &	single level (surface)	70.210	kg m^{-2} s^{-1}
Ocean flux of carbon dioxide &	single level (surface)	67.210	kg m^{-2} s^{-1}
Photosynthetically active radiation at the surface	single level (surface)	58.128	J m^{-2}
REC coefficient from Biogenic Flux Adjustment System (bias correction scaling factor for REC)	single level (surface)	79.228	unitless
Relative humidity	pressure levels	157.128	%
Runoff	single level (surface)	205.128	m
Sea ice fraction	single level (surface)	31.128	(0-1)
Sea surface temperature	single level (surface)	34.128	K
Skin temperature	single level (surface)	235.128	K
Snow albedo	single level (surface)	32.128	(0-1)
Snow density	single level (surface)	33.128	kg m^{-3}
Snow depth	single level (surface)	141.128	m of water equivalent
Snow evaporation	single level (surface)	44.128	m of water equivalent
Snowfall	single level (surface)	144.128	m of water equivalent
Snowmelt	single level (surface)	45.128	m of water equivalent

Soil temperature level 1	single level (surface)	139.128	K
Soil temperature level 2	single level (surface)	170.128	K
Soil temperature level 3	single level (surface)	183.128	K
Soil temperature level 4	single level (surface)	236.128	K
Specific cloud ice water content	model levels	246.128	kg kg^{-1}
Specific humidity	model and pressure levels	133.128	kg kg^{-1}
Sunshine duration	single level (surface)	189.128	s
Surface latent heat flux	single level (surface)	147.128	J m^{-2}
Surface net solar radiation	single level (surface)	176.128	J m^{-2}
Surface net solar radiation, clear sky	single level (surface)	210.128	J m^{-2}
Surface net thermal radiation	single level (surface)	177.128	J m^{-2}
Surface net thermal radiation, clear sky	single level (surface)	211.128	J m^{-2}
Surface sensible heat flux	single level (surface)	146.128	J m^{-2}
Surface solar radiation downwards clear sky	single level (surface)	129.228	J m^{-2}
Surface solar radiation downwards	single level (surface)	169.128	J m^{-2}
Surface thermal radiation downwards clear sky	single level (surface)	130.228	J m^{-2}
Surface thermal radiation downwards	single level (surface)	175.128	J m^{-2}
Temperature	model and pressure levels	130.128	K
TOA incident solar radiation	single level (surface)	212.128	J m^{-2}
Temperature of snow layer	single level (surface)	238.128	K
Top net solar radiation	single level (surface)	178.128	J m^{-2}
Top net solar radiation, clear sky	single level (surface)	208.128	J m^{-2}
Top net thermal radiation	single level (surface)	179.128	J m^{-2}
Top net thermal radiation, clear sky	single level (surface)	209.128	J m^{-2}
Total cloud cover	single level (surface)	164.128	(0-1)
Total column carbon monoxide	single level (surface)	127.210	kg m^{-2}
Total column cloud ice water	single level (surface)	79.128	kg m^{-2}
Total column cloud liquid water	single level (surface)	78.128	kg m^{-2}
Total column ozone	single level (surface)	206.128	kg m^{-2}
Total column rain water	single level (surface)	89.228	kg m^{-2}
Total column snow water	single level (surface)	90.228	kg m^{-2}
Total column water^^^	single level (surface)	136.128	kg m^{-2}
Total column water vapour	single level (surface)	137.128	kg m^{-2}
Total precipitation	single level (surface)	228.128	m
Vertically integrated moisture divergence	single level (surface)	213.128	kg m^{-2}
Volumetric soil water layer 1	single level (surface)	39.128	m^3 m^{-3}
Volumetric soil water layer 2	single level (surface)	40.128	m^3 m^{-3}
Volumetric soil water layer 3	single level (surface)	41.128	m^3 m^{-3}
Volumetric soil water layer 4	single level (surface)	42.128	m^3 m^{-3}
Wildfire flux of carbon dioxide&&	single level (surface)	80.210	kg m^{-2} s^{-1}
Wildfire flux of methane&&	single level (surface)	82.210	kg m^{-2} s^{-1}
U-component of wind	model and pressure levels	131.128	m s^{-1}
V-component of wind	model and pressure levels	132.128	m s^{-1}
Vertical velocity	model and pressure levels	135.128	Pa s^{-1}
Vorticity (relative)	model and pressure levels	138.128	s^{-1}

Table S1. List of parameters from the IFS CHE nature run dataset excluding the carbon monoxide surface emissions [kg m^{-2} s^{-1}] and carbon dioxide aviation 3D fluxes [kg m^{-2} s^{-1}] which are available from https://ads.atmosphere.copernicus.eu/cdsapp#!/dataset/cams-global-emission-inventories. Each field is identified with a given parameter. Note that the units of tracers for the total column need to be converted from kg m-2 to ppm as described in 2D Atmospheric Composition parameters. Details of model levels, pressure levels and surface layers are provided in Table 2. ^ To conversion of kg kg^{-1} to dry molar fraction the mixing ratios should be multiplied by M_{air}/M_{tracer} where M_{air}=28.9644 is the molar mass of dry air, M_{tracer} is the molar mass of the tracer (44.0095 g/mol for carbon dioxide 16.04 for methane, 28.01 g/mol for carbon monoxide. ^^ Carbon dioxide and methane column-mean molar fractions should be treated as dry molar fractions. ^^^Unit conversion of CO total column in kg m-2 to averaged-column dry molar fraction [ppb] require the factor [10^9 x g x M_{air}]/ [M_{co} x exp(lnsp)], where g=9.80665 (the earth gravity acceleration), M_{air}=28.9644 is the molar mass of dry air, M_{co}=28.01 is the molar mass of carbon monoxide, and lnsp is the logarithm of surface pressure. * The geopotential height can be calculated by dividing the geopotential by the Earth's gravitational acceleration, g; orography can be extracted from geopotential height at model level 1.** Surface pressure [Pa] can be obtained by computing the exponential of the logarithm of surface pressure. &Note that the sign of the surface fluxes and emissions towards atmosphere are negative and sinks towards surface are positive. &&Wildfire emissions are an exception with positive sign.

S2. Instructions for CHE nature run data access

The CHE global nature run dataset and the MARS data extraction features are freely available through ECMWF API (https://www.ecmwf.int/en/forecasts/access-forecasts/ecmwf-web-api) following a registration step (https://apps.ecmwf.int/registration/). The data can be accessed using python (https://www.python.org). The commands and steps required are detailed below.

- **Login** to https://www.ecmwf.int/en/forecasts/access-forecasts/ecmwf-web-api (top right corner)
- **Install ECMWF key.**

  The key information can be obtained from https://api.ecmwf.int/v1/key/

  1. Save your API key credentials into a file

  Copy / paste the text below into a blank text file and save it to your $HOME directory as **.ecmwfapirc** (If you use Windows, you have to put the file in C:\Users\<USERNAME>\.ecmwfapirc)

```
{
  "url": "https://api.ecmwf.int/v1",
  "email": "<EMAILADDRESSFROMREGISTRATION>",
  "key": "<KEY>"
}
```

  2. Set these environment variables before executing the Python script:

```
export ECMWF_API_URL="https://api.ecmwf.int/v1"
export ECMWF_API_KEY="21a9e24ff8315300210da27365fa1c3c"
export ECMWF_API_EMAIL="anna.agusti-panareda@ecmwf.int"
```

- **Install client libraries**
  The client currently supports both Python 2.7.x and Python 3. The ecmwf-api-client library was added to the Python Package Index (PYPI): https://pypi.org/project/ecmwf-api-client/

```
pip install --user ecmwf-api-client
```

- **Use python script to extract dataset**. Examples of python scripts for model levels, pressure levels and surface data are shown below.

```
from ecmwfapi import ECMWFDataServer
server = ECMWFDataServer(url="https://api.ecmwf.int/v1",key="<KEY>",email="<EMAILADDRESS>")

server = ECMWFDataServer()

# Extract model level data
# Carbon dioxide and methane mass mixing ratios on the lowest (level 1 is the top of
# the atmosphere) model level for all the forecast steps for 1 July 2015 interpolated
# to 0.1 x 0.1 deg regular latitude-longitude grid

server.retrieve({
    "class": "rd",
    "dataset": "research",
    "date": "2015-07-01",
    "expver": "ha58",
    "grid": "0.1/0.1",
    "levelist": "1/to/137",
    "levtype": "ml",
    "param": "210061/210062",
```

```
    "step": "0/to/24/by/3",
    "stream": "oper",
    "target": "ml_output.nc",
    "format": "nc",
    "time": "00:00:00",
    "type": "fc",
})
# Extract pressure level data
# Carbon dioxide and methane mass mixing ratios on all the pressure levels for all the
# forecast steps for 1 July 2015 interpolated to 0.1 x 0.1 deg regular latitude-longitude grid

server.retrieve({
    "class": "rd",
    "dataset": "research",
    "date": "2015-07-01",
    "expver": "ha58",
    "grid": "0.1/0.1",
    "levelist": "1/2/3/5/7/10/20/30/50/70/100/150/200/250/300/400/500/600/700/850/925/950/1000",
    "levtype": "pl",
    "param": "210061/210062",
    "step": "0/to/24/by/3",
    "stream": "oper",
    "target": "pl_output.nc",
    "format": "nc",
    "time": "00:00:00",
    "type": "fc",
})
# Extract column data
# Carbon dioxide and methane column mean molar fractions for all the forecast steps for 1 January
# 2015 interpolated to 0.1 x 0.1 deg regular latitude-longitude grid

server.retrieve({
    "class": "rd",
    "dataset": "research",
    "date": "2015-01-01",
    "expver": "ha58",
    "grid": "0.1/0.1",
    "levtype": "sfc",
    "param": "64.210/65.210",
    "step": "0/to/24/by/3",
    "stream": "oper",
    "target": "output.grib",
    "time": "00:00:00",
    "type": "fc",
})

# Extract surface data
# Natural biosphere flux and anthropogenic emissions of carbon dioxide for all the forecast steps
# for 31 December 2015 interpolated to 0.1 x 0.1 deg regular latitude-longitude grid
server.retrieve({
    "class": "rd",
    "dataset": "research",
    "date": "2015-12-31",
    "expver": "ha58",
    "grid": "0.1/0.1",
    "levtype": "sfc",
    "param": "68.210/69.210",
    "step": "0/to/24/by/3",
    "stream": "oper",
    "target": "output.grib",
    "time": "00:00:00",
    "type": "fc",
})
```