EYE-CLIMA
Verifying emissions of climate forcers

# Data Management Plan

## DELIVERABLE 6.2


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## Summary

The Data Management Plan (DMP) is a key element for the overall management of the EYE-CLIMA project. It describes the data management procedures from the collection of input data, processing, and the data to be generated by EYE-CLIMA. This document describes how the EYE-CLIMA consortium intends to make their research data findable, accessible, interoperable and reusable (FAIR), to ensure it is soundly managed. This DMP describes the types of data that will be used and generated during the course of the project, how the data will be shared within the consortium, and how this data will be made openly available through a repository. This DMP also includes a description of the data policy and the data standards (including meta-data) that will be used.



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# 1. Introduction

The primary objective of the EYE-CLIMA project is to support the need for independent verification of national greenhouse gas inventories (NGHGIs) by developing top-down methods based on atmospheric inversion to a level of readiness where they can be used to determine emissions at national and sub-national scales and be incorporated into NGHGIs. As such, EYE-CLIMA partners will be preparing flux estimates using both process-based and data-driven models, analysing satellite observations of the land biosphere and atmospheric composition, running atmospheric transport models and estimating fluxes based on atmospheric inversions.

These activities will support the following specific project objectives:

1. Further develop the atmospheric inversion methodology to the point where it can be used to verify and support NGHGIs. This includes: i) improving the spatial resolution to a level where national emissions can be accurately estimated and details such as hotspots and sub-national distributions can be resolved, ii) developing methods to ensure the consistency of national, regional and global atmospheric inversions, and iii) improving quantification of uncertainty, and developing methods to identify and minimize systematic errors.
2. Address the need for a transparent and repeatable verification method for estimates of climate forcer emissions, especially at national scale, by establishing guidelines on how to perform atmospheric inversions and evaluate the results.
3. Better understand the needs of NGHGI compilers for verification and improvement of NGHGIs by working together with them in pilot projects. And through this collaboration, prepare guidelines on how to use top-down data products to verify inventories and to make these data products available to NGHGI compilers.
4. Further develop methodologies to detect and quantify large emissions of $CH_4$ using high resolution satellite data and integrate these emission estimates into national inventories.
5. Improve estimates of $CO_2$, $CH_4$ and $N_2O$ land biosphere fluxes, and emissions and removals of $CO_2$ in the LULUCF sector, using combined atmospheric $CO_2$, $CH_4$ and $N_2O$ observations, advanced land surface modelling and remote sensing data. This will allow emissions (e.g. harvest, fires) to be separated from removals at sub-national scale, as well as the impact of management versus environmental changes on the GHG balance of the EU.
6. Support the implementation and monitoring of EU policy through providing accurate estimates of GHG fluxes and BC emissions at national level over multiple years.
7. Disseminate the developments in methodology, the atmospheric inversion benchmark, and data products to a large group of users, in particular, NGHGI compilers, national and EU decision makers and researchers in the field of GHG emissions accounting.

# 2. Data Summary

## 2.1 Description of data to be used

The data to be used in EYE-CLIMA can be broadly grouped into the following categories:

1. Remote sensing data of the land biosphere and atmosphere
2. Meteorological data
3. Ground-based atmospheric and flux observations
4. Emission inventories and activity data



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A detailed description for each of these data categories is provided below.

### 2.1.1 Remote sensing data

Remote sensing data of the land biosphere will be used to prepare maps of above ground biomass (AGB) and its changes to support data-driven modelling of $CO_2$ emissions and removals in the land-use land-use-change and forestry (LULUCF) sector. Satellite retrievals of total column $CH_4$ ($XCH_4$) will be used to detect and estimate large emission sources, which will be incorporated into emission inventories. In addition, these will be used in regional atmospheric inversions to determine fluxes. Retrievals of $CO_2$ total columns ($XCO_2$) will be used in atmospheric inversions to estimate $CO_2$ land-biosphere fluxes as a complimentary method to determine emissions and removals in the LULUCF sector. The specific remote sensing data sources that will be used are described in Table 1.

*Table 1. Summary of remote sensing data (and derived data products) to be used.*

| **Variable** | **Instrument/Product** | **Source** | **Comment** |
|---|---|---|---|
| $XCO_2$ | OCO-2 | NASA | This includes all required meta data and quality flags |
| $XCH_4$ | GOSAT(-2), TROPOMI Level 2 Data | JAXA, ESA CCI, Copernicus C3S, ESA ODA, CAMS | This includes all required meta data and quality flags |
| $XCH_4$ | PRISMA, ENMAP, S2 hyper- and multi-spectral Level 1 Data | Mission Data portals | This includes all required meta data |
| Biomass and biomass change | SMOS, Sentinel-1 and –2, ALOS PALSAR | NASA, ESA CCI Biomass, University of Maryland | |
| Landcover and plant functional type | Copernicus LC or HILDA+ | Copernicus, ESA world cover | |
| AGB | SMOS L-VOD | ESA | |
| Tree height and forest biomass | High-resolution imagery | planet.com | High resolution images in four multispectral RGB and NIR bands from Dove satellites |
| Wetland extent | BAWLD, WAD2M | University of Alberta (from Arctic Data Center), University of Maryland (from Zenodo) | |

### 2.1.2 Meteorological data

Meteorological data will be needed to drive the atmospheric transport models used in the inversions, and as input to process-based models of the land biosphere, which will be used to estimate land-biosphere fluxes of $CO_2$, $CH_4$ and $N_2O$. The datasets used are described in Table 2.



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*Table 2. Summary of meteorological data to be used.*

| Data product | Source | Comment |
|---|---|---|
| ERA5 meteorological reanalysis | ECMWF | Used to drive atmospheric transport models |
| ERA5-Land at 0.1° resolution and 3-hourly time steps | ECMWF | Bias correction using CRU.<br>Variables needed: air temperature, precipitation, short and long wave radiation, wind speed, specific humidity, air pressure |

### 2.1.3 Ground-based atmospheric observations

Observations of atmospheric mixing ratios (for $CO_2$, $CH_4$, $N_2O$, and the selected F-gases) and concentrations (for BC) from ground-based sites will be used in inversions. For $CO_2$ and $CH_4$, these will be in addition to remote sensing data (see Table 1). Ground-based observations will be used from established networks with an open access data policy. Networks and data products are chosen based on the data quality determined on the basis of the use of established measurement protocols and calibration scales. In addition, openly available flux datasets from open access publications will be used. The data are summarized in Table 3.

*Table 3. Summary of ground-based atmospheric observations to be used.*

| Variable | Description | Source | Comment |
|---|---|---|---|
| $CO_2$ | In-situ and flask measurements | ICOS, NOAA ObsPack, VERIFY | VERIFY data will be used prior to start of ICOS data |
| $CH_4$ | In-situ and flask measurements | ICOS, NOAA ObsPack, VERIFY | VERIFY data will be used prior to start of ICOS data |
| F-gases | In-situ and flask measurements | AGAGE, WDCGG, NOAA, NASA, IAGOS-CARIBIC | |
| BC | Filter absorption photometer data including time stamp, absorption coefficient, flags, and other meta data | ACTRIS, EMEP, FAN, and other publicly available on ebas.nilu.no | For conversion to equivalent black carbon (eBC) after source apportionment |
| $N_2O$ flux | Eddy-covariance and chamber flux measurements at European sites | ETHZ, Fluxnet, and other publicly available sources based on literature | |

### 2.1.4 Emission inventory and other flux data

Inventories of anthropogenic emissions of $CO_2$ (specifically fossil fuel, bio-fuels, biomass burning and cement production), $CH_4$, and $N_2O$ will be used in combination with the process-based model estimates as prior information in the inversions. A range of estimates from different datasets will be used to gauge



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the uncertainty in these estimates, in particular, the uncertainty per source sector, which will be propagated into the uncertainty per sector for the top-down emission estimates from the EYE-CLIMA project. Activity data on management (e.g. crops, harvest, fertilizer and manure application) and data on N-deposition will be used from various data sources. In addition, inland water and ocean flux estimates will be used as prior information for the inversions but will not be prepared in the framework of EYE-CLIMA.

*Table 4. Summary of emission and activity data to be used.*

| **Data product** | **Source** | **Comment** |
|---|---|---|
| Crops, harvest, fertilizer use | FAO | |
| Agricultural activity data | CAPRI | Crop and livestock production, changes in land use etc |
| Land use data | LUH2 | Harmonized set of land-use scenarios, agricultural management data |
| Crop sector inputs | ISIMIP3 | Crop sector data from the Intersectoral impact model intercomparison project |
| N-deposition | JRC | |
| EDGAR | JRC | Anthropogenic emissions of greenhouse gases |
| TNO | TNO | Anthropogenic emissions of greenhouse gases |
| CEDS | CMIP6 | Historical anthropogenic emissions data |
| Ocean fluxes of $CO_2$, $CH_4$ and $N_2O$ | GCP | Estimates from recent GCP global budgets using ocean biogeochemistry models |
| Fire emissions | GFAS, GFED | GFAS from CAMS |
| Inland waters | VERIFY project | Lake and river GHG fluxes prepared in VERIFY by P. Regnier and his group |
| Geological seeps | Etiope et al. 2019 | Annual climatological estimate for onshore seeps |
| Termites | CAMS | Climatological estimate for global termite emissions |

## 2.2 Description of data to be produced

Following the Description of Action, EYE-CLIMA will produce various data types, including gridded (or spatial) data, timeseries data, algorithms and code, as well as text data. These different types of data can be grouped into the following categories:

1. Maps of biomass and biomass change
2. Flux and emission data
3. Atmospheric mixing ratio and concentration data
4. Synthesized data products
5. Code and methodologies



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The data produced for each of these categories are described below along with their intended applications.

### 2.2.1 Biomass maps

Maps of above ground biomass will be derived using remote sensing data (see Table 1) and will be used to derive maps of total biomass carbon using tree carbon content and below ground expansion factors. The resulting biomass carbon maps will be used in conjunction with a book-keeping model to derive maps of carbon losses (emissions) resulting from fire/clearing and carbon gains (removals) due to recovery from past disturbances.

*Table 5. Summary of biomass and biomass change datasets.*

| Data description | Format | Size | Applications |
|---|---|---|---|
| Hybrid biomass map for the base year 2020 for Europe and Russia at 100 m resolution | GeoTIFF | Few GB | Used to derive maps of above ground biomass carbon and using under-ground expansion factors to total biomass carbon |
| Biomass change maps from 2010 to 2025 for Europe and Russia at 25 km resolution | GeoTIFF | Few GB | |
| Biomass change maps from 2010 to 2025 for Europe and Russia at high resolution (1 km) | GeoTIFF | Few GB | Used as input to study drivers of biomass change |
| Drivers of change | GeoTIFF | Few GB | Policy decisions |
| Maps of total biomass carbon from 2010 to 2025 for Europe and Russia at 25 km | NetCDF | Few GB | Used with book-keeping model for Europe to derive carbon source and sink maps |

### 2.2.2 Flux and emission data

Gridded fluxes of $CO_2$, $CH_4$ and $N_2O$ will be produced by process-based models for the whole globe but with a particular focus on Europe. In addition, gridded $N_2O$ fluxes from agricultural land will be produced for Europe using a data-driven model. Gridded fluxes of $CO_2$, $CH_4$ and $N_2O$ will be produced for Europe, and for $CO_2$ and $CH_4$ also for Russia, from atmospheric inversions. Emissions of BC and F-gases will be produced from atmospheric inversions globally. Lastly, a global inventory of point $CH_4$ emission sources will be produced using satellite remote sensing.

*Table 6. Summary of flux and emissions datasets.*

| Data description | Format | Size | Applications |
|---|---|---|---|
| GAINS emission inventory for Europe at 0.1° spatial resolution and monthly for $CH_4$, $N_2O$, BC and annually for F-gases. (Global emission inventory at 0.5° spatial resolution and annually) | NetCDF | Few GB | Prior information for inversions and for sectorial composition of emissions |



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|---|---|---|---|
| Global land-biosphere fluxes of $CO_2$, $CH_4$ and $N_2O$ from process-based models | NetCDF | Few GB | Prior information for inversions. Understanding driving factors for fluxes |
| European agricultural fluxes of $N_2O$ from data-driven model at 0.1° resolution | NetCDF | Few GB | Independent comparison with process-based model and inversion estimates |
| European fluxes of $CO_2$, $CH_4$, and $N_2O$ from atmospheric inversions at 0.5° resolution and monthly from 2005 | NetCDF | Few GB | Support European policy by providing observation based emission trends |
| European fluxes of $CO_2$, $CH_4$, and $N_2O$ from atmospheric inversions at 0.2° resolution and monthly from 2018 | NetCDF | Few GB | Support European NGHGIs and policy |
| Russian fluxes of $CO_2$ and $CH_4$ at 0.5° resolution and monthly from 2015 | NetCDF | Few GB | Support NGHGIs and policy |
| Global emissions of F-gases with at least 1.0° resolution from 2014 (for $SF_6$ from 2005) | NetCDF | Few GB | Support European NGHGIs and policy |
| European emissions of BC at 0.5° resolution from 2015 | NetCDF | Few GB | Support policy |
| Global emissions of BC at 1.0° resolution from 2015 | NetCDF | Few GB | Support policy |
| Global inventory of $CH_4$ point emission sources from remote sensing | NetCDF | Few GB | Support NGHGIs and policy |

### 2.2.3 Atmospheric mixing ratio and concentration data

Atmospheric data will be produced from the atmospheric transport models used in the inversions. Although these data are not main data products of EYE-CLIMA, they are useful for supporting future modelling studies (e.g. the 4D mixing ratio fields) and for evaluating the quality of the bottom-up flux estimates (used in the prior information) and the fluxes estimated by the inversions.

*Table 7. Summary of atmospheric datasets.*

| **Data description** | **Format** | **Size** | **Applications** |
|---|---|---|---|
| 4D mixing ratios fields of $CO_2$, $CH_4$, $N_2O$ and F-gases from nudged runs of FLEXPART-CTM | NetCDF | Few GB | Support regional atmospheric inversions |
| Simulated mixing ratios of $CO_2$, $CH_4$, $N_2O$ and F-gases from atmospheric transport models | ASCII | Few MB | Support evaluation of bottom-up flux estimates and the atmospheric inversions |



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|---|---|---|---|
| eBC concentrations from model simulations | ASCII | Few MB | Support evaluation of bottom-up flux estimates and the atmospheric inversions |
| eBC concentrations from observations attributed to solid fuel (e.g. biomass burning) and liquid fuel (e.g. fossil fuel) combustion sources | ASCII | Few MB | Used in inversions of BC and to support emission reduction policy |

### 2.2.4 Synthesized data products

To support the objectives of EYE-CLIMA, a number of synthesised data products will be produced that are aimed directly at stakeholders, in particular, NGHGI compilers and policy makers.

*Table 8. Summary of synthesised data products.*

| **Data description** | **Format** | **Size** | **Applications** |
|---|---|---|---|
| Maps of European emissions (and uncertainties) of $CO_2$, $CH_4$, $N_2O$ and BC by sector based on atmospheric inversions with at least annual resolution | NetCDF | Few GB | Support NGHGIs and policy |
| Maps of Russian emissions (and uncertainties) of $CO_2$ and $CH_4$ by sector based on atmospheric inversions with at least annual resolution | NetCDF | Few GB | Support NGHGIs and policy |
| Emissions (and uncertainties) of $CO_2$, $CH_4$, $N_2O$, F-gases and BC by sector for EU27+3 countries based on atmospheric inversions with at least annual resolution | ASCII | Few MB | Support NGHGIs and policy |
| Map of managed land for Russia | GeoTIFF | Few GB | Support NGHGIs and policy |

### 2.2.5 Code and methodologies

An important objective of EYE-CLIMA is to further develop the methodology of atmospheric inversion and how to use inversion data to support NGHGIs. In the context of this objective, EYE-CLIMA will produce code (and an associated report) on methodology for using top-down (inversion) estimates to derive emission variables that can be compared to what is reported in NGHGIs. In addition, EYE-CLIMA will produce best practice guidelines on atmospheric inversions to support NGHGIs in the form of a report. Lastly, EYE-CLIMA will contribute to the further development of the Community Inversion Framework (CIF).



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*Table 9. Summary of code and methodological products.*

| Description | Format | Application |
|---|---|---|
| Methodology for using top-down flux estimates to derive emissions comparable to what is required for reporting to the UNFCCC | Code and report | Support verification of NGHGIs |
| Best practice guidelines on atmospheric inversions for supporting NGHGIs | Report | Support verification of NGHGIs |
| Developments to the Community Inversion Framework (CIF) | Code | Atmospheric inversions |

# 3. FAIR Data

## 3.1. Making data findable, including provisions for metadata

All data produced in EYE-CLIMA will be made discoverable with specific meta-data using standard qualifiers as used in the disciplines of atmospheric and climate sciences. The list of metadata associated with each dataset may still evolve during the project following user feedback and experiences gained and will be reflected in the update to the DMP (due M36).

The naming of data files will follow a specific convention that has been defined by the executive board of EYE-CLIMA and which contains the key meta-data information. Such naming convention also takes care of the version numbers, as during the course of the project more than one version of a dataset may be delivered (see Table 10).

*Table 10. Meta-data to be included in the file names*

| Field | Examples | Description |
|---|---|---|
| Method | DAT: data driven model<br>MOD: model<br>INV: inversion<br>SYN: synthesis | Distinguishes the different methods used for the product derivation |
| Species | CO2, CH4, N2O, BC, HFC125 | Species name |
| Variable | FLUX<br>CONC | The main variable type in the file |
| Model | CIF<br>FLEXINVERT<br>FLEXPART<br>CHIMERE<br>TM5MP<br>ORCHIDEE | A reference enabling people to uniquely identify the dataset, including the type of simulation that is produced. In some cases, names may need to be combined, e.g. CIF_FLEXPART. |



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| | | |
|---|---|---|
| | LPJGUESS<br>JSBACH-HIMMELI<br>GAINS | |
| Institute | Official short name | The institute who produced the data (using the official short names) |
| Sector | ALL<br>AGRIC<br>FOSSIL<br>LULUCF | Precision on the ecosystem or sector covered |
| Region | EUR: Europe<br>RUS: Russia<br>GBL: Global | Region covered |
| Timestep | HOUR<br>DAY<br>MONTH<br>YEAR | The time frequency of the product |
| Version | VX | The version number |
| Timestamp | YYYYMMDD | The date of production |
| File type | .nc<br>.tiff<br>.txt<br>.csv | The file format |

Additional meta-data will be provided within the files following the Climate and Forecast meta-data convention (this is described further in section 3.3. Making data interoperable).

All public datasets from EYE-CLIMA will be assigned Digital Object Identifiers (DOIs) making them citable and trackable (this described further in section 3.2 Making data accessible).

## 3.2. Making data accessible

All data produced in EYE-CLIMA will be stored in the Zenodo repository (https://zenodo.org). Zenodo is a free repository funded by CERN and the European Union. Zenodo accepts all types of research data, including meta-data, without restriction on format. Uploaded datasets are versioned and provided with Digital Object Identifiers (DOIs) to make them citable and traceable. The only restriction in Zenodo is that for datasets exceeding 50 GB uploads need to be requested. This limit will not affect most datasets produced in EYE-CLIMA, and for any that do, a request will be made. On Zenodo we will use the "community" feature to create a collection of all data associated with the EYE-CLIMA project make the project's output more visible. We will also point to these datasets from the EYE-CLIMA website with a direct link to the data on Zenodo.



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Although we will aim to make all final datasets publicly available as soon as possible, some especially novel datasets will be embargoed until publications related to the dataset have been accepted for publication. The embargo period, however, will not extend beyond the end of the project (31 December 2026). Zenodo allows datasets to be put under an embargo before being made open access.

Once datasets are made open access, it will not be possible to ascertain the identity of people accessing the data, however, Zenodo does provide statistics on the number of views and downloads for each dataset. Data will be released under the Creative Commons International license (CC BY 4.0) (https://creativecommons.org/licenses/by/4.0/), which allows material to be redistributed and adapted, but under the condition that appropriate credit is given and that no legal terms or technical measures are applied that restrict others using the material in a way that the license permits. A request will be made on each dataset submission that users acknowledge the data provider and the EYE-CLIMA project and cite the DOI in any publication that uses the dataset.

Zenodo allows for rich meta-data of each dataset according to the DataCite meta-data schema (https://schema.datacite.org). Meta-data are indexed and searchable directly in Zenodo's search engine immediately after publishing. (Further details on meta-data are given in section 3.3).

Data stored on Zenodo are backed-up and will be retained for the lifetime of the repository, which is currently defined for the next 20 years.

## 3.3. Making data interoperable

We will seek to make all publicly available datasets produced in EYE-CLIMA as inter-operable as possible. To do this, we will adopt international conventions for the data formats and metadata.

For spatial data, we will use the Network Common Data Format (NetCDF), which is especially suited to data with multiple dimensions. This data format is accessible across different operating systems and readable/writeable by numerous programming interfaces (e.g. Python, Matlab, R, Fortran, C++). We will follow as closely as possible the Climate and Forecast (CF) convention (http://cfconventions.org), which has been established to promote the processing and sharing of NetCDF files. The meta-data defined by the CF convention are included in the same file as the data making it “self-describing”. The CF convention provides standard names for variables and standard units.

For timeseries data, we will use machine readable formats, such as .txt and .csv, which also allow the meta-data to be included in the same file as the data.

For map data, we will use the GeoTIFF data format, which allows georeferencing information to be embedded within a TIFF file. The potential additional information includes map projection, coordinate systems, ellipsoids, datums, and everything else necessary to establish the exact spatial reference for the file.

Qualified references will be included in datasets produced in EYE-CLIMA that depend on other EYE-CLIMA datasets. This can be done by citing the DOIs of data already uploaded to the repository in the data description.

## 3.4. Increase data re-use

We will make all data open access by the end of the project. Data will be released using the Creative Commons International (CC BY 4.0) license, which allows data to be redistributed and modified, with the condition that credit is given to the data providers. Rich meta-data including a detailed data description and keywords will be provided with the datasets in Zenodo and will follow international conventions (e.g. CF convention). We will use file formats that allow for self-description of the data and are readable by a wide range of programming interfaces (see section 3.3).



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We will also cite dataset DOIs in publications describing and/or using the datasets. This will increase the awareness of the data.

Quality of the data produced is ultimately the responsibility of the data provider, but we will, as far as possible, publish scientific articles that describe the methodology used to produce the data or results based on the data, which will be peer-reviewed. The data manager and the coordination team will check compliance of all datasets with the DMP. In general, EYE-CLIMA partners will strive for the highest quality data and meta-data.

# 4. Other Research Outputs

Zenodo allows also for the upload of publications, posters, presentations, videos, and code. As for datasets, there is the possibility to associate rich meta-data with the material and it is given a DOI. For code, Zenodo also allows to preserve a GitHub repository.

An advantage of using the Zenodo repository also for outreach material (publications, posters etc.) is that these can be directly associated with the EYE-CLIMA collection along with datasets.

# 5. General Data Management Issues

## 5.1 Allocation of Resources

The cost of making the data FAIR will be shared across the data providers (each partner of EYE-CLIMA) and the coordinator as follows:

- The data providers will make sure that their data are compliant with this DMP and provide the necessary data description and metadata of their datasets.
- The coordinator (NILU) will ensure that the DMP is implemented and that the metadata description, key words and file naming complies with EYE-CLIMA's protocol. The coordinator will ensure that the data are uploaded to the Zenodo repository.

Since Zenodo is a free repository, there are no additional costs related to its use. Data stored on Zenodo are backed-up and will be retained for the lifetime of the repository, that is, at least 20 years from present.

## 5.2 Data Security

Zenodo is a secure repository. All data files are stored in CERN Data Centres, primarily Geneva, with replicas in Budapest. Data files are kept in multiple replicas in a distributed file system, which is backed up to tape on a nightly basis. Data are stored for the lifetime of the repository, which is guaranteed for the next 20 years at least.

## 5.3 Ethics

There are no specific legal or ethical issues in relation to the activities, the data used, or the data produced in EYE-CLIMA. Specifically, EYE-CLIMA will not be using personal or confidential data and will not produce any data of confidential nature.

In general, EYE-CLIMA's partners will comply with the ethical principles as set out in Article 14 of the Grant Agreement, which states that all activities must be carried out in compliance with:

- ethical principles, including the highest standards of research integrity
- applicable EU, international and national law



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## 5.4 Other Issues

For the sharing of input data and intermediary results among the partners, EYE-CLIMA will use an SFTP server provided by the coordinator (NILU). The SFTP server will allow for secure (password protected) access to data and for the transfer of large data files. It is not intended, however, for long-term storage of data, and data there will not be backed-up.



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https://eyeclima.eu

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