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Contents

Abstract

The Copernicus Emergency Management Service (CEMS) Meteorological Data Collection Centre (METEO) collects, quality-controls and post-processes in situ and ground-based remote sensed meteorological data to provide input data tailored to the needs of CEMS European Flood Awareness System (EFAS), and the CEMS European Forest Fire Information System (EFFIS).

All data are quality controlled. Data post-processing includes the calculation of minimum, maximum, and mean values as well as the aggregation of totals over different accumulation periods. Data are then provided to CEMS as station lists and grids.

This report provides an overview of the data collection, quality control, and post-processing activities completed during the year 2025. In 2025, METEO collected real-time data for 11 parameters from 41 data providers and around 26,900 stations. On average, 9,500,000 records were added to the database each day. Furthermore, the database included more than 43,000 stations with historical data.

METEO constantly strives to improve the configuration of the database to enhance product generation. A substantially revised data validation protocol was implemented operationally in 2024 and used for the quality control of near-real time and historic data. This effort led to an updated version of the European Meteorological Observation high-resolution multi-variable gridded dataset. Finally, this report suggests a future data collection strategy.

Acknowledgements

The CEMS team, and particularly METEO, would like to thank the Partners and Data Providers of the European Flood Awareness System (EFAS) that contributed to the CEMS meteorological data collection. We would like to acknowledge their dedication to the EFAS project, their commitment and the sharing of their meteorological data. We thank them for their cooperation with METEO, both in the provision of data and for their proactive role in responding to the questions and solving issues. Without their collaboration and data provision, the delivery of this report would not be possible. In addition, we gratefully acknowledge the support provided by the Directorate-General for Defence Industry and Space (DG DEFIS) and the Copernicus programme.

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1 Introduction

The Copernicus Emergency Management Service (CEMS) Meteorological Data Collection Centre (METEO) was established to provide tailored quality controlled meteorological surface data to the CEMS Early Warning and Monitoring components. It is operated since 2016 by the KISTERS AG and Deutscher Wetterdienst (DWD). Current CEMS components served by CEMS METEO are the European Flood Awareness System (EFAS), and the European Forest Fire Information System (EFFIS). To fulfil this task, CEMS METEO collects in situ meteorological observations as well as ground-based remote-sensed data like radar observations of precipitation. Since 2023 METEO is operating on an extended domain with 1 arcmin spatial resolution, which covers the European continent and extends further south into North Africa, parts of Saudi-Arabia, Iraq and Iran. This extended domain constitutes the EFAS domain, and it sets the boundaries at: longitude: 25.25°W - 50.25°E, latitude: 22.75°N - 72.25°N. It is important to note that to avoid problems with gridding along the borders of the domain, METEO uses station data from a slightly larger region of 29.25°W - 54.25°E, 20.75°N - 74.25°N.

The data are received from many data providers using various channels, e.g., ftp-server, APIs or other web services delivering different file formats. All received data are quality controlled and integrated into a database before they are then post-processed to the needs of the CEMS applications. This includes the calculation of minimum, maximum and mean values as well as the aggregation and disaggregation of totals. Depending on the component, the data are either provided as station data or gridded/raster maps.

This annual report is intended to provide a general overview of METEO's approach and to highlight changes and improvements that happened in 2025.

2 Data providers

An overview about the current data providers and which data they provide to CEMS METEO is given in this section.

2.1 Data providers, parameters and time resolution

By the end of 2025, 41 data providers delivered real-time data to CEMS METEO, with an increment of 4 data providers compared to 2024. Table 1 provides the list of all active real-time data providers and delivered parameters in 2025, section 0 focuses on the new data providers added in 2025.

Table 1. List of active real-time data providers and delivered parameters (abbreviation). Parameter abbreviations are explained in Table 2. Note: the use of ICON Numerical Weather Prediction model data is a temporary solution to complement data transfer difficulties as a result of ongoing war in Ukraine: lack of observations for the Ukrainian territory would lead to a degradation of the EFAS forecasts (see also METEO annual report 2022, Lemke et al., 2023).

Name	Parameter										
	ClCo	**DT**	**Evap**	**Precip**	**ReAiHu**	**SunRad**	**SunD**	**AT**	**VP**	**WDir**	**WSpeed**
Agencia Estatal de Meteorología (Spain)	-	x	-	x	x	x	x	x	-	x	x
Agenzia Regionale Di Protezione Civile (Lazio, Italy)	-	-	-	x	x	x	-	x	-	x	x
Agenzia Regionale per la Protezione dell’Ambiente del Friuli Venezia Giulia (Italy)	-	-	-	x	x	x	x	x	-	x	x
Agenzia Regionale per la Protezione dell'Ambiente Lombardia (Italy)	-	-	-	x	-	-	-	-	-	-	-
Agenzia Regionale per la Prevenzione e l'Ambiente dell'Emilia-Romagna (Italy)	-	-	-	x	-	-	-	x	-	-	-
Agenzia Regionale per la Protezione Ambientale del Piemonte (Italy)	-	-	-	x	-	-	-	x	-	-	-
Automatic System of Hydrological Information (SAIH) for the Confederación Hidrográfica del Cantábrico (Spain)	-	-	-	x	-	-	x	-	-	-	-

Name	Parameter										
	ClCo	**DT**	**Evap**	**Precip**	**ReAiHu**	**SunRad**	**SunD**	**AT**	**VP**	**WDir**	**WSpeed**
Automatic System of Hydrological Information (SAIH) for the Ebro river basin (Spain)	–	–	–	x	x	x	–	x	–	x	x
Automatic System of Hydrological Information (SAIH) for the Guadalquivir river basin (Spain)	–	–	–	x	–	–	–	–	–	–	–
Czech Hydro-Meteorological Institute	–	–	–	x	–	–	–	x	–	–	–
Czech Hydro-Meteorological Institute – Open Data Portal (1)	–	–	–	x	x	–	x	x	x	x	x
Danish Meteorological Institute (Denmark & Greenland)	x	x	–	x	x	x	x	x	–	x	x
Deutscher Wetterdienst (Germany)	x	x	–	x	–	–	x	x	–	x	x
Deutscher Wetterdienst (Global)	x	x	–	x	x	x	–	x	–	x	x
Environment Agency (England)	–	–	–	x	–	–	–	–	–	–	–
Federal Hydrometeorological Institute (Bosnia-Herzegovina)	–	–	–	x	–	–	–	x	–	–	–
Finnish Meteorological Institute	x	x	–	x	x	–	–	x	–	x	x
Flanders Environment Agency (Belgium)	–	x	x	x	x	–	–	x	–	x	x
Hungarian Meteorological Service	–	–	–	x	x	x	–	x	–	x	x
Hydrological Information Centre (HIC) - Flanders Hydraulics Research (Belgium)	–	–	–	x	–	–	–	–	–	–	–

Name	Parameter										
	ClCo	**DT**	**Evap**	**Precip**	**ReAiHu**	**SunRad**	**SunD**	**AT**	**VP**	**WDir**	**WSpeed**
ICON Numeric Weather Prediction model	–	x	–	x	x	x	–	x	–	x	x
Institute for Ocean and Atmosphere (Portugal)	–	x	–	x	x	x	–	x	–	x	x
Institute of Meteorology and Water Management (Poland)	x	x	–	x	–	x	x	x	–	x	x
Israel Meteorological Service	x	x	x	x	x	x	x	x	–	x	x
Kosovo Hydrometeorological Institute	–	–	–	x	x	x	–	x	–	x	x
Latvian Environment, Geology and Meteorology Centre (Latvia)	–	–	–	x	x	–	–	x	–	x	x
Met Éireann (Ireland)	–	–	–	x	–	–	–	x	–	x	x
Met Éireann – Camp stations (Ireland) (2)	–	–	–	x	x	–	–	x	–	–	–
MeteoFrance	–	x	–	x	x	x	x	x	–	x	x
MeteoLux (Luxembourg)	x	x	–	x	x	–	x	x	–	x	x
MeteoSchweiz (Switzerland)	x	x	x	x	x	x	x	x	–	x	x
MeteoSchweiz CombiPrecip (Switzerland)	–	–	–	x	–	–	–	–	–	–	–
Monitoring Agricultural Resource system from JRC, European Commission (MARS; Global)	x	–	–	x	–	x	–	x	x	–	x
National Environmental Agency (Georgia)	x	x	–	x	–	–	–	x	–	x	x
Norwegian Meteorological Institute	x	x	–	x	x	–	–	x	–	x	x

Name	Parameter										
	ClCo	**DT**	**Evap**	**Precip**	**ReAiHu**	**SunRad**	**SunD**	**AT**	**VP**	**WDir**	**WSpeed**
Republic Hydrometeorological Service of the Republic of Srpska (Bosnia and Herzegovina)	–	–	–	x	–	–	–	x	–	–	–
Royal Netherlands Meteorological Institute	x	x	–	x	x	x	x	x	–	x	x
Servei Meteorològic de Catalunya (Spain)	–	–	–	x	x	x	–	x	–	x	x
Service public de Wallonie (Belgium)	–	–	–	x	–	–	–	–	–	–	–
Slovak Hydro-Meteorological Institute	–	–	x	x	–	–	–	x	–	–	–
Slovenian Environment Agency	–	–	–	x	x	x	–	x	–	x	x
Swedish Meteorological and Hydrological Institute	x	–	–	x	x	x	x	x	–	x	x
GeoSphere Austria	–	–	–	x	–	–	–	x	–	–	–

Source: CEMS.

(1) Czech Hydro-Meteorological Institute – Open Data Portal is the same partner as Czech Hydro-Meteorological Institute (see also section 2.2).
(2) Met Éireann – Camp stations is the same partner as Met Éireann (see also section 2.2).

Table 2. Parameter abbreviation and description.

Parameter abbreviation	Parameter description
ClCo	Cloud cover
DT	Dew point temperature
Evap	Evaporation
Precip	Precipitation
ReAiHu	Relative Air humidity

SunRad	Solar radiation
SunD	Sunshine duration
AT	Air temperature
VP	Water vapour pressure
WDir	Wind direction
WSpeed	Wind speed at 10 m above ground (WMO)

Source: CEMS.

In order to provide reliable maps for historical periods, used for example as input datasets to calibrate the hydrological model of EFAS, data providers are asked to deliver also historical data back to 1970 if possible. Historical data were also retrieved from research projects and gridded data sets. In case a country or region provided only historical data, real-time data are retrieved from two global data deliveries: MARS ([1]) and DWDSynop ([2]) (global). Table 3 shows all sources from which only historical data are available.

Table 3. List of data providers with only historical data and delivered parameters (abbreviation). Parameter abbreviations are given in Table 2.

Name	**Parameter**										
	ClCo	**DT**	**Evap**	**Precip**	**ReAiHu**	**SunRad**	**SunD**	**AT**	**VP**	**WDir**	**WSpeed**
CarpatClim	-	-	-	x	-	-	-	-	-	-	-
Danube ([1,2])	-	-	-	x	-	-	x	x	-	-	-
DWD Climatic ([1,2])	x	-	-	x	x	-	x	x	-	-	-
ECA ([1])	-	-	-	x	-	-	-	-	-	-	-
ERA-Interim-land ([2])	-	-	-	x	-	-	-	-	-	-	-
ERA5-land	-	-	-	x	-	-	-	-	-	-	-
Euro Synop ([1])	x	x	-	x	-	-	-	x	-	x	x
EURO4M-APGD by MeteoSchweiz (Switzerland)	-	-	-	x	-	-	-	-	-	-	-

[1] https://wikis.ec.europa.eu/display/GUIDANCEANDTOOLSFORCAP#Calculation_of_advanced_parameters; https://joint-research-centre.ec.europa.eu/monitoring-agricultural-resources-mars_en

[2] Copy of global data exchange between Meteorological Services, distributed via WMO Information System (WIS)

Name	Parameter										
	ClCo	**DT**	**Evap**	**Precip**	**ReAiHu**	**SunRad**	**SunD**	**AT**	**VP**	**WDir**	**WSpeed**
Hellenic National Meteorological Service (Greece)	x	-	-	x	x	-	x	x	x	-	x
MeteoConsult (1)	-	-	-	x	-	-	-	-	-	-	-
StrumaPILOT (2)	-	-	-	x	-	-	-	x	-	-	-

Source: CEMS.

(1) historic data received from JRC
(2) data was once collected but is not used for grid generation anymore (more recent data deliveries allow satisfactory coverage for the same areas and years).

A brief explanation of the main sources (research projects and gridded datasets) of historical data is provided below.

- *CarpatClim* is a historical daily precipitation product, including 2946 virtual stations covering the area between 44° and 50° E as well as 17° to 27° N (Hungary, Serbia, Romania, Ukraine, Slovakia, Poland, Czech Republic, Croatia) at a horizontal resolution of 0.1° (Spinoni et al., 2015), from 1970 to 2010. More information is available from http://www.carpatclim-eu.org/pages/home/ .
- *Danube* is a dataset of historical observations covering the years 1990-2003 and collected by the JRC from a number of national and regional hydro-meteorological institutes of the Danube basin (e.g. Romania National Institute for Hydrology and Water Management, Czech Hydro-Meteorological Institute, Bulgaria National Institute of Meteorology and Hydrology, Serbia Institute for Development of Water Resources Institute, Meteorological and Hydrological Service for the Republic of Croatia).
- *DWD Climatic Historical* is a dataset made available from the Deutscher Wetterdienst (DWD) Climate Data Centre (https://www.dwd.de/DE/Home/home_node.html).
- *ECA* – European Climate Assessment dataset contains series of daily observations at meteorological stations throughout Europe and the Mediterranean area. More information is available from https://www.ecad.eu/dailydata/
- *ERA-Interim-Land* is a global multi-variable reanalysis dataset for all land surface areas from 1979 to October 2016 at a 0.75° × 0.75° spatial resolution (Dee et al., 2011). More information is available from https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-interim . Note: This dataset is still in the METEO data collection, but not used to compute historical grids.
- *ERA5-land is a global multi-variable reanalysis dataset for all land surface areas from January 1950 to present* at a 0.1° x 0.1° spatial resolution. More information is available from https://cds.climate.copernicus.eu/datasets/reanalysis-era5-land?tab=overview .
- *Euro Synop* is a collection of data from manned and unmanned meteorological stations, as well as from mobile stations. SYNOP (surface synoptic observations) is a numerical code used for reporting weather observations.
- *EURO4M-APGD* is a daily precipitation dataset from 1971 to 2008 covering the Alps and adjacent flatlands (4.8° to 17.5° E and 43° to 49° N) (Isotta et al., 2014). More information is available from https://surfobs.climate.copernicus.eu/dataaccess/access_apgd.php.

— *Meteo Consult* is a 6 hourly precipitation dataset from 2007 to 2015 produced by Meteo Consult (part of MeteoGroup).
— *StrumaPILOT*

Data are provided with various temporal resolutions and aggregation intervals, depending on the parameter and data provider. The highest received temporal resolution and accumulation period is one minute (air temperature and precipitation from one data provider). Instantaneous parameters, like air temperature or wind speed, are mainly provided with temporal resolution of one, three and six hours, but also with higher and lower temporal resolutions. Most provided precipitation totals are accumulated over six and twelve hours, but also daily and one hourly total are often provided. Minimum and maximum air temperature are mostly provided with daily aggregation.

2.2 New and upgraded data providers in 2025

A continuous task for CEMS METEO is the acquisition and integration of additional data providers for real-time and historical data. This is done for two reasons: (1) to get more real-time information into the products and to increase reliability of the grids and (2) to enlarge the database with additional historical data needed for the calibration and validation of the hydrological model.
To enlarge the CEMS METEO database, 4 near-real time data providers were added within 2025:

— Automatic System of Hydrological Information (SAIH) for the Confederación Hidrográfica del Cantábrico (SAIH_CHC; Spain)
— Czech Hydro-Meteorological Institute – Open Data Portal (CHMI-ODP; Czech Republic)
— Latvian Environment, Geology and Meteorology Centre (LEGMC; Latvia)
— Met Éireann – Camp stations (METIE_Camp; Ireland)

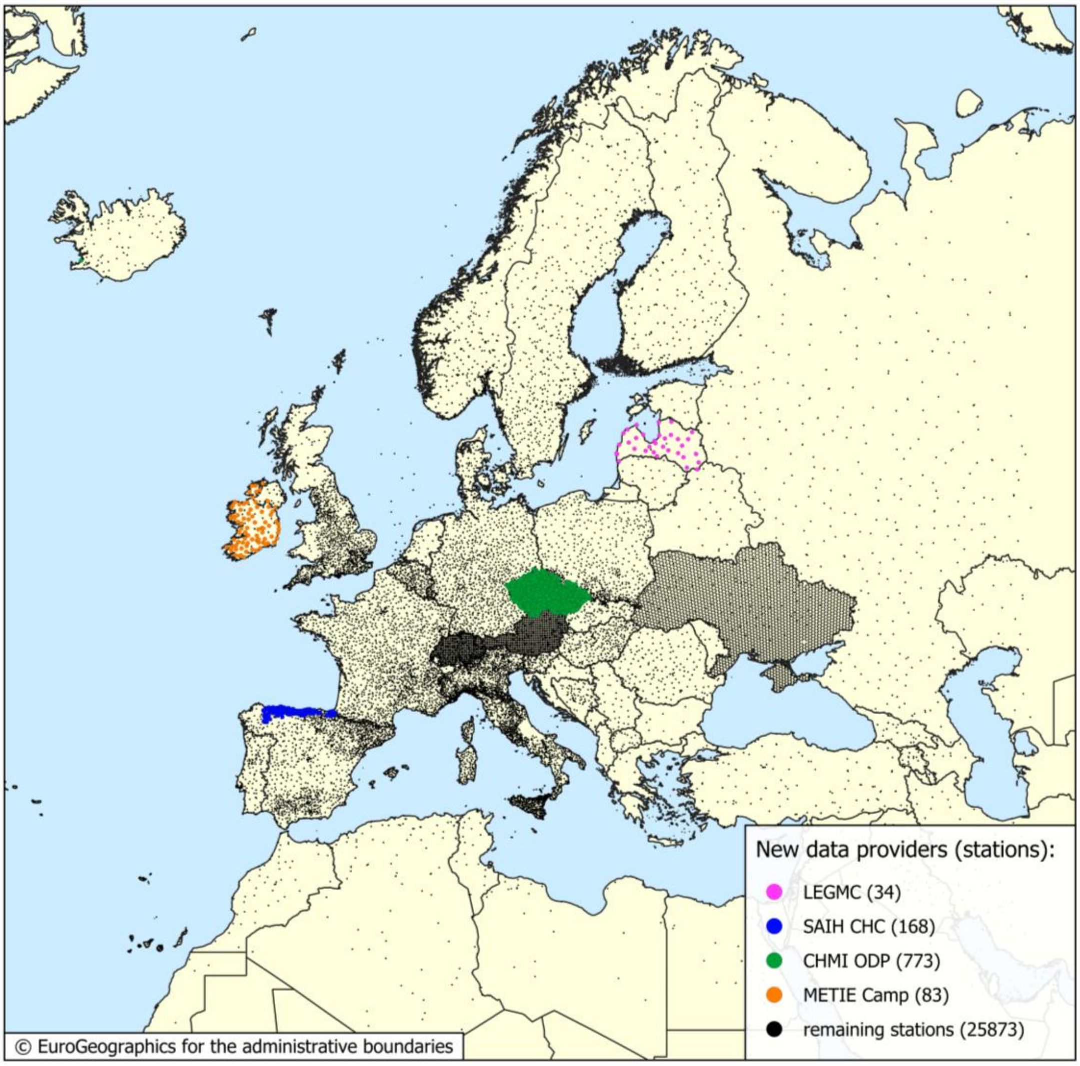
The station density is shown in Figure 1. The inclusion of SAIH_CHC, CHMI-ODP, LEGMC and METIE_Camp has increased this density relative to the previous year. CHMI-ODP and METIE_Camp are not new collaborators; they have been partners with EFAS for some time (CHMI and METIE, respectively) but are now supplying a broader set of stations and parameters, including historical data. This expanded coverage aligns with the high-priority goal of enhancing spatial density in Czech Republic and Ireland, see annual report for the reference year 2024, section 5.2 (Lemke et al., 2025).

In addition to the newly incorporated data providers, several existing sources have seen improvements. For the Institute of Meteorology and Water Management in Poland (IMGW) approximately 700 stations delivering near real time data were added, the integration of historical records for these stations is still ongoing while writing this report. The MARS archive was updated with corrected data for the years 2021-2024. For the "Service Public de Wallonie" in Belgium (SPW) there was a switch in the data source from FTP server to Open Data Portal, enhancing reliability. Further improvements were the integration of historical data for 165 stations of the data provider ARPA Lombardia, with the earliest records dating back to 2011. Unlike the report of the reference year 2024 stated, the integration of Júcar Hydrographic Confederation in Spain is still ongoing and will be fully completed in the near future.

To summarize the improvements for previously existing data providers, in 2025 data collection was enhanced for 4 data providers, namely IMGW, MARS, SPW and ARPA Lombardia, thanks to optimized data transfer protocols and to the inclusion of additional stations and historical data.

The above-described inclusion of new data providers and improvements to the collection of data from previously existing data providers, led to a significant increase of the total number of stations delivering real time and historical data. The total number of stations delivering real-time information in 2025 was 26,900 stations, an increment of about 10% compared to 2024 (approximately 24,500 station). The remaining stations in the database provide historical data only. More detailed database statistics are presented in Section 3.

Figure 1. Additional stations due to the integration of new data providers in comparison to the existing active station network. The number of stations for each new data provider is given in brackets. For information on the spatial distribution of real-time and historical stations see Figure 4 and Figure 5.



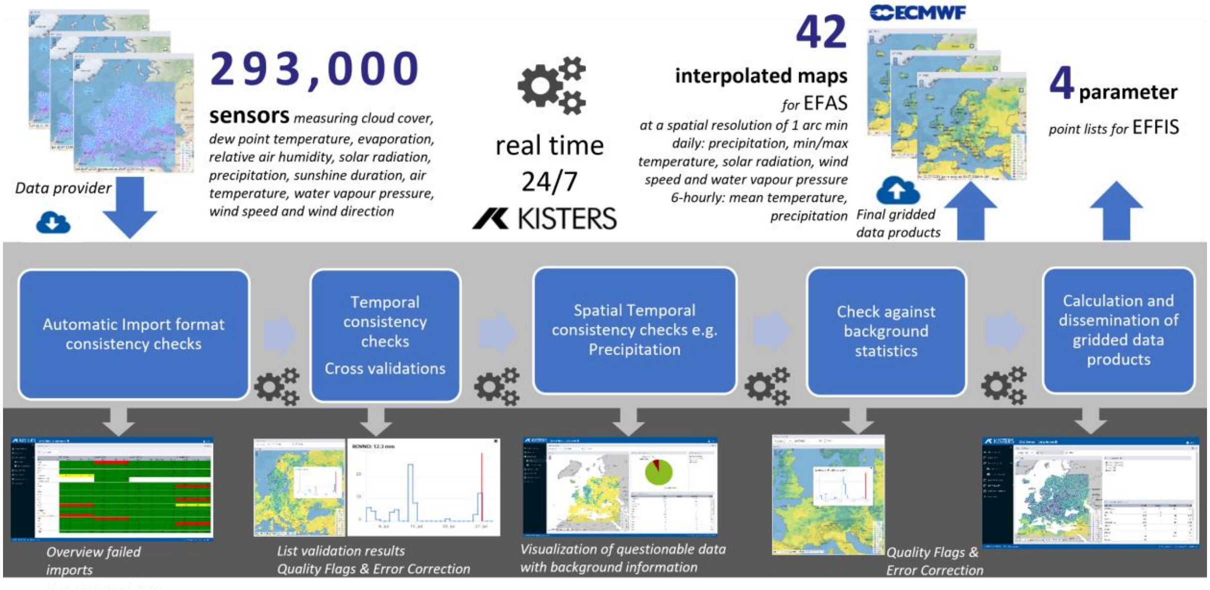
Source: CEMS Base map indicating countries and region borders from https://ec.europa.eu/eurostat/web/gisco/geodata/administrative-units/countries (CNTR_RG_01M_2024_3857, © EuroGeographics) and https://ec.europa.eu/eurostat/web/gisco/geodata/statistical-units/territorial-units-statistics (NUTS_RG_01M_2024_3857, © EuroGeographics).

3 Database

3.1 Data flow

The data flow within CEMS METEO is illustrated in Figure 2. Real-time data are delivered by the data providers via (s)ftp-servers (pulled by METEO/pushed to METEO) or web services/APIs in provider specific file formats. Historical data are delivered by data providers, research institutions or directly imported from open web-services (section 2.1) in the frame of historical data collection campaigns organised by METEO (with roughly yearly frequency). Finally, redelivered data which are re-sent by data providers to either fill in missing data points or replace already existing data in the database. All files are converted into a uniform and optimised file format for the integration into the METEO database.

Figure 2. Schematic illustration of the data flow within METEO. The amount of input and output data are shown as well as the processing and quality control steps within the data bank system. Interpolated maps are delivered for the last three days, and they include six daily parameters and two 6-hourly parameters (hence 42).



Source: CEMS.

The provided data are stored in a data bank super-system, named WISKI. Within WISKI, the parts of the quality control (see section 3.2) of the data and necessary aggregations (see section 4.1) are done. Finally, the data are extracted from the database as input for the interpolated maps and station lists provided to the CEMS components. The interpolation procedure is described in detail in section 4.2.

3.2 Quality control

A major upgrade to the data validation protocol started in 2022 (Lemke et al., 2023) and continued throughout 2023 and 2024 (Lemke et al., 2024; Lemke et al., 2025). The upgraded data validation protocol was adopted into operations in 2024. Further developments were applied in 2025 to enhance quality of the data validation. The following section covers the quality control as it is currently carried out in the operational METEO routines.

3.2.1 Operational quality control

Although the data is usually quality controlled by the data providers, an independent quality control procedure was established by CEMS METEO based on the experience that both real-time and historical data contain erroneous data points from time to time. Data providers are regularly informed about detected errors, and this feedback is an added value connected to the data provision to METEO. Two basic principles are applied in data validation: on one hand, quality control processes within WISKI are triggered as soon as new real-time, historical or redelivered data is imported (called “synchronous data validation”); on the other hand, additional quality check routines run regularly on a scheduled basis to achieve further improvements of the data (called “asynchronous data validation”). The dual-step data validation protocol guarantees the availability of quality checked data in the database for the generation of interpolated maps and station lists. Usually, quality checks are applied within so-called production time series, i.e., on the data originally delivered by the data providers. In some cases, quality checks are applied on the aggregated data, e.g., daily totals calculated from data originally delivered in different time resolutions (see section 4.1).

Quality flags are added to each data record in the quality control procedure. The following flags are in use: “good” if the value passes all quality checks, “suspect”, if it is inconsistent with other parameters (e.g., dew point temperature higher than air temperature), and “rejected”, if it did not pass at least one of the threshold checks. Additionally, a quality flag was defined for missing values in the time series. Moreover, it is here noted that the quality flag “suspect” is also added to data points shifted in time. For example, some stations provide six-, twelve-hourly and daily precipitation totals outside the needed time steps at 00, 06, 12 and 18 UTC. Such totals are shifted to the nearest needed date: the uncertainty added by the temporal shift is lower compared to splitting such data into hourly totals and then aggregate them.

3.2.1.1 Synchronous Data Validation

Synchronous Data Validation, as part of the WISKI, entails three principles: the comparison between imported values and lower/upper threshold values; where possible, the cross-validation of related variables; rate of change of the registered values. The methodology for the comparison between imported values and lower/upper threshold values was substantially improved in 2023 by the operational implementation of seasonal and geographical thresholds: the revised workflow is explained into detail in the second part of this section. The next paragraph briefly explains the consolidated principles for cross-validation of related variable, and rate of change of the registered values.

Cross-validation of related values

The Synchronous Data Validation protocol includes a cross-validation procedure against data from other parameters at the same station, e.g., dew point temperature is checked against air temperature. If the dew point temperature is 30°C below the air temperature or 0.2°C above the air temperature, then the dew point temperature is flagged as “suspect”. Wind speed and wind direction must either both indicate the presence of wind (non-zero values) or both indicate the absence of wind.

Rate of change

Rate of change validation is applied only to dew point temperature and to air temperature with the thresholds depending on the observation interval. For example, the maximum allowed variations are 15 degrees and 30 degrees if data are delivered with hourly and daily frequency, respectively.

Comparison between imported values and lower/upper threshold values.

As can be seen in Figure 3, the climate over the EFAS domain is quite diverse. Climate zone-specific thresholds were introduced to better adapt the thresholds for the five variables listed below to their location and thus make the data more representative of their climate zone. Climate zone-specific thresholds have been used since 2023 for the synchronous data validation, this was a major improvement compared to the original protocol, where the quality control was mainly based on fixed thresholds over the whole EFAS domain.

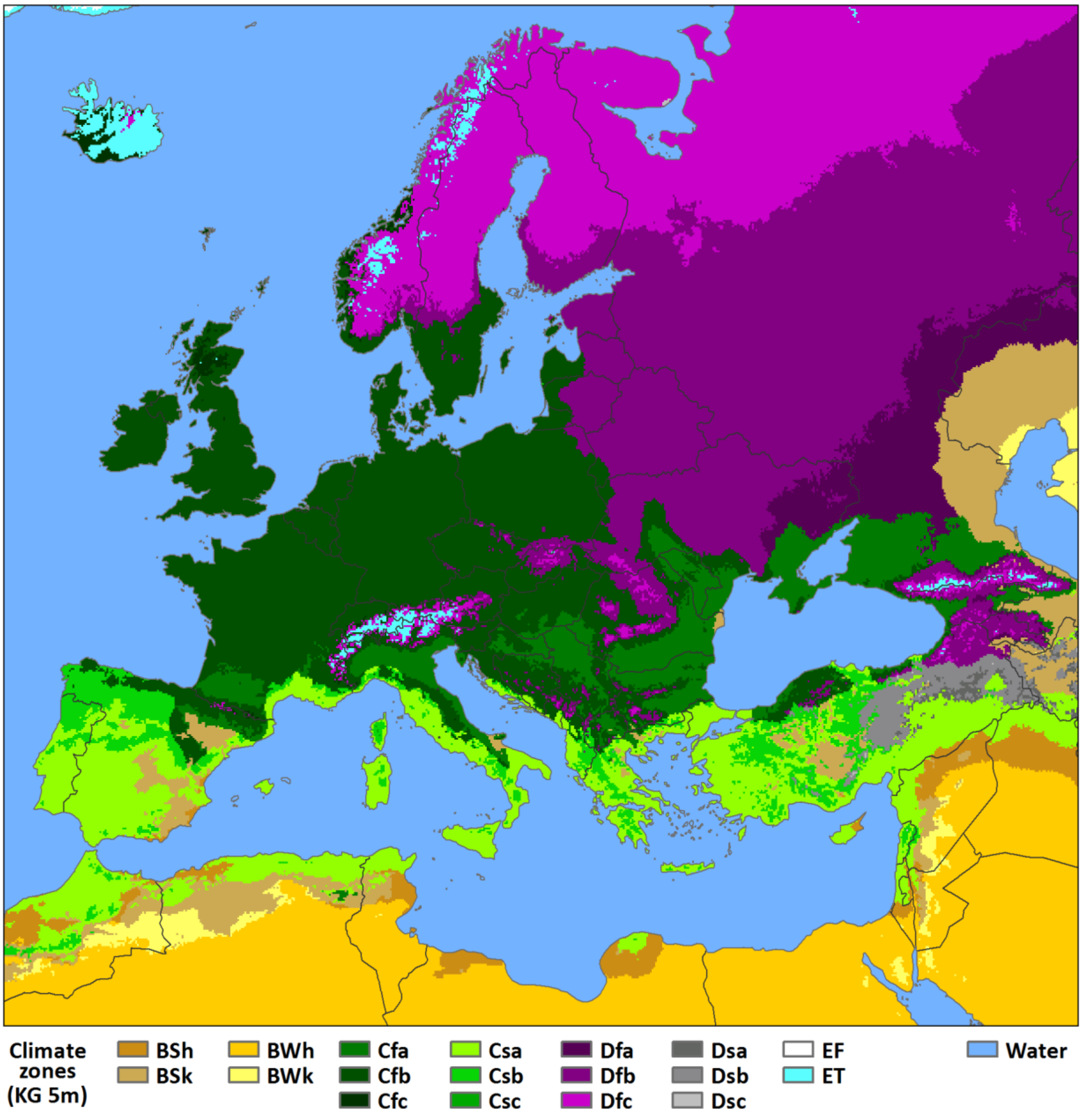
Conversely, synchronous data validation for evaporation, relative air humidity, cloud cover, wind direction, and wind speed make use of upper and lower threshold values which are constant in space and time (historical values of these variables did not show any dependency on season or climate zone). Fixed limit values for the variables above mentioned are summarised in Table 4. Similarly, thresholds for precipitation do not depend on season or climate zone. Different threshold values are used for different aggregation periods, see Table 5.

Table 4. Parameters with fixed thresholds.

Parameter	Min. threshold	Max. threshold
Cloud cover (ClCo)	0	9 oktas
Evaporation (Evap)	0	2 mm/15 min, 3 mm/hour or 15 mm/day
Relative Air humidity (ReAiHu)	5	100 %
Wind direction (WDir)	0	360 deg
Wind speed (WSpeed)	0	50 m/s

Source: CEMS.

Figure 3. Climate zones within EFAS domain, as defined in Kottek, M., et al., 2006.
B = arid climates; BS = steppe climates; BW = desert climates; BSh = hot steppe; BSk = cold steppe; BWh = hot desert; BWk = cold desert. C = warm temperate climates; Cf = warm temperate climate, fully humid; Cs = warm temperate climate, with dry summer. D = snow climates; Df = snow climate, fully humid; Ds = snow climate with dry summer. Third letter: a = hot summer, b = warm summer, c = cool summer and cold winter (e.g. Cfa = warm temperate climate, fully humid, hot summer; Dsb = snow climate with dry summer, warm summer). E = Polar climates; EF = frost climate; ET = tundra climate. Definitions in Tables 1, 2 of Kottek, M., et al., 2006.



Source: Kottek, M., et al., 2006.

Table 5. Thresholds for precipitation depending on the aggregation interval.

Aggregation interval [min]	Max precipitation threshold [mm]
15	125
30	200
60	250
180	350
360	425
540	475
720	500
900	525
1080	550
1440	600

Source: CEMS.

3.2.1.2 Asynchronous Data Validation

Asynchronous Data Validation can be triggered manually at any time or set up to run several tasks automatically in given schedules. The framework allows application of a variety of data validation algorithms. The points below explain the principles and type of rules that can be applied within the Asynchronous Data Validation framework. The rules currently in use are further detailed in the second part of this section.

- Consistency-type rules: check time series for conditions such as whether the timeseries are up-to-date, incomplete or if there are any gaps in the data.
- Validation-type rules: check whether individual data points in a time series conform to the algorithmic parameters detailed in the rule configuration. Data points that fail to conform are flagged as “incidents” and are tagged with a comment and, if requested, are also marked with a designated quality code. The validation rules can be split further into different groups: single target rules, comparison rules, and spatial rules.
    - Single target validation type rules are rules which only use data points from a single time series (the target time series) to validate the data, e.g., threshold, rate-of-change, range, etc.

- Comparison-type rules make use of other time series to validate data of a target time series. These can be generally split up into two groups: Inner Consistency and 'Outer' Comparison-type rules. Inner Consistency type rules only use data from time series located at the same station as the target. A common example of this might be a check to ensure that if a precipitation sensor records rainfall, then the humidity sensor at the same station should measure at least 50% relative humidity. An 'Outer' Comparison type rule will use time series from outside the target station in the validation. The key requirement for outer comparison type rules is that the relationships between the stations or time series must always be explicitly defined. This differentiates them from Spatial Type rules which select their neighbours based on spatial proximity alone.

- Spatial type rules make use of the spatial component of a measurement network to validate data. For this type of rules some additional considerations and parameters need to be thought of. In general, neighbour identification operates in three steps. The first step is to identify all possible neighbouring stations within a given search radius. In the second step, this list of neighbour candidates is reduced based on any disqualifying characteristics, e.g., stations where the elevation difference to the target station exceeds the maximum elevation difference parameter. Likewise, inactive stations with no data within the validation period are removed. In the third step, the remaining list of neighbours is sorted to prioritise and to be trimmed until the number of selected neighbours equals the group size parameter. Prioritization here is done by either orientation, quadrant or distance mode where orientation mode tries to select stations from each of the four cardinal directions and quadrant mode tries the same for each of the four quadrants around the target station. Distance mode ignores these restrictions and selects stations only on their proximity to the target station. This procedure is run for every station in the target data set.

— Correction-type rules: correct suspect values identified by one of the preceding rules or fill gaps. Different algorithms for correction or gap filling are available, e.g., use value from nearest neighbour or interpolate from values at the edges of a gap

Out of above types of validation rules generally available in the asynchronous data validation framework, METEO implemented the following validation-type rules for selected variables. The selection was based on (1) the conceptual consistency between the rule-type and the specific variable and (2) the relative importance of the variables for CEMS applications. A larger number of rules are dedicated to assessing precipitation data quality as this variable has primary importance for hydrological modelling. Some rules (e.g., spatial validation) can be applied to other variables in a future development. Consistency- and correction-type rules are currently not in use.

The following points describe into detail the rules which have been implemented.

— Value-Sequence detection (rule type "single target validation") for parameters precipitation, wind speed, air temperature and solar radiation: This rule detects sequences of repetitive identical values which are supposed to be unphysical, i.e., resulting from a measurement issue. This behaviour is also referred to as "Flatliner". Details of the definition of the Flatliner rule for each variable are presented below.

- Precipitation: The Flatliner rule for precipitation is intended to detect unusually long periods of 0.0 mm precipitation and remove them from further processing. For this purpose, the most frequently occurring climate zones in the EFAS domain were summarized as "Fully humid" (Cfa, Cfb, Cfc, Dfa, Dfb, Dfc, ET) and "Summer dry" (Csa, Csb, Csc, Dsa, Dsb, Dsc), whereby a distinction is also made between winter months (ONDJFM) and summer months (AMJJAS) in case of stations in summer dry climate zones. Several stations from the respective climate zones were randomly examined to identify realistic dry periods as limit values. This resulted in a limit value of max. 91 days without precipitation for stations in the "fully humid" and "summer dry"-winter group, and max. 151 days for the "summer dry"-summer group.

- Wind speed: This rule was implemented to filter out equal, consecutive values. If the station reports the same wind speed for longer than 48 hours, it is assumed that the sensor is defective and these values are excluded from further processing. The 48 hours limit is used in time series with time resolutions higher than daily. If only one value is supplied per day, the limit is 4 consecutive days with the same value. The temporal thresholds were the outcome of expert judgement.

- Air temperature: As per wind speed, the aim is to mark consecutive identical values, as this is likely to indicate a sensor error. For the sub-daily temporal resolutions, the limit is also 48 hours. For the daily EFAS-grids, only the minimum and maximum temperatures are used. The limit here is 8 consecutive days with the same minimum or maximum value. The temporal thresholds were the outcome of expert judgement.

- Solar radiation: This rule was introduced to identify and remove implausible sequences of identical daily values. If a station reports unchanged solar radiation measurements for more than three consecutive days, the sensor is assumed to be malfunctioning, and the corresponding data are excluded from further processing. To avoid false detections associated with polar night conditions, the check was applied only to stations located south of 66° N.

— Aggregation comparison (rule type "inner consistency-comparison) for parameter precipitation: This rule was configured to check time series of the same parameter provided by the same station. If a station reports the same parameter in several time resolutions, the values must be consistent. For example, the sum of four 6-hour values must be nearly identical as the daily value (a small discrepancy of 5 mm is tolerated).

— Detection of spatial duplicates (rule type "spatial") for parameter precipitation: As METEO receives data from two global networks (MARS, DWDSynop, see section 2.1) it often happens that data for the same station is delivered by MARS, DWDSynop, and a national or regional authority. Clearly, values for the same station and the same time step should be the same, regardless of the data provider. However, these values are not necessarily identical due to different methods of data processing and transfer applied by different data providers. The spatial duplicates-rule identifies stations for which data are delivered by different data providers: these stations are called "duplicates". Stations coordinates given by different data providers for the same station are not always identical, therefore, duplicates are identified by selecting stations which have a maximum distance of 1.5km. If duplicate stations have different values for a given time stamp, the values for this corresponding time stamp are flagged as "rejected" and excluded from further processing.

— Spatial comparison and spatial zero comparison (rule type “spatial”) for parameter precipitation: The spatial comparison rules check time series data at the target station against a range of values from neighbouring stations (see “Spatial type rules” above). The spatial comparison rule looks for up to eight neighbouring stations within a search radius of 50 km and a priority radius of 30 km (the search radius was retrieved from the analysis of precipitation station density in the EFAS domain), and a maximum elevation difference of 200 m. It then selects the closest stations from each of the four cardinal directions (prioritization by orientation). If less than 3 neighbouring stations can be identified, the rule is not applied.

The upper and lower boundaries for the spatial comparison are described by the following equation:

Equation 1. upper and lower boundaries for spatial comparison

$$\min(x_i^k) - \Delta^- < x^k < \max(x_i^k) + \Delta^+$$

where $\boldsymbol{x^k}$ is the value at the target station x for timestamp k, $\boldsymbol{x_i^k}$ is the range of values at all the neighbouring stations and $\Delta^{\pm}$ is the offset of the upper and lower bounds. The lower bound is thus the minimum value for the timestamp k from the range of neighbouring stations, and likewise for the upper bound. The offset $\Delta^{\pm}$ is selected as the maximum value among the following values:

- Standard deviation σ of all neighbouring stations $\boldsymbol{x_i^k}$, multiplied by two
- The mean of all neighbouring stations $\boldsymbol{x_i^k}$, multiplied by a positive and negative factor, which correspond to the upper and lower bounds respectively
- A constant offset value, $\boldsymbol{c_{abs}}$ (constant method)

These are summarised in the equation below. Based on variation tests, the constants in the equation had been defined as c_{rel+} = 30, c_{rel-} = 1000 and c_{abs} = 80:

Equation 2. offset calculation for spatial comparison

$$\Delta^{\pm} = \max \begin{cases} 2\sigma(x_i^k) \\ c_{rel\pm} \cdot \overline{x_i^k} \\ c_{abs} \end{cases}$$

The spatial comparison rule is used to reject values which are out of the confidence interval of the selected neighbouring stations (therefore, these values are attributed to instrument or data transfer error).

The spatial zero comparison rule is specifically used to reject 0.0 mm values from a station if all neighbouring stations (identification just as for the spatial comparison rule) have recorded at least 5.0 mm or more precipitation.

All the rules are applied on historical data and near real-time data.

The implementation of asynchronous validation rules within the operational protocol follows a stepwise protocol: each rule is activated only after thorough, offline validation. Therefore, the operational implementation started in 2023 and was concluded in 2024. In 2025 the asynchronous validation rules were extended by the previously described solar radiation flatliner.

Asynchronous data validation is performed on the entire historical archive only for specific purposes, e.g., before the generation of a new version of the historical gridded dataset (section 4.2). Furthermore, the asynchronous data validation protocol is triggered every day, to quality control the near-real-time data (last few days, weeks or months, depending on the rule) used for the daily generation of the initial conditions of the EFAS hydrological model (section 4.2).

3.2.2 Quality control statistics

Data are controlled and flagged as described in section **Error! Reference source not found.**. Table 6 shows the summary for the parameters used for gridding (EFAS) and station lists (EFFIS). It should be noted that the quality "suspect" in precipitation is mainly due to a shift of the reporting times in the post processing to meet the CEMS component needs.

Table 6. Quality control statistics of the quality codes "good", "suspect" and "rejected" for each parameter, given as relative and absolute values in 2025

		Quality					
		good		suspect		rejected	
	Parameter	relative [%]	absolute	relative [%]	absolute	relative [%]	absolute
EFAS Gridding	Temperature (6hourly mean) (AT)	98.10%	35,802,166	0.00%	363	1.90%	694,260
	Temperature (daily maximum) (TX)	97.45%	8,900,858	0.00%	10	2.55%	232,835
	Temperature (daily minimum) (TN)	98.00%	8,909,332	0.00%	344	1.99%	181,057
	Precipitation (6hourly totals) (Precip)	96.48%	34,382,582	2.27%	808,631	1.25%	444,717
	Precipitation (daily totals; 6 to 6 UTC) (Precip)	94.62%	8,963,939	3.69%	349,414	1.70%	160,721
	Solar radiation (SunRad)	96.47%	4,178,499	1.44%	62,184	2.09%	90,588
	Vapour pressure (VP)	99.98%	2,109,981	0.00%	0	0.02%	494
	Wind speed (WSpeed)	99.82%	6,886,410	0.02%	1,709	0.16%	10,952
EFFIS Station lists	Precipitation (daily totals; 12 to 12 UTC) (Precip)	93.34%	8,238,607	6.43%	567,875	0.23%	19,994
	Relative air humidity (at Noon) (ReAiHu)	99.92%	4,198,434	0.00%	0	0.08%	3,378

		Quality					
		good		suspect		rejected	
	Parameter	relative [%]	absolute	relative [%]	absolute	relative [%]	absolute
	Temperature (at Noon) (AT)	98.76%	9,214,797	0.00%	1	1.24%	115,694
	Wind speed (at Noon) (WSpeed)	99.88%	7,170,523	0.00%	2	0.12%	8,714

Source: CEMS.

3.3 Database statistics

By the end of 2025, the CEMS METEO database contained more than 60,000 stations, of which around 26,900 stations are delivering real-time data. The other stations provided real-time data before 2025, or only historical data. 4,695 of the stations with real-time data are so-called 'virtual stations', which are extracted from high-resolution gridded data sets (e.g., station adjusted radar quantitative precipitation estimations). It is here noted that 4,695 is the sum of the 1,324 virtual stations and of the 3,371 temporary virtual stations. 1324 virtual stations are extracted from CombiPrecip (488 virtual stations with hourly precipitation ([3])) and ZAMG-INCA (836 virtual stations with 6-hourly precipitation and temperature ([4])). 3371 virtual stations from DWD's numerical weather prediction model ICON (Icosahedral Nonhydrostatic) were included in the operational processing routines in 2022 as a temporary complement to in situ stations in war-affected Ukraine (Lemke et al., 2023) (see Table 1 and Figure 4).

CEMS METEO receives approximately 62,500 data files per day. All these files are processed, leading to an average of 9,500,000 data records added to the database – per day.

The spatial distribution of active (i.e., with real-time data) stations within the EFAS domain is depicted in Figure 4. It is obvious that the data coverage varies between countries and even within a single country. Please note that not all active stations deliver all needed parameters, e.g., many stations only deliver precipitation and temperature.

All stations currently not delivering real-time data are classified as "inactive". Even if these stations do not contribute to the real-time grids, they are highly valuable for historical grids: from time to time all data from the database are extracted to compute grids of historical periods (e.g., EMO-5 and EMO-1 high-resolution multi-variable gridded meteorological data set for Europe, Thiemig et al., 2022, ([5])). Figure 5 shows the spatial distribution of the inactive stations within the EFAS domain. To increase the data coverage over highly complex terrain and in data sparse areas, METEO integrated data sets from research projects (e.g., CarpatClim and EURO4M-APGD, see Table 3 in section 2.1), but also reanalysis products such as Copernicus Climate Change Service ECMWF ERA-reanalyses. Concerning the latter product, ERA-Interim was used for the generation of the historical grids up to 2022; in 2023 it was decided to replace ERA-Interim by ERA-5-Land. It should be noted that, in

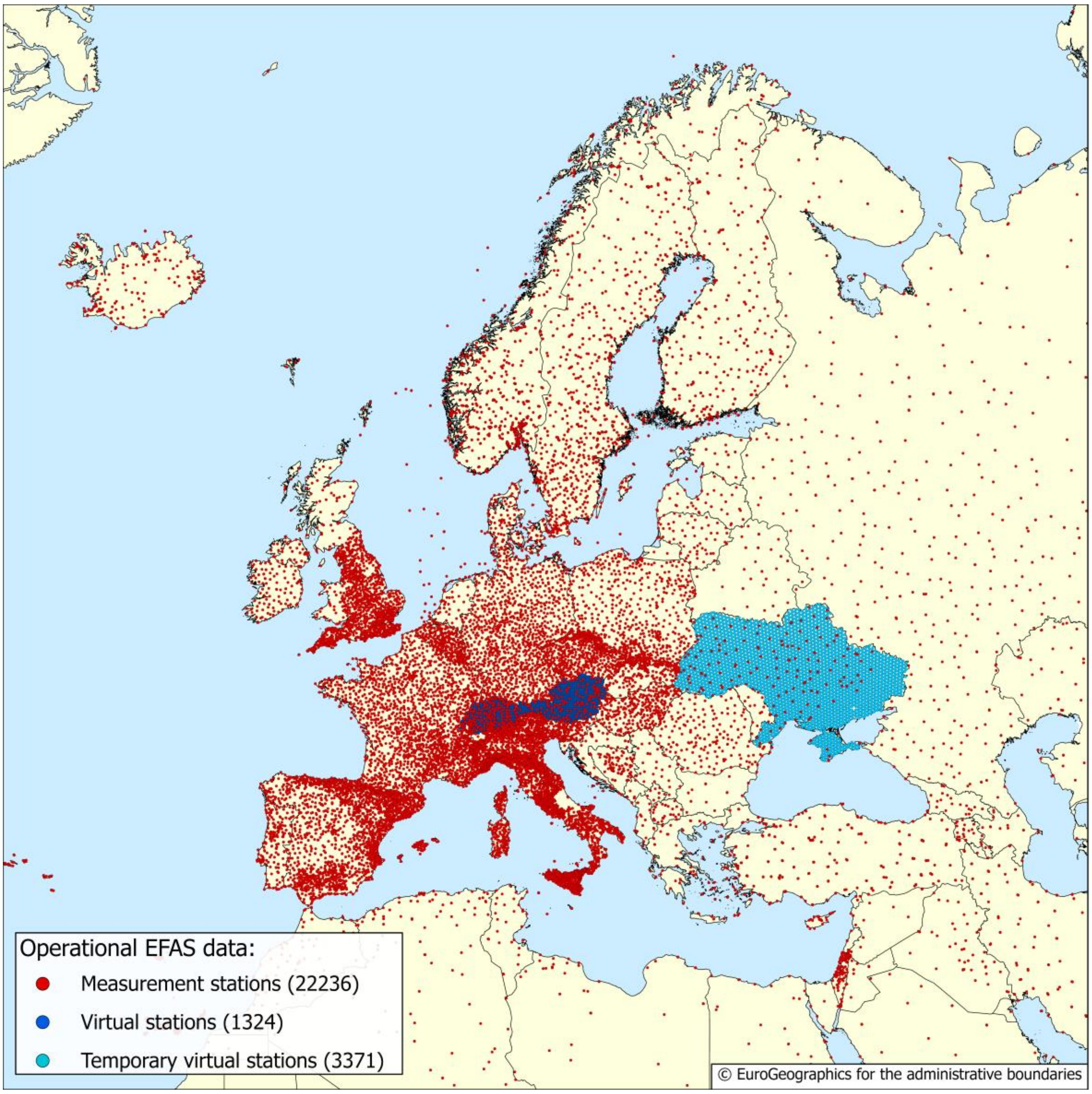
[3] https://www.meteoswiss.admin.ch/weather/warning-and-forecasting-systems/nowcasting.html

[4] https://www.geosphere.at/en

[5] https://data.jrc.ec.europa.eu/dataset/0bd84be4-cec8-4180-97a6-8b3adaac4d26

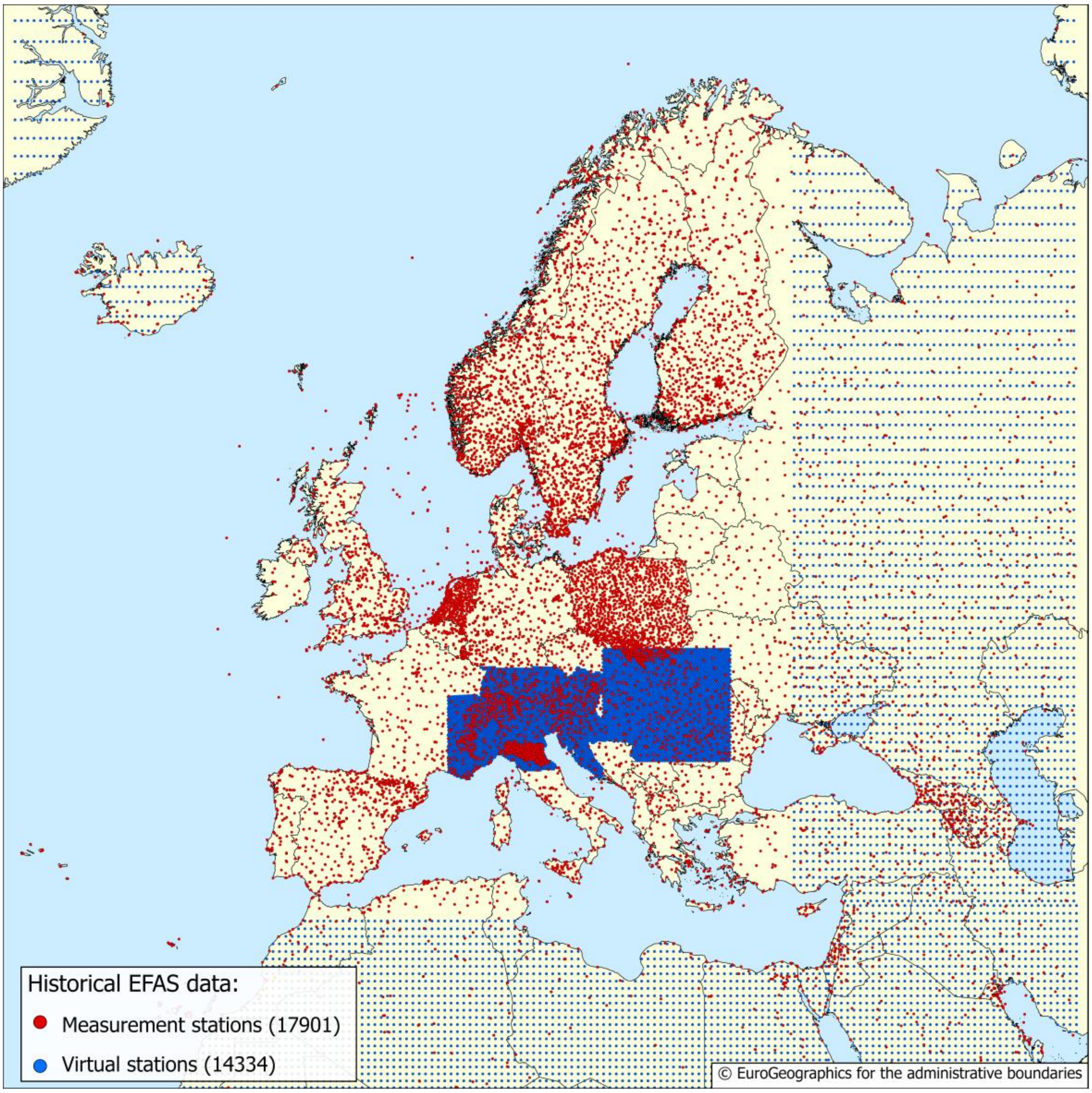
contrast to previous years in which the complete data collection of historical data was shown, only the historical data that is used to create the historical grids and does not provide real-time data is now shown in the Figure 5.

Figure 4. Spatial distribution of stations delivering real-time data of at least one parameter stored in CEMS METEO database. Maps per parameter are shown in **Error! Reference source not found.**. The number of stations is given in brackets, with the 3371 ICON stations being only an interim solution



Source: CEMS.

Figure 5. Spatial distribution of inactive stations. These stations deliver currently no real-time data, but data of former periods. The number of stations is given in brackets.



Source: CEMS.

4 Post-processing

The received data are post-processed to fulfil the needs of the CEMS components. The post-processing routines applied are partially different depending on the application case of each CEMS component. Only the quality-controlled data with quality flags “good” or “suspect” are used in the post-processing. Specifically, post-processing is done for the following subset of collected parameters:

— Precipitation;

— Air temperature;

— Wind speed;

— Solar radiation;

— Water vapour pressure;

— Relative air humidity.

Post-processing for the above parameters requires:

— Calculations of 6-hourly means/totals, except for solar radiation and water vapour pressure;

— Calculations of daily minimum, maximum and mean values, except for water vapour pressure;

— Calculation of daily totals for precipitation and solar radiation;

— Different definitions of the start and end time at a day, depending on the CEMS component;

— Aggregation and disaggregation of precipitation totals;

— Extraction of data from database;

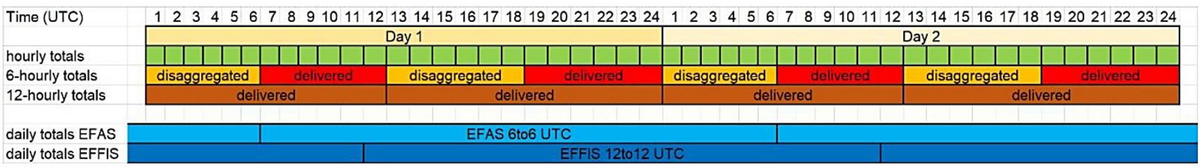
— Spatial interpolation of station data to generate grids;

— Generation of station lists.

4.1 Aggregation and disaggregation, calculation of minimum, maximum and mean

Precipitation totals are delivered with various accumulation periods, mainly 6 hours, 12 hours and 24 hours but also 5 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour or 3 hours. Additionally, the reporting behaviour of the stations differs between the data providers and sometimes even within the same data provider.

Figure 6. Aggregation and disaggregation scheme of precipitation totals. Disaggregated 6-hourly totals (orange) are the difference between the 12-hourly totals (brown) and the enclosed 6-hourly totals (red). Hourly totals are shown in green and can be aggregated to 6-hourly and daily totals.



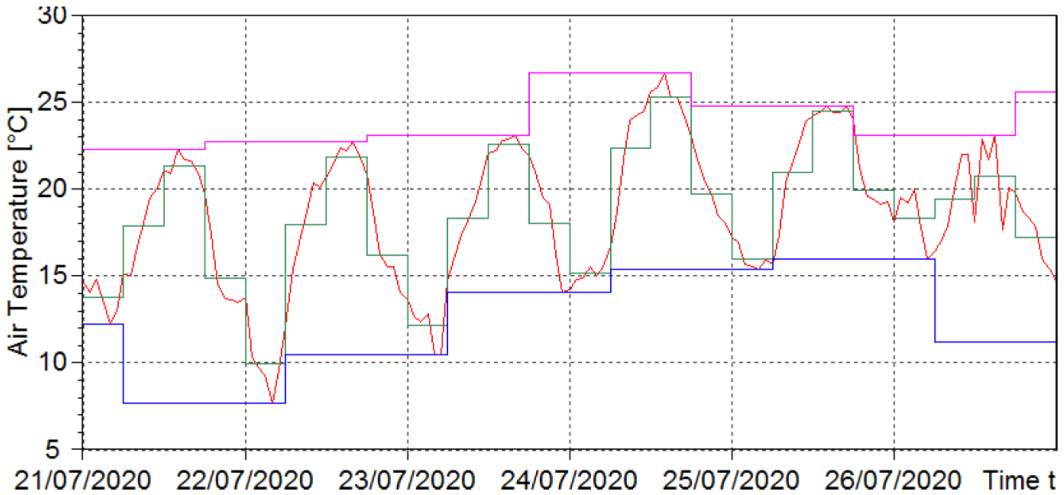
Source: CEMS.

To achieve a high temporal and spatial coverage of 6-hourly precipitation totals, the 12-hourly and 6-hourly totals have to be disaggregated, if the 6-hourly totals are within the 12-hourly total (Figure 6). The resulting merged 6-hourly time-series is often the basis for METEO's data deliveries to the CEMS. Where original data in higher resolution is available, 6-hourly totals are accumulated from the corresponding time-series, e.g., with 15 minutes temporal resolution.

Daily precipitation totals have to be provided as aggregated values from 6 UTC to 6 UTC of the following day and 12 UTC to 12 UTC of the following day (Figure 6). Whereas the daily totals at 6 UTC can be retrieved from the synoptic observations at 6 UTC and the higher temporal resolution time series, the daily totals at 12 UTC can only be computed from the higher time-resolution (disaggregated) time-series.

Minimum and maximum temperatures are calculated from instantaneous temperature data. (Figure 7). The minimum temperature is the lowest temperature between 18 UTC and 6 UTC of the next day, whereas the maximum temperature is calculated from the observations taken between 6 UTC and 18 UTC. Also, the 6-hourly mean air temperature is calculated from the instantaneous data. The data provider MARS is an exception for the calculation of the Minima and Maxima. As MARS does not report temperature between 6 p. m. and 6 a. m. local time, no minimum temperatures can be computed. The delivered minimum temperatures are thus used instead.

Figure 7. Delivered instantaneous air temperature (red) and therefrom calculated daily minimum temperature (blue), daily maximum temperature (magenta) and 6-hourly mean temperature (green). The magenta and blue lines of the plot allow to quickly identify the range of expected values.



Source: CEMS.

Additionally, daily means of wind speed and daily accumulated totals of solar radiation are calculated.

A minimum availability of data, subsequently referred to as "coverage", is required to compute minimum, maximum and mean values as well as aggregated totals. Precipitation totals are only computed if the aggregation period is fully covered by observational data (coverage = 100%). For all other parameters, a coverage of 87% is required. An exception is made for six and twelve hourly means with a minimum coverage of 66% to consider also stations reporting with a temporal resolution of six hours.

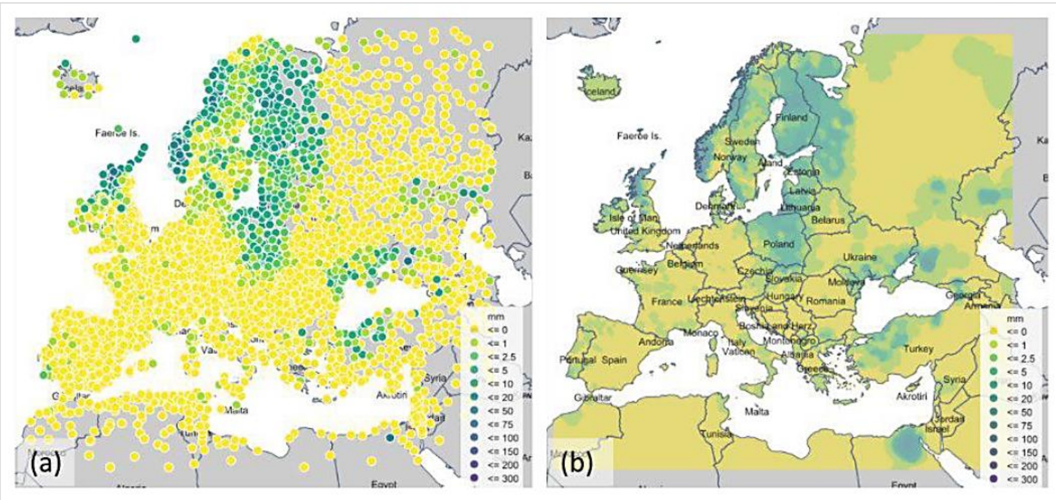
4.2 Gridding: meteorological grids for CEMS EFAS

The hydrological model[6] used by EFAS requires gridded input data. EFAS meteorological gridded dataset is known as European Meteorological Observations high-resolution, (sub-) daily, multi-variable gridded meteorological dataset, or EMO. An interpolation scheme must be used to compute the values of meteorological variables for the points of the required grid using information from the stations network. Two different interpolation schemes were used in METEO operations in 2025: modified SPHEREMAP was used for the generation of the real-time grids, while an in-house interpolation tool based on Angular Distance Weighting was used for the generation of an updated version of the EMO dataset. It is noted here that by the end of 2025, in parallel to SPHEREMAP, the in-house tool was added to the operational system for the purpose of a smooth transition to EFAS v6, which is in progress at the time this report was prepared. This paragraph explains the main features of SPHEREMAP, while Section 6 of Lemke et al. (2025) presents the in-house interpolation tool and explains the reasons that led to the replacement of SPHEREMAP.

The modified SPHEREMAP (Willmott, Rowe and Philpot, 1985) interpolation scheme is a geometric scheme, which considers the distances between the stations and the grid point as well as the clustering of stations. Additionally, an estimation of the grid reliability by means of the standard deviation (Yamamoto, 2000) was implemented. This method depends on the differences between the input data and the interpolated value.

The input data and output of the modified SPHEREMAP scheme, which was used in 2025 for the NRT grid creation, are illustrated in Figure 8 for the input stations (a) and the grid itself (b). A detailed discussion about the use of SPHEREMAP for the generation of EFAS grids can be found in Thiemig et al., 2022. The European Meteorological Observations (EMO) high-resolution, (sub-)daily, multi-variable gridded meteorological data is a CEMS product, and it is available for download from the JRC Data Catalogue ([7]).

Figure 8. Input and output of the gridding: (a) station observations, (b) gridded data. The maps depict the spatial distribution of daily precipitation totals.



[6] LISFLOOD Open Source, https://github.com/ec-jrc/lisflood-code

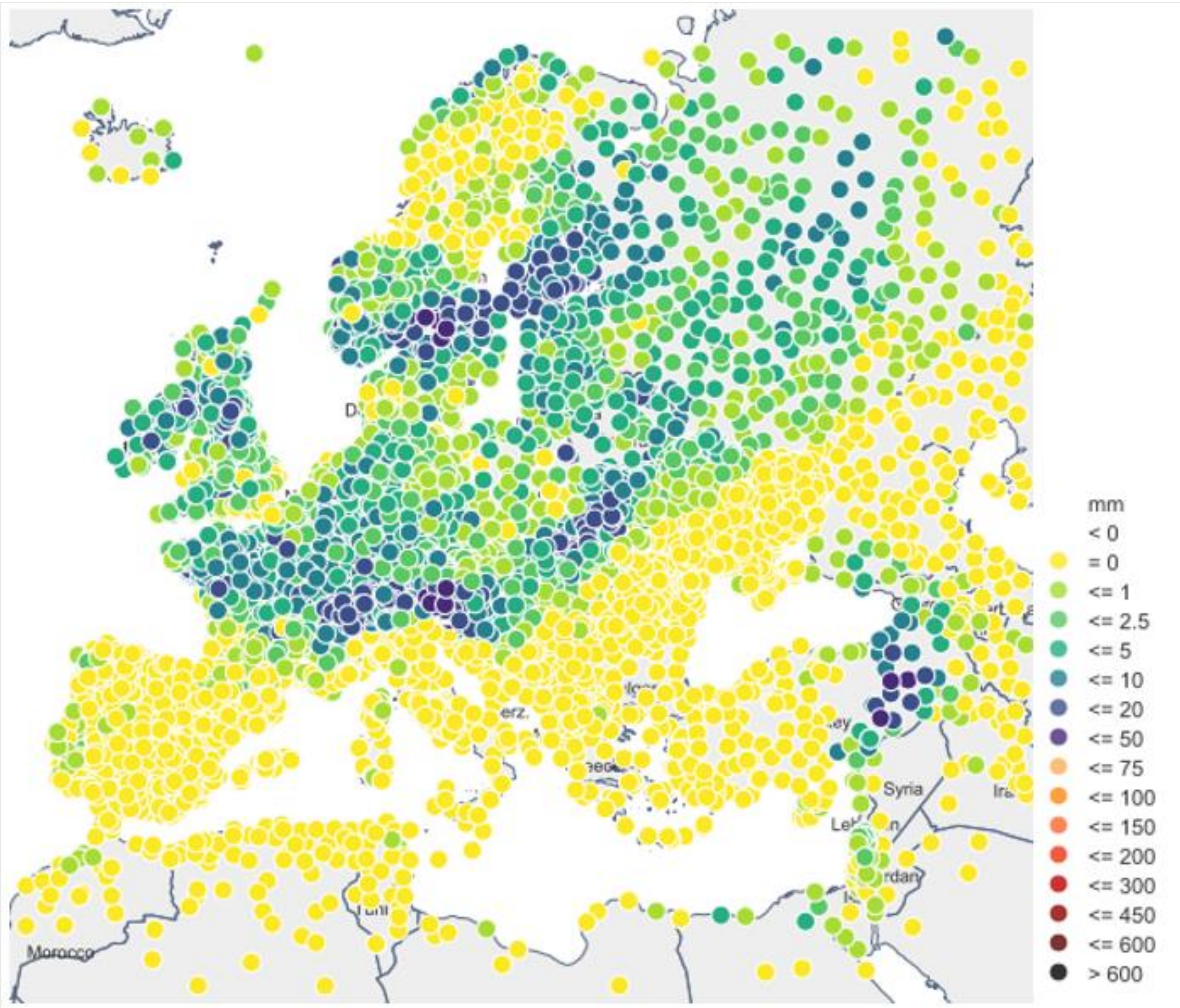
[7] https://data.jrc.ec.europa.eu/dataset/0bd84be4-cec8-4180-97a6-8b3adaac4d26

Source: CEMS.

4.3 Station lists for CEMS EFFIS

The European Forest Fire Information System (EFFIS) needs observations at station level for one date in a defined region. CEMS METEO provides such a list of quality controlled post-processed data. The spatial distribution of the station data summarised in a station list is depicted in Figure 9.

Figure 9. Spatial distribution of stations summarised in a station list, as provided to EFFIS. Depicted are stations that allow the calculation of 24-hourly precipitation totals at 12 UTC (end of time stamp, as explained in section 4.1).



Source: CEMS.

5 Gap analysis and data collection strategy

5.1 Gap analysis

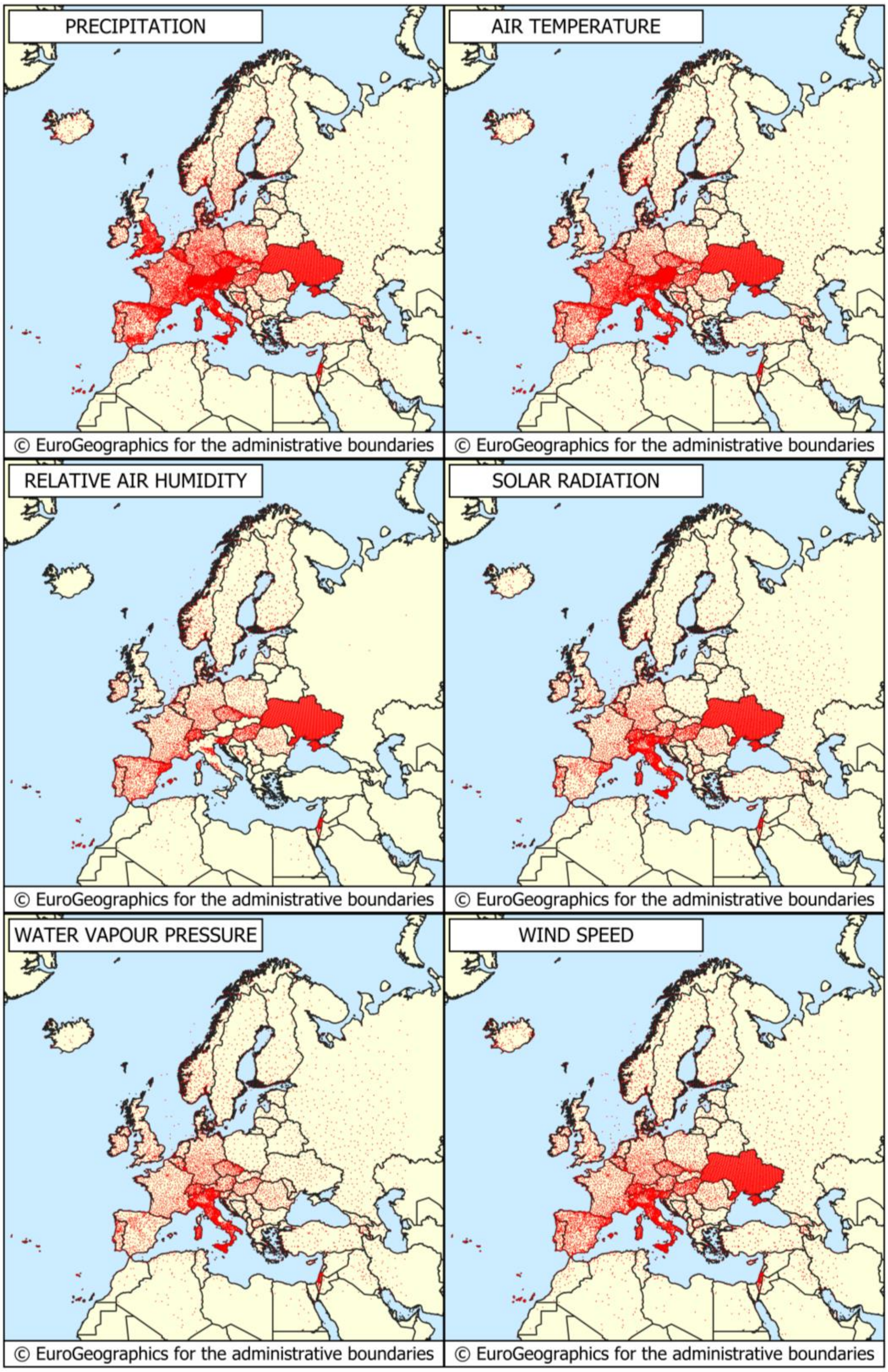
Stations network density and spatial distribution are essential to provide a reliable monitoring service and the primary factors affecting the accuracy of interpolated gridded datasets. Therefore, METEO constantly strives to analyse and improve the dataset of available in-situ stations.

Station density varies largely within the EFAS domain, and data availability depends on the parameter, as not all stations measure all variables and not all data providers deliver all parameters at every stations. Meteorological services usually operate many sensors at a station, but the station density is sometimes low, even if it is sufficient for the legal task of the specific service. On the other hand, hydrological services often operate a station network with a higher station density focusing mainly on precipitation with only a few stations observing temperature, wind or solar radiation. As currently not all existing meteorological and/or hydrological services are contributing with their data to the CEMS METEO database, the spatial distribution of available stations and parameters is heterogeneous. This section aims to detect gaps in the real-time data availability to identify priorities for future data collection activities.

The base information of the available data is fetched from the World Meteorological Organization (WMO) Global Telecommunication System (GTS). These data (referred to as "Deutscher Wetterdienst (Global)" in Table 1), exchanged from the national hydrological/meteorological services, cover the whole EFAS domain but are not spatially homogeneous as some countries exchange more data than others. This data exchange, however, covers nearly all required parameters. Such data can be densified by additional deliveries from national services based on agreements between the national data providers and the Copernicus program. As add-on, the deliveries from national meteorological services offer a redundant data delivery, while hydrological services provide a high density of mainly precipitation stations for certain administrative regions or catchment areas.

Figure 4 depicts the spatial distribution of the stations that delivered at least one parameter in real time in 2025. Figure 10 complements Figure 4 and it shows the spatial distribution of the stations that delivered one specific parameter in 2025. Both figures show that the station density in Algeria, Azerbaijan, Belarus, Bulgaria, Egypt, Greece, Iran, Iraq, Ireland, Jordan, Lebanon, Libya, Lithuania, Morocco, Poland, Russia, Saudi Arabia, Syria, Tunisia, Türkiye and in some parts of Italy is low when compared to the other countries of the EFAS domain.

Figure 10. Spatial distribution of active stations providing data for the parameter noted above the map. Upper row: precipitation (left) and air temperature (right). Middle row: relative air humidity (left) and solar radiation (right). Lower row: water vapour pressure (left) and wind speed (right).



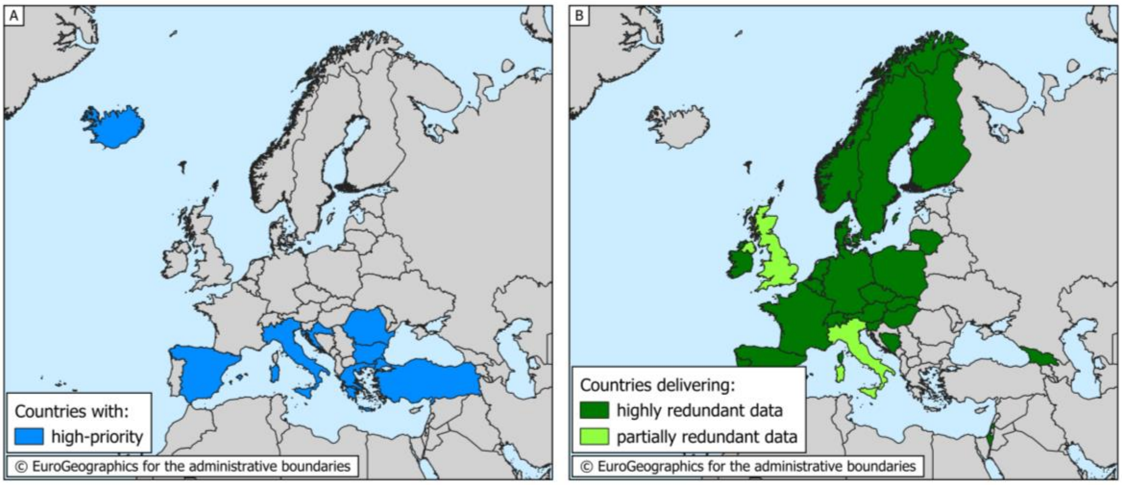
Source: CEMS Base map indicating countries and region borders from https://ec.europa.eu/eurostat/web/gisco/geodata/administrative-units/countries (CNTR_RG_01M_2024_3857, © EuroGeographics) and https://ec.europa.eu/eurostat/web/gisco/geodata/statistical-units/territorial-units-statistics (NUTS_RG_01M_2024_3857, © EuroGeographics).

5.2 Proposal for future data collection strategy

METEO aims to increase the spatial density of the stations network. To achieve this, METEO presents its work at the EFAS annual meetings, participates in EFAS trainings, collaborates closely with the other CEMS centres and contributes to workshops, conferences and meetings that extend beyond the EFAS community. The gap analysis of the previous section was complemented by pragmatic considerations (e.g. expected easiness of establishing a contact with the local data providers, needs due to technical changes) to define the list of countries for which stations should be included with a high priority. These countries are in alphabetic order Bulgaria, Croatia, Greece, Iceland, Italy, Romania, Spain and Türkiye (Figure 11 panel A).

Multiple data deliveries are currently implemented as a safety feature (in case of supplier failure) for countries marked in dark green in Figure 11 (panel B). In alphabetic order these are Austria, Belgium, Bosnia and Herzegovina, Czech Republic, Denmark, Finland, France, Georgia, Germany, Hungary, Ireland, Israel, Latvia, Luxembourg, Kosovo, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and Switzerland, and due to the integration of regional or hydrological data providers regional in Italy and the United Kingdom of Great Britain and Northern Ireland. These countries are marked in light green in Figure 11 (panel B).

Figure 11. Map of the EFAS domain with (A) countries proposed to give a high priority to establish a data provision to METEO and (B) countries with redundant data deliveries (dark green) and redundant data deliveries for parts of the country (light green) to METEO.



Source: CEMS Base map indicating countries and region borders from https://ec.europa.eu/eurostat/web/gisco/geodata/administrative-units/countries (CNTR_RG_01M_2024_3857, © EuroGeographics) and https://ec.europa.eu/eurostat/web/gisco/geodata/statistical-units/territorial-units-statistics (NUTS_RG_01M_2024_3857, © EuroGeographics).

Regarding the measured parameters, for the integration of additional stations, the highest priority should be given to increase the amount of available precipitation observations and secondly to a more homogeneous delivery of solar radiation data. This priority list has been defined according to the following reasoning: precipitation is of high importance in the hydrological modelling because it is a critical input variable with high spatial and temporal variability; solar radiation is currently provided by a limited and heterogeneously distributed number of stations (section 5.1). Additionally, the calculation of not provided parameters from available data should be implemented, e.g., water vapour pressure can be calculated from dew point temperature and air temperature values.

6 Conclusions and future work

This report provides an overview about the status and progress of the Copernicus Emergency Management Service (CEMS) Meteorological Data Collection Centre (METEO) in 2025.

CEMS METEO collects, quality-controls and post-processes in-situ and ground-based remote sensed meteorological data to provide input data tailored to the needs of the CEMS EFAS, and CEMS EFFIS. All real-time and historical data are quality-controlled in the same manner during the import to the database. Only data that passed the quality control are processed further and provided as station lists or grids including an uncertainty estimation.

Within 2025, four additional real-time data providers were integrated as well as additional real-time and historical data for two already existing data suppliers.

The status of the METEO data collection in Europe at the end of 2025 is summarised as follows: real-time data are delivered by 41 providers for 11 parameters from around 26,900 stations (an increase of 4 data providers and approximately 2,400 stations compared to 2024). On average, 9,500,000 records are being added to the database each day. Additionally, the database includes more than 43,000 stations with historical data.

During 2025 METEO undertook several activities to further improve data collection and validation, and the delivery of products to CEMS. First, a gap analysis regarding the available data allowed to define a priority list in terms of countries and parameters. Second, additional quality checks have been used. These additional quality checks along with the inclusion of new stations further improved the quality and accuracy of the collection and monitoring of the meteorological variables in the European domain.

Future work envisaged for 2026 includes further improvements to in-situ data collection, with a special focus on the inclusion of additional stations and optimized data collection strategies for existing data, as well as further improvements to the data validation protocol, including the application of existing routines to more parameters (e.g., the application of flat-liner asynchronous validation rule to Relative air humidity and spatial validation of solar radiation).

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List of abbreviations and definitions

Abbreviations	Definitions
%	Percent
°C	Degree Celsius
API	Application Programming Interface
ARPA	Regional Environment Protection Agency, Italy
AT	Air Temperature
BWh	Hot desert climate zone
CarpatClim	Historic dataset (1961-2010) for climate data in the Carpathian region
CEMS	Copernicus Emergency Management Service
Cfb	Warm temperate climate, fully humid, warm summer
CHMI-ODP	Czech Hydro-Meteorological Institute – Open Data Portal
ClCo	Cloud cover
Danube	Historic dataset (1990-2003) provided by JRC
Dfc	Snow climate, fully humid, cool summer and cold winter
DT	Dew point temperature
DWD	Deutscher Wetterdienst (German weather service)
DWD Climatic Historic	Climatic Historic dataset (1990-2005) provided by JRC
ECA	Historic dataset (varying time periods) provided by JRC
EFAS	European Flood Awareness System
EFFIS	European Forest Fire Information System
EMO	European Meteorological Observations high-resolution multi-variable gridded meteorological dataset for Europe

Abbreviations	Definitions
ERA5	ECMWF atmospheric reanalysis of the global climate (1940-present)
ERA-Interim-land	Global land surface reanalysis dataset (1979-2010)
Euro Synop	Synop Historic dataset (2003-2009) provided by JRC
EURO4M-APGD	Alpine precipitation grid dataset (1971-2008)
Evap	Evaporation
ftp	File Transfer Protocol
GTS	Global Telecommunication System
h	hour
HIC	Hydrological Information Centre, Belgium
hPa	hectopascal
ICON	Icosahedral Nonhydrostatic numerical weather prediction model
IMGW	Institute of Meteorology and Water Management, Poland
JRC	Joint Research Center
$J/(sm^2)$	Joules per second per square meter
K	Kelvin
LEGMC	Latvian Environment, Geology and Meteorology Centre
ll	Lower limit
MARS	Monitoring Agricultural Resource System
METEO	Meteorological Data Collection Centre
MeteoConsult	Historic dataset (2007-2015) provided by JRC
METIE_Camp	Met Éireann – Camp stations, Ireland

Abbreviations	**Definitions**
min	Minutes
mm	Millimetres
NA	Not available
Precip	Precipitation
ReAiHu	Relative air humidity
SAIH	Automatic System of Hydrological Information, Spain
SPW	Service, public de Wallonie, Belgium
SunD	Sunshine duration
SunRad	Solar radiation
SYNOP	Synoptic observations
TN	Daily minimum temperature
TX	Daily maximum temperature
ul	Upper limit
UTC	Universal Time Coordinated
VP	Water vapour pressure
WDir	Wind direction
WISKI	Water Information Systems by KISTERS
WMO	World Meteorological Organization
WSpeed	Wind speed
W/m^2	Watt per square meter

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