EUMETNET SRNWP-EPS EFI/SOT: from research to operations in AEMET-γSREPS

45th EWGLAM and 30th SRNWP meeting
(Reykjavik, 25th-28th September 2023)

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Software main features

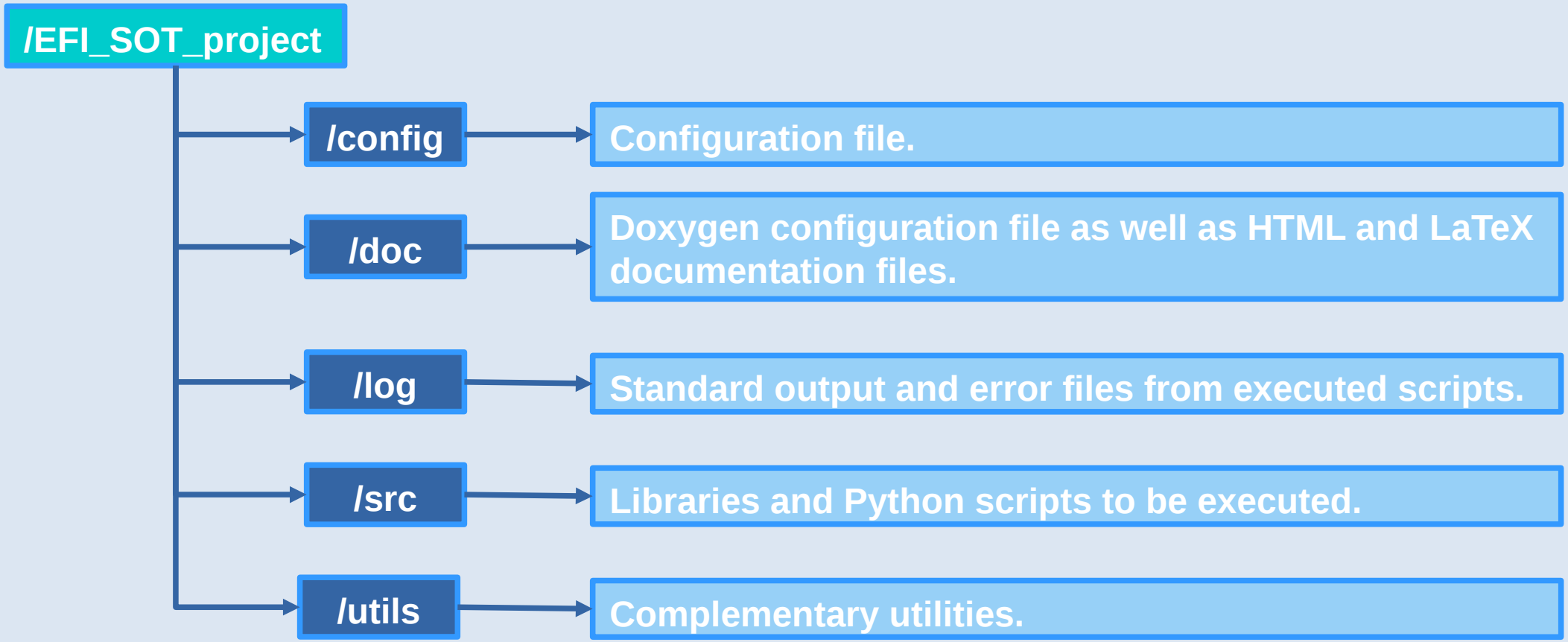
The aim of the **EUMETNET SRNWP-EPS EFI/SOT project** is to develop a software that implements EFI and SOT indexes in LAM-EPS and explore the behaviour of both indexes under different experimental conditions.

The software is designed in **Python 3**.

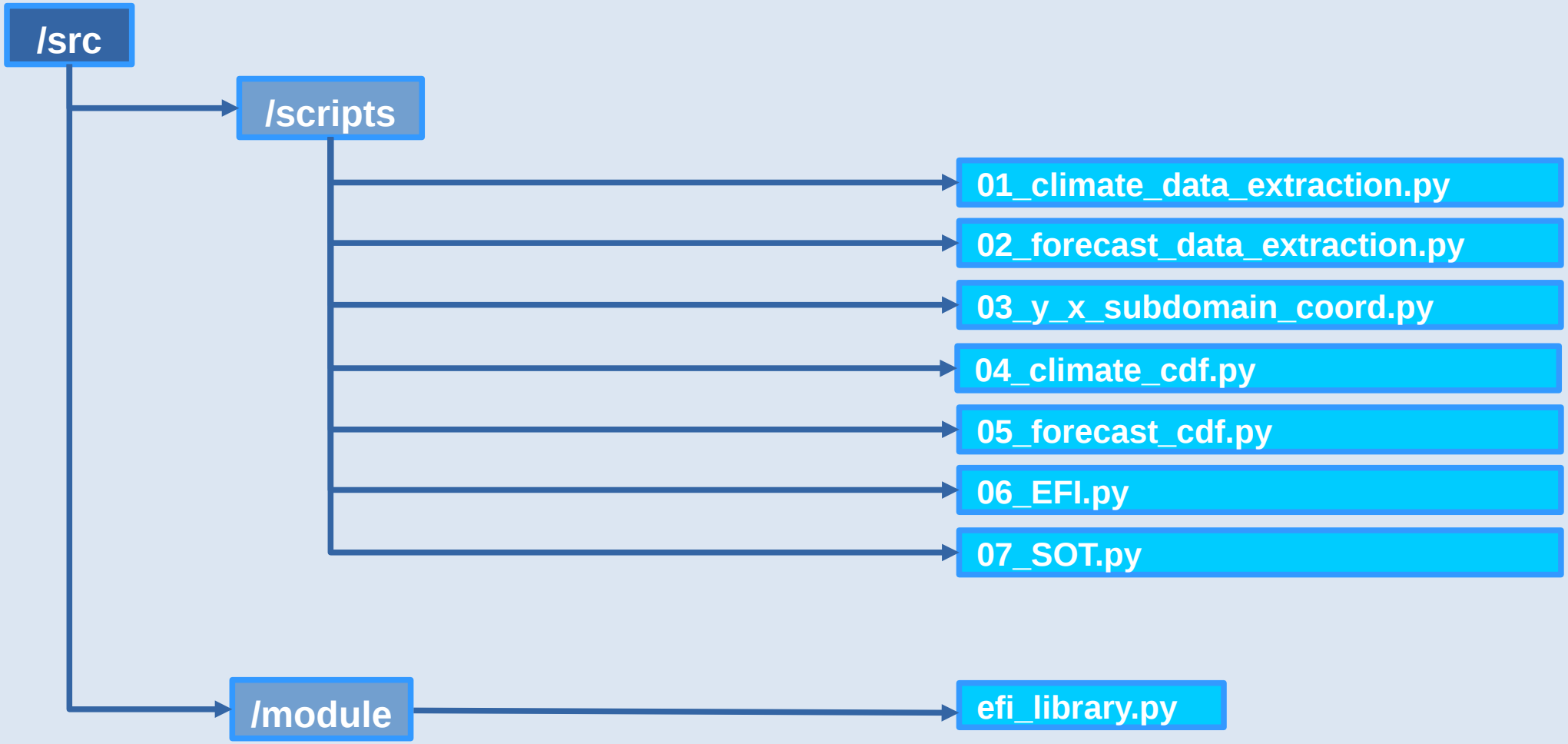
The software has been developed in **ECMWF ATOS HPCF**.

Tested with **GRIB files** from six LAM-EPS: **γSREPS**, **IT-EPS**, **MFAromeEPS**, **COMEPS**, **IREPS** and **MOGREPS**.

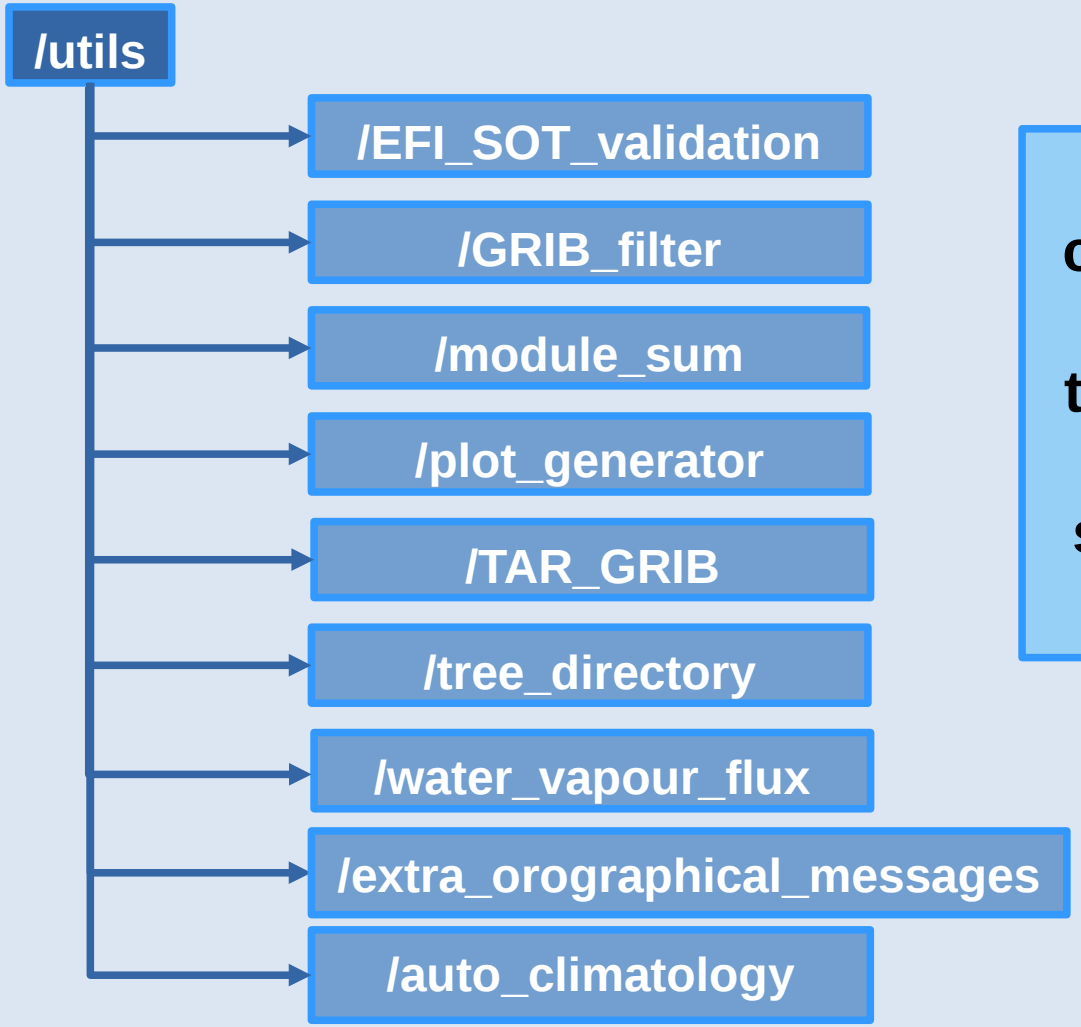
Software structure



Software structure



Software structure



These utilities have been designed as complementary tools that the user is free to make use of. They provide functionalities that the user may need to implement before or after running the main scripts of the software (that is, the ones from *src/scripts* directory).

All the utilities contain a configuration file that the user must edit.

Methodology

Most of the methodology followed to calculate EFI/SOT is based on that described by Météo-France in 2018 Laure Raynaud's article "***Detection of Severe Weather Events in a High-Resolution Ensemble Prediction System Using the Extreme Forecast Index (EFI) and Shift of Tails (SOT)***"

Main similarities with Météo-France methodology

- **Historical LAM-EPS GRIB files** are used to construct the EPS-climatology.
- The software has been tested using the GRIB files from the **EUMETNET SRNWPEPS database**, stored in **ECMWF ECFS**.
- **The lack of a long-term historical LAM-EPS database** makes it necessary to implement **relaxation techniques** in order to increase the number of data conforming the EPS-climatology.
- **Temporal relaxation**: definition of a **temporal window** (around the EFI/SOT calculation date and for the different years considered) where it is assumed that the meteorological data respond to the same climatology.
- For the EFI/SOT calculation year, the nearest three days are not considered as their data may be correlated to the meteorological situation of the EFI/SOT calculation date.
- **Spatial relaxation**: definition of a **neighbouring area** (centered at the grid point where EFI/SOT will be calculated) where it is assumed that the meteorological data contained within respond to the same climatology.

Methodology

Temporal relaxation

```
"""*****************************************************************************"""
"""LAM-EPS CLIMATOLOGY CONFIGURATION"""
"""*****************************************************************************"""

"""Variable to indicate whether the user wants to generate an automatic
climatological range of dates (mode = "automatic") or a manually-defined
list of dates (mode = "manual")."""
mode = "manual"


"""Starting year of the LAM-EPS climatological dataset."""
#NOTE: This variable will only be used if "mode = automatic".
initial_year = 2019


"""EFI/SOT calculus date."""
#NOTE: Specify it in the following format: "YYYY/MM/DD"
efi_date = "2021/08/18"


"""TEMPORAL RELAXATION used for the construction of the LAM-EPS climatology
(expressed in number of days)."""
#NOTE: This variable will only be used if "mode = automatic".
delta_days = 8


"""Manually-defined list of dates for the LAM-EPS climatology."""
#NOTE: This variable will only be used if "mode = manual".
#NOTE: Specify the dates in the following format: "YYYY/MM/DD"
date_list = ["2021/08/01","2021/08/02","2021/08/03","2021/08/04","2021/08/05",
             "2021/08/06","2021/08/07","2021/08/08","2021/08/09","2021/08/10",
             "2021/08/11","2021/08/12","2021/08/13","2021/08/14","2021/08/15"]

"""LAM-EPS members to be considered for the construction of the LAM-EPS
climatology."""
```

Spatial relaxation

In the configuration file the user can specify the **radius of the circle** considered for the spatial relaxation.

```
#SPATIAL RELAXATION - CIRCLE
"""Insert the radius (expressed in number of grid points) of the spatial
relaxation circle."""
radius = 4
```

The user can activate a **group of additional spatial filters**:

I. Land/Sea filter.
II. Orographic filter.
III. Random sampling.

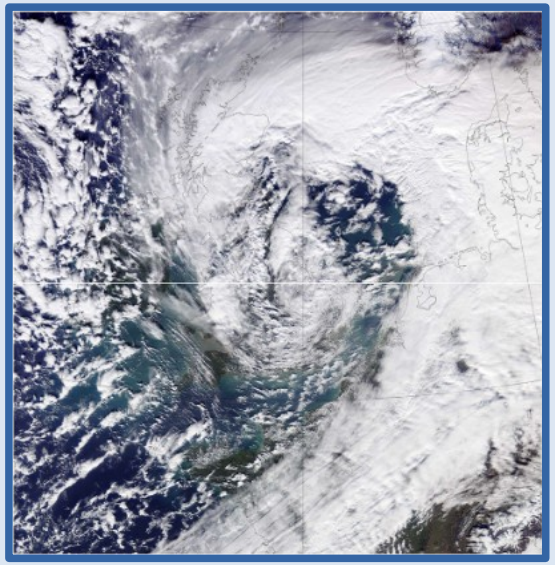
Functionalities not developed in Laure Raynaud's article

Already developed in Laure Raynaud's article

It is possible to define a **minimum percentage of data points** so, if in some circular neighbourhood the number of data points that have survived to a filter is lower than that percentage, the filter is cancelled in that neighbourhood.

EFI/SOT test: Eunice storm

Storm Eunice was an intense extratropical cyclone that affected several countries of NW Europe between 17th and 19th February 2022. The storm, which produced heavy rainfall and snowfall, set a new record for the fastest wind gust recorded in England (196 km/h).



Satellite image of Eunice storm over the British Islands (18/02/2022)

EFI/SOT test: Eunice storm

EXPERIMENT SETTINGS

- **LAM-EPS:** IREPS (Met Eireann)
- **Meteorological variables:** 24h-AccPcp / 24h-AccSnw
- **EFI/SOT forecast day:** 18th to 20th February 2022
- **EPS-climatology dates:** January, February and March 2021-2022

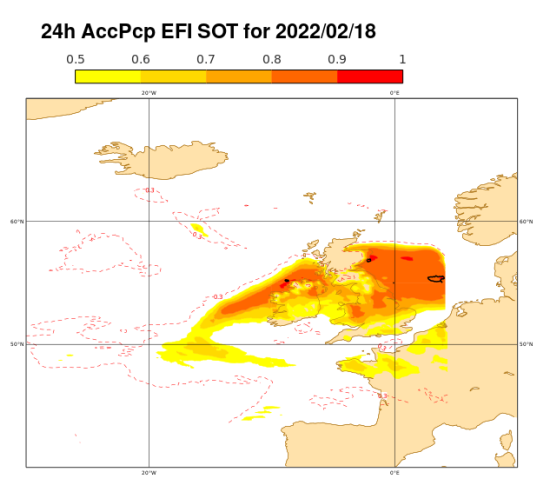
(February 2022 does not include days from 15th to 22nd)

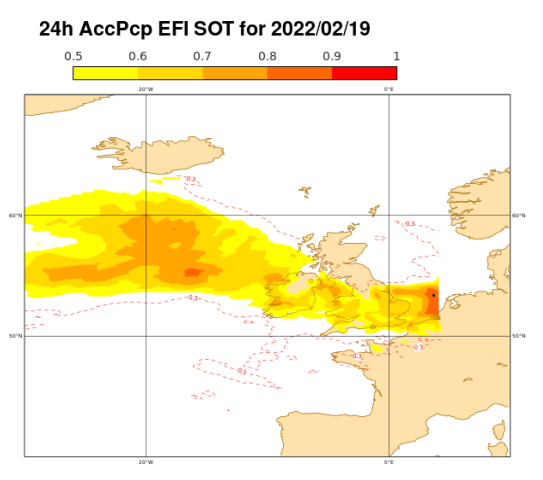
- **Radius spatial relaxation circle:** 4 (# grid points)
- **Random filter:** NO
- **Land-Sea filter:** YES
- **Orographical filter:** NO

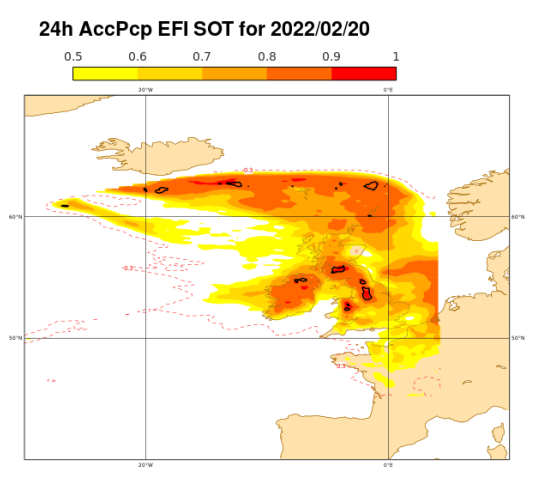
Approximated effective size of EPS-climatology: 153.000 (IREPS)

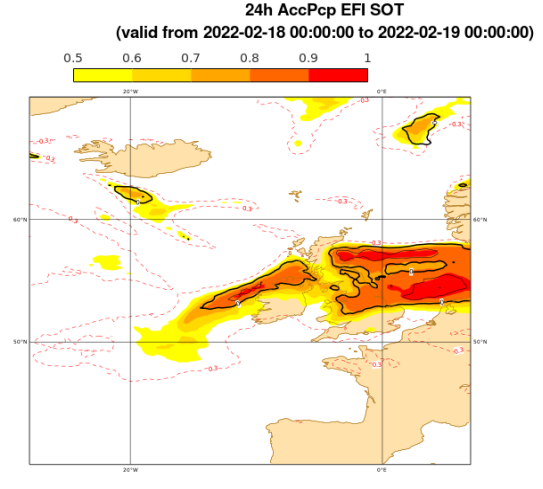
```
"""*****************************************************************************"""
"""LAM-EPS CDF CONFIGURATION"""
"""*****************************************************************************"""


"""Please, set the size of the x and y dimensions of the slicings that will be
performed on the previously defined LAM-EPS subdomain to fasten the calculation
of the LAM-EPS CDF."""
delta_x = 50
delta_y = 50


"""User, do you want to obtain just a subset of percentiles ("partial") or
the full set of percentiles that can be obtained from the LAM-EPS
climatology ("total")?."""
#WARNING: "total" mode is not still operative.
cdf_mode = "partial"


"""Percentile step that will define the subset of percentiles to be computed
from the LAM-EPS climatological dataset."""
#NOTE: This variable will be used if "cdf_mode = partial".
percentile_step = 1


#SPATIAL RELAXATION - CIRCLE
"""Insert the radius (expressed in number of grid points) of the spatial
relaxation circle."""
radius = 4


#SPATIAL RELAXATION - MINIMUM PERCENTAGE
"""Insert the minimum percentage of data (from 0 to 100%) to be used for each
grid point in the process of calculating the LAM-EPS CDF."""
#NOTE: This percentage will not compute the missing data associated to days
#or EPS members without data. For example, if you set "min_percentage" to 50%
#and there is a 50% of climatological days without data, the "min_percentage"
#refers to the 50% of the remained data.
min_percentage = 50


#SPATIAL RELAXATION - RANDOM FILTER
"""User, do you want to activate the random filter? (True/False)
If so, please, specify the percentage of data (from 0 to 100%) that must be
randomly selected."""
activate_random_filter = False
random_percentage = 60
```

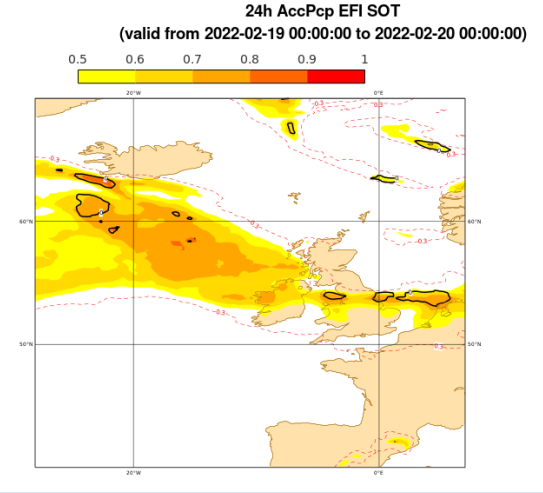
EFI/SOT test: Eunice storm

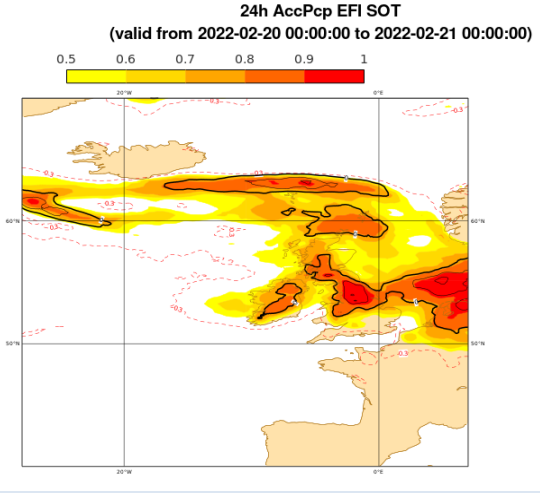








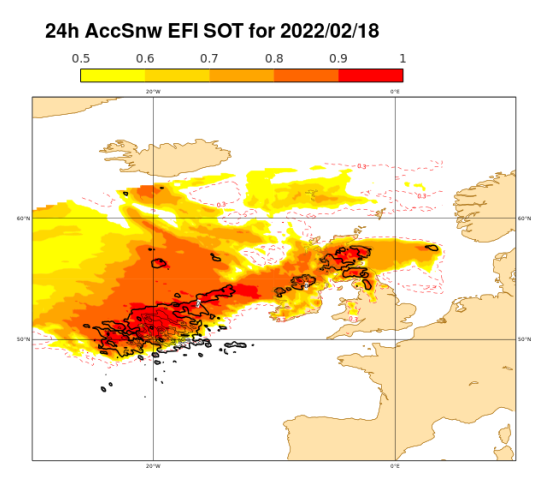


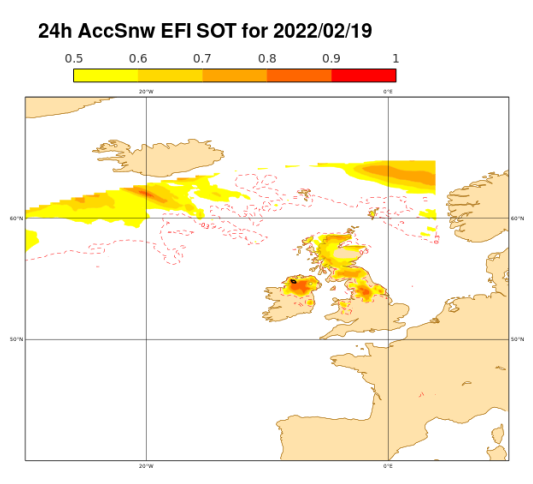


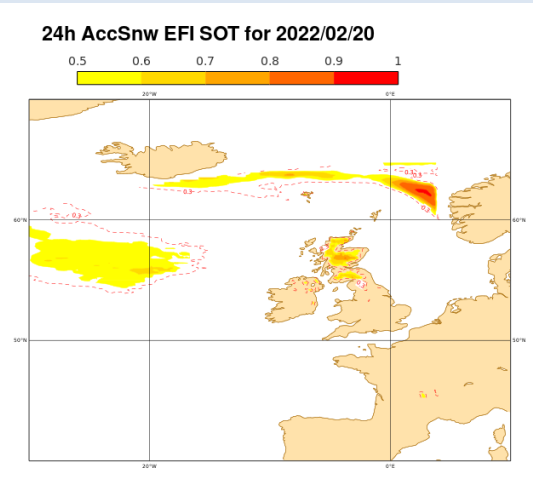
24h-AccPcp EFI SOT from 18th to 20th February 2022

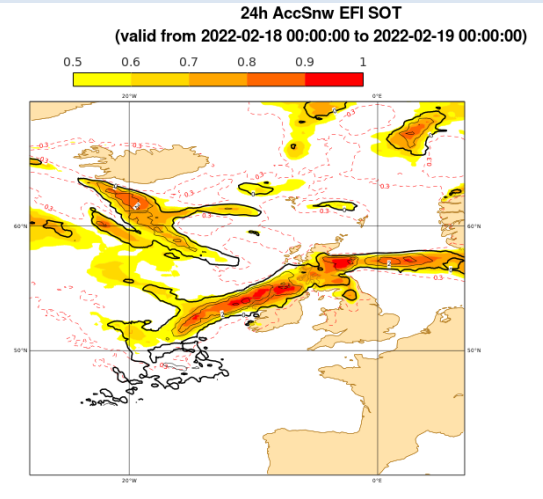
Comparison between EUMETNET and ECMWF EFI SOT products.

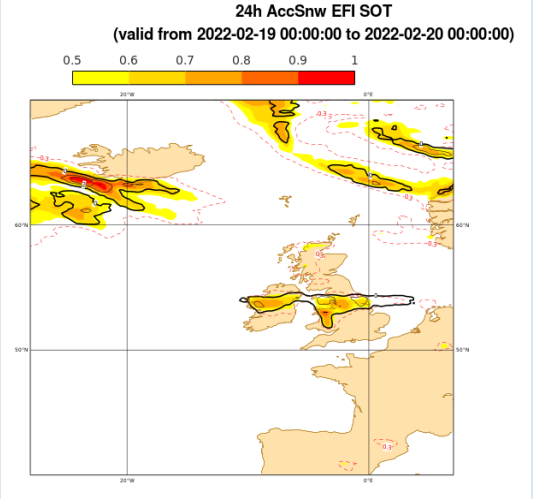
EFI/SOT test: Eunice storm

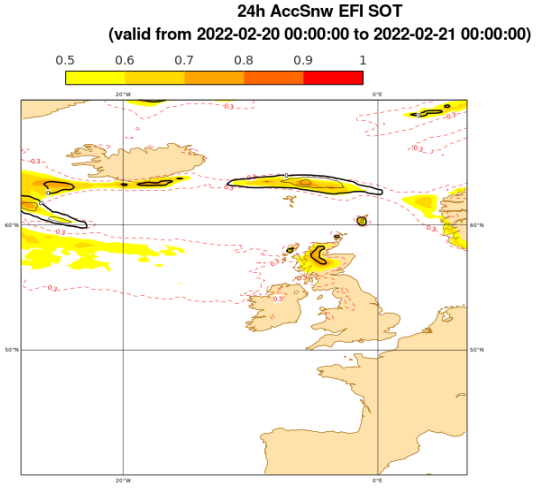












24h-AccSnw EFI SOT from 18th to 20th February 2022

Comparison between EUMETNET and ECMWF EFI SOT products.

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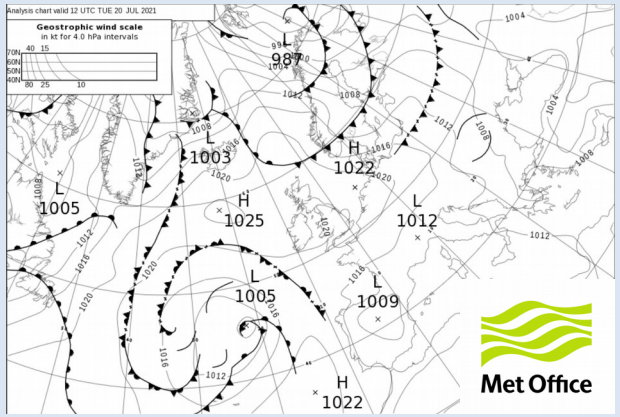
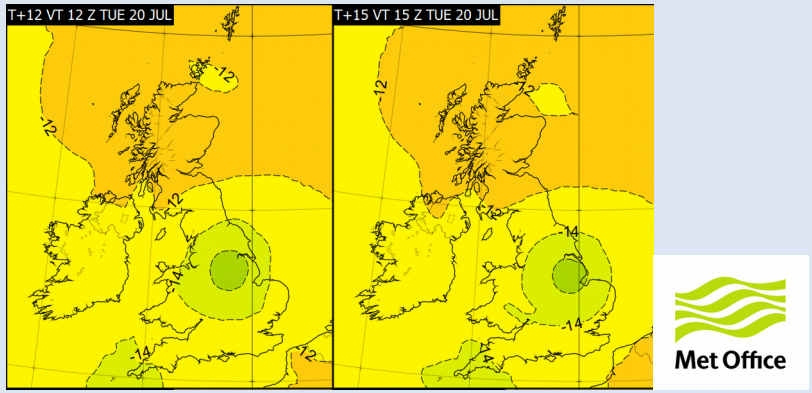
from research to operations in AEMET-γSREPS
45th EWGLAM and 30th SRNWP meeting (Reykjavik, September 2023)

EFI/SOT test: convective storm event

During the 20th July 2021 afternoon, several areas in South and South East England experienced intense heavy rainfalls (for example, in Kibworth (Leicestershire) 70 mm of precipitation were recorded in just 1 hour) due to a convective storm event.

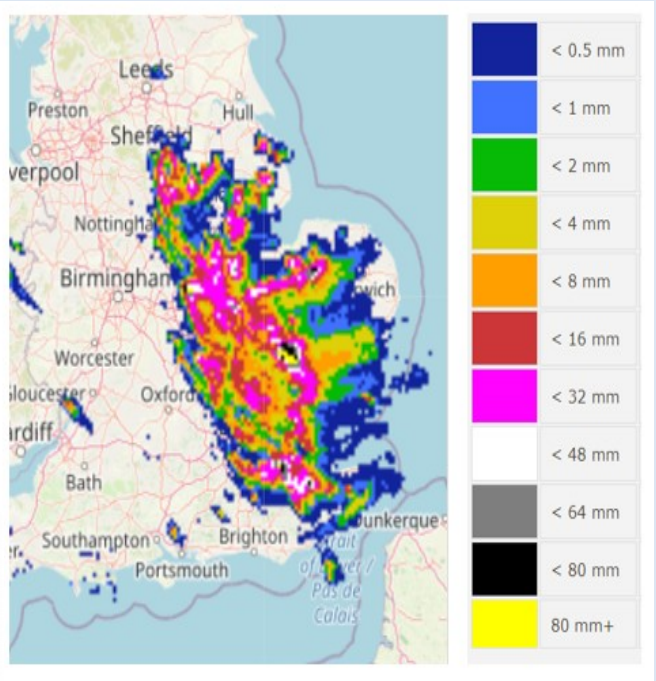


Sea-level pressure analysis valid for 12UTC 20th July 2021



500 hPa temperature valid for 12UTC (left) and 15UTC (right) 20th July 2021

Even though high pressures were dominating the UK (with many regions presenting hot, dry and sunny weather), a deeply unstable airmass lied across SE quadrant of the UK with potential for severe convection. A small-scale upper trough disrupted into a cut-off vortex across eastern areas.



12h-radar derived rainfall accumulations valid up to 00UTC 21st July 2021

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MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
Agencia Estatal de Meteorología

EFI/SOT test: convective storm event

EXPERIMENT SETTINGS

- **LAM-EPS:** MOGREPS (Met Office)
- **Meteorological variables:** 24h-AccPcp
- **EFI/SOT forecast day:** 20th July 2021
- **EPS-climatology dates:** 1st to 15th July 2020-2021-2022
- **Radius spatial relaxation circle:** 4 (# grid points)
- **Random filter:** NO
- **Land-Sea filter:** YES
- **Orographical filter:** NO

Approximated effective size of EPS-climatology: 65.600 (MOGREPS)

```
"""*****************************************************************************"""
"""LAM-EPS CDF CONFIGURATION"""
"""*****************************************************************************"""


"""Please, set the size of the x and y dimensions of the slicings that will be
performed on the previously defined LAM-EPS subdomain to fasten the calculation
of the LAM-EPS CDF."""
delta_x = 50
delta_y = 50


"""User, do you want to obtain just a subset of percentiles ("partial") or
the full set of percentiles that can be obtained from the LAM-EPS
climatology ("total")?."""
#WARNING: "total" mode is not still operative.
cdf_mode = "partial"


"""Percentile step that will define the subset of percentiles to be computed
from the LAM-EPS climatological dataset."""
#NOTE: This variable will be used if "cdf_mode = partial".
percentile_step = 1


#SPATIAL RELAXATION - CIRCLE
"""Insert the radius (expressed in number of grid points) of the spatial
relaxation circle."""
radius = 4


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#NOTE: This percentage will not compute the missing data associated to days
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min_percentage = 50


#SPATIAL RELAXATION - RANDOM FILTER
"""User, do you want to activate the random filter? (True/False)
If so, please, specify the percentage of data (from 0 to 100%) that must be
randomly selected."""
activate_random_filter = False
random_percentage = 60
```
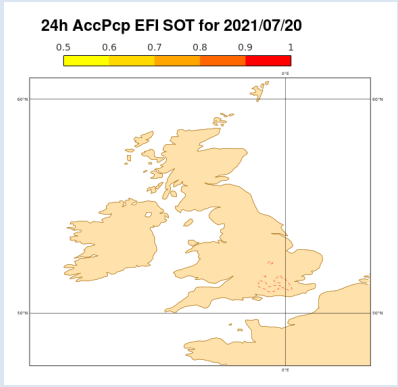
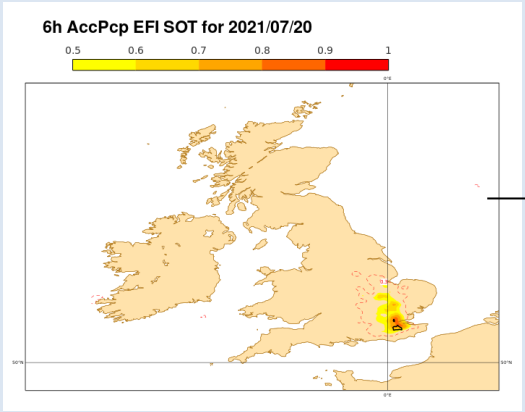
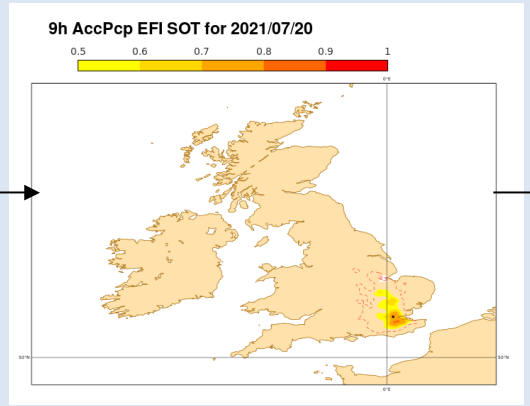

EFI/SOT test: convective storm event

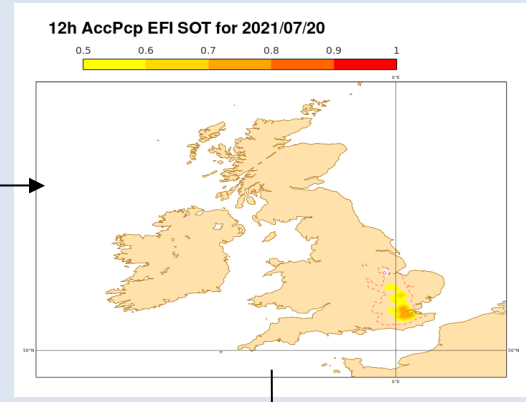
24h-AccPcp EFI SOT
From the 20th July 2021 00UTC MOGREPS cycle

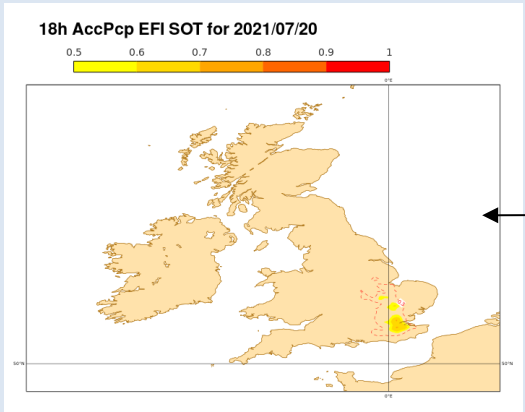


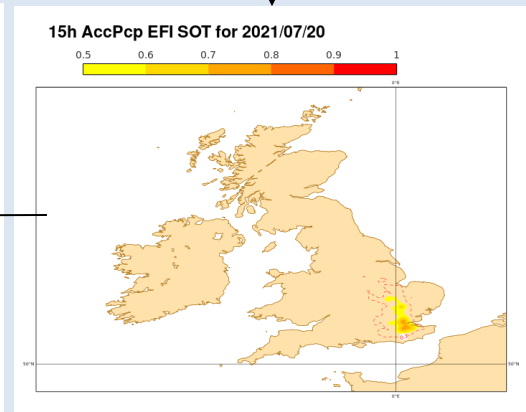
6h, 9h, 12h, 15h and 18h AccPcp EFI SOT
From the 20th July 2021 12UTC MOGREPS cycle











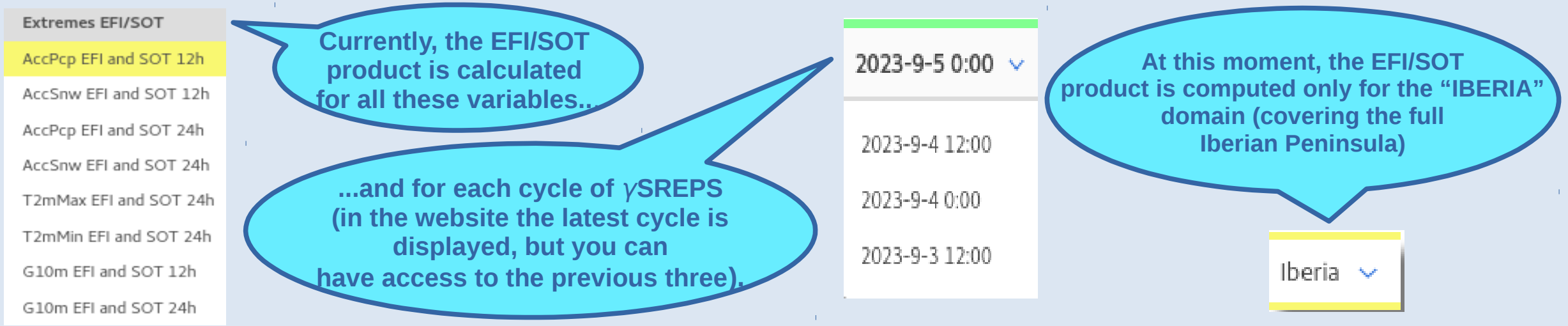
The 24h-AccPcp EFI SOT plot does not show any relevant signal in the affected area (just little areas of EFI taking values between 0.3 and 0.5). That is due to the fact that the heavy precipitation took place in a short period of time.

However, when considering the 6h-AccPcp (from the MOGREPS 12UTC cycle) we can see that the EFI signal is very intense in the affected area (even with positive SOT values). As the accumulated period increases, the EFI SOT signal weakens, as expected.

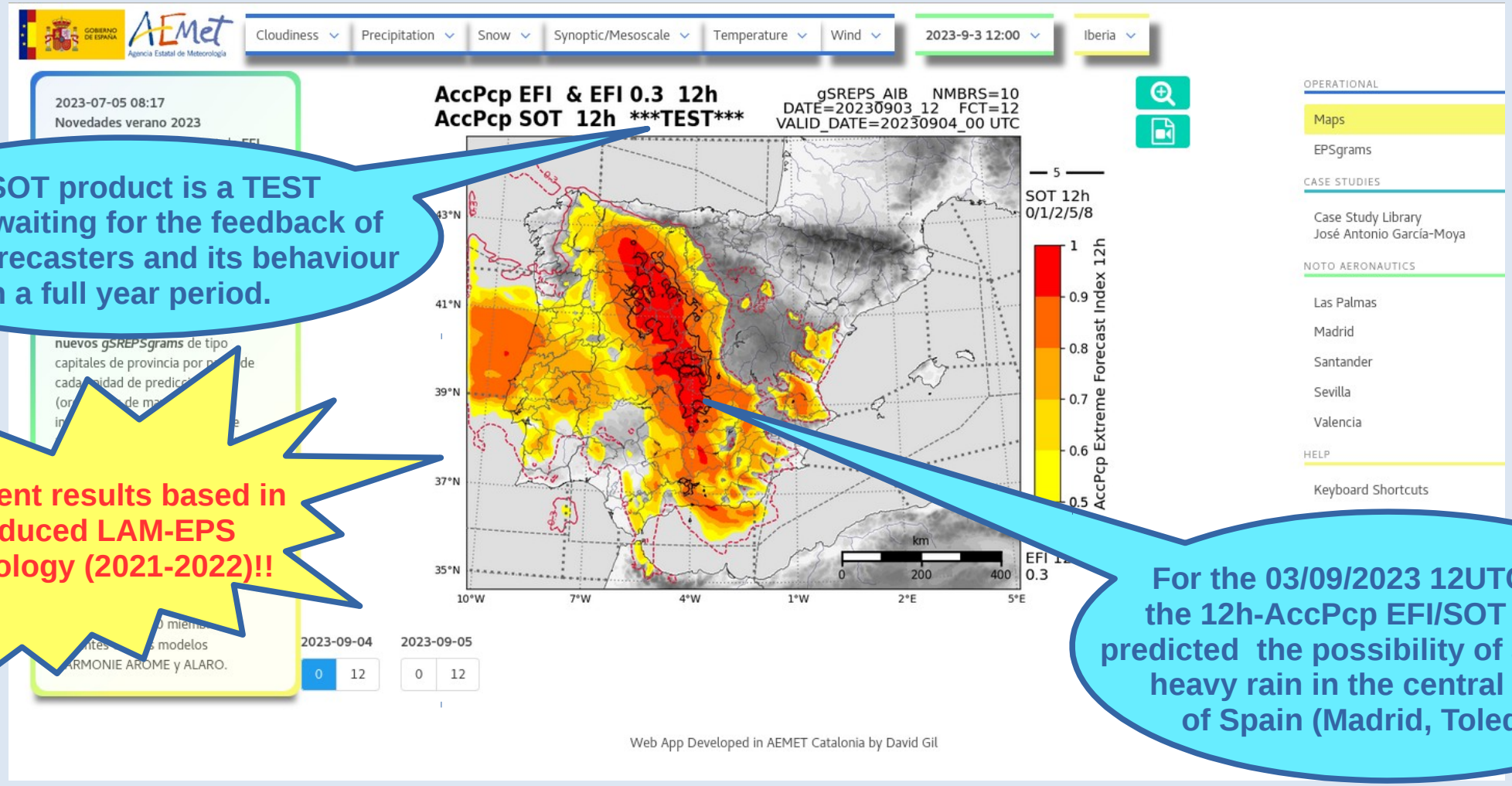
Implementation in AEMET-γSREPS

In May 2023 the EUMETNET LAM-EPS EFI/SOT software was implemented in AEMET-γSREPS.

- Once the firsts results proved to be coherent, **in June 2023 the product was included in the operative γSREPS website as a TEST product**.
- At this moment, **the γSREPS EFI/SOT product is based on a LAM-EPS climatology that covers two years (2021-2022)**. It was constructed from the γSREPS GRIB files stored in the EUMETNET SRNWP-EPS ECFS database.
- This is a **fixed monthly climatology**: for each month, the LAM-EPS climatology is centered in the 15th day of the month and covers a temporal window of 40 days (forward and backward).



Implementation in AEMET-γSREPS



EFI/SOT product is a TEST product waiting for the feedback of AEMET forecasters and its behaviour in a full year period.

Consistent results based in a reduced LAM-EPS climatology (2021-2022)!!

For the 03/09/2023 12UTC cycle, the 12h-AccPcp EFI/SOT product predicted the possibility of anomalous heavy rain in the central regions of Spain (Madrid, Toledo...) .

Implementation in AEMET-γSREPS

Ongoing work being performed to improve the γSREPS EFI/SOT product

- First of all, an **update of the LAM-EPS climatology** will be performed: instead of using the one based on the period 2021-2022 (γSREPS GRIB files stored in EUMETNET SRNWP-EPS ECFS database) we will use the GRIB files stored in the γSREPS ECFS database, **which covers the period 2018-2023**, that is, the period of time in which γSREPS can be considered a stable and consistent LAM-EPS. **This climatology will be still a monthly fixed one. Now the temporal window has an extension of 30 days.**
- This **new γSREPS climatology** will be calculated **for the three domains of γSREPS**: AIB (Iberian Peninsula), AIC (Canary Islands) and AIL (Livingston Island, Antarctica).
- However, the final target will be to obtain a **mobile γSREPS climatology**, **that could be updated, for example, once per week**, trying to resemble the LAM-EPS climatology calculated by the ECMWF (which is updated twice a week).
- In addition, we expect to **increase the number of meteorological variables to compute the EFI/SOT indexes:** mean temperature, relative humidity, wind speed at 10, 100 and 200 m, 850hPa temperature, water vapour flux, precipitable water, CAPE and CIN.
- The aim is to **make the γSREPS EFI/SOT product as similar as posible to the ECMWF IFS EFI/SOT product** in order to facilitate the comparison between them.

ECMWF ⟷ EUMETNET

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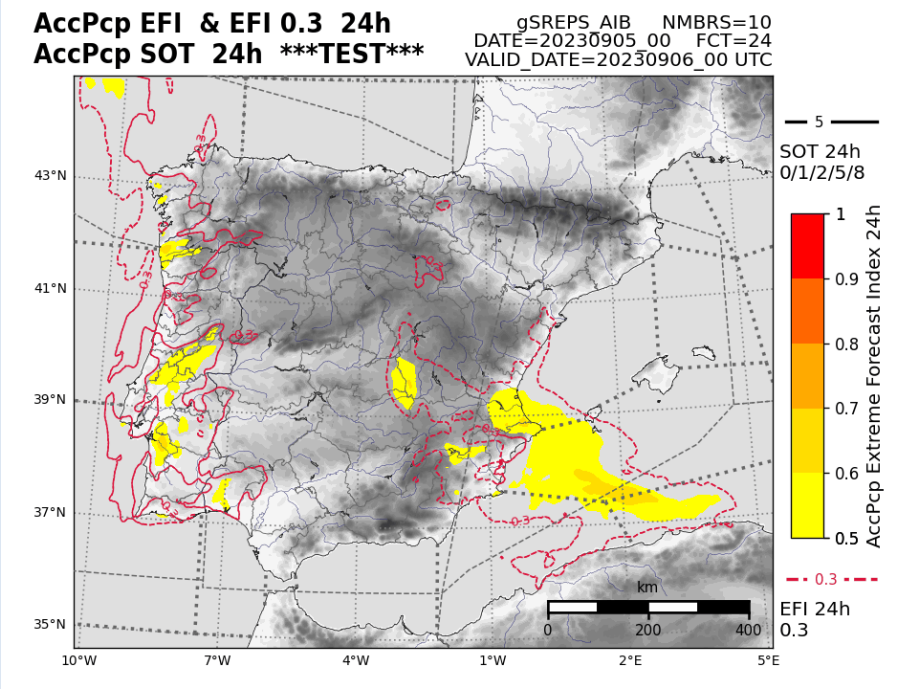
AEMet Agencia Estatal de Meteorología

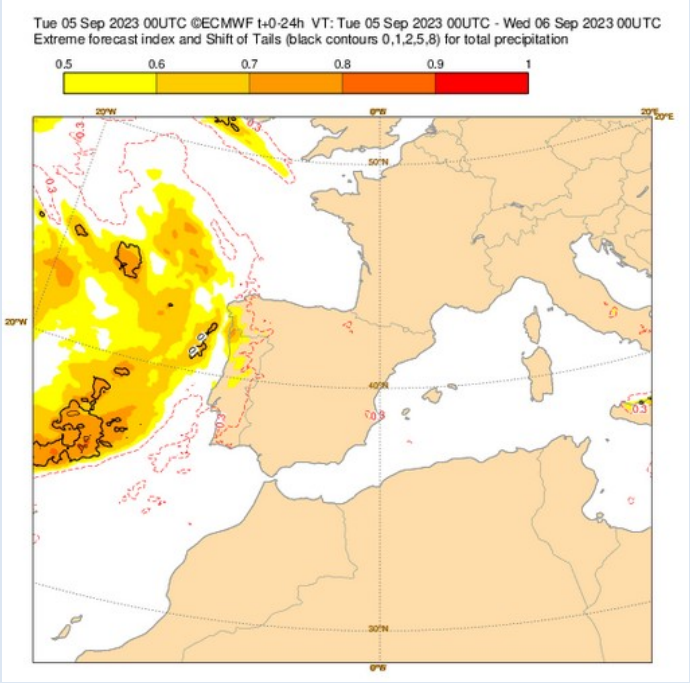
Implementation in AEMET-γSREPS

As an example, and following the idea exposed in the last point, let's going to compare the current γSREPS EFI/SOT product with the one from ECMWF IFS.

- This comparison is 100% honest, that is, it has been considered the EFI/SOT products for the day of making this presentation (the 5th September 2023); this is not a pre-selected day where comparison is nice.

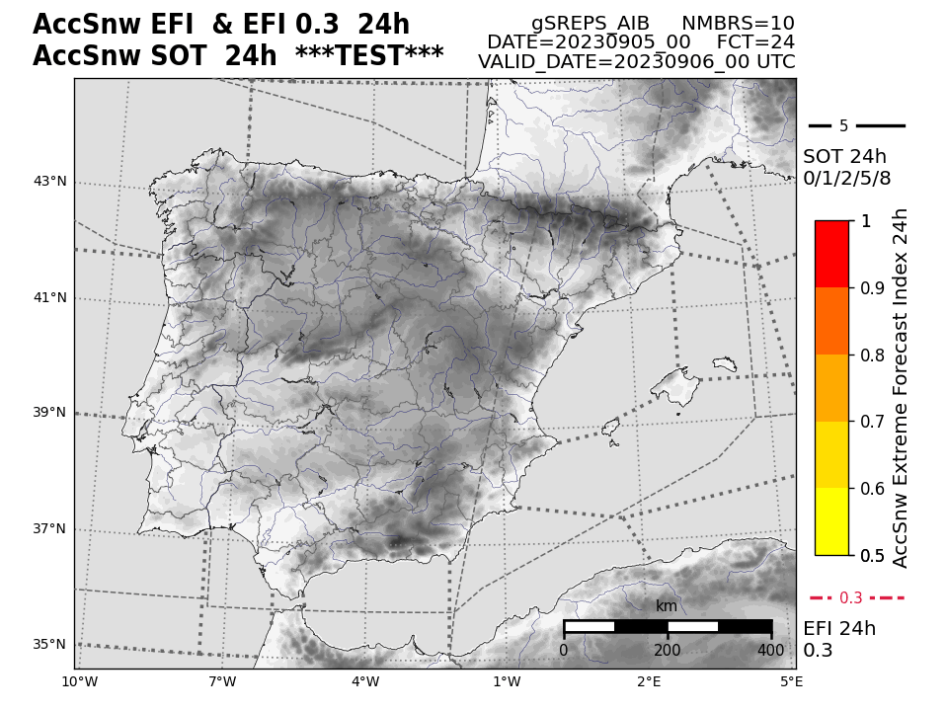


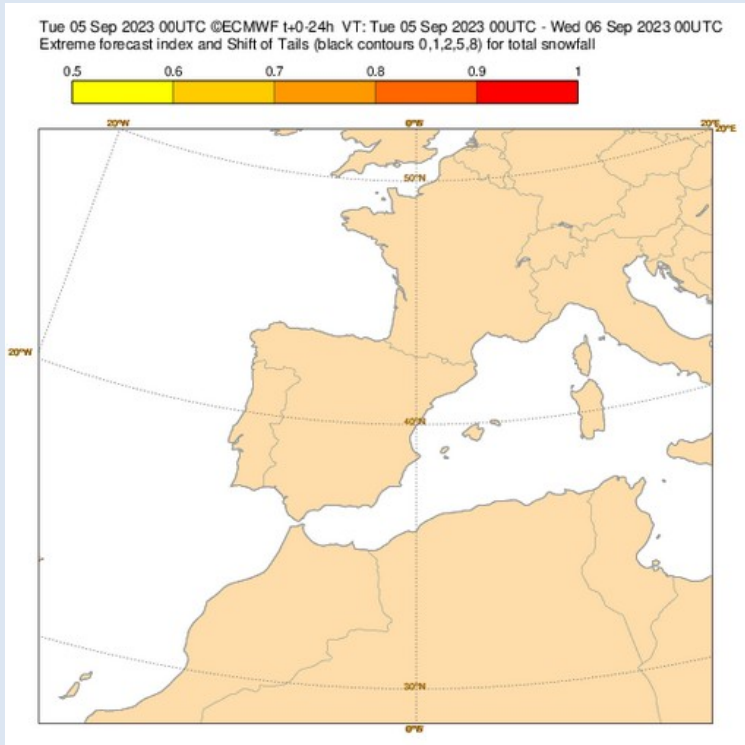
24h-AccPcp (Total precipitation)



Implementation in AEMET-γSREPS

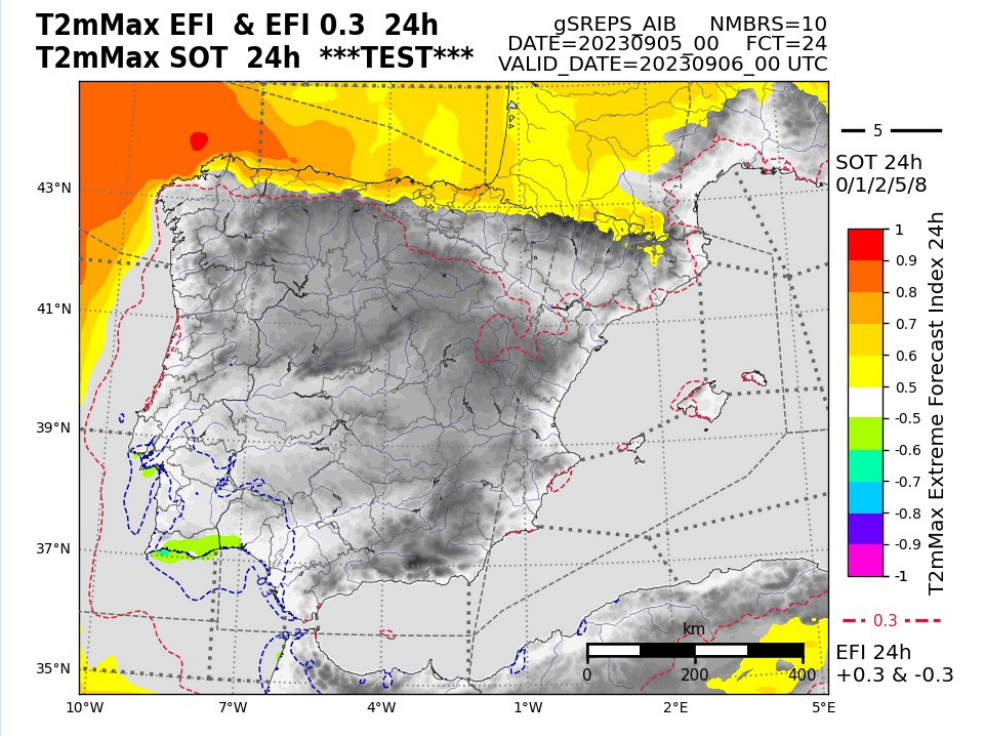
24h-AccSnw (total snowfall)

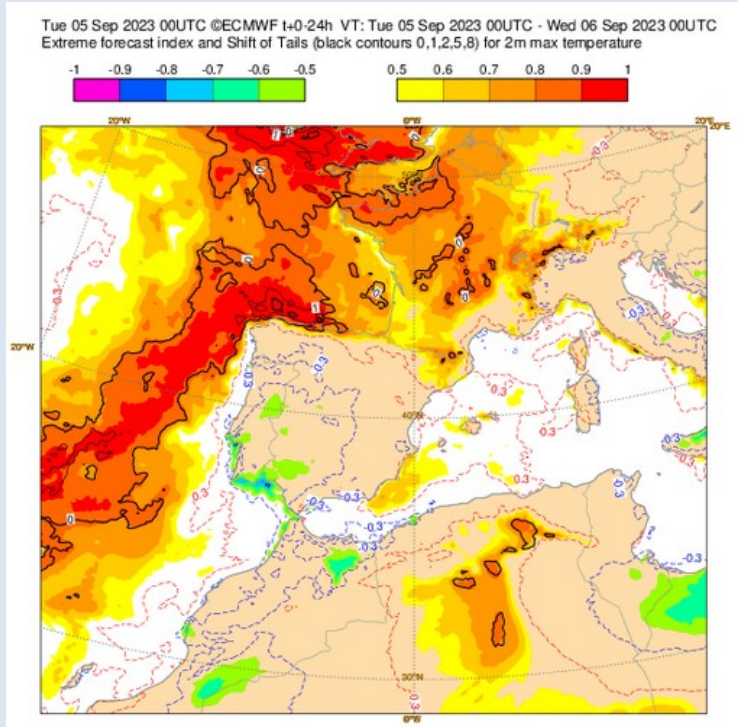




Implementation in AEMET-γSREPS

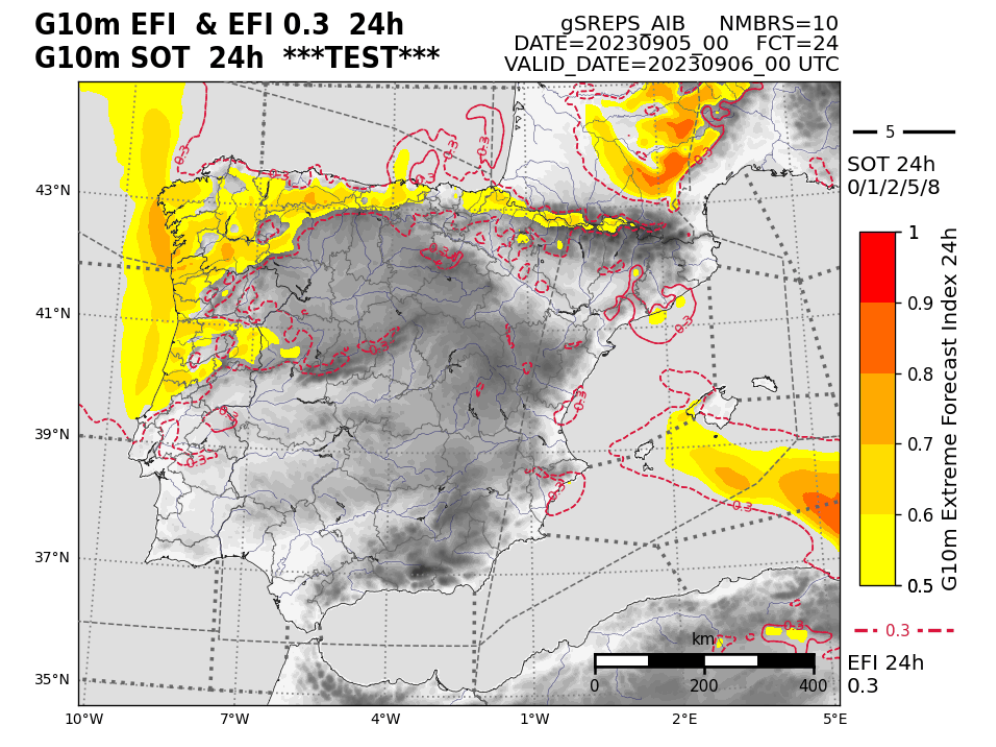
24h-T2mMax (Maximum temperature)

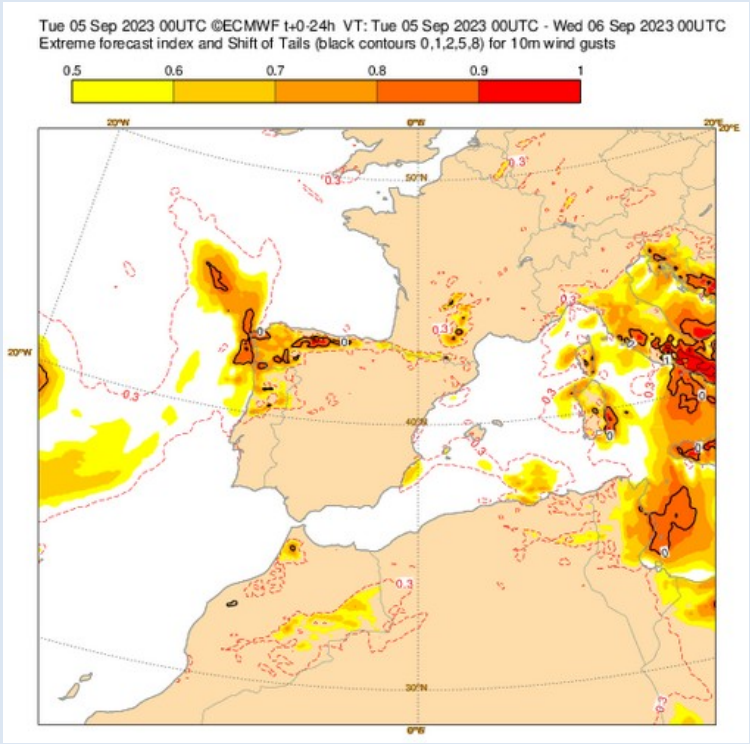




Implementation in AEMET-γSREPS

24h-G10m (Maximum wind gust)

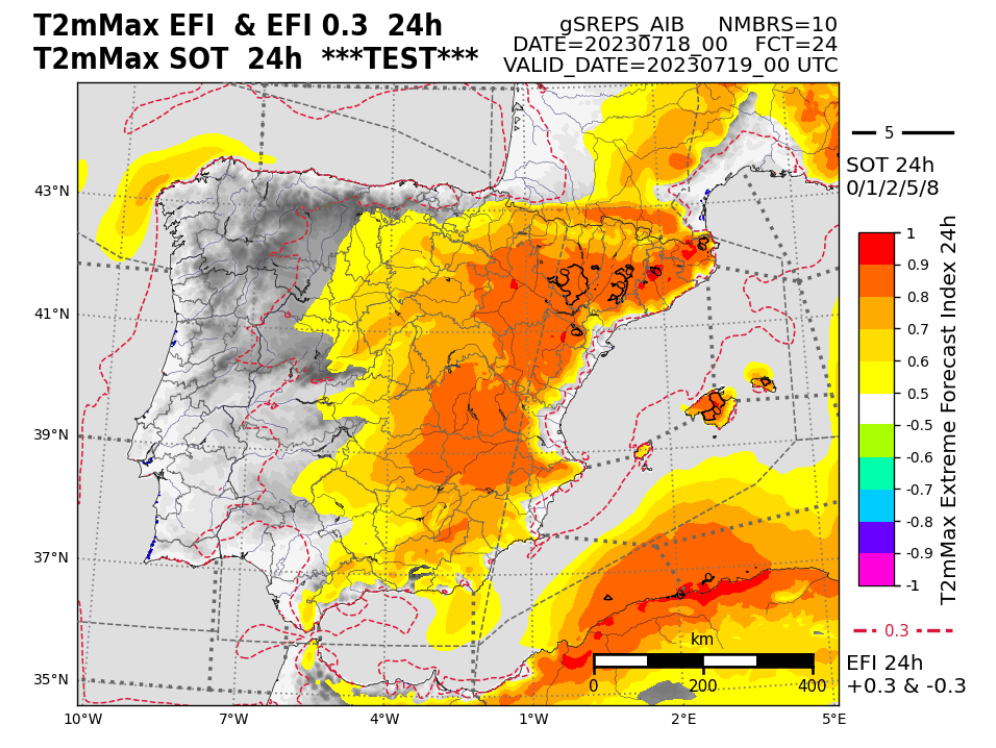




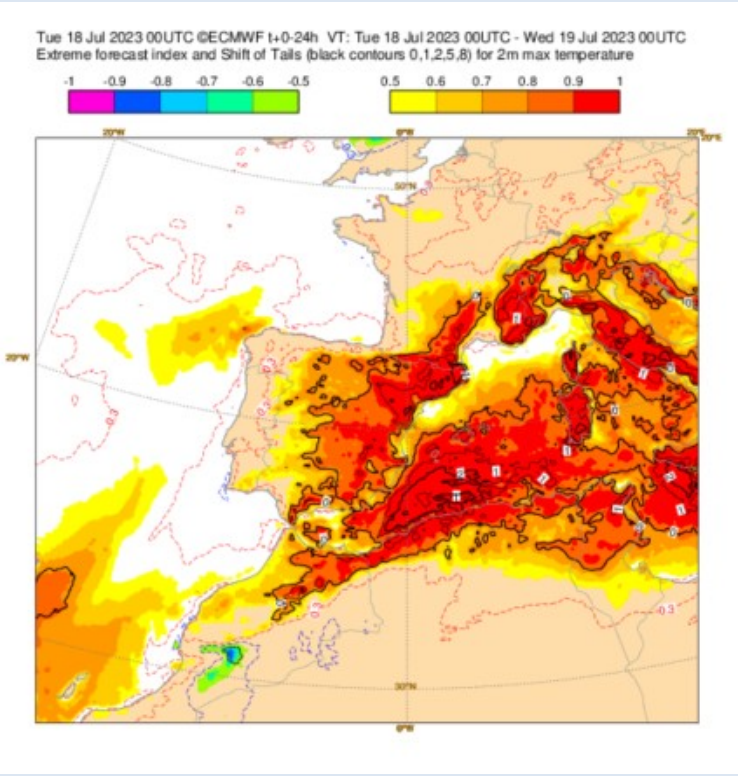
EUMETNET SRNWPEPS EFI/SOT:
from research to operations in AEMET-γSREPS
45th EWGLAM and 30th SRNWP meeting (Reykjavik, September 2023)

Interesting summer events in Spain

24h-T2mMax (Maximum temperature)



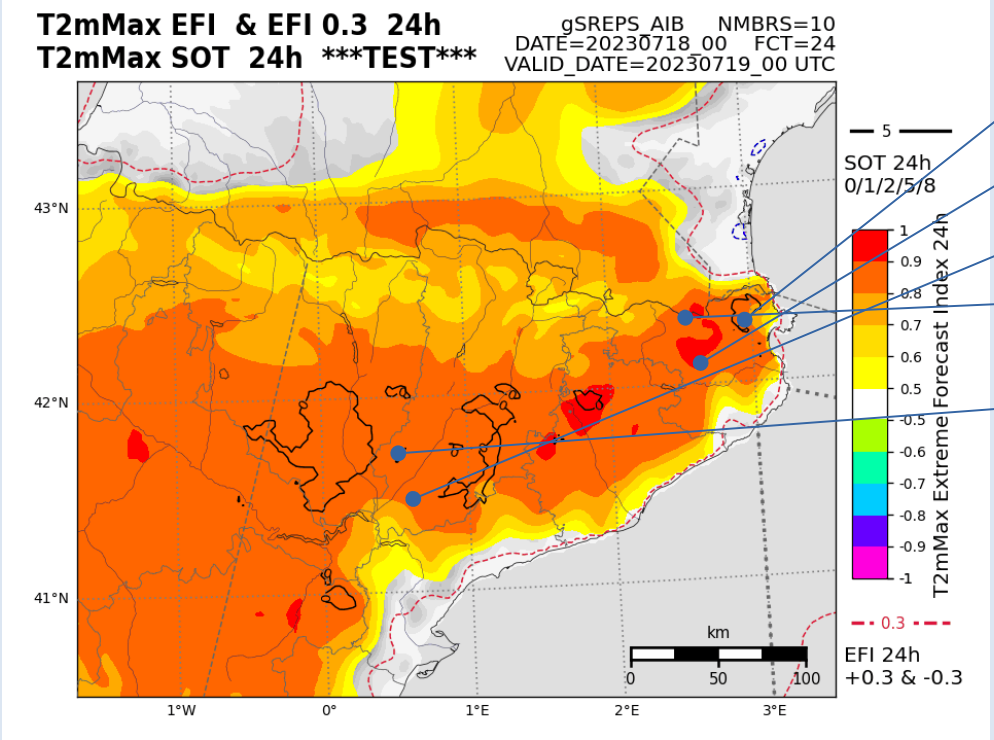
Heat wave (18/07/2023)



In the current scenario of climate change, what is more useful for a weather forecaster: an EFI/SOT product based in a recent years LAM-EPS climatology (last 5 years, for example) or a larger one (last 30 years, for instance)??

Interesting summer events in Spain

24h-T2mMax (Maximum temperature)



- Figueres (Girona): 45,4 ºC
- Porqueres (Girona): 44,3 ºC
- El Soleràs (Lleida): 43,5 ºC
- Maçanet de Cabrenys (Girona): 43,3 ºC
- Lleida: 43,2 ºC

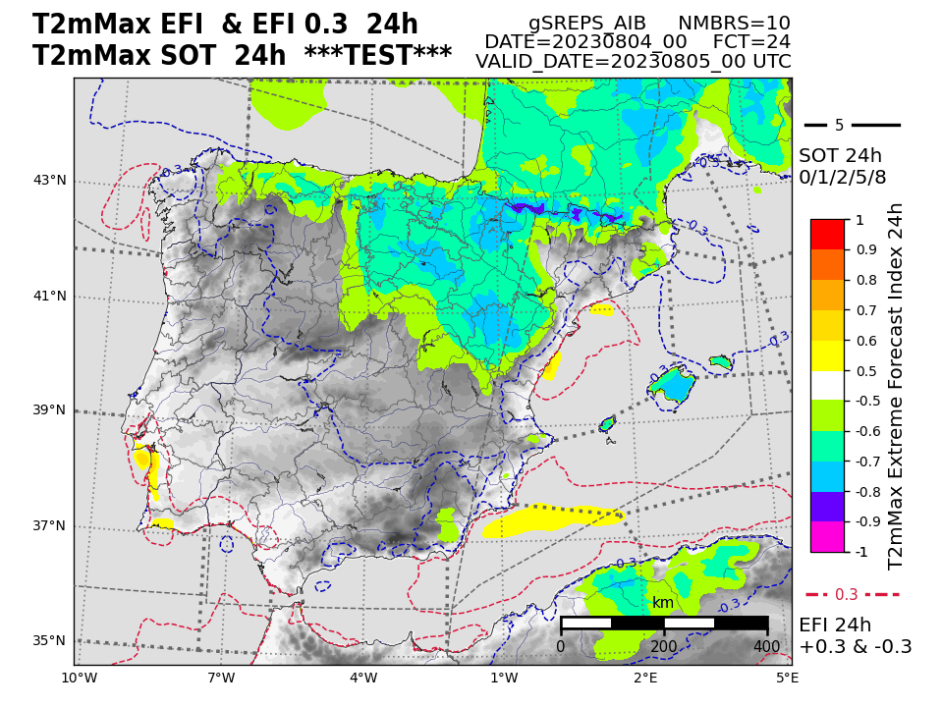
HISTORICAL RECORD IN CATALONIA

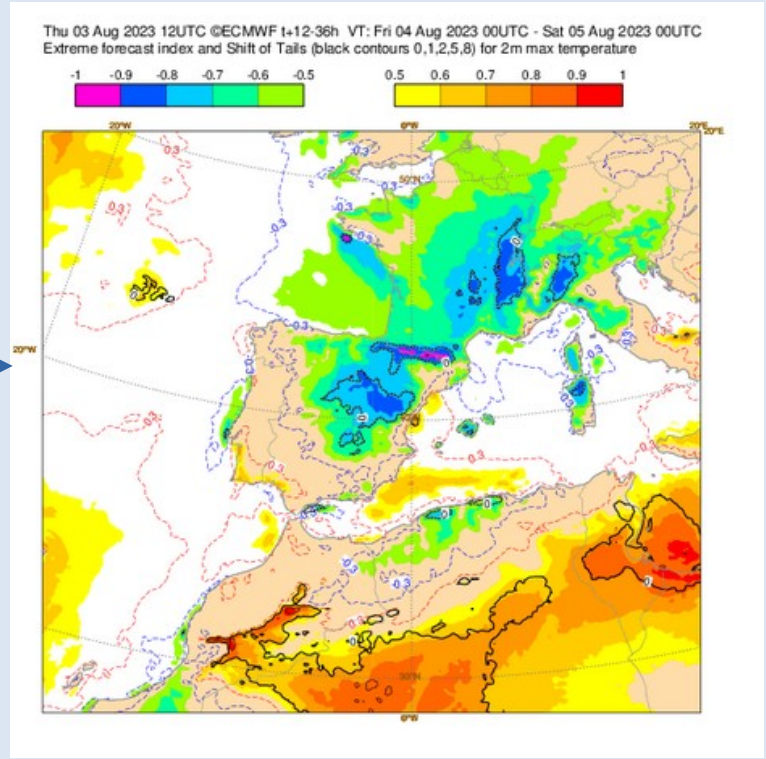
Heat wave (18/07/2023)

EUMETNET SRNWPEPS EFI/SOT:
from research to operations in AEMET-γSREPS
45th EWGLAM and 30th SRNWP meeting (Reykjavik, September 2023)

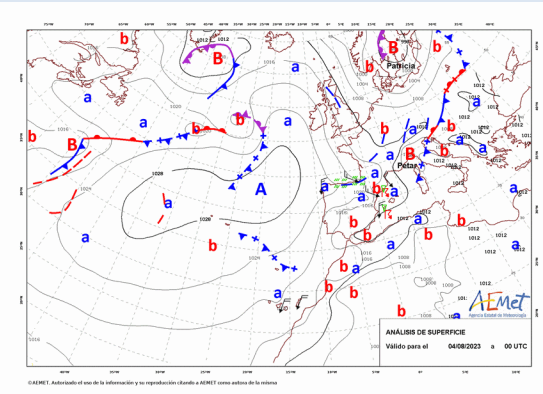
Interesting summer events in Spain

24h-T2mMax (Maximum temperature)





Northern winds (04/08/2023)



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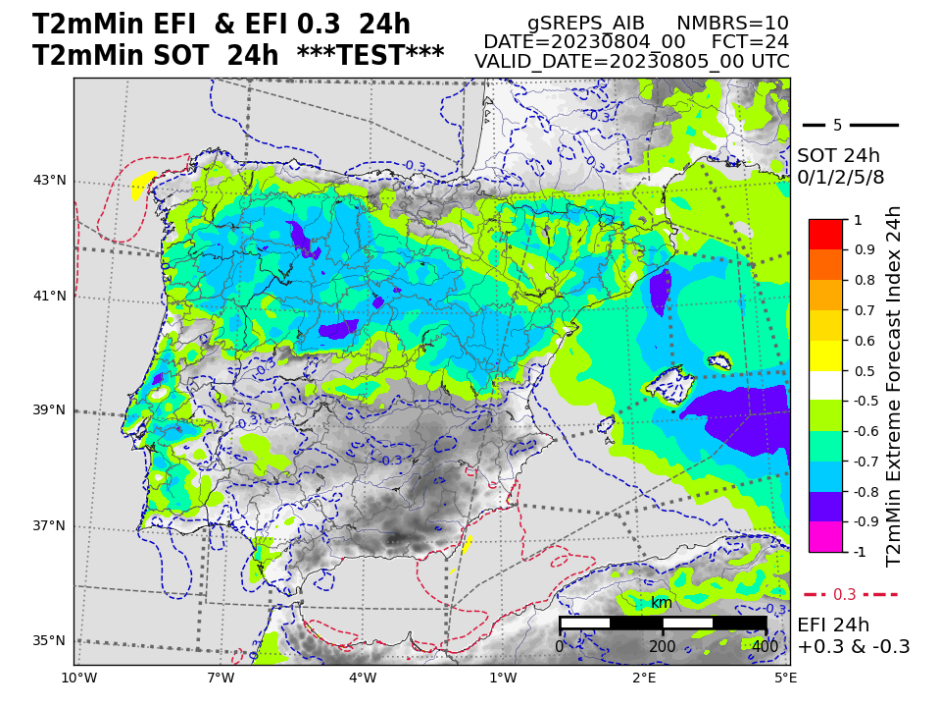
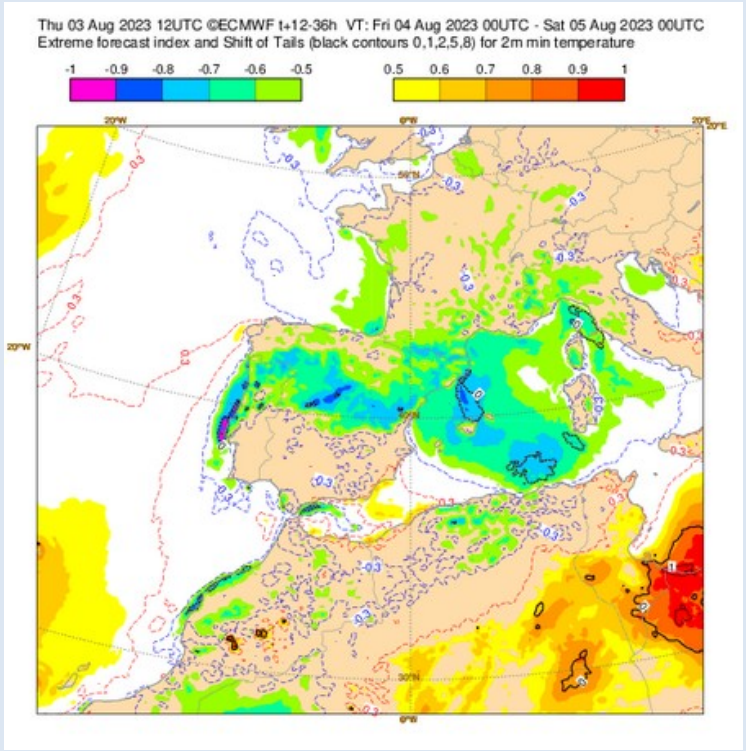
45th EWGLAM and 30th SRNWP meeting (Reykjavik, September 2023)

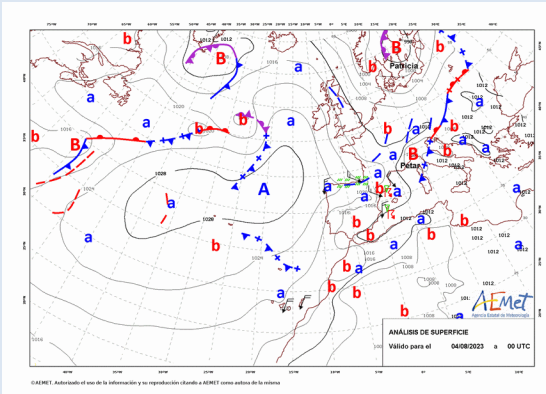
Interesting summer events in Spain

24h-T2mMin (Minimum temperature)





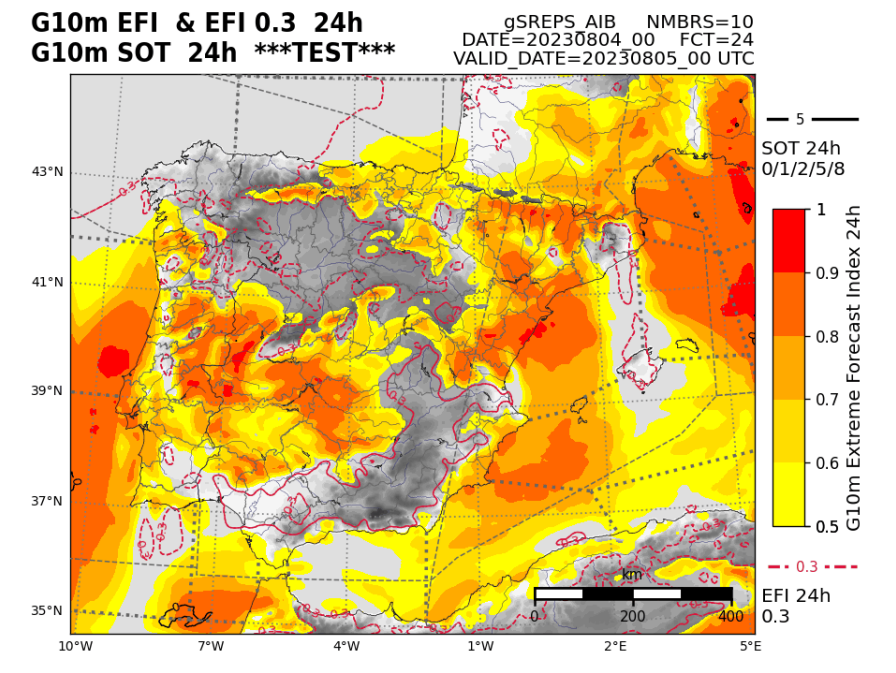
Northern winds (04/08/2023)

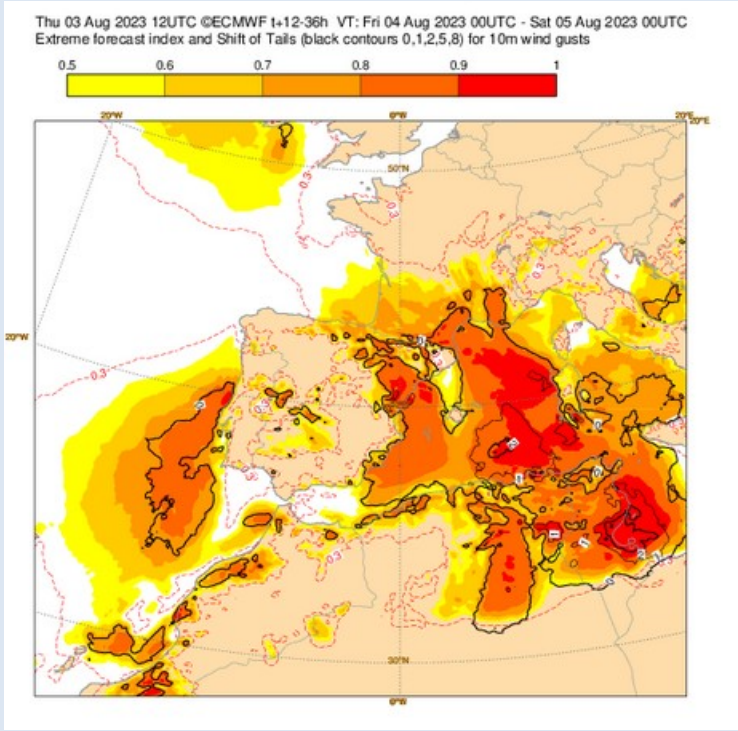


EUMETNET SRNWPEPS EFI/SOT:
from research to operations in AEMET-γSREPS
45th EWGLAM and 30th SRNWP meeting (Reykjavik, September 2023)

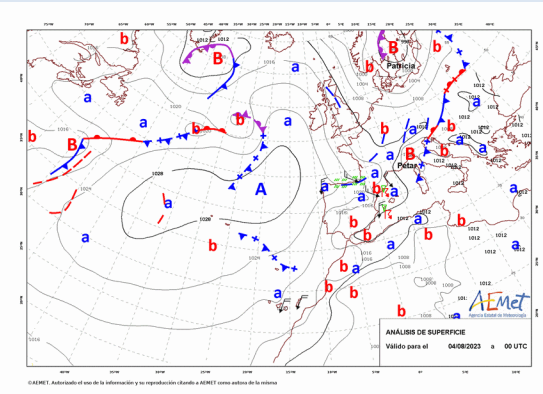
Interesting summer events in Spain

24h-G10m (Maximum wind gust)





Northern winds (04/08/2023)



EUMETNET SRNWPEPS EFI/SOT:
from research to operations in AEMET-γSREPS
45th EWGLAM and 30th SRNWP meeting (Reykjavik, September 2023)

Software documentation

Documentation is available at `/doc/html` directory.

EUMETNET LAM-EPS EFI SOT software

Implementing EFI and SOT indexes in EUMETNET LAM-EPSs.

Main Page | Namespaces | Classes | Files

SOFTWARE GENERALITIES AND USER'S GUIDE

INTRODUCTION

Dear user, welcome to the documentation of the **EUMETNET LAM-EPS EFI SOT software**. Th
EUMETNET SRNWP-EPS project. The aim of this software is to provide a tool to implement the **E**
State Members LAM-EPSs.

> Note: it is noticed that the **EUMETNET LAM-EPS EFI SOT software** is in its **beta version**
> susceptible to be modified in future versions in order to improve its efficiency and final resul

The following sections provide relevant information about different aspects of the software in o

SOFTWARE STRUCTURE

The software is divided into four main directories:

1. **CONFIGURATION DIRECTORY** (/config)
2. **DOCUMENTATION DIRECTORY** (/doc)
3. **LOGGING DIRECTORY** (/log)
4. **SOURCE DIRECTORY** (/src)
5. **UTILS DIRECTORY** (/utils)

In the next paragraphs, detailed information about the contents and usage of each directory is

CONFIGURATION DIRECTORY (/config)

This directory contains a Python file named **configuration_file.py**. In this file, the user can co
place in the computation of the **Extreme Forecast Index (EFI)** and **Shift Of Tails (SOT)**. De
same file.

USER'S GUIDE

STEP 0: BEFORE RUNNING THE SOFTWARE

Before start using the **EUMETNET LAM-EPS EFI SOT software**, the user must be in possesion of the LAM-EPS GRIB files that will be used for the computation indexes and have them saved in a coherent tree directory that identifies the properties of the LAM-EPS GRIB files (that is, a tree directory where each directory the year, month, day, cycle, member or lead time of the LAM-EPS GRIB files contained within). If that is not the case, the software offers two utils that are desig user in these previous steps.

- If the user lacks a tree directory where to save the LAM-EPS GRIB files, the **/tree_directory** util has been designed to offer the user the possibility to crea tree directory.
- In case the user doesn't have the desired LAM-EPS GRIB files to compute the calculation of the EFI and SOT indexes, the software offers a util named **/TAR** the user download the desired LAM-EPS TAR GRIB files from the EUMETNET SRNWP-EPS database and extract from these the desired LAM-EPS GRIB files.

Once the user has the LAM-EPS GRIB files and they are properly saved in a tree directory, it is the moment to start running the **EUMETNET LAM-EPS EFI SOT** see the different steps that must be followed.

STEP 1: CONFIGURATION FILE SETTINGS

The first step consists in opening the **configuration_file.py** file, which is saved in **/config** directory, and set the different parameters in order to fit with the us requirements. This configuration file lets the user define the paths where the input LAM-EPS GRIB files are saved, the paths where the output LAM-EPS EFI SOT saved, specify the meteorological variable to implement the EFI and SOT indexes, the LAM-EPS to be considered, among others.

The **configuration_file.py** is commented in a very detailed way, in order to make it easy for the user to fill and configure the different parameters that conforr

After correctly configuring the configuration file, the user is now ready to run the different Python scripts that conform the main body of the software.

STEP 2: RUNNING THE PYTHON SCRIPTS

The Python scripts to be run are saved in `/src/scripts` and detailed information about the usage and content of each of them can be found **here**.

> This software has been tested in the ECMWF ATOS HPCF system. It is recommended to run the scripts through `sbatch` command. In addition, as some parts software are based in parallel programming techniques, it is recommended to run scripts **01_climate_data_extraction.py**, **02_forecast_data_extraction** **04_climate_cdf.py** and **05_forecast_cdf.py** from the **np** queue.

The Python scripts are labelled in numerical order to indicate the user the order in which they must be executed.

- **01_climate_data_extraction.py** stores the LAM-EPS climatology data in a binary file.
- **02_forecast_data_extraction.py** stores the LAM-EPS forecast data in a binary file.
- **03_y_x_subdomain_coord.py** calculates the LAM-EPS subdomain(s) grid point coordinates and stores them in a binary file.
- **04_climate_cdf.py** computes the CDF associated to the LAM-EPS climatology and saves it in a binary file.
- **05_forecast_cdf.py** computes the CDF associated to the LAM-EPS forecast and saves it in a binary file.
- **06_EFI.py** computes the EFI values in the LAM-EPS subdomain(s) and saves them in a GRIB file (optionally, they can be also saved in a binary file).
- **07_SOT.py** computes the SOT values in the LAM-EPS subdomain(s) and saves them in the same GRIB file containing the EFI values (optionally, they can b binary file).
- **08_extra_data.py** saves some complementary extra information (mostly related to orographical properties of the LAM-EPS subdomain(s)) in the GRIB fil and SOT values (optionally, they can be also saved in a binary file).

STEP 3: OBTAINING THE EFI SOT PLOTS

Once the software has generated the output LAM-EPS EFI SOT GRIB files, the user is free to plot EFI SOT messages. However, the software includes a utility call **/PLOT_GENERATOR** that, once executed, generates EFI SOT plots for each LAM-EPS subdomain defined by the user in the **configuration_file.py**.

Generated by

Functions

def **lonlat2RotNoRot** (poleLON, poleLAT, LON, LAT, poleSN, rot_derot)
Function that rotates (or derotates) geographical coordinates (longitude, latitude) of a specific point according to the displacement of the coordinates of the North (or South) Pole.

def **automatic_climate_dates** (initial_year, efi_date, delta_days)
Function that generates a list containing the dates that will conform the EPS-climatology.

def **grib_filename** (grib_filename_template, year, month, day, member, cycle, lead_time)
Function that constructs the specific name of a GRIB file from a generic template (defined by the user in the **configuration_file**).

def **output_grib_filename** (output_grib_filename_template, subd, year, month, day, cycle, lead_time)
Function that constructs the filename of the EFI/SOT GRIB file from a generic template (defined by the user in the configuration file).

def **grib_path** (grib_path_template, year, month, day, member, cycle, lead_time)
Function that constructs the path where specific EPS GRIB file(s) will be saved.

def **scanning_array** (scan, array, nx, ny)
Function that performs a scanning of the flattened array extracted from an EPS GRIB file, reshaping it according to gSREPS scanningMode.

def **read_grib_process** (date, member, cycle, lead_time, gribs_not_found_list)
Function that reads a specific EPS GRIB file, extracts the desired meteorological values and saves them in a NumPy array.

def **meteo_data_extraction** (date_list)
Function that collects the desired meteorological data from the EPS GRIB files corresponding to the dates contained in "date_list" (taking into account the user's settings in terms of EPS members, cycles and lead times -specified in the configuration file-).

def **meteo_data_stat_process** (activate_stat_process, type_stat_process, meteo_array)
Function that performs statistical calculus on meteorological data contained in a NumPy array.

Many thanks for your attention

The different versions of the EUMETNET SRNWP-EPS EFI SOT software are saved in the following path in the ECMWF ECFS:

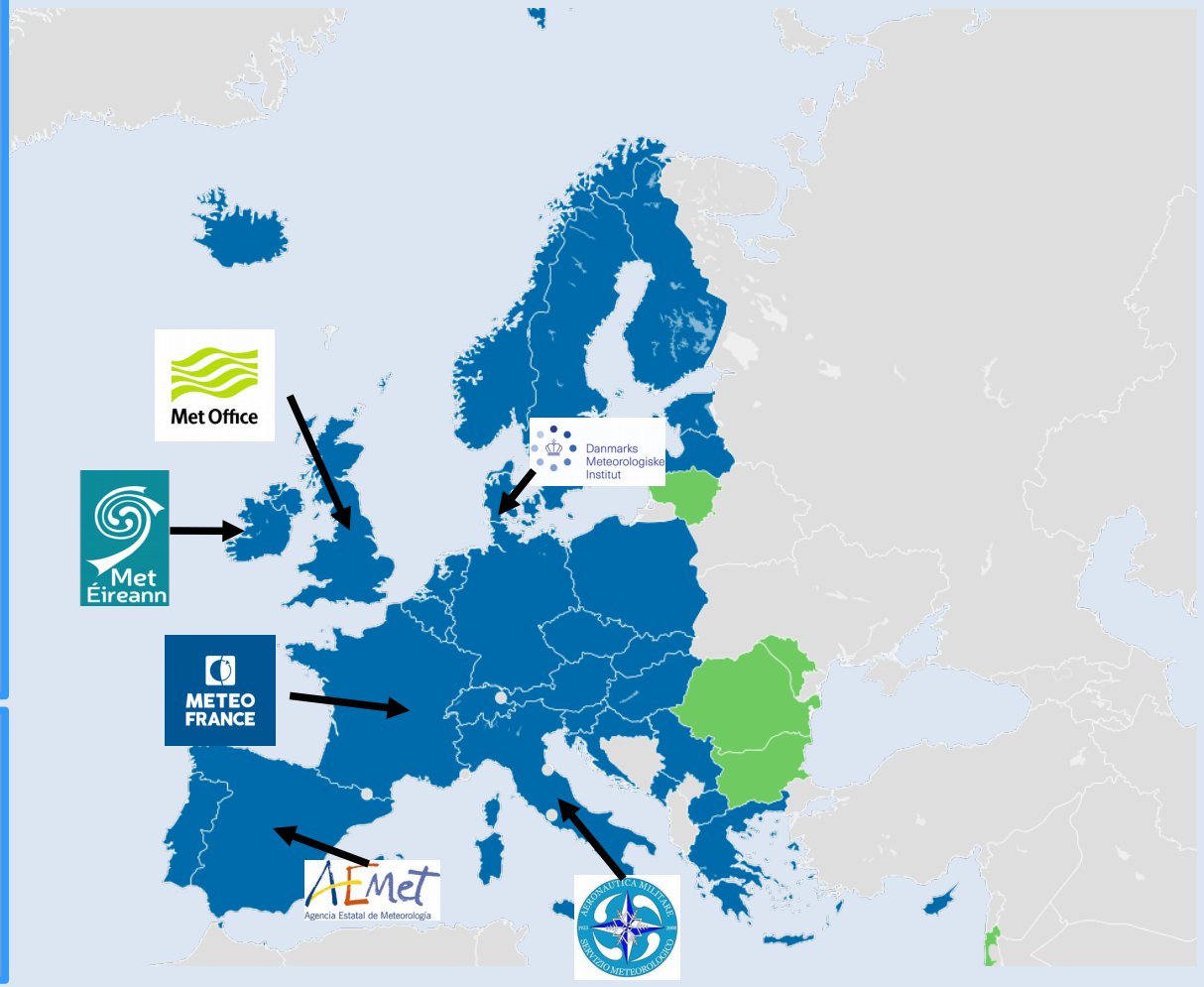
`ec:/srnwpeps/ApplicationTasksSoftwareDelivery/EFIandSOT`

and in the new EUMETNET portal at

`FORECASTING → NWP-Cooperation → SRNWP-EPS → Documents → SRNWPEPS_EFI_SOT_software`

Support on any issue related to the software is offered at

srnwpeps_efi@aemet.es



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MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet Agencia Estatal de Meteorología