Met Office

Coding guidance; tailoring the Objective Seasonal Outlook Package (OSOP) for extreme seasonal heat

WISER
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Document history

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0.1	Draft	03/09/2025
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Contents

1. Introduction

This document provides guidance on editing the Objective Seasonal Outlook Package (OSOP) code to produce tailored seasonal forecasts, focusing on extreme seasonal heat. The document was produced by the UK Met Office to support the Red Cross Red Cresent Climate Centre and Agence Nationale de la Météorologie du Burkina Faso (ANAM-BF) in customising the OSOP toolkit to generate seasonal forecasts of temperature and extreme heat for Burkina Faso. The text, as laid out here, serves as a baseline for how to get started with the package. As such, the user can modify or change the OSOP toolkit beyond guidance provided here to suit their requirements. This document is based on the latest version of the OSOP toolkit updated in August 2025. Any future changes to the toolkit by the producers may not be covered in this guidance document. It is recommended to regularly update the toolkit locally to ensure it is in sync with the main remote branch and includes all recent updates. Guidance on how to do this can be found in Appendix 2.

The Objective Seasonal Outlook Package (OSOP) is a toolkit designed to support objective seasonal forecasting. It contains a subset of Python and shell scripting that can be edited and tailored to the user's needs. The code is hosted on the OSOP GitHub repository[1] in the Objective Seasonal Forecasting (OFS) Tools GitHub page[2]. The OSOP toolkit is fully open-sourced; it allows the user to access and adapt global forecast data from global producing centres[3]. Users can routinely access up-to-date seasonal forecast and hindcast data through the OSOP toolkit, allowing them to evaluate which models best suit their region. Users can edit the parameters and tailor the open-source code to generate locally relevant forecasts.

The OSOP tool processes the daily averaged mean temperature by month. It calculates hindcasts and terciles, then generates verification plots and both 1-month and 3-month seasonal forecasts from nine different global predicting systems across eight different producing centres, listed in Appendix 1. Separate verification and seasonal forecast plots are generated for each model.

This document hence-forth is split up into two main steps:

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[1] OSOP Repository https://github.com/OSFTools/osop/tree/main
[2] OSF Tools https://github.com/OSFTools/
[3] Global Producing Centres for Long-Range Forecasts https://community.wmo.int/en/activity-areas/climate-services/global-producing-centres-long-range-forecasts

1. **Calculate hindcasts, terciles and plot verification measures**. This section provides detailed guidance on generating hindcasts used to evaluate the skill and calibrate the forecasting system. It explains the process of calculating terciles and producing skill verification plots for various metrics. The section also includes instructions on running specific shell scripts to generate hindcasts and verification plots, and how to tailor the code to meet specific requirements.
2. **Seasonal forecasting**. This section focuses on tailoring the OSOP code to produce seasonal forecasts. It provides instructions on setting parameters in the forecasting script to match those used in the hindcasts scripts. The section also explains how to generate and view seasonal forecast plots, and how to ensure the forecasting systems are up to date. Additionally, it includes guidance on editing download locations to prevent overwriting files when changing tercile categories.

Any changes should be performed in this order; hindcasts need to be produced and terciles calculated before running the seasonal forecast.

Guidance on how to use the GitHub repository on a local system can be found in Appendix 2. General guidance on setting up and running the code can be found in Appendix 3 or the README in the GitHub repository.

2. Calculate hindcasts, terciles and plot verification measures

Hindcasts are retrospective forecasts that simulate past seasonal conditions using the same model set-up and parameters as those used to generate the real-time forecasts. Hindcasts are used to evaluate the skill and calibrate the forecasts (Weisheimer et al., 2020) and play a key role in assessing how well a forecasting system performs. Detailed guidance on recommended procedures for the verification of operational probabilistic seasonal forecasts is given in the WMO Guidance on Verification of Operational Seasonal Climate Forecasts[4].

[4] WMO Guidance on Verification of Operational Seasonal Climate Forecasts
https://library.wmo.int/viewer/56227/download?file=1220_en.pdf&type=pdf&navigator=1
https://library.wmo.int/viewer/56227/download?file=1220_en.pdf&type=pdf&navigator=1

2.1. Hindcasts (1991-2016) and forecast verification in the OSOP toolkit

It is necessary to calculate hindcasts for the reference period (1991-2016) and extract terciles before generating seasonal forecasts with the OSOP tool. The same scripts that download and process the data also generate skill verification results and plots using a range of metrics (see Appendix 1). If any changes are made to the terciles or parameters, the hindcast scripts should be run again before generating the seasonal forecasts.

There are two shell scripts for generating hindcasts: `master.test.sh` and `master.sh`, both located in the local `/osop/scripts` directory. The `master.test.sh` shell script is used to check the code before running the main `master.sh` shell script. It includes a limited number of producers, allowing for rapid testing. By default, the `master.test.sh` runs the data from one producing centre, Meteo-France, which can be changed as shown in Figure 1. After making changes, save the scripts and run from the terminal following instructions in Appendix 3.

```
82
83  # loop over all centres of interest and get data
84  #for centre in meteo_france dwd cmcc ncep ukmo ecmwf jma eccc ;do
85  for centre in meteo_france ;do
86      set +e
87      python get_any_hindcast.py \
88          --centre $centre \
89          --month $month \
90          --leads $leads \
91          --area $area \
92          --variable $variable\
93          --downloaddir $downloaddir \
94          > $logdir/download_log_${variable}_${centre}.txt 2>&1
95      exitcode=$?
96      set -e
```

Figure 1*. To change the producing centre in* `master.test.sh`*; edit line 85 and replace* `meteo_france` *with your preferred producer (listed in Appendix 1). Save the changes and run the script from the terminal.*

The `master.sh` script calculates terciles and generates hindcasts and skill verification plots for multiple predicting systems. By default, it is configured to use the following producing centres: `meteo_france`, `dwd`, `cmcc`, `ncep`, `ukmo`, `ecmwf`, `jma`, `eccc_can` and `eccc_gem5`. These can be changed as shown in Figure 2 to suit specific forecasting needs.

```
51
52  # Services in use:
53  cat <<EOF > "$parseyml"
54  Services:
55      ecmwf: 51
56      meteo_france: 9
57      dwd: 22
58      cmcc: 4
59      ncep: 2
60      jma: 3
61      eccc_can: 4
62      eccc_gem5: 5
63      ukmo: 604
64  EOF
65  echo "YML file created: $parseyml"
66
```

```
84  # loop over all centres of interest and get data
85  for centre in meteo_france dwd cmcc ncep ukmo ecmwf jma eccc ;do
86      set +e
87      python get_any_hindcast.py \
88          --centre $centre \
89          --month $month \
90          --leads $leads \
91          --area $area \
92          --variable $variable\
93          --downloaddir $downloaddir \
94          > $logdir/download_log_${variable}_${centre}.txt 2>&1
95      exitcode=$?
96      set -e
```

Figure 2. *The numbers next to the centres in lines 55 o 63 refer to the system version in use (see Section 3.4.1 for more details). To change to the producing centres in* `master.sh`*; edit line 85 with preferred producing centres. Save and run the script from the terminal.*

2.1.1 Assessing forecast skill

Forecast skill refers to how well forecasts perform compared to actual outcomes (Daron, 2019). It is recommended to evaluate the performance of the individual forecasts using the hindcast verification scores generated from the `master.sh` script. These scores can be used to assess and weight models based on their reliability. Forecast skill should also be reviewed when generating the multi-model mean.

In addition to evaluating forecast skill, it may be necessary to assess how well a model simulates large-scale climate features and processes that influence local conditions (World Meteorological Organization (WMO), 2020). Providers of seasonal outlooks are encouraged to document the skill of issued forecasts, reflect on their performance, and use these insights to improve both the forecasting process and its communication (WMO, 2020). Given the wide range of available verification scores, it is advisable to select a limited number that are most relevant to the service provider. The choice of verification metrics should be guided by the specific needs and priorities of the intended audience.

2.2. Tailoring the code

The code can be tailored to calculate hindcasts and produce verification plots that meet the needs of the user or specific seasonal outlook requirements.

2.2.1. Set parameters

The parameters in the `master.test.sh` and `master.sh` shell scripts can be edited to produce a more tailored product. By default, the parameters are set to the following:

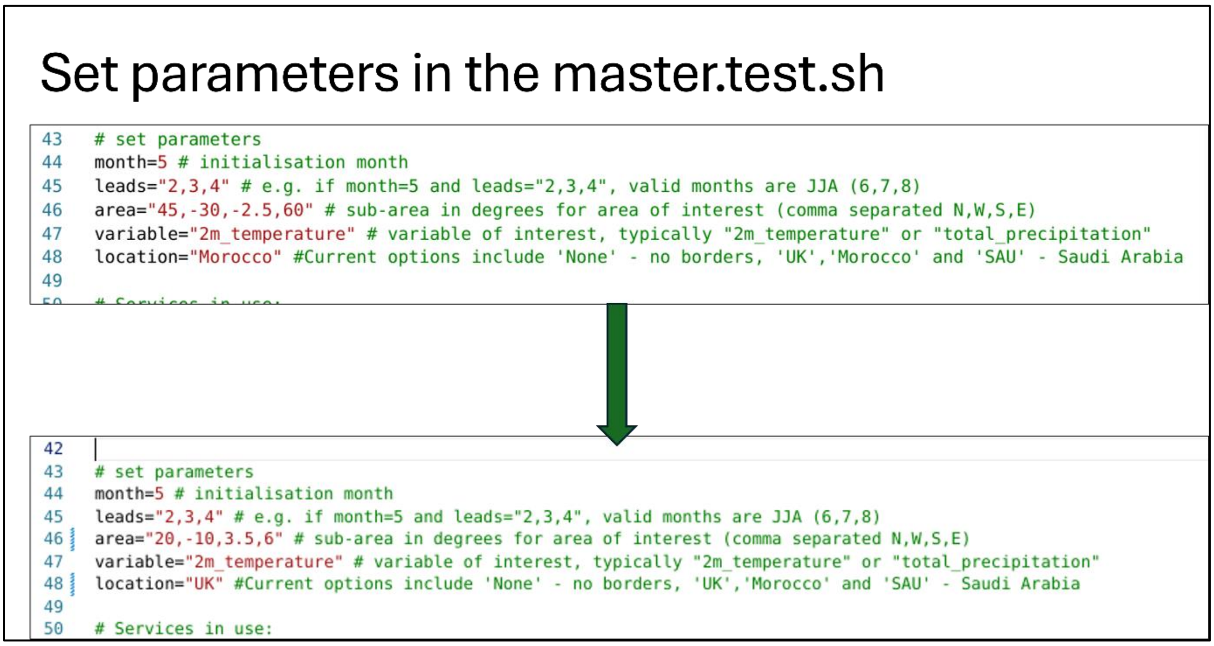
- `month=5` (forecast initialisation month e.g. month 5 is May)
- `leads="2,3,4"` (The forecast lead time in months e.g. if month=5 and leads="2,3,4", valid months are June-July-August (6,7,8))
- `area="45,-30,-2.5,60"` (the sub area in degrees for the area of interest, comma separated N,W,S,E)
- `variable="total_precipitation"` (variable of interest; typically, "2m_temperature" or "total_precipitation")
- `location="Morocco"` (Current options include 'None' (no borders), 'UK', 'Morocco' and 'SAU' (Saudi Arabia) recognised borders. Further details on boarders are in Appendix 1.

To generate a seasonal forecast using June-July-August (JJA) period with a 1-month lead time for 2m air temperature, using Burkina Faso as a case study, the following parameter changes are suggested:

- `month=5`
- `leads="2,3,4"`
- `area="20,-10,3.5,6”`

- `variable="2m_temperature"`
- `location="UK"`[5]

The `month` will require updating for each forecast. For example, if forecasts are generated monthly, the parameter will need to be adjusted accordingly each month to reflect the new initialisation month. Figures 2 and 3 demonstrate examples of parameter changes in the scripts. Parameters should be set exactly to the standard shown within the comments of the code.



Set parameters in the master.test.sh

```
43  # set parameters
44  month=5 # initialisation month
45  leads="2,3,4" # e.g. if month=5 and leads="2,3,4", valid months are JJA (6,7,8)
46  area="45,-30,-2.5,60" # sub-area in degrees for area of interest (comma separated N,W,S,E)
47  variable="2m_temperature" # variable of interest, typically "2m_temperature" or "total_precipitation"
48  location="Morocco" #Current options include 'None' - no borders, 'UK','Morocco' and 'SAU' - Saudi Arabia
49
```

```
42
43  # set parameters
44  month=5 # initialisation month
45  leads="2,3,4" # e.g. if month=5 and leads="2,3,4", valid months are JJA (6,7,8)
46  area="20,-10,3.5,6" # sub-area in degrees for area of interest (comma separated N,W,S,E)
47  variable="2m_temperature" # variable of interest, typically "2m_temperature" or "total_precipitation"
48  location="UK" #Current options include 'None' - no borders, 'UK','Morocco' and 'SAU' - Saudi Arabia
49
50  # Services in use:
```

Figure 3. *To customise the hindcasts modify the parameters in lines 44 to 48 in the* `master.test.sh` *shell script. Save the script and run in the terminal.*

[5] Location refers to the country boarders; ‘None’ applies no boarders. ‘UK’ applies global boarders as recognised by the UK. ‘Morocco’ applies global boarders as recognised by Morocco and ‘SAU’ applies global boarders as recognised by Saudia Arabia.

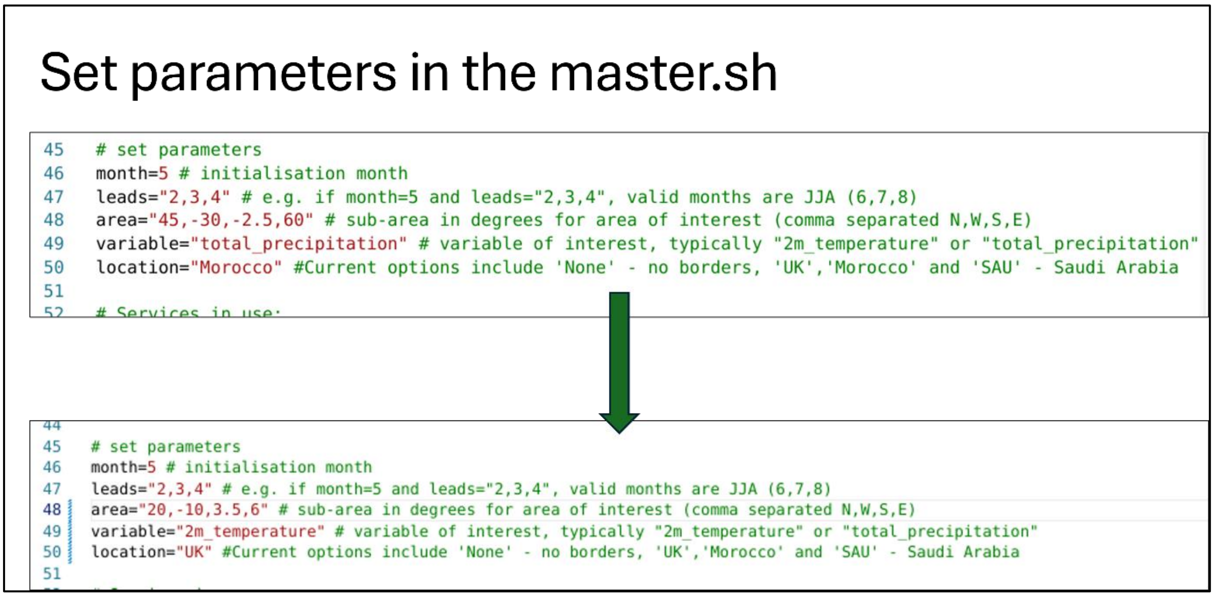


***Figure 4**. To customise the hindcasts, make amendments to the parameters in lines 46 to 50 in the `master.sh` shell script. Save the script and run in the terminal.*

2.2.2. *Changing the terciles*

The terciles are defined in the `compute_products_func.py` Python script located in the `/osop/lib/osop` directory. By default, the terciles are set to the standard 33% thresholds, entered in the script as: `1 / 3.0, 2 / 3.0`. These values can be manually adjusted to reflect alternative percentile thresholds, as demonstrated in Figure 5.

2.2.3. *Calculating extreme heat*

Warm extremes typically occur when maximum or minimum temperatures exceed the upper 10% of values in a reference period; commonly referred to as the 90th percentile. This threshold represents the point above which 10% of historical temperatures fall. These temperatures are expected to occur 10% of the time (or one in every ten years) and any values above this threshold are considered warm extremes.

In the `compute_products_func.py` script, the quantiles can be set to `0.1, 0.9`, corresponding to the 10th and 90th percentiles, to generate forecasts for extreme seasonal heat. This indicates the likelihood of seasonal temperatures falling withing the top 10% of values in the hindcast reference period. For monitoring moderate seasonal heat, thresholds of 0.2 and 0.8, representing the 20th and 80th percentiles, may be more appropriate. The thresholds can be further tailored to user preferences. Figure 5 provides an example of suggested changes for forecasting extreme seasonal heat using the 90th percentile.

Changing the tercile categories can affect forecast skill, as a model's ability to predict extreme seasonal temperatures may differ from its performance with standard tercile thresholds. It is therefore recommended to evaluate forecast skill before adjusting the categories to reflect more extreme seasonal temperature thresholds.

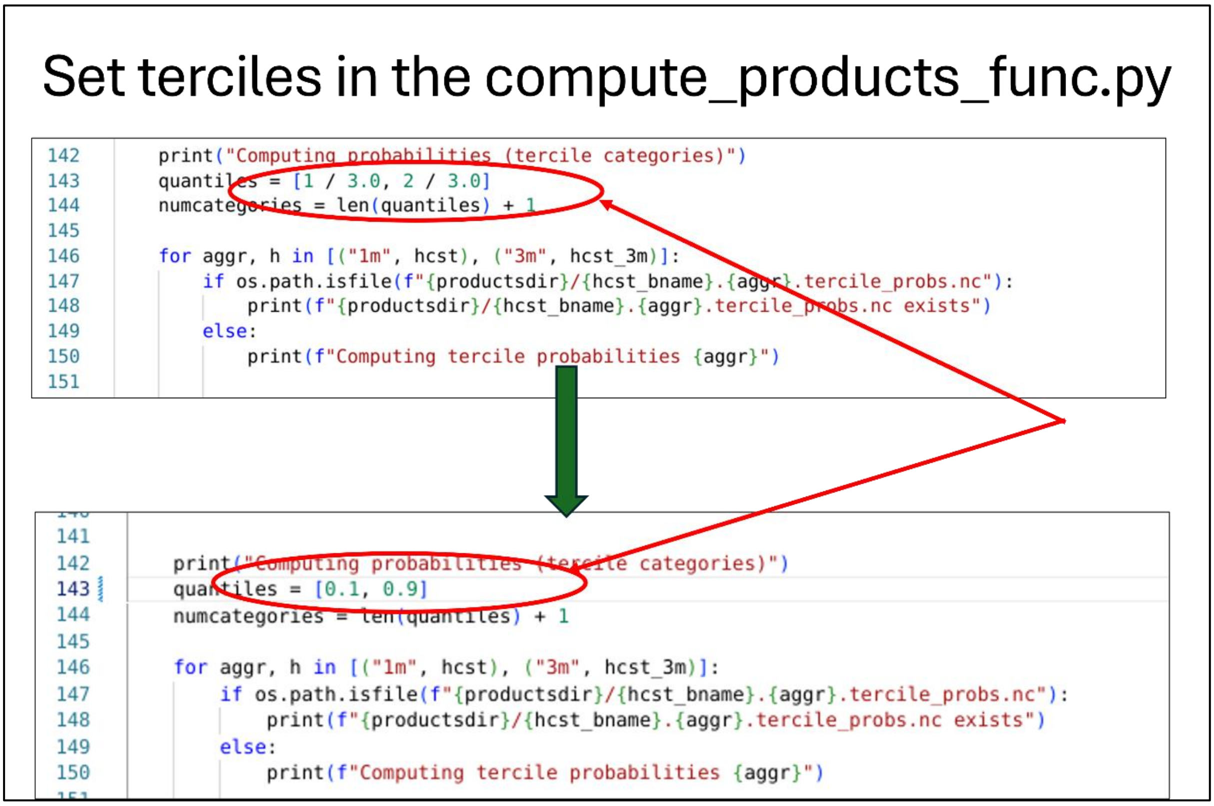


***Figure 5**. To adjust the terciles, modify line 143 of the* `compute_products_func.py` *Python script. Save the scripts and run the hindcast shell scripts to calculate the hindcasts and verification plots for the new percentiles.*

2.2.4. Changing the download locations

When making amendments to the quantile thresholds, any existing data and plots with previously calculated terciles will be overwritten. To avoid this, it is recommended to change the download directory for each run.

The default download locations in the code are set as follows:

- `downloaddir=$SCRATCH/seafoam/data/master/hindcast/downloads`

- `productsdir=$SCRATCH/seafoam/data/master/hindcast/products`
- `scoresdir=$SCRATCH/seafoam/data/master/hindcast/scores`
- `plotdir=$SCRATCH/seafoam/data/master/hindcast/plots`
- `logdir=$SCRATCH/seafoam/data/master/hindcast/logfiles`

The following examples illustrate how the download locations can be configured:

- `downloaddir=$SCRATCH/seafoam/data/master/hindcast/downloads`
- `productsdir=$SCRATCH/seafoam/data/master/hindcast/third_tercil` `es/products`
- `scoresdir=$SCRATCH/seafoam/data/master/hindcast/` `third_terciles/scores`
- `plotdir=$SCRATCH/seafoam/data/master/hindcast/` `third_terciles/plots`
- `logdir=$SCRATCH/seafoam/data/master/hindcast/` `third_terciles/logfiles`

An example of the file location changes is shown in Figure 6.

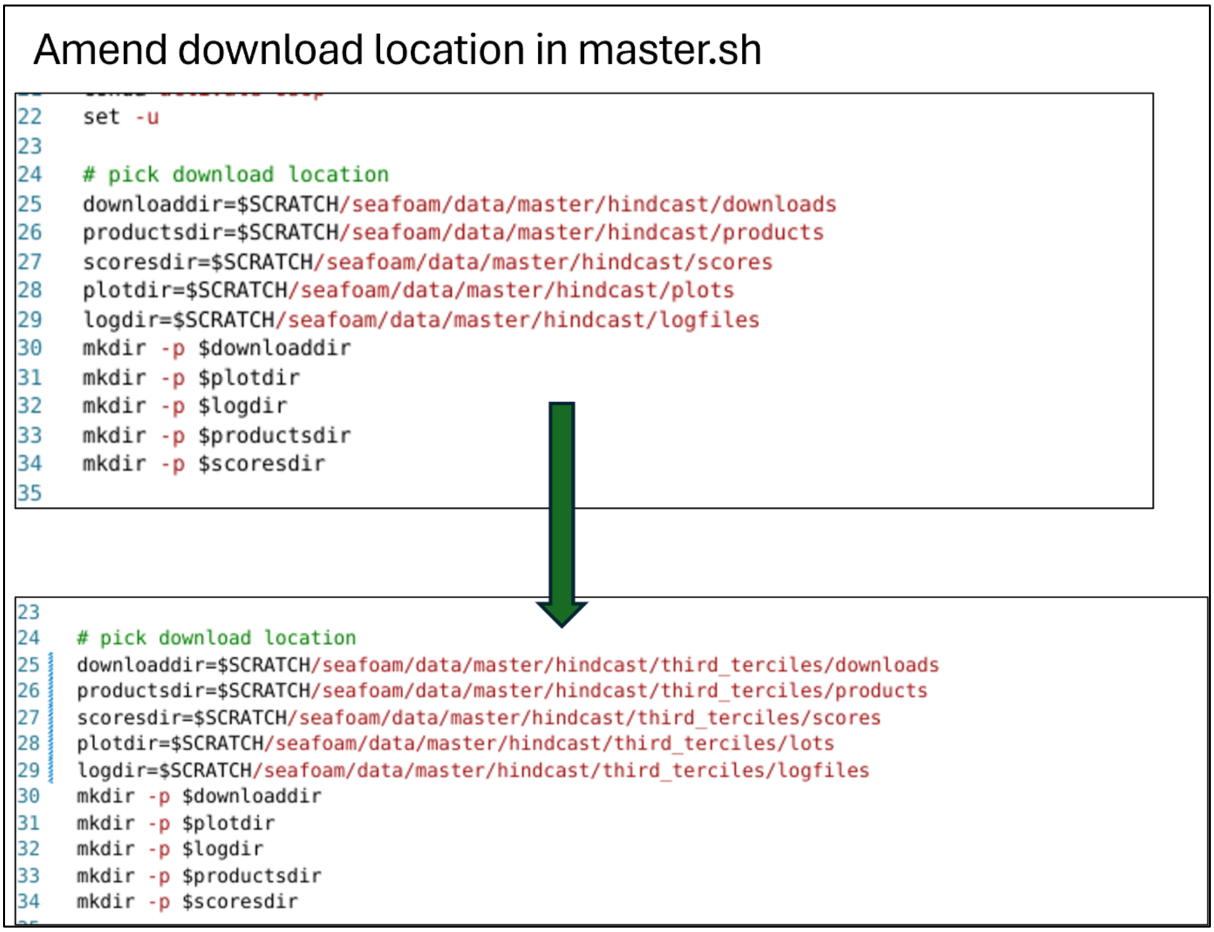


Figure 6. *To amend the download locations, modify lines 25 to 29 in both the* `master.sh` *and lines 37 to 38* `master.forecast.sh`*. The figure above shows an example of alternative file names for tercile categories. The names and number of directories can be tailored to the user's needs and the number of tercile categories calculated.*

Any changes to the download locations should be made in both the `master.sh` and `master.forecast.sh`. Caution should be taken when using the SCRATCH directory as some systems automatically wipe these periodically. Files can be stored permanently by moving (`mv`) or copying (`cp`) them to another location. For example, the command `$ mv -r $SCRATCH/seafoam/ ~/home_directory/` relocates the files from the specified source to a new target directory named `home_directory`.

2.3. The download and generated data

The `master.sh` script will create five `$SCRATCH` directories in the `/osop/` directory. The contents of each directory are as follows:

- `/downloads/` Stores the dataset GRIB files
- `/products/` Contains the datasets after reconfiguration and statistical processing, such as average values and tercile thresholds
- `/scores/` Holds the hindcast verification scores for the datasets
- `/plots/` Contains the plots generated for each dataset including verification score plots
- `/logfiles/` Stores the output from the code and used for error and debugging

2.3.1. Viewing the verification plots

To view the skill verification plots, open a new bash terminal in the user interface and navigate to the appropriate directory. The verification plots are located via the following path (the pathway may differ if the location has been amended in the `master.sh` script): `$SCRATCH/seafoam/data/master/hindcast/plots/`. Further guidance on viewing the verification plots can be found in Appendix 3.

Data size

The OSOP tool currently use monthly average temperatures and a limited default area. This restriction helps to limit the size of the data downloaded, making the tool less data-heavy than it would be if hourly data were used or the default area were larger. To get an idea of the data downloaded and generated the sizes of the `$SCRATCH` directories can be assessed for the following parameters (for the standard terciles):

- `month=8`
- `leads="2,3,4"`
- `area="45,-30,-2.5,60"`
- `variable="2m_temperature"`
- `location="UK"`

The `$SCRATCH` hindcast file sizes are as follows:

- `$SCRATCH/seafoam/` = 659M
- `/products/` = 444M
- `/logfiles/` = 144K
- `/downloads/` =172M
- `/plots/` = 34M
- `/scores/` = 11M

2.4. Sense testing

The producing centres included in the OSOP toolkit align with those used by the World Meteorological Organisation, European Centre for Medium-Range Weather Forecasts (ECMWF) and Copernicus Climate Change Service (C3S). The verification plots generated by the OSOP toolkit can be compared to the outputs generated by organisations that use the same producing centres to generate their data. This is useful for initially sense-testing the code and outputs. Model verification plots and metrics are presented in Table 1.

Table 1. *The global producing centres for long-range forecasts and associated verification plots and scores available for sense-testing.* Relative operating characteristic (ROC), Ranked Probability Score (RPS), Brier Skill Score (BS), Root Mean Square Error (RSME), Anomaly Correlation Coefficient (ACC), Mean Square Skill Score (MSSS))

Organisation	Verification plots and scores generated	Geographical area	Producers	Link
ECMWF C3S seasonal forecast verification plots	• Spearman's correlation • RPS • ROC	Global	All producers	C3S seasonal forecasts verification plots - Copernicus Knowledge Base - ECMWF Confluence Wiki
ECMWF (SEAS5) charts	• Anomaly correlation coefficient • ROC skill scores • ROC diagram • Reliability diagram	Global	ECMWF (SEAS5)	ECMWF | Charts
WMO	• ACC • RMSE • MSSS (mean squared skill score) • GSS	Global Continental	All producers	WMO SP MME

Euro-Mediterranean Center on Climate Change	• ROC • ACC • Bias • RMSE • MSSS • Reliability diagram • ROC curve	Global NH SH Tropics	CMMC	Verification | CMCC Seasonal Prediction System
Met Office, United Kingdom	• ROC maps • ROC plots • Reliability plots For terciles, outer quintiles and two categories.	Global Tropics Africa Asia Europe North America South America Central America Australia Pacific West Africa Horn of Africa Southern Africa	UKMO	Global long-range model probability skill maps - Met Office
Météo-France	• Brier • ROC • Mass • Correlation • Ratio scores for upper and lower terciles and 2 extreme categories		Météo-France	Seasonal forecast models - Scores | seasonal.meteo.fr
Climate Change Canada (ECCC):	• Percentage correct	Canada	ECCC	Skill of the Deterministic Forecast System - Environment Canada
Japan Meteorological Agency (JMA):	• ACC • Reliability • ROC curves	Northern hemisphere Tropics	JMA	Verification of one-month prediction
Deutscher Wetterdienst (DWD):	• ACC • BSS	Global	DWD	Wetter und Klima - Deutscher Wetterdienst - Our services - Seasonal forecasts: Maps
National Centers for Environmental Prediction (NCEP):	• RMSE • Correlation	Global	NCEP	CFS diagnoses - Anomaly RMSE and corlelation

2.5. Considerations when tailoring the code

Some verification metrics are affected when the sub area is changed. This is particularly true for deterministic methods such as Pearson and Spearman's correlation, which yield different results based on the domain size. Although the seasonal forecast remains unaffected, it is recommended to use the default area when analysing verification metrics sensitive to sample size. Other verification metrics, such as ROC, are not influenced by the size of the domain. This is mostly due to plotting algorithms used; designed to be easily interpreted at larger scales.

3. Step 2: Seasonal forecasting

3.1. Tailor the code to produce a seasonal forecast

The seasonal forecasting code in the OSOP toolkit can be amended manually to produce a tailored seasonal forecast. The changes made to the parameters in the forecasting code must match the parameters in the hindcast `master.sh` script. The hindcast must be generated before the forecast is produced, and new hindcasts must be generated for every amendment made to the parameters. The forecasting script, `master.forecast.sh`, is in the `/osop/scripts` directory.

3.1.1. Set the parameters

By default, the parameters in `master.forecast.sh` are set to the following:

- `month=5` (initialisation month)
- `leads="2,3,4"` (The forecast lead time in months e.g. if month=5 and leads="2,3,4", valid months are June-July-August (6,7,8))
- `area="45,-30,-2.5,60"` (sub area in degrees for area of interest, comma separated N,W,S,E)
- `variable="2m_temperature"` (variable of interest, typically "2m_temperature" or "total_precipitation")
- `location="Morocco"` (Current options include 'None' - no borders, 'UK', 'Morocco' and 'SAU' - Saudi Arabia. Further details on boarders are in Appendix 1).
- `years=2025` (forecast year; forecasts for past years can be generated but the model version may need amended as explain in Section 3.4.1).

Figure 5 shows an example of the changes made to `master.forecast.sh.` The parameters can be modified in lines 51 to 56.

The suggested changes to the forecast parameters using Burkina Faso as a case study are as follows:

- `month=5`

- `leads="2,3,4"`
- `area="20,-10,3.5,6"`
- `variable="2m_temperature"`
- `location="UK"`
- `years=2025`

The parameters should be set exactly as stated in comments (e.g. no spaces between code). Save the changes and run the script in the terminal as stated in the guidance in Appendix 3. The initialisation month will vary depending on when the forecasts are generated. The terciles can be amended as explained in *Section 2.2.2 Changing the terciles*.

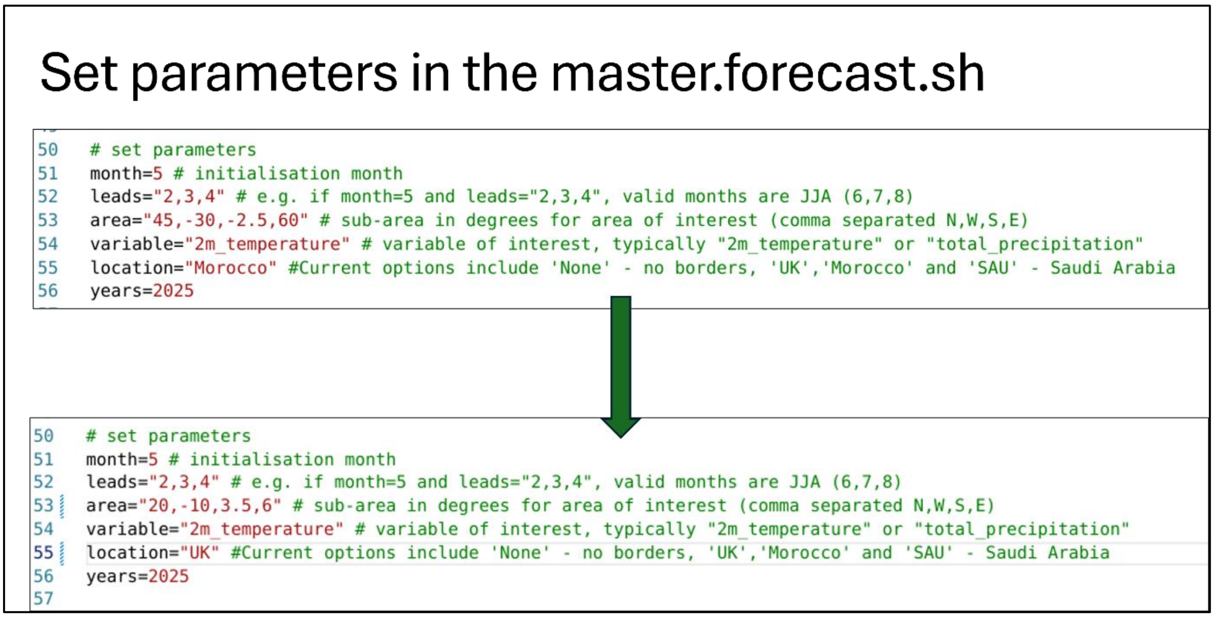


***Figure** 7. To tailor the forecast code, make amendments to the parameters in lines 51 to 56 in the* `master.forecast.sh` *shell script. Save the script and run it in the terminal.*

As with the hindcast scripts, the download locations can be edited to store the different forecast products in separate directories. This prevents files from being overwritten when the quantile thresholds are changed. Examples of download location changes are presented in Figure 8.

The default `$SCRATCH/` directory locations are set to:

- `downloaddir=$SCRATCH/seafoam/data/master/forecast/downloads/`
- `productsdir=$SCRATCH/seafoam/data/master/forecast/products/`
- `scoresdir=$SCRATCH/seafoam/data/master/forecast/scores/`
- `plotdir=$SCRATCH/seafoam/data/master/forecast/plots/`
- `logdir=$SCRATCH/seafoam/data/master/forecast/logfiles/`

The following examples illustrate how the download locations can be configured:

- `downloaddir=$SCRATCH/seafoam/data/master/forecast/third_terciles/downloads/`
- `productsdir=$SCRATCH/seafoam/data/master/forecast/third_terciles/products/`
- `scoresdir=$SCRATCH/seafoam/data/master/forecast/third_terciles/scores/`
- `plotdir=$SCRATCH/seafoam/data/master/forecast/third_terciles/plots/`
- `logdir=$SCRATCH/seafoam/data/master/forecast/third_terciles/logfiles/`

The file paths for hindcast relatives must match the corresponding hindcast download and product locations, and changed from the default locations which are set as follows:

- `productshcdir=$SCRATCH/seafoam/data/master/hindcast/products`
- `downloadhcdir=$SCRATCH/seafoam/data/master/hindcast/downloads`

The file locations must reflect the new directory locations. Examples for third-tercile categories are as follows:

- `productshcdir=$SCRATCH/seafoam/data/master/hindcast/third_terciles/products`
- `downloadhcdir=$SCRATCH/seafoam/data/master/hindcast/third_terciles/downloads`

Amend download location in master.forecast.sh

```
23
24    # pick download location
25    downloaddir=$SCRATCH/seafoam/data/master/forecast/downloads
26    productsdir=$SCRATCH/seafoam/data/master/forecast/products
27    scoresdir=$SCRATCH/seafoam/data/master/forecast/scores
28    plotdir=$SCRATCH/seafoam/data/master/forecast/plots
29    logdir=$SCRATCH/seafoam/data/master/forecast/logfiles
30    mkdir -p $downloaddir
31    mkdir -p $plotdir
32    mkdir -p $logdir
33    mkdir -p $productsdir
34    mkdir -p $scoresdir
35
36    #locations for hindcast relatives
37    productshcdir=$SCRATCH/seafoam/data/master/hindcast/products
38    downloadhcdir=$SCRATCH/seafoam/data/master/hindcast/downloads
39
```

```
24    # pick download location
25    downloaddir=$SCRATCH/seafoam/data/master/forecast/third_tercile/downloads
26    productsdir=$SCRATCH/seafoam/data/master/forecast/third_tercile/products
27    scoresdir=$SCRATCH/seafoam/data/master/forecast/third_tercile/scores
28    plotdir=$SCRATCH/seafoam/data/master/forecast/third_tercile/plots
29    logdir=$SCRATCH/seafoam/data/master/forecast/third_tercile/logfiles
30    mkdir -p $downloaddir
31    mkdir -p $plotdir
32    mkdir -p $logdir
33    mkdir -p $productsdir
34    mkdir -p $scoresdir
35
36    #locations for hindcast relatives
37    productshcdir=$SCRATCH/seafoam/data/master/hindcast/third_tercile/products
38    downloadhcdir=$SCRATCH/seafoam/data/master/hindcast/third_tercile/downloads
39
```

Figure 8. *Make amendments to the file and plot download locations in lines 25 to 34 in both the `master.forecast.sh script`. The figure above shows an example of alternative file names for tercile categories. The name and number of directories can be tailored to the user's needs and the number of tercile categories calculated. Ensure that the product locations of the hindcast files in lines 37 to 38 match those in the `master.sh file`.*

3.2. View the plots

For general guidance on viewing the verification plots generated, refer to Appendix 3. To access the verification plots, open a new bash terminal in the user interface and navigate to the appropriate directory. The verification plots can be found at the following path: `seafoam/data/master/forecast/plots`. Note that this pathway may differ if the file locations have been modified in the `master.forecast.sh` script to avoid files being overwritten.

3.3. Sense testing

As explained in *Section 2.4*. the producing centres included in the OSOP toolkit align with those used by the World Meteorological Organisation (WMO), European Centre for Medium-Range Weather Forecasts (ECMWF) and Copernicus Climate Change Service (C3S). The seasonal forecast plots generated by the OSOP toolkit, as with the hindcasts, can be compared to the outputs generated by organisations that use the same producing centres to generate the data.. This comparison is useful for initially sense-testing the code and data. For example, the seasonal forecast plots generated by the OSOP tool can be compared to those generated by the individual producing centre on the C3S seasonal charts page or the ECMWF seasonal forecast charts.[6].

3.4. Considerations when tailoring the code

3.4.1. Seasonal forecasting system versions

The forecasting system used by each producing centre will require upgrading at some point, resulting in different versions of the system being available (ECMWF, 2025). While only one version of each system will be used to produce real-time forecasts, multiple versions may be available for producing hindcasts and past seasonal forecast. Details of each forecasting system are available from the ECMWF C3S Seasonal Forecasts: dataset documentation[7] and in Section '*Versioning of forecasting systems contributing to C3S'* of the 'Description of the C3S seasonal multi-system'[8]. All forecasting system versions in the `master.forecast.sh` script must match latest version of the forecasting system. The OSOP code may not be up to date with the latest system version in use. If the versions are not up to date, the forecasting system data

[6] ECMWF seasonal forecast charts https://charts.ecmwf.int/?facets=%7B%22Product%20type%22%3A%5B%5D%2C%22Parameters%22%3A%5B%5D%2C%22Range%22%3A%5B%22Long%20%28Months%29%22%2C%22Seasonal%22%5D%2C%22Type%22%3A%5B%22Forecasts%22%5D%7D
[7]C3S Seasonal Forecasts: dataset documentation.
Summary of available data https://confluence.ecmwf.int/display/CKB/Summary+of+available+data
[8] Description of the C3S seasonal multi-system Description of the C3S seasonal multi-system - Copernicus Knowledge Base - ECMWF Confluence Wiki

download will fail, and the system will not generate a forecast. The system versions can be updated in lines 63 to 71 in `master.forecast.sh`, as shown in Figure 9. Is it suggested to check the current system version in use to those listed in the OSOP toolkit scripts before generating a forecast.

The system versions in the hindcast code in `master.sh` script will need updating to match those used in the `master.forecast.sh`. This can be updated in lines 55 to 63 in `master.sh`, shown in Figure 10.

```
59  # Services in use:
60  # edit as approprite to the most up to date systems.
61  cat <<EOF > "$parseyml"
62  Services:
63      ecmwf: 51
64      meteo_france: 9
65      dwd: 22
66      cmcc: 35
67      ncep: 2
68      jma: 3
69      eccc_can: 4
70      eccc_gem5: 5
71      ukmo: 604
72  EOF
73  echo "YML file created: $parseyml"
74
```

Figure 9. *Example of updating system versions in the* `master.forecast.sh` *script. Ensure that the system versions (lines 63 to 71) match the latest versions used by the forecasting system to avoid download failures and ensure accurate forecast generation.*

```
52  # Services in use:
53  cat <<EOF > "$parseyml"
54  Services:
55      ecmwf: 51
56      meteo_france: 9
57      dwd: 22
58      cmcc: 4
59      ncep: 2
60      jma: 3
61      eccc_can: 4
62      eccc_gem5: 5
63      ukmo: 604
64  EOF
65  echo "YML file created: $parseyml"
66
```

Figure 10. *The system version in the* `master.sh` *script for the hindcast code must align the forecasting system being used. Update the system versions in the* `master.sh` *script can be edited in lines 55 to 64.*

3.5. The download and generated data

The `master.sh` script will produce five `$SCRATCH` directories in the `/osop/` directory.

- `downloads/` Directory stores the dataset Grib files
- `products/` Holds the datasets after they have been reconfigured and statistical versions have been produced, such as average values and tercile thresholds
- `scores/` Is empty as it is intended for hindcast verification scores only
- `plots/` Contains the forecast plots generated for each dataset
- `logfiles/` Stores the printouts from the code which can be used for error tracking and debugging

3.5.1. The forecasts

Four seasonal forecasts are generated for each model, and these can be accessed in the `$SCRATCH plots/ directory`:

1. A seasonal (three-month period) forecast that includes month leads 2, 3, 4 from the initialisation month. For example, if the initialisation month (month 1) is August, the three-month forecast covers September, October and November (SON).

2. A one-month forecast for month lead 2 from initialisation month 1. For example, if the initialisation month (month 1) is August, a forecast will be produced for September (lead 2).
3. A one-month forecast covering month lead 3 from initialisation month 1. For example, if the initialisation month (month 1) is August, a forecast will be produced for October (lead 3).
4. A one-month forecast covering month lead 4 from initialisation month 1. For example, if the initialisation month (month 1) is August, a forecast will be produced for November (lead 4).

An example of the plots generated for the CMCC forecasting system are presented in Figure 11. Further examples of the forecast plots generated for the default area and the suggested sub-area can be found in Appendix 4.

a. `cmcc_4_2025-2025_monthly_mean_8_234_20:-10:3.5:6_2m_temperature.3m.png`
b. `cmcc_4_2025-2025_monthly_mean_8_234_20:-10:3.5:6_2m_temperature.imonth_0.png`
c. `cmcc_4_2025-2025_monthly_mean_8_234_20:-10:3.5:6_2m_temperature.imonth_1.png`
d. `cmcc_4_2025-2025_monthly_mean_8_234_20:-10:3.5:6_2m_temperature.imonth_2.png`

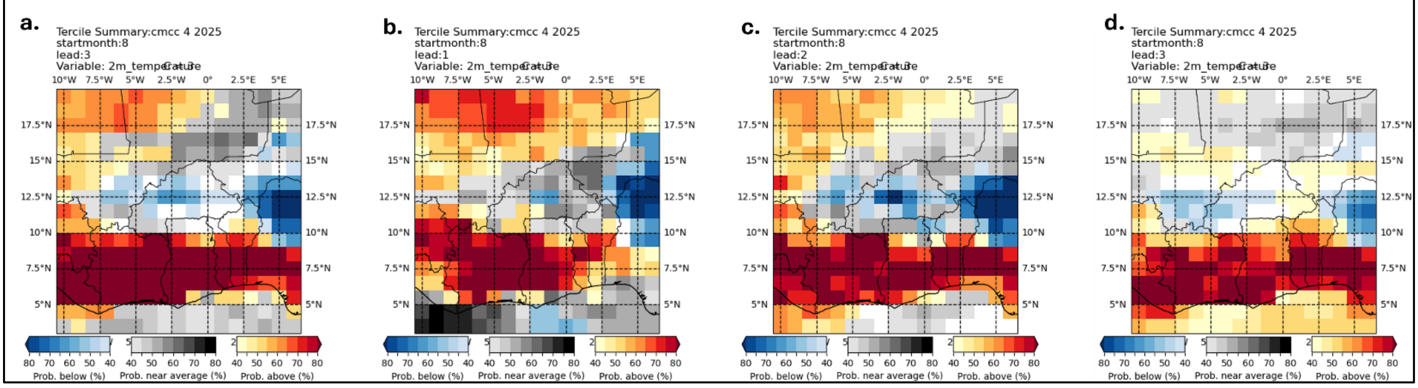


Figure11. *The four different files, and corresponding plots generated for the cmmc_4 predicting system. August 2025 was set for the initialisation month in this example (month 8). The 'leads = 2,3,4' in the* `master.forecast.sh` *script correspond to September, October and November. The plot names for the cmcc_4 example are listed:*

- *cmcc_4_2025-2025_monthly_mean_8_234_20:-10:3.5:6_2m_temperature.3m.png is the forecast for September, October and November initialised in August.*
- *cmcc_4_2025-2025_monthly_mean_8_234_20:-10:3.5:6_2m_temperature.imonth_0.png is the forecast for September initialised in August.*

- *cmcc_4_2025-2025_monthly_mean_8_234_20:-10:3.5:6_2m_temperature.imonth_1.png is the forecast for October initialised in August.*
- *cmcc_4_2025-2025_monthly_mean_8_234_20:-10:3.5:6_2m_temperature.imonth_2.png is the forecast for November initialised in August.*

3.5.2. Data size

The scripts in the OSOP toolkit currently use monthly data, and the default area is limited. To get an idea of the data downloaded and generated for the forecasts, the sizes of the `$SCRATCH` directories for the following parameters can be assessed (for the standard terciles):

- `month=8` (initialisation month)
- `leads="2,3,4"` (e.g., if month=8 and leads="2,3,4", valid months are SON (9,10,11))
- `area="45,-30,-2.5,60"` (sub-area in degrees for area of interest (comma separated N,W,S,E))
- `variable="2m_temperature"`
- `location="UK"`
- `years=2025`

The `$SCRATCH` file sizes are as follows:

- `seafoam/` = 25M
- `products`/ = 4.1M
- `logfiles/` = 100K
- `downloads/` =17M
- `plots/` = 4.2M
- `scores/` = 4.0K

The total size `$SCRATCH/seafoam/` directory including the forecasts and hindcast data (based on the parameters outlined) is 684M.

Summary

This guidance document, developed by the UK Met Office, outlines how to tailor the Objective Seasonal Outlook Package (OSOP) toolkit to produce seasonal forecasts focused on extreme heat, with a case study for Burkina Faso. It provides guidance on generating hindcasts, calculating terciles and percentiles, and producing seasonal forecasts using data from nine global forecasting systems.

The OSOP toolkit is fully open-source and enables national meteorological services to generate locally relevant seasonal forecasts by adjusting parameters and modifying tercile categories to reflect extreme heat thresholds.

This document aims to build technical capacity for delivering reliable and locally relevant seasonal forecasts.

References

- Daron, J., (2019) HOW TO APPROACH A METEOROLOGICAL SERVICE TO ACCESS AND USE SEASONAL FORECASTS (No. 2). In*: A Practical Guide to Seasonal Forecasts*. Red Cross Red Crescent Climate Centre, 7-10. Available from: https://www.climatecentre.org/downloads/files/A%20practical%20guide%20for%20seasonal%20forecasts_SHEAR.pdf [Accessed 04 November 2025]
- ECMWF (2025) *Seasonal forecasts and the Copernicus Climate Change Service* [online], ECMWF, Available from https://confluence.ecmwf.int/display/CKB/Seasonal+forecasts+and+the+Copernicus+Climate+Change+Service [Accessed 09 October 2025]
- Weisheimer, A., Befort, D.J., MacLeod, D., Palmer, T., O'Reilly, C., Strømmen, K., (2020). Seasonal Forecasts of the Twentieth Century. *Bulletin of the American Meteorological Society,* 101, E1413–E1426, DOI: https://doi.org/10.1175/BAMS-D-19-0019.1
- World Meteorological Organization (WMO), (2020) *Guidance on Operational Practices for Objective Seasonal Forecasting*. Geneva: World Meteorological Organization. Available from: https://library.wmo.int/viewer/57090#page=1&viewer=picture&o=bookmark&n=0&q= [Accessed 04 November 2025]

Appendices

Appendix 1: Additional OSOP toolkit details

Table presenting details of the OSOP toolkit. The table includes the verification metrics generated in the verification plots, the choice of parameters, the boarder options and the eight different producing centres.

Verification metrics	Parameter options	Boarder options	Producing centres: code name
• Relative operating characteristic (ROC) • Reliability (REL) • Pearsons Correlation • Spearman Correlation • Ranked Probability Score (RPS) • Relative Operating Characteristic Skill Score (ROCSS) • Brier Score (BS)	Temperature; 2m_temperature Precipitation: total_precipitation	None: no boarders UK: boarders as recognised by the UK Morocco: boarders as recognised by Morocco. SAU (Saudi Arabia): boarders as recognised by Saudi Arabia	• Météo-France: **meteo_france** • Deutscher Wetterdienst (DWD): **dwd** • Euro-Mediterranean Center on Climate Change (CMCC): **cmcc** • Met Office, United Kingdom: **ukmo** • European Centre for Medium-Range Weather Forecasts (ECMWF): **ecmwf** • Japan Meteorological Agency (JMA): **jma** • National Centers for Environmental Prediction (NCEP): **ncep** • Climate Change Canada (ECCC): **eccc_can** and **eccc_gem5**

Appendix 2: Guidance on using the GitHub repository on your local system.

Cloning the OSOP GitHub Repository and making temporary changes

Details on how to clone the GitHub repository and create a local branch are outlined in this section. Further details on using the GitHub repository can be found in the general GitHub guidance available in GitHub Docs[9]. This section also provides information on mirroring the local and remote branches when making temporary changes.

Clone the OSOP GitHub repository and create a local temporary branch

The OSOP repository on GitHub is known as the remote repository and can be accessed on GitHub.com in the following repository OSFTools/osop: Objective Seasonal Outlooks Package

.

To clone the GitHub repository and create a local main branch using the Bash terminal, navigate to the directory in which the repository will be located and use the `git clone` command.

`$ git clone` https://github.com/OSFTools/osop.git

`$ cd osop`

This will create a local copy of the OSOP repository in a folder named `osop/` in your current directory and enter the new `osop/` directory.

When cloning, it is typical to create a local temporary branch from the local main clone and switch between the branches and main in the local clone. Ensure the main clone is up to date before creating a local temporary branch.

`$ git checkout main`

`$ git pull`

[9] Repositories documentation https://docs.github.com/en/repositories

To create a local temporary branch for making temporary changes to the seasonal forecasts, such as the adjustments suggested in this document for tailoring the forecast, run the following command in the Bash terminal.

```
$ git checkout -b name-of-branch
```

Replace `name-of-branch` with an appropriate name. The command creates a new local branch called *name-of-branch* from the main local clone and switches to the newly created temporary branch. A consistent naming convention that clearly identifies each branch can facilitate collaboration when sharing code changes on the GitHub repository.

Make changes to the local temporary branch

Any changs made to the local temporary branch will be isolated from the main branch. The changes can be committed locally if needed.

```
$ git add
```

```
$git commit -m "message"
```

Delete local temporary branches

To remove the local temporary branch when finished, run the following code:

```
$ git checkout main
```

```
$git branch -D name-of-branch
```

Otherwise, to keep the branch but reset everything including staged changes.

```
$ git reset --hard
```

To discard uncommitted changes, use the following command (specify the path to restore):

```
$ git restore
```

To discard changes in all modified files use:

```
$ git restore .
```

Or to discard all uncommitted changes including new files use:

```
$ git clean -fd
```

Keep the local main branch updated with any changes to the remote main branch

The OSOP GitHub repository is under continued development. It is recommended to keep the local main branch in sync with the remote main.

To check if the local main branch is in sync with the remote main branch. Switch to the local main branch. A status update will indicate if branches have diverged, with an example as follows:

```
Switched to branch 'main'
Your branch is behind 'origin/main' by 2 commits, and can be fast-forwarded.
  (use "git pull" to update your local branch)
```

Otherwise, use the following command to check the status once in the main local branch.

```
$ git status
```

An example of the status message is:

```
On branch main
Your branch and 'origin/main' have diverged,
and have 1 and 14 different commits each, respectively.
  (use "git pull" if you want to integrate the remote branch with yours)
```

Regularly check the status and update the local main branch to ensure all recent updates made to the remote GitHub repository are merged with the local main branch.

To ensure the local branch always mirrors the remote branch run the following commands.

```
$ git pull origin main
```

This will fetch and merge the remote changes into the local main branch without overwriting or deleting local changes.

To include any new changes that have been pulled into the local main branch with changes from the remote main branch, use the following commands:

```
$ git checkout local_temporary_branch
```

```
$ git merge main <this may result in conflicts>
```


You can sign up to receive email alerts and stay informed about updates to the code.

Revert to the repositories README for further instructions on how to run the code.

Appendix 3: General guidance on running the scripts in the OSOP toolkit.

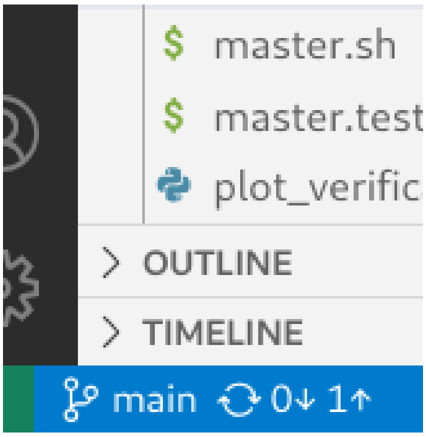
This guidance is suitable for users of VS code user interface.

1. Clone the repository.

Clone the repository onto your local branch using the guidance in Appendix 2 and create a temporary branch as desired.

2. Open up in your User Interface (e.g. VS Code)

In VS Code, open the cloned directory File > open Folder > osop. Make sure the correct branch is in use. To change the branch, click on the branch symbol in the bottom left-hand corner and change as required.



3. Edit the scripts

Edit the scripts. Before running, save any changes.

4. Run the shell scripts

Open up a terminal in the user interface and navigate to the location of the scripts `/osop/scripts/`

In the terminal run the following scripts with the following commands:

- Master.test.sh: `$ ./master.test.sh`

- master.sh script: `$ ./master.sh`
- master.forecast.sh: `$ ./master.forecast.sh`

5. View the plots

To view the verification plots, open a new terminal and navigate to the `$SCRATCH` files using the following command `$ cd $SCRATCH/seafoam/data/master/hindcast/plots`

To view the list of plots, use the commend `$ ls`

To view a plot, use the following command `$ code plot_name`

Replace *plot_name* with the name of the plot to view.

The forecast plots can be located in the following directory: `$ cd $SCRATCH/seafoam/data/master/forecast/plots`

Use the same commands to view the forecast plots as used to view the verification plots.

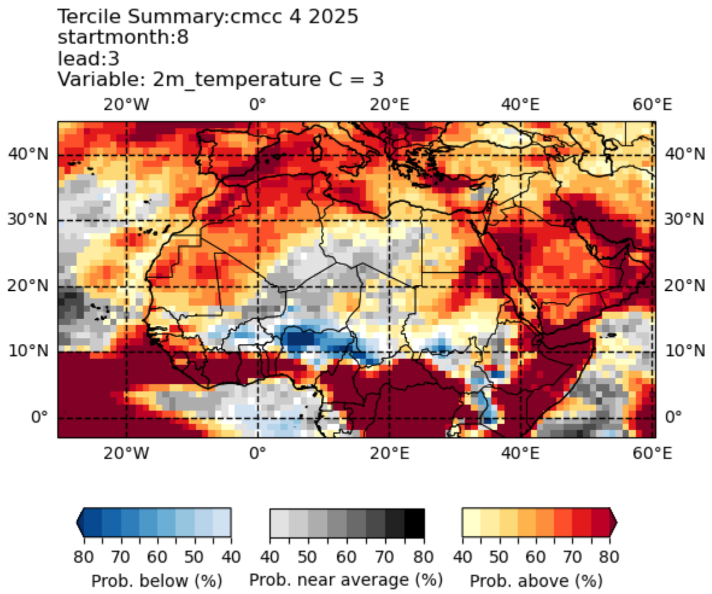
Appendix 4: Examples of three-month forecast plots

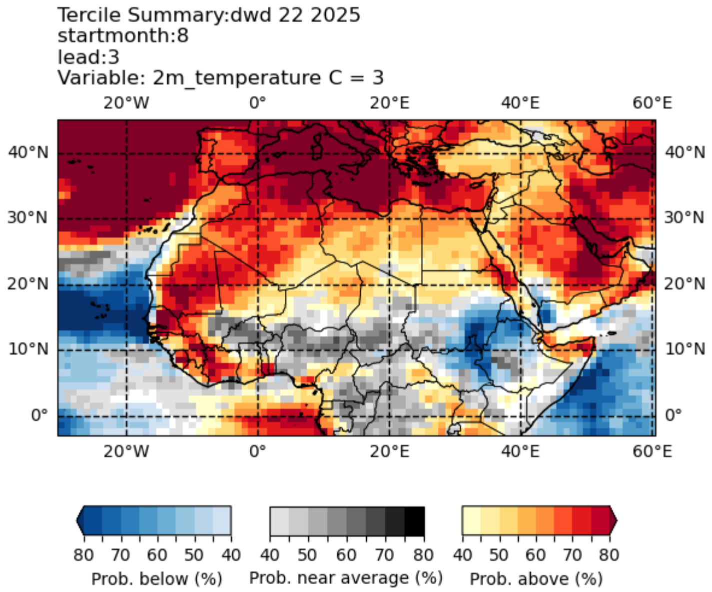
Examples of the seasonal forecast plots are included below for the default area and for Burkina Faso domain.

Parameters

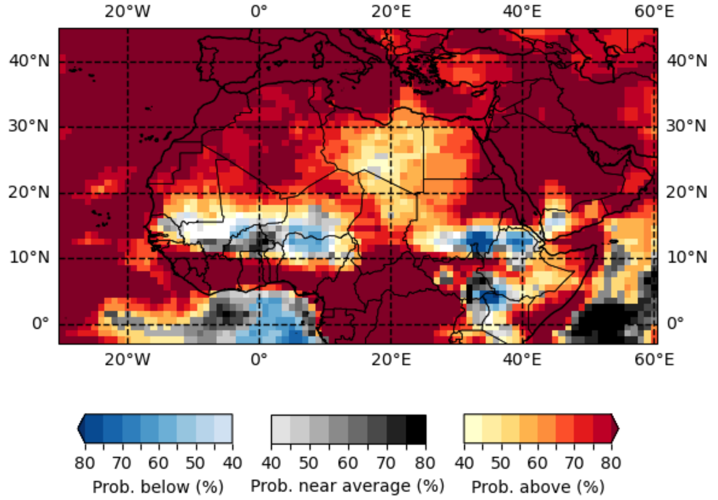
- `month=8` # initialisation month
- `leads="2,3,4"` # e.g. if month=8 and leads="2,3,4", valid months are SON (9,10,11)
- `area="45,-30,-2.5,60"` # domain in degrees for area of interest (comma separated N,W,S,E)
- `variable="2m_temperature"` # variable of interest, typically "2m_temperature" or "total_precipitation"
- `location="UK"` #Current options include 'None' - no borders, 'UK', 'Morocco' and 'SAU' - Saudi Arabia

Forecast plots – terciles (default area)

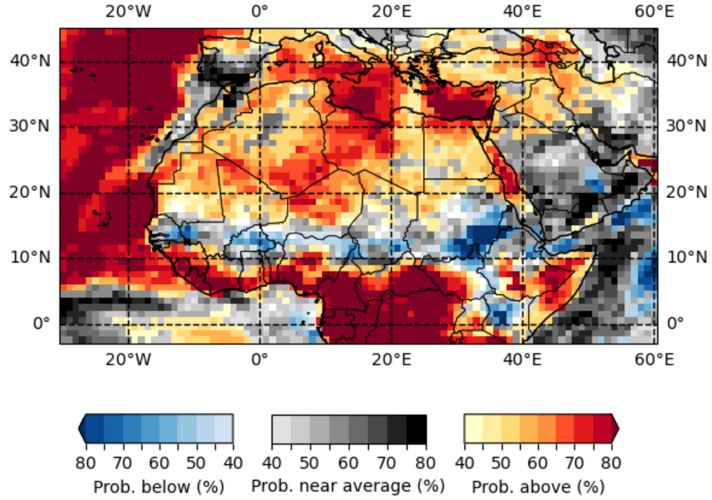




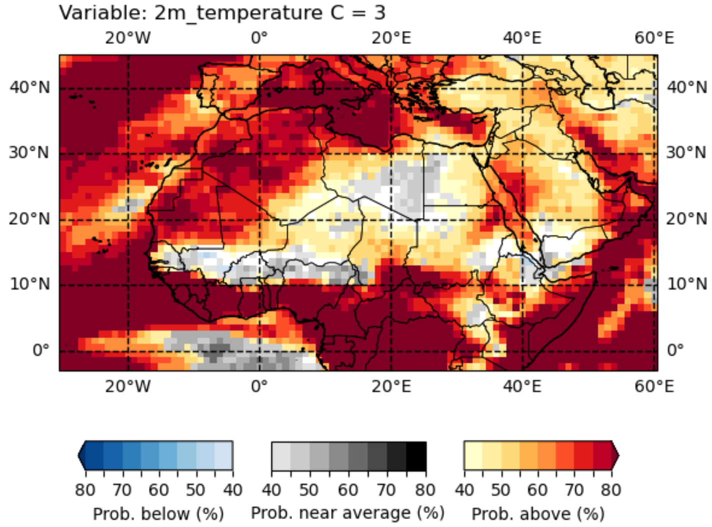
Tercile Summary:eccc 4 2025
startmonth:8
lead:3
Variable: 2m_temperature C = 3



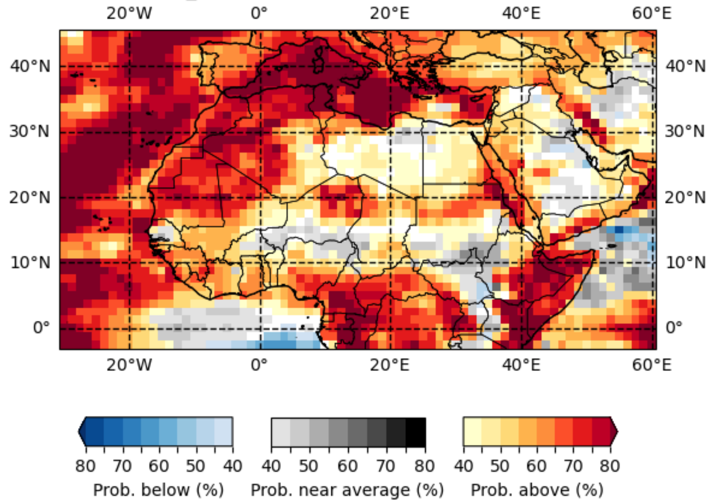
Tercile Summary:eccc 5 2025
startmonth:8
lead:3
Variable: 2m_temperature C = 3

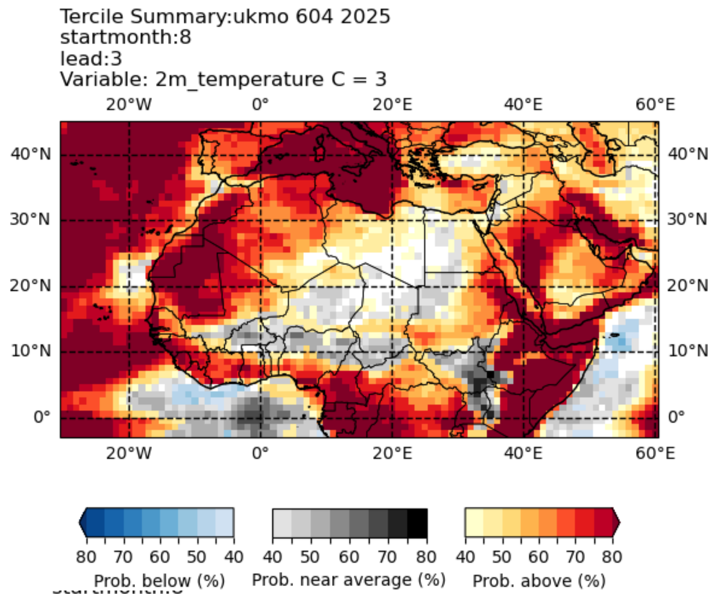


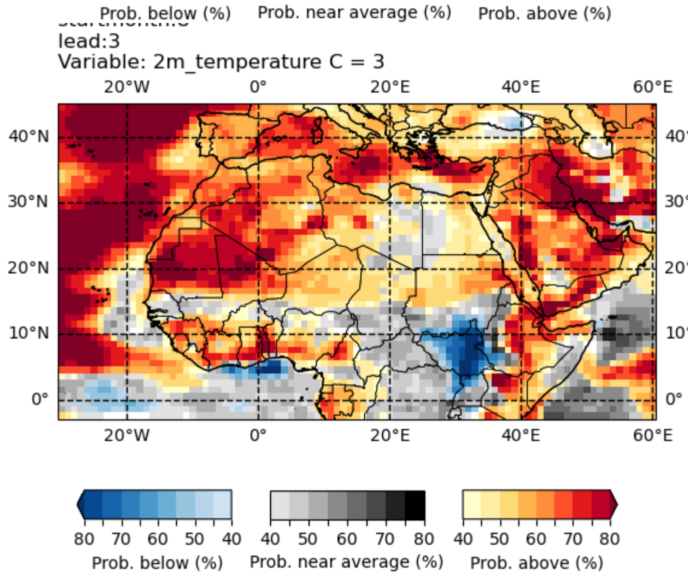
Tercile Summary:ecmwf 51 2025
startmonth:8
lead:3
Variable: 2m_temperature C = 3

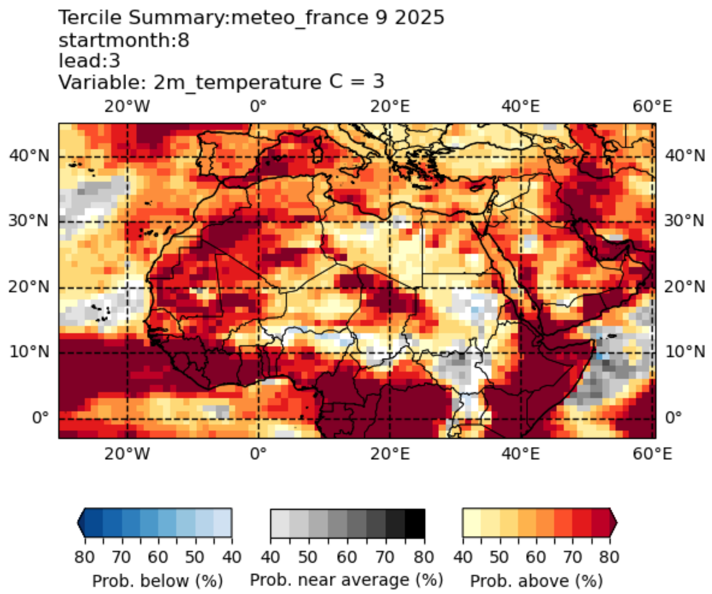


Tercile Summary:jma 3 2025
startmonth:8
lead:3
Variable: 2m_temperature C = 3



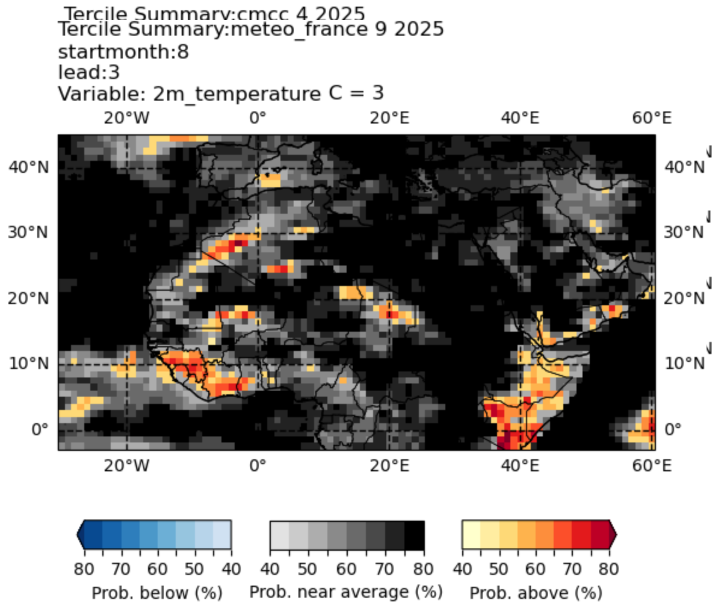


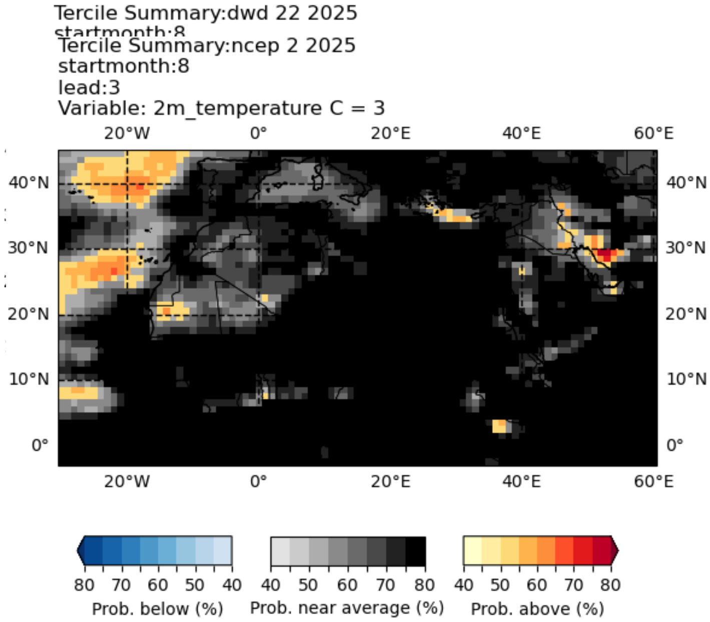


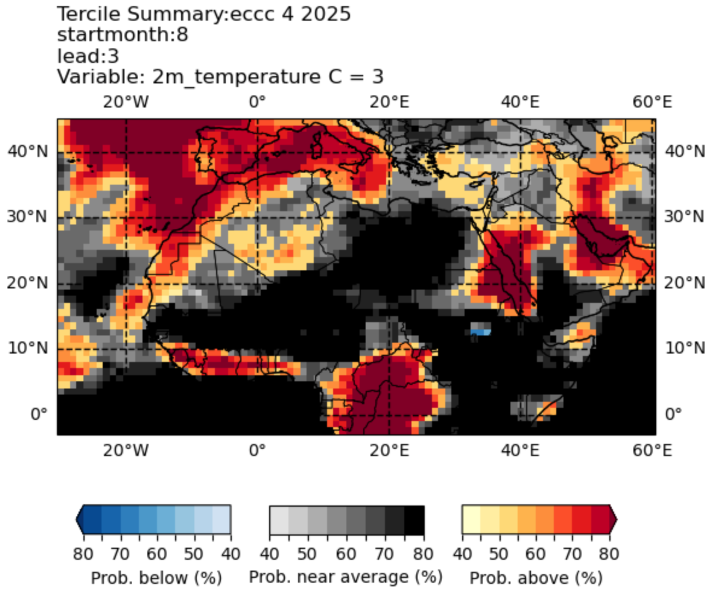


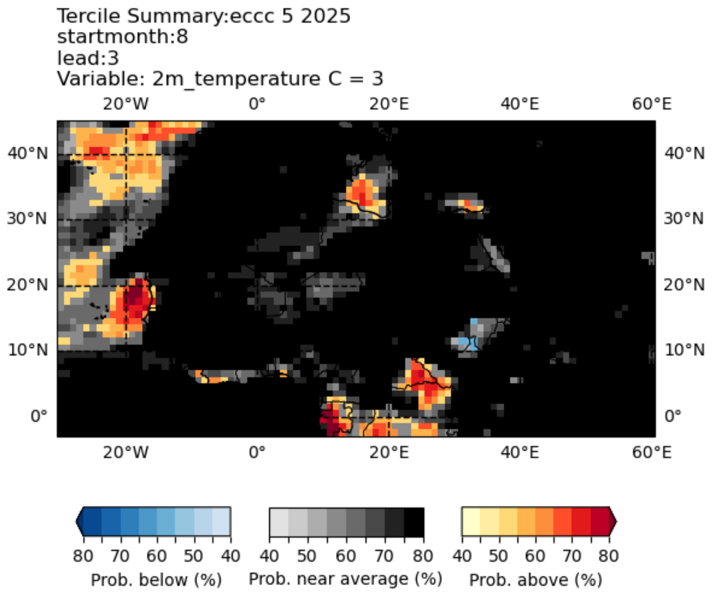
Forecast plots – percentiles (default area)

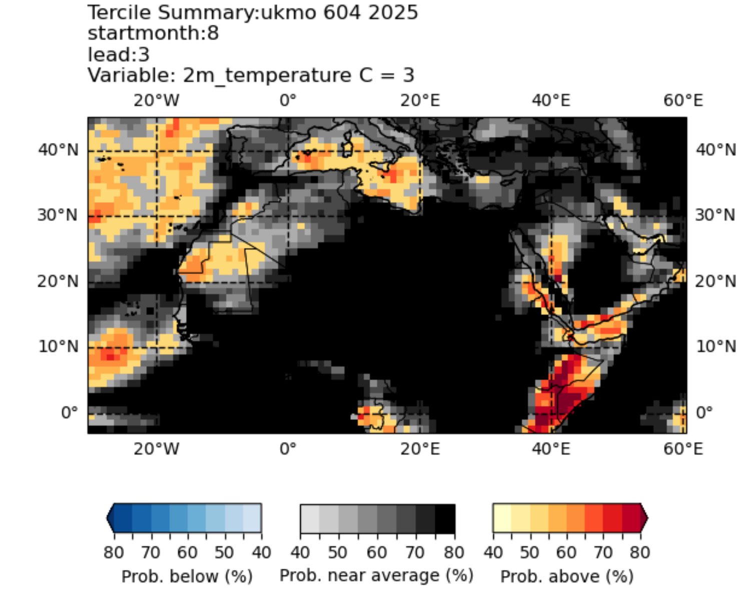
Forecast plot generated for the 10th and 90th percentiles. 'Near average' in these plots refers to the middle 80% of seasonal temperatures.

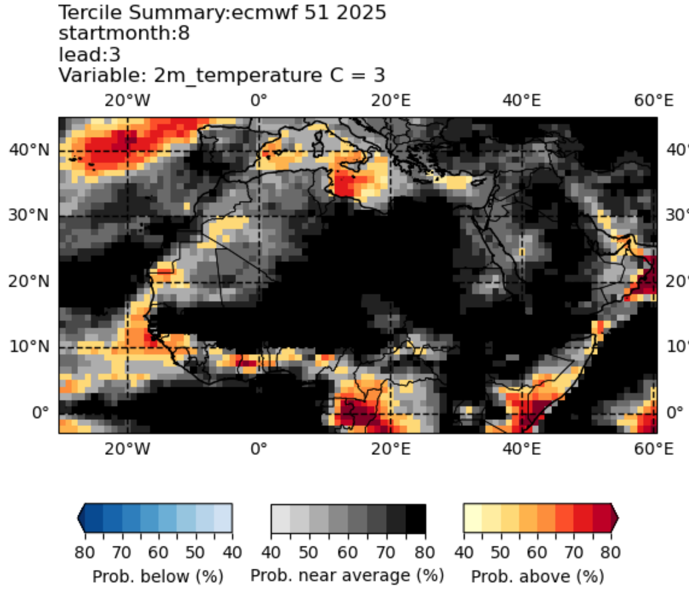

Tercile Summary:cmcc 4 2025
Tercile Summary:meteo_france 9 2025
startmonth:8
lead:3
Variable: 2m_temperature C = 3
20°W 0° 20°E 40°E 60°E
40°N 30°N 20°N 10°N 0°
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)

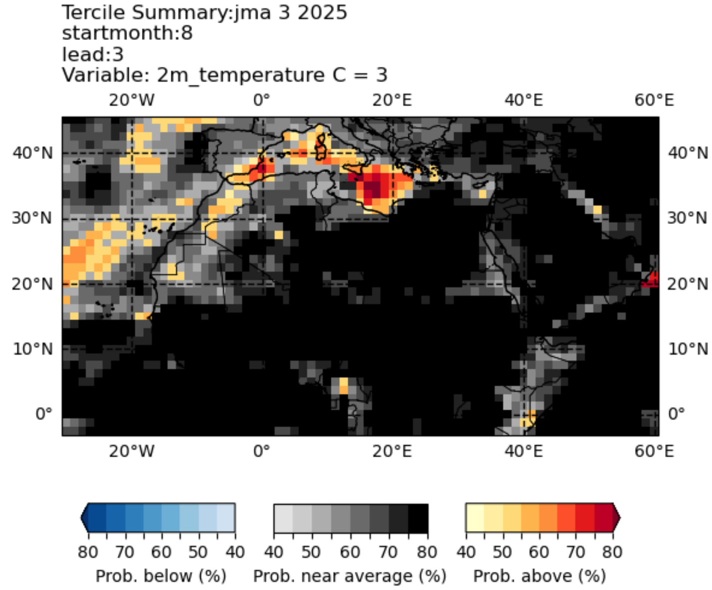

Tercile Summary:dwd 22 2025
Tercile Summary:ncep 2 2025
startmonth:8
lead:3
Variable: 2m_temperature C = 3
20°W 0° 20°E 40°E 60°E
40°N 30°N 20°N 10°N 0°
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)


Tercile Summary:eccc 4 2025
startmonth:8
lead:3
Variable: 2m_temperature C = 3
20°W 0° 20°E 40°E 60°E
40°N 30°N 20°N 10°N 0°
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)


Tercile Summary:eccc 5 2025
startmonth:8
lead:3
Variable: 2m_temperature C = 3
20°W 0° 20°E 40°E 60°E
40°N 30°N 20°N 10°N 0°
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)





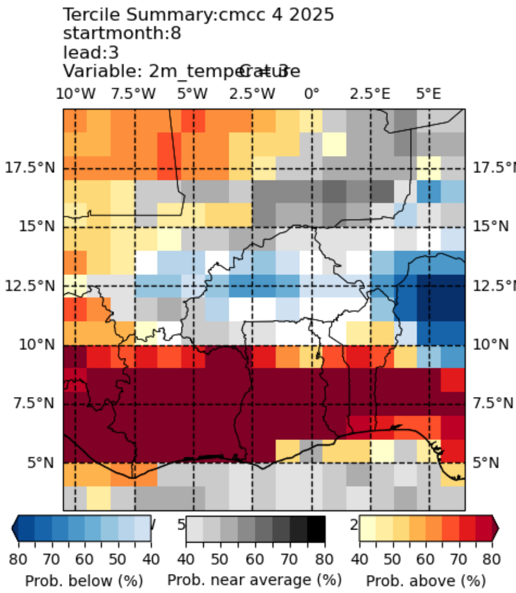


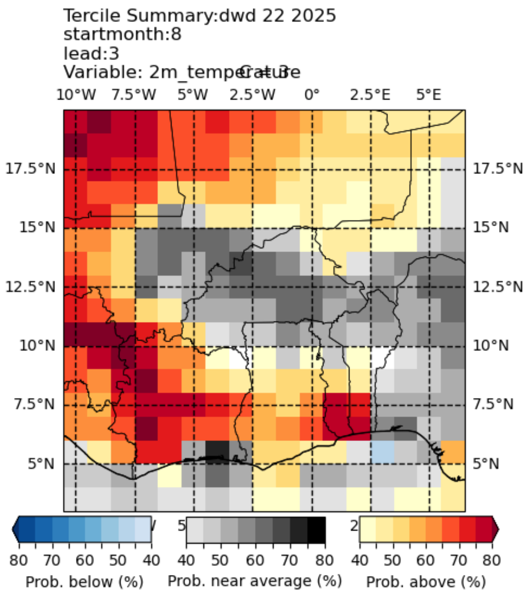
Forecast plots – third-terciles (Burkina Faso domain)

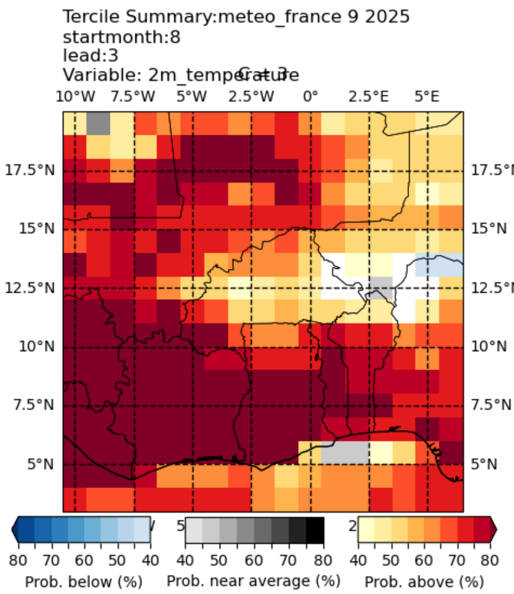
Parameters

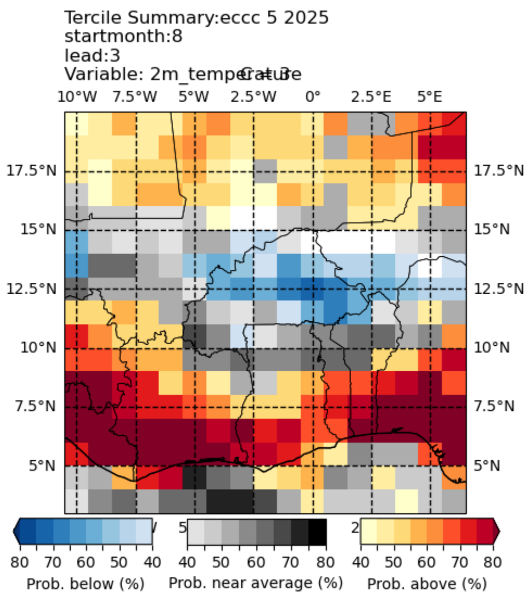
- `month=8` # initialisation month
- `leads="2,3,4"` # e.g. if month=8 and leads="2,3,4", valid months are SON (9,10,11)
- `area="20,-10,3.5-6"` # domain in degrees for area of interest (comma separated N,W,S,E)
- `variable="2m_temperature"` # variable of interest, typically "2m_temperature" or "total_precipitation"

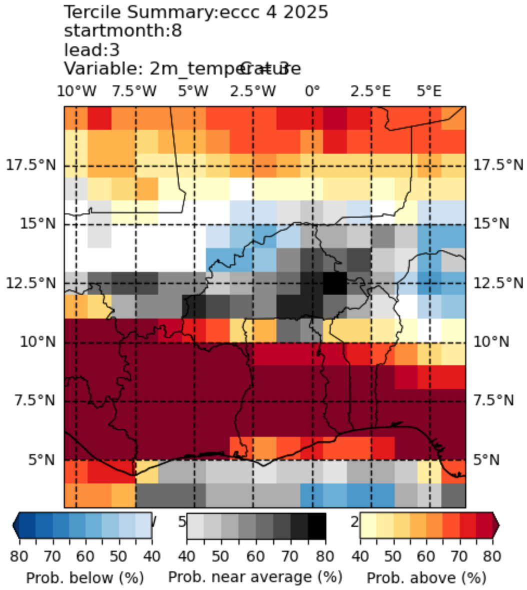
- `location="UK"` #Current options include 'None' - no borders, 'UK', 'Morocco' and 'SAU' - Saudi Arabia

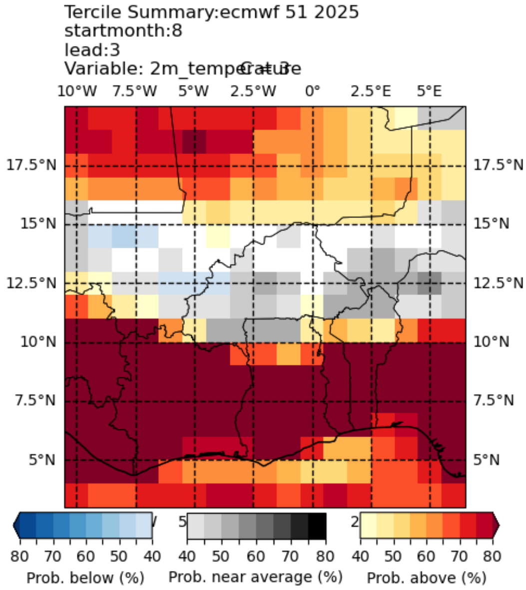


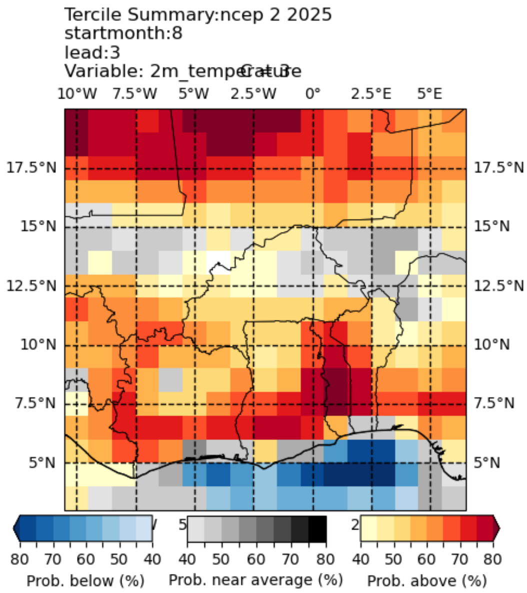


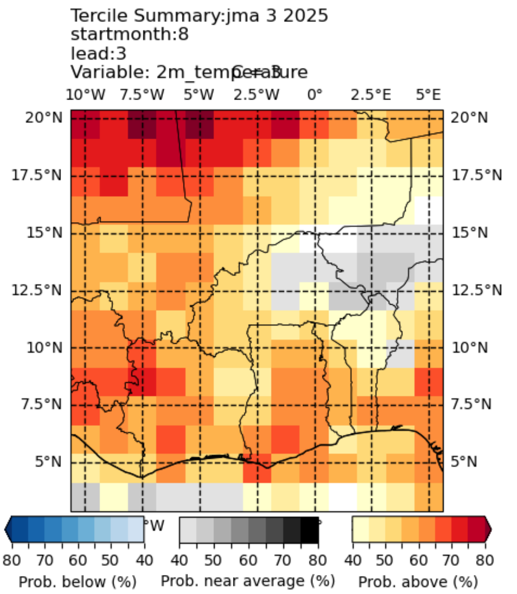


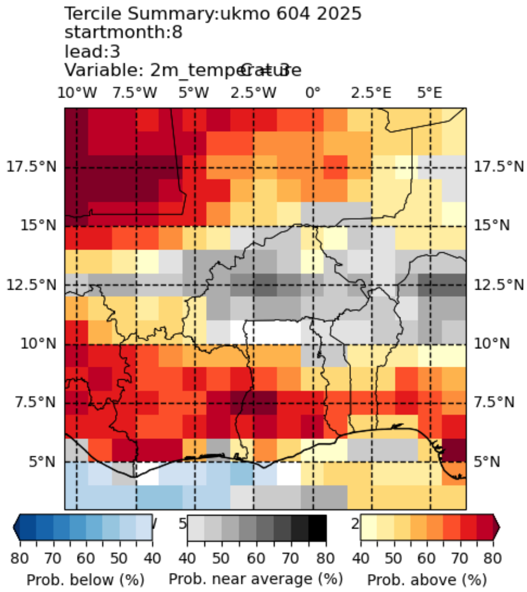



Tercile Summary:eccc 4 2025
startmonth:8
lead:3
Variable: 2m_temperature
Prob. below (%)
Prob. near average (%)
Prob. above (%)


Tercile Summary:ecmwf 51 2025
startmonth:8
lead:3
Variable: 2m_temperature
Prob. below (%)
Prob. near average (%)
Prob. above (%)

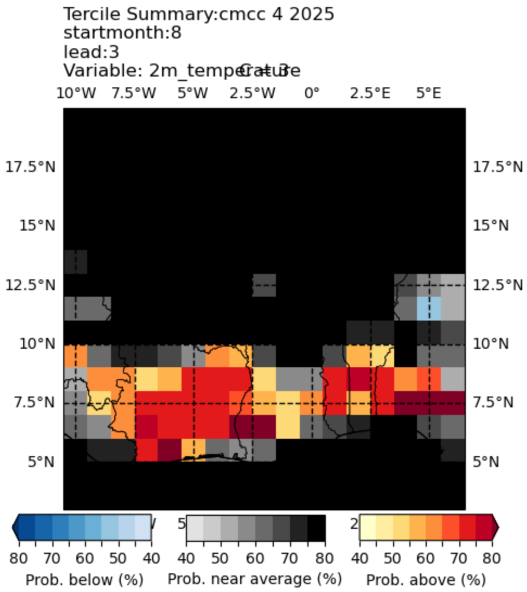

Tercile Summary:ncep 2 2025
startmonth:8
lead:3
Variable: 2m_temperature
Prob. below (%)
Prob. near average (%)
Prob. above (%)

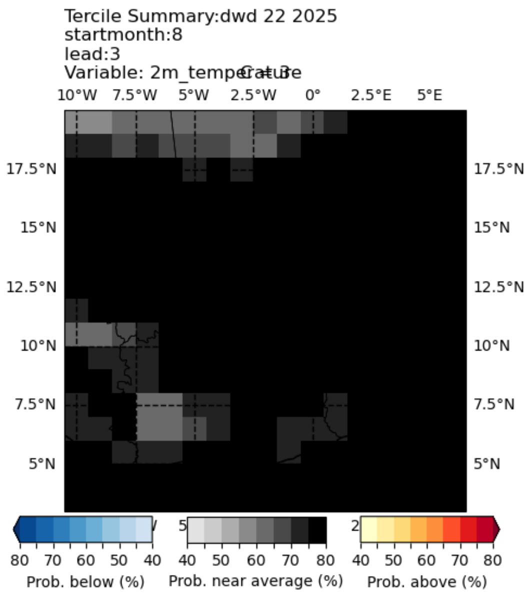

Tercile Summary:jma 3 2025
startmonth:8
lead:3
Variable: 2m_temperature
Prob. below (%)
Prob. near average (%)
Prob. above (%)

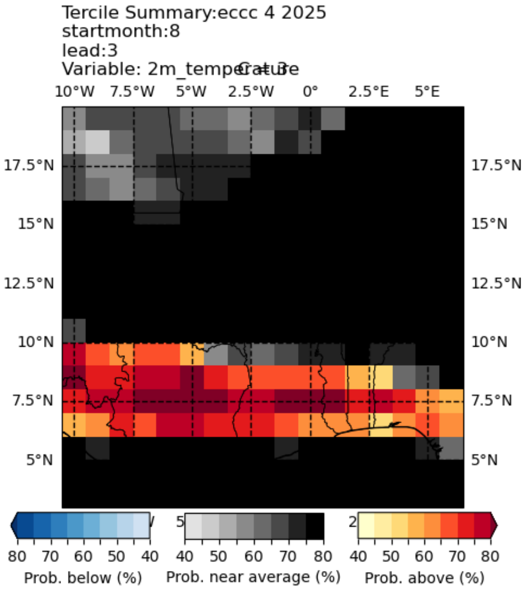


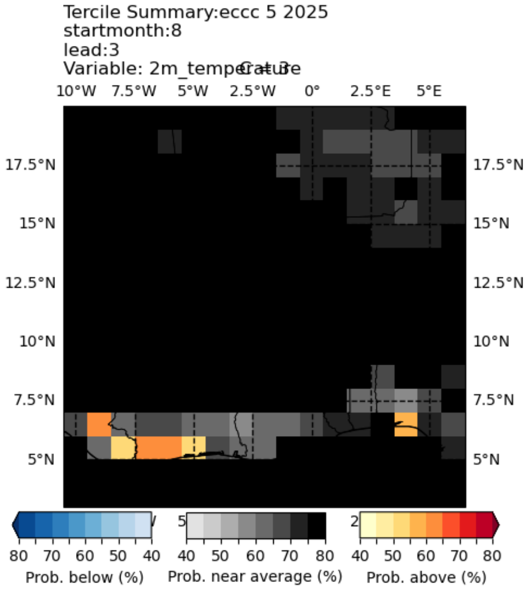
Forecast plots – percentiles (Burkina Faso domain)

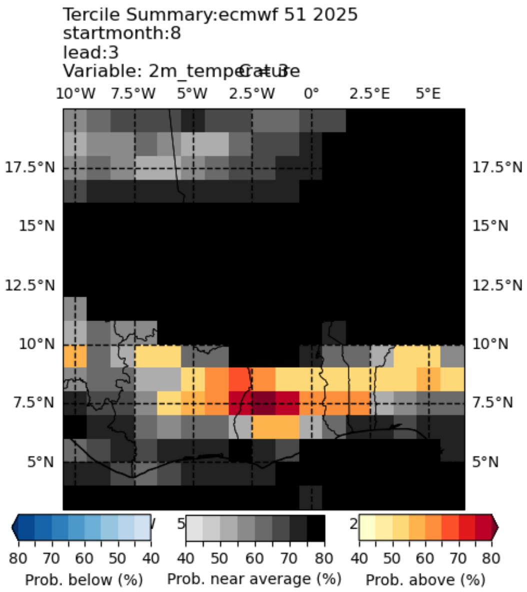
Forecast plot generated for the 10th and 90th percentiles. ‘Near average’ in these plots refers to the middle 80% of seasonal temperatures

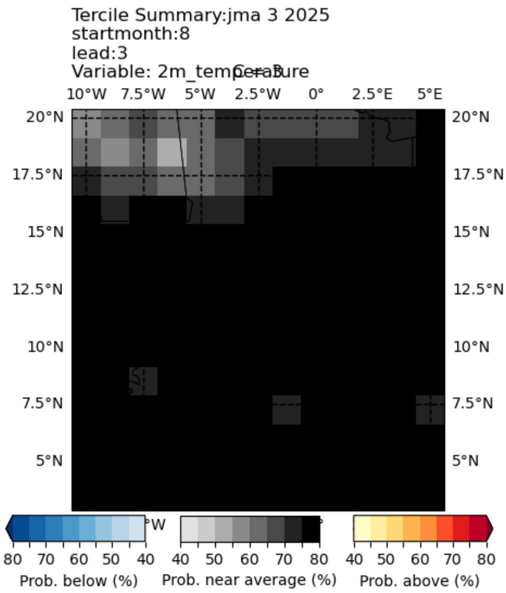


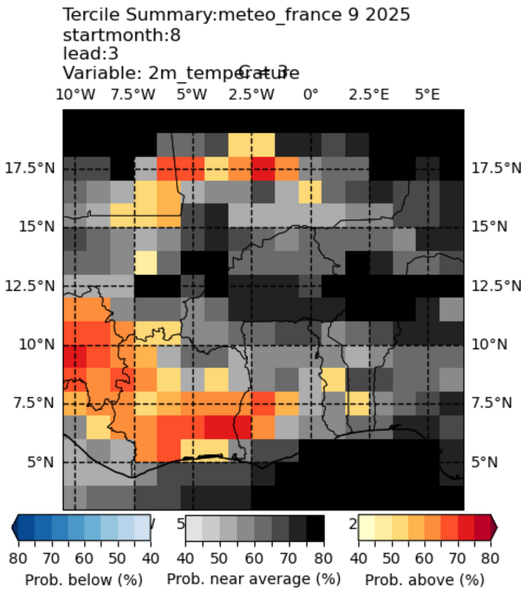


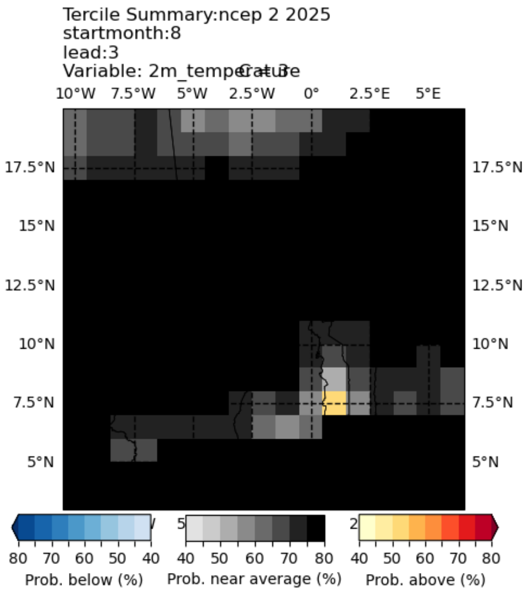

Tercile Summary:eccc 4 2025
startmonth:8
lead:3
Variable: 2m_temperature
10°W 7.5°W 5°W 2.5°W 0° 2.5°E 5°E
17.5°N
15°N
12.5°N
10°N
7.5°N
5°N
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)

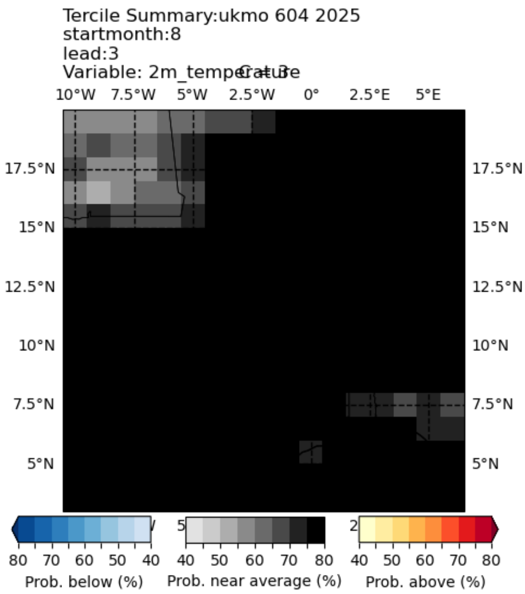

Tercile Summary:eccc 5 2025
startmonth:8
lead:3
Variable: 2m_temperature
10°W 7.5°W 5°W 2.5°W 0° 2.5°E 5°E
17.5°N
15°N
12.5°N
10°N
7.5°N
5°N
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)


Tercile Summary:ecmwf 51 2025
startmonth:8
lead:3
Variable: 2m_temperature
10°W 7.5°W 5°W 2.5°W 0° 2.5°E 5°E
17.5°N
15°N
12.5°N
10°N
7.5°N
5°N
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)


Tercile Summary:jma 3 2025
startmonth:8
lead:3
Variable: 2m_temperature
10°W 7.5°W 5°W 2.5°W 0° 2.5°E 5°E
20°N
17.5°N
15°N
12.5°N
10°N
7.5°N
5°N
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)


Tercile Summary:meteo_france 9 2025
startmonth:8
lead:3
Variable: 2m_temperature
10°W 7.5°W 5°W 2.5°W 0° 2.5°E 5°E
17.5°N 15°N 12.5°N 10°N 7.5°N 5°N
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)


Tercile Summary:ncep 2 2025
startmonth:8
lead:3
Variable: 2m_temperature
10°W 7.5°W 5°W 2.5°W 0° 2.5°E 5°E
17.5°N 15°N 12.5°N 10°N 7.5°N 5°N
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)


Tercile Summary:ukmo 604 2025
startmonth:8
lead:3
Variable: 2m_temperature
10°W 7.5°W 5°W 2.5°W 0° 2.5°E 5°E
17.5°N 15°N 12.5°N 10°N 7.5°N 5°N
80 70 60 50 40
Prob. below (%)
40 50 60 70 80
Prob. near average (%)
40 50 60 70 80
Prob. above (%)

AI transparency statement: This document was reviewed and refined using Microsoft Copilot to enhance the clarity, grammar, spelling, and overall quality of the writing. all AI-generated suggestions were reviewed and verified by a scientist to ensure accuracy and quality.