AEMet

WMO Northern Africa RCC Network

WMO RA VI RCC Network

MedCOF Mediterranean Climate Outlook Forum

WMO OMM

Production of OSF for Mediterranean region
On-line Training Workshop
31st May 2022

Introduction to operational Objective Seasonal Forecasting

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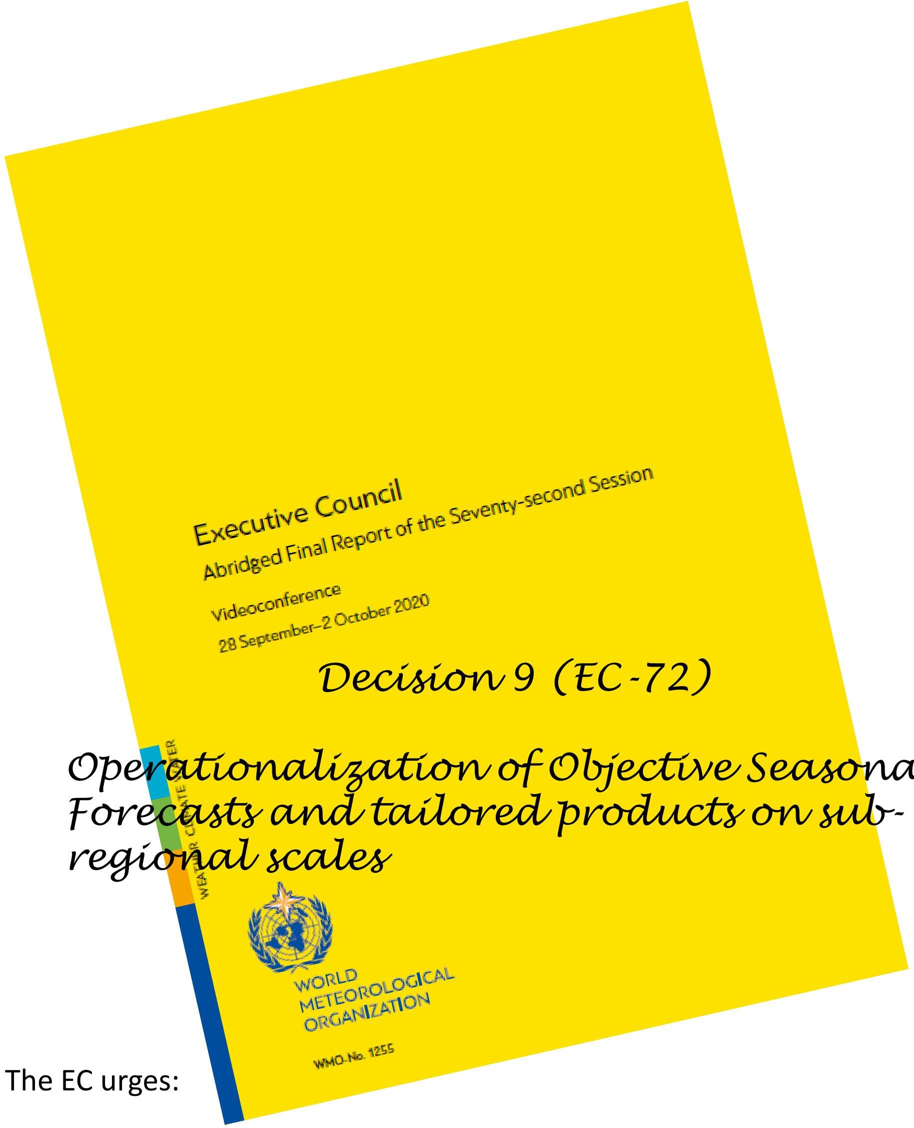
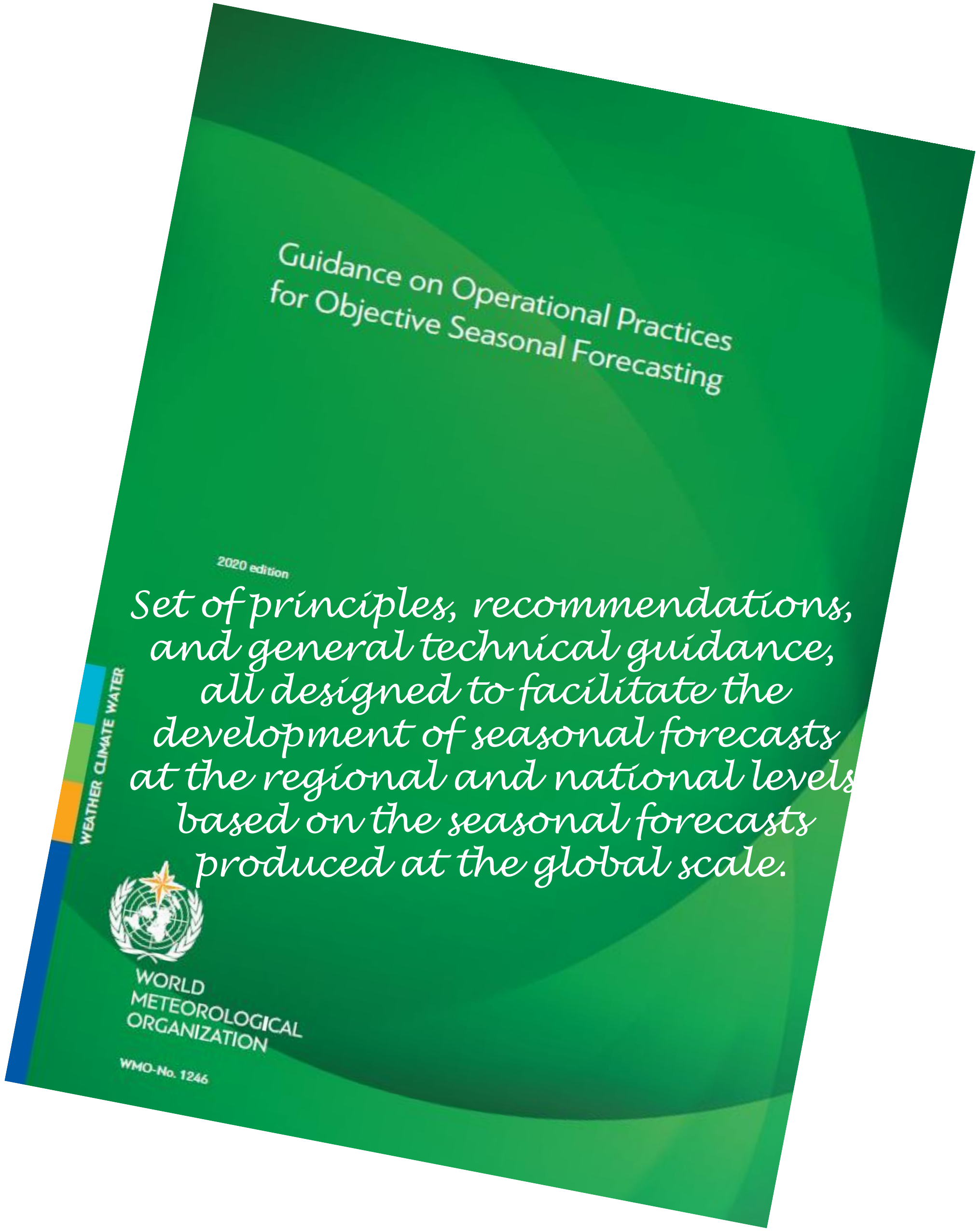


Decision 9 (EC-72)

Operationalization of Objective Seasonal Forecasts and tailored products on sub-regional scales

The EC urges:

(a) RCCs, RCC networks and other relevant organizations cooperating on RCFs worldwide to actively contribute to the implementation of the proposal in the respective regions;
(b) WMO GPCs for LRF and the LC for MME LRF to facilitate access to required data sets and ensure timely and regular provision of objective sub-seasonal and seasonal forecast products, in suitable formats to RCCs, RCFs, and NMHSs



Set of principles, recommendations, and general technical guidance, all designed to facilitate the development of seasonal forecasts at the regional and national levels based on the seasonal forecasts produced at the global scale.

Guidance on Operational Practices for Objective Seasonal Forecasting. WMO-No. 1246

Content

4. GUIDANCE ON GOOD PRACTICES FOR DEVELOPING OBJECTIVE SEASONAL FORECASTS

- 4.1 Catalogue and document regional climate variability and its drivers
  - 4.1.1 Document seasonal climatology
  - 4.1.2 Document climatology for the drivers of climate variability
  - 4.1.3 Document recent trends.
- 4.2 Establish a schedule for seasonal forecasts
- 4.3 Review and document the performance of issued forecasts
- 4.4 Provide a discussion of the current state of the climate to set the context for the seasonal forecast for the coming season(s)
- 4.5 Provide seasonal forecasts in probabilistic format
- 4.6 Provide a discussion of the physical basis for the seasonal forecast
- 4.7 Establish feedback mechanisms and engagement with users
- 4.8 Recommend an approach for producing operational objective seasonal forecasts
- 4.9 Establish good practices for communicating seasonal forecasts
  - 4.9.1 Include information about past forecast quality
  - 4.9.2 Include guidance on the interpretation of forecast probabilities
  - 4.9.3 Include a discussion on managing user expectations .
- 4.10 Good practices for establishing and maintaining credibility
  - 4.10.1 Using objective methods which are reproducible and traceable
  - 4.10.2 Ensuring that methods are properly documented
  - 4.10.3 Maintaining archives of past seasonal forecasts.
  - 4.10.4 Verification as part of seasonal forecast quality assurance.

Drawbacks of current practices in many RCOFs

- a subjective, consensus-based forecast process that is **neither traceable nor reproducible**;
- forecasts are packaged in a **fixed, one size-fits-all tercile probability format** that seldom addresses the requirements of specific applications;
- forecasts are generally **unavailable in digitized form**, and therefore, if needed, cannot be used in terms of quantitative inputs feeding into application models or decision support tools;
- forecasts are **not amenable to standardized verification** and skill assessments, thereby making forecast quality ambiguous, and also making future improvements difficult;
- forecast preparation requires a **high degree of manual activity**, which limits the frequency of forecast updates and the diversity of products.

Further regional documents (I)

- Guidance for Mediterranean Climate Outlook Forum (MedCOF) sub-region to enable operational production of objective seasonal forecasts (8th July 2021)

Outline

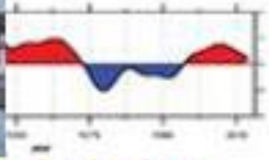
1. Introduction
2. Current MedCOF operations
3. Identify needs and gaps
4. Guidance objective seasonal operational forecast
5. Summary of recommendations

Further regional documents (II)

- Annex: Summary of discussion on Guidelines for Objective SF (Dec 2021)

  - **Most participants are firm defenders of the consensus maps** as a fundamental outcome of MedCOF, whereas many of them point out that the existence of gridded data would be useful.
  - A **MedCOF multi-model** would be better than using applications based C3S data.
  - **Weighted combination of models and/or members** was the preferred option for combining SFSs although a simple model selection could be reasonably an initial first step in the development process.
  - Importance of analyzing both the **current situation and its probable evolution in terms of drivers and variability patterns** as a key factor for helping to understand and communicate climatic parameters forecasts in a coherent way.
  - Agreement on the **need of additional human resources**, being mentioned the possibility of hiring dedicated personnel during transition to OSF, although depending on available funds. A quick survey done live during the meeting showed that for most participants two years is a reasonable time for keeping parallel operations.
  - Exploration of different ways of **incorporating empirical information** to the process and of blending it with information coming from models. The possibility of using Machine Learning techniques in addition to linear procedures was also pointed out. General agreement on the idea of starting operations from a simple approach and adding complexity with a steady evolution of methods and procedures.
  - **Human resources and training** were identified as the main critical points for the implementation of OSFs and the subsequent development of downstream applications.
  - **Harmonization** with the rest of RCOFs around the world
  - **Detailed survey** among the MedCOF community in order to have a more accurate idea about their resources, needs and preferences with regard to some of the main issues raised during the two PreCOF events (29th Nov and 16th Dec 2021).

ERA4CS MEDSCOPE: designed as the scientific arm of MedCOF



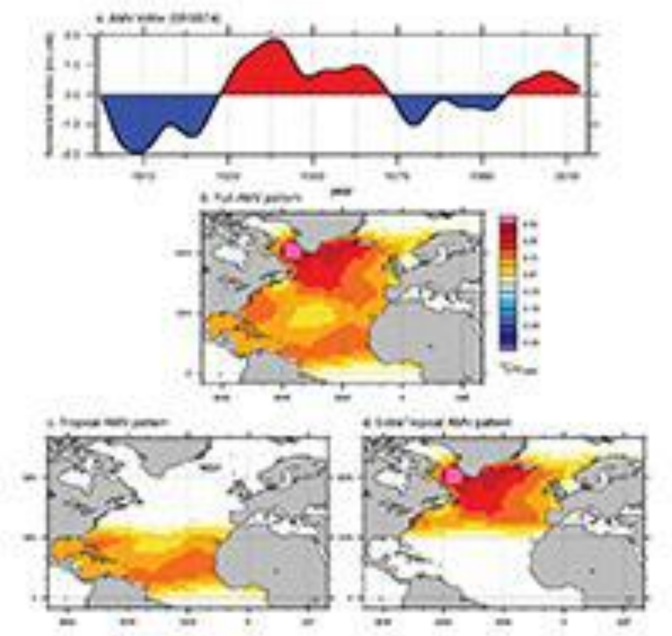
MedCOF community and national users

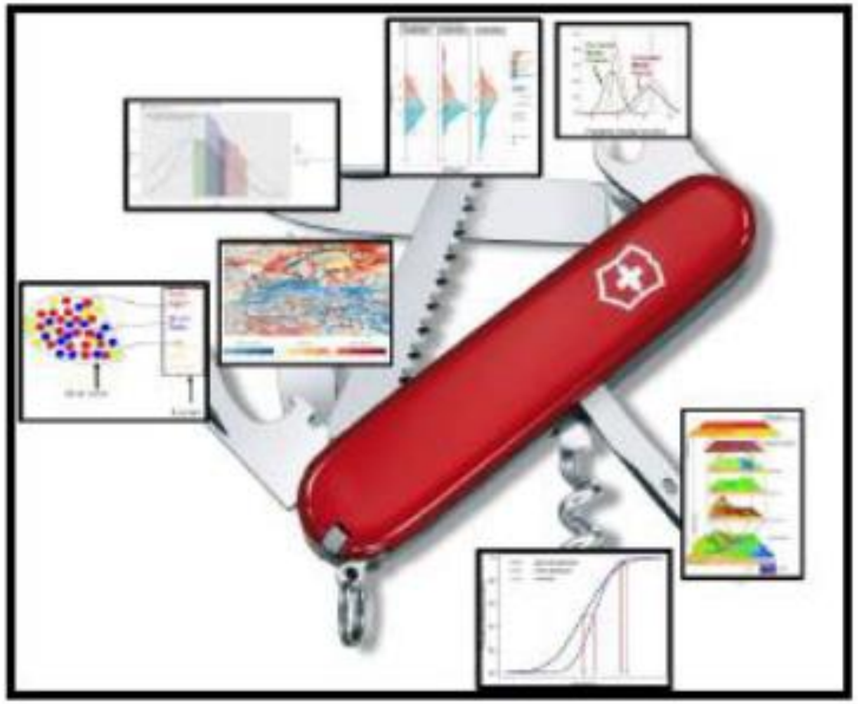
Research community and seasonal forecast producers (e.g. Copernicus)

(Thanks to S. Gualdi, CMCC)

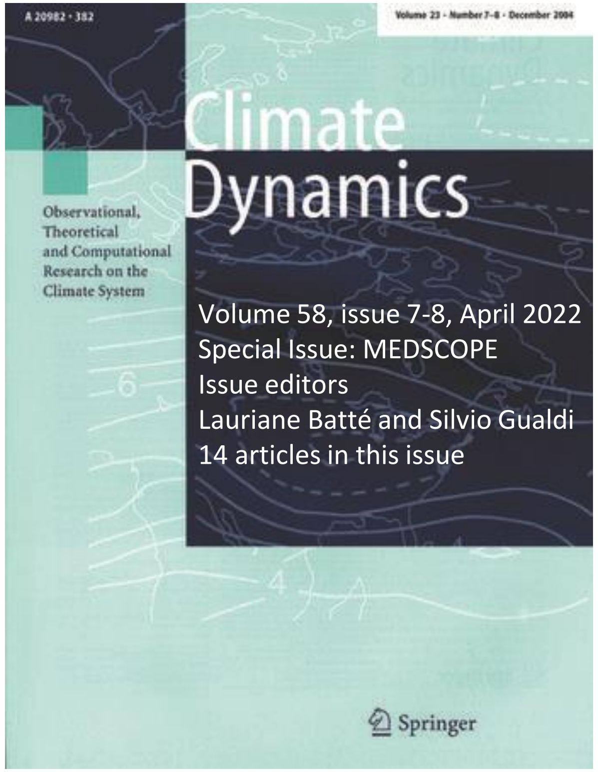
ERA4CS MEDSCOPE Project:

main objectives

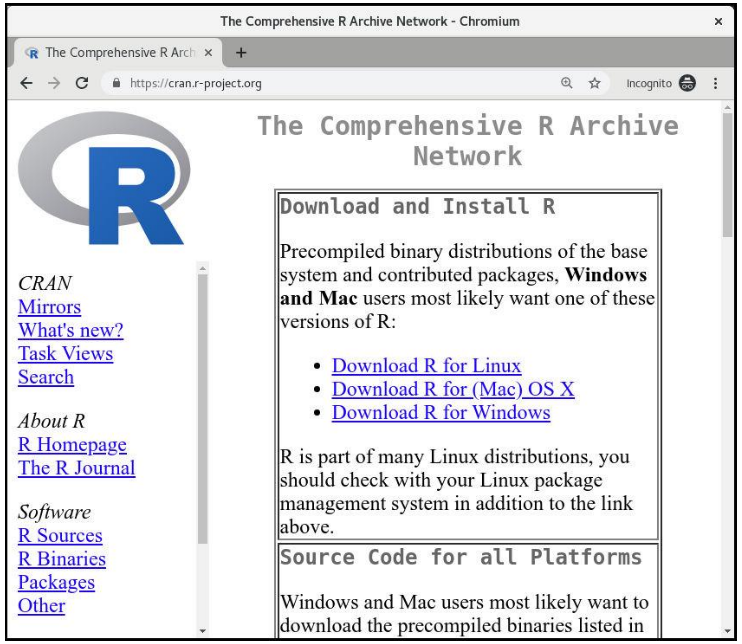




ERA4CS MEDSCOPE Project:
output



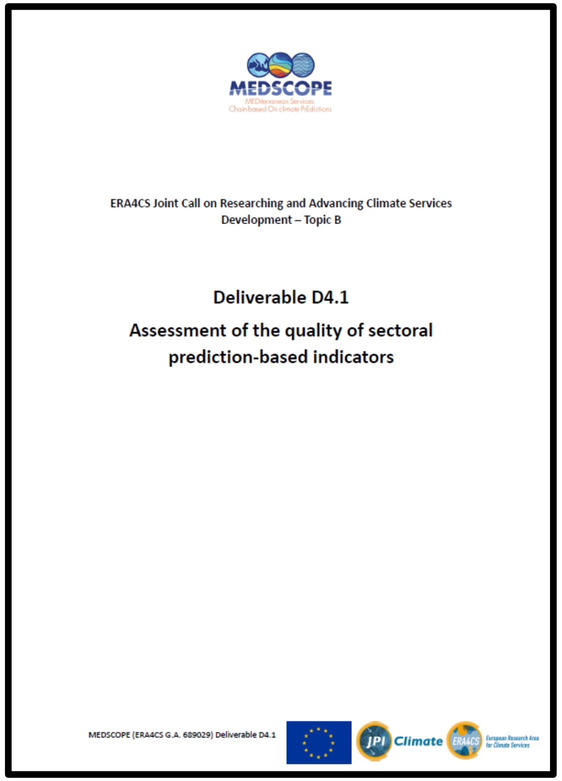
MEDSCOPE Special Issue: advancing the understanding of variability and predictability over the Mediterranean region at seasonal to decadal time scales



Climate Services Toolbox (CSTools) primarily designed to merge all the required steps on seasonal forecast post-processing

Climate Services developed and evaluated for 3 sectors: renewable energy, water and agroforestry

Climate services based on seasonal predictions for the Mediterranean


MEDSCOPE

ERA4CS Joint Call on Researching and Advancing Climate Services Development – Topic B

Deliverable D4.1

Assessment of the quality of sectoral prediction-based indicators

MEDSCOPE (ERA4CS G.A. 689029) Deliverable D4.1

- A detailed description of all services developed during the project -including their evaluation is provided in deliverable D4.1 (available from https://www.medscope-project.eu)

- Co-production of Climate Services: A diversity of approaches and good practice from the ERA4CS projects (2017–2021). https://doi.org/10.3384/9789179291990

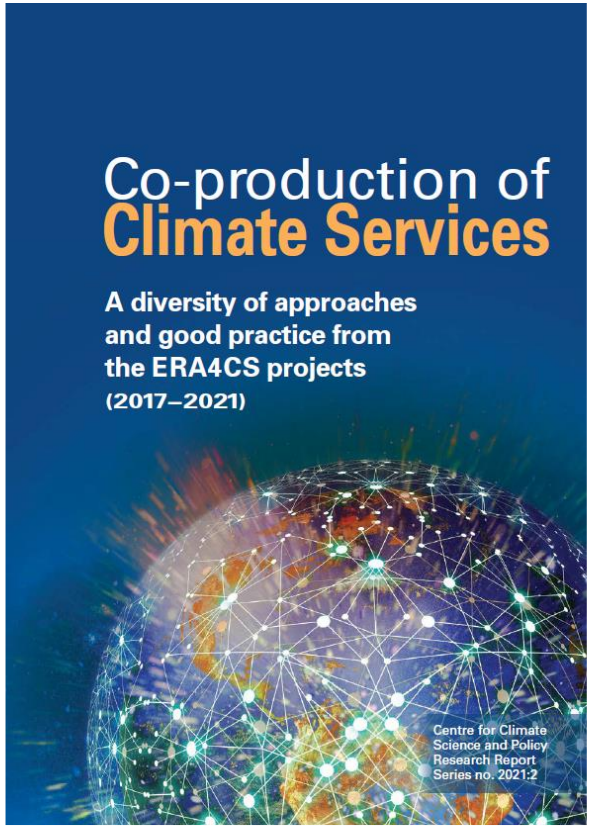
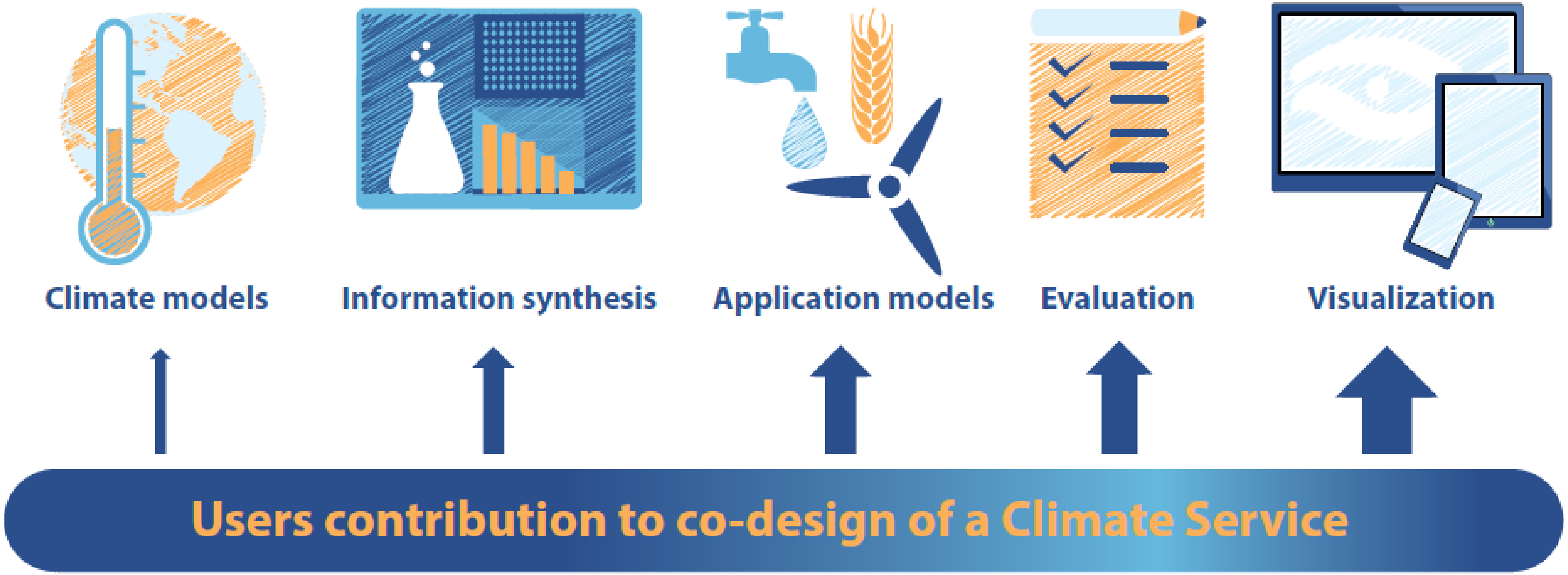
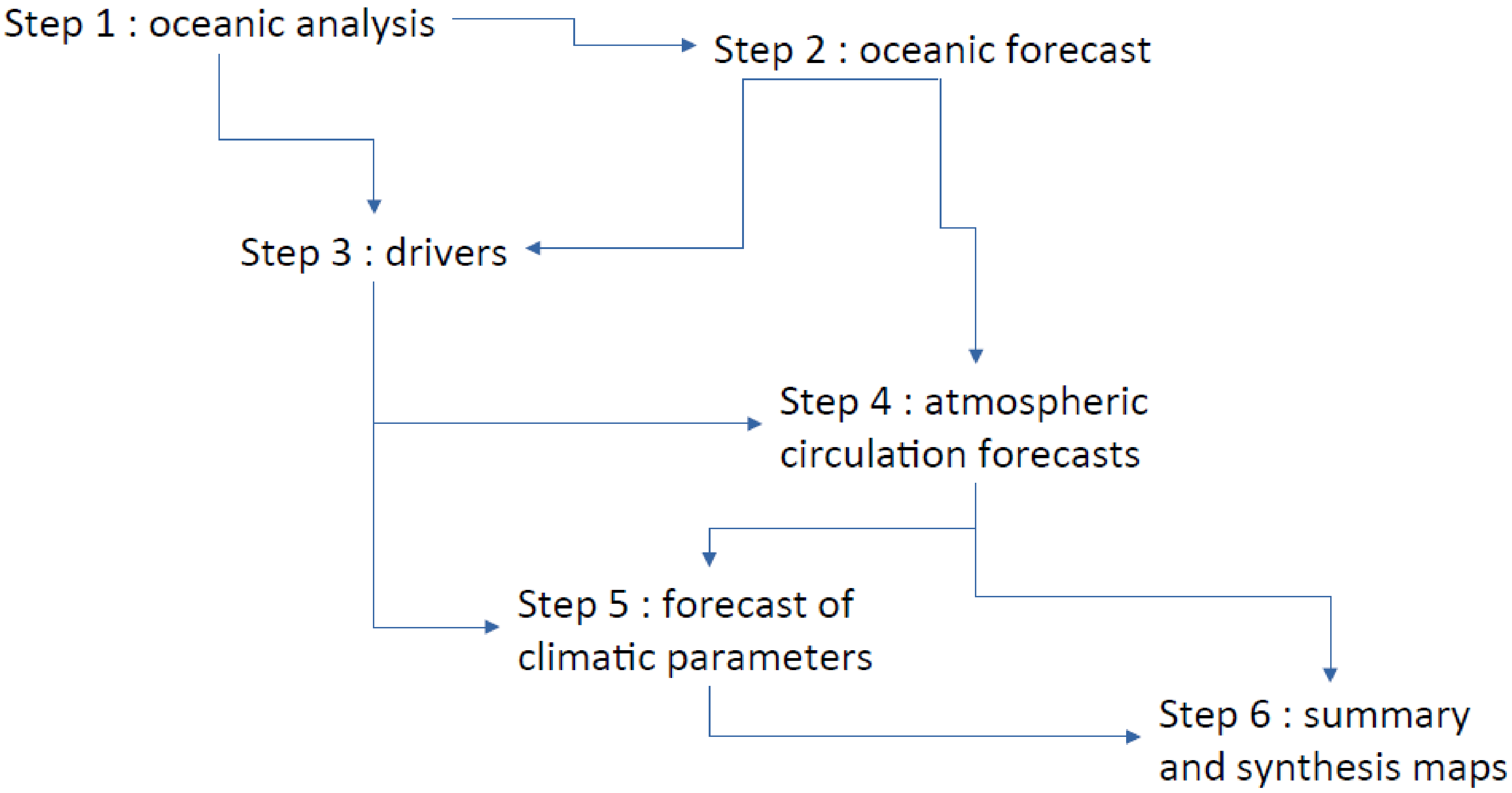


Diagram with a simplified climate services chain based on climate predictions. Users' contribution to co-design is represented by the gradual increase in thickness of the arrows



Máñez Costa et al. (2021). Co-production of Climate Services. CSPR Report No 2021:2, Centre for Climate Science and Policy Research, Norrköping, Sweden. https://doi.org/10.3384/9789179291990

Current MedCOF procedure



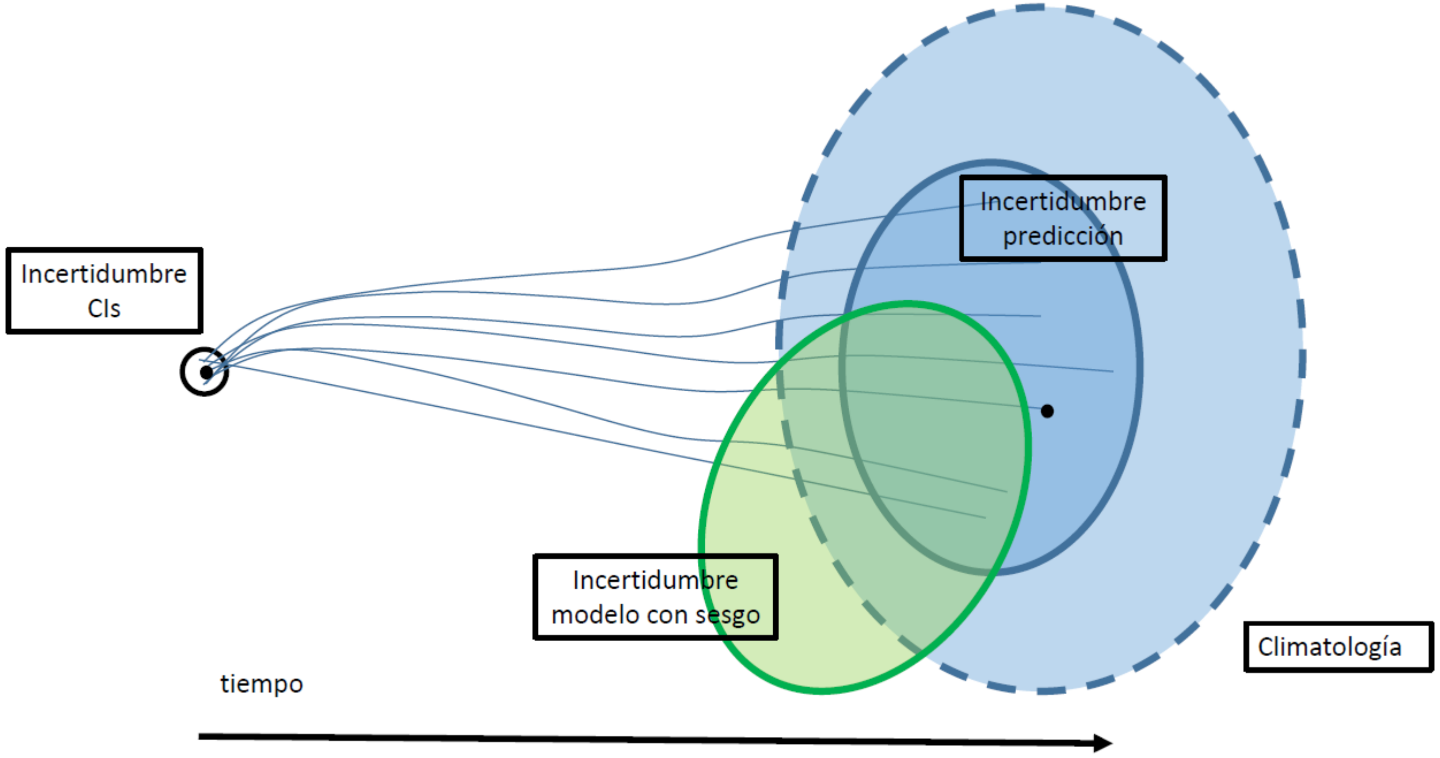
Recommendations for producing operational objective seasonal forecasts (WMO 2020)

- Follow a **traceable, reproducible, and well-documented** procedure (including **model selection, bias correction, calibration and statistical downscaling**) that is amenable to assessments of forecast quality (verification);
- Use **dynamical climate models**, including multi-model ensembles, as the primary basis for seasonal forecasts;
- Maintain **observational databases** of adequate quality, length of record and spatial resolution **for verification, bias correction and calibration** and to **monitor drivers** of seasonal predictability;
- Identify and monitor **drivers of predictable climate variability** and assess their **representation** in models;
- Ensure that **forecasts are verified** according to established standards;
- Provide **forecast information together with historical performance** (for example, skill and reliability);
- Use clear and non-technical language to **communicate seasonal forecasts**, including **emphasizing the probabilistic**
- **Collaborate across regions** influenced by the same climate drivers in forecast production through e.g. **RCOFs**;
- Provide seasonal forecasts as well as regular updates on a **fixed operational schedule**;
- Establish **user feedback** and product upgrade mechanisms and support co-production of tailored products.

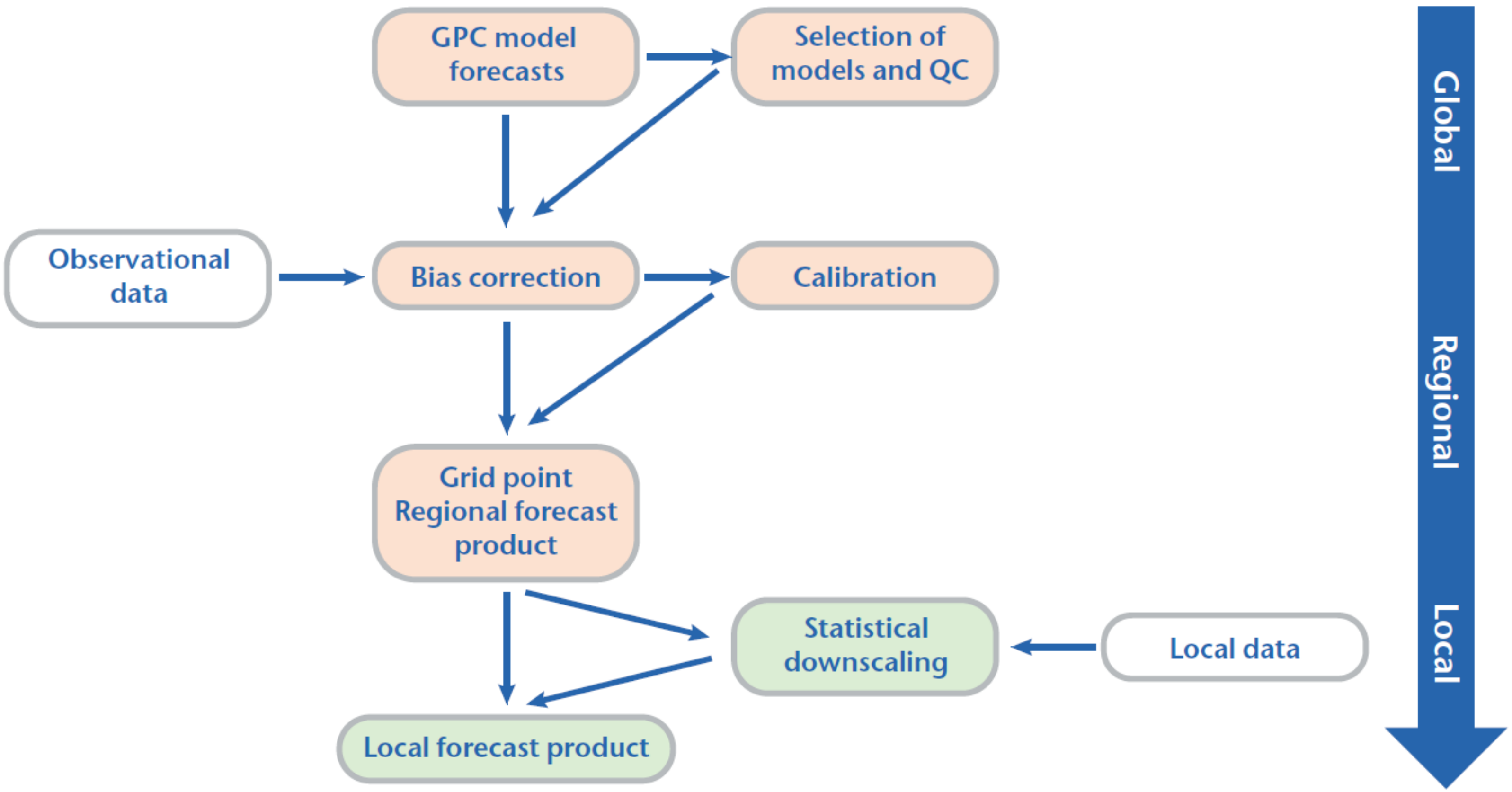
Models have their own climatology

Two broad categories for corrections for systematic errors:

- **Bias correction**: adjusts properties of the **modelled climate to match those of the observed climate** without reference to prediction quality or skill, in other words, without pairing hindcasts and observations.
- **Calibration**: modifies forecast values to optimize hindcast quality or skill. It requires consideration of **paired hindcast and observed values**



Recommended procedure for developing SFs at the regional and national levels (WMO 2020)



An outline of the recommended procedure for developing seasonal forecasts at the regional and national levels starting from the forecasts from GPCs-LRF (WMO 2020)

The CSTools Toolbox

Retrieval and transformation	CST_Load, CST_Anomaly, CST_SaveExp, CST_MergeDims, CST_SplitDims, as.s2dv_cube, s2dv_cube
Classification	CST_MultiEOFS, CST_WeatherRegimes, CST_RegimesAssign, CST_CategoricalEnsCombination
Downscaling	CST_Analogs, CST_RainFarm, CST_RFTemp, CST_AdamontAnalogs, CST_AnalogsPredictors
Correction	CST_BEI_Weighting, CST_BiasCorrection, CST_Calibration, CST_QuantileMapping, CST_DynBiasCorrection
Assessment	CST_MultiMetric, CST_MultivarRMSE
Visualization	PlotCombinedMap, PlotForecastPDF, PlotMostLikelyQuantileMap, PlotPDFsOLE, PlotTriangles4Categories

Table 1.-. Summary of the functions and methods by category. Prefix CST refers to functions working on a specific object class called s2dv_cube (from Perez-Zanón et al. 2021a).

- The package contains process-based state-of-the-art methods for loading and transformation requirements, forecast calibration, bias correction, statistical and stochastic downscaling, optimal forecast combination and multivariate verification, as well as basic and advanced tools to obtain tailored products.
- All functions are documented in a standard reference manual on the CRAN website (https://CRAN.R-project.org/package=CSTools).
- The documentation also includes vignettes describing some of the methodologies included in CSTools, as well as information on how to use the package to conduct specific analysis.
- Thanks to the toolbox design in individual functions, users can develop their own post-processing chain.

C3S → Quality Assurance for Multi-model Seasonal Forecast Products (QA4Seas)

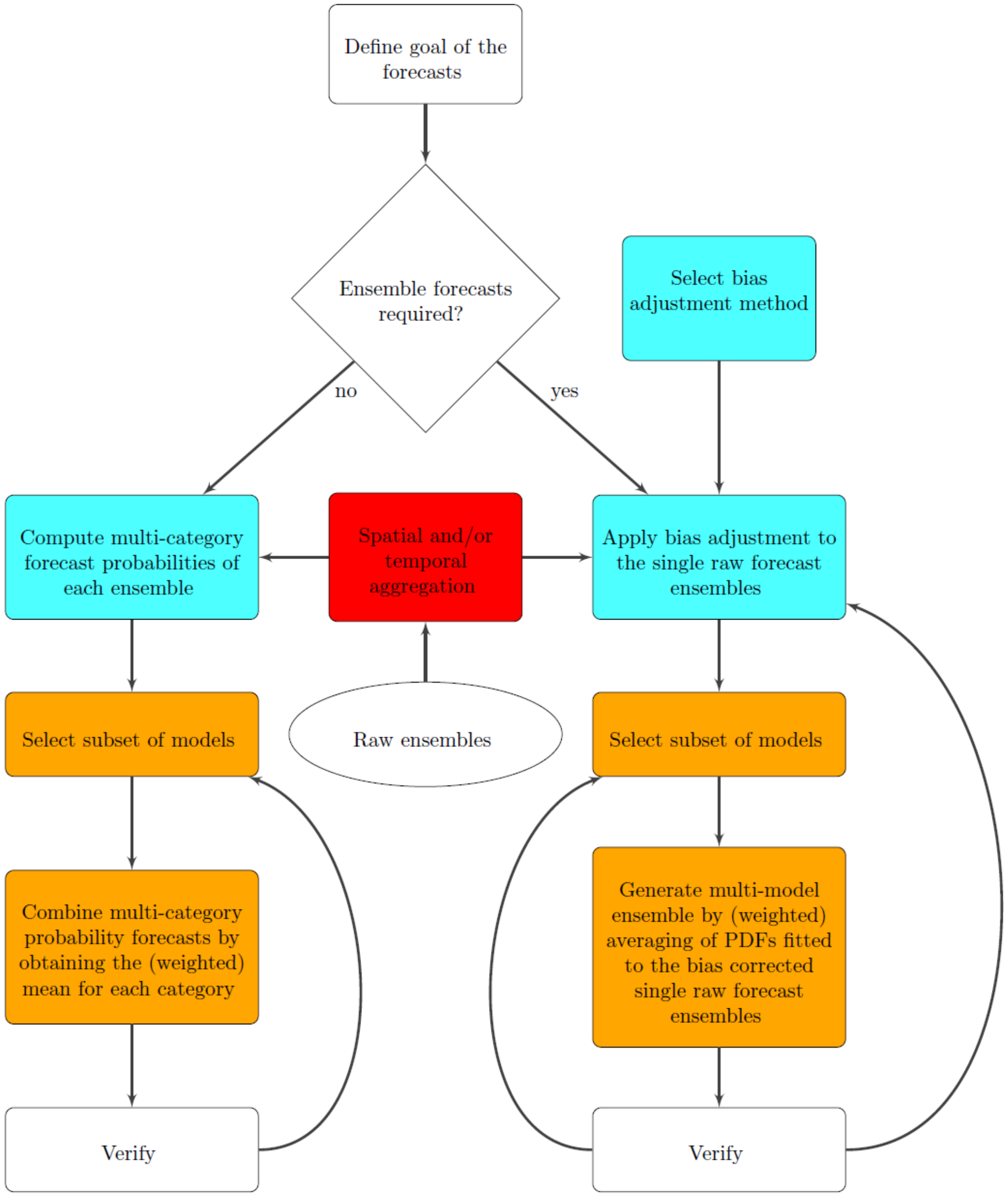


Fig. 1 Flowchart illustrating the generation of seasonal forecast products within the framework of QA4Seas. The box colors refer to the processing steps defined in Sect. 4: **a** aggregation in red; **b** bias correction in cyan; **c** combination in orange

Combination approach should depend on the purpose of the system:

- If the **final product is simply probabilities** for climatic parameters falling in different categories →, probability averages for every category usually provide the best result.
- If SF data are intended for **feeding sectorial applications**, a complete ensemble is needed → evaluation of different calibration techniques and combination procedures to build a multimodel ensemble

Hemri et al. 2020: How to create an operational multi-model of seasonal forecasts?

No general consensus

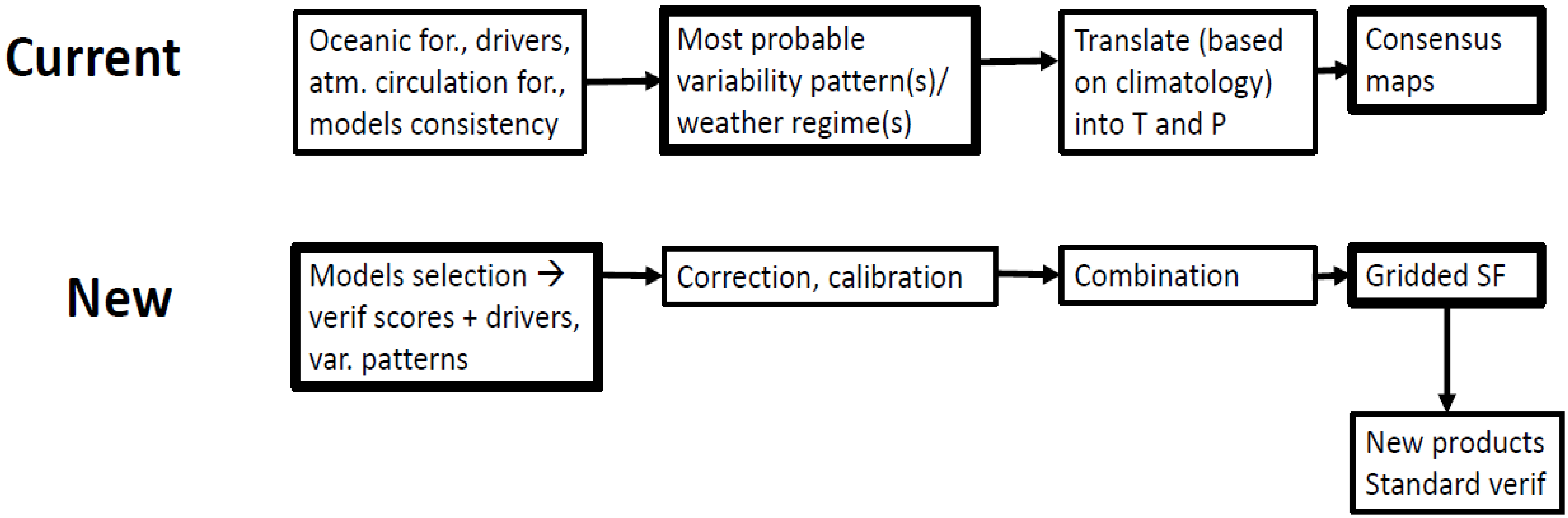
on how to post-process and assess seasonal MME predictions

→ different possible strategies

However:

- Typically, **MM combination of seasonal ensemble forecasts leads to a forecast skill, which is greater than the one of the best single forecast system**. Besides error compensation, multi-model combination also improves consistency and reliability.
- The effects of **MM combination and single model calibration on forecast skill are comparable**.
- **MMs tend to benefit less from additional calibration than single models**.
- Effects of calibration and multi-model combination vary **strongly among geographical areas, variables, and the forecast models** considered.
- Some results indicate that a **simple equally weighted multi-model on average outperforms** two different unequally weighted multi-models.
- Sophisticated processing of seasonal forecasts is impaired by the **small sample size of less than 30 years of hindcasts**.

Current versus new approaches to SF

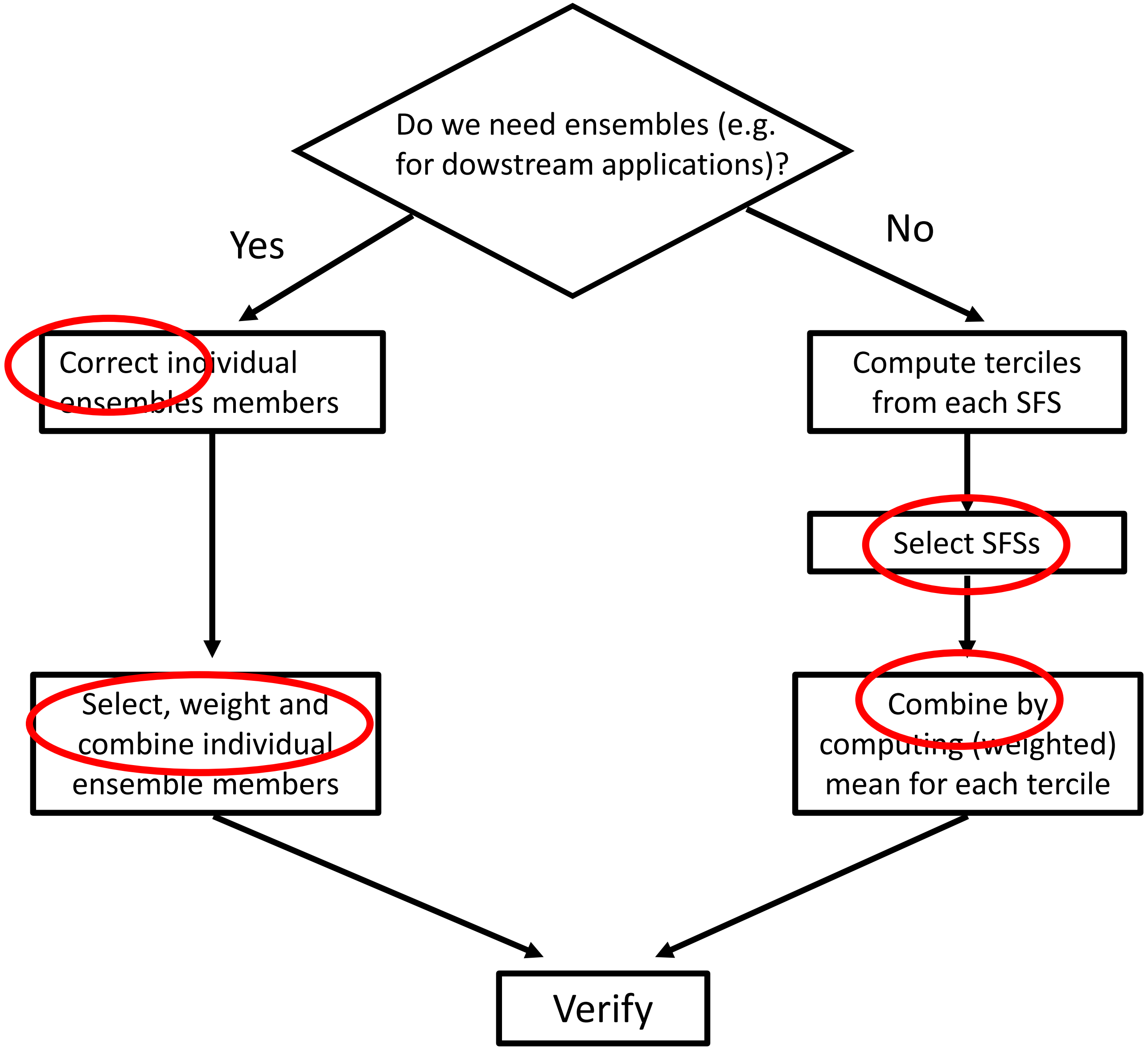


Recommendations for implementing MedCOF OSF (I)

- **Two successive lines of development**: i) Provide data of categorical forecasts by giving the probability for each category. This line would be based on averaging probabilities for each category and could initially skip any forecast correction. ii) Delivery of ensemble members including their previous correction and calibration and some strategy for their combination. More appropriate for development of complex downstream climate services
- The new objective procedure for generating MedCOF SFs could be initially **implemented in parallel with the current consensus** forecast to facilitate the transition between both procedures and to compare their performance. The new procedure corresponding to the first line will be based on a multi-model system paying special attention to the selection and combination of models. Criteria and metrics for models selection will be a priority task to be agreed and coordinated with North African and RA VI RCC LRF nodes and sub-regional RCOFs.
- As **C3S models** meet more common characteristics -related to spatial/temporal resolution, minimum hindcast period, minimum ensemble size for hindcast and forecast, coupled atmosphere–ocean systems, issuance time, etc.- than WMO LRF MME models, it is recommended as an initial option to make the selection of models among the 8 C3S models.
- Considering the large-scale fidelity of simulations as criteria for selection, it is **advisable to select models based on an analysis of their ability to simulate climate drivers, climate variability patterns and teleconnections** that are relevant at a seasonal scale over the region of interest.

Recommendations for implementing MedCOF OSF (II)

- As for hindcast periods shorter than 50 years, **unequal weighting schemes are unlikely to improve upon the results of an equal weighting** scheme and given the simplicity of blending by averaging among the selected models, it seems recommendable to start the operations using this approach and at the same time progress with the development of more advanced weighting methods.
- Historical performance of MedCOF objective seasonal forecast, based on hindcast with a sufficient number of years and members, should be computed following **standard verification procedures** (WMO 2018) and made accessible to users together with the forecast itself.
- Additionally to forecasts verification from hindcast, data should be also **made freely available for downstream services** developers and users to facilitate the evaluation of new climate services based on MedCOF OSFs.
- A **rational distribution of work among the twinned RCC** nodes from RA VI (MF) and North African (DMN) jointly with other MEDSCOPE project partners (e.g., CMCC, BSC and AEMET).
- Efforts aiming at a **fully exploitation and operational implementation of research results obtained from the MEDSCOPE** project should be pursued. In particular through the optimal application of available CSTools functions.
- Given the diverse level of development and expertise on operational seasonal forecasting within the MedCOF region, PreCOF events devoted to **facilitate knowledge sharing and transferring among participant countries should be fostered**.



Define strategy

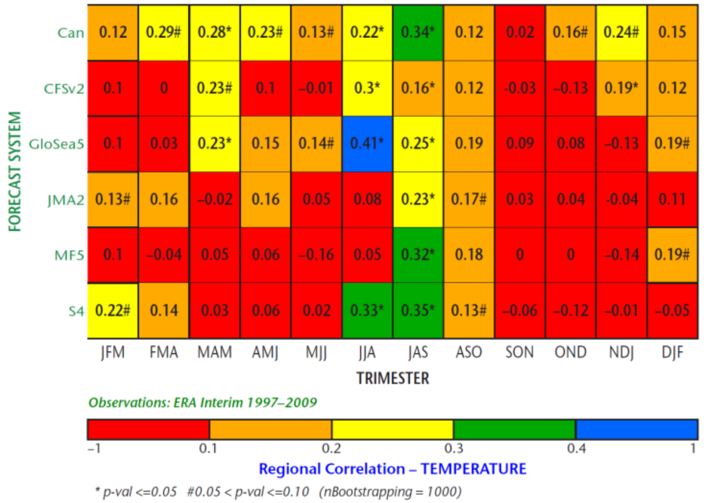
- Selection: methods/metrics
- Combination procedure
- Verification scores

Selecting the most appropriate model(s) (I)

- Different models have different biases that influence their ability to predict the observed climate in light of varying climate situations and for various regions. For **one climate situation and region, one model may be preferable**; however, this same model may not be appropriate for use in other regions and seasons.
- Moreover, for some regions and seasons, the **relatively short historical hindcast period** that is generally available may **prevent an unequivocal identification of the best model(s)**.

Selecting the most appropriate model(s) (II)

- Selection of a **set of candidate seasonal forecasting models**. By default, the 13 models included in the WMO LC-LRFMME share a **minimum list of characteristics related to spatial/temporal resolution, minimum hindcast period, minimum ensemble size for hindcast and forecast, minimum issuance frequency,** and so forth.
- **Regional performance** of seasonal forecasting systems.
  - A comparison of **objective verification scores** computed over a common hindcast period provides insight on the quality of different systems. Also recommended that **two observational datasets** be used for verification purposes in order to check the dependency of results on the observational dataset selected.
  - Ability of models to **simulate climate drivers, climate variability patterns and teleconnections** that are relevant at a seasonal scale over the region of interest. Once the relevant drivers and variability patterns have been identified for all seasons, in addition to assessing the skill of the forecast system based on hindcasts, it is a good practice to analyse candidate models for their ability
    - i) to forecast patterns that contribute to the climate variability for each season and
    - ii) to simulate the proper teleconnections linking remote drivers and climate variability patterns.



FORECAST SYSTEM	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ	DJF
Can	0.12	0.29#	0.28*	0.23#	0.13#	0.22*	0.34*	0.12	0.02	0.16#	0.24#	0.15
CFSv2	0.1	0	0.23#	0.1	−0.01	0.3*	0.16*	0.12	-0.03	−0.13	0.19*	0.12
GloSea5	0.1	0.03	0.23*	0.15	0.14#	0.41*	0.25*	0.19	0.09	0.08	−0.13	0.19#
JMA2	0.13#	0.16	−0.02	0.16	0.05	0.08	0.23*	0.17#	0.03	0.04	-0.04	0.11
MF5	0.1	−0.04	0.05	0.06	−0.16	0.05	0.32*	0.18	0	0	−0.14	0.19#
S4	0.22#	0.14	0.03	0.06	0.02	0.33*	0.35*	0.13#	−0.06	−0.12	−0.01	−0.05

Advisable to select models based on an analysis of their

ability to simulate climate drivers, climate variability patterns and teleconnections

that are relevant at seasonal time scale over the region of interest

- Block 1: Sources of seasonal predictability in the Mediterranean region
  - Predictability from ENSO/PDO
  - Predictability from Siberian snow cover
  - Additional sources of predictability
- Block 2: Available seasonal climate information
  - Seasonal forecast information at C3S
  - Other sources of information and empirical forecasts

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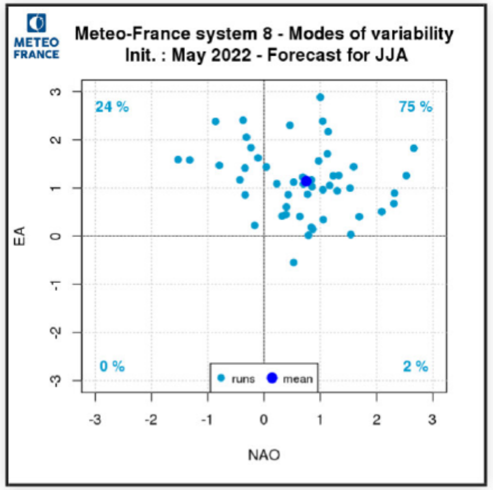
  - Other sources of information and empirical forecasts

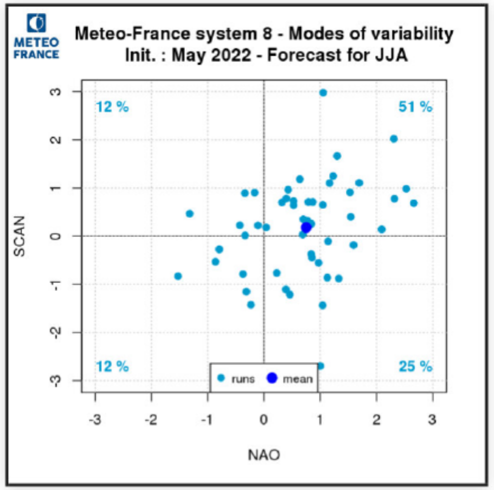
Modes of variability : forecast

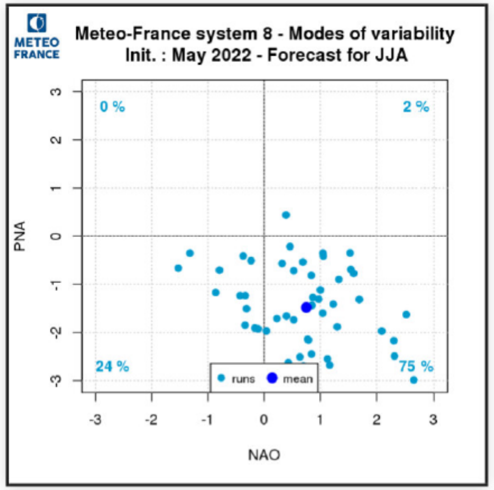
High confidence in a negative PNA

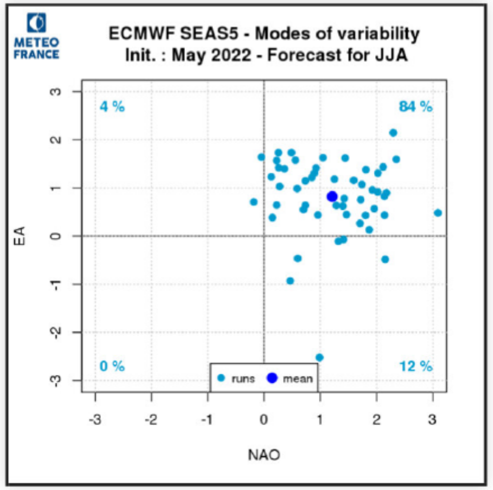
Strong signal for positive NAO and EA.

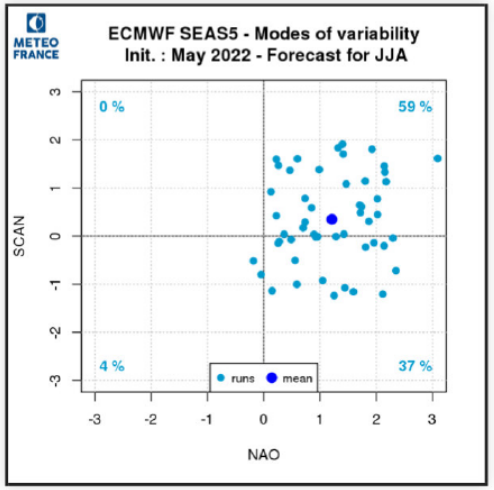
No clear signal for SCAN.

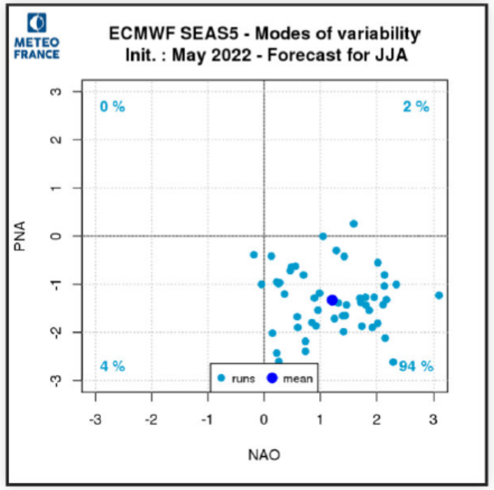








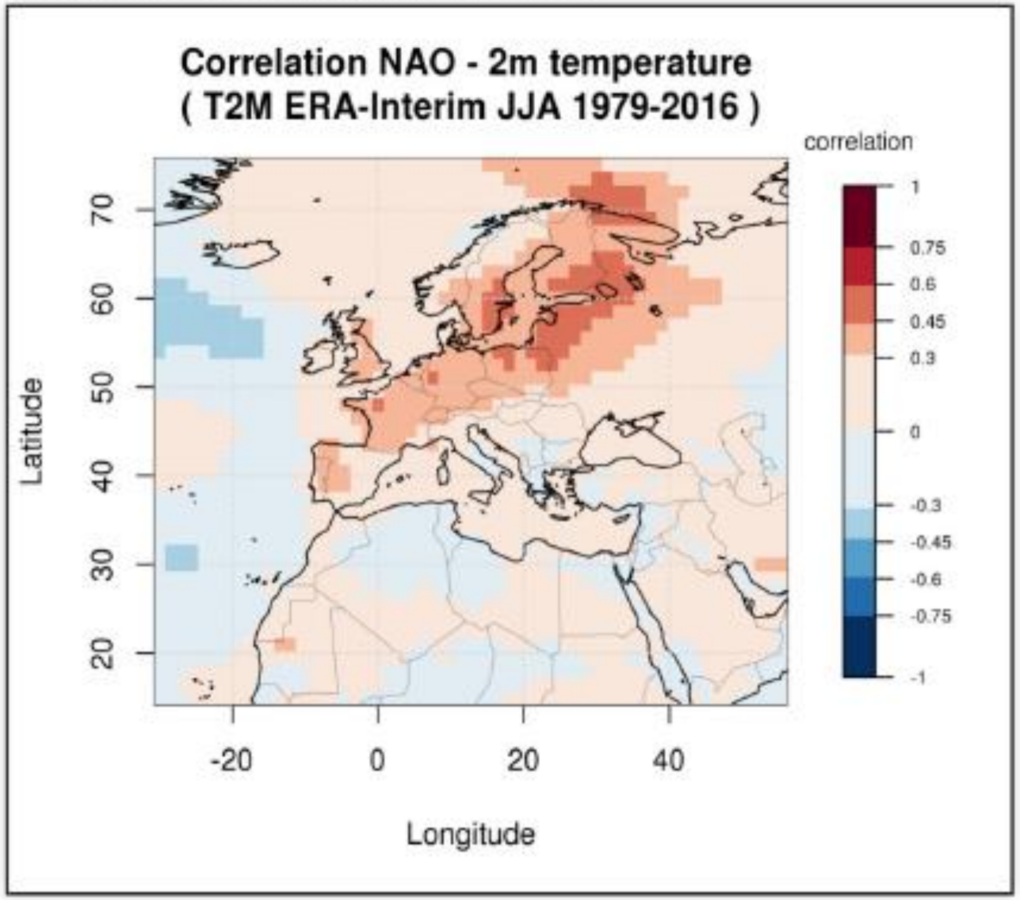


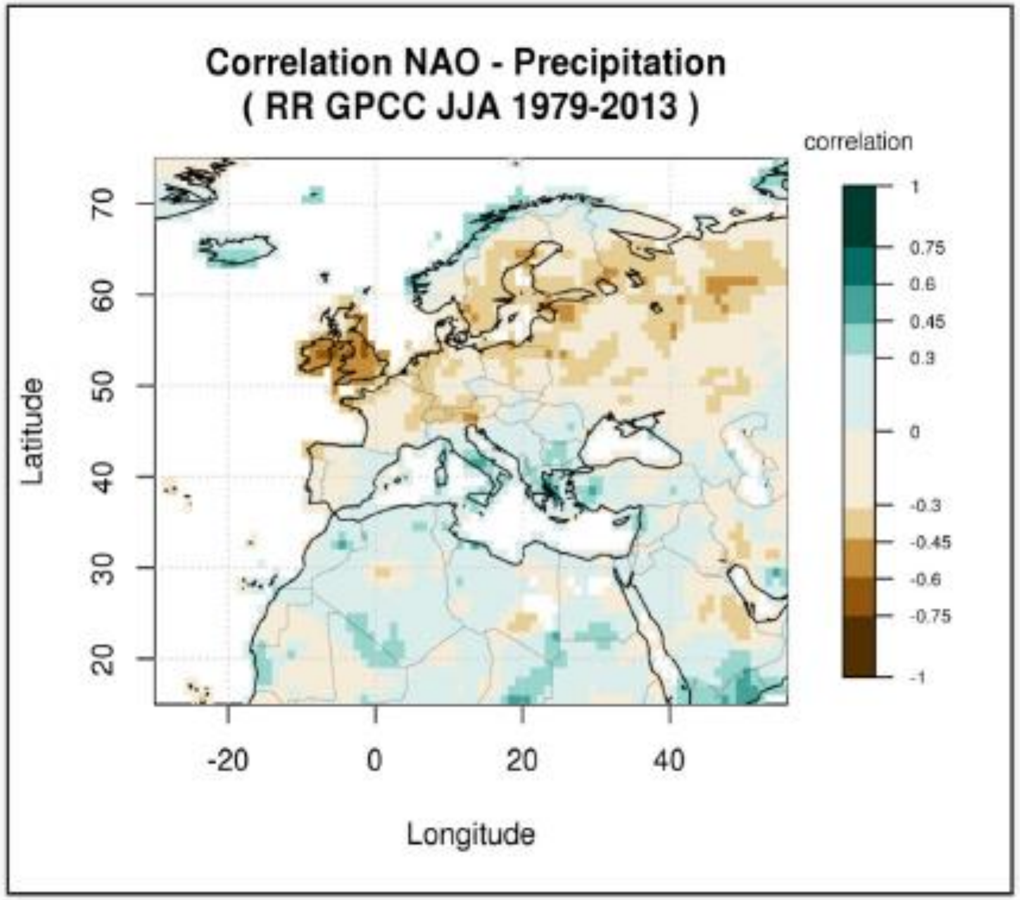


See the modes of variability patterns

Modes of variability : NAO impacts

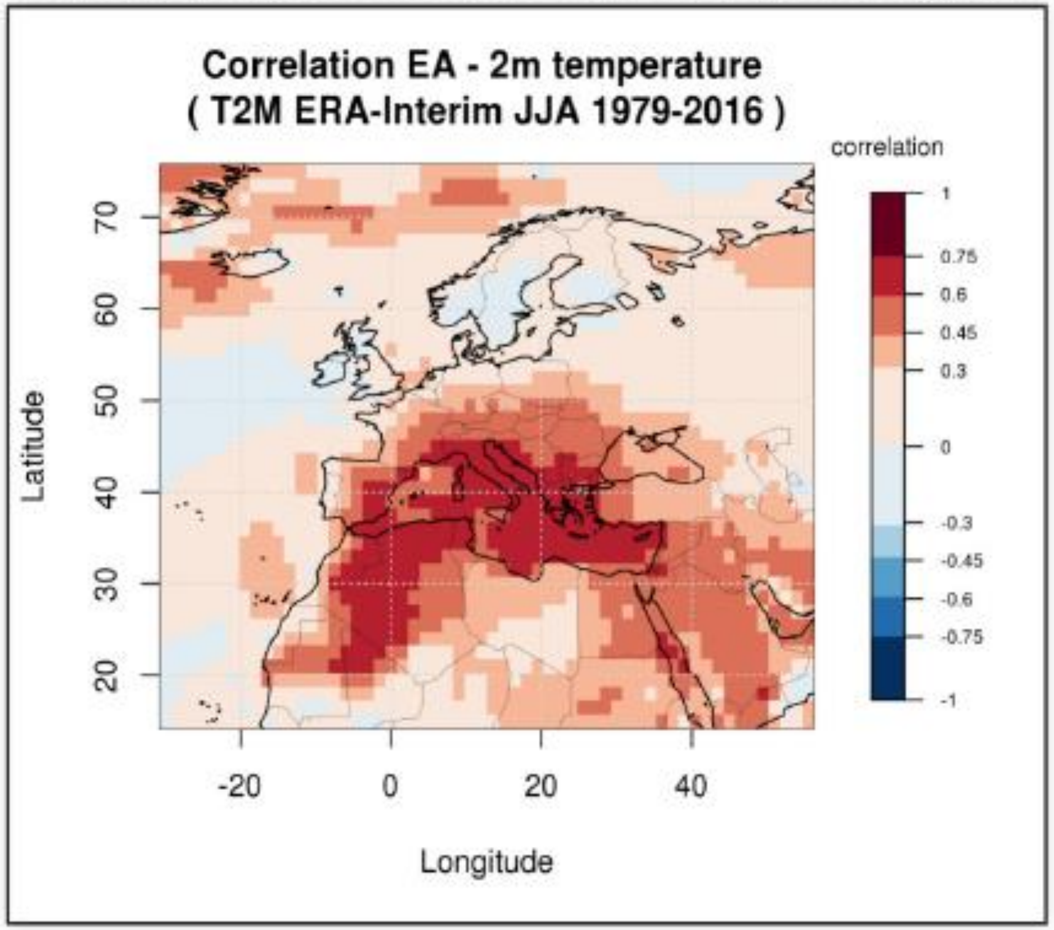
Positive phase of the NAO next quarter

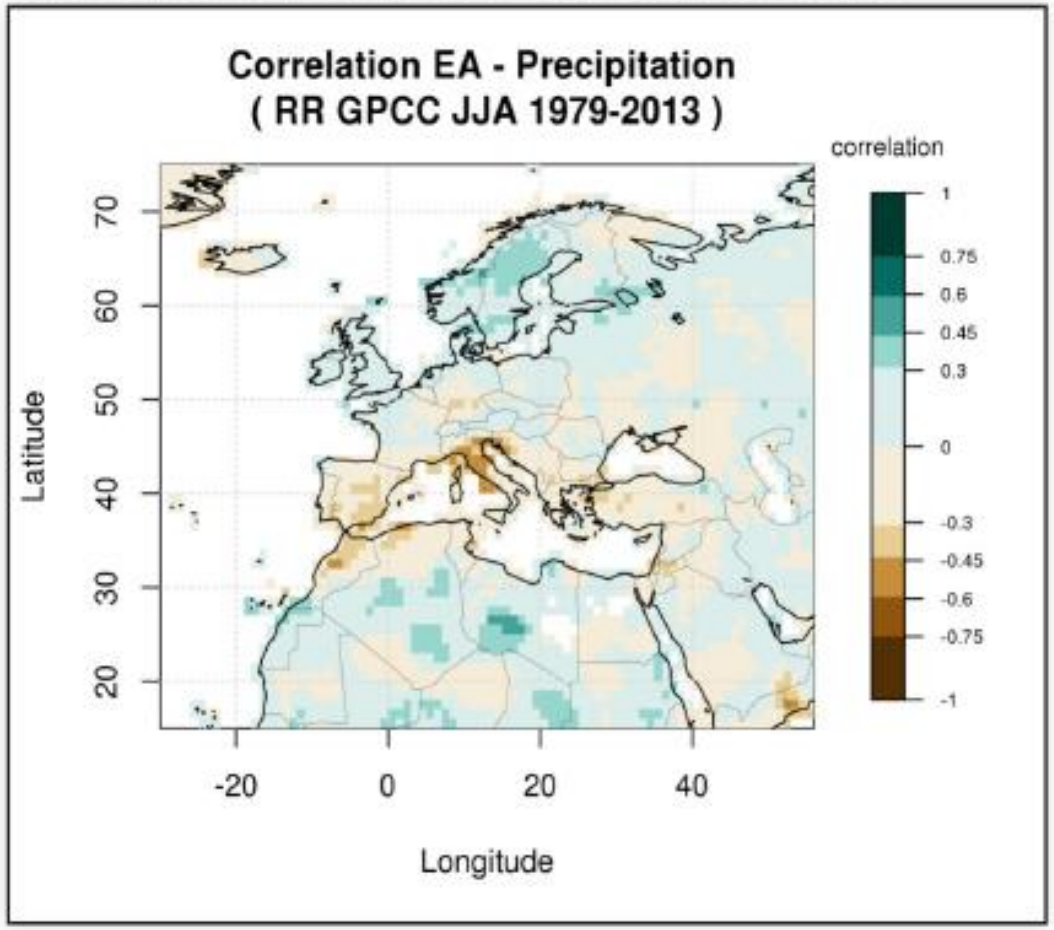




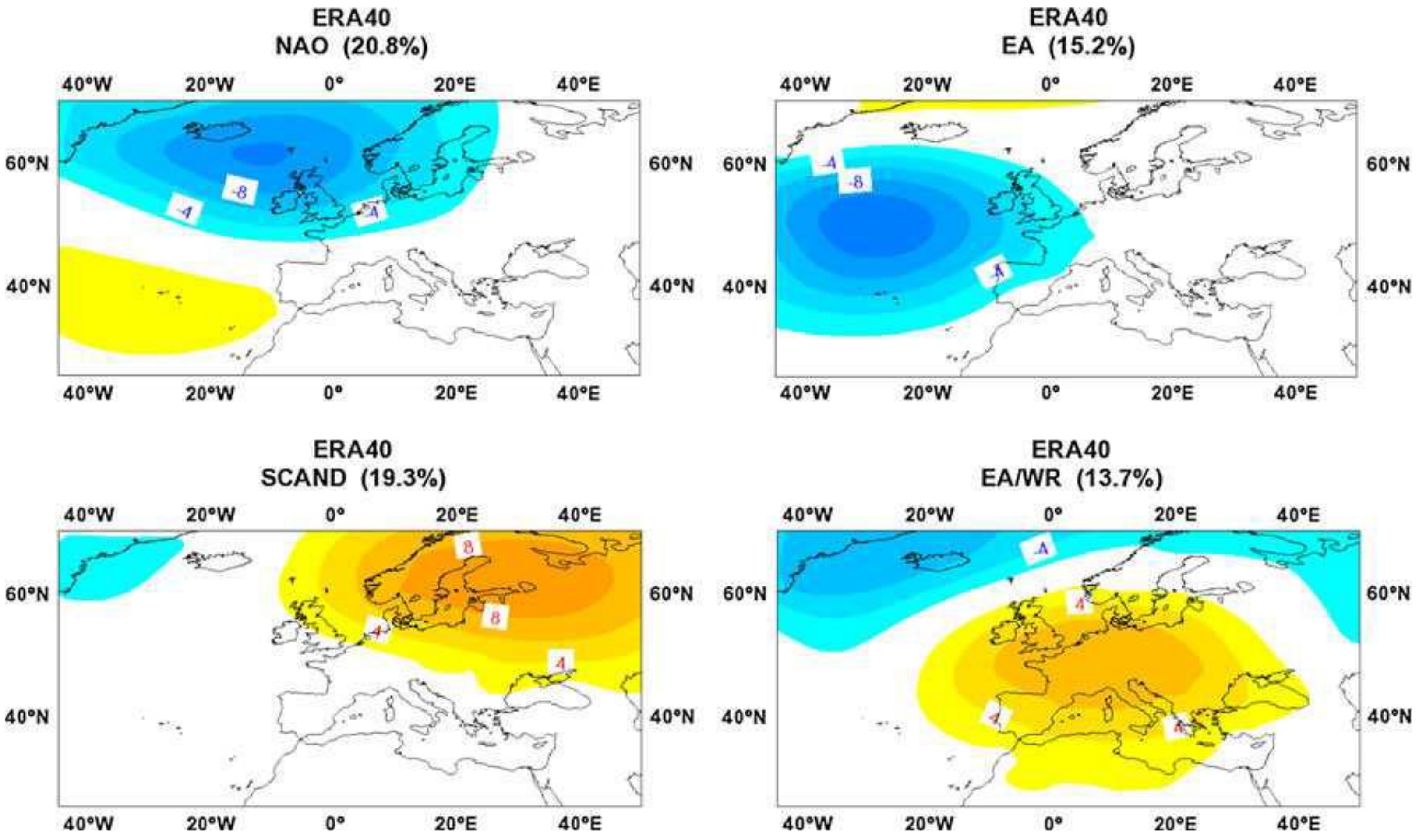
Modes of variability : EA impacts

Positive EA is expected last quarter. This mode has a strong influence in particular on the temperature on the south of Europe.





How well are represented variability patterns by different models?



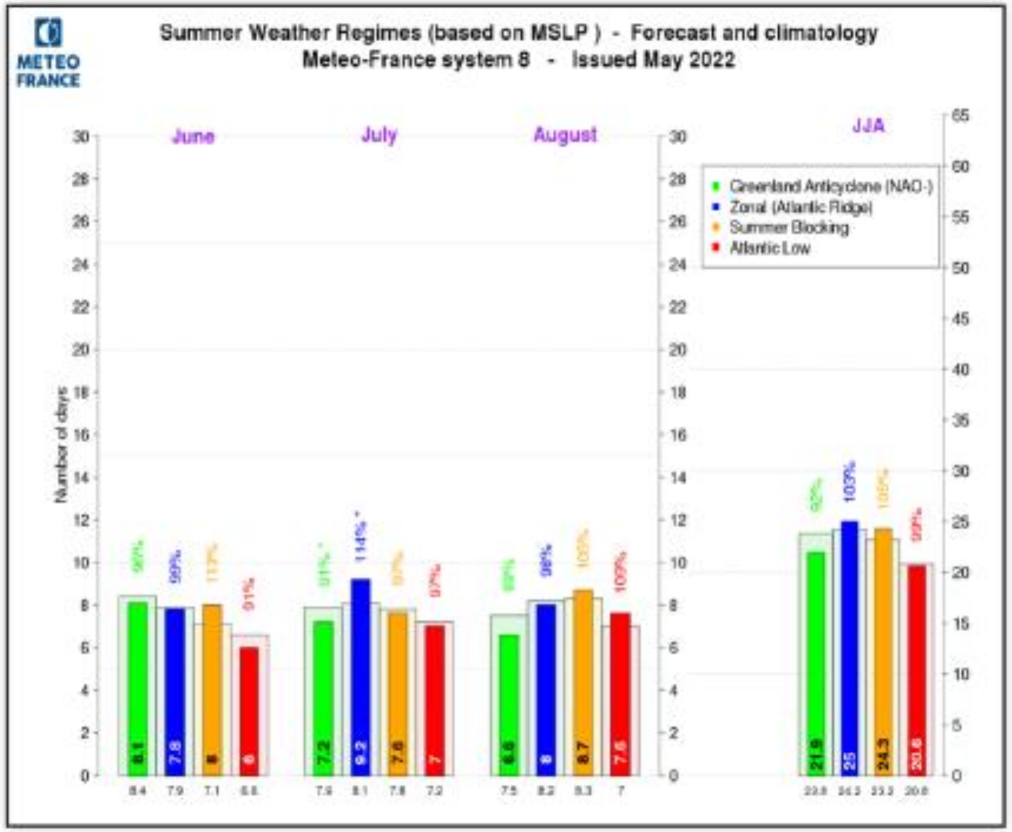
In terms of:

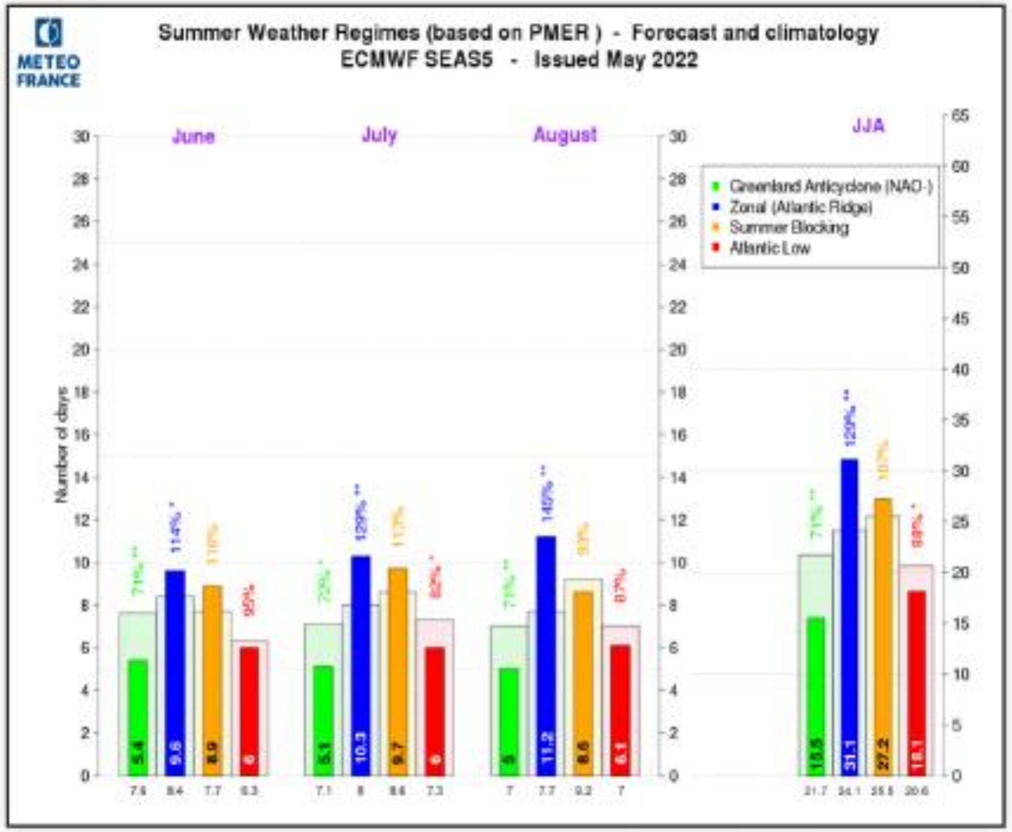
- Explained variance
- Space features
- Time features

Casado and Pastor (2011): Clim. Dyn., doi: 10.1007/ s00382-011-1077-2

Weather regimes : summer MSLP

The zonal regime is signicantly privileged by ECMWF-SEAS5. No clear signal with MF-S8.

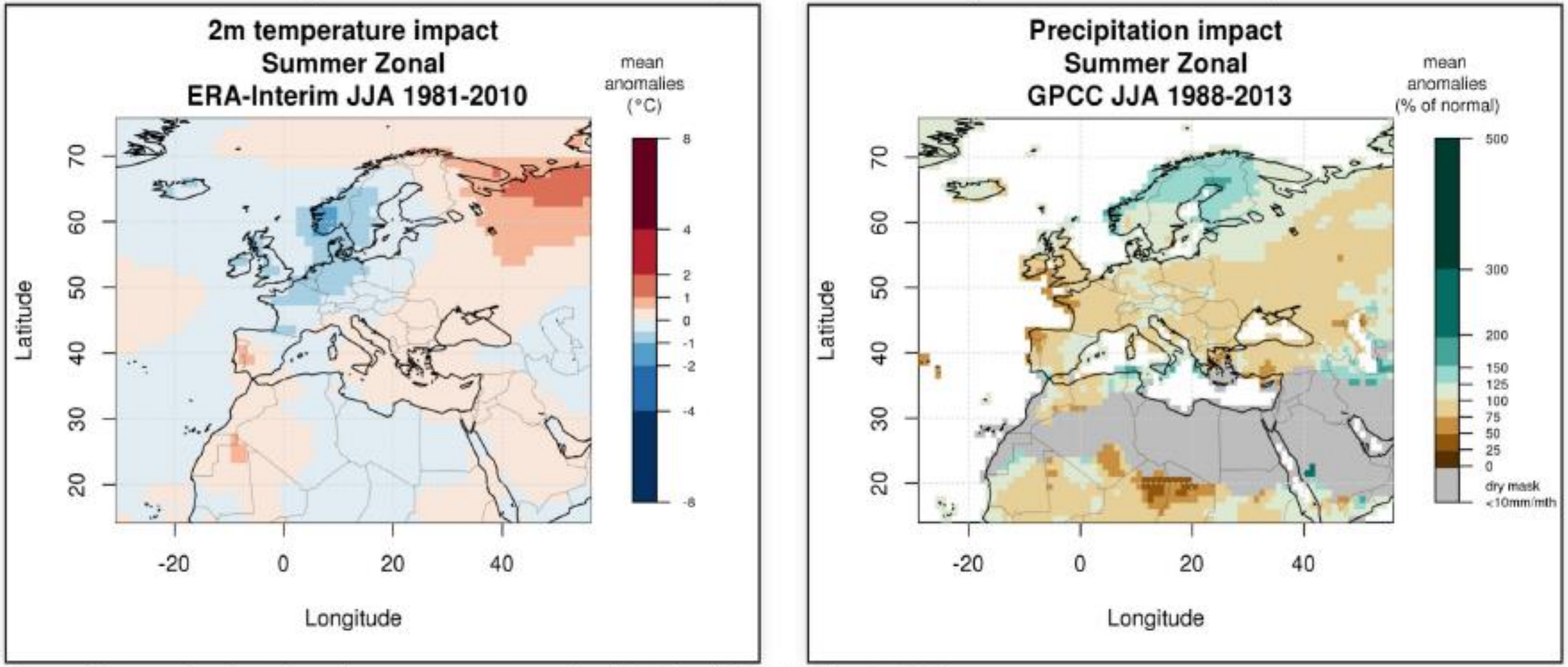




Frequency of SLP weather regimes, compared to model's own climatology, for the next three months and aggregation over the entire quarter, for MF-S8 (left) and SEAS5 (right).

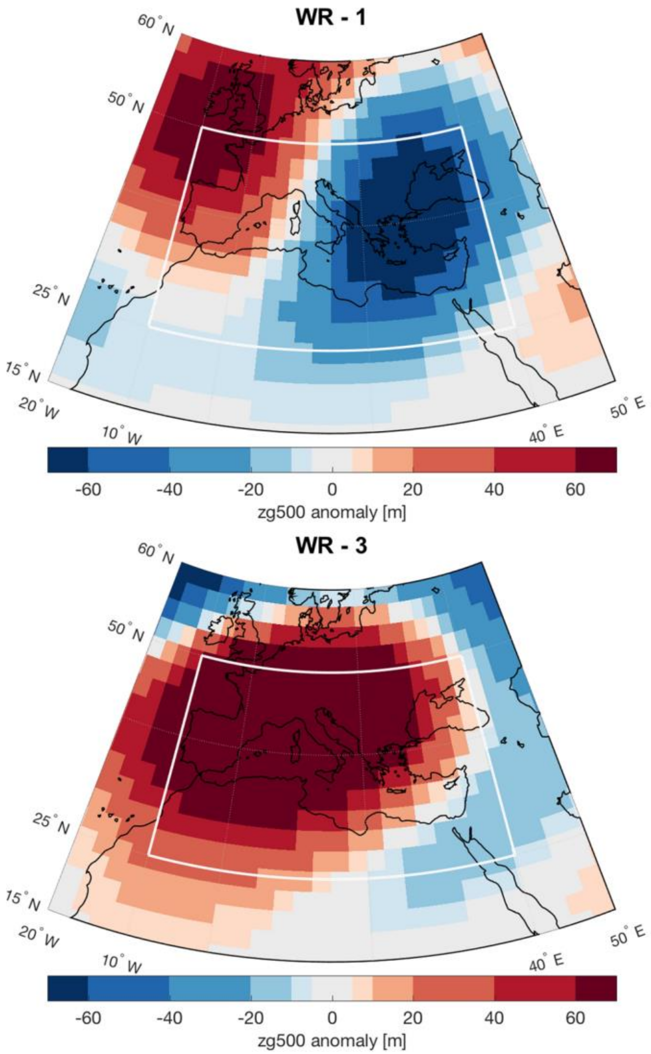
Weather regimes : Impacts

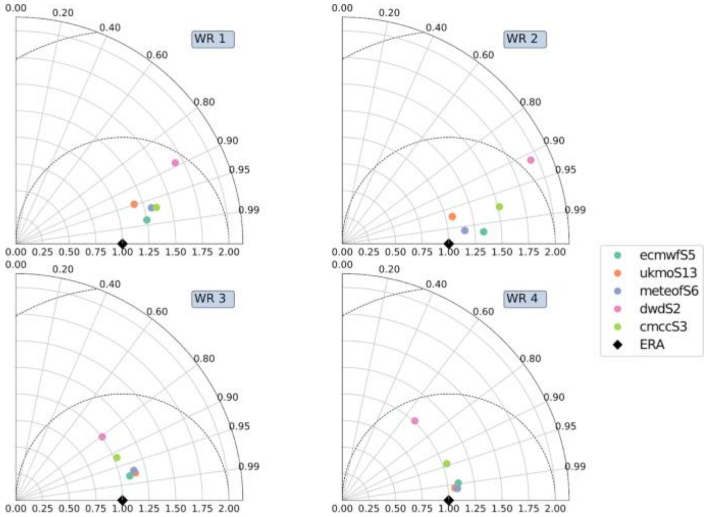
Summer Zonal weather regime is favored. *Over western Europe it is* favourable to dry conditions and cool temperature.

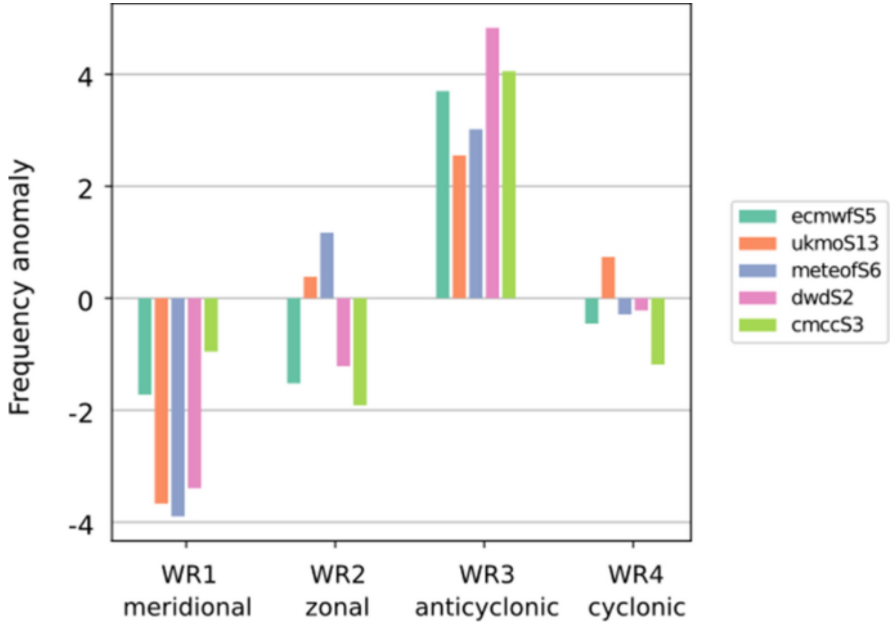


Impact of Summer Zonal weather regimes on temperature and precipitation. (ref ERA-interim 1981-2010)

How well are represented weather regimes by different models?







Giuntoli et al. (2021): Clim. Dyn. https://doi.org/10.1007/s00382-021-05681-42021

Combining seasonal forecasts from multiple inputs

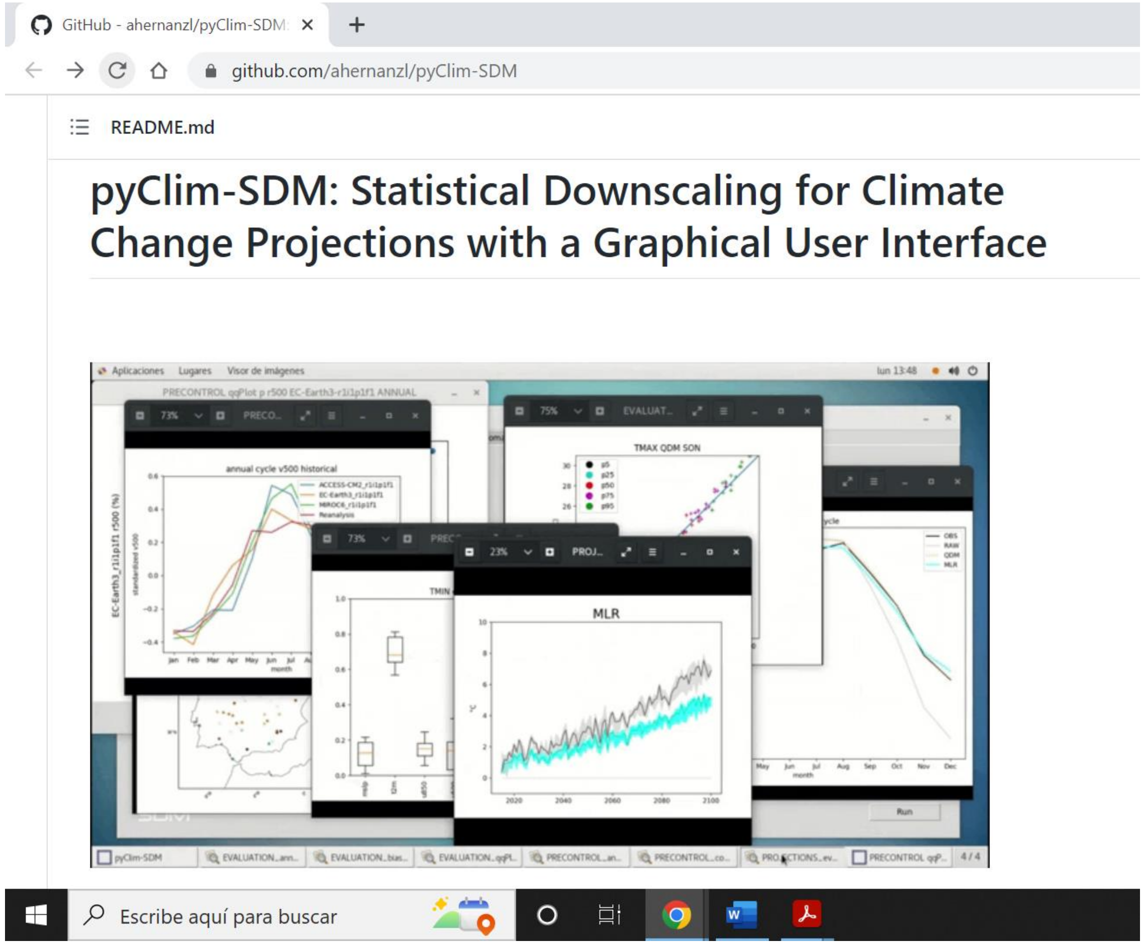
- **Combining different climate model** predictions advantageous and an **advisable approach**
- It is **not a simple matter** to establish with certainty which is (are) the **most skillful SFS**(s).
- However, because of **short hindcast periods**, equal weighting generally performs better than the use of unequal weights. Recent results show that for **hindcast periods shorter than 50 years, unequal weighting schemes are unlikely to improve** upon the results of an equal weighting scheme. For larger sample sizes, the weights can be estimated more robustly, and the unequal weighting scheme may produce more skillful forecasts

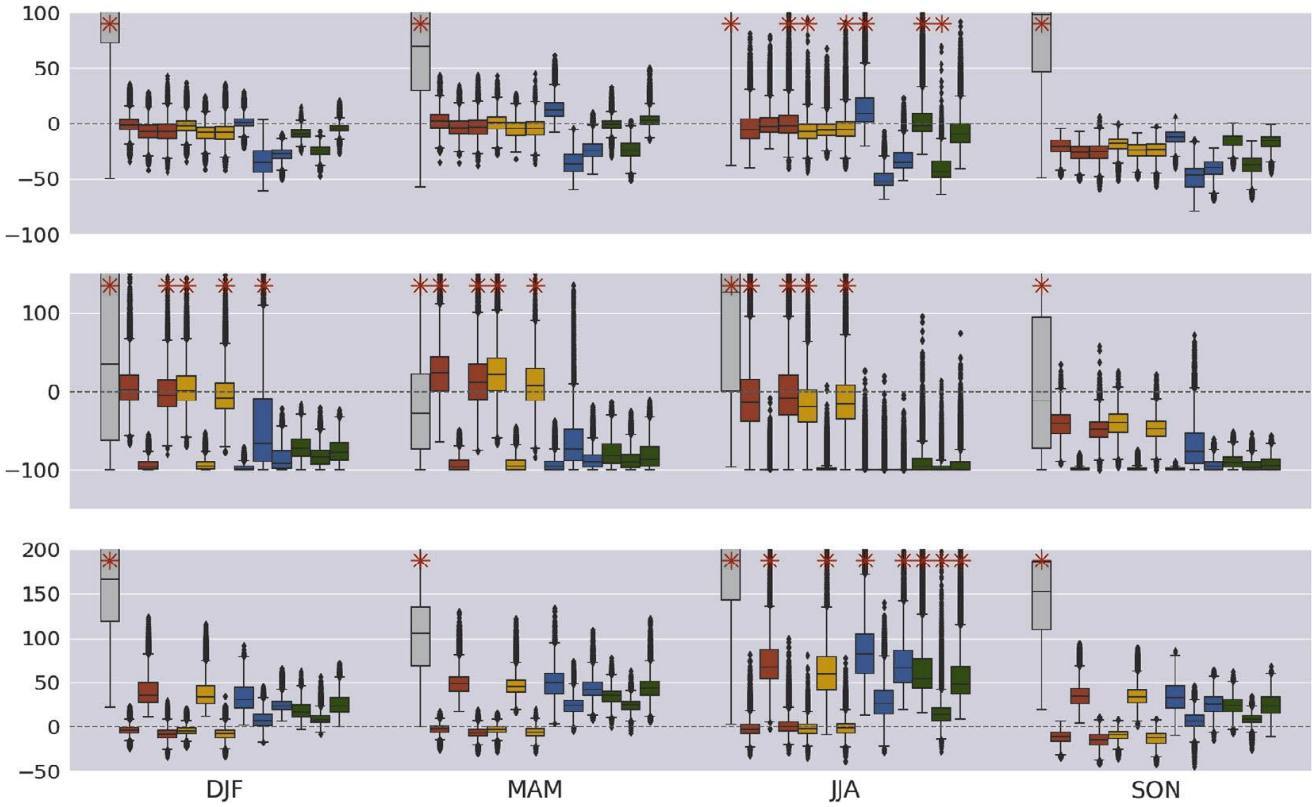
Downscaling of real time SFs

- Downscaling is the process of **increasing the spatial and/or temporal resolution** of the original variable of interest in the forecasts in order to provide more detailed forecast information for use in various applications.
- If **high resolution and quality observational data are available**, statistical downscaling can be performed to provide seasonal forecasts for those locations not resolved by the coarse resolution model.
- In general, downscaling may be **worthwhile in instances where the forecast being downscaled has skill** and there is some reason to expect that downscaling will further add to skill (and will provide further details).
- The development of several kinds of climate services, for example, in hydrology or agriculture, also requires that seasonal forecasts be provided at **higher temporal resolution**, for example, daily timescales. there exist multiple statistical methods to disaggregate seasonal climate forecasts. This temporal statistical downscaling or disaggregation consists of computing sub-seasonal characteristics that are statistically consistent with the seasonal prediction.
- **Many statistical downscaling techniques** have been developed and are available in CSTools to derive local information from large-scale GCMs outputs.

Downscaling of real time SFs

https://github.com/ahernanzl/pyClim-SDM





Relative bias (%) for PRCPTOT (upper row), R95p (middle row) and R01 (lower row) of precipitation by season. Methods coloured by families: RAW (grey), ANA-SYN-1, ANA-SYN-N and ANA-SYN-PDF (red), ANA-LOC-1, ANA-LOC-N and ANA-LOC-PDF (orange), REG-LIN, REG-EXP and REG-CUB (blue), ANN, SVM and KRR (green).

Hernanz et al. (2021): Int J Climatol. DOI: 10.1002/joc.7271.

Purpose of this training workshop

- Provide elements aiming at implementing the MedCOF OSF
- Diseminate and facilitate access to knowledge and tools generated by the MEDSCOPE Project
- Promote discussion for evolving on an agreed way from our consensus SF to a new OSF meeting the WMO requirements
- Generate training material (videos, examples, texts, etc.) for further reference

Final considerations

- OSF implementation is a WMO recommendation following EC-72 (decision 9)
- WMO has already provided a set of principles, recommendations, and general technical guidance, all designed to facilitate the development of OSF at the regional and national levels (WMO-No. 1246)
- MedCOF was the main beneficiary of the ERA4CS MEDSCOPE project directly aiming at providing new knowledge on predictability at seasonal scale, advance tools for postprocessing GPC outputs and examples of feasible climate services for the Mediterranean region
- As there is no general agreement on how to post-process and assess seasonal MME predictions different possible strategies can be envisaged
- As in previous MedCOF developments, it is important and recommendable to progress in the implementation of OSF following agreed procedures based on the best available science
- Important to start moving in the OSF direction first implementing simple solutions, as sophisticated processing of seasonal forecasts may be constrained by the small sample size of currently available hindcasts

Thanks for your attention!