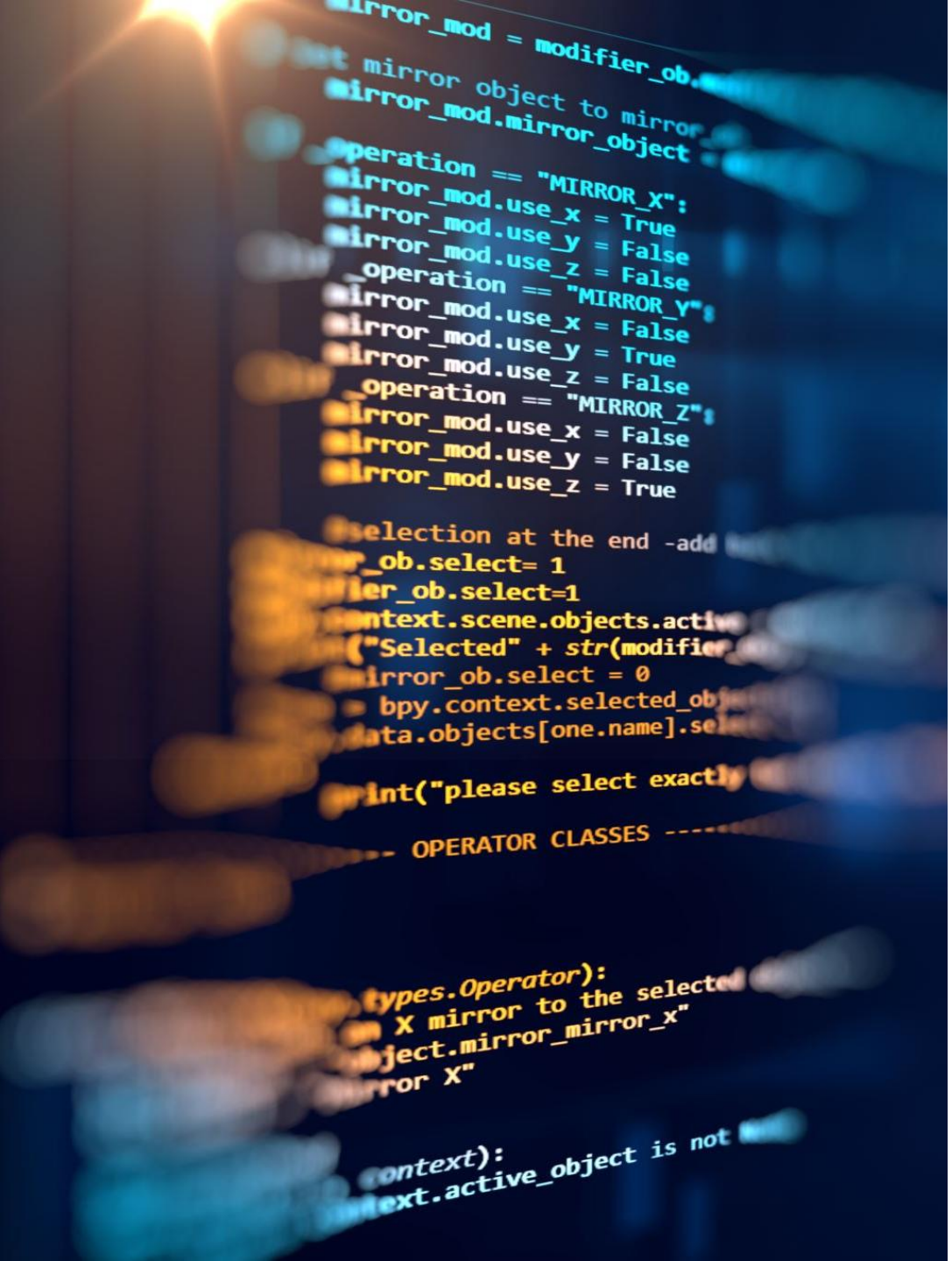
Towards objective seasonal forecasting across the MENA region.

Contributions from DGM Morocco and WISER MENA programme

Wafae Badi, DGM Morocco

Nick Savage, Met Office, UK

Supported by:



Outline

- Current process in RCC-NA-RAI (WB)
- Motivation for OSF for RCC-NA-RAI (WB)
- Intro to WISER MENA (focus on SeaFOAM and SeaSCAPE) (NS)
- Progress on OSF (WB)
- Software for OSF (NS)
- Future plans for OSF

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CURRENT PROCESS IN RCC-NA-RAI

SEASONAL FORECAST PROCESS

SUBJECTIVE FORECAST

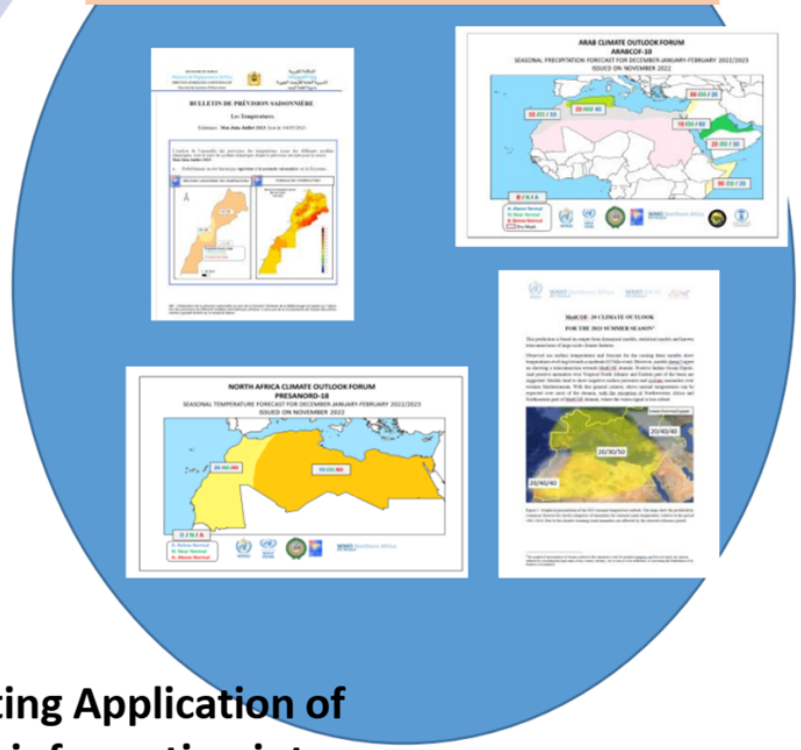
DYNAMICAL &STATISTICAL MODELS

CLIMATE DRIVERS

CURRENT CONDITIONS

A set of regular products:

- National bulletin
- RCC NORAF Outlook
- PRESANORD, MEDCOF and ARABCOF Outlooks



Collaboration UK METOFFICE (WISER MENA) → OBJECTIVE → Promoting Application of climate information into different sectors

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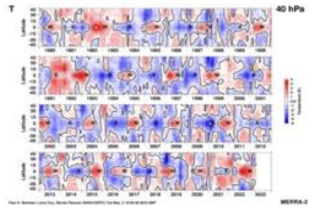
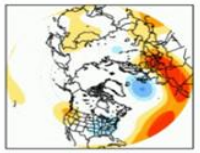
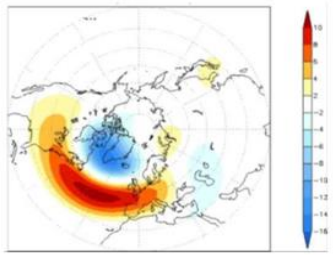
PRECIPITATION AND TEMPERATURE DRIVERS



QBO



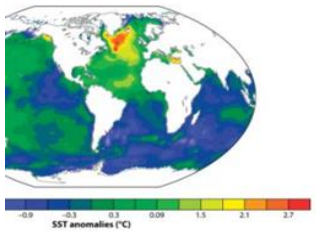
EA



NAO

NTA

Precipitation
&
Temperature



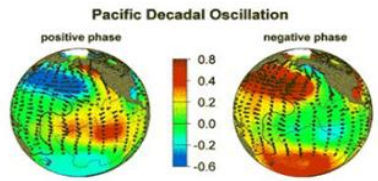
AMO

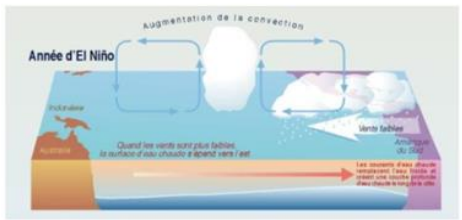
ENSO

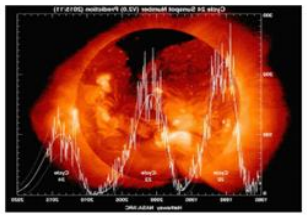
SF

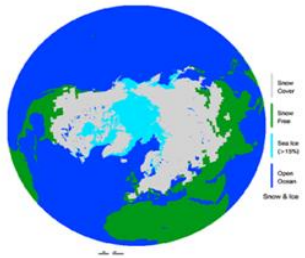
NH snowcover

PDO









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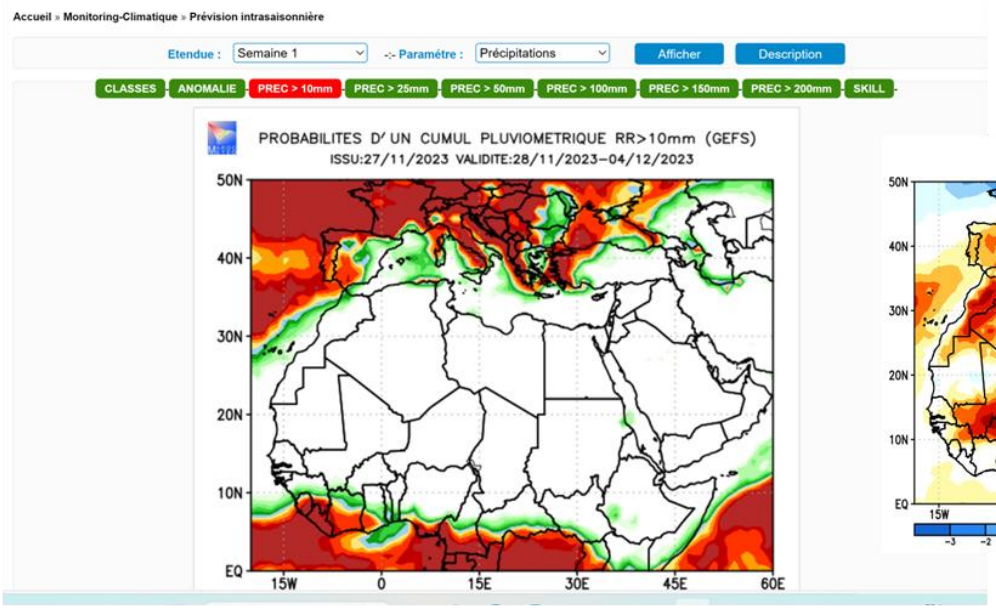
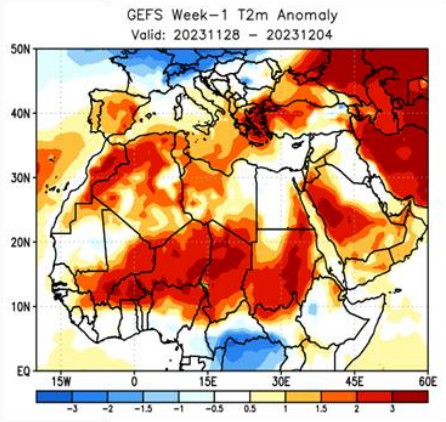
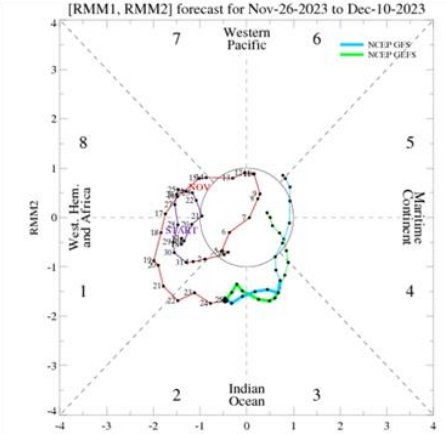
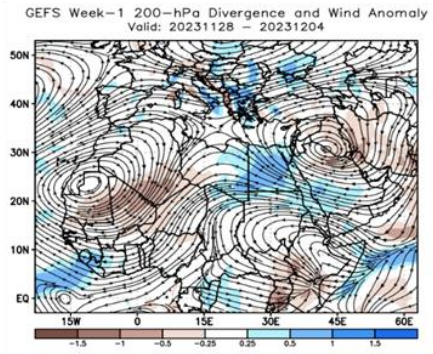
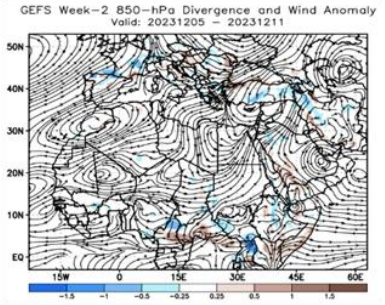
SUBSEASONAL FORECAST

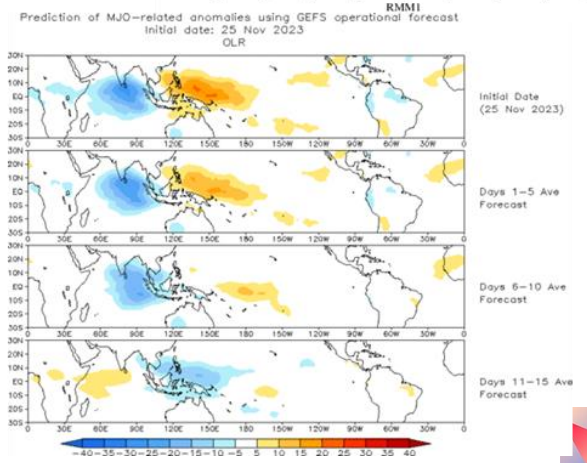












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MOTIVATION OF OBJECTIVE SEASONAL FORECAST

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REQUIREMENTS FOR OSF FOR RCC-NA-RAI

- The **World Meteorological Organization (WMO)** emphasizes the importance of objective seasonal forecasts that :
  - Traceable
  - Reproducible
  - Well-documented

Collaboration UK METOFFICE (WISER MENA) → **OBJECTIVE** → **Promoting Application of climate information into different sectors**

Canonical Correlation Analysis:	Machine learning	Linear regression
• Observed SST, predicted SST, predicted precipitation, predicted temperature	• : Calibration, including the information from Climate Drivers used to be included in subjective way	• Skillful region • Temperature

WISER MENA PROGRAMME

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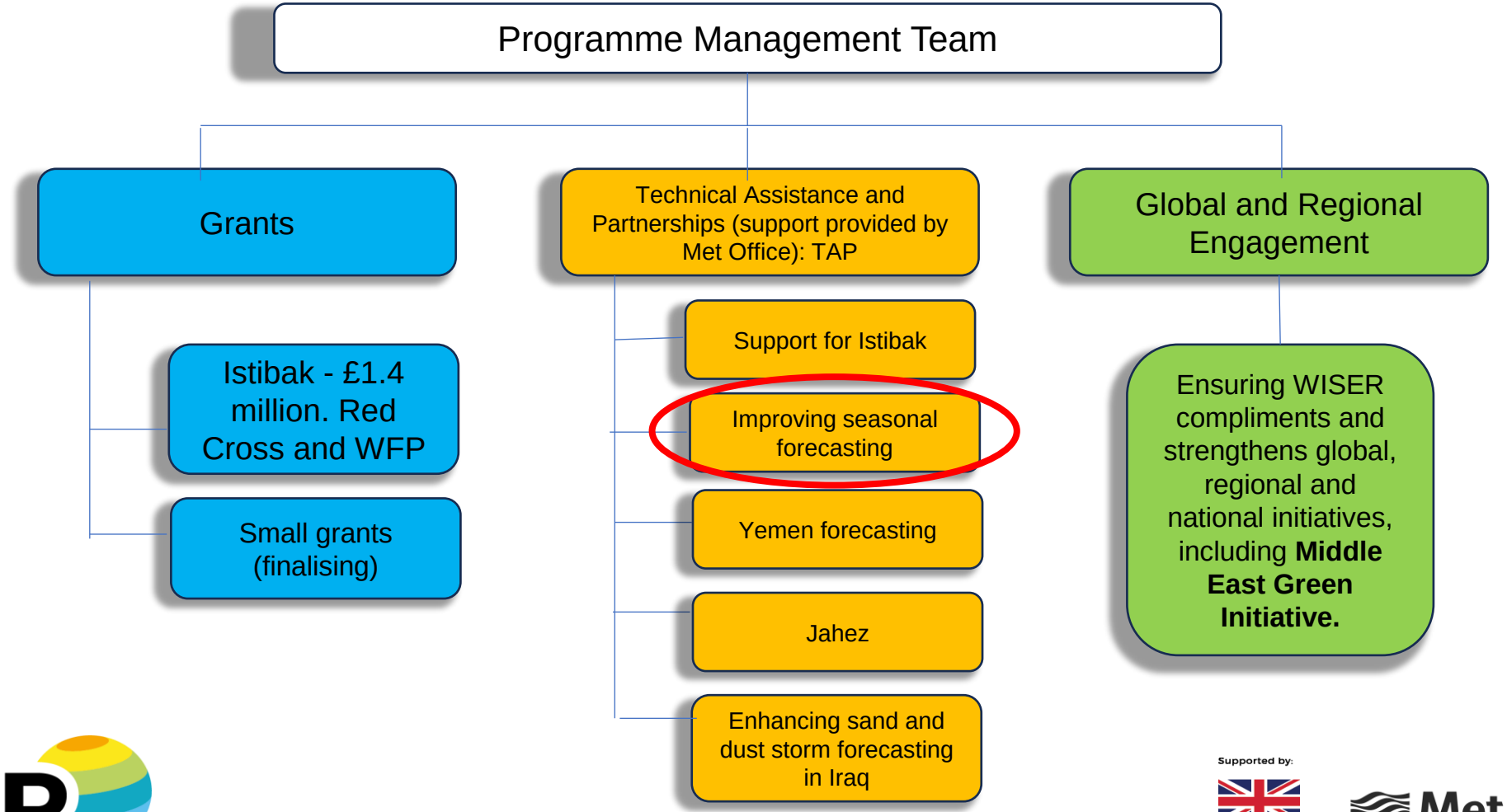
WISER MENA - Programme Overview

Theory of Change and Logframe (*strategy which defines what the programme will achieve*)

£5 million programme (2022-2026) which aims to deliver transformation in the generation and use of co-produced weather and climate services



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from the British people

Met Office

Weather & Climate Information Services – MENA

"Aims to deliver co-produced WCIS to support decision making and building resilience to the impacts of climate change".

Seasonal Forecasting Across MENA (SeaFoAM)

Aims to support the MENA region's transition from subjective consensus to objective seasonal forecasting, through…

- Assessing skill, verification & climate drivers
- Producing objective outlooks that are bias corrected & calibrated.
- Understanding the feasibility of machine learning techniques.

Seasonal Co-Production & Application in MENA (SeaSCAPE)

Aims to co-produce sustainable & accessible seasonal services that are useable, useful & used to assist in decision making, planning & preparedness, through…

- RCOF engagement & coproduction
- Capability building
- Tailoring outlooks, products & services

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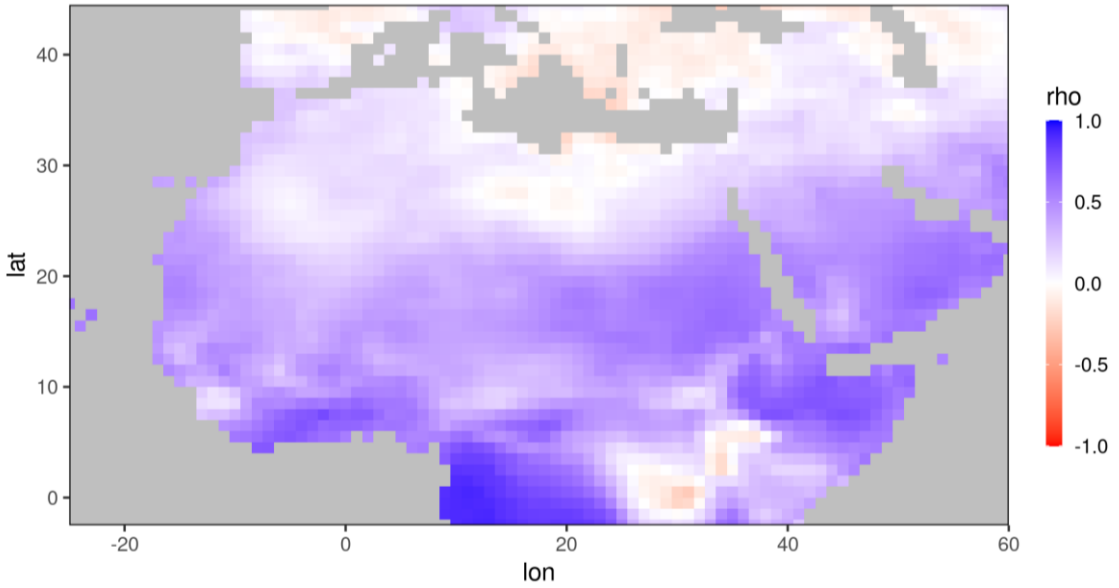
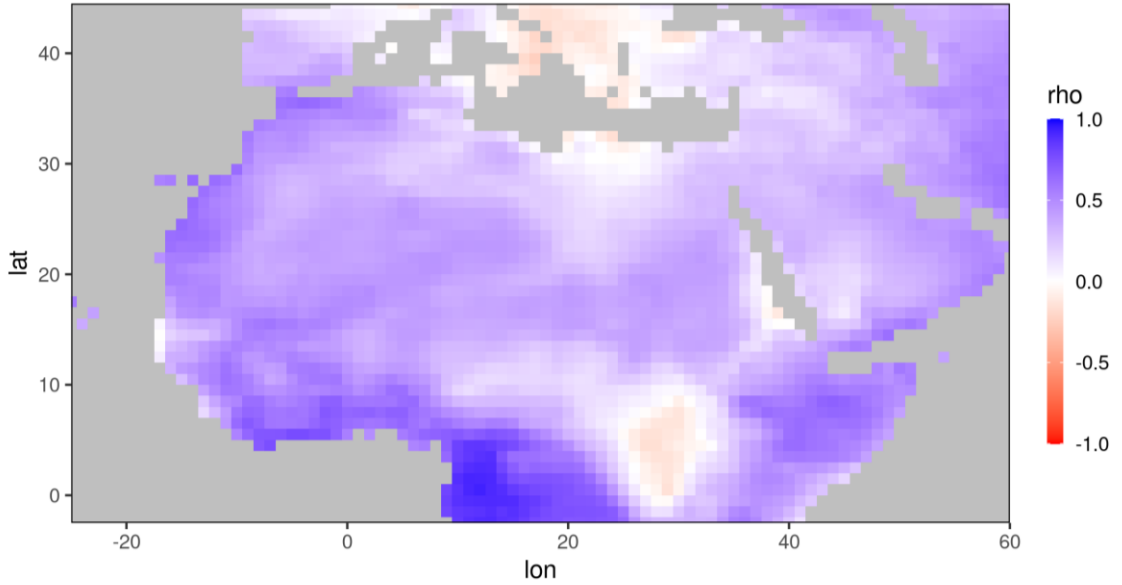
SKILL OF DIRECT GCM FORECASTS

Results: GCM direct tercile forecasts – temperature DJF 1993-2016 PCC

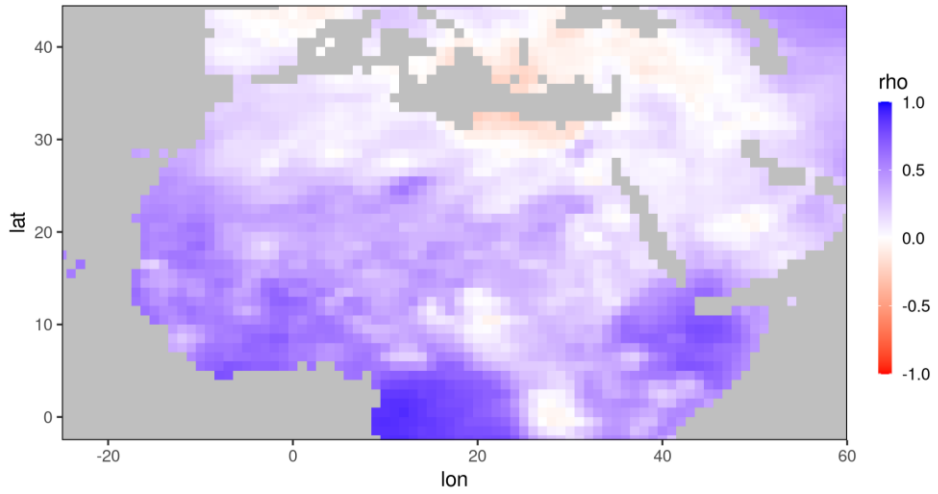
ECMWF



Met Office



Meteo France



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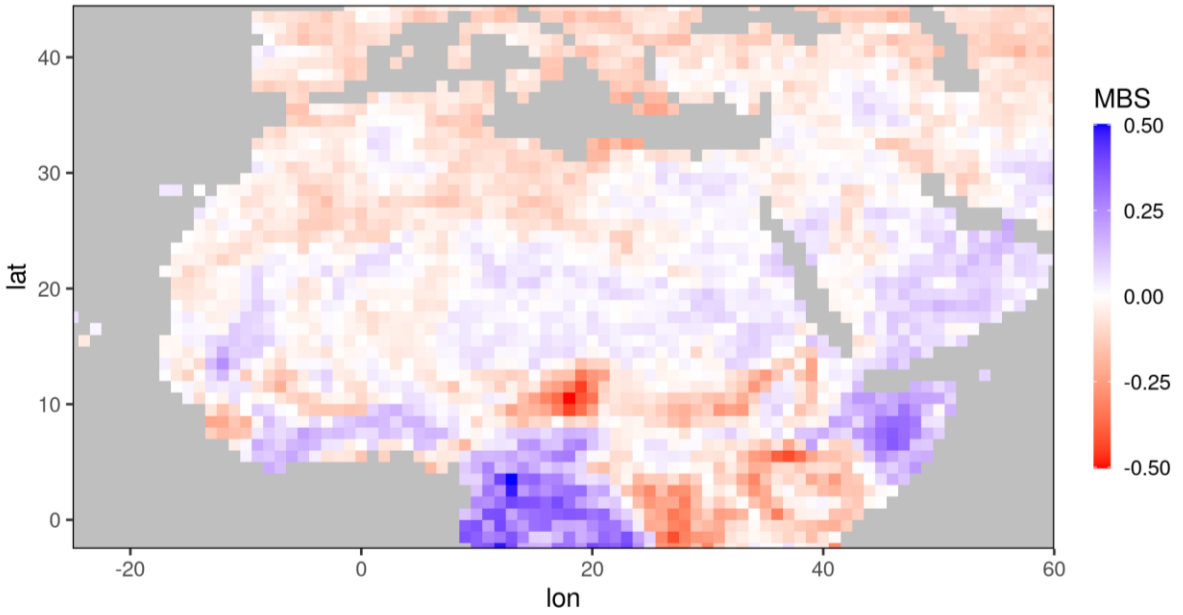
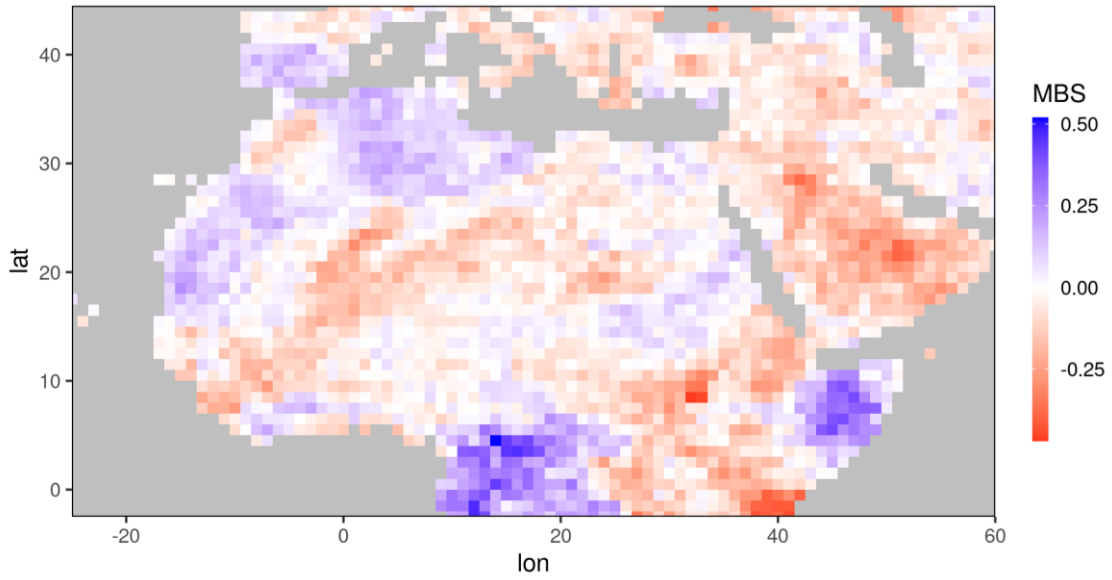
Results: GCM direct forecasts – temperature Multicategory Brier Skill Score

ECMWF



ECCC



Results: skill of GCM direct forecasts – temperature

- most models have some good correlations
  - different models with different areas having high correlations => use of MME
  - worth considering linear regression for bias adjustment

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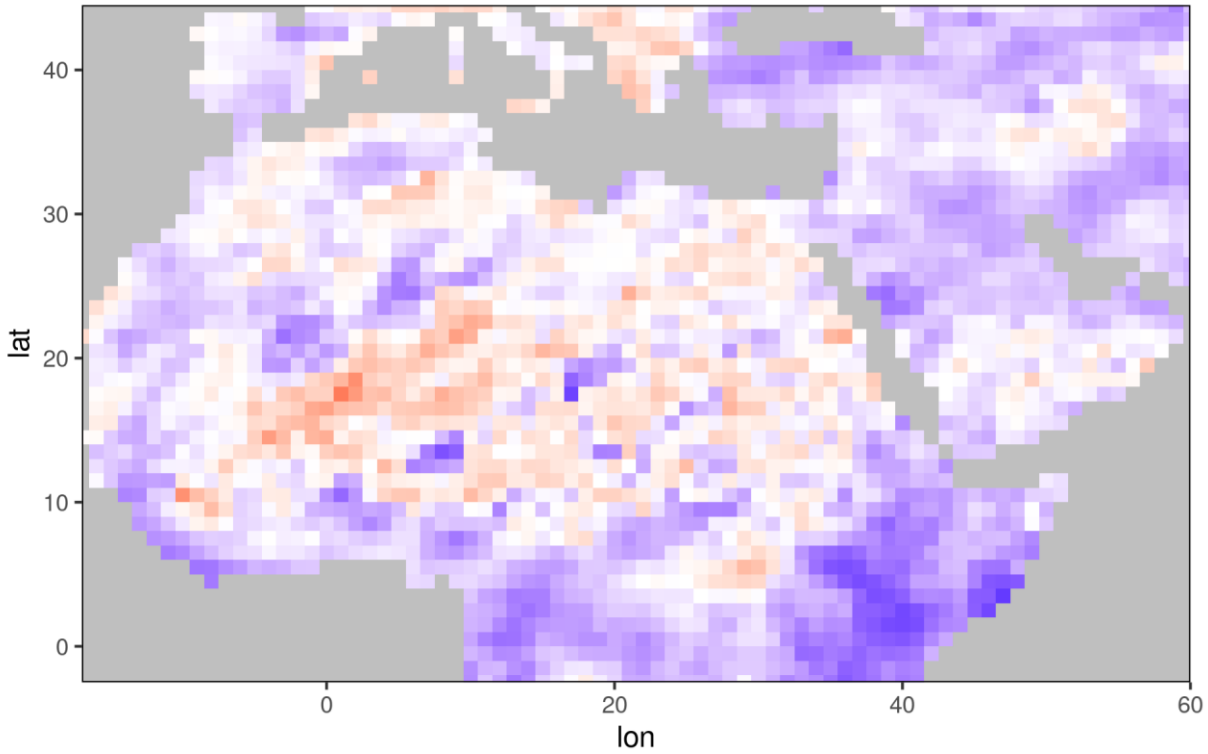
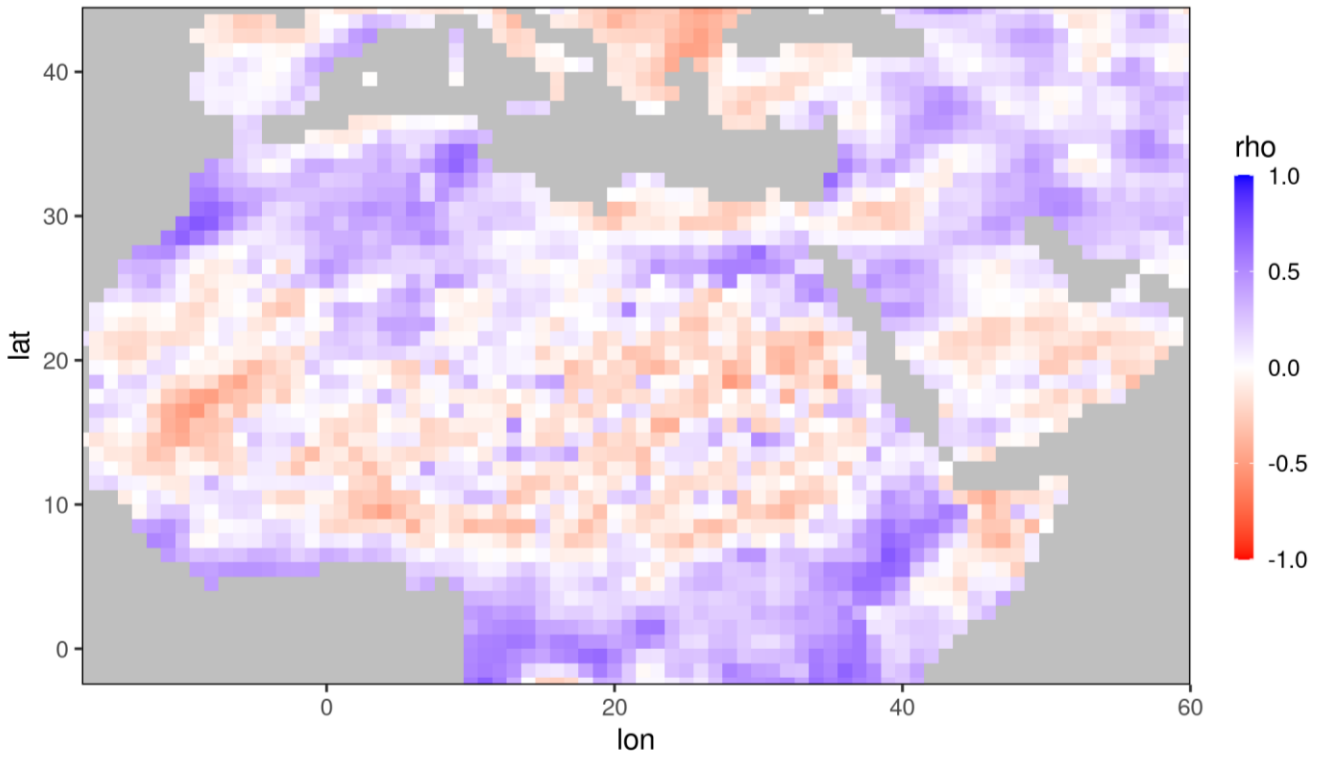
Results: correlation of GCM direct tercile forecasts – precipitation DJF 1993-2016

ECMWF



NCEP



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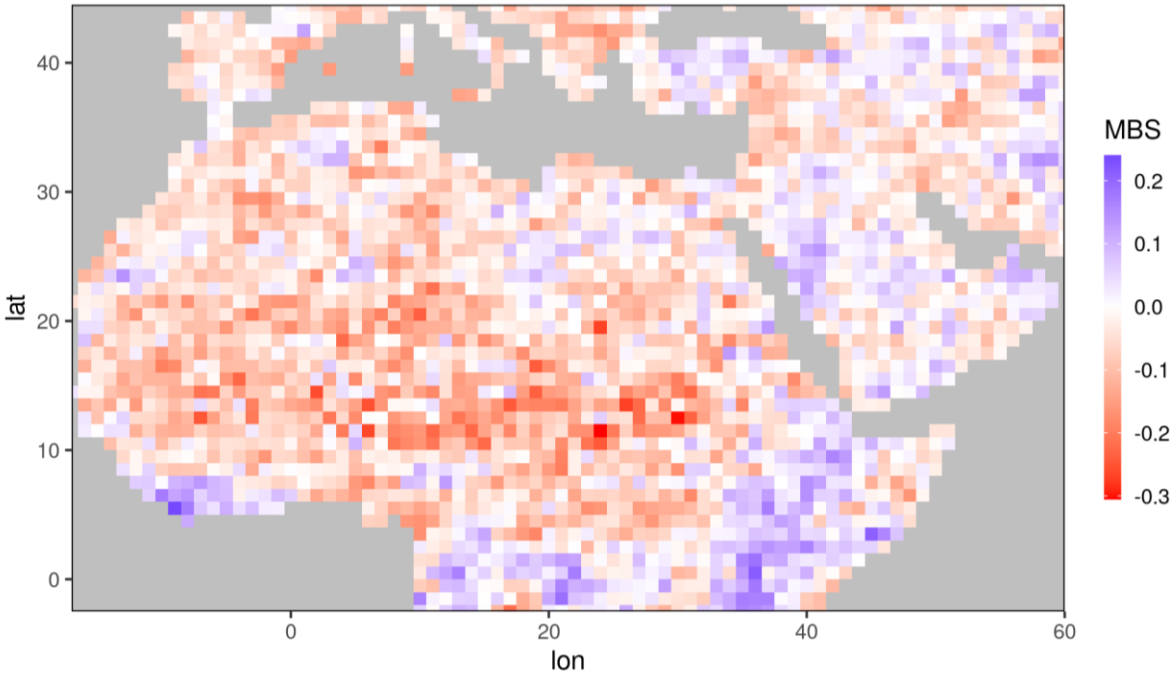
Results: GCM direct forecasts – precipitation Multicategory Brier Skill Score

ECMWF



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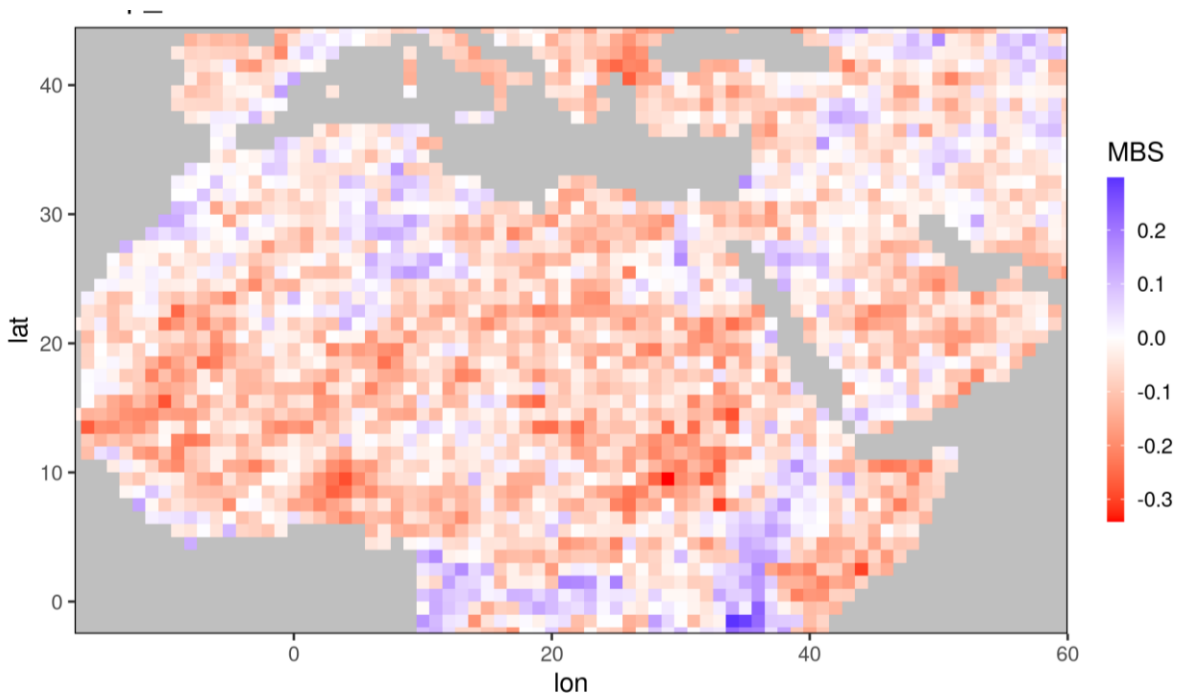

Results: skill of GCM direct forecasts - precip

- Correlations and Briar Skill Scores are low everywhere in the region of interest for precipitation
- more sophisticated techniques for using the models are likely to be needed here and forecasts based on the model terciles alone should be used with caution, in any multi-model forecasts
- contrast to East Africa where direct model forecasts are a valuable part of the skill

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PROGRESS ON OSF

- **Sophisticated Multi Model Forecasts**

Dynamical Forecast =

Direct signal	+	Indirect signal	+	noise
correctly predicted information Anomaly of correct size predicted in correct place at correct time		Includes Linear errors Spatial errors Circulation error eg. Wrongly positioning an ENSO teleconnection use CCA in CPT to correct bias		Not predictable (Chaos)

Colman et al.2020

First year SEAFOAM
CCA work: Led by Andrew Colman

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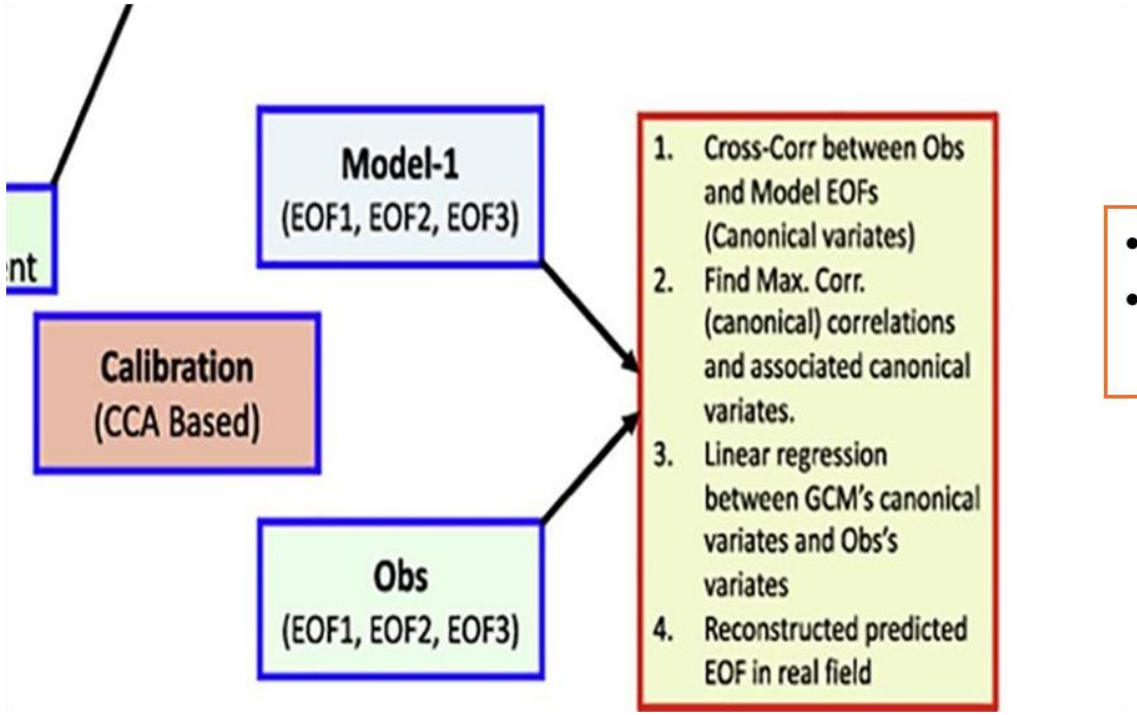
- **Canonical Correlation Analysis**



(Acharya et al.2021)

- C3S&NMME models
- Observation: Renalysis

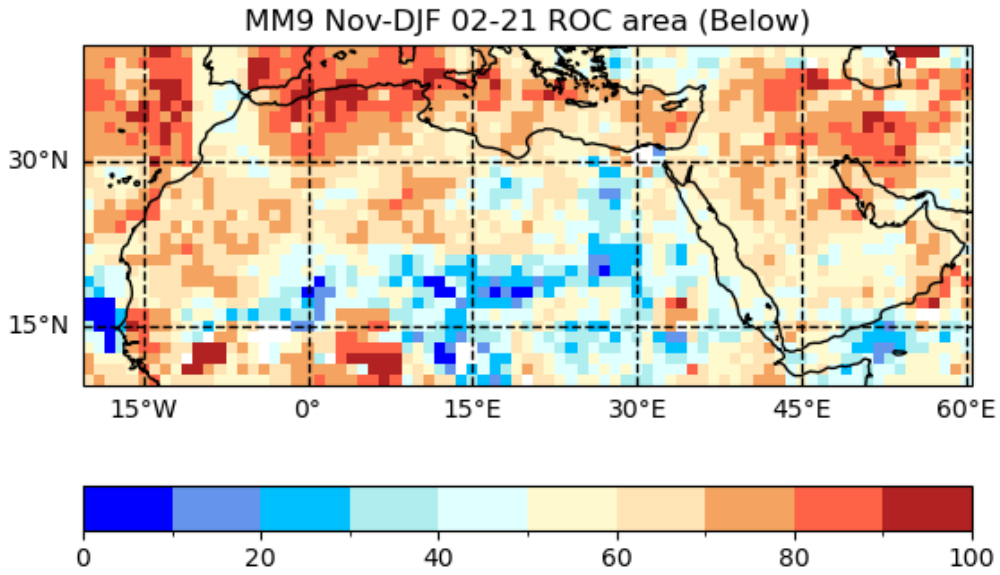
Calibrated prediction

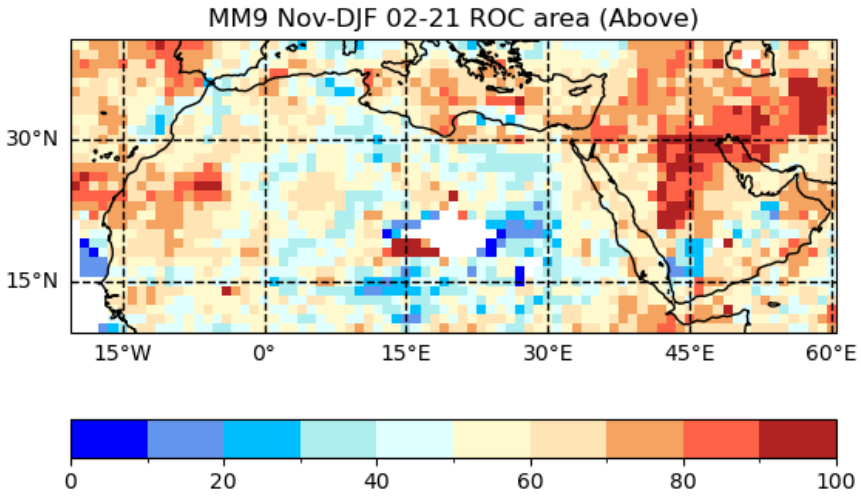
- **Combination of 3 MME and CCA Calibration**
  - **Tropical influence**

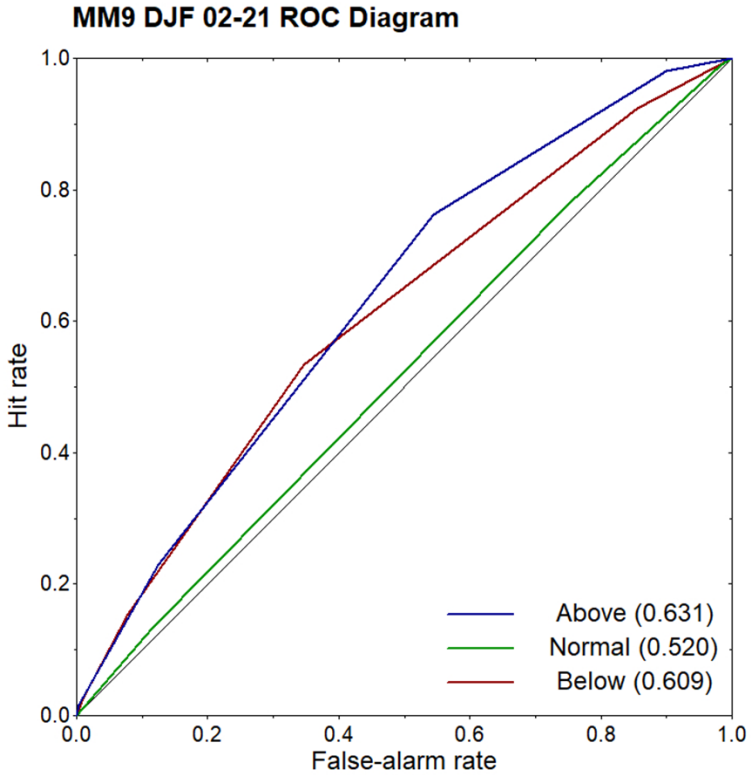
SYSTEM	CFS	CANSIPS	COLA CCSM4
40N-40S SST CCA			
40N-40S PPN CCA			
ENSEMBLE			

Colman et. al. (2020)

we used just 3 models for our initial study, the CFS, CanSIPS-IC3 and COLA CCSM4. These were chosen because of the longevity of their hindcasts (1982-2022) which allowed one to split the data into two 20-year periods, one to train the forecasts and the second for an independent test of their skill







First year SEAFOAM CCA work: Led by Andrew Colman

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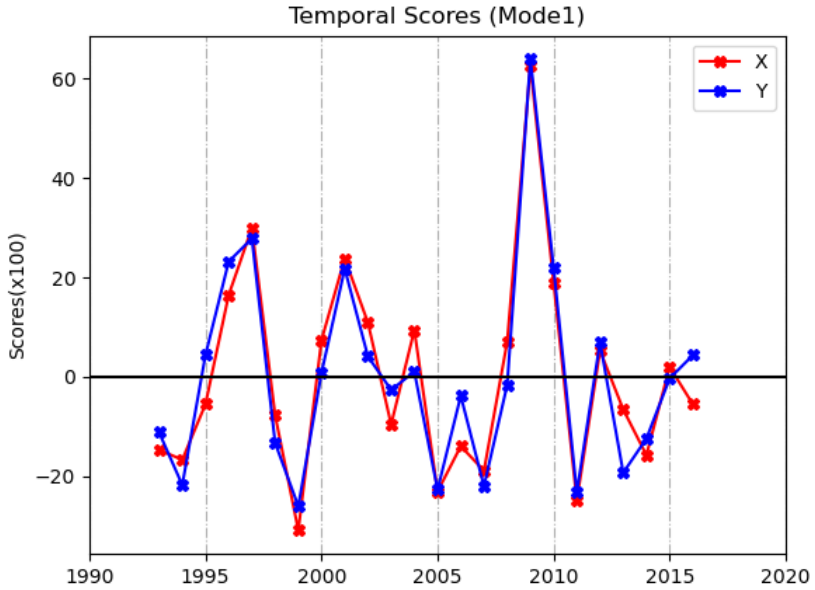
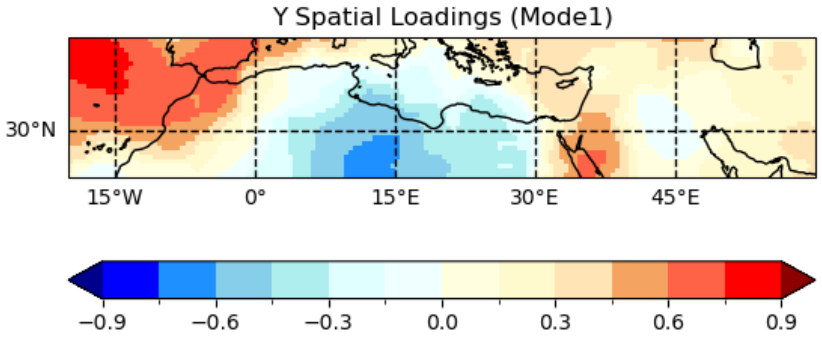
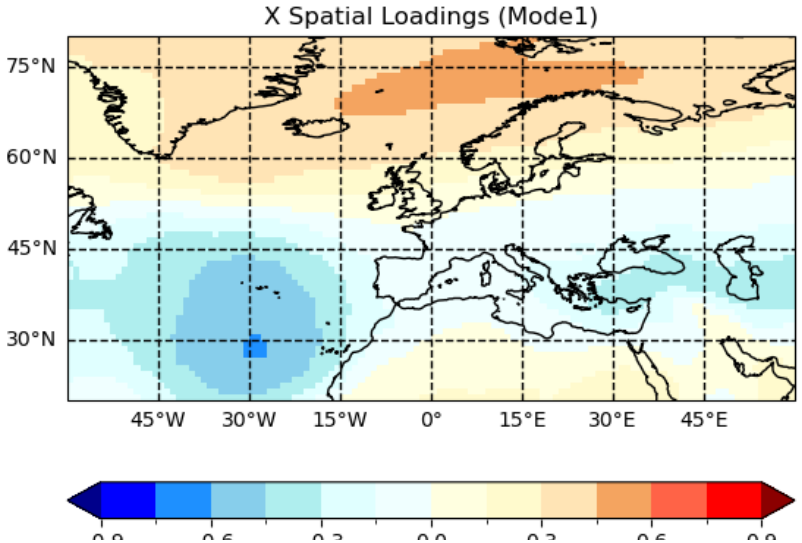
• Investigation into best predictors for CCA

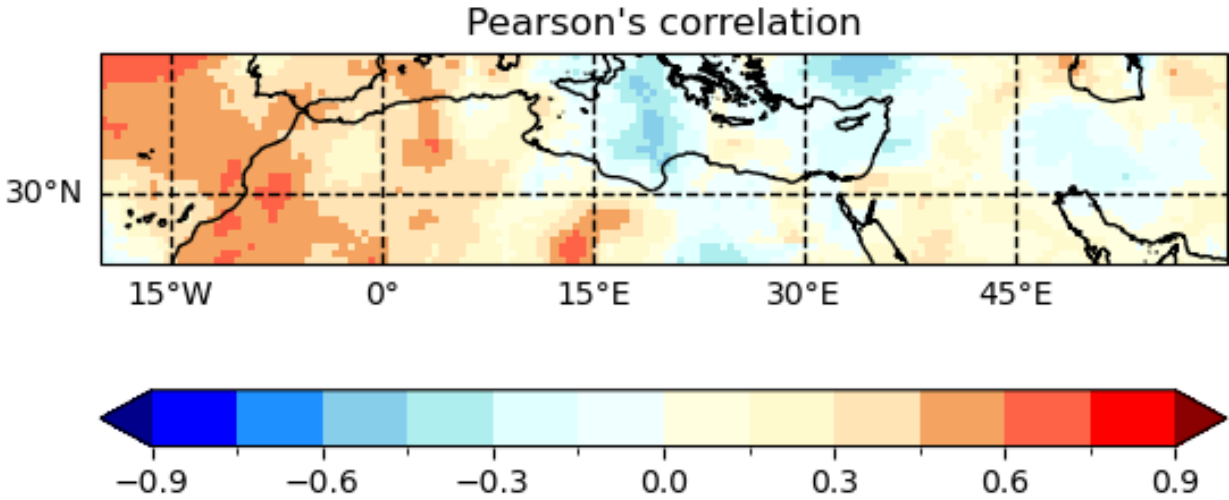
• Extratropical influence(North Atlantic Oscillation)

Glosea6 NAO region SLP forecasts for DJF (X) with DJF MENAN GPCP (Y), with time series of the first CCA pair top, correlation of Glosea6 with the timeseries middlle and orrelation of the GPCP bottom.









Model	Period	Predictor Variable	Mean Pearson correlation
GloSea6.0	1993-2016	MSLP	0.268
GloSea6.0	1993-2016	Precipitation	0.325
ECMWF	1981-2016	925mb Height	0.130
ECMWF	1993-2016	925mb Height	0.058
ECMWF	1981-2016	500mb Height	0.094
ECMWF	1981-2016	Precipitation	0.071
Meteo France	1993-2016	500mb Height	0.191
M France	1993-2016	925mb Height	0.209
M France	1993-2016	Precipitation	0.182
CMCC Italy	1993-2016	500mb Height	0.144
CMCC Italy	1993-2016	925mb Height	0.144
CMCC Italy	1993-2016	Precipitation	0.046
CanSIPS3	1981-2022	500mb Height	0.133
CanSIPS3	1993-2016	500mb Height	0.073
CFS(NMME)	1993-2016	Precipitation	0.158
DWD	1993-2016	500mb Height	0.125
NASA	1981-2022	500mb Height	0.079
COLA CCSM4	1993-2016	Precipitation	0.156
COLA CCSM4	1982-2022	Precipitation	0.237
GFDL	1993-2016	Precipitation	0.098
GFDL	1992-2022	Precipitation	0.105

Investigation into best predictors for CCA

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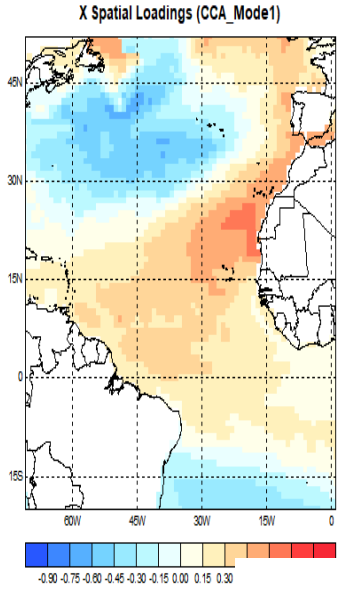
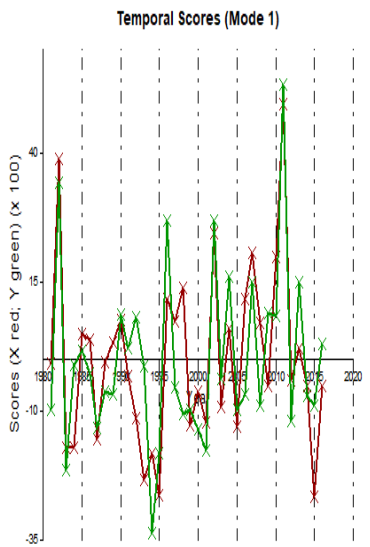
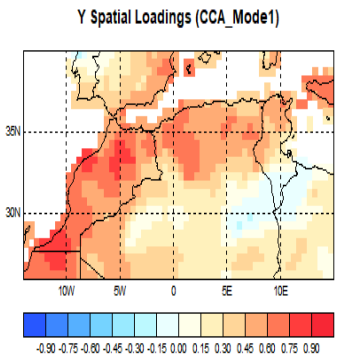
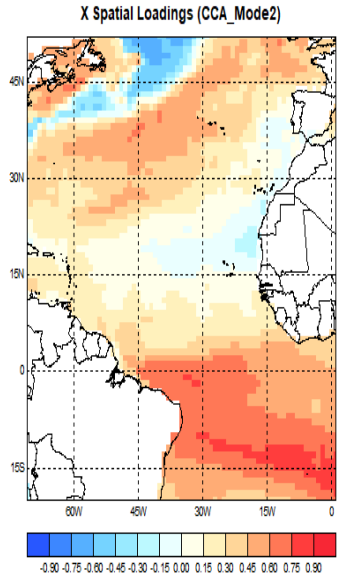
• Investigation into best predictors best predictors for CCA

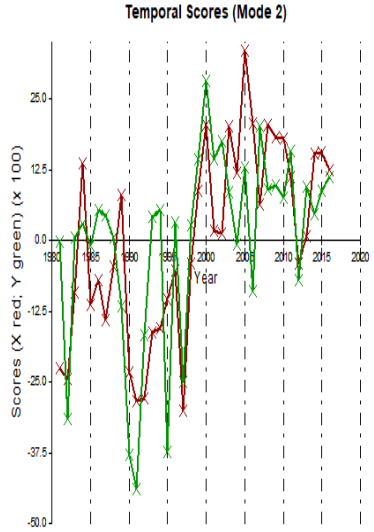
• Atlantic SST Influence

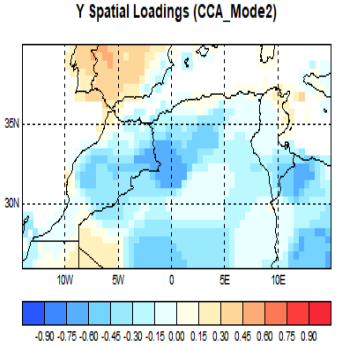


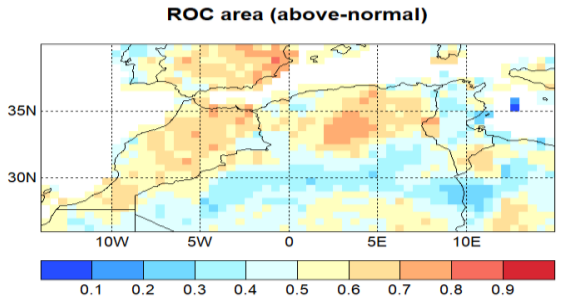


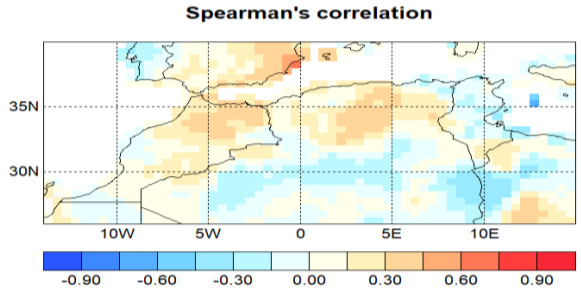


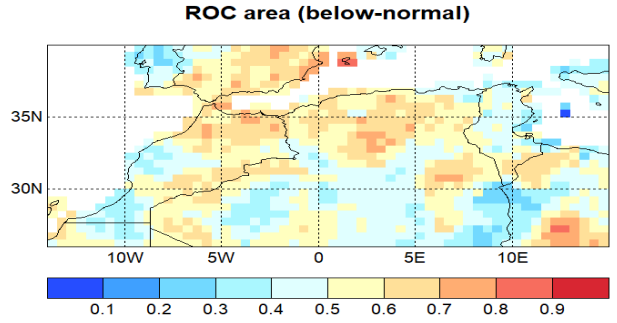












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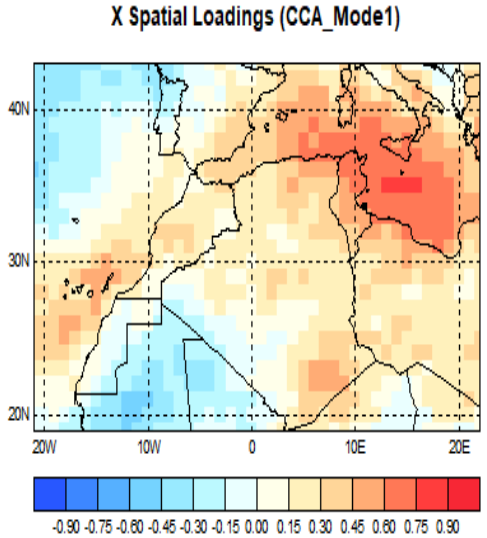
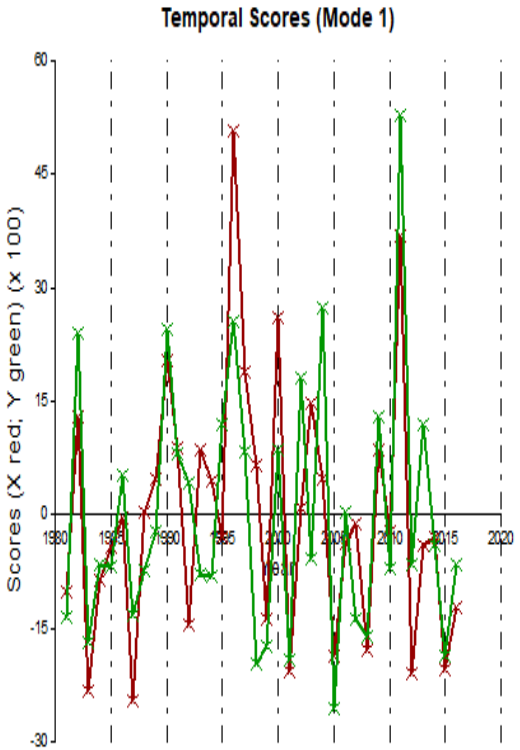
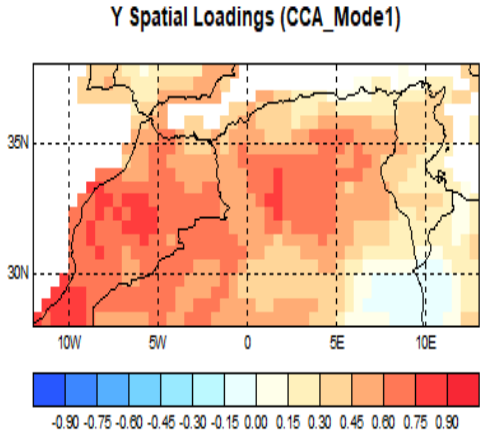
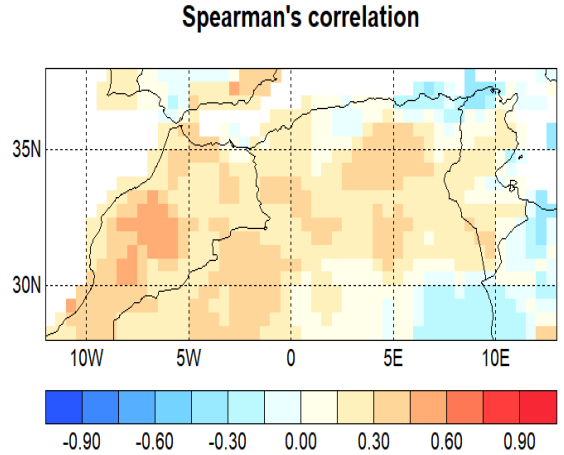
- **CCA Calibration using observed precipitation**
  - **Spring Precipitation**







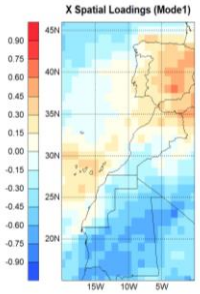


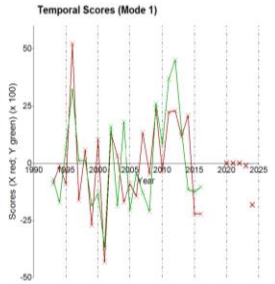
Canonical Correlation Calibration using predicted precipitation, kind of correction of geographical precipitations patterns

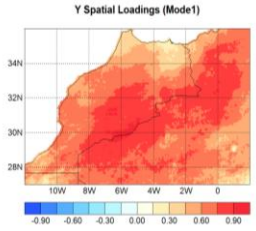
- **CCA Calibration using observed precipitation**

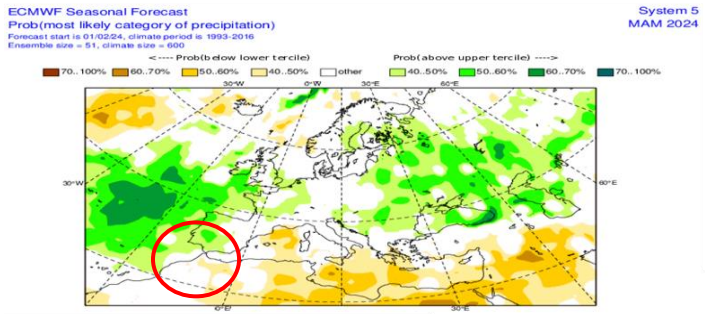
Case study: Calibrated Precipitation from ECMWF over Morocco

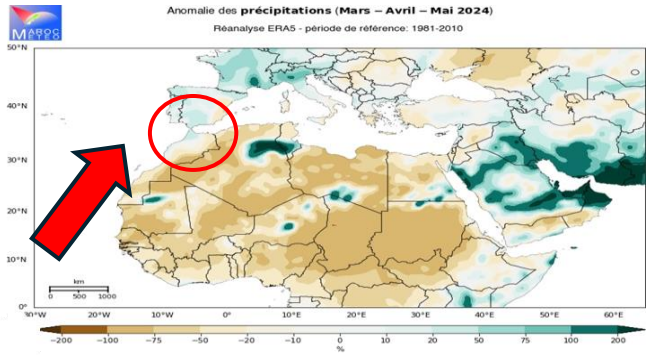
- **Spring (MAM 2024)**

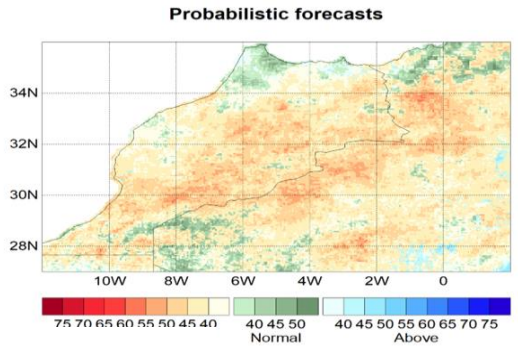


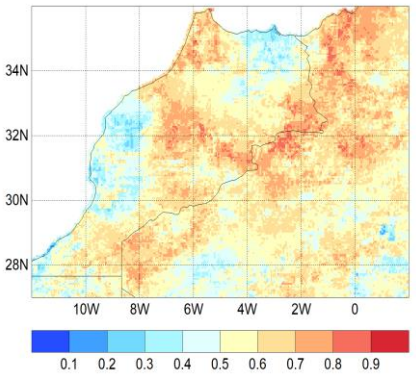


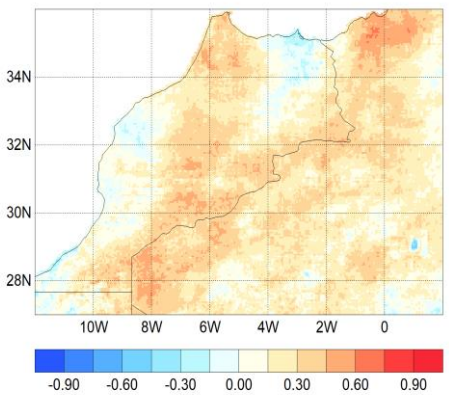


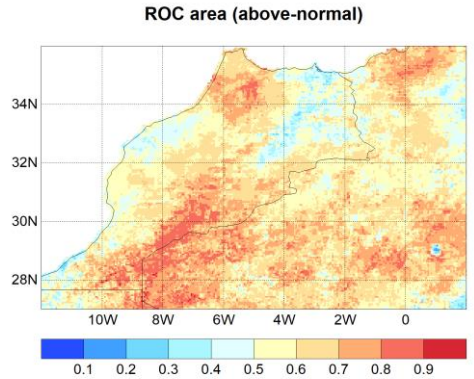












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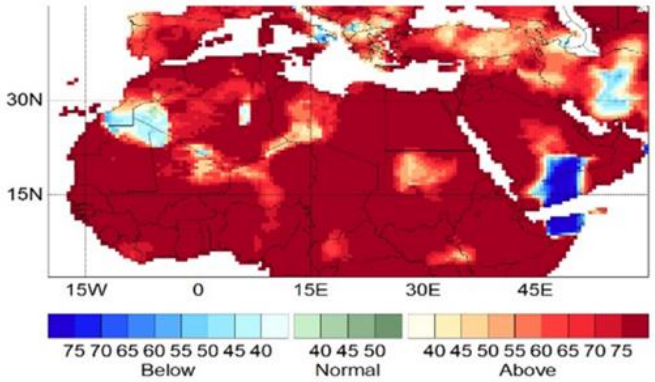
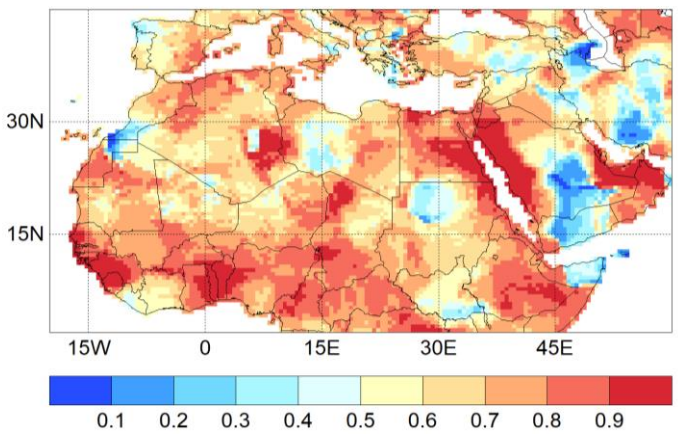
- **CCA CALIBRATED TEMPERATURE FORECAST**
  - **JJA 2024**

GFDL

Probabilistic forecasts

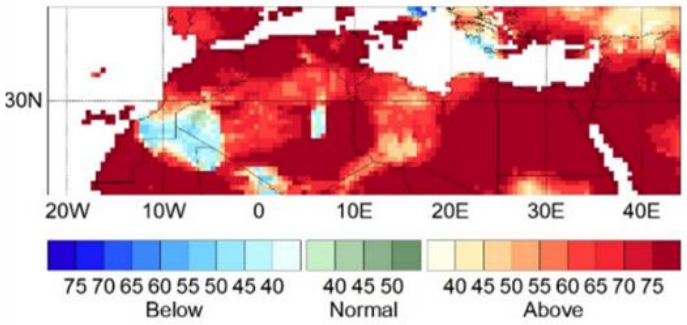


ROC area (above-normal)

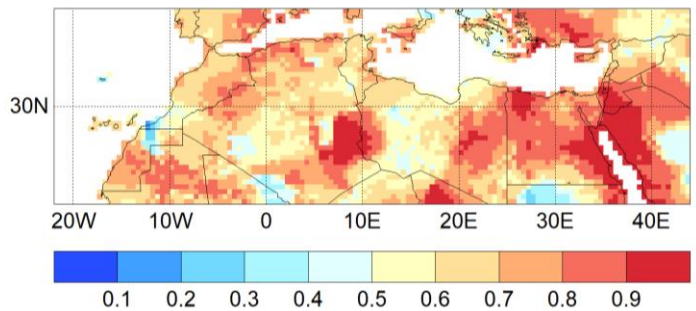


CANSIPS

Probabilistic forecasts

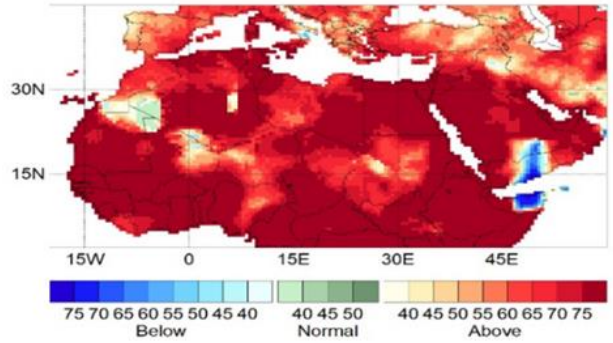


ROC area (above-normal)

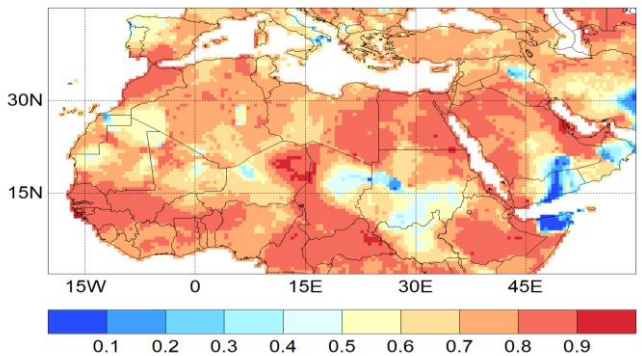


NASA

Probabilistic forecasts



ROC area (above-normal)



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DJF 2023-24 FORECAST

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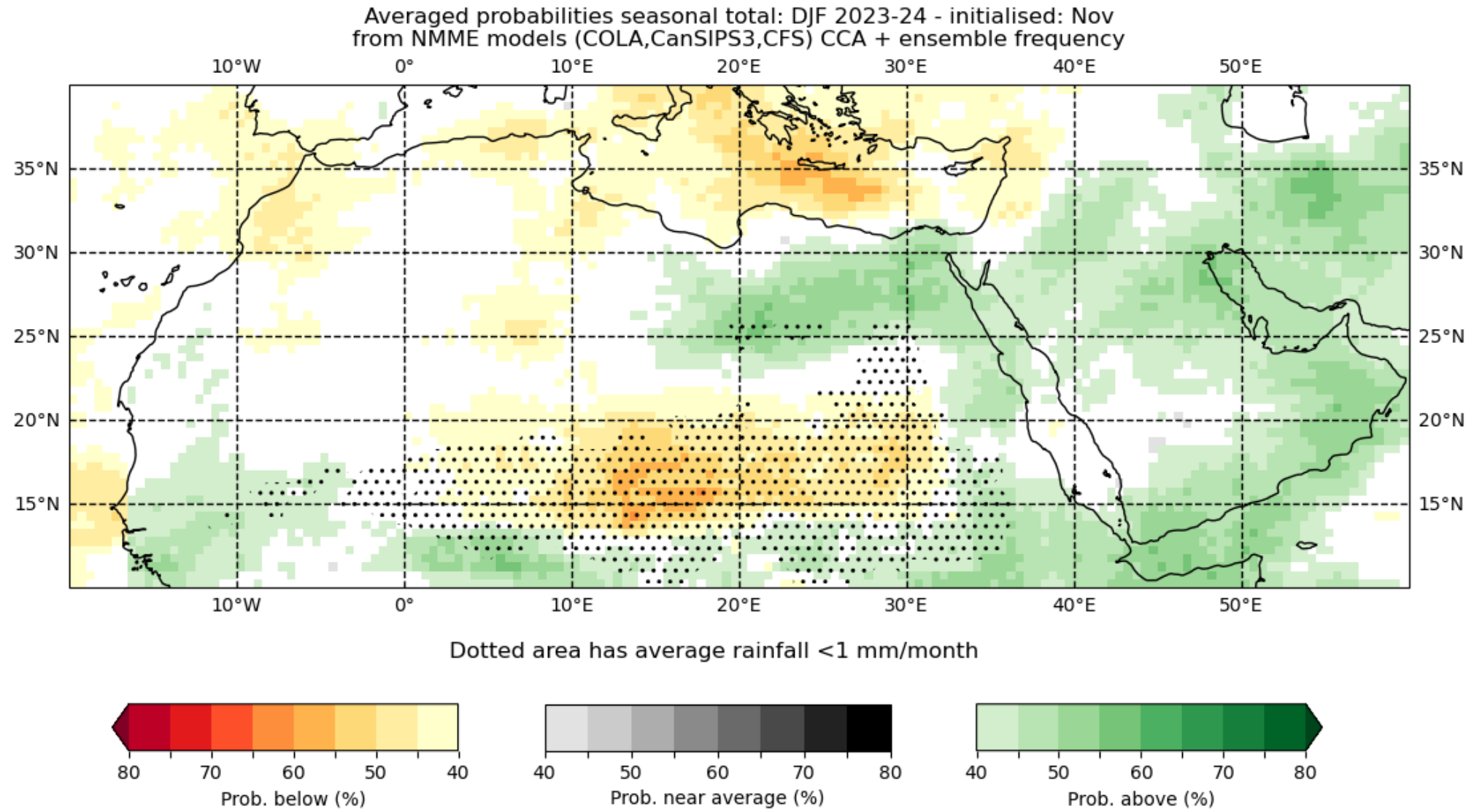
DJF 2023-24 precipitation forecast



9 member MME – 3 direct GCM forecasts, 3 CCA forecasts from tropical PPT and 3 from tropical SST

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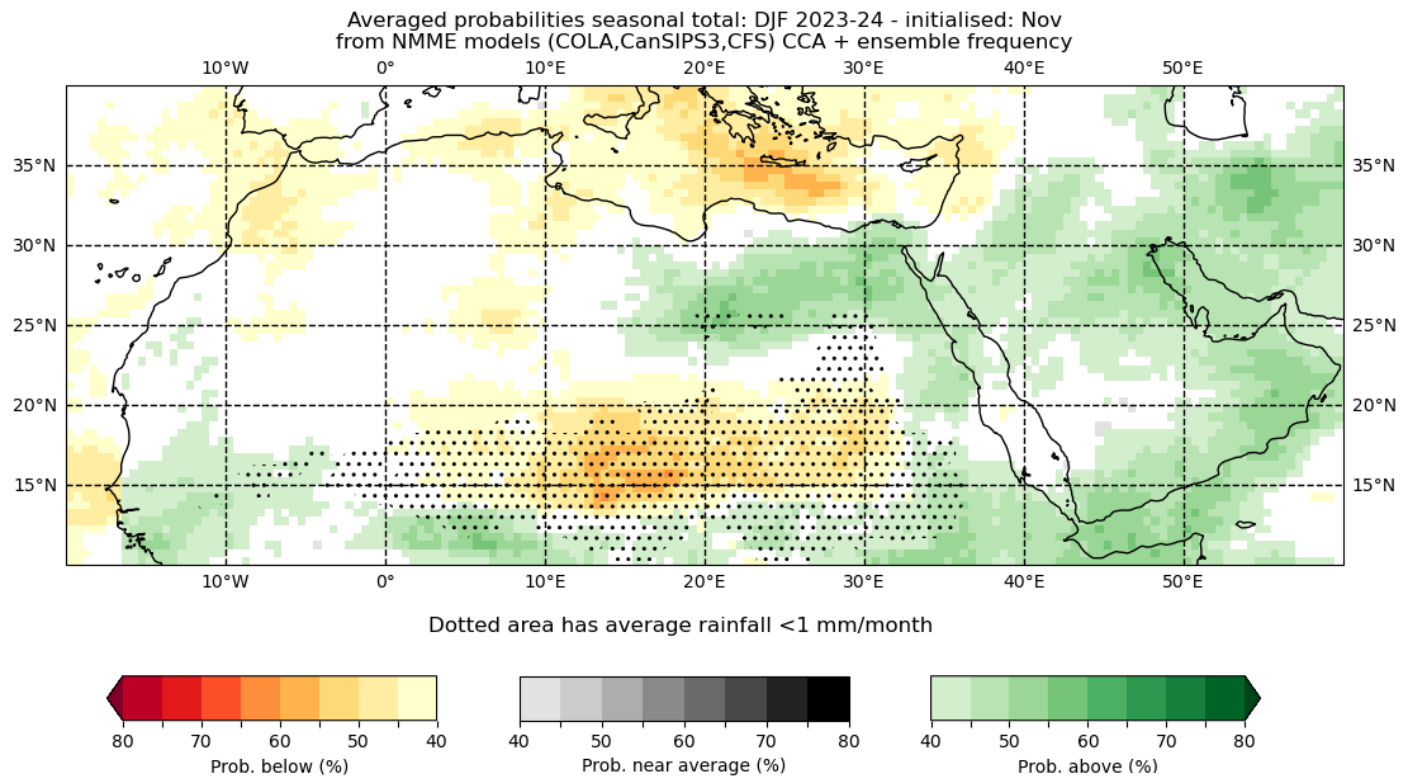
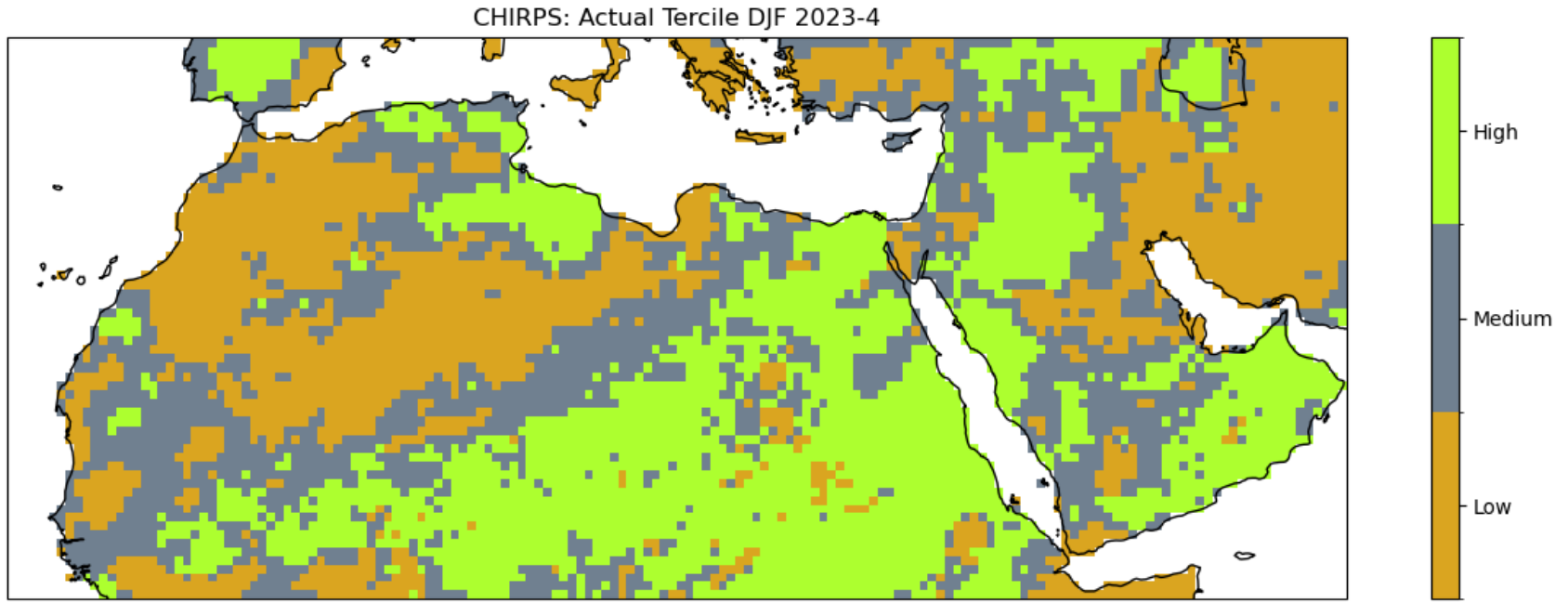
DJF 2023-24 precipitation forecast - evaluation





SOFTWARE FOR OSF

Software for OSF Aims

Single programming language

Re-use of other people's code where possible

Easy to adapt for new domains

Modular enough to be easy to maintain and open source

Use both models from CDS and from NMME (via IRI)

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Languages, libraries etc

Python

- Able to deal with larger datasets using dask
- Widely used in community including by PyCPT
- Jupyter notebooks for training/exploration

Xarray

- Handles grib data well (with cfgrib plugin)
- Used in PyCPT
- Large user base

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Progress to date

Data

- Code to download hindcasts from CDS (using CDSAPI) and IRI (using pycptdl).

Read in GCMs

- Read in all grib files from CDS and CPT IRI
  - Handles lagged ensembles from NCEP, JMA and UKMO cleanly

Load obs

- Load CHIRPS and calculate precipitation tercile for each month on Seasonal Forecast model grid

Calculate

- Calculate uncalibrated terciles for hindcast
- Prototype CPT forecast in Jupyter NB

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To do

01

Replace SeaVal (R-code) with evaluation code in Python

02

Extend to include remaining NMME models not available from C3S

03

Convert current code developed in Jupyter notebooks to a library (still usable from notebooks but in a neater way)

04

Expand prototype PyCPT into workflow consistent with CCA work in year 1

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PLANS

OSF Plans for 2024-5

- Further development of CCA (Andrew Colman and Wafae Badi)
  - ❑investigate additional sources of predictability
  - ❑prototype heatwave forecasts
- Development of software (Nick Savage)
- Machine Learning – diffusion models (Alex Chamberlain Clay)
  - ❑Explore adjustment of existing AI diffusion models to ensemble generation
  - ❑Use model to generate AI-ensembles of seasonal forecast models with large ensemble sizes
  - ❑Investigate whether AI-ensembles capture signal of NAO like real ensembles
  - ❑Use skilful AI ensembles to improve predictive skill of NAO in seasonal forecast
- ML – investigate methods to understand climate drivers using ML (WB)

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Conclusions

- CCA offers useful skill in the MENA region
  - ❑further development needed to make most of all drivers
- Machine learning offers exciting new possibilities but is still at an early stage of development
- Development of an open source Python toolkit should make wider use of the code possible
- MedCOF approaches to OSF e.g. clustering approaches should also be investigated
- MENA is a large domain, so classification into homogenous climate regimes is important
  - ❑e.g. NAO important for Maghreb regions but not further East

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