Gli eventi della Rete Rurale

Previsioni climatiche: cosa sono, come si fanno e quali possibilità di applicazioni offrono

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TAVOLO NAZIONALE DI COORDINAMENTO
NEL SETTORE DELL'AGROMETEOROLOGIA
Incontro tematico
30 maggio 2022

Preamble

Climate predictions provide information about the **probability** of anomalous climatic conditions occurring in a relatively **near future (months, seasons, a few years)**, helping to address, manage and mitigate potential severe impacts across a broad spectrum of socio-economic sectors.

Therefore, climate predictions represent an extremely useful **tool for adaptation** in a changing climate

Outline

The **main objective** of this talk is to provide a (quick) **overview of climate predictions** (mainly seasonal and decadal), of the **quality (skill)** of the forecasts produced by state–of–the–art prediction systems (e.g., C3S operational multi–system) and some **examples of applications**.

1. **What do we mean with "climate predictions"?**
2. **The basis for climate predictions**
3. **How we do climate predictions**
4. **Climate predictions and their skill in the Mediterranean region**
5. **Examples of applications**
6. **Summary and Outlook**

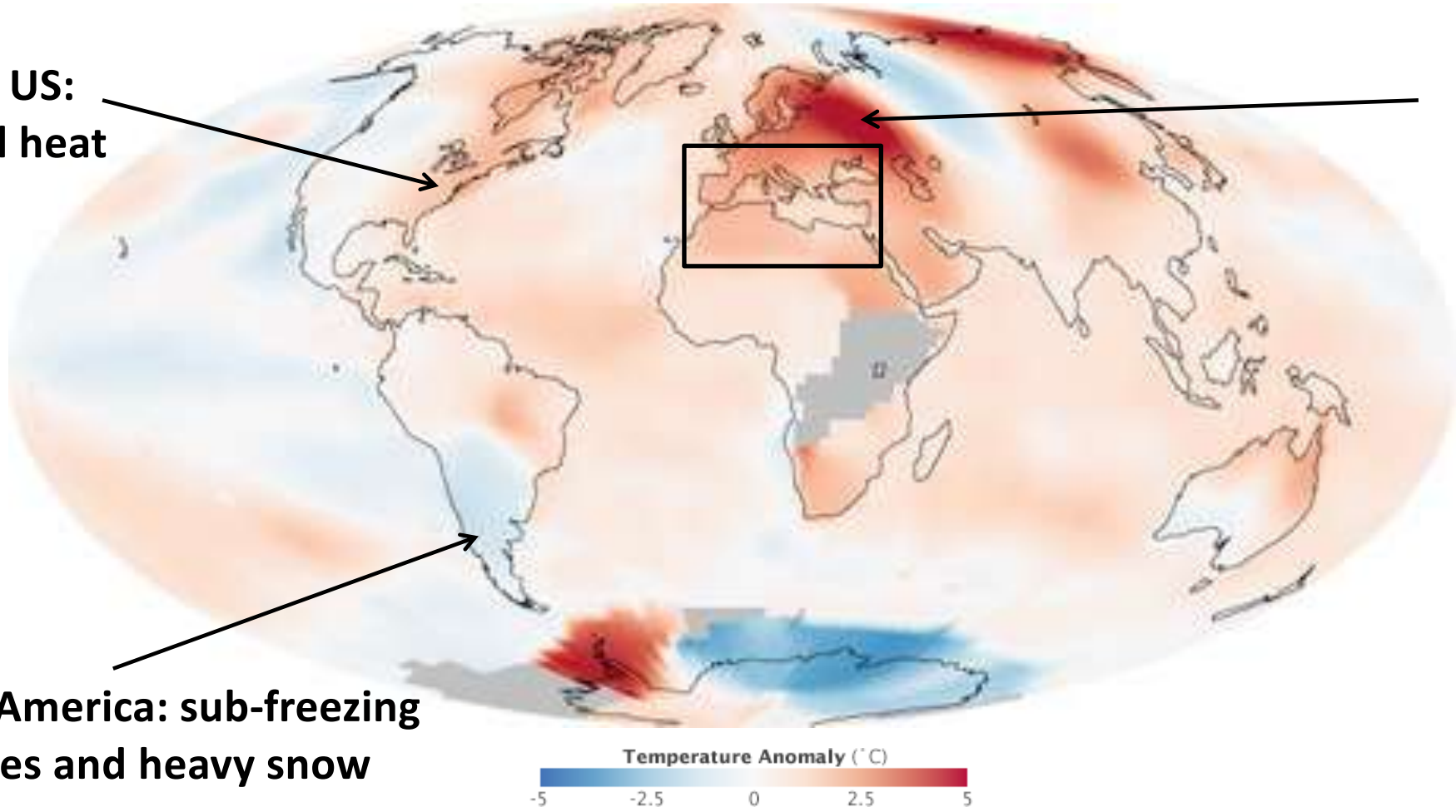
What do we mean with “climate predictions”?

The global average temperature for July 2010 was 0.6 C warmer than climatology (1951-80)

Temperature anomalies for July 2010

Eastern US: unusual heat

Eastern Europe: 5C warmer than climatology – severe wildfires

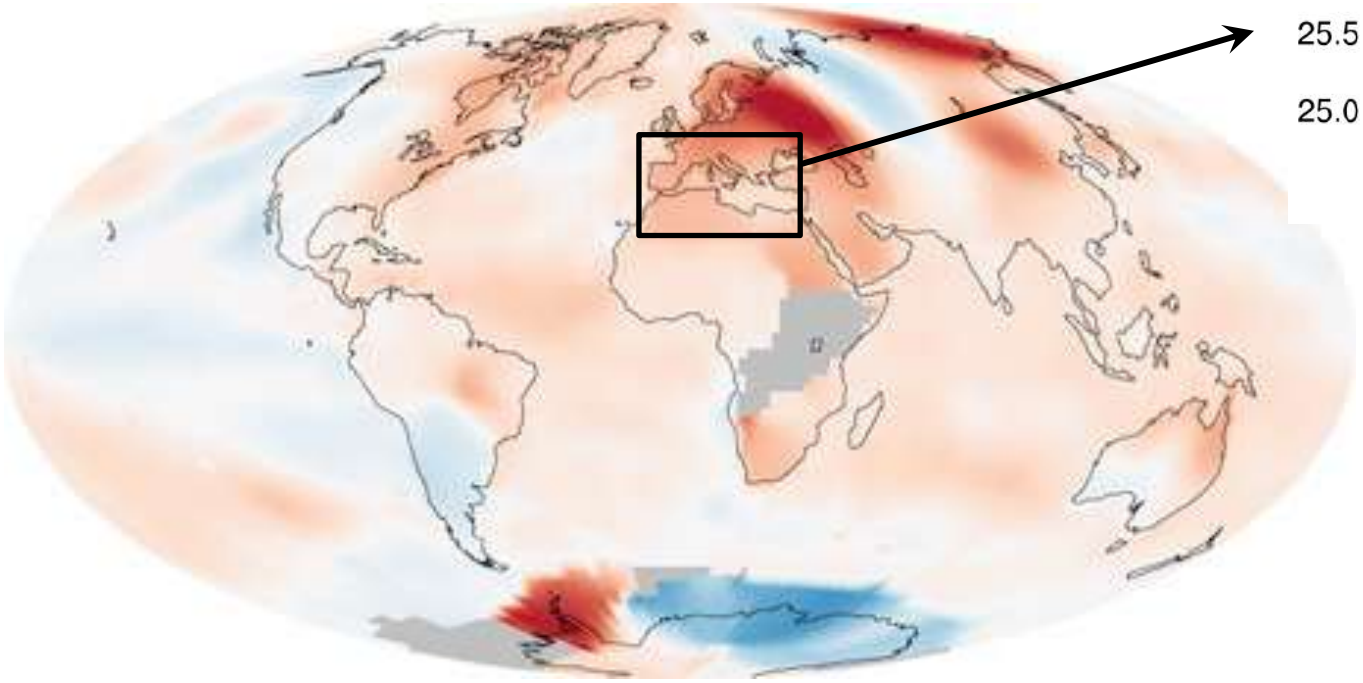


Parts of S. America: sub-freezing temperatures and heavy snow

Image from NASA’s Terra satellite

What do we mean with “climate predictions”?

Regional Variability



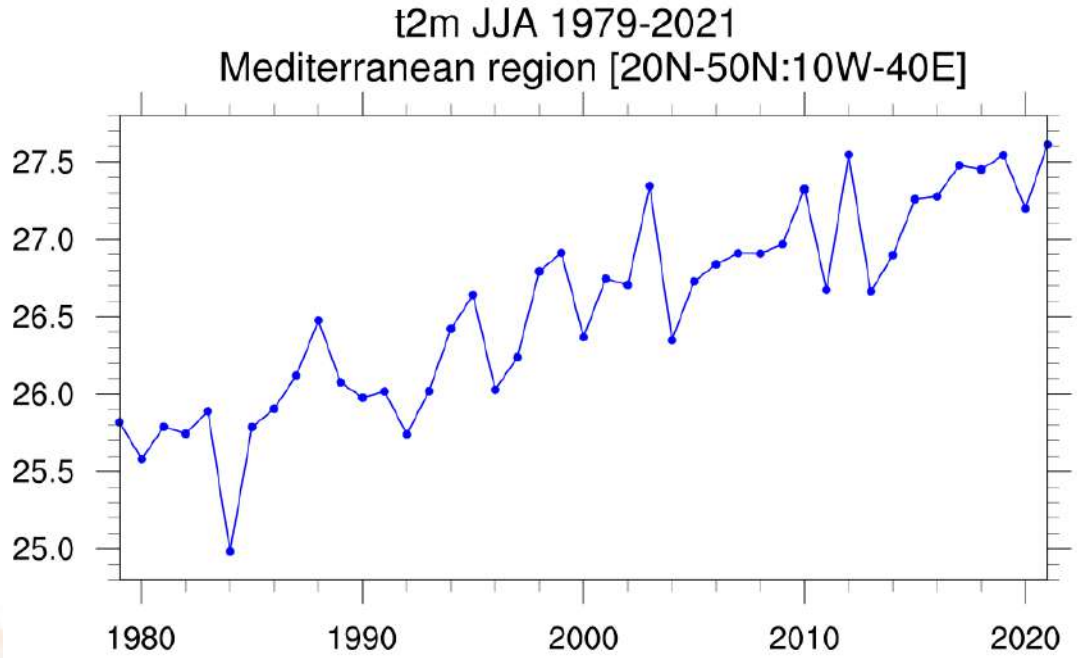
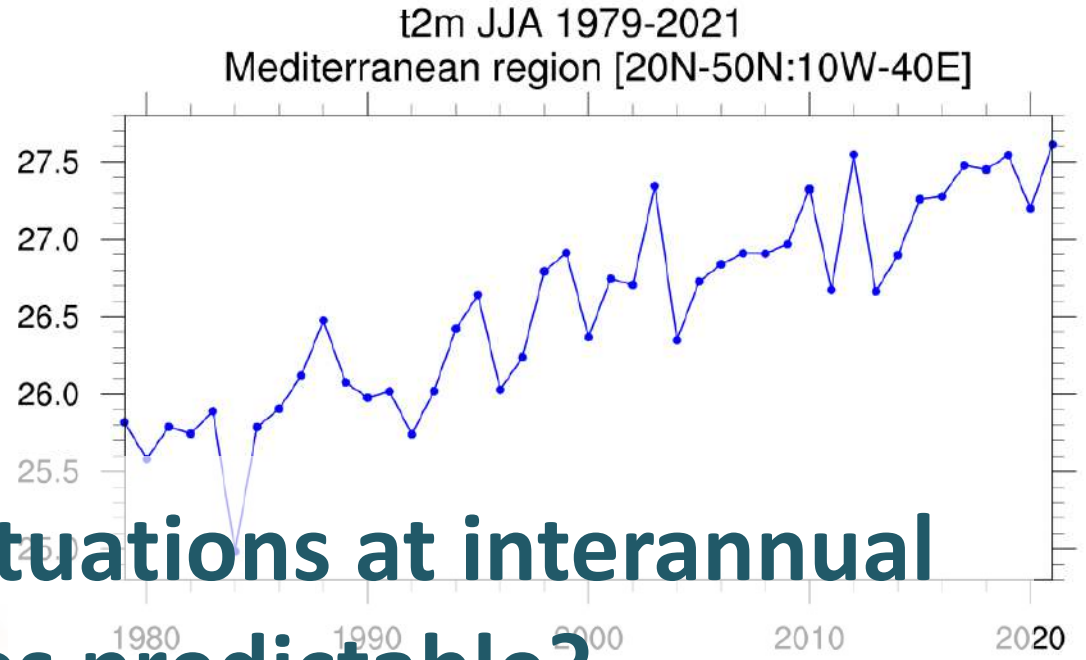


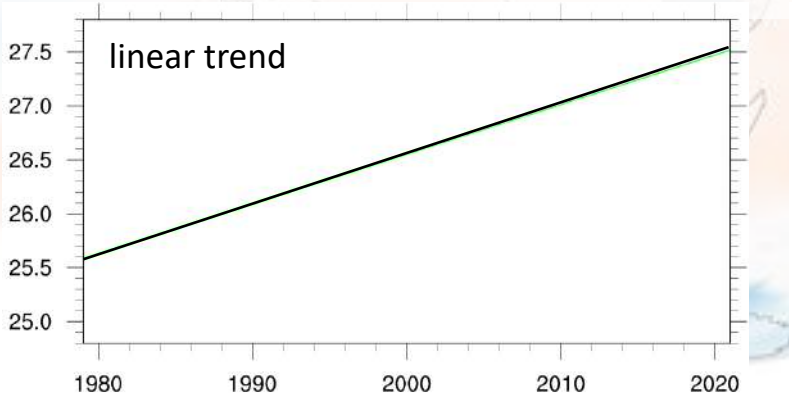
Image from NASA’s Terra satellite

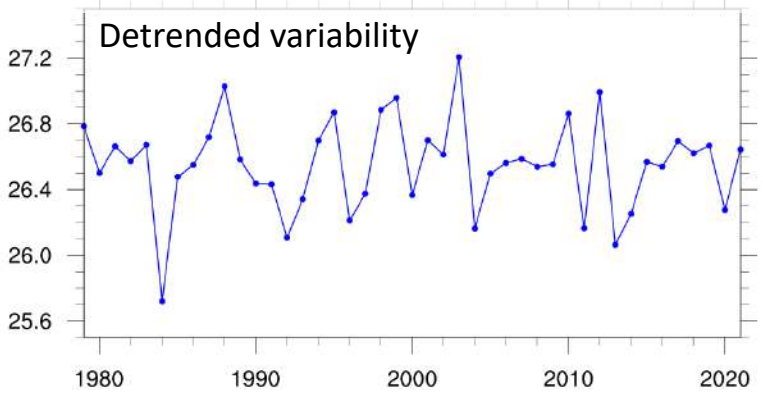
What do we mean with “climate predictions”?

Time Scales of Variability



Are these climatic fluctuations at interannual and decadal time scales predictable?





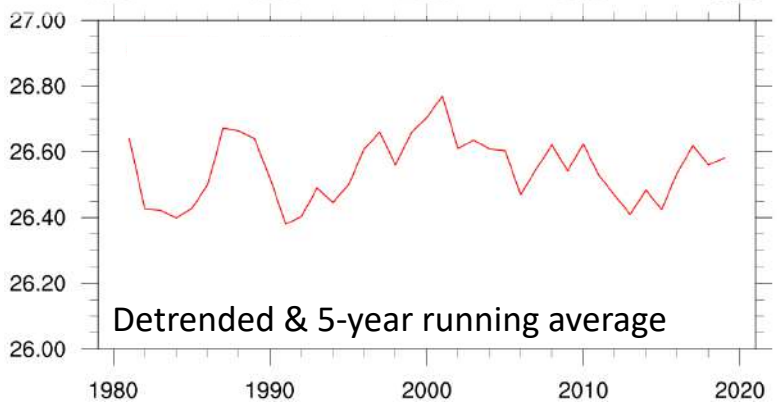
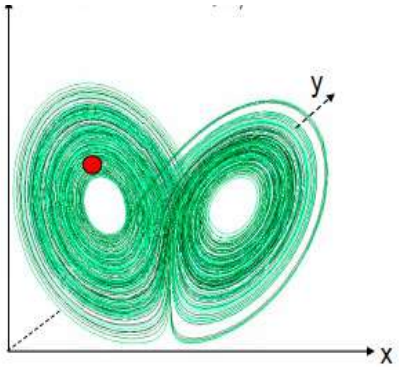


Image from NASA’s Terra satellite

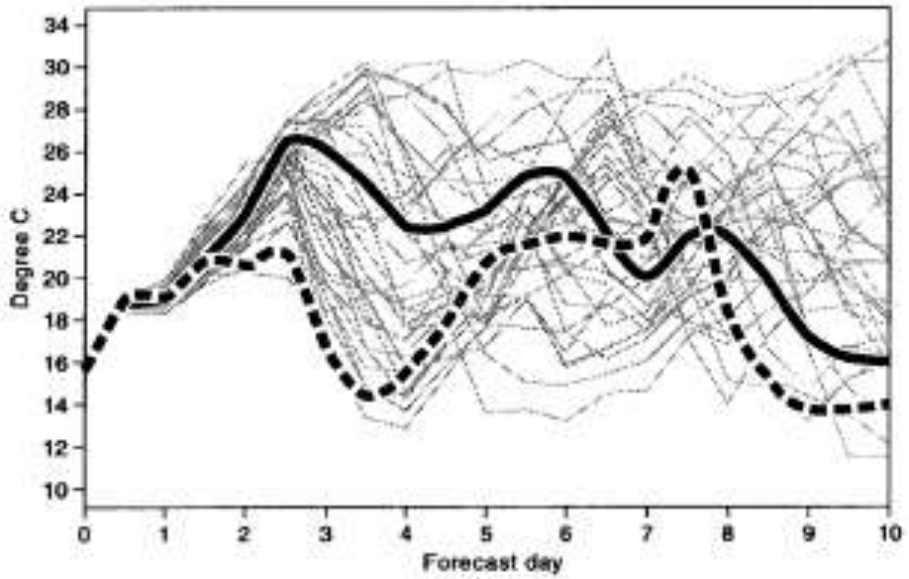
The basis for climate predictions

How is it possible to make climate predictions considered that weather is a chaotic system?

Edward N. Lorenz (1917–2008)



The atmosphere is a **chaotic system**: due to the strong non–linearity of the atmospheric dynamics, simulations (predictions) of the evolution of the atmosphere are very sensitive to (small) changes in their initial conditions.



Limit of deterministic predictability: given by the growth rate of the (inevitable) errors in the initial state → the atmosphere loses memory of its initial conditions after a **few days** (limit of about 10–15 days).

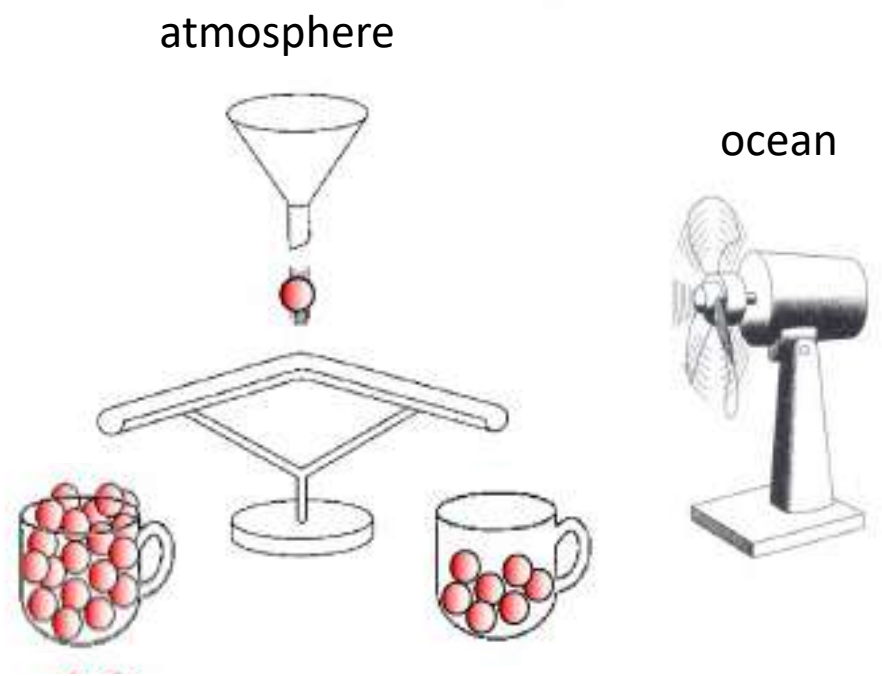
Predictability of the first kind (or initial value problem)

The memory of the **land–surface** (snow, soil moisture, vegetation) to initial conditions can extend **to several months**

The memory of the **ocean** to initial conditions can range **from months to (many) years**.

The basis for climate predictions

Ocean, land surface and sea–ice are characterised by slower dynamical processes, providing a **long–term memory** which leads to **skill in predicting climate evolution.**



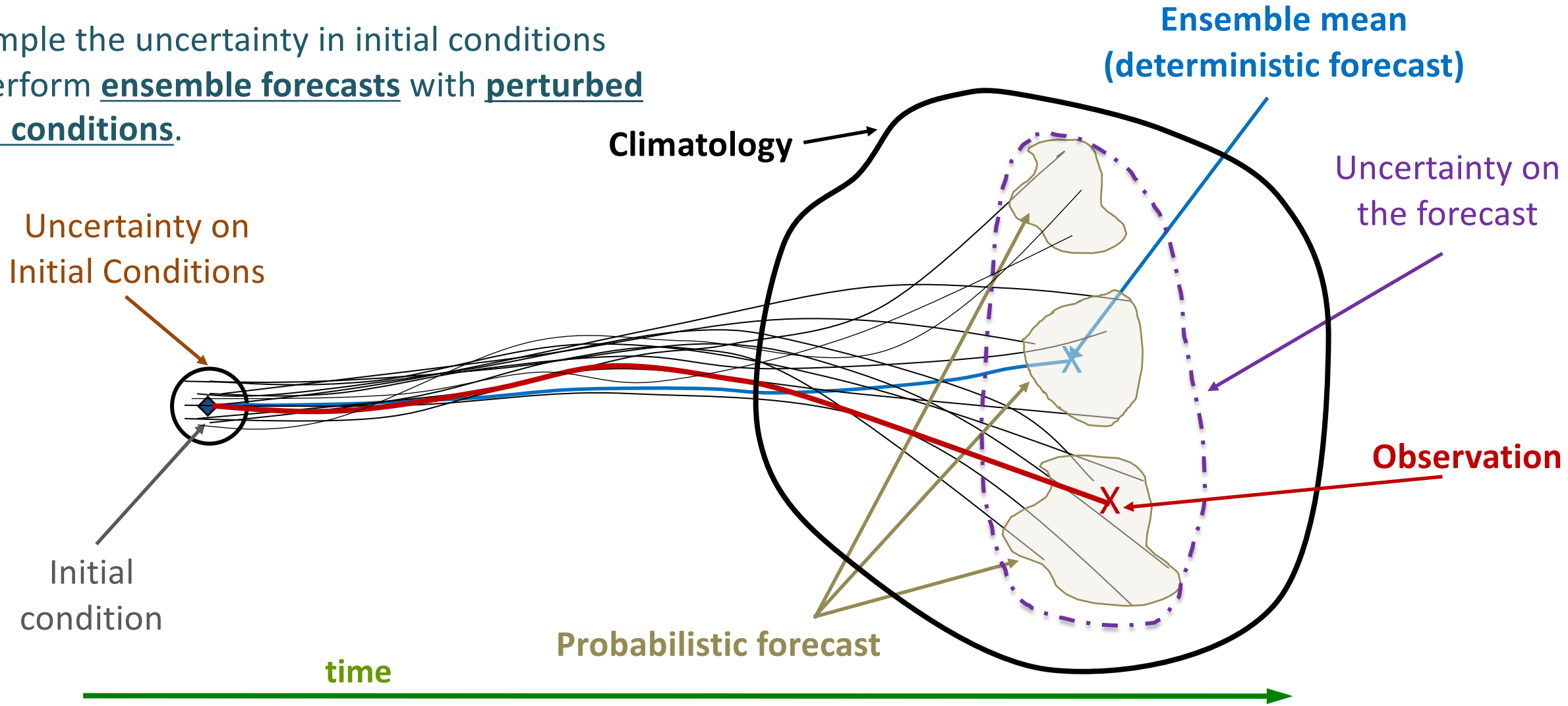
(Palmer, 1998)

Even though **individual weather events** are not predictable beyond 10 days, the ***average weather behaviour*** (climate) may be **influenced by predictable boundary conditions** (e.g. land–surface, ocean, …) for **several months or longer**.

Predictability of the second kind (or boundary conditions problem)

How we do climate predictions

To sample the uncertainty in initial conditions we perform **ensemble forecasts** with **perturbed initial conditions**.



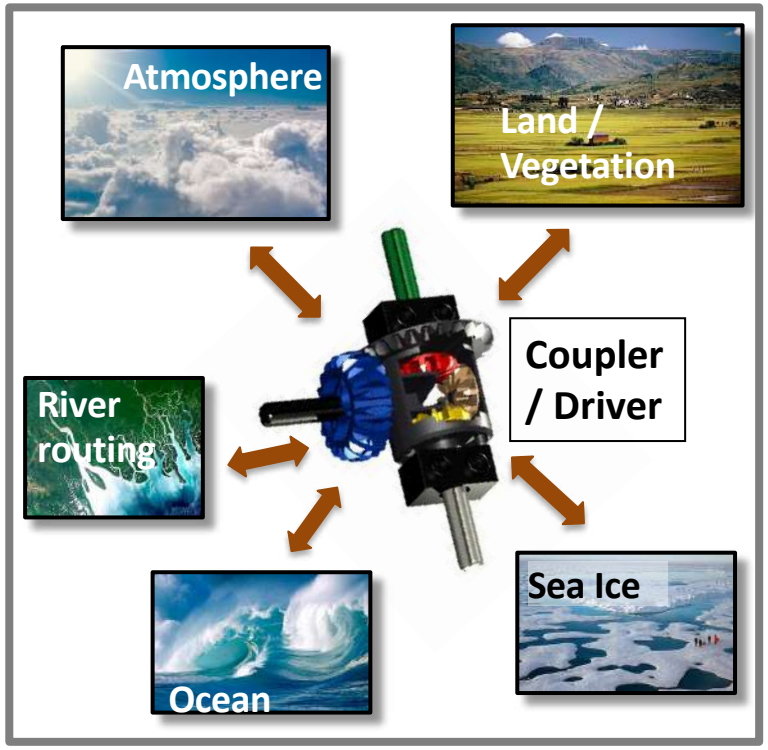
Readapted from Trzaska (http://portal.iri.columbia.edu)

The external forcing makes some state more probable than others

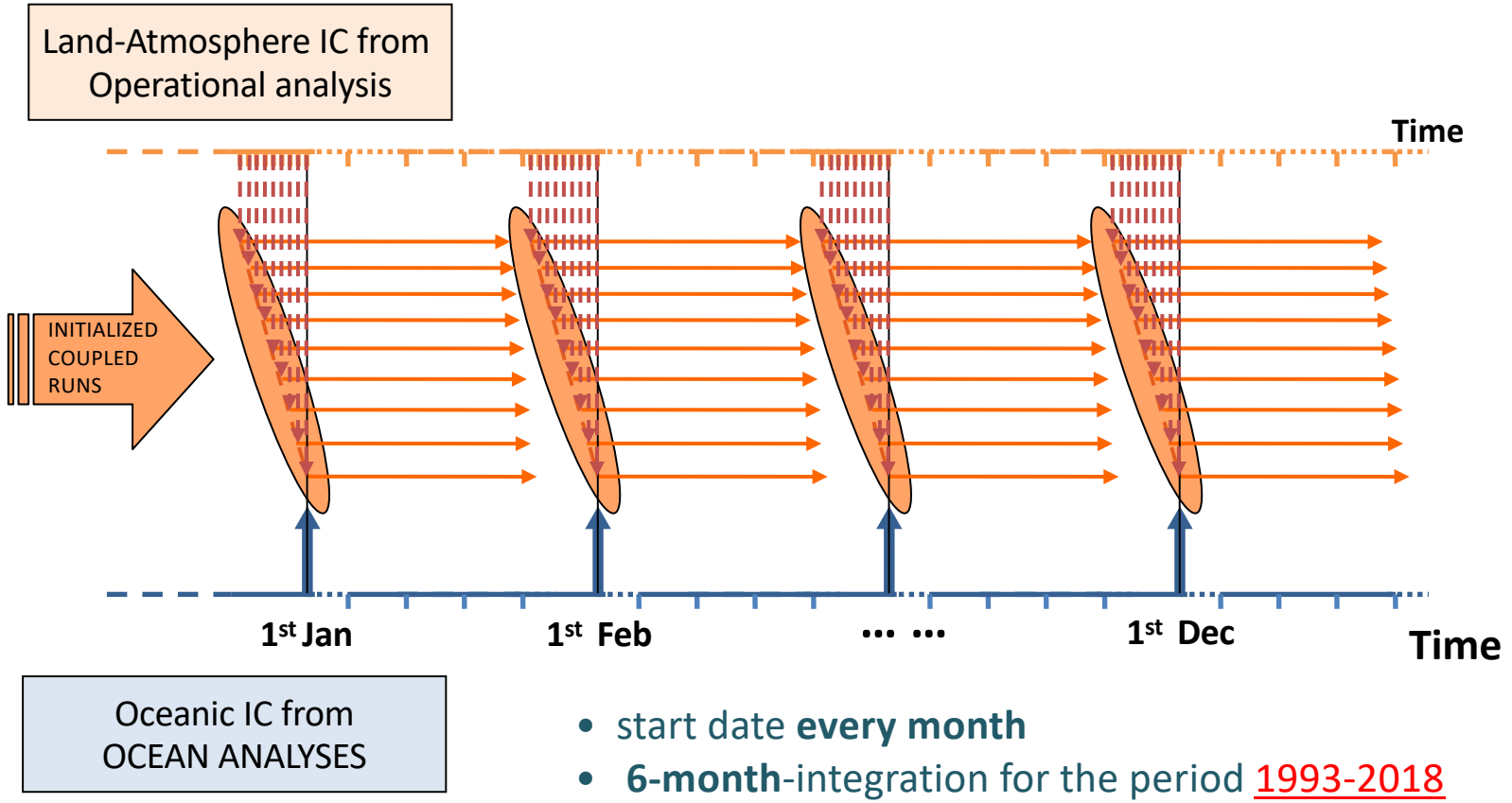
How we do climate predictions

The operational setup: forecast and re-forecasts (forecast in the past) for validation) and calibration

Climate Model



Seasonal

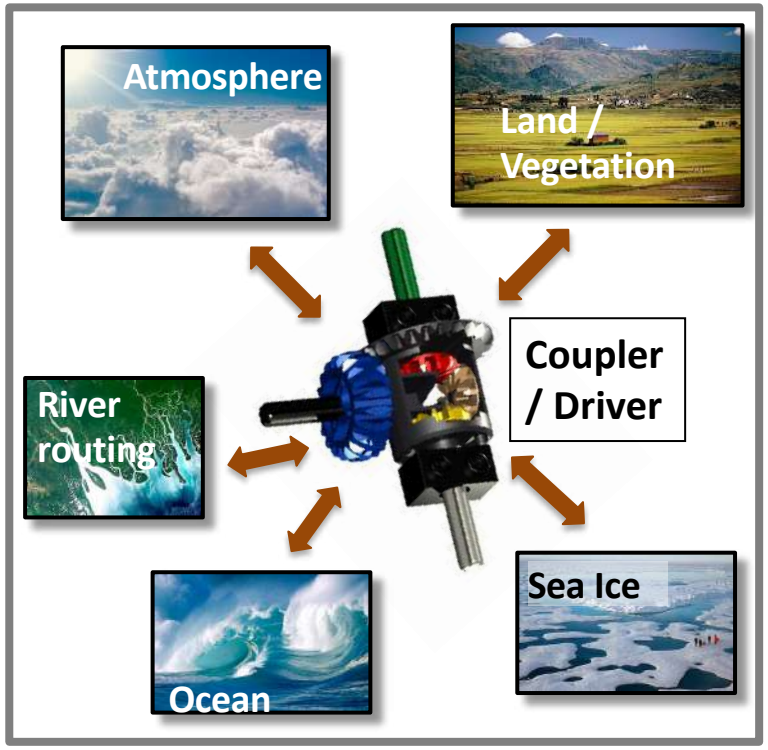


- start date **every month**
- **6-month**-integration for the period 1993-2018
- **12 start dates** per year (once a month)
- **50 ensemble members** for each start date

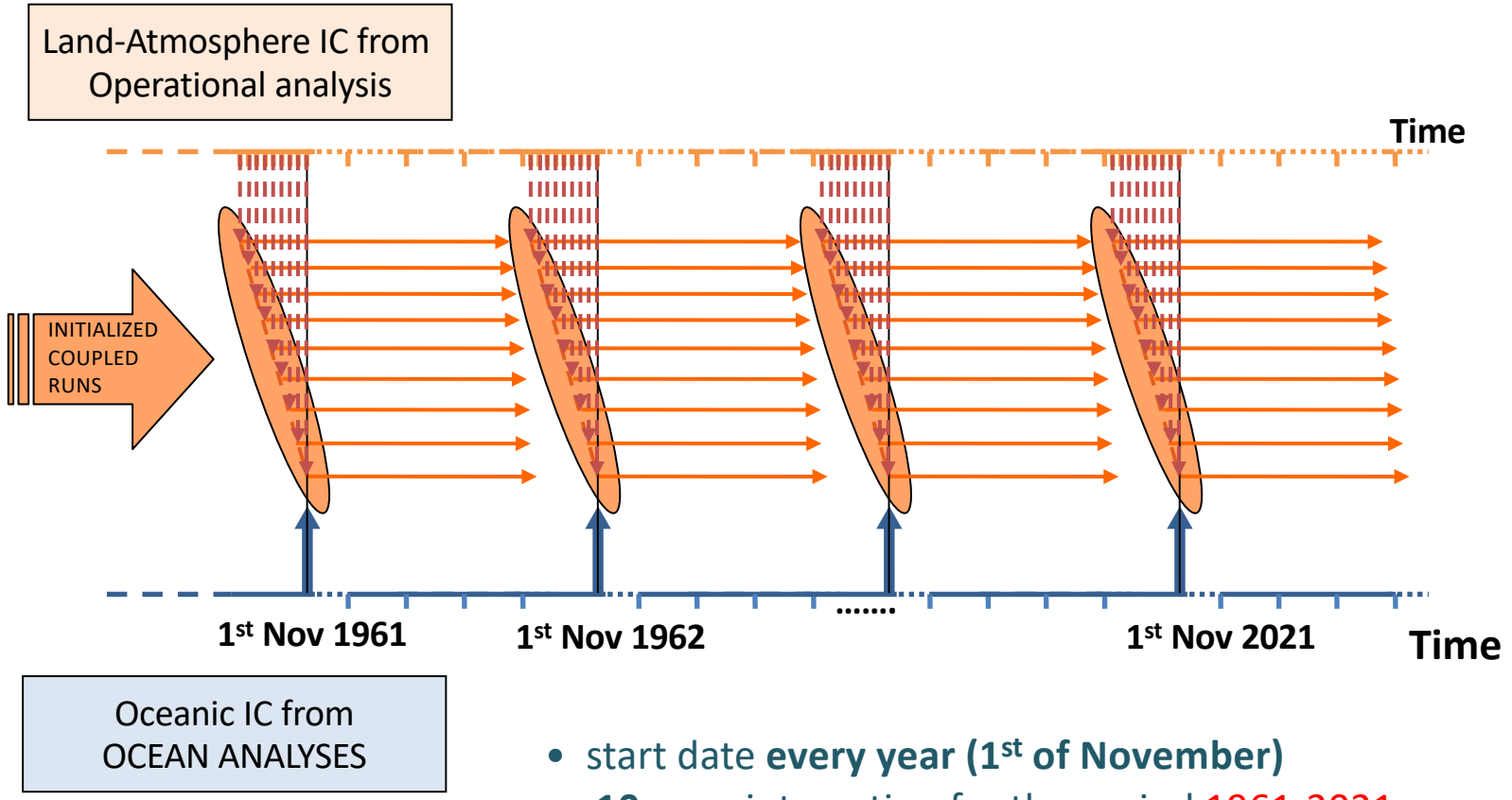
How we do climate predictions

The operational setup: forecast and re-forecasts (forecast in the past) for validation) and calibration

Climate Model



Decadal



- start date **every year (1st of November)**
- **10-year**-integration for the period 1961-2021
- **20 ensemble members** for each start date

How we do climate predictions

Climate Change

C3S multi-system seasonal forecast

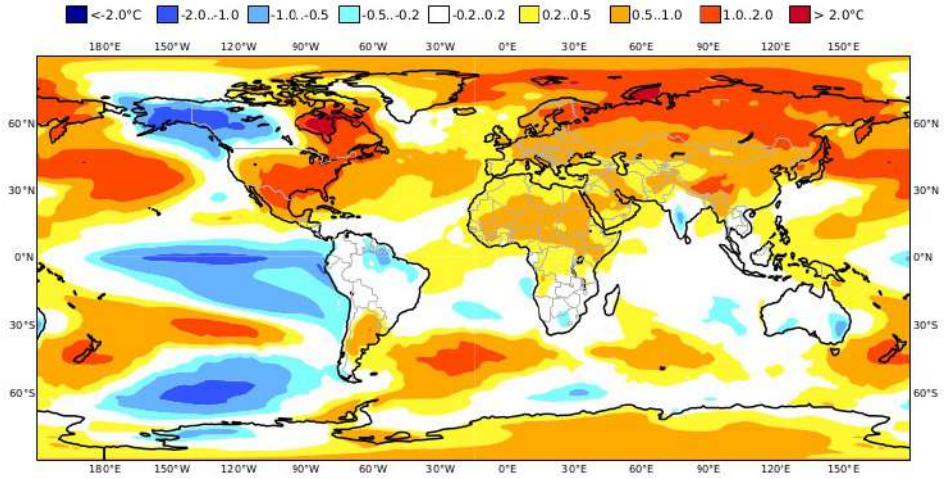
DJF 2021-2022 Prediction – Start date: 2021 November 1st

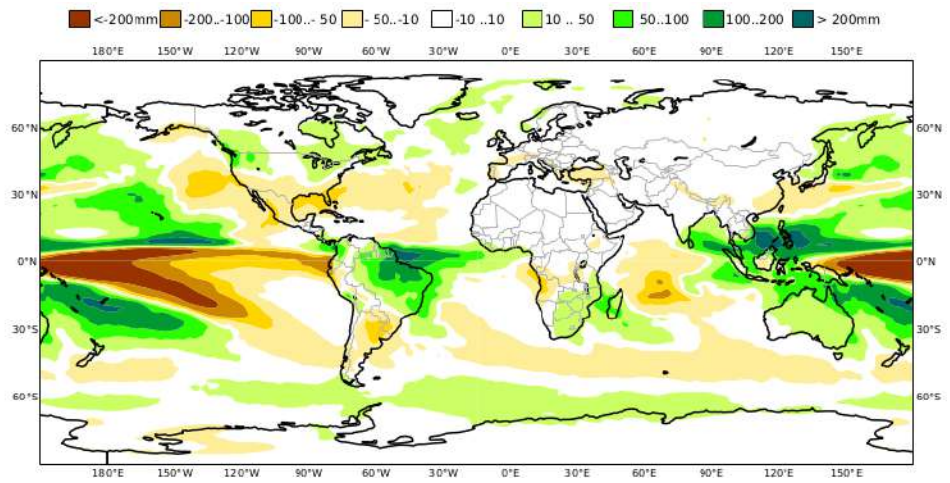
(reference period 1993–2016)

T2m

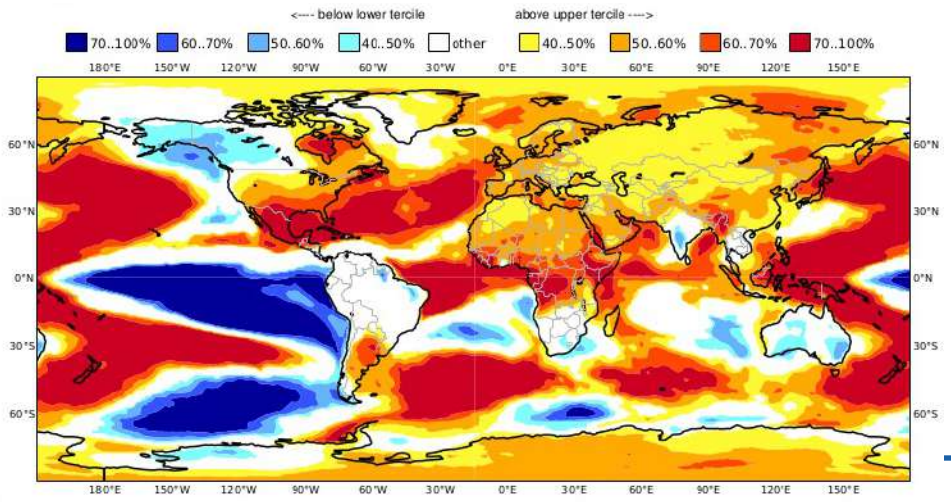
Precipitation

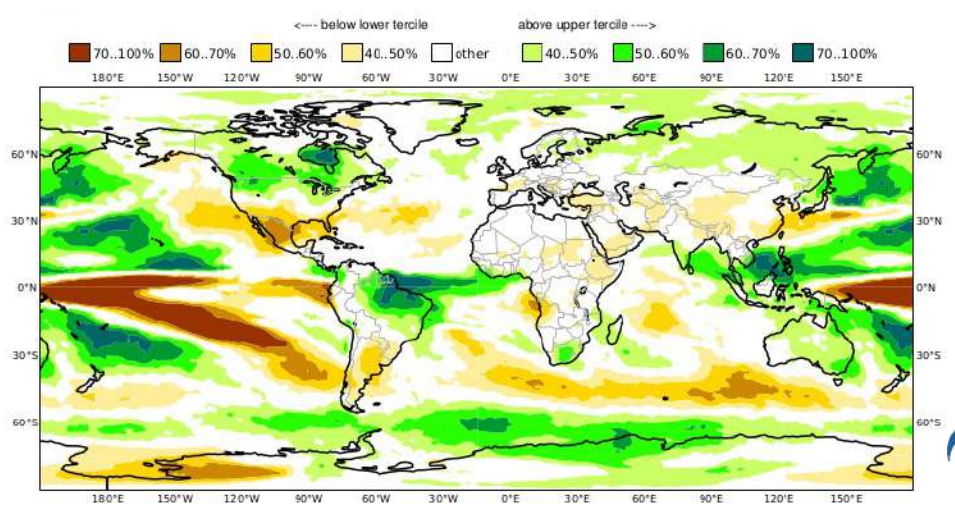
DJF mean anomaly





DJF probabilistic forecast





How we do climate predictions

T2m ACC

(reference period 1993 – 2016)

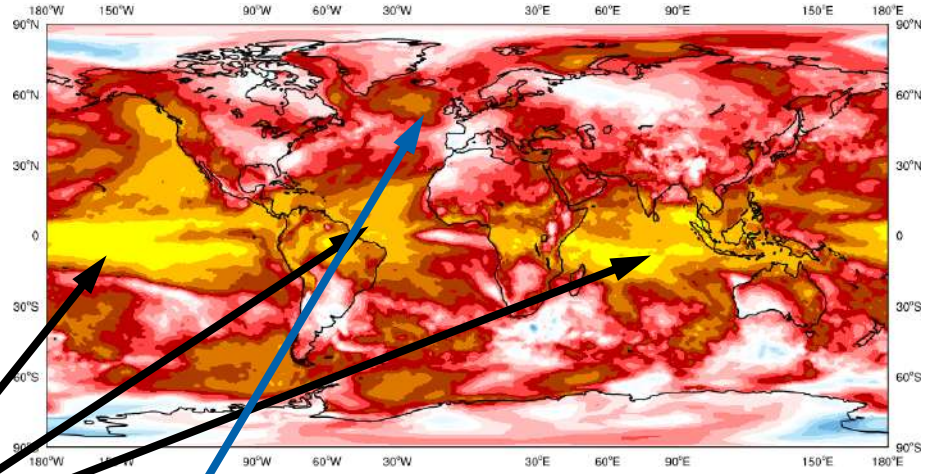
Lead season 1

Lead time 1 refers to the season starting one month after the start date (e.g. Feb lead 1 = MAM)

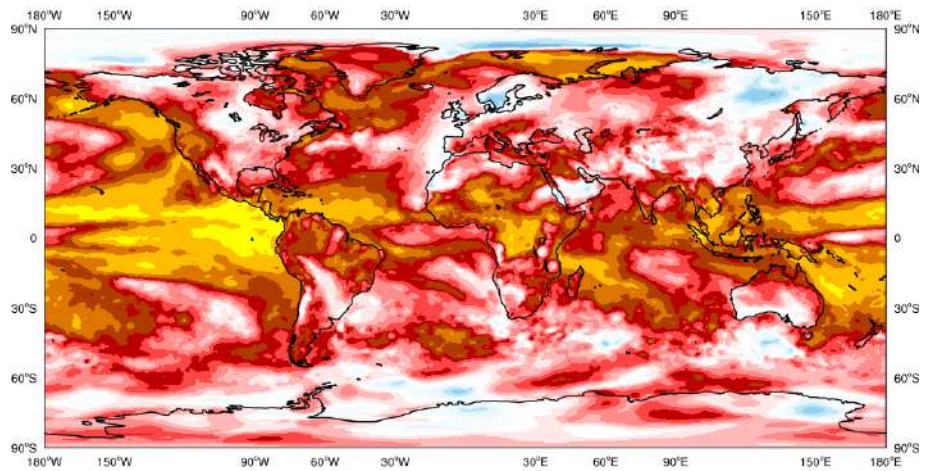
- Skill is higher in the Tropical oceans (ENSO and teleconnections) and extra-trop. Pacific

- Good skill in the northern Atlantic region, particularly in the winter and the spring

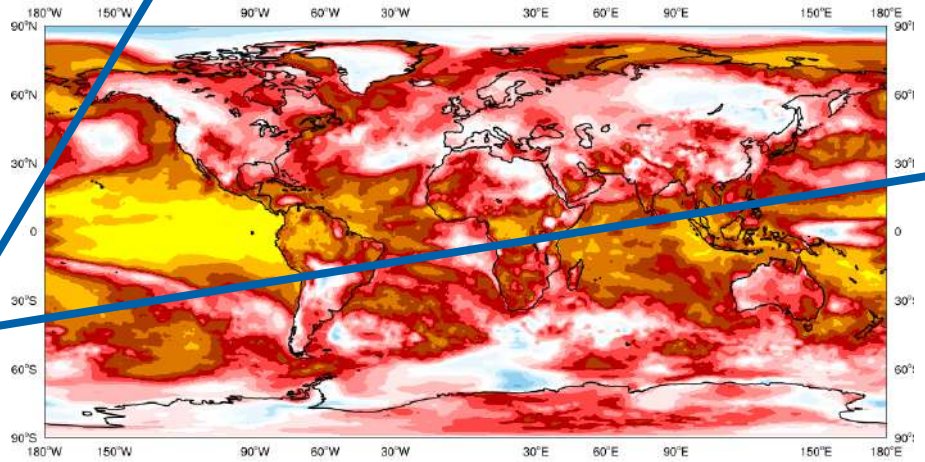
Feb 1st → MAM



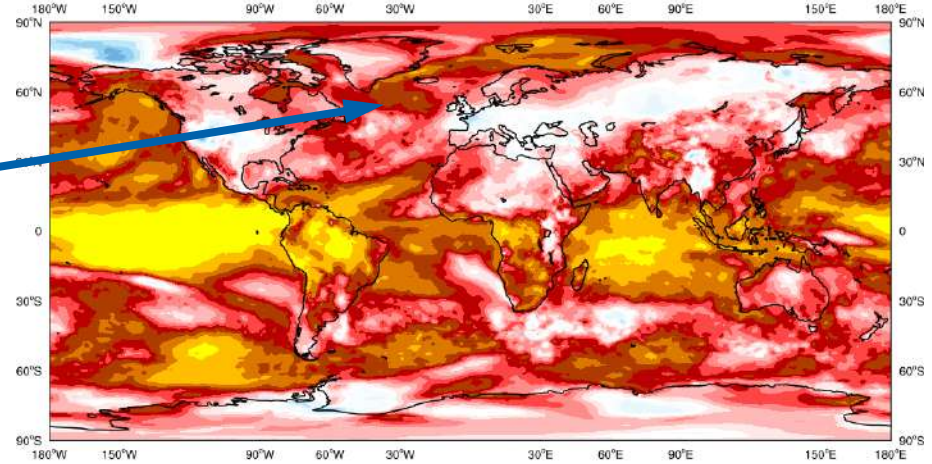
May 1st → JJA



Aug 1st → SON



Nov 1st → DJF



CMCC SPS3.5 (Gualdi et al. 2020)

How we do climate predictions

Precip ACC

(reference period 1993 – 2016)

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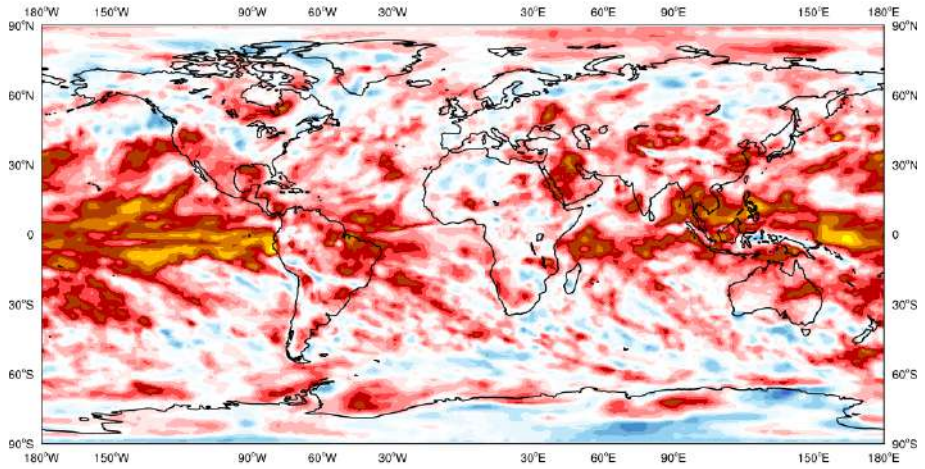
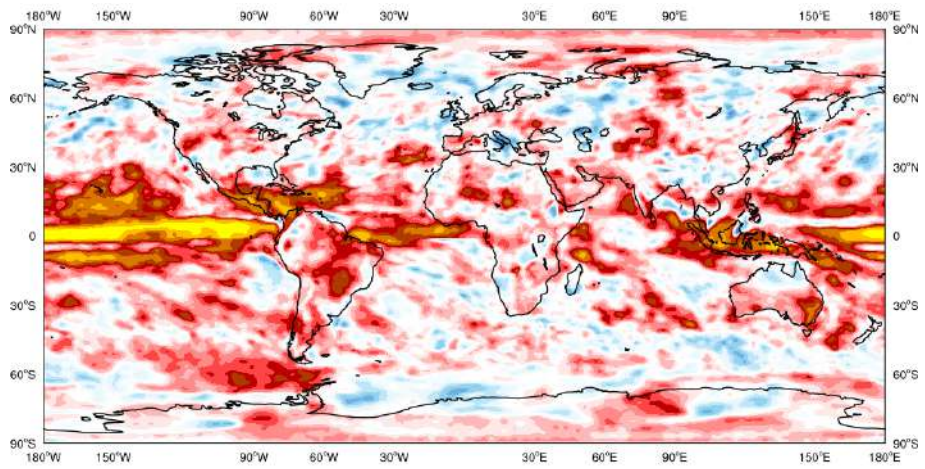
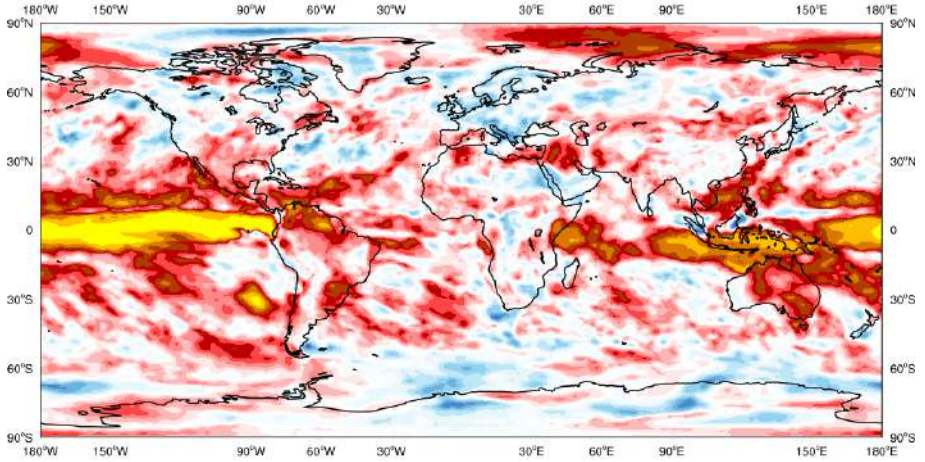


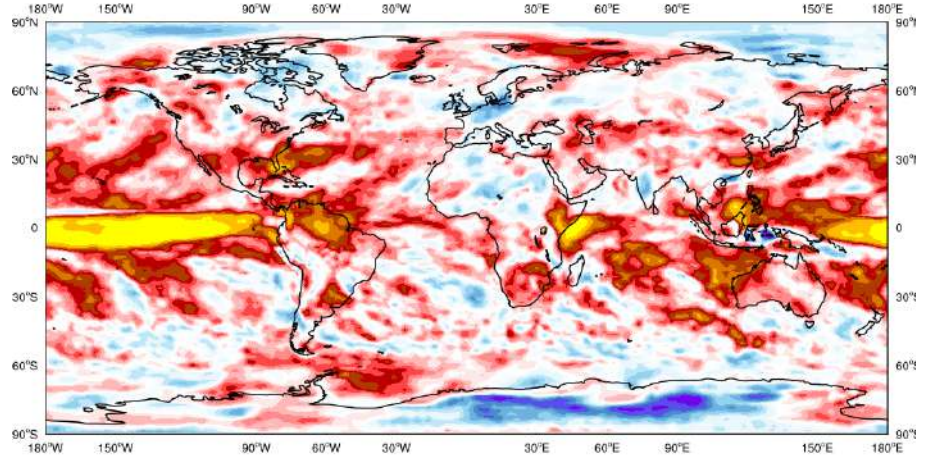
May 1st → JJA



Aug 1st → SON



Nov 1st → DJF



CMCC SPS3.5 (Gualdi et al. 2020)

Climate predictions and their skill in the Mediterranean region

DJF Forecasts **initialised on** **November 1st**

Anomaly Correlation Coefficients

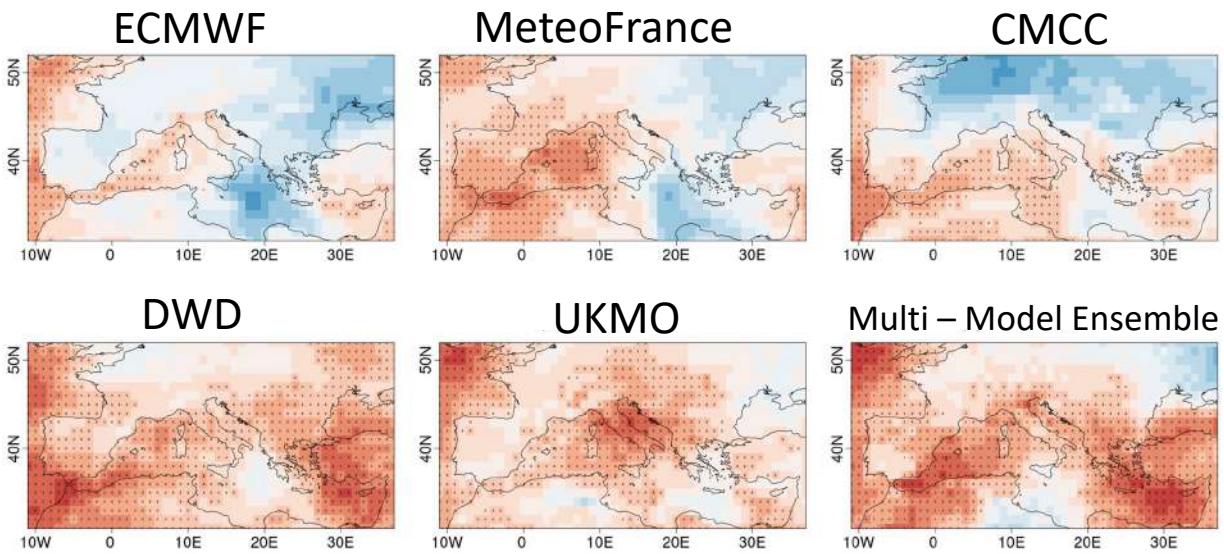
with respect to ERA5, 1993 – 2014

C3S multi–system

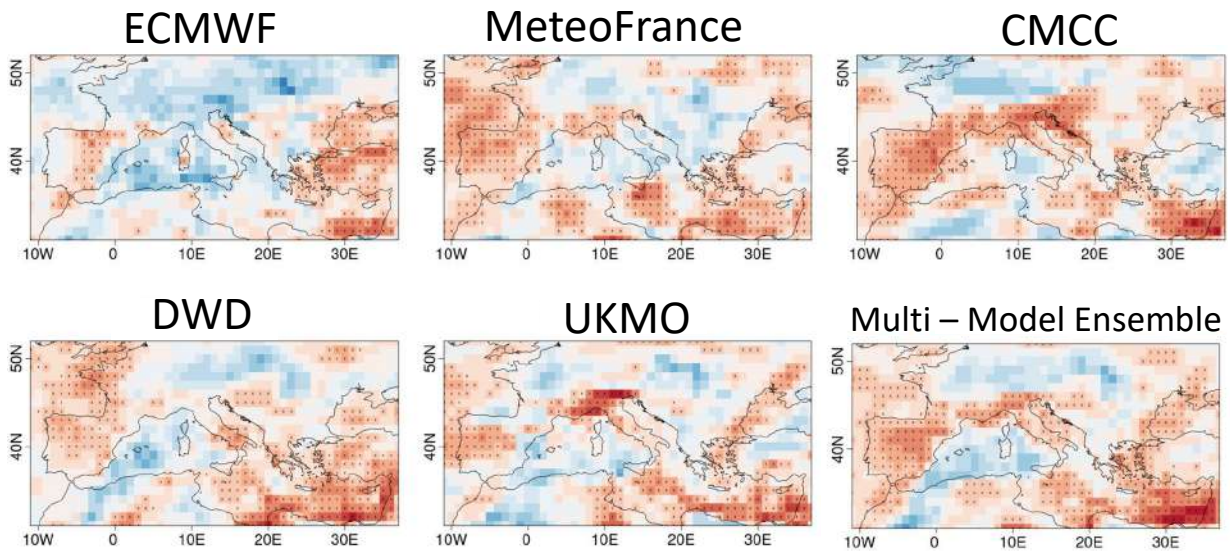
(5 prediction systems)

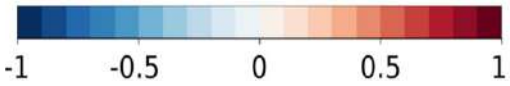
Climate Change

2m-Temperature



Precipitation





Stippling = significant correlations (95% confidence level).

Modified from Calì Quaglia et al. 2021

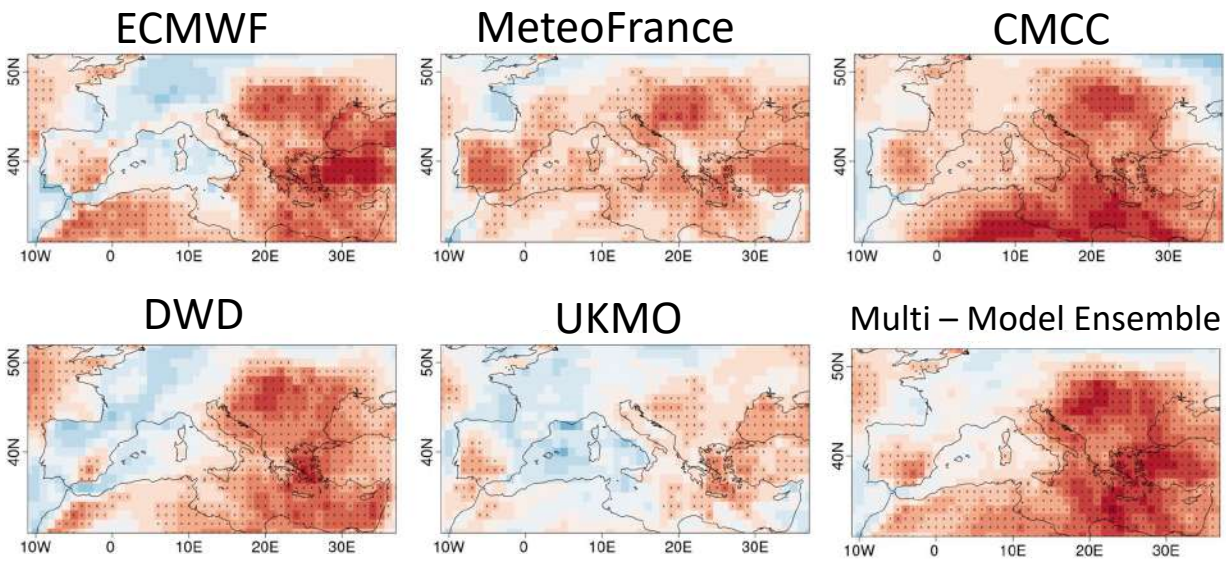
Climate predictions and their skill in the Mediterranean region

JJA Forecasts **initialised on** **May 1st**

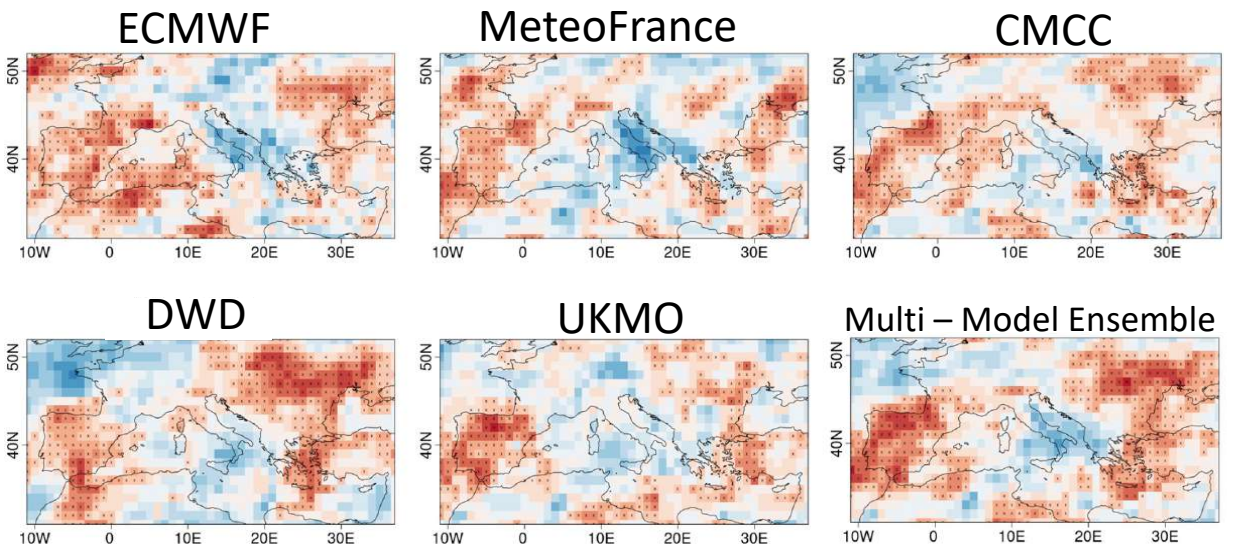
C3S multi–system
(5 prediction systems)

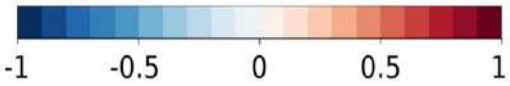
Anomaly **C**orrelation **C**oefficients
with respect to ERA5, 1993 – 2014

2m-Temperature



Precipitation





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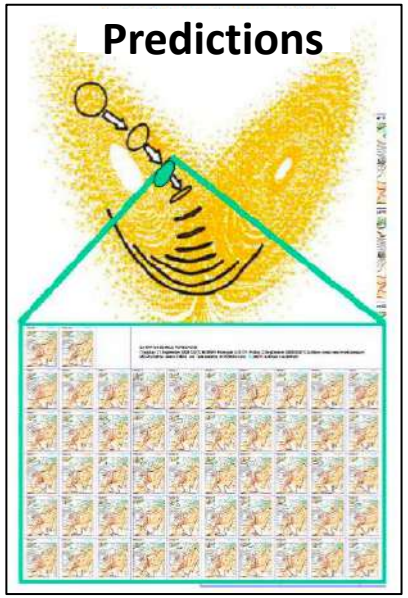
Modified from Calì Quaglia et al. 2021

Examples of application

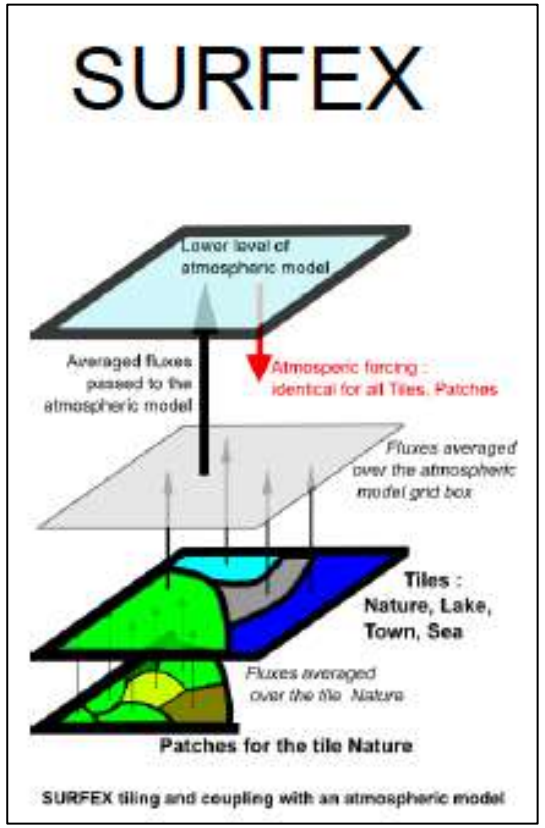
S-ClimWaRe (Seasonal Climate predictions in support of Water Reservoirs management)



CSTools

Bias adjustement and downscalibng
Analogs

Bias adjustement is essential before using a non–linear impact model



- **Domain of application**: All water reservoirs in Spain
- **Potential user(s):** dam managers
- **Decision making process**: Partition of water resources among main users: agriculture, energy, public supply

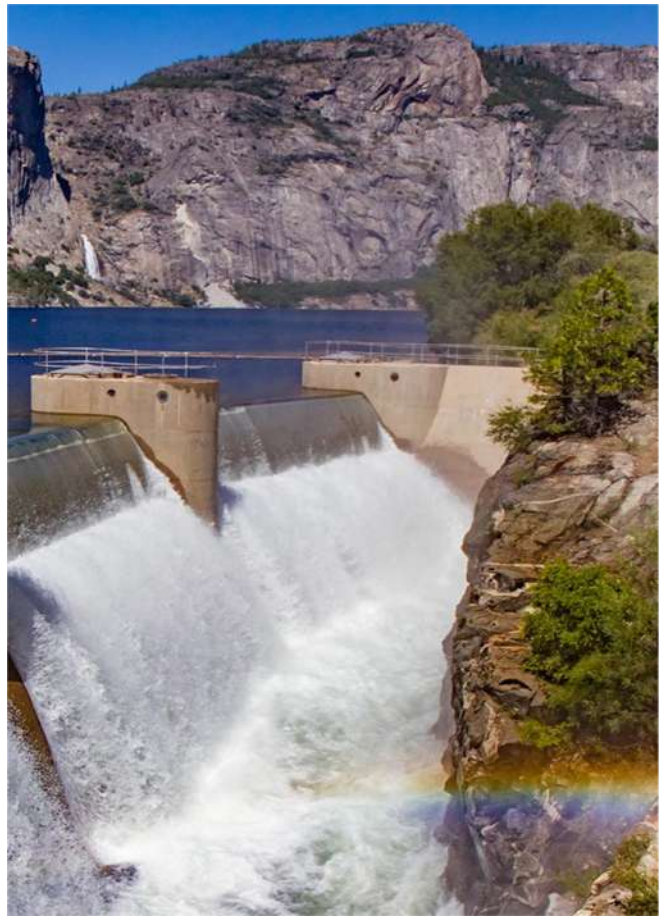
CSTools

Calibration
NAO weighting

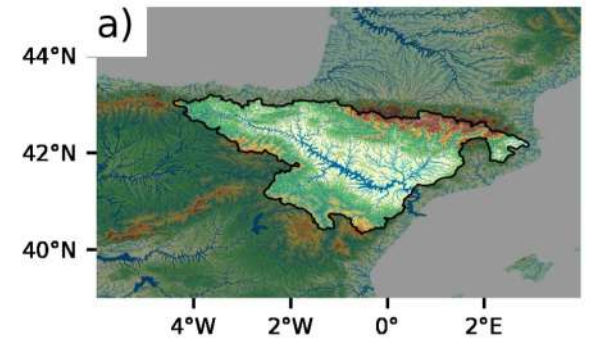
https://www.aemet.es/en/serviciosclimaticos/apoyo_gestion_embalses

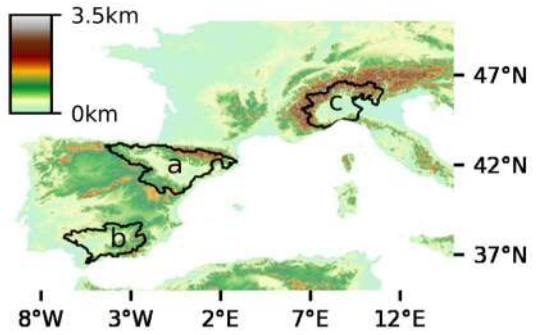
Examples of application

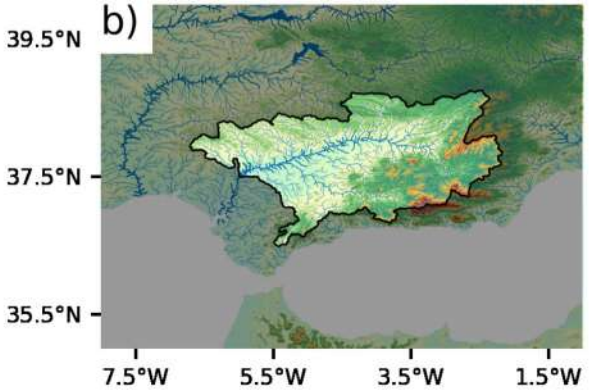
Application on Hydropower for ENEL Green Power

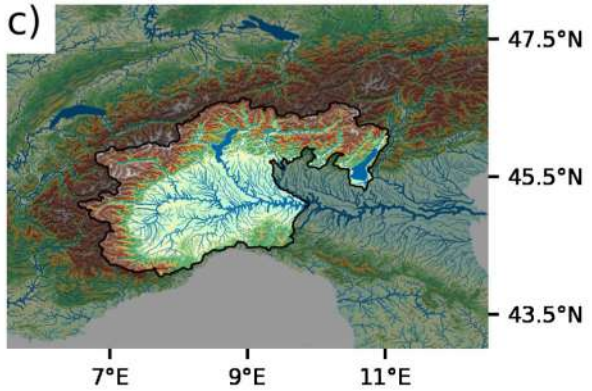


Predict precipitation over each basin for 1-10 forecast years temporal aggregation.









Drainage basins:

a) Ebro
b) Guadalquivir
c) Po

Examples of application

Precipitation Anomalies Correlation Skill

CMIP6 Decadal Prediction Systems:

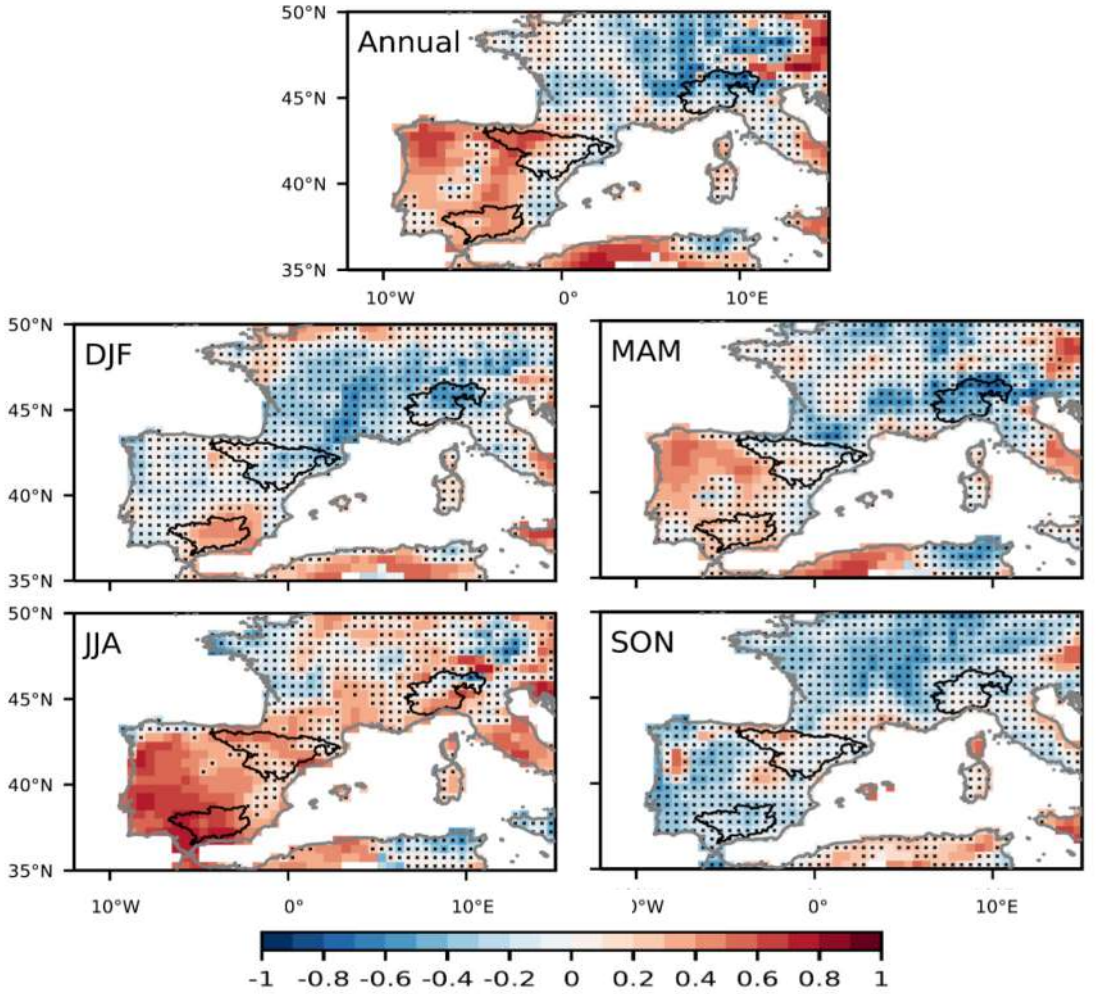
Initialized in November, every year from 1960 to 2019

- CMCC-CM2-SR5 (14 members)
- DePreSys4 (10 members)
- MPI-ESM1-2-HR (10 members)
- EC-Earth3 (10 members)

Verification Dataset: E-OBS (1961-2019)

Basins	Annual	DJF	MAM	JJA	SON
Guadalquivir	0.42	0.34	0.14*	0.67	-0.19*
Ebro	0.17*	-0.28*	-0.08*	0.29*	0.05*
Po	-0.38*	-0.25	-0.6*	-0.06*	-0.19*

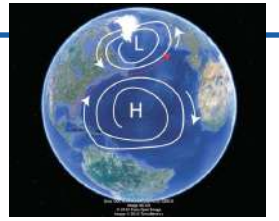
*Statistically insignificant values at 95% level.



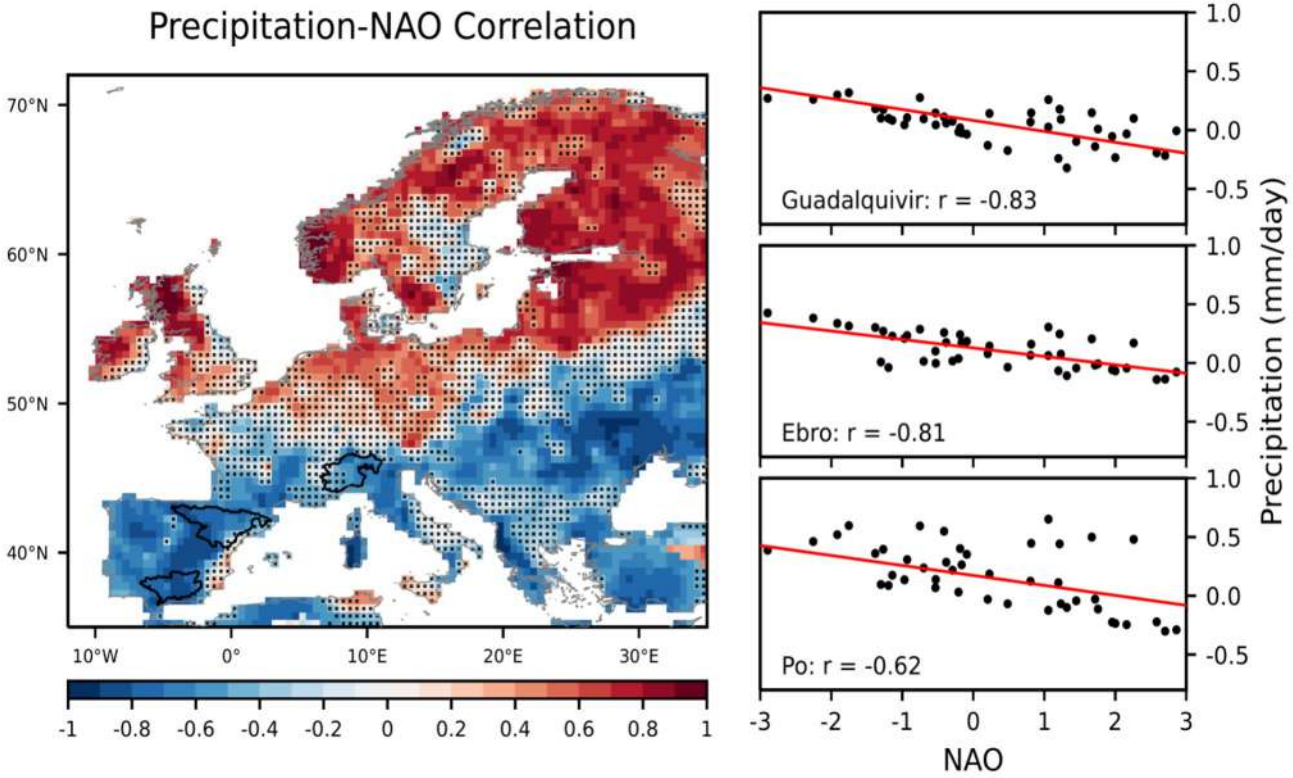
Tsartsali et al. 2022

Examples of application

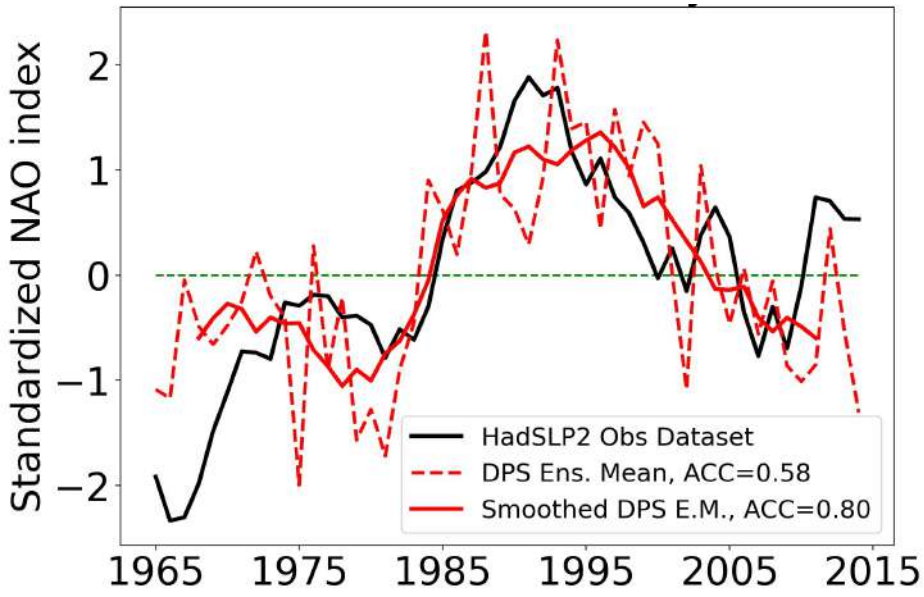
Can NAO be a good predictor?



From observations



Observed and **predicted**
DJFM NAO index for lead year 1–9

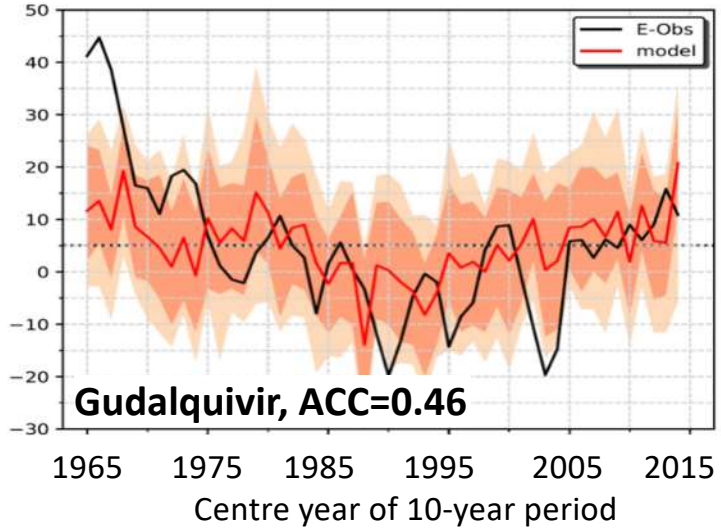


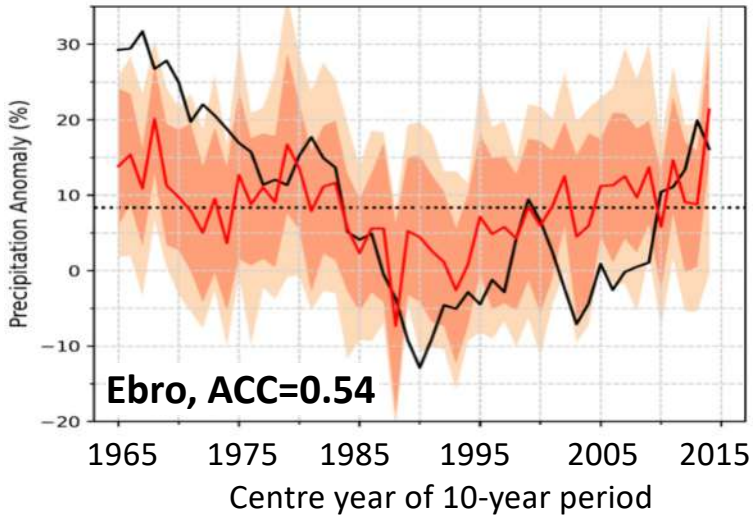
- High NAO skill
- High correlation between NAO and precipitation in the three basins.

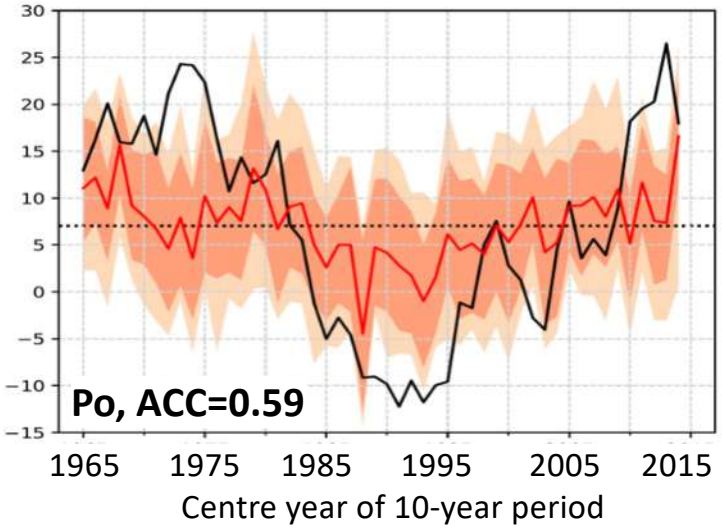
Build a hybrid model based on the linear observed relationship between NAO and precipitation and the dynamical predictions of NAO

Examples of application

Hybrid Model Skill







GUADALQUIVIR			
Above-average Precip		Observed: Yes	Observed: No
Predicted	Yes	19 Hits	9 False alarms
	No	6 Misses	16 Correct rejections
Hit Rate:		76%	
False Alarm Rate:		36%	

EBRO			
Above-average Precip		Observed: Yes	Observed: No
Predicted	Yes	22 Hits	6 False alarms
	No	3 Misses	19 Correct rejections
Hit Rate:		88%	
False Alarm Rate:		24%	

PO			
Above-average Precip		Observed: Yes	Observed: No
Predicted	Yes	23 Hits	5 False alarms
	No	3 Misses	19 Correct rejections
Hit Rate:		89%	
False Alarm Rate:		21%	

Summary and Outlook

- **Climate predictions have skill and provide information that can be used by decision makers to improve their practices.**
- **Seasonal predictions have higher skill in the Tropics (ENSO) and in the Extratropics where tropical influences are strong.**
- **Decadal predictions have remarkable skill in the North Atlantic (NAO).**
- **Forecasts (both seasonal and decadal) can be improved by combining dynamical and statistical systems (Hybryd).**
- **Post–processing techniques of ensemble predictions (e.g. subsampling) are currently in development, also exploiting A.I. and machine learning methodologies.**
- **Further improvements of the climate models used to make the simulations and of the initial conditions (data assimilation) are essential in order to make climate predictions more skillful and effectively usable.**

Summary and Outlook

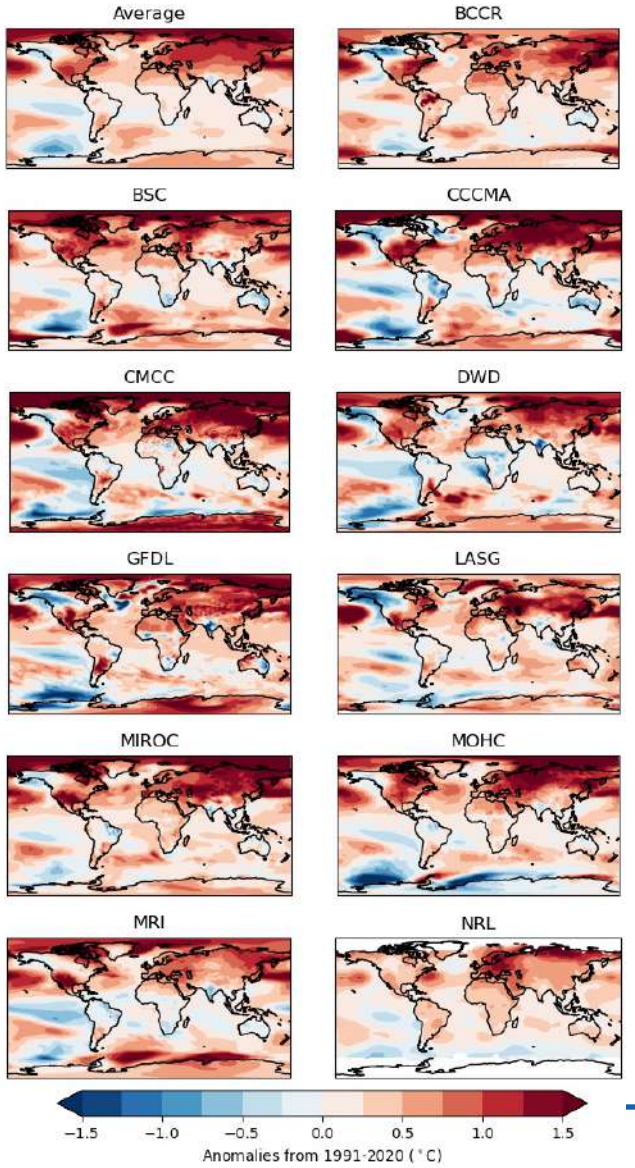
International Program for Operational Decadal Predictions

WMO Lead Centre for Annual-to-Decadal Climate Prediction

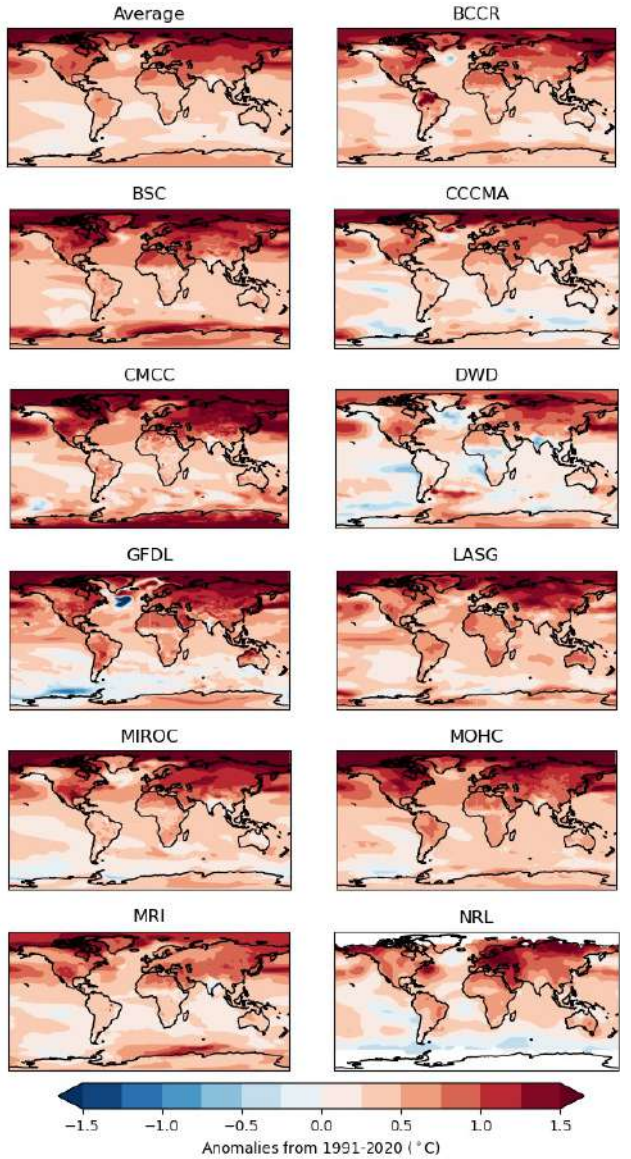
The Lead Centre for Annual-to-Decadal Climate Prediction collects and provides hindcasts, forecasts and verification data from a number of contributing centres worldwide.

https://hadleyserver.metoffice.gov.uk/wmolc/

2021 predictions for 2022 surface temperature



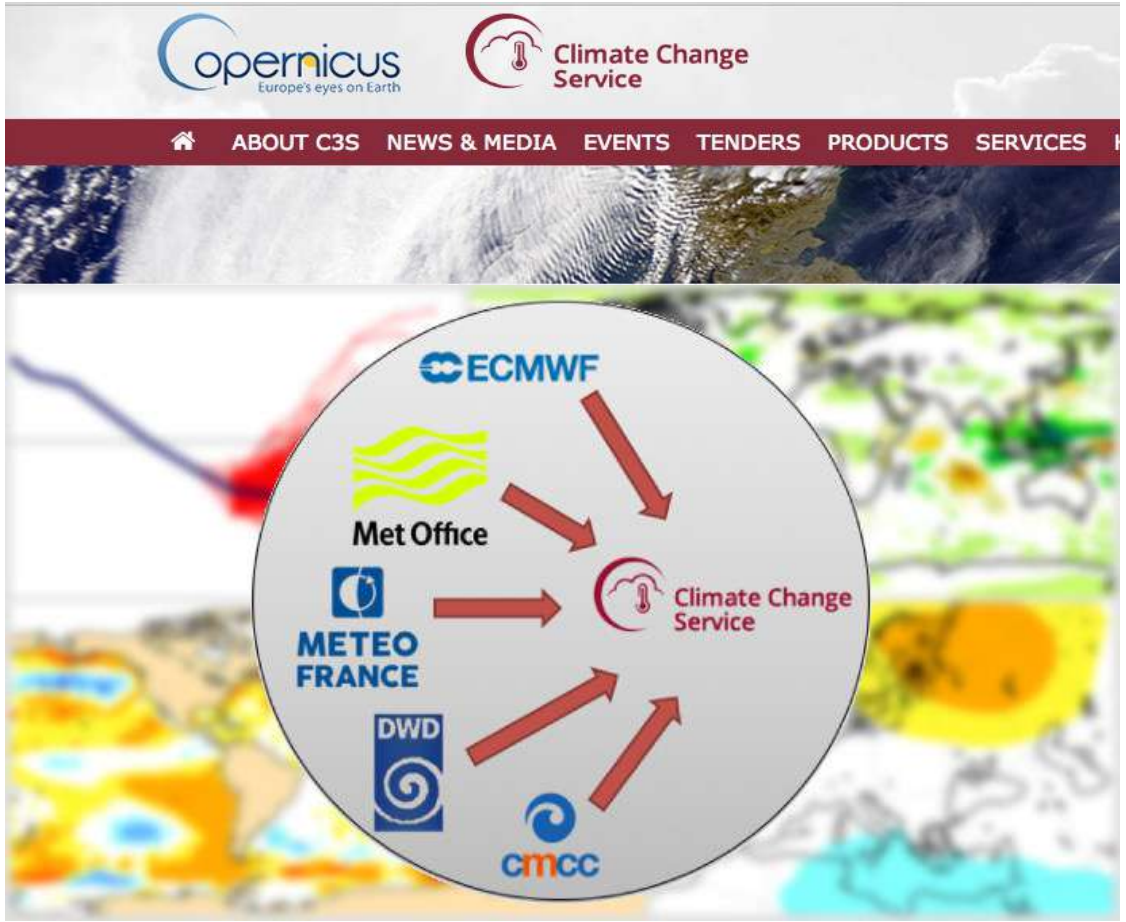
2021 predictions for 2022 – 2026 surface temperature



Examples of application

International Program for Operational Seasonal Predictions

https://www.wmolc.org/

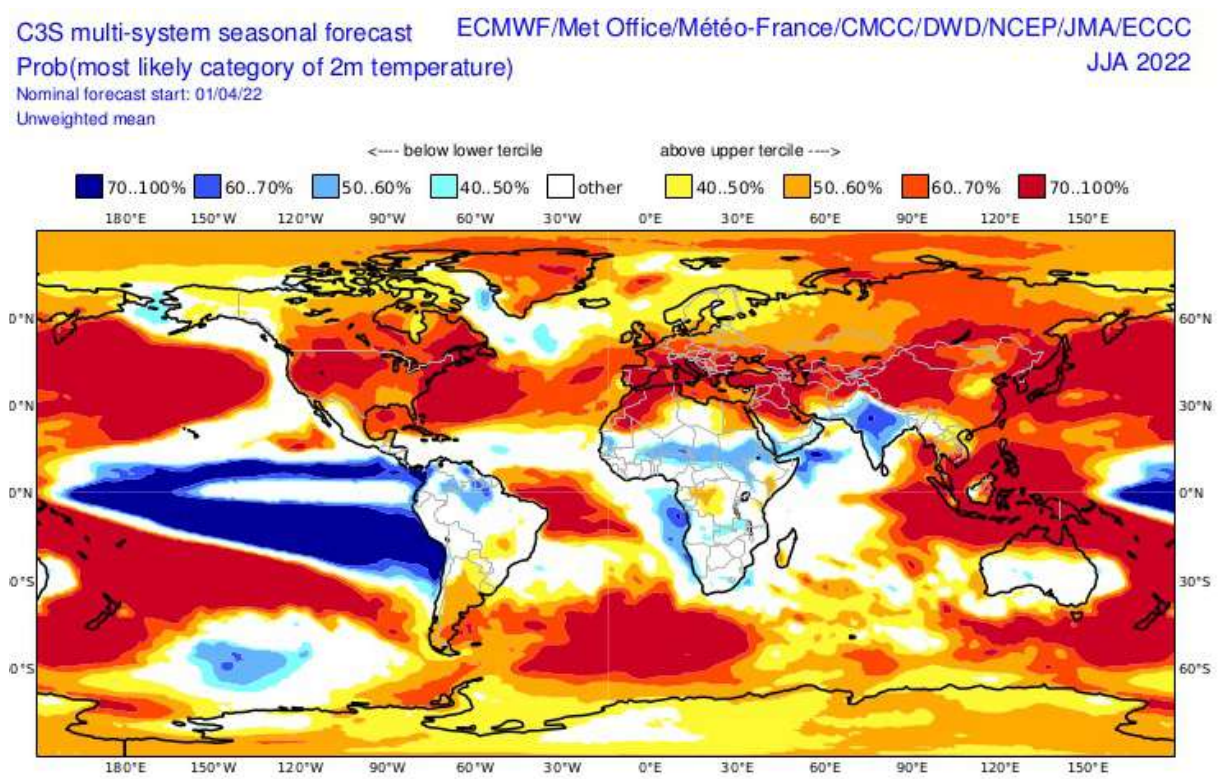


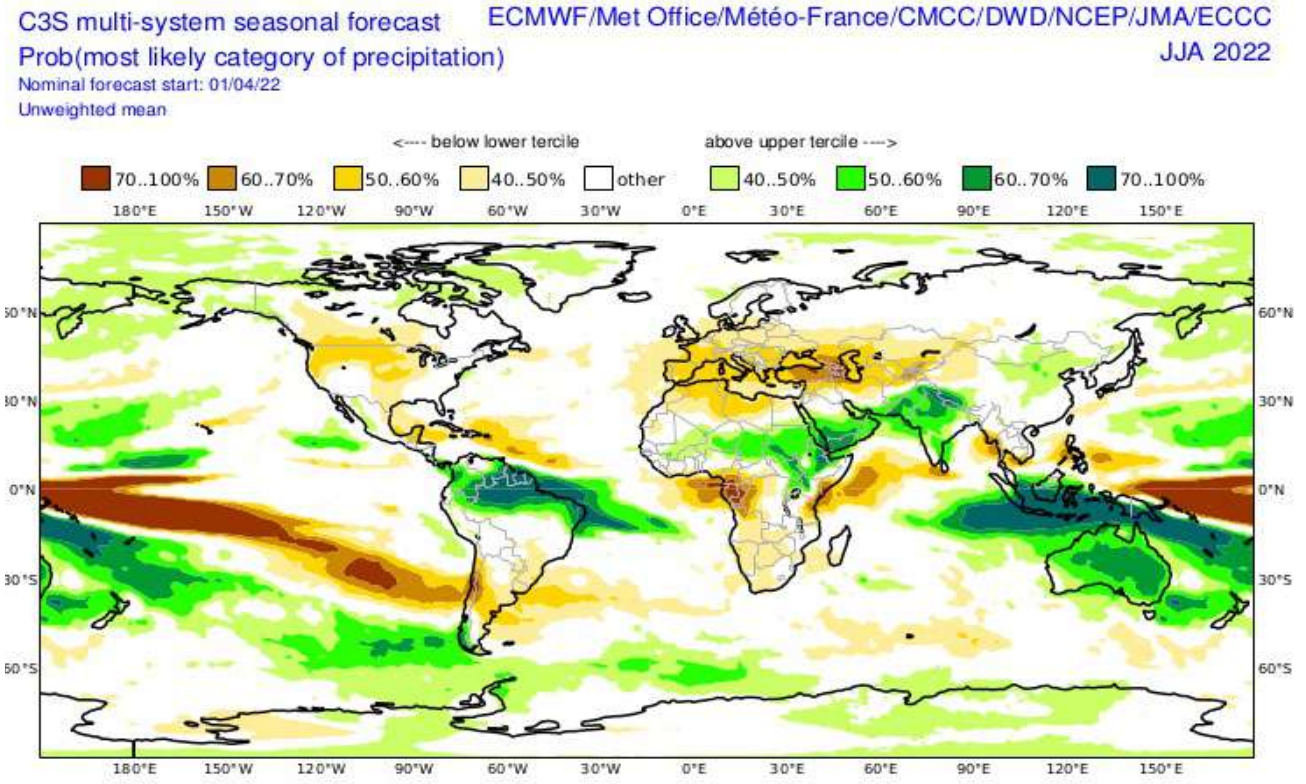
https://climate.copernicus.eu/seasonal-forecasts

Examples of application

June-July-August Prediction – Start date: 2022 May 1st

(anomalies wrt to the reference period 1993 – 2016)





Climate Change Service

Thanks

cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici