Seasonal predictability in the Mediterranean region and windows of opportunity

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cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici

The Euro Mediterranean Center on Climate Change

cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici

- Research Center on Climate Science and Policy
- Network of public and private research institutes, partially funded by the Italian Ministries: MIUR (University & Research), MATTM (Environment) and MEF (Economy & Finance).
- IPCC focal point for Italy

Mission: Investigate and model the climate system and its interactions with society to provide reliable, rigorous, and timely scientific results to stimulate sustainable growth, protect the environment and to develop science-driven adaptation and mitigation policies in a changing climate.

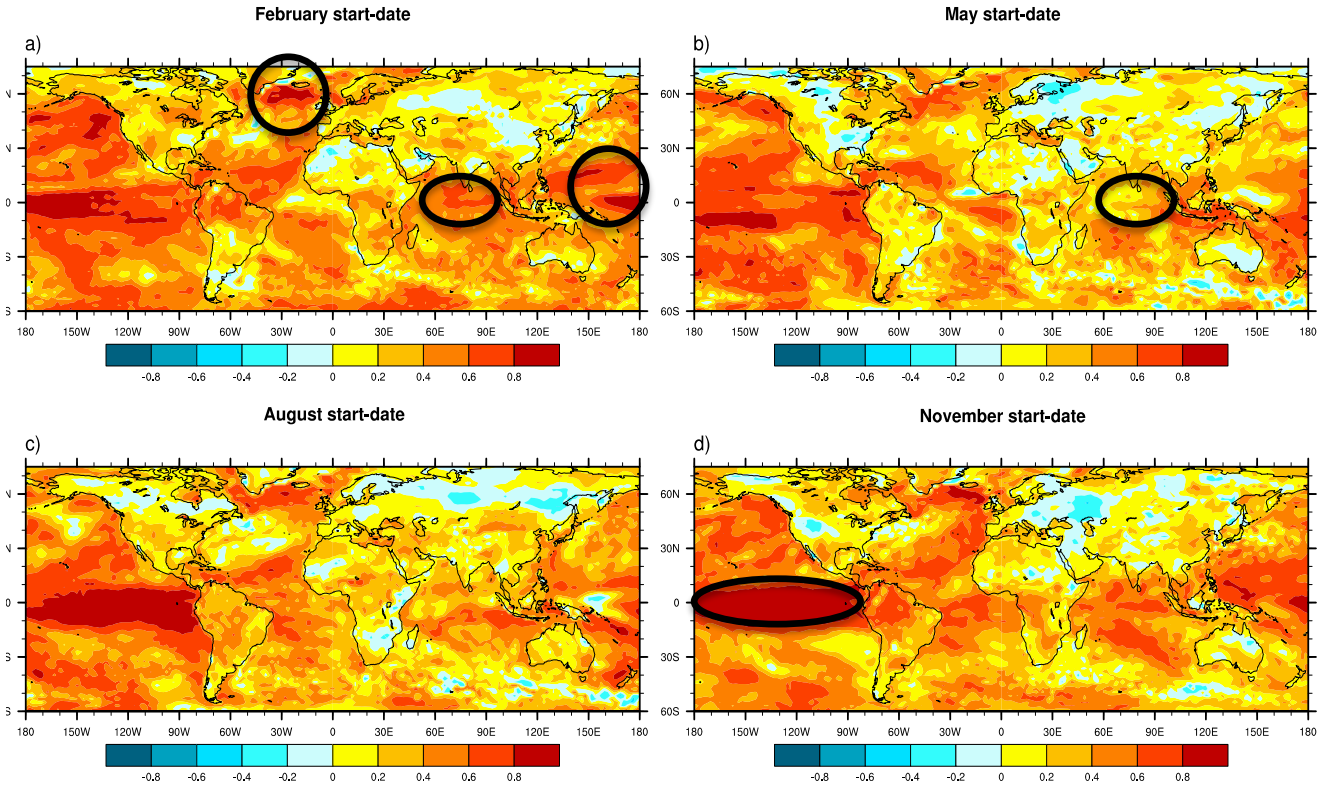
CMCC Network

CSP (Climate Simulation and Predictions)

- Production of climate **predictions at seasonal to decadal time-scale and climate change projections** (global scale, regional focuses).
- **Communication of the results** and information to a broad range of users: decision makers and stakeholders, political bodies, researchers from other disciplines.

Global skill of the CMCC-SPSv2

Tsurf Anomaly Correlation (ACC) lead time 1



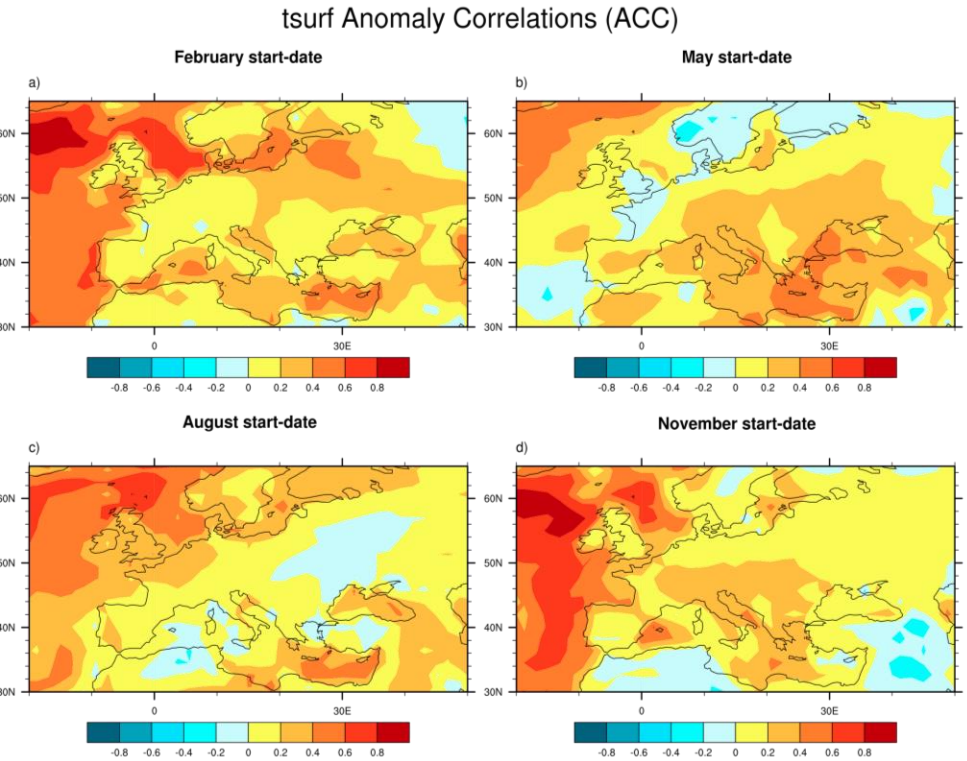
Lead time 1 refers to the season starting one month after the start date (e.g. Feb lead 1 = MAM)

- Predictability is higher in the Tropics and in the oceans than on continents.
- High skill in the ENSO area and teleconnected regions
- Indian Ocean SST is better represented in the winter and after-monsoon seasons, than in the initial and ongoing phases of the monsoon
- Fairly good prediction skill in N Atlantic, especially in the winter

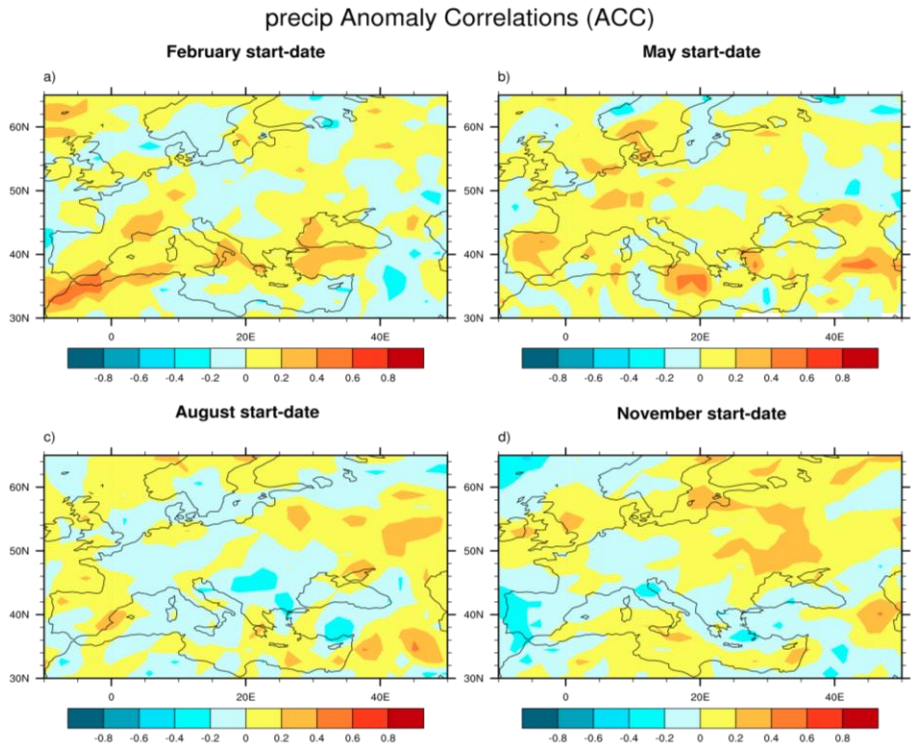
Seasonal Predictions in the Euro-Mediterranean region

Skill of the predictions in the Euro-Mediterranean region

2-meter Temperature



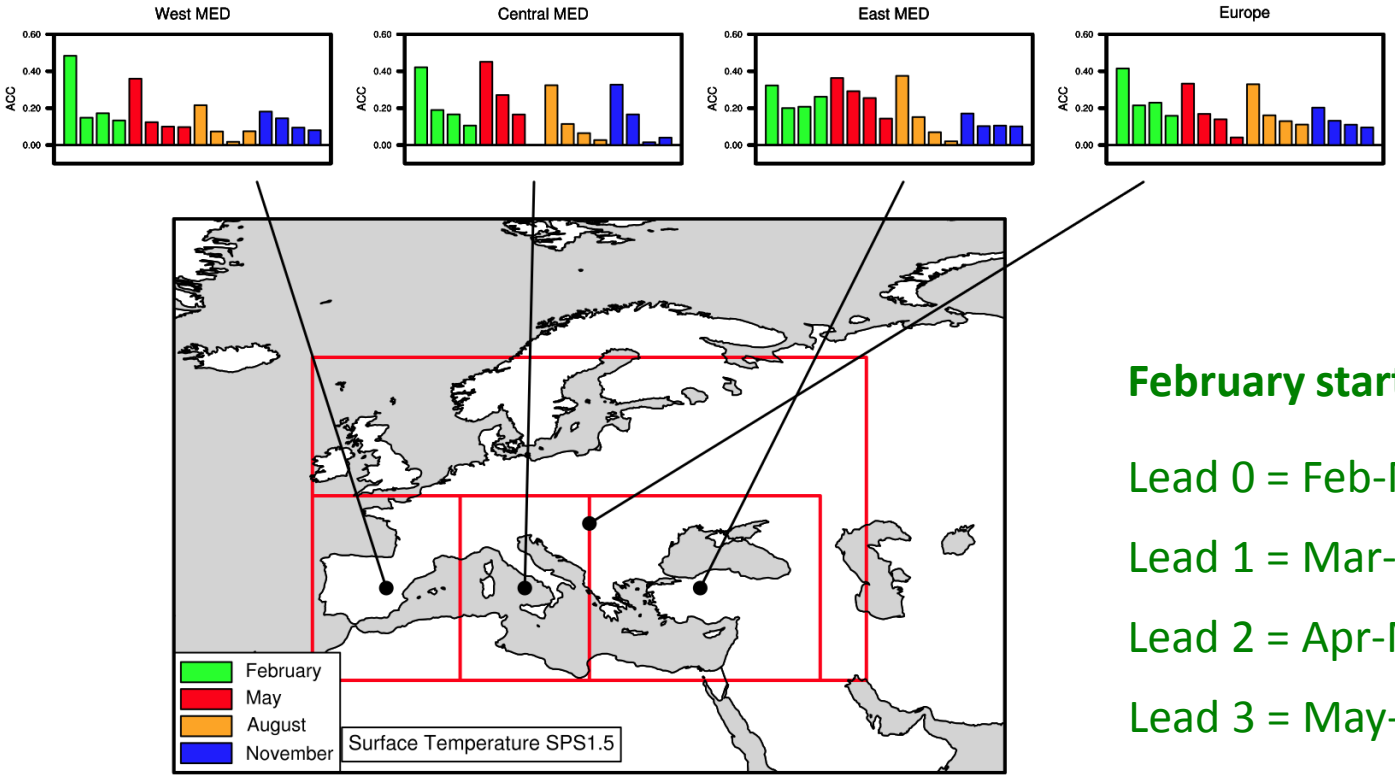
Precipitation



Seasonal Predictions in the Euro-Mediterranean region

Even in a small region such as the Mediterranean prediction skill is not homogeneous in space and time

2-meter Temperature anomaly correlation for different start dates and lead times



February start date case:

Lead 0 = Feb-Mar-Apr

Lead 1 = Mar-Apr-May

Lead 2 = Apr-May-Jun

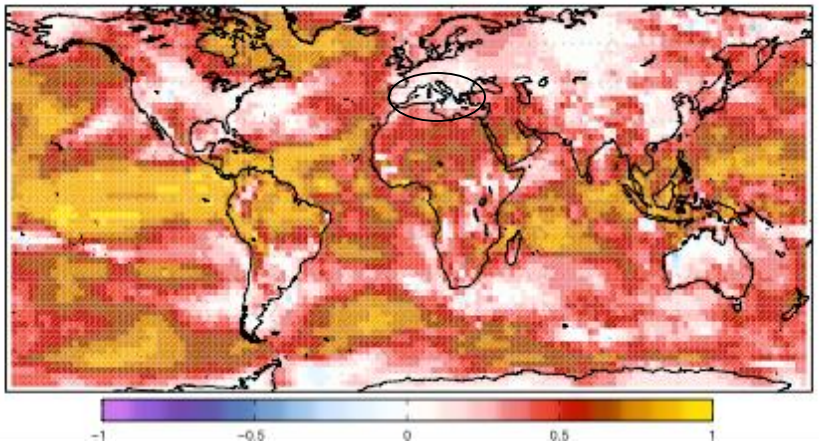
Lead 3 = May-Jun-Jul

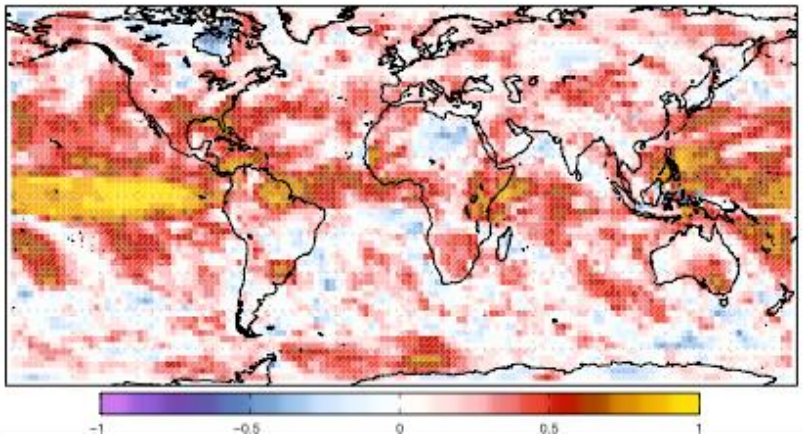
Seasonal Predictions in the Euro-Mediterranean region

2-meter Temperature
(DJF, November start date)

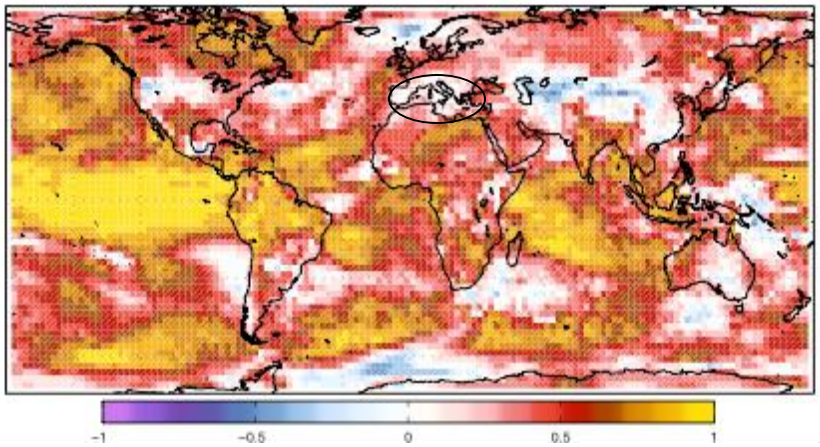
Precipitation
(DJF, November start date)

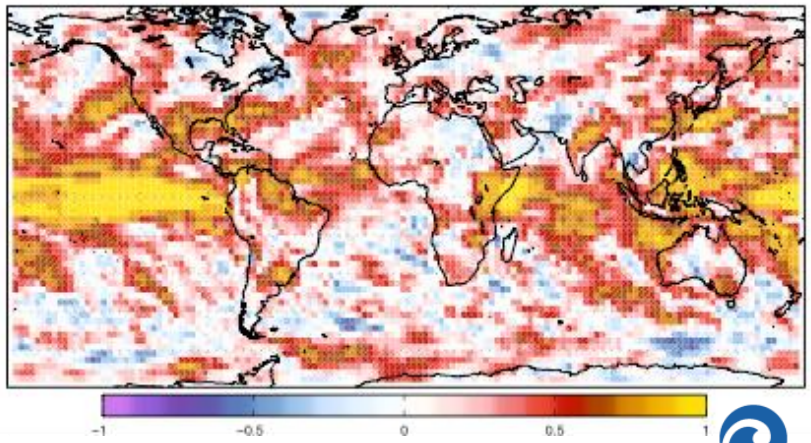
CFSv2





UKMO





Seasonal Predictions in the Euro-Mediterranean region

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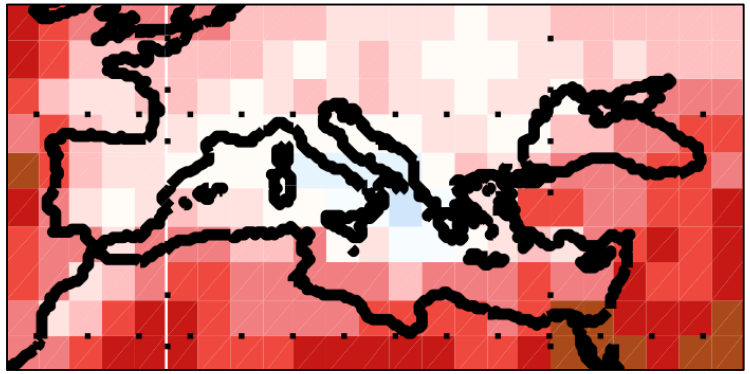

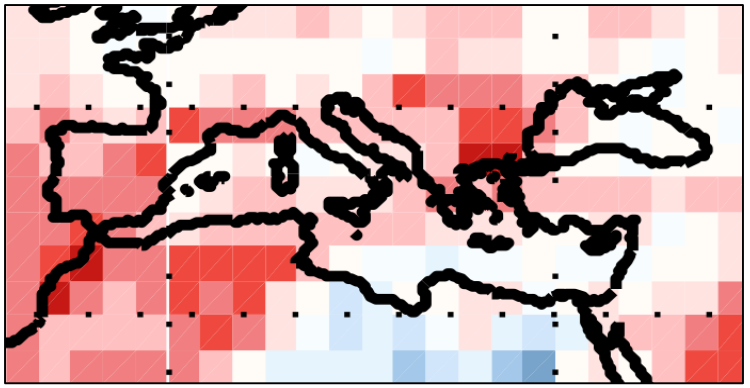

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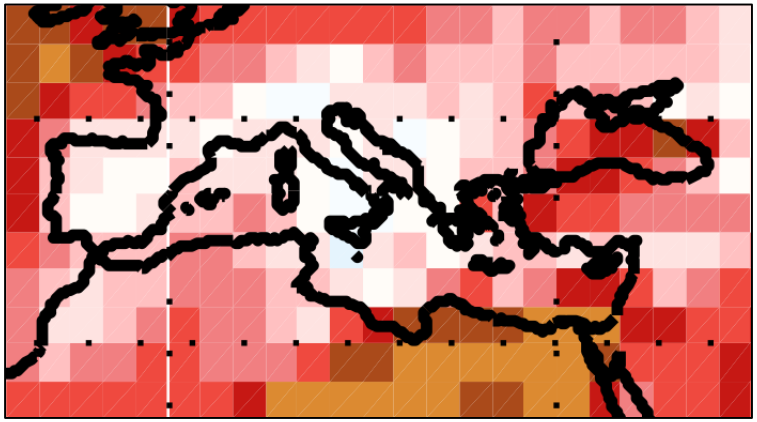

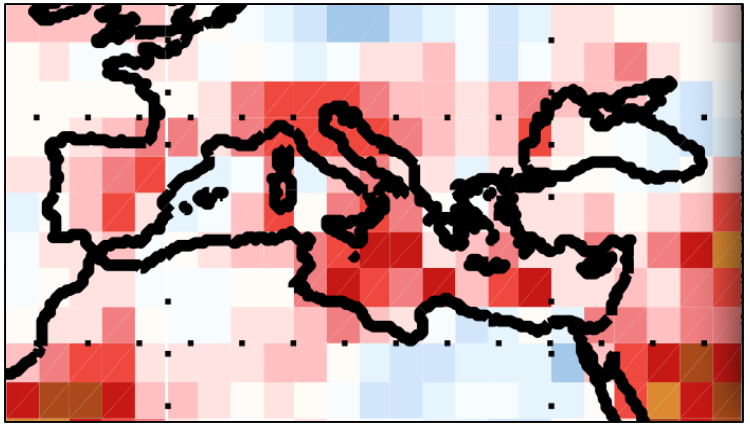

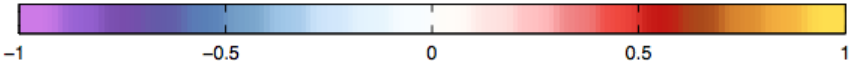

Why is predicting climate not easy in the Mediterranean?

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- The region also has a complex topography that modulates the climate at finer spatial scales (e.g., Lionello et al. 2006).

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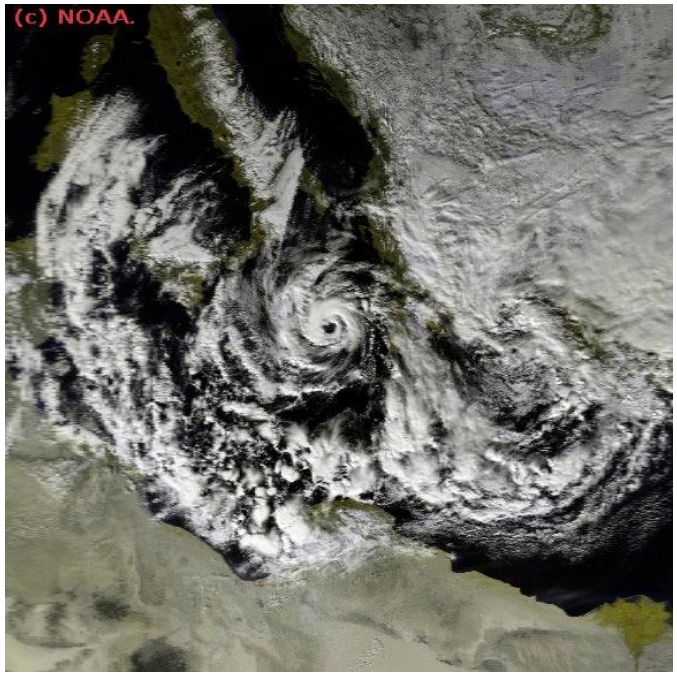
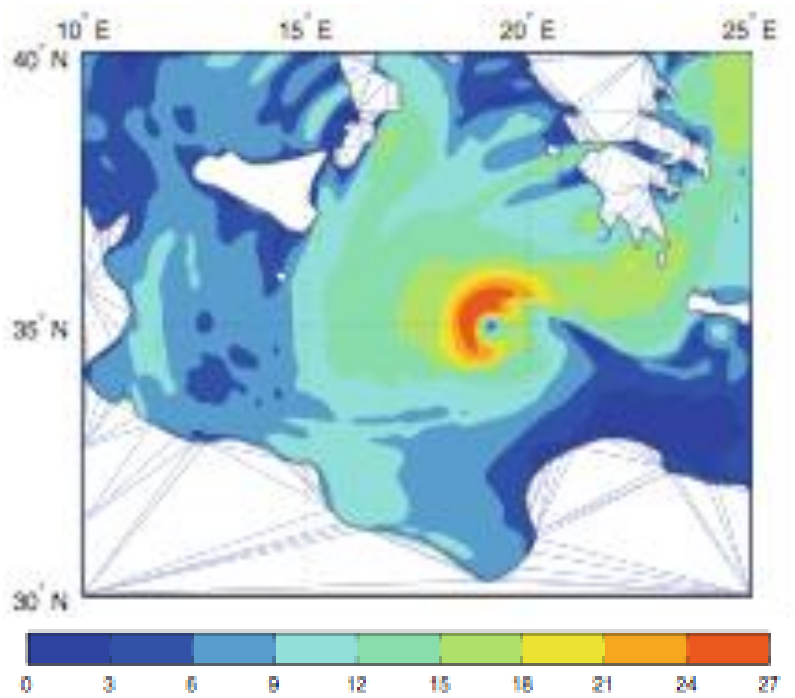
Tropical occurrences in an extra-tropical region

Medicanes (*Medi*terranean hurri*canes*) are strong mesoscale storms with peculiar features that remind tropical cyclones, such as:

- a spiral shaped cloud structure with a cloud-free eye
- vertical symmetry and a warm core
- winds up to the hurricane speed





Satellite picture and model simulation of wind speed for a medicane in January 1995

When they make landfall, medicanes are often associated with extreme weather and damage along the coasts.

Tropical connections

The Monsoon-desert

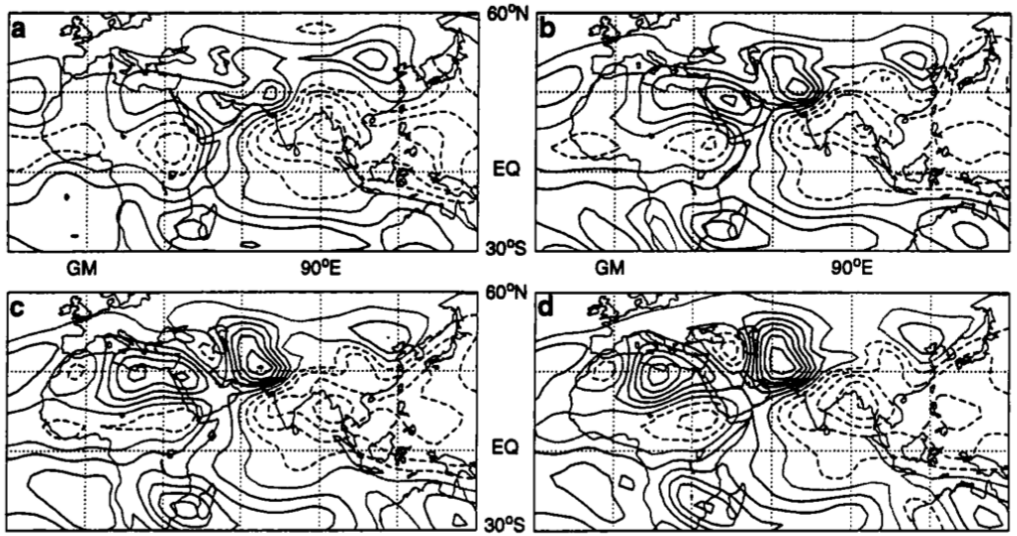
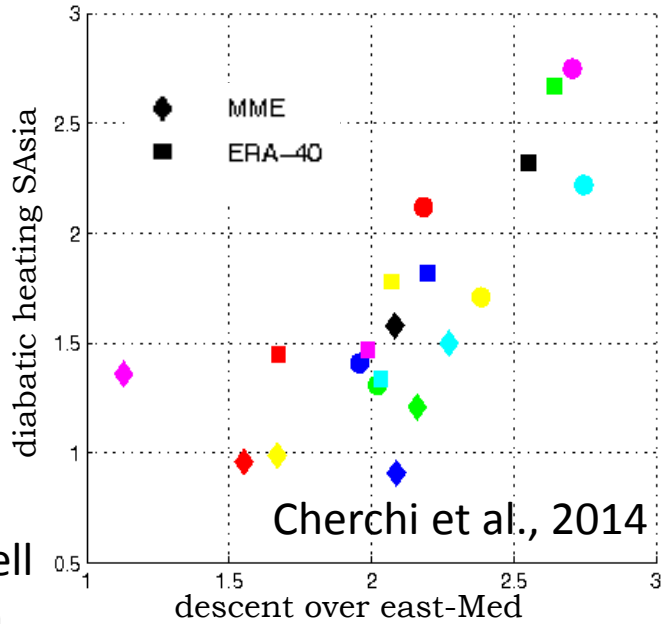


Figure 5. Vertical velocity, ω, on 477 hPa for the standard integration: (a) day 7; (b) day 9; (c) day 11; (d) day 13. The contour interval is 0.5 hPa hr^{-1}.

CMIP5 models are able to catch the mechanism right



Cherchi et al., 2014

The monsoon-desert mechanism appears to explain the dry summertime climates of the east Sahara-Mediterranean, as well as the rapid strengthening of descent over East Mediterranean during the monsoon onset (Rodwell and Hoskins, 1996).

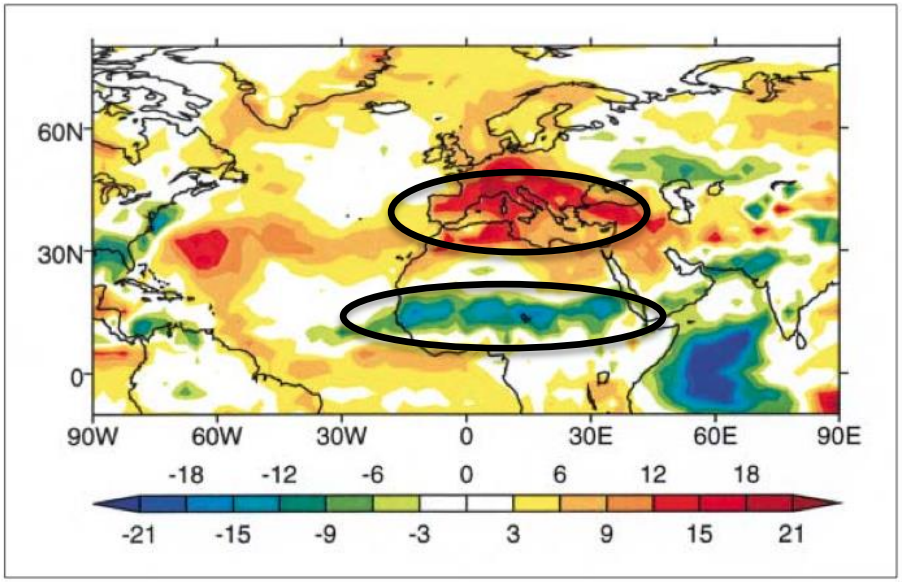
The descent is a consequence of the interaction between westward propagating Rossby waves, generated by the diabatic heating associated with the summer monsoon rainfall in South Asia, and the mean westerly flow north of the region. The conceptualized model of RH96 reveals the importance of orography in the process.

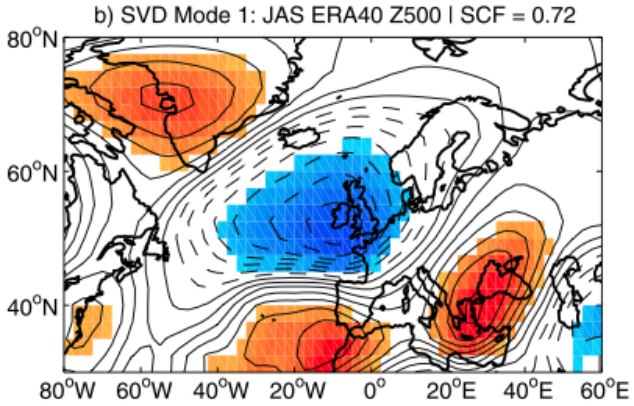
Tropical connections

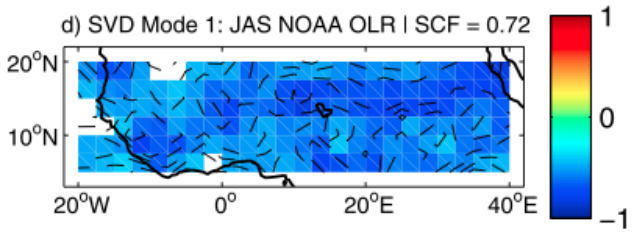
West African Monsoon

Though many studies already pointed out the reverse influence, the role of WAM in driving the mid-latitude circulation starts being clarified.

The heat wave of summer 2003 was partially triggered by the anomalous northward position of the ITCZ over N Africa (Black et al. 2004)







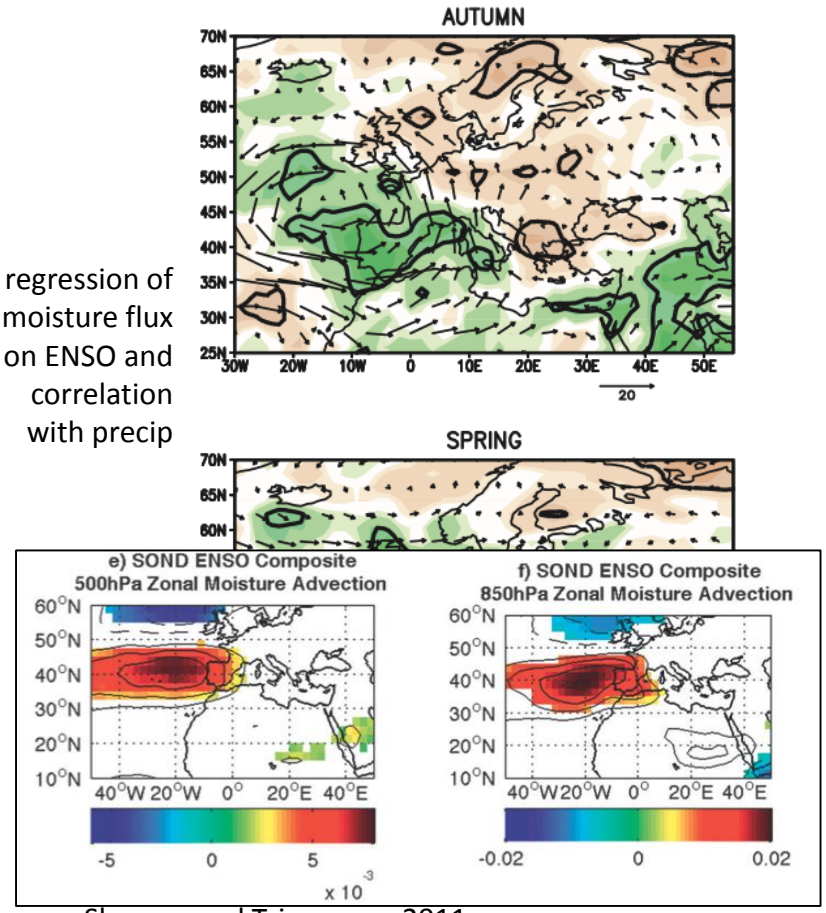
Strong convection in Sudan-Sahel related to HP over eastern Mediterranean and positive NAO-like pattern. When the monsoon circulation is clearly developed over West Africa the stronger covariance is found between tropical and extra-tropical latitudes (Gaetani et al., 2011)

Tropical connections

ENSO

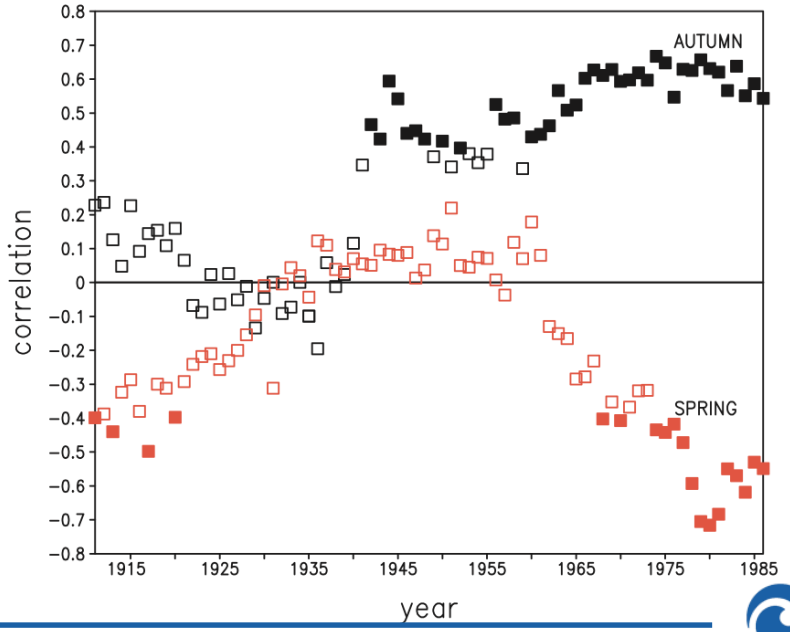
Already in 2002, Mariotti et al. had found strong influence of ENSO over the Euro-Mediterranean compartment, in particular on precipitation during the spring and autumn seasons, whose leading mode is clearly separated from the secondary one.

regression of moisture flux on ENSO and correlation with precip

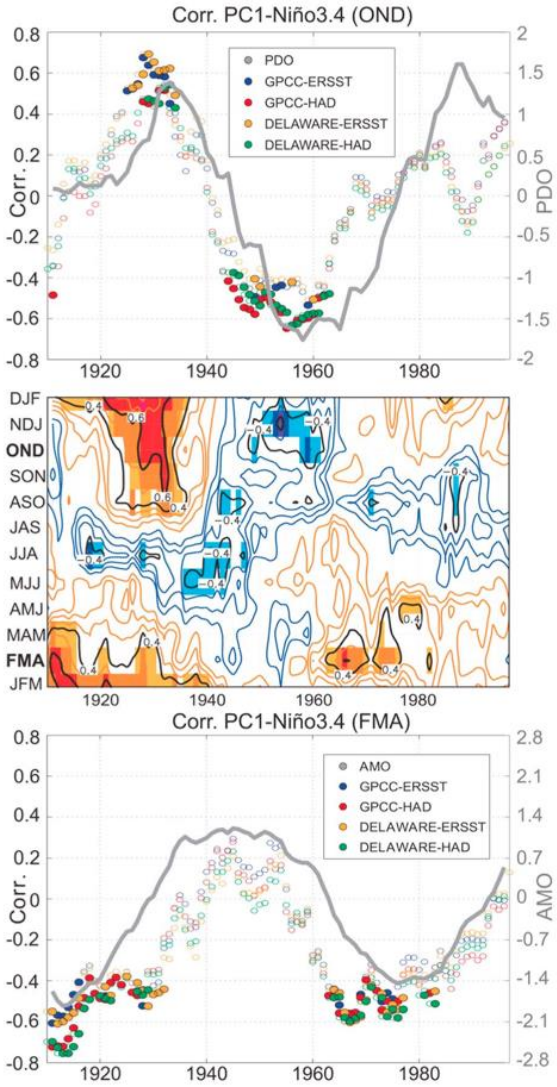


Shaman and Tziperman, 2011

The fact that these relationships have changed enormously during the course of the last century demonstrates that ENSO cannot be the only large-scale player for Euro-Med climate variability

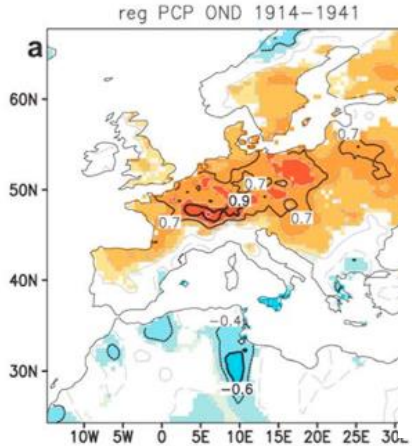


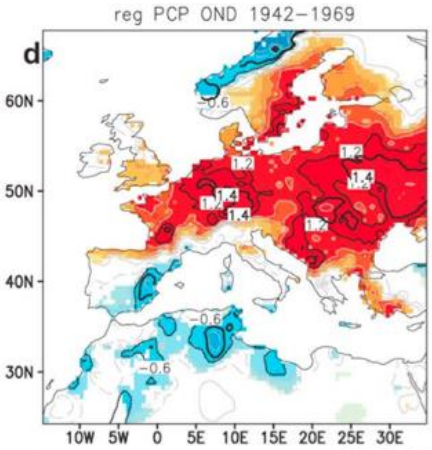
Tropical to extra-tropical connections

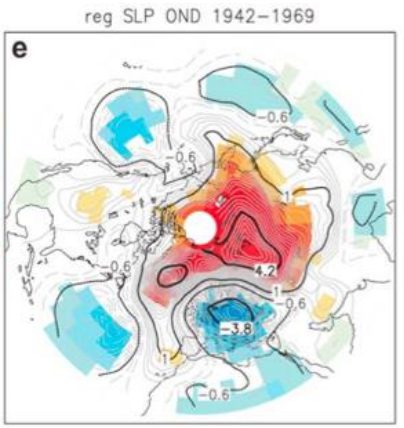


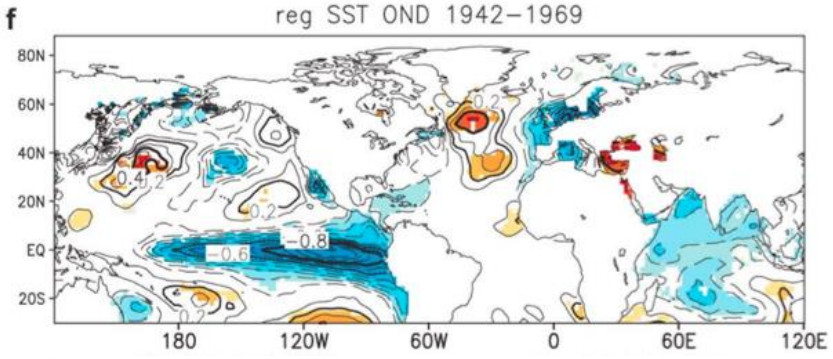
Correlation between PC1 in the EuMed region and NINO34 index

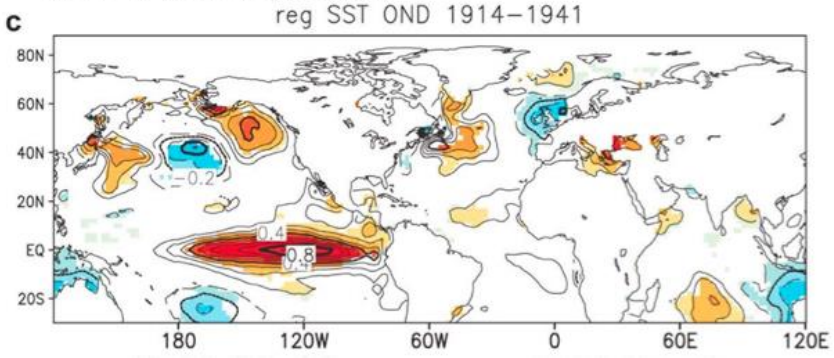
Regression of EuM rainfall PC1 for sel periods of PDO











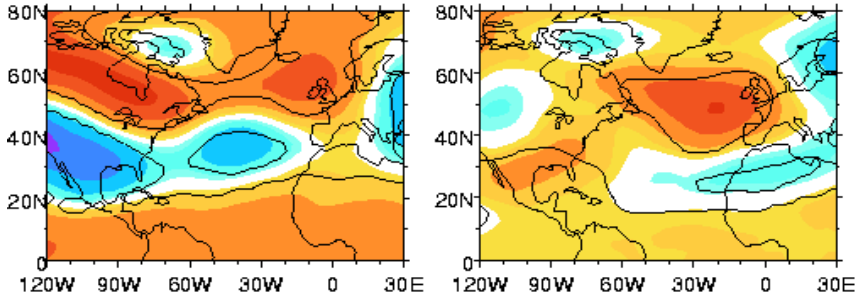
from Lopez-Parages and Rodriguez-Fonseca (2012)

Combined effect of ENSO and the Atlantic

1997 El Nino

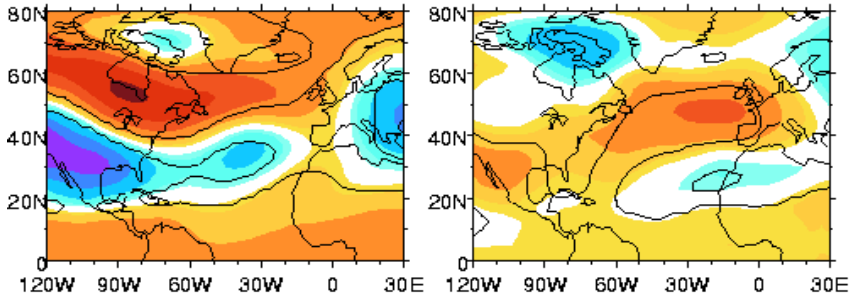
1998: La Nina

Global ocean forcing



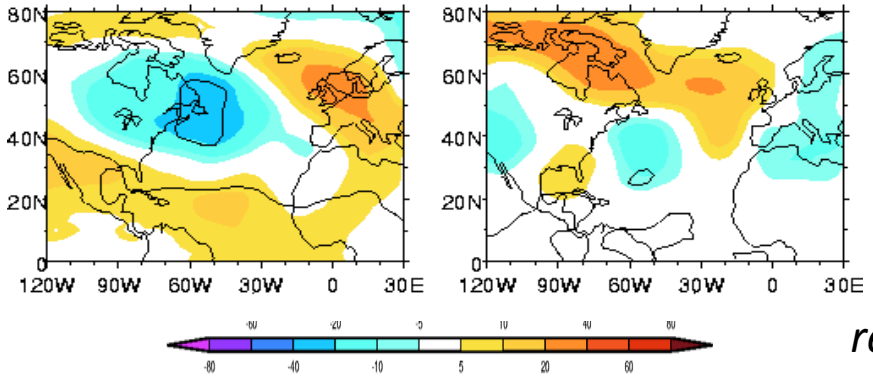
500 hPa anomalies

No Atlantic forcing



El Nino/La Nina affects the seasonal climate of the Atlantic in a potentially predictable manner.

Implied effect of Atlantic

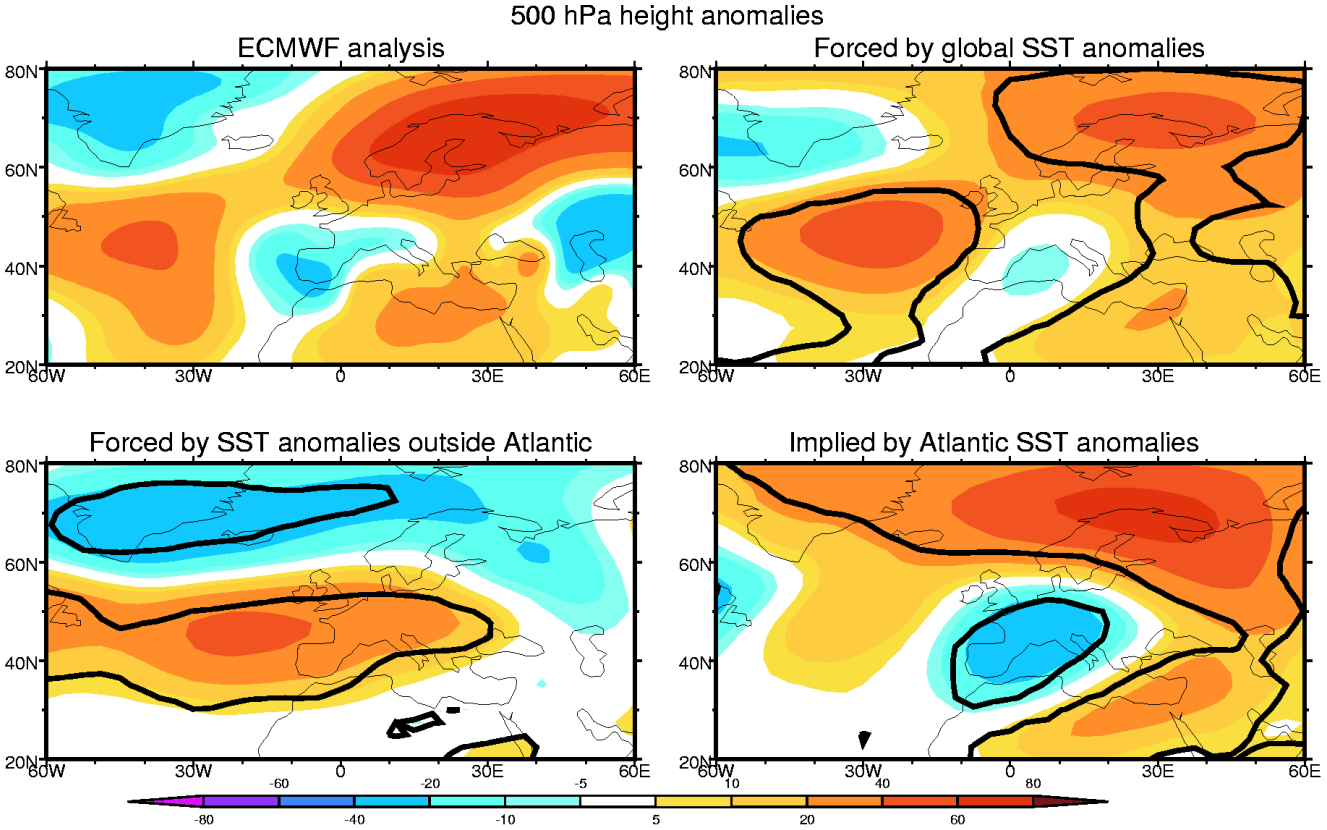


The forcing from the Pacific dominates when El Nino/La Nina is strong.

readapted from Slingo (2002)

So what role for the Atlantic?

Consider another year (1999) when El Nino/La Nina was weaker:

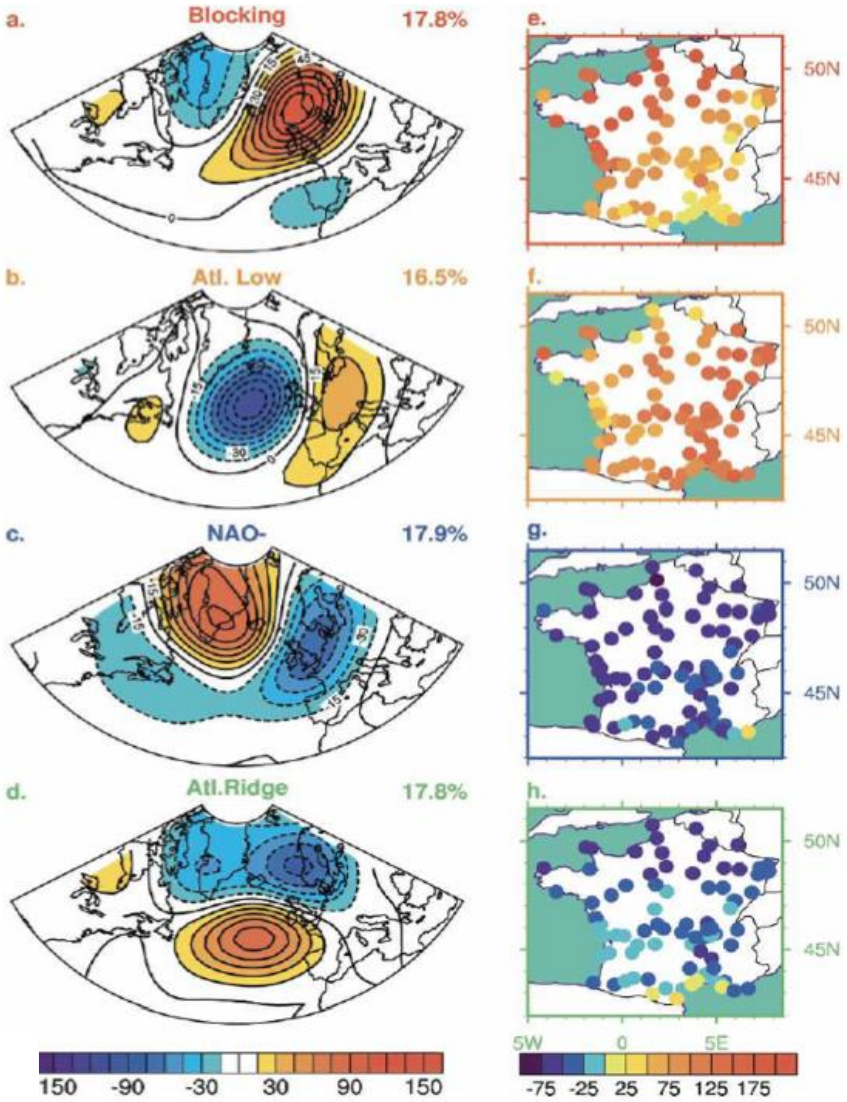


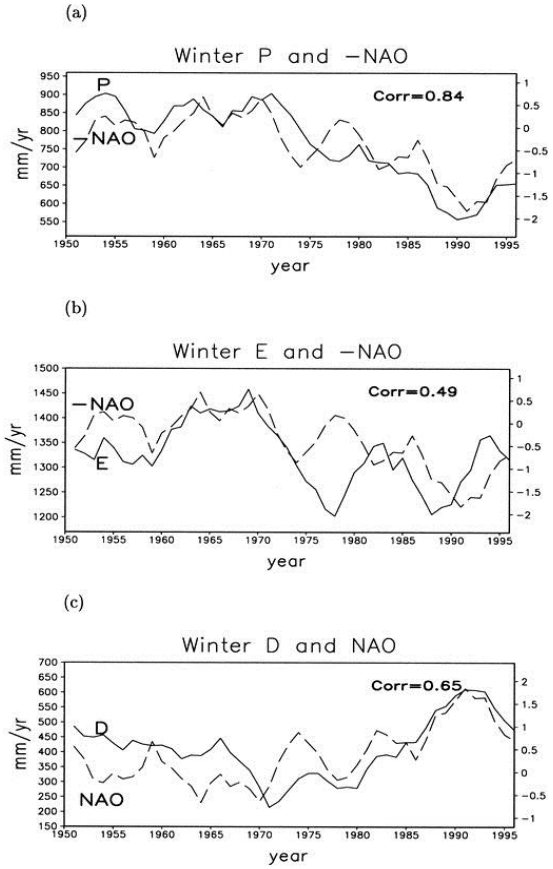
In the absence of strong Pacific forcing, the state of the Atlantic Ocean is important for seasonal predictability.

Strong evidence that the Atlantic Ocean affects the climate of western Europe.

readapted from Slingo (2002)

So what role for the Atlantic?





Time series of five-winter (DJFM) running means of the NAO index and area-averaged Mediterranean precipitation, evaporation, and moisture divergence.

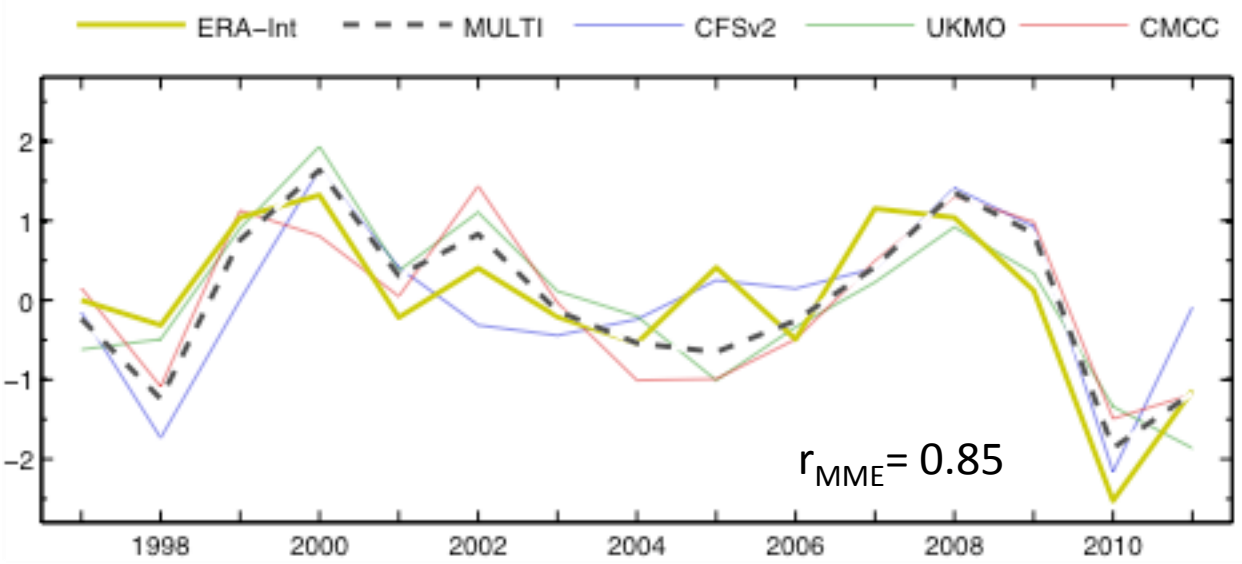
Cassou et al. (2005) have identified four modes of Atlantic variability, each explaining a similar amount of variance, that influence summer temperature over Western Europe

A multi-model approach

A multimodel system for the Mediterranean region improves simulation of physical processes involved in the complex, intricate interaction of land, air, sea (CIRCE - Gualdi et al., 2013)

The multimodel ensemble approach allows to deal with single model systematic biases, and potentially increases the skill of seasonal forecast

NAO index as calculated by ERAinterim, three seasonal prediction systems and the multimodel ensemble



from Athanasiadis et al., submitted

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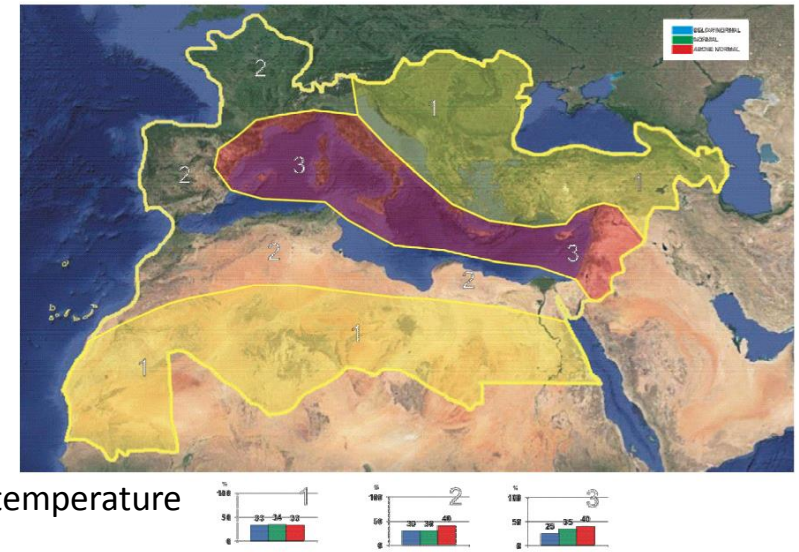
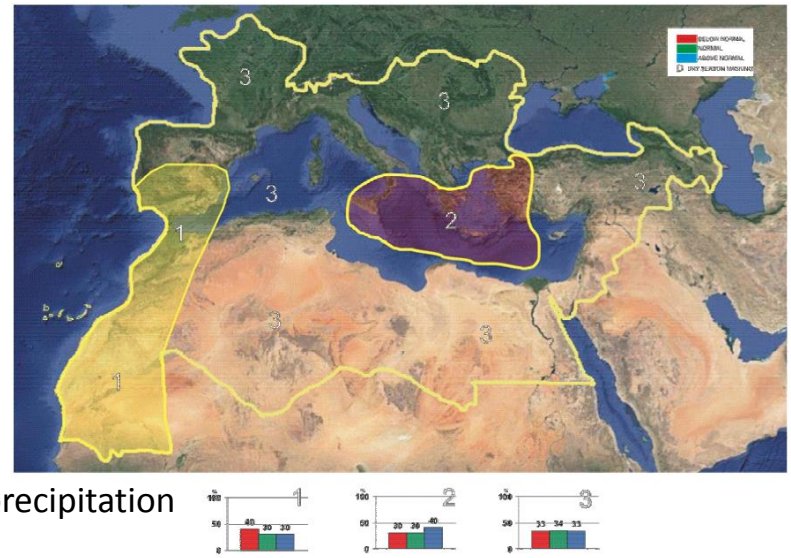


temperature



precipitation

The direction taken by MedCOF seems then to be the right one. Besides, the incorporation of empirical-statistical drivers for the consensus forecast can add further sources of predictability.

Criticality: in a working-group of scientist, the agreement upon the final forecast is NOT AT ALL easy to find

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- The region also has a complex topography that modulates the climate at finer spatial scales (e.g., Lionello et al. 2006).

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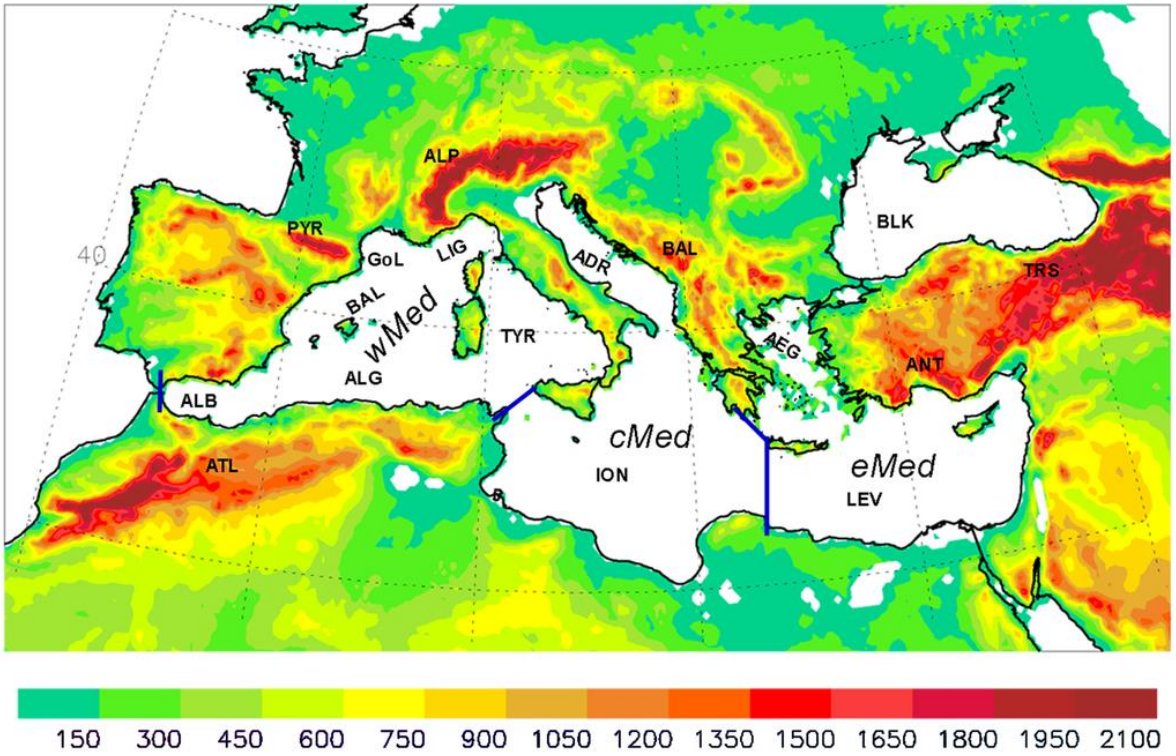
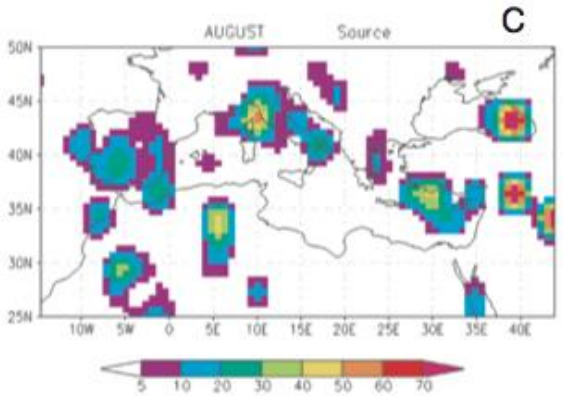
Orography in the Mediterranean



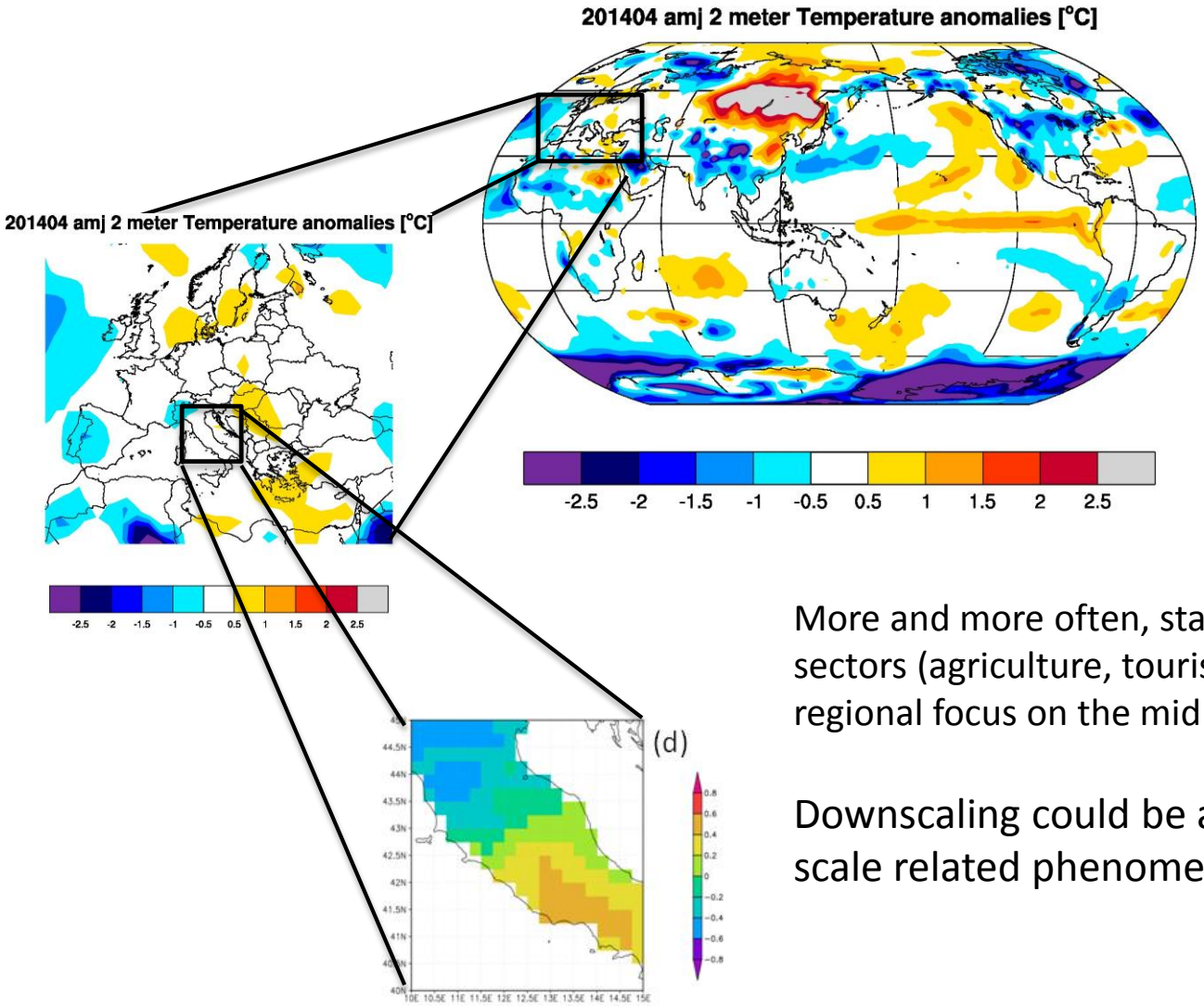
The complex orography strongly impacts patterns of meso-scale and covective precipitation (Alhammoud et al., 2014)

Almost impossible to predict with classic dynamical forecast



Orography changes the baroclinic instability allowing the development of cyclons on the leeside of mountain chains (Lionello et al. 2006)

Think global, act local ™

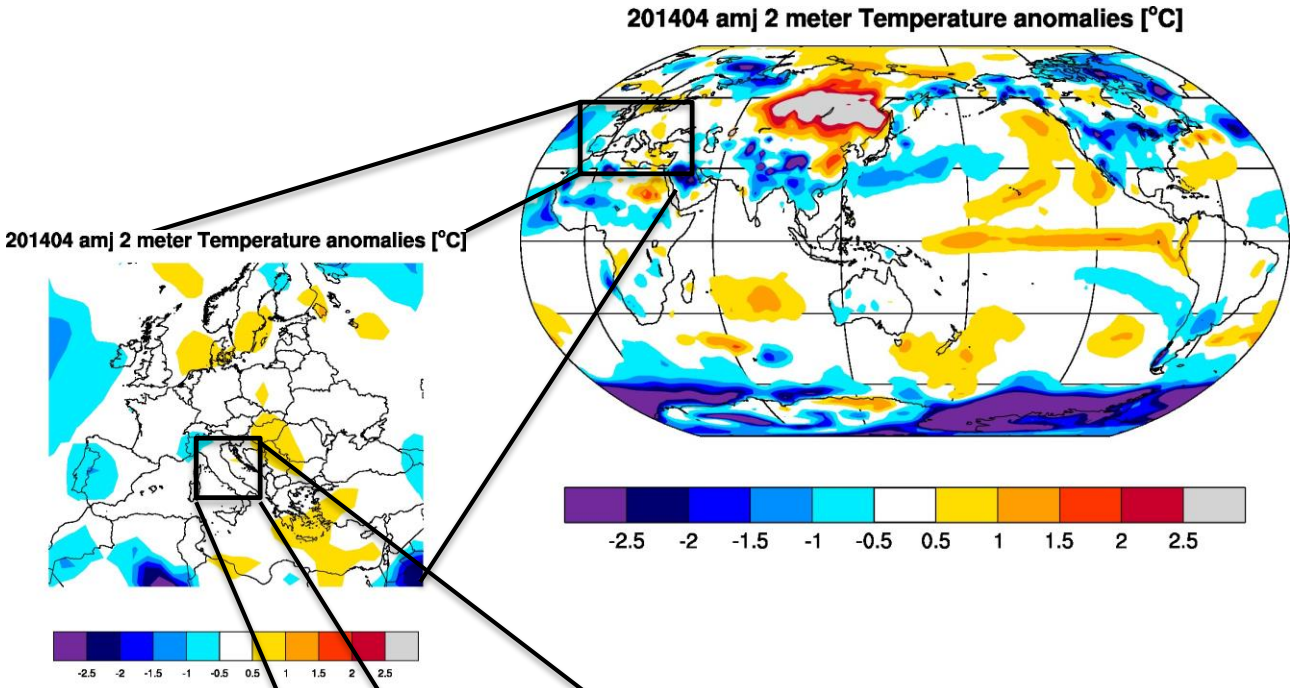


Global scale cannot be disregarded when we produce seasonal forecasts: through **teleconnections**, the climate of a region may be strongly influenced by anomalies occurring in distant areas of the world.

More and more often, stakeholders from different sectors (agriculture, tourism, energy) require regional focus on the mid and small scales.

Downscaling could be a solution to deal with small scale related phenomena

Think global, act local ™



Two types of downscaling are generally used as post-processing of our numerical model outputs:

- Dynamical downscaling, that uses a regional higher resolution model whose boundary condition are given by global models
- Statistical downscaling, that makes use of observed statistical relationships between large and small scale

Dynamical downscaling

- computationally expensive
- has to deal with systematic bias
- many physical processes involved
- implicitly includes sources of uncertainty, crucial for probabilistic forecast

Statistical downscaling

- has to deal with changing climate
- lack of HR dataset with complete spatial coverage
- computationally cheap
- may correct bias of the dynamical forecast by using observations

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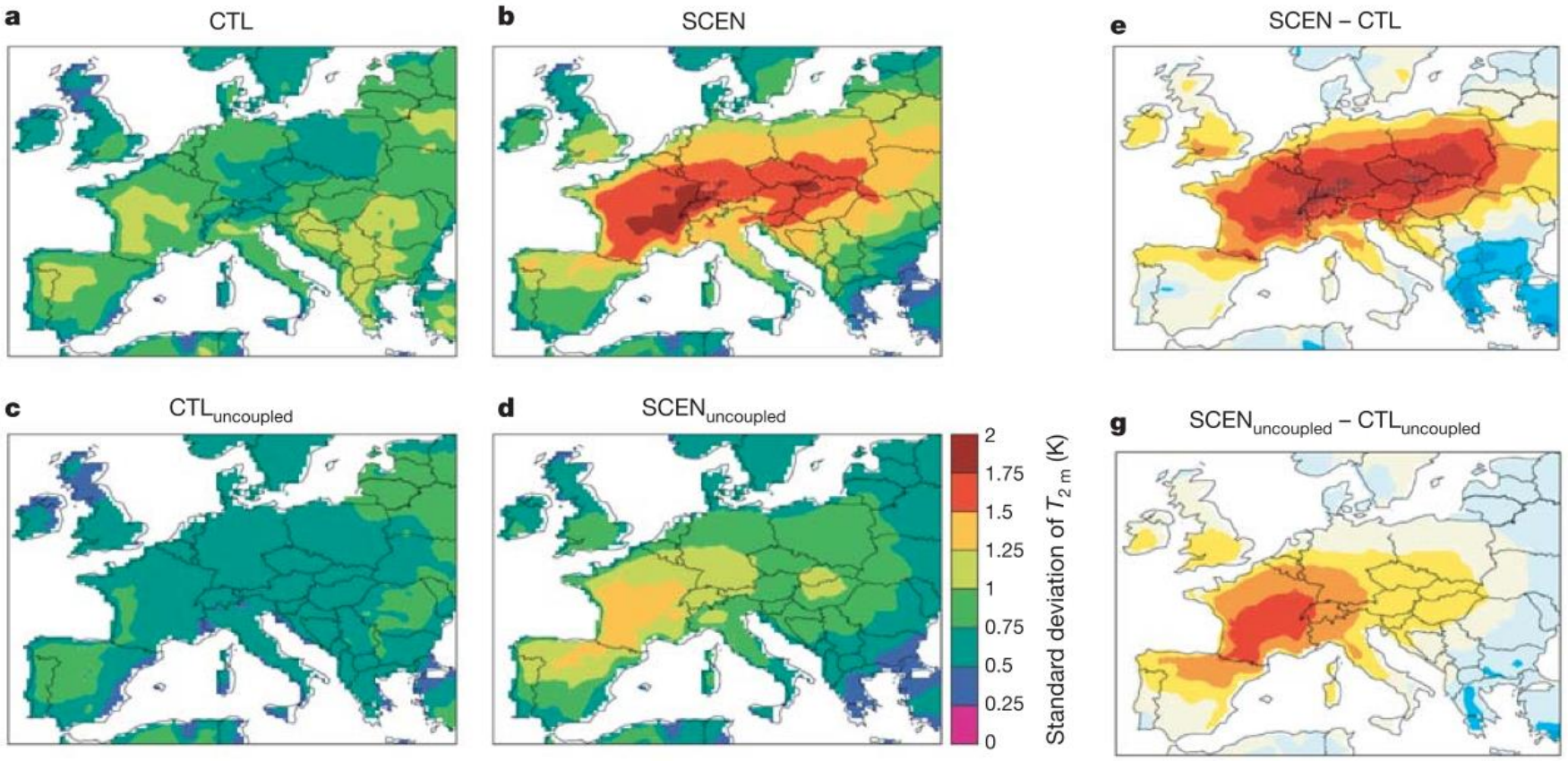
Land-atmosphere coupling



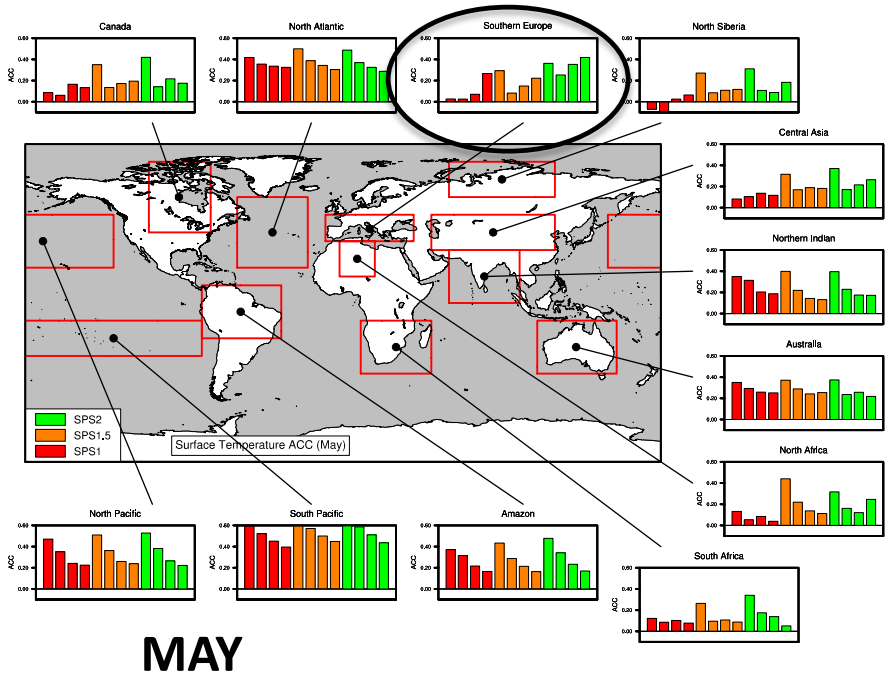
Standard deviation of 2-meter temperature

Seneviratne et al., 2006

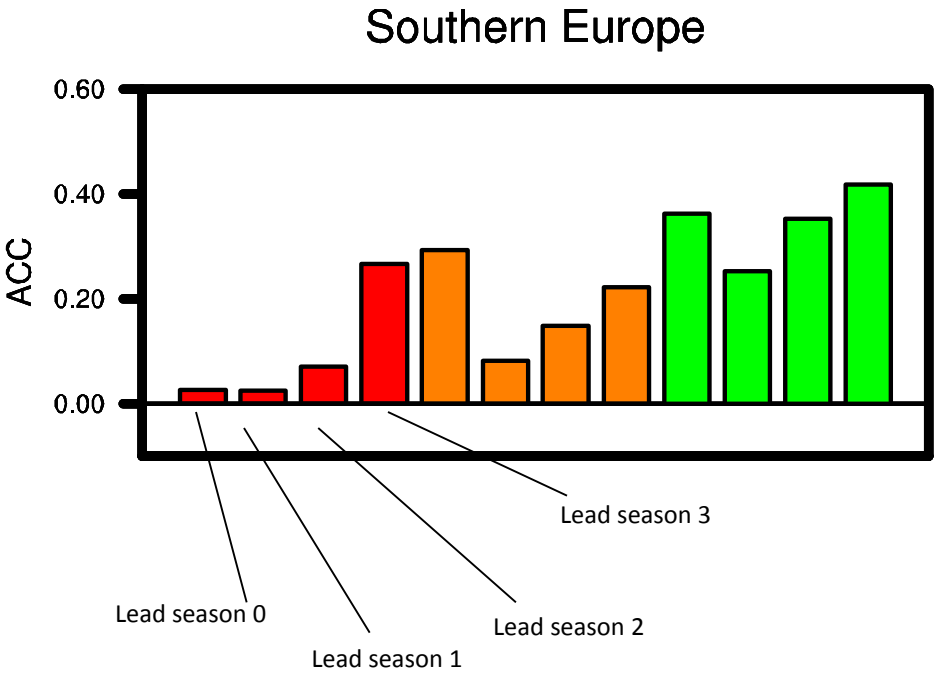
Unperturbed simulations for **present** and **future climate**: in the *uncoupled exp.* instantaneous soil moisture is replaced with climatology.

How can we get a prediction right if we are not able to catch the variability of our target?

The importance of land surface initialization



MAY



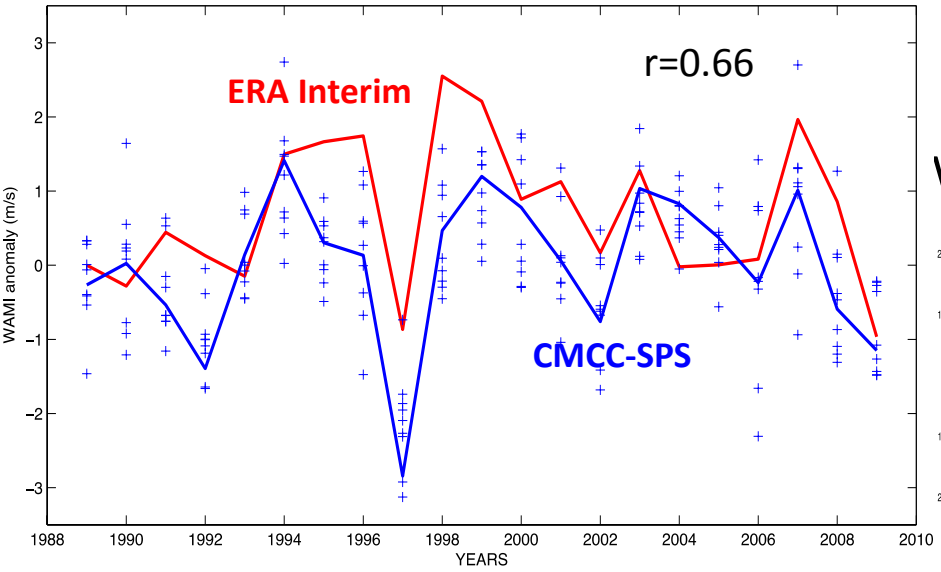
Temperature anomaly correlation for the tree version of CMCC-SPS, each differing for the initialized component

initiaized component

O **OA** **OAL**

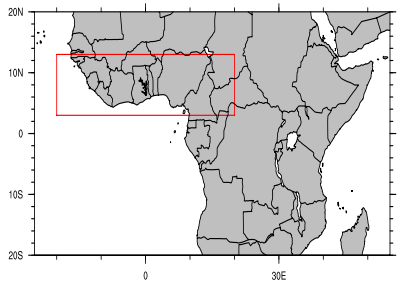
The importance of land representation

WAMI anomaly (m/s) May start date, lead 1 (JJA)

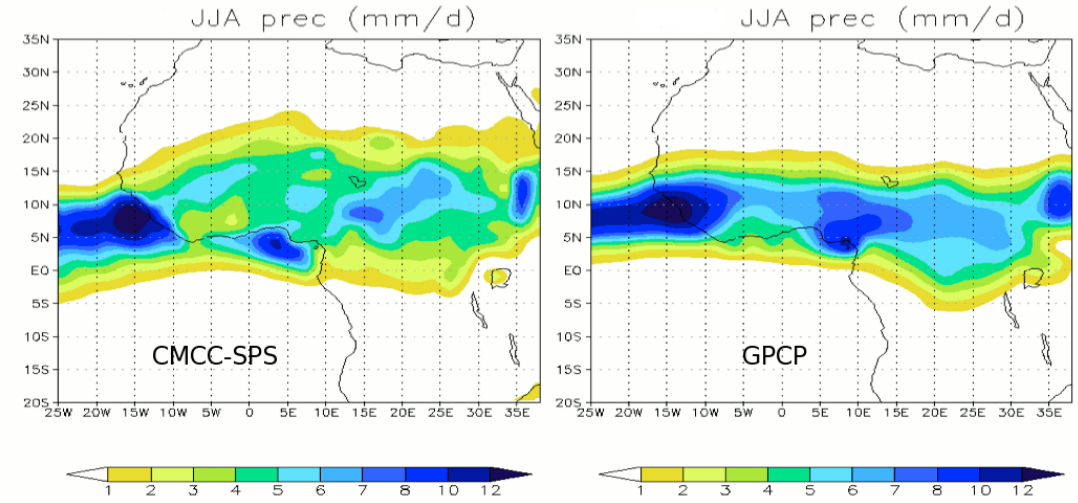


West African Monsoon

$WAMI = u_{850hPa} - u_{200hPa}$



CMCC-SPS intercepts the interannual variability of Monsoon winds.

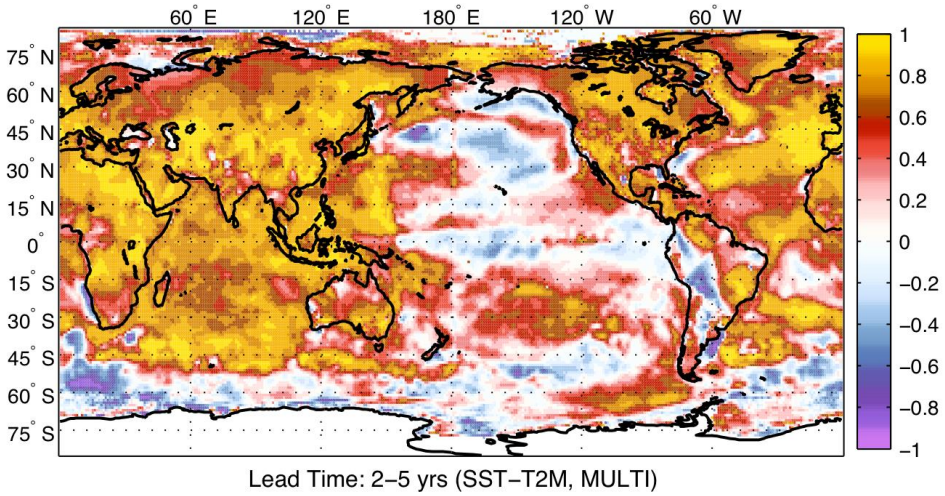


Nevertheless, precipitation during summer, turns out to be too weak and to penetrate too much inland. This is most likely due to a poor representation of land surface processes in this version of the model (Borrelli et al., in preparation).

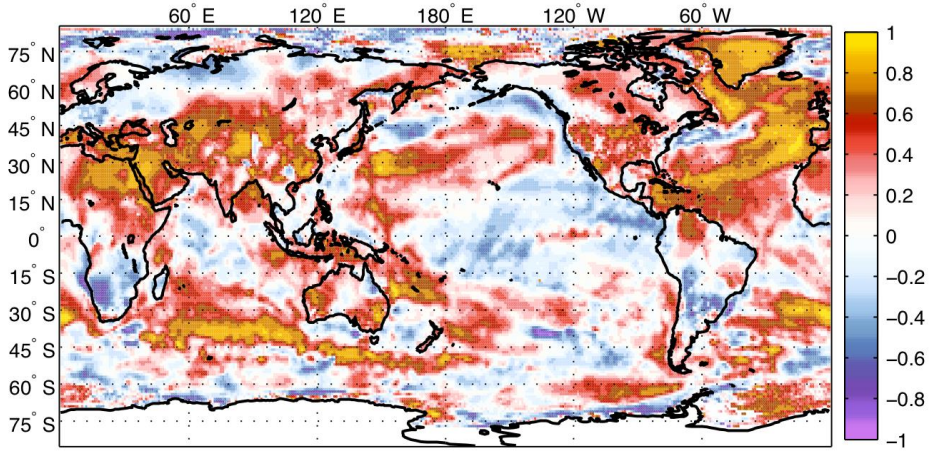
The impact of temperature trend

Statistically significant (90%, ACC>0.47) correlations over extensive portions of ocean and land.

After detrending, **local forecast skill undergoes a dramatic reduction**, over most of the global domain.



Lead Time: 2–5 yrs (SST–T2M, MULTI)



Lead Time: 2–5 yrs (SST–T2M–detrended, MULTI)

This study was designed for decadal prediction, and shows that a few areas maintain high predictability after detrending. The information contained in the trend, which is implicitly present in our dynamical models through boundary conditions (GHG forcing), is crucial for our seasonal forecasts, and adds predictability to the system.

[Bellucci et al., 2014]

Summary

- There are many reasons why predicting climate in the Mediterranean sector is a challenging task. Many drivers of predictability from Tropics and extra-Tropics, a complex orography and land surface as a source of local predictability makes the forecast very challenging

- Substantial systematic error are still affecting the model performing dynamical forecasting. The multimodel approach has a big potential for the improvement of our seasonal prediction

- There is a need to improve our global model, improving the representation of physical processes and their representation into the system. Also, initialization of poorly-observed components of the climate can be crucial

- Post-processing of forecasts through downscaling can be of great importance for end-users

Thanks

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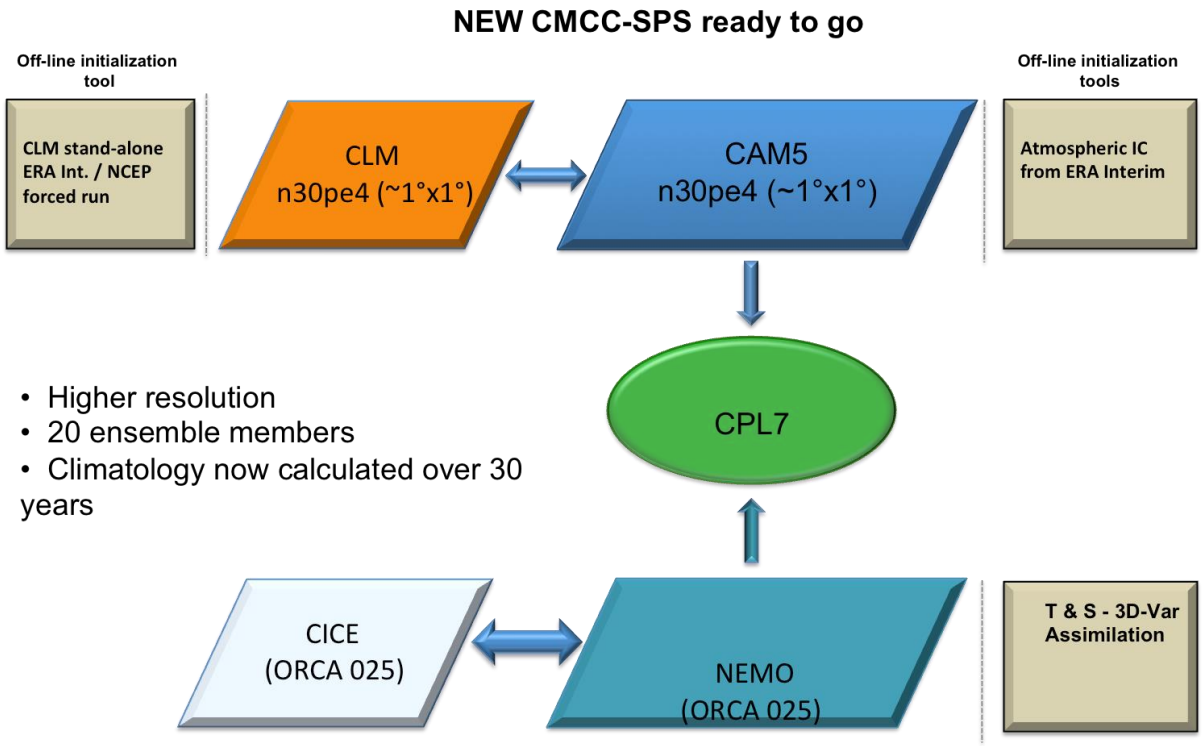
The new seasonal prediction system: CMCC-SPS.v3



Main novelties with respect to the previous seasonal prediction system:

- New model
- More realistic initialization land surface;
- Increased resolution for both the atmosphere and ocean;
- Increased number of ensemble members, through two perturbations for the land surface and 10 for the atmosphere;
- Longer climatology for a more realistic definition of the anomaly predicted.

What is the status of the new seasonal prediction system?

- We have a functioning model supporting the seasonal prediction system, running at ¼° for the ocean and 1° for the atmosphere; tests to assess the model performance have just started;
- We are building the initial state for the four components (ocean and sea ice, atmosphere, land surface) for the 30-year hidcasts (from 1981 to 2010)

The new seasonal prediction system: CMCC-SPS.v3

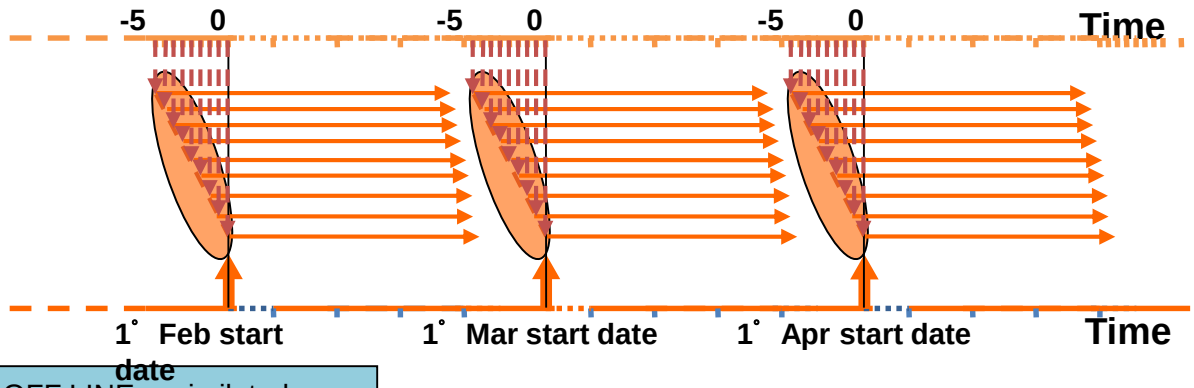
Initialization strategy

OFF LINE CLM4 forced with **ECMWF atmospheric forcing to Land Surface**

OFF LINE CLM4 forced with **NCEP atmospheric forcing to Land Surface**

Day lag every 12 hours

OFF LINE interpolated Atmosphere IC from ERA interim operational analysis



OFF LINE assimilated OCEAN ANALYSIS

- Perturbation is performed for land surface and atmosphere;
- TWO perturbations for land surface, obtained by running the CLM4 land surface model in offline mode, with atmospheric forcing coming from ECMWF and NCEP;
- TEN perturbations for the atmosphere, obtained by starting the run with atmospheric initial conditions every 12 hours back in time up to five days prior to the start date;
- In this way, we obtain 20 ensemble members which accounts for uncertainty in the observation and in the land model systematic error