Diagnostics and physical evaluation of seasonal models over the Mediterranean region

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Thanks to: **S. Gualdi, P. Athanasiadis, A. Bellucci, A. Borrelli, A. Sanna,L. Cavicchia, E.Scoccimarro, A. Cherchi**

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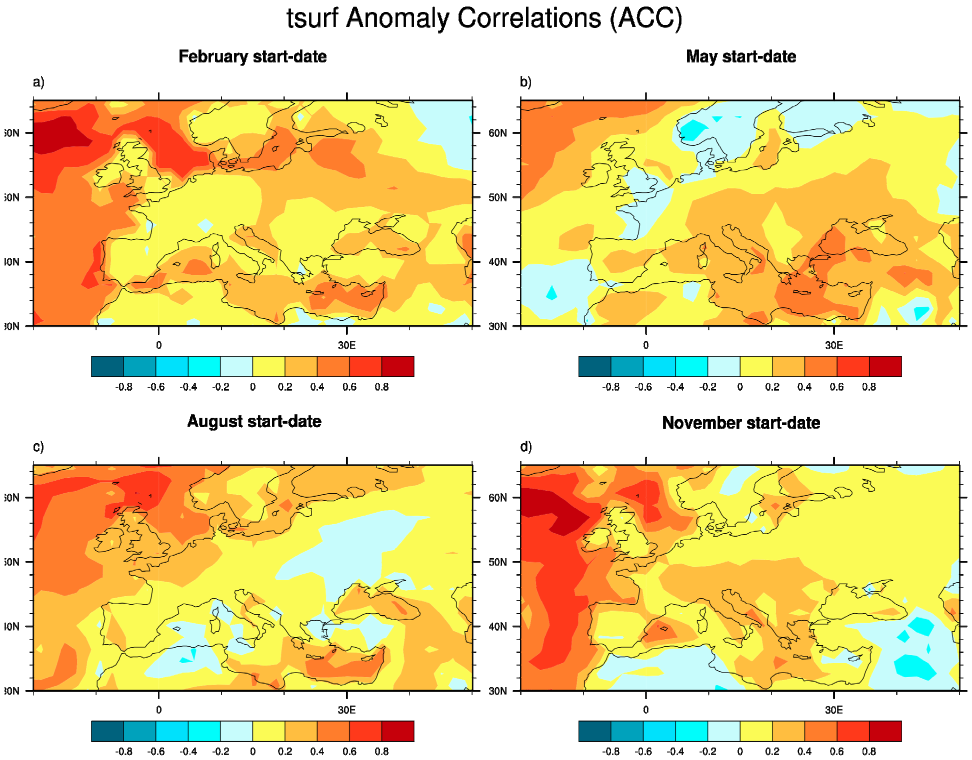
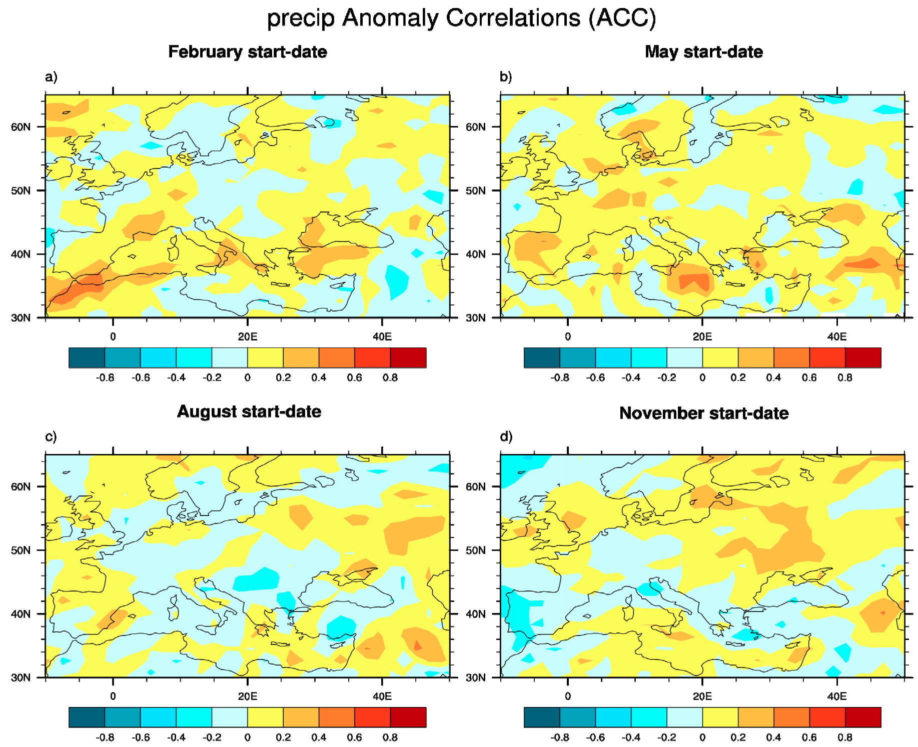
Seasonal Predictions in the Euro-Mediterranean region

Skill of the predictions in the Euro-Mediterranean region

2-meter Temperature



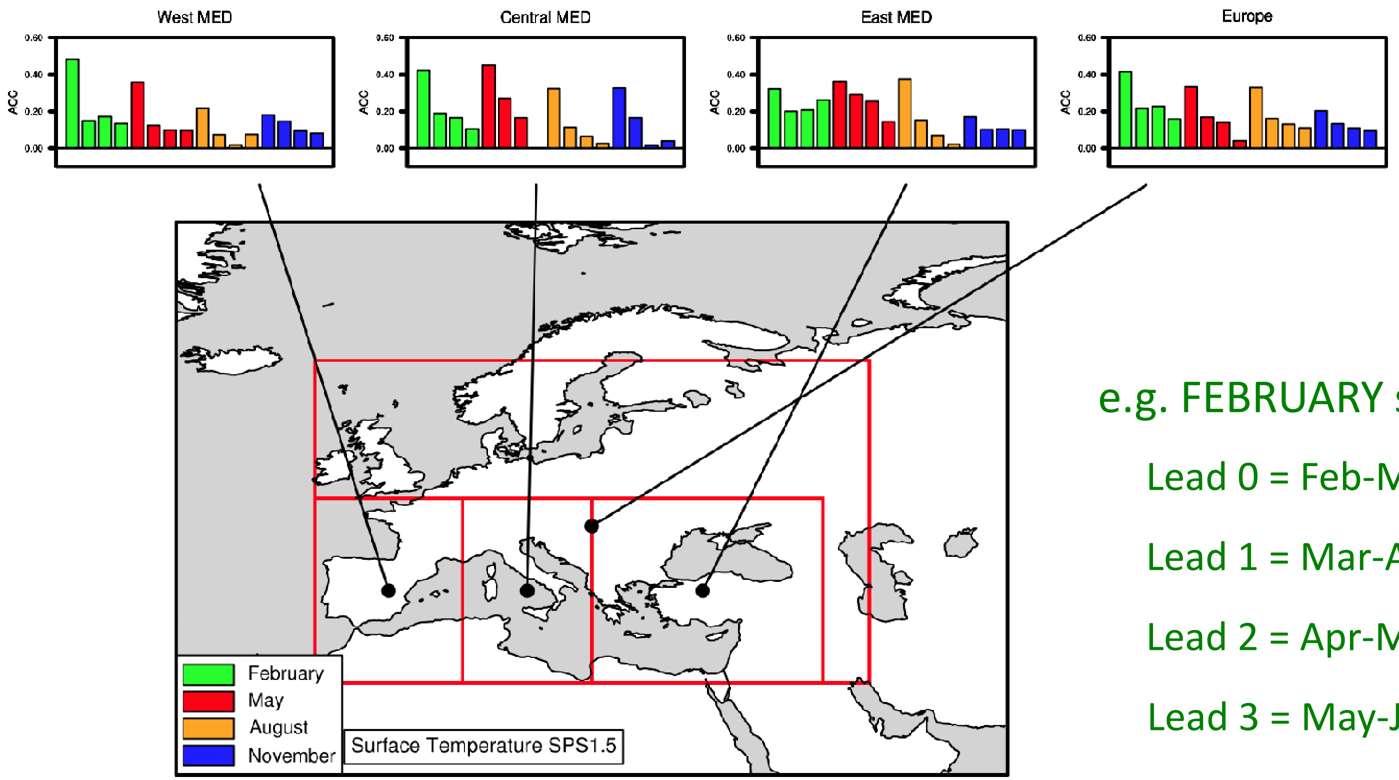
Precipitation



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



e.g. FEBRUARY start date

Lead 0 = Feb-Mar-Apr

Lead 1 = Mar-Apr-May

Lead 2 = Apr-May-Jun

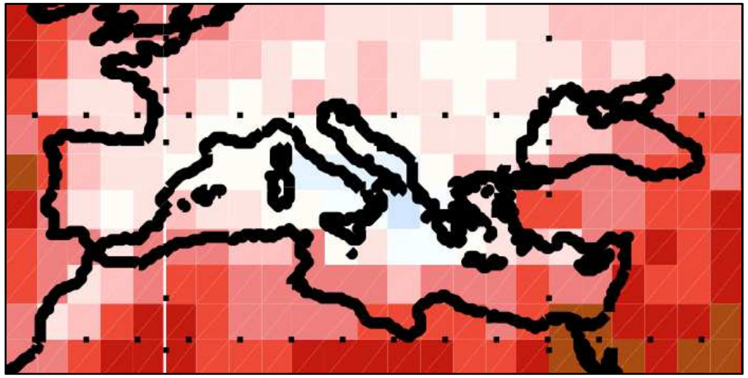
Lead 3 = May-Jun-Jul

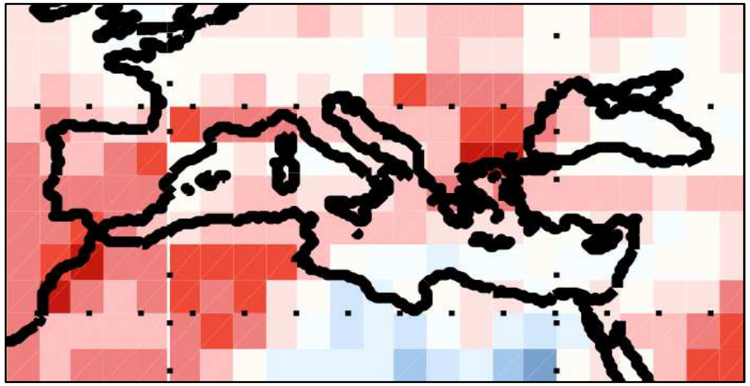
Seasonal Predictions in the Euro-Mediterranean region

2-meter Temperature
(DJF, November start date)

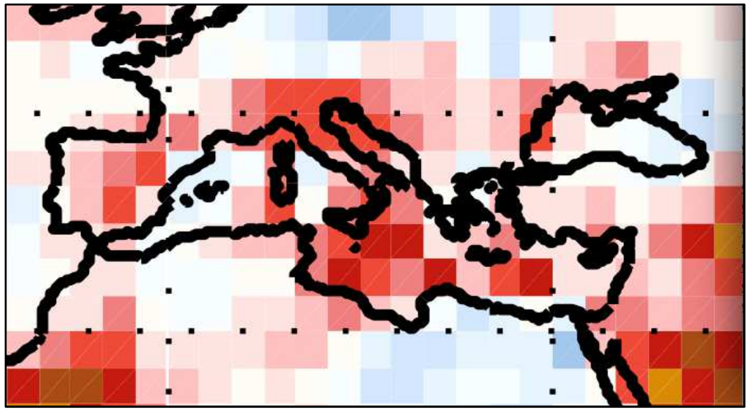
Precipitation
(DJF, November start date)

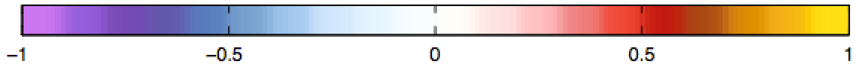
CFSv2





UKMO



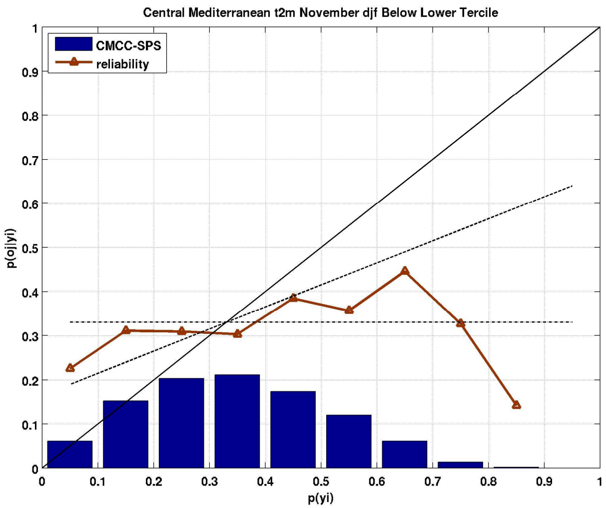


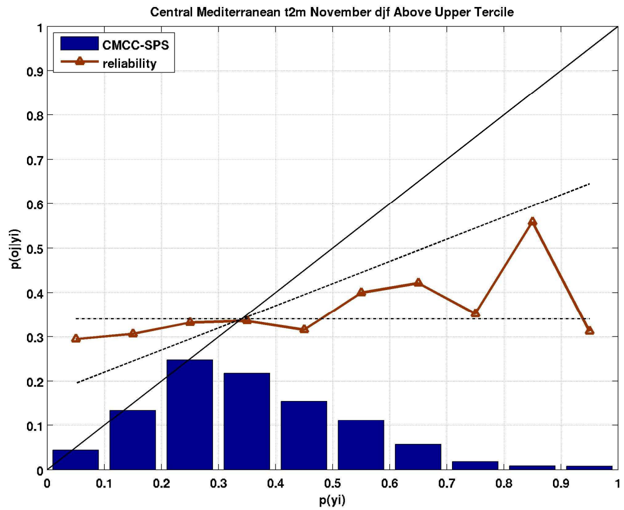
Reliability diagrams in the Euro-Mediterranean region

2-meter Temperature

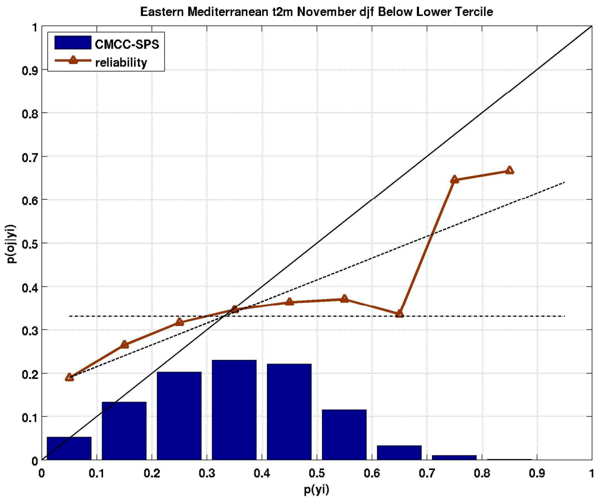
(DJF, November start date)

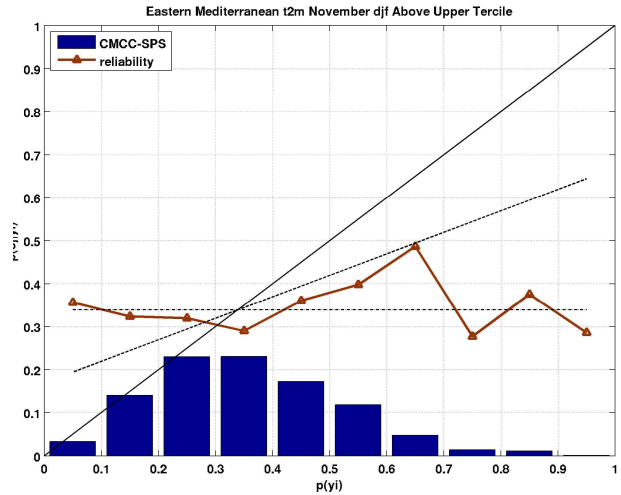
Central Mediterranean





Eastern Mediterranean





Panos said

SKILL COMES LAST,
FIRST COMES MODEL PERFORMANCE

- *In order for a seasonal prediction system to make skillful forecasts, it has to simulate well all the major physical processes associated to seasonal predictability.*

- *This is possible only if the model has a realistic climate and variability thereof.*

Why is predicting climate in the Mediterranean a challenging task?

- The Mediterranean sector lies in a transition zone between the arid climate of North Africa and the wet climate of central Europe. Its climate is influenced by interactions between midlatitude and tropical processes (Raicich et al. 2003; Giorgi and Lionello 2008).

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

- Part of the predictability in the Mediterranean is due to antecedent land surface conditions (van der Hurk et al., 2012), which are known to be hardly measured (therefore initialization has to rely on forced land models) and imperfectly represented by climate models.

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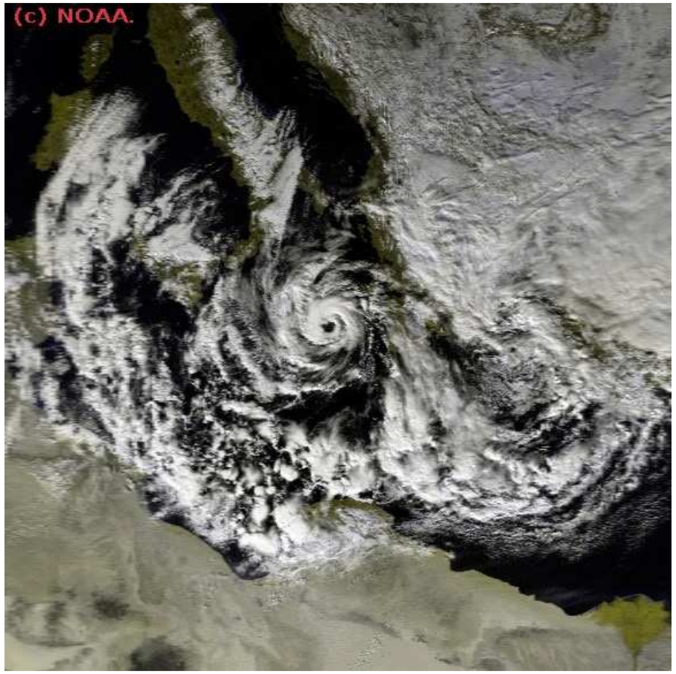
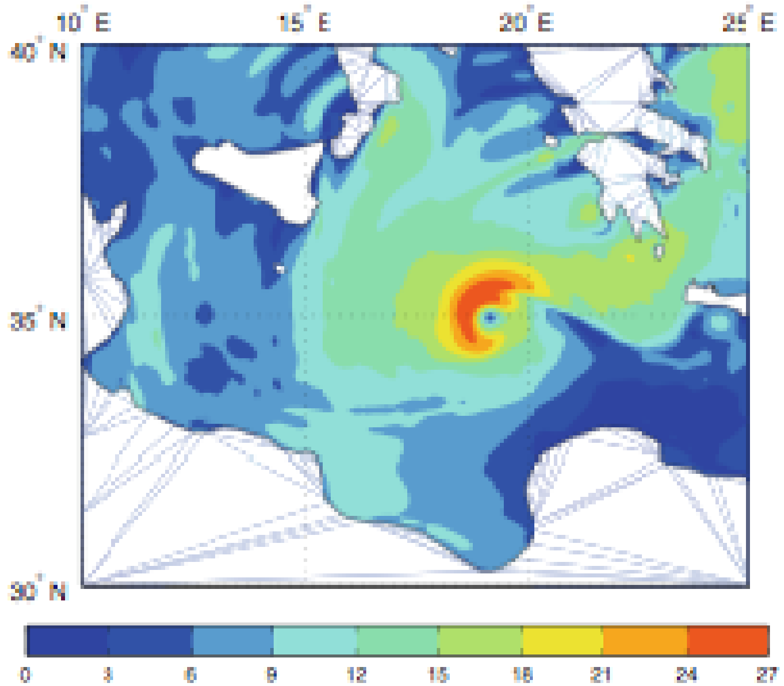
Tropical occurrences in an extra-tropical region

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



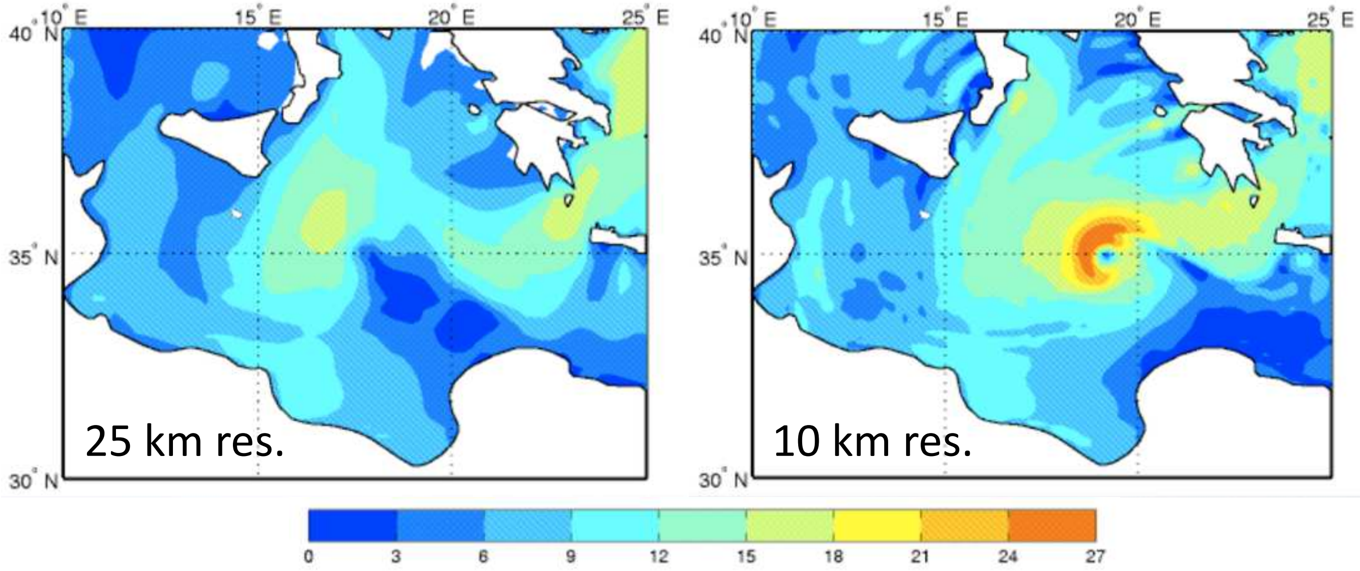


Satellite picture and model simulation of wind speed for the January 1995 medicane

When they make landfall, medicanes are often associated with extreme weather (in particular rainfall and wind) and damage along the coasts.

Tropical occurrences in an extra-tropical region

We need very high resolution to represent their speed and structure



- Maximum wind speed ~ 25 m/s in satellite measurement and high resolution simulation
- 30% lower in the low resolution simulation
- fine structure of the storm visible in the high resolution simulation, showing a windless air column in the storm center, corresponding to the cyclone's eye

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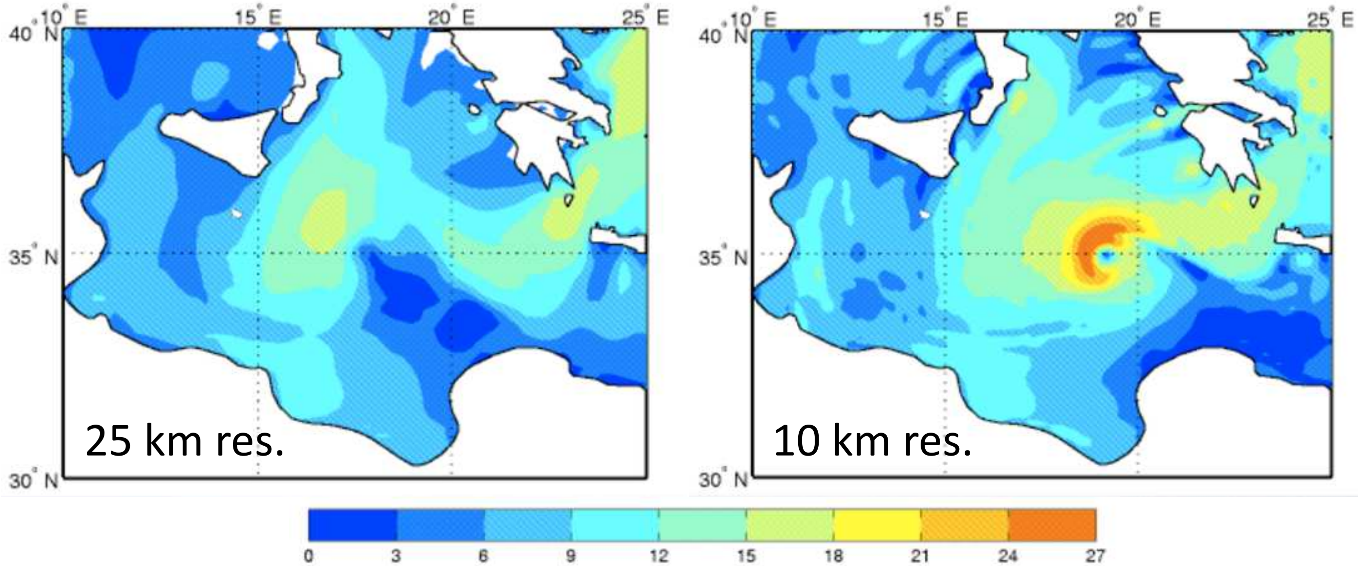

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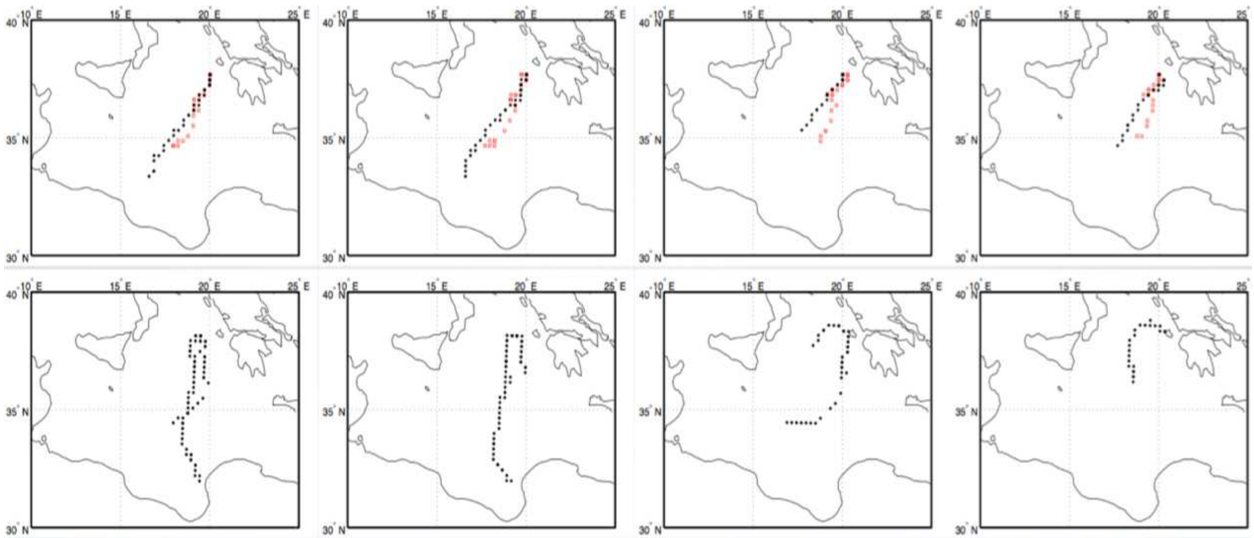
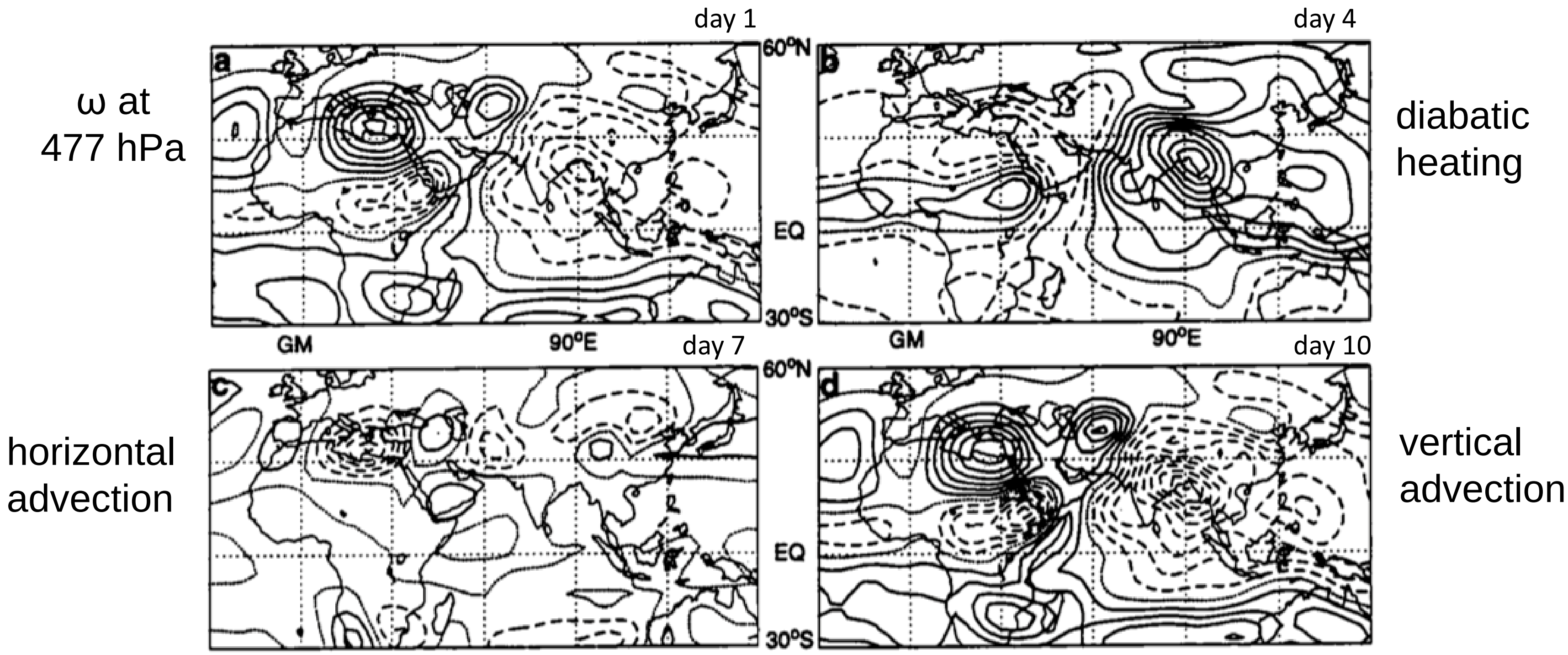


Problematic to get the storm tracking right with no data assimilation

Storm evolution in a nudged (TOP panels) and not nudged (BOTTOM panels) ensemble of experiments (Cavicchia et al., 2014).

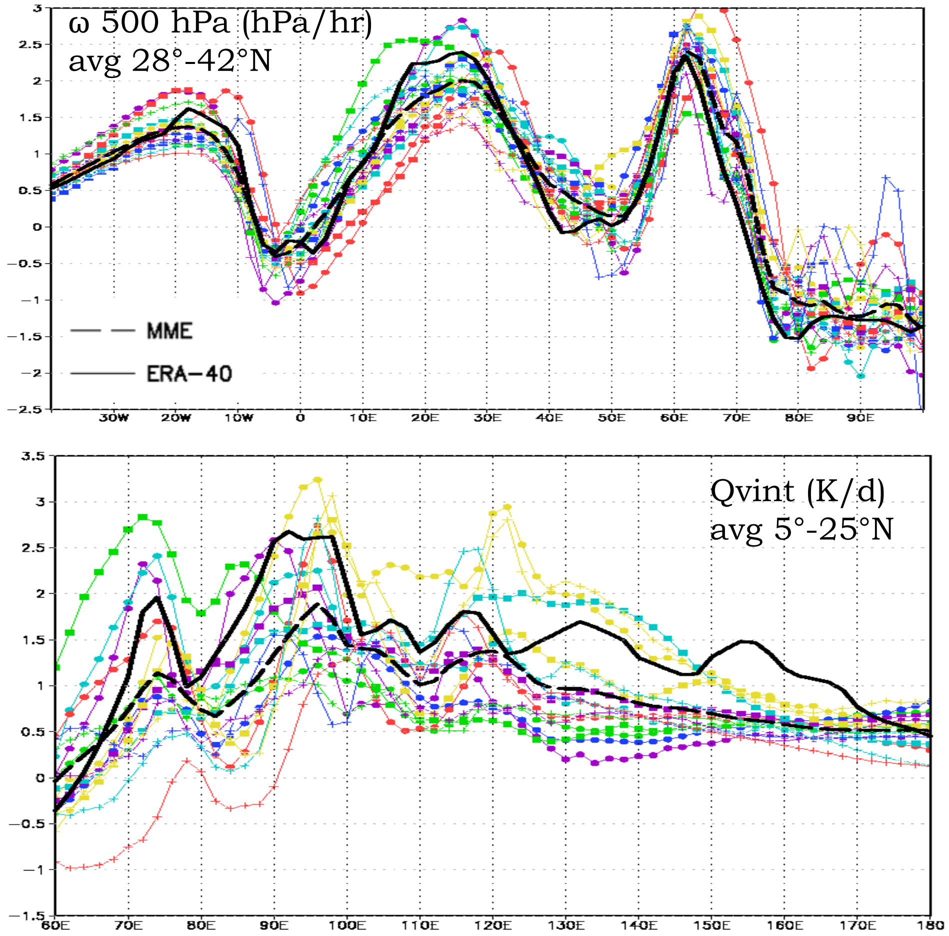
Monsoon-desert mechanism (Rodwell and Hoskins, 1996)

Remote diabatic heating in the Asian monsoon region can induce a Rossby-wave pattern to the west. Integral with the Rossby-wave solution is a warm thermal structure that interacts with air on the southern flank of the mid-latitude westerlies causing it to descend. This adiabatic descent is localized over the eastern Sahara and Mediterranean



The monsoon-forced adiabatic descent results in clear sky and, therefore, a local diabatic enhancement which effectively doubles the strength of descent. This conclusion is supported by the observed dramatic strengthening of descent over the Mediterranean and east Sahara during the onset of the Asian monsoon (Rodwell and Hoskins, 1996)

Descent in east Med & diabatic heating over South Asia (JJA)



• subsidence: spread among models mostly in terms of intensity (from 1 to 3 hPa/hr);

• diabatic heating: spread among models mostly in terms of location of max heating;

Cherchi et al. (2014)

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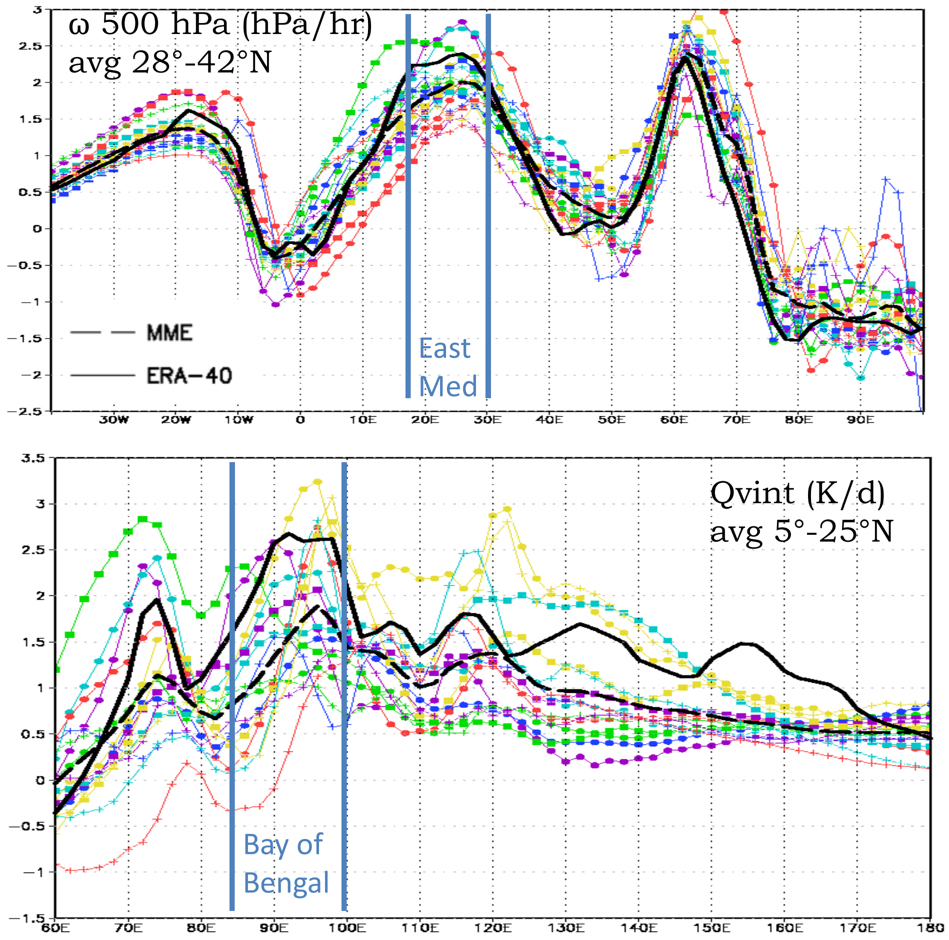

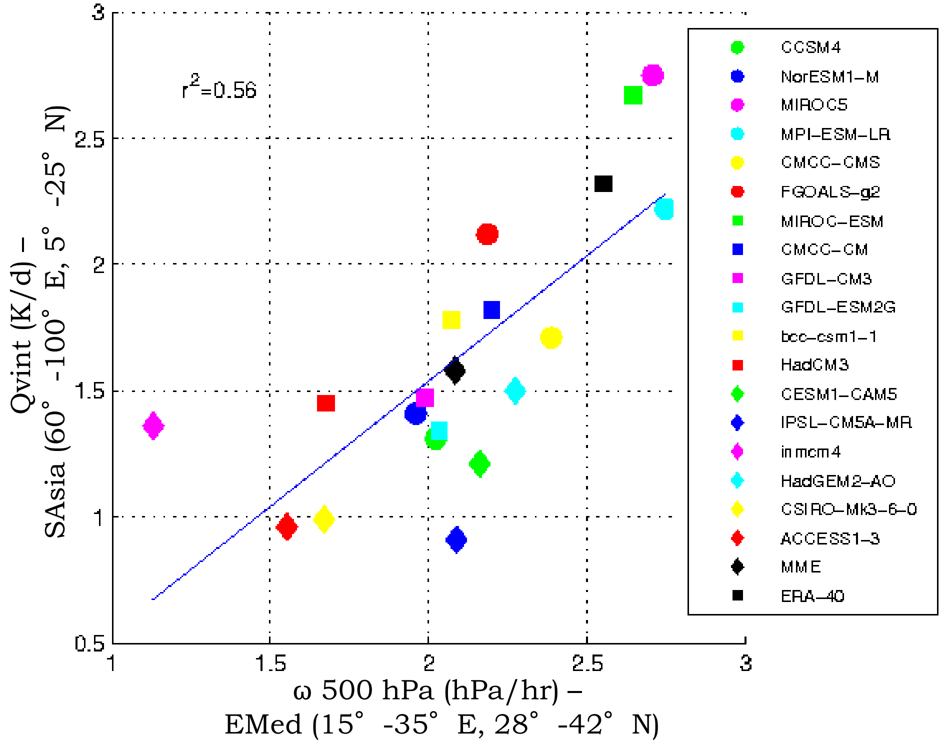

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Despite the variety of location and intensity of the diabatic heating over Asia, the response in terms of subsidence in the Mediterranean region is coherent and realistic in space

Cherchi et al. (2014)

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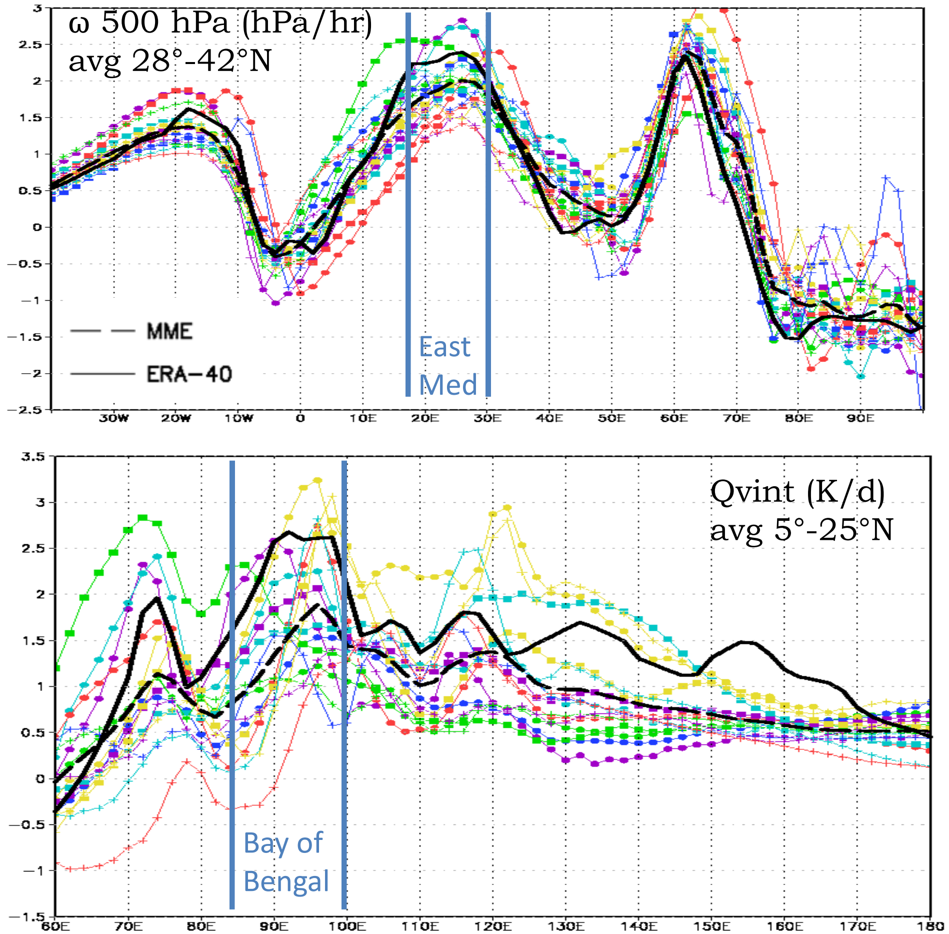

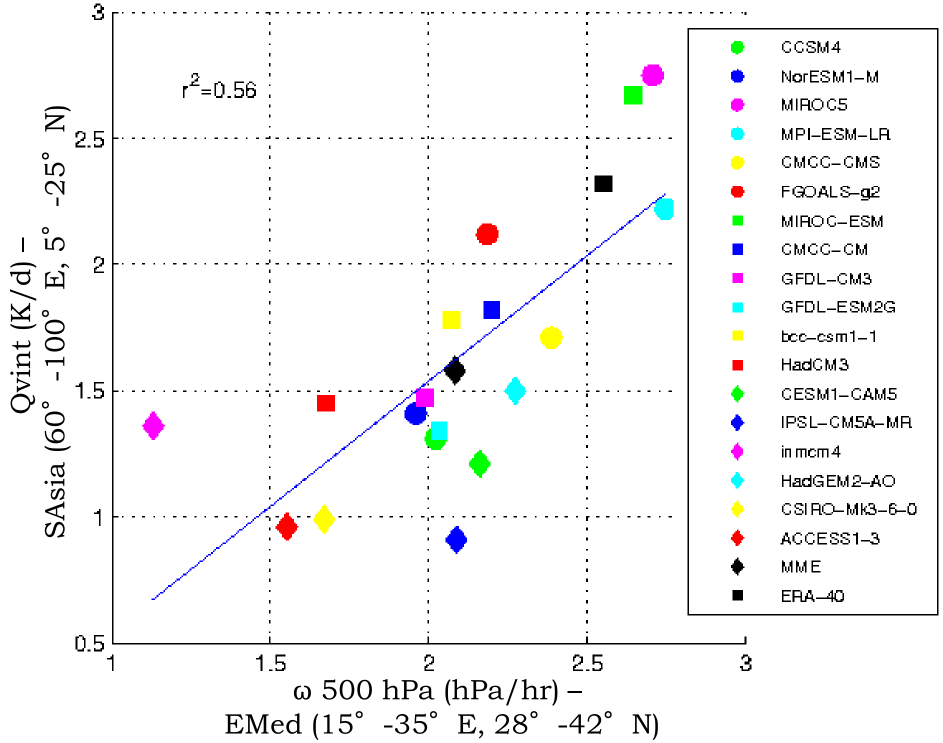

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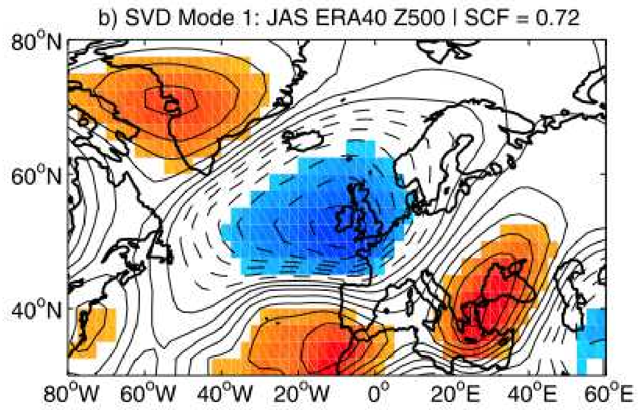
A realistic initialization of both the ocean and atmosphere components is crucial for the Monsoon onset prediction (Alessandri et al., 2015). This, in turn, may boost prediction skill over eastern Mediterranean.

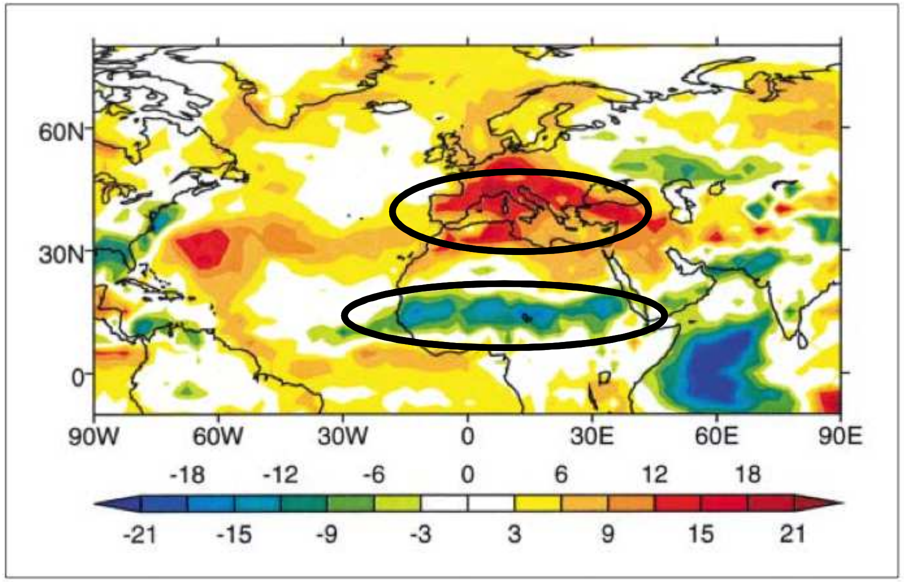
Tropical connections

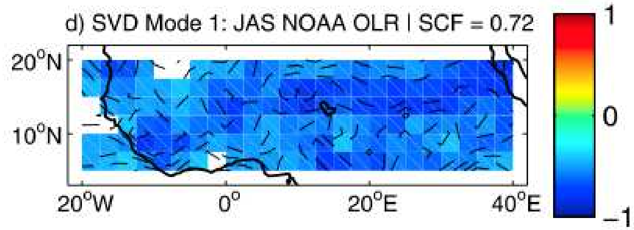
West African Monsoon

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)

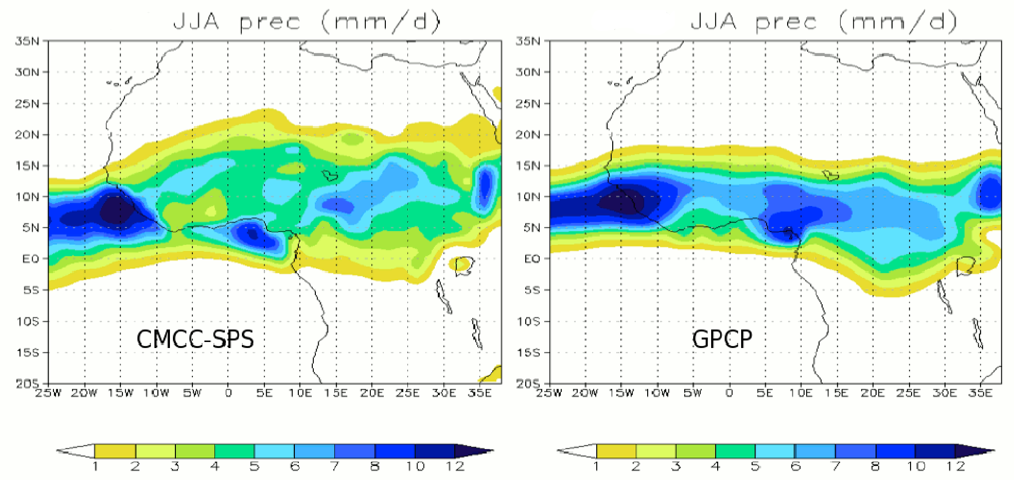




Strong convection in Sudan-Sahel related to HP over eastern Mediterranean and positive NAO-like pattern. When the monsoon circulation is clearly developed over West Africa the stronger covariance is found between tropical and extra-tropical latitudes (Gaetani et al., 2011)

Prediction of West African Monsoon

West African Monsoon



Predicted monsoon precipitation are too weak and to penetrate too much inland, but CMCC-SPS intercepts the interannual variability of Monsoon winds. Failure in representing precipitation amounts and location is due to a poor representation of land surface processes and initialization in this version of the model (Materia, in prep.).

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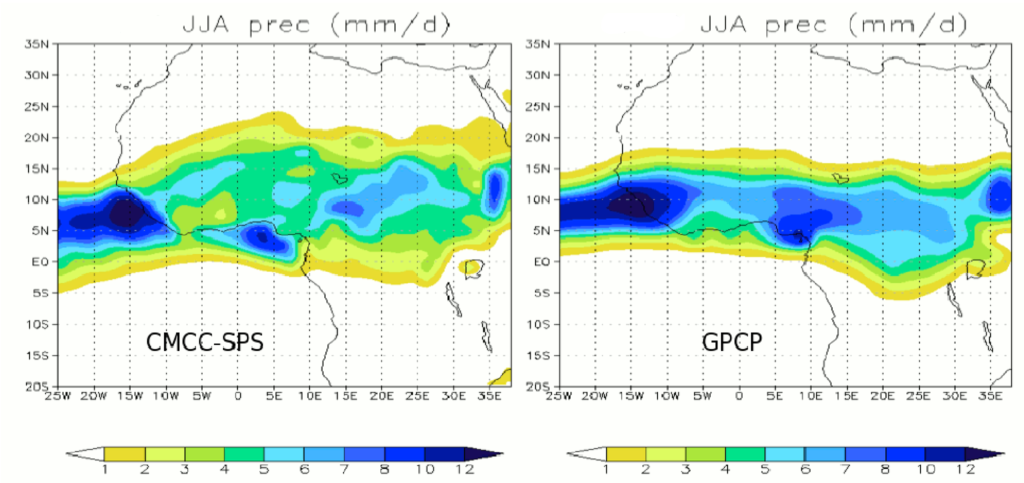

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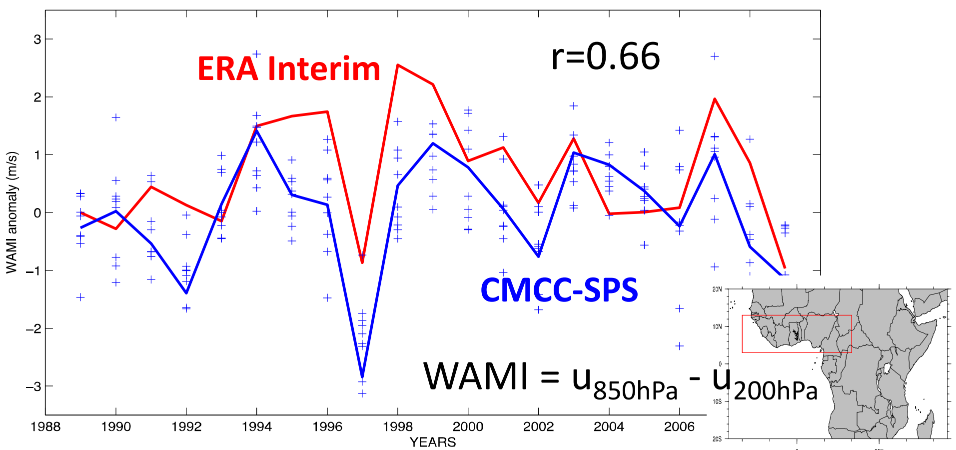
WAMI anomaly (m/s) May start date, lead 1 (JJA)



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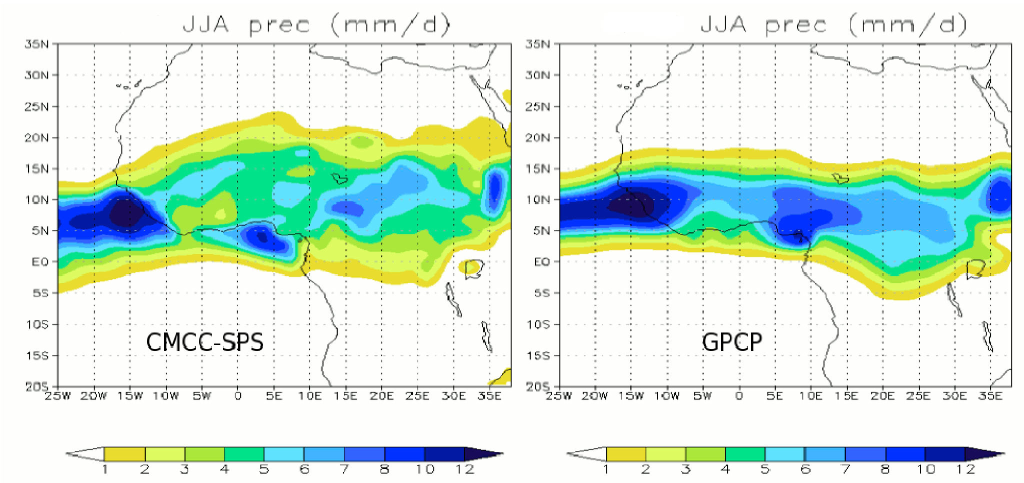

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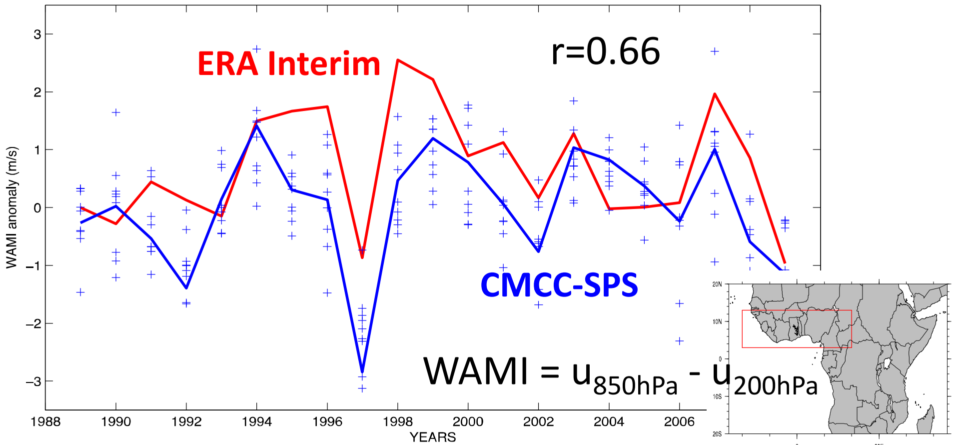
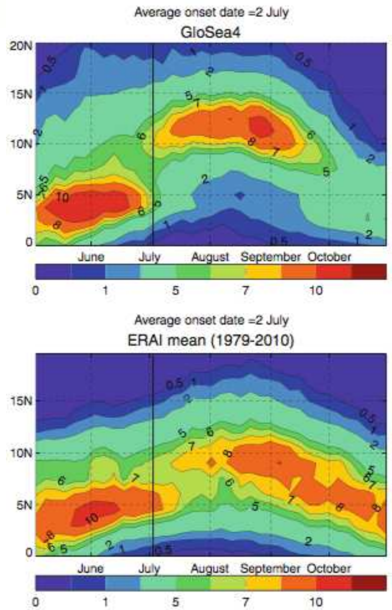


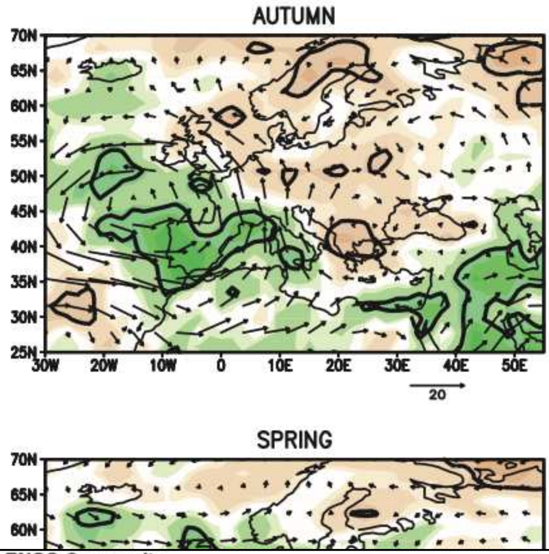


GloSea4, with an improved land surface initialization, is able to catch precipitation amount and monsoon onset (Vellinga et al., 2013)

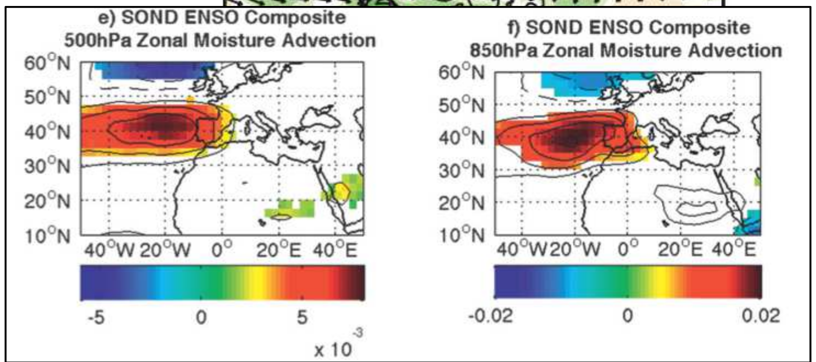
Tropical connections

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.

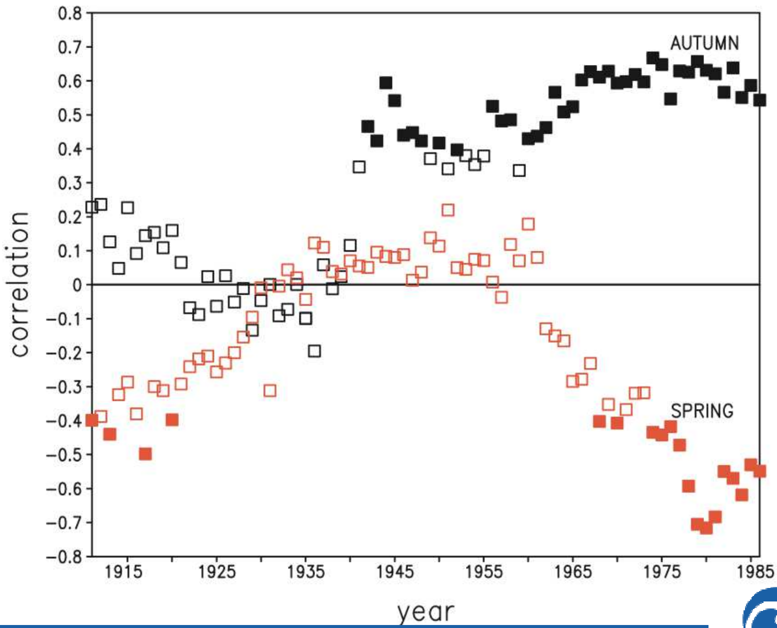


regression of moisture flux on ENSO and correlation with precip



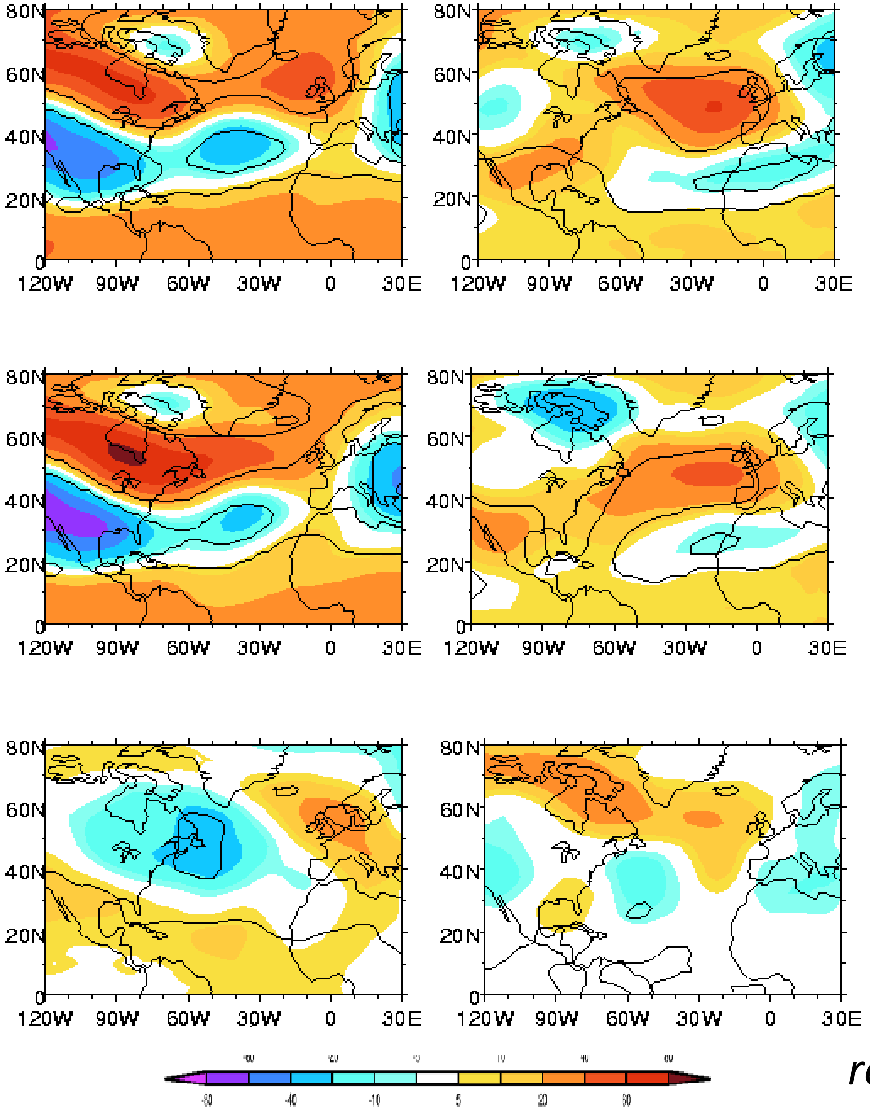
Shaman and Tziperman, 2011

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



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.

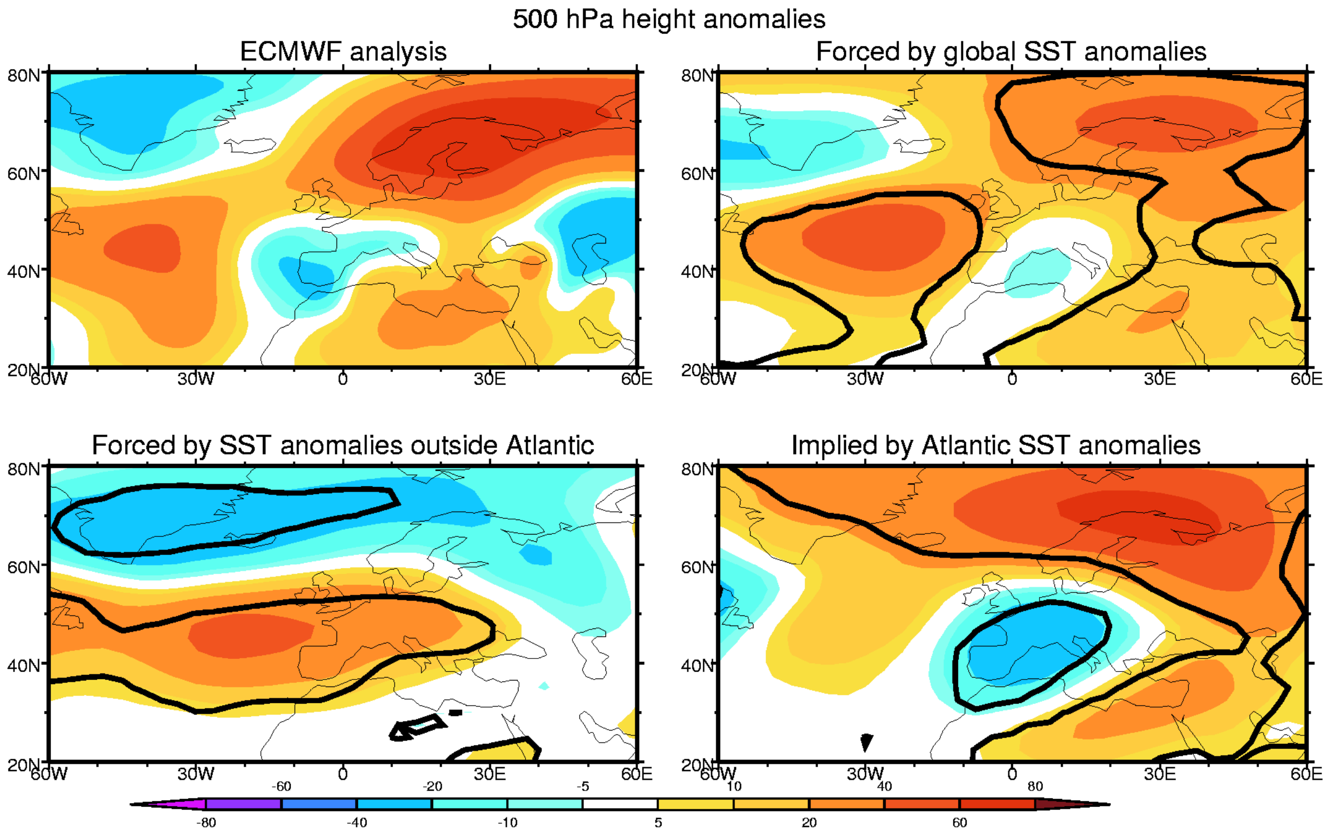
Implied effect of Atlantic

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:

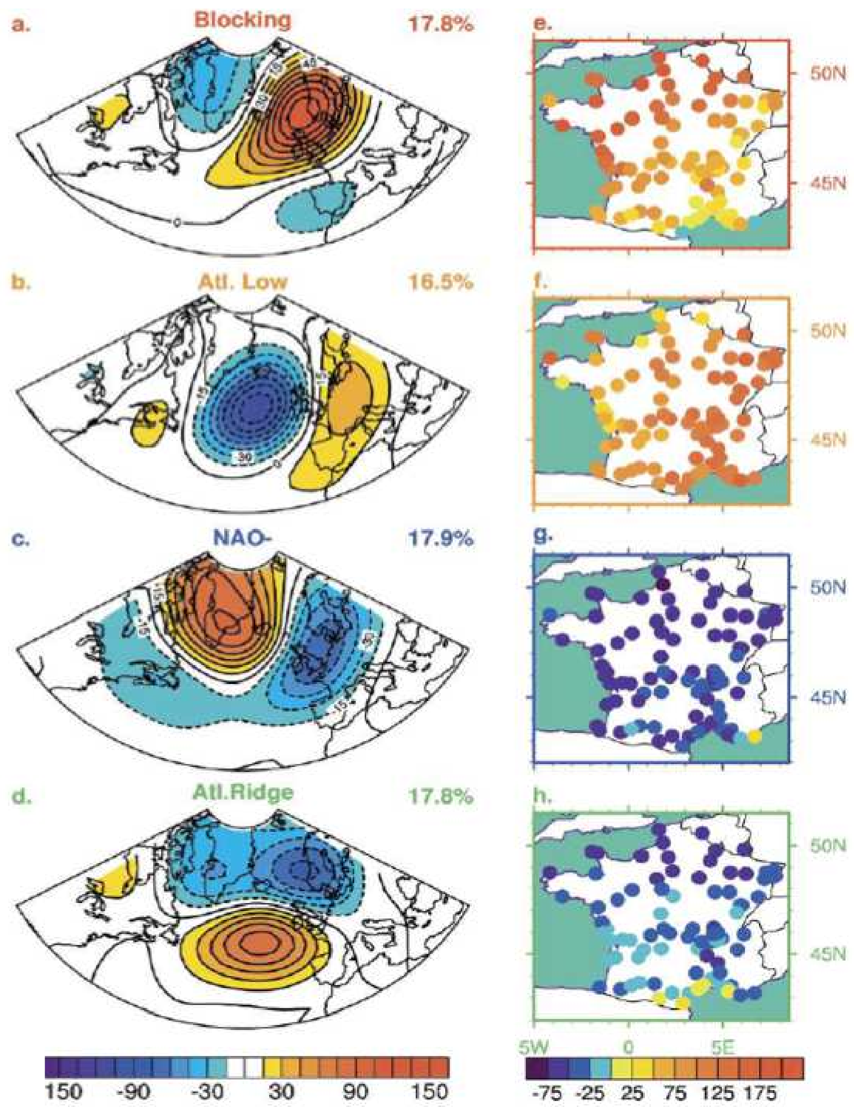


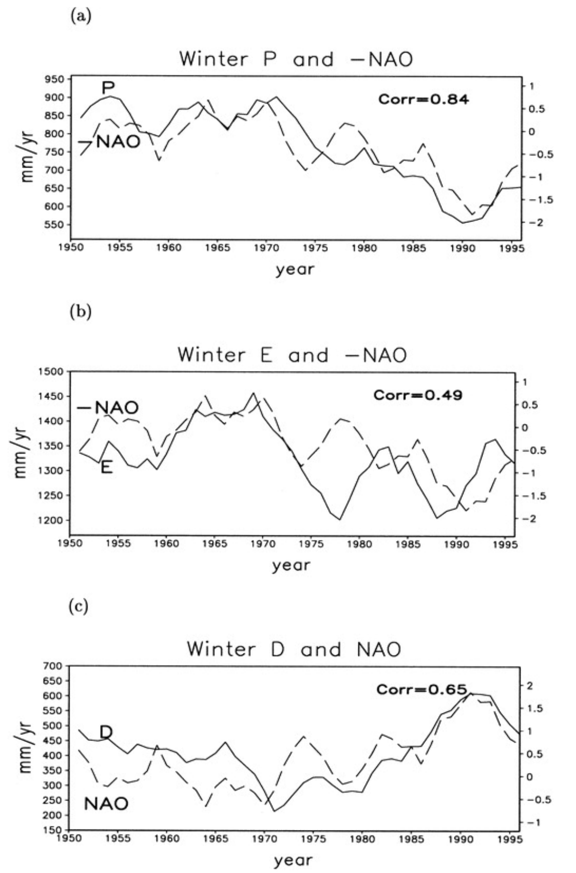
In the absence of strong Pacific forcing, the state of the Atlantic Ocean is important for seasonal predictability.

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

readapted from Slingo (2002)

The role of the Atlantic Ocean



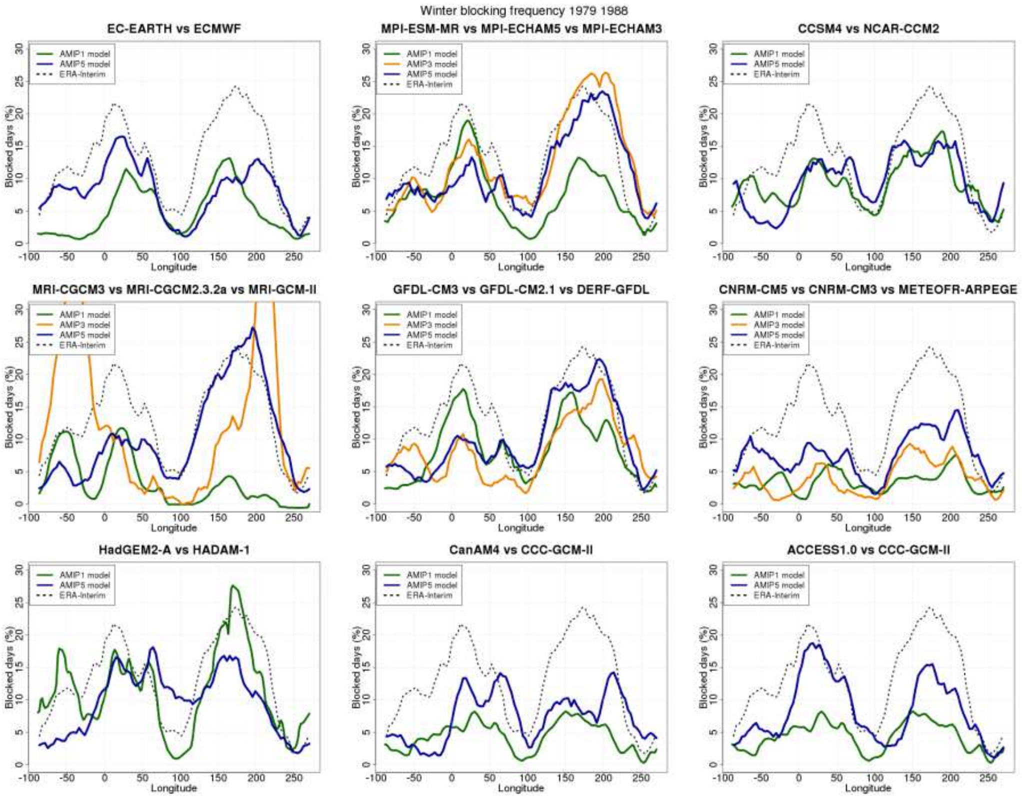


Time series of five-winter (DJFM) running means of the NAO index and area-averaged Mediterranean precipitation, evaporation, and moisture divergence.

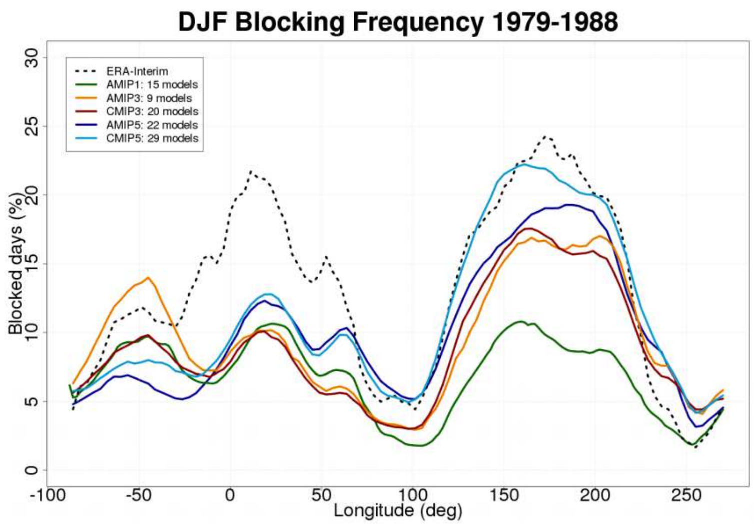
Cassou et al. (2005) have identified four modes of Atlantic variability, each explaining a similar amount of variance, that influence summer temperature over Western Europe

20 years of improvements in blocking representation

Davini and D'Andrea analyzed 20 years of GCM developments. Although large improvements are seen over the Pacific Ocean, only minor advancements have been achieved over the Euro-Atlantic sector. Some of the most recent GCMs still exhibit the same blocking frquency and geopotential height biases as 20 years ago in this region. Some individual models, nevertheless, have improved and do show good performances in both sectors.



Some individual model, have improved and show good performances in both sectors. Negligible differences emerge among ocean-coupled or atmosphere-only simulations, suggesting weak relevance of SST biases.

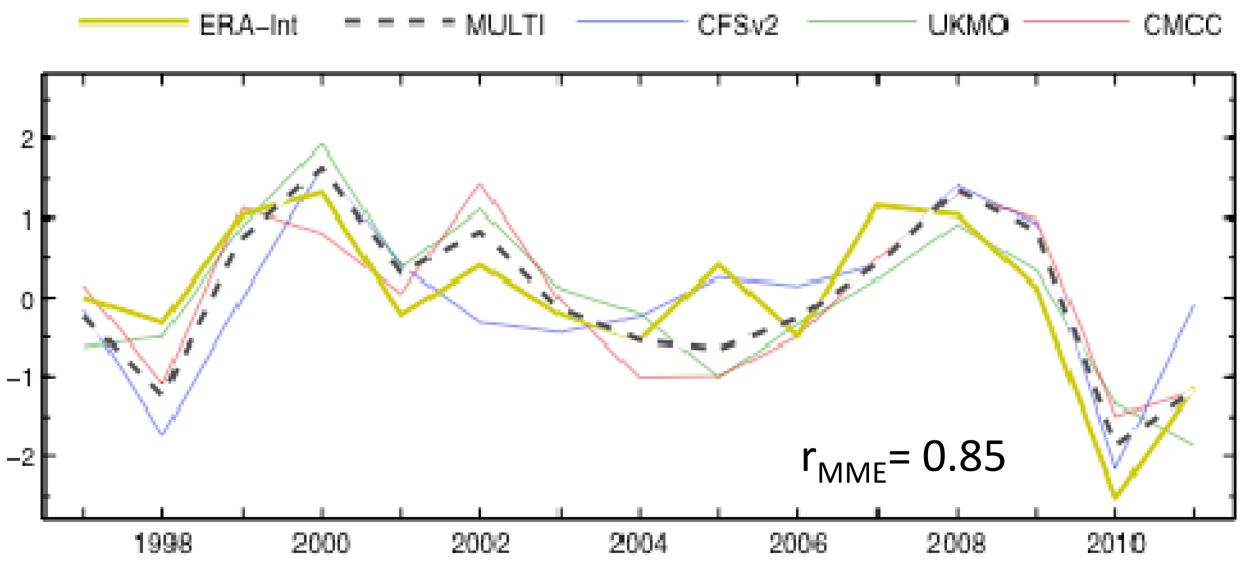


A multi-model approach

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., 2016

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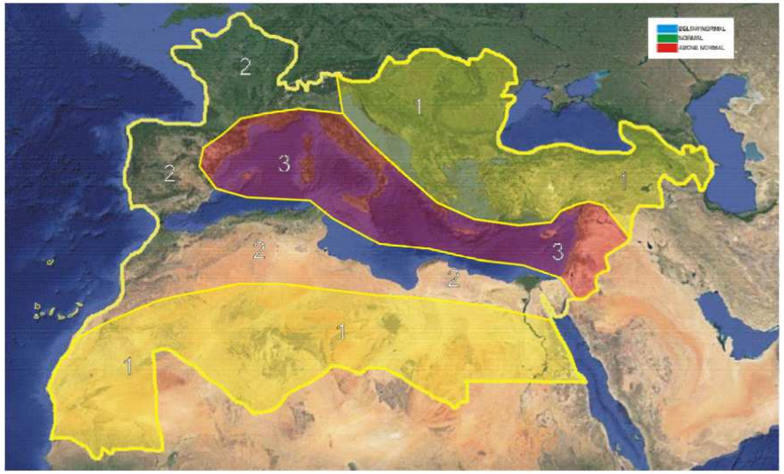
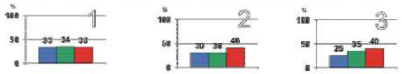
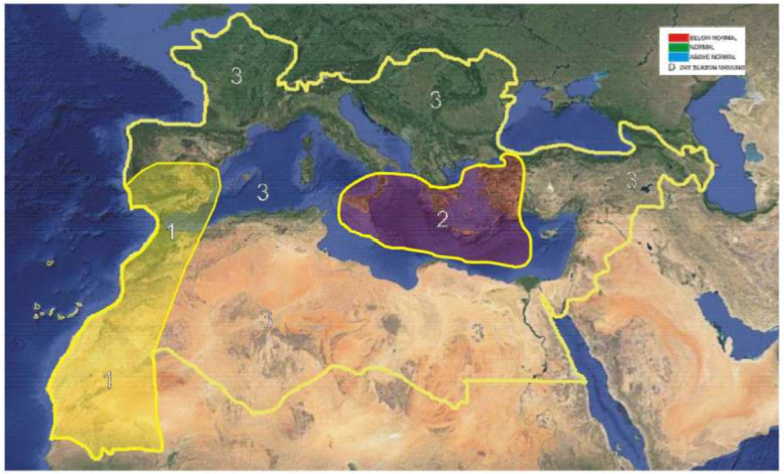


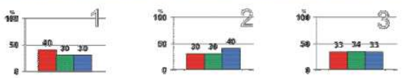
temperature



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.



precipitation



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

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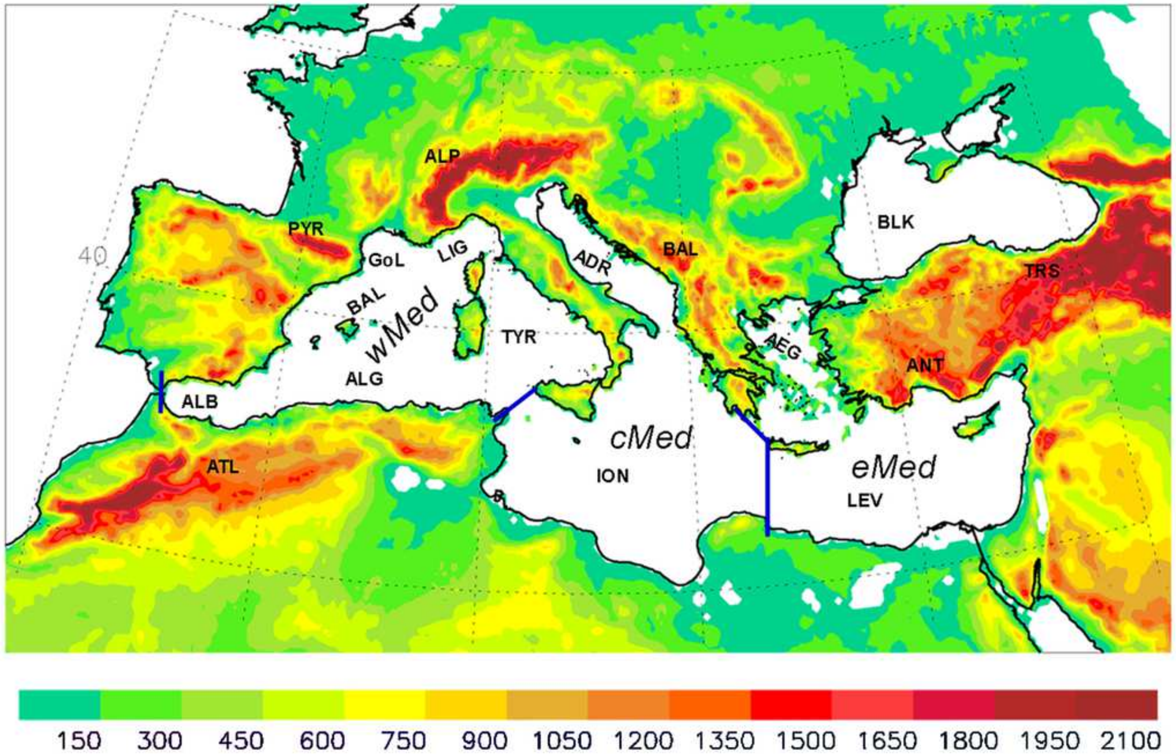
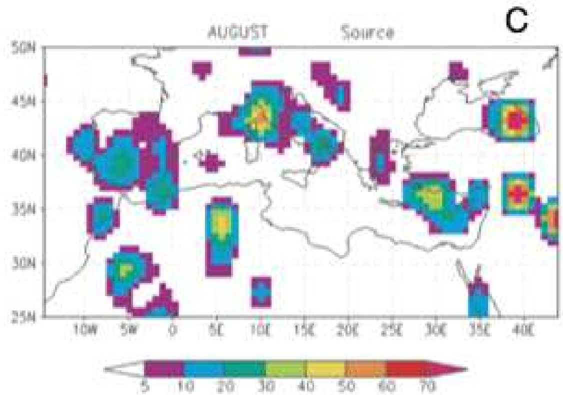
Orography in the Mediterranean



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

Almost impossible to predict with classic dynamical forecast, whose global resolution is still too low



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

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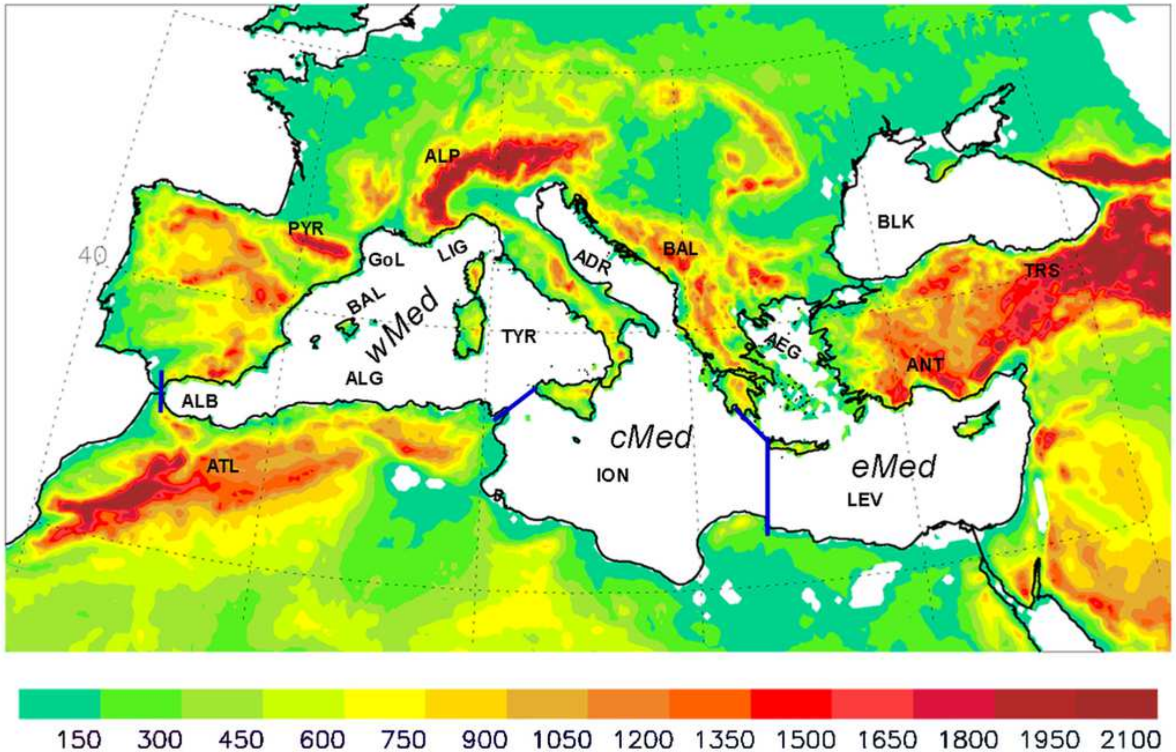

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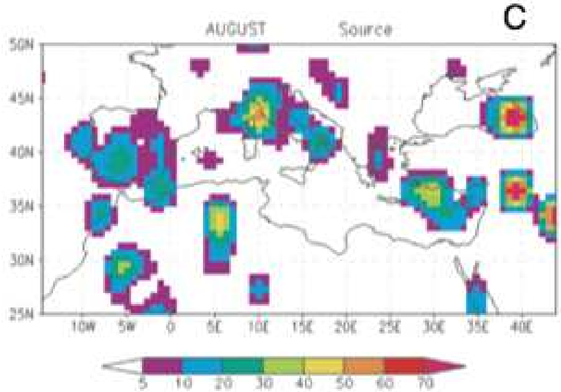

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Will downscaling techniques alleviate this issue?

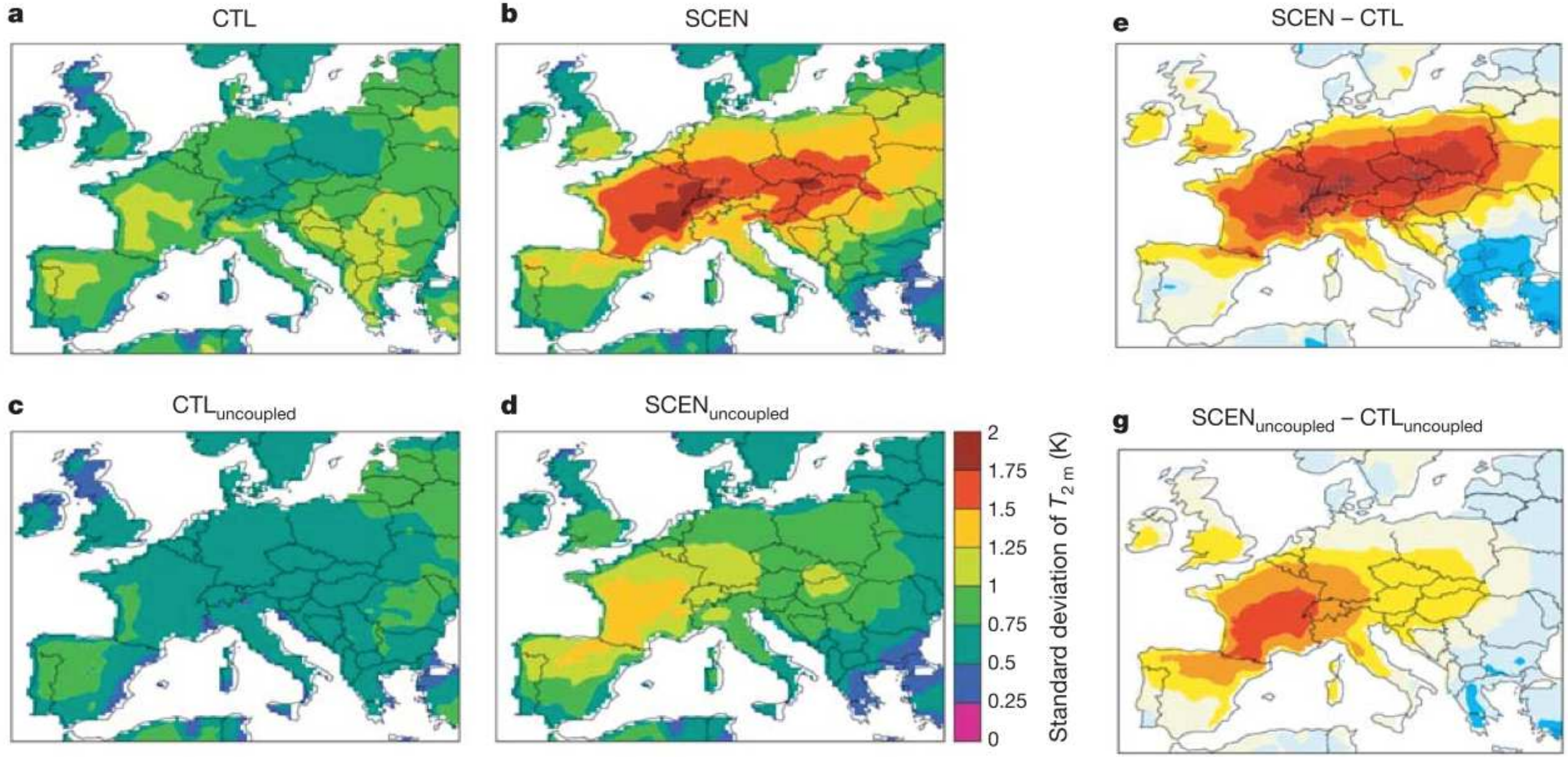
Why is predicting climate in the Mediterranean a challenging task?

- The Mediterranean sector lies in a transition zone between the arid climate of North Africa and the wet climate of central Europe. Its climate is influenced by interactions between midlatitude and tropical processes (Raicich et al. 2003; Giorgi and Lionello 2008).

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

- Part of the predictability in the Mediterranean is due to land surface conditions (van der Hurk et al., 2012), which are known to be hardly measured, therefore initialization has to rely on forced land models, that are often imperfectly represented by climate models.

Land-atmosphere coupling



Standard deviation of 2-meter temperature

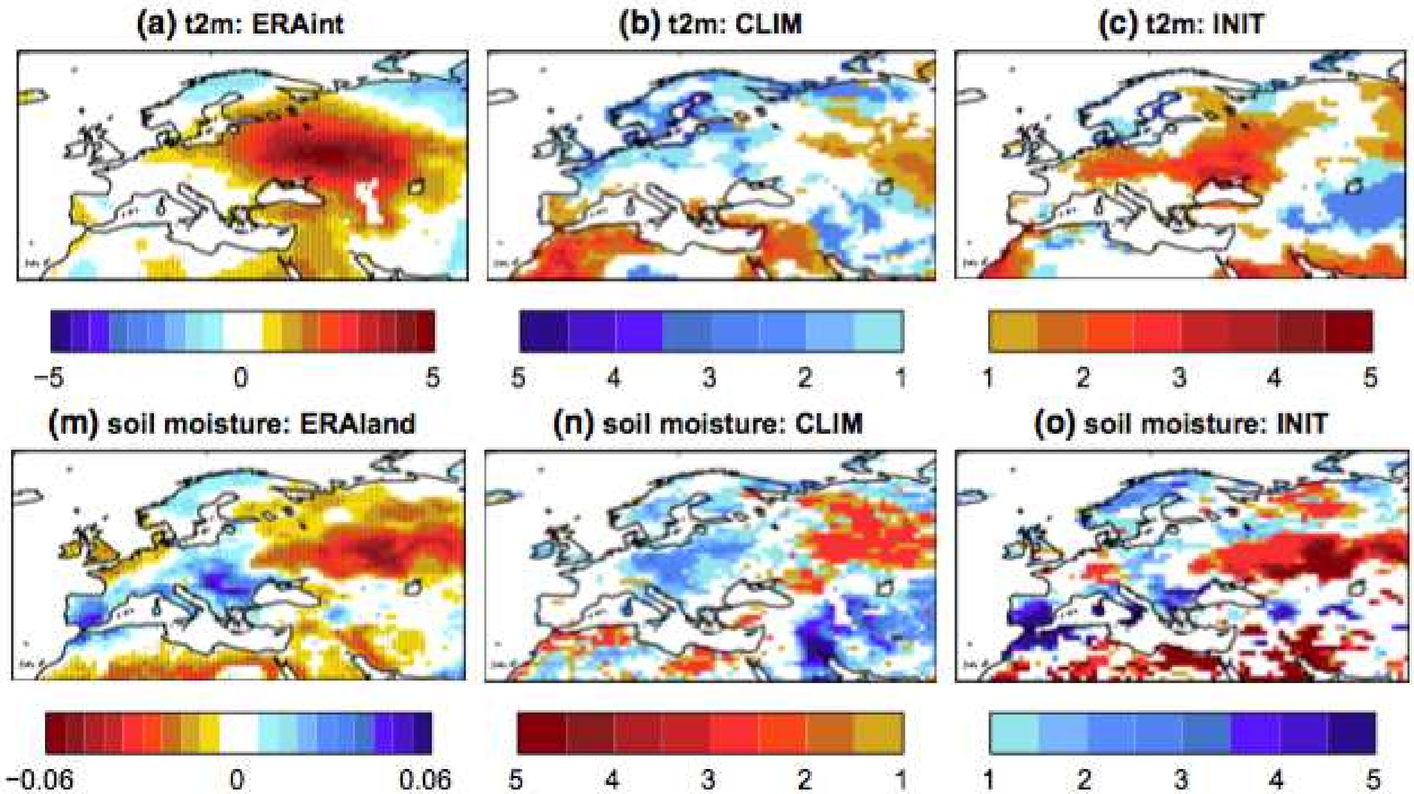
Seneviratne et al., 2006

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?

Anomalies development and persistence may be affected by local initial state of land variables

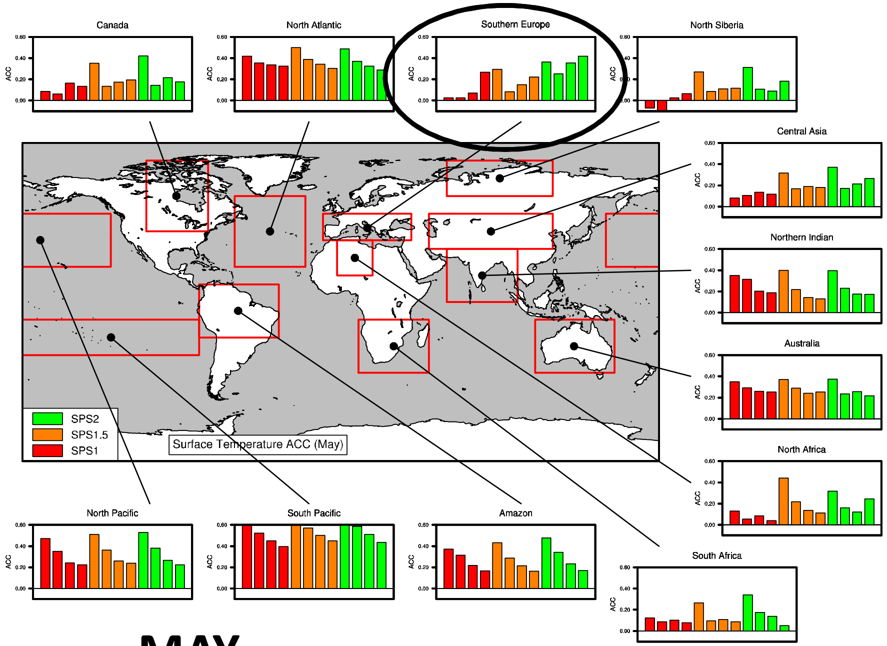
Anomalous initial state of local soil wetness, which may influence the future rainfall and temperature anomalies through the contribution of (a) land memory and (b) feedback mechanisms initiated by the land-atmosphere coupling



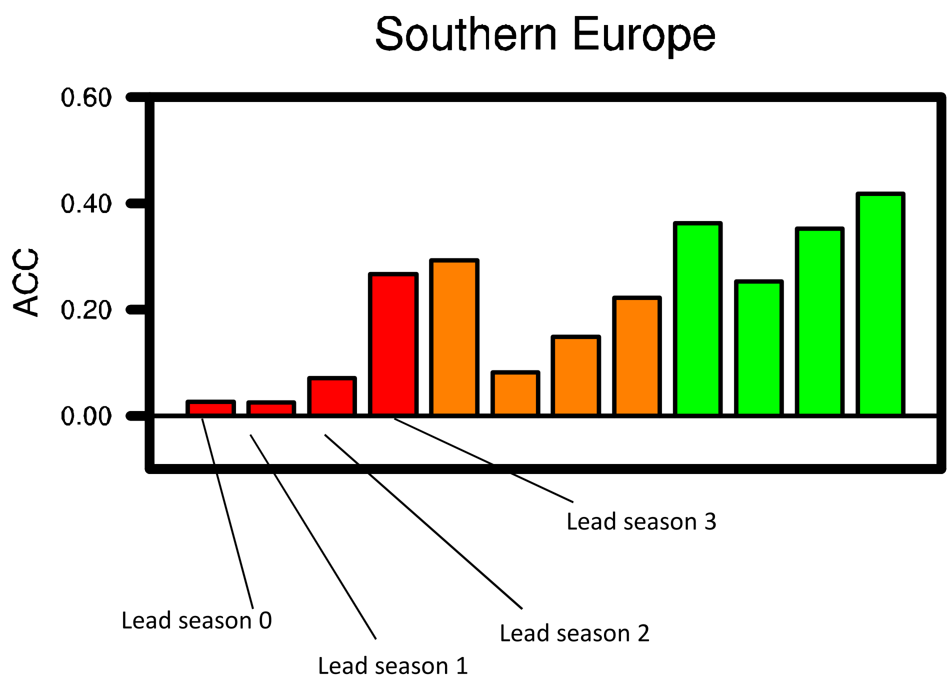
Prediction of the 2010 drought in Eastern Europe is impossible, for dynamical seasonal forecast, when the land component is NOT initialized (CLIM experiment). When it is (INIT experiment) prediction of both t2m and soil moisture are accurate compared to OBS (left panel).

Prodhomme et al. 2015

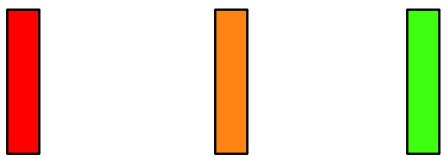
The importance of land surface initialization



MAY



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



initiaized component **O** **OA** **OAL**

A possible new metric for seasonal forecast in the Mediterranean

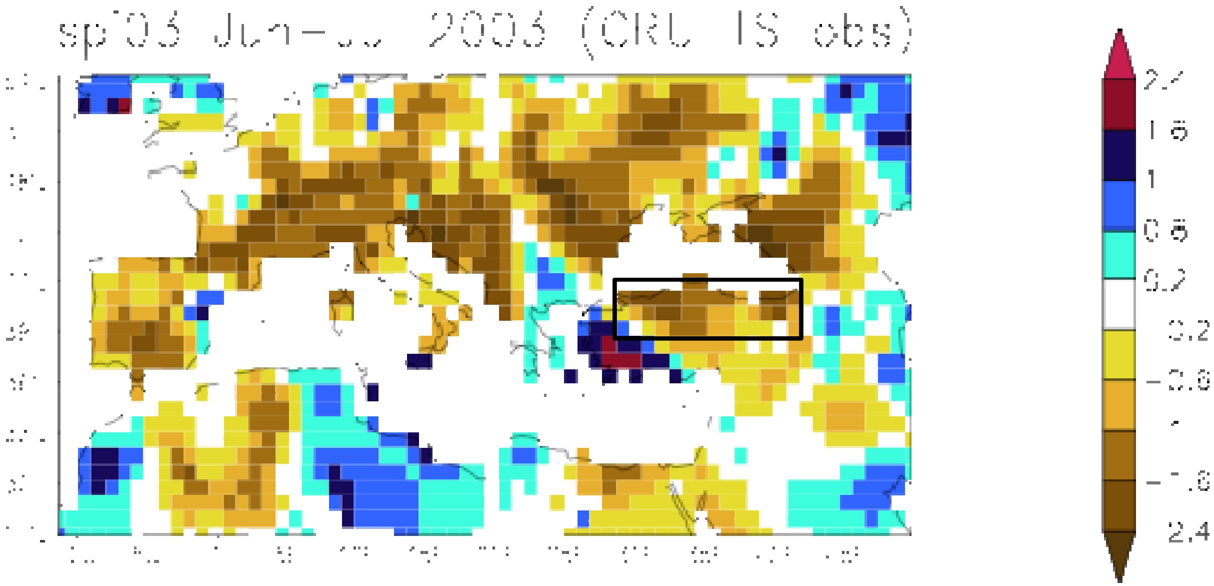
Many economic sectors (tourism, agriculture, energy, transport, industry) would benefit from the added value provided by seasonal forecasts, because this information could be spent to set up short-term mitigation and adaptation plans.

Often, this information cannot be use because of lack of simplicity

A possible new metric for seasonal forecast in the Mediterranean

Many economic sectors (tourism, agriculture, energy, transport, industry) would benefit from the added value provided by seasonal forecasts, because this information could be spent to set up short-term mitigation and adaptation plans.

In summer 2003, a brief but very intense drought hit the Black Sea region, so that the harvest needed to be anticipated and a large loss in productivity was estimated (Ustaoglu, 2012)



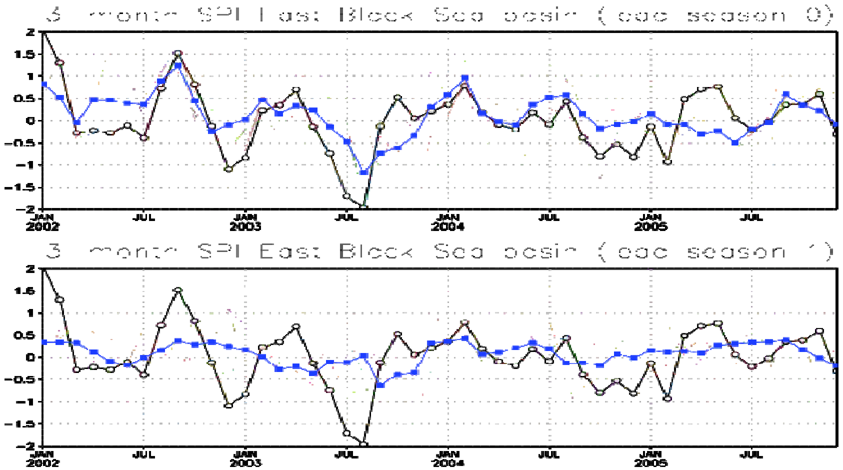
A multimodel approach

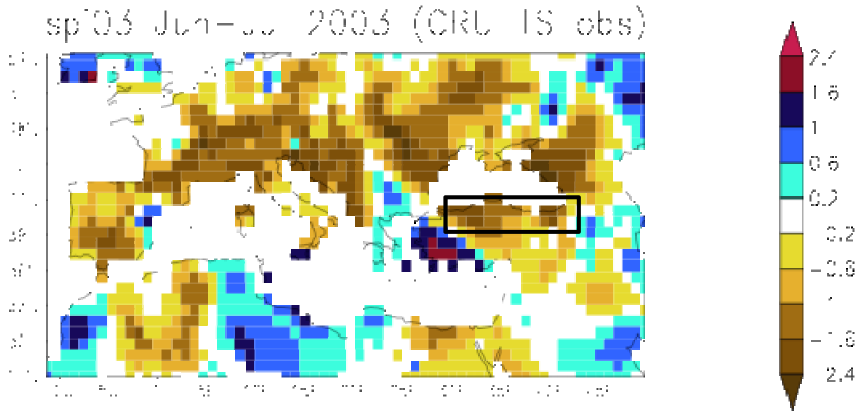
	Institution	Resolution	Ens size	ReForecast Period
CMCC-SPSv2	CMCC	T63L19	9	1981-2010
CFSv2	NCEP	T126	12*	1984-2009

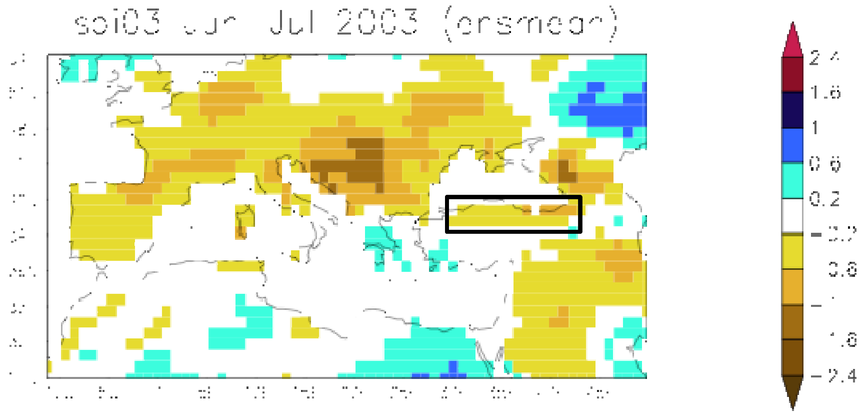
We will perform seasonal forecast of SPI index and see whether our Multi-Model is able to give an early warning of this extreme event, and how long before it is able to provide a useful warning.

* CFSv2 reforecast have 24 ensemble members, we only used the four members from the first, the four from the second and the four from the third forecast day of the month, in order for our lead time 0 to be minimally influenced by the already observed data.

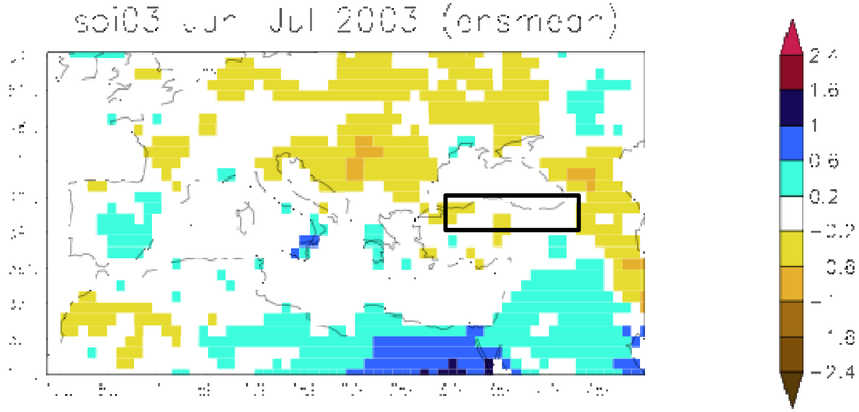
Seasonal forecast of 3-month SPI





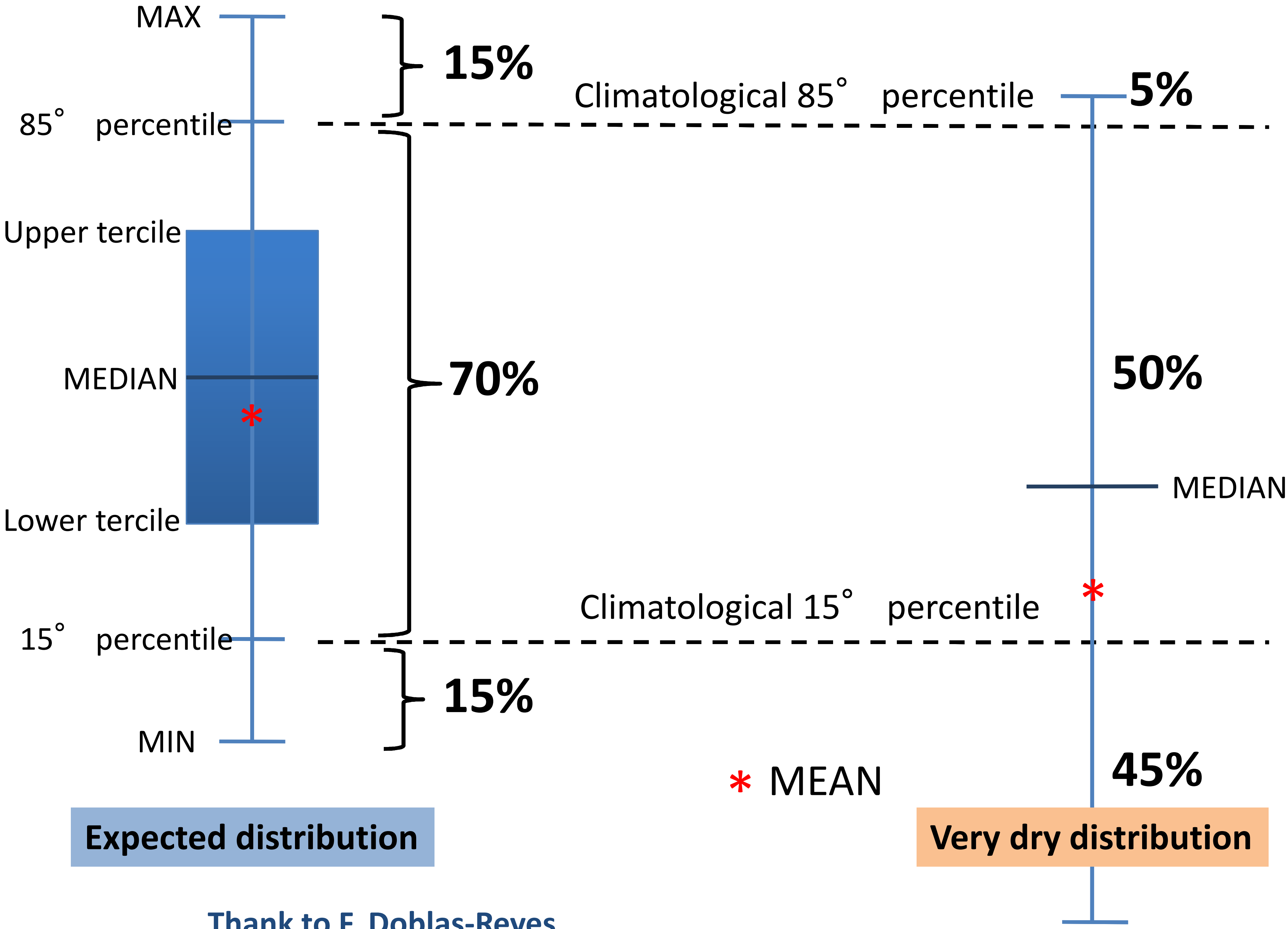


Lead 0 (June start date)



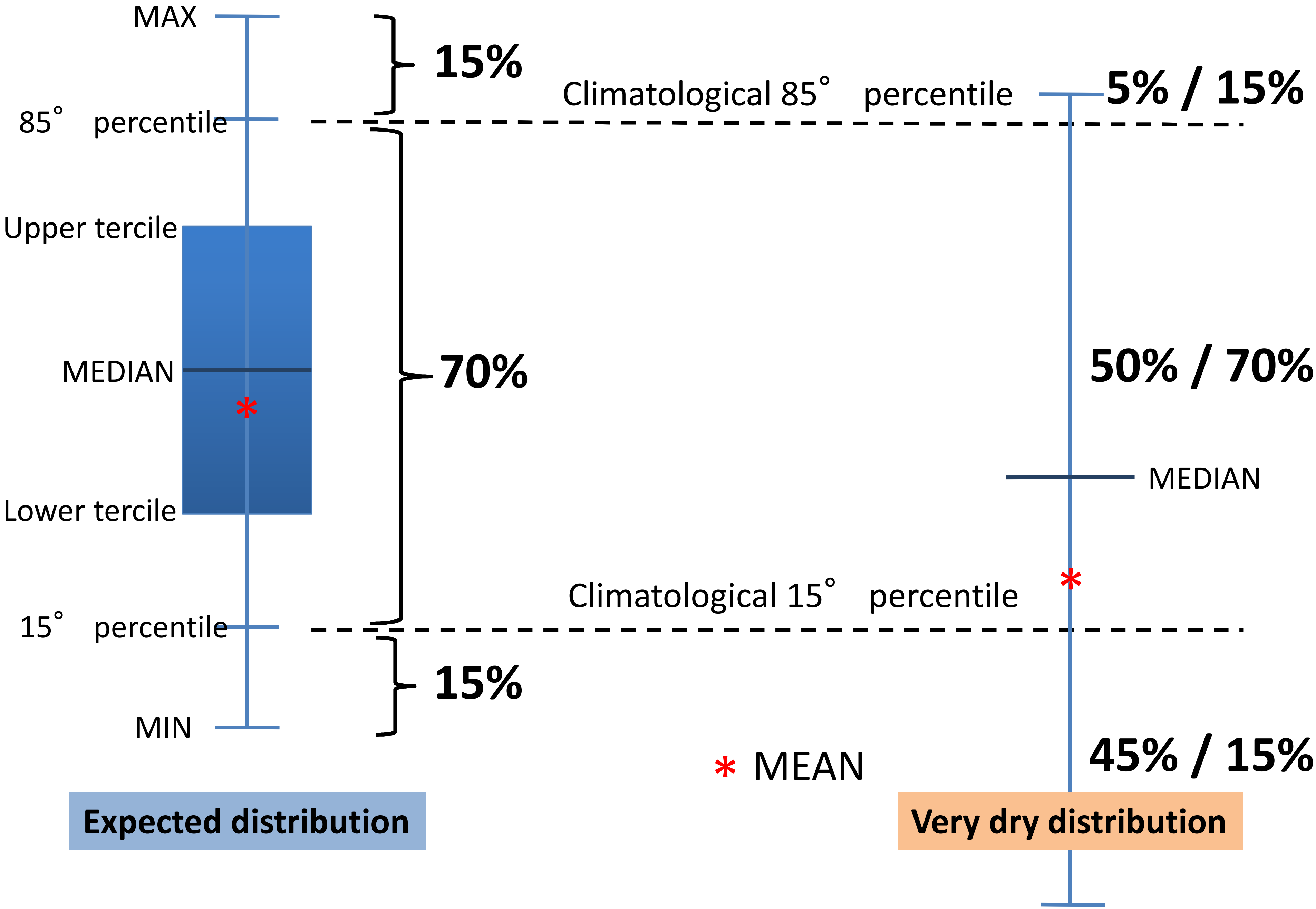
Lead 1 (May start date)

ODDS RATIO

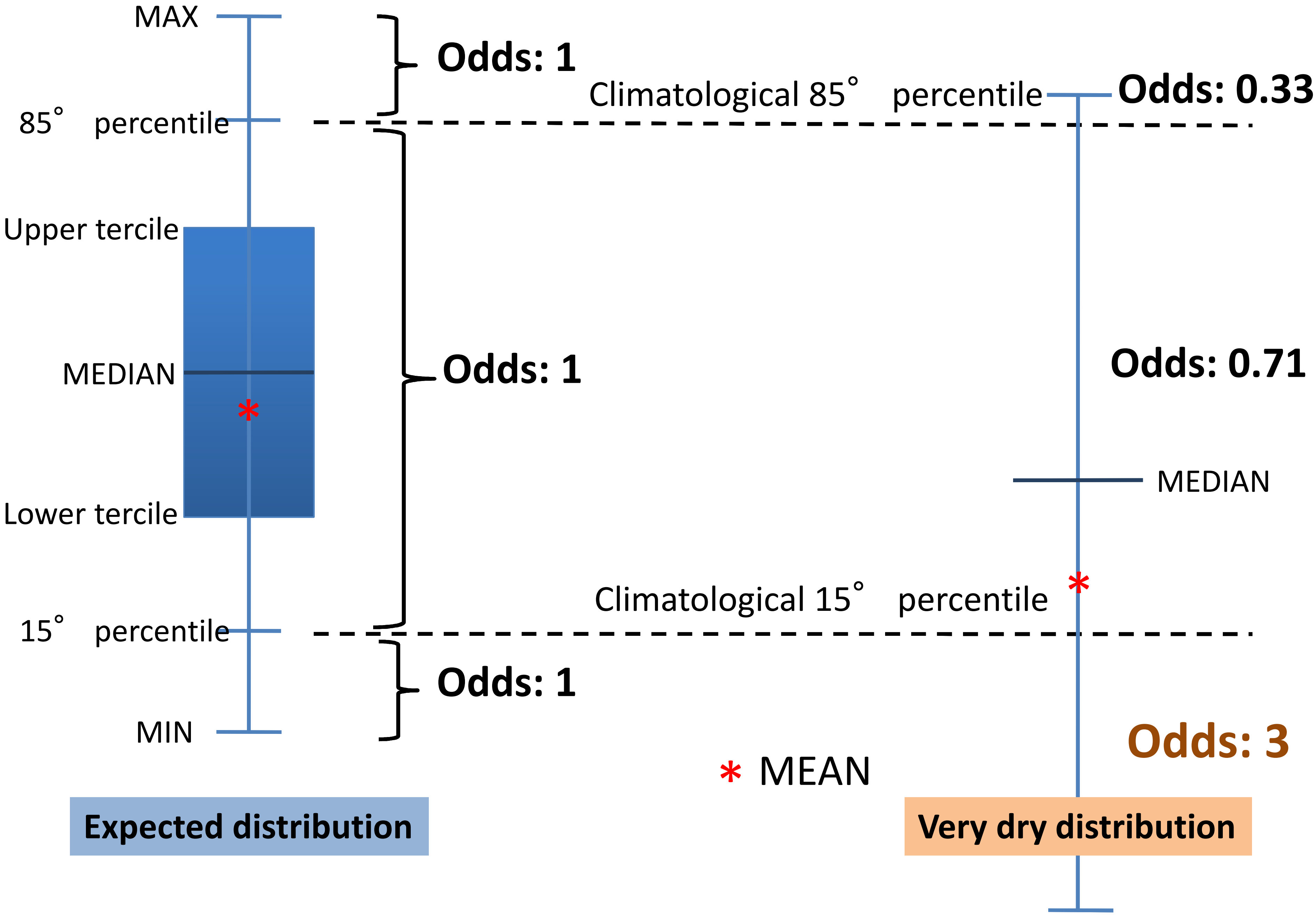


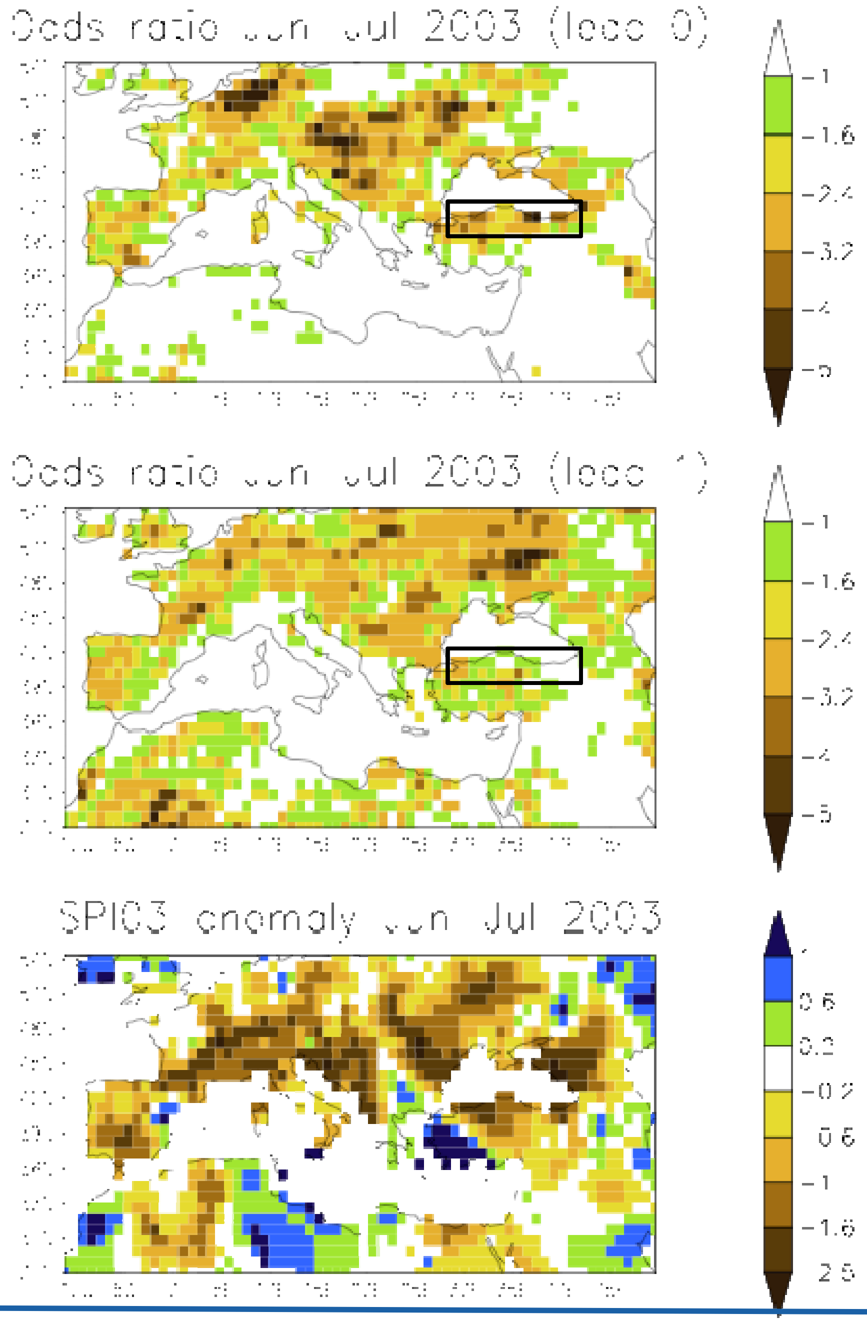
Thank to F. Doblas-Reyes

ODDS RATIO


MAX
85° percentile
Upper tercile
MEDIAN
Lower tercile
15° percentile
MIN
15%
70%
15%
Climatological 85° percentile
Climatological 15° percentile
5% / 15%
50% / 70%
MEDIAN
45% / 15%
* MEAN
Expected distribution
Very dry distribution

ODDS RATIO


MAX
85° percentile
Upper tercile
MEDIAN
Lower tercile
15° percentile
MIN
Odds: 1
Odds: 1
Odds: 1
Climatological 85° percentile
Odds: 0.33
Odds: 0.71
MEDIAN
Climatological 15° percentile
Odds: 3
* MEAN
Expected distribution
Very dry distribution



A possible new metric for seasonal forecast in the Mediterranean

In the prediction started in June, high values of odds ratio indicate that an hazard is in place: there is a substantial probability of a very extreme event. E.g., absolute values of 4 indicate that 60% of our ensemble members are predicting an event which is expected only 15 times out of 100.

In the prediction started in May, instead, no early warning is signalled by the Multi-Model. Absolute values lower than 2 may not be taken as a reliable call for a future hazard

cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici

Thanks

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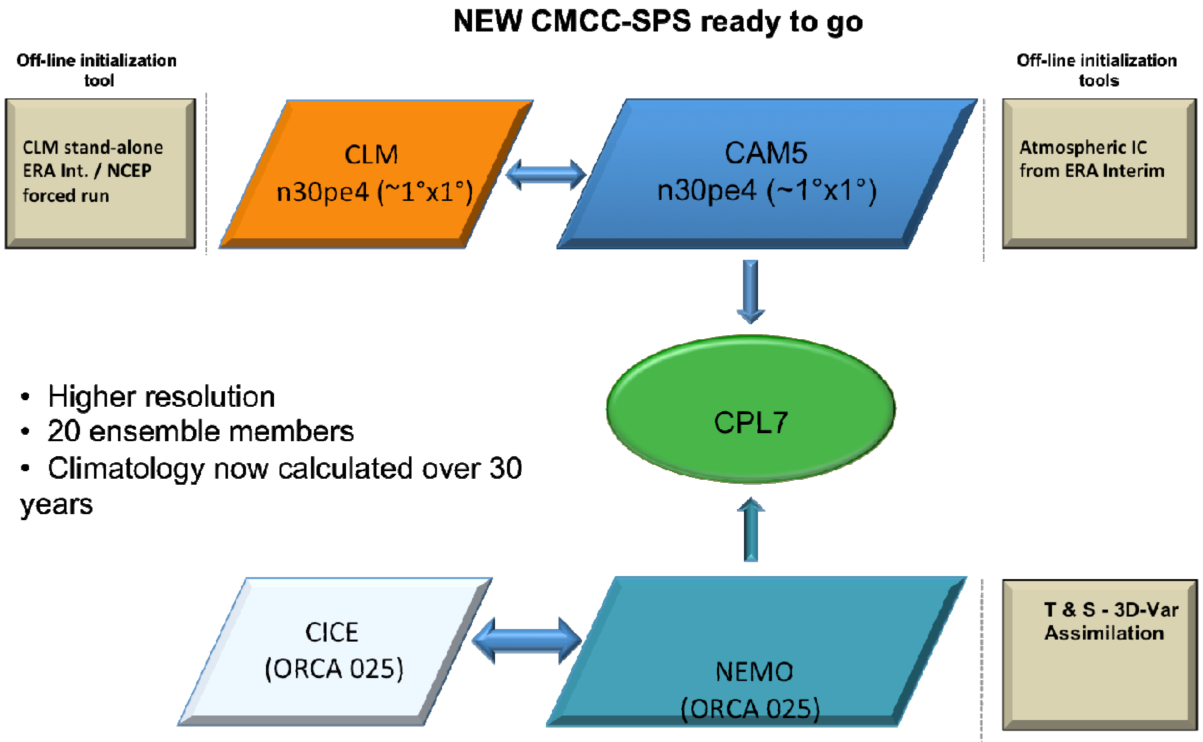
Centro Euro-Mediterraneo sui Cambiamenti Climatici

The new seasonal prediction system: CMCC-SPS.v3



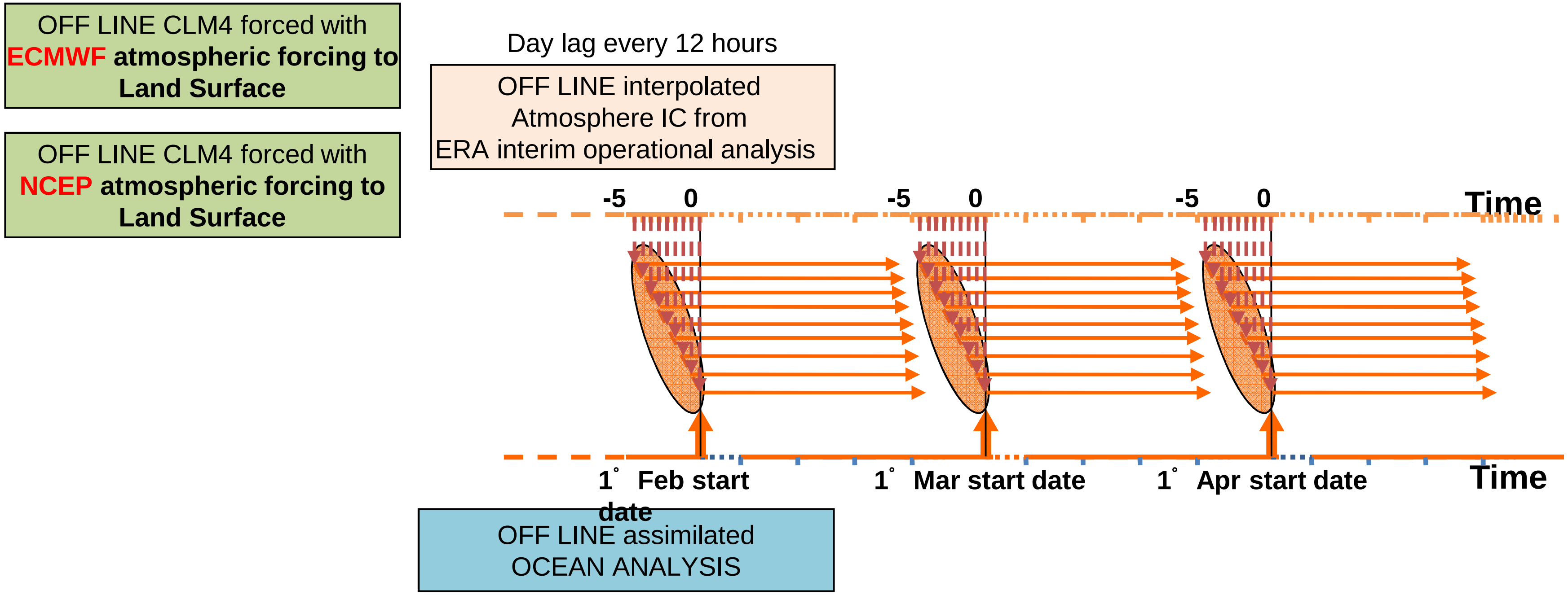
Main novelties with respect to the previous seasonal prediction system:

- 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)

Initialization strategy



- 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