The CMCC contribution to WP3

The decadal horizon;

benefiting from realistic initialization.

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CMCC Centro Euro-Mediterraneo sui Cambiamenti Climatici | 20 Years

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Principal Scientist.

Head of the Earth System Modelling and Data Assimilation division.

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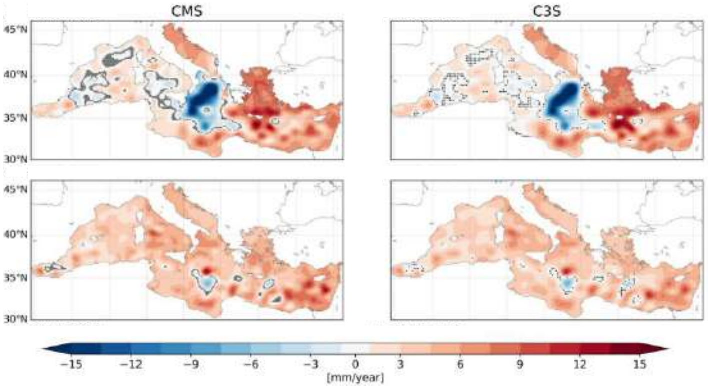
In CMCC leads the production of decadal predictions.

Role in RIVIERADE:
WP3 scientist

Examples of decadal variability and trends in the MED.

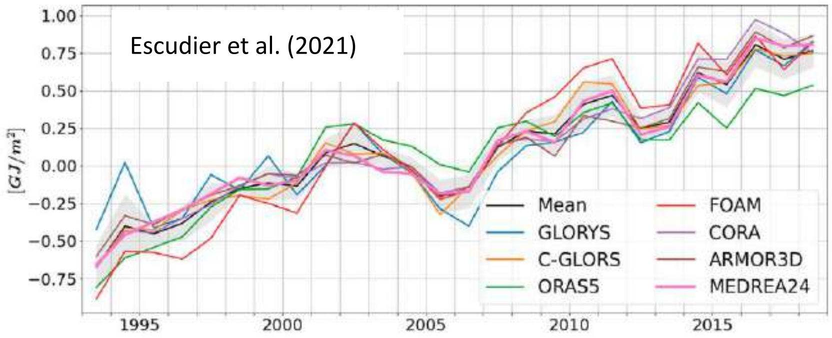
1993–2002

2003–2012

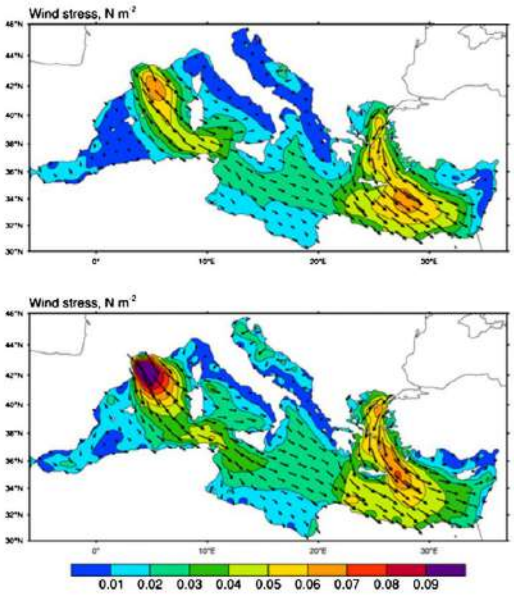


Sea level trends from CMS and C3S.

Borile et al. (2025)



Area averaged OHC_{700} anomaly in the Mediterranean Sea.



1987–1996

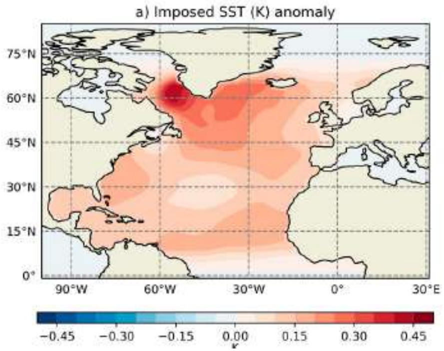
1997–2006

Wind stress amplitude and direction averages.

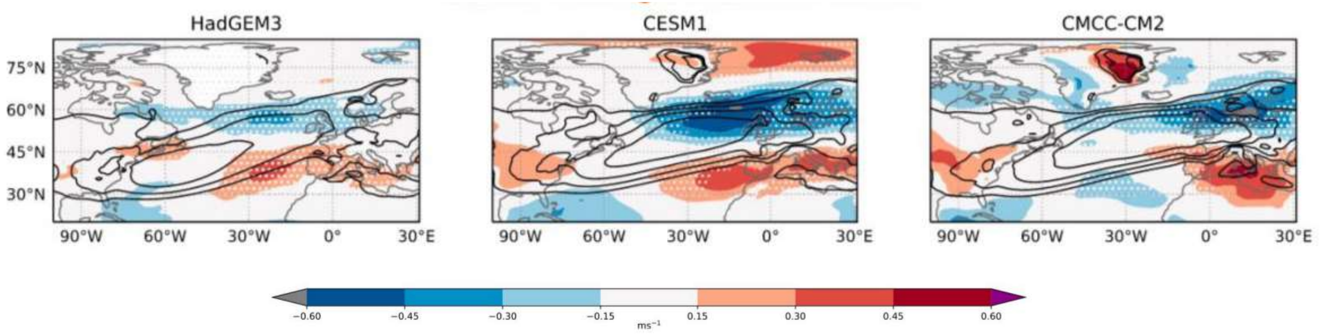
Pinardi et al. (2015)

The AMV affects winds over the MED and BAL

Models with significant skill for the NAO in decadal hindcasts exhibited an equatorward jet shift in response to AMV+



AMV anomaly imposed in the DCPP-C experiments.



850 hPa zonal winds

Ruggieri et al., 2020

AMV and NAO exhibit significant decadal predictability

npj | Climate and Atmospheric Science

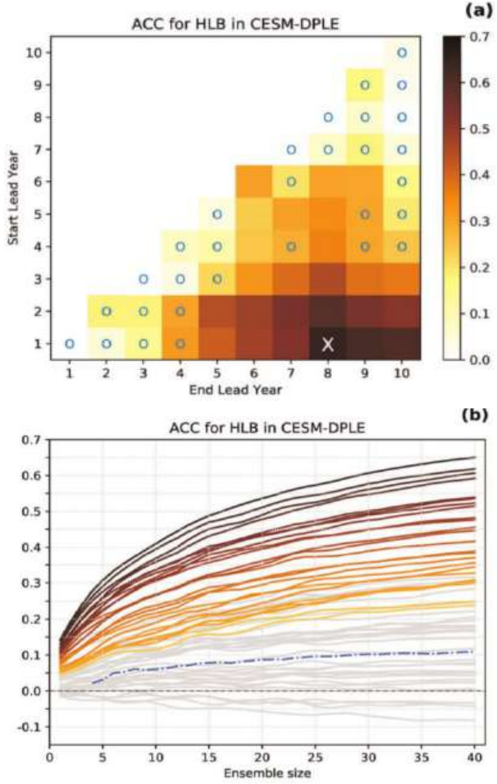
ARTICLE OPEN

Decadal predictability of North Atlantic blocking and the NAO

Panos J. Athanasiadis[1✉], Stephen Yeager[2], Young-Oh Kwon[3], Alessio Bellucci[1], David W. Smith[4] and Stefano Tibaldi[1]

Can multi-annual variations in the frequency of North Atlantic atmospheric blocking and mid-latitude circulation regimes be skilfully predicted? Recent advances in seasonal forecasting have shown that mid-latitude climate variability does exhibit significant predictability. However, atmospheric predictability has generally been found to be quite limited on multi-annual timescales. New decadal prediction experiments from NCAR are found to exhibit remarkable skill in reproducing the observed multi-annual variations of wintertime blocking frequency over the North Atlantic and of the North Atlantic Oscillation (NAO) itself. This is partly due to the large ensemble size that allows the predictable component of the atmospheric variability to emerge from the background chaotic component. The predictable atmospheric anomalies represent a forced response to oceanic low-frequency variability that strongly resembles the Atlantic Multi-decadal Variability (AMV), correctly reproduced in the decadal hindcasts thanks to realistic ocean initialization and ocean dynamics. The occurrence of blocking in certain areas of the Euro-Atlantic domain determines the concurrent circulation regime and the phase of known teleconnections, such as the NAO, consequently affecting the stormtrack and the frequency and intensity of extreme weather events. Therefore, skilfully predicting the decadal fluctuations of blocking frequency and the NAO may be used in statistical predictions of near-term climate anomalies, and it provides a strong indication that impactful climate anomalies may also be predictable with improved dynamical models.

npj Climate and Atmospheric Science (2020)3:20 ; https://doi.org/10.1038/s41612-020-0120-6

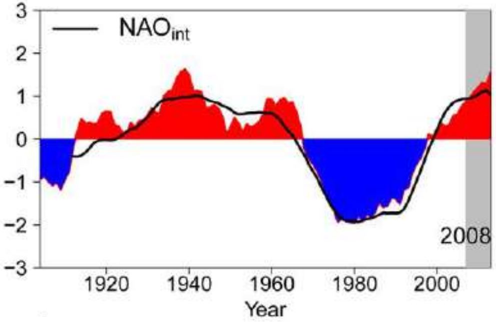


(a) The predictive skill for the CESM-DPLE ensemble-mean measured by the anomaly correlation coefficient (ACC) for high-latitude blocking (HLB). Each cell below the diagonal corresponds to a different lead-year range defined by the start lead-year (ordinate) and the end lead-year (abscissa). The cyan markers (o) indicate not statistically significant correlations, while the X marker indicates the lead-year range with the highest ACC (0.65 for HLB). **(b)** The respective skill is computed as a function of the ensemble size (averaged for all possible member combinations). Each line corresponds to a different lead-year range. The dashed-dotted line shows the skill of the sub-ensemble mean against a single member of the ensemble (averaged for all possible combinations).

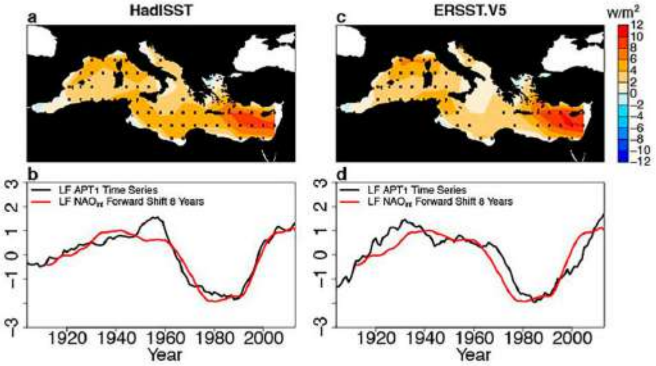
Athanasiadis et al., 2020

Predictable remote drivers determine low-frequency variability in the MED

Correlation between HadISST and NAOI.
Marullo et al. (2011)



Yan & Tang (2021)

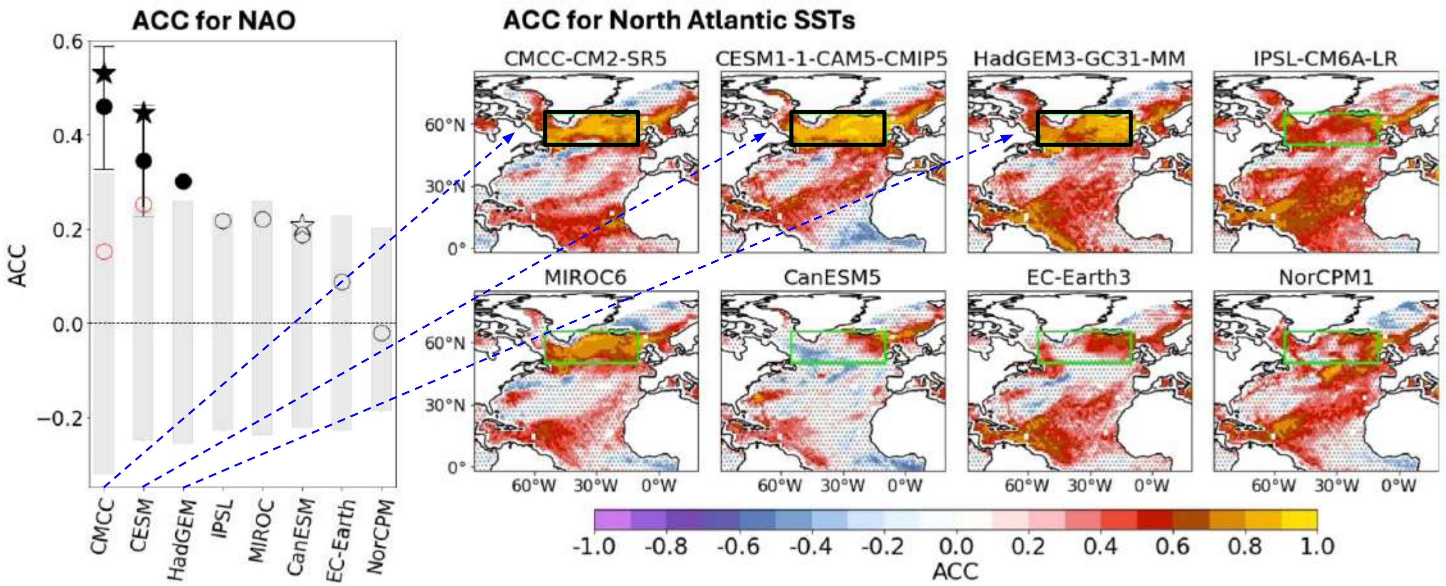


Yan et al. (2023)

(LEFT) Normalized 10-year running mean of SSTA in the eastern Mediterranean Sea in winter (shading) and the NAOint (shifted forward by 8 years to account for the lagged relationship).

(RIGHT) Relationships between the decadal predictability of SST in MED and the net surface heat flux and cumulative impacts of NAO. (a) The regression pattern of the net surface heat flux (unit: Wm^2) against the time series associated with the most predictable pattern calculated based on the HadISST dataset. (b) 10-yr running mean of the time series associated with the most predictable pattern (black) calculated based on the HadISST dataset, in comparison with the 8-yr forward-shifted 10-yr running mean of the NAOint index (red). (c),(d) As in (a) and (b), respectively, but based on the ERSST.v5 dataset.

The CMCC decadal prediction system excels in predicting the NAO



Patrizio et al. (2025)

"Ocean- atmosphere feedbacks key to NAO decadal predictability"

npj Clim Atmos Sci, https://doi.org/10.1038/s41612-025-01027-7

The CMCC Decadal Prediction System

	DPS.v2 2020, CMIP6
Ocean	NEMO v3.6 1° x 1° – 50 levs
Atmosphere	CAM5 1° x 1° – 30 levs no stratosph.
Land	CLM4.5 + River routing scheme
Ensemble size (start dates)	40 (every year, 1960–2023)
Initial Conditions	Ocean (CMCC) Atmosphere (ECMWF) Land surface (ECMWF-CMCC)

	Data source	No. of initial conditions (ICs)	Procedures
Land	Land-only analyses forced by two different atmospheric datasets, namely CRUNCEPv7 (Viovy, 2016) and GSWP3 (Kim, 2017). Note that, from 2015 onwards, the atmospheric fluxes to force the land-only analysis are taken from the National Centers for Environmental Prediction (NCEP) reanalysis (instead of CRUNCEPv7) and from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 (instead of GSWP3)	Two ICs (two runs forced by two different datasets, providing instantaneous 2 m air temperature and humidity, 10 m winds, and surface pressure every 6 h, as well as accumulated radiation and precipitation every 3 h)	Direct interpolation on target grid from land restarts
Atmosphere	ERA40 (Uppala et al., 2005) for 1960–1978 start dates, ERA-Interim (Berrisford et al., 2011) for 1979–2018 start dates, and ERA5 (Hersbach et al., 2020) from 2019 onwards	Two ICs (derived from time-lagging perturbations, using 1 and 2 November)	Direct interpolation on a target grid from the atmospheric 3D state of temperature, specific humidity, and horizontal wind components
Ocean	CHOR (Yang et al., 2016) for 1960–2010 start dates and CGLORSv7 (Storto and Masina, 2016) for 2011–present start dates	Five ICs (from three realizations of the global ocean/sea ice reanalysis and two ICs from linear combinations of the former three ICs)	Direct interpolation on target grid from 3D state of temperature, salinity, and horizontal components of the ocean currents
Sea ice			Direct interpolation on target grid of sea ice temperature, sea ice volume, sea ice area, and snow volume

Nicolì et al., 2023

The CMCC work-plan in WP3

CMCC plans to **assess the added-value of initialization and that of dynamical downscaling** in simulating marine extremes and low-frequency variations in the Mediterranean Sea and the Black Sea through the use of an ensemble of decadal re-forecasts contributed to DCPP and used currently in the C3S decadal operational service (C3S2_375 contract).

For this CMCC willl employ a **regional configuration of NEMO[1] at 1/16° resolution** and will run this model with lateral and surface boundary conditions provided by the global decadal predictions (ocean-only dynamical downscaling).

This exercise will be repeated running **an ensemble of simulations for a number of start-dates** —regularly spaced in the post-1960 historical period— so as to allow for an assessment of both the realism of the extremes and the predictive skill of low-frequency variations in the Med & Black Seas against observations & ocean reanalyses.

The rationale of this work lays in the fact that without using decadal predictions (e.g., when combining uninitialized historical simulations and projections with dynamical downscaling for the marine environment) key regional marine variability stemming from predictable components of the internal variability of the climate system are completely missed.

After the added value of initialization and downscaling is demonstrated, the natural extension of these retrospective downscaled regional marine forecasts will be to run respective **real-time forecasts**, an exercise that we commit to conduct in the second half of the project.

1: Similar to the one used by the CMCC regional forecasting systems, currently running at 1/24° for the needs of the Copernicus Marine Service.

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