Impacts of climatic oscillations on Mediterranean hydrology

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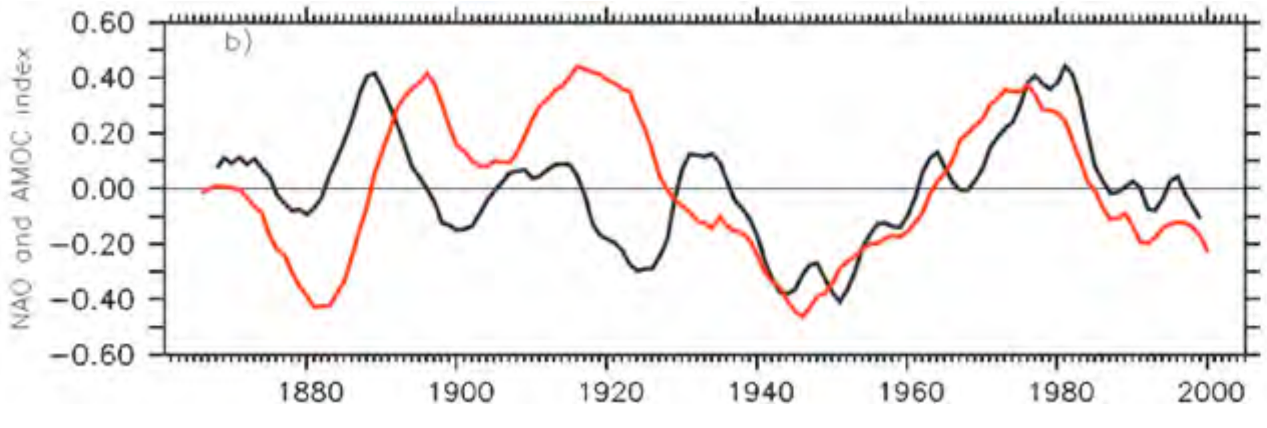
Atlantic Meridional Overturning Circulation (*AMOC*)

- Global warming is expected to weaken the *AMOC* due to melting of Greenland ice cap [*Cheng et al., 2013*; *Rahmstorf et al., 2015*]
- A slowing down of the *AMOC* would alter the **course** and **amplitude** of the Gulfstream and, hence, the path of Atlantic storm tracks [*Joyce and Zhang, 2010]*



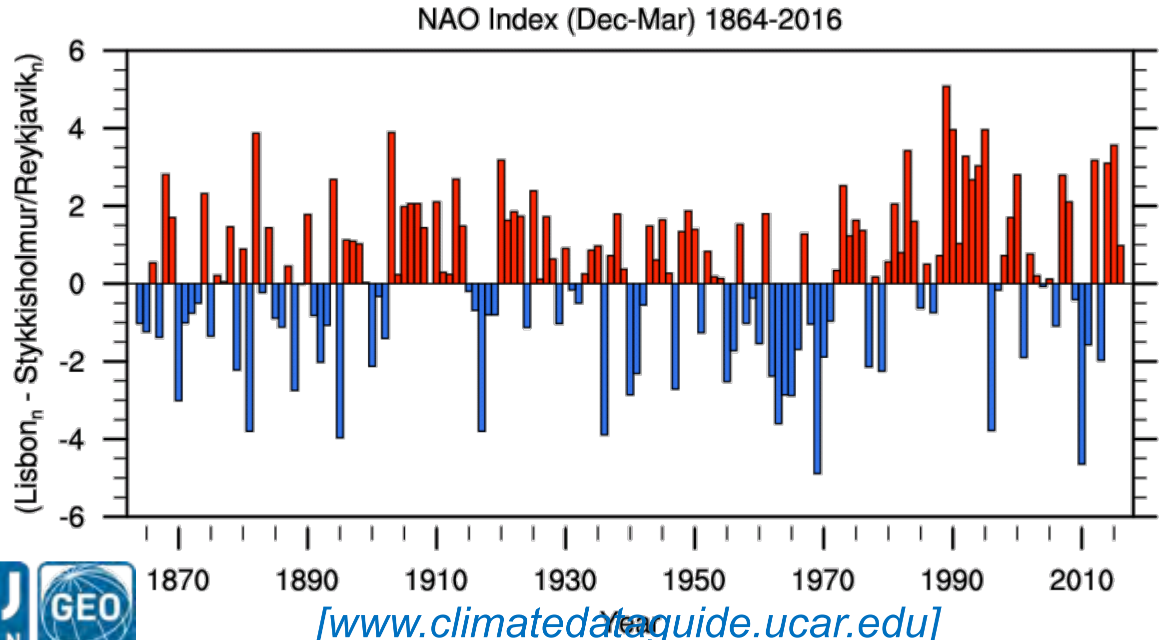
red: *NAO*, **black**: *AMOC*

[Cheng et al., 2013]

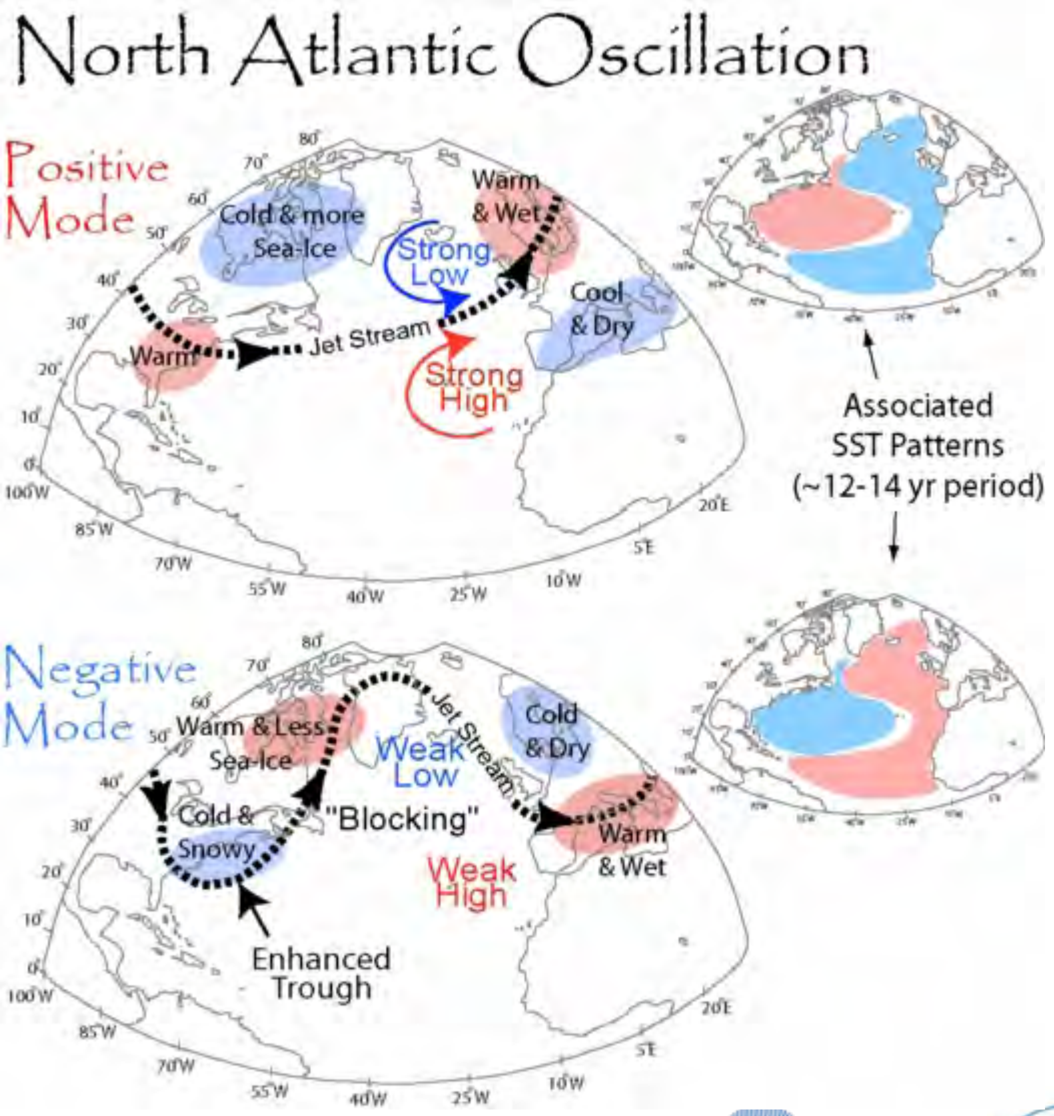
Climate modes as drivers of climate variability

North **A**tlantic **O**scillation is one of the main drivers of Mediterranean climate variability

- *NAO* index is based on the difference of normalized sea level pressure (*SLP*) between Lisbon, Portugal and Stykkisholmur/Reykjavik, Iceland

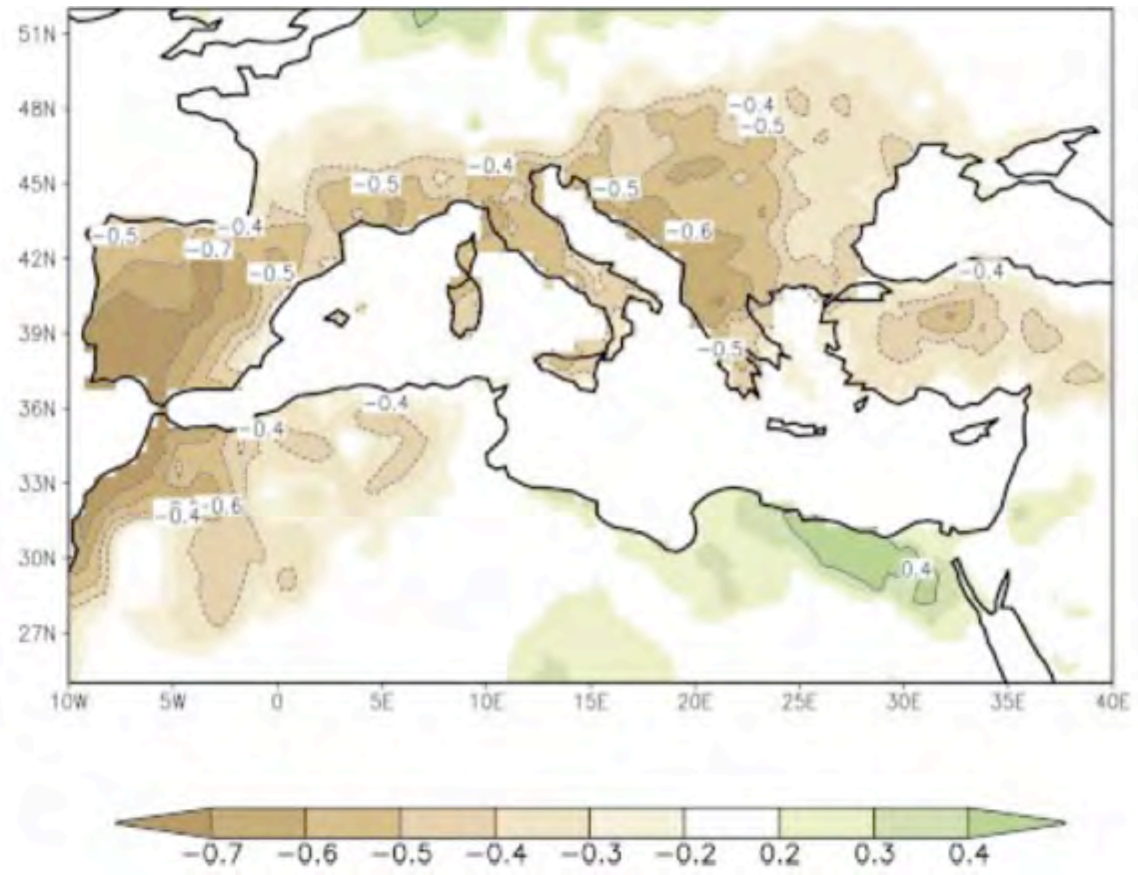


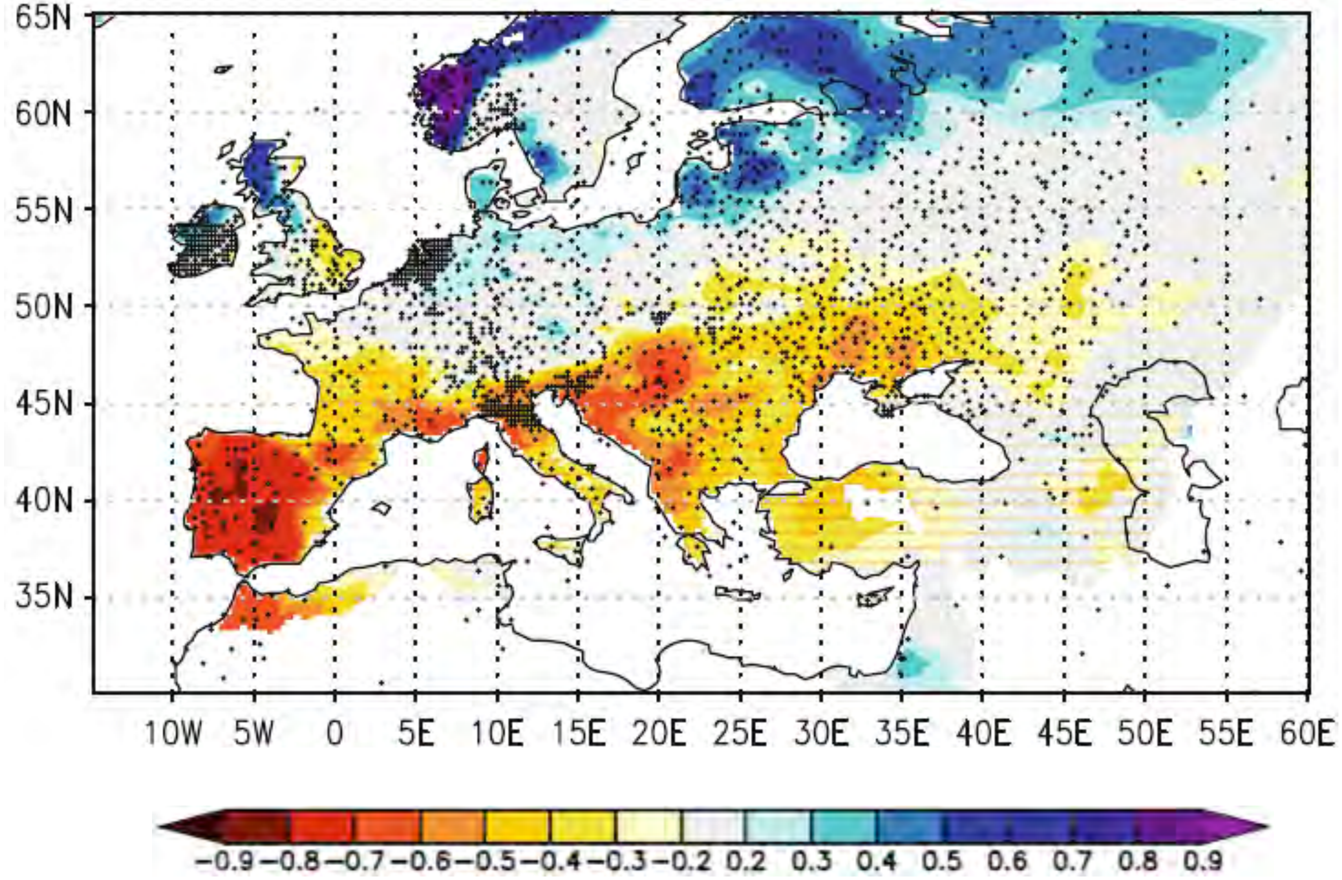
[www.climatedataguide.ucar.edu]



[www.newx-forecasts.com]

Clear link between NAO and gauge-based precipitation





Correlation between *CRU* precipitation and *NAO* for the winter season (1949-1996)

[Mariotti et al., 2001]

Correlation between the winter *NAO* index and E-OBS precipitation (1950-2010)

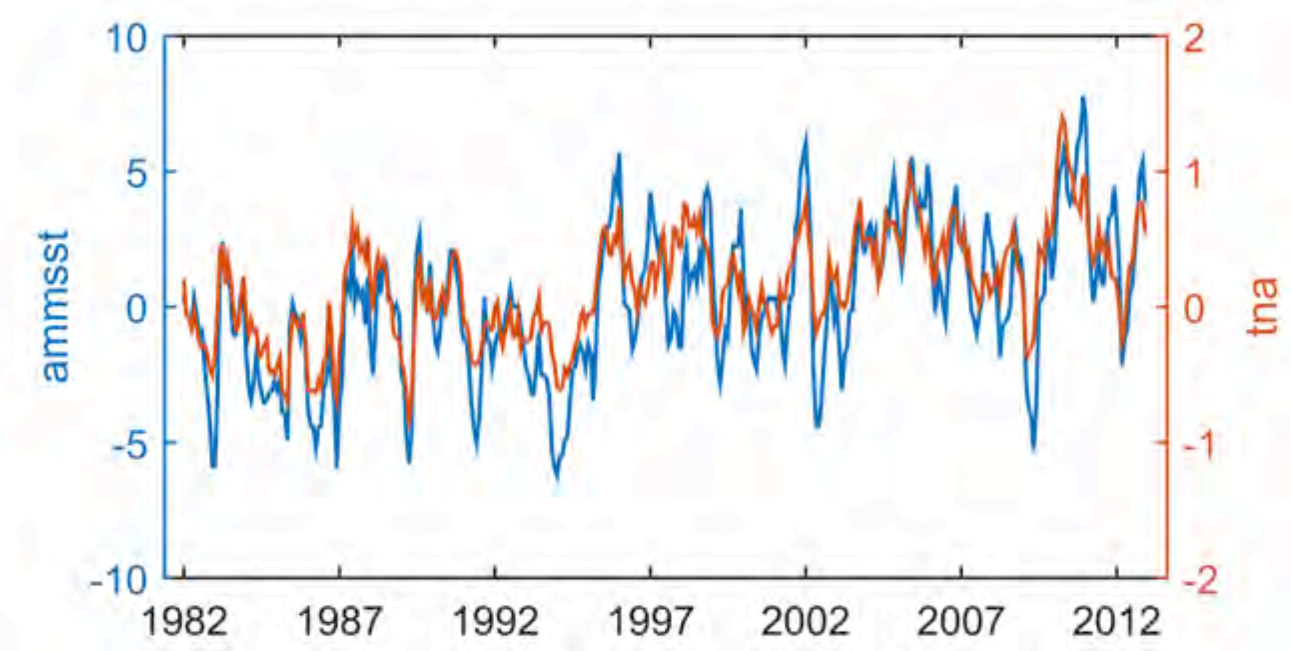
[Bladé et al., 2011]

Study objective

Can our understanding of climate mode impacts on precipitation be improved based on satellite observations?

Challenges:

- Can we disentangle the individual impact of co-varying multiple climate modes?
- Uncertainties in the observations
- Climate modes may have impacts at various lags



AMMSST: Atlantic Meriodonal Mode SST
TNA: Tropcial Northern Atlantic

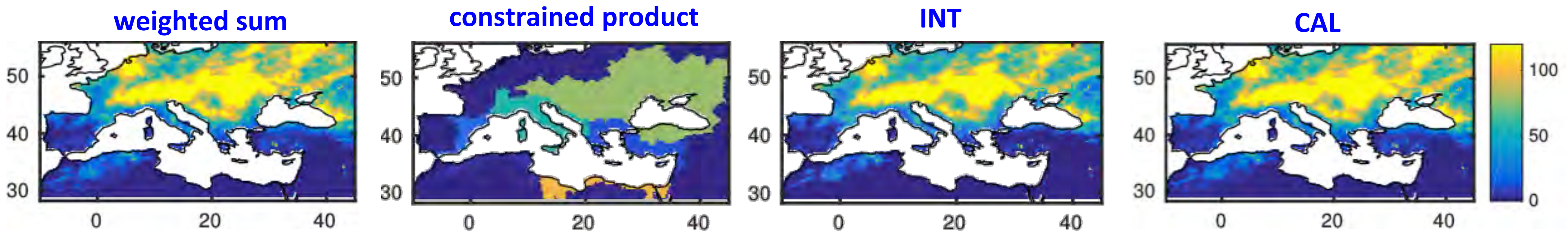
Target variables: WACMOS-MED multiple satellite products

- Provides optimised estimates of water balance terms (P, ET, ΔTerrestrial Water Storage)
- Weighted sum of various precipitation datasets (CMORPH, PERSIANN, GPCP, …)
- Constrained product → closes the water budget at sub-basin scale
- INTegration estimate (limited temporal extent: 2004-2009)
- CALibration estimate (long temporal coverage: 1980-2012)

Advantages:

- minimizes uncertainties
- consistent → better solves the water budget
- long time coverage

temporal resolution: **monthly**
spatial resolution: **0.25°**
detrended anomalies



Predictor variables: Climate Oscillation Indices

Temporal resolution: **monthly**
Considered lag times: **0-5 months**

102 features

CLIMATE OSCILLATION INDICES
Atlantic Meridional Mode (**AMMSST**)
Atlantic Multidecadal Oscillation (**AMO**)
Dipole Mode Index (**DMI**)
East Atlantic (**EA**)
East Atlantic / Western Russia (**EAWR**)
East Pacific-North Pacific (**EPNP**)
Northern Annular Mode (**NAM**)
North Atlantic Oscillation (**NAO**)
Pacific Decadal Oscillation (**PDO**)
Polar / Eurasia (**PEA**)
Pacific / North American Index (**PNA**)
Southern Annular Mode (**SAM**)
Scandinavia (**SCAND**)
Southern Oscillation Index (**SOI**)
Tropical Northern Atlantic (**TNA**)
Tropical Southern Atlantic (**TSA**)
Western Pacific (**WP**)

LASSO - Least Absolute Shrinkage and Selection Operator

- Machine learning regression method

$$\beta = \operatorname{argmin}\left\{\sum_{i=1}^{n}\left(y_i - \beta_0 - \sum_{j=1}^{p}\beta_j x_{ij}\right)^2 + \alpha\sum_{j=1}^{p}|\beta_j|\right\}$$

β … p-dimensional vector with the estimated regression coefficients

n … number of training samples in the dataset

y_i … value of the target variable in sample i

p … number of features

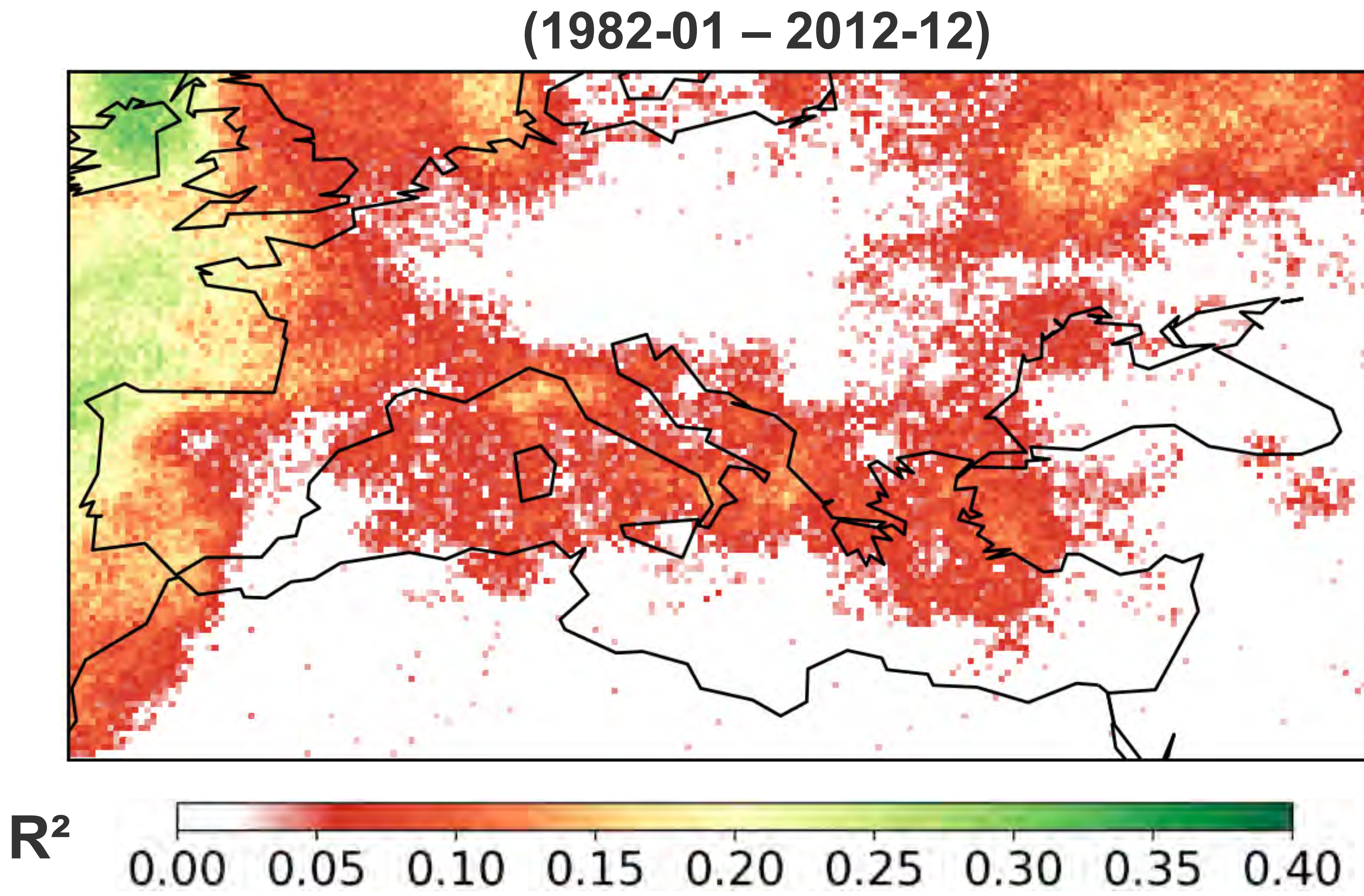
x_{ij} … value of feature j in sample i

$\alpha\sum_{j=1}^{p}|\beta_j|$ … regularization that minimizes the sum of the absolute values of the coefficients

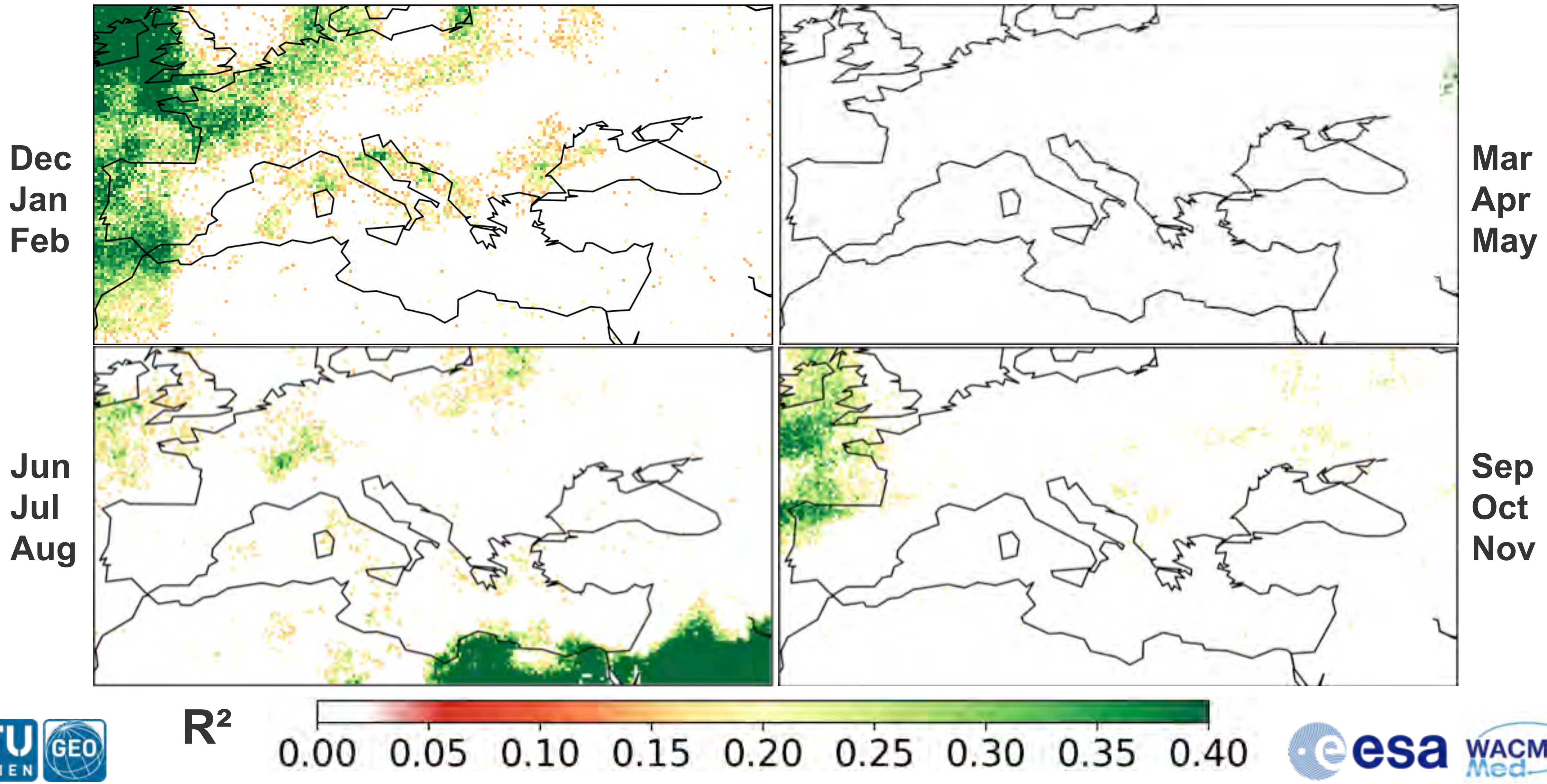
→ prevents overfitting of the model by reducing its complexity

- Nested 5-fold cross validation (CV)
  - 5-fold CV for determination of α
  - 5-fold CV for calculation of **R^2** (= coefficient of determination) between y and y_{pred}
- Significance test

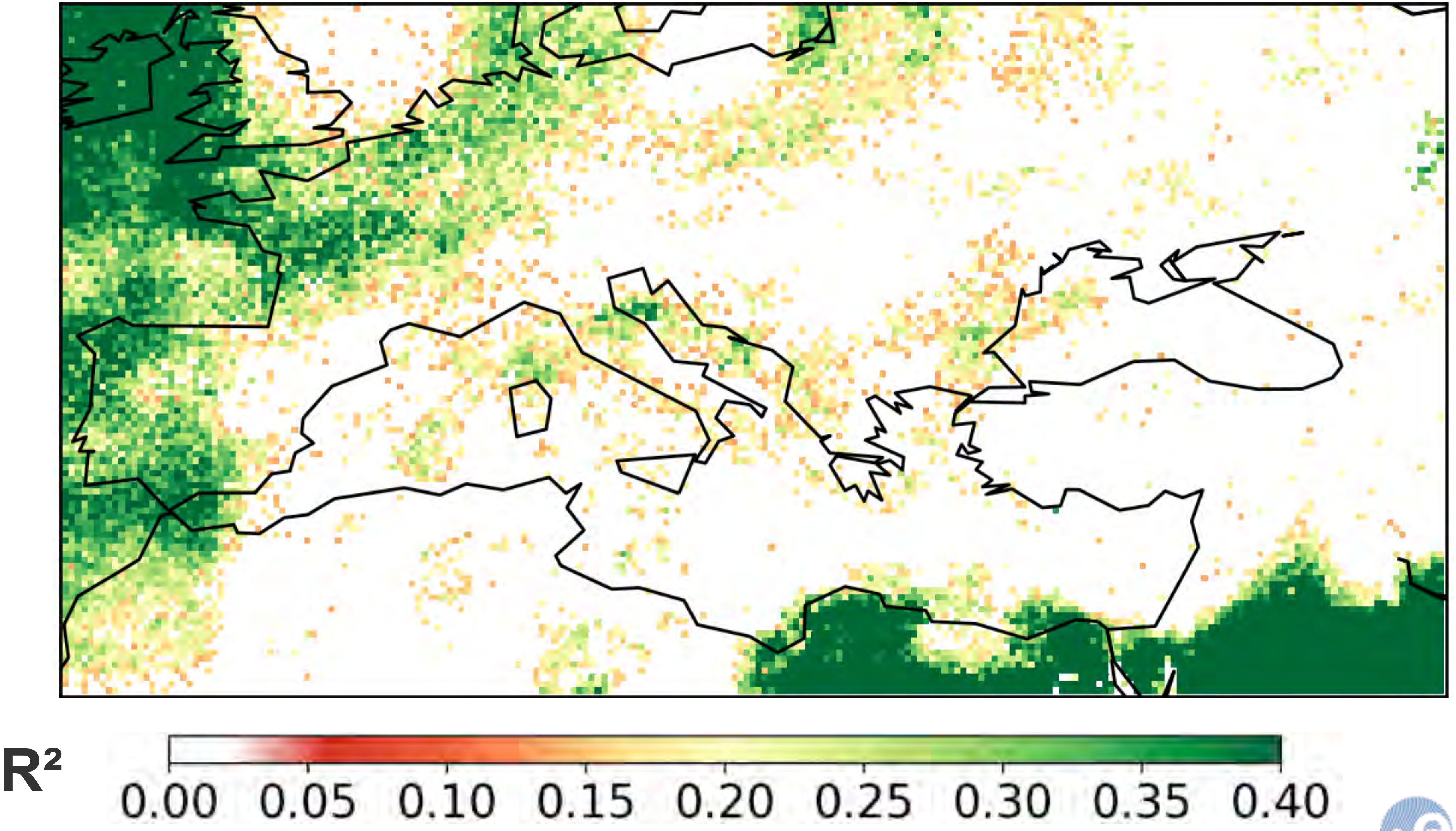
Total explained variance in P anomalies based on all-year data



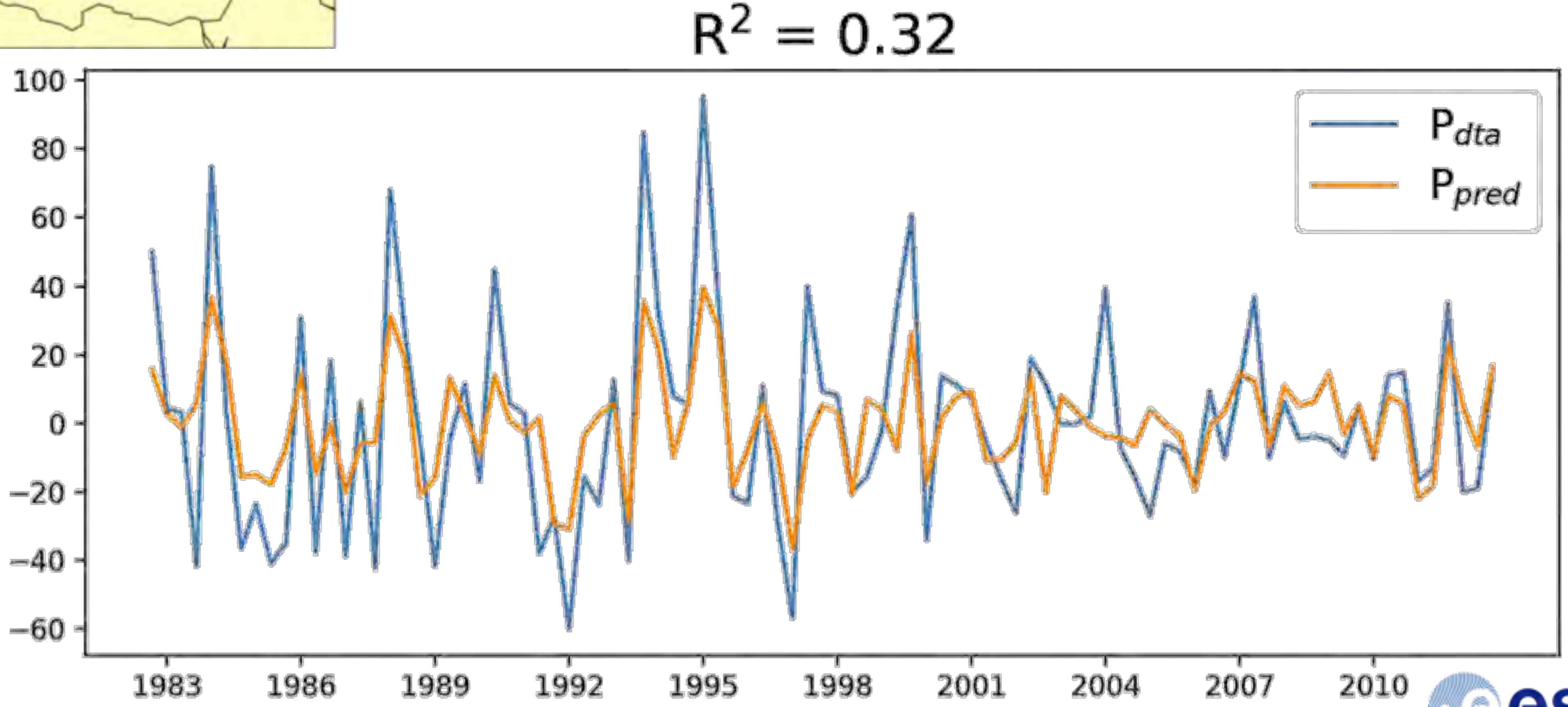
Total explained variance for seasonal models (1982-01 – 2012-12)



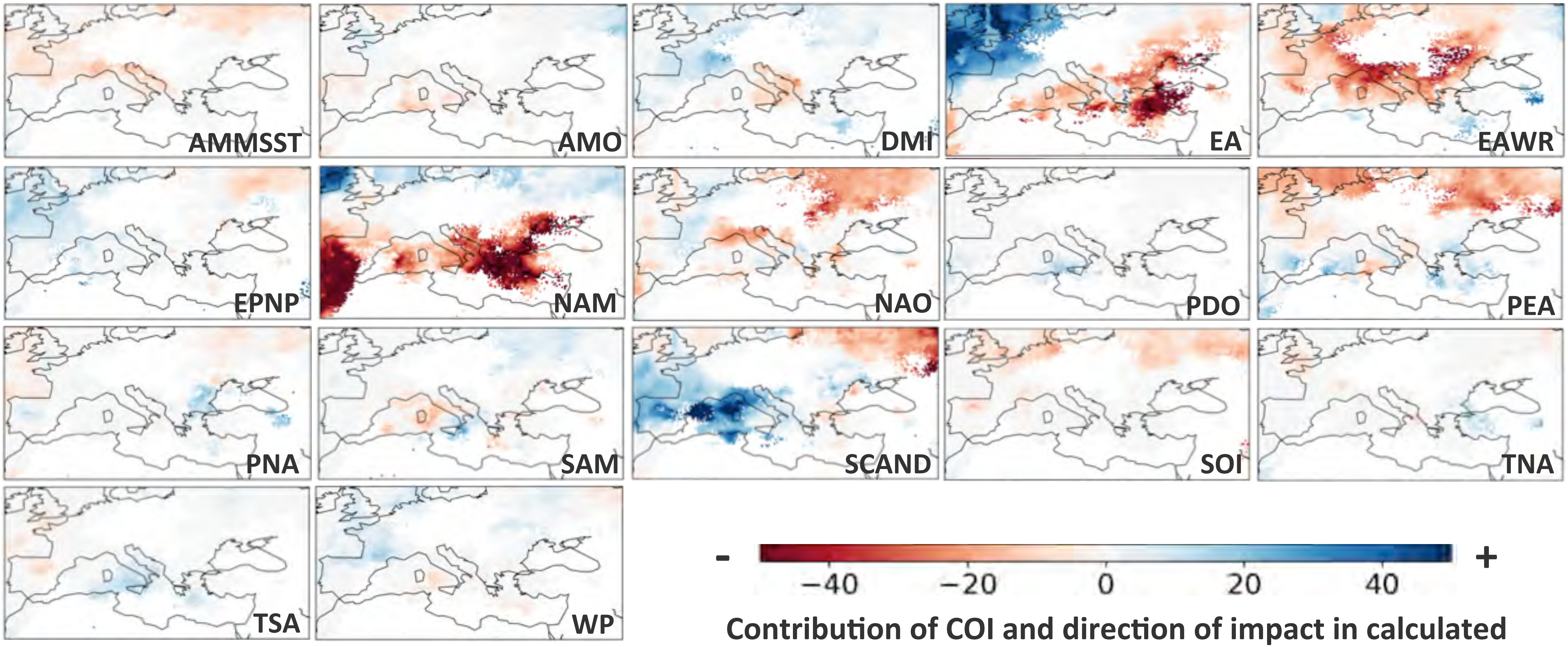
Total explained variance of combined seasonal models



Temporal dynamics

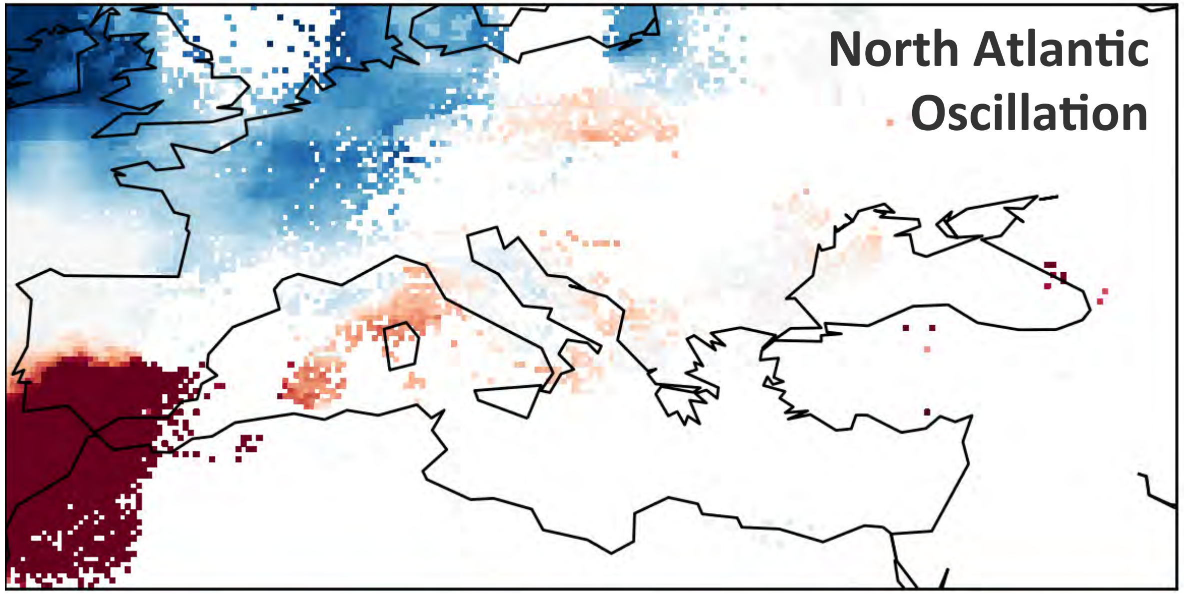


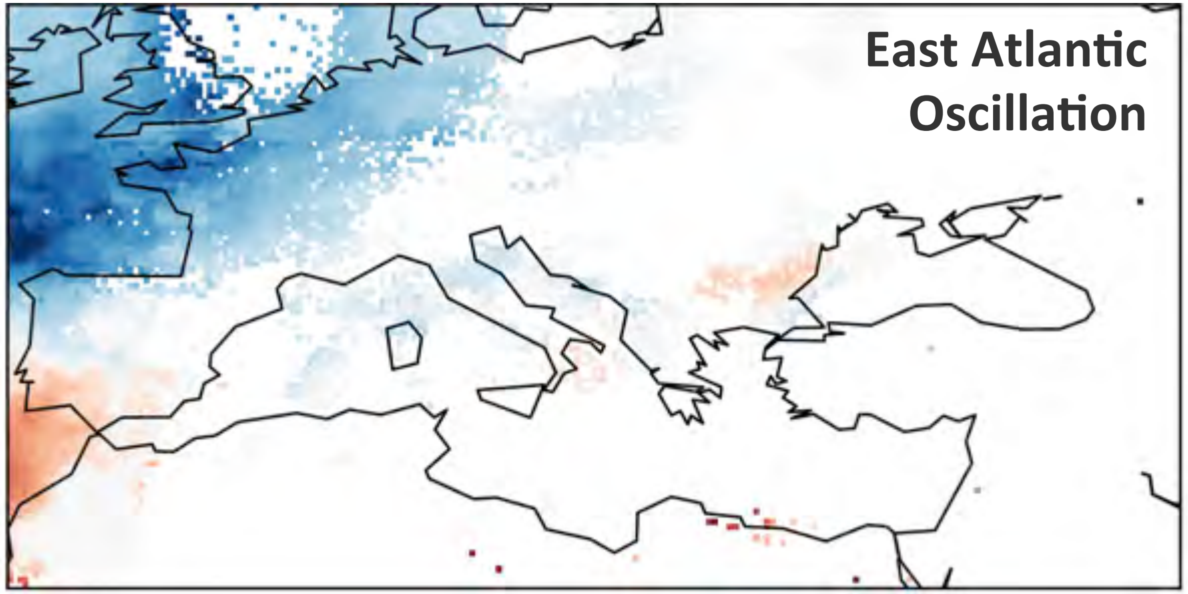
COI coefficients – all-year data

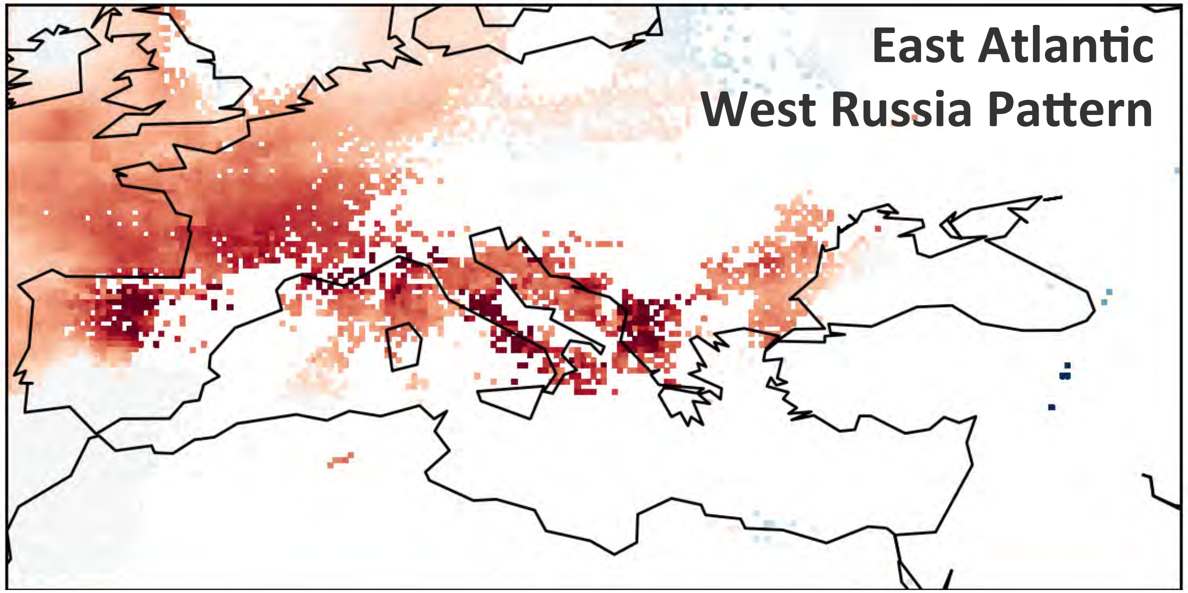


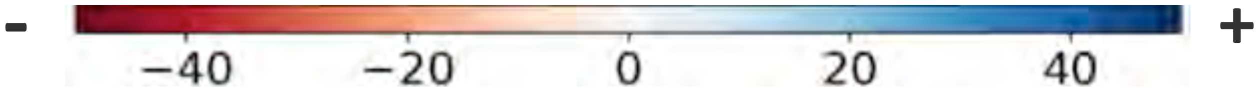
Contribution of COI and direction of impact in calculated model [%]

COI coefficients – Dec-Jan-Feb model





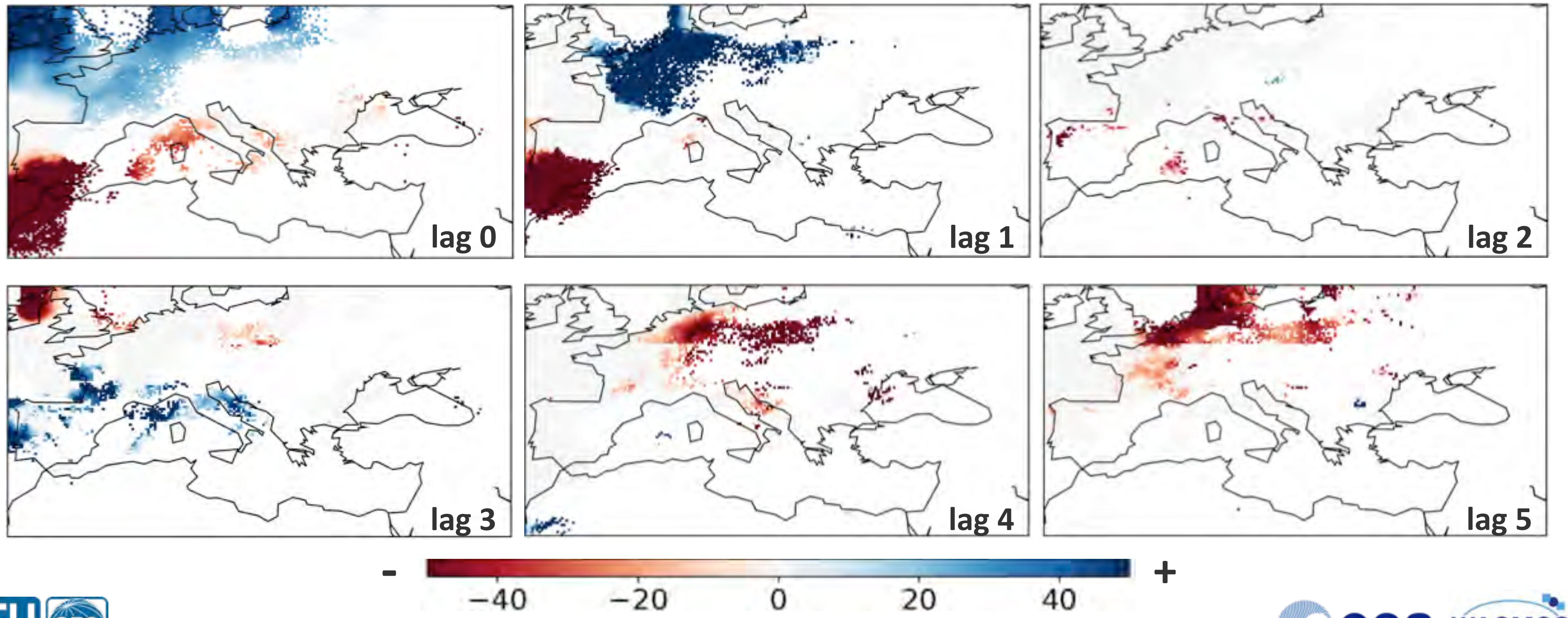




Contribution of COI and direction of impact in calculated model [%]

Impact of lags

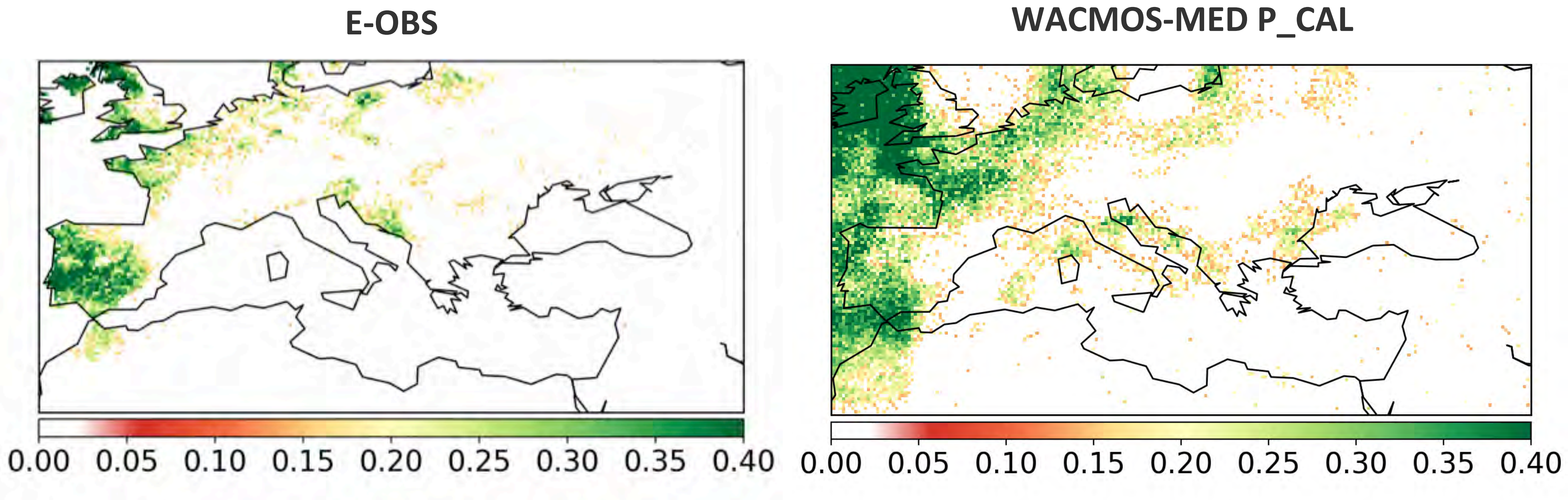
- Coefficients for NAO with monthly time lags (Dec-Jan-Feb model)



Contribution of COI and direction of impact in calculated model [%]

Are Earth Ooservations a valuable alternative to gauge-based data?

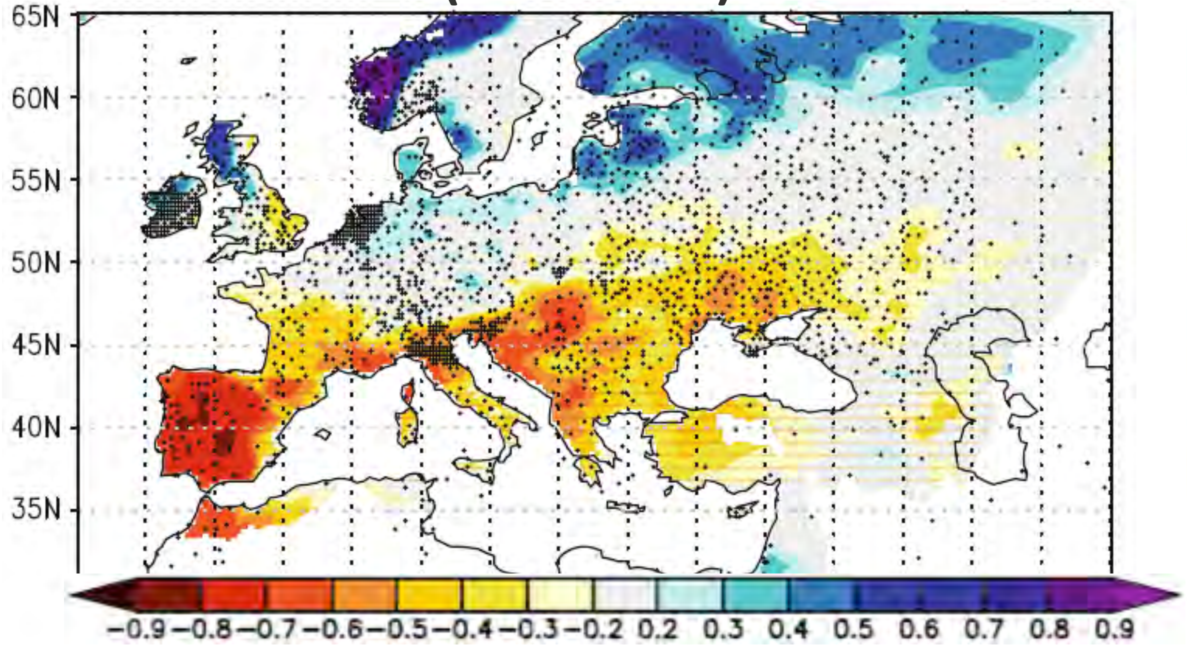
- LASSO regression winter (DJF) precipitation
- Period 1982-2012



R^2

What is the added value of LASSO?

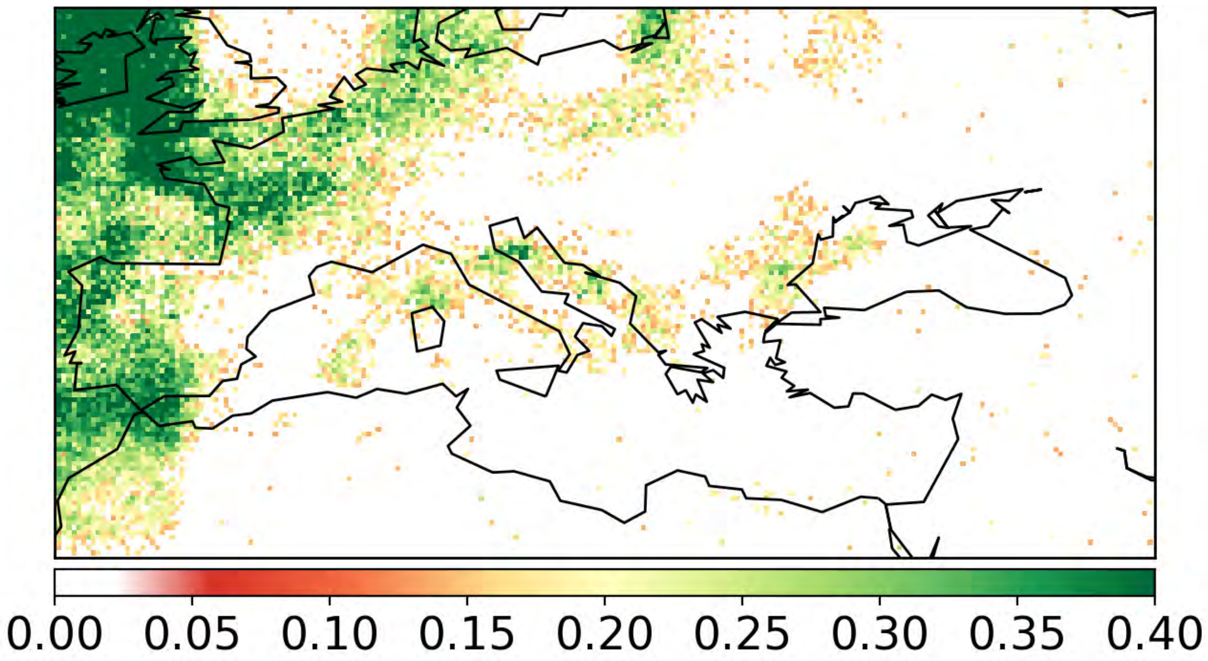
Correlation analysis NAO – E-OBS (1950-2010)



[Bladé et al., 2011]

R

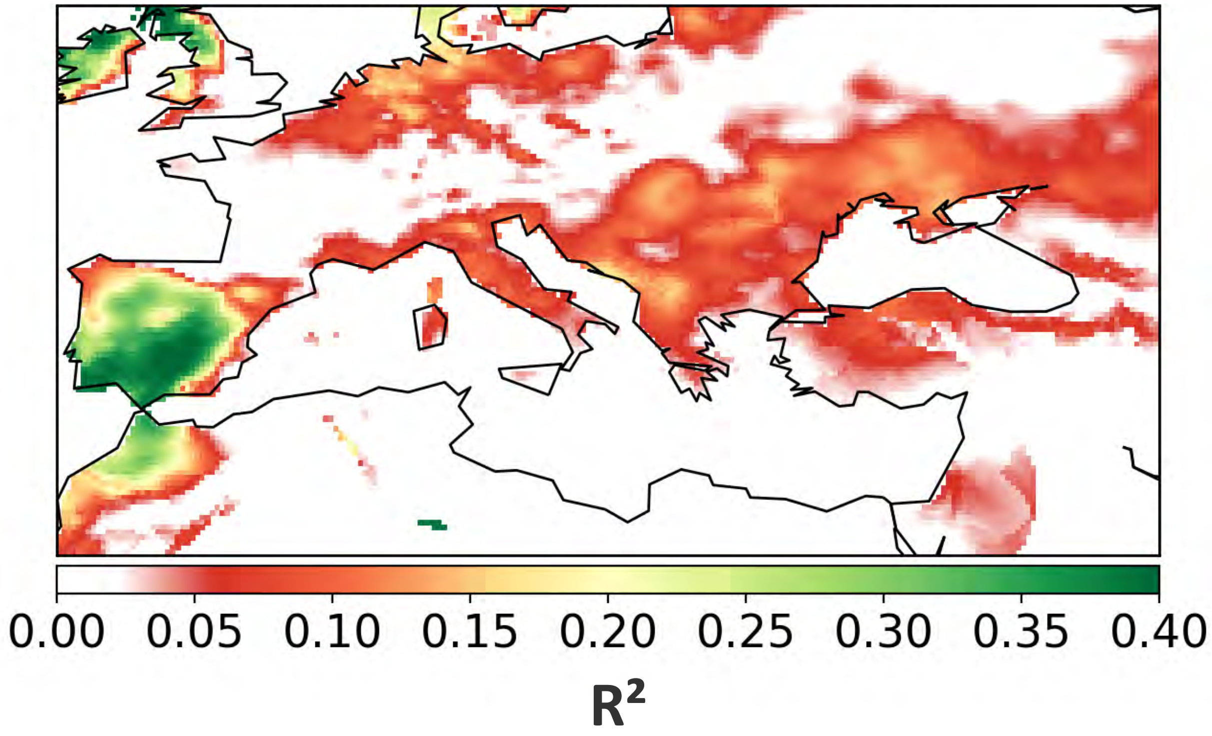
LASSO regression WACMOS-MED (1982-2012)



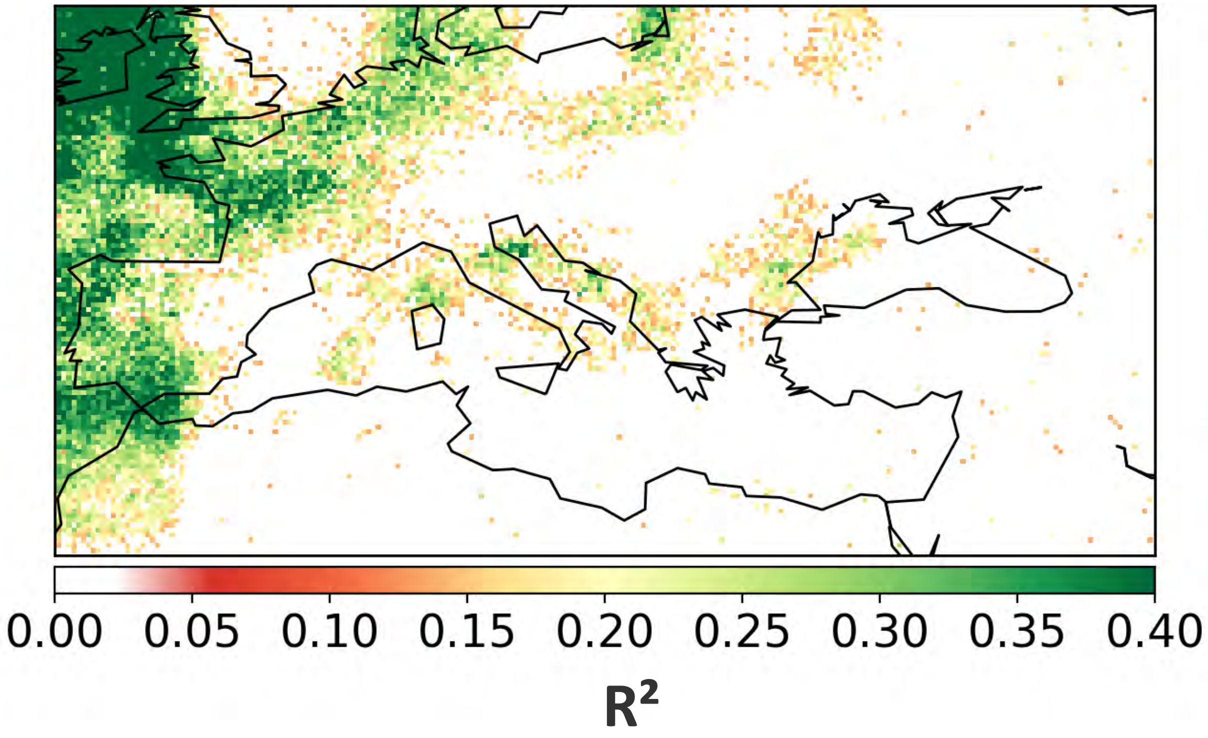
R^2

What is the added value of LASSO?

Squared correlations NAO - E-OBS (1950-2010)



LASSO regression WACMOS-MED (1982-2012)



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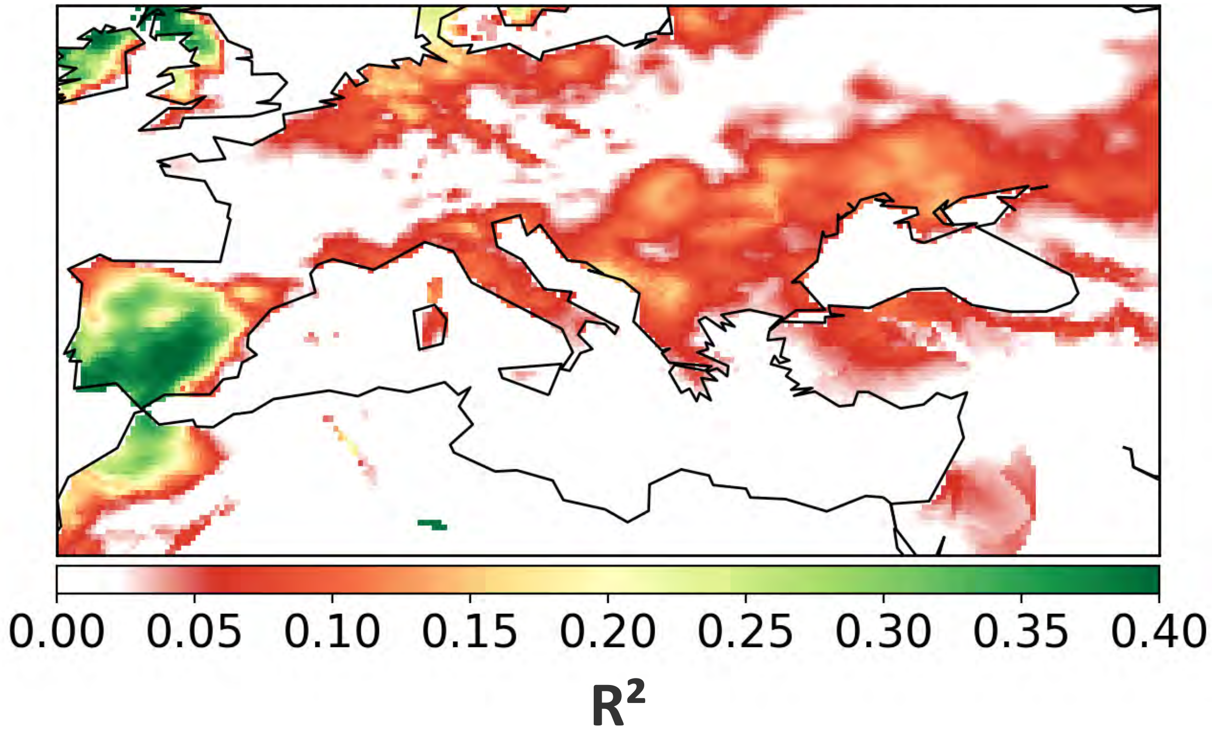
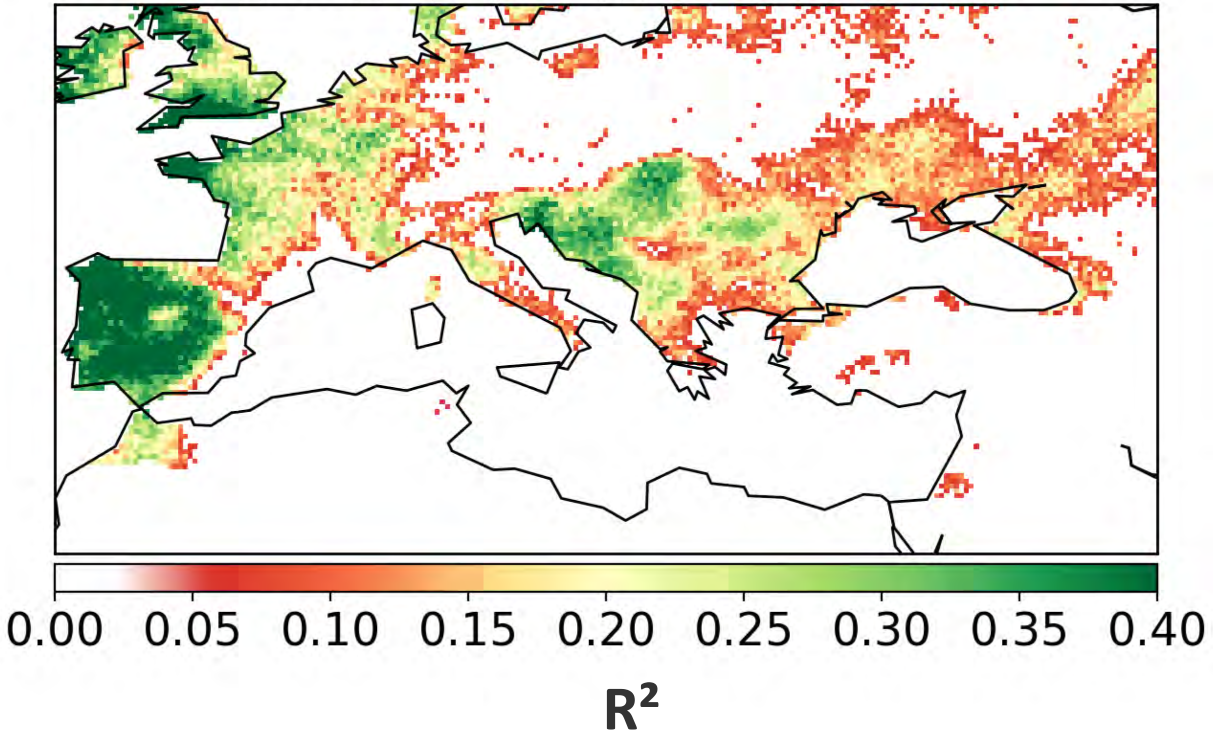


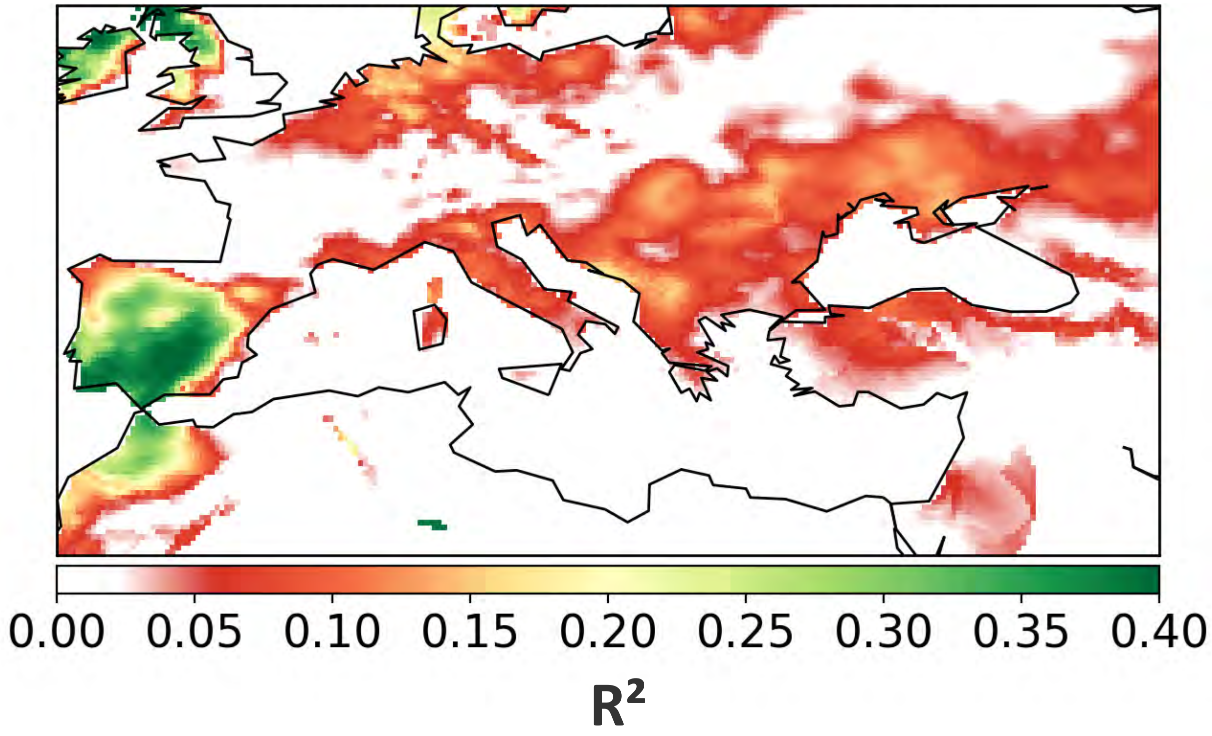
LASSO regression E-OBS (1950-2010)



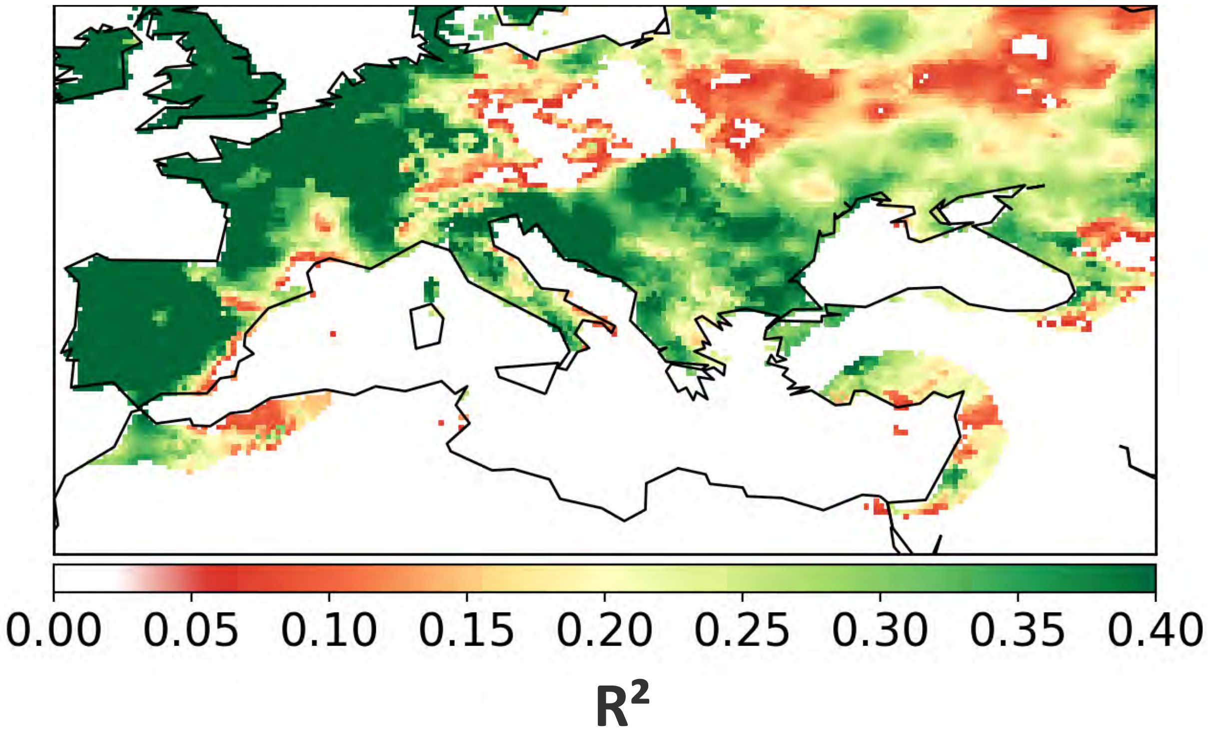
What is the added value of LASSO?

- Impact of model cross validation

Squared correlations NAO - E-OBS (1950-2010)



LASSO regression E-OBS without nested CV (1950-2010)



Conclusions

- LASSO Regression can be used to disentangle the impact of multiple, potentially correlated COIs on Mediterranean precipitation
- All-year and seasonal models show deviating importance of individual climate modes
- In the winter months (DJF), precipitation anomalies primarily driven by:
  - North Atlantic Oscillation
  - East Atlantic Oscillation
  - East Atlantic West Russia Pattern
- Earth observations are suitable for this purpose
  - But, are limited by the temporal coverage

Thank you for your attention

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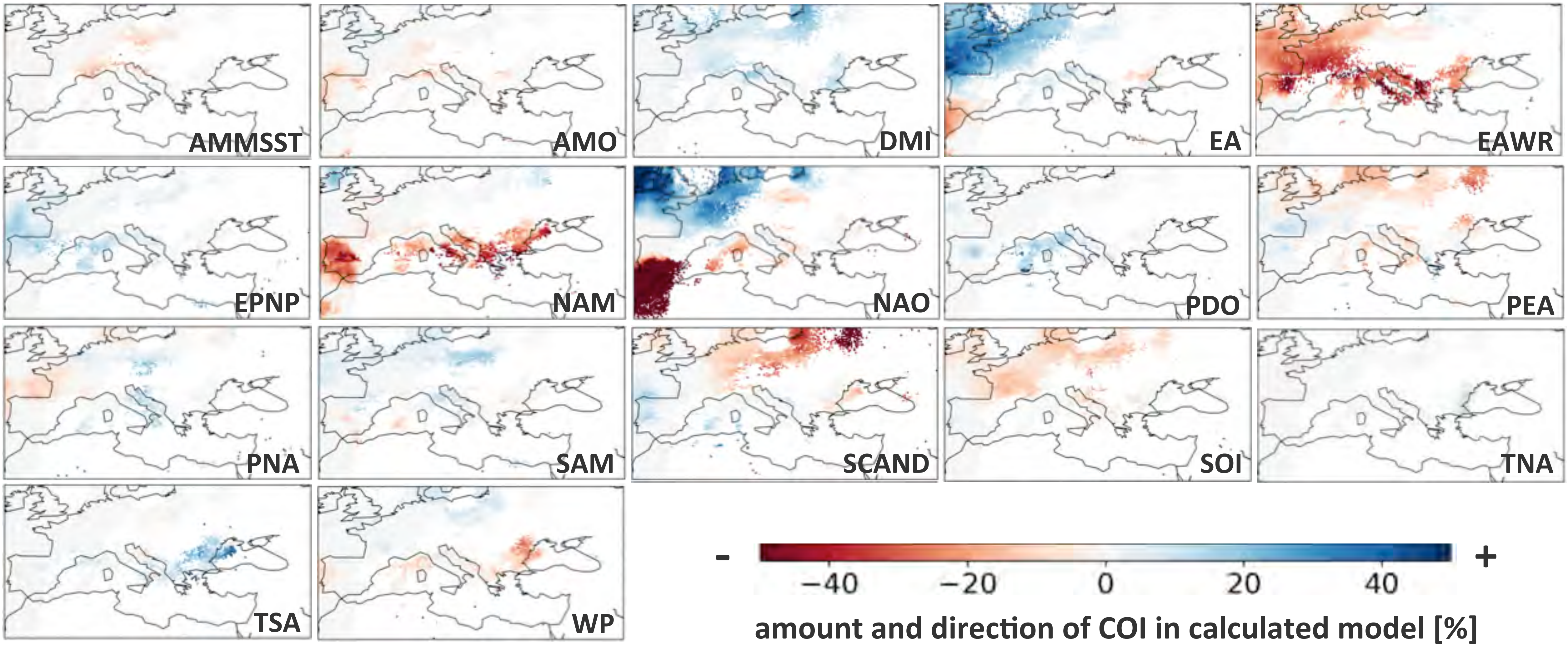
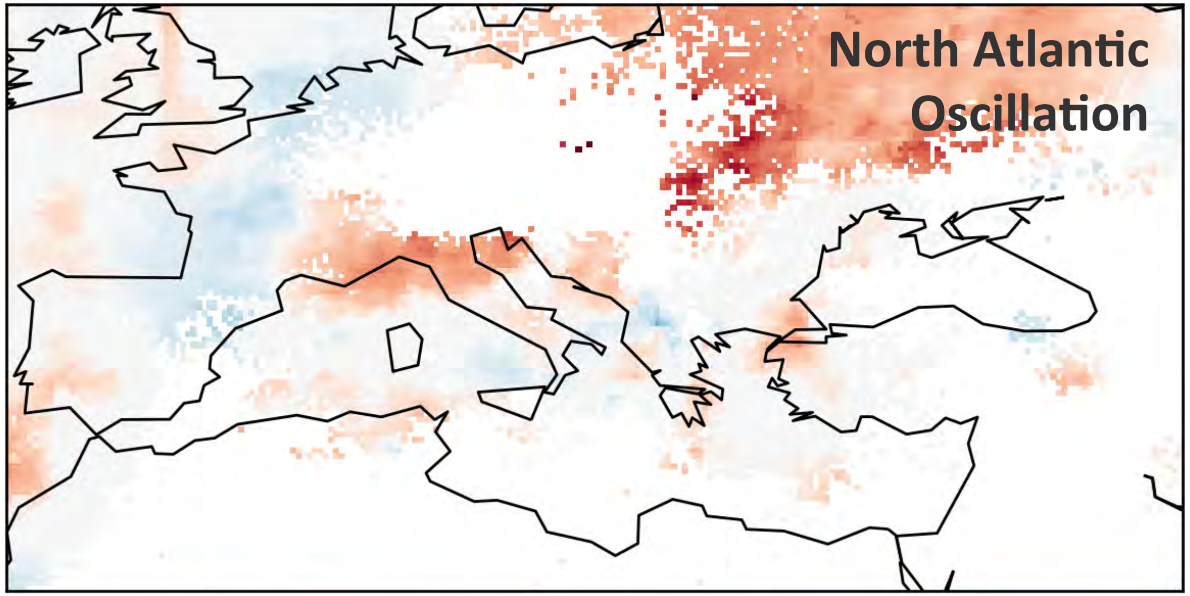
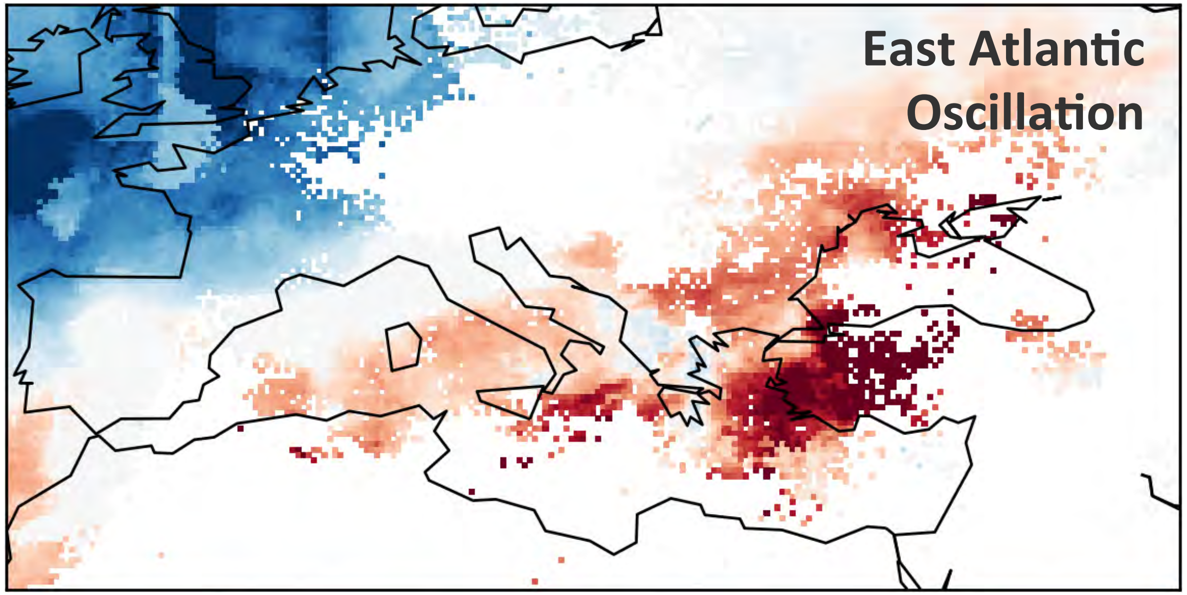
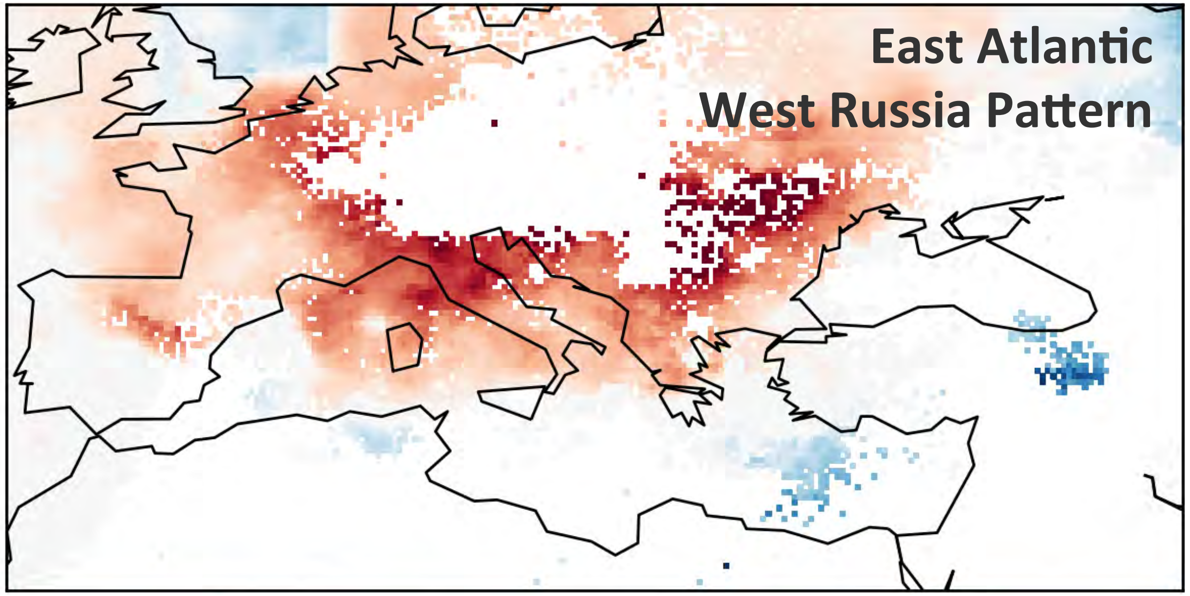
coefficients – seasonal Dec-Jan-Feb

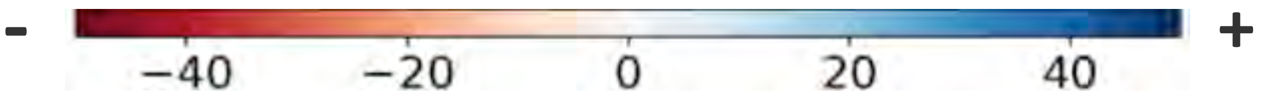


Coefficients – entire time period









amount and direction of COI in calculated model [%]