The role of teleconnection patterns in the increased drought frequency in Mediterranean climate: Some hints from central Italy

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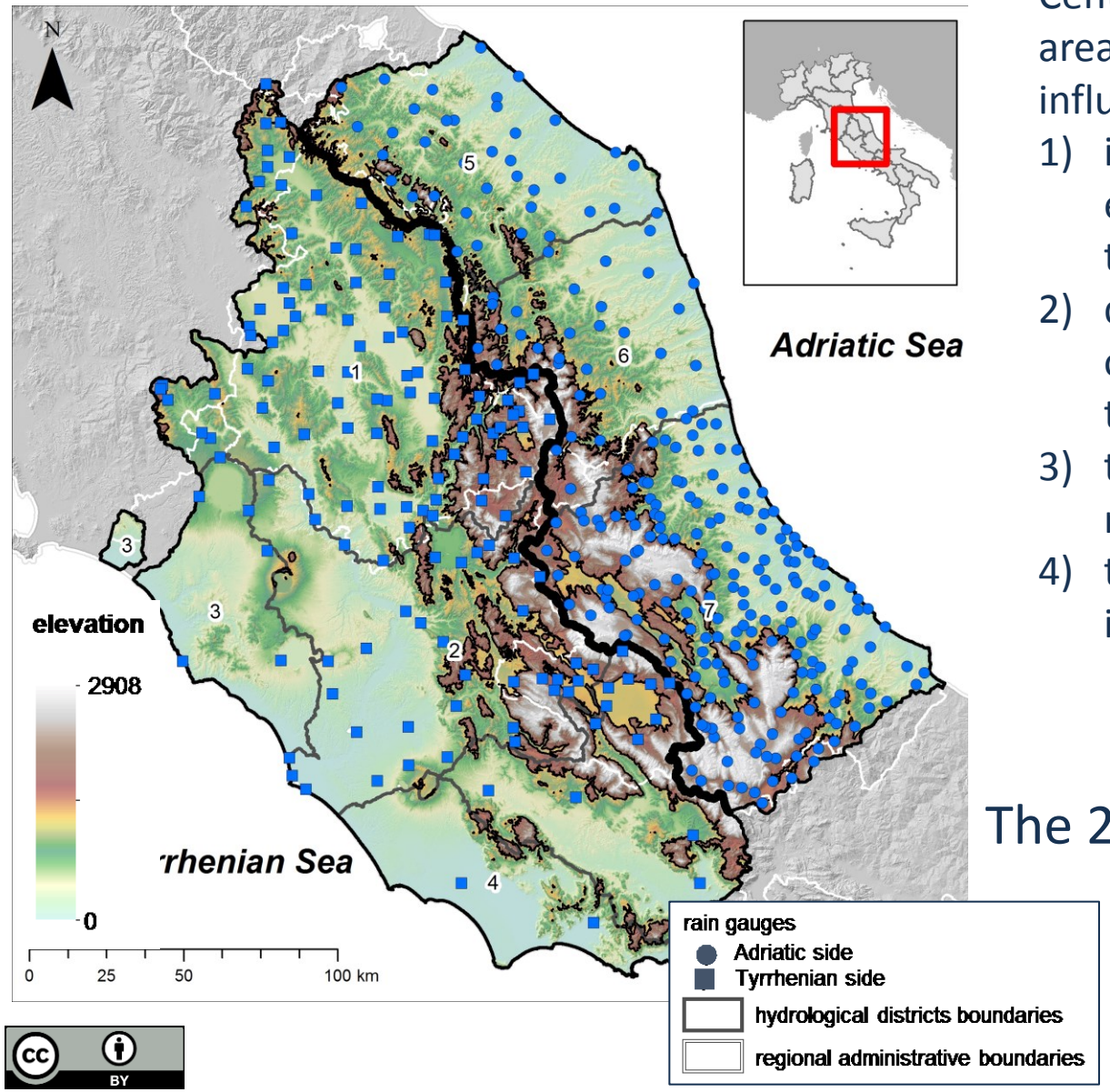
Drought and water scarcity: monitoring, modelling and forecasting to improve hydro-meteorological risk management

MOTIVATIONS



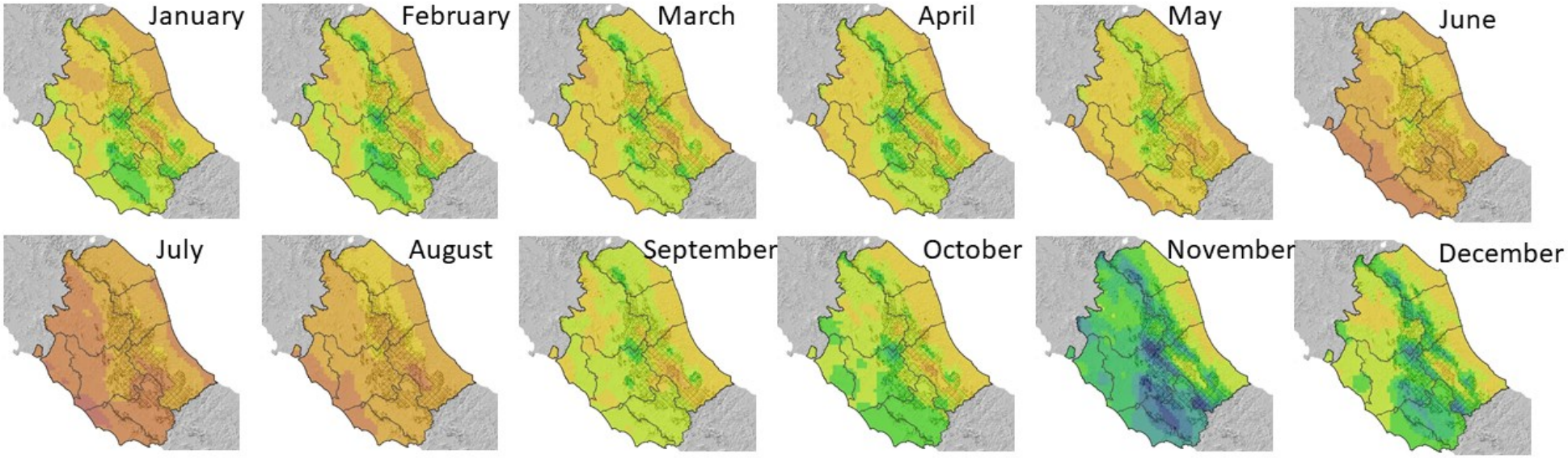
Central Italy located the middle of the northern Mediterranean area, prone to drought. Precipitation regime possibly influenced by global, regional and local factors:

1) it includes both Tyrrhenian and Adriatic sides, the first exposed to Atlantic perturbation and generally more rainy, the second one possibly exposed also to Balkan streams;
2) due to the short distance between the two coasts (few tens of kilometers), also the more internal areas may be prone to the influence of the sea;
3) the highest reliefs of the Apennine chain are located in the region;
4) the Northern areas of the Adriatic side experience the influence of the continental climate, due to the Po Valley.

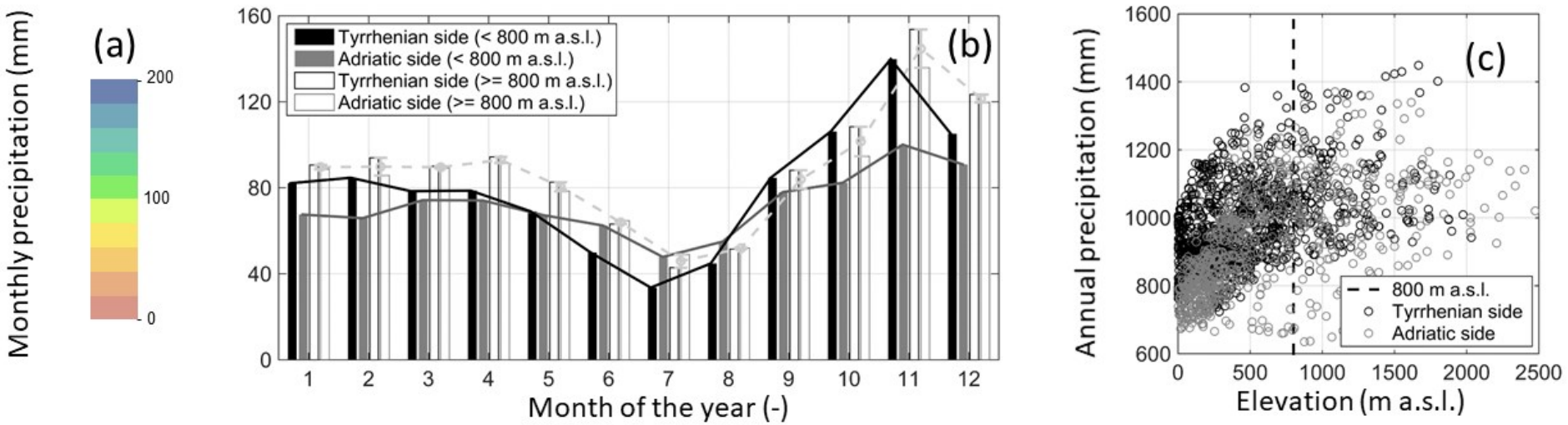
The 2017 drought in Central Italy: an “extreme event”?

Analysis of the precipitation regime (1960-2019)

PRECIPITATION REGIME (1965-2019)



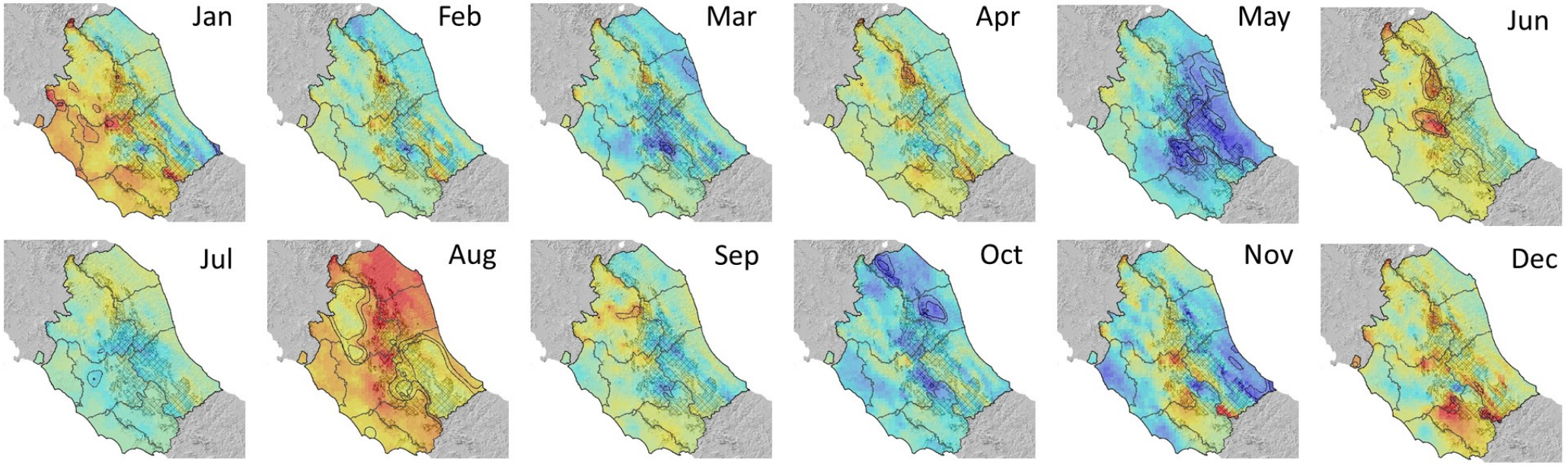
Mean (1965-2019) monthly precipitation



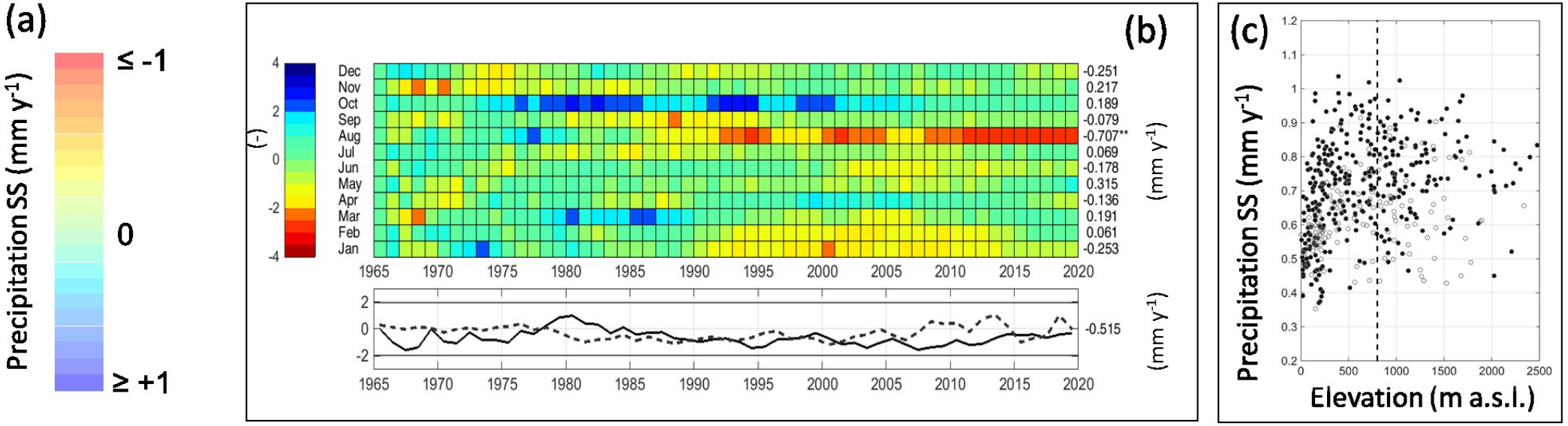
Dependence on the elevation and side

TREND ANALYSIS (1965-2019)

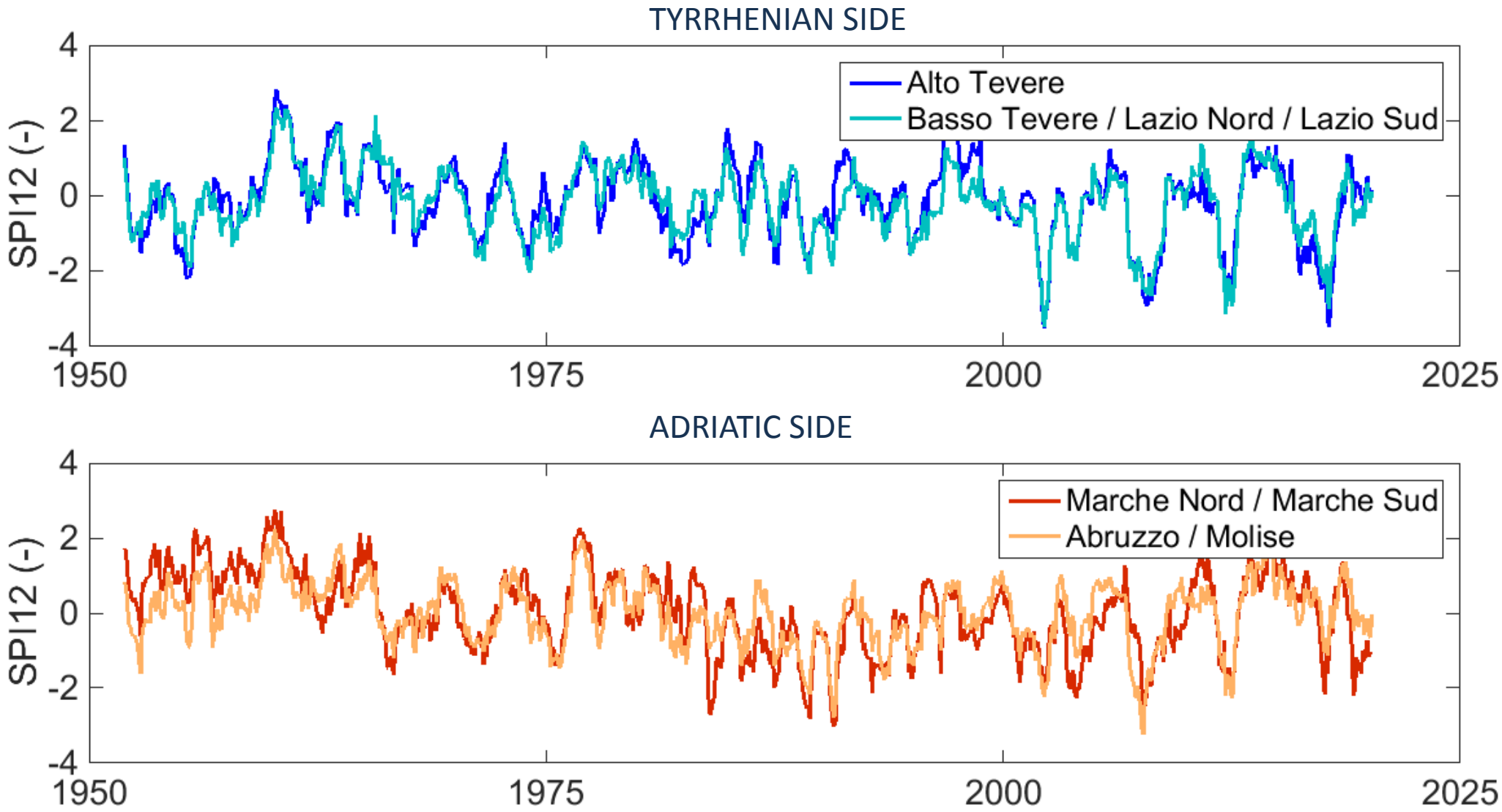
Monthly precipitation Sens' slope



Sequential Mann-Kendall

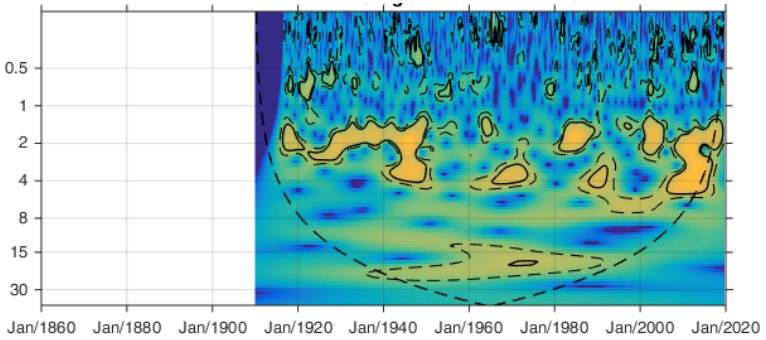


PRECIPITATION REGIME (1960-2019)

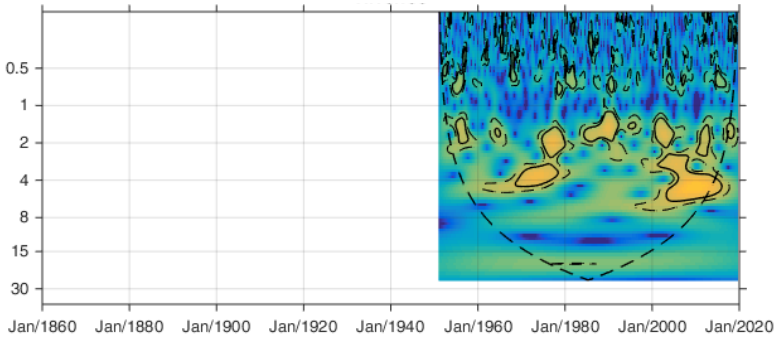


WAVELET ANALYSIS - PRECIPITATION

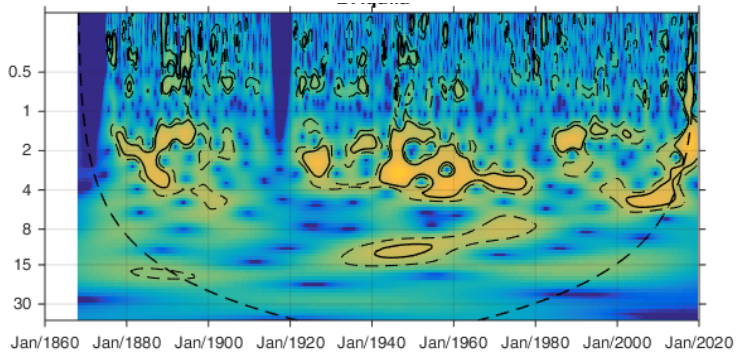
PERUGIA RAINFALL GAUGE



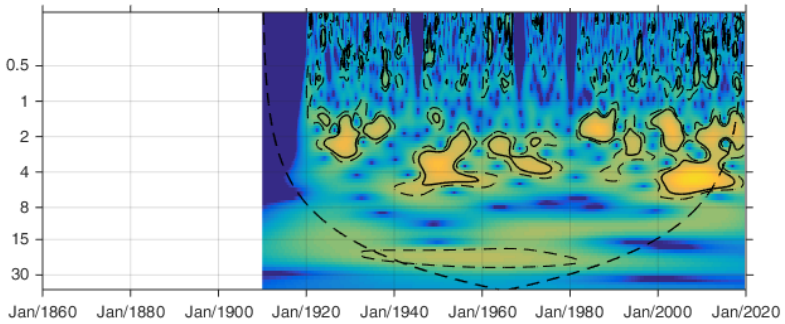
TYRRHENIAN SIDE



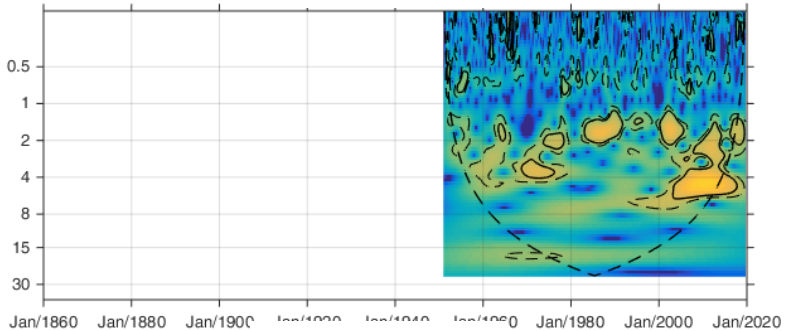
L'AQUILA RAINFALL GAUGE



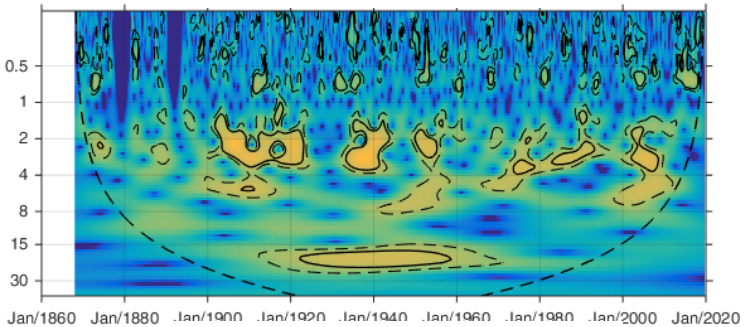
ORVIETO RAINFALL GAUGE



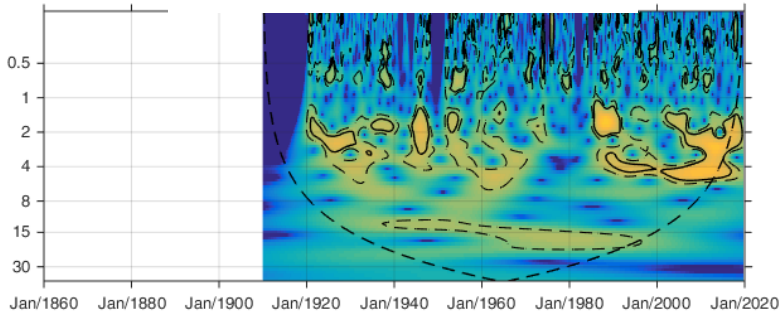
CENTRAL ITALY



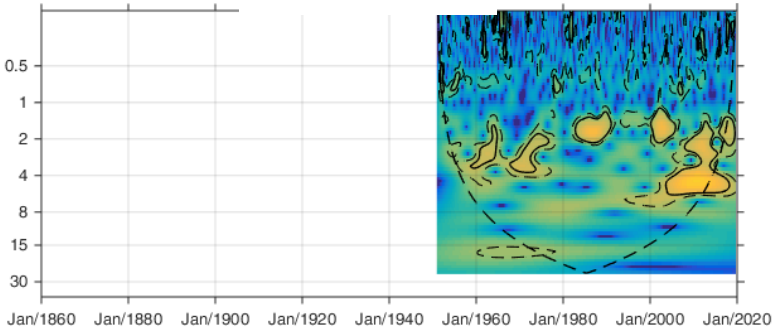
CHIETI RAINFALL GAUGE



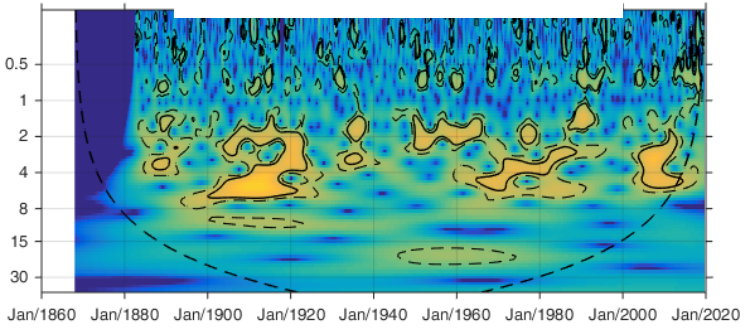
LEONESSA RAINFALL GAUGE



ADRIATIC SIDE

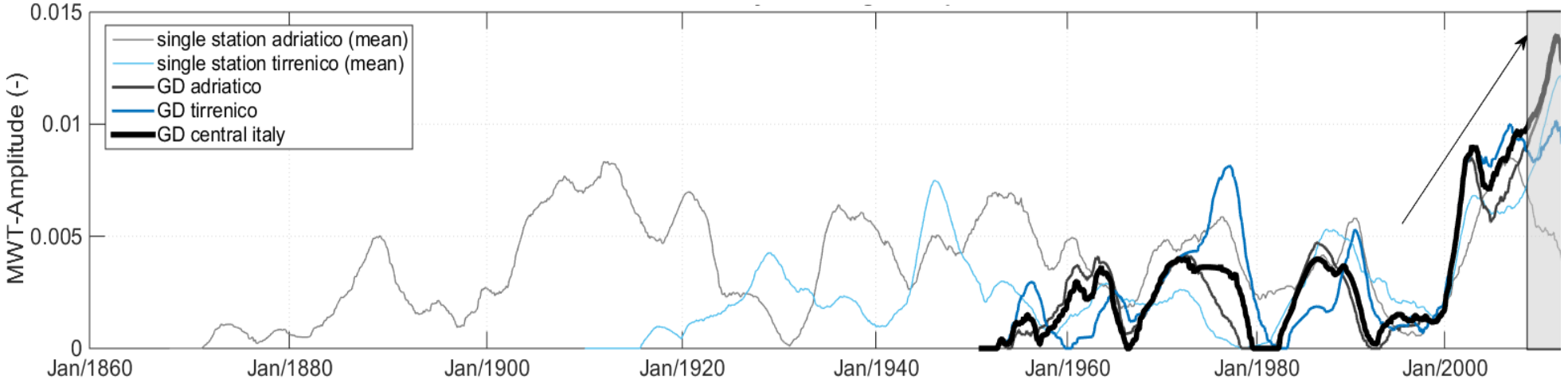


TERAMO RAINFALL GAUGE

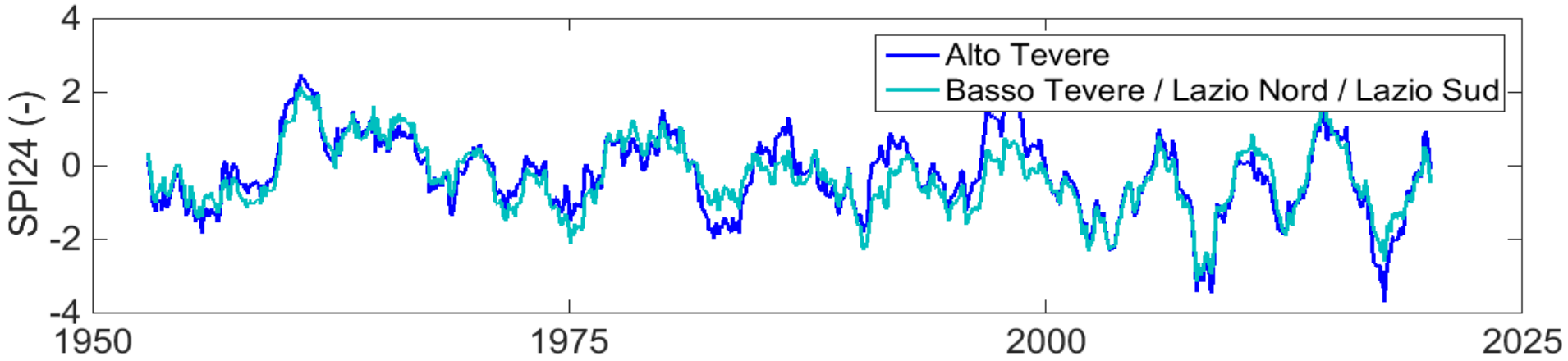


WAVELET ANALYSIS - PRECIPITATION

1 -8 YEARS PERIOD SUM



Increasing in amplitude of the periodic signal since ‘2000



Possible increasing in frequency of the periodic signal since ‘2000

TELECONNECTION PATTERNS

NORTH ATLANTIC OSCILLATION - NAO

EAST ATLANTIC - EA

EAST ATLANTIC / WEST RUSSIA – EA/WA

EAST PACIFIC / NORTH PACIFIC - EP/NP

PACIFIC / NORTHERN AMERICA -PNA

POLAR/EURASIA - POL

SCANDINAVIAN - SCA

EAST PACIFIC / NORTH PACIFIC

WINTER NAO

PACIFIC DECADAL OSCILLATION - PDO

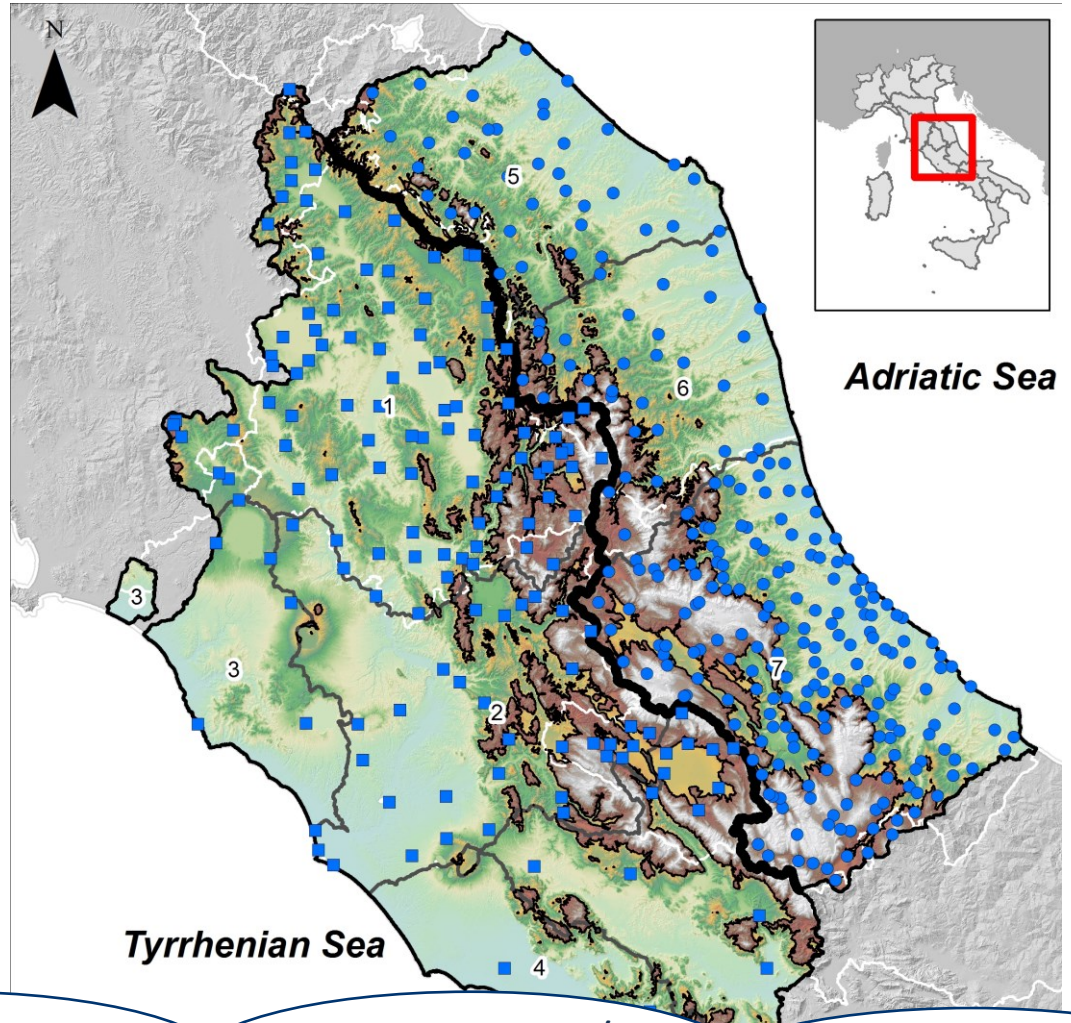
EL NINO

ATLANTIC MULTIDECADAL OSCILLATIO

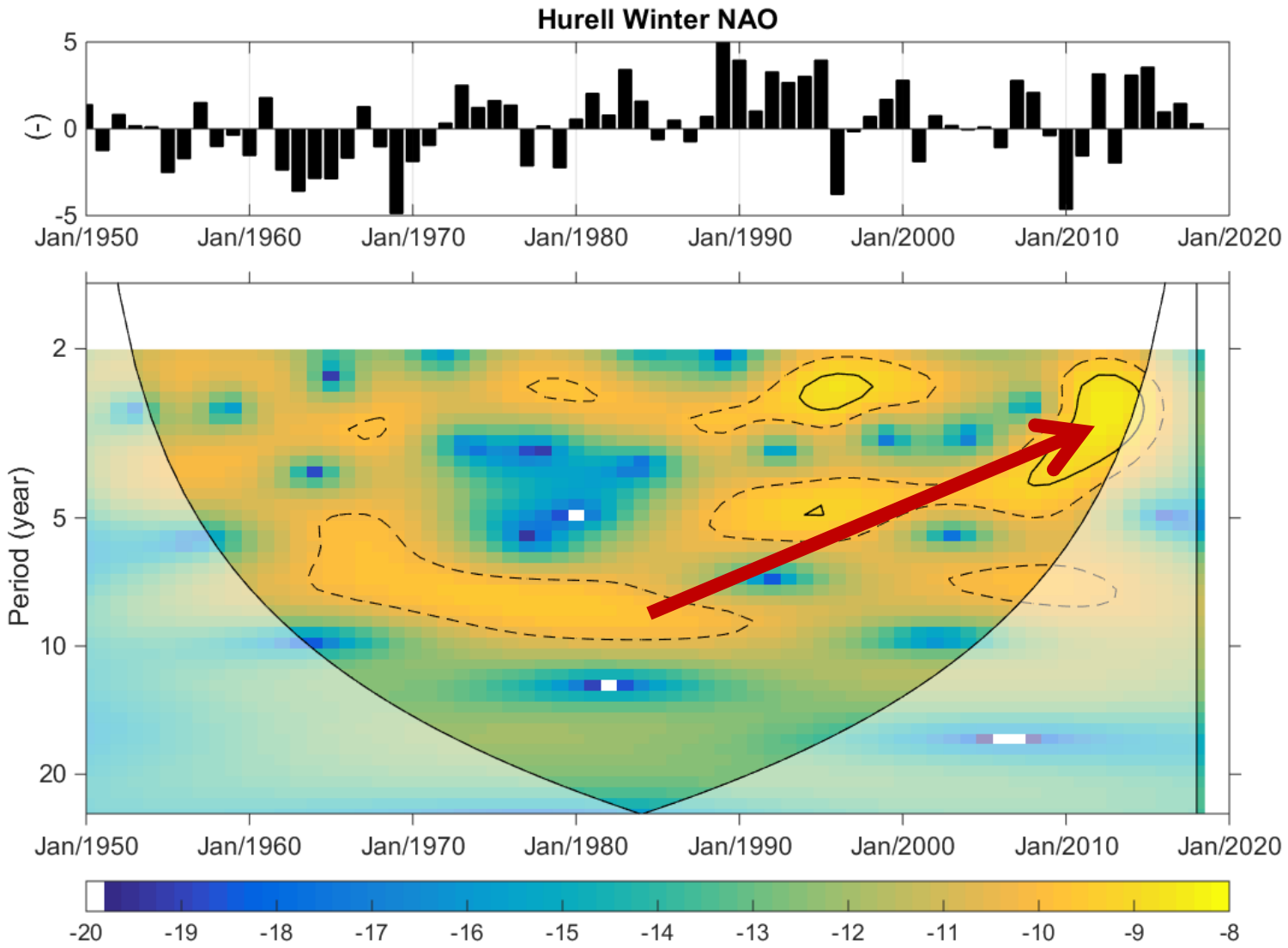
ARCTIC OSCILLATION - AO

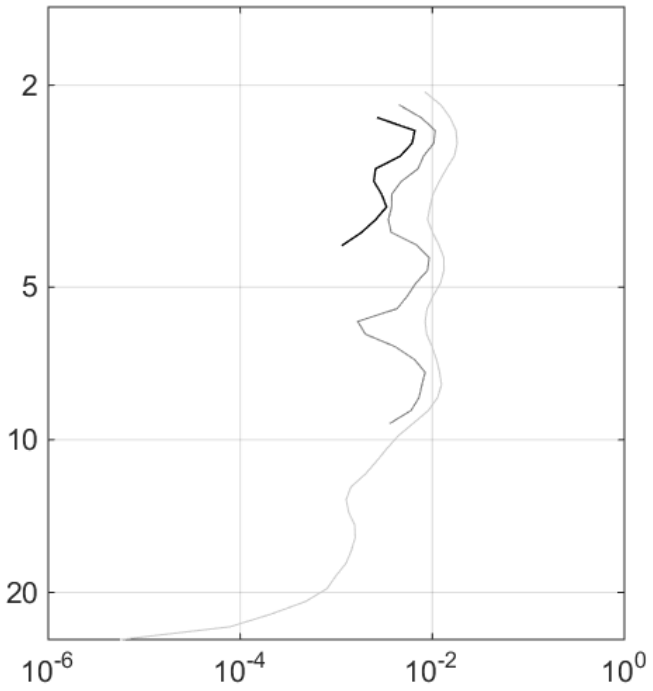
WEST PACIFIC - WP

SOUTHERN OSCILLATION -SO

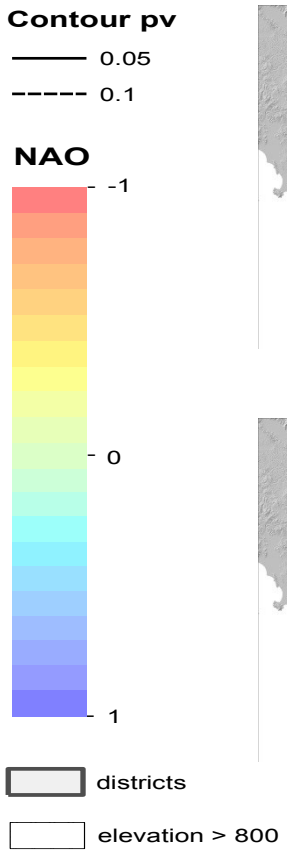


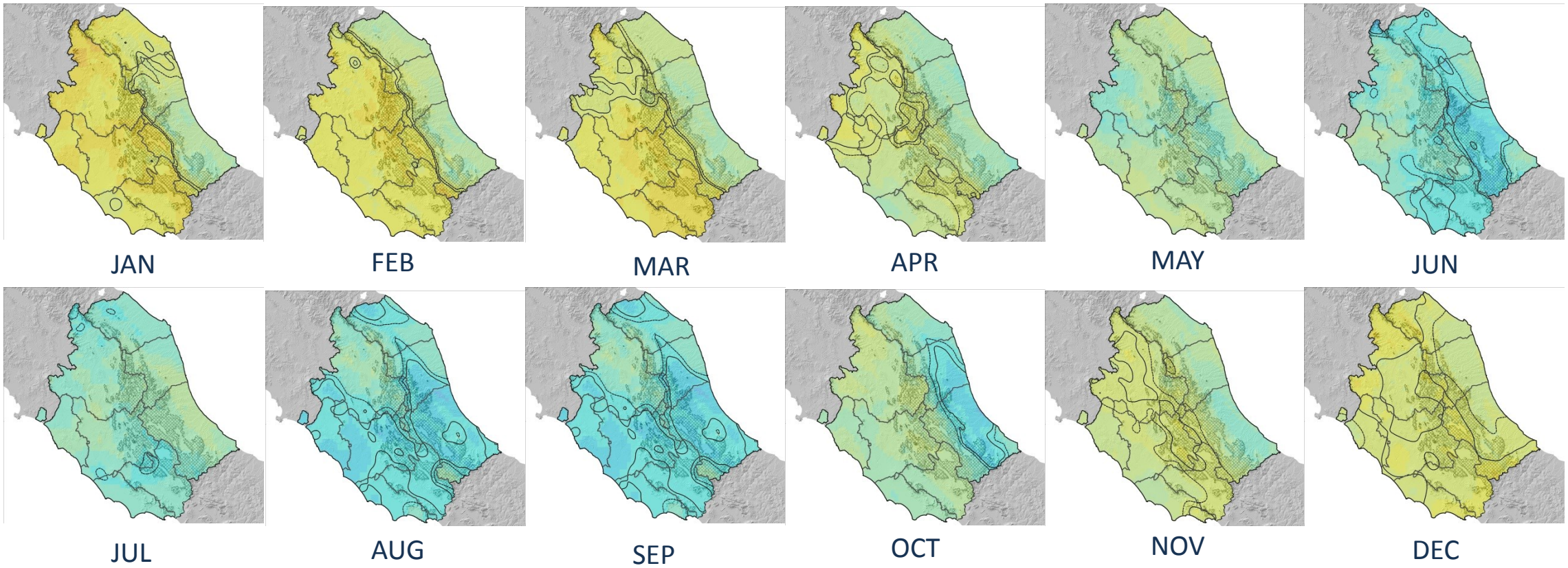
FREQUENCY ANALYSIS – WINTER NAO



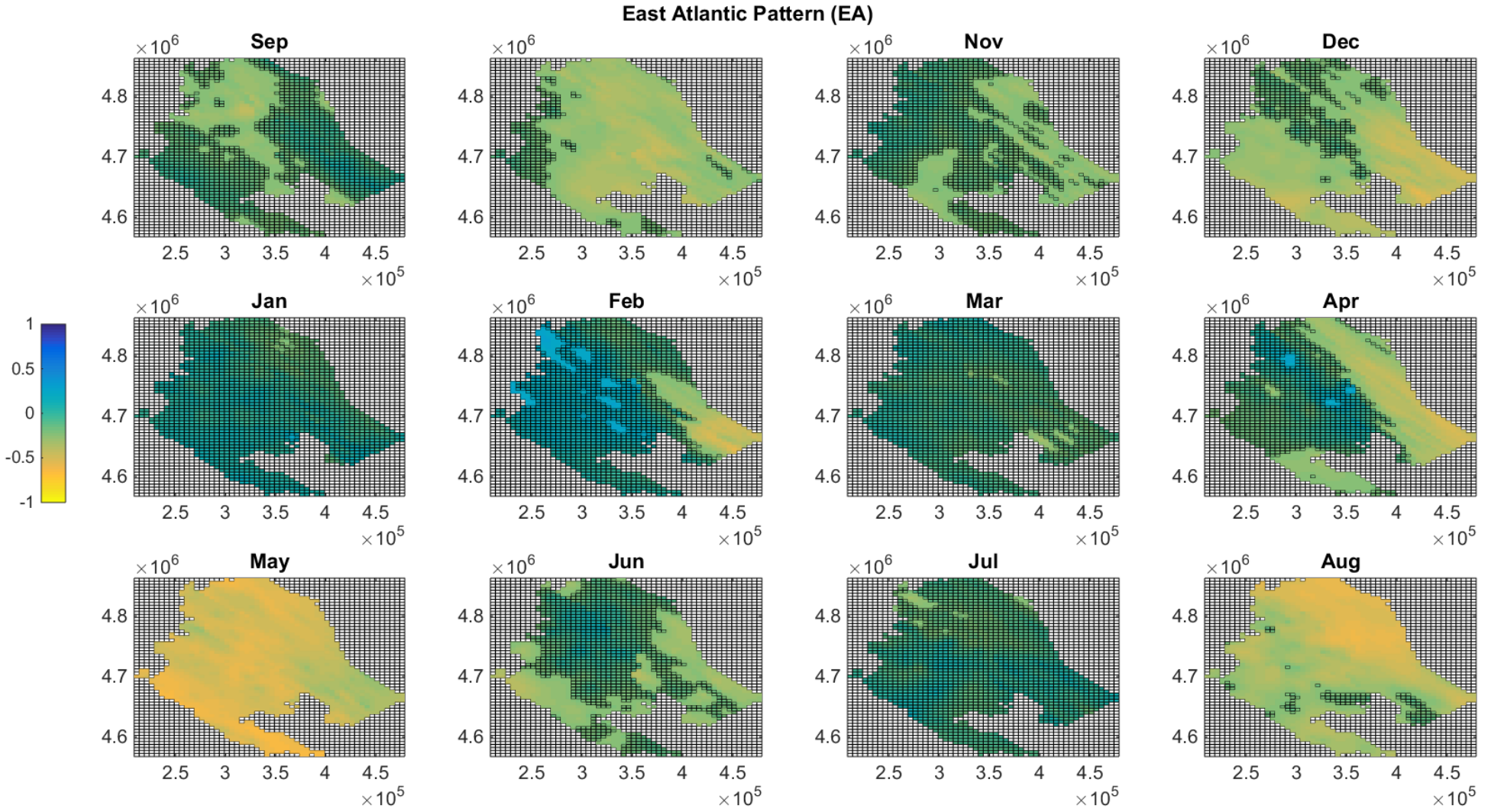


CORRELATION ANALYSIS
MONTHLY PRECIPITATION NORTH ATLANTIC OSCILLATION





CORRELATION ANALYSIS MONTHLY PRECIPITATION – EAST ATLANTIC PATTERN



CORRELATION ANALYSIS MONTHLY PRECIPITATION – TELECONECTION PATTERNS

ADRIATIC COAST (HEIGHT < 800 m asl)

PEARSON'S CORRELATION COEFFICIENT (p<0.1 ON AT LEAST 60% OF THE WHOLE AREA)

	J	F	M	A	M	J	J	A	S	O	N	D
NAO								0.29				
EA				-0.36	-0.46			-0.50		-0.30		-0.35
WP												
EP/NP	0.34											
PNA					-0.28							
EA/WR					-0.28							-0.34
SCA								0.36				
TNH												
POL												
W												
AO												
AMO												
ENSO ns								0.34				
ENSO s								0.34				
SOI						0.28						
WeMOI				0.33								

CORRELATION ANALYSIS MONTHLY PRECIPITATION – TELECONECTION PATTERNS

TYRRENHIAN COAST (HEIGHT < 800 m asl)

PEARSON'S CORRELATION COEFFICIENT (p<0.1 ON AT LEAST 60% OF THE WHOLE AREA)

	J	F	M	A	M	J	J	A	S	O	N	D
NAO	-0.39	-0.35	-0.36					0.28				-0.29
EA					-0.53			-0.34		-0.29		-0.32
WP												
EP/NP	0.40								0.37		0.27	
PNA												
EA/WR	-0.43	-0.45	0.26		-0.27					-0.31	-0.29	-0.48
SCA	0.43	0.27				0.33		0.37	0.34	0.33	0.36	
TNH		-0.34										
POL						0.32					0.34	
W	-0.40	-0.30									-0.28	-0.36
AO												
AMO												
ENSO ns												
ENSO s												
SOI			0.32									
WeMOI	0.26			0.41					0.31	0.35		

CORRELATION ANALYSIS MONTHLY PRECIPITATION – TELECONECTION PATTERNS

APENNINE RIDGE (HEIGHT < 800 m asl)

PEARSON'S CORRELATION COEFFICIENT (p<0.1 ON AT LEAST 60% OF THE WHOLE AREA)

	J	F	M	A	M	J	J	A	S	O	N	D
NAO	-0.38	-0.37	-0.35					0.28				-0.29
EA					-0.48			-0.38		-0.34		-0.35
WP												
EP/NP	0.42			0.30					0.34			
PNA					-0.28							
EA/WR	-0.41	-0.42			-0.28					-0.29	-0.34	-0.51
SCA	0.33							0.37	0.35	0.29		
TNH		-0.34										
POL						0.34	0.31				0.34	
W	-0.40	-0.32									-0.30	-0.34
AO												
AMO												
ENSO ns												
ENSO s												
SOI		-0.25	0.31			0.25						
WeMOI	0.27		0.32	0.47						0.39	0.32	

CONDITIONAL PROBABILITY ANALYSIS

t : current month
M : forecast lag

Random variables:

$$\begin{cases} X_1 = SPIk_i\ (t) \\ X_2 = SPIk_j(t+M) \\ Z = NAO(t) \end{cases}$$

Bonaccorso et al. 2015

1) Transition probability from $X_1 \in C_0$ a $X_2 \in C_M$

$$P[X_2 \in C_M | X_1 \in C_0] = \frac{\int_{C_M}\int_{C_0} f_{X_1,X_2}(t,s)\,dt\,ds}{\int_{C_0} f_{X_1}(t)\,dt}$$

- $f_{X_1} = \frac{1}{(2\,\pi)^{1/2}\,\sigma} \cdot \exp\left(-\frac{1}{2}\left(\frac{X_1-\mu}{\sigma}\right)^2\right)$

- $f_{X_1,X_2} = \frac{1}{2\,\pi\,|\Sigma|^{1/2}} \cdot \exp\left(-\frac{1}{2}\,\boldsymbol{X}^T\Sigma^{-1}\boldsymbol{X}\right)$

$$\Sigma = \begin{bmatrix} 1 & cov(X_2,X_1) \\ cov(X_1,X_2) & 1 \end{bmatrix}$$

2) Transition probability from $X_1 \in C_0$ a $X_2 \in C_M$ known $Z \in C_w$

$$P[X_2 \in C_M | X_1 \in C_0, Z \in C_w] = \frac{\int_{C_M}\int_{C_0}\int_{C_w} f_{X_1,X_2,Z}\,(t,s,w)\,dt\,ds dw}{\int_{C_0}\int_{C_w} f_{X_1,Z}\,(s,w)\;\,ds\,dw}$$

- $f_{X_1,X_2,Z} = \frac{1}{(2\,\pi)^{3/2}|\Sigma_1|^{1/2}} \cdot \exp\left(-\frac{1}{2}\boldsymbol{X}^T\Sigma^{-1}\boldsymbol{X}\right)$

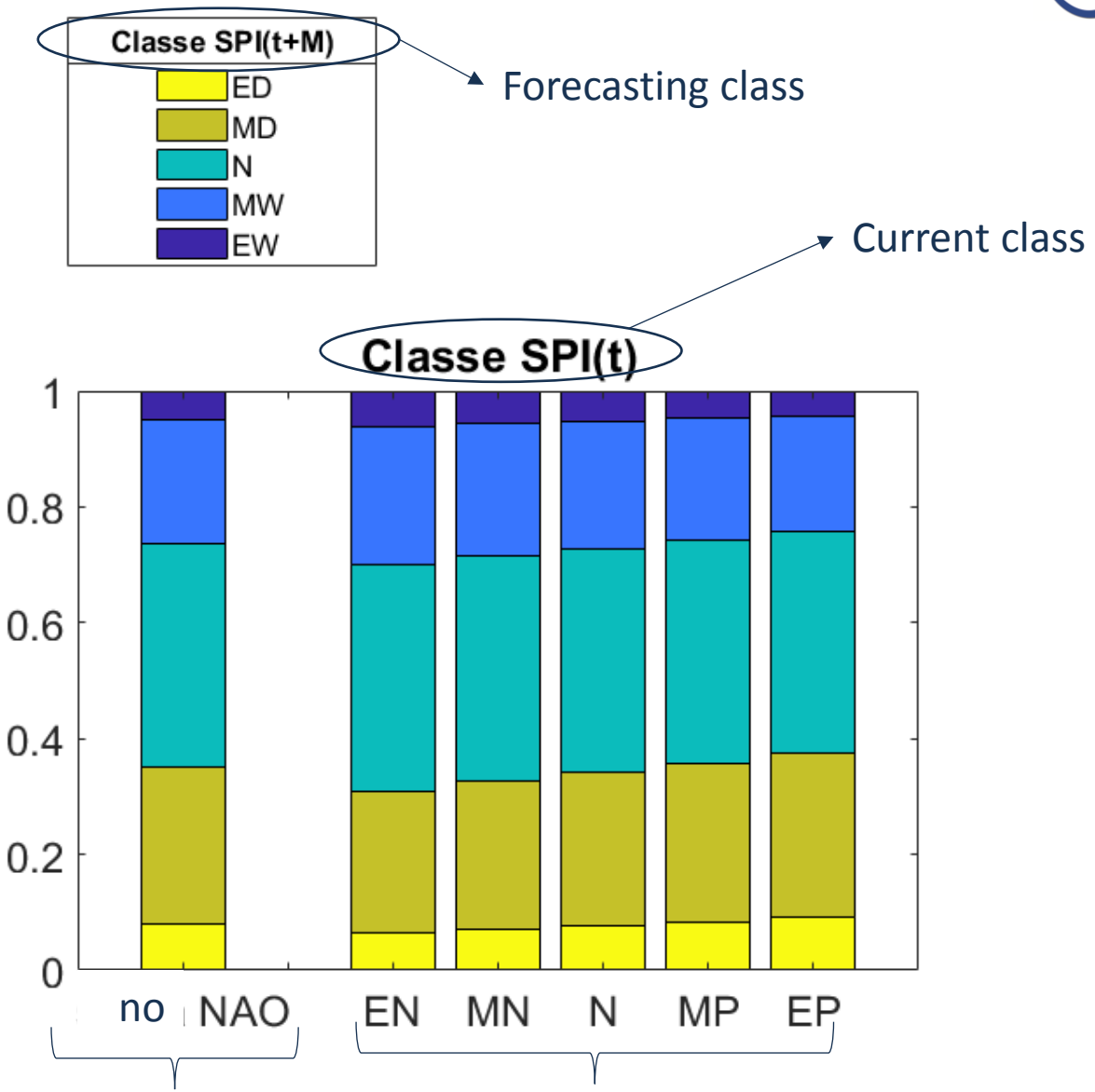
$$\Sigma_1 = \begin{bmatrix} 1 & cov(X_2,X_1) & cov(X_2,Z) \\ cov(X_1,X_2) & 1 & cov(X_1,Z) \\ cov(Z,X_2) & cov(Z,X_1) & var(Z) \end{bmatrix}$$

- $f_{X_1,Z} = \frac{1}{2\,\pi\,|\Sigma_2|^{1/2}} \cdot \exp\left(-\frac{1}{2}\,\boldsymbol{X}^T{\Sigma_2}^{-1}\boldsymbol{X}\right)$

$$\Sigma_2 = \begin{bmatrix} 1 & cov(X_1,Z) \\ cov(Z,X_1) & var(Z) \end{bmatrix}$$

CONDITIONAL PROBABILITY ANALYSIS

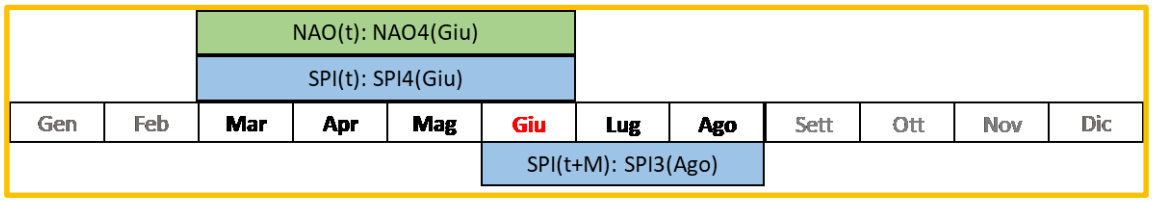
Range	Class SPI (C_M, C_0)	Class NAO (C_w)
<-1.5	Extremely dry (ED)	Extremely negative (EN)
-1.49 : -0.5	Moderately dry (MD)	Moderately negative (MN)
-0.49 : 0.49	Normal (N)	Normal (N)
0.5 : 1.49	Moderately wet (MW)	Moderately positive (MP)
>1.5	Extremely wet (EW)	Extremely positive (EP)

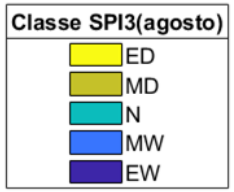


1) $P[X_2 \in C_M | X_1 \in C_0]$

2) $P[X_2 \in C_M | X_1 \in C_0, Z \in C_w]$

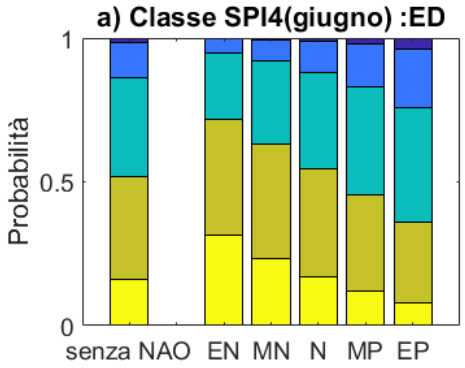
CONDITIONAL PROBABILITY ANALYSIS

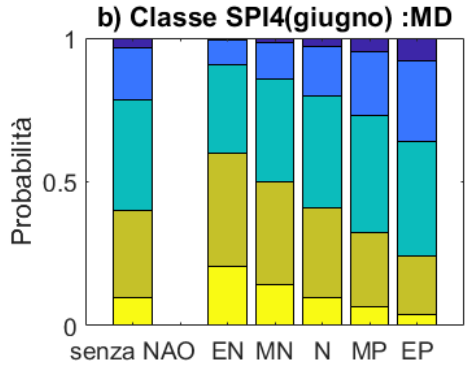


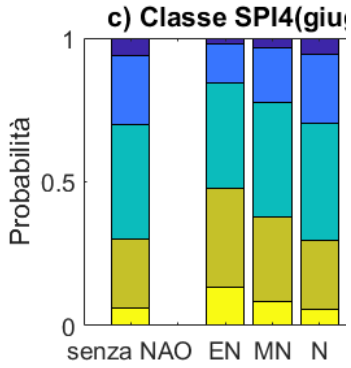


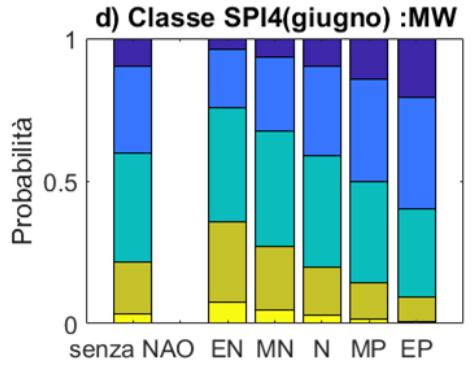
Correlation coefficient:

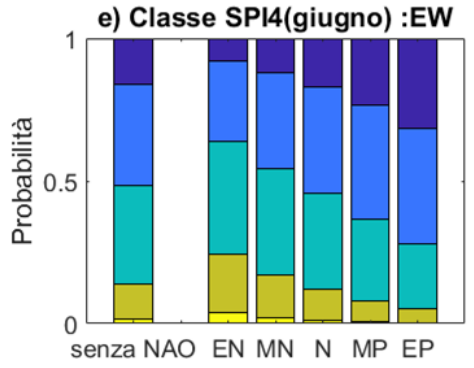
$$R\left(SPI3(ago), NAO(giu)\right) > 0$$

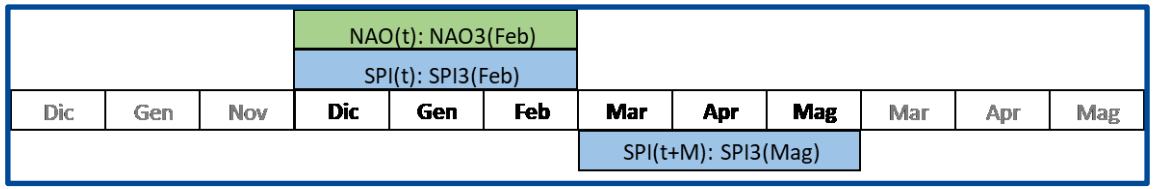


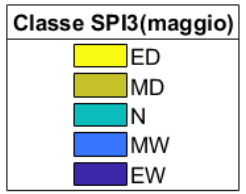






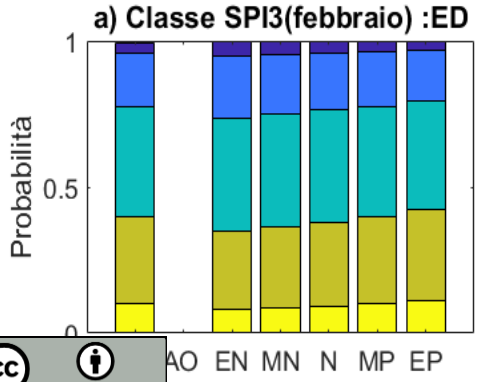


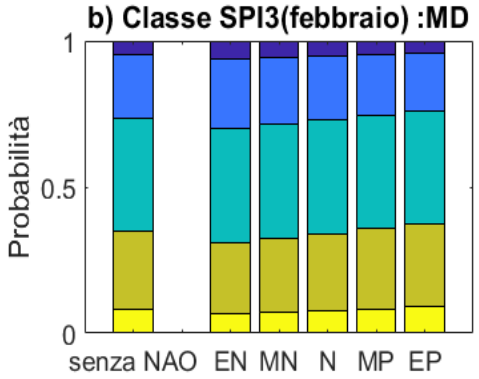


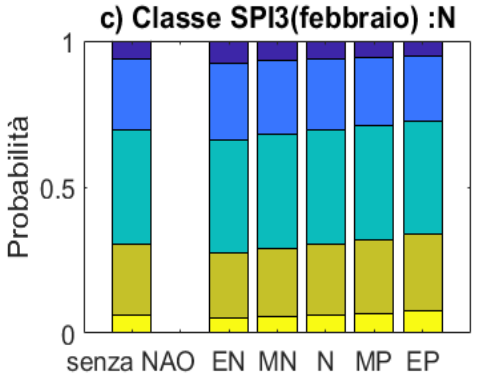


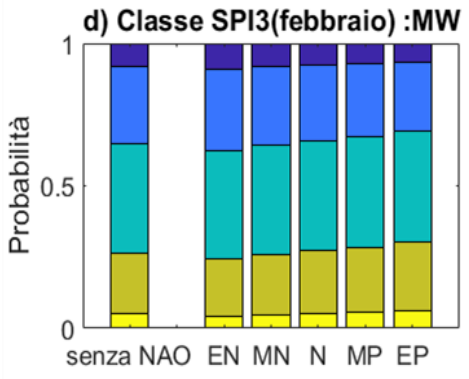
Coefficiente di correlazione:

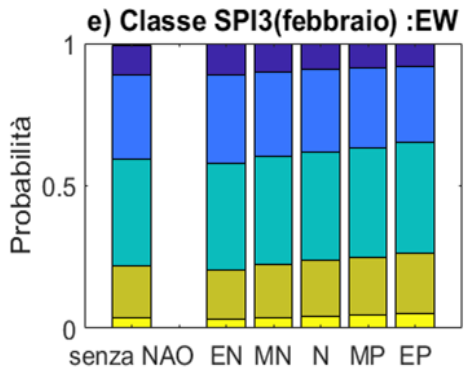
$$R\left(SPI3(mag), NAO(feb)\right) < 0$$











RANDOM FOREST