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PRELIMINARY EXPLORATION OF RELEVANT PREDICTORS USABLE ON AN EMPIRICAL SEASONAL FORECASTING SYSTEM FOR THE MOSES PROJECT PILOT REGIONS

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1.- INTRODUCTION AND MOTIVATION

The MOSES project (www.moses-project.eu) was created to facilitate planning of irrigation water resources with the aim of saving water and reducing monetary and energy costs. One of the main tools to achieve these goals is seasonal forecasting. The skill of seasonal forecasts provided by any system based on statistical algorithms relies heavily on adequate selection of the relevant predictors for the target region, season and predictands.

As a previous step in the search for and investigation of the best predictors leading to more accurate forecasts, a preliminary exploration has been carried out among the usual global and regional teleconnection indices. This exploration has been conducted over four MOSES pilot areas (in Spain, Morocco, Romania and Italy) and covers up to four seasons prior to the forecasted one. The list of considered predictors discussed here is not exhaustive and should be considered as a first approximation to be completed and expanded upon using other sources of predictability arising from tropical and mid-latitudes, oceans, extent of sea-ice and snow-covered land, soil moisture, etc.

2.- DATA

1. Predictands

- ***Surface air temperature:*** from ERA-interim (Dee et al. 2011).
- ***Precipitation:*** from GPCC (Schneider et al. 2011) and ERA-Interim.

2. Predictors

Predictor	Description	Predictor	Description	Predictor	Description
WP	West Pacific index	NPGO	North Pacific Gyre Oscillation	AO	Arctic Oscillation
PNA	Pacific/North American index	IOD	Indian Ocean Dipole index	WEMO	Western Mediterranean Oscillation
NINO1+2	Nino 1+2 index	NAO	North Atlantic Oscillation	QBO	Quasi-Biennial Oscillation
NINO3	Nino 3 index	*EA*	East Atlantic pattern	SAI-d	Daily Snow Advance index
NINO3.4	Nino 3.4 index	*EA-WR*	East Atlantic/Western Russia pattern	SAI-w	Weekly Snow Advance index
NINO4	Nino 4 index	*AMO*	Atlantic Multidecadal Oscillation	SAI-w-ext	Extended SAI-w
EMI	El Niño Modoki index	*AT*	Atlantic Tripole	SVI	Snow Variability index
SOI	Southern Oscillation index	SCAND	Scandinavia pattern		
PDO	Pacific Decadal Oscillation	TNA	Tropical Northern Atlantic index		

The period used for the predictors and predictands is 1981-2010. Due to data availability, the period for SAI-d, SAI-w and SVI is 2000-2010 and for TNA is 1981-2000.

3.- METHODOLOGY

To explore the best predictors for temperature and precipitation over the selected areas, the method proposed by Eden et al. (2015) has been followed. This approach computes Pearson correlation and p-value (for estimation of significancy) between the two predictands (temperature and precipitation) and each of the predictors for spring (MAM), summer (JJA), autumn (SON) and winter (DJF).

Four different lags have been used for the computation of the correlation between pairs of predictands and predictors, always averaged for 3 month periods. Lead times of 1, 4, 7 and 10 months have been explored. For example, 4 months lead (ml) time means that the averaged predictor for JJA is correlated with the average predictand for NDJ, and so on.

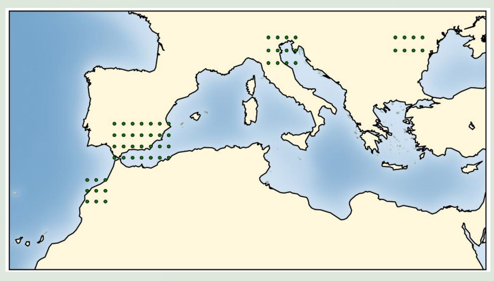

Figure 1 shows the computational grid points for the 4 selected pilot areas over Spain, Morocco, Romania and Italy.

Figure 1: Computational domains where the Pearson correlation between teleconnection indices and lagging precipitation and temperature is computed.

4.- RESULTS

Figure 2: Number of grid points over Spain, Morocco, Romania and Italy domains (expressed in percentage) with significant correlation coefficient (at 95% confidence level) between teleconnection indices and lagging precipitation (left column) and temperature (right column) from ERA-Interim (E) and GPCC (G). The colours (red, yellow and green) are used to represent the average value of the correlation coefficient (■ 10-30% ■ 30-60% ■+60%). Correlation coefficients are computed for the period 1981-2010. TNA index (*) is referred to 1981-2000 and snow advance indices (**) are referred to the period 2000-2010. 1ml, 4ml 7ml, and 10ml correspond to teleconnection indices leading 1, 4, 7 and 10 months respectively. The correlation for the snow advance indices is only computed for DJF.

The relevancy of the predictors computed is expressed (see Figure 2) as the number (percentage) of grid points with significant correlation (at 95% confidence level). A table showing the results for each predictor, season and month lead time, has been obtained for each pilot area and predictand (temperature and precipitation*)*.

Temperature

- For the Spanish pilot area, the only predictor with a high percentage of grid points with significant correlation is AT for autumn temperature. There are no significant predictors in winter, and only a few predictors with moderate percentages (mostly Atlantic indices) in spring and summer.
- For the Moroccan pilot area, only few predictors with moderate percentages appear for all seasons. Over this area only two relevant predictors -high percentage of grid points with significant correlation- are identified: IOD in spring and AT in autumn.
- For the Romanian pilot area, a big number of predictors with high or very high percentages are spread across all seasons. Many of these predictors are clustered in autumn, and correspond both to Pacific and Atlantic indices. In spring, only few Pacific indices show good results.
- For the Italian pilot area, a great number of predictors are identified with high or very high percentages as well as several predictors with moderate percentages are distributed among all seasons. In summer, NINO indices adequately predict summer temperature (with high percentages) for several consecutive lead times. This is in contrast to the rest of the areas, where predictability associated to a given teleconnexion index is not maintained for increasing lead times.

Precipitation

- For all pilot areas, several potential predictors distributed over all seasons are identified.
- For the Spanish, Moroccan and Italian pilot areas the snow advance indices show very high percentages for winter precipitation using both databases, being these indices key predictors for winter precipitation over these pilot areas.
- For the Spanish pilot area the only relevant predictors with high percentages are WP for spring, EMI for summer and snow advance indices for winter. The NINO indices for summer and autumn maintain their predictability over time, while the rest don't. Although in general, the predictability for temperature is higher than the predictability for precipitation, the opposite occurs over the Spanish pilot area.
- For the Moroccan pilot area, relevant predictors with high percentages appear only in spring (WP and PNA) and winter (some Atlantic predictors as well as snow advance indices).
- For the Romanian pilot area, relevant predictors with high percentages can be found in spring (Pacific indices), autumn (Atlantic indices) and winter. In particular, AT shows maintained high predictability for autumn precipitation up to 4ml.
- For the Italian pilot area, the only relevant predictors with high percentages are snow advance indices and WP (1ml) in winter. The other seasons do not seem to have relevant predictors.
- Small differences can be noticed in the percentage values of certain pilot areas and predictors when different databases are used. These differences are more noticeable for the Moroccan pilot area, where ERA-Interim shows significantly higher percentages than GPCC. This difference could be attributed to the lack of observations over this area, which may negatively affect the results from GPCC which is solely based on the available observations.

5.- CONCLUSIONS

BEST PREDITORS FOR MOSES AREA

		Spain				Morocco				Romania				Italy			
		MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF
P	ERA	WP			SAI-d SAI-w SVI	WP TNA			SAI-d SAI-w SAI-w-e NAO AO	Nino3.4 Nino3 SOI		EA EA-WR AT TNA QBO					WP SAI-d SAI-w
	GPCC		EMI		SAI-d SAI-w SAI-w-e SVI	TNA WP			SAI-d SAI-w SAI-w-e AT	PDO Nino3.4 SOI		AT NAO					WP SAI-d
T	ERA			AT		IOD		AT		EMI SOI NPGO	NAO	PNA Nino4 SOI PDO EA EA-WR SCAND AO QBO	IOD	Nino4 EMI IOD AMO SCAND	Nino3.4 Nino3 SOI PDO AMO AO WEMO	WP Nino3.4 SOI EA EA-WR QBO	Nino3.4 SOI IOD

Figure 3: Table summarizing the list of teleconnection indices significantly correlating with lagging precipitation and temperature computed from ERA-Interim (ERA) and GPCC. Only indices with significant correlation equal or more than 50% of grid points in the corresponding domain are included.

- There are fewer predictors with significant correlation over the Spanish and Moroccan pilot areas, as compared with the Romanian and especially the Italian pilot areas, where the higher number of predictors with high correlations for most seasons (both from Pacific and Atlantic indices) will ensure better skill for a statistical forecasting system based on such predictors (see Figure 3).
- Snow advance indices are very relevant predictors for winter precipitation for all pilot areas, except for the Romanian one.
- Regarding temperature, the predictability associated to a certain teleconnexion index for a given pilot area does not seem to be maintained for increasing lead time, whereas for precipitation several teleconnexion indices tend to maintain predictability as lead time increases.
- Over the Moroccan pilot area, there are noticeable differences for the precipitation predictors using both databases. This may be due to the lack of observations in this domain causing significant differences in both data bases.

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References for the predictors

- NINO3.4, QBO, AMO, IOD, WP, SOI, EA, NAO, AO, SCAND: https://climexp.knmi.nl//start.cgi?id=someone@somewhere
- EMI: *www.jamstec.go.jp/*
- WEMO: *http://www.ub.edu/gc/English/wemo.htm*
- NPGO: *http://www.o3d.org/npgo/*
- PDO: *http://research.jisao.washington.edu/pdo/*
- NINO1+2, NINO3, NINO4, AT, TNA: http:*//www.esrl.noaa.gov/psd/data/climateindices/list*
- SAI-d, SAI-w, SAI-w-ext, SVI: provided by Federico Franco Manzano (AEMET)