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European Geosciences Union
General Assembly 2010
Vienna, 02-07 May 2010

CL4.3 Regional Climate Modeling and impacts

Dynamical downscaling of snow trends in Northern Iberia based on ENSEMBLES regional simulations

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Abstract

A recent study by ***Pons et al.*** **(2009)** reported a **significant decreasing trend of snow occurrence (-4.8 days/decade) in the Northern Iberian Peninsula since the mid seventies**. This study was based on observations of annual snow frequency (measured as the annual number of snow days) from a network of 33 stations ranging from 60 to 1350 meters.

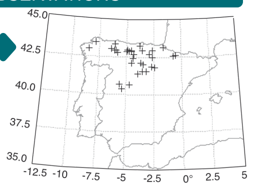
In the present work **we analyze the skill of dynamical downscaling methods to reproduce this trend in present climate conditions and also to further project it into the future** from A1B-scenario global simulations. In particular, we consider the regional simulation **dataset from the ENSEMBLES project**, consisting in ten state-of-the-art RCMs at 25km resolution run with different forcings.

Results

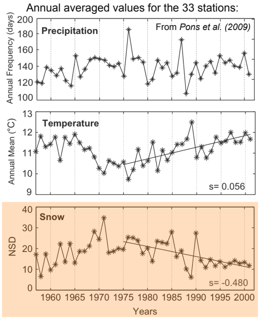
Firstly, all RCMs appropriately reproduce the interannual variability and the observed trends (after bias removal) using perfect boundaries from ERA40 (**the ensemble mean presents a trend of -4.8 days/decade**). For the case of transient global simulation boundaries the results are quite variable with the greatest uncertainty being associated with the particular GCM used (ECHAM5 or HadCM3) with trends ranging from -4.7 to 0.8 days/decade, respectively. Finally, the trends for the **future 2010-2040 A1B runs** were approx. **-3.5 days/decade** for both models, indicating a future decreasing trend.

1. DATASETS: OBSERVATIONS

We consider snow frequency (Number of Snow Days per year, **NSD**) from 33 stations in the Northern Iberia with low-mid heights (60 to 1350 m), exhibiting a decreasing trend (-4.8 days/decade) in the last quarter of the XX[th] century (more details in *Pons et al. 2009)*.



Annual averaged values for the 33 stations:



Station	Height	Latitude	Longitude	NSD
Grado[a]	60	43.38	−6.06	2.00
Santesteban[a]	131	43.13	−1.66	4.36
Villacarriedo[a]	212	43.23	−3.80	4.67
Montaos-Ordes	306	43.04	−8.42	1.59
As Pontes de Garcia[a]	343	43.45	−7.86	3.14
Cenicero Industrial[a]	430	42.48	−2.64	7.67
Miranda de Ebro[a]	520	42.68	−2.96	7.51
Urrunaga 'Presa'	540	42.96	−2.65	6.30
Villarcayo	595	42.94	−3.57	12.72
Javierregay	690	42.59	−0.74	7.69
Monzon de Campos[a]	754	42.12	−4.49	7.61
Osorno	809	42.41	−4.36	9.24
San Miguel de Bernuy	839	41.40	−3.95	12.65
Pantano de Sta. Teresa[a]	840	40.67	−5.60	12.46
Alar del Rey[a]	851	42.66	−4.31	17.60
San Esteban de Gormaz[a]	860	41.57	−3.20	12.11
Retuerta	900	42.03	−3.51	17.77
Linares de Arroyo[a]	911	41.53	−3.56	12.91
Bescos de Garcipollera	920	42.63	−0.50	13.58
Torrecilla del Monte	949	42.09	−3.69	7.82
La Magdalena[a]	998	42.78	−5.80	15.84
Pantano de Cervera	1000	42.87	−4.53	23.23
Garray	1010	41.82	−2.45	9.59
Pantano de Requejada[a]	1024	42.91	−4.53	26.13
Boca de Huergano	1104	42.97	−4.93	32.98
Prioro[a]	1123	42.89	−4.96	34.24
Avila 'Observatorio'	1130	40.65	−4.68	16.49
Embalse Cuerda del Pozo	1150	41.88	−2.70	25.32
Rabanal de Luna[a]	1150	42.93	−5.97	33.80
Genestoso	1180	43.06	−6.40	49.54
Huergas de Babia	1222	42.96	−6.09	45.27
Pantano de Camporredondo[a]	1253	42.90	−4.74	36.18
Zapardiel de La Ribera	1353	40.36	−5.33	28.82
Mean values	823	42.42	−4.26	16.93

2. DATASETS: REGIONAL MODELS (RCMs)

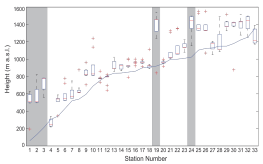
We considered the ENSEMBLE RCM multi-model simulations (10 models in the rows of the table below) at 25km resolution with different boundary conditions (in columns):

- ERA40 (1961-2002).
- A1B-scenario (1961-2040): HadCM3 (METO-HC) and ECHAM5 (MPIMET) global models have been used (they have at least four coupled RCMs).

RCM \ GCM	ERA40	METO-HC, Std	MPIMET
METO-HC *HadRM*	1961–2002	1951–2100	~~1951–2100~~
MPIMET *REMO*	1961–2002		1951–2100
CNRM *ALADIN*	1961–2002		
DMI *HIRHAM*	1961–2002		1951–2100*
ETH *CLM*	1961–2002	1951–2100	
KNMI *RACMO*	1961–2002		1951–2100
~~ICTP *RegCM*~~	~~1961–2002~~		~~1951–2100~~
SMHI *RCA3*	1961–2002		1951–2100*
UCLM *PROMES*	1961–2002	1951–2050	
Met.No *HIRHAM*	1961–2002	1951–2050	

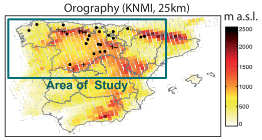
The ENSEMBLES RCM simulations at 25 km resolution (*see van der Linden and Mitchell 2009*). Available ENSEMBLES models with snow data from http://ensemblesrt3.dmi.dk

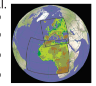
Since each RCM has a different rotated grid, we compared the heights for each of the 33 stations with those from the closest RCM grid points (represented by the 'box-and-whiskers' plot in the figure below), **discarding those stations differing over 300m** (the five shaded in the figure).



Thus, 28 stations were considered in this study and RCM values were interpolated to the stations' locations.

Orography (KNMI, 25km)



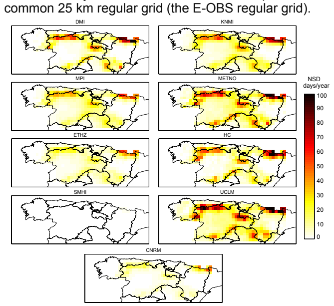


ENSEMBLES European and African domains.

The 25km grid of a typical model (KNMI) is illustrated in the figure above displaying the height of the grid points.

Snow frequency (NSD) was obtained from snow flux (kg m^{-2} s^{-1}) using a threshold of 1 mm/day.

The figure below shows the NSD values given by the 9 RCMs driven by ERA40 in the period 1961-2000. For the sake of clarity, the values have been interpolated to a common 25 km regular grid (the E-OBS regular grid).



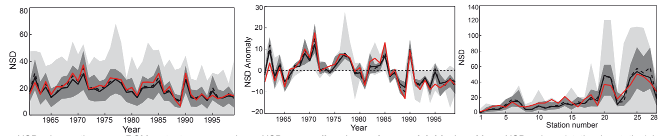
The Pearson correlation coefficient for the RCM values averaged over the 28 stations and the corresponding observations were computed for NSD, precipitation frequency (days > 1mm) and mean temperature.

MODEL	NSD	PRECIP	TEMP
DMI	0.940	0.787	0.872
MPI	0.909	0.851	0.898
KNMI	0.902	0.803	0.873
HC	0.896	0.718	0.825
METNO	0.893	0.846	0.922
ETHZ	0.883	0.877	0.928
CNRM	0.703	0.442	0.796
UCLM	0.675	0.630	0.764
SMHI	0.293	0.784	0.875

The three models in red were discarded.

3. RESULTS FROM ERA40-COUPLED SIMULATIONS

The red curve in the figures below shows the interannual variability of the mean observed NSD in the period 1961-2000 (see Sec. 1), together with the 9- and 6 RCM-member ensemble (in light and dark grey, respectively), and the corresponding mean values (dashed and solid lines, respectively). It can be seen that the selected RCMs appropriately reproduce the interannual variability.



NSD observations vs. RCM outputs, averaged over the 28 stations (raw or interpolated values)

NSD **anomalies (removing model bias)** from observations vs. RCM outputs.

Mean NSD values (station by station) in the whole (1961-2000) period.

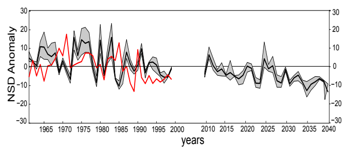
4. TRANSIENT AND FUTURE A1B PROJECTIONS

The table below shows the slopes (days/year) for the different simulation in the transient (1961-2000) and future (2010-2040) projections corresponding to A1B scenario runs (for the sake of comparison, the slopes for the ERA40 forced simulations are also shown). Note that the RCM coupled to the different global models (ECHAM5 and HADCM3) exhibit a different performance over the transient period, with no significant trends in the former case. However, all RCM simulations exhibit similar results for the period 2010-2040, with an average trend of -3.5 days/decade.

		1960-2000 (A1B)		2010-40 (A1B)	
	ERA40	ECHAM5	HADCM3	ECHAM5	HADCM3
DMI:	-0.40	-0.02		-0.44	
MPI	-0.41	0.13		-0.34	
KNMI	-0.48	0.13		-0.34	
HC	-0.55		-0.50		-0.34
METNO	-0.54		-0.65		-0.43
ETHZ	-0.26		-0.25		-0.19
CNRM	-0.19				
UCLM	-0.88				
SMHI	0.00				
Mean	**-0.44**	**0.08**	**-0.47**	**-0.37**	**-0.32**

Trends (days/year) for the simulations of the different RCMs coupled to ERA40 or to different GCMs under transient or future A1B scenarios.

Transient and future projections (A1B) for the ensemble of 3 RCMs coupled to the **HadCM3** global model. The simulations capture the decreasing trend observed since the mid 70s and further project it into the XXI[st] century at a -3.7 days/decade rate.



References

- Pons, M.R., D. San-Martín, S. Herrera and J.M. Gutiérrez (2009), Snow Trends in Northern Spain. Analysis and simulation with statistical downscaling methods, International Journal of Climatology, DOI. 10.1002/joc.2016
- van der Linden and Mitchell (eds.) 2009 "ENSEMBLES: Climate Change and its Impacts: Summary of research and results from the ENSEMBLES project". http://ensembles-eu.metoffice.com/

Acknowledgements: We acknowledge AEMET and ENSEMBLES (DMI) for providing the data for this work.