Analysis of 21st Century monthly temperature in Basque Country

Gaztelumendi S.[1,2], Egaña J.[1,2] , Hernandez R.[1,2]

1- Basque Meteorology Agency (Euskalmet).
2- Meteorology Area, Energy and Environment Division, Tecnalia R&I.

Abstract

This contribution deal on observed mean regional climate, and particularly in temperature monthly behavior during twenty-first century, focusing in the Basque Country area at north part of Iberian Peninsula. We present some statistical data, tables, graphs and maps for maximum, minimum and mean monthly temperature in order to a better explanation of 21st century temperature behavior in Basque Country. We also include some comments about extreme seasons and months in the study area. Finally some preliminary trend analysis and conclusions are presented.

In this preliminary study we use four weather stations representing different areas of the Basque Country with different climatic characteristics. The classification of the mean temperature is determined by a frequency index, based on a simple criterion, in particular, in calculating percentiles with a distance of 20%. This leads to five classes (very cold, cold, normal, warm, very warm), plus two, when the value exceeds the minimum or maximum registered (extremely cold, extremely hot). The nonparametric Mann-Kendall (MK) test is used for trend analysis.

Introduction.

Is a extended practice in many Weather Services (WS) the regular (monthly, seasonal and yearly) publications of weather summaries or reports. Those documents are one of the most important and available official publication of climatological data for each country. The basic monthly, seasonal and annual summaries of temperature, rainfall and other climate elements provide an essential resource fro many users (WMO 2003). In some cases those reports includes anomalies information usually for temperature and precipitation for a given spatial coverage.

Basque Meteorology Agency (Euskalmet) produces monthly, seasonal and yearly a variety of reports with meteorological and climatological analysis for Basque Country. This documents content detailed explanations of the local weather, including different statistics for weather elements, description of severe weather episodes and anomalies, among others elements (see Hernandez et al 2009, Gaztelumendi et al 2010).

By instance, in monthly weather review, the section referring to temperatures begin with a comment from observed temperature anomalies during this month. Those reports are very popular for media and users, due to its “climatic” content and easy accessibility. Referred reports, at the end, are a key piece in media/public perception of normality and source of popular comments about abnormality linked with climate change.

Methodology

DATA:

Data used in this work are AEMET daily temperatures available in the area. from different climate repositories (e.g. ECA&D - Klein 2002) Here we consider Basque Country temperatures by means of daily observations from four weather stations (BI,SS,VI,LO) representative of areas with different climatic characteristics .

ANOMALIES:

The normal reference period taken for calculus are 1971-2000 The classification of temperatures is determined by a frequency index (f), based in percentiles with a distance of 20%. Extremely Hot/Cold: when value are never recorded in the reference period. Very Hot/Cold: when value are in the 20% of hot/cold years (f < 20% / f >80%). Hot/Cold: when value are in the 20-40% of hot/cold years (20% ≤ f < 40% / 60% ≤ f < 80%). Normal: temperature value are around median (40% ≤ f < 60%)

Same stations and methodology that are used for the official monthly and seasonal temperature classification available for the Basque Country from monthly weather bulletins until 2015 (see Hernández et al., 2009 for details).

TRENDS:

In order to a preliminary study of temperature trends we perform two types of statistical analyses. First we test the presence of a monotonic increasing or decreasing trend with the nonparametric Mann-Kendall (MK) test and secondly we estimate the slope of the linear trend with the nonparametric Sen’s method (Mann 1945; Sen 1968, Kendall 1975; Gilbert 1987, Salmi et al. 2002). For time series with less than 10 years the S test (Gilbert 1987) is used, and for the rest the normal approximation (Z statistics).

Results and Discussion

.ANOMALIES:

For analysis and discussion, data are presented in two tables with calendar format and colors showing cold and warm departures from normal and anomalies value in degrees Celsius (see tab 1 and tab 2). Histograms are presented for Tmean (tg), Tmax (tx) and Tmin (tn) for different aggregation periods (yearly, monthly and seasonally) , for the whole territory (fig 2 and 3)and for SS,BI and VI (fig 3).

General behavior

During this period there is a tendency to positive anomalies for temperature and negative for precipitation in seasonal and monthly data. We can see seasonal and monthly observed histograms in Fig.1 and Fig.2).

During 21st century 55% of months shown positive monthly mean temperature anomalies and just 20% shows negative anomalies. No negative anomalies for yearly mean temperature are observed. The warmest years are 2003, 2006, 2011 and 2014 with positive anomalies above 1 °C. If we make the average annual anomalies a positive anomaly close to 1 ° C is obtained in the study period.

Every month presents positive anomalies, except the months of December and February that break that trend with slight negative values. Highlight April, June and October with values above 1 ° C.

A seasonal analysis for 21st century in the Basque Country shows spring and autumn with mean temperature positive anomalies, those seasons are dynamically very active with high influence of mobile pressure systems. Summers shows a positive anomaly around 0.5 ° C, not particularly hot possible due to mean influence by the sea proximity. Highlight that winters have a behavior different from other seasons, with values slightly below normal. This is possible due to some influence from the slowdown of the Gulf Stream (Rahmstorf et al, 2015) and some changes of synoptic patterns, favoring cold air invasions in Western Europe that would affect to the Basque Country. Anyway, mild winters with positive NAO and intense zonal circulation are also present, such as winter 2013-2014 when few snow events registered but high number of wave events.

Relevant anomalies.

In August 2003 the Basque Country, as many others European countries was affected by one of the more relevant heat wave episode ever recorded, as a climatic consequence August reaches a mean temperature of 4 ° C above normal. This situation in the Basque Country is also preceded by an unusual month of June with a positive anomaly also near 4 ° C. During 2003 summer the sea surface temperature (SST) in the Basque coast reach values never before registered, rising to 26 ° C (punctually higher), with an average August SST around 25 ° C. In the opposite side 2002 was the year “without summer”, summer period was one of the coldest of the past 70 years. Negative anomalies in the months of July and August above 1 ° C are produced.

The autumn of 2006, one of the warmest autumns in many parts of Europe, present in the Basque Country case positive anomalies above 3 ° C for the months of October and November. 2011 and 2014 autumns have also been very warm autumns, but without reaching 2006 anomalies values.

In 2011 besides a warm autumn also a warm spring occurs, especially April, with positive anomaly that exceeds 4 ° C, being the warmest April ever recorded since we have data. Meanwhile, in 2013 the spring is cold, especially May with a negative anomaly above 2 ° C. June is also cold with negative anomaly about 1 ° C.

2004-2005 and 2005-2006 winters were really severe with high negative anomalies especially during February and December 2005 . During 2005-2006 winter six relevant cold air entries are produced, where usually no more than one or two relevant entries each winter occurs. Also highlight the cold wave in February 2012 that occurs during the first half of the month, one of the cold waves more relevant in Europe, although far from the famous cold wave of February 1956. This cold wave is responsible for a negative anomaly around 3 ° C. Recent winters have been particularly warm, highlighting the winter of 2013-2014, with very few snow or cold events.

Remarks

In this work we have presented some statistical data, tables, and graphs based on data categorization schemes usually provided by Weather Services. In the Basque Country case during 21st century and due to observed temperatures and 71-00 normal consideration, “extremely or very” hot/cold months has been reported 72/19 times, and normal+hot+cold 89 times, just 50% months.

Moving reference period, as recommended from WMO, from 1971-2000 to 1981-2010 has impact in message transmission and public perception. New normal period suppose for last five years (tab 2) an increase in cold extremes and a decrease in hot extremes, contributing on one hand to transmit the new climate reality and a increasing in variability. But on the other hand contributing to relax warming.

This aspect need to be considered . for communication purposes, and perhaps better to retain some kind of normal referred to 20st century, and the coexistence of different reference periods

Unless no trend is clear during 21-st century (0,01ºC per year with less than 90% significance) in our area using mentioned stations and methodology, a trend (90% sig) of 0,05 ºC per year is found in a preliminary experiment based on temperatures available from Basque Government AWS network (not shown).

Fig 1 Basque Country and SS (1) ,BI(2),VI (3) and LO(4) location.

	Extremely Cold	Very Cold	Cold	Normal	Hot	Very Hot	Extremely Hot
	EC	VC	C	N	H	VH	EH

TG	WIN	SPR	SUM	FAL
2001	1,0	1,4	0,7	-0,2
2002	0,1	0,7	-0,7	0,8
2003	0,5	2,0	3,2	0,5
2004	0,3	-0,5	1,3	0,6
2005	-1,2	1,2	1,4	0,4
2006	-1,7	1,8	1,6	2,8
2007	0,7	1,0	0,2	-0,8
2008	1,0	0,8	0,1	-0,8
2009	-0,6	0,6	1,6	1,3
2010	-0,7	0,6	0,5	-0,4
2011	-0,1	2,5	0,4	2,1
2012	-0,4	1,0	1,2	0,4
2013	0,0	-0,5	0,6	1,0
2014	0,9	1,4	0,7	2,8
2015	-0,7	1,5	1,8	0,4

JAN		1	3	2	4	5						
FEB	2	1	4	2	4	2						
MAR		1	1	4	5	2	2					
APR				3	4	6	2					
MAY		1	1	3	5	5						
JUN		1		1	2	7	4					
JUL		1	4	4	1	3	2					
AUG		1	2	6		5	1					
SEP			4	4	4	3						
OCT			3	3	1	7	1					
NOV		3	4	2		6						
DEC		6	2	2	3	2						

2001	0	2	2	2	1	4	1					
2002	0	2	1	1	3	5	0					
2003	0	0	2	1	3	3	3					
2004	0	1	2	4	1	3	1					
2005	1	1	2	2	1	4	1					
2006	0	3	1	0	0	5	3					
2007	0	2	3	2	2	3	0					
2008	0	1	3	3	2	3	0					
2009	0	0	1	4	2	5	0					
2010	0	1	5	4	1	1	0					
2011	0	0	1	0	4	6	1					
2012	1	0	1	3	4	3	0					
2013	0	2	2	2	4	1	1					
2014	0	0	0	4	2	4	2					
2015	0	1	1	1	4	3	2					

Tab 1. Monthly anomalies and classification, counts per month and year.

TG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2001	1,2	0,2	3,5	0,1	0,6	1,1	-0,3	1,5	-1,3	2,8	-1,9	-3,2
2002	1,9	1,5	1,7	0,6	-0,3	0,5	-1,3	-1,3	-0,4	1,0	1,6	2,5
2003	0,1	-1,1	2,8	2,2	0,8	4,3	1,4	4,0	1,1	-0,7	1,3	0,4
2004	1,6	-1,2	-1,4	-0,2	-0,1	2,7	0,0	1,1	1,1	1,8	-1,0	0,1
2005	-0,6	-3,3	0,5	1,3	1,9	3,3	1,1	-0,1	-0,1	2,1	-0,8	-2,5
2006	-0,9	-1,9	2,1	1,5	1,9	2,6	3,3	-0,9	1,9	3,4	3,0	-1,1
2007	0,8	2,2	-0,4	2,5	0,8	1,2	0,0	-0,6	-0,9	-0,2	-1,4	-1,0
2008	1,7	2,2	0,0	1,2	1,2	0,5	-0,2	0,1	-0,7	-0,9	-0,9	-1,0
2009	-0,2	-0,7	0,1	0,3	1,4	2,2	1,3	1,3	0,4	1,4	2,1	-0,4
2010	-0,8	-1,0	0,1	2,3	-0,6	0,2	1,0	0,3	-0,2	-0,3	-0,6	-1,7
2011	0,5	0,8	1,0	4,3	2,4	0,9	-1,0	1,2	2,1	1,3	3,0	1,0
2012	0,7	-3,0	1,3	-0,3	2,0	2,1	-0,4	1,7	0,4	0,5	0,2	0,6
2013	0,7	-1,5	0,4	0,4	-2,5	-1,1	2,6	0,3	0,9	2,3	-0,3	-0,3
2014	2,4	0,5	1,0	3,2	-0,1	1,9	0,2	-0,1	2,4	3,6	2,4	0,0
2015	0,0	-2,2	0,2	2,7	1,5	2,2	2,2	1,0	-1,2	0,5	2,1	2,5

WINTER	0	2	3	5	3	2	0					
SPRING	0	0	2	0	3	8	2					
SUMMER	0	1	0	2	4	3	5					
FALL	0	2	1	1	4	4	3					

Tab 2. Seasonal anomalies and classification, counts per season and year.

2011	0,2	1,0	0,4	3,7	1,8	0,1	-1,4	0,8	1,9	0,8	2,6	1,1
2012	0,4	-2,8	0,7	-0,9	1,4	1,3	-0,8	1,4	0,1	0,0	-0,2	0,7
2013	0,5	-1,3	-0,1	-0,2	-3,1	-2,0	2,2	-0,1	0,6	1,7	-0,6	-0,2
2014	2,2	0,7	0,4	2,6	-0,6	1,0	-0,2	-0,4	2,2	3,0	2,1	0,1
2015	-0,2	-2,0	-0,4	2,1	0,9	1,3	1,7	0,6	-1,5	-0,1	1,8	2,6

Tab 3. 2011-05 tg monthly anomalies (reference period 81-10) and histograms for 81-10 and 71-00).

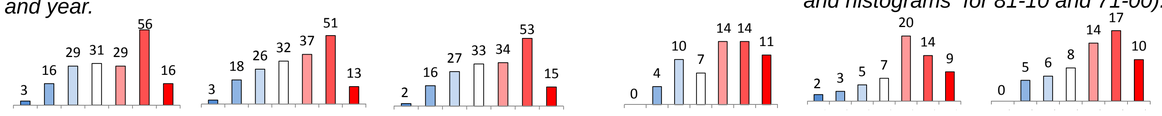


Fig 2. tn, tx and tg histograms for monthly and seasons classification

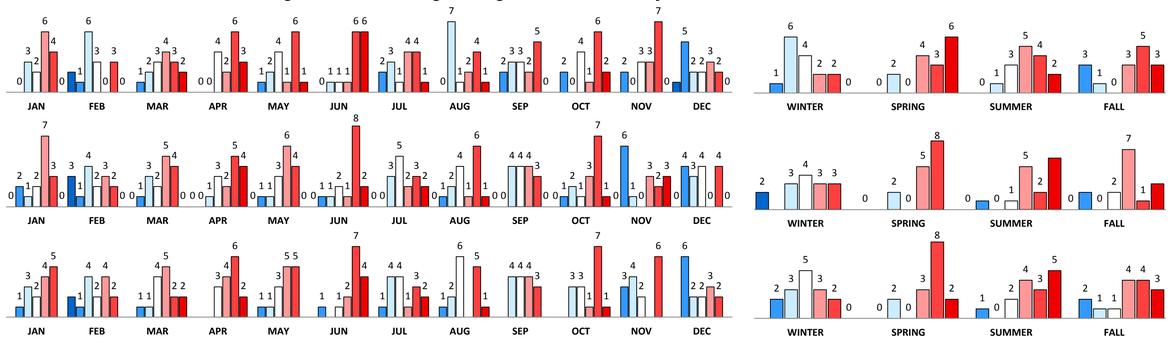


Fig 3. tn, tx and tg histograms for monthly and seasons classification (top to down left to right)

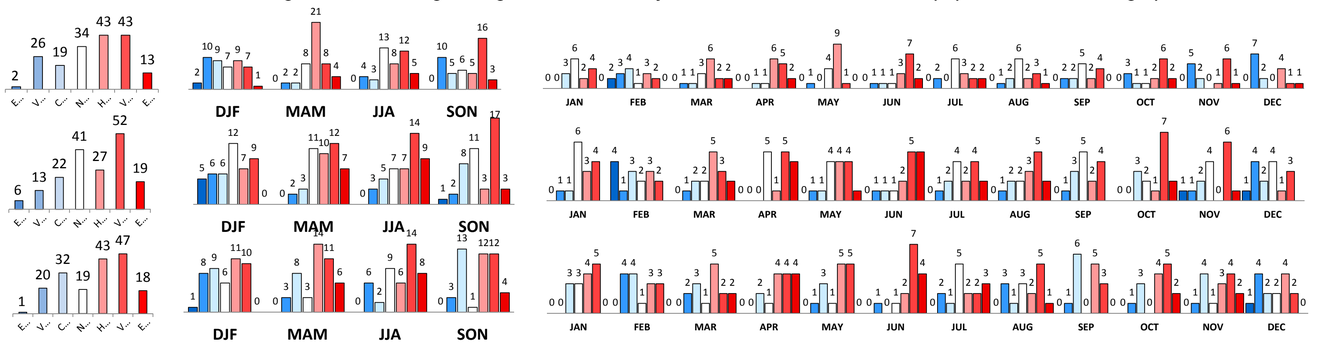


Fig 4. tg-SS, tg-BI, tg-VI histograms for yearly, seasonal and monthly classification (top to down left to right)

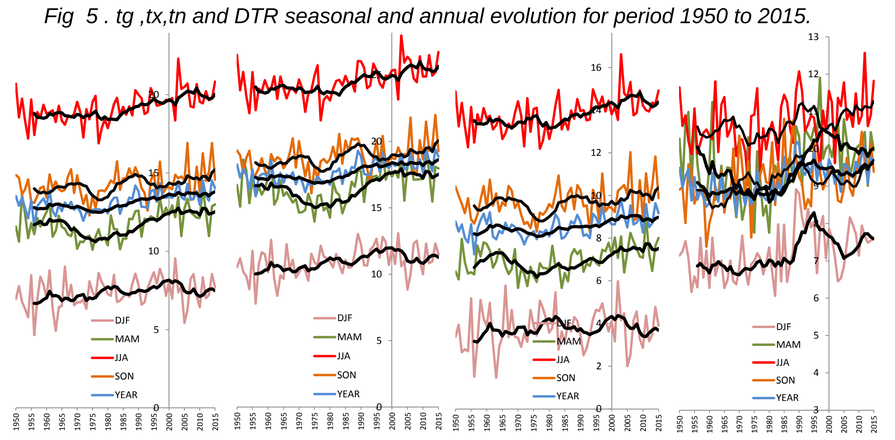
TRENDS:

In figure 5 we can see annual and seasonal behavior of Tmean(tg), Tmax(tx) Tmin(tn) and DTR (tx-tn) , we can appreciate that trends are widely present. In table 4 we have trends value (in ºC/decade) for different time aggregation and variables (including standard deviation) and MK test significance.

For period 1950-2015 a positive Tg trend is found for tg (0,18), tx(0,25), tn(0,12) and dtr(0,14) mainly driven by tx trend that double the tmin trend. Tg trend is similar in winter and fall (over 0.1) and much higher in summer and spring (over 0,2). Positive trend in Tmax are higher in spring and summer (0,3) that in fall and winter (0,2). Tmin positive trend are only significative in spring (0,14) and summer (0,2).

During last 50 years of 20st century, two different behaviors can be observed during period 1950-1974 significant negative trends are produced during 1975-1999 positive ones are present. In first case tg negative trend of 0,3 are observed with double contribution for tx that tn. In second case positive trend of 0,4 with tx (0,6) and tn (0,3). Spring shows during this period a tg positive trend of 0,85 with a tx trend of 1,27. Remark that negatives values for 50-74 period are also the most relevant.

Fig 5 . tg ,tx,tn and DTR seasonal and annual evolution for period 1950 to 2015.



Tab 4. Trend value for different periods with level of significance in green intensity from 0.001 – 99,9% to 0.1%-90%, white color for less than 90%significance.

	YEAR				DJF				MAM				JJA				SON			
	00_15	50_15	50_74	75_99	00_15	50_15	50_74	75_99	00_15	50_15	50_74	75_99	00_15	50_15	50_74	75_99	00_15	50_15	50_74	75_99
TMEAN	0,11	**0,18**	*-0,30*	**0,40**	0,20	*0,14*	0,06	0,23	0,00	**0,22**	*-0,55*	**0,83**	0,33	**0,25**	-0,14	*0,53*	0,72	*0,14*	-0,19	0,34
TMAX	0,28	**0,25**	-0,36	**0,60**	0,11	**0,21**	-0,05	0,43	0,12	**0,31**	*-0,79*	**1,27**	0,36	**0,31**	-0,17	0,58	0,68	**0,20**	-0,12	0,19
TMIN	0,07	**0,12**	-0,15	0,31	0,09	0,08	0,19	0,02	0,05	**0,14**	-0,24	0,42	0,17	**0,20**	-0,12	*0,63*	0,63	0,08	-0,30	0,25
DTR	0,21	**0,14**	-0,19	**0,38**	0,23	**0,15**	-0,12	0,46	-0,01	**0,16**	**-0,48**	**0,93**	-0,09	*0,11*	-0,18	0,04	0,50	**0,11**	0,08	-0,02
SIGTG	-0,06	0,00	0,06	-0,08	-0,11	-0,02	-0,03	-0,04	-0,38	0,01	0,08	0,00	-0,12	0,03	0,12	0,04	0,56	0,01	0,01	*-0,22*
SIGTMAX	0,01	0,01	0,06	-0,08	-0,07	-0,01	-0,09	-0,05	-0,29	0,05	0,18	0,08	-0,09	0,03	0,11	-0,06	*0,64*	-0,01	0,07	*-0,25*
SIGTMIN	-0,12	*-0,03*	0,00	-0,06	-0,19	-0,01	0,09	-0,04	-0,26	*-0,05*	0,02	-0,03	-0,19	-0,02	0,02	0,02	0,35	0,00	-0,11	*-0,16*

Focusing on 21st century, hiatus period with no significate trend are found, neither for the whole period nor 00-07 and 08-15.

Unless results are just preliminary, trend analysis are very sensitive to the period and season analyzed, and details are important, many similarities with other studies for Iberian Peninsula are found. Mean daily maximum temperatures have risen more quickly than the corresponding minimum temperatures, this implies an increase in the DTR. Spring and summer trends are the key for overall trends. No markedly trends are found for 21st century (e.g. Gonzalez-Hidalgo 2016, OPCC 2013, Bladé et al 2010, Brunet et al 2007

Acknowledgements

The authors would like to thank the Emergencies and Meteorology Directorate – Security Department - **Basque Government** for public provision of data and operational service financial support., and all our **Euskalmet** colleagues for their daily effort in promoting valuable services for the Basque community. We also would like to thank open-data (particularly data providers in the ECA&D project) and free software community (particularly R developers) for his contribution to technical and scientific advance. -

References

Bladé I, Castro-Díez Y. 2010. Tendencias atmosféricas en la Península ibérica durante el periodo instrumental en el contexto de la variabilidad climática. In Clima en España: Pasado, Presente y Futuro, Perez F, Boscolo R (eds). MedCLIVAR: Madrid, 25–42

Brunet, M., P. D. Jones, J. Sigró, O. Saladié, E. Aguilar, A. Moberg, P. M. Della-Marta, D. Lister, A. Walther, and D. López (2007), Temporal and spatial temperature variability and change over Spain during 1850–2005, J. Geophys. Res., 112, D12117, doi:10.1029/2006JD008249.

GV: 2015. Climate Change Strategy of the Basque Country to 2050. Basque government 2015.

Gaztelumendi, S., Otxoa de Alda, K., and Hernandez, R. (2003): Some aspects on the operative use of the automatic stations network of the basque country,3th ICEAWS Conference.

Gaztelumendi, S. Hernández, R. K. Otxoa de Alda, J. Egaña, I.Gelpi (2008): “Basque Meteorology Agency annual meteorological bulletins”. P0144, EMS2008–A–00722. 8th Annual Meeting of the EMS / 7th ECACAmsterdam, The Netherlands, 29 Sep - 3 Oct , 2008

Gilbert, R.O. 1987 . Statistical Methods for Environmental Pollution Monitoring, Wiley, NY

Gonzalez-Hidalgo J.C, Dhais Peña-Angulo, Michele Brunetti, Nicola Cortesi, Recent trend in temperature evolution in Spanish mainland (1951-2010): from warming to hiatus, International Journal of Climatology, 2016, 36, 6, 2405

Hernández, R. Gaztelumendi, S. Otxoa de Alda, K. J. Egaña, I.Gelpi (2009). Basque meteorology agency monthly meteorological bulletins. 9th EMS Annual Meeting - 9th European Conference on Applications of Meteorology (ECAM) 28 September – 02 October 2009 Toulouse, France

Kendall, M.G. 1975. Rank Correlation Methods, 4th edition, Charles Griffin, London

Klein-Tank AM, Winjgaard JB, Können GP, Demaree G, Gocheva A, Mileta M, Pasgiardis S, Hejkrlik L, Kern-Hansen C, Heino R, Bessemoulin P, Müller-Westermeier G, Tzanakou M, Szalai S, Palsdottir T, Fitzgerald D, Rubin S, Capaldo M, Maugueri M, Leitass A, Bukantis A, Aberfeld R, Van Engelen AFV, Forland E, Mietus M, Coelho F, Mares C, Razuvaev V, Nieplova E, Cegnar T, Lopez JA, Dahlsjtrom B, Moberg A, Kirchhofer W, Ceylan A, Pachaliuk O, Alexander LV, Petrovic P. 2002. Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. Int. J. Climatol. 22: 1441–1453

Mann, H.B. 1945. Non-parametric tests against trend, Econometrica 13:163-171.

OPCC 2013. Memoria final Acción Clima. 2013. Observatorio Pirenaico del cambio climático. POCTEFA –EFA 235/11

Salmi T, Määttä A, Anttila P, Ruoho-Airola T, Amnell T (2002). Detecting trends of annual values of atmospheric pollutants by the mann-kendall test and sen’s slope estimates -the excel template application makesens. Publications on Air Quality No. 31 Report code FMI-AQ-31. 36 pp. ISBN 951-697-563-1 ISSN 1456-789X Edita Finnish Meteorological Institute

Sen PK. 1968. Estimates of the regression coefficient based on Kendall’s tau. J. Am. Stat. Assoc. 63: 1379–1389.

Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, UK and New York, NY, 1535 pp

Tremberth KE, Fasullo JT. 2013. An apparent hiatus in global warming?. Earth’s Future 1: 19–32.

Trenberth KE, Fasullo JT, Branstator G, Phillips AS. 2014. Seasonal aspects of the recent pause in surface warming. Nat. Clim. Change 4: 911–916.

Contact info:

santiago.gaztelumendi@tecnalia.com

TECNALIA

Parque Tecnológico de Bizkaia
C/ Geldo Edificio 700
E-48160 DERIO (Bizkaia) Spain
www.tecnalia.com

16th EMS Annual Meeting
11th European Conference on Applied Climatology (ECAC)
12–16 September 2016 , Trieste, Italy