

# Validation and homogenization of hybrid temperature and precipitation series in mainland Portugal

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### RESUME



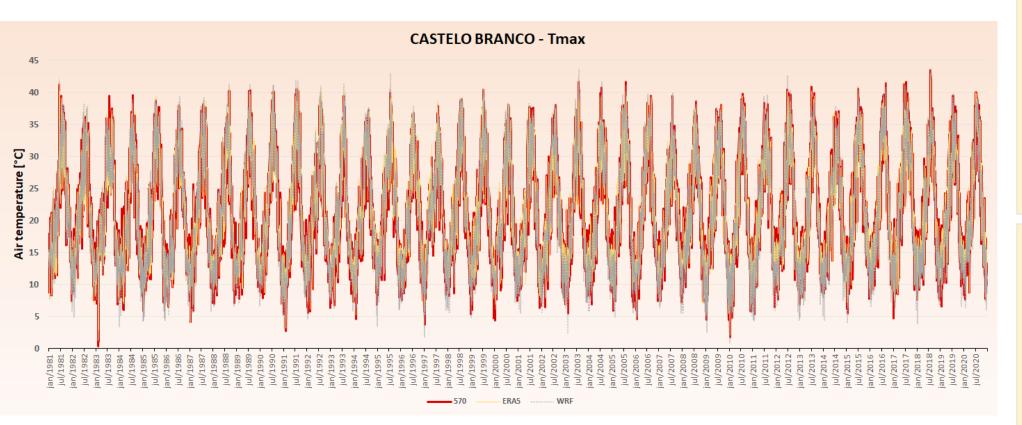
Knowledge of the climate is fundamental in the planning and management of socio-economic activities and essential to mitigate the consequences and the risks associated with climate change. The analysis of climate data provides support for the evaluation of historical data and for decision-making, especially in studies on climate change. Ensuring its quality is essential. The data collection process, through meteorological stations, can present problems, where inconsistencies can occur. The Portuguese Institute for Sea and Atmosphere, I.P. (IPMA) has meteorological data series, whose first observations date back to 1865. Maintaining their quality and homogeneity is fundamental. For the calculation of the 1981-2010 and 1991-2020 climate normal, a rigorous treatment of temperature and precipitation climate data series from the IPMA network was carried out, using validation and homogenization processes.

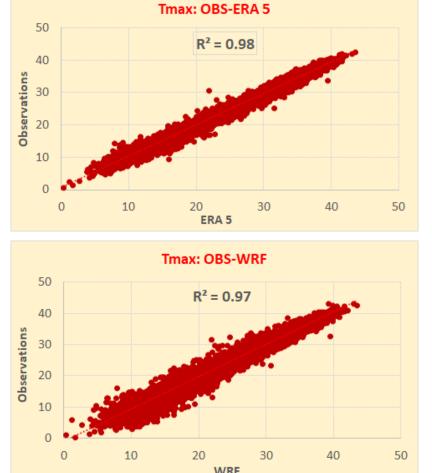
## DATA SERIES

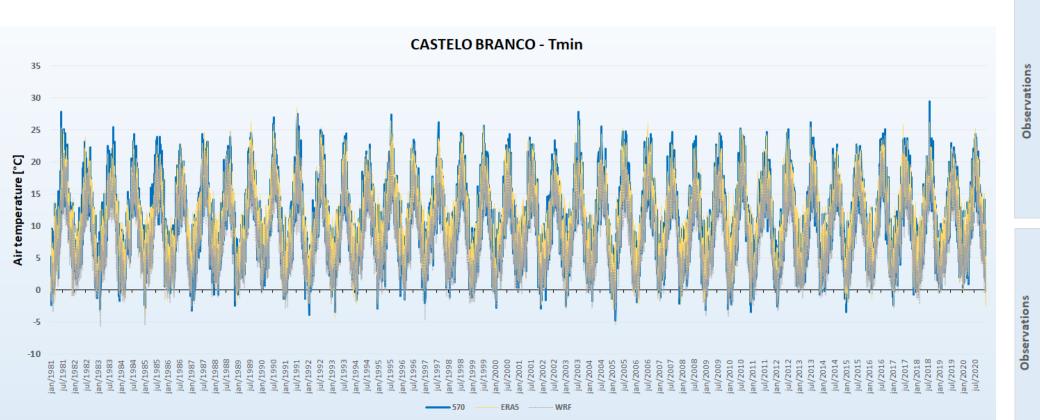
For each meteorological station, series of daily air temperature and precipitation data were considered for the period of 1981 to 2020. The first phase of the process consisted of building daily data series obtained from various types of records: classic meteorological stations, automatic weather stations (AWS), recording instruments and values obtained from SYNOP.

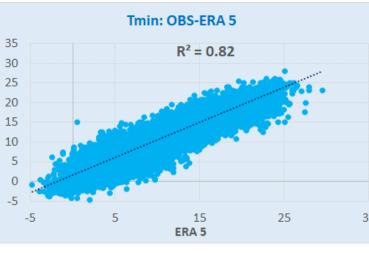
#### OBS vs ERA 5 vs WRF

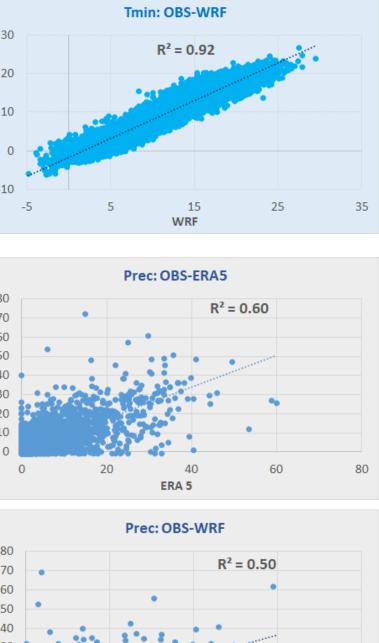
ERA 5 and WRF reanalysis data are not real measurements, but reanalysis products, and was necessary to verify whether these data can be used as a replacement for temperature and precipitation missing data measurements. The different models were evaluated on the test set according to accuracy and root-mean-square error (RMSE) metrics.







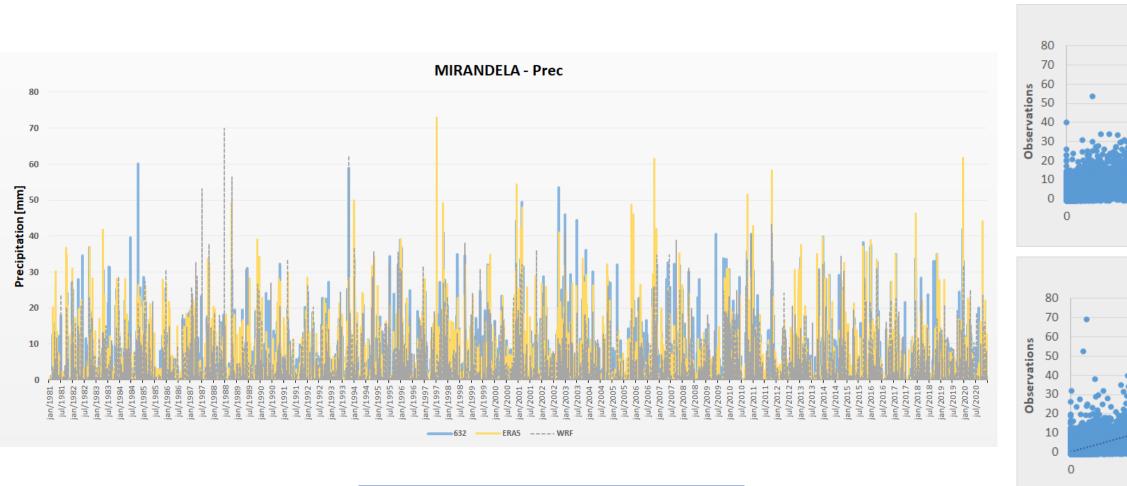




Station	Source Classic EMA RCIIMDex ERA 5 WRF MAXIMUM TEMPERATURE	
Penhas Douradas	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Sines	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Monção	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Elvas	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Miranda do Douro	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Montalegre	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Mértola	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Neves Corvo	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2005 2005 2005 2005 2005 2005	05 2005
Viana do Alentejo	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Anadia	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Nelas	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Mirandela	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Mogadouro	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Coruche	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Zambujeira	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Alvega	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Cabril	1988 1988 1988 1988 1988 1988 1988 1988	19 2020
VRSAntónio	<b>1981 1982 1983 1984 1985 1986 1987</b> 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019	19 2020
Alcácer do Sal	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
Alvalade	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201	19 2020
	Source Classic EMA RClimDex ERA 5 WRF PRECIPITATION	
Station		
Station Penhas Douradas	1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019	
	1981   1982   1983   1984   1985   1986   1987   1988   1990   1991   1992   1993   1994   1995   1996   1997   1998   1999   2000   2001   2002   2003   2004   2005   2006   2007   2010   2011   2012   2013   2014   2015   2016   2017   2018   2019     1981   1982   1983   1986   1987   1988   1990   1991   1995   1996   1997   1998   1999   2000   2001   2002   2003   2004   2005   2006   2007   2008   2010   2011   2012   2013   2014   2015   2016   2017   2018   2019   2014   2015   2016   2017   2018   2019   2014   2015   2016   2017   2018   2014   2015   2016   2017   2018   2017   2018   2017   2018   2017   2018   2017   2018   2017   2018   2017   2018   2017   2018   2017   2018	019 2020
Penhas Douradas Sines Monção	1981   1982   1984   1985   1986   1987   1988   1990   1991   1995   1996   1997   1998   1999   2000   2001   2002   2005   2006   2007   2008   2010   2011   2012   2013   2014   2015   2016   2017   2018   2018   2018   2018   2018   2018   2018   2018   2014   2015   2016   2017   2018   2018   2018   2018   2018   2018   2018   2018   2018   2018   2014   2015   2016   2017   2018   2018   2018   2014   2015   2016   2017   2018   2017   2018   2018   2014   2015   2016   2017   2018   2018   2014   2015   2016   2017   2018   2019   2018   2018   2014   2015   2016   2017   2018   2018   2014   2015   2016   2017   2018   2019   2018   2014   2015   2016   2017   2018   2019   2018   2014	019 2020 9 2020
Penhas Douradas Sines Monção Elvas	1 982   1 983   1 984   1 985   1 983 <th< th=""><th>019 2020 9 2020 019 2020</th></th<>	019 2020 9 2020 019 2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro	1 982   1 984   1 984   1 985   1 986   1 987   1 988   1 990   1 991   1 995 <th< th=""><th>119     2020       9     2020       019     2020       019     2020</th></th<>	119     2020       9     2020       019     2020       019     2020
Penhas Douradas Sines Monção Elvas Miranda do Douro Montalegre	1   1	119     2020       9     2020       119     2020       119     2020       119     2020       9     2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro Montalegre Mértola	1   1	119 2020   9 2020   119 2020   119 2020   9 2020   9 2020   9 2020
Penhas Douradas Sines Monção Elvas Miranda do Douro Montalegre Mértola Neves Corvo	1   1	119 2020   9 2020   119 2020   119 2020   9 2020   9 2020   9 2020   9 2020   9 2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alentejo	1982   1982 <	119 2020   9 2020   119 2020   119 2020   9 2020   9 2020   9 2020   9 2020   5 2005   9 2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alenteio Anadia	1982   1983   1984   1986 <	119     2020       9     2020       119     2020       119     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alentejo Anadia Nelas	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alenteio Anadia Nelas Mirandela	1   1	19     2020       9     2020       119     2020       119     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alentejo Viana do Alentejo Nelas Mirandela Mogadouro	1   1	119     2020       9     2020       119     2020       119     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020
Penhas Douradas Sines Monção Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alenteio Anadia Nelas Mirandela Mogadouro Coruche	1981   1982   1983   1984   1985   1986   1987   1988   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981   1987   1981 <	2020       9     2020       9     2020       119     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020       9     2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alentejo Viana do Alentejo Viana do Alentejo Mirandela Mogadouro Coruche Zambujeira	1   1	19     2020       9     2020       19     2020       119     2020       9     2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alentejo Anadia Nelas Mirandela Mogadouro Coruche Zambujeira Alvega	1     1	2020       9     2020       9     2020       19     2020       9     2020
Penhas Douradas Sines Monção Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alenteio Anadia Nelas Mirandela Mogadouro Coruche Zambujeira Alvega Cabril	1981   1982   1984   1985   1986   1987   1986	2020       9     2020       9     2020       19     2020       19     2020       9     2020
Penhas Douradas Sines Moncão Elvas Miranda do Douro Montalegre Mértola Neves Corvo Viana do Alentejo Anadia Nelas Mirandela Mogadouro Coruche Zambujeira Alvega	1981     1984     1985     1986     1987     1988     1986     1987     200    200    200     2	2020       9     2020       9     2020       19     2020       19     2020       9     2020

#### HOMOGENIZATION

The homogenization process was performed using the **RClimDex package software**. The IPMA observation network has changed considerably during the last 20-30 years, introducing non-climatic changes such as automation and relocation. Homogenization was therefore necessary to provide a consistent basis for the new normal:



OBS-ERA 5			OBS-WRF		
	RMSE	VIES	RMSE	VIES	
Tmin	2.5	0.4	2.5	-1.9	
Tmax	1.0	0.1	1.6	-0.2	
Prec	3.1	0.4	3.2	-0.3	

Best R<sup>2</sup> and RMSE results for maximum temperature data series.

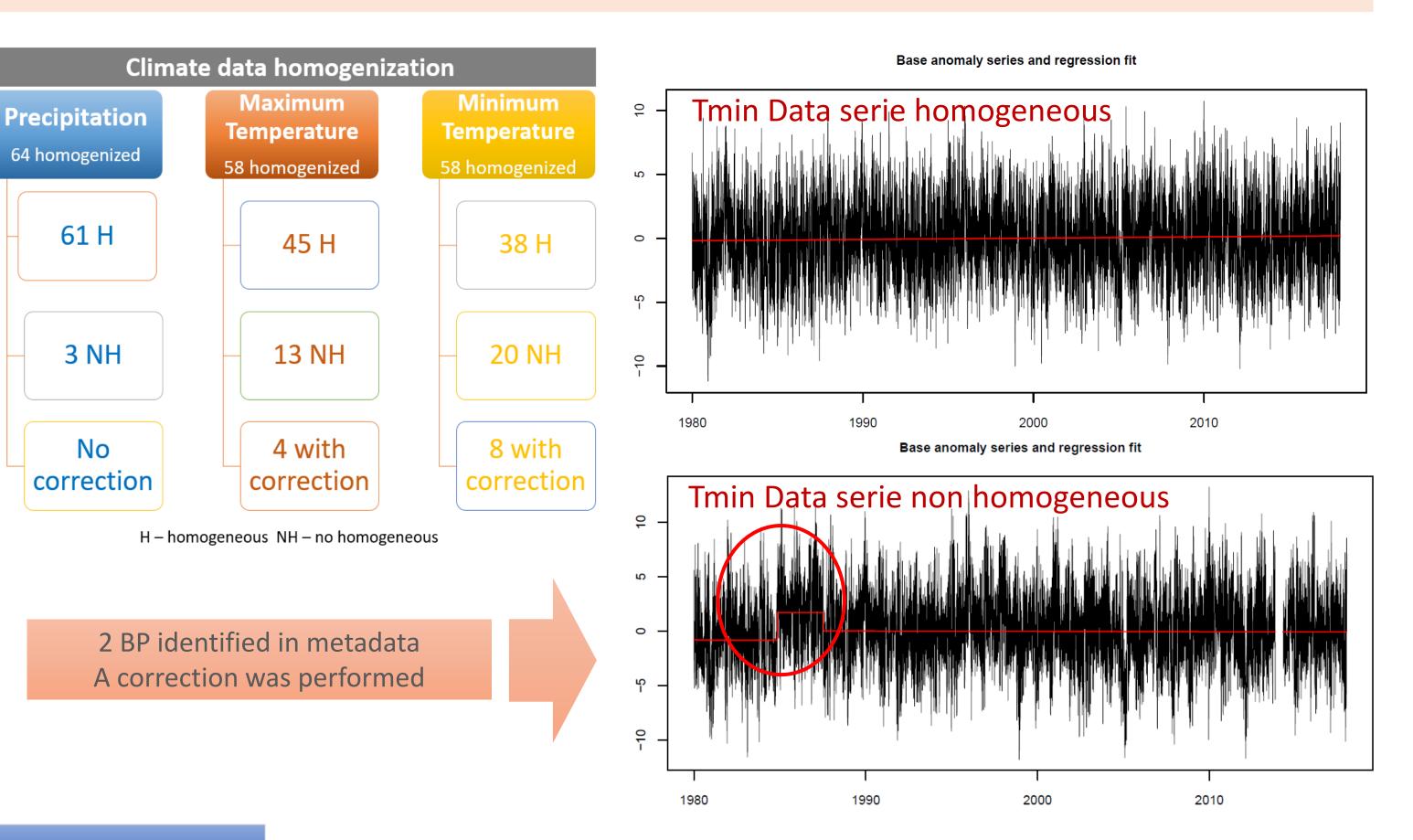
**Lower** R<sup>2</sup> and higher RMSE values for precipitation (more outliers).

□ Higher dispersion for minimum temperature compared with maximum temperature.

□ Best results for ERA 5 in the maximum temperature and for WRF in the minimum temperature.

□ In precipitation better results in ERA 5.

- 1. Homogenization process without filling the gaps with data from ERA 5 and WRF model.
- 2. Homogenization process with the introduction of model data.
- 3. Breakpoints identified and validated or rejected according to the metadata of the series.
- 4. It was decided which breakpoints are accepted as in-homogeneities.
- 5. The discontinuities are adjusted and the data is corrected.



## CLIMATOLOGICAL NORMALS

After the validation and homogenization process the 1981-2010 and 1991-2020 climate normal were calculated for temperature and precipitation data series. Example of Beja meteorological station (south of Portugal).

