Temperature and precipitation in the Balearic Islands: Recent trends and future scenarios

10th Plinius Conference on Mediterranean Storms
(Nicosia, Cyprus, 22 - 24 September 2008)

R. Romero, V. Homar, S. Alonso and C. Ramis

Universitat de les Illes Balears

Grup de Meteorologia Departament de Física

IPCC Fourth Assessment Report

- The **Mediterranean region** is a very sensitive area to the human-induced climate change

- **Temperature increase** during the period 1979-2005 lays between **2.5 – 3.5 ºC/century**

- **Precipitation decrease** estimated at **5 – 20 %** during the period 1901-2005 (although changes less than 3% are obtained for the period 1979-2005)

- But … large spatial variability: **sub-regional tendencies** are needed

- Great concern for a tourist pole as the **Balearic Islands**

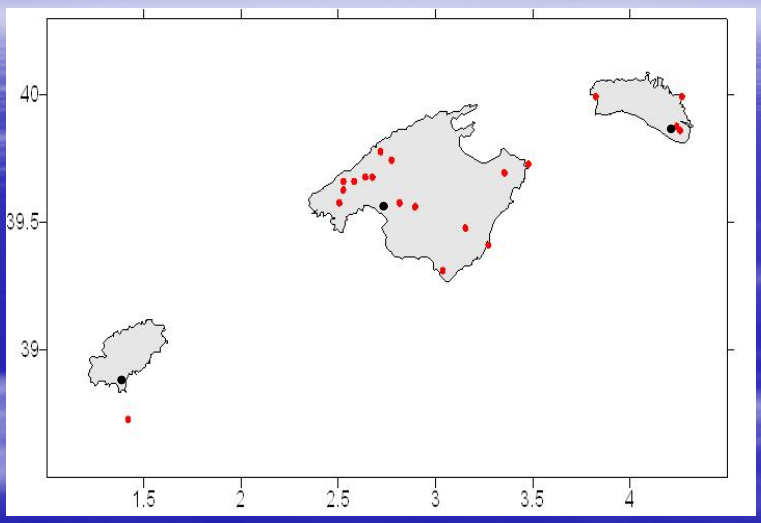
Available observations (INM)

-Temperature (1976-2006)

3 stations

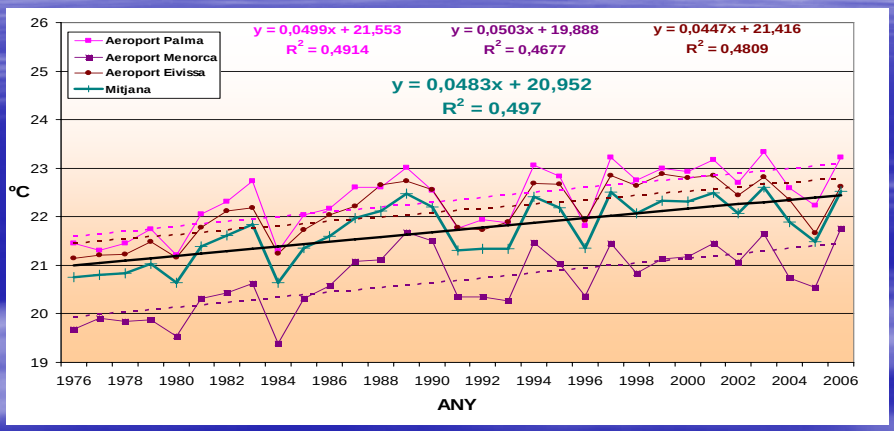
- Precipitation (1951-2006)

20 stations



Temperature

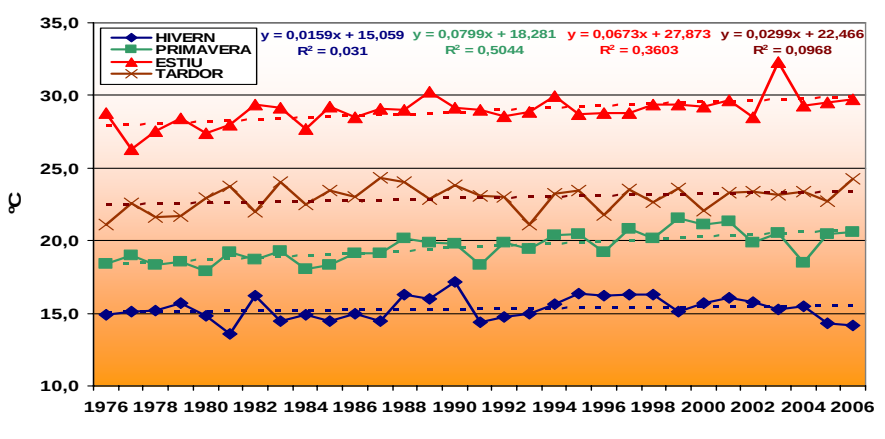
Annual-mean Max. Temp. (Islands)



Annual-mean Max. Temp. (Islands)

Station	Trend (ºC / 100 yr)	Statistical Confidence in "Temperature Increase"	Extremely likely range of the trend (ºC / 100 yr)	
			Lower limit	Higher limit
Mallorca Airport	+4.99	Virtually certain	+3.43	+6.92
Menorca Airport	+5.03	Virtually certain	+2.99	+7.07
Ibiza Airport	+4.47	Virtually certain	+2.71	+6.23
Mean	+4.83	Virtually certain	+2.98	+6.68

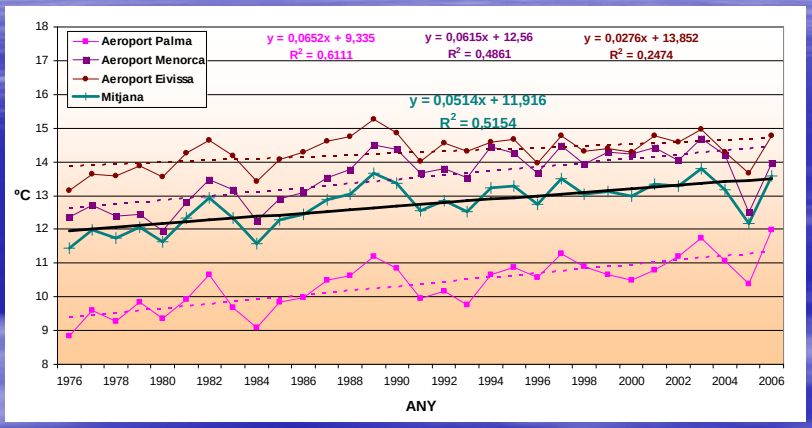
Seasonal-mean Max. Temp.



Seasonal-mean Max. Temp.

Season	Trend (ºC / 100 yr)	Statistical Confidence in "Temperature Increase"	Extremely likely range of the trend (ºC / 100 yr)	
			Lower limit	Higher limit
Winter	+1.59	Likely	-1.79	+4.97
Spring	+7.99	Virtually certain	+4.98	+11.00
Summer	+6.73	Virtually certain	+3.32	+10.14
Fall	+2.99	Very likely	-0.48	+6.46

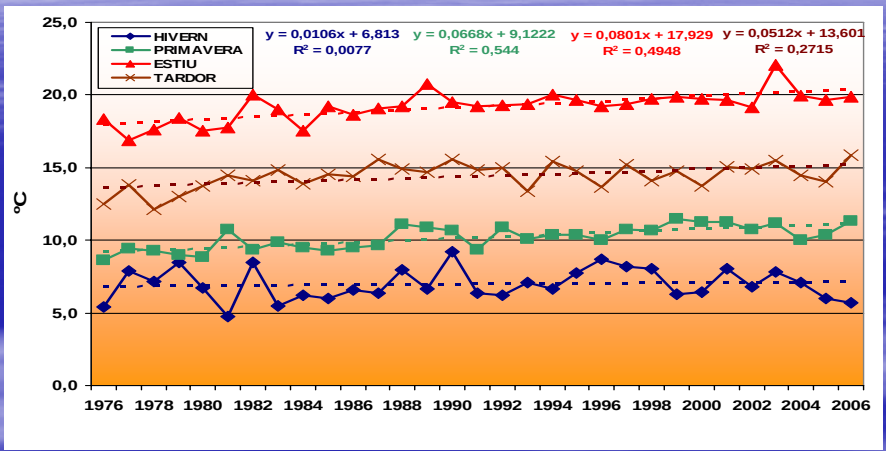
Annual-mean Min. Temp. (Islands)



Annual-mean Min. Temp. (Islands)

Station	Trend (ºC / 100 yr)	Statistical Confidence in "Temperature Increase"	Extremely likely range of the trend (ºC / 100 yr)	
			Lower limit	Higher limit
Mallorca Airport	+6.52	Virtually certain	+4.54	+8.50
Menorca Airport	+6.15	Virtually certain	+3.75	+8.55
Ibiza Airport	+2.76	Virtually certain	+0.93	+4.59
Mean	+5.14	Virtually certain	+3.25	+7.03

Seasonal-mean Min. Temp.

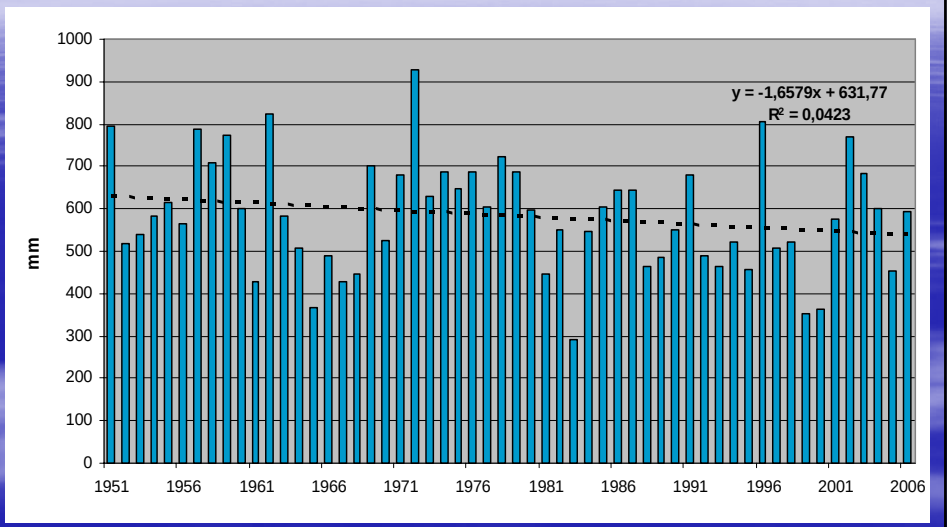


Seasonal-mean Min. Temp.

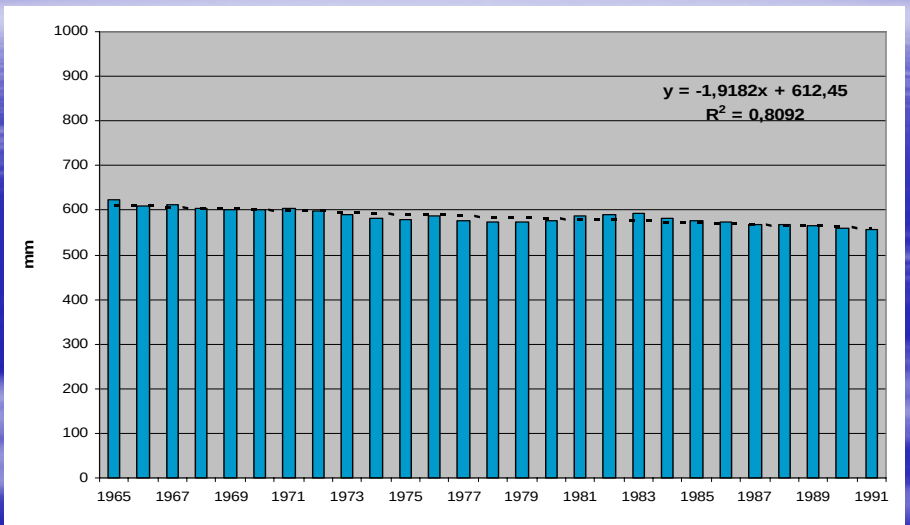
Season	Trend (°C / 100 yr)	Statistical Confidence in "Temperature Increase"	Extremely likely range of the trend (°C / 100 yr)	
			Lower limit	Higher limit
Winter	+1.06	About as likely as not	-3.51	+5.63
Spring	+6.68	Virtually certain	+4.36	+9.00
Summer	+8.01	Virtually certain	+4.94	+11.08
Fall	+5.12	Virtually certain	+1.95	+8.30

Precipitation

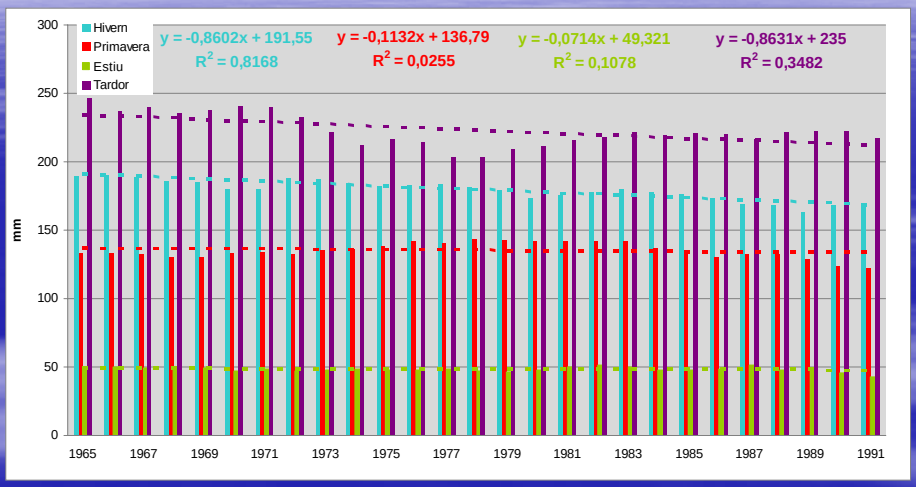
Annual-mean Precip.



Annual-mean Precip. (30-yr filter)



Seasonal-mean Precip. (30-yr filter)



Seasonal-mean Precip. (30-yr filter)

Season	Trend (mm / 100 yr)	Statistical Confidence in "Precipitation Decrease"	Extremely likely range of the trend (mm / 100 yr)	
			Lower limit	Higher limit
Winter	-86	Virtually certain	-102	-69
Spring	-11	About as likely as not	-40	+18
Summer	-16	Very likely	-16	+1
Fall	-86	Virtually certain	-135	-38

Daily precipitation categories

Category	Precipitation (mm)
“trace”	<1
a	1-4
b	4-16
c1	16-32
c2	32-64
d1	64-128
d2	>128

Categories

Category	Mean (days/ yr)	Trend (days/100 yr)	Statistical Confidence in trend (+ or -)
trace	17.65	+3.79	Very likely
a	19.36	+7.01	Virtually certain
b	23.99	-4.86	Likely
c1	7.63	-4.20	Virtually certain
c2	2.79	-1.40	Likely
d1	0.45	+0.07	About as likely as not
d2	0.04	+0.04	About as likely as not

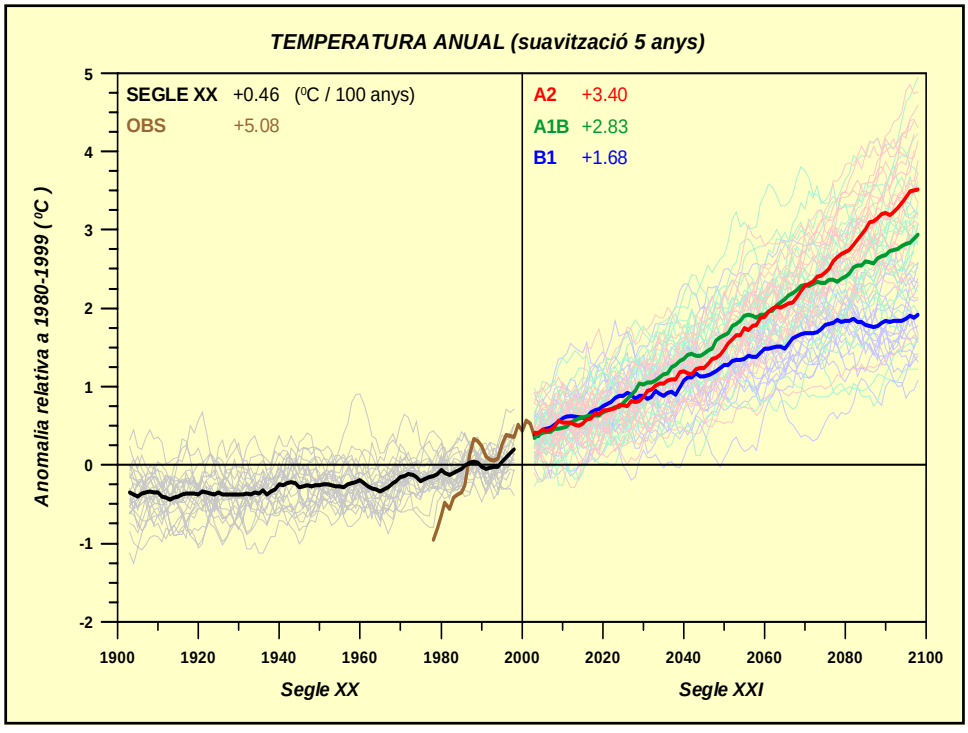
Future scenarios - 1

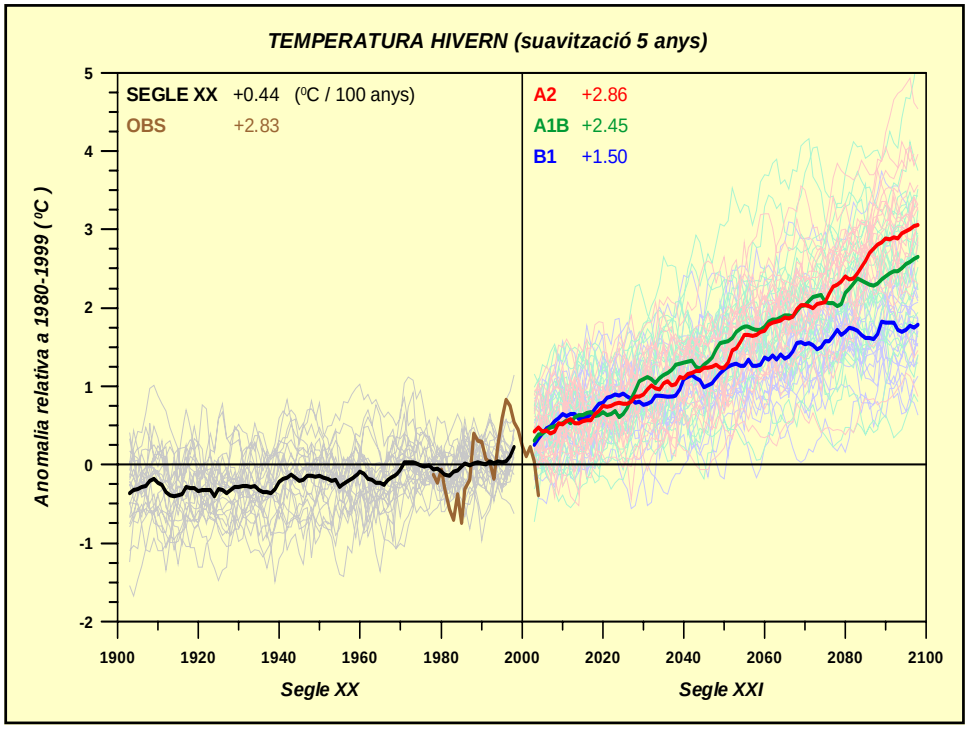
Directly from the outputs of Global Climate Models

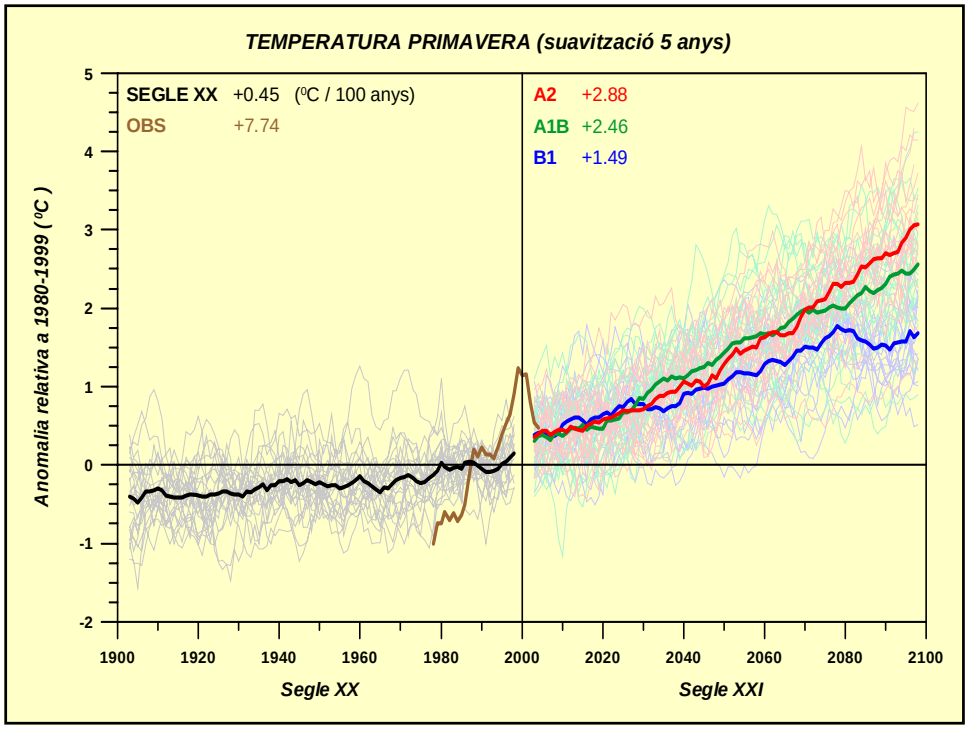
Number of available GCMs

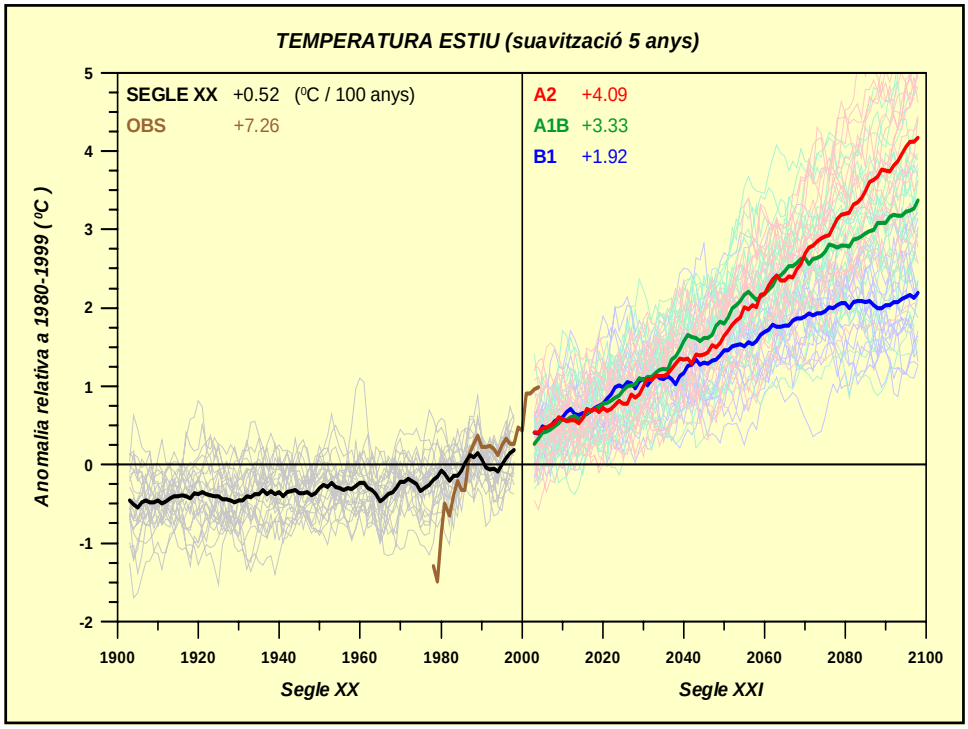
RUN	Temperature	Precipitation
20th CENTURY	24	24
SRES A2	19	19
SRES A1B	23	23
SRES B1	21	20

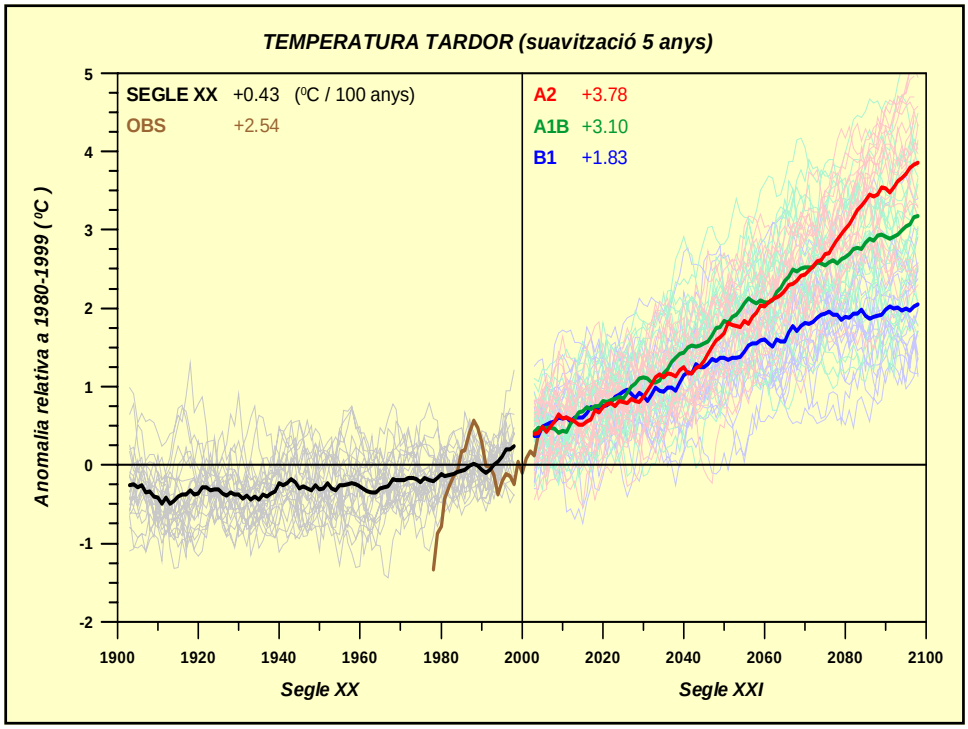
Temperature




TEMPERATURA HIVERN (suavització 5 anys)
SEGLE XX +0.44 (ºC / 100 anys)
OBS +2.83
A2 +2.86
A1B +2.45
B1 +1.50
Anomalia relativa a 1980-1999 (ºC)
5
4
3
2
1
0
-1
-2
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


TEMPERATURA PRIMAVERA (suavització 5 anys)
SEGLE XX +0.45 (ºC / 100 anys)
OBS +7.74
A2 +2.88
A1B +2.46
B1 +1.49
Anomalia relativa a 1980-1999 (ºC)
5
4
3
2
1
0
-1
-2
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI

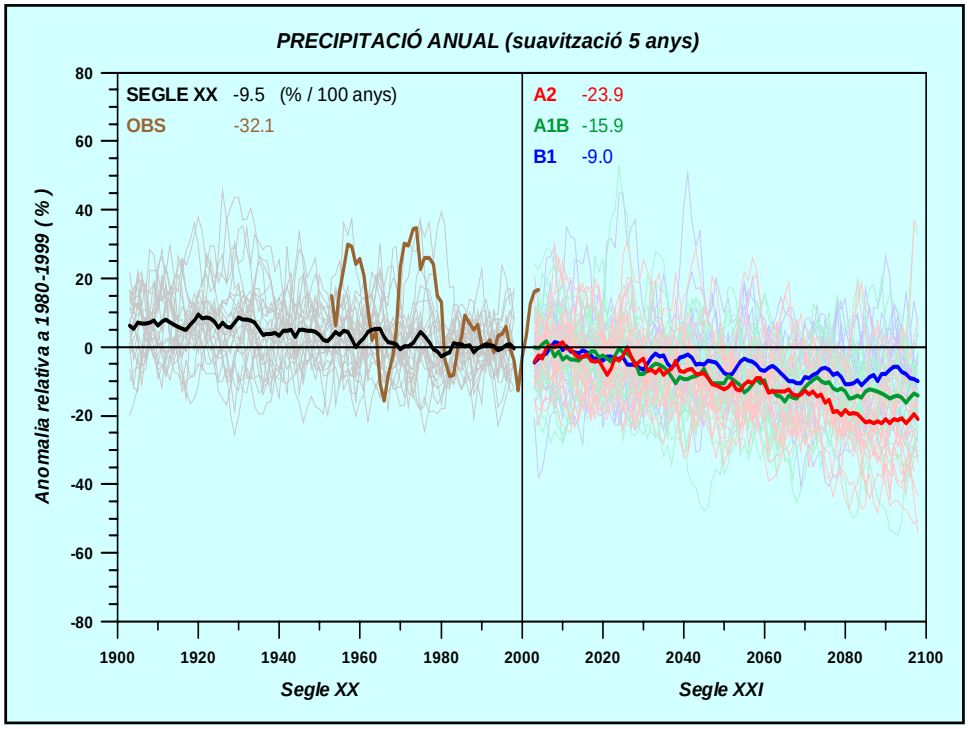

TEMPERATURA ESTIU (suavització 5 anys)
SEGLE XX +0.52 (ºC / 100 anys)
OBS +7.26
A2 +4.09
A1B +3.33
B1 +1.92
Anomalia relativa a 1980-1999 (ºC)
5
4
3
2
1
0
-1
-2
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI

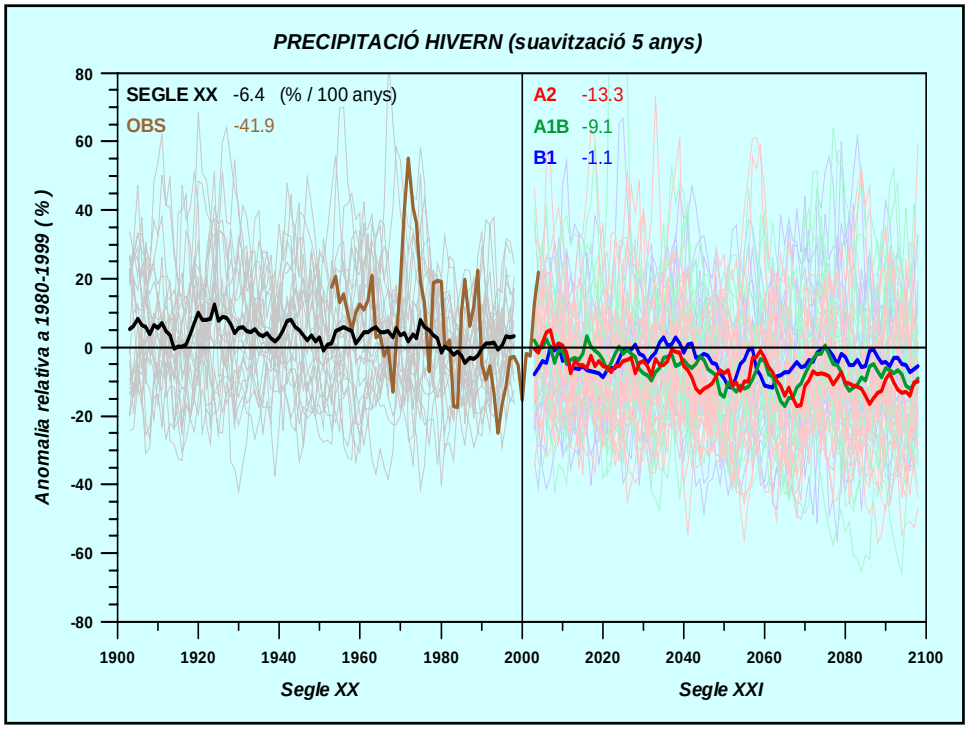

TEMPERATURA TARDOR (suavització 5 anys)
SEGLE XX +0.43 (ºC / 100 anys)
OBS +2.54
A2 +3.78
A1B +3.10
B1 +1.83
Anomalia relativa a 1980-1999 (ºC)
5
4
3
2
1
0
-1
-2
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI

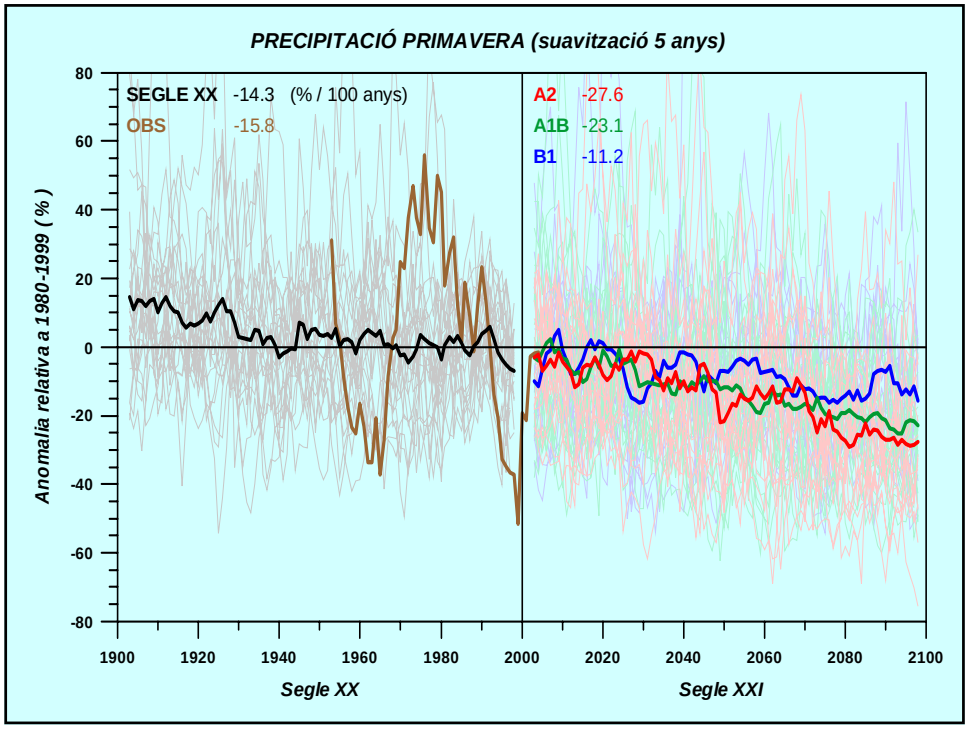
TEMPERATURA Trend (5-yr filter)

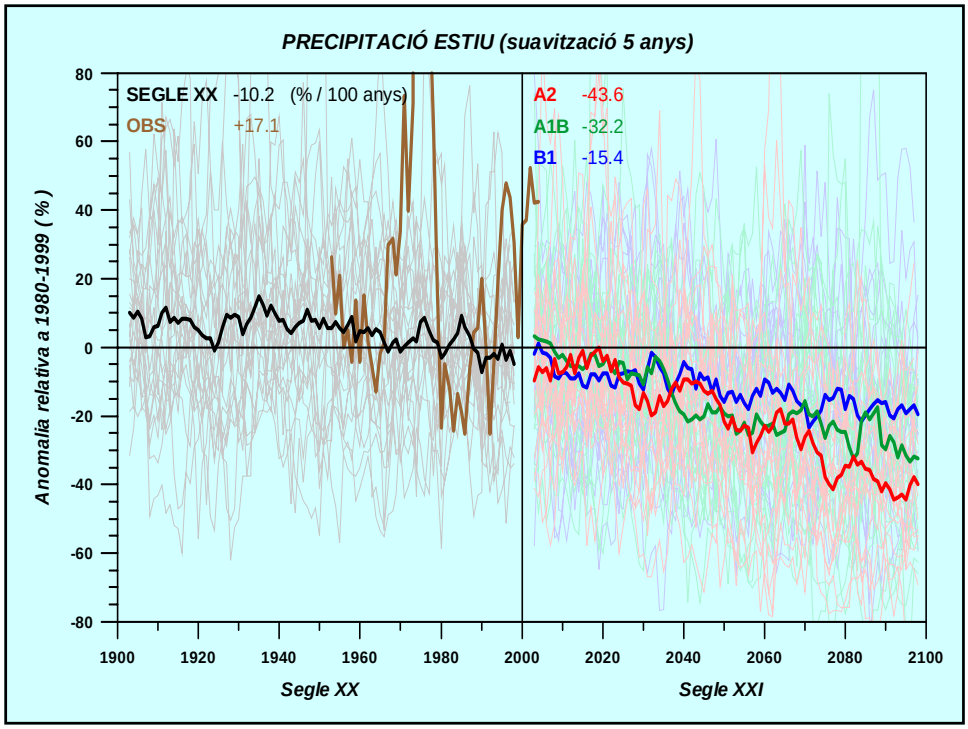
in ^{0}C / 100 yr	ANNUAL	Winter	Spring	Summer	Fall
20th CENTURY	+0.46	+0.44	+0.45	+0.52	+0.43
OBS 1976-2006	+5.08	+2.83	+7.74	+7.26	+2.54
SRES A2	+3.40	+2.86	+2.88	+4.09	+3.78
SRES A1B	+2.83	+2.45	+2.46	+3.33	+3.10
SRES B1	+1.68	+1.50	+1.49	+1.92	+1.83

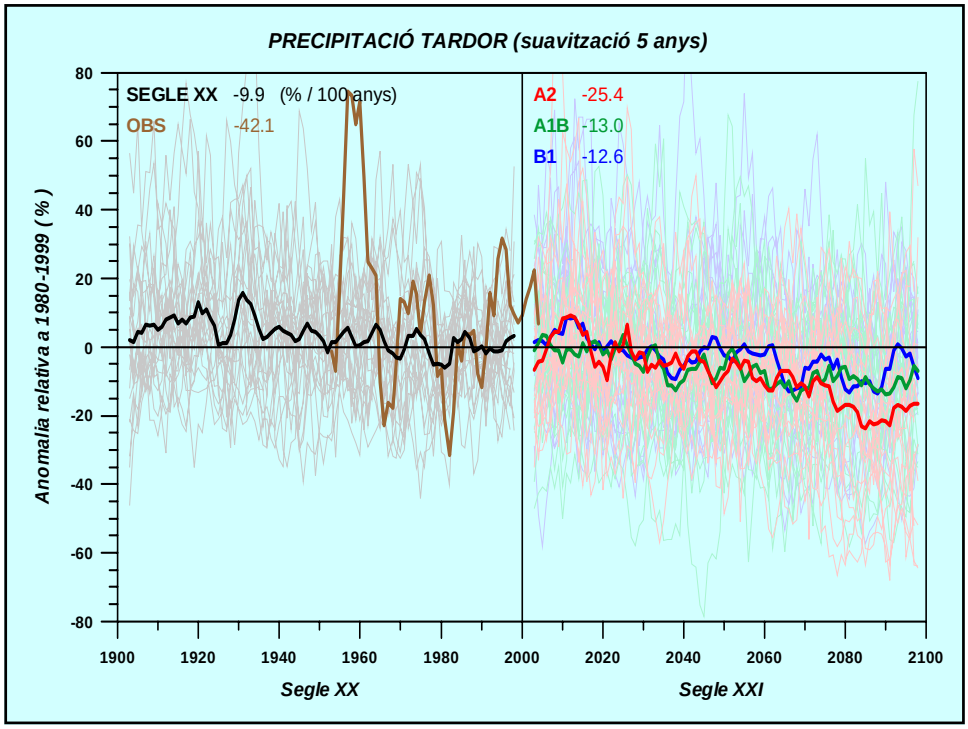
Precipitation


PRECIPITACIÓ ANUAL (suavització 5 anys)
SEGLE XX -9.5 (% / 100 anys)
OBS -32.1
A2 -23.9
A1B -15.9
B1 -9.0
Anomalia relativa a 1980-1999 (%)
80
60
40
20
0
-20
-40
-60
-80
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


PRECIPITACIÓ HIVERN (suavització 5 anys)
SEGLE XX -6.4 (% / 100 anys)
OBS -41.9
A2 -13.3
A1B -9.1
B1 -1.1
Anomalia relativa a 1980-1999 (%)
80
60
40
20
0
-20
-40
-60
-80
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


PRECIPITACIÓ PRIMAVERA (suavització 5 anys)
SEGLE XX -14.3 (% / 100 anys)
OBS -15.8
A2 -27.6
A1B -23.1
B1 -11.2
Anomalia relativa a 1980-1999 (%)
80
60
40
20
0
-20
-40
-60
-80
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


PRECIPITACIÓ ESTIU (suavització 5 anys)
SEGLE XX -10.2 (% / 100 anys)
OBS +17.1
A2 -43.6
A1B -32.2
B1 -15.4
Anomalia relativa a 1980-1999 (%)
80
60
40
20
0
-20
-40
-60
-80
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI



PRECIPITATION Trend (5-yr filter)

in % / 100 yr	ANNUAL	Winter	Spring	Summer	Fall
20th CENTURY	-9.5	-6.4	-14.3	-10.2	-9.9
OBS 1951-2006	-32.1	-41.9	-15.8	+17.1	-42.1
SRES A2	-23.9	-13.3	-27.6	-43.6	-25.4
SRES A1B	-15.9	-9.1	-23.1	-32.2	-13.0
SRES B1	-9.0	-1.1	-11.2	-15.4	-12.6

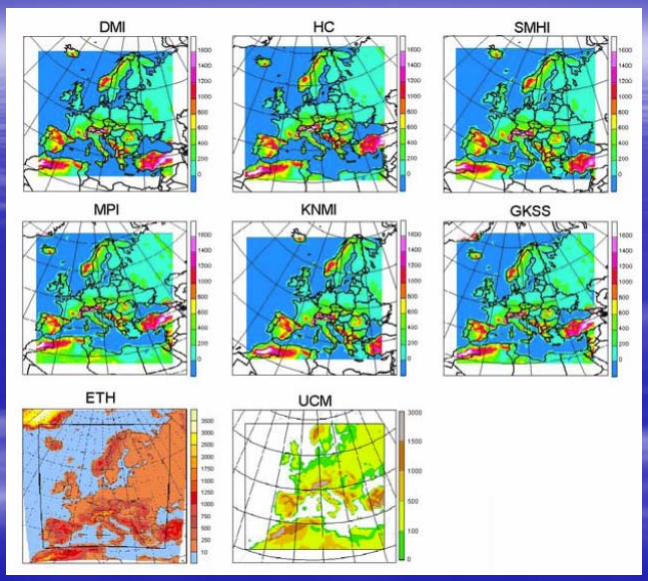
Future scenarios - 2

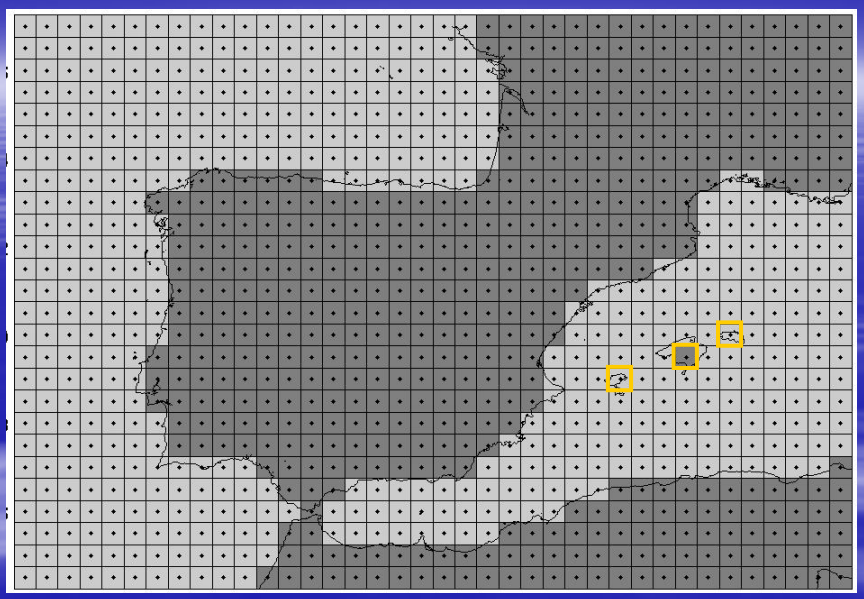
Using the first results of dynamical and statistical downscaling methods over Spain

Dynamical Downscaling

PRUDENCE Project

Centro	Modelo	Resolución horizontal y nº de celdillas (nx x ny)
CNRM	ARPEGE	50-70 km (sobre Europa)
ETH	CHRM	0.5° (55 km) 81 x 91
HC	HadRM	0.44° (50 km) 106 x 111
DMI	HIRHAM	0.44° (50 km) 110 x 104
MPI	REMO	0.5° (55 km) 97 x 109
ICTP	RegCM	50 km Lambert 119 x 98
UCM	PROMES	50 km Lambert 112 x 96
GKSS	CLM	0.5º (55 km) 101 x 107
SMHI	RCAO	0.44° (50 km) 90 x 86
KNMI	RACMO	0.44° (50 km) 94 x 80



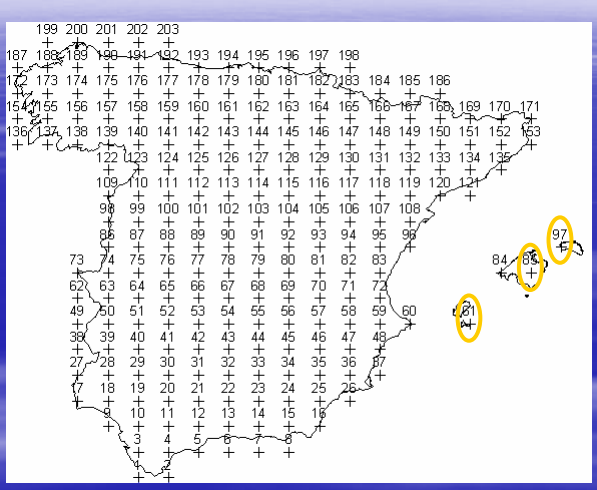


Statistical Downscaling

Analogue Method-FIC

Temperature Stations:	***MALL (25)***	***MEN (3)***	***IBI (5)***
Precipitation Stations:	***MALL (185)***	***MEN (19)***	***IBI (13)***

Analogue Method-INM



SDSM Method-INM

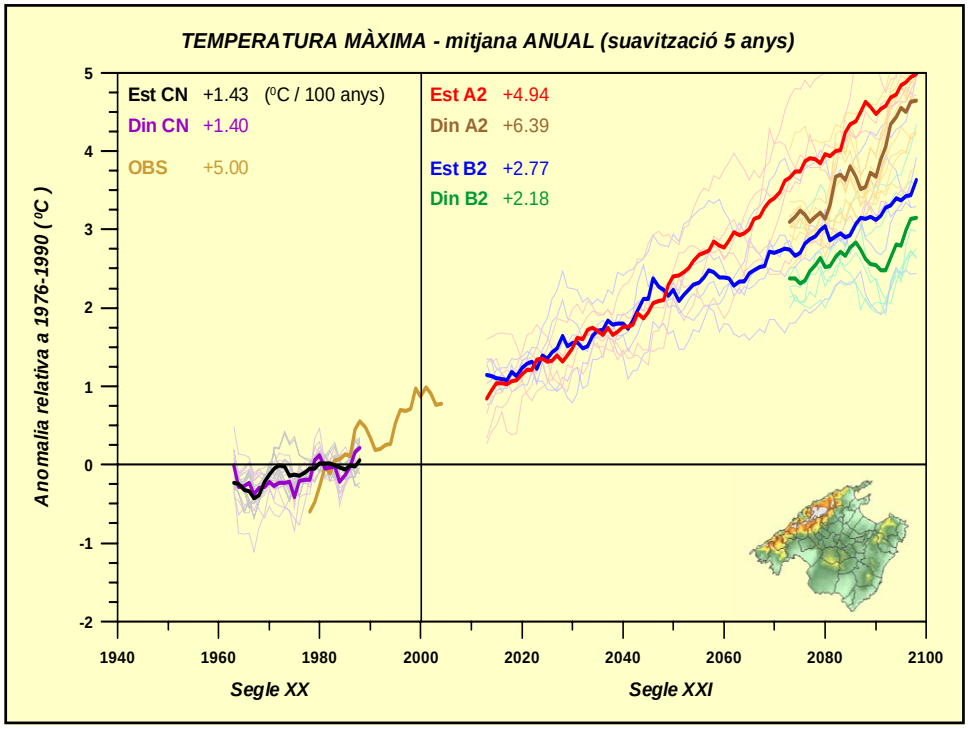
Temperature Stations: ***MALL (1)*** ***MEN (0)*** ***IBI (2)***

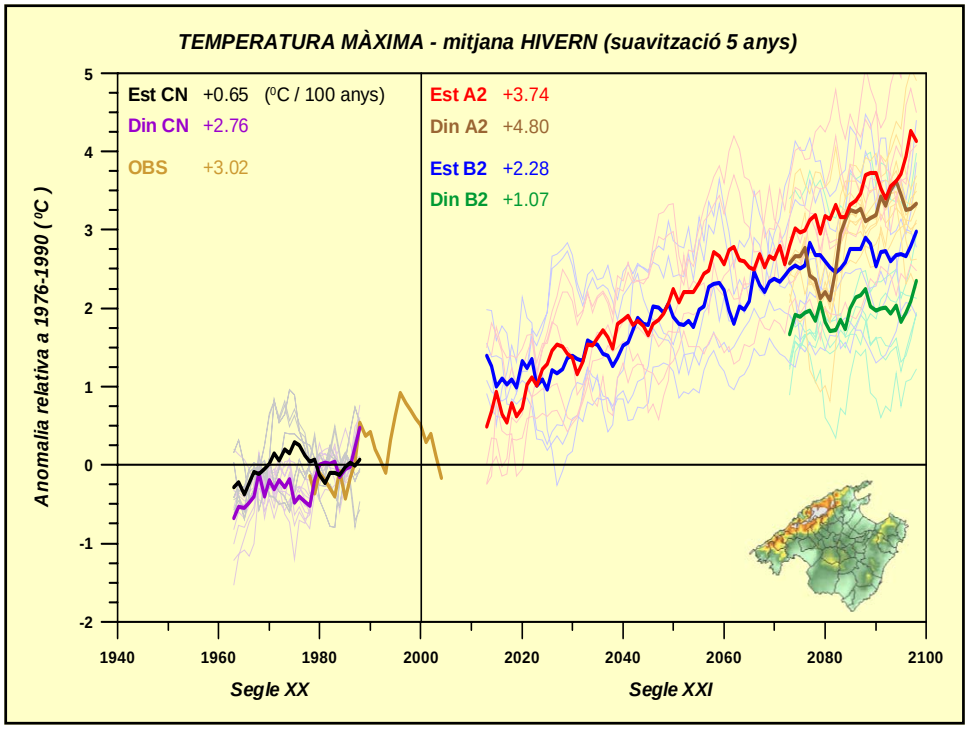
Precipitation Stations: ***MALL (103)*** ***MEN (7)*** ***IBI (9)***

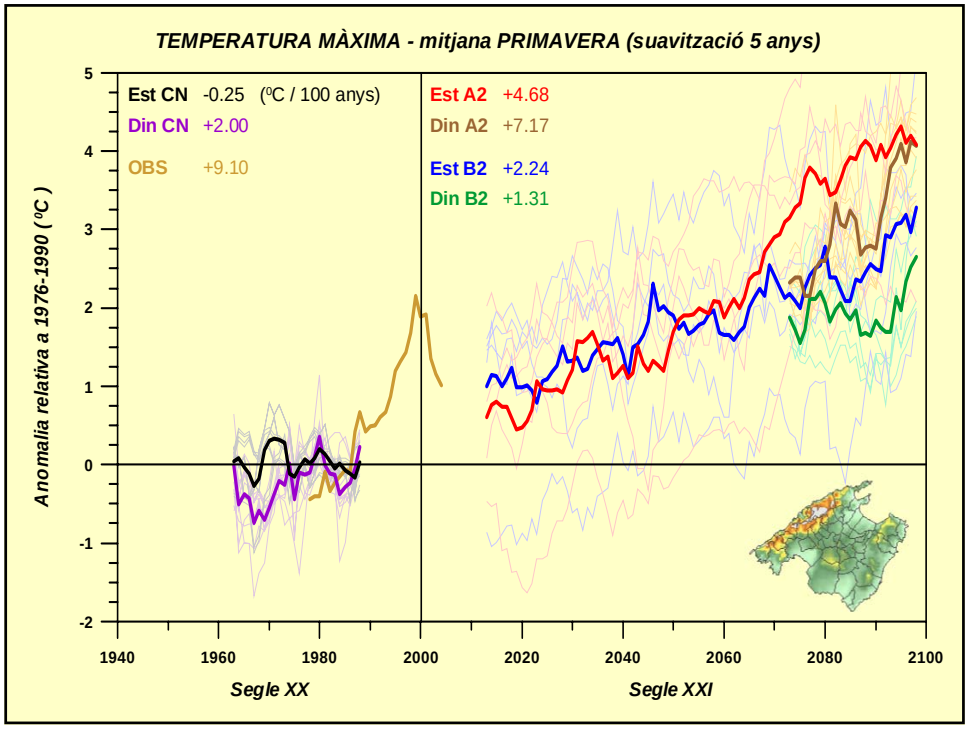
Number of available downscaling outputs

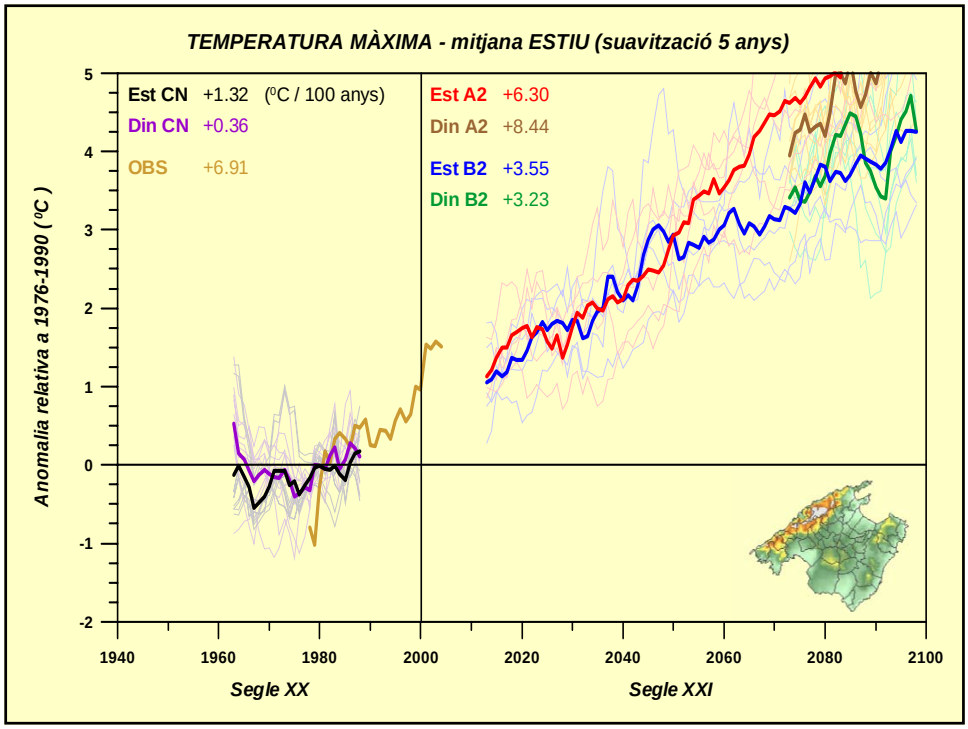
DOWNSCALING	Maximum Temperature	Minimum Temperature	Precipitation
Est CN 1961-1990	10	10	10
Din CN 1961-1990	11	11	12
OBS 1976-2006	1	1	-
OBS 1951-2006	-	-	1
Est A2 2011-2099	5	5	5
Din A2 2071-2100	11	11	12
Est B2 2011-2099	5	5	5
Din B2 2071-2100	6	6	7

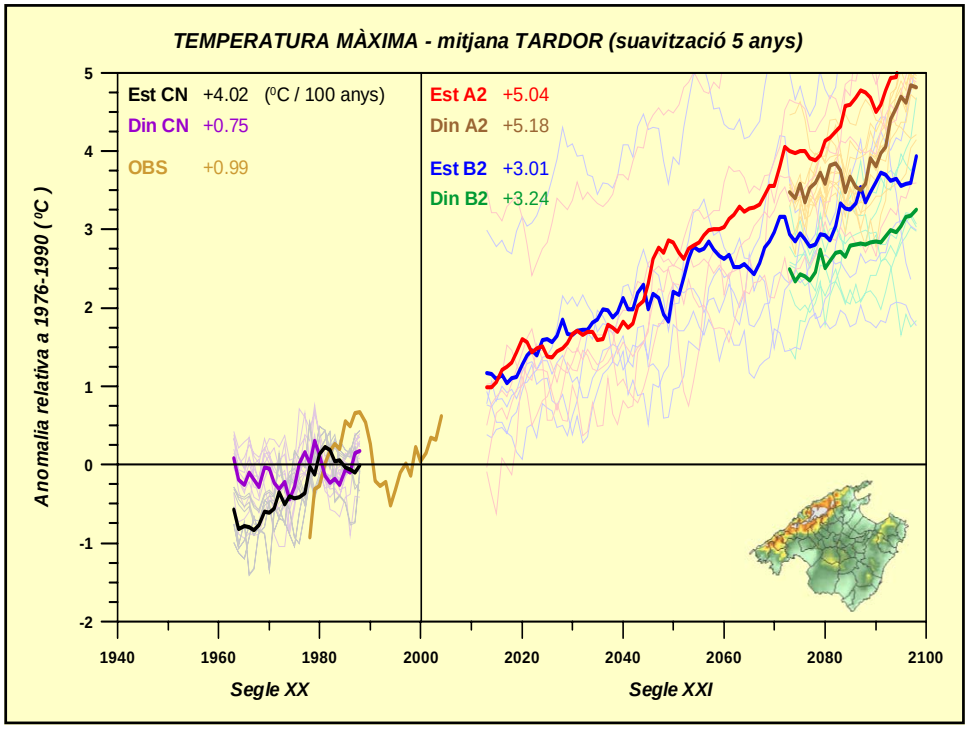
Maximum Temperature


TEMPERATURA MÀXIMA - mitjana ANUAL (suavització 5 anys)
Est CN +1.43 (ºC / 100 anys)
Din CN +1.40
OBS +5.00
Est A2 +4.94
Din A2 +6.39
Est B2 +2.77
Din B2 +2.18
Anomalia relativa a 1976-1990 (ºC)
5
4
3
2
1
0
-1
-2
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI

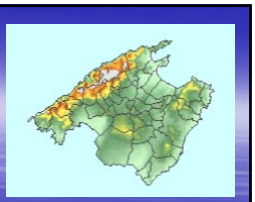

TEMPERATURA MÀXIMA - mitjana HIVERN (suavització 5 anys)
Est CN +0.65 (ºC / 100 anys)
Din CN +2.76
OBS +3.02
Est A2 +3.74
Din A2 +4.80
Est B2 +2.28
Din B2 +1.07
Anomalia relativa a 1976-1990 (ºC)
5
4
3
2
1
0
-1
-2
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


TEMPERATURA MÀXIMA - mitjana PRIMAVERA (suavització 5 anys)
Est CN -0.25 (ºC / 100 anys)
Din CN +2.00
OBS +9.10
Est A2 +4.68
Din A2 +7.17
Est B2 +2.24
Din B2 +1.31
Anomalia relativa a 1976-1990 (ºC)
5
4
3
2
1
0
-1
-2
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


TEMPERATURA MÀXIMA - mitjana ESTIU (suavització 5 anys)
Est CN +1.32 (ºC / 100 anys)
Din CN +0.36
OBS +6.91
Est A2 +6.30
Din A2 +8.44
Est B2 +3.55
Din B2 +3.23
Anomalia relativa a 1976-1990 (ºC)
5
4
3
2
1
0
-1
-2
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI

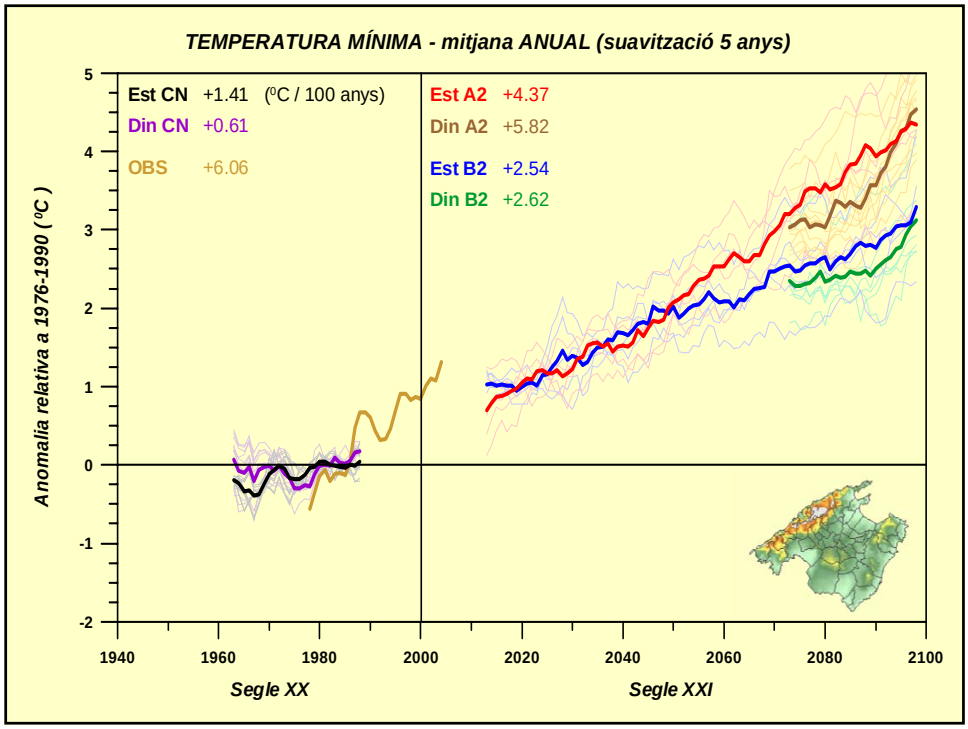


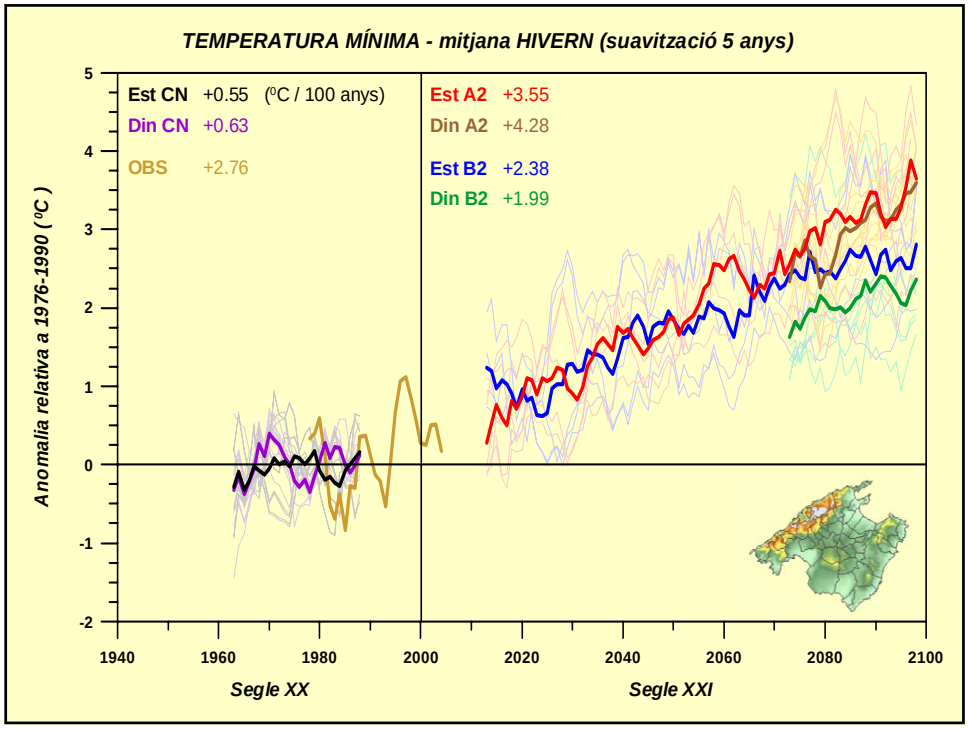
MAXIMUM TEMPERATURE Trend (5-yr filter)

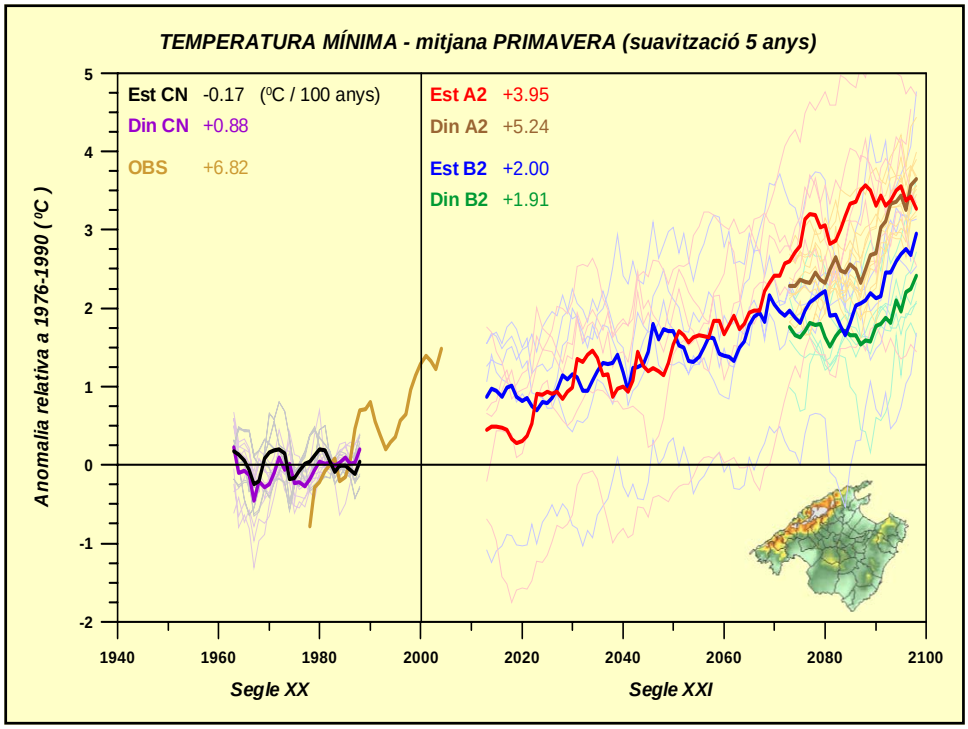


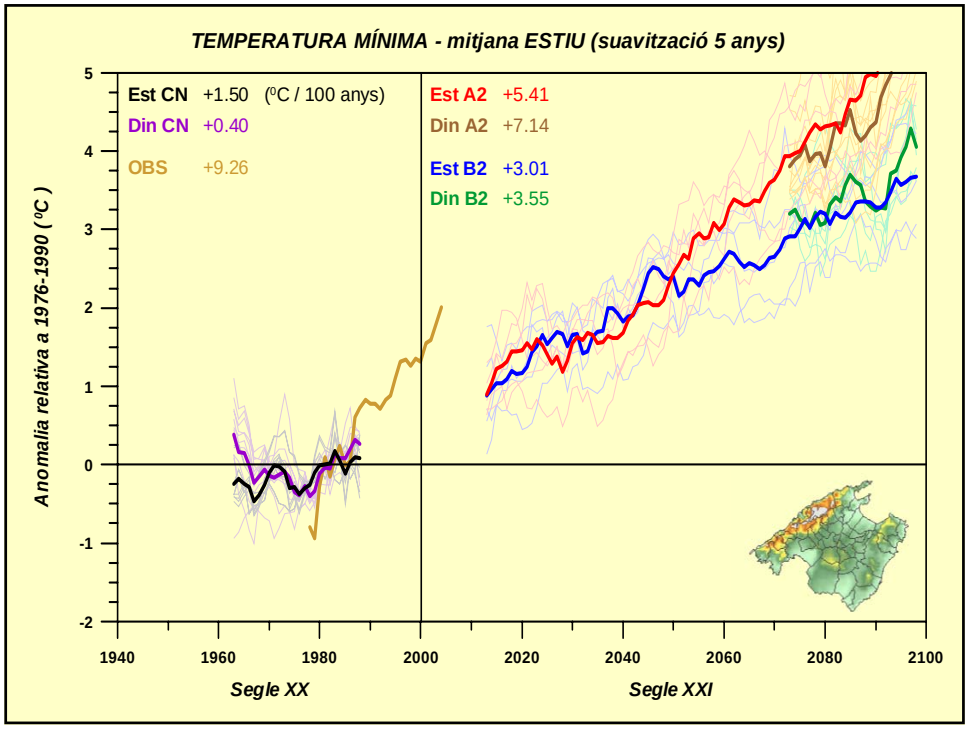
in ºC / 100 yr	ANNUAL	Winter	Spring	Summer	Fall
Est CN 1961-1990	+1.43	+0.65	-0.25	+1.32	+4.02
Din CN 1961-1990	+1.40	+2.76	+2.00	+0.36	+0.75
OBS 1976-2006	+5.00	+3.02	+9.10	+6.91	+0.99
Est A2 2011-2099	+4.94	+3.74	+4.68	+6.30	+5.04
Din A2 2071-2100	+6.39	+4.80	+7.17	+8.44	+5.18
Est B2 2011-2099	+2.77	+2.28	+2.24	+3.55	+3.01
Din B2 2071-2100	+2.18	+1.07	+1.31	+3.23	+3.24

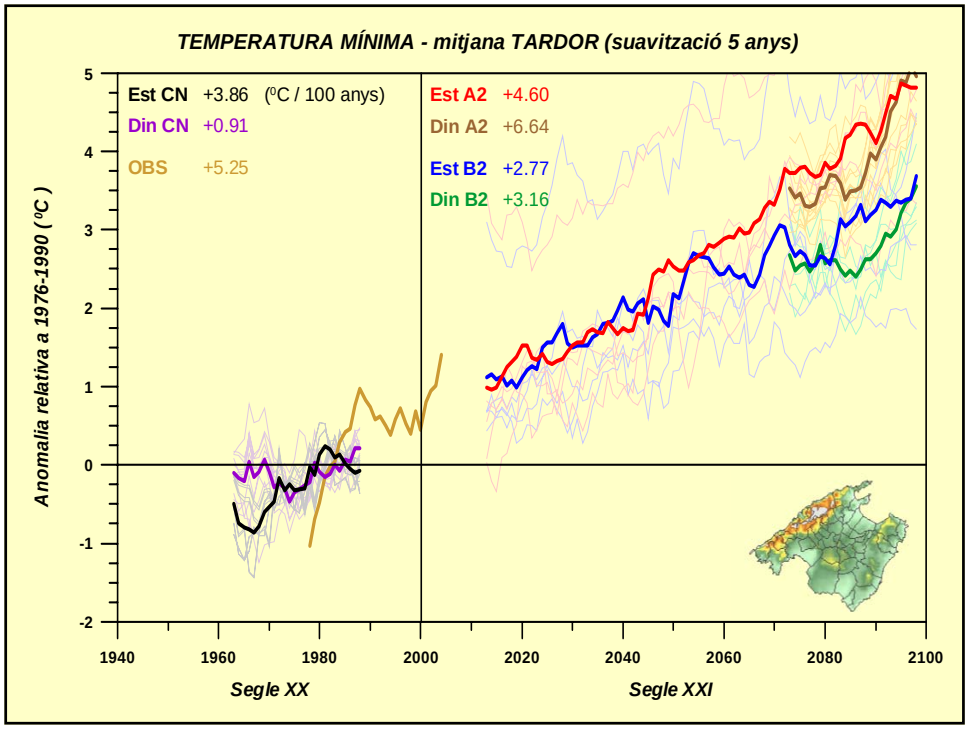
Minimum Temperature



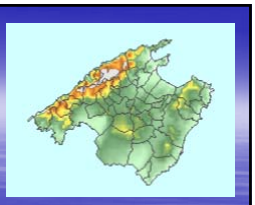

TEMPERATURA MÍNIMA - mitjana HIVERN (suavització 5 anys)
Est CN +0.55 (ºC / 100 anys)
Din CN +0.63
OBS +2.76
Est A2 +3.55
Din A2 +4.28
Est B2 +2.38
Din B2 +1.99
Anomalia relativa a 1976-1990 (ºC)
5
4
3
2
1
0
-1
-2
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


TEMPERATURA MÍNIMA - mitjana PRIMAVERA (suavització 5 anys)
Est CN -0.17 (ºC / 100 anys)
Din CN +0.88
OBS +6.82
Est A2 +3.95
Din A2 +5.24
Est B2 +2.00
Din B2 +1.91
Anomalia relativa a 1976-1990 (ºC)
5
4
3
2
1
0
-1
-2
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


TEMPERATURA MÍNIMA - mitjana ESTIU (suavització 5 anys)
Est CN +1.50 (ºC / 100 anys)
Din CN +0.40
OBS +9.26
Est A2 +5.41
Din A2 +7.14
Est B2 +3.01
Din B2 +3.55
Anomalia relativa a 1976-1990 (ºC)
5
4
3
2
1
0
-1
-2
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI

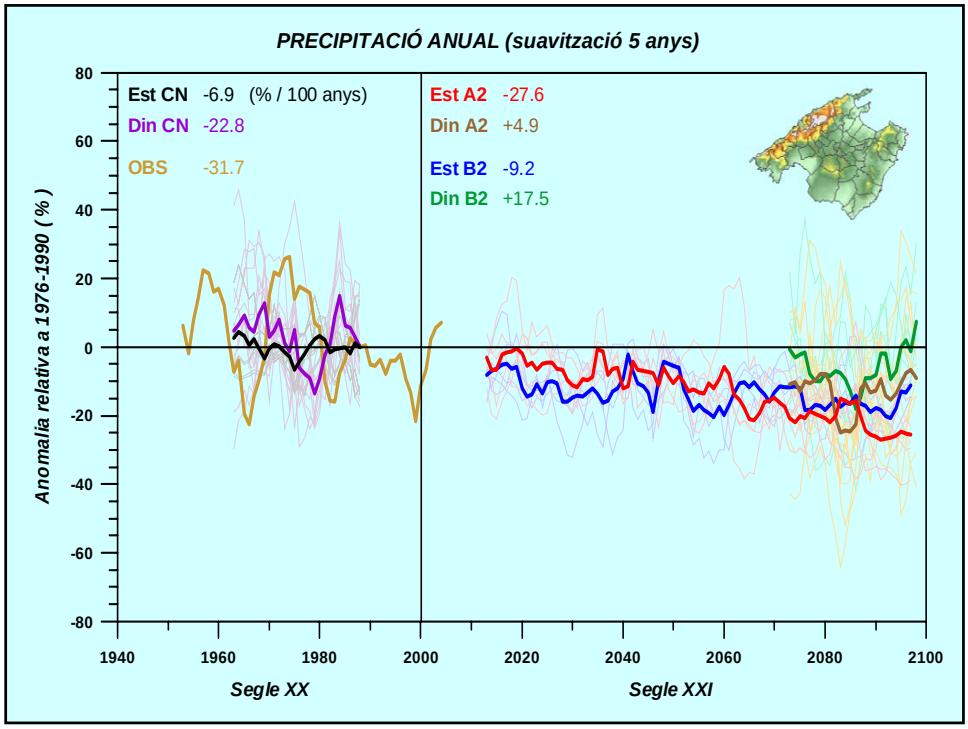

TEMPERATURA MÍNIMA - mitjana TARDOR (suavització 5 anys)
Est CN +3.86 (ºC / 100 anys)
Din CN +0.91
OBS +5.25
Est A2 +4.60
Din A2 +6.64
Est B2 +2.77
Din B2 +3.16
Anomalia relativa a 1976-1990 (ºC)
5
4
3
2
1
0
-1
-2
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI

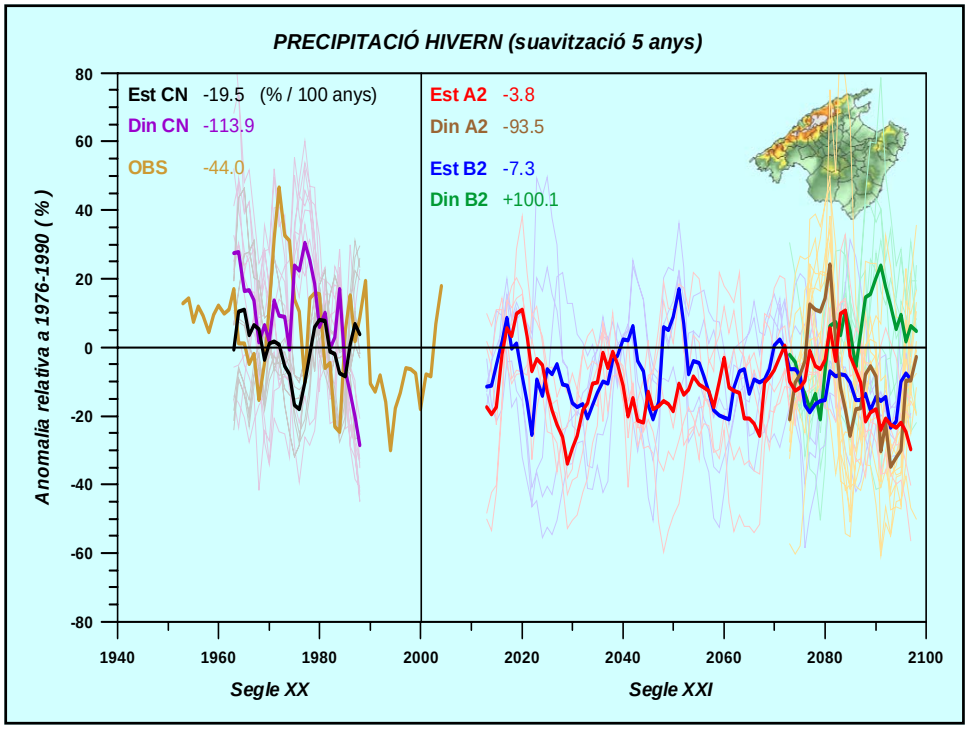
MINIMUM TEMPERATURE Trend (5-yr filter)

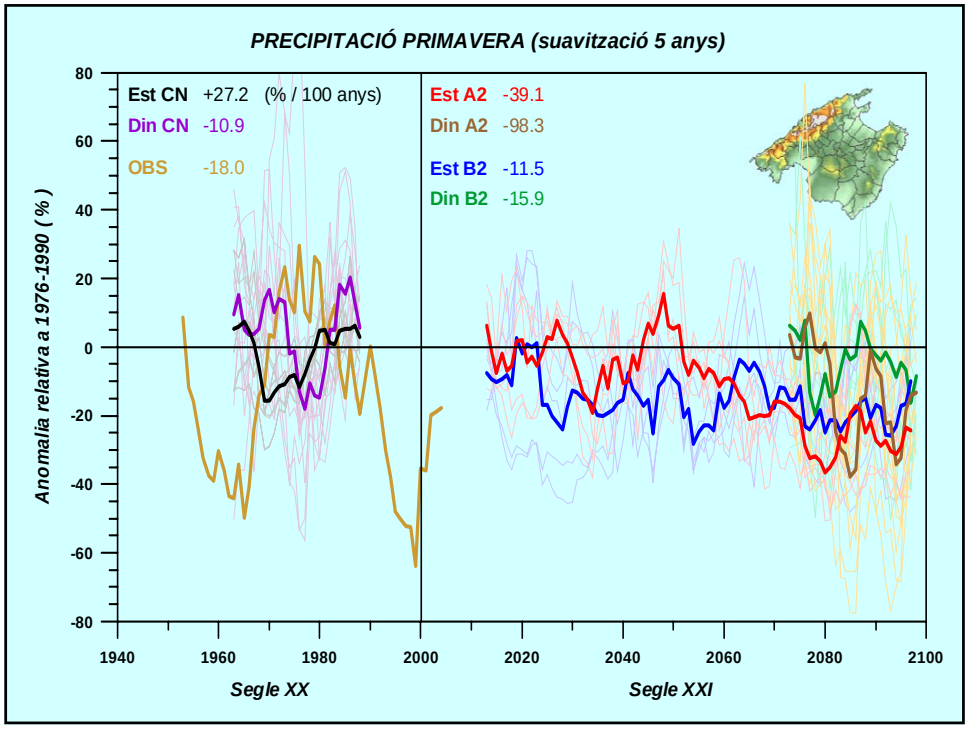


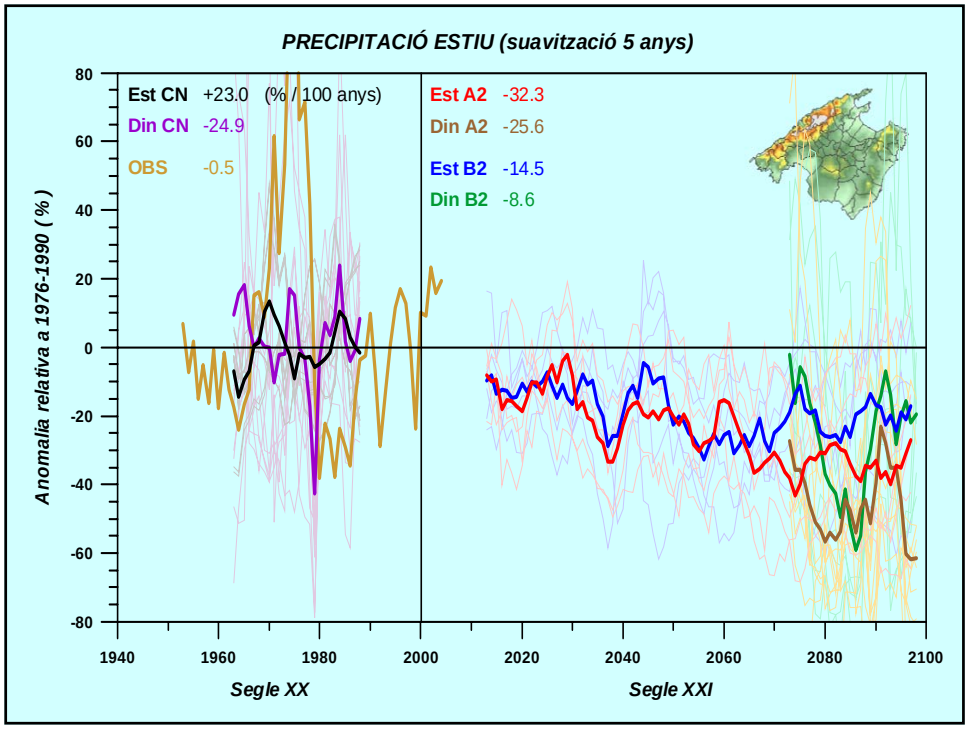
in ^{0}C / 100 yr	ANNUAL	Winter	Spring	Summer	Fall
Est CN 1961-1990 **Din CN** 1961-1990	+1.41 +0.61	+0.55 +0.63	-0.17 +0.88	+1.50 +0.40	+3.86 +0.91
OBS 1976-2006	+6.06	+2.76	+6.82	+9.26	+5.25
Est A2 2011-2099 **Din A2** 2071-2100	+4.37 +5.82	+3.55 +4.28	+3.95 +5.24	+5.41 +7.14	+4.60 +6.64
Est B2 2011-2099 **Din B2** 2071-2100	+2.54 +2.62	+2.38 +1.99	+2.00 +1.91	+3.01 +3.55	+2.77 +3.16

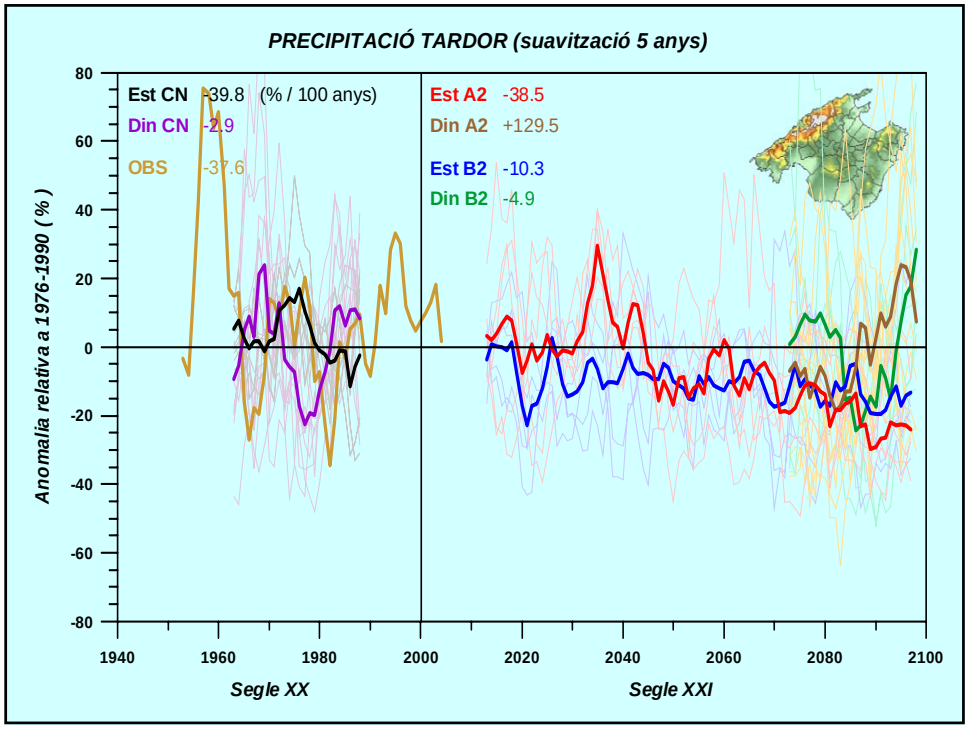
Precipitation


PRECIPITACIÓ ANUAL (suavització 5 anys)
Est CN -6.9 (% / 100 anys)
Din CN -22.8
OBS -31.7
Est A2 -27.6
Din A2 +4.9
Est B2 -9.2
Din B2 +17.5
Anomalia relativa a 1976-1990 (%)
80
60
40
20
0
-20
-40
-60
-80
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI

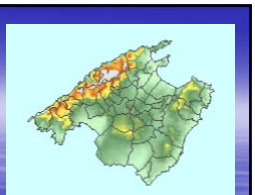

PRECIPITACIÓ HIVERN (suavització 5 anys)
Est CN -19.5 (% / 100 anys)
Din CN -113.9
OBS -44.0
Est A2 -3.8
Din A2 -93.5
Est B2 -7.3
Din B2 +100.1
Anomalia relativa a 1976-1990 (%)
80
60
40
20
0
-20
-40
-60
-80
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


PRECIPITACIÓ PRIMAVERA (suavització 5 anys)
Est CN +27.2 (% / 100 anys)
Din CN -10.9
OBS -18.0
Est A2 -39.1
Din A2 -98.3
Est B2 -11.5
Din B2 -15.9
Anomalia relativa a 1976-1990 (%)
80
60
40
20
0
-20
-40
-60
-80
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI


PRECIPITACIÓ ESTIU (suavització 5 anys)
Est CN +23.0 (% / 100 anys)
Din CN -24.9
OBS -0.5
Est A2 -32.3
Din A2 -25.6
Est B2 -14.5
Din B2 -8.6
Anomalia relativa a 1976-1990 (%)
80
60
40
20
0
-20
-40
-60
-80
1940
1960
1980
2000
2020
2040
2060
2080
2100
Segle XX
Segle XXI



PRECIPITATION Trend (5-yr filter)



in % / 100 yr	ANNUAL	Winter	Spring	Summer	Fall
Est CN 1961-1990	-6.9	-19.5	+27.2	+23.0	-39.8
Din CN 1961-1990	-22.8	-113.9	-10.9	-24.9	-2.9
OBS 1951-2006	-31.7	-44.0	-18.0	-0.5	-37.6
Est A2 2011-2099	-27.6	-3.8	-39.1	-32.3	-38.5
Din A2 2071-2100	+4.9	-93.5	-98.3	-25.6	+129.5
Est B2 2011-2099	-9.2	-7.3	-11.5	-14.5	-10.3
Din B2 2071-2100	+17.5	+100.1	-15.9	-8.6	-4.9

Thank you
for your attention !!!