ESTIMACIÓN DE LAS TENDENCIAS SUBREGIONALES DE PRECIPITACIÓN PARA LOS PRÓXIMOS 100 AÑOS EN LA ESPAÑA MEDITERRÁNEA

100-year estimates of sub-regional precipitation trends in Mediterranean Spain

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GKSS FORSCHUNGSZENTRUM

AIM OF THE STUDY

GCM future climate simulation

ECHAM-OPYC3 simulation for 1860-2099

- *T42 ECHAM4 model*: 19 vertical levels / 2.8 deg horizontal resolution
- *OPYC3 model*: 11 vertical levels / finer horizontal resolution in the tropics
- *1860-1990*: Historical greenhouse gas concentration
- *After 1990*: Scenario A (IPCC)

↓

DOWNSCALING METHOD ?

↓

Precipitation changes for Mediterranean Spain at the end of the present century ?

ESTABLISHED BACKGROUND TO THE STUDY

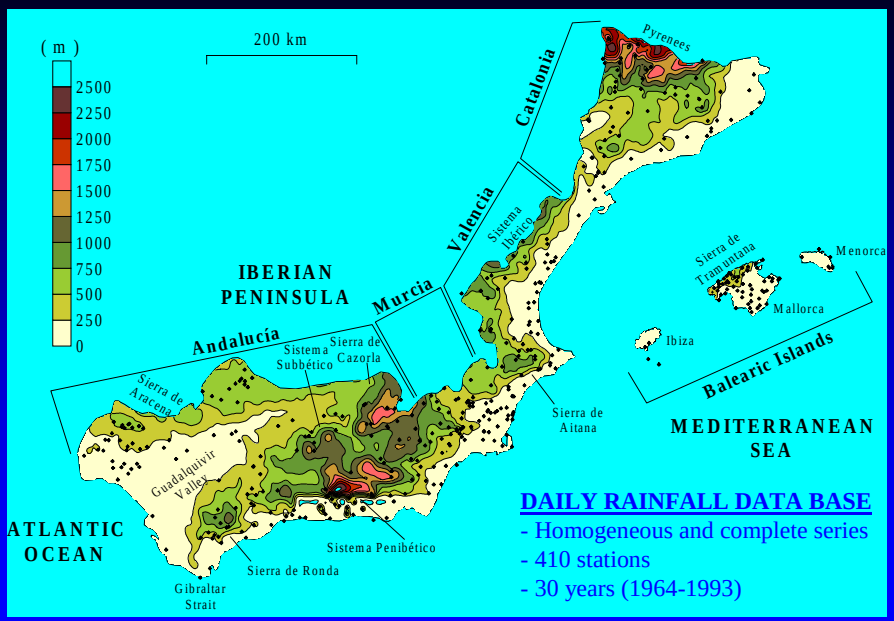
Daily Rainfall Patterns in Mediterranean Spain

• *Daily rainfall patterns in the Spanish Mediterranean area: An objective classification (1999)*	*Romero, R.* *Ramis, C.* *Guijarro, J. A.*	*Int. J. Climatol.* *Vol. **19**, 95-112*

QUANTITATIVELY LINKED

Rainfall-Producing Atmospheric Circulation Patterns

• *A classification of the atmospheric circulation patterns producing significant daily rainfall in the Spanish Mediterranean área (1999)*	*Romero, R.* *Sumner, G. N.* *Ramis, C.* *Genovés, A.*	*Int. J. Climatol.* *Vol. **19**, 765-785*



DAILY RAINFALL DATA BASE

- Homogeneous and complete series
- 410 stations
- 30 years (1964-1993)

METHODOLOGY RAINFALL PATTERNS

		Win	Spr	Sum	Aut
Significant rainfalls 1964-93	*5 % - 5 mm*	*3941 days*	*(30.0%*	*29.6%*	*13.6%*	*26.8%)*

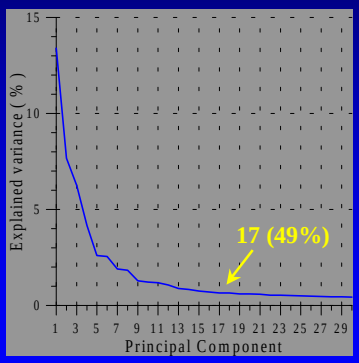
T-mode
(day-by-day)
correlation matrix

↓

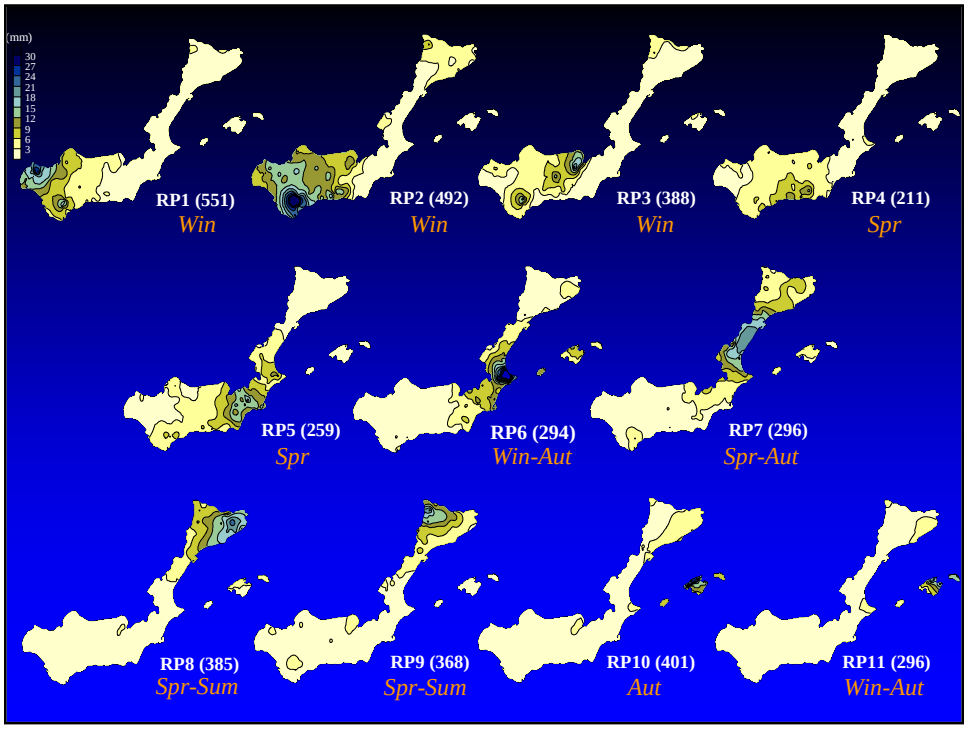
Principal Components Analysis
PCA

↓

Cluster Analysis (k-means)
CA



11 RPs

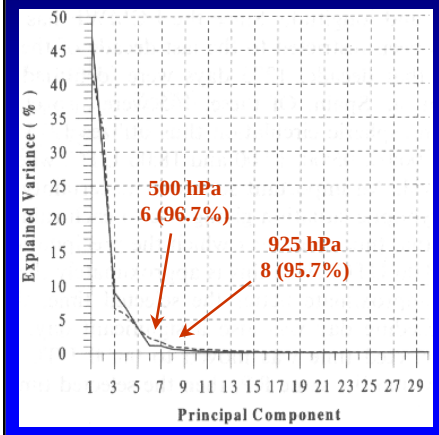


METHODOLOGY ATMOSPHERIC PATTERNS

ECMWF analyses on significant days (1984-93) ⟹ *1275 days*

Geographical window 33.75N-45.75N 11.25W-6.00E ⟹ *408 grid points*

Classification based on geopotential height at 500 and 925 hPa



T-mode
(day-by-day)
correlation matrix

↓

Principal Components Analysis
PCA

↓

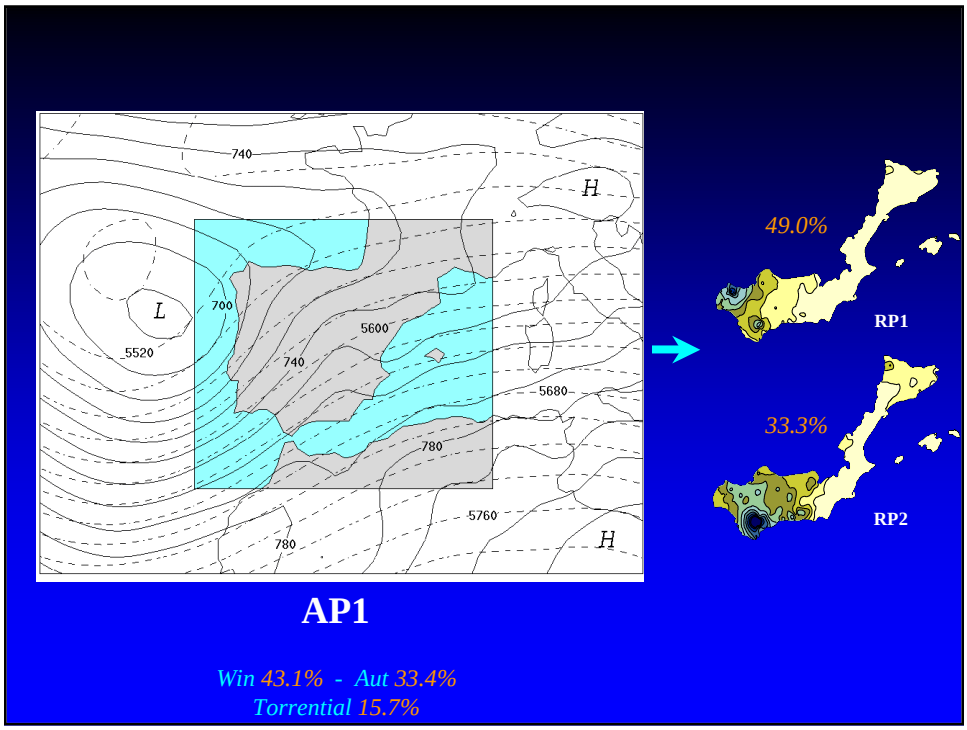
Cluster Analysis (k-means)
CA

19 APs

Table II. Percentage frequency of the 11 daily RPs within the 19 APs (in bold, percentages greater than 15%) and seasonal distribution of the APs (in bold, percentages greater than 30%)

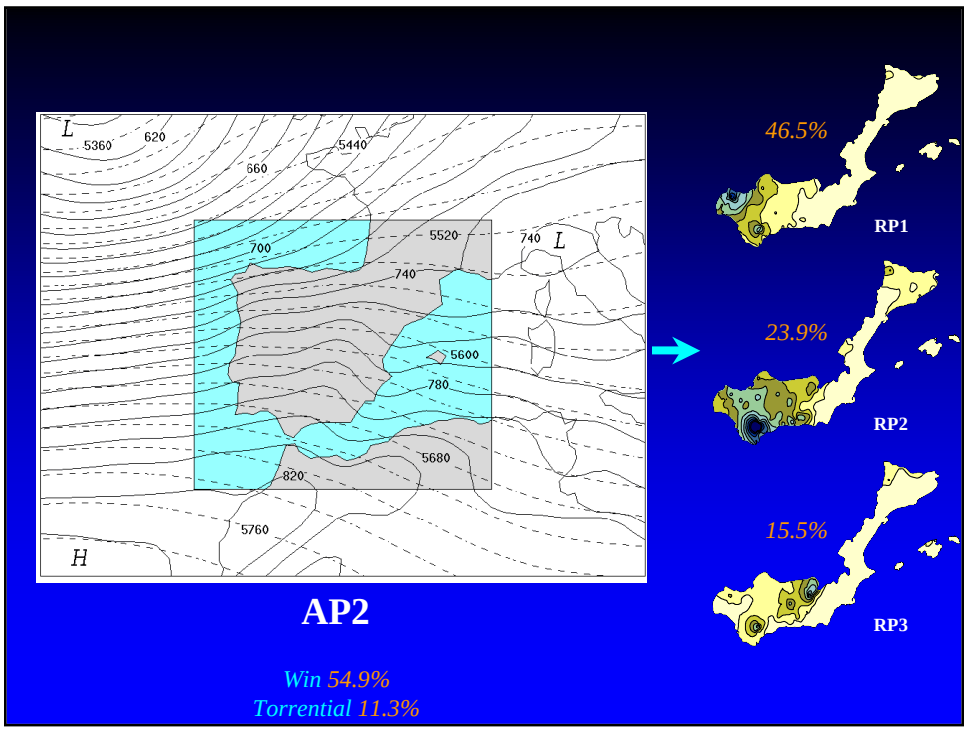
Atmospheric pattern	Number of days	RP1	RP2	RP3	RP4	RP5	RP6	RP7	RPO	RP9	RP10	RP11	Winter	Spring	Summer	Autumn
AP1	51	**49.0**	**33.3**	0.0	2.0	0.0	0.0	5.9	5.9	2.0	0.0	1.9	**43.1**	17.6	5.9	**33.4**
AP2	71	**46.5**	**23.9**	**15.5**	0.0	1.4	0.0	0.0	2.8	1.4	4.2	4.3	**54.9**	18.3	1.4	25.4
AP3	84	**35.7**	**36.9**	0.0	1.2	4.8	1.2	8.3	8.3	2.4	0.0	1.2	20.2	19.0	6.0	**54.8**
AP4	105	**30.5**	**36.2**	4.8	0.0	0.0	1.0	8.6	2.9	12.4	1.9	1.7	25.7	29.5	3.8	**41.0**
AP5	58	**22.4**	**25.9**	0.0	12.1	**15.5**	5.2	8.6	0.0	6.9	1.7	1.7	25.9	**36.2**	0.0	**37.9**
AP6	78	**17.9**	**15.4**	5.1	7.7	**21.8**	9.0	**17.9**	3.8	0.0	0.0	1.4	29.5	**33.3**	9.0	28.2
AP7	100	13.0	9.0	**25.0**	4.0	3.0	2.0	2.0	14.0	**25.0**	2.0	1.0	22.0	**35.0**	8.0	**35.0**
AP8	76	2.6	13.2	**15.8**	1.3	3.9	0.0	10.5	**23.7**	**21.1**	6.6	1.3	7.9	**42.1**	23.7	26.3
AP9	86	2.3	8.1	**41.9**	3.5	0.0	1.2	2.3	**16.3**	4.7	10.5	9.2	**45.3**	29.1	9.3	16.3
AP10	28	3.6	10.7	0.0	0.0	10.7	14.3	14.3	**28.6**	3.6	7.1	7.1	**46.4**	10.7	0.0	**42.9**
AP11	70	1.4	1.4	4.3	2.9	4.3	11.4	11.4	**30.0**	**20.0**	7.1	5.8	5.7	**30.0**	**41.4**	22.9
AP12	23	0.0	0.0	0.0	8.7	4.3	**69.6**	0.0	4.3	0.0	8.7	4.4	**47.8**	17.4	0.0	**34.8**
AP13	66	1.5	3.0	0.0	3.0	**28.8**	**40.9**	12.1	4.5	1.5	4.5	0.2	**53.0**	19.7	3.0	24.3
AP14	56	3.6	3.6	8.9	3.6	**17.9**	**16.1**	**21.4**	3.6	14.3	5.4	1.6	8.9	**35.7**	**33.9**	21.5
AP15	25	4.0	8.0	0.0	**16.0**	**20.0**	4.0	**24.0**	0.0	8.0	8.0	8.0	16.0	**32.0**	12.0	**40.0**
AP16	73	4.1	4.1	0.0	9.6	**16.4**	8.2	6.8	**20.5**	0.0	**17.8**	12.5	12.3	28.8	**38.4**	20.5
AP17	52	0.0	3.8	0.0	5.8	9.6	**36.5**	0.0	1.9	0.0	**19.2**	**23.2**	**30.8**	23.1	15.4	**30.7**
AP18	86	2.3	2.3	8.1	0.0	4.7	7.0	2.3	**17.4**	2.3	**24.4**	**29.2**	26.7	**41.9**	8.1	23.3
AP19	87	0.0	1.1	1.1	4.6	1.1	5.7	1.1	10.3	1.1	**37.9**	**36.0**	**34.5**	**40.2**	4.6	20.7
Total	1275	13.7	13.6	8.5	3.8	7.8	9.1	7.5	10.9	7.5	9.1	8.3	28.2	29.9	12.1	29.8

CLEAR ASSOCIATION



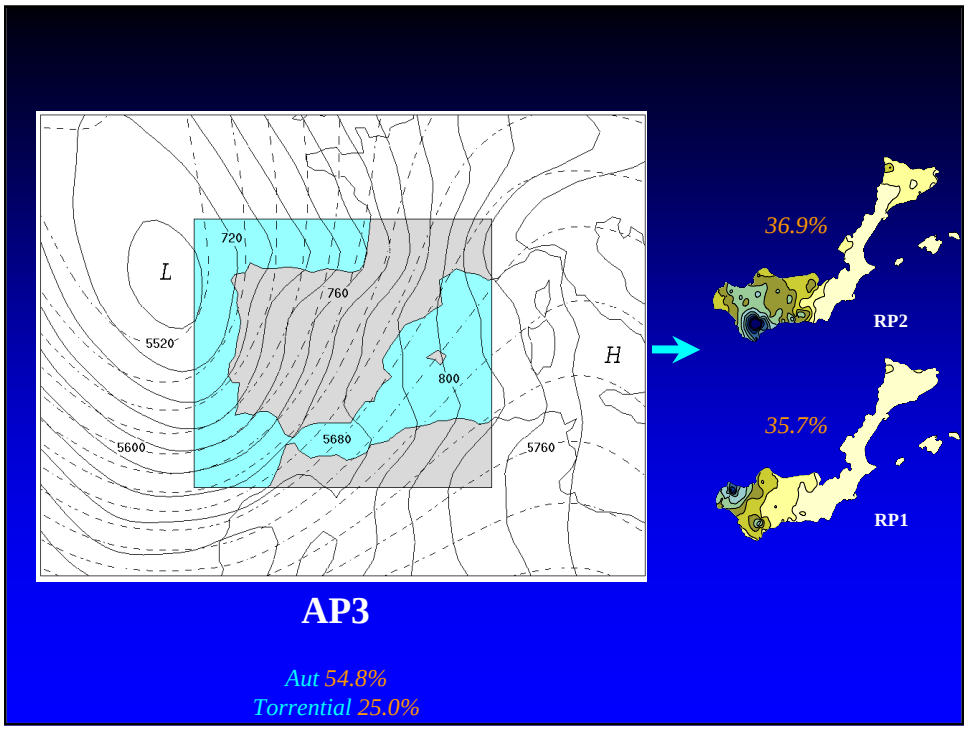
AP1

Win 43.1% - Aut 33.4%
Torrential 15.7%



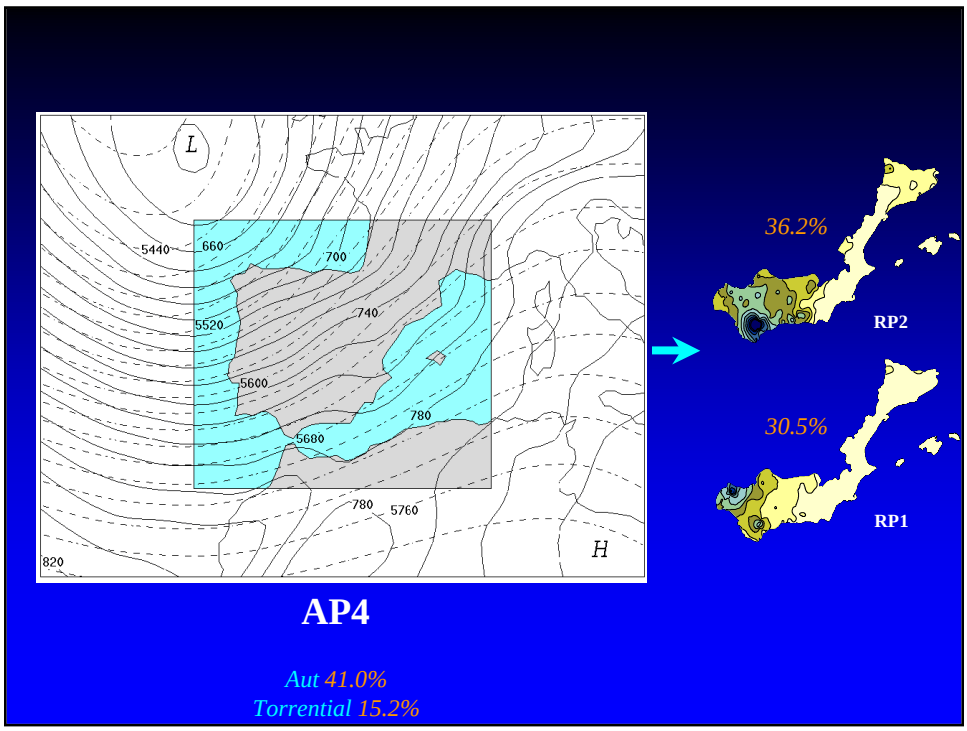
AP2

Win 54.9%
Torrential 11.3%



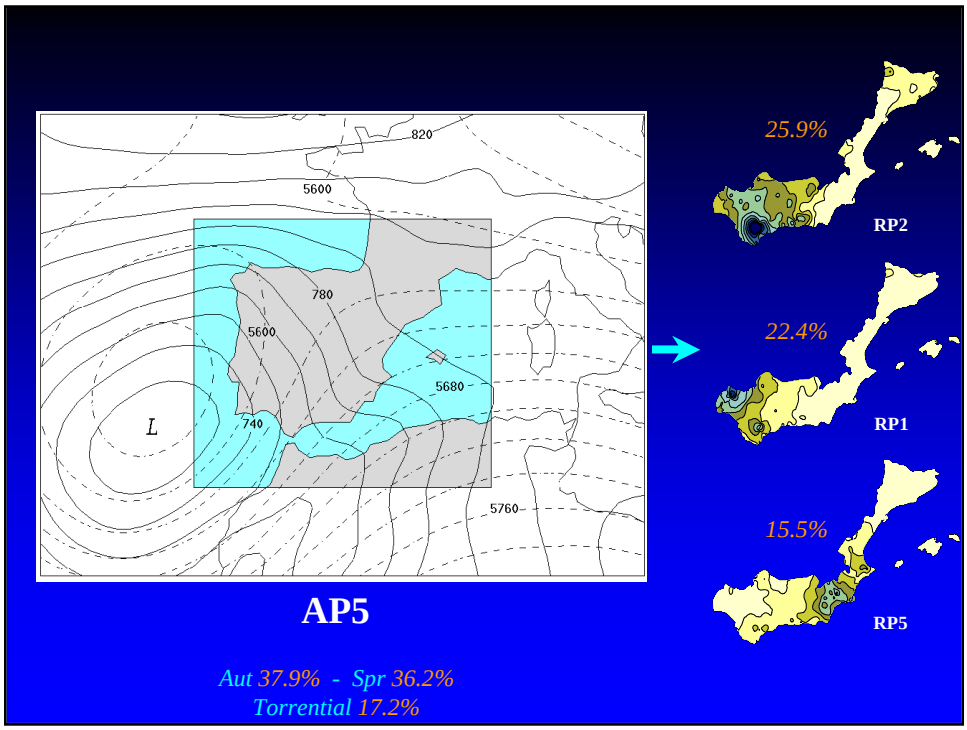
AP3

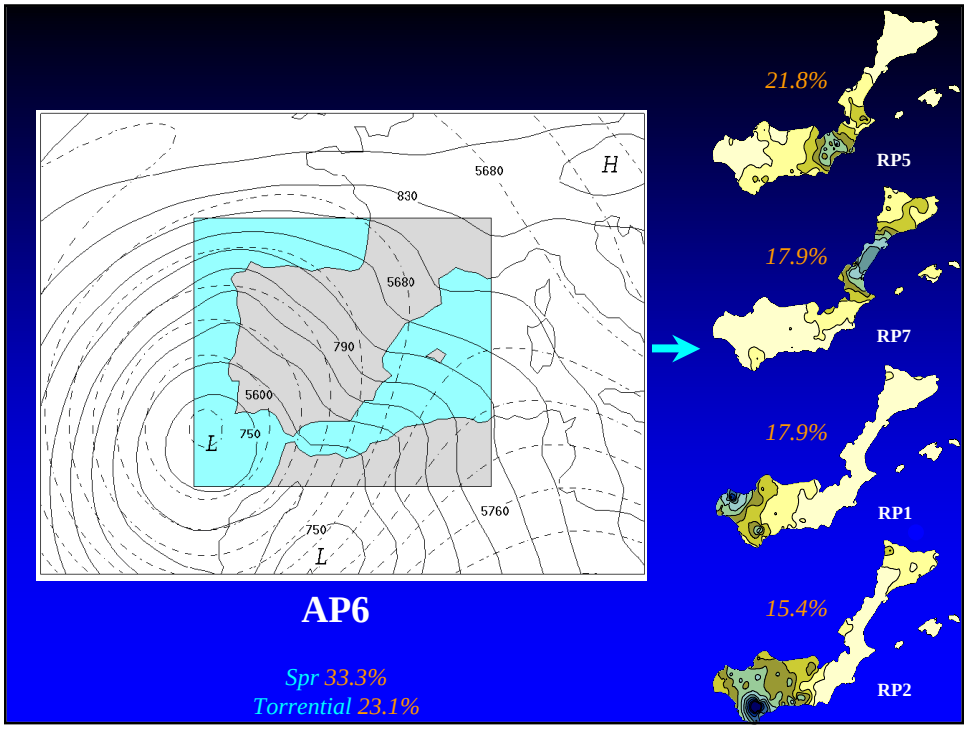
Aut 54.8%
Torrential 25.0%

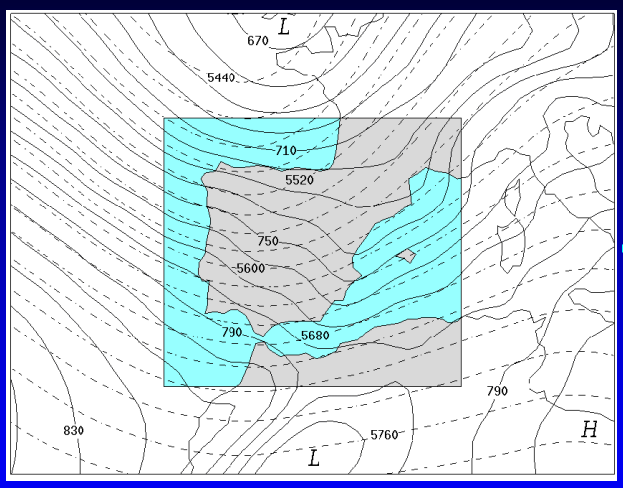


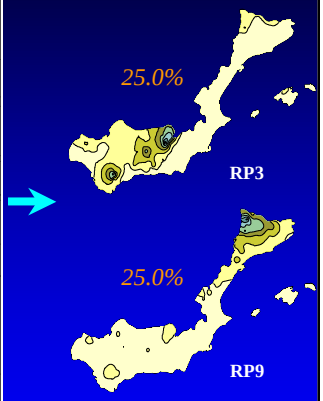
AP4

Aut 41.0%
Torrential 15.2%


820
5600
780
5600
5680
740
L
5760
25.9%
RP2
22.4%
RP1
15.5%
RP5
AP5
Aut 37.9% - Spr 36.2%
Torrential 17.2%

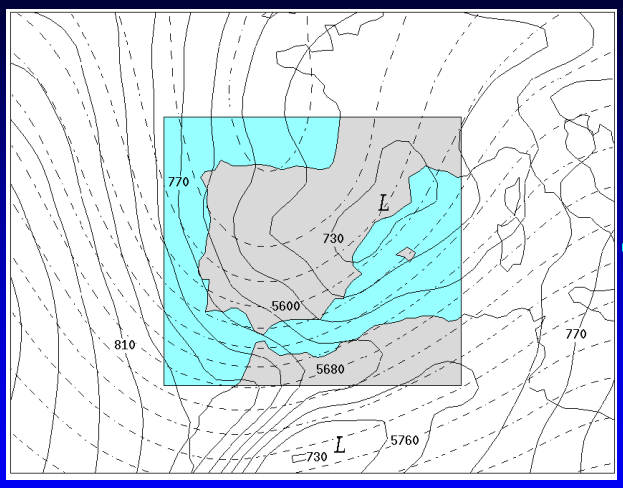

5680
H
830
5680
790
5600
L
750
5760
750
L
21.8%
RP5
17.9%
RP7
17.9%
RP1
15.4%
RP2
AP6
Spr 33.3%
Torrential 23.1%

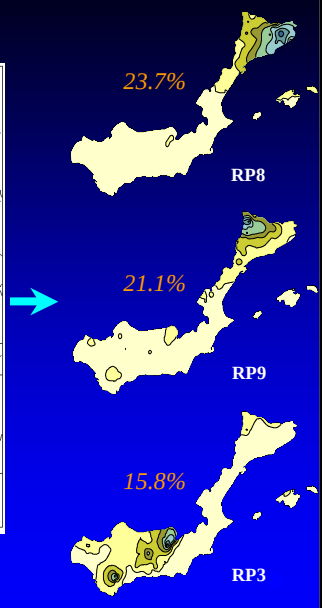




AP7

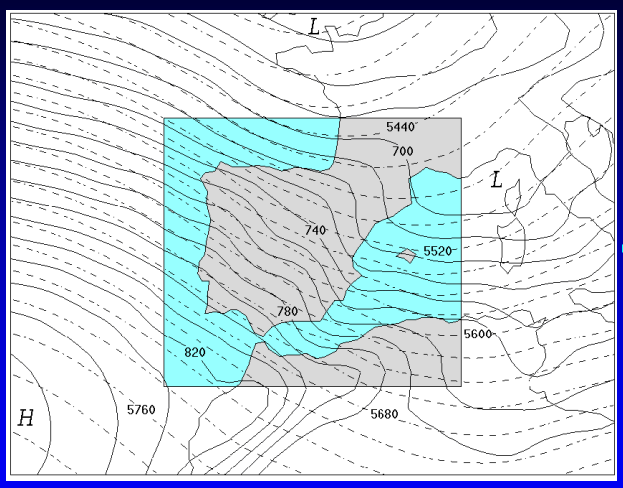
Spr 35.0% - Aut 35.0%
Torrential 2.0%

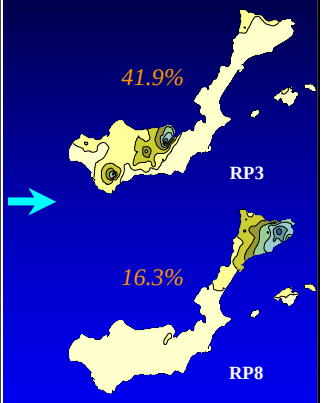




AP8

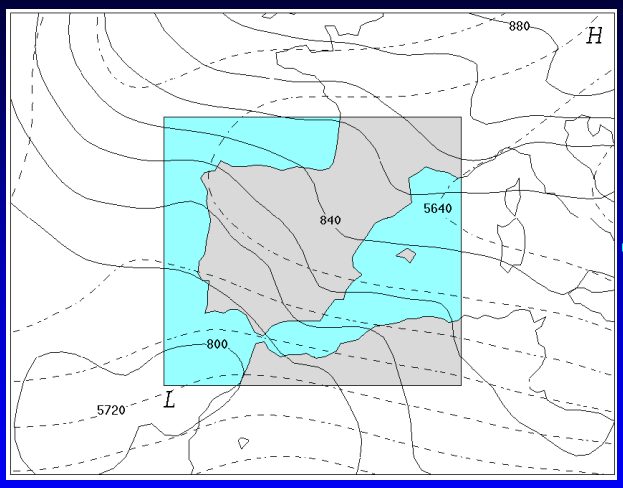
Spr 42.1%
Torrential 7.9%

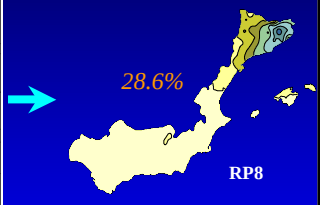




AP9

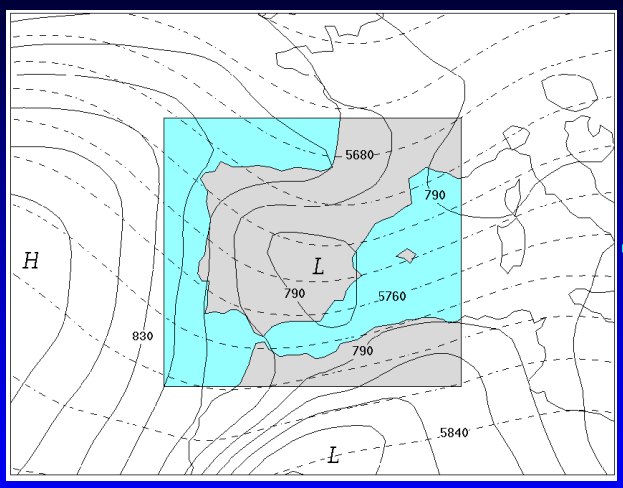
Win 45.3%
Torrential 3.5%

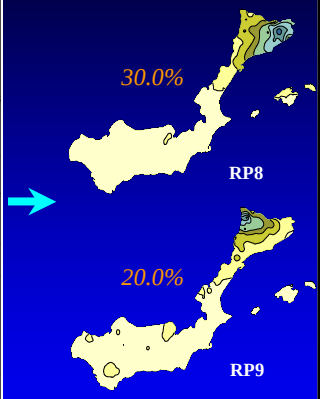




AP10

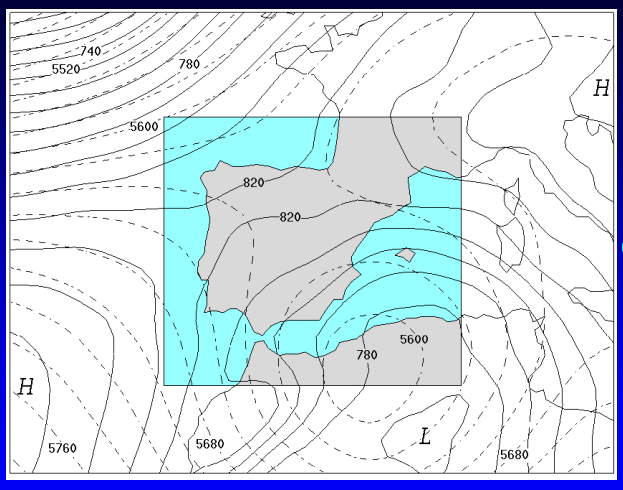
Win 46.4% - Aut 42.9%
Torrential 10.7%

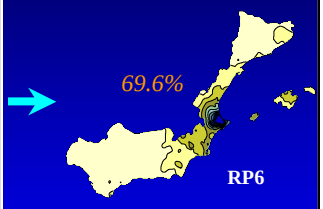




AP11

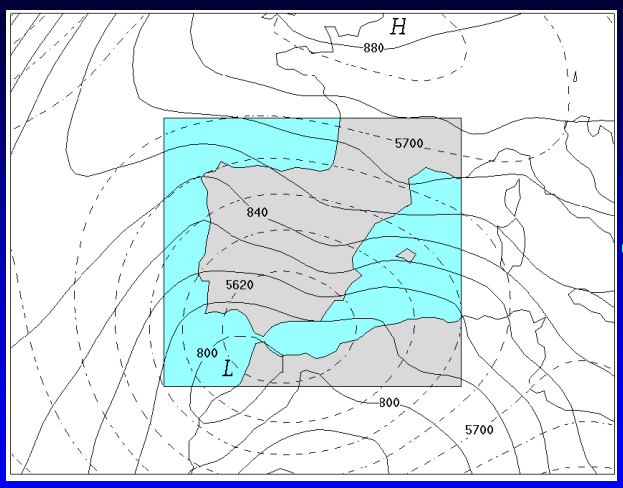
Sum 41.4% - Spr 30.0%
Torrential 0.0%

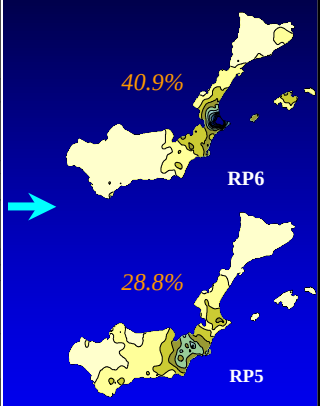




AP12

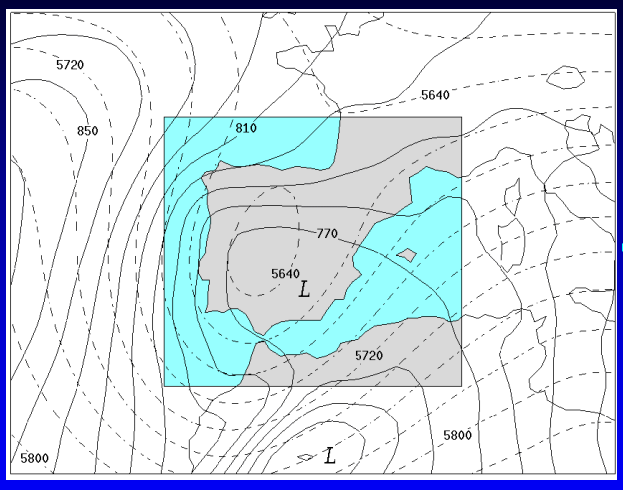
Win 47.8% - Aut 34.8%
Torrential 21.7%

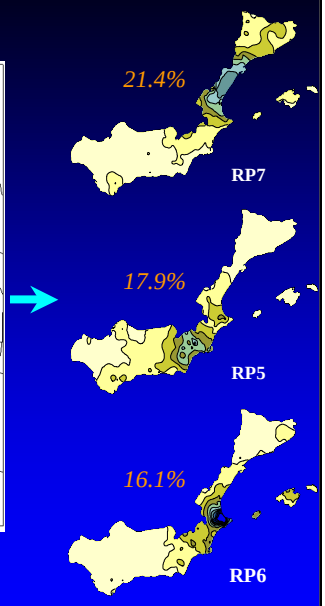




AP13

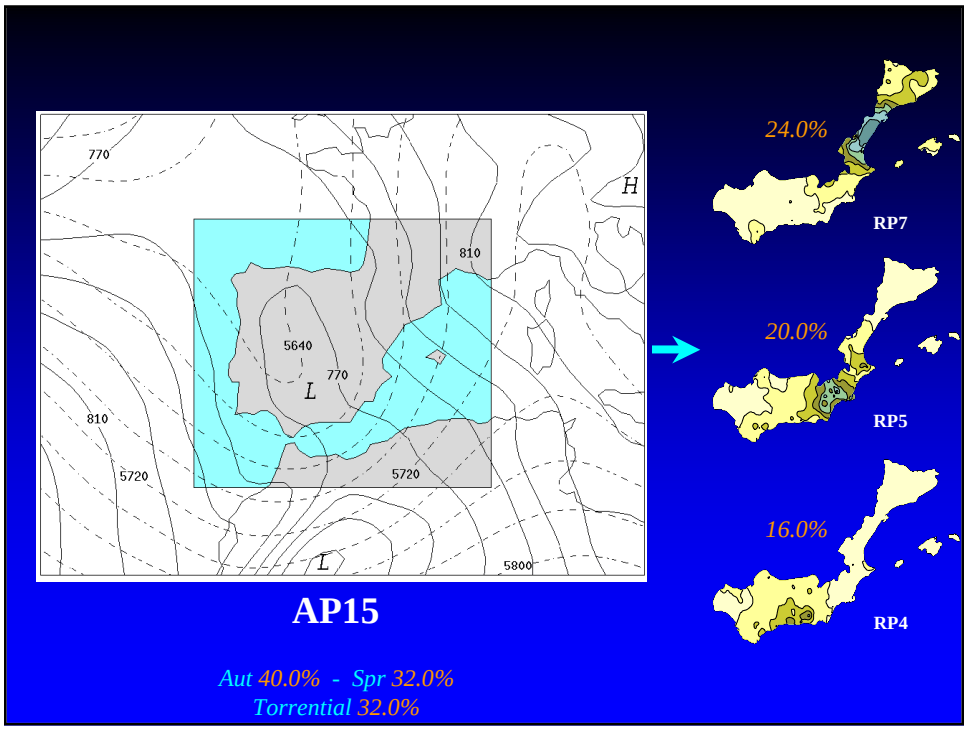
Win 53.0%
Torrential 37.9%

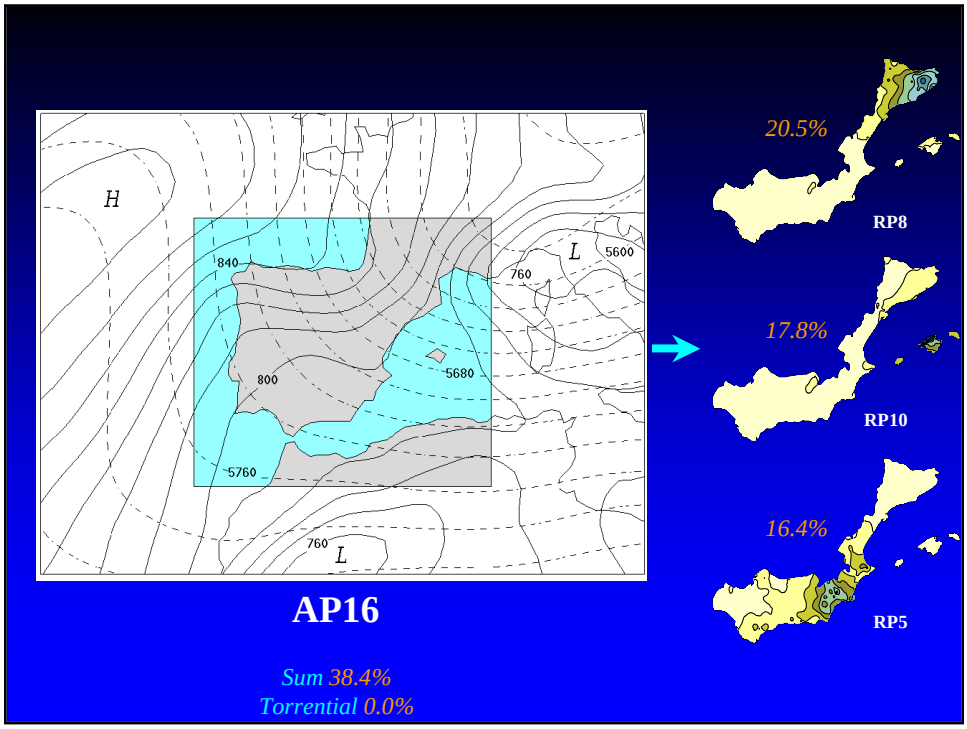


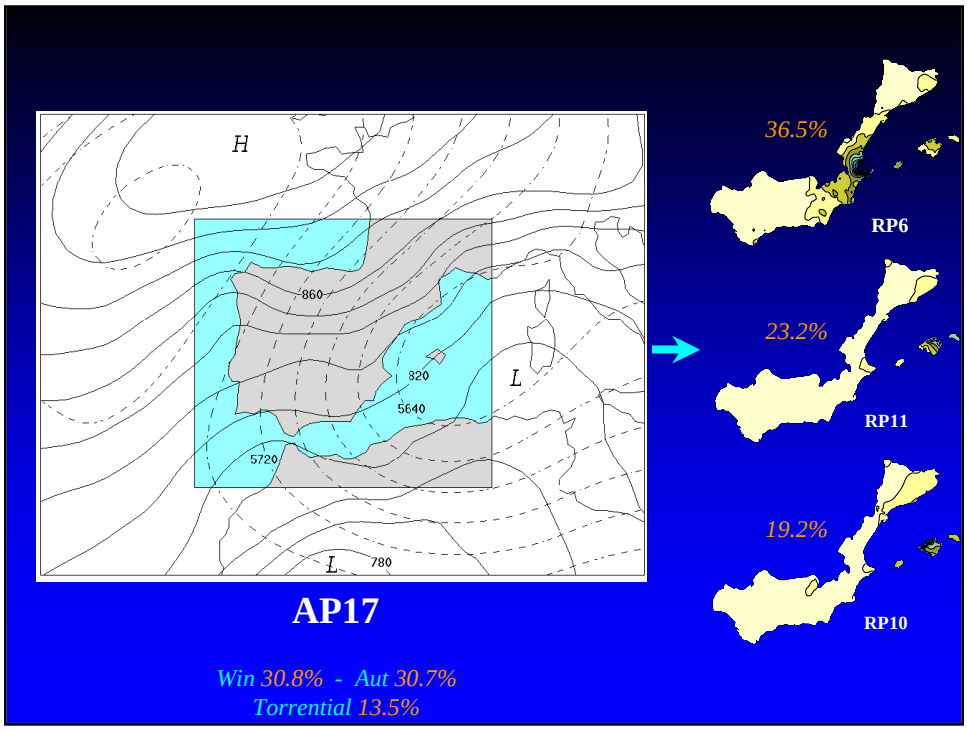


AP14

Spr 35.7% - Sum 33.9%
Torrential 19.6%

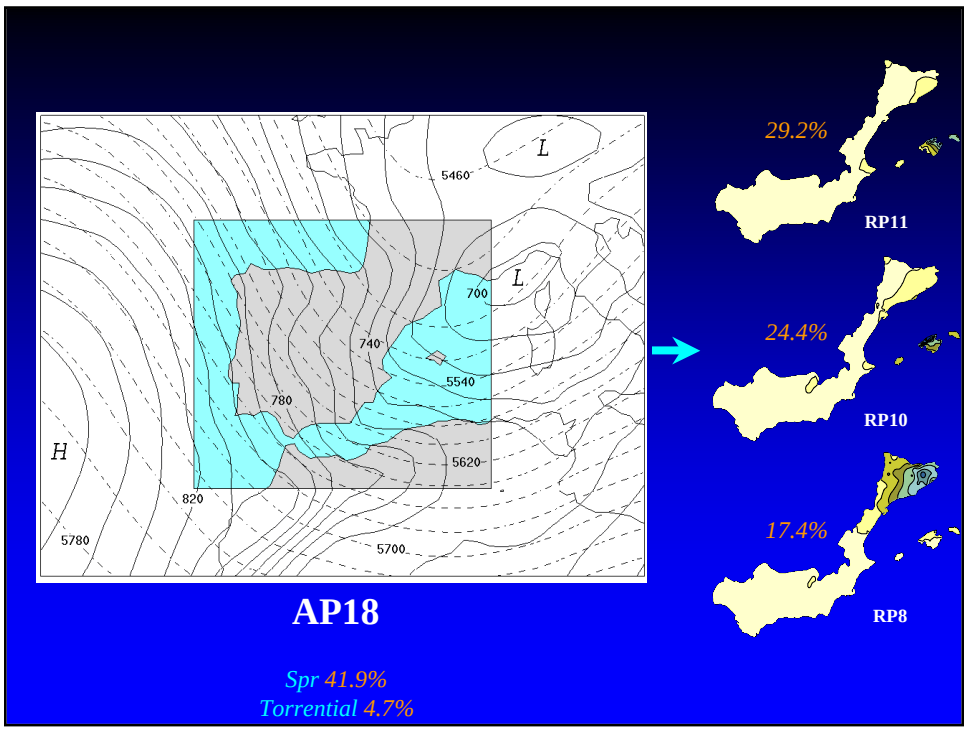

770
H
810
5640
770
L
810
5720
5720
L
5800
24.0%
RP7
20.0%
RP5
16.0%
RP4
AP15
Aut 40.0% - Spr 32.0%
Torrential 32.0%


H
840
800
5760
760
L
L
5600
760
5680
20.5%
RP8
17.8%
RP10
16.4%
RP5
AP16
Sum 38.4%
Torrential 0.0%



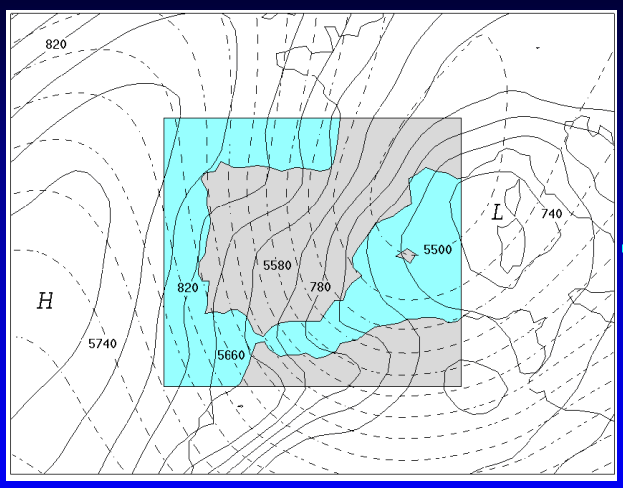
AP17

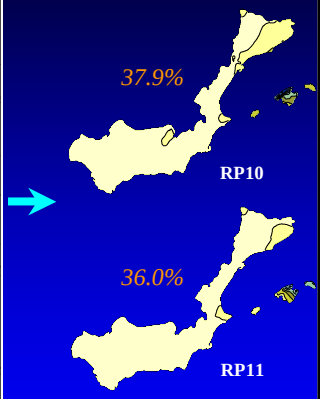
Win 30.8% - Aut 30.7%
Torrential 13.5%



AP18

Spr 41.9%
Torrential 4.7%





AP19

Spr 40.2% - Win 34.5%
Torrential 11.5%

STRATEGY

Table II. Percentage frequency of the 11 daily RPs within the 19 APs (in bold, percentages greater than 15%) and seasonal distribution of the APs (in bold, percentages greater than 30%)

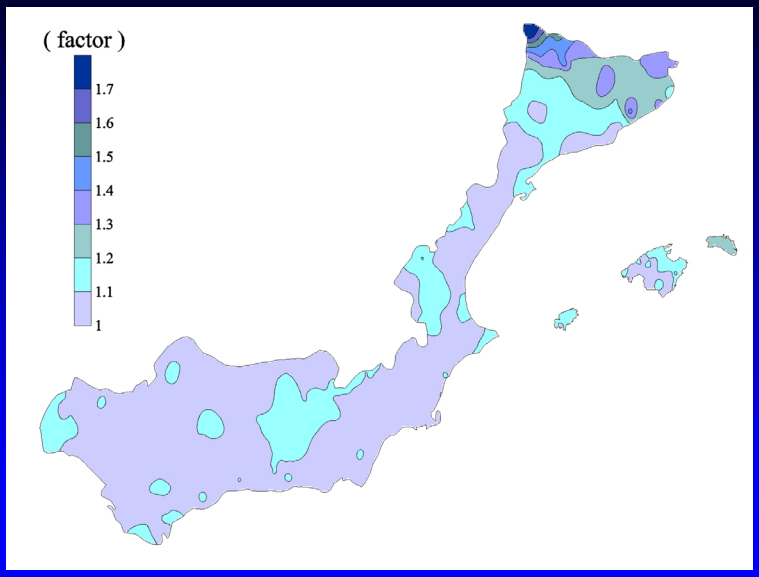
Atmospheric pattern	Number of days	RP1	RP2	RP3	RP4	RP5	RP6	RP7	RPO	RP9	RP10	RP11	Winter	Spring	Summer	Autumn
AP1	ECHAM FUTURE	**49.0**	**33.3**	0.0	2.0	0.0	0.0	5.9	5.9	2.0	0.0	1.9	**43.1**	17.6	5.9	**33.4**
AP2		**46.5**	**23.9**	**15.5**	0.0	1.4	0.0	0.0	2.8	1.4	4.2	4.3	**54.9**	18.3	1.4	25.4
AP3		**35.7**	**36.9**	0.0	1.2	4.8	1.2	8.3	8.3	2.4	0.0	1.2	20.2	19.0	6.0	**54.8**
AP4		**30.5**	**36.2**	4.8	0.0	0.0	1.0	8.6	2.9	12.4	1.9	1.7	25.7	29.5	3.8	**41.0**
AP5		**22.4**	**25.9**	0.0	12.1	**15.5**	5.2	8.6	0.0	6.9	1.7	1.7	25.9	**36.2**	0.0	**37.9**
AP6		**17.9**	**15.4**	5.1	7.7	**21.8**	9.0	**17.9**	3.8	0.0	0.0	1.4	29.5	**33.3**	9.0	28.2
AP7		13.0	9.0	**25.0**	4.0	3.0	2.0	2.0	14.0	**25.0**	2.0	1.0	22.0	**35.0**	8.0	**35.0**
AP8		2.6	13.2	**15.8**	1.3	3.9	0.0	10.5	**23.7**	**21.1**	6.6	1.3	7.9	**42.1**	23.7	26.3
AP9		2.3	8.1	**41.9**	3.5	0.0	1.2	2.3	**16.3**	4.7	10.5	9.2	**45.3**	29.1	9.3	16.3
AP10		3.6	10.7	0.0	0.0	10.7	14.3	14.3	**28.6**	3.6	7.1	7.1	**46.4**	10.7	0.0	**42.9**
AP11		1.4	1.4	4.3	2.9	4.3	11.4	11.4	**30.0**	**20.0**	7.1	5.8	5.7	**30.0**	**41.4**	22.9
AP12		0.0	0.0	0.0	8.7	4.3	**69.6**	0.0	4.3	0.0	8.7	4.4	**47.8**	17.4	0.0	**34.8**
AP13		1.5	3.0	0.0	3.0	**28.8**	**40.9**	12.1	4.5	1.5	4.5	0.2	**53.0**	19.7	3.0	24.3
AP14		3.6	3.6	8.9	3.6	**17.9**	**16.1**	**21.4**	3.6	14.3	5.4	1.6	8.9	**35.7**	**33.9**	21.5
AP15		4.0	8.0	0.0	**16.0**	**20.0**	4.0	**24.0**	0.0	8.0	8.0	8.0	16.0	**32.0**	12.0	**40.0**
AP16		4.1	4.1	0.0	9.6	**16.4**	8.2	6.8	**20.5**	0.0	**17.8**	12.5	12.3	28.8	**38.4**	20.5
AP17		0.0	3.8	0.0	5.8	9.6	**36.5**	0.0	1.9	0.0	**19.2**	**23.2**	**30.8**	23.1	15.4	**30.7**
AP18		2.3	2.3	8.1	0.0	4.7	7.0	2.3	**17.4**	2.3	**24.4**	**29.2**	26.7	**41.9**	8.1	23.3
AP19		0.0	1.1	1.1	4.6	1.1	5.7	1.1	10.3	1.1	**37.9**	**36.0**	**34.5**	**40.2**	4.6	20.7
Total		13.7	13.6	8.5	3.8	7.8	9.1	7.5	10.9	7.5	9.1	8.3	28.2	29.9	12.1	29.8

2080 – 2089

2090 – 2099

1) Same relationship between APs and RPs
2) Similar amounts of precipitation due to the RPs
3) Same scaling factor $\phi_i = R_i / S_i$ to obtain totals

FUTURE PRECIPITATION



STRATEGY (continued)

Table II. Percentage frequency of the 11 daily RPs within the 19 APs (in bold, percentages greater than 15%) and seasonal distribution of the APs (in bold, percentages greater than 30%)

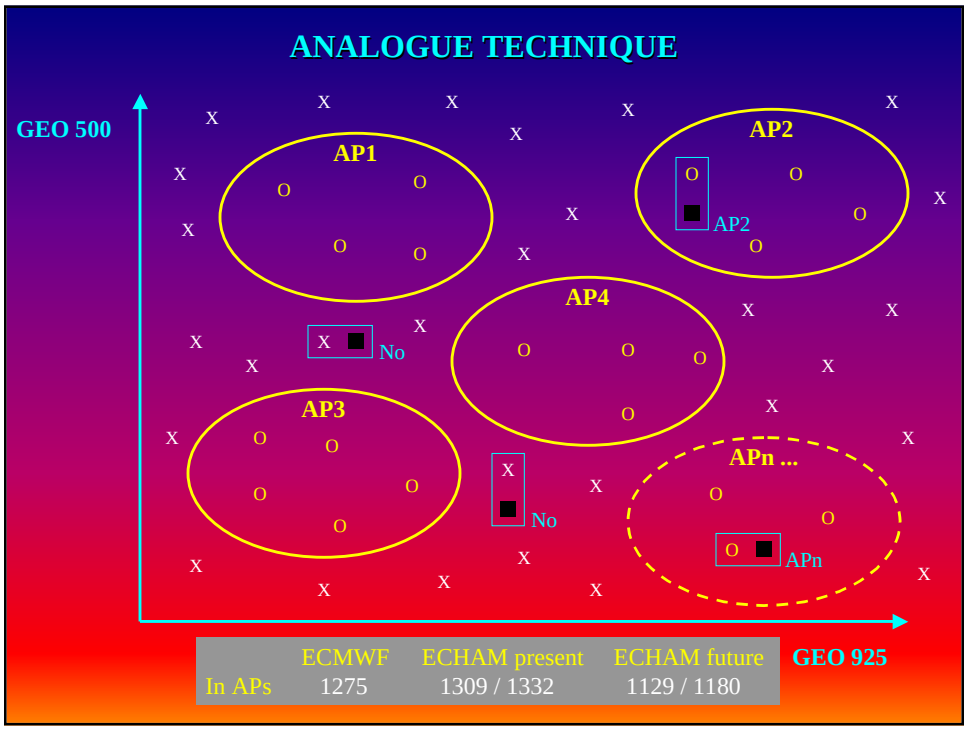
Atmospheric pattern	Number of days	RP1	RP2	RP3	RP4	RP5	RP6	RP7	RPO	RP9	RP10	RP11	Winter	Spring	Summer	Autumn
AP1	ECHAM PRESENT	**49.0**	**33.3**	0.0	2.0	0.0	0.0	5.9	5.9	2.0	0.0	1.9	**43.1**	17.6	5.9	**33.4**
AP2		**46.5**	**23.9**	**15.5**	0.0	1.4	0.0	0.0	2.8	1.4	4.2	4.3	**54.9**	18.3	1.4	25.4
AP3		**35.7**	**36.9**	0.0	1.2	4.8	1.2	8.3	8.3	2.4	0.0	1.2	20.2	19.0	6.0	**54.8**
AP4		**30.5**	**36.2**	4.8	0.0	0.0	1.0	8.6	2.9	12.4	1.9	1.7	25.7	29.5	3.8	**41.0**
AP5		**22.4**	**25.9**	0.0	12.1	**15.5**	5.2	8.6	0.0	6.9	1.7	1.7	25.9	**36.2**	0.0	**37.9**
AP6		**17.9**	**15.4**	5.1	7.7	**21.8**	9.0	**17.9**	3.8	0.0	0.0	1.4	29.5	**33.3**	9.0	28.2
AP7		13.0	9.0	**25.0**	4.0	3.0	2.0	2.0	14.0	**25.0**	2.0	1.0	22.0	**35.0**	8.0	**35.0**
AP8		2.6	13.2	**15.8**	1.3	3.9	0.0	10.5	**23.7**	**21.1**	6.6	1.3	7.9	**42.1**	23.7	26.3
AP9		2.3	8.1	**41.9**	3.5	0.0	1.2	2.3	**16.3**	4.7	10.5	9.2	**45.3**	29.1	9.3	16.3
AP10		3.6	10.7	0.0	0.0	10.7	14.3	14.3	**28.6**	3.6	7.1	7.1	**46.4**	10.7	0.0	**42.9**
AP11		1.4	1.4	4.3	2.9	4.3	11.4	11.4	**30.0**	**20.0**	7.1	5.8	5.7	**30.0**	**41.4**	22.9
AP12		0.0	0.0	0.0	8.7	4.3	**69.6**	0.0	4.3	0.0	8.7	4.4	**47.8**	17.4	0.0	**34.8**
AP13		1.5	3.0	0.0	3.0	**28.8**	**40.9**	12.1	4.5	1.5	4.5	0.2	**53.0**	19.7	3.0	24.3
AP14		3.6	3.6	8.9	3.6	**17.9**	**16.1**	**21.4**	3.6	14.3	5.4	1.6	8.9	**35.7**	**33.9**	21.5
AP15		4.0	8.0	0.0	**16.0**	**20.0**	4.0	**24.0**	0.0	8.0	8.0	8.0	16.0	**32.0**	12.0	**40.0**
AP16		4.1	4.1	0.0	9.6	**16.4**	8.2	6.8	**20.5**	0.0	**17.8**	12.5	12.3	28.8	**38.4**	20.5
AP17		0.0	3.8	0.0	5.8	9.6	**36.5**	0.0	1.9	0.0	**19.2**	**23.2**	**30.8**	23.1	15.4	**30.7**
AP18		2.3	2.3	8.1	0.0	4.7	7.0	2.3	**17.4**	2.3	**24.4**	**29.2**	26.7	**41.9**	8.1	23.3
AP19		0.0	1.1	1.1	4.6	1.1	5.7	1.1	10.3	1.1	**37.9**	**36.0**	**34.5**	**40.2**	4.6	20.7
Total		13.7	13.6	8.5	3.8	7.8	9.1	7.5	10.9	7.5	9.1	8.3	28.2	29.9	12.1	29.8

1971 – 1980

1981 – 1990

MODEL VALIDATION / CALIBRATION

COMPENSATED FUTURE


ANALOGUE TECHNIQUE
GEO 500
AP1
AP2
AP2
AP4
No
AP3
APn ...
No
APn
GEO 925
ECMWF
ECHAM present
ECHAM future
In APs
1275
1309 / 1332
1129 / 1180

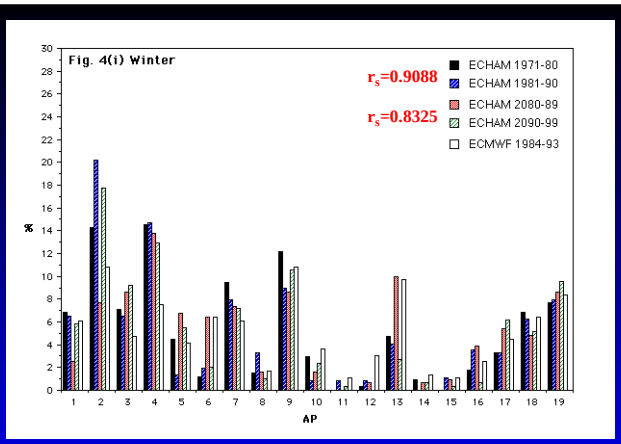


Fig. 4(i) Winter
r_s=0.9088
r_s=0.8325
ECHAM 1971-80
ECHAM 1981-90
ECHAM 2080-89
ECHAM 2090-99
ECMWF 1984-93
%
AP

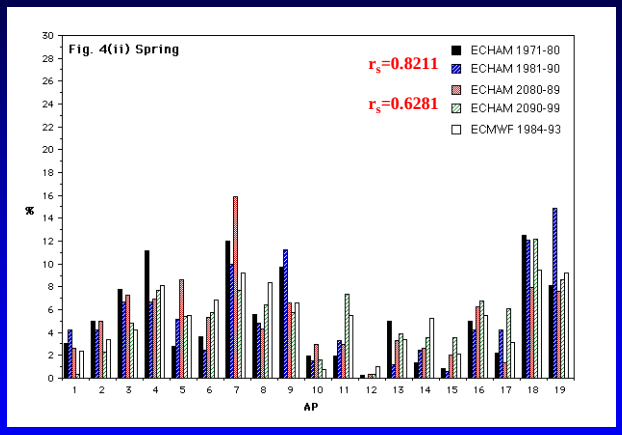


Fig. 4(ii) Spring
r_s=0.8211
r_s=0.6281
ECHAM 1971-80
ECHAM 1981-90
ECHAM 2080-89
ECHAM 2090-99
ECMWF 1984-93
%
AP

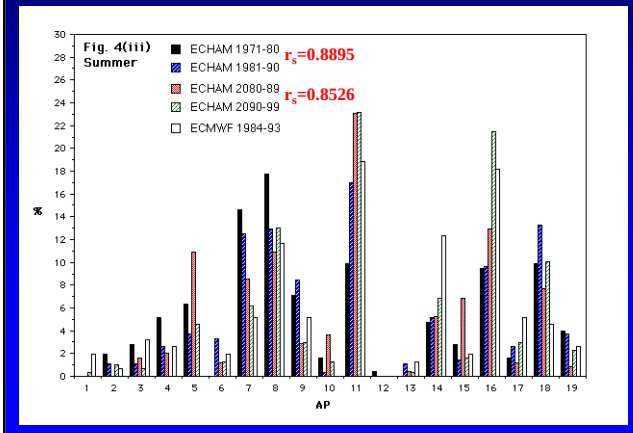
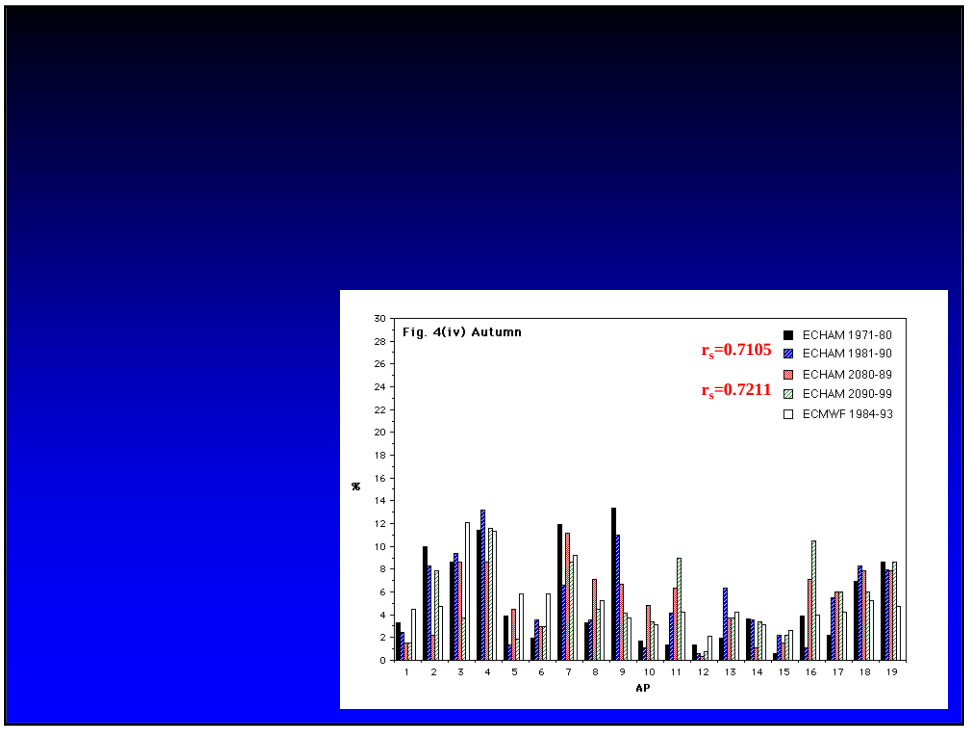
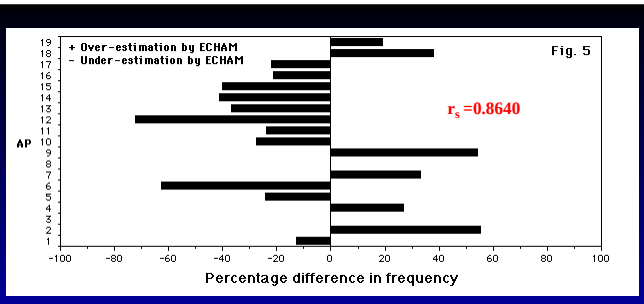


Fig. 4(iii)
Summer
ECHAM 1971-80
ECHAM 1981-90
ECHAM 2080-89
ECHAM 2090-99
ECMWF 1984-93
r_s=0.8895
r_s=0.8526
%
AP



ECHAM 1971-90

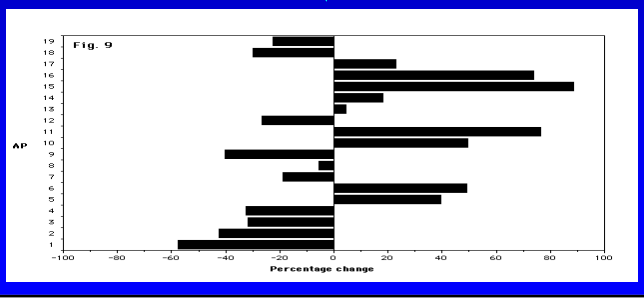


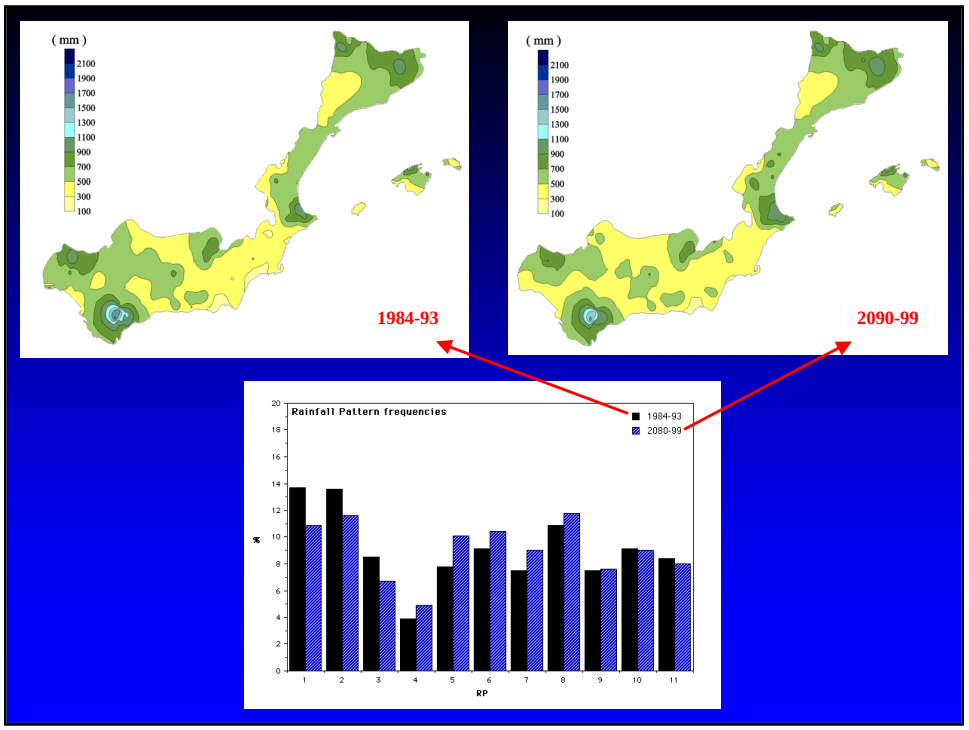
COMPENSATING THE FUTURE Ap_j

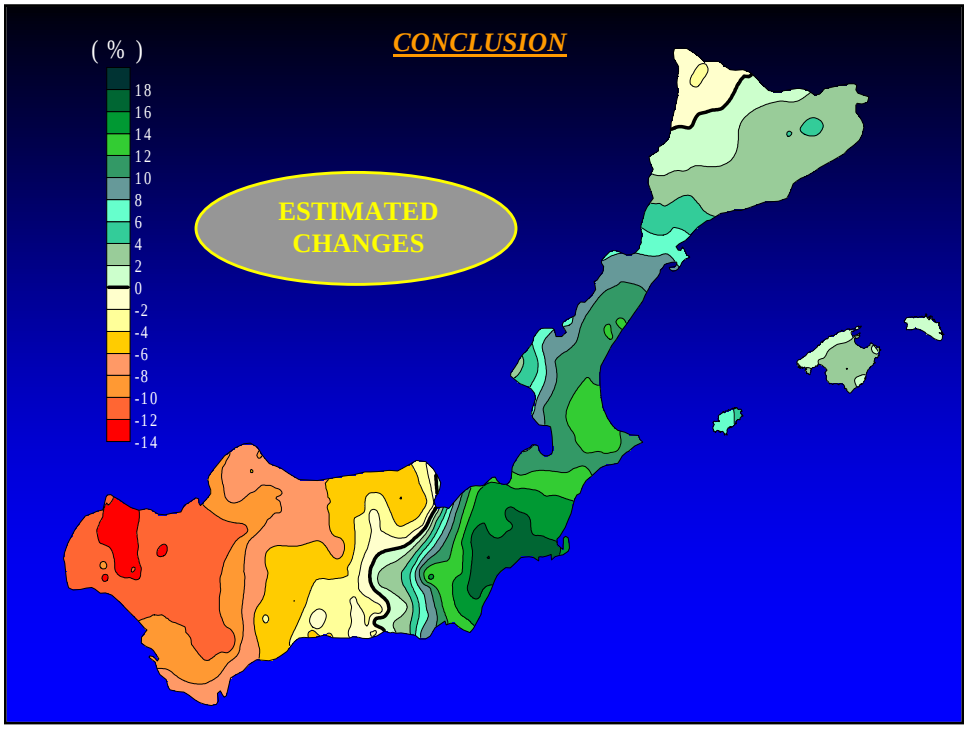
σ_j = ECMWF$_j$ / ECHAM(present)$_j$

ECHAM(future)$_j$ = σ_j ECHAM(future)$_j$

ECHAM 2080-99 (compensated)




(mm)
2100
1900
1700
1500
1300
1100
900
700
500
300
100
1984-93
(mm)
2100
1900
1700
1500
1300
1100
900
700
500
300
100
2090-99
Rainfall Pattern frequencies
1984-93
2080-99
%
RP
0
2
4
6
8
10
12
14
16
18
20
1
2
3
4
5
6
7
8
9
10
11


CONCLUSION
(%)
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
ESTIMATED
CHANGES