

Modelli climatici a scala regionale: scenari futuri a confronto

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Arpa-Sim Bologna*

Trentino Clima 2008
Evoluzione del clima: tendenze, effetti e scenari futuri
Trento, 21-22 febbraio 2008

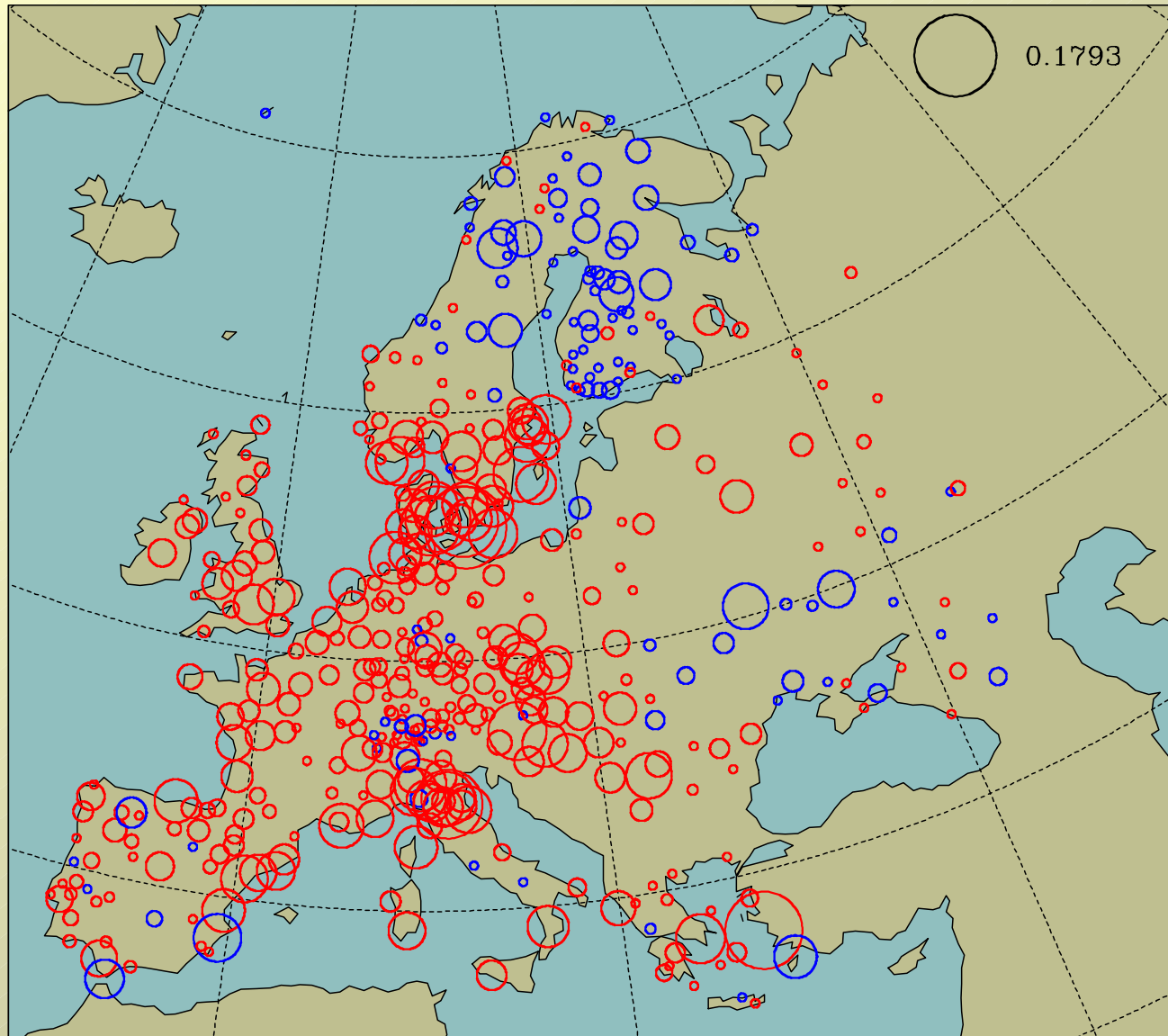
Schema della presentazione

- Il cambiamento in corso a scala europea, nazionale e regionale
- I segnali di cambiamento a scala regionale (ottenuti con uso di RCMs e tecniche di regionalizzazione dinamico/statistica)

Fonti:
IPCC IV Rep. - Progetti UE-FP5:
Stardex, Prudence Mice

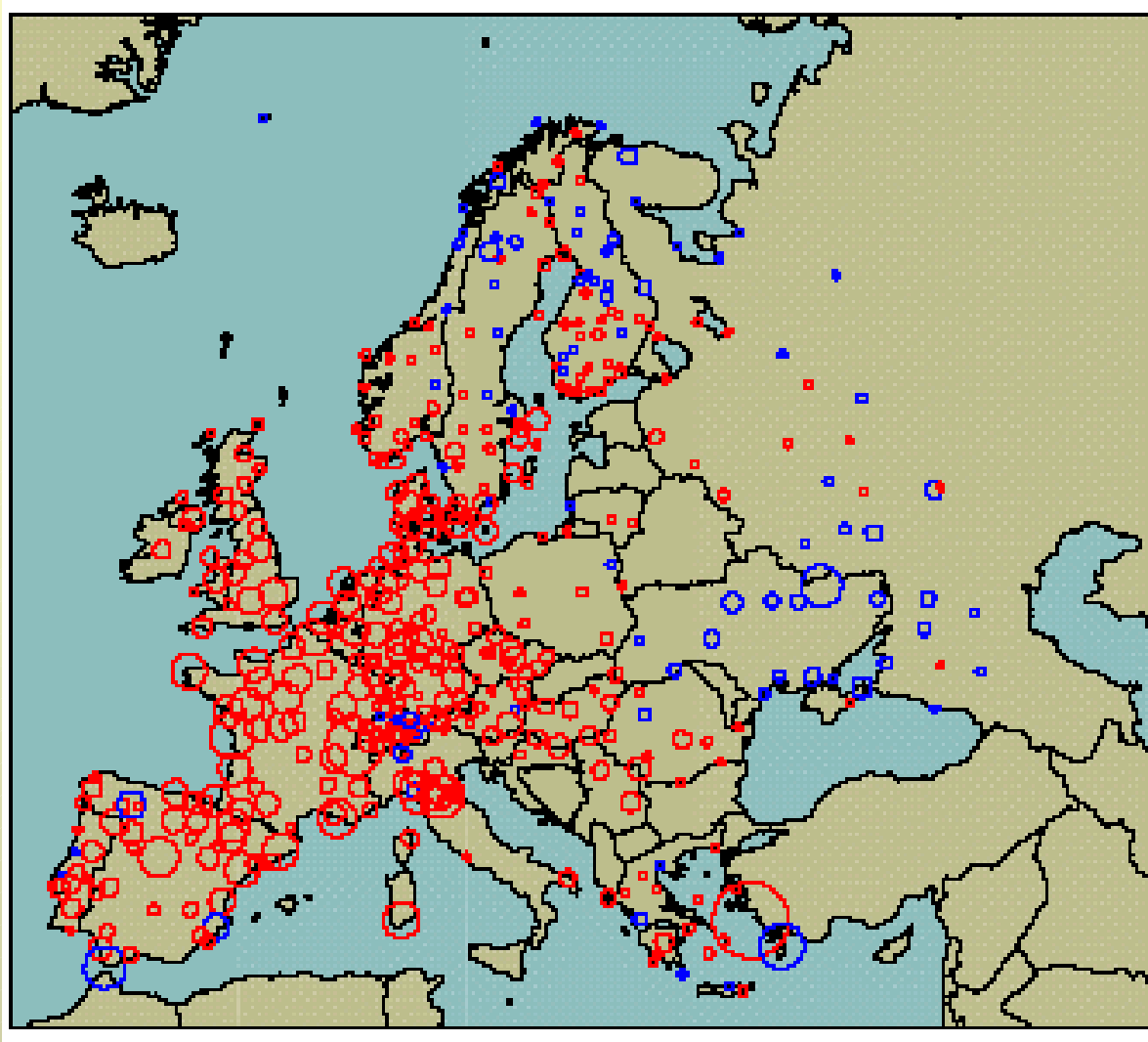
In progress: progetto UE-FP6: Ensemble

1958-2000 trend JJA durata onde di calore



Scala: giorni/anno. Rosso cresce

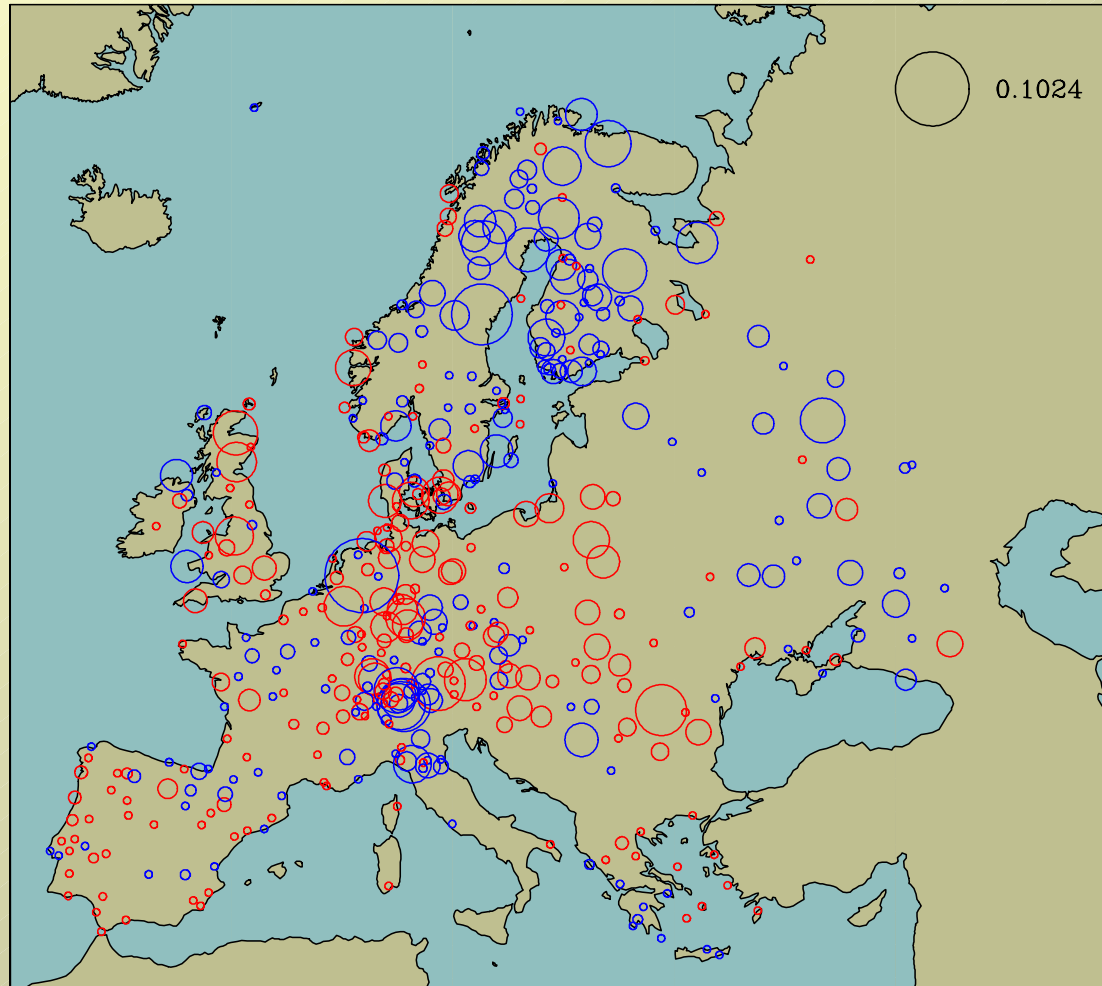
1958-2000 trend giorni “caldi” estate (JJA)



Scala: giorni/anno. Rosso cresce *Malcolm Haylock, UEA/STARDEX*

1958-2000 trend

Eventi intensi di pioggia estate (JJA)

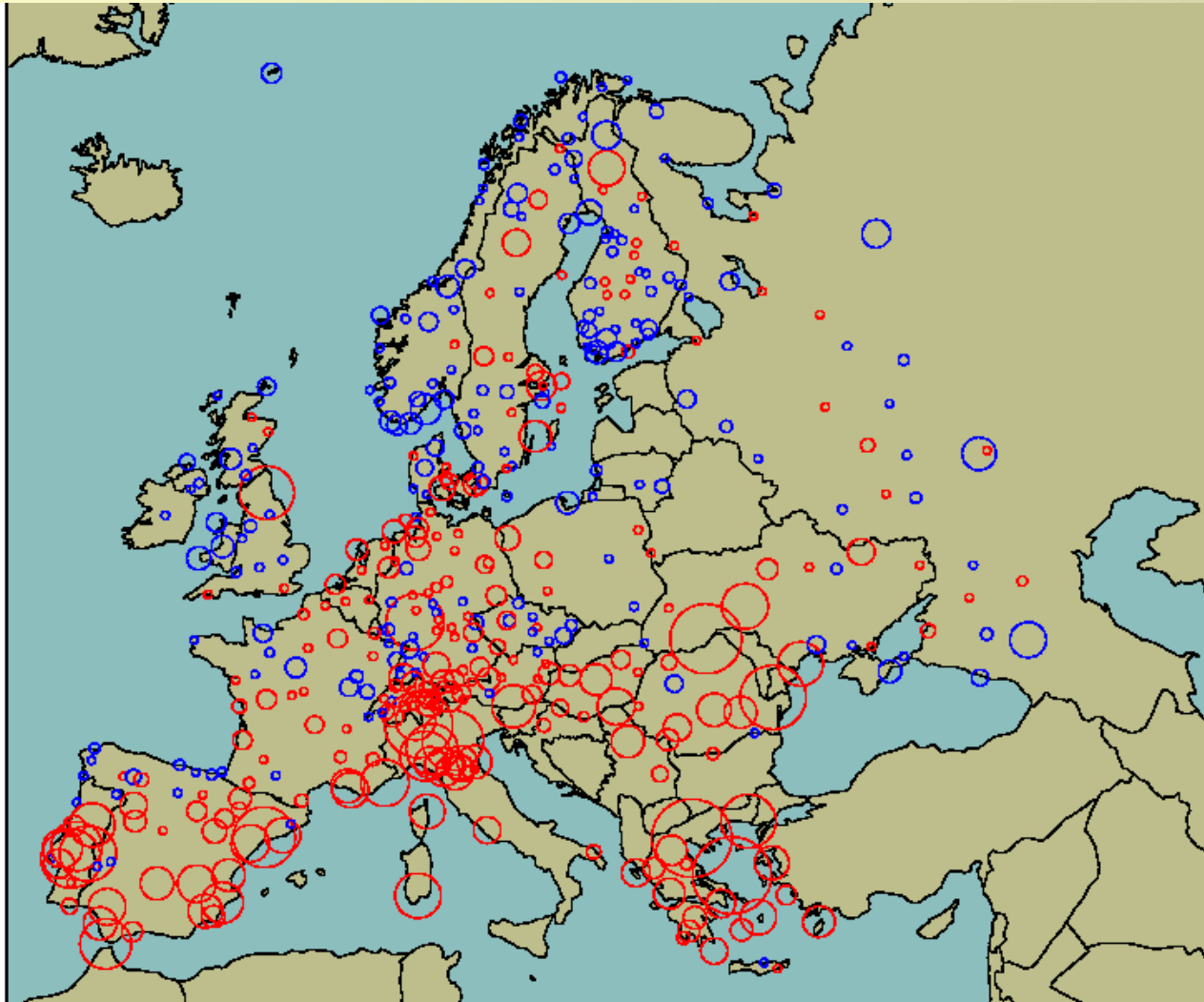


Scala: giorni/anno. Blue aumenta

Malcolm Haylock, UEA/STARDEX

1958-2000 trend

Giorni consecutivi senza pioggia inverno



Scala: giorni/anno. Blue cala

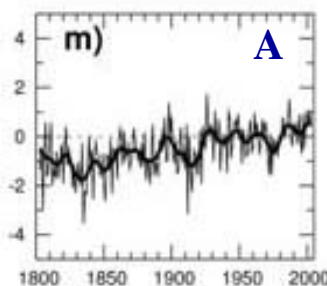
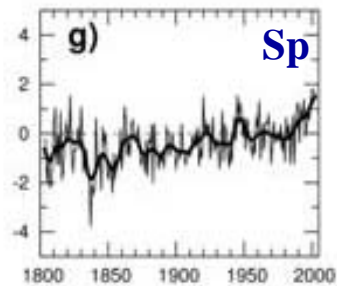
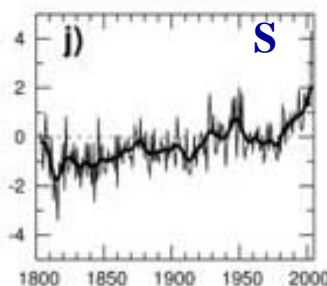
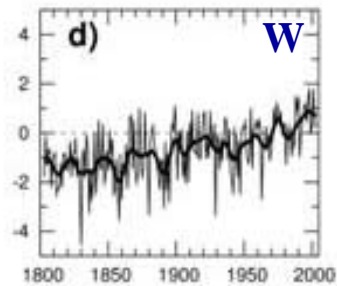
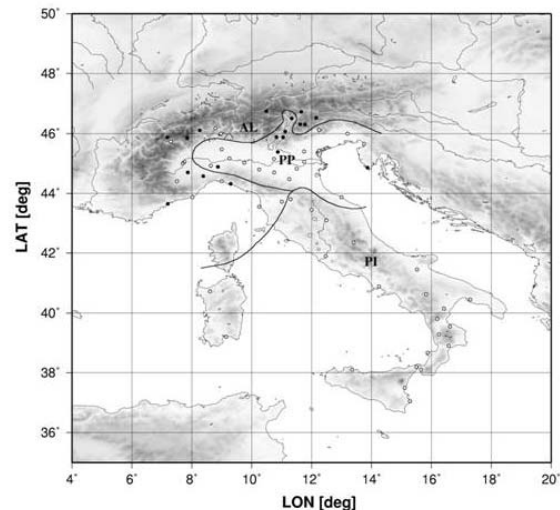
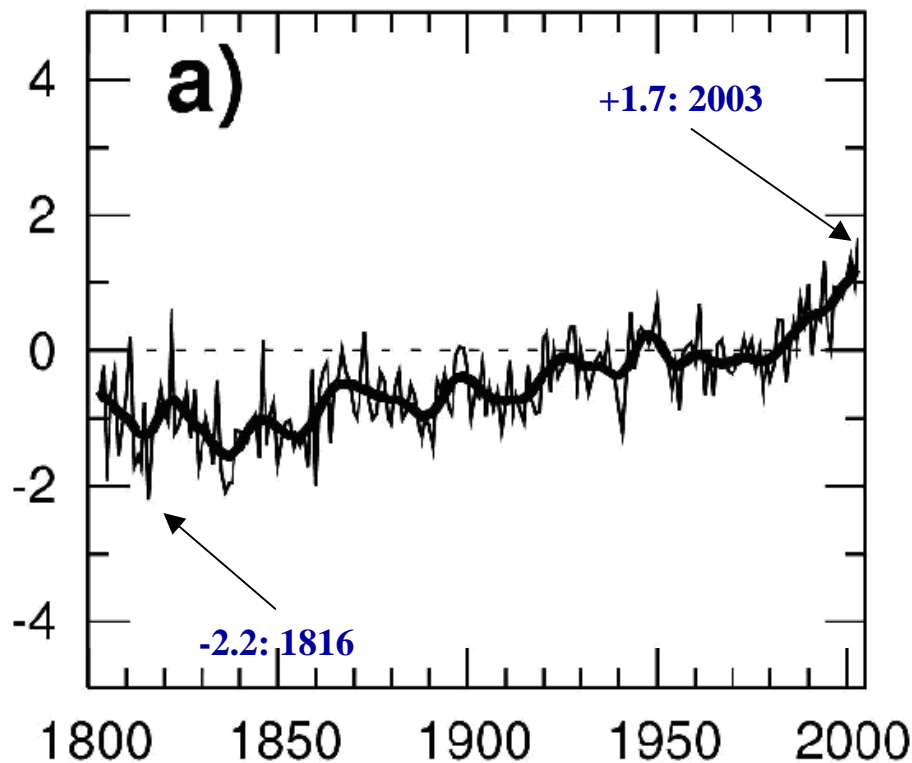
Malcolm Haylock, UEA/STARDEX

ITALIA

Alcuni risultati: le temperature

REGIONALIZZAZIONE (Principal Component Analysis)

ANDAMENTI: ANNO E STAGIONI



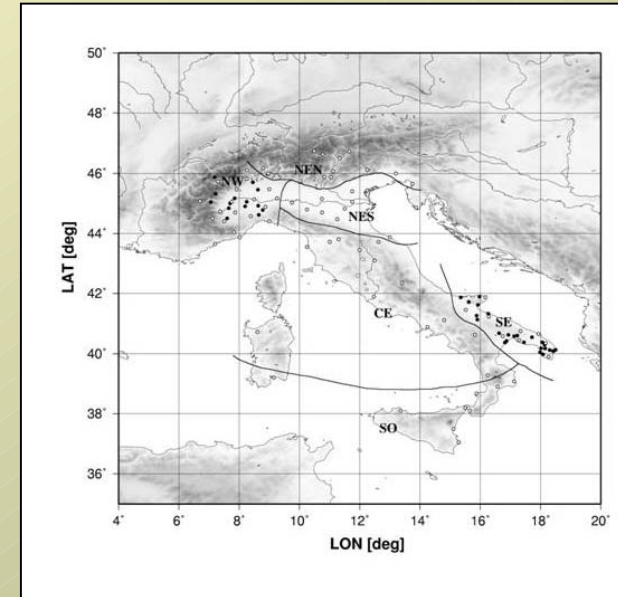
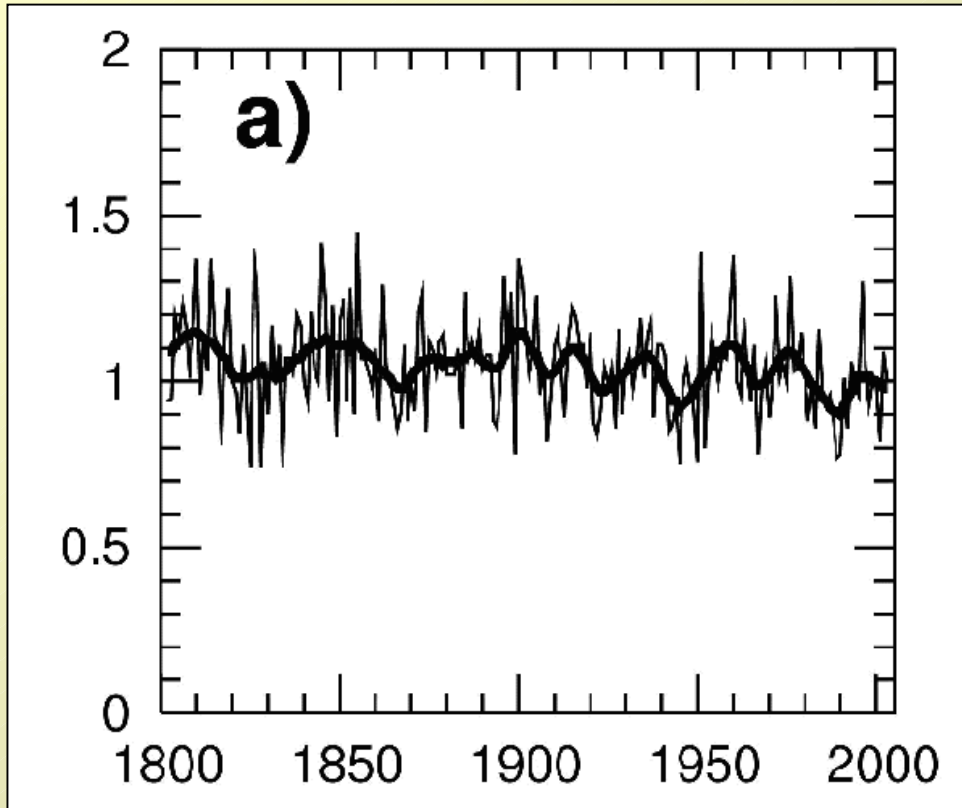
Brunetti M, Maugeri M, Monti F, Nanni T. 2006. *Temperature and precipitation variability in Italy in the last two centuries from homogenised instrumental time series.*

Int. J. Climatol, 26, 345-381

Alcuni risultati: le precipitazioni

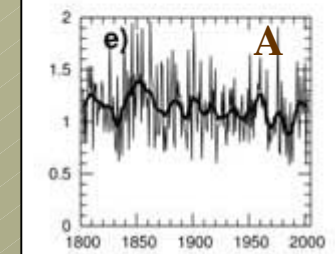
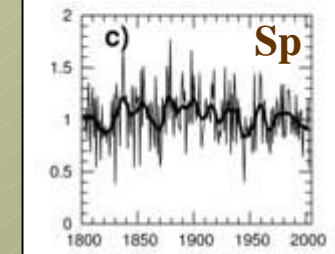
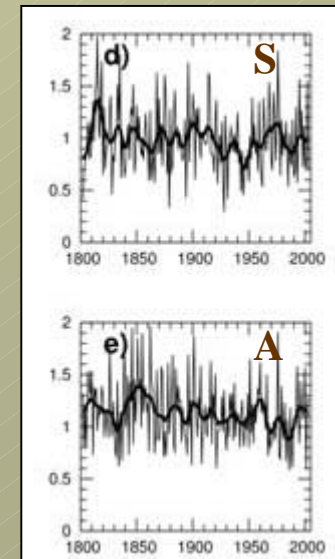
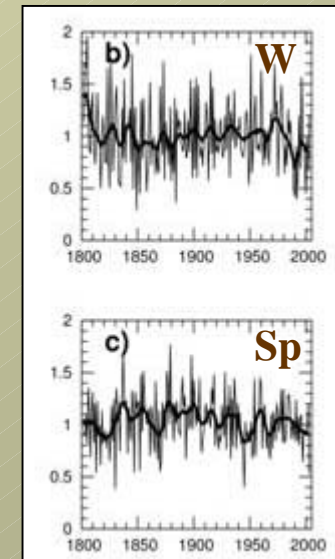
REGIONALIZZAZIONE (Principal Component Analysis)

ANDAMENTI ANNUALE E STAGIONALE

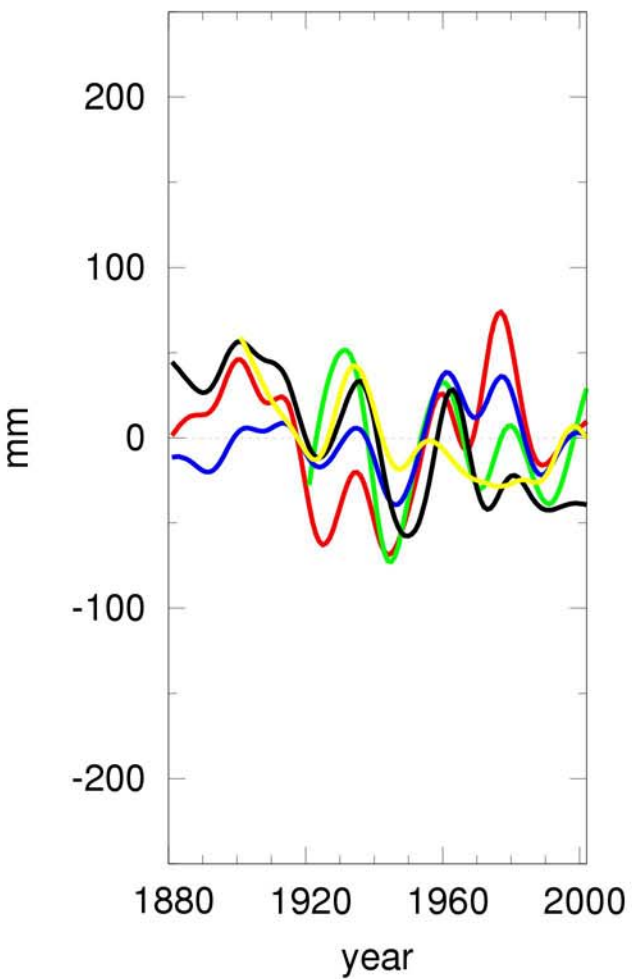


Brunetti M, Maugeri M, Monti F, Nanni T. 2006. *Temperature and precipitation variability in Italy in the last two centuries from homogenised instrumental time series.*

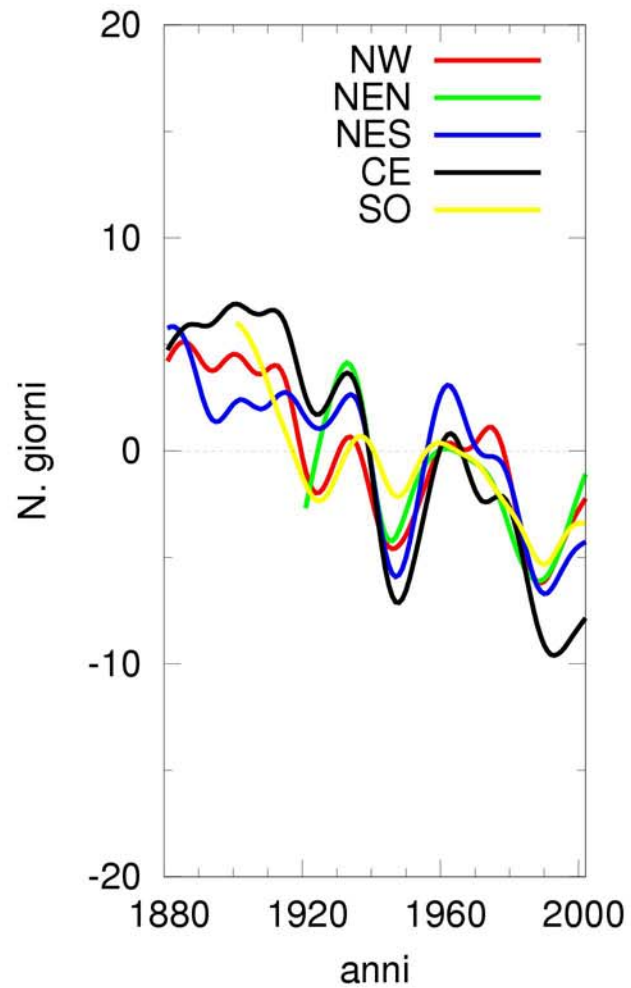
Int. J. Climatol, 26, 345-381



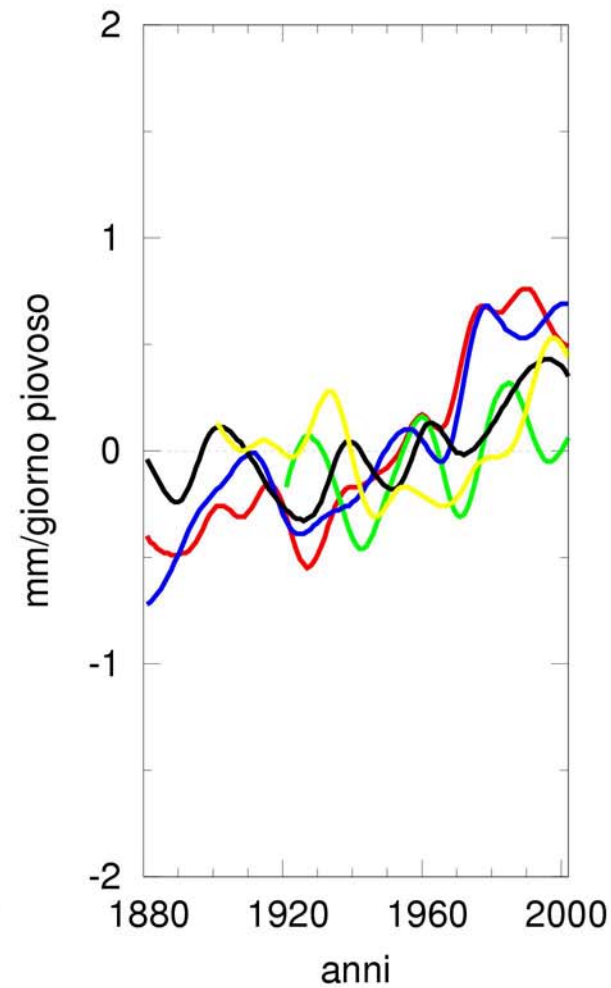
Precipitation



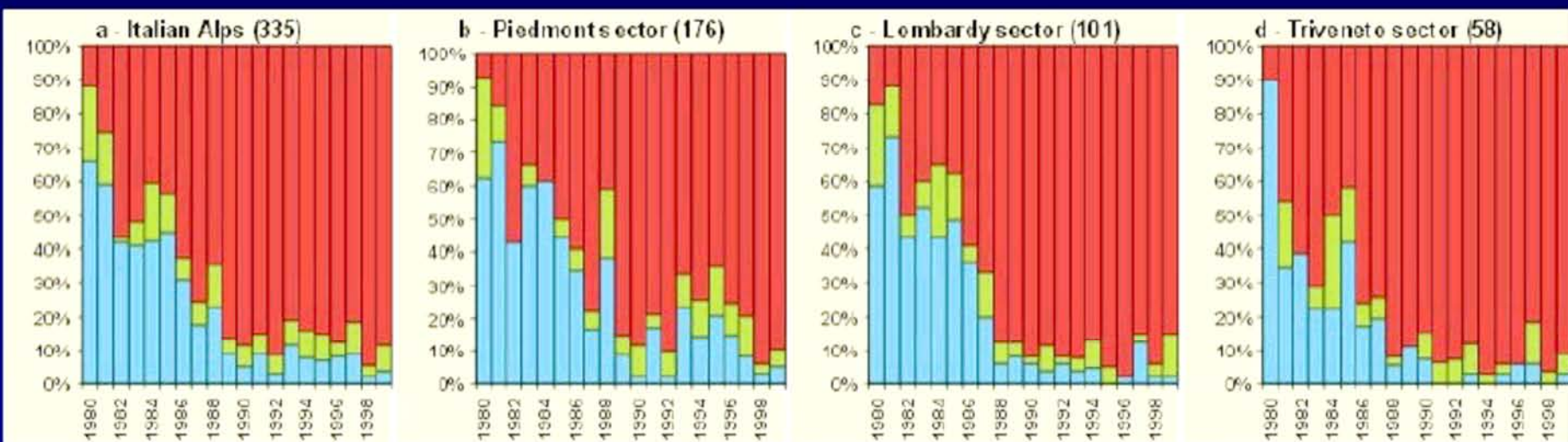
Giorni piovosi



Intensita'

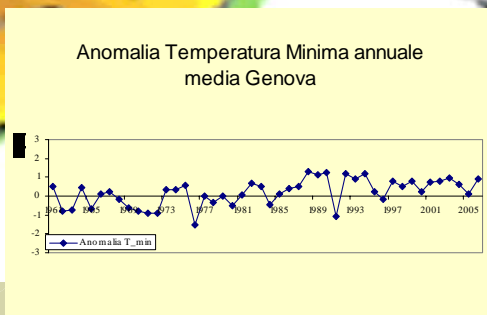
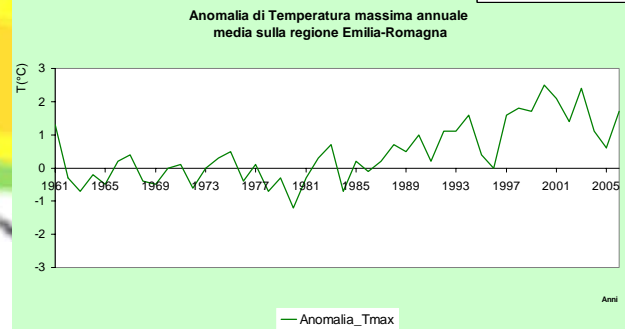
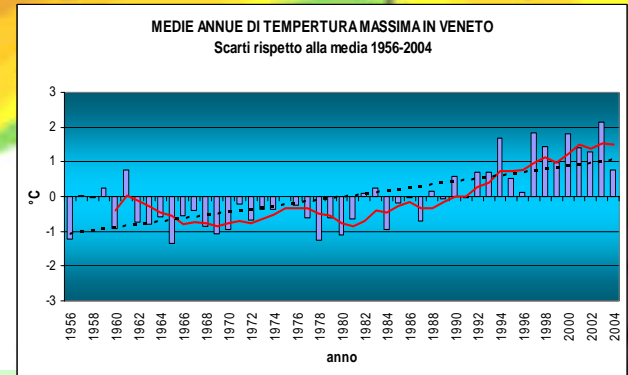
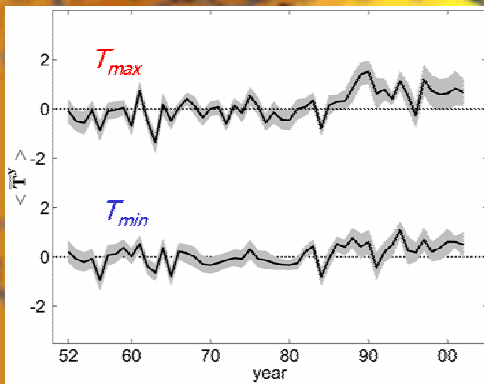
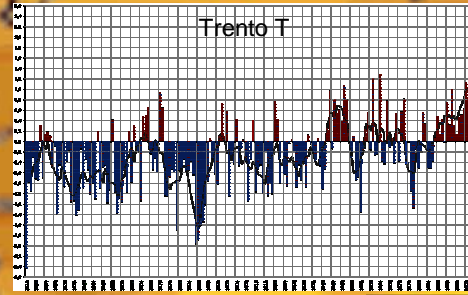
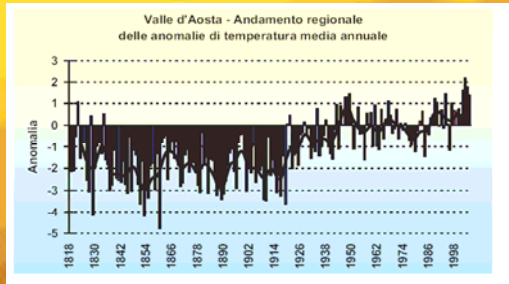


Variazione dei ghiacciai delle Alpi Italiane

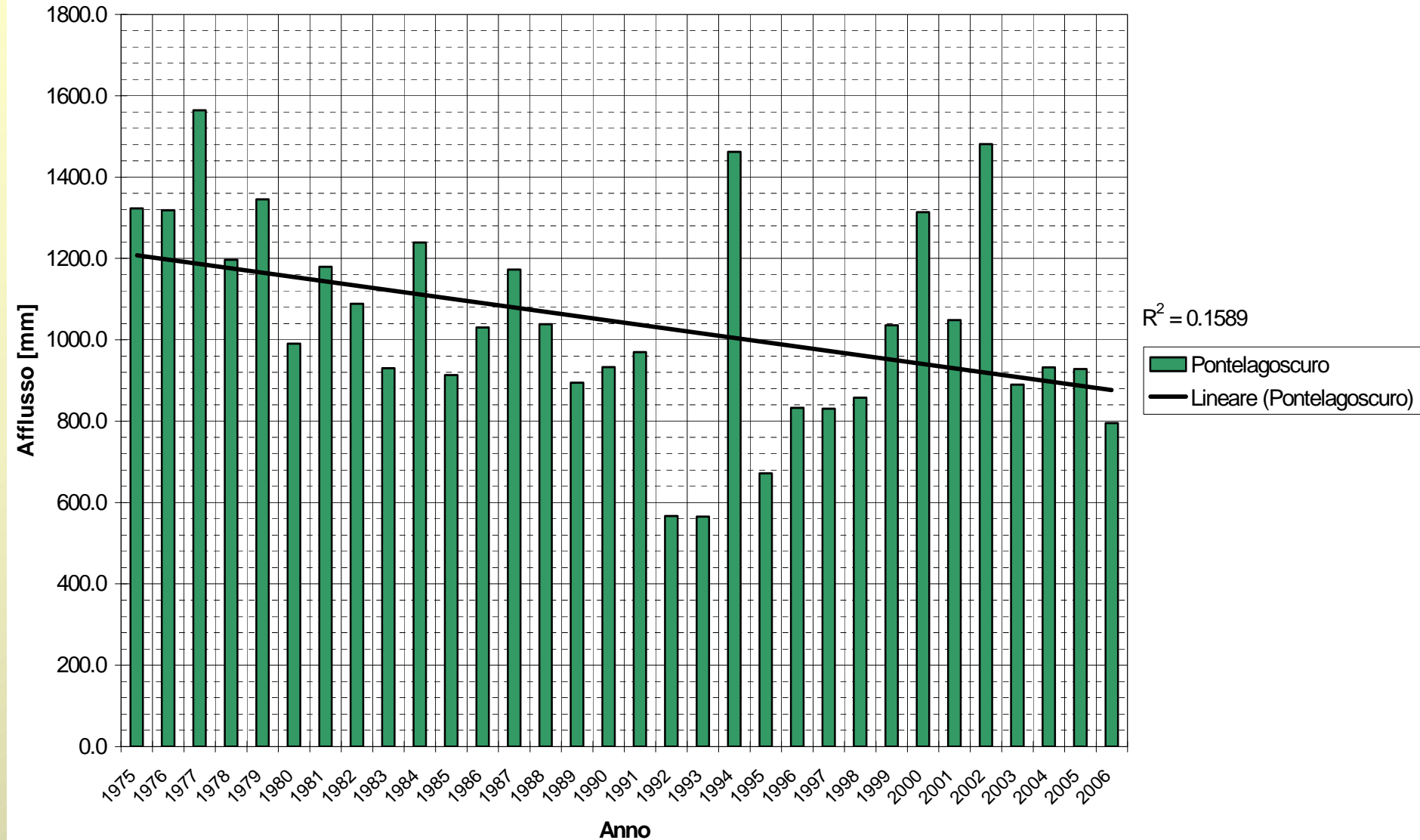


Percentuale di ghiacciai in avanzata (blu), stazionari (verde) e in ritiro (rosso) nelle Alpi italiane (a) e nei tre settori in cui sono suddivise (b, c, d), nel periodo 1980-1999 (in parentesi è riportato il numero di ghiacciai che costituisce il campione). La percentuale di ghiacciai in avanzata scende dal 66% nel 1980 al 4% nel 1999, mentre quella dei ritiri sale dal 12% all'89%. La diminuzione del numero di ghiacciai in avanzata si manifesta dapprima nel settore Triveneto e successivamente in quelli Lombardo e Piemontese-Valdostano (elaborazione M. Santilli).

GLI ANDAMENTI TERMICI

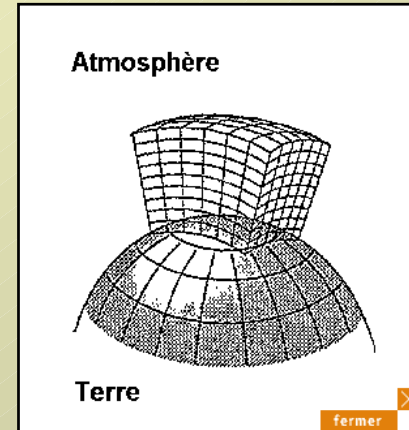
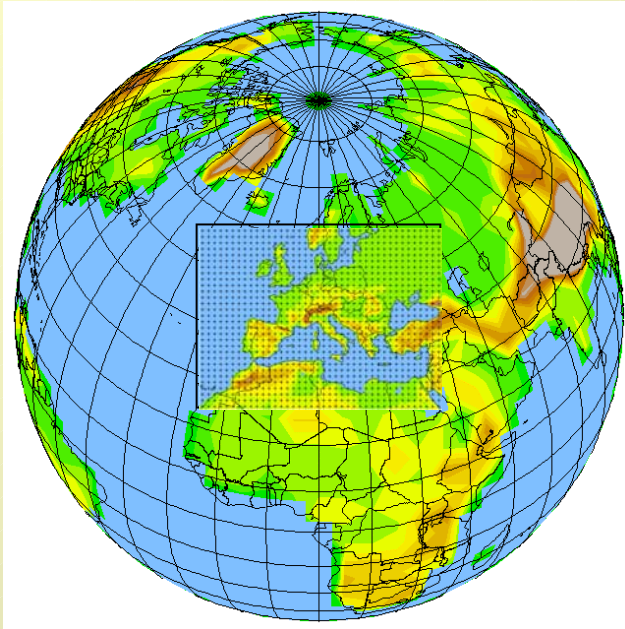


PIOGGE MEDIE ANNUALI SUL BACINO DEL PO DAL 1975 AL 2006: 20% riduzione



GLI SCENARI FUTURI

Utilizzo di AOGCM o AGCM



$$\frac{d\mathbf{v}}{dt} = -\alpha \nabla p - \nabla \phi - 2\boldsymbol{\Omega} \times \mathbf{v} + \dots$$

← Conservazione del momento

$$\frac{\partial \rho}{\partial t} = -\nabla \cdot (\rho \mathbf{v})$$

← Conservazione della massa

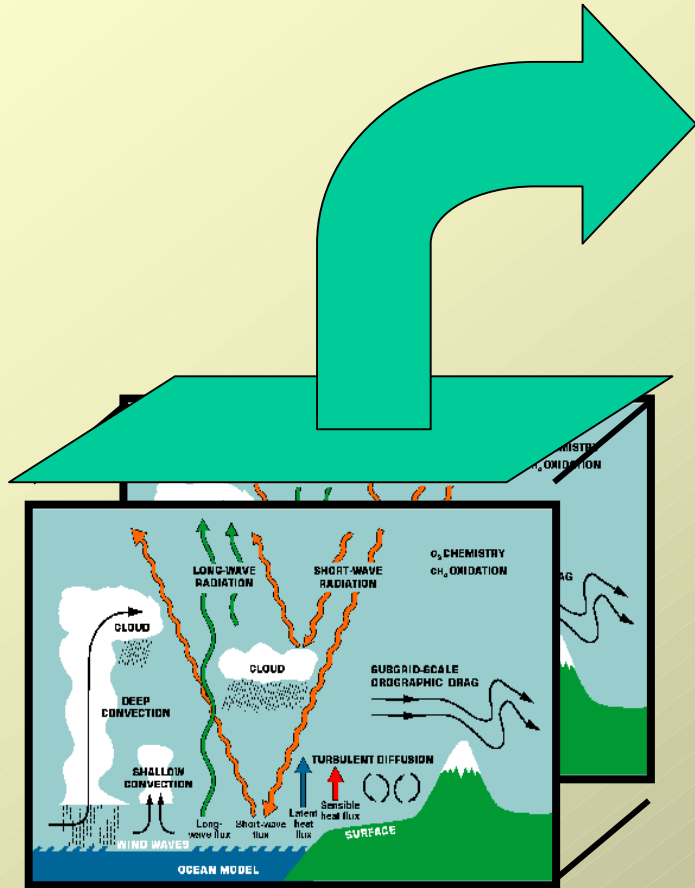
$$p\alpha = RT$$

← Legge dei Gas Perfetti

$$Q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt} + \dots$$

← Conservazione dell'energia

Le parametrizzazioni fisiche

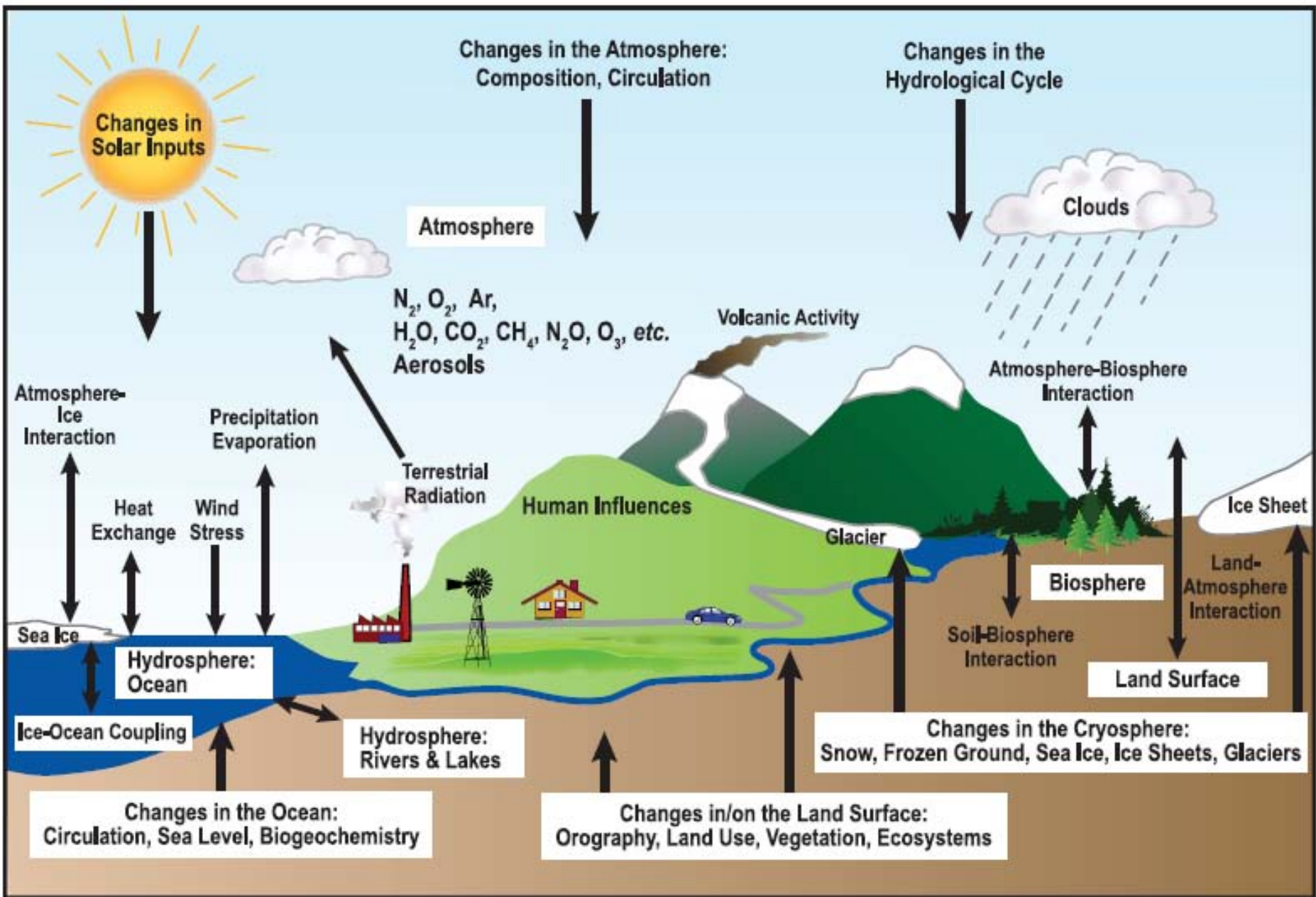


T, u, v, q, ps

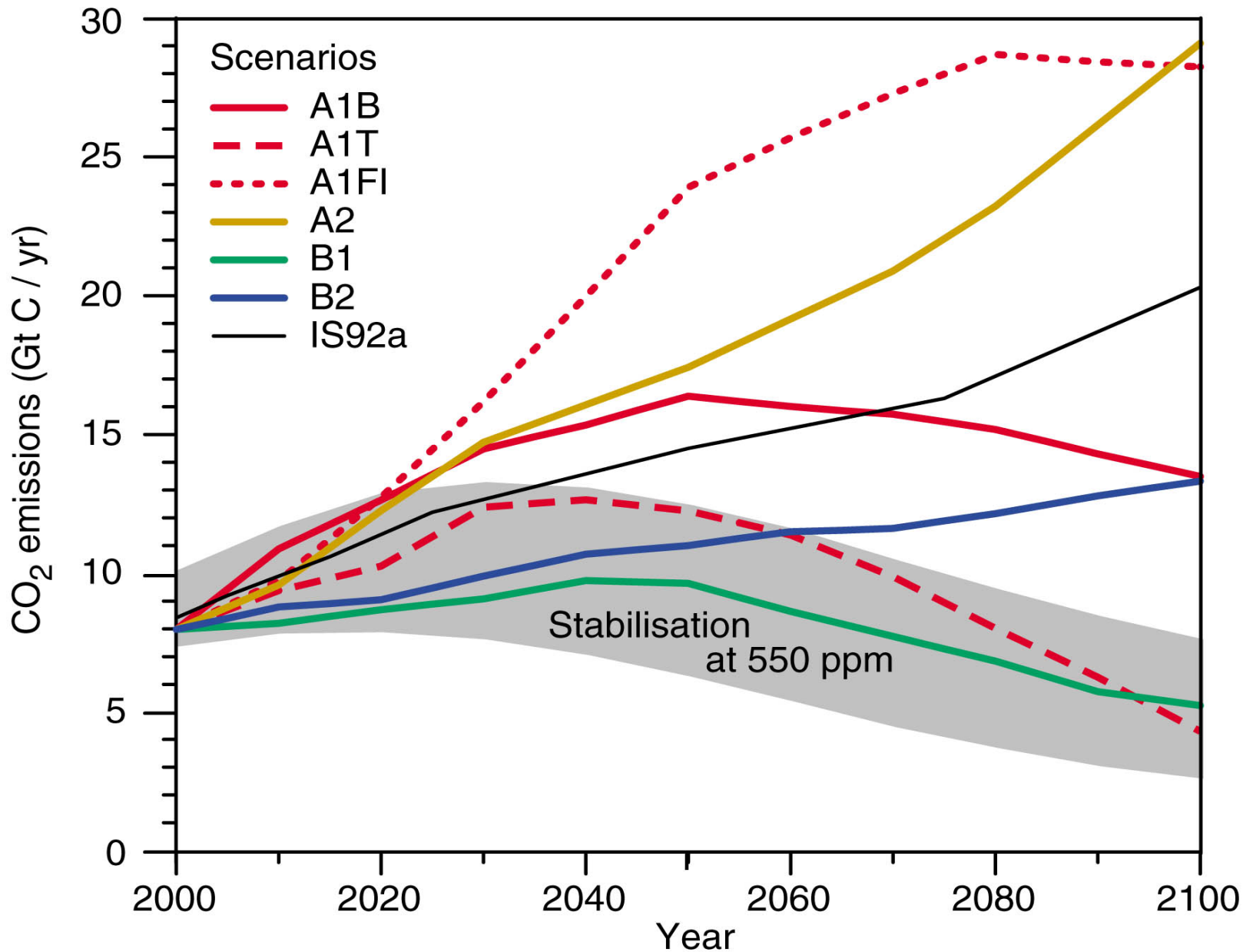
I processi fisici che operano all'interno delle box devono essere parametrizzati in funzione delle grandezze definite sui punti di griglia

....Processi Fisici

- Radiazione
- Turbolenza
- Processi microfisici (umidi)
- Precipitazione a grande scala
- Precipitazione convettiva
- Effetti orografici
- Suolo

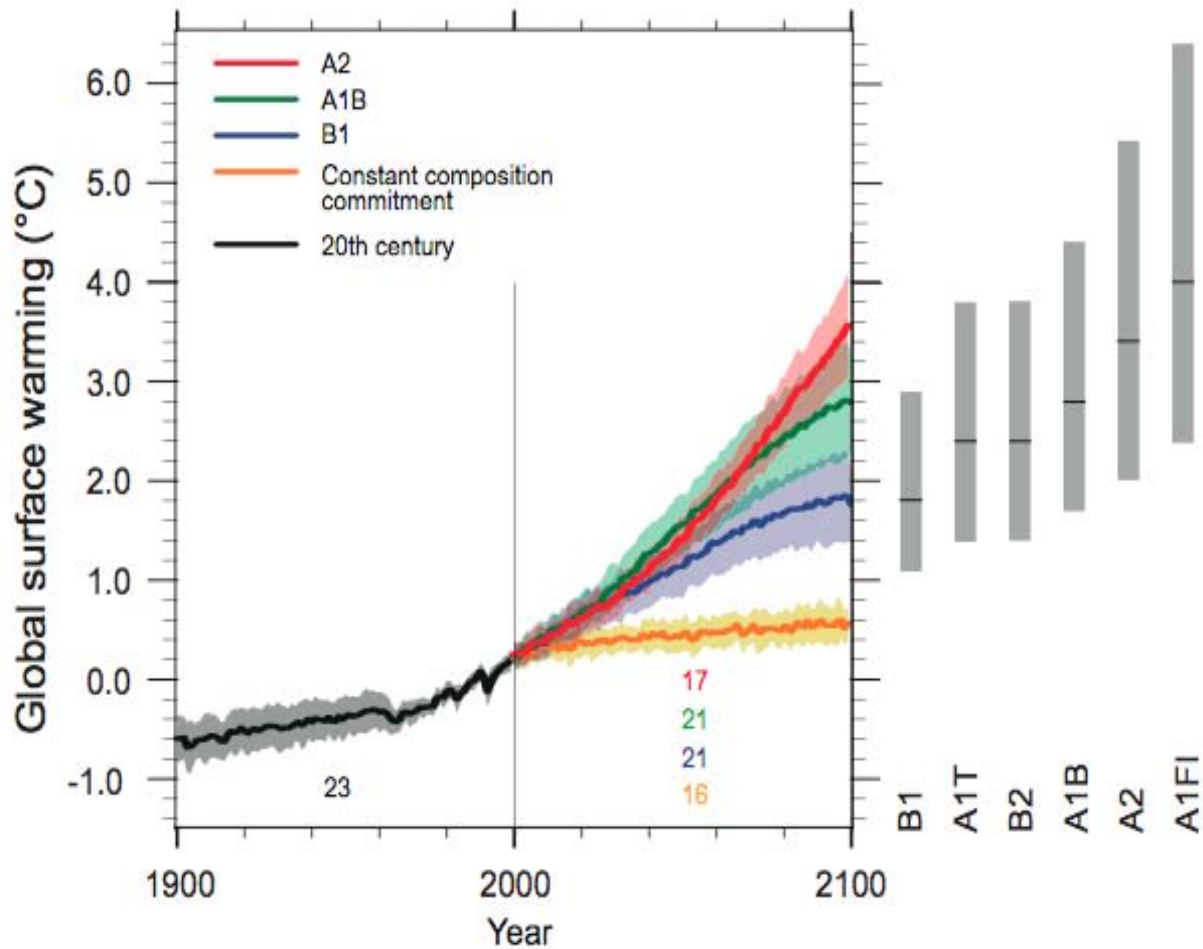


FAQ 1.2, Figure 1. Schematic view of the components of the climate system, their processes and interactions.



Scenari delle emissioni di CO₂ del SRES

PROIEZIONI GLOBALI: TEMPERATURA



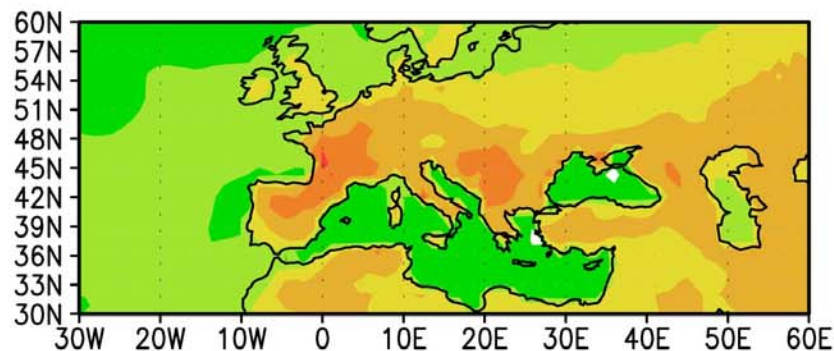
A scala globale si è visto che (IPCC 2007)

- Per i prossimi due ventenni è previsto un riscaldamento di circa 0.2°C per decennio per un vasto range di scenari di emissioni.**
- Anche se le concentrazioni di gas serra e aerosol fossero mantenute costanti ai livelli del 2000, c'è comunque da attendersi un riscaldamento di circa 0.1 grado per decennio**

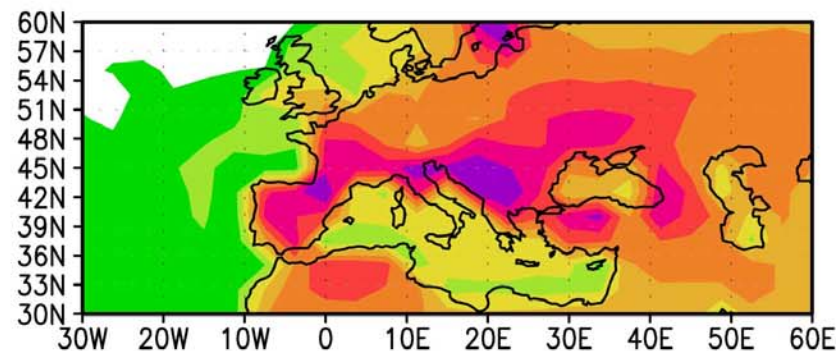
I modelli globali Europa

Proiezioni di temperatura a 80 anni: (2061-2090)-(1961-1990)

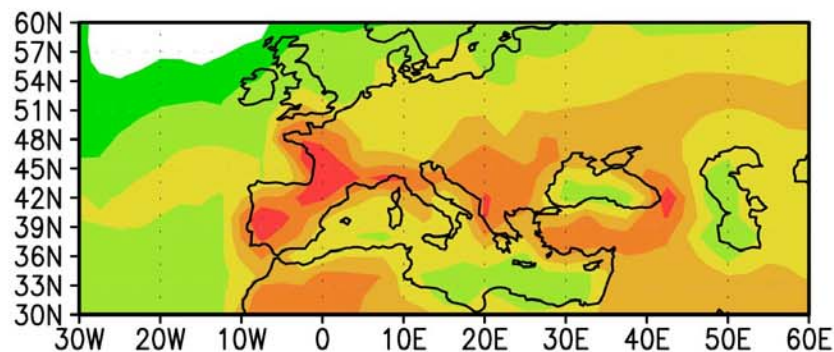
INGV



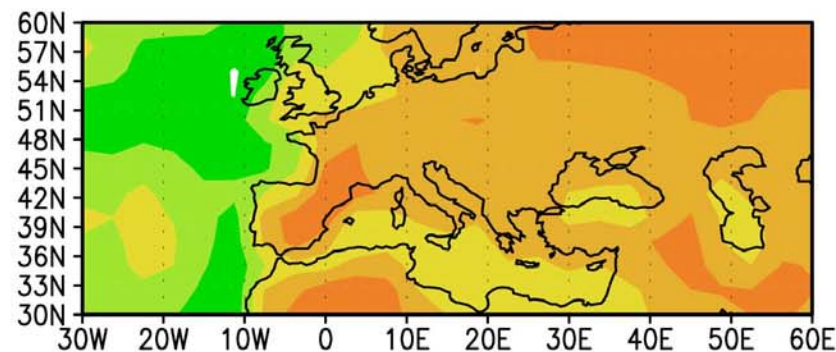
UKMO



GFDL

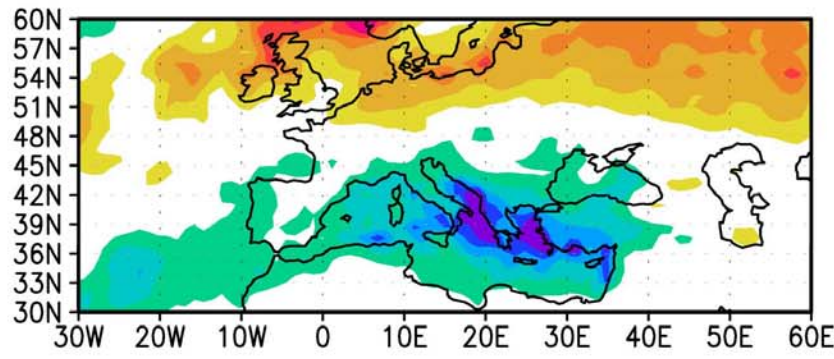


IPSL

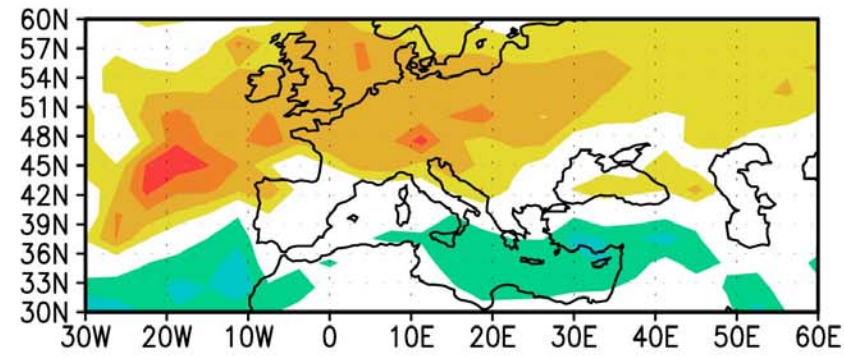


Proiezioni di precipitaz. a 80 anni: (2061-2090)-(1961-1990)

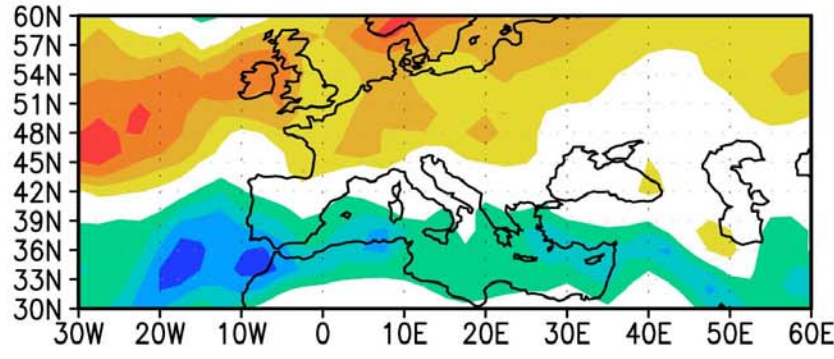
INGV



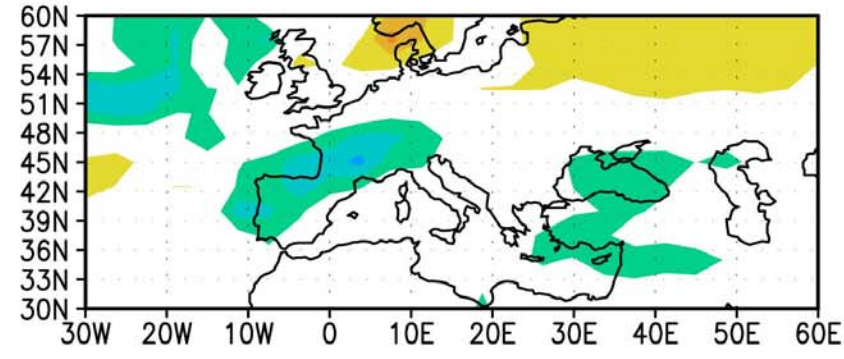
UKMO



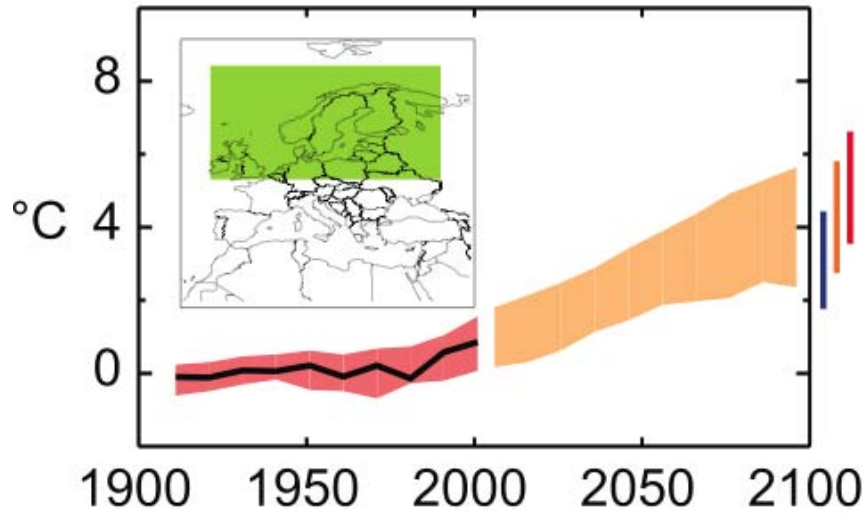
GFDL



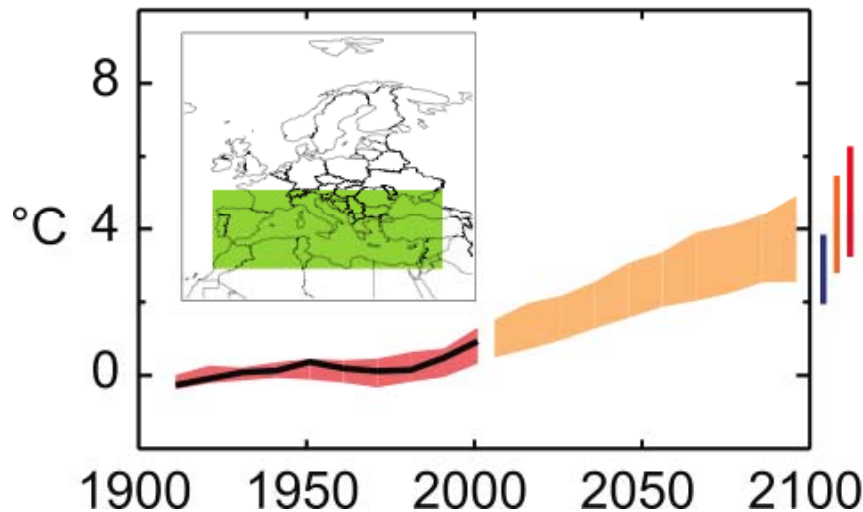
IPSL



NEU



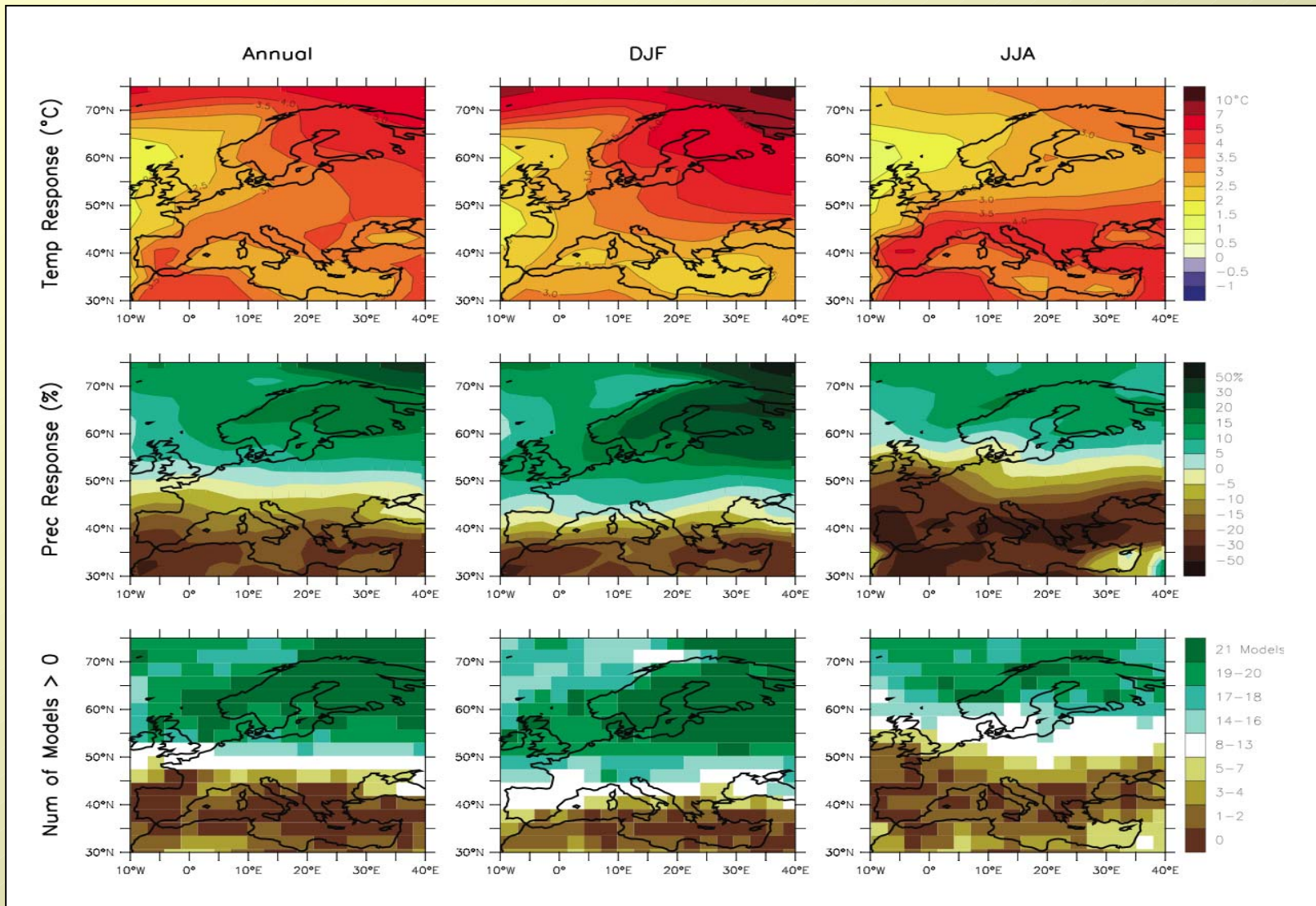
SEM



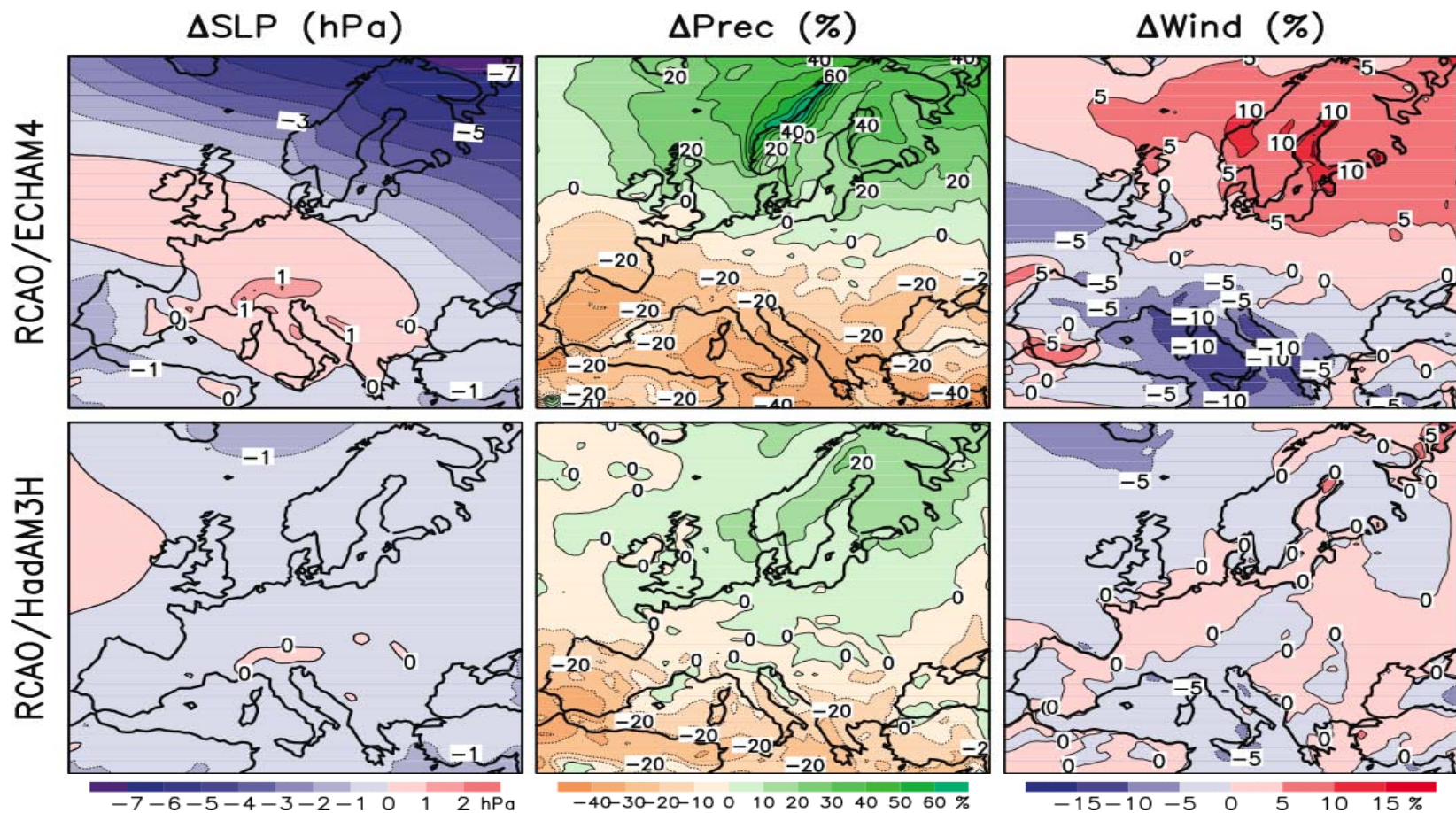
Anomalie delle temperature (rispetto al clima 1901- 1950) per due regioni europee..

Simulate da un ensemble di modelli globali

**Scenario B1 (blue),
Scenario A1B (arancione)
Scenario A2 (rosso).**

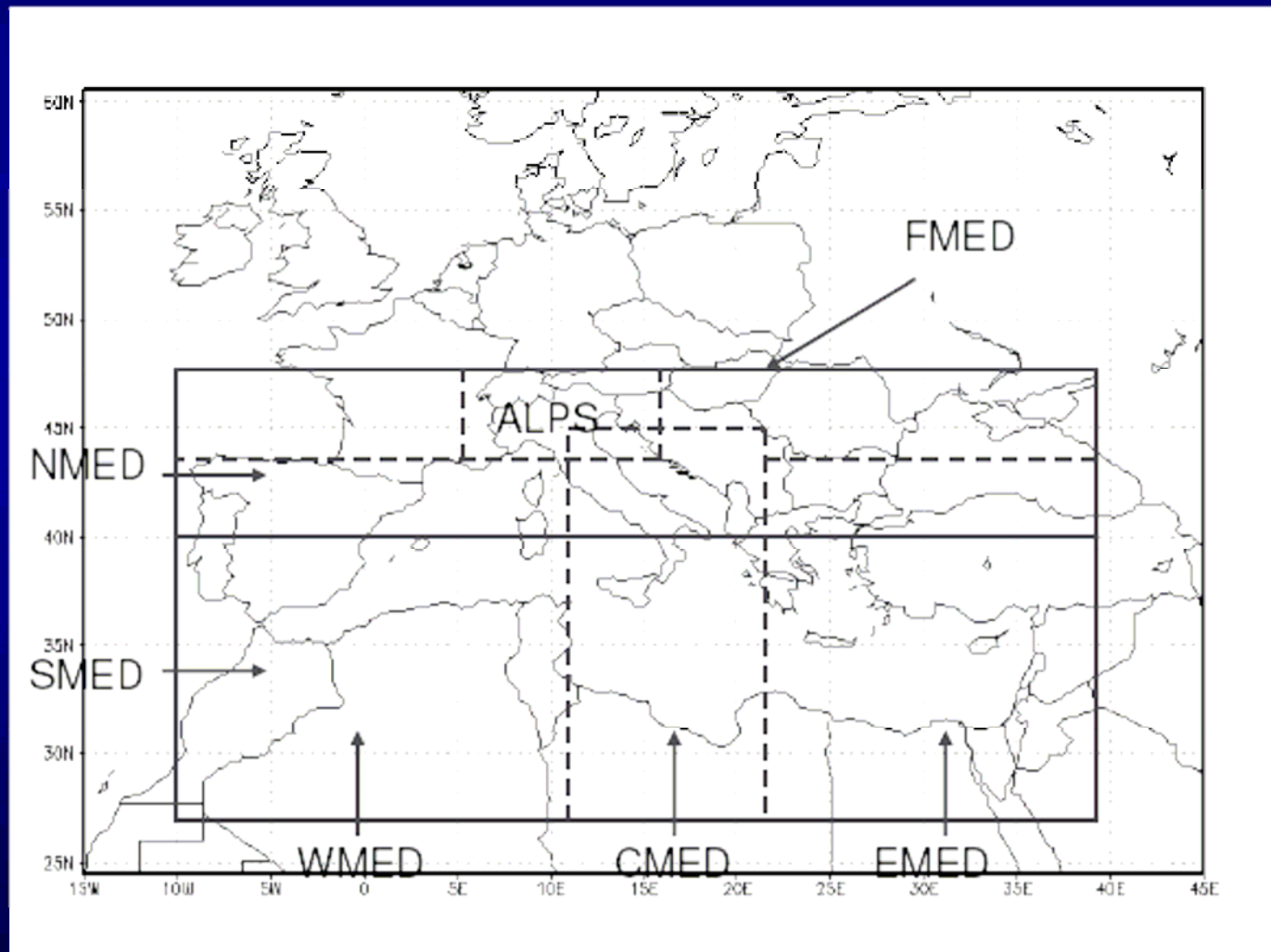


Temperature and precipitation changes over Europe from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation.



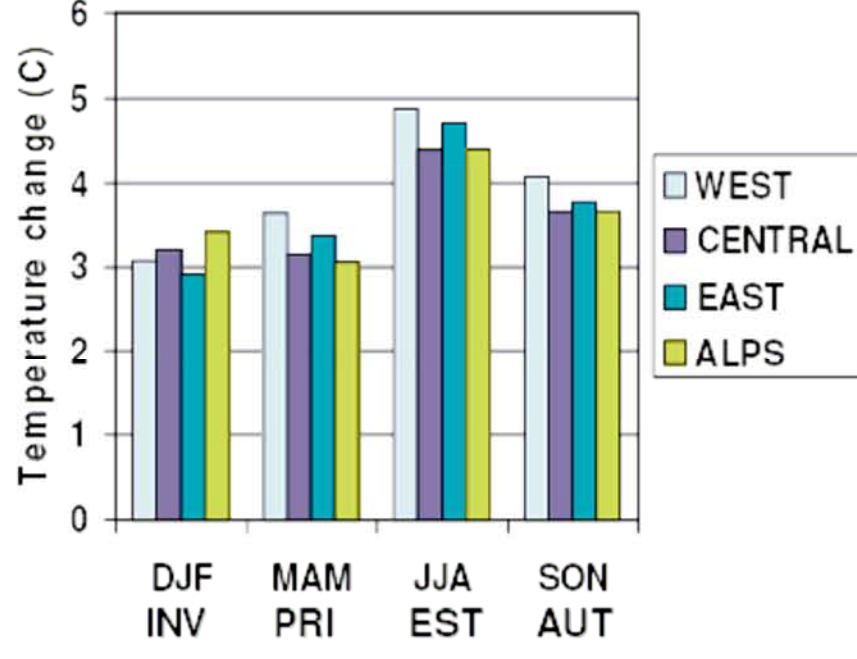
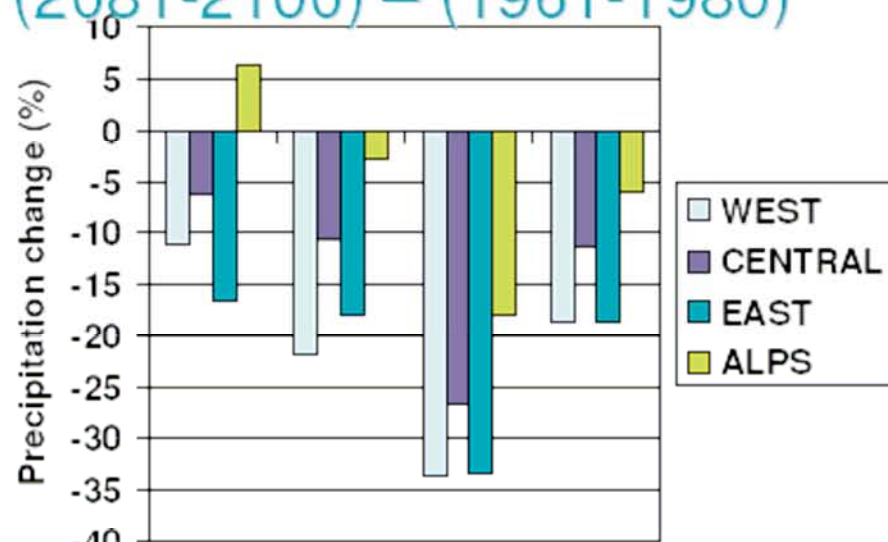
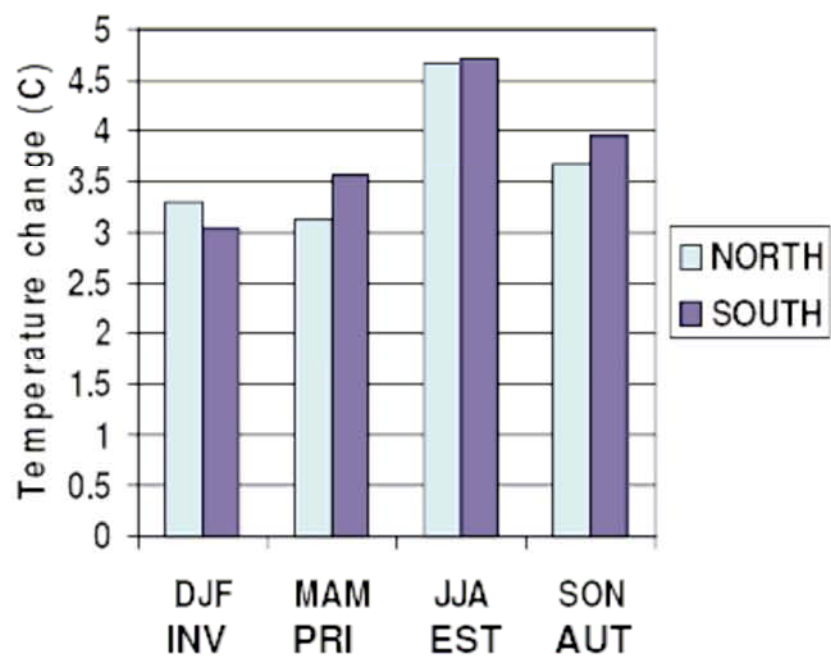
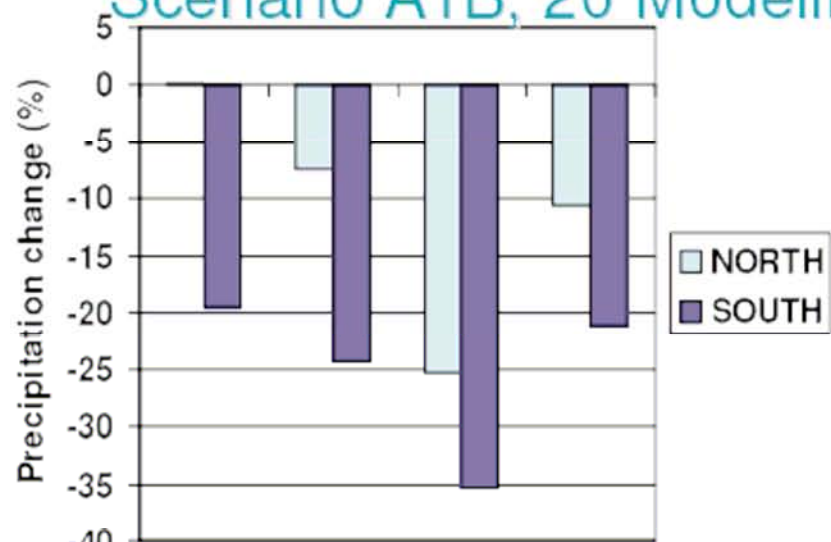
Simulated changes in annual mean sea level pressure (Δ SLP), precipitation (Δ Prec) and mean 10-m level wind speed (Δ Wind) from the years 1961 to 1990 to the years 2071 to 2100. The results are based on the SRES A2 scenario and were produced by the same RCM (Rossby Centre regional Atmosphere-Ocean model; RCAO) using boundary data from two global models: ECHAM4/OPYC3 (top) and HadAM3H (bottom) (redrawn from Rummukainen et al., 2004).

Analisi dei cambiamenti climatici su diverse regioni del Mediterraneo



Cambiamento di precipitazione e temperatura su diverse regioni del Mediterraneo

Scenario A1B, 20 Modelli, (2081-2100) – (1961-1980)



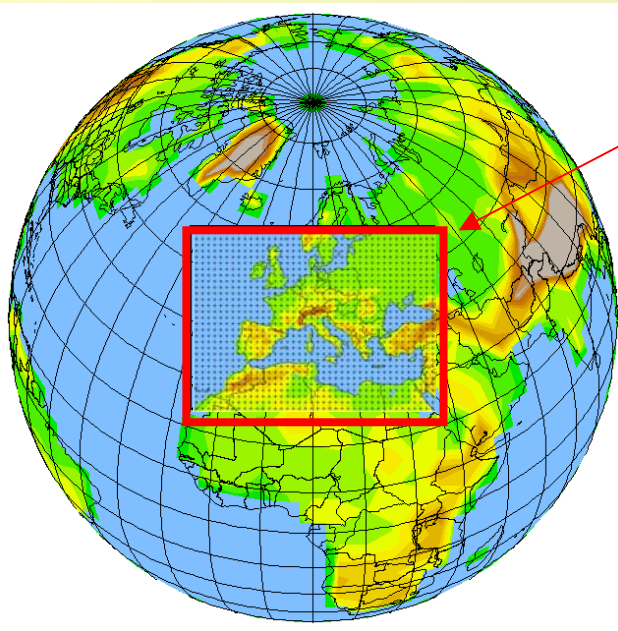
Regionalizzazione

Approccio deterministico (RCMs)

Approccio dinamico-statistico (SD)

Approccio deterministico (RCMs)

- Utilizzo di Regional Climate Models innestati sui AOGCM o su AGCM



Condizioni al contorno

$$\frac{d\mathbf{v}}{dt} = -\alpha\nabla p - \nabla\phi - 2\boldsymbol{\Omega} \times \mathbf{v} + \dots$$

Conservazione del momento

$$\frac{\partial\rho}{\partial t} = -\nabla \cdot (\rho\mathbf{v})$$

Conservazione della massa

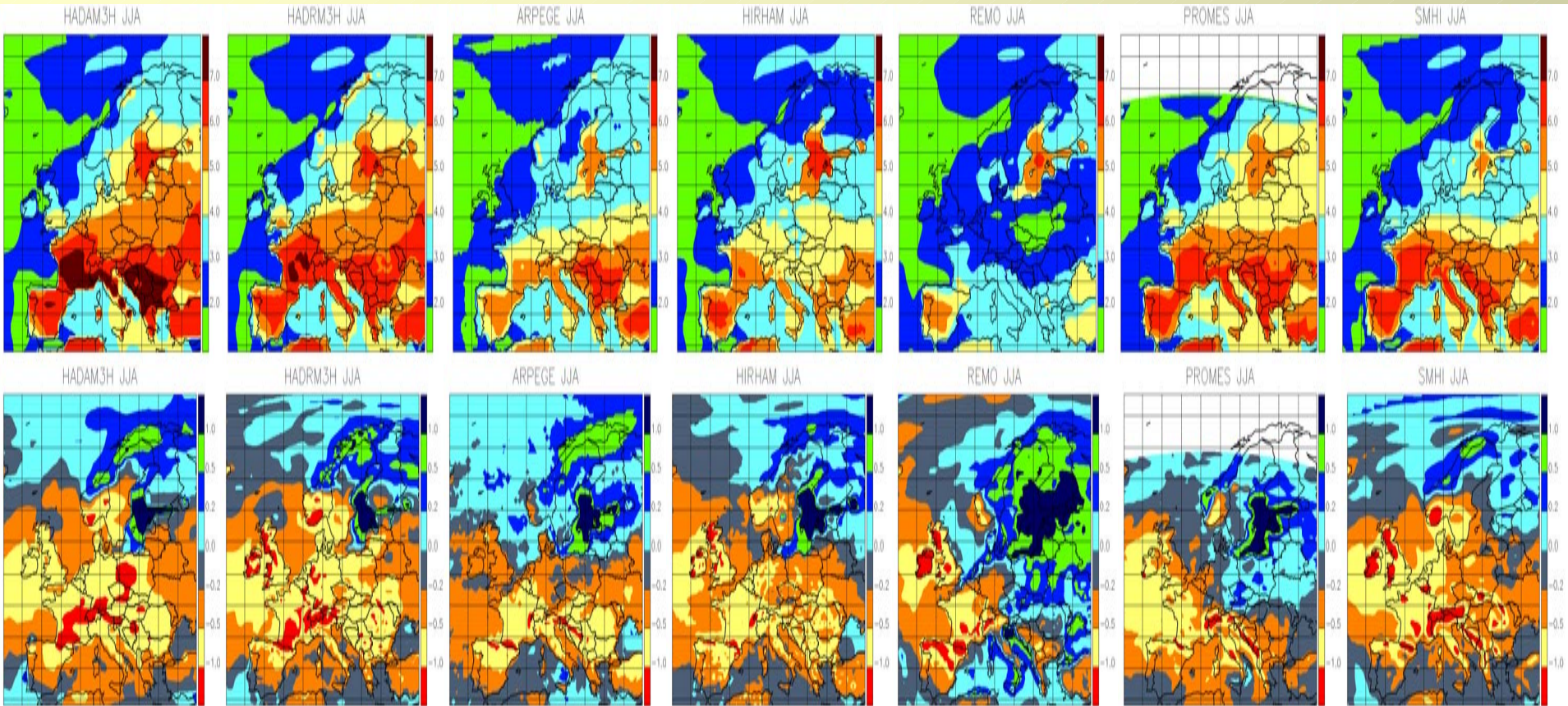
$$p\alpha = RT$$

Legge dei Gas Perfetti

$$Q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt} + \dots$$

Conservazione dell'energia

Cambiamenti Estate (JJA): 2071-2100 - 1961-1990



Colonna 1: HadAM3. Colonne 2-7: 6 European RCMs

Prima riga: temperatura. Seconda riga: piogge

Mediterraneo ed Europa

La temperatura in Europa potrà crescere più della media globale. In inverno il maggior riscaldamento potrebbe verificarsi sul Nord Europa, in Estate sul Mediterraneo. Le temperature minime in inverno potranno crescere più della media sul Nord Europa. Le temperature massime d'estate potranno crescere più della media sull'Europa meridionale e nel Mediterraneo

La precipitazione potrà crescere in Europa del Nord e decrescere in gran parte dell'area del Mediterraneo. Nell'Europa centrale, la precipitazione potrà crescere in inverno ma diminuire in estate. precipitazioni giornaliere estreme sul Nord Europa.

Numero di giorni con pioggia in calo nell'area del Mediterraneo

Rischio di siccità estiva in crescita in Europa centrale e sul Mediterraneo

Minore durata della stagione con neve in gran parte dell'Europa, e diminuzione dell'altezza del manto nevoso

alpi

Figure 5: A schematic overview of seasonal changes as simulated by the PRUDENCE regional models. In each panel, rows are the analysis areas, columns correspond to models. Rows of panels signify the four seasons, the left column of panels are temperature change (left color bar, degrees C), whereas the right column of panels signifies precipitation (right color bar, relative change). Areas not covered by a particular model are indicated by black squares.

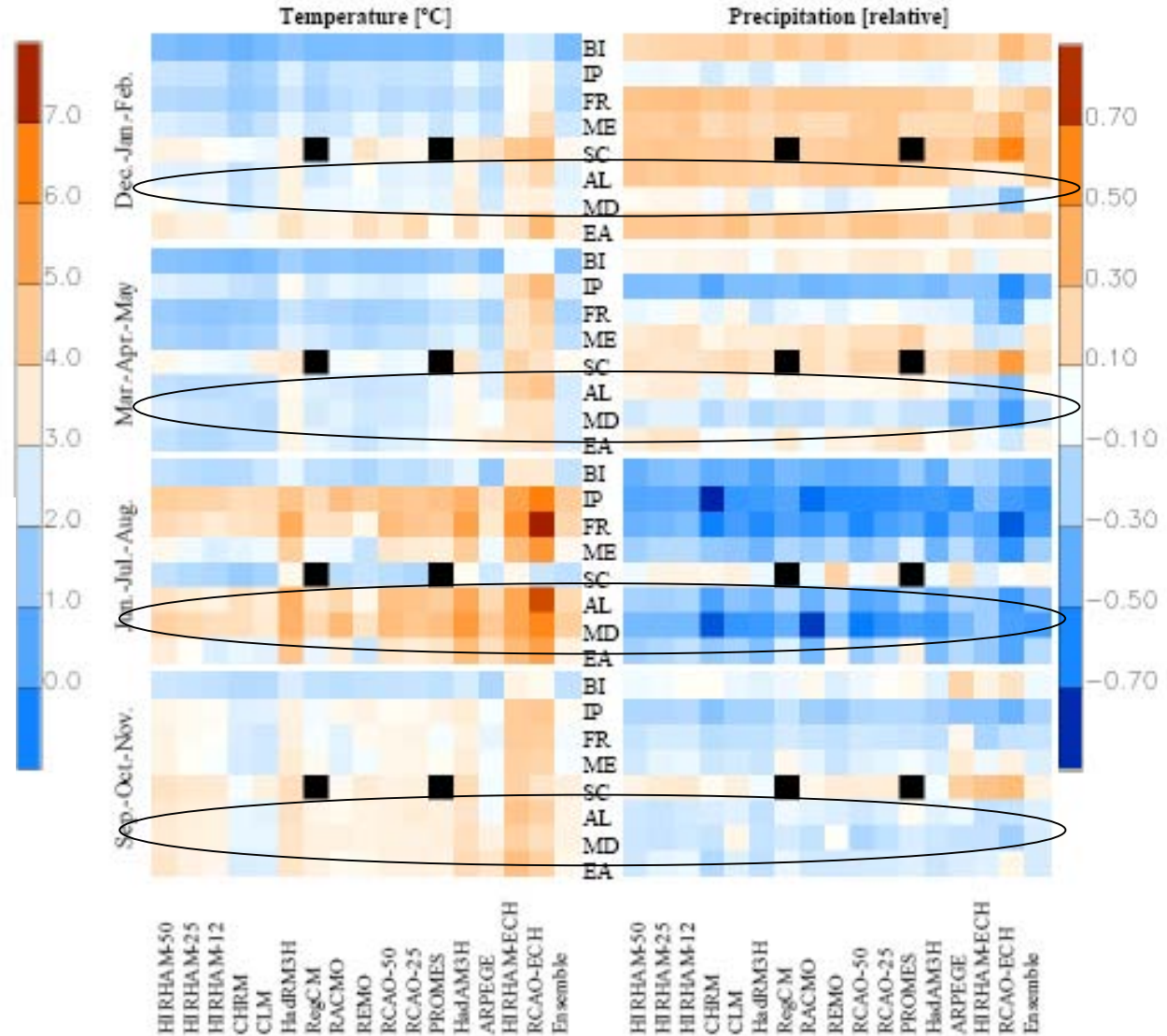
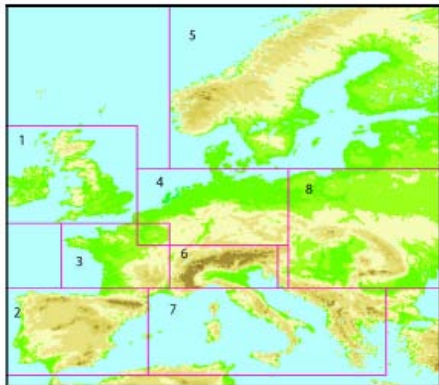


Figure 4: European sub-areas

Area	West	East	South	North
1 (BI) British Isles	-10	2	50	59
2 (IP) Iberian Peninsula	-10	3	38	44
3 (FR) France	-3	3	44	50
4 (ME) Mid-Europe	2	16	48	55
5 (SC) Scandinavia	5	30	55	70
6 (AL) Alps	5	15	44	48
7 (MD) Mediterranean	3	25	36	44
8 (EA) Eastern Europe	18	30	44	55



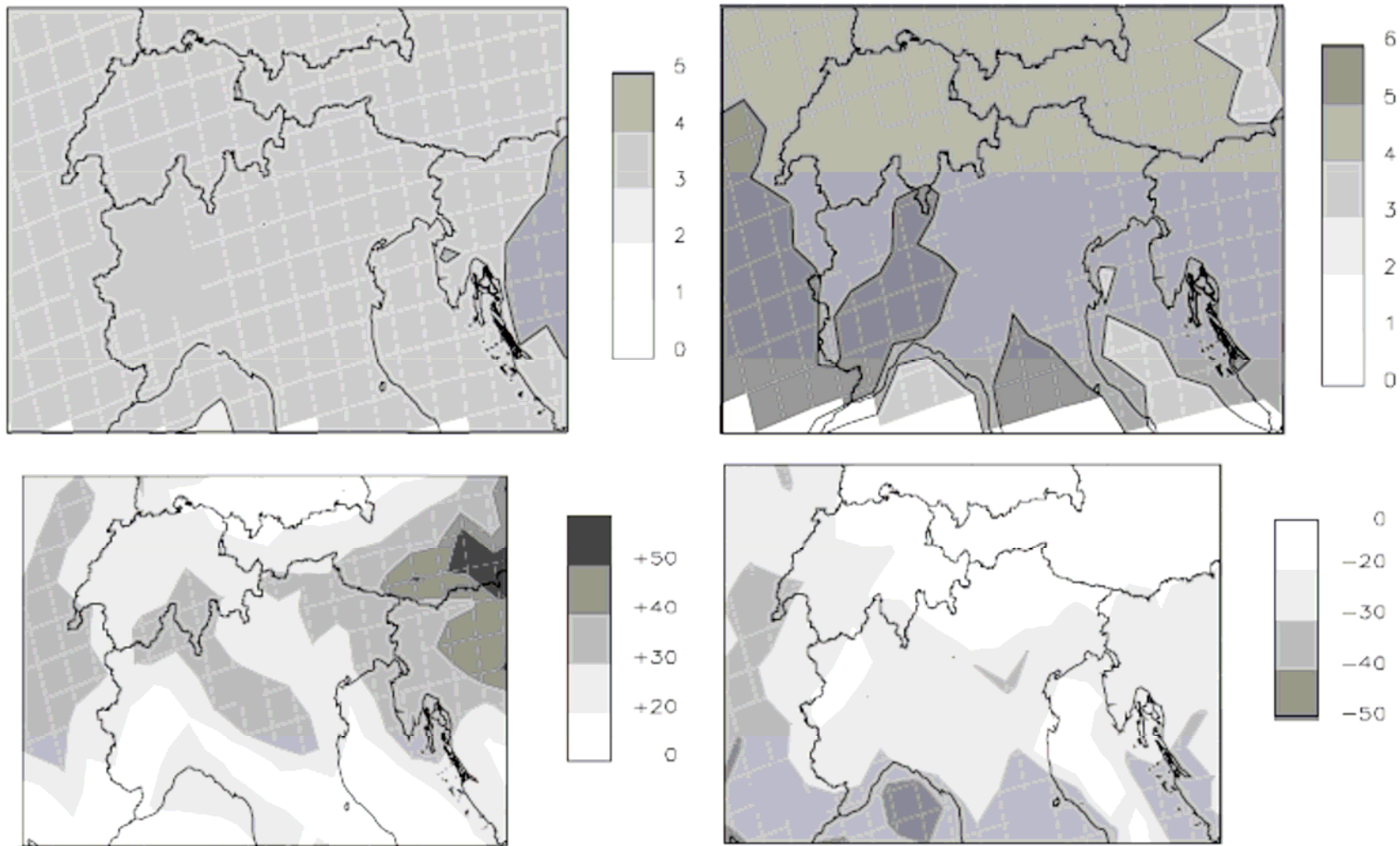
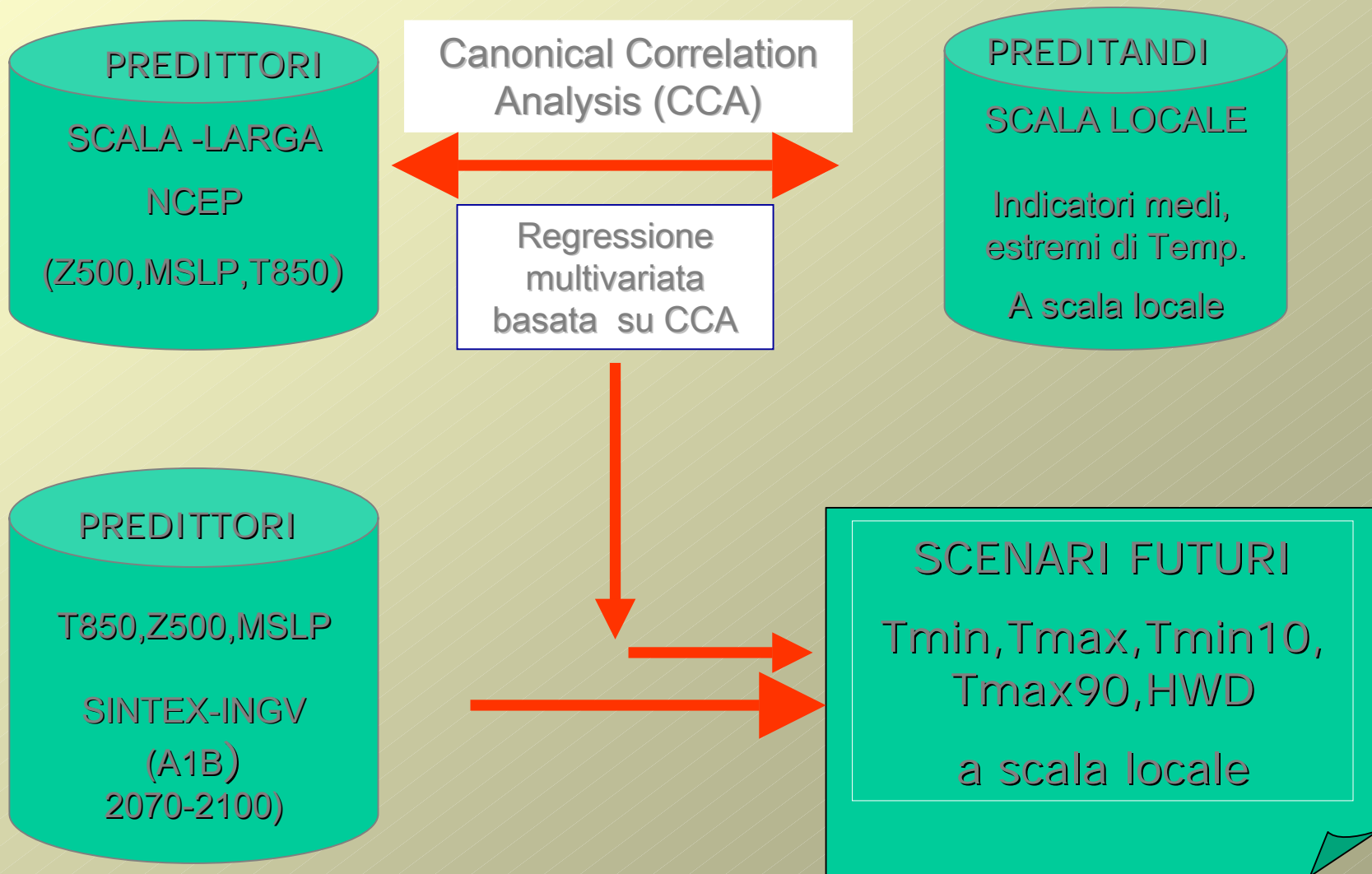


Figure 8

RCM results for climatic change in the Alpine region in the period 2071–2100 compared to the climatological average period 1961–1990. Upper left: Change in mean winter (DJF) temperatures (°C); Upper Right: Change in mean summer (JJA) temperatures (°C). Lower left: Change in mean winter (DJF) precipitation (%); Lower right: Change in mean summer (JJA) precipitation (%).

**ZOOM SUL
NORD ITALIA
(downcaling statistico)**

Approccio dinamico-statistico



Downscaling statistico su Nord Italia ed in Emilia–Romagna

scenari climatici basati su più modelli climatici ed a scala nazionale

Lavori in corso...



Modelli climatici

	<u>CNR</u> <u>M-</u> <u>CM3</u>	<u>MPI-</u> <u>ECHAM5-</u> <u>MPI-OM</u>	<u>DMI-ECHAM5-</u> <u>MPI-OM</u>	<u>NERSC</u>	<u>FUB-</u> <u>EGMAM</u>	<u>INGV</u> <u>SINT</u> <u>EX-G</u>	<u>IPSL-</u> <u>CM4</u>	<u>ME</u> <u>TO-</u> <u>HC</u>
20 CM	X	X		X		X	X	
B2	X	X					X	
A2	X	X					X	
A1B	X	X				X	X	

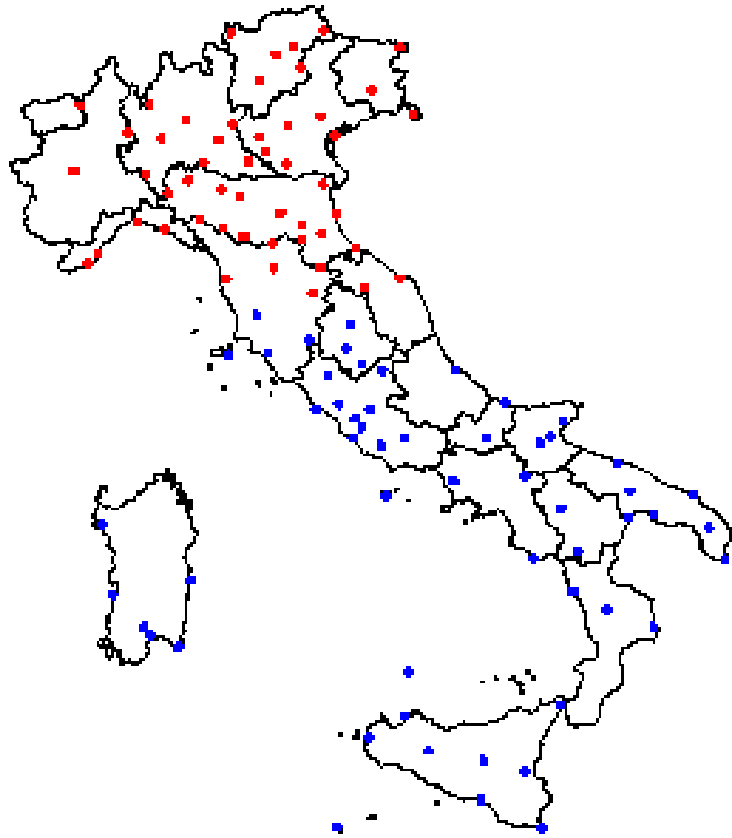
FUB =Univ.of Berlin

MPI=Max Planck Institute

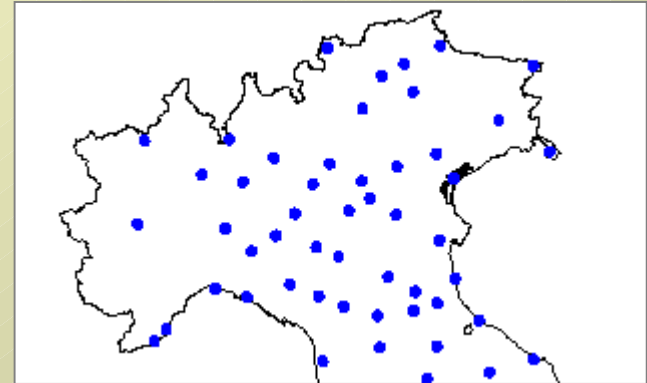
NERSC= Nansen Env.and Remote Sensing Center(Norway)

Scala nazionale-stazioni Tmax e Tmin

Mappa stazioni di temperatura

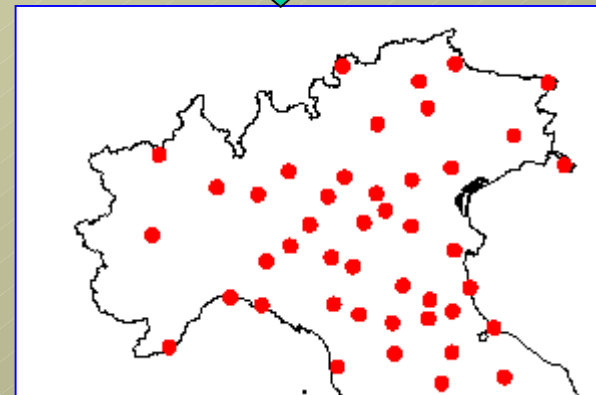


53 stazioni



utilizzabile

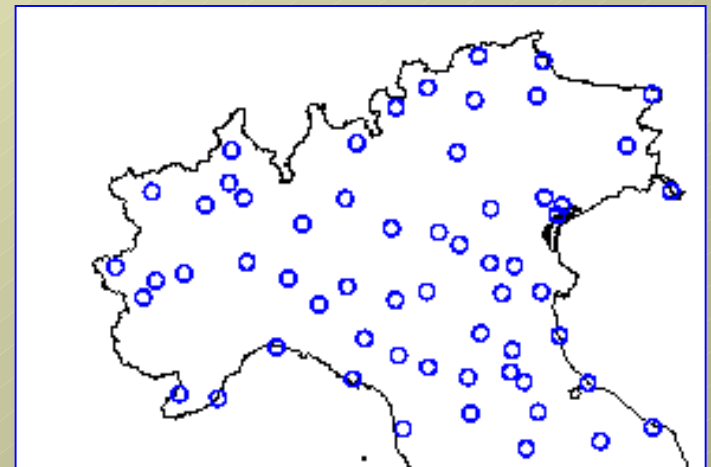
45 stazioni



stazioni
precipitazioni

Mappa stazioni
prec. (selezione)
fonte: APAT

Utilizzabile N-Italia



Indicatori osservati disponibili a scala Nazionale

- Livello: stagionale,
- Periodo: 1961-2002/2006,

- T_{min}, T_{max}, F_d, $35^{\circ}\text{C} < T_{\text{max}} < 30^{\circ}\text{C}$
- Precipitazione, numero di giorni piovosi

fonte: APAT, ARPA-SIM

Qualche risultato di cambiamento in Italia basato su SINTEX-G

SINTEX-G = modello accoppiato oceano-atmosfera

Atm. = ECHAM4.6, resolution T106 (1.125°x1.125°)

Ocean = OPA 8.2

Sea ICE = LIM (Louvain La Neuve sea-ice model)

Coupler = OASIS 2.4

Runs: - control run (1870-2000)

- A1B, A2 (2001-2100)

Modello statistico di downscaling (SD)

- Il metodo delle CCA permette di trovare la migliore combinazione lineare tra due matrici di dati e seleziona coppie di patterns spaziali delle variabili tali che sia ottima la correlazione delle corrispondenti serie temporali (von Storch, 1991).
- Von Storch H (1995) Spatial Patterns: EOFs and CCA. In: von Storch H, Navarra A (eds) Analysis of climate variability. Application of statistical techniques. Springer pp 227–258;
- Von Storch H, Zorita E, Cubasch U (1993) Downscaling of climate change estimates to regional scales: an application to the Iberian winter time. J Climate 6: 1161–1171

Scelta dei predittori...

Lo skill dei modelli dipende da:

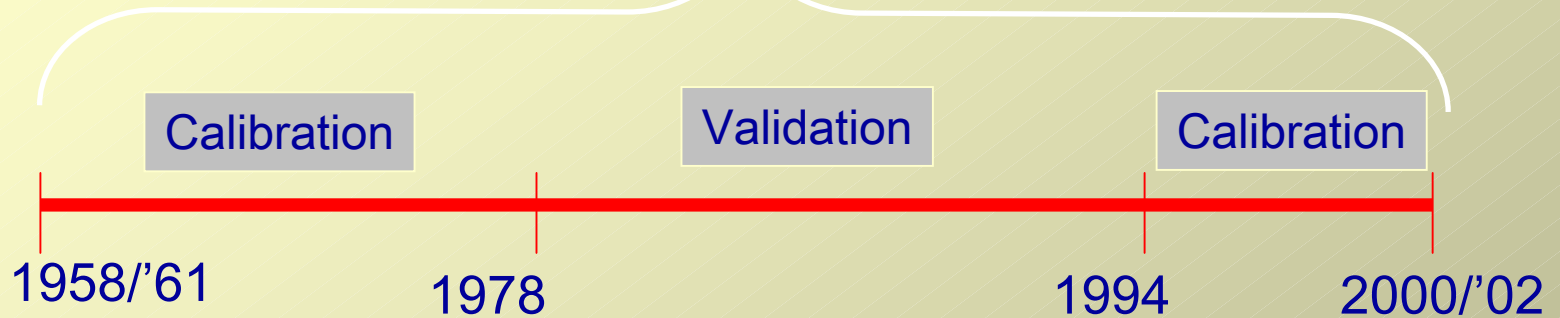


- Predittori;
- area dei predittori;
- numero di CCA utilizzate nel modello di regressione

Nota:

Il legame tra i predittori e predittandi deve essere stabile, forte e di significato fisico (NCEP-rianalisi);

Set-up SDM



skill - SDMs

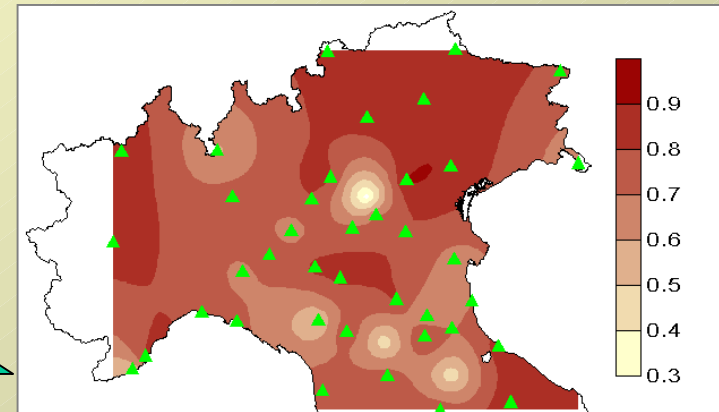
- correlation coefficient (Spearman coefficient);

- $$BIAS = \langle index_{model} \rangle_{verification} - \langle index_{obs} \rangle_{verification}$$

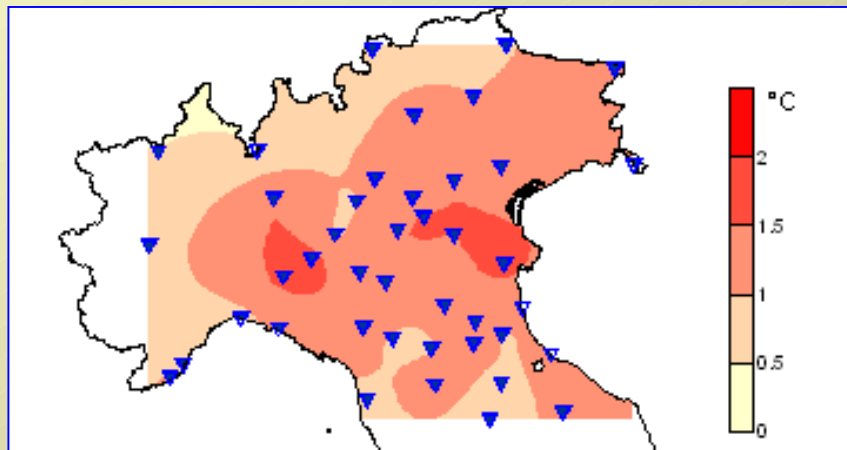
- $$RMSE = \sqrt{\frac{1}{N} \sum_{i \in verificationperiod} [index_{model}(i) - index_{obs}(i) - BIAS]^2}$$

Tmin

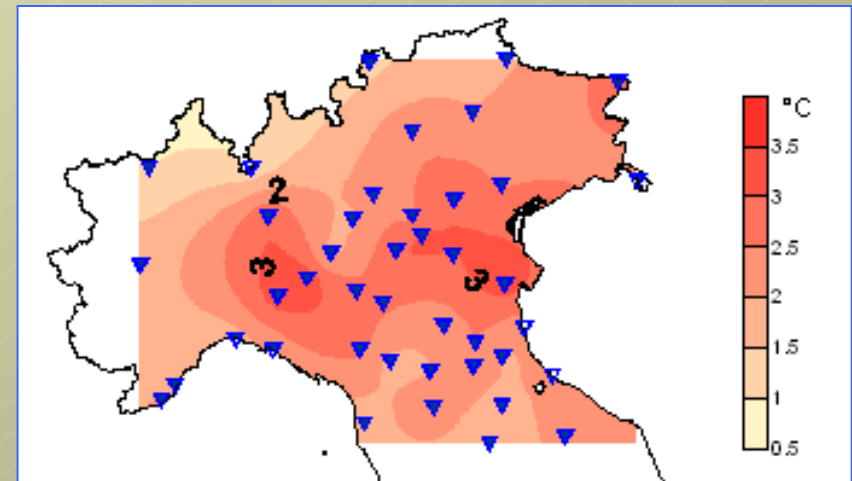
Coeff. di correlazione tra il valore downscalato ed osservato (periodo 1979-1993)



Tmin (DJF)- a1b (2021:2050-1961-1990)



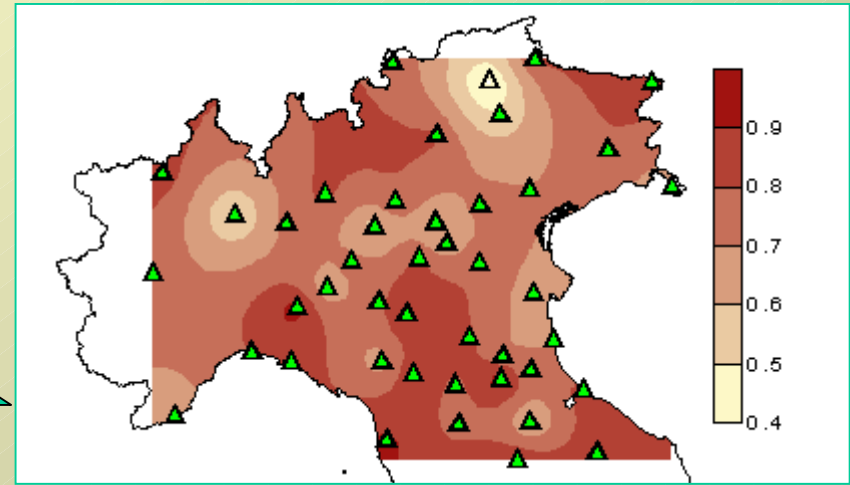
Tmin (DJF)- a1b (2071:2100-1961-1990)



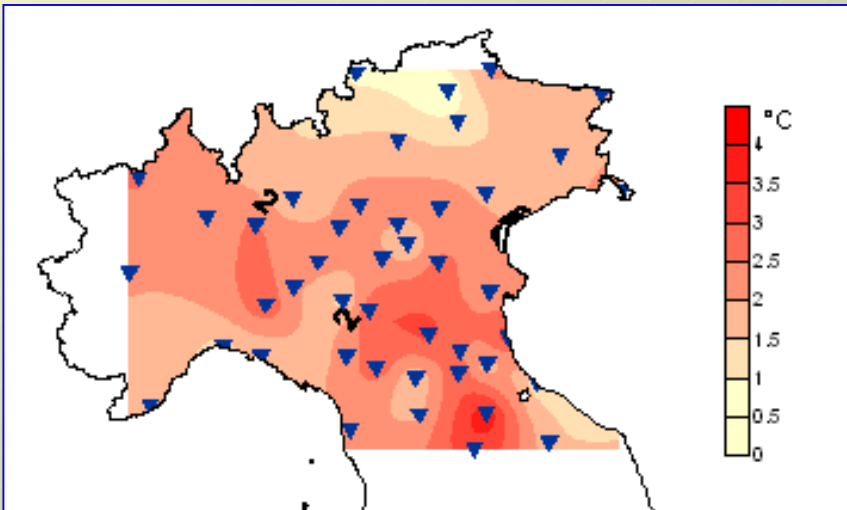
Tmax

Coeff. di correlazione tra il valore downscalato ed osservato (periodo 1979-1993)

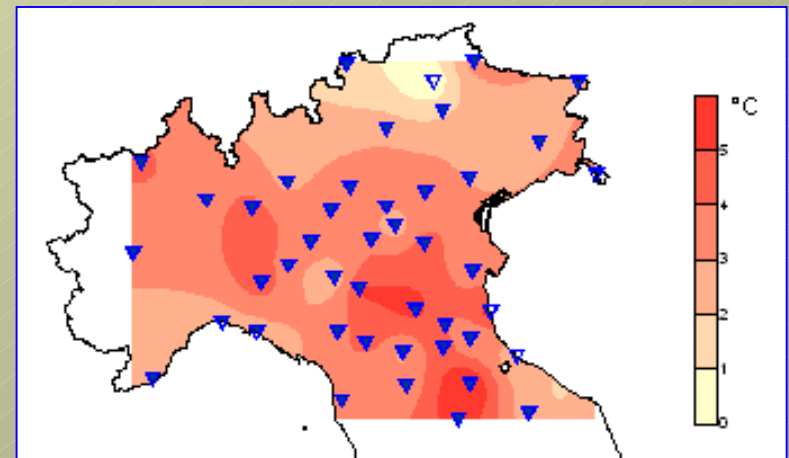
Pred. T850



Tmax (JJA)- a1b (2021-2050)



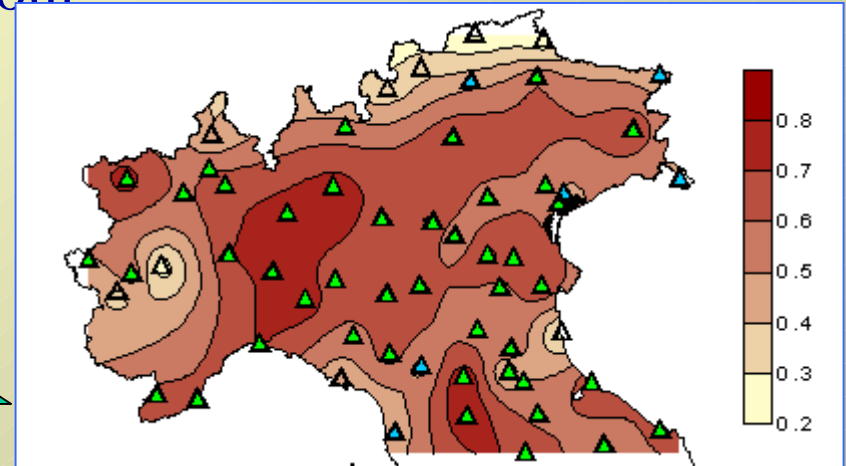
Tmax (JJA)- a1b (2071-2100)



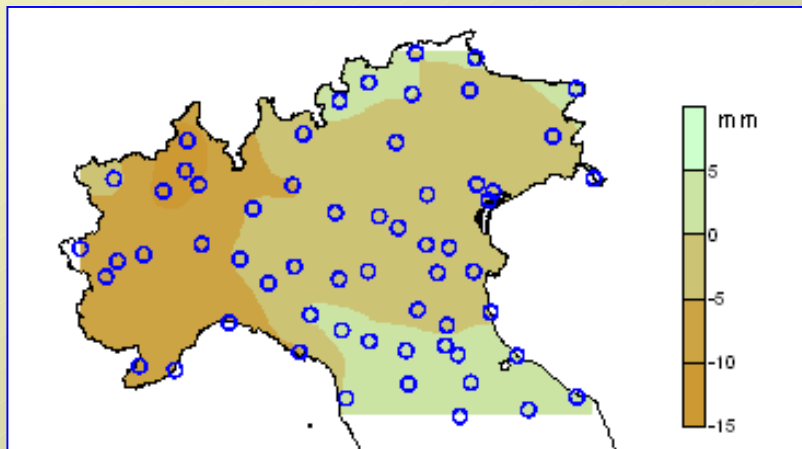
Precipitazioni

Coeff. di correlazione tra il valore downscalato ed osservato (periodo 1979-1993)

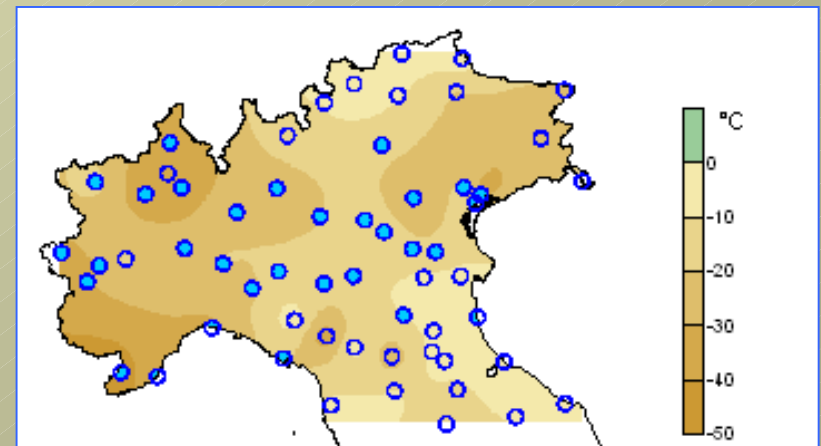
Pred. MSLP



A1B-DJF (2021:2050 – 1961:1990)

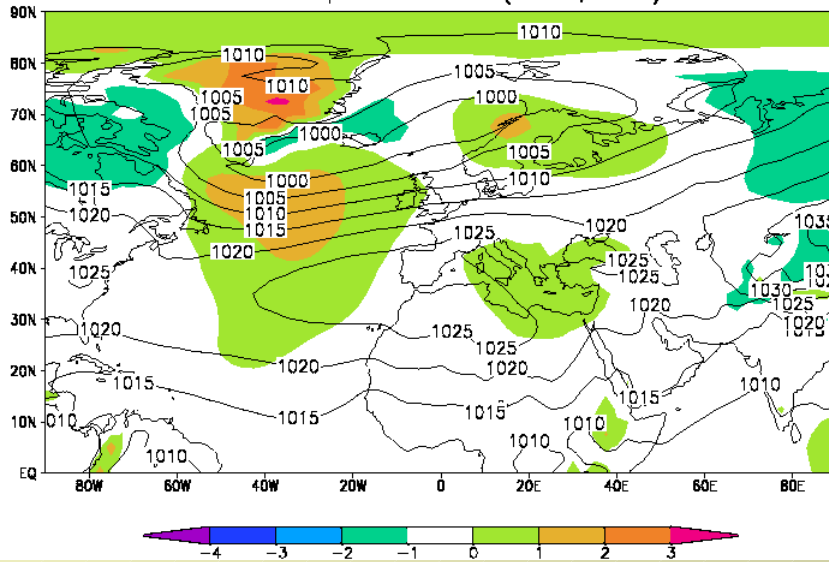


A1B-DJF (2071:2100 - 1961:1990)

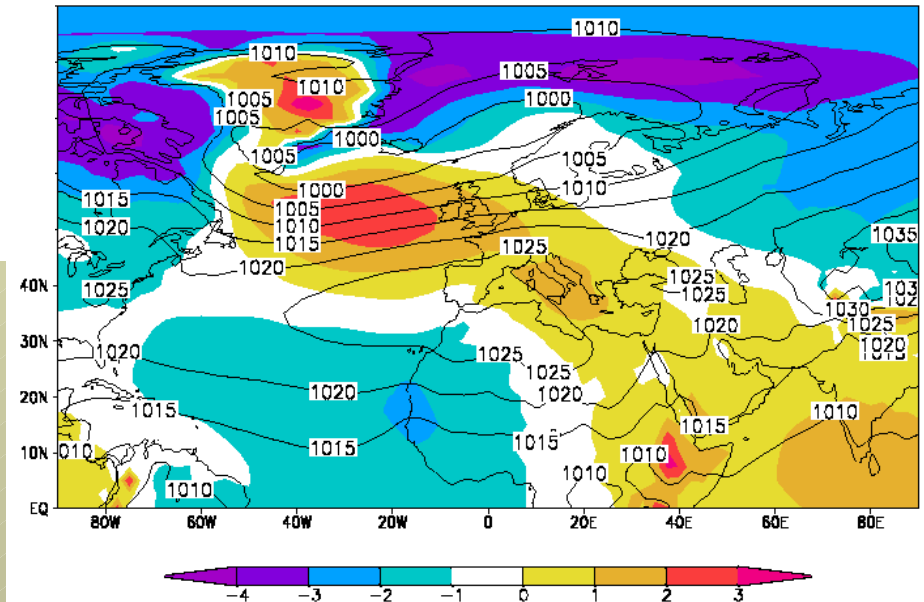


A1B-MSLP (SINTEX-g)

Winter mslp anomalies (2021,2050)

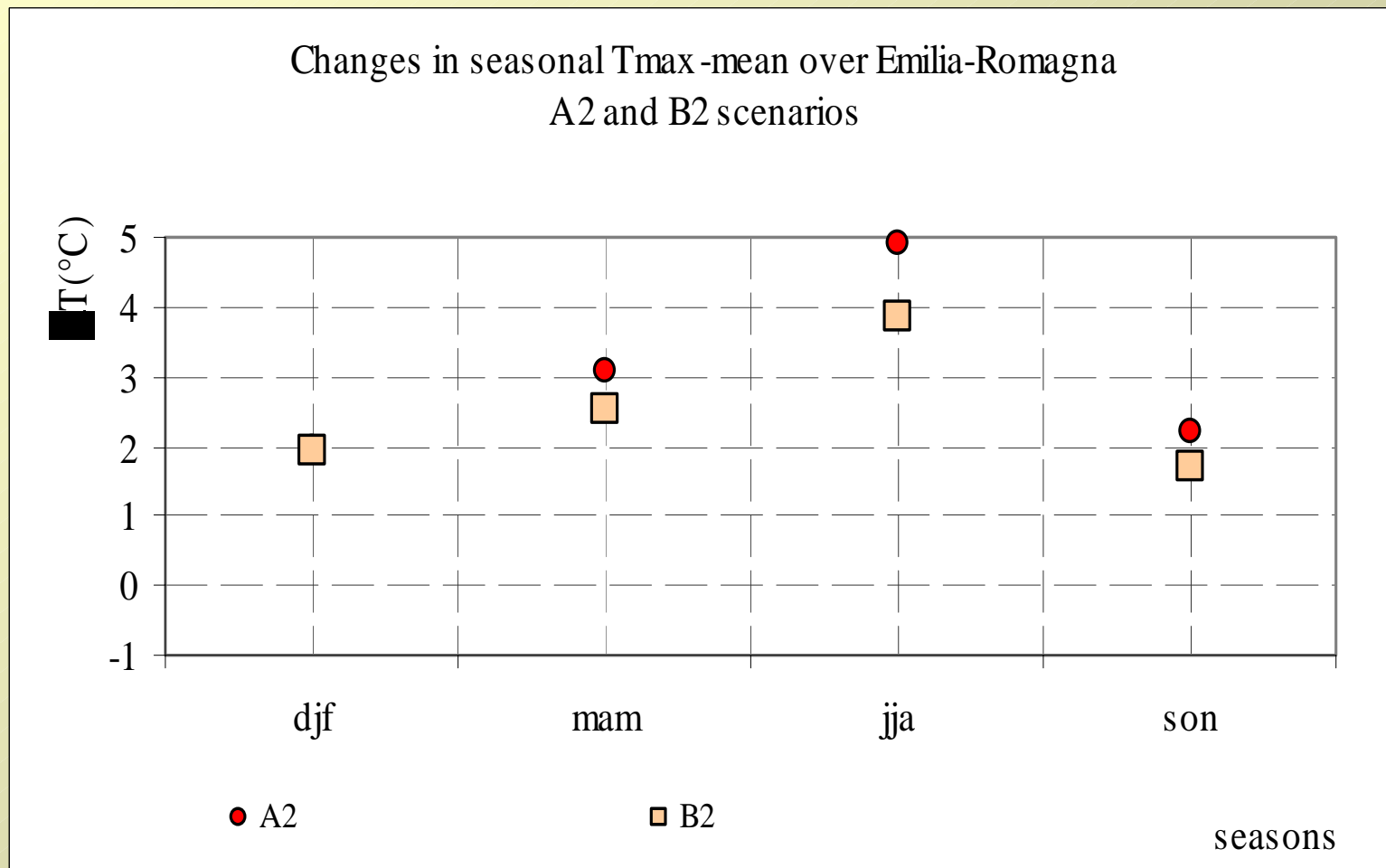


Winter mslp anomalies (2071,2100)



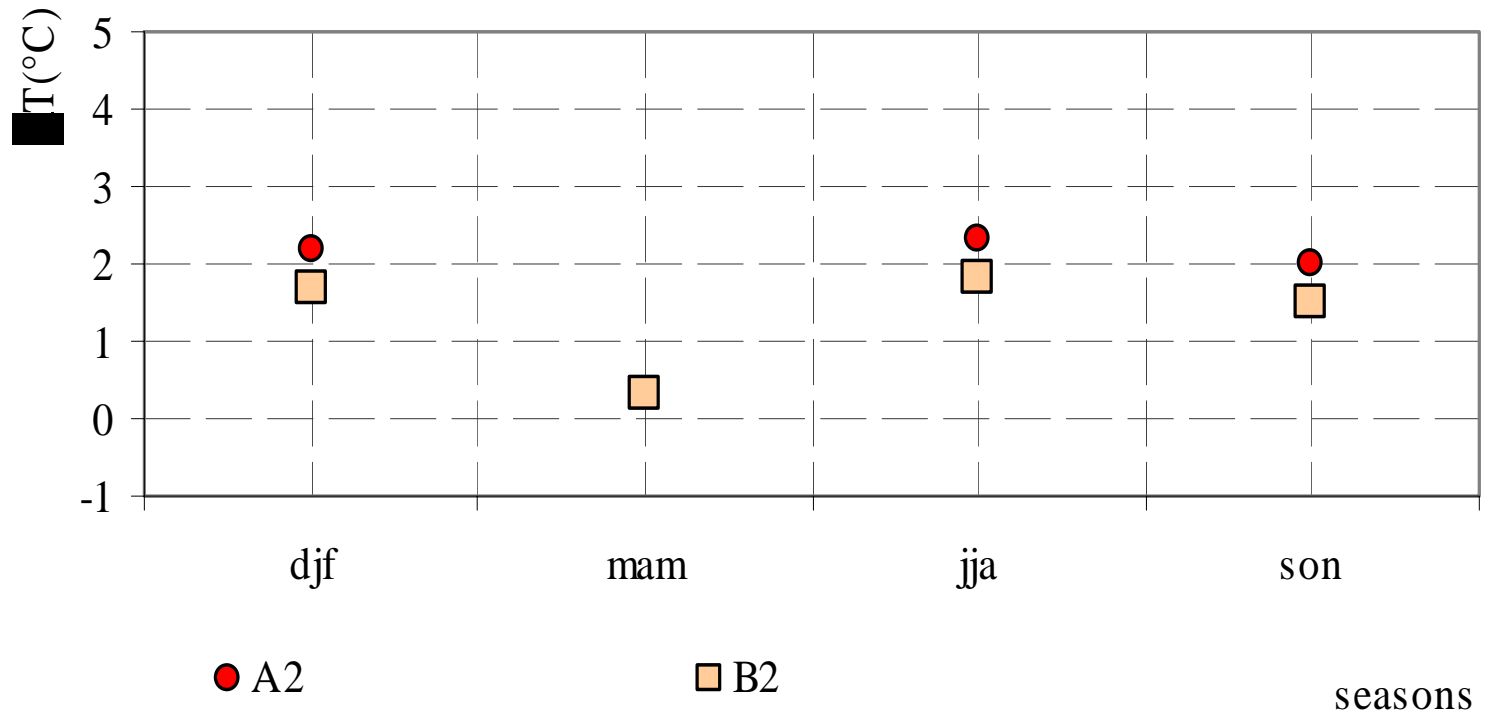
Ancora più...locale
Emilia-Romagna

E) Scenari di cambiamento climatico Tmax (2071-2100)



Tmin (2071:2100-1961:1990)

Changes in seasonal Tmin -mean over Emilia-Romagna
A2 and B2 scenarios



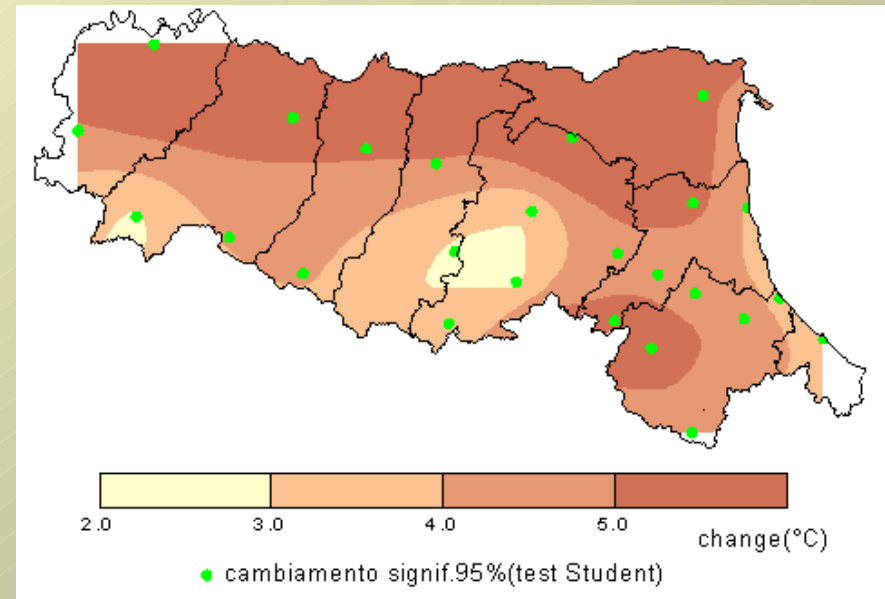
Tmin10 ...

Scenario A2-Tmin10 (DJF)

• **Incremento** significativo in **Tmin10** in tutte le stagioni , più intenso in inverno.

• Durante la primavera e l'estate incremento medio di 2°C sulla regione

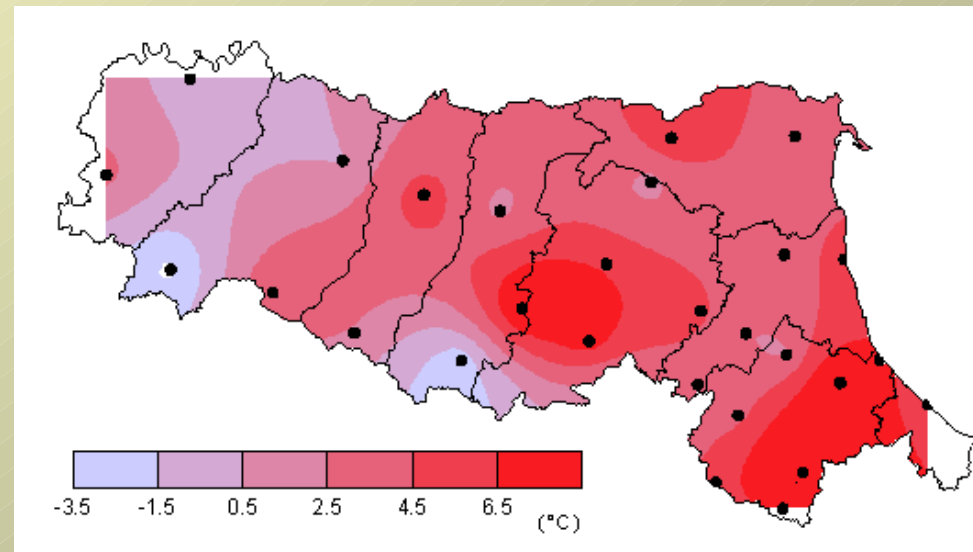
• Durante l'autunno incremento medio di circa 1°C sulla regione



Tmax90

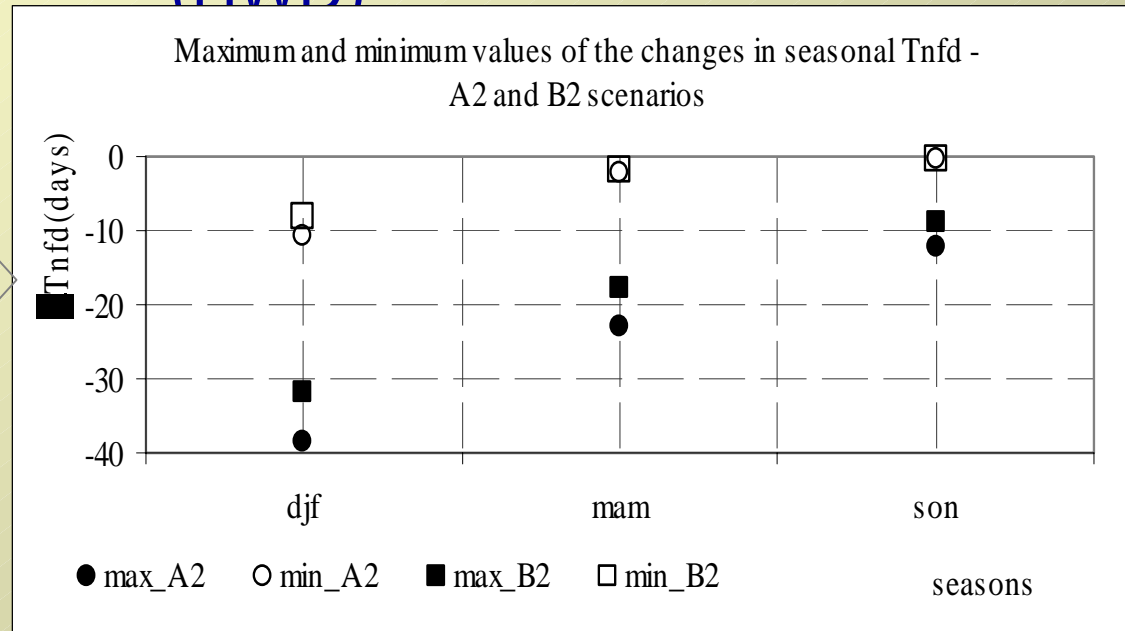
- **Incremento** significativo in Tmax90 in tutte le stagioni, più intenso in estate (media di 4°C) ed autunno (media sulla regione di 2°C)

Scenario A2-Tmax90 (estate)



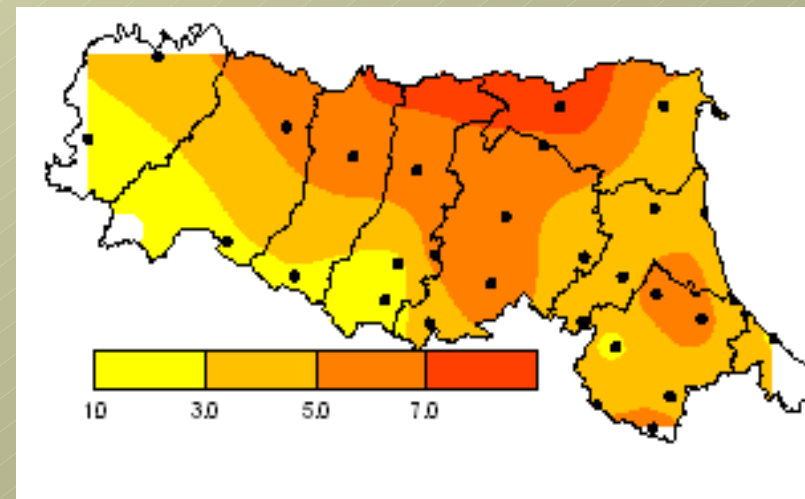
Giorni con il gelo (FD) ; Heat Wave Duration (HWD)

- Tendenza di diminuzione in Fd
- (A2 and B2)

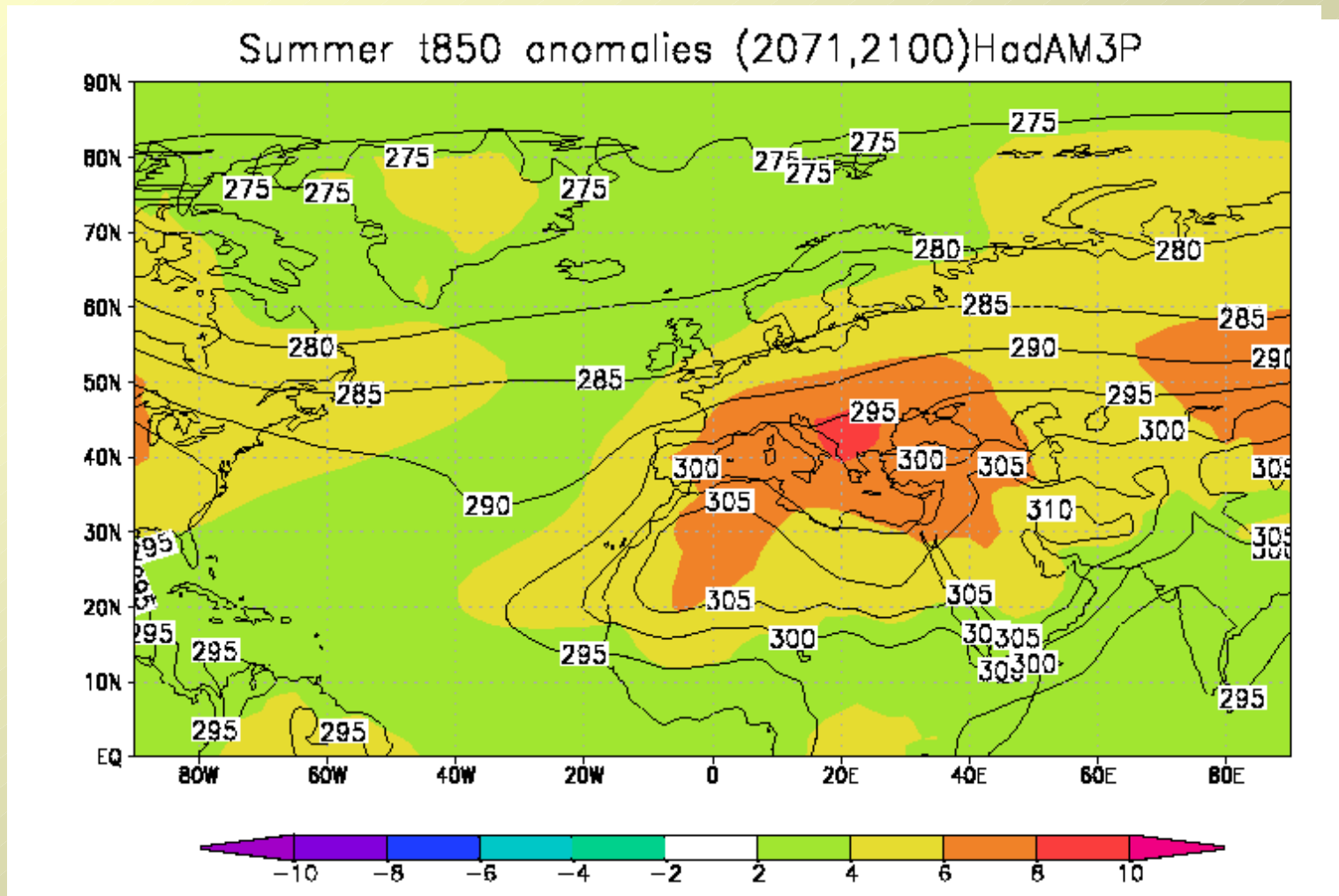


- Incremento HWD,in tutte le stagioni, maggiormente significativa in primavera

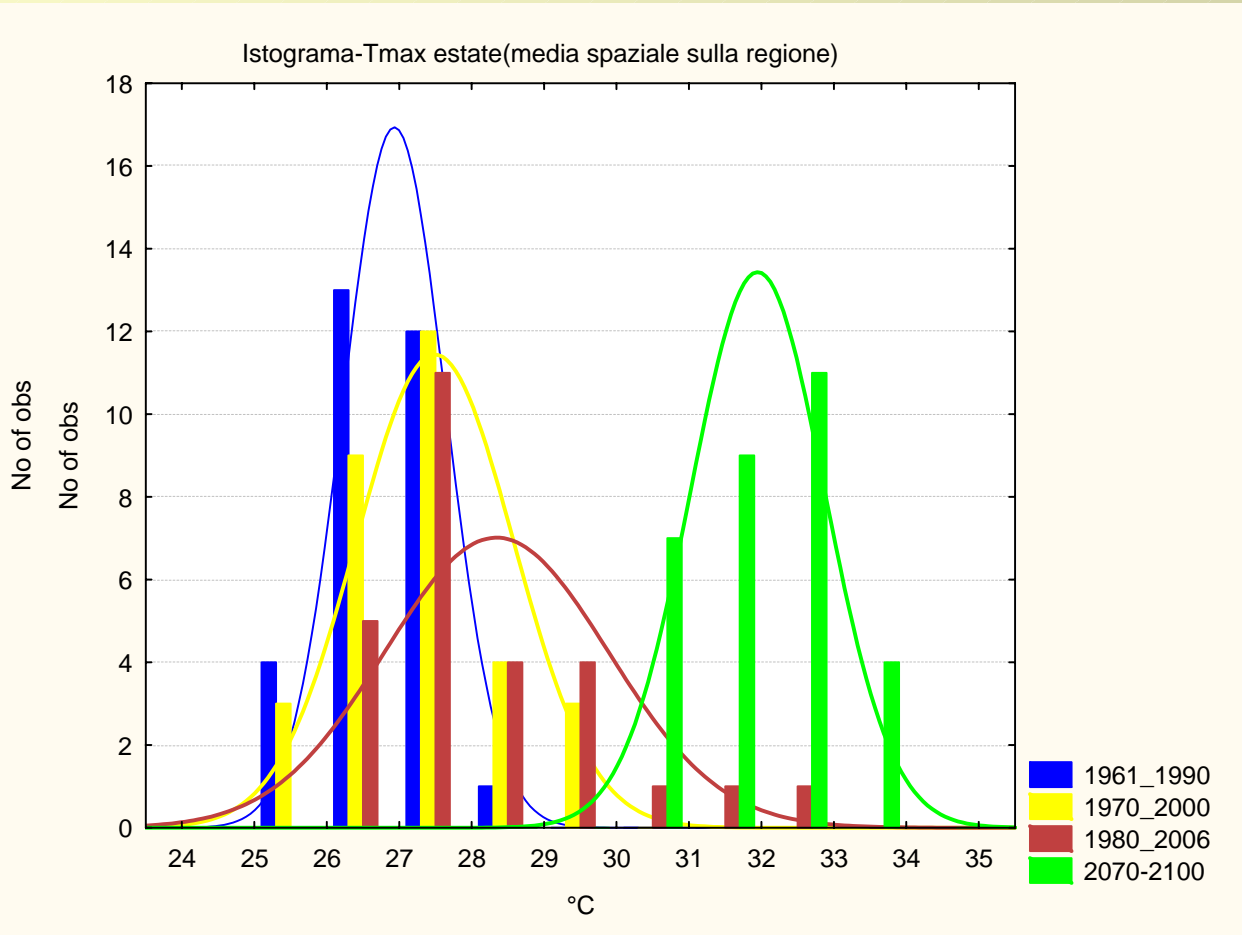
HWD- MAM



Un' occhiata nel HadAM3P (2071-2100) scenario A2

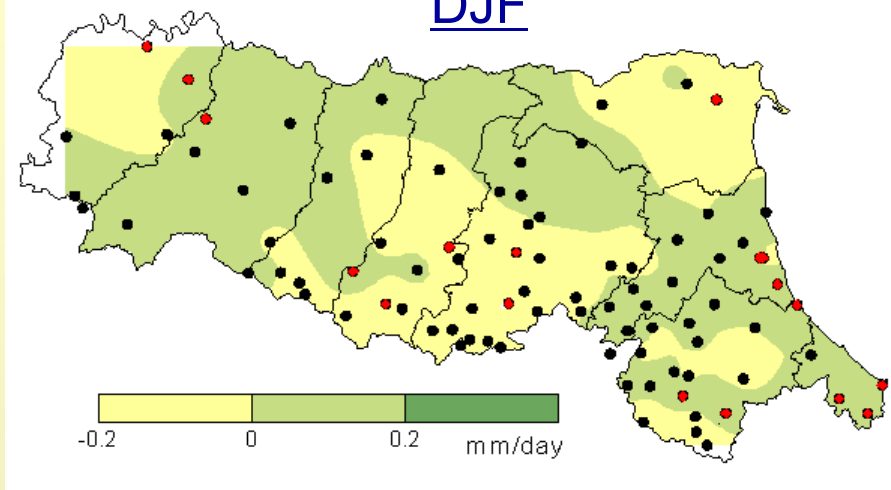


Estate... presente e futuro

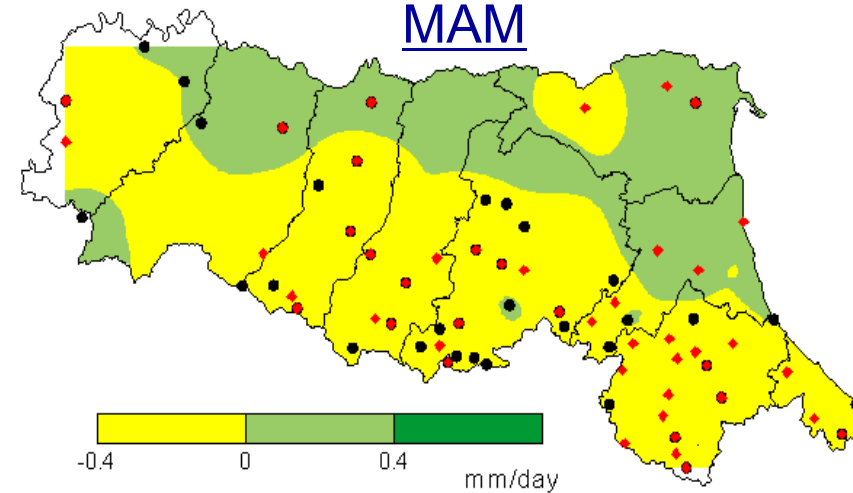


Cambiamenti in (PAV) 2071:2100-1961:1990

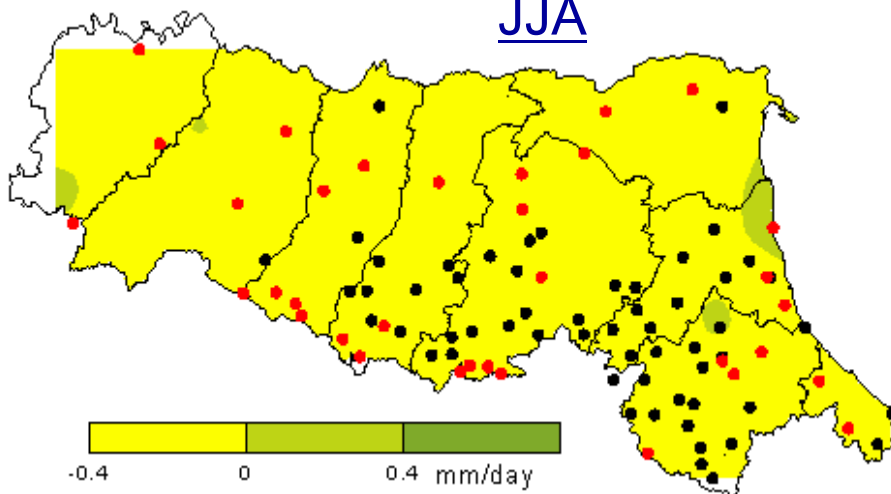
DJF



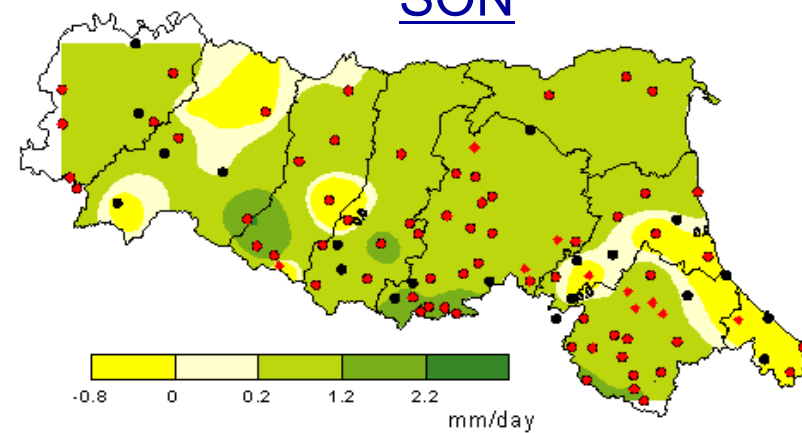
MAM



JJA



SON



CONCLUSIONI

- aumento delle temperature minime in tutte le stagioni, di circa 2° /2.5° C in media sulla regione
- aumento delle temperature max in tutte le stagioni, più intenso d'estate (media 5° C) ed in primavera (media 3° C)
- Aumento dell'intensità e della durata delle "ondate di calore" (Heat Waves)
- Diminuzione del numero di giorni di gelo
- Segnale di diminuzione delle piogge estive ed aumento delle piogge autunnale

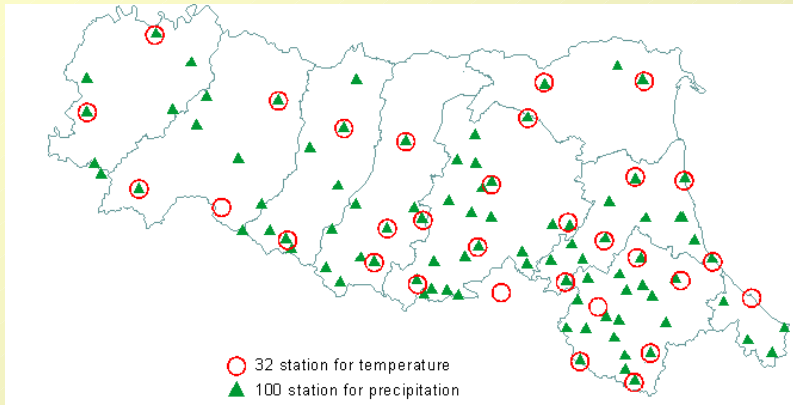
Tomozeiu R., Cacciamani C., Pavan V., Morgillo A., and Busuioc A. (2007)
Climate change scenarios for surface temperature in Emilia-Romagna (Italy) obtained using statistical downscaling models. *Theoretical and Applied Climatology*. DOI 10.1007/s00704-006-0275-z

Fine. Grazie per l'attenzione



A) Data-set

Scala locale - Preditandi



Larga scala- Predittori

- Temperature at 850hPa (T850)
- Mean sea level pressure(MSLP)
- Geopotential height at 500hPa (Z500)

source:

- NCEP-re-analysis 1958-2000
- HadAM3P: control run=1960-1990
scenario A2, B2=2070-2100

resolution= $2.5^{\circ} \times 2.5^{\circ}$,
area= $90^{\circ}W-90^{\circ}E, 0^{\circ}N-90^{\circ}N$

- Tmin (Tmin)
- Tmax (Tmax)
- 10mo percentile Tmin (Tmin10)
- 90mo percentile of Tmax (Tmax90)
- No. giorni con il gelo(Fd)
- Durata delle onde di calore(HWD)
- Precipitazione media giornaliera (PAV)

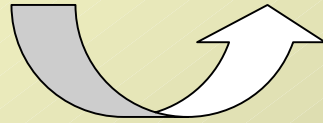
HadAM3P....

- modello atmosferico con 19 livelli verticali e risoluzione orizzontale 2.5 x 3.75, comparabile con T42.
- La SST (sea surface temperatures), usata per guidare il modello, è data dalle osservazioni per il periodo attuale, e dal modello accoppiato oceano-atmosfera HadCM3, per le simulazioni degli scenari.

Pope VD, Gallani ML, Rowntree PR, Stratton RA (2000): The impact of new parameterizations in the Hadley Centre model: HadAM3. *Climate Dyn* 16: 123–146

C) Scelta dei predittori...

Lo skill dei modelli dipendono da:



- Predittori;
- area dei predittori;
- numero di CCA utilizzate nel modello di regressione

Nota:

Il legame tra i predittori e predittandi deve essere stabile, forte e di significato fisico (NCEP-rianalisi);

Predittori :

- T850;
- MSLP;
- Z500;
- shum

CODE	AREA (LONG./LAT.)
Area A	90°W-90°E / 0°N-90°N
Area B	60°W-60°E / 20°N-90°N
Area C	35°W-35°E / 30°N-60°N
Area D	12.5°W-30°E / 30°N-55°N
Area E	5°E-35°E / 30°N-50°N
Area F	5°W-20°E / 37.5°N-50°N

Skill dei modelli usando predittori e aree diverse

MSLP

Tmax90_djf	(90°W-90°E; 0-90°N)		
Station	BIAS	RMSE	CORR
Bobbio	0.34	0.41	0.609
S.Lazzaro A.	0.58	0.38	0.652
Bedonia	-0.29	0.58	0.143
Parma	1.1	0.42	0.612
Bologna	0.41	0.46	0.424
Firenzuola	0.63	0.41	0.343
Alfonsine	0.82	0.36	0.281
Verghereto	-0.24	0.52	0.171

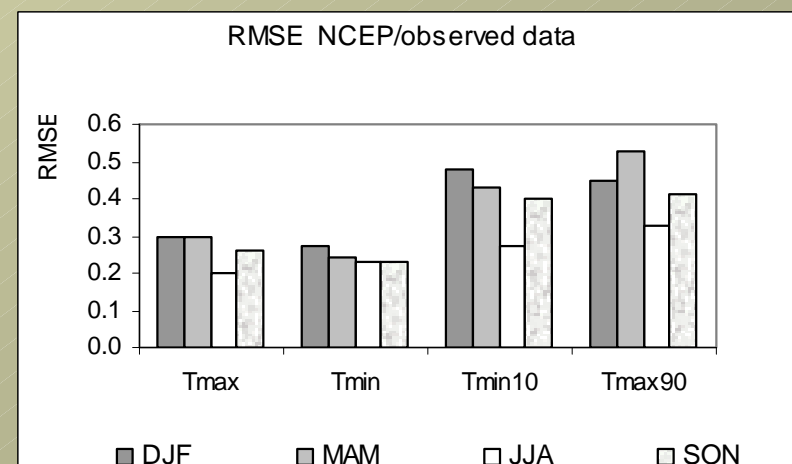
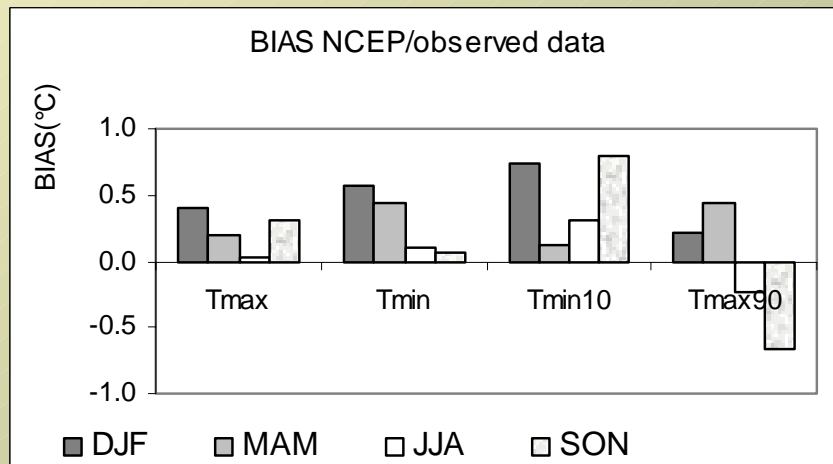
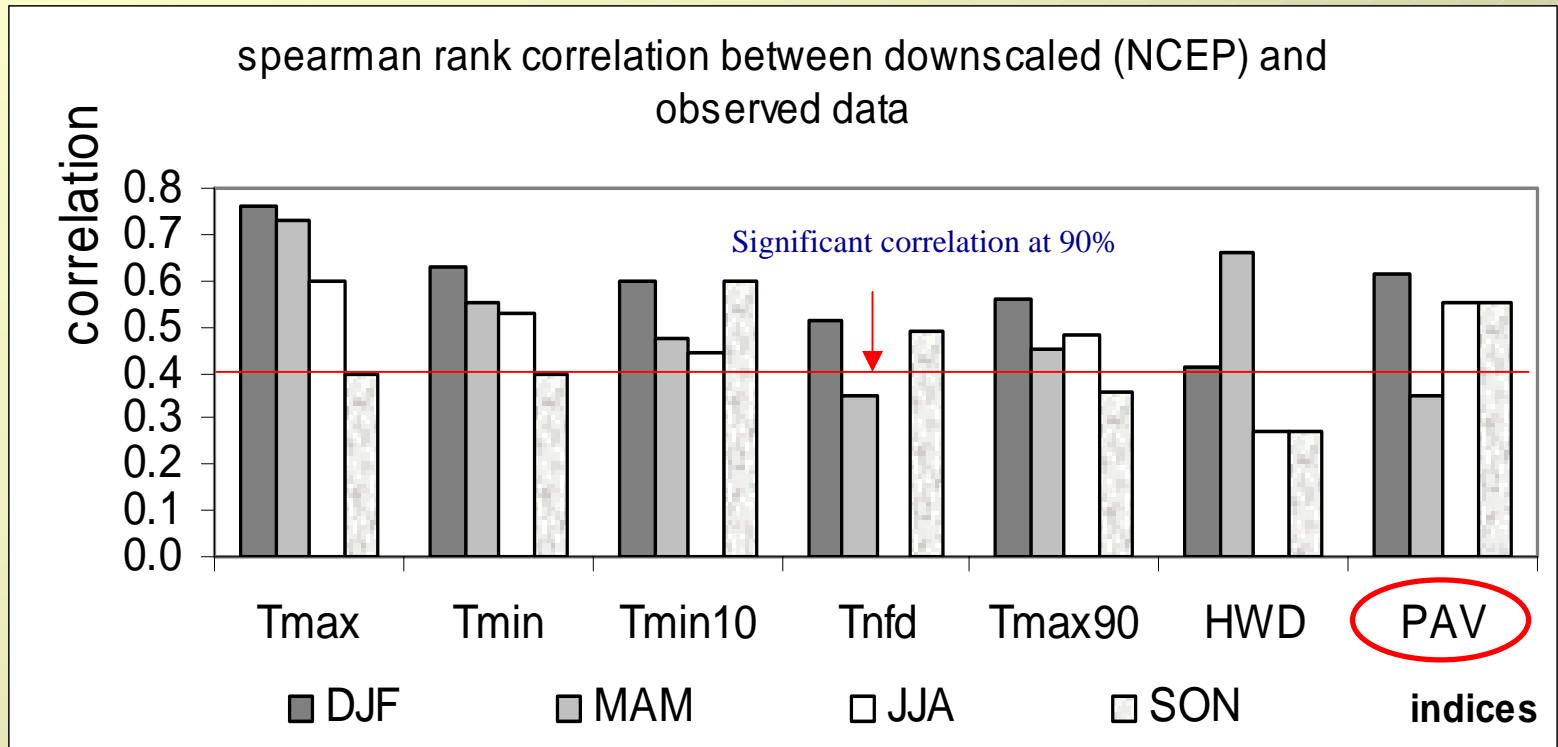
Tmax90_djf	(35°W-35°E;30°N-60°N)		
Station	BIAS	RMSE	CORR
Bobbio	0.36	0.46	0.62
S.Lazzaro A.	0.5	0.39	0.82
Bedonia	-0.28	0.57	0.20
Parma	1	0.45	0.80
Bologna	0.33	0.43	0.82
Firenzuola	0.47	0.41	0.36
Alfonsine	0.76	0.32	0.76
Verghereto	-0.33	0.52	0.08

T850

Tmax90_djf	(90°W-90°E; 0-90°N)		
Station	BIAS	RMSE	CORR
Bobbio	0.42	0.48	0.57
S.Lazzaro A.	0.63	0.4	0.756
Bedonia	-0.43	0.55	0.3843
Parma	1	0.47	0.728
Bologna	0.59	0.45	0.845
Firenzuola	0.57	0.41	0.379
Alfonsine	1	0.35	0.769
Verghereto	-0.08	0.46	0.582

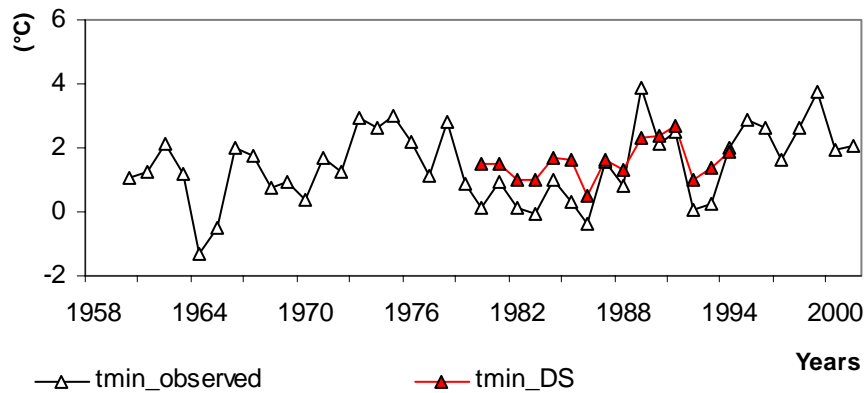
Tmax90_djf	(35°W-35°E; 30°N-60°N)		
Station	BIAS	RMSE	CORR
Bobbio	0.35	0.32	0.80
S.Lazzaro A.	0.44	0.23	0.87
Bedonia	-0.42	0.59	0.24
Parma	1	0.31	0.84
Bologna	0.48	0.3	0.86
Firenzuola	0.6	0.35	0.58
Alfonsine	0.85	0.25	0.78
Verghereto	0.1	0.42	0.63

Quali sono i campi meglio previsti con DS?

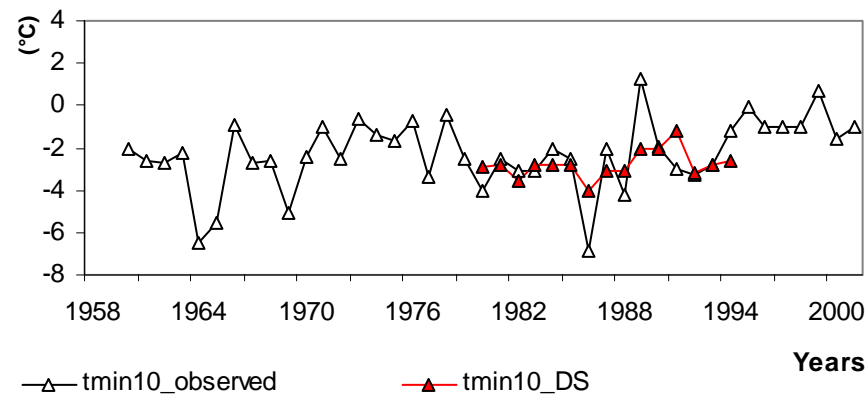


Example of SDM for Bologna station

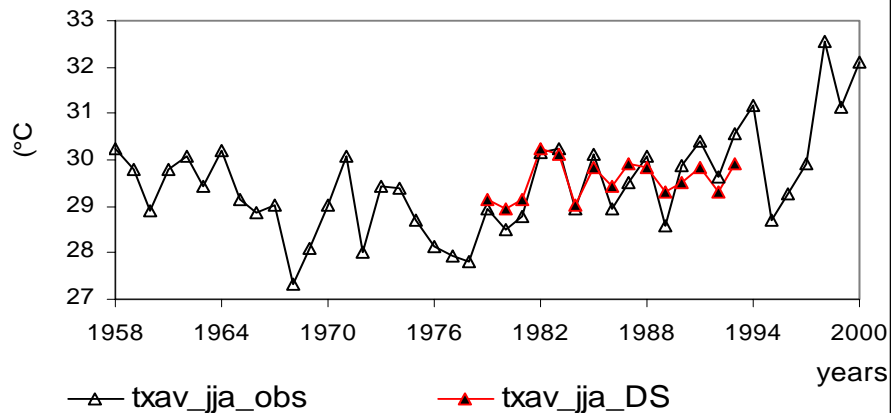
Tmin_DJF-Bologna station (51m)



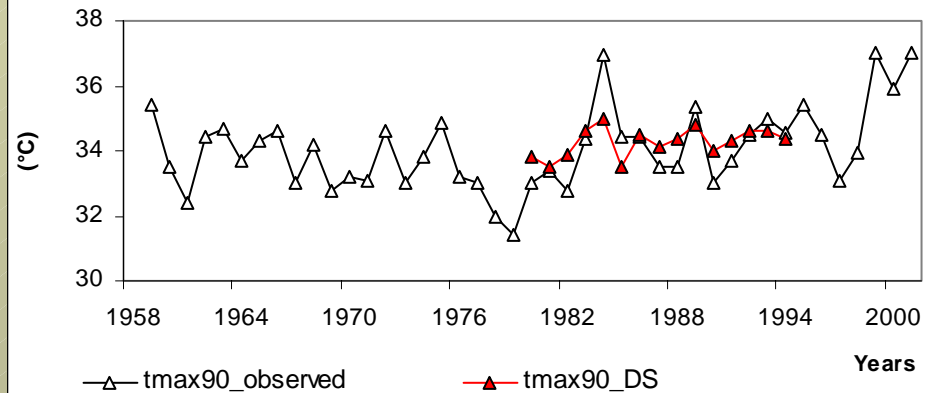
Tmin10_DJF-Bologna station (51m)



Tmax_JJA- Bologna station(51m)

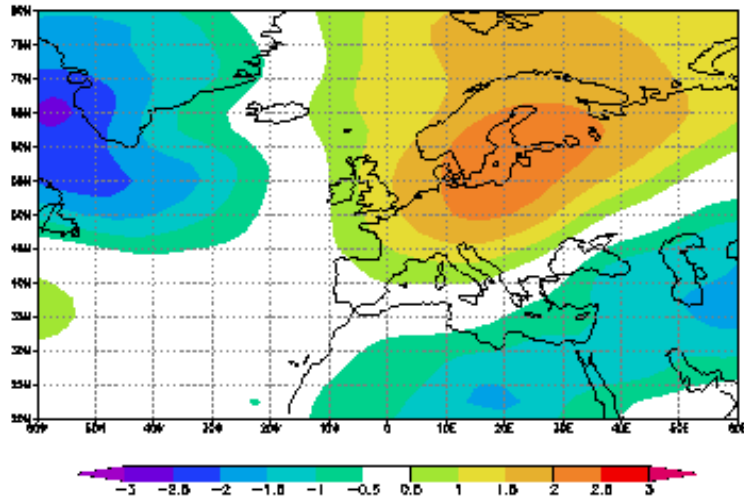


Tmax90_JJA-Bologna station(51m)

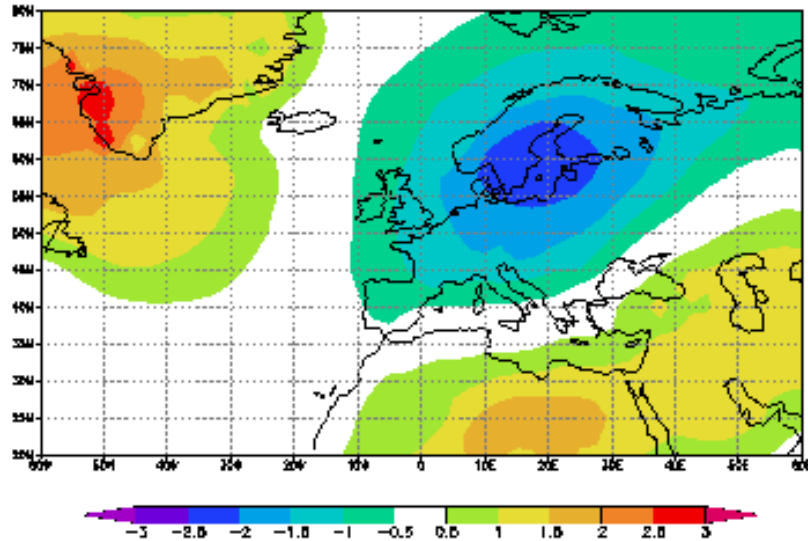


... passiamo ad HadAM3P..

a) T850 NCEP DJF EOF1 -33.3%



a) T850 MOD DJF EOF1 -30.5%



correlazione spaziale tra i patterns (T850, DJF)



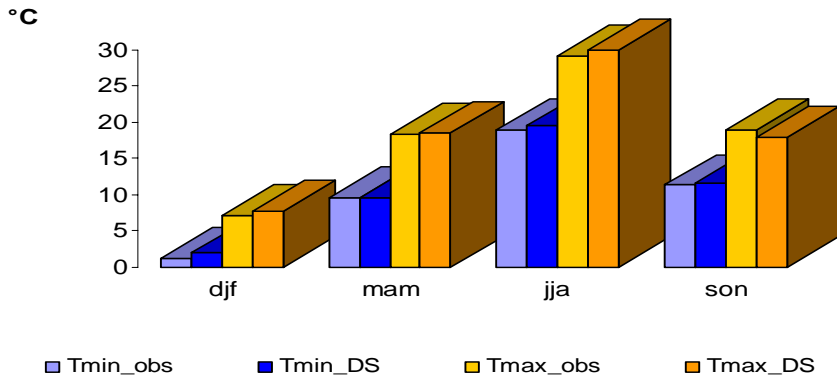
	mod_eof1	mod_eof2	mod_eof3	Mod_eof4
Ncep_eof1	-0.96	0.06	-0.05	-0.14
Ncep_eof2	-0.13	0.72	0.46	-0.07
Ncep_eof3	-0.05	0.32	-0.24	0.77
Ncep_eof4	0.23	-0.39	0.76	0.26

...

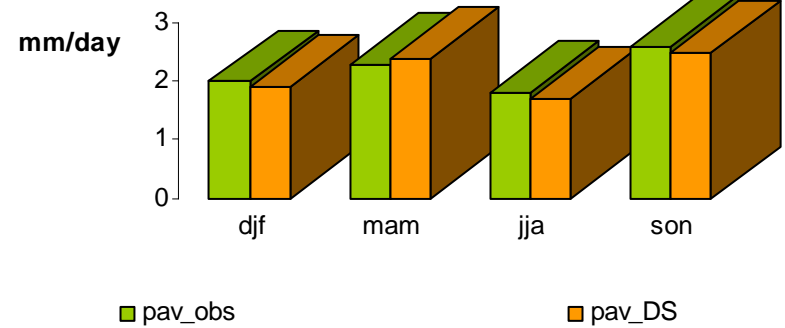
- HadAM3P model riproduce abbastanza bene le caratteristiche dei patterns di EOF di T850, SLP e Z500
- Le stagioni con lo skill migliore sono inverno, primavera ed autunno per Z500 e SLP, ed autunno ed inverno per T850

Come sono rappresentati il ciclo stagionale, il trend, dai modelli DS con HadAM3P?

Observed and Downscaled values (HadAm3P - ctr.run) Tmin/Tmax for the period 1961-1990

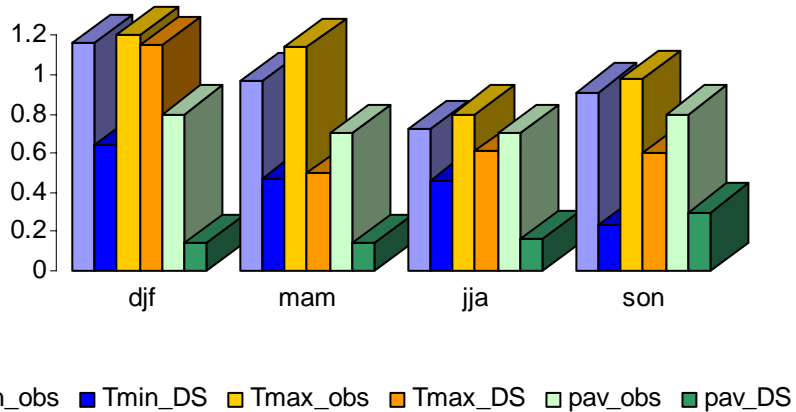


Observed and Downscaled values (HadAm3P - ctr.run) precip. for the period 1961-1990

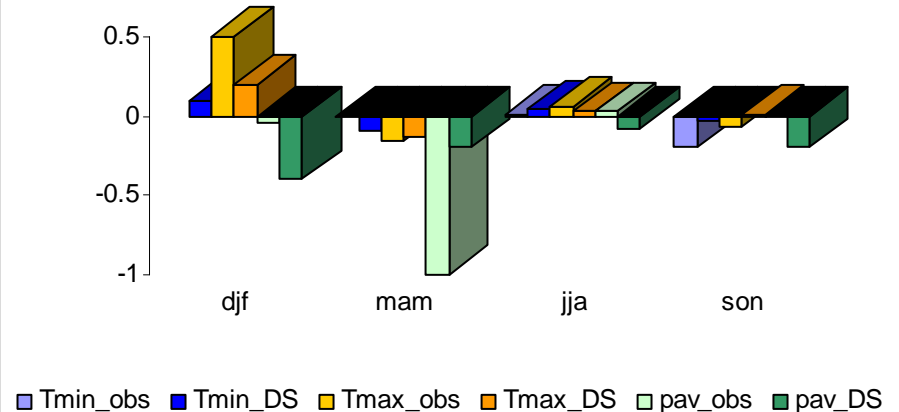


Bologna

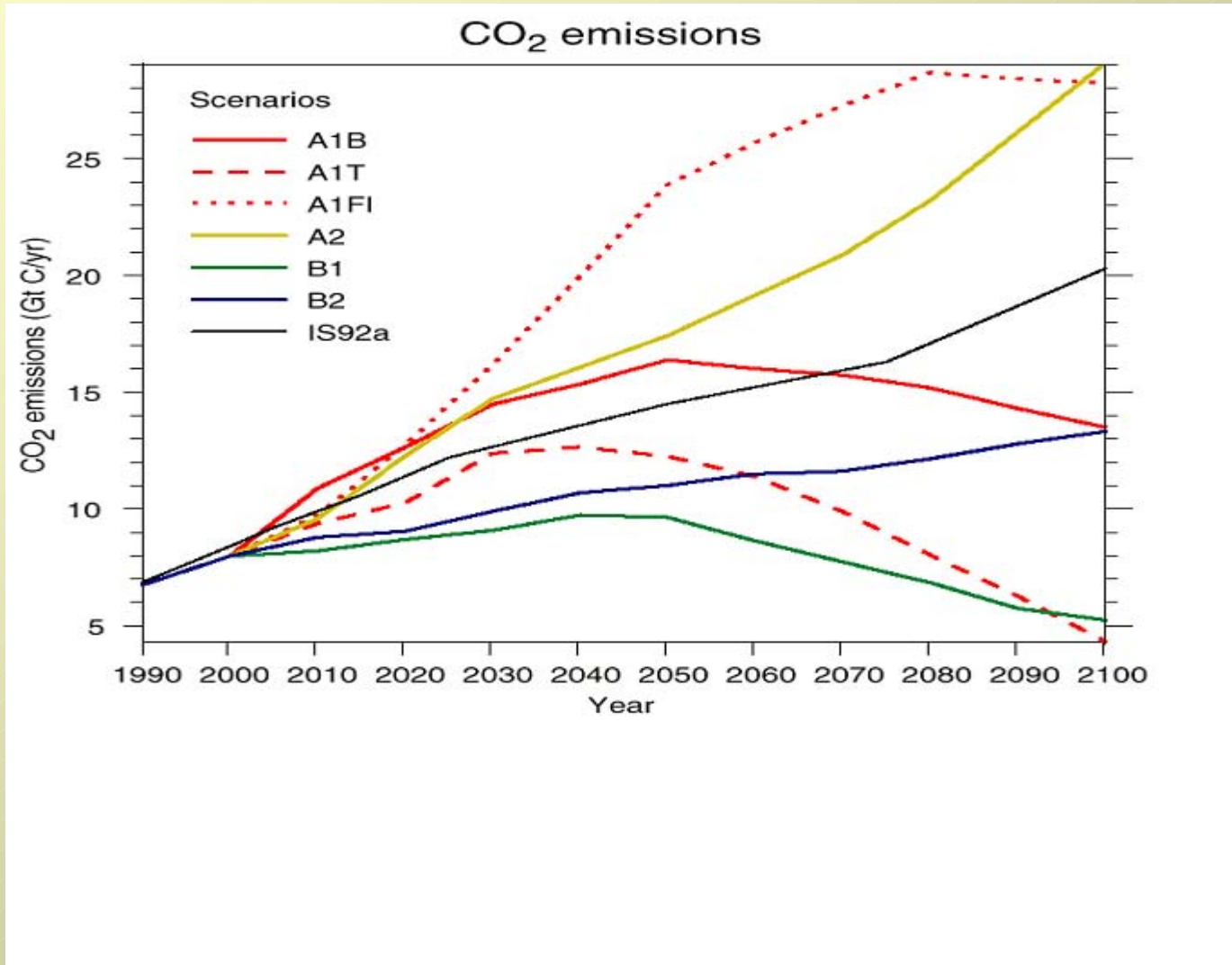
Standard deviation-observed/downscaled



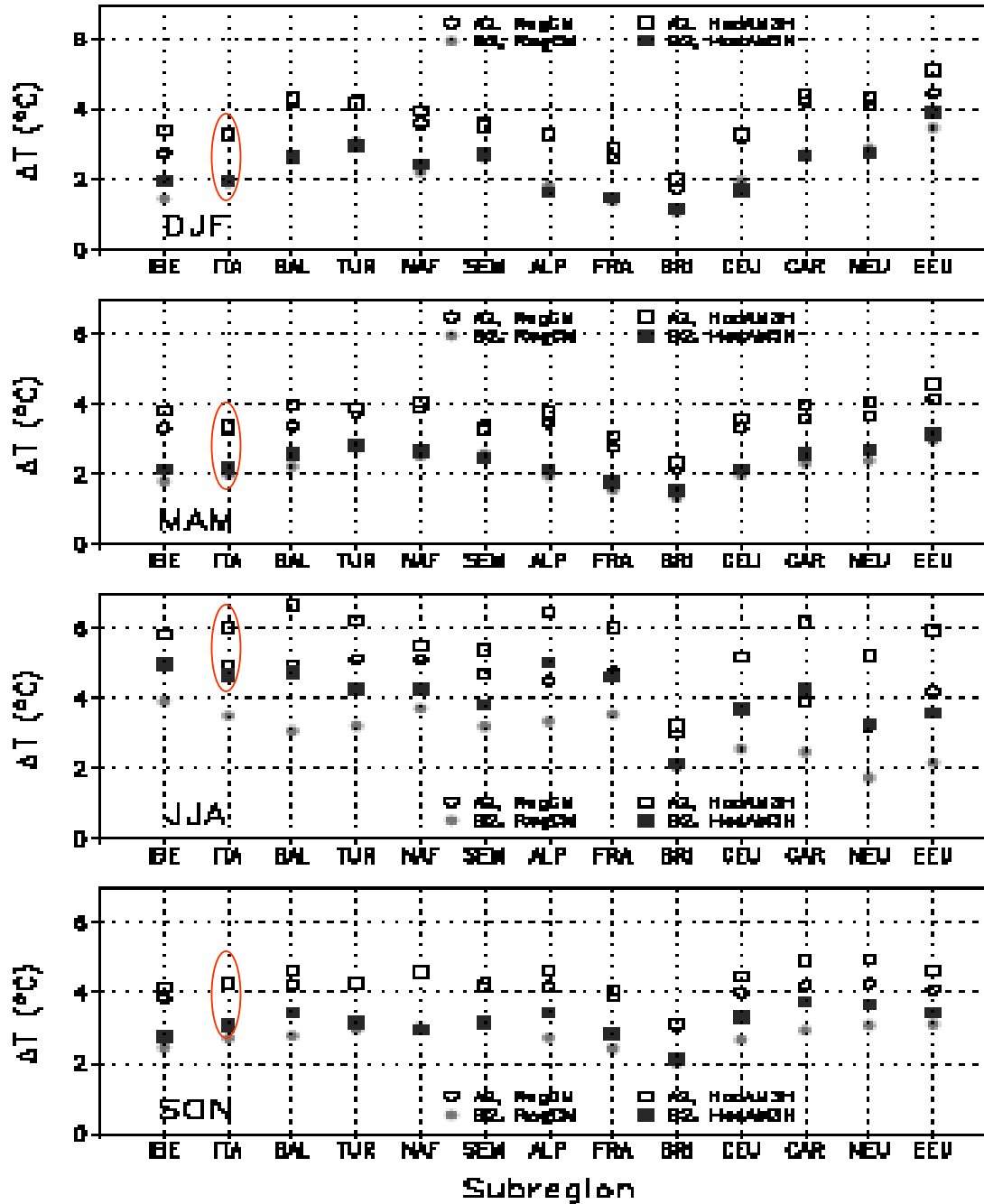
Trend (units/10years)-observed/downscaled



Passiamo agli scenari....



Temperature Change

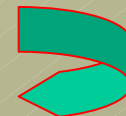


elli?

● RegCM(Giorgi et al.)

□ HadAM3H

Giorgi F, Bi X and Pal JS (2004b): Mean, interannual variability and trends in a regional climate change experiment over Europe. II. Climate change scenarios (2071-2100). Clim Dyn



GRAZIE!

