The Abdus Salam
International Centre for Theoretical Physics

2210-3

MedCLIVAR Workshop on: "Scenarios of Mediterranean Climate Change under Increased Radiative Active Gas Concentration and the Role of Aerosols

23 - 25 September 2010

Accuracy and uncertainty in Climate Models : an intercomparison between regional climate models (RCMs) and global climate models (GCMs) for monthly precipitation and temperature fields over the Mediterranean region

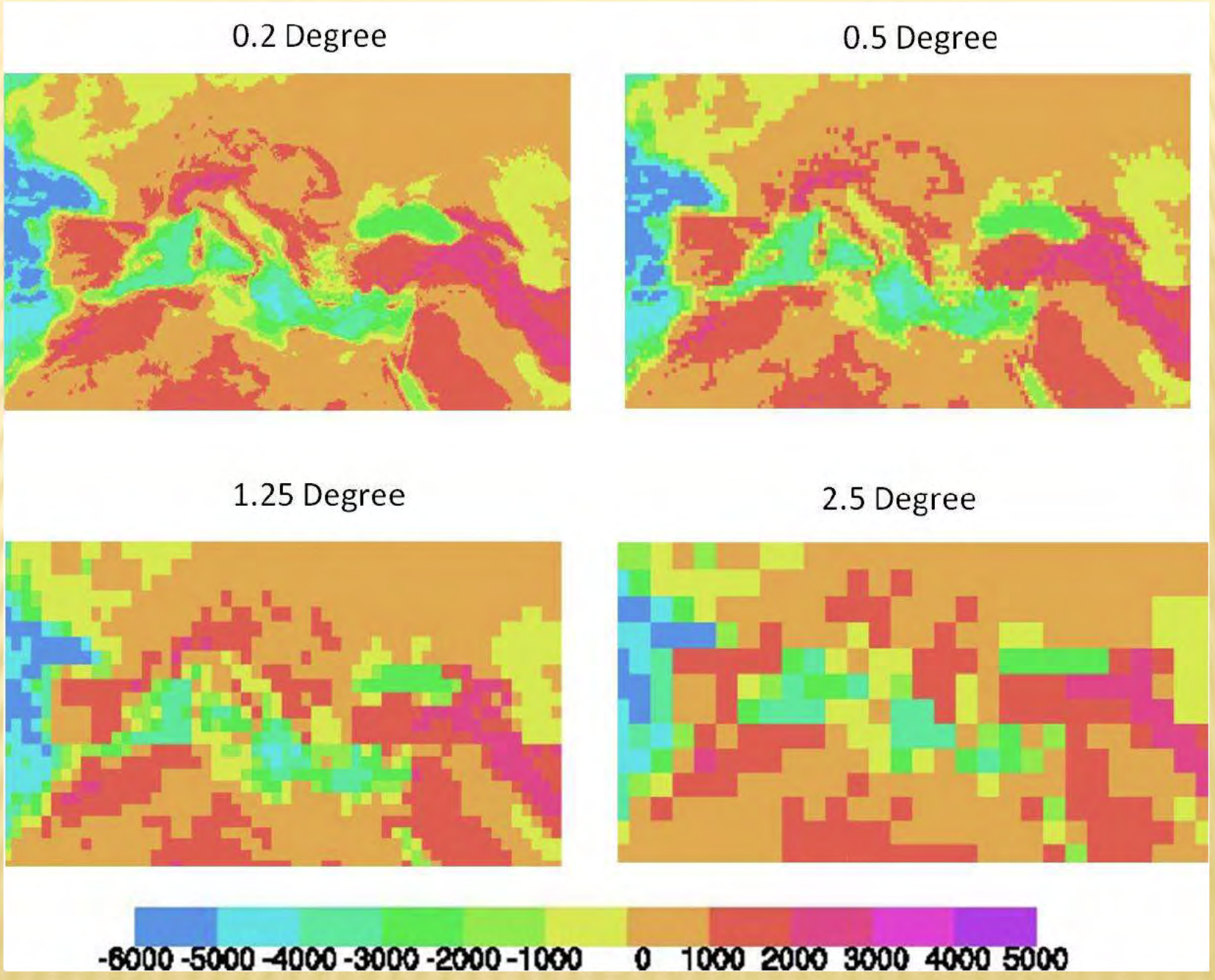
LIONELLO Piero and Congedi L.
Universita' di Lecce Dipartimento di Fisica
Via Per Arnesano, 73100
Lecce
ITALY

Accuracy and uncertainty in Climate Models : an intercomparison between regional climate models (RCMs) and global climate models (GCMs) for monthly precipitation and temperature fields over the Mediterranean region

P.Lionello, L.Congedi
University of Salento

Aim:
To analyze the monthly precipitation and temperature fields of Regional climate models (RCMs) that cover the whole Mediterranean region in the ENSEMBLES and PRUDENCE projects and compare them with the global climate models (GCMs) providing the initial and boundary conditions.

Motivation:
RCMs are expected to produce more accurate results than GCMs, because of their higher resolution, which plays an important role in general, and particularly over regions with complex morphology such as the Mediterranean region.


0.2 Degree
0.5 Degree
1.25 Degree
2.5 Degree
-6000 -5000 -4000 -3000 -2000 -1000 0 1000 2000 3000 4000 5000

ENSEMBLES project

Considering recent results of the ENSEMBLES project (available at http://ensembles-eu.metoffice.com/), two global **AOGCM** simulations have been used:

✓Echam5 r3 (dx*dy= 1.875 x 1.875)

(E. Roeckner et. all, 2003:The atmospheric general circulation model ECHAM5Report No. 349OM: Marsland et. all, 2003:The Max-Planck-Institute global ocean/sea ice modelwith orthogonal curvelinear coordinatesOcean Model., 5, 91-127.OM: Haak, H. et. all, 2003:Formation and propagation of great salinity anomalies,Geophys. Res. Lett., 30 , 1473,10.1029/2003GL17065)

✓HadCM3Q0 (dx*dy= 3.75 x 2.5)

(Collins et al, 2006, Clim. Dyn., DOI 10.1007/s00382-006-0121-0)

PRUDENCE project

(Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects)

For PRUDENCE project (available at http://prudence.dmi.dk/) the **AOGCM** used is :

✓ HADAM3H (dx*dy= 1.875 x 1.25)

References to RCMs : GCMs have been used for generating a set of RCMs (only Atmospheric models) simulations.

Driving GCM	Institute	RCM - Model
ECHAM5-r3	KNMI	**RACMO**
	SMHI	**RCA**
	MPI	**REMO**
	ICTP	**RegCM**

Driving GCM	Institute	RCM - Model
HadCM3Q0	METNO	**HIRHAM**
	UCLM	**PROMES**
	ETHZ	**CLM**
	METO-HC	**HadRM3Q0**

Driving GCM	Institute	RCM - Model
HADAM3H	KNMI	**RACMO**
	GKSS	**CLM**
	MPI	**REMO**
	ICTP	**RegCM**
	UCM	**PROMES**
	ETH	**CHRM**
	DMI	**HIRHAM**

VALIDATION over LAND

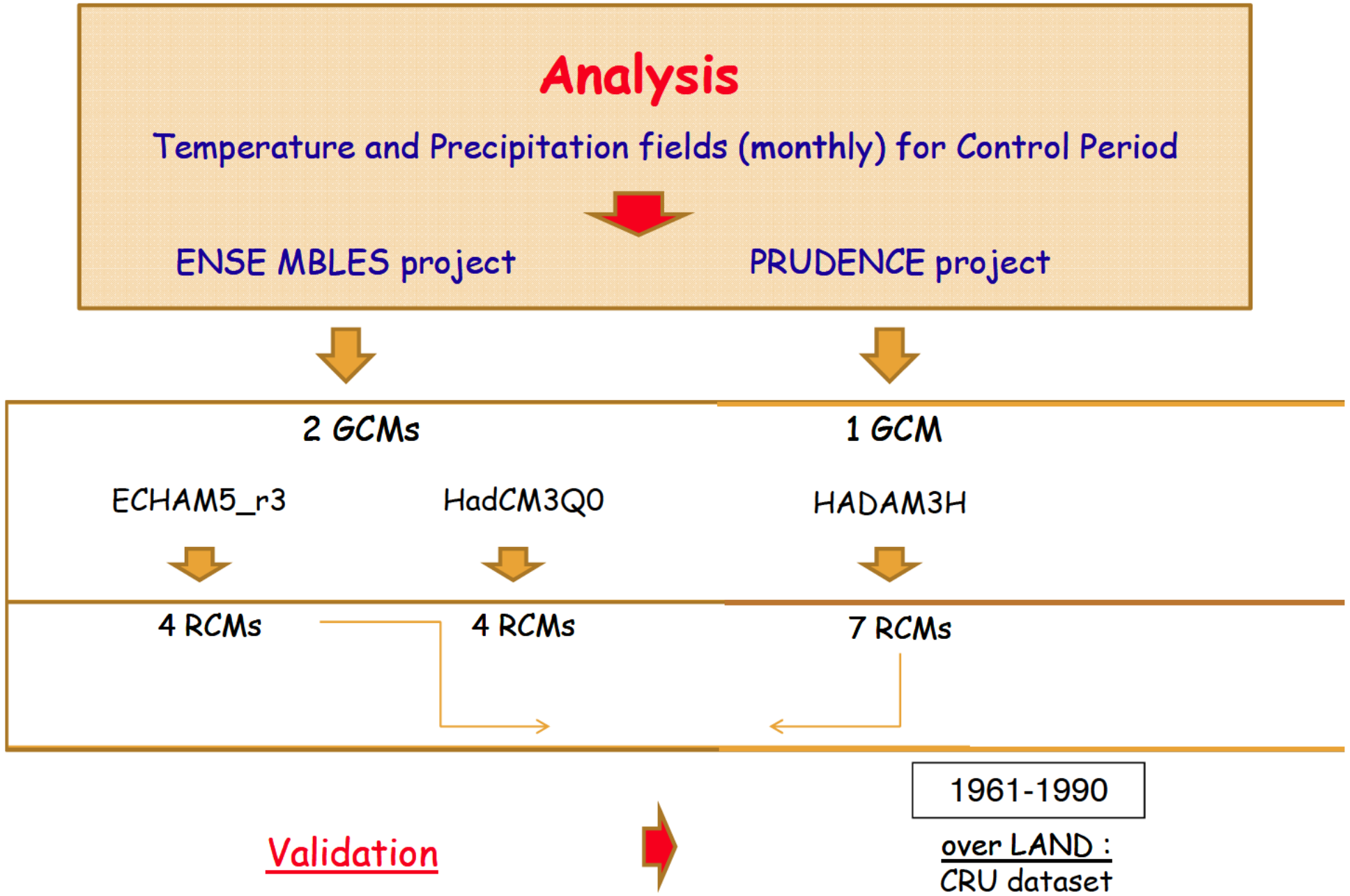
- **CRU(Climatic Research Unit)** → These datasets (global gridded) have been developed from data acquired from weather stations around the world (from http://www.cru.uea.ac.uk/).

- **Resolution** →(dx*dy = 0.5*0.5)

- **References** →

New, M., Hulme, M. and Jones, P.D., 1999: Representing twentieth century space-time climate variability. Part 1: development of a 1961-90 mean monthly terrestrial climatology. *Journal of Climate* 12, 829-856

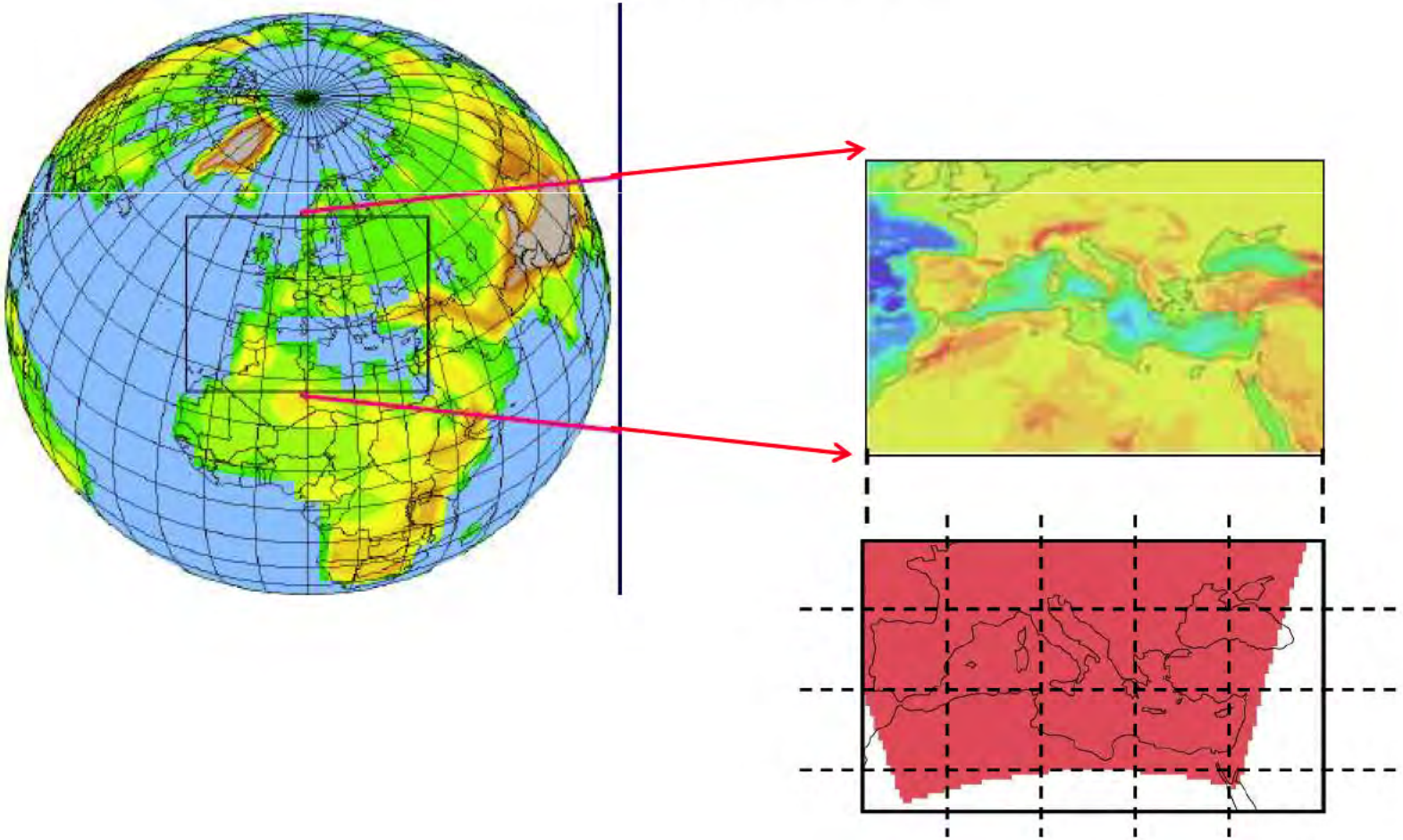
CRU dataset (Climatic Research Unit)


Analysis
Temperature and Precipitation fields (monthly) for Control Period
ENSE MBLES project
PRUDENCE project
2 GCMs
1 GCM
ECHAM5_r3
HadCM3Q0
HADAM3H
4 RCMs
4 RCMs
7 RCMs
1961-1990
Validation
over LAND :
CRU dataset

GRID of LMR
(Large Mediterranean Region)

The analysis was conducted in the domain following :

longitude → from 10 W to 45 E
latitude → from 25 N to 50 N
dx * dy = 0.5 x 0.5

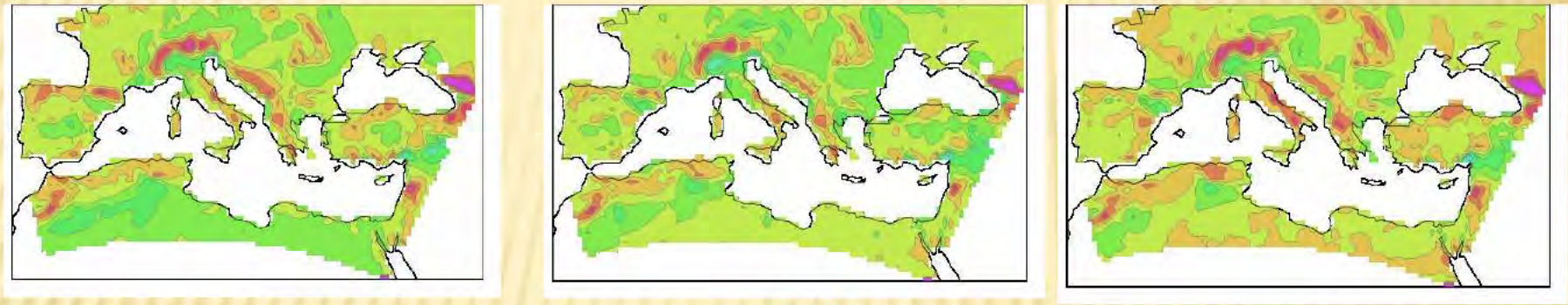


BIAS: (respect to CRU)
ANNUAL Temperature (degreeC)
LAND

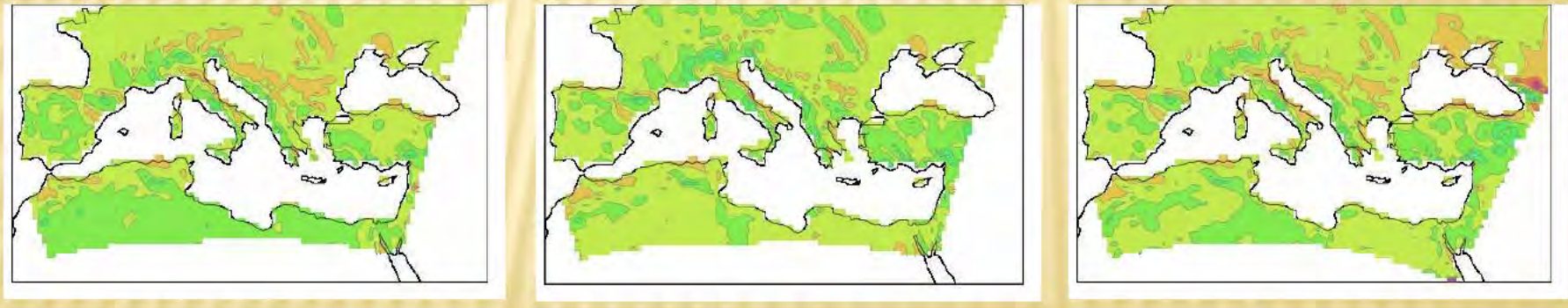
Significant statistically BIAS at the 95% confidence level according to Mann Whitney Test (All maps have a number of statistically significant points > 50% TOT points)

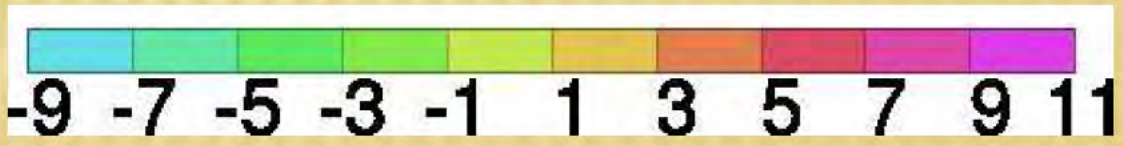
ECHAM5 **Hadcm3Q0** **HADAM3H**

GCM



RCM



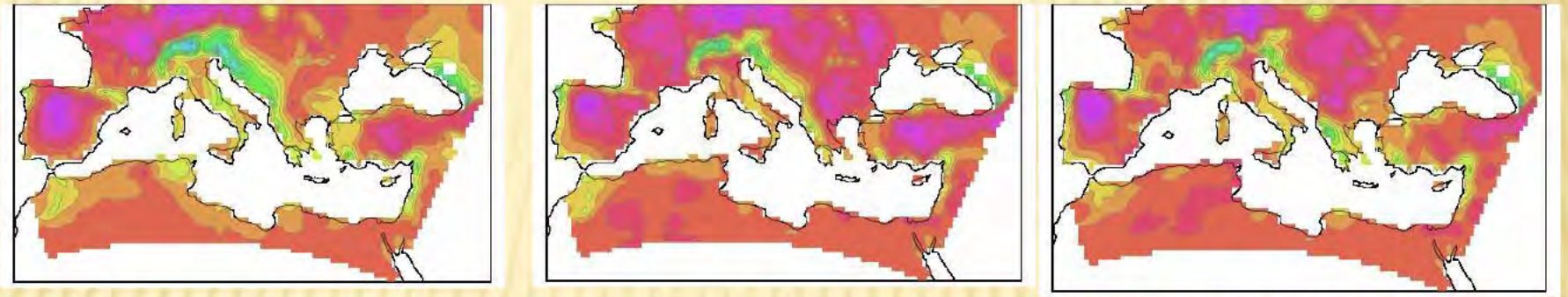


BIAS: (respect to CRU)
ANNUAL Precipitation (mm/month)
LAND

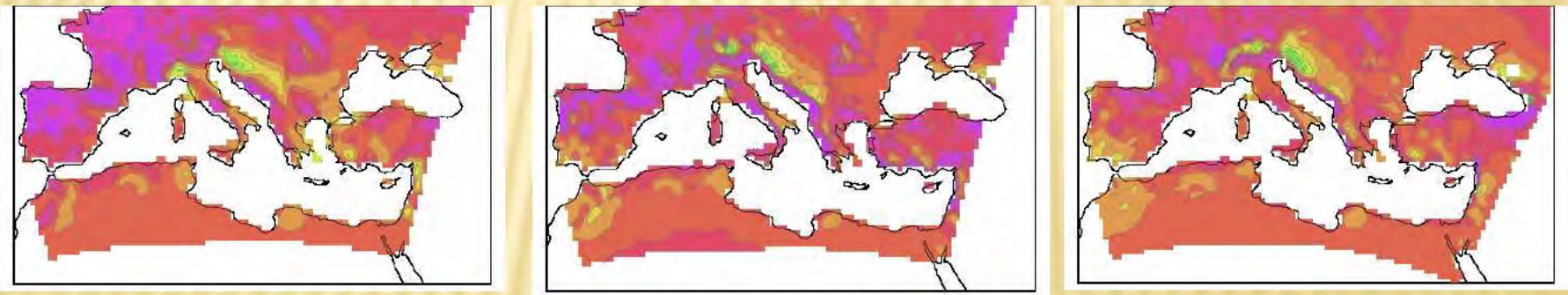
Significant statistically BIAS at the 95% confidence level according to Mann Whitney Test (All maps have a number of significant tatistically points > 50% TOT points)

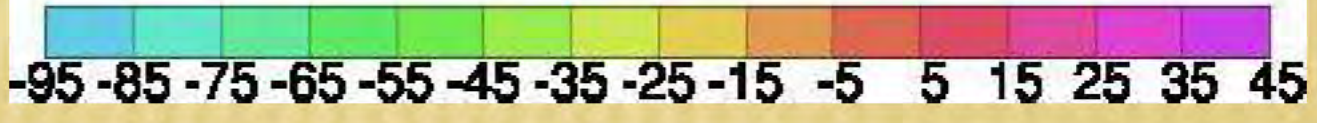
ECHAM5 | **Hadcm3Q0** | **HADAM3H**

GCM



RCM

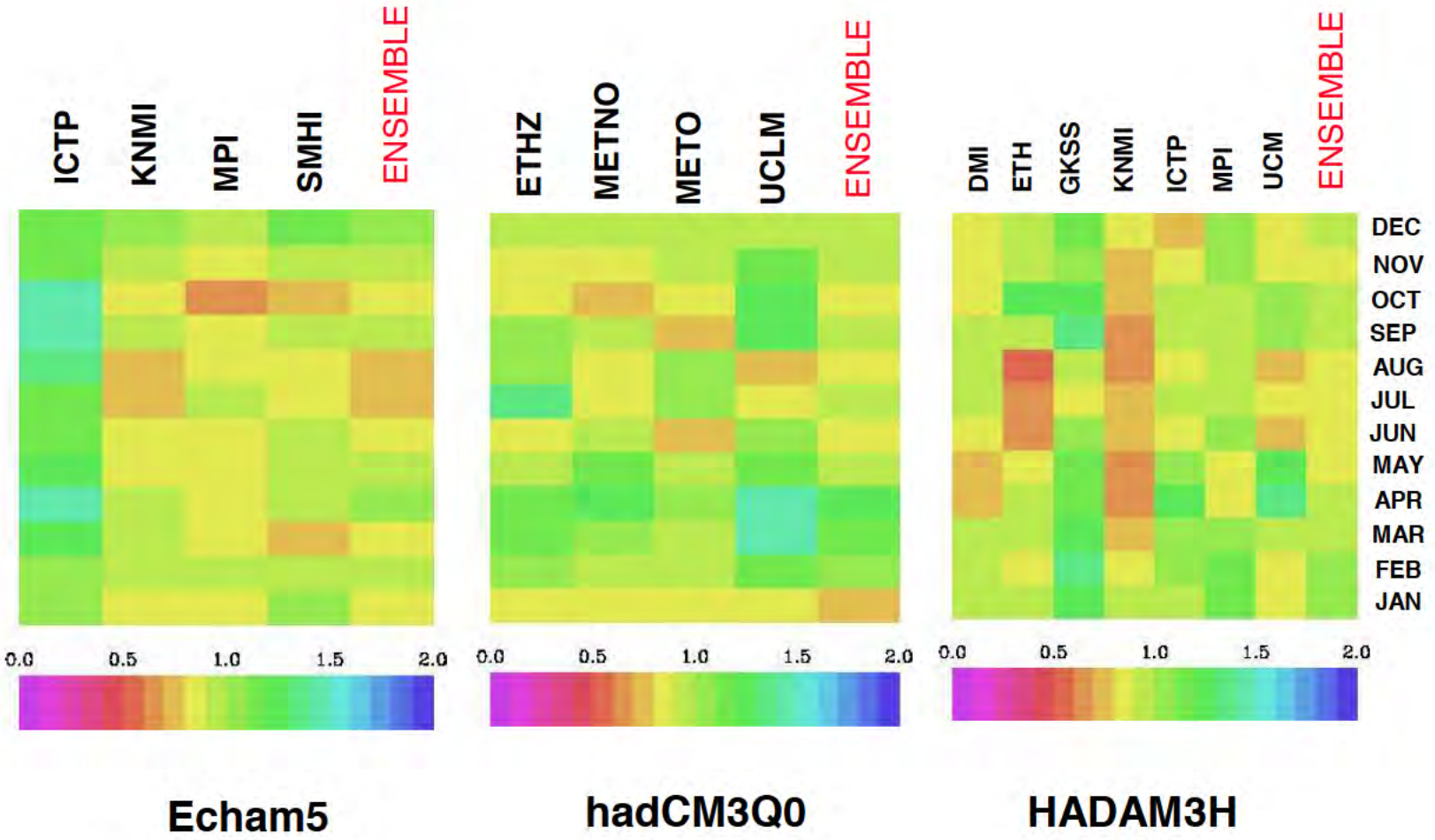




RMS - Temperature - Land

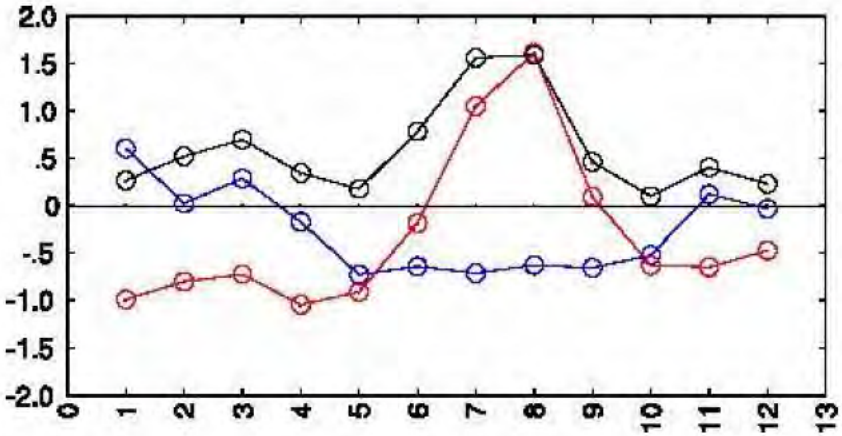
$$\frac{\sqrt{\sum_{i,j}(RCM - Instrumental\ data)^2_{i,j}/(Nx*Ny)}}{\sqrt{\sum_{i,j}(GCM - Instrumental\ data)^2_{i,j}/(Nx*Ny)}}$$

← RMS (Root Mean Square) annual cycle

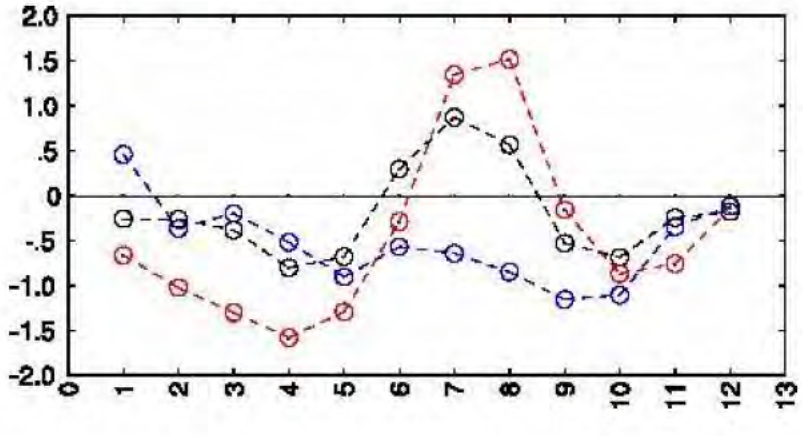


Annual Cycle Bias (Temperature- degreeC)

GCM –Land



Ensemble RCM –Land

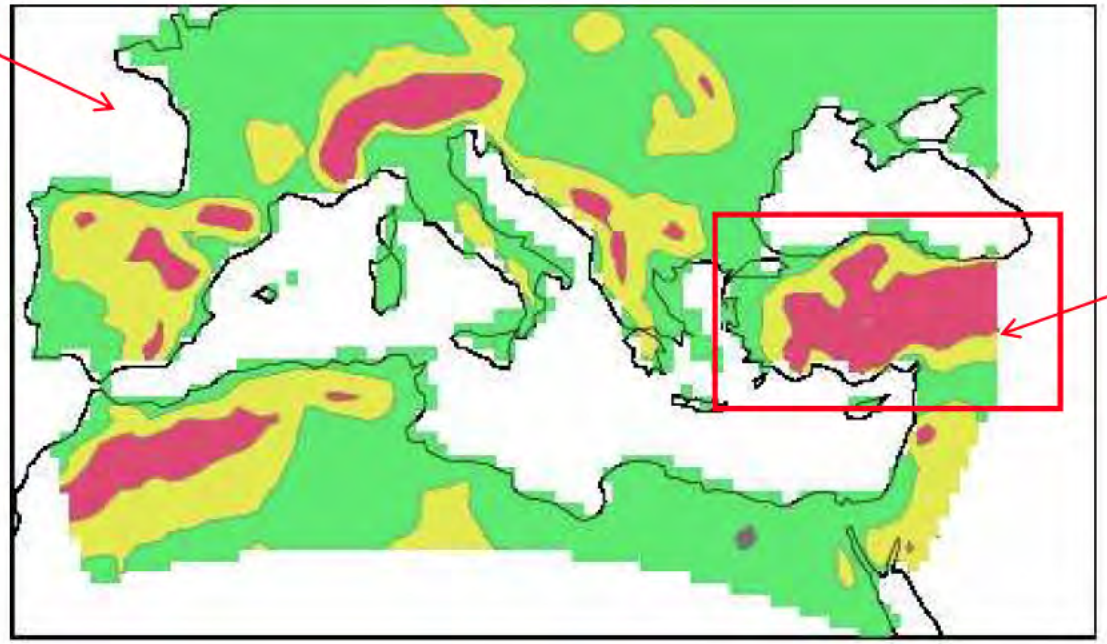


Hadcm3Q0 Echam5 HADAM3H

Monthly statistically significant (at 95% MW-test) bias for number points >50% total points

Orography of CRU (m)

Mediterranean region



Turkey

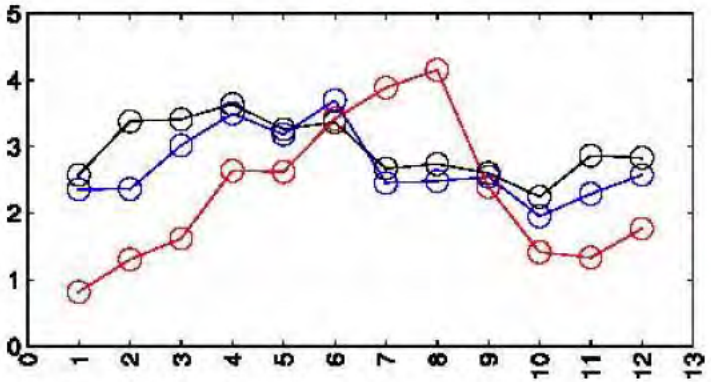
Temperature Bias (degreeC)

0 0 0

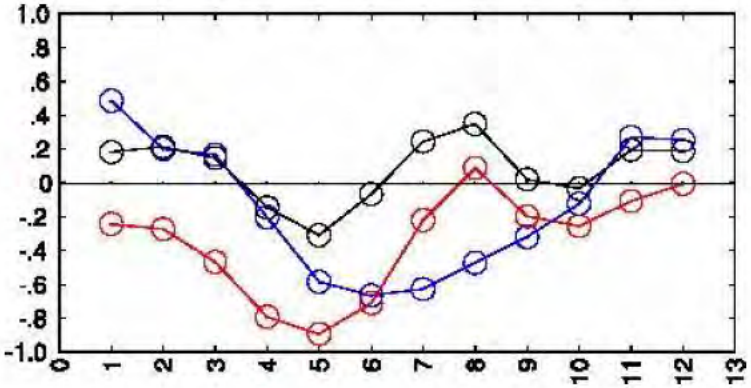
⇩

Statistically significant Monthly bias (at 95% MW-test) for number points >50% total points

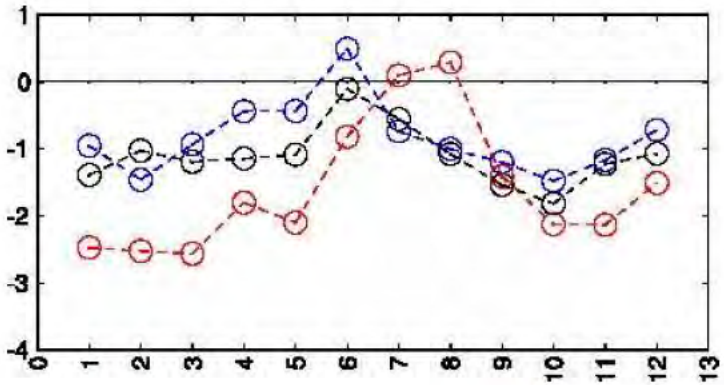
Areas at Elevation > 1200 m (no Turkey)



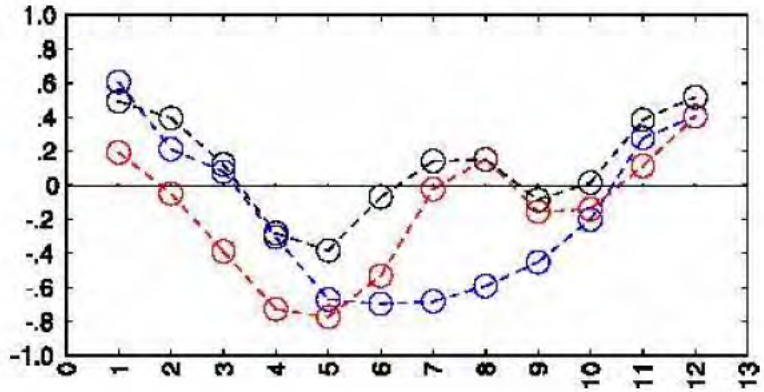
Coastal *LAND areas*



GCM



RCM

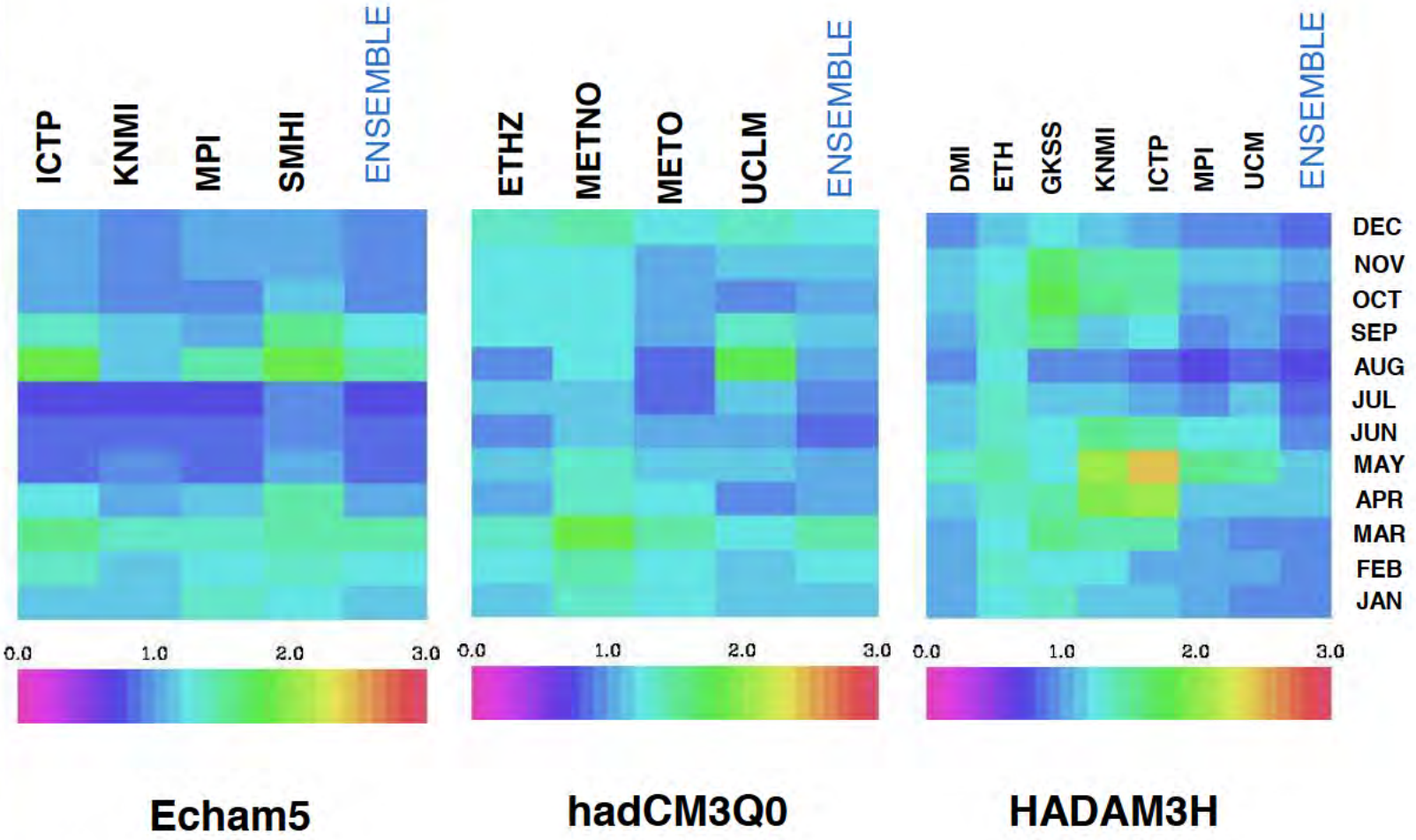


Hadcm3Q0 Echam5 HADAM3H

RMS - Precipitation - Land

$$\frac{\sqrt{\sum_{i,j}(RCM - Instrumental\ data)^2_{i,j}/(Nx*Ny)}}{\sqrt{\sum_{i,j}(GCM - Instrumental\ data)^2_{i,j}/(Nx*Ny)}}$$

← RMS (Root Mean Square) annual cycle

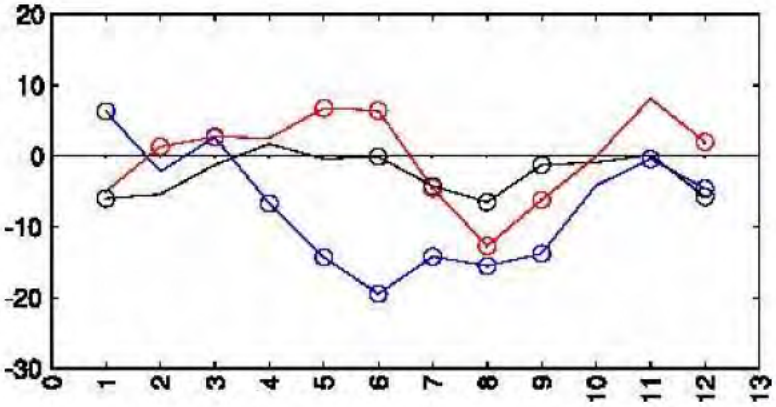


Annual Cycle Bias (Precipitation - mm/month)

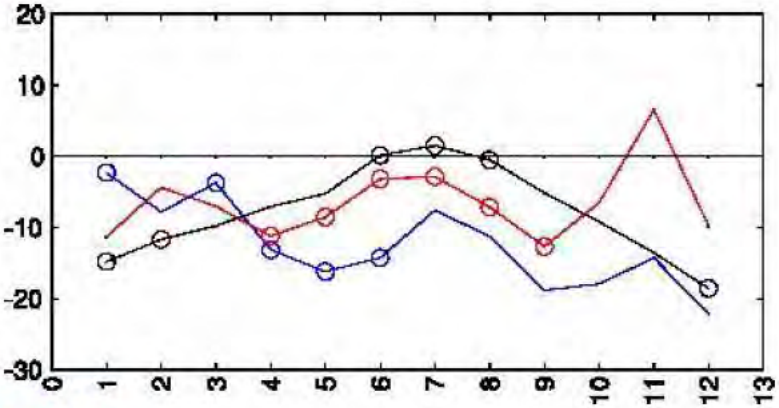
Hadcm3Q0 Echam5 HADAM3H

GCM

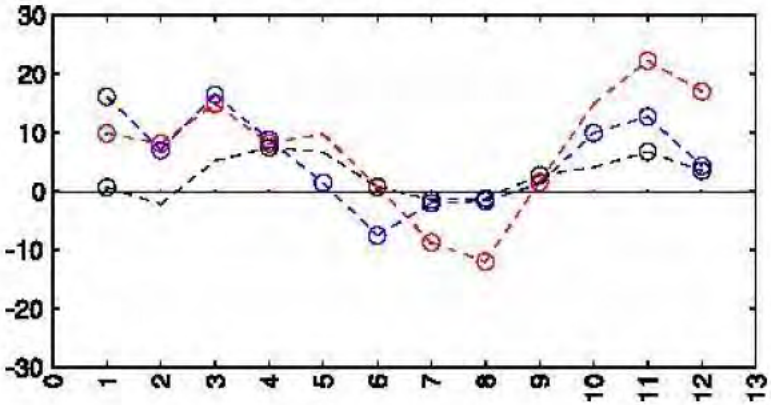
Land

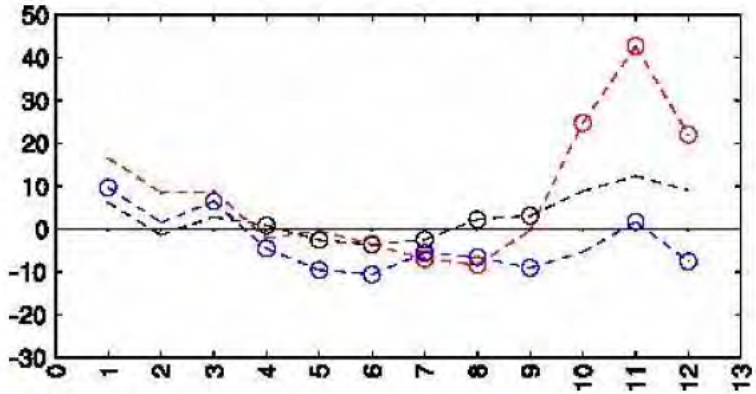


Sea



Ensemble RCM





Monthly statistically significant (at 95% MW-test) bias for number points >50% total points

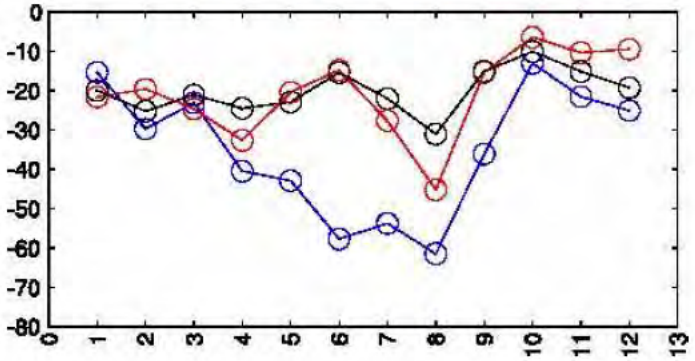
Precipitation Bias (mm/month)

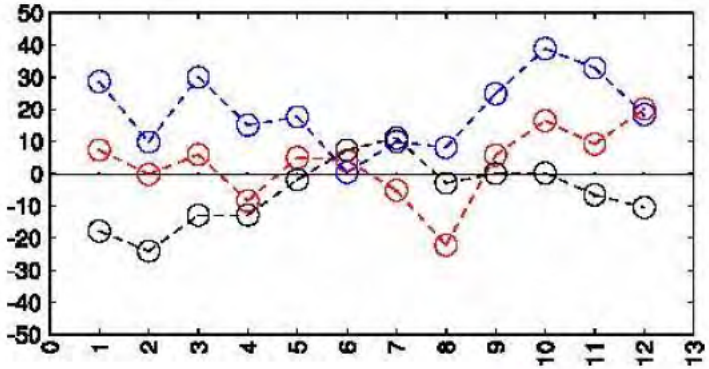
0 0 0

⇩

Statistically significant Monthly bias (at 95% MW-test) for number points >50% total points

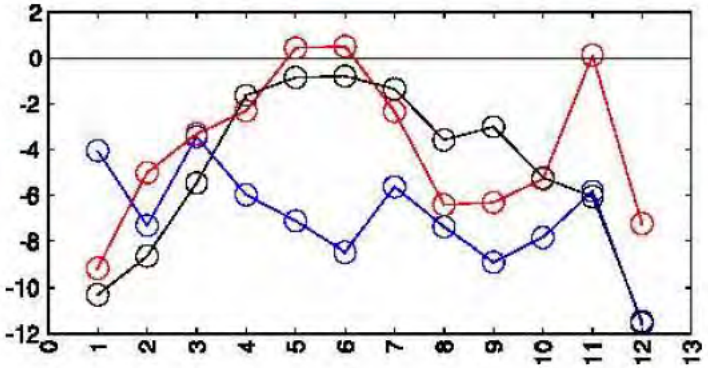
Areas at Elevation > 1200 m (no Turkey)



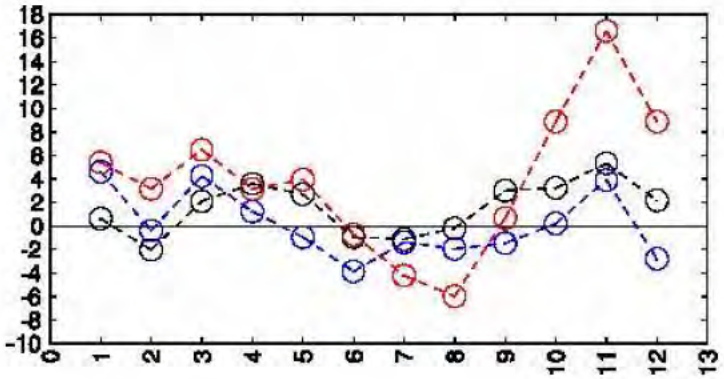


Coastal *LAND areas*

GCM



RCM



Hadcm3Q0 Echam5 HADAM3H

Climate classification of Koppen

(*from* ***MARKUS KOTTEK1, JÜRGEN GRIESER2, CHRISTOPH BECK2, BRUNO RUDOLF2 and FRANZ RUBEL*** *- World Map of the Köppen-Geiger climate classification updated - Meteorologische Zeitschrift, Vol. 15, No. 3, 259-263 , June 2006)*

Classification criteria (Type)

Type	Description	Criterion
A	**Equatorial climates**	$T_{min} \geq +18\ ^{\circ}C$
Af	Equatorial rainforest, fully humid	$P_{min} \geq 60$ mm
Am	Equatorial monsoon	$P_{ann} \geq 25\,(100 - P_{min})$
As	Equatorial savannah with dry summer	$P_{min} < 60$ mm in summer
Aw	Equatorial savannah with dry winter	$P_{min} < 60$ mm in winter
B	**Arid climates**	$P_{ann} < 10\,P_{th}$
BS	Steppe climate	$P_{ann} > 5\,P_{th}$
BW	Desert climate	$P_{ann} \leq 5\,P_{th}$
C	**Warm temperate climates**	$-3\ ^{\circ}C < T_{min} < +18\ ^{\circ}C$
Cs	Warm temperate climate with dry summer	$P_{smin} < P_{wmin}$, $P_{wmax} > 3\,P_{smin}$ and $P_{smin} < 40$ mm
Cw	Warm temperate climate with dry winter	$P_{wmin} < P_{smin}$ and $P_{smax} > 10\,P_{wmin}$
Cf	Warm temperate climate, fully humid	neither Cs nor Cw
D	**Snow climates**	$T_{min} \leq -3\ ^{\circ}C$
Ds	Snow climate with dry summer	$P_{smin} < P_{wmin}$, $P_{wmax} > 3\,P_{smin}$ and $P_{smin} < 40$ mm
Dw	Snow climate with dry winter	$P_{wmin} < P_{smin}$ and $P_{smax} > 10\,P_{wmin}$
Df	Snow climate, fully humid	neither Ds nor Dw
E	**Polar climates**	$T_{max} < +10\ ^{\circ}C$
ET	Tundra climate	$0\ ^{\circ}C \leq T_{max} < +10\ ^{\circ}C$
EF	Frost climate	$T_{max} < 0\ ^{\circ}C$

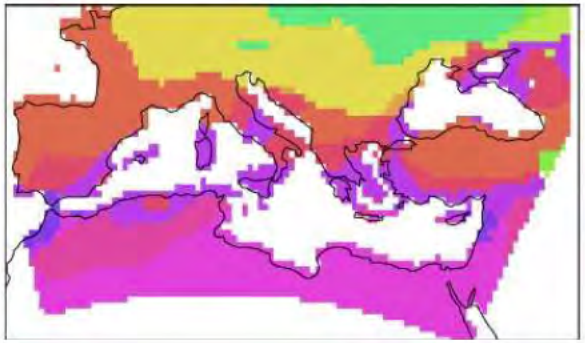
Classification criteria (Sub-Type)

Table 2: Key to calculate the third letter temperature classification (h) and (k) for the arid climates (B) and (a) to (d) for the warm temperate and snow climates (C) and (D). Note that for type (b), warm summer, a threshold temperature value of +10 °C has to occur for at least four months. The criteria are explained in the text.

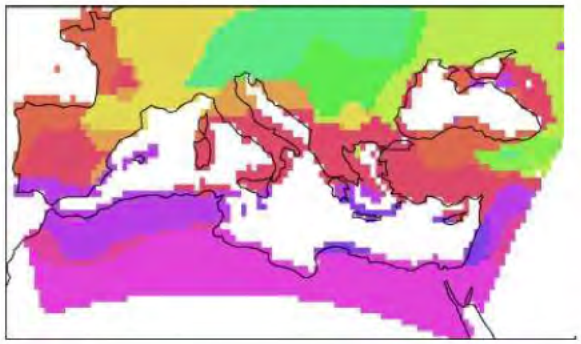
Type	Description	Criterion
h	Hot steppe / desert	$T_{ann} \geq +18\ ^{\circ}C$
k	Cold steppe /desert	$T_{ann} < +18\ ^{\circ}C$
a	Hot summer	$T_{max} \geq +22\ ^{\circ}C$
b	Warm summer	not (a) and at least 4 $T_{mon} \geq +10\ ^{\circ}C$
c	Cool summer and cold winter	not (b) and $T_{min} > -38\ ^{\circ}C$
d	extremely continental	like (c) but $T_{min} \leq -38\ ^{\circ}C$

Climate classification of Koppen

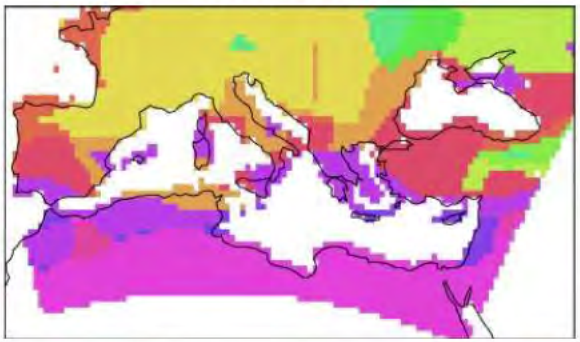
Echam5



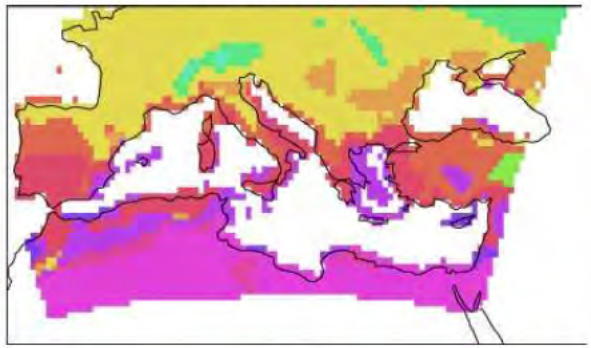
HadCM3Q0



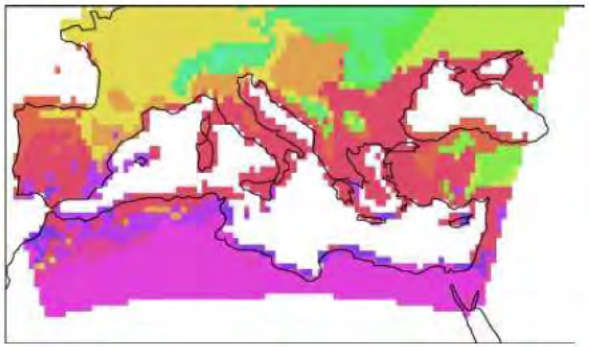
HADAM3H



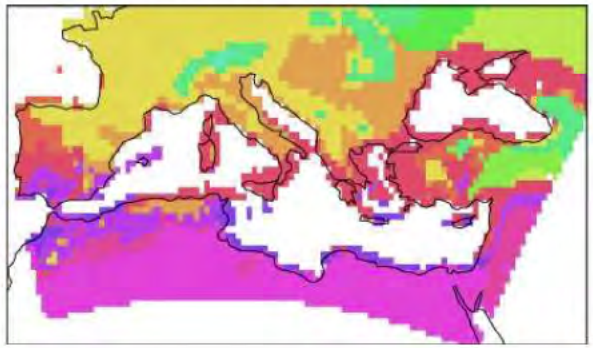
Ensemble Echam5



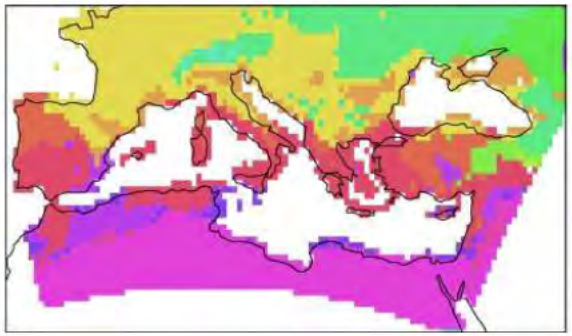
Ensemble HadCM3Q0



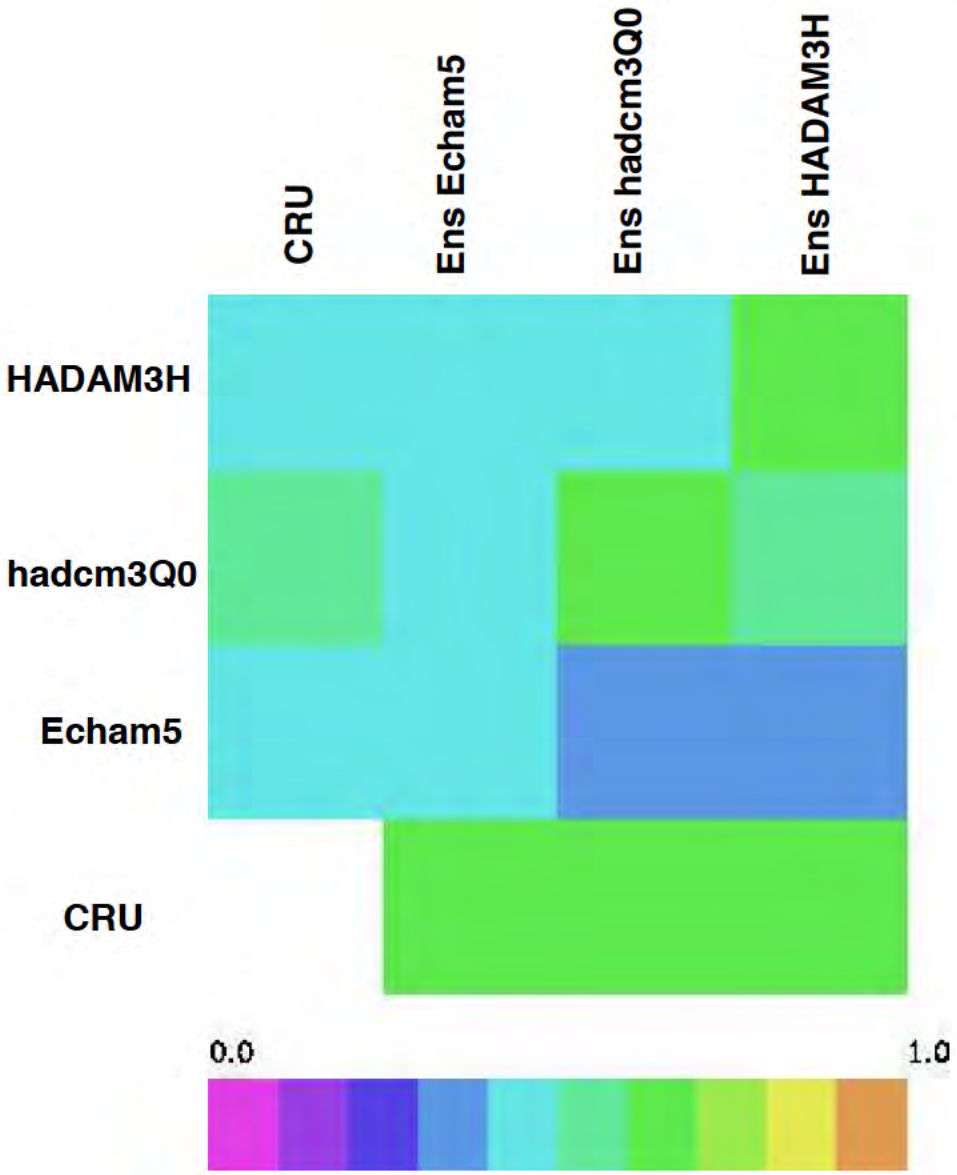
Ensemble HADAM3H



CRU



K SCORE
- CLASSES of KOPPEN -



K-score = (Pa-Pe)/(1-Pe)

Pe = frequency (probability) of points in the same class in the two sets of data assuming a random simulation

Pa = actual frequency (percent) of ponts in the same class

CONCLUSIONS

RCM are very good at compensating the GCM bias for temperature, not as good for precipitation. They are less effective on the actual rms, meaning that improvements during some months/areas is partially spoiled by deterioration during other months/areas.

Errors on P are lower than errors on T, in general. However improvements of RCM are larger (unfortunately) for T than for P. Improvements are convincing during summer, not for winter precipitation.

Errors of GCM on temperature, cannot be substantially improved by a (connstant in space and time) lapse rate correction accounting for wrong elevation

Improvements by RCM are concentrated in coastal areas and at high level over complicated orography. For precipitation, RCMs do not always improve results over large continental areas, where actually they can get worse.

RCMs clearly are more accurate than GCMs when considering climate types