The Abdus Salam
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2210-5

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

23 - 25 September 2010

Applying Analysis of Variance on a Multi-Model Ensemble of Global Climate Models in the Mediterranean Area

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Germany

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KLIWEX-MED

Applying Anova on a multi-model ensemble of GCMs in the Med-Area

Gernot Vogt
University of Wuerzburg, Germany

5th ESF-MedCLIVAR Workshop 23.09.2010, Trieste

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Global model simulations (GCMs) from CMIP3

- WCRP CMIP3 Multi-Model Dataset Archive at PCMDI
- ~24 GCMs
- GHG-Emission-Scenarios: A1b, A2, B1 (former times: 20c3m)
- Spatial resolution (Long: 5-1.13°/Lat: 4-1.13°)
- Earliest and latest simulated year:

  1850/2349 i.e. miroc3 med run1/ ccsm3 run7

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Method

- Variables: Precipitation, Temperature, Sea-level pressure
- Processing Steps:

Spatial Interpolation

Correct time and space outcut

Preprocessing

Spatial resolution on 3x3°

Total time slice from 1901-2098 (special focus on 1901-2098, 1961-2000, 1961-2050, 2001-2098)

Mediterranean Area: 21°W - 45°E/24°S - 45°N

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Available Models and Runs

Scenario→ ↓Model	A1B	A2	B1
bccr:bcm2.0	1	1	1
cnrm:cm3	1	1	1
gfdl:cm2.0	1	1	1
gfdl:cm2.1	1	1	1
giss:aom	2	0	2
iap:fgoals1.0g	3	0	3
ipsl:cm4	1	1	1
ingv:echam4	1	1	0
miroc3.2 hires	1	0	1
miroc3.2 medres	3	3	3
mri:cgcm2.3.2a	5	5	5
csiro:mk3.0	1	1	1
csiro:mk5.0	1	1	1
mpi:echam5	4	3	3
ncar:ccsm3	7	5	8
ncar:pcm1	4	4	2
ukmo:hadcm3	1	1	1
ukmo:hadgem3	1	1	0

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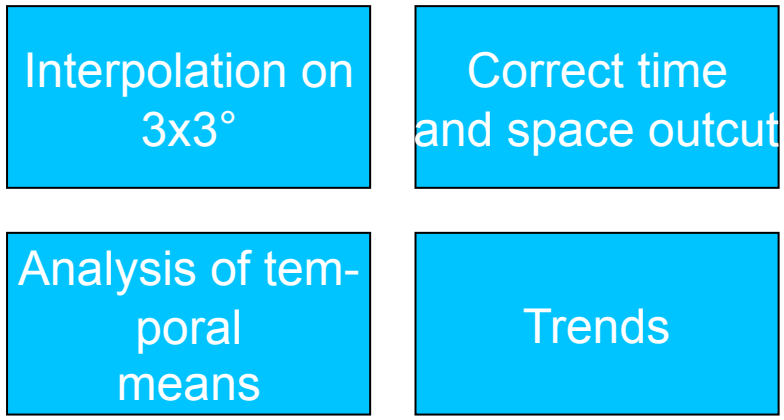
Method

- All data is based on monthly means
- Calculation of yearly values (JFMAMJJASOND = yea) …and
- Calculation of seasonal values (DJF = win; MAM = spr; JJA = sum; SON = aut)
- Processing Steps:



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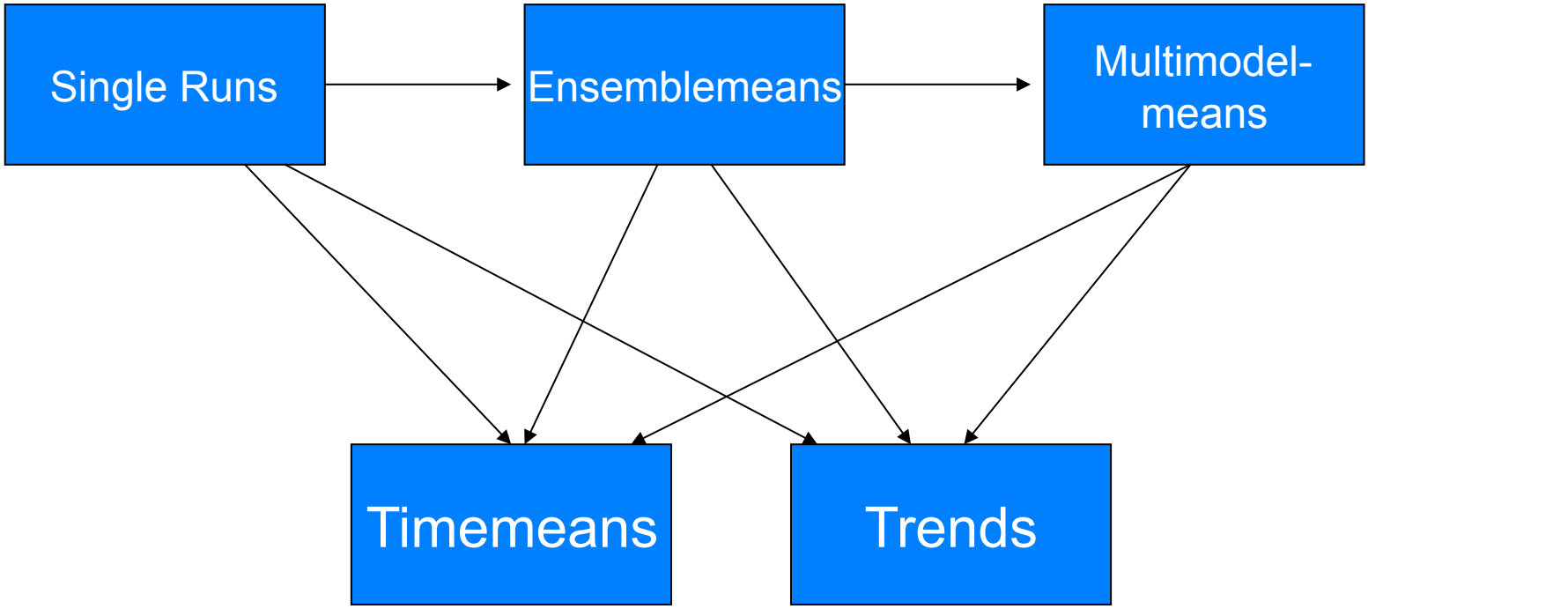
Processing

Szenarios: A1B, A2, B1

- Procesing over **time**



Precipitation, Temperature, Pressure,…

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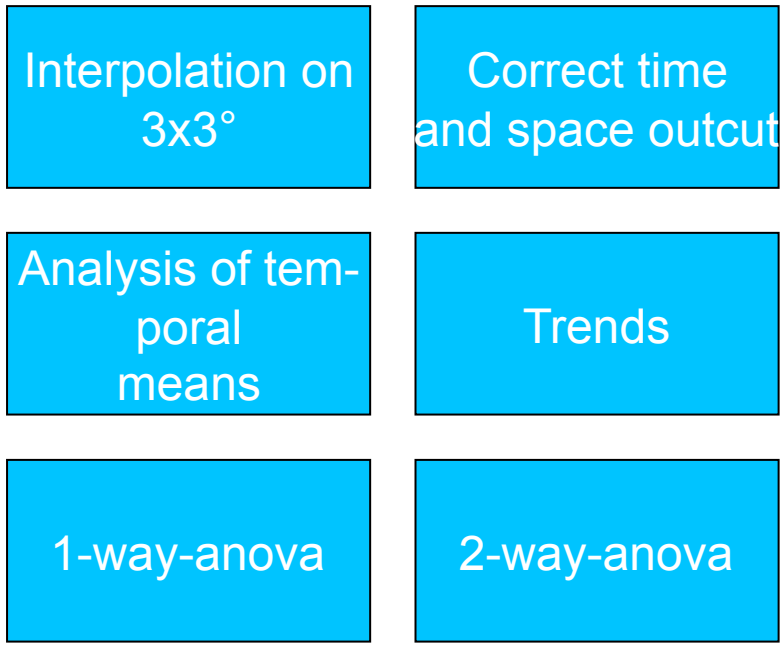
Method

- All data is based on monthly means
- Calculation of yearly values (JFMAMJJASOND = yea) …and
- Calculation of seasonal values (DJF = win; MAM = spr; JJA = sum; SON = aut)
- Processing Steps:



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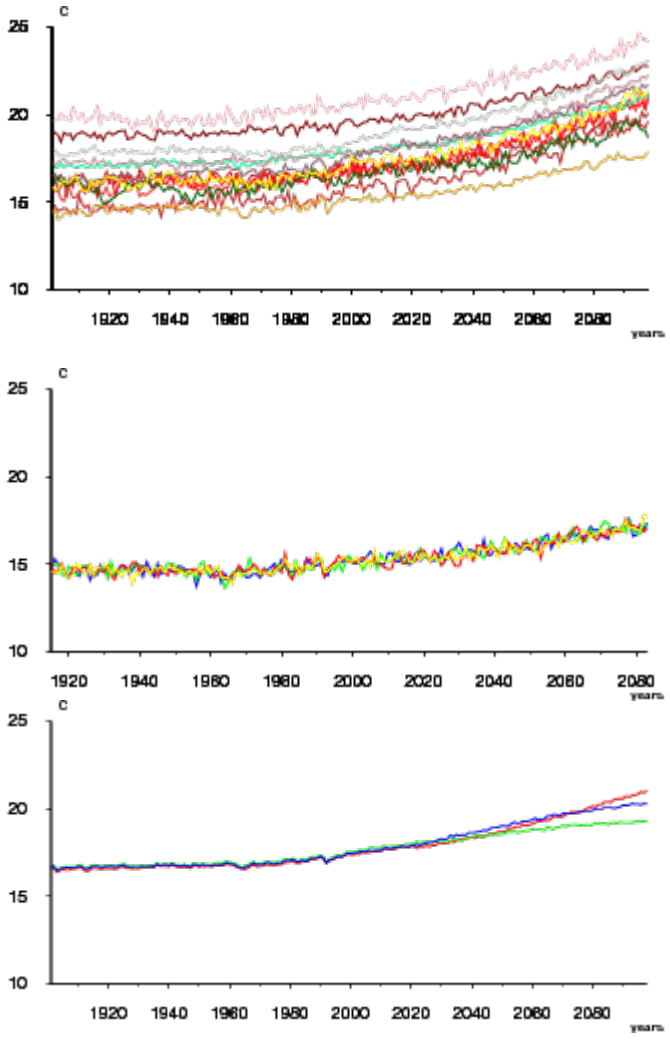
Probable sources of uncertainty in climate simulations

- Climate Model (t2m, A2)
- Single Run (t2m, A2)
- Scenario (t2m)



Analysis of Variance

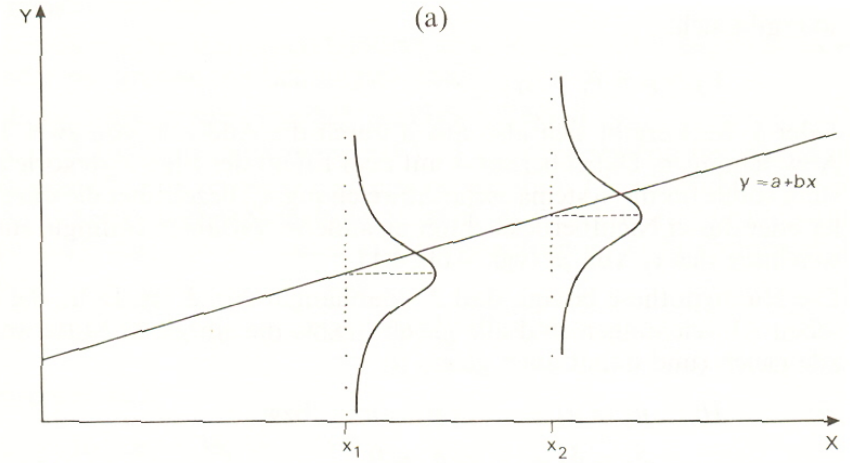
-Some kind of regression analysis.

-But the dependent variable is metric and the independent variable is in a nominal or ordinal scale

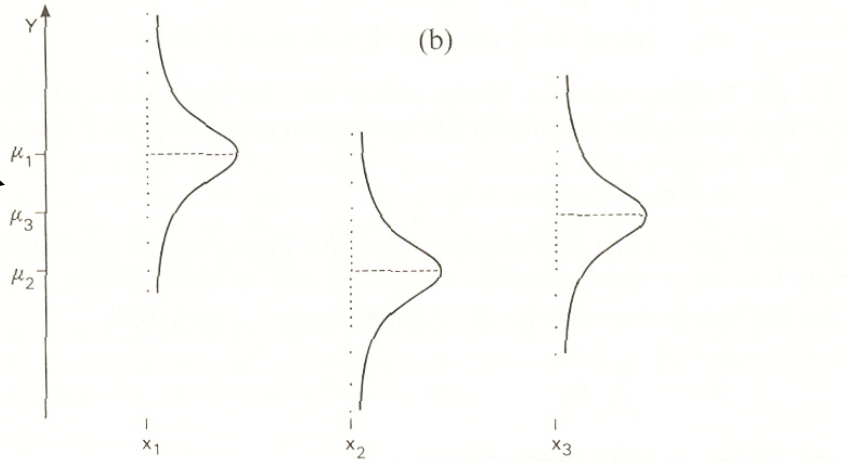
(Bahrenberg et al. 2008)

$$Y = \alpha + \beta X + \varepsilon$$

Regression analysis



Analysis of variance



-A linear dependence cannot be determined. Though it is possible to detect significant influences of variable X on variable Y

Anova

1) $$\delta_i = \mu_i - \mu$$

2) $$\varepsilon_{ji} = y_{ji} - \mu_i$$

i=1…n runs

j=1…m time units

So within the time i of the model j the observed value can be described with a simple linear ansatz.

$$y_{ji} = \mu + \delta_i + \varepsilon_{ji}$$

To prove whether the different mean values have significant influence on the total mean, the total amount of variation
(sum of square errors or total variance) is calculated and divided into a known and an unknown part of variance

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With using the sum of square errors the Anova is finally based on the decomposition of the total variance into its different partitions dedicated to a common signal and ist noise

$$\sum_{i=1}^{q}\sum_{j=1}^{n_i}(y_{ij}-\overline{Y})^2=\sum_{i=1}^{q}\sum_{j=1}^{n_i}((y_{ij}-\overline{Y}_i)+(\overline{Y}_i-\overline{Y}))^2$$

i=1…n runs

j=1…m time units

$$=\sum_{i=1}^{q}\sum_{j=1}^{n_i}((y_{ij}-\overline{Y}_i)^2+\sum_{i=1}^{q}\sum_{j=1}^{n_i}(\overline{Y}_i-\overline{Y})^2+2\sum_{i=1}^{q}\sum_{j=1}^{n_i}(y_{ij}-\overline{Y}_i)+(\overline{Y}_i-\overline{Y})$$

$$2\sum_{i=1}^{q}\sum_{j=1}^{n_i}(y_{ij}-Y_i)+(\overline{Y}_i-\overline{Y})=2\sum_{i=1}^{q}((\overline{Y}_i-\overline{Y})\sum_{j=1}^{n_i}(y_{ij}-Y_i)) \quad =0$$

0

Differences between the runs = epsilon

$$\sum_{i=1}^{q}\sum_{j=1}^{n_i}(y_{ij}-\overline{Y})^2=\sum_{i=1}^{q}\sum_{j=1}^{n_i}((y_{ij}-\overline{Y}_i)^2+\sum_{i=1}^{q}\sum_{j=1}^{n_i}(\overline{Y}_i-\overline{Y})^2$$

Sum of square errors

Differences in time = beta

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1-Way-Anova

- A measure of the uncertainty of a model
- Relation between single runs and the ensemblemean
- Divided in unknown variability (residuals = epsilon) and known variability (common treatment of all runs = beta)

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1-way-Anova A2 t2m ECHAM5 2001-2098

epsilon ↓

0 5 10 20 30 40 50 60 70 80 90 100

Year

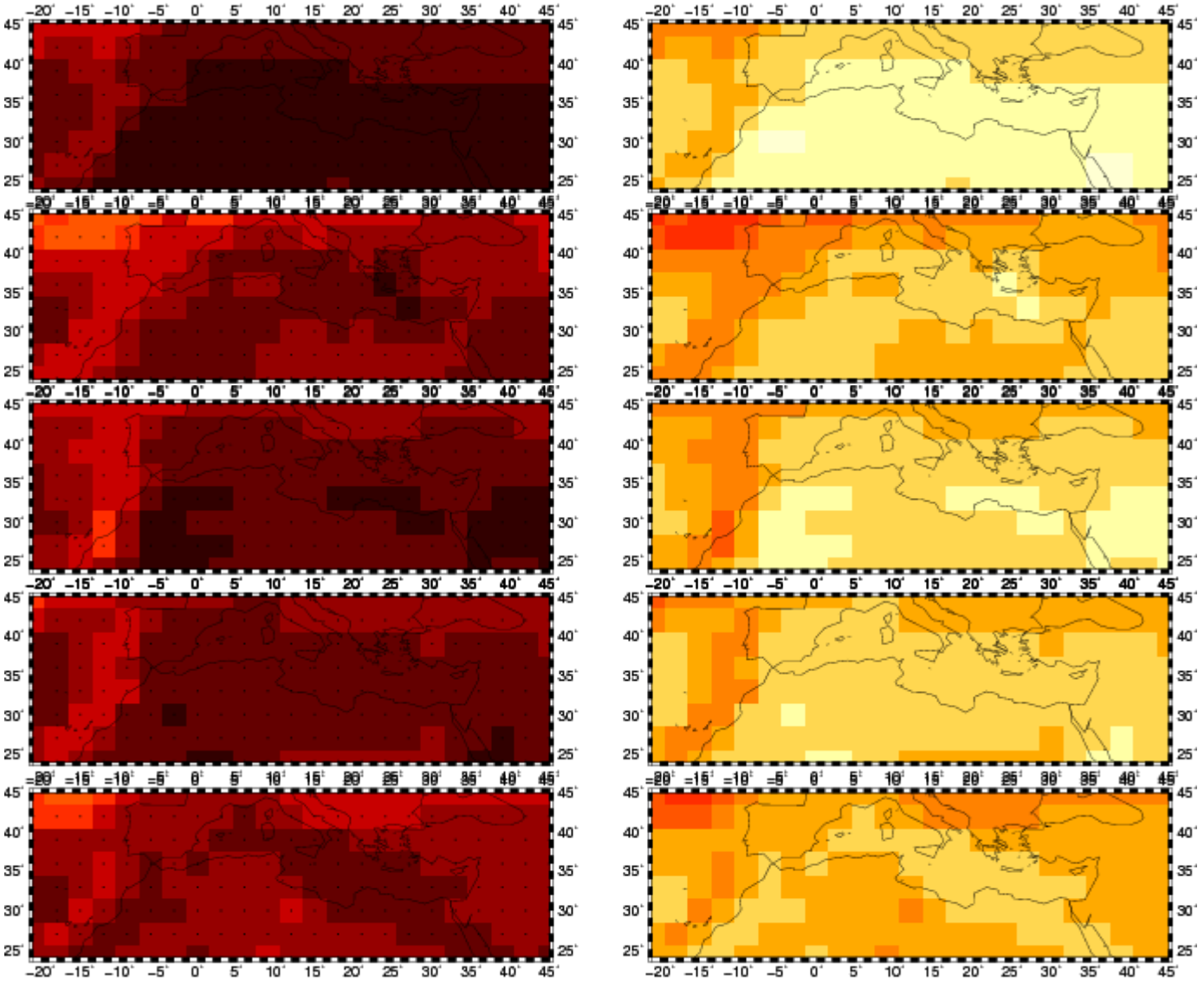
beta ↓

Spring

Summer

Autumn

Winter



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1-way-Anova B1 t2m ECHAM5 2001-2098

epsilon ↓

beta ↓

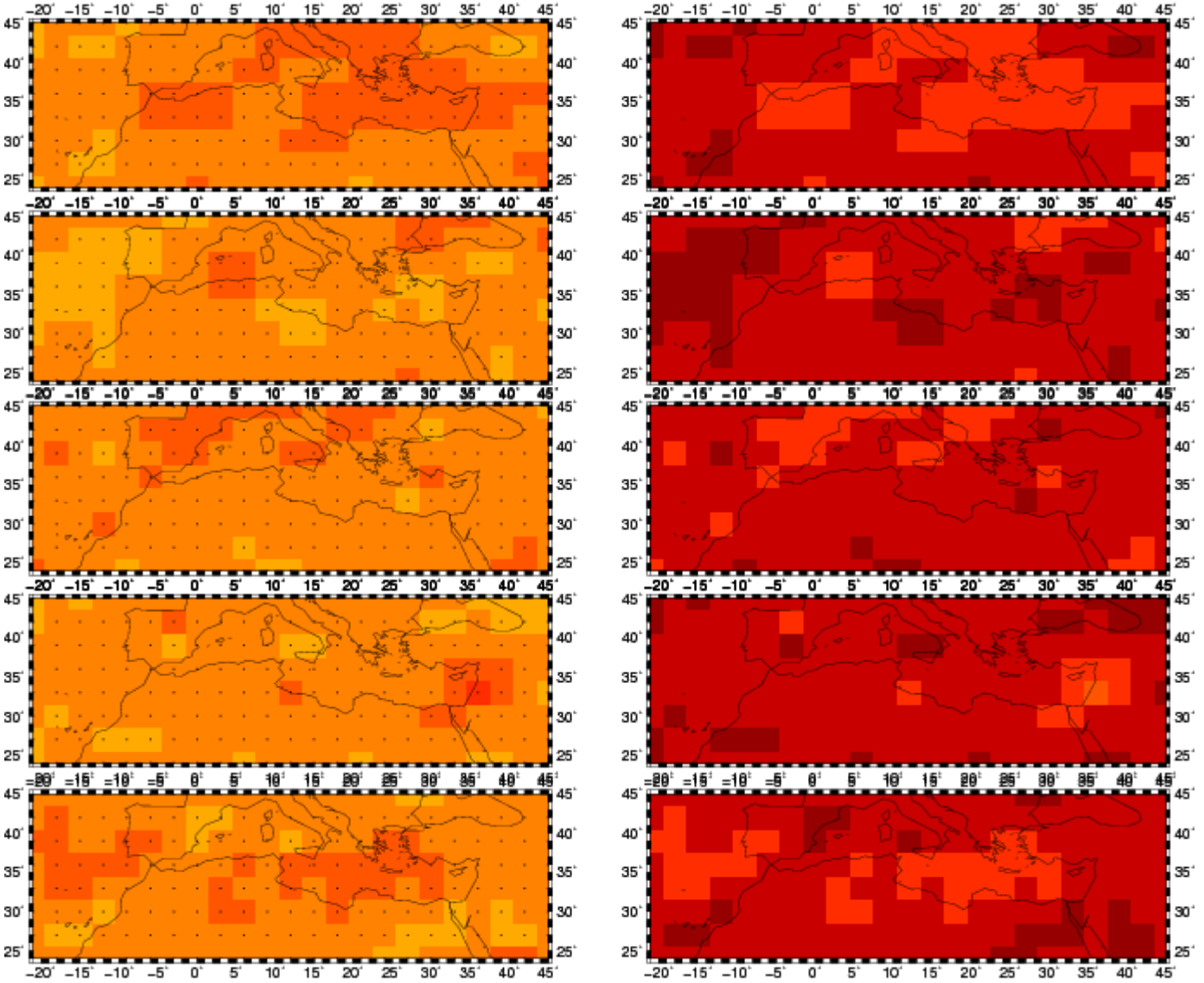
Year

Spring

Summer

Autumn

Winter



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1-way-Anova 20c3m t2m ECHAM5 1961-2000

epsilon ↓

0 5 10 20 30 40 50 60 70 80 90 100

Year

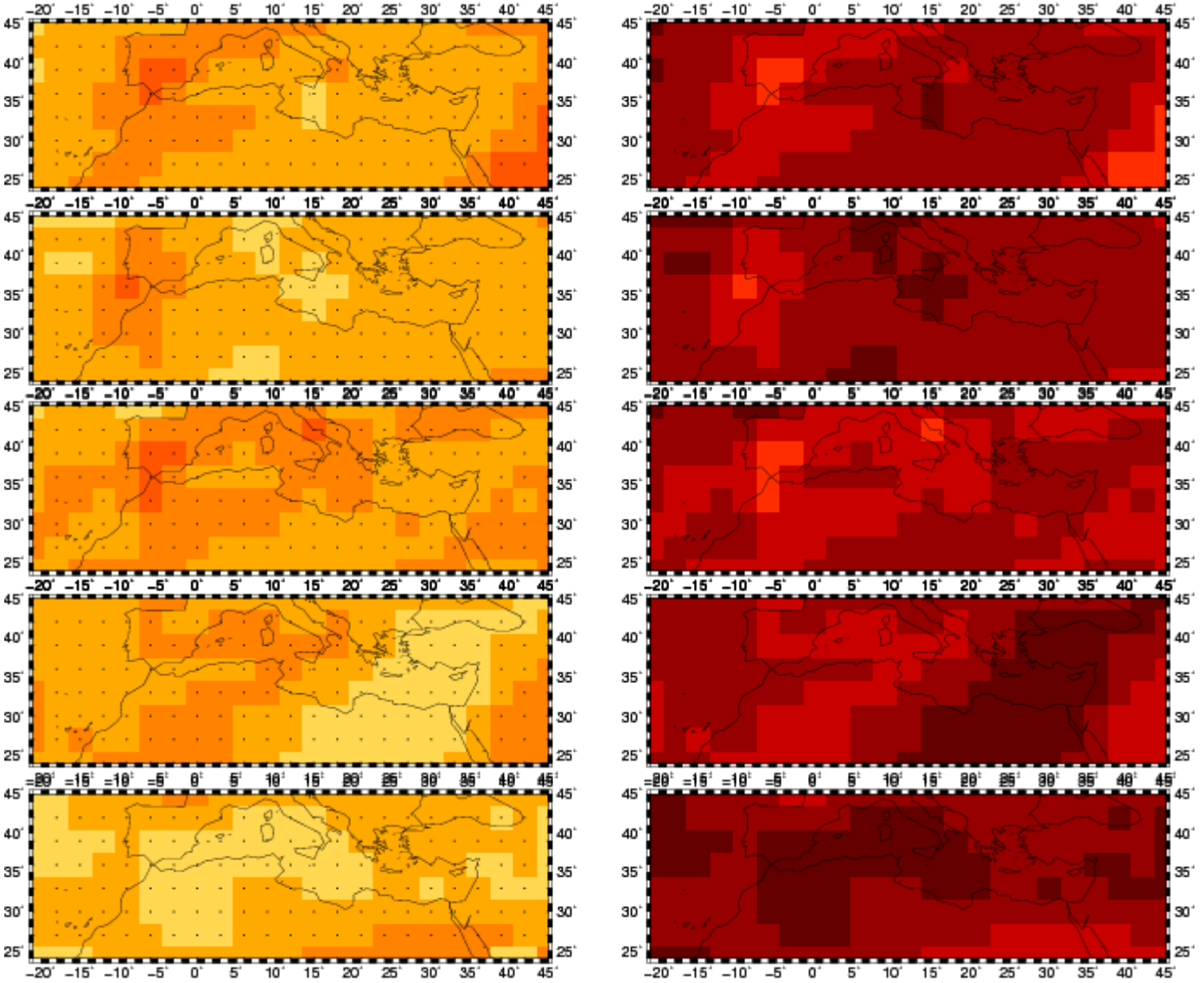
beta ↓

Spring

Summer

Autumn

Winter



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1-way-Anova A2 pre ECHAM5 2001-2098

epsilon ↓

0 5 10 20 30 40 50 60 70 80 90 100

Year

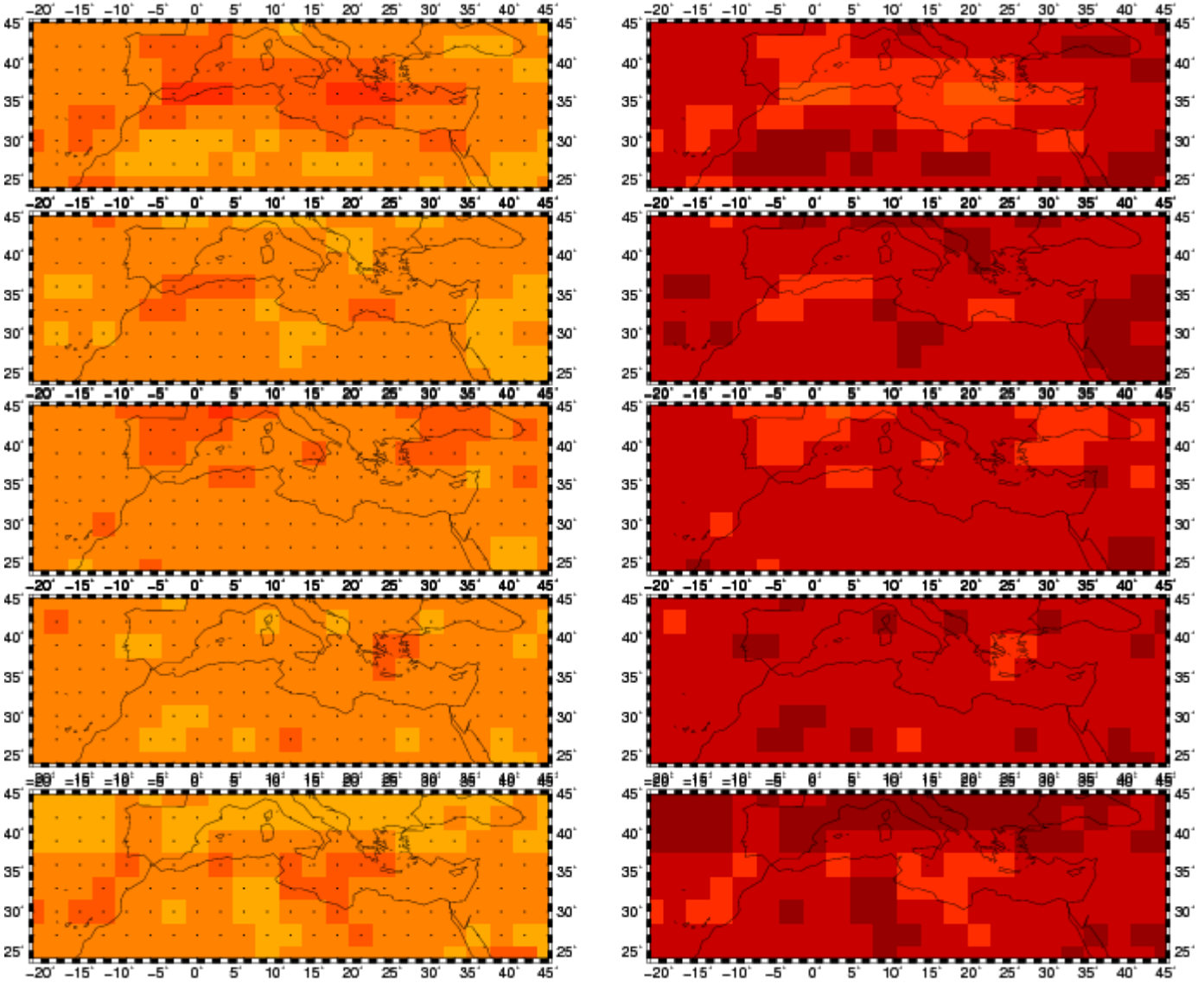
beta ↓

Spring

Summer

Autumn

Winter



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1-way-Anova A2 slp ECHAM5 2001-2098

epsilon ↓

0 5 10 20 30 40 50 60 70 80 90 100

Year

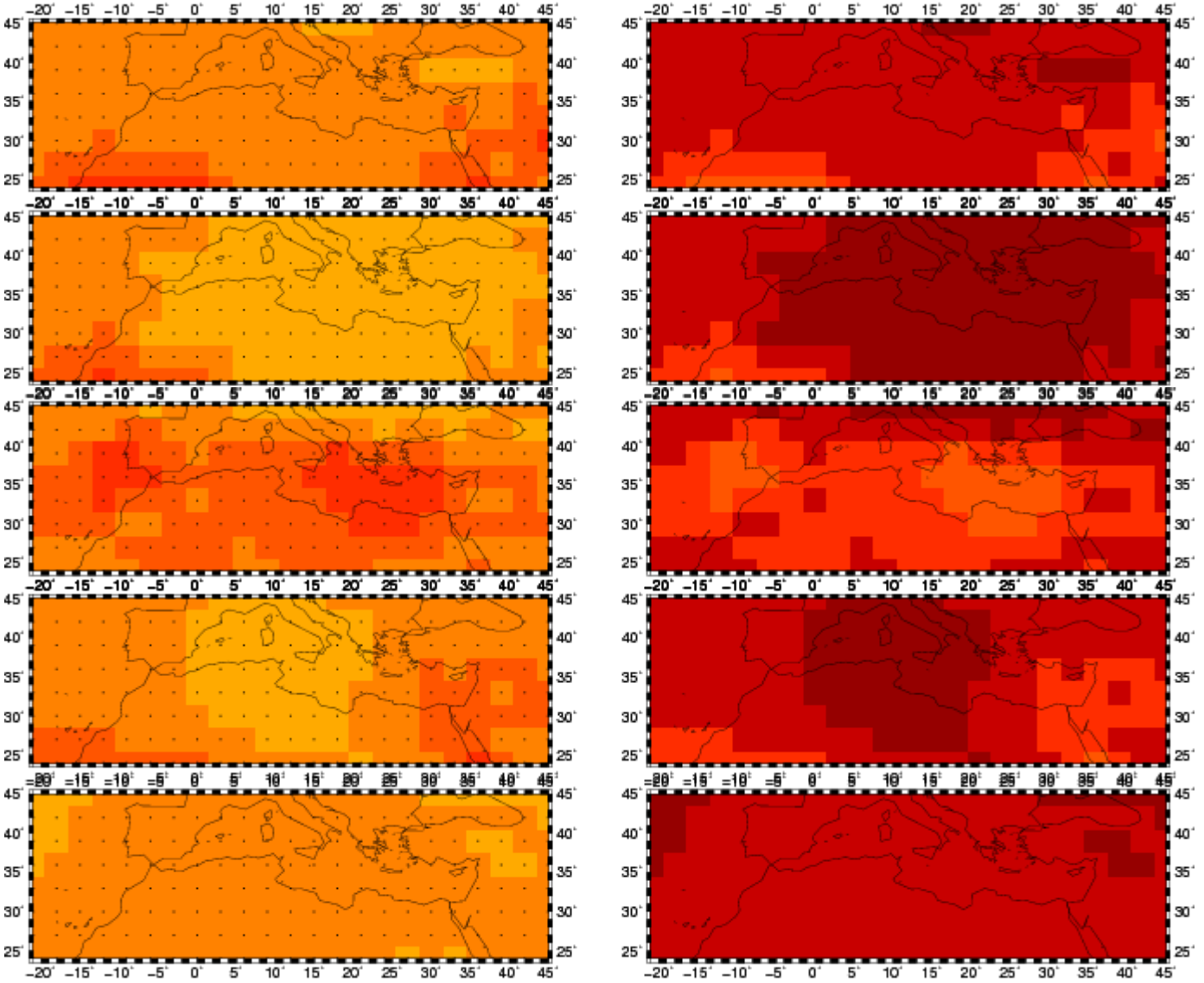
beta ↓

Spring

Summer

Autumn

Winter



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Temporal approach 1-Way-Anova

- 30year time window is used to create means
- This time slice is shifted over the whole time-period from 1901-2098

⇒ new timeslice from 1915-2083

- Anova is calculated for each year in this sliding window, where the 30yr mean value is projected to the mid-year of this period

⇒ Temporal evolution of the Anova…

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Temporal Approach 1-Anova
ECHAM5 **A2** t2m 1915-2083

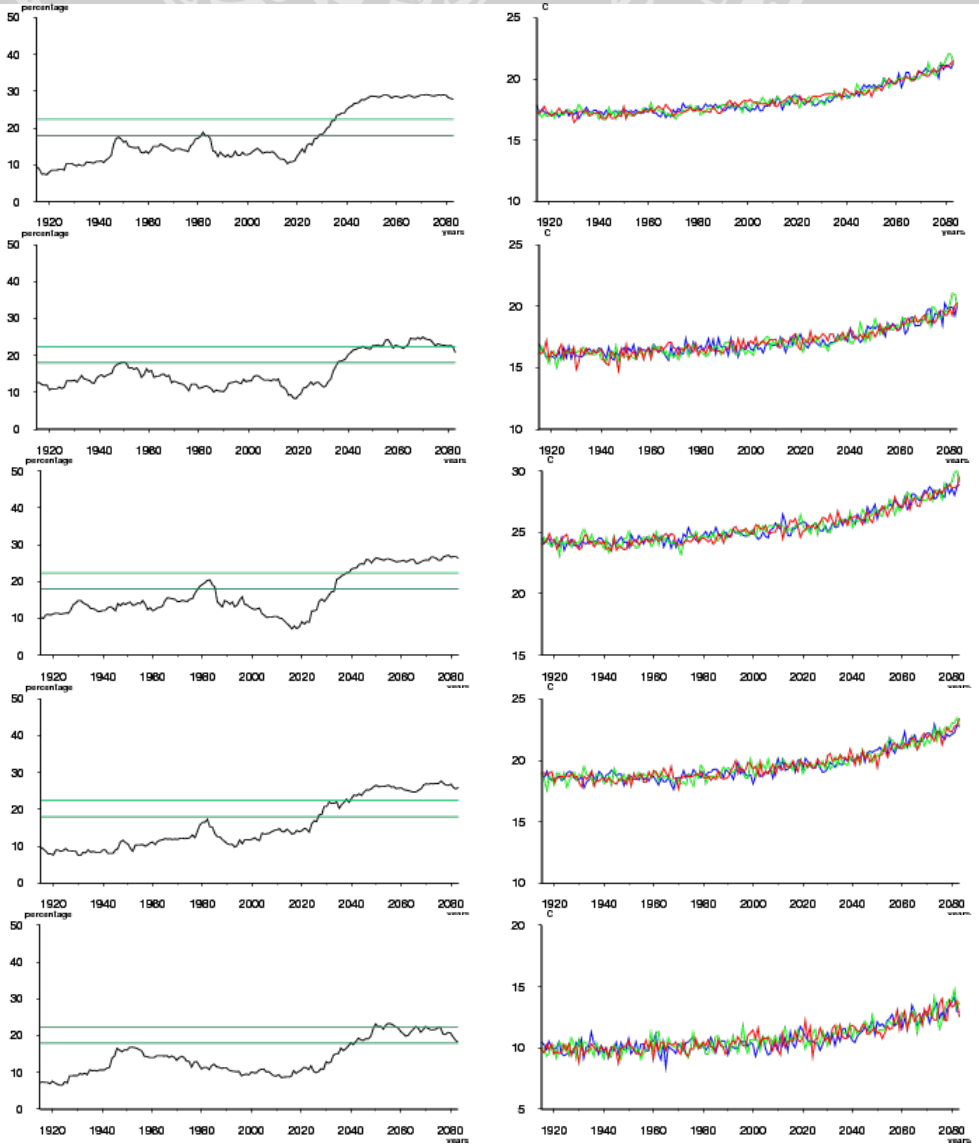
Year

Spring

Summer

Autumn

Winter



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Temporal Approach 1-Anova
ECHAM5 **B1** t2m 1915-2083

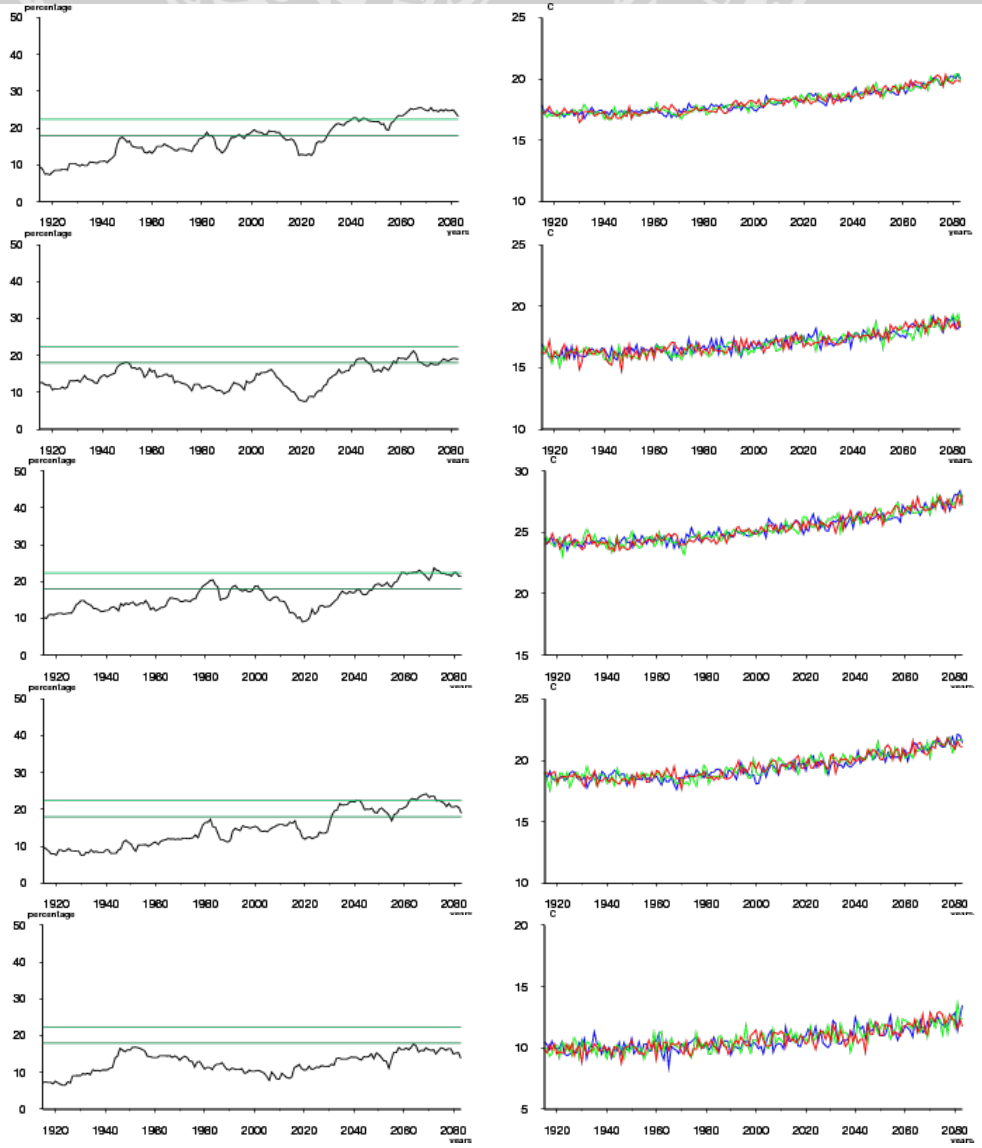
Year

Spring

Summer

Autumn

Winter



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Temporal Approach 1-Anova
FGOALS 1 B1 **pre** 1915-2083

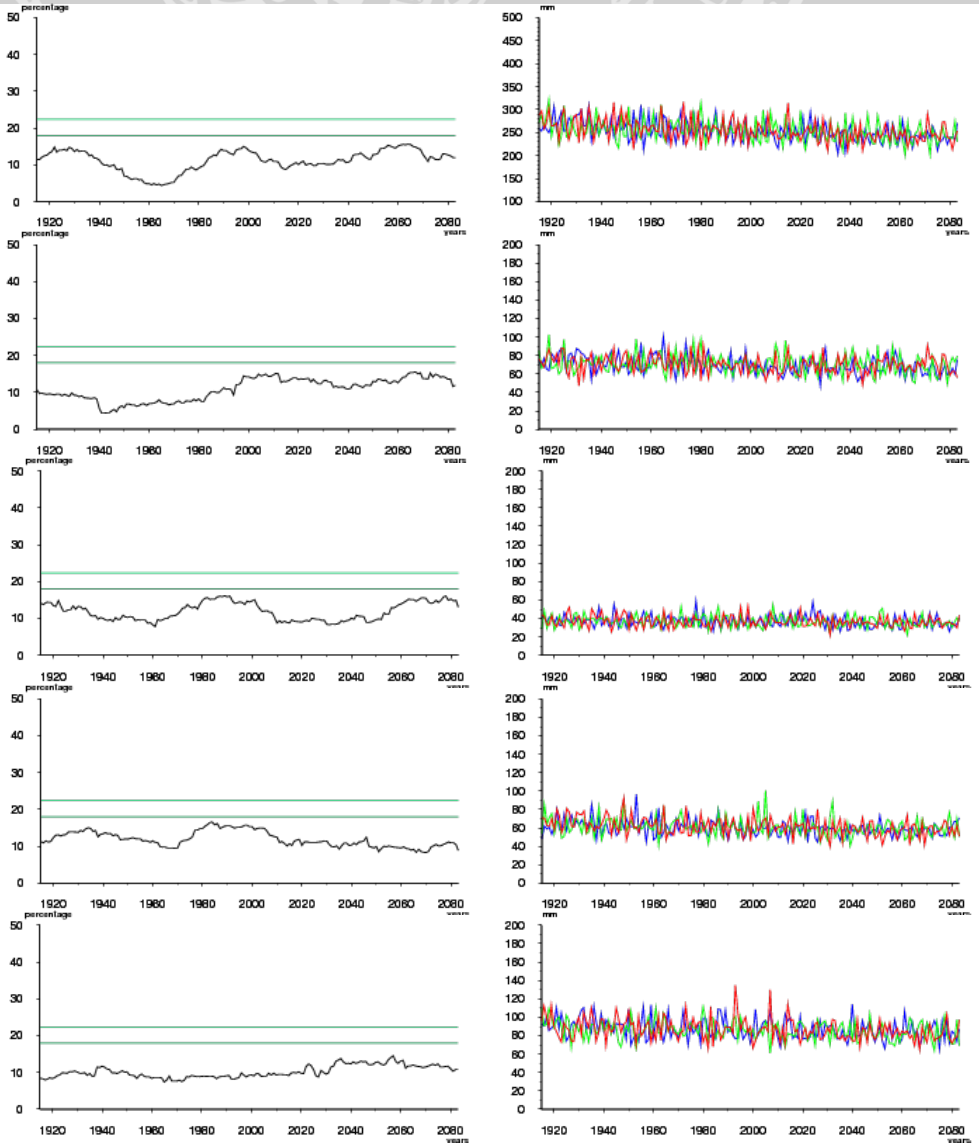
Year

Spring

Summer

Autumn

Winter



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Temporal Approach 1-Anova
FGOALS 1 **A1B slp** 1915-2083

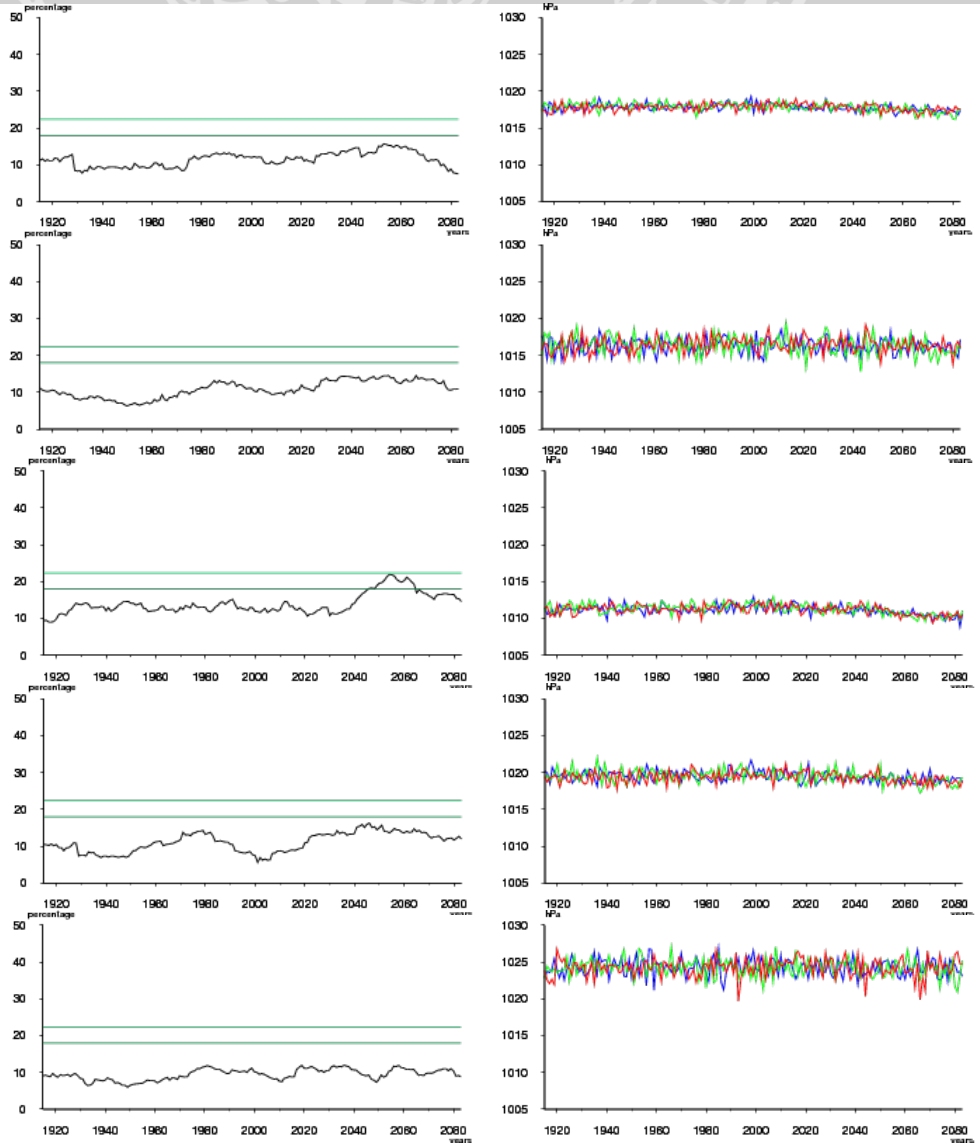
Year

Spring

Summer

Autumn

Winter



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2-Way-Anova

- A measure of the uncertainty of a several climate models
- Relation between single runs and the ensemblemean and the multimodelmean
- Divided in

- common model uncertainty/failing (alpha)
- common treatment effect/influence of the scenario (beta)
- influence of different forcings which is time dependant (gamma)
- internal model variability (epsilon)

….in percentage

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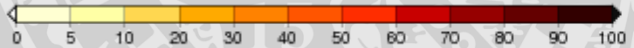
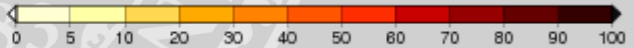
2-way-Anova A2 t2m 2001-2098

beta ↓





Year

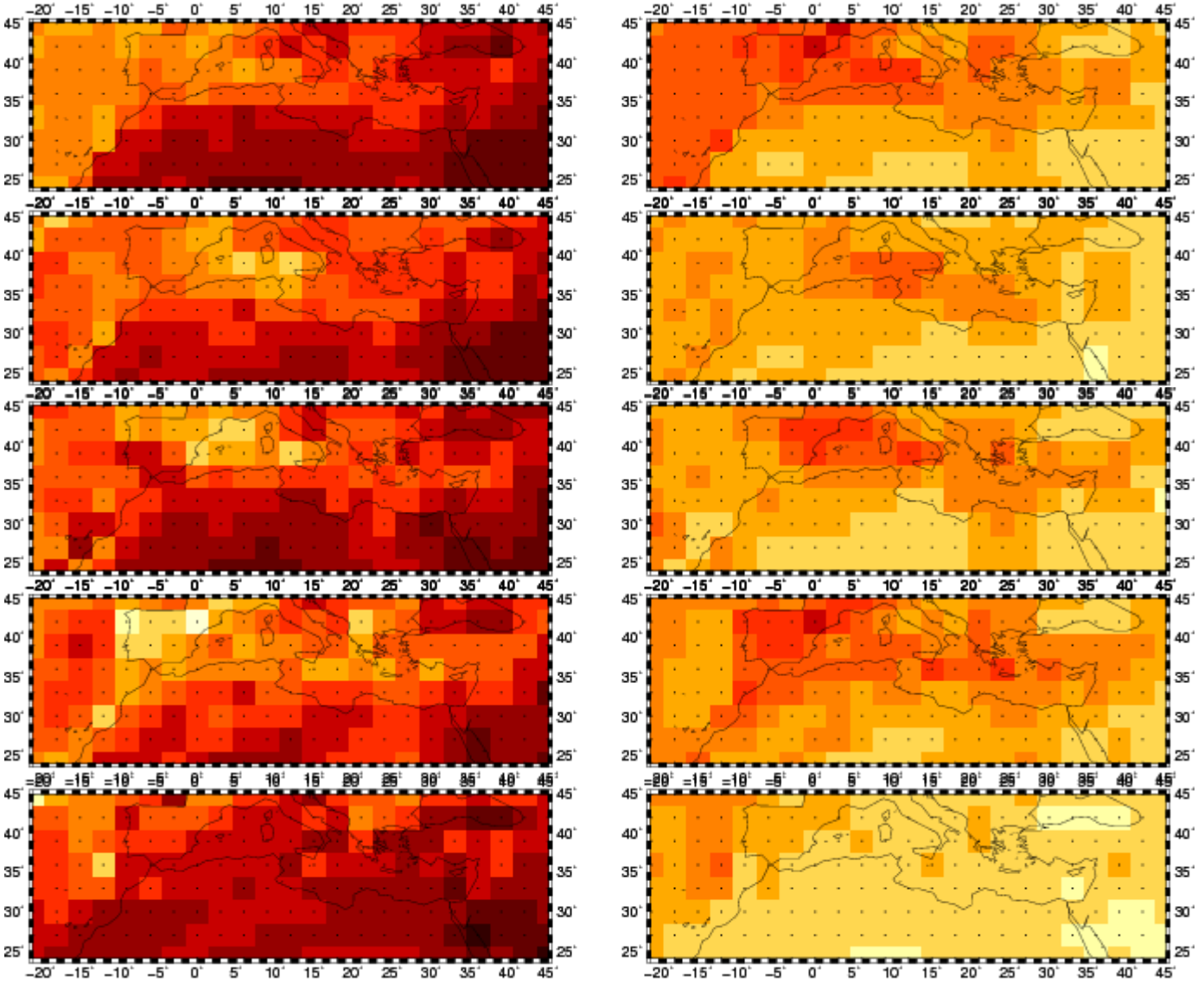
alpha ↓

Spring

Summer

Autumn

Winter



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2-way-Anova A2 t2m 2001-2098

epsilon

0 5 10 20 30 40 50 60 70 80 90 100

Year

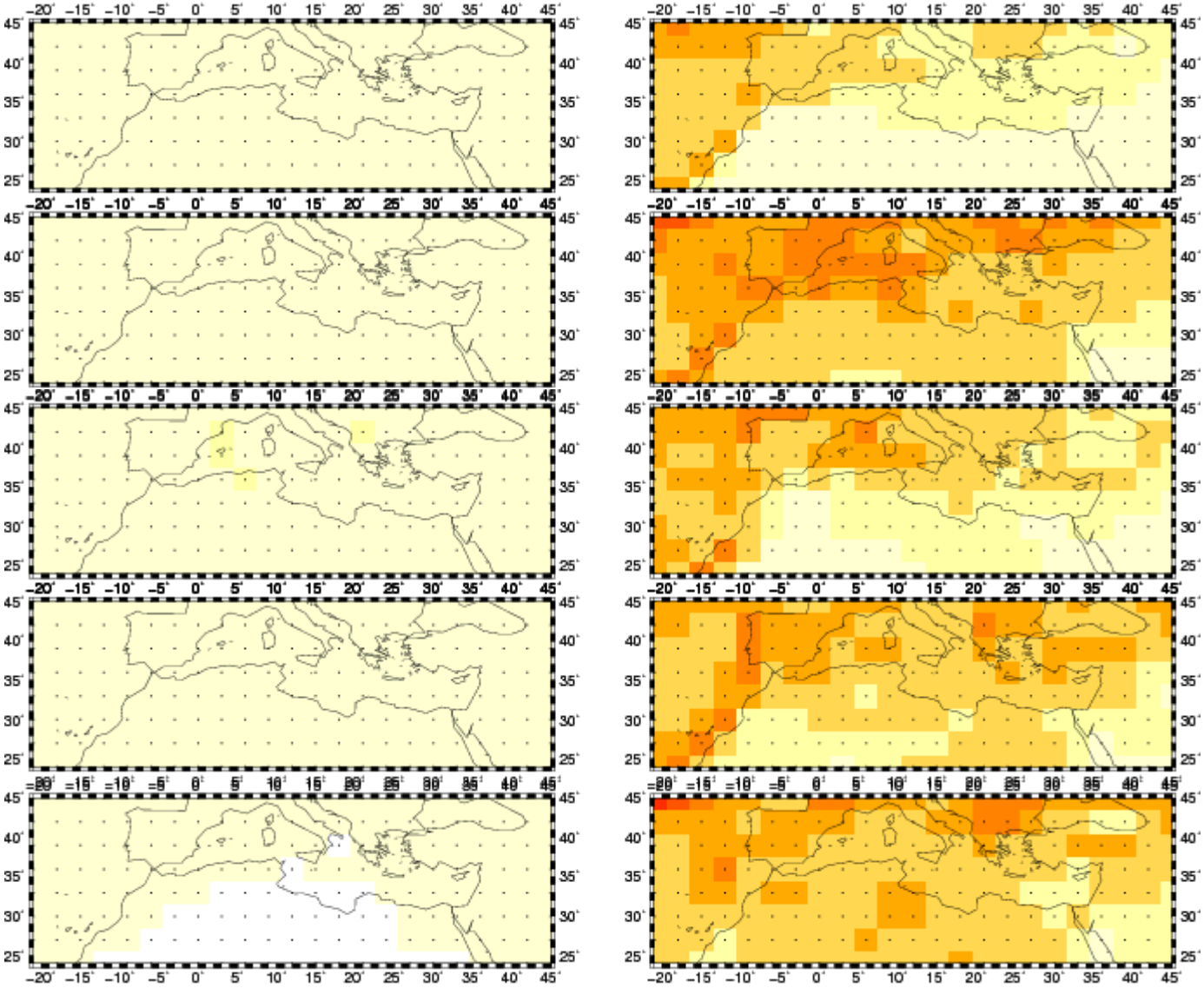
gamma

Spring

Summer

Autumn

Winter



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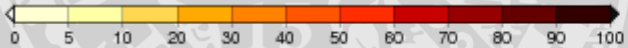
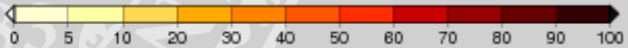
2-way-Anova A2 pre 2001-2098

beta ↓





Year

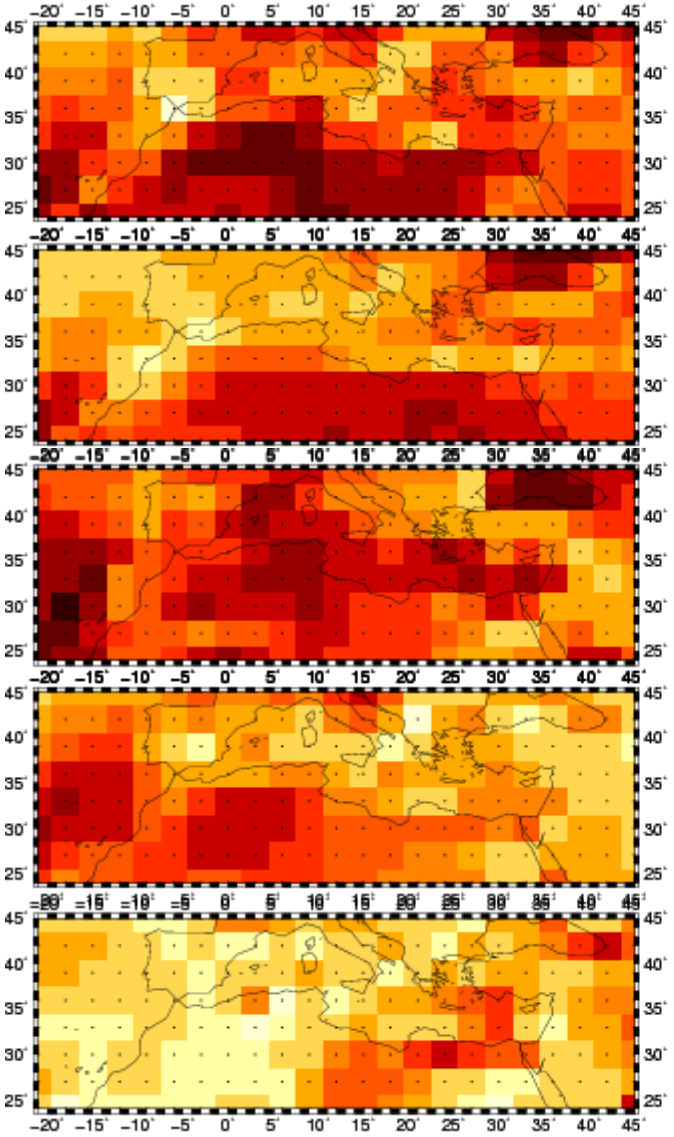
alpha ↓

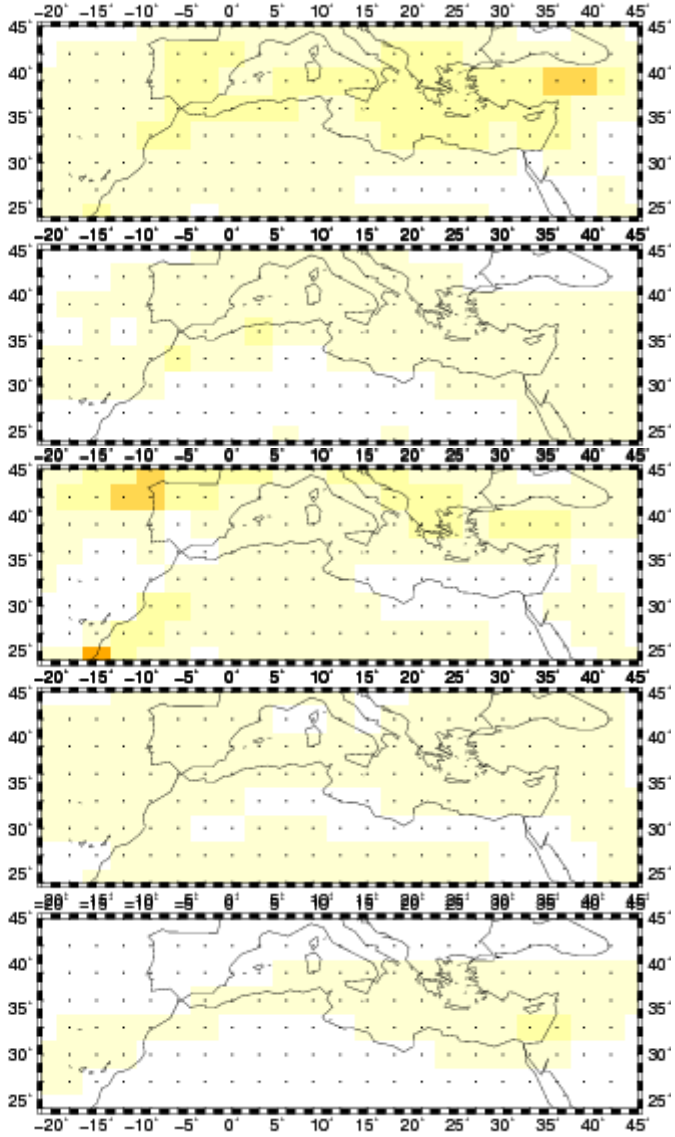
Spring

Summer

Autumn

Winter





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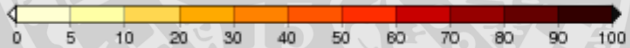
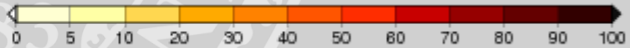
2-way-Anova A2 pre 2001-2098

epsilon





Year

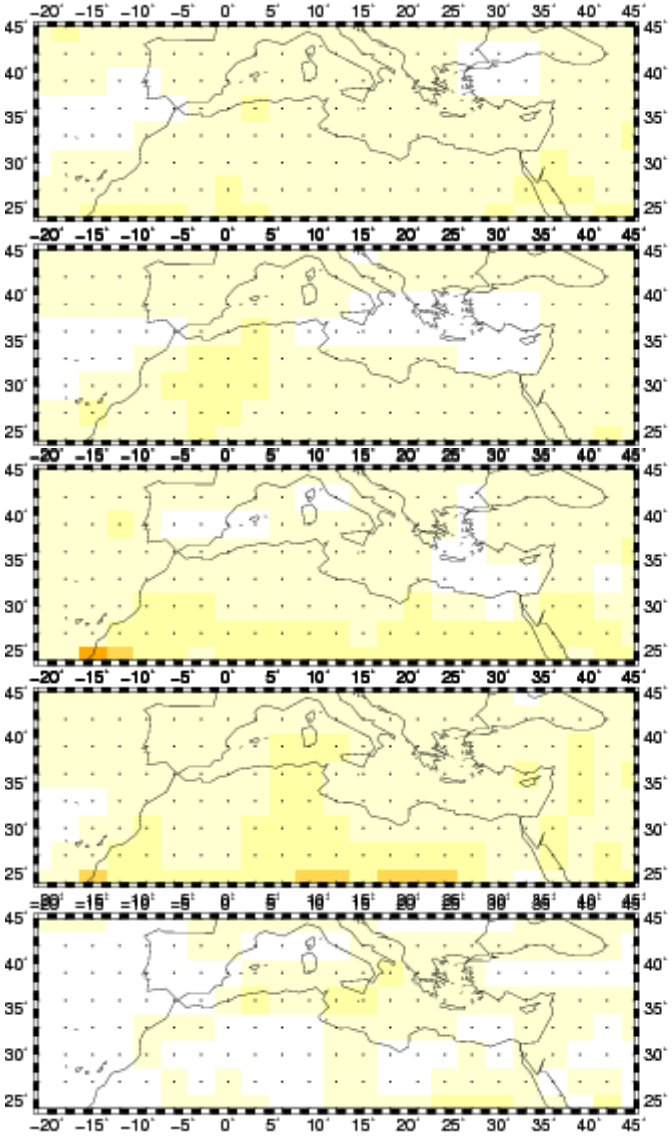
gamma

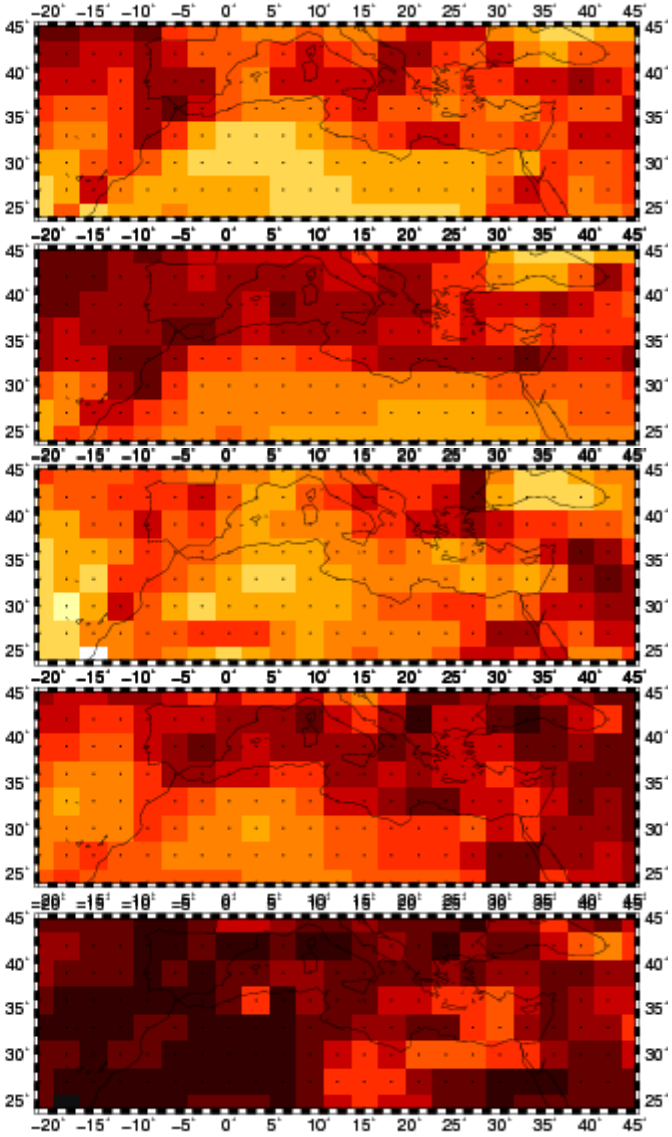
Spring

Summer

Autumn

Winter





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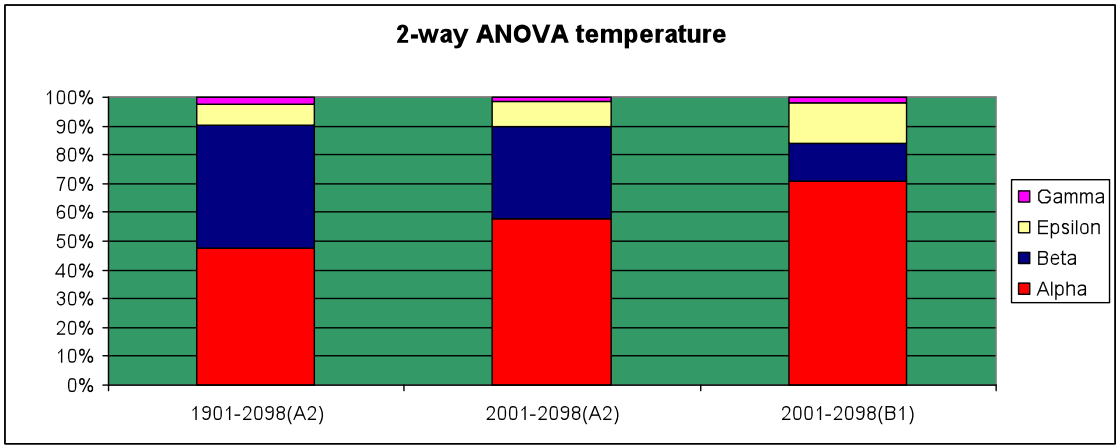
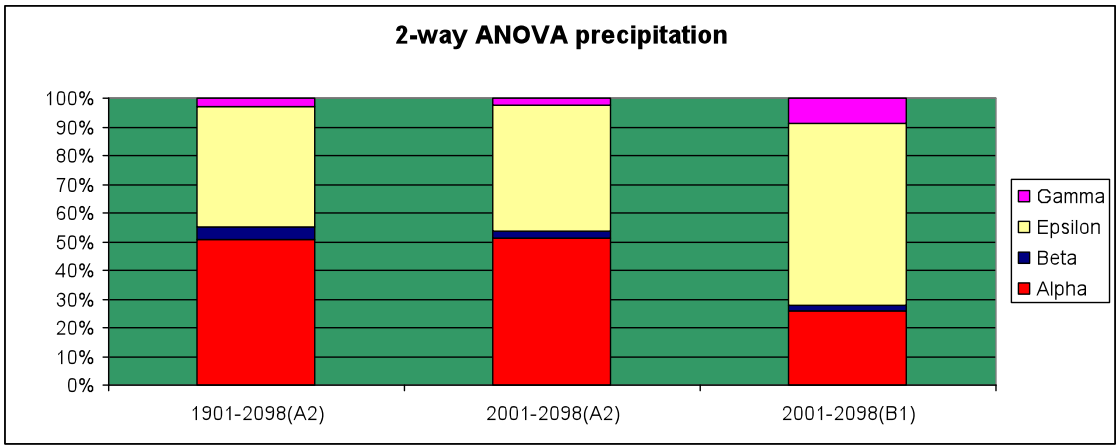
Regional means of the 2-way Anova

-temperature shows a higher common signal than precipitation

-the longer the time slice, the higher is beta

-the common signal seems to be stronger for A2 than for B1





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Summary

- The relative importance of GCMs and runs depends strongly on

→ the chosen time slice

→ the region

→ the climate variable

→ the season

→ the scenario

→ →The higher the variability over -maybe GCMs- the more the choice -of the “best” GCMs- matters

- Weighting of models?

→ Future Research: 1) sorting out erroneous data of slp

2) investigation of temporal evolution of the 2-Anova

3) investigation of extremes with daily GCM-data

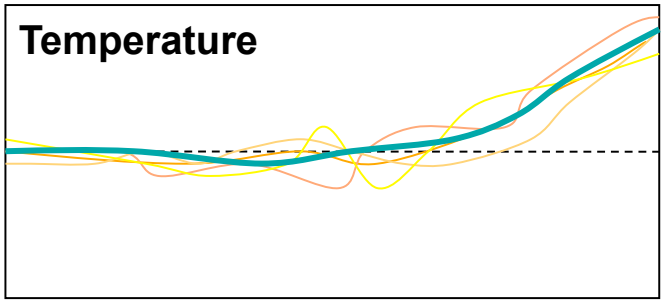
4) Analysis of Variance with Extremes…?


Thank you for your attention!!!

GCMs-Analysis of Variance

- Signal-to-noise ratio

$$= \frac{External Variability}{Internal Variability}$$



With respect to inter-model variability

external forcing variability ← Variability induced by a specific scenario

internal model variability ← Variability induced by different initial states of the atmosphere

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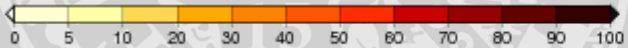
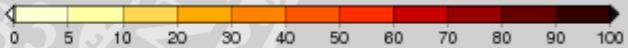
2-way-Anova B1 t2m 2001-2098

beta ↓





Year

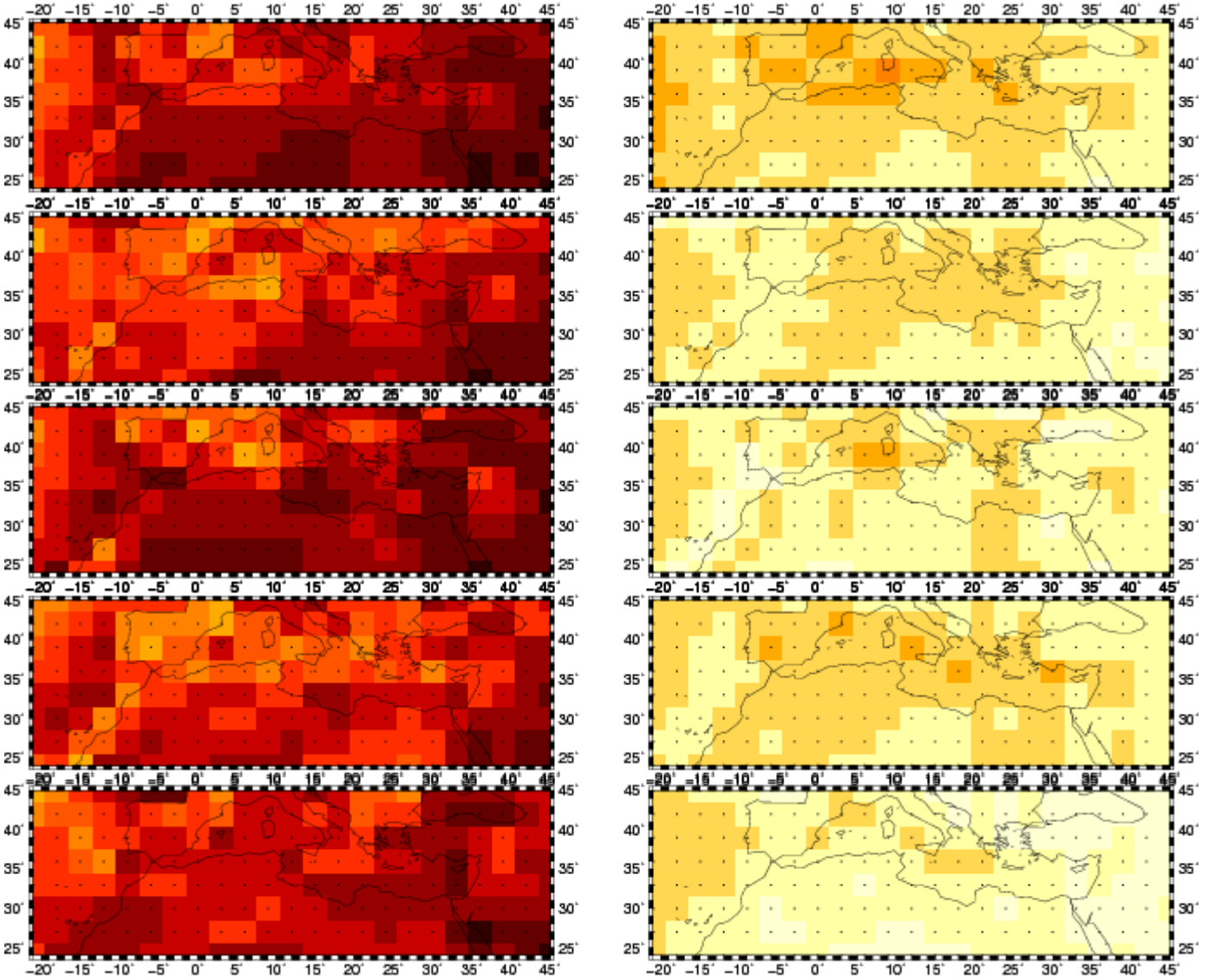
alpha ↓

Spring

Summer

Autumn

Winter



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2-way-Anova B1 t2m 2001-2098

epsilon

0 5 10 20 30 40 50 60 70 80 90 100

Year

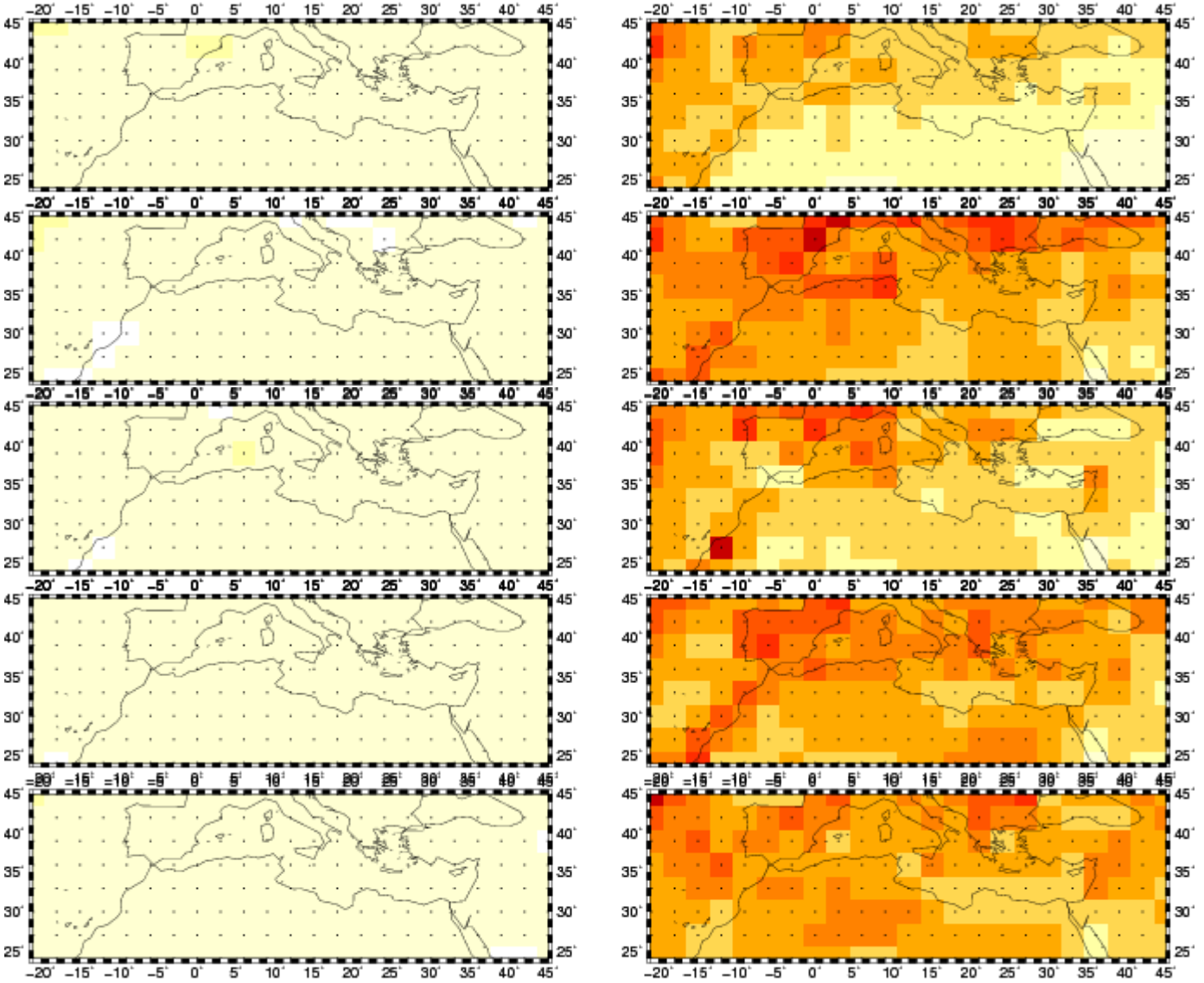
gamma

Spring

Summer

Autumn

Winter



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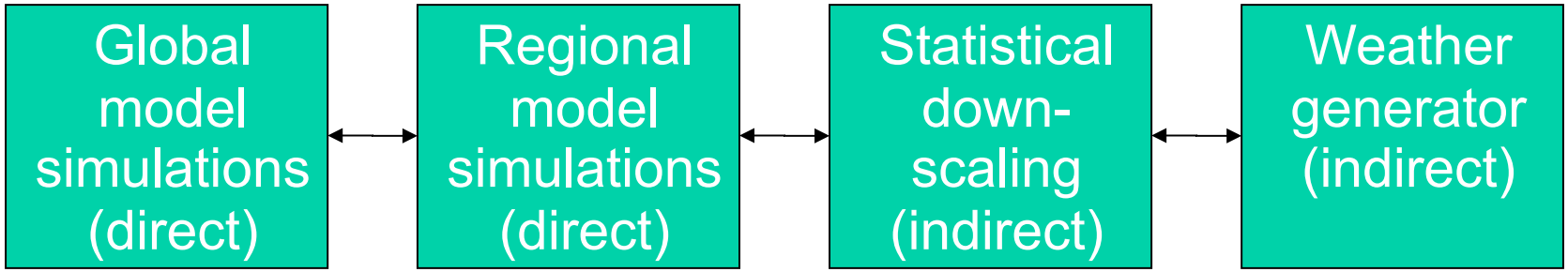
Project overview

- Main goal:
  Detection of climate change and extreme events in the Mediterranean basin and probabilistic quantification of uncertainties
- Broad spectrum of different methods:



- Comparison of different scenarios and models
  → evaluation with observations

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Processing

- Procesing over **time**