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Detection of an anthropogenic climatic change over the Mediterranean area

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Detection of an anthropogenic climatic change over the Mediterranean area

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Météo-France, CNRM-GAME

- Introduction to detection and attribution
- Available data for the analyses
- Formal methods and pattern similarity method
- Results for temperature and precipitation
- Conclusions

Some definitions or terms

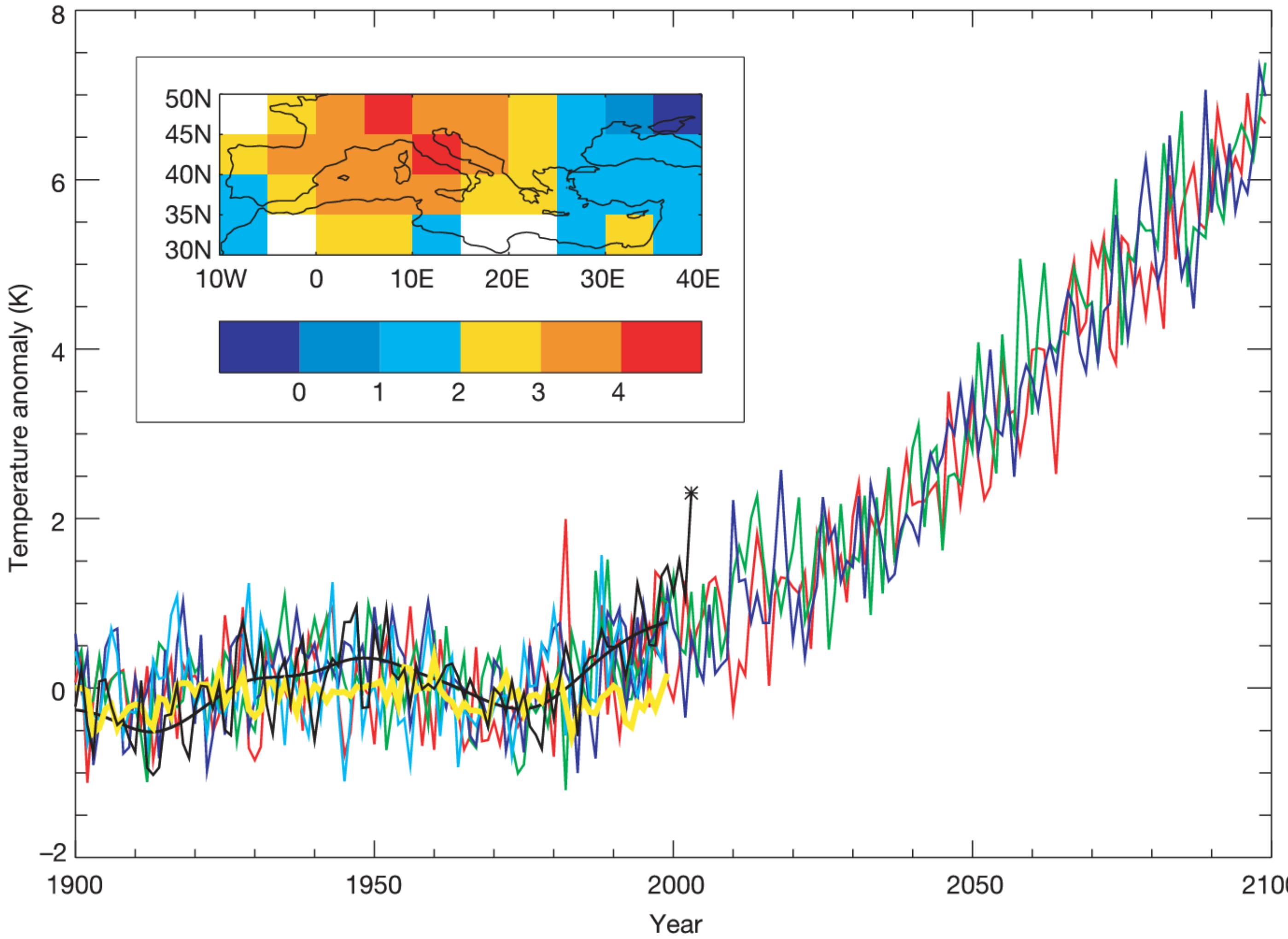
- *Detection* is the process of demonstrating that climate has changed in some defined statistical sense, without providing a reason for that change" (IPCC, 2007). For « formal » detection studies, a statistical test is applied to assess whether observations contain evidence of the expected responses to external forcing that is distinct from variation generated within the climate system (internal variability).

- *Attribution* "of causes of climate change is the process of establishing the most likely causes for the detected change with some defined level of confidence" (IPCC, 2007). For « formal » attribution studies, individual forcings are combined linearly to provide the best fit to the observations. Alternative physically-plausible combination of forcings should be excluded to complete the attribution process.

Previous detection studies over Southern Europe

- Stott et al (2004) detected human influence on the temporal pattern of averaged summer temperature over southern Europe, a region close to the Mediterranean area.

Observed and simulated Summer temperature anomalies relative to 1961–90 over Southern Europe (Stott et al, 2004)



Previous detection studies over Southern Europe

- Stott et al (2004) detected human influence on the temporal pattern of averaged summer temperature over southern Europe, a region close to the Mediterranean area.

- Zhang et al (2006) detected a spatio-temporal pattern of greenhouse and sulphate aerosol forcing on annual mean temperature over the same region and for the two periods 1900-1949 and 1950-1999.

- They are not however attribution studies since all the sources of climate variability were not explored as solar and volcanic forcings.

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The basic components of « formal » detection/attribution studies

- Observations to analyse climate variability and change. For the analysis of recent climate change, these observations consist in long and homogenized data series covering at least the last 50 years but preferably at least the last century.

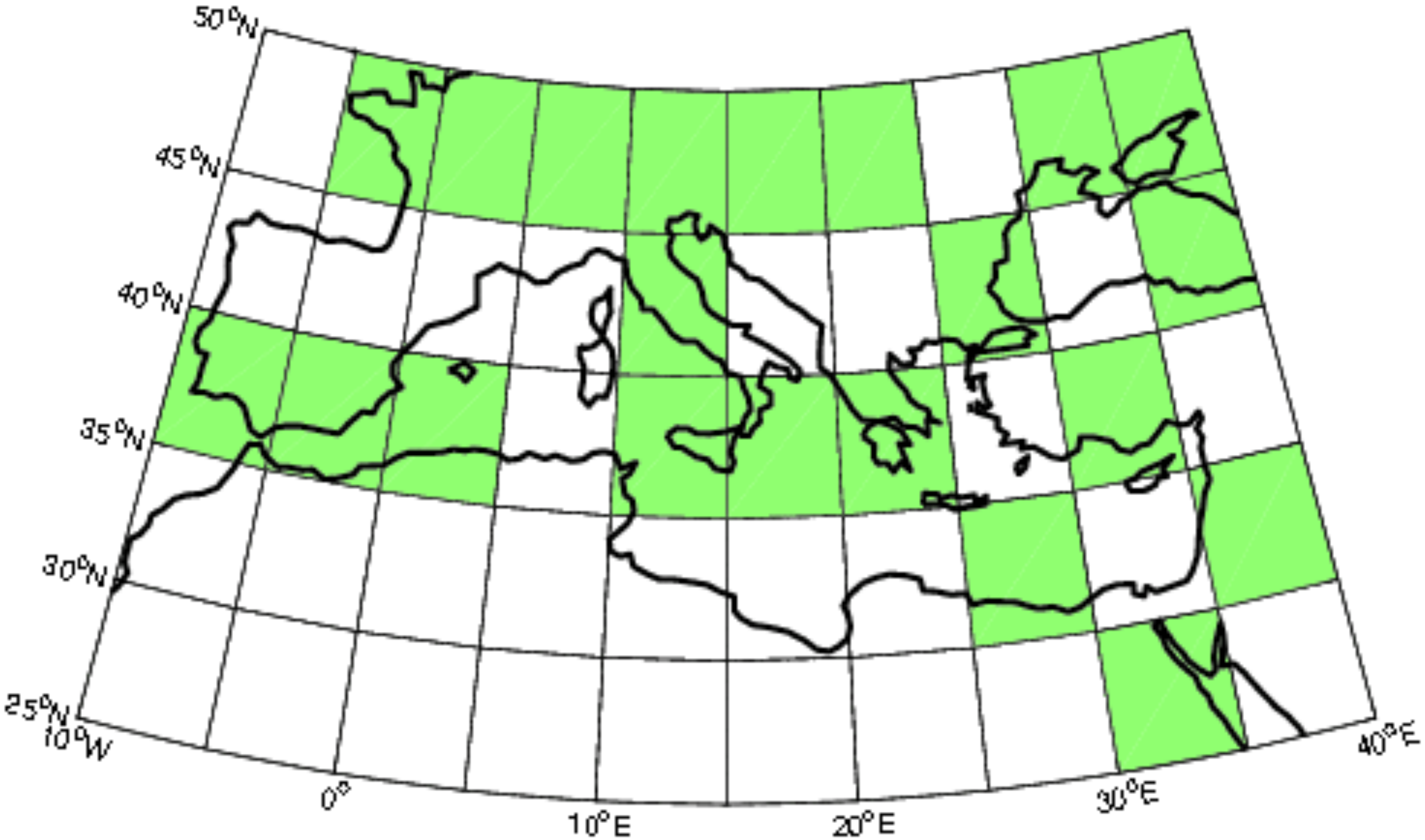
- Signals of climate change corresponding to specific forcings to be detected in the observations or aiming at attributing the observed changes to a combination of factors. For the analysis of recent climate change, these signals are provided by model simulations covering the last or the next century depending on the methodology of detection/attribution.

- An estimate of internal climate variability for the application of the statistical tests. This estimate is either provided by long data series or by model simulations under « no-forcing » conditions.

Observations of temperature and precipitation

- Observed temperature dataset on a 5°X5° covering the period 1900-2006: HadCRUTv of Climate Reasearch Unit, combination of monthly values of air temperature anomalies and sea surface temperature anomalies relative to 1961-1990 (Jones et al, 2001).

Data coverage over the 1900-2006 period

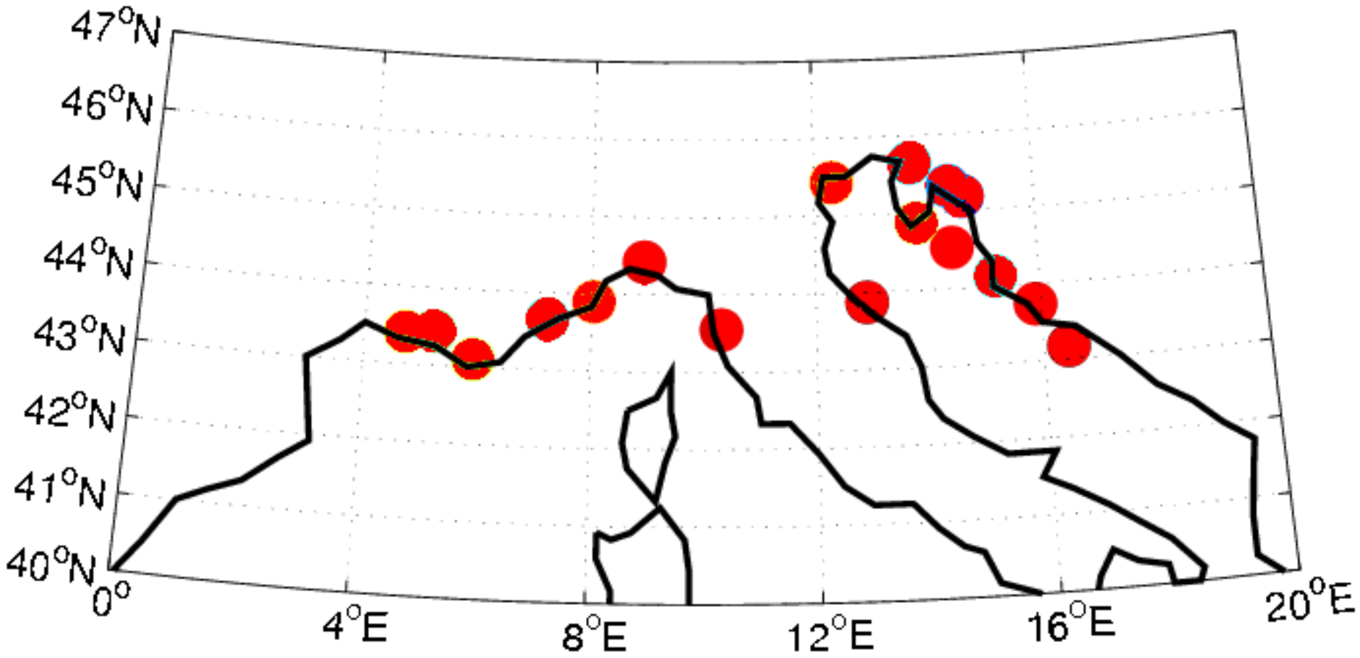


Observations of temperature and precipitation

- Observed temperature dataset on a 5°X5° covering the period 1900-2006: HadCRUTv of Climate Reasearch Unit, combination of monthly values of air temperature anomalies and sea surface temperature anomalies relative to 1961-1990 (Jones et al, 2001).

- Precipitation dataset from CIRCE european project: 17 series of monthly precipitation from Croatian, French and Italian coastal stations homogenized at Bern University following a methodology presented in Kuglitsch et al (2009).

Location of the 17 stations associated to long time series of precipitation (Bern University)



Model simulations

- 24 AOGCMs that contributed to the CMIP3 simulation exercise with 22 included in the AR4 list of models with resolutions from 1.4° to 5° in the atmosphere and 0.5° to 5° in the ocean; simulations covering the 20th century and climate change simulations using the A1B and A2 SRES scenario.

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General framework for formal detection

- $\Psi = (\psi_{i,t})$: matrix of observed climate variable available at different locations (index i), seasonally or annually averaged at a given time (index t). It is a superposition of a deteministic climate change signal and a random realization of internal climate variability:

$$\psi_{i,t} = \boxed{\psi_{i,t}^{(s)}} + \boxed{\psi_i^0 + \phi_{i,t}}$$

- Time-space separation assumption with, in particular, μ being the temporal pattern and g the spatial pattern:

$$\psi_{i,t}^{(s)} = g_i \mu_t$$

- Internal climate variability (centered in time) is an autoregressive process with ($\tilde{\Phi}_{i,t}$) normally distributed:

$$\phi_{i,t} = \alpha \phi_{i,t-1} + \tilde{\phi}_{i,t}$$

General framework for formal detection

- Detection process consist in testing H_0 hypothesis saying that the observation matrix is derived from internal climate variability statistics versus H_1 saying that some signal is added to this internal climate variability.

- Exemple: for the « optimal fingerprint » (Hasselmann, 1993), g and C the spatial covariance matrix of the internal climate variability, are supposed to be known. In this case, the most powerful statistical test is obtained when applying the test to the detection variable:

$$d_f = f^T \psi; \quad with : f = C^{-1} g$$

The « Regularized Optimal Fingerprint » (Ribes et al, 2009-a)

- g , is supposed to be known but not C . This matrix is replaced by an estimate (Ledoit and Wolf, 2004) that leads to a more powerful test than the « optimal fingerprint »:

$$\hat{C}_I = \gamma\hat{C} + \rho I$$

- The threshold of rejection of the null hypothesis and the p-values are determined through a bootstrap technique.

The « Temporal Optimal Detection » (Ribes et al, 2009-b)

- Here, contrary to the « fingerprint method », only μ is supposed to be known. It is inferred from climate change simulations and is calculated from spatial averages of the climate variable, either globally or over the region of interest. A penalized estimation technique is used to smooth the temporal pattern.

- It can be shown that the problem reduces to a multivariate regression problem and the test of the null hypothesis to a so-called Hotelling test:

$$\tilde{\psi}_{i,t} = (1-\alpha)\psi_i^0 + \boxed{\hat{g}_i}\tilde{\mu}_t + \tilde{\phi}_{i,t}$$

The « Pattern similarity » (Bhend and von Storch, 2008)

- It consists in asking whether the most recent observed patterns of temperature or precipitation changes are consistent with climate change simulations including the response to anthropogenic forcings.

- The methods consist in using pattern similarity statistics: the centred and un-centred pattern correlation statistics, regression.

- To estimate confidence intervals, the moving block bootstrap test (Wilks, 1997) is applied.

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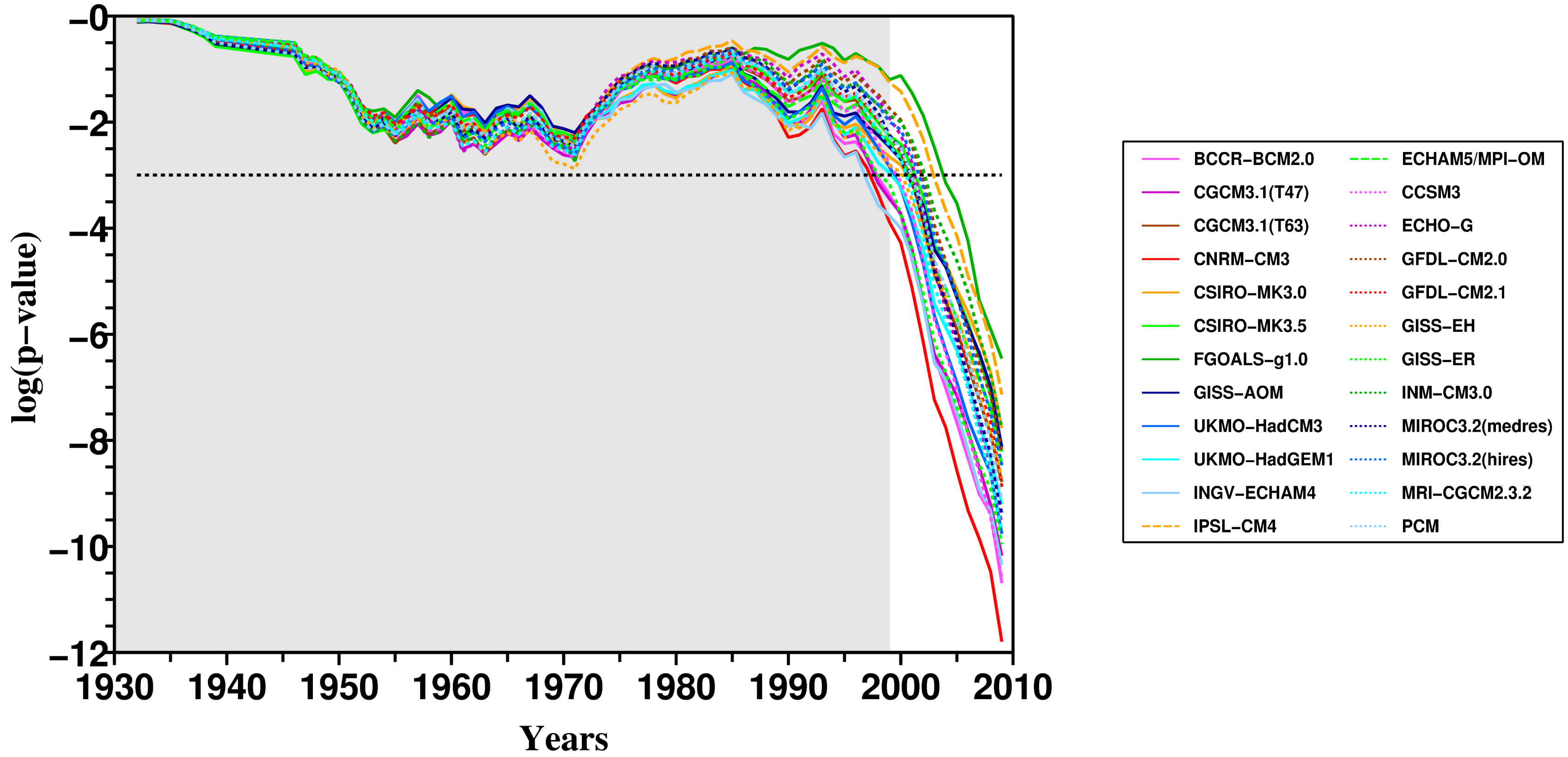
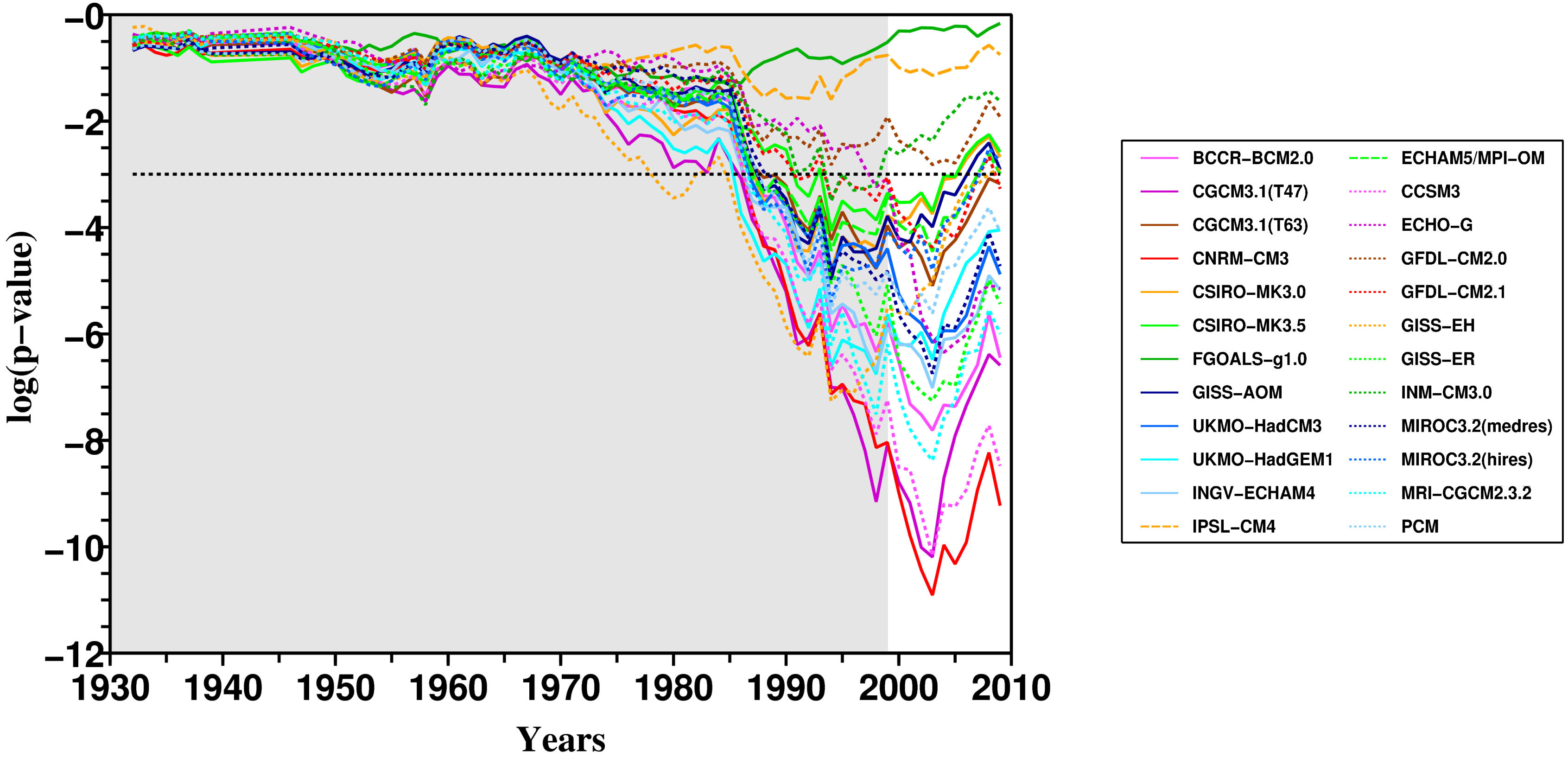
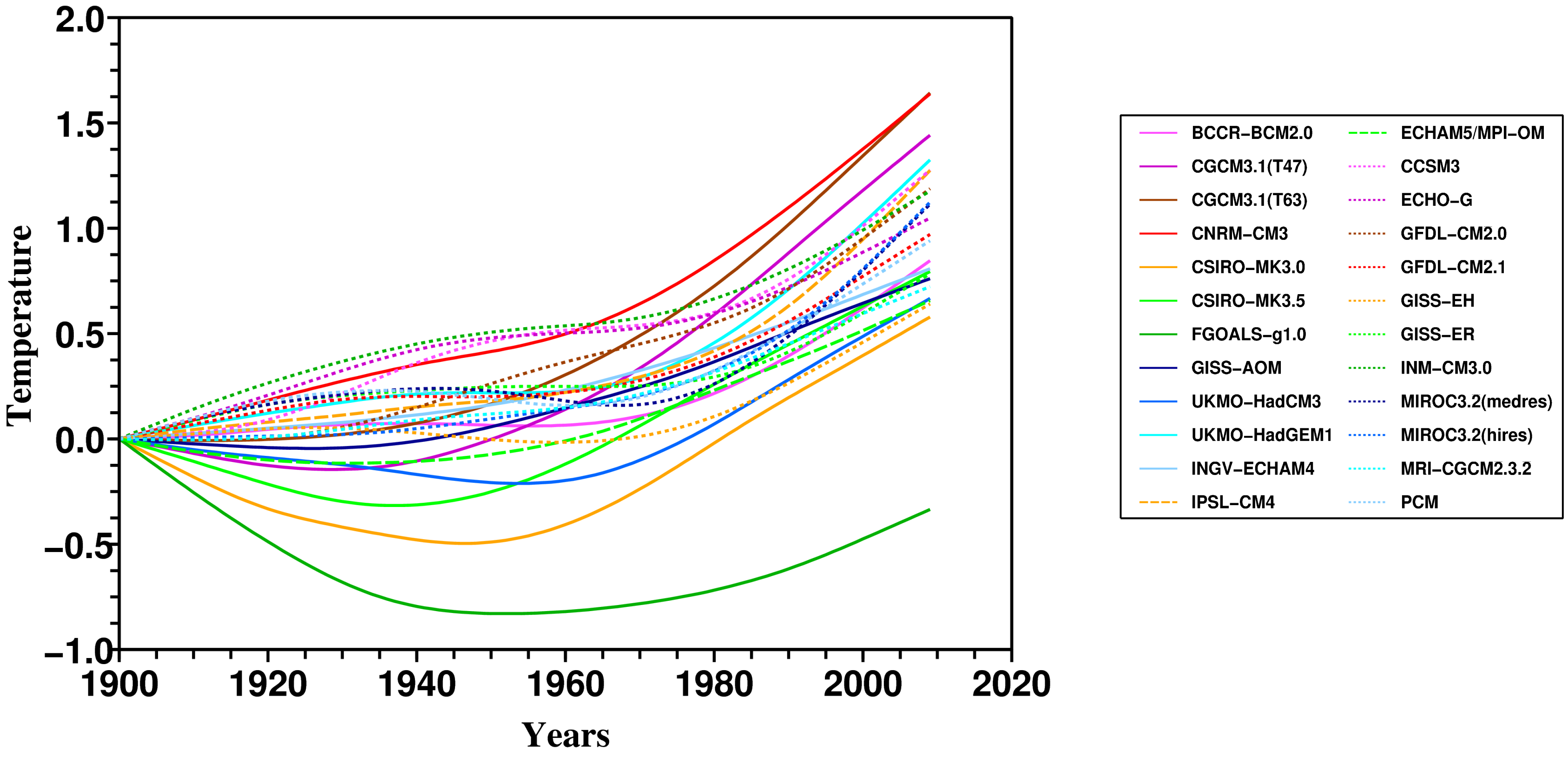
Detection of annual mean temperature change with the ROF method



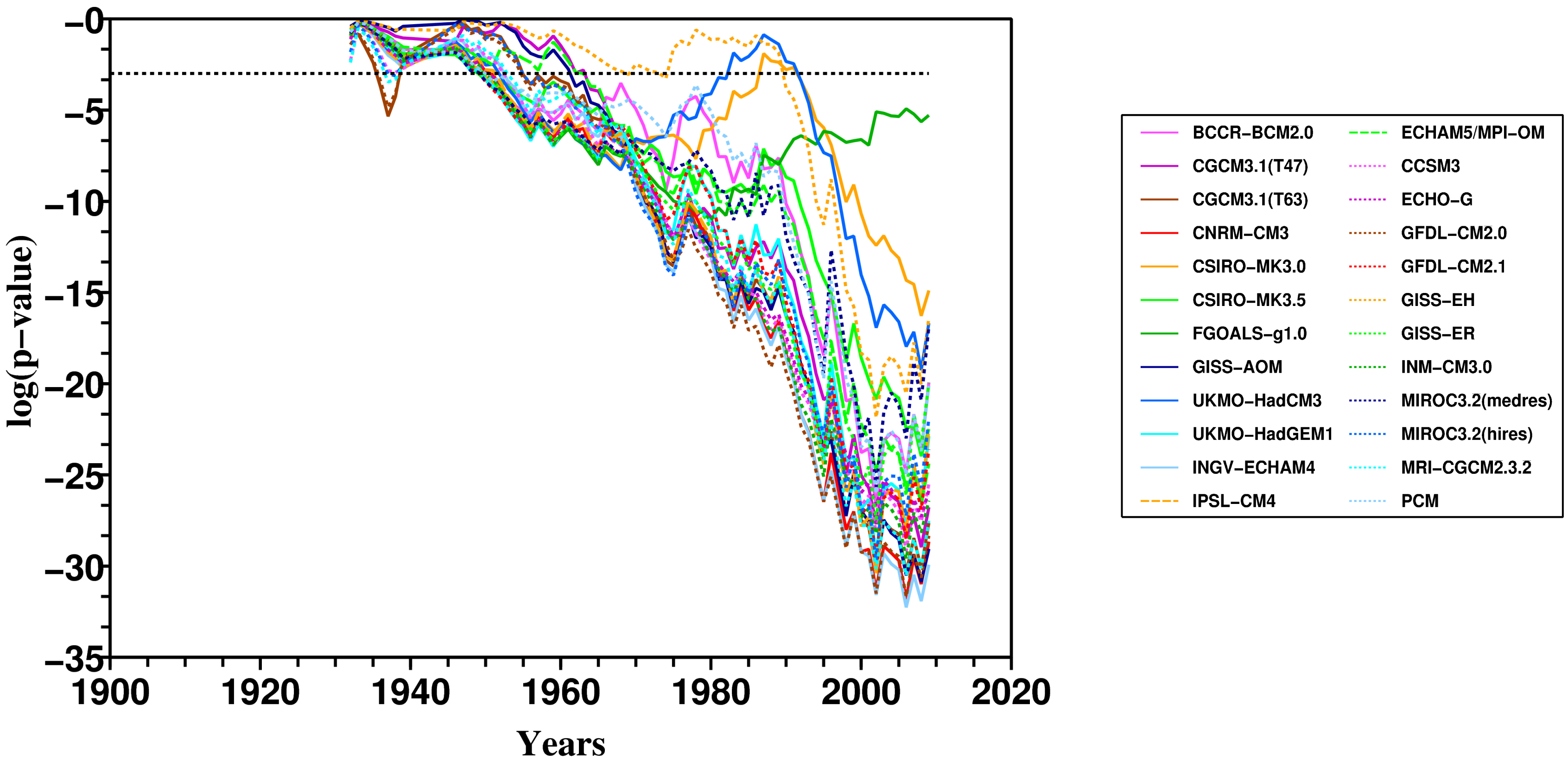
Detection of spatially centred annual mean temperature change with the ROF method



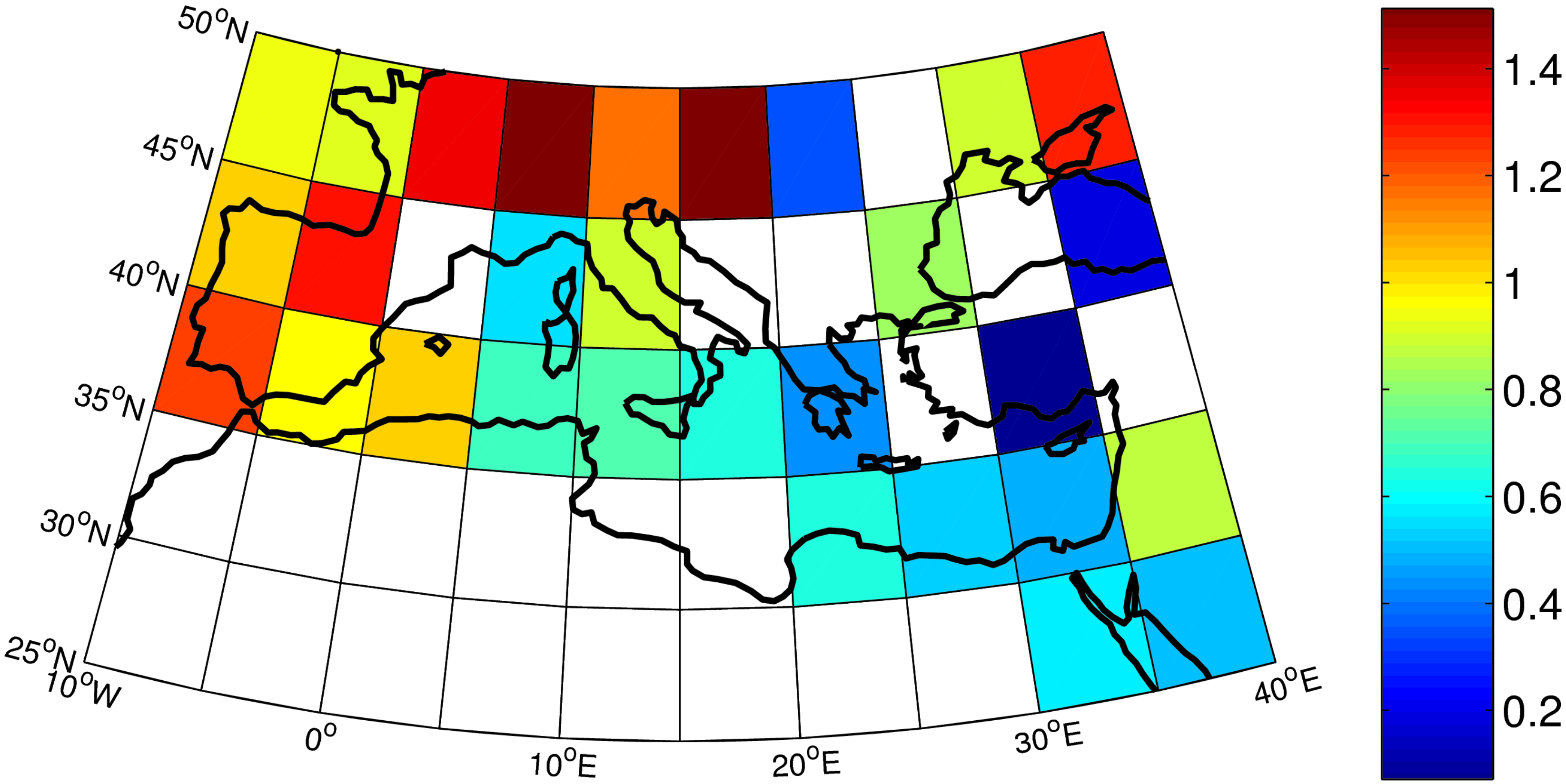
Temporal guess-patterns of Mediterranean area temperature



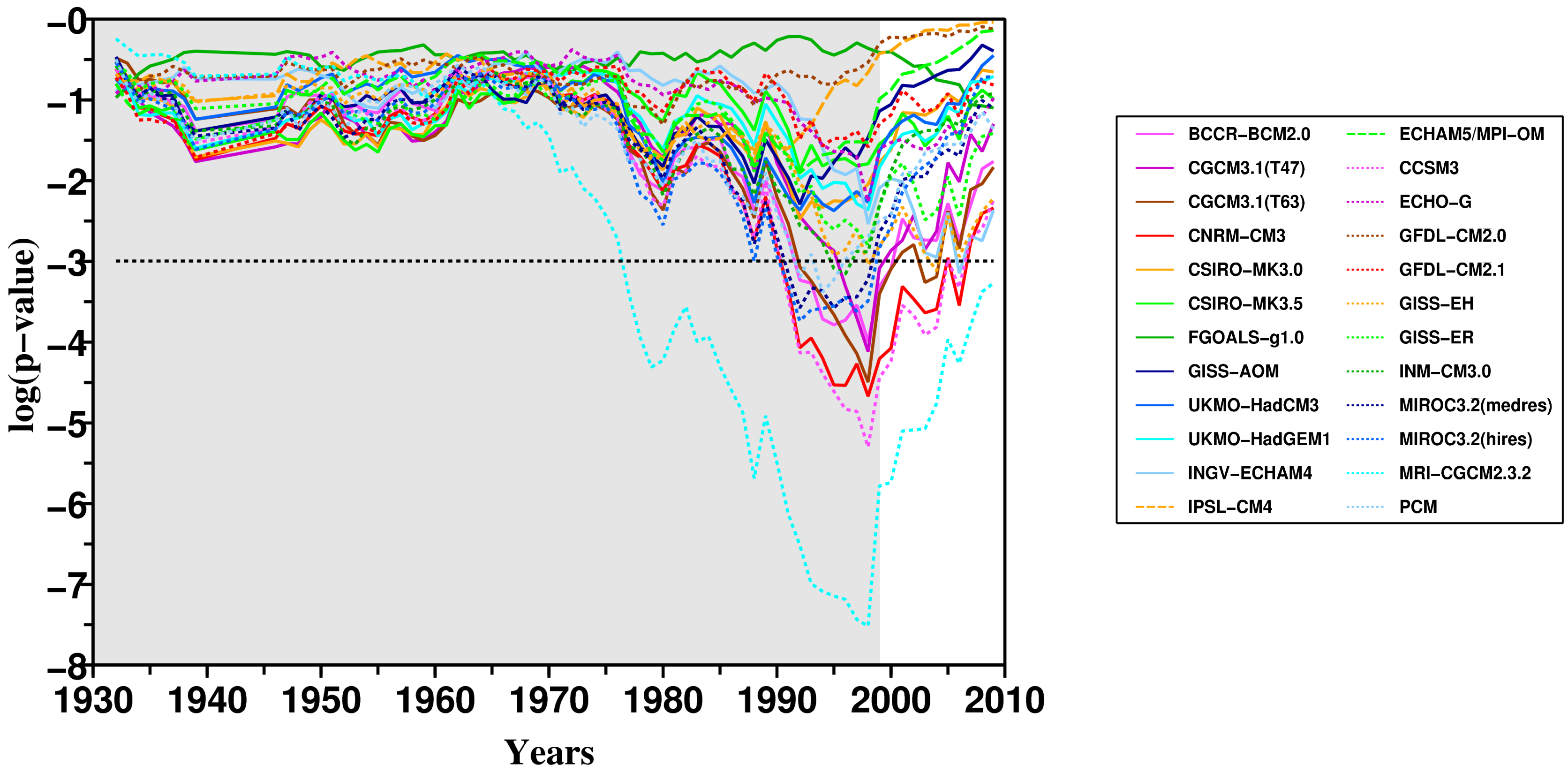
Detection of spatially centred annual mean temperature change with the TOD method (regional pattern)



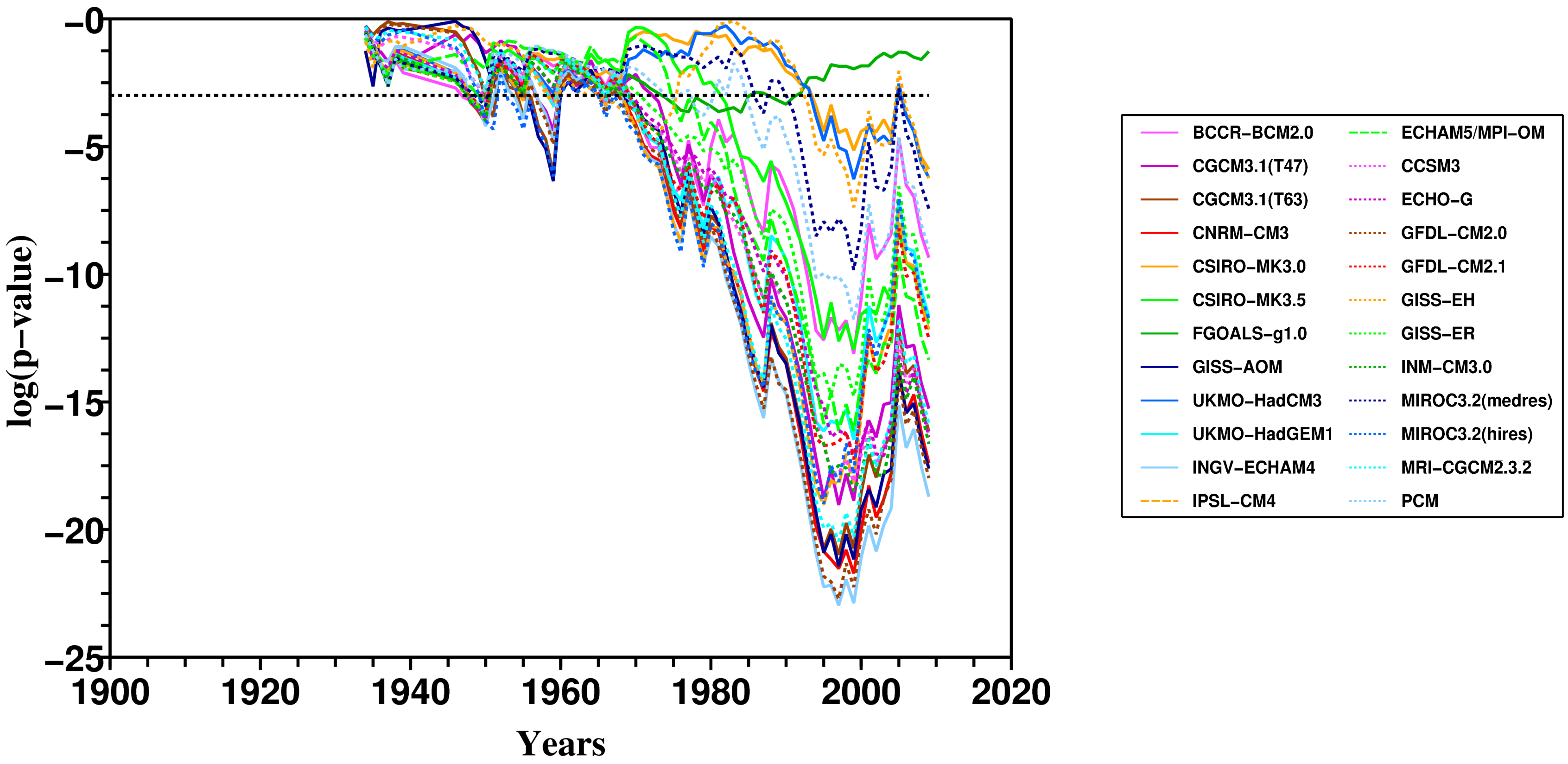
Spatial pattern of annual mean temperature from the TOD method (regional pattern)



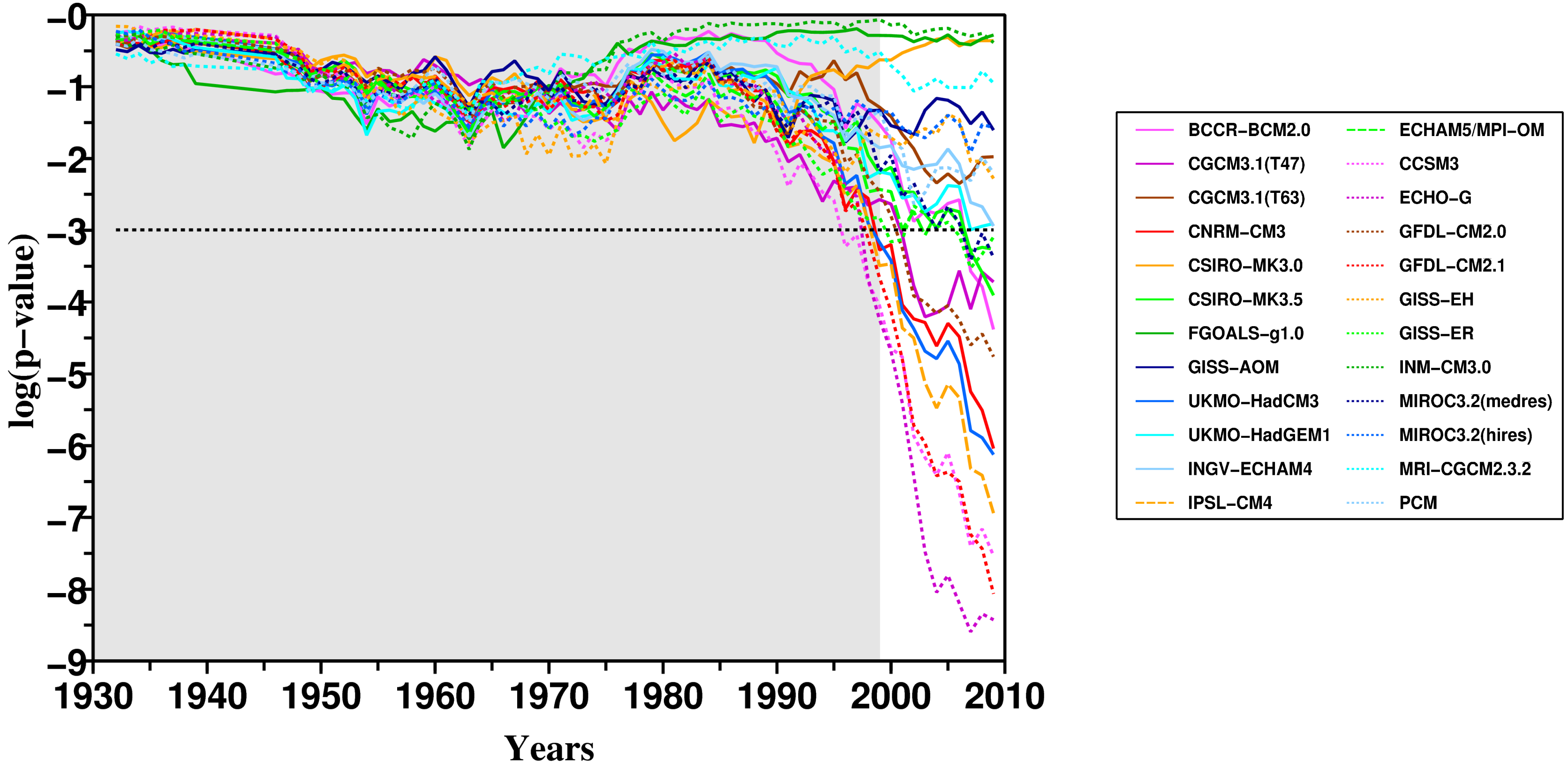
Detection of spatially centred winter mean temperature change with the ROF method



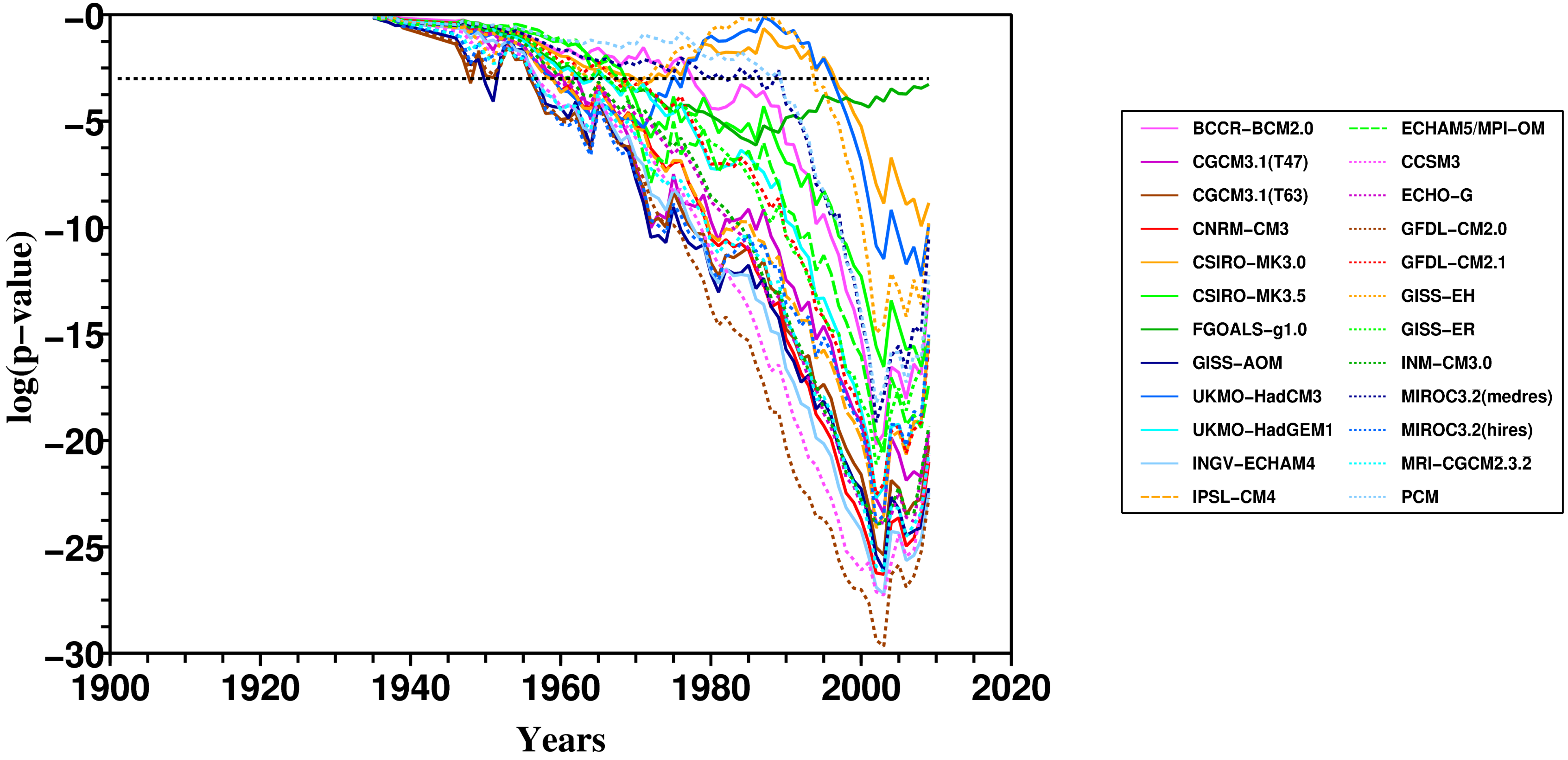
Detection of spatially centred winter mean temperature change with the TOD method (regional pattern)



Detection of spatially centred summer mean temperature change with the ROF method

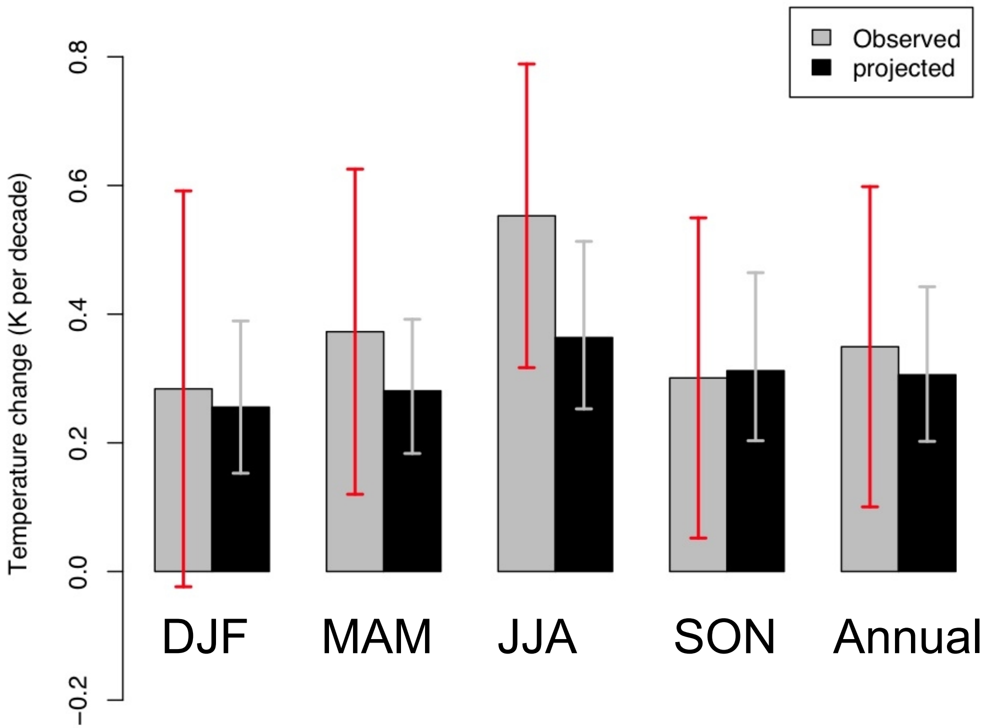


Detection of spatially centred summer mean temperature change with the TOD method (regional pattern)



Consistency of observed temperature trends over the Mediterranean region with climate change projections

A. Barkhordarian (2010)

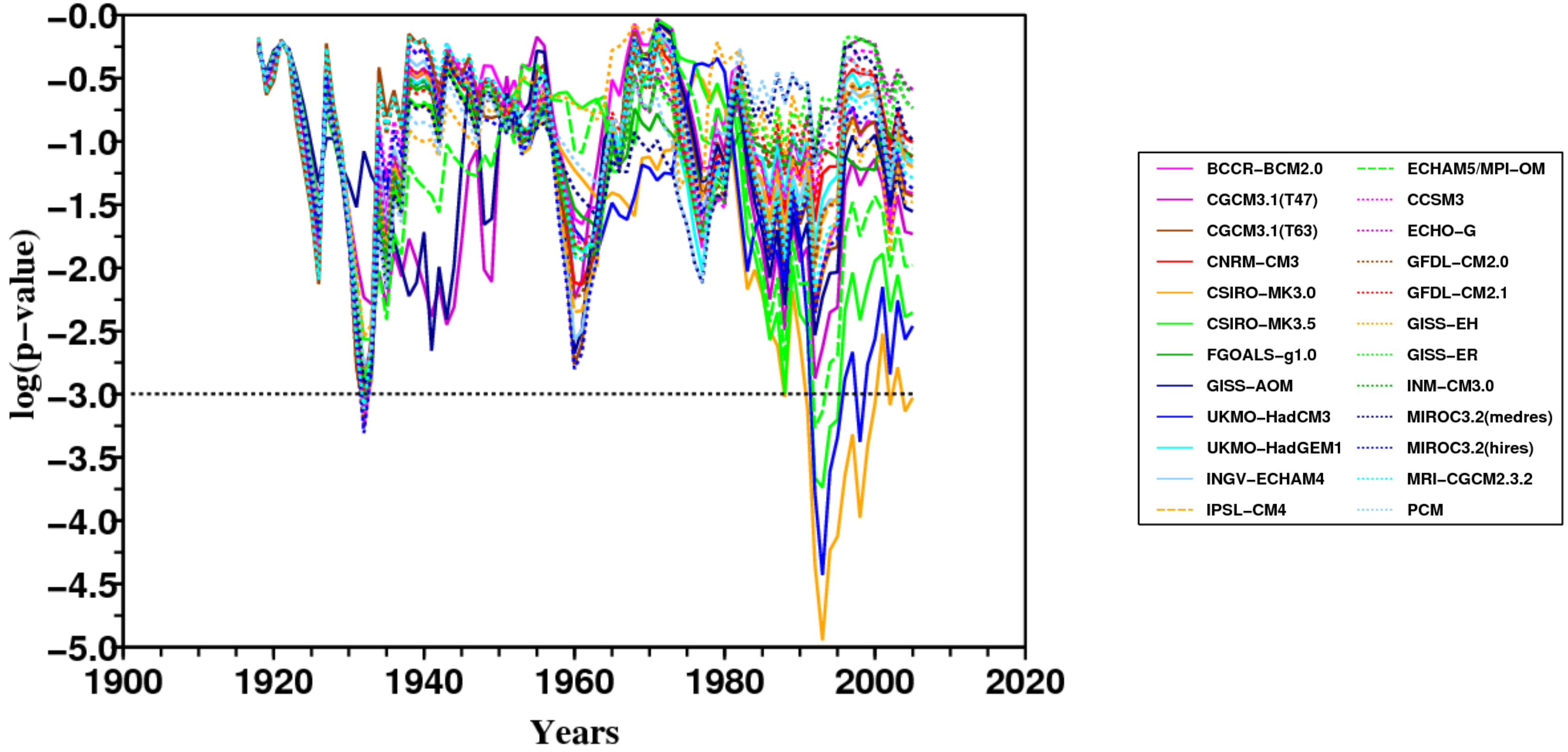


Observed and simulated trends over the period 1979-2009

PS indices for simulated trends over the period 1979-2009

	DJF	MAM	JJA	SON
Un-centred correlation	0.74	0.84*	0.95**	0.87***
Centred correlation	0.36	0.10	0.37**	0.34
Regression	1.1*	1.3**	1.5**	0.96*

Detection of annual mean precipitation change over the 17 costal stations with the TOD method (global pattern)



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Conclusions

- We have used new formal detection methodologies (ROF and TOD) developed within the context of the CIRCE project, in order to try to improve the ability to detect a climate change signal at the regional scale.

- The application of the two methods on **annual mean temperature** reveals a detection at the 5% significance level with the most part of the AOGCMs. The TOD method is even more conclusive for this detection since the results show a clear detection with centred mean temperature.

- The spatial pattern of climate change inferred from the TOD method is likely of anthropogenic origin but further investigation with attribution methodologies are required to confirm this hypothesis.

Conclusions

- The application of the TOD method to **winter mean temperature** shows the detection of a climate change signal at the 5% significance level when considering periods covering at least the 1900-1980 period and for the most part of the CMIP3 ensemble.

- The same detection occurs earlier for **summer mean temperatures** and the significance level decreases for the longest periods.

- The application of the PS method not surprisingly corroborates these results since we find that anthropogenic forcing is a plausible explanation of the observed changes in area mean change of near-surface temperature over the Mediterranean region.

- These results extend previous ones obtained by the application of formal detection procedures to so-called “southern Europe” domains (Stott et al, 2004; Zhang et al, 2006).

Conclusions

- The application of the two formal detection methods to **annual, winter and summer precipitation** of the CIRCE precipitation dataset don’t allow to reject the null hypothesis saying that the observed changes are due to internal climate variability.

- The main conclusion of this study concerning precipitation is thus that we cannot detect formally a signal of climate change on Mediterranean precipitation collected at a few locations of the Northern Mediterranean coast. However, further investigation is needed with a more complete dataset.