



# Climatic Resources for Tourism in Europe

## An Application of the Tourism Climatic Index on a Daily Basis

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# Goal and Approach of Research

## Goal

- Determine how climatic resources might change in Europe due to climate change.

## Approach

- Use of the “Tourism Climatic Index” by Mieczkowski (1985) as a metric for “favourable climate” for tourism
- Calculation of the potential future change in index by means of climate model projections
  - from regional climate models: high spatial resolution
  - from daily values: high temporal resolution
  - from several climate models: robustness analysis possible



# The Tourism Climatic Index (TCI)

A metric to quantify and summarize “favourable climate” for average sightseeing tourism developed by Miezkowski (1985).

$$TCI = 2 * (4 C_{dt} + C_{dl} + 2 R + 2 S + W)$$

$C_{dt}$       *daytime comfort*

$C_{dl}$       *daily comfort*

$R$         *precipitation*

$S$         *sunshine*

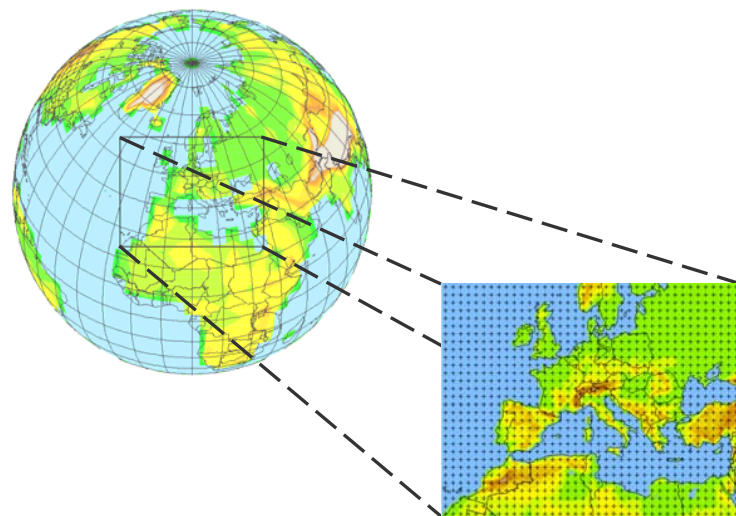
$W$         *wind*

*All indices are rated with a maximum of 5 points yielding an overall possible maximum TCI of 100 points.*

score	category	
90 to 100	ideal	
80 to 89	excellent	
70 to 79	very good	
60 to 69	good	
50 to 59	acceptable	
40 to 49	marginal	
30 to 39	unfavourable	
20 to 29	very unfavourable	
10 to 19	extremely unfavourable	
-20 to 9	impossible	

# Climate Simulation Models

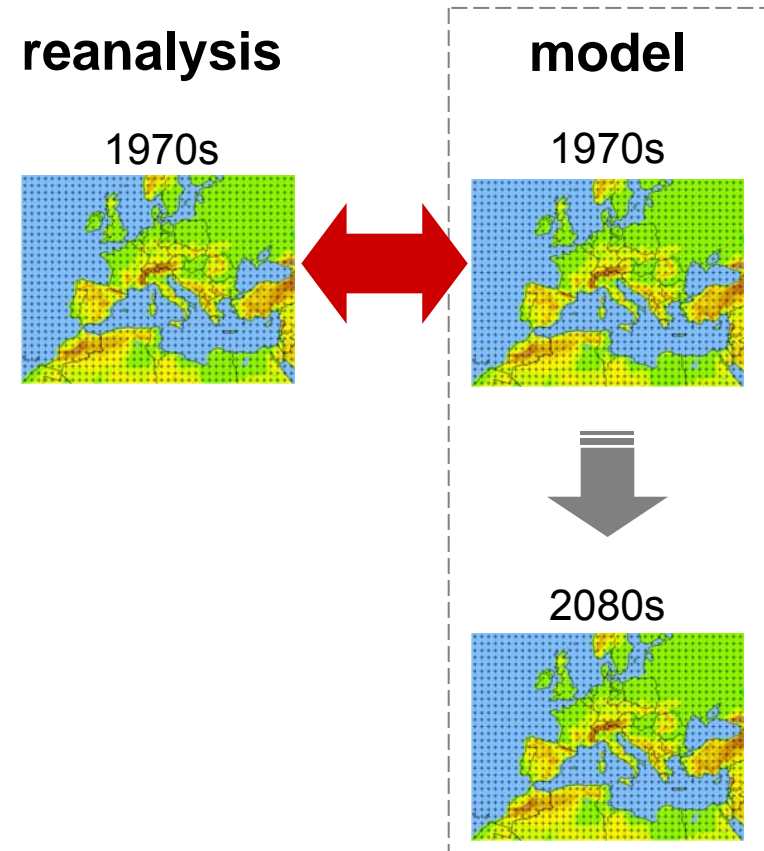
- 5 regional models “nested” within 2 global circulation models from the PRUDENCE project
- assumed GHG emissions: all A2 scenarios (upper limit of projections)
- time: comparison of contemporary climate (1961 – 1990) and the end of the century (1971 – 2000).
- spatial scale: 50 to 55 km resolutions



regional model	driving global climate model
HIRHAM	ECHAM5
HIRHAM	HadAM3H
REMO	HadAM3H
CHRM	HadAM3H
HadRM3P	HadAM3P

# Quality of Climate Model Simulations

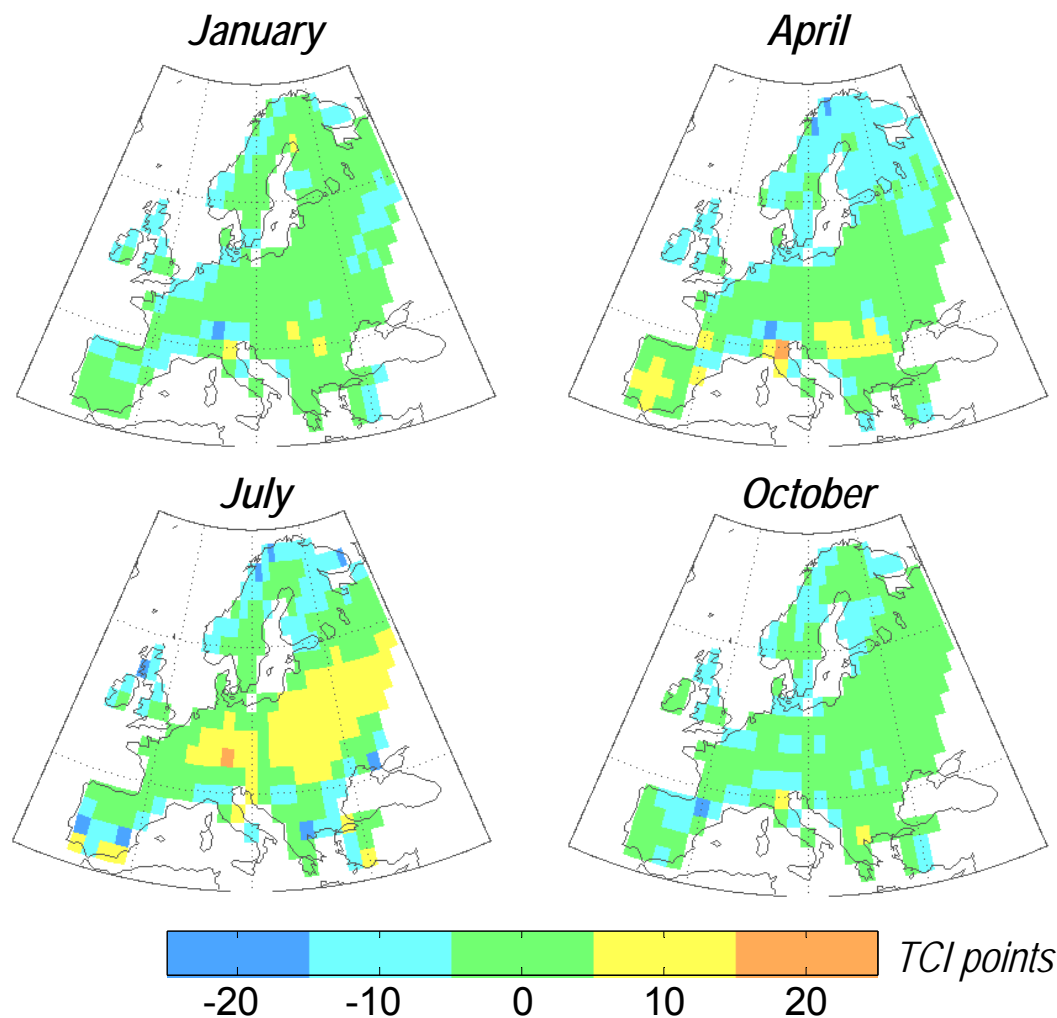
- comparison of model simulations for contemporary climate with reanalysis data
- reanalysis data is a gridded data set created from **observed** climate data
- reanalysis data from the NCEP/NCAR reanalysis 1 project, also daily values, but lower resolution
- comparison:
  - compare “new model” = mean of all 5 models
  - only include land area
  - for each month (average of 30 years)



# Comparison of Reanalysis & Simulation for Mean TCI

- all simulations significantly different from reanalysis
- in general very similar patterns across Europe for all months
- the model mean lies on average **2.3 TCI points lower** than the reanalysis
  - from 5.4 points too low (March) to 1.1 points too high (June)
- less well represented:
  - Scandinavia consistently too low, especially in spring and summer
  - central Europe too high in summer

## *Simulated TCI minus Reanalysis TCI*

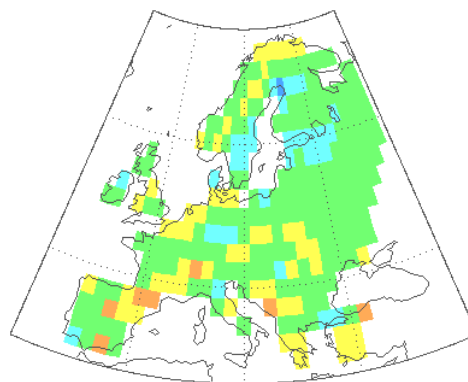


# Comparison of Reanalysis & Simulation for TCI Variability

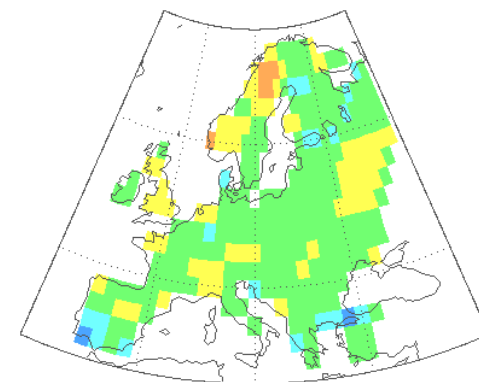
- in general very similar patterns across Europe for all months
- the model variability lies on average **0.2% lower** than the reanalysis (in standard deviation)
  - from 8.1% too low (July) to 4.8 % too high (October)
- less well represented:
  - heterogenous patterns across regions and months
  - tendency towards too large variability Oct – Mar and too small May - Aug

*% difference in TCI standard deviation*

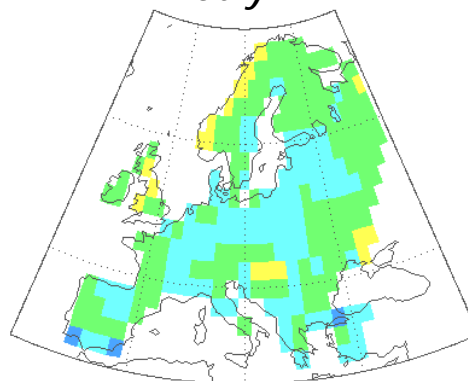
*January*



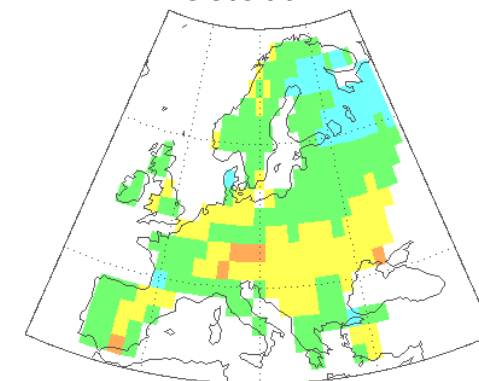
*April*



*July*



*October*



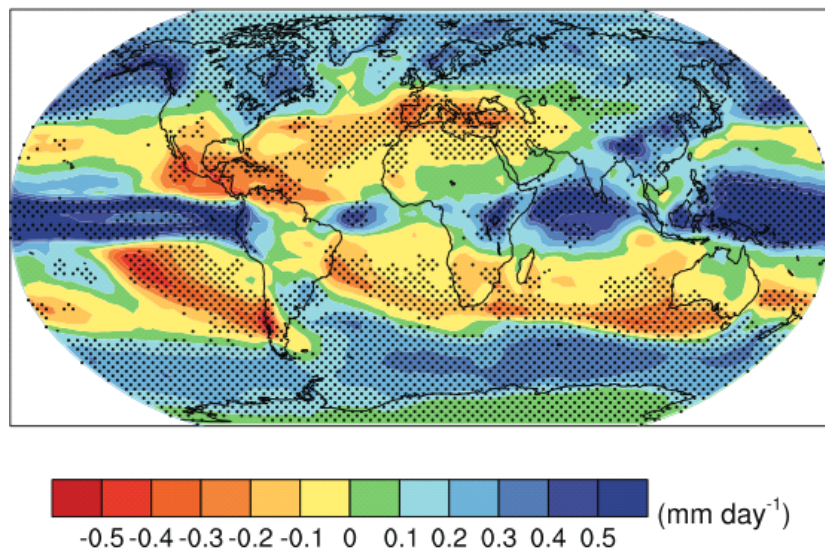


# How Robust are Climate Change Projections?

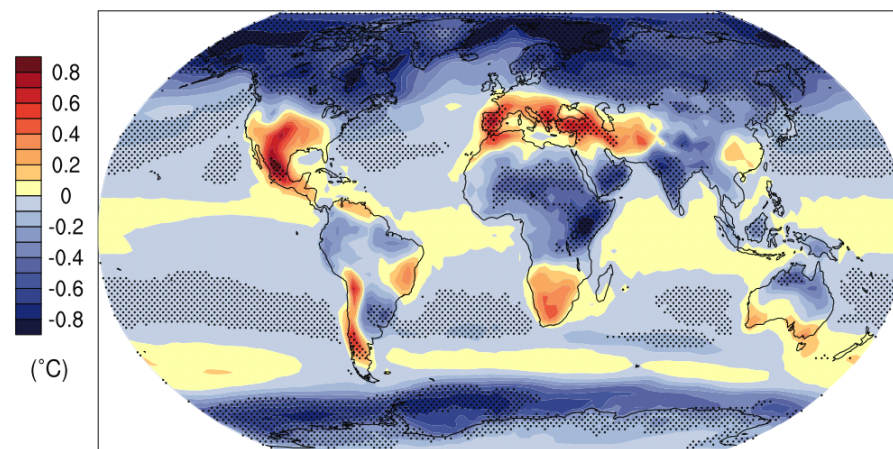
For a number of climate variables and regions, today's climate models **do not agree** on the future change. The stiplings in these graphs of the IPCC AR4 denote regions, where models do not agree (sometimes not even in the sign of change).

**Therefore it is indispensable to compare the results from different models.**

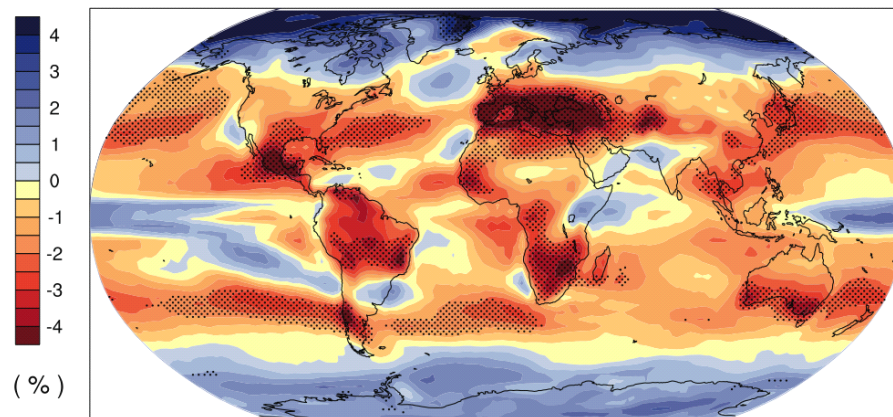
*change in precipitation*



*change in diurnal temperature range*



*change in cloud area fraction*

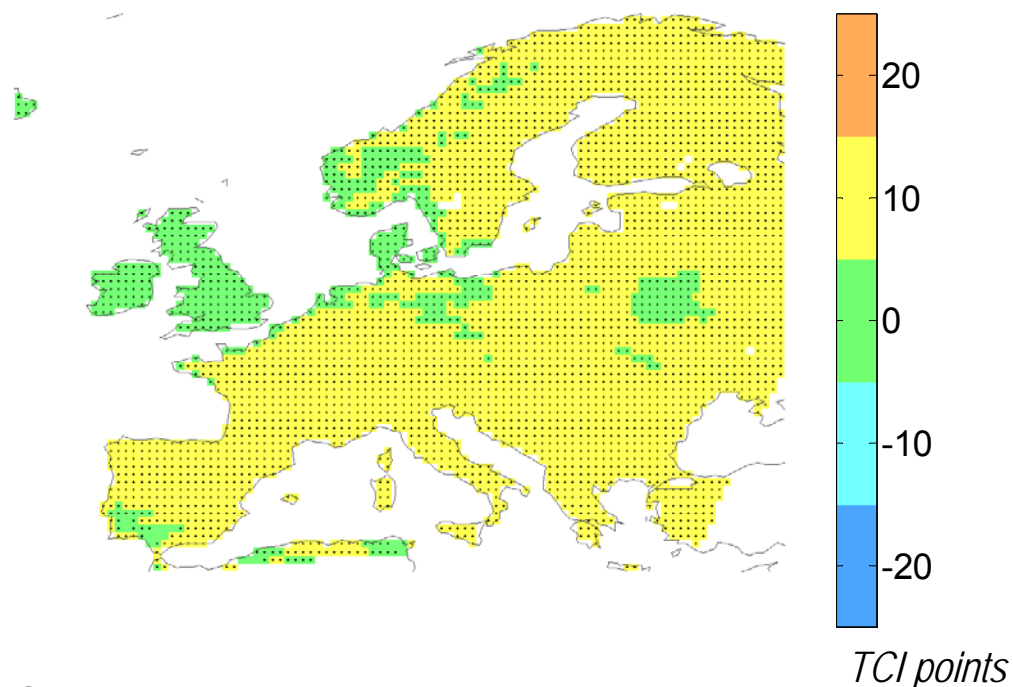


IPCC, AR4



# Results April

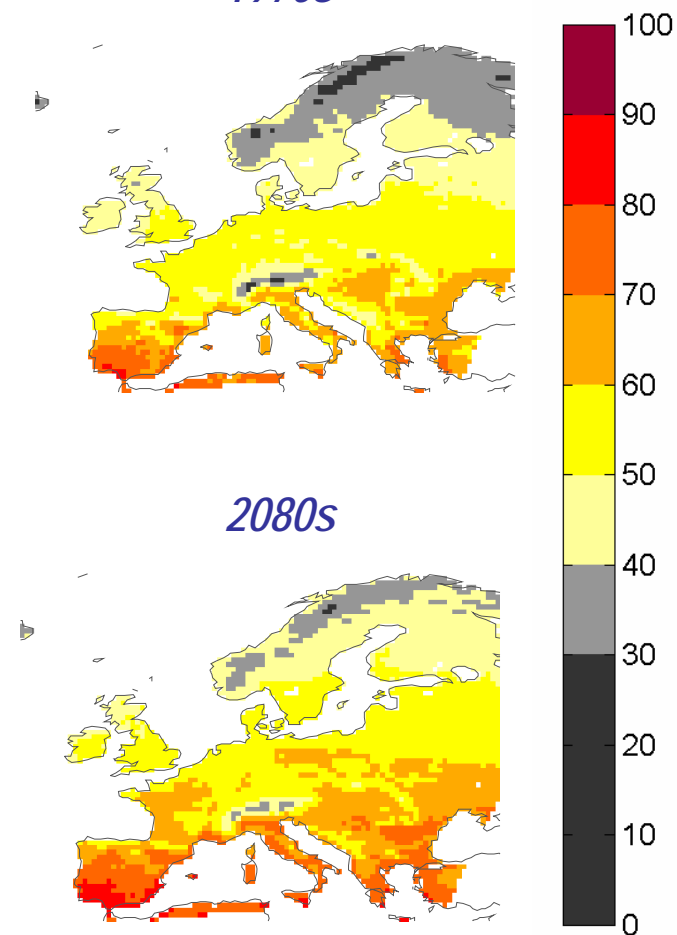
*change in main TCI*



Stipling means that the models agree on change (i.e. that the mean model difference is larger than the standard deviation of the model differences)

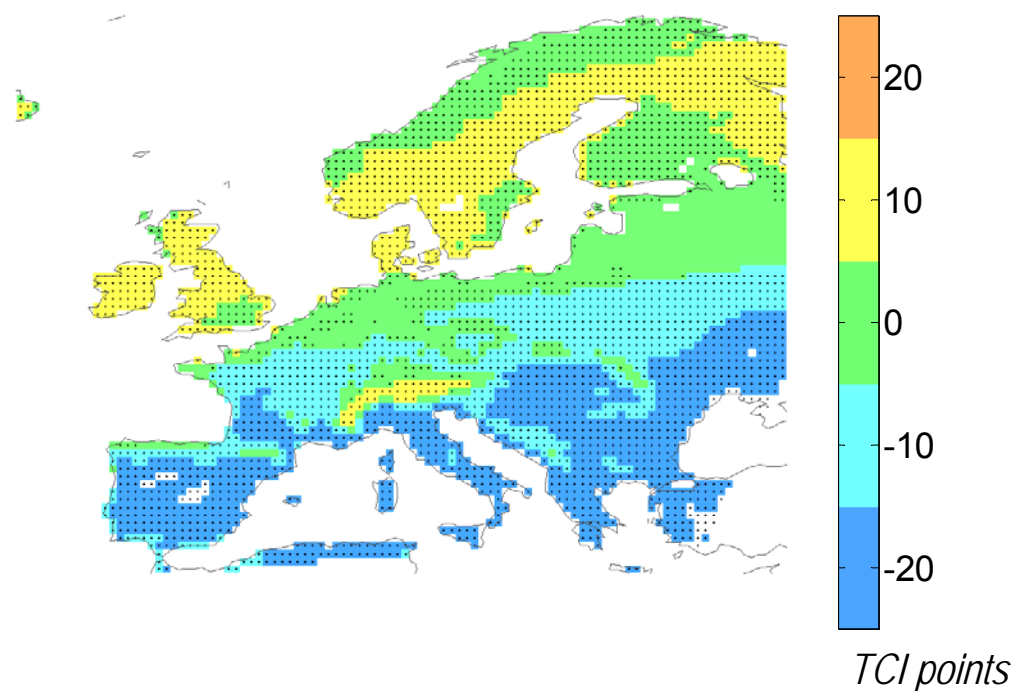
→ uniform increase in nearly all of Europe

*1970s*



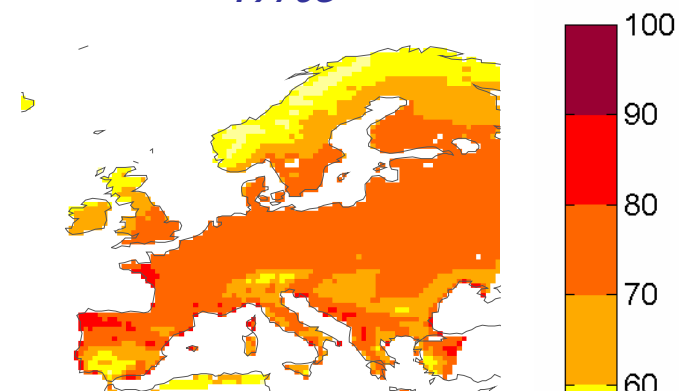
## Results July

*change in main TCI*

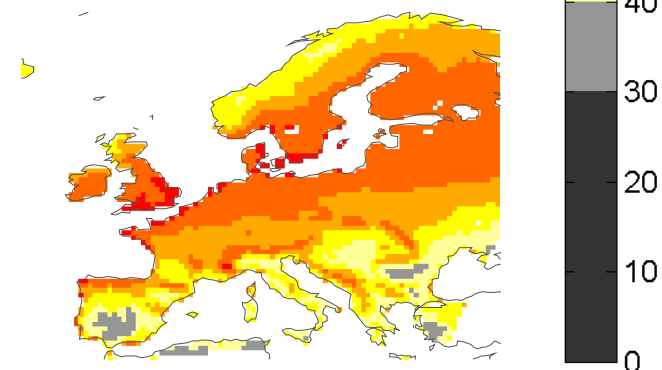


→ an increase in Scandinavia and Great Britain, but a strong decrease in all Southern Europe

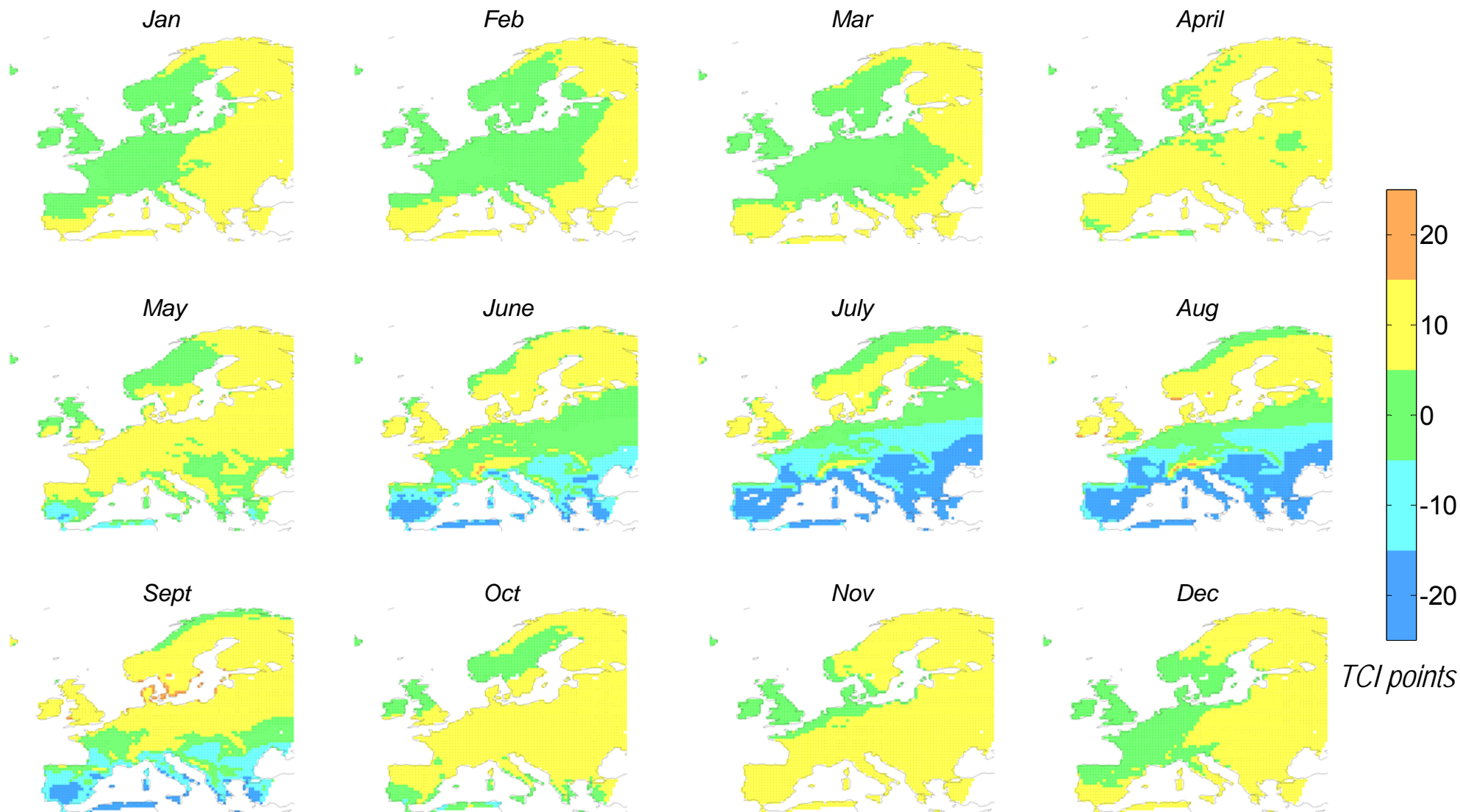
*1970s*



*2080s*

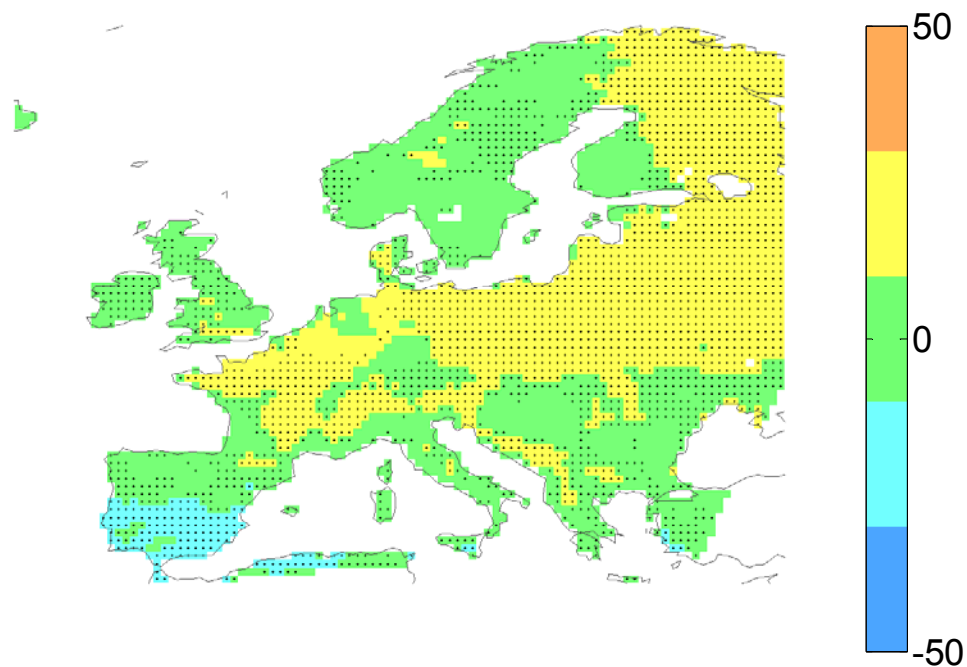


# Changes throughout the Year



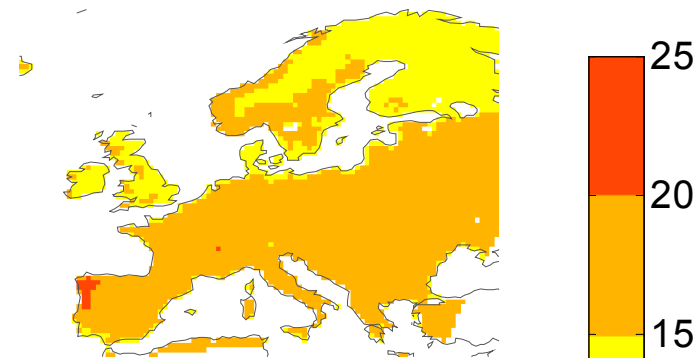
## Results Variability April (standard deviation)

*change in TCI variability in %*

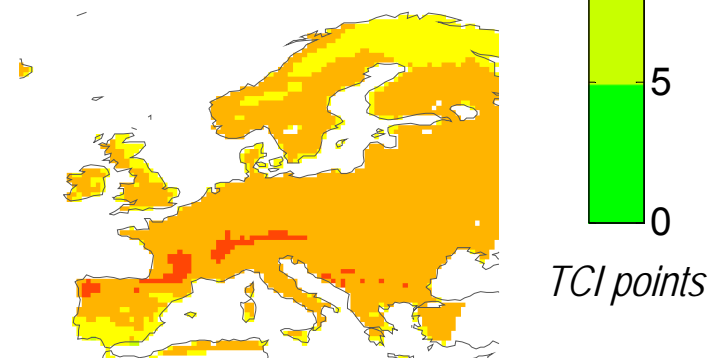


→ an increase in many parts, a decrease in Southern Spain and Portugal

*1970s*

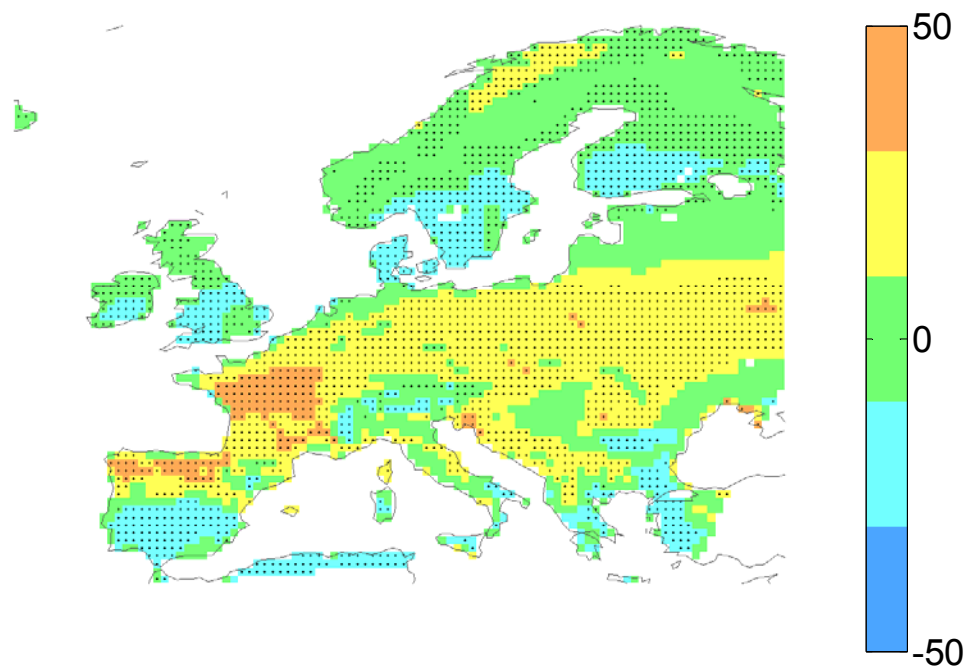


*2080s*



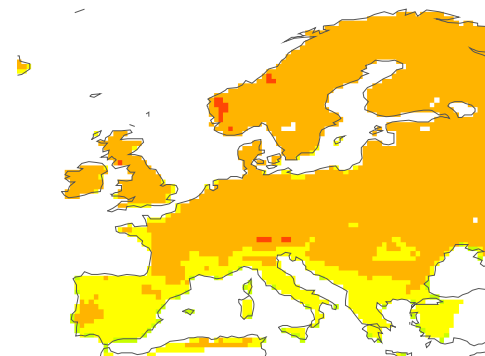
## Results Variability July (standard deviation)

*change in TCI variability in %*

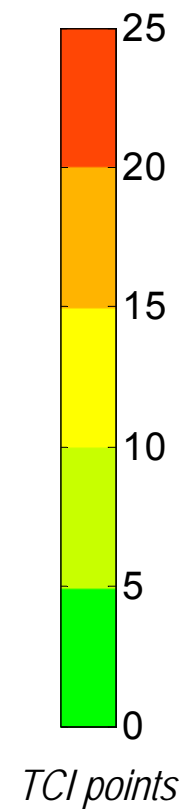
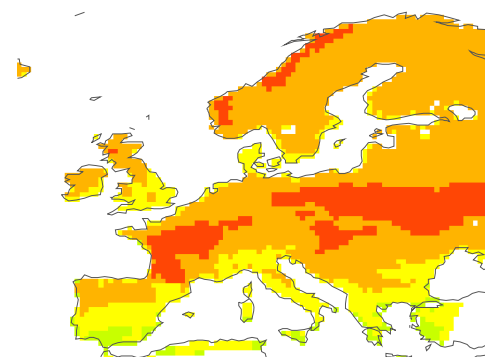


→ an increase in central Europe, a decrease to the North and South

*1970s*

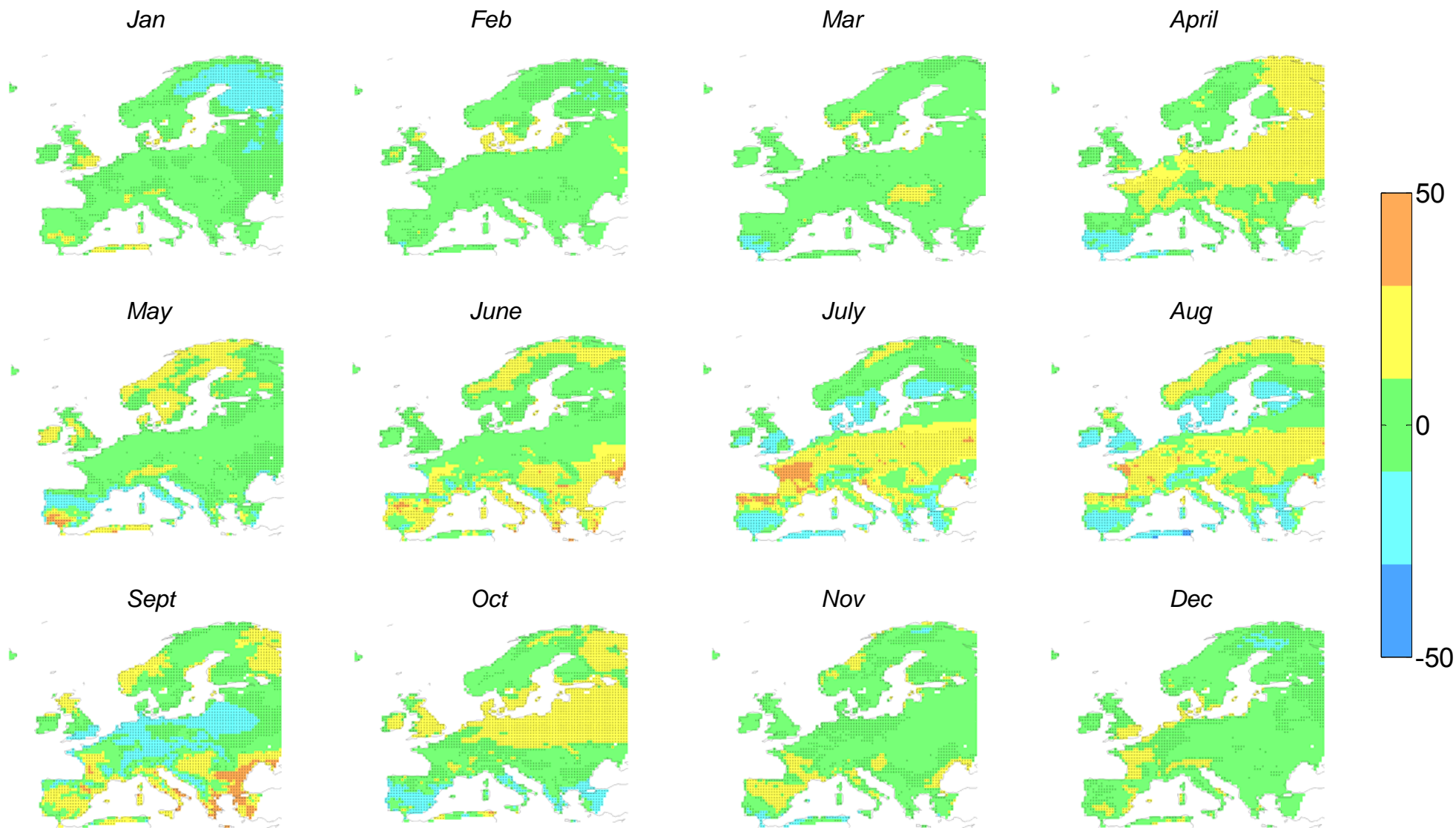


*2080s*





# Changes throughout the Year





## Limitations

## Solutions


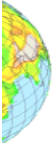

- ... of the TCI as a metric
    - subjective construction (weighting of sub-indices)
    - does not consider over-riding effect of physical parameters
    - only applicable to “sightseeing tourism”
  - ... of the climate model simulations
    - **do not fully captured uncertainty**: regional projections are heavily conditioned by the behaviour of the driving global model: only two global models included! It has been shown that other global models yield different results.
- 
- 
- 
- use the new index being developed by de Freitas et al.
  - use weather types (see Poster by Bas Amelung & Sabine Perch-Nielsen)
  - wait for new regional model simulations
  - or: in addition, use a number of GCMs to compare to, even though resolution is a lot lower



# Conclusions

Using a tourism climate metric...

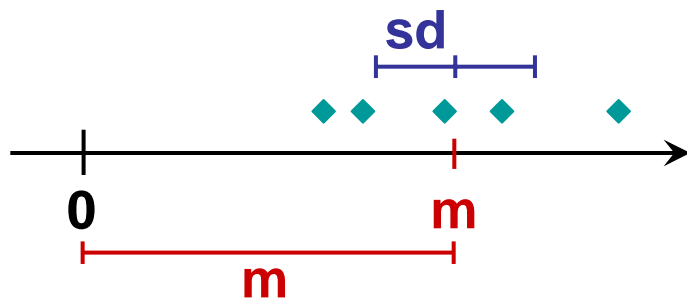
- has its limitations
  - subjective and selective choice of “optimal climate”
  - “optimal climate” differs culturally and also changes with time
  - covers only one aspect of the effect of climate change on tourism (no information on extreme events, water availability, effects of mitigation policies etc.)
- but is a valuable contribution to analysing the impacts of climate change on tourism
  - ➔ daily data > monthly data (gave different results and allows variability analysis)
  - ➔ high resolution > low resolution, but not of much use if this is at the cost of using less global model results
  - ➔ comparing different model results is very important for robustness



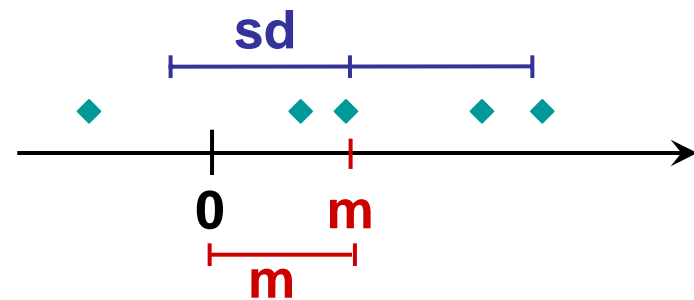
## Robustness of results: Do all Models Agree?

Method to determine when “models agree”:

- take the difference between 2080s and 1970s for each model
- if the mean of these is larger than their standard deviation, the models agree on the change for that gridpoint:



**mean > standard deviation**

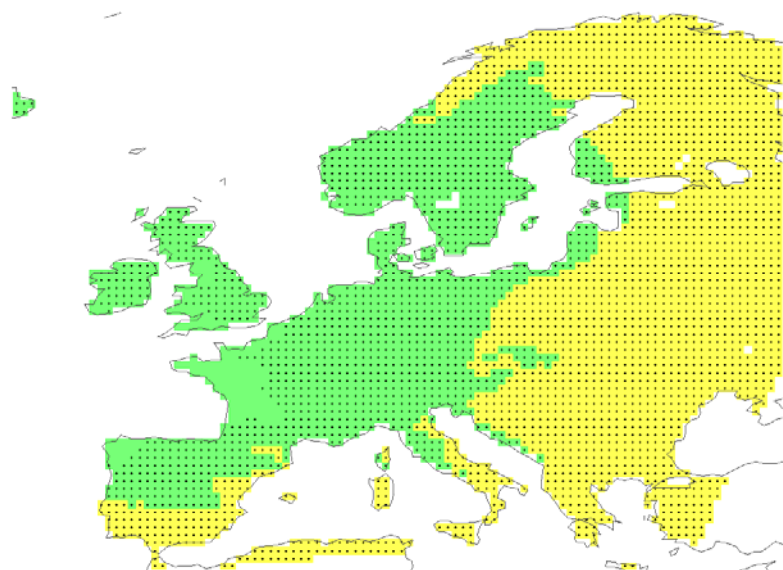


**mean < standard deviation**



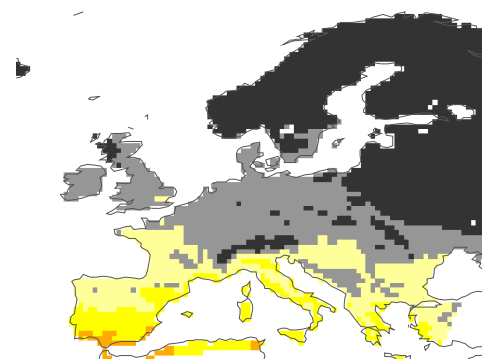
# Results January

*change in main TCI*

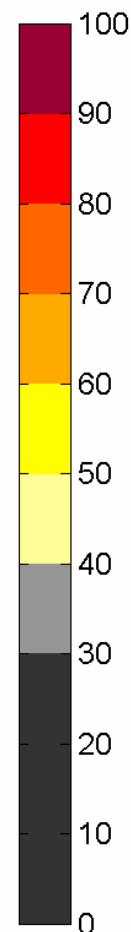
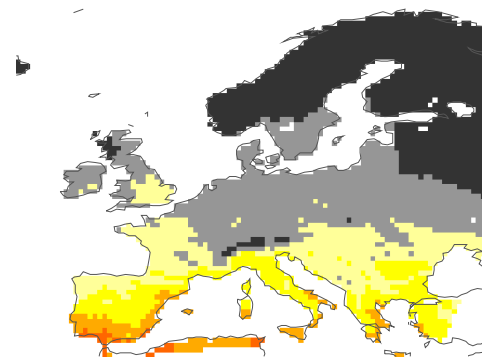


→ increase in Southern and Eastern Europe but most of Eastern Europe is still “unfavourable”

*1970s*

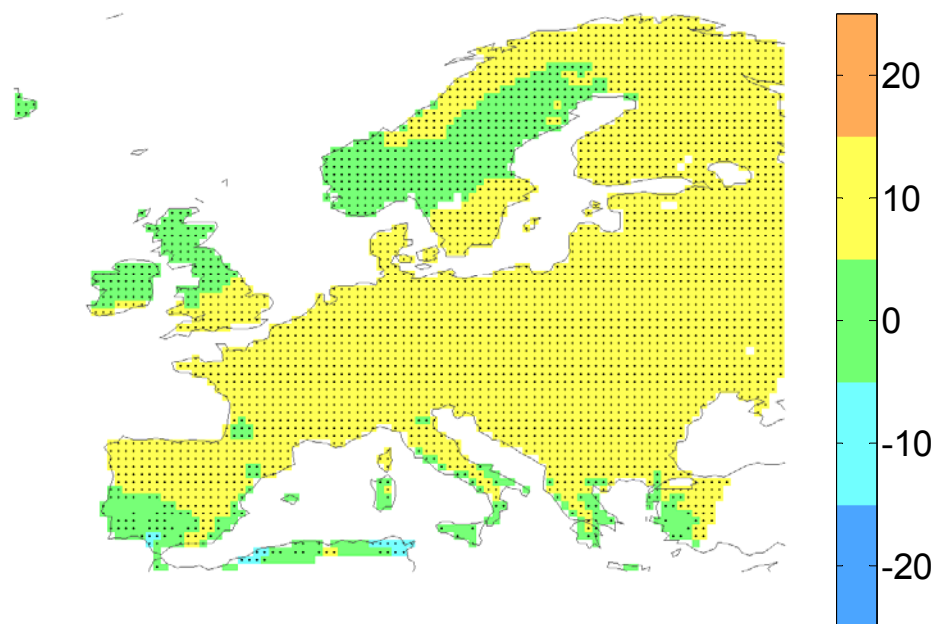


*2080s*



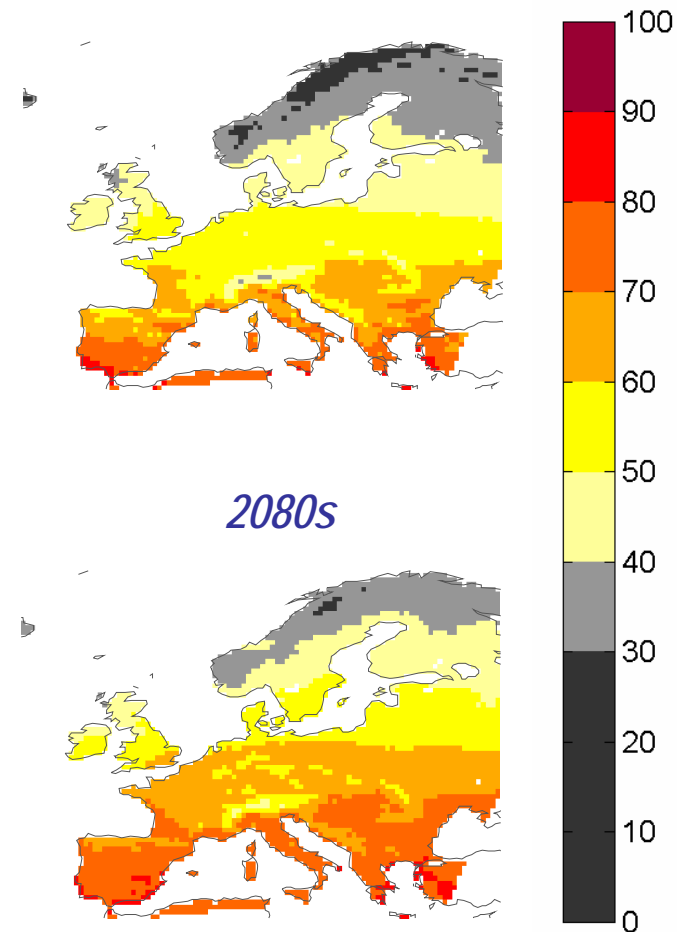
## Results October

*change in main TCI*

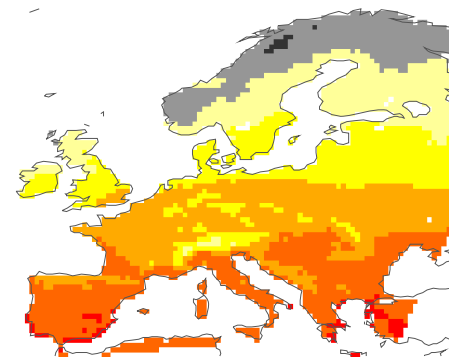


→ very similar to April, uniform increase nearly all over

*1970s*



*2080s*



# Development of the TCI throughout the Year

