Regional och lokal klimatinformation

SMHI

Rossby Centre 20 År
13-14 SEPT 2017
NORRKÖPING, SVERIGE

Is there a role for regional climate modelling in the next decade?

Jens Hesselbjerg Christensen
DMI

SMHI

Is there a role for regional climate modelling in the next decade?

Jens Hesselbjerg Christensen

Niels Bohr Institute, University of Copenhagen
&
UNI Research Climate, Bergen, Norway
&
Danish Meteorological Institute

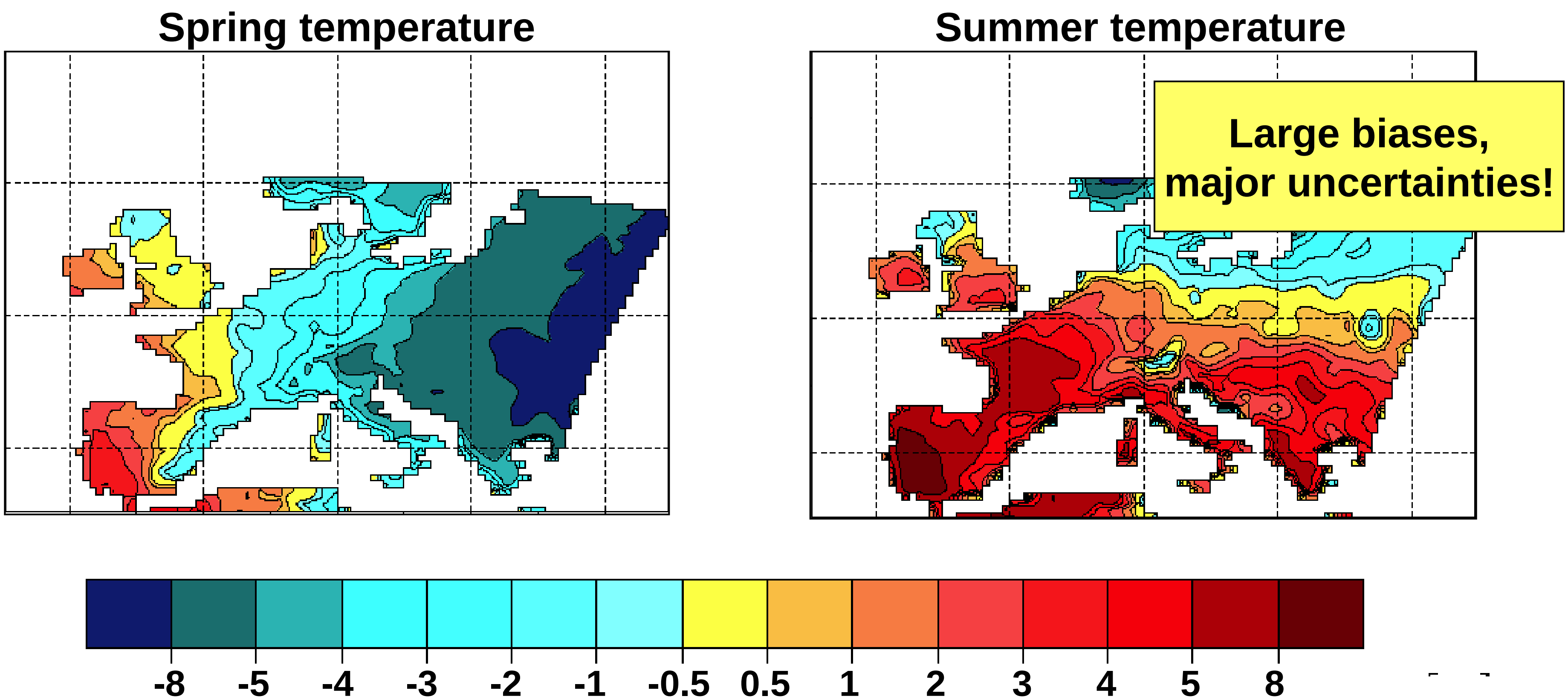
Framing thoughts

- Looking back
  - Learning from the past informs us about the future (?)
  - What are the real remaining issues of regional modeling for future projections?
  - Signal-to-noise
- GCMs catching up on resolution
  - so what?
- RCMs catching up
  - Added value
- May we be using ensembles in a wiser way?
- Bias correction (not time for this)?
- Using the GCM/RCM/RCP matrix; is it possible?
- A possible (my) answer to the question posed?

Regional climate simulations 20 years ago

ECHAM4 (T42, 250 km) => RegCM2 (70 km)

Bias of control run (CTRL-CRU), 5 years



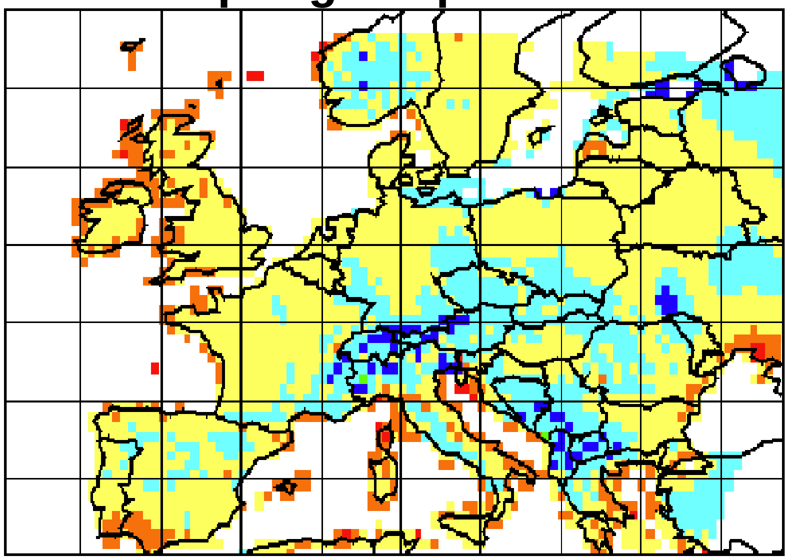
EU Projects REGIONAL and RACCS (1992-1996); Machenhauer et al. (1998, MPI-Report 275)

Climate simulations 15 years ago

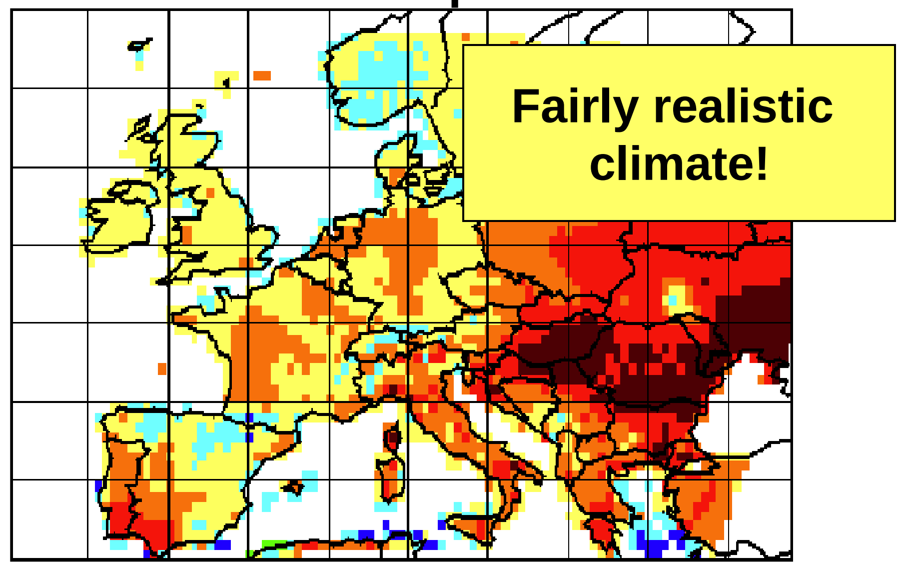
HadAM3 (120 km) => PRUDENCE Regional Models (50 km)

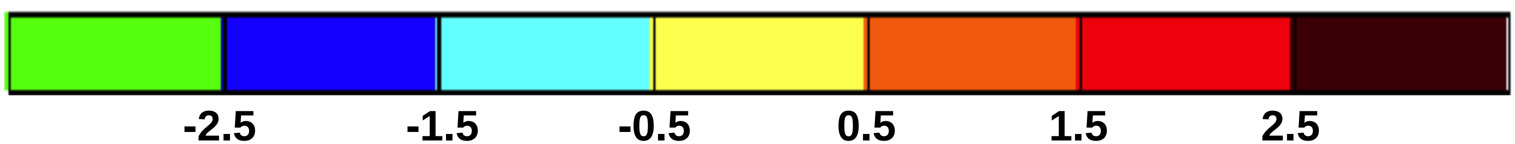
Bias of control run (CTRL-CRU), 30 years

Spring temperature



Summer temperature





EU Project PRUDENCE (2001-2004). Coordinator: Jens H. Christensen, DMI, Copenhagen

Climate simulations 10 years ago

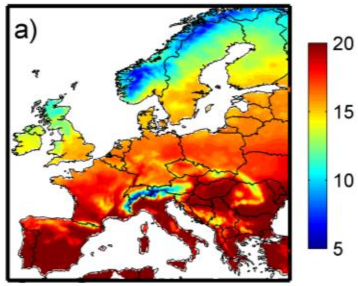
ECMWF re-analysis => ENSEMBLES Regional Models (25 km)

Bias of perfect boundary run, 30 years compared with CRU

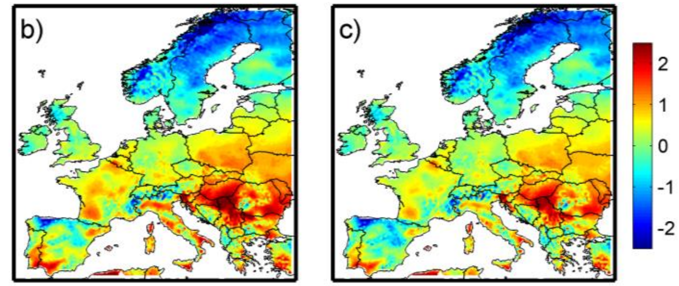
EU Project ENSEMBLES (2004-2009). Coordinator: J. Mittchel, Met Office, UK

ENSEMBLES JJA temperatures - ERA40 driven

OBS



Ens Mean Bias



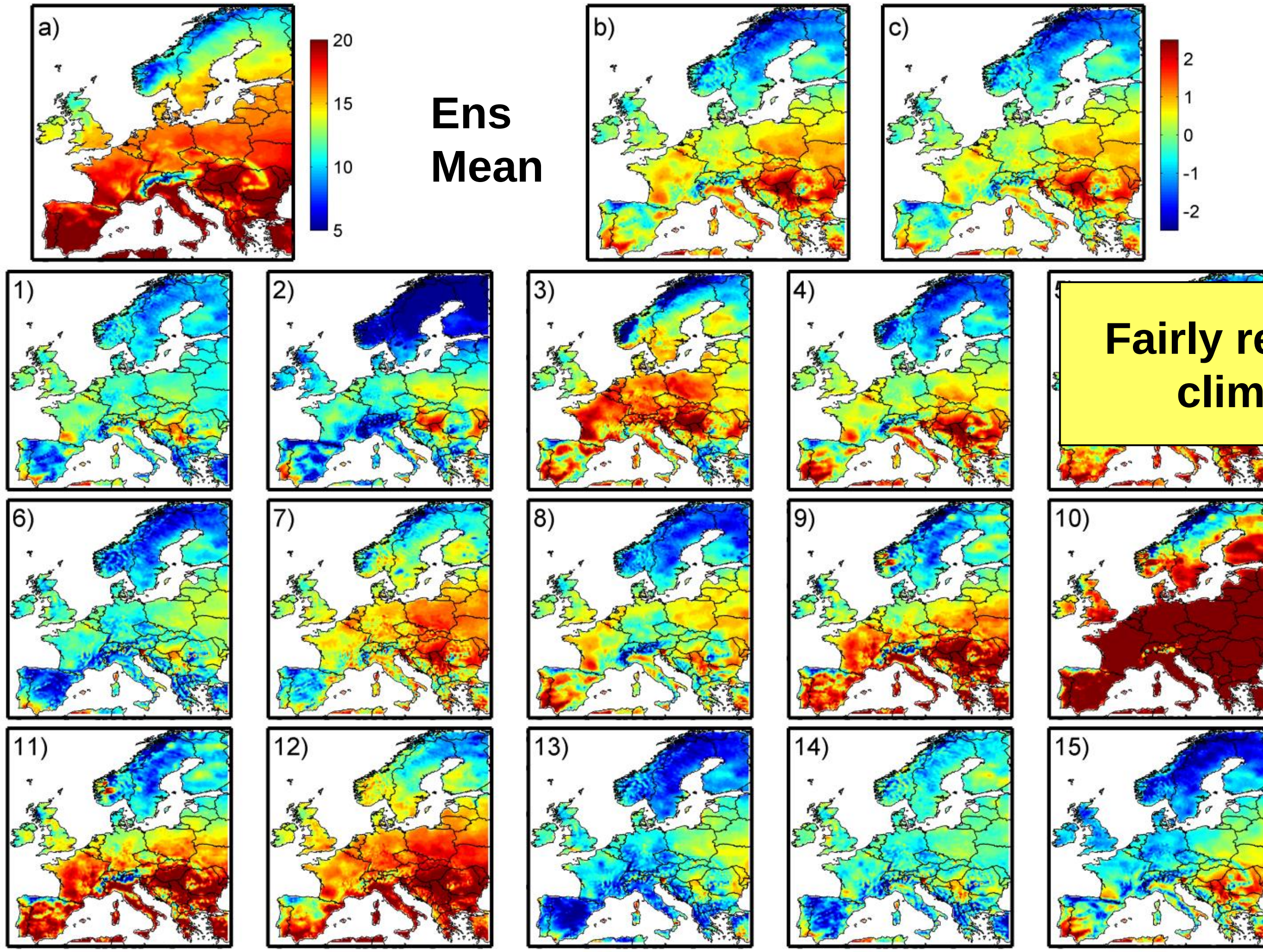
Fairly realistic climate!

ENSEMBLES JJA temperatures - ERA40 driven

OBS

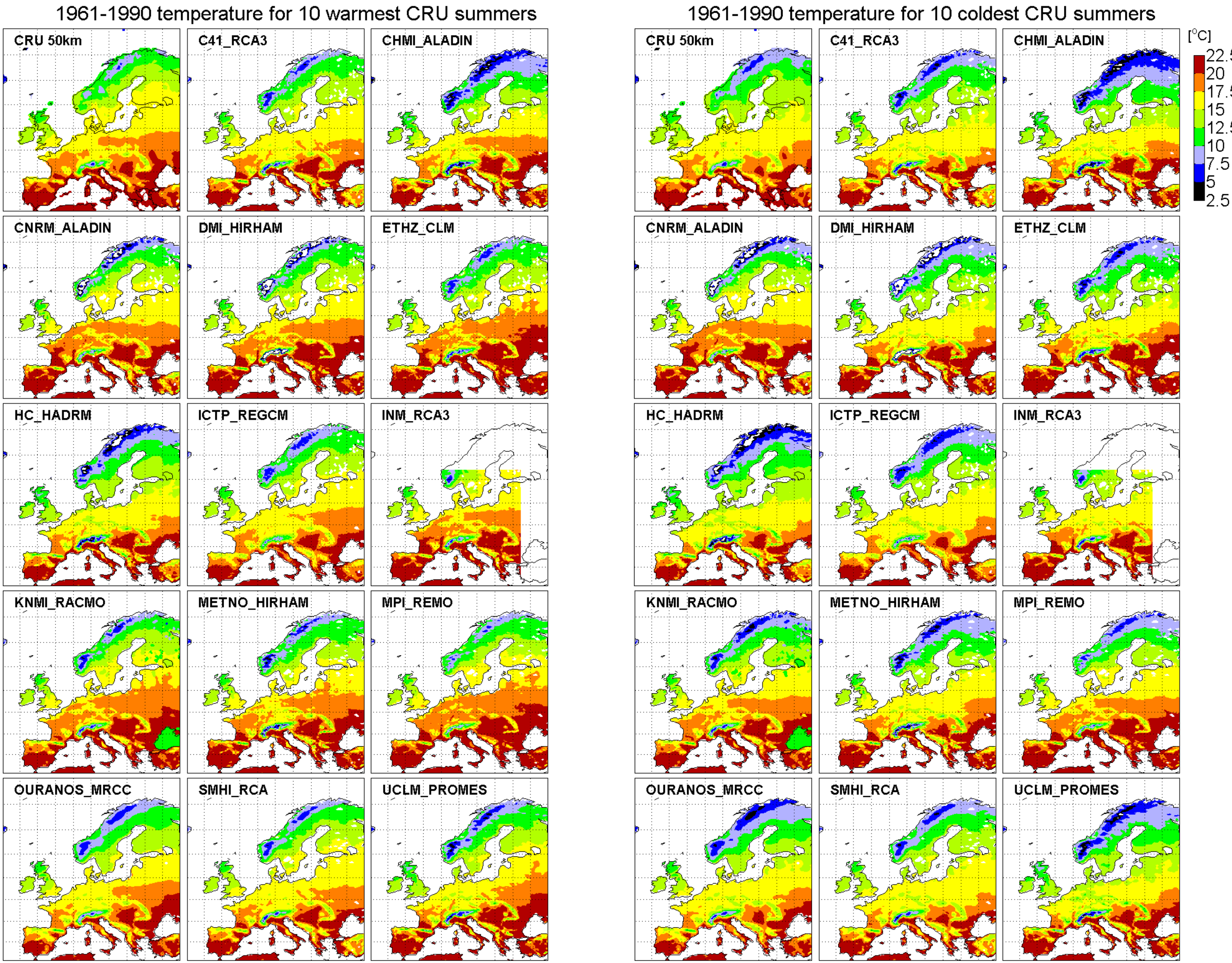
Ens Mean

Bias

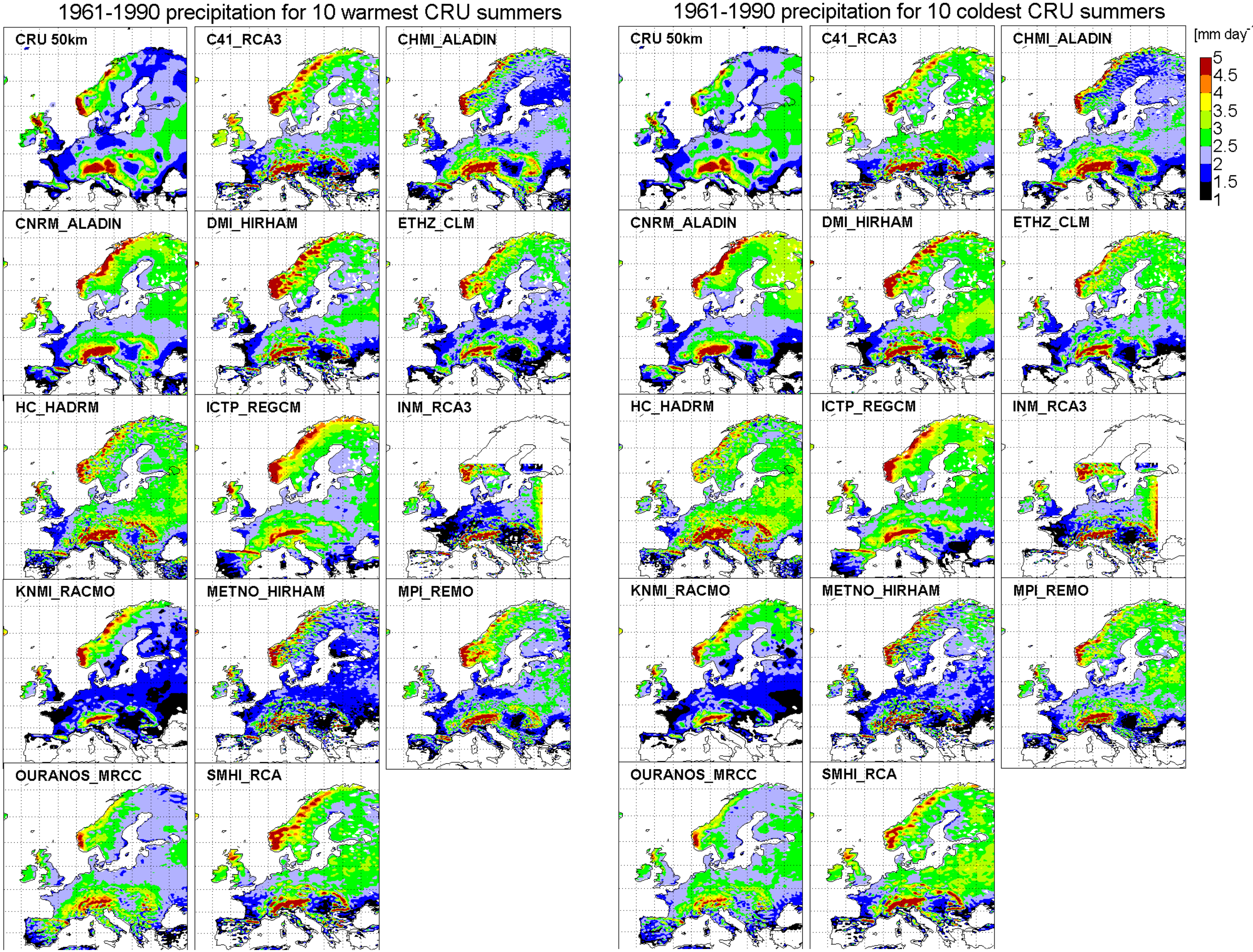


Fairly realistic climate!

Christensen et al. (2010)

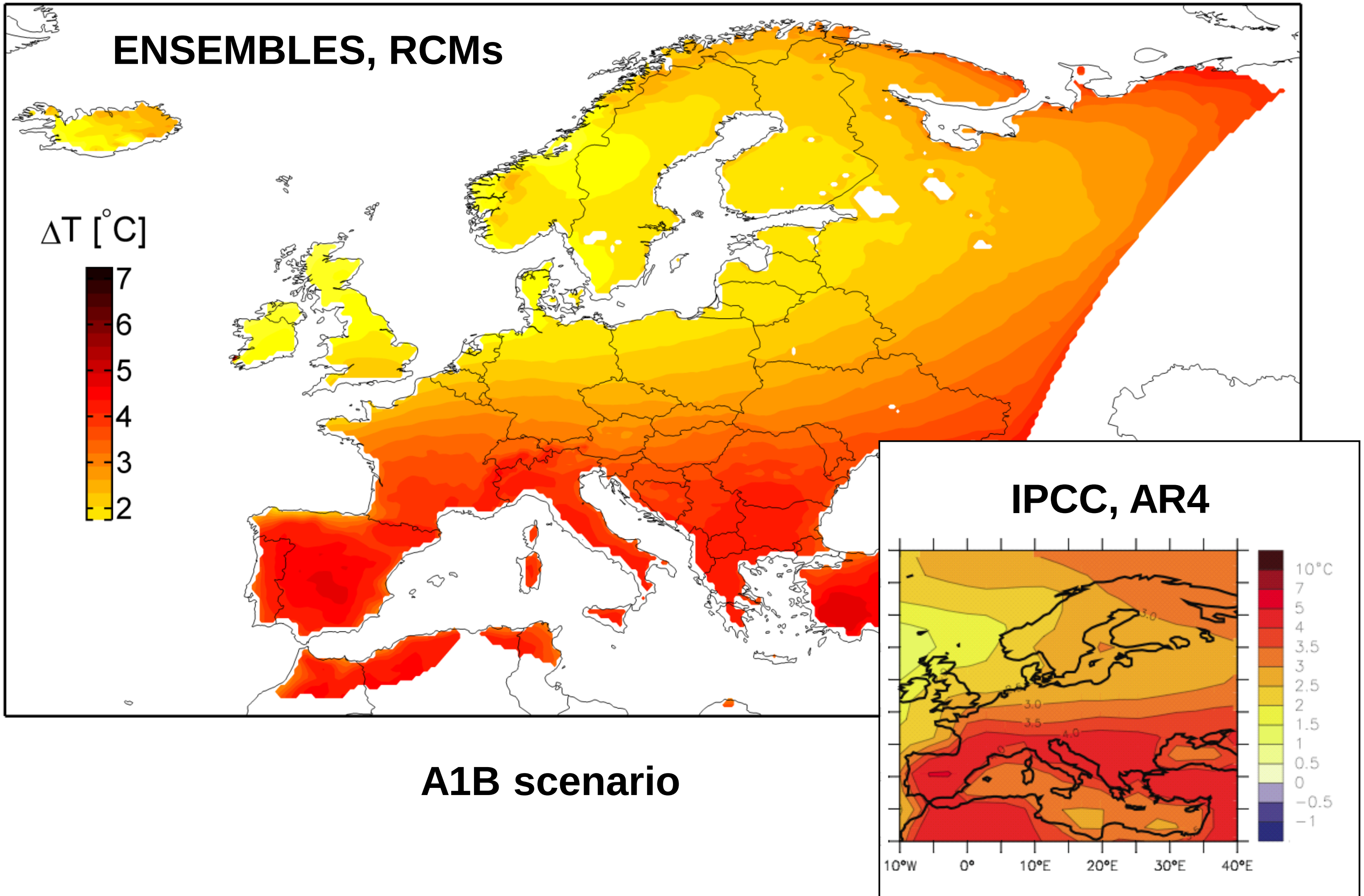


1961-1990 temperature for 10 warmest CRU summers
1961-1990 temperature for 10 coldest CRU summers
CRU 50km
C41_RCA3
CHMI_ALADIN
CNRM_ALADIN
DMI_HIRHAM
ETHZ_CLM
HC_HADRM
ICTP_REGCM
INM_RCA3
KNMI_RACMO
METNO_HIRHAM
MPI_REMO
OURANOS_MRCC
SMHI_RCA
UCLM_PROMES
[°C]
22.5
20
17.5
15
12.5
10
7.5
5
2.5


1961-1990 precipitation for 10 warmest CRU summers
1961-1990 precipitation for 10 coldest CRU summers
[mm day-1]
5
4.5
4
3.5
3
2.5
2
1.5
1
CRU 50km
C41_RCA3
CHMI_ALADIN
CNRM_ALADIN
DMI_HIRHAM
ETHZ_CLM
HC_HADRM
ICTP_REGCM
INM_RCA3
KNMI_RACMO
METNO_HIRHAM
MPI_REMO
OURANOS_MRCC
SMHI_RCA

JJA

$$\langle T_{change} \rangle = \langle T_{2071-2100} - T_{1961-1990} \rangle$$



A1B scenario

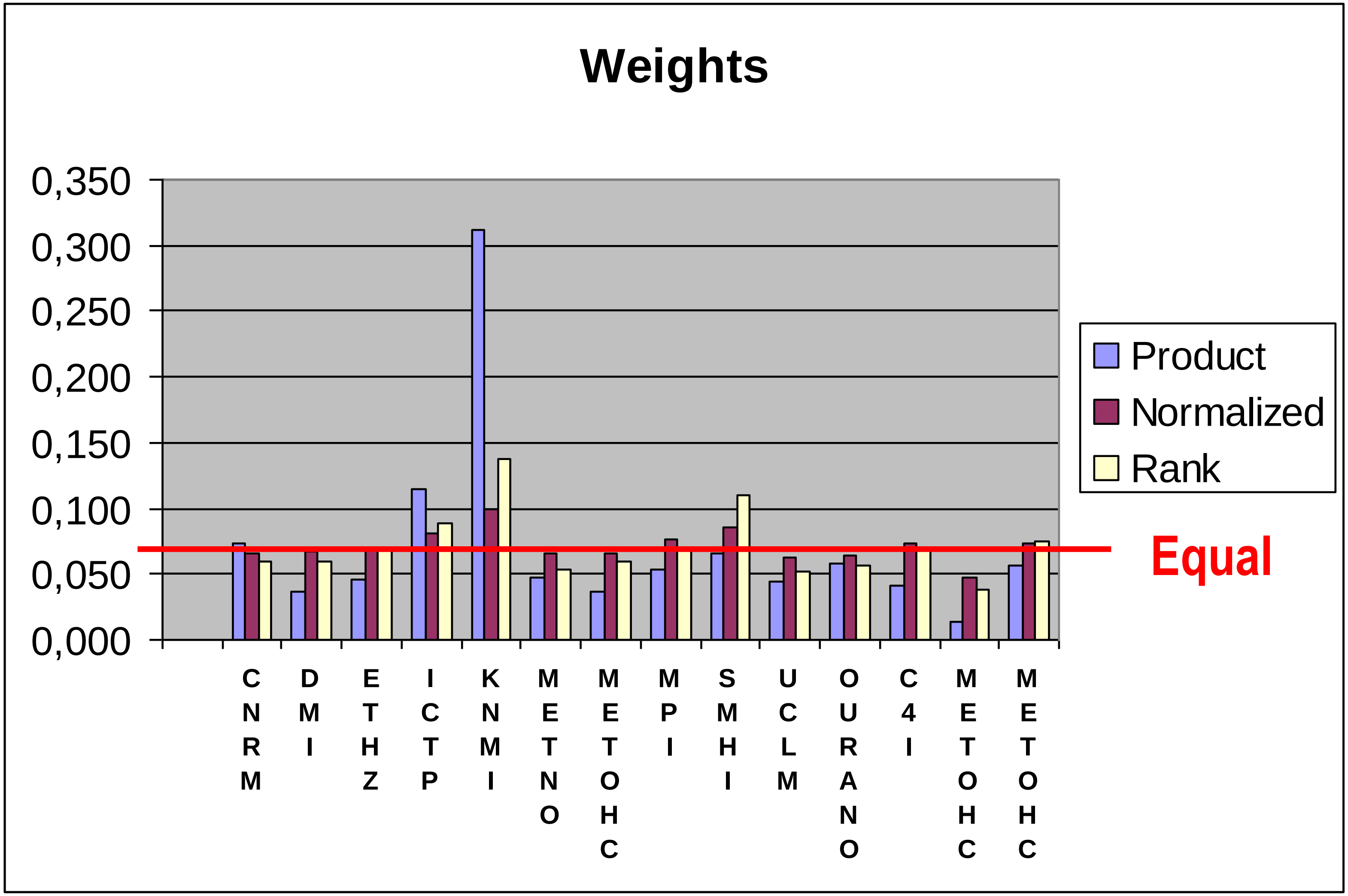
Methodological approach

Six metrics identified based on ERA40-driven runs

- **F1: Large scale circulation and weather regimes (CNRM)**
- **F2: Temperature and precipitation meso-scale signal (ICTP)**
- **F3: PDFs of daily precipitation and temperature (DMI, UCLM,SHMI)**
- **F4: Temperature and precipitation extremes (KNMI; HC)**
- **F5: Temperature trends (MPI)**
- **F6: Temperature and precipitation annual cycle (CUNI)**

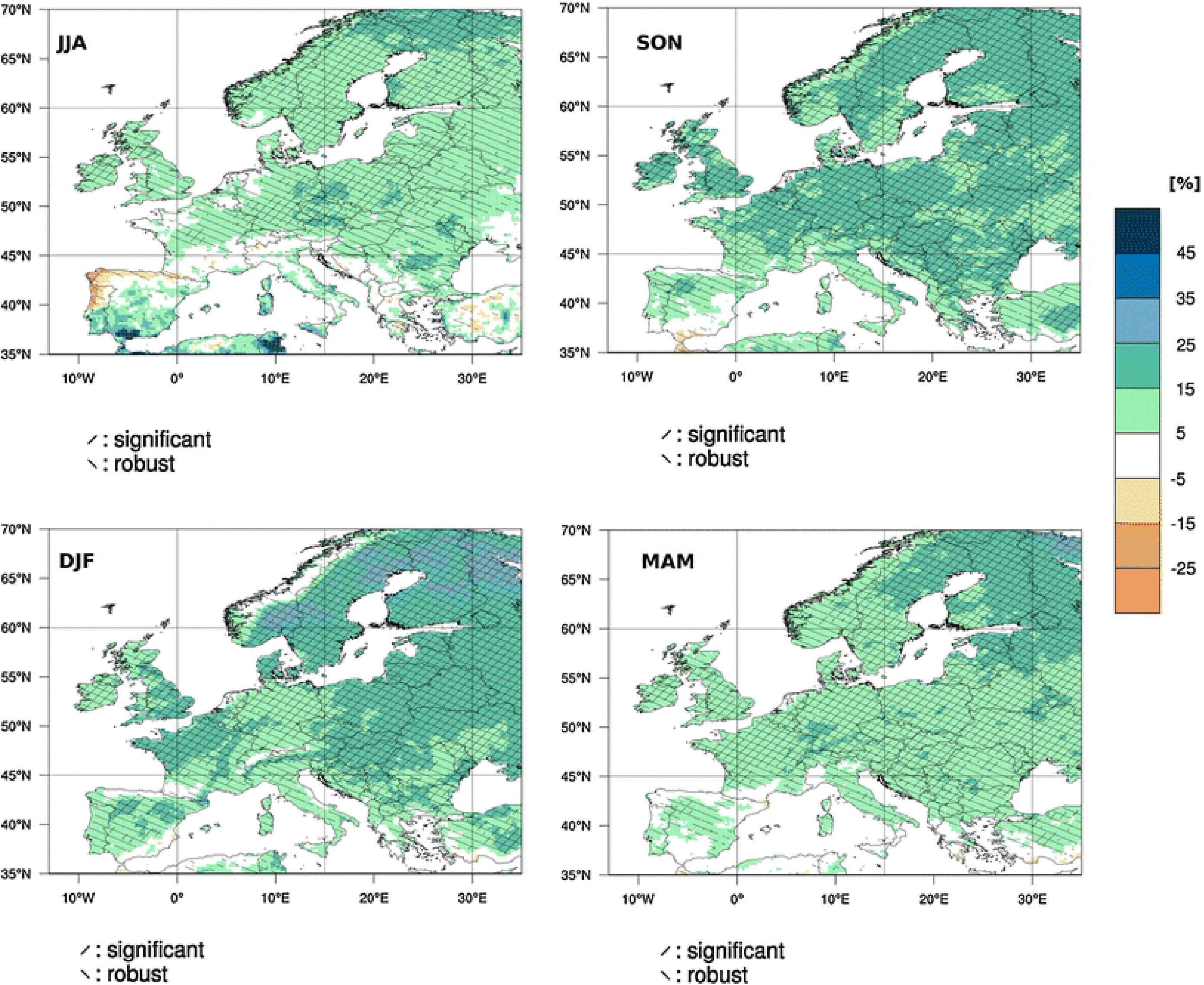
$$w_{RCM} = \prod_{i=1}^{6} f_i^{n_i}$$

The winner is



Climate simulations 5 years ago

ENSEMBLES

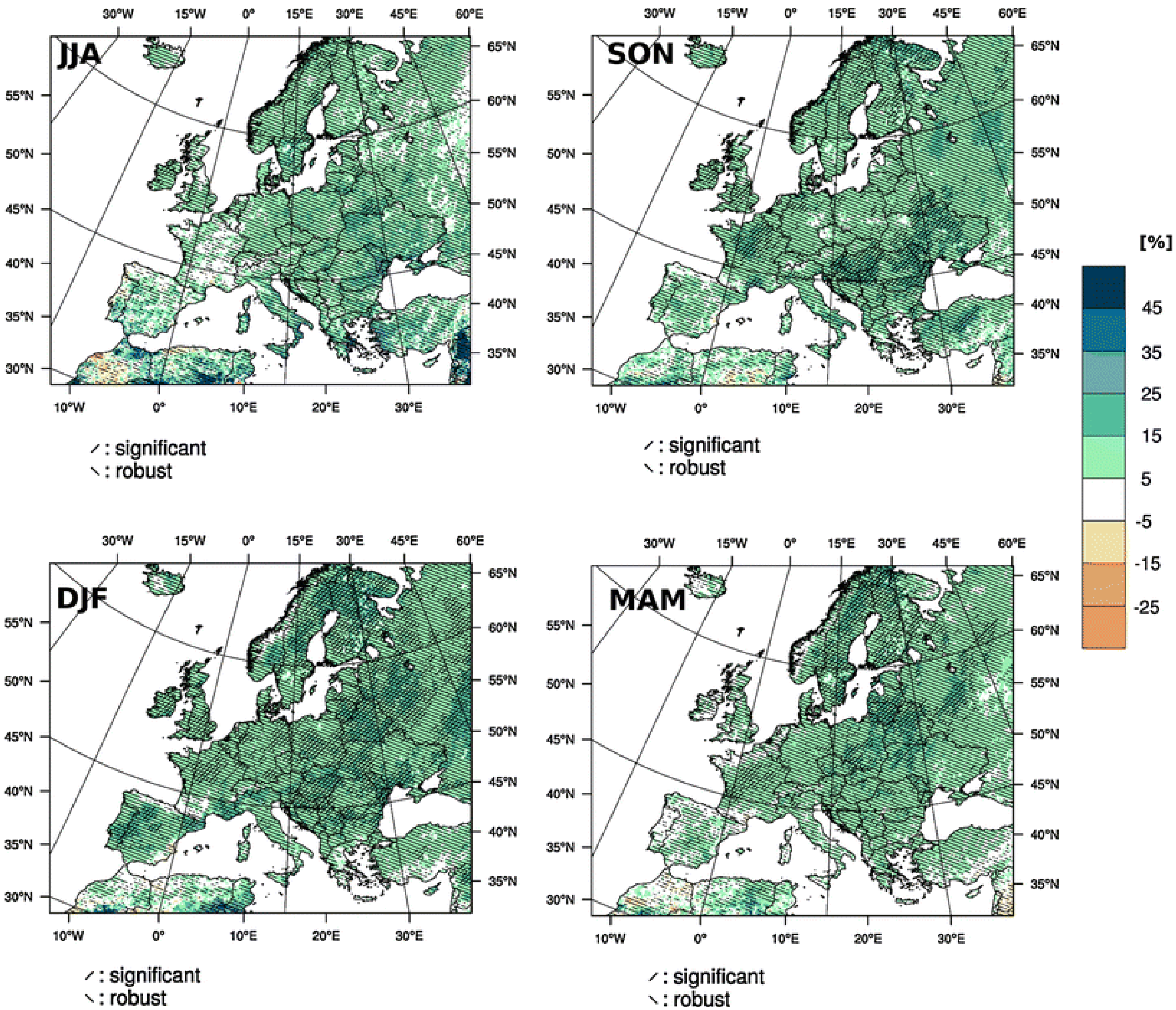


Projected seasonal changes of heavy precipitation (%) based on A1B
2071–2100 compared to 1971–2000. *Hatched* areas indicate regions with robust and/or statistical significant change

Jacob et al. (2014)

Climate simulations 5 years ago

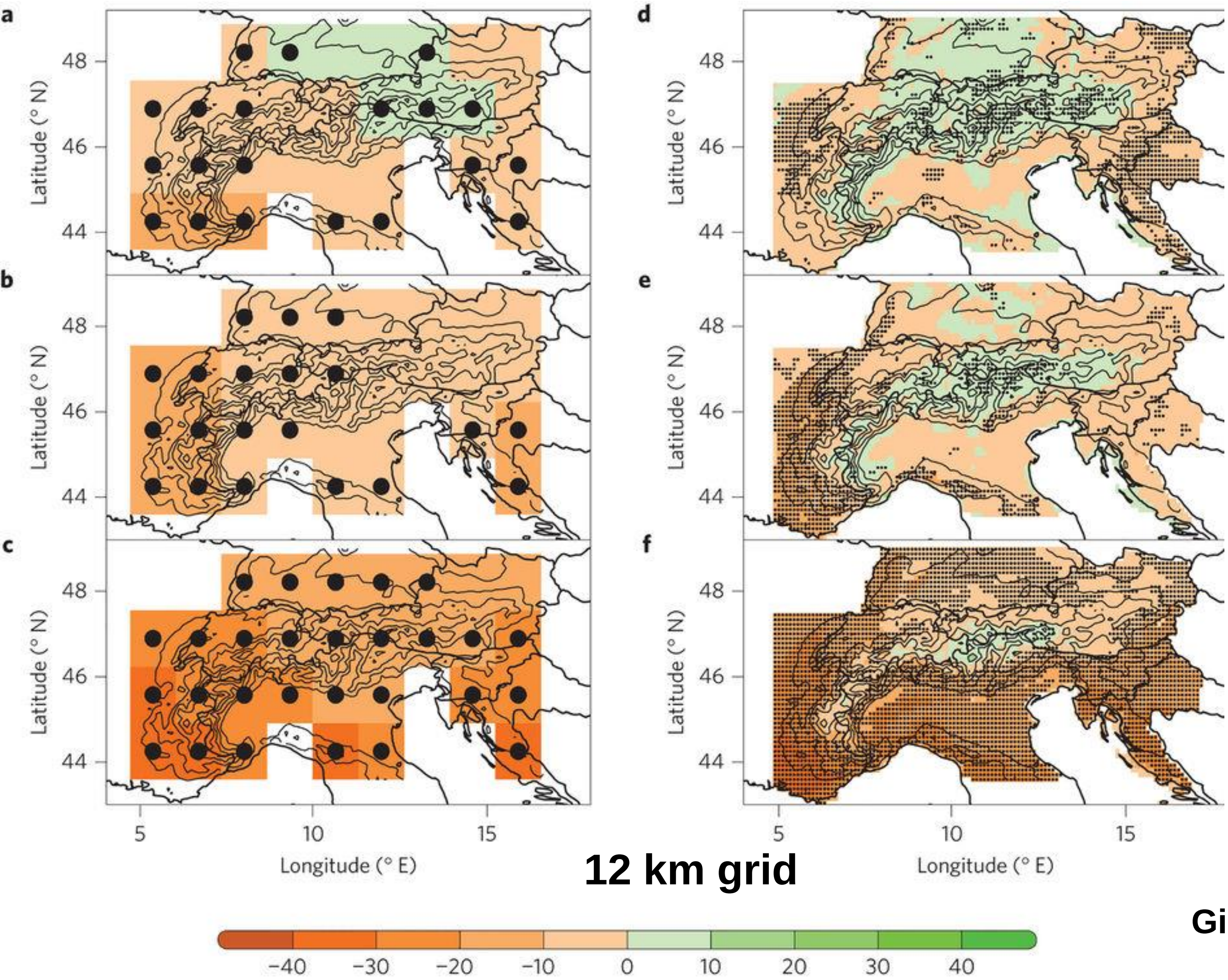
EURO-CORDEX



Projected seasonal changes of heavy precipitation (%) based on RCP4.5
2071–2100 compared to 1971–2000.
Hatched areas indicate regions with robust and/or statistical significant change

Jacob et al. (2014)

Resolution matters – multi-model mean

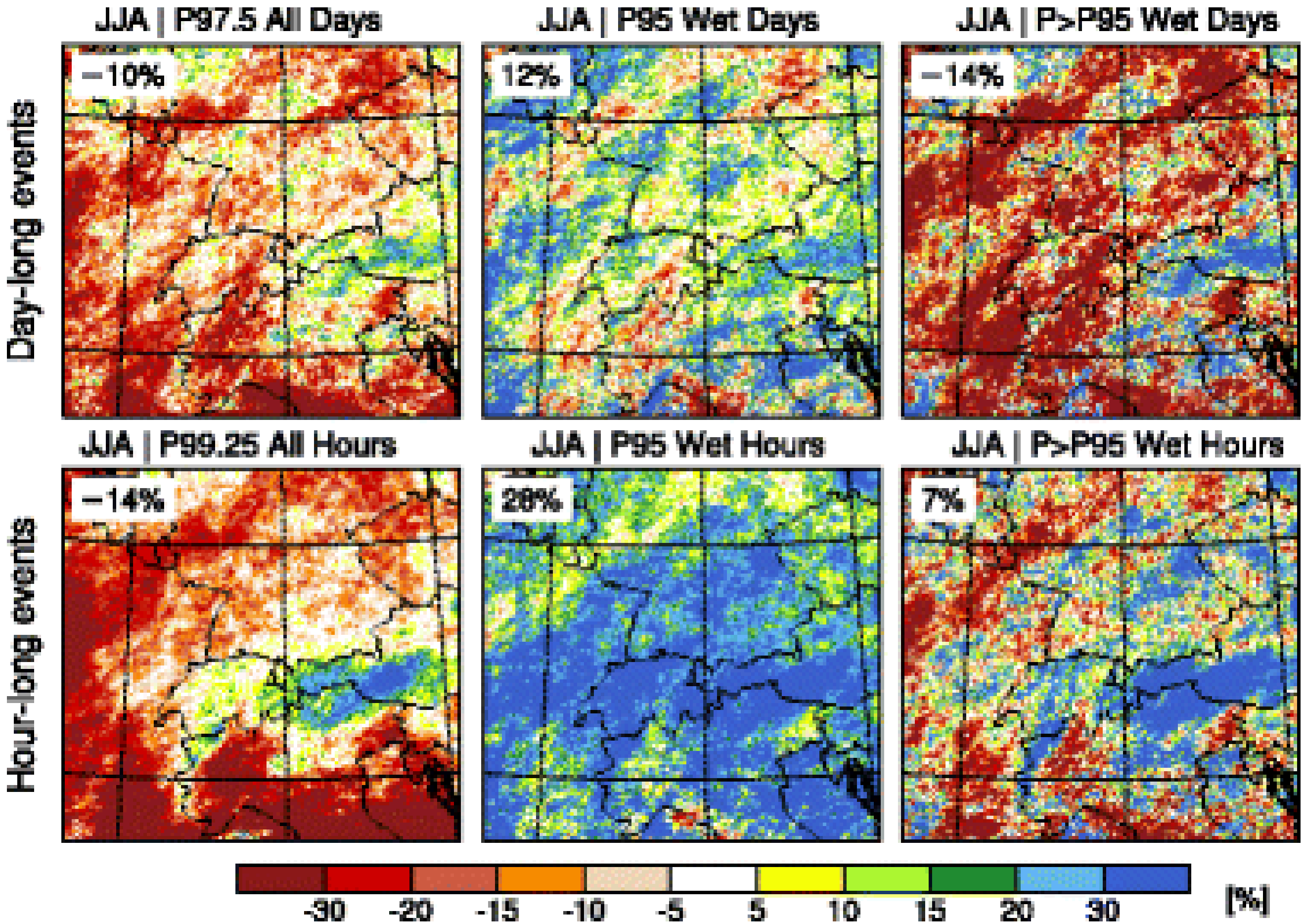


Giorgi et al. (2016)

Ever higher resolution

2.2km grid spacing

Heavy summer precip end century RCP8.5 vs. present day



all-day percentiles

wet-day percentiles

frequency of exceedance of threshold

(Schär et al. 2016)

Annual mean surface air temperature change (RCP4.5: 2081-2100)

42 CMIP5 models (IPCC, 2013)

Spatial structure of surface warming

Patterns of warming very similar in CMIP3 (used in AR4) and CMIP5 models (used in AR5):

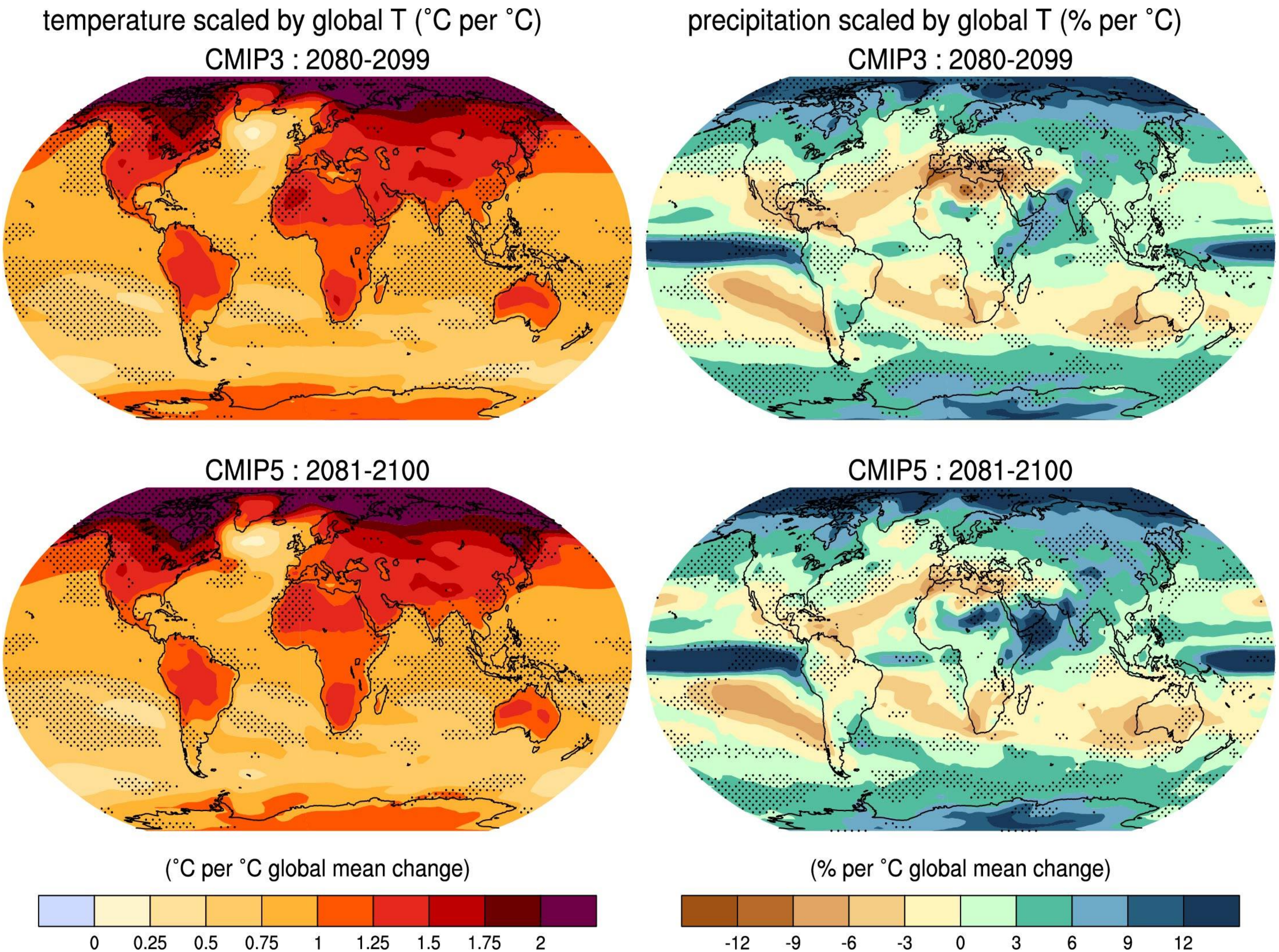
- **Greatest warming over the Arctic**
- **Land warms more than ocean**
- **Minimum warming over northern North Atlantic and parts of Southern Ocean**

Spatial patterns of warming also similar among different RCP scenarios

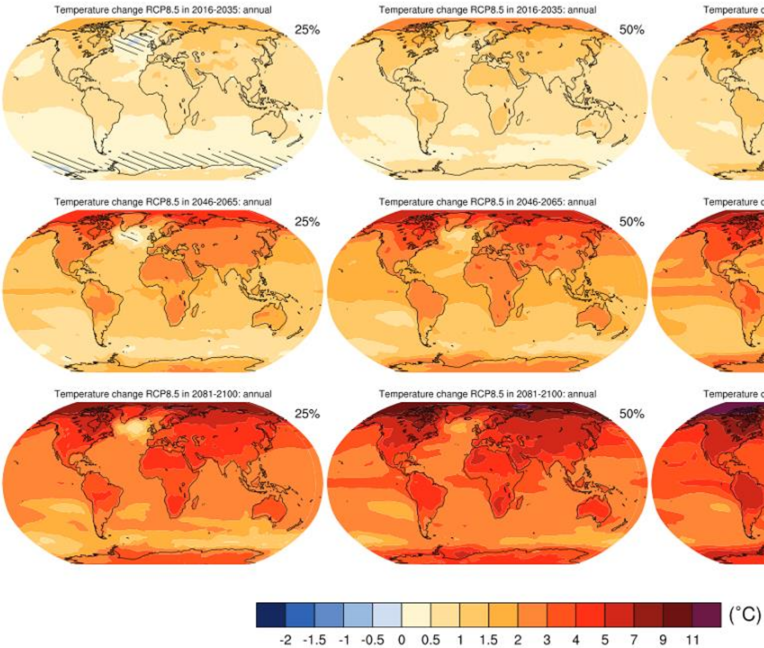
- **Caveat, though as e.g. spatial and temporal differences in e.g. sulphate aerosols can cause differences in patterns**

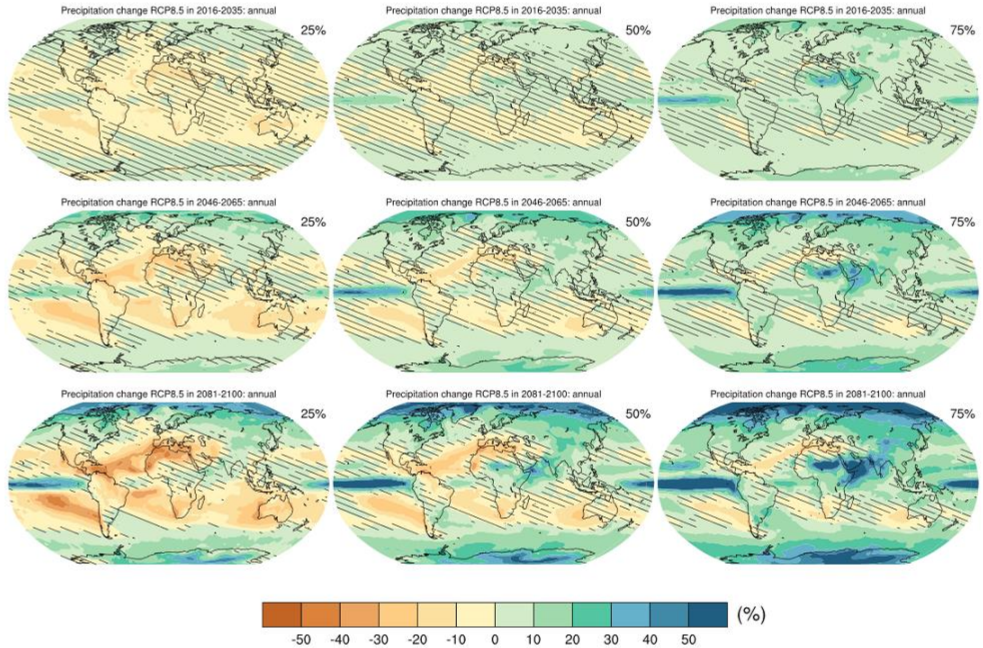
AR6?

Spatial structure of surface warming

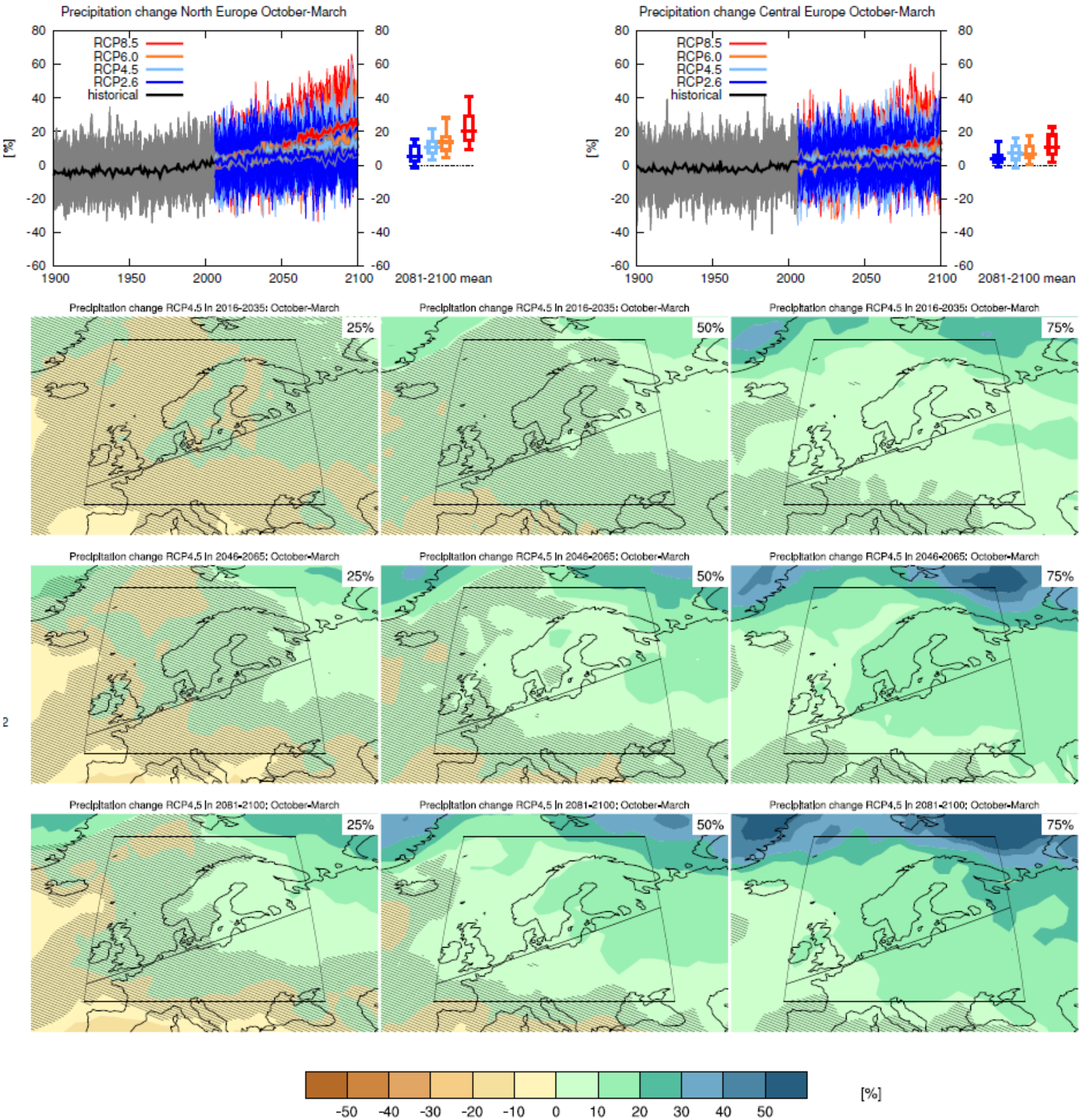


Uncertainty in projections





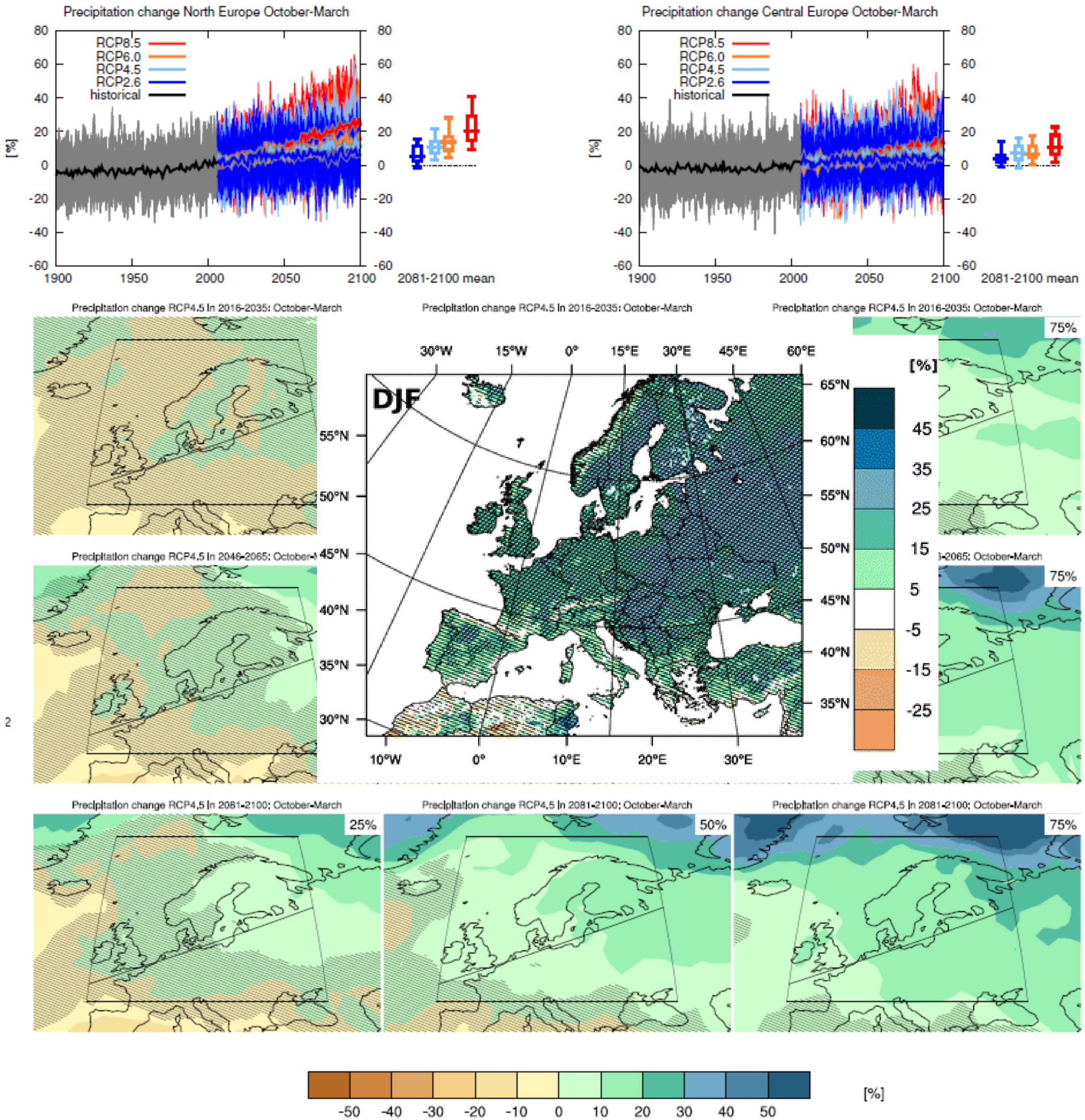
IPCC AR5 Atlas (2013)



Precipitation change North Europe October-March
Precipitation change Central Europe October-March
RCP8.5
RCP6.0
RCP4.5
RCP2.6
historical
[%]
80
60
40
20
0
-20
-40
-60
1900
1950
2000
2050
2100
2081-2100 mean
Precipitation change RCP4.5 in 2016-2035: October-March
Precipitation change RCP4.5 in 2046-2065: October-March
Precipitation change RCP4.5 in 2081-2100: October-March
25%
50%
75%
-50 -40 -30 -20 -10 0 10 20 30 40 50
[%]

2

(IPCC, 2013)

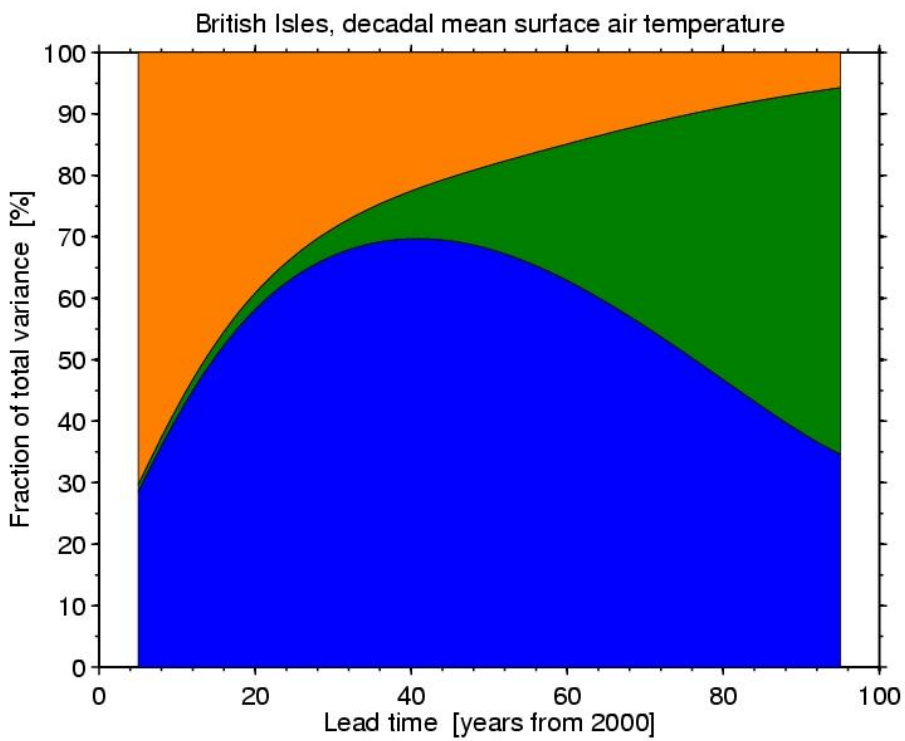


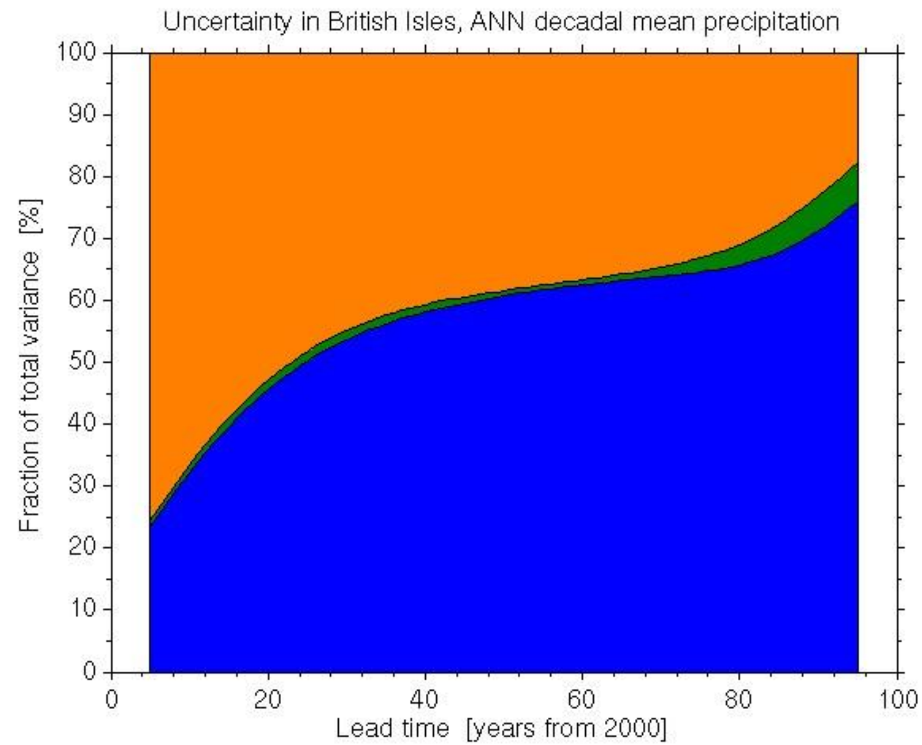
(IPCC, 2013)
(Jacob et al., 2014)

Natural climate variability

Relative importance of different sources of uncertainty

UK - 10 years mean temp. and precip.



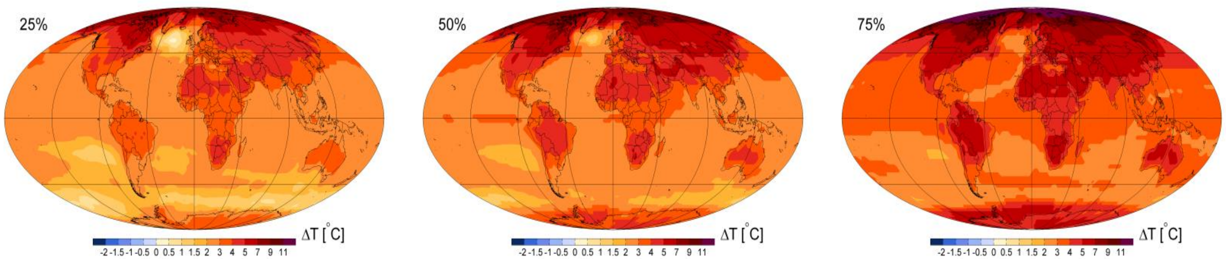


Blue: Uncertainty due to climate models (GCMs)
Green: Uncertainty due to GHG emission scenarios
Orange : Uncertainty due to internal (natural) variability

Hawkins and Sutton, 2009 & 2010

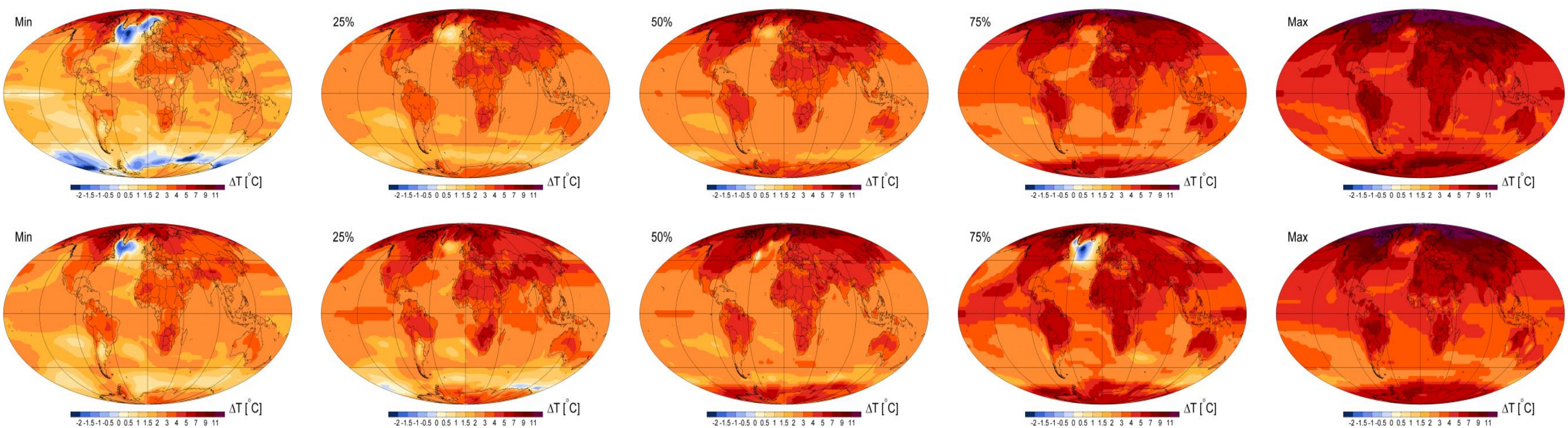
Uncertainty in projections

Grid point statistics



Uncertainty in projections

Grid point statistics



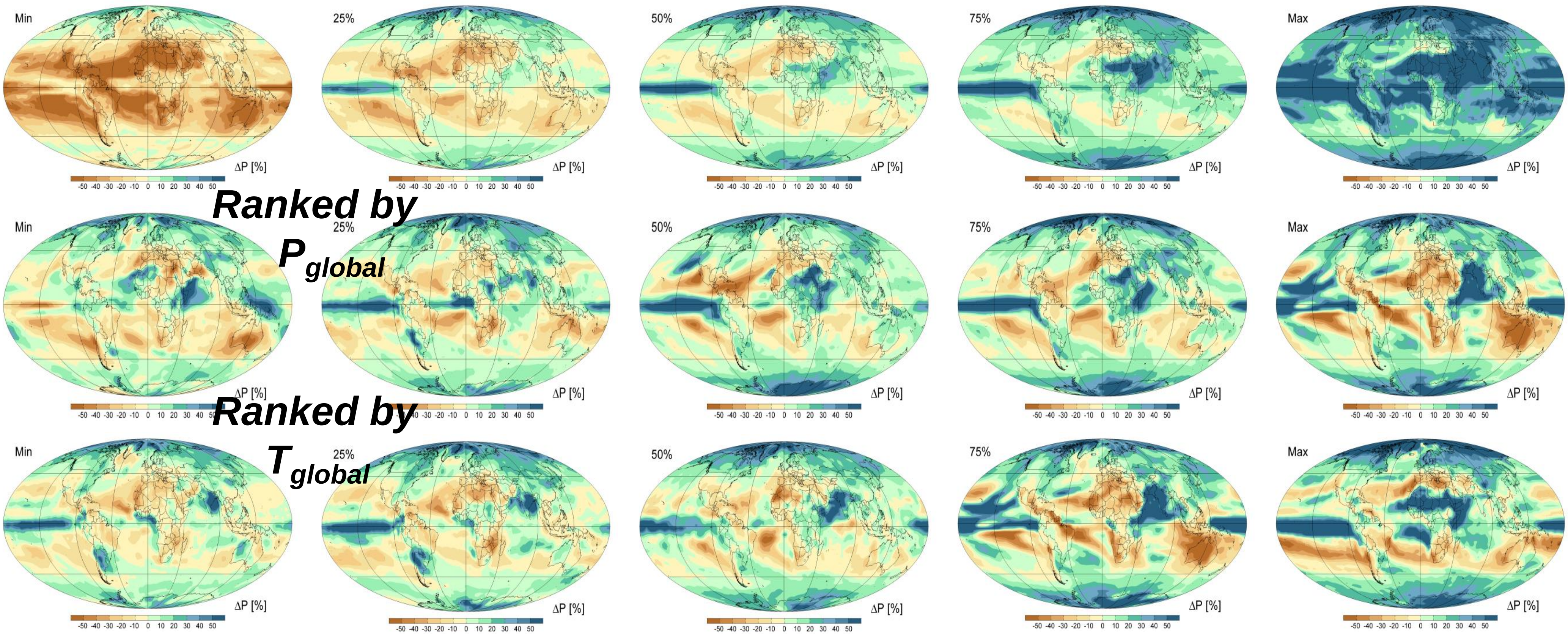
Model statistics

Ranked by T_{global}

Madsen et al. 2017 (submitted)

Uncertainty in projections

Grid point statistics



Ranked by P_{global}

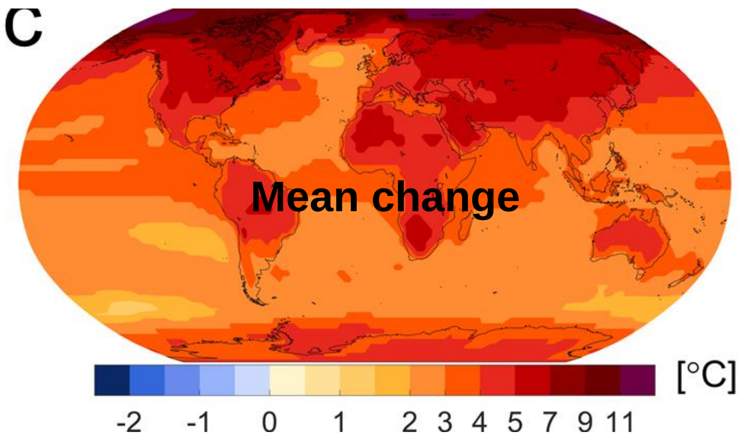
Ranked by T_{global}

Model statistics

Madsen et al. 2017 (submitted)

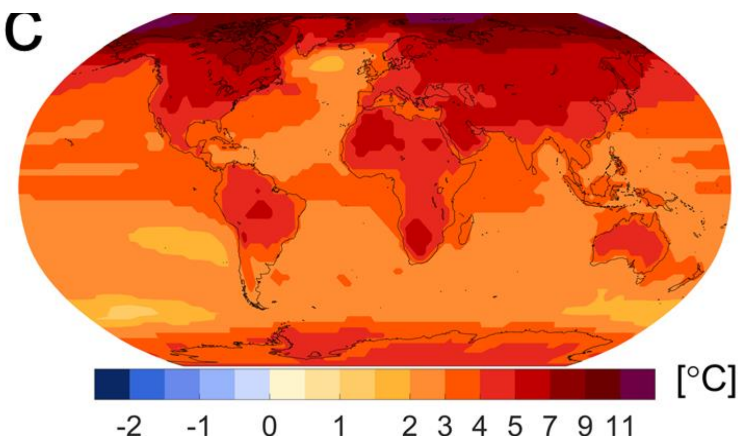
Uncertainty in projections

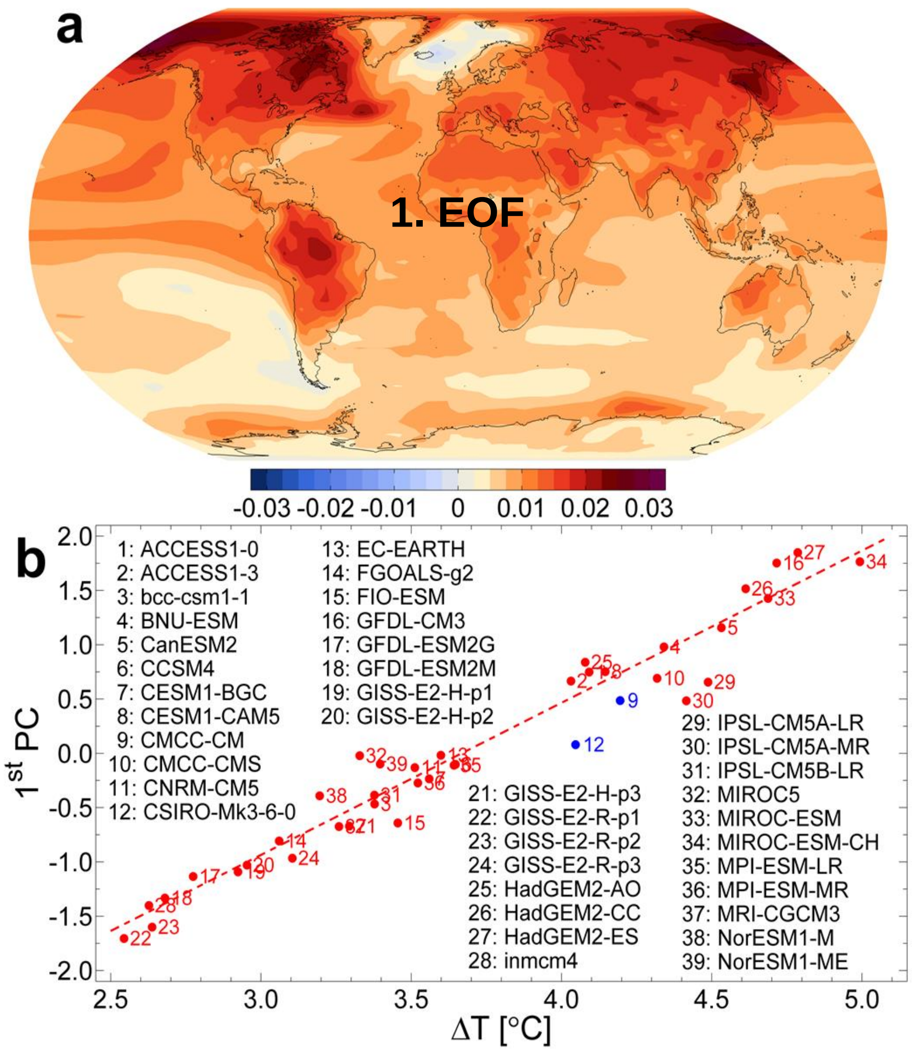
Climate sensitivity and scaling



Uncertainty in projections

Climate sensitivity and scaling





Summary

- Looking back
  - We have come a long way in terms of model quality
  - Signal-to-noise remains a challenge
- GCMs catching up on resolution
  - so what?
  - RCMs are catching up km scale
- Exploring ensembles of models has just begun
  - Using the GCM/RCM/RCP matrix

- Is there a role for regional climate modelling in the next decade?
- YES – many unresolved issues

Providing regional climate data and information for Africa

Grigory Nikulin
Rossby Centre, SMHI

SMHI

SMHI

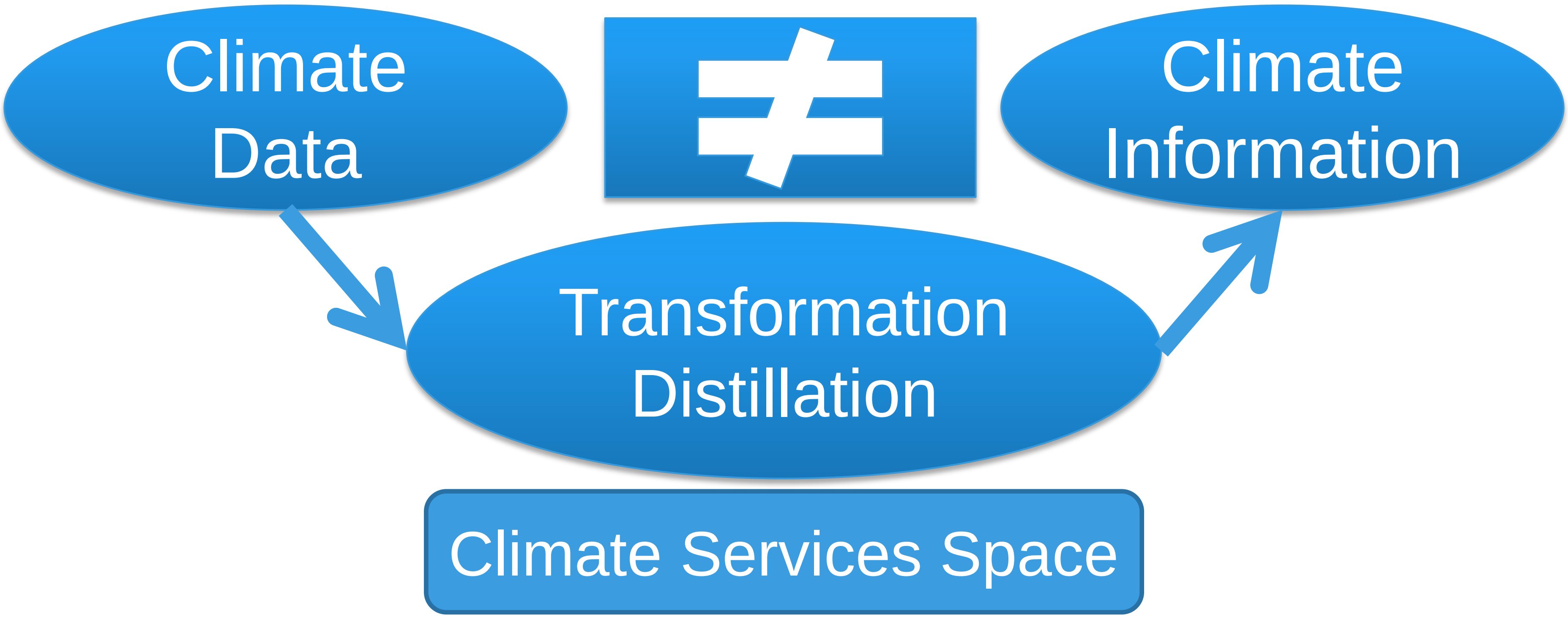
Providing regional climate data and information for Africa

Grigory Nikulin

Rossby Centre
Swedish Meteorological and Hydrological Institute

Data vs information

- a high demand on regional and local climate information
- many sources of climate data: observations, global and regional climate models, statistical downscaling, spatial disaggregation etc.

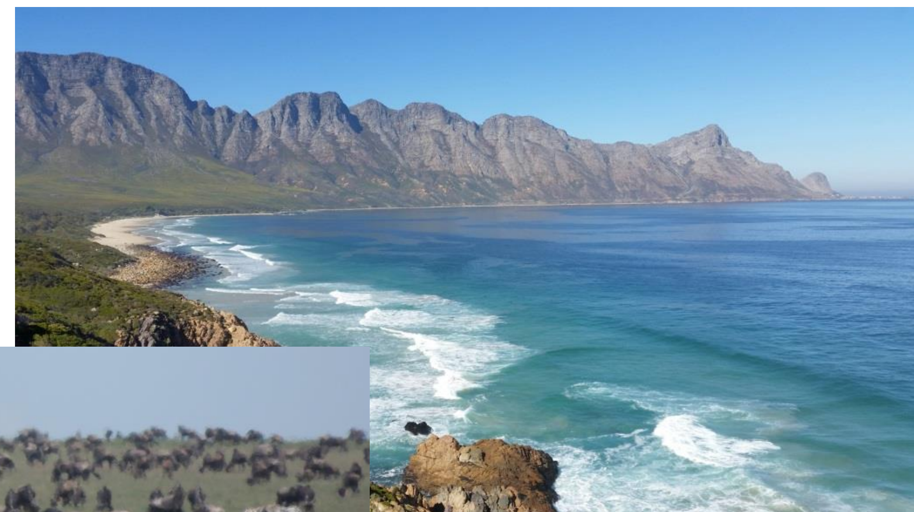
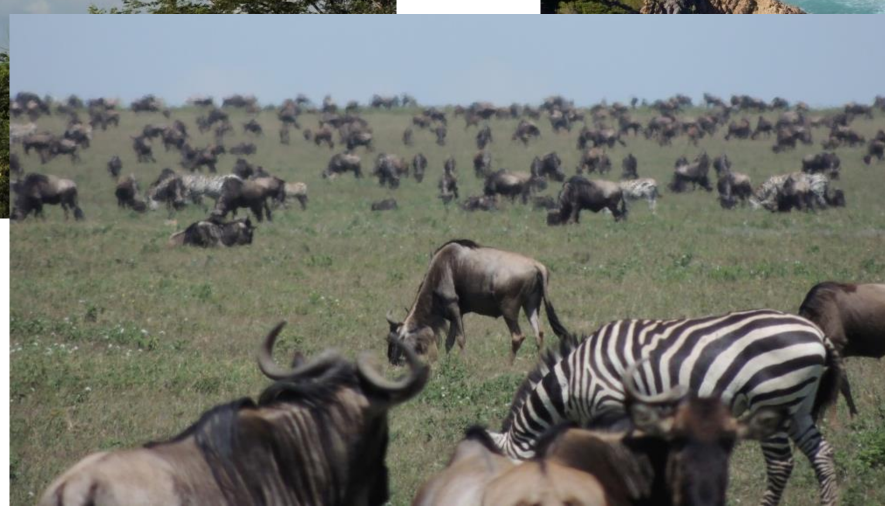


- no clear guidance/instructions on how to transform/distil
- information is useful and useable in a relevant context

Why Africa ?

SMHI

- large natural climate variability (droughts occur regularly)
- low adaptive capacity, poverty, rain-fed agriculture
- and if climate change on the top of it …..
- water supply, food security and health are of critical importance
- a beautiful continent with many problems but a lot of potential

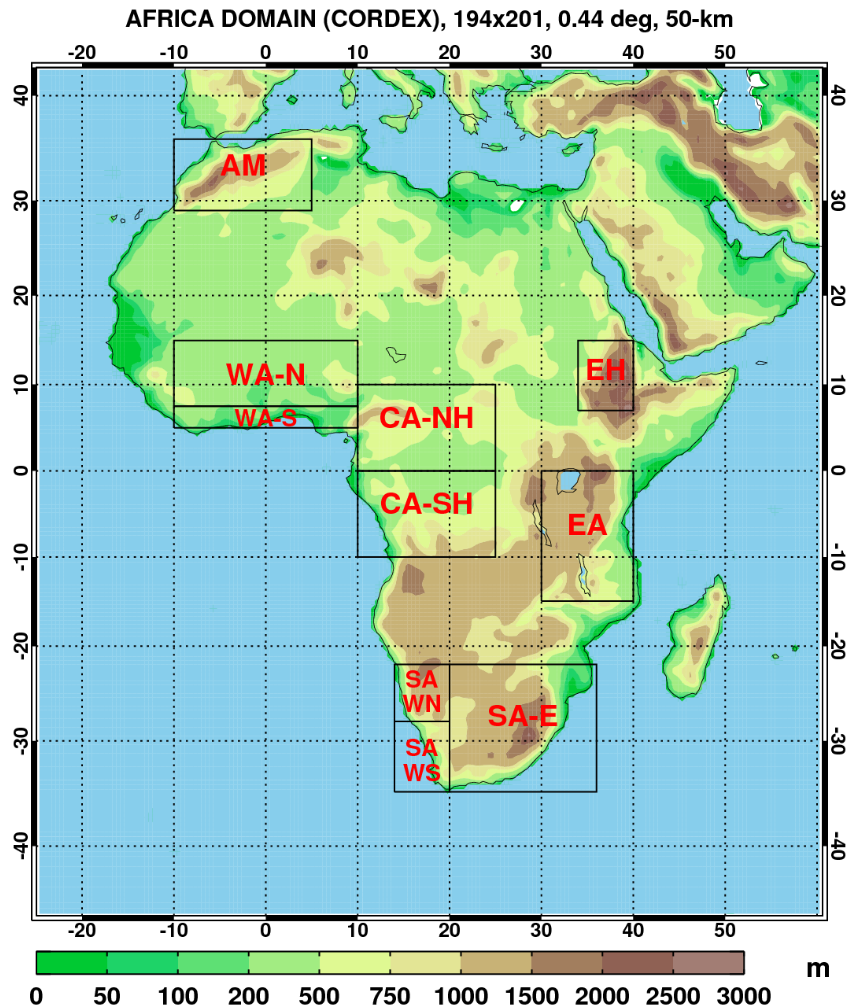




CORDEX-Africa

- **Co**ordinated **R**egional climate **D**ownscaling **E**xperiment WCRP project, running since 2009, **www.cordex.org**

<u>Focus on Africa</u>

- SMHI have downscaled 10 global climate models with RCP4.5 and 8.5 scenarios (+ 5 of them with RCP2.6)
- the largest CORDEX-Africa ensemble generated by one regional model **SMHI-RCA4**
- all simulations are available on the Swedish ESGF data node (Earth System Grid Federation)
- many simulations have been distributed to African scientists on external disks (efficient)



CORDEX-Africa Analysis Campaign

SMHI

- coordinated by Climate Section Analysis Group (University of Cape Town)
- more than 30 African scientists (4 teams: west, central, east and southern Africa)
- SMHI has been working in the Campaign since the beginning in 2011

Aims

1. analyze CORDEX downscaled regional climate data over Africa
2. train young climate scientists in climate data analysis techniques
3. engage users of climate information (sector and region specific applications)

Phase 1: 4 training workshops (2011-2012) (funded by START), 11 publications
Phase 2: 2 workshops (2015/2016) (funded by Sweden)
Phase 3: 4 workshops in 2017-2018 (funded by Sweden); contribution to the 1.5deg IPCC report (6-7 papers in "Focus Collection" of Environ. Research Letters)

interest to such regional training workshops is very large but funding is the main problem

Africa Impact Atlas – Kinga Project

SMHI

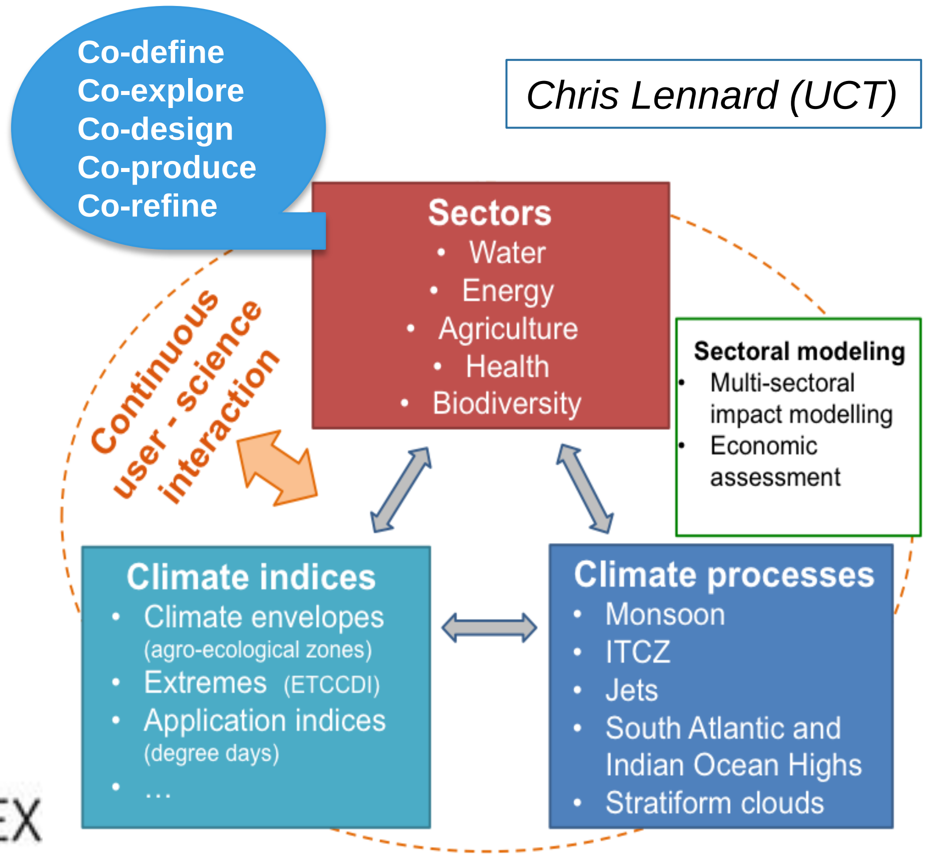
- A systematic analysis of impacts in Africa under climate change
- *The word "**Kinga**" is Swahili for "Prevent" or "Protect".*
- coordinated by Climate Section Analysis Group (University of Cape Town)

- a CORDEX Flagship Pilot Study proposal -> a demonstrator -> WCRP and CORDEX proposed this concept presented at COP-22 (Marrakesh 2016)

Sweden has provided funding for 2017

- proof of concept (a prototype)
- both global and regional climate models as input climate data
- 1.5 and 2°C global warming levels
- first focus on agriculture in western Africa (5 crops selected)
- the atlas will be based at UCT
- a platform for Climate Services not information for decision-making

Chris Lennard (UCT)



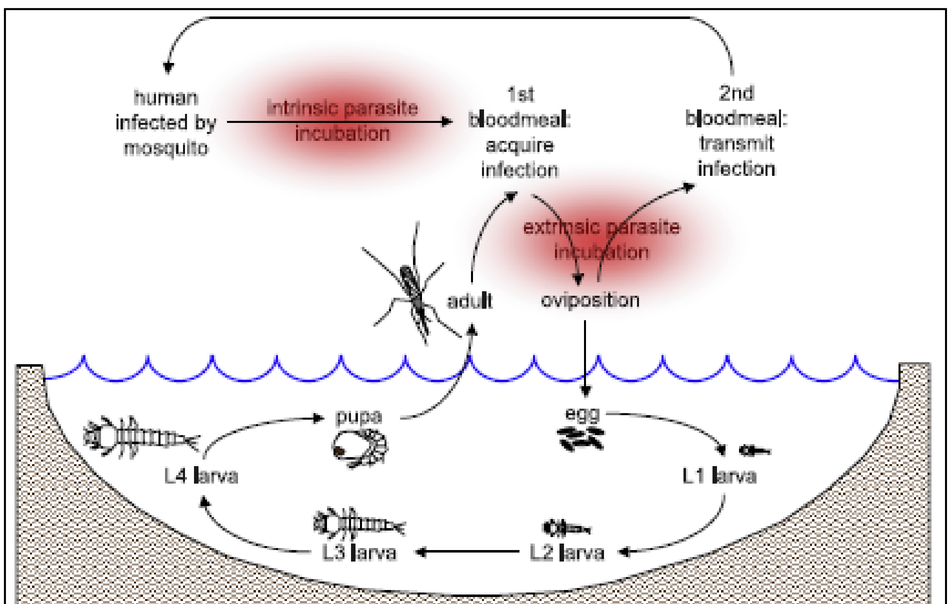
HEALTHY FUTURES

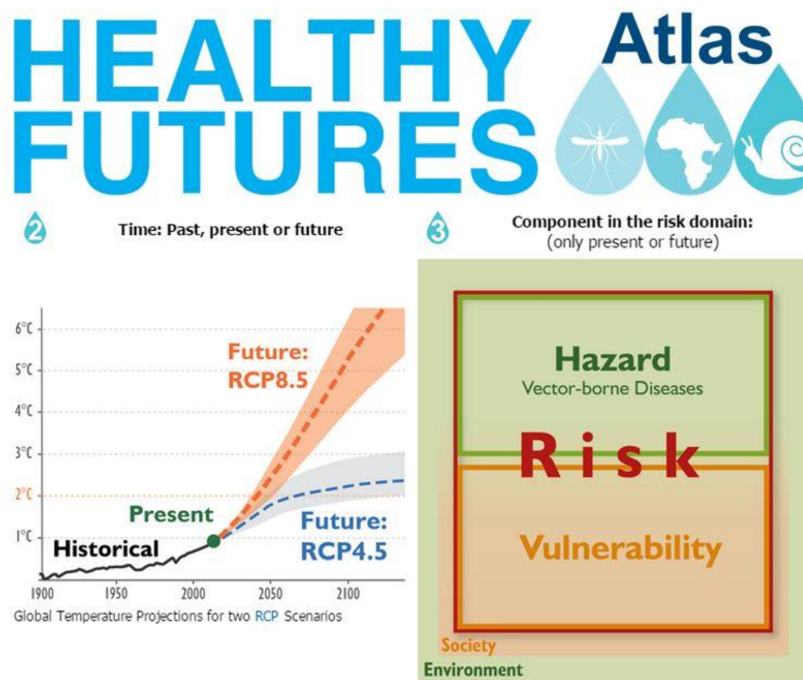
EU funded (FP7, 2010-2014), 15 institutions (8 in Africa)

Focus: impact of environmental changes on 3 Vector-Borne Diseases (malaria, Rift Valley Fever and schistosomiasis) in eastern Africa

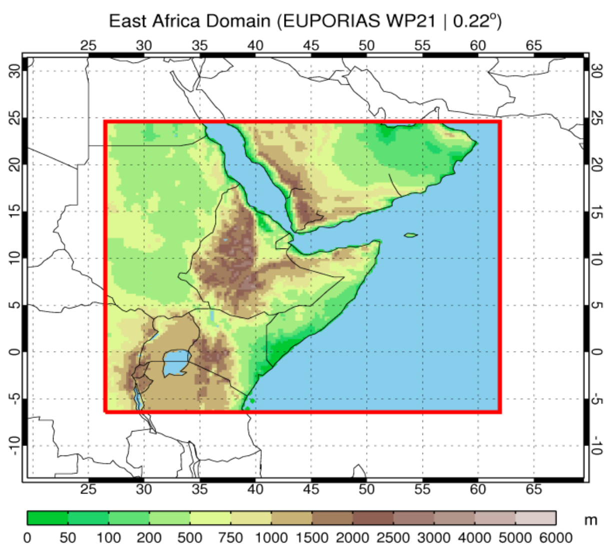
climate is one of stressors

Rossby Centre has contributed by providing bias-adjusted CORDEX pan-Africa simulations at 50km and by generating high-resolution (17km) SMHI-RCA4 simulations over eastern Africa

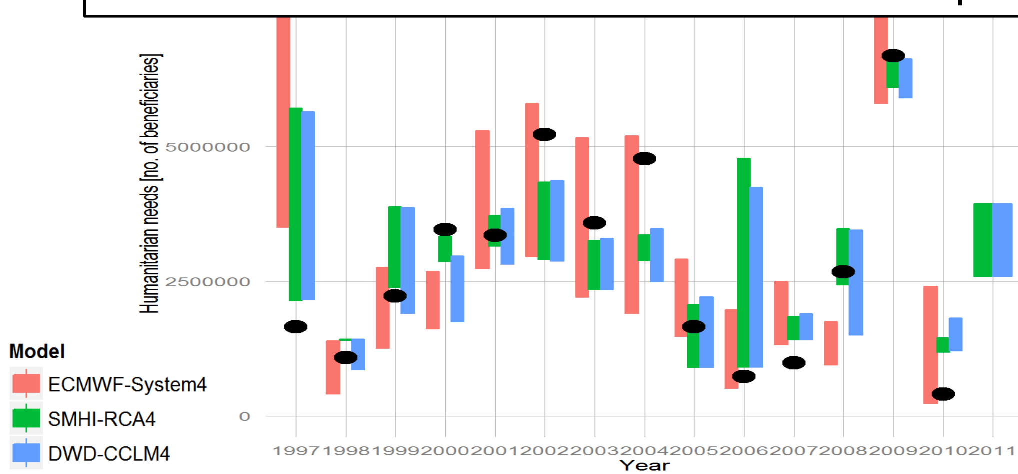




- **EU**ropean **P**rovision **o**f **R**egional **I**mpact **A**ssessment on **S**easonal-to-Decadal Timescales (EU funded, FP7, 2012-2016, 24 institutes)
- <u>**Focus:**</u> developing end-to-end impact prediction services, operating on seasonal to decadal timescales, and clearly demonstrating their value in informing decision–making
- Rossby Centre coordinated a work package on downscaling of a global seasonal forecast over eastern Africa (only one non-European activity)
- usability of downscaling was tested in the Livelihoods, Early Assessment and Protection (LEAP) system for Ethiopia (World Food Programme)
- downscaling shows no clear added value (if the added value of downscaling is defined as a higher predictive skill)



Needs for humanitarian interventions in Ethiopia



FUTURE CLIMATE FOR AFRICA

FRACTAL

FUTURE RESILIENCE FOR AFRICAN CITIES AND LANDS

SMHI

- **F**uture **R**esilience For **A**frican **C**ities and **L**ands, UK funded (Future Climate for Africa) 2015-2019, 12 core partners, 27 organizations
- **<u>Focus:</u>** use of climate information within an urban decision making context on the 5-40 year time scale
- Cities in southern Africa: Windhoek, Lusaka, Maputo, Blantyre, Gaborone, Harare, Cape Town, Durban, Johannesburg
- How to co-produce relevant climate knowledge under real-world constraints?

Bruce Hewitson (UCT)

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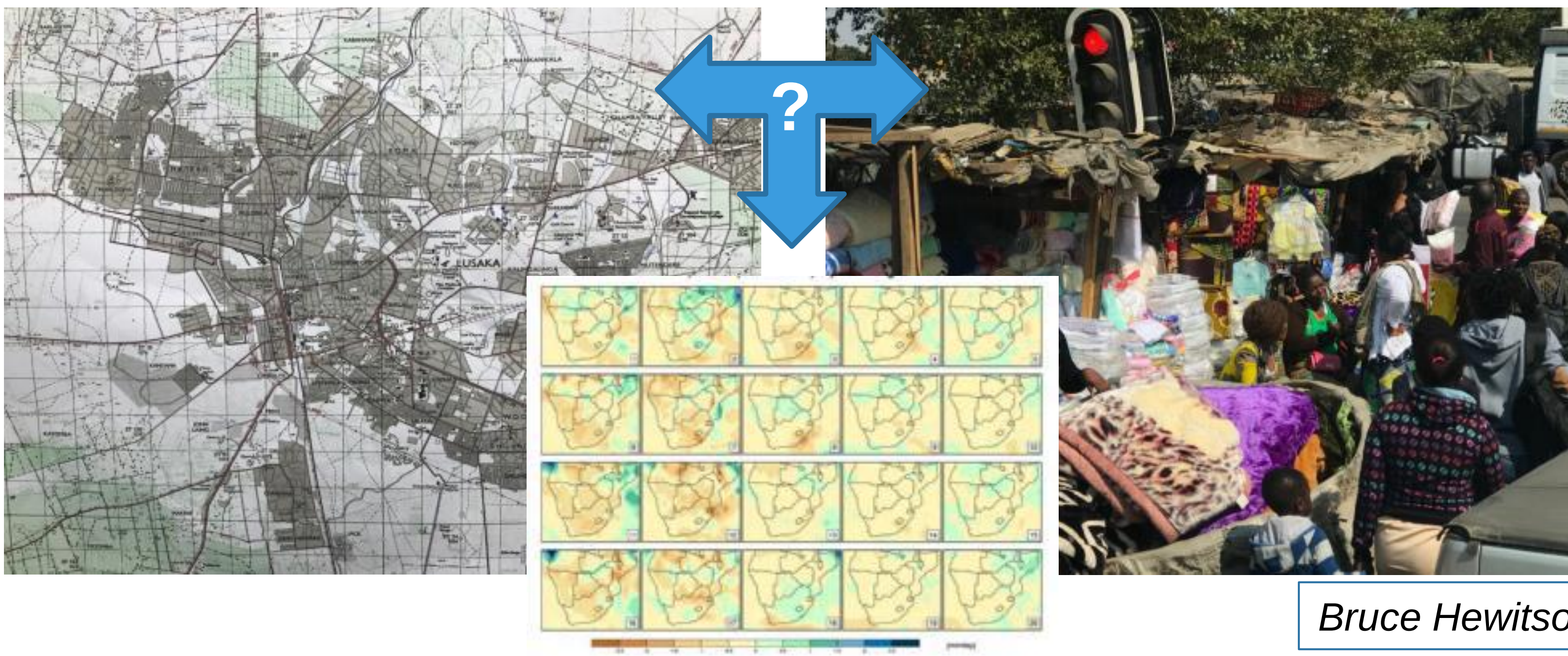
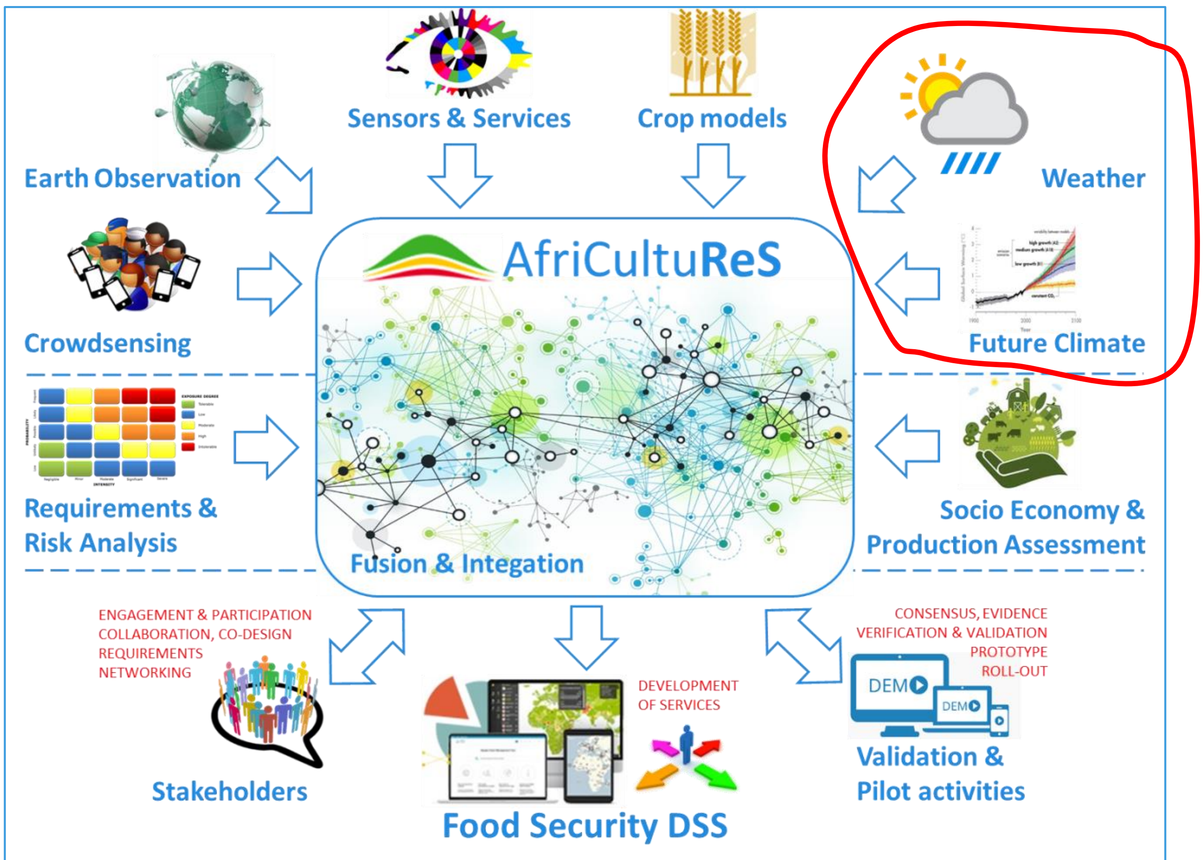


Bruce Hewitson (UCT)

- city learning labs, embedded researches, climate narratives ….

AfriCultuReS

- *Enhancing Food Security in **AFRI**can Agri**CULTU**ral Systems with the Support of **RE**mote **S**ensing*
- EU funding (H2020), 2018-2021, 17 organizations (8 in Africa)
- *providing decision makers with tools for tackling Food Security in Africa*
- in-situ and satellite data, weather and climate data, crop models



SMHI coordinates assessment and provision of environmental data sets with different lead times:

- weather forecast
- seasonal forecast
- decadal predictions
- climate projections

Lessons learnt

SMHI

- often providing “climate information” (or what we call “climate information”) we actually provide post-processed climate data

- there are many ways to transform/distil climate data to “climate information” and provide it to users but ask yourself “Has this information been really used”?

- climate information is useful and useable in a relevant context with many dependencies: e.g. from different spatial and time scales (physical space) to different cultural and historical traditions across users (social space)

- <u>real trans-disciplinary projects:</u>
  - very complex and difficult
  - can be even confusing: *if top-down climate information supply chain mentality meets bottom-up context driven multi-stressor system dynamics* (*Bruce Hewitson, UCT*)

Tripling of extreme Sahelian storms over the last 35 years

Danijel Belusic
Rossby Centre, SMHI

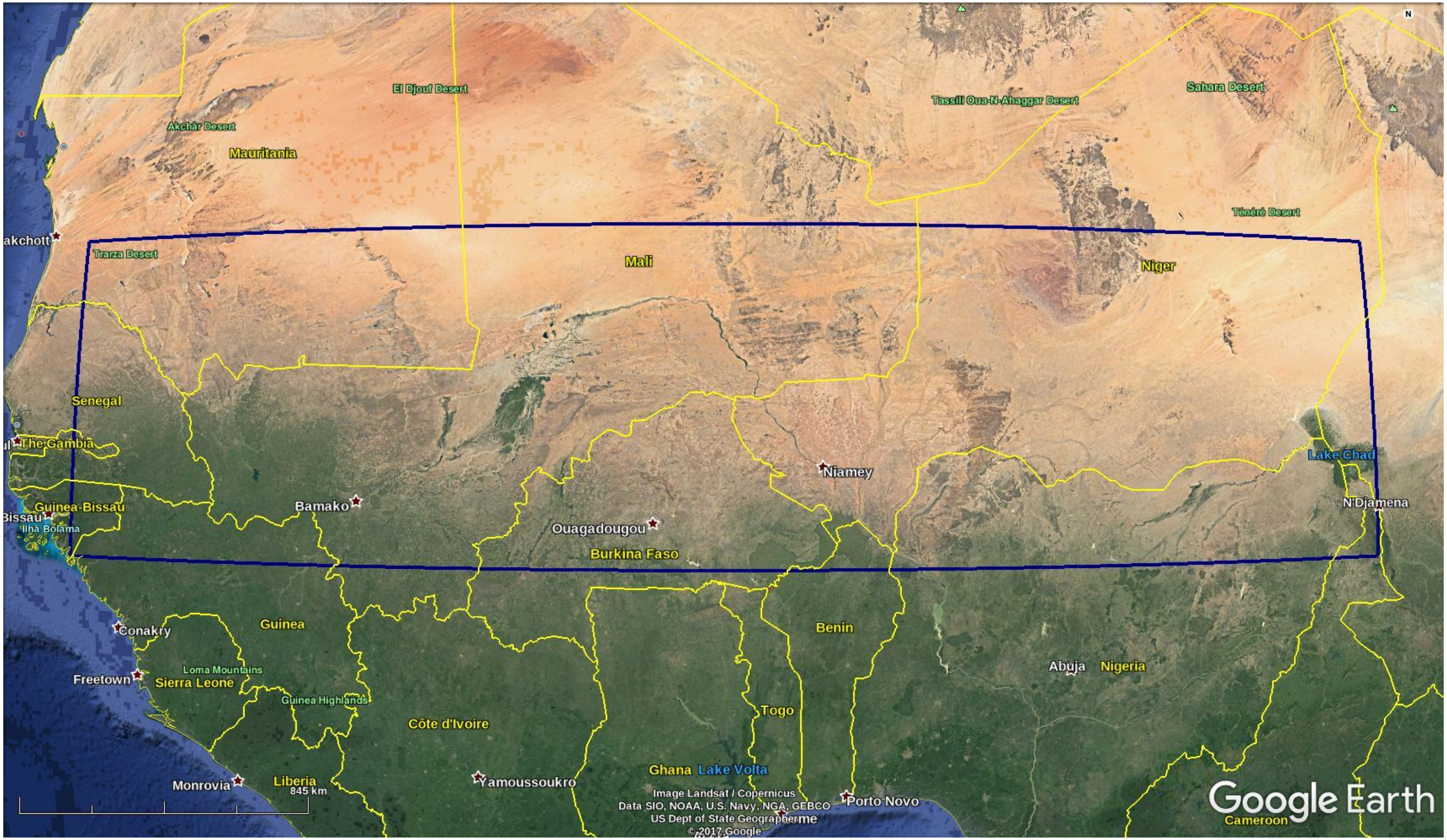
Tripling of extreme Sahelian storms over the last 35 years

Danijel Belušić, Rossby Centre, SMHI
danijel.belusic@smhi.se

From Taylor, Belušić, Guichard et al., 2017: Frequency of extreme Sahelian storms tripled since 1982 in satellite observations, Nature, 544, 475–478

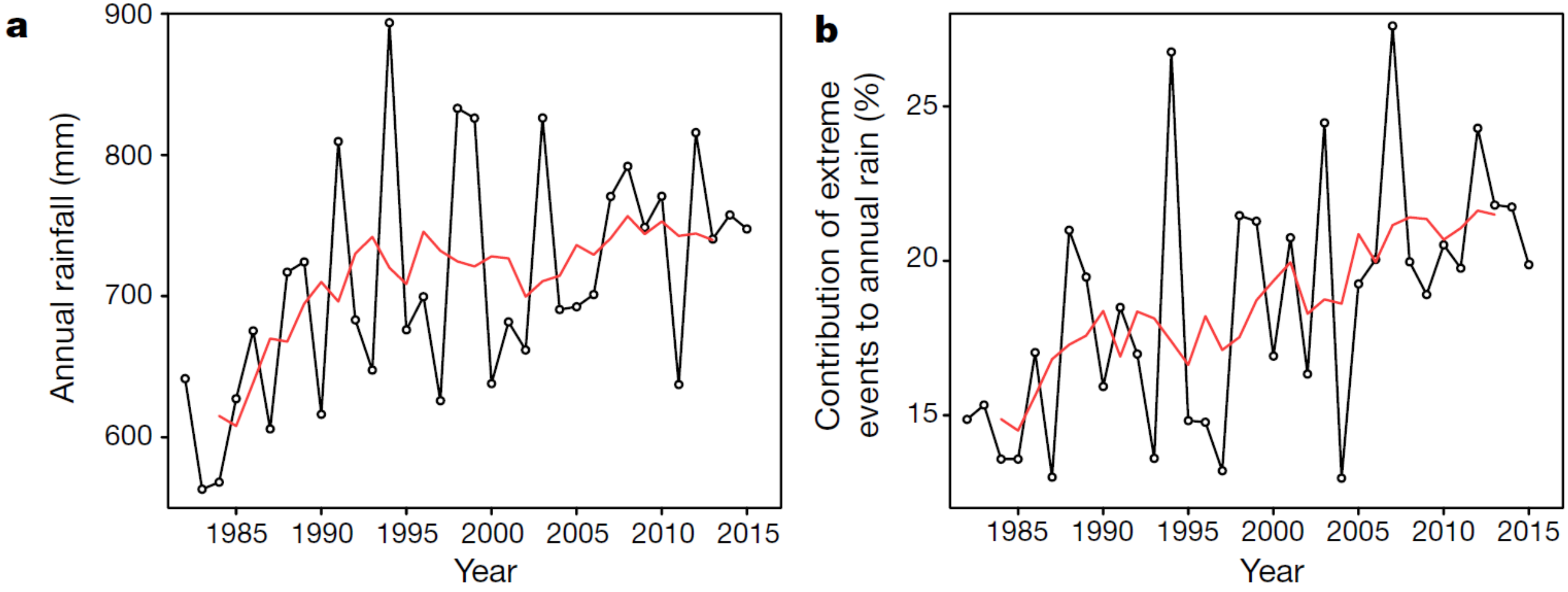
SMHI

Sahel study area



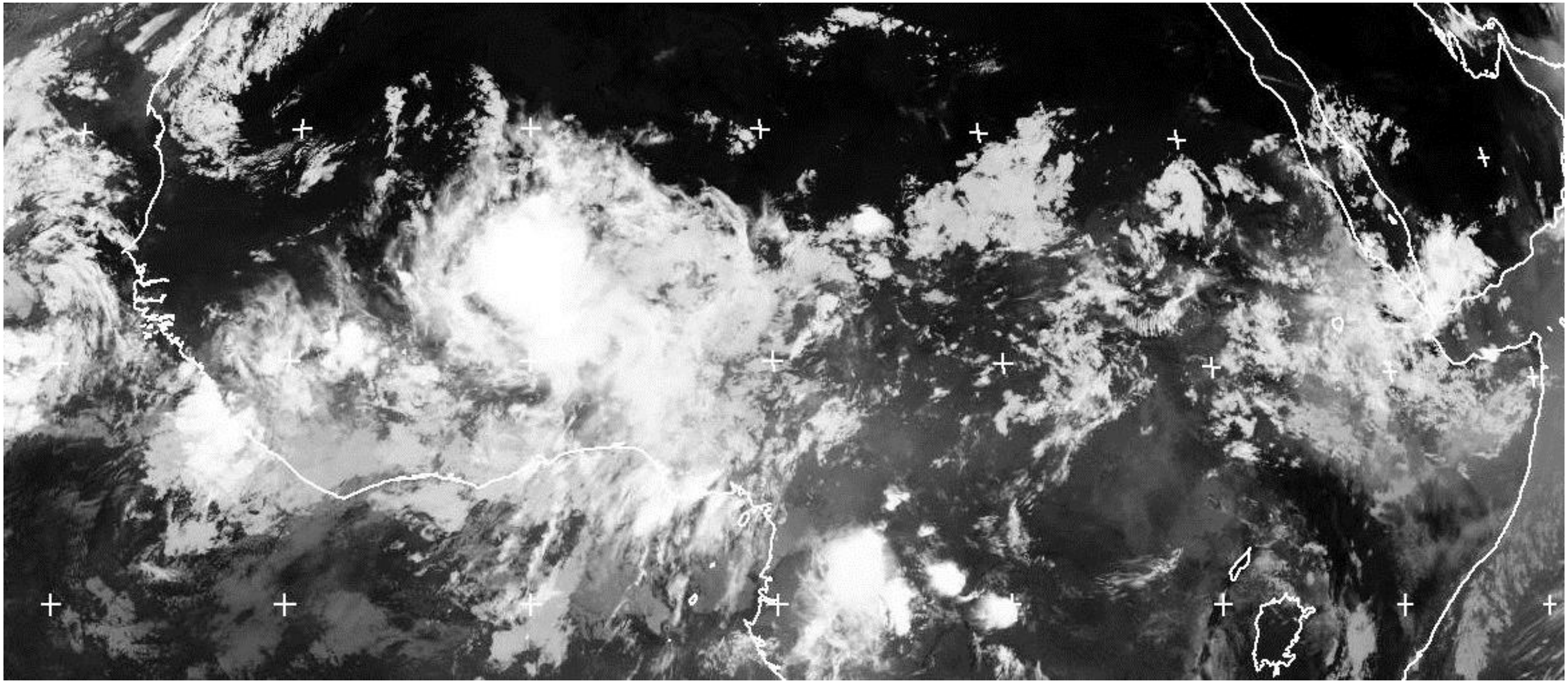
Sahel rainfall

From rain gauges



Data: Meteosat 1st & 2nd gen

- Cloud top IRT; 1982 – 2016
- MCS = contiguous cloud area > 25 000 km² with T < -xy °C

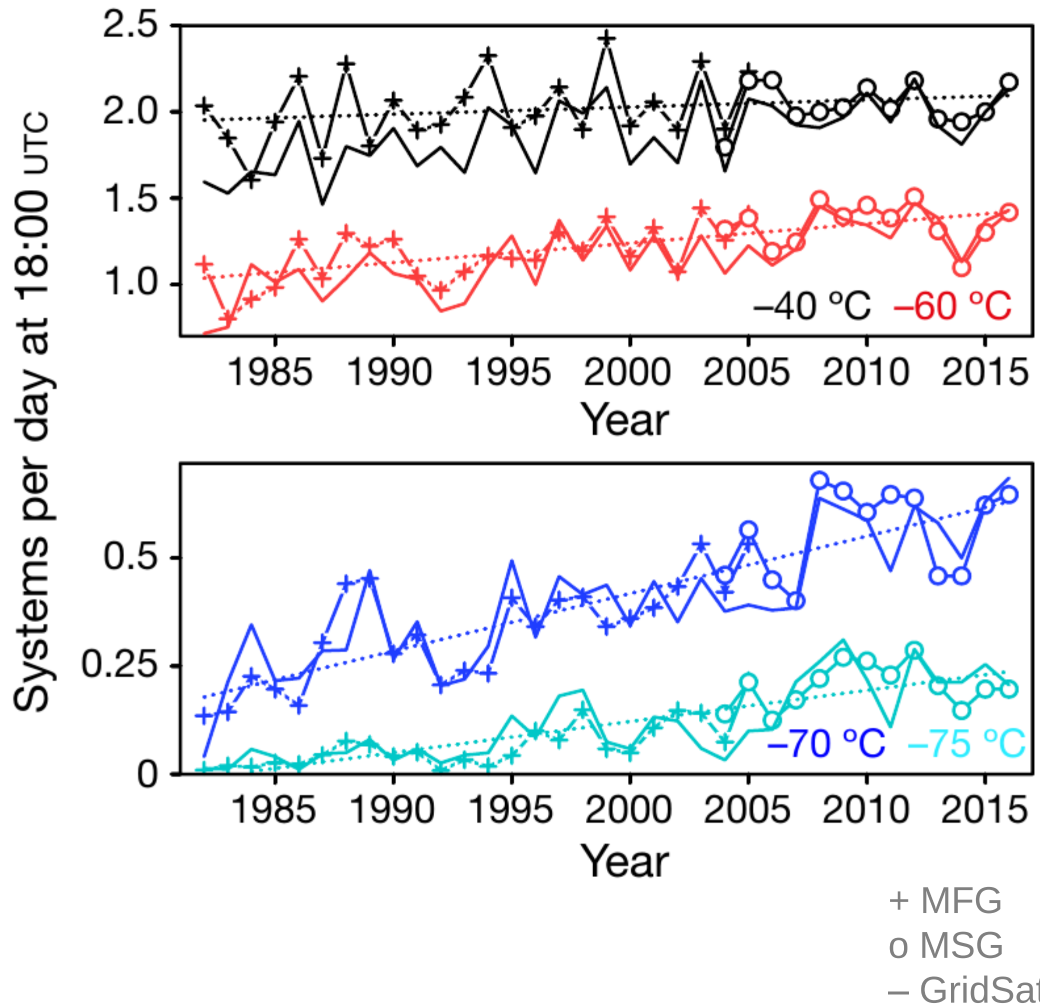


Three main messages ...

1. What the data show

- MCS frequency at 18 UTC:

  3.5-fold increase over 35 years at T < -70°C

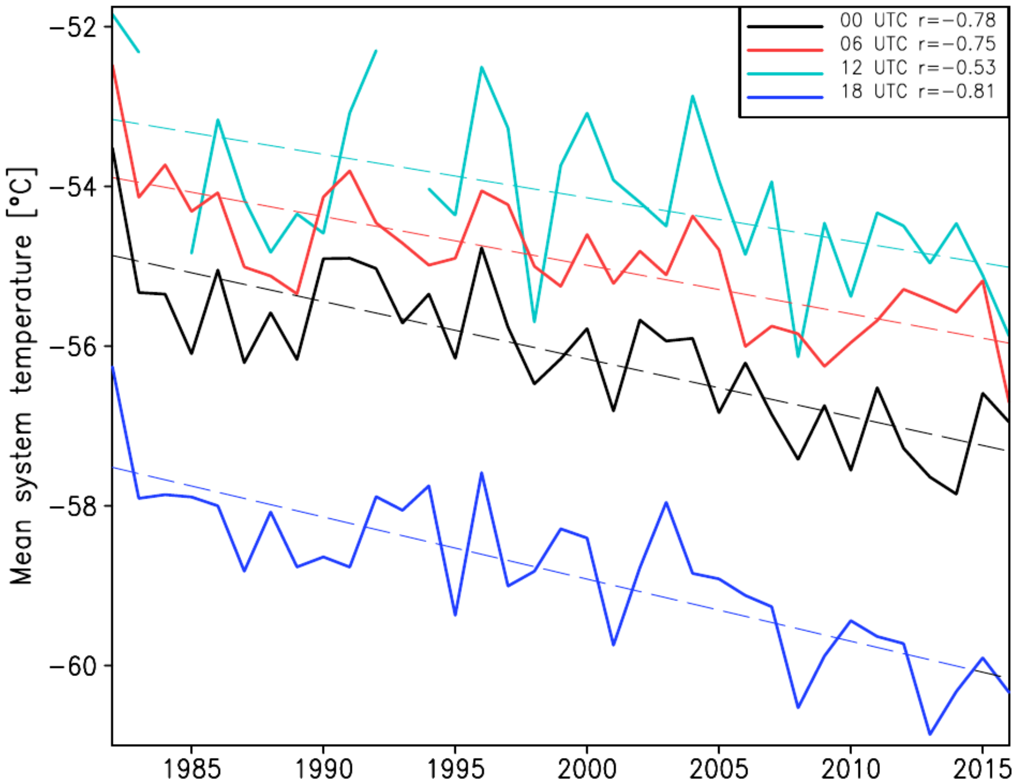


MCS = contiguous cloud area > 25 000 km² with T < -xy °C

1. What the data show

- MCS mean T for systems with T < -40°C:

  -0.78°C / 10yr



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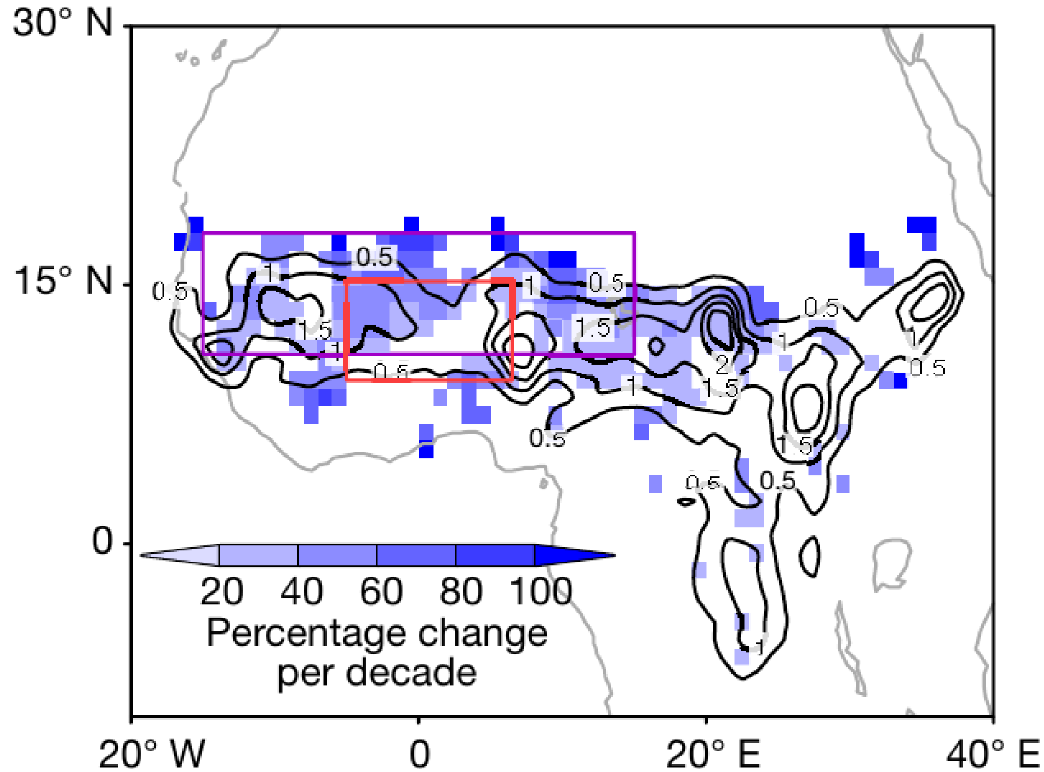
1. What the data show

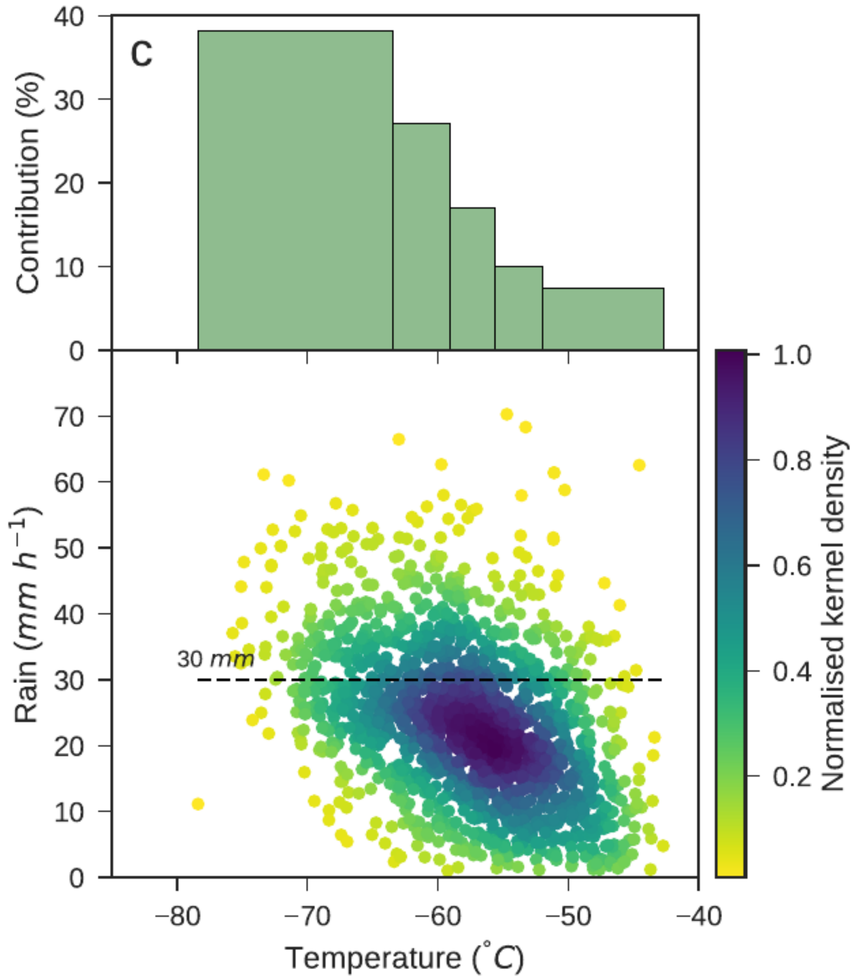
- Cloud cover for MCS with T < -70°C



1. What the data show

→ MCSs intensify

→ This leads to more extreme rainfall

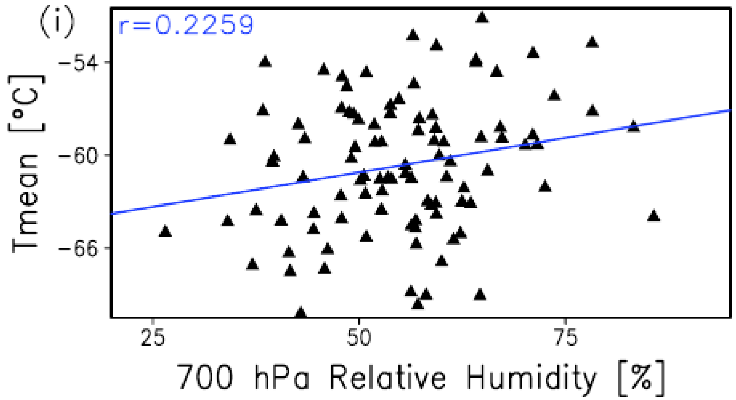


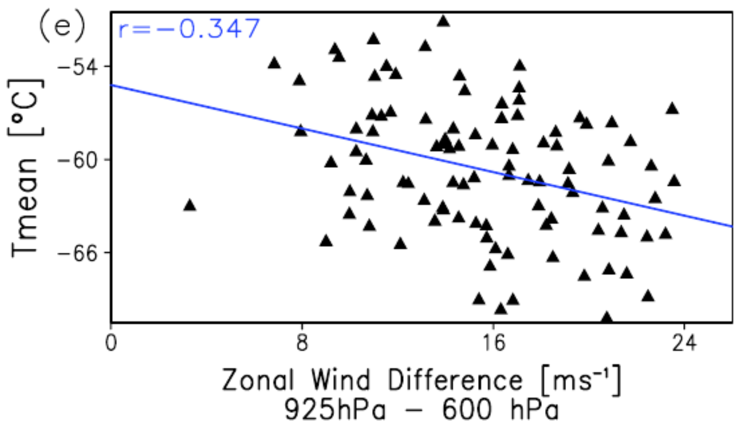
TRMM max rain rate vs. MCS mean T

2. What are the (likely) mechanisms?

MCS likes T, q (RH), dU/dz:

- *Not related to local T or q (RH) (unexpected!)*
- *Mid-level drying → stronger MCS*
- *MCS intensify with dU/dz*

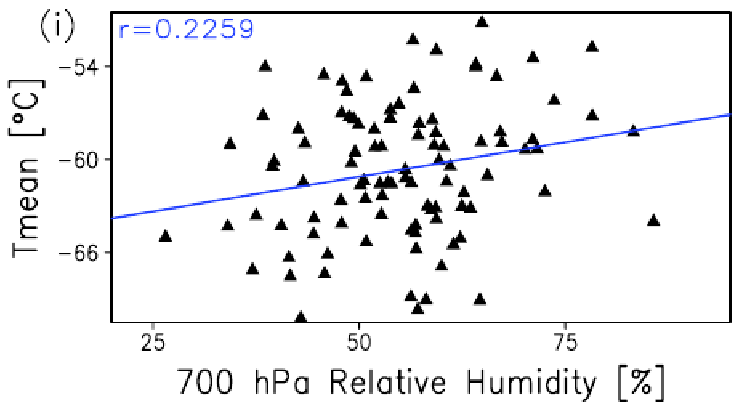


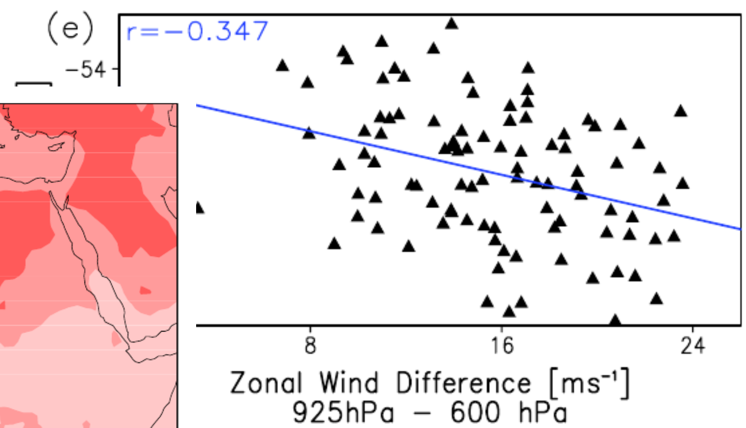


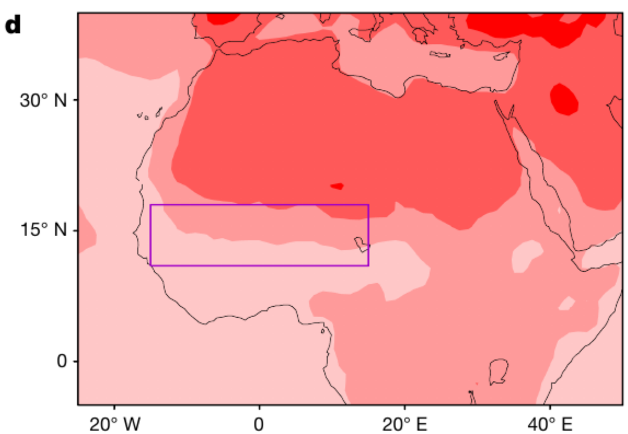
2. What are the (likely) mechanisms?

MCS likes T, q (RH), dU/dz:

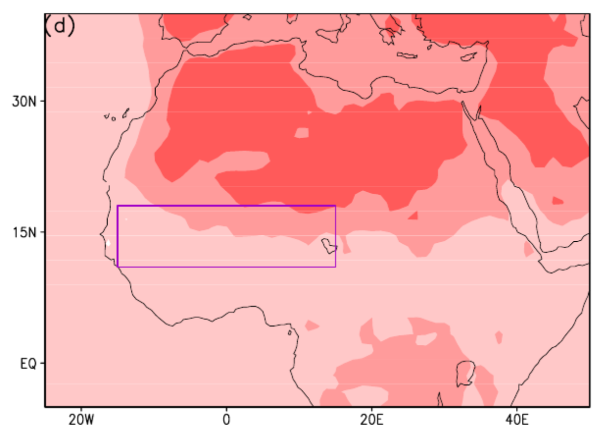
- *Not related to local T or q (RH) (unexpected!)*
- *Mid-level drying → stronger MCS*
- *MCS intensify with dU/dz*
  → meridional grad(T)







CMIP5 T

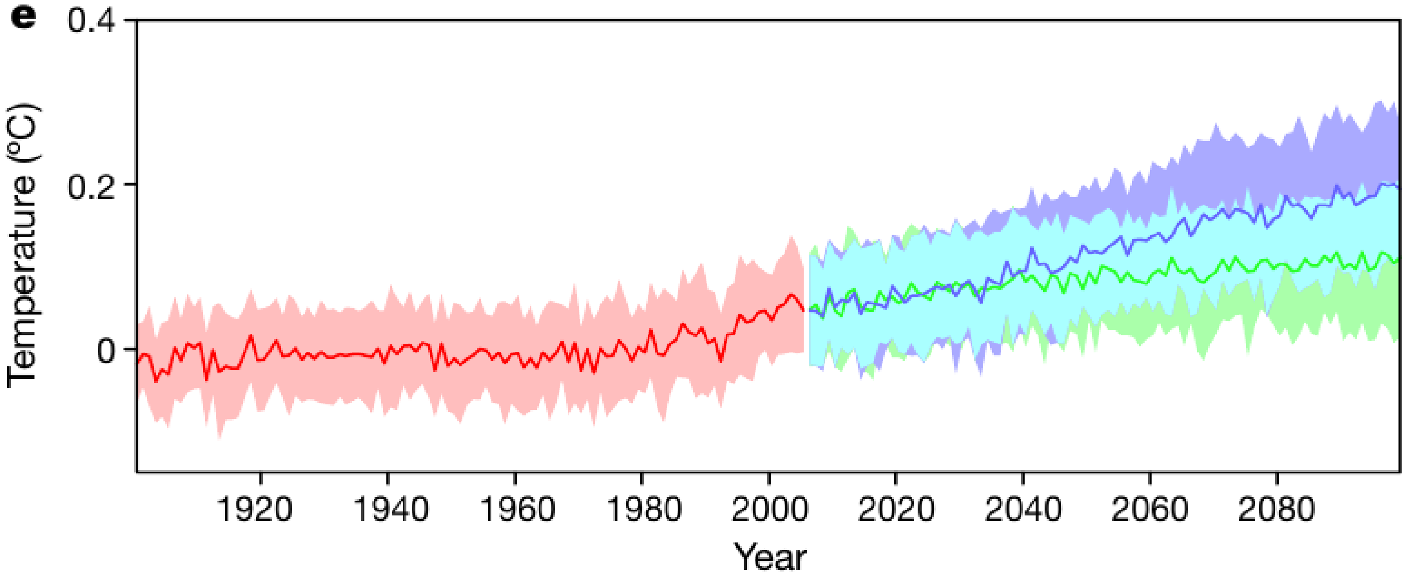


CMIP5 T: All F - Natural F

3. What about the future?

CMIP5 meridional grad(T)

(historical, RCP4.5, RCP8.5)



Can we model this?

- Not at current CORDEX Africa grid spacing
- What grid spacing is required?

Conclusions

- Severe storms over the Sahel intensify
  - → More extreme rainfall, but not more total rainfall
  - → Increased risk of floods, but droughts not changing
  - → Most likely due to anthropogenic warming of Sahara
- Future projections indicate even stronger intensification
- More detailed information needed for appropriate action, adaptation and mitigation → we need models at sufficiently high resolution
- We are getting there…

The impact of roughness length change on extratropical cyclones density and their associated precipitation over Europe

Ramón Fuentes Franco
Rossby Centre, SMHI

SMHI

Ramón Fuentes Franco – Danijel Belusich – Gustav Strandberg

The impact of roughness length change on extratropical cyclones density and their associated precipitation over Europe

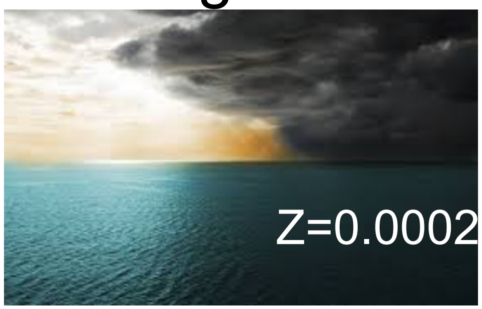
SMHI

Aim of the study

- To assess the impact of the roughness length change in the extratropical cyclones over Europe, considering especifically:
  - Spatial distribution and density
  - Duration
  - Precipitation associated to them

Roughness length

Z is equivalent to the height at which the wind speed theoretically becomes zero. It is typically related to the height of terrain roughness elements.



the roughness length is approximately one-tenth of the height of the surface roughness elements

Simulations

- Control
- Deforestation
- Afforestation
- Roughness length (Z0) from afforestation with deforestation values for albedo, evapotranspiration, etc.

- All simulations were performed with RCA model over the EURO-CORDEX domain, for the period 1981-2010 forced by ERA Interim.

Cyclone detection and tracking algorithm

SMHI

Identification of objects:

- Surface pressure > 100000 Pa
- Windspeed at 850 hPa > 5 ms^{-1}

If Object:

- Eccentricity > 0.95
- Pressure gradient within it > 200 Pa

then it is considered a cyclone and its centroid is saved.

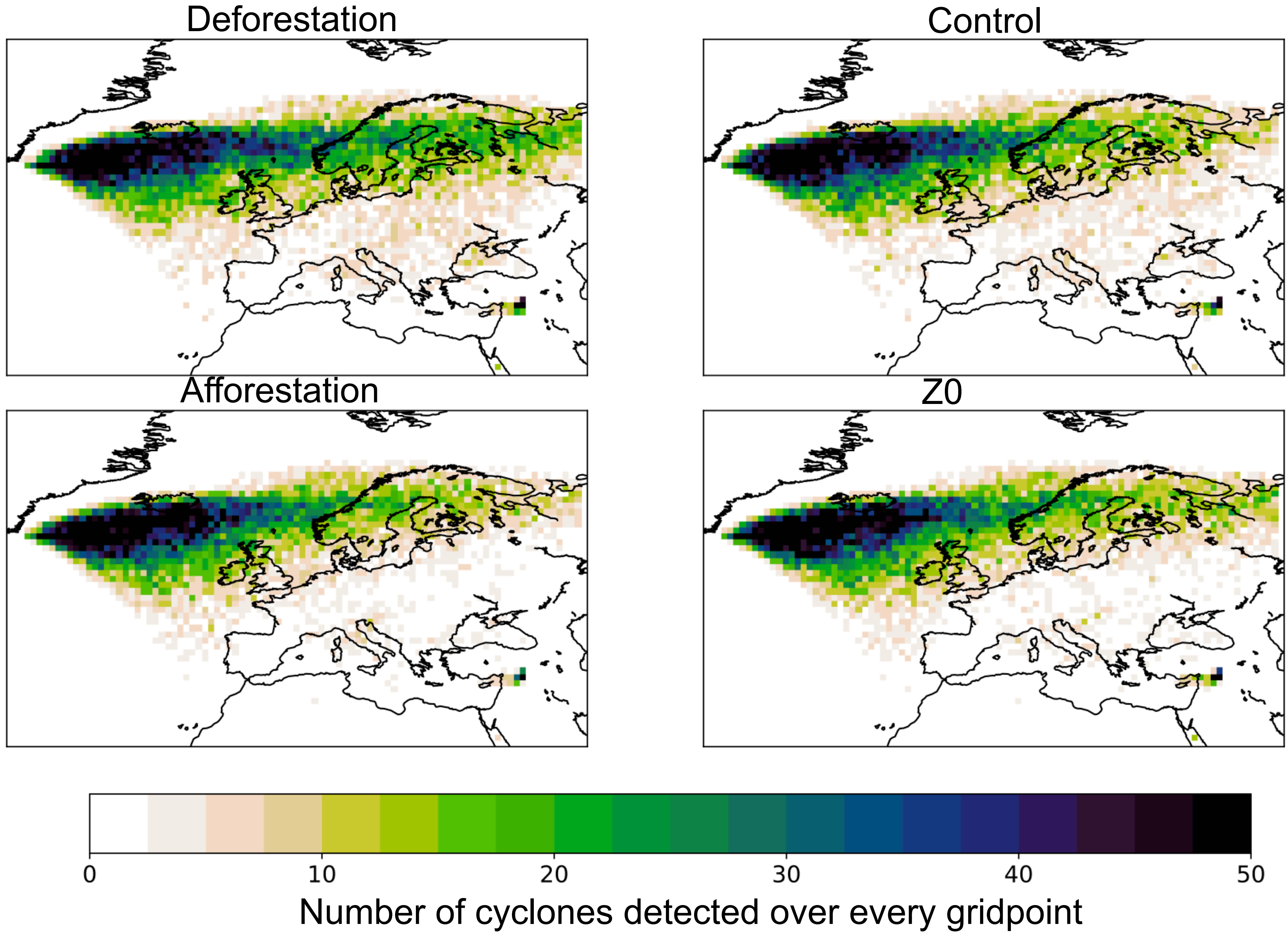
Tracking:

- Centroids from objects within a spatio-temporal window of 24h and 6 degrees are considered to belong to the same track.

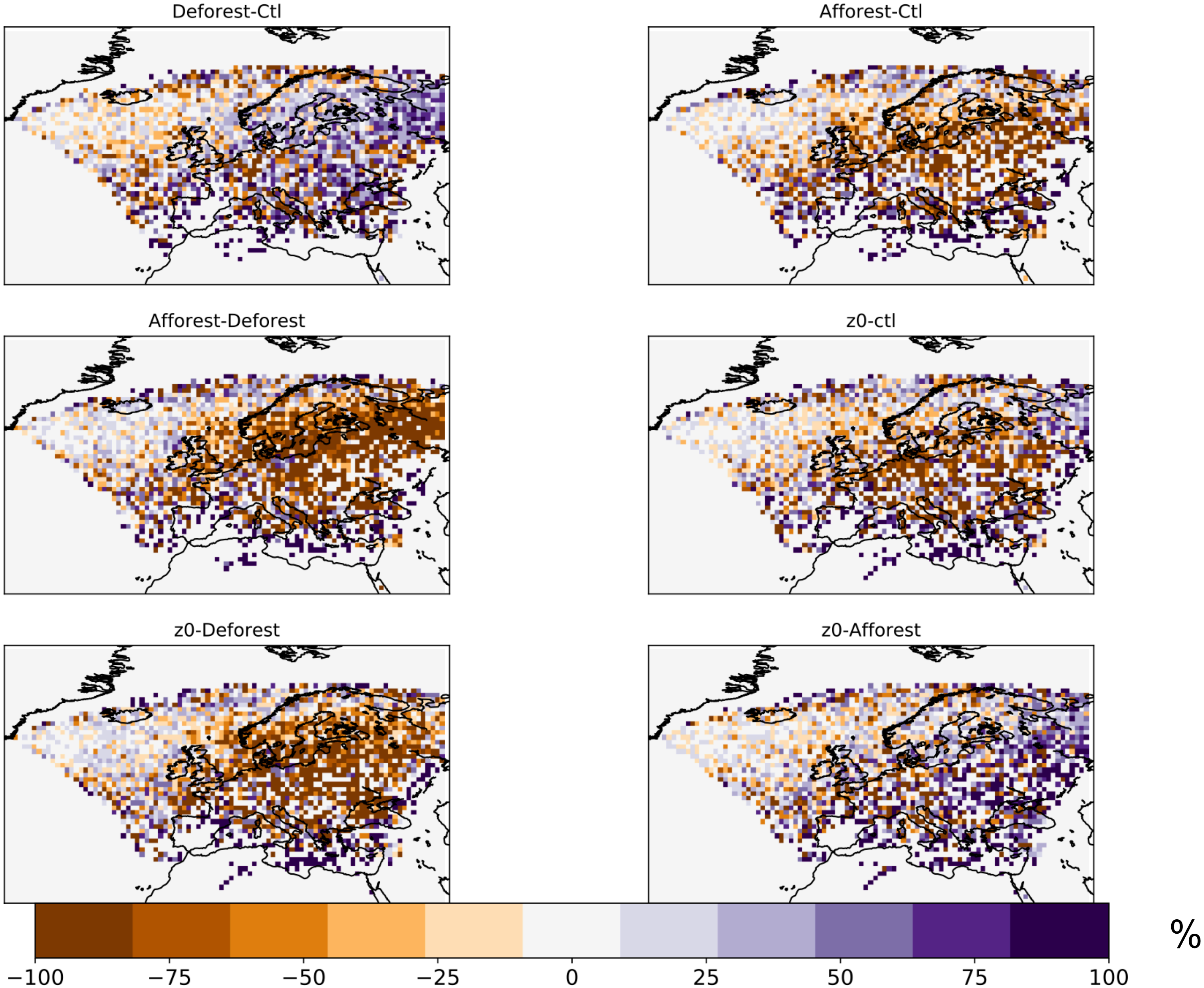
Precipitation associated to cyclone:

- 5 degrees windows were extended to the border gridpoints of every object to consider the precipitation as part of the cyclone.

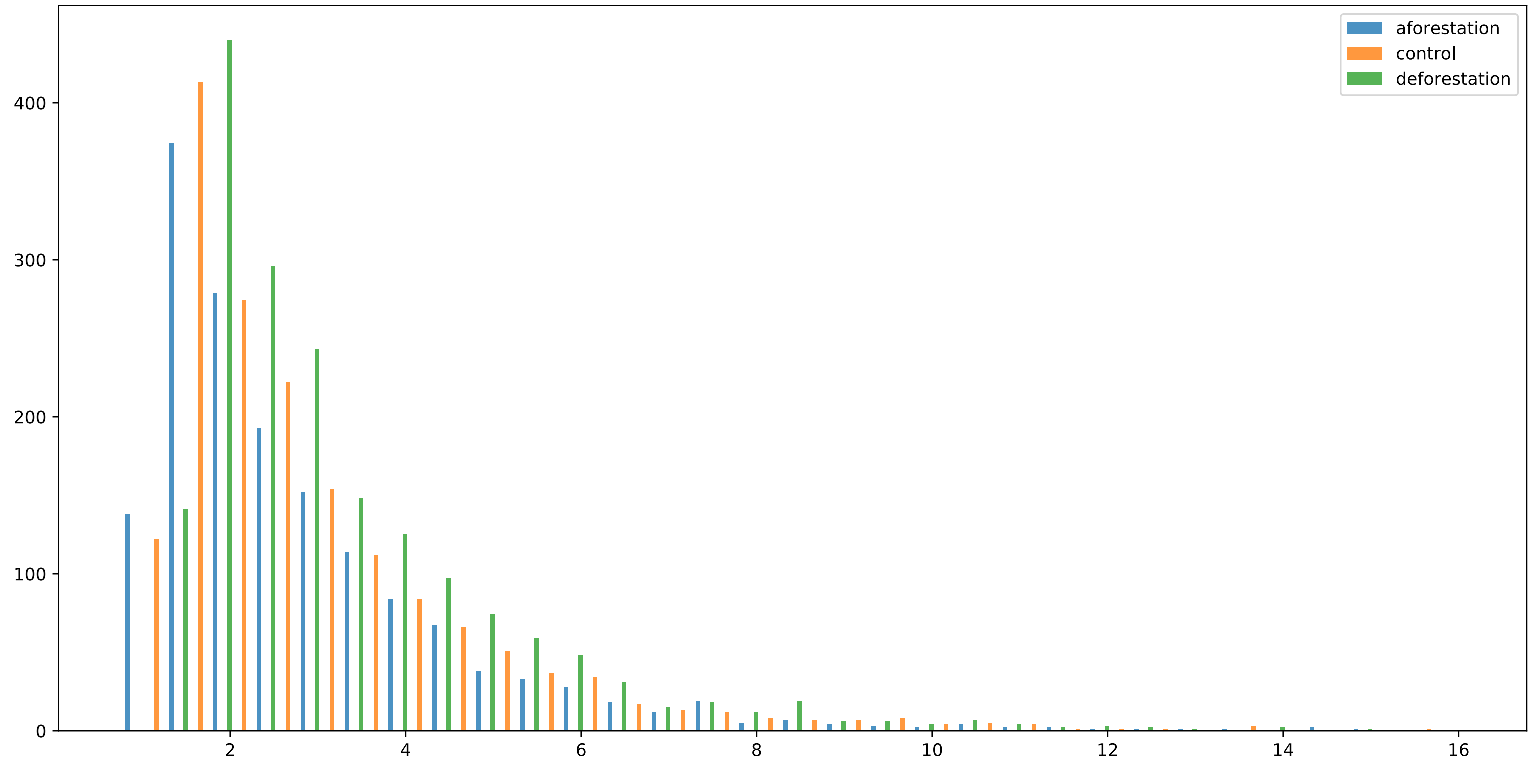
Cyclone density



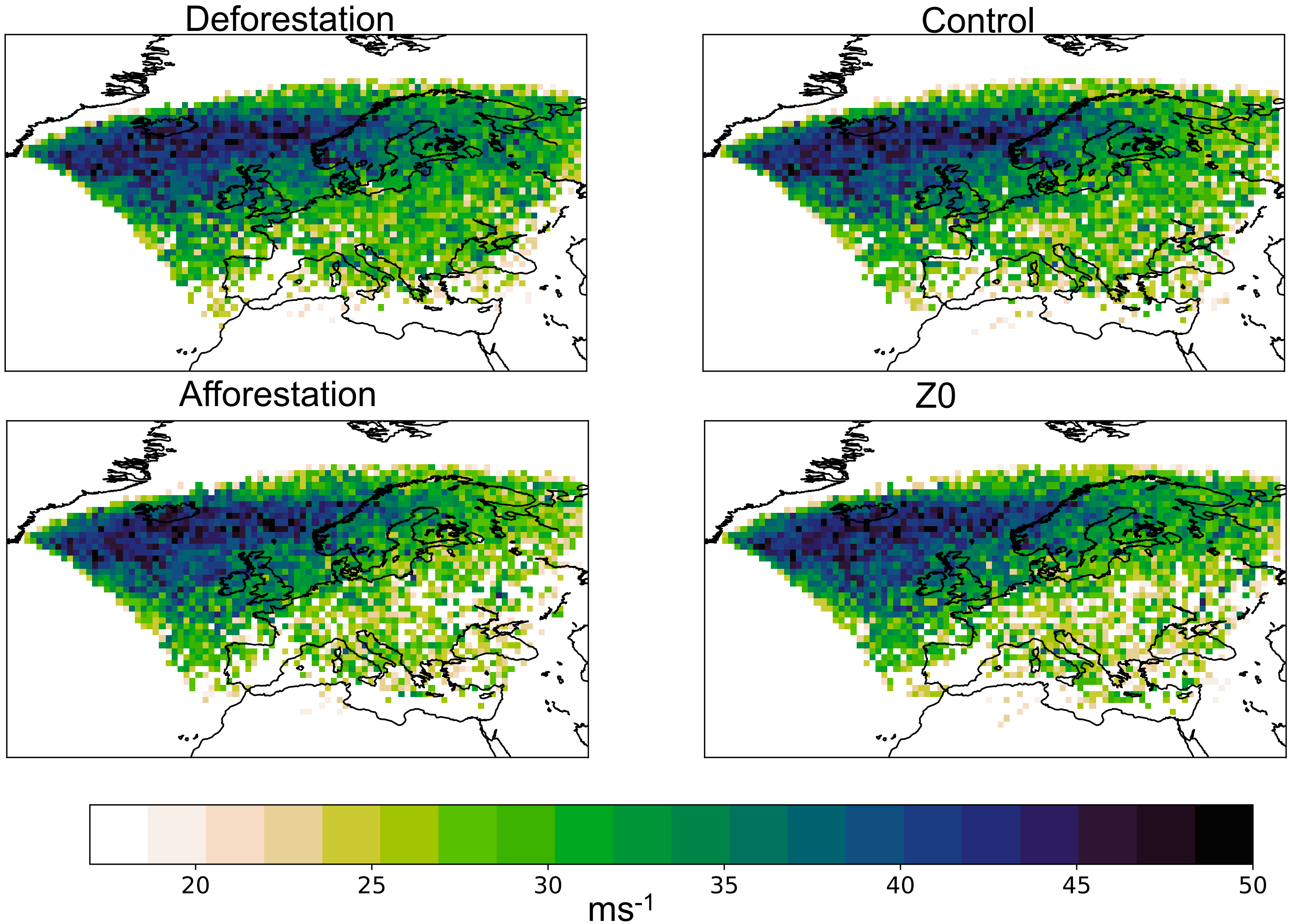
Cyclone density differences among experiments



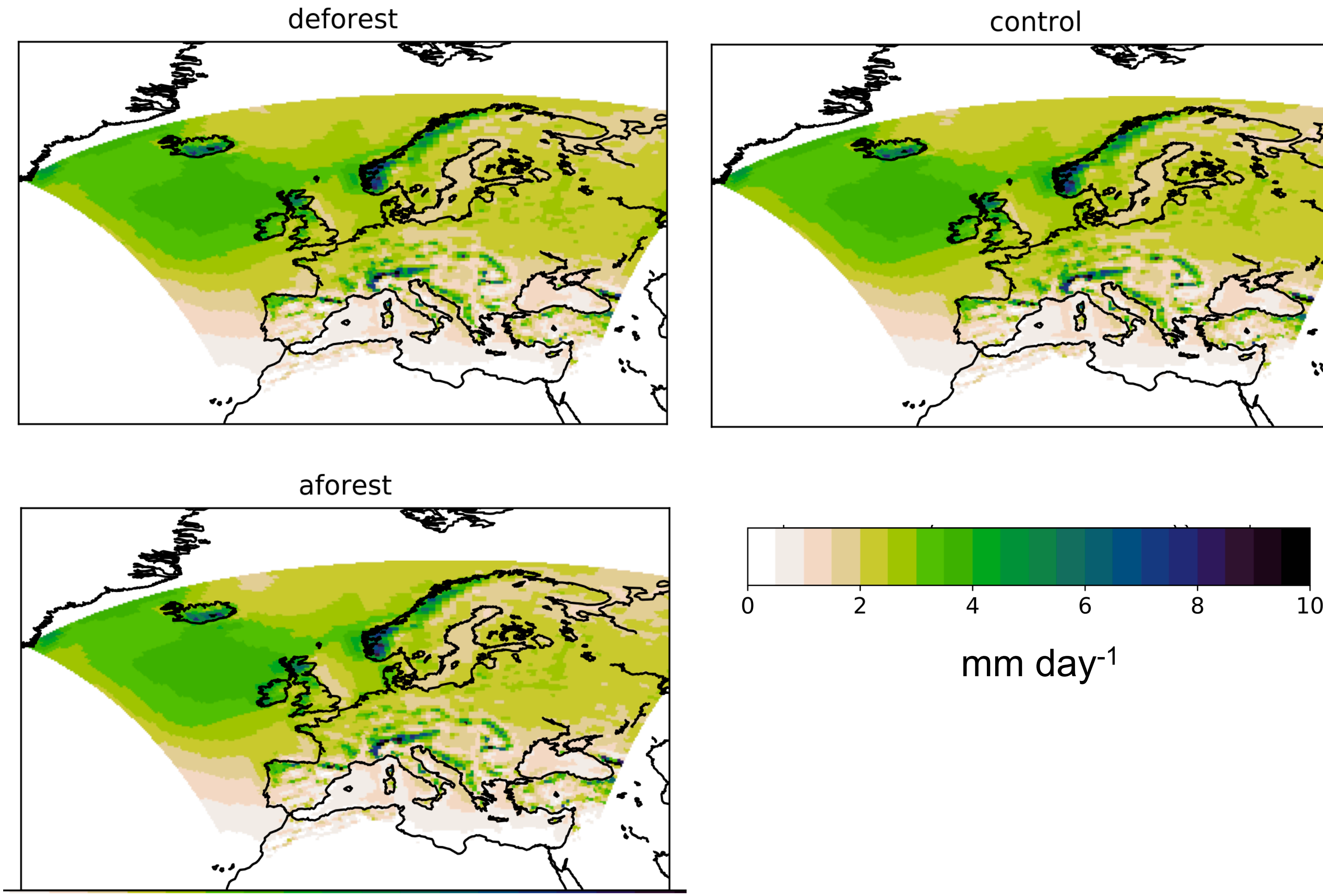
Duration of extratropical cyclones



Maximum wind speed reached by the cyclones

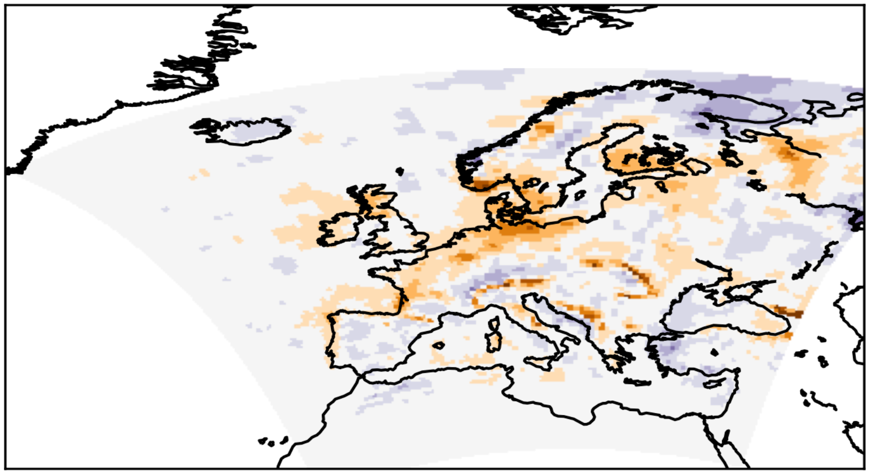


Precipitation climatology

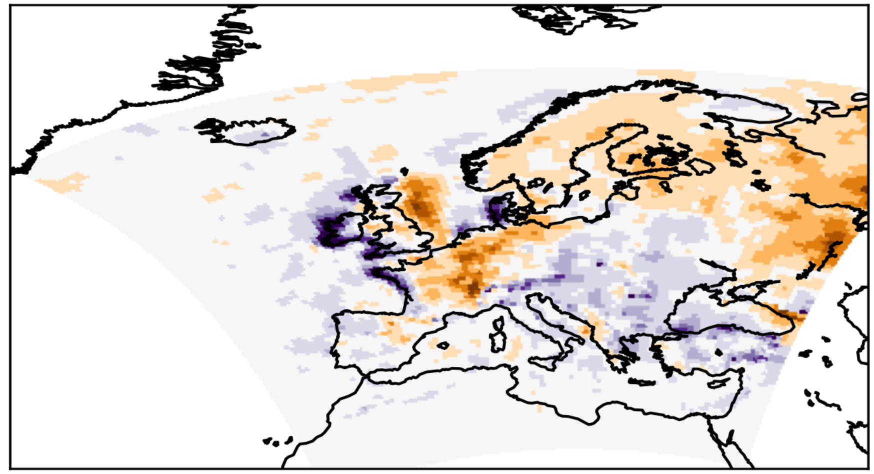


Precipitation climatology differences

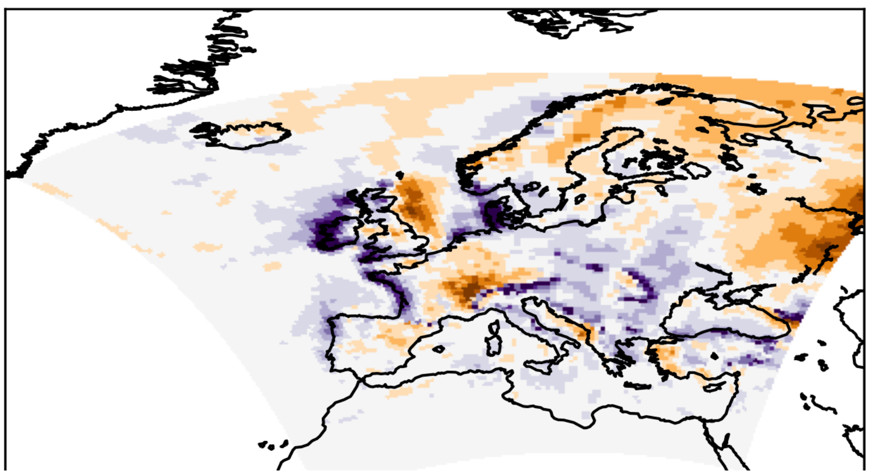
Deforest-Ctl

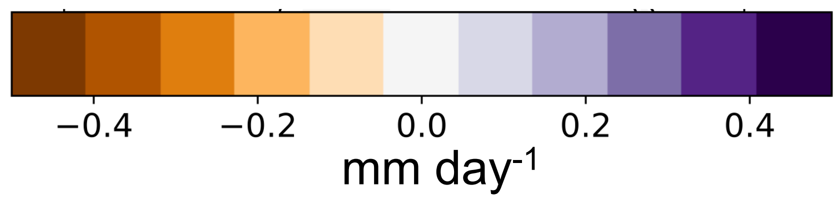


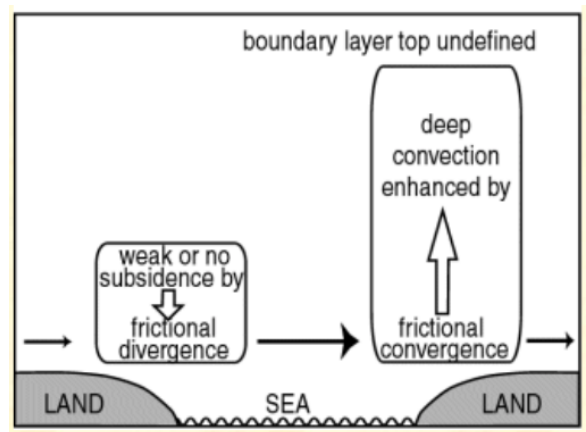
Aforest-Ctl



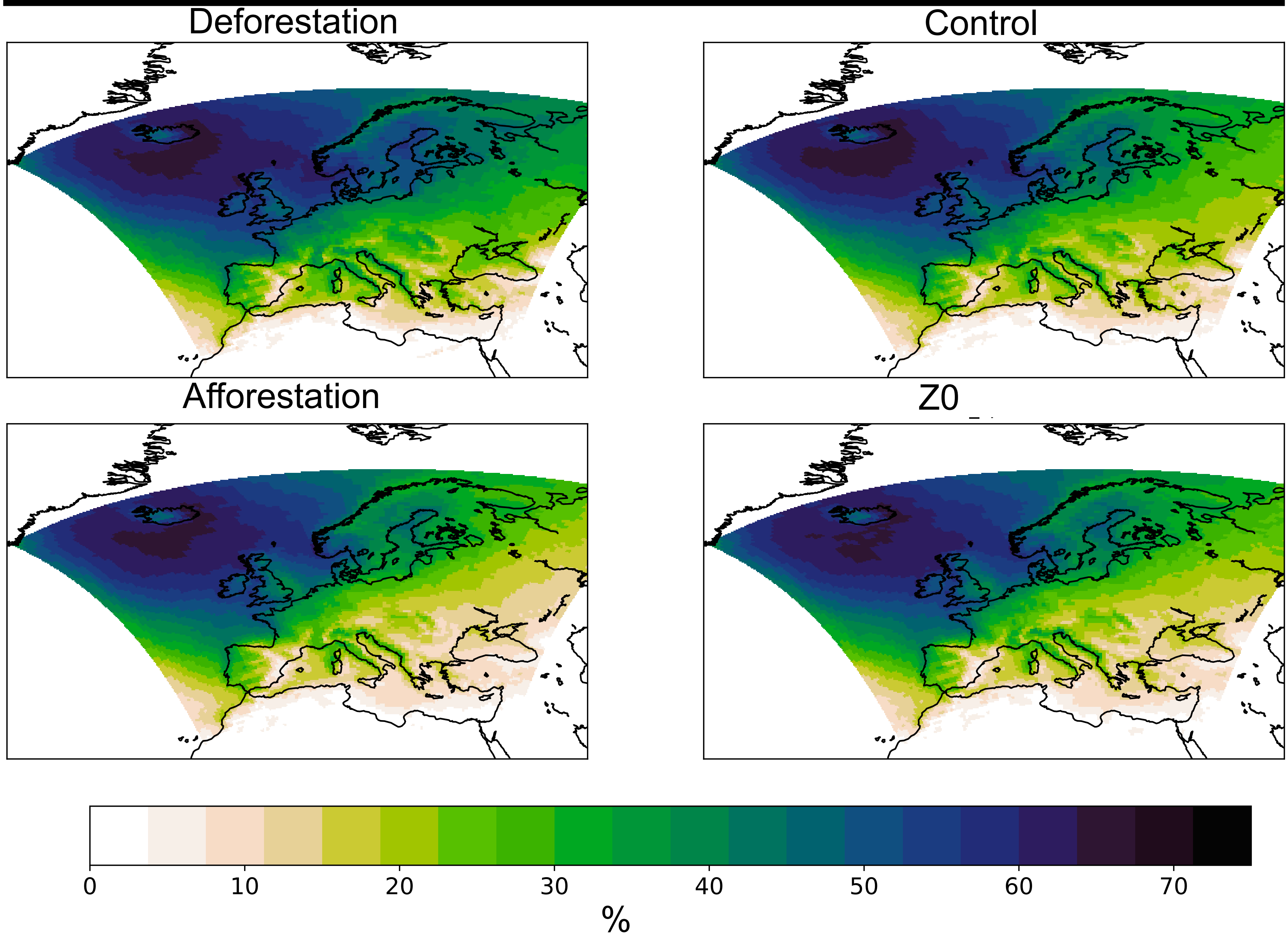
Aforest-Deforest



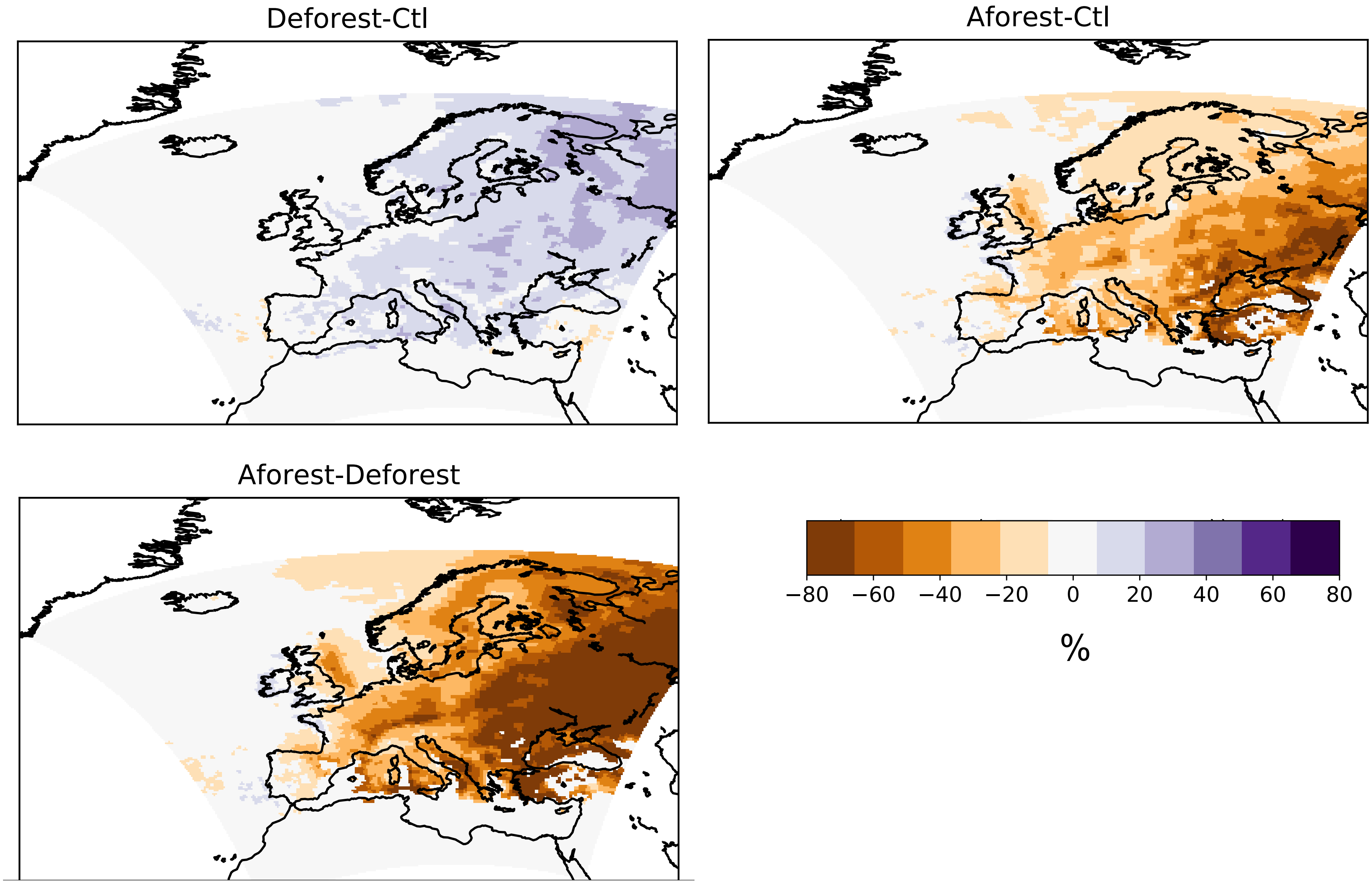




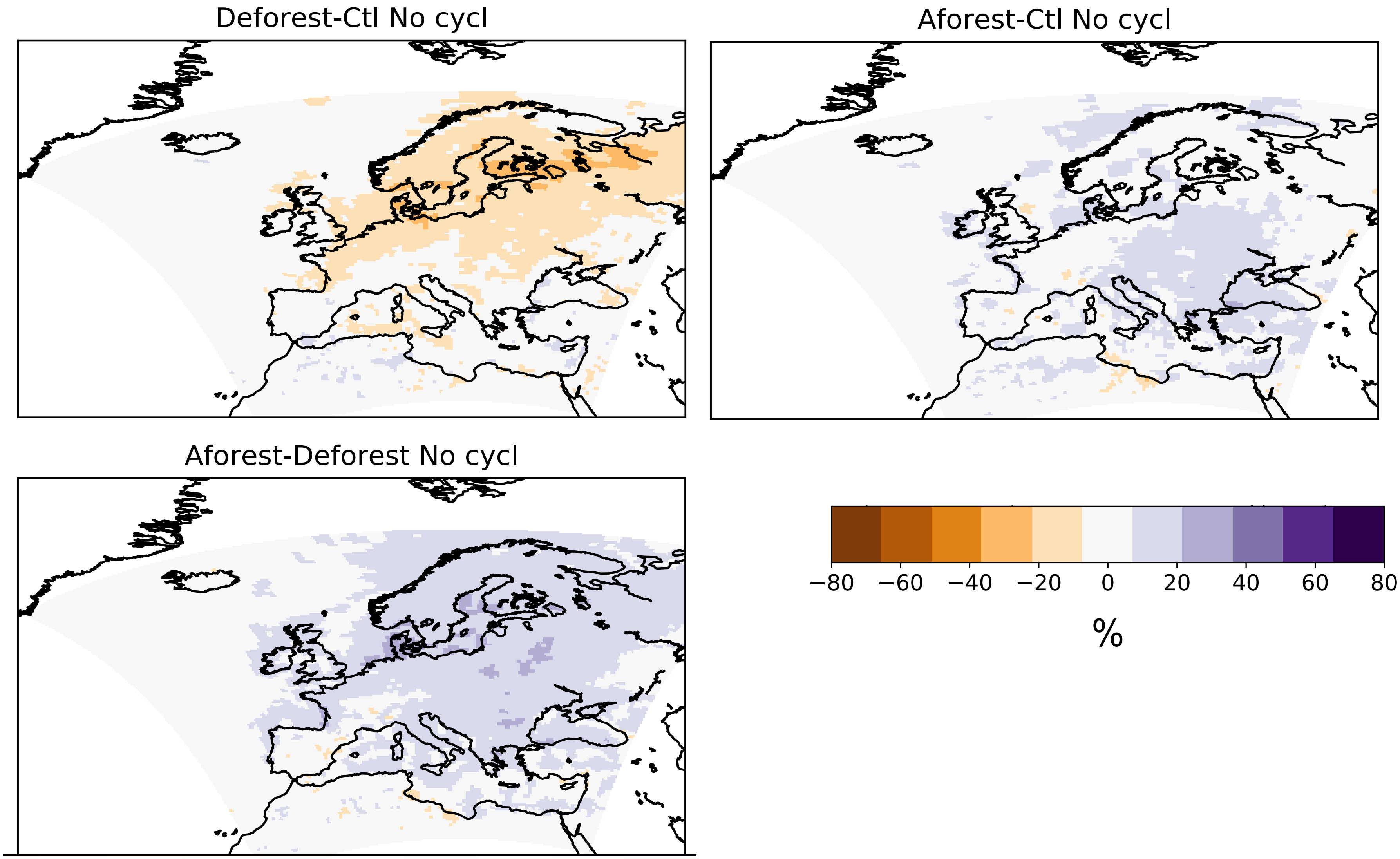
% Cyclone precip / Total precip



Difference Cyclone/Total precipitation percentages among experiments



Difference NO Cyclone/Total precipitation percentages among experiments



Preliminary conclusions

- Roughness lenght increase caused:
  - Cyclone disipation, resulting in shorter cyclone tracks, and therefore
  - A reduction of cyclones travelling from West to East within Europe.
  - Wetter conditions over the western European coasts due to cloud saturation caused by an induced rising motion above the coastline due to roughness difference (roughness convergence).
- Roughness lenght decrease caused opposite results, as expected.
- Z0 experiments using same evapotranspiration, albedo, etc. as for deforestation produced similar results as afforestation, allowing us to confirm the role of roughness length change on cyclone tracks.

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THANK YOU!!

Rossby Centre 20 År
13-14 SEPT 2017
NORRKÖPING, SVERIGE

Bias adjustment on climate model output data

Renate Wilcke
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Bias adjustment on climate model output data

Renate A. I. Wilcke

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Swedish Meteorological and Hydrological Institute
Rossby Centre

13 september 2017

OUTLINE

Bias in climate model output data

Where does the bias come from?

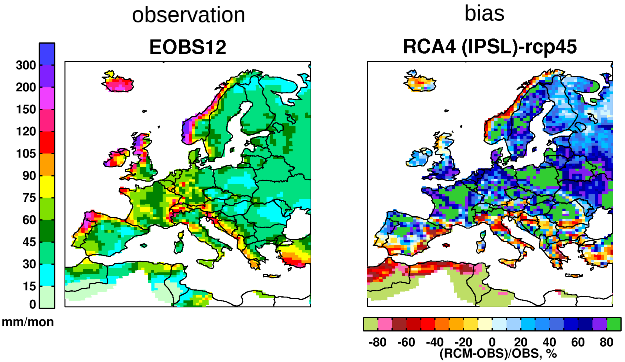
How to adjust model output data?

Results of bias adjustment

Summary

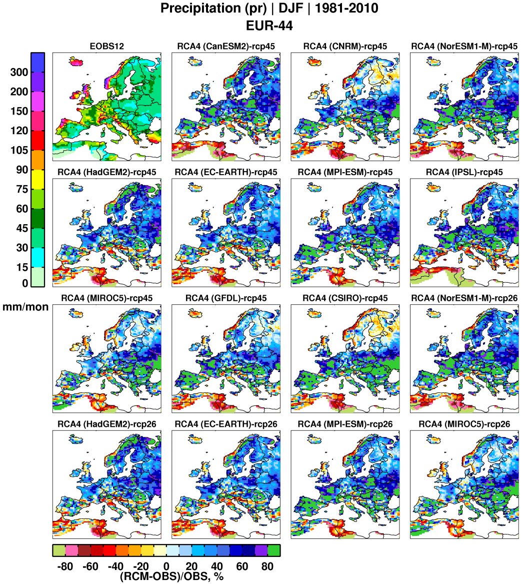
Example 1 - rel. bias in precipitation

Bias in precipitation, DFJ (winter), 1981-2010



Courtesy to Grigory Nikulin

Example 2 - rel. bias in precipitation



Courtesy to Grigory Nikulin

Where does the bias come from?

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Why? Because of ...

- gaps in knowledge about physics
- systematic errors
- model simplifications (model not reality)
- insufficient observations
- scale discrepancy between climate models (grid) and observations (point)

What can we do about the bias?

- continously improving our models
- continously enhance and extend observational data

  and
- statistical bias adjustment

Example - Motivation to adjust bias

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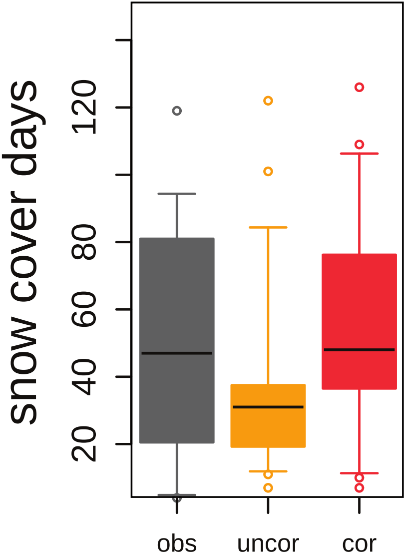
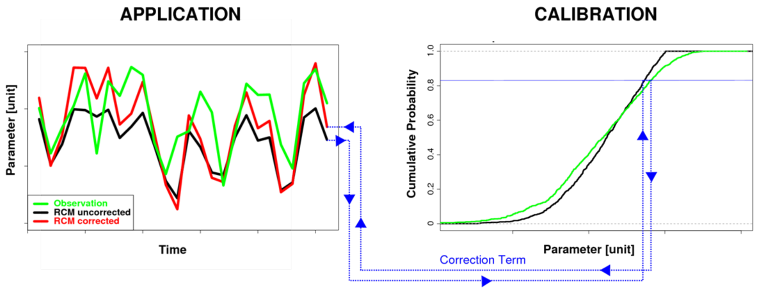


- single station (point observations)
- snow model (AMUNDSEN) using 5 surface variables from climate model simulations

Methods - How to adjust for biases?

SMHI

at SMHI: distribution based scaling (DBS) and empirical quantile mapping

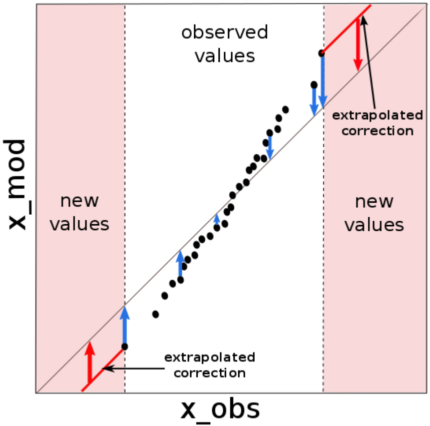


Courtesy to Matthias Themeßl

Methods - How to adjust for biases?

SMHI

adjusting scenario data outside the observed distribution (new extremes)



Requirements - How to adjust for biases?

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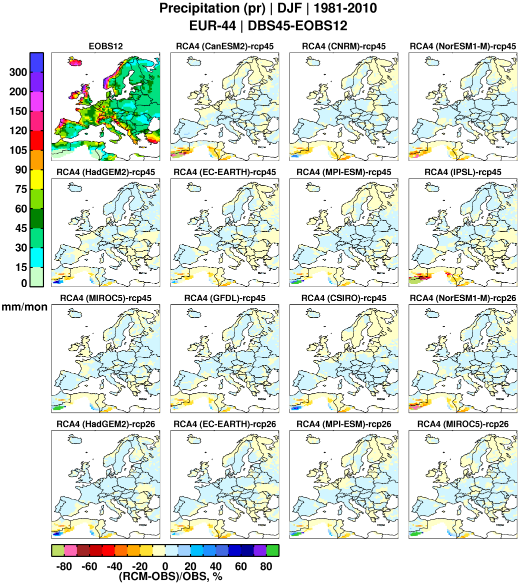
Assumptions for distribution based bias adjustment

- stationarity of bias distribution
  - distribution of the bias is not changing over time
- "perfect" observational data

Requirements

- as good observational data as possible
  - quality
  - densitiy / resolution
  - period (rule of thumb: at least 30 years)
- clear application task

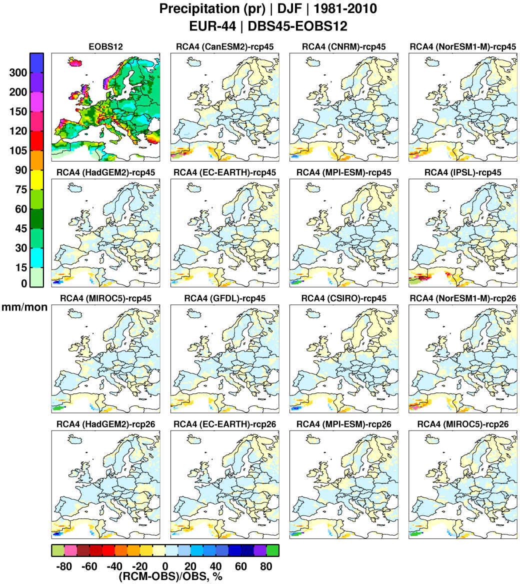
Example DBS - Result of bias adjustment

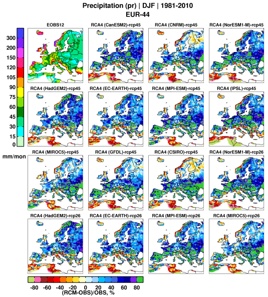


Courtesy to Grigory Nikulin

Example DBS - Result of bias adjustment

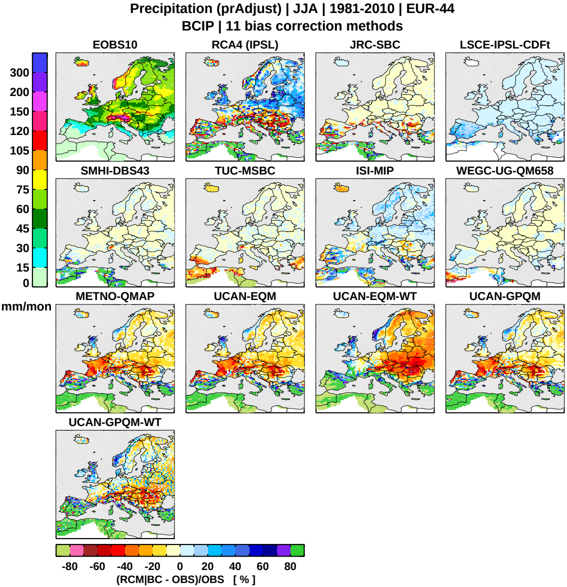
SMHI





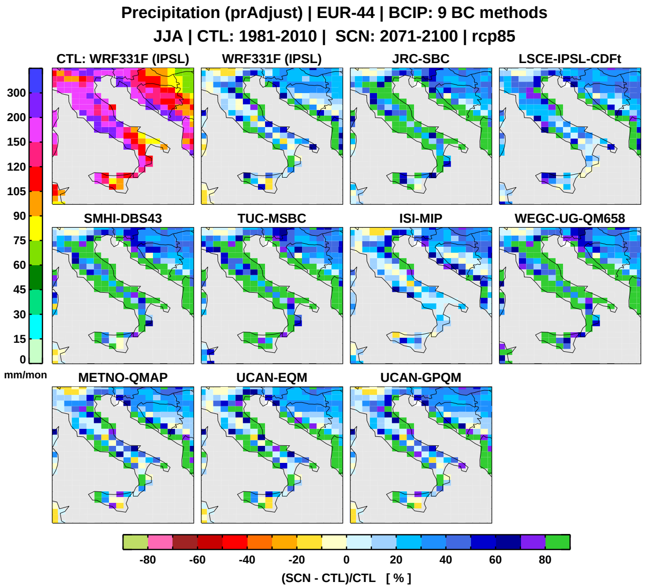
Courtesy to Grigory Nikulin

Bias correction intercomparison project - BCIP



Courtesy to Grigory Nikulin

Precipitation change signal, summer - BCIP



Courtesy to Grigory Nikulin

Summary

Summary

- Climate model output data have biases
- Bias adjustment is essential for many climate impact studies
- Many bias adjustment methods with different advantages
- Choose bias adjustment method fitting your application/focus/interest/budget
- Results depend on observational data

research questions/tasks

- better understanding the effects and differences of bias adjustment techniques
- enhancing and extending observational data sets
- improving and developing verification and validation techniques (scale gap)