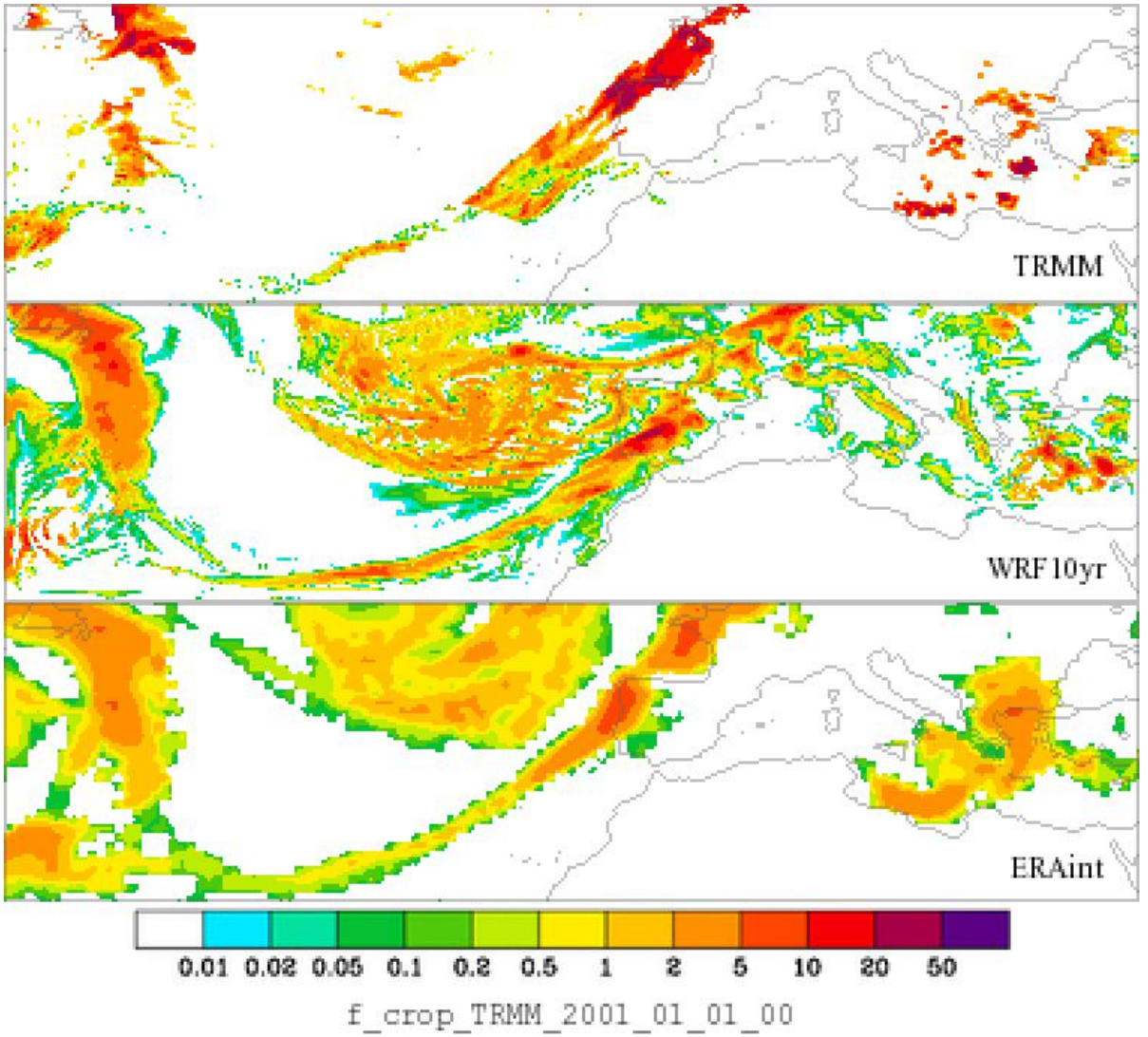
Uncertainties in regional climate models in the mid-latitudes

Nedjeljka Žagar, Luka Honzak, Andrej Ceglar, Gregor Skok, Rahela Žabkar and Jože Rakovec

University of Ljubljana and Center of Excellence SPACE-SI

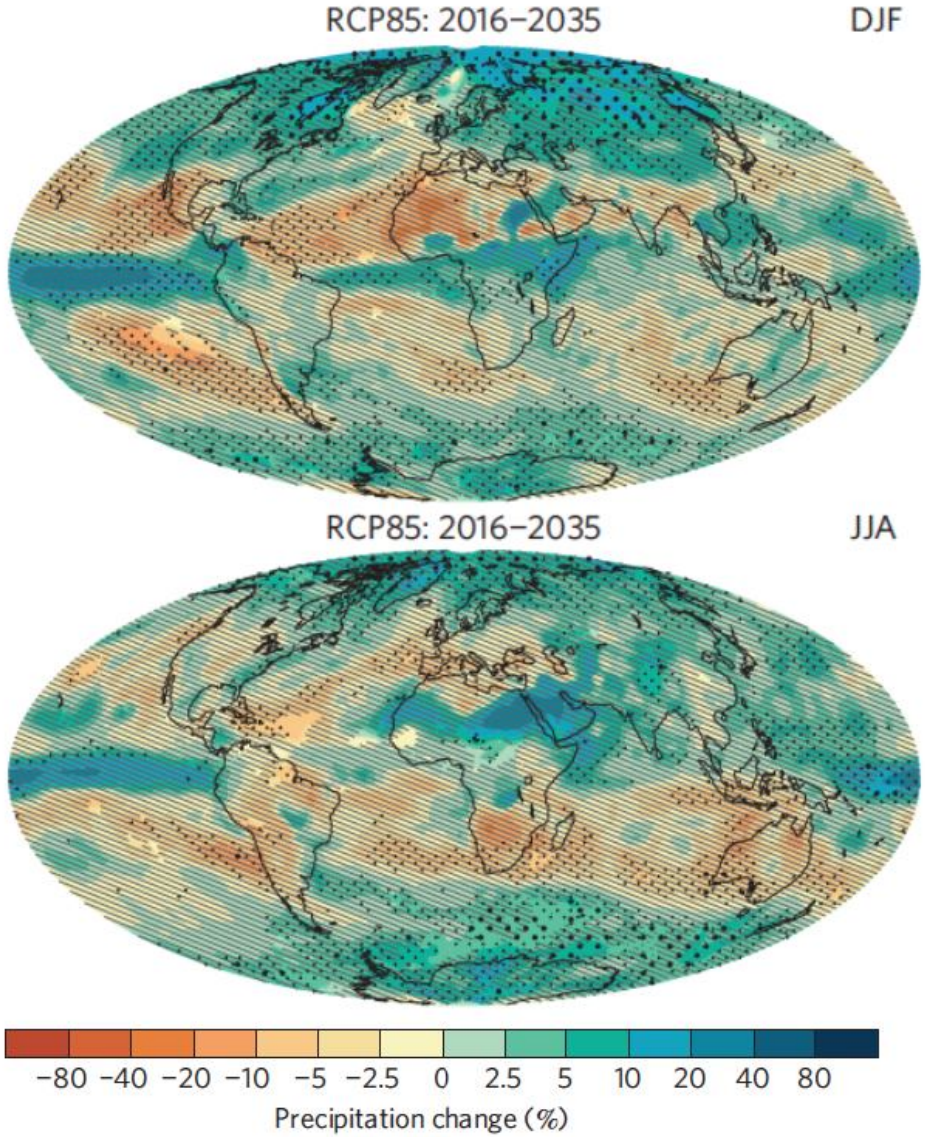
Challenges in meteorology 3: EXTREME WEATHER AND IMPACT ON SOCIETY, Zagreb, 21-22 Nov 2013

Regional climate: weather impacts



Challenges: near-term climate projections

Projections of the mean precipitation changes between 1986-2005 and 2016-2035



CMIP5

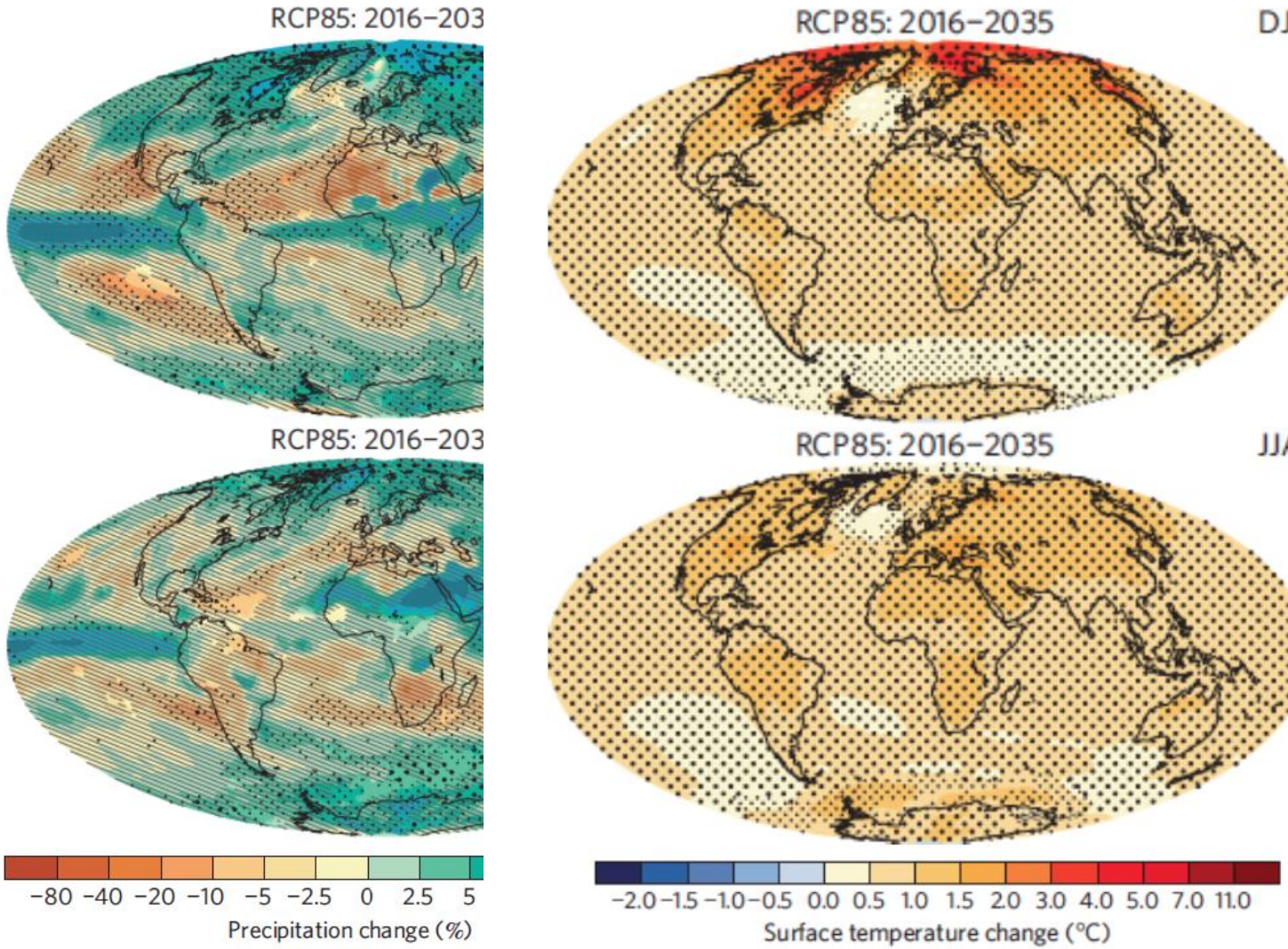
In the stippled areas changes are robust

In the hatched areas changes are not significant with respect to natural variability

From Knutti and Sedlacek, 2012, Nature CC

Challenges: near-term climate projections

Projections of the mean precipitation and **temperature** changes between 1986-2005, 2016-2035 and 2081-2035



CMIP5

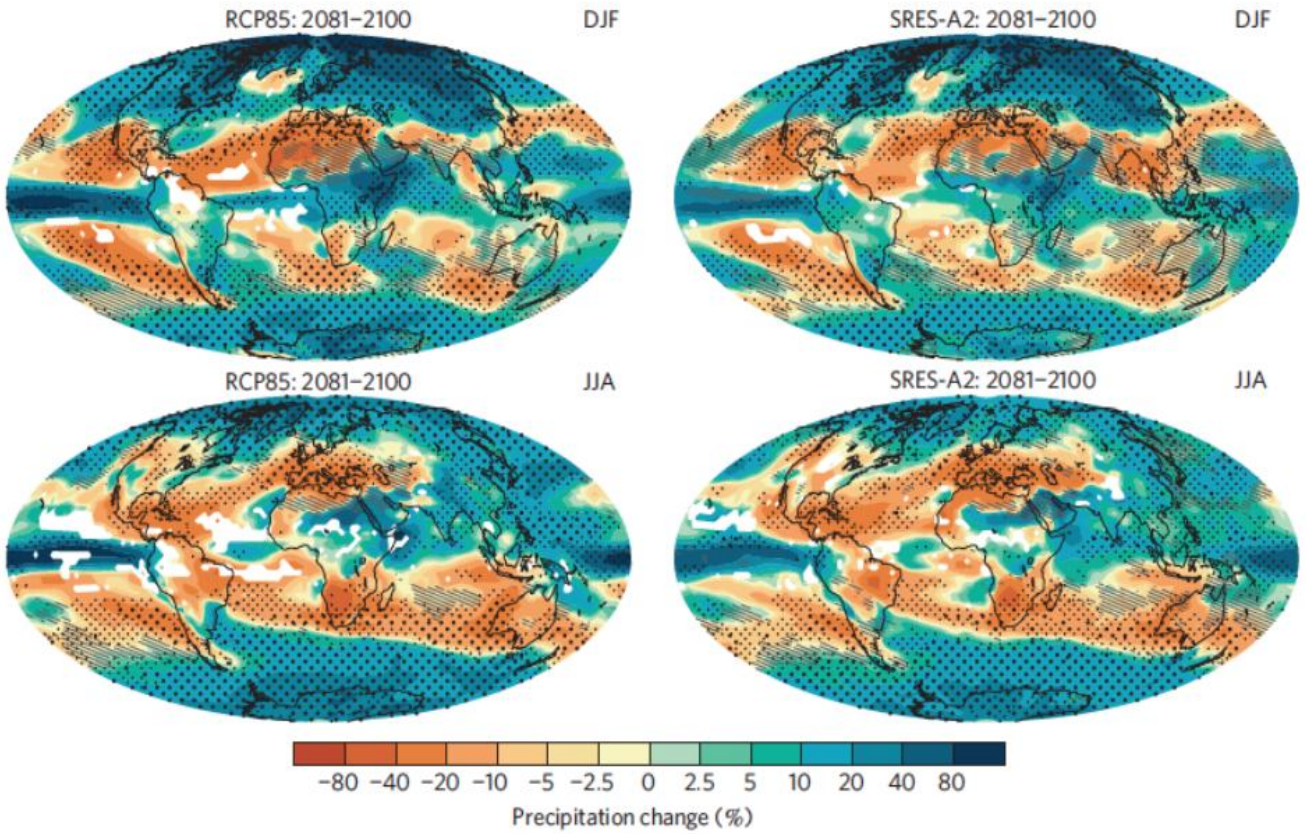
In contrary to precipitation, the predicted changes for temperature are robust

Projected precipitation change is coupled to projected changes in the properties of circulation

From Knutti and Sedlacek, 2012, Nature CC

Challenges: reduction of uncertainties

Projections of the mean precipitation changes between 1986-2005 and 2081-2100 in CMIP3 and CMIP5



CMIP5

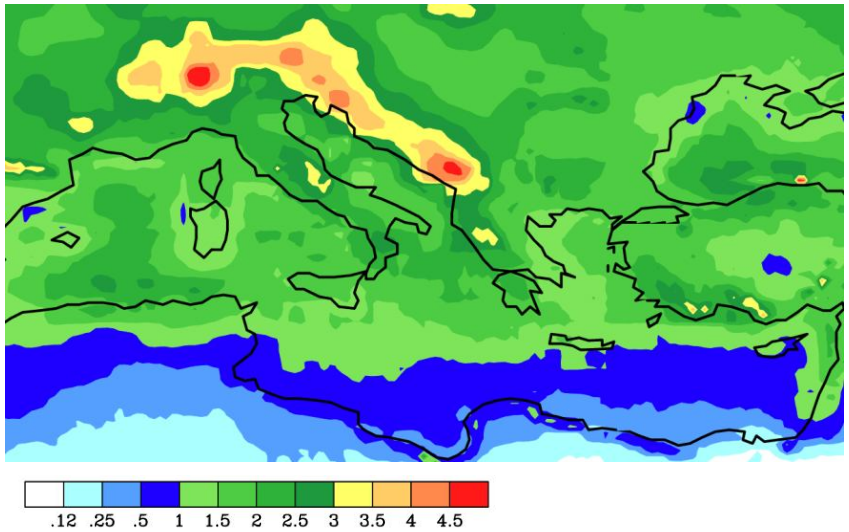
CMIP3

There is little difference between projected precipitation changes in CMIP3 and CMIP5

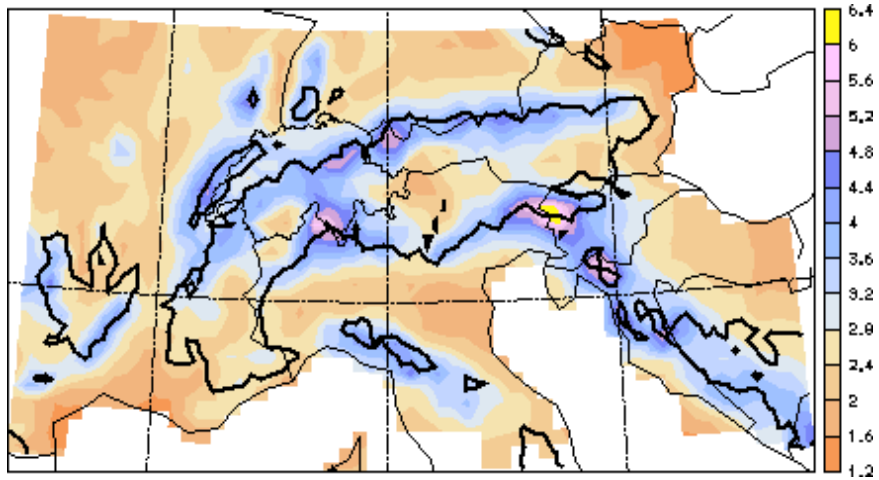
Related to biases in modelled circulation

From Knutti and Sedlacek, 2012, Nature CC

Precipitation climatology in the Alpine region



Mean daily precipitation measured by the TRMM satellite (0.25x0.25 grid), 12-year average



Mean daily precipitation over Alpine region (0.25x0.25 grid), 20-year average (Frei and Schär, 1998)

Climate of small countries across Europe is a subgrid-scale process in current climate models

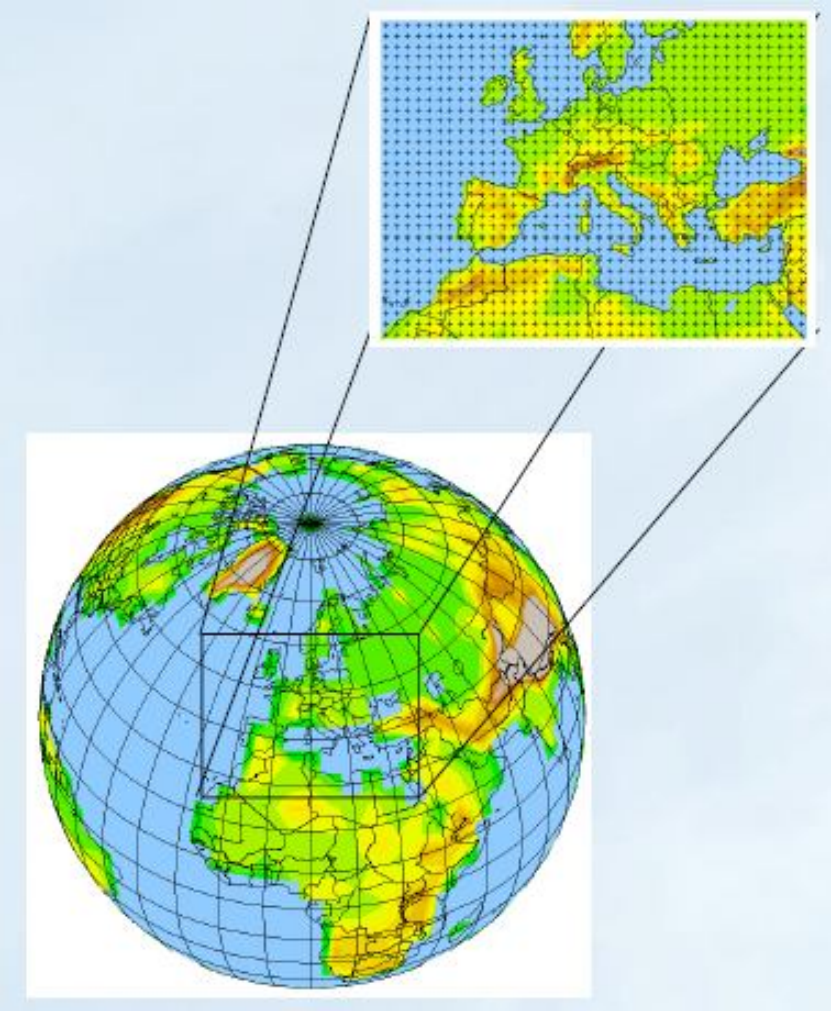
It particularly applies to regions with complex orography, complex land-sea shapes, and heterogeneous land propertis

Regional climate modelling as a magnifying glass

Common errors sources in GCM and RCM: numerical solutions of finite resolution, parametrization of subgrid-scale processes, equations in general only approximate

Extra error sources in RCM: domain size, nesting approach, resolution difference between GCM and RCM, temporal density of LBCs update, LBCs errors

Problem: verification of RCMs



Tenets of regional climate modelling

1. RCMs are capable of generating small-scale features absent in the driving fields supplied as LBCs
2. The small scales that are generated have the appropriate amplitudes and climate statistics
3. The generated small scales accurately represent those that would be present in the driving data if it were not limited by resolution
4. RCM generated small scales are uniquely defined for a given set of LBCs
5. Large scales within the RCM domain a) remain unaffected, b) may be improved owing to reduced truncation and explicit treatment of some mesoscale processes with increased resolution within the RCM domain, c) are degraded because the limited domain is too small to handle these adequately.

Based on Larprise et al., 2008

Tenets of regional climate modelling

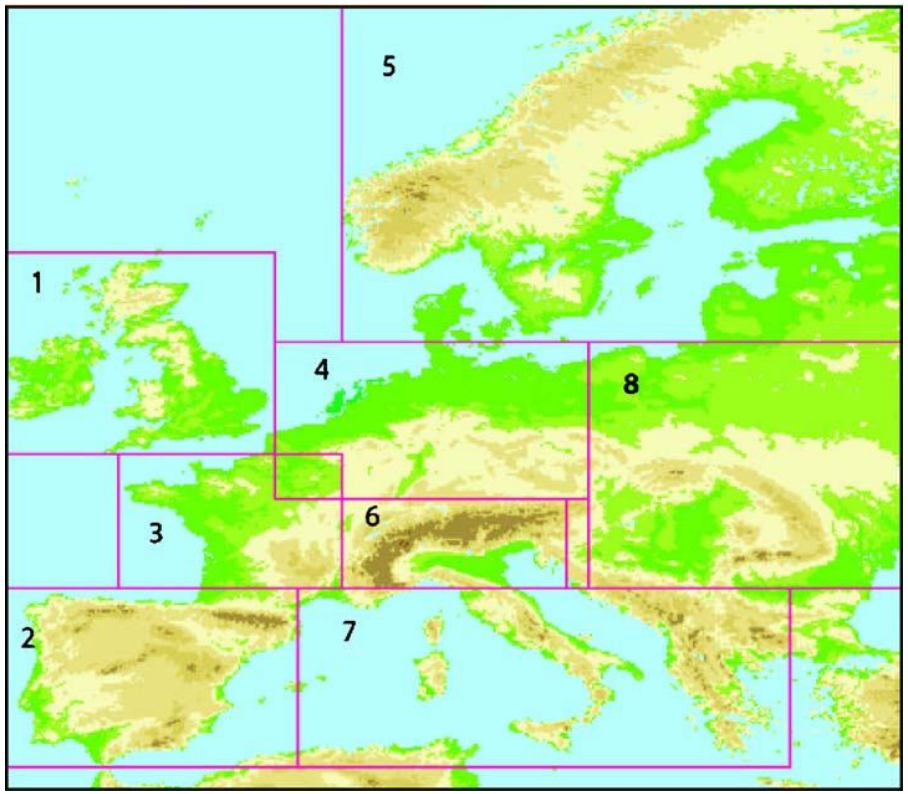
1. RCMs are capable of generating small- scale features absent in the driving fields supplied as LBCs → holds
2. The small scales that are generated have the appropriate amplitudes and climate statistics → holds (in general and for large enough mid-lat domain)
3. The generated small scales accurately represent those that would be present in the driving data if it were not limited by resolution → does not hold for weather, for averages ok
4. RCM generated small scales are uniquely defined for a given set of LBCs → does not hold (internal variability)
5. Large scales within the RCM domain a) remain unaffected, b) may be improved owing to reduced truncation and explicit treatment of some mesoscale processes with increased resolution within the RCM domain, c) are degraded be- cause the limited domain is too small to handle these adequately. → for perfect model a) holds

Based on Larprise et al., 2008

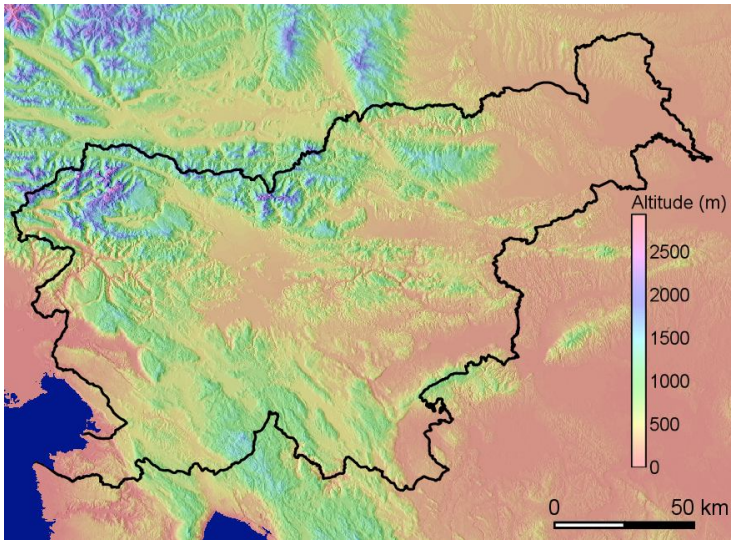
Regional climate modelling over Europe

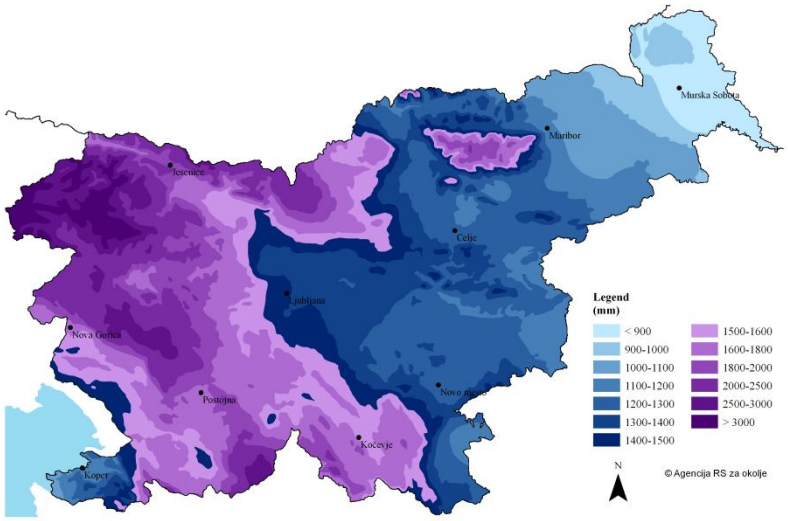
Large EU projects ENSEMBLES and PRUDENCE

Analyses focused on eight European sub-regions

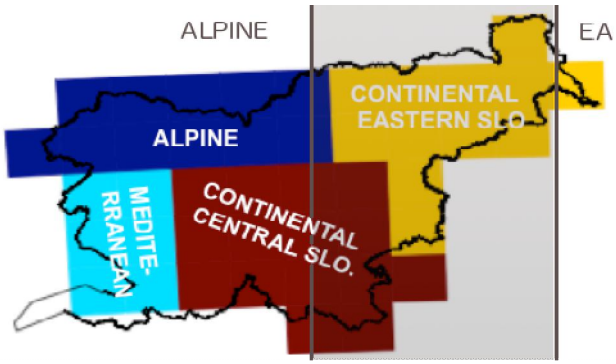


Analysis of ENSEMBLES models over Slovenia





Climate classification for comparison of observations and ENSEMBLES simulations



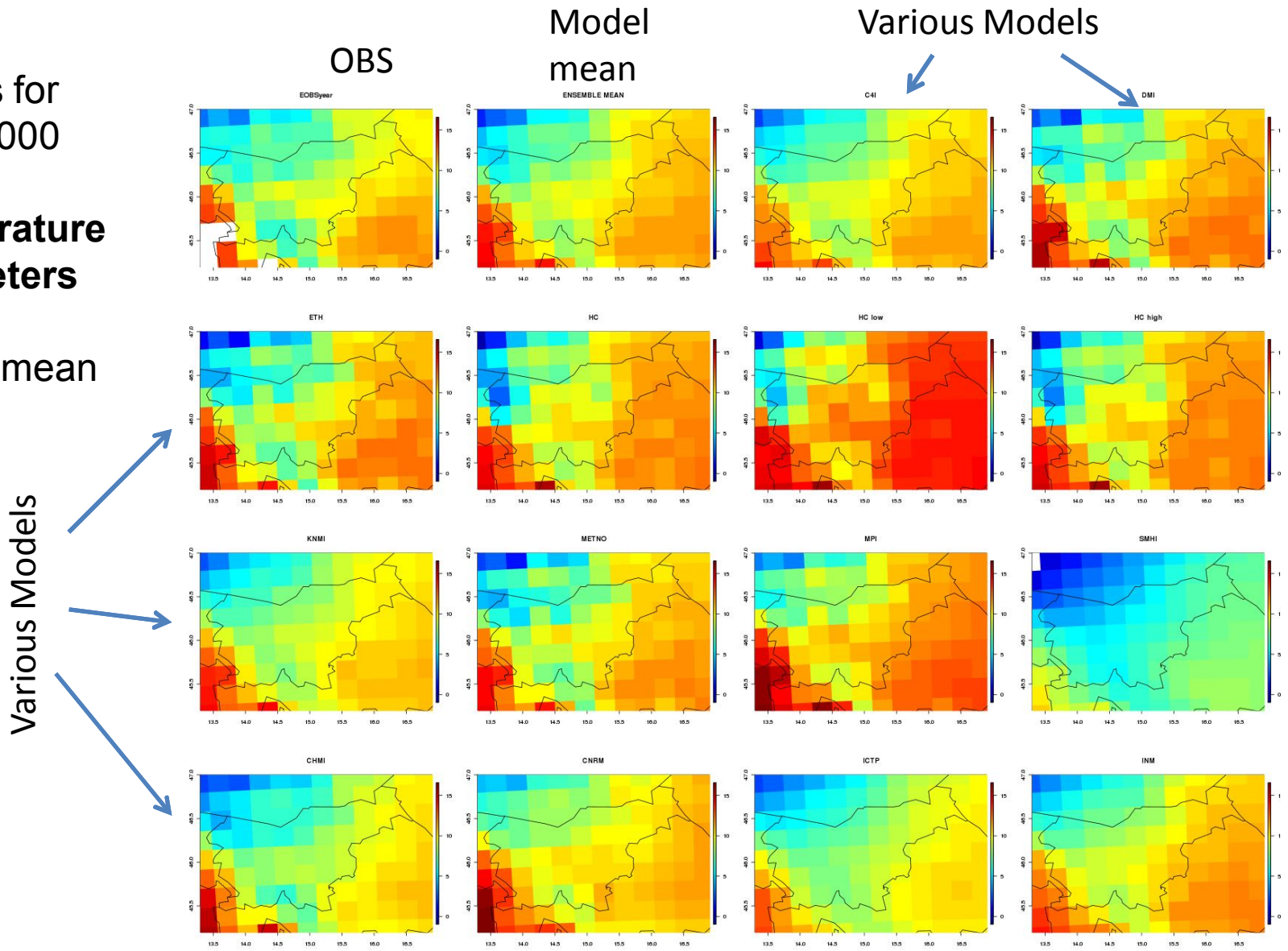
Based on Ceglar et al., 2013: under revision for Int. J. Climatol.

ENSEMBLES results over Slovenia: uncertainties

Results for 1960-2000

Temperature at 2 meters

annual mean

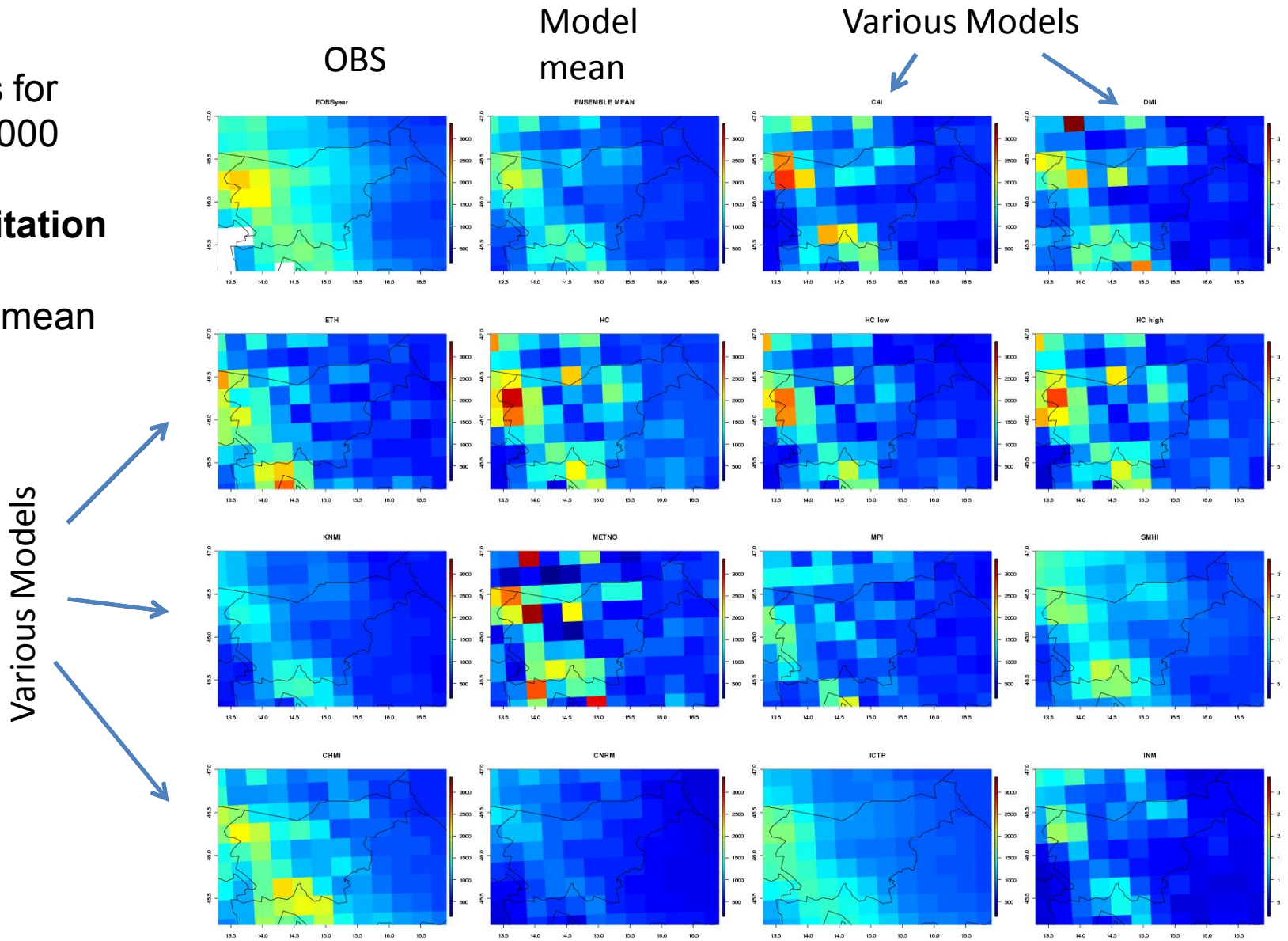


ENSEMBLES results over Slovenia: uncertainties

Results for 1960-2000

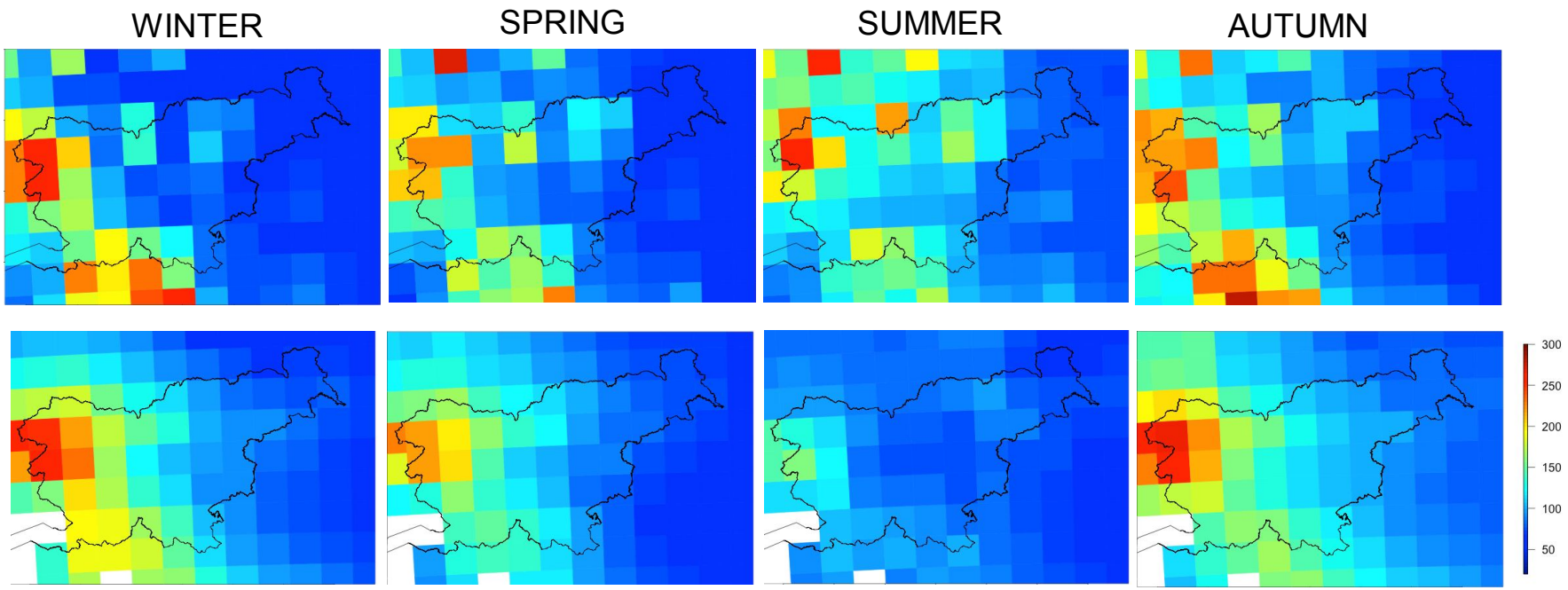
Precipitation

annual mean



Analysis of ENSEMBLES models over Slovenia

Comparison of precipitation variability



Top raw: 14 ENSEMBLES simulations

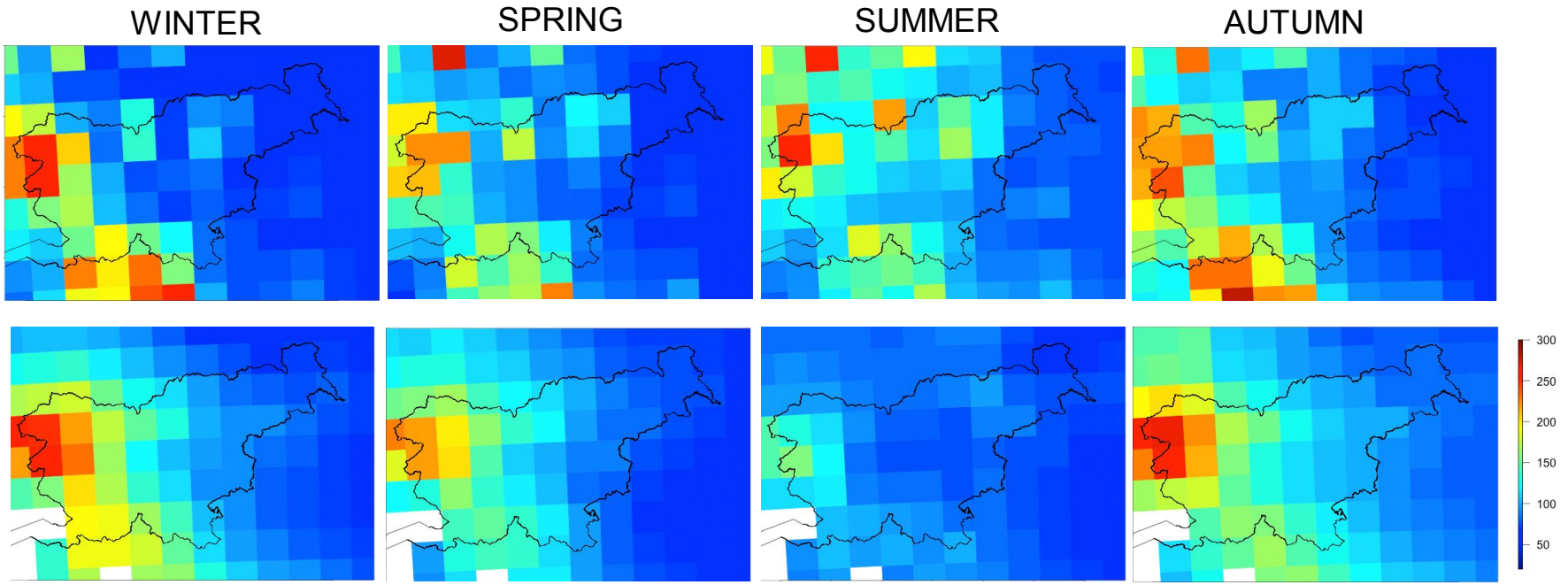
Bottom raw: Observations

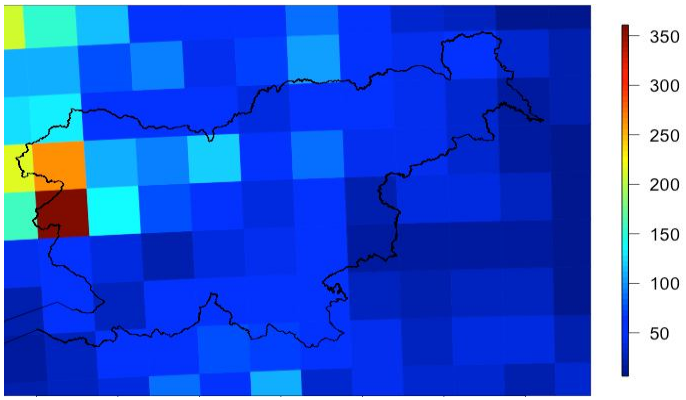
Based on period 1960-2000

Ceglar et al., 2013:
under revision for Int. J. Climatol.

Analysis of ENSEMBLES models over Slovenia

Comparison of precipitation variability





Spread of the orography among 14 ENSEMBLES models

Ceglar et al., 2013:
under revision for Int. J. Climatol.

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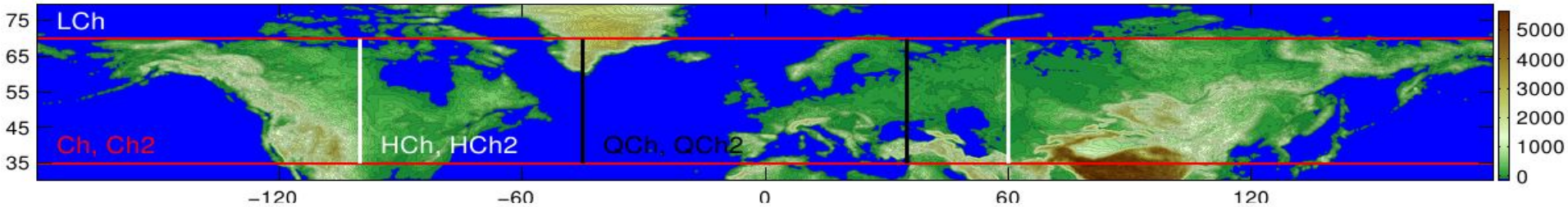
Based on Larprise et al., 2008

Study of internal variability by WRF

Study limited to the impact of imperfect nesting methodology in relation to the domain size and differences between GCM and RCM

Two kinds of simulations

- Simulations nested into ECMWF analyses
- Simulations nested within WRF (a perfect-model network)



LCh, Ch, HCh, QCh directly nested into ECMWF analyses

Ch2, HCh2, QCh2 nested into LCh.

Internal variability: 3 simulations on each domain

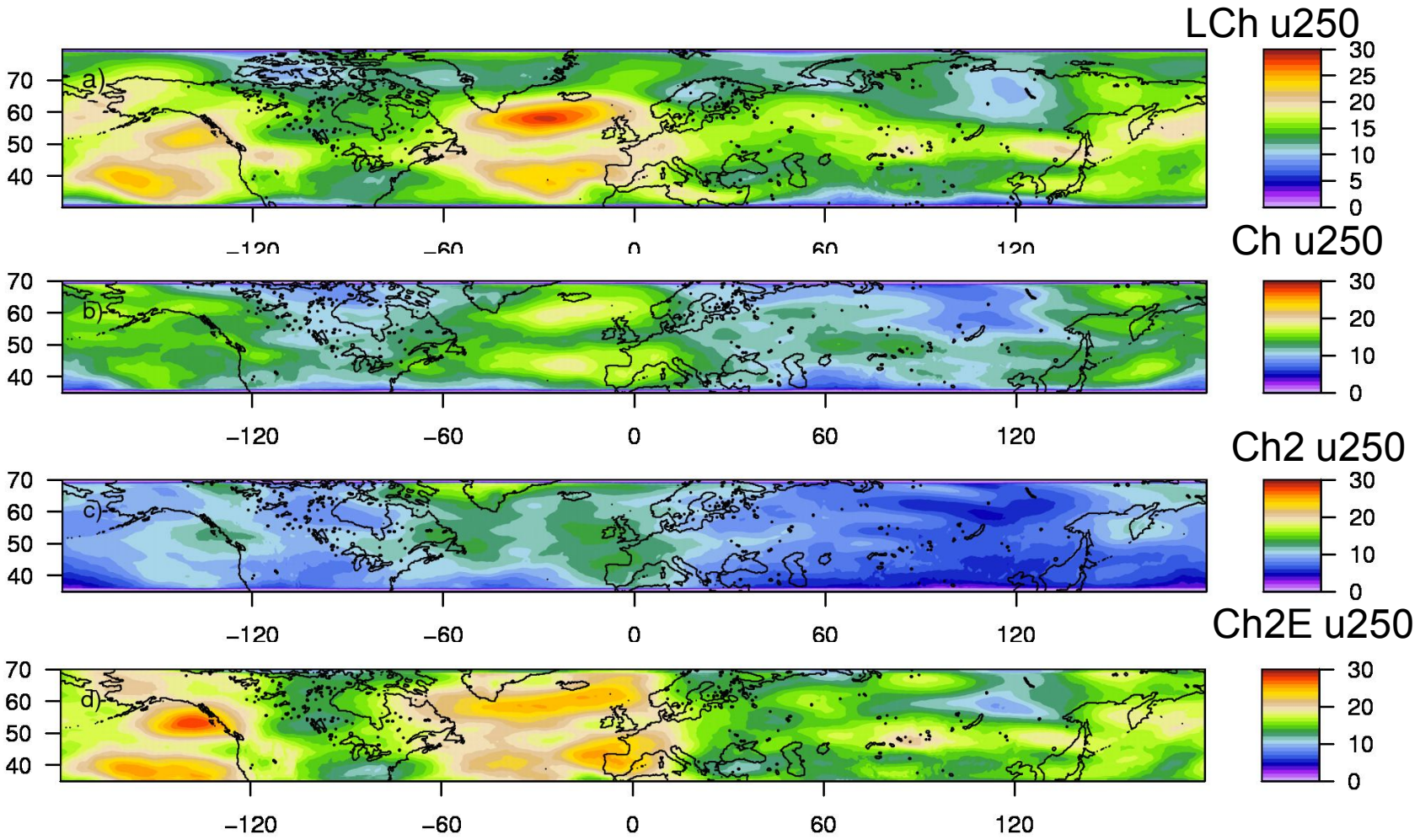
Horizontal resolution: 0.25 x 0.25 degrees.

Verification against ECMWF analyses and LCh.

From Zagar et al., 2013: JGR Atmosphere

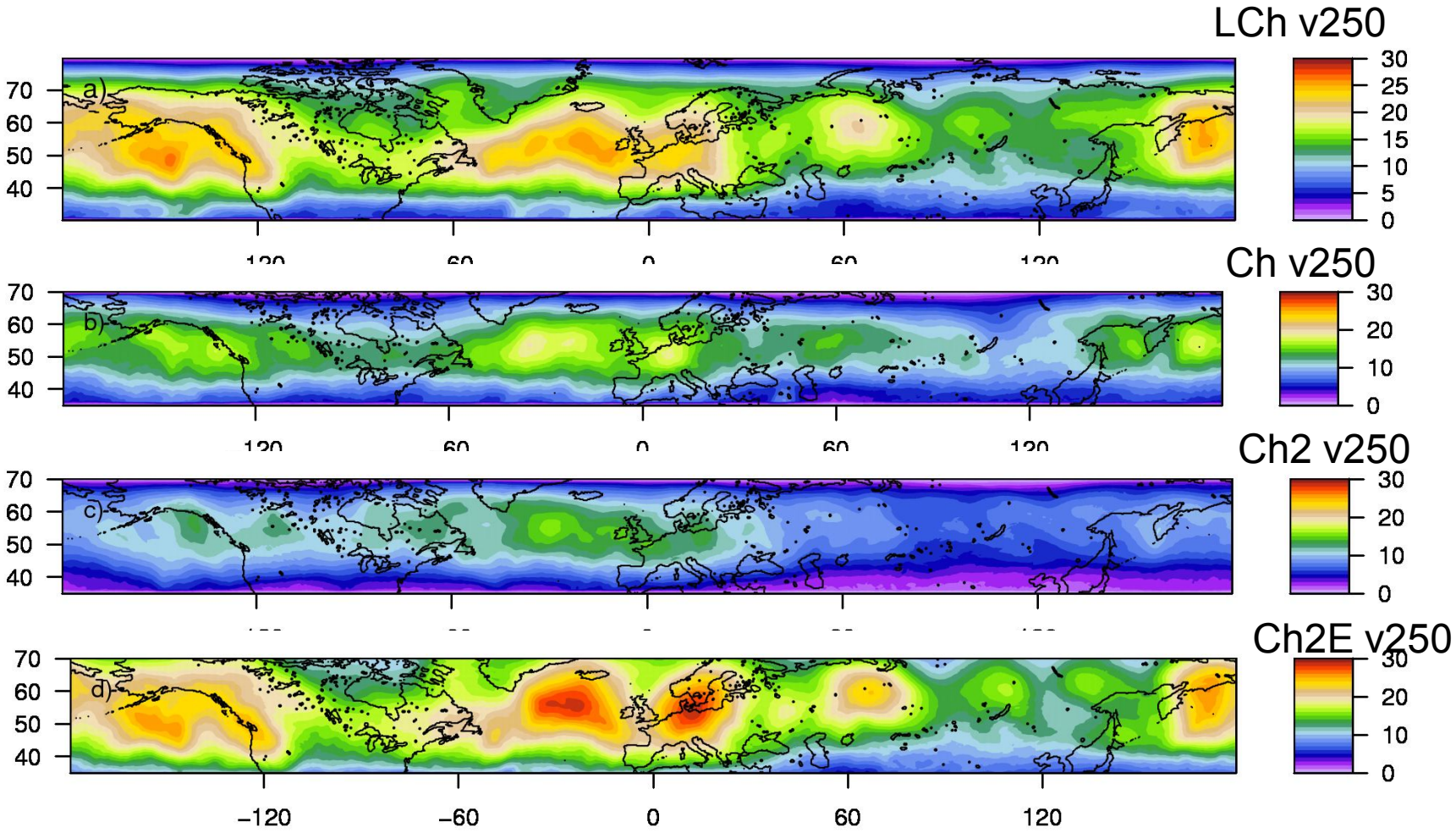
Internal variability: time-averaged rmsd, u wind

Impact of model differences and impact of imperfect nesting



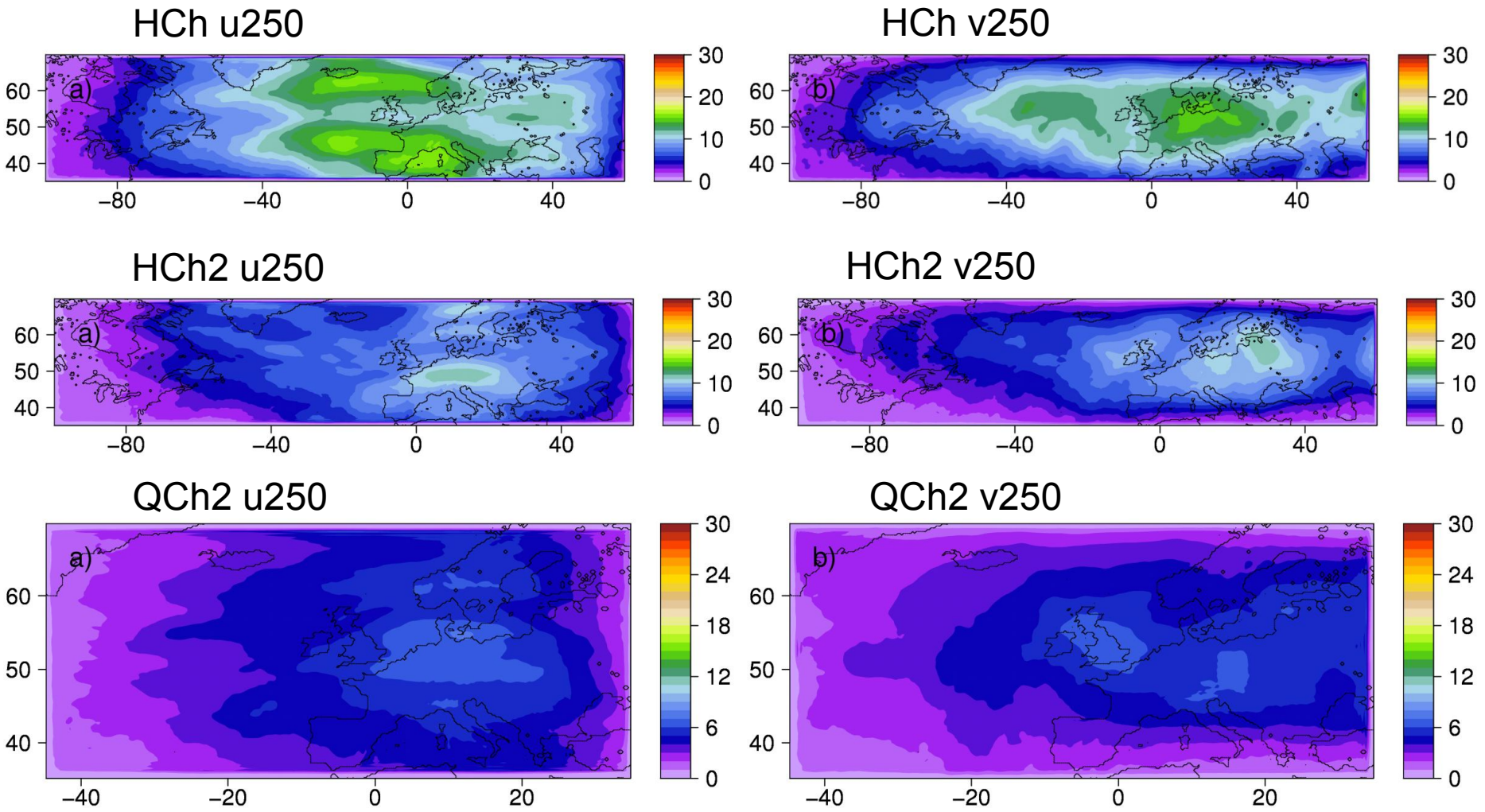
Internal variability: time-averaged rmsd, v wind

Big impact always centered in the model domain



Internal variability: sensitivity to the domain size

The HCh domain keeps the main propeties found in the Ch domain.
However, QCh domain has a very small variability at very different places

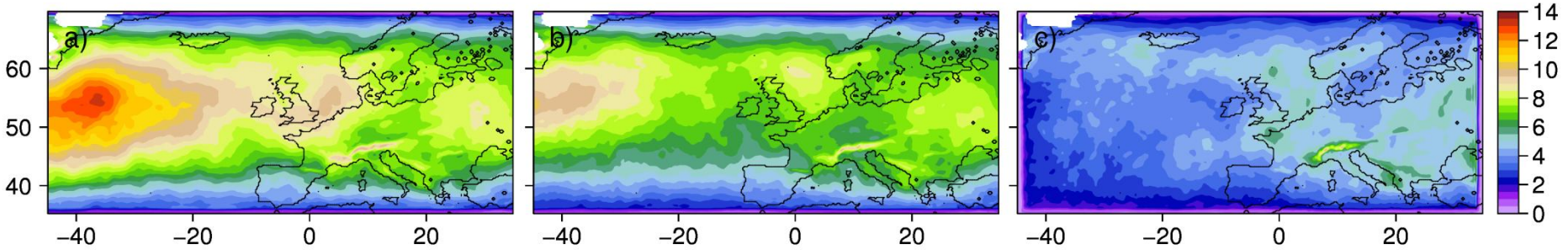


Internal variability: ensemble spread

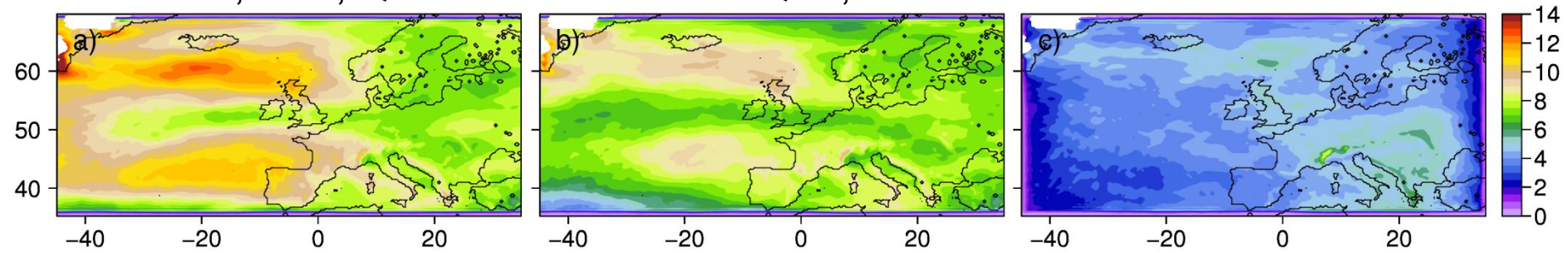
In the QCh domain, which is stil larger than most of domains used for RCM in Europe, internal varibility of circulation becomes almost negligible.

When resolution is different, IV arises due to resolution

Ch, HCh, QCh on the domain of QCh, u wind at 700 hPa

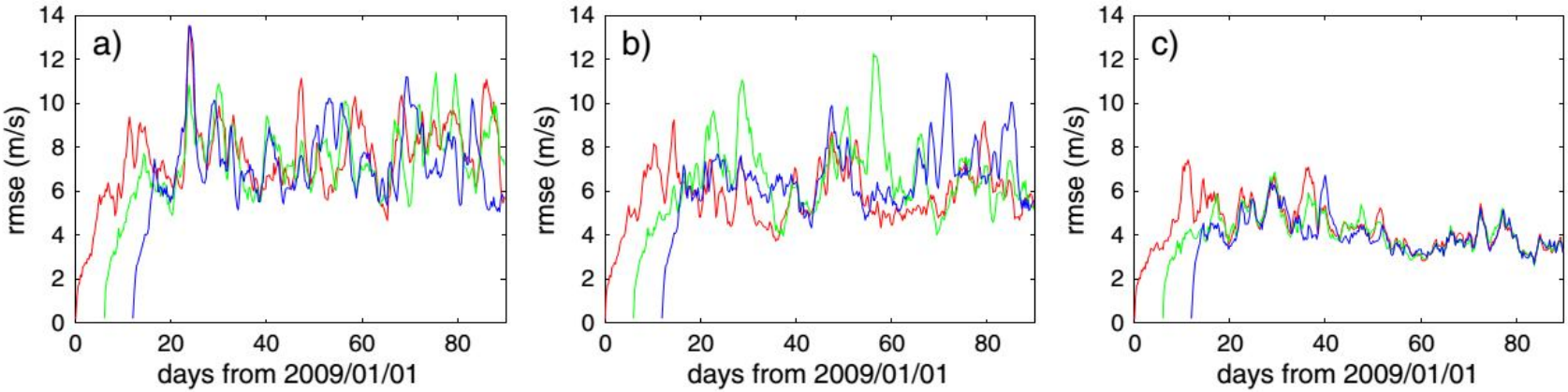


Ch, HCh, QCh on the domain of QCh, v wind at 700 hPa



Internal variability: time evolution of rmsd

Domain-averaged time-series of meridional wind component at 700 hPa



Ch HCh QCh

Summary

The focus is on regional impacts of climate change and regional climate modelling

Large uncertainties are present on regional scales in GCMs

Uncertainties amplify in RCMs.

For small countries in central Europe we can not confidently say what the climate scenarios are

Performed RCMs experiments illustrate the impact of the domain size and lateral boundaries on downscaling results: For simulations focusing on Europe location of western boundary is important. By studying impact of coupling deficincies on RCM results we found that the largest errors in the mid-latitudes circulation are over Atlantic and Pacific. In smaller domains, errors are are nearly spatially homogeneous and internal variability small.