Climate change at the Croatian Adriatic - observations and regional climate models' simulations

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Outline

* The Croatian Adriatic
  - orography and land-sea contrast at small scales

* Observed climate and climate change (1961-1990)
  - from 5 island and 8 coastal stations
  - T2m, precipitation

* Model simulation of reference climate
  - 5 regional climate models (RCMs) from the ENSEMBLES project
  - all RCMs at ~25-km resolution
  - lateral boundary forcing by ERA40 and by ECHAM5/MPI-OM GCM

* Future climate change
  - based on the IPCC A1B scenario

* Some conclusions

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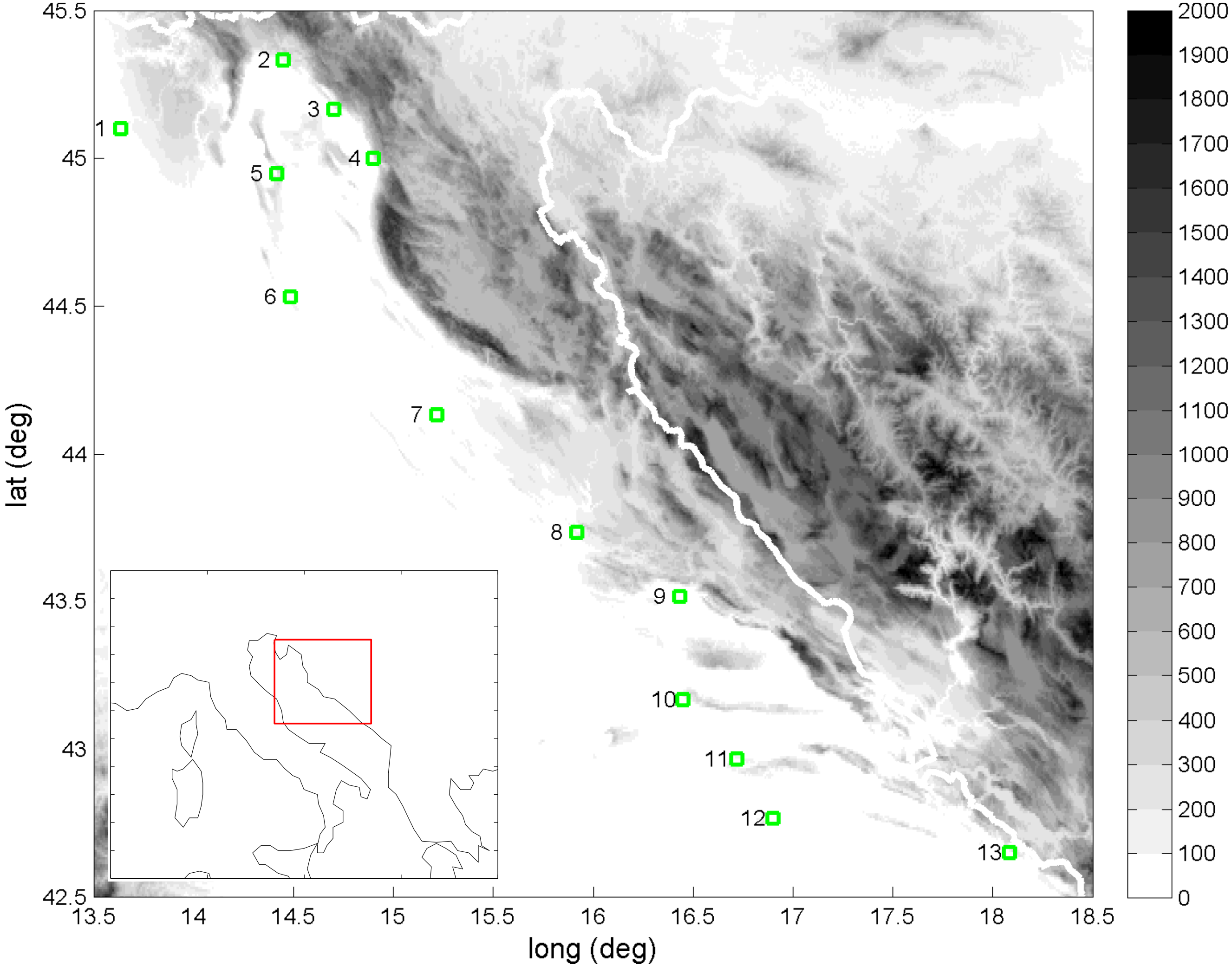
The Croatian Adriatic – small scales

* Complex coastline and orography: 600 islands, coast length 5,500 km
* Reasonably well covered by climatological stations (8 coastal, 5 islands)



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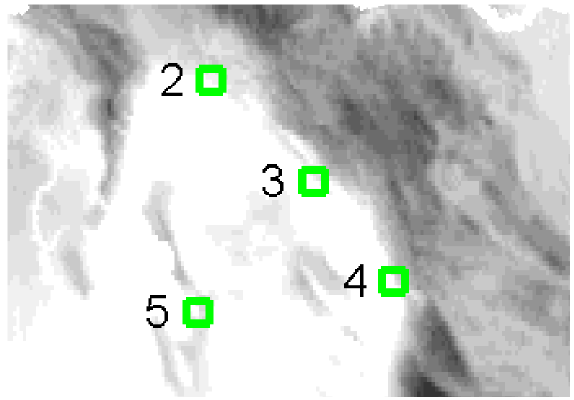
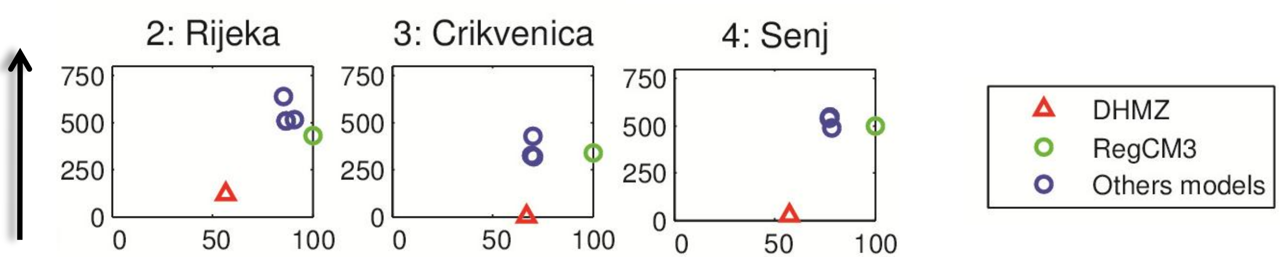
The Croatian Adriatic - orography

* Important in the north – maximum heights over 1700 m (steep gradients)
  - less important elsewhere (islands)



* Is small-scale orography represented well in (25-km) RCMs?

orography height (m)



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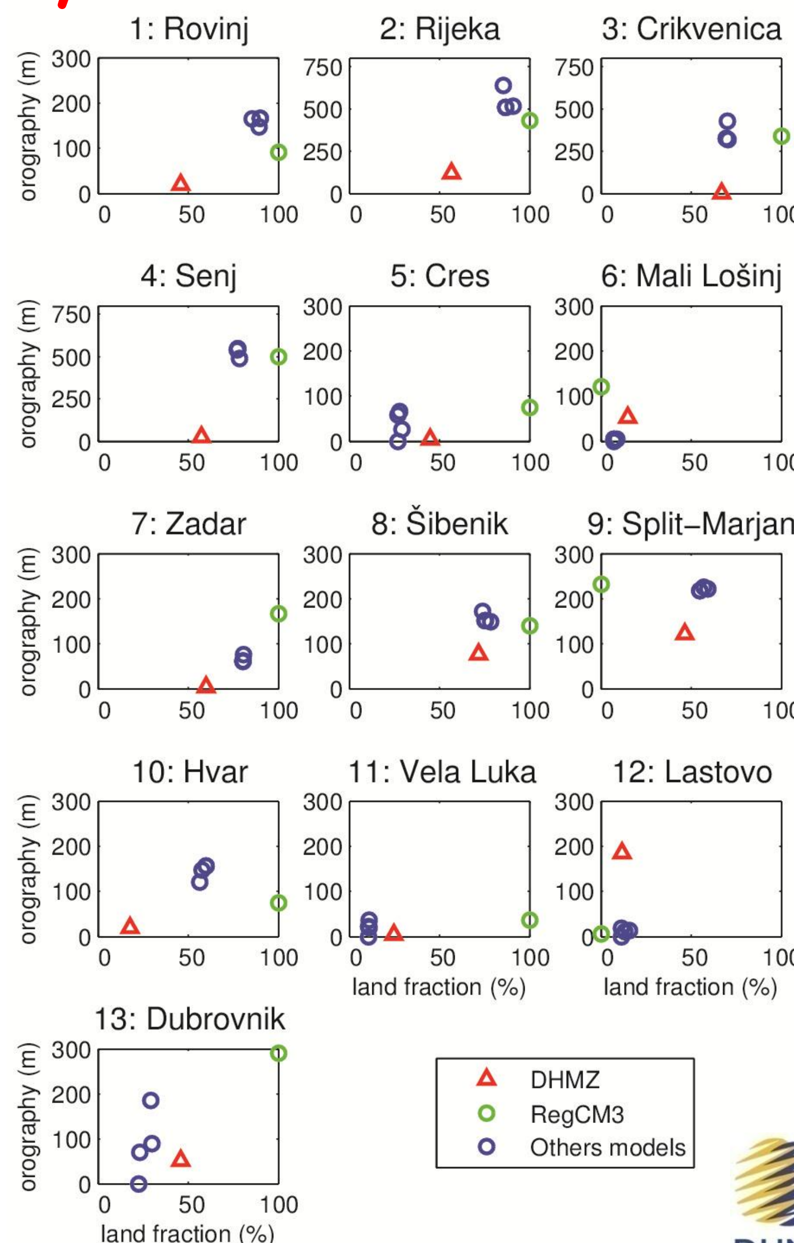
The Croatian Adriatic – orography in RCMs

* In most models, the height of grid-point closest to station's location is within 100-150 m of the station true altitude (except for 2, 3, 4 and 12)

* RCMs generally overestimate orography, except for two island stations (6, 12)

height



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The Croatian Adriatic – land-sea contrast

* The US 1-km GTOPO30 dataset

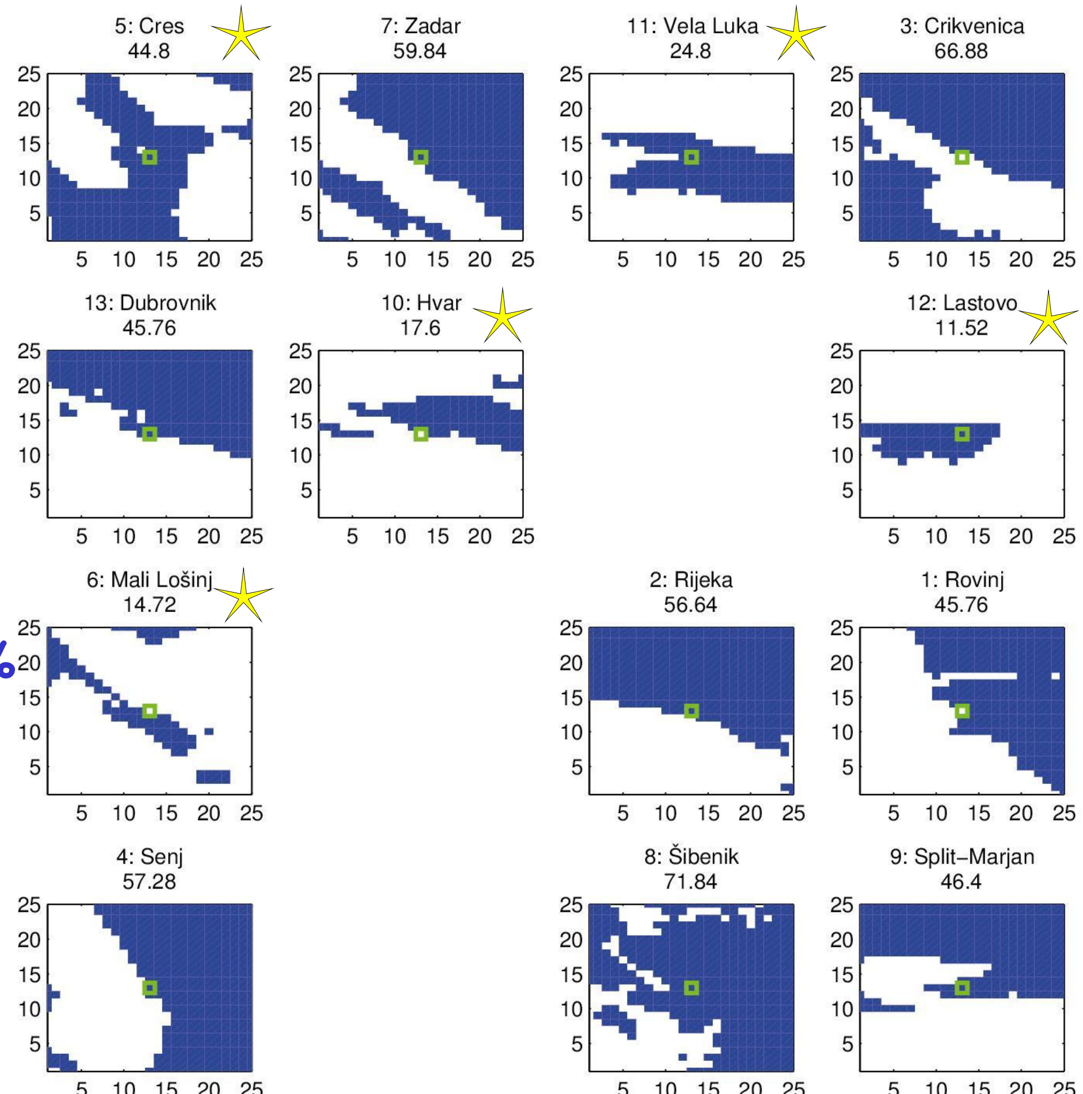
* "True" land-sea fraction (LSF) from 25km × 25km squares

* Percentage of land in a 25-km square

* Island stations ☆: LSF<50%

* For 3 land stations LSF=46%

* Is LSF represented well in (25-km) RCMs?



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The Croatian Adriatic – land-sea contrast in RCMs

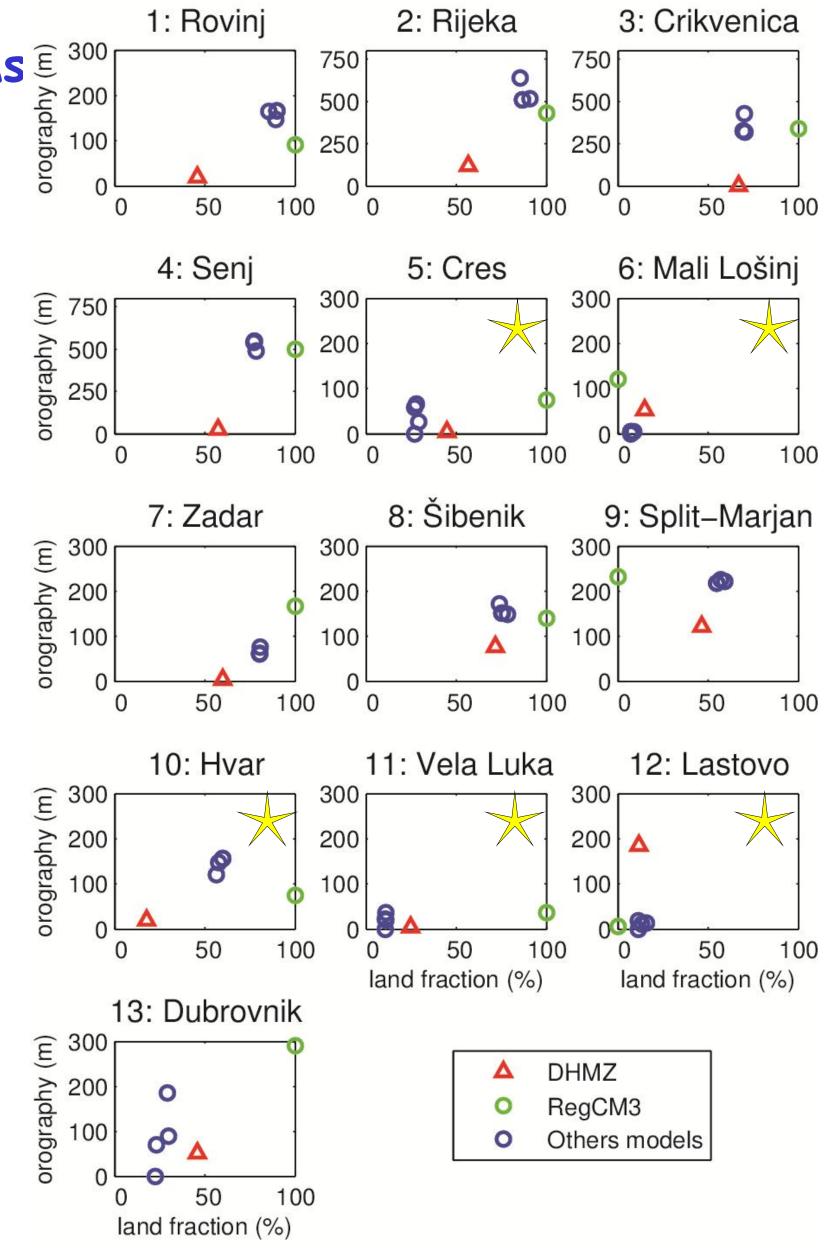
* For most coastal locations, LSF in RCMs (slightly) overestimated (except 13)

* For most island locations ☆, LSF (slightly) underestimated (except 10)

* RegCM: 0 or 100%

sea ⟷ land

LSF



The Croatian Adriatic – small scales

* Small-scale variability defined mainly by coastal configuration and land-sea contrast; orographic variability has major impact in the north and extreme south

* Land-sea fraction (LSF) – partial impact of land surface processes in a RCM grid-box

* Can land surface processes in such a complex (small-scale) environment be well simulated?

* Land surface scheme needs to represent:
  - surface energy balance
    - shortwave radiation, albedo, longwave radiation, emissivity, sensible heat flux, latent heat flux, vegetation cover & type, soil type, roughness length, ...
  - surface water balance
    - precipitation, evaporation, runoff, percolation, root uptake, transpiration, soil moisture, snow, ...

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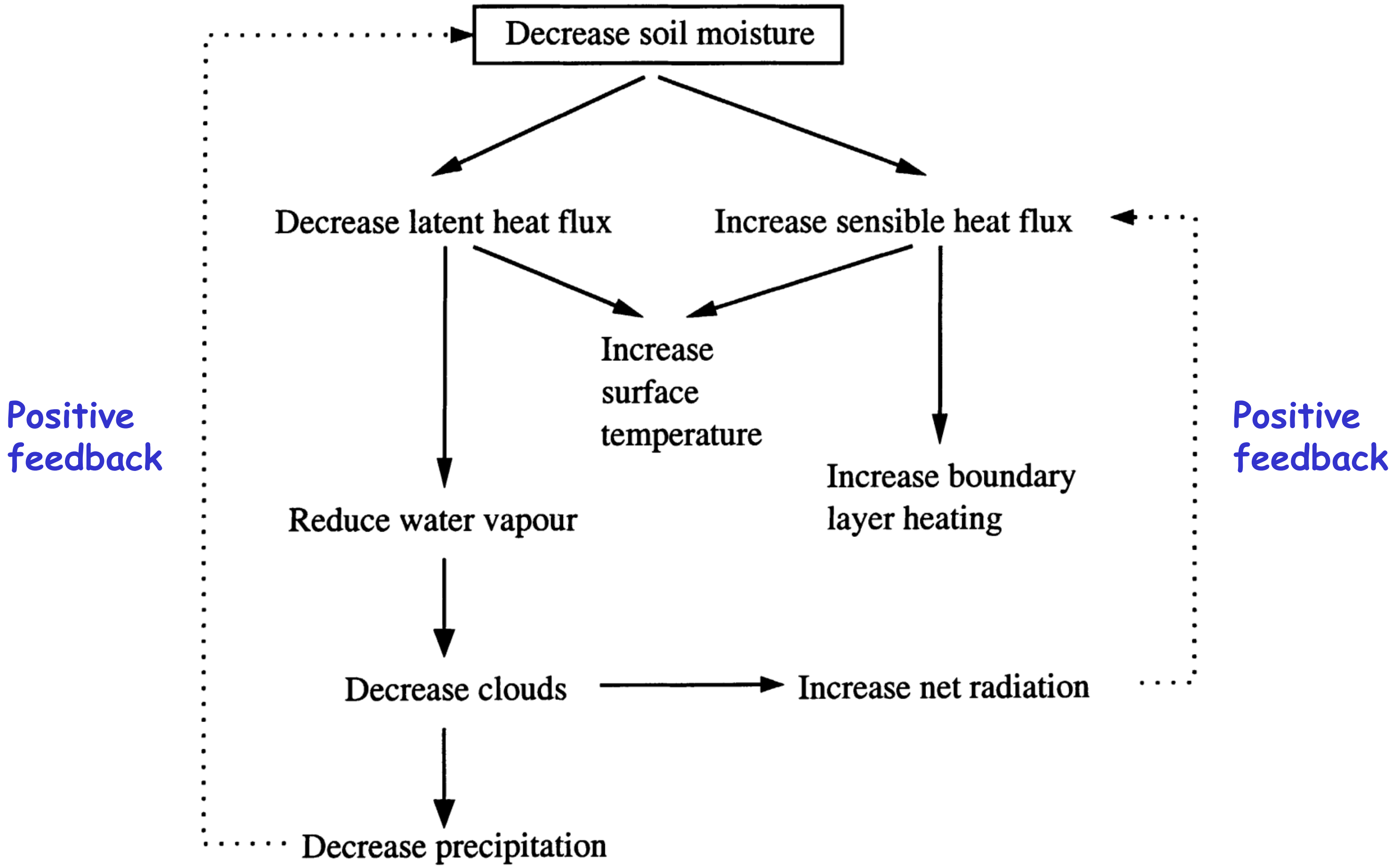
Impact of land surface

* An example for one variable



Source: Pitman, Int. J. Clim. 2003

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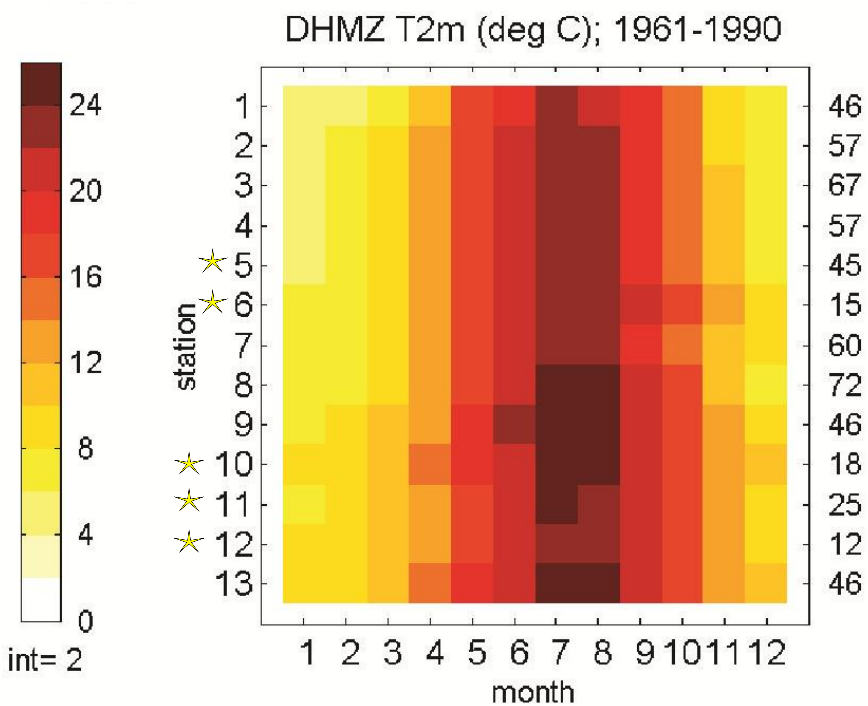
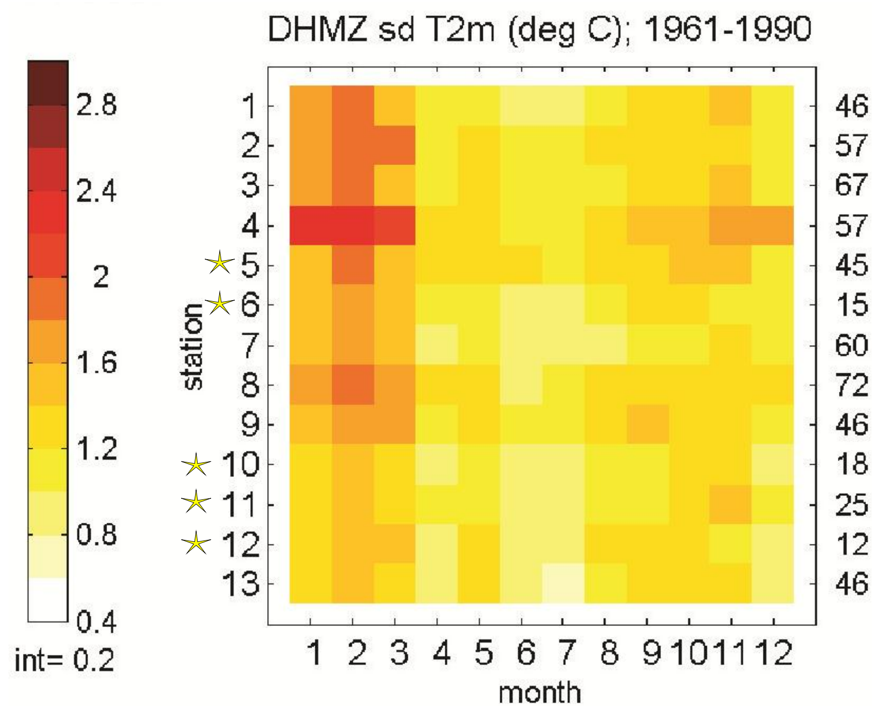
Observed climate – temperature at 2m (T2m) 1961-1990

* Mean annual T2m – from 13°C in the north to 16°C at the southern islands
* Winter most variable in the north, summer least variable
* Variability in T2m consistent with variability of the Adriatic SST
* Variability in extreme T2m largest in Jan and Feb and could be related to the incidence of cold bora wind – dependence on large (regional)-scale flow



Monthly mean T2m



Interannual variability

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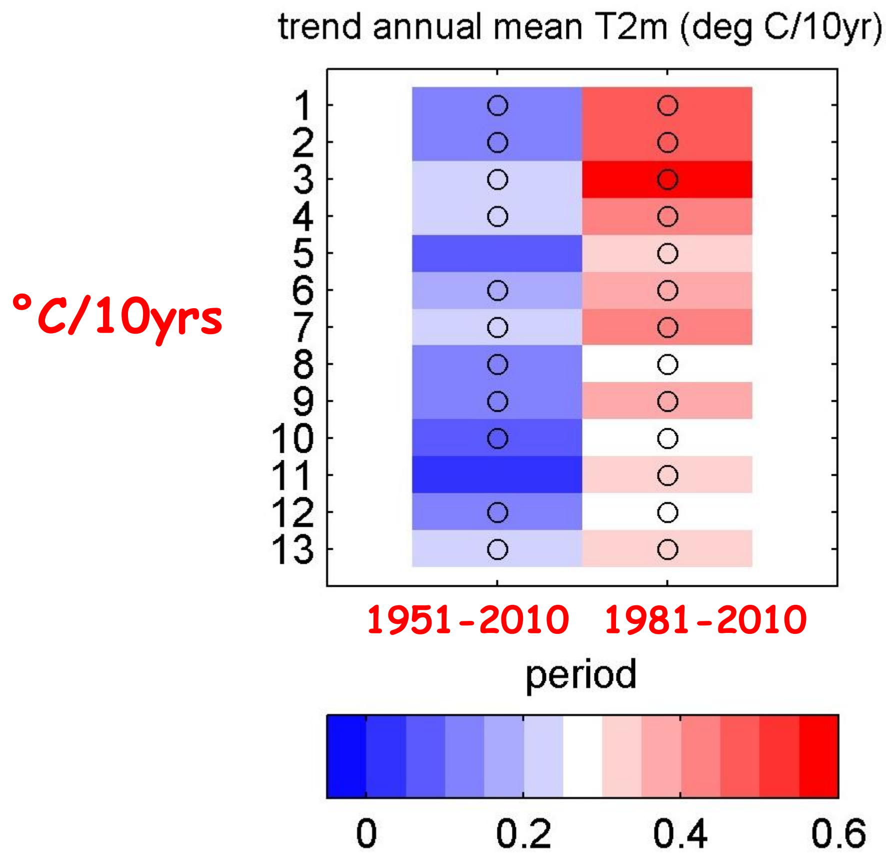
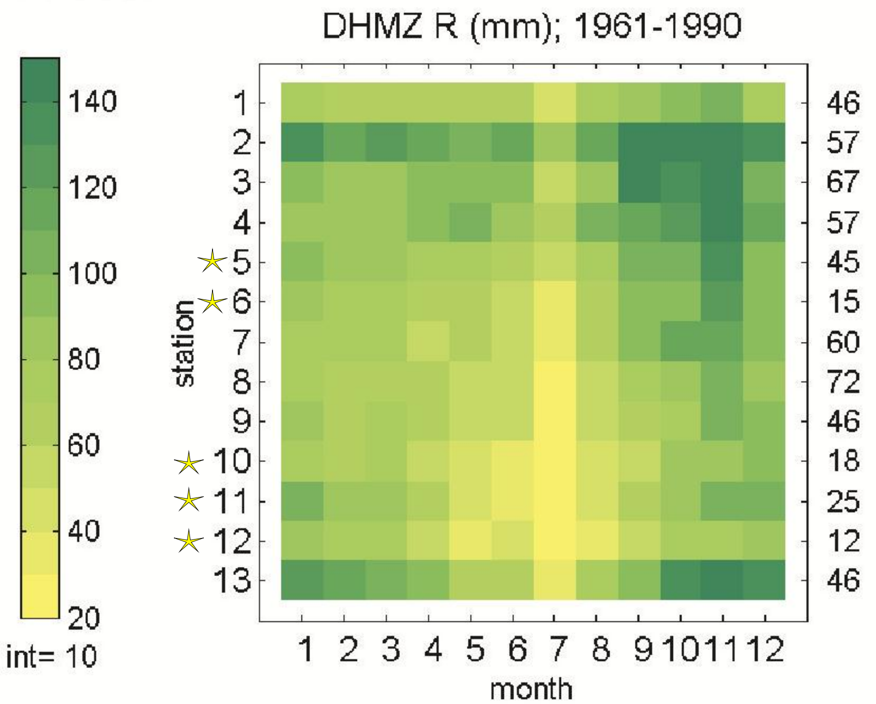
Observed climate – T2m trends (1951-2010, 1981-2010)

* Almost all annual-mean trends statistically significant
* In the summer, trends at all but one location statistically significant
* Largest trend 0.98 (°C/10yrs) in summer for station 3
* For station 11 weak negative trend in autumn and winter (significant!)
* Climate change (warming) already observed in the past (present) climate

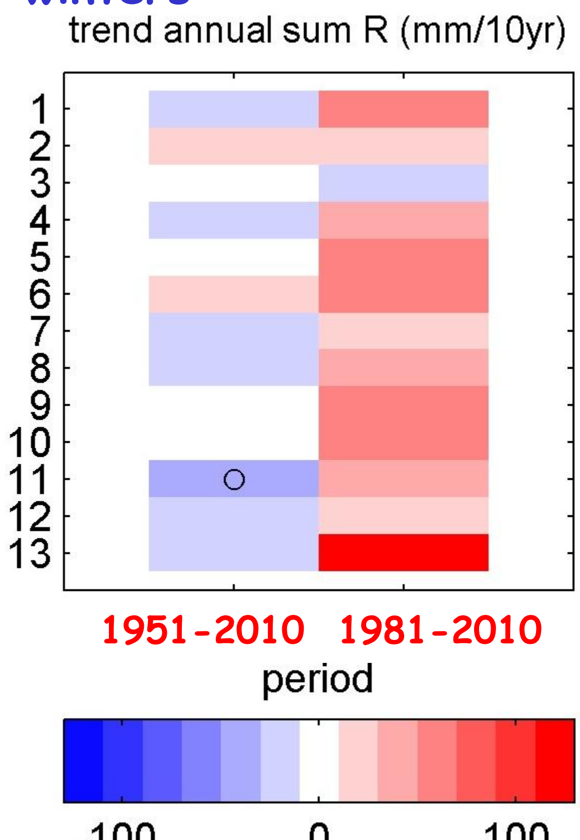


Observed climate – precipitation 1961-1990

* Largest amounts in the autumn (November) at the foot of mountains (2, 3, 4 and 13)
* Highest variability in July – summer convective showers
* Weak negative annual trends prevail in 1951-2010
* Positive trends in 1981-2010 due to wetter winters



Monthly accumulated precipitation



1951-2010 1981-2010

Annual trend (mm/10yrs)

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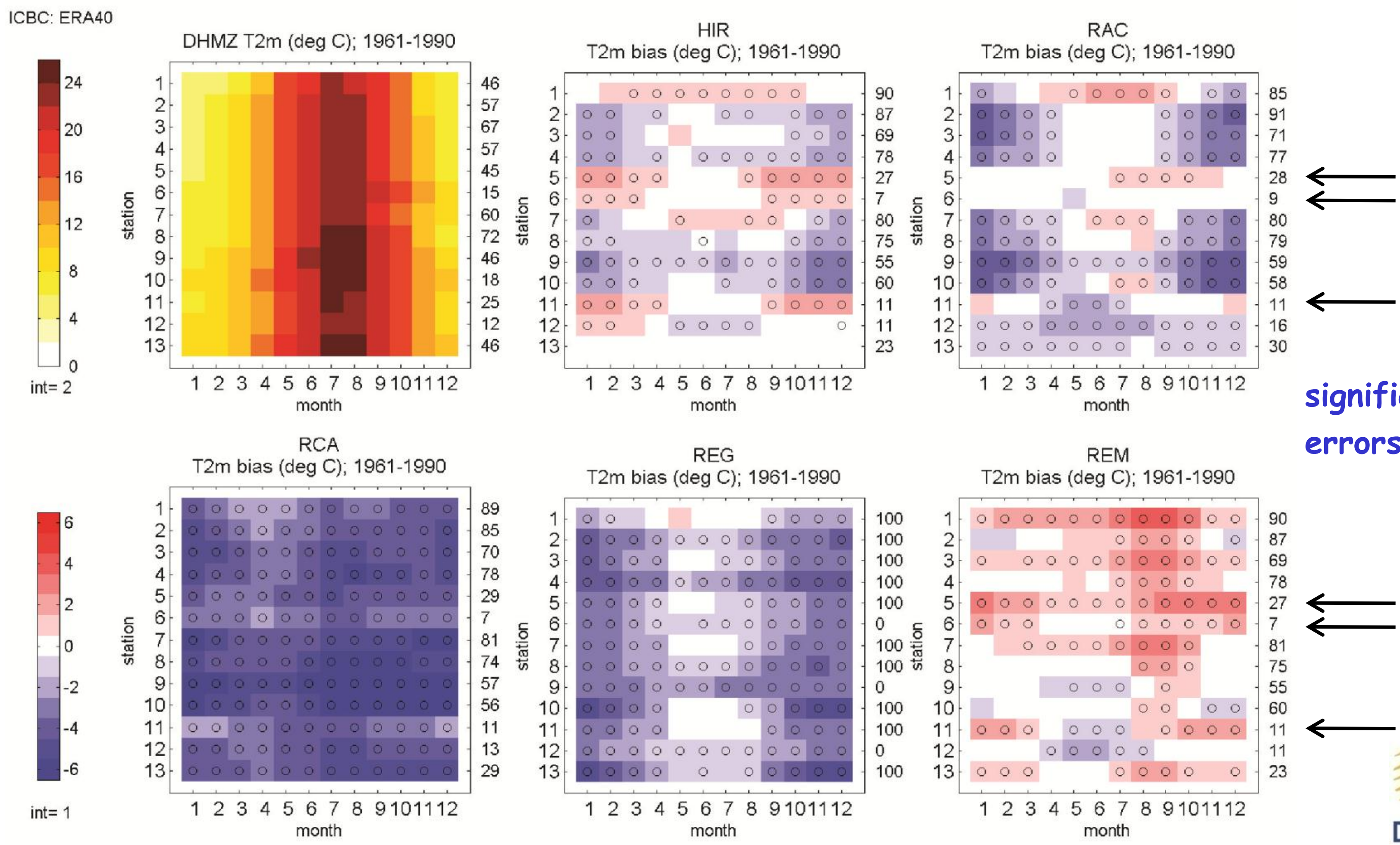
Simulations with ERA40 b. forcing – T2m mean (corr.)

* RCMs' genuine errors
* Cold bias dominant (winter), up to -5°C
* Associated with an overestimation of surface pressure
* Warm bias up to +3°C; weak warm or less cold bias for islands 5, 6 and 11



significant errors ○

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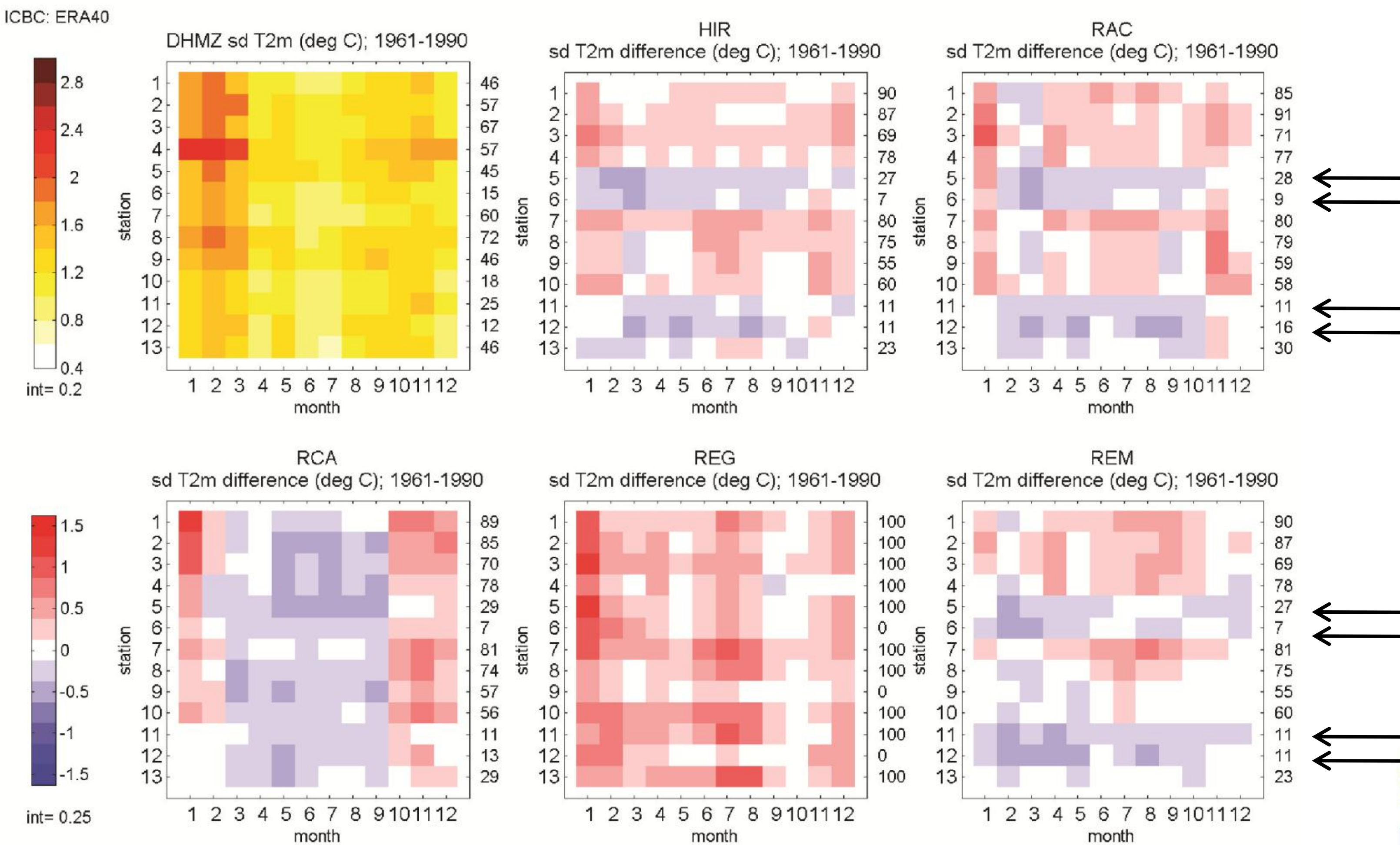
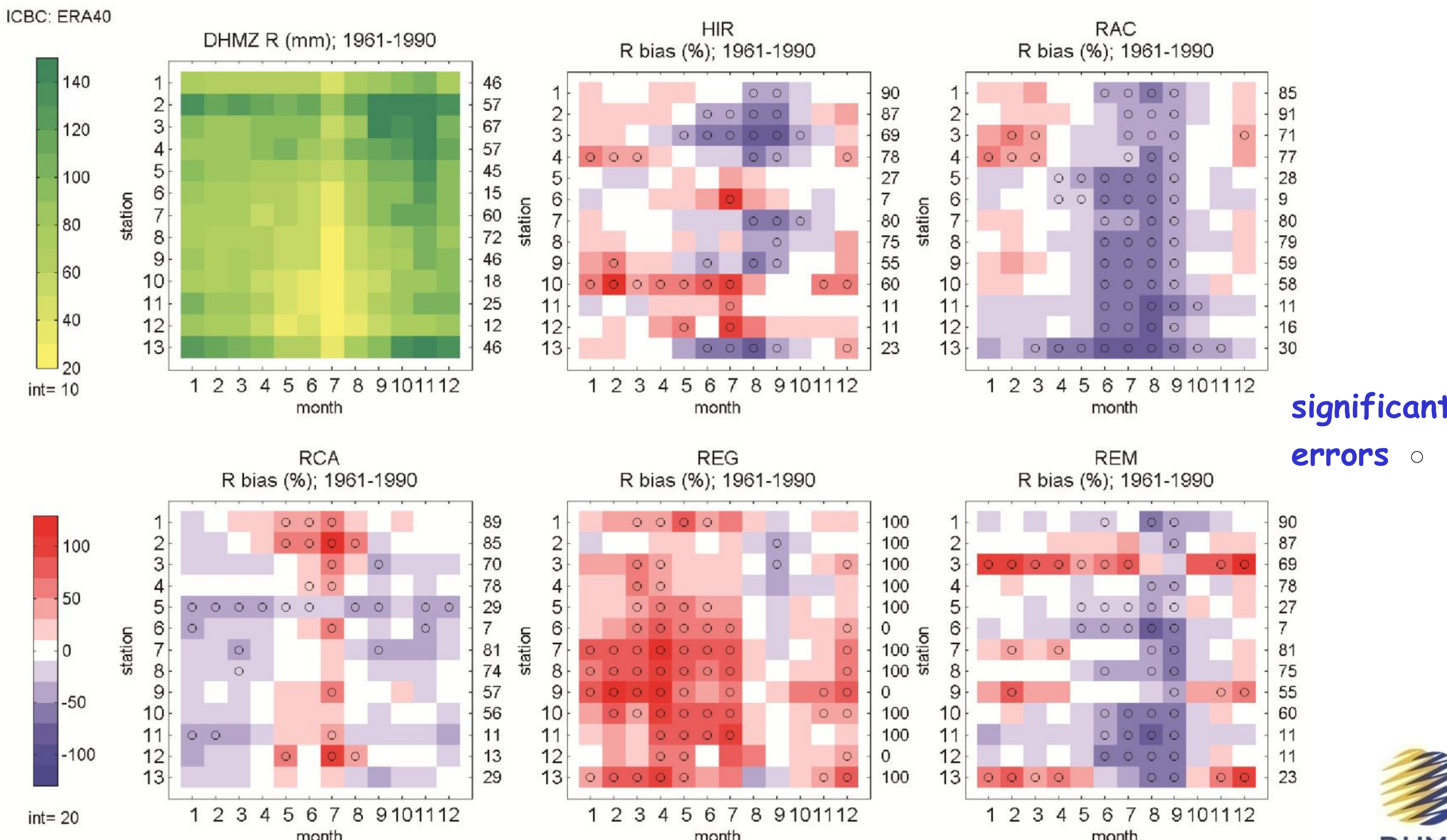
Simulations with ERA40 b. forcing – T2m variability

* Errors in variability much smaller than errors in the mean (up to ±1°C)
* No regular pattern, but variability generally underestimated at islands
* Sea points - consistent with low SST variability in ERA40



Simulations with ERA40 b. forcing – precipitation

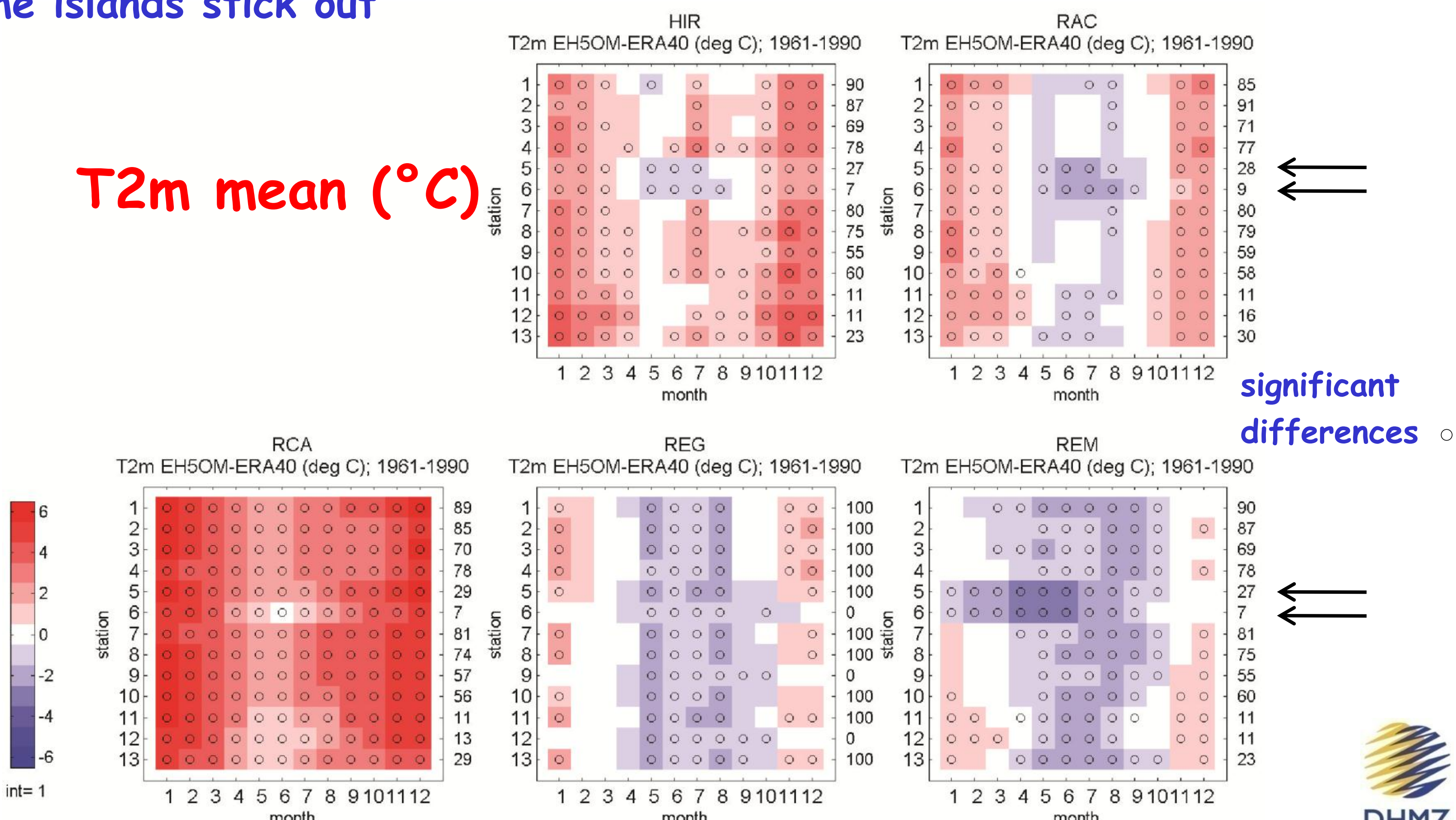
* Variable sign and error pattern; little coherence
* Largest errors broadly coincide with smallest amounts (summer)
* RCMs overestimate minimum precipitation (drizzling effect)



Simulations with GCM b. forcing (diff wrt ERA40 b.f.)

* Biases "imported" from the GCM
* Warming in the cold half-year and cooling (less warming) in the warm half-year imply a reduction of the amplitude in the annual cycle
* Indicative of too much clouds
* Some islands stick out

T2m mean (°C)

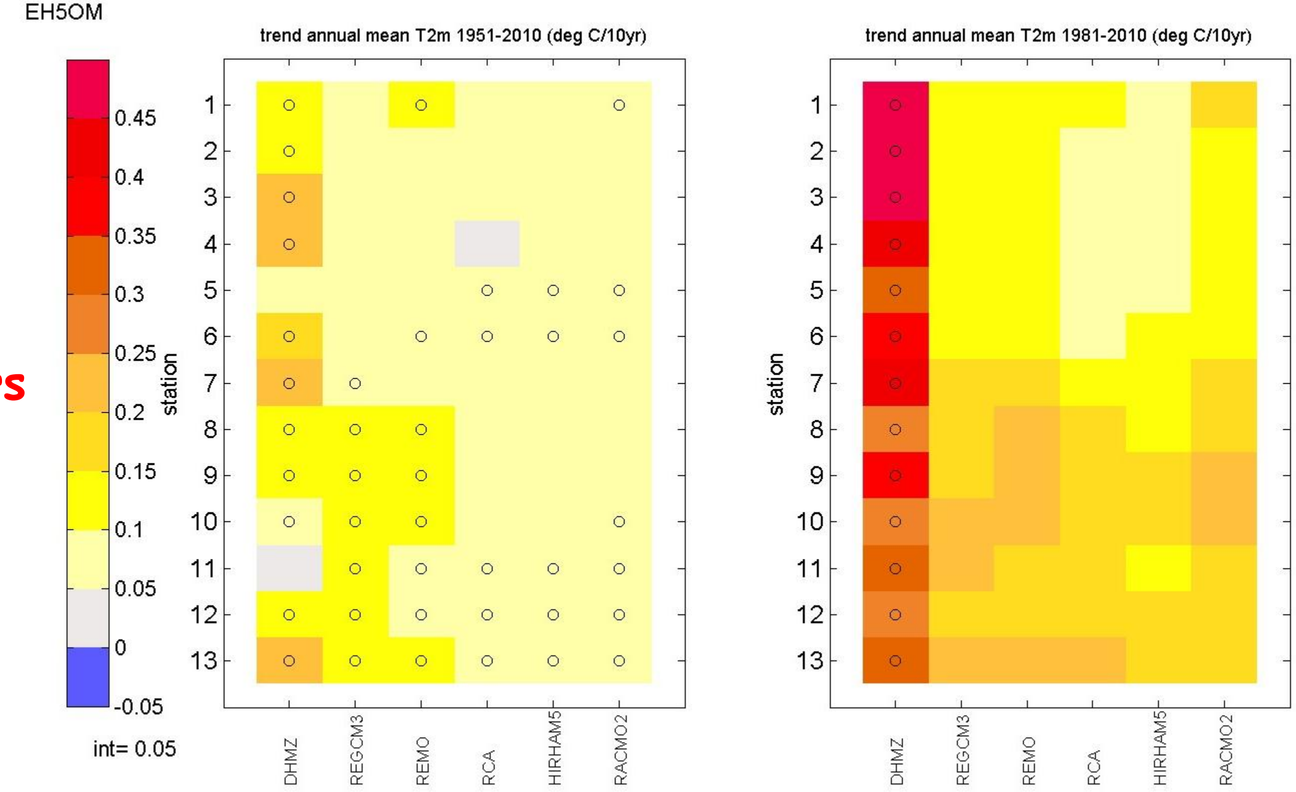


Simulations with ECHAM5 b. forcing – T2m trends

* Trends in T2m in the past climate generally underestimated by RCMs, particularly in the north for the last 30 years
* This may be, at least partly, due to inadequate SST representation (more land than sea points)

°C/10yrs

1951-2010 1981-2010



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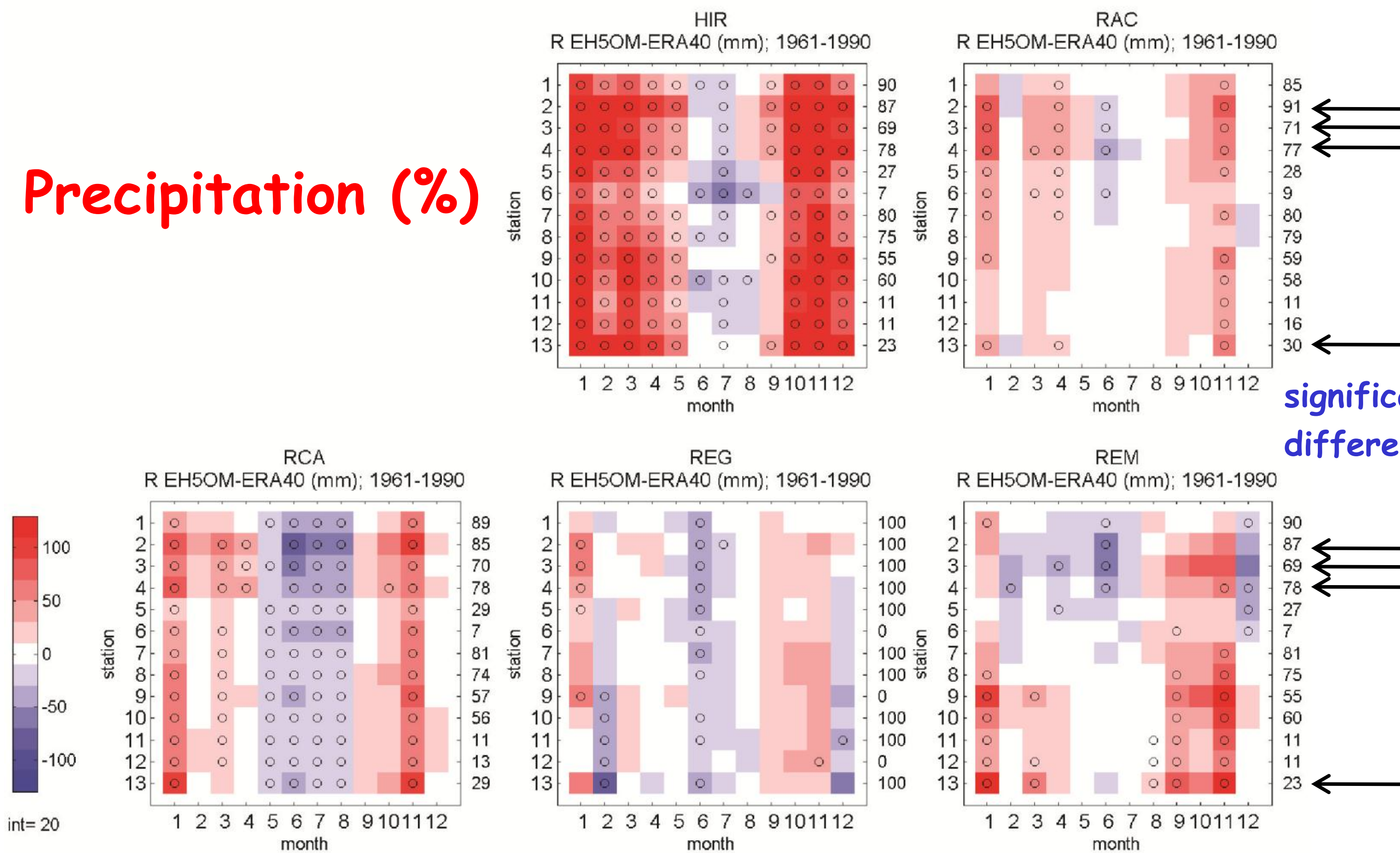
Simulations with GCM b. forcing (diff wrt ERA40 b.f.)

* Increase of precip in the cold-half; decrease in the warm-half
* Largest differences at the foothill locations – why?

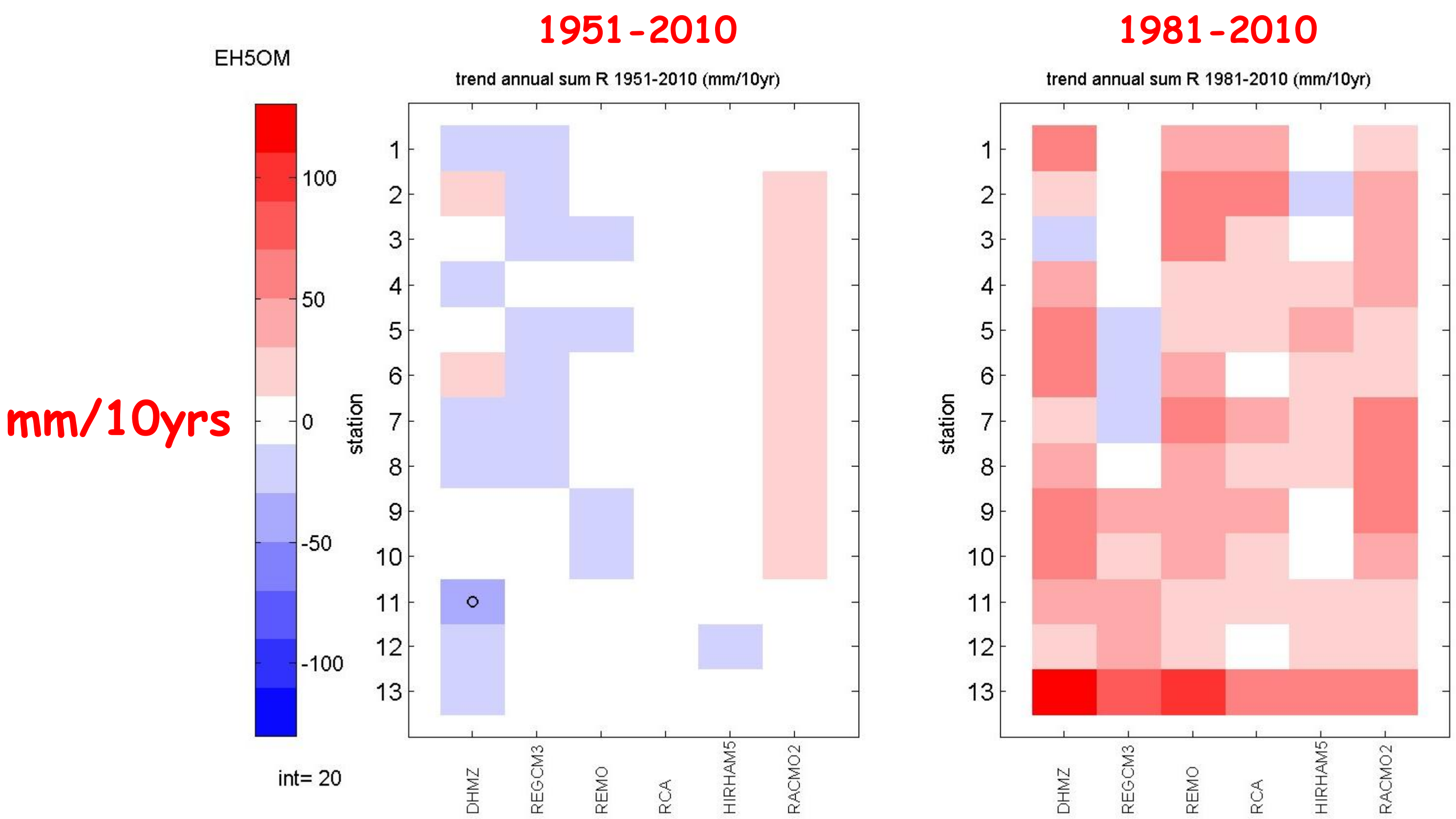
Precipitation (%)



significant differences ○

Simulations with ECHAM5 b. forcing – precip trends

* RCMs simulate reasonably well observed precipitation trends



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Future climate change - uncertainties

* Internal variability of climate system
    - natural fluctuations can "mask" future climate change

* Modelling uncertainty
    - limited understanding of climate system
    - numerical approximations
    - parameterisations of unresolved processes
    - uncertainties in initial conditions

* Uncertainty in future emissions of greenhouse gases

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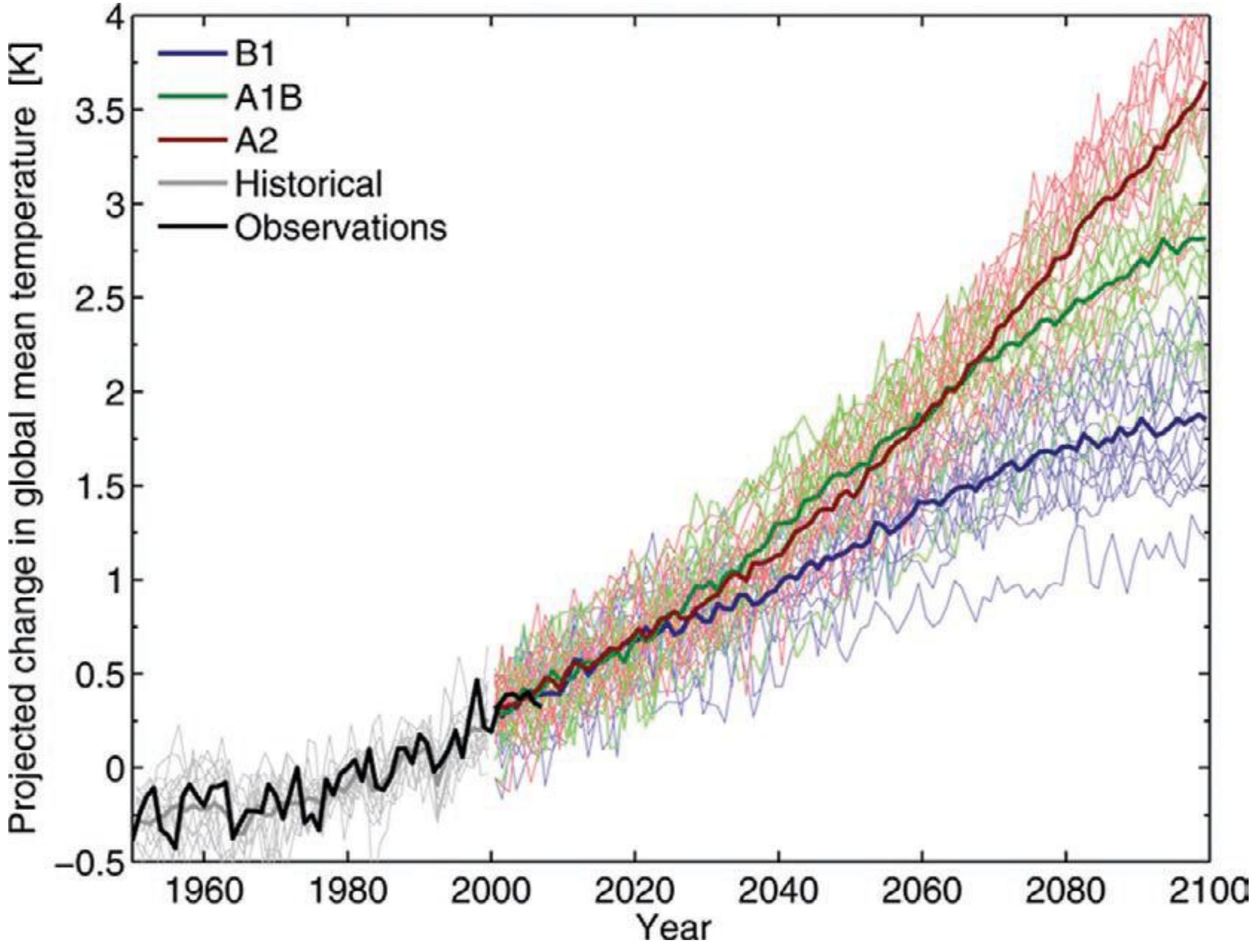
Future climate change – uncertainties (temp. anomaly)



Source: Hawkins and Sutton, Bull.Amer.Meteor.Soc. 2009

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* Uncertainty in future emissions of greenhouse gases

* Donald Rumsfeld, US Secretary of Defense (2002)

- there are known knowns; there are things we know we know
- there are known unknowns; we know there are some things we do not know
- there are also unknown unknowns-the ones we do not know we do not know

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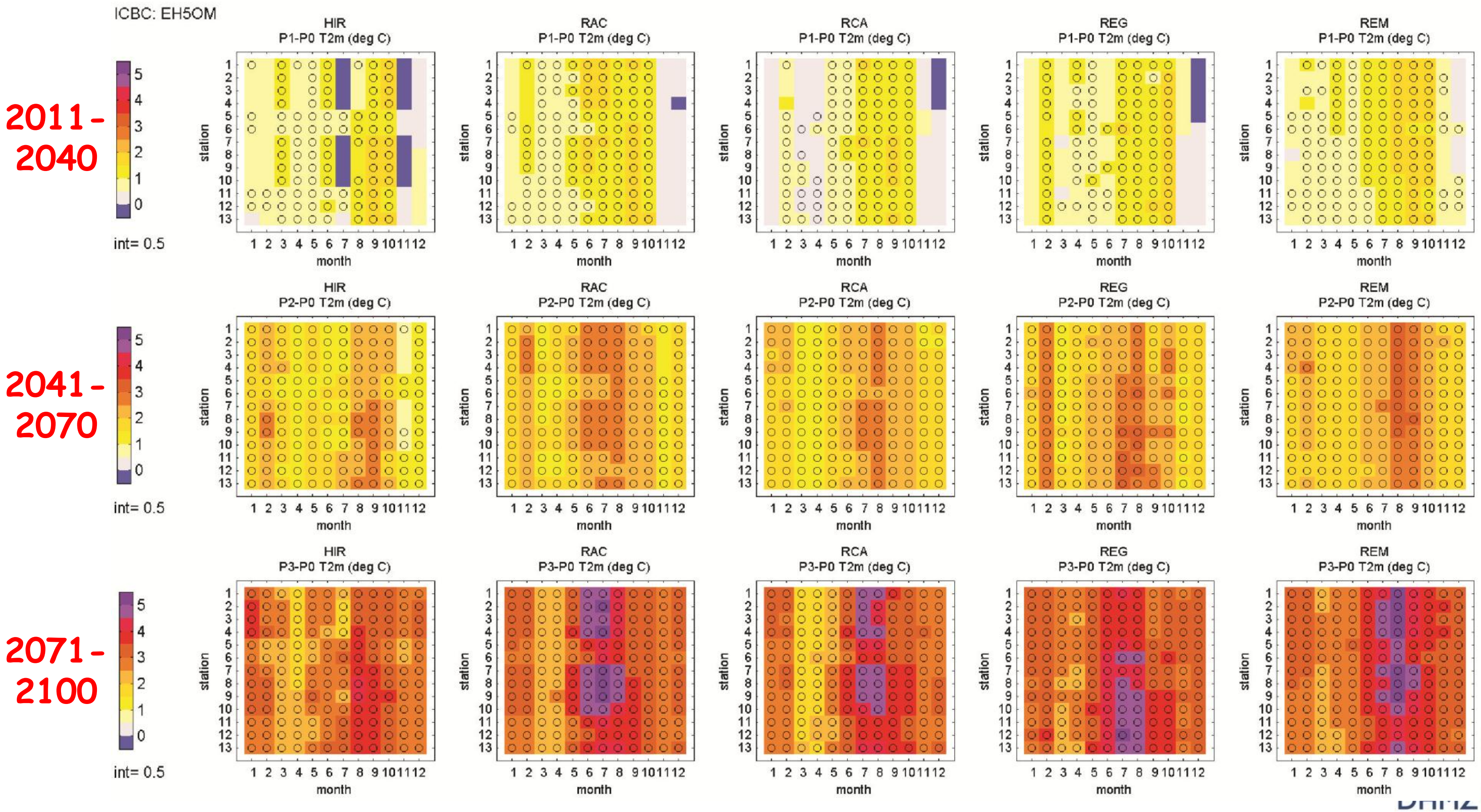
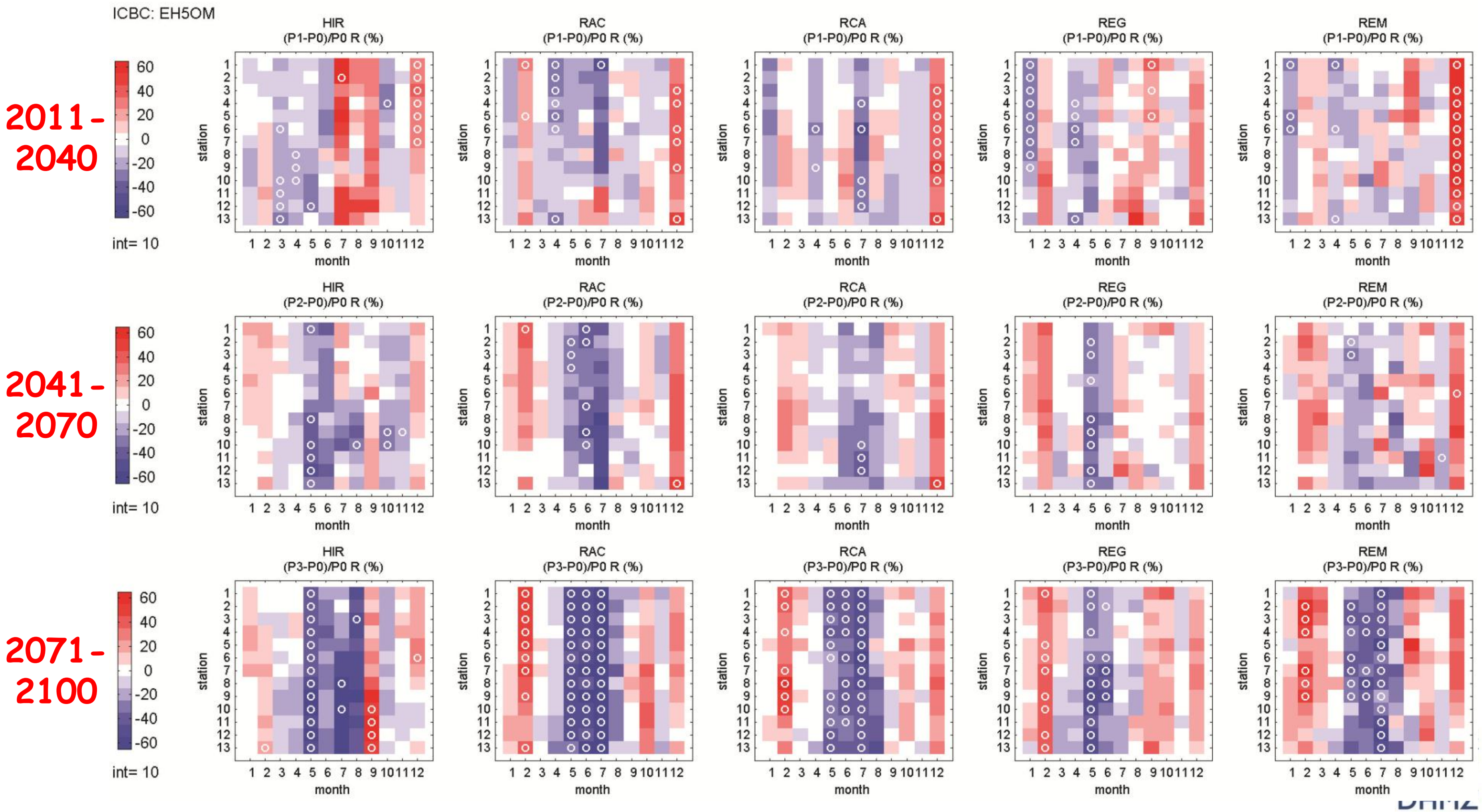
Future climate change – T2m diff wrt 1961-1990 (°C)

* Three 30-yr periods: 2011-2040, 2041-2070, 2071-2100; A1B scenario
* Warming: generally largest in late summer and autumn – up to +2, 3.5, 5°C
* In some models the warming weaker at the islands (SSTs or/and LSF)



Future climate change – precip diff wrt 1961-1990 (%)

* 1st period: no clear signal
* 2nd: reduction of precip in the warm half-year, increase in winter (DJF)
* 3rd: significant drying (>50%) in warm half, a weak increase in winter

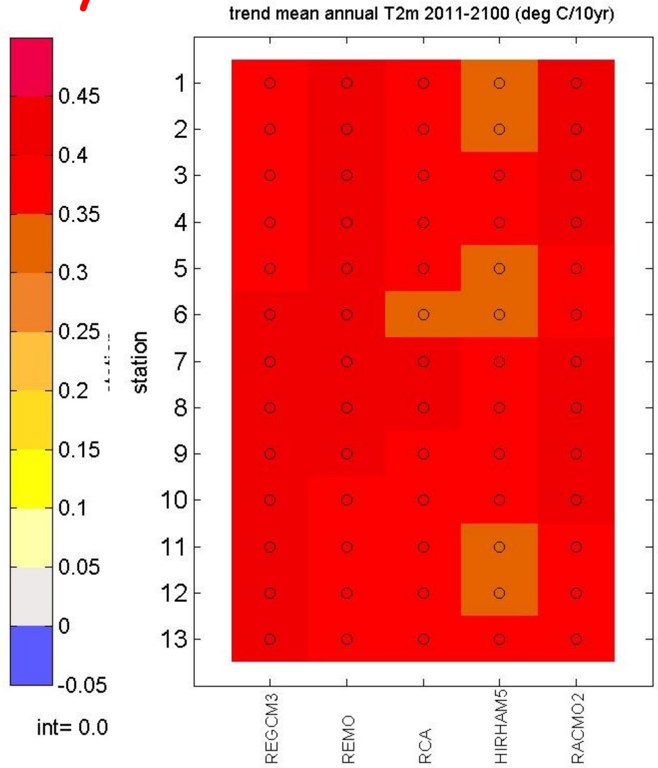


Future climate change – trends in 2011-2100

* For T2m trends between 0.3-0.4 °C/10yrs; but could be underestimated
* For precipitation trends negligible

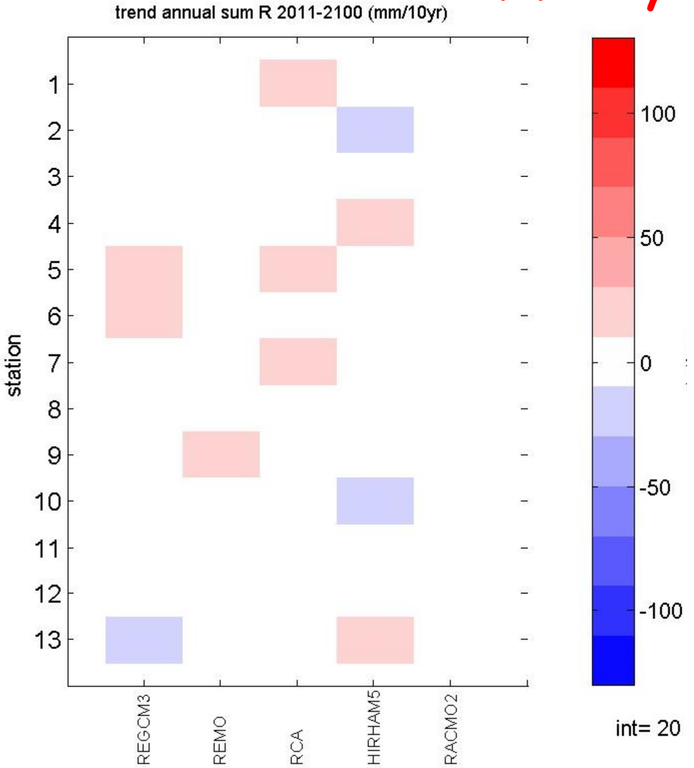
T2m

°C/10yrs



Precipitation

mm/10yrs



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Some conclusions (summary)

* Croatian Adriatic - climate and climate variation at small scales
* Local (coastal) orography enhances precipitation
* The Adriatic Sea (small LSF) moderates T2m
* Trends in T2m increased in the recent periods (warming)

* T2m biases in GCM-forced simulations partly offset those of ERA40
* Interannual variability in T2m well simulated
* RCM precipitation response variable; biases largest for locations with smallest amounts
* Minimum precipitation substantially overestimated

* Though variable across RCMs and stations, significant warming a major characteristic of the future climate change
* Warming somewhat weaker at the islands
* Reduction in precipitation in the warm part of the year dominant only in the 2nd half of the 21st century

* RCMs generally capable in reproducing climate and climate change in the eastern Adriatic
* New generation of GCMs and RCMs? New scenarios? ...

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