Regime-dependent evaluation of accumulated precipitation in the COSMO model

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Overview

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- 2. Method and Data
- 3. Regime classifications
- 4. Results
- 5. Discussion and conclusion

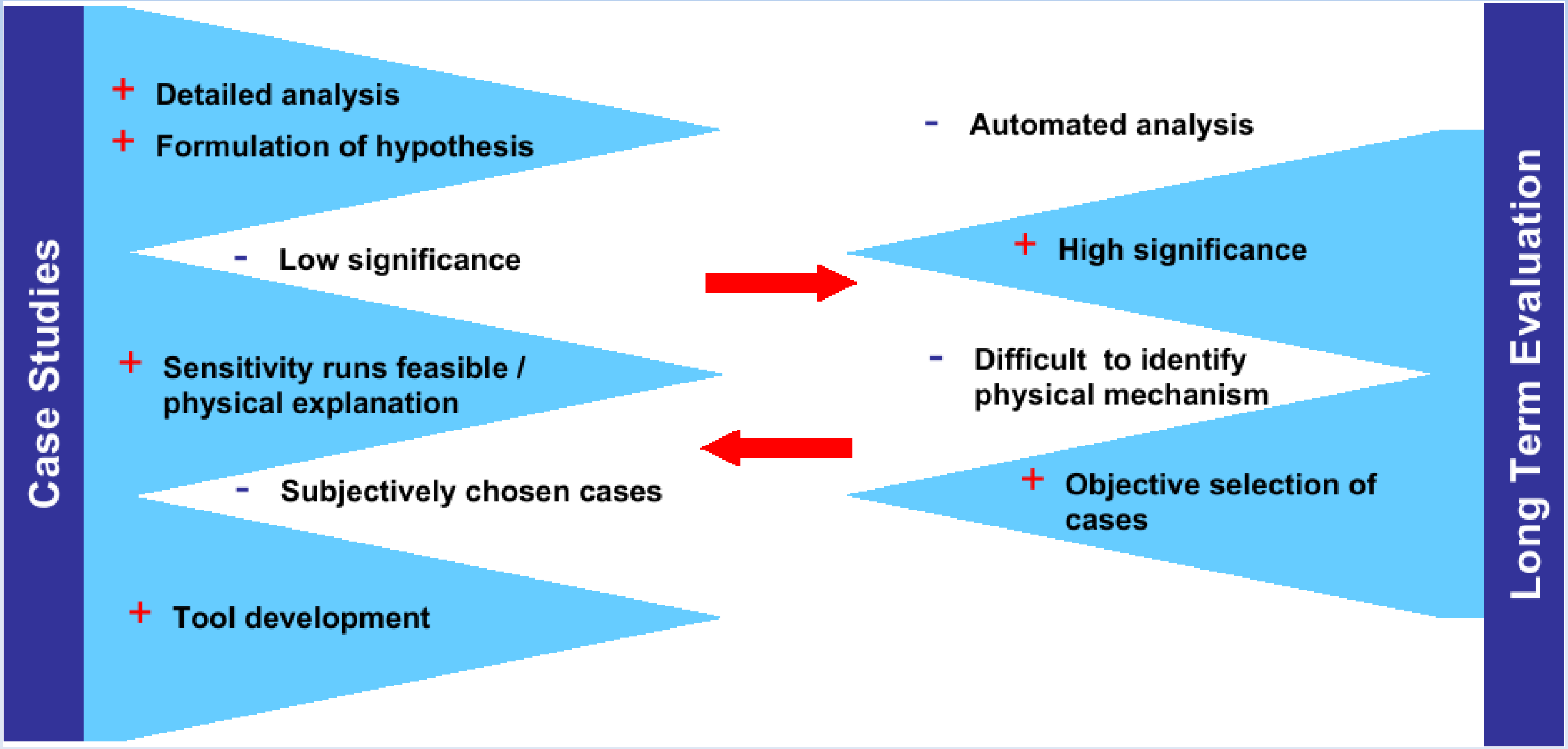
1. Introduction

Regime-dependent evaluation is a relatively **new approach** to assess model performance. It consists of classifying the model biases according to a discrete number of regimes, and evaluating model output within each regime.

1. Introduction

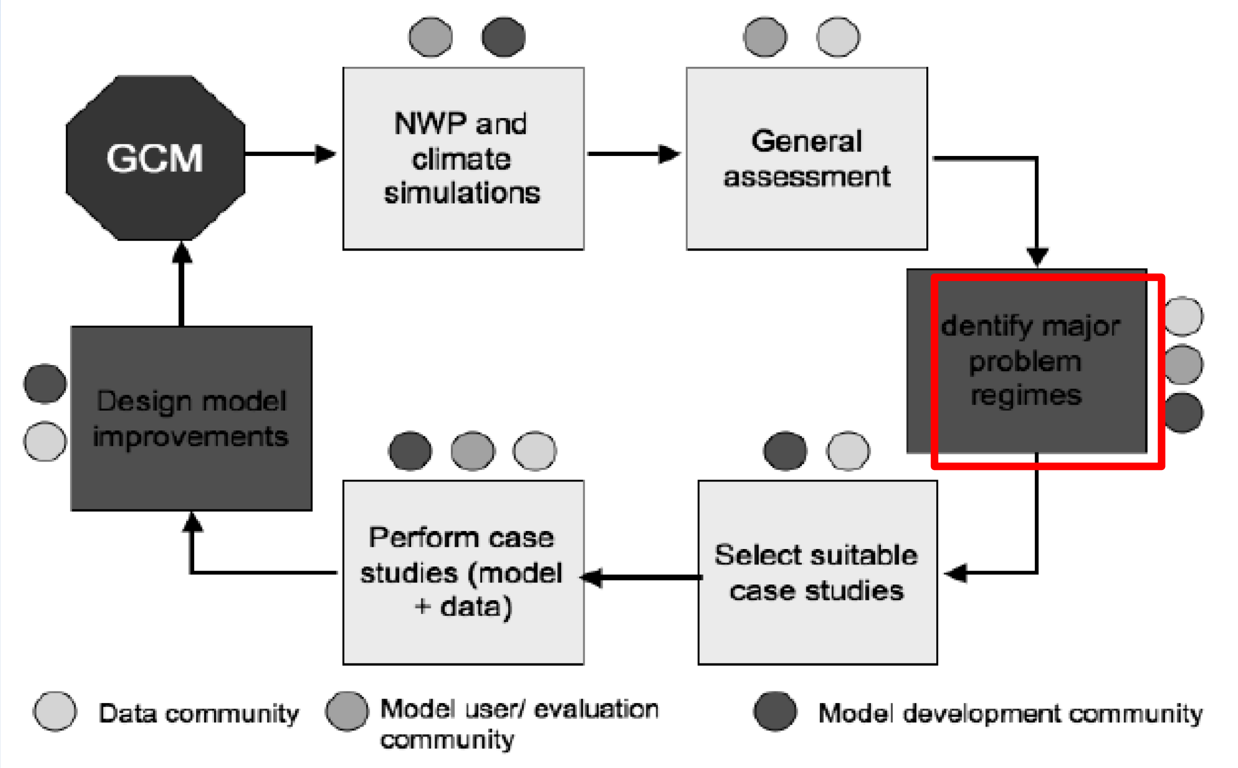
- Identification of situations in which the model bias is higher than average: so-called ***problem regimes***.
- Allows for an easy, automated and objective way to select suitable case studies, necessary to evaluate and develop a model (Jakob, 2004).
- Bridging the gap between estimating overall model biases (with long-term assessment) and case studies
- Unmasking of systematic model biases which could be hidden when evaluating with conventional methods (Rossa et al., 2008).

1. Introduction



Source: Felix Ament

1. Introduction



Source: Jakob, 2004

1. Introduction

In this research:

- Evaluation of accumulated precipitation from COSMO, a non-hydrostatic NWP model
- Calculation of the average model bias in every regime
- Two kind of regimes are defined:
  - *Atmospheric circulation regimes, "weather classification" (A)*
  - *Temperature regimes (B)*
- Hence, two evaluations will be performed:
  - *Circulation-dependent evaluation (A)*
  - *Temperature-dependent evaluation (B)*

2. Method & Data

2.1. Model output

- COSMO: non-hydrostatic NWP model
  - *COSMO-DE*: res. 2.8km, convection resolved, boundary conditions from COSMO-EU:
  - *COSMO-EU*: res. 7km, Tiedtke parameterization, boundary conditions from GME (global, res. 40km)
- Derived parameter: accumulated precipitation (mm/6h)
- Model forecasts start every 3 hours for target times ranging from 0 to 21h in advance: a lagged-forecast ensemble of up to 8 different forecasts is available.
- All forecast lead times are taken into account by calculating the average model output

2. Method & Data

2.2. Observations

- Evaluation with an extensive dataset, composed during the General Observation Period (GOP) campaign in 2007-2008.
- Raingauge product (RANIE1) is an interpolated surface precipitation analysis with 6h precipitation sums (mm/6h) on a 1km spatial resolution.
- Some quality checks are applied and orographical influence is taken into account by a regression method.

2. Method & Data

2.3. Creating the evaluation dataset

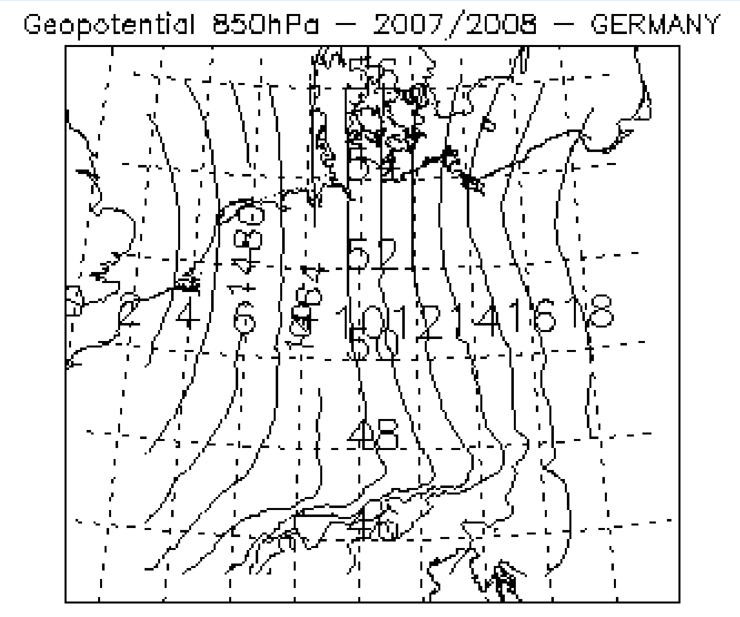
- RANIE product is converted to the COSMO grid by means of an aggregation algorithm
- RANIE fields are then subtracted from the respective COSMO model output
- This forms the *evaluation-dataset* with model biases (mm/6h) for each accumulation period in the years 2007-2008: 00-06UTC, 06-12UTC, ...
  - Positive bias: model overestimation
  - Negative bias: model underestimation

3. Regime classifications

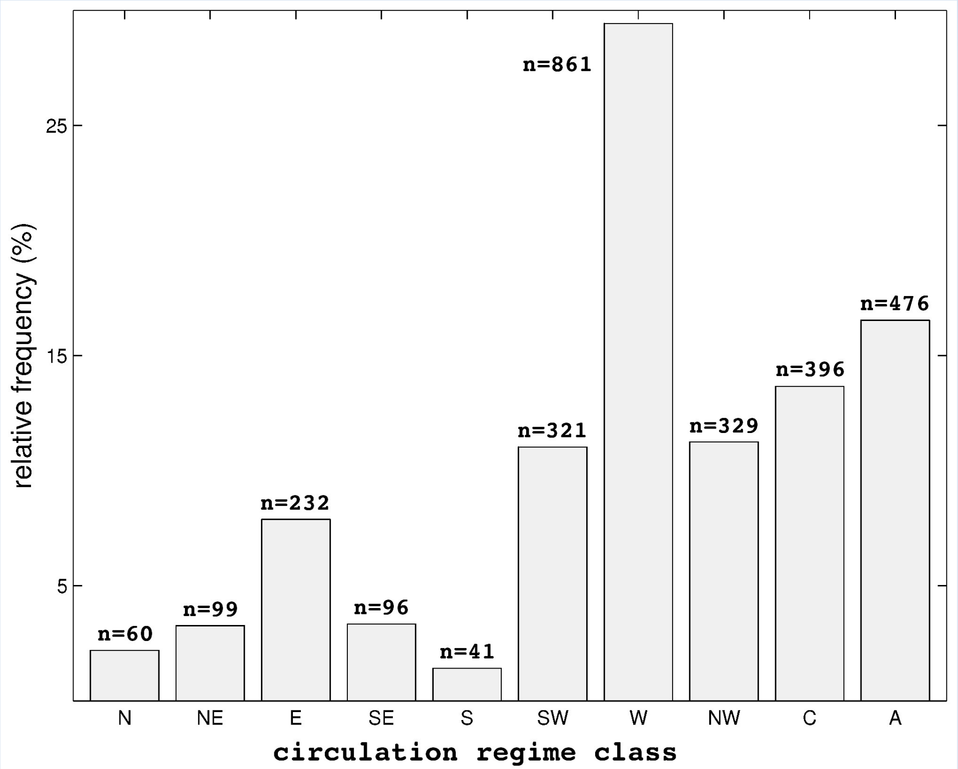
	Evaluation A	Evaluation B
regimes defined by	atmospheric circulation: pressure fields	temperature tresholds
data source ext. parameter	COSMO-DE analyses	German radiosoundings
number of regimes	[illegible]	[illegible]
regime classes	N, NE, E, SE, S, SW, W, NW, anti-cyclonic, cyclonic	“no-snow”, summer, all data, winter, “snow-only”
evaluation period	[illegible]-[illegible]	
model output to be evaluated	COSMO accumulated precipitation (mm/6h)	
observations for evaluation	RANIE interpolated rain gauge product (mm/[illegible]h)	

3. Regime classifications

3.1. Circulation regimes (A)



Example: average pressure field in northern circulation regime

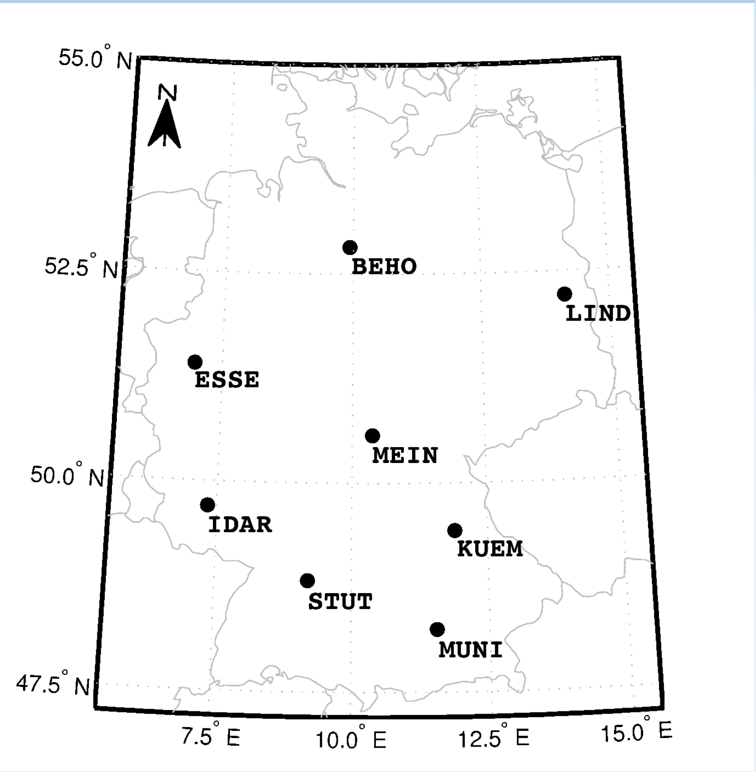


Relative occurence frequency of circulation regimes

3. Regime classifications

3.2. Temperature regimes (B)

- Is based on average radiosounding temperatures at 850hPa (0-12UTC)
  - Treshold >281K: regime in which no solid precipitation is supposed to exist, called the *”no-snow” regime* (n=719)
  - Treshold <266K: regime in which much precipitation is supposed to be frozen, called the *”snow” regime* (n=86)
  - Purely chronologic: months MJJAS, called the *summer regime* (n=1219)
  - Purely chronologic: months NDJFM, called the *winter regime* (n=1209)



4. Results: COSMO-DE

A. Circulation-dependent model evaluation

- **No** circulation dependency detected.
- **But**, a uniform bias pattern is visible in all circulation regimes, being a systematic height-related overestimation.

4. Results

A. Circulation-dependent m

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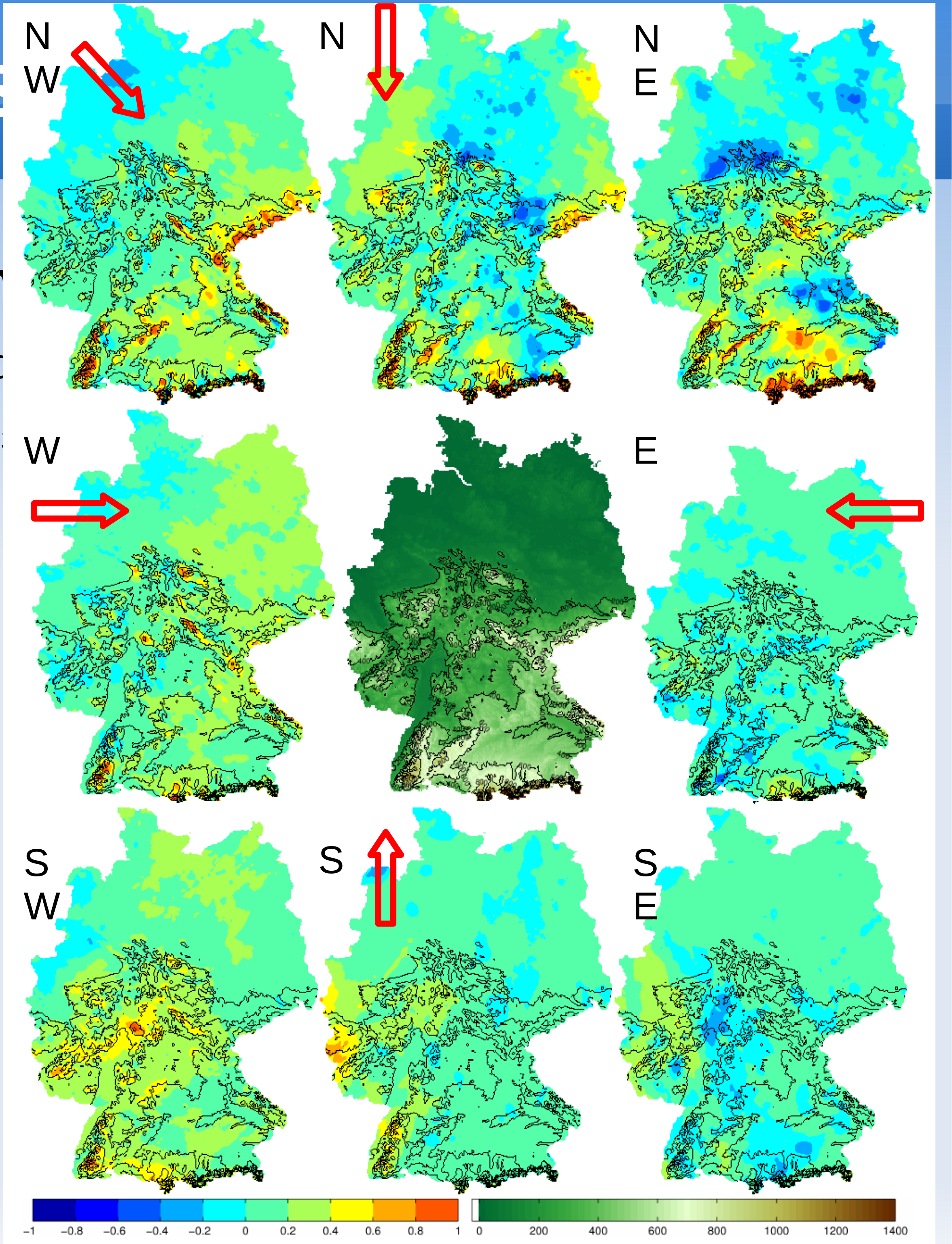
- **But**, a uniform bias pattern i regimes, being a systematic

Red arrows indicate wind direction in the respective circulation regime composits



4. Results: COSMO-DE

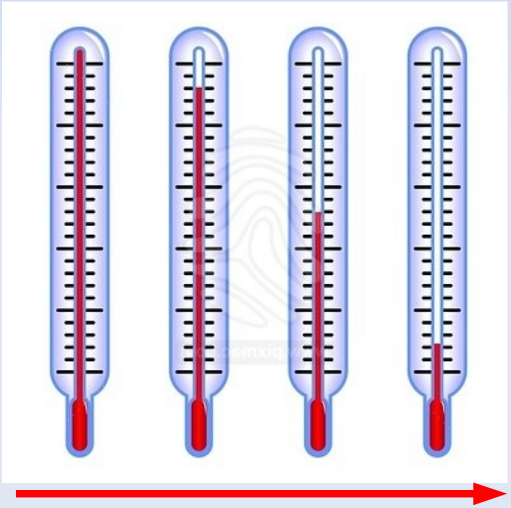
A. Circulation-dependent model evaluation

- **No** circulation dependency detected.
- **But**, a uniform bias pattern is visible in all circulation regimes, being a systematic height-related overestimation.
- Possible reasons? Investigate with temperature-dependent evaluation.

4. Results: COSMO-DE

B. Temperature-dependent model evaluation

- Temperature dependency: a positive height-related bias increases in magnitude, with a gradient from warm to cold regimes.



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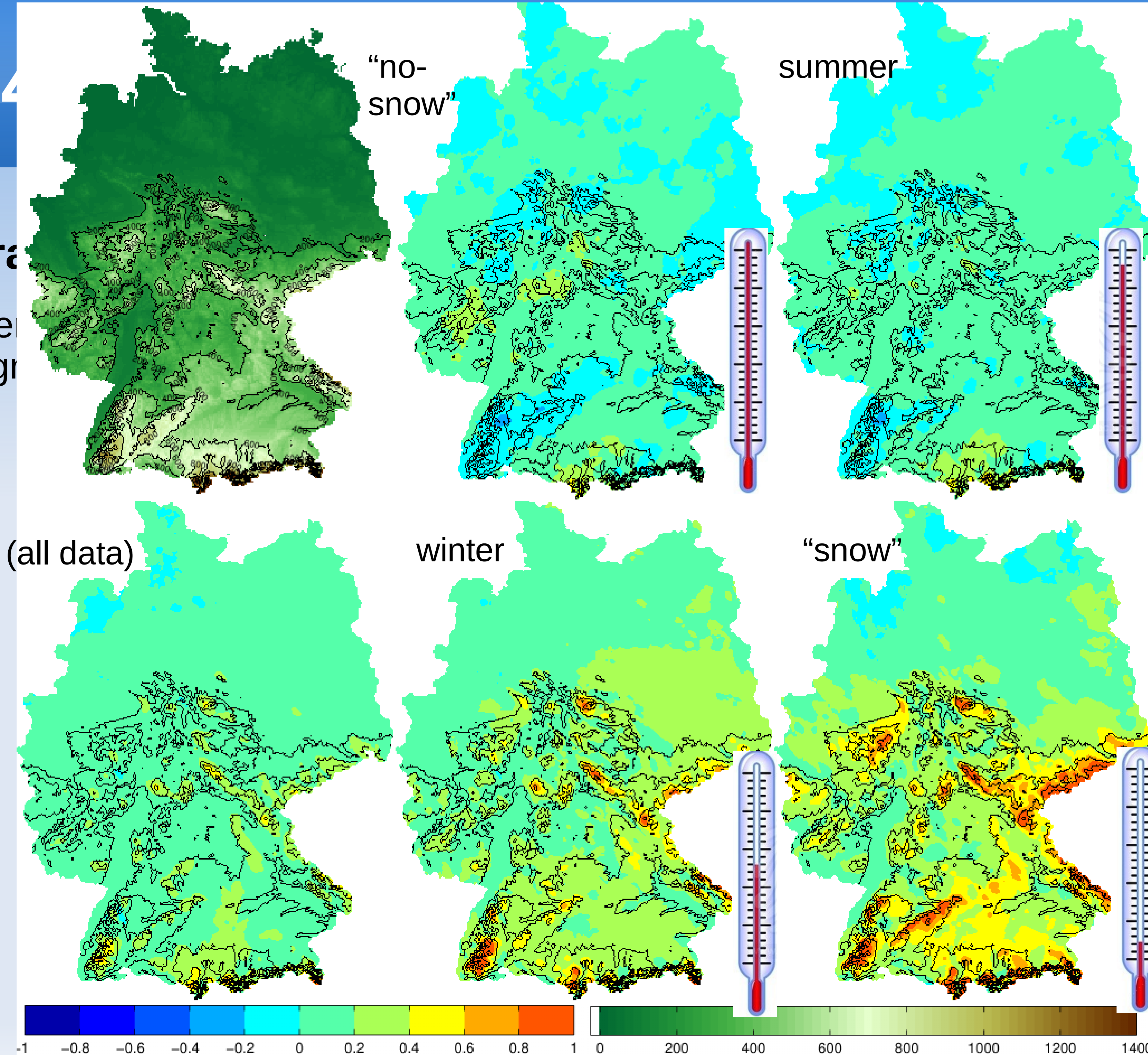


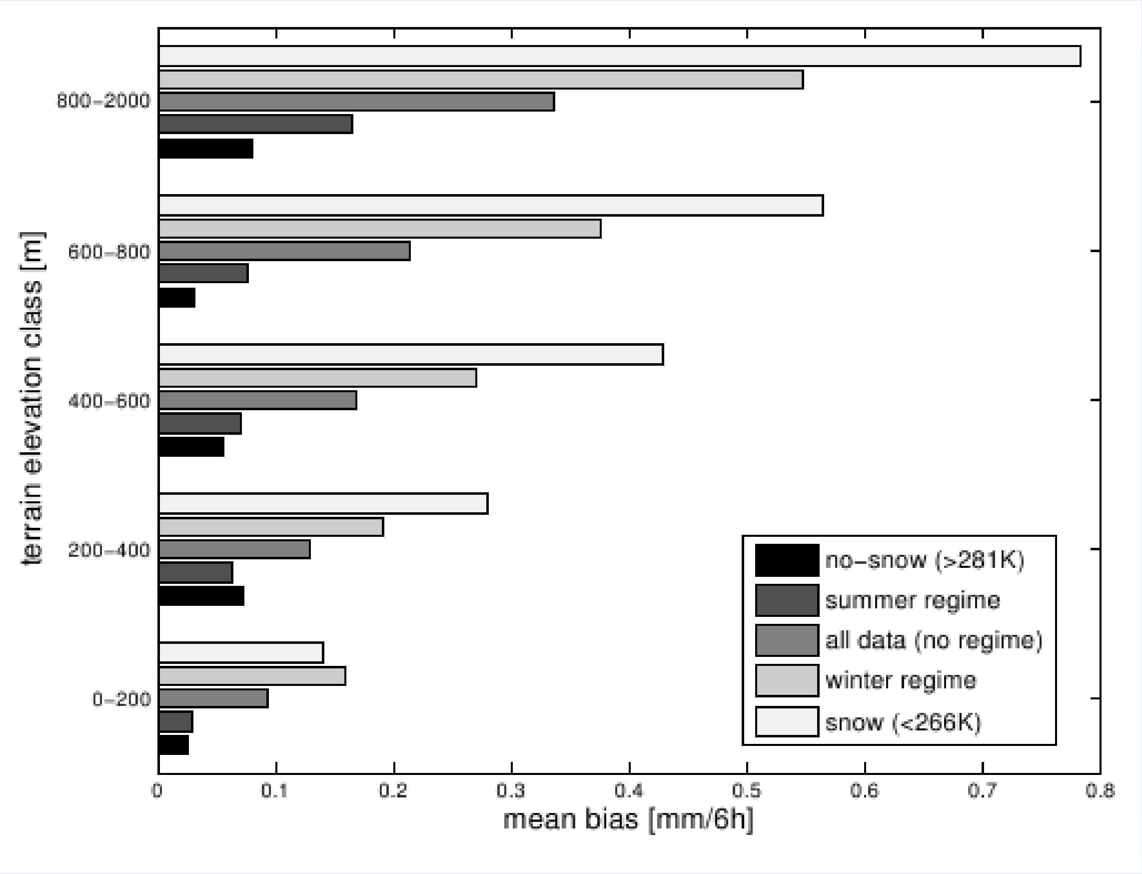
4. Results: COSMO-DE

B. Temperature-dependent model evaluation

- Temperature dependency: a positive height-related bias increases in magnitude, with a gradient from warm to cold regimes.
- The coldest regime (the snow regime) exhibits the strongest positive biases, which indicates that **solid precipitation** is possibly the main problem (in observations or model, cfr discussion)
- The fact that this effect is stronger on higher elevations confirms this hypothesis.
- This kind of bias is called ”**solid precipitation bias**”

4. Results: COSMO-DE

- To quantify the results, the areal-averaged precipitation bias is calculated separatly for five elevation classes, 0-200m, 200-400m, 400-600m, 600-800m, and 800-2000m (resp. 48%, 24%, 20%, 6% and 2% areal proportion) and for all the temperature regimes
- In all elevation categories, the mean bias is positive, indicating an overall positive bias.



4. Results: COSMO-EU

A. Circulation-dependent model evaluation

- Circulation dependency: positive biases on the windward sides of the orography and negative biases on the crest and lee sides.

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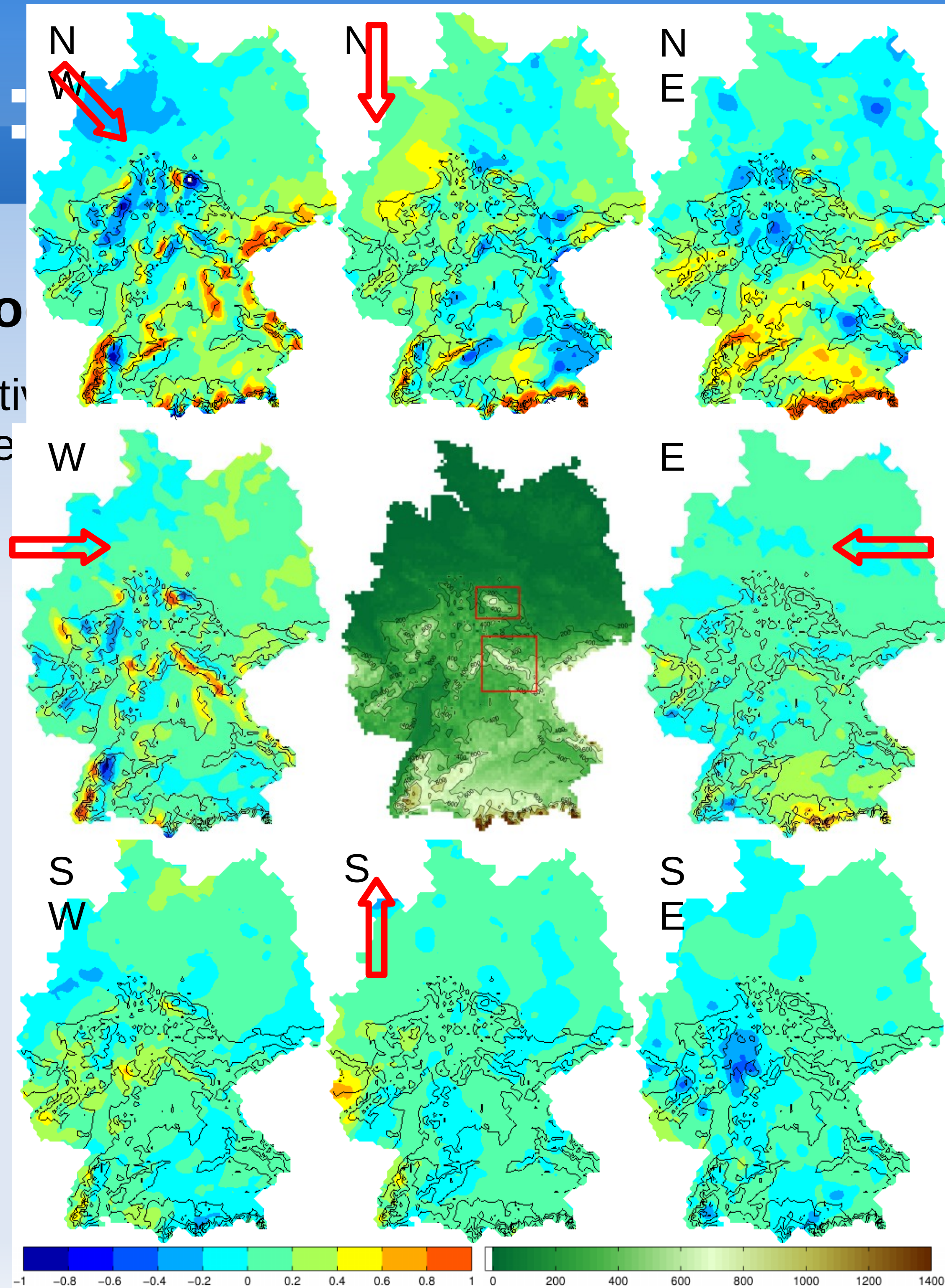

4. Results: COSMO-EU

A. Circulation-dependent model evaluation

- Circulation dependency: positive biases on the windward sides of the orography and negative biases on the crest and lee sides.
- Larger biases where the hill/mountain ridge is perpendicular to the wind direction: larger area with forced flow uplift.
- In some regimes the biases are smaller (e.g. E, SE, S). This is due to
  - a lower absolute rainfall amount (continental vs. maritime airmasses) and
  - a significant lower sample size, limiting the probability that spatially fixed biases will overcast random events.
- Also called the ”**convection bias**”, cfr discussion.

4. Results: COSMO-EU

B. Temperature-dependent model evaluation

- the windward/lee (convection) bias is visible in all temperature regimes
- The windward and lee sides of topography are defined by the dominance of the westerly circulation regime in each temperature bias composit.
- However, the bias is also depending on temperature regime

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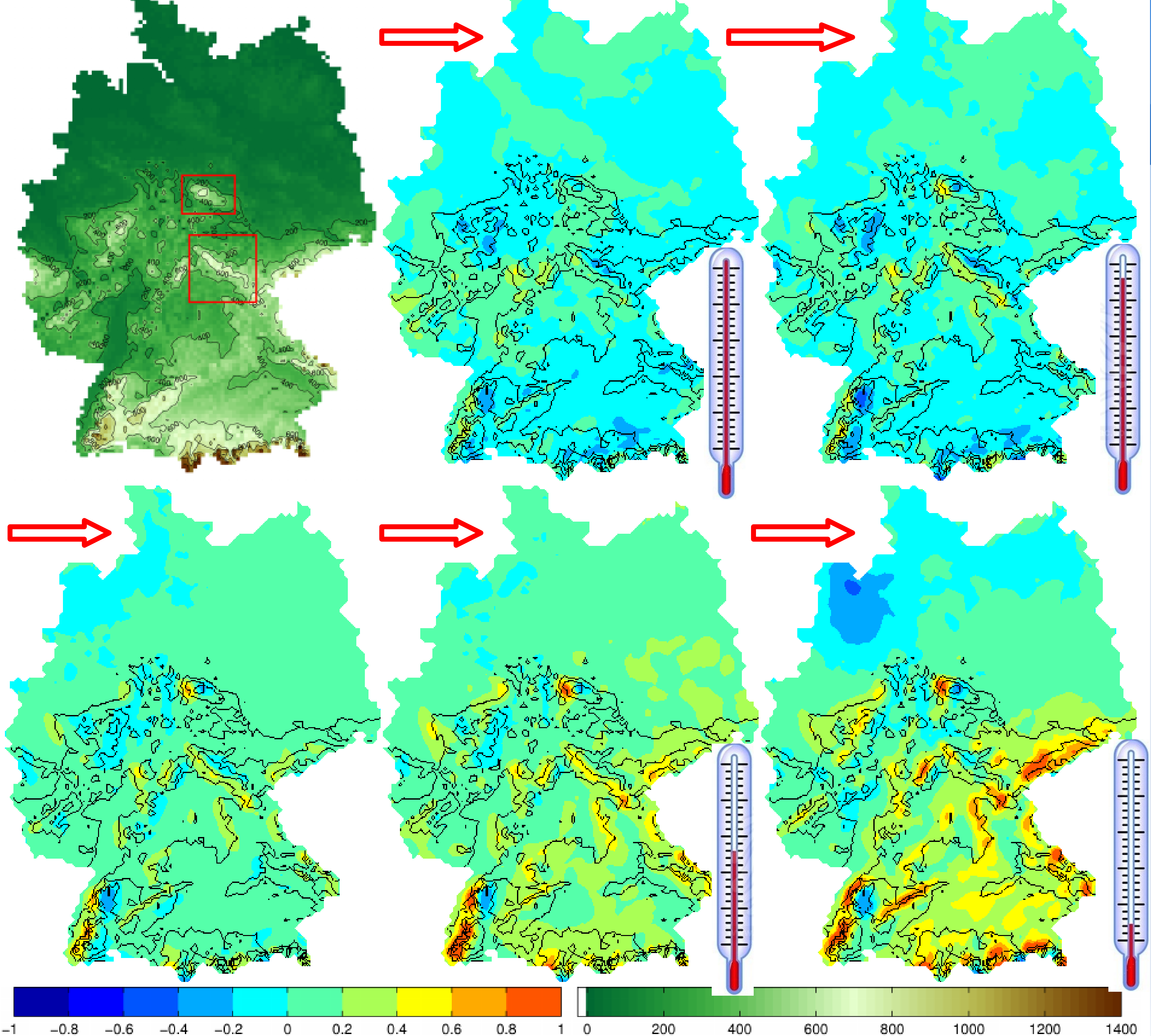


4. Results: COSMO-EU

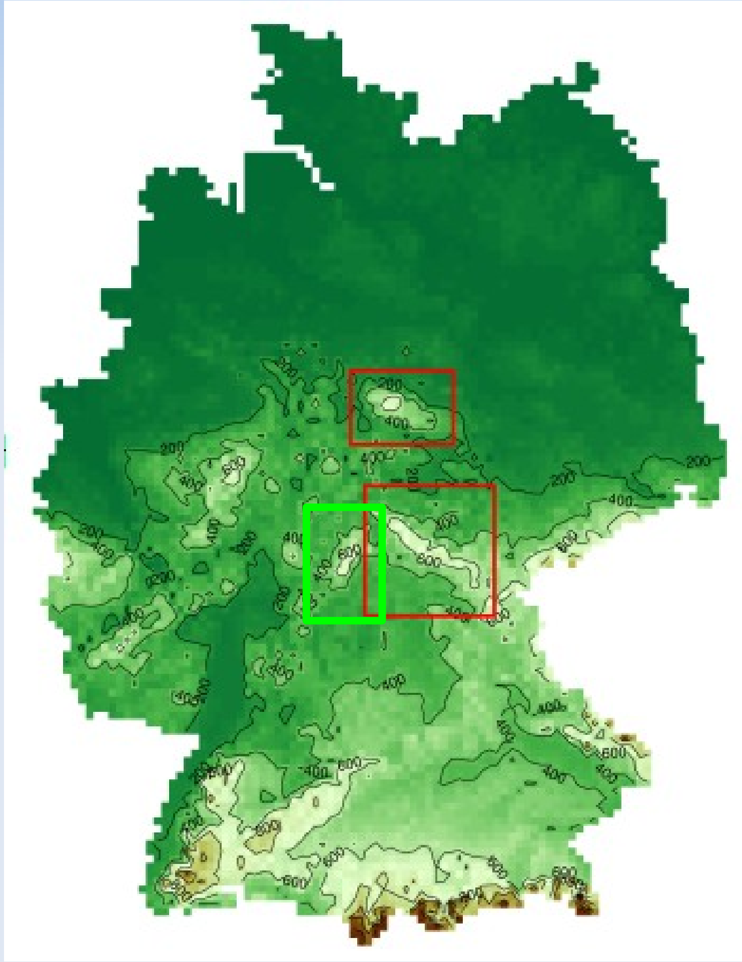
B. Temperature-dependent model evaluation

- the windward/lee bias is visible in all temperature regimes
- The windward and lee sides of topography are defined by the dominance of the westerly circulation regime in each temperature bias composit.
- However, the bias is also depending on temperature regime
- In the colder regimes, the windward effect is amplified, indicating a similar (positive) solid precipitation bias in COSMO-EU as seen in COSMO-DE
- The results can interpreted as the joint bias of two **superimposed biases**, namely the *convection bias* and the *solid precipitation bias.*

4. Results: case study

A cross section has been made perpendicular to a NE-SW oriented hill ridge: the Rhön Mountains (light green on map).

- directly compare COSMO-DE and COSMO-EU
- check possible interpolation effects in the RANIE product

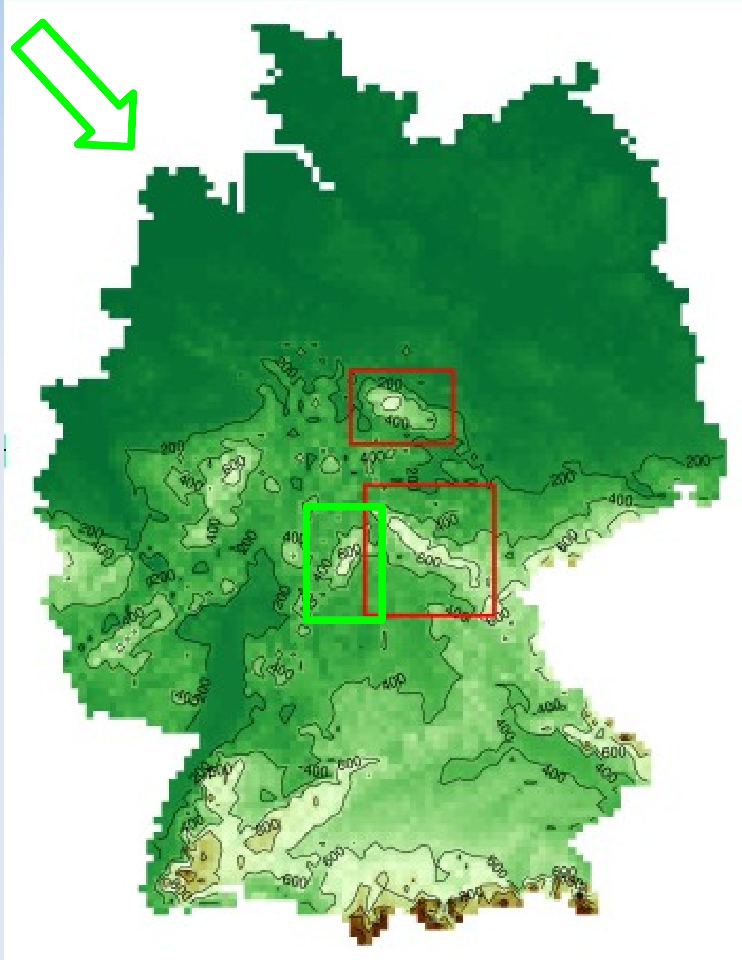


4. Results: case study

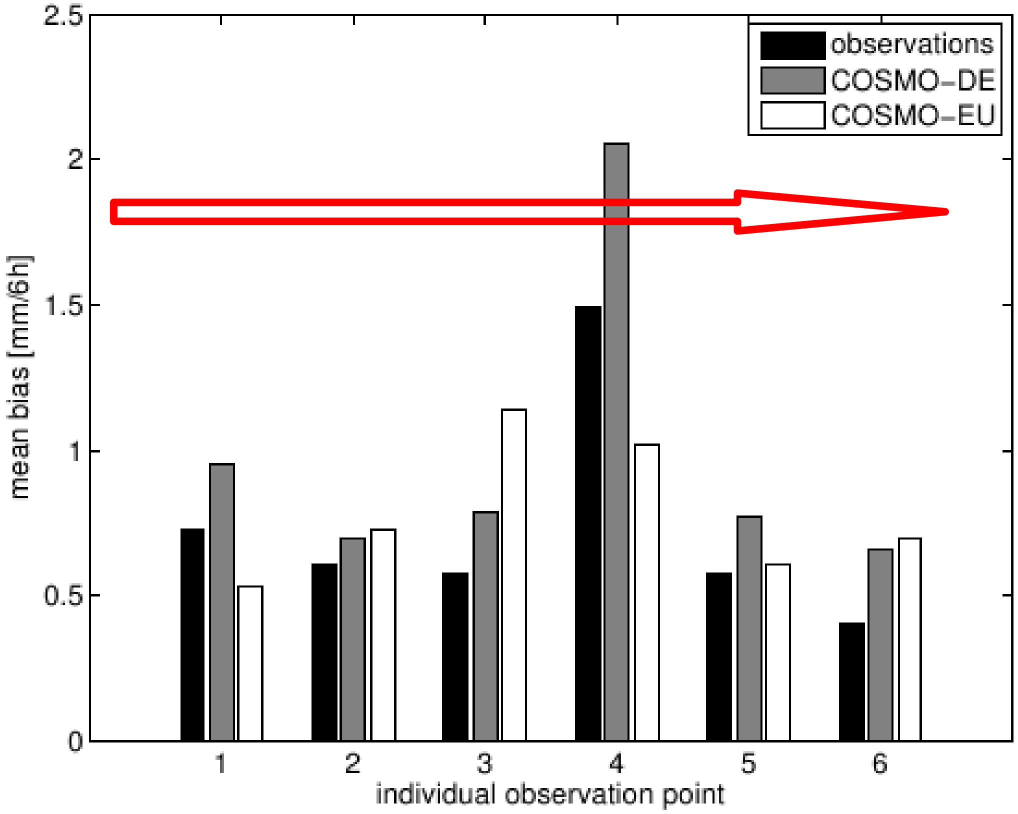
A cross section has been made perpendicular to a NE-SW oriented hill ridge: the Rhön Mountains (light green on map).

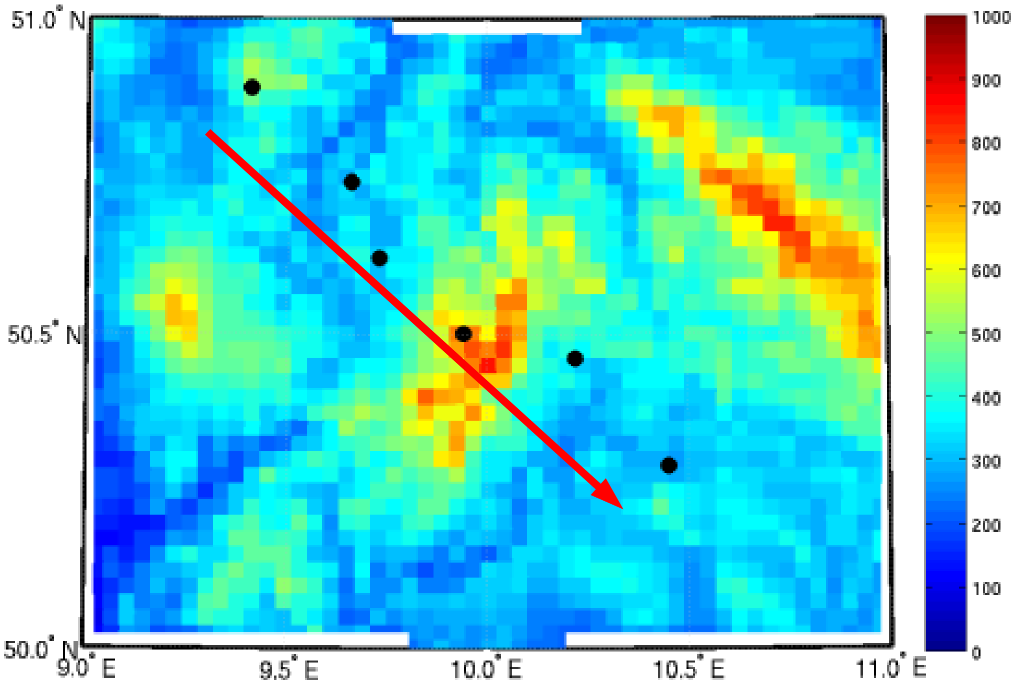
- directly compare COSMO-DE and COSMO-EU
- check possible interpolation effects in the RANIE product

Individual rain gauge data is compared with model output for all time periods with the **northwestern circulation regime** during wintertime.



4. Results: case study





- a clear COSMO-DE overestimation at the crest (**point 4**)
- At **point 3**, on the windward side of the ridge, the solid precipitation bias in COSMO-EU is superimposed on the positive convection bias, resulting in a large positive bias.
- On the crest and lee side (**point 4 and 5**) the solid precipitation bias is partly compensating the negative convection bias in COSMO-EU.

5. Discussion & conclusion

Circulation dependency

How to explain the ”convection bias”?

- COSMO-EU makes use of the convection parametrisation scheme, the revised Tiedtke scheme.
- The scheme triggers convection too often at the windward side of hills and low mountains instead of the ridges/crests.
- This “windward/leeward effect” is commonly found in mesoscale NWP and climate models which require convection parametrisation, such as COSMOCH7, ALADIN, MM5 and ETA.

5. Discussion & conclusion

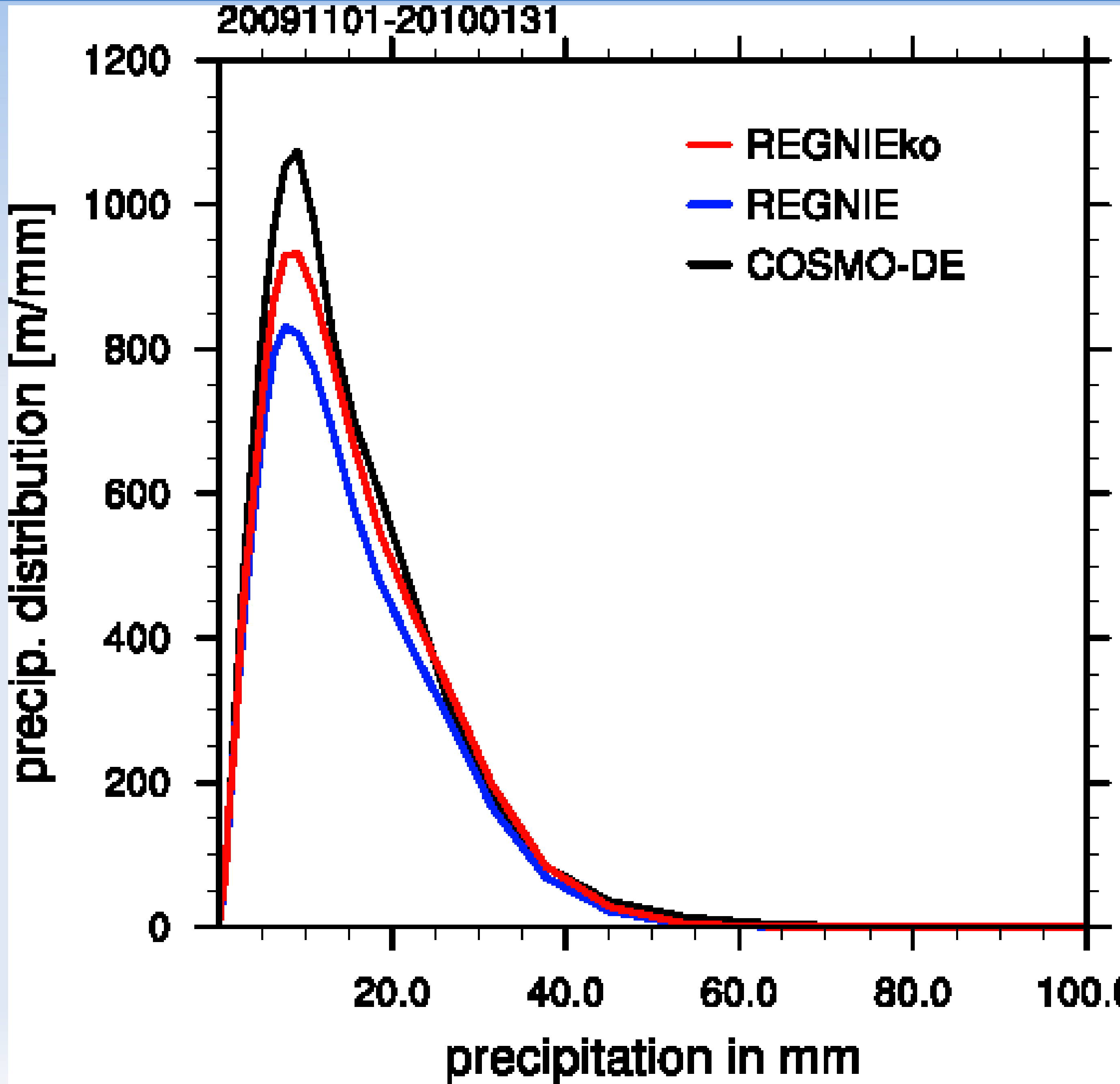
Temperature dependency

How to explain the positive ”solid precipitation bias”? Potential sources of errors are deficiencies in ***observations (1)*** and deficiencies in the ***model (2)***

1. The reliability of rain gauge **observations** depends on precipitation phase and wind speed: less snow than rain is captured with higher windspeeds.

- Experiments from the hydrology department of DWD: rain gauge product REGNIE was modified for wind speed and precipitation phase with the *Richter* algorithm.
- Overall COSMO wintertime (NDJ 2009-2010) precip bias has been decreased significantly with about 50% (!)

5. Discussion & conclusion



5. Discussion & conclusion

Rain gauge uncertainties are likely to be a substantial source of error. On the other hand, observational errors alone cannot entirely explain the difference between model and measurements.

2. Model deficiencies can be related to model dynamics or parametrisation of physical processes.

- No dependency of the model bias on synoptic scale patters: deficiencies in large-scale model *dynamics* can be ruled out as a sources of error.
- A likely candidate is the *parametrisation of microphysical processes*, i.e. precipitation phase, snow habit and fall speed, e.g. when
  - snow **fall speed** is too high..
  - **graupel** forms too often or too fast.. (only COSMO-DE)

Vielen Dank!