

# Present and future snow cover in the alps:

## Using MODIS satellite observations to evaluate and bias correct the EURO-CORDEX regional climate model ensemble



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# Motivation & objectives

- Evolution of future snow (cover) in the Alps is relevant for ecology, society, and economy.
- With climate change less snow is expected.
- But: Need for more precise and local estimates.

Traditional approach	Alternative
Use a dedicated snow model, forced by projections from GCM/RCM	Use snow from GCM/RCM directly
<ul style="list-style-type: none"><li>+ accurate physics</li><li>+ high spatial resolution possible</li><li>- computationally intensive for large areas</li><li>- decoupling of climate and hydrology</li></ul>	<ul style="list-style-type: none"><li>? (only a) by-product</li><li>- low (GCM: ~100s km) to moderate (RCM: ~10s km) spatial resolution</li><li>+ large areas covered</li><li>+ climate-hydrology feedbacks</li></ul>

# Data

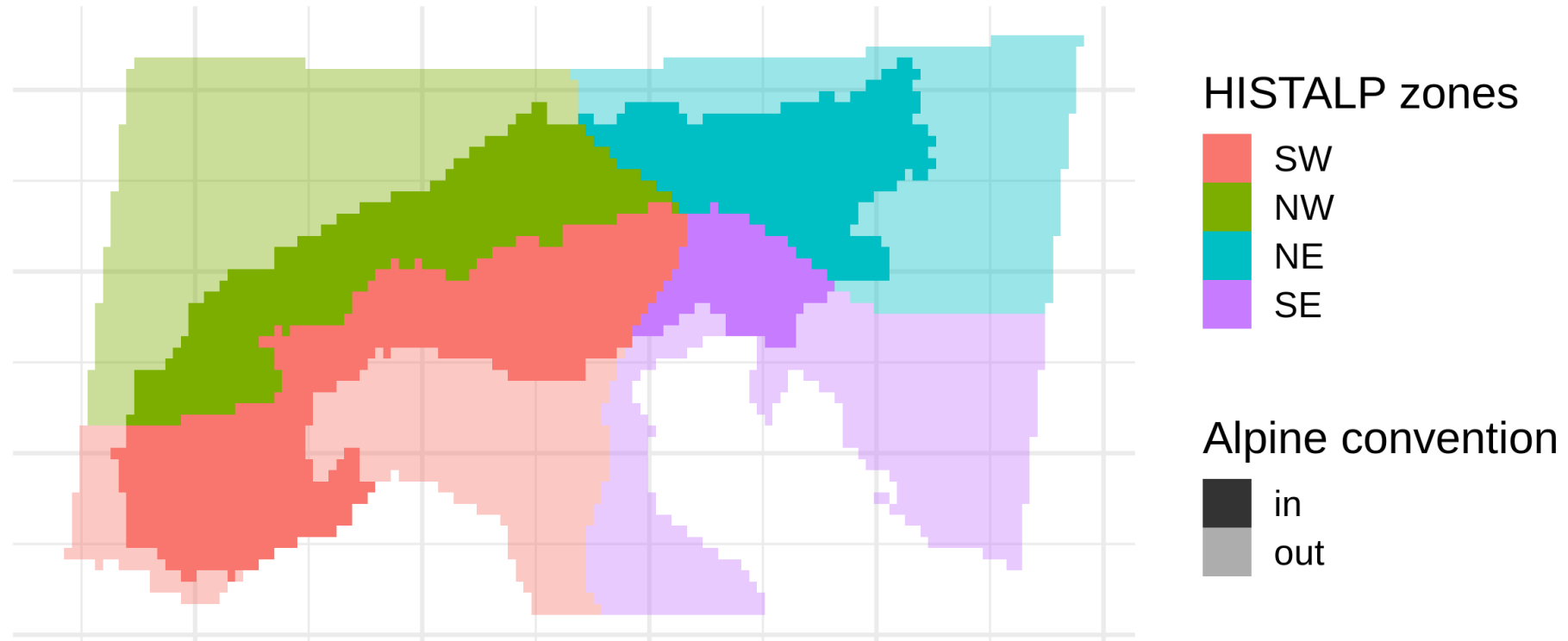
Observation (snow cover)	Auxiliary	RCM (snow cover)
MODIS snow cover maps <ul style="list-style-type: none"> <li>• Greater alpine region</li> <li>• Daily, 250m resolution</li> <li>• Jul 2002 – Dec 2017</li> </ul>	HISTALP temperature <ul style="list-style-type: none"> <li>• Greater alpine region</li> <li>• Monthly, <math>\sim 0.08^\circ</math></li> <li>• 1780 – 2014</li> </ul> HISTALP climate zones <ul style="list-style-type: none"> <li>• 4 regions</li> </ul> Altitude: <ul style="list-style-type: none"> <li>• MODIS (SRTM), HISTALP, each RCM</li> </ul>	EURO-CORDEX ensemble <ul style="list-style-type: none"> <li>• Europe</li> <li>• Daily, <math>0.11^\circ</math> resolution</li> <li>• 5 RCMs that have snow cover output</li> <li>• Evaluation (<math>\sim 1980</math>-<math>\sim 2010</math>) : forced by reanalysis ERA-Int</li> <li>• Driven by 6 GCMs; sum of GCM-RCM combinations = 16</li> <li>• Historical: 1950/70 – 2005</li> <li>• Projections: 2005-2100 (RCP2.6, 4.5, 8.5)</li> </ul>

Preprocess:

1. Cloud removal MODIS (combinations of temporal and snow/land line filters)
2. Upscaled MODIS to RCM resolution
3. Remapped rest (HISTALP, RCM) to upscaled MODIS grid: snow cover (nearneigh), temperature (bilinear)

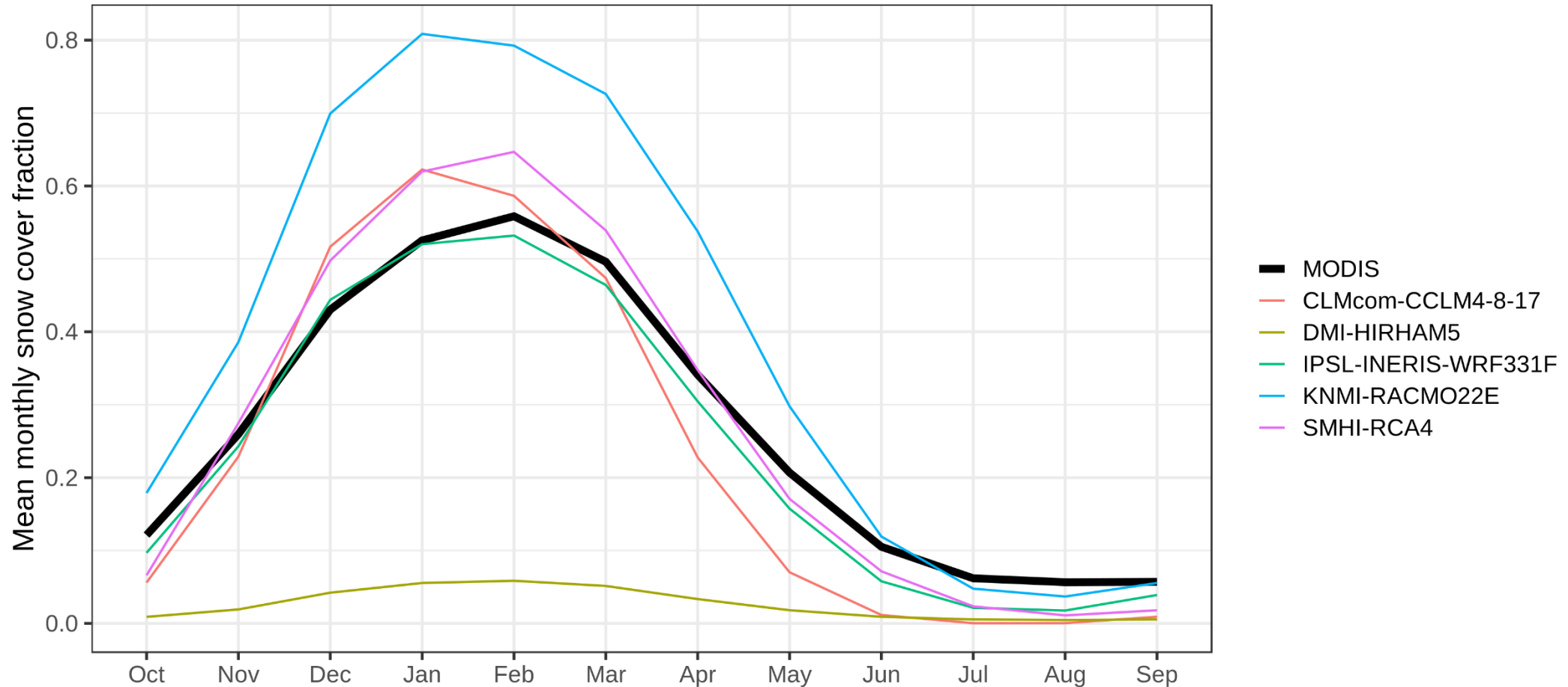
# Part 0: The setting

HISTALP climate zones and Alpine convention boundary



# Part 0: The big picture

Snow cover dynamics over the Alps (Oct/2002 - Sep/2008)  
As seen by MODIS and 5 RCMs (forced by ERA-Int)



# Part 1: Evaluation

Known issues with EURO-CORDEX RCMs:

- Orographic smoothing (Kotlarski et al. 2015)
- Cold bias in the alps (Smiatek et al. 2016)

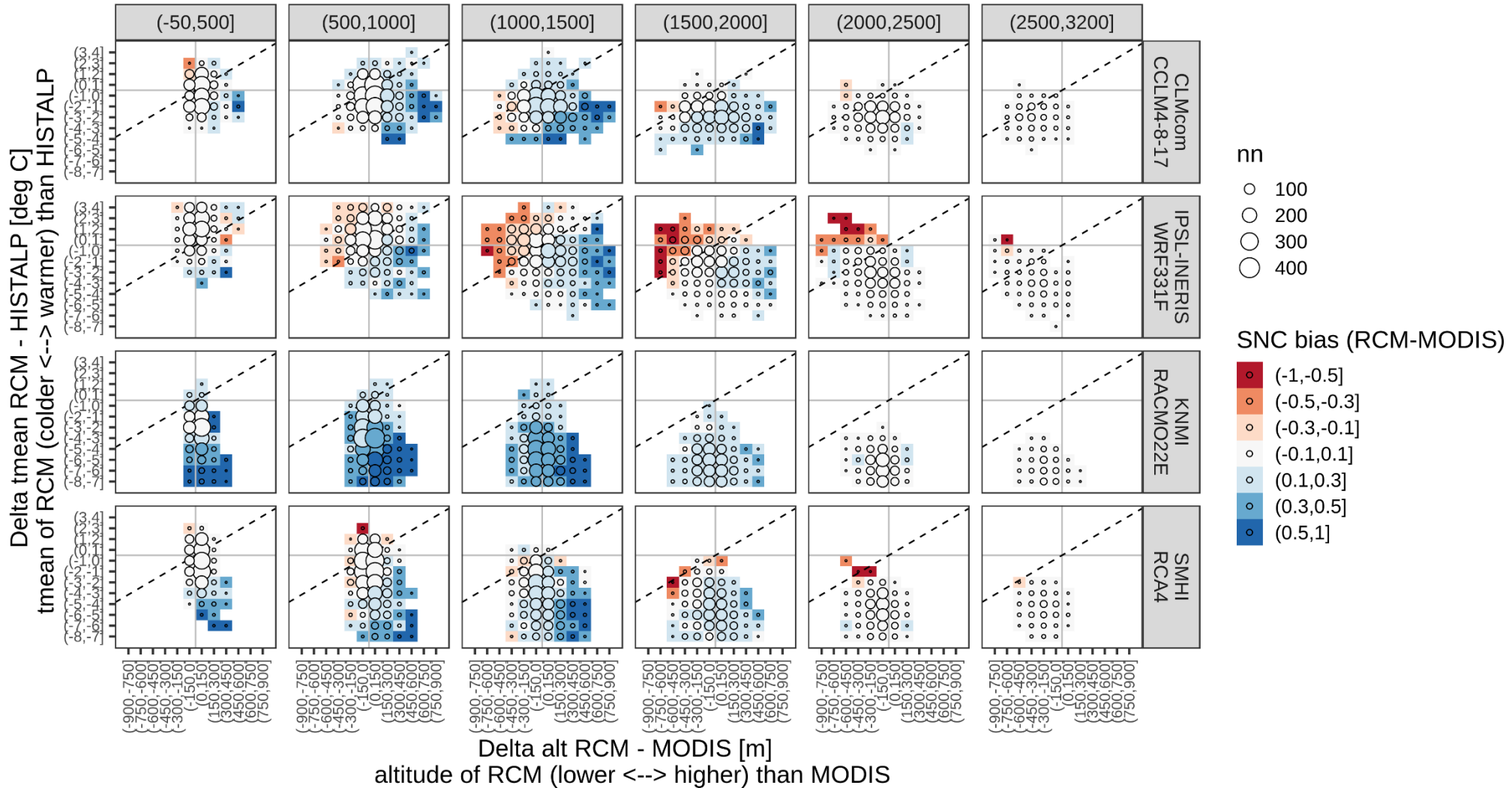
How does this relate to bias in snow cover?

- Common evaluation period of MODIS and RCMs (forced by reanalysis):  
Oct 2002 – Sep 2008 (6 hydro-years)

# Part 1: Evaluation – Winter: January

January bias in snow cover area (SNC) w.r.t. differences in RCM orography and temperature

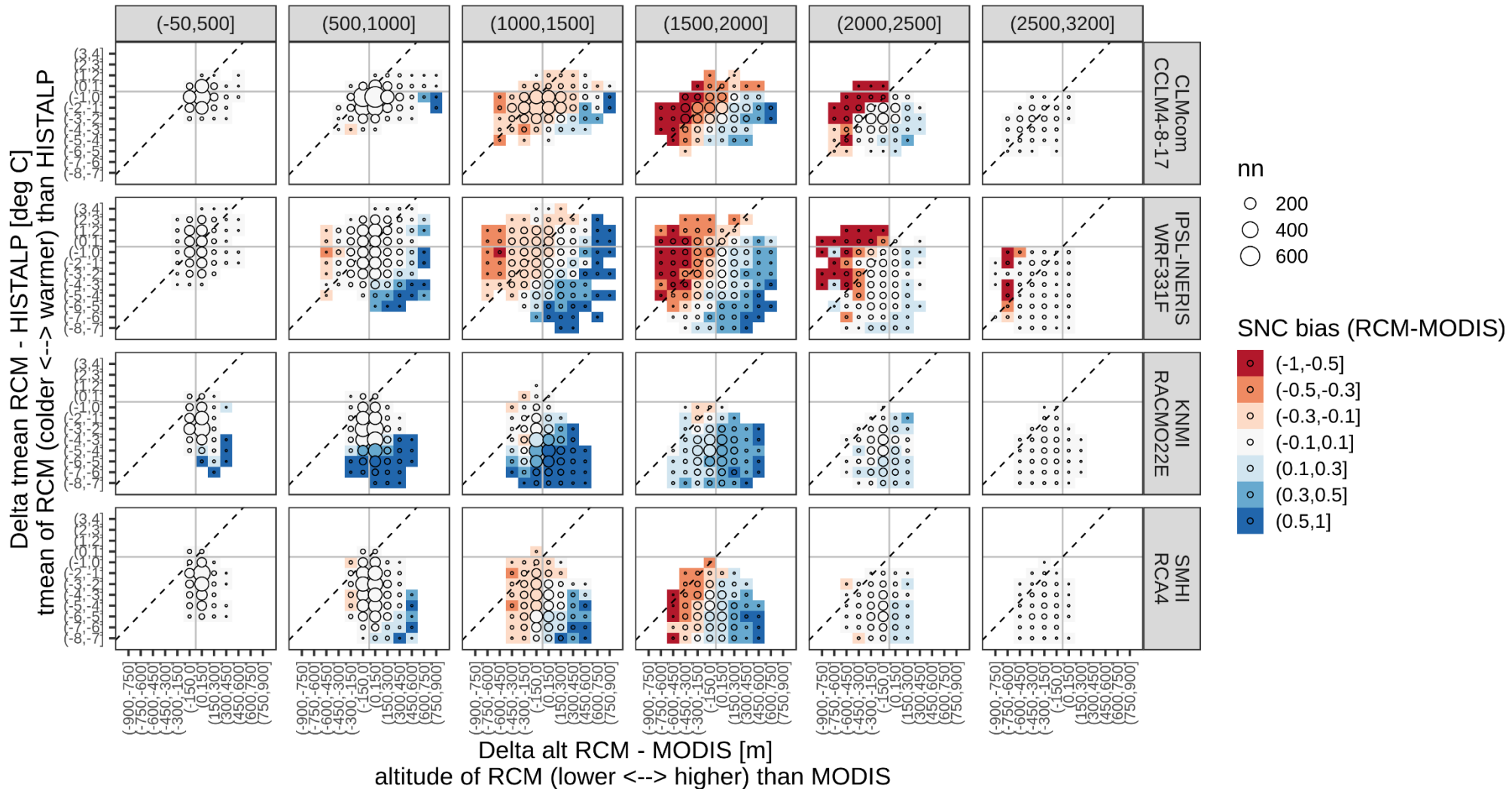
Columns: MODIS altitude classes, Rows: RCMs



# Part 1: Evaluation – Spring: April

April bias in snow cover area (SNC) w.r.t. differences in RCM orography and temperature

Columns: MODIS altitude classes, Rows: RCMs





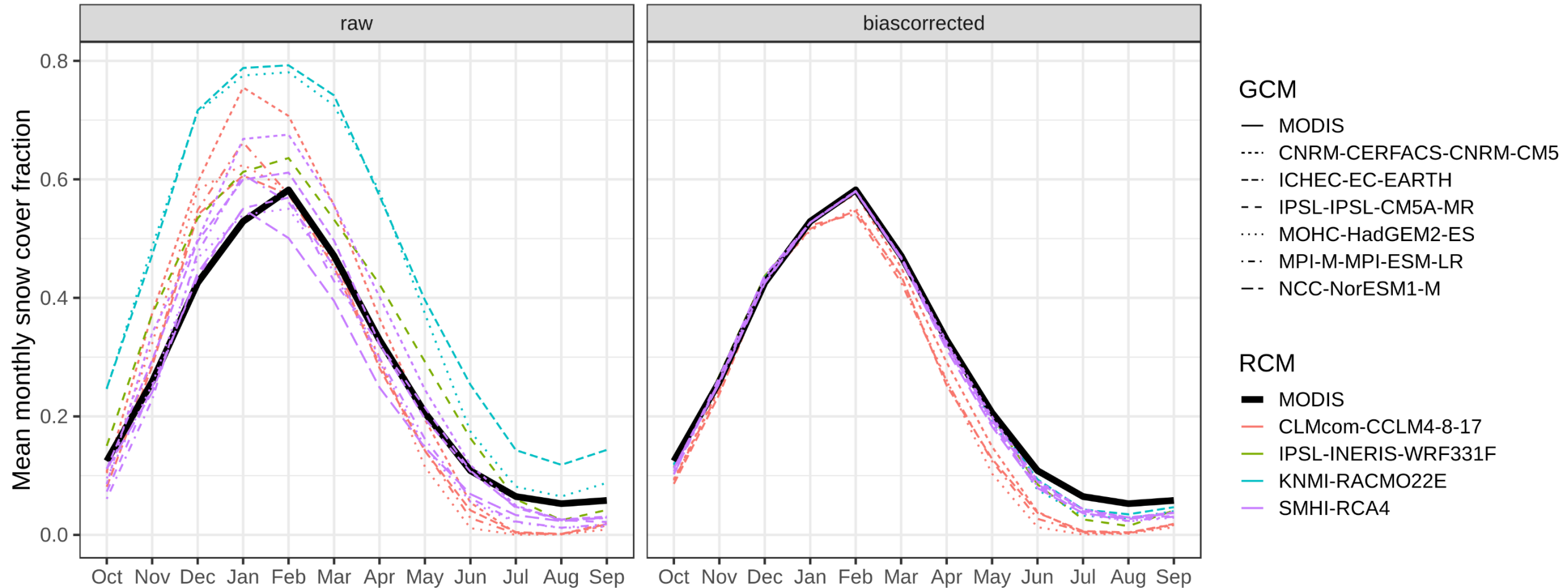
# Part 1: Evaluation - conclusion

- Snow in RCMs adequate but not perfect
- Related to RCM orography and temperature deficiencies
- But, in principle: Trustworthy
- So: Biascorrection makes sense (in order to compare model changes to present situation)
  - Quantile Delta Mapping (QDM), Cannon et al. 2015, extension of the QM (Quantile Mapping) that preserves (relative) changes in climate models
  - Applied to snow cover:
    - Month-by-month, pixel-by-pixel
    - Relative changes
    - Here: only rcp8.5 shown
    - Past: 2002-2017
    - Future: 2071-2100

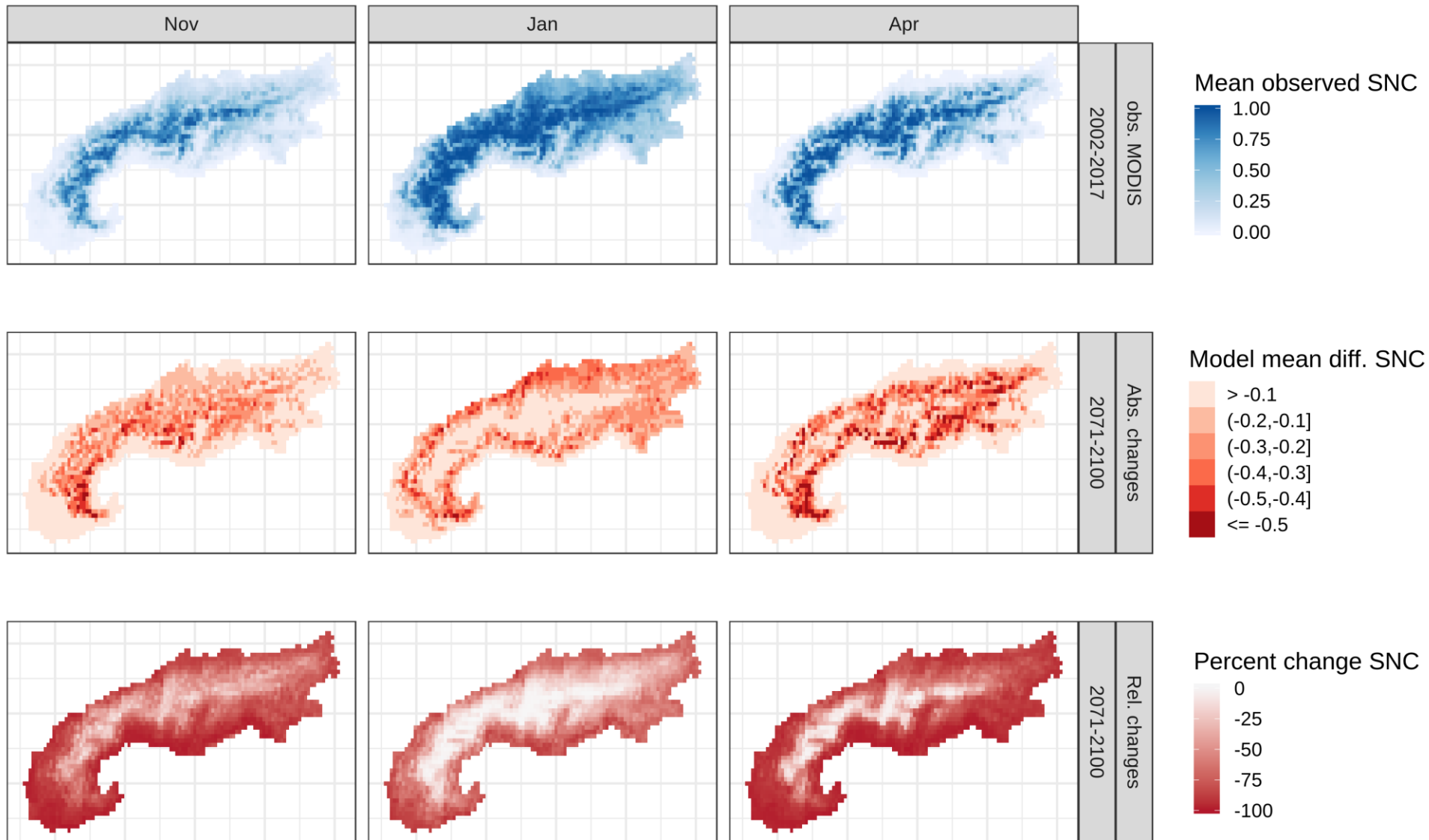
# Part 2: Bias correction (prelim) - Past

Snow cover dynamics over the Alps (Oct/2002 - Sep/2017)

As seen by MODIS and 13 RCM-GCMs (rcp8.5)



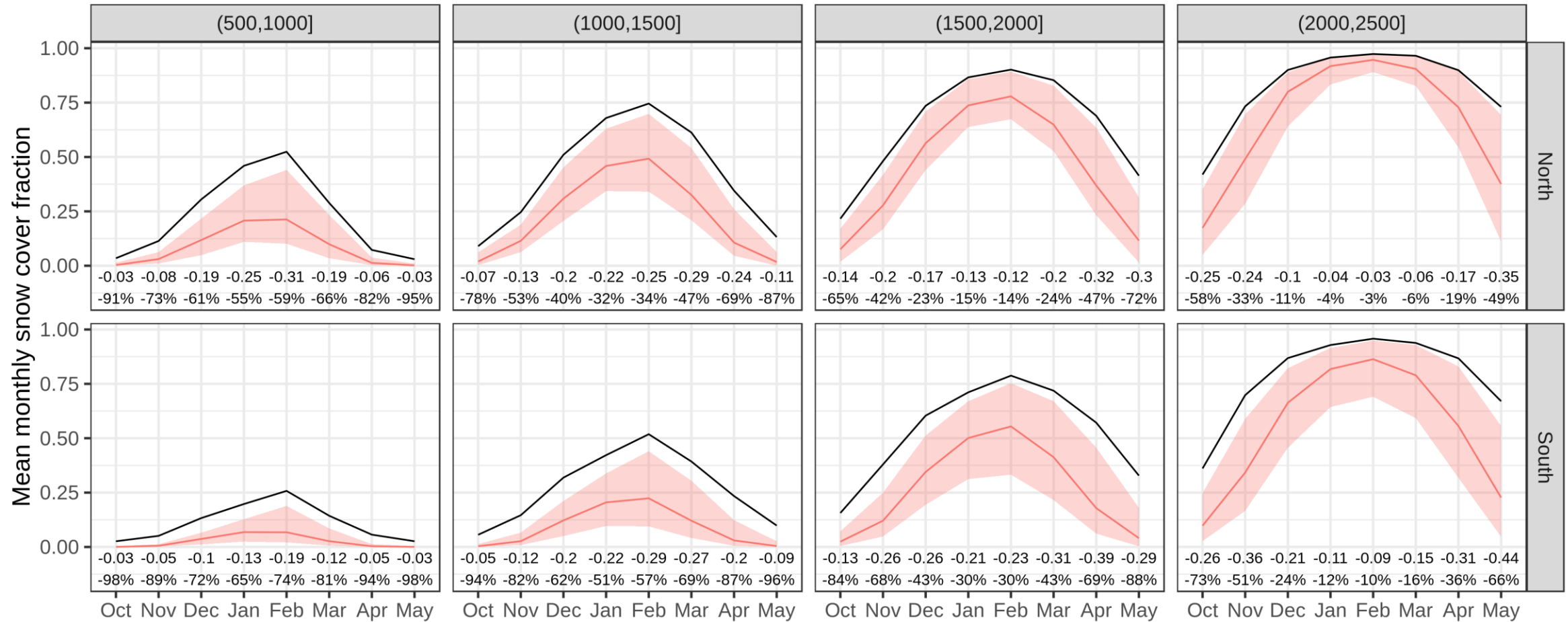
# Part 2: Bias correction (prelim) – Maps





# Part 2: Bias correction (prelim) - Future

Past and future snow cover dynamics over the Alps  
As seen by MODIS and 13 biascorrected RCM-GCMs



future model mean and range (2071-2100, rcp8.5) past observed (MODIS, 2002-2017)

# Conclusions & Outlook

- RCM snow cover in the alps works in principle, but has biases that depend
  - On the RCM deficiencies in orography and temperature
  - On the RCM snow modules
- Biascorrection useful to bring models closer to present observations (and thus put projections in context)
- (preliminary) Projections for 2071-2100 under rcp8.5 show
  - largest changes in spring/fall; but < 1500m also in winter
  - stronger decreases in southern than in northern alps

## Future steps:

- Further investigation of bias correction
- Downscaling of RCM output using MODIS
- Comparison to traditional approach of forecasting snow using e.g. hydrological models for some case study

# There is more...

EGU2019-10940 | Orals | [CL5.01](#)

Past and future European snow conditions as represented by the EURO-CORDEX ensemble

**Claas Teichmann**, Sven Kotlarski, Katharina Bülow, and Christian Steger

Wed, 10 Apr, 15:00–15:15 Room 0.14

EGU2019-10786 | Orals | [CR2.1](#)

The Snow Climate Change Initiative - Towards a long term global snow climate data record from satellite data

**Thomas Nagler**, Chris Derksen, Gabriele Schwaizer, Richard Essery, David Gustafsson, Gerhard Krinner, Kari Luojus, Carlo Marin, Sari Metsaemaeki, Lawrence Mudryk, Kathrin Naegeli, Claudia Notarnicola, Arnt-Borre Salberg, Rune Solberg, Andreas Wiesmann, Stefan Wunderle, and Anna-Maria Trofaier

Thu, 11 Apr, 10:45–11:00 Room N2



# Contact

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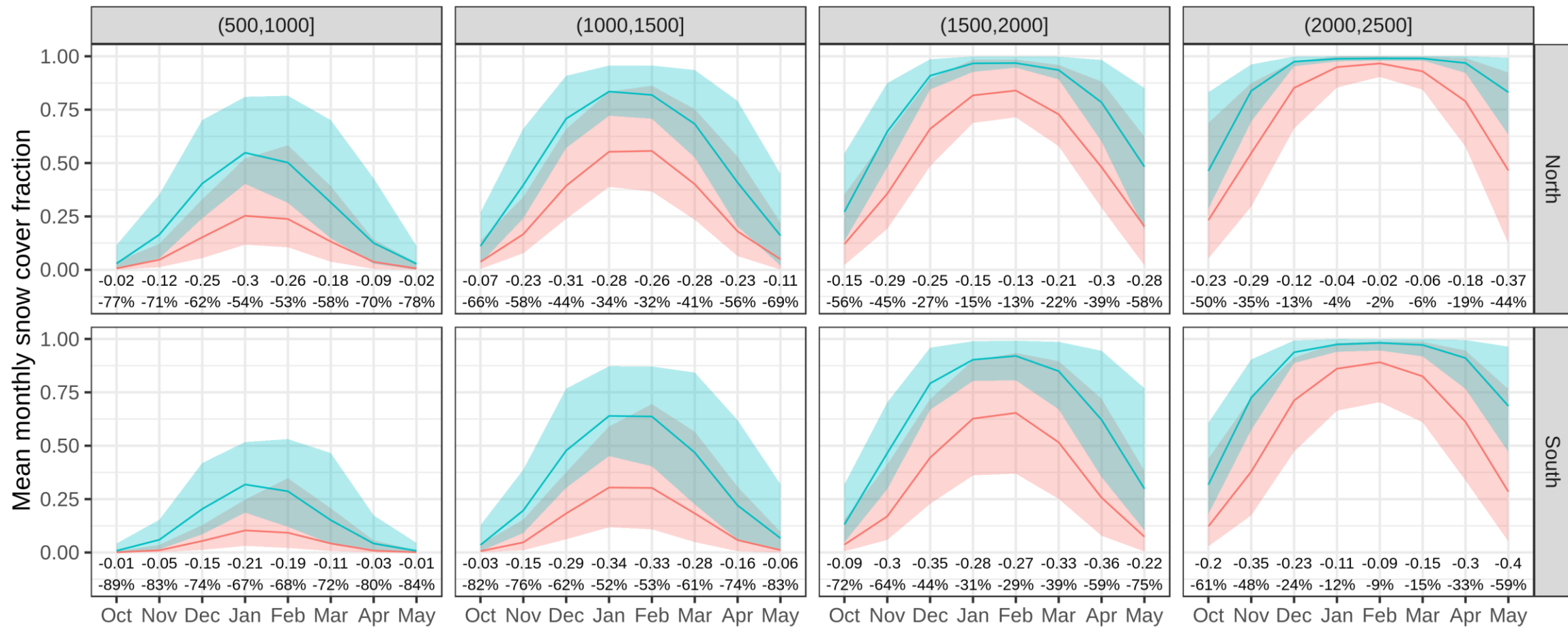


(If you accidentally took photos of the talk, mind sending them to me? -> Horizon2020 reporting)

# Aux: Non-biascorrected past-future

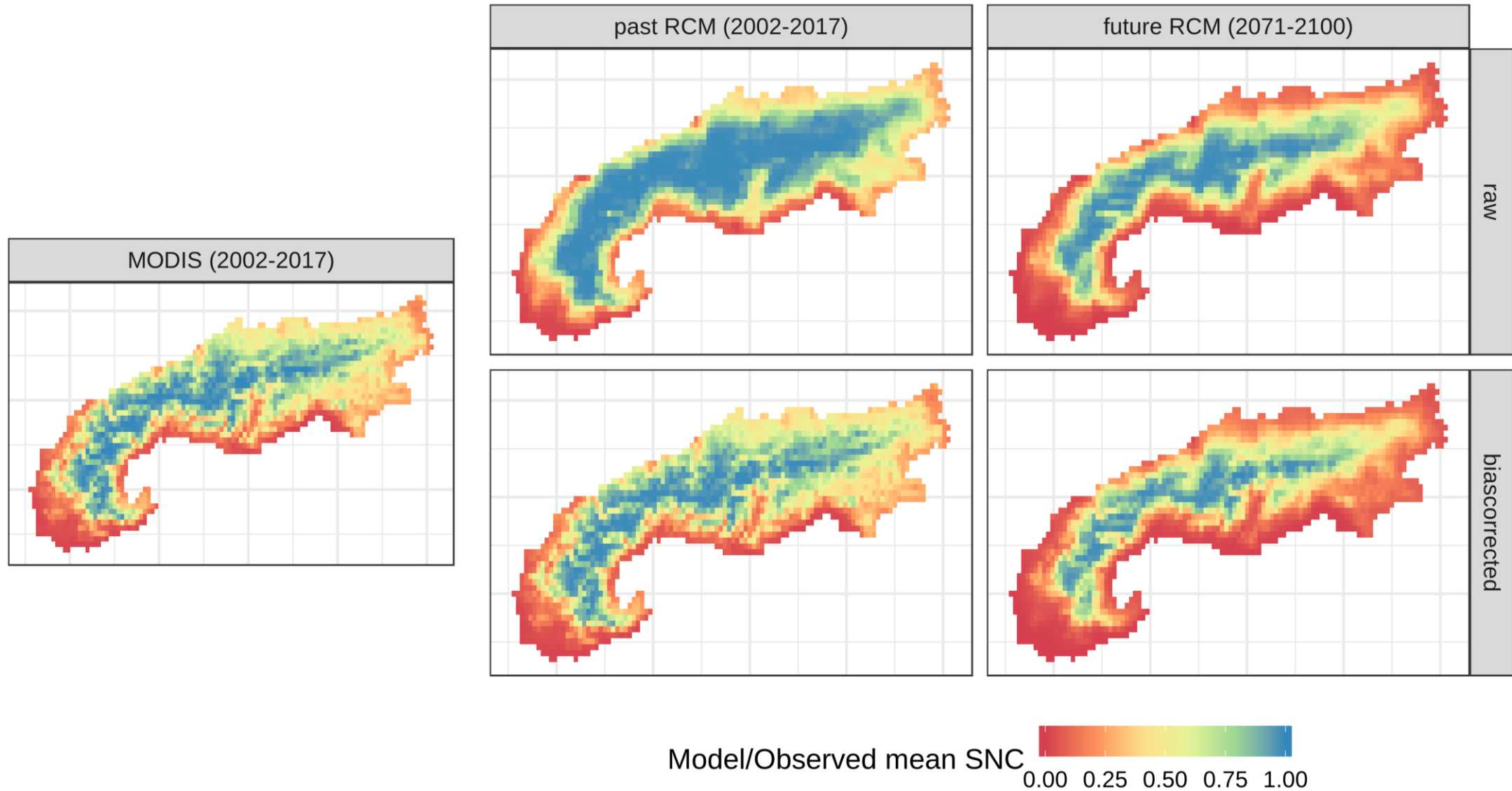
Past and future snow cover dynamics over the Alps

As seen by 13 RCM-GCMs (raw output)



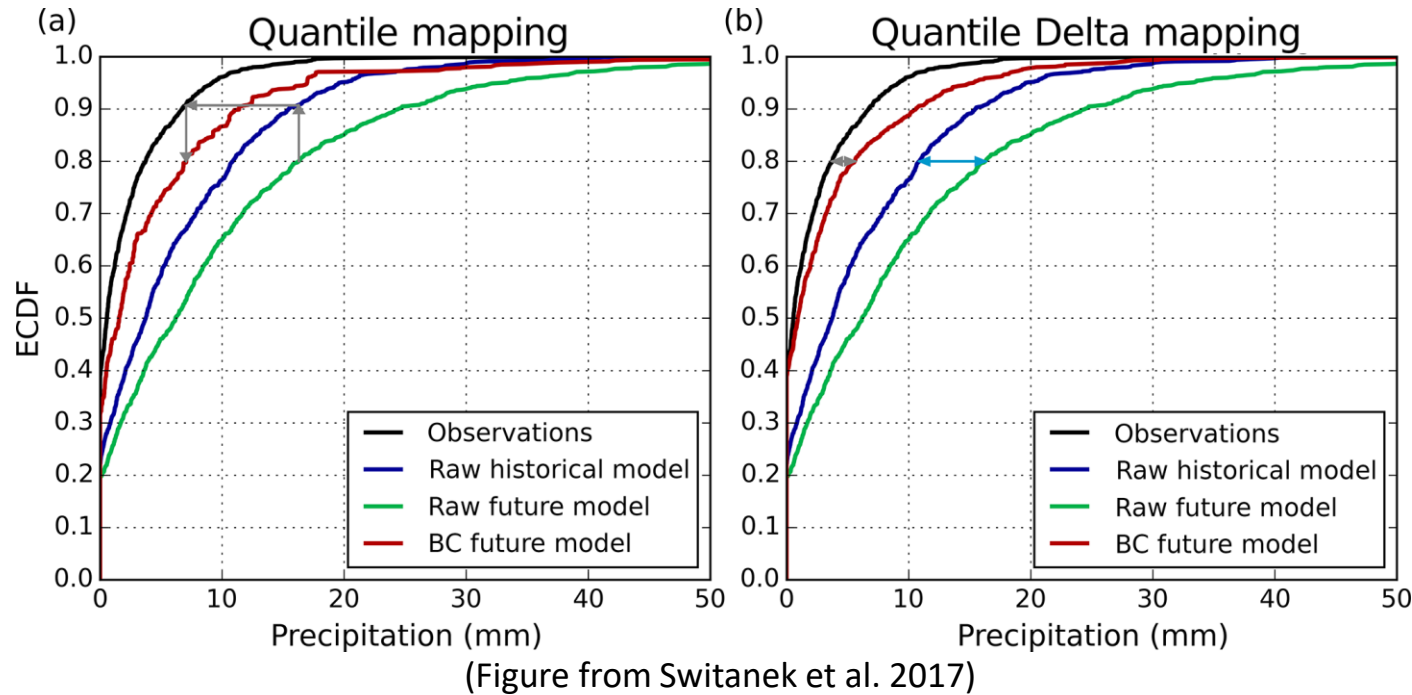
Model mean and range — future (2071-2100, rcp8.5) — past (2002-2017, rcp8.5)

# Aux – Example BC maps - January





# Part 2: Bias correction - Intro



Quantile Delta Mapping (QDM):  
Cannon et al. 2015

Extension of the QM that preserves (relative) changes in climate models

Applied to snow cover:

- Month-by-month, pixel-by-pixel
- Relative changes
- Here: only rcp8.5 shown. Past: 2002-2017 / Future: 2071-2100