

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

Data

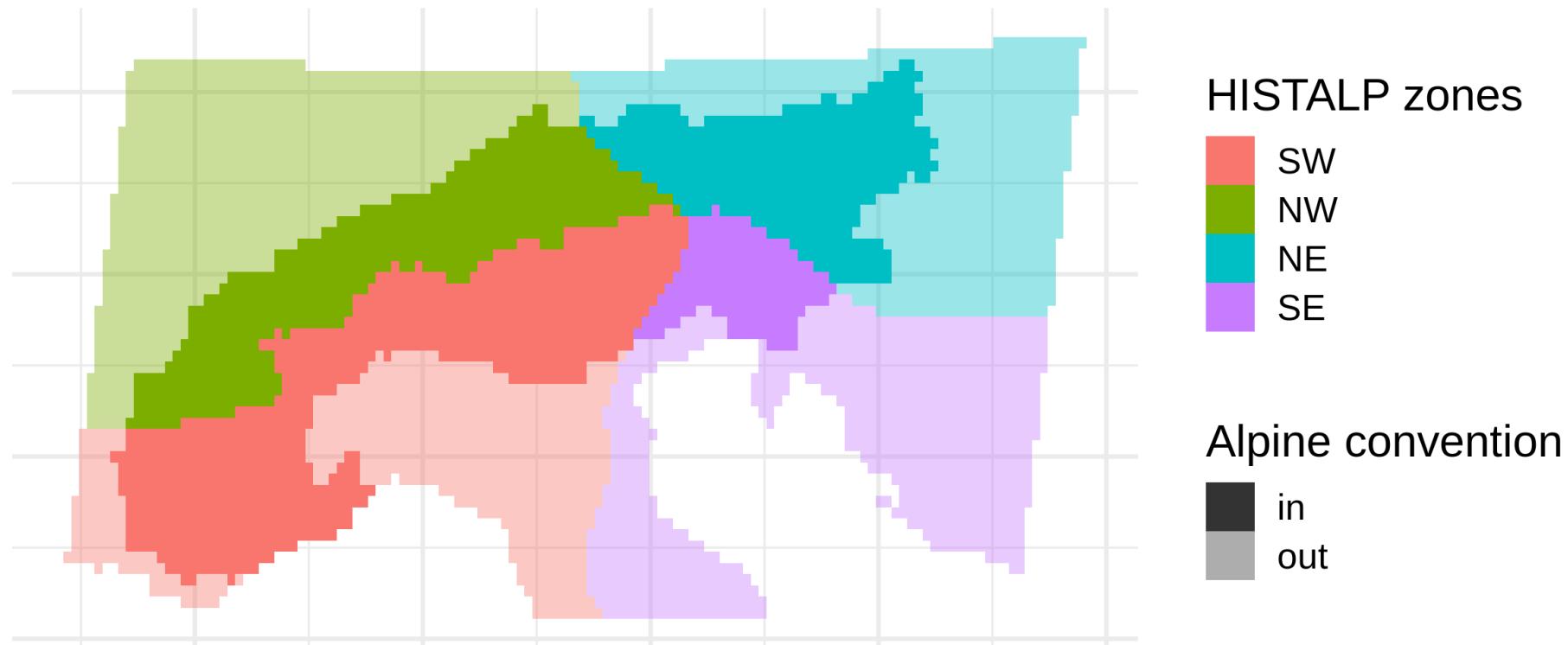
Observation (snow cover)	Auxiliary	RCM (snow cover)
<p>MODIS snow cover maps</p> <ul style="list-style-type: none">• Greater alpine region• Daily, 250m resolution• Jul 2002 – Dec 2017	<p>HISTALP temperature</p> <ul style="list-style-type: none">• Greater alpine region• Monthly, $\sim 0.08^\circ$• 1780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

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)

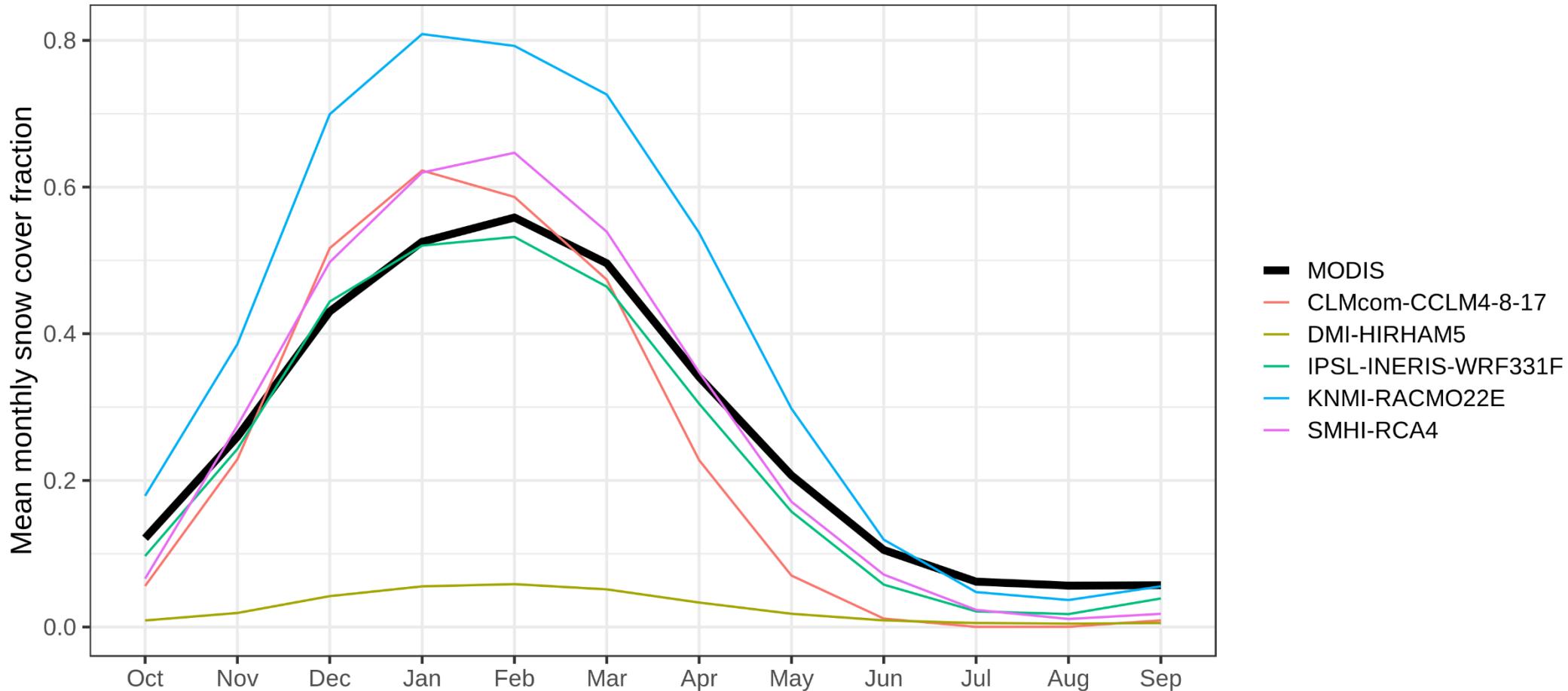
Part 0: The setting

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)

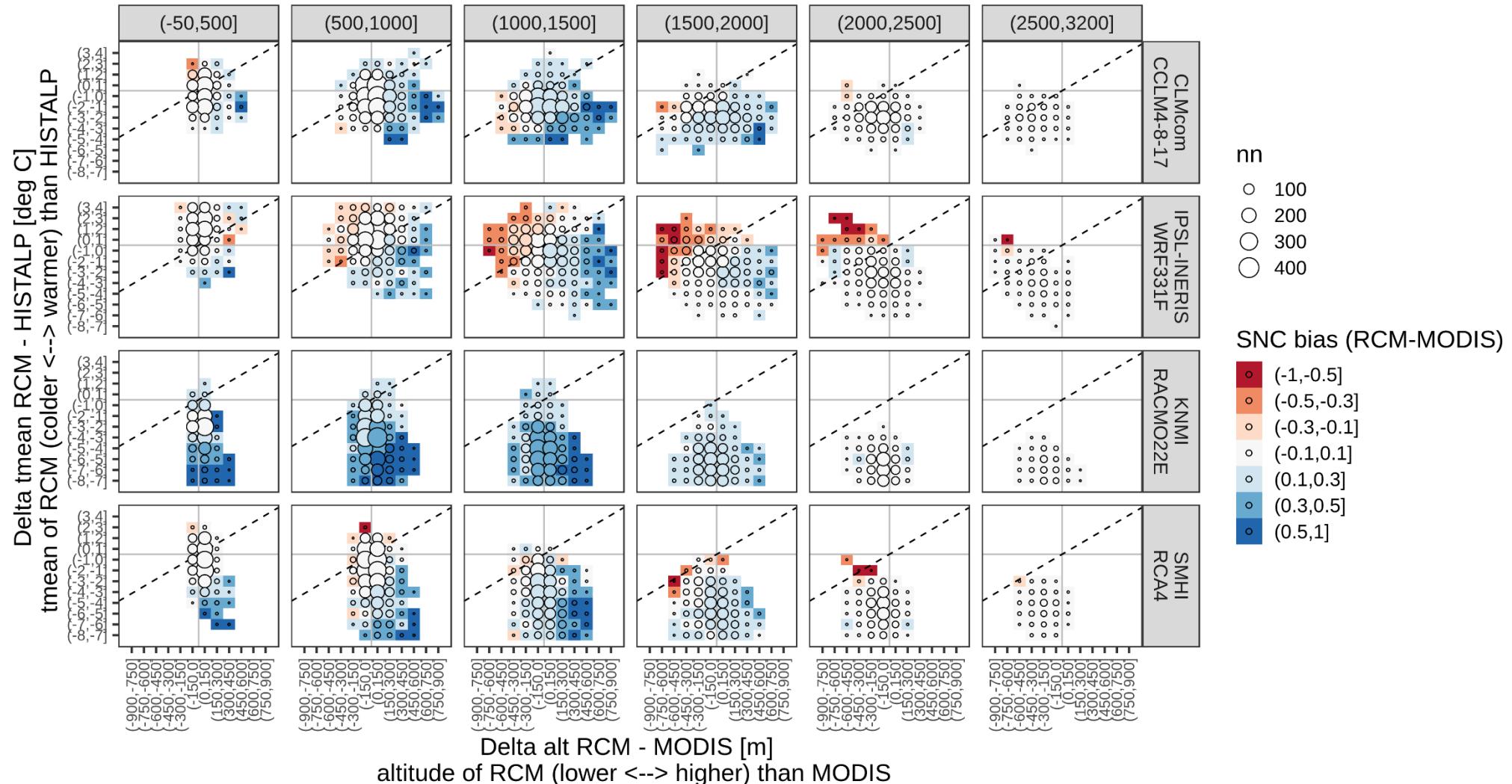
How does this relate to bias in snow cover?

- 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

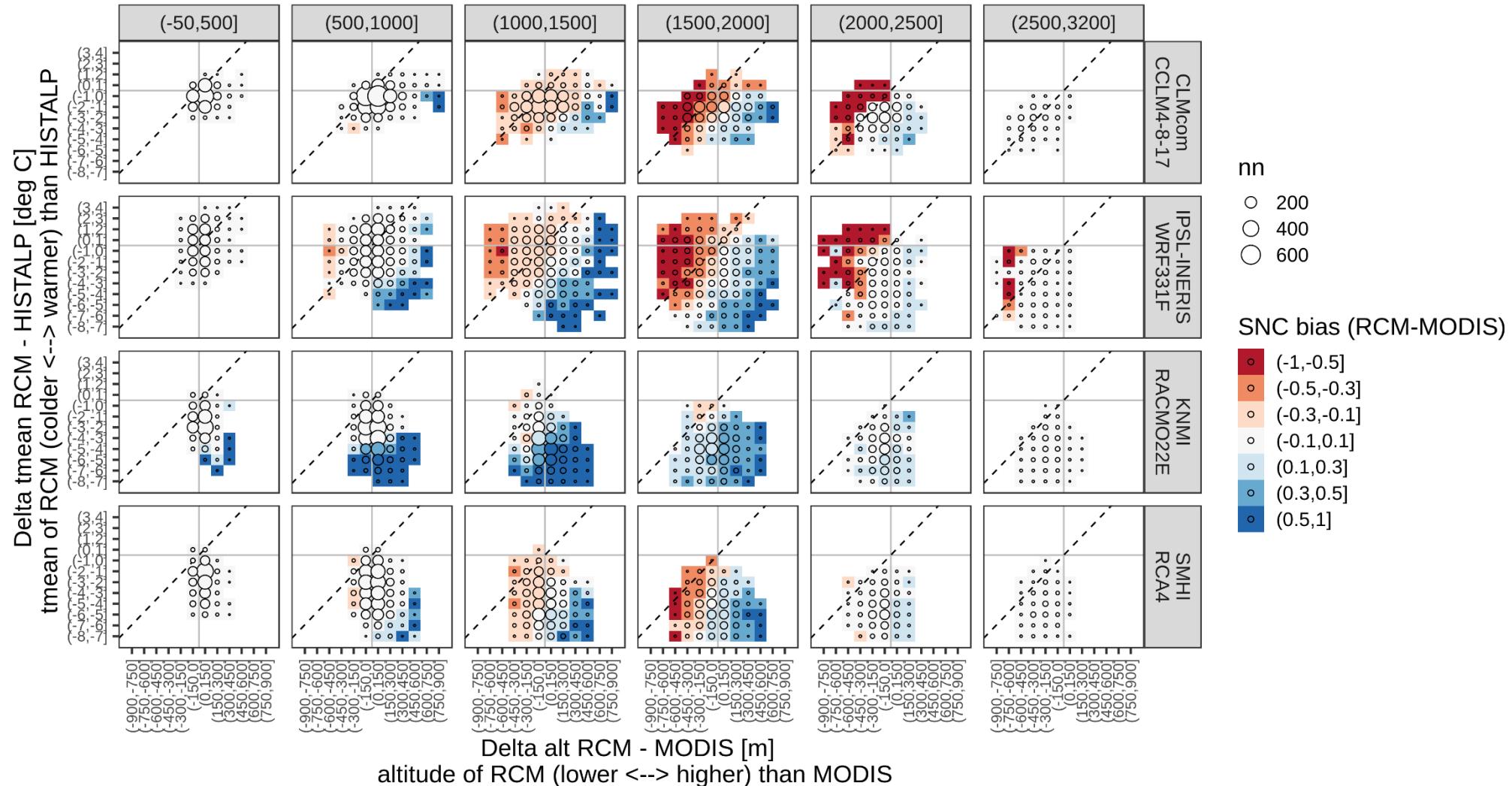
Columns: MODIS altitude classes, Rows: RCMs



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



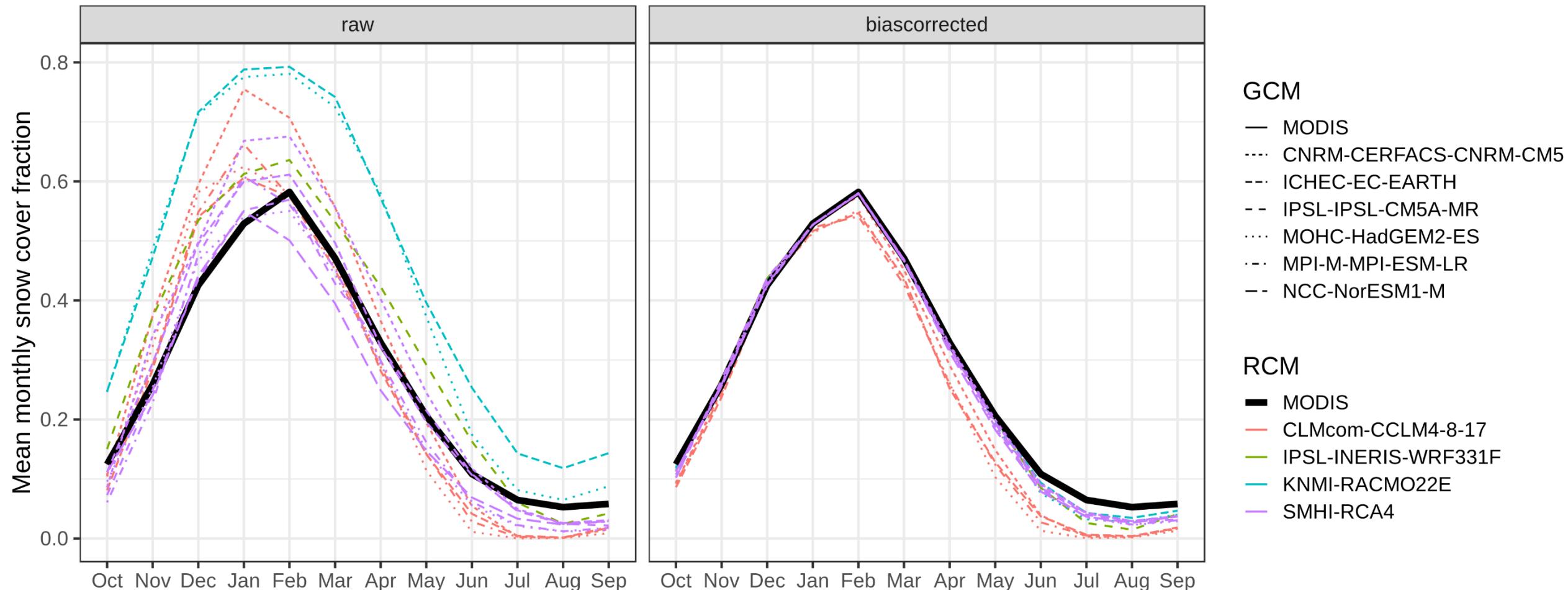
Part 1: Evaluation - conclusion

- 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

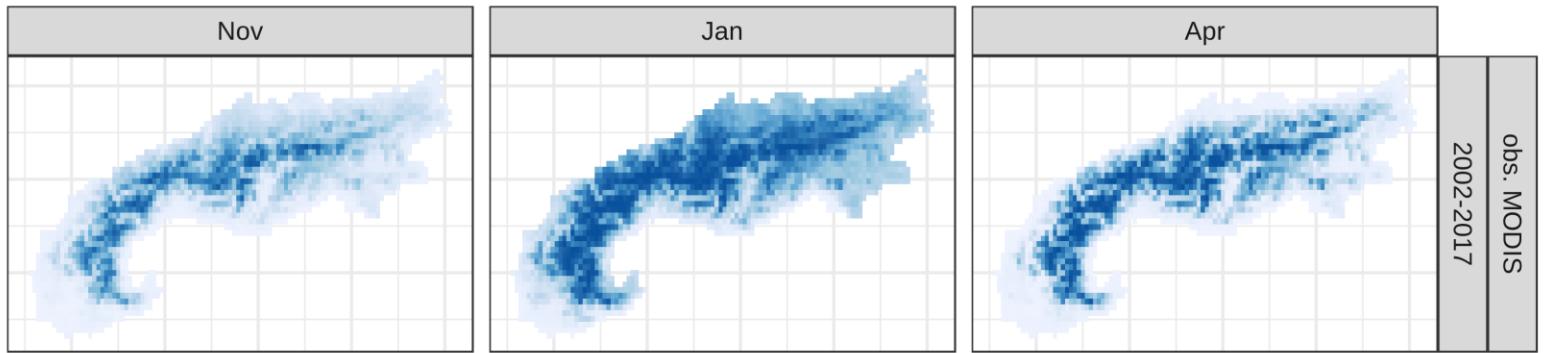
Part 2: Bias correction (prelim) - Past

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

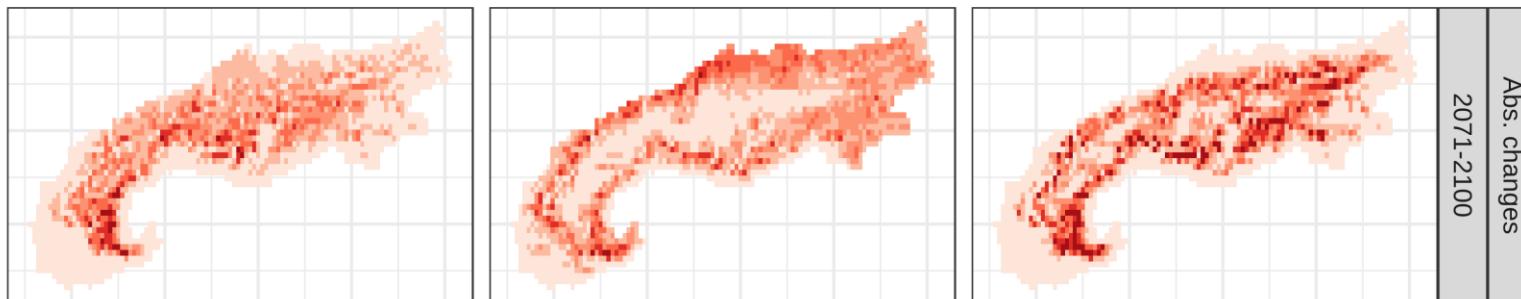
As seen by MODIS and 13 RCM-GCMs (rcp8.5)



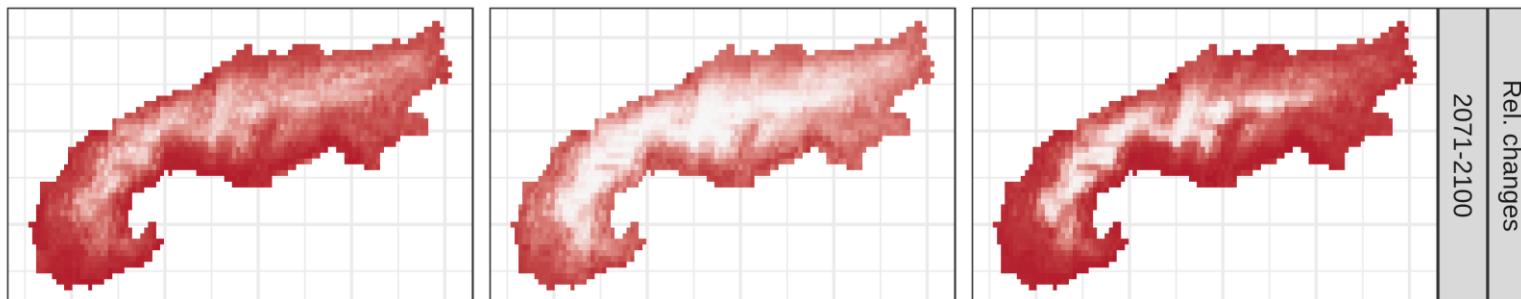
Part 2: Bias correction (prelim) – Maps



Mean observed SNC
1.00
0.75
0.50
0.25
0.00



Model mean diff. SNC
> -0.1
(-0.2, -0.1]
(-0.3, -0.2]
(-0.4, -0.3]
(-0.5, -0.4]
<= -0.5

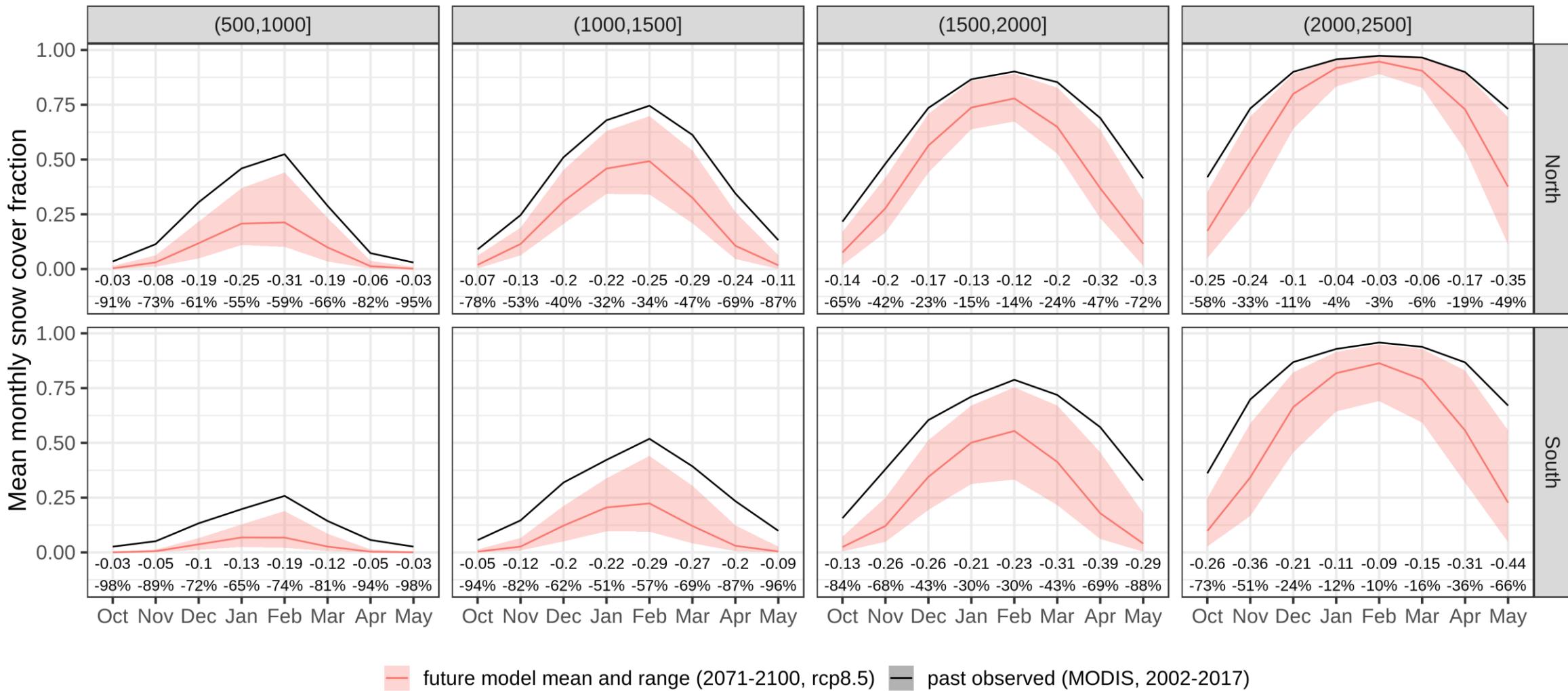


Percent change SNC
0
-25
-50
-75
-100

Part 2: Bias correction (prelim) - Future

Past and future snow cover dynamics over the Alps

As seen by MODIS and 13 biascorrected RCM-GCMs



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 Metsaemaeiki, 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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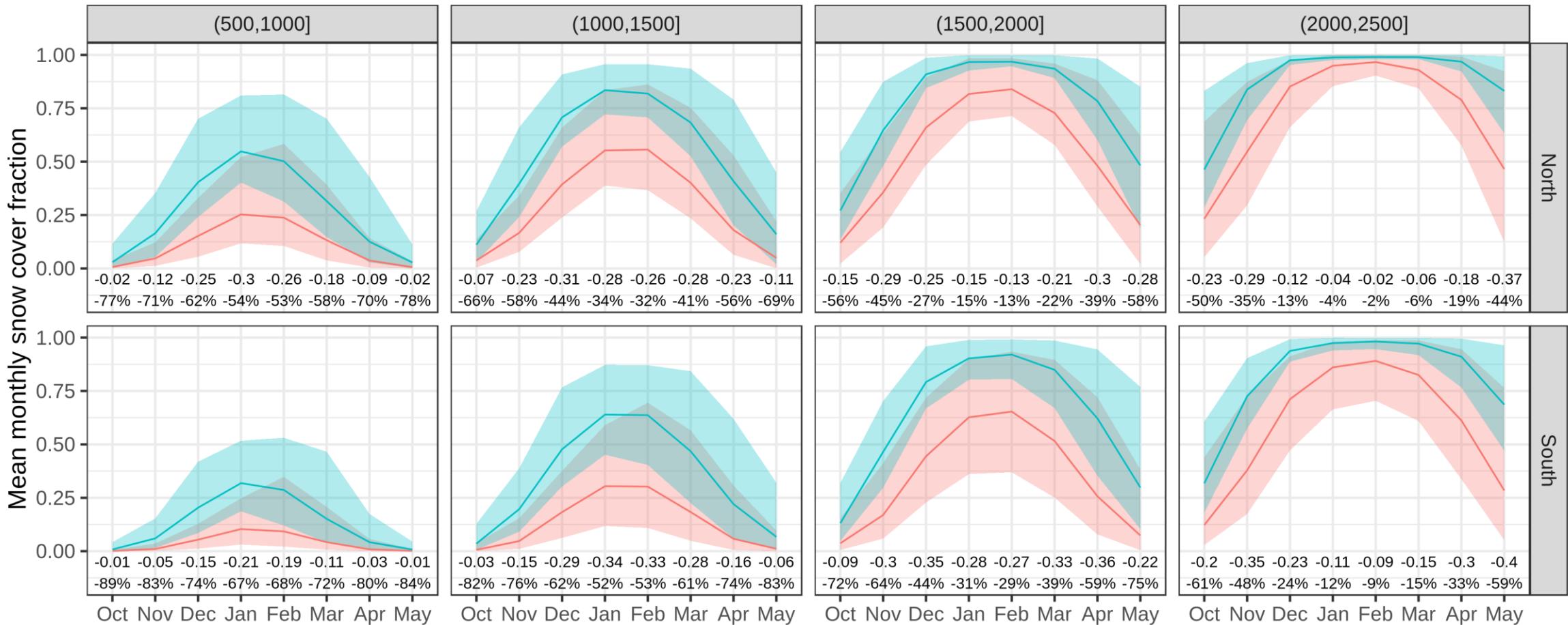


(If you accidentally took photos of the talk, mind sending them to me? -> Horizon2020 reporting)

Aux: Non-biascorrected past-future

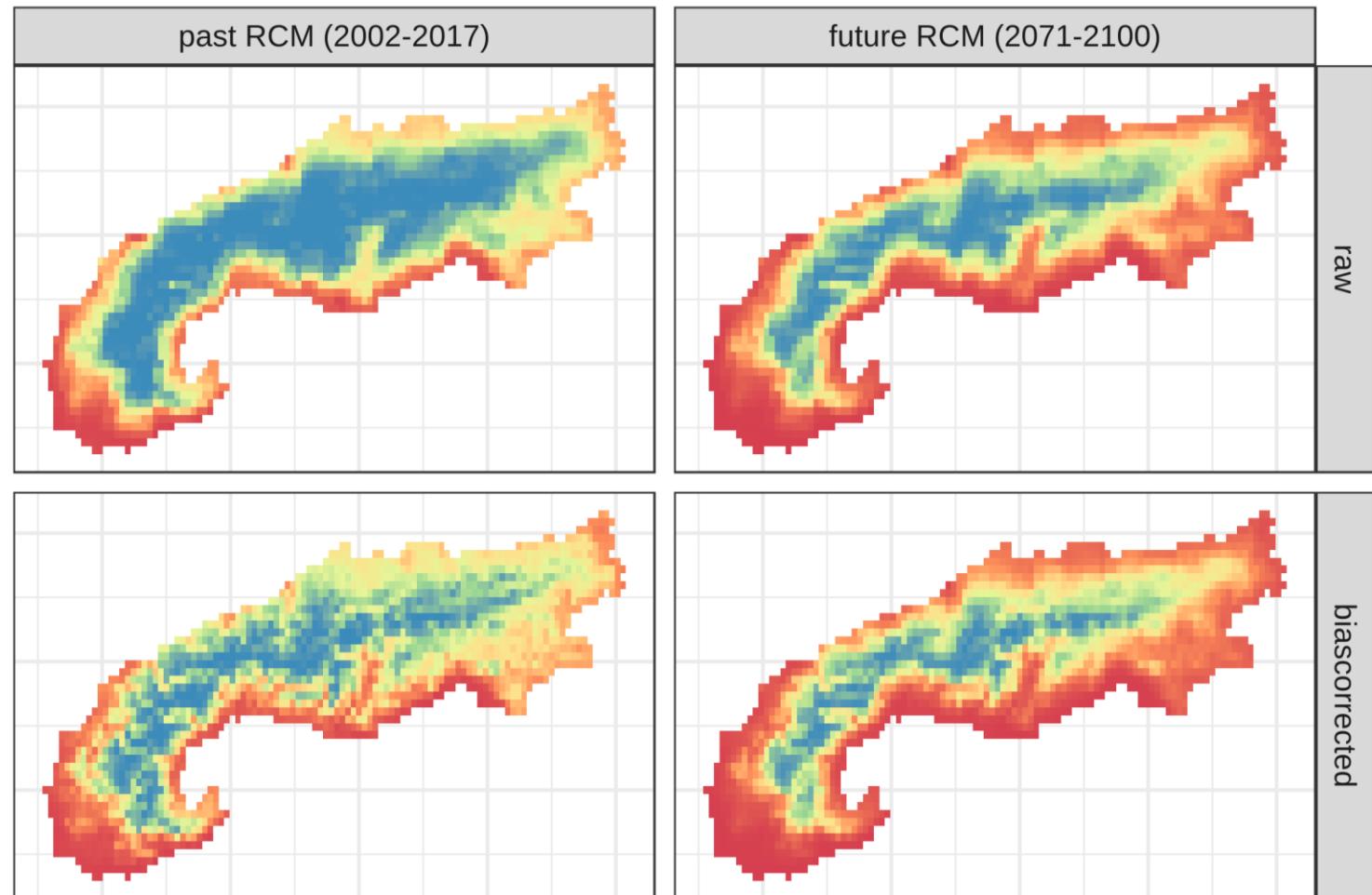
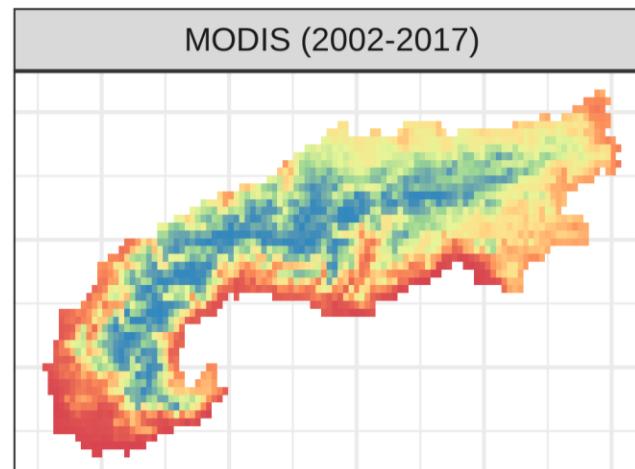
Past and future snow cover dynamics over the Alps

As seen by 13 RCM-GCMs (raw output)

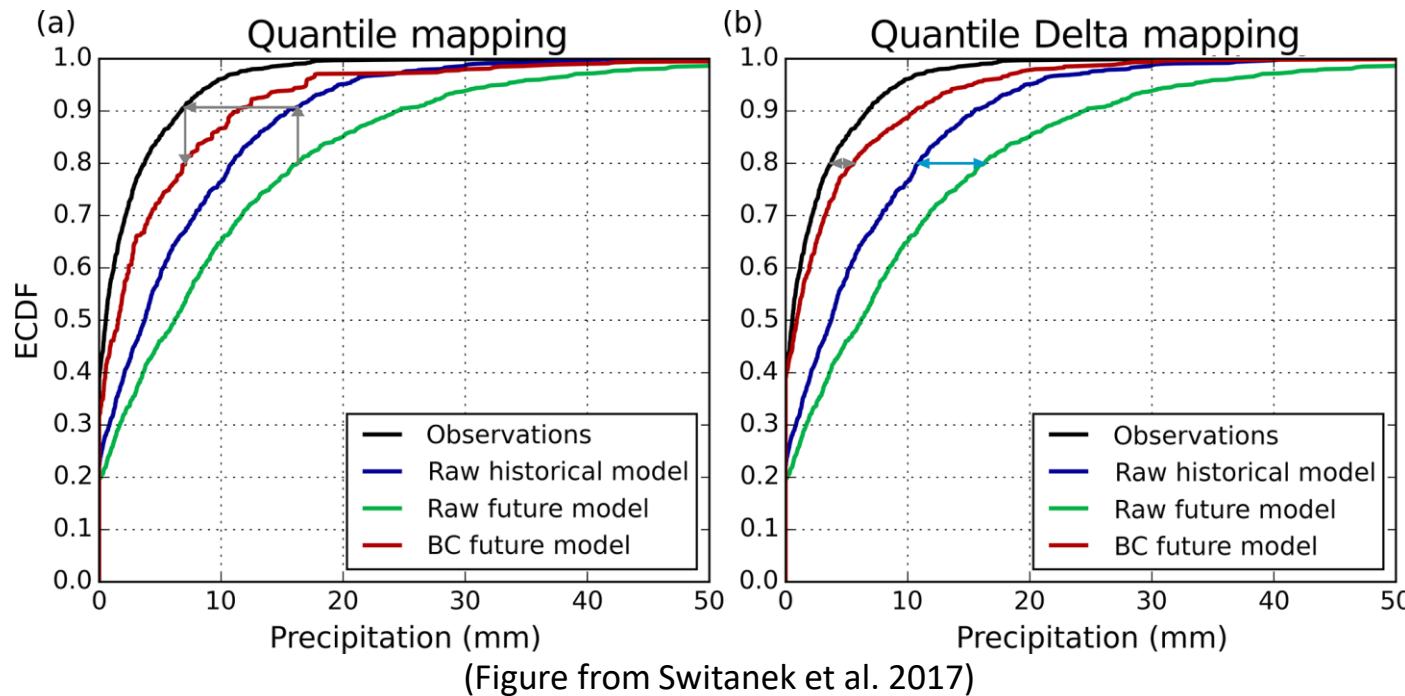


Model mean and range ■ future (2071-2100, rcp8.5) ■ past (2002-2017, rcp8.5)

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