Bias correction with CDF-Transform

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Berlin-Dahlem, 4-6 October 2016

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- Systematic biases in the Regional Climate Models

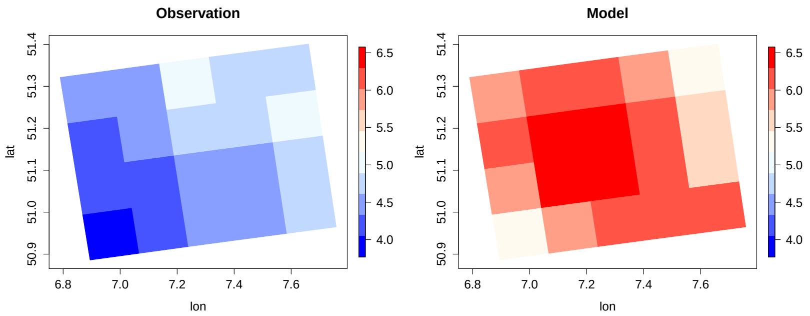

Figure: Mean of daily precipitation (mm/day) at Wupper catchment (case of July)

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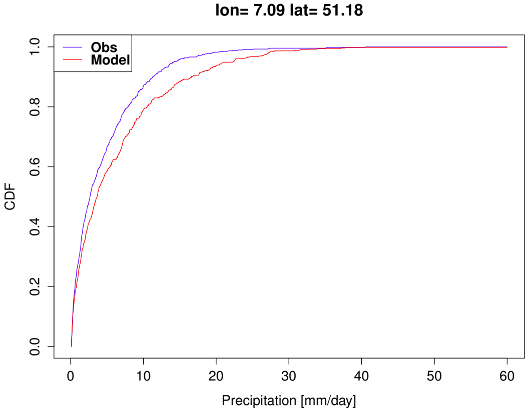
- Difference in the distribution



- Need to correct the whole distribution and not only the mean

Existing bias correction methods

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Existing bias correction methods

Mean-based approaches

- Linear scaling *[Lenderink et al., 2007]*
- Local intensity scaling *[Schmidli et al., 2006]*
- Variance scaling *[Leander and Buishand, 2007]*
- Power transformation (for precipitation) *[Chen et al., 2013]*

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Distribution-based approaches

- Quantile-mapping *[Panofsky and Brier, 1968]*
- CDF-Transform *[Michelangeli et al., 2009]*

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Table of contents

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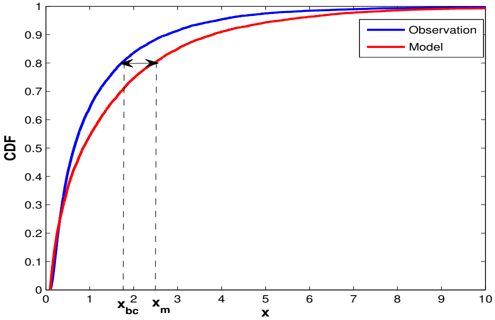
Quantile-mapping

- $F_o \rightarrow$ CDF of observations
- $F_m \rightarrow$ CDF of model output

$$F_o(x_o) = F_m(x_m) \Longrightarrow x_{bc} = F_o^{-1}[F_m(x_m)]$$



- Quantile-mapping can be used with both empirical and parametric CDF

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Limit of the Quantile-mapping

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Limit of the Quantile-mapping

- Future simulation
- Observations do not cover the same time period as the model output

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Limit of the Quantile-mapping

- Future simulation
- Observations do not cover the same time period as the model output

  Example:

  • Model output $\rightarrow$ $1980 - 2026$ (historical+future)

  • Observations $\rightarrow$ $1980 - 2016$ (historical)

  QQ-mapping $\rightarrow$ CDF observations $(1980 - 2016)$ = CDF observations $(1980 - 2026)$

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Limit of the Quantile-mapping

- Future simulation
- Observations do not cover the same time period as the model output

  Example:

  • Model output $\rightarrow$ 1980 $-$ 2026 (historical+future)

  • Observations $\rightarrow$ 1980 $-$ 2016 (historical)

  QQ-mapping $\rightarrow$ CDF observations (1980 $-$ 2016) = CDF observations (1980 $-$ 2026)

- Quantile mapping does not take into account any information on the distribution of the future modelled dataset

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CDF-Transform

	Historical period	Future period
Observation	$F_{o,h}(x)$	$F_{o,f}(x)$
Model	$F_{m,h}(x)$	$F_{m,f}(x)$

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CDF-Transform

	Historical period	Future period
Observation	$F_{o,h}(x)$	$F_{o,f}(x)$
Model	$F_{m,h}(x)$	$F_{m,f}(x)$

• If it is possible to estimate $F_{o,f}$, then future model output can be corrected through quantile-mapping:

$$x_{bc} = F_{o,f}^{-1}\left[F_{m,f}(x)\right]$$

CDF-Transform

	Historical period	Future period
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- If it is possible to estimate $F_{o,f}$, then future model output can be corrected through quantile-mapping:

$$x_{bc} = F_{o,f}^{-1}\left[F_{m,f}(x)\right]$$

How can we approximate $F_{o,f}$?

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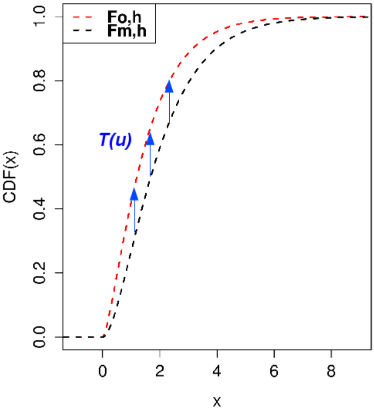
A solution to approximate $F_{o,f}$

	Historical period	Future period
Observation	$F_{o,h}(x)$	$F_{o,f}(x)$
Model	$F_{m,h}(x)$	$F_{m,f}(x)$

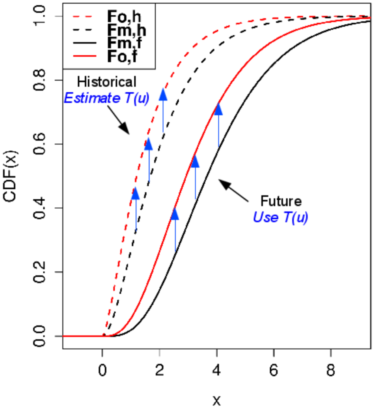


- T: $[0,1] \longrightarrow [0,1]$,

$$T(F_{m,h}(x)) = F_{o,h}(x) \tag{1}$$

A solution to approximate $F_{o,f}$

	Historical period	Future period
Observation	$F_{o,h}(x)$	$F_{o,f}(x)$
Model	$F_{m,h}(x)$	$F_{m,f}(x)$



- T: $[0,1] \longrightarrow [0,1]$,

$$T(F_{m,h}(x)) = F_{o,h}(x) \tag{2}$$

$$T(F_{m,f}(x)) = F_{o,f}(x) \tag{3}$$

A solution to approximate $F_{o,f}$

	Historical period	Future period
Observation	$F_{o,h}(x)$	$F_{o,f}(x)$
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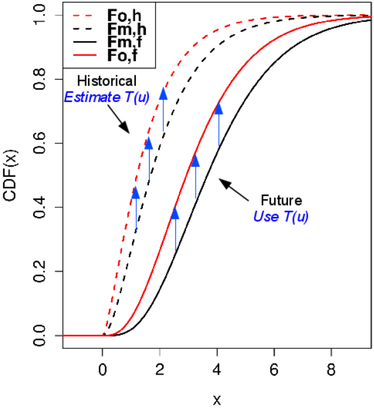

- T: $[0, 1] \longrightarrow [0, 1]$,

$$T(F_{m,h}(x)) = F_{o,h}(x) \tag{4}$$

$$T(F_{m,f}(x)) = F_{o,f}(x) \tag{5}$$

T is modelled by replacing x by $F_{m,h}^{-1}(u)$,

$$T(u) = F_{o,h}(F_{m,h}^{-1}(u)) \tag{6}$$

ans thus,

$$F_{o,f}(x) = F_{o,h}(F_{m,h}^{-1}(F_{m,f}(x))) \tag{7}$$

Application

- Wupper catchment (Germany)
- Model output from COSMO-CLM (1979-2015)
- WFDEI used as reference data (1979-2013)

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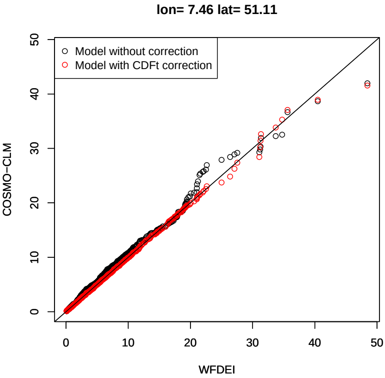
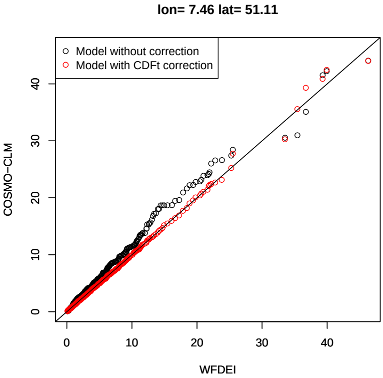
QQplot of daily precipitation (mm/day): January (left) - July (right)





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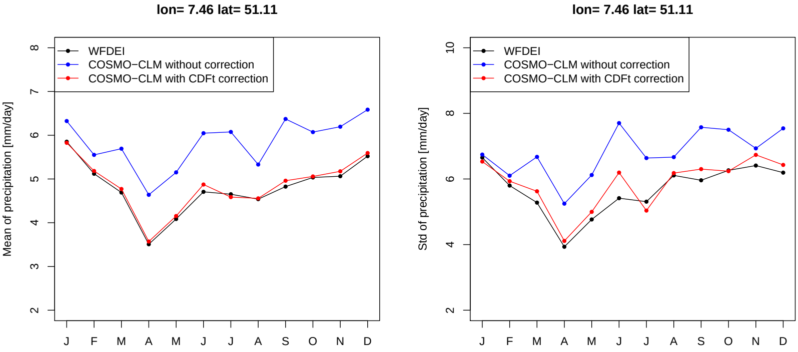
Monthly mean (left) and standard deviation (right) of daily precipitation



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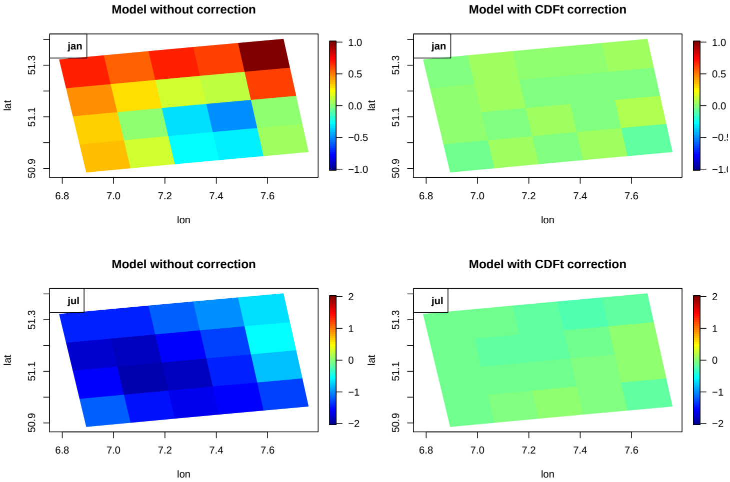
Deviation in the mean [$Mean(reference) - Mean(model)$] for January and July



Bias correction for decadal climate predictions with CDF-t

- **Goal:** Bias correction of daily MiKlip decadal predictions (spatial resolution = 0.11°)

	Historical (1979-2014)	Future (2015-2004)
MiKlip	$F_h^{(M11)}$	$F_f^{(M11)}$
WATCH	$F_h^{(W11)}$	$F_f^{(W11)}$

$$\text{CDF-t} \Longrightarrow F_f^{(W11)}(x) = F_h^{(W11)} \left\{ F_h^{(M11)-1} \left[F_f^{(M11)}(x) \right] \right\}$$

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Bias correction for decadal climate predictions with CDF-t

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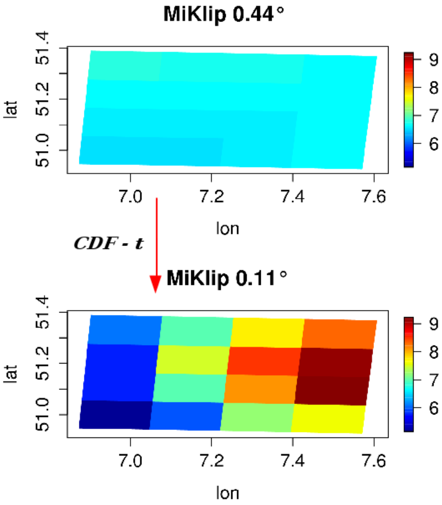
$$\text{CDF-t} \Longrightarrow F_f^{(W11)}(x) = F_h^{(W11)}\left\{ F_h^{(M11)-1}\left[F_f^{(M11)}(x) \right] \right\}$$

- **Problem:** MiKlip historical simulations are only available for spatial resolution of 0.44°

Use CDF-t as statistical downscaling method



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Summary

- Compared to the quantile-mapping, CDF-t has advantage to take into account the change in the distribution for the future period
- Satisfactory results are obtained with CDF-t
- CDF-t can be used for statistical downscaling
- Need of reliable multivariate and spatial bias correction methods

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Acknowledgements

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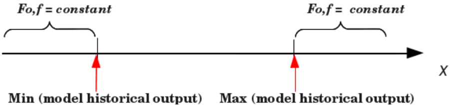
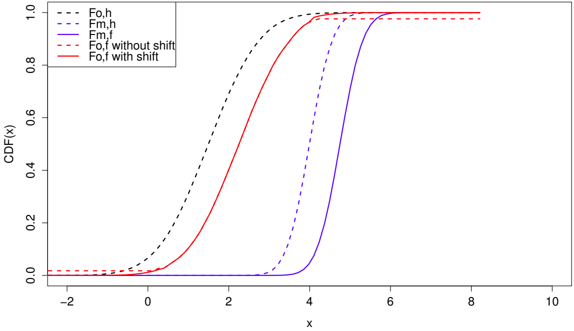
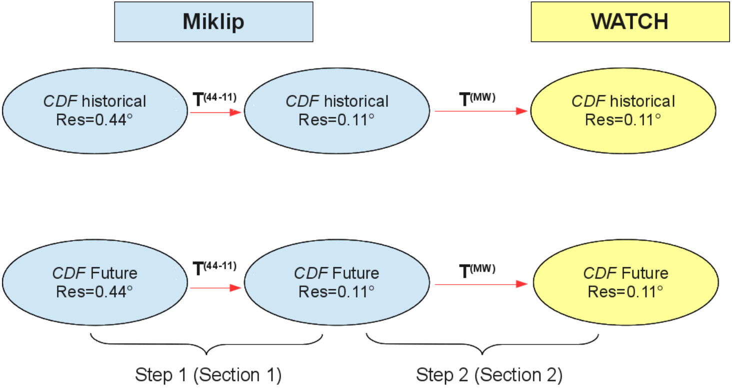
THANK YOU FOR YOUR ATTENTION

Future simulation CDFs off the range of the historical ones

$$F_{o,f}(x) = F_{o,h}(F_{m,h}^{-1}(F_{m,f}(x)))$$






Miklip
WATCH
CDF historical
Res=0.44°
T(44-11)
CDF historical
Res=0.11°
T(MW)
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Step 1 (Section 1)
Step 2 (Section 2)