All slides are available at

www.pik-potsdam.de/~menz/CapTainRain/Webinar

CapTainRain

Introduction into regional climate scenarios and sensitivities of heavy rainfall indicators

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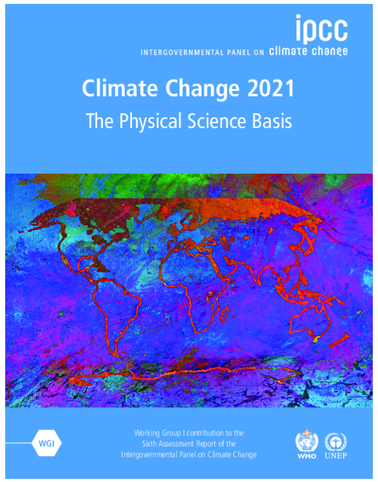
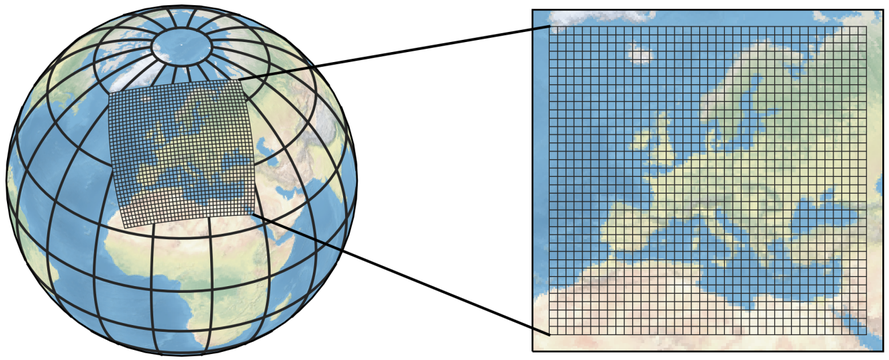
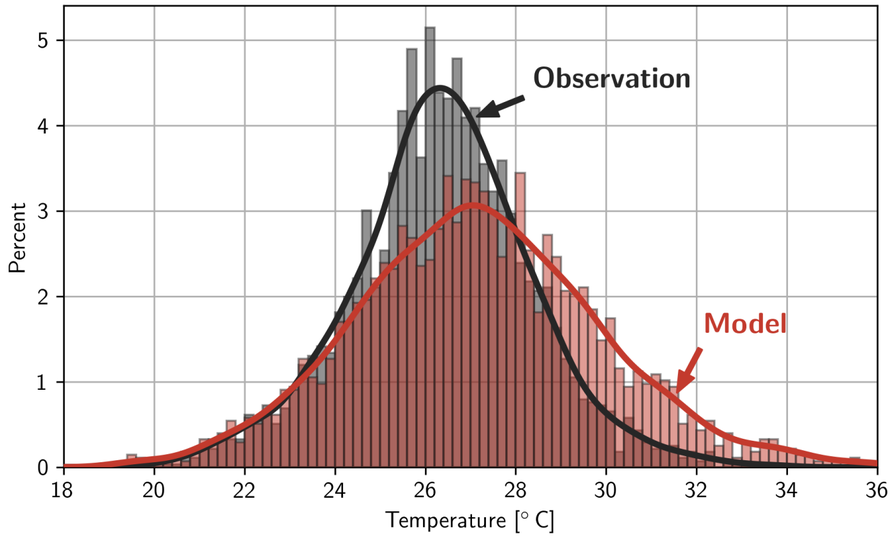
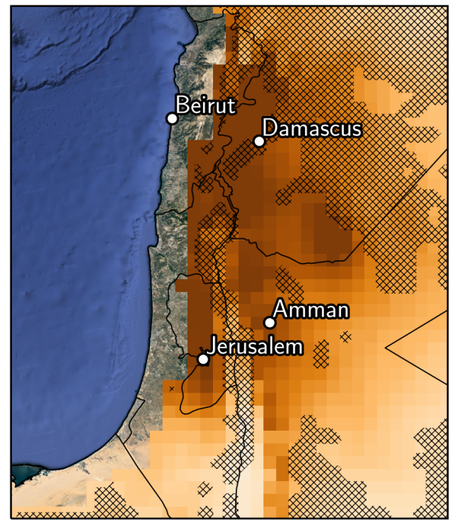
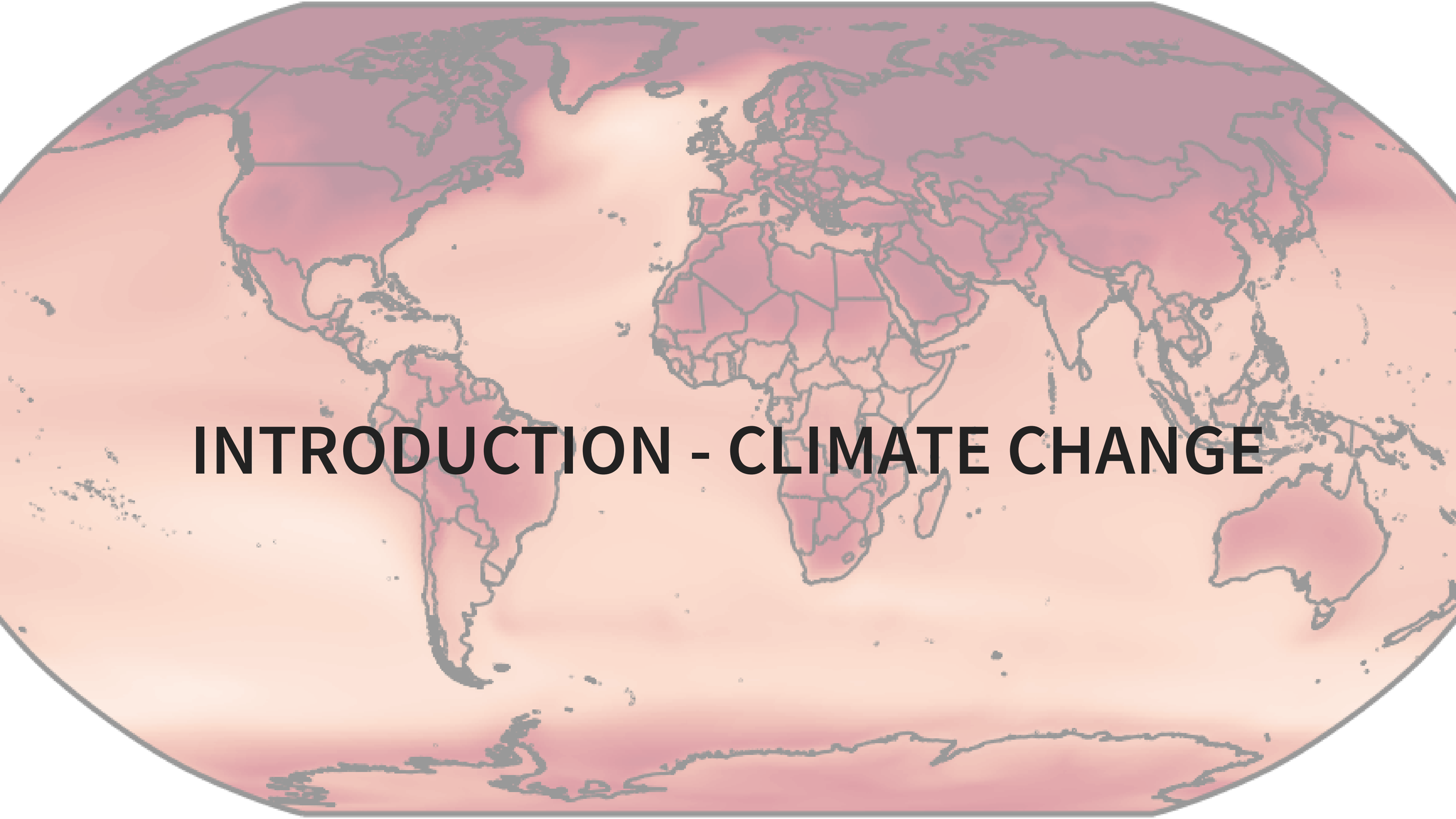


TABLE OF CONTENT





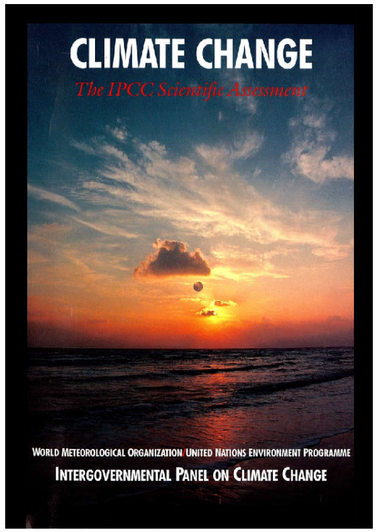
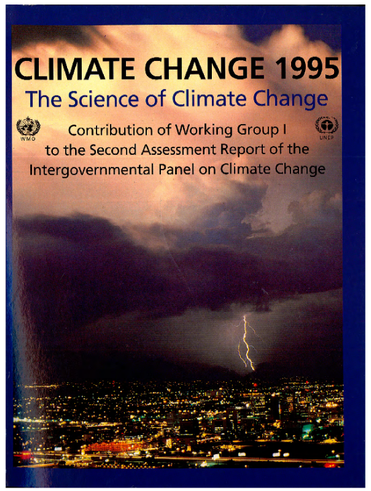
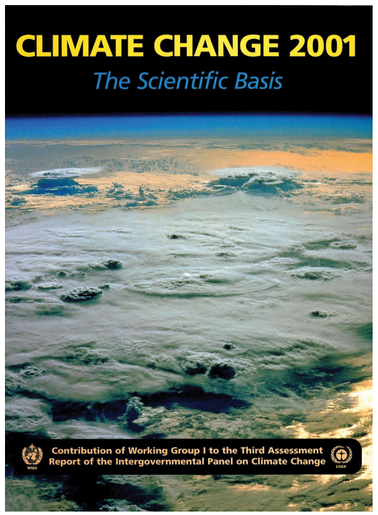
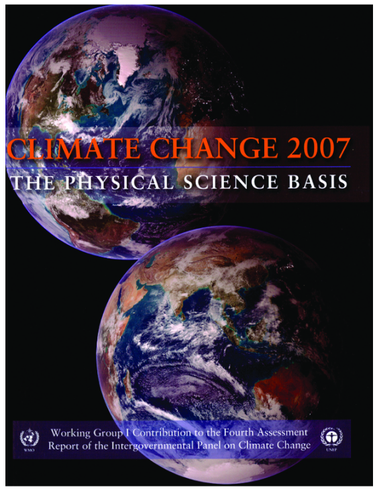
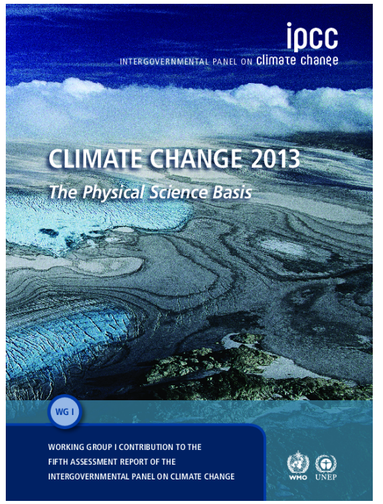
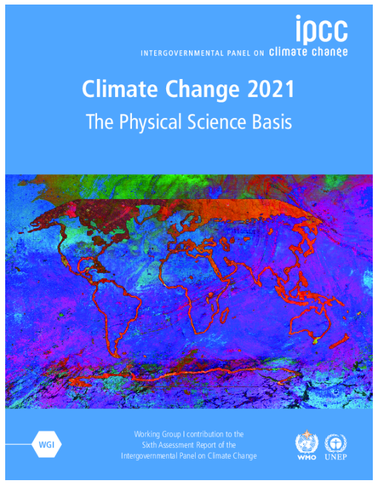




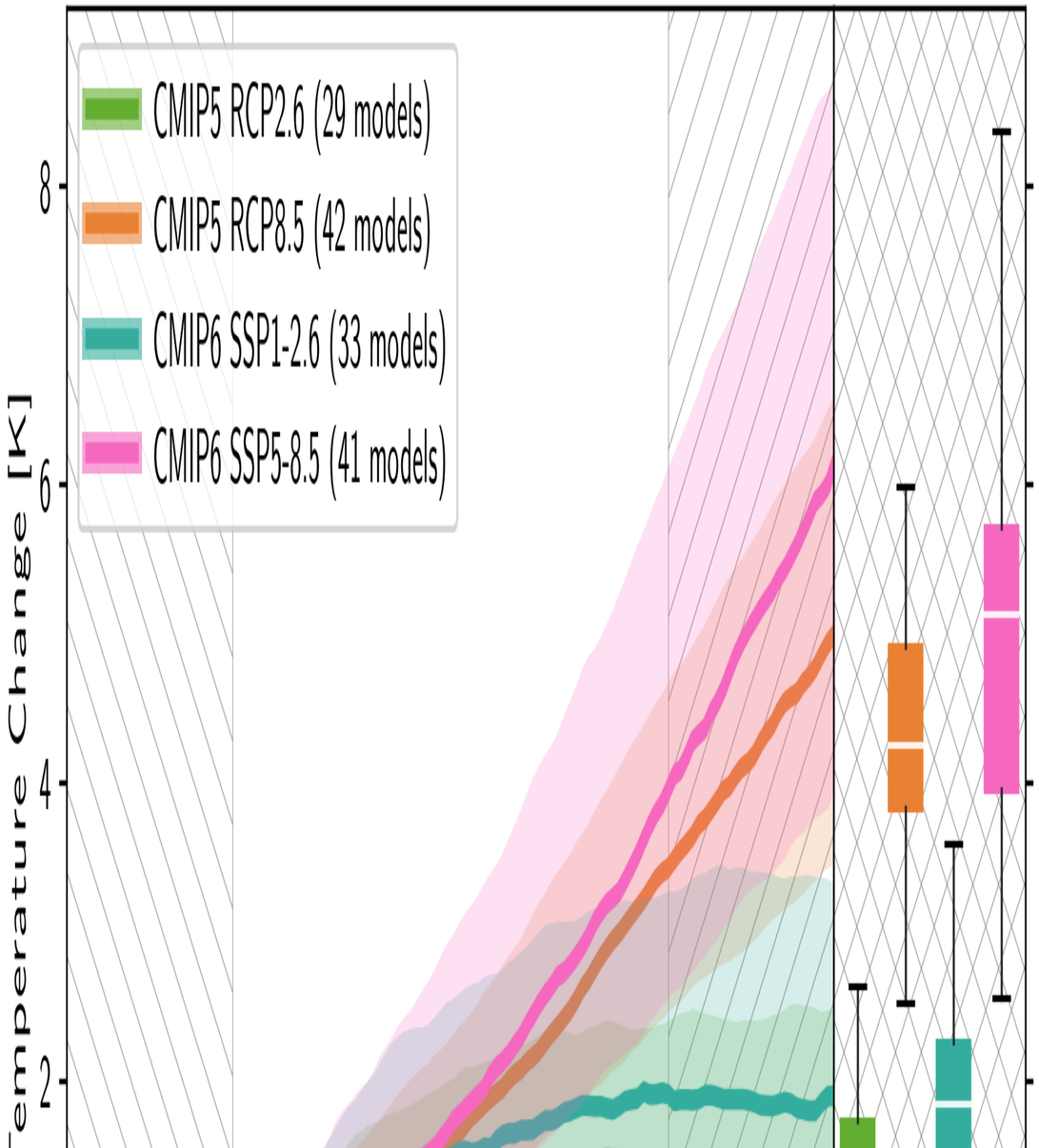
INTRODUCTION - CLIMATE CHANGE

ASSESSMENT REPORTS

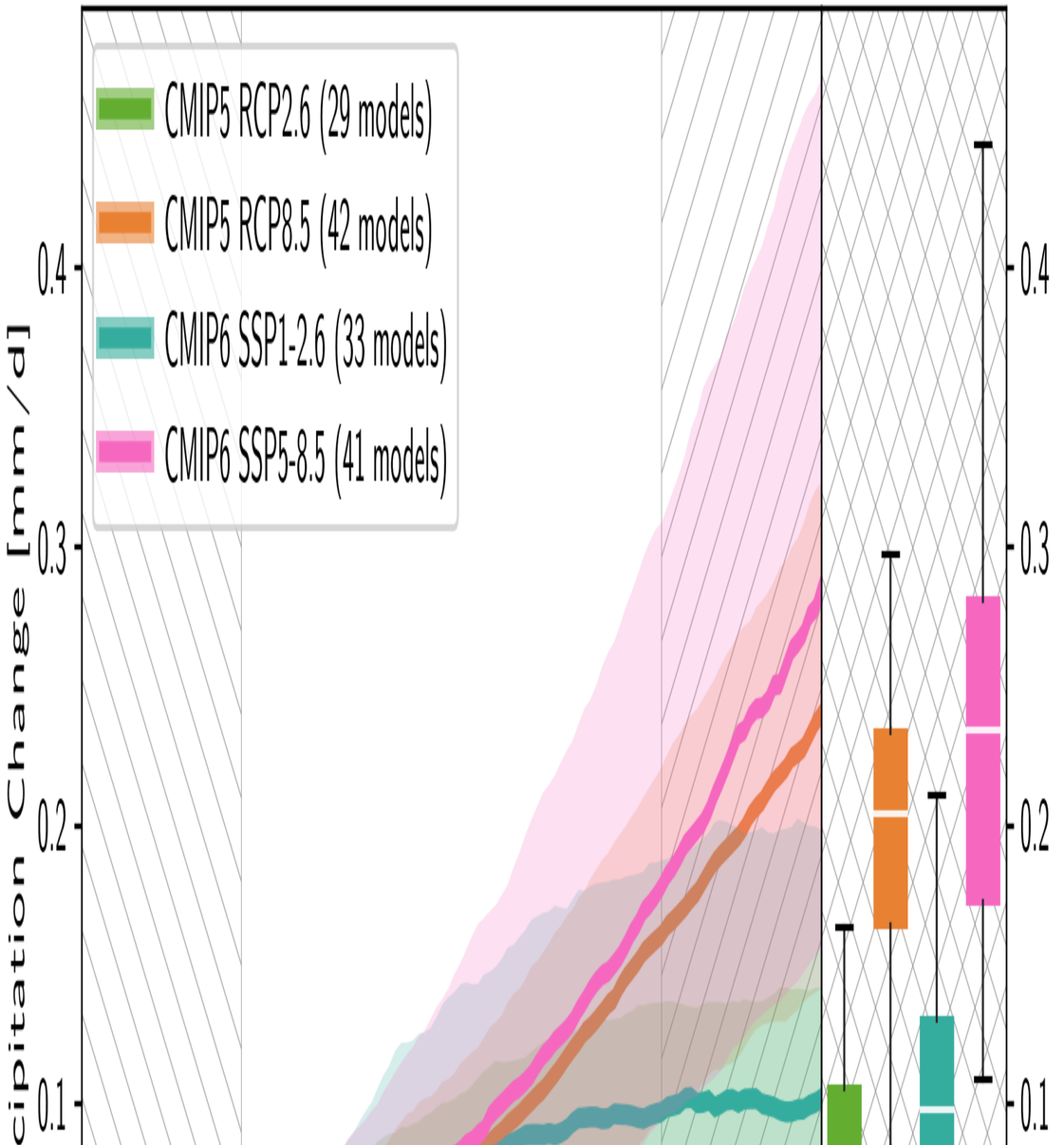
WG1: PHYSICAL SCIENCE BASIS

1990	1995	2001	2007	2013	2021
					
414P	588P	893P	1007P	1552P	3175P

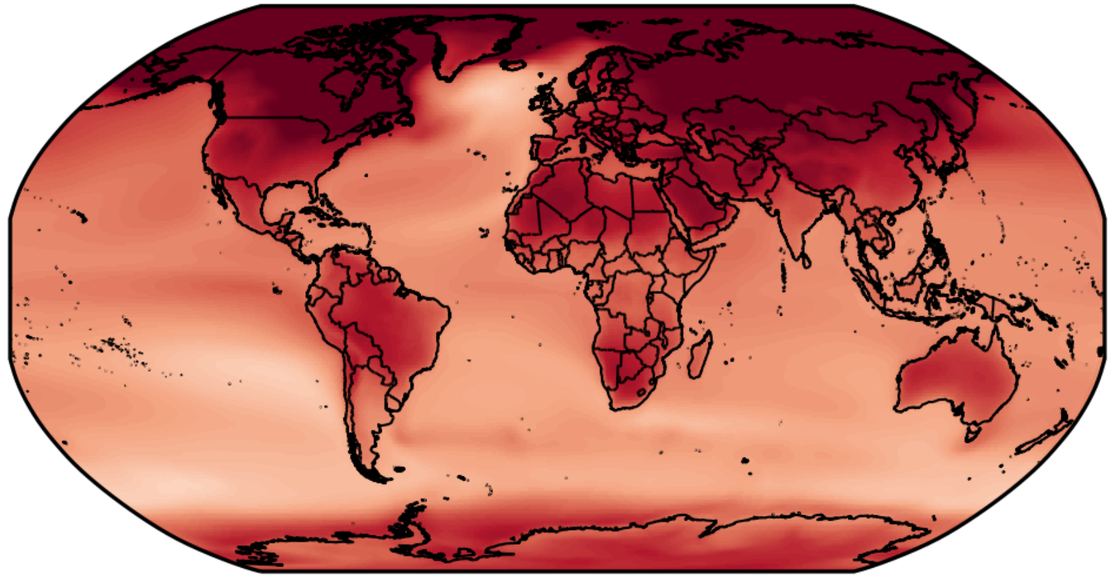
TEMPERATURE



PRECIPITATION



TEMPERATURE



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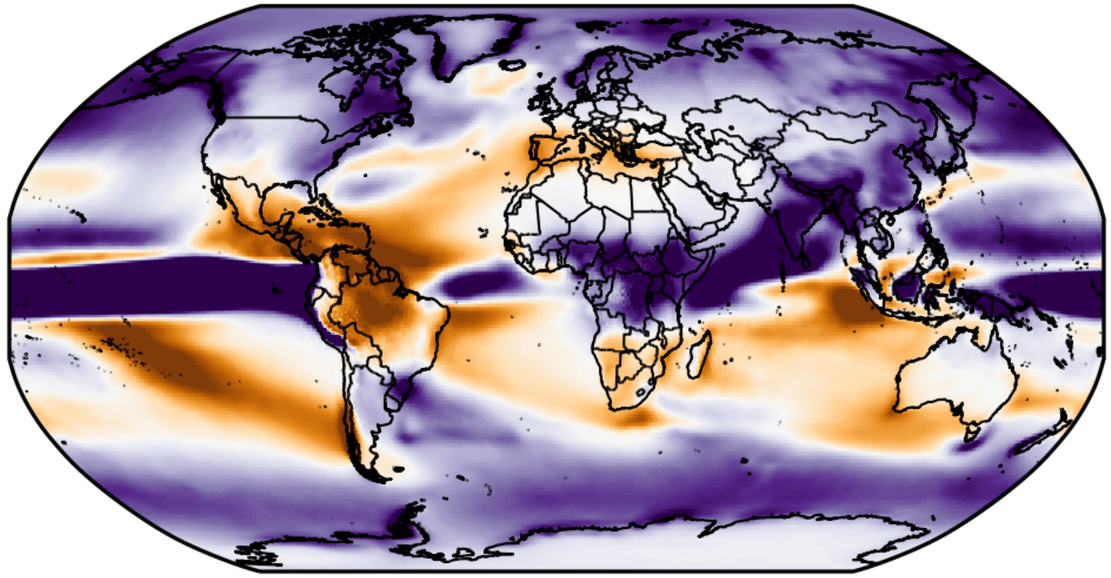
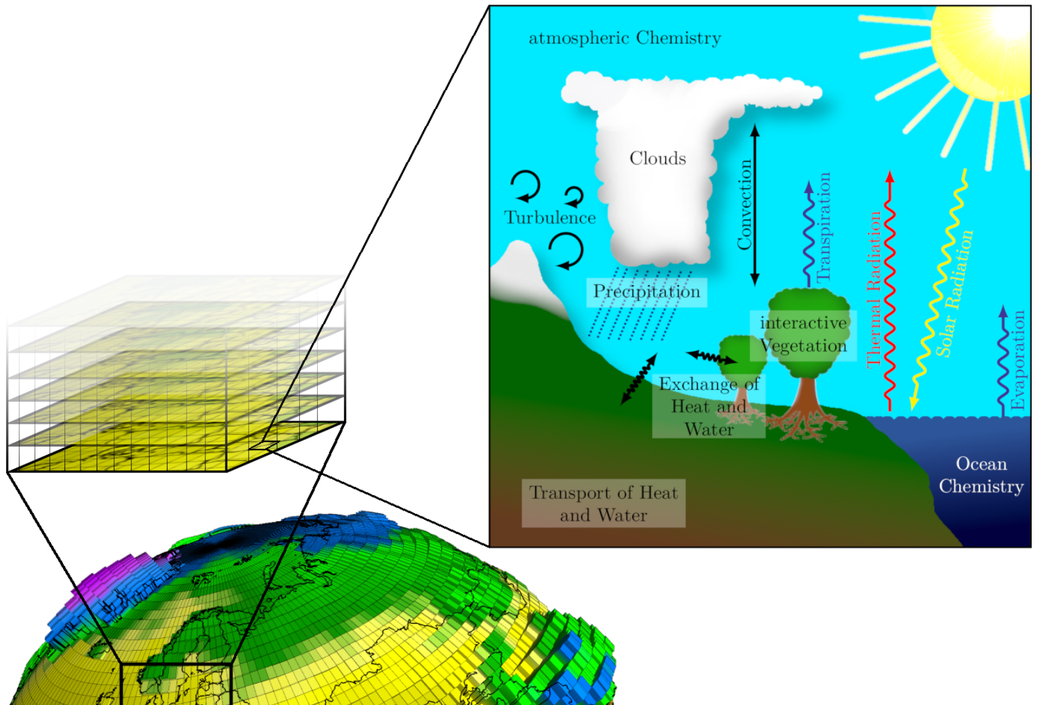
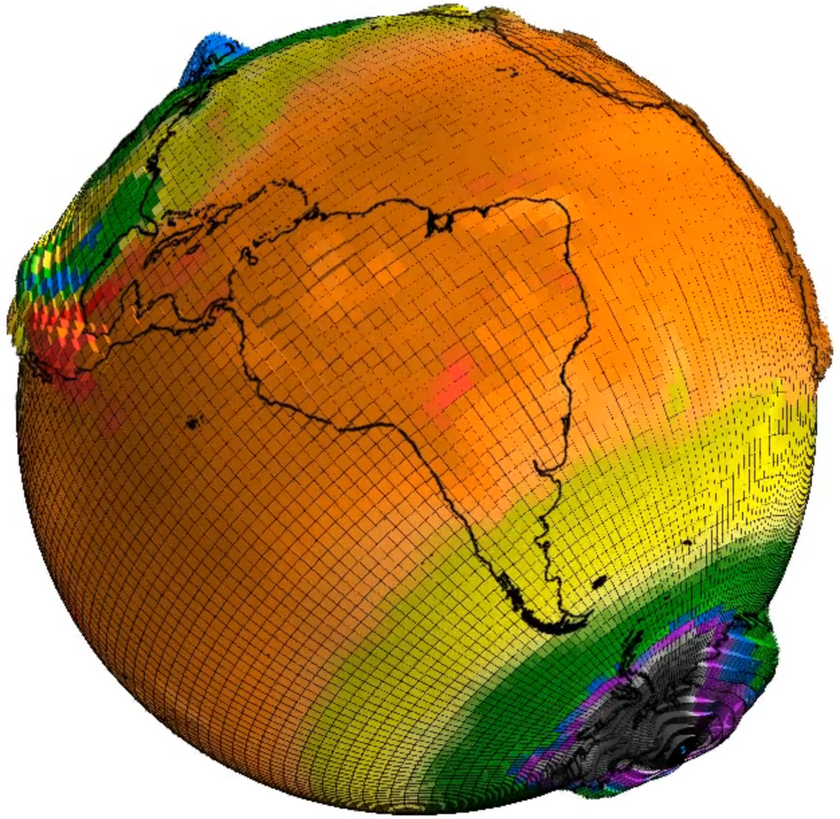


CLIMATE CHANGE FROM GLOBAL

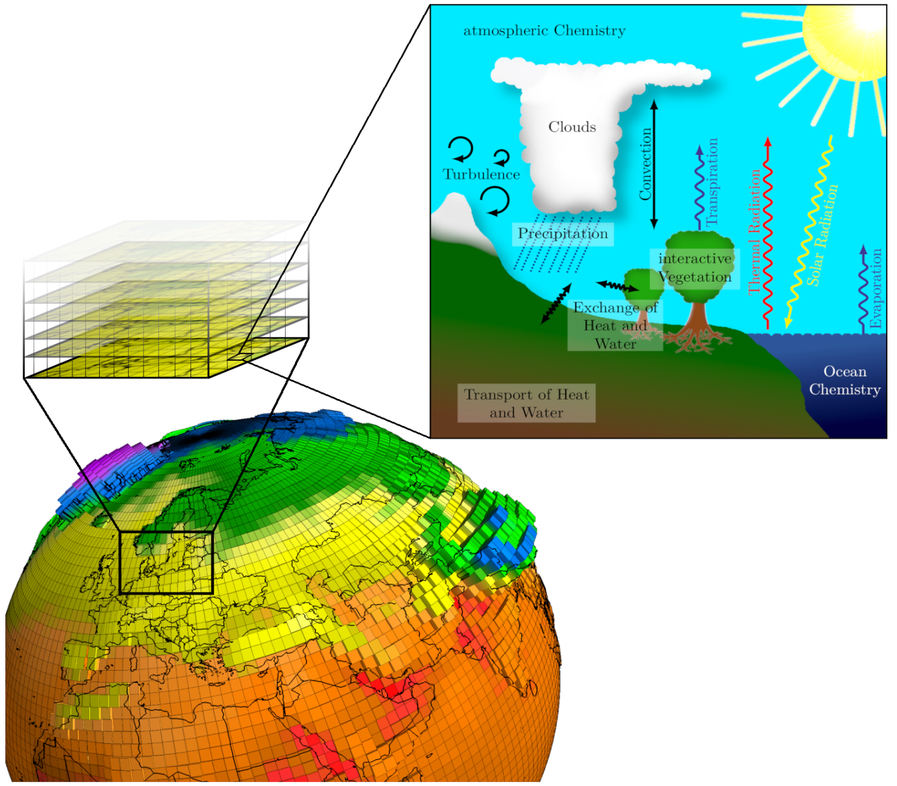
CLIMATE MODELS PERSPECTIVE





GLOBAL CLIMATE MODELS

- Global Climate/Circulation Models - GCMs
- Earth System Models - ESMs
- Simulate the climate system considering all relevant physical and bio-geo-chemical processes
- Typical spatial resolution: 100–200 km
- Temporal resolution down to daily and sub-daily
- Needs supercomputer for simulation
- Model ensembles:
  - Coupled Model Intercomparison Project 5 and 6 (CMIP5 and CMIP6)

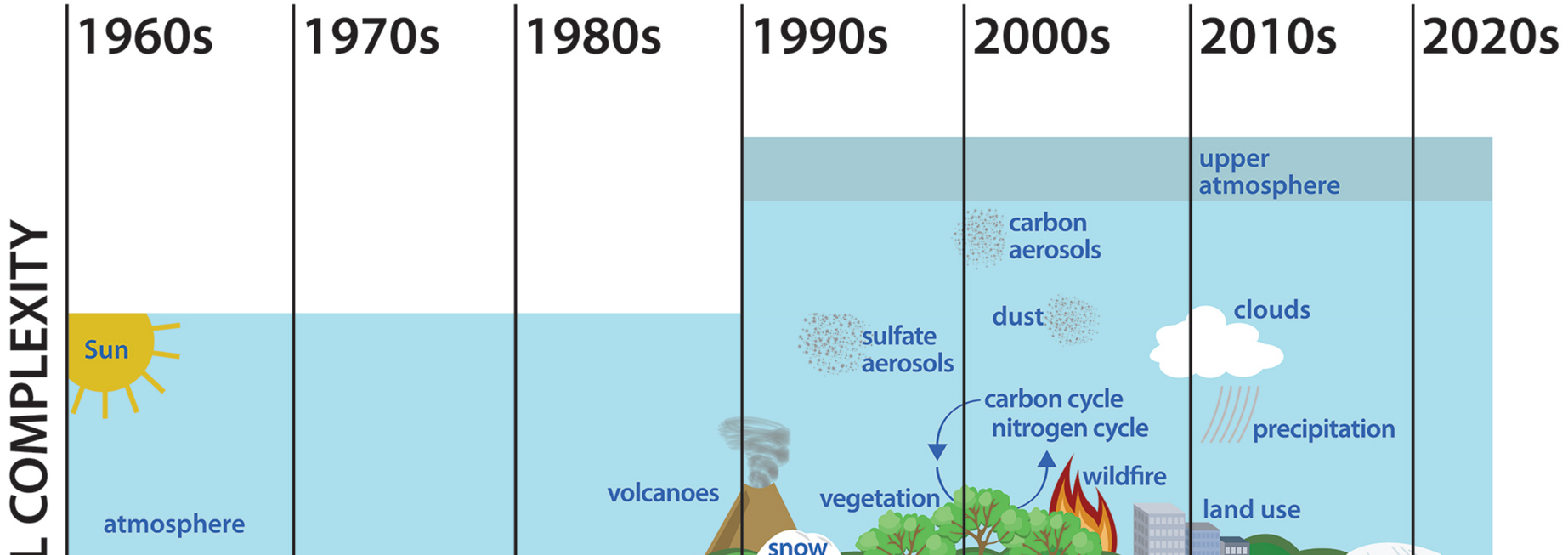


$$\rho\frac{d\vec{\mathbf{v}}}{dt} = -\vec{\nabla}p + \rho g - 2\vec{\mathbf{\Omega}} \times (\rho\vec{\mathbf{v}}) - \vec{\nabla}\overleftrightarrow{\mathbf{t}}$$

$$\frac{d\rho}{dt} = -\rho\vec{\nabla}\vec{\mathbf{v}}$$

$$\rho\frac{dq^x}{dt} = -\vec{\nabla}\vec{\mathbf{J}}^x + I^x$$

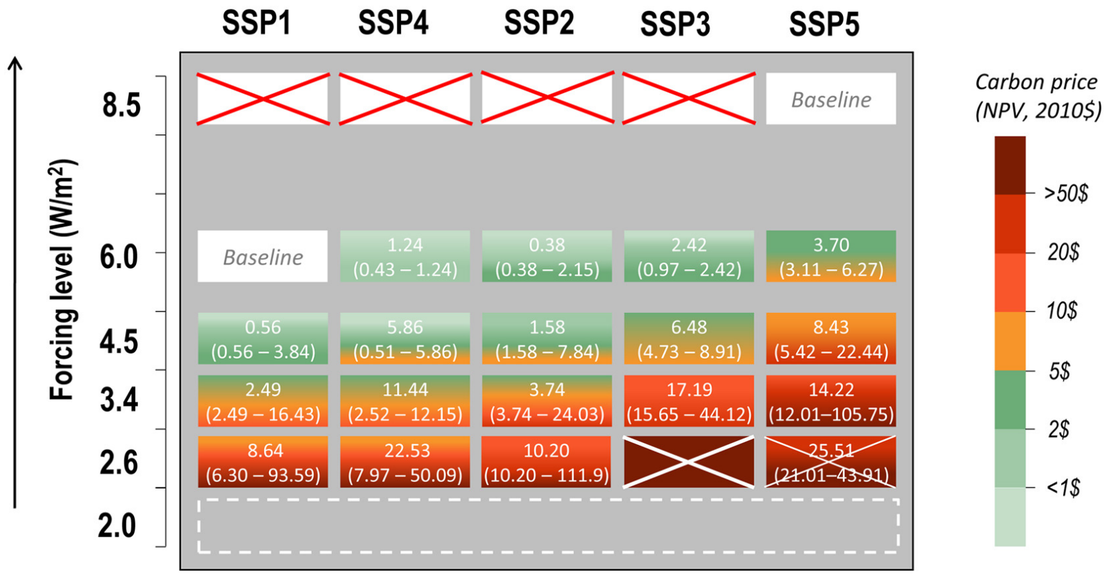
DEVELOPMENT OF GLOBAL MODELS



RCP: REPRESENTATIVE CONCENTRATION PATHWAYS

SSP: SHARED SOCIOECONOMIC PATHWAYS

- Scenarios representing greenhouse gas concentrations in the atmosphere
- Narratives for future socio-economic evolution
- No adaptation/mitigation to climate change
- Similar in CMIP5 and CMIP6
- van Vuuren et al. (2011) and Riahi et al. (2017)



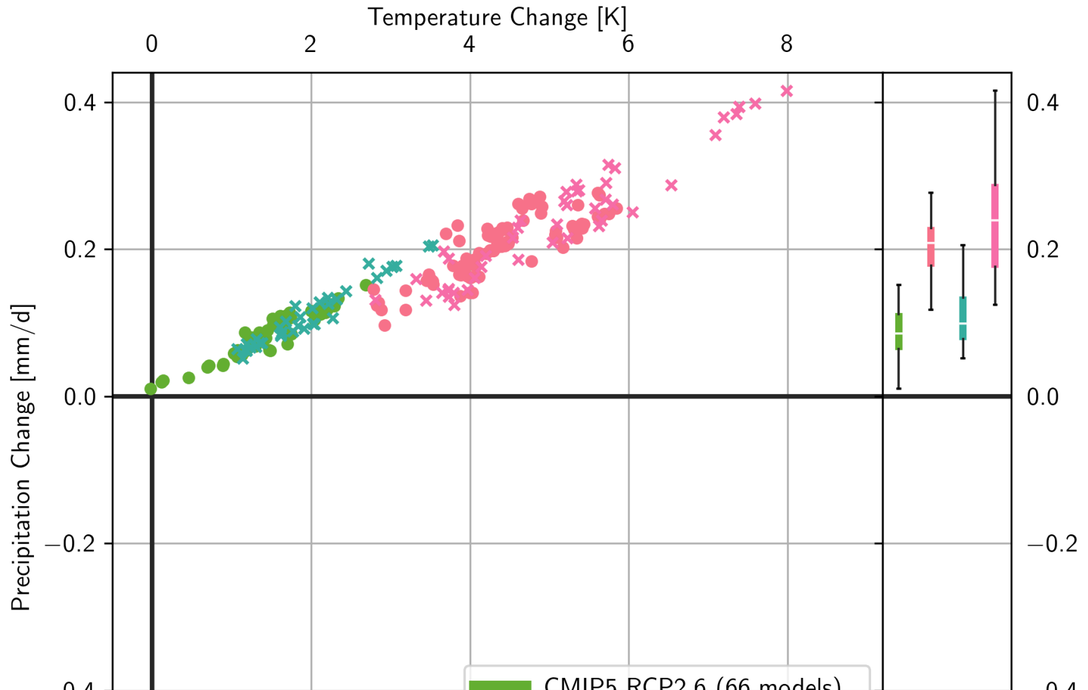
Historical

Observations

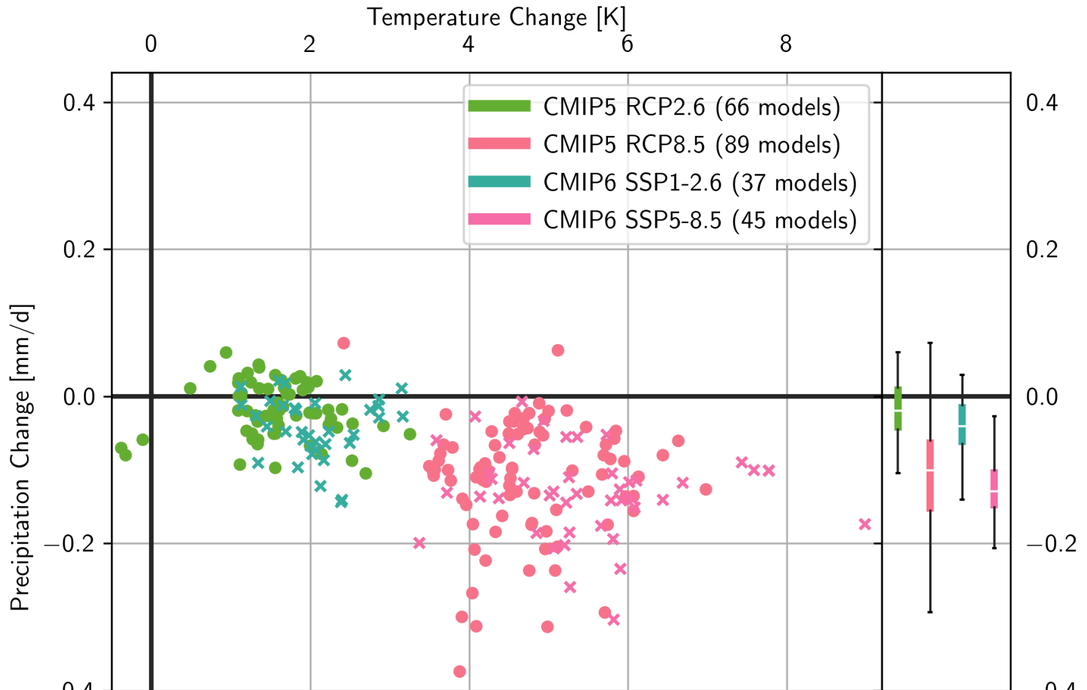
TEMPERATURE VS PRECIPITATION

2071-2100 vs. 1971-2000 - annual mean

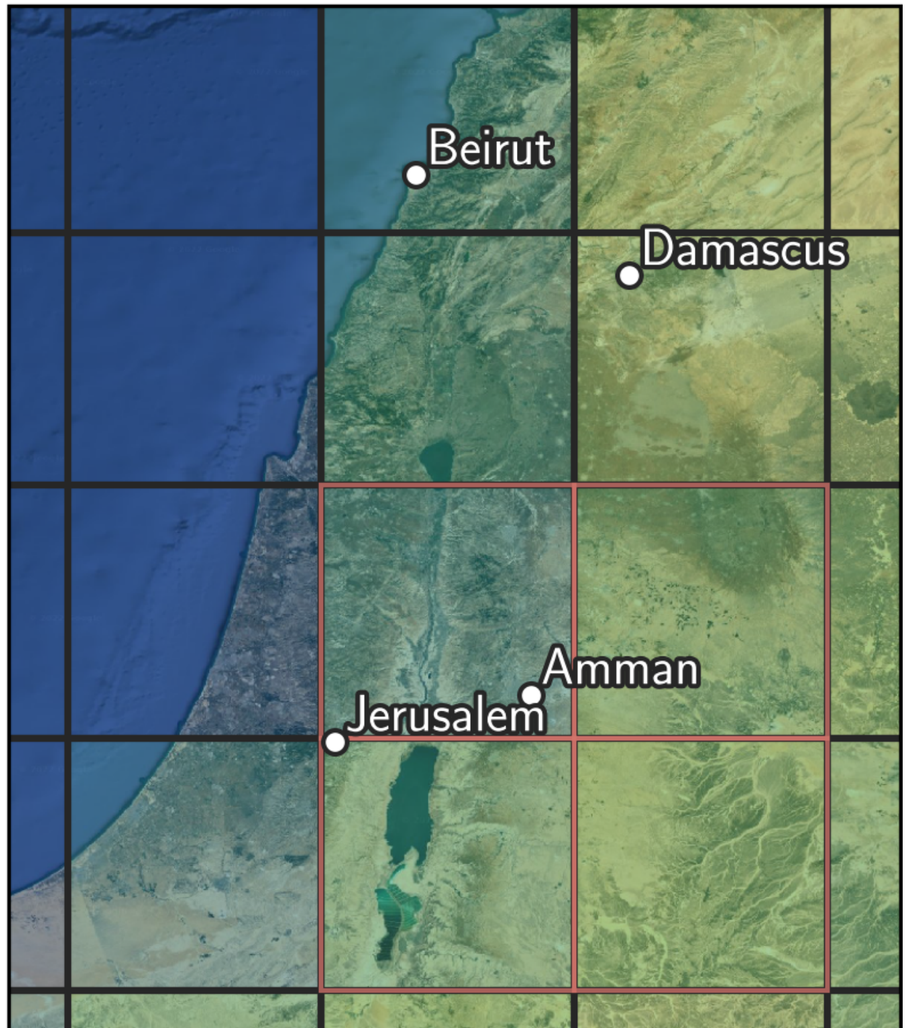
Global

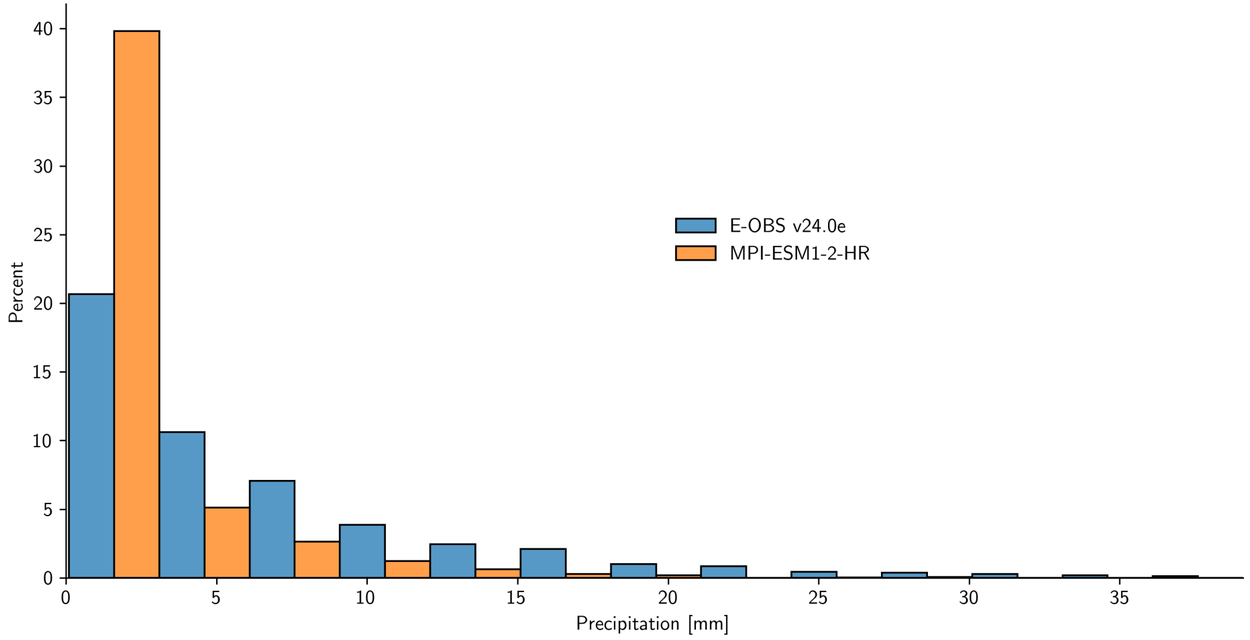


Amman

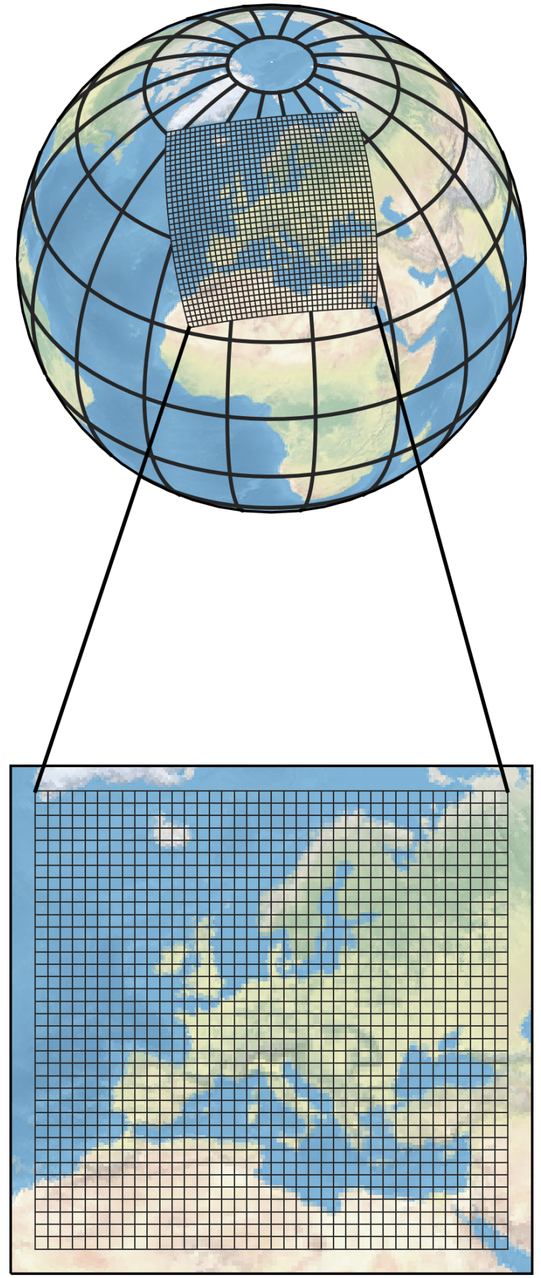


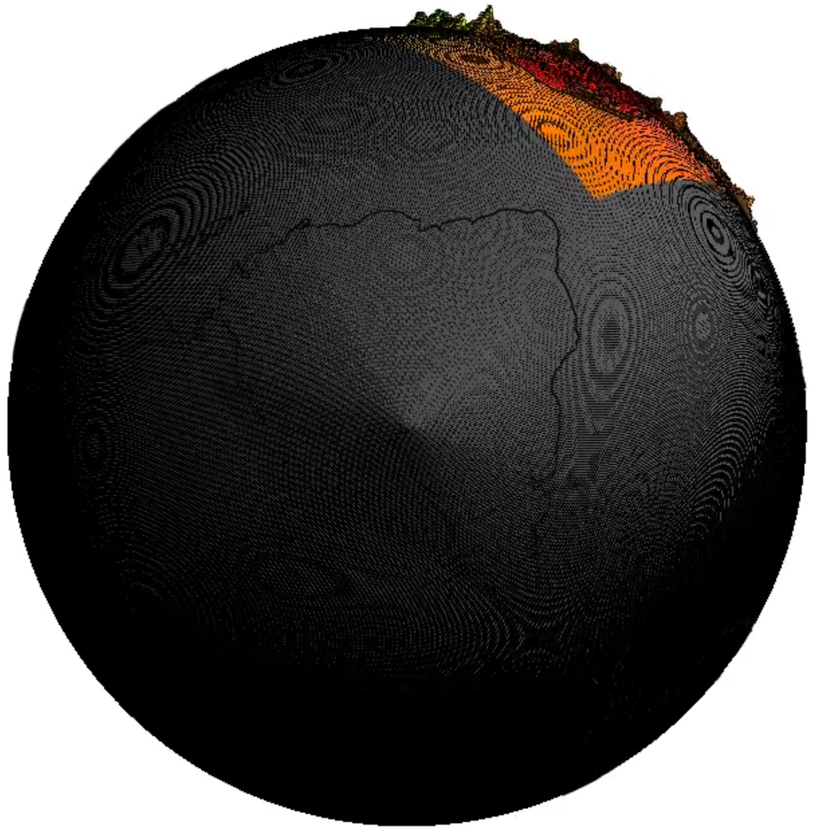
DISTRIBUTION OF PRECIPITATION





CLIMATE CHANGE FROM REGIONAL CLIMATE MODELS PERSEPCTIVE

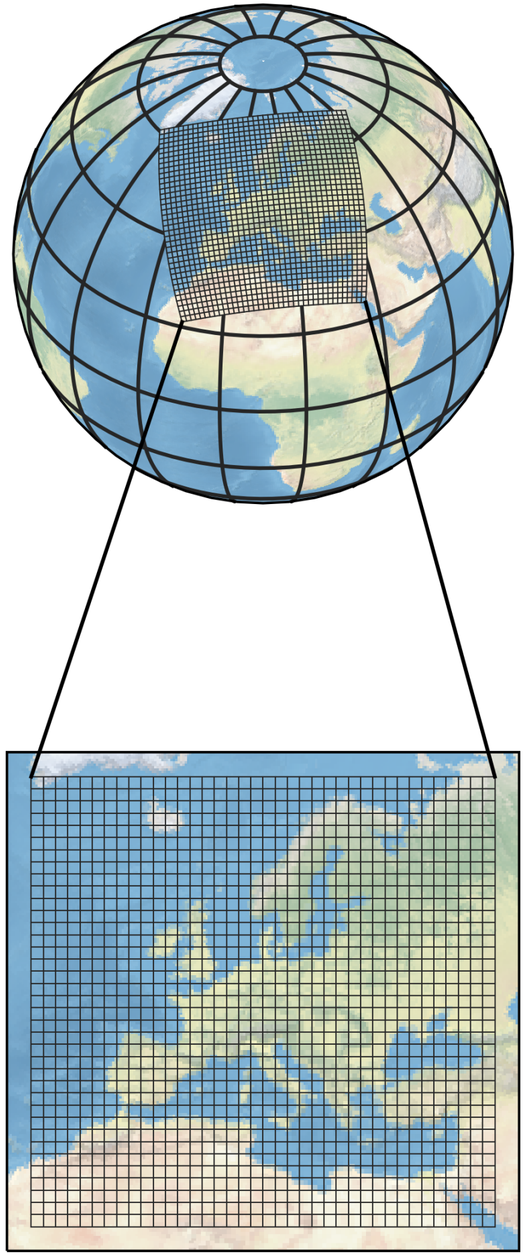




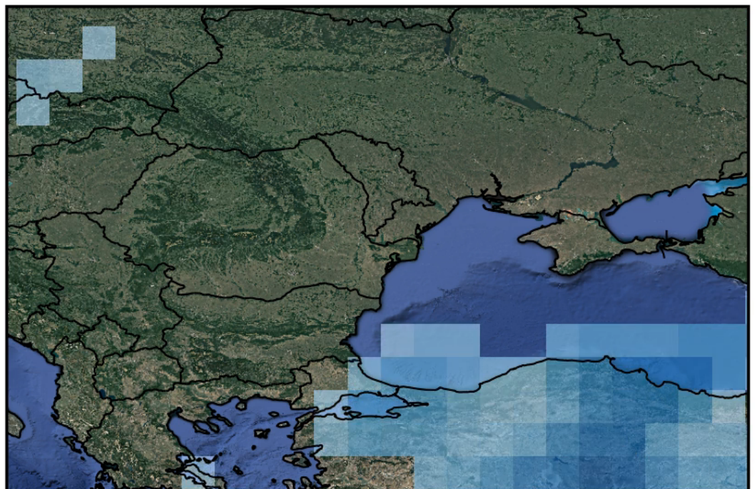
REGIONAL CLIMATE MODELS

- Regional Climate Models - RCMs
- Similar to GCMs but simulate only a finite domain
- Needs a driving model (usually GCM)
- Mostly land-atmosphere models
- Typical spatial resolution: 1–50 km
- Temporal resolution down to daily and sub-daily
- Model ensemble:
  - Coordinated Regional Downscaling Experiment (CORDEX)

WCRP CORDEX
Coordinated Regional Climate Downscaling Experiment

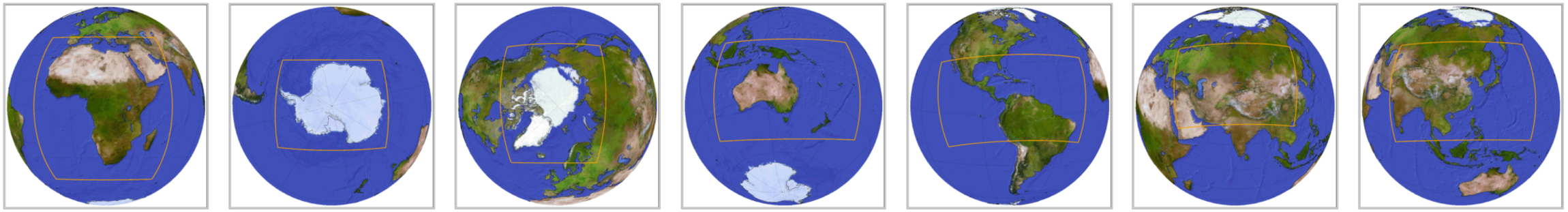


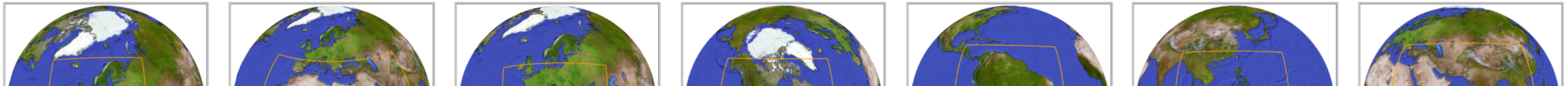
EVOLUTION OF DAILY MEAN PRECIPITATION



CORDEX

- Coordinated Regional Downscaling Experiment
- Description for 14 Regions accross globe
- Most Regions in different resolution (~50km, ~25km and ~12.5km)

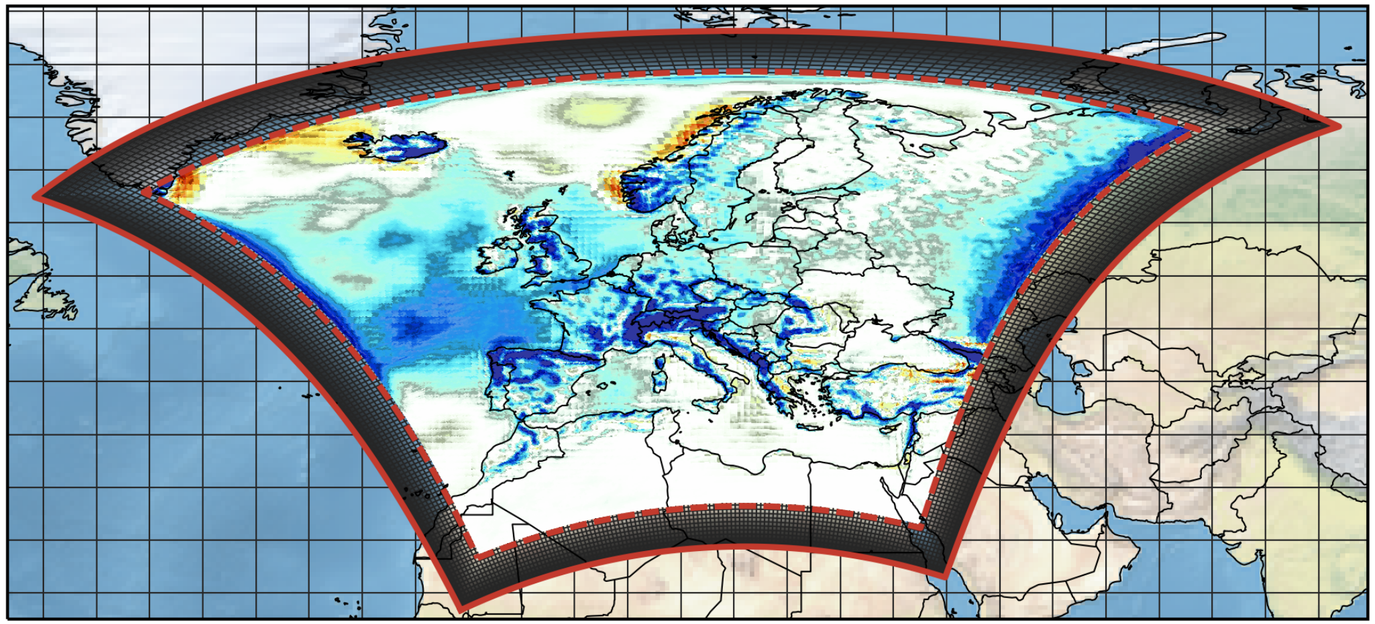




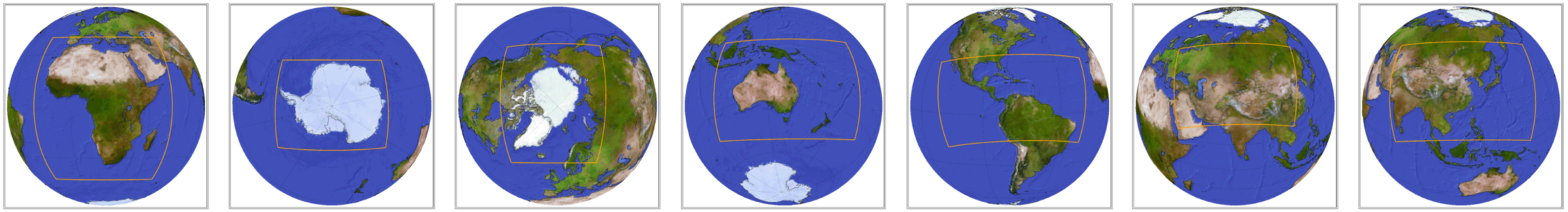
BOUNDARY PROBLEM

- RCMs are limited area models driven at boundaries by external forcing (usually Reanalysis or GCM data)
- Discrepancy in spatial and temporal resolution of RCM and driver
- Leads to boundary effects
- Boundary zone coupling:

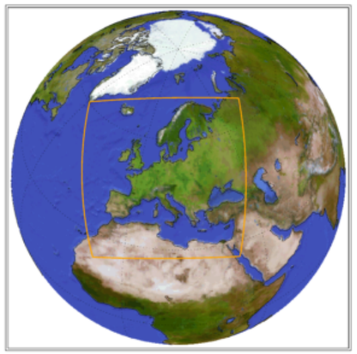
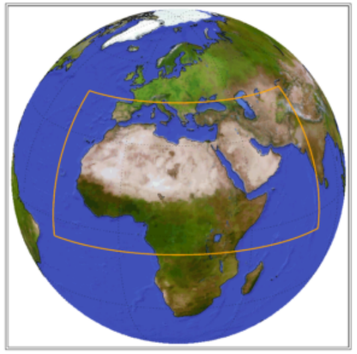
$$\psi^{n+1} = \psi^* - \alpha_b(\psi^* - \psi_b^{n+1})$$

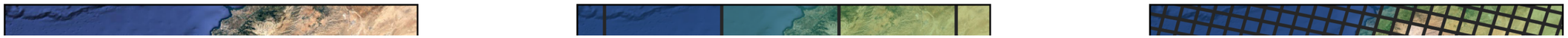


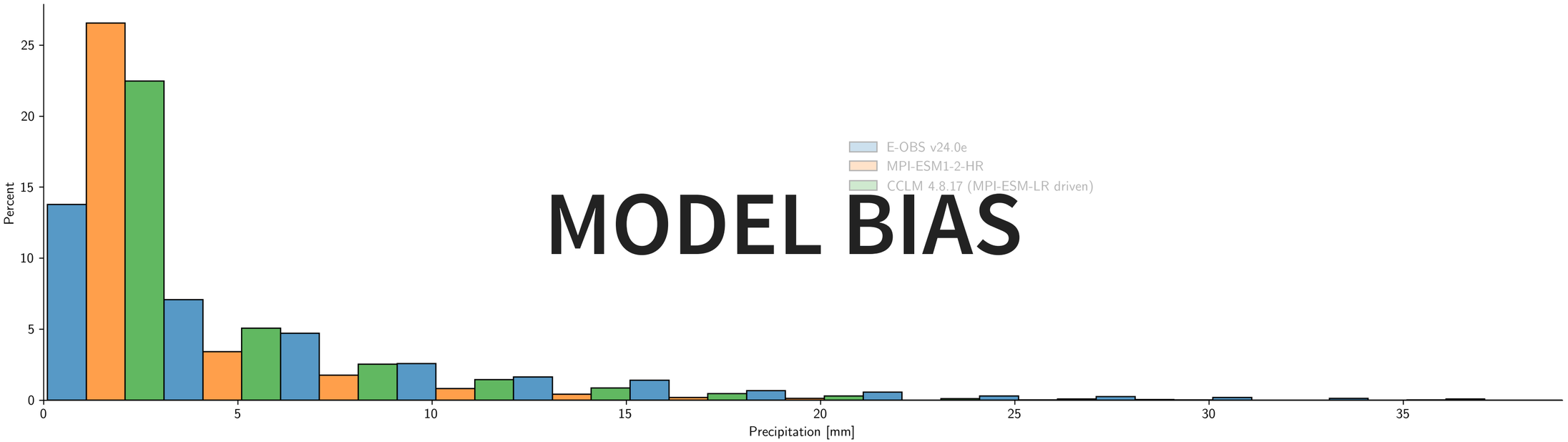
WHICH SHOULD BE USED FOR JORDAN?



WHICH SHOULD BE USED FOR JORDAN?

		RCP 2.6	RCP 4.5	RCP 8.5
				
CORDEX-EUR44	~50km	11	21	26
CORDEX-EUR11	~12km	18	17	37
				
CORDEX-MNA44	~50km	1	4	4
CORDEX-MNA22	~25km	-	1	2
				
CORDEX-MED11	~12km	-	-	-

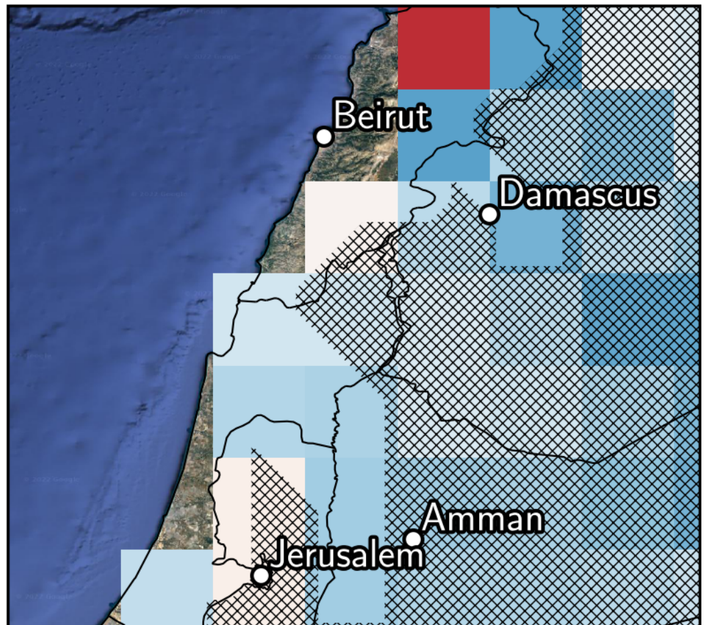



E-OBS v24.0e
MPI-ESM1-2-HR
CCLM 4.8.17 (MPI-ESM-LR driven)
Percent
0
5
10
15
20
25
Precipitation [mm]
0
5
10
15
20
25
30
35

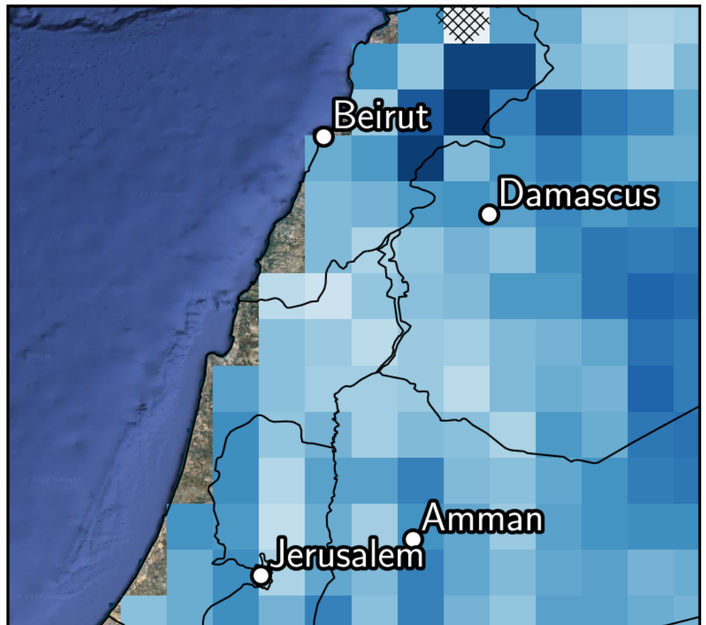
MODEL BIAS

TEMPERATURE BIAS - ANNUAL - ENSEMBLE MEDIAN - 1981-2010

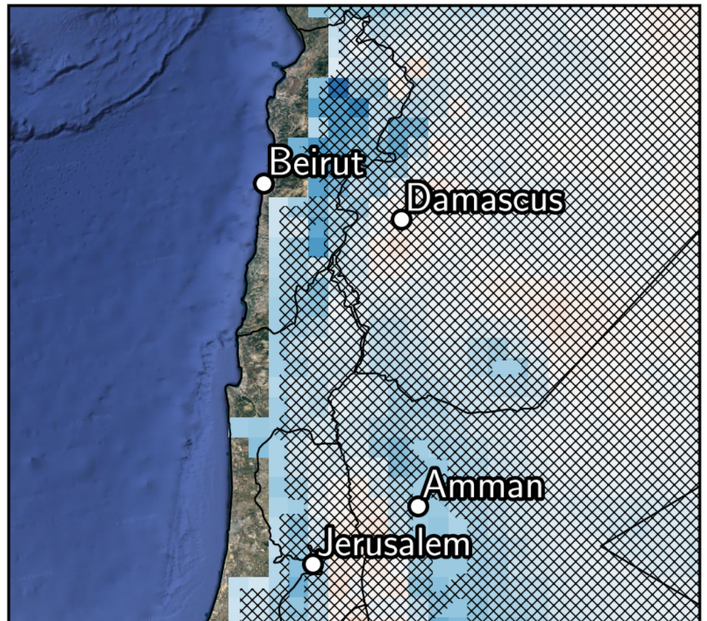
CORDEX-MNA44



CORDEX-MNA22

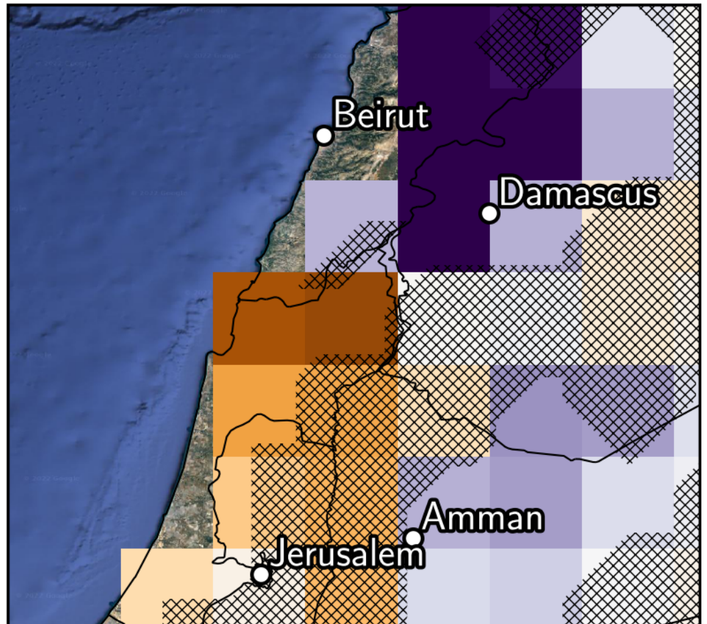


CORDEX-EUR11

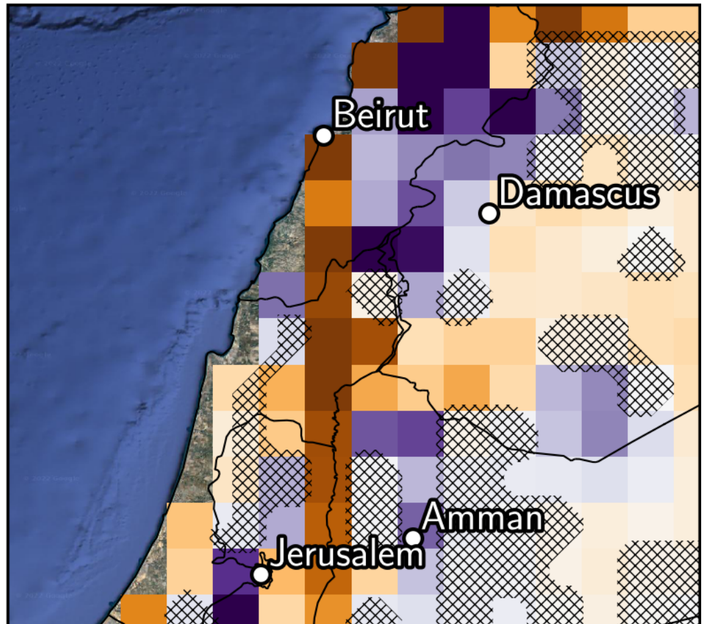


PRECIPITATION BIAS - ANNUL - ENSEMBLE MEDIAN - 1981-2010

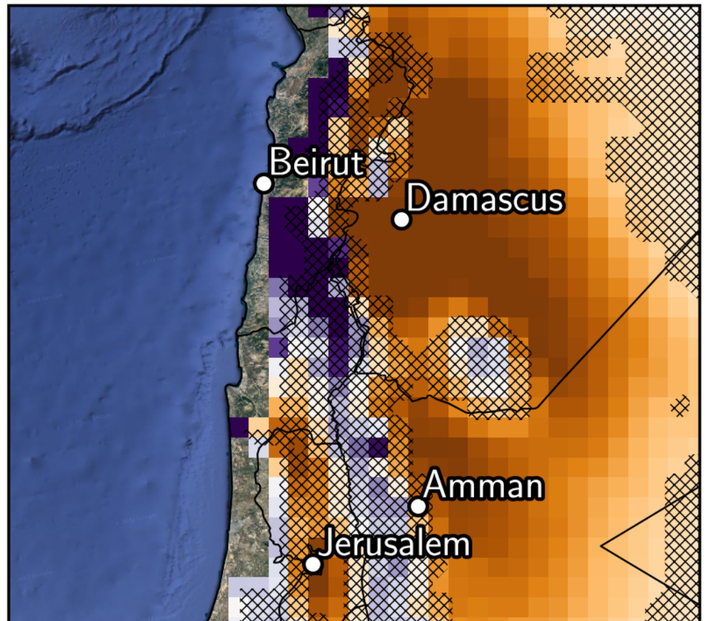
CORDEX-MNA44



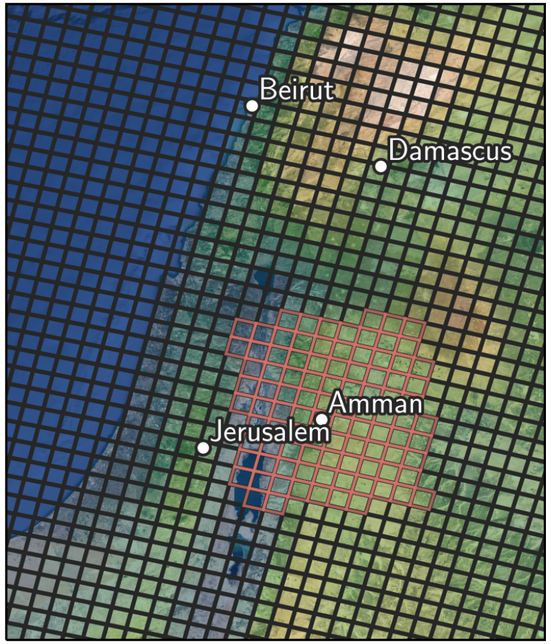
CORDEX-MNA22

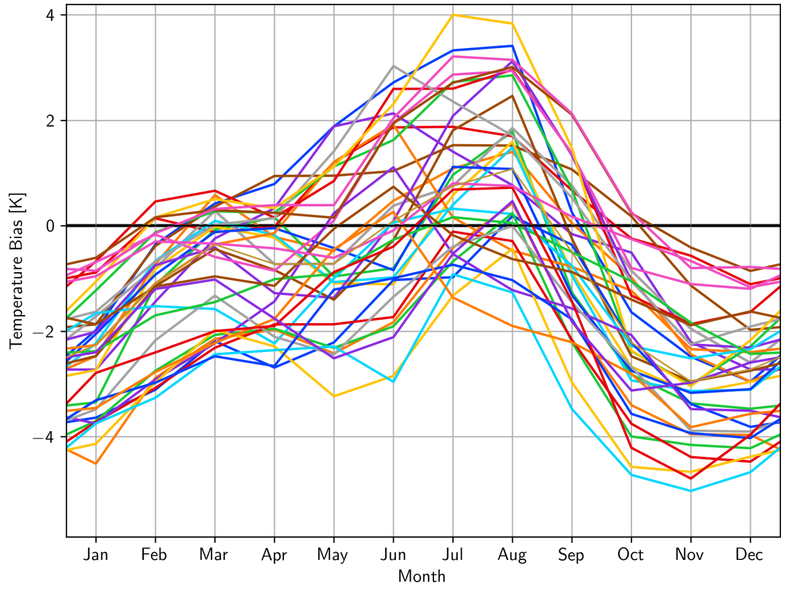


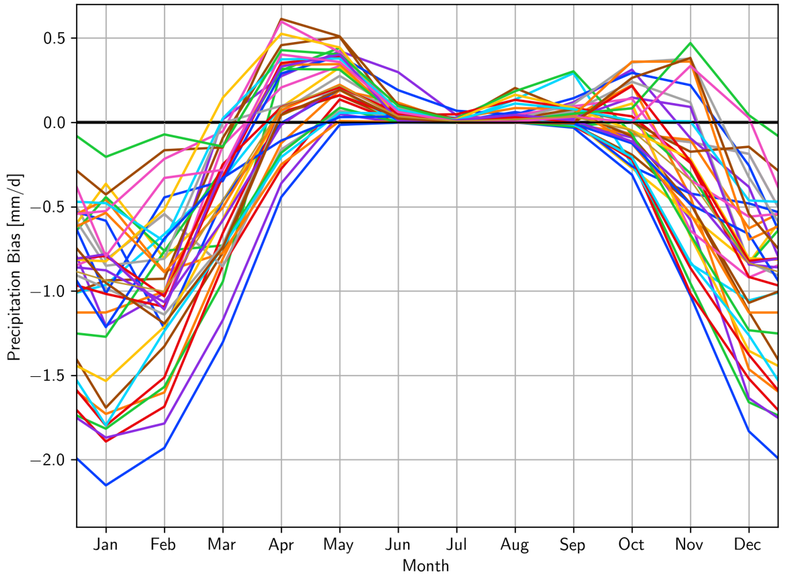
CORDEX-EUR11

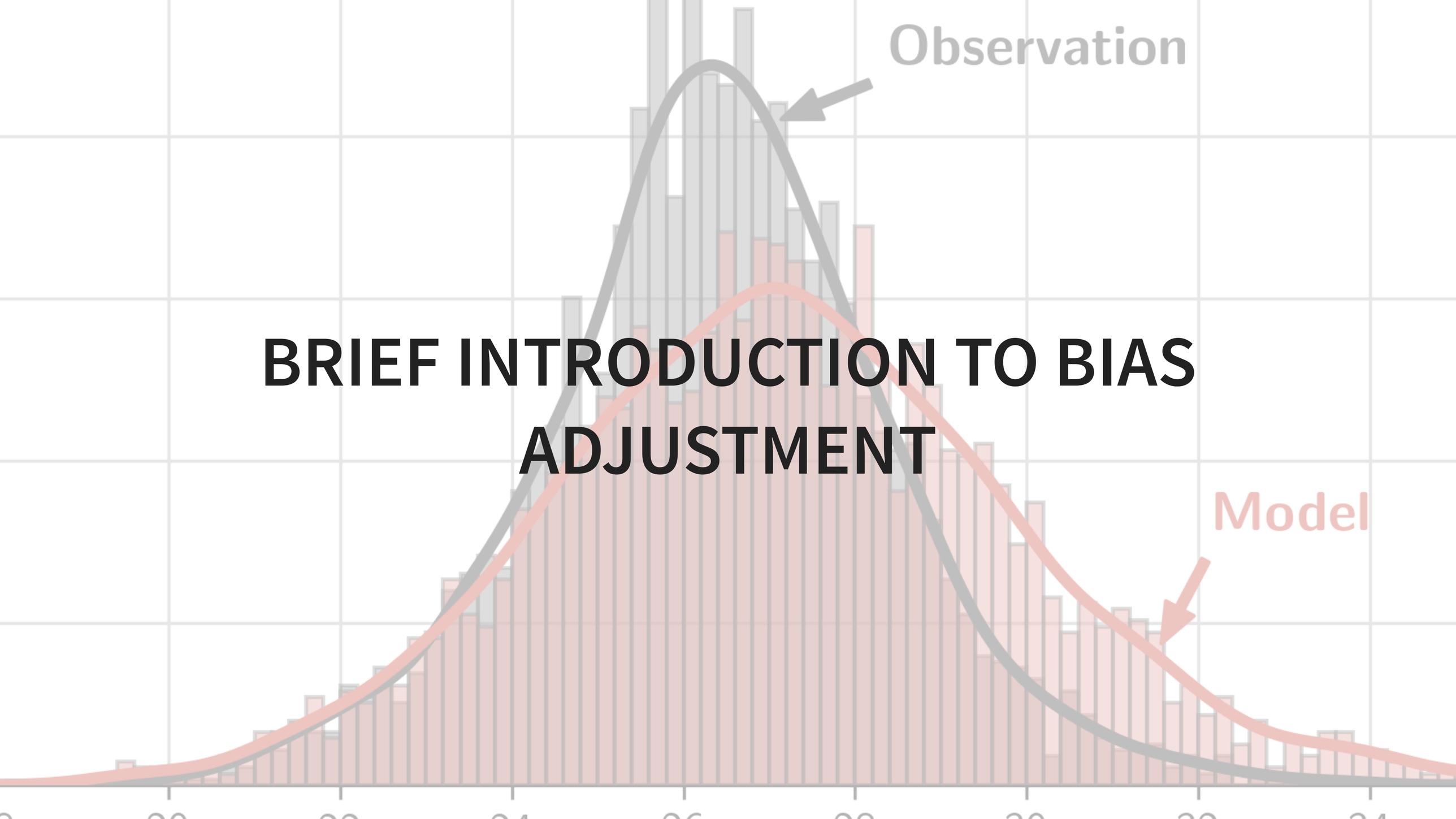


TEMPERATURE AND PRECIPITATION BIAS SEASONALITY



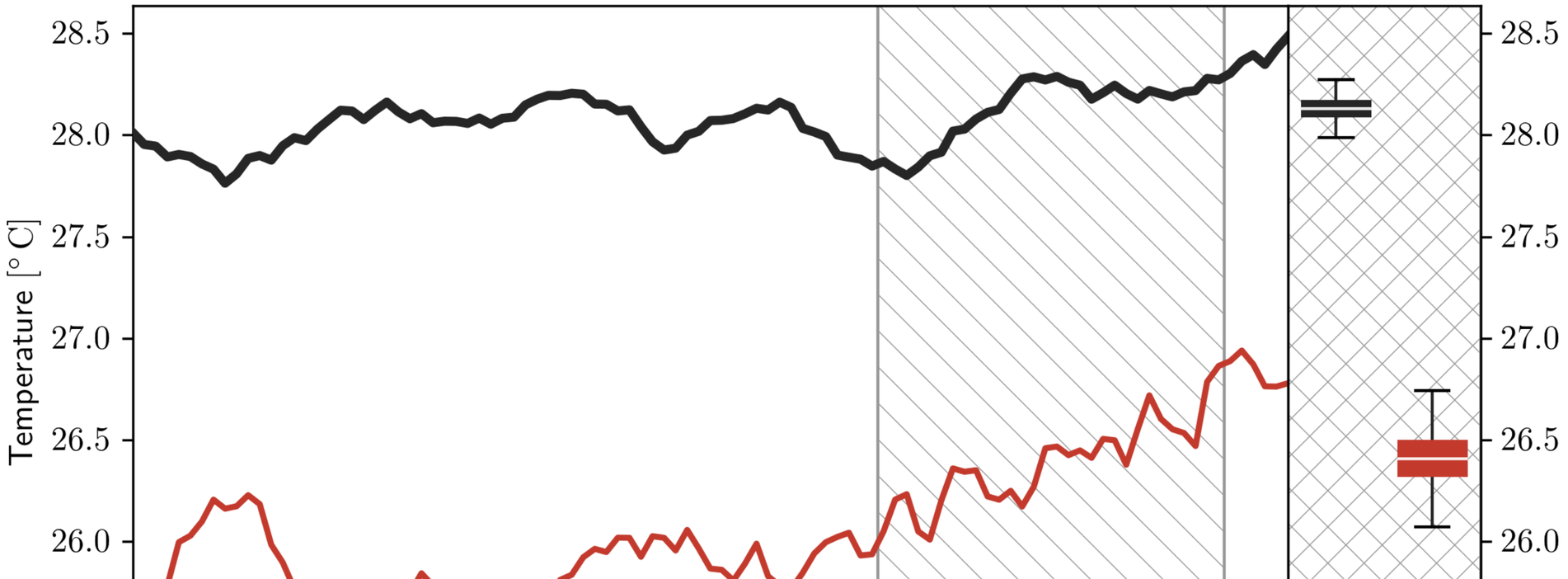




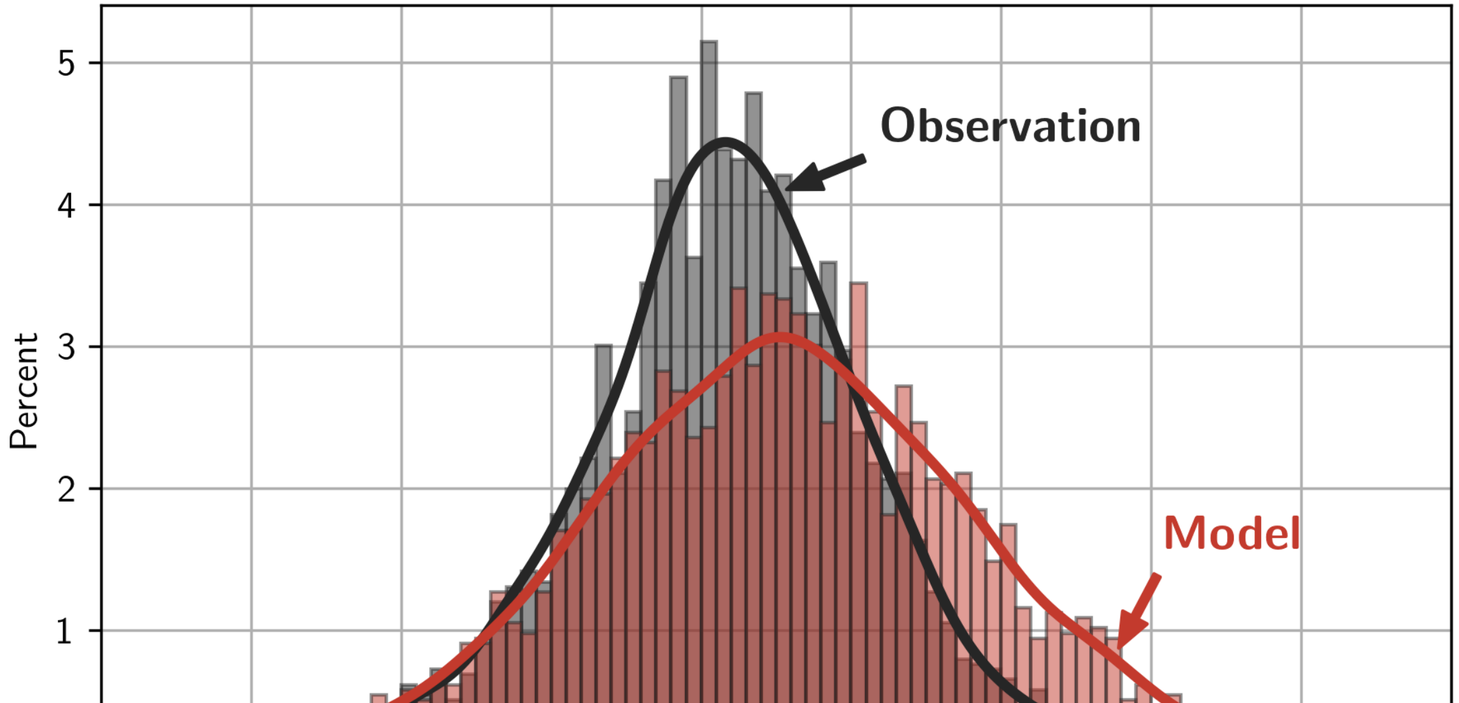


BRIEF INTRODUCTION TO BIAS ADJUSTMENT

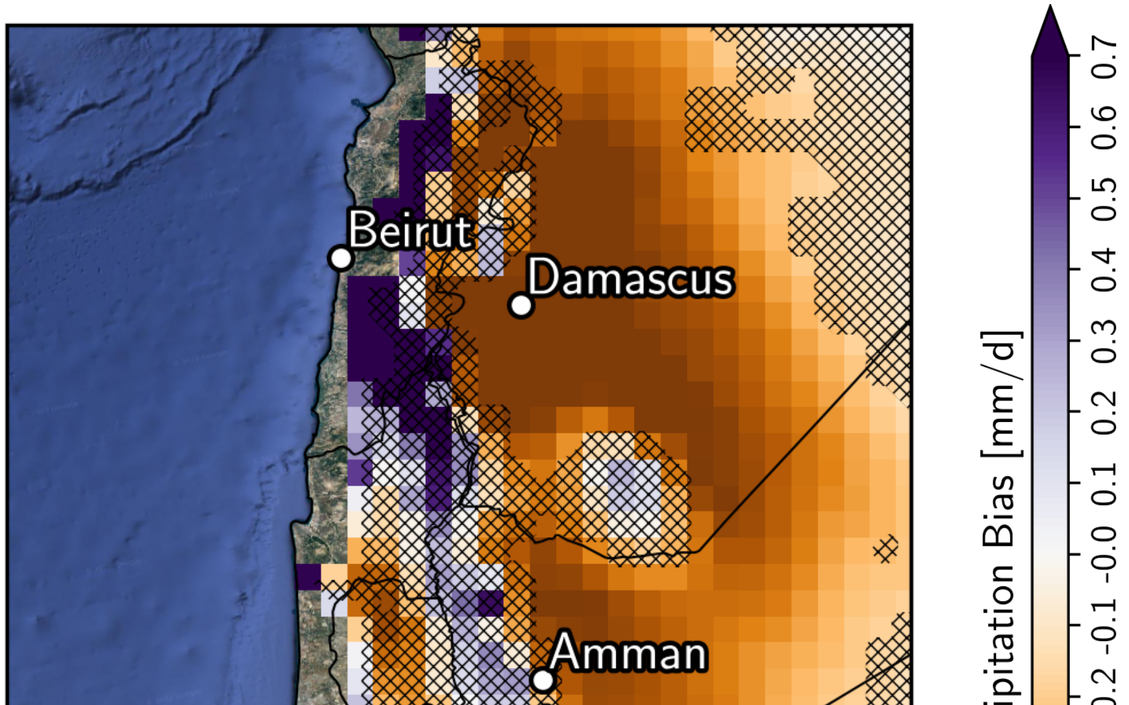
EXAMPLE OF MODEL BIAS



EXAMPLE OF MODEL BIAS

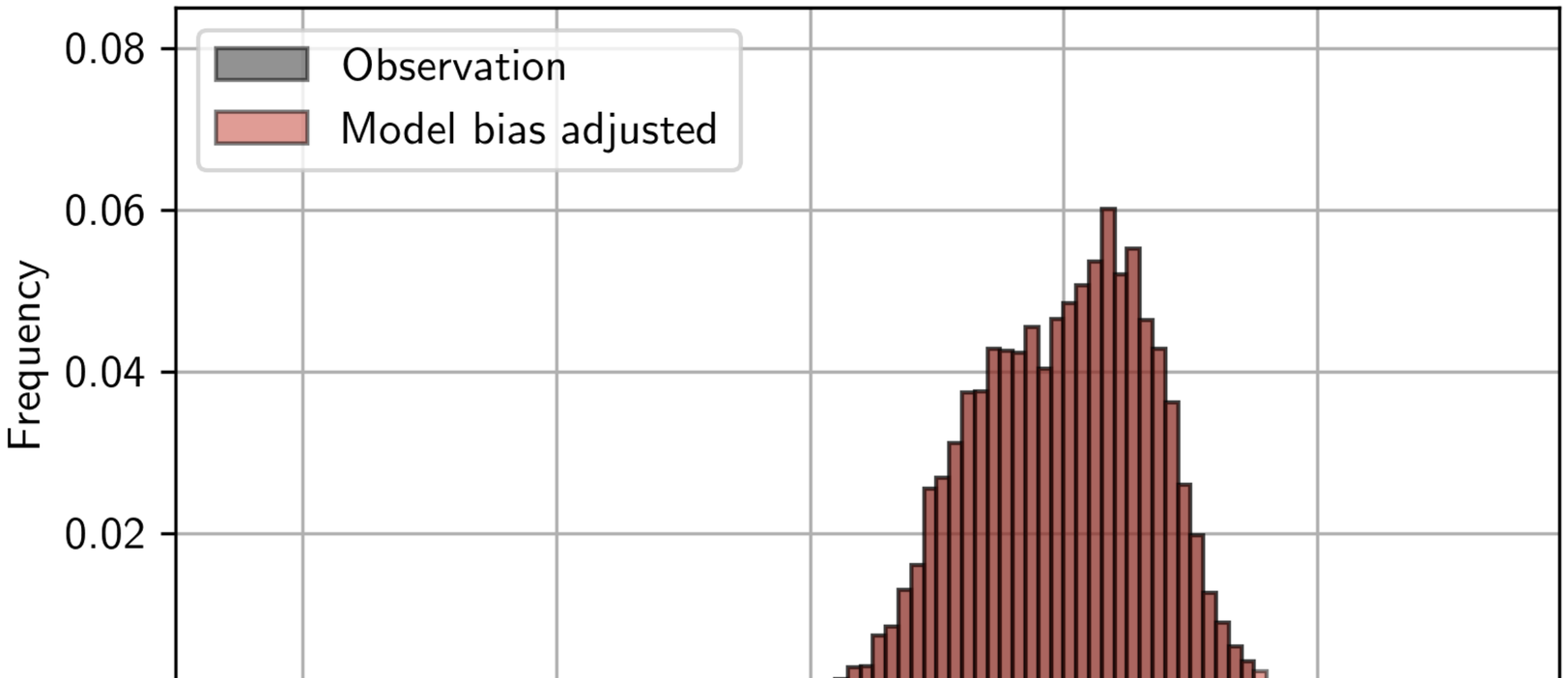


EXAMPLE OF MODEL BIAS



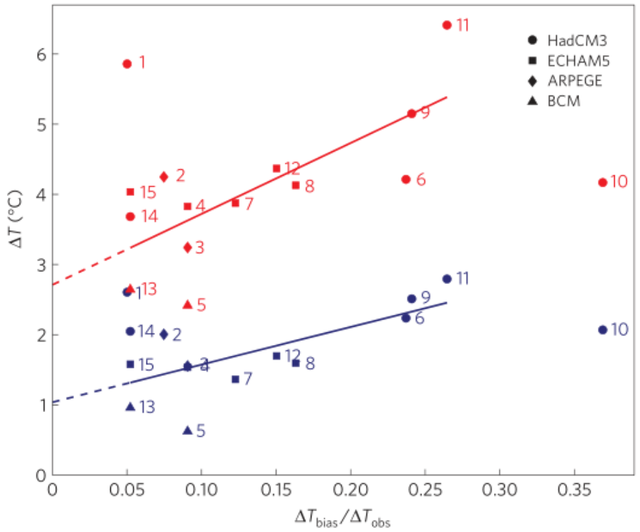
GOAL OF BIAS ADJUSTMENT

- Assume the model simulation to be a result of a random process with **wrong** statistics
- Bias adjustment should **adjust** the **statistics** towards a **reference**
- In an idealized world we would like to care about **temporal evolution**
- In an idealized world we would like to adjust the bias towards **reality**
- In an idealized world we would like to adjust the bias in **every statistic**



PROBLEMS WITH BIAS ADJUSTMENT

- Univariate and Multivariate bias adjustment to preserve inter-variable or spatial correlations
- Trend preserving bias adjustment
- Model bias changing in time
- Climate change signal depending on model bias

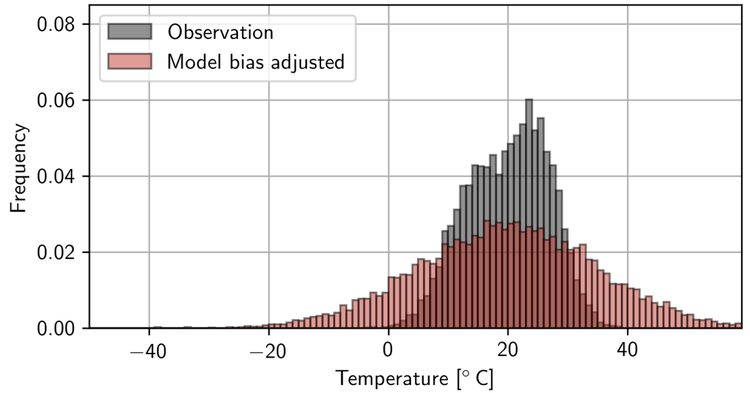


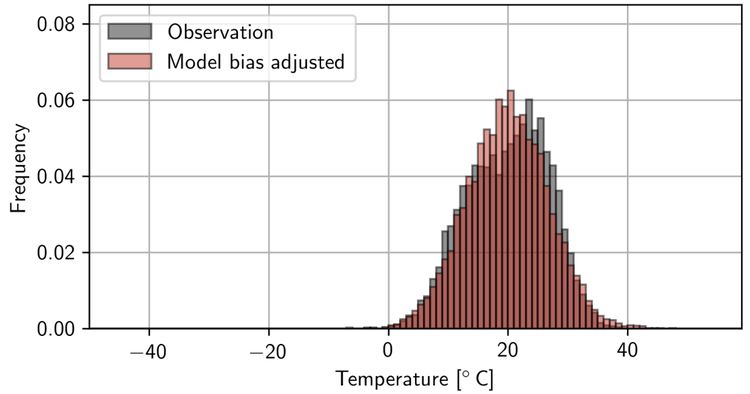
1. C4I HadCM3Q16	6. ETHZ HadCM3Q0	11. HC HadCM3Q16
2. CNRM ARPEGE	7. ICTP ECHAM5	12. MPI ECHAM5
3. DMI ARPEGE	8. KNMI ECHAM5	13. SMHI BCM
4. DMI ECHAM5	9. HC HadCM3Q0	14. SMHI HadCM3Q3
5. DMI BCM	10. HC HadCM3Q3	15. SMHI ECHAM5

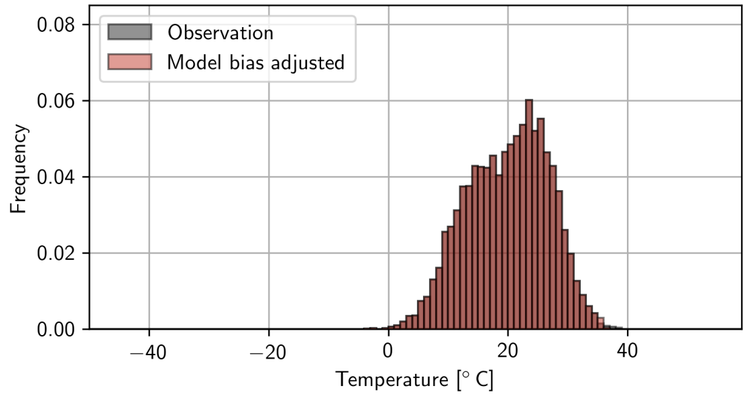
2021-2050

2071-2100

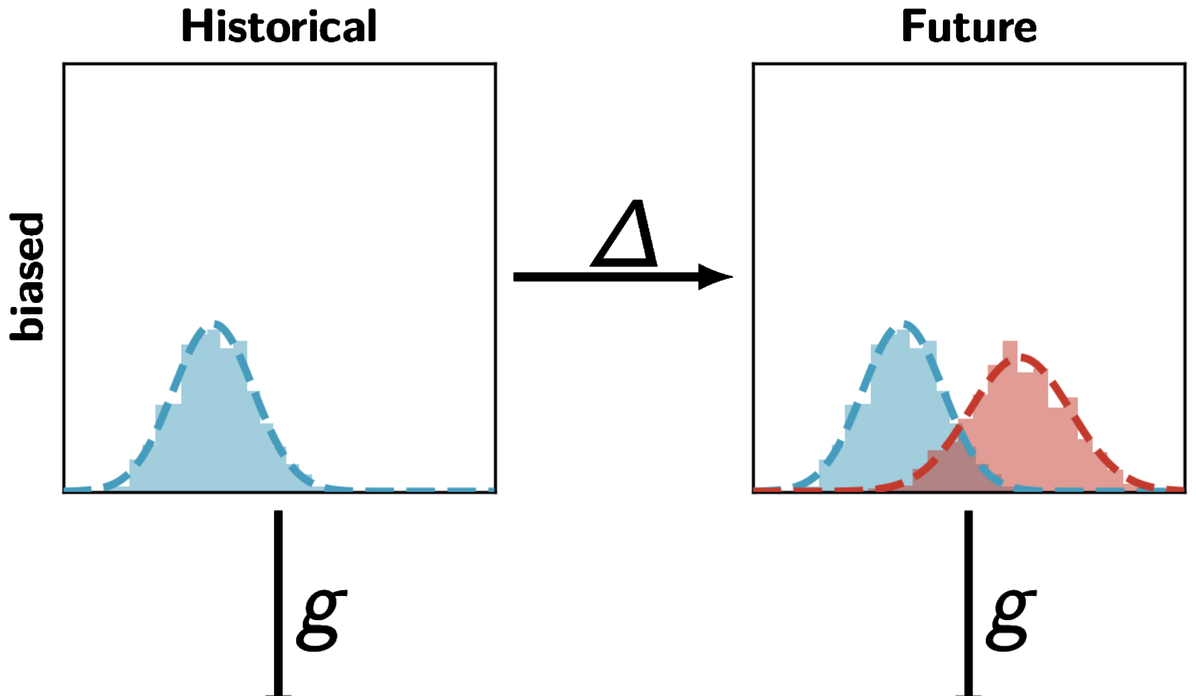
Boberg and Christensen (2012)





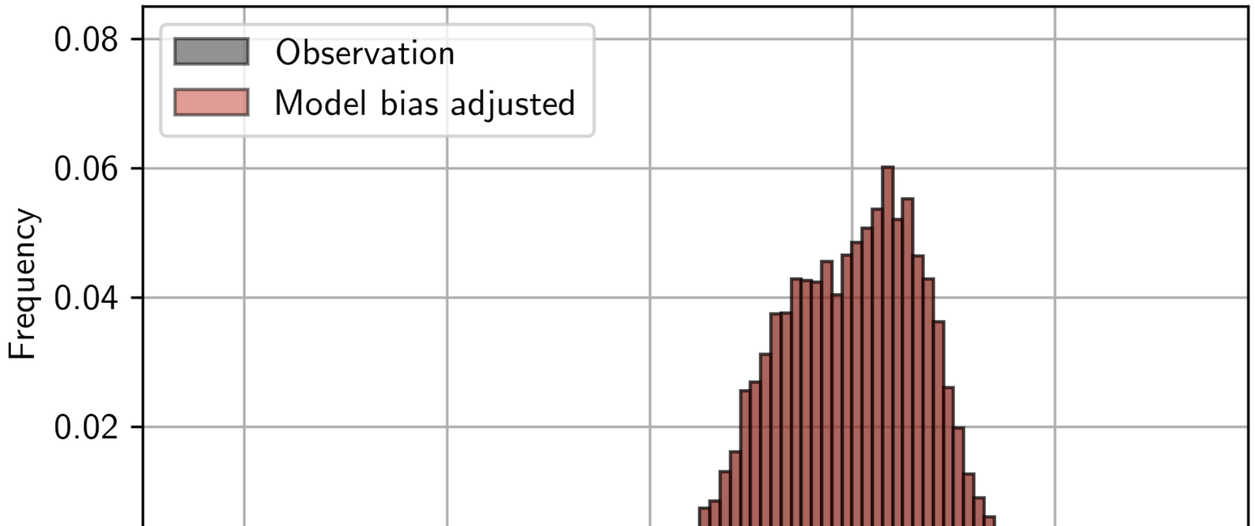


BIAS ADJUSTMENT - WORKFLOW



CHOSEN BIAS ADJUSTMENT METHOD

- ISIMIP3BASD method used for bias adjustment
- Parametric quantile mapping
- Trend preserving



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Geoscientific Model Development
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Trend-preserving bias adjustment and statistical downscaling with ISIMIP3BASD (v1.0)

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Abstract. In this paper I present new methods for bias adjustment and statistical downscaling that are tailored to the requirements of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP). In comparison to their predecessors, the new methods allow for a more robust bias adjustment of extreme values, preserve trends more accurately across quantiles, and facilitate a clearer separation of bias adjustment and statistical downscaling. The new statistical downscaling method is stochastic and better at adjusting spatial variability than the old interpolation method. Improvements in bias adjustment and trend preservation are demonstrated

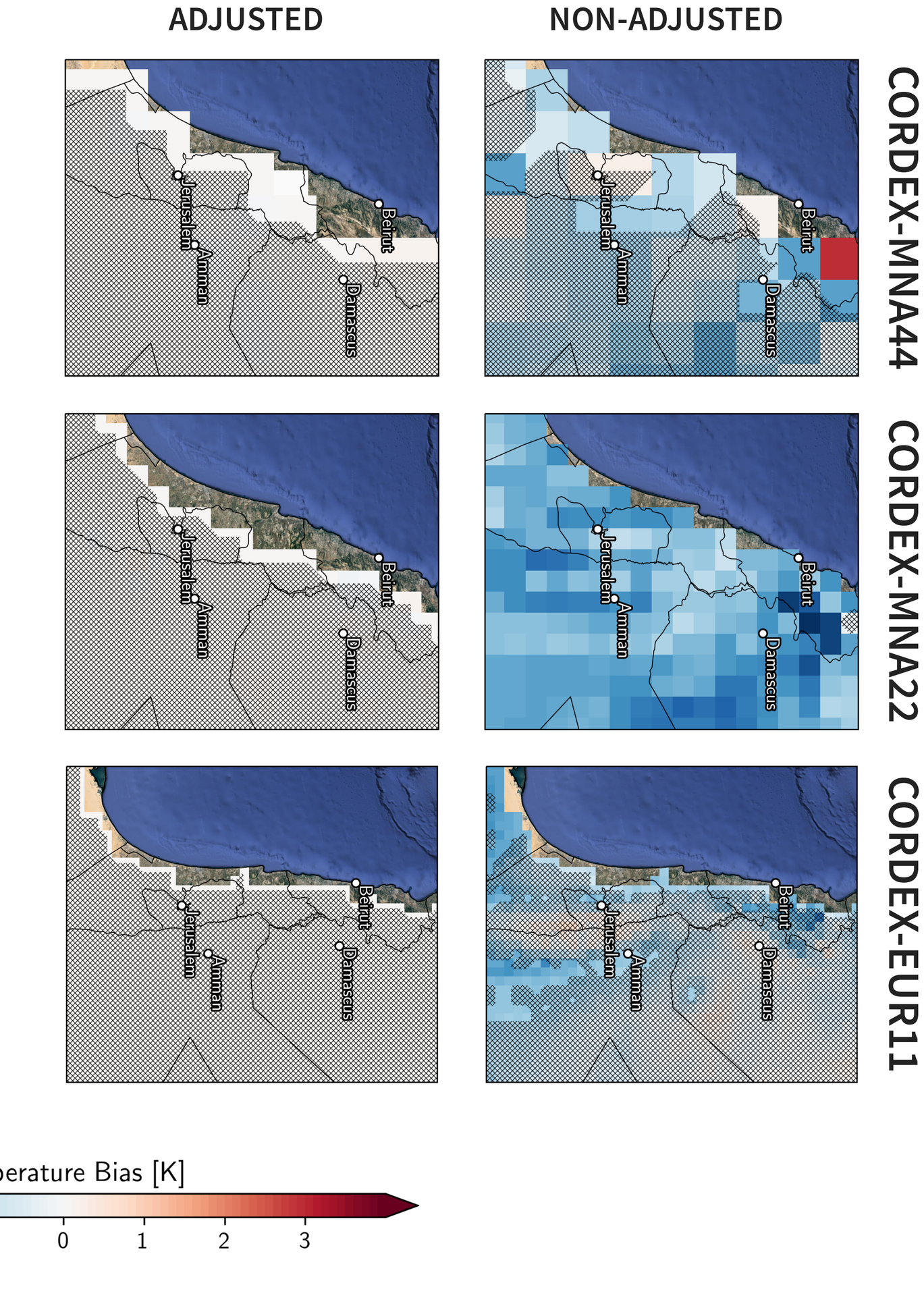
bias adjustment as it is commonly understood involves two distinct problems: (i) the actual bias adjustment at the spatial resolution of the simulation data and (ii) a statistical downscaling to the spatial resolution of the observation data.

Commonly, the bulk of resources for the development of solutions to these problems is allocated to problem (i), and problem (ii) is solved by a mere spatial interpolation of the simulation data to the spatial resolution of the observation data prior to bias adjustment. For example, this approach was adopted in the ISIMIP Fast Track (Hempel et al., 2013), in ISIMIP2b (Frieler et al., 2017) and for the generation of

TEMPERATURE BIAS

Annual - Ensemble Mean

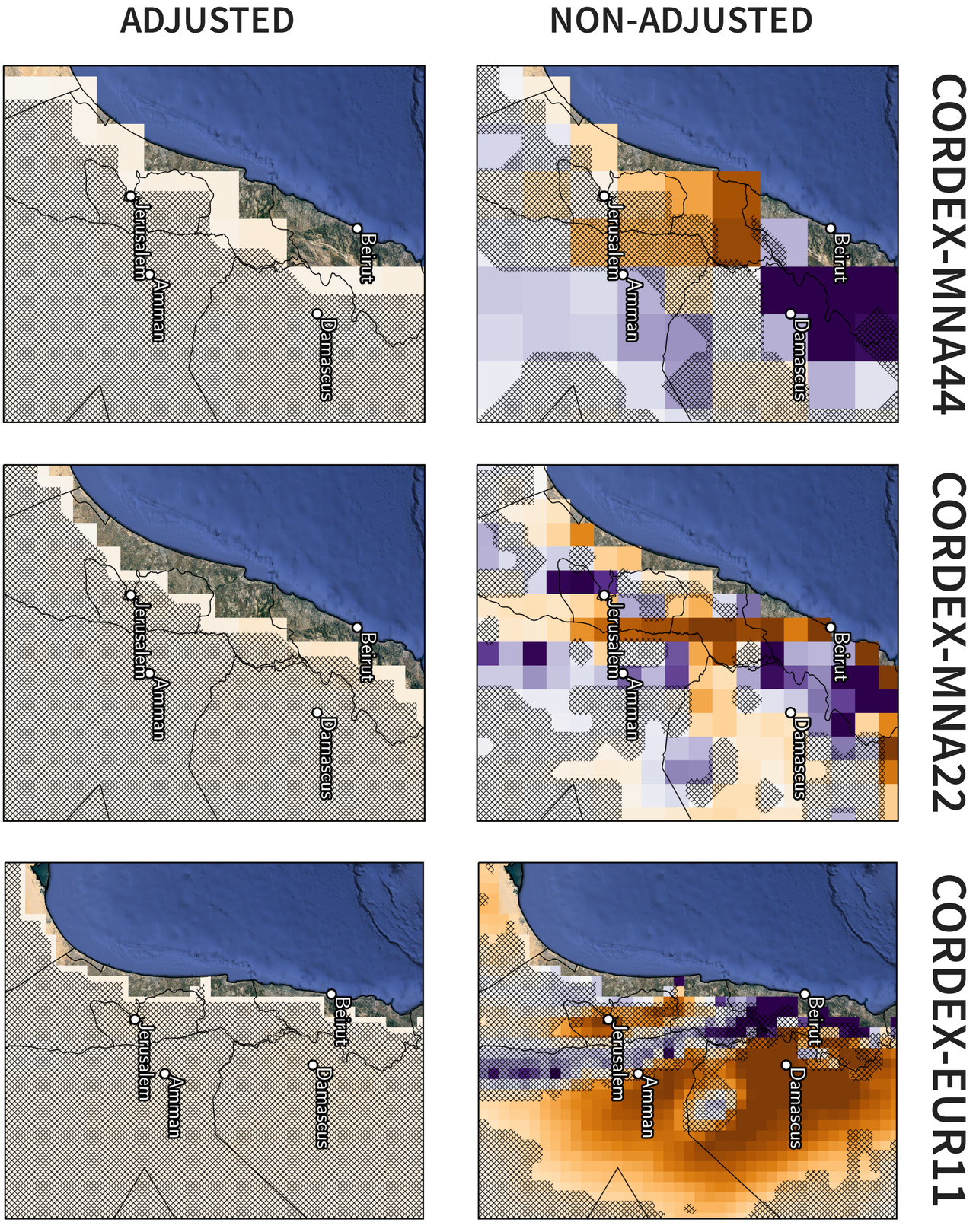
1981-2010

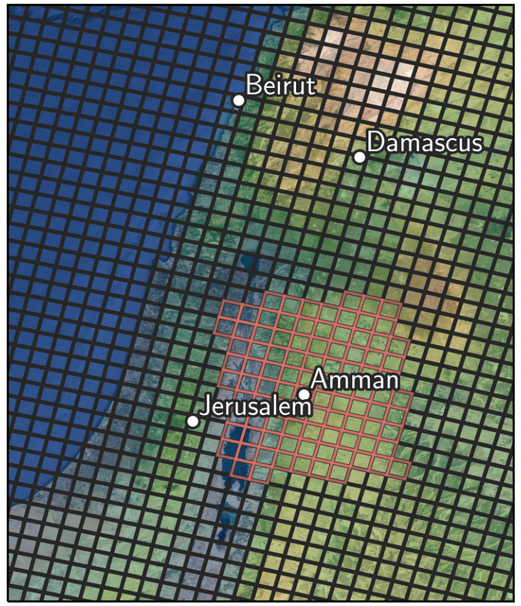


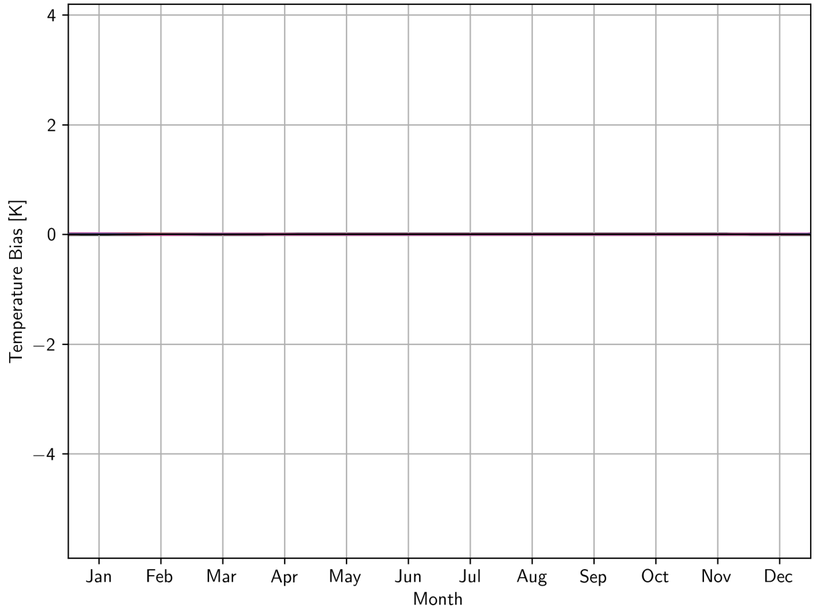
PRECIPITATION BIAS

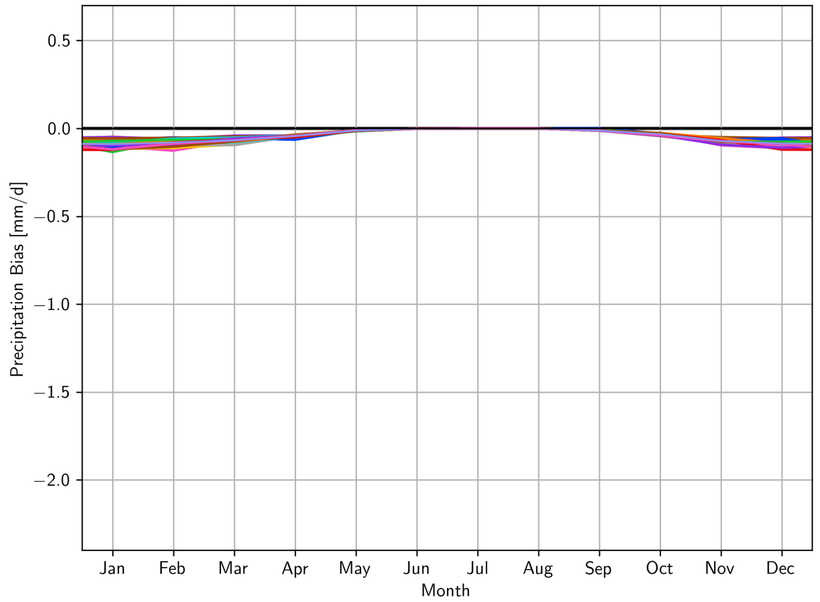
Annual - Ensemble Mean

1981-2010




Beirut
Damascus
Amman
Jerusalem

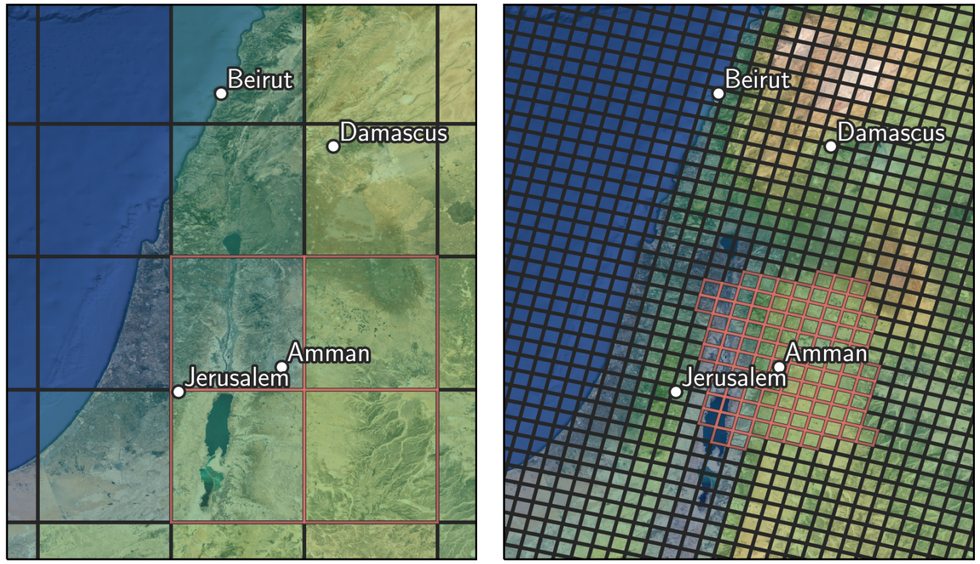

Temperature Bias [K]
4
2
0
−2
−4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

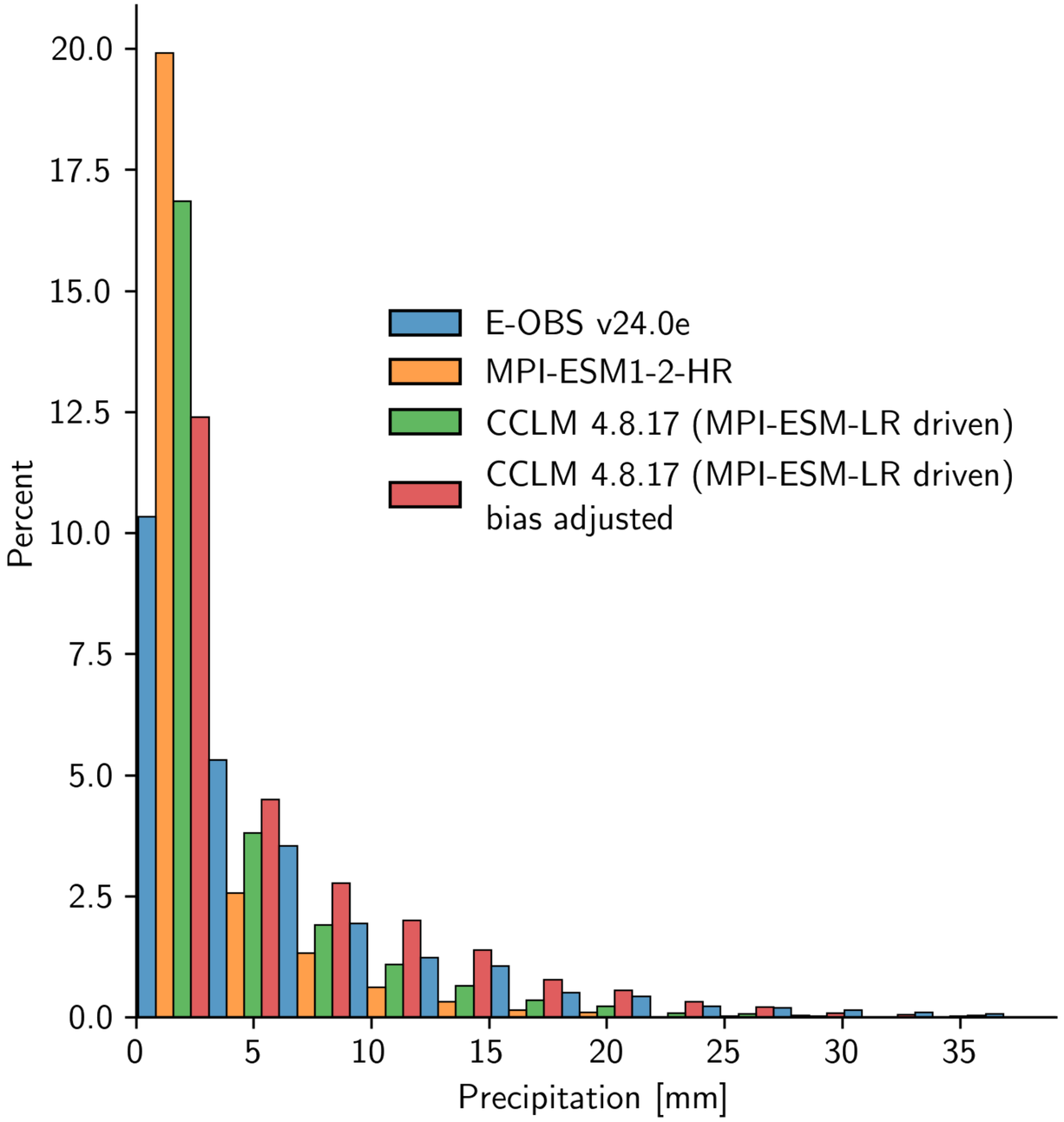

Precipitation Bias [mm/d]
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

1971-2005

MPI-ESM1-2-HR

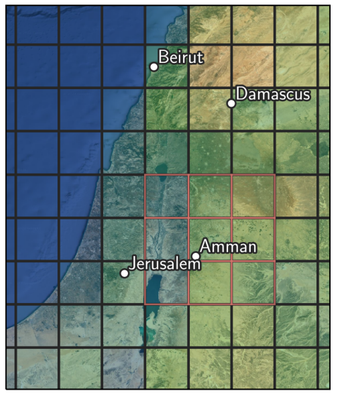
CCLM 4.8.17



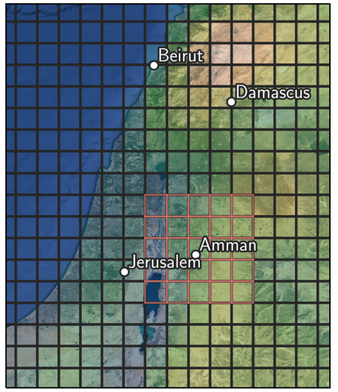


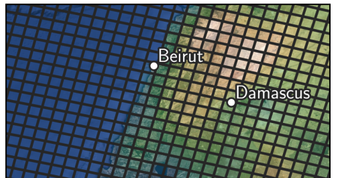
- 1971-2000


PROJECTED PRECIPITATION CHANGE
Amman
Jerusalem



- Global climate model projections of
  - CMIP 5: up to 42 simulations
  - CMIP 6: up to 41 simulations
- Regional climate model projections of
  - CORDEX-MNA44: up to 4 simulations
  - CORDEX-MNA22: up to 2 simulations
  - CORDEX-MNA44: up to 37 simulations
- Bias adjustment using ISIMIP3BASD
- Projections until 2100 under



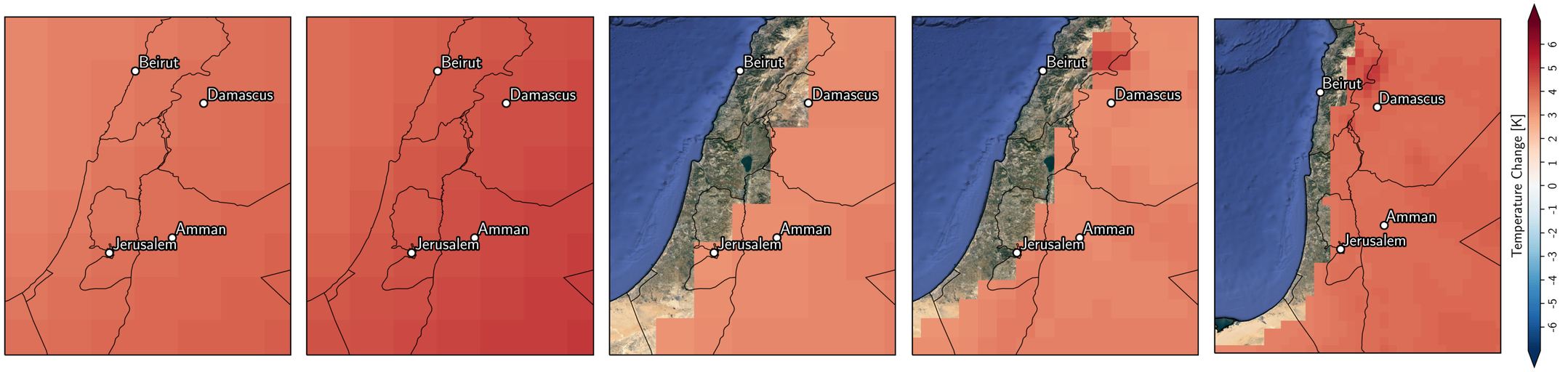


CLIMATE CHANGE SIGNAL - NDJFM

2071 - 2100 vs. 1981 - 2010

CMIP5 RCP 8.5 | CMIP6 SSP5-8.5 | CORDEX-MNA44 RCP 8.5 | CORDEX-MNA22 RCP 8.5 | CORDEX-EUR11 RCP 8.5

Temperature



PRECIPITATION EVENTS

number of rainy days (RR1)

≥1mm

number of vey wet days (R20mm)

≥20mm

NDJFM

Projection period

2071-2100

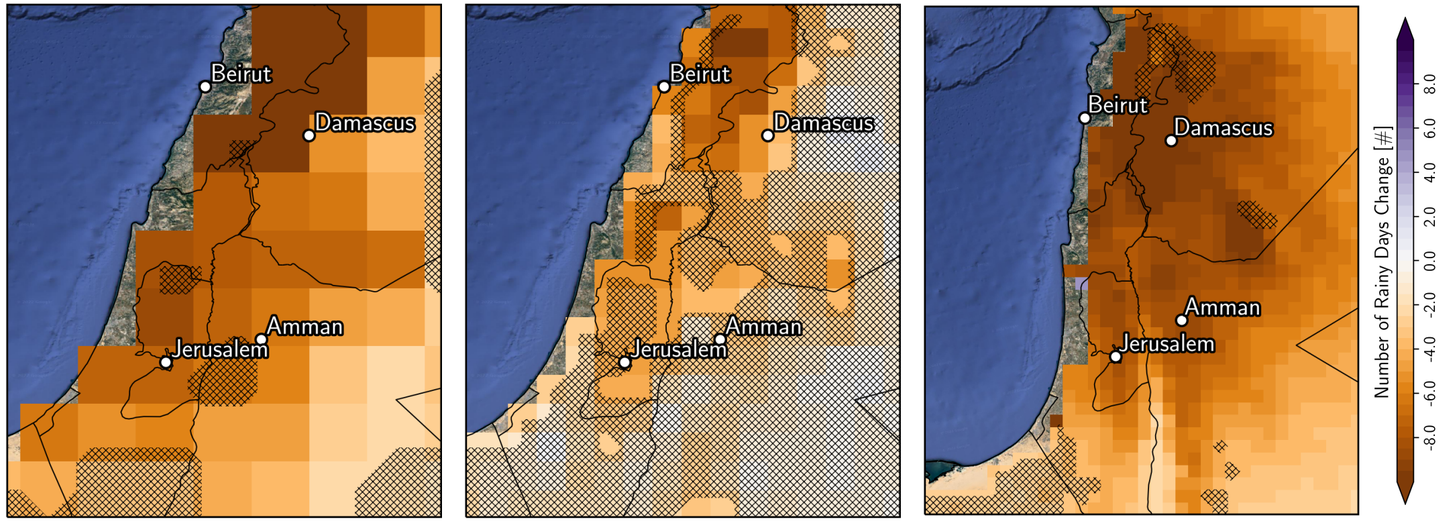
Reference period

1981-2010

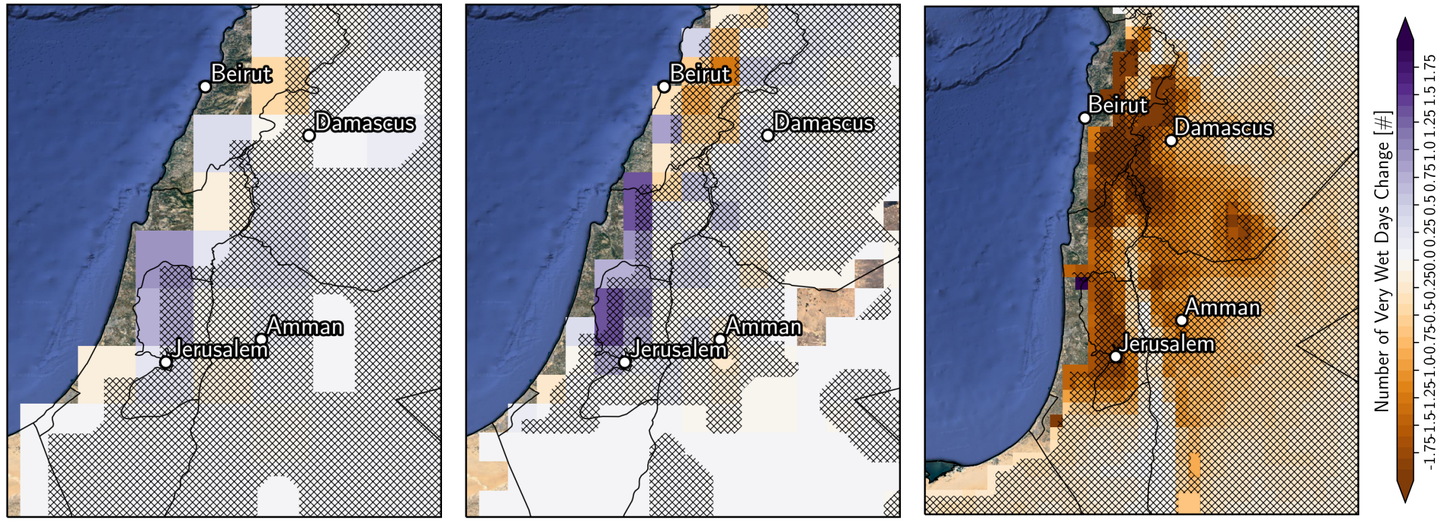
90% significance level

CORDEX-MNA44 CORDEX-MNA22 CORDEX-EUR11

rainy days (≥1mm)



very wet days (≥20mm)

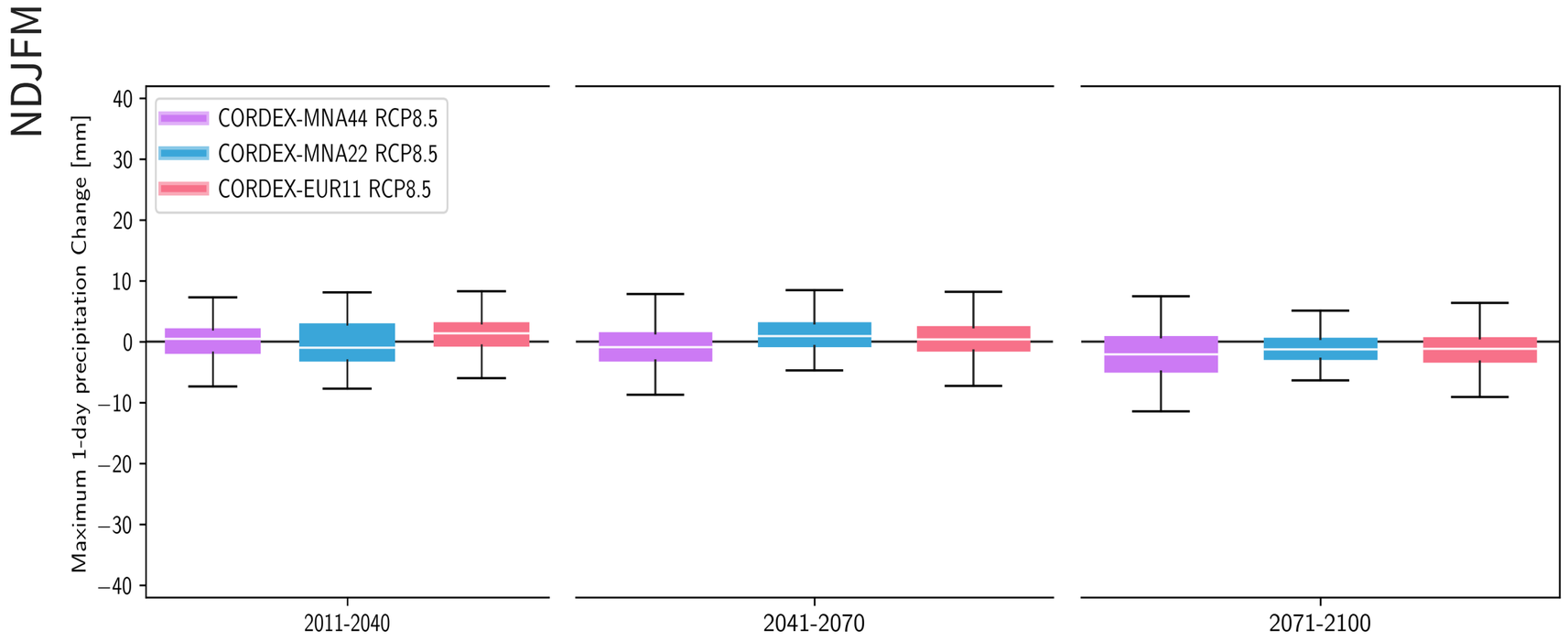


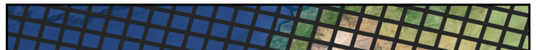
PRECIPITATION EVENTS

Seasonal maximum precipitation (RX1day)

Reference period

1981-2010





GENERALIZED EXTREME VALUE DISTRIBUTION

Annual maximum precipitation

Empirical distribution fitted to GEV probability density

Projection period

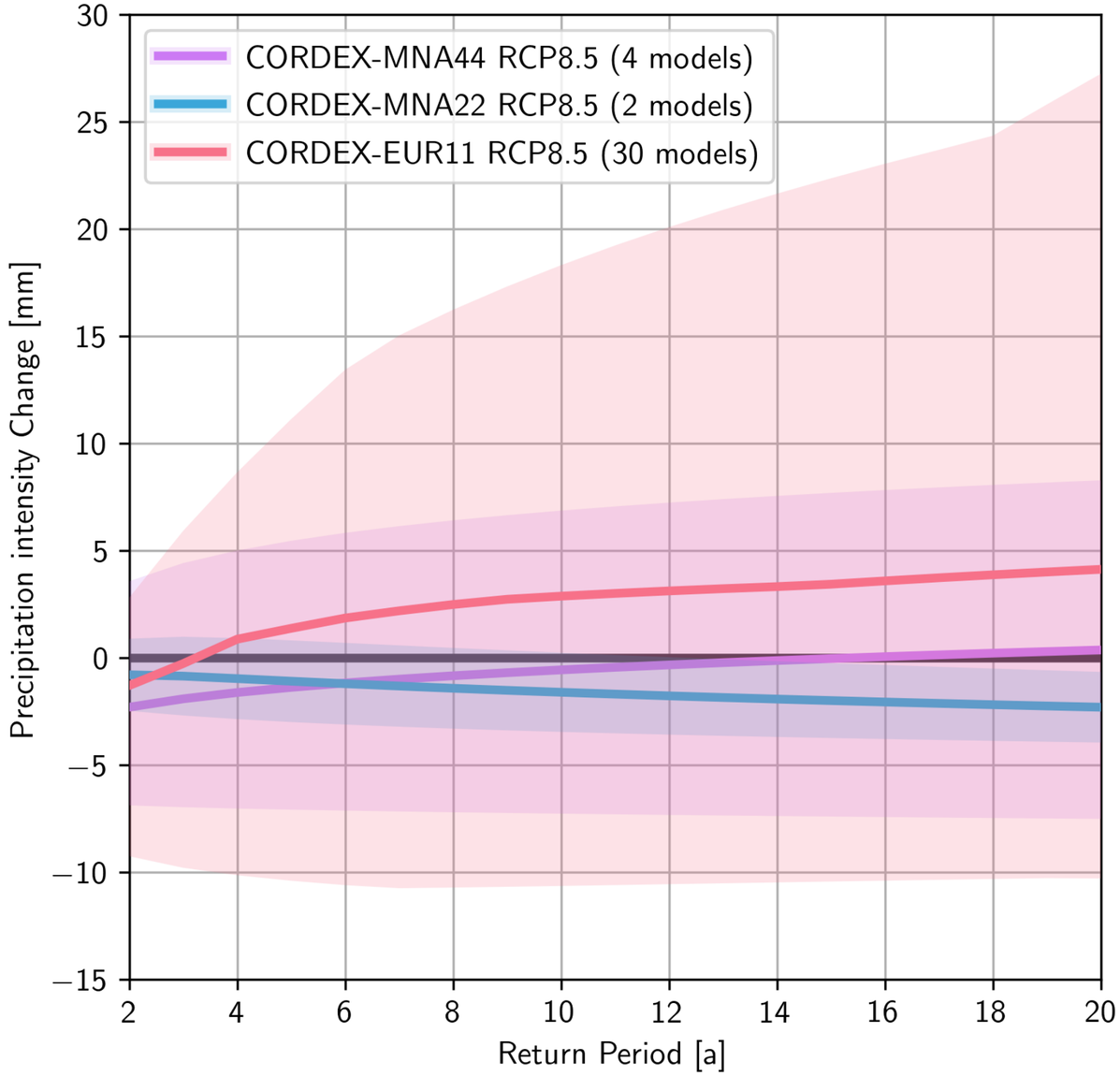
2071-2100

Reference period

1981-2010

Standardized pdf

$$f(s;\xi) = \begin{cases} \exp(-s)\exp\Big(-\exp(-s)\Big) & \text{for} \quad \xi = 0 \\ \Big(1+\xi s\Big)^{-(1+1/\xi)} \exp\Big(-(1+\xi s)^{-1/\xi}\Big) & \text{for} \quad \xi \neq 0 \quad \text{and} \quad \xi, s > -1 \\ 0 & \text{otherwise.} \end{cases}$$



CLIMATE CHANGE SUMMARY - AMMAN

		JJAS				NDJFM			
Variable	Unit	1981-2010	2011-2040	2041-2070	2071-2100	1981-2010	2011-2040	2041-2070	2071-2100
Temperature	°C	**26.6**	**1.3**	**2.9**	**4.8**	**12.5**	**1.0**	**2.3**	**3.9**
Precipitation	mm/d	**0.01**	0.025	0.039	0.032	**2.02**	−0.089	−0.265	**−0.508**
Rainy Days	#	**0.1**	0.06	0.04	0.02	**33.7**	−0.43	**−0.98**	**−1.61**
R10mm	#	**0.03**	0.08	0.08	0.07	**10.3**	−0.6	−1.6	**−2.9**
R20mm	#	**0.03**	0.013	0.017	0.015	**2.92**	0.001	−0.062	−0.167
RX1day	mm/d	**1.4**	1.7	2.3	1.8	**30.1**	1.2	0.5	−1.5
RX5day	mm/5d	**1.4**	2.5	3.6	2.8	**63.8**	0.4	−3.2	−8.8

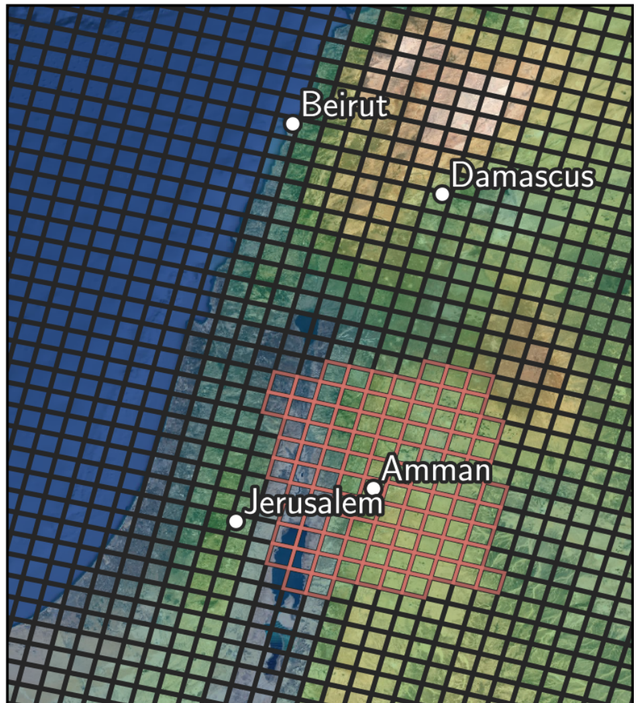
CONCLUSION

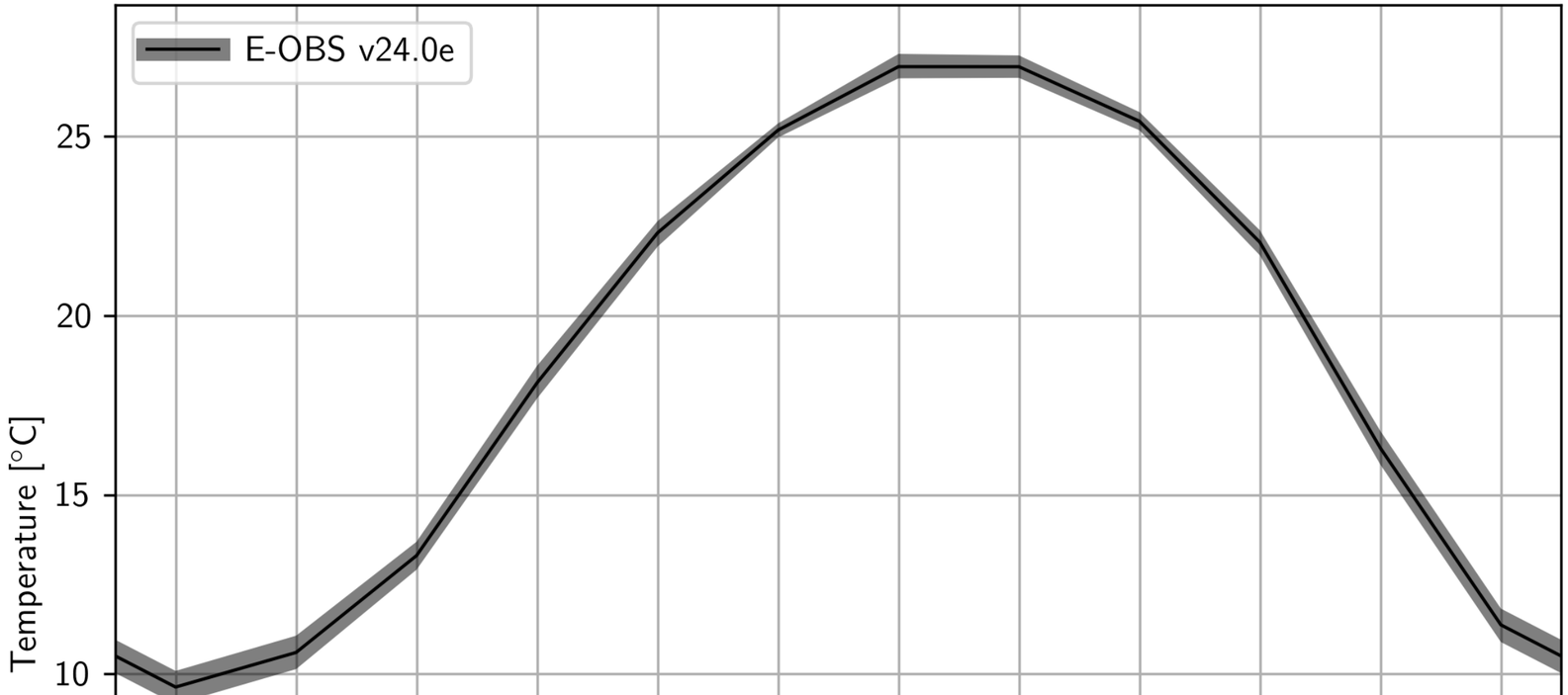
- Resolution of GCMs insufficient for regional climate change impact studies
- Resolution of RCMs more suitable but boundary problem and low number of simulations
- Bias adjustment absolutely necessary especially when focussing of precipitation extremes
- Considerable temperature increase over whole region
- NDJFM precipitation and extremes decrease (considerably)
- JJAS precipitation and extremes increase (negligible)
- Nearly all precipitation changes below significance level

THE END

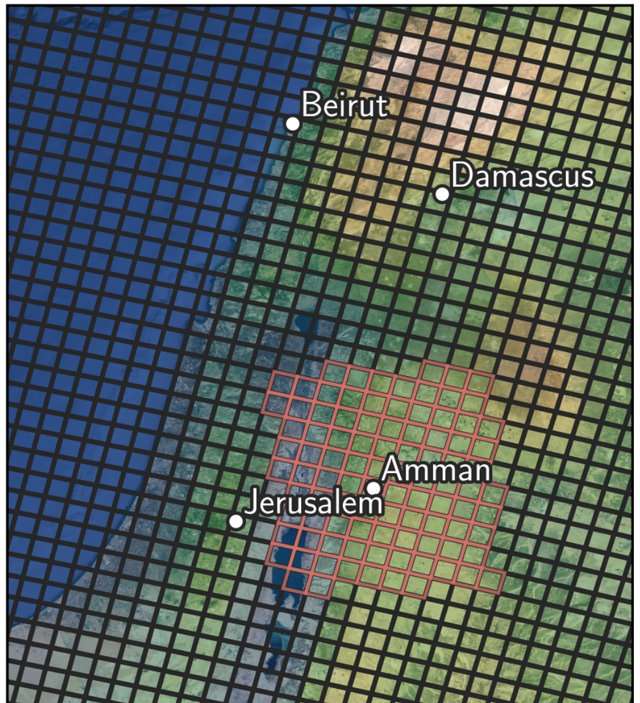
BACKUP SLIDES

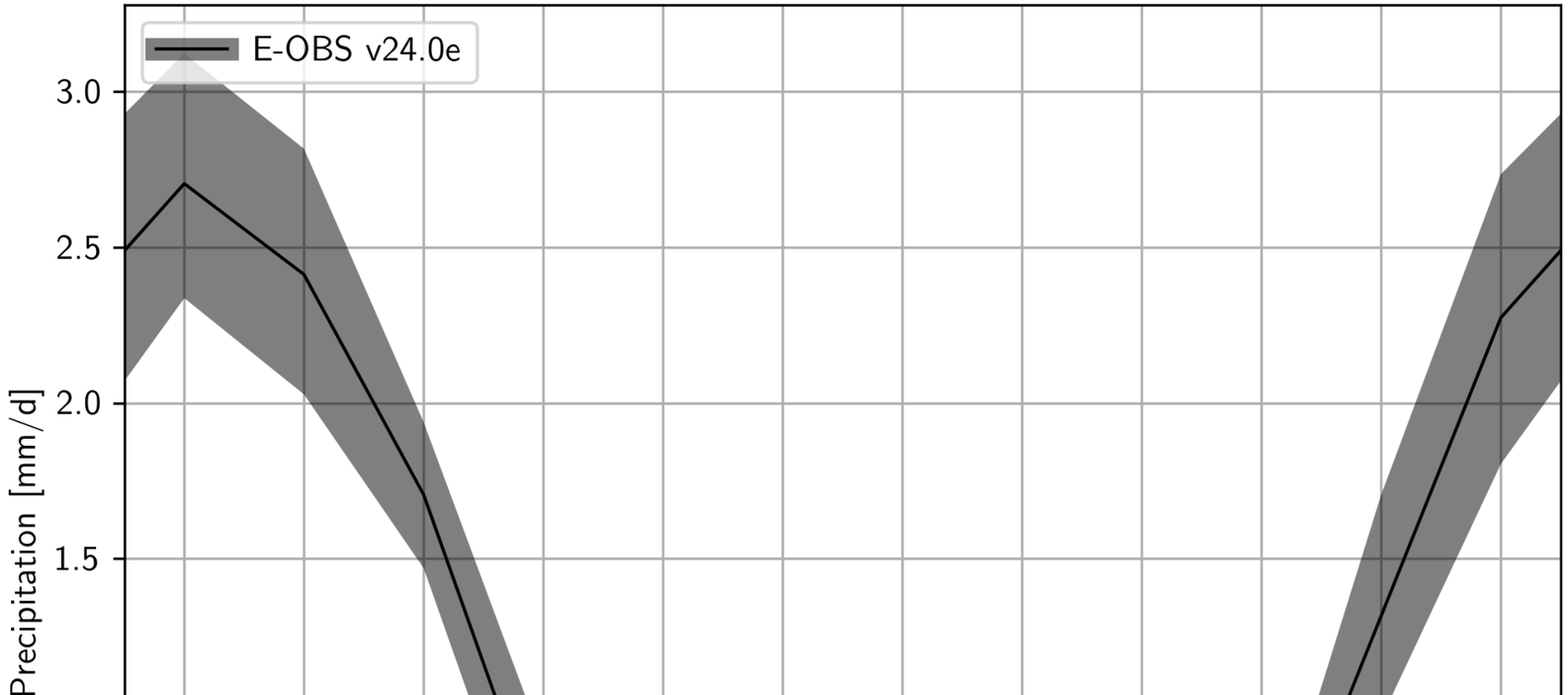
TEMPERATURE CLIMATOLOGY

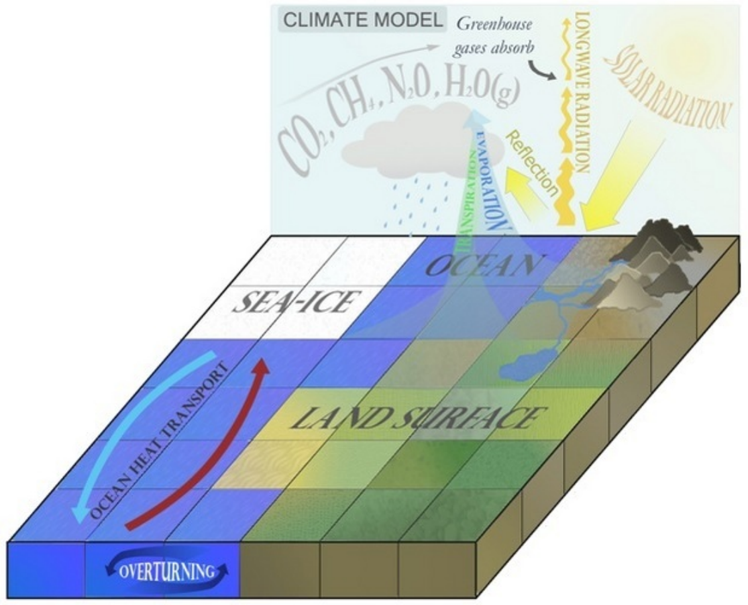


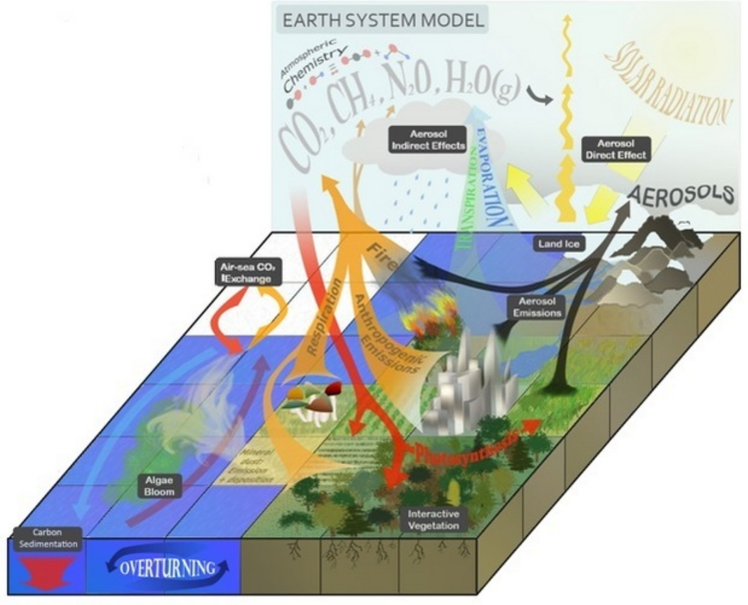


PRECIPITATION CLIMATOLOGY

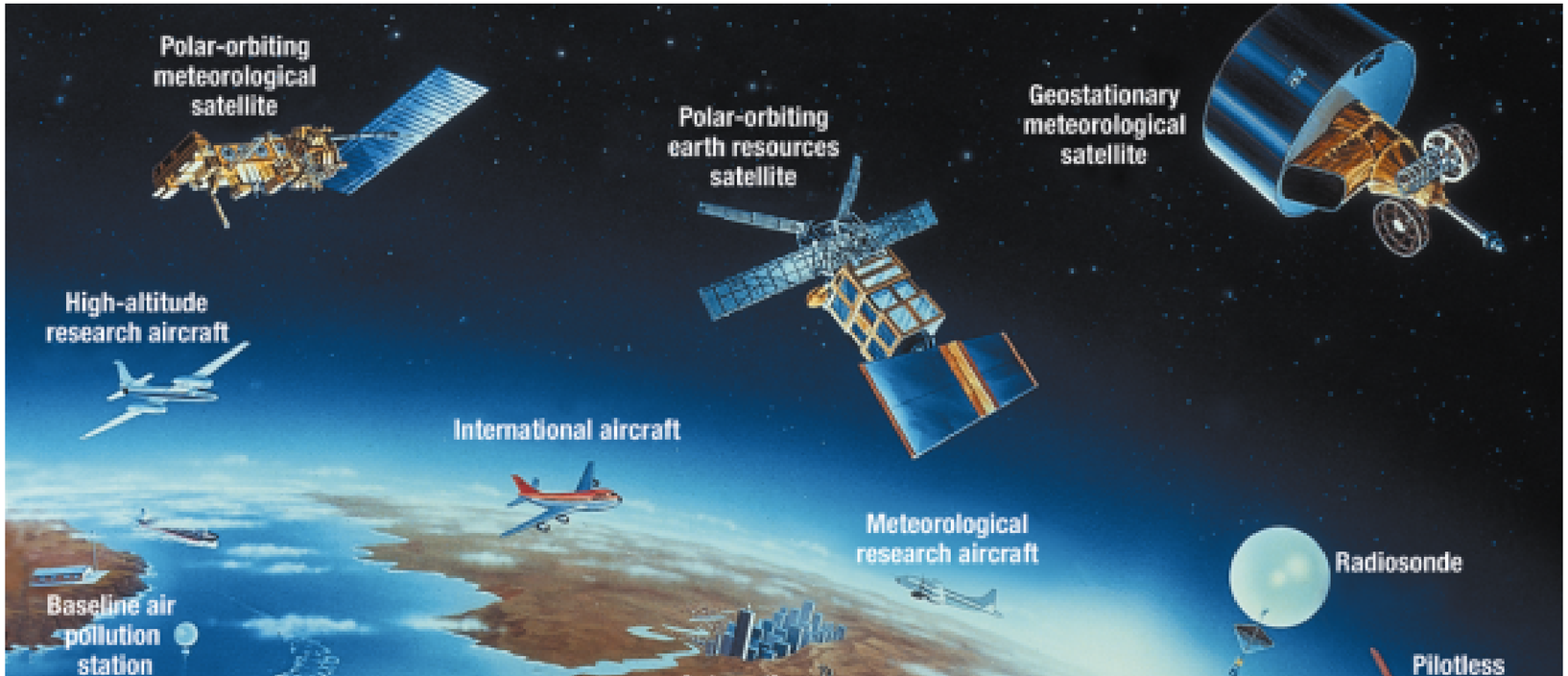





CLIMATE MODEL
Greenhouse gases absorb
$CO_2, CH_4, N_2O, H_2O(g)$
LONGWAVE RADIATION
SOLAR RADIATION
Reflection
EVAPORATION
TRANSPIRATION
OCEAN
SEA-ICE
LAND SURFACE
OCEAN HEAT TRANSPORT
OVERTURNING

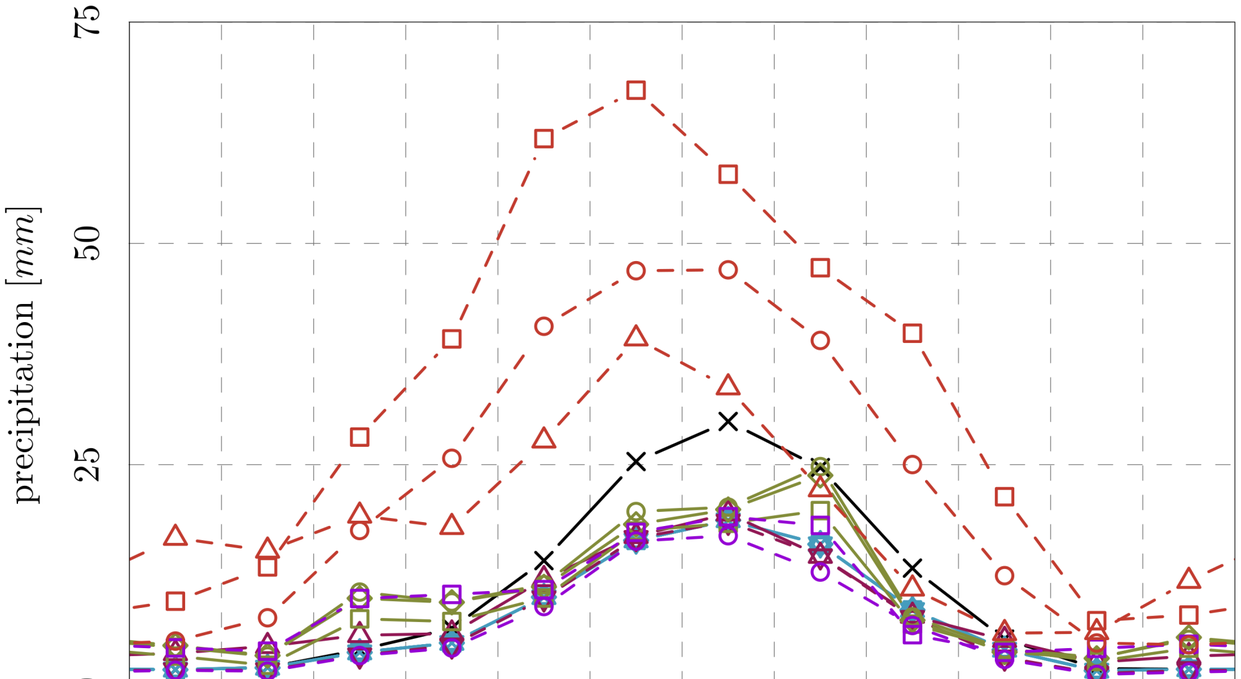

EARTH SYSTEM MODEL
Atmospheric Chemistry
$CO_2, CH_4, N_2O, H_2O(g)$
SOLAR RADIATION
Aerosol Indirect Effects
Aerosol Direct Effect
EVAPORATION
TRANSPIRATION
AEROSOLS
Land Ice
Air-sea CO_2 Exchange
Fire
respiration
Anthropogenic Emissions
Aerosol Emissions
Photosynthesis
Algae Bloom
Interactive Vegetation
Carbon Sedimentation
OVERTURNING

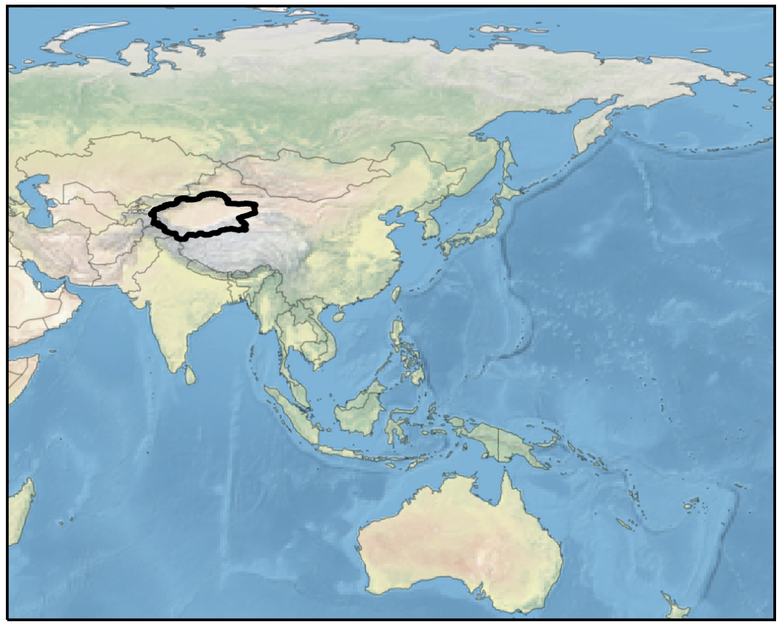
OBSERVATION DATA



OBSERVATION VS. REFERENCE DATASET

Tarim Basin



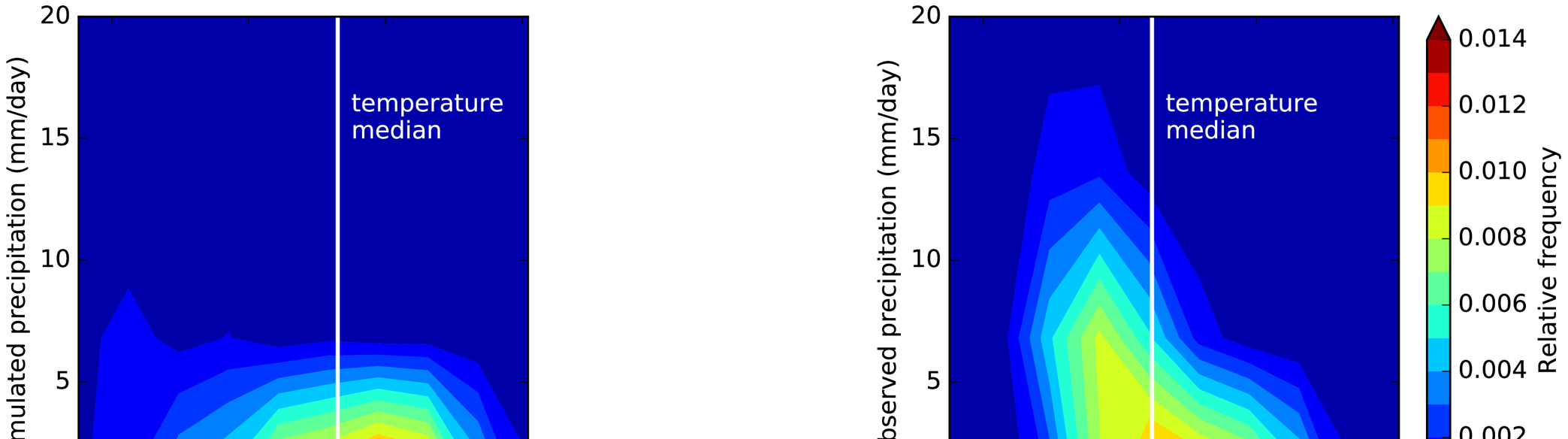


MULTIVARIATE BIAS ADJUSTMENT

- Physical/Statistical dependencies between variables ignored so far (only univariate distributions adjusted)
- How can we adjust multivariate distributions:
  - Conditional quantile mapping for single bins (Piani and Haerter, 2012)
  - Random rotations of variable-vector combined with univariate quantile mapping (Cannon, 2017)

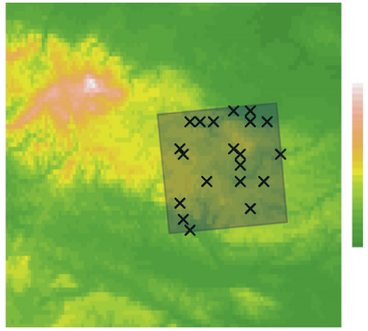
Simulation

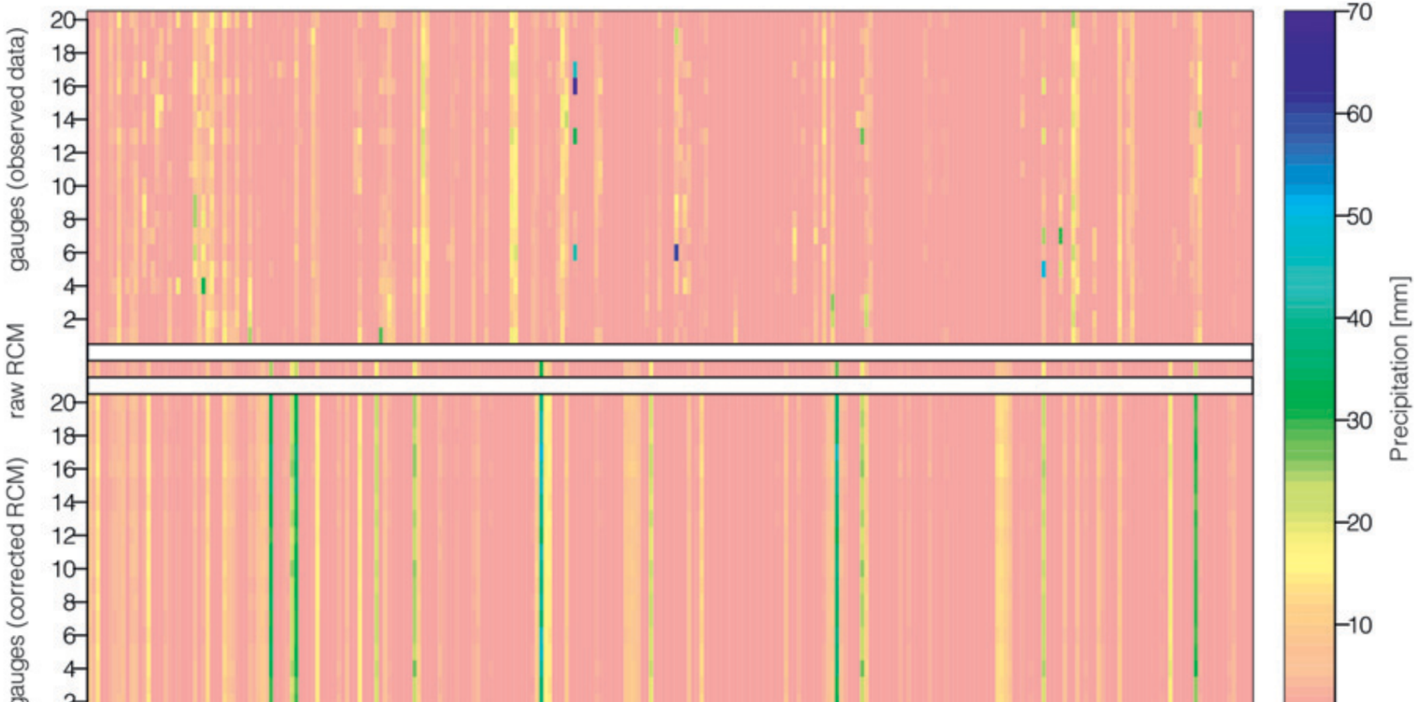
Observation



VARIANCE INFLATION

- Bias adjustment $\neq$ downscaling (Maraun, 2013)
- Bias adjustment can lead to **variance inflation** in case of large scale gaps
- Former local extremes are transfered to every station within a grid cell





FURTHER ISSUES

- Statistical adjustment **NO** physical reasoning
- We assume that $g(x_{\mathrm{sim}})$ does **not change in time**
- Seperate bias adjustement for different season, month or day of year might be necessary
- Bias adjustment can change temporal structure of timeseries on different scales
  - Naive QM can distort climate trend
- Bias adjustment using conditional resampling of huge ensemble (Sippel et al., 2017)

HOW TO CHOOSE A SUITABLE BIAS ADJUSTMENT?

- Which biases and how large (data exploration)?
- What is important in your impact assessment (goal exploration)?