



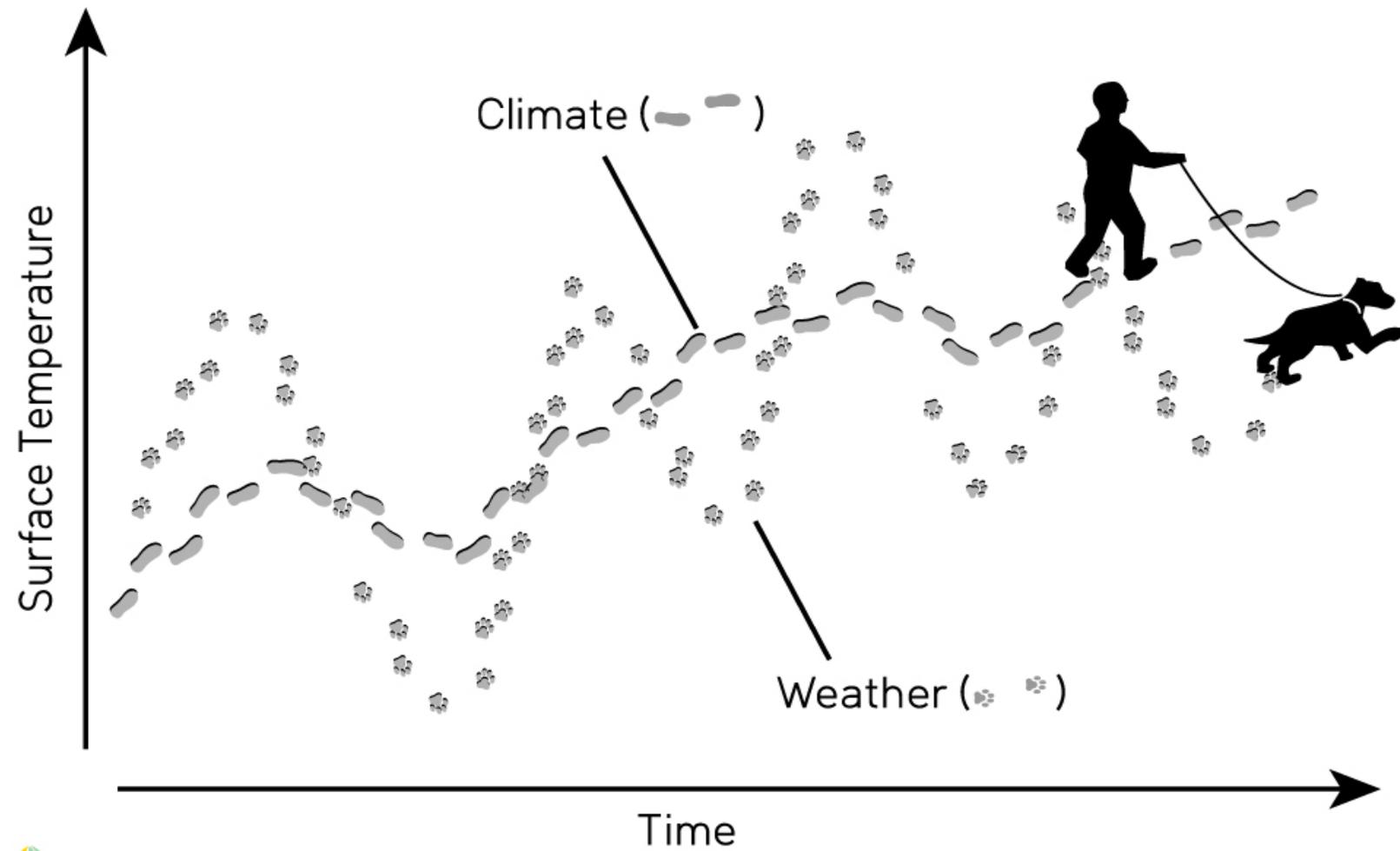
Climate Change in Central Asia

Dr. Bijan Fallah





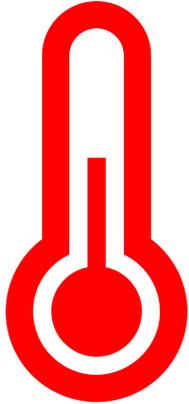
What is Climate?

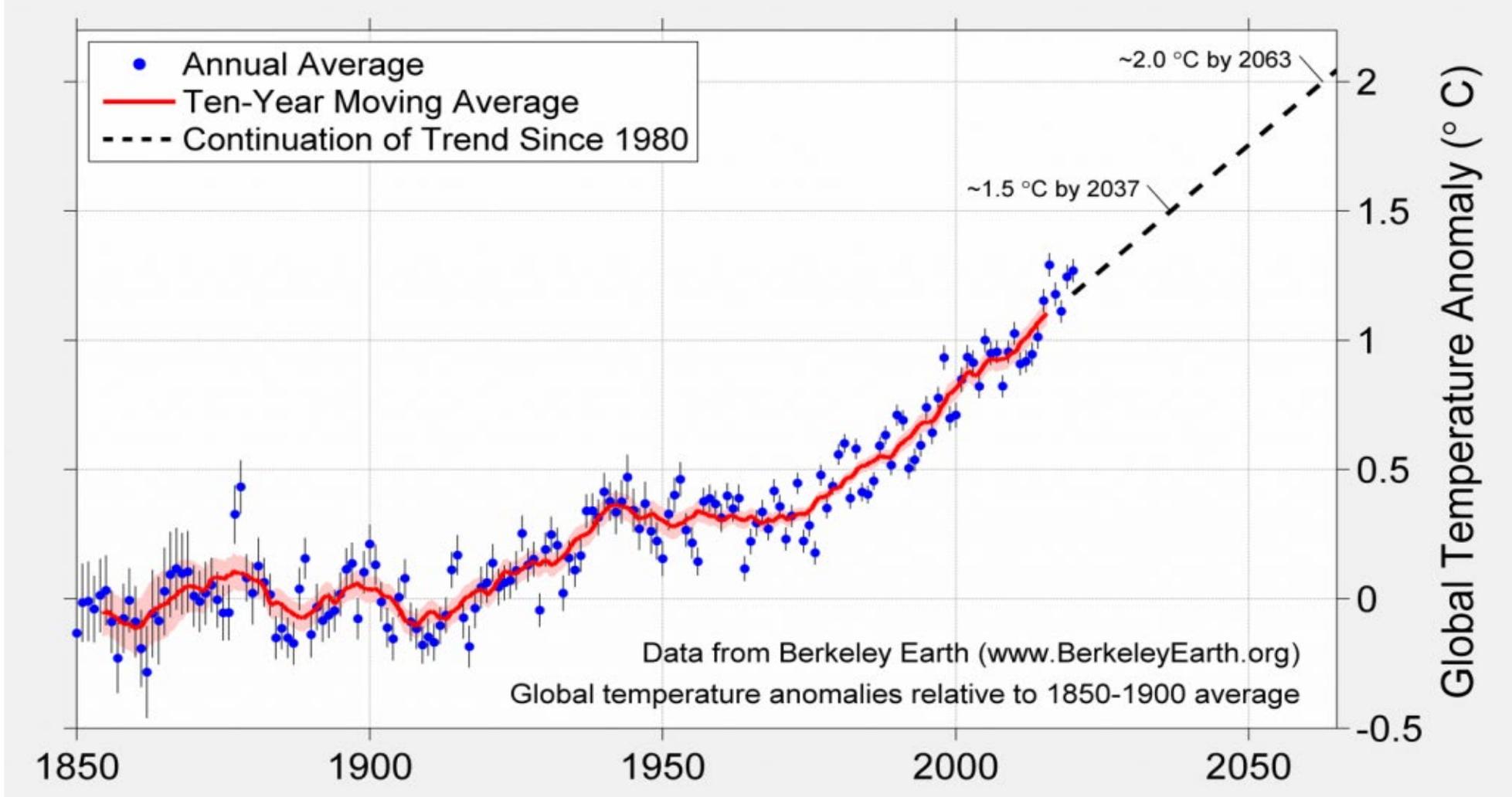


Redrawn from TeddyTVNorge, <https://www.youtube.com/watch?v=e0vj-0imOLw>

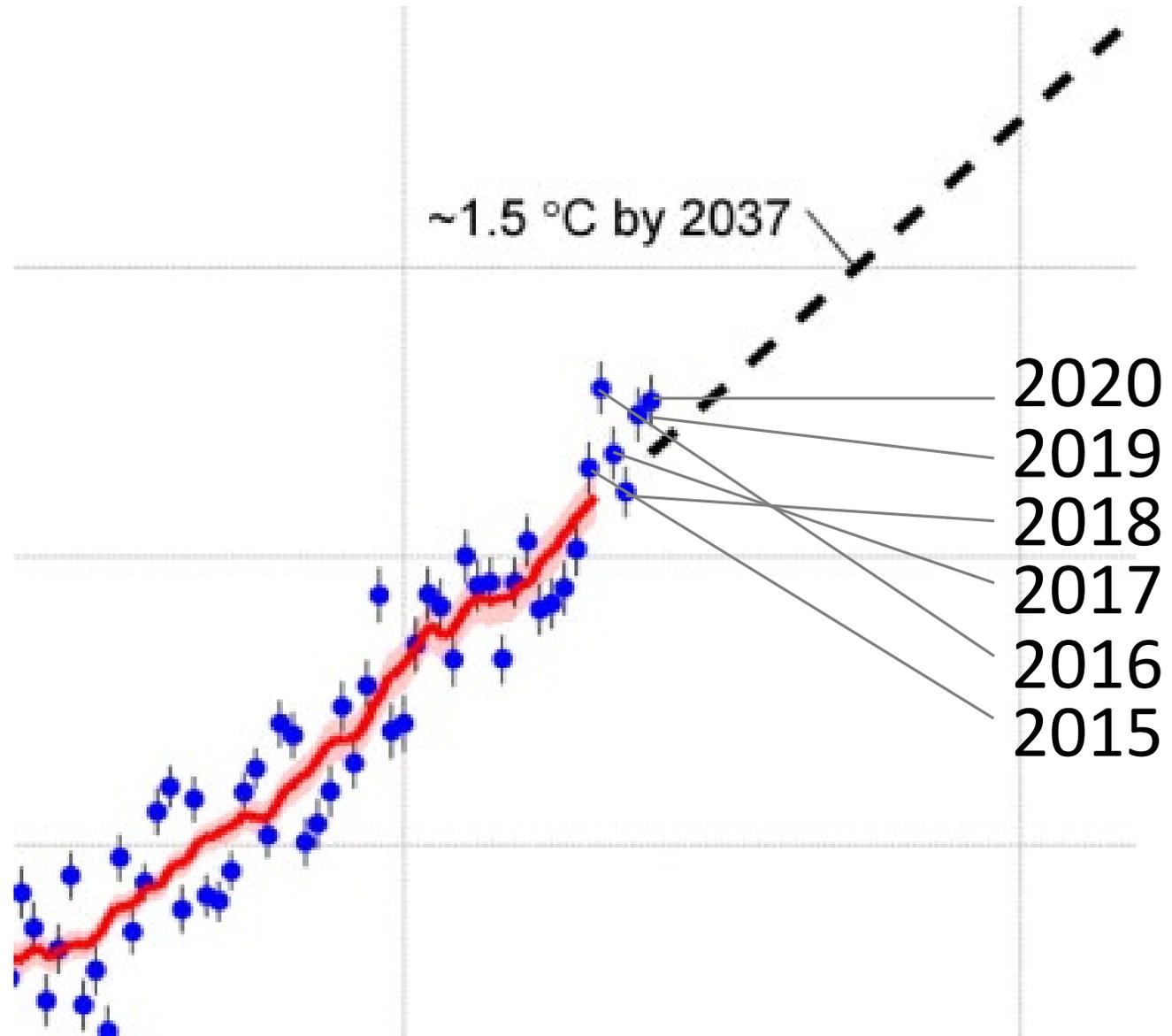


How do we feel the climate change?



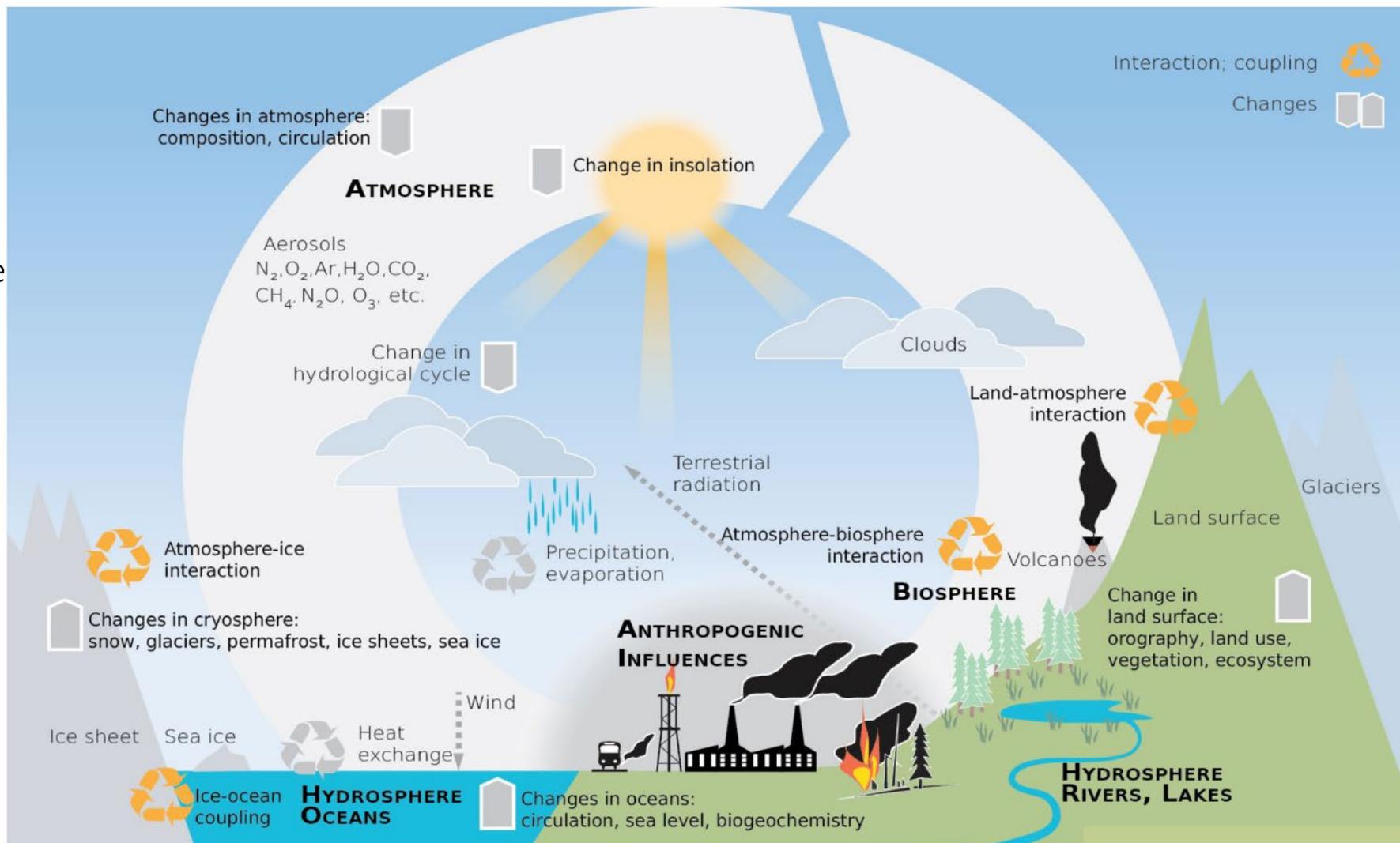


Data from Berkeley Earth (www.BerkeleyEarth.org)
Global temperature anomalies relative to 1850-1900 average

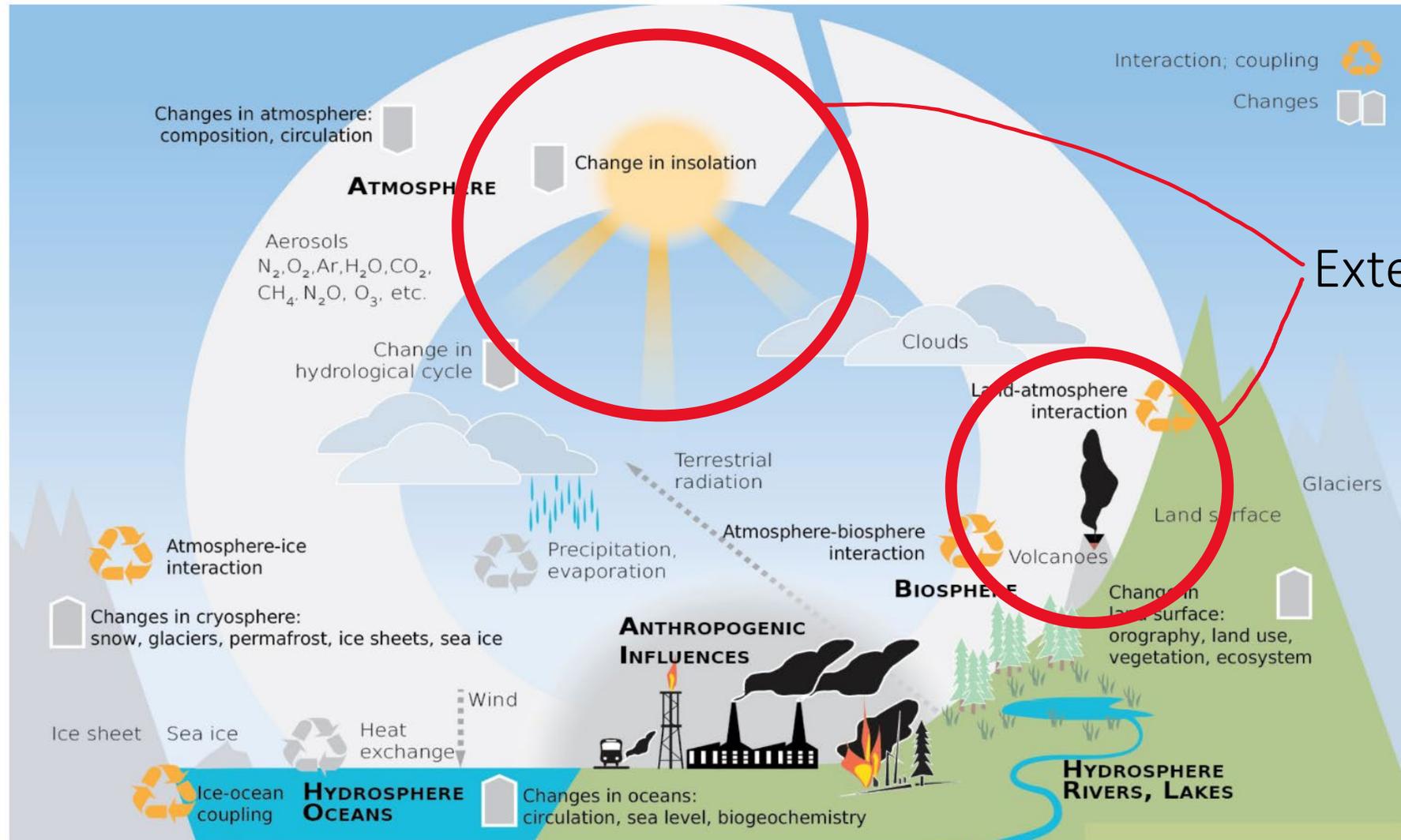


5 Components of the Earth Climate System

- 1- Atmosphere
- 2- Hydrosphere
- 3- Cryosphere
- 4- Lithosphere
- 5- Biosphere



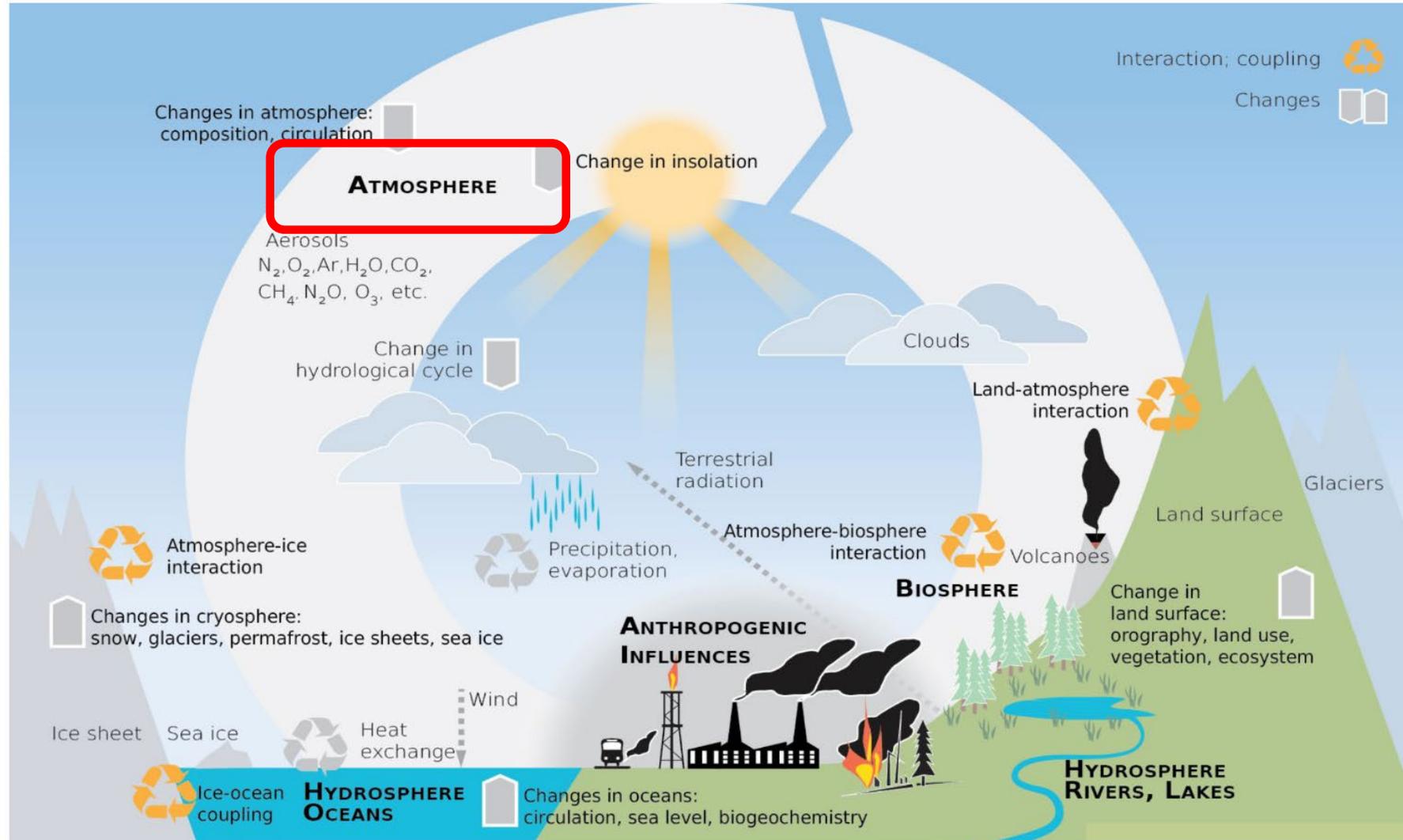
5 Components of the Earth Climate System



External Forcings

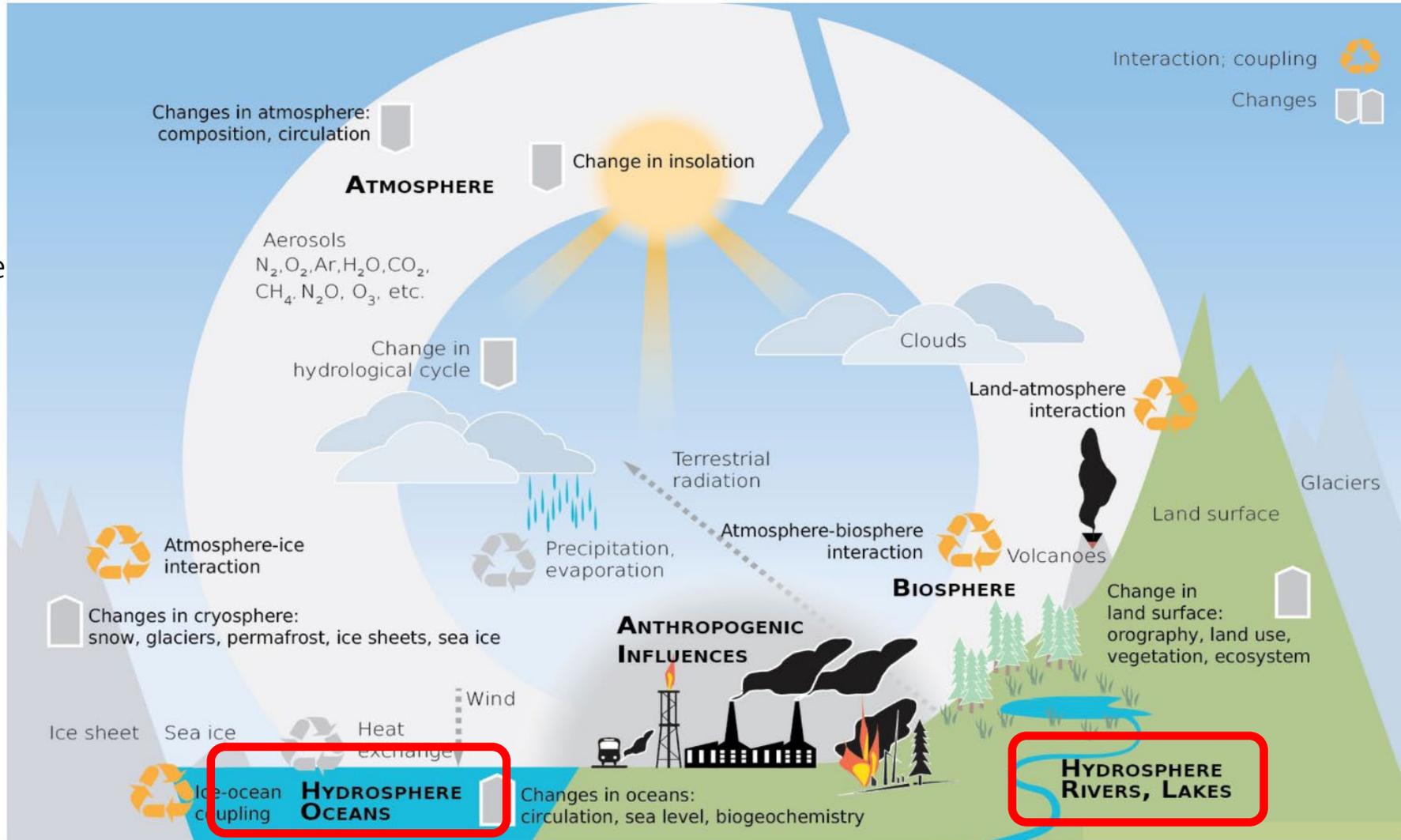
5 Components of the Earth Climate System

1- Atmosphere



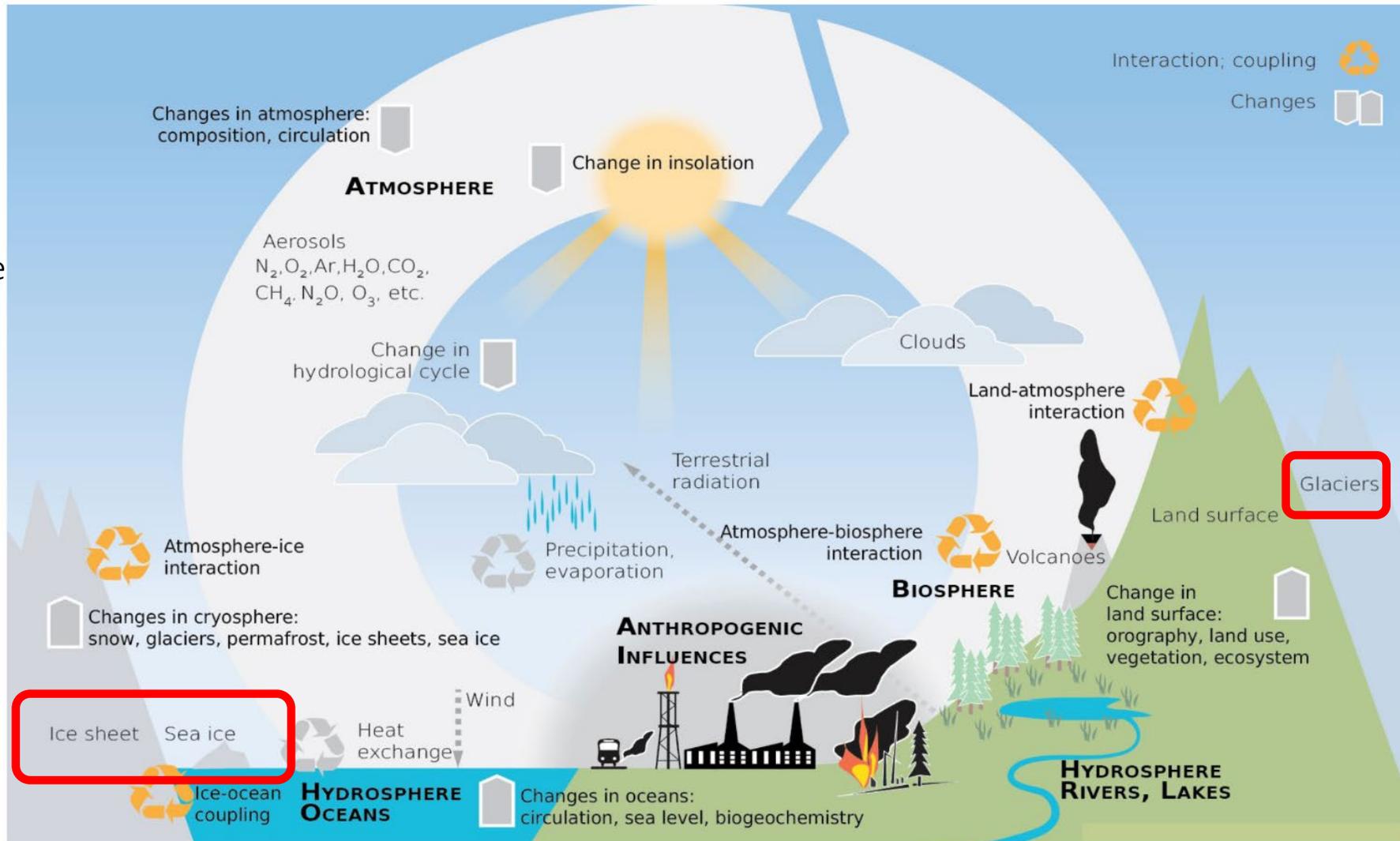
5 Components of the Earth Climate System

- 1- Atmosphere
- 2- Hydrosphere



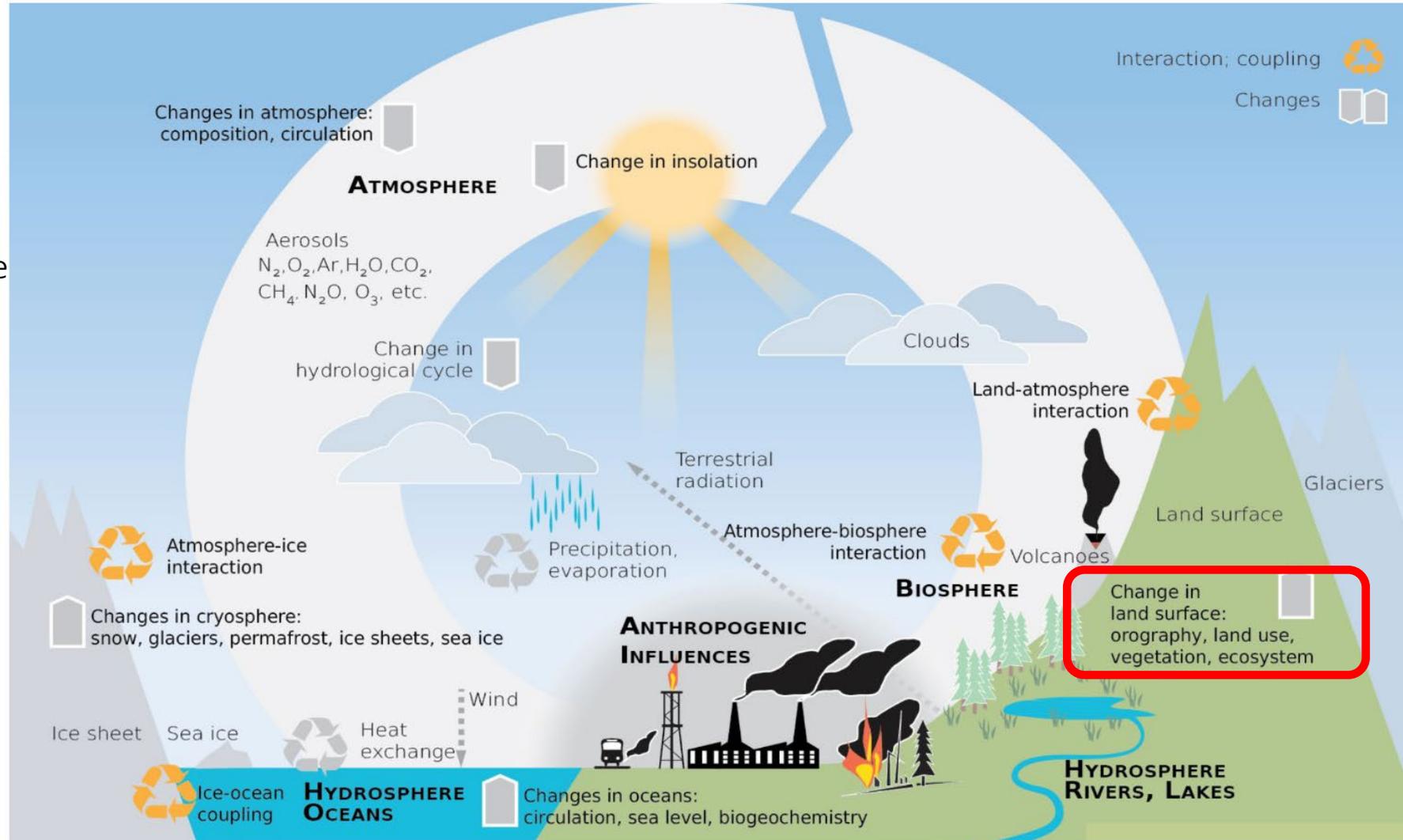
5 Components of the Earth Climate System

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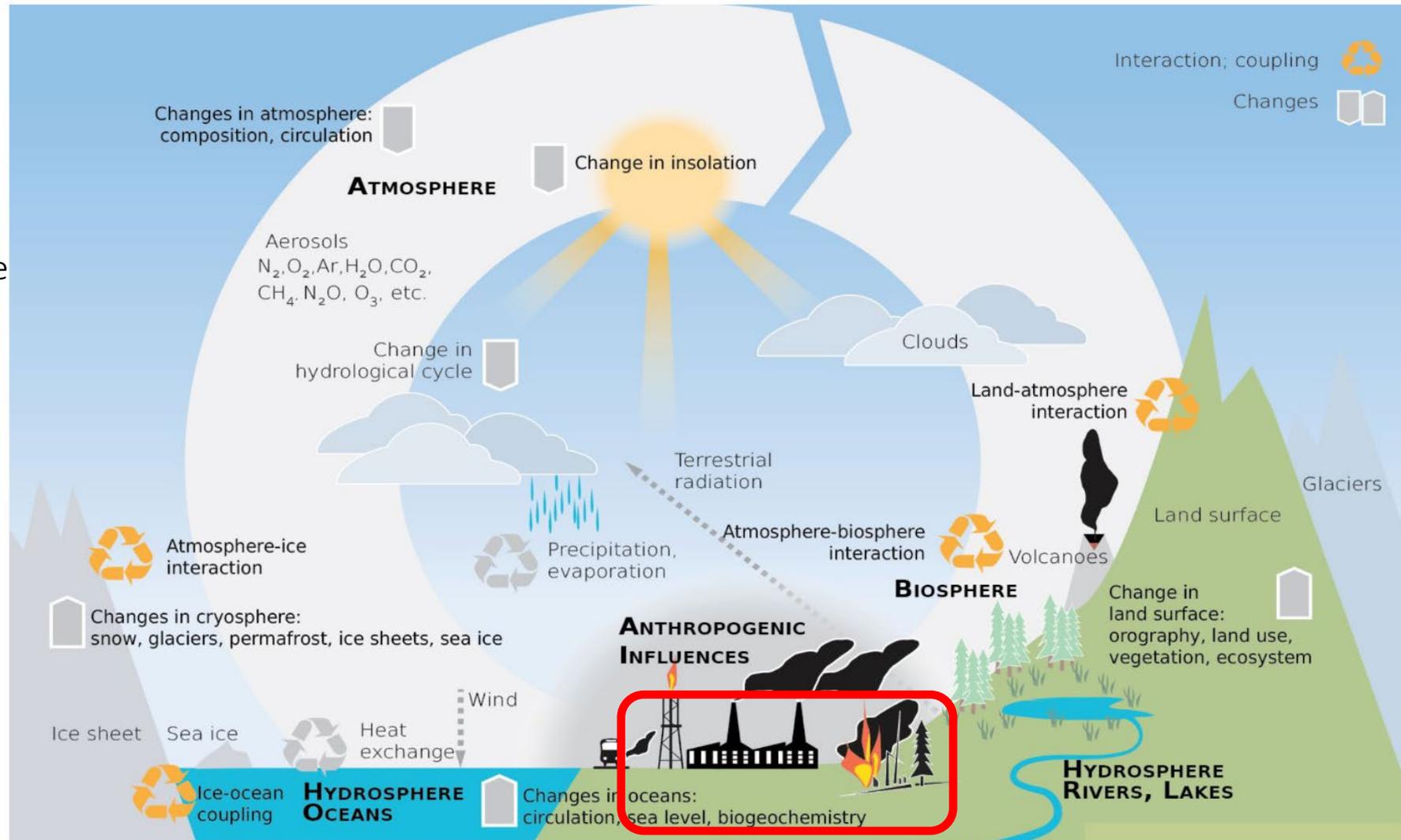
5 Components of the Earth Climate System

- 1- Atmosphere
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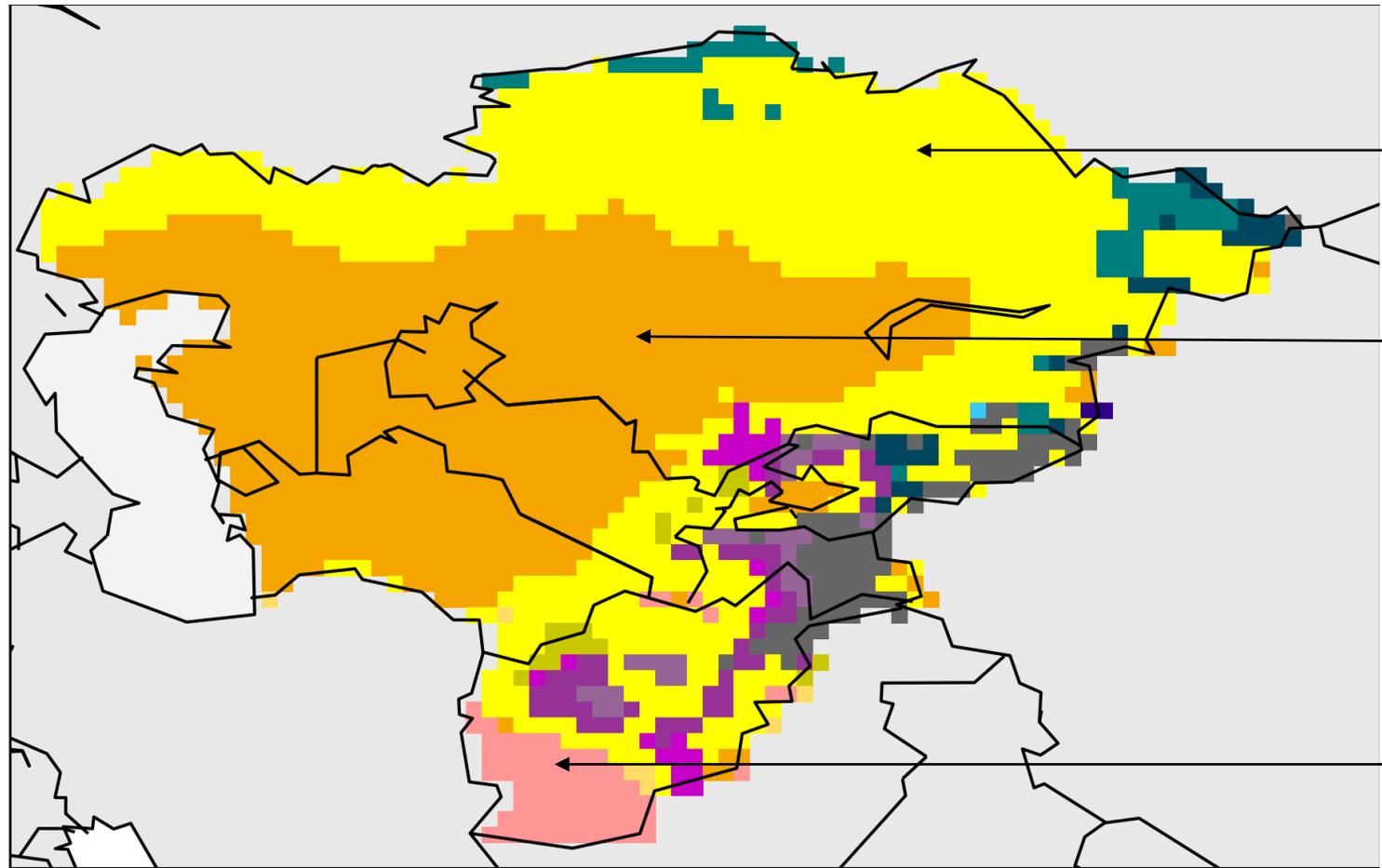


5 Components of the Earth Climate System

- 1- Atmosphere
- 2- Hydrosphere
- 3- Cryosphere
- 4- Lithosphere
- 5- Biosphere



Köppen Climate Classification



Csa : temperate dry hot summer

BSh : arid hot steppe

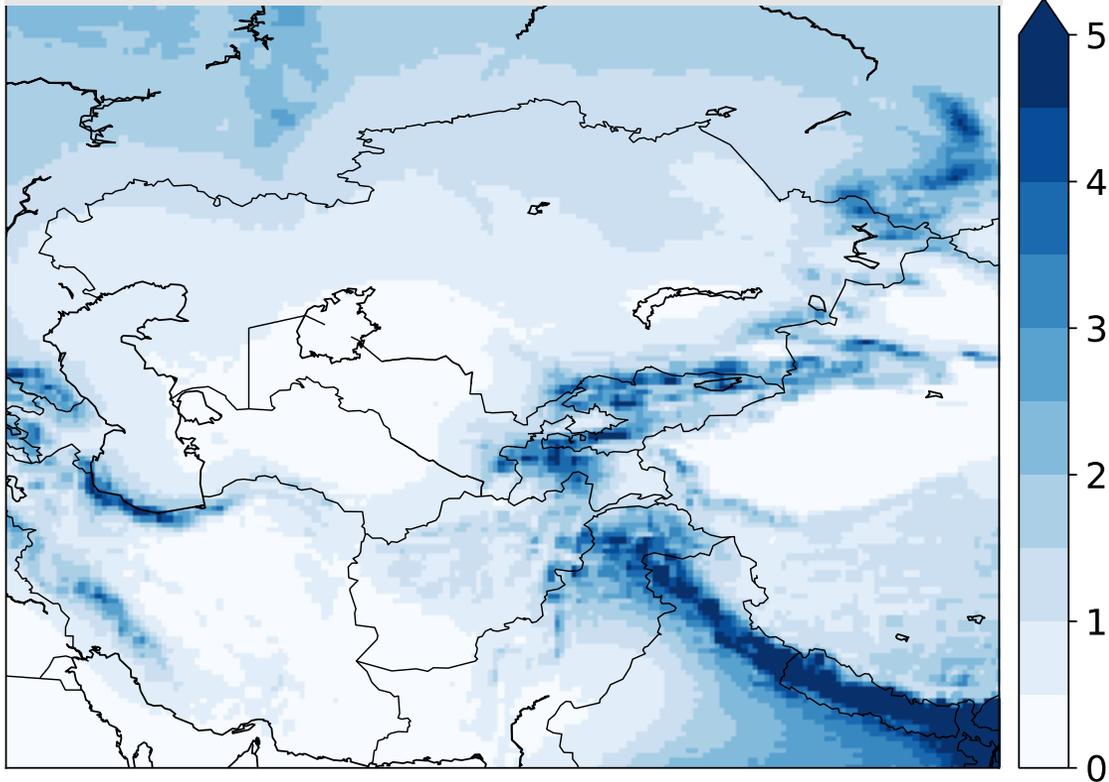
BWk: arid cold desert

 Am	 BSh	 Cwb	 Dsc	 Dfb
 Aw	 BSk	 Cfa	 Dwb	 Dfc
 BWh	 Csa	 Dsa	 Dwc	 ET
 BWk	 Cwa	 Dsb	 Dfa	 EF

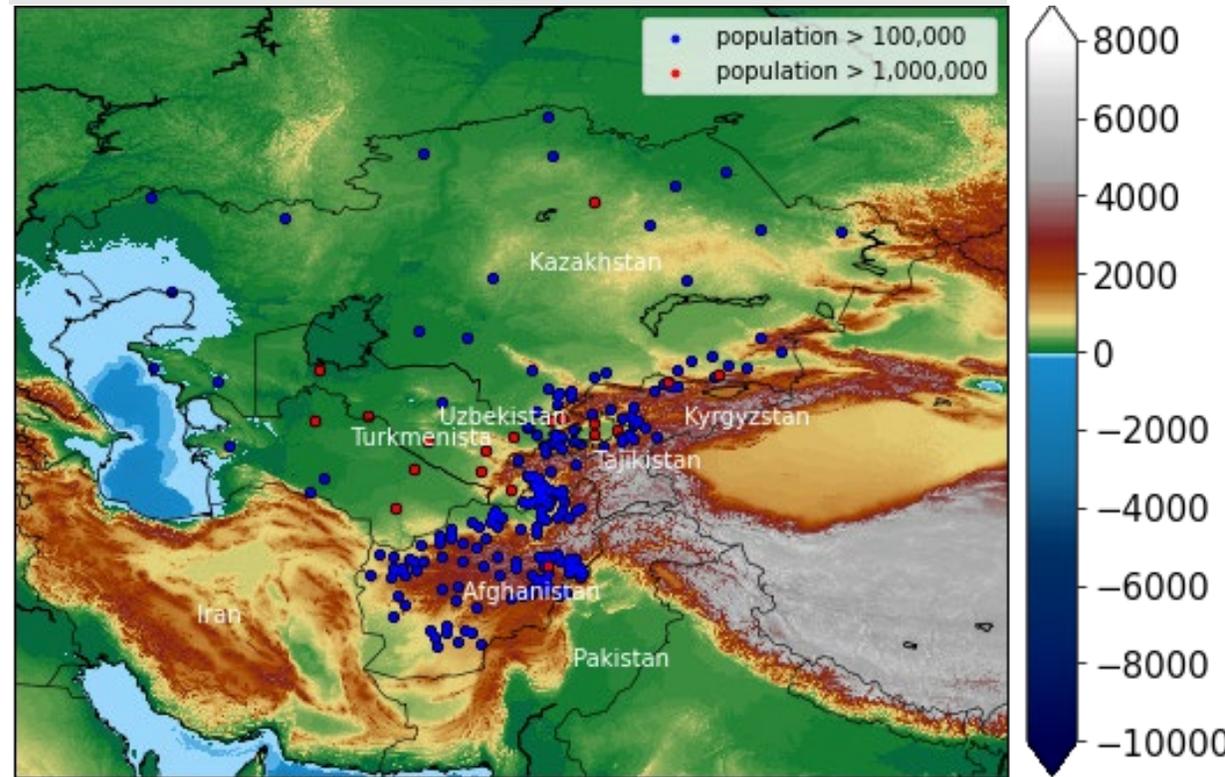
source: Bijan Fallah

Central Asian Climate

Annual Precipitation mm/day (1990-2020)

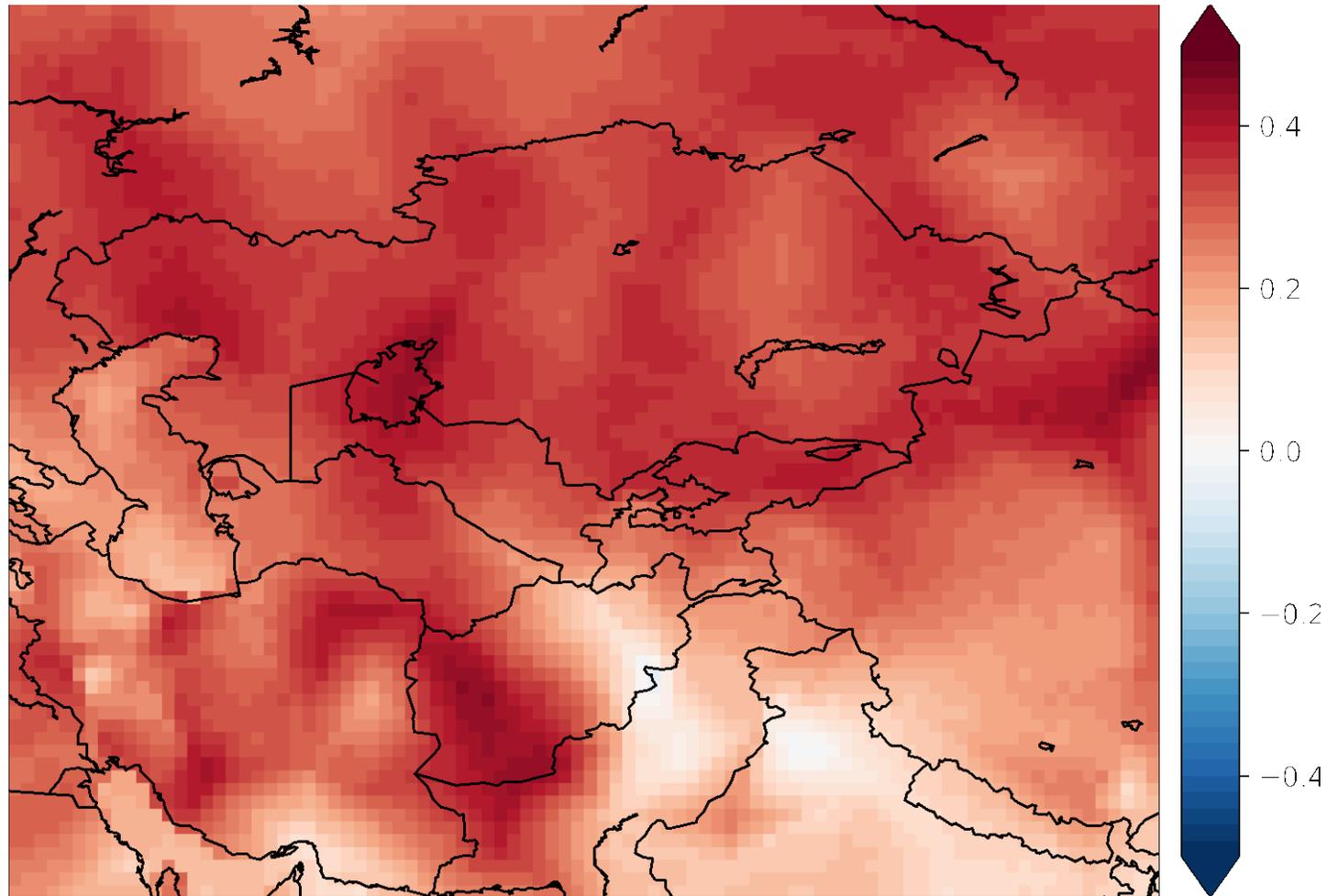


Topography and Population



source: Bijan Fallah

Temperature Trend

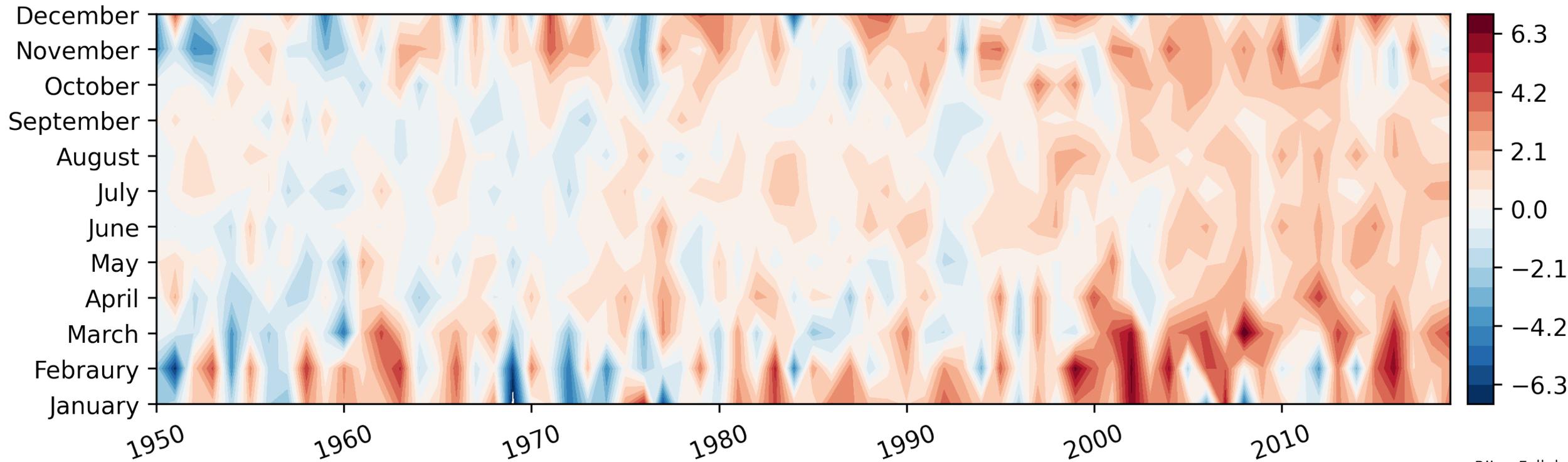


K / decade

source: Bijan Fallah

Temperature Change

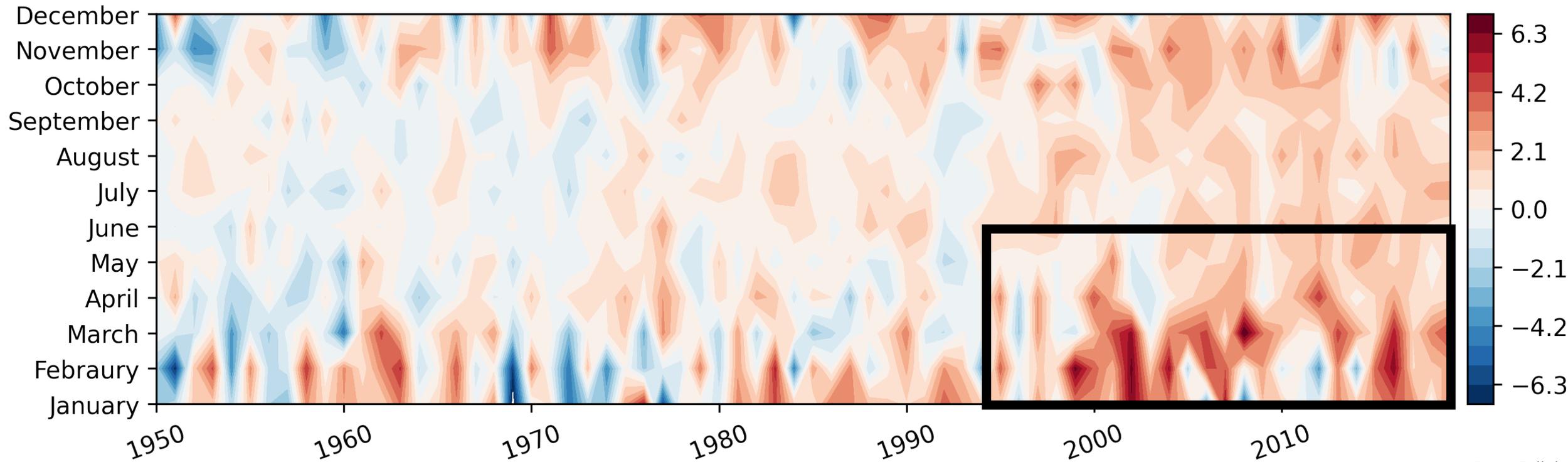
w.r.t. 1950-1979



source: Bijan Fallah

Temperature Change

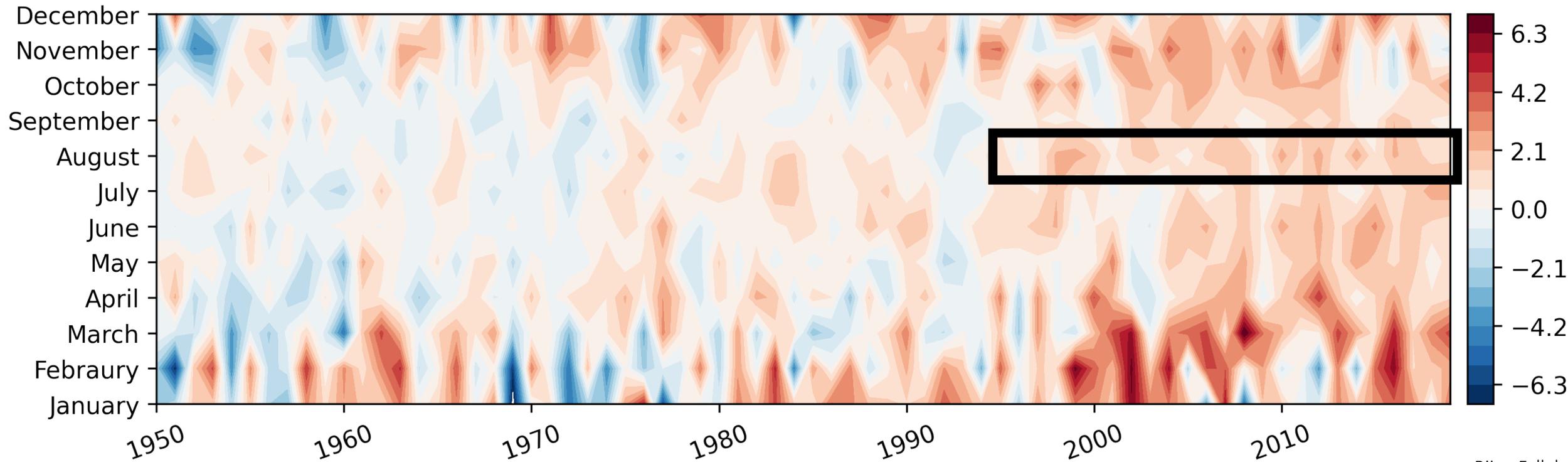
w.r.t. 1950-1979



source: Bijan Fallah

Temperature Change

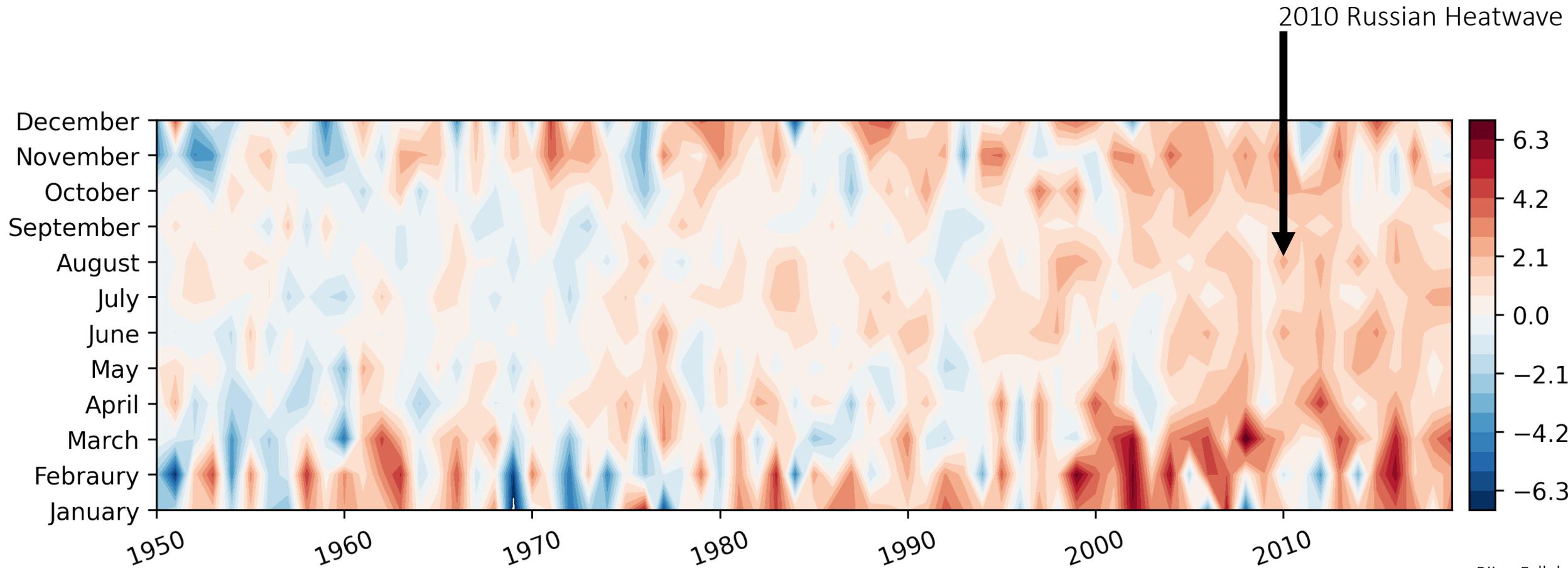
w.r.t. 1950-1979



source: Bijan Fallah

Temperature Change

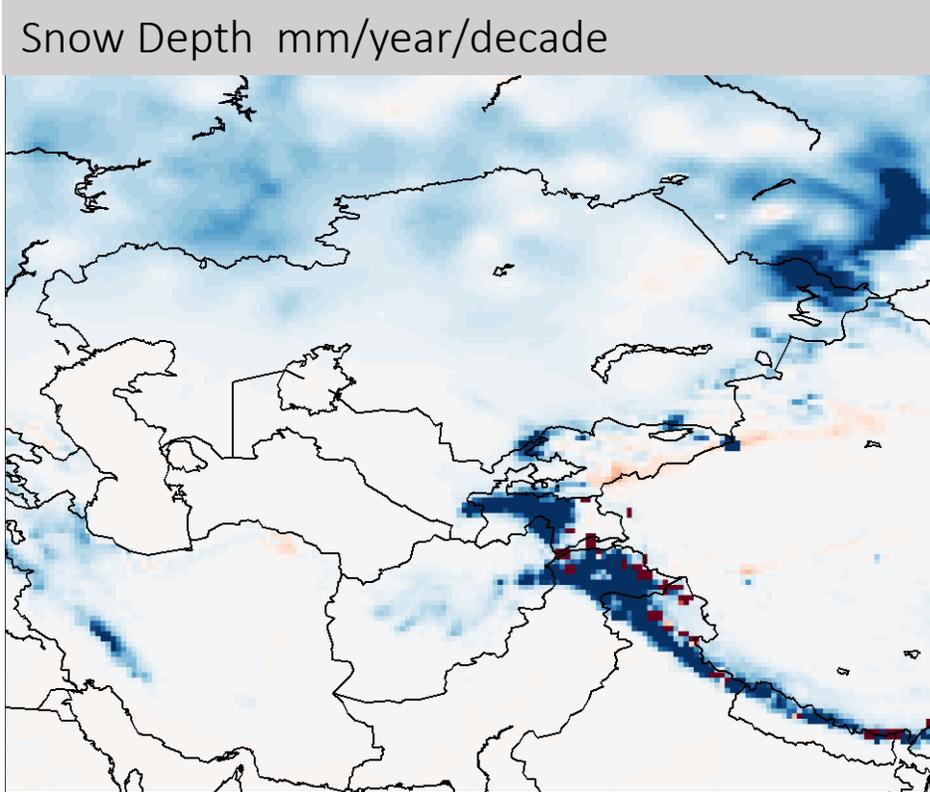
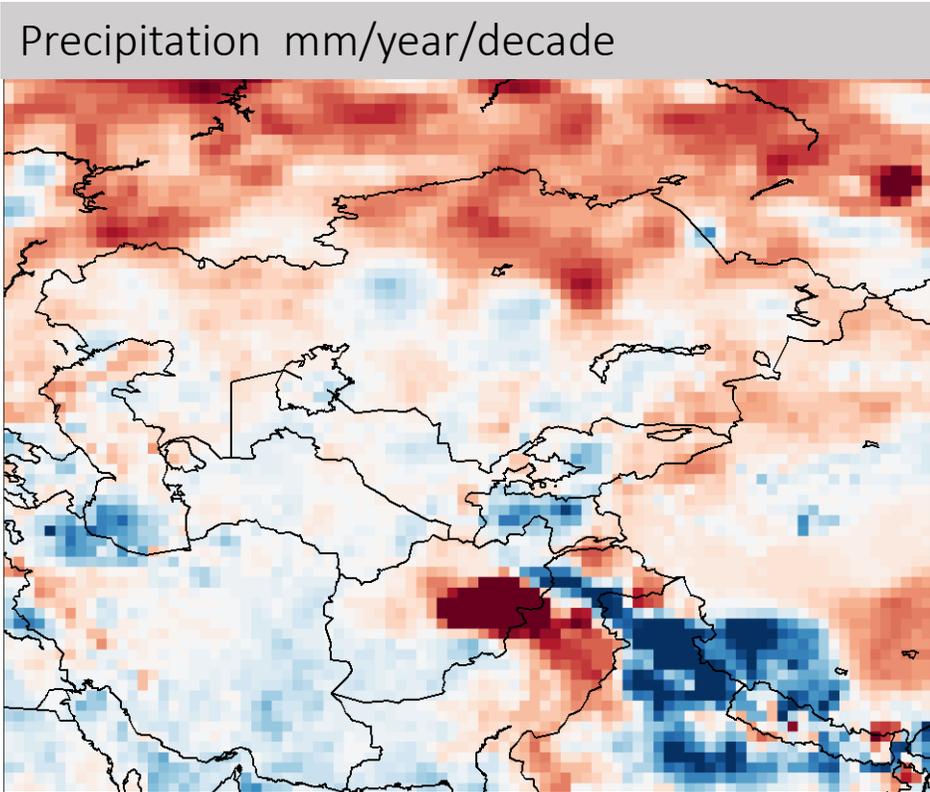
w.r.t. 1950-1979



source: Bijan Fallah



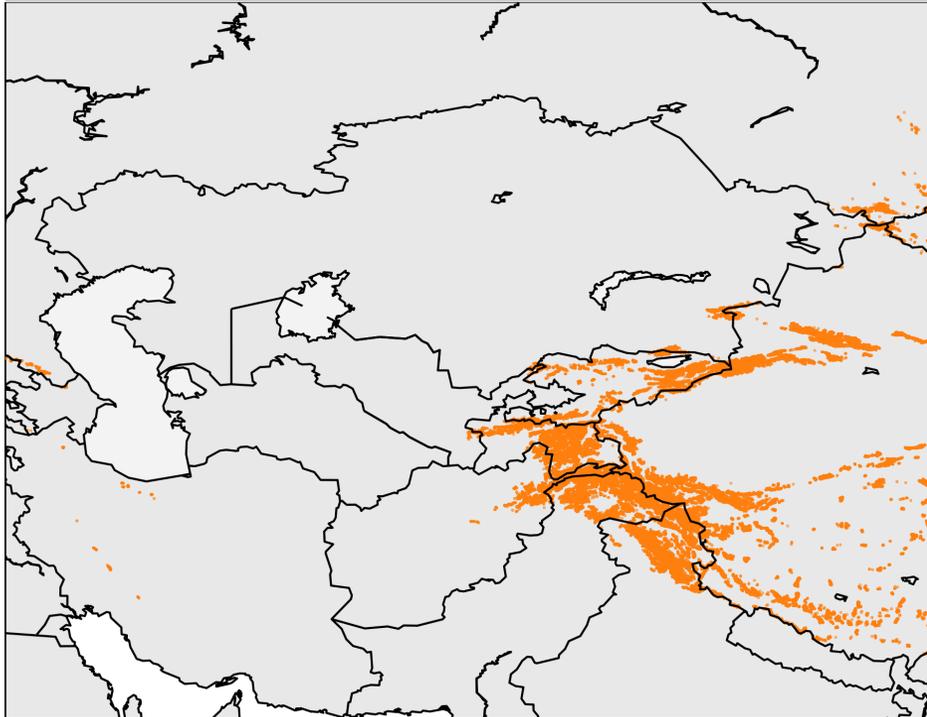
Climate Trends



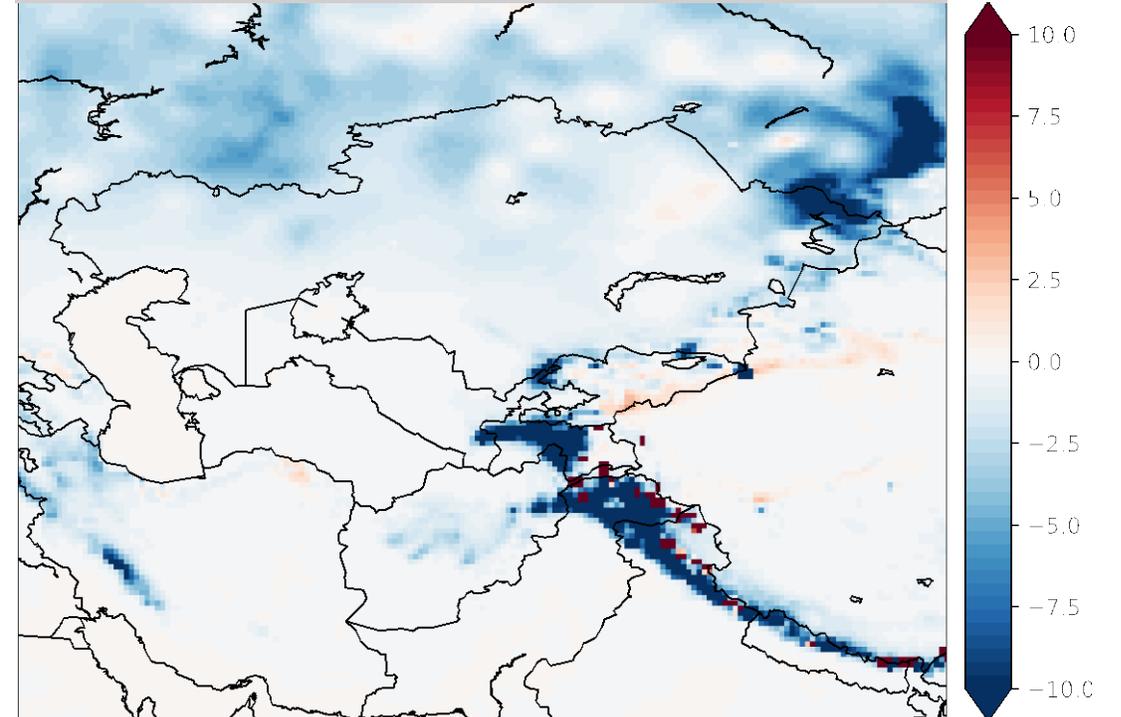
source: Bijan Fallah

Climate Trends

Location of Glaciers

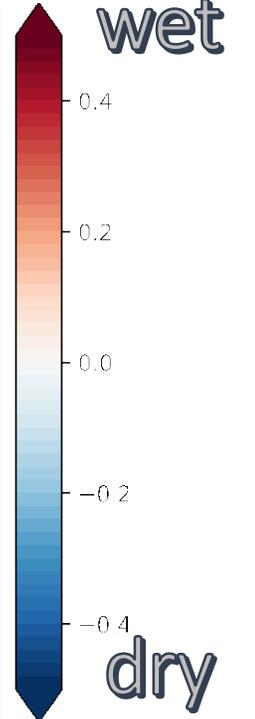
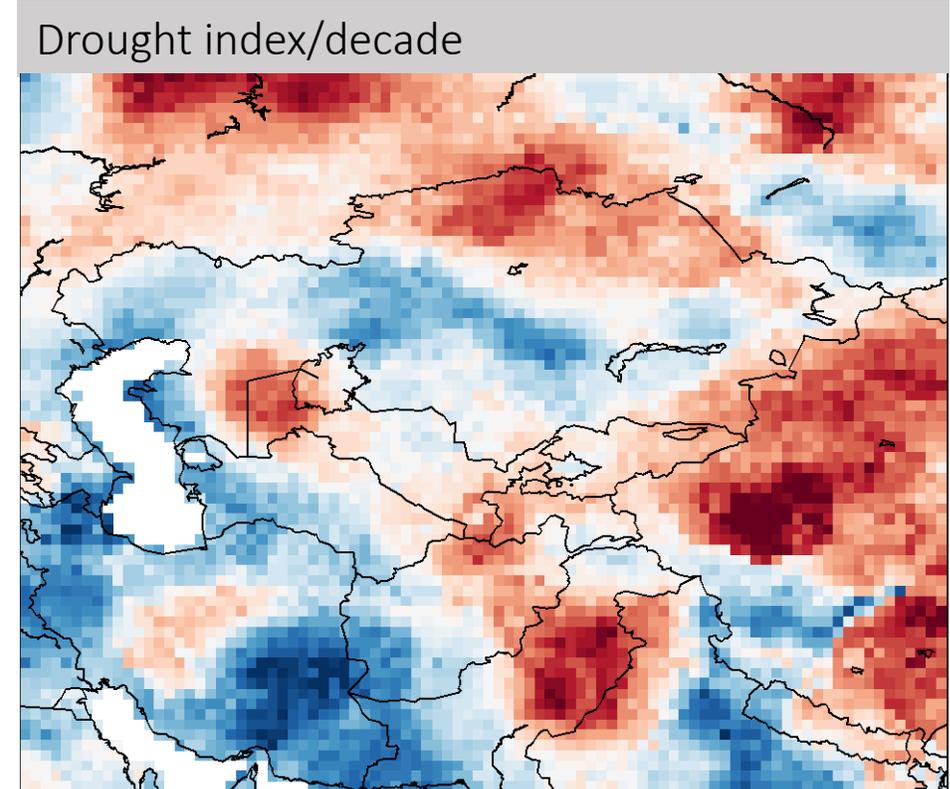
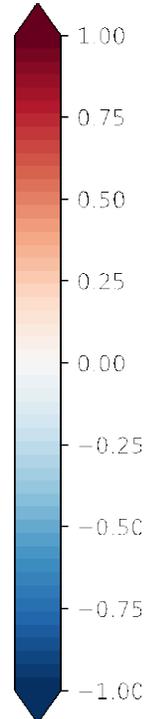
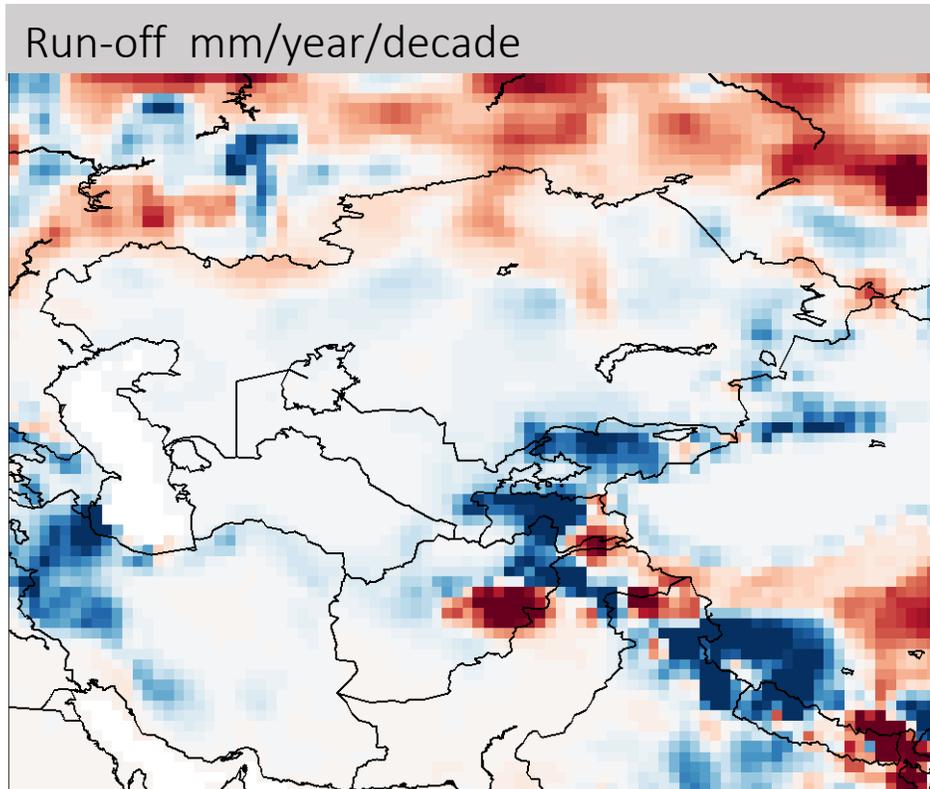


Snow Depth mm/year/decade



source: Bijan Fallah

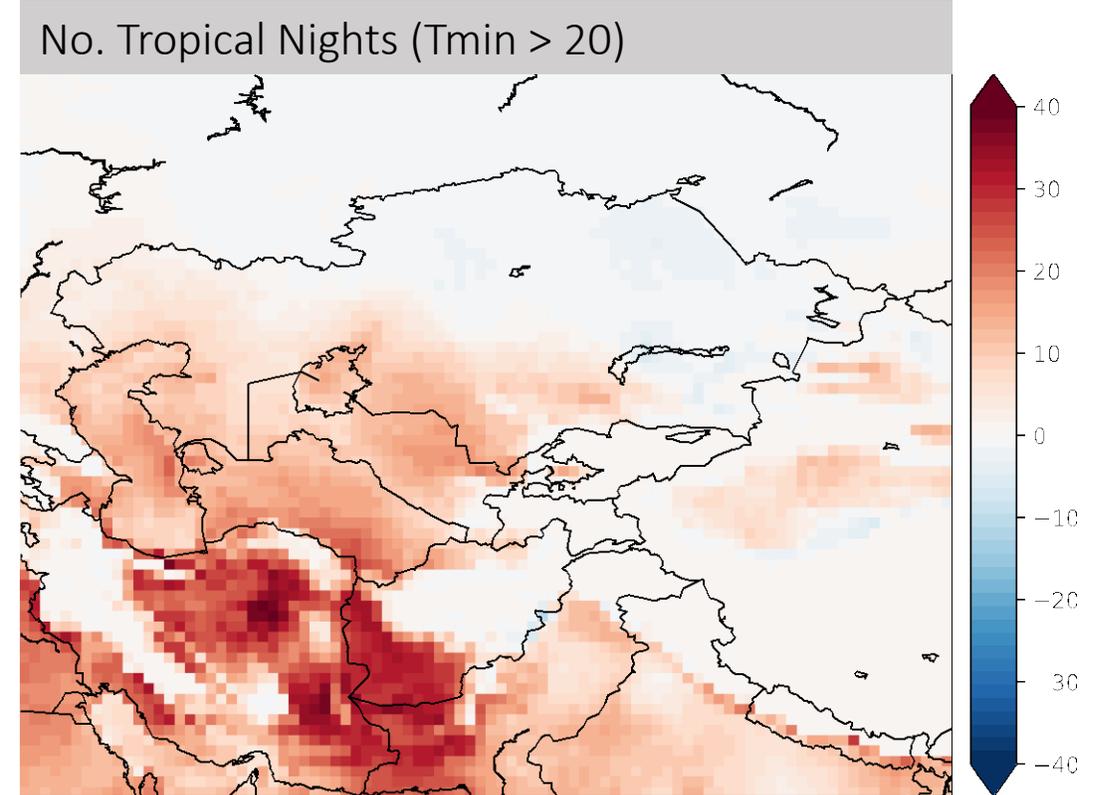
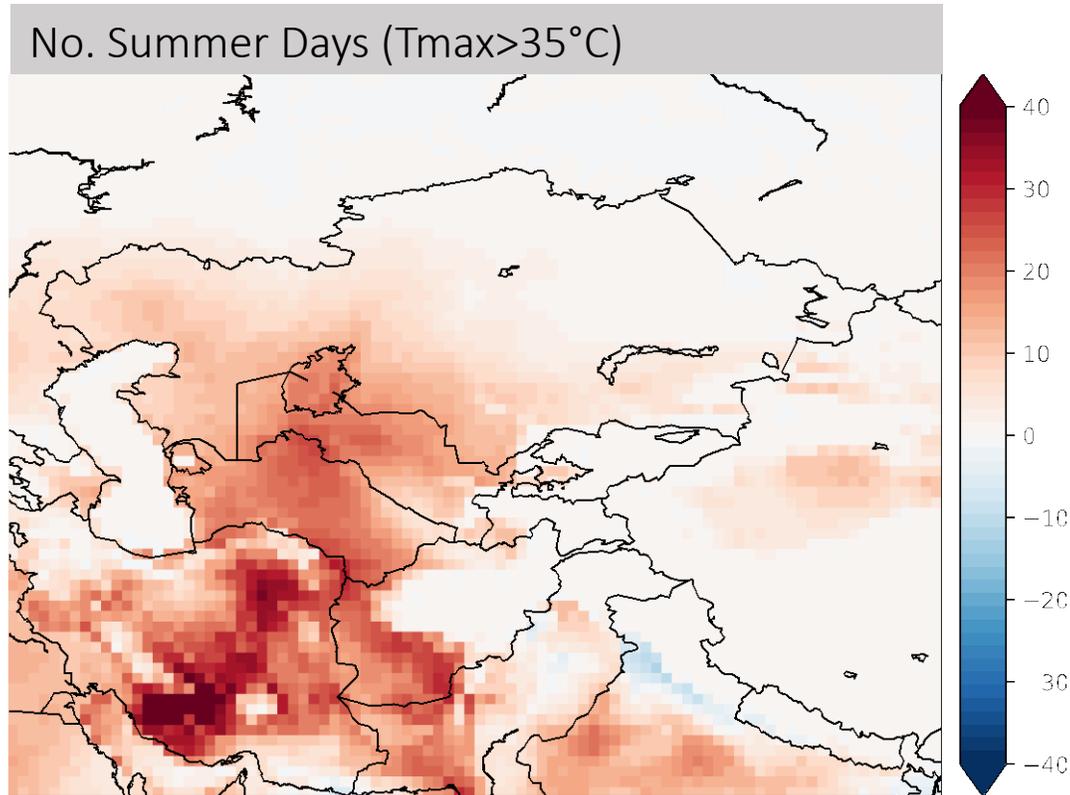
Climate Trends



source: Bijan Fallah

Climate Extremes

Difference : 1990-2019 minus 1950-1979

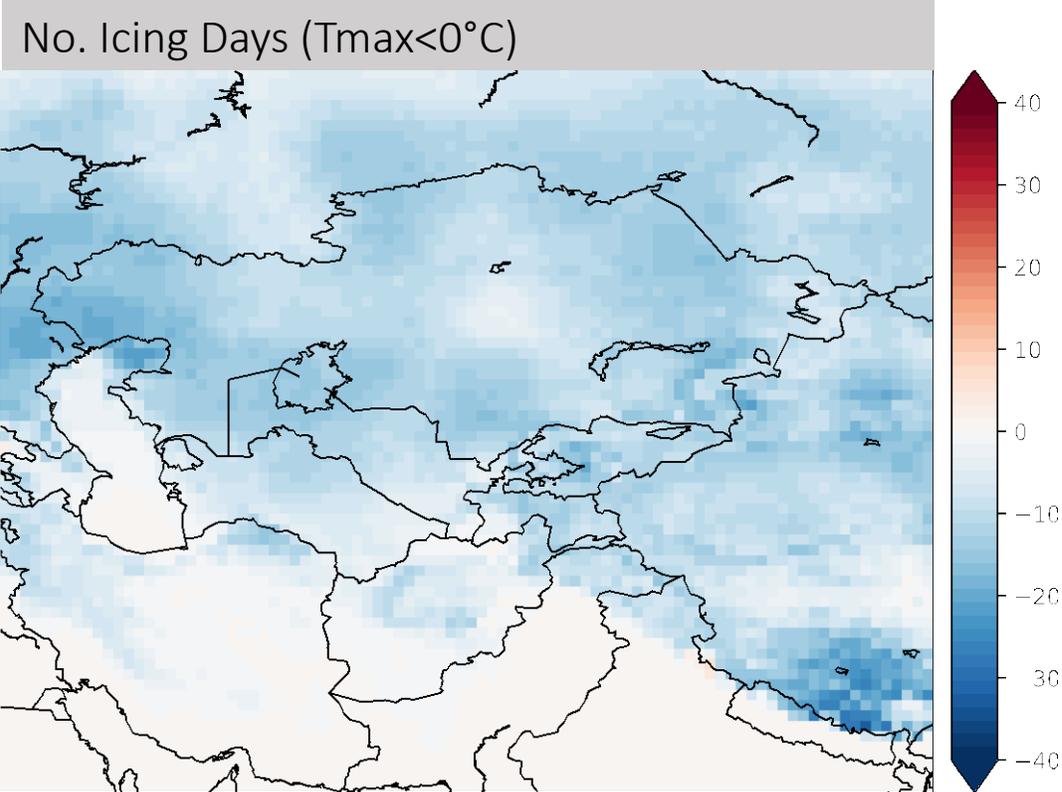
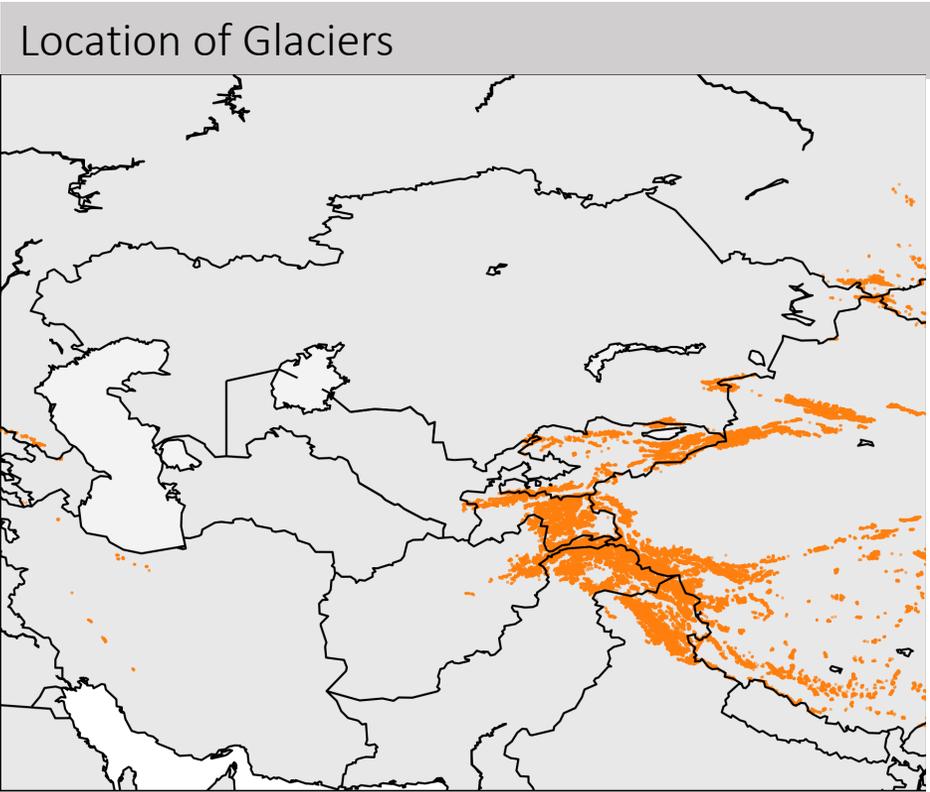


source: Bijan Fallah



Climate Extremes

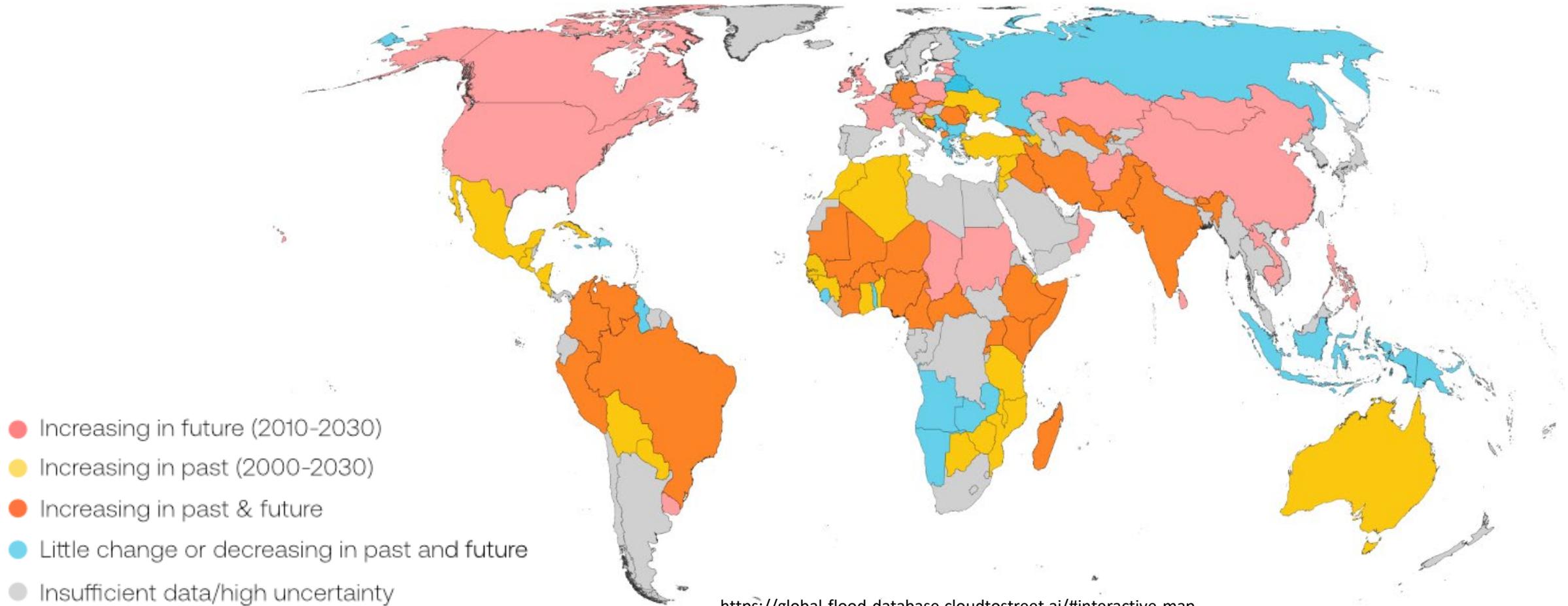
Difference : 1990-2019 minus 1950-1979



source: Bijan Fallah

Floods' Risk

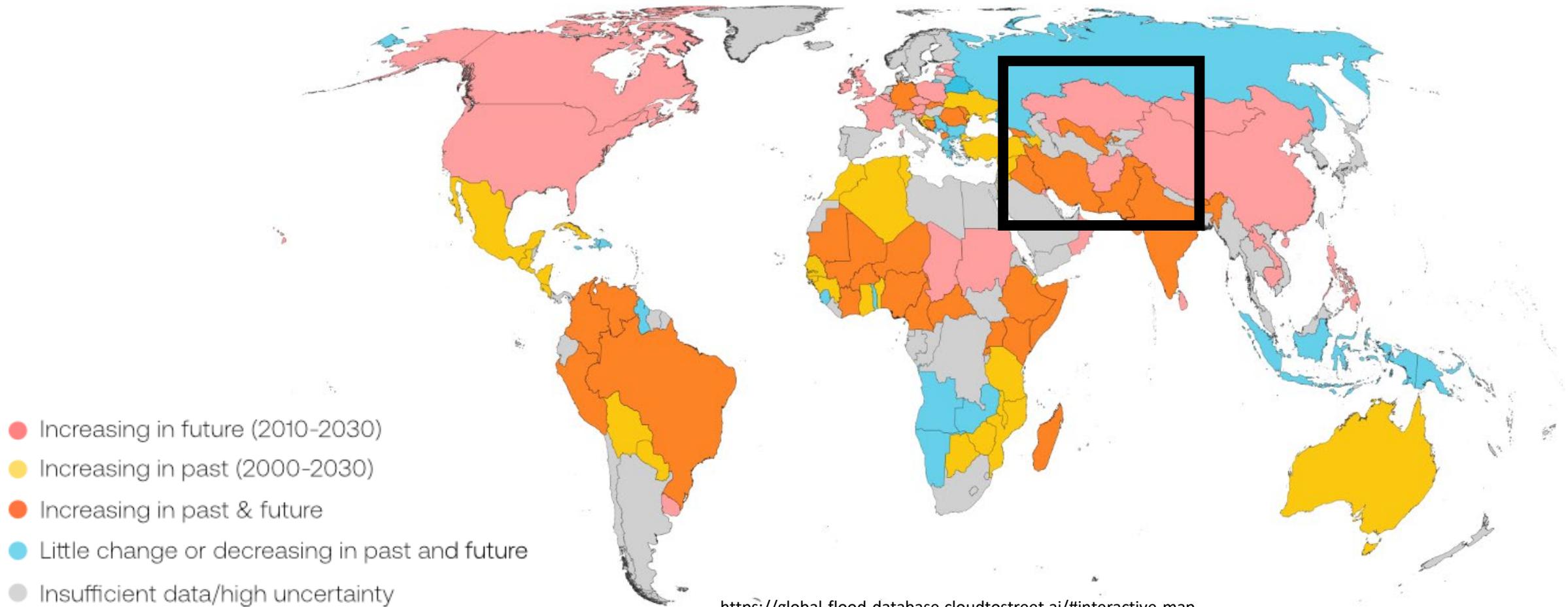
Change in portion of population exposed to floods



<https://global-flood-database.cloudtostreet.ai/#interactive-map>

Floods' Risk

Change in portion of population exposed to floods



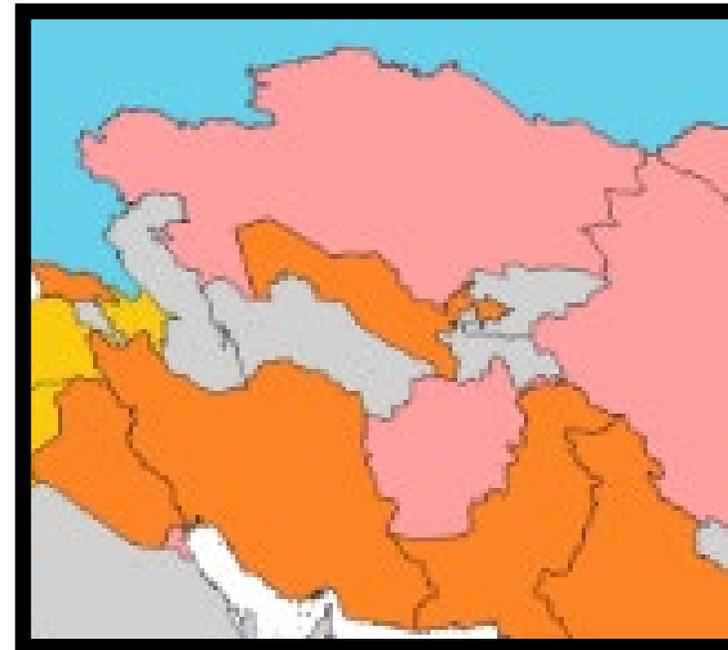
<https://global-flood-database.cloudtostreet.ai/#interactive-map>



Floods' Risk

Change in portion of population exposed to floods

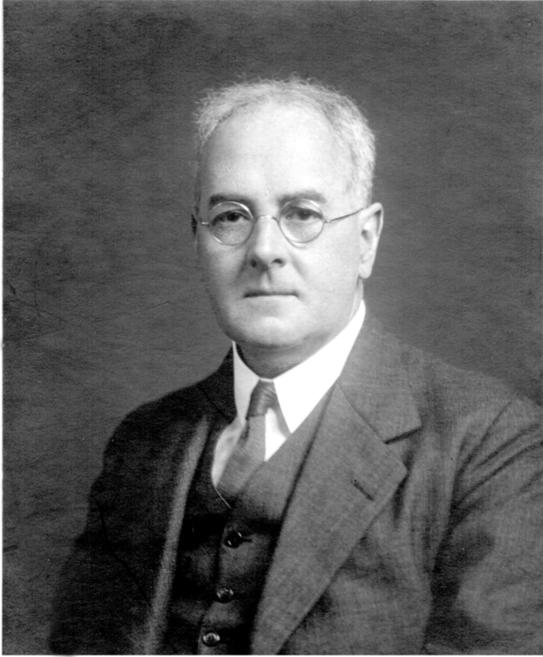
- Increasing in future (2010-2030)
- Increasing in past (2000-2030)
- Increasing in past & future
- Little change or decreasing in past and future
- Insufficient data/high uncertainty



<https://global-flood-database.cloudtostreet.ai/#interactive-map>



Richardson's Fantasy: Forecast Factory



L. F. Richardson, 1931

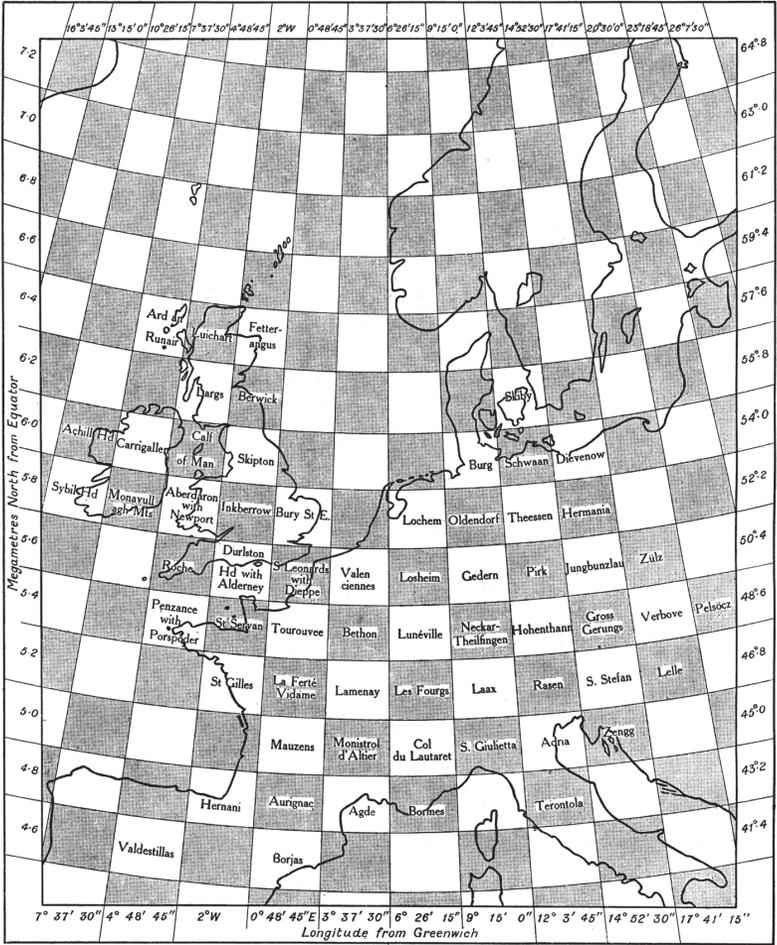
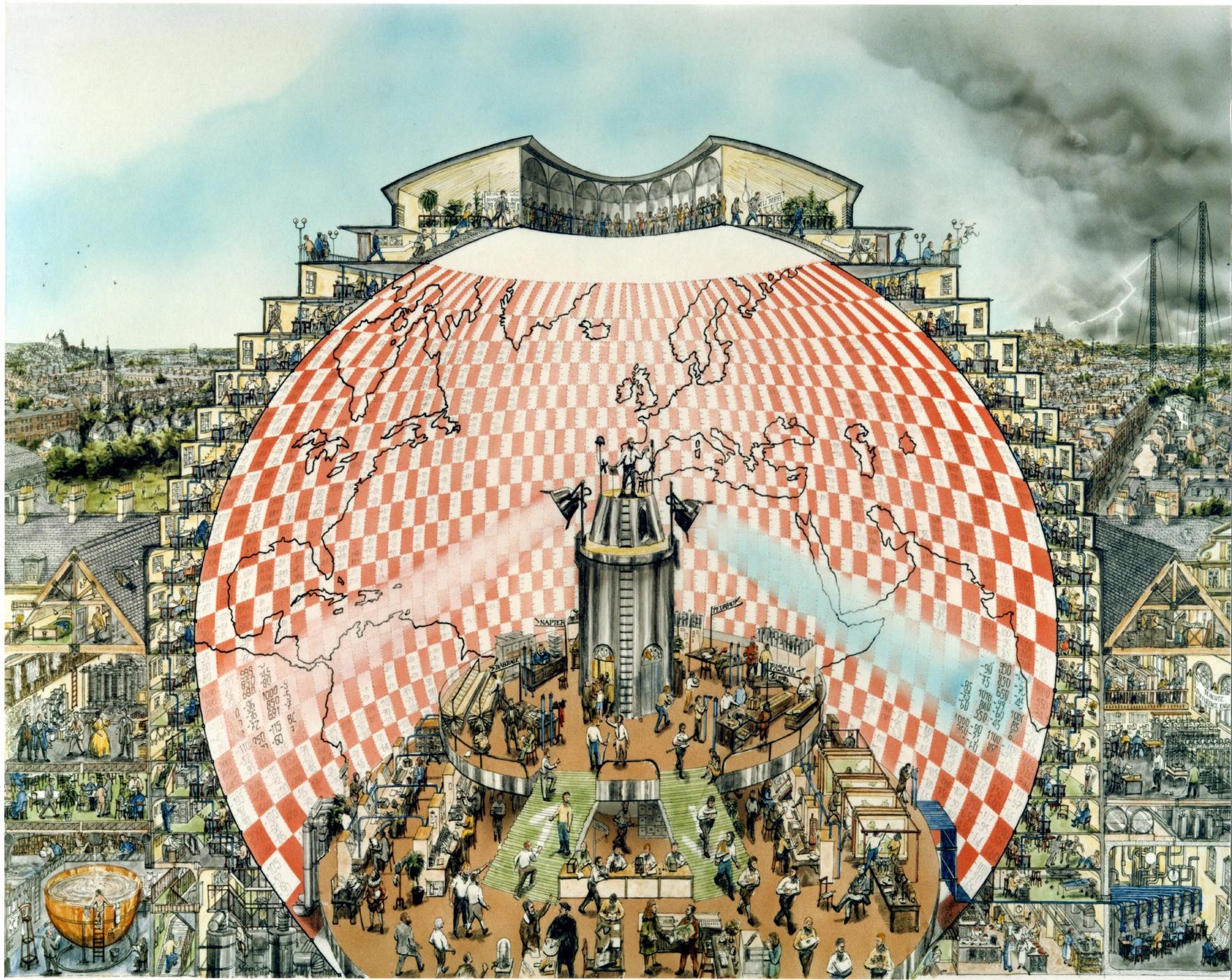


Figure 2. Frontispiece of Richardson's *Weather Prediction by Numerical Process*.



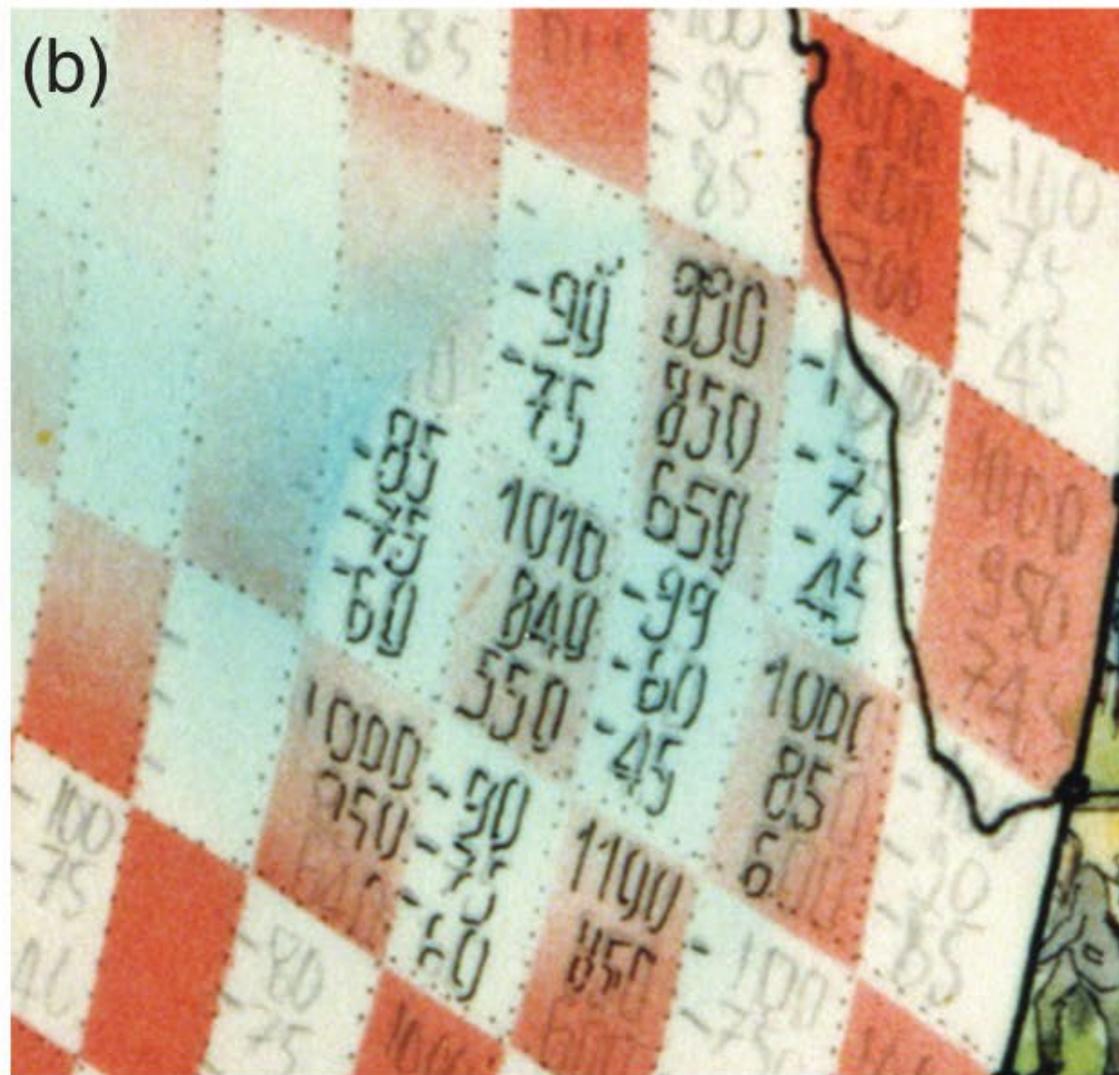
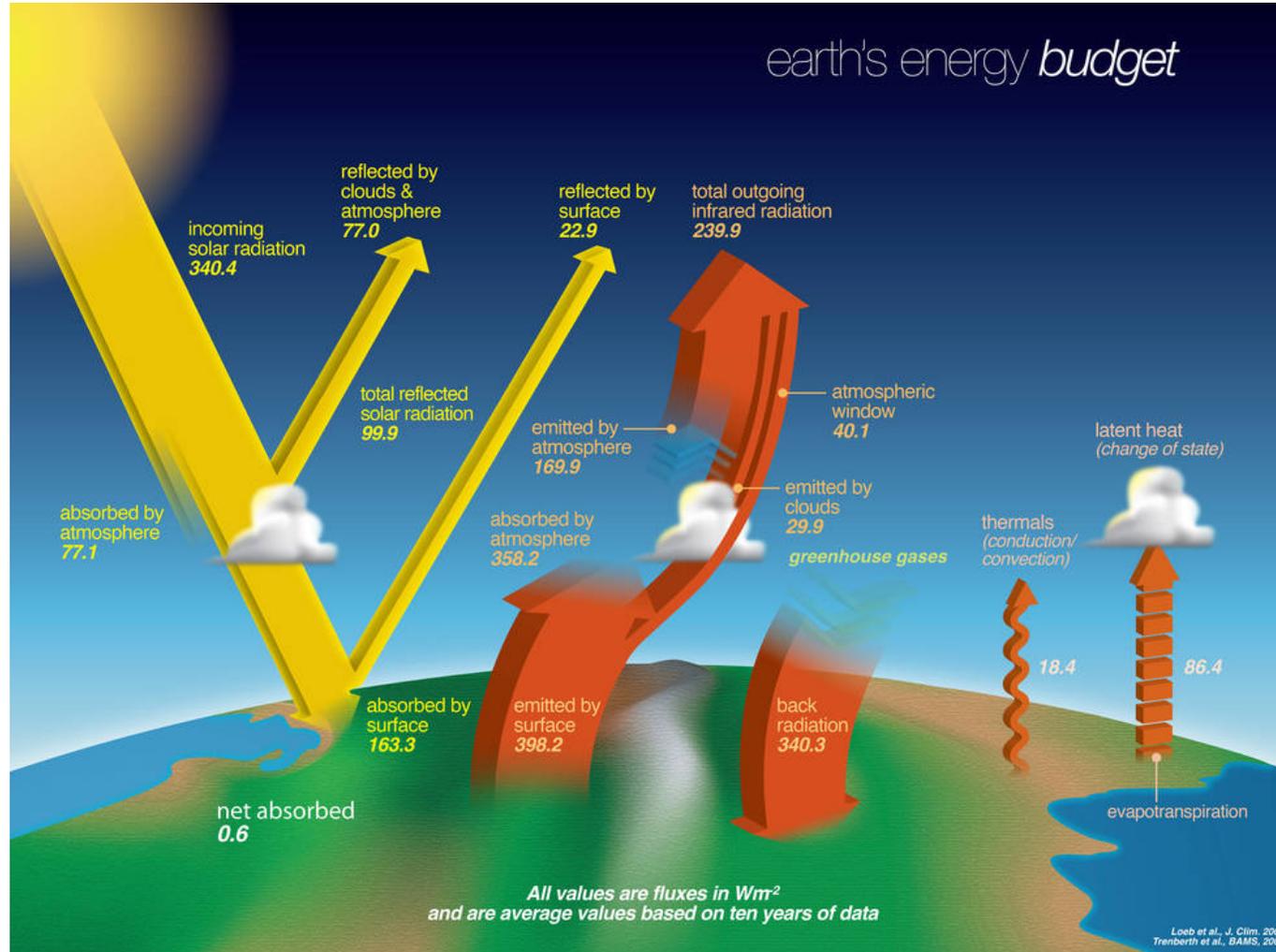


Figure 3. (a) Computers working on the region around Hudson Bay. (b) A section of the computational grid.

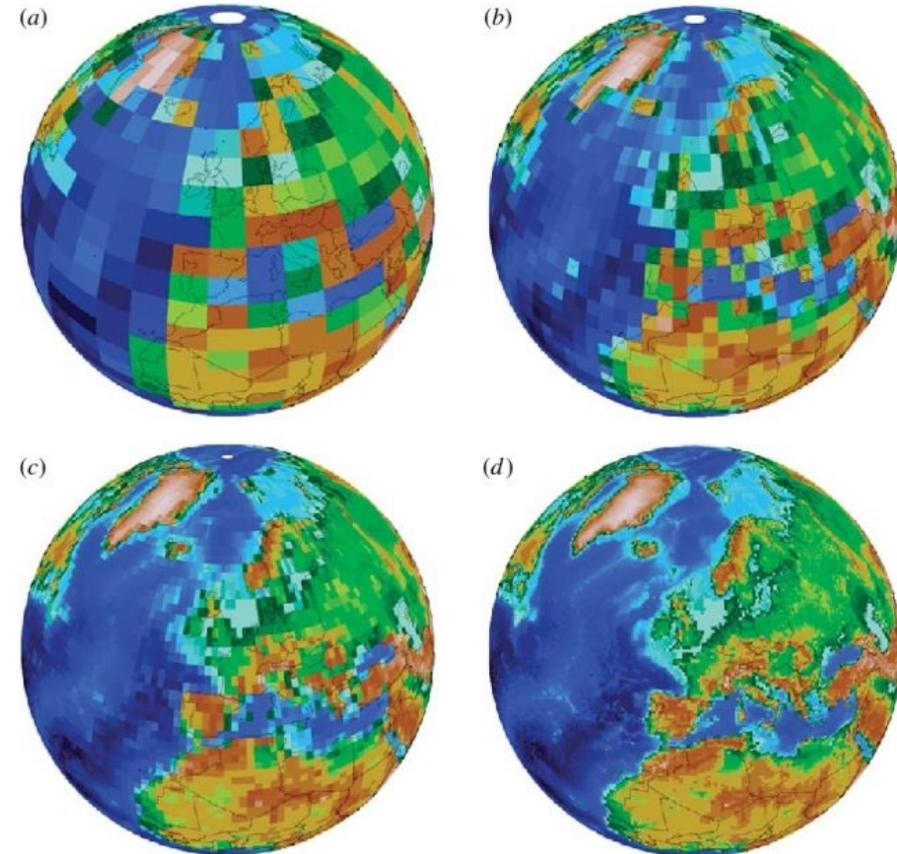
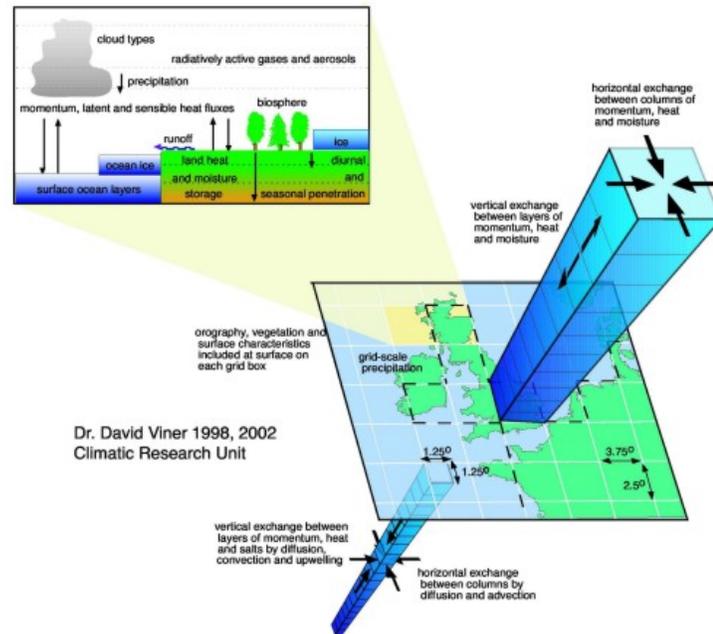




Energy balance models

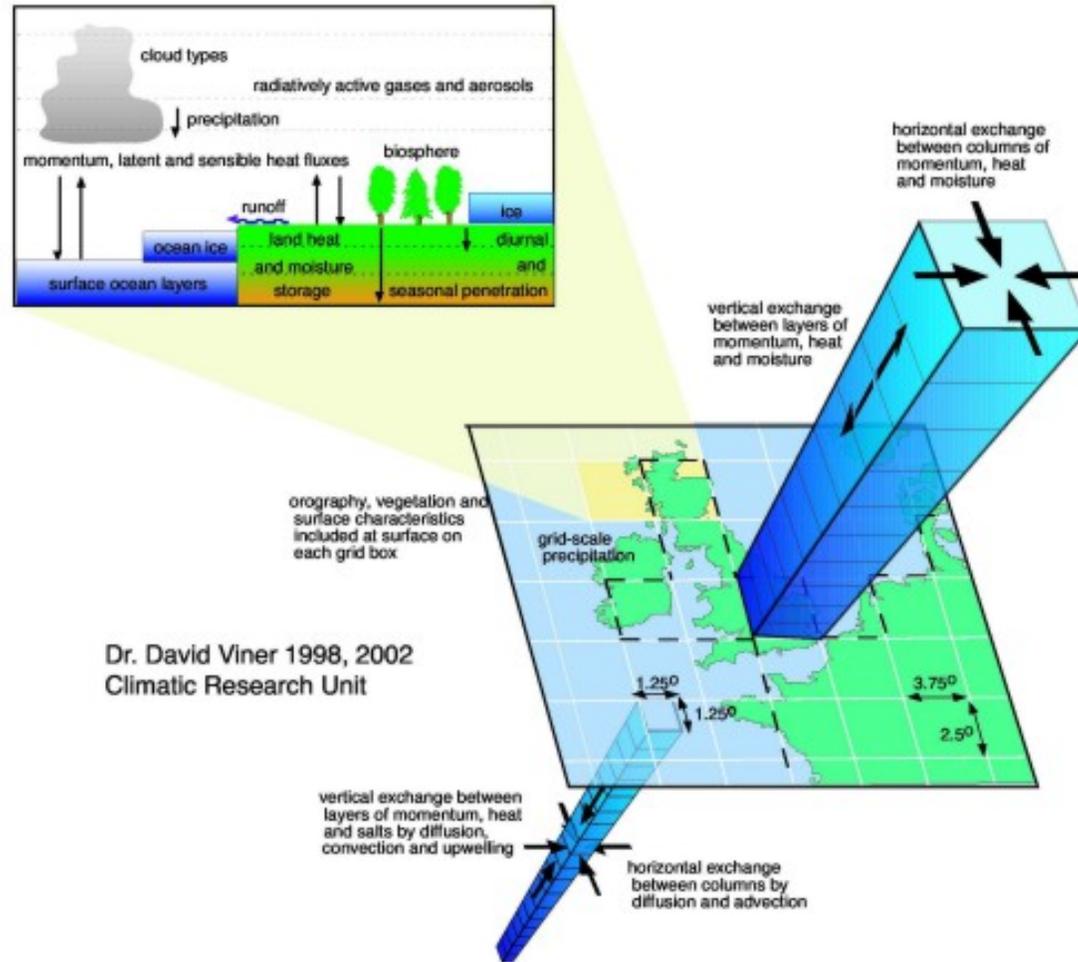


General Circulation Models



https://www.researchgate.net/publication/23668865_The_computational_future_for_climate_and_Earth_system_models_On_the_path_to_petaflop_and_beyond

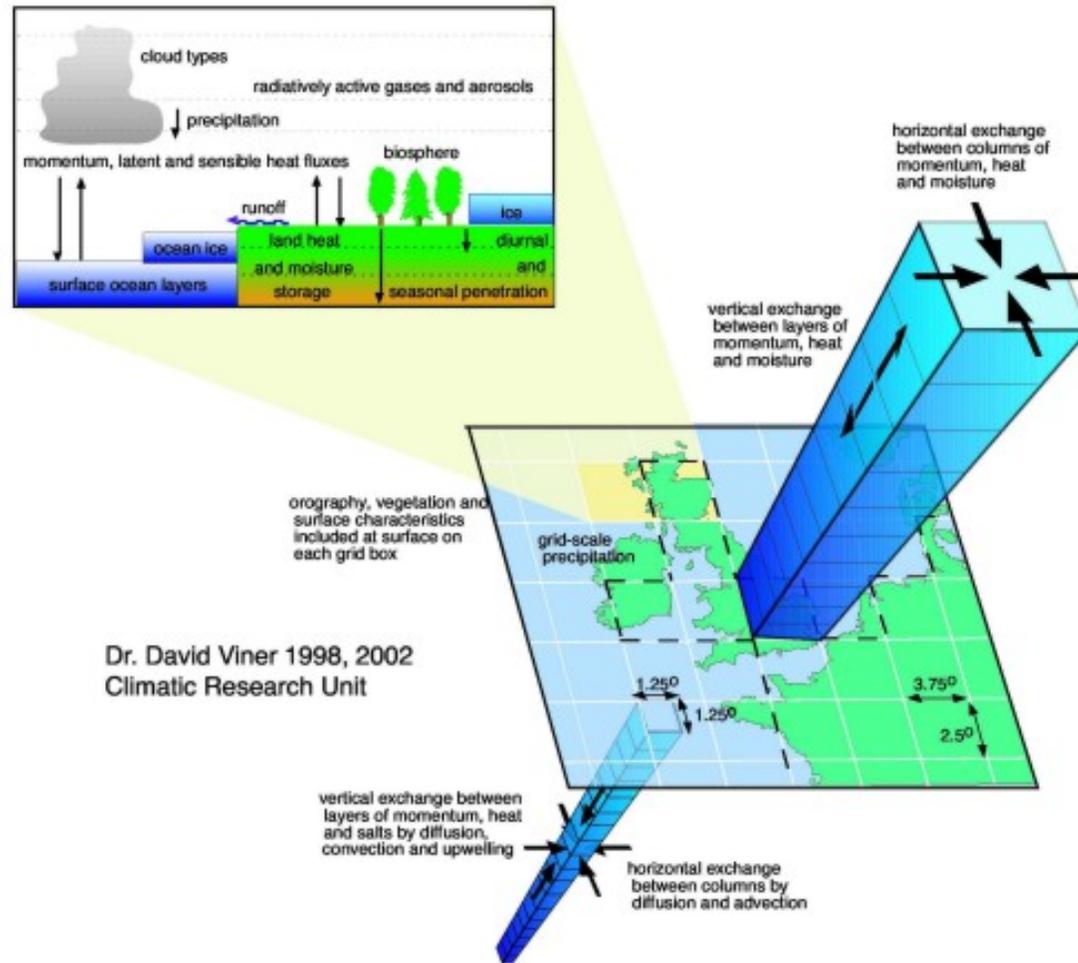
General Circulation Models



Dr. David Viner 1998, 2002
Climatic Research Unit

https://www.researchgate.net/publication/23668865_The_computational_future_for_climate_and_Earth_system_models_On_the_path_to_petaflop_and_beyond

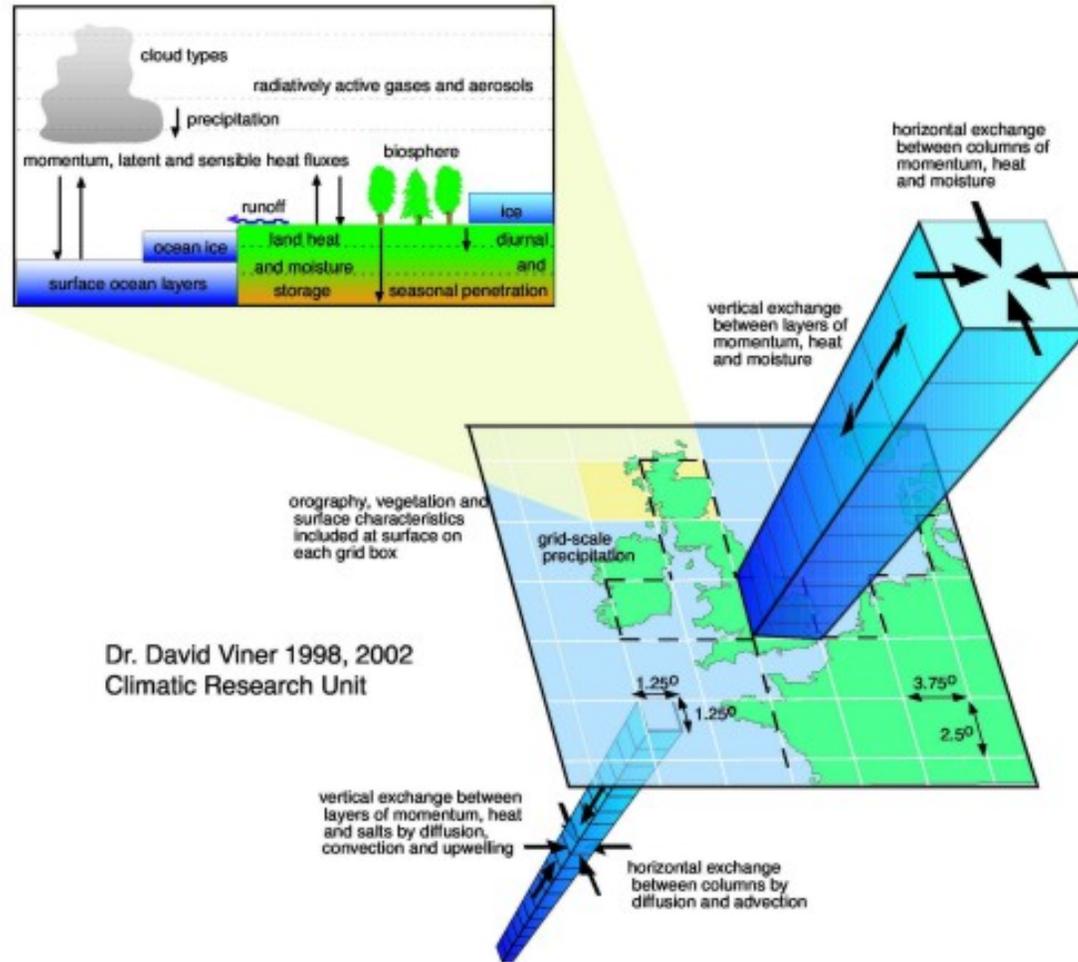
General Circulation Models



Atmospheric Ocean GCM
(AOGCM)

https://www.researchgate.net/publication/23668865_The_computational_future_for_climate_and_Earth_system_models_On_the_path_to_petaflop_and_beyond

General Circulation Models



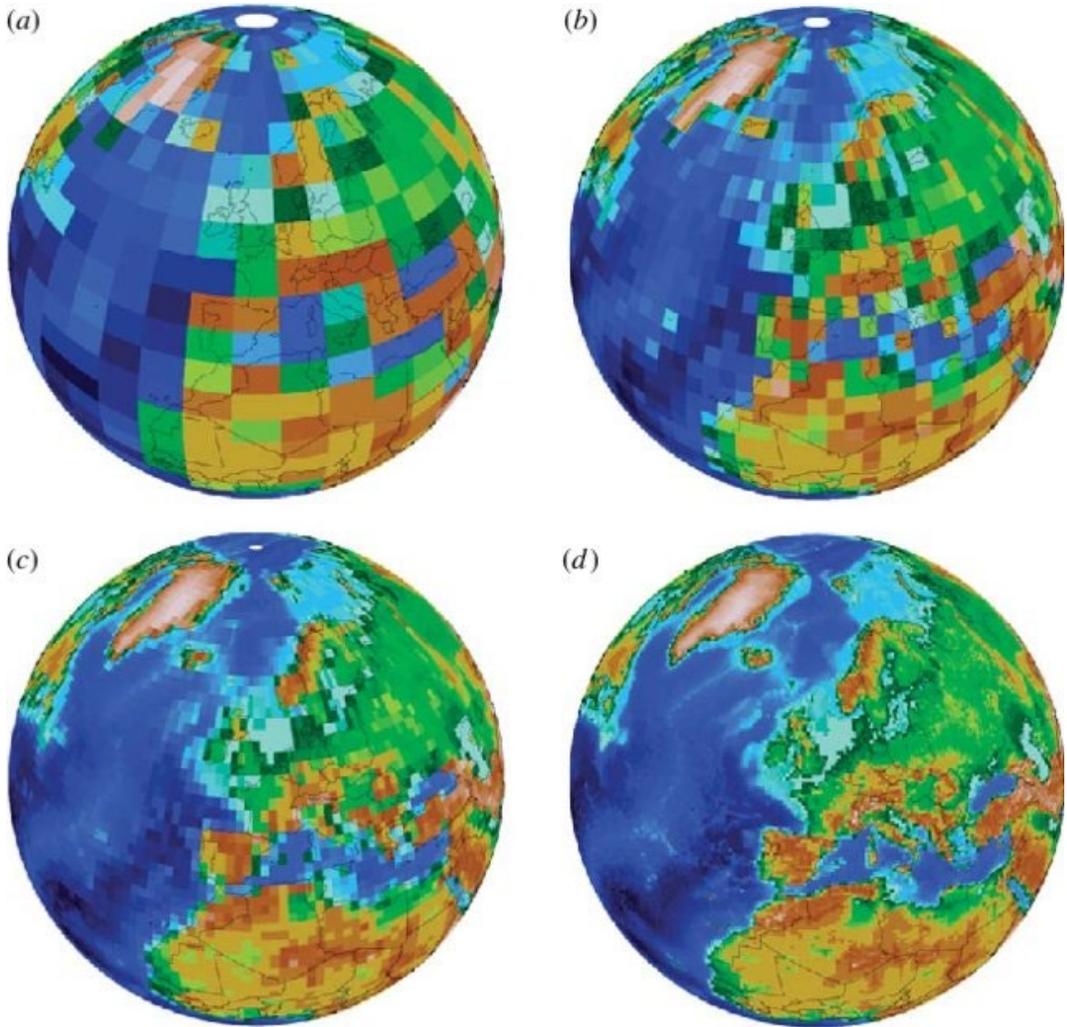
Fully Coupled Models.

Dr. David Viner 1998, 2002
Climatic Research Unit

https://www.researchgate.net/publication/23668865_The_computational_future_for_climate_and_Earth_system_models_On_the_path_to_petaflop_and_beyond



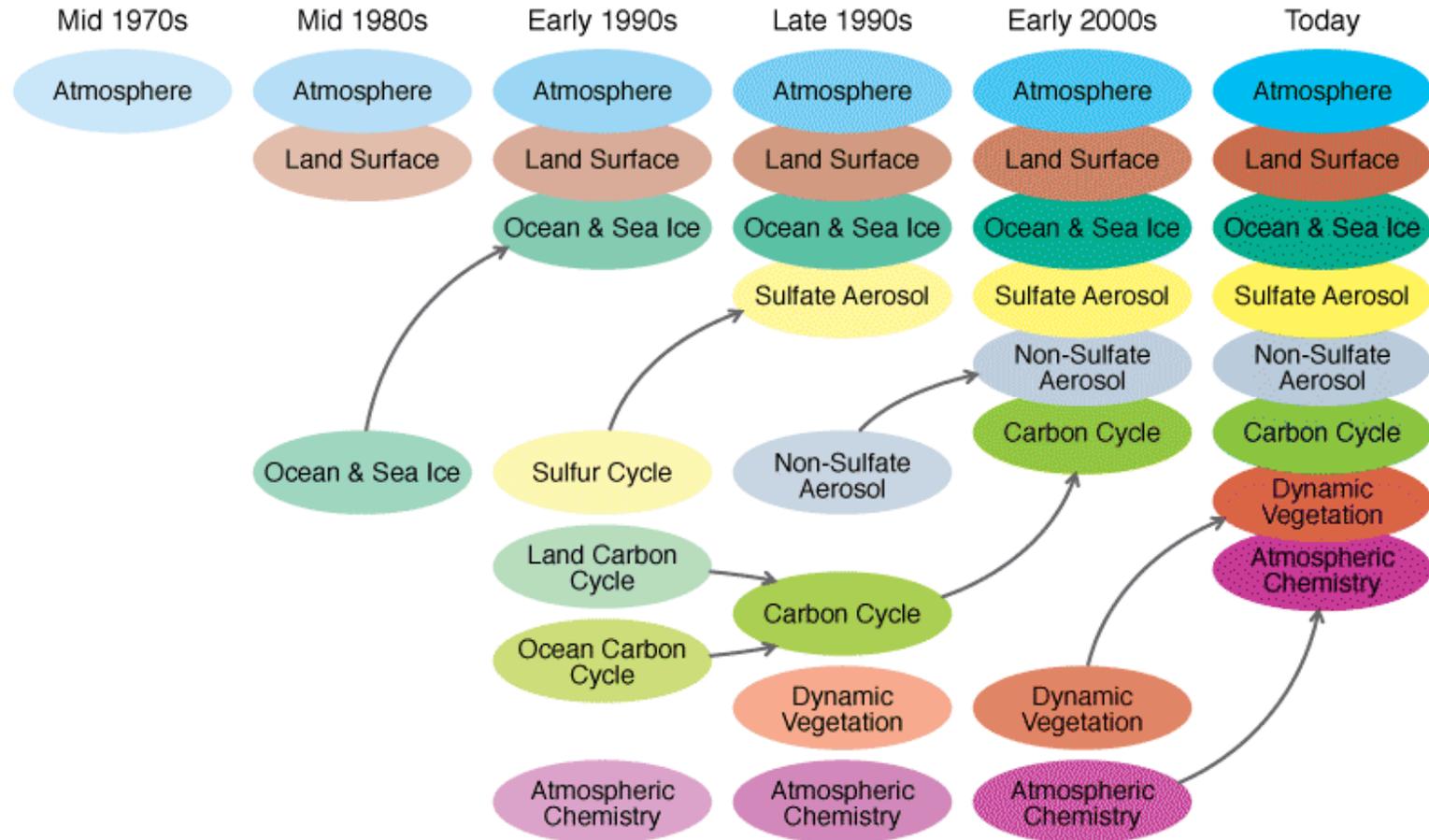
General Circulation Models



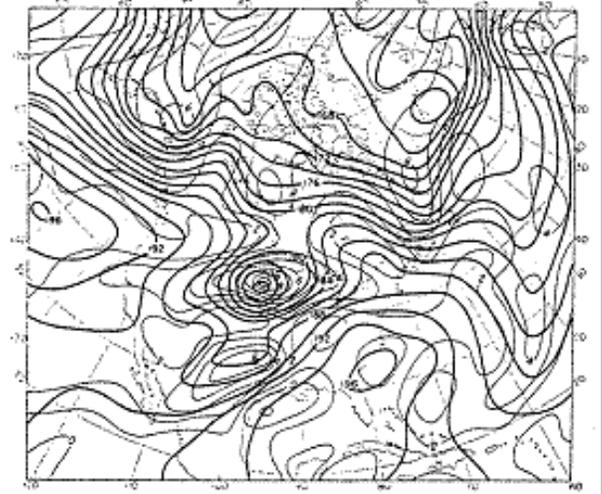
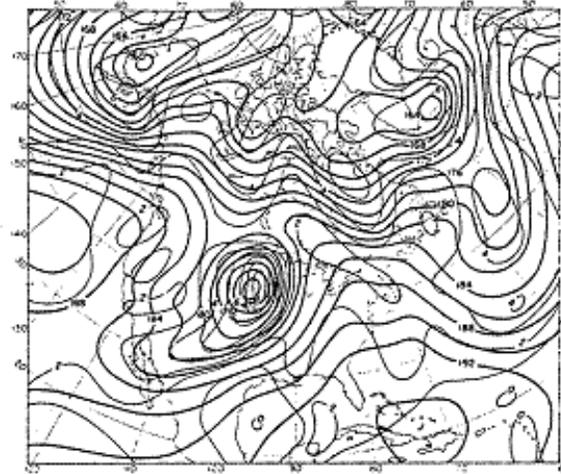
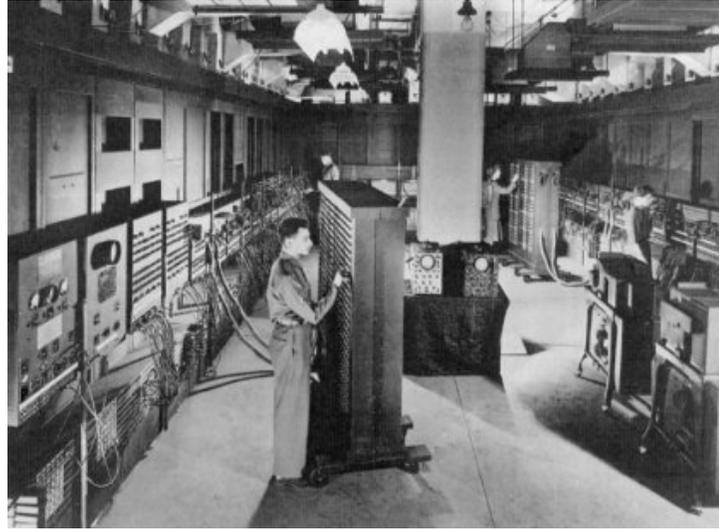
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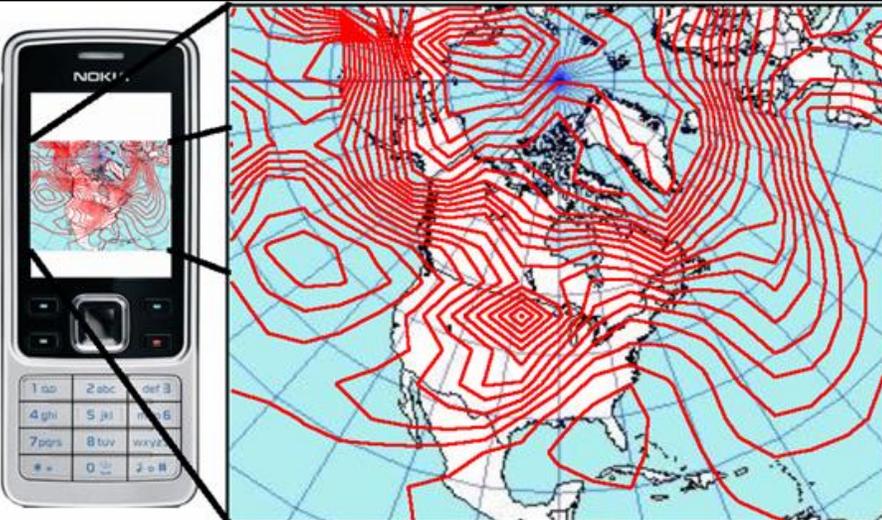
Development of Climate Models



Dramatic increase in computer' power

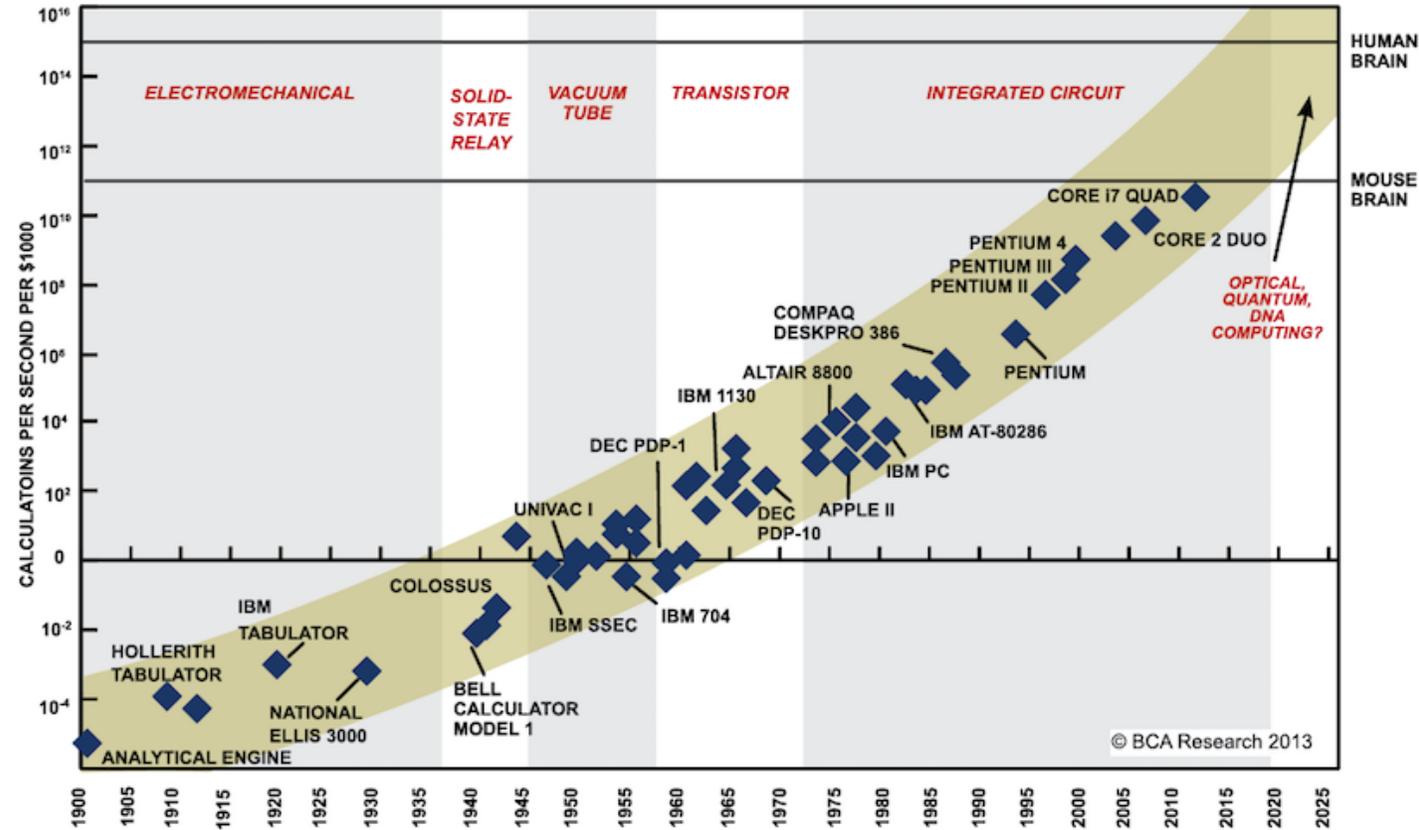


The ENIAC, 1950



The Nokia 6300, 2008

Moore's law of computational power



© BCA Research 2013

SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, THE VIKING PRESS, 2006. DATAPPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.



General Circulation Models

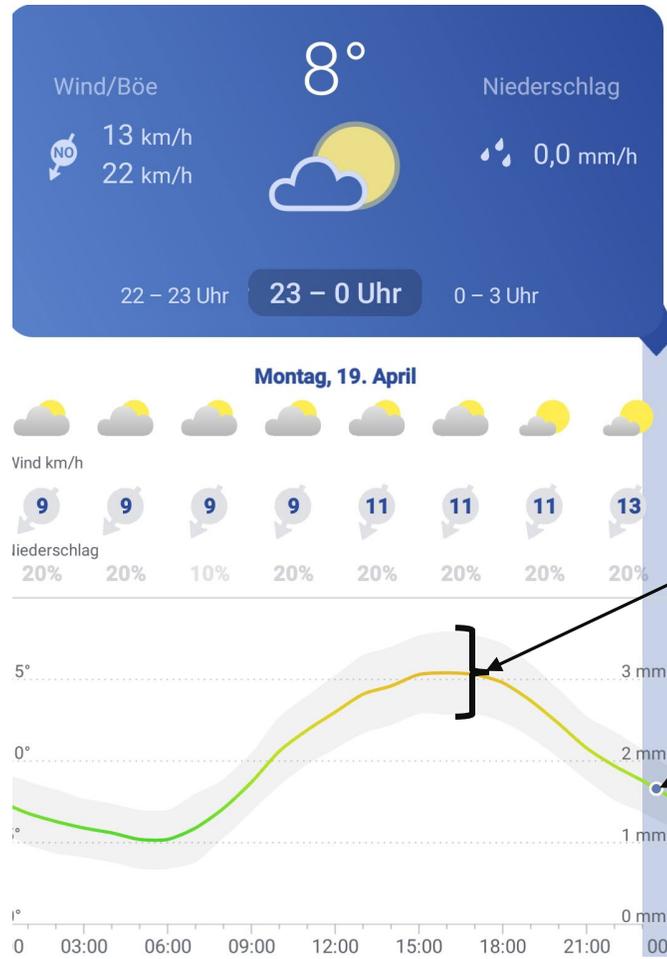
- Evaluate them for the recent observed era
- Weather forecasting
- Hypothesis testing
- Future projection

Why Ensemble of Models?



<https://mpimet.mpg.de/en/science/projects/integrated-activities>

Why Ensemble of Models?

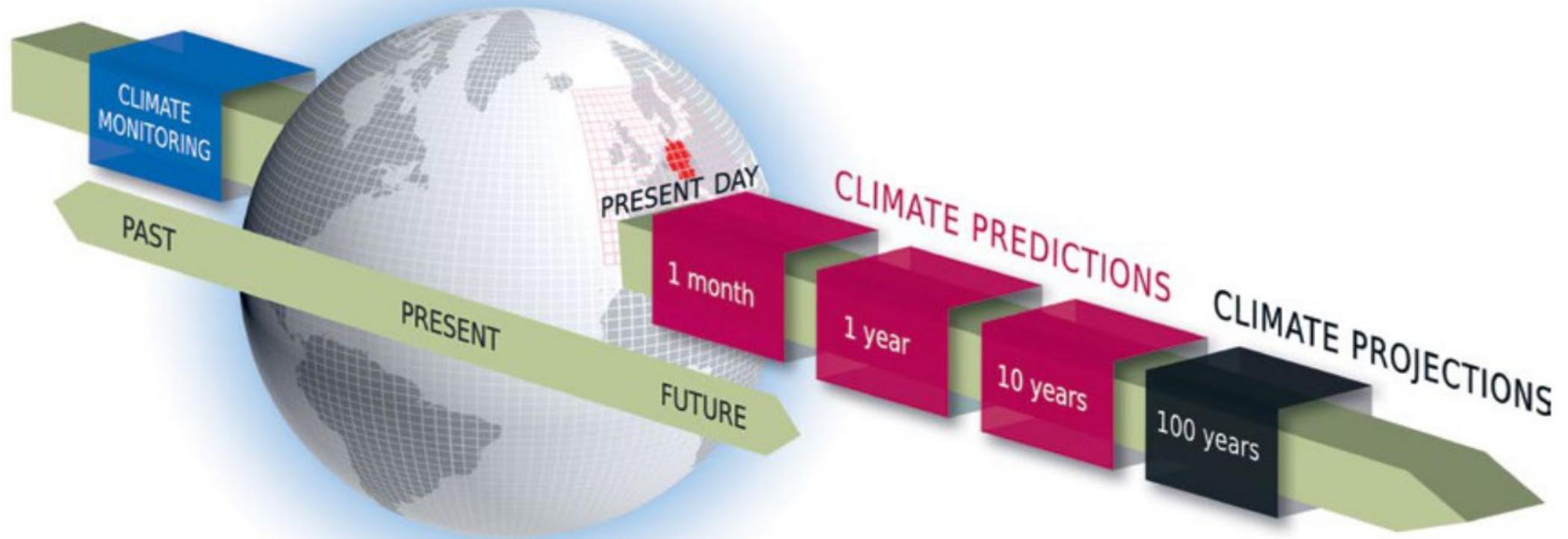


Ensemble Spread

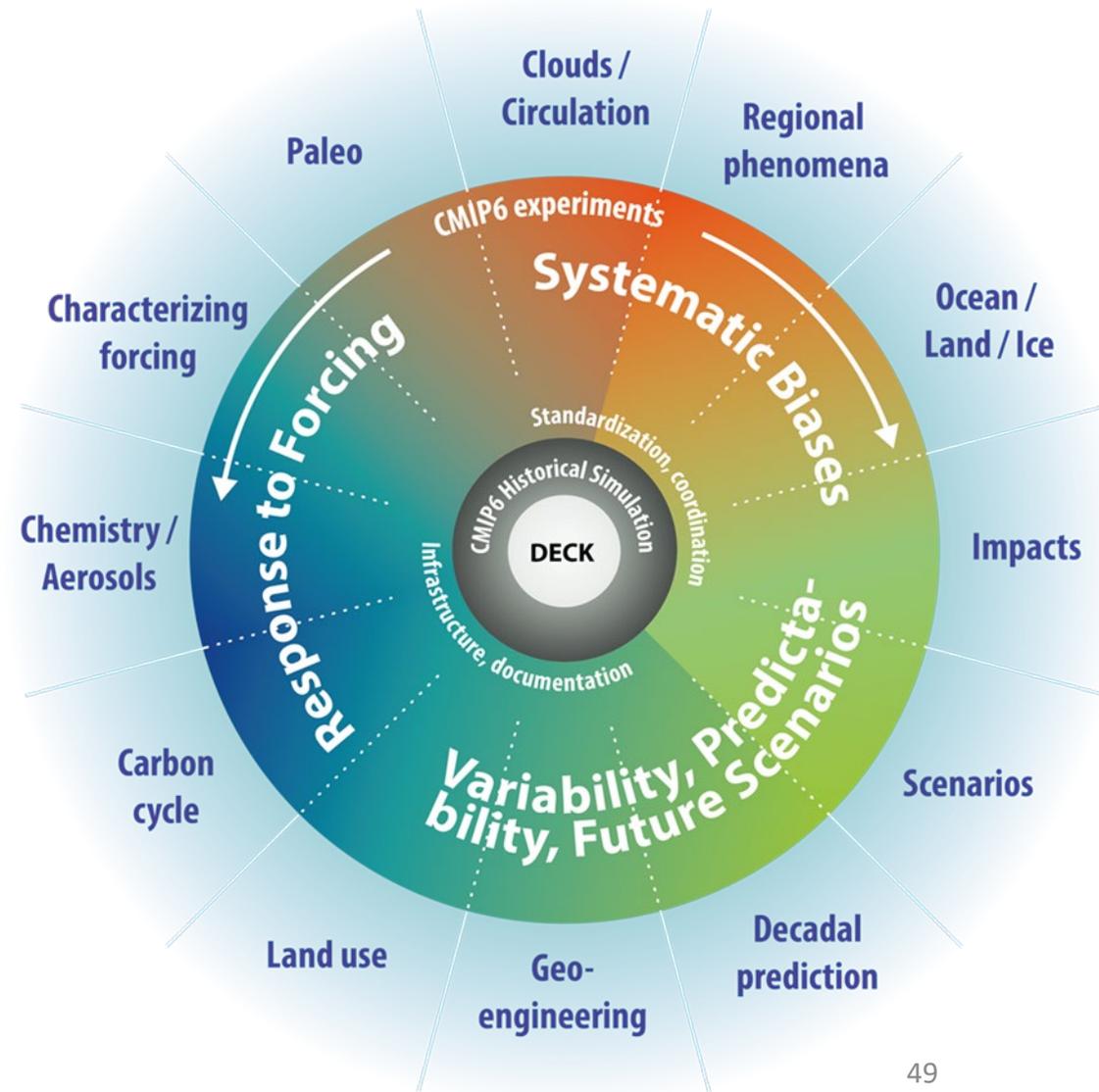
Ensemble Mean

Screen shot of DWD app

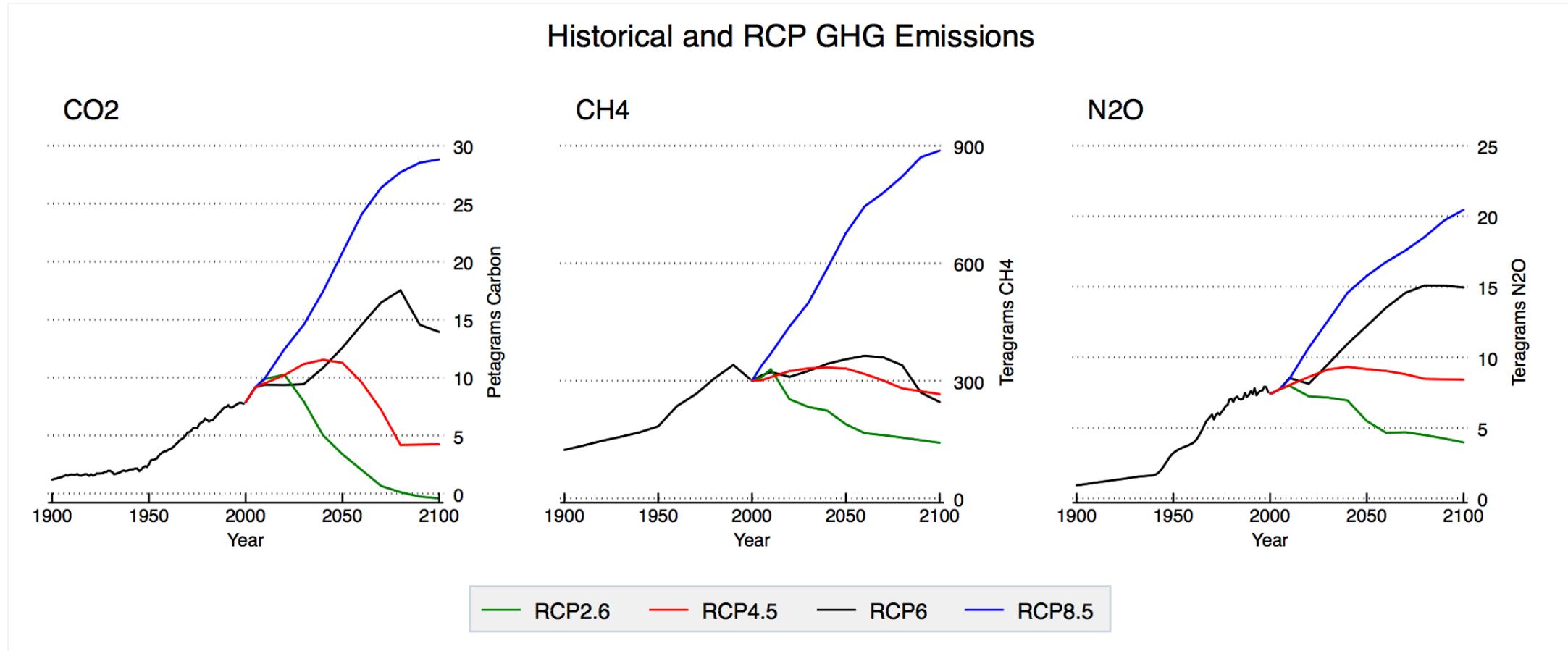
Time scale of simulations



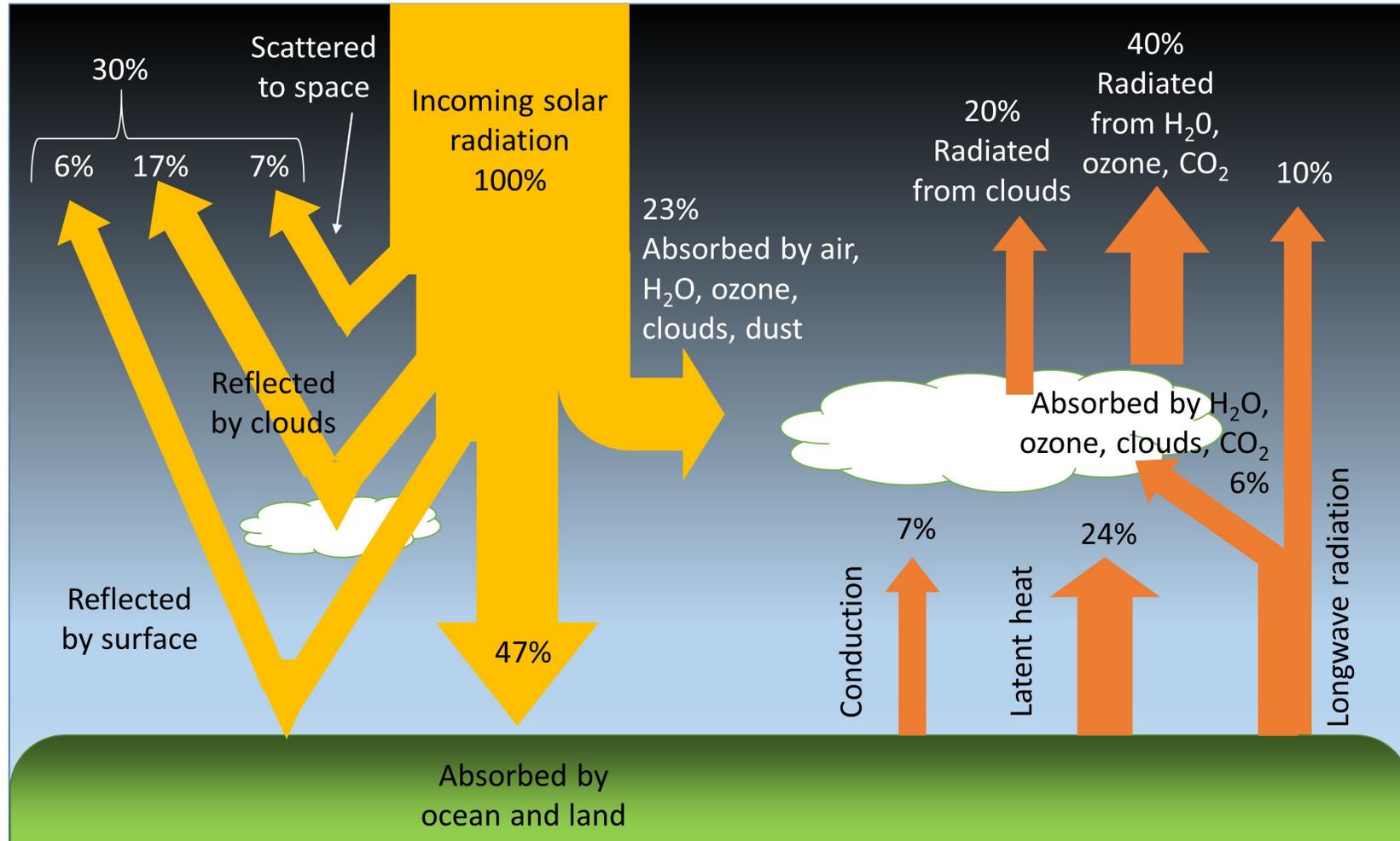
Coupled Model Intercomparison Project



Projection of the Climate Change: CMIP5



Radiative Forcing



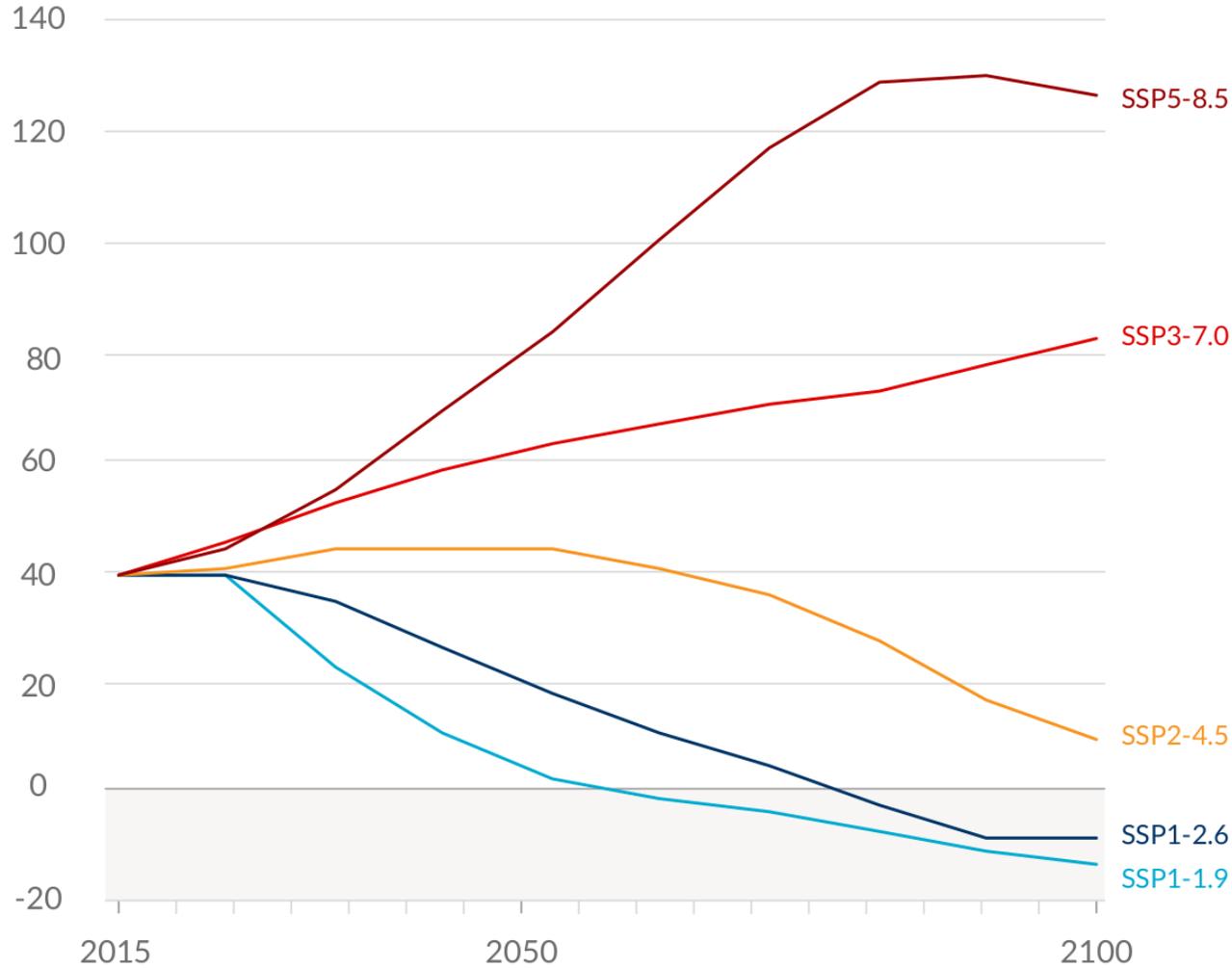


Projection of the Climate Change: CMIP5

- **RCP2.6:** radiative forcing reached nearly 3 W/m^2 and will decrease to 2.6 W/m^2 by 2100
- **RCP4.5:** Stabilization with overshooting. 4.5 W/m^2 by 2100
- **RCP6:** Stabilization with overshooting. 6 W/m^2 by 2100
- **RCP8.5:** rising radiative forcing, leading to 8.5 W/m^2 by 2100

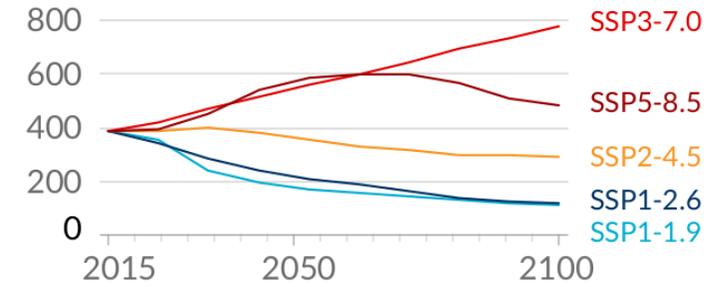
Projection of the Climate Change: CMIP6

Carbon dioxide (GtCO₂/yr)

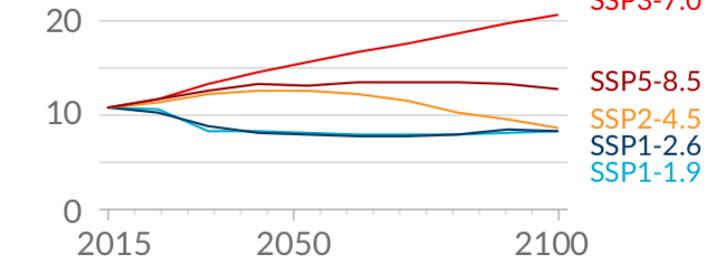


Selected contributors to non-CO₂ GHGs

Methane (MtCH₄/yr)

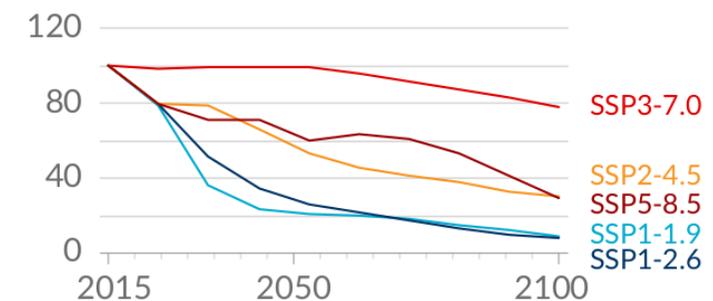


Nitrous oxide (MtN₂O/yr)

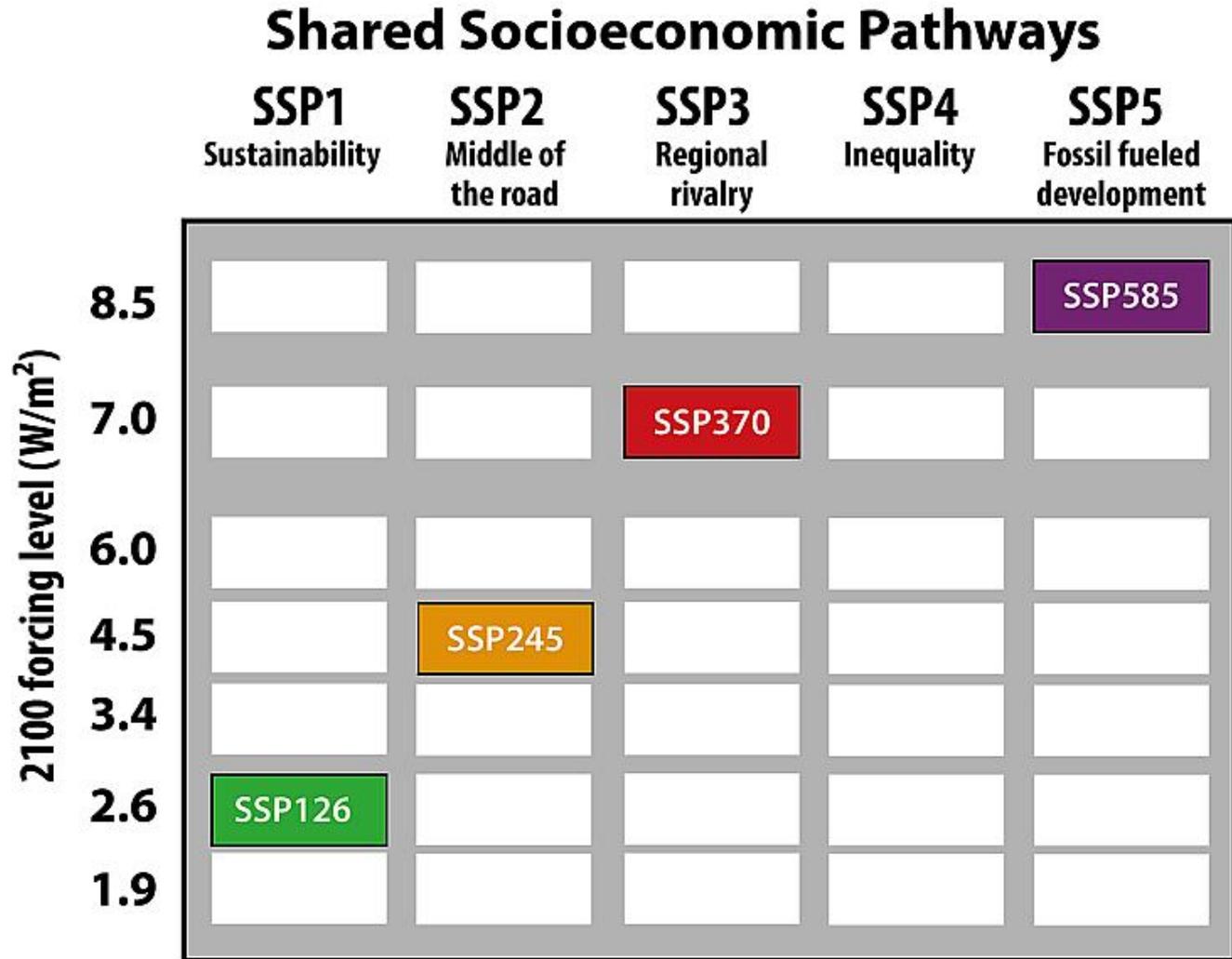


One air pollutant and contributor to aerosols

Sulfur dioxide (MtSO₂/yr)



Projection of the Climate Change: CMIP6

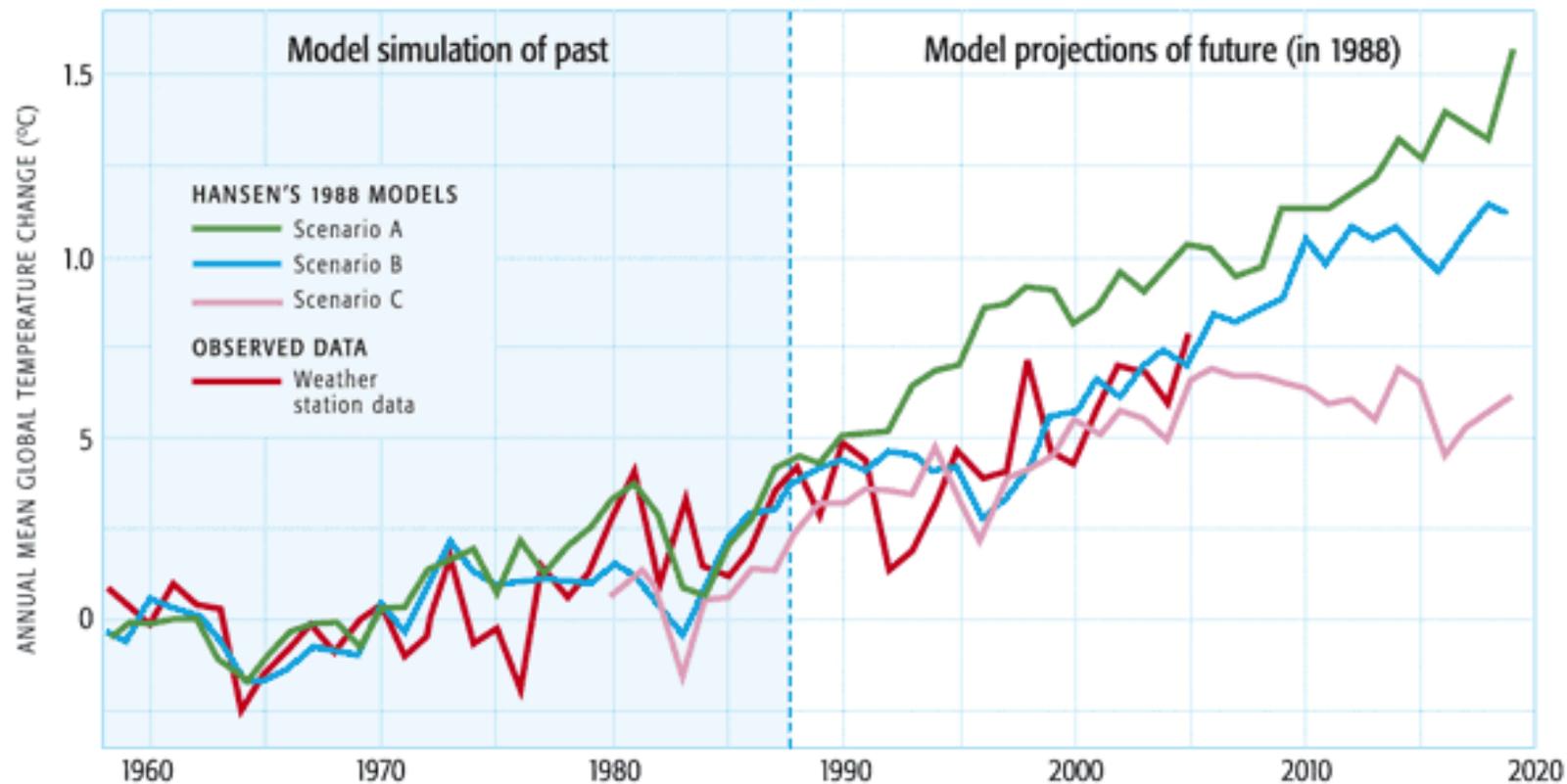


After O'Neill et al., 2016

© DKRZ

Are climate models useful?

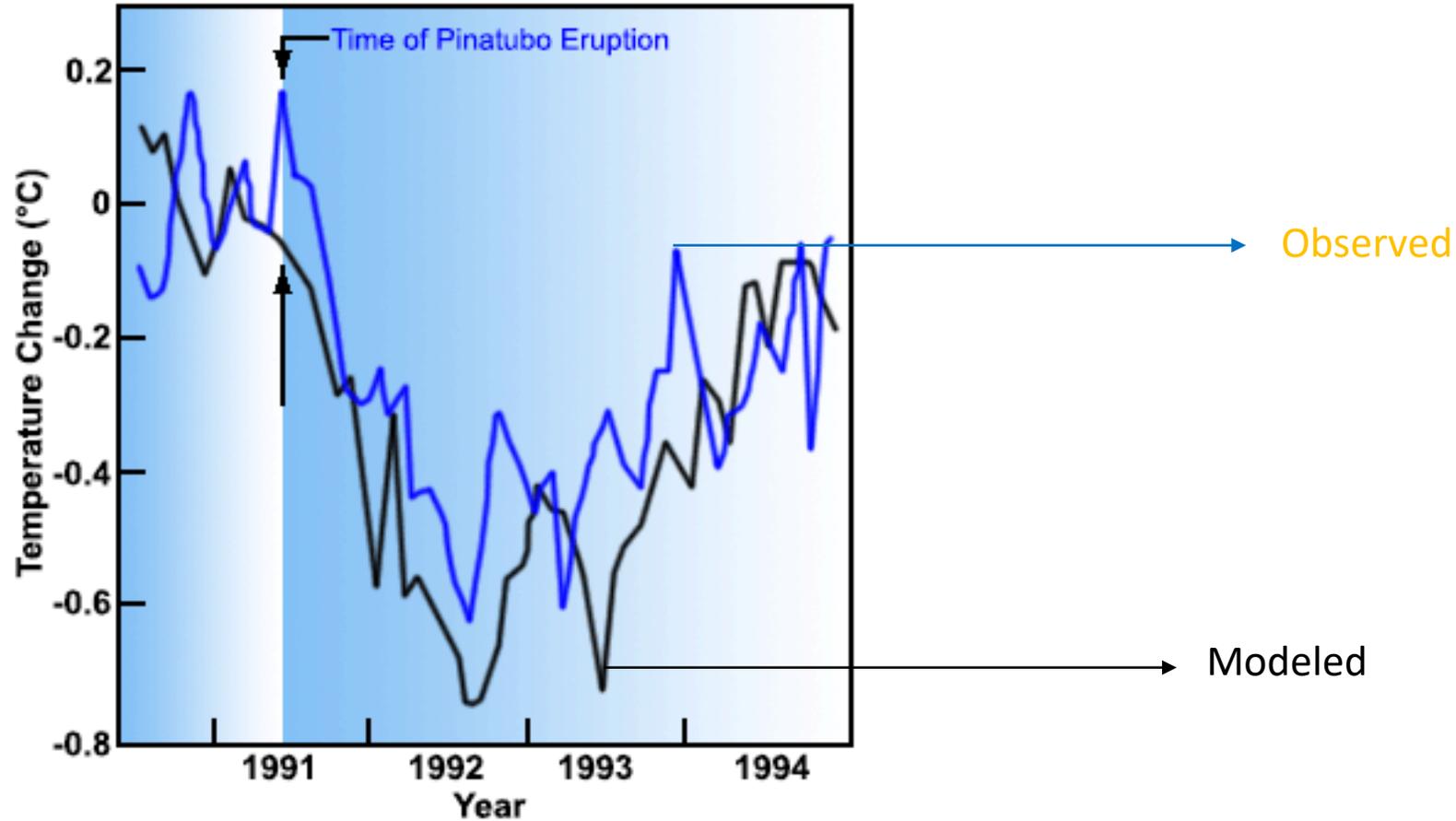
HANSEN'S THREE PROJECTED GLOBAL WARMING SCENARIOS



© 2009 Pearson Education, Inc.

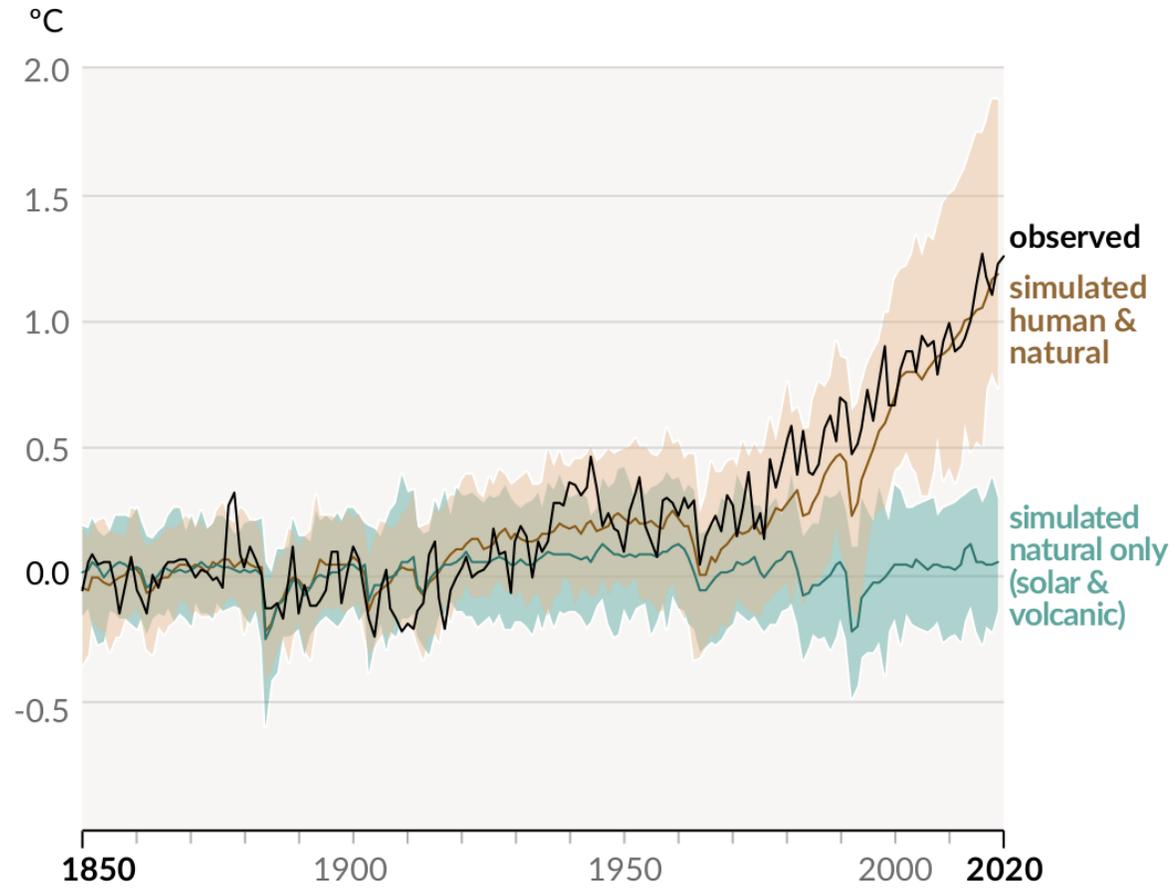


Are climate models useful?

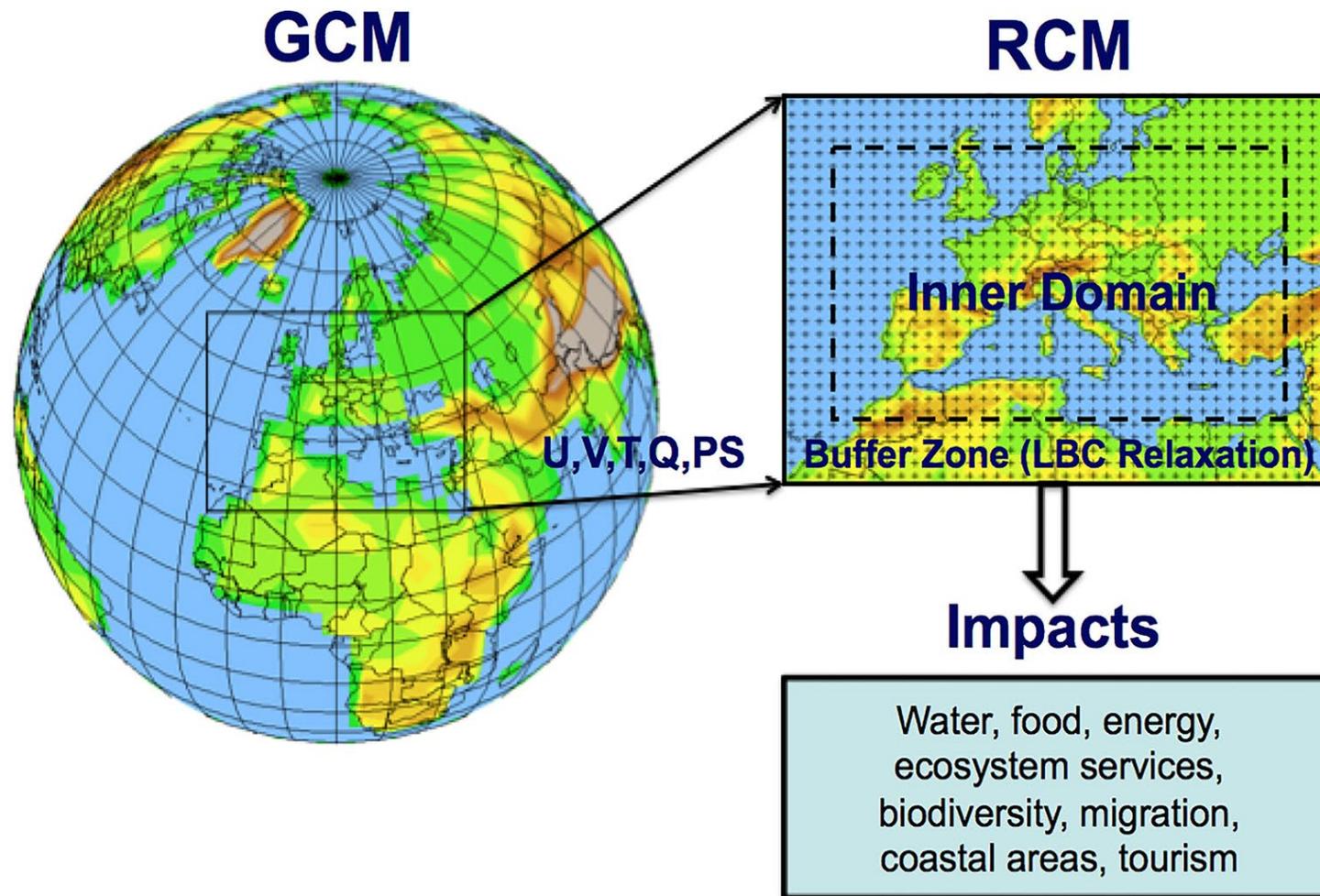


State of the Global Climate Change

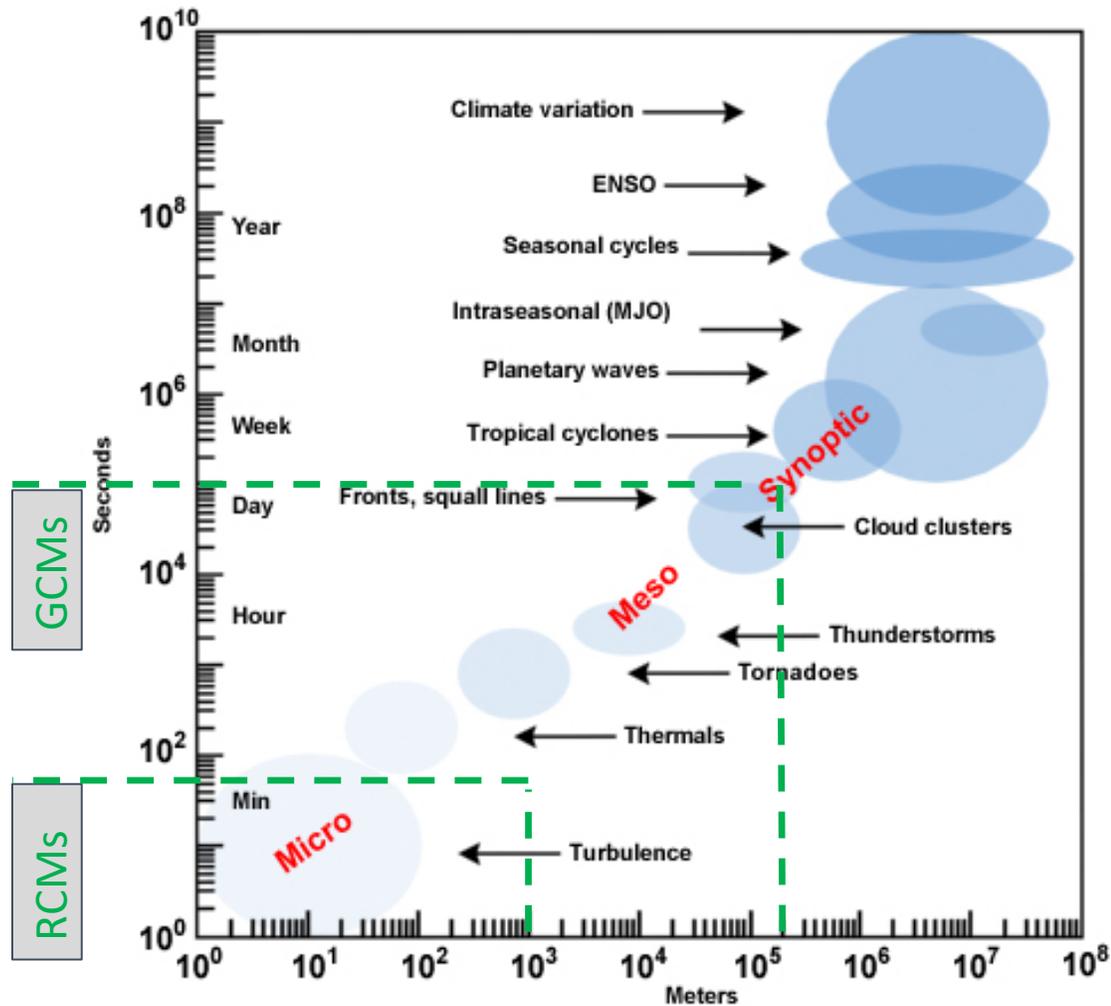
b) Change in global surface temperature (annual average) as **observed** and simulated using **human & natural** and **only natural** factors (both 1850-2020)



Regional Climate Models



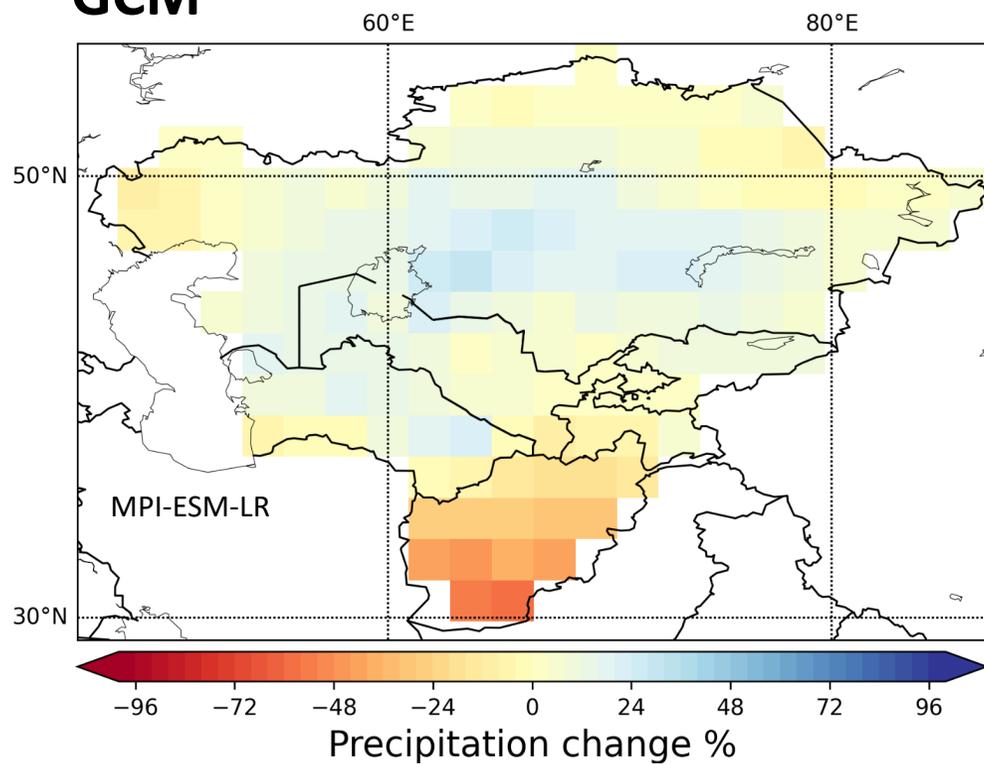
Regional Climate Models



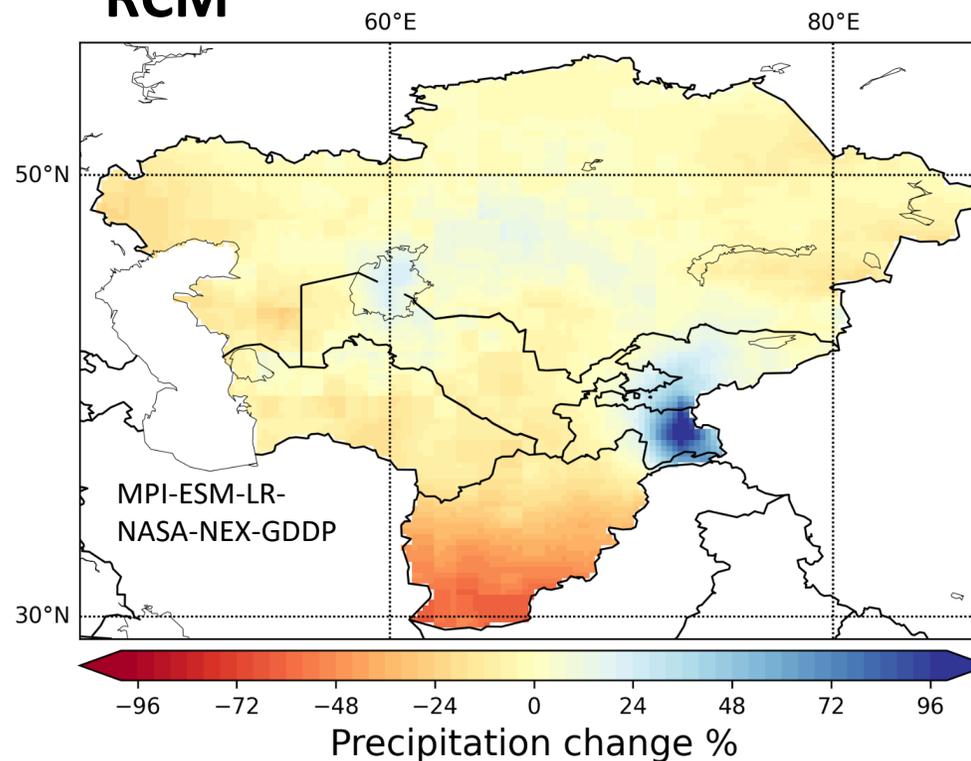
©The COMET Program

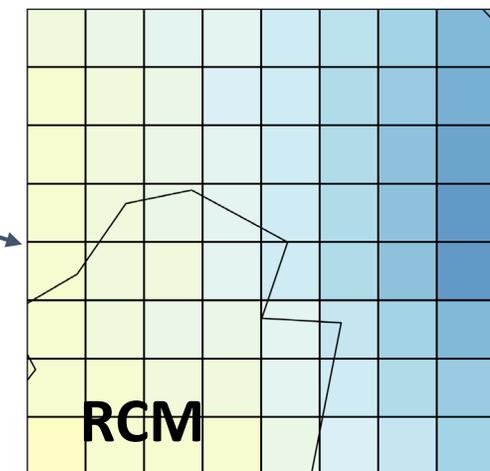
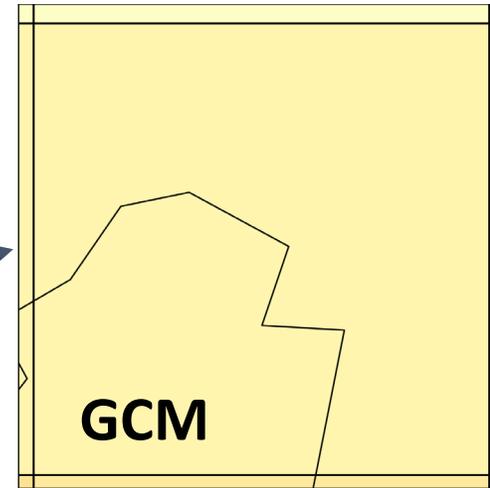
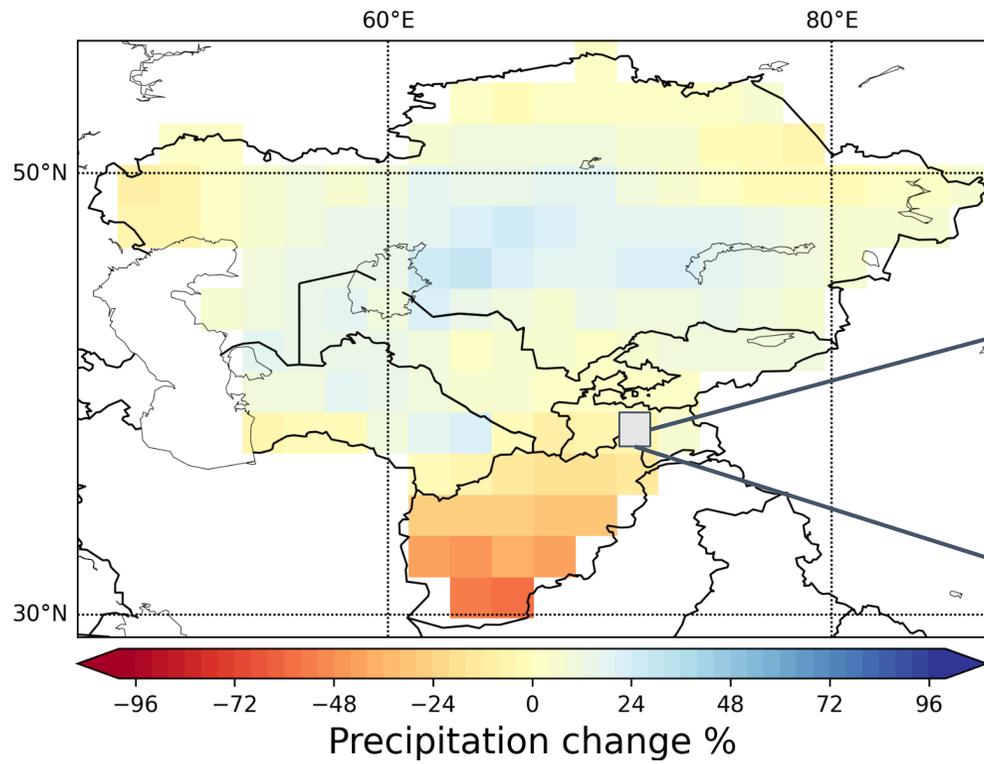
2070-2100 vs 1975-2004

GCM

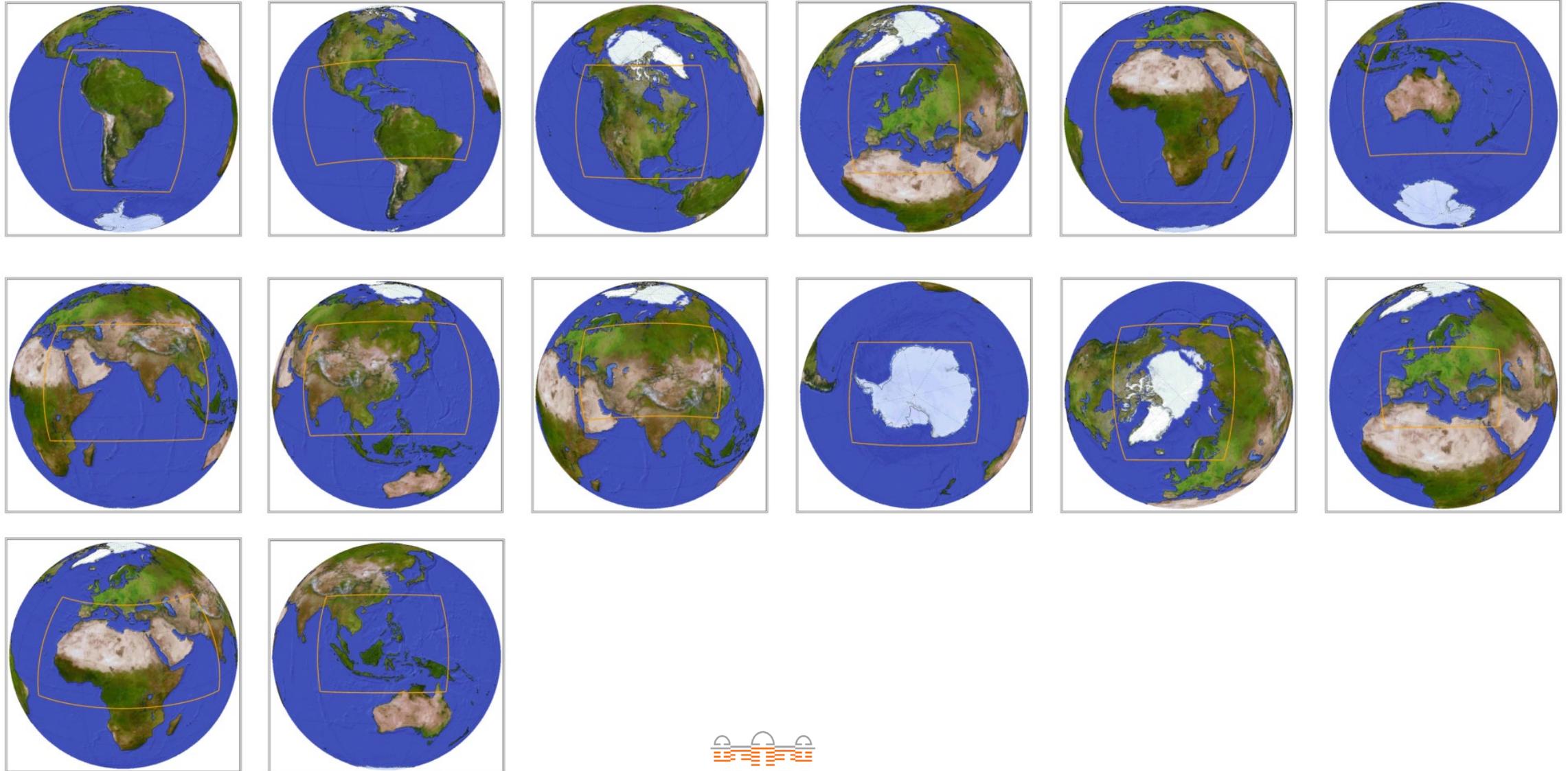


RCM



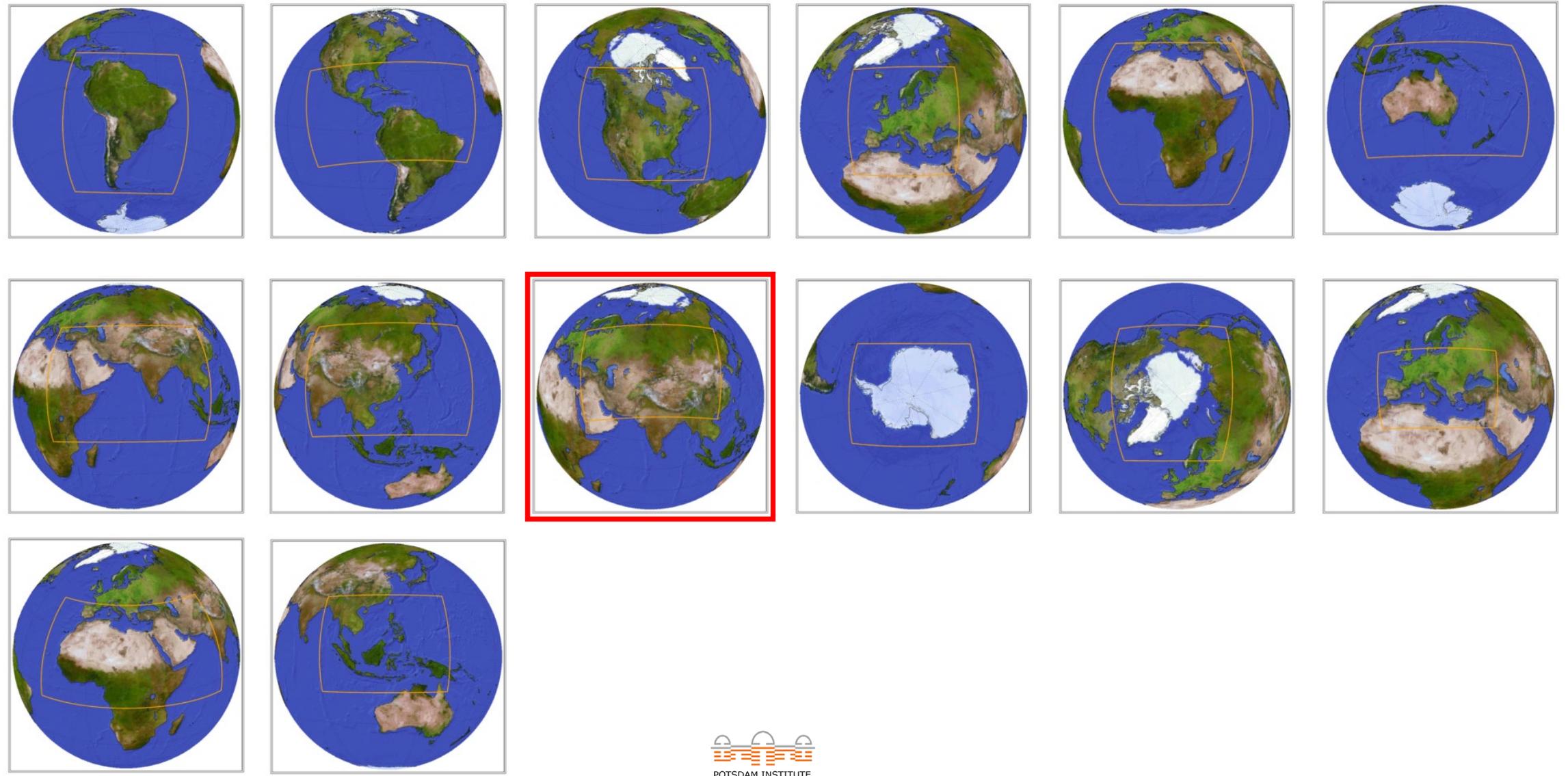


Coordinated Regional Climate Downscaling Experiment

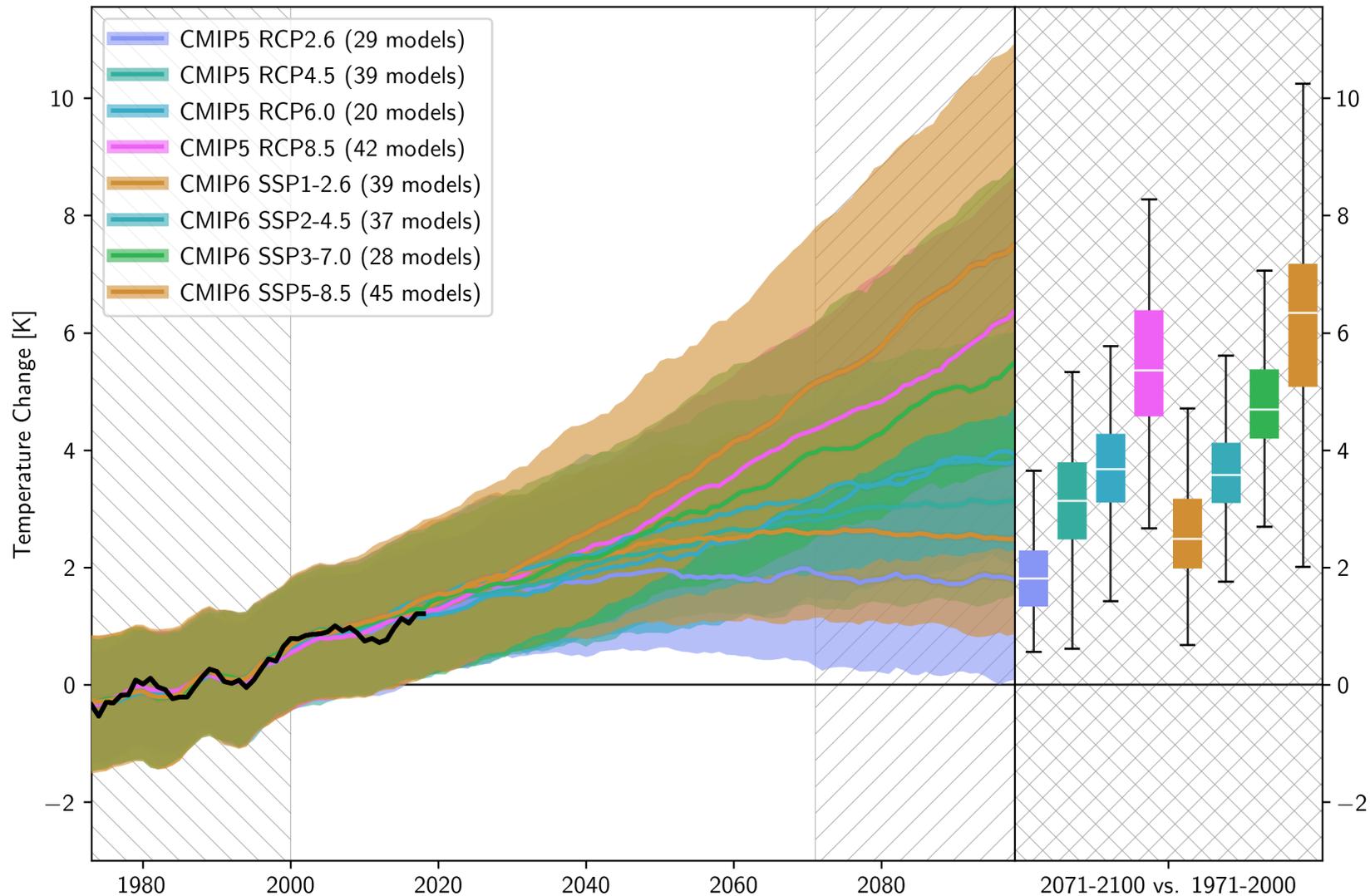




Coordinated Regional Climate Downscaling Experiment

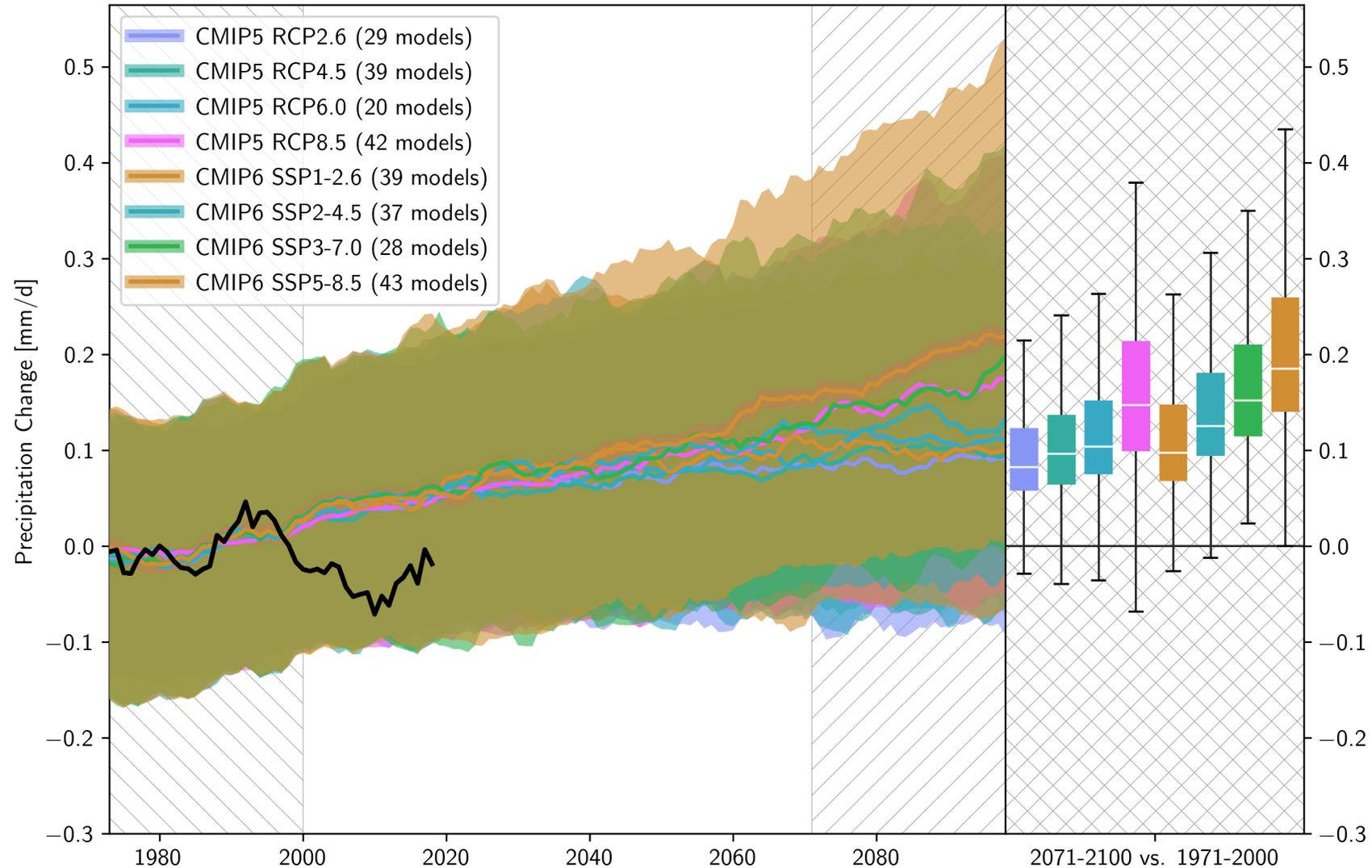


Central Asian Temperature Change



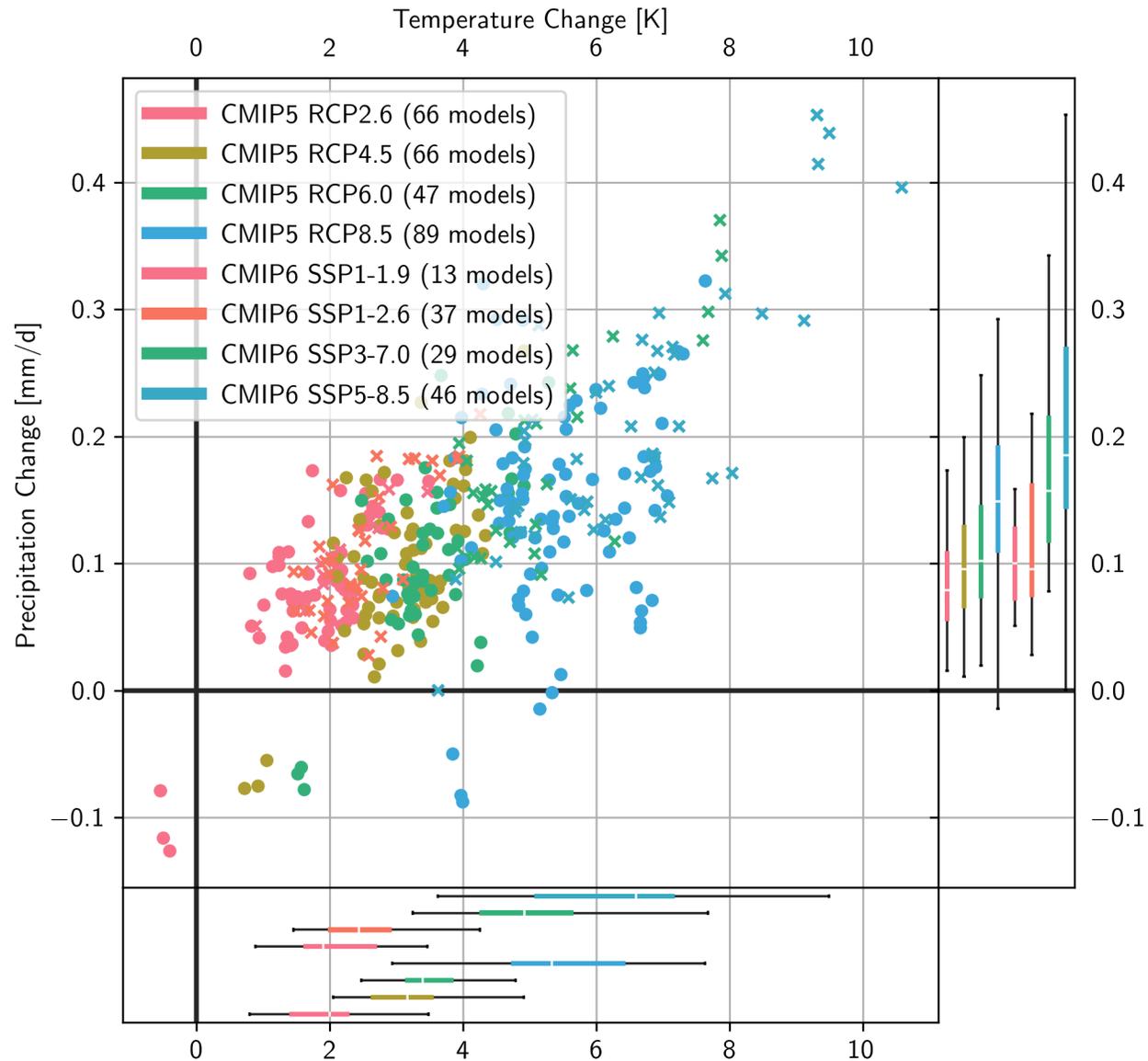
source: Bijan Fallah

Central Asian Precipitation Change



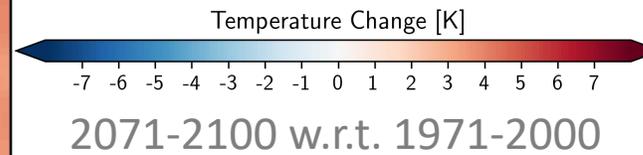
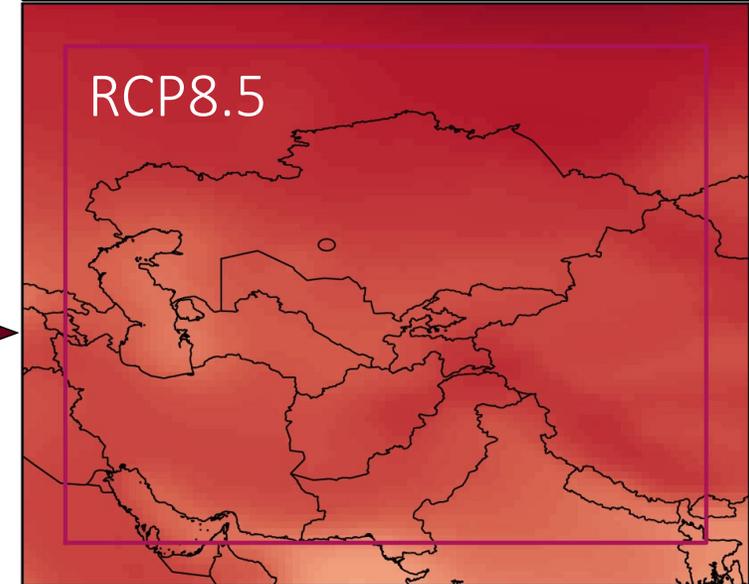
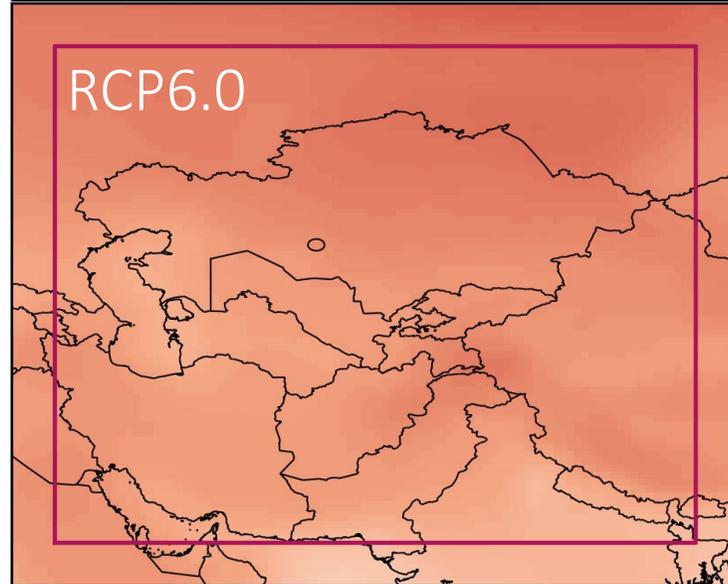
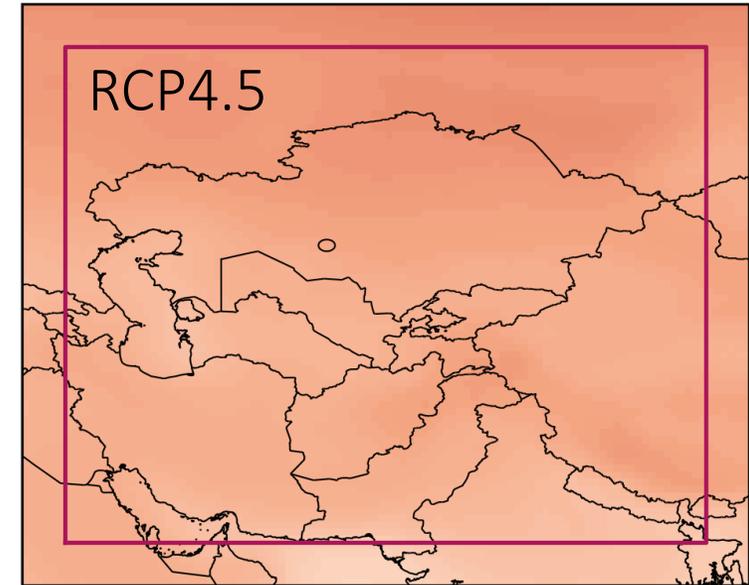
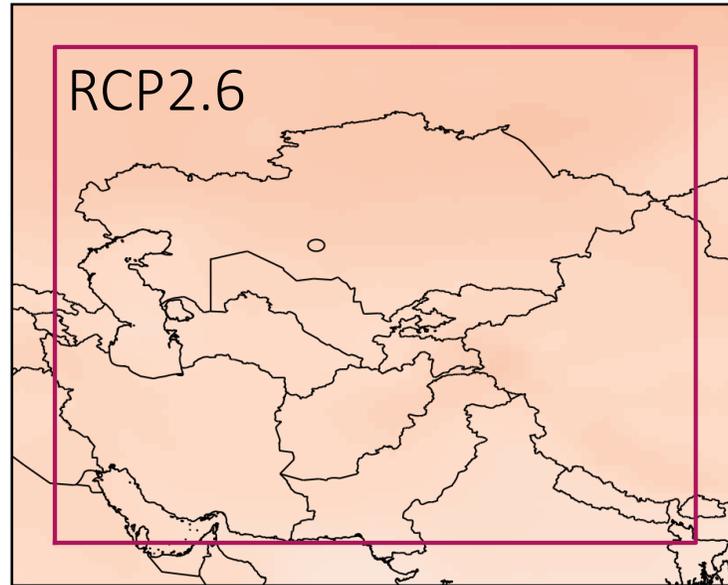
source: Bijan Fallah

Projection of the Central Asian Climate Change



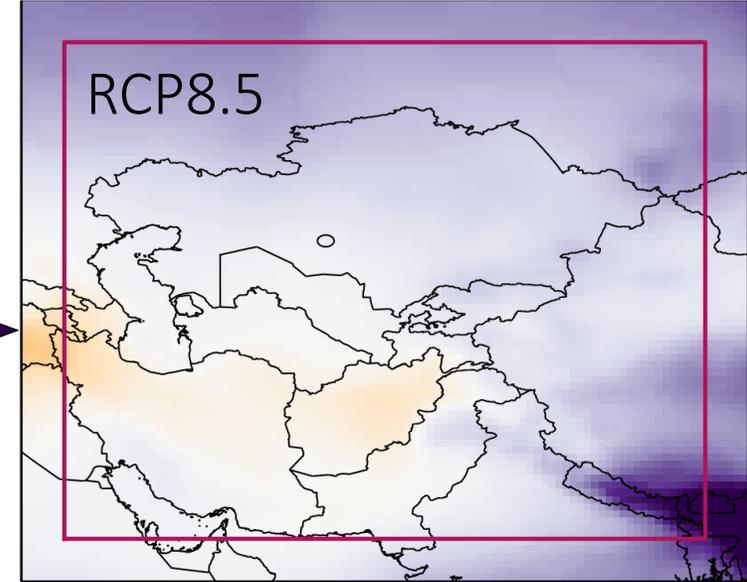
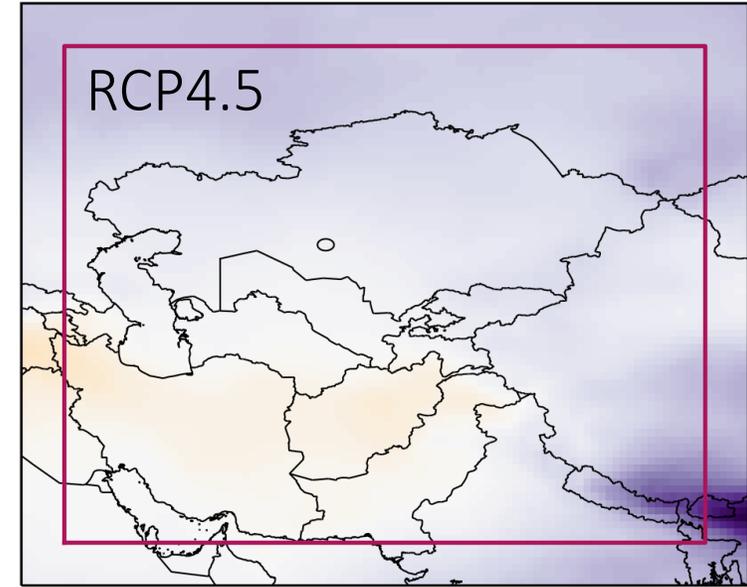
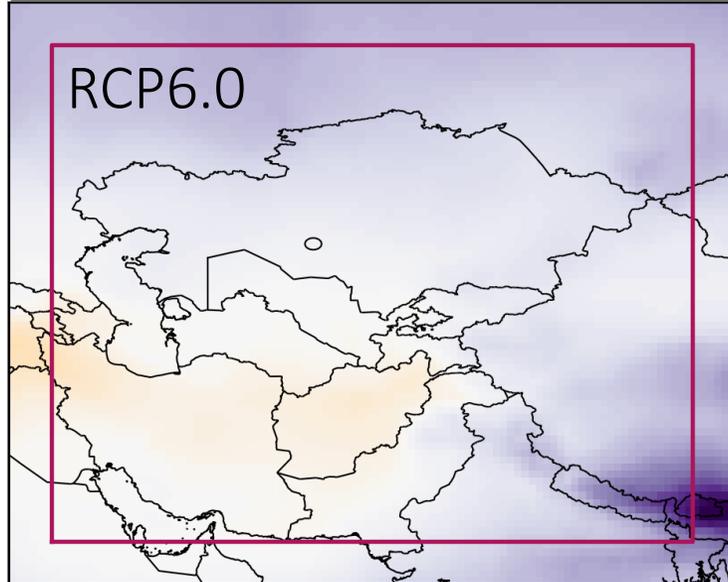
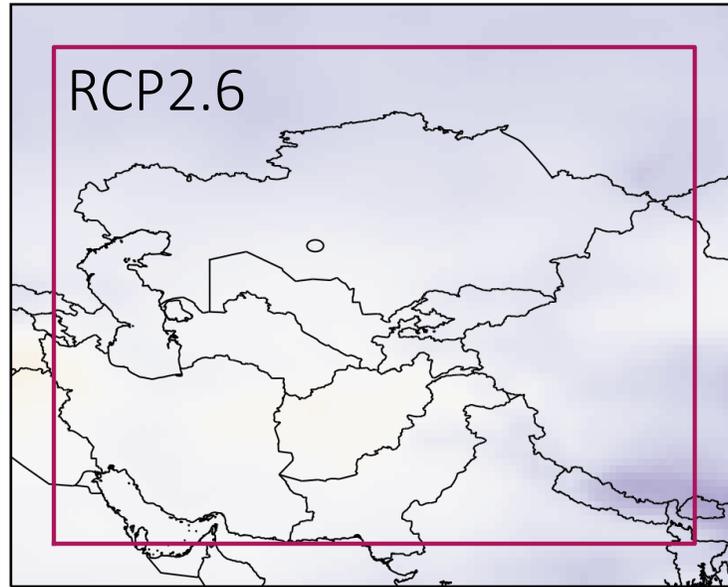
source: Bijan Fallah

Temperature Change CMIP5



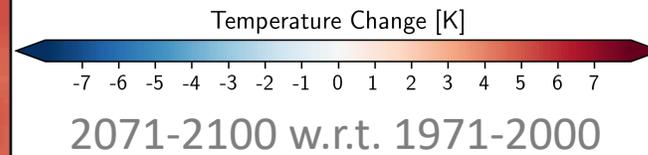
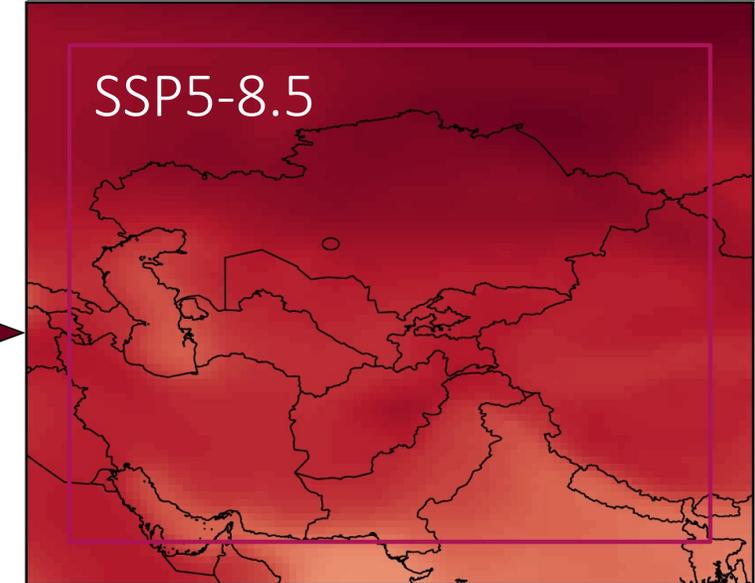
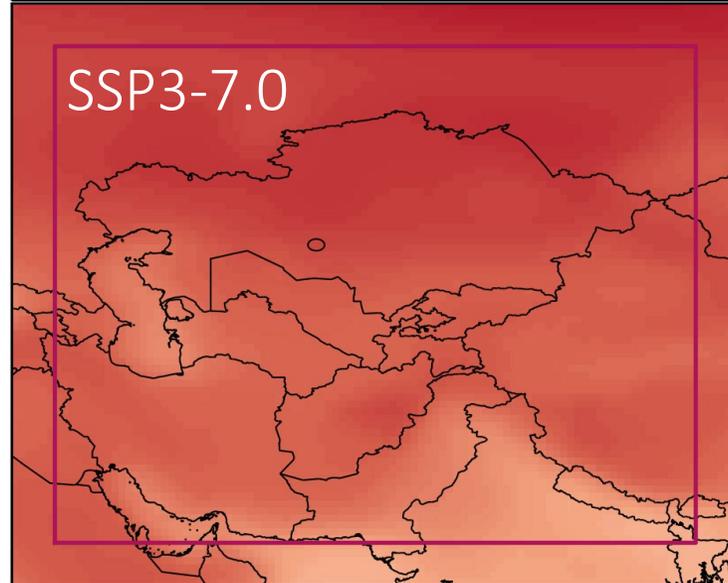
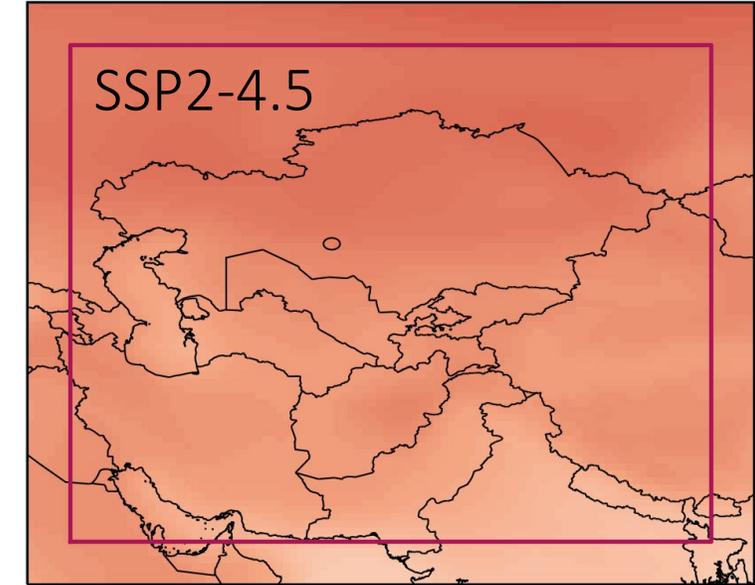
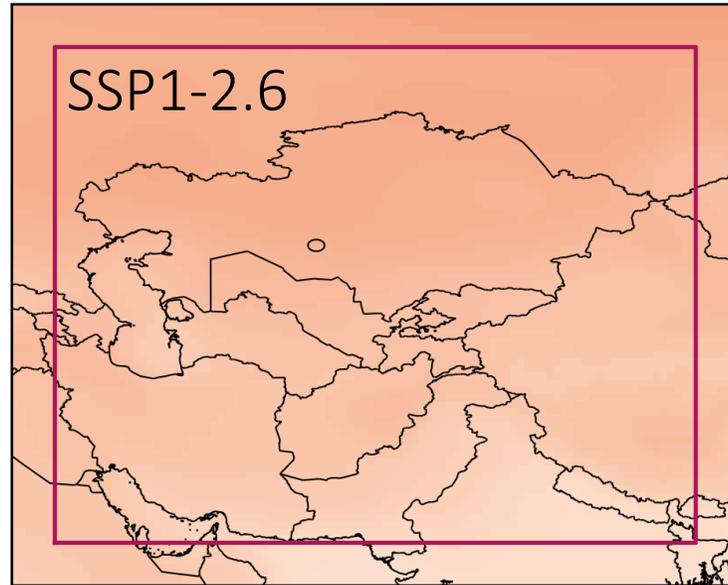
source: Bijan Fallah

Precipitation Change CMIP5



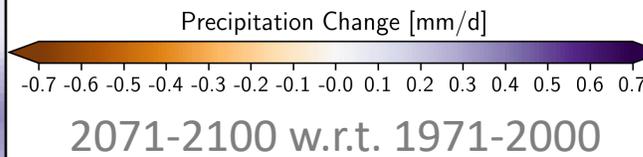
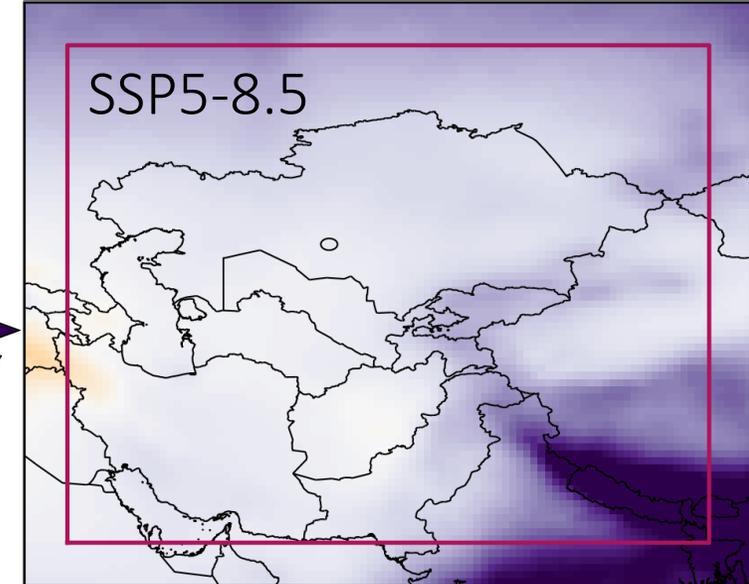
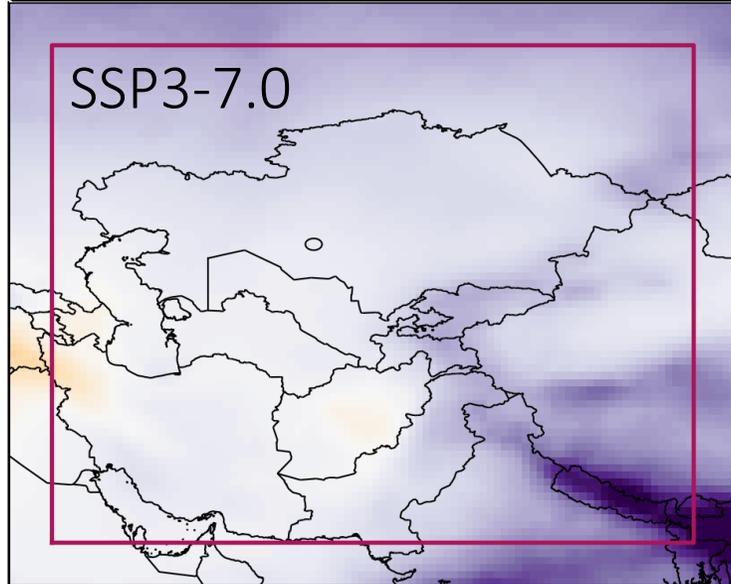
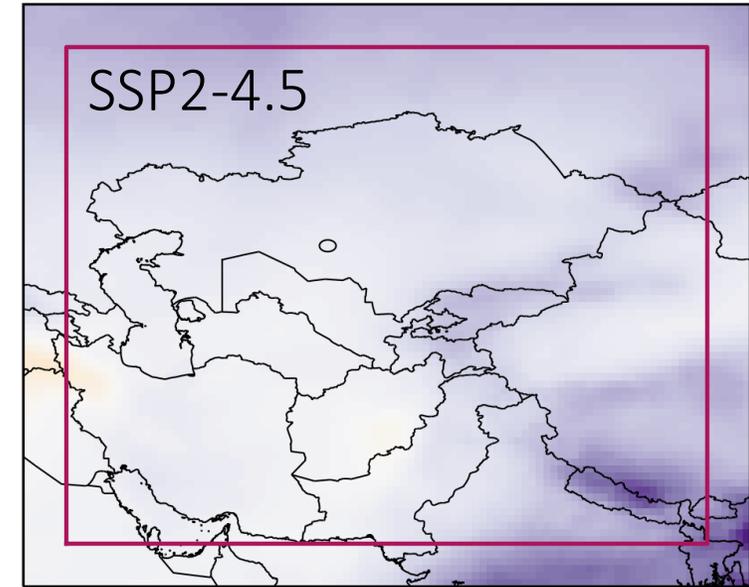
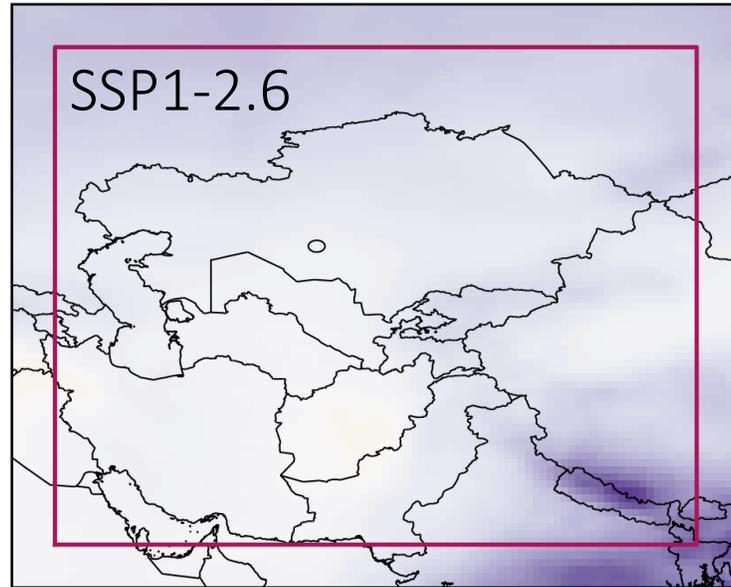
source: Bijan Fallah

Temperature Change CMIP6



source: Bijan Fallah

Precipitation Change CMIP6



source: Bijan Fallah



Take-home message

- Central Asia is warming up faster than the global trend
- Central Asia is at risk of droughts and floods
- Mountainous regions are at risk with increasing warming
- Future projections show 2-6 K warming in both CMIP5 and CMIP6 models & different scenarios
- CMIP6 models are warmer and wetter than CMIP5 ones
- There exists a linear relation between the warming and precipitation in Central Asia



Outlook

- High-resolution downscaling of CMIP6 simulations over Central Asia
- Analyze the climate change impacts : agriculture, hydropower, Health...