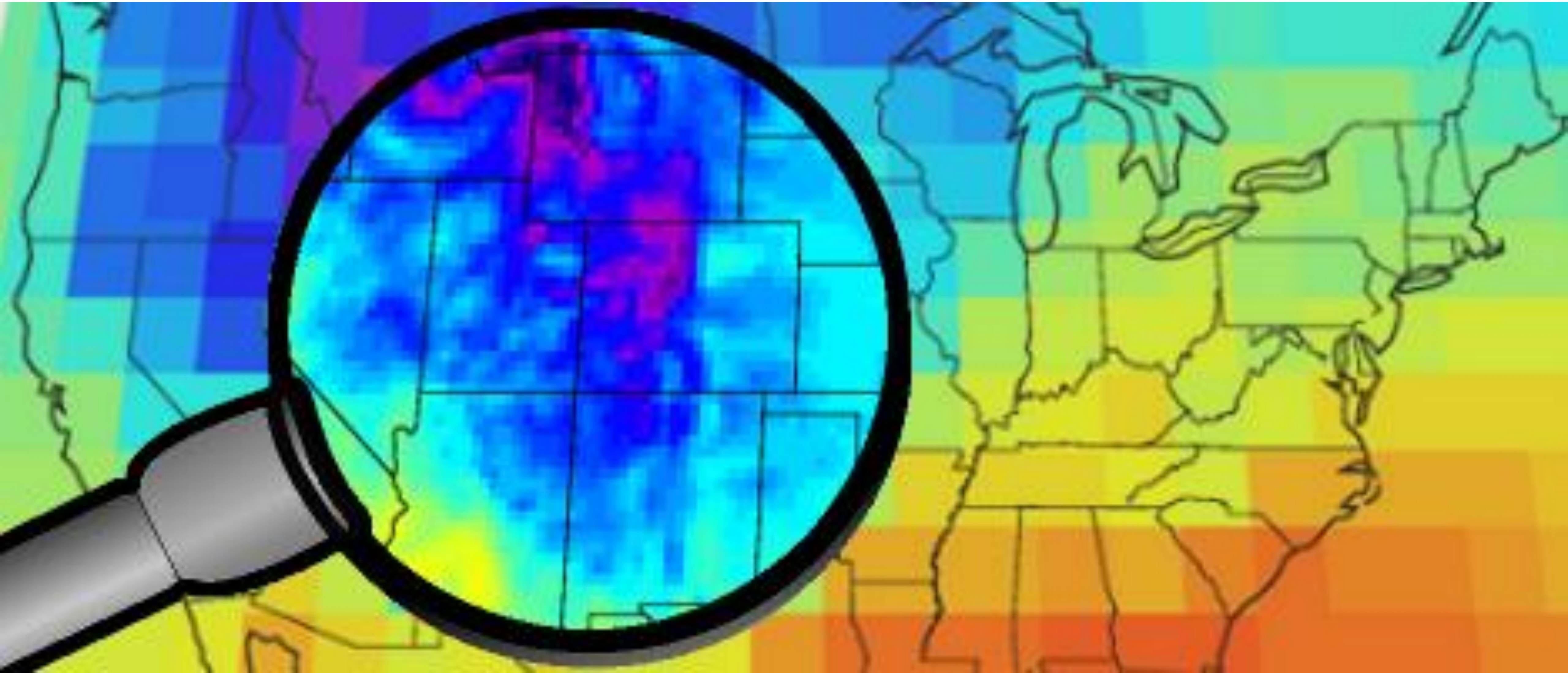
Challenges and prospects on the road to 1km ISIMIP3b daily climate data

Dirk Nikolaus Karger - Swiss Federal Research Institute WSL



Why 1km?

Several Sector in ISIMIP often
Require higher resolution than 50km
To effectivly model e.g.:

Vegetation dynamics
Biodiversity
Regional Forests
Agriculture
Etc.

Why not numerical models?

*"Currently global kilometer scale models are only able to archive a simulation throughput of 0.043 SYPD (Simulated years per day), which amounts to an 100 x shortfall compared to computationally efficient simulations defined as **1 SYPD**."*

Maybe in +/- 1 decade…

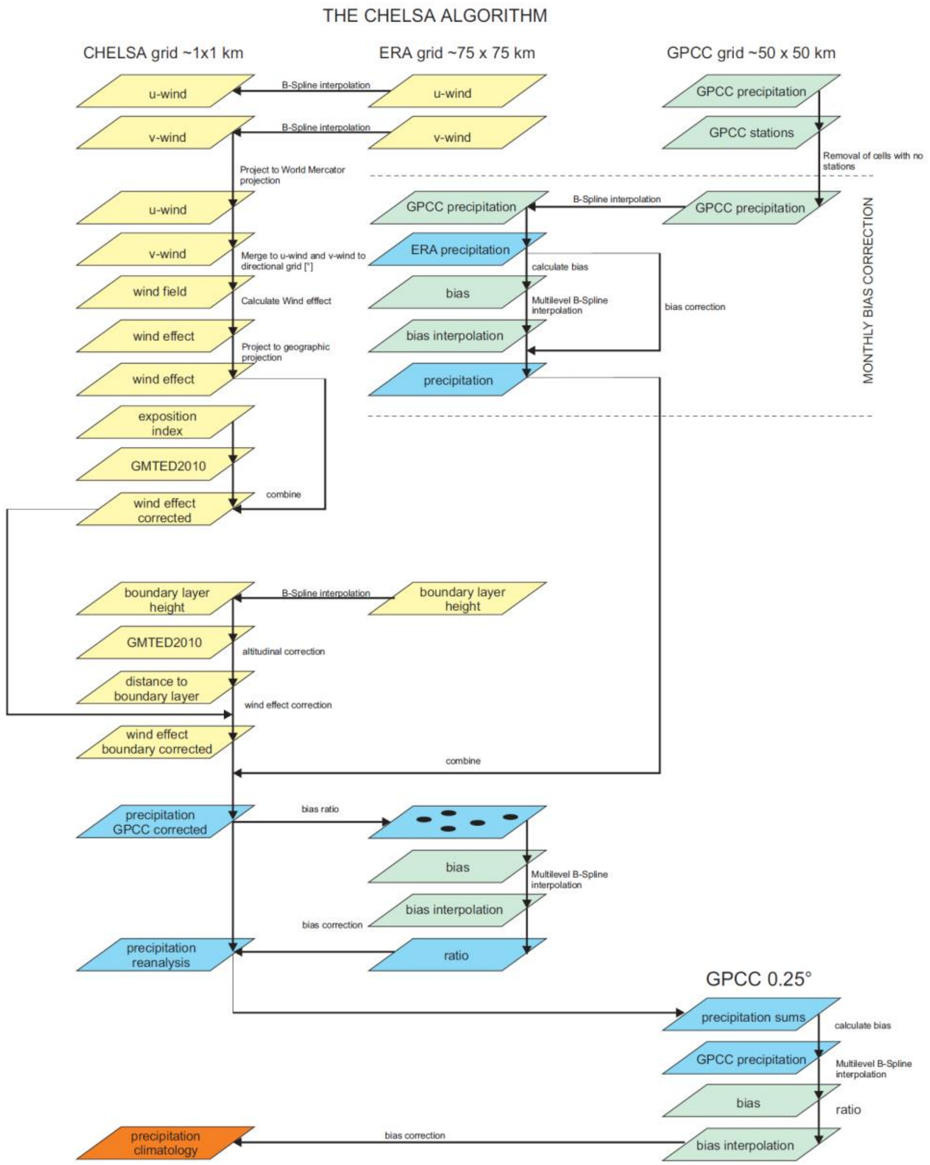
Schär, C. *et al.* Kilometer-scale climate models: Prospects and challenges. *Bull. Am. Meteorol. Soc.* **101**, (2019).

Schulthess, T. C. *et al.* Reflecting on the goal and baseline for exascale computing: a roadmap based on weather and climate simulations. *Comput. Sci. Eng.* **21**, 30–41 (2018).

The CHELSA V2.1 algorithm

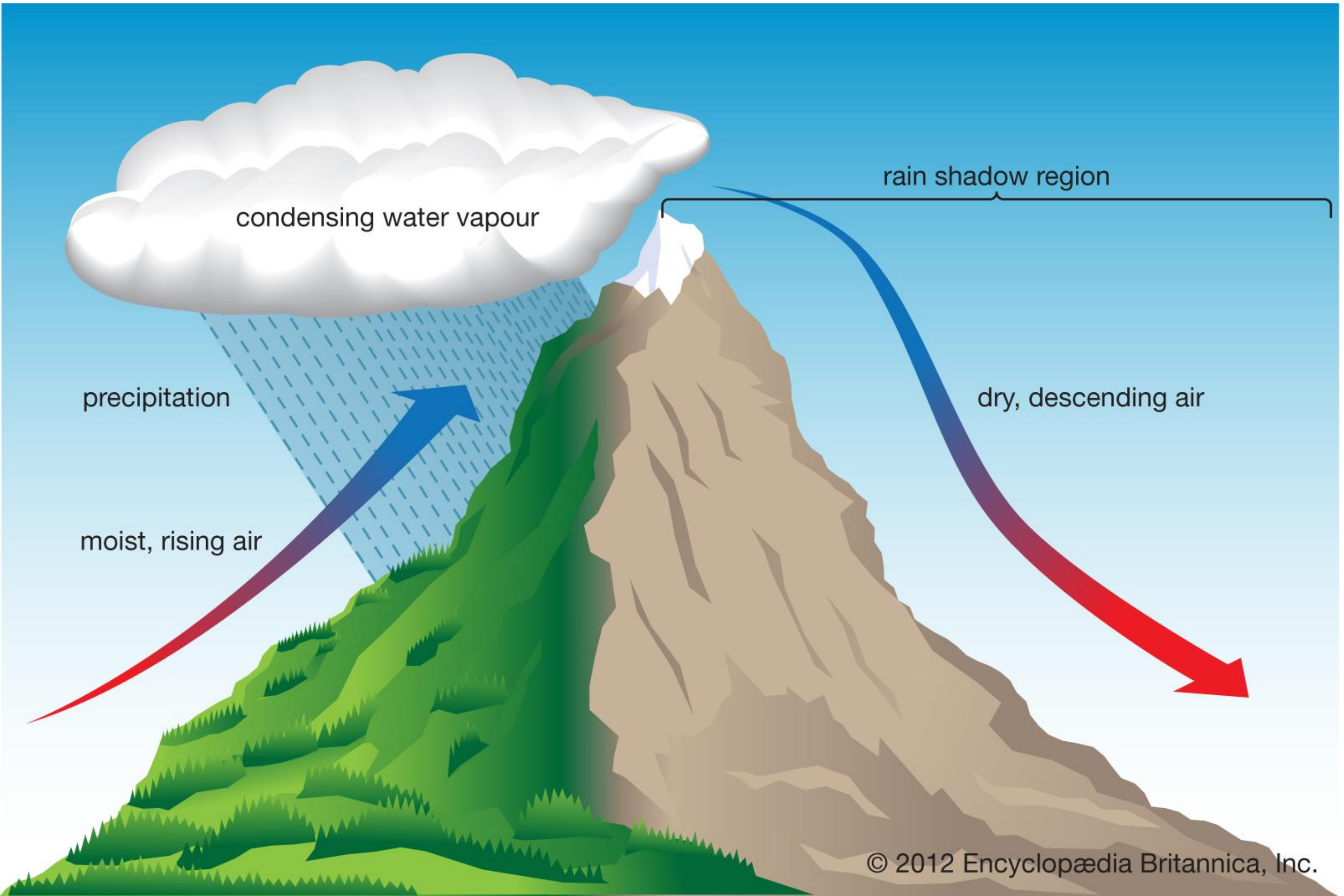
- Model output statistics based on GCM
- Parameteric estimation of orographic effects on small scale precipitation, cloud cover, and solar raditation based on RCM wind components and boundary layer conditions
- Atmospheric lapse rate based downscaling of temperatures

- Computational efficient : 1SYPD on 400 CPUs
- Focus on a few variables (tas, tasmax, tasmin, rsds, pr),
- daily resolution
- 1km resolution



Precipitation algorithm works with a simple parametrization of the orographic effects.

- Relativly fast to estimate from v and u wind components and condensation levels
- Does not explixitly resolve convective systems



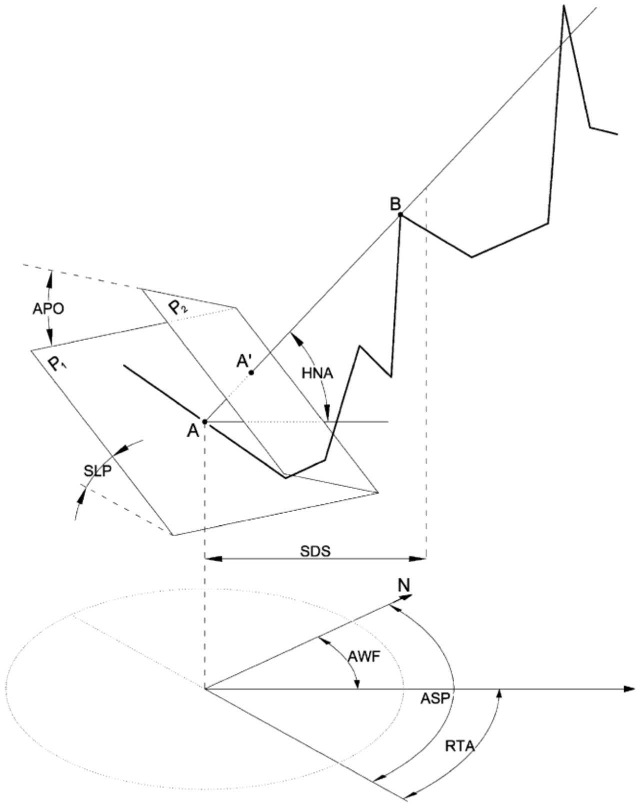
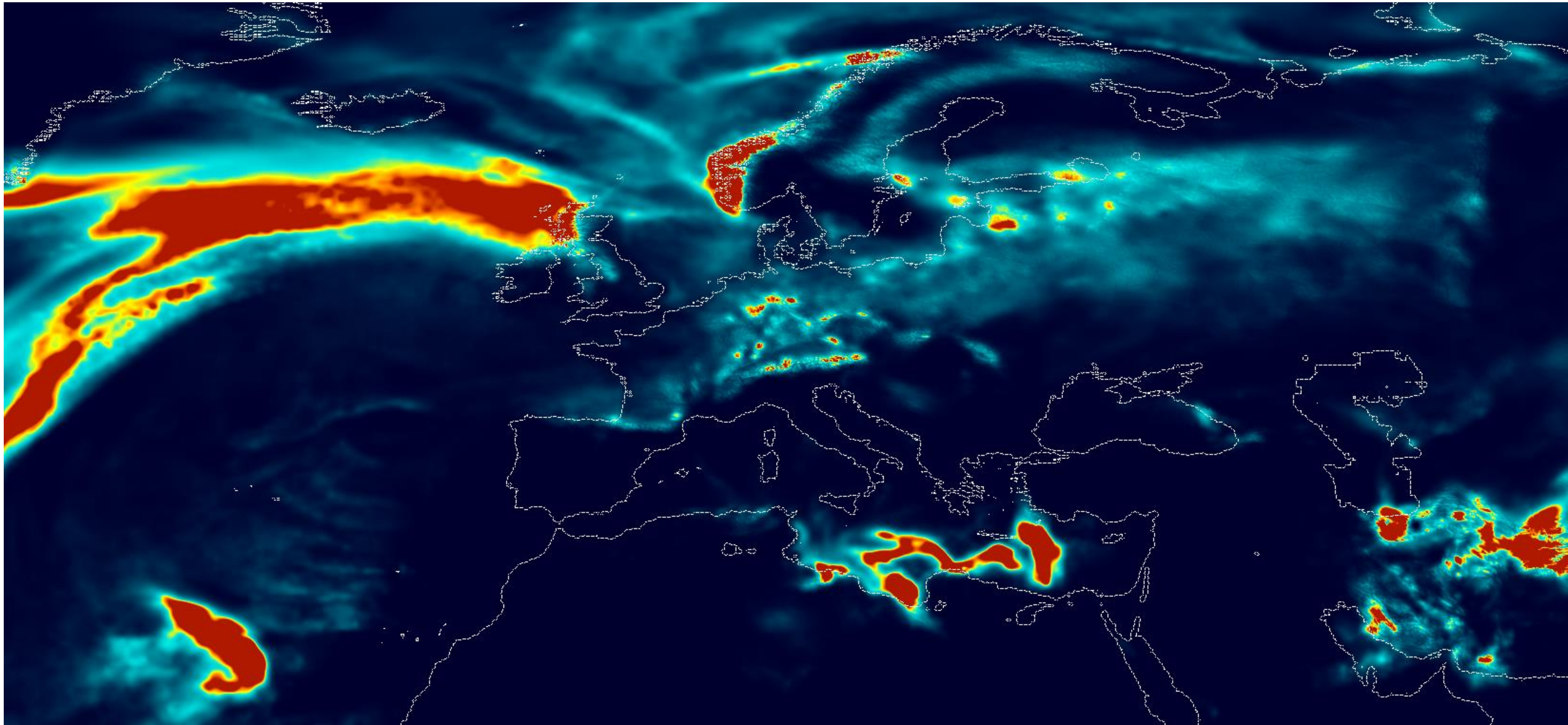
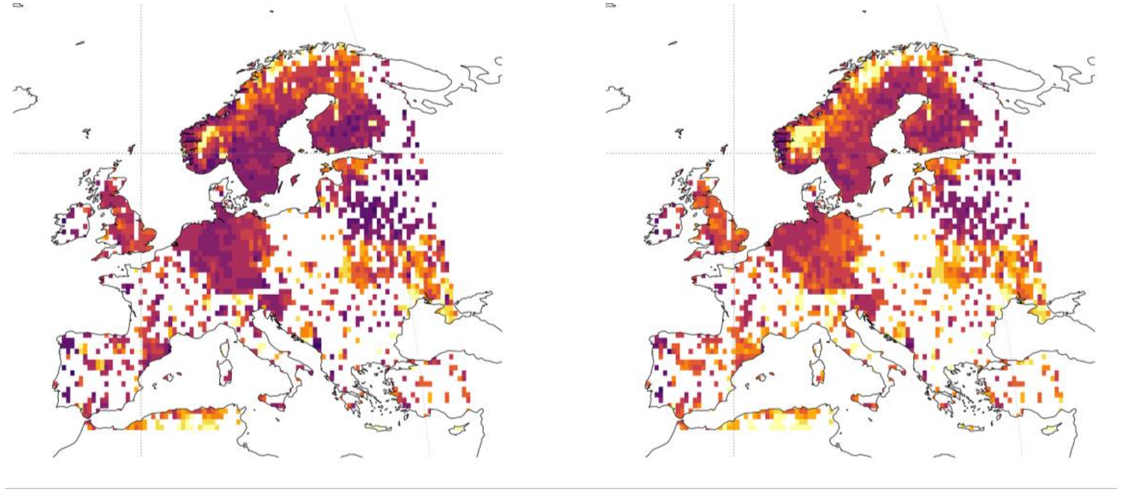


FIGURE 14 Schematic presentation of estimators of topographic exposure to wind. Bold line represents land surface. N indicates north. Terrain around the point A has the slope (SLP) and aspect (ASP). Relative terrain aspect (RTA) is absolute angle distance between the terrain aspect and the azimuth of wind flux (AWF). Horizon angle (HNA) of point A for given azimuth of wind flux is determined by the point B under the chosen search distance (SDS) — note that a change of search distance may change horizon angle. The angle between a plane which locally represents terrain (P_1) and plane orthogonal to the wind (P_2) is denoted by APO (the point A′ is a projection of the point A on the orthogonal plane).

First evaluations of the precipitation algorithm

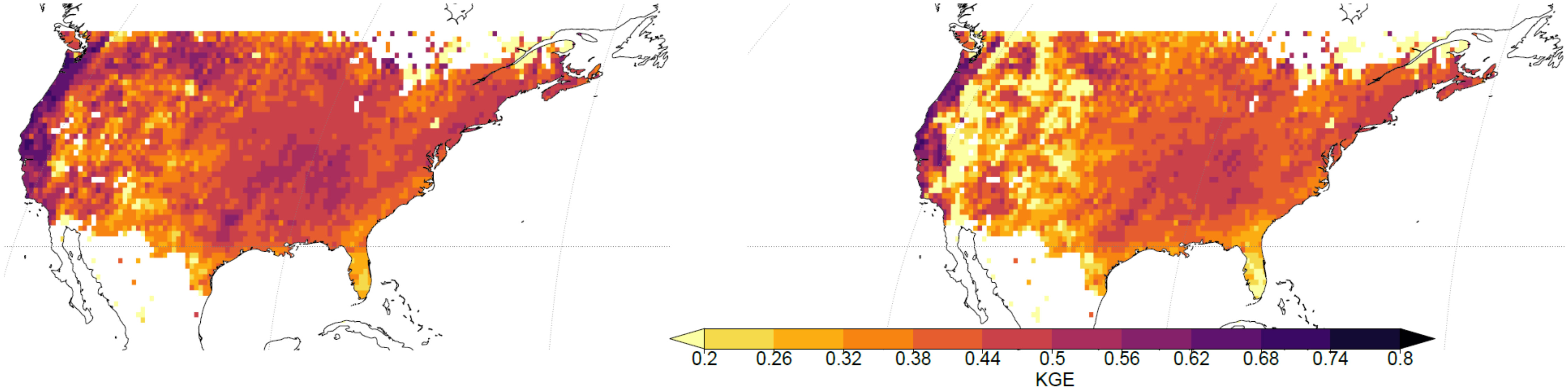


Comparison of daily precipitation rates from CHELSA and ERA5 to those observed in GHCN (Global Historical Climate Network)

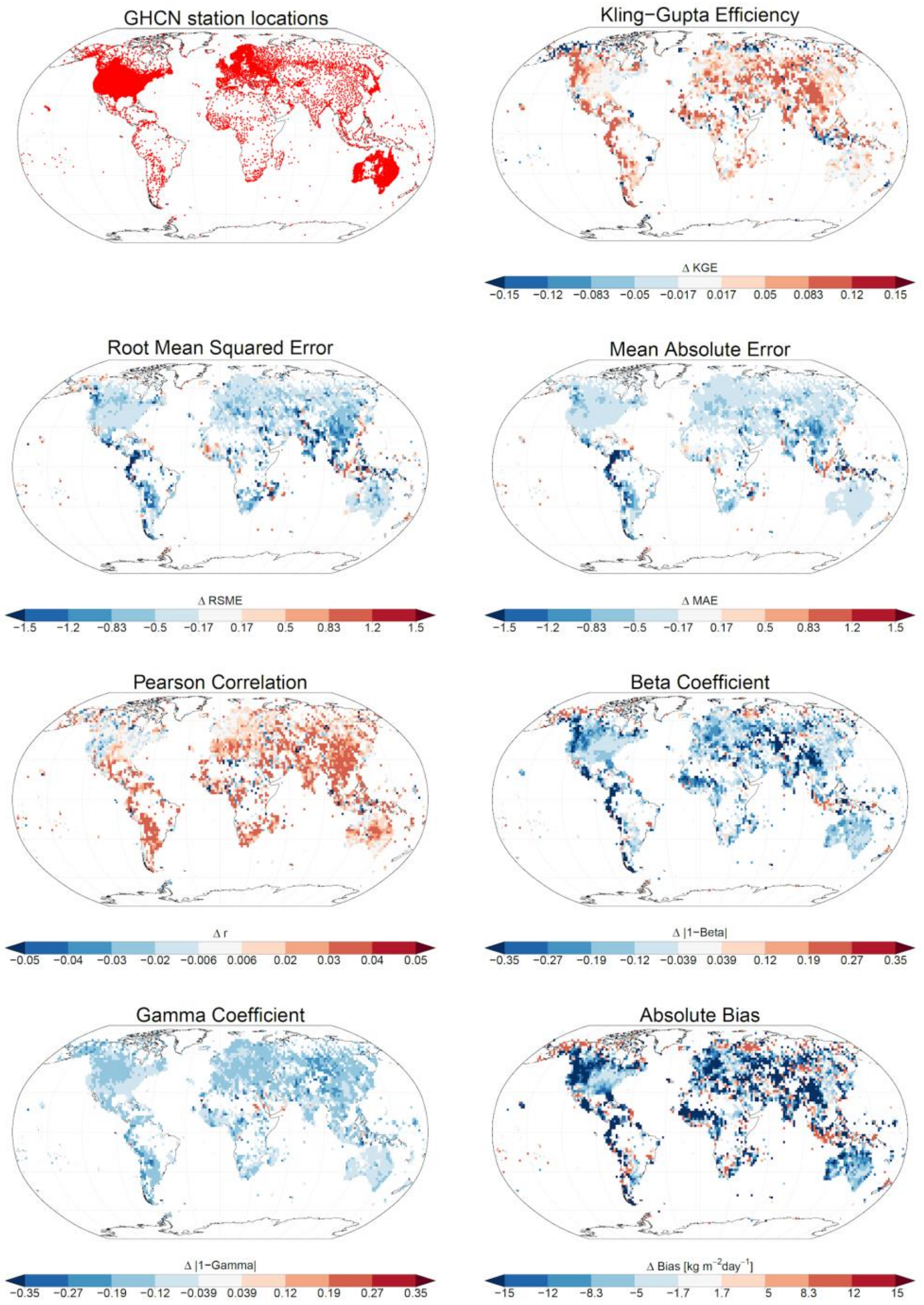


Comparison using Kling-Gupta Efficiency

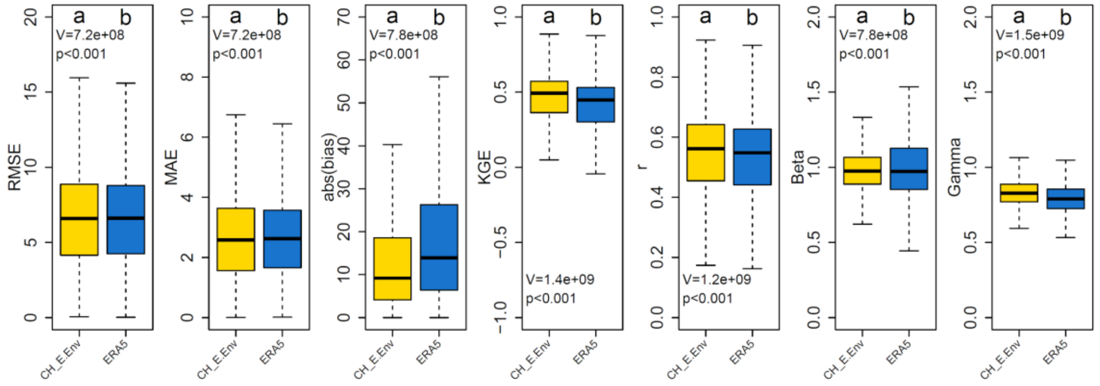
Increase in performance while downscaling
From 0.5° to 1km



Karger, D.N., Wilson, A.M., Mahony, C., Zimmermann, N.E. & Jetz, W. (2020) Global daily 1km land surface precipitation based on cloud cover-informed downscaling. *arXiv:2012.10108 [physics]*.



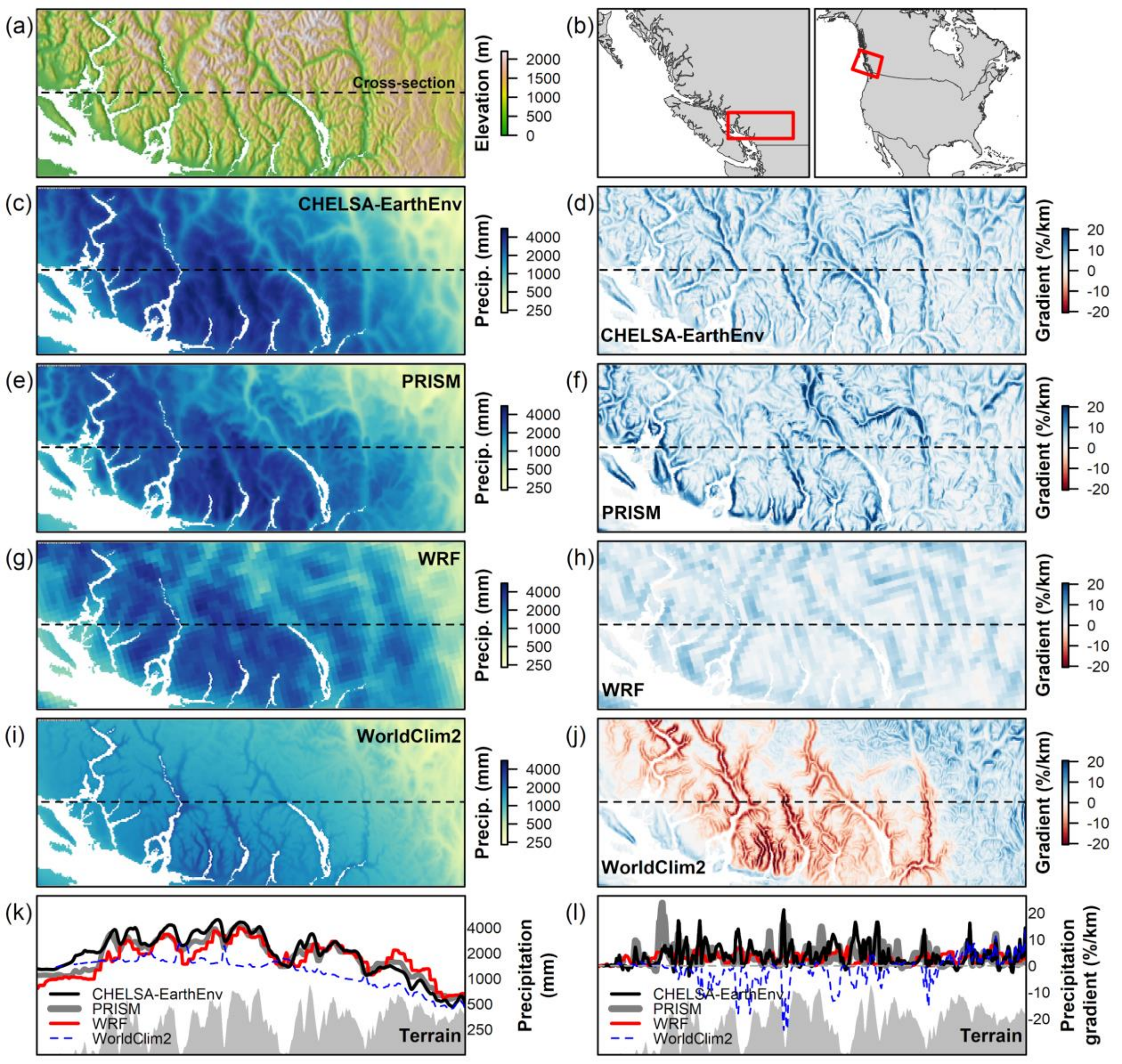
Comparison of daily precipitation rates from CHELSA and ERA5 to those observed in GHCN (Global Historical Climate Network)



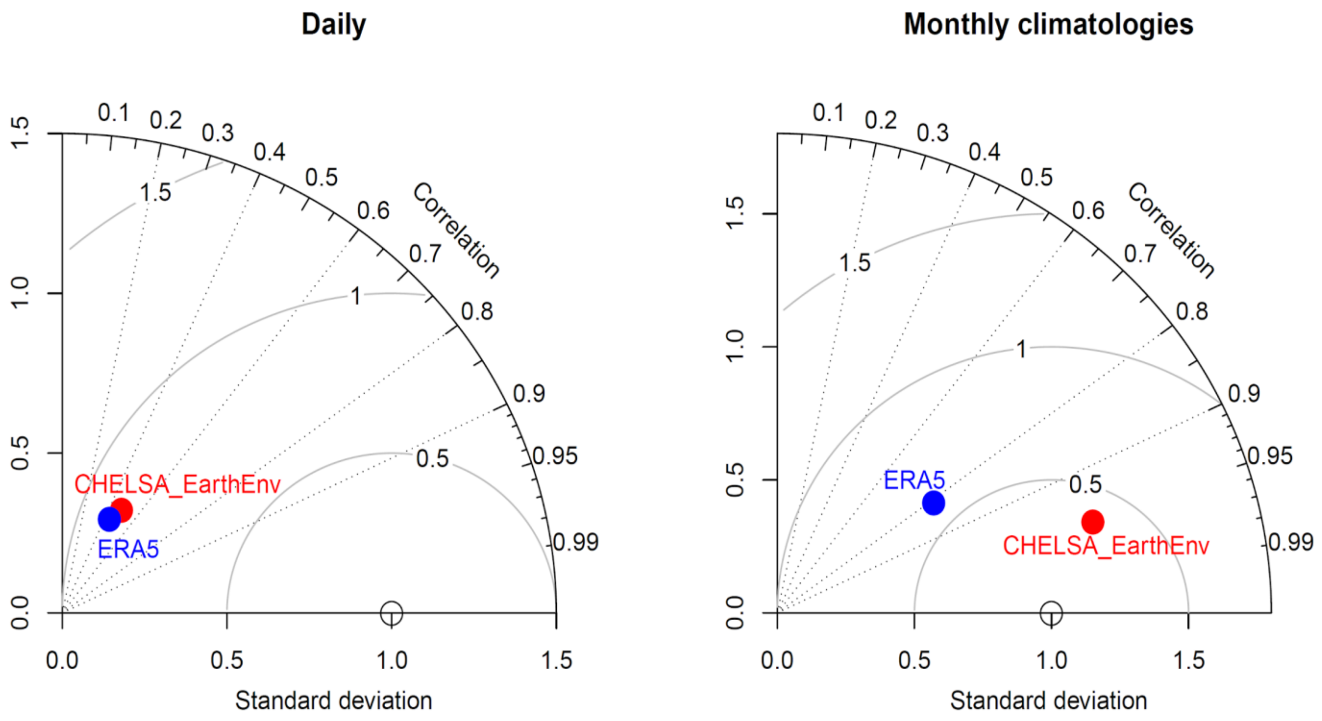
Increase in performance in all aspects

- Lower bias
- Higher correlation
- Better temporal signal
- Better climatological performance
- More realistic precipitation lapse rates

Karger, D.N., Wilson, A.M., Mahony, C., Zimmermann, N.E. & Jetz, W. (2020) Global daily 1km land surface precipitation based on cloud cover-informed downscaling. *arXiv:2012.10108 [physics]*.



Karger, D.N., Wilson, A.M., Mahony, C., Zimmermann, N.E. & Jetz, W. (2020) Global daily 1km land surface precipitation based on cloud cover-informed downscaling. *arXiv:2012.10108 [physics]*.

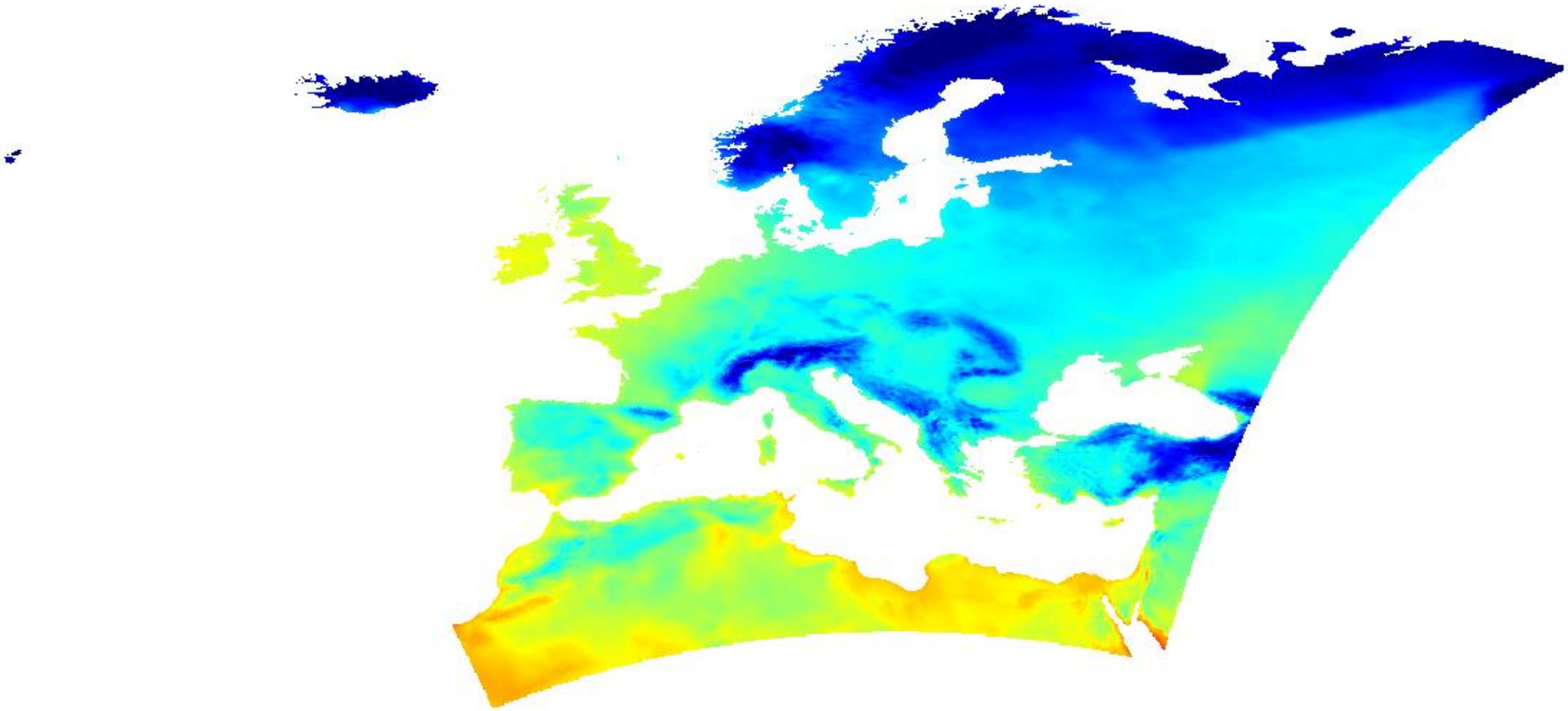


Increase in performance in all aspects

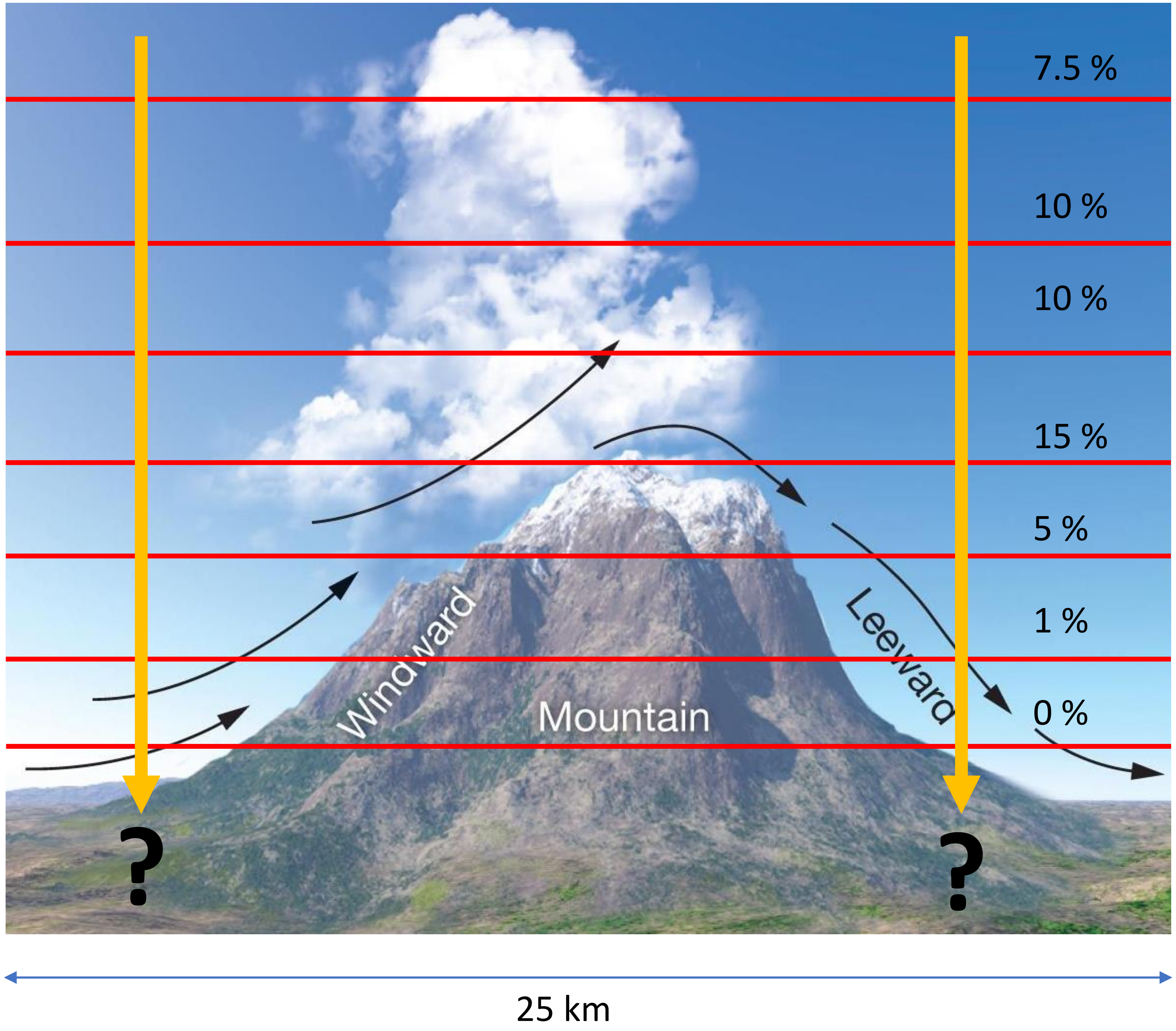
- Lower bias
- Higher correlation
- Better temporal signal
- Better climatological performance
- More realistic precipitation lapse rates

Karger, D.N., Wilson, A.M., Mahony, C., Zimmermann, N.E. & Jetz, W. (2020) Global daily 1km land surface precipitation based on cloud cover-informed downscaling. *arXiv:2012.10108 [physics]*.

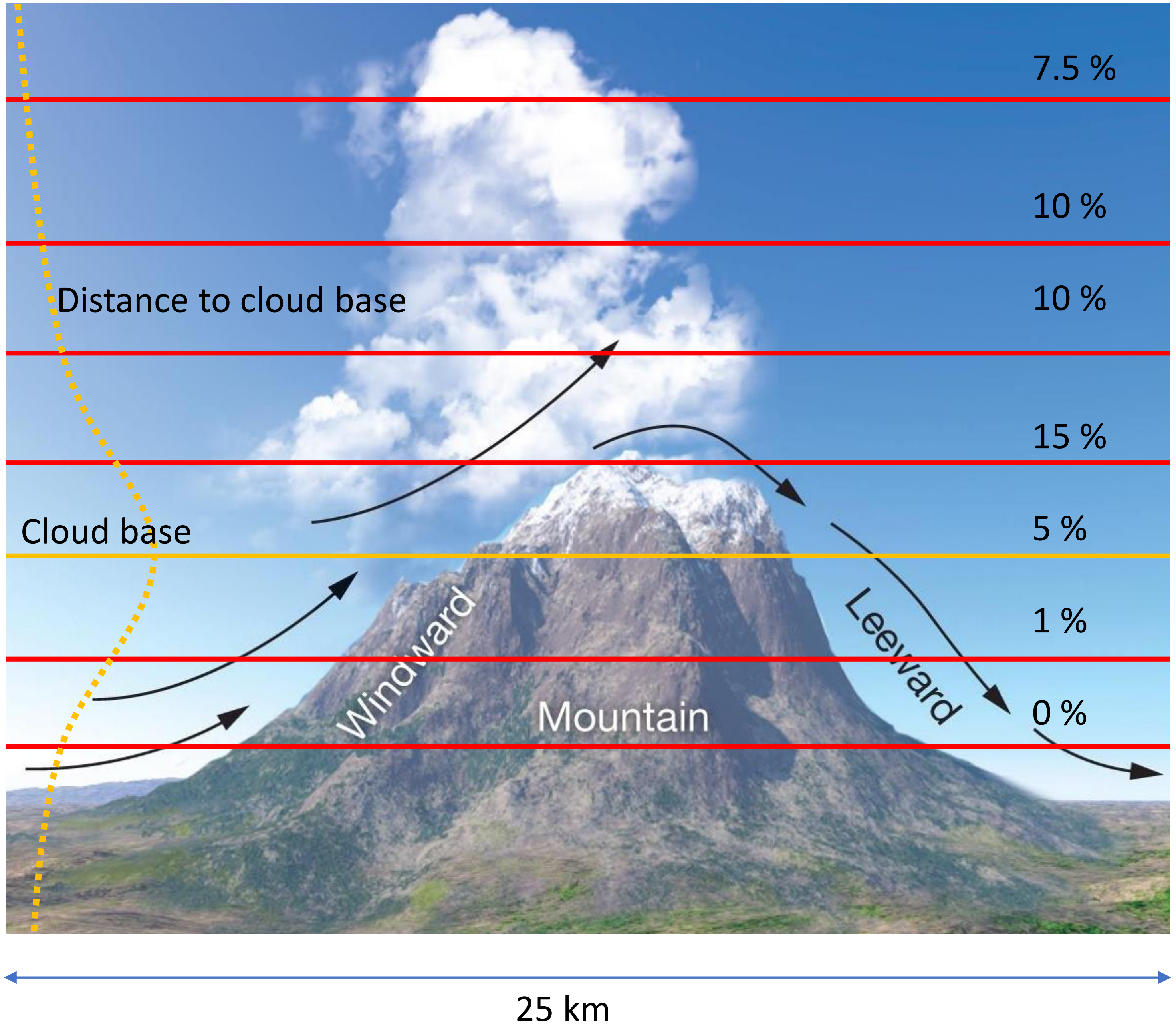
Temperature and radiation



Clouds are problematic



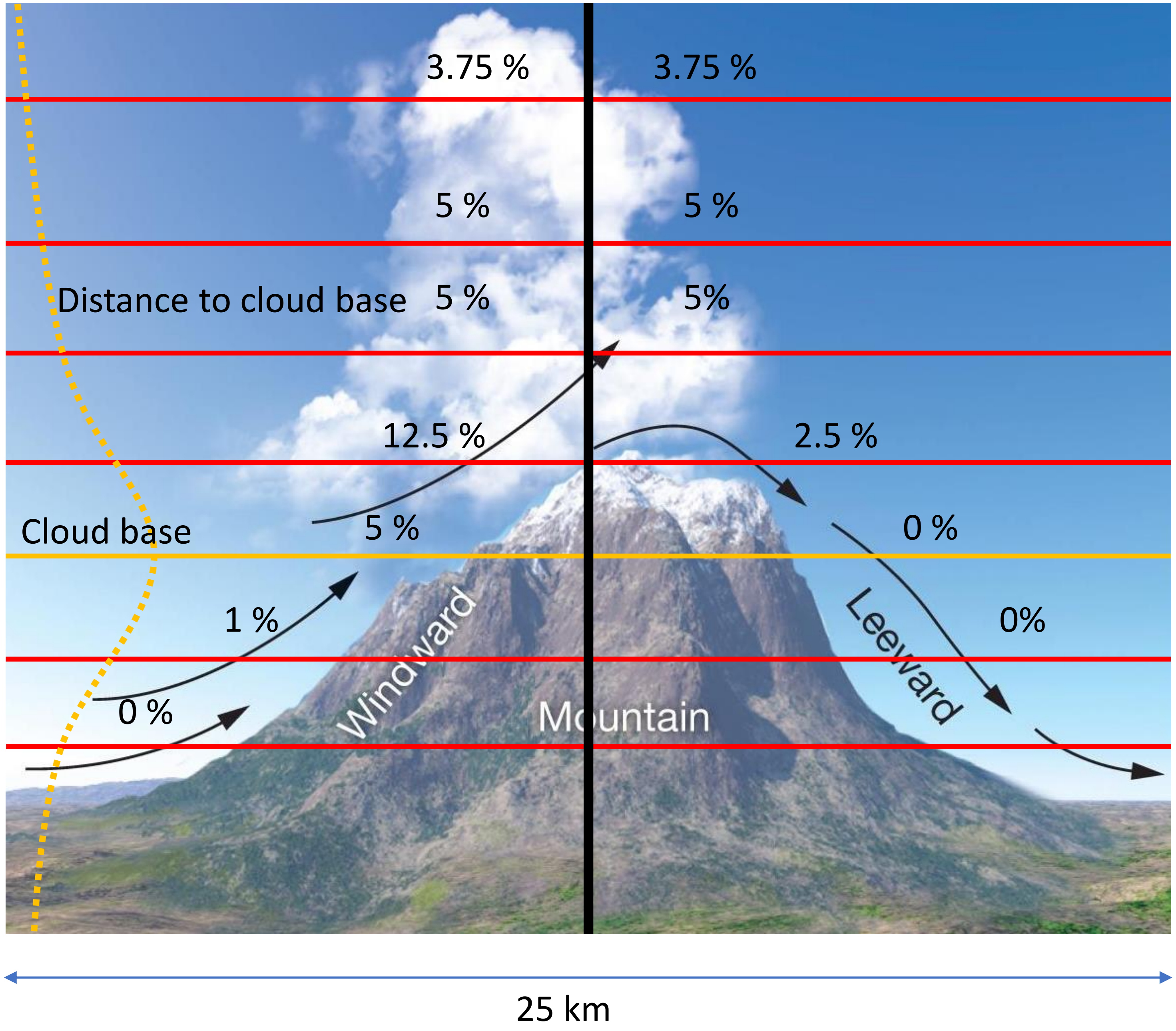
Algorithm to downscale cloud cover from atmospheric cloud cover fractions



Algorithm to downscale cloud cover
From atmospheric cloud cover fractions

Function describing distance from cloud base

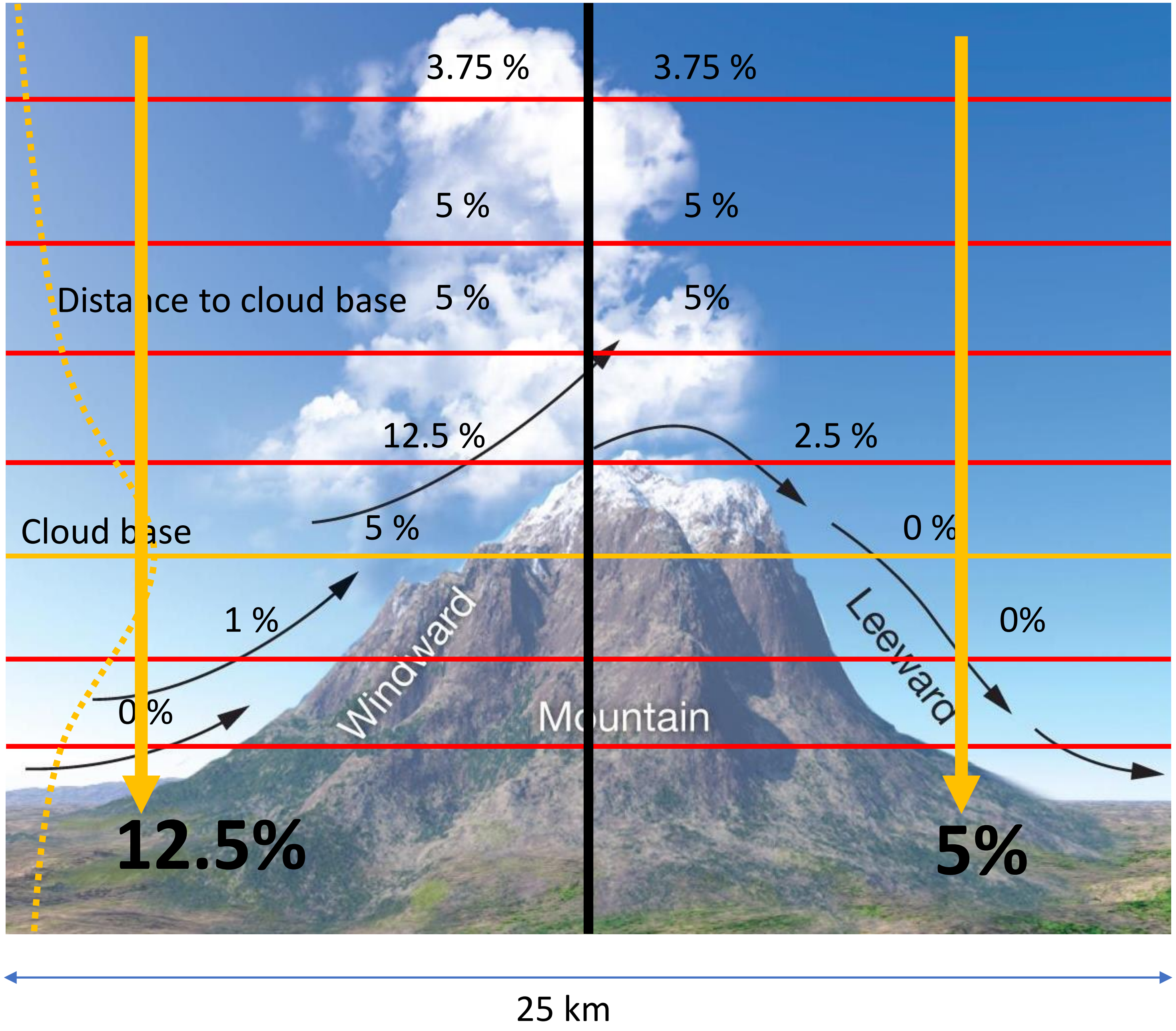
Windward leeward index



Algorithm to downscale cloud cover
From atmospheric cloud cover fractions

Function describing distance from cloud base

Windward leeward index

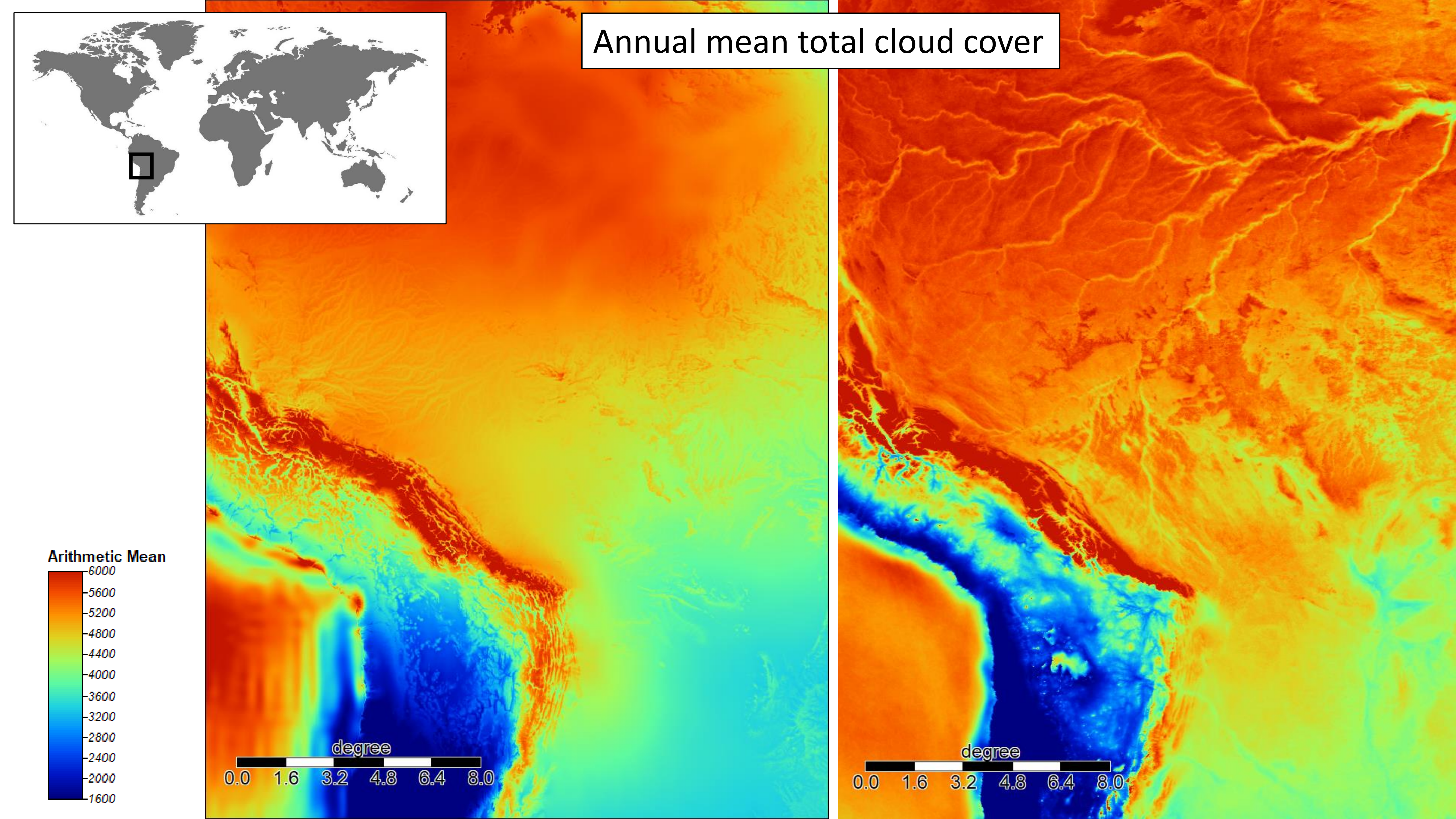


Algorithm to downscale cloud cover
From atmospheric cloud cover fractions

Function describing distance from cloud base

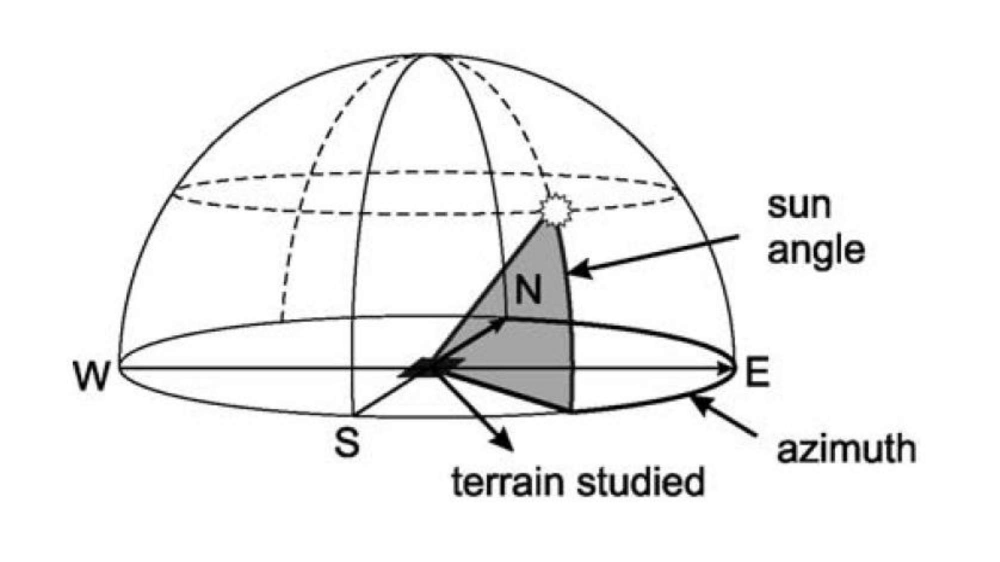
Windward leeward index

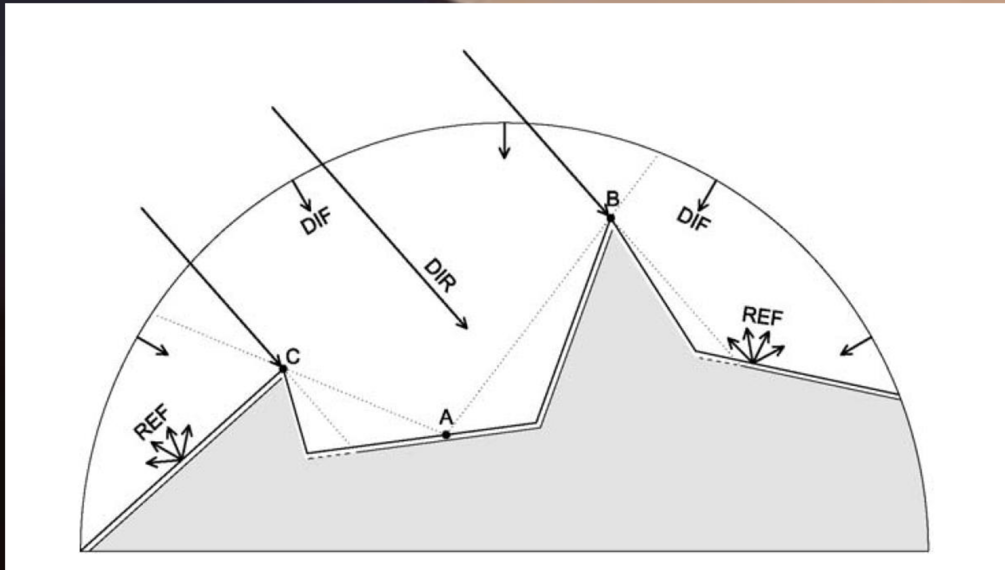
Distribute cloud cover based on windward
Leeward position of a pressure level and
Its distance to cloud base height


Annual mean total cloud cover
Arithmetic Mean
6000
5600
5200
4800
4400
4000
3600
3200
2800
2400
2000
1600
degree
0.0 1.6 3.2 4.8 6.4 8.0
degree
0.0 1.6 3.2 4.8 6.4 8.0

Problems with cloud cover

- No convection included
- Still huge biases in the forcing data (e.g. ERA5) compared to observations -> maybe a bias correction of the ERA5 data is needed
- Not all CMIP6 models have cloud cover through the atmosphere available. Here a simpler algorithm is used -> more interpolation errors -> would be ‘nice to have output’ from the CMIP6 models





Solar radiation based on terrain exposition and sun angle

- Clear sky conditions
- Direct and diffuse radiation

Solar radiation based on Terrain exposition and sun angle

First approximation

Combine with cloud cover
To get total incoming
solar radiation at surface

$$R = R_0(1 - 0.75n^{3.4})$$

where:

R= solar radiation

n= cloud cover (0.0 - 1.0)

and

$$R_0 = 990 \sin\phi - 30$$

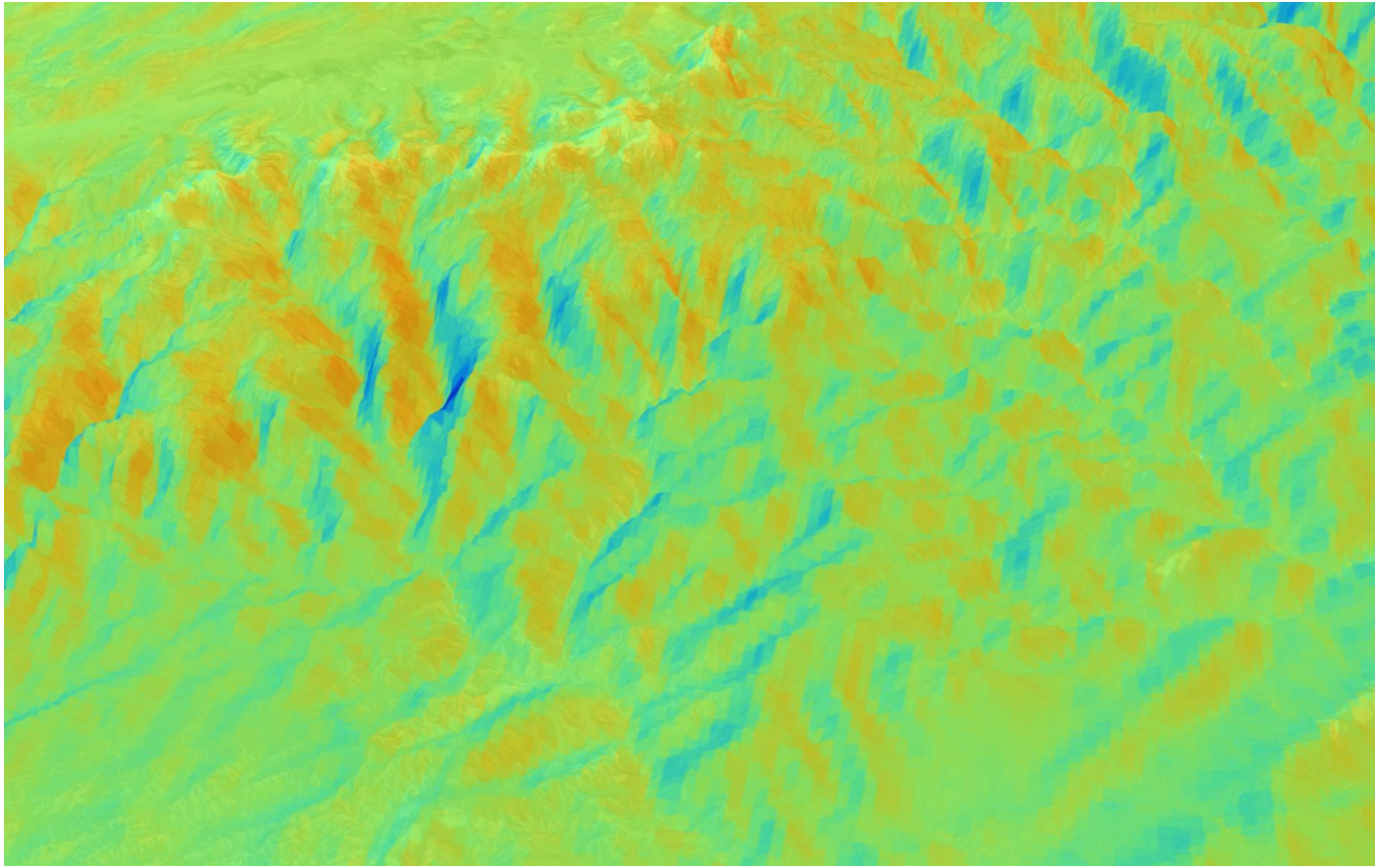
where:

$$\phi = \frac{\phi_{tp} + \phi_p}{2}$$

ϕ_{tp} = previous hour solar elevation angle

ϕ_p = current hour solar elevation angle

R_0 = clear sky insolation ($W \cdot m^2$)

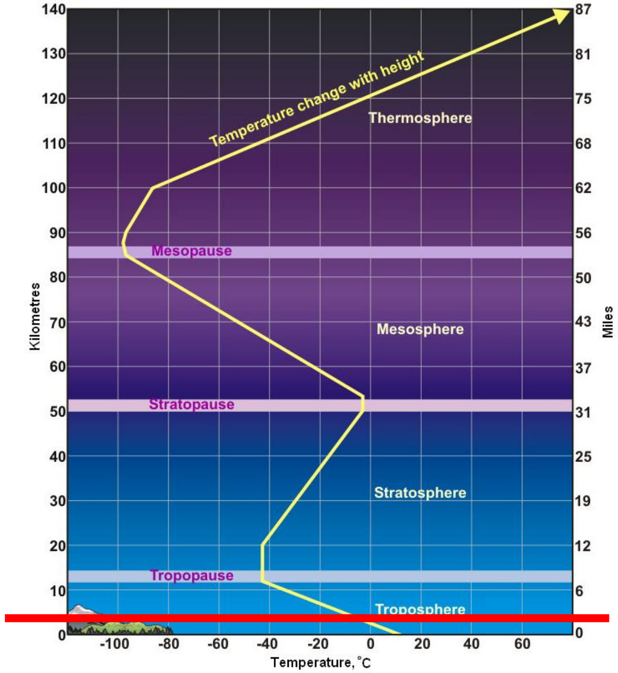


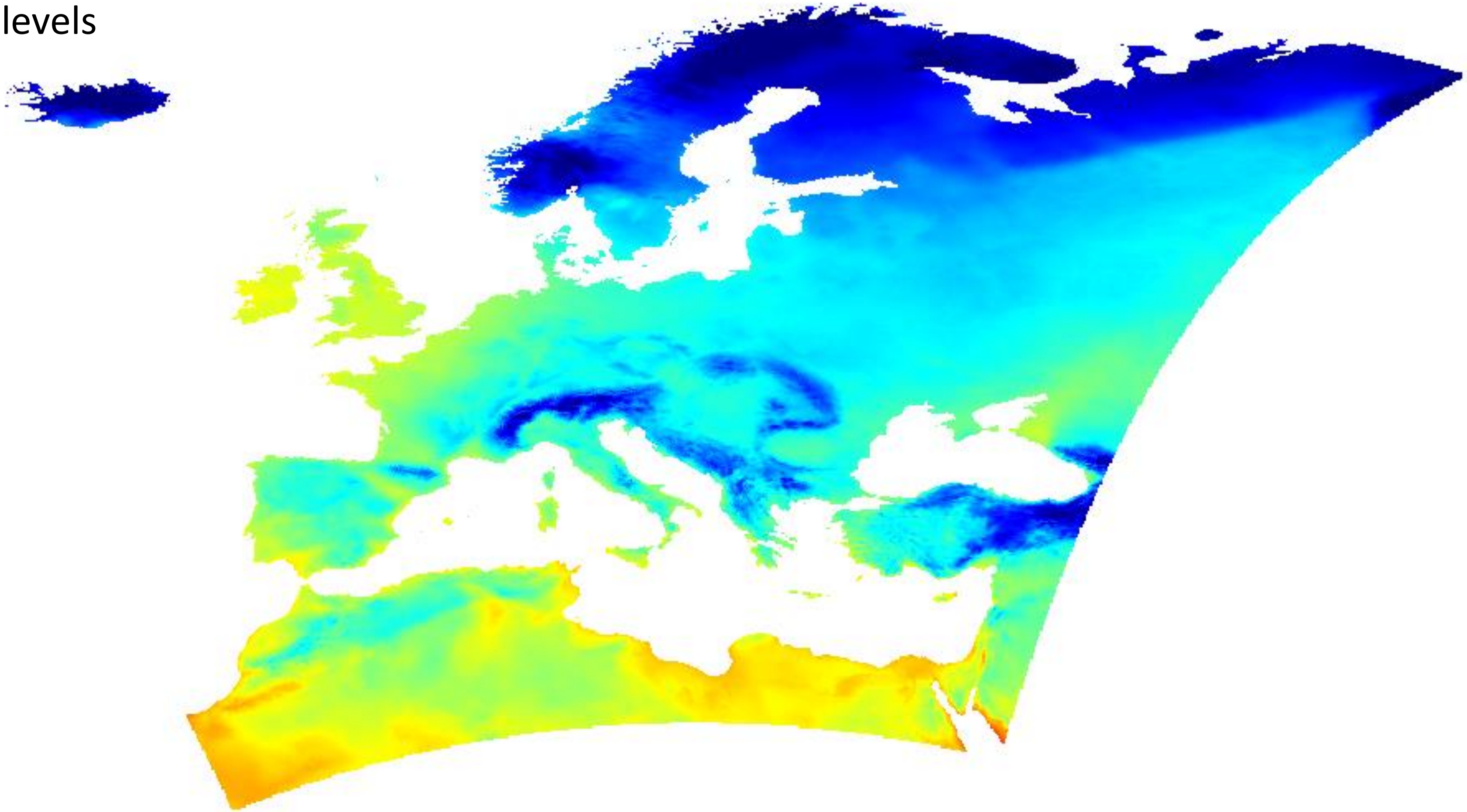
Temperatures

Lapse rate based temperature downscaling

Using two surface near pressure levels
From the respective GCM.

Not elegant, but **fast**...





Pros & Cons of the downscaled data

- Pros

1. Fast. 1 SYPD (400 CPUs)
2. Increased performance compared to coarse grid climate
3. Runs on any GCM with little code adjustment needed

- Cons

1. Correlation structure between variables not preserved
2. Interpolation artefacts
3. No convection
4. Large storage space needed

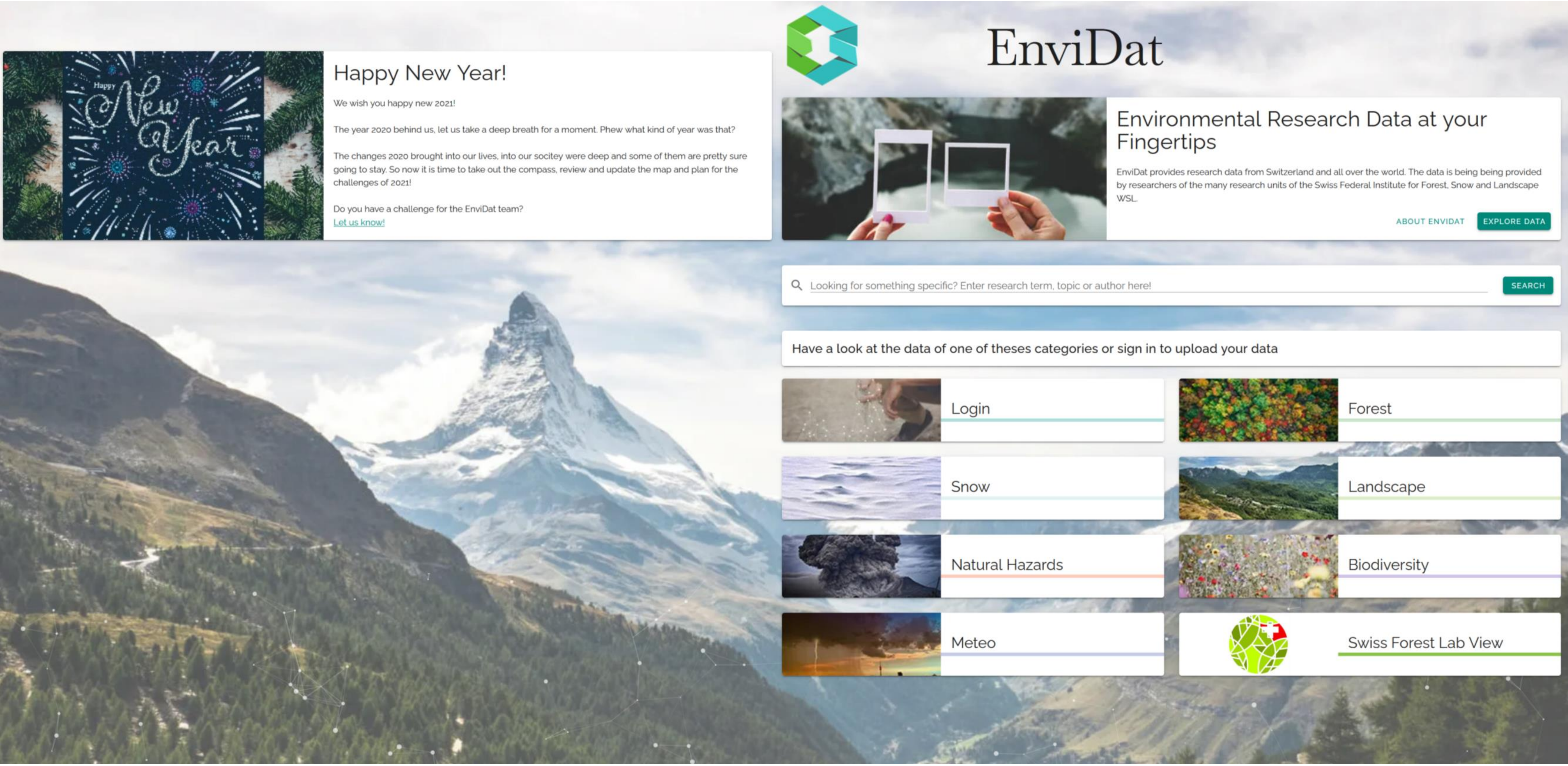
Currently available data

Model	Forcing	Times	Resolution
CHELSA V.2.1	ERA 5	1979-2019	daily, 1km
CHELSA W5E5	W5E5	1979-2016	daily, 1km

Currently available data

Model	Forcing	Times	Resolution
CHELSA V.2.1	ISIMIP3b_BA	1981-2010 2011-2040 2041-2070 2071-2100	30 year means

https://envicloud.wsl.ch/#/?prefix=chelsa%2Fchelsa_V2



www.envidat.ch

Home Bioclim Last Glacial Maximum Climate Timeseries Future (CMIP5) Known issues

CHELSAcruts (1901-2016) changelog High resolution climate data for Europe Downloads

exChelsa – extended bioclim

CHELSA

Climatologies at high resolution for the earth's land surface areas

Downloads

Downloads are provided via our download server. There you can download all files manually, or use Cyberduck or WGET to download files in bulk:

DOWNLOAD SERVER

The technical documentation including a description of the different datasets, the available variables, and the different units can be found here:

CHELSA V1.2: Technical specifications.

When using the data, you agree to cite the respective original peer-reviewed publication AND the respective dataset (Why are data citations neccessary?):

Original peer-reviewed publications (mandatory):

CHELSA V1.0 – V1.xx (including CMIP5, PMIP3, and timeseries data)

Karger, D.N., Conrad, O., Böhner, J., Kawohl, T., Kreft, H., Soria-Auza, R.W., Zimmermann, N.E., Linder, P., Kessler, M. (2017). Climatologies at high resolution for the Earth land surface areas. ***Scientific Data***. 4 170122. https://doi.org/10.1038/sdata.2017.122

CHELSA_cmip5_ts

www.chelsa-climate.org

Next steps

- Validation of W5E5
- Solving the storage and distribution problem
- Peer reviewed publication of CHELSA W5E5

Acknowledgements

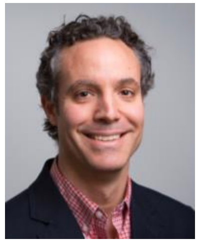
Co-authors


Christopher Reyer
Stefan Lange

Project partners

Signe Normand, Babek Dabagchian, Colin Mahony, Adam Wilson,
Niklaus E. Zimmermann, Walter Jetz, Catherine Graham




Funders & Partner institutions

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
University at Buffalo – The State University of New York
NASA
Universität Zürich UZH
WSL
Universität Hamburg – DER FORSCHUNG | DER LEHRE | DER BILDUNG
FNSNF – Fonds National Suisse, Schweizerischer Nationalfonds, Fondo Nazionale Svizzero, Swiss National Science Foundation
ETH zürich
AARHUS UNIVERSITY
Yale University
ISIMIP – Inter-Sectoral Impact Model Intercomparison Project
biodiversa
UiT The Arctic University of Norway
PIK – Potsdam Institute for Climate Impact Research