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Introduction to dynamic downscaling

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Presentation for Bangladesh Meteorological Institute

Why downscaling?

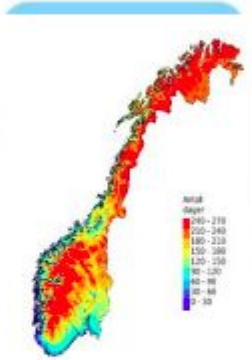
➔ Global Climate Models (GCMs) simulate the climate of the past, present and future given different emission scenarios.

➔ Due to coarse spatial resolution and parametrizations, GCMs typically represent large scale features of climate well, but not the local response.

➔ The local climate response to the large scale climate can be

- modeled by dynamical downscaling
  - Regional Climate Models (RCMs)
- estimated by empirical-statistical downscaling (ESD)

Empirical statistical downscaling



Adaptation
Government
Agriculture
Water
managment

1. Emission scenarios

2. Global climate models

3. Regional climate models

4. National projections

5. Users

Fig: Oskar Landgren, MET

Bias adjustment
Hydrological modeling

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Empirical statistical downscaling (ESD)

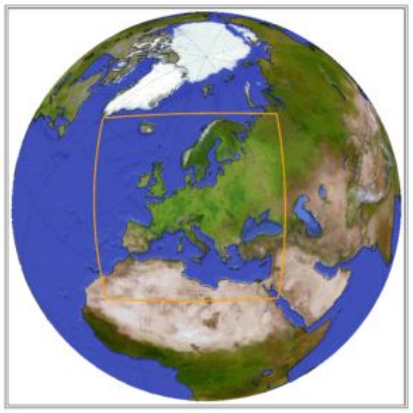
+ Gives **climate information** for stations from GCM data
+ Fast and computationally cheap
+ Can be applied to **large ensembles**
- Depends on high quality data and realistic GCM simulations
- The predictor-predictand relationships can be non-stationary

Dynamical downscaling

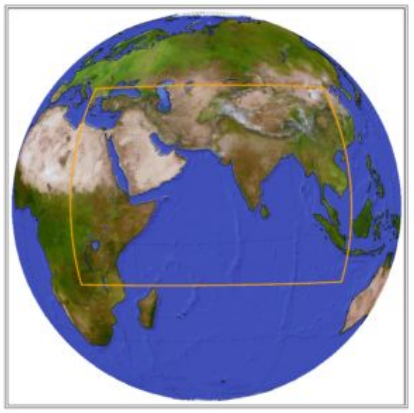
+ Gives high resolution (2-50 km) **climate information** from GCM data
+ Resolves small scale atmospheric processes
+ Physically **modelled** response to external forcings
- Computationally expensive
- Rarely applied to large ensembles of climate scenarios
- (often) requires bias-adjustment

CORDEX

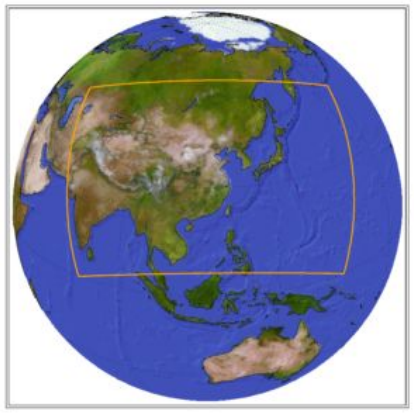
- **Coordinated** Regional Downscaling Experiment
- Initiated in 2009
- Aims:
  - A **common** framework for evaluation and comparison of downscaling model performance
  - Define **common** downscaling domains and experiment setups



Europe
EUR



South Asia
WAS



East Asia
EAS

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- Evaluation of downscaling model performance:
  - The models downscale global reanalyses, e.g. ERA5
    → evaluation runs not affected by GCM biases
    (but maybe biases in the reanalysis)

  - The models downscale the historical period of GCM simulations
    → historical runs are affected by GCM biases in the forcing fields
    (e.g. temperature, humidity, circulation)
    → A bias correction is often needed

- In both evaluation exercises, the evaluation is carried out on the performance on **representing the current climate**
- Examples: number of heatdays, mean temperature, max. temperature (over all)
- This is different from NWP, where the actual weather needs to be reproduced

CORDEX

- CMIP5 downscaling: Several GCMs/RCMs/scenarios
- CMIP6 downscaling: ongoing/starting
- Data distributors (examples!)
  - ESGF (Earth System Grid Federation), e.g https://esgf-data.dkrz.de/
  - Copernicus Climate Data Store https://cds.climate.copernicus.eu

Copernicus CDS evaluation:
https://confluence.ecmwf.int/display/CKB/Evaluation+of+CDS+climate+projections

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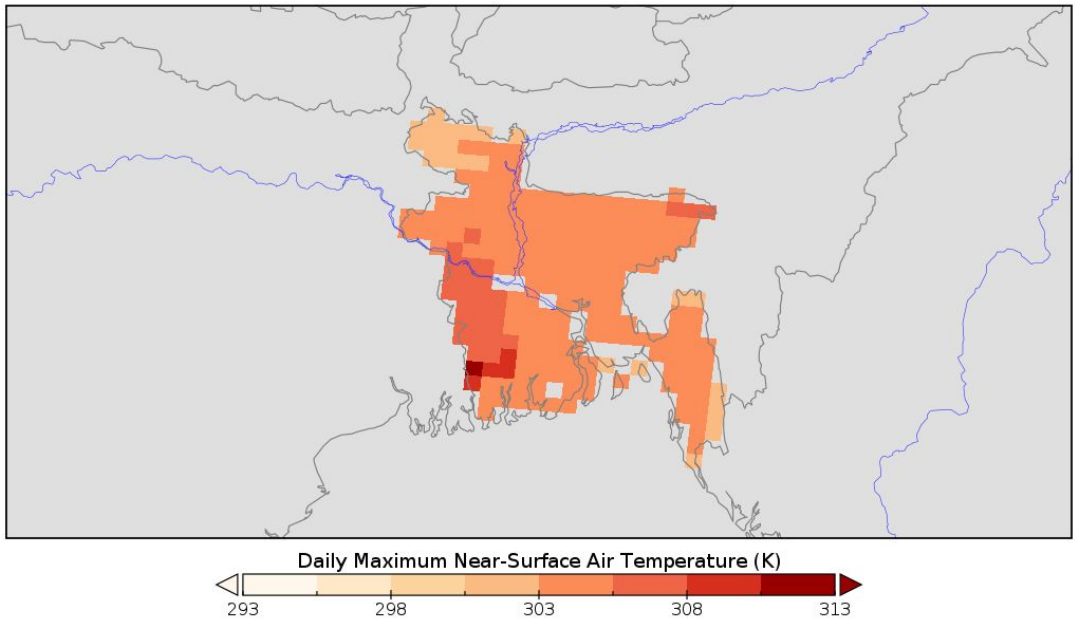
Case study: number of hot days

- 4 example RCM runs (2GCMs, 2 RCMs, RCP8.5) with daily tasmax from CORDEX-WAS22
- Bangladesh mask



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Download the data

```
wget
https://thredds.met.no/thredds/fileServer/metusers/andreasd/tilBMD/WAS22/Bangladesh_mask/
masked_BDbox_tasmax_WAS-22_NCC-NorESM1-M_rcp85_r1i1p1_GERICS-REMO2015_v1_day_1970-2100.nc

wget
https://thredds.met.no/thredds/fileServer/metusers/andreasd/tilBMD/WAS22/Bangladesh_mask/
masked_BDbox_tasmax_WAS-22_NCC-NorESM1-M_rcp85_r1i1p1_CLMcom-ETH-COSMO-crCLIM-v1-1_v1_day
_1950-2099.nc

wget
https://thredds.met.no/thredds/fileServer/metusers/andreasd/tilBMD/WAS22/Bangladesh_mask/
masked_BDbox_tasmax_WAS-22_MPI-M-MPI-ESM-LR_rcp85_r1i1p1_GERICS-REMO2015_v1_day_1970-2100
.nc

wget
https://thredds.met.no/thredds/fileServer/metusers/andreasd/tilBMD/WAS22/Bangladesh_mask/
masked_BDbox_tasmax_WAS-22_MPI-M-MPI-ESM-LR_rcp85_r1i1p1_CLMcom-ETH-COSMO-crCLIM-v1-1_v1_
day_1950-2099.nc
```

Or go to
https://thredds.met.no/thredds/catalog/metusers/andreasd/tilBMD/WAS22/Bangladesh_mask/catalog.html

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cdo – climate data operators

https://code.mpimet.mpg.de/projects/cdo/

- Developed at MPI-MET in Hamburg, Germany (publicly available since 2003)
- Reads both NetCDF and GRIB
- Can do lots of different operations on NetCDF files in both time and space
- Calculation of statistics (average, max/min/median/percentiles) at different time levels (hour, day, month(s), season, year)
- Use metadata from the NetCDF file to quickly slice
- Interpolation, regridding, ...
- Good manual: https://code.mpimet.mpg.de/projects/cdo/embedded/cdo.pdf
- "Reference card"/"Cheat sheet" 4 pages to print and keep on your desk: https://code.mpimet.mpg.de/projects/cdo/embedded/cdo_refcard.pdf
- Basic syntax: cdo –operator input-file output-file

Calculate heat days

Using cdo (climate data operators)
Basic syntax: cdo –operator input-file output-file

```
cdo "expr,heatday=(tasmax-273.15)>36;"
masked_BDbox_tasmax_WAS-22_MPI-M-MPI-ESM-LR_rcp85_r1i1p1_CLMcom-ETH-COSMO-crCLIM-v1-1_v1_
day_1950-2099.nc
heatdays_MPI-ESM-LR_rcp85_r1i1p1_CLMcom-ETH-COSMO-crCLIM-v1-1_v1_day_1950-2099.nc

(1 line!)
```

- converts tasmax from K to °C and checks if it is > 36 °C
- Output: 1/0 at each day and grid-point

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Calculate monthly frequency

```
cdo monmean
heatdays_MPI-ESM-LR_rcp85_r1i1p1_CLMcom-ETH-COSMO-crCLIM-v1-1_v1_day_1950-2099.nc
monmean_heatdays_MPI-ESM-LR_rcp85_r1i1p1_CLMcom-ETH-COSMO-crCLIM-v1-1_v1_day_1950-2099.nc

(1 line!)
```

- calculates the monthly mean number of days > 36 °C
- in intervall [0,1]

Split into single months

```
cdo splitmon,%B
monmean_heatdays_MPI-ESM-LR_rcp85_r1i1p1_CLMcom-ETH-COSMO-crCLIM-v1-1_v1_day_1950-2099.nc
monmean_heatdays_MPI-ESM-LR_rcp85_r1i1p1_CLMcom-ETH-COSMO-crCLIM-v1-1_v1_day_1950-2099

(1 line!)
```

- Splits the file into one file for each calendar month
- %B: uses month names instead of numbers in the output files

Next step: evaluation

Important questions: Are the models biased? Can we trust the projections?

- evaluate how well the models represent the observed number of heatdays in the current climate (e.g. 1990-2020 or 1970-2020)
- mean and monthly frequencies are important
- we used a fixed threshold of 36°C → biases in tasmax have a direct impact
- trends in the current climate are less important (can be strongly influenced by decadal variability)
- A small ensemble (4 runs, 2 GCMs, 1 scenario) → add more to get a more robust picture

NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6)

- **Statistically** downscaled CMIP6 models
- Bias correction included
- Spatial resolution: 0.25 degrees (25 km)
- Temporal Resolution: daily
- Multiple variables

- NetCDF format → “easy” to calculate heat days using the cdo command given above

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Questions?