IS-ENES3 Climate Impact Autumn School
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Climate indices and standards, uncertainties/ensembles, challenges in use of climate data

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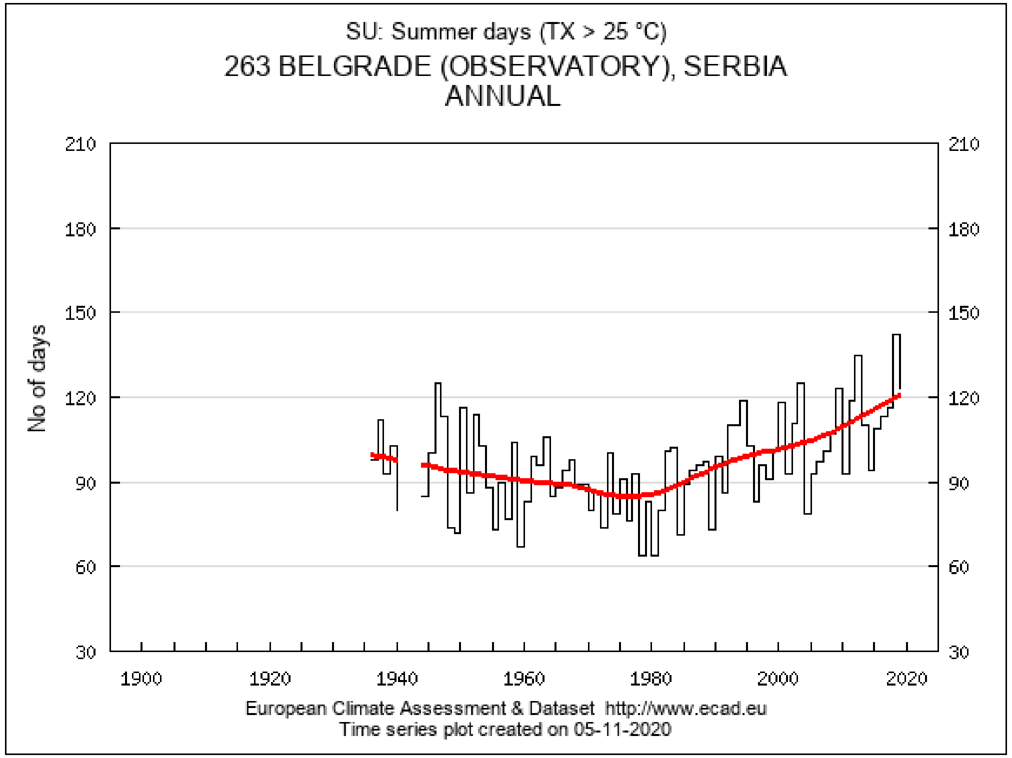
Climate indices

Climate indices* = simple diagnostic quantities used to describe aspect of geophysical system

- Mostly single climate variable used, e.g temperature, precipitation, pressure
- Variety of methods used to derive indices
- Often represented as time series for the index
- Indices to describe almost any event in climate system
- Some indices known by several names or index with same name but different methods.



[*] no simple/single definition, almost like a turbulence ... for turbulent flow there is no definition, but "you'll know it when you see it", so better to list some facts and show some examples of well-known climate indices ...

Climate indices: examples

ETCCDI indices (Expert Team on Climate Change Detection and Indices)

27 core indices based on essential climate variables (TG, TX, TM and RR), basically defined to measure extreme events.

- *Number of summer days - SU, index with* ***fixed*** *threshold*
  Definition: *Annual nr. days when TX (daily maximum temperature) > 25°C*
- *Number of icing days - ID, index with* ***fixed*** *threshold*
  Definition: *:Annual nr. days when TX (daily maximum temperature) < 0°C*
- *Warm spell duration index - WSDI, index with* ***percentile*** *threshold*
  Definition: *Annual nr. days with at least 6 consecutive days when TX > 90th percentile*

Teleconnection indices: ENSO (El Nino), NAO (North Atlantic Oscillation), AO (Arctic Oscillation), etc.

- Characterize aspect of large-scale circulation pattern
- Use station measurements, measurements over area, or based upon empirical orthogonal functions https://www.cpc.ncep.noaa.gov/data/teledoc/teleindcalc.shtml

Drought indices

- Drought characteristics: duration, intensity, frequency, severity …
- Use single/multiple variables (e.g. precipitation: SPI; precipitation and temperature: SPEI and PDI)

Climate indices: why use them?

- Track + communicate extremes
  Number of summer days are increasing (SU index)
- Present extensive amount of spatial data with a single number
  Understand continental circulation with North Atlantic Oscillation index
- Present multiple variables with single number
  SPEI drought index calculated from temperate and precipitation
- To analyze changes in a system that is sensitive to climate conditions
  GSL - Growing season length, period of year when crops/plants grow successfully, depends on the temperature thresholds
- To establish relation between climate and system that is sensitive to climate
  Find/introduce index that is important to your system/problem ...

Climate indices: how to find or calculate?

Europe (Observations)

- www.ecad.eu/download/millennium/millennium.php (**ECA&D** - station data)
- surfobs.climate.copernicus.eu/dataaccess/access_eobs.php (**E-OBS** - gridded data)
- www.indecis.eu/data.php (**Indecis**: 125 sector-oriented indices (Agriculture and Food Security, Disaster Risk Reduction, Energy, Health, Water and Tourism), both data and visuals)

Global (Observations)

- www.climdex.org/ (**Climdex** (HadEX2/3, GHCNDEX))

Teleconnection

- climexp.knmi.nl/selectdailyindex.cgi?id=someone@somewhere (**Climate explorer**)

Projections (model)

- climate4impact.eu/impactportal/general/index.jsp (IS-ENES **Climate4Impact**)

Climate indices: how to find or calculate?

Available software (both online and offline):

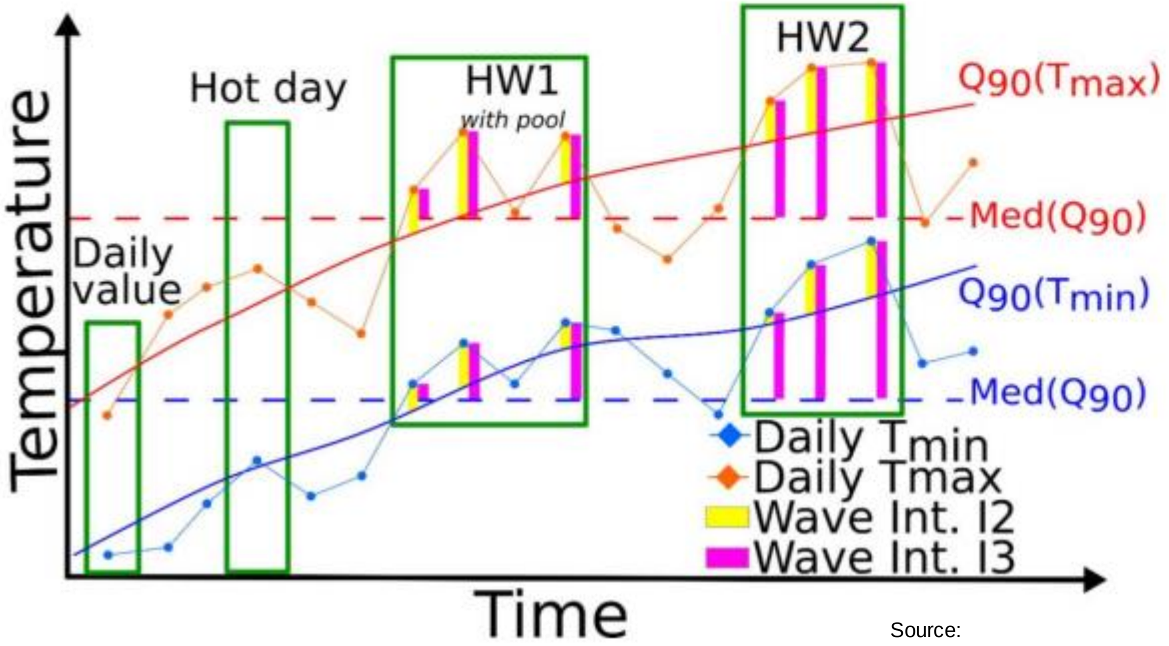
- IS-ENES **Climate4Impact**
  climate4impact.eu/impactportal/general/index.jsp
- **CDO** (Climate Data Operators)
  code.mpimet.mpg.de/projects/cdo/embedded/cdo_eca.pdf
- R-Packages
  - **ClimPact**: climpact-sci.org/
  - **ClimInd**: cran.r-project.org/web/packages/ClimInd/index.html
- Python
  - Index Calculation **CLIMate**: icclim.readthedocs.io/en/latest/
  - **Drought indices**: pypi.org/project/climate-indices/
- Additional info provided by **Indecis** project: www.indecis.eu/software.php

Climate indices: challenges

Arise from diversity of available options:

- Data sources (observations, models)
- Time periods (year, season, month, …)
- Definitions
- Software
- Data formats ...

… and there is no universal "solution"



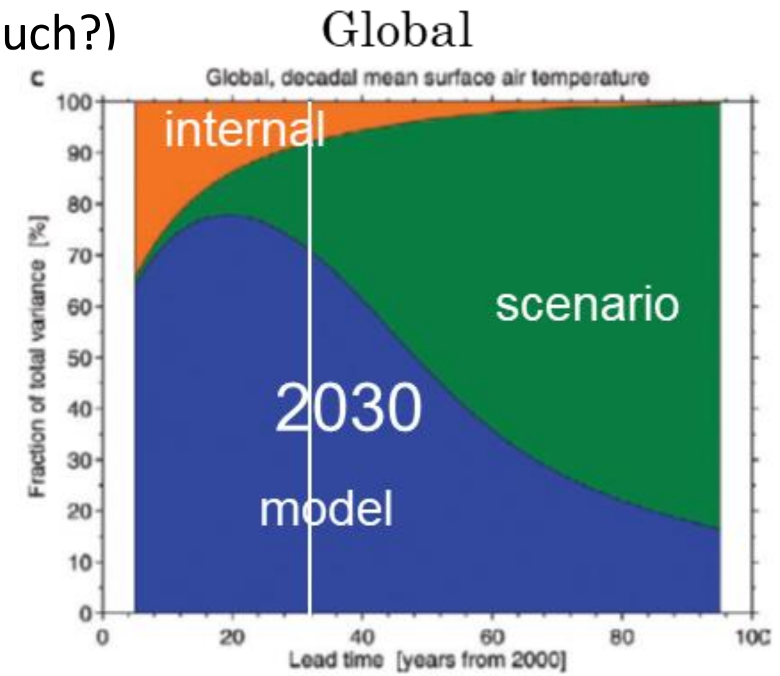
Source: https://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_heatColdWaveIndex.pdf

Example: heat wave index – probably 15+ different definitions

Advice: First think and explore then calculate ...

Uncertainties and ensembles

(Everything is uncertain but the question is how much?)



In climate model results different types of uncertainties:

- Natural/internal variability uncertainties
- model uncertainties
- scenario uncertainties

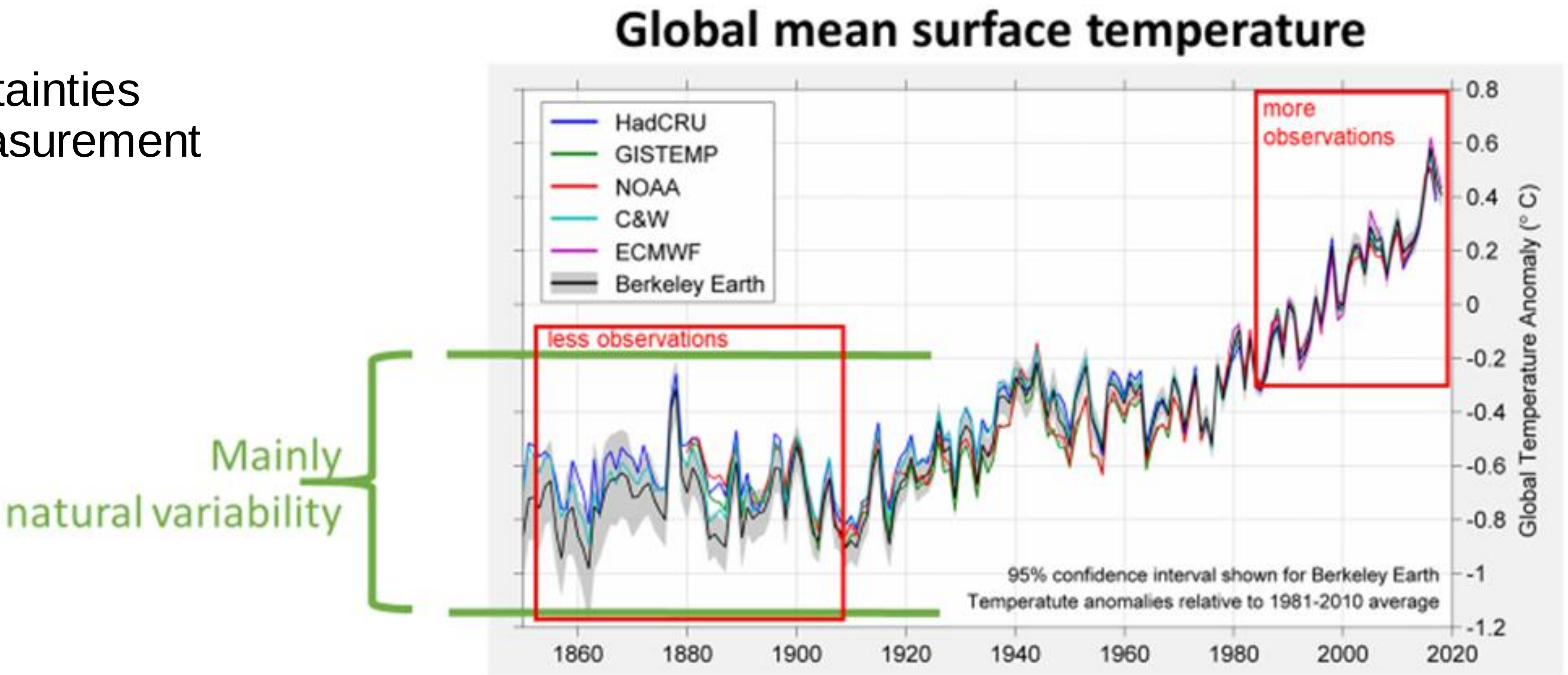
Consequently different ways to deal with these uncertainties:

- **Natural variability** cannot be reduced, but it can be quantified with statistics. More observations, ensembles of model runs may result in better statistics.
- **Model and scenario uncertainties** can be reduced by doing more research (better understand climate and societal system). Important message about emission scenarios: <u>no probability </u>assigned to the scenarios.

Uncertainties: natural variability

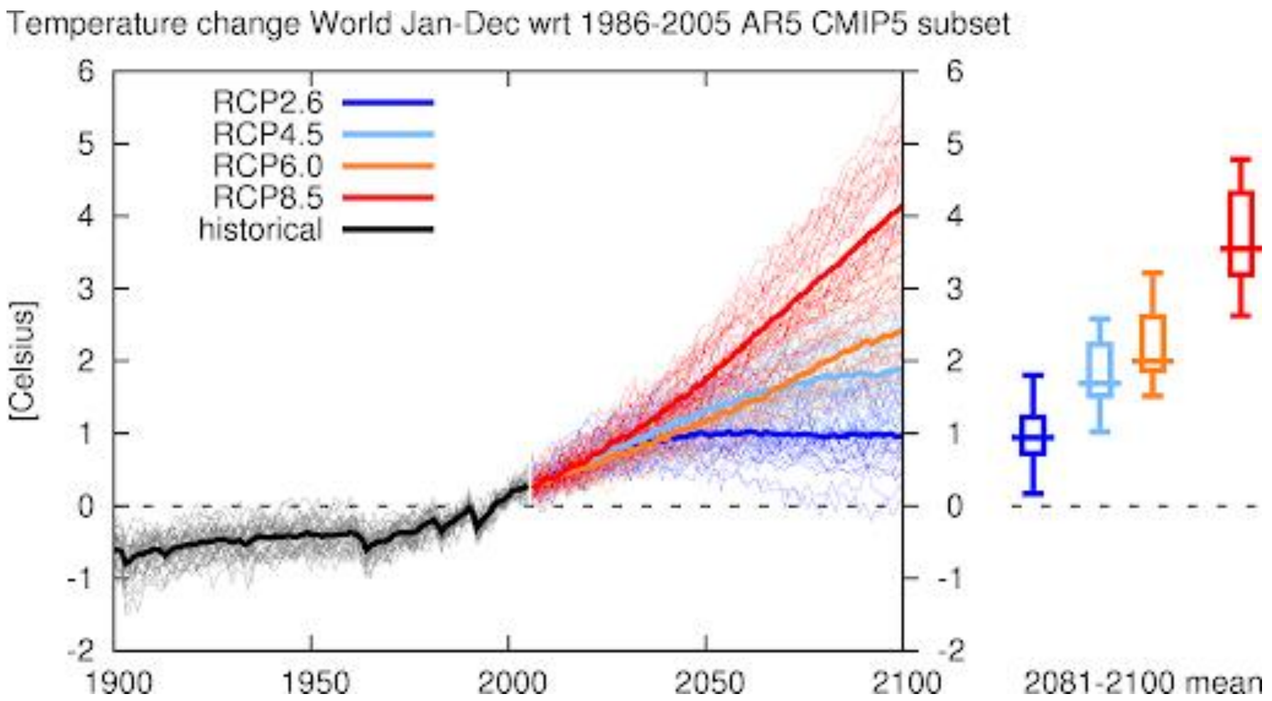
- Variation around a mean state due to natural processes
- Day-to-day, year-to-year, decade-to-decade variation
- Due to “internal” (e.g. El Niño), or “external” (e.g. sun) factors.

- Also uncertainties due to measurement limitations



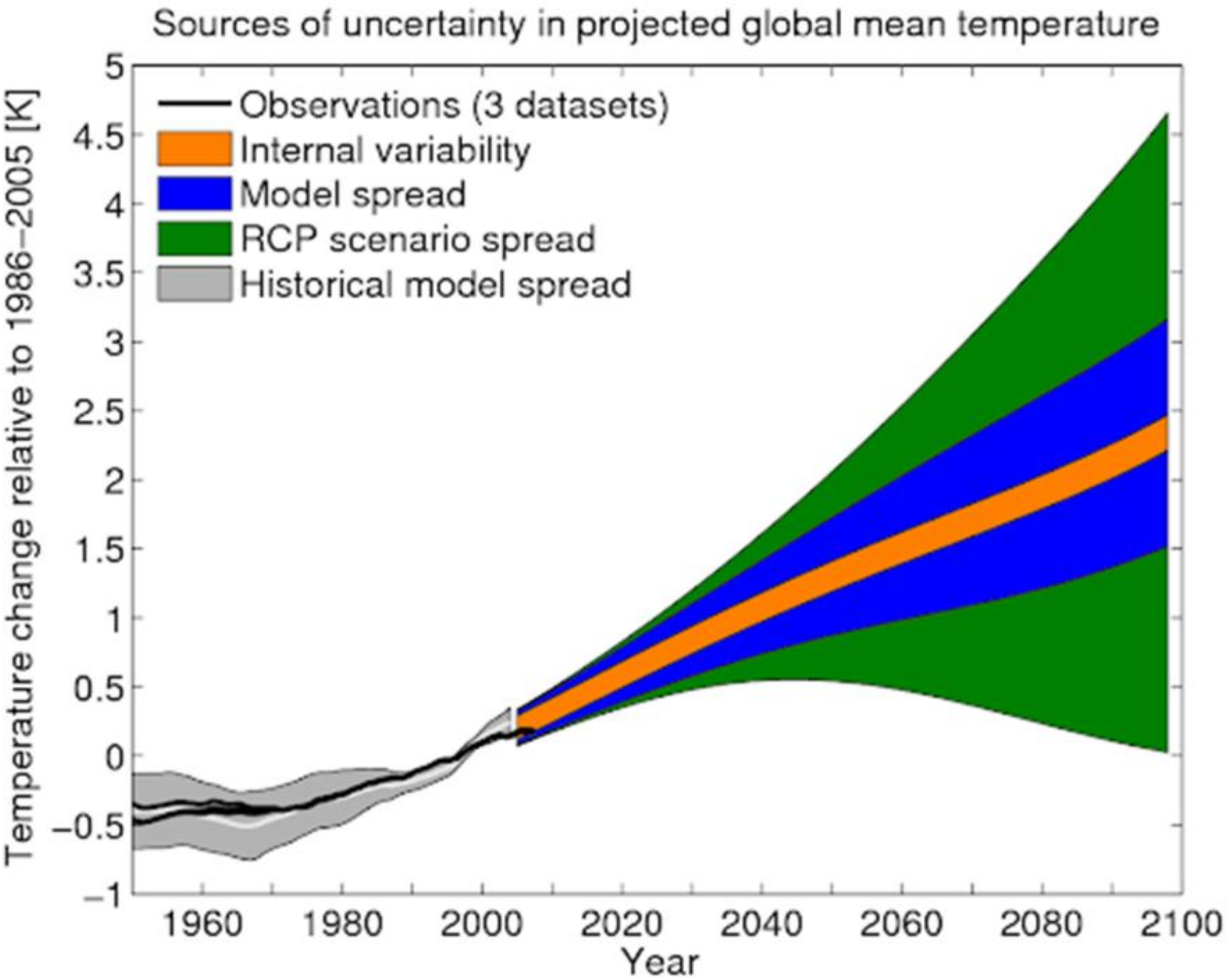
Uncertainties: model and scenario

- **Model uncertainty**: incomplete knowledge about climate system. Quantified with large number of climate models for same emission scenario.
  - E.g. climate models: physical equations and **parametrisations.** Parametrisations may differ between models.
- **Scenario uncertainty**: incomplete knowledge about socio-economic system and **future emissions.** Different socio-economic developments assumed to span the range of possible futures, not to predict them.



- Each thin line: 1 single model (some have just one, but some have more)
- Each color: 1 emission scenario
- Thick lines: ensemble averages

Uncertainties and ensembles



We can estimate any of the three uncertainties:

- **Internal variability**: with ensemble of one model (different initial conditions)
- **Model uncertainty**: ensemble of models with same emission scenario (multi-model ensemble and perturbed physics ensemble)
- **Scenario uncertainty**: difference between averages for different emission scenarios

Uncertainties and ensembles

- Climate model output as input for impact models
- Hence existing uncertainties propagate further
- Also uncertainties in impact models (may be > than uncertainties from climate data)

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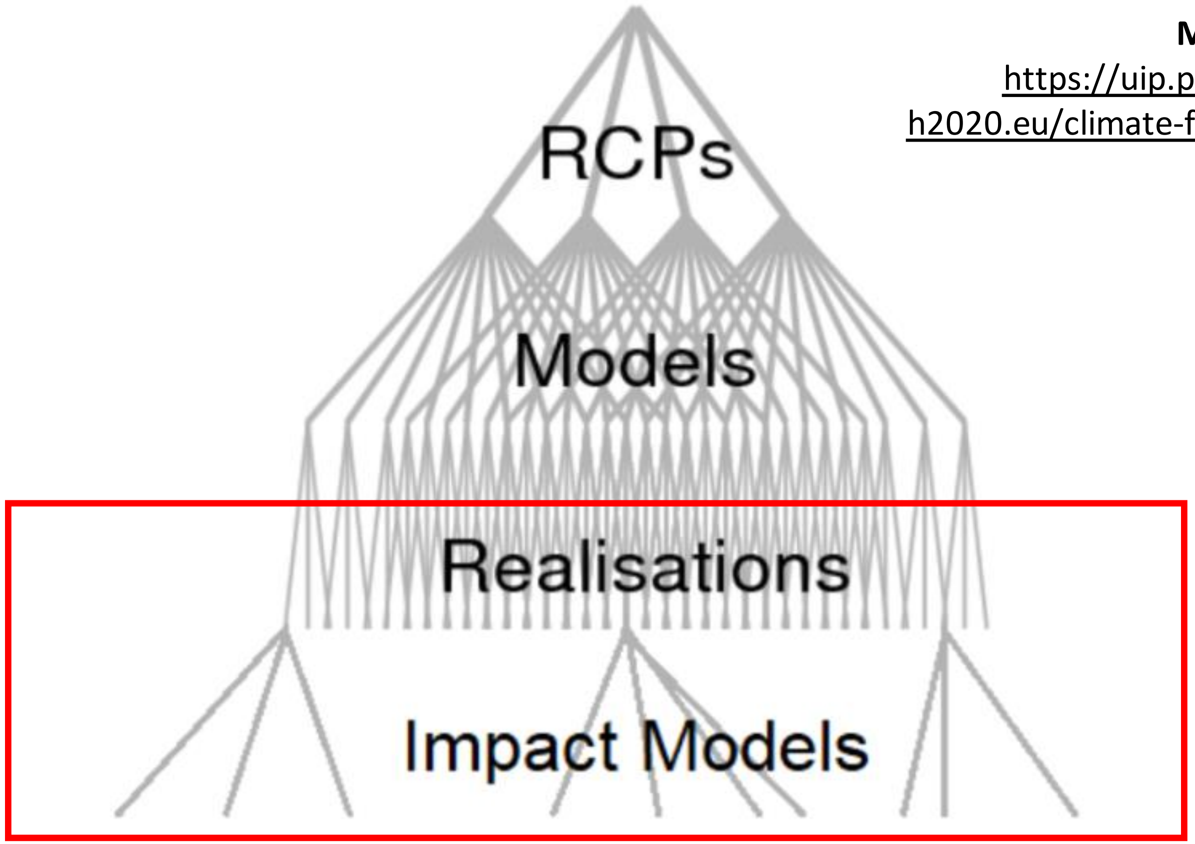
More info:
https://uip.primavera-h2020.eu/climate-factsheets



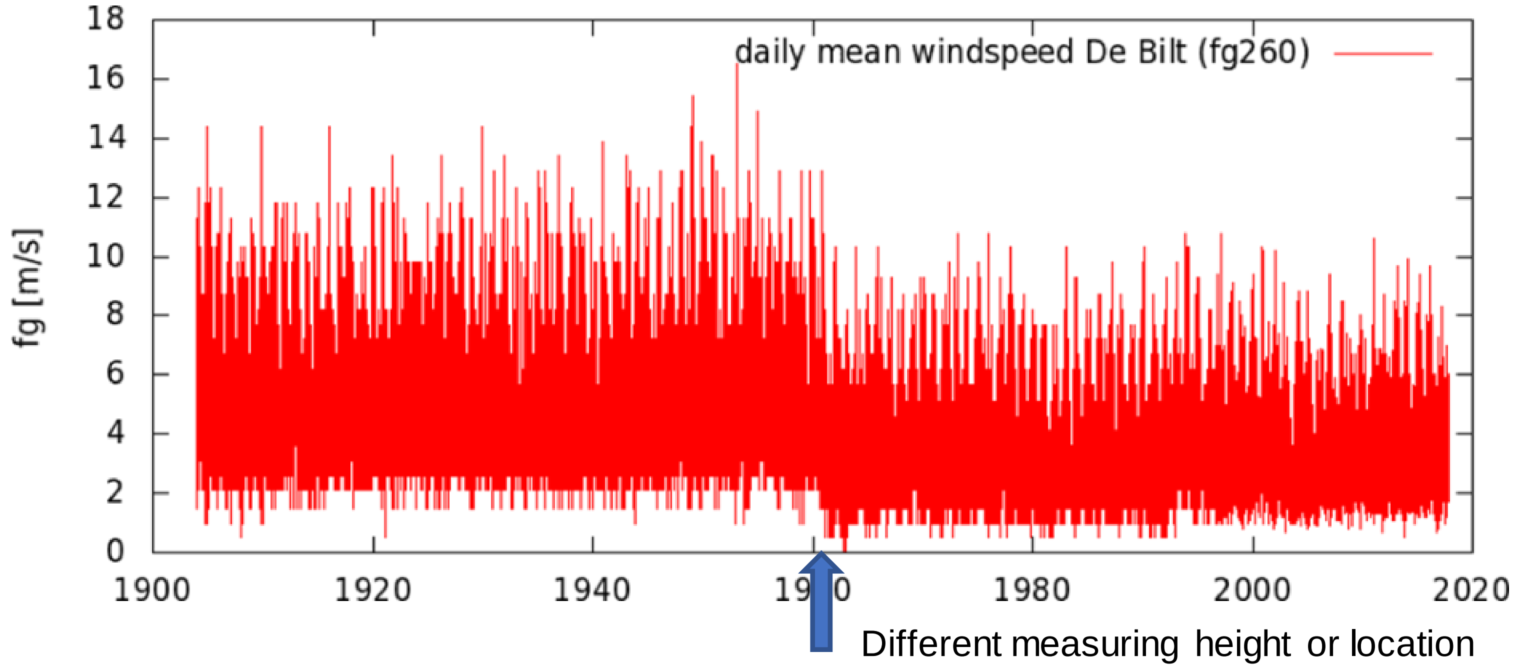
Schematic cascade of uncertainty, from RCP scenarios, climate models and realizations to impact models.

After Hawkins, www.climate-lab- book.ac.uk/2014/cascade-of-uncertainty/

Challenges in use of climate data

Observations

- **Inhomogeneities:** apparent changes in averages, statistics, etc. due to physical causes e.g. change of instruments, re-locations, etc.): homogenisation needed
- **Mixing data from different networks**
  Sometimes different measuring networks for
  variable (different instruments: systematically higher/lower values)



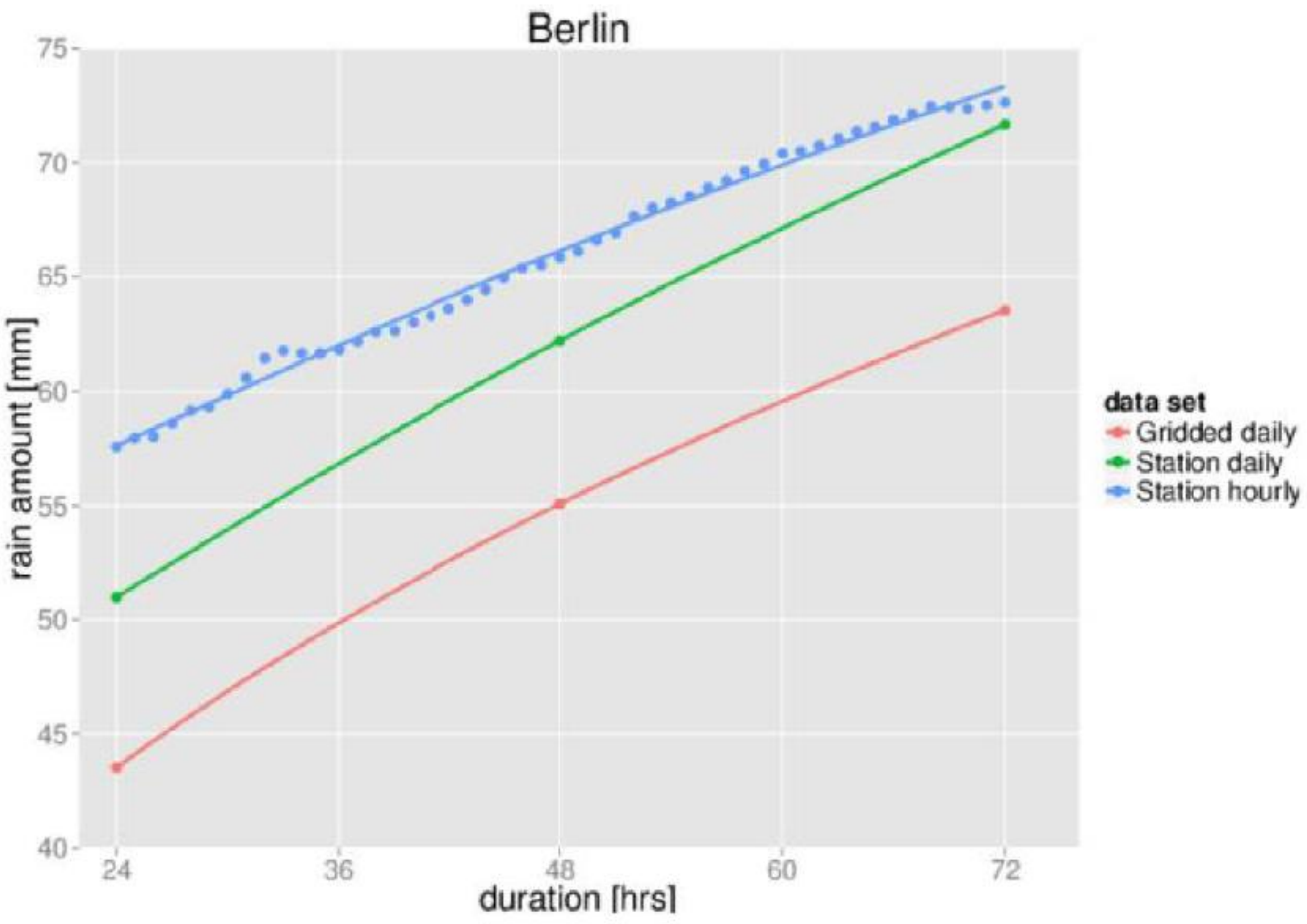
Challenges in use of climate data

- **Calculation and interpretation of statistics**

Daily data is not the same as “24 hours”-data

- Calculation and interpretation of **point and areal statistics**

Station vs gridded data



Intensity-Duration-Frequency curves for once in 10 year events for different rainfall durations
Source: RAIN project D2.5

Challenges in use of climate data

How to find certain climate model runs and climate variables

File naming conventions + rules how data are packed

- always in **netcdf** format, has metadata inside file

Example

file - **tos_OMED-11i_MPI-ESM-LR_rcp85_r1i1p1_UNIBELGRADE-EBUPOM2c_v1_mon_210001-210012.nc**

tos – variable name

NETCDF header:

:cordex_domain = "OMED-11i" ;

:driving_model_id = "MPI-ESM-LR" ;

:experiment_id = "rcp85" ;

:driving_model_ensemble_member = "r1i1p1" ; *[one single GCM model can have multiple runs]*

:institute_id = "UNIBELGRADE" ;

:model_id = "UNIBELGRADE-EBUPOM2c" ;

:rcm_version_id = "v1" ;

CORDEX DATA FILES RULES: is-enes-data.github.io/cordex_archive_specifications.pdf

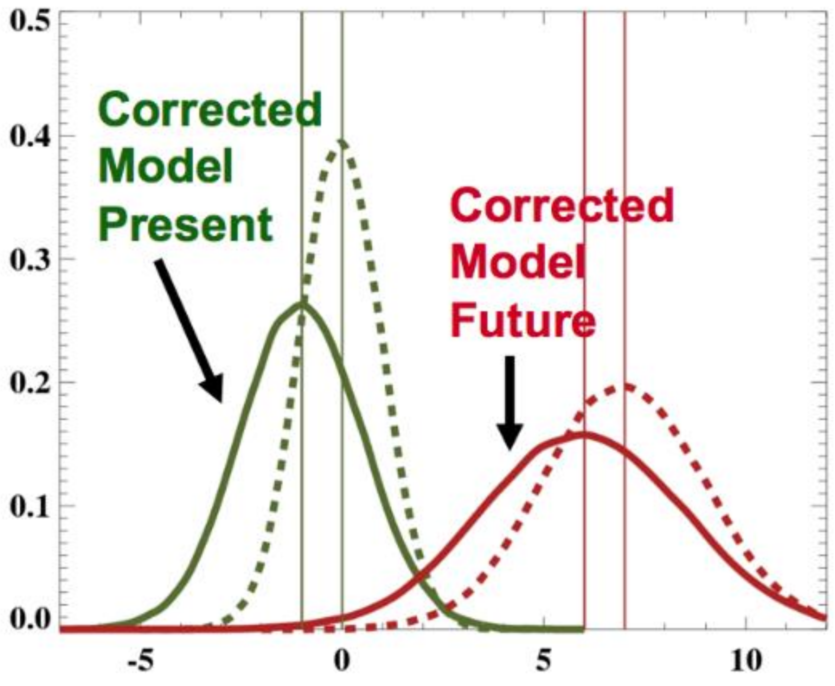
Challenges in use of climate data

Processing and using of climate model data. Recommended steps:

- Start with one model and one scenario (historical + future period)
- Check how model compares with observations for historical period, even when results are bias-adjusted.
- If not bias-adjusted, do bias-adjustment

  (various methods Raisanen i Raty, 2012)

  Climate models always contain some bias: systematic deviations from reality. To determine bias, runs for the past are compared with observations (assumption: projections for future contain same bias).



Probability Density Functions

- Select various models and/or scenarios

There are no user guides for this or single metric!

Challenges in use of climate data

Some preliminary practical checks!

- Do all data/models have same units for same variables (it should be, but better to check!)
- Do all models cover same periods, past and future (some models finish integration in 2099, or 2049!)
- Do all models (in case of daily data) have same calendar (some older use 360 days calendar, often software take care of this, better to check!)

Some guidance's how to select:

- Compare different models (historical) with observations, select models that have better performance.
- Try to populate your ensemble with models from different “families”
- Try to cover "wide" range of uncertainty (e.g. compare full ensemble range with range of your selection)
- Try to cover different scenarios with a same number of models (not 10 for RCP8.5 and 2 for RCP4.5)

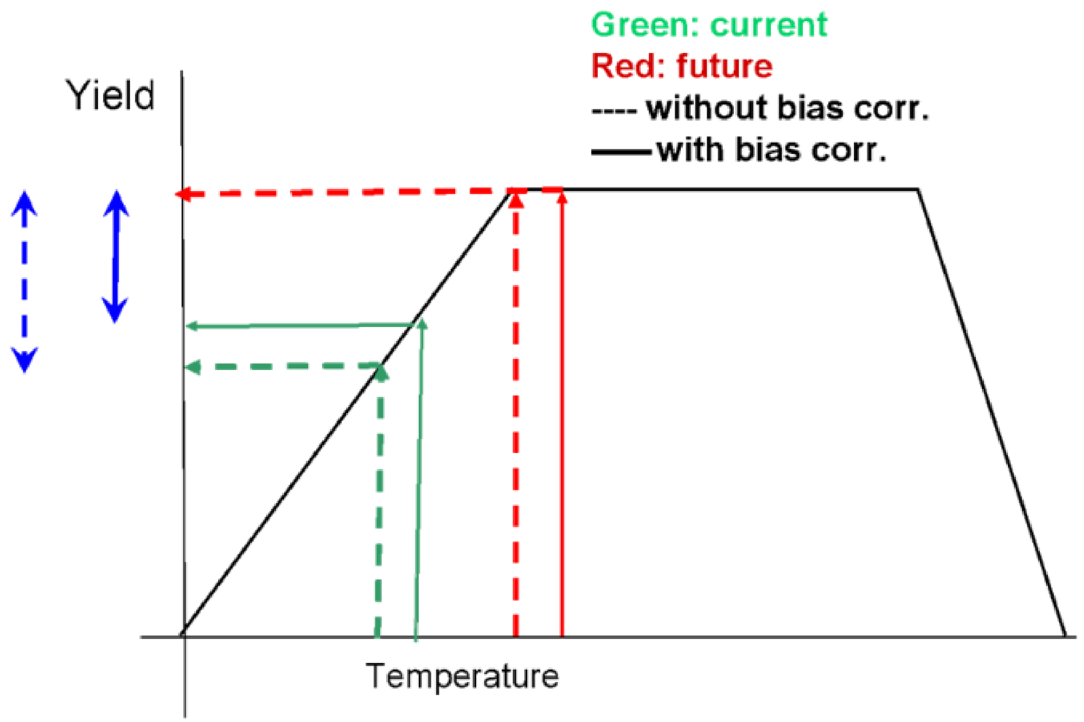
Bad examples of climate data use

- Comparing “raw” climate model projections directly with observations.

- Determine change in impacts with “raw” climate model data

- Selecting the “middle” climate scenario

    the “middle” scenario not the most probable one (although often implicitly assumed)



Bad examples of climate data use

- Averaging climate scenarios or using just one scenario

  In general, various scenarios are presented for the future to show the uncertainties, and to make it easier for users to deal with uncertainties in the future.

- Picking out individual years

  Use of "reference" or "standard" years: individual year does not show the natural variation

Thank you

& thanks to Janette and PRIMAVERA project for inputs