Data resources for climate variables

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- Climate model projections
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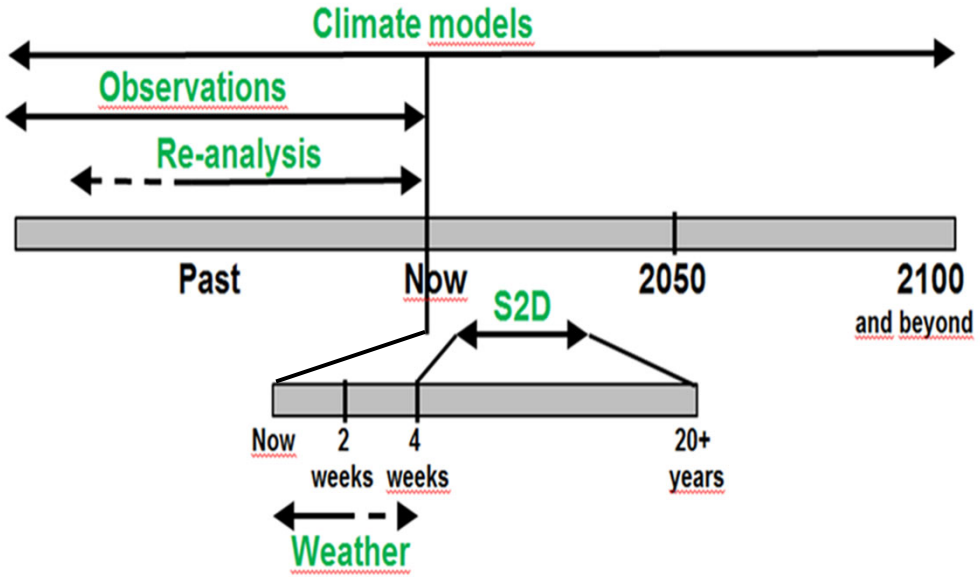
Climate data resources overview



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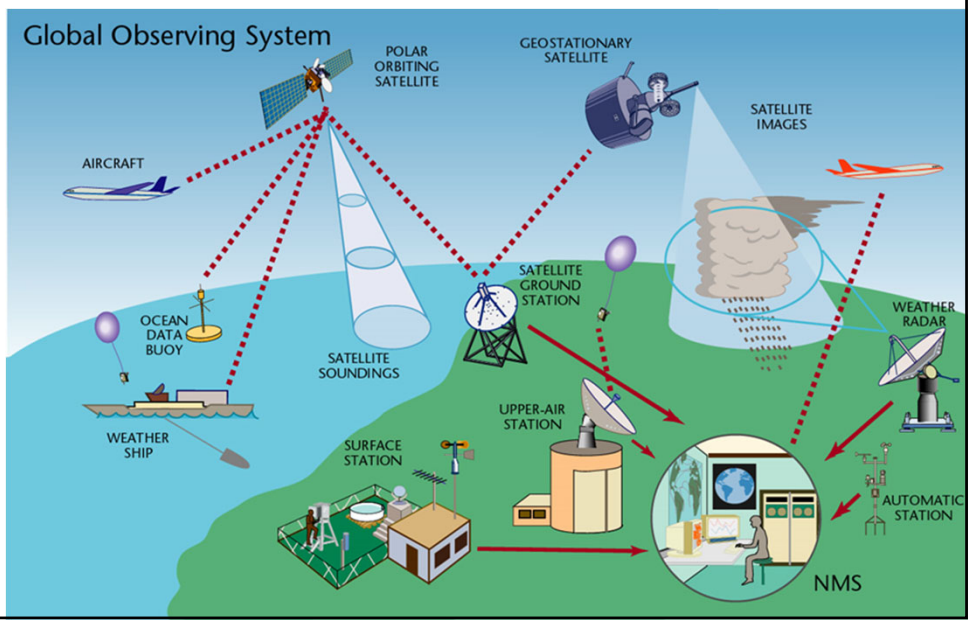
Observations

- provide information on the past and current climate
- traditional observation stations on land
- many more direct or indirect observation methods



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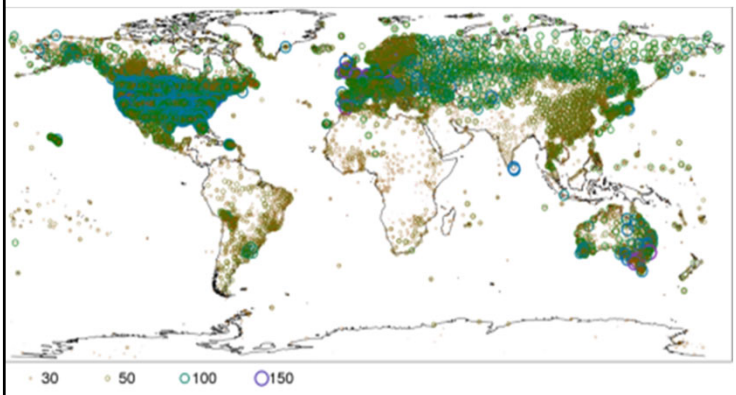
Weather stations on land



Weather stations with temperature data on land, used within the EUSTACE-project. As can be seen the number of stations is not evenly distributed over the earth (Source: EUSTACE (1))

- thousands of weather or meteorological stations measuring at or near the Earth's surface
- meteorological parameters such as atmospheric pressure, wind speed and direction, air temperature and relative humidity
- at one location, or "in situ"
- not evenly distributed over the Earth
- World Meteorological Organisation (WMO) formulated standards (see: WMO Best practices)

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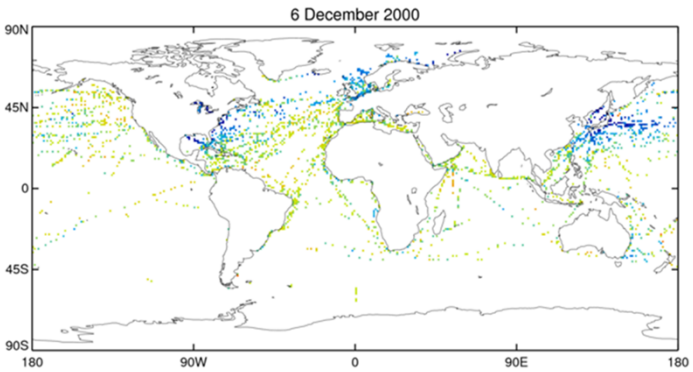
Observations at sea



Schip observations overview in 2000: blue indicates a higher number of observations (Source: EUSTACE (2))

Over the oceans the Global Observing System (GOS) relies – in addition to satellites – on:

- ships
- moored and drifting buoys
- stationary platforms.

Ships: often same variables as at in situ stations, but provide information on trajectories

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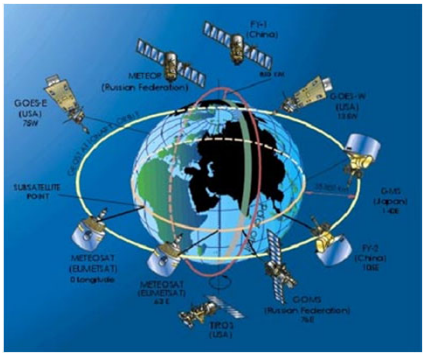
Satellites

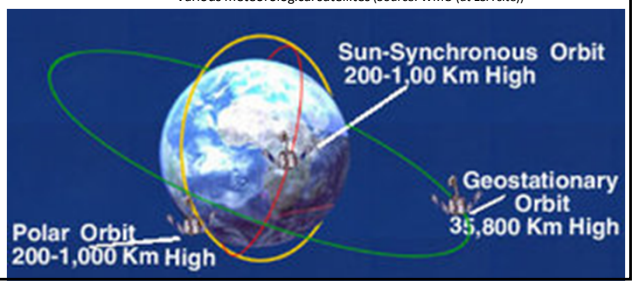
Normally equipped with visible and infra-red imagers and sounders from which meteorological parameters can be derived. Geostationary satellites can be used to measure e.g. wind velocity in the tropics by tracking clouds and water vapour.

geostationary satellite: constantly observes the same part of the earth

polar orbiting satellite: passes over the north and south poles each round. Each pass monitors an area to the west of the previous pass, together these "strips" produce a picture of a larger area.



Various meteorological satellites (Source: WMO (at ESA site))



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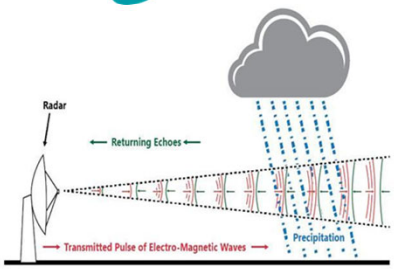
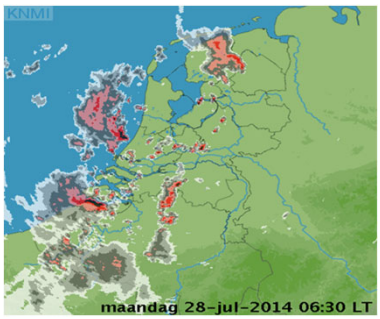
Radar and lidar





- **Ra**dar **D**etection **A**nd **R**anging: RADAR
- For rainfall detection
- method is based on sending out a radar pulse and measuring the return signal. Signal has to be translated into a precipitation rate with the help of in situ measurements
- Dual polarized or doppler radars can measure wind and rainfall. More accurate determination of precipitation types and sizes

- **Li**ght **D**etection **A**nd **R**anging: LIDAR
- uses laser light
- used to study, among others, atmospheric gases, aerosols, clouds, wind and temperature

https://www.youtube.com/watch?v=ItuNNhY5WBw
(3.35" minutes; National Weather Service Nevada)

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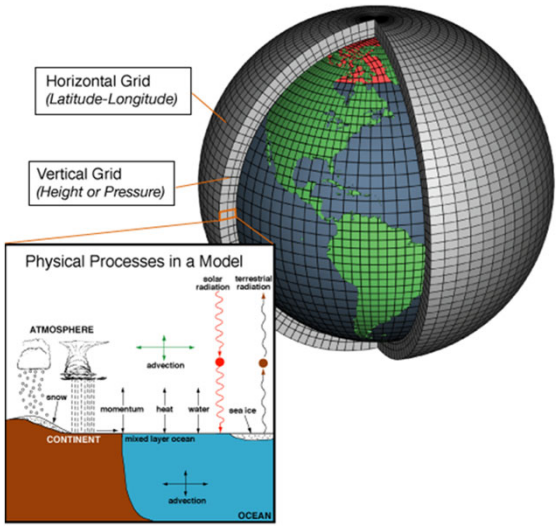
What is a climate model?

Climate model: A numerical representation of the climate system based on

- physical
- chemical
- biological

properties of its components, their interactions and feedback processes.

- To "run" a model, earth divided into 3-dimensional grid
- calculate winds, heat transfer, radiation, relative humidity, and surface hydrology within each grid and evaluate interactions with neighboring points



https://www.youtube.com/watch?v=Pn3ZKB1XLiQ
(1.33" minutes; UK Metoffice)

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Weather and climate models

Both based on the basic laws of physics, fluid motion, and chemistry, but differ in some aspects

Weather model	Climate model
Initial value problem	Boundary value problem
When and where	Statistics
Predicts weather until about 2 weeks into future	Projects changes into far future

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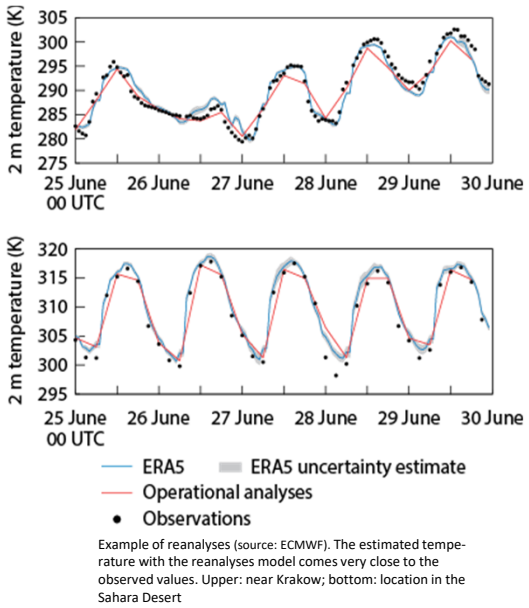
Re-analysis

Re-analysis = numerical description of the recent climate, produced by combining models with past observations (assimilation of observations in a climate model)

- Weather models: observations only in the starting conditions
- Reanalyses: assimilate observations during the whole period simulated.

- Re-analysis form various institutes. ERA5 now commonly used for Europe



Example of reanalyses (source: ECMWF). The estimated temperature with the reanalyses model comes very close to the observed values. Upper: near Krakow; bottom: location in the Sahara Desert

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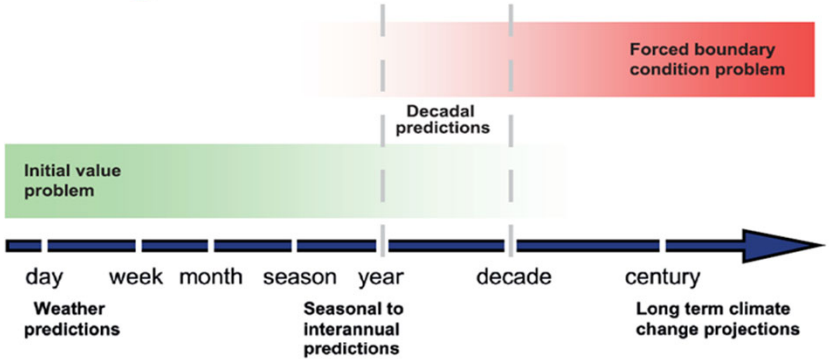
Seasonal to decadal predictions



This figure shows that in Seasonal to Decadal (S2D) predictions **both initial values and boundary conditions** are important.

What will happen in the near future, up to a decade or two ahead, is the combination of natural variability and human-induced climate change:

- The next few years may be relatively cold, although the long-term trend is increasing temperature. The next season maybe extremely dry in a region, although the long-term trend can be an increase in rainfall.

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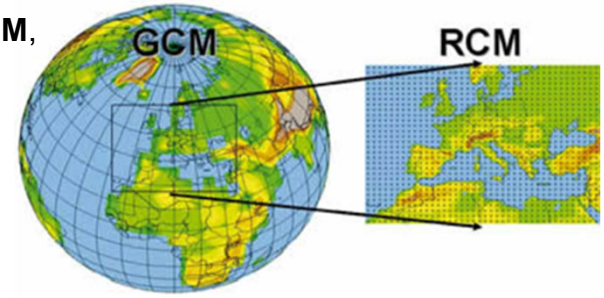
Global and regional climate models

Climate models used to make projections for future based on certain emission scenarios

- **Representative Concentration Pathways (RCP)**
- **Shared Socio-economic Pathways (SSP)**

- simulate climate for whole world (Global Climate/Circulation Model = **GCM**, Earth System Model = **ESM**)
- simulate climate only for part of world (Regional Climate Model = **RCM**)



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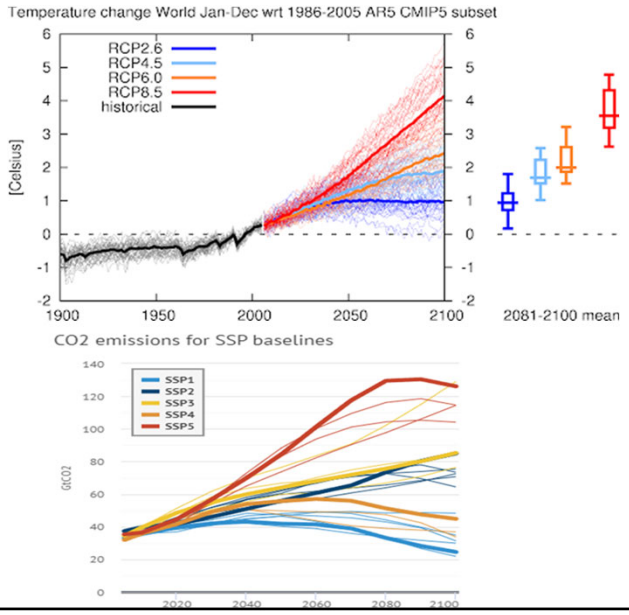
RCP's and SSP's



Emission scenarios: descriptions of how greenhouse gases emissions could evolve, depending on various hypotheses.

Translated into **Representative concentration Pathways** (RCP's), named after their radiative forcing in 2100 (+2.6, +4.5, +6.0, and +8.5 W/m^2).

https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change

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SSP's

Shared Socioenomic Pathways (SSPs) describe the societal developments that could lead to certain RCP's.

Not all combinations of RCP and SSP possible. Often used SSP1-2.6 and SSP5-8.5

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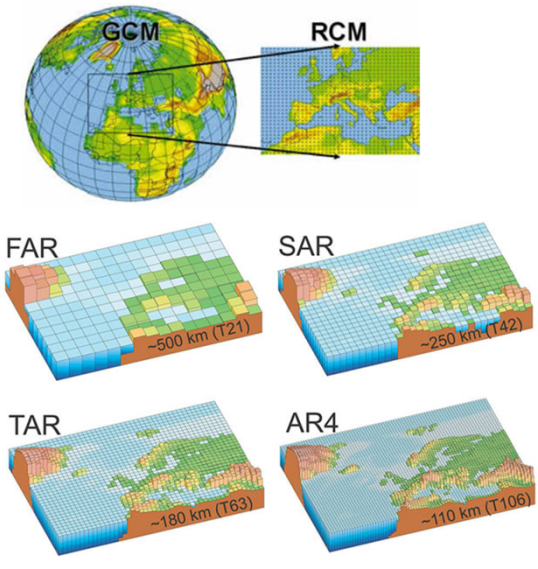
Regional climate models



Increase in spatial resolution from the First (FAR) to the Fourth (AR4) IPCC assessment reports (Source: IPCC, 2007)

- RCMs simulate in a similar way as GCMs, but for a limited area of the Earth
- RCMs can generally be run more quickly (less computational power required) and at a higher spatial resolution than GCMs.
- **RCMs use information from a GCM at their boundaries** (nested regional climate modelling technique)
- driving data at the boundaries from GCMs
- 'regional' in RCMs refers to regions as large as Europe or a large part of Europe.

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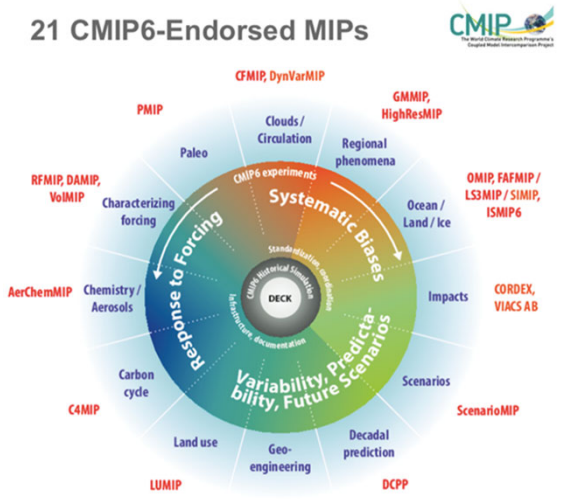
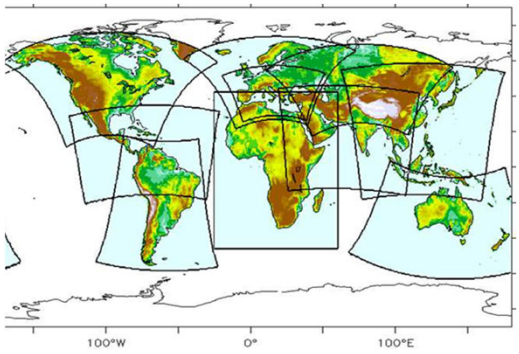
Climate model comparisons

CMIP Coupled Model Intercomparison Project



https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6

Regional models: **CORDEX** domains
(coordinated regional climate downscaling experiment)



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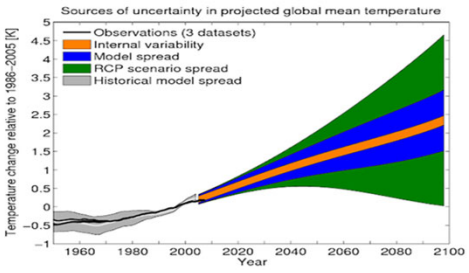
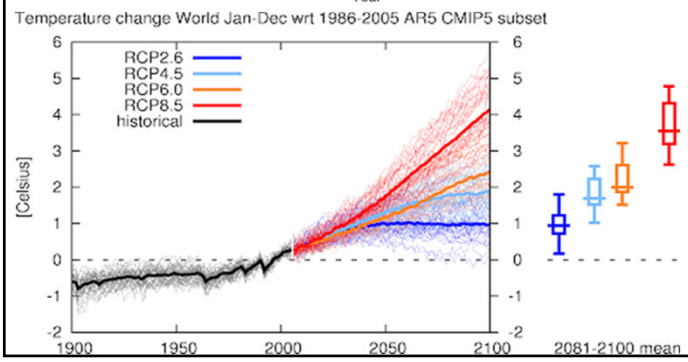
Ensembles and uncertainties





Ensemble = combination of model runs: usually made to characterize uncertainties or variability

- **initial conditions** slightl changed; same model run again (single-model ensemble)
- Models with different ways of describing various processes, or different parameter values (**multi-model** or perturbed physics **ensemble**)
- **Different forcings** (emission scenarios)

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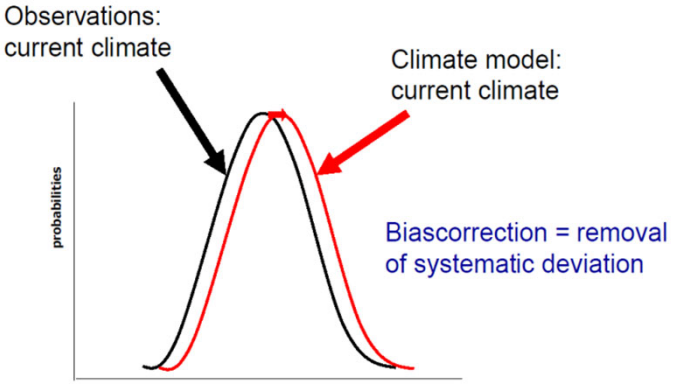
Climate model bias

Models are simplifications of reality: never represent reality exactly.

Differences in statistics of the observations for the reference period and the climate model simulation for the same period we call **biases**.



Source: ROADAPT

Schematic presentation of climate model bias: the systematic difference between model output and observations.

https://www.youtube.com/watch?v=XGi2a0tNjOo
(first 3 minutes of 14.50" minutes; University British Columbia)

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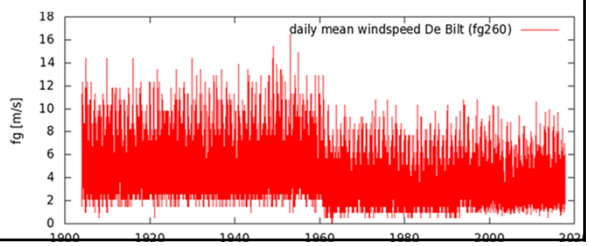
Advantages + disadvantages in situ stations

from weather stations at land (in situ)

Advantages:
- long time series. Some starting in 1850, from 1950 many more stations
- direct measurements of essential climate variables (ECV's)

Disadvantages:
- no equal distribution over the earth
- time series often contain "inhomogeneities": apparent changes in climate due to e.g. the use of better instruments or changes in the environment

Weather station at De Bilt, Netherlands



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Advantages + disadvantages sea observations

Advantages:

- important for weather models, since they provide information for regions with a low density of observations
- direct measurements of essential climate variables (ECV's)

Disadvantages:

- schips and drifting buoys do not have a fixed location
- no long time series at fixed locations

Schip measurements at sea
(Source: Marine institute Ireland)

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Advantages + disadvantages satellites

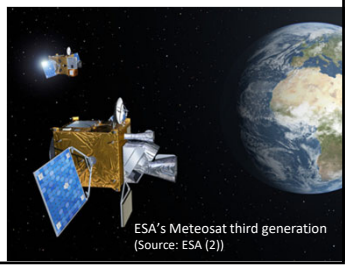
Advantages:

- high spatial coverage (also data for regions without ground stations) and high spatial resolution
- data almost directly available

Disadvantages:

- no long time series yet (from about the end of the '90 on)
- satellite signal has to be translated into the desired climate variable. Introduces additional uncertainties and ground observations are needed to make this translation
- systematic disturbances in the signal due to the atmosphere

Advantages and disadvantages of **radar and lidar** are similar.



ESA's Meteosat third generation
(Source: ESA (2))

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Advantages + disadvantages re-analysis

Advantages:
- estimates for climate variables where and when there were no observations
- area-average data, which can be used to determine the skill of climate model projections/simulations and S2D predictions

Disadvantages:
- rather coarse spatial resolution
- may contain some biases, especially where there are few observations that could be assimilated

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Advantages + disadvantages S2D

From seasonal to seasonal to decadal predictions

Advantages:
- provide information for the near future (seasons to decade)
- can be used for characterising the natural variability more accurately than with observations only (use of ensembles)

Disadvantages:
- poor skill of S2D models in large part of Europe
- Can contain biases, especially when forecasting for a longer period ahead

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Advantages + disadvantages climate models

From climate model simulations/projections

Advantages:
- provide data for past and far future
- can be used for characterizing the natural variability and to determine the probability of extremes more accurately than with observations only (use of ensembles)

Disadvantages:
- presence of biases
- often relatively low spatial resolution

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To next presentation

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Introduction to the course

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Aim of this course and set-up

Introduction to climate data for impact studies: 28 – 29 November

- Introduction to climate model data sources and their advantages and disadvantages
- Introduction to finding, accessing and processing climate data and practical experience using some tools
- Challenges in using climate data for impact studies

Case study: 29-30 November

• Challenges for working in inter/transdisciplinary projects, how to create understanding between different types of researchers, demonstrate the value of interaction

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Your name and discipline?

Experience with working with climate data? What climate data?

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