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FINNISH METEOROLOGICAL INSTITUTE

Observations for climatic variables: obs. system, specifics, challenges

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https://public.wmo.int/en/our-mandate/what-we-do/observations

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Observations

Tags: Observations

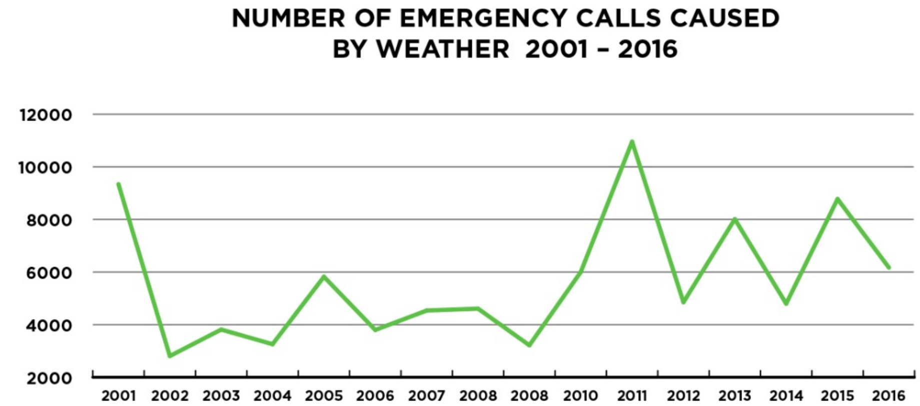
Observations are key to our understanding of how the Earth system – the atmosphere, oceans, freshwater bodies, land and the biosphere – shapes our weather, climate and hydrology.

Currently, well over 10 000 manned and automatic surface weather stations, 1 000 upper-air stations, 7 000 ships, 100 moored and 1 000 drifting buoys, hundreds of weather radars and 3 000 specially equipped commercial aircraft measure key parameters of the atmosphere, land and ocean surface every day. Add to these some 30 meteorological and 200 research satellites to get an idea of the size of the global network for meteorological, hydrological and other geophysical observations. Once collected, observations are quality-controlled, based on technical standards defined by the WMO Instruments and Methods of Observation Programme (IMOP), then made freely available to every country in the world through the WMO Information System (WIS).

Weather observations are produced according to World Meteorological Organization (WMO) regulations (WMO-No.8, CIMO Guide).

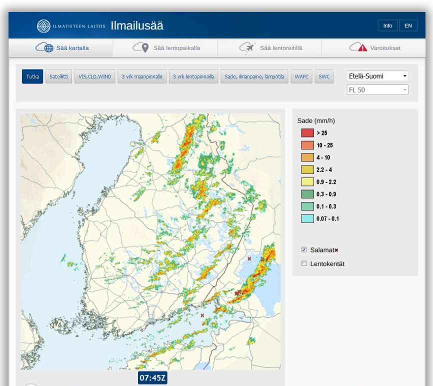
Weather has high impact to societies→ need for observations

- In Finland, weather has caused more damages in 2010s than in the previous decade
- In 2010–2015, the number of annual rescue operations has been > 5000 (see also 2000–2009)
- The proportion of damage prevention tasks of the rescue service has increased during this decade



Significance of observations

- Observations are needed for understanding the current state of the atmosphere
  - Initial conditions in Numerical Weather Prediction (NWP) forecasts
  - Forecast verifications
- Climate monitoring by using past observations → climate change
- Direct use of meteorologists to provide forecasts and warnings
- Critical to aviation to promote safety and cost-efficiency
- Weather impact assessments



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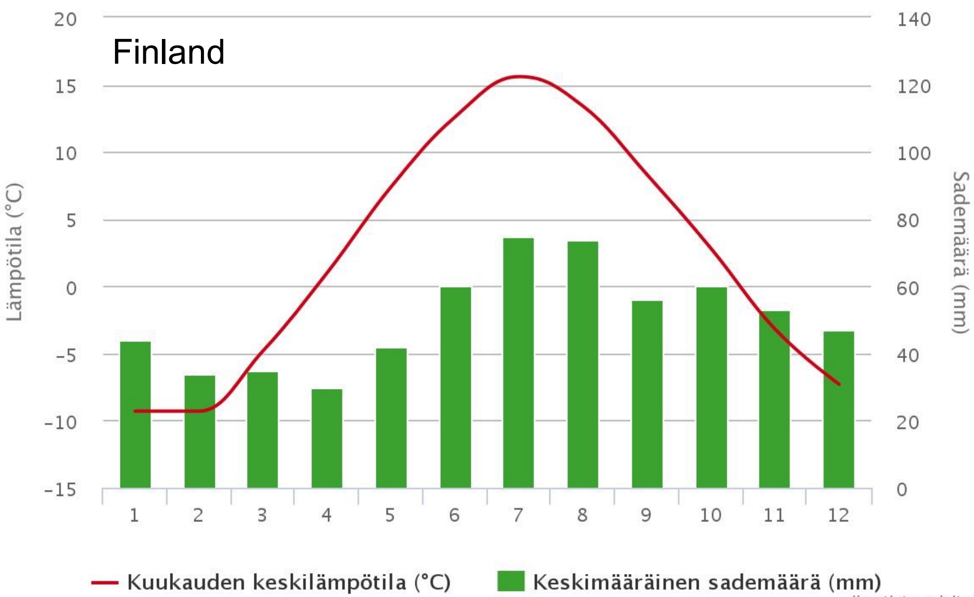
Climate is the long-term average of weather parameters

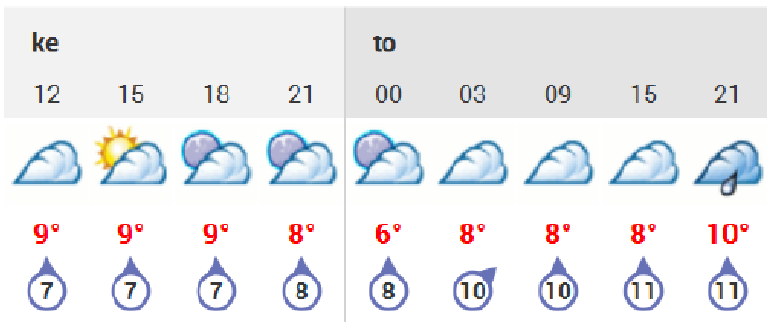
Climate
(typical 30 years’ average)



Monthly average temp

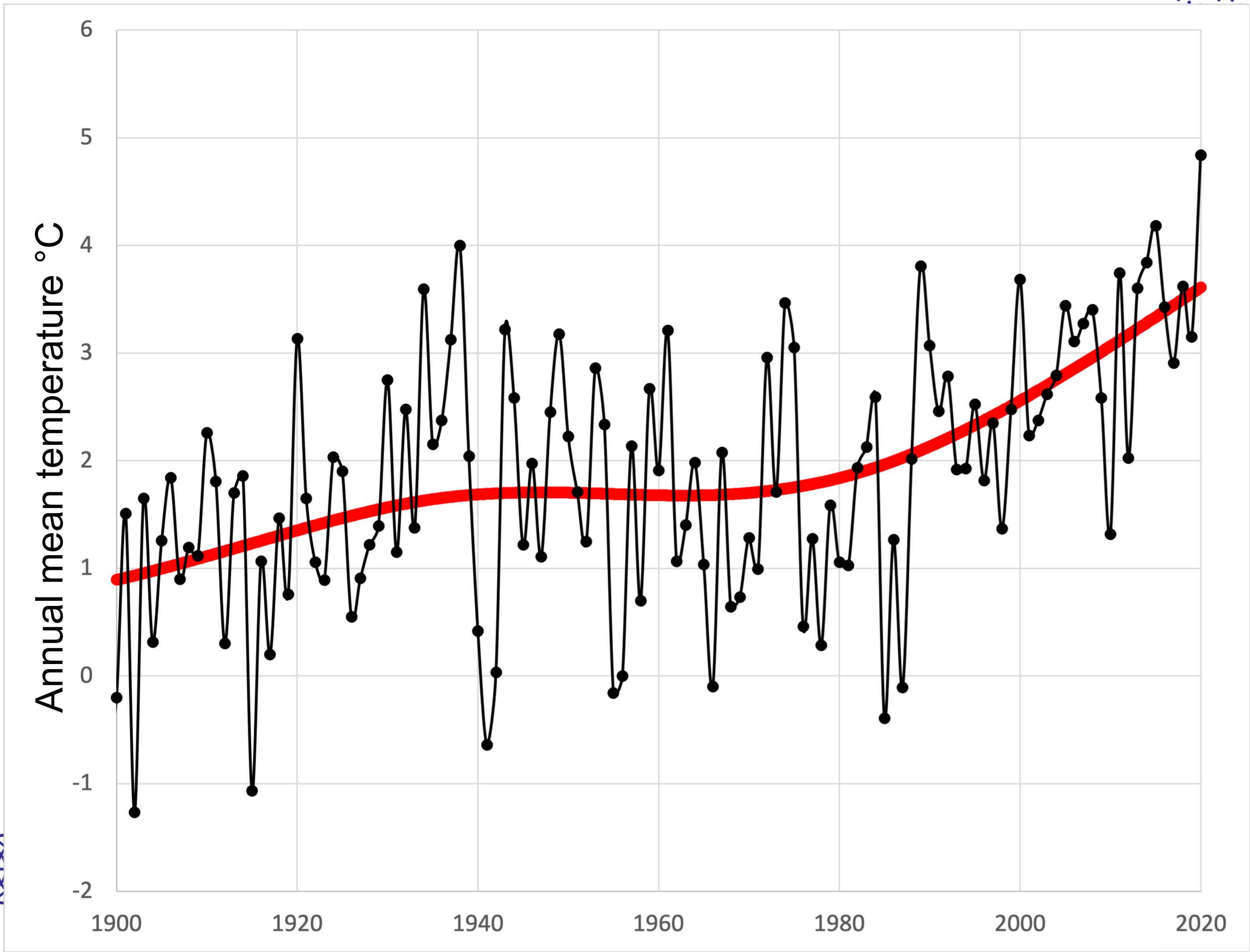
Average precipitation

Weather
(short term)



(compare to the average October temperature in Kaisaniemi 1980–2010: 6.6°C)

According to observations, climate has changed already in Finland



Observation systems and their specifics and challenges

System types

- Meteorological observation systems are typically divided in
  - In situ
  - Remote sensing
- In situ -observations observe atmospheric conditions in specific point with respect to time
  - (Automatic) weather stations, precipitation gauges, air quality, atmospheric soundings, etc
  - “Good”: possible to get the most accurate observation
  - “Bad”: very limited spatial coverage
- Remote sensing systems observe atmospheric conditions remotely
  - Weather radar, satellites, lightning location, etc
  - “Good”: excellent spatial coverage
  - “Bad”: How accurate are the measurements?

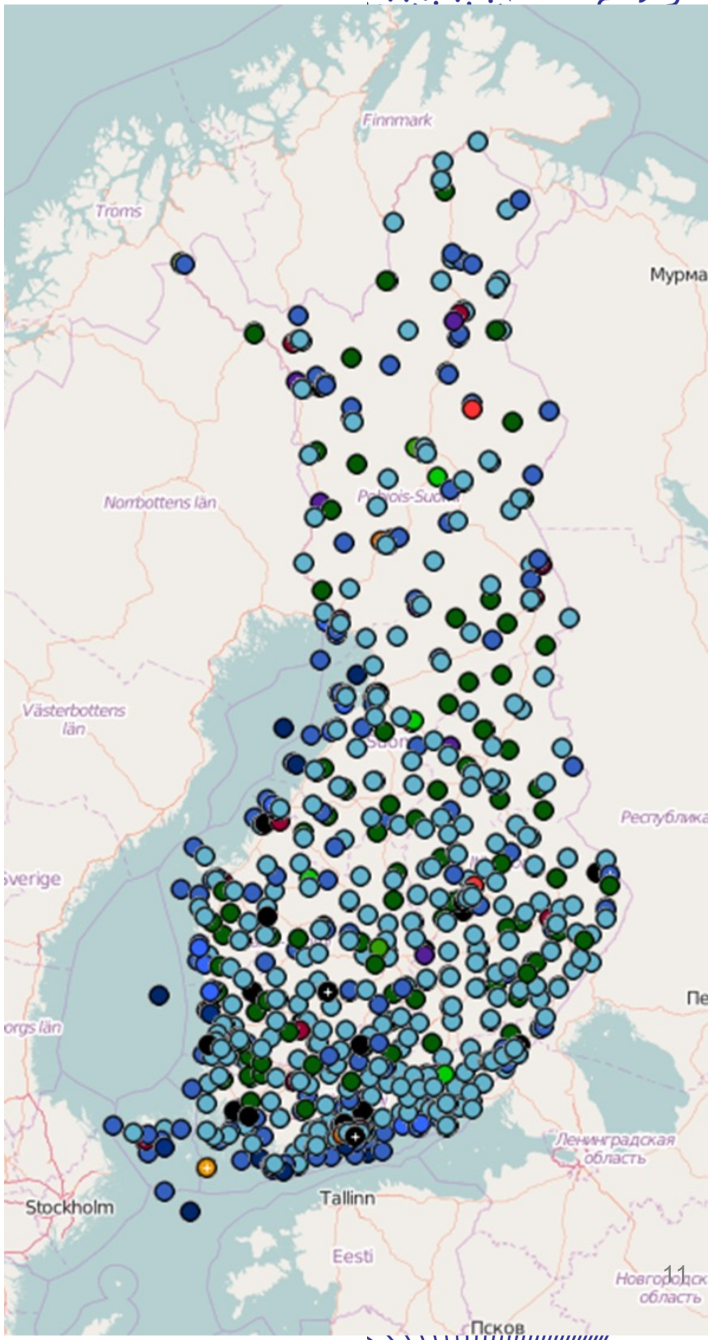
Observations

https://en.ilmatieteenlaitos.fi/observations

Finnish Meteorological Institute makes observations of the atmosphere, sea and space at over 400 stations around Finland, and using remote sensing instruments such as radars and satellites. In addition to weather observations we monitor e.g. air quality, radioactivity and properties of the upper atmosphere.

Example: observation network of FMI

Operative stations Automation % of weather stations	c. 500 c. 99 %
Weather stations	178
Weather radars	10
Aviation weather stations	23
Radio sounding stations	2
Lightning location sensors	8
Mareographs	14
Buoys	3
Masts	3
Air quality stations (background measurement stations, incl. radioactivity)	30
Precipitation stations	88
Sea ice observation stations	22
Auroral cameras	7
Magnetometers	13
Research and special measurements	circa. 50 (incl. 5 Lidars)



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Temperature

Air temperature is measured at a height of two meters. The probe is situated inside a well-ventilated radiation shield, which gives cover from direct sunlight and rain.

Temperature is also measured near the surface of the ground. This is called measuring the surface minimum temperature. The automatic measurement is done during the summer season at a height of 5 cm on an artificial grass or cut grass area. The probe is lifted above the snow during the winter season and is placed at a height of 5 cm above the snow. The probe is lifted above the snow every time after snowfall. The measuring principle is the same as with the two-meter temperature measurement. The surface level temperature probe needs to be in an open space, so that the heat radiation leaving the ground is not obstructed and the measurements are representative.

Wind

Wind speed and direction are measured at the weather station with an acoustic anemometer, or with a weather vane and a cup anemometer. An acoustic anemometer consists of three to four ultrasonic transducers that work as senders and receivers. The sound travels through the air and based on that it is possible to calculate the wind quantities. The speed of sound is dependent on the air temperature. Regular wind measurements are done through hourly and ten-minute averages. A three second maximum gust measurement is calculated from the regular wind measurements (maximum three second average on a ten-minute period).
Wind direction and speed is measured at an altitude of ten meters above the ground surface, above major obstacles near the station. Because of this, the measuring altitude changes depending on the weather station.
Challenges for wind measurements are:

- changes in the observation environment
- observation sensitivity at low wind speeds with a cup anemometer
- freezing conditions in the winter
- obstacles at certain measuring directions
- damage caused by birds

Challenges are reduced by planning, technical solutions and by appropriate maintenance and quality control processes.

Anemometer in Hanko Tulliniemi

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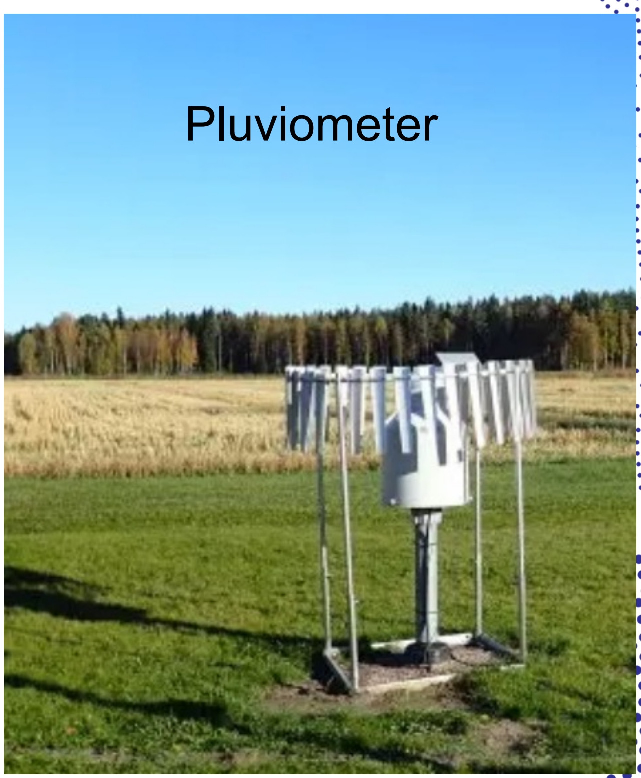
Solar radiation

The most central quantities of solar radiation are global radiation, UV-radiation and amount of sunlight. Global radiation, also known as total radiation, is the measurement of shortwave broadband radiation (W/m2) that meets the probe from across the entire firmament.

Pyranometers on the Meteorological Institute headquarters rooftop in Kumpula, Helsinki.



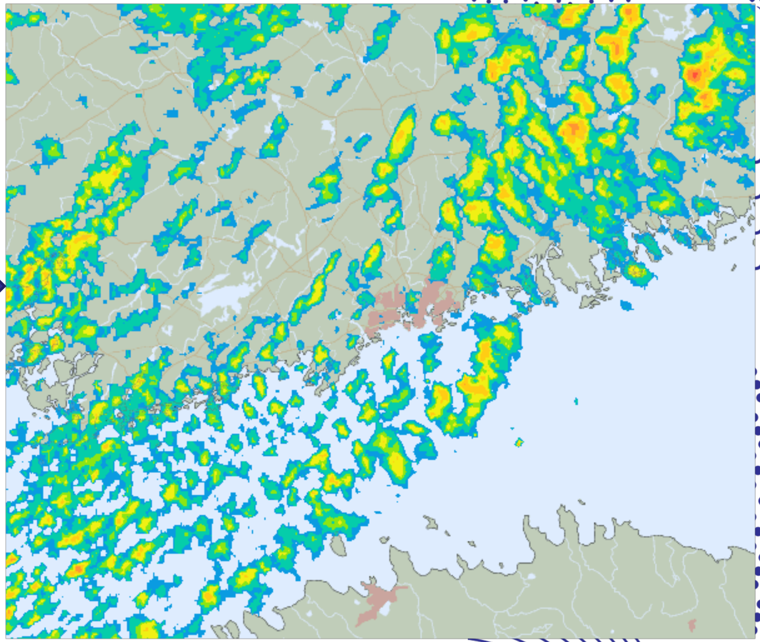
Precipitation

Automatic rain gauges, also known as pluviometers, are weight scales. The measuring of precipitation is based on weighing the mass of the liquid precipitation in the pluviometer, which is then mathematically converted into millimeters. An automatic pluviometer reports the amount of precipitation every hour, and a 12-hour and 24-hour accumulation is calculated by summing up the last hourly measurements. The pluviometer can also produce data of the intensity of the precipitation. The pluviometer is protected from the wind by using a wind protector around the gauge. The wind protector is useful especially during snowfall, as the protector stops the lightweight snowflakes from traveling past the pluviometer opening. The pluviometer is equipped with a defrost liquid during the winter, to properly observe snowfall amounts. The opening of the pluviometer is also equipped with a heater, so it doesn't get filled with snow during heavy snowfall. The opening of the pluviometer is placed at a height of 1,5 meters. An optimal place for the gauge is where possible obstacles are at a distance twice their own height from the observation spot.

Snow depth

Snow depth is measured automatically with an ultrasound snow sensor. The snow sensor is pointed straight down, and it measures the distance between the transmitter and the top of the snow. The ground under the snow sensor is a flat surface with artificial grass as the base material. The artificial grass keeps the ground flat and stable. The snow sensor is set at a standard height off the ground, and once the distance between the sensor and the ground decreases, the difference is reported as the snow depth. Due to the observation method, strong drifting of snow, litter on the observation site, ground frost and animals can cause disturbance with the measurements. The disturbances are avoided by using technical solutions and by maintaining the observation site properly. The distance between the spot of measurement and the nearest obstacles or plants should follow the same principle as with precipitation measurements, therefore they should be at least twice the distance of their height away from the observation spot. The measurement is done at a single point, so the snow depth can differ from the regional average.

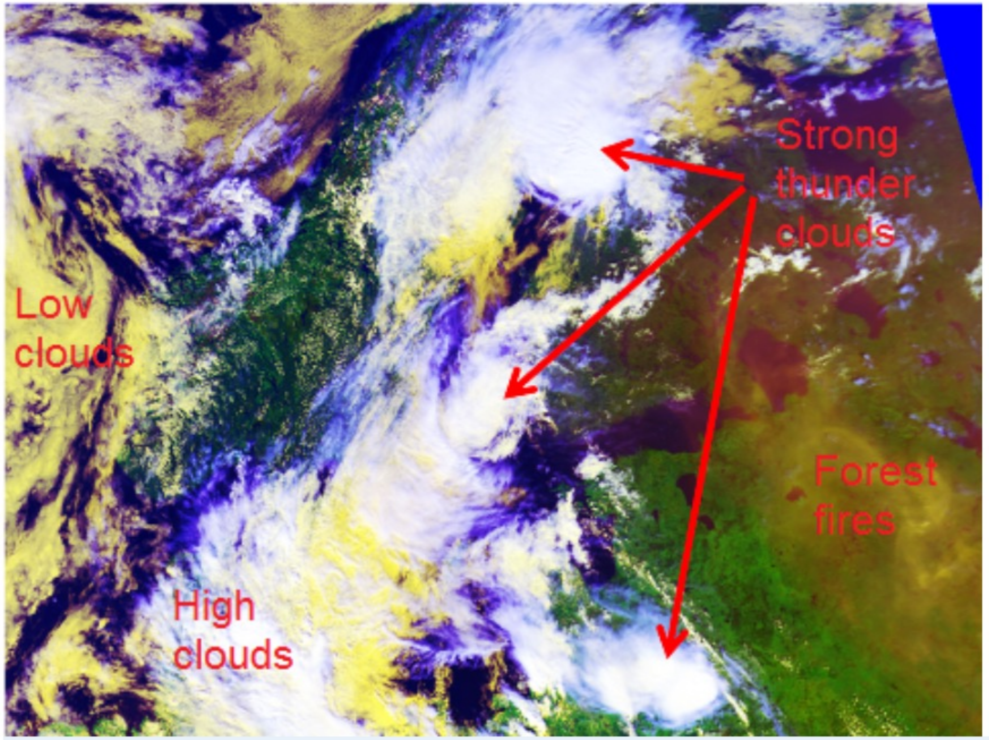
Weather radar – electromagnetic signal analysed as precipitation



Challenge: radar does not measure precipitation at ground

Satellites observing the weather

- Satellites make it possible to observe wide areas in good temporal and spatial resolution.
- Cloud images are probably the best known satellite applications but also other meteorological parameters can be derived from satellite measurements:
  - These include temperature and humidity profiles, wind velocity and direction, lightning, etc



Satellite images can be used to observe many kinds of phenomena. 8 August 2010 Finland was struck by several strong thunderstorms. At the same time in Russia there were forest fires in wide area.

Pallas Atmosphere-Ecosystem Supersite

The Pallas Supersite consists of versatile research infrastructure for monitoring and studying the atmosphere, ecosystems and their interactions. **Pallas is located 170 km north of the Arctic Circle**, partly in the area of Pallas-Yllästunturi National Park.

The Finnish Meteorological Institute (FMI) has a long history of atmospheric monitoring at Pallas: the first weather station was established near Lake Pallasjärvi in 1935. The measurements of atmospheric composition were started in 1991, and the Sammaltunturi station was established as a node of the Pallas–Sodankylä Global Atmosphere Watch (GAW) station in 1994. Currently, Pallas comprises one of the most important research infrastructures in Finland and in the wider circumpolar region, contributing to numerous **European and global research programmes**, such as **GAW**, **ICOS**, **ACTRIS** and **EMEP**. Pallas also serves as a **platform for scientific collaboration** with international as well as national research institutes (**LUKE**, **SYKE** and **GTK**).


One of the research stations in the Pallas area is located on the top of Sammaltunturi. Photo: Pia Anttila

Calibration and quality checking

- In situ –systems need to be calibrated
  - The vendor/manufacturer provides certain measurement error margins → are these correct?
  - For example, FMI has a calibration laboratory for testing all of our sensors
  - E.g. systematic biases can be corrected
- Quality check of measurements
  - Even the state-of-the-art systems may have temporary technical issues
  - Environmental issues such as frozen sensors, wind-damaged shields, etc

- Remote sensing systems have their own quality-related issues
  - These may vary according to season, day, hour, etc
  - For example, weather radars suffer from the precipitation type classification: large hail is interpreted as very heavy precipitation → filtering algorithms etc

Some specific challenges

- The number and type of observation systems typically change in time
  - How to determine e.g. long-term trends from changed network? What are the uncertainties?
- Reposition of sensors
  - Sometimes sensor location must be changed → how to ensure homogeneous observational datasets?
- From manual (human) observations to automatic observations
  - Changes in observation systems should always be examined carefully
  - Optimally, old and new systems measure some period together → differences
- Citizen observations
  - Plenty of new observations are nowadays available from citizens but how reliable are they?

Summary

- Meteorological observations are the backbone of meteorology/climatology
  - Present conditions of atmosphere (+oceans, air quality, etc)
  - Long-term statistics, i.e., climate and its changes
  - Initial conditions in forecasting + verification
  - Observations and their linkage to weather impacts
- Observations are always a balance between “accurate and sparse” vs “not-so-accurate but spatially large”
- It is important to observe systematically according to global standards
  - This ensures good quality and global homogeneity of observations
- Meteorological data is big data
  - Every minute tremendous amounts of data are available
- The added value of new observations
  - Citizen observations and their value in improving weather forecasts

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Thank You!