Course Remote Sensing and Climate

Summer 2026
University of Frankfurt

2. Day (R. Hollmann)

- ➔ **Content and Structure of Course**
- ➔ Motivation and background
- ➔ A short introduction in Physics
- ➔ Radiative Transport and retrieval basics
- ➔ Satellite orbits and instruments
- ➔ Climatologies based on satellite instrument and usage

1. day (U. Pfeifroth, M. Stengel, A. Niedorf)

- ➔ Examples for Radiation (solar & thermal), Clouds, Precipitation and Water Vapour in the atmosphere
- ➔ Presentation of themes for seminar work

Notes to PDF-Version

This PDF is based on the presentation given in the summer term 2025 of University Frankfurt as part of the course „remote sensing and climate“.

It is meant to recall the content the content of the lecture and is for the personal use of the participants of the course and <u>not</u> for a wider audience.

Parts in this document have been taken from other lectures, books, publications, the internet or other sources. These parts are not always have a correct acknowledgment or a proper citation.

Thus, please contact me (rainer.hollmann@dwd.de) in case you would like to cite from this pdf.

Content and structure of course (I)

On-site am 21.04.2026

- 10:00 – 13:00 *Introduction into satellite remote sensing (I)*
  - Introduction
  - Basic definitions
  - radiative transfer equation

13:00 – 14:00 break

- 14:00 – 14:30 *Introduction into satellite remote sensing (II)*
  - Satellites and Orbits
- 14:30– 15:45 Satellite *Climatologies and usage*
  - *An European view*
- 15:45 – 16:00 *Discussion*

On-Site am 20.04.2026

- 10:00 – 11:30 Retrievals for radiation
- 11:30 – 13:00 Retrievals for clouds

13:00 – 14:00 break

- 14:00 – 15:30 Retrievals for water vapour and precipitation
- 15:30 – 16:00 Presentation of themes for seminar work

Content and structure of course (II)

From 21.04.2026 to June 2026

„on-site" on tbd at DWD

- Perform own studies
- Introduction in R-Tools if needed
- Support from lecturer team depending on chosen topic. U. Pfeifroth, M. Stengel, R. Hollmann, A. Niedorf
- write a seminar report
- Prepare a presentation
- **Submit a draft ToC until 01.07.2026**

- 10:00 – 12:00 :

  Presentations from participants incl. discussion
- 12:00 – 12:30 Final discussion / Feedback

Seminar Report is due by 31.07.2026 latest

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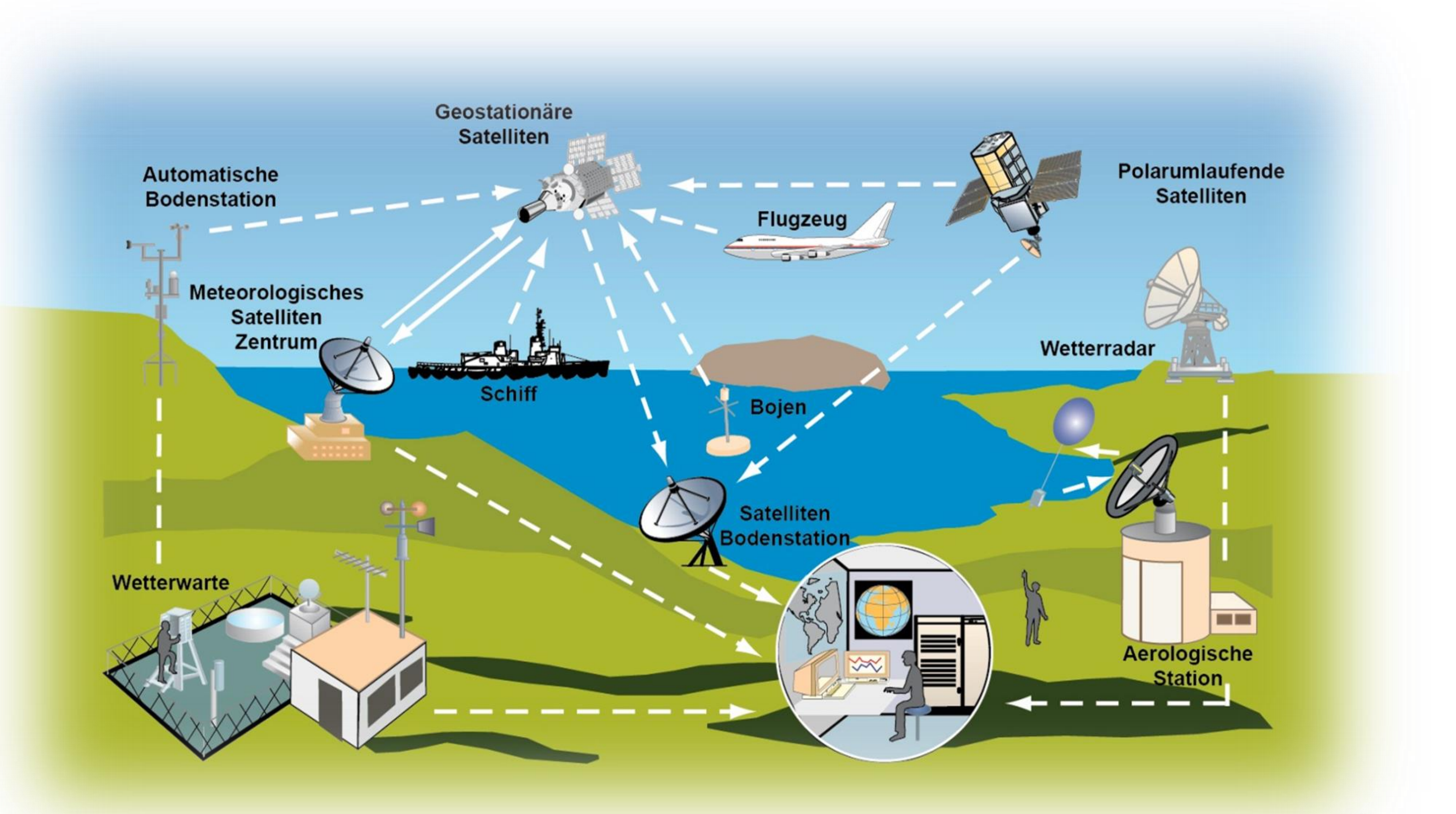
Motivation and background

Content

- ➔ Observations system for climate
  - ➔ In-situ, surface based
  - ➔ Radar remote sensing
  - ➔ Satellite based remote sensing

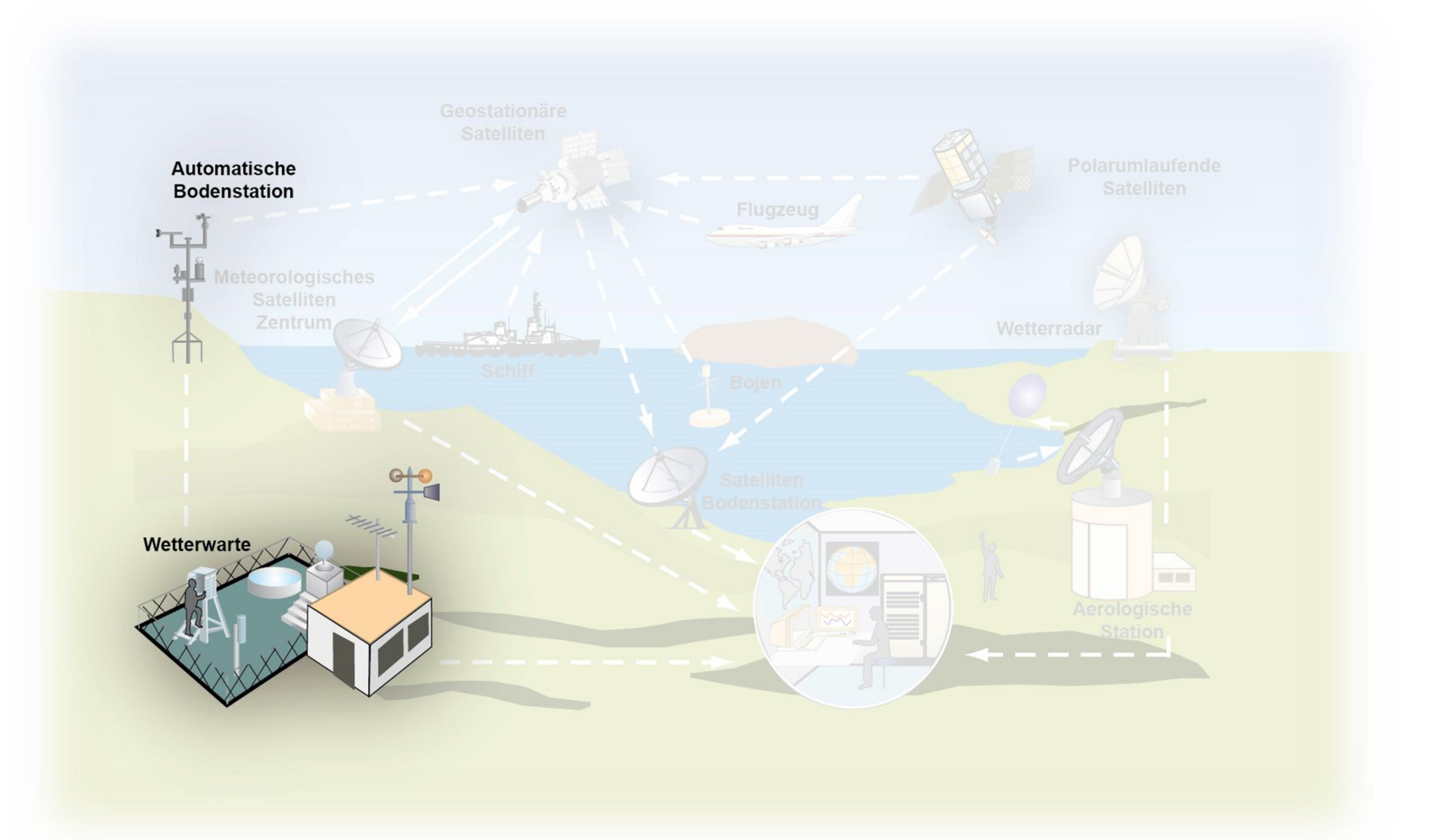
- ➔ What can be measured with satellites?

Data sources for climate monitoring at DWD



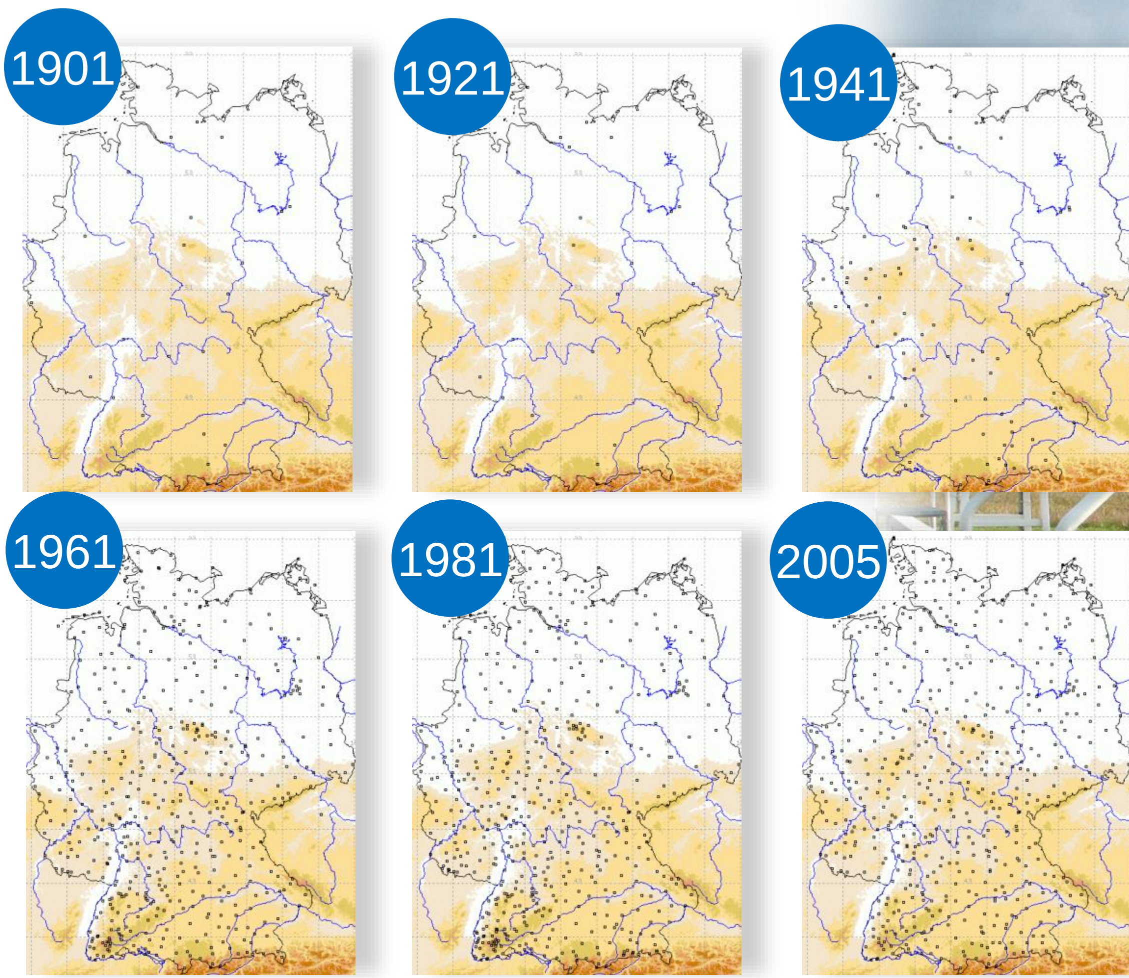
Important components of a climate observing system

1. Stations



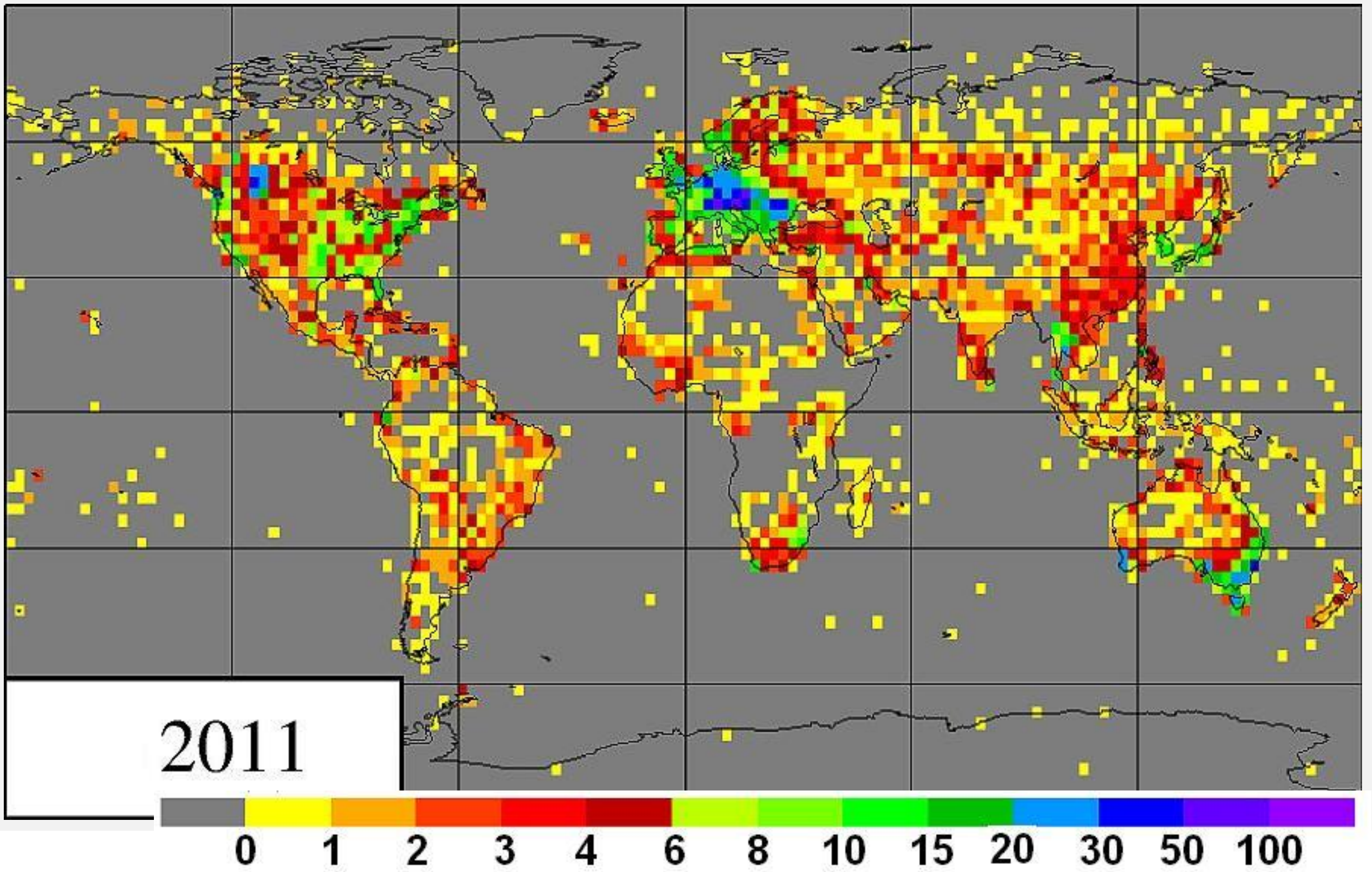
Important components of a climate observing system

Stations for climate observations in Germany



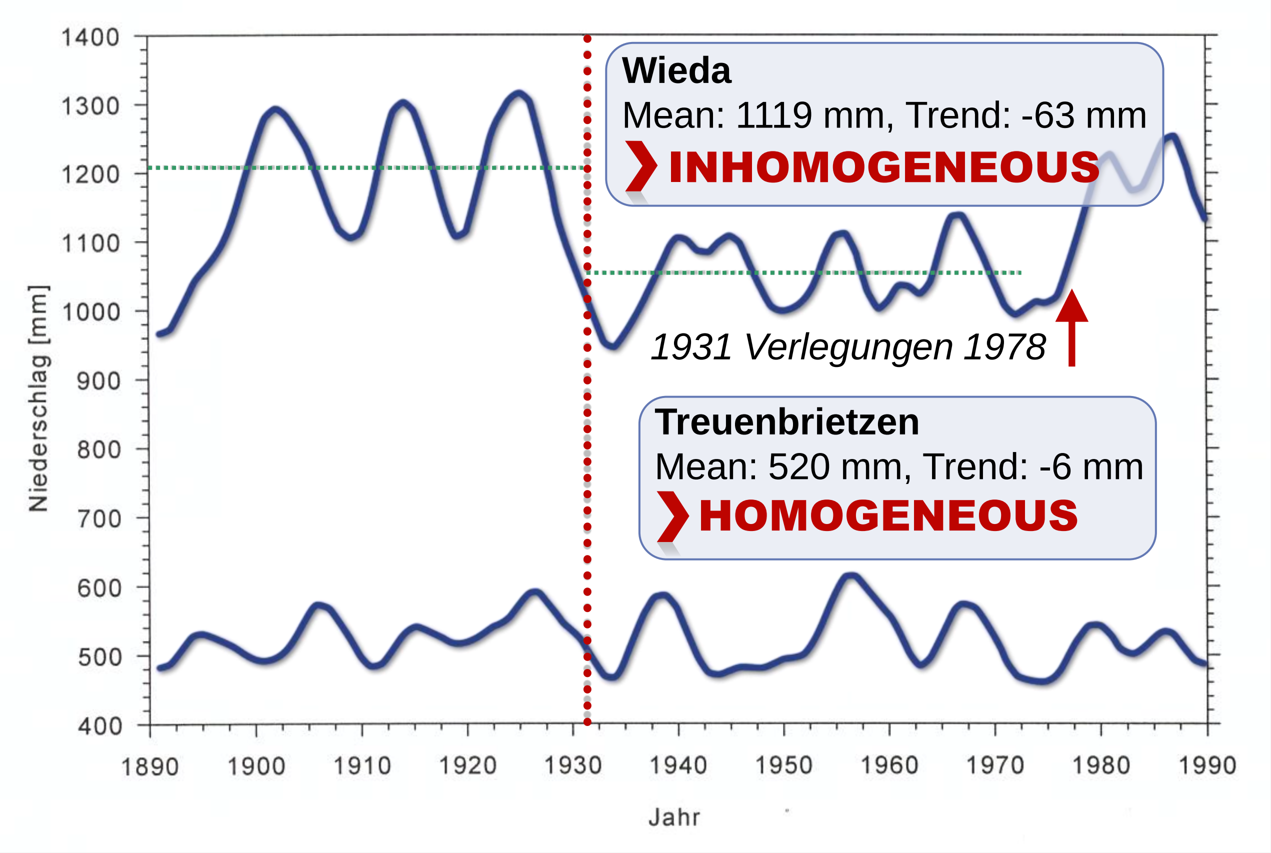
Important components of a climate observing system

Challenge of conventional measurements: Representativity



Challenge of conventiponal observations: temporal Inhomogenity

Annual Sums of Precipitation



Important components of a climate observing system

human Inhomogeneities

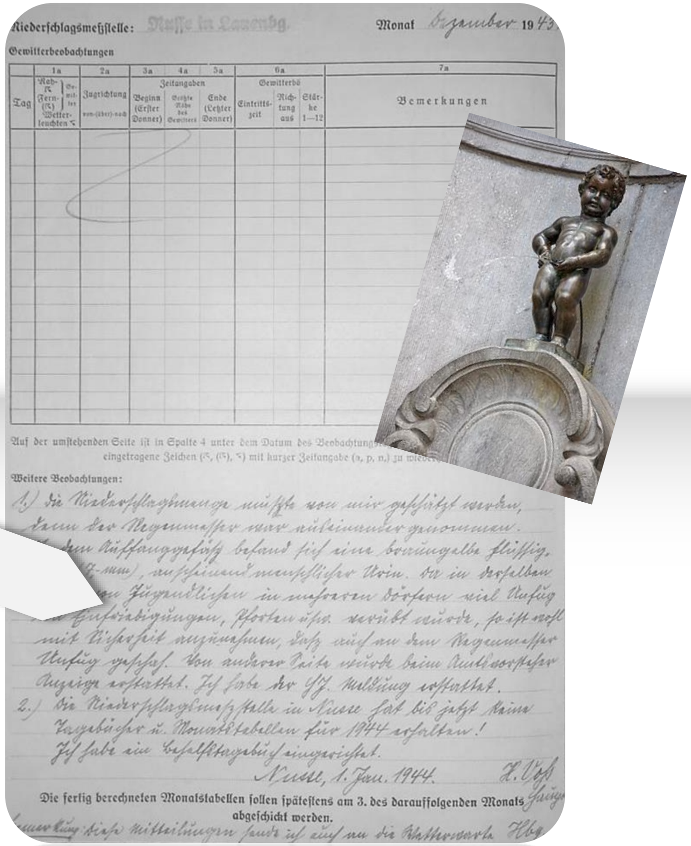
Extract from recording

the amount of precipitation had to be estimated by me, [...]. The collecting vessel contained a brownish-yellow liquid (7.0 mm), apparently human urine.

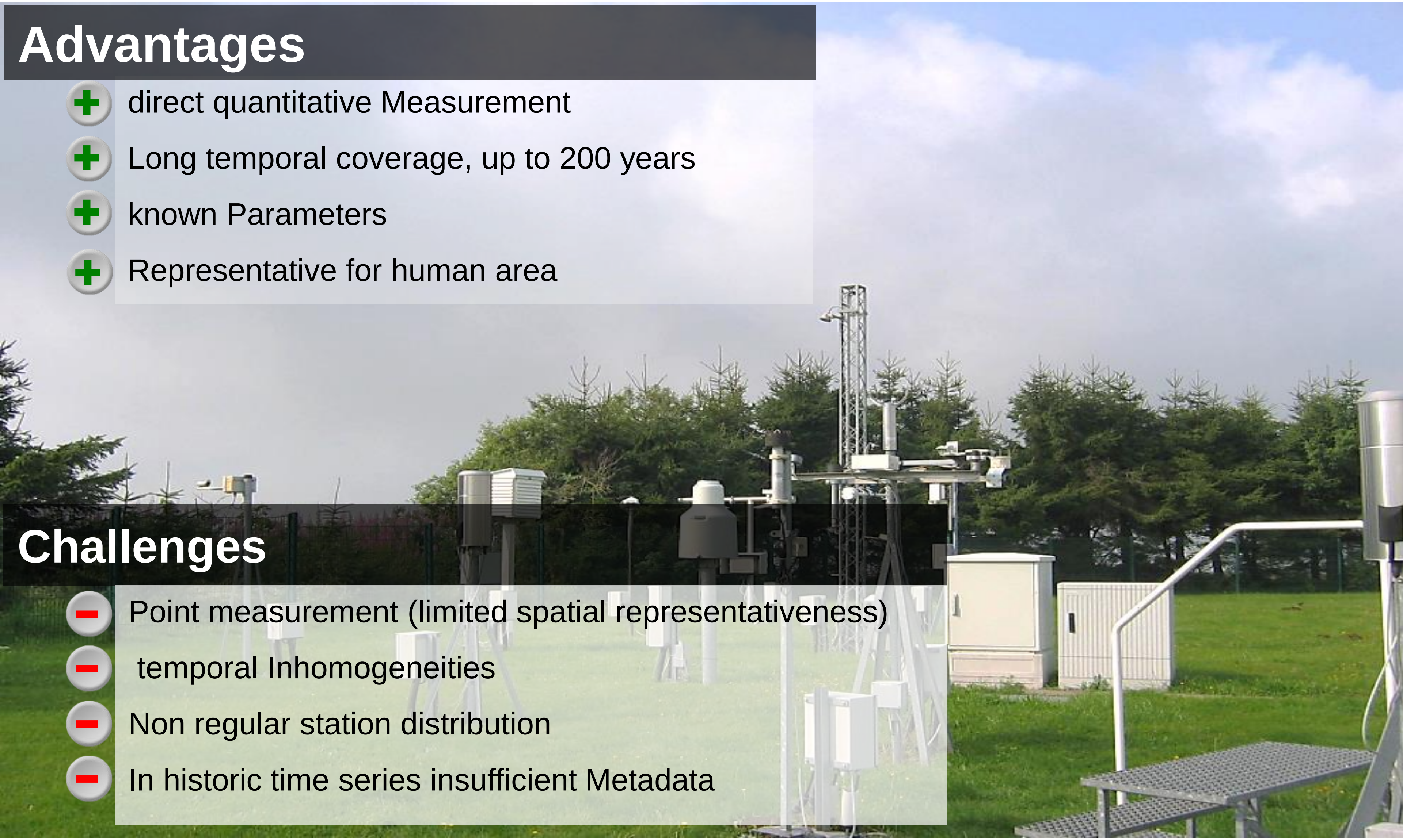
Since [...] a lot of mischief was committed by young people [...] on enclosures, gates, etc., it can be safely assumed that the rain gauge was also mischievous.“

Eintragung vom 1. Januar 1944

Station recording, Nusse


Niederschlagsmeßstelle: Nusse in Lauenbg.
Monat Dezember 1943
Gewitterbeobachtungen
Tag
Bemerkungen
Weitere Beobachtungen:
Nusse, 1. Jan. 1944.
Die fertig berechneten Monatstabellen sollen spätestens am 3. des darauffolgenden Monats abgeschickt werden.

Important components of a climate observing system



Advantages

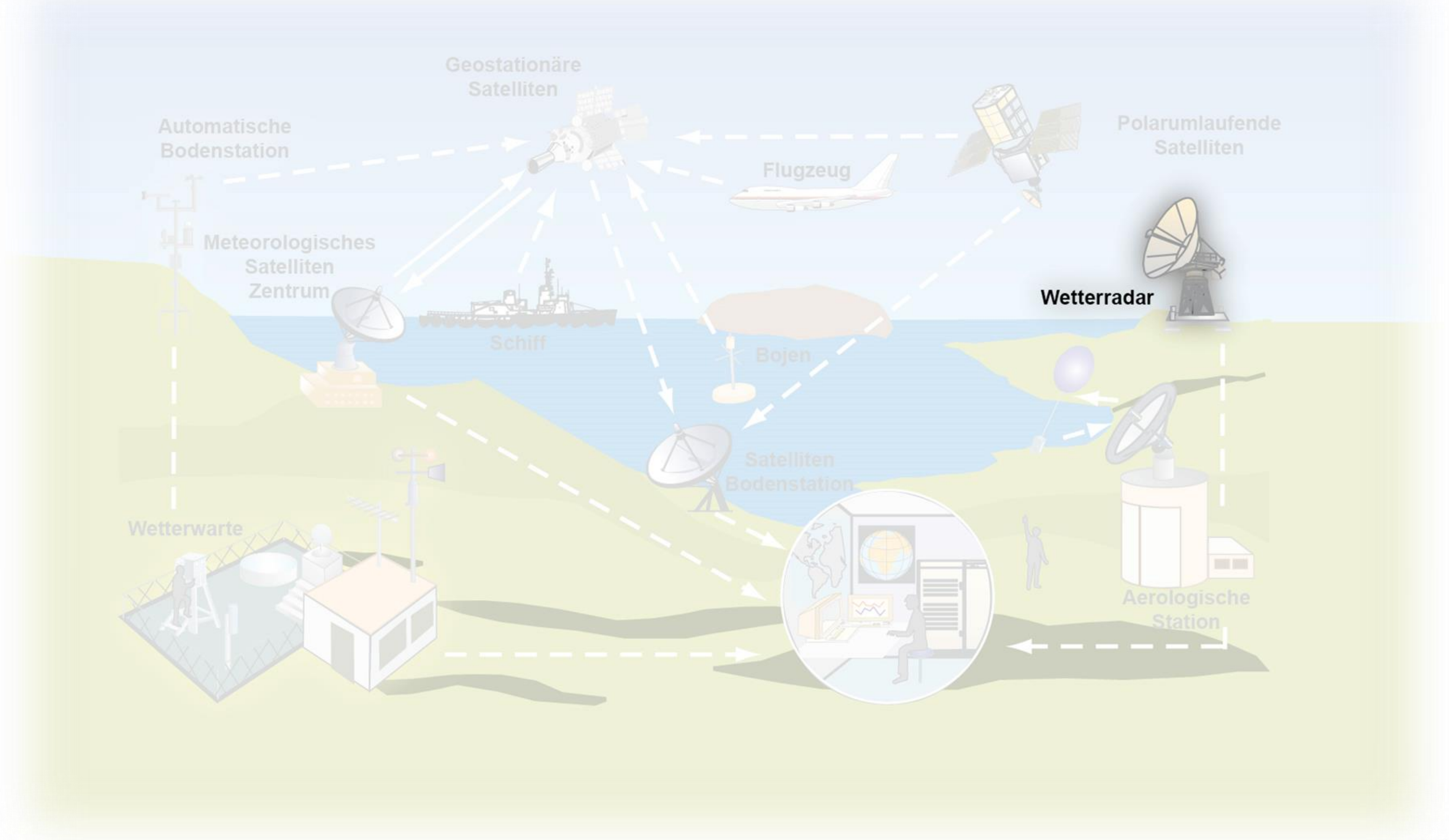
- direct quantitative Measurement
- Long temporal coverage, up to 200 years
- known Parameters
- Representative for human area

Challenges

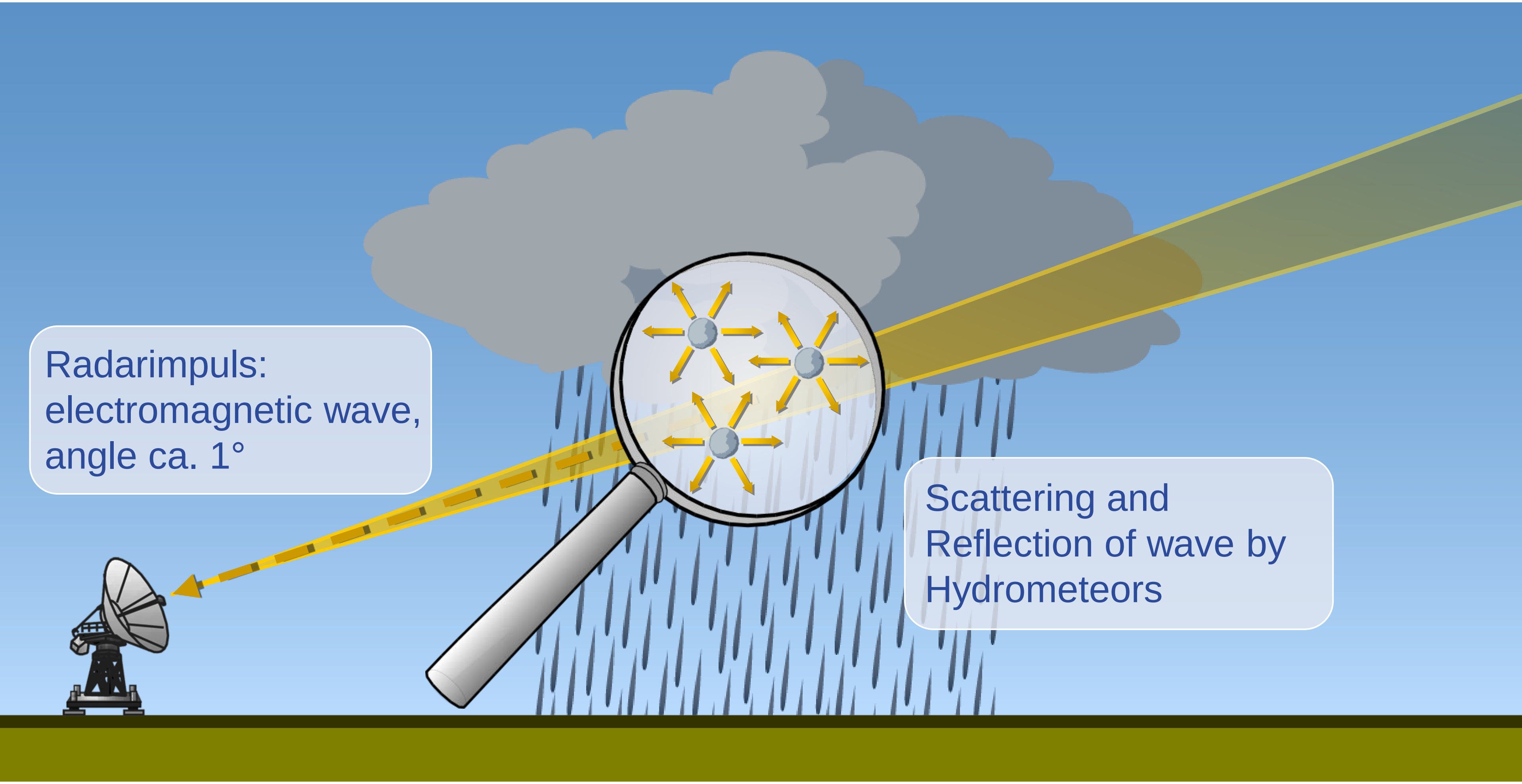
- Point measurement (limited spatial representativeness)
- temporal Inhomogeneities
- Non regular station distribution
- In historic time series insufficient Metadata

Important components of a climate observing system

2. Radar

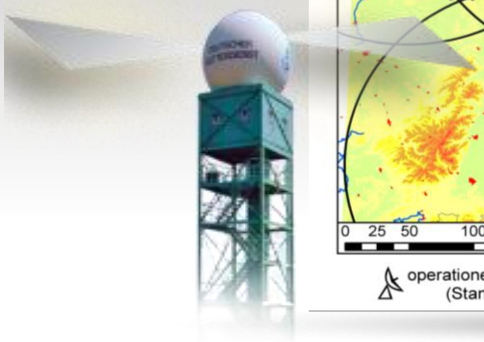


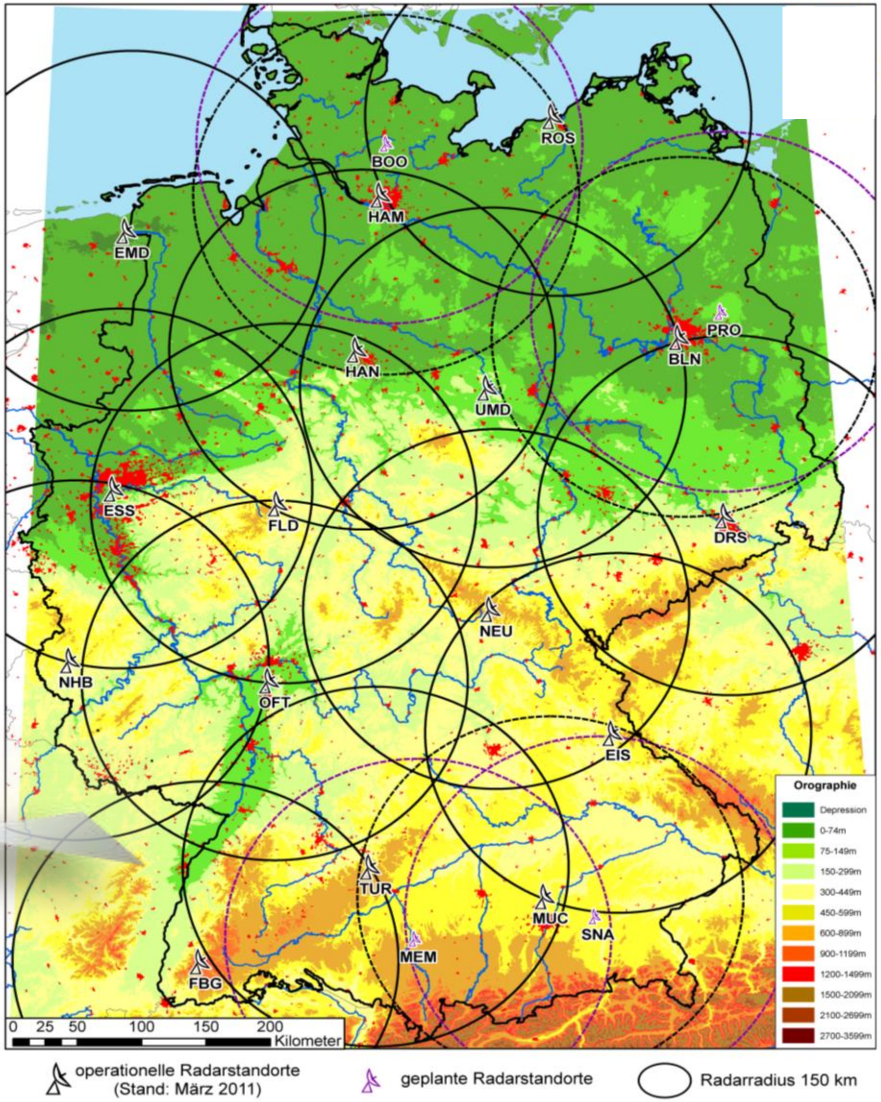
Principle of Precipitation radar measurement



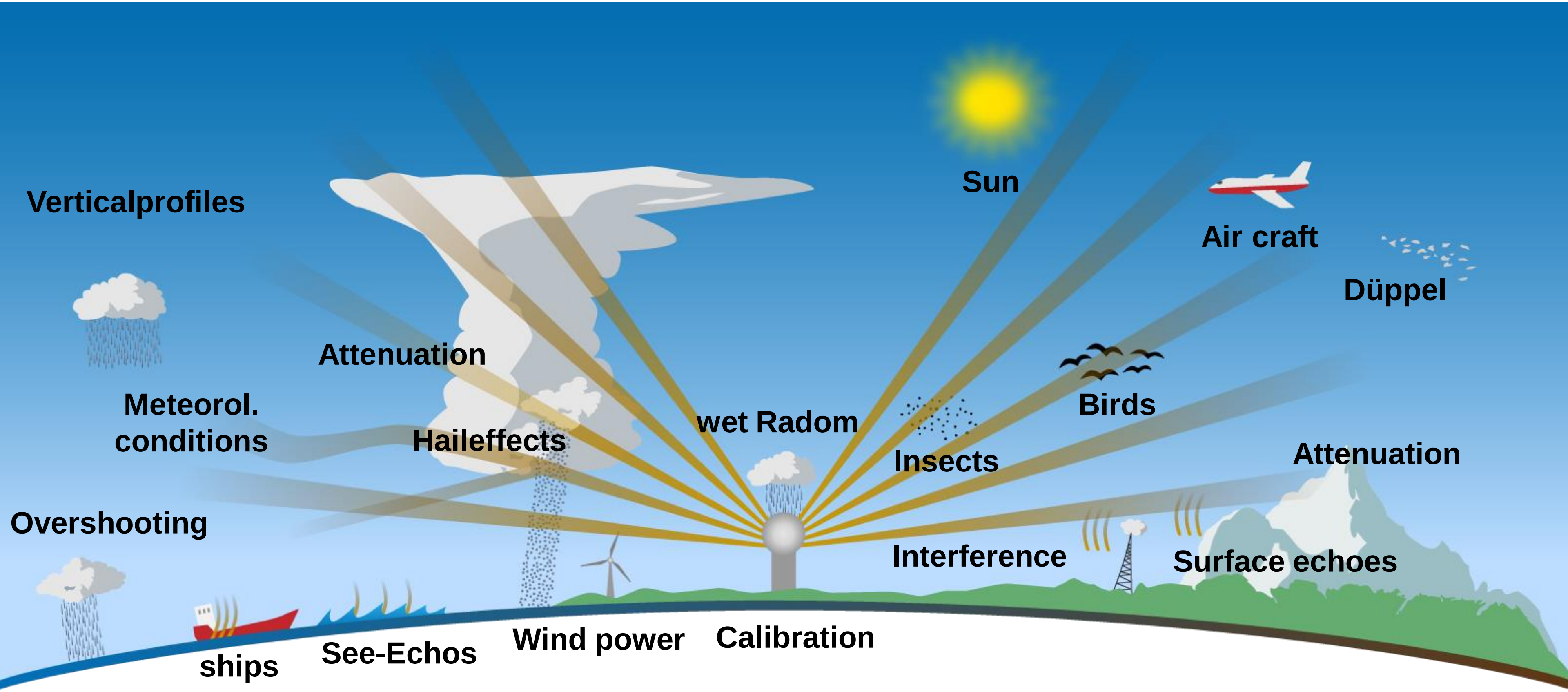
Important components of a climate observing system

- Radar Composite:
  - 17 Instruments
  - Radius 150 km,
  - C-Band 5 cm,
  - Precipitation-Scan 5 min



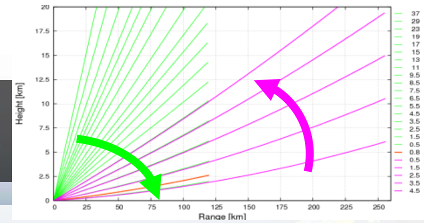


Challenges of precipitation radar measurement
Impact on Quality

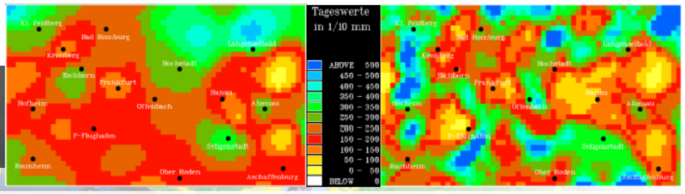


After Holleman et al., 2006, Quality information for radars and radar data, OPERA workpackage 1.2

Important components of a climate observing system



— + — volume scan — precip scan



Boden- und angeeichte Radarniederschlagsverteilung
(Tageswerte am 29.07.1996; 40 Stationen auf 2.100 km²)

Advantages

- **Only a few locations**

  17 needed for *quantitative* Precipitation analyses and Nowcasting for Germany, high temporal frequency, detection of small scale events

- **Spatial temporal coverage**

  a) with high spatial (1 km²) and temporal resolution (5 Min.) of PBL and

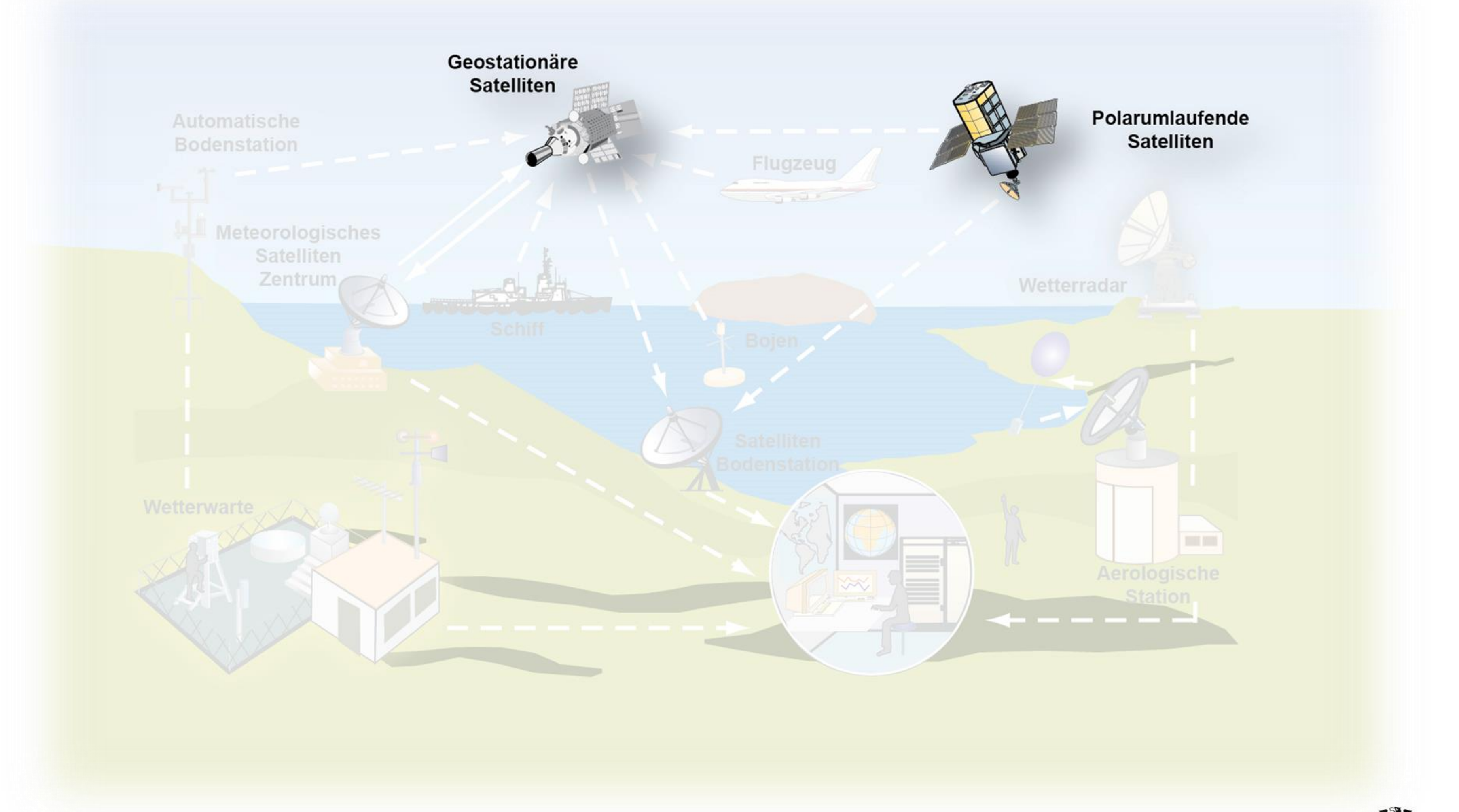
  b) Atmosphere up to 12 km Height („volume scan“) in 4 km² and 15 Min

Challenges

- Very short temporal coverage
- High computing demand
- No coverage of Ocean etc.
- Challenging calibration

Important components of a climate observing system

3. Satellites

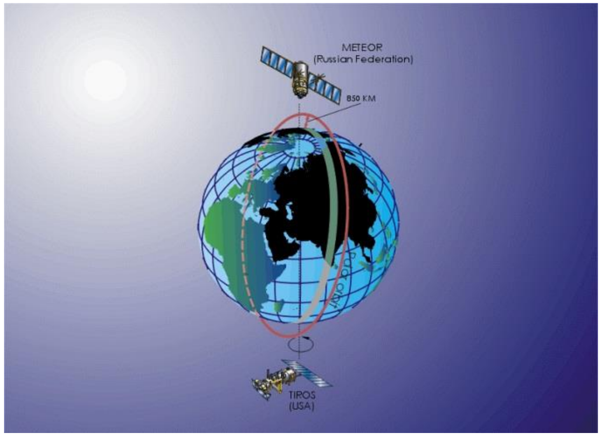


Earth observation

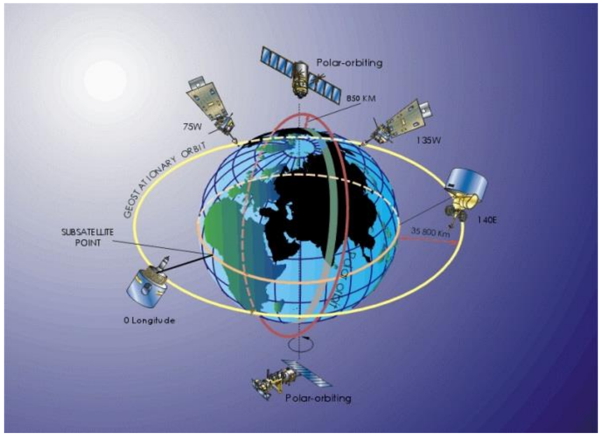
- **Earth observation satellites** are satellites for observing the earth. Depending on the area of application, a distinction is made between weather satellites and environmental satellites. The aim of the observations is to obtain an accurate picture of the atmosphere, the oceans, the Earth's heat and radiation balance, the vegetation cover and the soil (e.g. soil erosion) in order to use this data to make predictions for the future development of the Earth and to record historical developments.
- An **environmental satellite** is an earth observation satellite that is primarily used to observe and map the state of the earth. In particular, they are used to study the Earth's atmosphere (composition, trace gas concentrations, temperature determination, etc.), the Earth's surface (vegetation, soil conditions, disaster monitoring, etc.), the sea surface (sea surface temperature, salinity, algae growth, pollution, etc.) and the polar ice caps.
- A **weather satellite** is an earth observation satellite that is used to observe meteorological processes, i.e. physical and chemical processes in the earth's atmosphere. Data from weather satellites is indispensable, especially in areas where on-site observation is not possible or very expensive (e.g. oceans).

System development

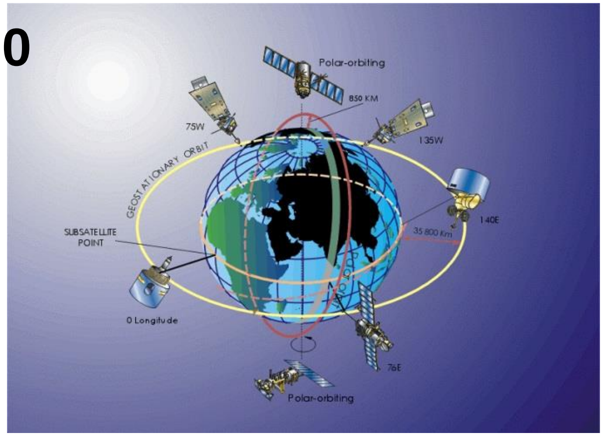
1961



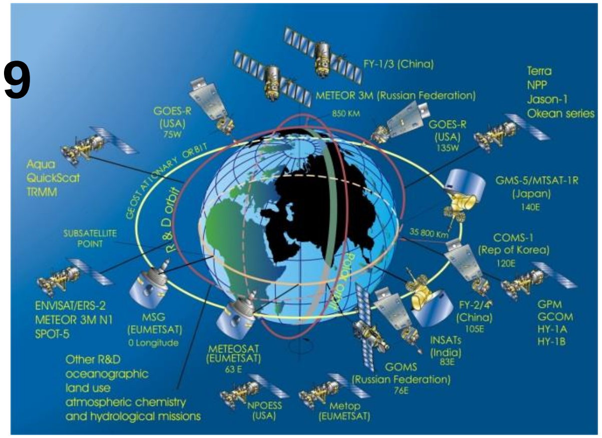
1978



1990



2009



Courtesy WMO, B. Ryan

Satellite component of Global Observing System (GOS)

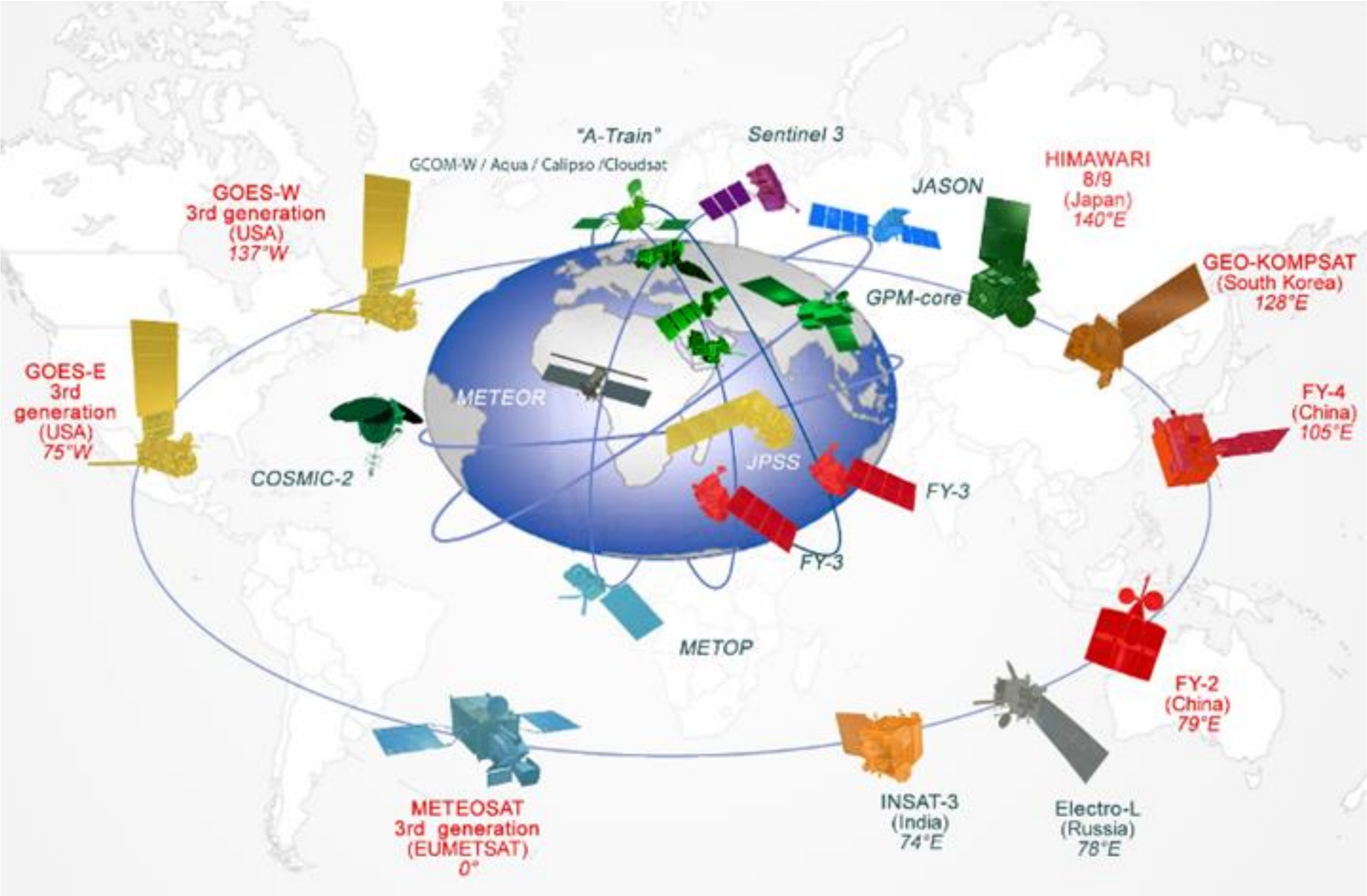


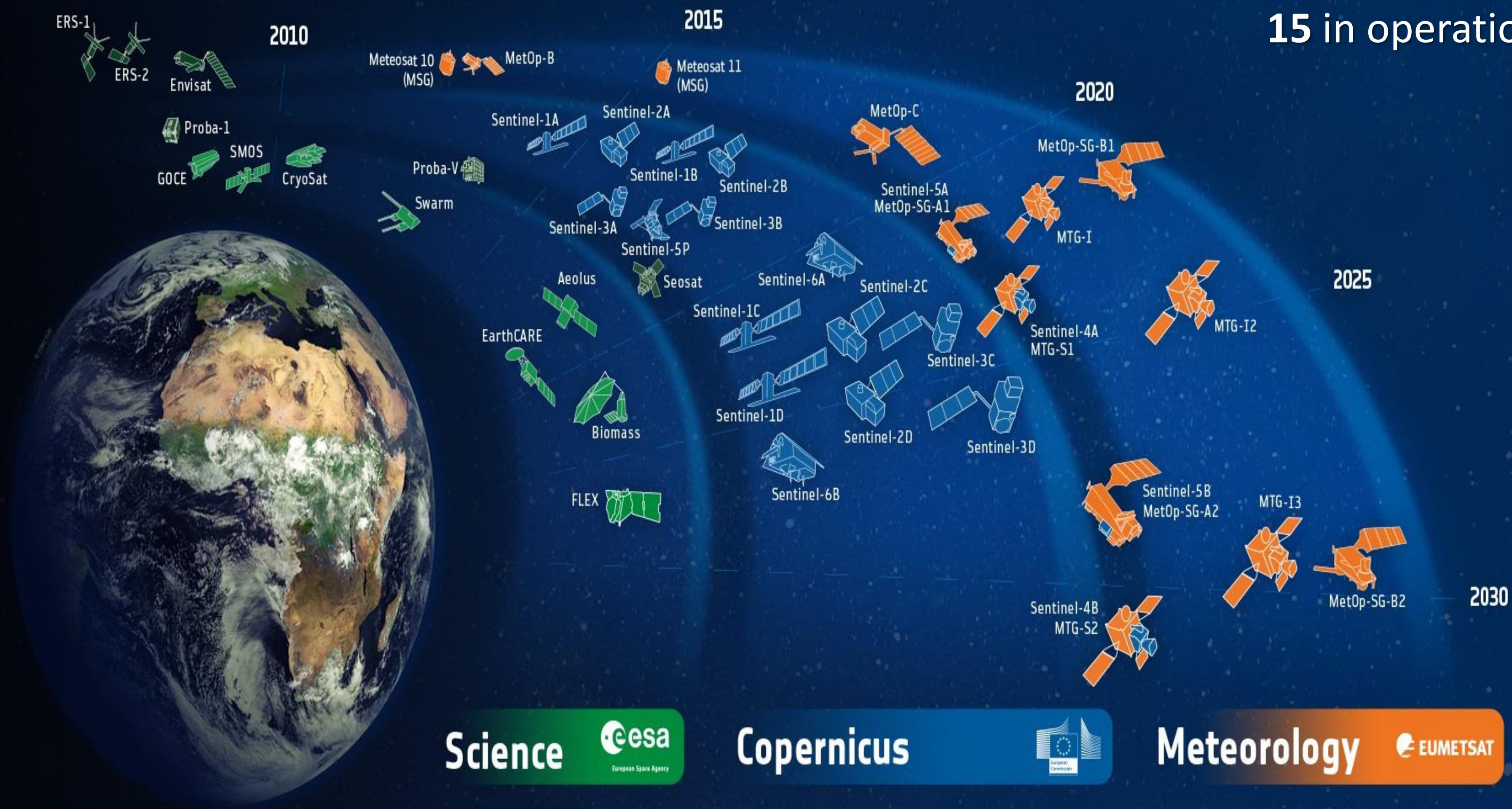
Fig.: Satellite component GOS.

(WMO (2025): Programmes. Space. Space-based GOS. Global Planning. <https://wmo.int/activities/global-observing-system-gos/global-observing-system-gos> (last access: 2025-04-12).)

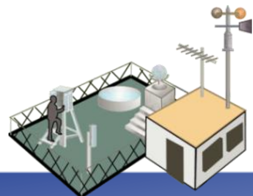
What comes next?

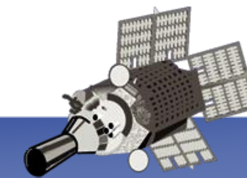
ESA Developed Earth Observation Missions

Satellites
25 under development
15 in operation



Comparison of observation systems





Surface measurement	*Pro* (Satellite)	*Con* (Satellite)
Calibration and technical maintenance of stability easy	+ Measurements in data spars areas	− Calibration complex
For higher spatial coverage a lot of Stations are necessary	+ global coverage	Stability difficult, indirect − Maintenance difficult
Single point measurement	+ High spatial Integration and Homogeneity by design	− Spatial resolution
Observations since 19. Century	+ Reliable Observations since 1980 available	
Single profiles at specific points	+ High temporal Information (e.g. vertical profiles Temperature, humidity	

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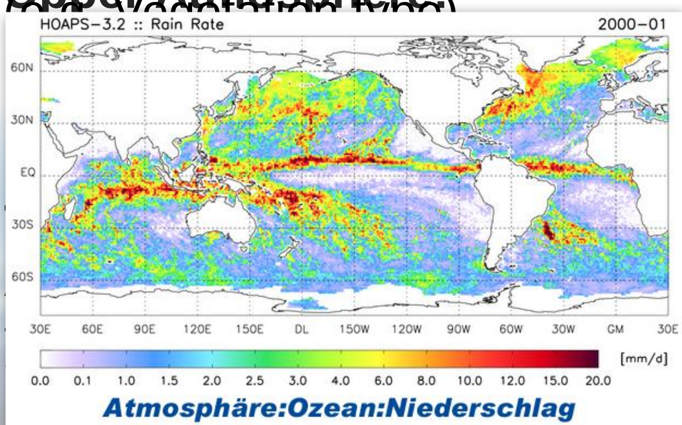
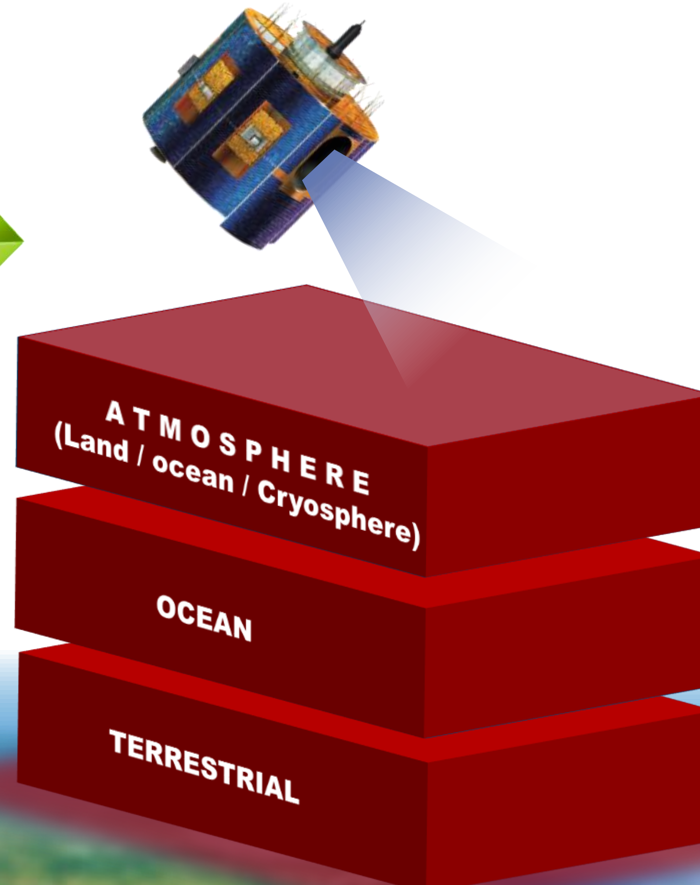
Satellites: Limitations and Chances

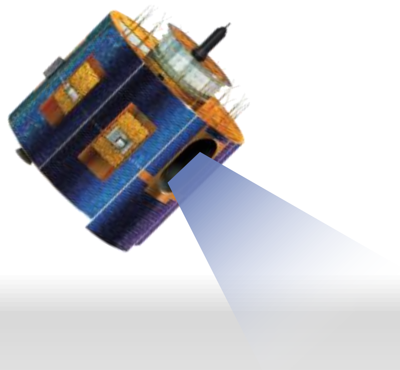
With satellite observable and generated

- **Surface:**
- Snow coverage,
- Glaciers and ice caps,
- Albedo
- Land use (e.g. Vegetation type)
- **Surface:**
- Ocean colour (important for biological activity), sea ice, sea level, salinity, sea surface temperature
- Precipitation, Radiation, Wind
- **Upper Atmosphere:**

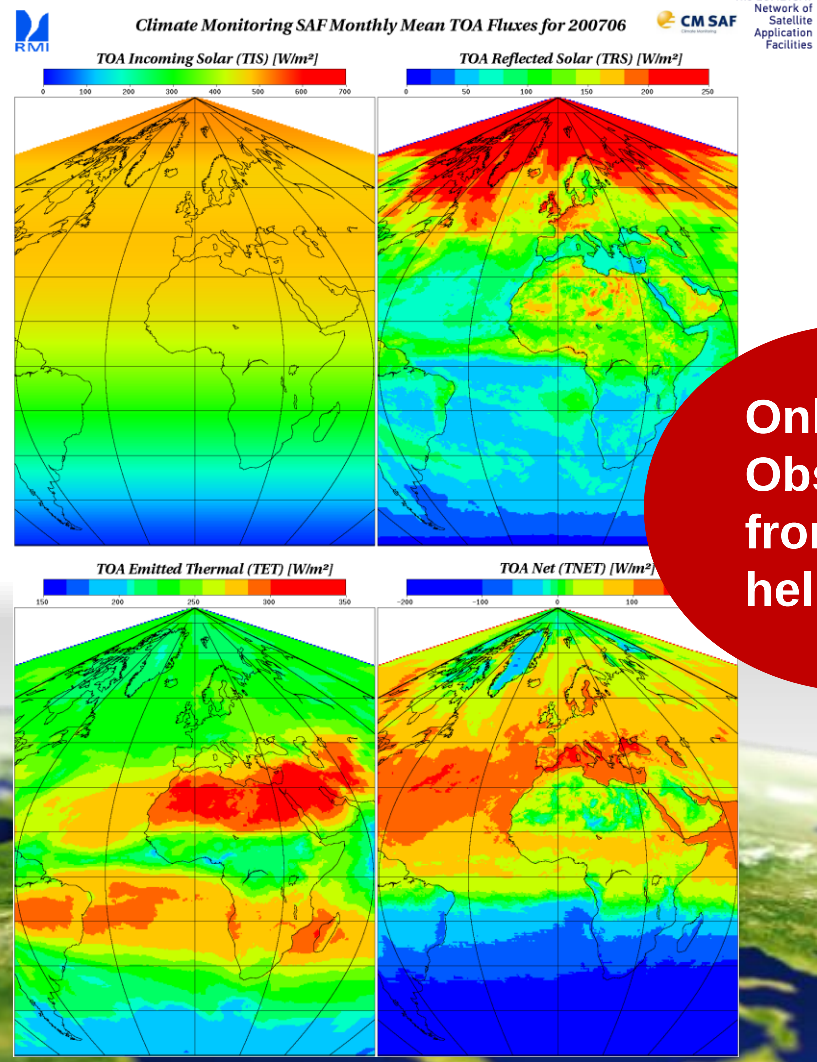




What is the Energy of the Earth System?



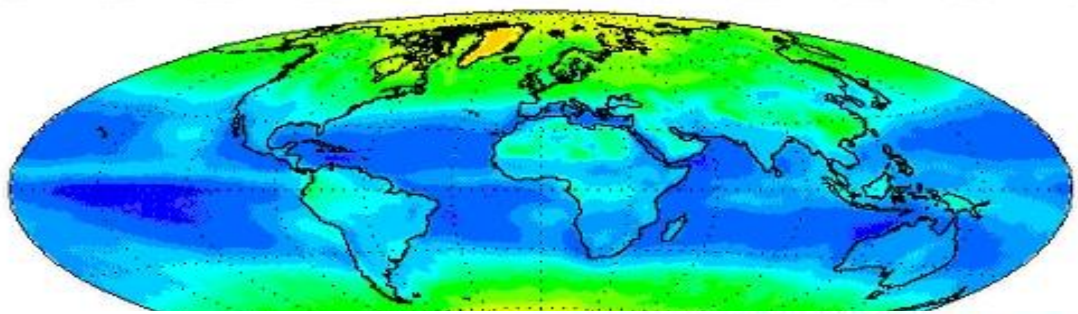
Monthly mean of radiation fluxes at ToA for June 2007



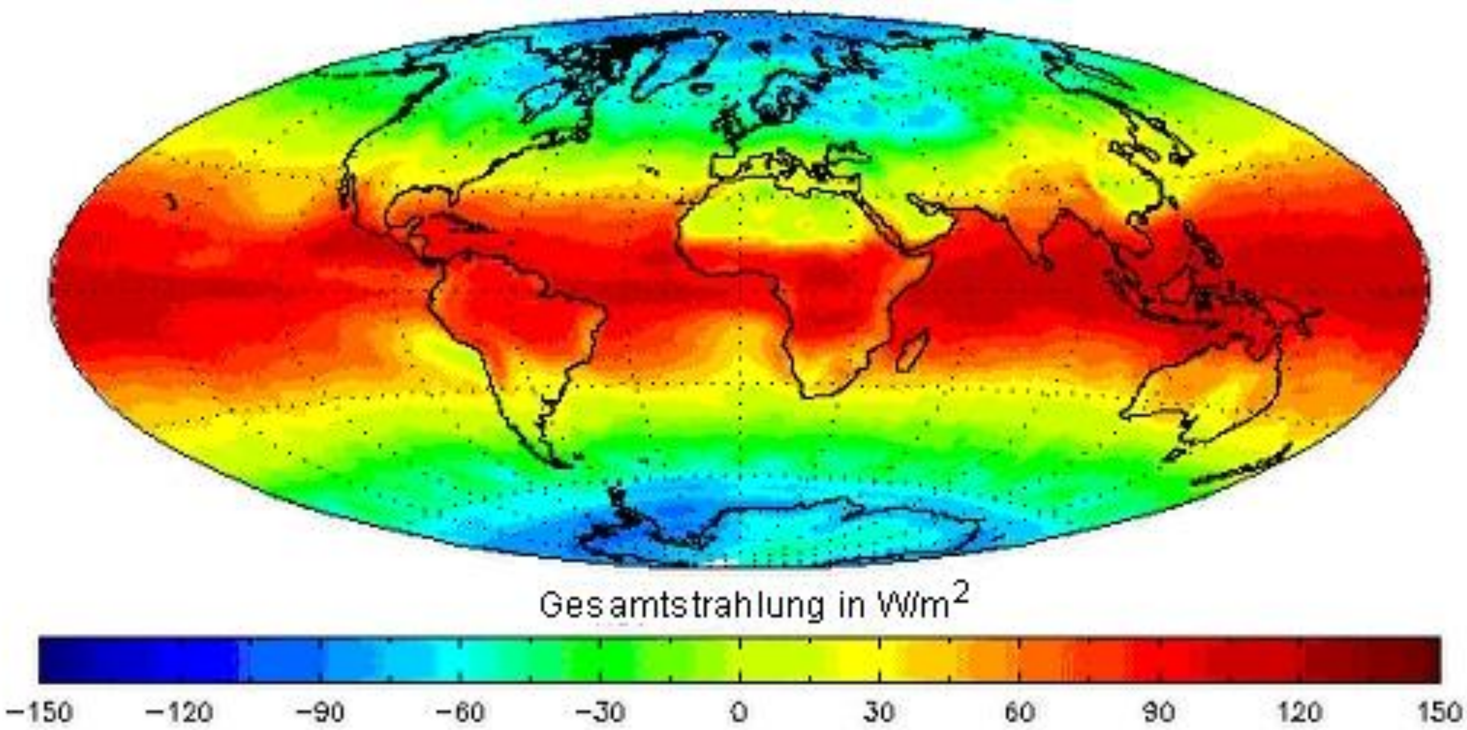
CM SAF
Climate Monitoring

Only Observations from satellite help

Radiation budget at the Top of the atmosphere



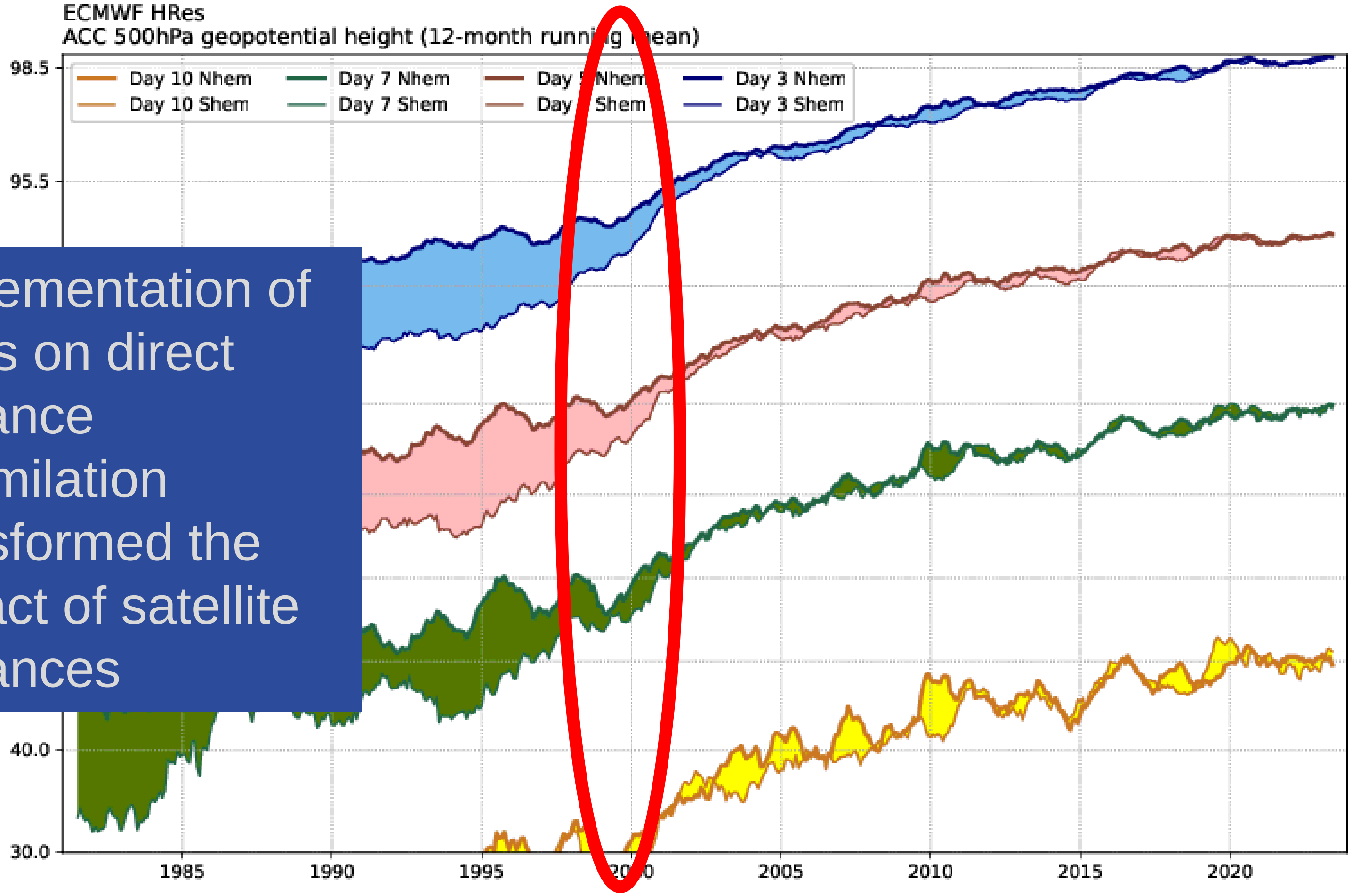
Annual means
1994/1995
ScaRaB



Usage of Satellite data

- ➔ **Directly to apply retrieval to generate ECV's**
  - ➔ **Climate status (Means, Extremes)**
  - ➔ **Trends & understanding of physical processes**
- ➔ **Assimilation in NWV models**
  - ➔ **Improved data coverage**
  - ➔ **physical constraints**
  - ➔ **Usually as brightness temperatures/radiances**

Weather forecast skill
What happened in the late 1990s?



Implementation of ideas on direct radiance assimilation transformed the impact of satellite radiances

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

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  - ➔ **Improved data coverage**
  - ➔ **physical constraints**
  - ➔ **Usually as brightness temperatures/radiances**
- ➔ **Reference data sets for climate models**
  - ➔ **Comparison with models**
  - ➔ **Improvement of models**