An introduction to atmospheric microwave radiometry

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An introduction to atmospheric MW radiometry

- Introduction
  - Why MW radiometry?
  - Very brief history
- Basic concepts
  - Natural MW radiation
  - What MW radiometry can provide?
  - Advantages and limitations
- MWR networking
  - MWRnet
  - Towards operational service
- Summary and conclusions

Introduction
Why microwave radiometry?

- Real-time continuous geophysical measurements
  - Temperature profiles
  - Humidity profiles
  - Total column water vapor and cloud liquid amounts

- Robust, all-weather, unattended instruments

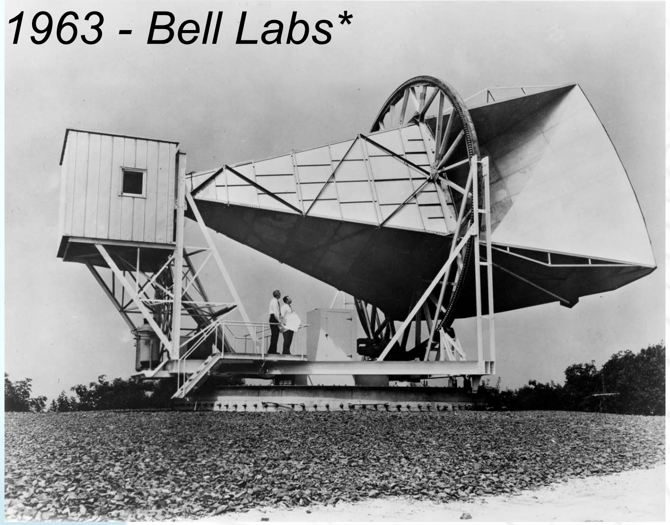
- Passive technique: natural emission from the atmosphere



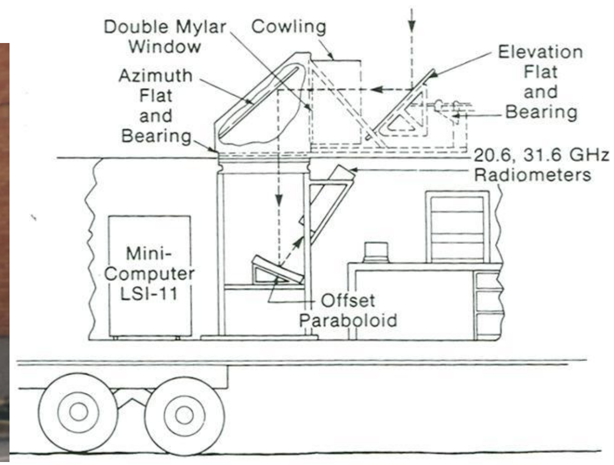
Introduction
Very Brief History

- First experiments in 1960s

1963 - Bell Labs*



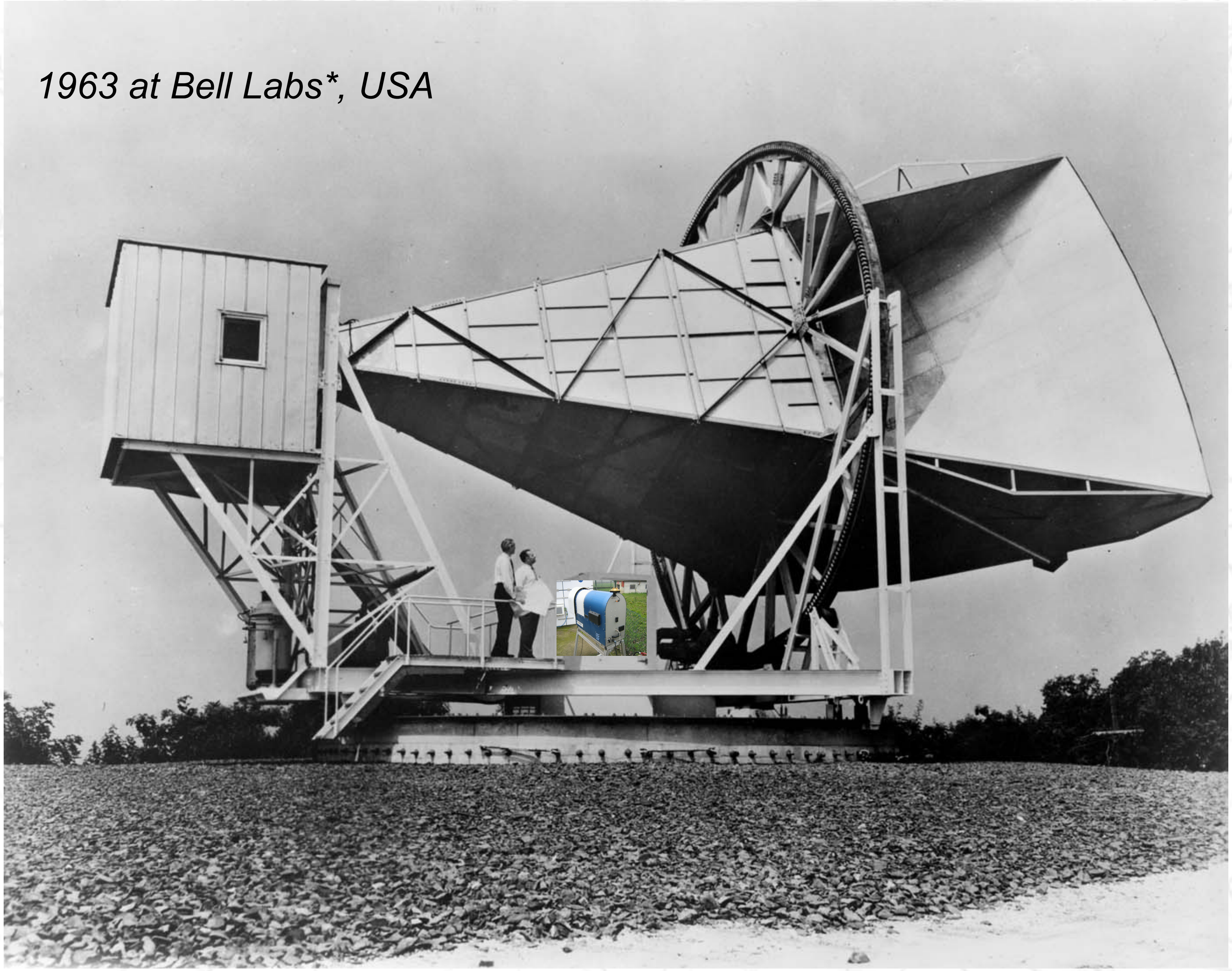
1978 - NOAA (2-chan)



- Commercial units in late 1980s

*Penzias and Wilson, Nobel Prize in Physics 1978 for discovering the cosmic microwave background radiation

Introduction
Very Brief History



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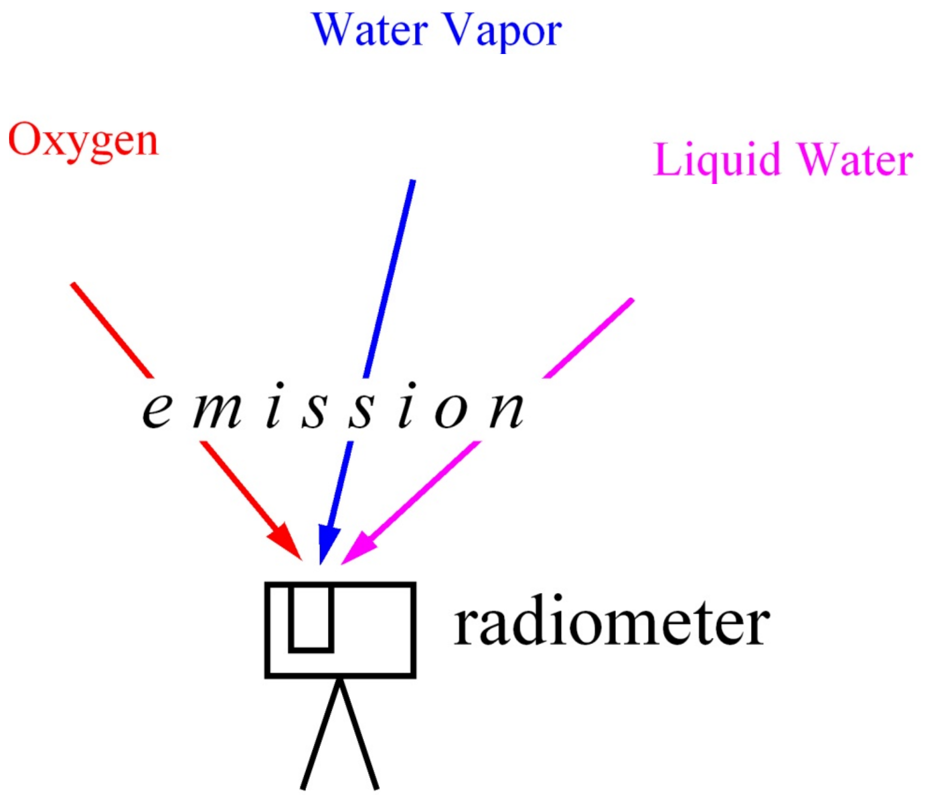
Basic concepts
Natural MW radiation

- MW radiometers (MWR) perform measurement of thermal radiation
  - The observed thermal radiation comes primarily from:
    - Atmospheric gases (oxygen and water vapor)
    - Hydrometeors (mainly liquid water)

- The measured quantity is Radiance (*R*)
  - *R* is converted to *Tb* (brightness temperature)
  - Intuitive units [K]

- Typical spectral range 20-60 GHz
  - $\lambda \sim 1.5$ cm to 5 mm

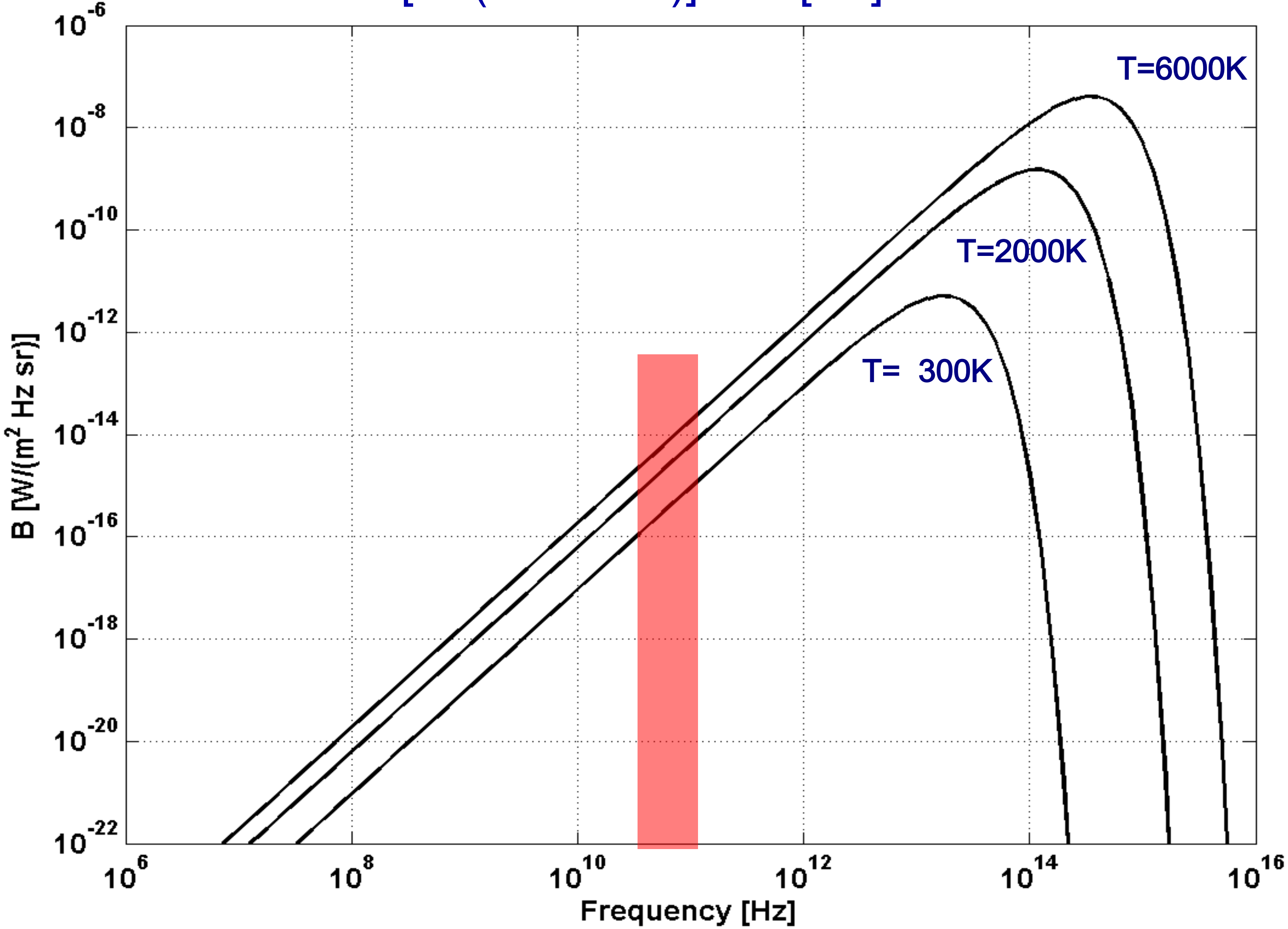


Basic concepts
Natural MW radiation

Thermal radiation

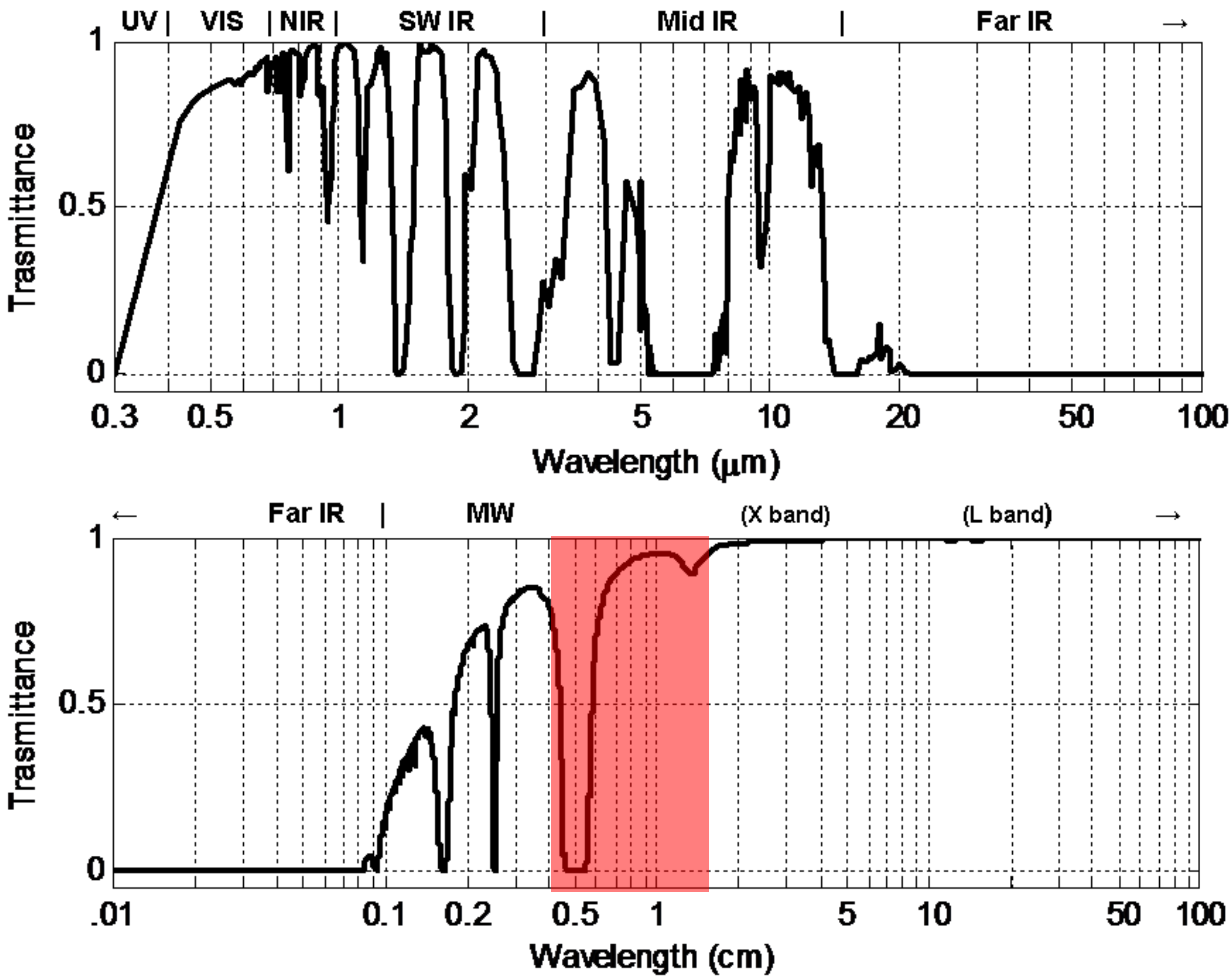
Black Body Planck's curves

B[W/(m^2 Hz sr)] vs. f[Hz]



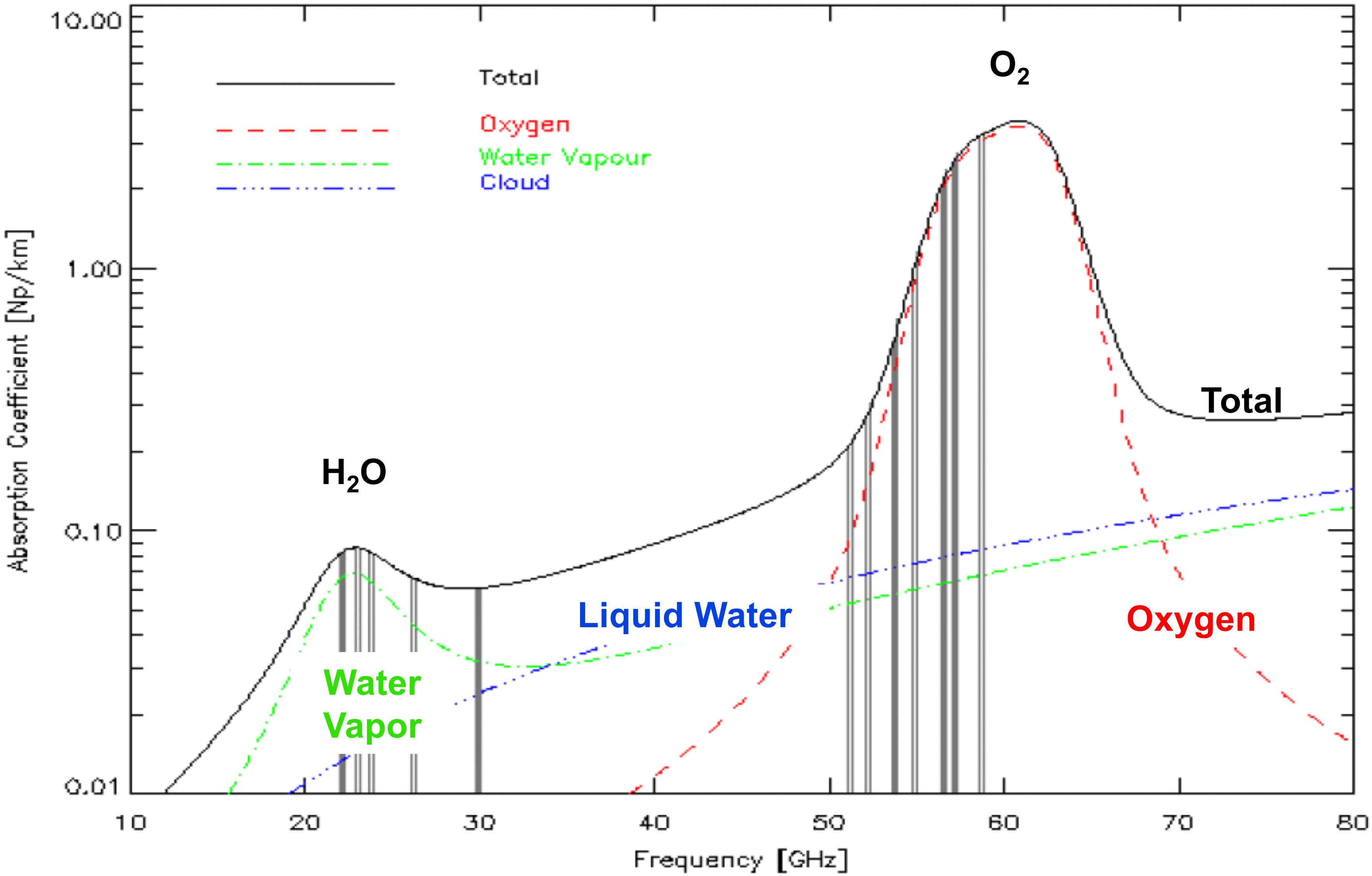
Basic concepts
Natural MW radiation

Atmospheric Transmittance (absorption only)



Basic concepts
Natural MW radiation

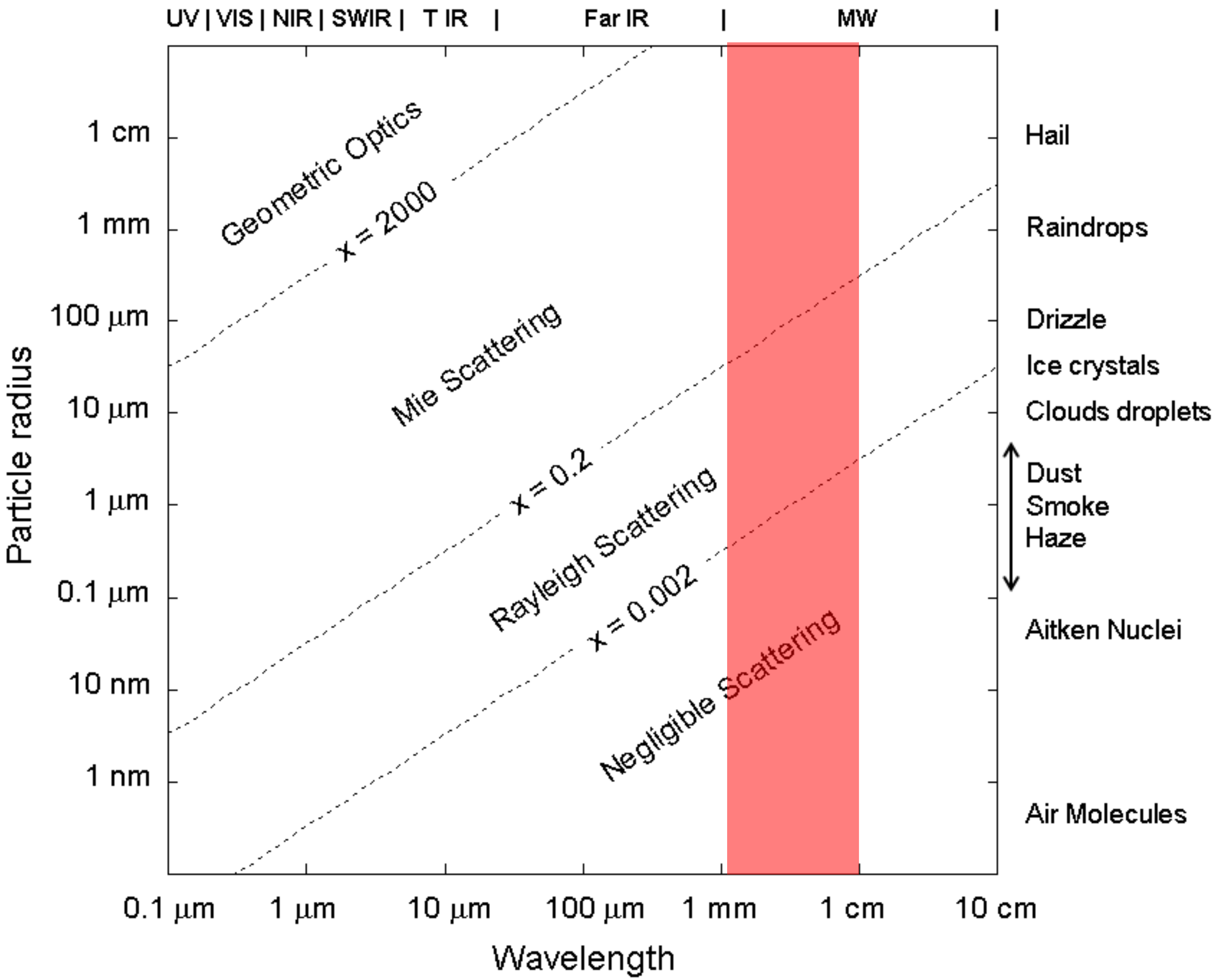
- The Atmosphere is NOT a black body:
  - Atmospheric absorption coefficient in the MW



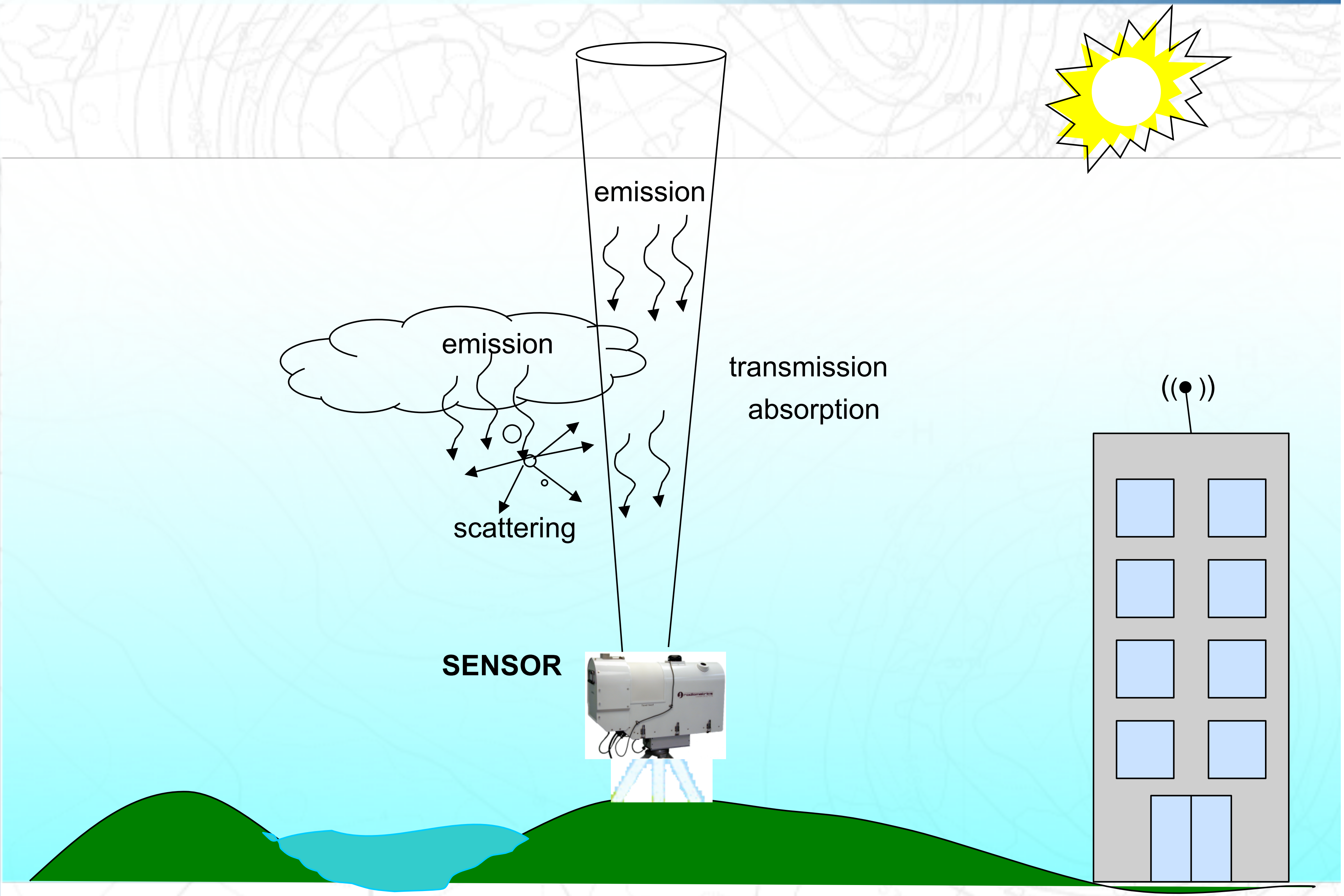
Basic concepts
Natural MW radiation

Dimension parameter and scattering regimes

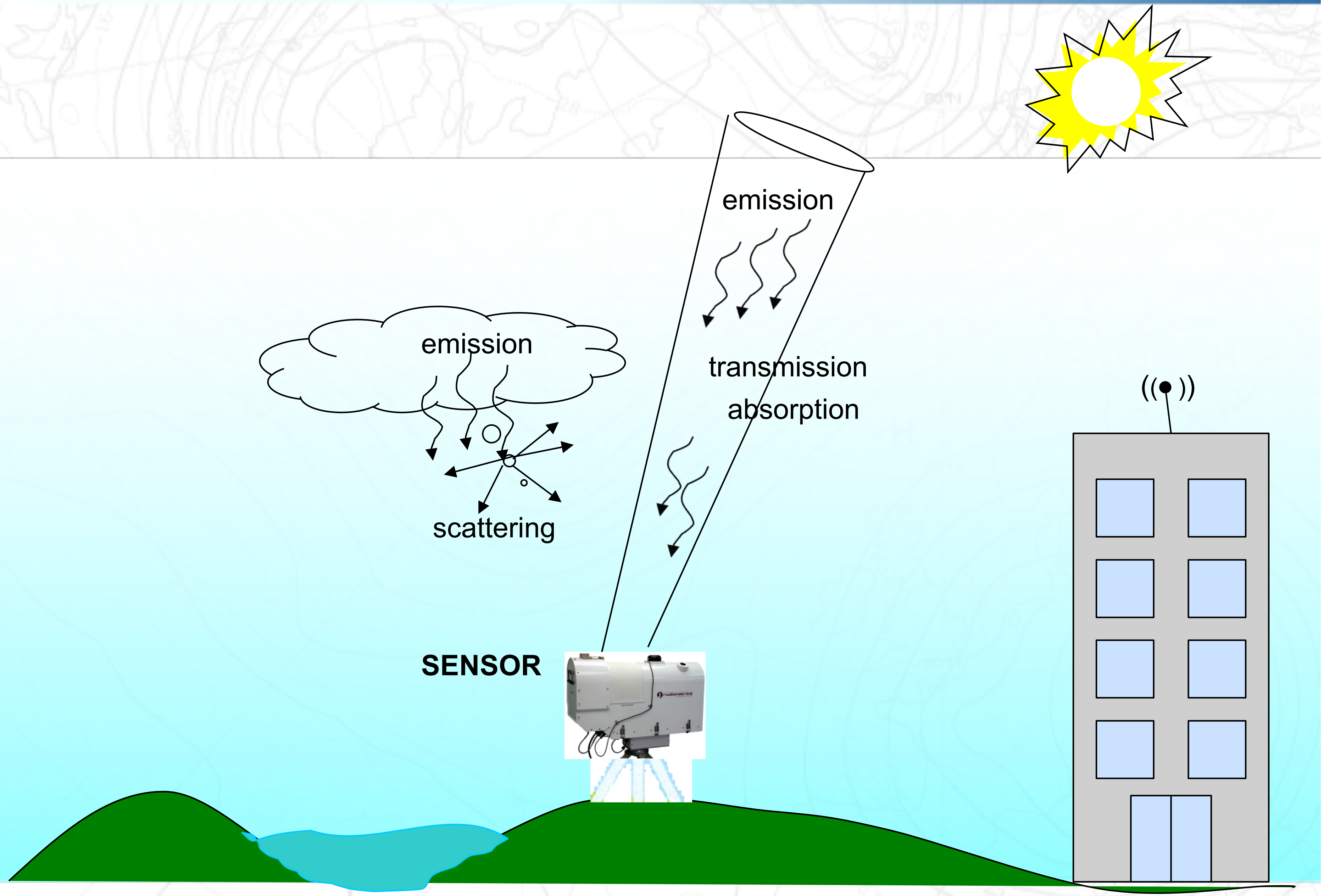
$$x=2\pi r/\lambda$$



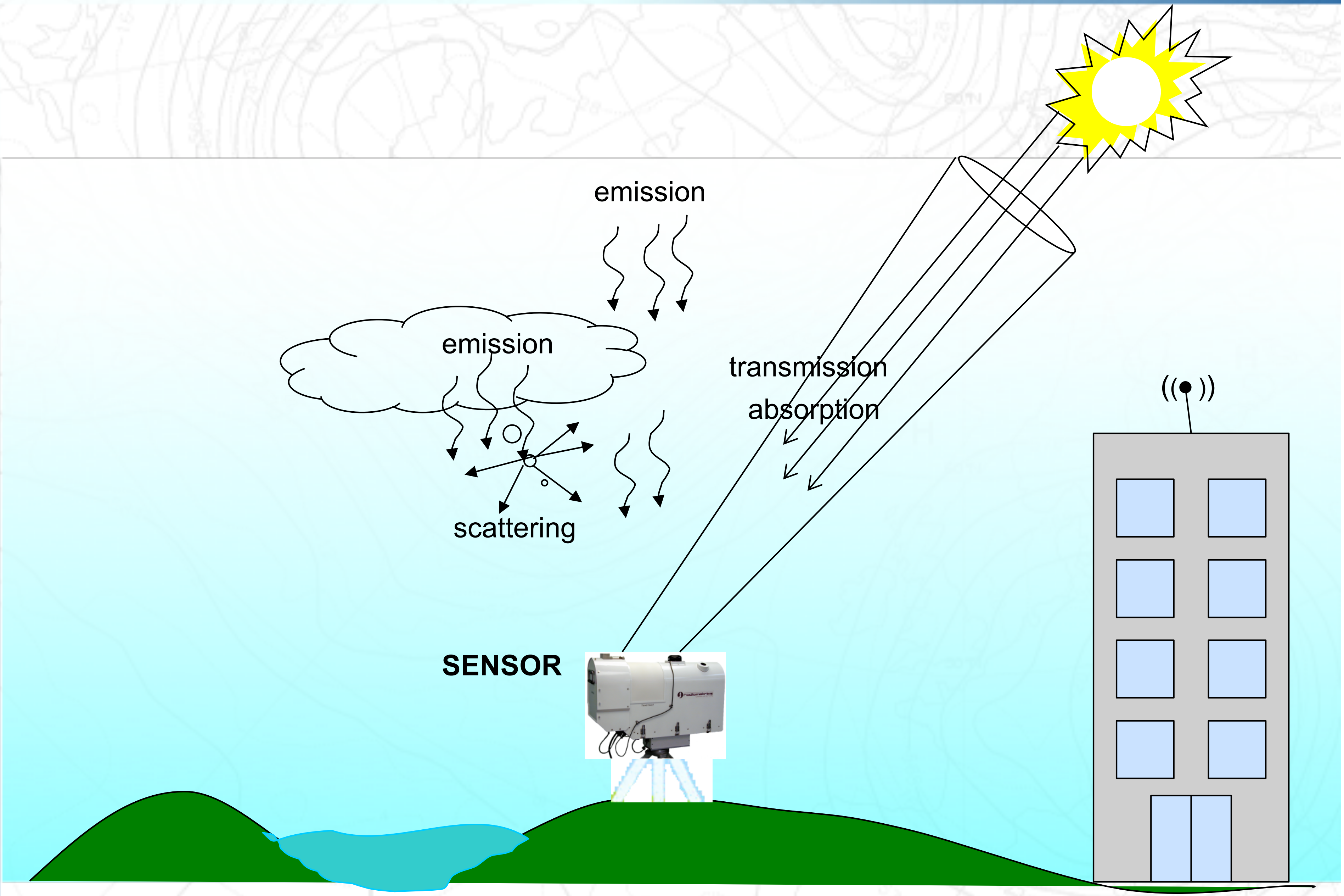
Basic concepts
Natural MW radiation



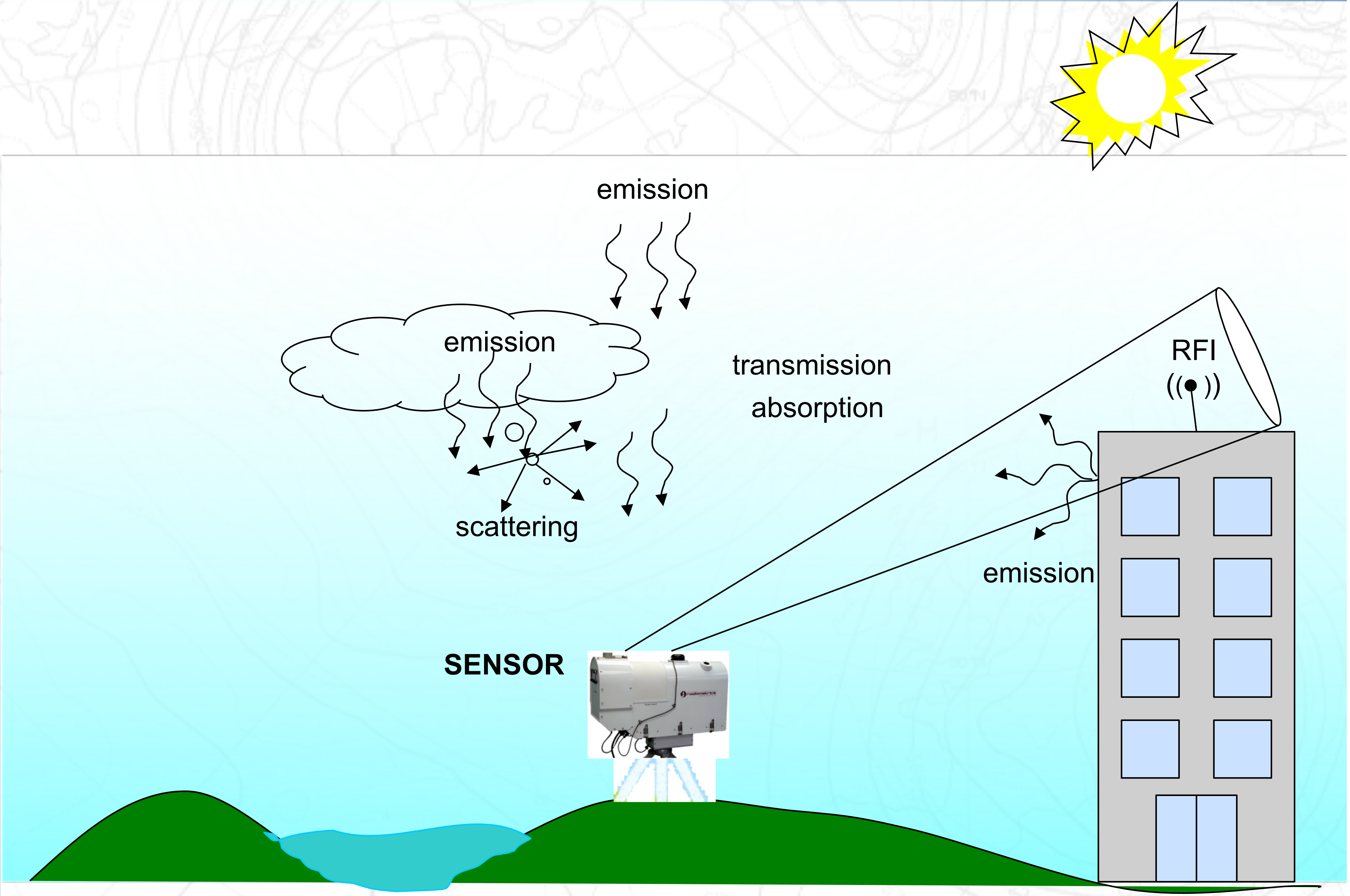
Basic concepts
Natural MW radiation



Basic concepts
Natural MW radiation



Basic concepts
Natural MW radiation

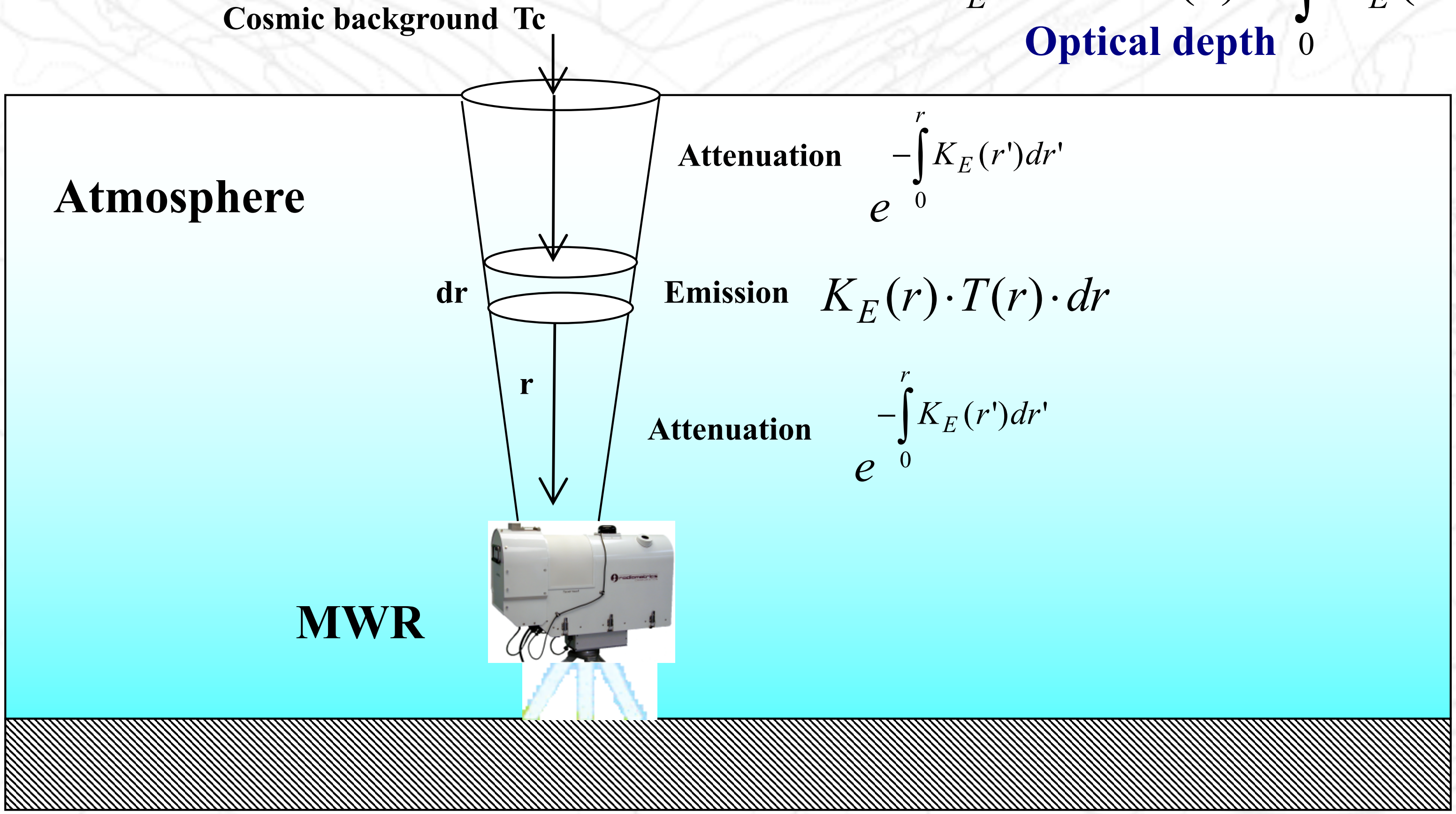


Basic concepts
Atmospheric MW radiative transfer

$$\underbrace{T_b}_{\text{Measured quantity}} = \underbrace{T_c \cdot e^{-\tau(0,\infty)}}_{\substack{\text{Cosmic background term} \\ \text{(attenuated along the path)}}} + \underbrace{\int_0^\infty K_E(r) \cdot T(r) \cdot e^{-\int_0^r K_E(r)dr'} \cdot dr}_{\substack{\text{Atmospheric term} \\ \text{(emitted \& attenuated along the path)}}}$$

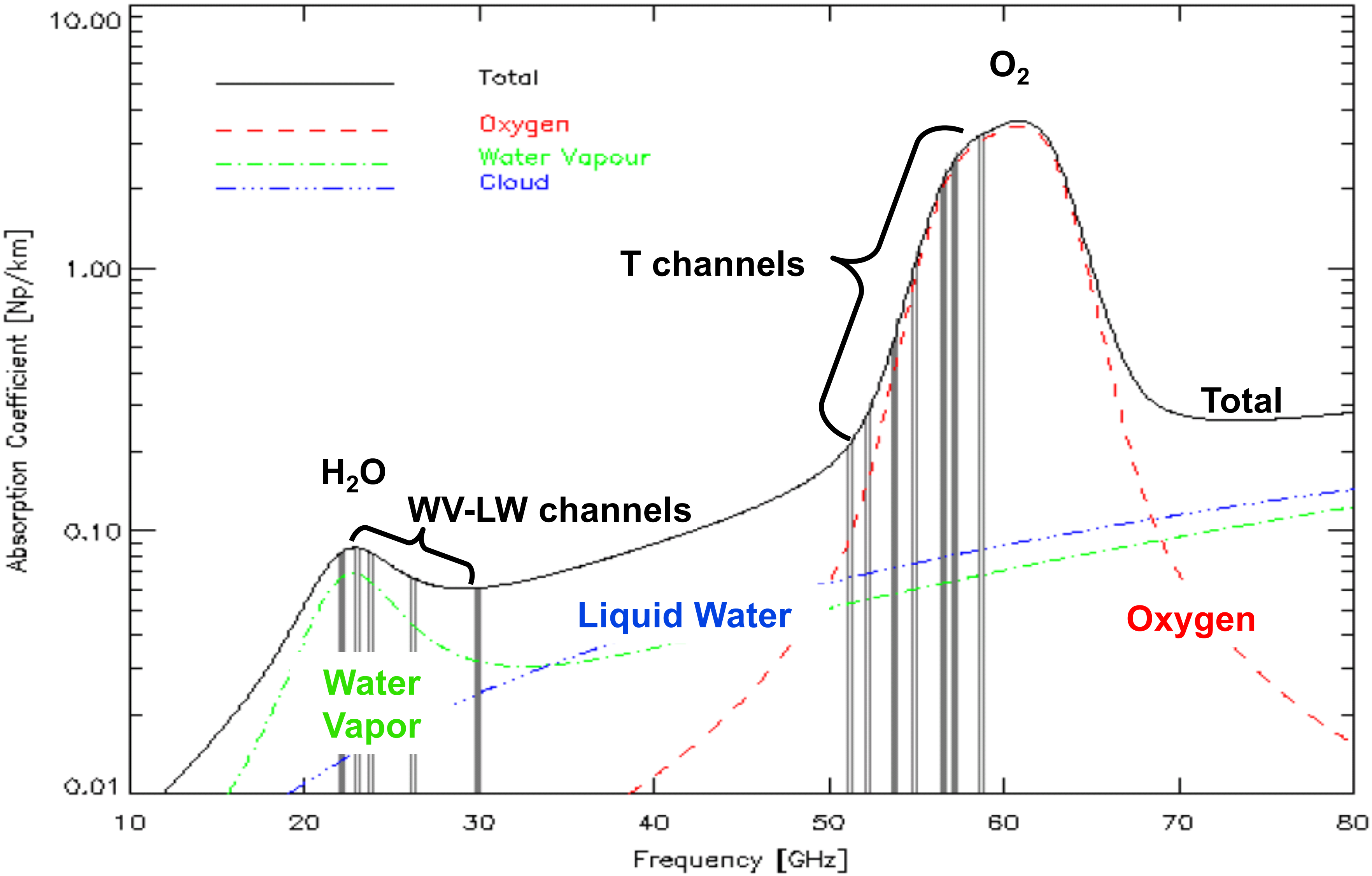
$$d\tau = K_E \cdot dr \Rightarrow \tau(r) = \int_0^r K_E(r')dr'$$

Optical depth



Basic concepts
What can MW radiometers provide?

- The Atmosphere is NOT a black body:
  - Atmospheric absorption coefficient in the MW

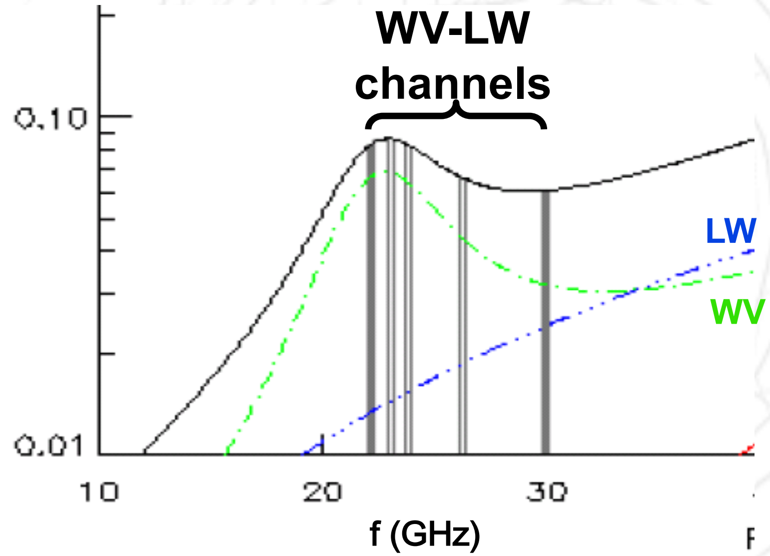


Basic concepts
What can MW radiometers provide?

- **WV radiometers**
  - 20-35 GHz band for WV and liquid water sensing

- Dual-channel
  - integrated water vapor (IWV) and liquid water (ILW) only
    - IWV ≡ PWV, TCWV; ILW ≡ LWP, TCLW

- Multiple channels
  - IWV, ILW, and WV profiles

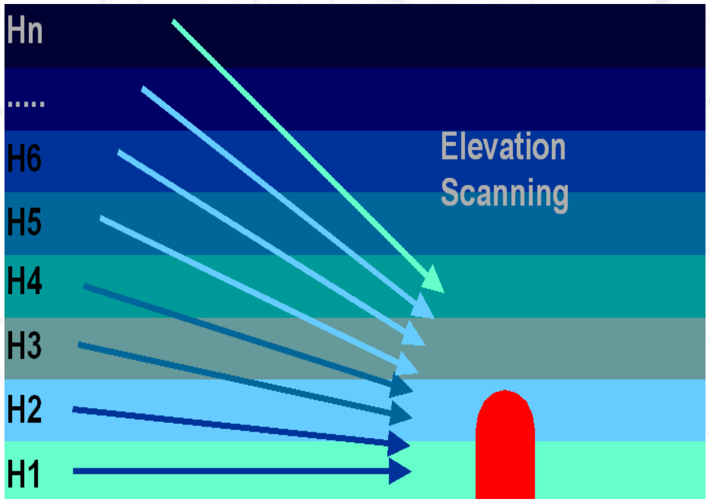


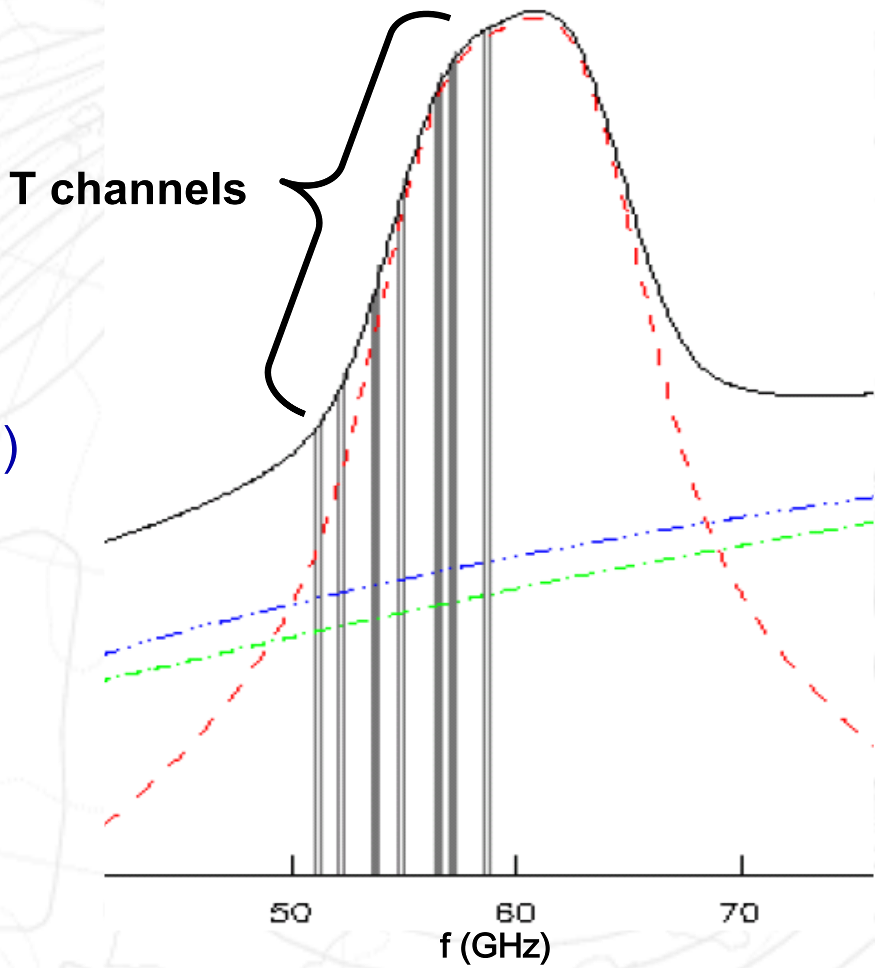
Basic concepts
What can MW radiometers provide?

- **T profiling radiometers**
  - 50-60 GHz band for T sensing

- One channel
  - Multiangle
  - Usually limited to lower ~1km
  - BL characterization

- Multiple channels
  - Single- or multi-angle
  - Extended range (<10 km)
  - BL characterization (if multi-angle)

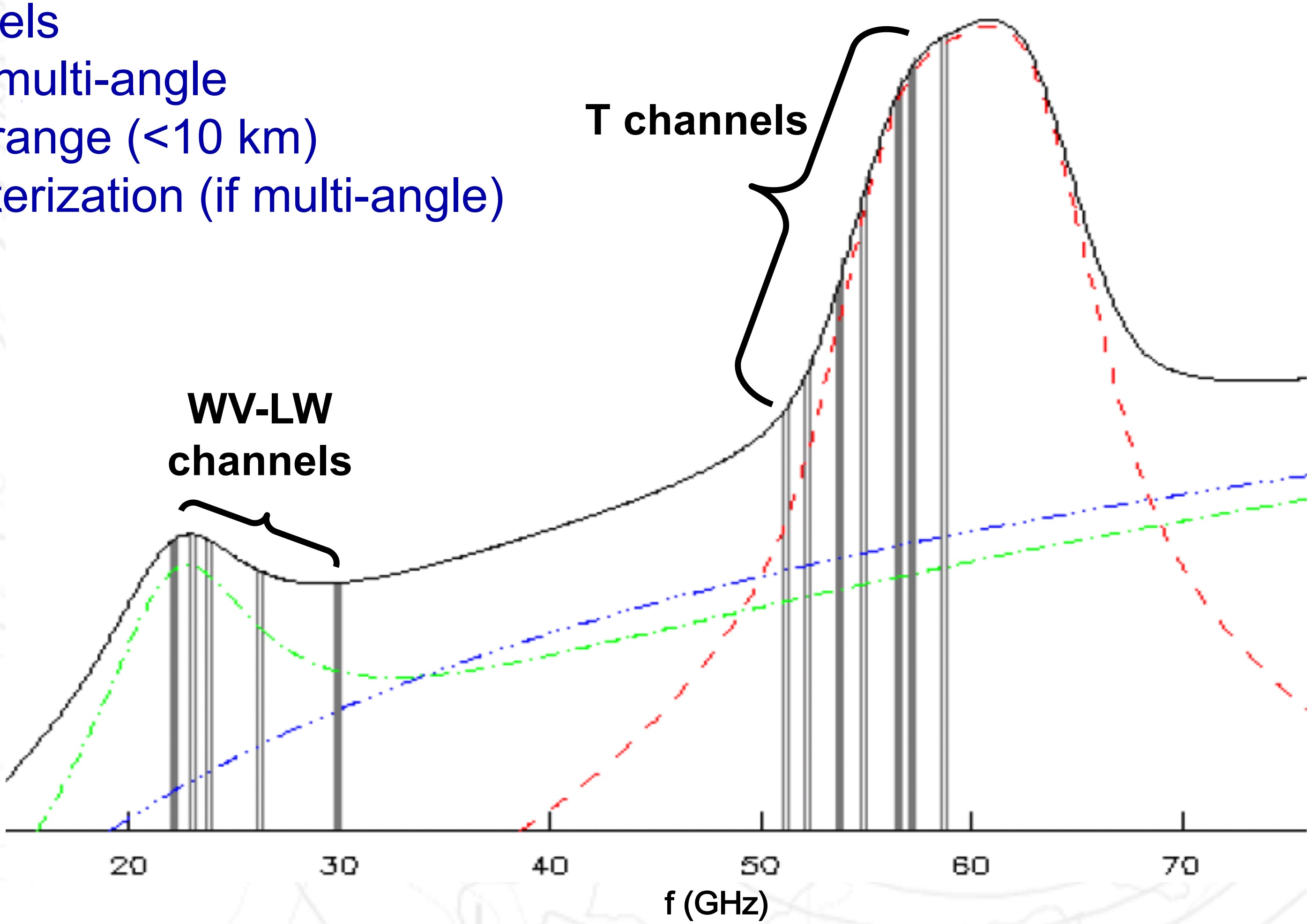




Basic concepts
What can MW radiometers provide?

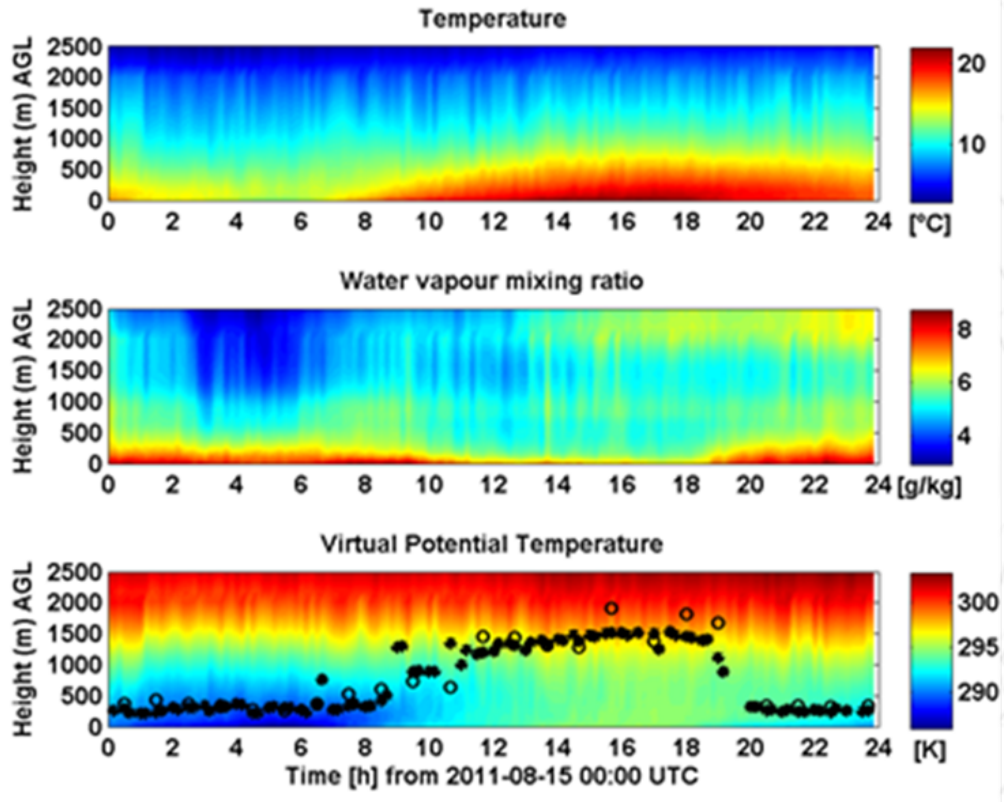
- **WV and T profiling radiometers**
  - 20-60 GHz band for T, WV, and liquid water sensing

- Multiple channels
  - Single- or multi-angle
  - Extended range (<10 km)
  - BL characterization (if multi-angle)



Basic concepts
What can MW radiometers provide?

- **Derived products from T and WV profiles**
  - Virtual potential temperaure
  - Mixing layer height (Parcel Method)
  - Forecast indeces (e.g. K-index)



Basic concepts
Advantages and limitations

- Advantages of MWR:
  - Good accuracy for Tb
  - Azimuth and elevation scanning
  - Suitable for all weather conditions
    - Clear, cloudy, precipitation
  - Continuous unattended operations at ~1min temporal resol.
  - Ideal measurements for:
    - Data assimilation into NWP
    - Synergy with other profiling instruments (cloud radar, lidar, wind profiler)

Basic concepts
Advantages and limitations

- Limitations of MWR:
  - Proper calibration needs monitoring and maintenance
  - Low-to-moderate vertical resolution
    - Intrinsic in passive observations
    - Specially true for WV and LW profiles
    - Higher resolution for T profiles in the BL
  - Performances degrade under precipitation
    - Retrieved products may be not reliable
    - Mitigation solutions
      - hydrophobic coating, blowers, side-views
    - Perfomances depend on precipitation rate

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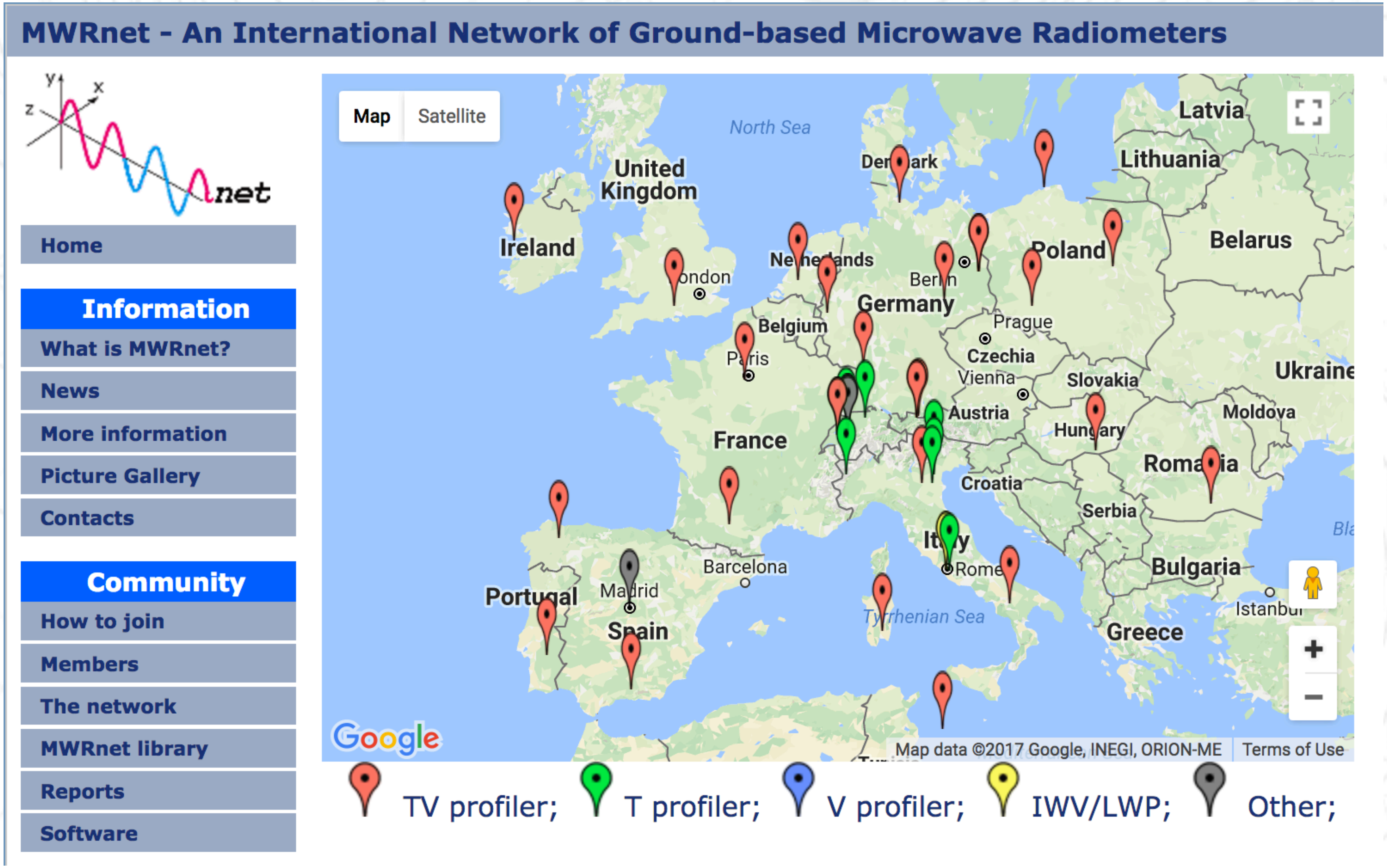
MWR networking
MWRnet

- Bottom-up network grouping about 30 MWR in Europe
  http://cetemps.aquila.infn.it/mwrnet



MWR networking
MWRnet

- **Aim**: Addressing the lack of coordination and increase the utilization of quality controlled MWR data

- **Goals**:

  - Establish the “**best practices**” for MWR observations and retrievals

  - Facilitate the **access** of well documented and quality controlled MWR observations and retrievals

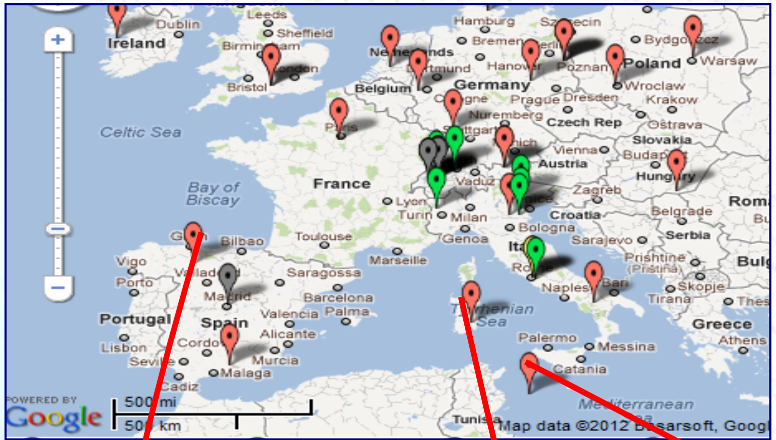
  - Encourage the **use** of MWR data for NWP and climate applications

  - Providing a **data hub** for MWR data and retrievals

MWR networking
Towards operational service

Data assimilation experiment: 13 MWR, 1-month dataset (Oct –Nov 2011)

MWRnet



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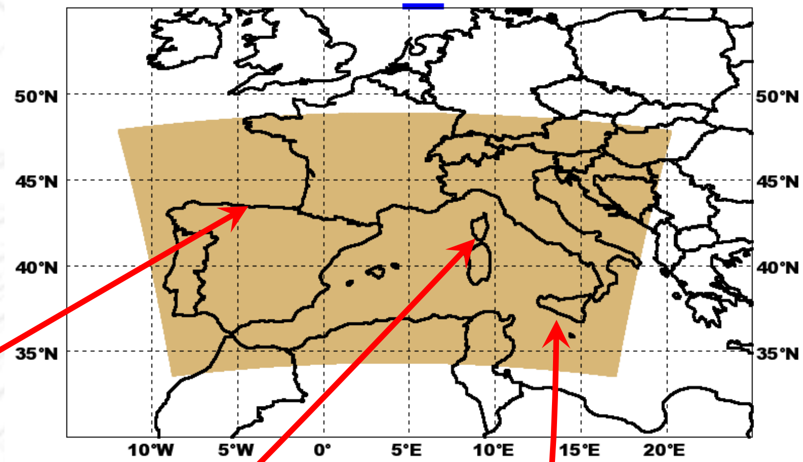

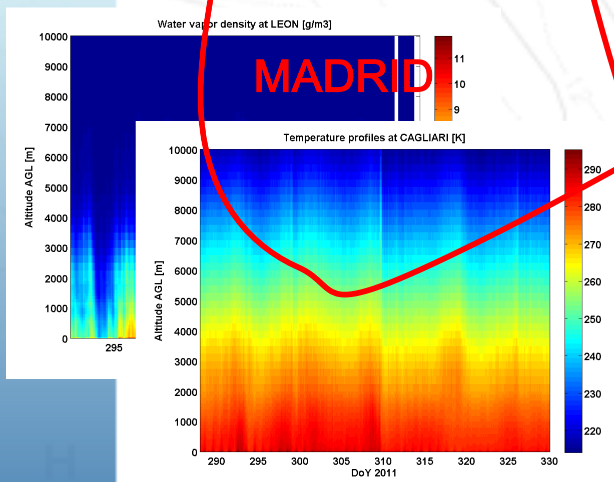

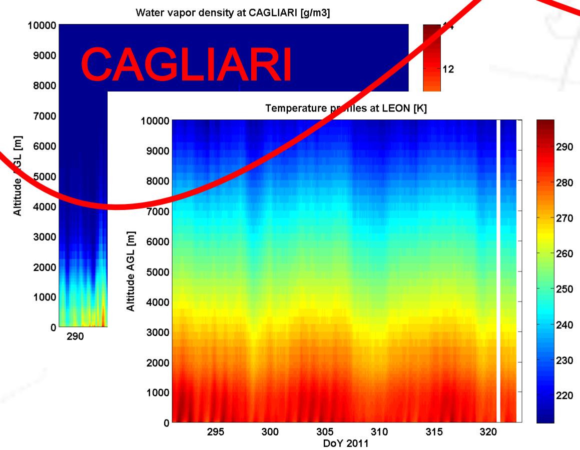

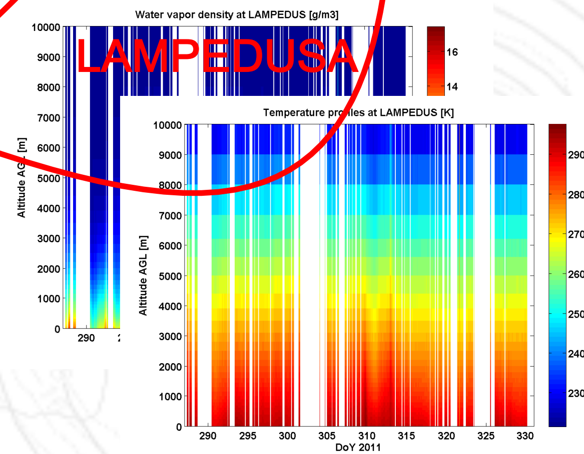

MWR networking
Towards operational service

- EUMETNET (Network of 31 EU National Meteorological Services)
- EUMETNET Profiling Programme (E-PROFILE) for coordinating vertical profiles of wind, aerosols and clouds
  - radar wind profilers
  - Doppler wind lidars
  - automated Lidar/Ceilometer

1st phase: 2013 - 2018

- Proposal to EUMETNET STAC and PFAC*:
  - Addition of MWR to E-PROFILE for profiling BL T and H
  - Subject to approval for E-PROFILE 2nd phase (2019-2023)

*Scientific Technical Advisory Committee and Policy and Finance Advisory Committee

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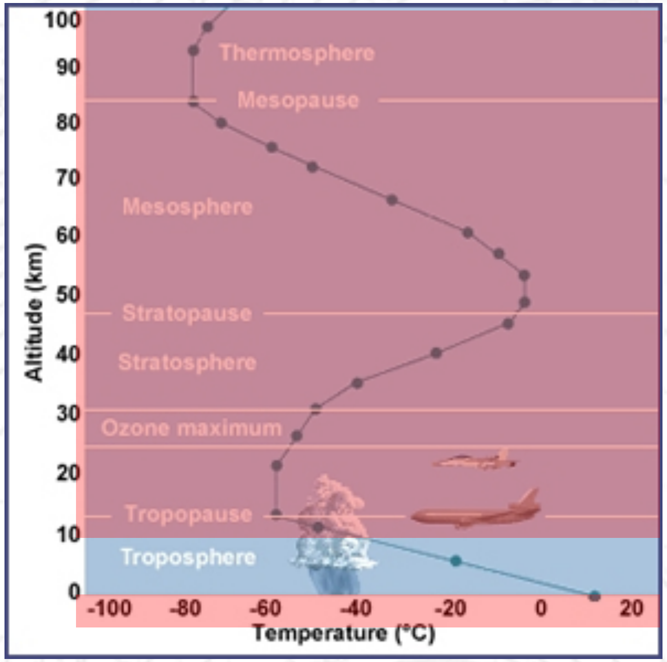
Summary and Conclusions

- MW radiometry is a mature technique
  - Robust, (nearly) all-weather, unattended instruments
    - Retrievals shall be quality-flagged (precipitation, RFI,…)
  - Low (moderate?) maintenance
    - Calibration monitoring, radome integrity
  - Low-to-moderate vertical resolution
  - 24/7 with ~1 min temporal resolution
  - Suitable for network deployment
- Can complement radiosonde with high temporal resolution
- Most of the information is in the atmospheric boundary layer

How can MWR be beneficial for operational meteorology and NWP?

Summary and Conclusions

- The planetary boundary layer (PBL) is the single most important under-sampled part of the atmosphere*



- Observation gap in the PBL, particularly important in nowcasting and severe weather initiation

- 2nd top-priority atmospheric variables not currently adequately measured**:
  - temperature and humidity profiles (in cloudy areas)

*U.S. National Research Council Reports
**WMO guidance on observations for NWP

Summary and Conclusions

MWR are **complementary to**

Radiosondes
+ Better temporal resolution (diurnal cycle at ~1min)
+ Information on cloud liquid water (total column)
– Moderate/low vertical resolution

Satellites
+ Better temporal resolution (diurnal cycle at ~1min)
+ Higher accuracy in the PBL
– Low spatial coverage (representative column)

Radiosonde	Satellite	MWR
vertical resolution	*spatial coverage*	*temporal resolution*

Yet MWR observations are not assimilated by any NWP system

References

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