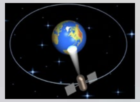
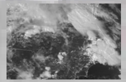
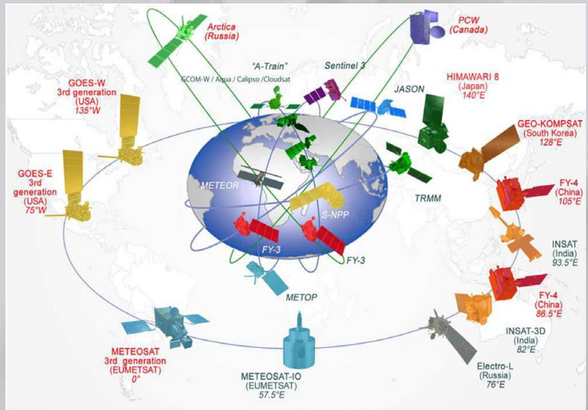
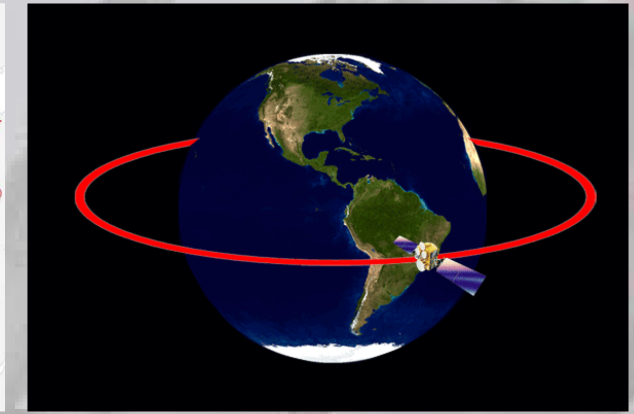
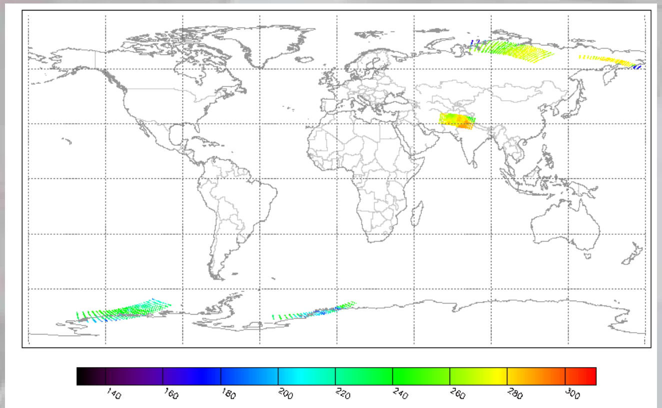
Remote sensing - Satellite



Orbit	Geostationary	Polar
Orbit altitude	36000 km	ca. 900 km
Orbit period	24 hours	ca. 90 minutes
USA NOAA	GOES	NOAA
EUMETSAT	METEOSAT, GOES, GMS	NOAA, Meteor, EPS Metop
Time between 2 images	1min Rapid Scan 	12 Std Equator 90 min Pole area







Remote sensing – IR Brightness Temperature TB

Passive Remote Sensing: TB Brightness Temperature

The Brightness Temperature TB is the temperature of a blackbody, that would emit the same amount of radiation as the targeted one in a specified spectral band.

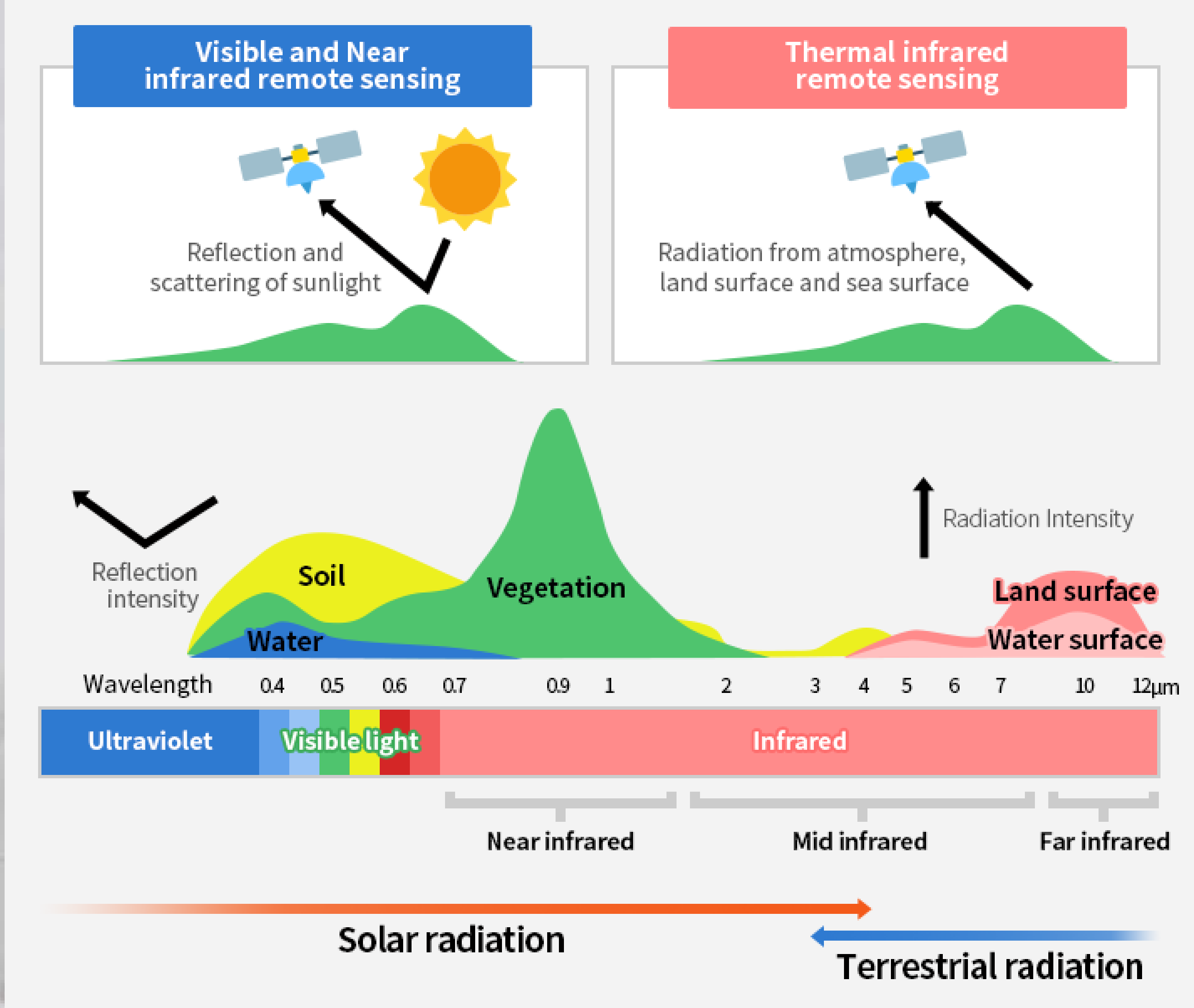
- TB is the basis of passive (receiving signal only, not transmitting like Radar) Infrared IR remote sensing.

- TB depends on properties of the target, e.g. Soil Temperature, Moisture, organic matter (plants, leaf area index), sea roughness (waves, foam)

REMOTE SENSING – SPECTRAL PROPERTIES OF RADIATION

Remote Sensing:
Criteria for the frequency selection

- For Satellite Remote Sensing, reflected reflected solar radiation (VISIBLE) is used as well as emitted radiation (INFRARED)
-



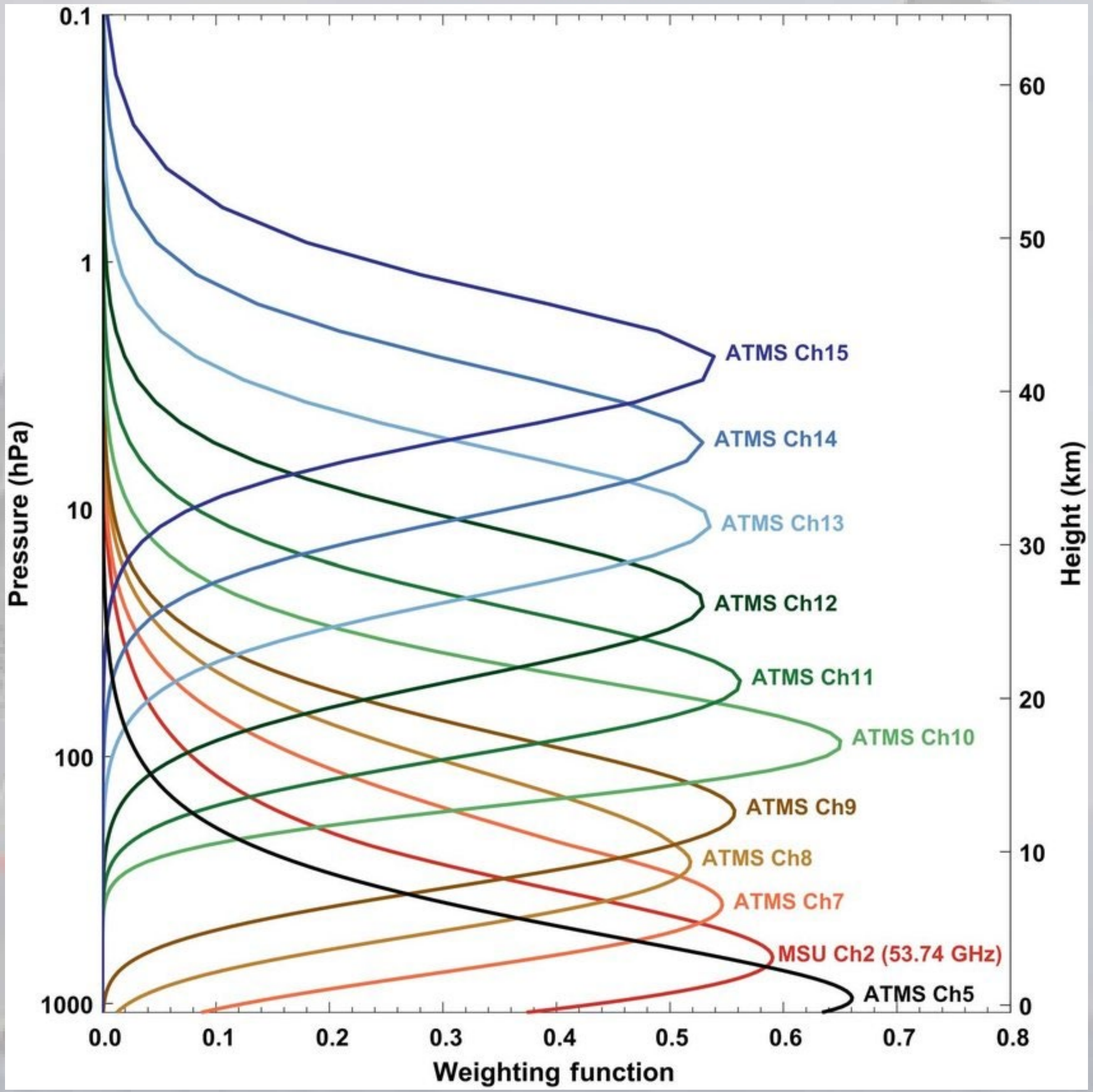
REMOTE SENSING – MULTI-SPECTRAL, WEIGHTING FUNCTION

Passive Remote Sensing: Weighting Function, Multi-spectral sensors

- Vertical Profiles (typical: Temperature) are retrieved using multispectral sensors.

- The maximum contribution of a sensor signal depends on height in the atmosphere and is specific on frequency. It is described by the Weighting function.

- By appropriate selection of neighbouring frequencies (multi-spectral) it is possible to derive vertical profile information from satellite.



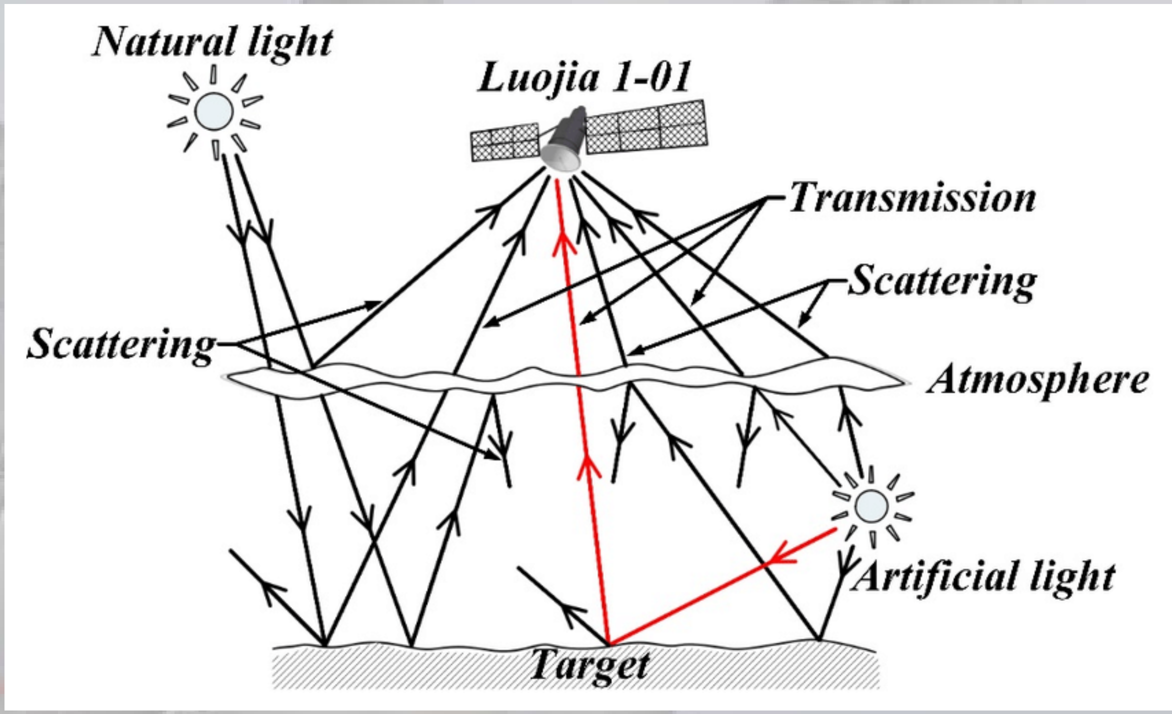
Remote sensing – Radiative Transfer in the Atmosphere

Radiative Transfer Equation

- Definition of Remote sensing:
  From the state of an electro-magnetic field at one site (sensor) it is concluded to matter that interacts with this electro-magnetic field at another place (target).

- The signal received by the satellite passes through and interacts with the atmosphere. This interaction is described by the Radiative Transfer Equation (RTE), the signal has to be corrected for these effects, mainly scattering, also absorption

- By this effect of the atmosphere, passive remote sensing of the earth's surface or lower tropospheric phenomena is sometimes inhibited (mostly by clouds)



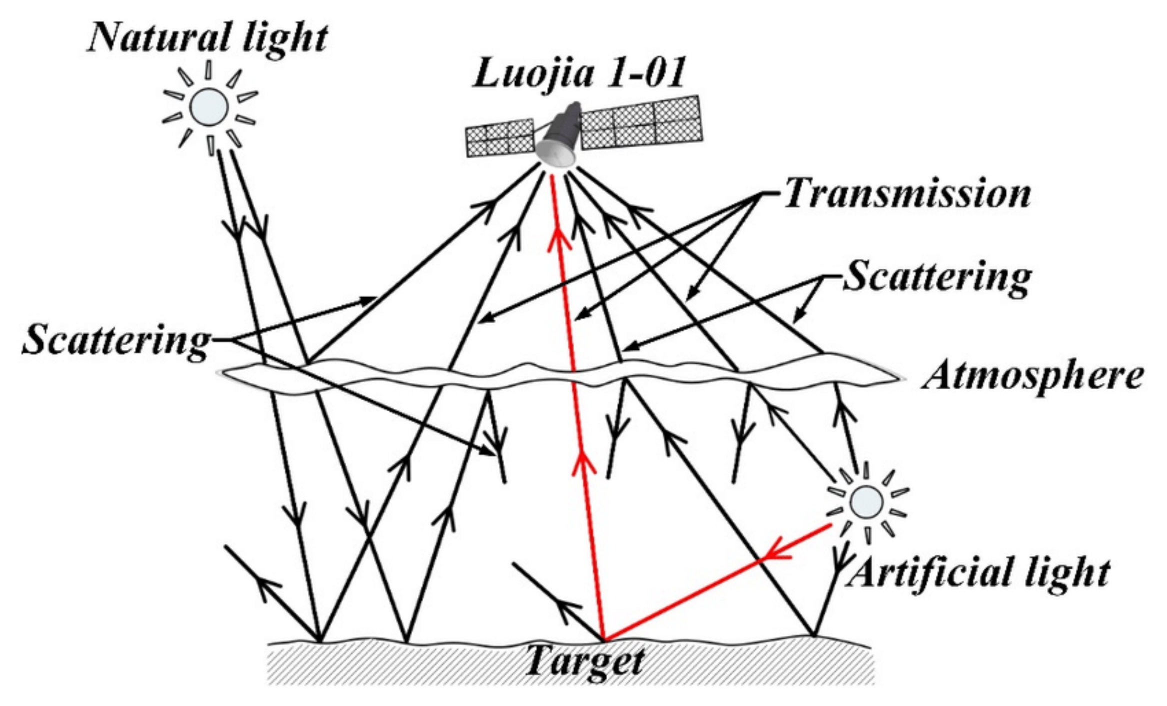
Remote sensing – Inversion Calculations

Inversion calculations

- The received signal undergoes correction for the effects mentioned above and is then subject to mathematical inversion calculations to obtain the physical information of interest.

- These ‘Inversion calculations‘ have made tremendous progress in the past and allow to receive data from the satellite with a coverage and frequency that cannot be obtained by any other observing systems.

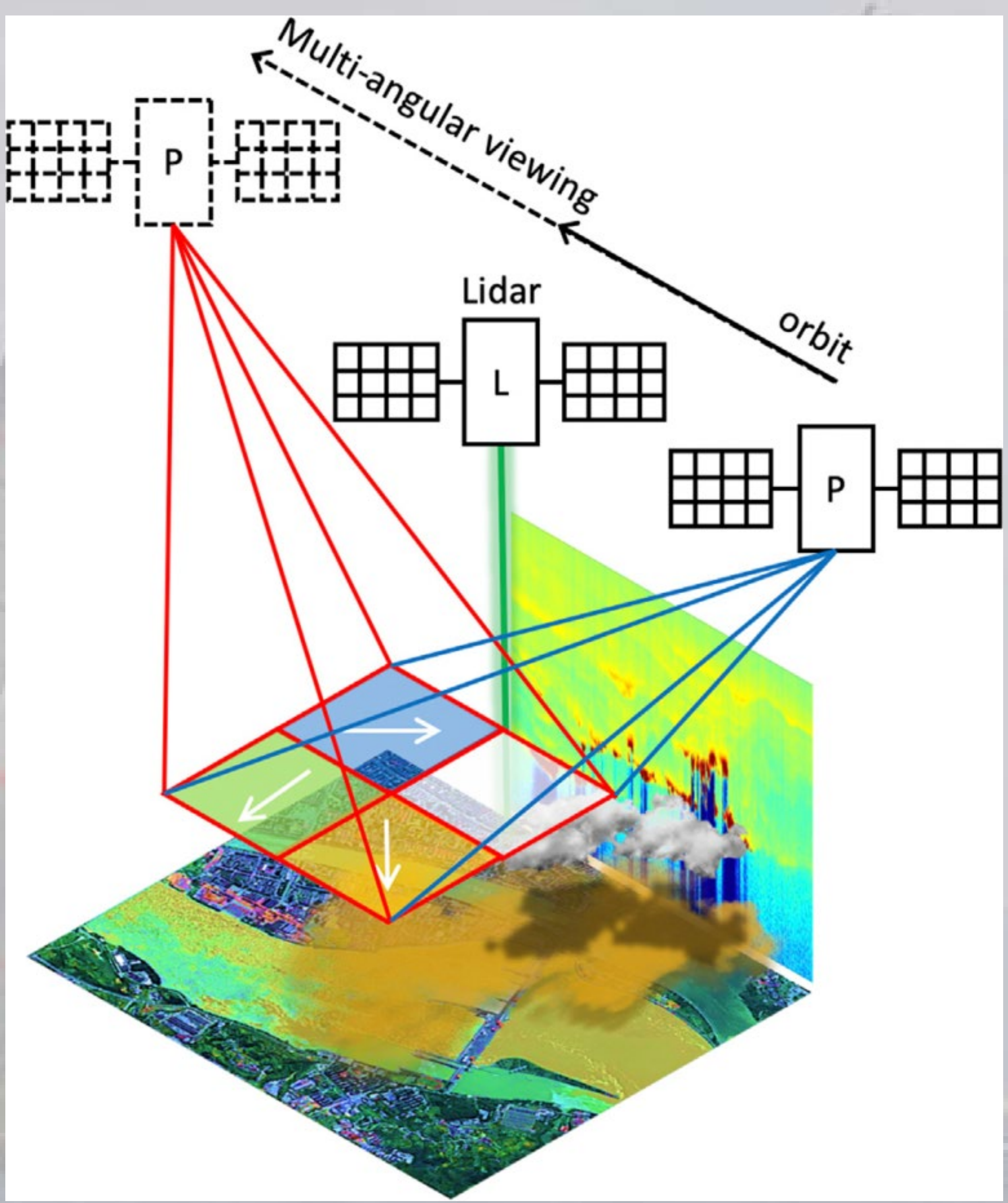
- Important for effective inversion calculations are ground-truth data, i.e. intercomparison with conven-tional data to which the remote sensing data are adjusted.



Remote sensing – Spectral Properties of Radiation

- Using appropriate satellites, sensors and orbits using multi-angular orbits allows 3D information of the earth's surface.

- These technologies can be used in Geodesy and Surveying



REMOTE SENSING – USE OF SATELLITES IN WEATHER FORECASTING

Use of satellites in meteorology

- **Multiple satellites for better coverage / higher image frequency**

- **Cloud structure image processing for windspeed detection (AMV)***

- **Multiple frequencies for special applications**
  - VIS Visible: Presentation similar to the human eye
  - IR Infrared: black-to-white scale corresponds to warm-to-cold
  - Multispectral channels to detect profiles of temperature and humidity
  - Multispectral channels to discriminate between fog and clouds

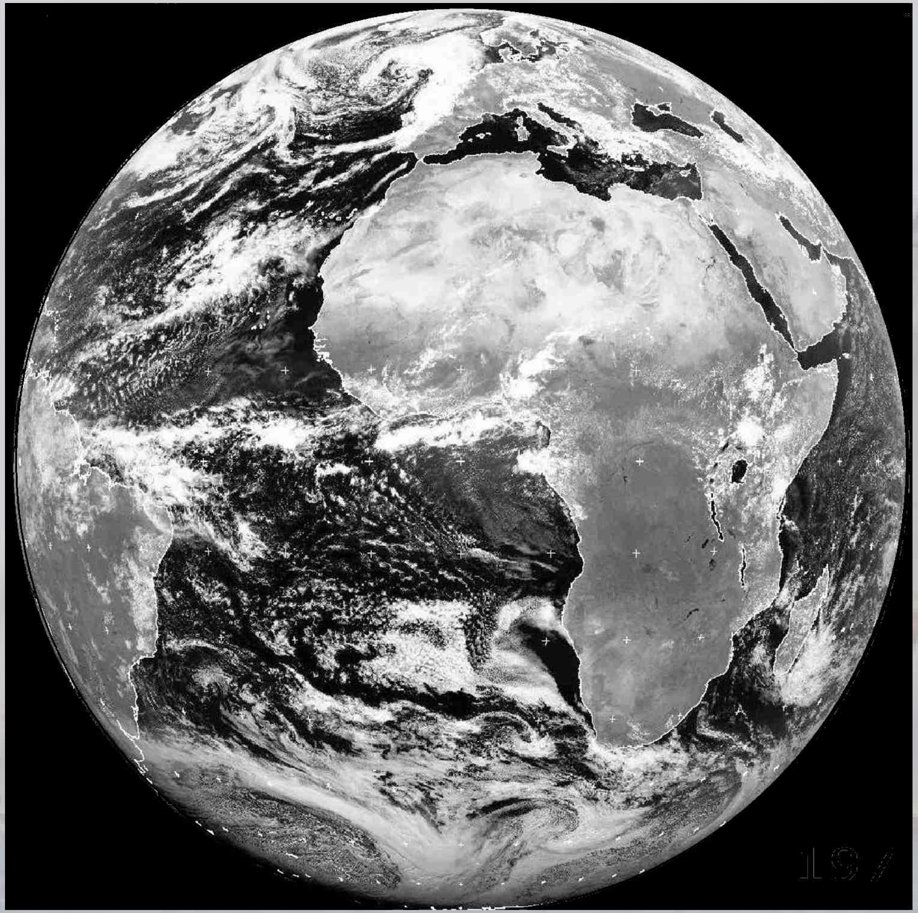
* AMV Atmospheric Motion Vector

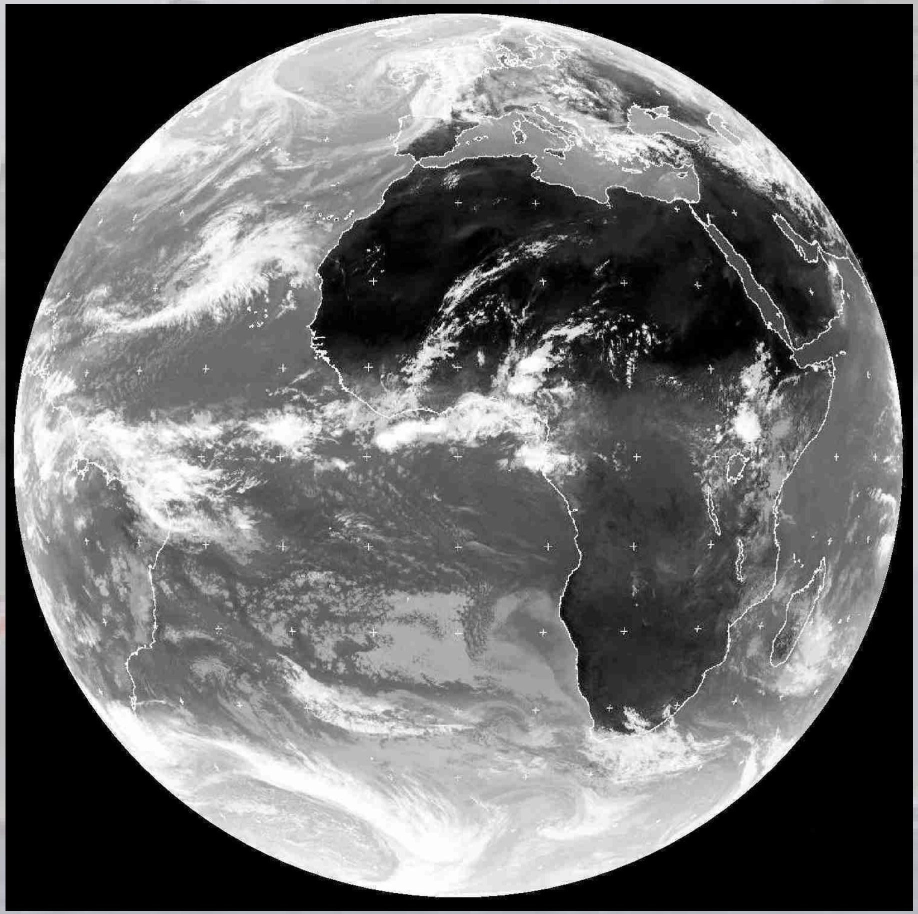
REMOTE SENSING – SPECTRAL PROPERTIES OF RADIATION

Further meteorological and geophysical satellite applications

- IR-properties of Earth surface (sea covered / not covered with foam)
- Ice detection, altimetry (solid Earth, sea and swell, sea ice coverage)
- Measurement of global radiation budget (global change)
- Initialization of numerical prediction models
- Weather forecasting: surface analysis of frontals systems
- Monitoring of Hurricanes

Remote sensing – Geostationary Satellite Meteosat



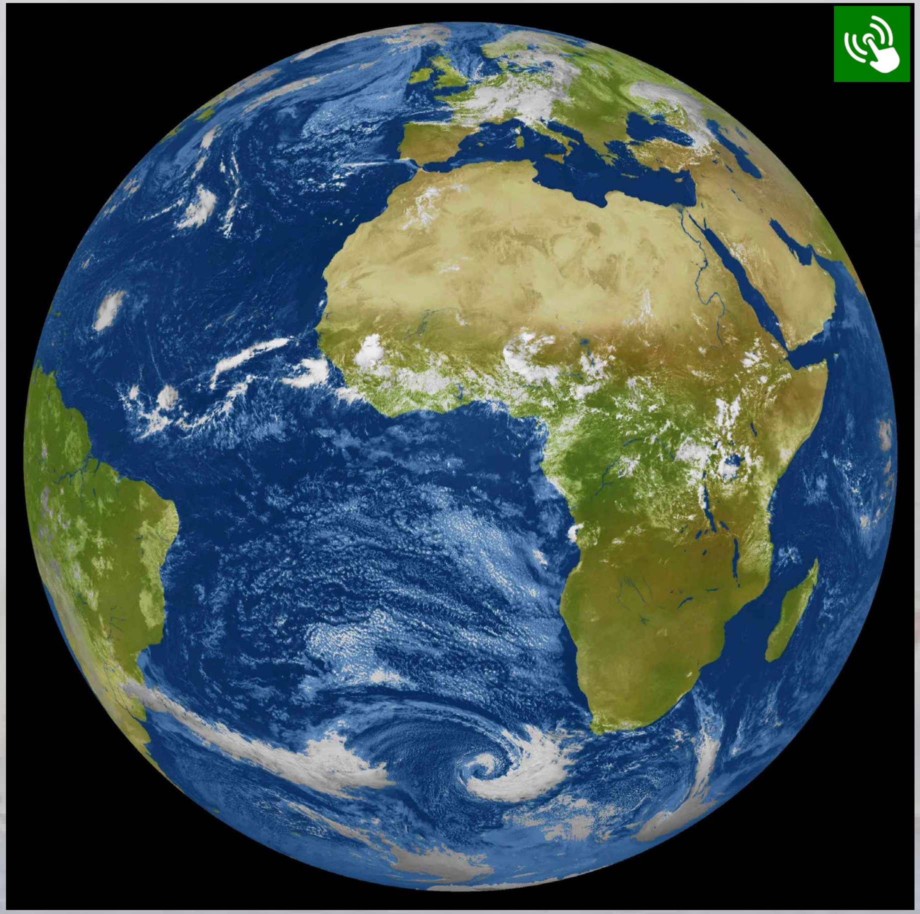


REMOTE SENSING – GEOSTATIONARY SATELLITE METEOSAT

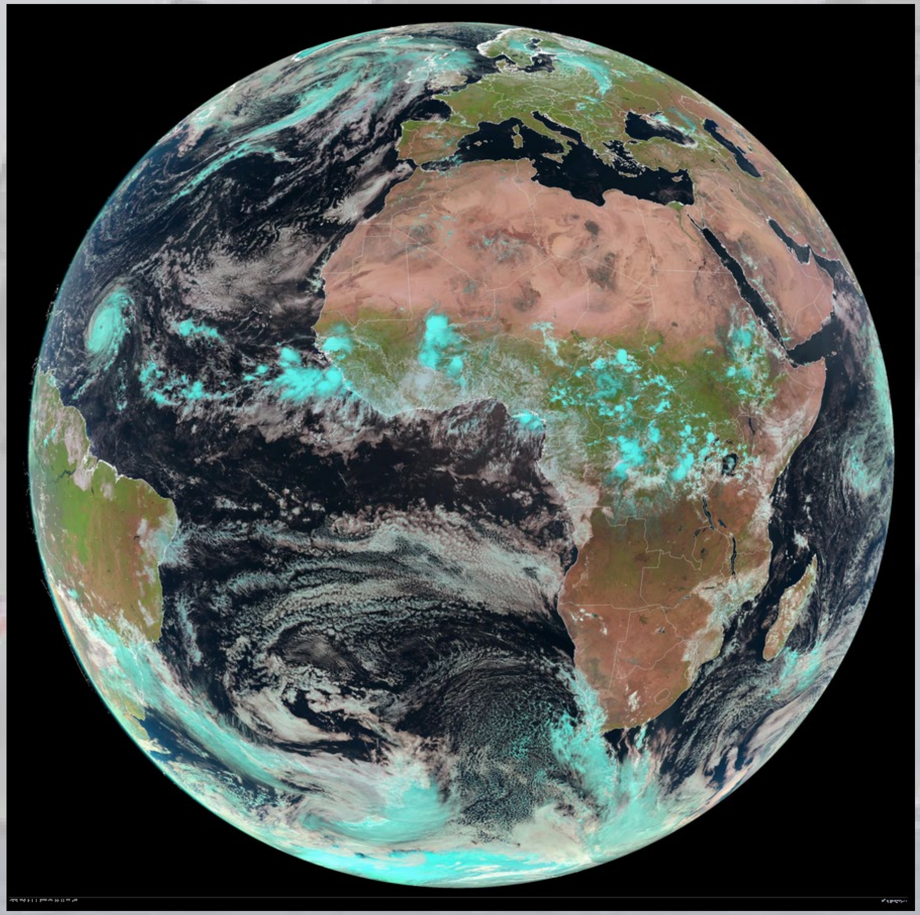
Meteosat Visible-Kanal
Like the human eye

R-G-B processing
Thematic Enhancement (clouds, fog)

VIS



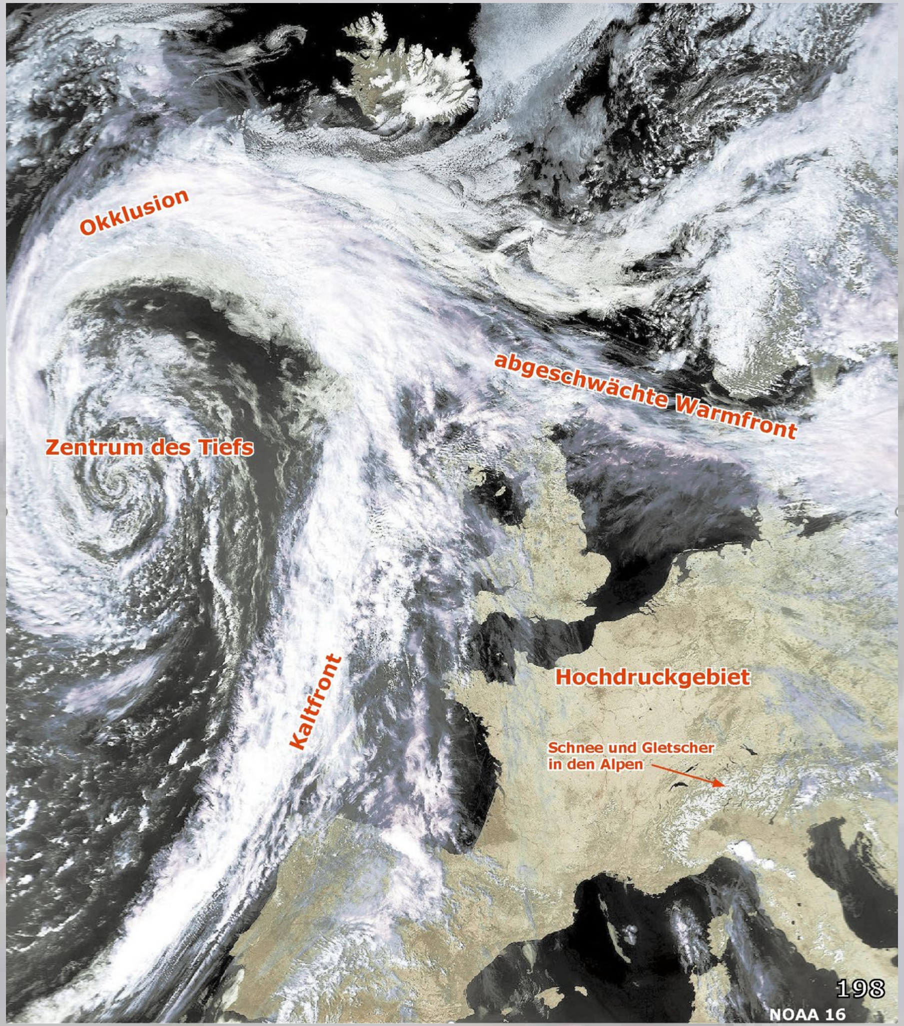
RGB False color



Remote sensing – Polar orbiting Satellite NOAA

NOAA Polar orbit

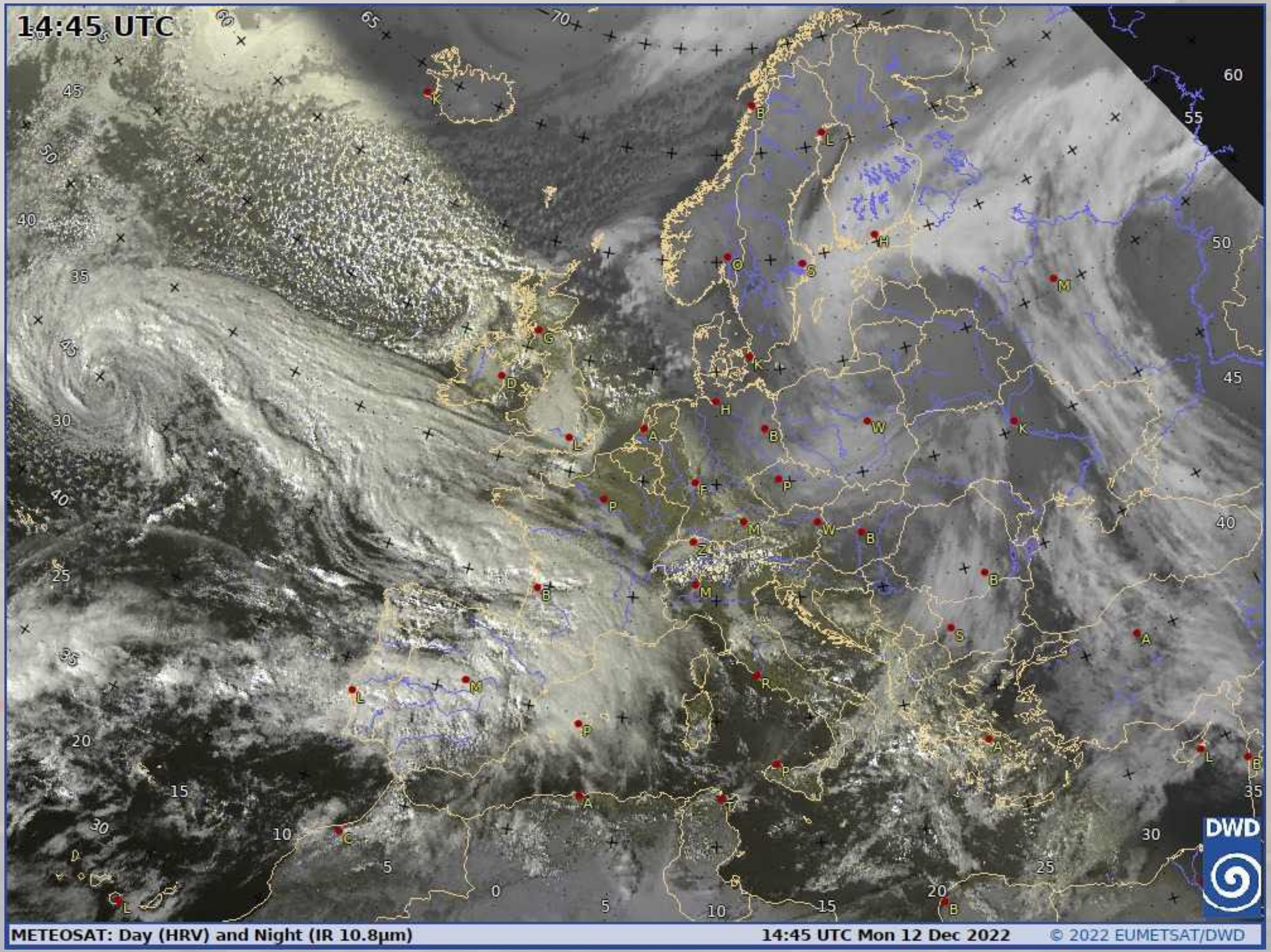
VIS sensibility like human eye



Remote sensing – Use of Satellites in Weather Forecasting

Synoptic Use of Satellite Data: <u>Visible Channel</u>

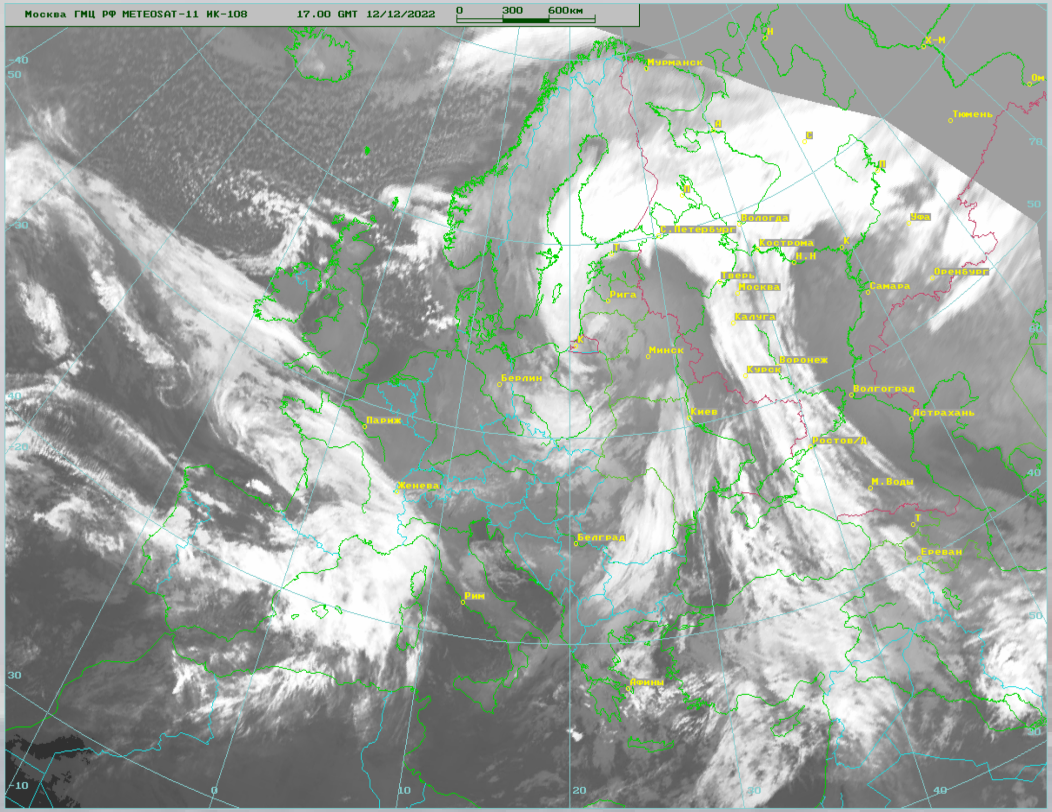
- Offers ‚eye-like‘ view
- Pros: Familiar interpretation, excellent contrast clouds – cloud-free
- Cons: No qualitative cloud-information, dark@night

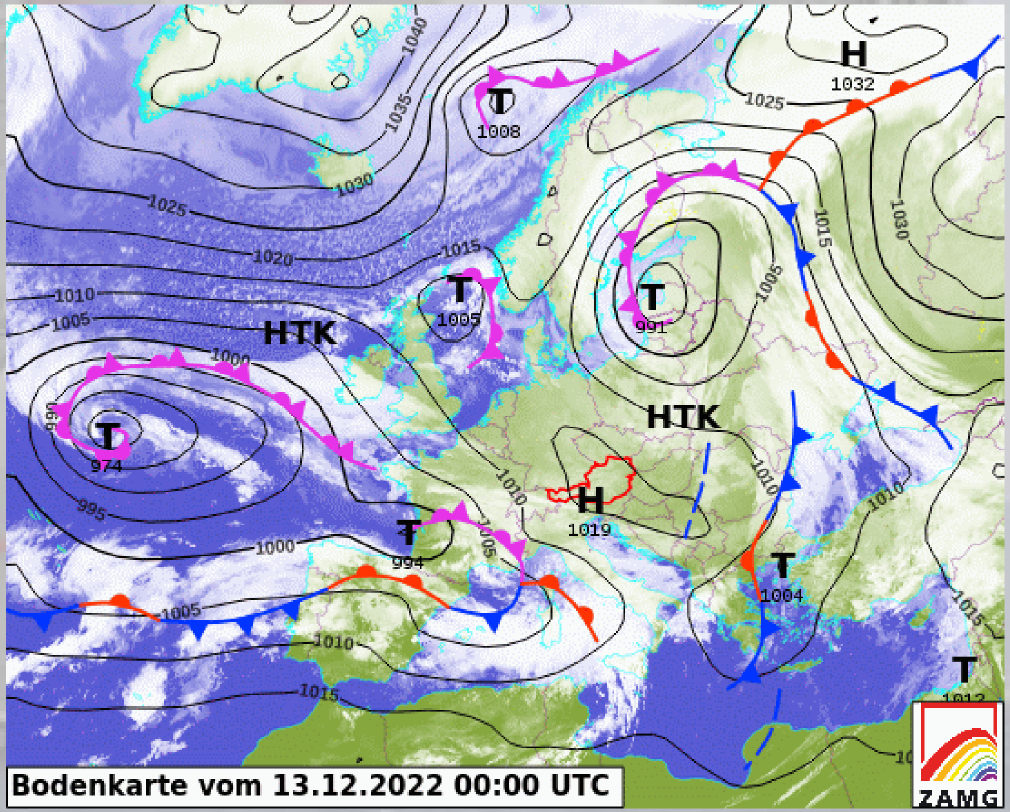


Remote sensing – Use of Satellites in Weather Forecasting

Synoptic Use of Satellite Data: Infrared IR Channel

- Greyscale is used as ‚warmest = black' ‚coldest = white'
- Pros: Information about vertical extent of clouds, info avlbl@night
- Cons: Not so easy ‚intuitive' interpretation

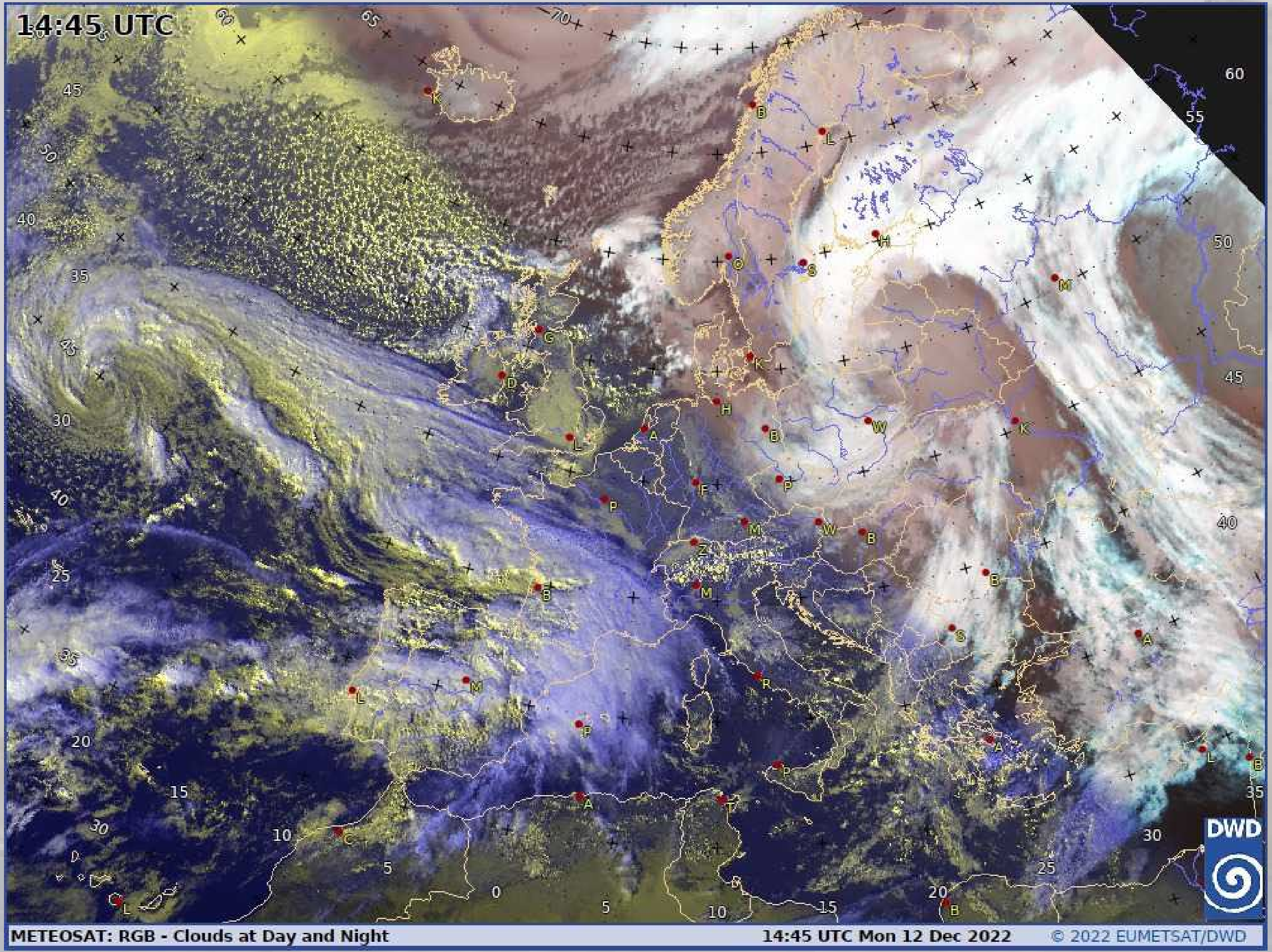




REMOTE SENSING – SPECTRAL PROPERTIES OF RADIATION

Synoptic Use of Satellite Data: Enhanced Channel **Cloud-Type**

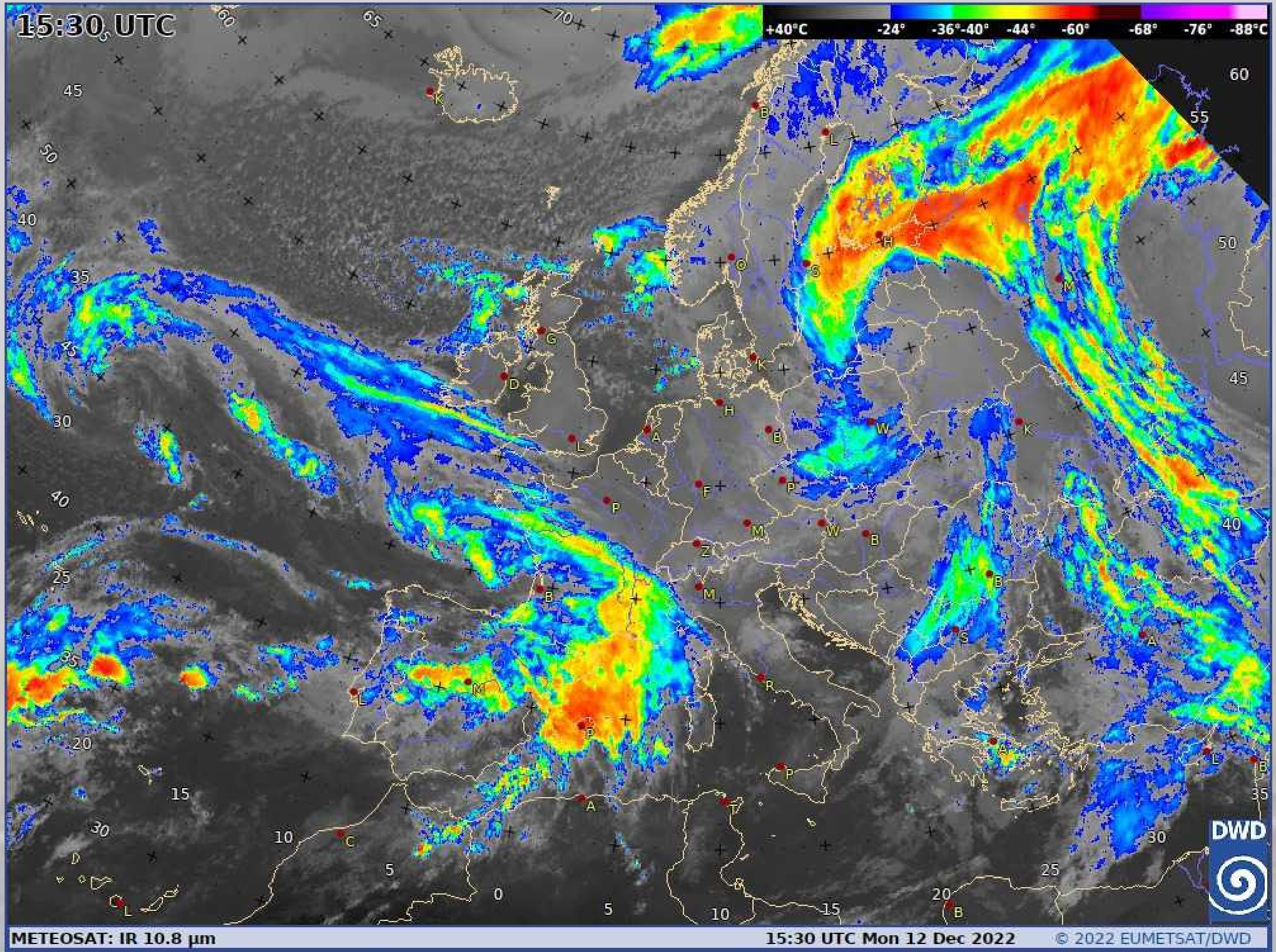
- Contrast enhancement to discriminate clouds – fog - etc

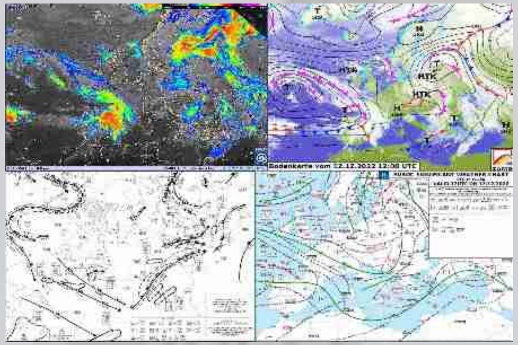


REMOTE SENSING – USE OF SATELLITES IN WEATHER FORECASTING

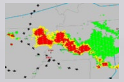
Synoptic Use of Satellite Data: Enhanced Channel **Cloud Top Temperature** +ANA

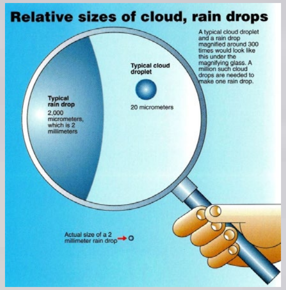
- Color enhancement for easy identification of clout top temperature



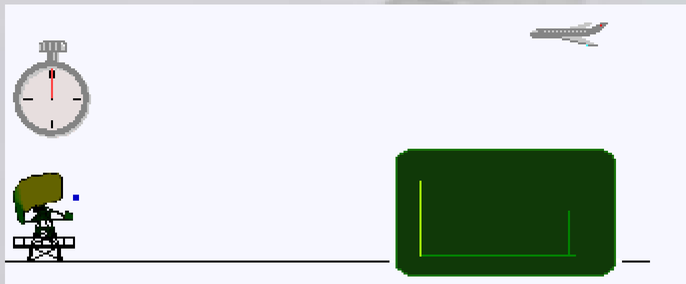


REMOTE SENSING - RADAR

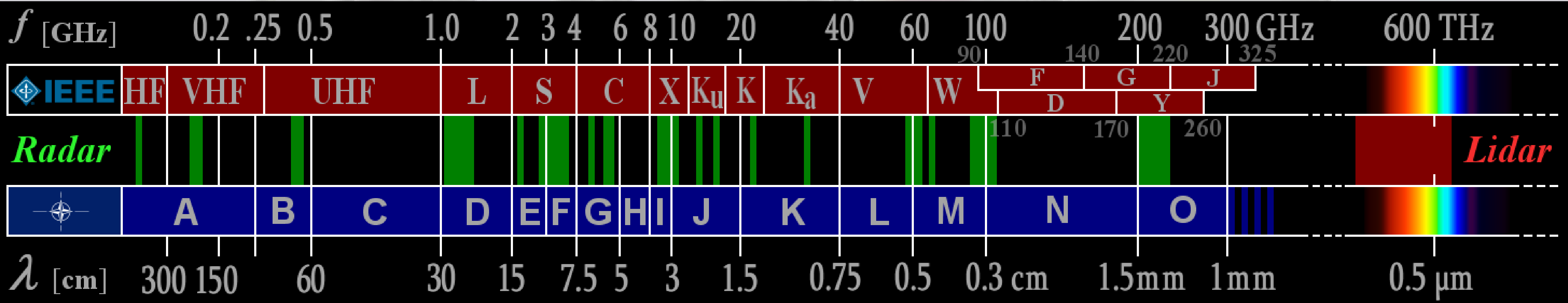




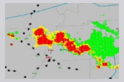
- RAdio Detecting And Rangeing (runtime measurement)



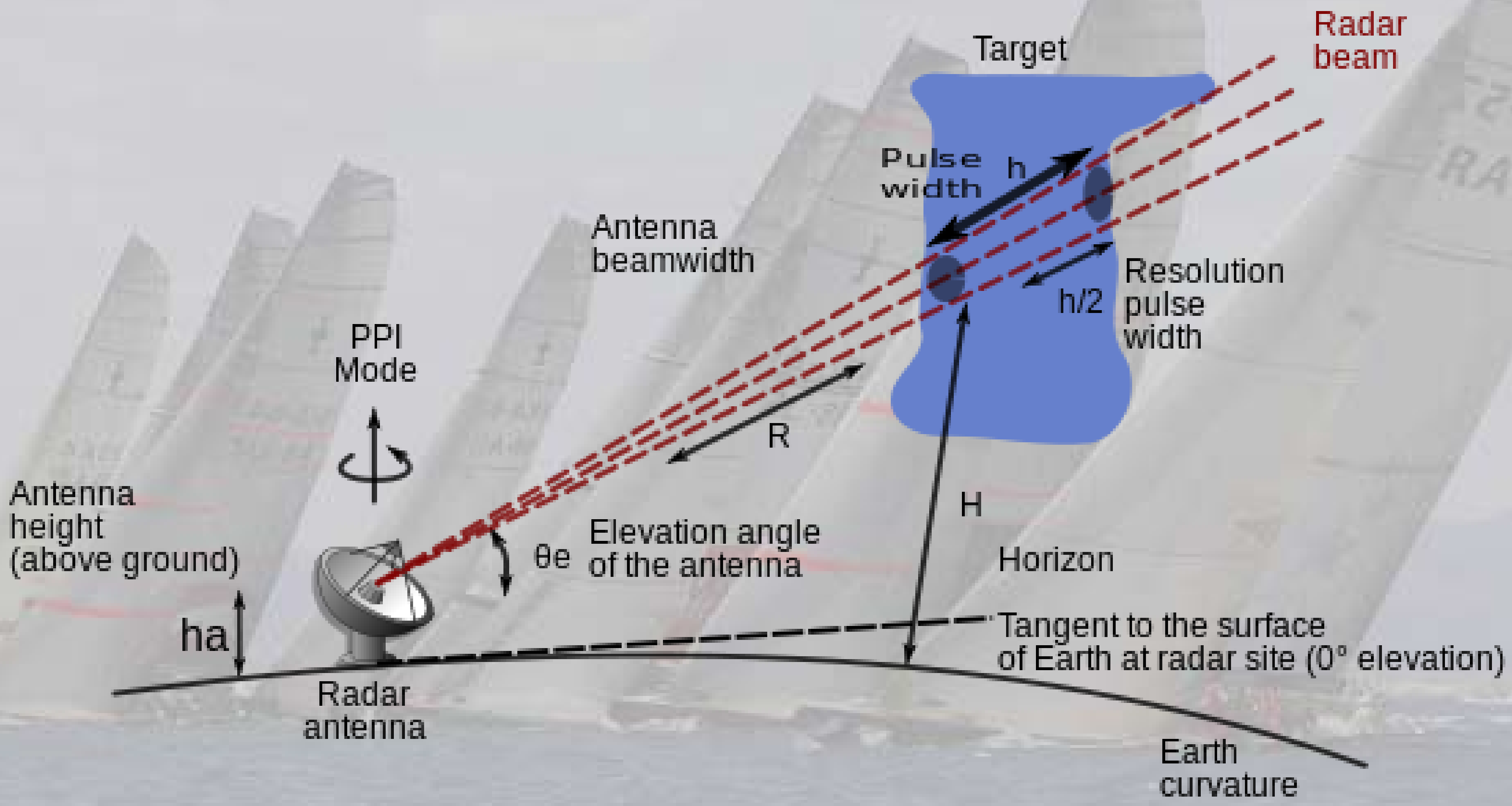
- Detects raindrops, no cloud droplets
- Operates in microwave region
  (wavelength ~cm, frequencies ~GHz Giga Hertz)
- Spectral Bands and Radar band code letters



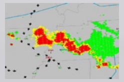
REMOTE SENSING - RADAR



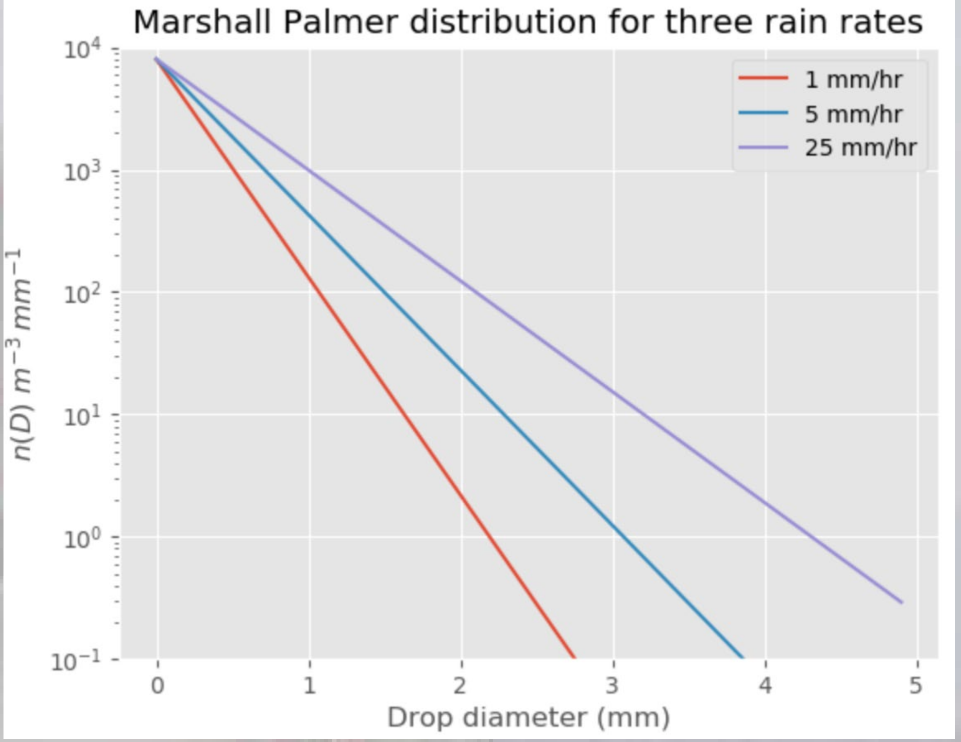
- **Curvature of earth: height of radar beam height at d=250 km: approx. 7 km**



REMOTE SENSING - RADAR



- **Curvature of earth: height of radar beam at d=250 km: 7 km**
- **Getting Rainfall Amount Measurement from Radar requires information about the via Droplet-Size-Spectrum:**
- **Z: Radar-Signal-Strength**
- **R: Rainfall Amount, Goal of Radar Measurement**
- **Z – R – Relation based on Marshall-Palmer-Spectrum allows Radar detection of rainfall rates**



REMOTE SENSING – RADAR Z - R - RELATION

- **Curvature of earth: height of radar beam at d=250 km: 7 km**

- **Rainfall Amount Measurement via DropletSize-Spectrum:**
- **Z: Radar-Signal-Strengt**
- **R: Rainfall Amount, Goal of Radar Measurement**
- **Z – R – Relation: Marshall-Palmer-Spectrum:**

The rainrate (R) is equal to number of particules ($N(D)$), their volume ($\pi D^3/6$) and their falling speed ($v(D)$):

$$R = \int_0^{Dmax} N(D)(\pi D^3/6)v(D)dD$$

The radar reflectivity Z is:

$$Z_{rain} = |K_{rain}|^2 \int_0^{Dmax} N(D)D^6 dD$$ where K is the Permittivity of water

Z and R having similar formulation, one can solve the equations to have a Z-R of the type:[5]

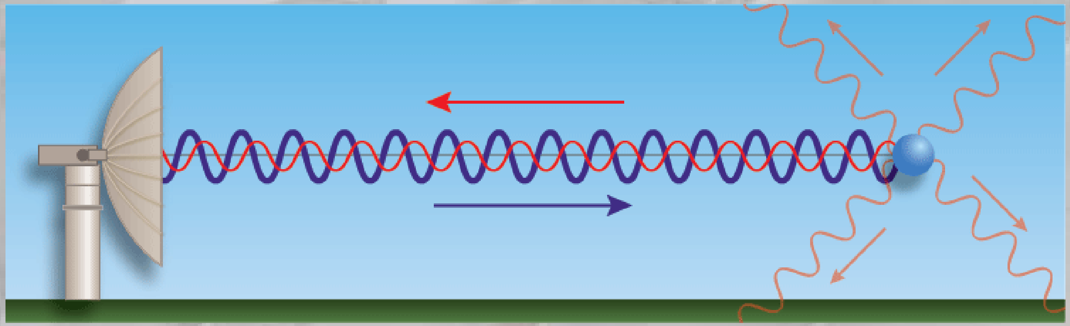
$$Z_{rain} = aR^b$$

Where a and b are related to the type of precipitation (rain, snow, convective (like in thunderstorms) or stratiform (like from nimbostratus clouds) which have different Λ, K, N_0 and v.

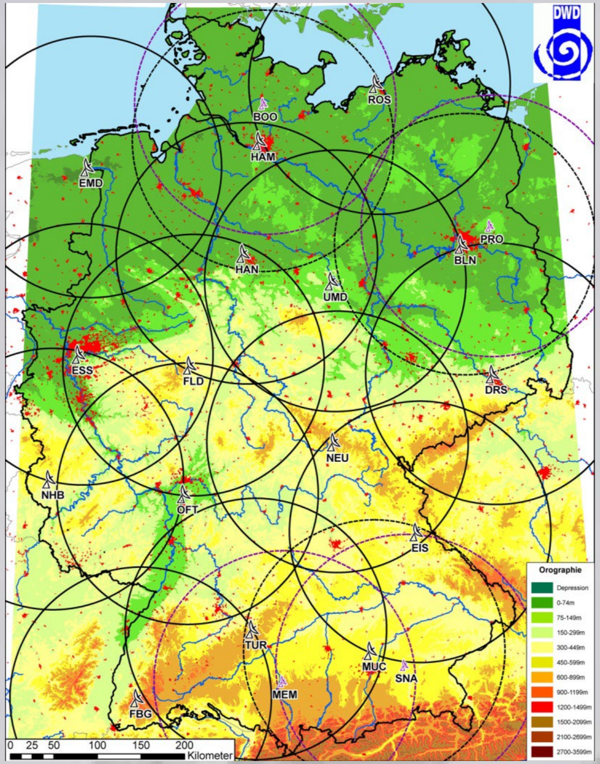
The best known of this relation is the Marshall-Palmer Z-R relationship which gives a = 200 and b = 1.6.[6] It is still one of the most used because it is valid for synoptic rain in mid-latitudes, a very common case. Other relationships were found for snow, rainstorm, tropical rain, etc.[6]

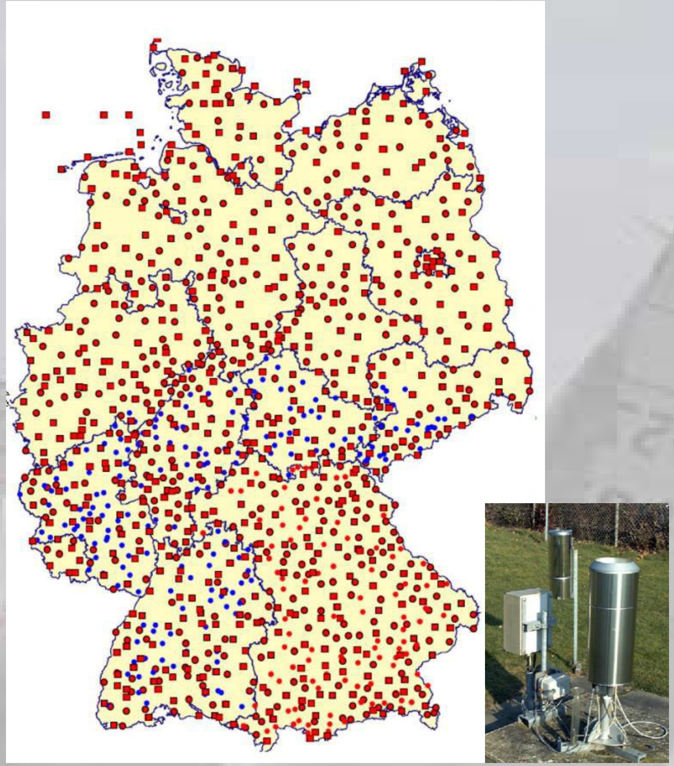
Remote sensing – Doppler / Dual Polarization Radar

- Z– R – Relation: Marshall-Palmer-Spectrum:
- Additional Information by Signal-processing
- (Wind) by Doppler-Radar: Detection of raindrop velocity towards / away from Radar site
- Dual-Polarisation-Radar: Horizontal / vertical Polarization signal allows description of dropsize spectra



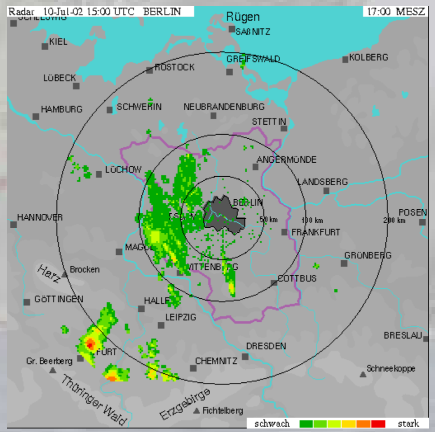
Remote sensing – RADAR Composite Networks

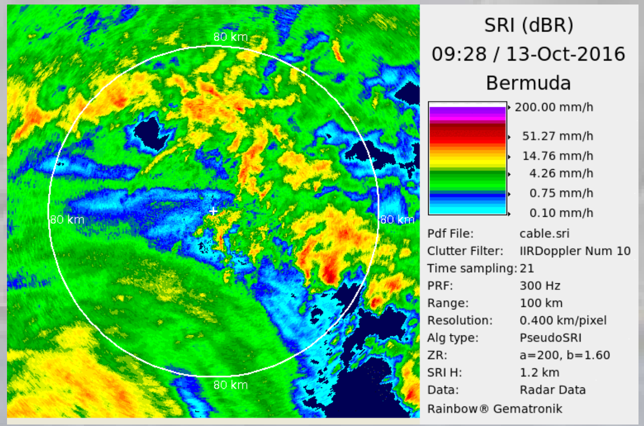


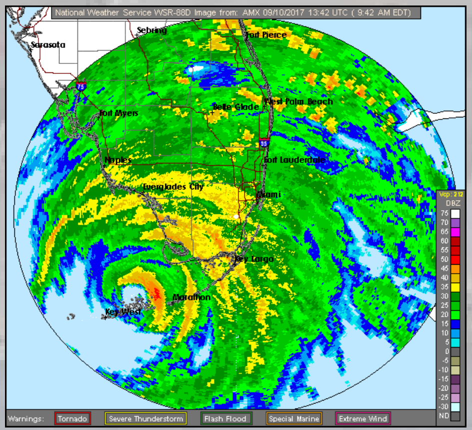


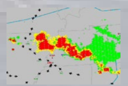
Radar-Composite (17)

Ombrometer raingauges (1300)

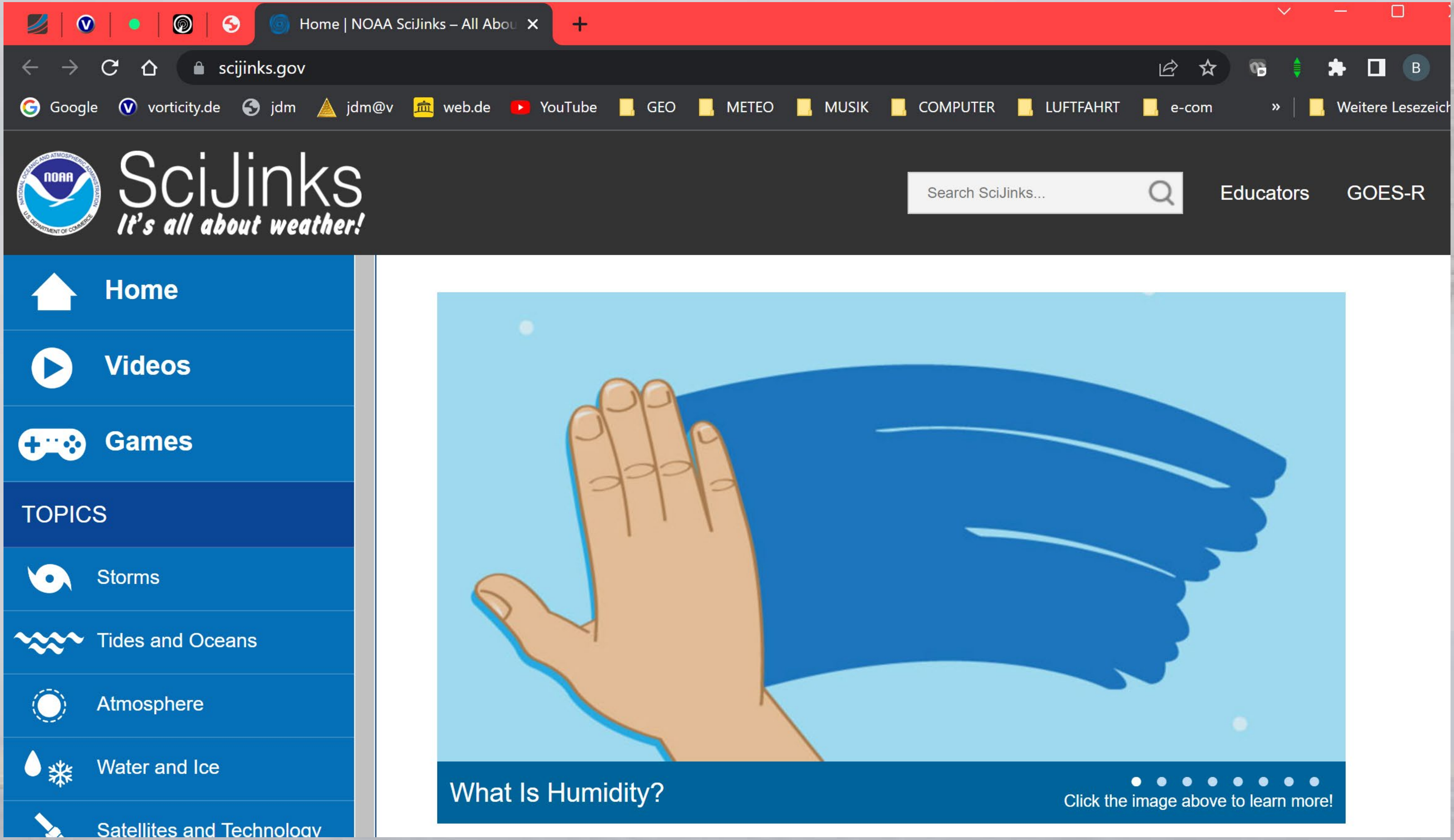








https://scijinks.gov



Questions you should be able to answer Remote Sensing

Please check vorticity – ENG – MISCellaneous
https://www.vorticity.de//vorticity_en.php#0_ANKER_V

- ✓ What does the IR Greyscale of satellite images represent?
  - ✓ A temperature scale: black is warm, white is cold
- ✓ What is the intention of using multi-spectral channels
  - ✓ To get many neighbouring data from heights where the channel specific weighting-function has ist maximum to deduce a vertical profile information, typically a temperature profile
- ✓ What can be a problem with Radar in heavy precipitation?
  - ✓ Attenuation. The heavy precipitation inhibits signals from rain areas behind observed precipitation, which can be even more intense than the one detected (Aviation!)
- ✓ What is the advantage of Doppler Radar
  - ✓ It offers information about the relative speed of raindrops toward or away from the radar antenna thus allowing to retrieve windspeeds, windshear and even rotational windspeed patterns (Tornado)

QUESTIONS YOU SHOULD BE ABLE TO ANSWER REMOTE SENSING

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Questions you should be able to answer Remote Sensing

- ✓ What is a basic problem of quatitative precipitation amount measurements using Radar?
  - ✓ Radar gives the intensity of the emitted signal after reflection by the raindrops (Z: Reflectivity).
    In order to get quantitavive rainfall amount R, so called Z-R-Relations have to be used.
    They depend on type of rain (drizzle, shower), climatology and drop-size-distribution.
    Simple approximations are used and OK, but the accuracy is limited.
    Improvements are can achieved by ‚adjusting' Radar rainfall rates with rainfall gauges.
    Another option of improvement is Doppler Radar to better describe the drop-size-distribution