# An overview of CM SAF cloud retrieval methods

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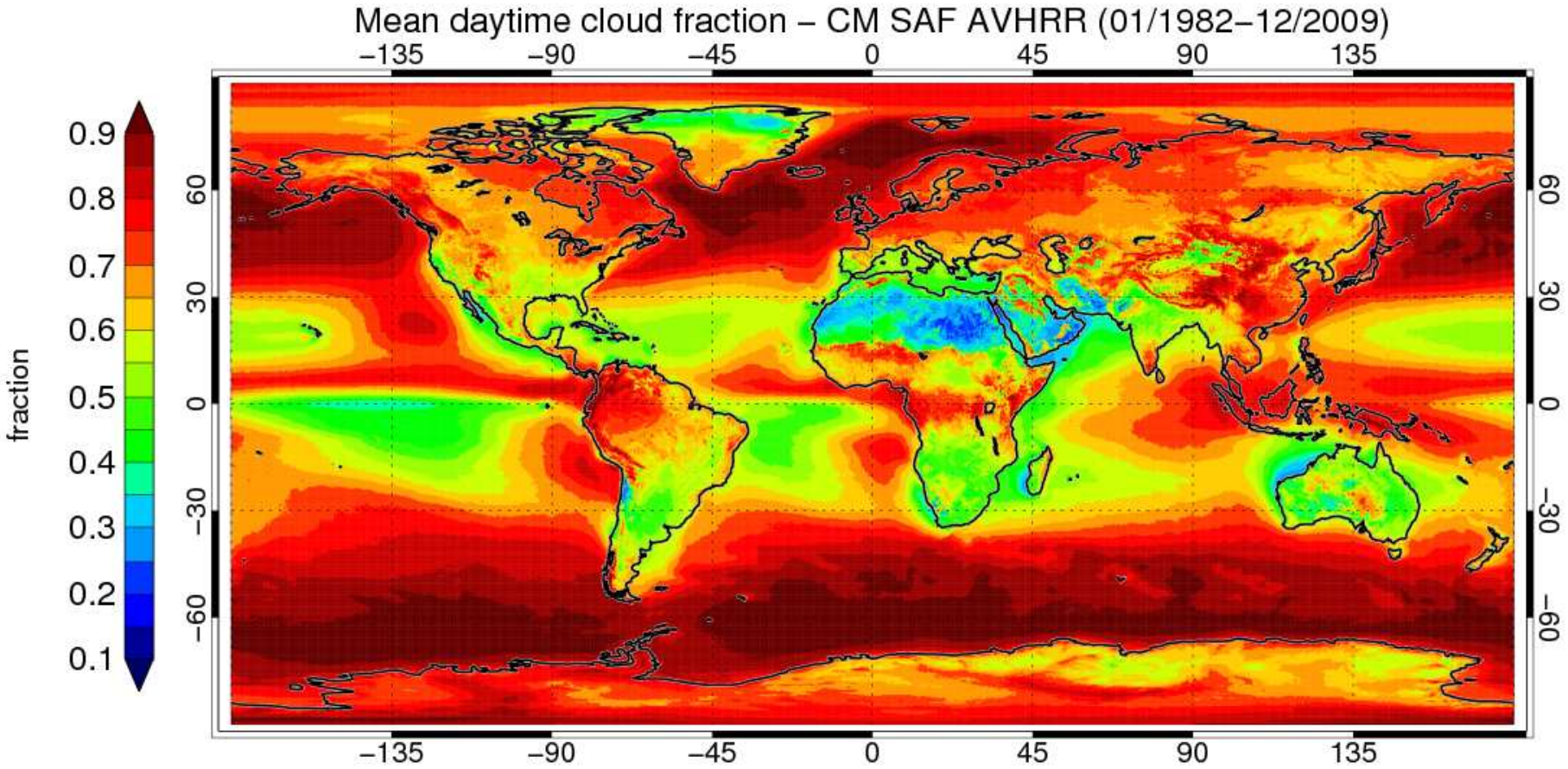
## Outline:

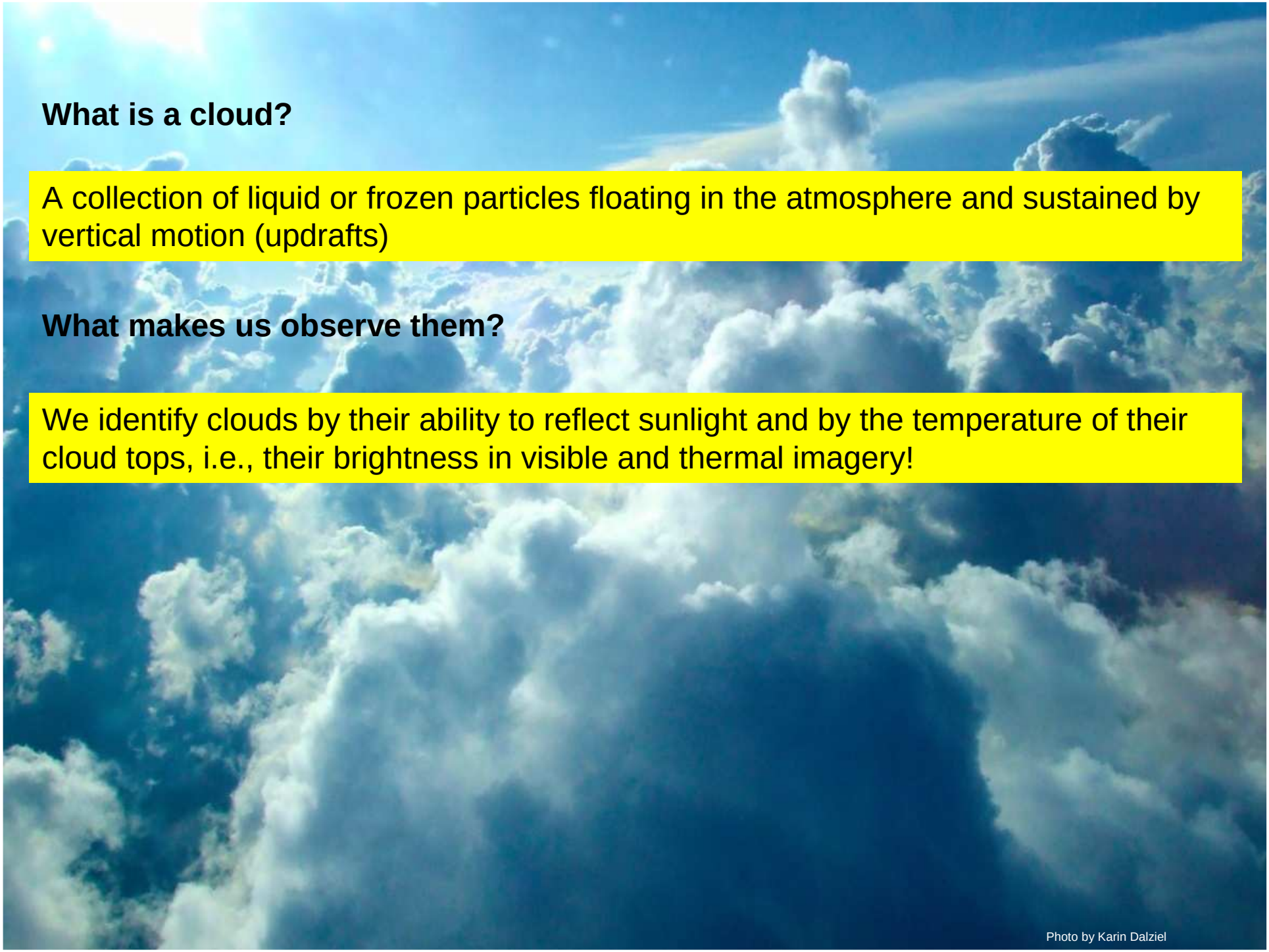
- How do we observe clouds from space?
- Which cloud properties can be observed from space?
- Which satellites and sensors are most useful?
- Which retrieval methods are used in the CM SAF?

**Could you please click on the map and indicate where you are?**

(Maybe we can deduce which participant gets most sunshine!)




What is a cloud?
What makes us observe them?
Photo by Karin Dalziel



**What is a cloud?**

A collection of liquid or frozen particles floating in the atmosphere and sustained by vertical motion (updrafts)

**What makes us observe them?**

We identify clouds by their ability to reflect sunlight and by the temperature of their cloud tops, i.e., their brightness in visible and thermal imagery!

Photo by Karin Dalziel

# Observation of clouds

**What other conditions need to be fulfilled for successful cloud detection from space (please tick!)?**

- ❑ Clouds must be precipitating
- ❑ Rocket engines must be active
- ❑ The atmosphere itself must be transparent
- ❑ No airplanes should intersect at observation time
- ❑ International Space Station must be out of sight
- ❑ Clouds must appear brighter than the Earth surface
- ❑ Migrating birds must be on ground
- ❑ No rainbows should interfere
- ❑ Cloud tops must be colder than the Earth surface
- ❑ No Quidditch games allowed at observation times

# Observation of clouds

**What other conditions need to be fulfilled for successful cloud detection from space (please tick!)? Correct choices:**

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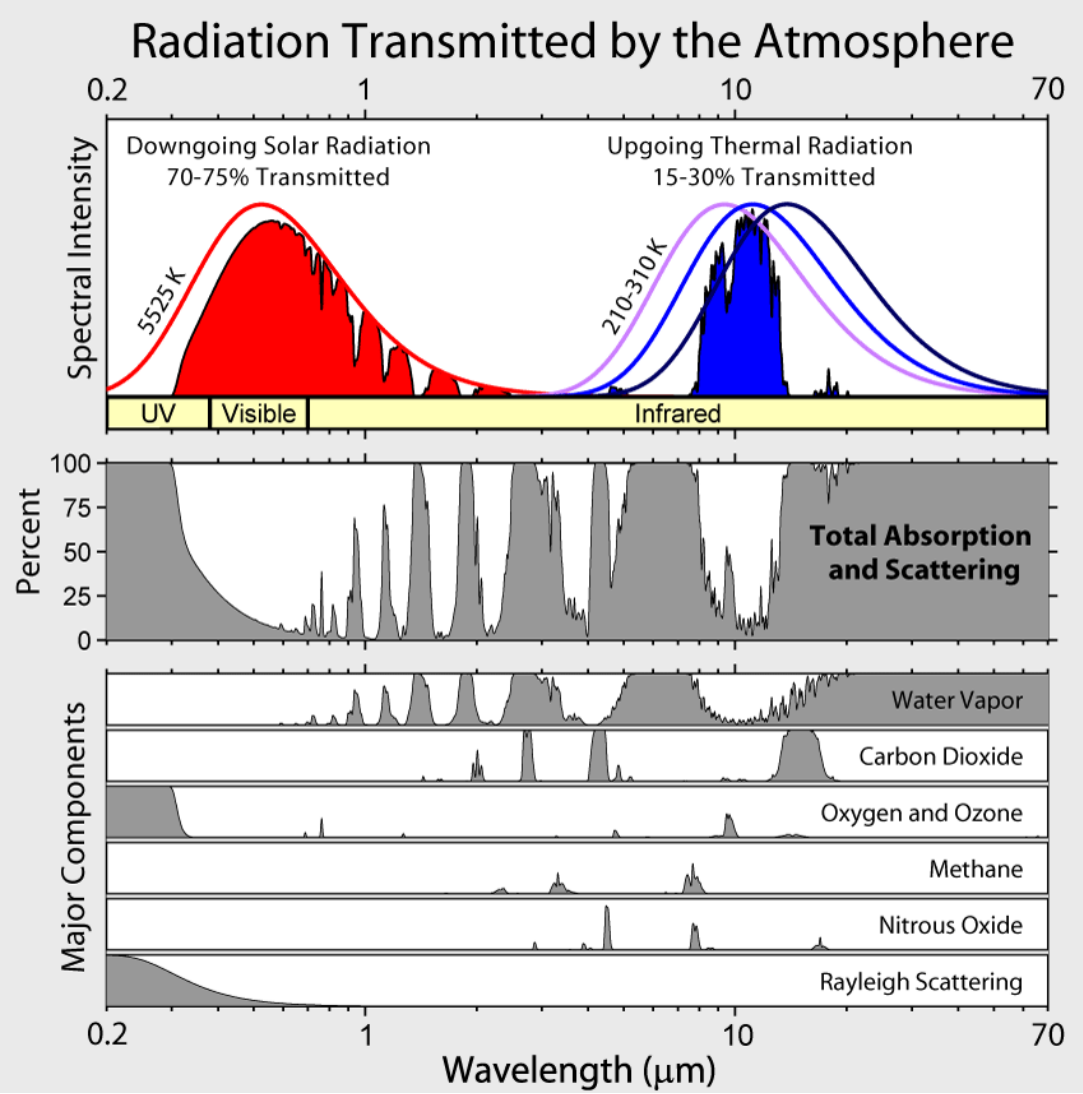
# Observation of clouds

**We need a transparent atmosphere to be able to observe clouds in imagery!**



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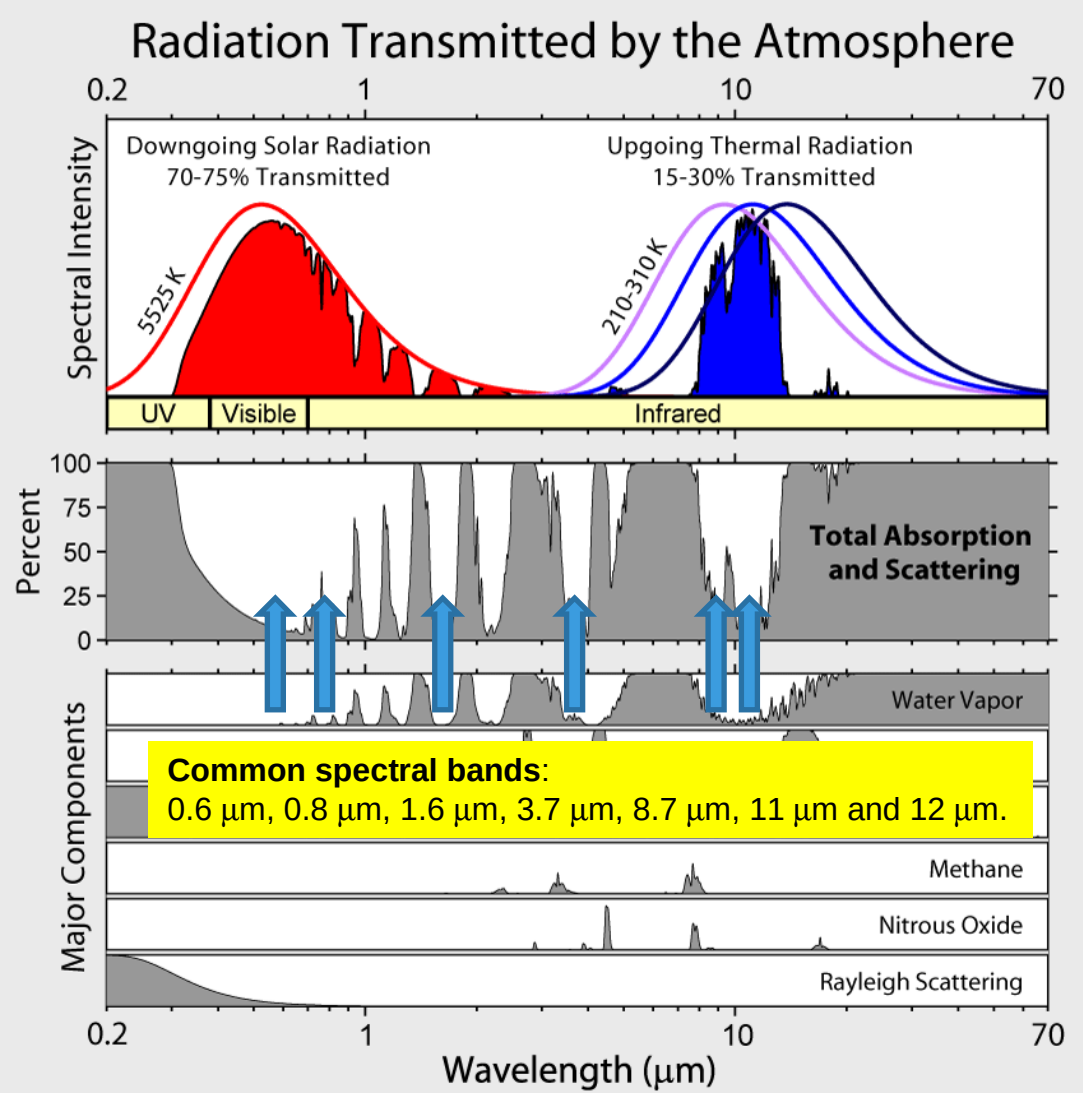
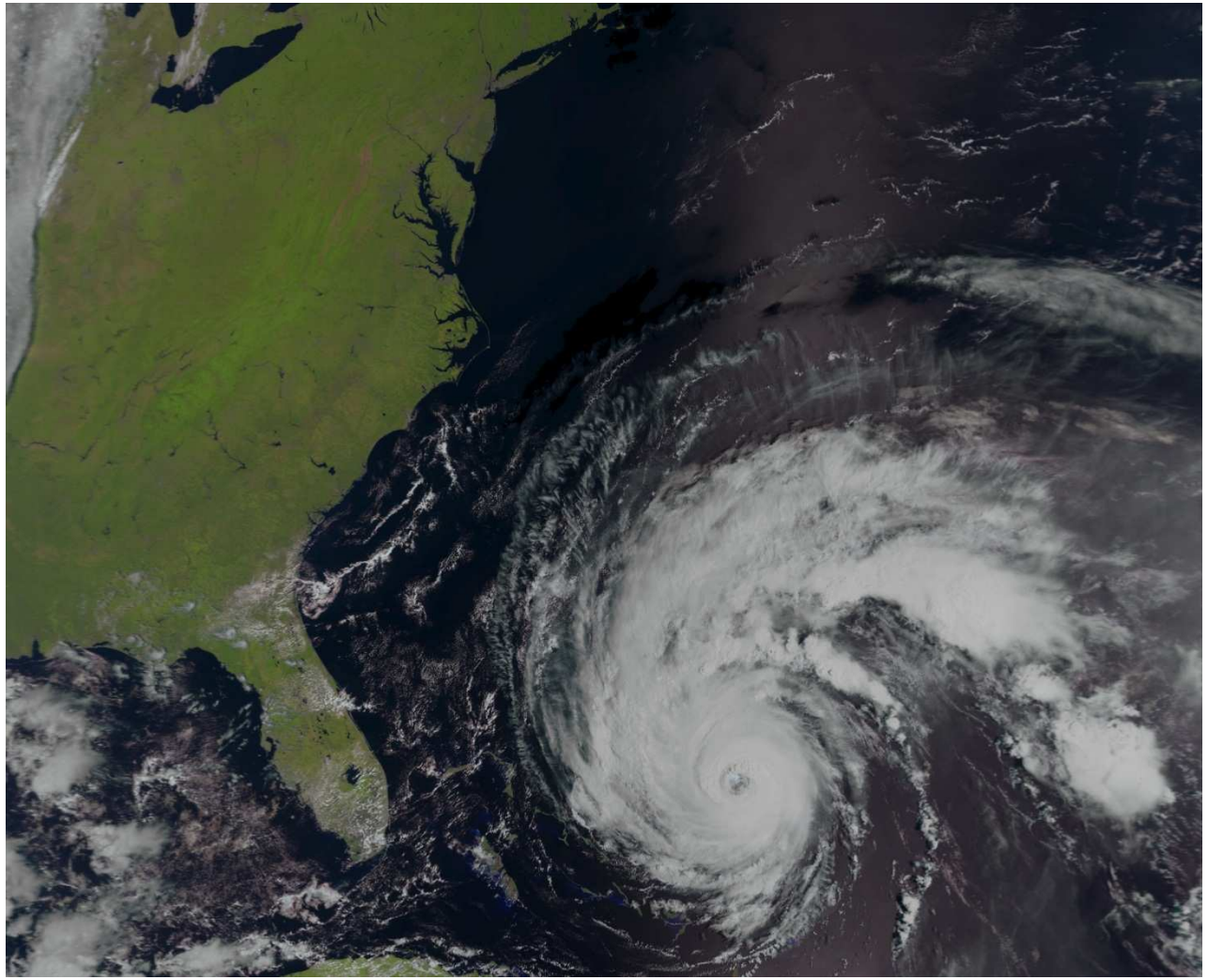


# Observation of clouds

**We need contrast between clouds and other objects to be able to detect clouds in imagery!**



# Observation of clouds

**Are there clouds that could remain undetected?**

# Observation of clouds



**Are there clouds that could remain undetected?**

Yes, there are actually several occasions when this might occur:

1. Bright clouds over bright surfaces, e.g., over snow-covered or desert surfaces

2. Cold clouds over cold surfaces, e.g. over almost all polar surfaces in the polar winter + thin cirrus clouds over snow-covered surfaces

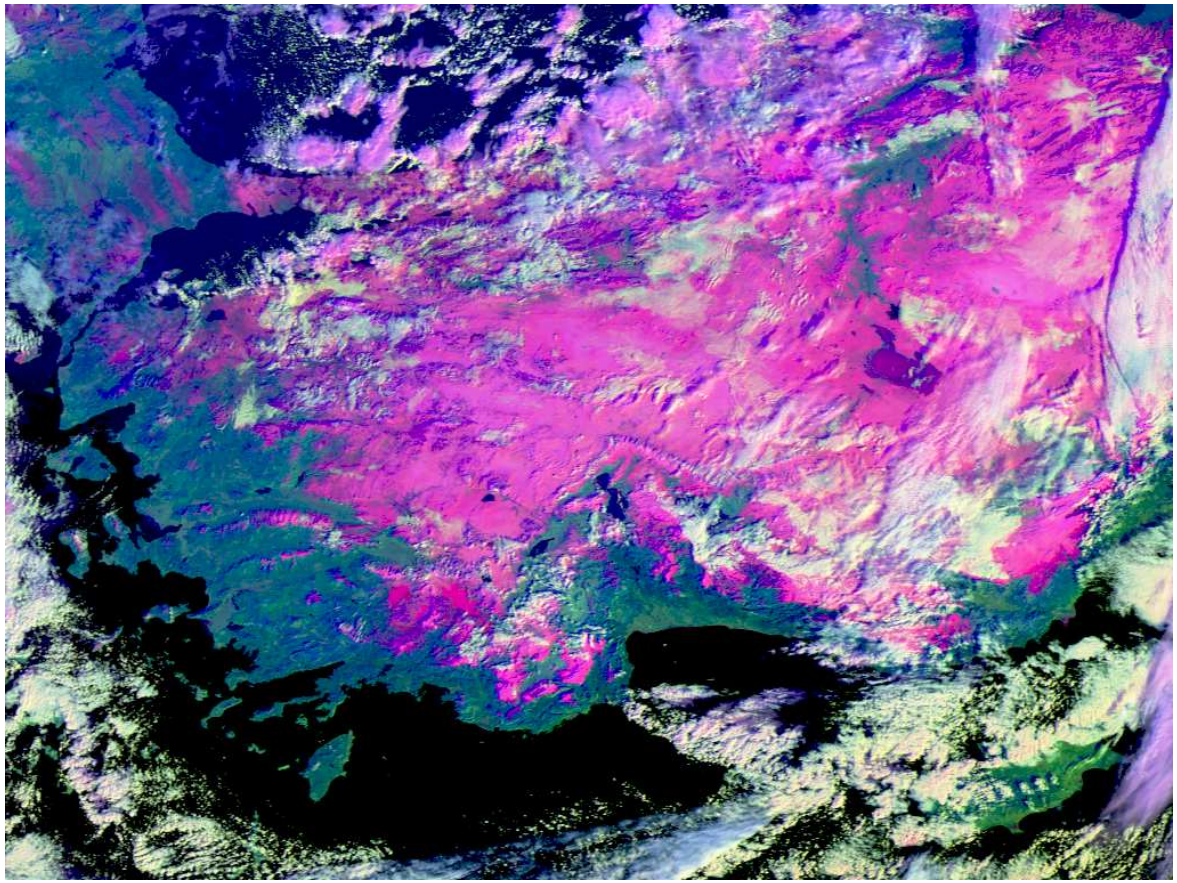
3. Extreme cases: Low clouds are warmer than the surface (e.g., stratus clouds over the Arctic ocean in polar summer)

4. Warm clouds in twilight situations

# Optimal detection of clouds

**Use differences in the appearance of clouds in different spectral channels!**

**Example below over Turkey: Clouds over snow-cover (magenta) can easily be detected if utilising that they reflect in the 1.6 micron channel while snow is not!!!**



Metop-A RGB Composite

17 January 2012
VIS0.6, NIR1.6, IR11.0
07:49:00 UTC

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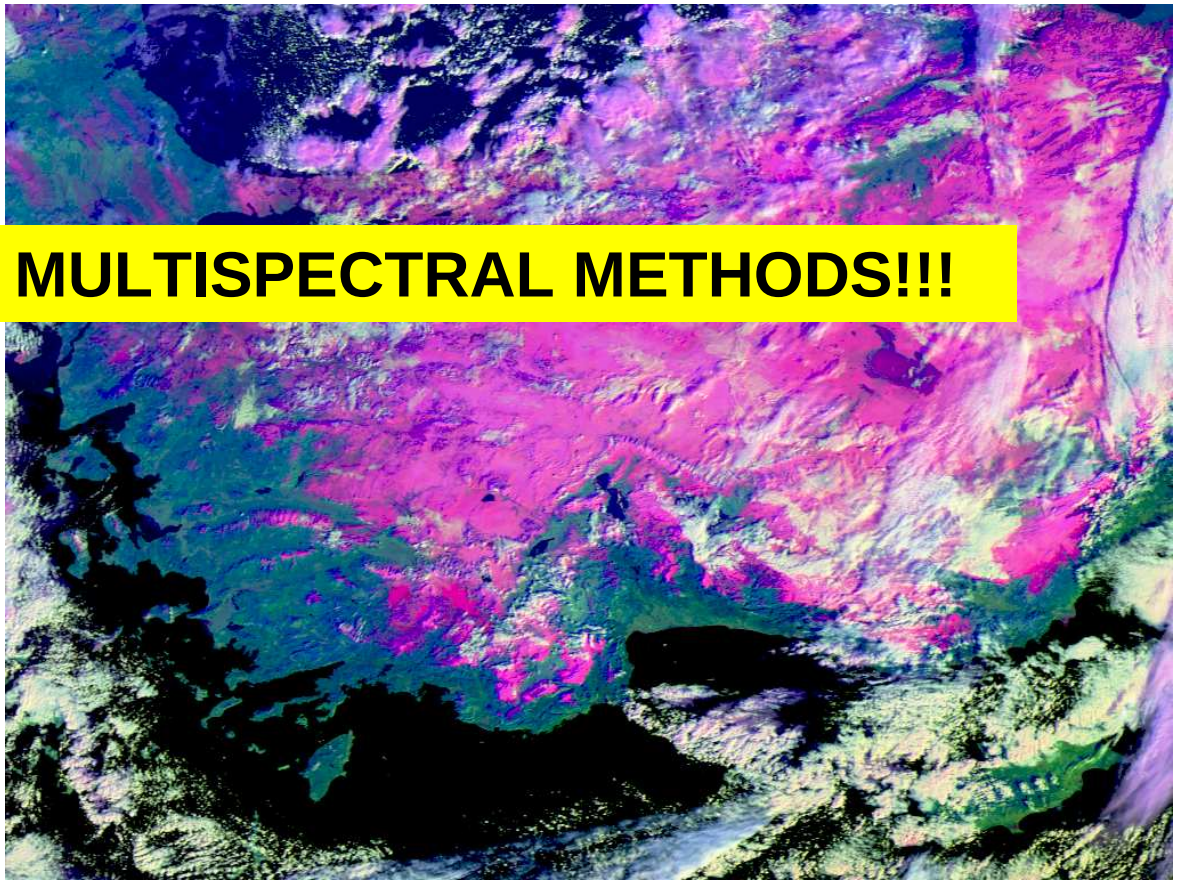
**➔ USE MULTISPECTRAL METHODS!!!**



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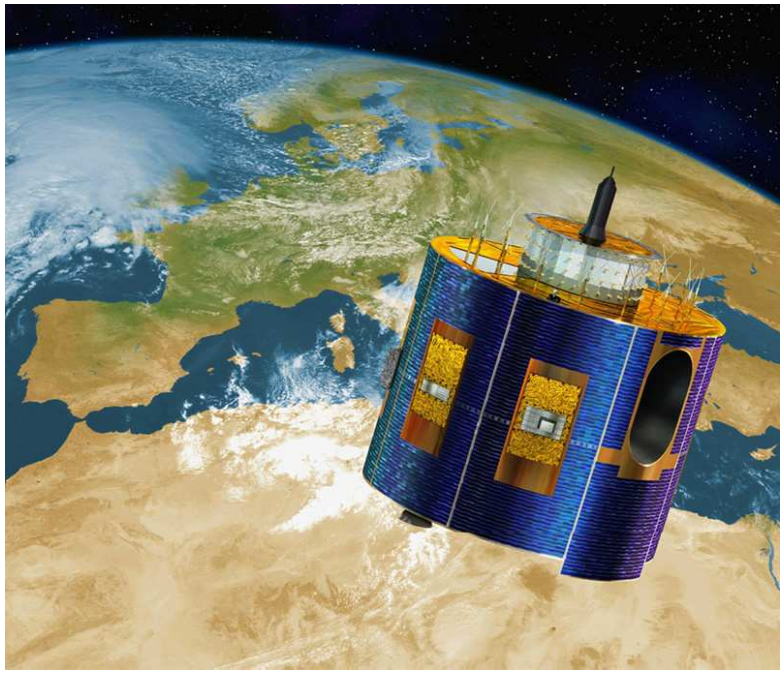
# Suitable sensors for cloud screening

**The main objective for the EUMETSAT CM SAF is to use sensors from operational weather satellites for climate monitoring.**

**Most suitable image sensors is then AVHRR on polar orbiting NOAA/Metop satellites and SEVIRI on the geostationary METEOSAT satellite**

The Metop-A satellite carrying AVHRR imager with 6 spectral bands

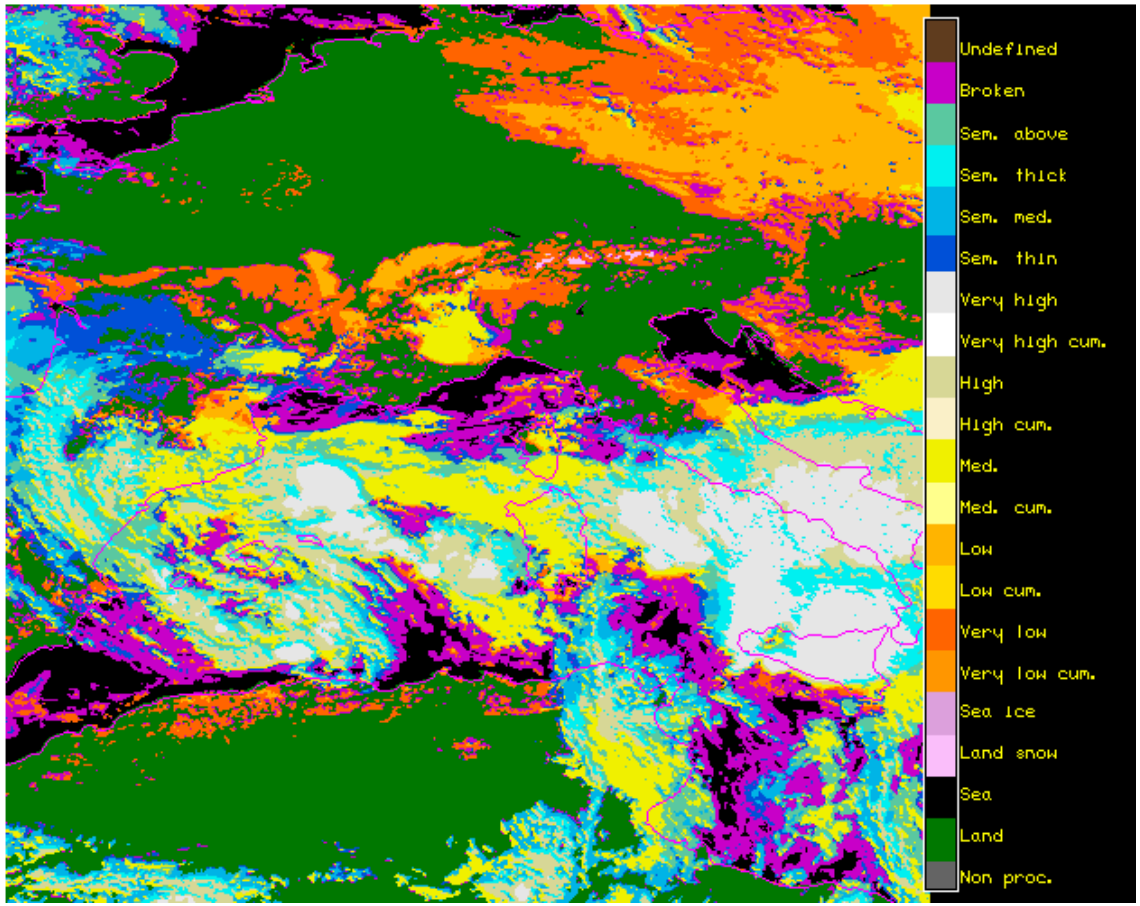


The METEOSAT satellite carrying SEVIRI imager with 12 spectral bands

# Basic cloud screening in CM SAF

**Two multispectral cloud processing methods are used in the CM SAF:**

**The PPS (Polar Platform System) and MSG cloud processing packages provided by the EUMETSAT Nowcasting SAF project**




Example of NWC SAF MSG cloud type product from 14 October 2003

***(animation available for download!)***

# Basic cloud screening in CM SAF

**Common basic methodology for the PPS (Polar Platform System) and MSG cloud processing packages:**

**•Multispectral thresholding, i.e., a pixel is labelled cloudy if radiances exceed thresholds in a number spectral channels or channel combinations (e.g. radiance differences)**

**•Thresholds depend on illumination conditions, viewing angles and the atmospheric background state (taken from ERA-Interim)**

**•For several tests, thresholds are based on simulations of radiances from cloud-free surfaces**

# Basic cloud screening in CM SAF

**PPS (Polar Platform System) and MSG cloud processing packages – Major features used in cloud screening:**

- **Clouds are brighter than Earth surfaces in visible channels**
- **Clouds are colder than Earth surfaces in infrared channels**
- **Water clouds reflect radiation at short-wave infrared channels (1.6 micron and 3.7 micron) while Earth surfaces do not reflect**
- **Thin ice clouds are less transparent at longer infrared wavelengs, i.e., cirrus can be detected using difference between 11 and 12 micron channels**
- **Water clouds at night are not black-bodies in 3.7 micron channel, i.e., can be detected using difference between 3.7 and 11 micron**
- **Pixel-size clouds can be detected using simple texture measures**

# Cloud top determination

**Cloud height retrievals from passive imagers in space are difficult. Why?**

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One major reason:

We measure the vertically integrated (i.e., along the line of sight) radiation that enters the sensor detector in space

➔ If we observe a thin transparent cloud, radiation contributions come in various proportions from the cloud itself and all underlying clouds/surfaces!

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➔ If we observe a thin transparent cloud, radiation contributions come in various proportions from the cloud itself and all underlying clouds/surfaces!

Another fundamental problem:

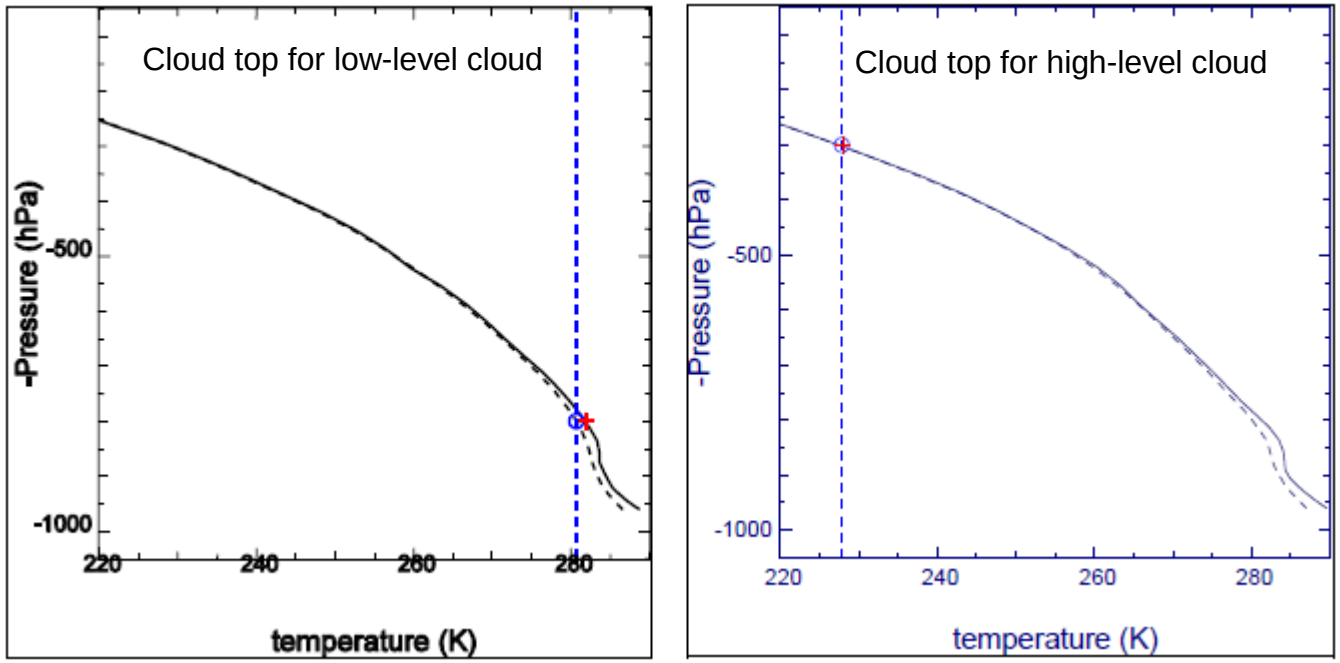
•Even if the cloud is opaque (thus, we are able to estimate the true cloud top temperature), this temperature can often be found at several altitudes in the atmosphere (due to inversions)

# Cloud top determination

**Methods used for the CM SAF datasets (still based on NWC SAF packages):**

**For opaque clouds**
(negligible brightness temperature difference between 11 and 12 micron channels):

•Matching of measured brightness temperatures (horizontal dashed line) with simulated ones (dashed curve, using radiative transfer methods like RTTOV) and reference profiles from ERA-Interim(solid curve)

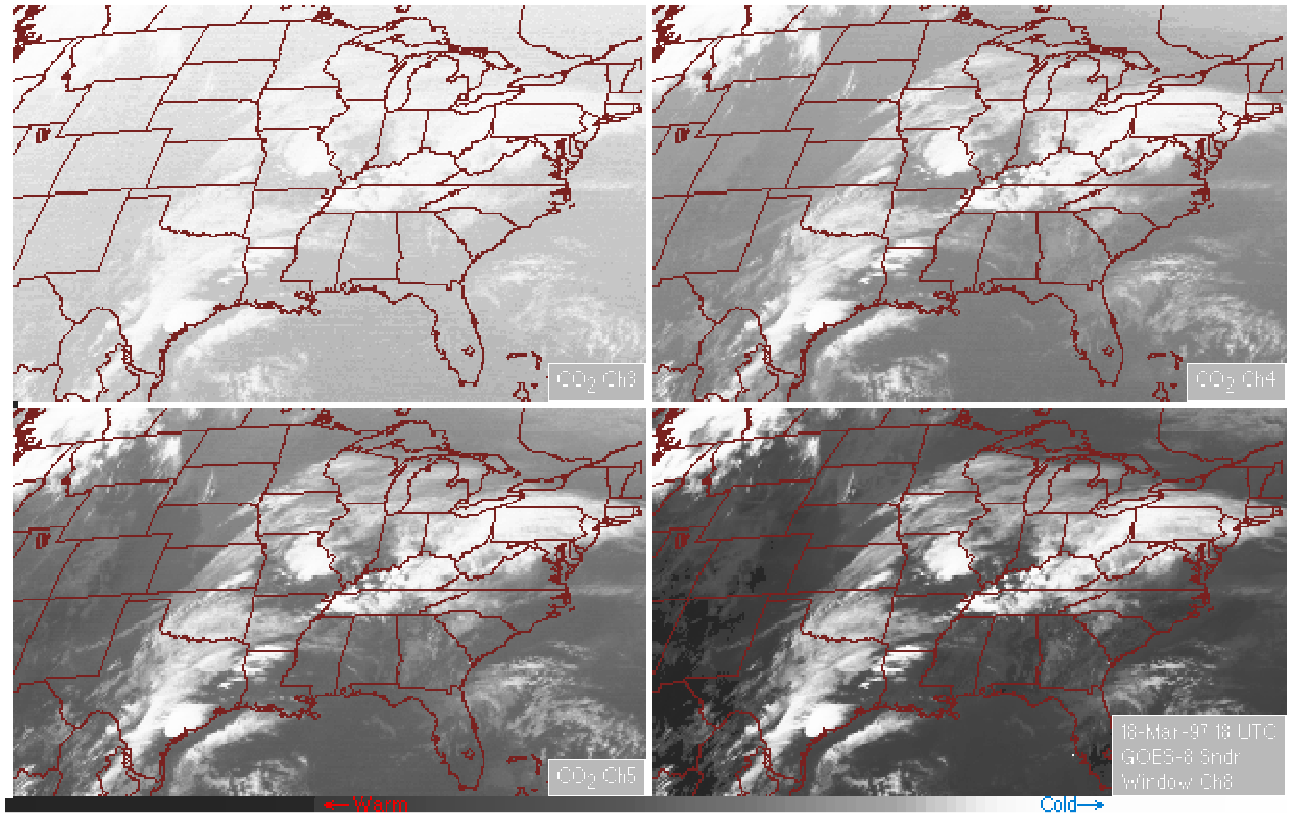


# Cloud top determination

**Methods used for the CM SAF datasets (still based on NWC SAF packages):**
**For semi-transparent clouds**: Alternative 1 (MSG)

Form quotas of radiances in two channels with different transmissivities –
the quota is a function of pressure in an atmosphere without temperature inversions
(called Radiance Ratioing or $CO_2$ slicing– only applicaple to MSG SEVIRI!)

**Sounding channel** *(only high clouds visible)*



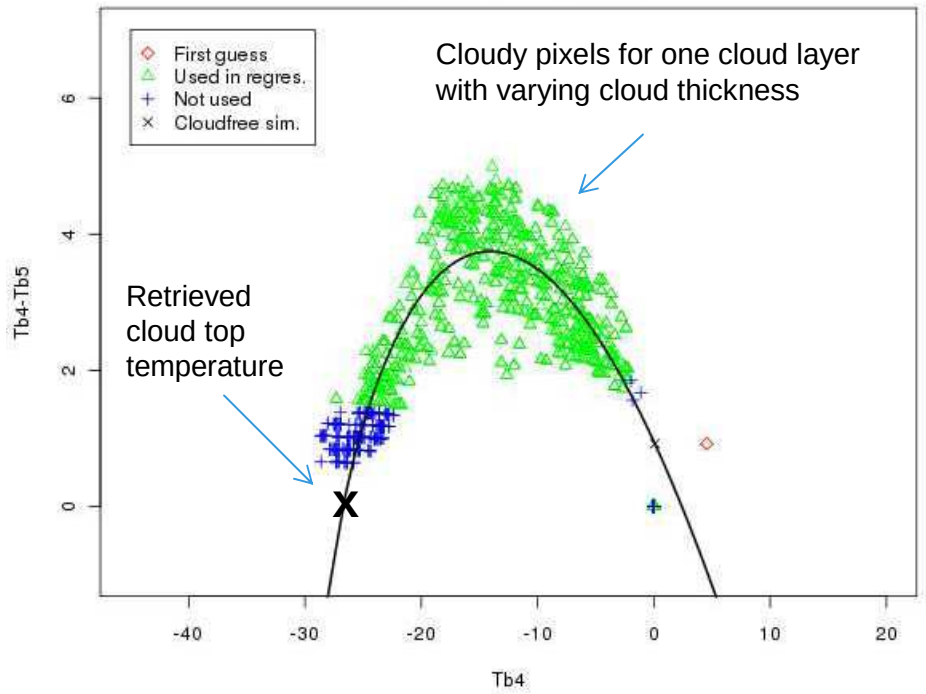

**Window channel** *('All' clouds visible)*

# Cloud top determination

**Methods used for the CM SAF datasets (still based on NWC SAF packages):**

**For semi-transparent clouds**: Alternative 2 (PPS)

Create plot of brightness temperature differences between 11 and 12 micron channels over a sub-segment of the image – then, fit an arch curve (polynomial) to find out the corresponding (opaque) cloud top temperature



# Cloud Physical Products (CPP)

**What can we say about cloud properties on the cloud particle scale?**

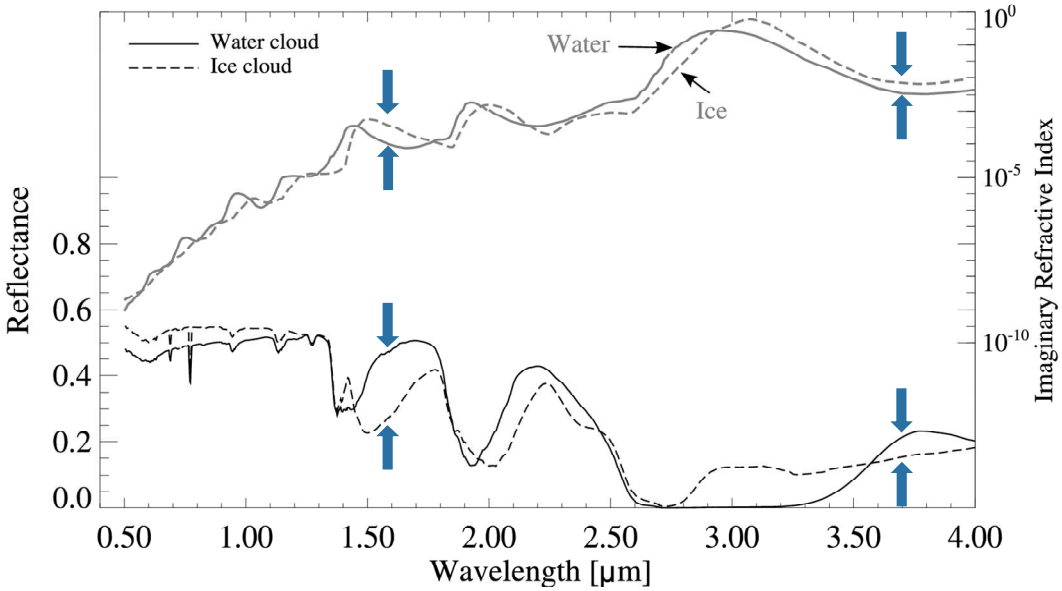
**CM SAF datasets include a set of cloud products that we call Cloud Physical Products (CPP). These are**

- Cloud Optical Thickness = *Integrated dimensionless extinction coefficient*
- Cloud Effective Radius = *'Average' particle size*
- Cloud Phase = *Liquid or frozen*
- Liquid Water Path = *Integrated liquid substance in* $kgm^{-2}$
- Ice Water Path = *Integrated ice substance in* $kgm^{-2}$

# Cloud Physical Products (CPP)

**Basic principles for CPP retrievals:**

- Reflectance of clouds at a non-absorbing wavelength in the visible region (VIS: 0.6 or 0.8 micron) is strongly related to the optical thickness
- Reflectance of clouds at an absorbing wavelength in the near-infrared region (NIR: 1.6 or 3.7 micron) is primarily related to particle effective radius
- Ice clouds absorb more (reflects less) radiation at NIR wavelengths

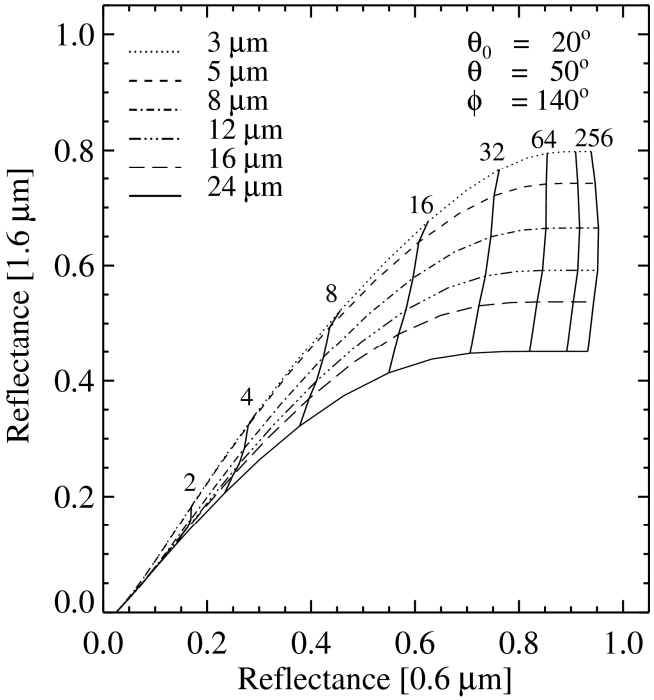


**Practical implementation: Search in lookup tables (LUT) with simulated radiances for water clouds (left) and ice clouds (right)**

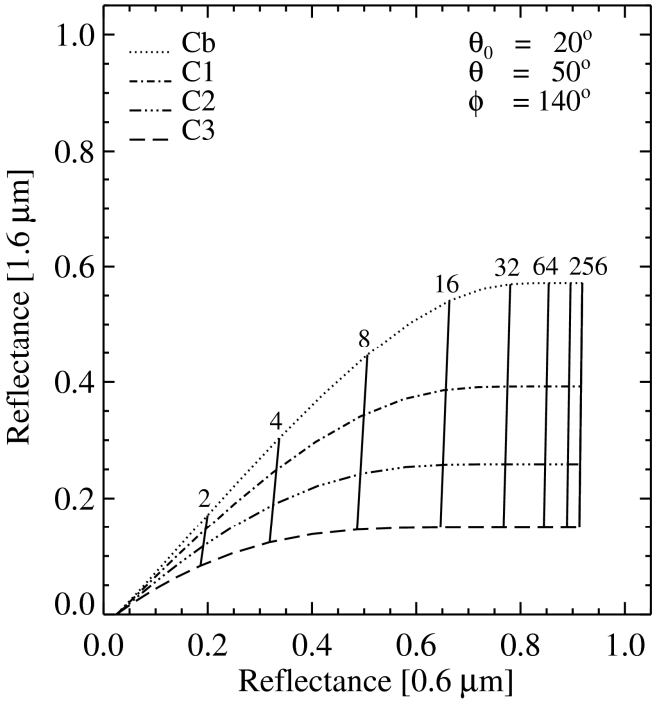
Curves show optical thickness values vertically and effective radii horizontally

Radiance transfer simulations made with DAK (Doubling-Adding KNMI model)

**Water clouds**

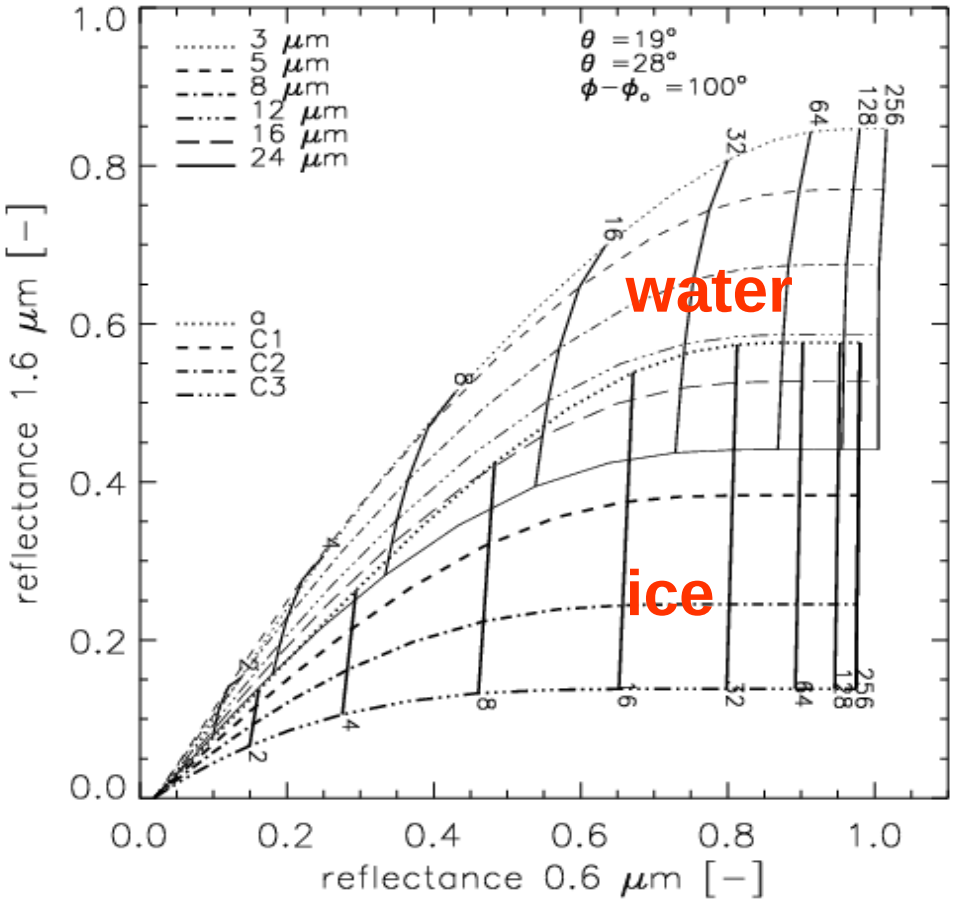



**Ice clouds**



**Strategy including method when simulations overlap:**

- Try both phases
- Use also cloud-top temperature (CTT) threshold



# Cloud Physical Products (CPP)



**Computation of liquid (*LWP)* or ice water (*IWP)* paths:**

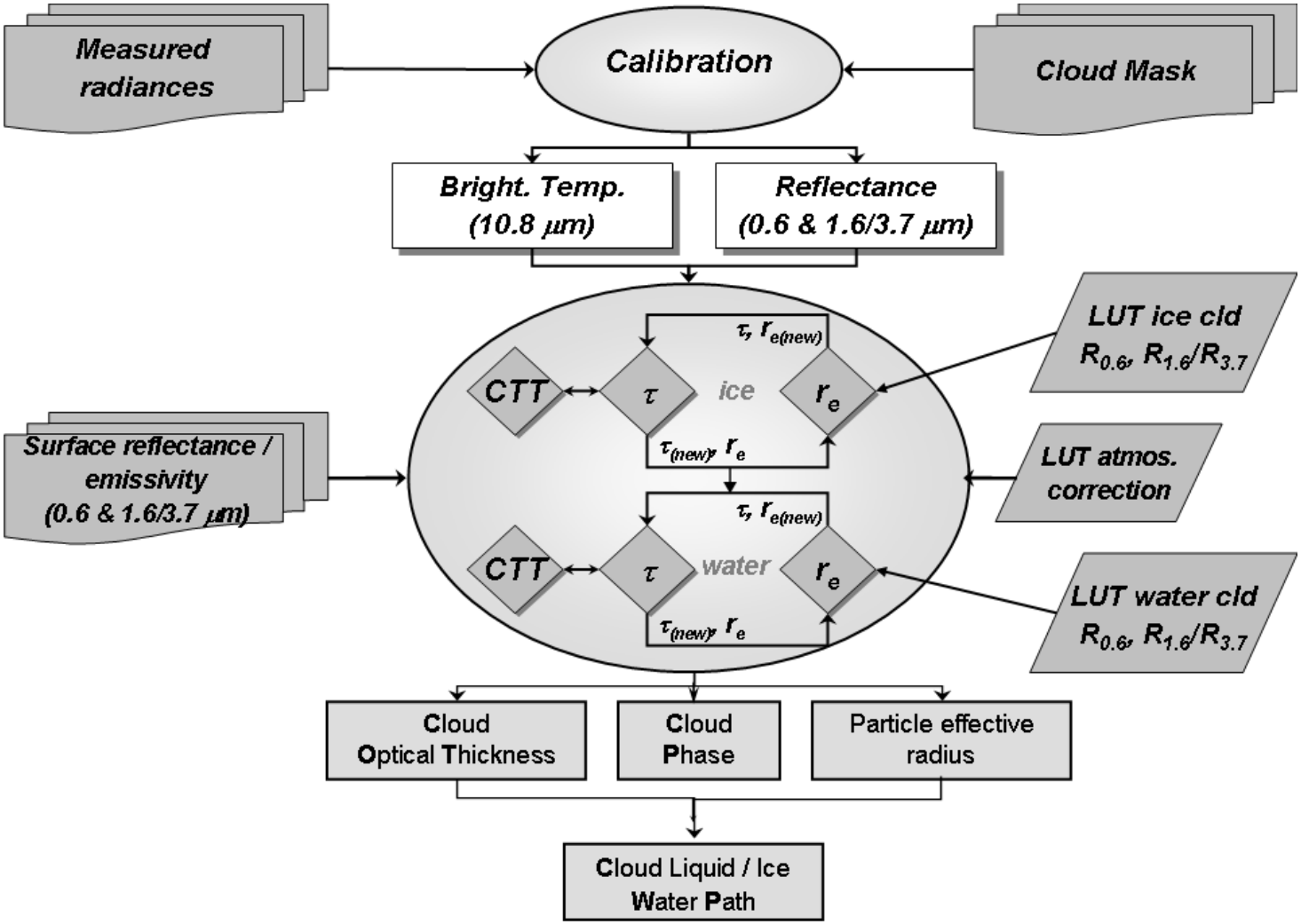
**Products derived from optical thickness $\tau$ and effective radius $r_e$ using the following parameterisation**

$$LWP / IWP = \frac{2}{3} \tau r_e \rho_{l/i}$$

**where $\rho$ is density.**

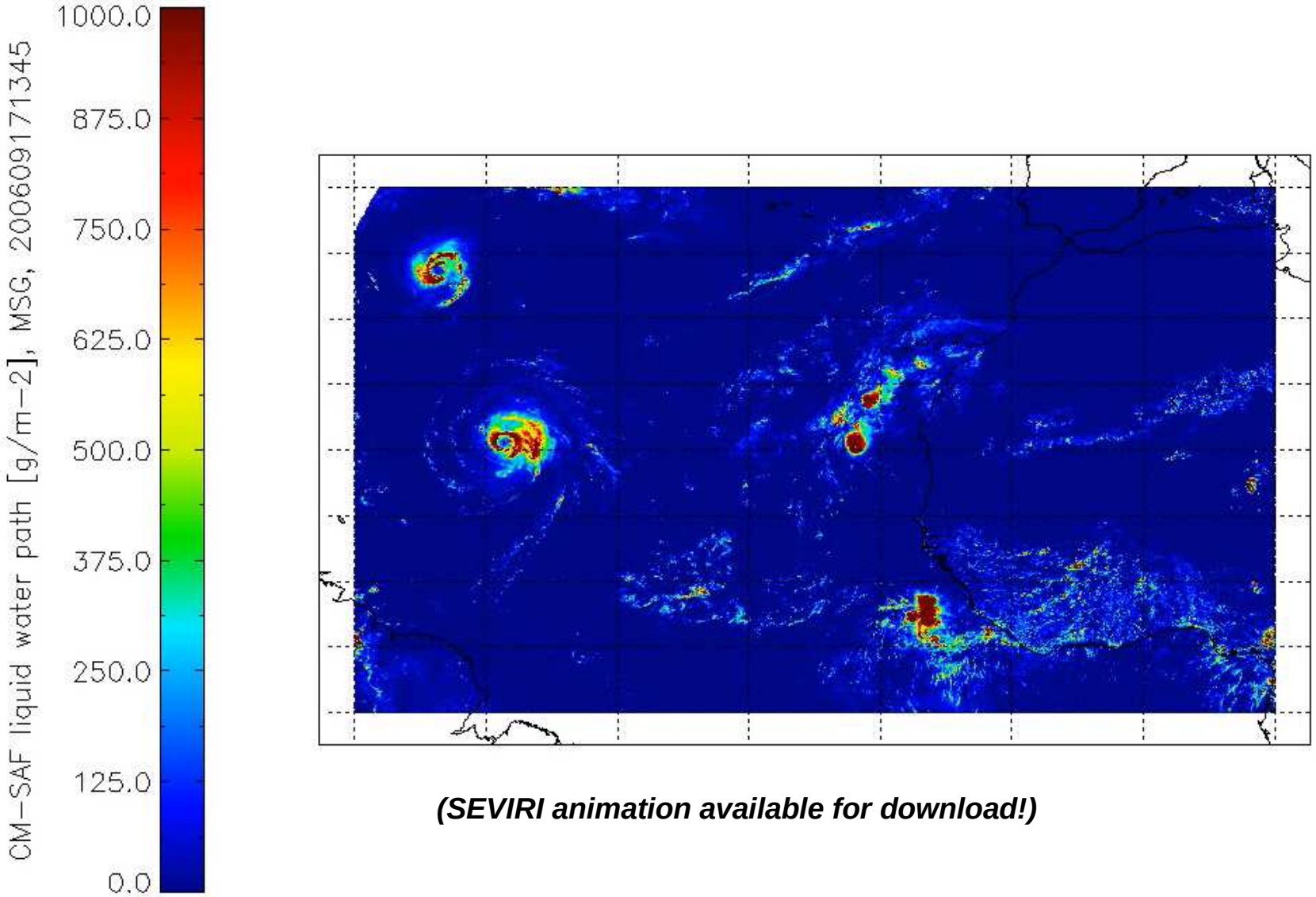
# Cloud Physical Products (CPP)

## Flow chart for CPP retrievals:



# Cloud Physical Products (CPP)

## Demonstration of liquid water path product (hurricane Helene Feb 2009):




***(SEVIRI animation available for download!)***

# Conclusions

**•Multispectral analysis of SEVIRI and AVHRR radiances allows efficient cloud detection and cloud type identification**

*- NWC SAF algorithms used by CM SAF*

*- Some problems at twilight and in cold winter situations*

**•Cloud top determination is more difficult and requires sophisticated methods heavily depending on radiative transfer calculations**

**•Deeper analysis of cloud properties on the microscale is possible by use of near-infrared and and short-wave infrared channels at 1.6 and 3.7 microns**

*- CM SAF relying on methods developed by KNMI*

# The end