Current capabilities for atmospheric monitoring

François-Marie Bréon

Laboratoire des Sciences du Climat et de l'Environnement

CEA-CNRS-UVSQ

What I understood…

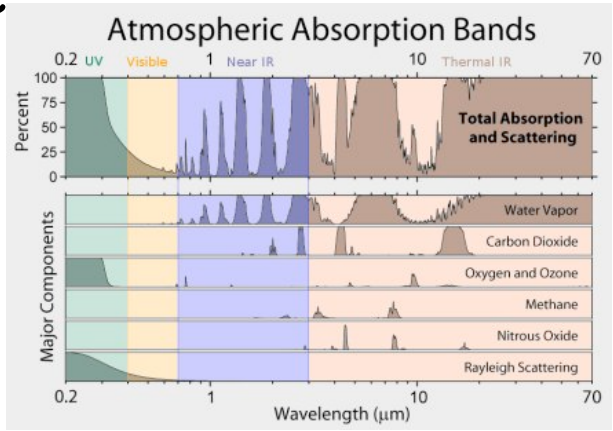
- High energy particles generate fluorescence and Cherenkov light
- This light propagates through the atmosphere
- It is then measured by ground detectors
- One seeks information about the high energy particles from the characteristics of the Cherenkov light.
- The characteristics of atmospheric radiative transfer must be know precisely.
- Cherenkov light is in the visible spectral domain, with a dominance of short wavelength (blue)
- The processes to consider are
    - Absorption (gases)
    - Scattering (molecules and aerosols)
- Accuracy requirements ?

Atmospheric radiative transfer

In the visible and near UV part of the spectrum…

Very little absorption

- Ozone (Chappuis bands). A few percent of absorption, but mostly in stratosphere
- NO_2. Small but maximum in the blue
- Oxygen A-band around 765 nm



Significant scattering

- Molecules. Function of air density. Varies as λ^{-4}
- Water droplets (i.e. clouds). Large, spectrally neutral
- Aerosols. Highly variable in space, time, altitude and scattering properties

Presentation objectives

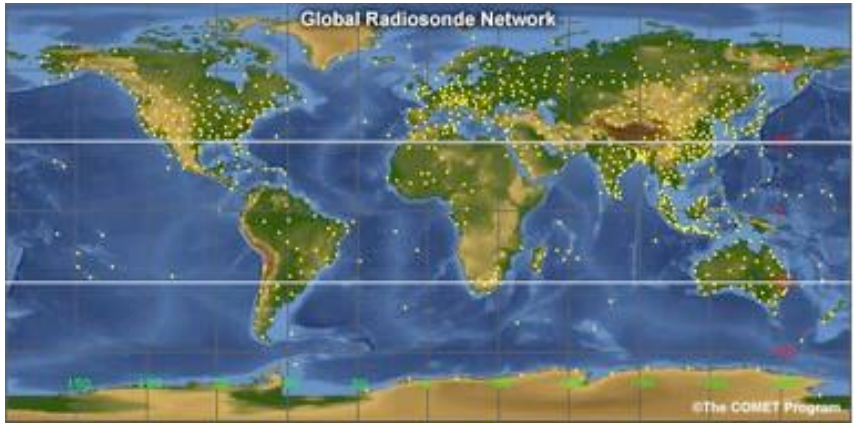
Describe the currently available observations of the Earth atmosphere that may be of interest to your community

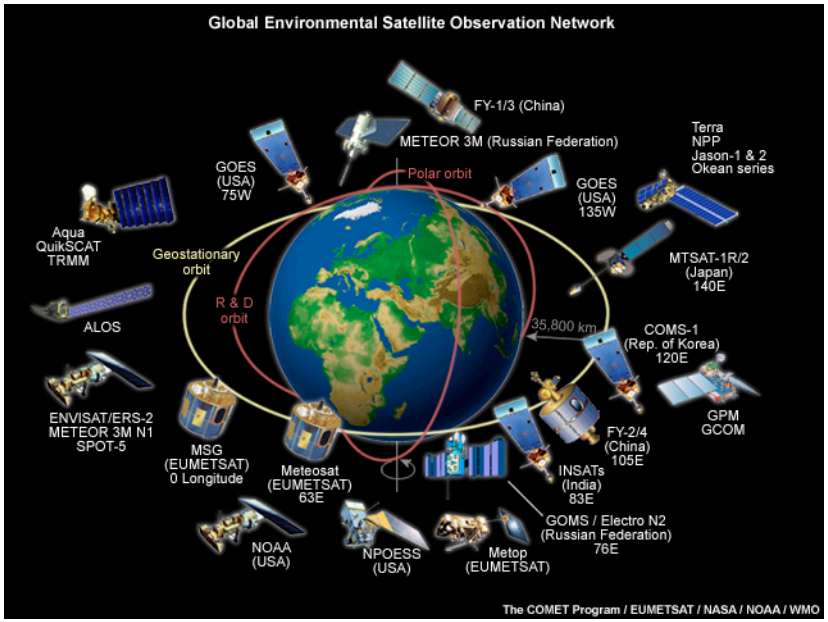
- Temperature (density) profile of the atmosphere, from the surface and by satellite
- Cloud cover and cloud parameters by satellite
- Aerosol extinction profile by ground-based Lidar
- Aerosol extinction profile by spaceborne Lidar
- Aerosol scattering properties

- + Climate change prospects

Temperature (density) profile

In-situ measurements by a network of ≈1300 stations with twice daily sounding

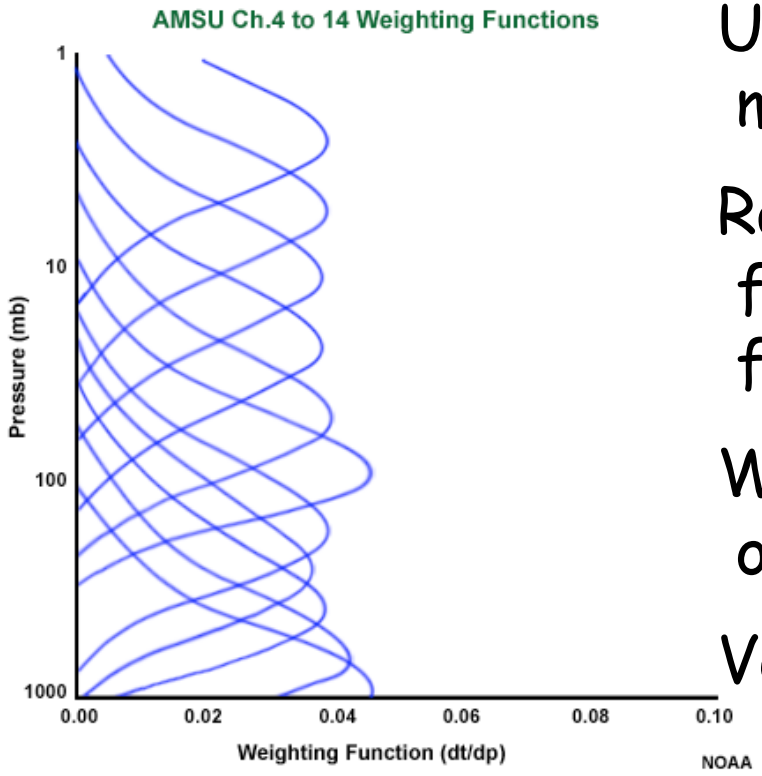




Completed by spaceborne observations

Both in-situ and satellite observations are assimilated by Numerical Weather Prediction systems. In Europe, ECMWF

Satellite Temperature sounding



Uses thermal IR (5-20 mm) or microwaves (20-200 GHz)

Radiance at satellite equals to Planck function T(z) convolved with weighting function w(z)

Weighting function depends primarily on measurement wavelength

Vertical resolution is a few km

Thermal IR offers much better vertical resolution BUT is affected by clouds

Although temperature profile can be derived from the measurements, NWP assimilates directly radiances

ECMWF assimilated fields

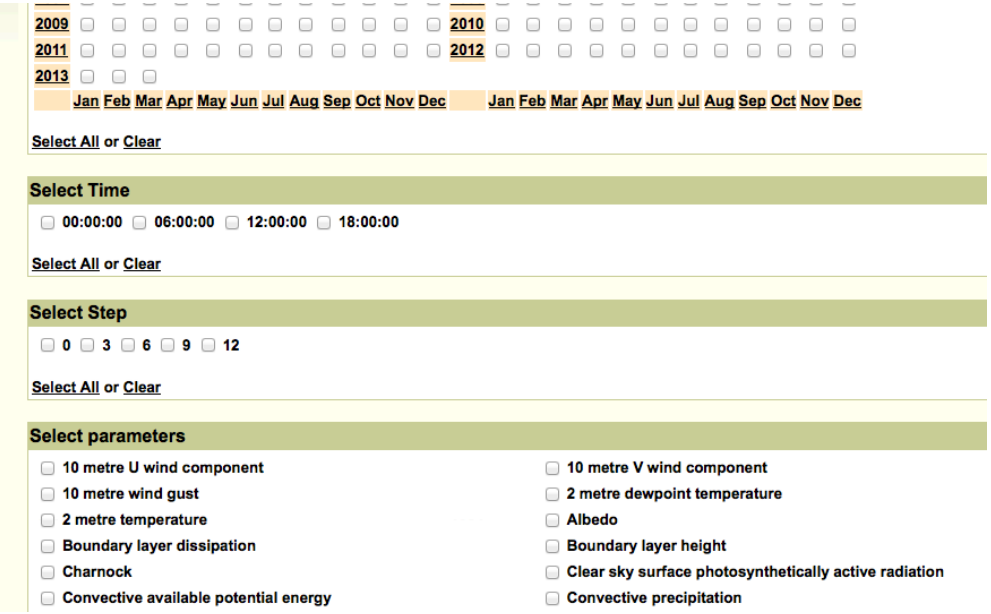
The European Center for Medium-Range Weather forecast assimilates a large number of in-situ and remotely sensed observations

These observations, together with a model of atmospheric dynamics, generate fields of atmospheric variables.

Vertical resolved on 137 levels from surface to 0.01 hPa.

Some products are available on a public server. Other products need registration. Fairly easy for research purposes.

http://data-portal.ecmwf.int/data/d/interim_full_daily/



Cloud Cover: Daily

Clouds are easy to observe by satellites, either from their high reflectance (day only) or their cold temperature.

Difficult situations are low clouds during the night

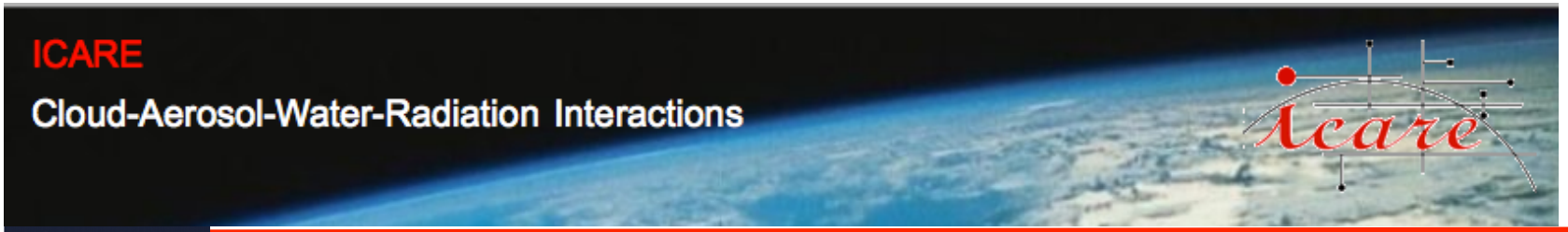
Best product for global coverage is from the MODIS instrument.

Cloud cover available twice daily, near global scale, 1 km resolution.

MOD35 : Cloud mask product

MOD06 : Various cloud parameters

Data available from NASA. In France, from the ICARE thematic center



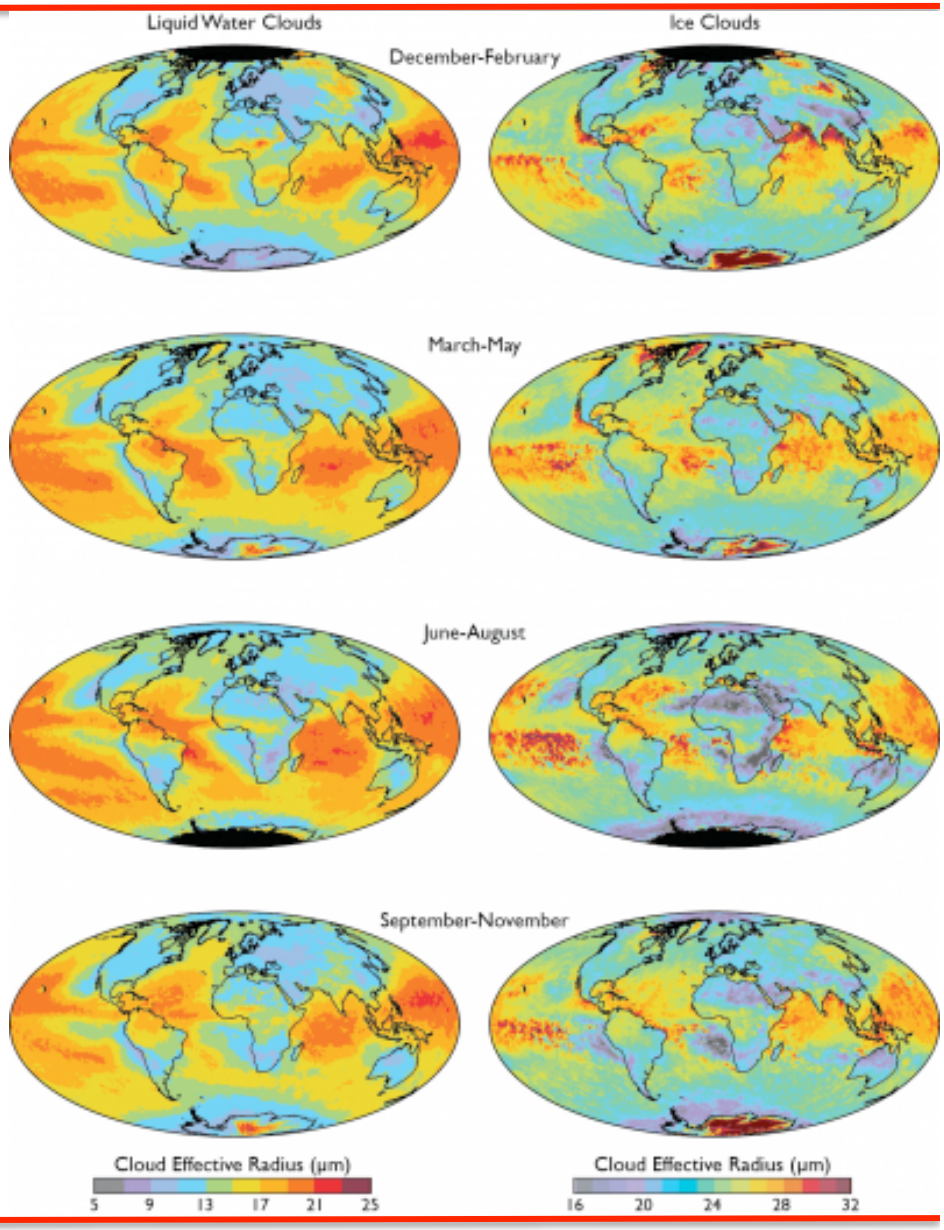
Cloud Cover: Climatologies

Several monthly averages of cloud cover have been developed

MOD08 : Monthly statistics of cloud parameters derived from MODIS observations.

Cloud cover, optical depth, phase, height, temperature…

Clearly, all sites are not equal in term of cloud cover



Aerosols. Intro (1/2)

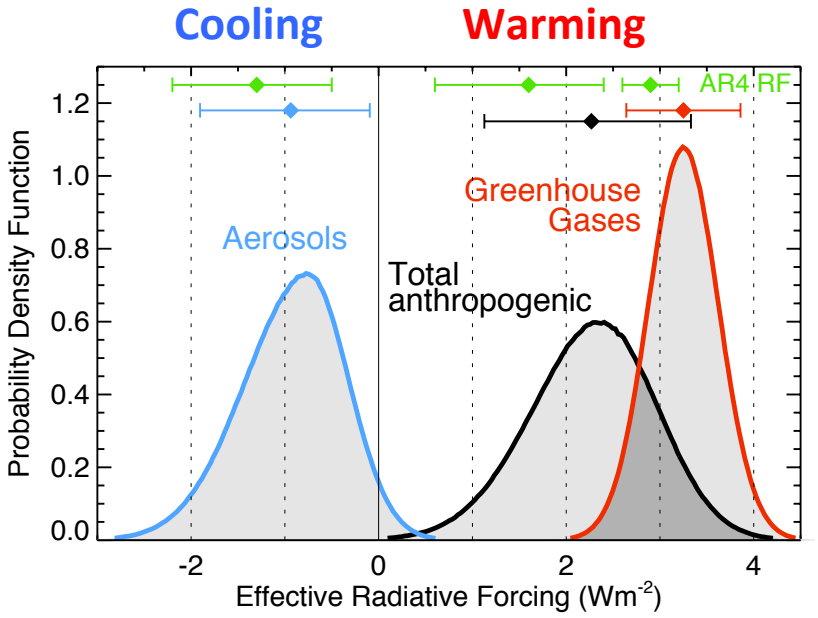
Aerosols are all solid or liquid particles, in suspension in the atmosphere, except for clouds (water). Some are natural, some are generated by anthropogenic activities.
Short atmospheric lifetime (≈ a week)
VERY variable in space and time

Aerosols. Intro (2/2)

Aerosols are important for climate because

- They scatter sunlight back to space (cooling effect)
- Some (Black Carbon) absorb sunlight (warming effect)
- They have an impact on cloud microphysics and life cycle (Cooling, but very uncertain)

The aerosols generated by human activities compensate partly warming by greenhouse gases. The quantification of the effect (very likely cooling) is still very uncertain



Anthropogenic forcing on climate

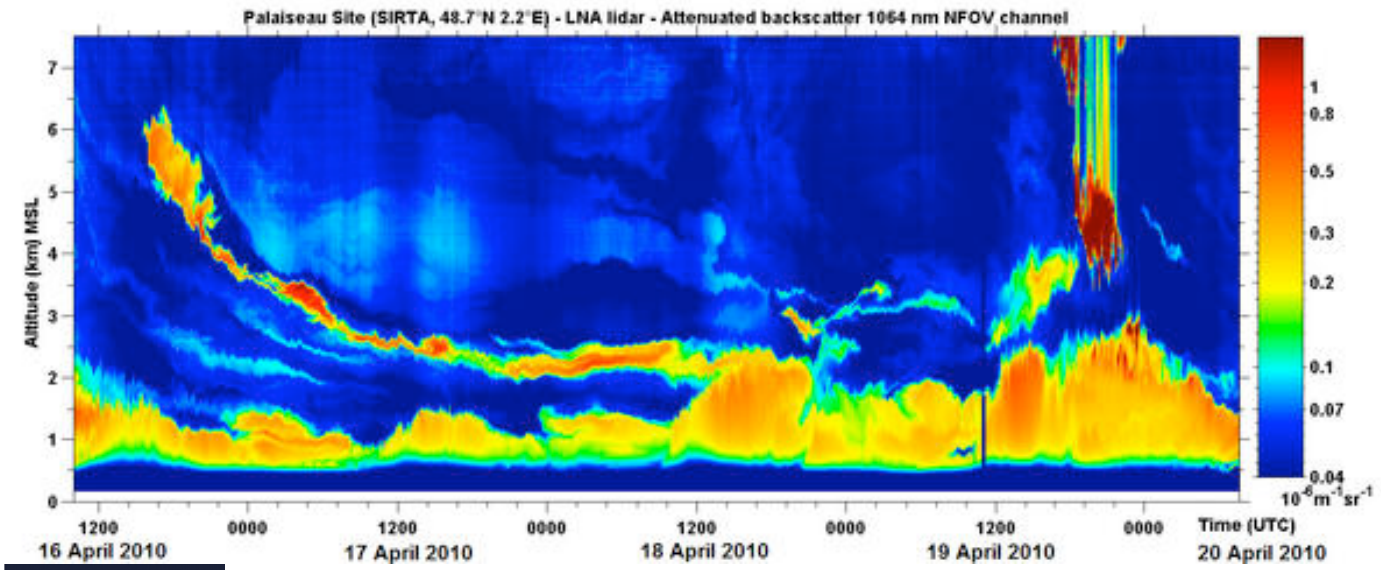
Ground-based lidar observations

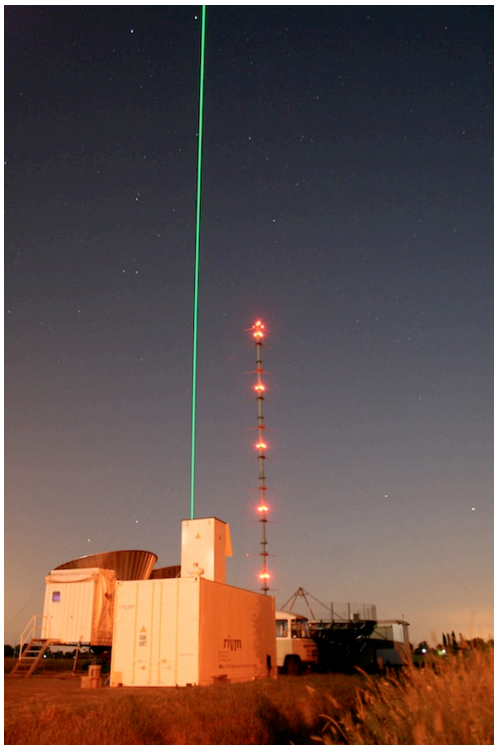
Ground-based lidars are well suited to monitor the vertical and temporal distribution of aerosols.

Very operational products. In Europe, 27 sites form the European Aerosol Research Lidar Network (EARLINET)

Works (best) at night

Provides extinction and backscatter

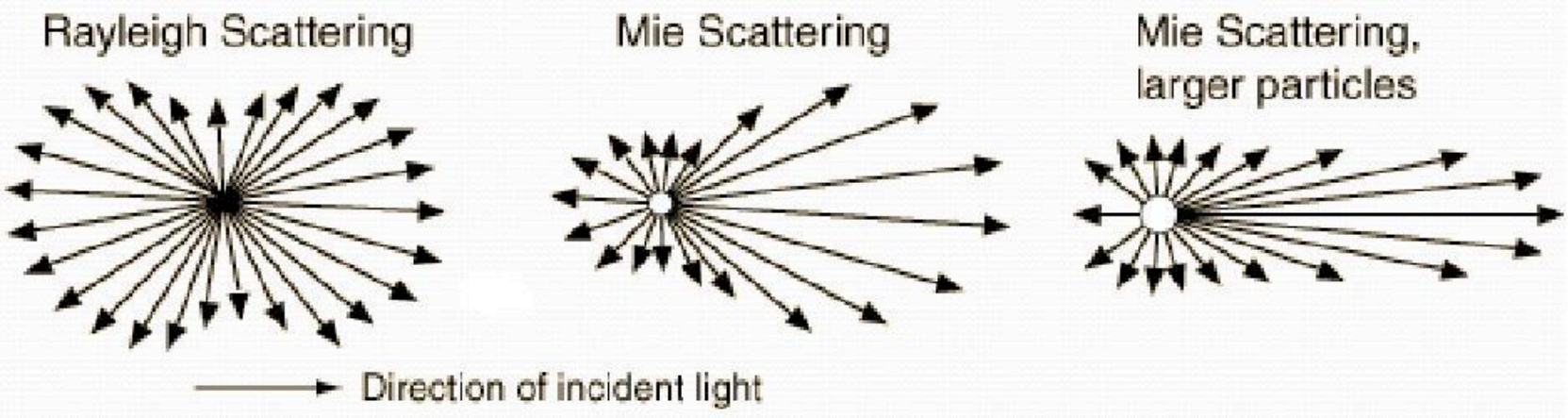




Ground based Lidar : limitations

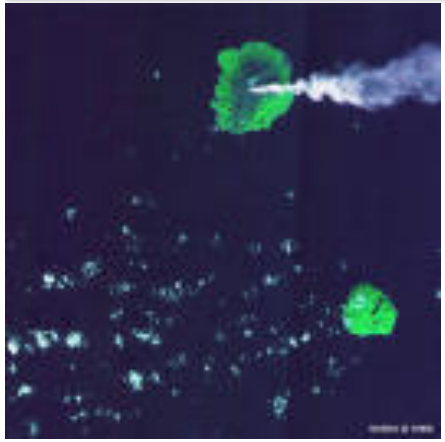
Ground based lidar appear well suited for your purposes

BUT : No (little) information on the scattering characteristics of the aerosol

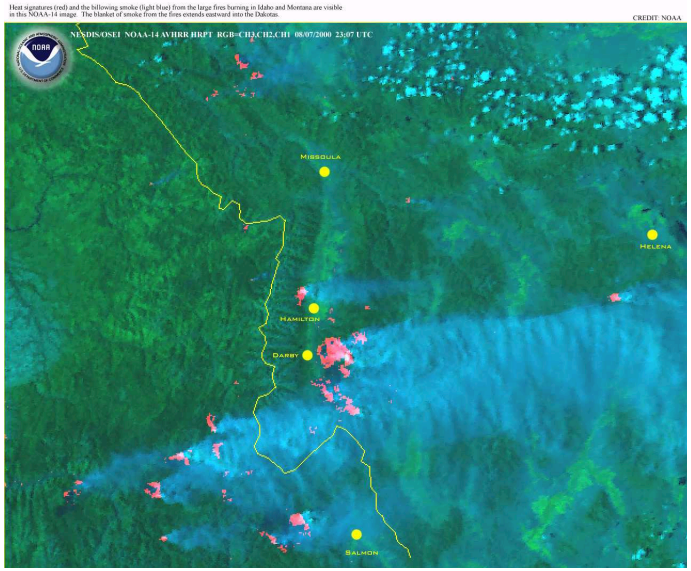


Also, many lidar are single wavelength. One may need several channels to get the spectral variations

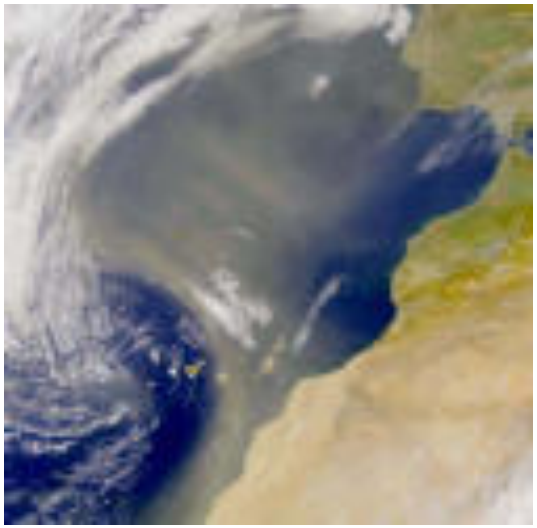
Aerosol plumes from space



Volcano (Japan)



Forest Fire Smoke (Amazone)

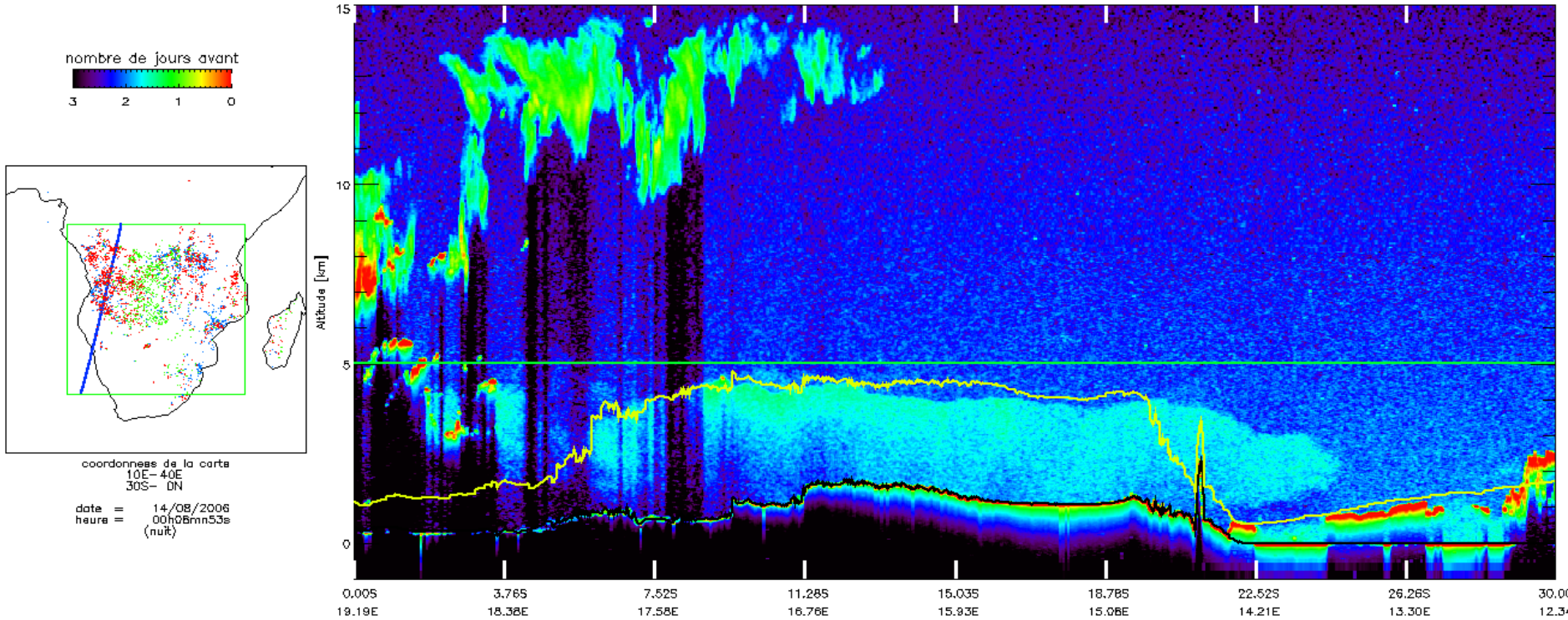


Desert Dust
(Sahara)

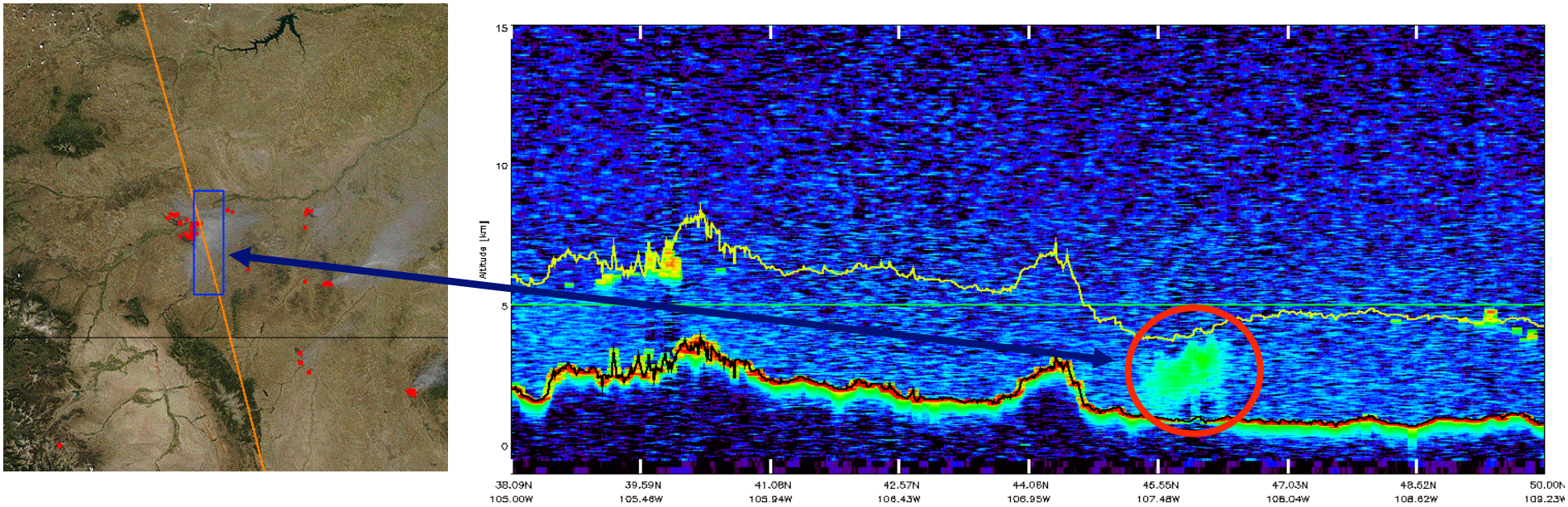
Satellite observation is well suited to monitor atmospheric aerosol sources and transport

Lidar in space

Active Sensing provide the expected information on aerosol vertical distribution
Calipso (NASA/CNES) was launched in 2006
Part of the A-Train series of satellites



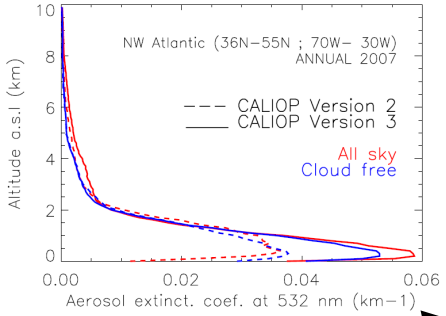
Biomass burning plumes

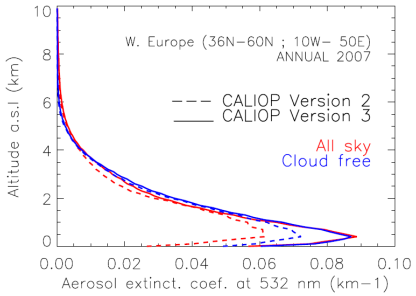


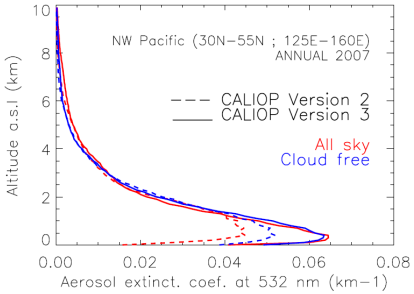
CALIPSO is a great tool to observe dense aerosol plumes

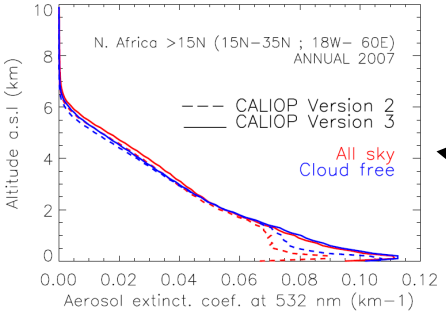
Useful in particular for injection height analysis

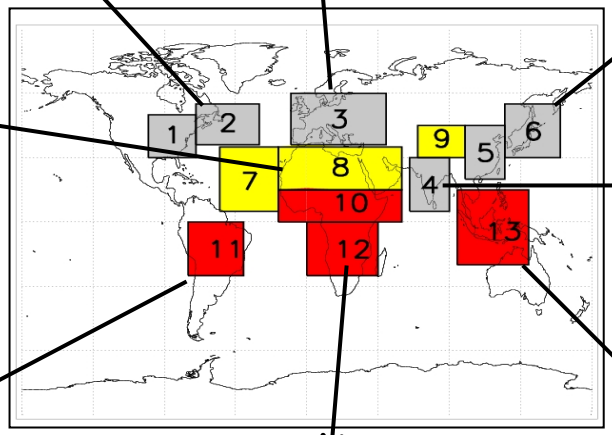
Mean Vertical Profiles

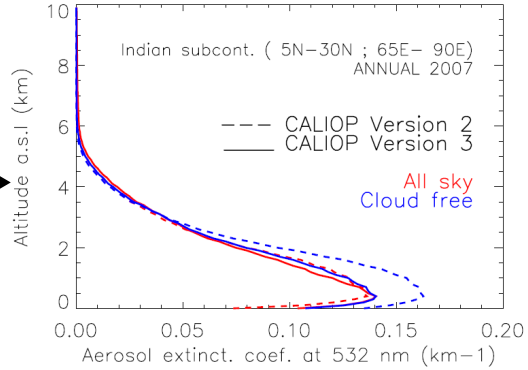


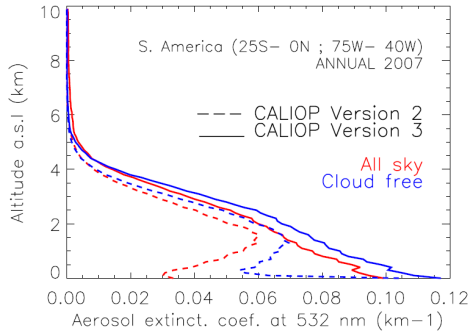


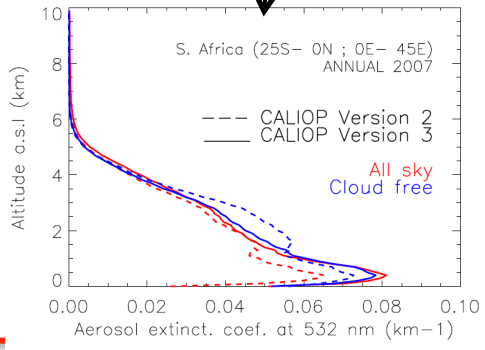


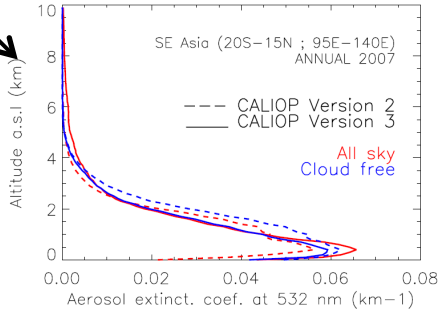












Koffi et al. 2010

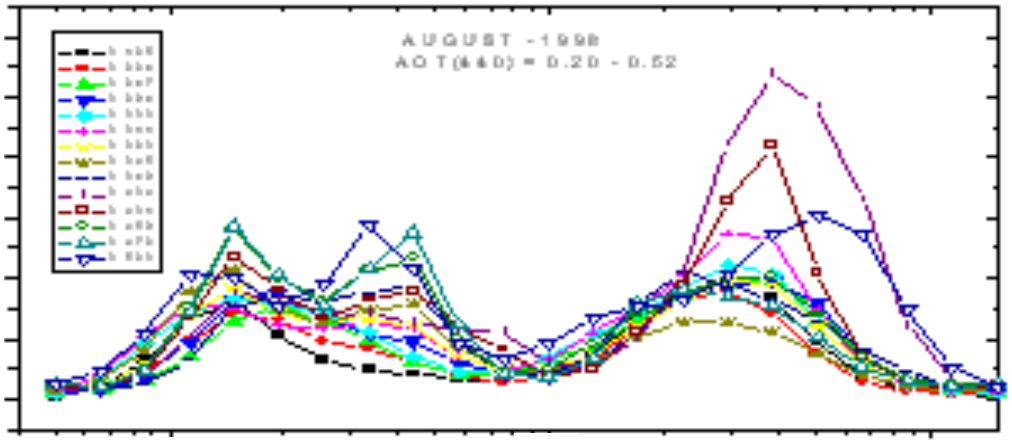
Sunphotometer measurements

A sunphotometer aims at the sun and measures the direct sunlight.

The sunlight is attenuated as a function of the optical thickness. It provides a near-direct measurement of the AOD $\tau(\lambda)$

The spectral variation of $\tau(\lambda)$ can be used to derive the fraction of large and small particles.

Sky radiance measurements are used to estimate the size distribution



Aerosols distribution have a "fine mode" and a "coarse mode"

Sky radiance measurements

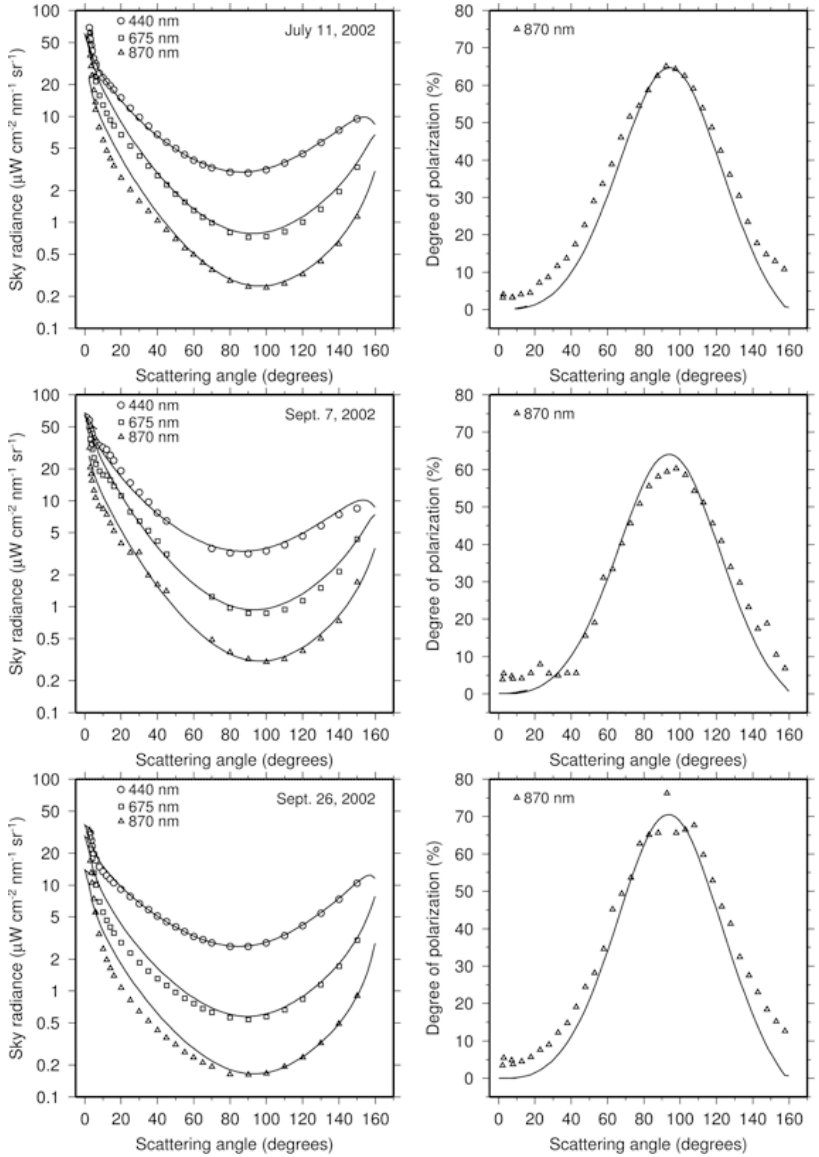
The aerosol scattering phase function is necessary to properly model the radiative transfer

Very variable with aerosol size distribution and composition (and shape)

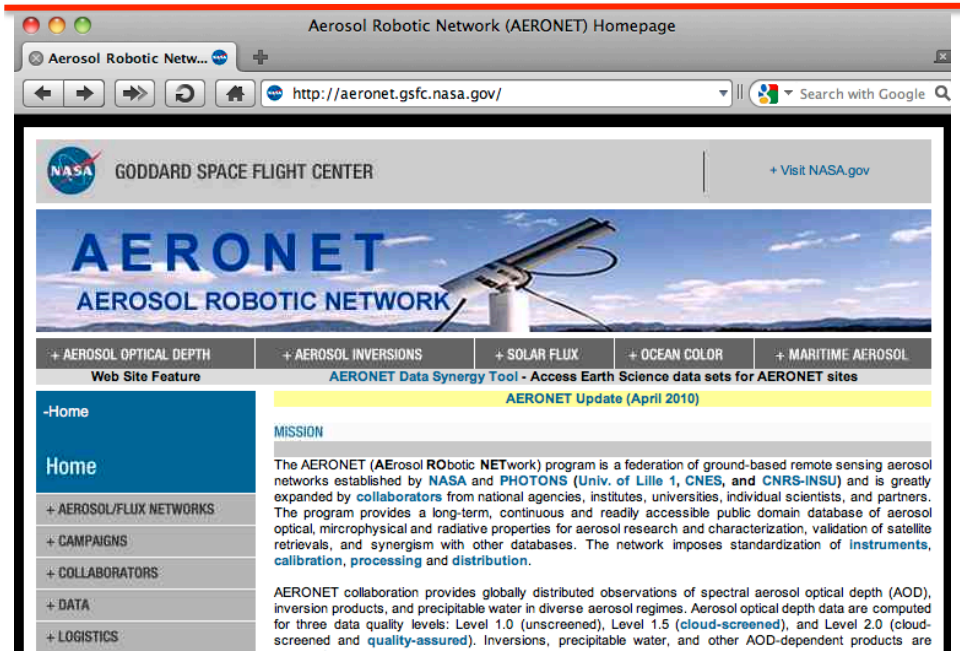
In "sky" mode, the sunphotometer measures the sunlight scattered by the atmosphere as a function of the scattering angle.

Polarization information is also available

Problem : Only during day-time



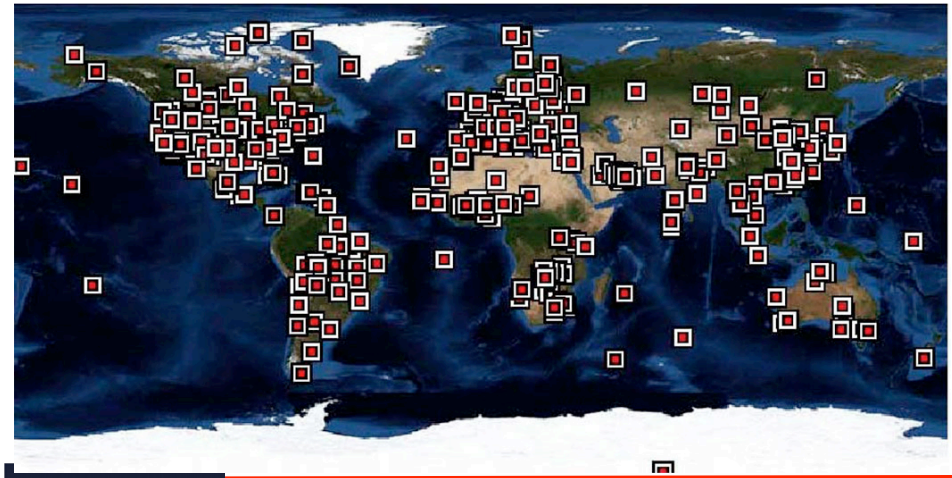
Aeronet



Sunphotomer measurements are standardized and freely accessible through AERONET.

200+ sites

It is an impressive achievement of international collaboration among researchers with the help of funding agencies



Polarization ?

Depending on the accuracy requirements, it may be necessary to account for polarization in the atmospheric radiative transfer

Any reason that Cherenkov light might be polarized ?

Spaceborne observations by the POLDER instrument led to better insight on the polarization properties of atmospheric aerosols

Climate Change

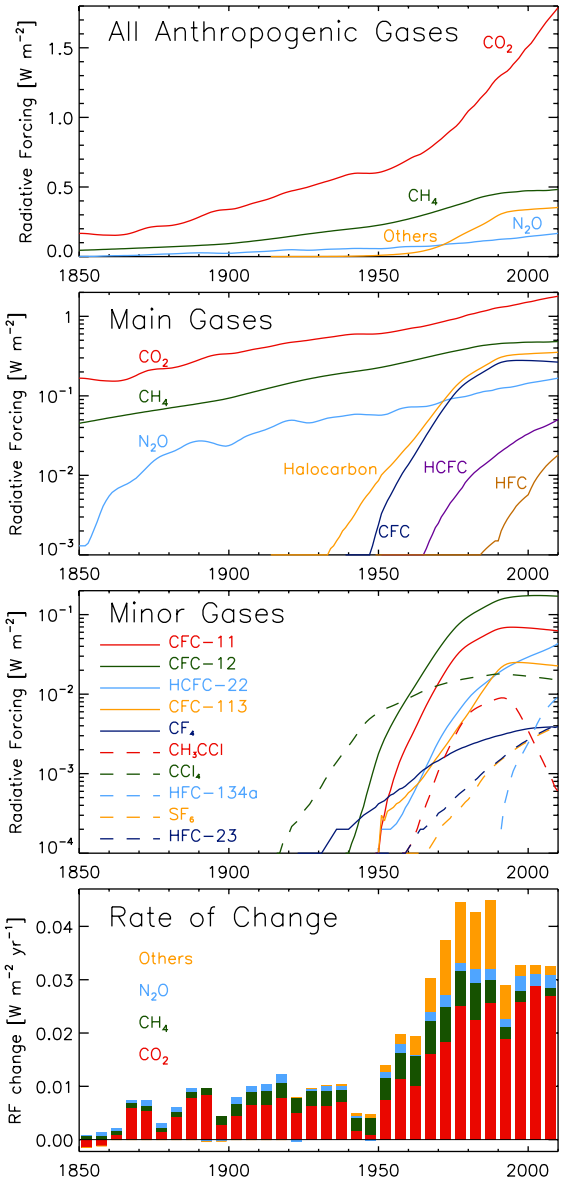
Climate change is ongoing

There is a rapid increase of greenhouse gases concentrations (CO_2, CH_4, N_2O) fuelled by anthropogenic emissions

Temperature increase is virtually certain (i.e. all model agree)

The impact on cloud cover, precipitation and extreme events is very uncertain (i.e. different models say different things)

No reliable prediction to select an observing site (avoid coastlines)



Recommendation…

From what I have understood, I believe one needs

- Access to temperature profiles either from radiosonde or numerical weather analysis
- Ground based lidar for cloud coverage + Optical depth and vertical distribution of the aerosol
- Sunphotometer for a full characterization of the aerosols. Only works during the day. Aerosol characteristics may be extrapolated from day to night