IMAA activities on the study of clouds

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CIAO scientific mission

"Ground-based profiling of aerosol and cloud properties (and their interactions) over long term"

Main research lines currently active at CIAO

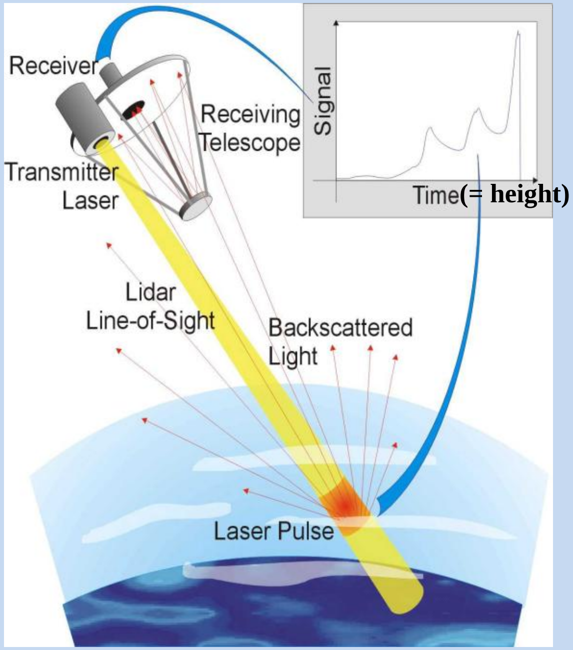
1) design and implementation of lidar systems for aerosol, water vapour and cloud measurements;
2) development of algorithms for the integration of lidar and microwave radiometer measurements;
3) definition of measurement protocols, quality assurance programmes and data managing strategies;
4) definition of a suitable strategy for the satellite CAL/VAL;
5) analysis of the physical and dynamical processes related to aerosol transport, their modification and classification;
6) analysis and physical interpretation of observations provided by both active and passive sensors for the study of aerosol-cloud interactions and nucleation processes;
7) organization and participation in measurement campaigns;
8) development of methods for the evaluation of aerosol transport and mesoscale weather prediction models;

CIAO equipment and mobile facilities

- 2 fixed/mobile multi-wavelength Raman lidar systems (EARLINET)
- 1 Ka-band polarimetric Doppler radar (METEK MIRA-36)
- 1 Microwave profiler 12 channels (Radiometrics MP3014)
- 3 manual/automatic radiosounding stations designed for Vaisala RS92-SGP sonde (P, T, RH, O_3 and wind profiles)
- 1 CIMEL sunphotometer (AERONET)
- 2 Ceilometers (Jenoptik CHM15k, VAISALA CT25K)
- Automatic surface radiation station (2 Pyranometers, 1 pyrgeometer, 1 perieliometer)
- GPS antenna/receiver (IWV)

Lidar and radar

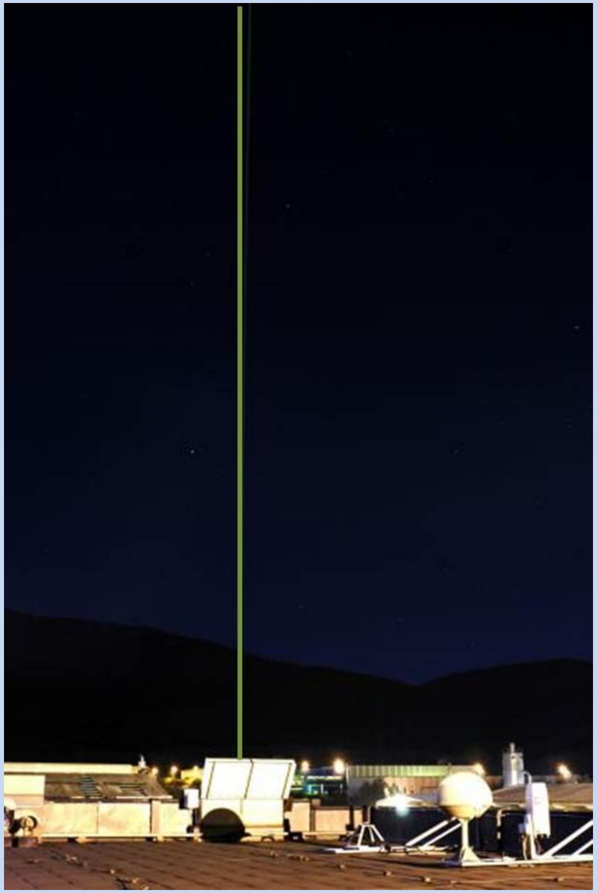
Lidar (**li**ght **d**etection **a**nd **r**anging) and **radar** (**ra**dio **d**etection **a**nd **r**anging) are two active remote sensing techniques which allow to obtain the vertical profiles of the properties of atmospheric constituents, such as aerosols, water vapor and clouds, with high vertical and temporal resolution. They can employ ground-based or satellite sensors



The lidar transmits and receives light pulses (λ = 250 ÷ 1100nm), which are strongly attenuated by clouds, while the radar transmits and receives microwave pulses (λ = 1 ÷ 100mm) which can pass through clouds. So, unlike the lidar, the radar can work in presence of dense clouds and bad weather conditions.

The lidar is mostly sensitive to particles smaller than 50 μm, such as aerosols and the finest water droplets (drizzle), while the radar is mostly sensitive to larger particles, such as water drops and ice crystals forming the clouds.

Instruments



Multi-wavelength Raman lidar

Ka-band Doppler polarimetric radar

Transmission/Detection: ν = 35.5GHz , λ=8.45mm

Transmission: 355 ,532 and 1064nm
Detection: 355 ,532 and 1064nm (elastic backscattering)
387 and 607nm (Raman backscattering from N_2)
407nm (Raman backscattering from H_2O)

Microwave profiler

<u>passive remote sensing instrument</u>: riceives the microwave radiation naturally emitted from the atmosphere at 12 frequencies:

- 5 frequencies in K-band around 22 GHz (water vapour resonance band): 22.235, 23.0335, 23.835, 26.235, 30.000 GHz

- 7 frequencies in V-band around 60 GHz (spyn-rotation oxygen band): 51.250, 52.280, 53.850, 54.940, 56.660, 57.290, 58.800 GHz

<u>Output products</u>: Temperature, water vapour, relative humidity and cloud liquid water profiles up to 10 km above the ground (vertical resolution: 100 m from 0 to 1 km, 250 m above)

<u>Ancillary parameters</u>: Cloud base temperature measured using an infrared thermometer (IRT) and surface meteorological parameters (T, RH, p)

Lidar products

From lidar signals , properly processed , we can obtain the vertical profiles of:

1) **aerosol optical properties :**

   - *exctintion/backscattering coefficient* (α / β) directly dependent on the concentration of aerosol particles (the higher the concentration, the higher the coefficient)
   - *lidar ratio* *LR = α/β* which gives information about the type of aerosol particles
   - *particle depolarization ratio (at 532nm)* which gives information about the shape of aerosol particles or their level of asphericity
   - *Angstrom exponents* which indicate how α and β vary with wavelength. The Angström exponents are inversely related to the average size of the particles in aerosol (the smaller the particles, the higher the exponents)

2) **water vapor content in the atmosphere:**
   - *water vapor mixing ratio* WVMR
   - *relative humidity* RH

Radar products

From radar signals , properly processed, we can obtain the vertical profiles of:

- **Radar reflectivity factor Ze** which is directly related to the concentration and size of cloud constituents (water droplets and ice crystals)
- **Linear Depolarization Ratio (LDR)** which gives information about the shape of cloud particles
- **Doppler velocity** that is the vertical velocity of cloud particles, which gives information also about the weight and size of cloud particles

Lidar-Radar-Microwave profiler synergy

- Radar and lidar are complementary due to their very different dependence on particle size; this means that the combination of the two offers the most accurate estimates of cloud properties

- From radar reflectivity factor measurements, supported by lidar and microwave radiometer measurements, it is possible to obtain (Cloudnet algorithms):

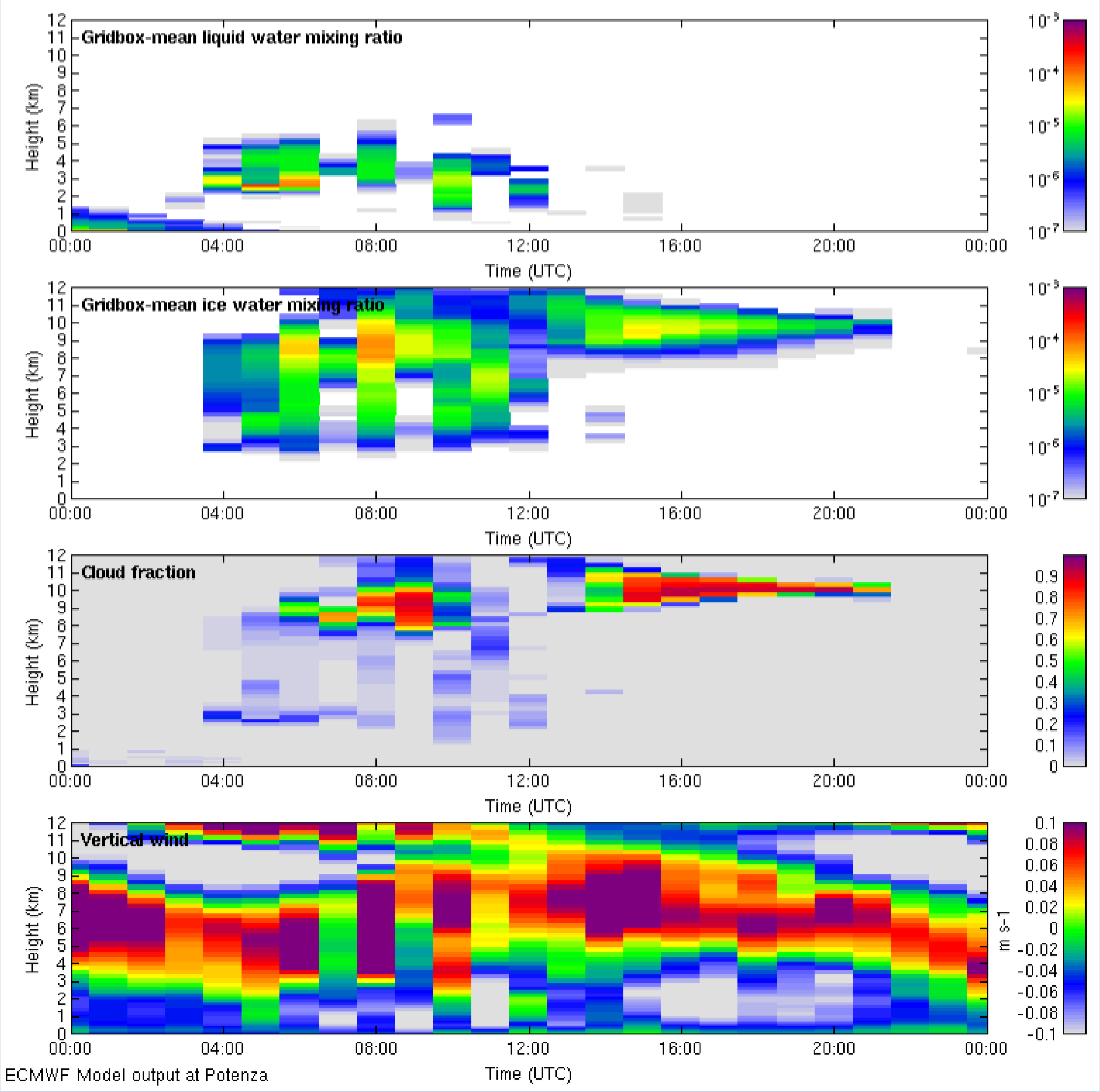
  - **cloud geometrical depth (cloud base and top)**

and the vertical profiles of:

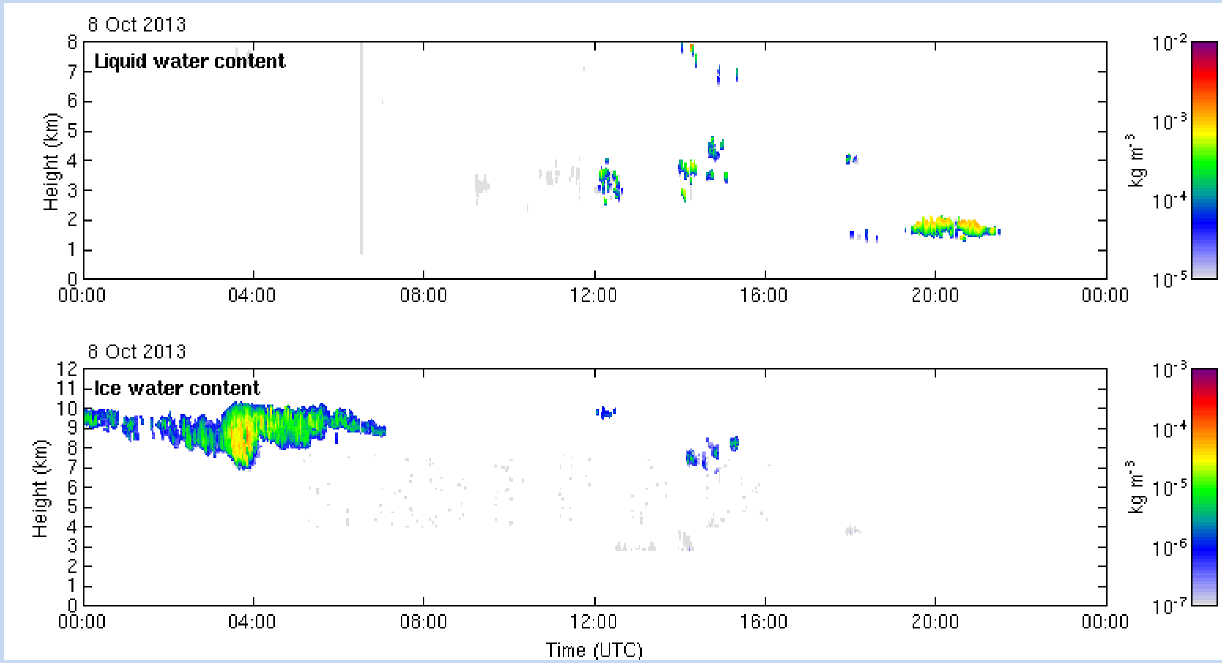
- **Liquid Water Content/mixing ratio in clouds** which is the mass of liquid water per unit volume/mass in clouds
- **Ice Water Content/mixing ratio in clouds** which is the mass of ice water per unit volume/mass in clouds
- **Effective radius** which is the average radius of cloud particles

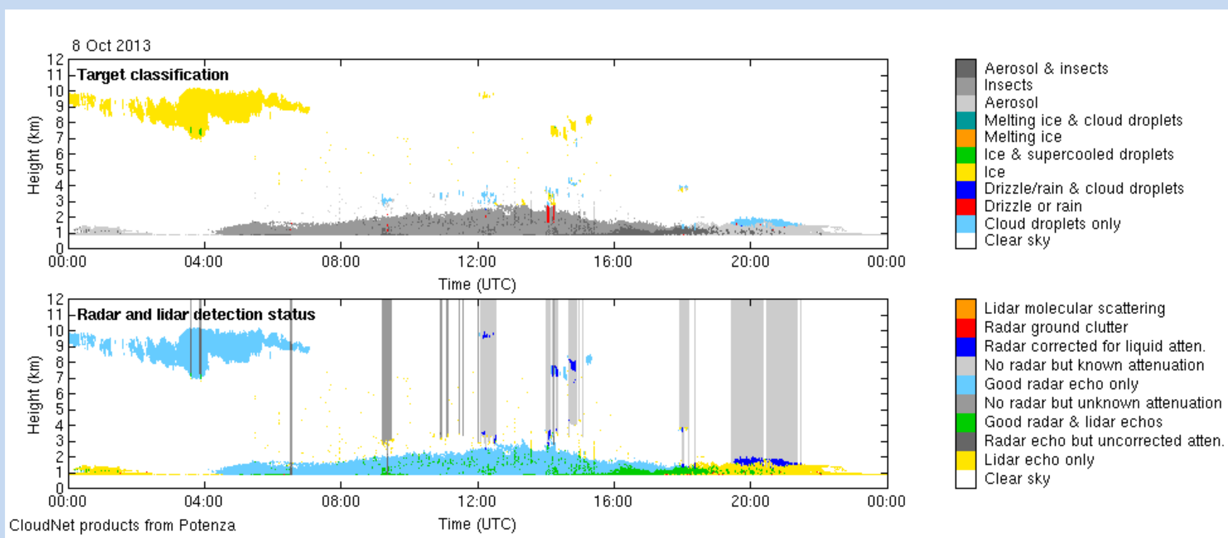
Cloudnet model data in Potenza

12 October 2013



Cloudnet products in Potenza

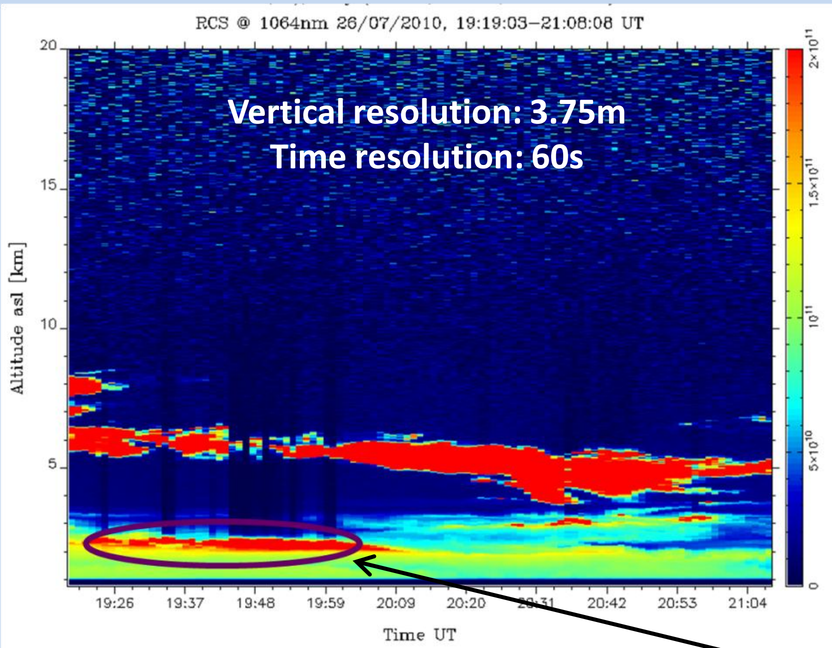


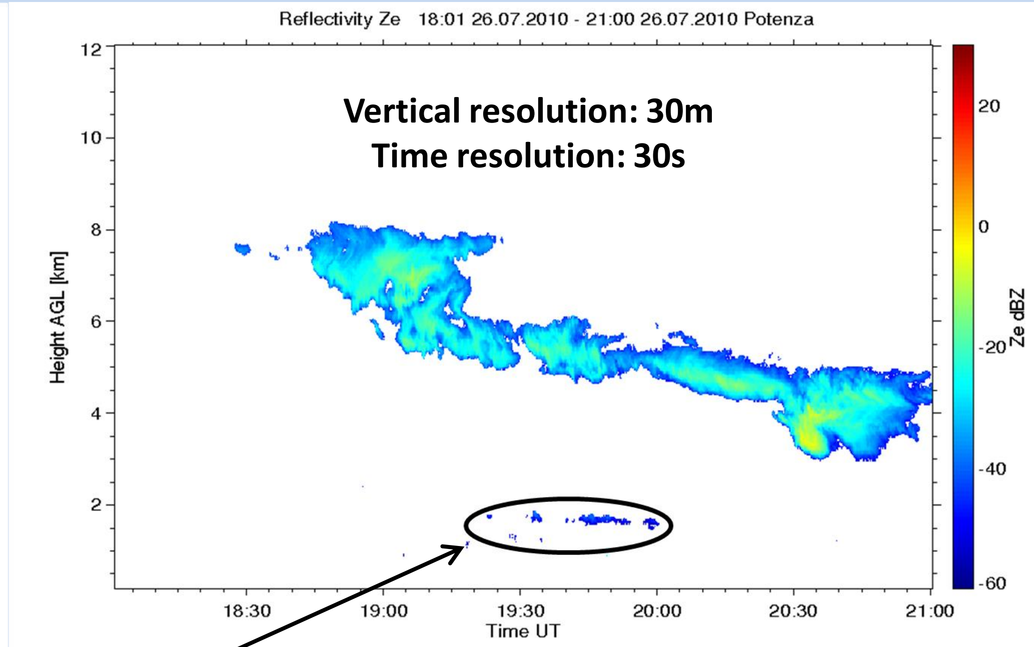


Current activities on clouds

- Comparison between lidar products and Cloudnet retrievals within ACTRIS (WP5)
- Aerosol – clouds interactions within ACTRIS (WP5)
- Cirrus clouds with models
- Cloud nucleation in presence of volcanic aerosol
- Study of twilight zone (intermediate conditions between clouds and aerosol in clear sky)
- Thin liquid water clouds: low or midlevel mixed-phase clouds characterized by a low liquid water content (LWP < 100 g m^{-2})
  - ➢ Ground-based Raman lidar and Doppler radar techniques allow us to obtain the vertical profiles of aerosol, water vapor and cloud properties below, inside and above these clouds, with high vertical and temporal resolution
  - ➢ Good target to study the droplet activation process

EXAMPLE: CIAO, POTENZA, ITALY, (40.60 N, 15.72 E, 760.0m asl), 26/07/2010





optically thin broken clouds between 2.0 and 3.0 km a.s.l. (1.2 and 2.2 km a.g.l.) in a time window from 19:20 to 20:00 UT

The liquid phase of these clouds is identified in two ways:

- ✓ absence of any signature (low values) in the radar LDR time series (not shown)
- ✓ cloud base height below the freezing level, using the vertical profile of atmospheric temperature provided by a co-located radio-sounding or by the microwave radiometer

Cloud layer properties

15 case studies with thin liquid water clouds		
Vertical extension of activation region	405 m (min)	805m (max)
Cloud base height	1740 m a.s.l. (min)	3710 m a.s.l. (max)
Cloud top height	2220 m a.s.l. (min)	4210 m a.s.l. (max)
Cloud base temperature	272 °K	287 °K
Cloud top temperature	268 °K	286 °K
Cloud layer thickness	235m (min)	545m (max)
Liquid Water Path (LWP)	5 gm^{-2}	150 gm^{-2}

Future work

- ✓ Retrieving the size distributions of aerosol particles [according to the algorithm by Veselovskii, I., and Coauthors, 2010, JGR]

- ✓ Studying statistical correlations between aerosol properties and cloud properties in order to improve the parameterization of droplet activation and aerosol-cloud interactions in weather and climate models

- ✓ Correlate thermodynamic properties with updrafts and downdrafts measured in thin liquid water clouds with the Doppler radar

- ✓ Using Large Eddy Simulation (LES) models to interpret the observations

Thanks for your attention!