Titolo: Characterization of the Antarctic atmosphere with (mostly) optical methods: the COMPASS project

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Outline

• Introduction: studying the Antarctic atmosphere
• The Physics Shelter at Concordia station, an atmospheric physics laboratory in Antarctica
• The REFIR infrared spectroradiometer
• Water vapor and climate: studying the vertical structure of the Antarctic troposphere
• Cirrus and Climate: analysis of the radiative properties of cirrus in the far-infrared
The Antarctic atmosphere

Antarctic Plateau:

- Extremely low amounts of water vapor (due to low temperatures and high altitude).
- Absence of orographic features provide an unperturbed system over several hundreds of kilometers.
Concordia Station

Italian-French base: Concordia Station
3.200 m a.s.l.
75° S, 123° E
The Physics shelter

An Italian-French atmospheric physics research laboratory in the middle of the Antarctic plateau...

- HAMSTRAD μW radiometer (Meteo France)
- SAOZ UV radiometer (LATMOS-IPSL)
- REFIR-PAD spectroradiometer (INO-CNR)
- Tropospheric LIDAR (INO-CNR)
- Stratospheric LIDAR (ISAC-CNR)
- ICE-CAMERA (INO-CNR)
- AWS, Sky cameras, GPS
The COMPASS project

COncordia Multi-Process Atmospheric StudieS
Remote sensing with optical (& sonic) methods

- **Planetary boundary layer**: structure, composition, meteorology (SODAR, IR spectrometer, radiometers, sonics)
- **Troposphere**: radiative properties and microphysics of clouds and water vapor (tropospheric LIDAR, IR spectrometer)
- **Stratosphere**: monitoring of the ozone column during night time (stratospheric LIDAR, IR spectrometer)
The COMPASS setup

- Surface-Layer Mini SODAR (in a dedicated shelter)
- IR and VIS-UV radiometers, sonic anemometers, AWS (Physics shelter)
- REFIR Infrared FTS (Physics shelter)
- 2 LIDARs (Physics shelter)
Making measurements at Concordia

Antarctic installation issues:

- **Continuous operation**: a significant dataset can be built only if measurements extend beyond the ~3 months of summer season.
- **Autonomous, (almost partially) unattended operation**: during 9 months a year the station operates with a reduced crew and in extreme environmental conditions → very limited possibilities of human intervention on the instrument.
- **Thermal control problems**: not only the expected (i.e. low temperatures), but more often overheating problems due to inefficient heat dissipation and packing of instrumentation in small spaces...
- **Small (if any) bandwidth for data transfer**: data link provides 512 kbps to share between all scientific projects and crew → need for local storage of large amount of raw data and on-line data analysis.
REFIR-PAD FT spectroradiometer

Compact, self-contained FTS with 100 – 1900 cm\(^{-1}\) spectral range and up to 0.25 cm\(^{-1}\) spectral resolution

- Room temperature operation
- On board radiometric calibration
REFIR-PAD measurement capabilities:

- **Spectrally resolved radiometry**: characterization of the Earth's radiation budget with the possibility to separate and evaluate the different contributions due to water vapor, greenhouse gases, clouds.
- **Composition and structure of the atmosphere**: through the inversion of spectral data it is possible to retrieve vertical profiles of water vapor and temperature, cloud optical thickness and columnar values of other atmospheric constituents.
- **Radiative signature of clouds**: in the particular case of thin clouds like cirrus, the contribution to ERB is still to be understood and characterized systematically (*NEXT TALK, Gianluca Di Natale*).
Almost the entire Earth's thermal emission spectrum is measured, providing vertical tomographic information on atmospheric composition.
REFIR-PAD data analysis

- LBLRTM v. 12.0 forward model
- MINUIT routines (from CERN) to perform $\chi^2$ minimization
- Fitted variables: 5 atmospheric levels per profile ($\text{H}_2\text{O}, \text{T}$), cloud optical thickness, ILS, frequency correction

Microwave radiometer windows

Midlatitude sum/win: sea level, Antarctic sum/win: 3.2 km a.s.l.
More than 2 orders of magnitude in PWV: between atmospheric window and water vapor rotational band there are always strong and non saturated water lines.
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**REFIR-PAD measurement capabilities**

REFIR-PAD Downwelling radiance spectra

Retrieved profiles

Measured downwelling radiance spectrum
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Water vapor & temperature profiles

REFIR–PAD h2o VMR map

RS–92 h2o VMR map

REFIR–PAD temperature map

RS–92 temperature map
Water vapor & temperature profiles

Clouds...
Cirrus and Climate

High troposphere, low temperatures ↓
Lower thermal emission, Warming effect +
Cloud albedo effect (Cooling)
Cirrus and Climate

About 30% permanent global cover, up to 70% in the tropics. High altitude, low temperature.

Radiative forcing strongly dependent on microphysical properties of clouds

- Thin clouds, large particle size: up to 20 W/m² warming
- Thick clouds, small particle size: up to -40 W/m² cooling

Contributes to the largest source of uncertainty in radiative forcing
NEXT TALK: Gianluca Di Natale, “Caratterizzazione ottica e microfisica delle nubi sottili antartiche tramite la combinazione di misure lidar e spettroscopiche nell'infrarosso termico.
Thanks!