INO-CNR
ISTITUTO
NAZIONALE DI
OTTICA

Caratterizzazione ottica e microfisica delle nubi sottili antartiche tramite la combinazione di misure lidar e spettroscopiche nell'infrarosso termico

Gianluca Di Natale,
Luca Palchetti,
Giovanni Bianchini,
Massimo Del Guasta

Largo Enrico Fermi 6, 50125 Firenze
Tel. +39 055 23081 - Fax +39 055 2337755

OUTLINE

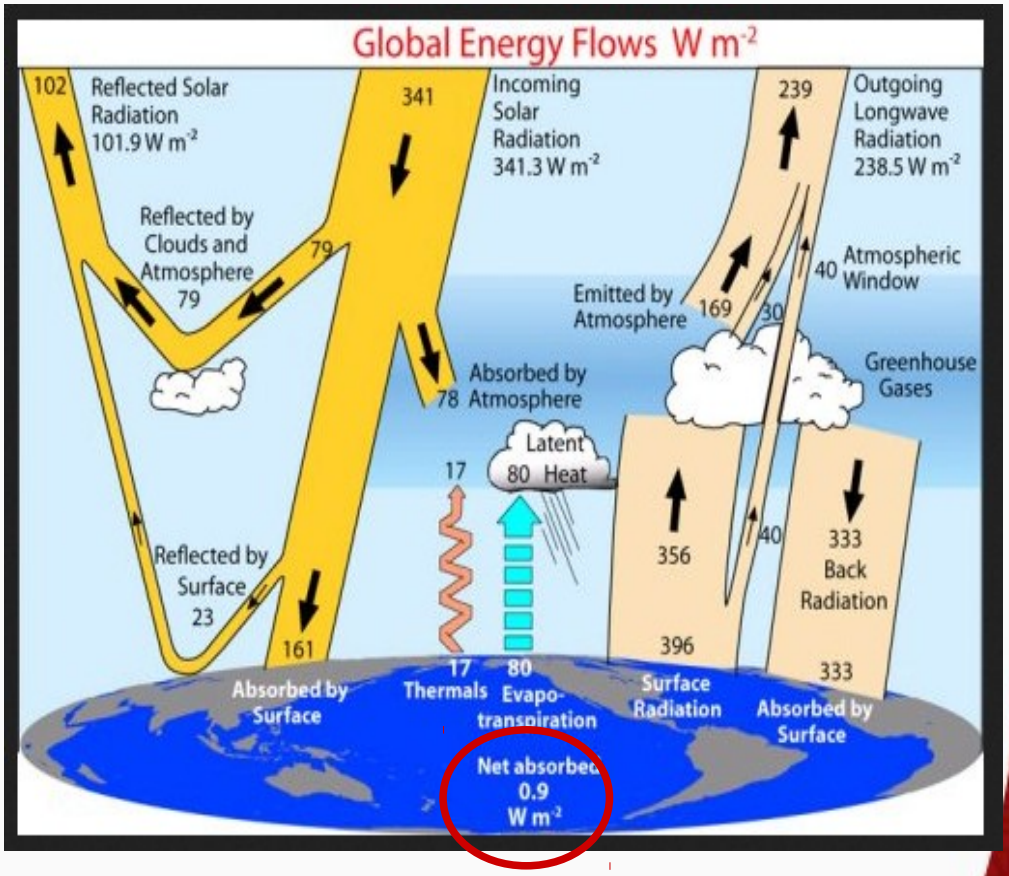
- Introduction to cirrus clouds and ERB
- Introduction to REFIR-PAD spectroradiometer
- REFIR-PAD measurements field campaigns
- Radiative transfer theory for clouds
- Cirrus clouds physical models
- Forward and retrieval model
- Sensitivity study
- Data analysis and results
- Conclusions

EFFECT OF ICE CLOUDS

WHY STUDY CIRRUS CLOUDS?

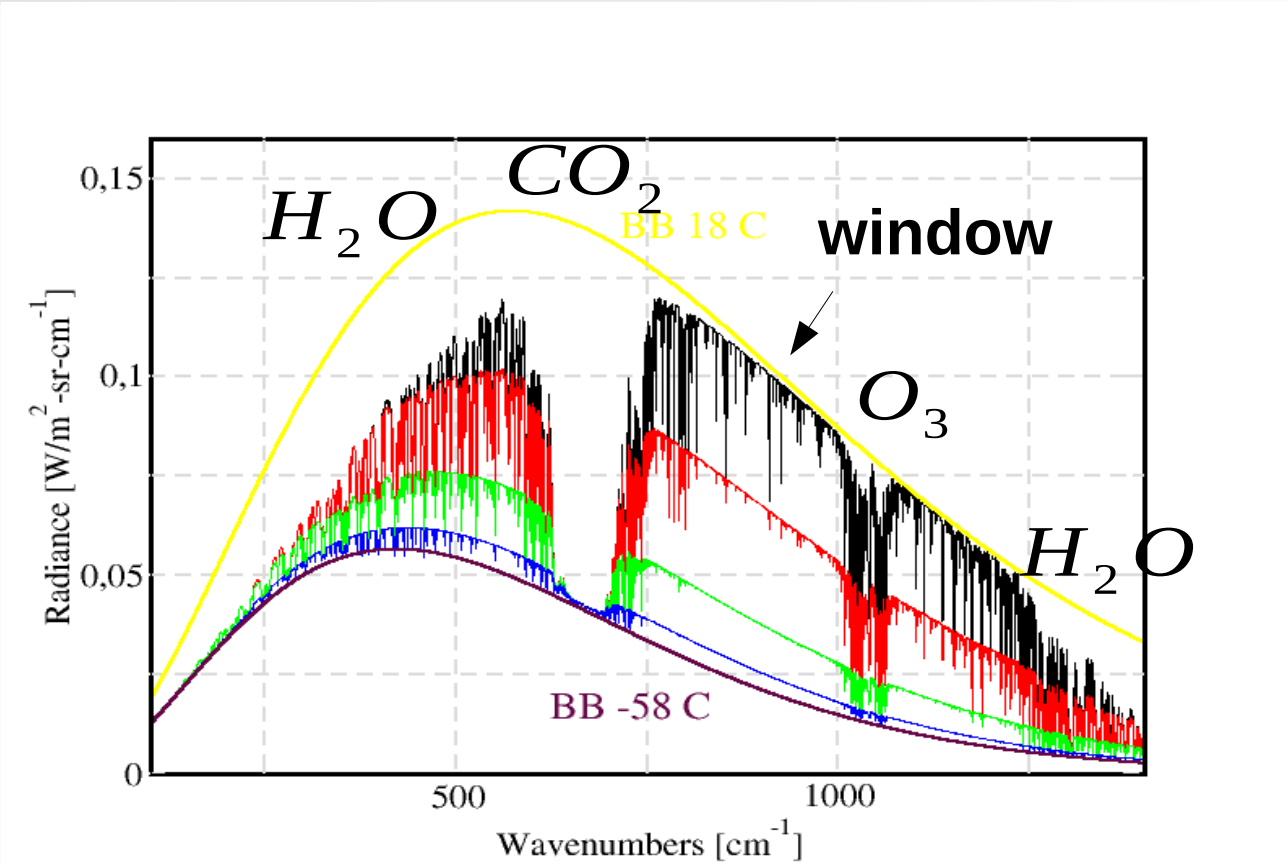
This kind of clouds play a key role in Earth radiation budget since they cover permanently about 30% of the planet surface (60% at tropical zone)

Depending on their optical and micro-physical properties, they modulate the incoming solar radiation and the outgoing thermal emission producing either a cooling and a warming



IPCC 2013 (Intergovernment Panel on Climate Change)

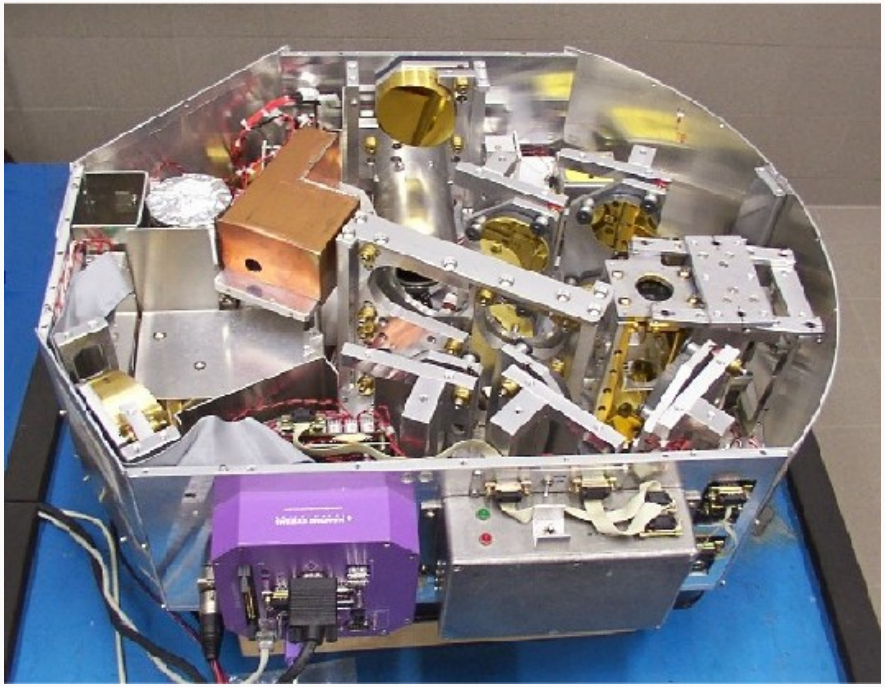
EFFECT OF THE ICE CLOUDS

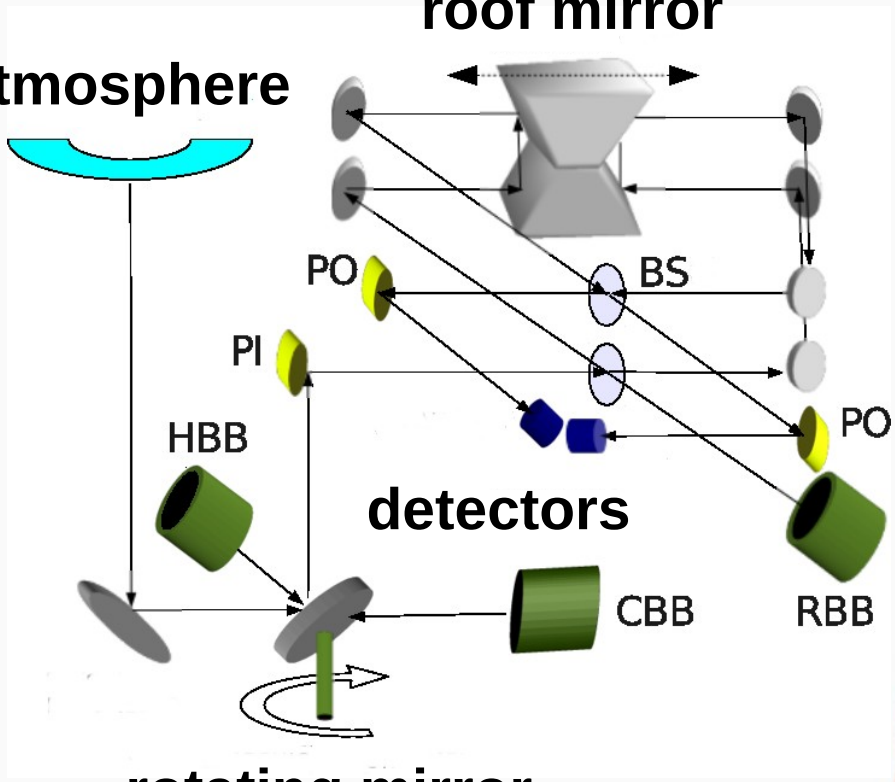


<u>Upwelling radiance</u> for clouds at different heights and in different phases

INO-CNR
ISTITUTO
NAZIONALE DI
OTTICA

REFIR-PAD SPECTRORADIOMETER





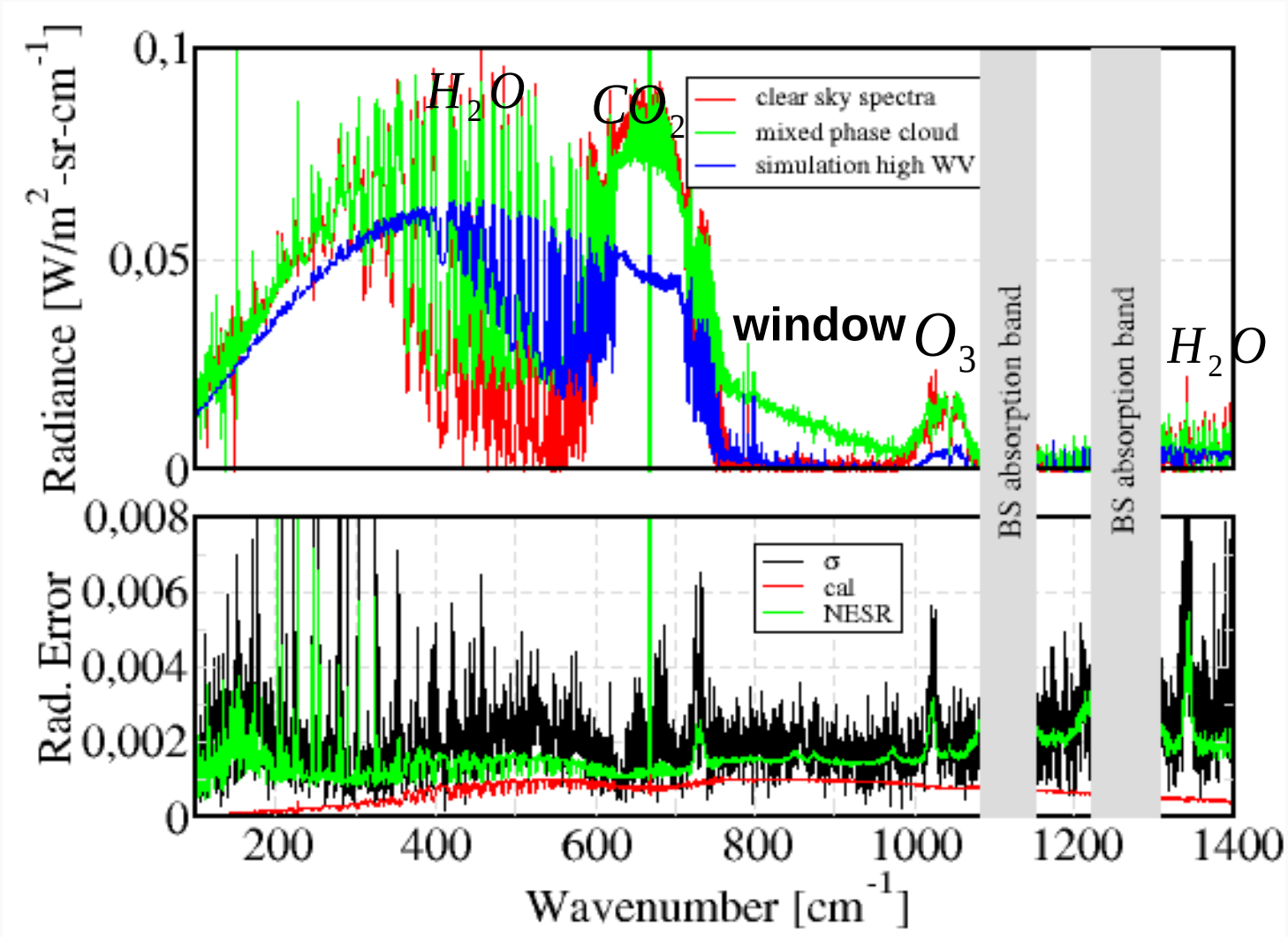
INSTRUMENT SPECIFICATIONS

Mach-Zehnder interferometer
Spectral band = 100-1400 cm^{-1}
Spectral resol. =0.25 – 0.5 cm^{-1}
BT error≈0.1K (@280K), NESR≈1 mW /m^2-sr-cm^{-1}

Ground based zenith looking observation geometry

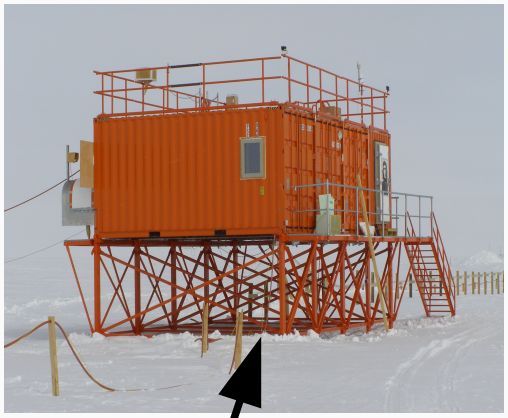
INO-CNR
ISTITUTO
NAZIONALE DI
OTTICA

MEASUREMENTS & UNCERTAINTY

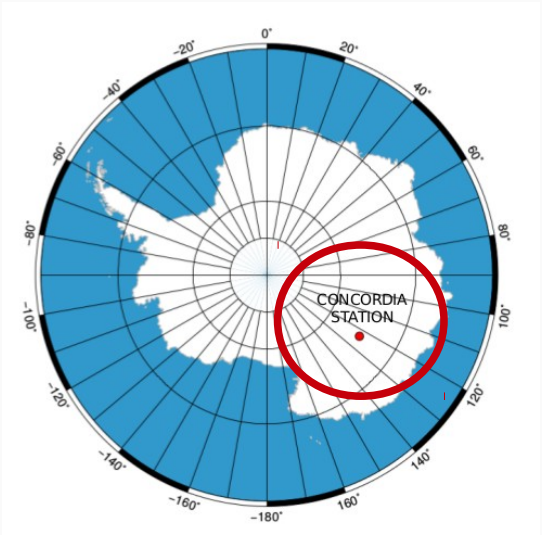


INO-CNR
ISTITUTO
NAZIONALE DI
OTTICA

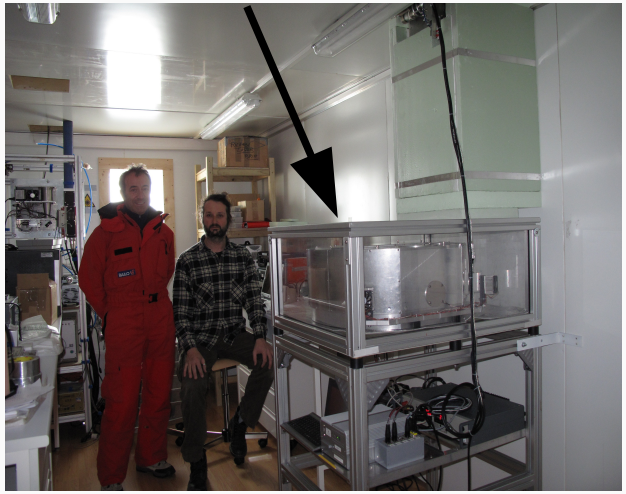
ANTARCTICA FIELD CAMPAIGN



Physics shelter



REFIR-PAD



<u>Concordia</u> base at <u>Dome C</u>,

Antarctica, 3233 m a.s.l.

RADIATIVE TRANSFER EQUATION

$$D_e = \frac{3}{2}\frac{\int\left[\sum f_i(L)V_i(L)\right]n(L)\,dL}{\int\left[\sum f_i(L)A_i(L)\right]n(L)\,dL}$$

$$\tau = \tau(D_e, IWP)$$
$$\omega = \omega(D_e)$$
$$g = g(D_e)$$

A, B, C, Λ

Coefficients depending on optical thickness, asymmetry factor and single scattering albedo

$$\frac{dI_\nu}{d\tau_\nu} = -I_\nu(\tau) + \frac{\omega_\nu}{2}\int_{-1}^{+1} P(\mu,\mu')I_\nu(\mu')\,d\mu' + (1-\omega_\nu)B_\nu(T)$$

$$I_\nu(\tau) = I_\nu(0)e^{-\tau} + A(T_e)\left(1-e^{-\tau}\right) + B(1-\Lambda)^{-1}\left(1-e^{\tau(\Lambda-1)}\right) + C(1+\Lambda)^{-1}\left(1-e^{\tau(\Lambda+1)}\right)$$

2-fluxes δ-scaled Eddington solution for downwelling radiance for a **single uniform layer**

CIRRUS CLOUDS MODELS

Parameterizations for cirrus clouds composed of hexagonal columns:

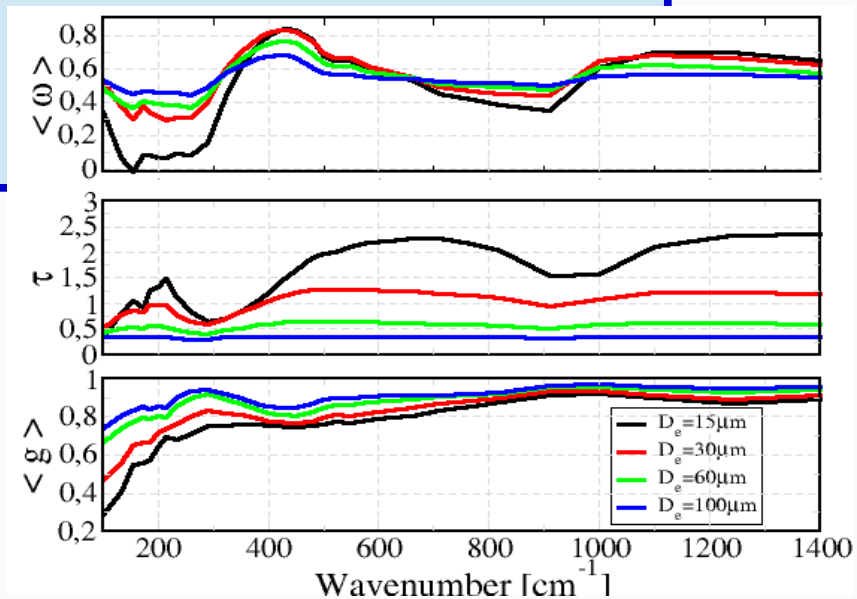
Fu et al., "An accurate parameterization of the infrared radiative properties of cirrus clouds for climate models", A.M.S.,2223-2237, 1998.

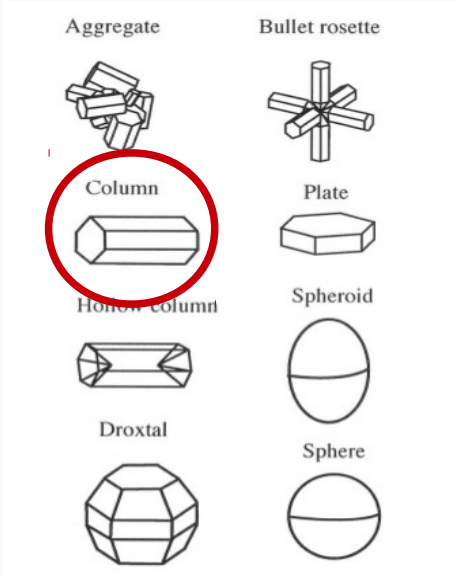
$$\tau_e = IWP\left(a_0 + a_1 / D_{ge} + a_2 / D_{ge}^2\right)$$

$$\tau_a = \frac{IWP}{D_{ge}}\left(b_0 + b_1 D_{ge} + b_2 D_{ge}^2 + b_3 D_{ge}^3\right)$$

$$g = a_0 + c_1 D_{ge} + c_2 D_{ge}^2 + c_3 D_{ge}^3$$

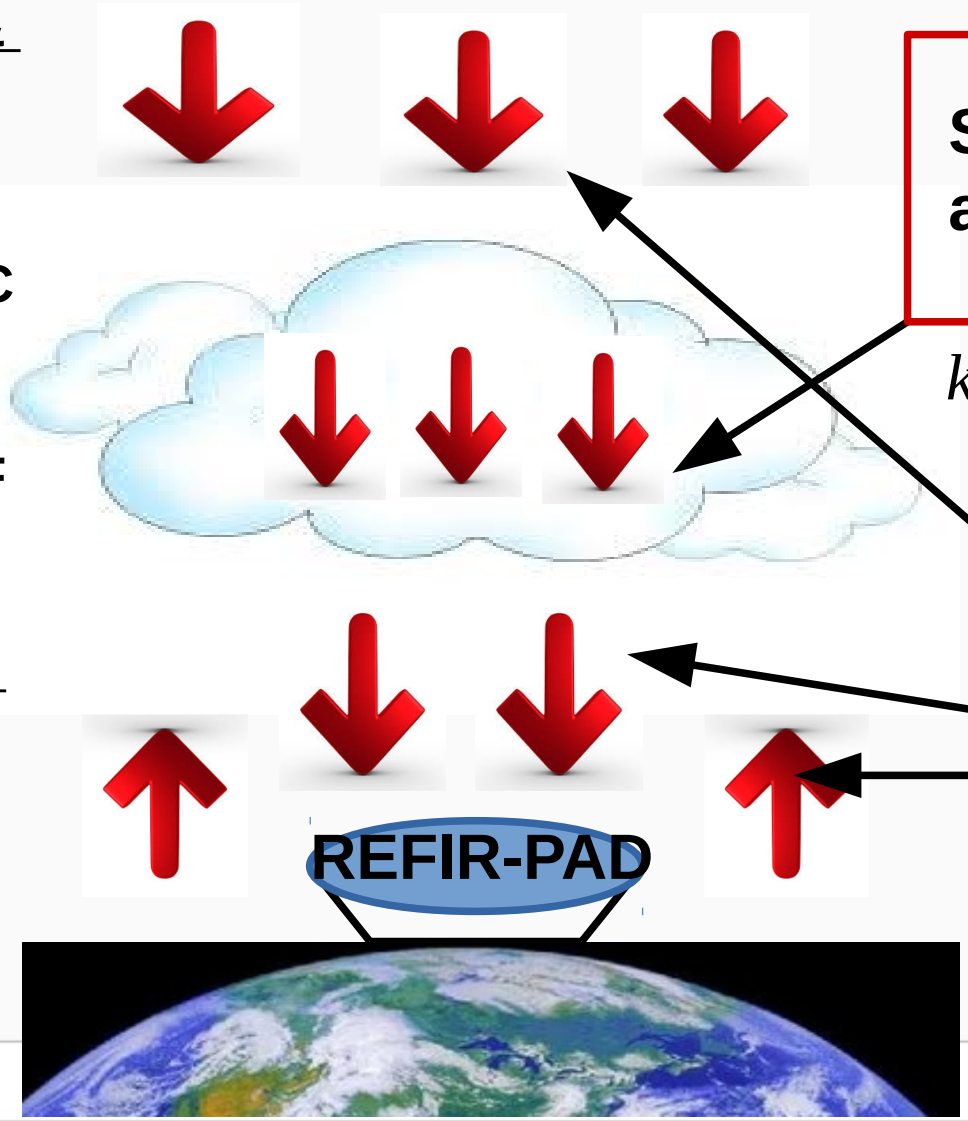
$$\omega = 1 - \frac{\tau_a}{\tau_e}$$



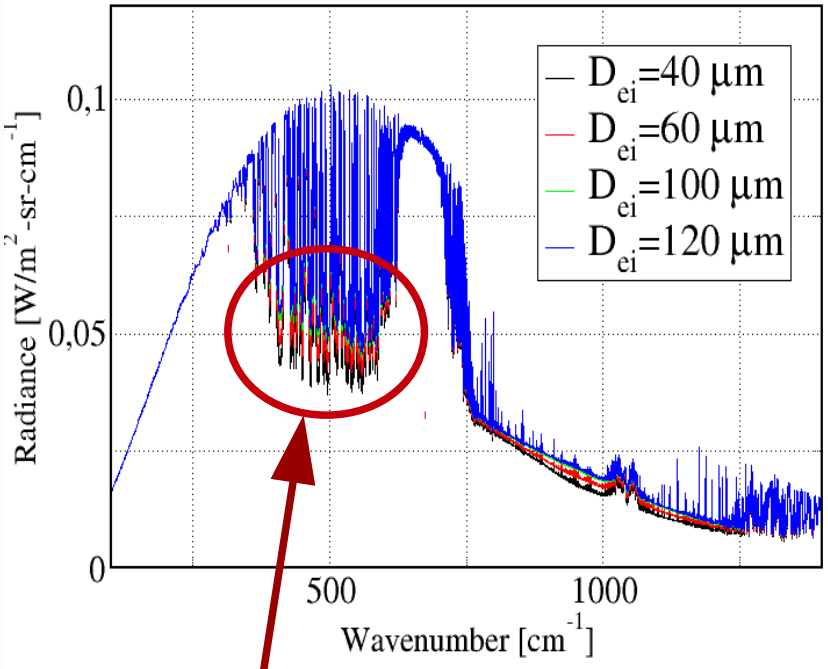


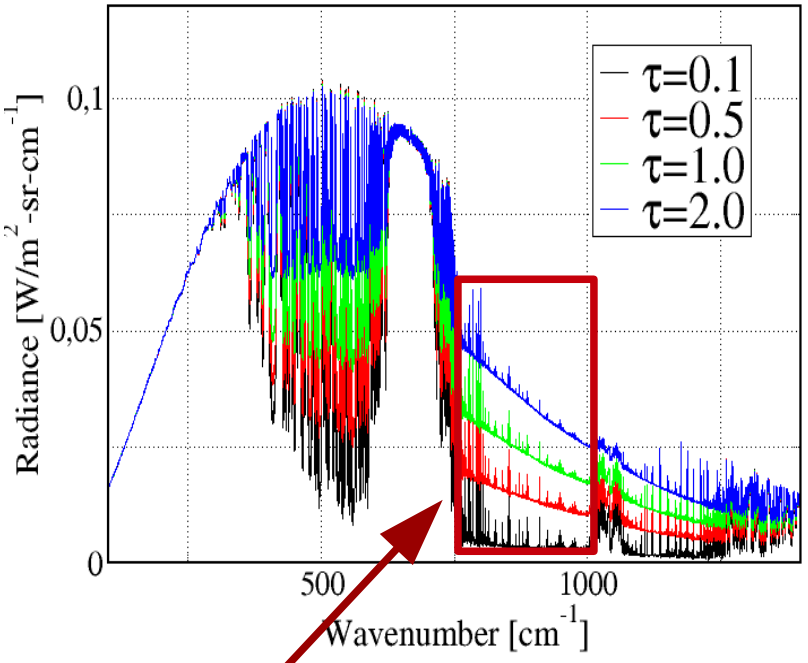
FORWARD & RETRIEVAL MODEL

A FORWARD & RETRIEVAL MODEL SIMULATING ATMOSPHERIC RADIANCE IN PRESENCE OF ICE & MIXED PHASE CLOUDS WERE DEVELOPED



SENSITIVITY TO THE CLOUD PARAMETERS



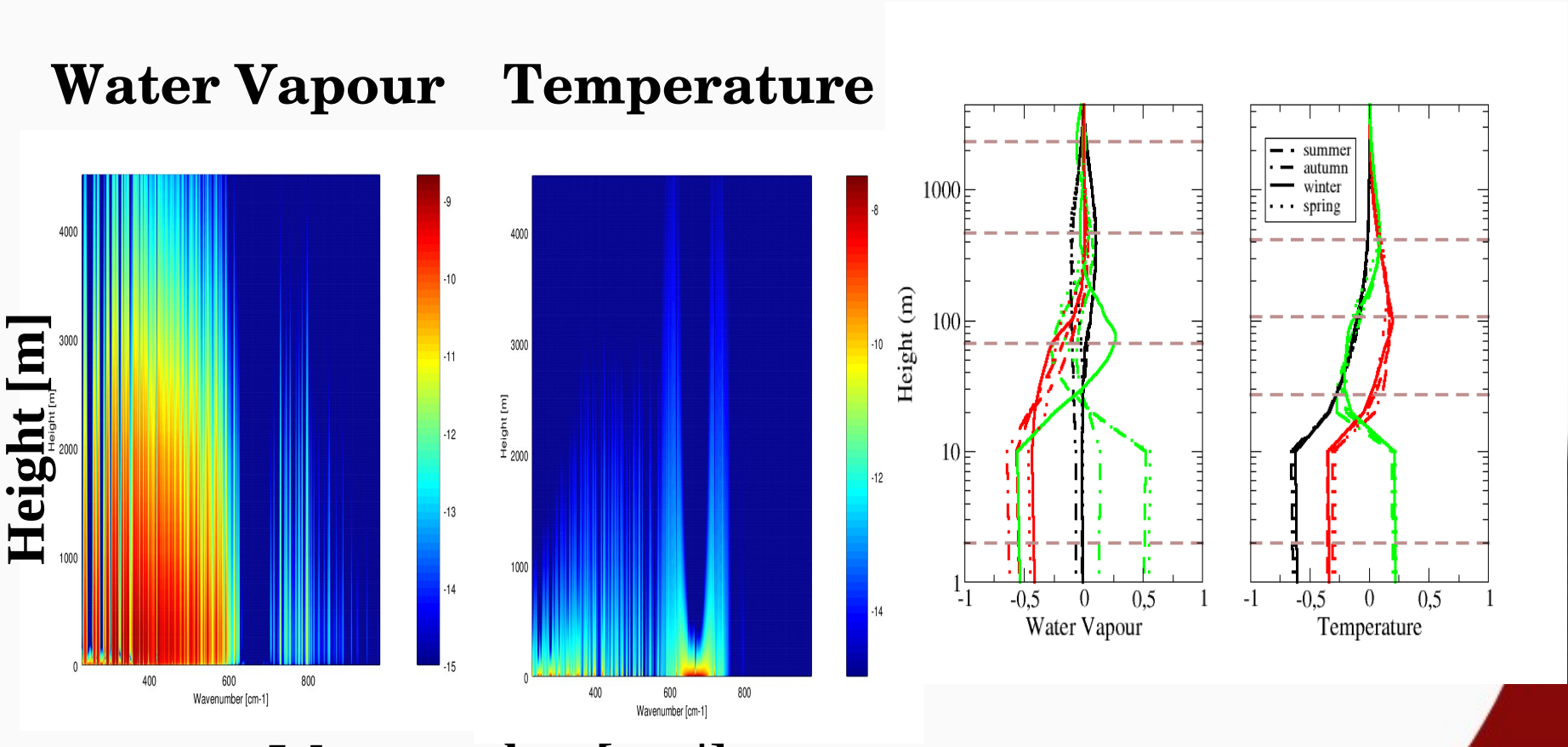


High sensitivity to diameter
Far InfraRed (below 600 cm^{-1})

High sensitivity to optical depth
Mid InfraRed (window, 820-980 cm^{-1})

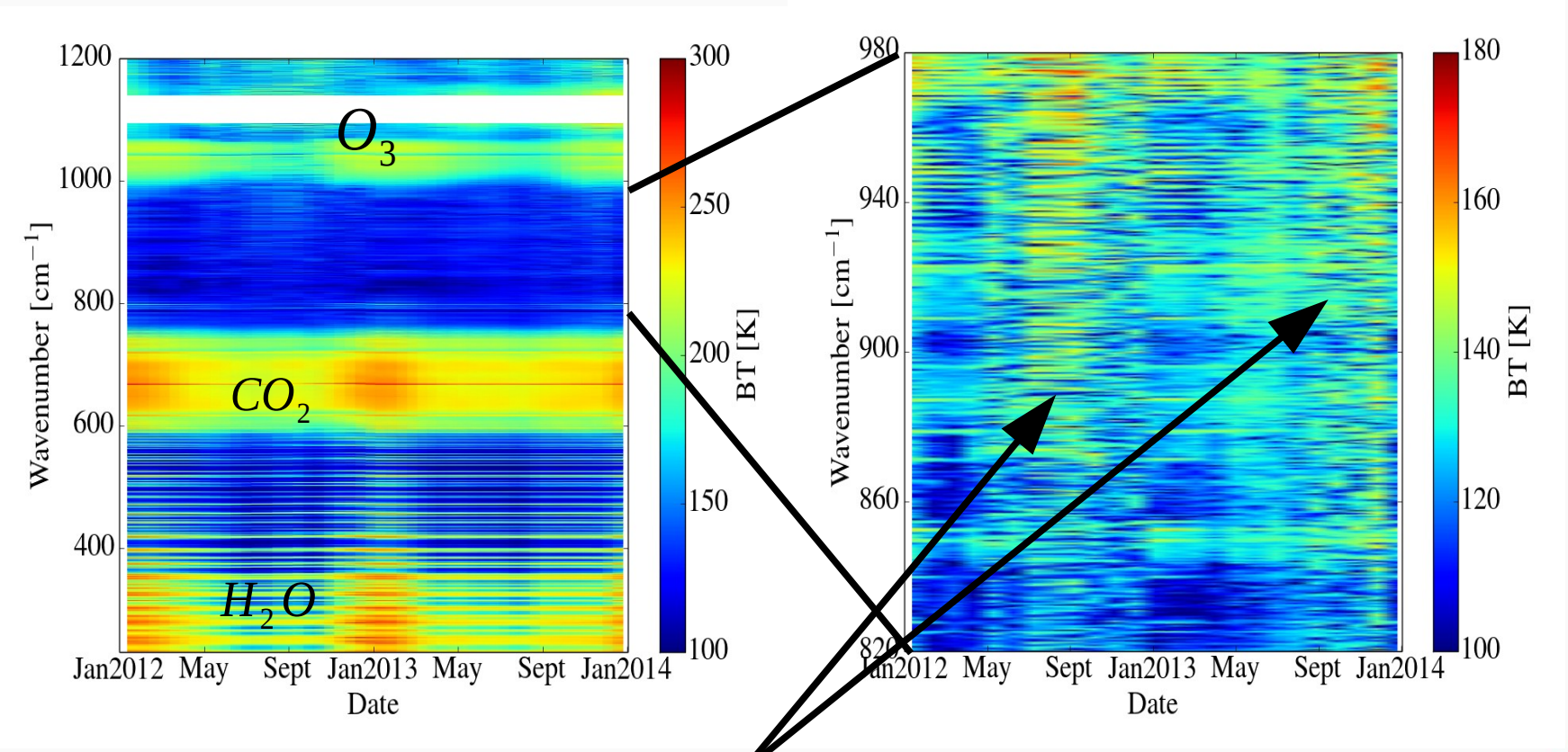
SENSITIVITY TO THE ATMOSPHERIC PARAMETERS

SINGULAR VALUE DECOMPOSITION of information matrix to optimize the atmospheric variables fit



DATA ANALYSIS

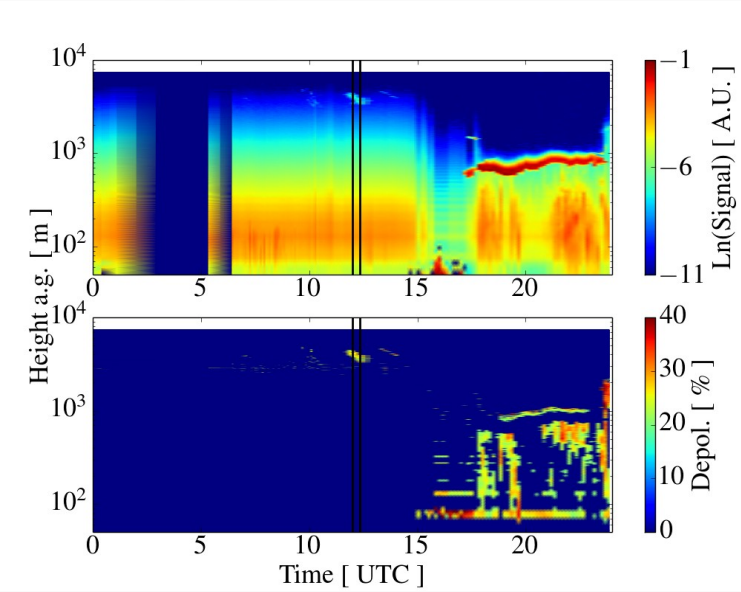
Huge database starting from December 2011

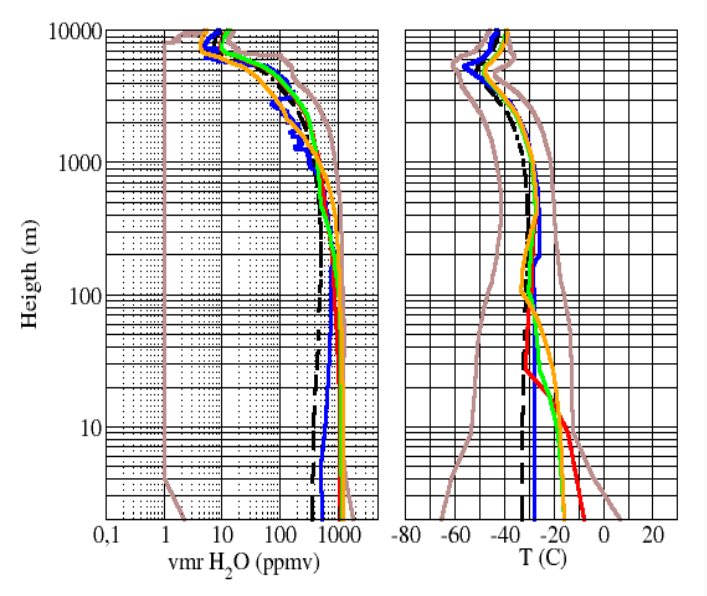


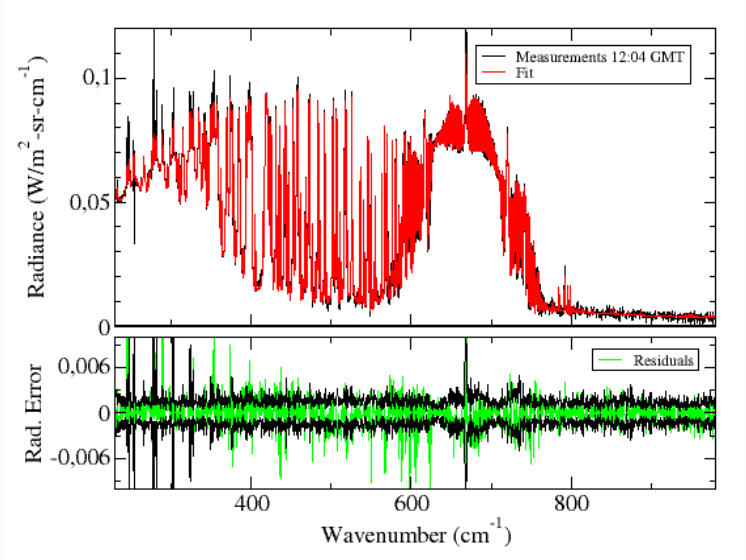
CLOUDS

INO-CNR
ISTITUTO NAZIONALE DI OTTICA

DATA ANALYSIS: SUMMER







Day 02/01/2013, res. 0.4 cm^{-1}

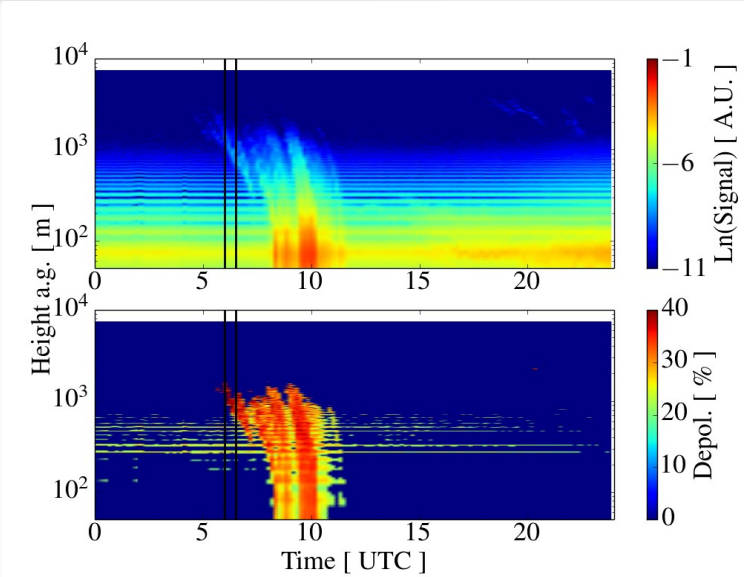
D_e=35µm IWP = 3g/m²

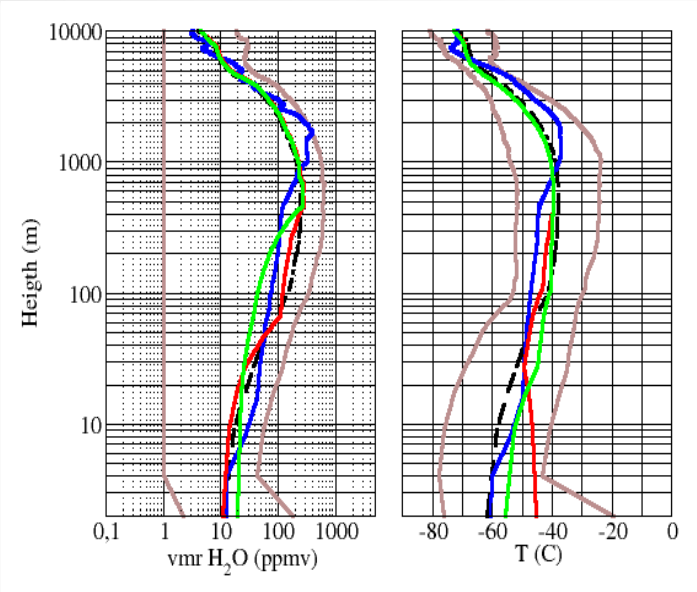
T_e=-47°C, OPD=0.3

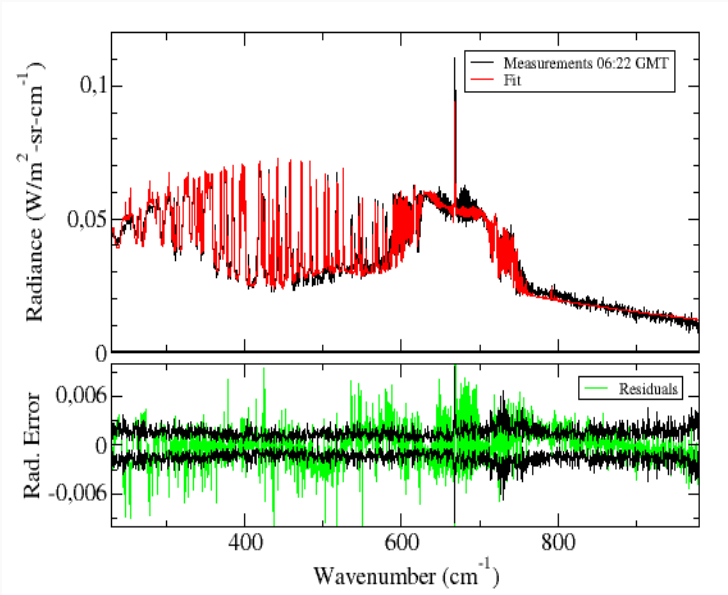
TOP at 7.5 km

BOTTOM at 6.5 km

DATA ANALYSIS: WINTER







Day 10/06/2013, res. 0.4 cm^{-1}

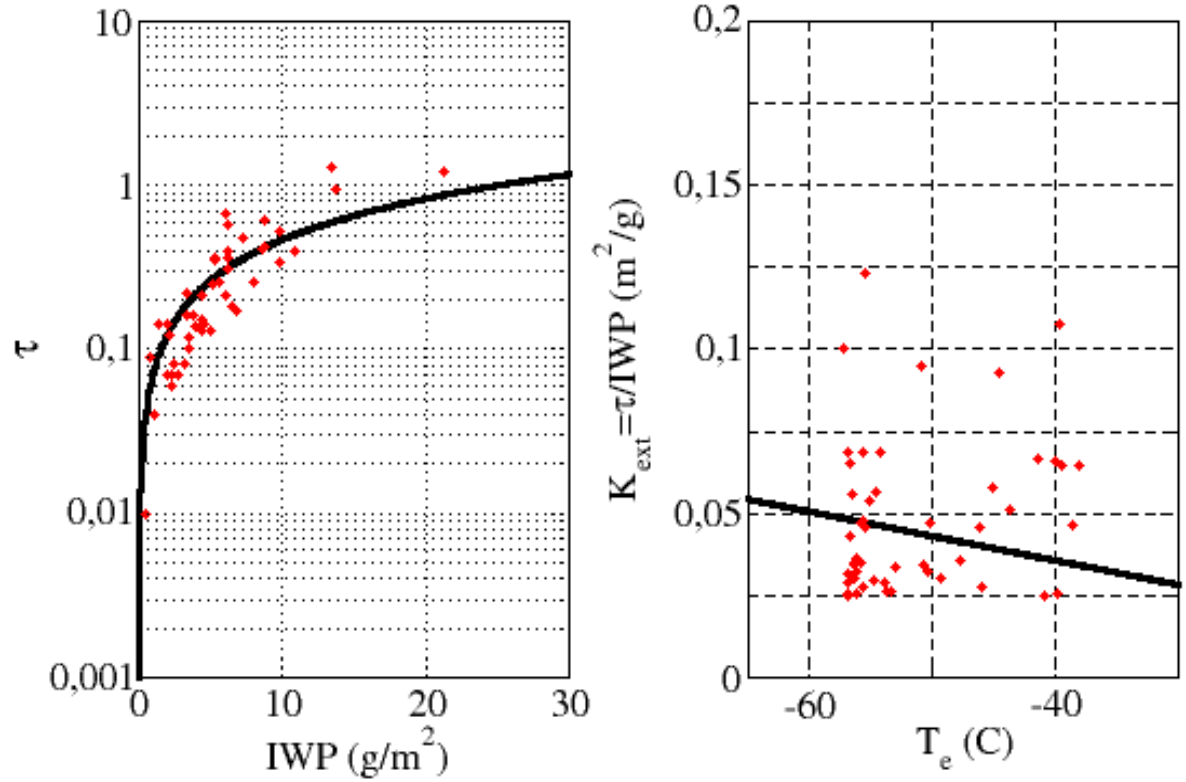
D_e=78µm IWP = 23g/m²

T_e=-47°C, OPD=1.0

TOP at 4.0 km

BOTTOM at 5.2 km

HEYMSFIELD STATISTICS



COMPARISON TO HEYMSFIELD STATISTICS (TESTA GRIGIA 2007/11 ANALYSIS)

INO-CNR
Istituto
Nazionale di
Ottica

CONCLUSIONS

- Many different measurements field campaigns were carried out using REFIR-PAD, last one still in place since 2012 in Antarctica
- Huge database of spectral radiance for the Antarctic atmosphere
- A FORWARD & RETRIEVAL model to simulate radiative transfer in atmosphere in presence of clouds were developed and allowed to retrieve the clouds properties
- Cirrus models provided by Fu and Yang are suitable to retrieve optical and micro-physical parameters of cirrus clouds
- Far InfraRed is very important to characterise the state of the atmosphere and the clouds optical and microphysical properties


Thanks for your attention!!