Analysis of down-welling radiances in presence of thin ice clouds: data from the ECOWAR-COBRA Experiment

Far-Infrared Workshop

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Contributors

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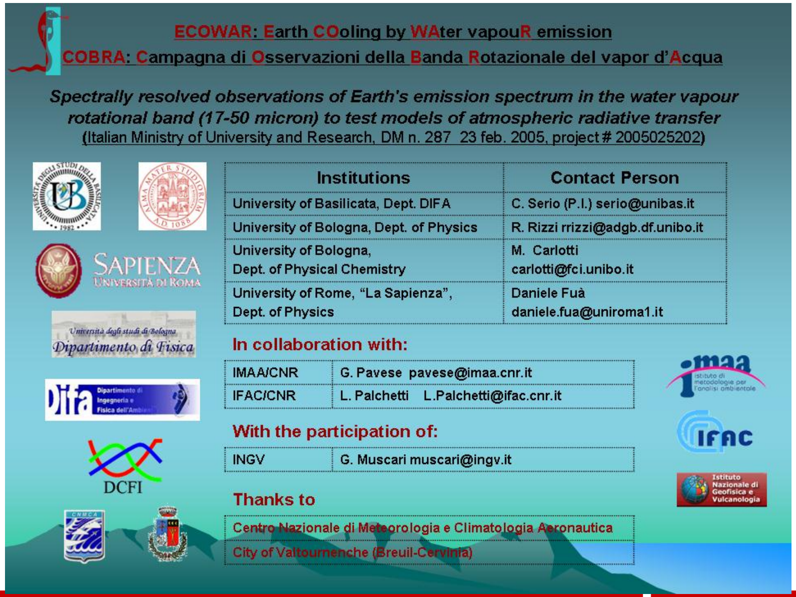


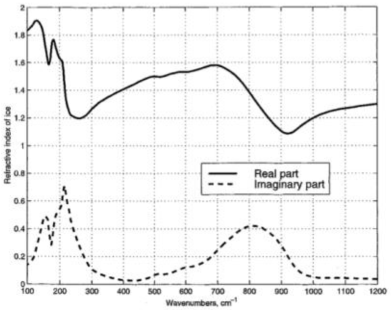
Summary: the key points

Limited available data from cloudy fields in the FIR (100-600 cm^{-1}) pose some important questions:

- How well do we **model the FIR** in presence of cirrus clouds?
- Is the FIR adding cloud **information** with respect to the 800-1200 cm^{-1} window band
- How **sensitive** is the cloud signal in the FIR to changes in atmospheric and cloud parameters?

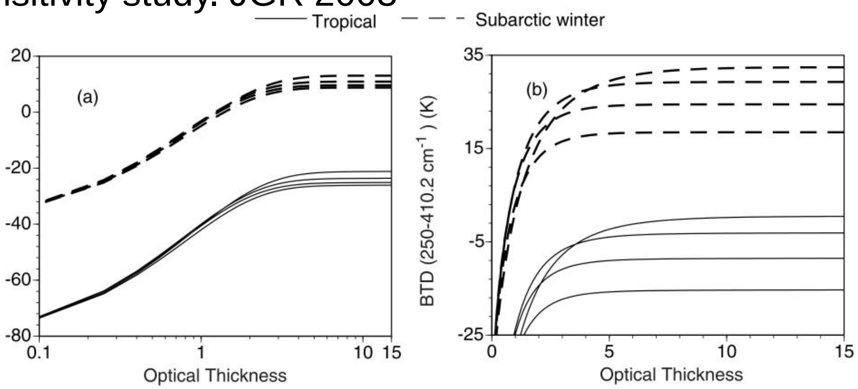
History and State of the Art

Naud et al., Remote Sensing of Cirrus Cloud Properties of Cirrus in the Far Infrared. Spiee Proc. 2001



The fir bands (410 cm^{-1} and 550 cm^{-1}) presents a serious advantage for particle size identification in thick clouds …and they can characterise large particles better than 11-12 µm

Yang et al., Spectral signatures of ice cluods in the far-infrared region: single scattering calculations and radiative sensitivity study. JGR 2003



BT difference between 250 and 559.5 cm^{-1} is shown to be sensitive to optical thickness for optically thin clouds (ot < 2)

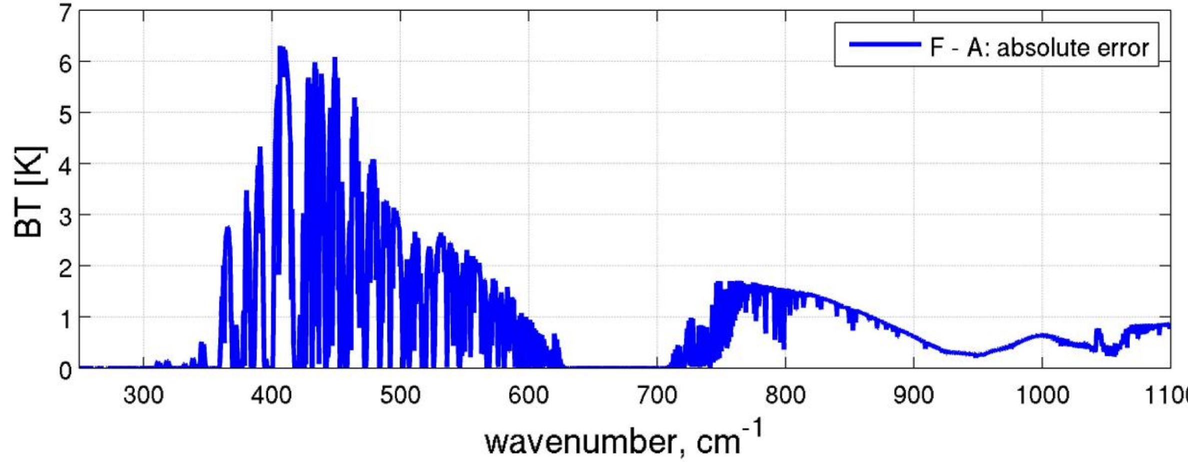
…for optically thick ice clouds (ot > 8), the BT difference between 250 and 410.2 cm^{-1} is shown to be sensitive to the effective particle size…

Cox et al., Measurement and simulation of mid- and far-infrared spectra in the presence of cirrus. Q. J. R. Meteorol. Soc. 2010

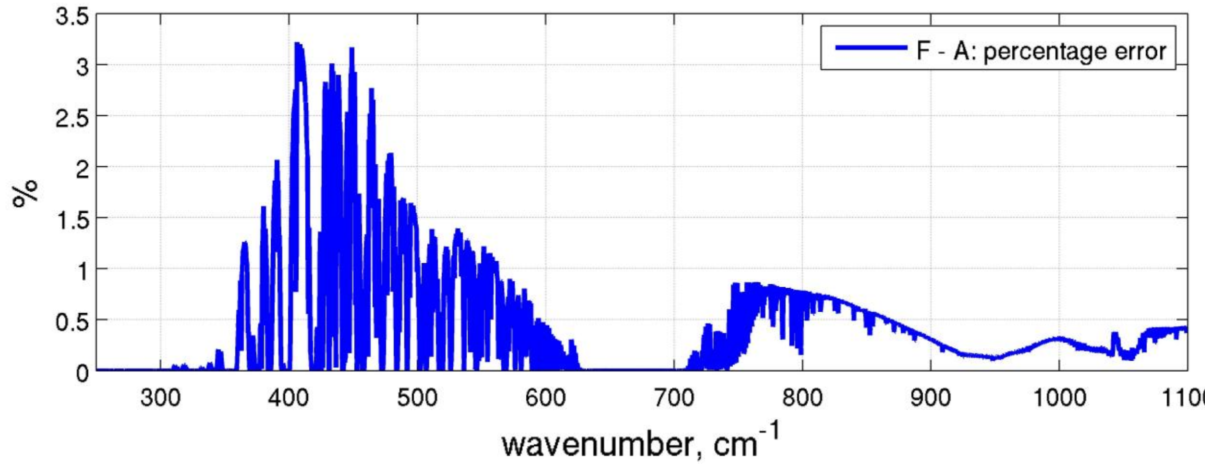
The model was not able to consistently reproduce the observed radiance across the entire region, and was particularly poor in the 330–600 cm^{-1} region of the far infrared. Possible causes are thought to be primarily model input uncertainties arising from inadequate sampling of cloud and atmosphere.

Simulating ice clouds in the IR/FIR

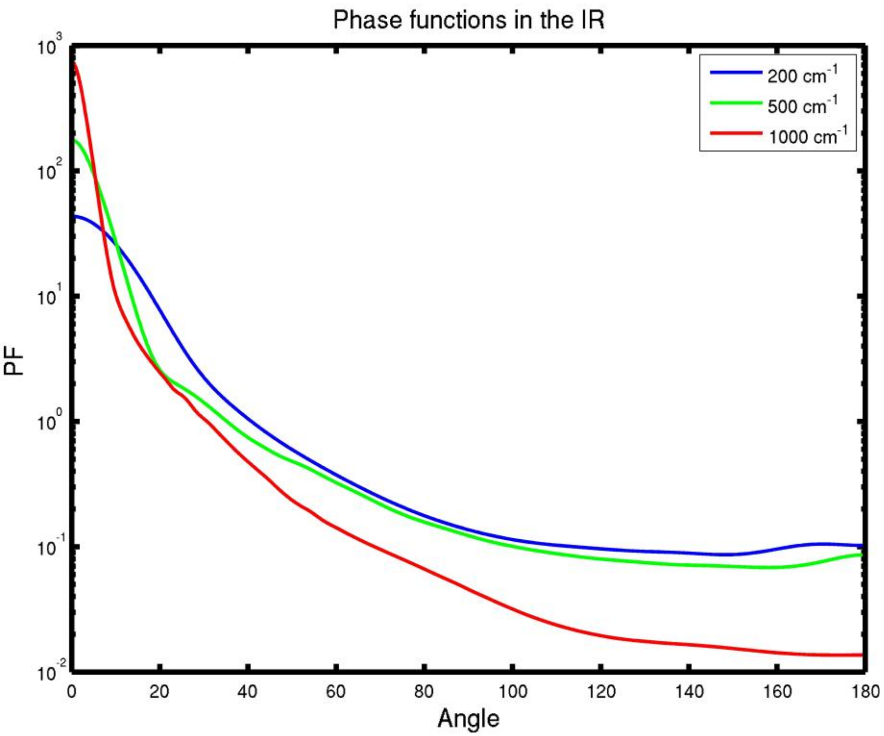
Scattering in the FIR is more important than in the IR and easier to simulate.

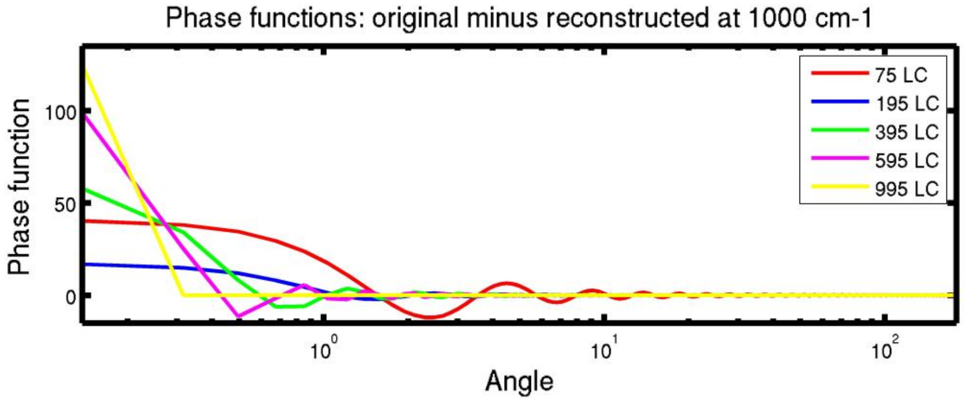


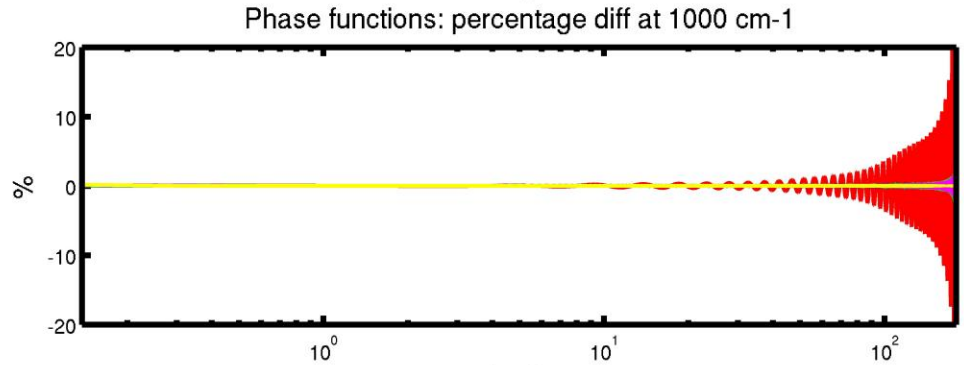
Scattering is anyway a weak effect also in the 400-500 cm^{-1} band



Phase functions in the IR







IR Phase functions have a large (few degrees) forward peaks. Multiple scattering codes required PF representation through Legendre polynomials.

The higher the # of Leg. Coefficients, the higher the # of quadrature zenit angles and the higher the computational time.

We will use 395 LC corresponding to a gaussian integration over 100 zenit angles per hemsphere (LC=4*Angles-5)

COBRA experiment

At Cervinia Station

I-BEST
Fourier Transform Spectometer in the thermal and far infrared
Contact Person
Francesco Esposito, DIFA-UNIBAS
More Details

BASIL
Raman Lidar
Contact Person
Paolo Di Girolamo, DIFA-UNIBAS
More Details

FieldSpec
Spectoradiometer covering 325-1075 nm
Contact Person
Giulia Pavese, IMAA-CNR
More Details

Avantes Visibile Spectometer
Spectrometer covering 400-900 nm with resolution of 1.5 nm
Contact Person
Giulia Pavese, IMAA-CNR
More Details

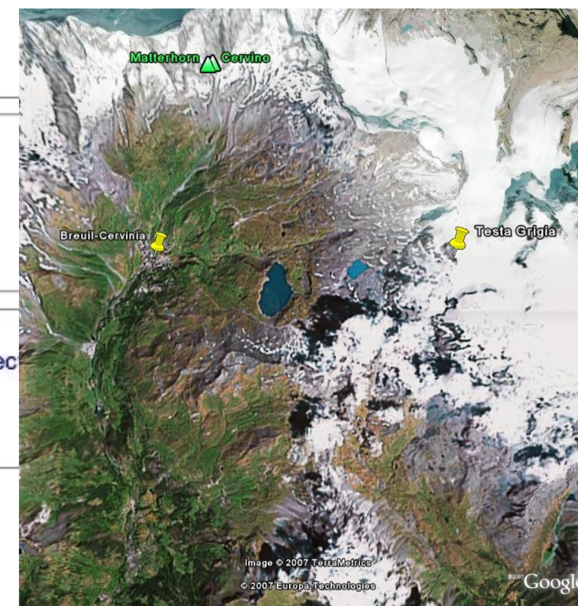
Radiosounding System
Vaisala Radiosonde RS92
Contact Person
Francesco Esposito, DIFA-UNIBAS
More Details

Kipp & Zonen
Pyranometer covering 200-3600nm
Contact Person
Giulia Pavese, IMAA-CNR
More Details

At Testa Grigia Station

REFIR PAD
Fourier Transform Spectometer in the thermal and far infrared
Contact Person
Luca Palchetti, IFAC-CNR
More Details

GBMS
Ground-Based Millimeter-wave Spec
Contact Person
Giovanni Muscari, INGV
More Details



Cervinia and Testa Grigia are about 5 km distant

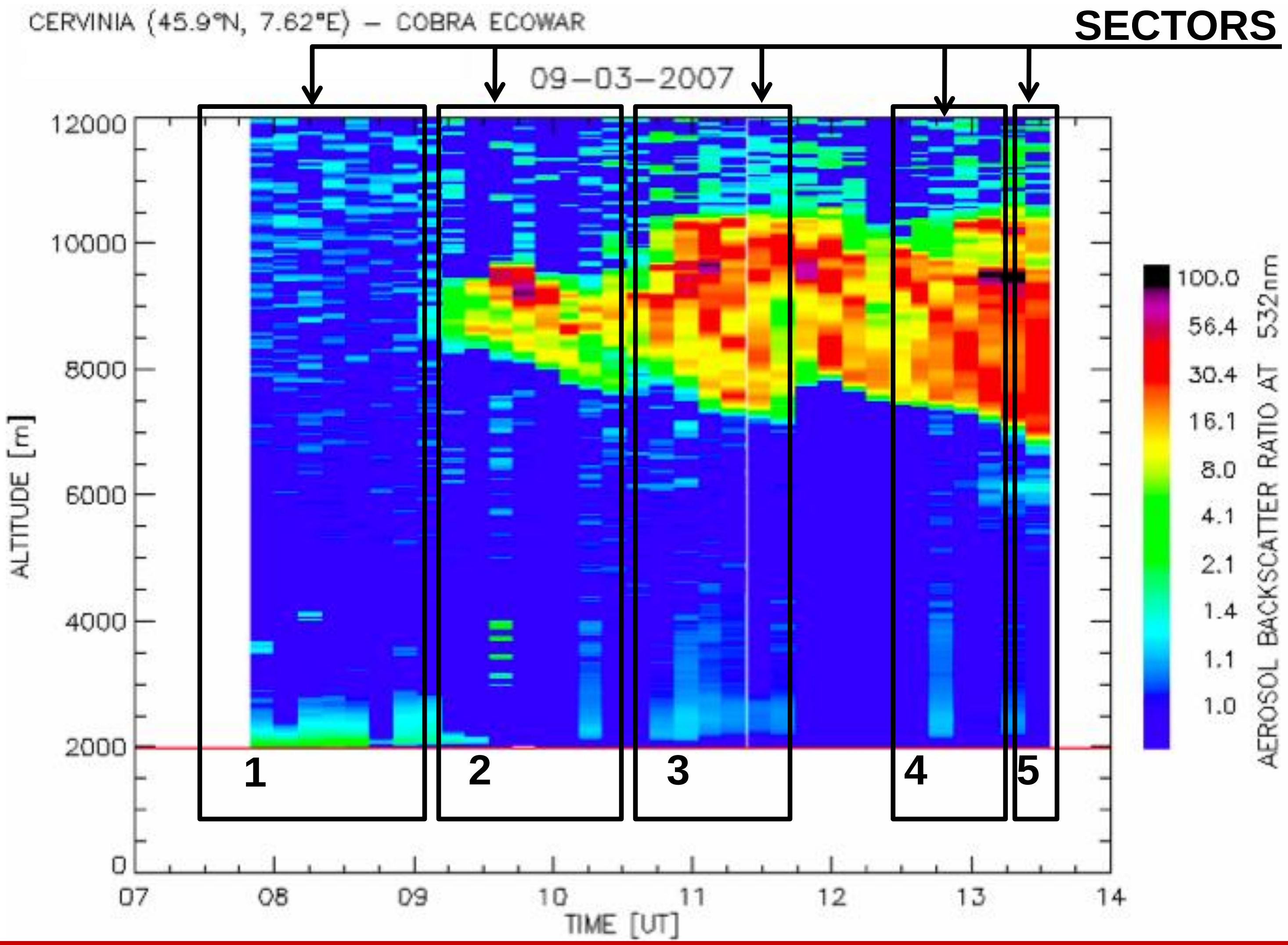
REFIR-PAD

REFIR-PAD

Radiation Explorer in the Far InfraRed – Prototype for Applications and Development

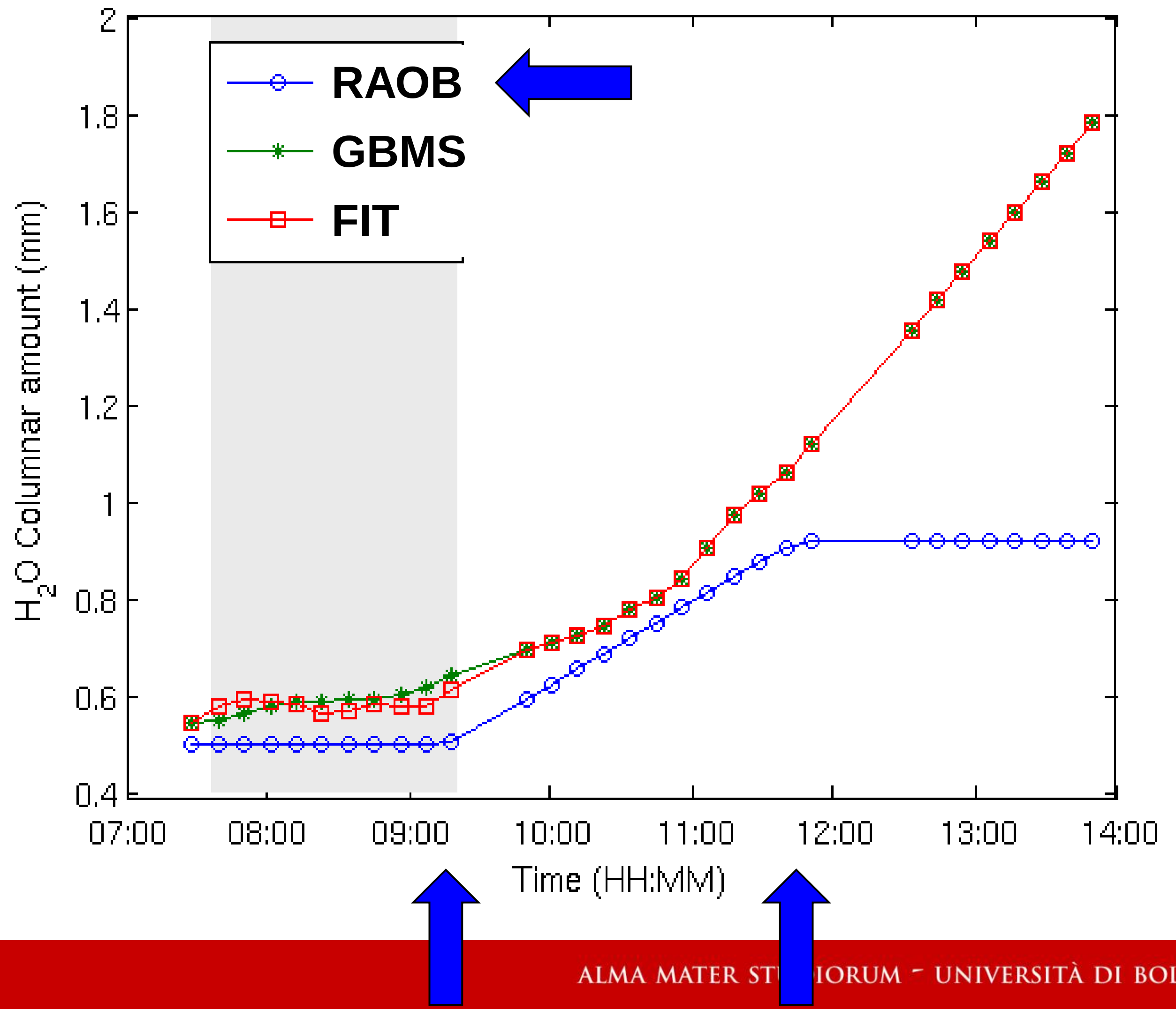
- Fourier Transform Spectrometer
- Mach-Zehnder interferometer: Ge on PET beam splitters and DLATGS pyroelectric room-temperature detectors
- Spectral coverage = 100-1400 cm^{-1},
- Resolution 0.5 cm^{-1} double-sided
- NESR in the range 0.8-2.5 $mW/(m^2\ sr\ cm^{-1})$ with 30 s. acquisition time
- Small Payload: 62 cm dia., 55 kg weight, 50 W avg power

9 March 2007



CERVINIA (45.9°N, 7.62°E) – COBRA ECOWAR
SECTORS
09–03–2007
12000
10000
8000
6000
4000
2000
0
ALTITUDE [m]
07
08
09
10
11
12
13
14
TIME [UT]
1
2
3
4
5
100.0
56.4
30.4
16.1
8.0
4.1
2.1
1.4
1.1
1.0
AEROSOL BACKSCATTER RATIO AT 532nm

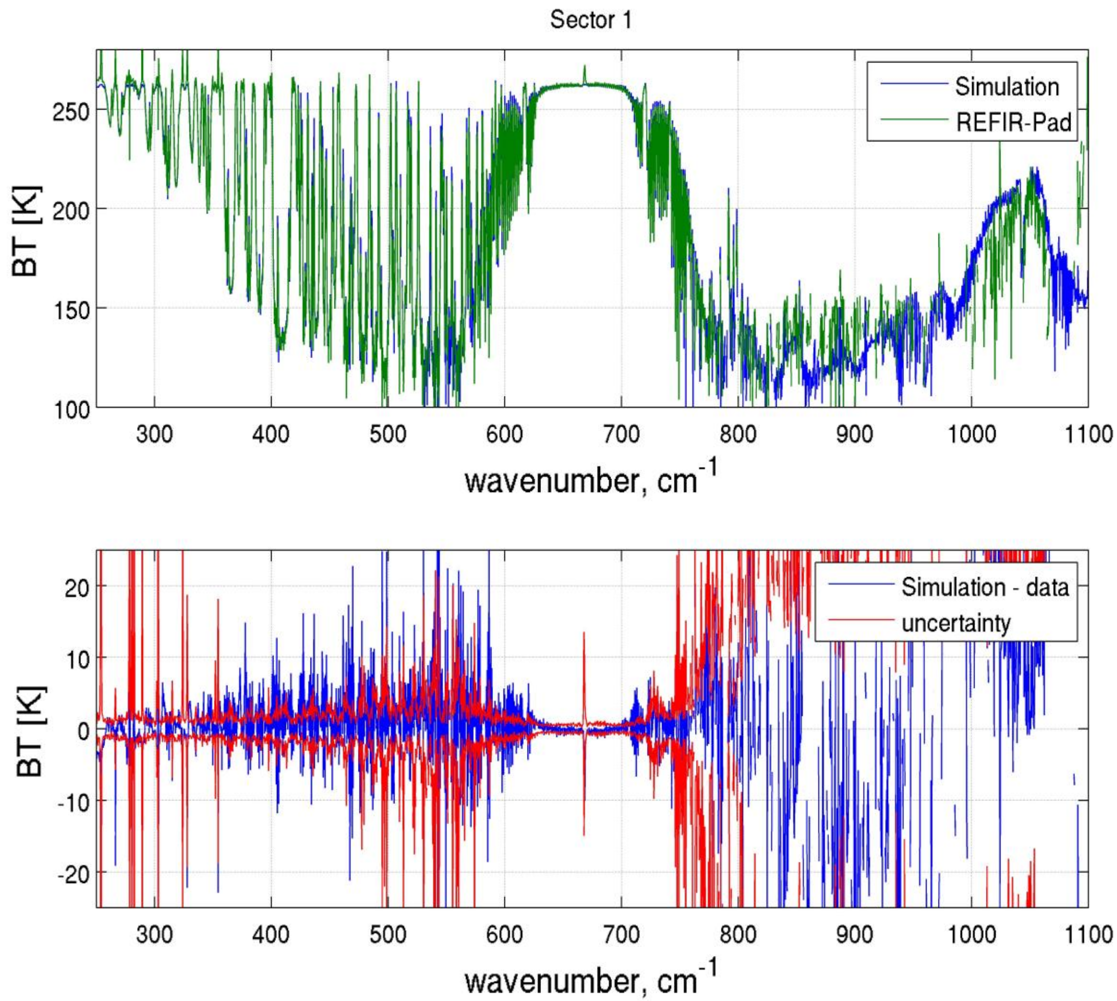
Water Vapor and T profile



The Clear Sky Sector

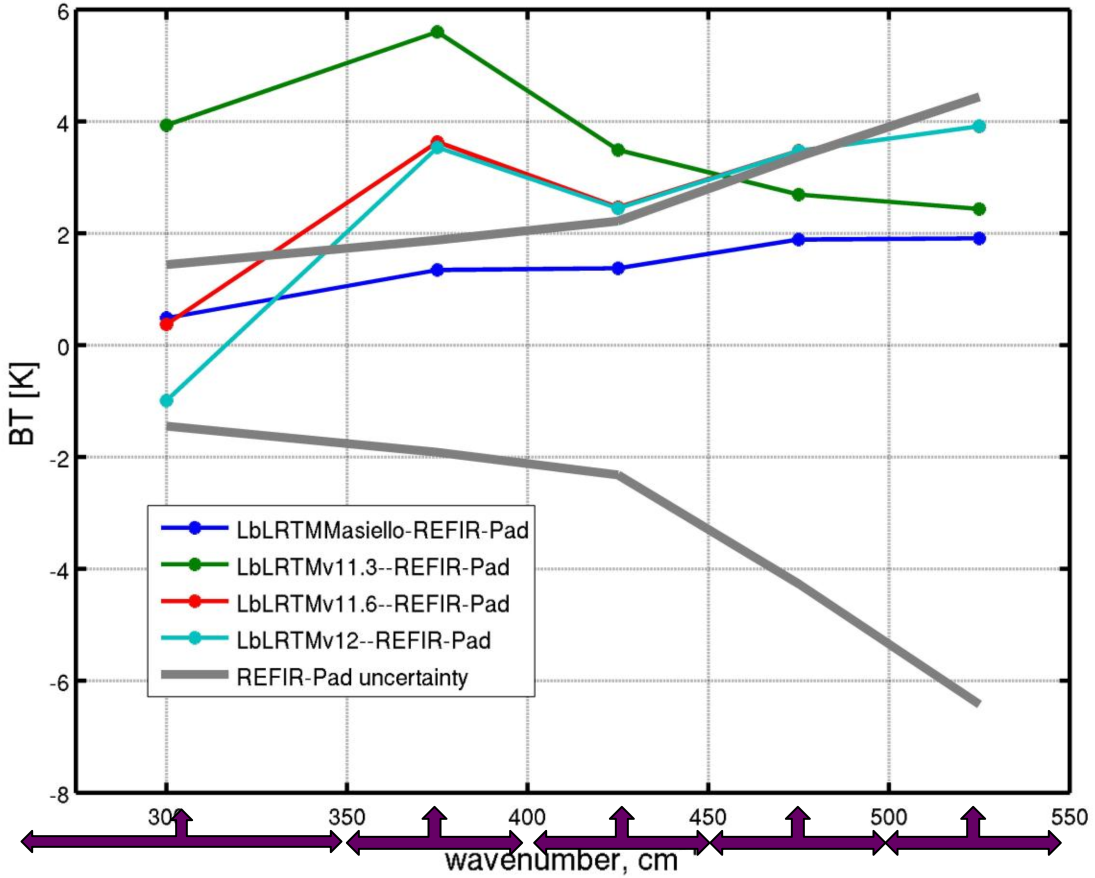
LbLRTM with ECOWAR/COBRA continuum (Masiello)

The mean of 10 clear sky radiance measurements is considered and the standard deviation from the mean is used to represent the **total uncertainty** that accounts for detector noise, random errors and natural scene variability.



WV continua for selected windows

When analyzing clouds in the FIR the interest is on microwindows where the continuum has an influence.

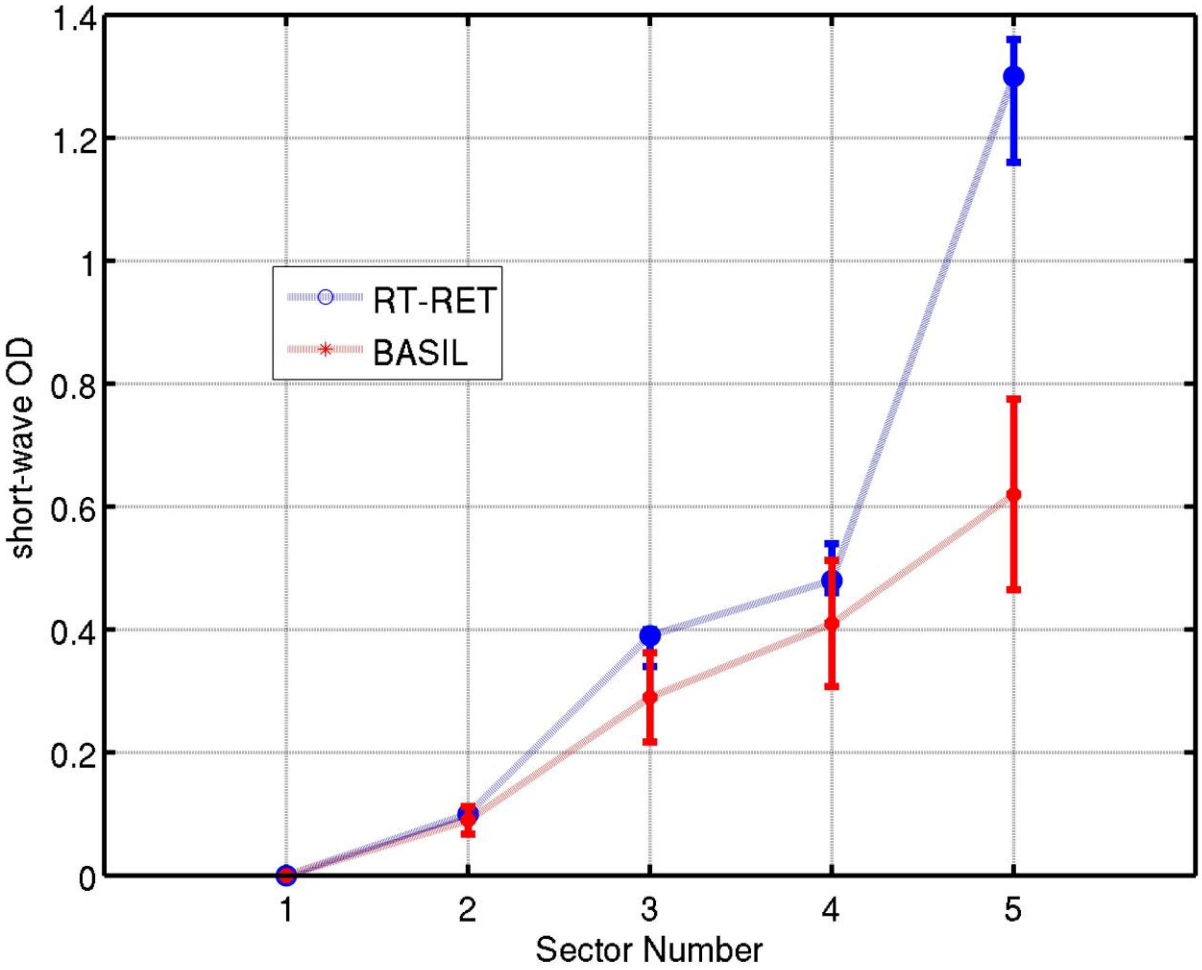


Clear sky: 1-2 K difference in all FIR microwindows between continuum derived by Masiello et al. [Serio et al., Op. Expr. 2008] and the one used in LbLRTM v12

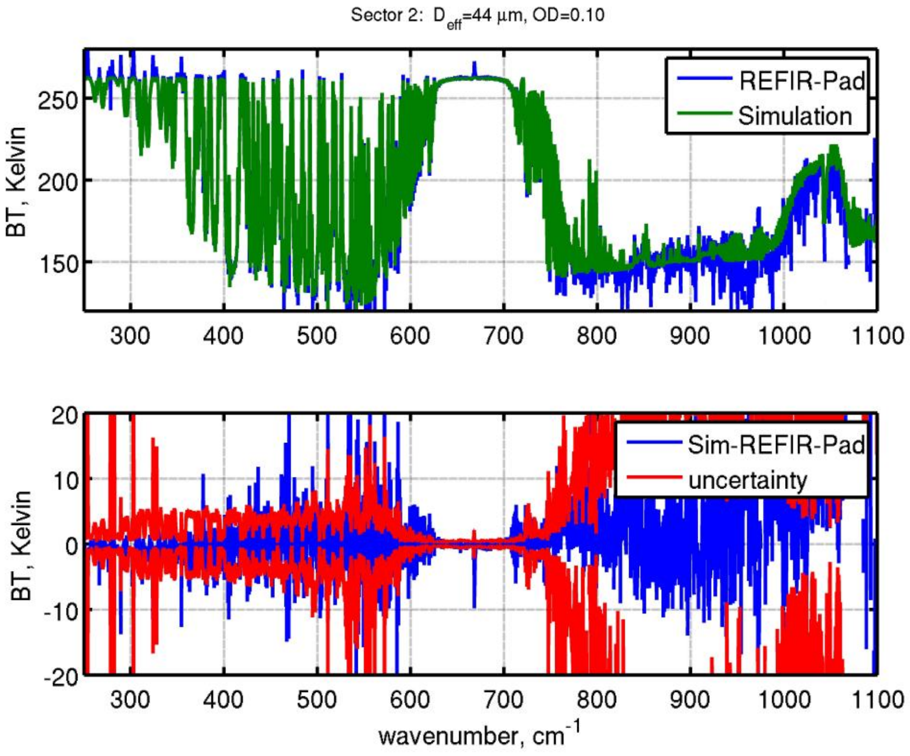
The Cloudy sky sectors

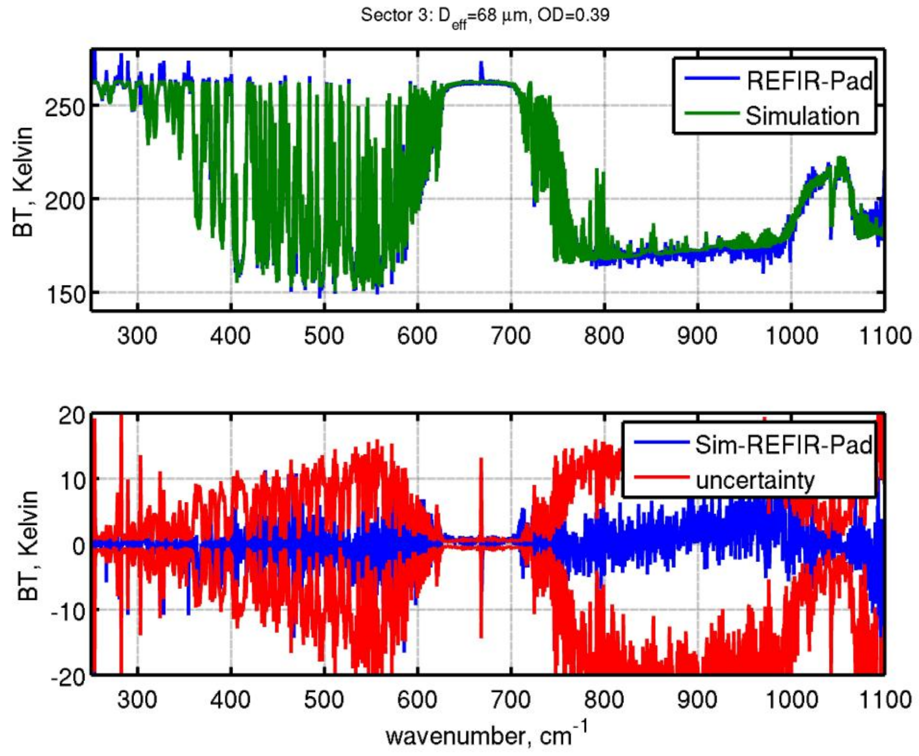
- Use the **BASIL lidar** information to constrain cloud geometry
- Assume a **mixture of particle habits** [Bozzo et al., GRL 2008] already tested for ML cirrus on NAST-I data [Maestri et al., Atm. Res. 2010]
- Retrieve OD and D_{eff} from the 800-1000 cm^{-1} window band with **RT-RET** [Maestri and Holz, TGRS 2009])
- Perform **forward simulations** based on retrieved parameters over the extended spectral range using RTX [Rizzi et al., 2007]
- Evaluate **residuals (in BT!)** in selected IR and FIR microwindows
- Perform **sensitivity studies** on particle size, WV continua, RH profile and Temperature profile.

Results: OD retrievals



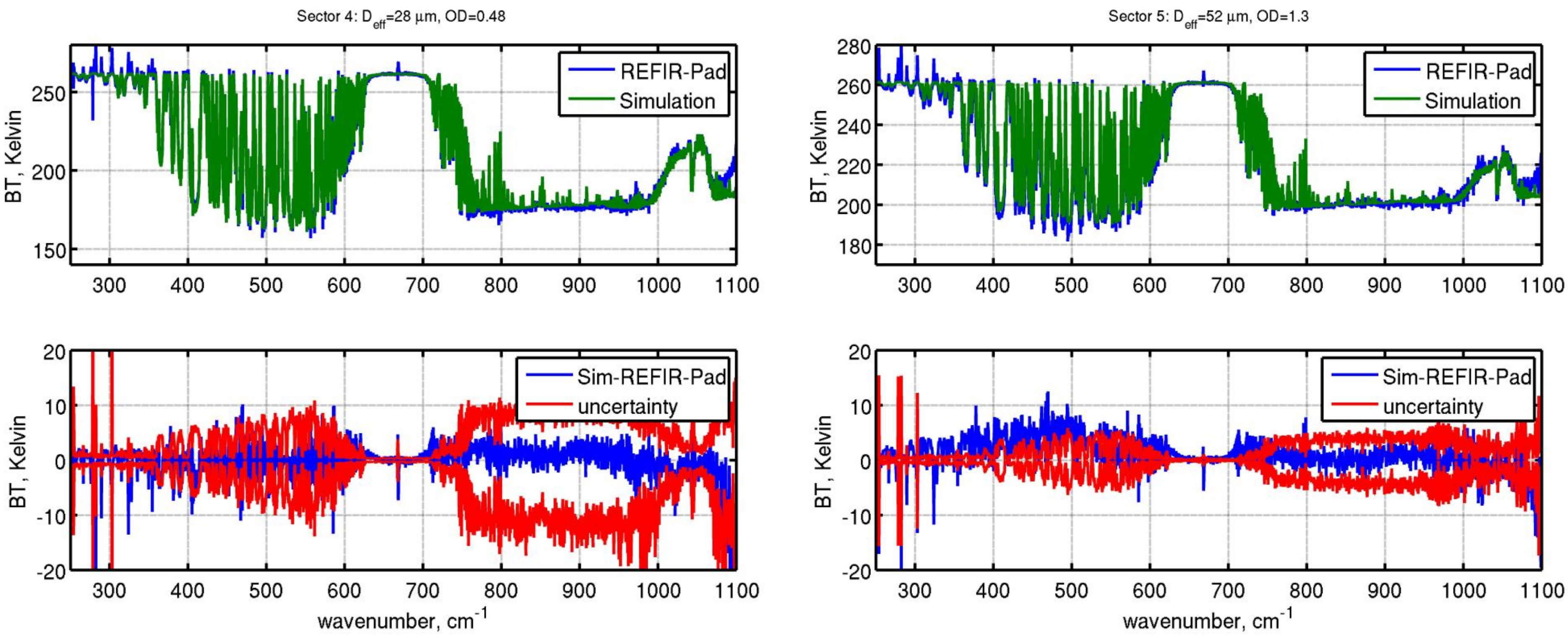
Forward simulations (S2, S3)





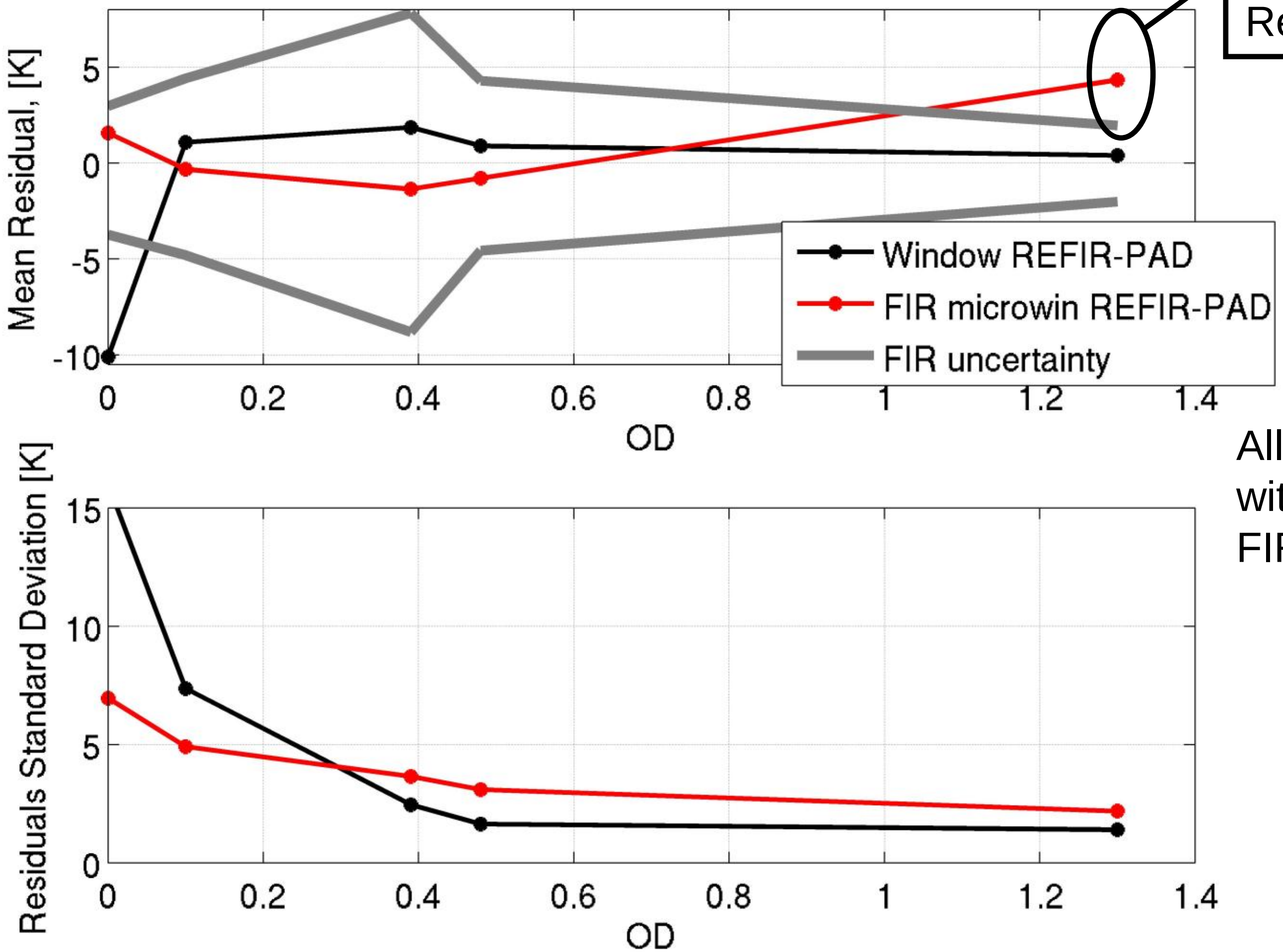
REFIR-PAD measurements in the main IR window show very low radiance values

Forward simulations (S4, S5)



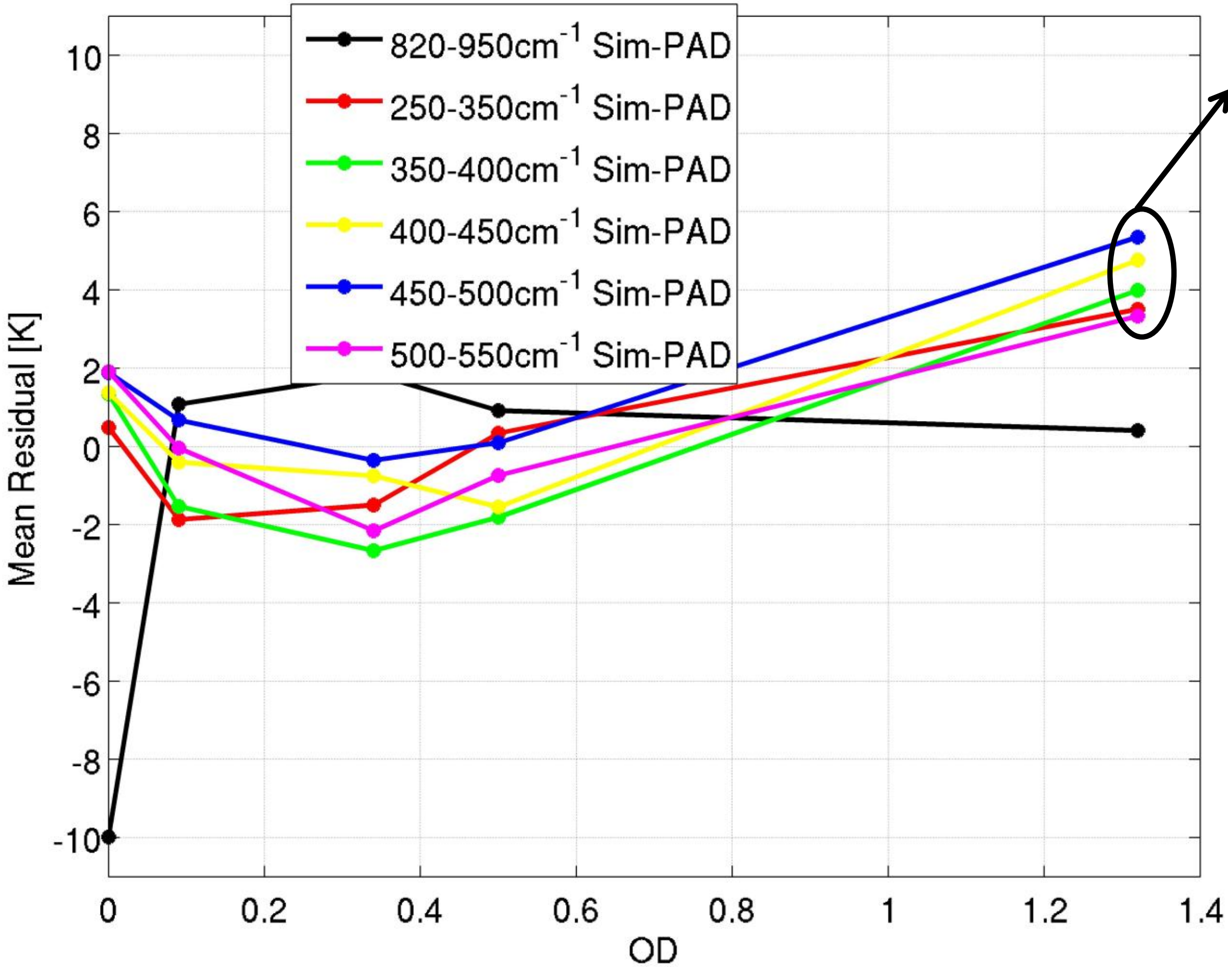
Overall FIR and WIN Residuals

Sector 5
Ret. OD=1.3
Ret. D_{eff}=52 μm



All residuals are within 2 K in the FIR

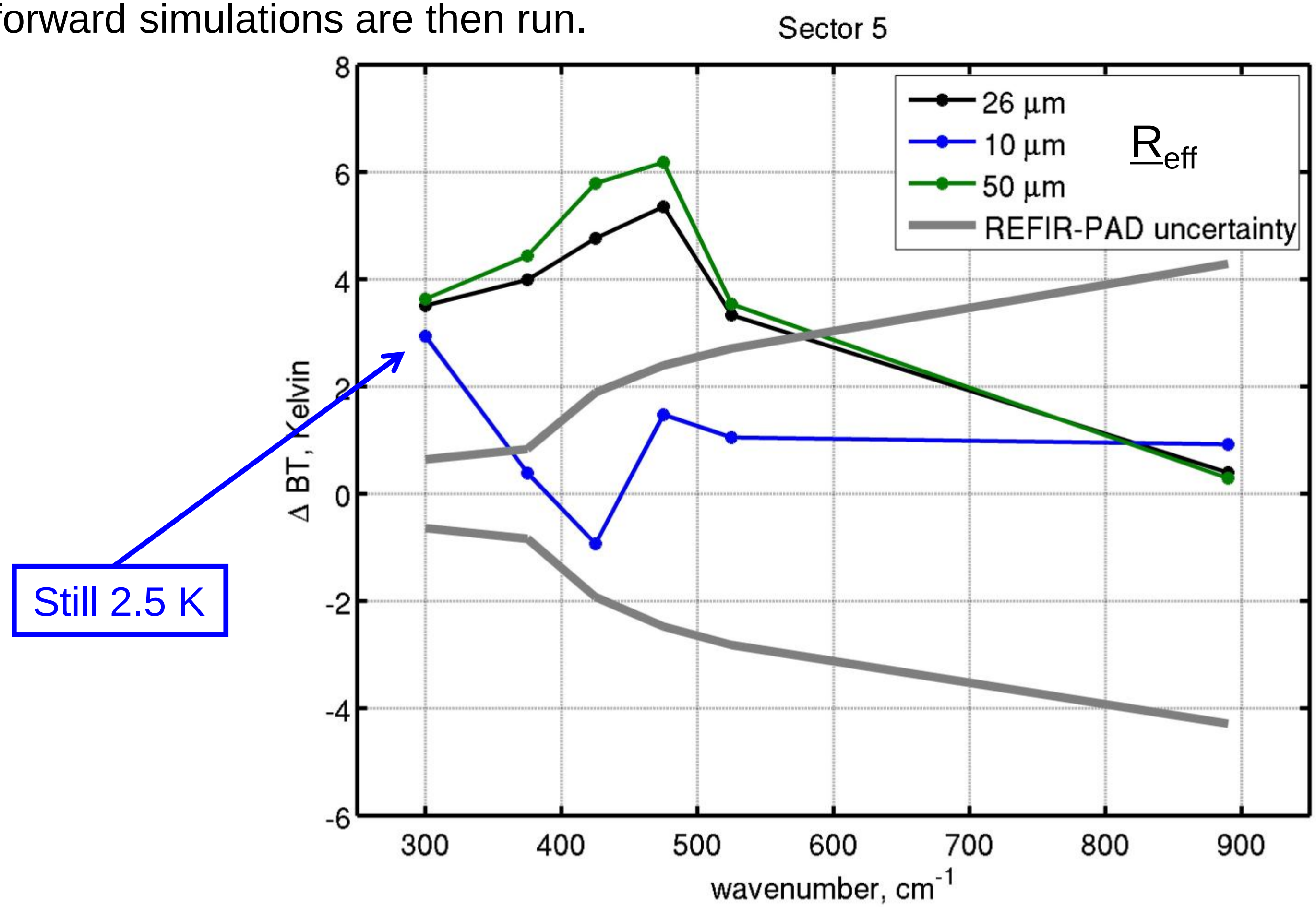
Band FIR and WIN Residuals



Sector 5
Ret. OD=1.3
Ret. D_{eff}=52 μm

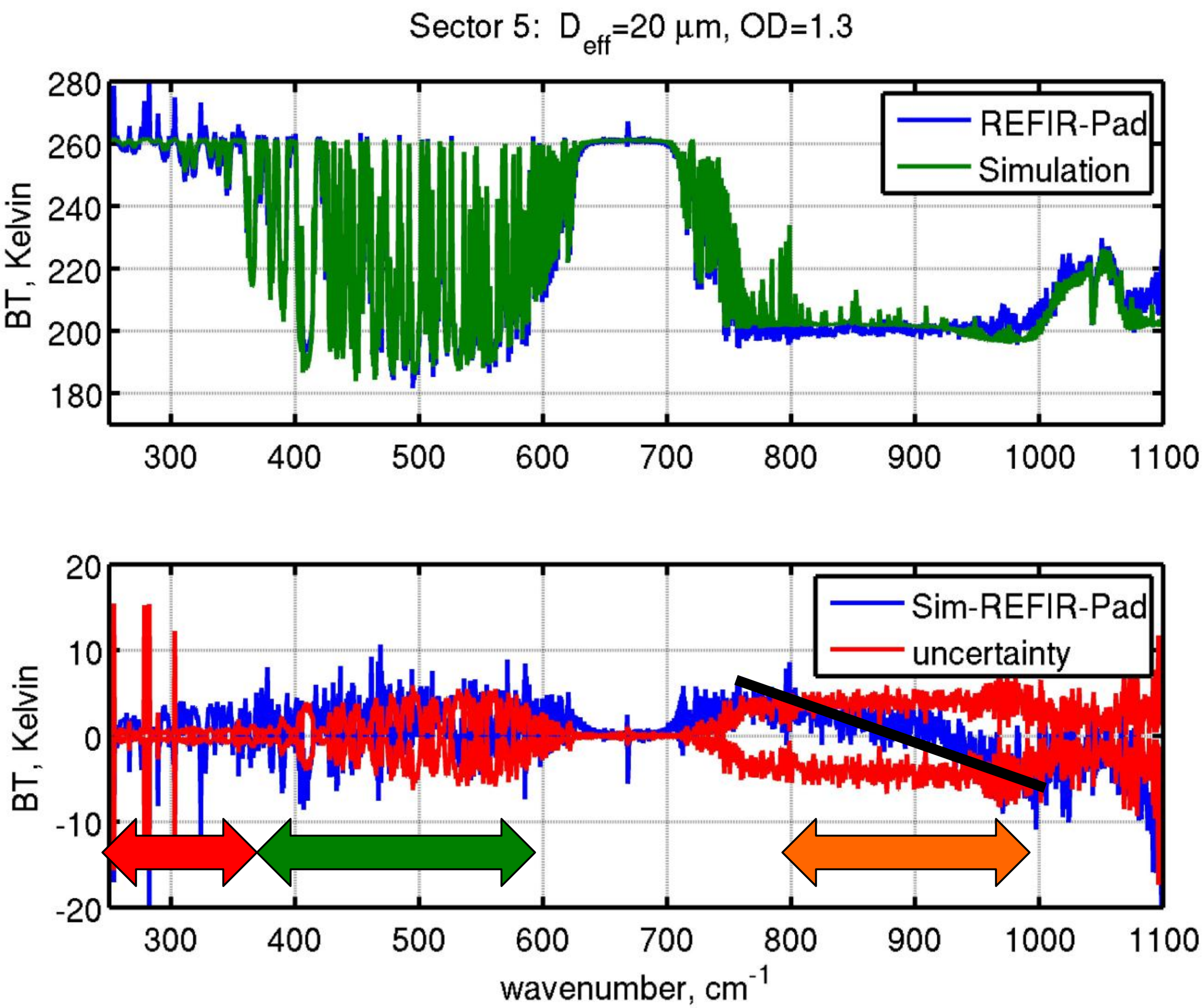
Sensitivity to cloud microphisics

Retrieval is forced for small (D_{eff}=20 μm) and large (D_{eff}=100 μm) effective dimensions. The forward simulations are then run.



Large sensitivity is found in the microwindow bands centered at 375, 425 and 475 cm^{-1} and small in the 250-350 cm^{-1} band

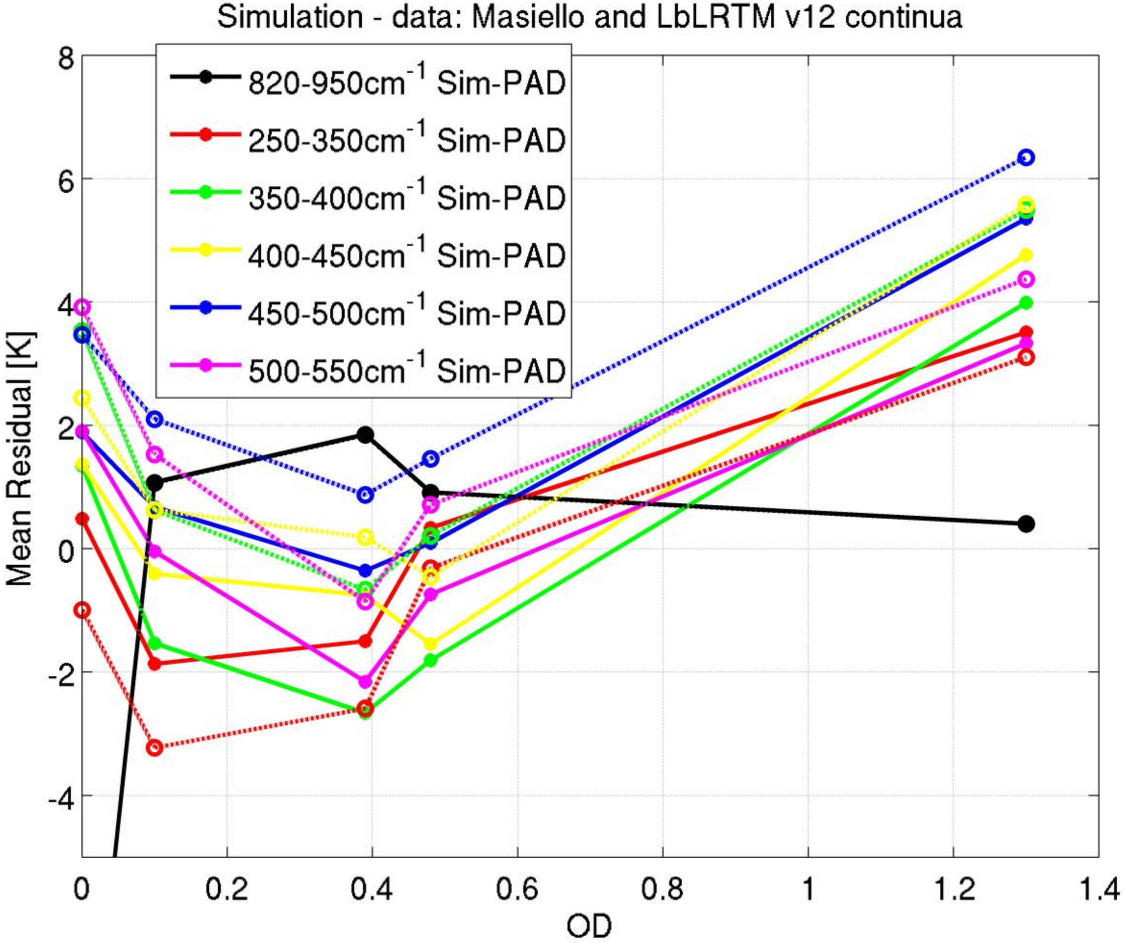
Sensitivity to cloud microphysics



Sensitivity to WV continuum

CLEAR SKY

1-2 K



CLOUDY SKY

0.5-1 K

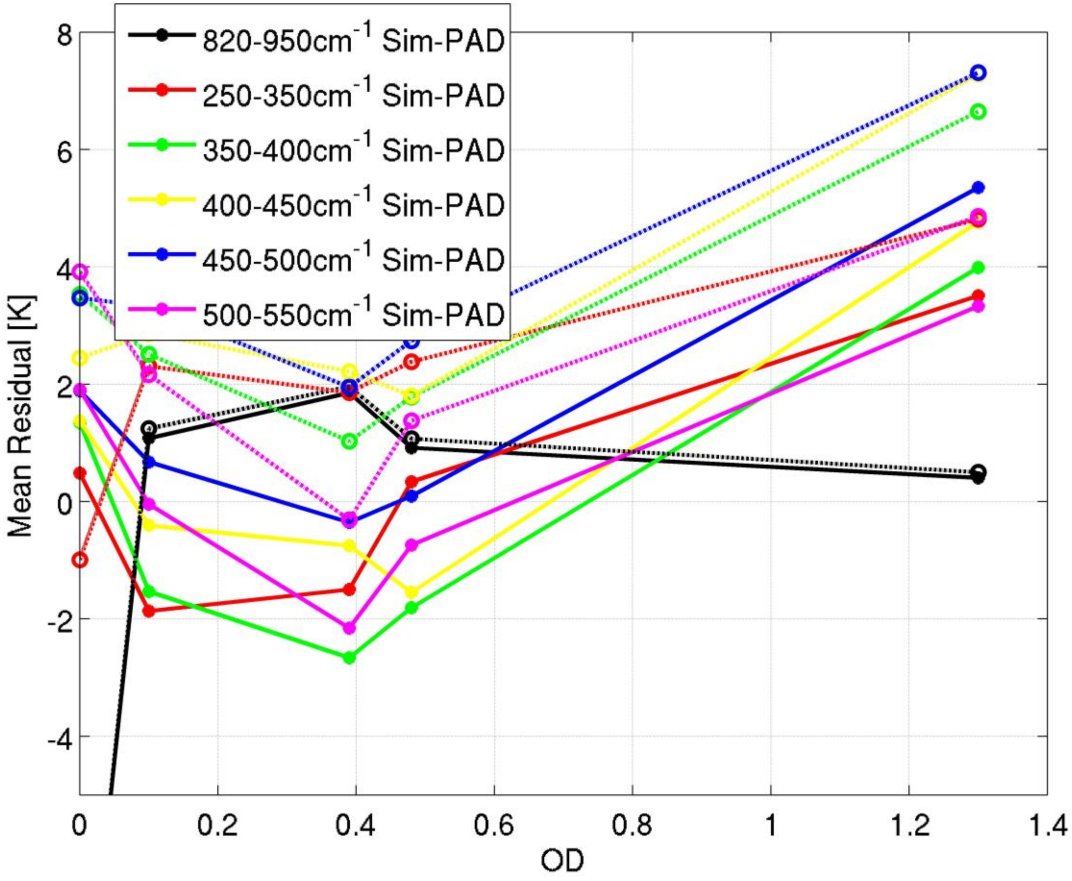
WV continuum has an effect also in presence of optically thin cirrus clouds (1.3 OD)

Sensitivity to RH profile

A 10% increase in RH profile is assumed. Results depend on band and on the original RH and T profile

CLEAR SKY

1 - 2.5 K



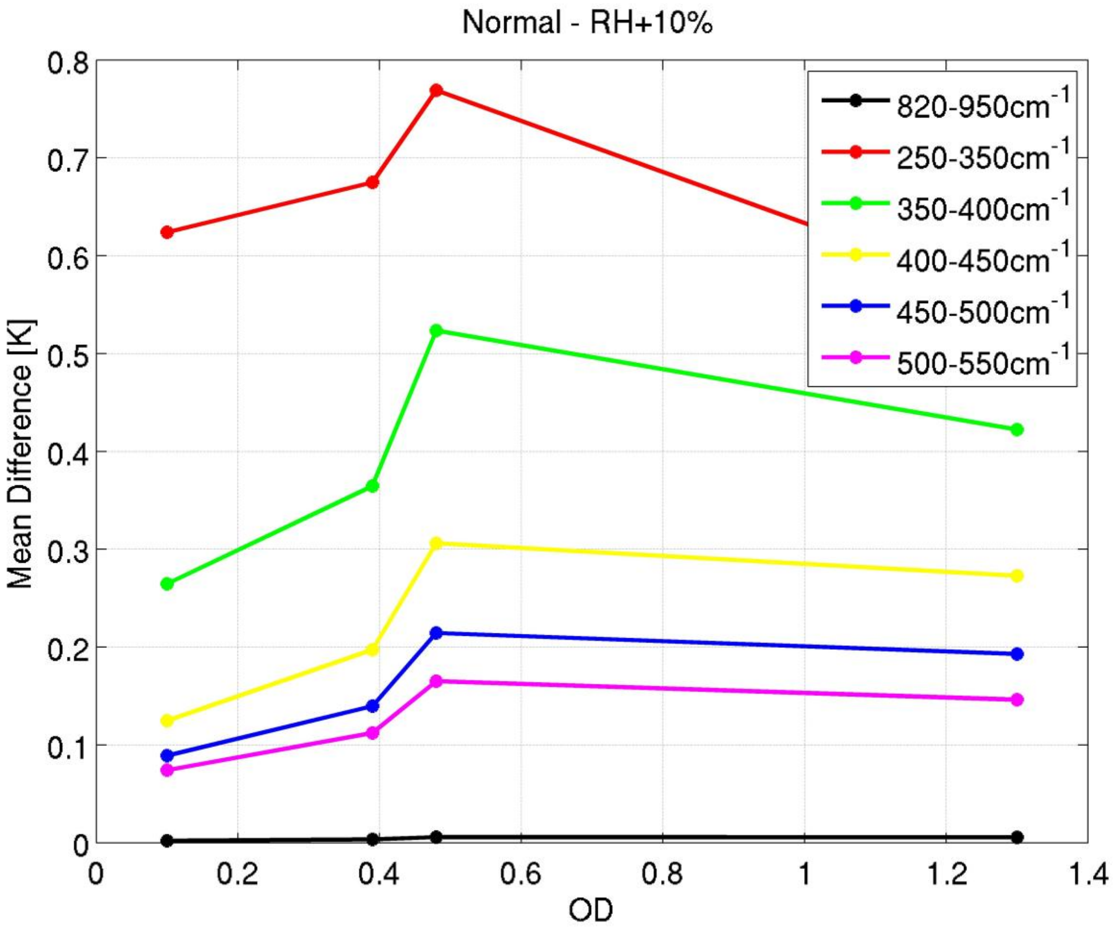
CLOUDY SKY

1 - 4 K

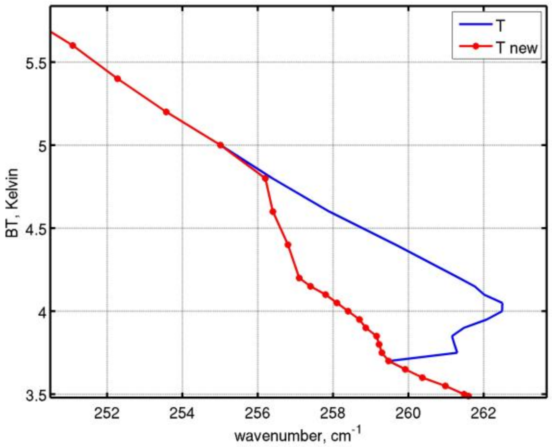
Changes in the residuals depend on wavenumber, cloud features and T and RH profile

WV profile sensitivity from above?

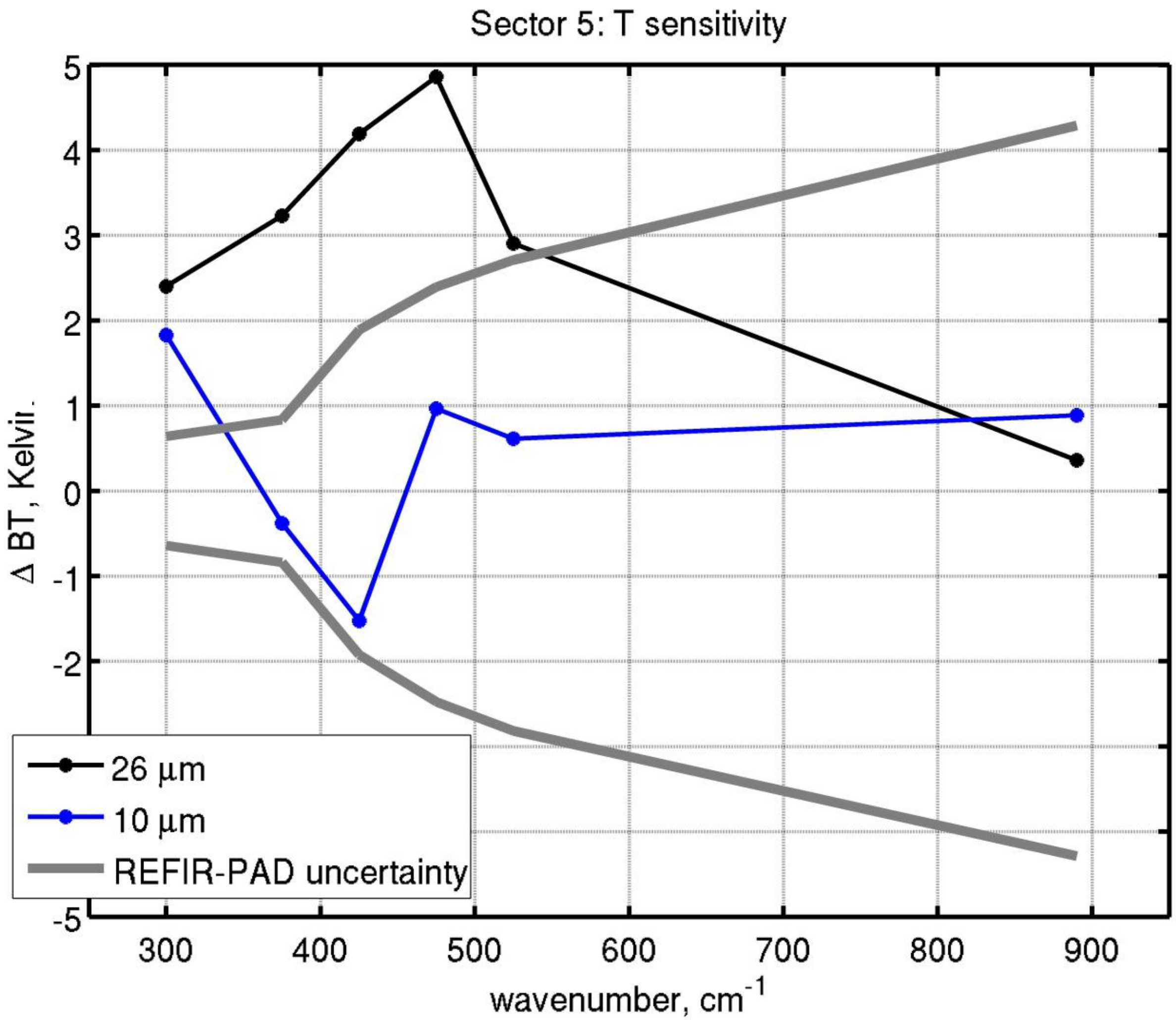
Upwelling radiances are less sensible to water vapor profile than downwelling



Sensitivity to T profile



RS launched from Cervinia at 11.19 am measured a T inversion that is likely disappeared at 1.40 pm



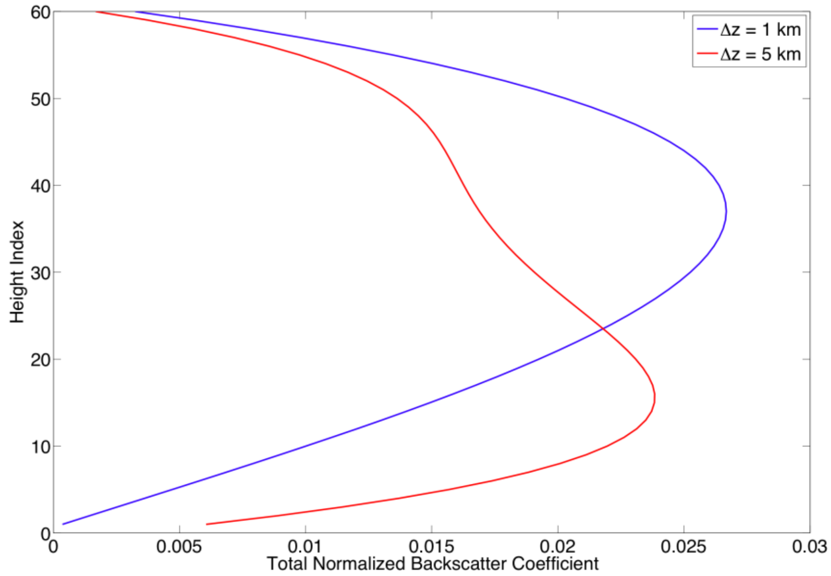
Cirrus global widespread occurrence

Table 2. Cirrus clouds cover obtained from the reduced database, RD.

	Day	Night	Total
Midlatitudes North	36 %	35 %	36 %
Tropics	35 %	39 %	37 %
Midlatitudes South	32 %	30 %	31 %

Table 3. Cirrus clouds cover obtained from the final database, FD.

	Day	Night	Total
Midlatitudes North	8 %	10 %	9 %
Tropics	6 %	7 %	6 %
Midlatitudes South	8 %	9 %	8 %



Veglio and Maestri: Statistics of vertical backscatter profile of cirrus clouds. www.atmos-chem-phys-discuss.net/11/25813/2011/

Conclusions

- Thin cirrus clouds are frequently observed and play an important role in the global energy budget
- Results from the ECOWAR-COBRA Experiment were presented and showed that:
  1. A **methodology** which only uses IR/FIR high resolution measures is defined
  2. **Cloud microphysical properties** strongly affect FIR downwelling radiances
  3. BT derived from measures in the FIR are critically **affected** by water vapor profile, water vapor continuum assumptions and temperature profile
  4. **Upwelling** radiances have less sensitivity to changes in atmospheric parameters and assumptions of water vapor continuum.
- Among other advantages satellite measurements of cluody fields in the FIR would allow:
  1. A quantification of cirrus clouds total radiance trap/emission
  2. A complete and coherent evaluation of current ice crystal single scattering databases
  3. More accurate derivations of cloud radiative properties

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