Analysis of day- and night-time Arctic clouds by means of hyperspectral infrared and ground-based observations

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Satellite cloud detection in polar regions is difficult because of:

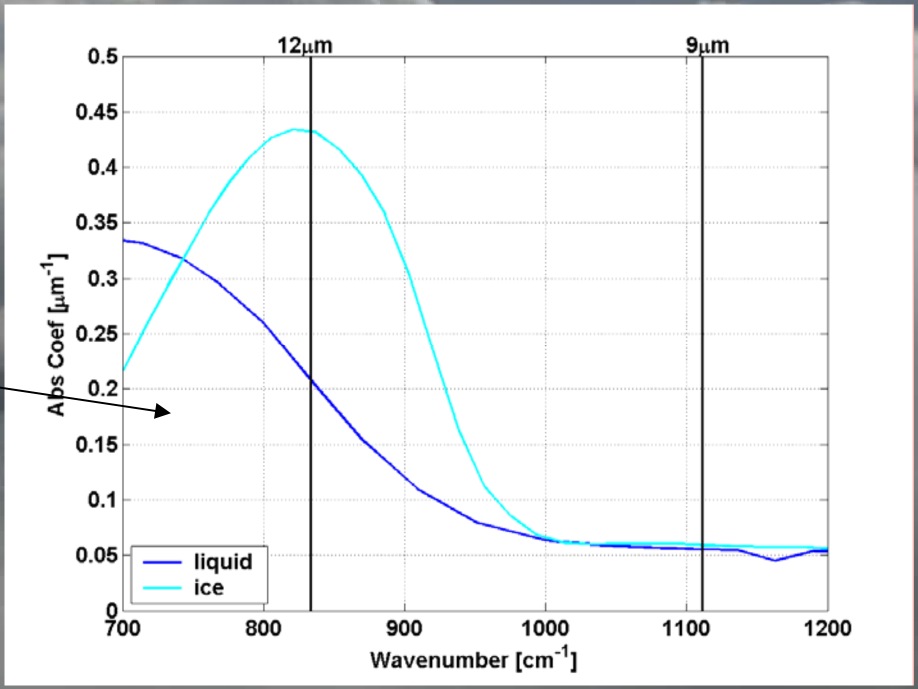
- extremely cold surface temperatures
- little infrared and visible contrast with snow/ice surface
- strong temperature inversions
- usually low and thin clouds

During polar nights, cloud detection is even more difficult:

- poor or no solar contribution
- reflectance tests are unusable (e.g. 1.6 μm test)

Current MODIS and AIRS IR spectral tests are based on climatological mean temperature, water/ice spectral absorption, water vapor continuum, temperature inversion strength.

Ice /water Absorption Coefficient



Nighttime Polar Cloud Detection Tests

AIRS

1) BT(800)-BT(1100) = BT12.5-BT9.1 < Tr1
2) BT(800)-BT(1100) = BT12.5-BT9.1 > Tr2   cloudy tests
3) BT(960)-BT(1100) = BT10.4-BT9.1 > Tr3
4) max(BT(6.7-8.3mm))-BT(10mm) > Th4   clear test

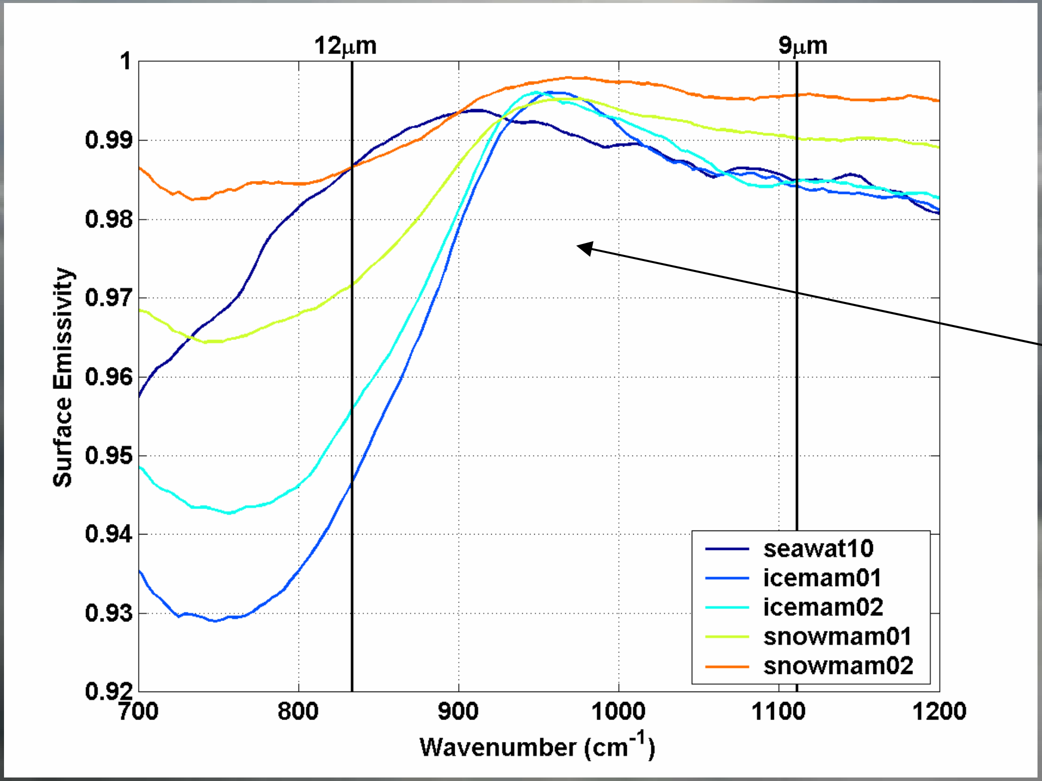
Based on Holtz and Ackerman, Proc. AMS, 2005

Liu et al., Night Time Polar Cloud Detection with MODIS, Rem. Sens. Env., 2004.
Ackerman et al., Discriminating clear-sky from clouds with MODIS, J. Geo. Res., 1998

Holtz and Ackerman, Arctic Winter High Spectral Resolution Cloud Height Retrievals, Proc. AMS, 2005.

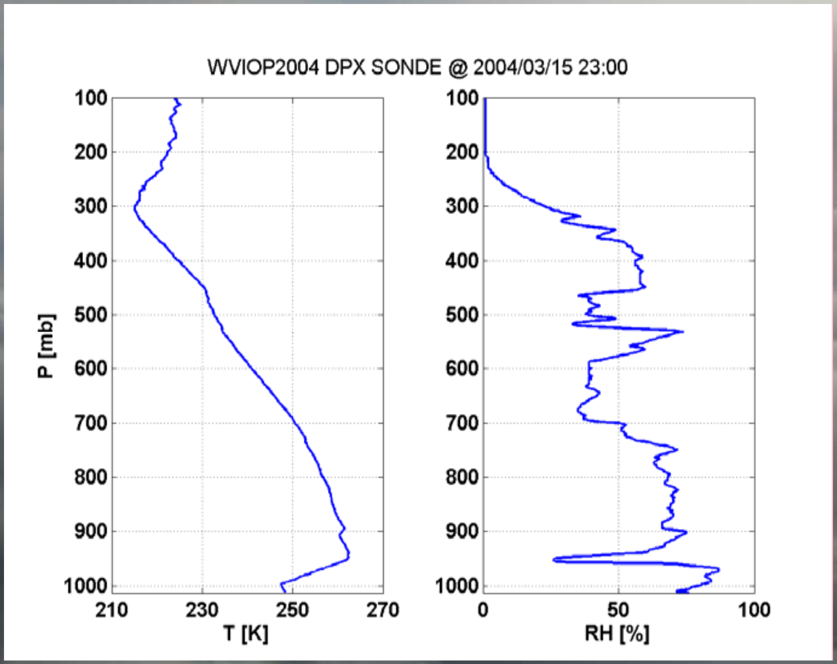
Surface polar regions are a combination of ice, snow, and sea water.

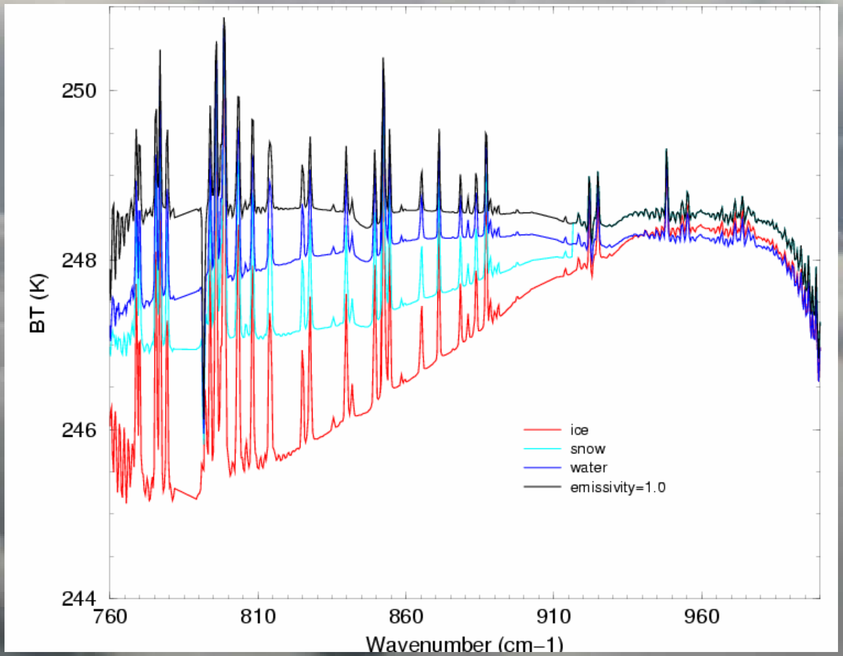
IR spectral emissivities differ significantly and it can play a crucial role in cloud detection due to the spectral features in the 700-1200 cm^{-1} range.



from MODIS UCSB Emissivity Library (PI: Zhengming Wan)

AIRS Tb spectra are simulated in clear sky using RTTOV (Eyre, J.R., 1991)





AIRS Tb spectra are simulated in cloudy sky using RTX

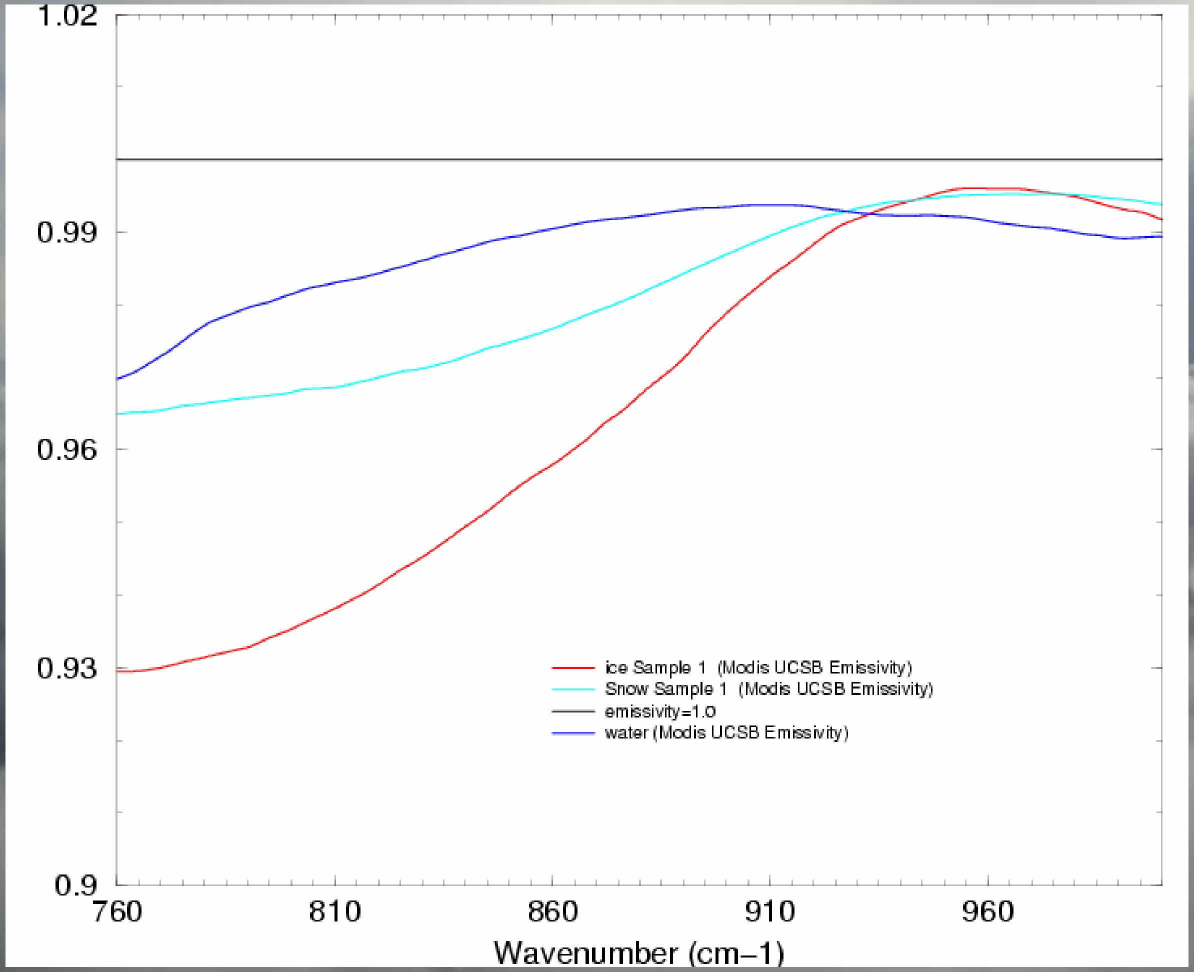
The numerical model RTX [Rizzi et al., 2001; Amorati and Rizzi, 2002, Maestri et al., 2005], solves the radiative transfer equation with the adding and doubling method taking into account the multiple scattering by randomly-oriented particles with a plane of symmetry. Polarized radiation is considered in term of Stokes parameters under the hypothesis of a plane-parallel and vertically inhomogeneous atmosphere including both thermal and solar sources.

Spectral properties of atmospheric gases are computed with the RTTOV model while the extinction and scattering coefficients, the single scattering albedo and the Lagrange coefficients to expand the scattering matrix are computed for a gamma-modified size distribution of spherical cloud particles (water and ice) using a Mie code (Wiscombe 1979).

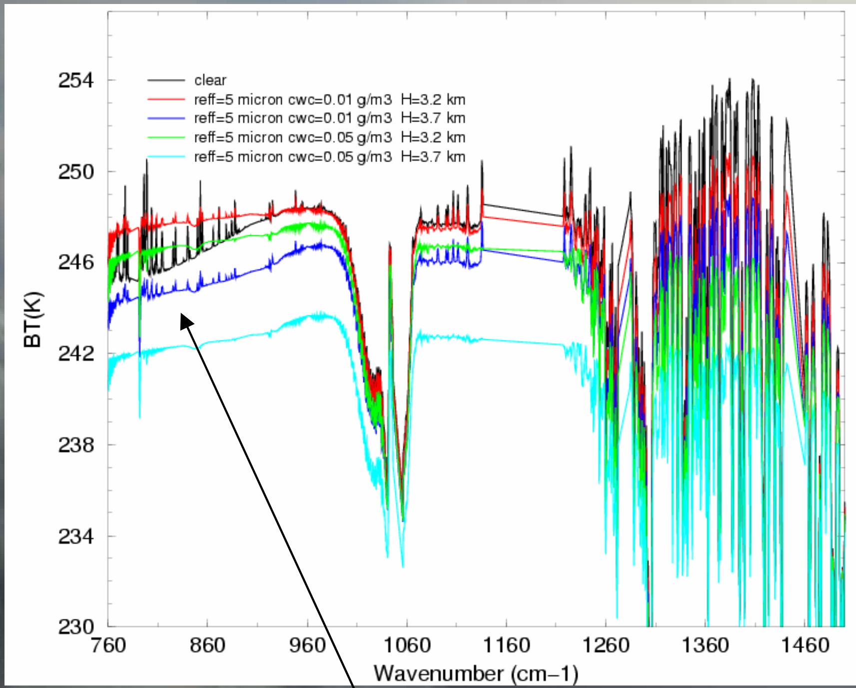
Cloud parameters for cloud spectra simulation

- T and RH profiles
- cloud top 2.2, 2.7, 3.2, 3.7, 5.1, 5.5 km
- Cloud phase: liquid, ice, mixed phase
- Effective radius: 5, 15, 25, 30, 50, 70 μm
- Ice or water liquid content : 0.001 0.005 0.01 0.03 0.05 0.07

Surface emissivity (ε): sea water, ice , snow plus ε=1

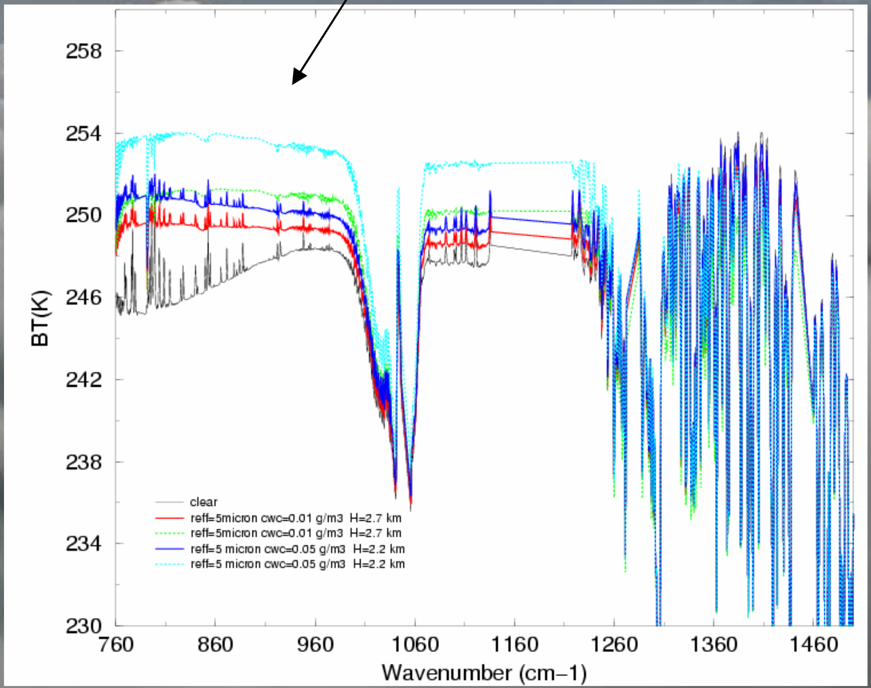


Clear and cloud spectra using ice emissivity



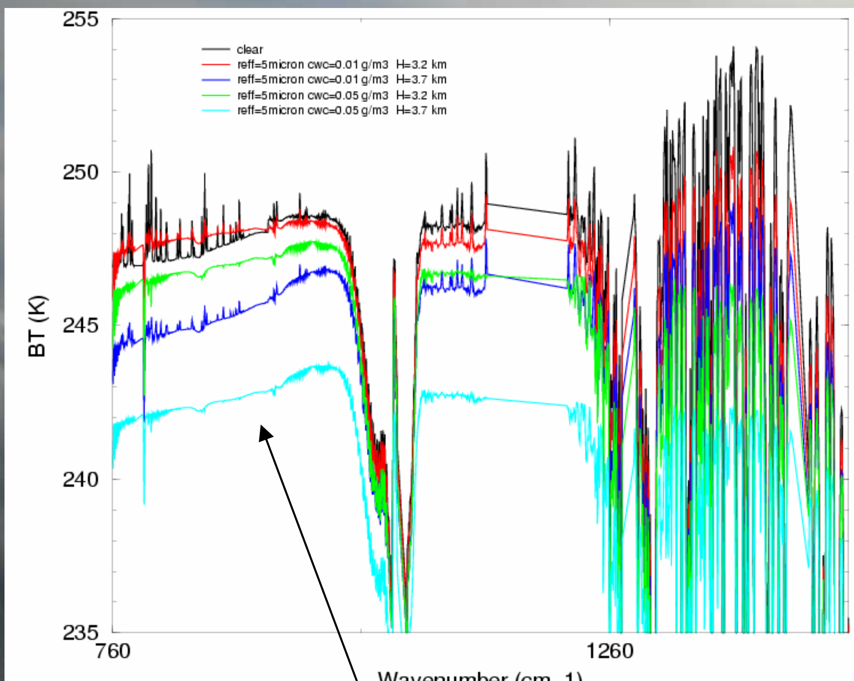
Ice clouds

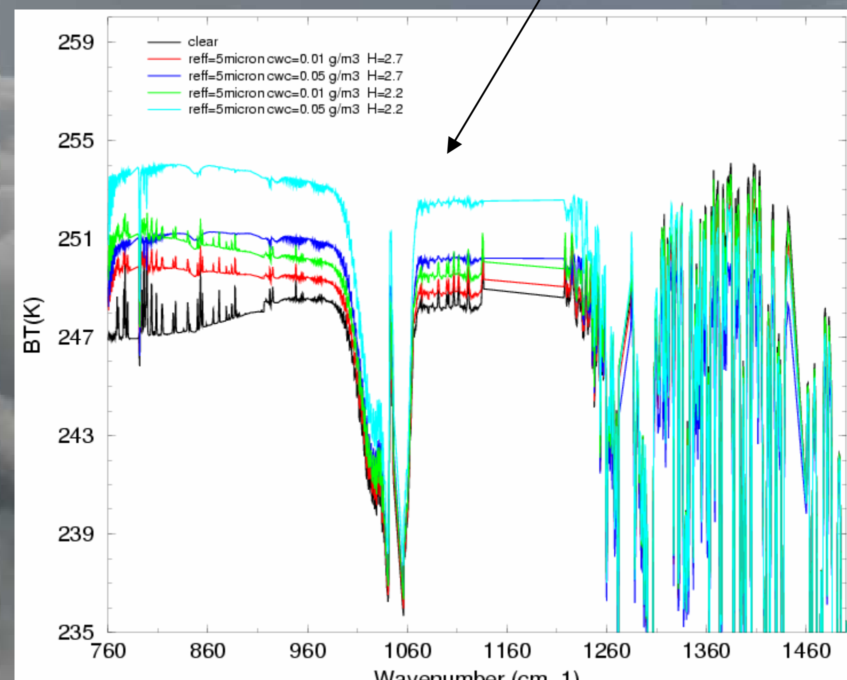
Water clouds



Clear and cloud spectra using snow emissivity

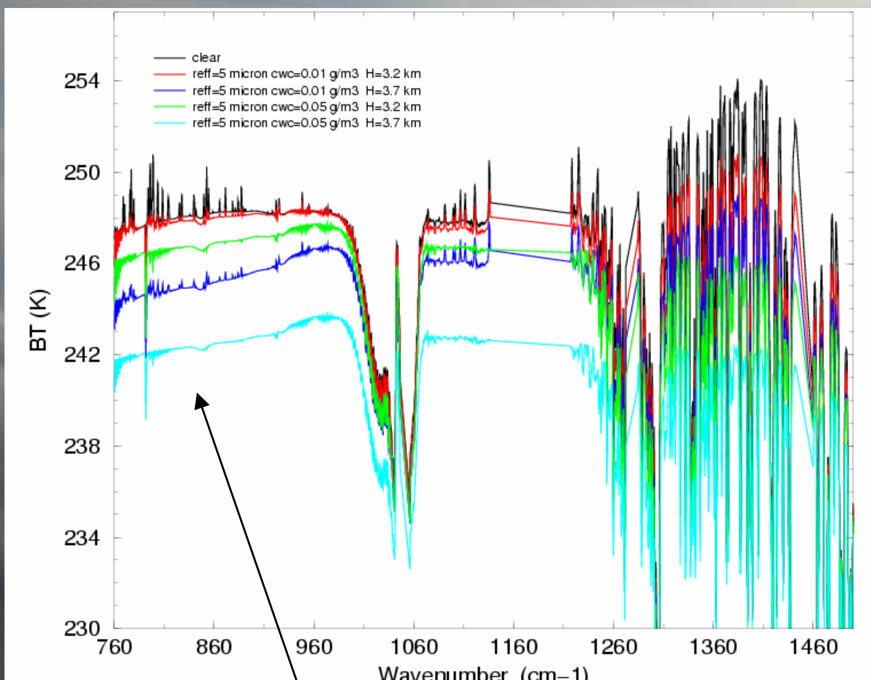
Water clouds



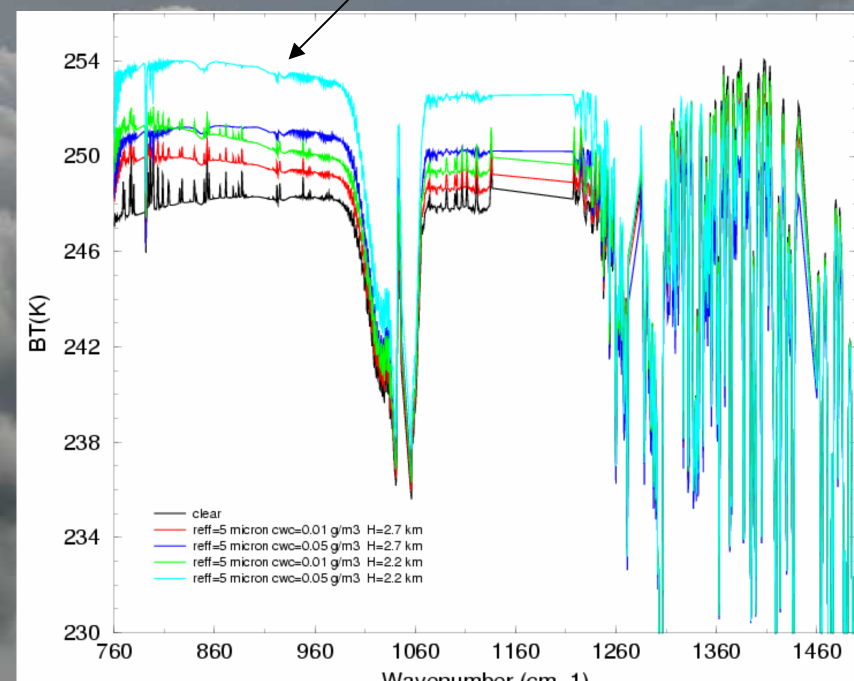


Ice clouds

Clear and cloud spectra using water emissivity

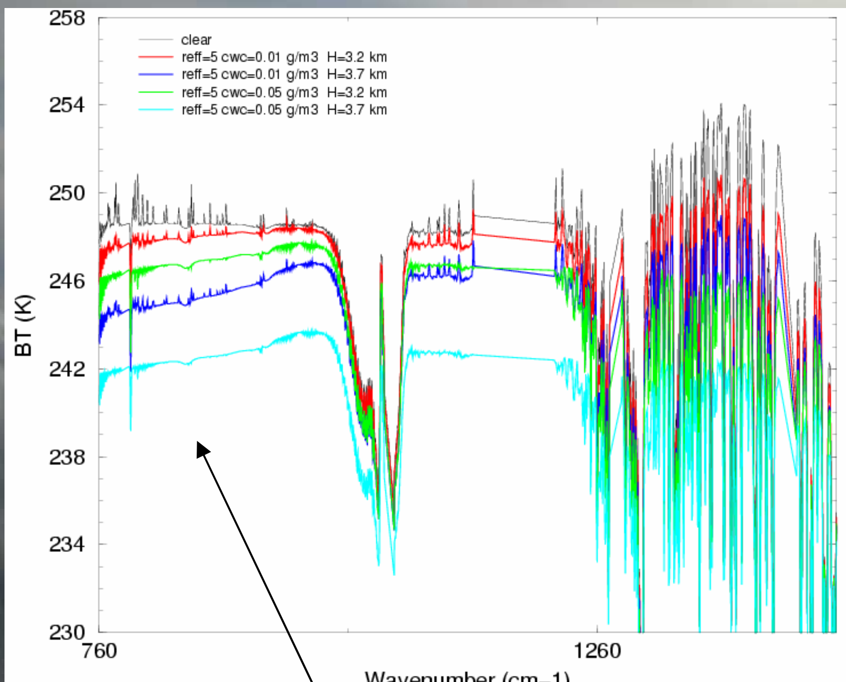


Water clouds

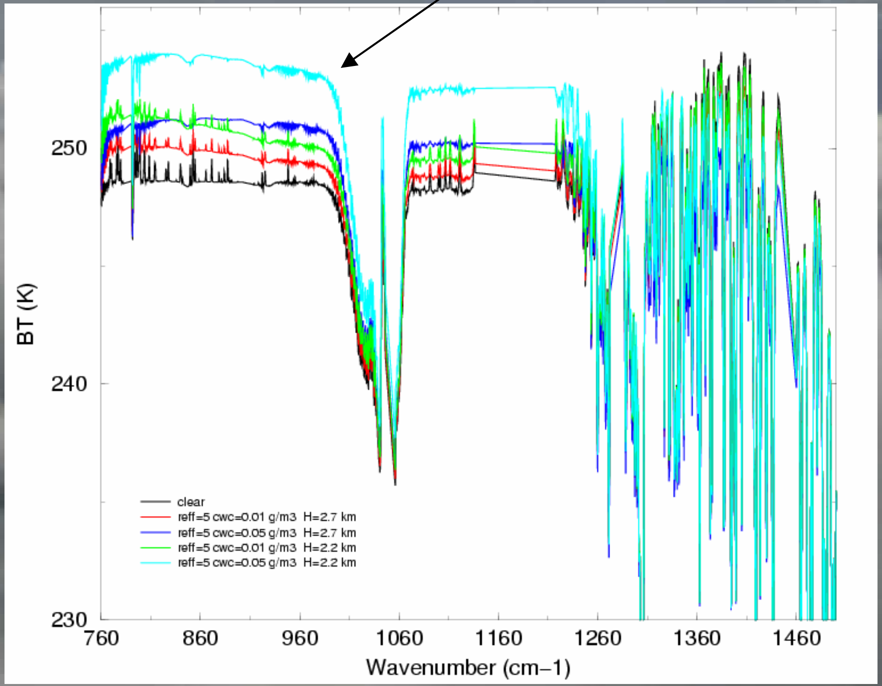


Ice clouds

Clear and cloud spectra using costant emissivity (ε =1)



Water clouds



Ice clouds

Test Results

	Percentage of “cloud-detected-clear”
Ice	22 %
Snow	29 %
Water	30 %
Emissivity=1.	30 %

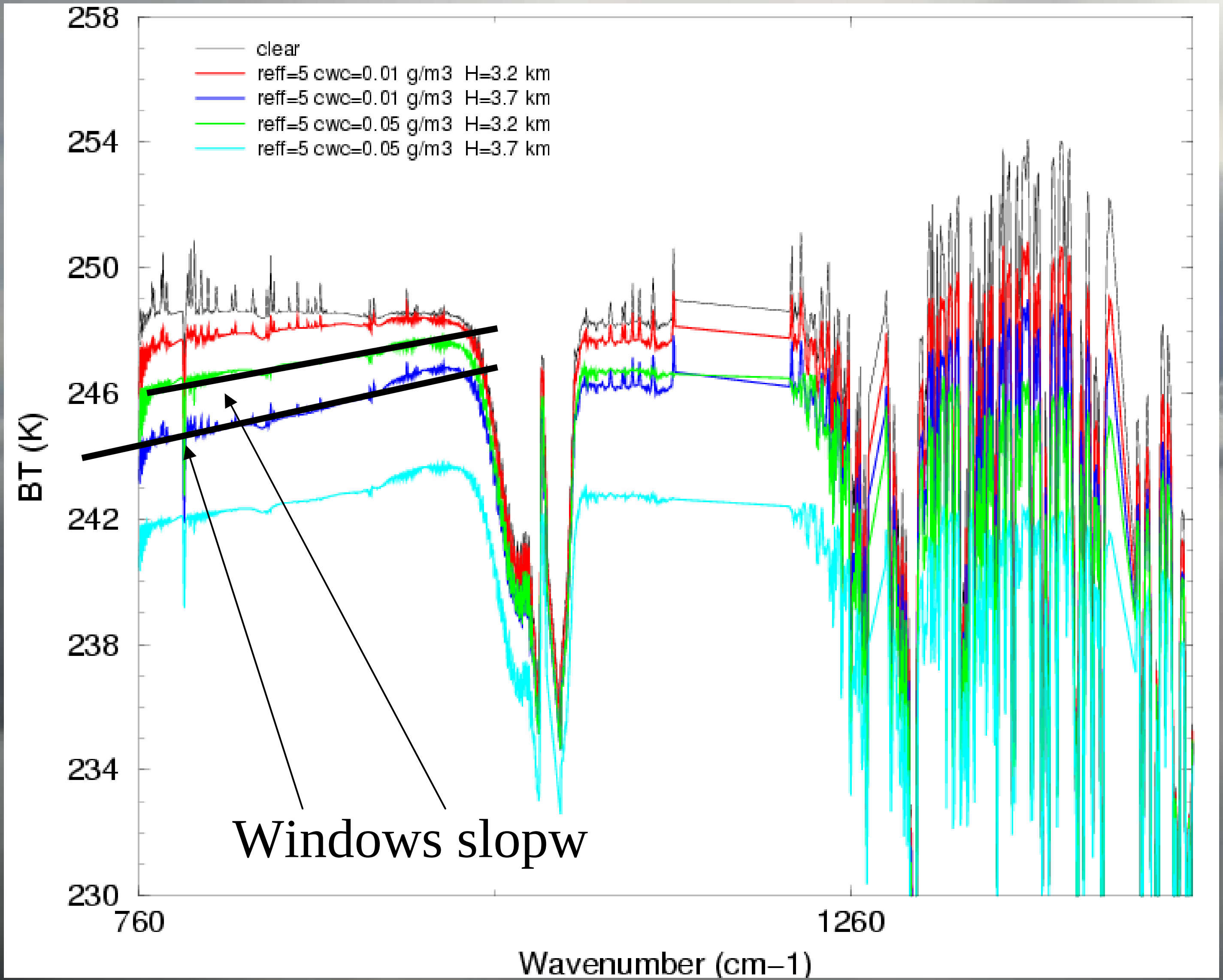
140*4 spectra

Clear spectra are correctly detected for water and costant emissivity only

AIRS Tb spectra are simulated in clear sky using RTTOV for 305 artic profiles

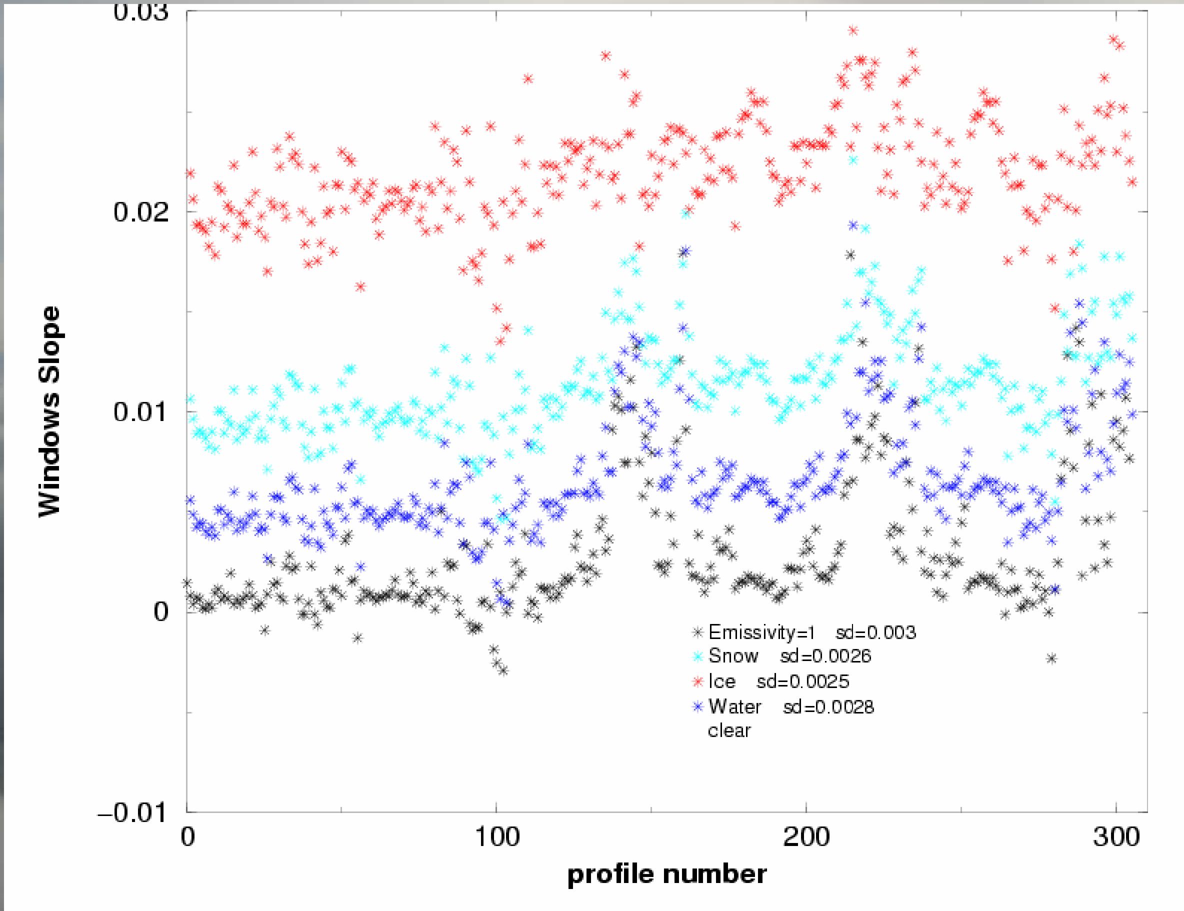
Test Results

	Percentage of “clear-detected -cloud”
ICE	100 %
SNOW	100 %
WATER	15 %
ε=1.	12%

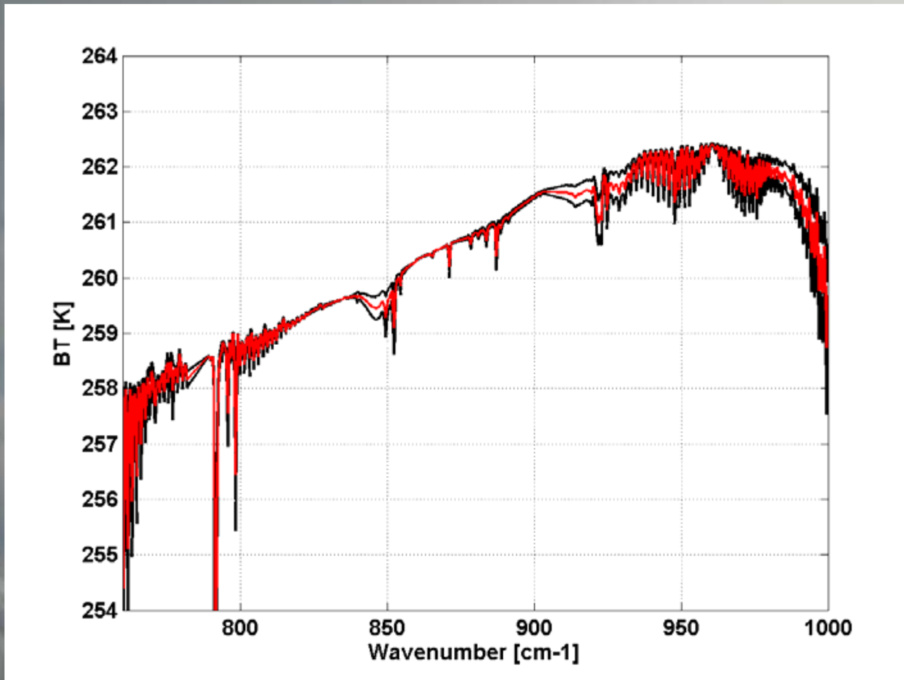


clear
reff=5 cwc=0.01 g/m3 H=3.2 km
reff=5 cwc=0.01 g/m3 H=3.7 km
reff=5 cwc=0.05 g/m3 H=3.2 km
reff=5 cwc=0.05 g/m3 H=3.7 km
BT (K)
258
254
250
246
242
238
234
230
760
1260
Wavenumber (cm–1)
Windows slopw

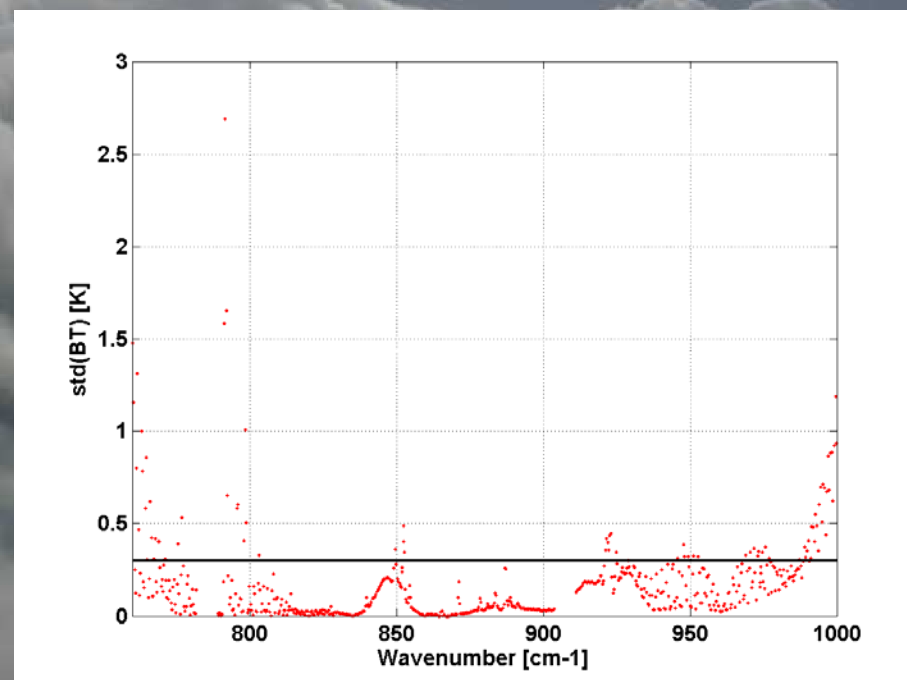
Window Slope Analysis



Spectra for different geometry



Standard Deviation for simulated spectra



Window Slope test

	Percentage “cloud-detected-clear”
ICE	1%
SNOW	8%
WATER	5%
ε=1.	2%

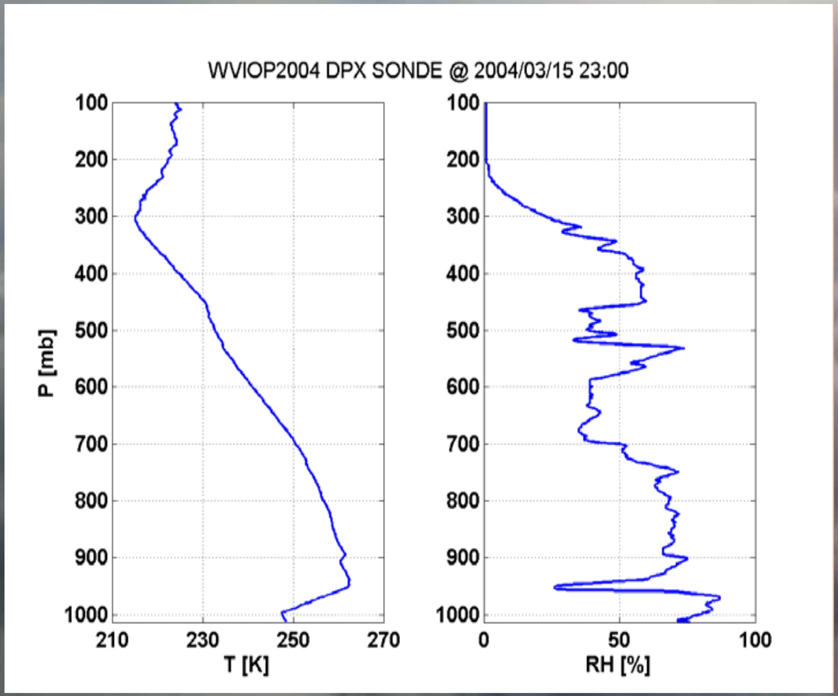
Clear spectra are detected correctely

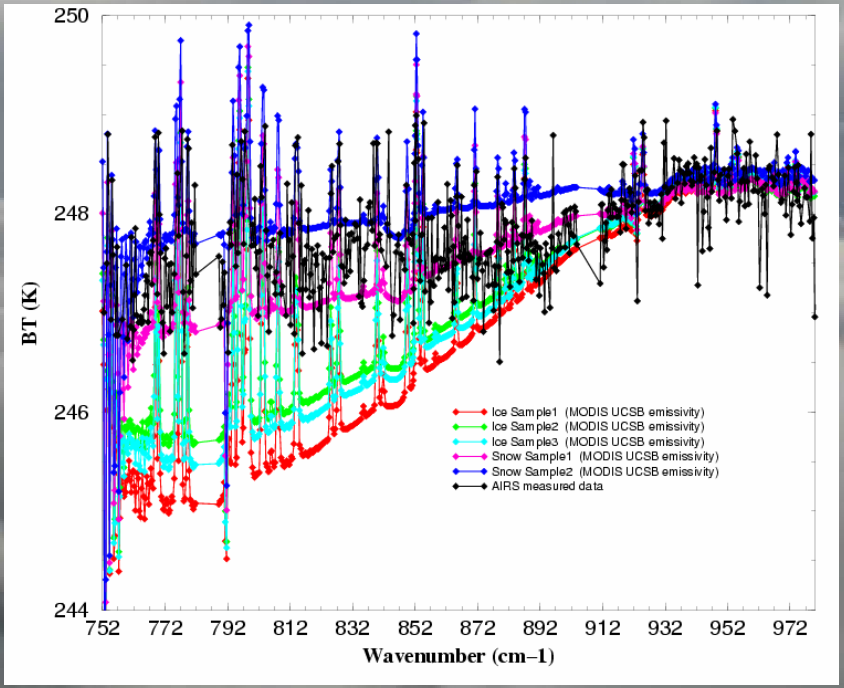
Window slope test

Test based on window slope, estimated in clear condition at different time/day.

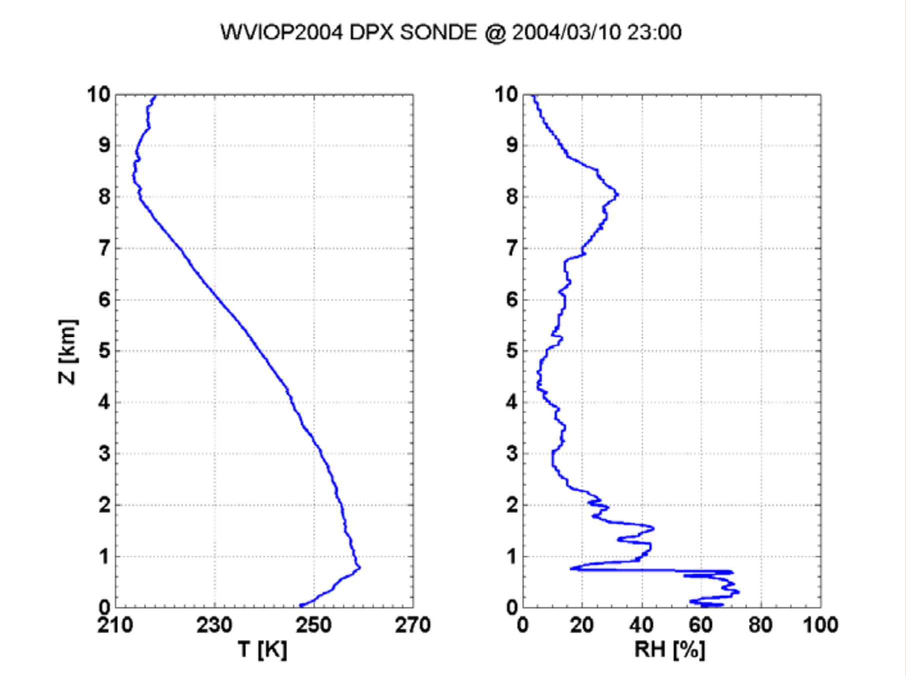
MODIS or AVHRR channel at 1.6 μm for clear identification .

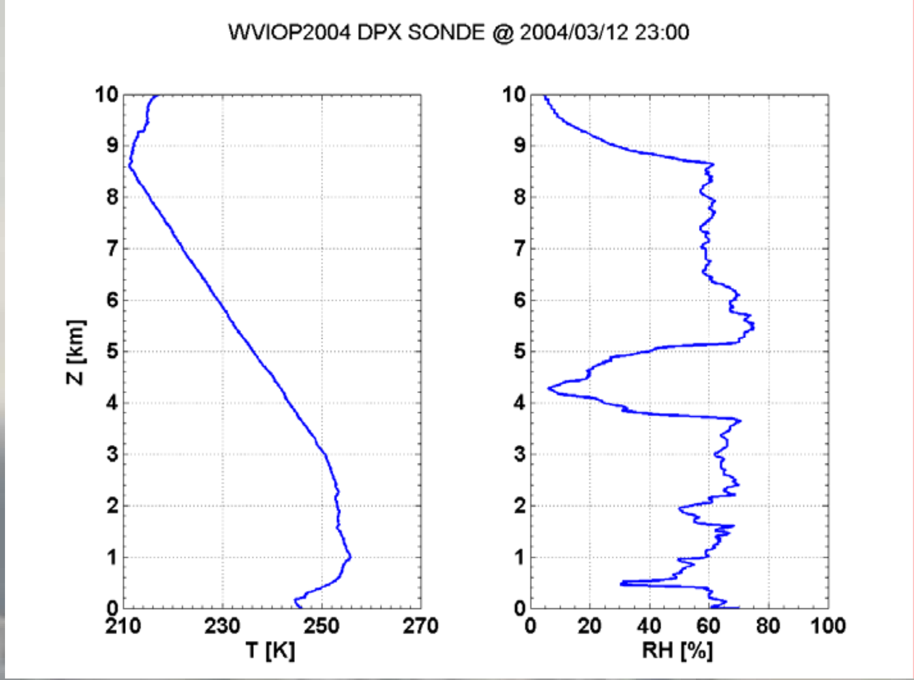
Measured data

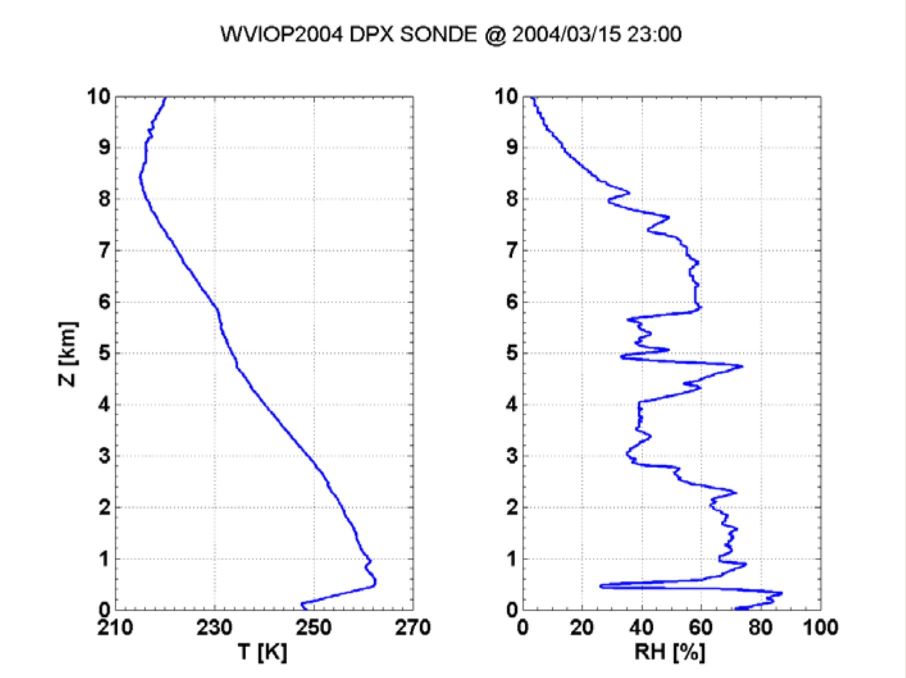


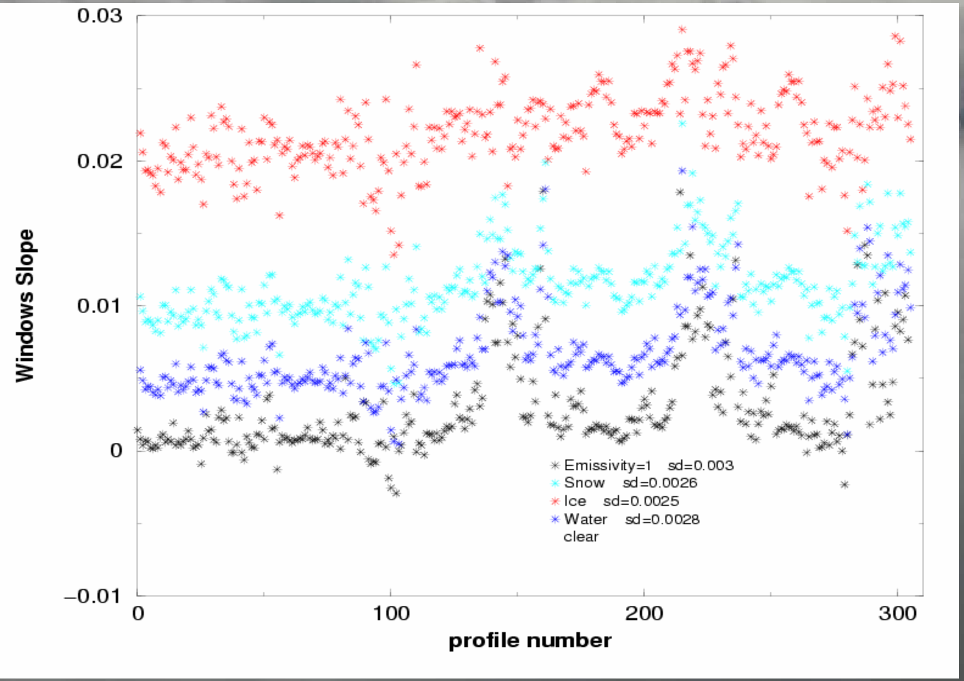


Radiosonde data are from WVIOP2004 (PI: Ed Westwater).

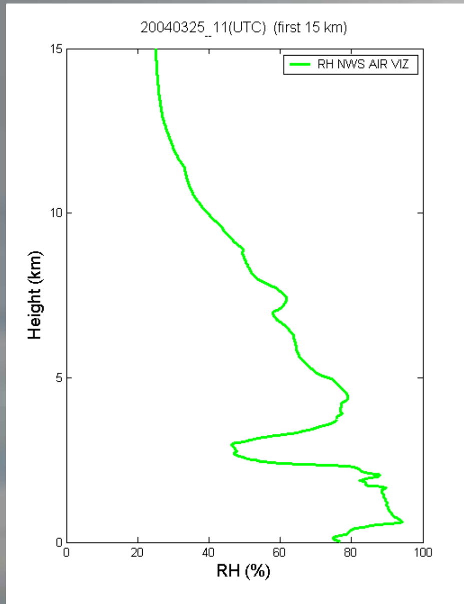

WVIOP2004 DPX SONDE @ 2004/03/10 23:00
Z [km]
T [K]
RH [%]

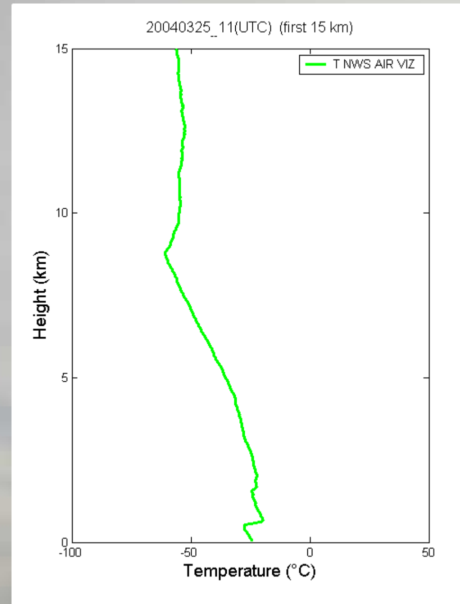

WVIOP2004 DPX SONDE @ 2004/03/12 23:00
Z [km]
T [K]
RH [%]

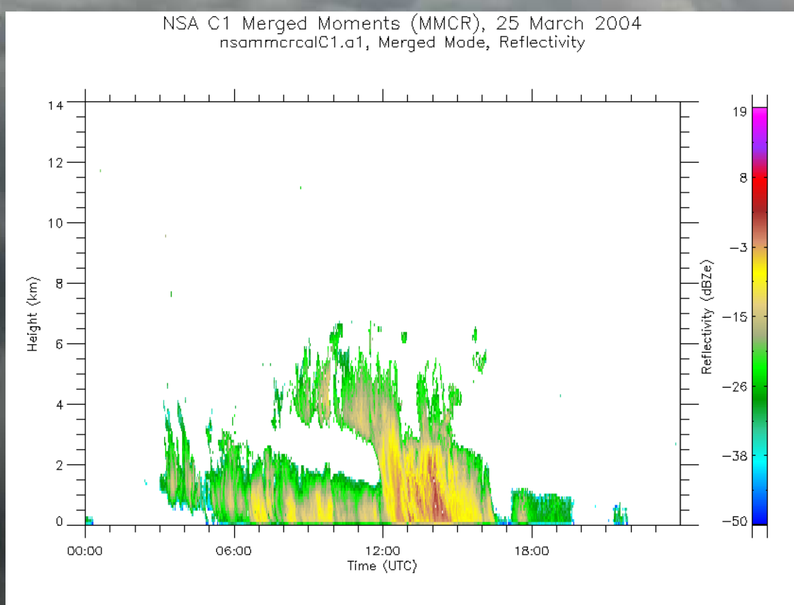

WVIOP2004 DPX SONDE @ 2004/03/15 23:00
Z [km]
T [K]
RH [%]

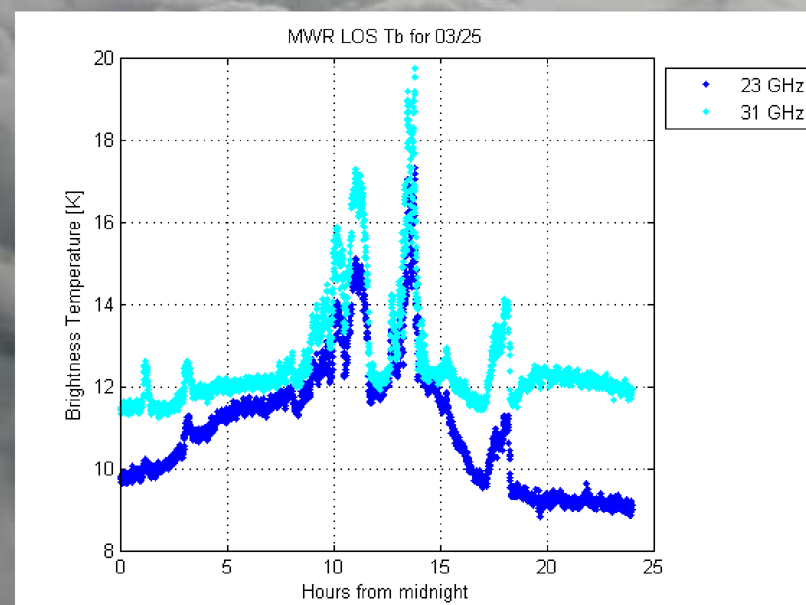

Windows Slope
profile number
Emissivity=1 sd=0.003
Snow sd=0.0026
Ice sd=0.0025
Water sd=0.0028
clear

25 March 2004









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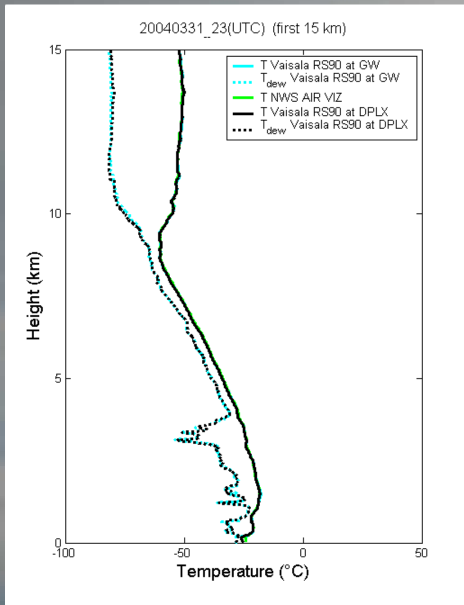
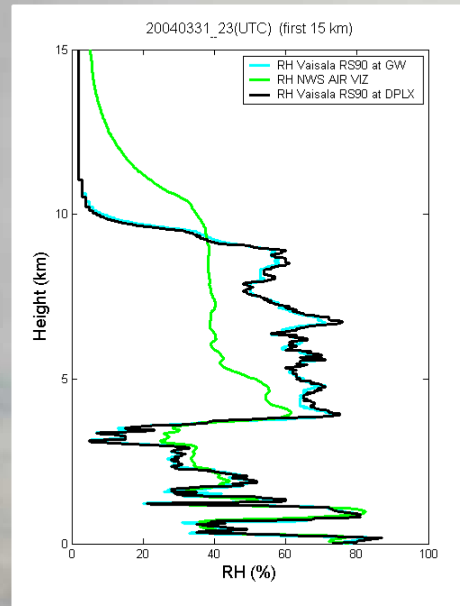
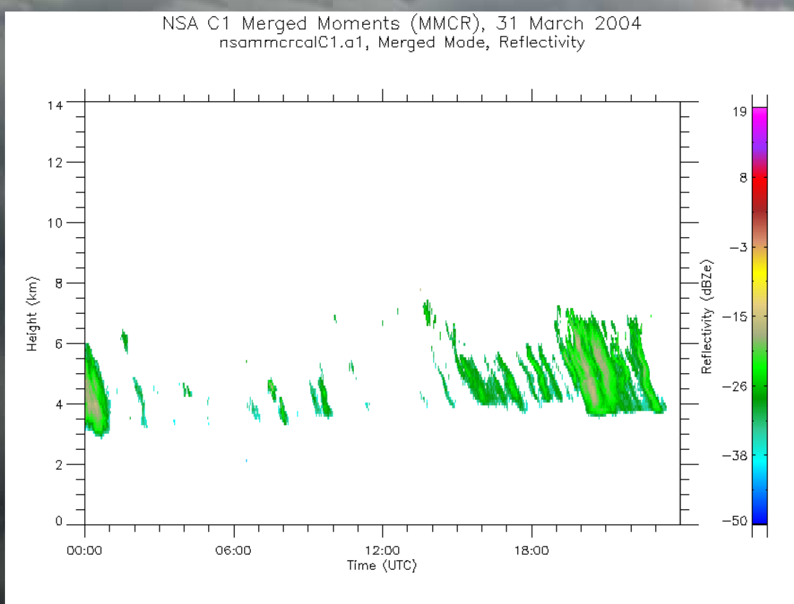
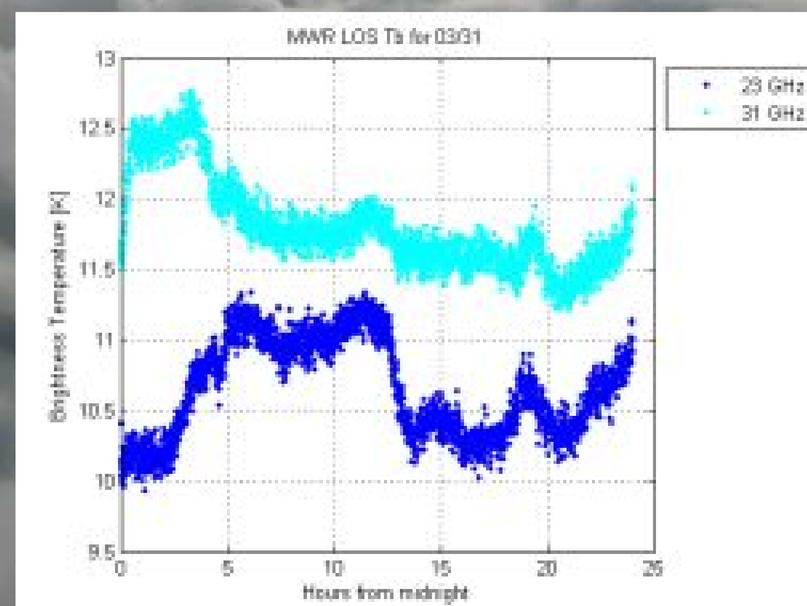
31 March 2004

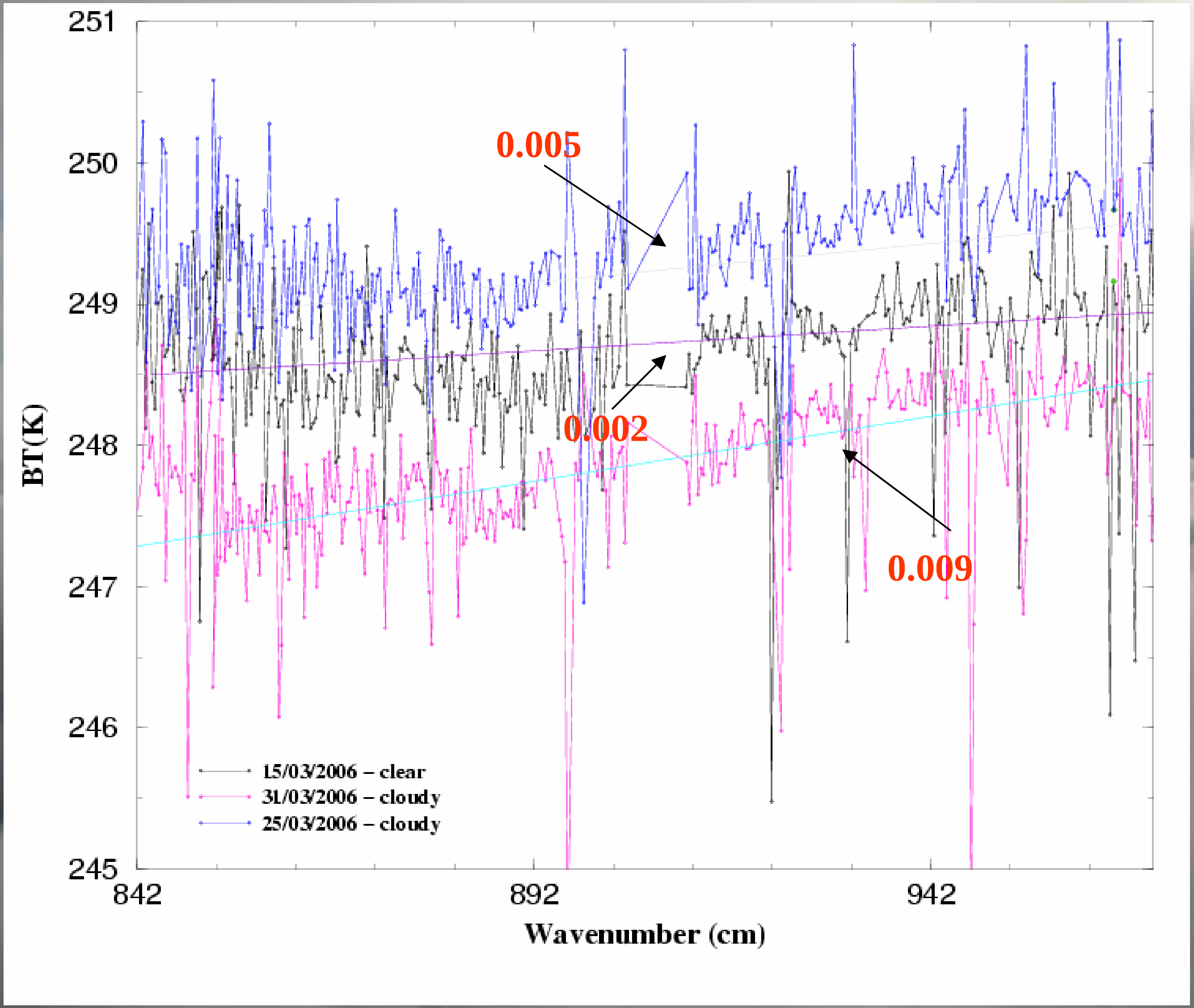








Window slope



Clonclusion and Future work

Using currently available polar nighttime cloud detection algorithms for AIRS:

- **clear-sky spectra with ε=1 are detected correctely**
- **clear-sky spectra with ε for water are not always detected correctly**
- **clear-sky spectra with ε for ice/snow are always misidentified as cloudy**
- **Information on clear window slope spectra can improve current tests.**

- **Analysis of the tests will be extend to a large measured data set.**

For further results on MODIS and IASI see poster A24 by D. Cimini