# Analysis of Artic clouds by means of hyper-spectral satellite

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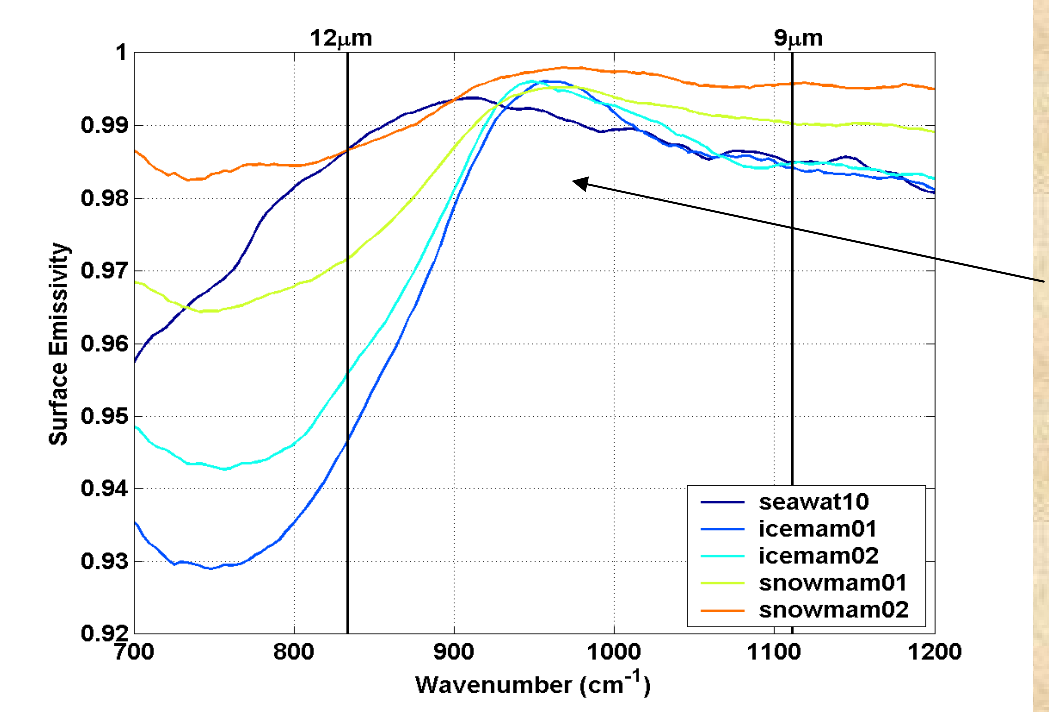
**Satellite cloud detection in polar regions is difficult because of:**

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

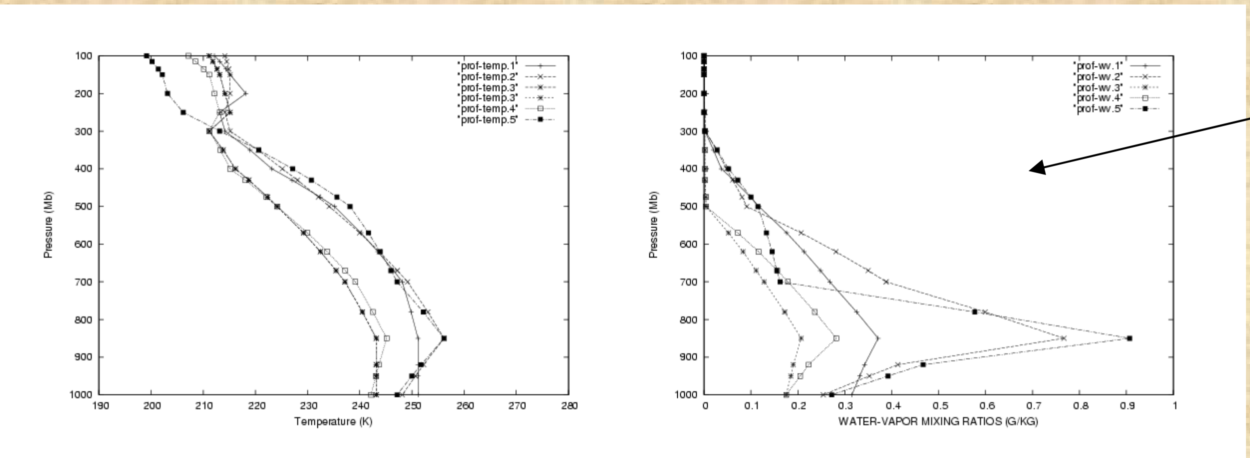
**In addition during polar nights there is not possible apply reflectance tests (e.g. 1.6 μm test).**

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

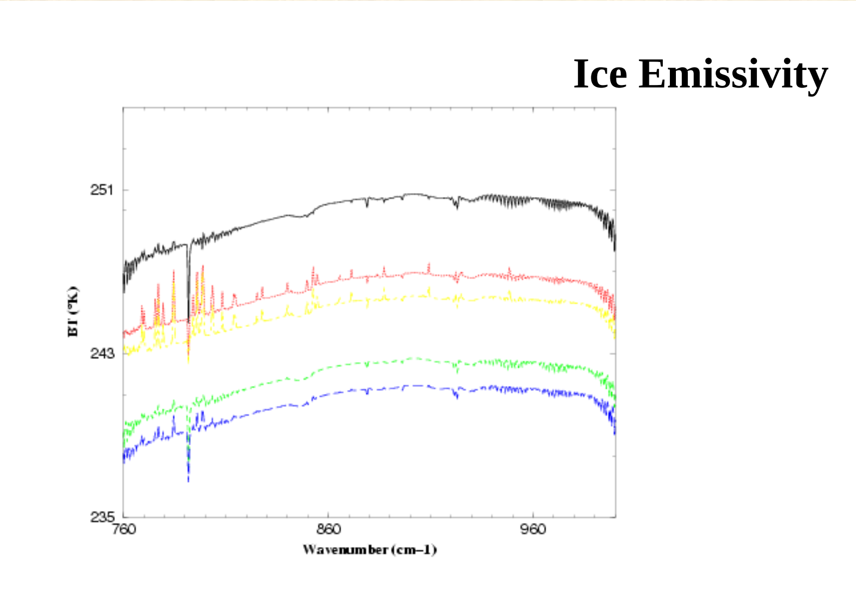


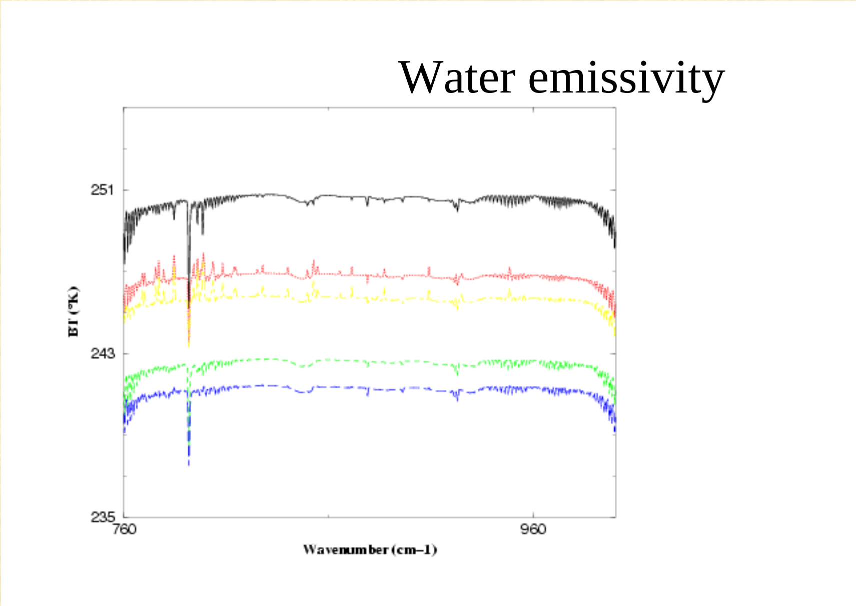

**from MODIS UCSB Emissivity Library (PI: Zhengming Wan)**

# IASI Tb spectra are simulated in clear sky using LBLRTM for 305 arctic profiles




**Water and temperature profiles**



# IASI Tb spectra are simulated in cloudy sky using RTX

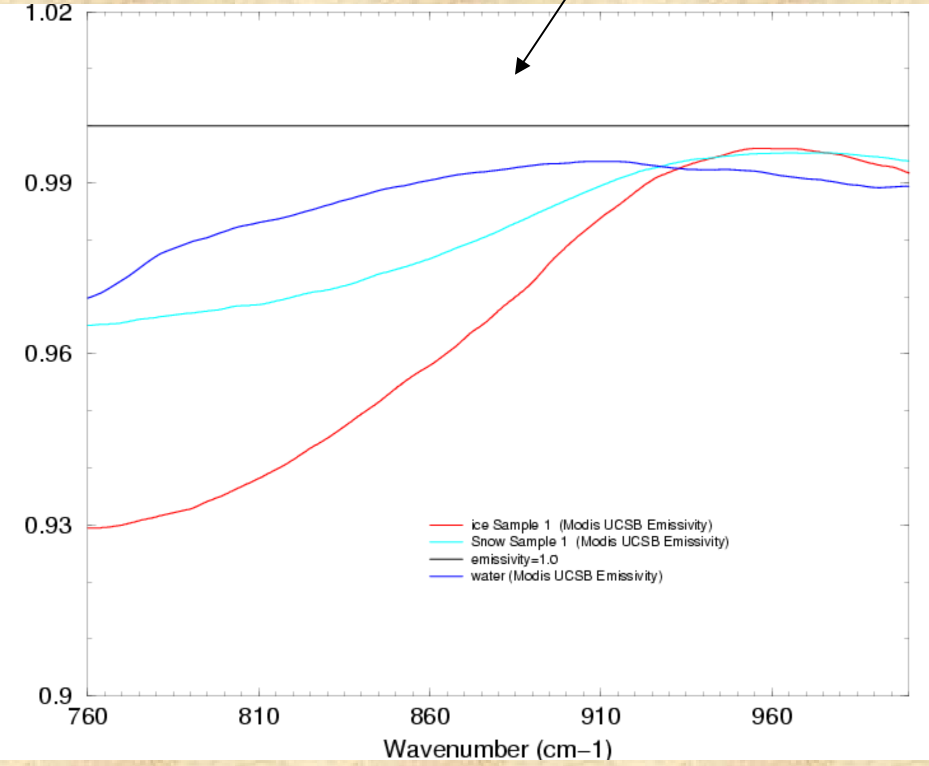
**The numerical model RTX [Rizzi et al., 2001; Amorati and Rizzi, 2002, Maestri et al., 2005], solves the radiative transfer equation with the adding and doubling method taking into account the multiple scattering by randomly-oriented particles with a plane of symmetry. Polarized radiation is considered 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 LBLRTM model while the extinction and scattering coefficients, the single scattering albedo and the Lagrange coefficients are computed for a gamma-modified size distribution of spherical cloud particles (water and ice) using a Mie code (Wiscombe 1979).**

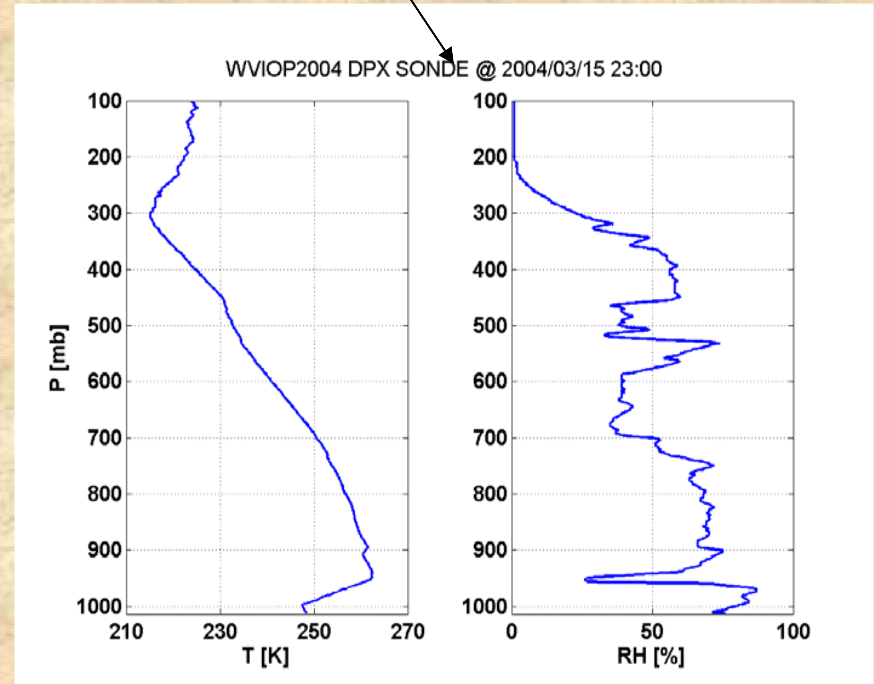
# Cloud parameters for cloud spectra simulation

- 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

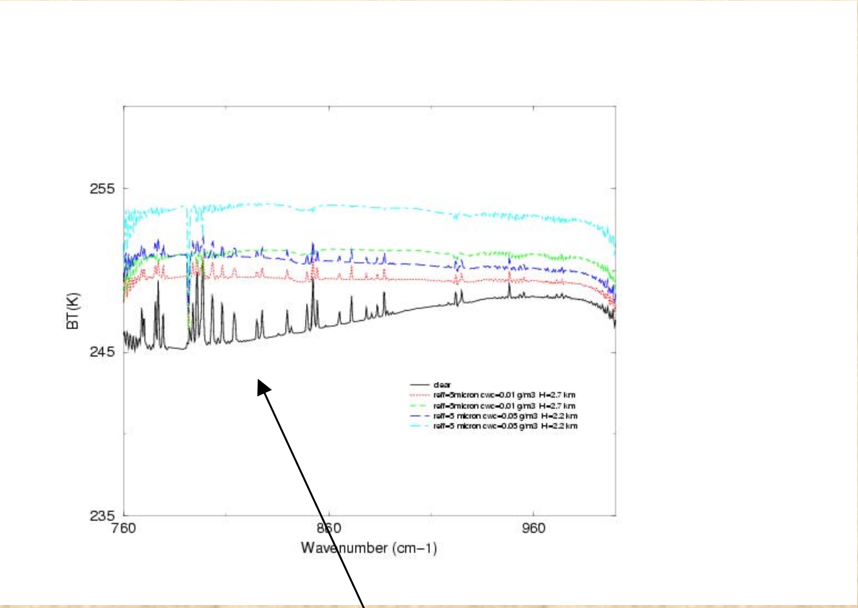
# Surface emissivity (ε): sea water, ice  and snow



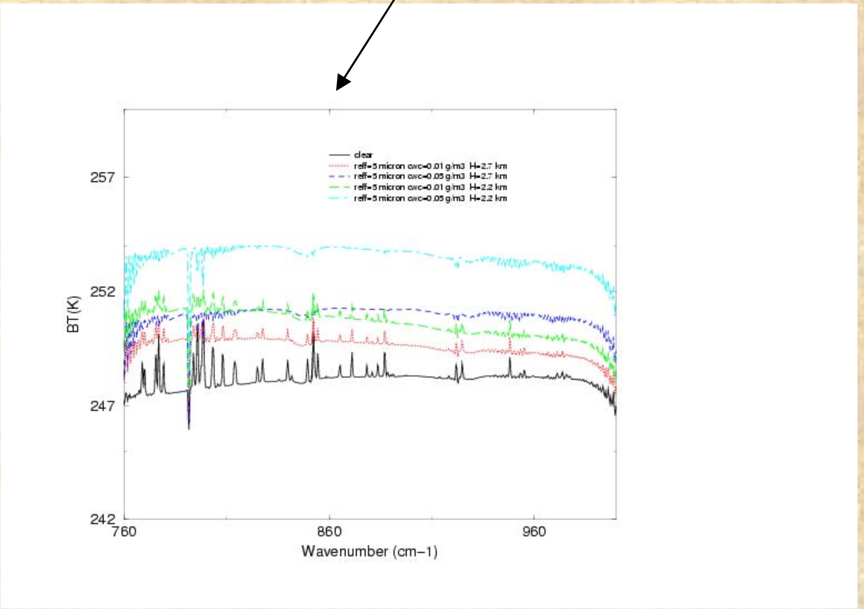

## Temperature and water vapour Profile



# Clear and cloudy spectra using ice emissivity

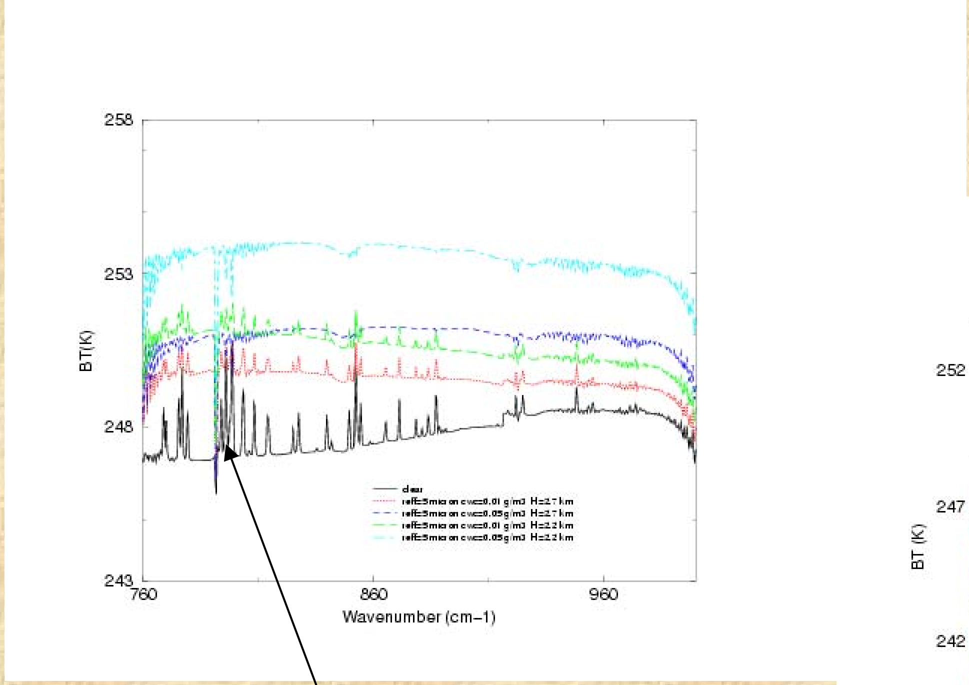


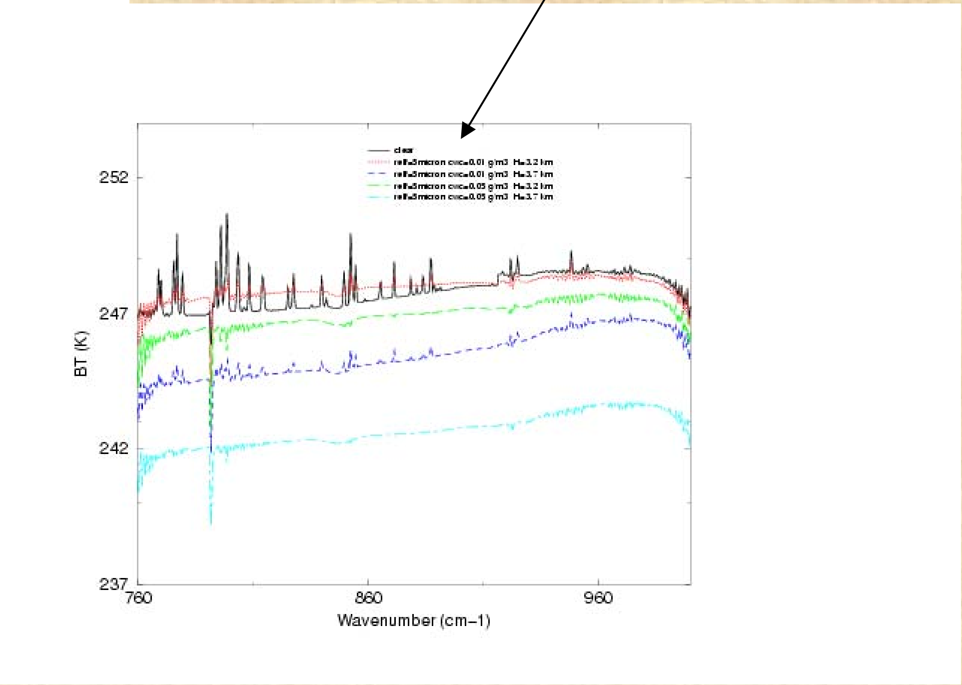

**Water clouds**




**Ice clouds**

# Clear and cloudy spectra using snow emissivity

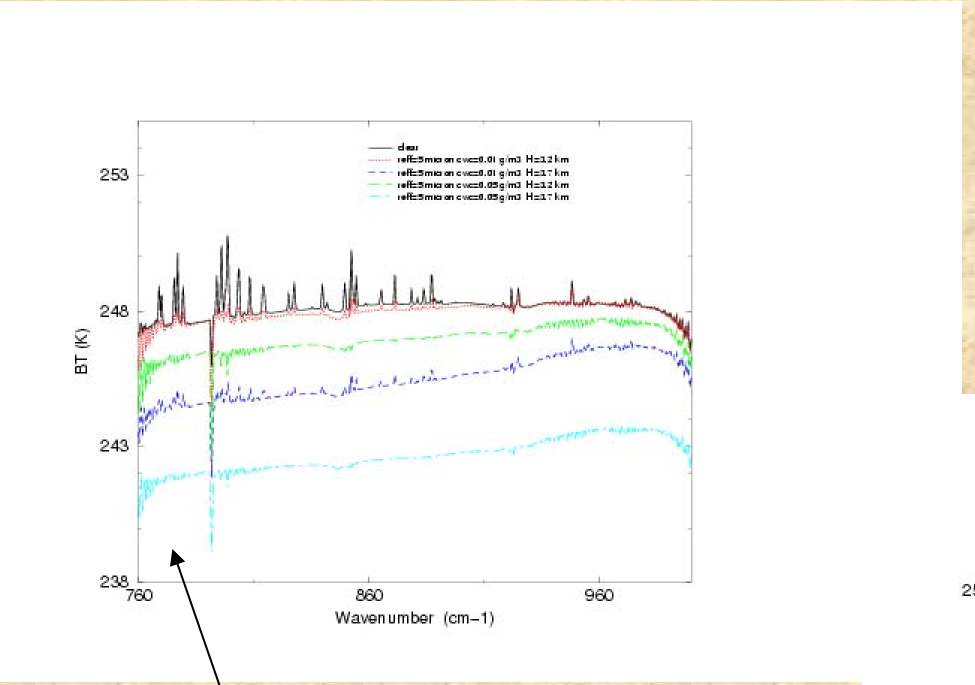


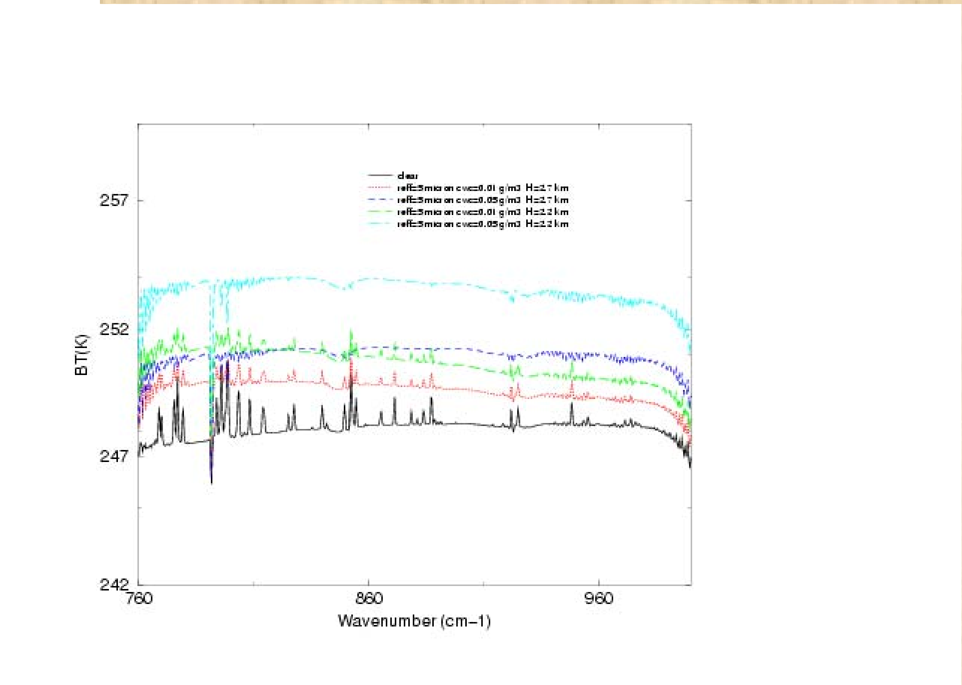

**Water clouds**

**Ice clouds**

# Clear and cloudy spectra using water emissivity




**Water clouds**




**Ice clouds**

**It is evident that spectral features caused by emissivity typical of polar surfaces are very similar to cloud spectral signatures.**
**It is evident that the clouds and the emissivity cause the slope of the atmospheric window to change significantly, but it seems difficult to detect on the basis of window spectral region clouds presence.**
**Ice clouds for instance increase the slope for a constant emissivity, but decrease the slop for ice surface emissivity.**

# Cloud detections

**We have developed an identification algorithm that exploits the expected spectral signal in the window region for polar region.**

**Examining the slope in the 750-980 cm-1 range for clear-sky spectra with different surface emissivity and different temperature and humidity profiles, it is evident that the slope values remains within a different range for each emissivity and the window shape it is the same for the same emissivity, the same satellite zenith angle and the same solar illumination.**

# Slope window test

The test is restricted to a suitable set of micro window differences.

Central wavenumbers of micro windows:

790.0 cm-1
803.5 cm-1
885.7 cm-1
953.0 cm-1

# Thresholds

**The thresholds have been derived using a measured and a simulated clear dataset. Simulated data also provide a useful estimates of variability around the mean value which should be exploited.**
**In this approach, the difference between predicted and measured channels must be within a range, whose medium value is calculated from measured data, while the boundaries (minimum and maximum) are estimated from simulated data.**

**The algorithm selects the thresholds according to satellite zenith angle, surface type, solar illumination and the brightness temperature ranges of the image.**

# Correlation test

**When the probability to be clear or cloud is low, we apply the correlation test. We have built a database based on clear spectra on artic region for different satellite zenith angles, solar illumination and surface type, identified using the Cloud Profiling Radar data and ground measurements.**

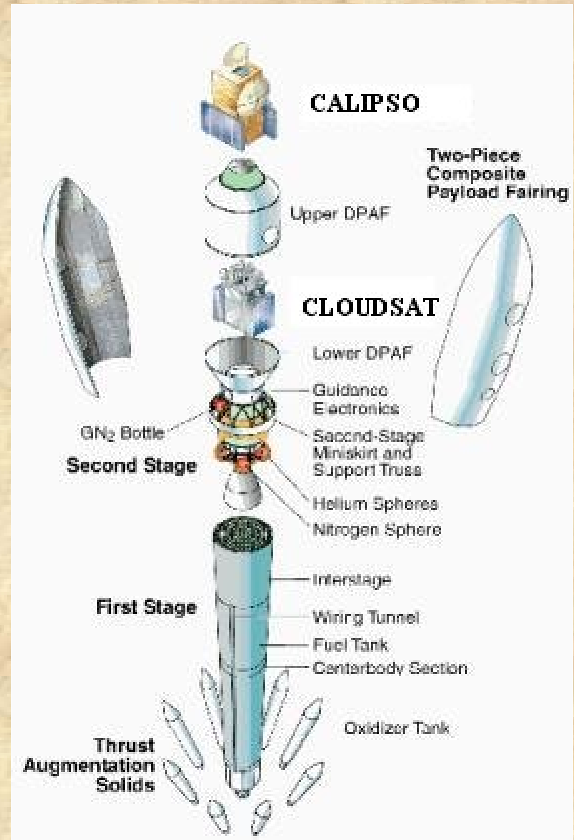
**The fit is restricted to a suitable set of 20 wavenumbers that give a fine representation of the atmospheric window shape.**

**The correlation index is compute on a restricted set of spectra according to surface, solar zenith angle and solar illumination of the examined IASI spectrum :**

$$r = \frac{\mathrm{cov}(BT, BT_0)}{(\mathrm{var}(BT)\,\mathrm{var}\,BT_0)^{1/2}}$$

# The Cloud Profiling Radar (CPR)

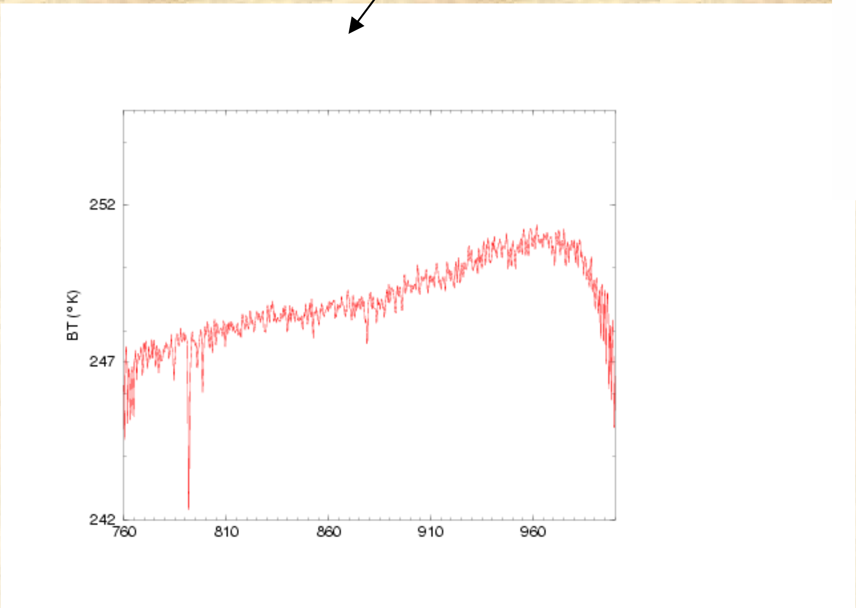
**The Cloud Profiling Radar (CPR) is a 94-GHz nadir-looking radar which measures the power backscattered by clouds as a function of distance from the radar.**

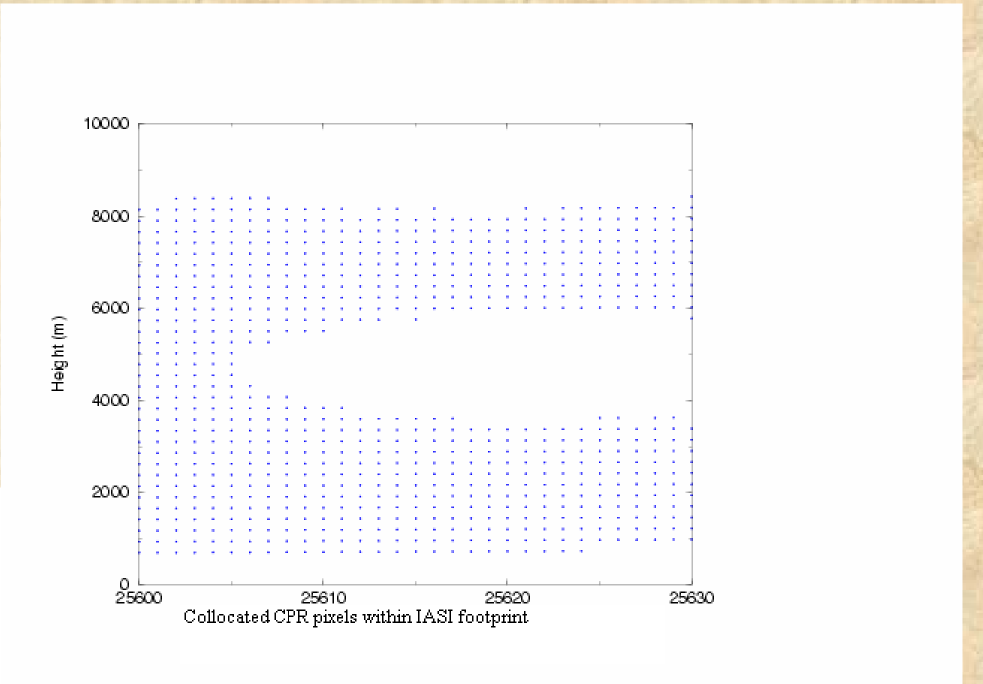



| | |
|---|---|
| **Nominal Frequency** | **94 GHz** |
| **Pulse Width** | **3.3 μsec** |
| **PRF** | **4300 Hz** |
| **Minimum DetectableZ** | **-29 dBZ** |
| **Data Window** | **0-25 km** |
| **Antenna Size** | **1.85 m** |
| **Dynamic Range** | **70 dB** |
| **Integration Time** | **0.16 sec** |
| **Vertical Resolution** | **500 m** |
| **Cross-track Resolution** | **1.4 km** |
| **Along-track Resolution** | **1.7 km** |
| **Data Rate** | **15 kbps** |

**CPR System Characteristics**

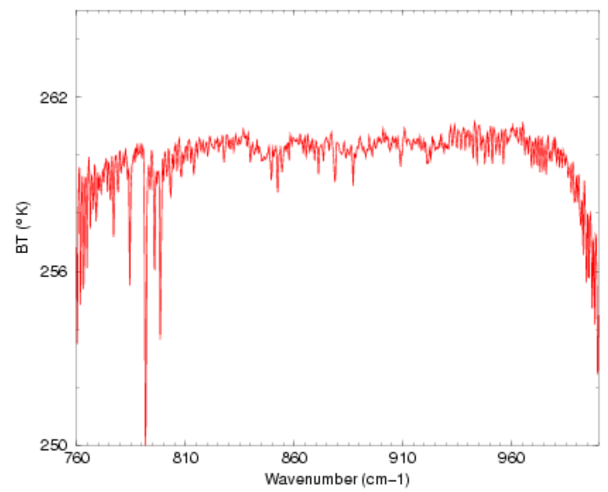
**IASI spectra**

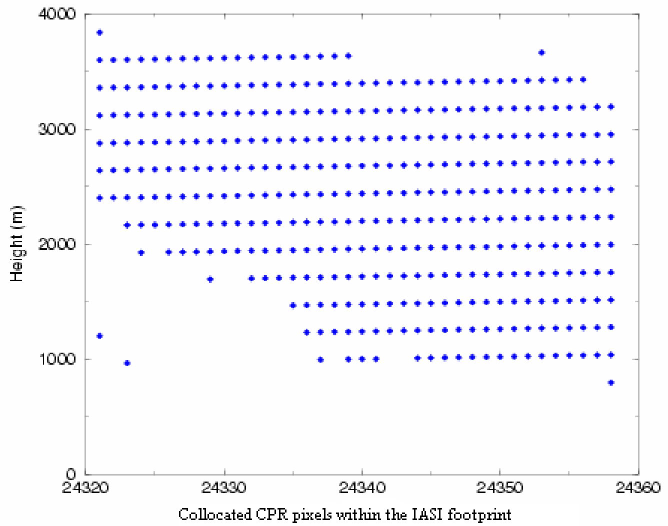


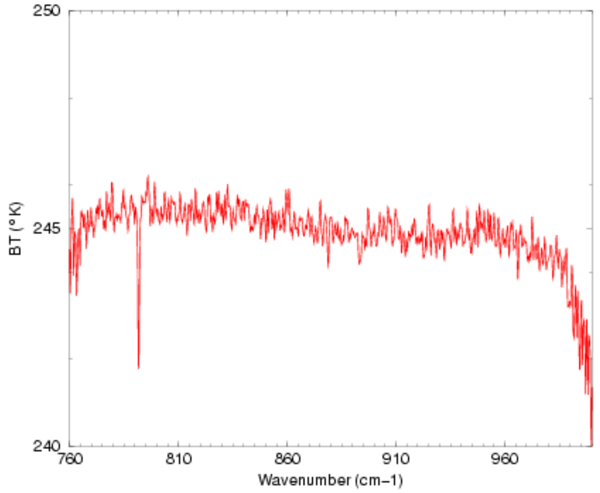

**Collocated CPR Cloud profiles**

# IASI spectrum

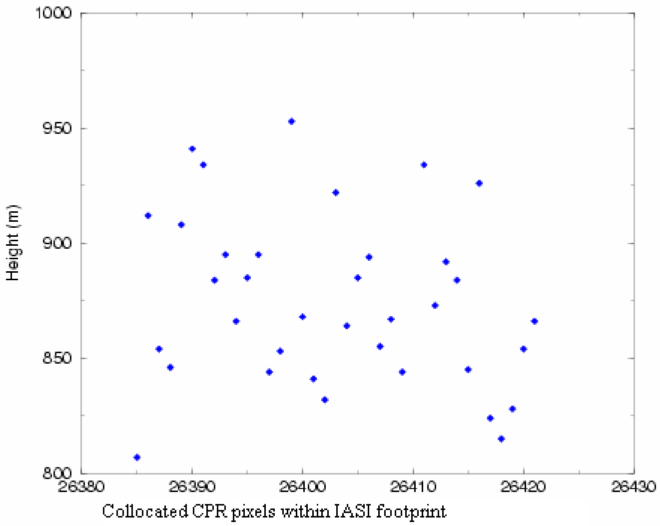


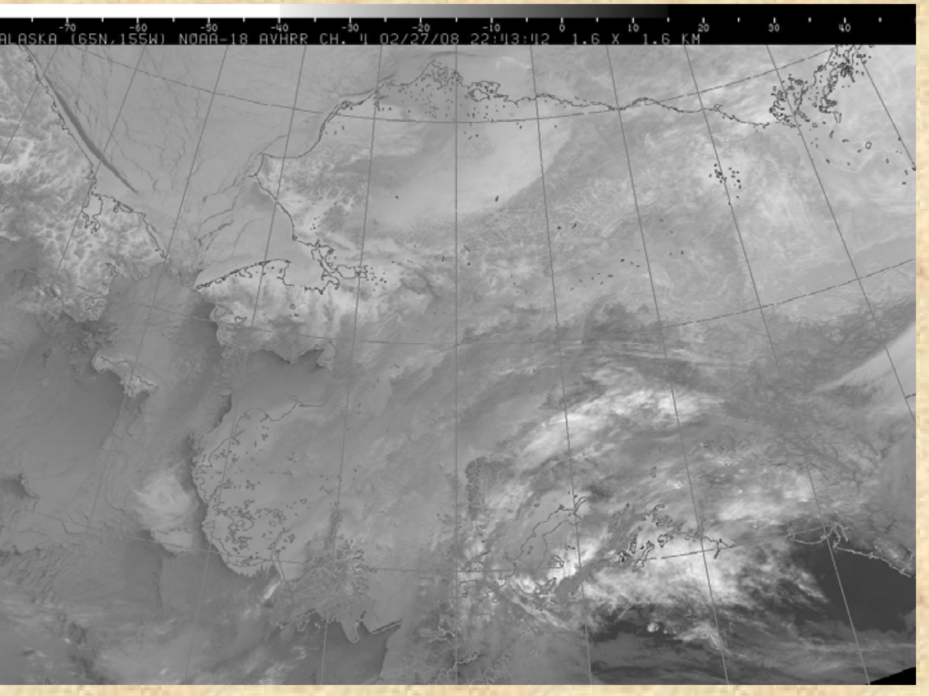

# Collocated CPR Cloud profiles



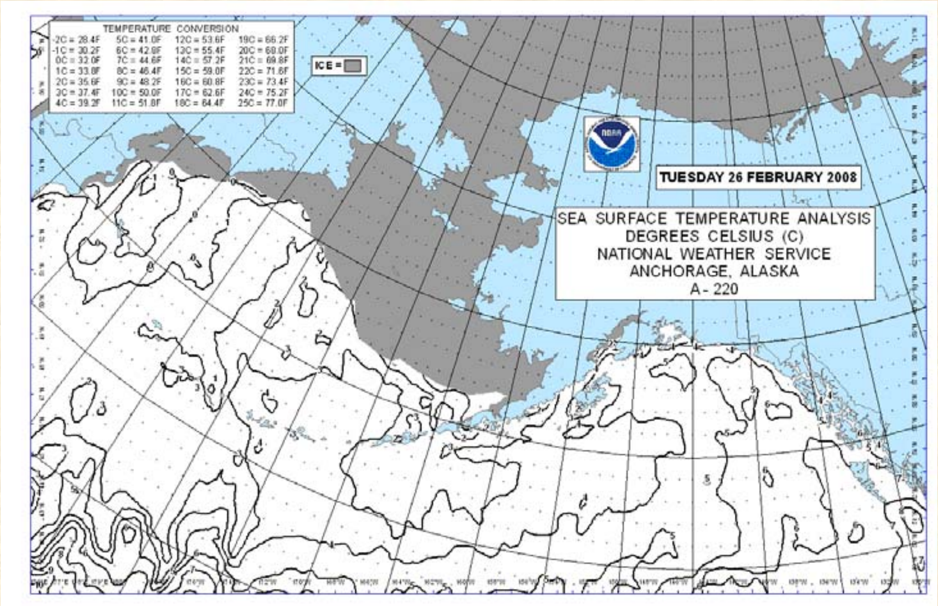

**IASI spectrum**




**Collocated CPR Cloud profiles**

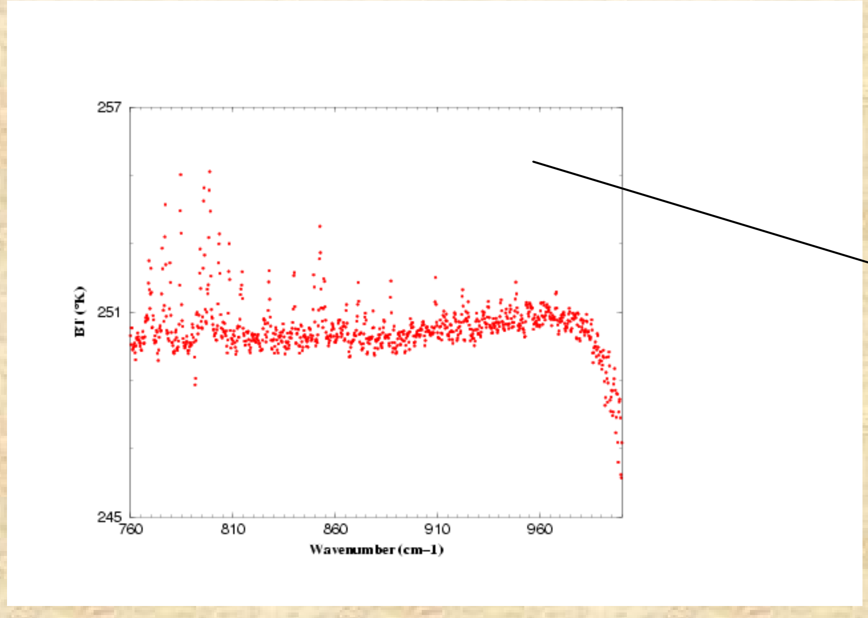




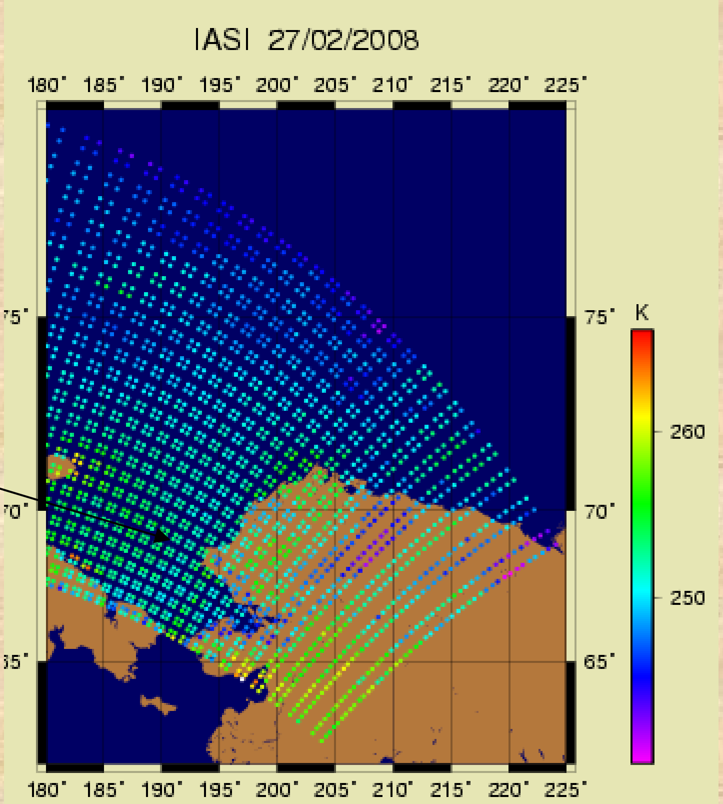




## Clear IASI FOV on ice surface







# Cloud Test Results

| | |
|---|---|
| Percentage of “clear–detected-clear” | 96.9 % |
| Percentage of “cloud–detected-cloud” | 98.7 % |
| Percentage of “clear–detected-cloud” | 3.03 % |
| Percentage of “cloud–detected-clear” | 3.70 % |

**1221 OVERCAST IASI FOVs.**

**IASI FOV homogeneity => on the basis on collocated AVHRR pixels within IASI footprint.**

# Cloud Test Results

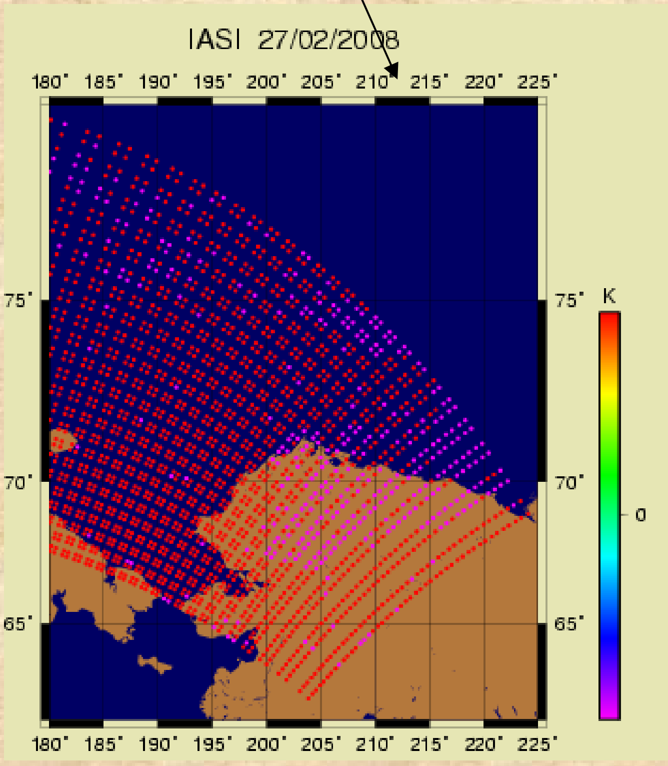
| | |
|---|---|
| Percentage of “partially cloudy–detected-partially cloudy” | 80.14 % |
| Percentage of “partially cloudy–detected-cloudy” | 5.00 % |
| Percentage of “partially cloudy–detected-clear” | 14.00 % |

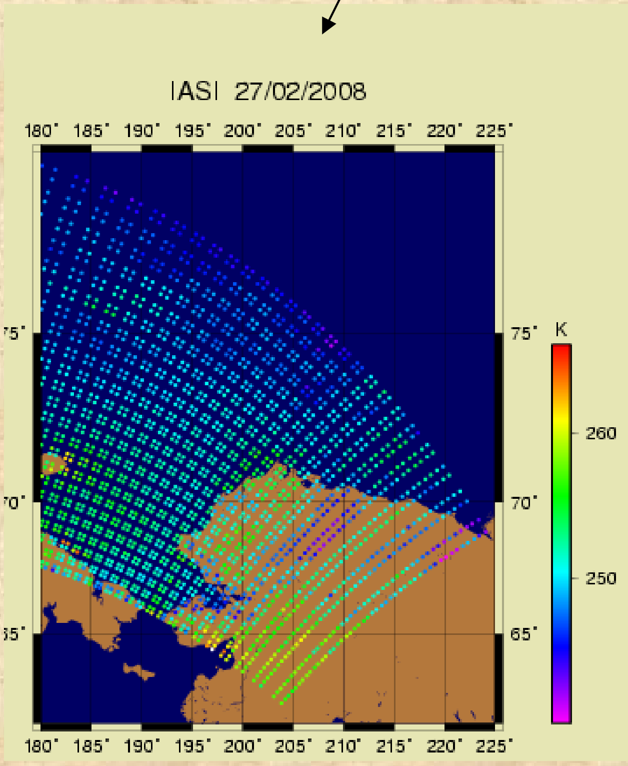
**564 Partially cloudy IASI FOVS**

**IASI FOV homogeneity => on the basis on collocated AVHRR pixels within IASI footprint**

**IASI cloud mask**

**IASI (926. cm-1)**



# SUMMARY

**The cloud detection scheme developed is able to detect cloud IASI FOVs for the different surfaces, also for ice surfaces.**

**For overcast IASI FOVs the scheme classifies as cloudy 98.7% of the pixels classified by CPR as cloudy and 96.9% as clear of the pixels classified by CPR as clear.**

**For partially cloudy IASI pixels the scheme detect 80.14% pixels correctly.**