15th International TOVS Study Conference, October 04-10, 2006, Maratea, Italy

On the role of IR surface emissivity in polar night-time cloud detection

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RATIONALE

Satellite cloud detection in polar regions is difficult because:

- extremely cold surface temperatures
- little thermal and visible constrast with snow/ice surface
- persistence of strong temperature inversions (Fig.1A)
- usually low, thin, and mixed-phase clouds

During polar nights, cloud detection is even more difficult:

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

Current MODIS and AIRS algorithms rely on IR spectral tests based on climatological mean temperature, water/ice spectral absorption (Fig.1B), water vapor continuum, temperature inversion strength [1,2].

Misidentification rates are 3-20% as problems still exist with thin clouds, weak inversions, and surface inhomogeneities.

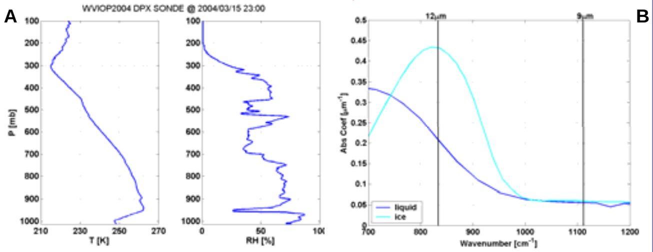

Fig.1: (A) Radiosonde profile in the Arctic Winter ([3]). (B) Liquid and ice water absorption coefficient spectra.

Polar regions are characterized by a combination of ice, snow, and sea-water surfaces; IR spectral emissivities differ significantly, even for the same surface type, due to roughness, impurities, grain size, wetness, etc…[4] (Fig.2).

Uncertainties in surface emissivity may play an important role in cloud detection due to the spectral features in the 700-1200 cm^{-1} range (Fig.2B).

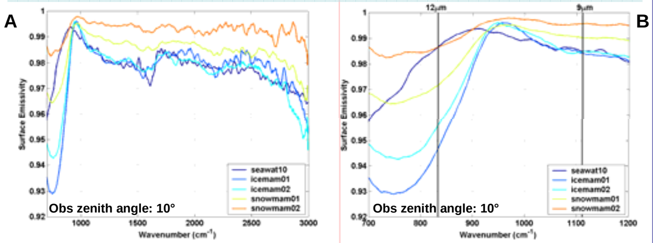

Fig.2: Emissivity spectra for sea water, ice, and snow surfaces ([4]).

ANALYSIS

Tb spectra for MODIS, AIRS, and IASI are simulated in clear and cloudy sky using LBLDIS ([5]) with:

- T and RH profiles in Fig.1A, cloud top at 4 km (~600mb)
- Surface emissivity (ε): sea water, ice, snow (Fig.2) plus ε=1
- Cloud phase (C_P): liquid, ice, mixed
- Effective radius (R_e): 5, 15, 50 μm
- Cloud optical depth (τ) in geometric limit: 0.1, 1.0, 10.0
- Ice particle habit (SS): sphere, plate, solid column, aggregate, bullet rosette [6].

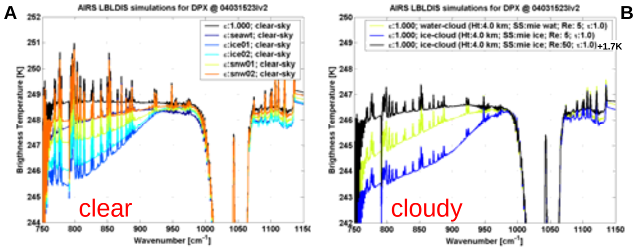

Fig.3: AIRS Tb spectra using different ε (A) and C_P, R_e and T_{surf} (B).

Clear-sky Tb spectra computed using emissivity for polar surfaces (Fig.3A) do resemble cloud signatures (Fig.3B), and therefore may confuse cloud detection techniques relying on thresholds.

Other sources of confusion are C_P (Fig.4A), R_e (Fig.4B), τ (Fig.4C), and SS (Fig.4D), although these appear of the same order of, if not smaller than, surface emissivity effects.

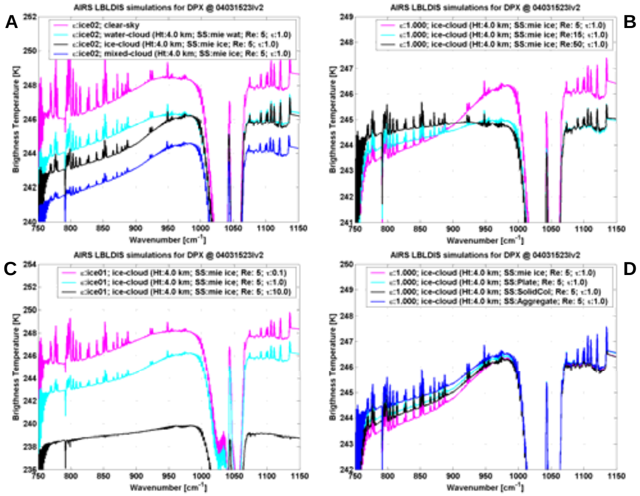

Fig.4: AIRS Tb spectra using different C_P (A), R_e (B), τ (C), SS (D).

REMARKS

Using currently available polar nighttime cloud detection algorithms (PNCDA) for MODIS [1], AIRS [2], and IASI (adapted from [2]) with the simulated data set (752 spectra):

- clear-sky spectra with ε=1 are always well detected (MR2=0.0)
- clear-sky spectra with ε for ice/snow/seawater are always misidentified as cloudy (MR2=1.0)
- in general, relatively low “cloudy-as-clear” (MR1) but large “clear-as-cloudy” (MR2) misidentification rates
- thin clouds may sometimes be correctly detected because of emissivity features of underlying surface
- slightly better scores for IASI with respect to AIRS

A PNCDA coupled with *a priori* knowledge/retrieval of emissivity features may improve the scores (see pres. 3.3 by F. Romano).

Tab.1: Scores for polar nighttime cloud detection with MODIS [1], and AIRS/IASI [2]. HITS: cloud detection accuracy. MR1: misidentification rate “cloudy-as-clear”. MR2: misidentification rate “clear-as-cloudy”(#).

	MODIS			AIRS			IASI		
	ε=1	ice01	mix	ε=1	ice01	mix	ε=1	ice01	mix
HITS	0.54	0.95	0.87	0.63	0.77	0.69	0.65	0.77	0.70
MR1	0.45	0.04	0.12	0.37	0.23	0.30	0.34	0.23	0.29
MR2	0.00	1.00	0.88	0.00	1.00	0.63	0.00	1.00	0.63

(#) HITS = N11/(N11+N00+N01+N10); MR1 = N10/(N11+N10); MR2 = N01/(N00+N01).

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Acknowledgments: LBLDIS was kindly provided by D. D. Turner. Radiosonde data are from WVIOP2004 (PI: Ed Westwater). Emissivity spectra are from UCSB Emissivity Library (PI: Zhengming Wan).

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