Frozen Surface Classification Scheme for ATMS and GMI.

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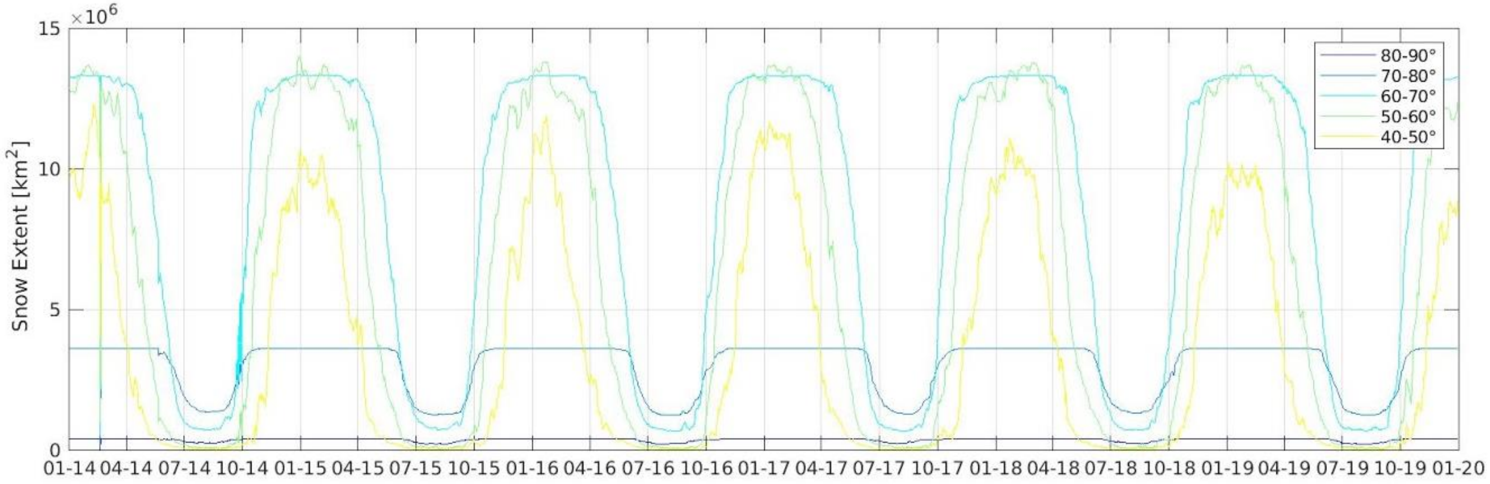
Main goal of this work

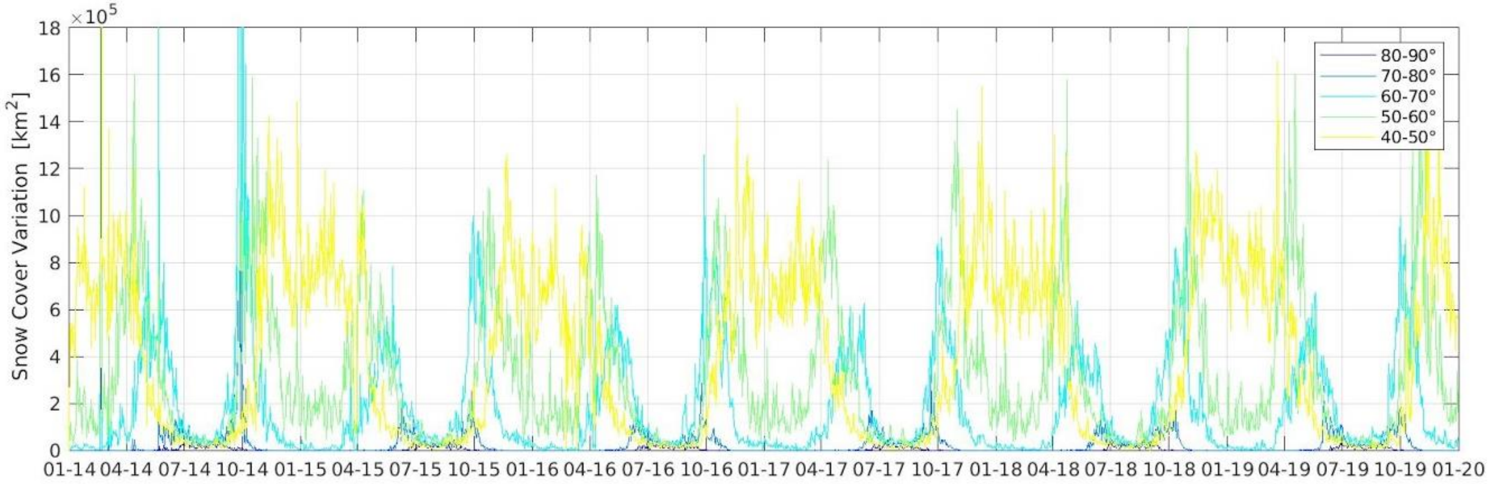
- Define a Passive Microwave classification scheme of frozen surfaces (snow and ice)
- That is applicable potentially to all satellite-borne microwave radiometers (conical and cross track) at the time of overpass.
- That analyzing the spectral features of low frequency channels (<=90 GHz) allows to better constrain the high frequency emission (more sensitive to cloud and snowfall-related signal).

At the time of overpass..

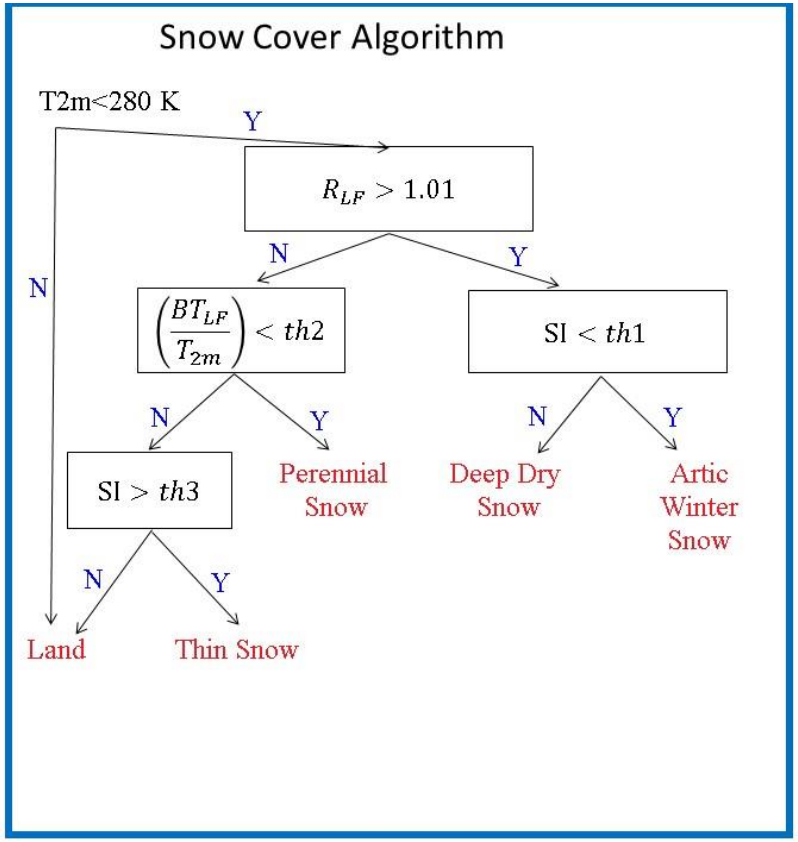
As demonstrated by many recent studies (e.g., *Tabkiri et al.*, 2019, *Ebtehaj and Kummerow* 2017, *Panegrossi et al.*, 2017), **the microwave signal related to snowfal**l is strongly influenced by the surface conditions, and the response of the observed brightness temperatures to the presence and intensity of snowfall depends on complex interconnections between environmental conditions (surface temperature, water vapor content, snow water path, cloud depth, presence of supercooled droplets) and the **different surface conditions** (wet or dry snow cover, sea ice concentration and type, etc.). The use of surface classification climatological datasets results inadequate for the purpose because of the **extreme variability of the frozen surface conditions**. It is therefore necessary to be able to identify the background surface condition as close as possible (in space and time) to that of the observation

Daily variation of snow cover





Analysis of 6 years of GMASI-Autosnow over the Northern Hemisphere. Top panel shows the snow cover extent for different latitude ranges as indicated in the legend. Lower panel shows the area that experiences a variation of the snow cover fraction from one day to the next.



Variable	GMI	ATMS
R_{LF}	TB_{19V} / TB_{37V}	TB_{23v}/TB_{31v}
SI	TB_{19V} - TB_{89V}	TB_{23V} - TB_{89HV}
TB_{LF}	TB_{19V}	TB_{23V}
th1	Absent	T2m-257
th2	(360 K-T2m)/(100 K)	(465 K - T2m)/(225 K)
th3	5 K	3 K

The 4 snow classes are:

1.Deep Dry Snow: Seasonal snow with relatively high snow depth, radiometrically characterized by R_{LF} >1 and by intense scattering at 90 GHz (high SI)

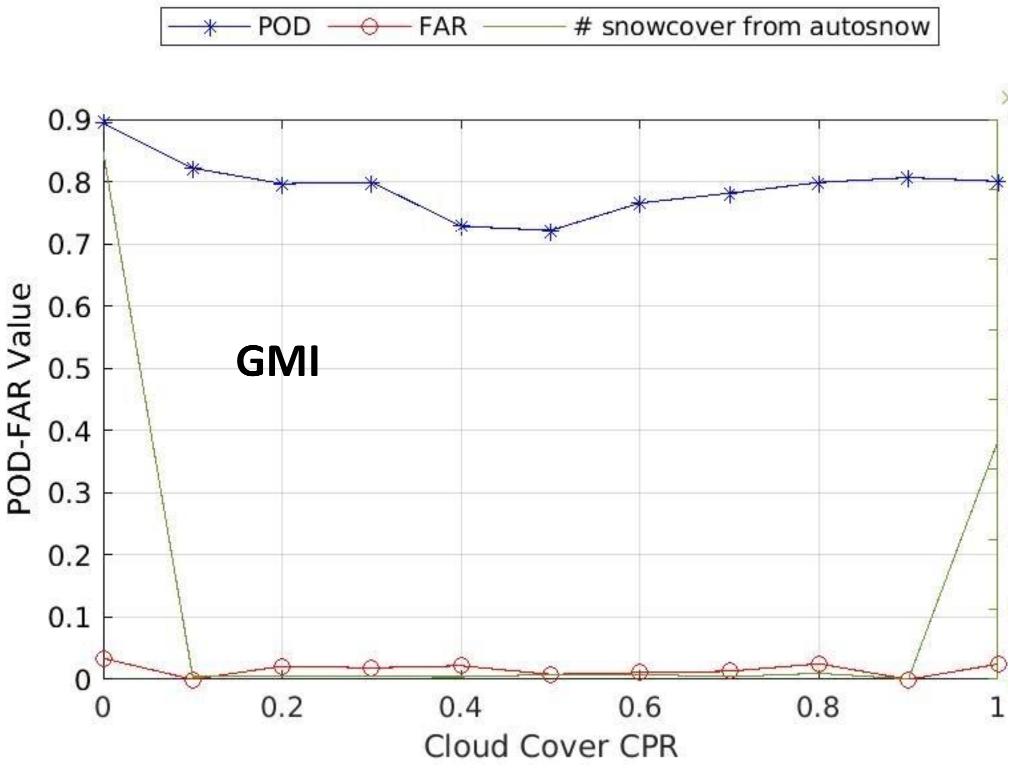
2.Arctic Winter Snow: This class of snow has been found only in the inner Antarctica and Greenland in the Winter season. It has not been observed by GMI because these areas fall outside the GMI coverage. It is characterized by R_{LF} >1 and by low SI.

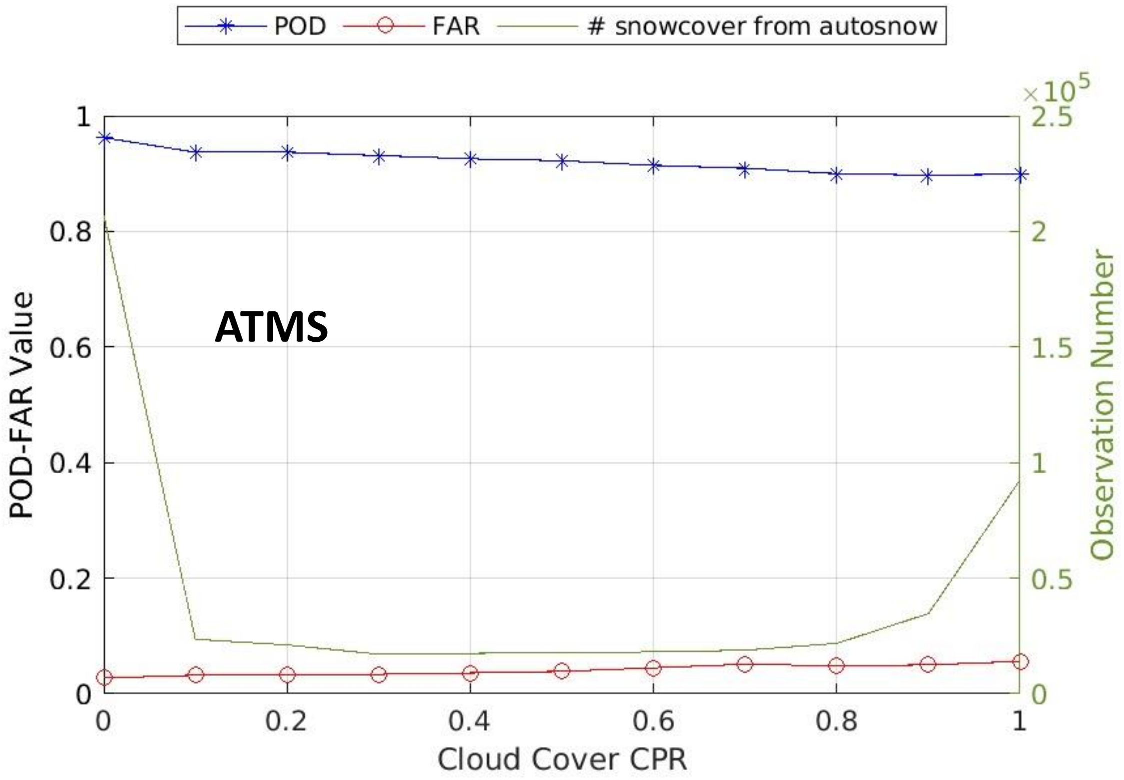
3.Perennial Snow: present at higher latitudes and at low temperatures, it is characterized by R_{LF} <1 an by scattering at very low frequency (even at 19 GHz). It is probably related to old snow with deep hoar, recognized by *Grody and Basist 1996* as "glacial arctic ice".

4.Thin Snow: it is a seasonal snow associated with the smallest retrievable thickness it is only visible from scattering at relatively high frequency (~90 GHz).

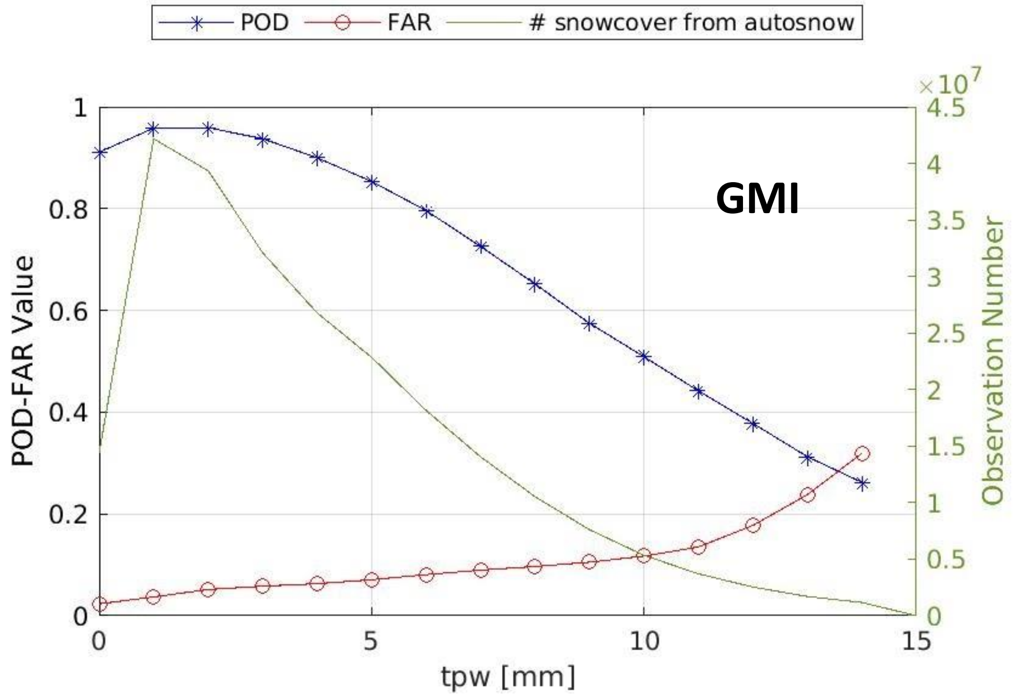
Snow/ no Snow statistics: Independant from Cloud

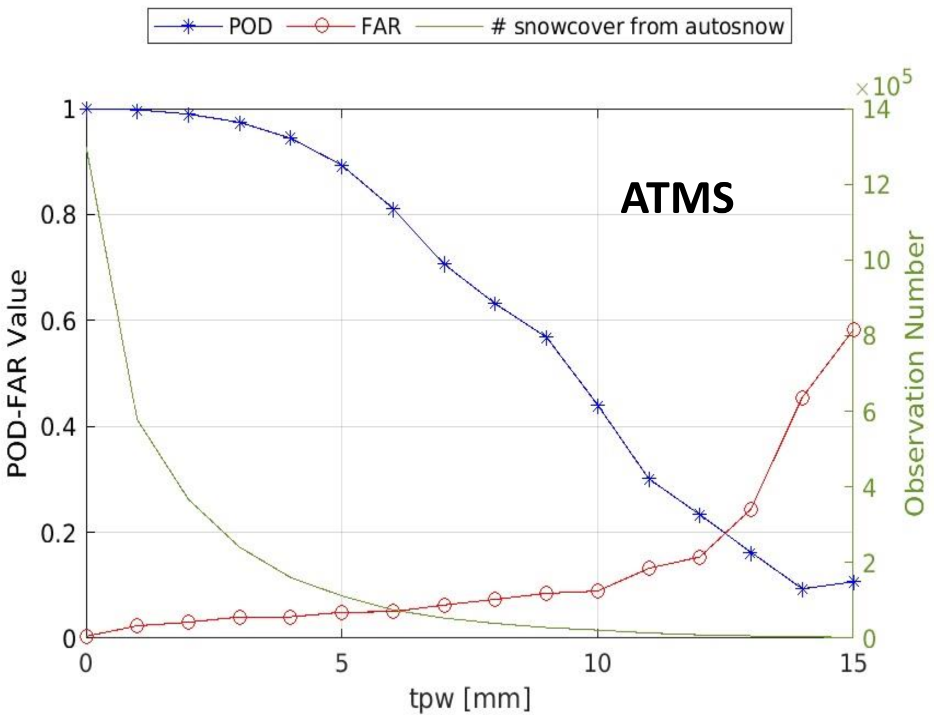
The algorithm performances are almost un-affected by the presence of cloud cover. The use of the 90 GHz channels that is sensitive to dense cloud ice and supercooled water droplets could raise some issues about the effect of clouds on the algorithm performances.



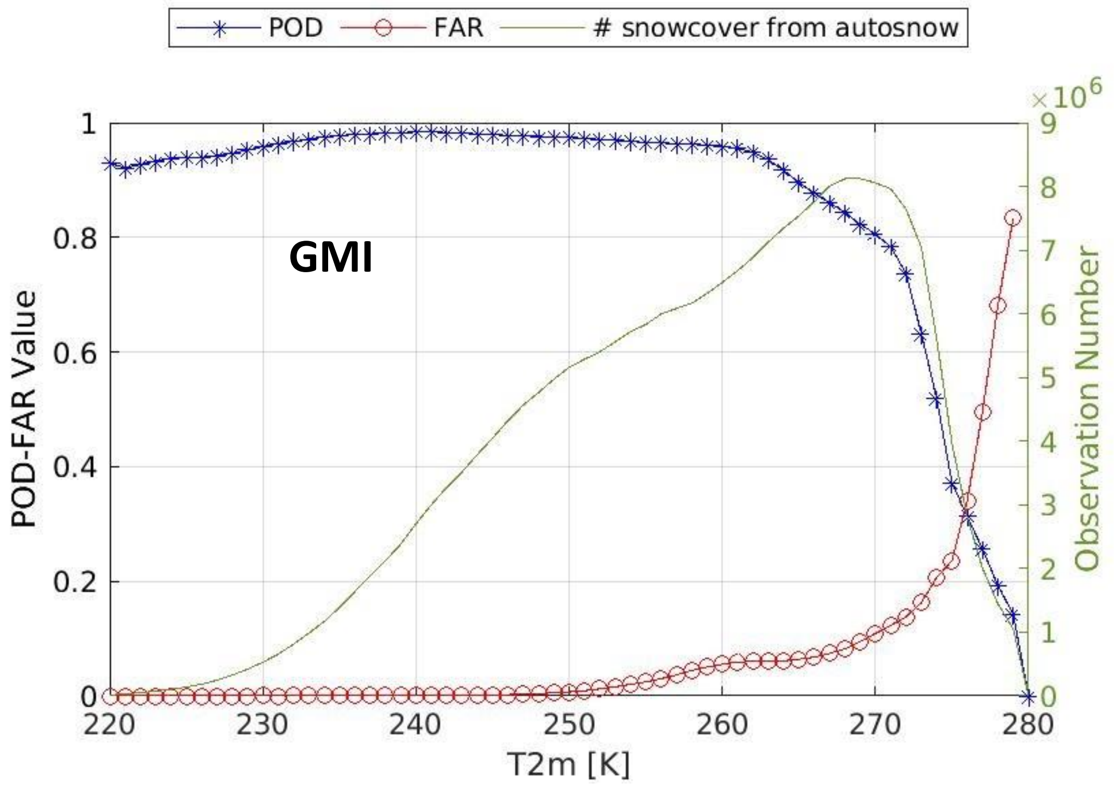


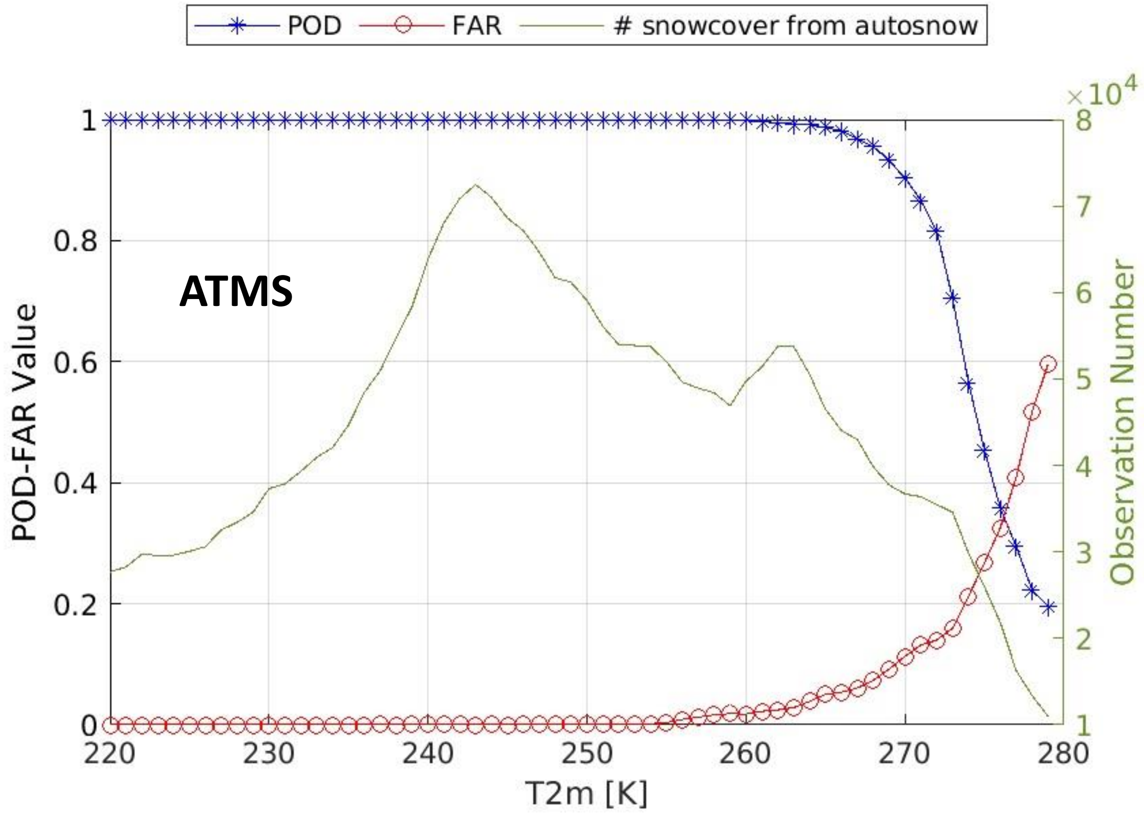
Snow/ no Snow statistics: Strong dependance on WV



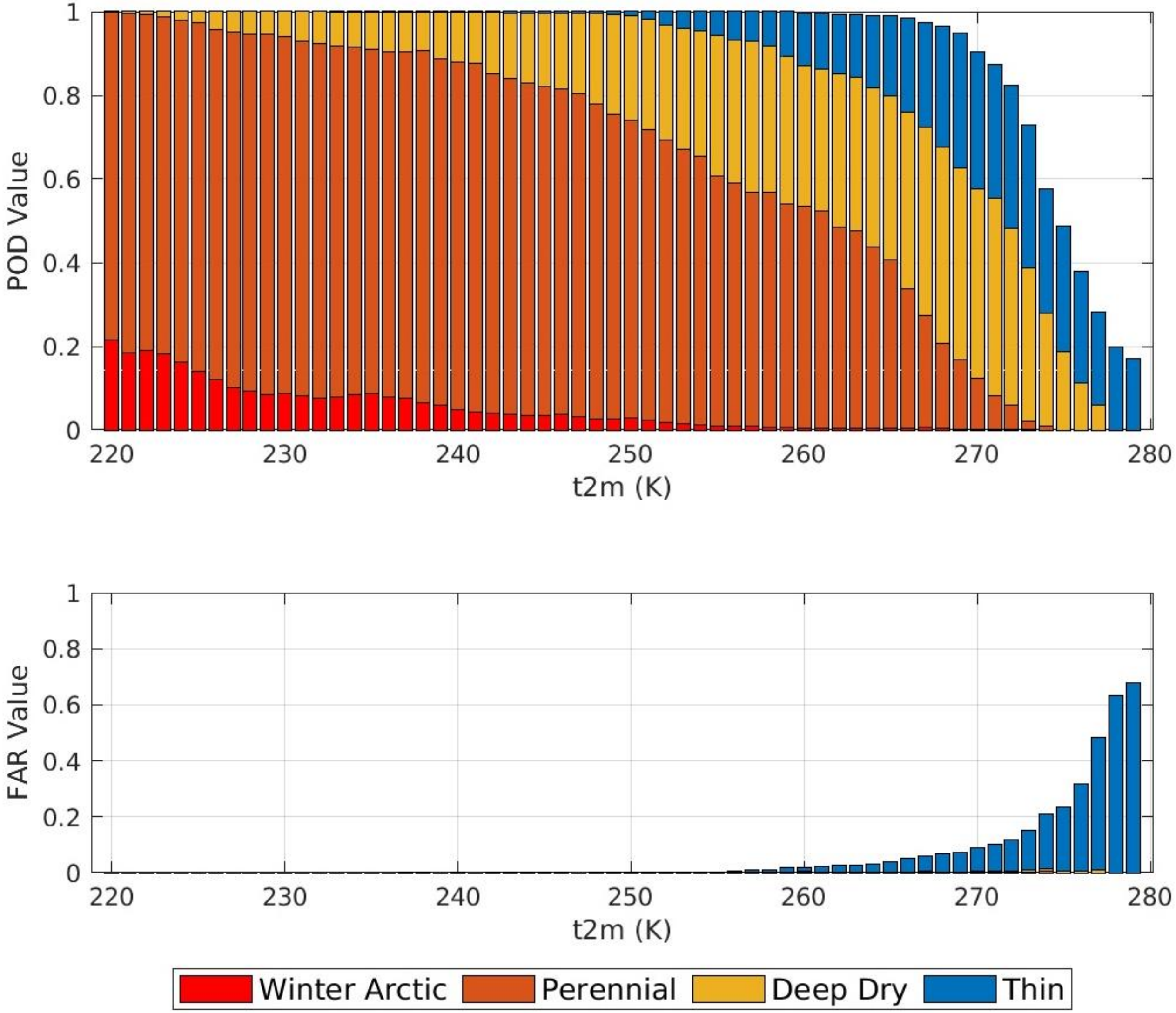


Snow/ no Snow statistics: Strong dependance on 2m Temperature



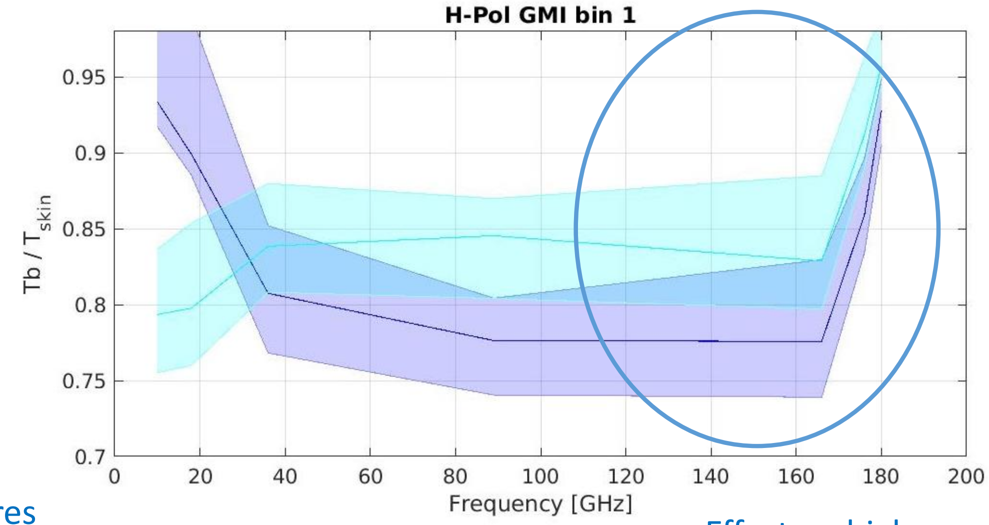


POD and FAR by snow classes



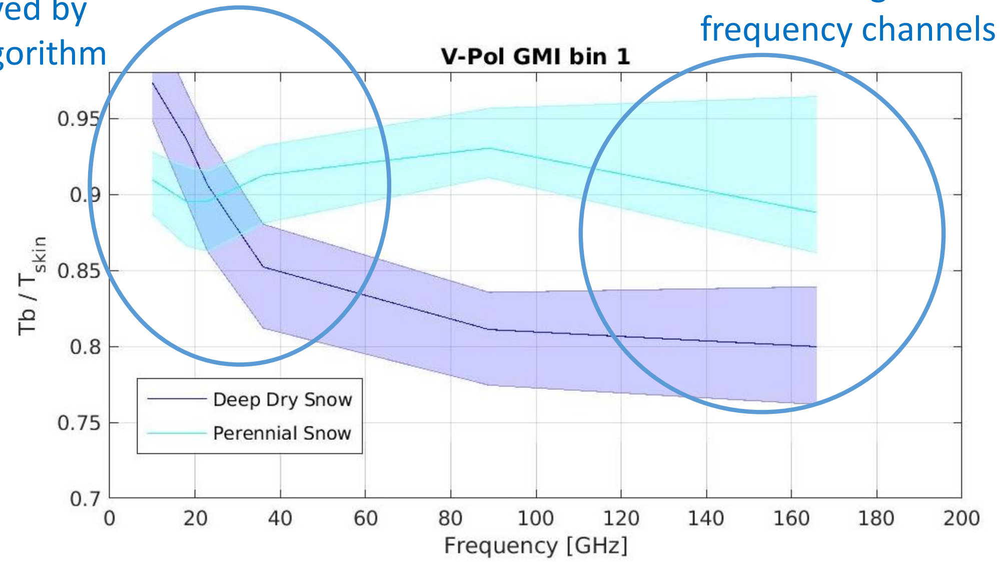
The region between 260 K and 270 K is where the wet snow class is more important. The various snow classes are mainly clustered according to temperature, with the "coldest" snow class corresponding to "Arctic Winter Snow" followed by Perennial Snow, Deep Dry Snow and finally Thin Snow

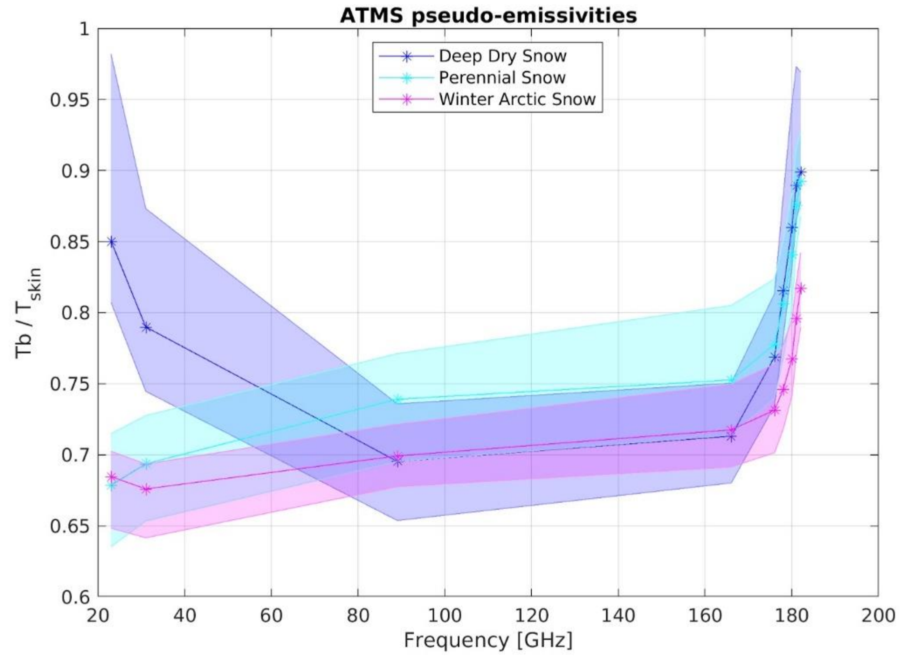
Approximated emissivity spectra: Dry Snow



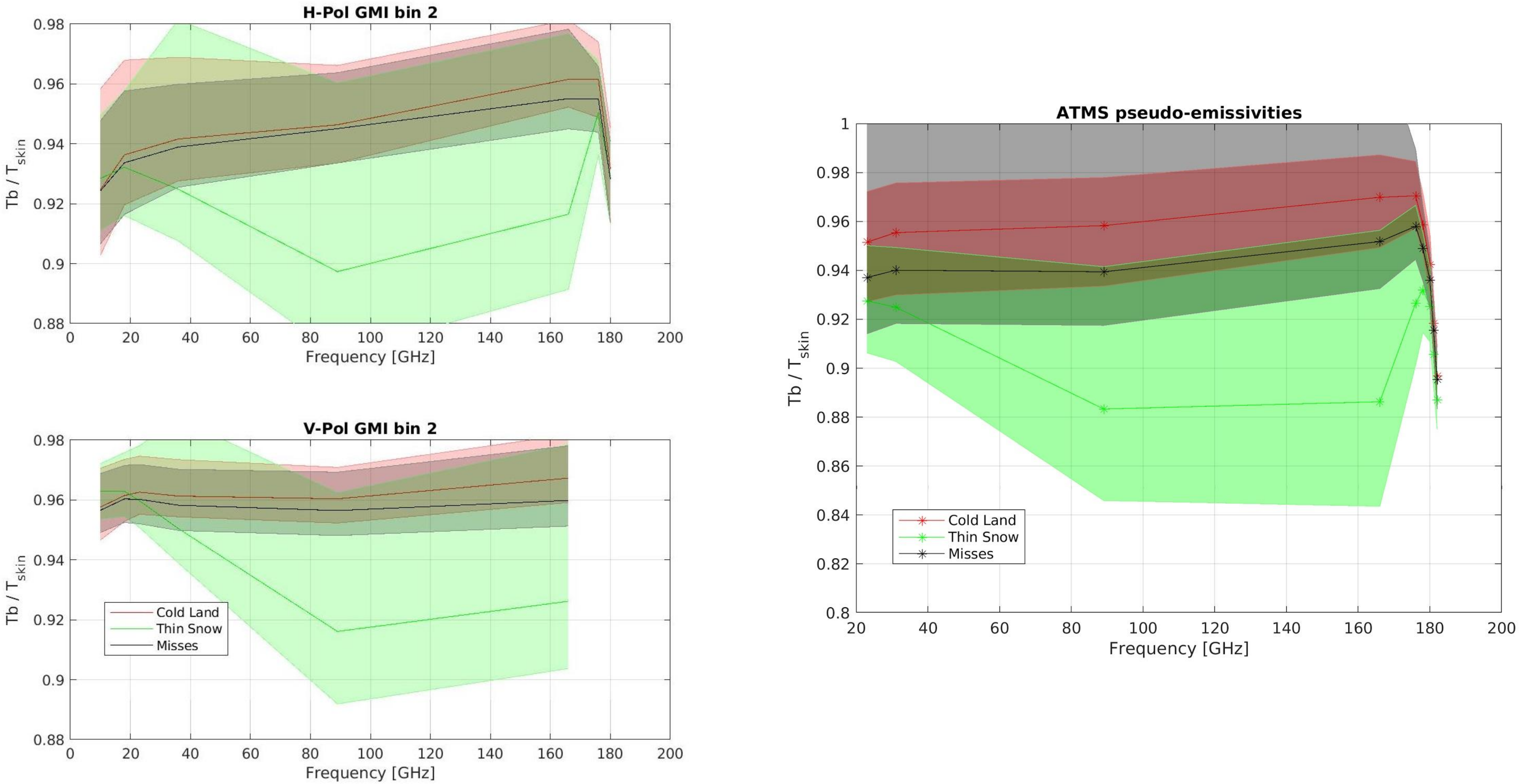
Features observed by the algorithm

Effect on high frequency channels

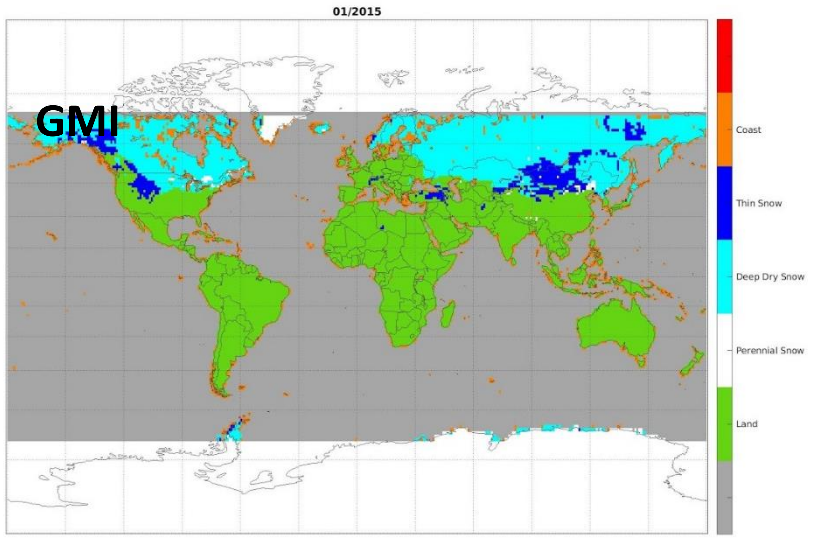


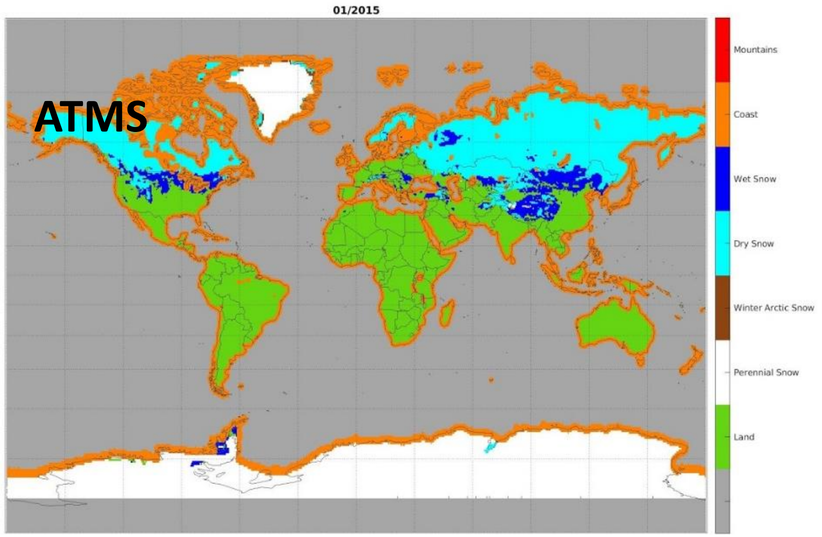


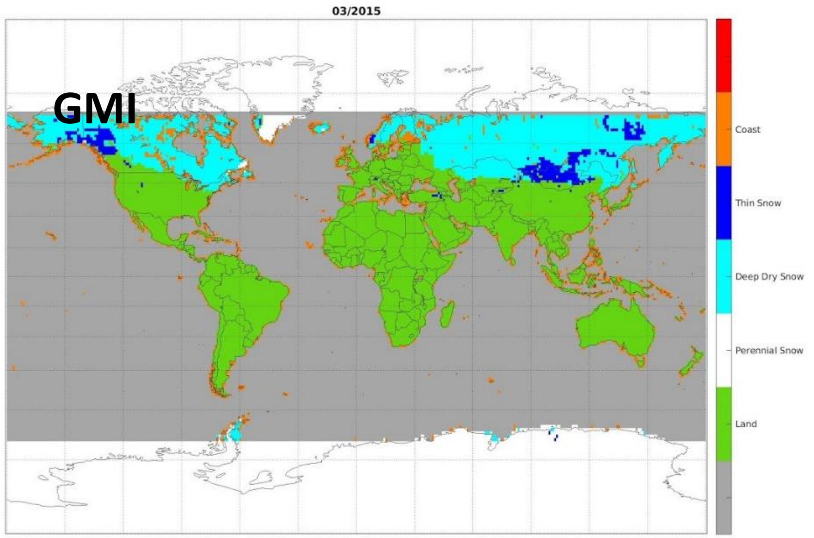
Approximated emissivity spectra: Thin Snow

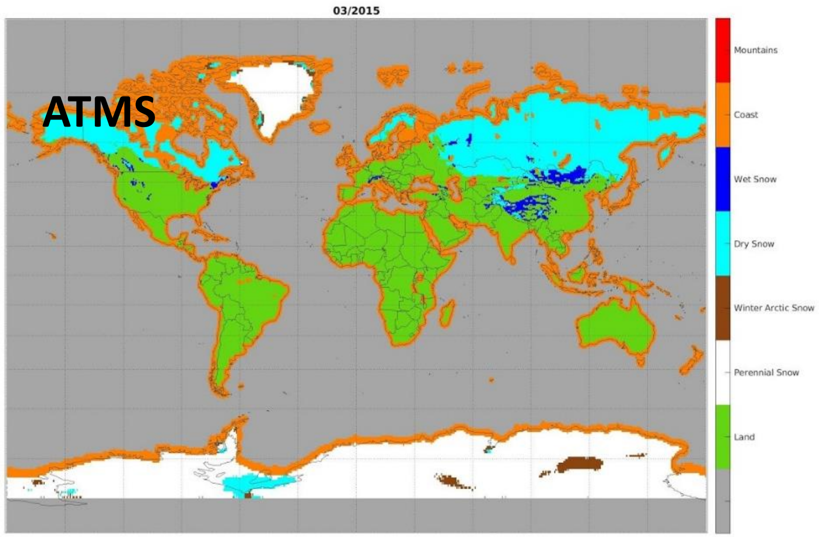


Example of monthly maps









Discussion

- Limitations of the algorithm:
  - No wet snow class : not an issue (no radiometric signal)
  - Upper limits on TPW and T2m
  - Important issues over Mountains
  - Some differences in the thin/dry snow classification between ATMS and GMI
- Strenghts:
  - Good Snow/No-snow Statistics
  - The emission spectra is characterized at high frequency
  - No dependance on presence of clouds
  - Possibility to tune the algorithm for other radiometers (MHS,MWS, SSM/I, SSMIS, AMSR-E, AMSR-2, MWI)