Analysis of satellite-derived infrared and microwave emissivities over deserts: relationship with surface characteristics

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INTRODUCTION

Key role of surface emissivity

- In Ts estimates:
  - in the IR (clear sky): signal proportional to eT^4 in a first approx.
  - in the MW (cloudy sky): signal proportional to eT in a first approx.

- In related longwave radiation budget… both directly and through the Ts estimates…

- In the inversion of surface sensitive channels from atmospheric sounders, both in the IR and in the MW

Often crudely estimated in inversion procedures or in climate models

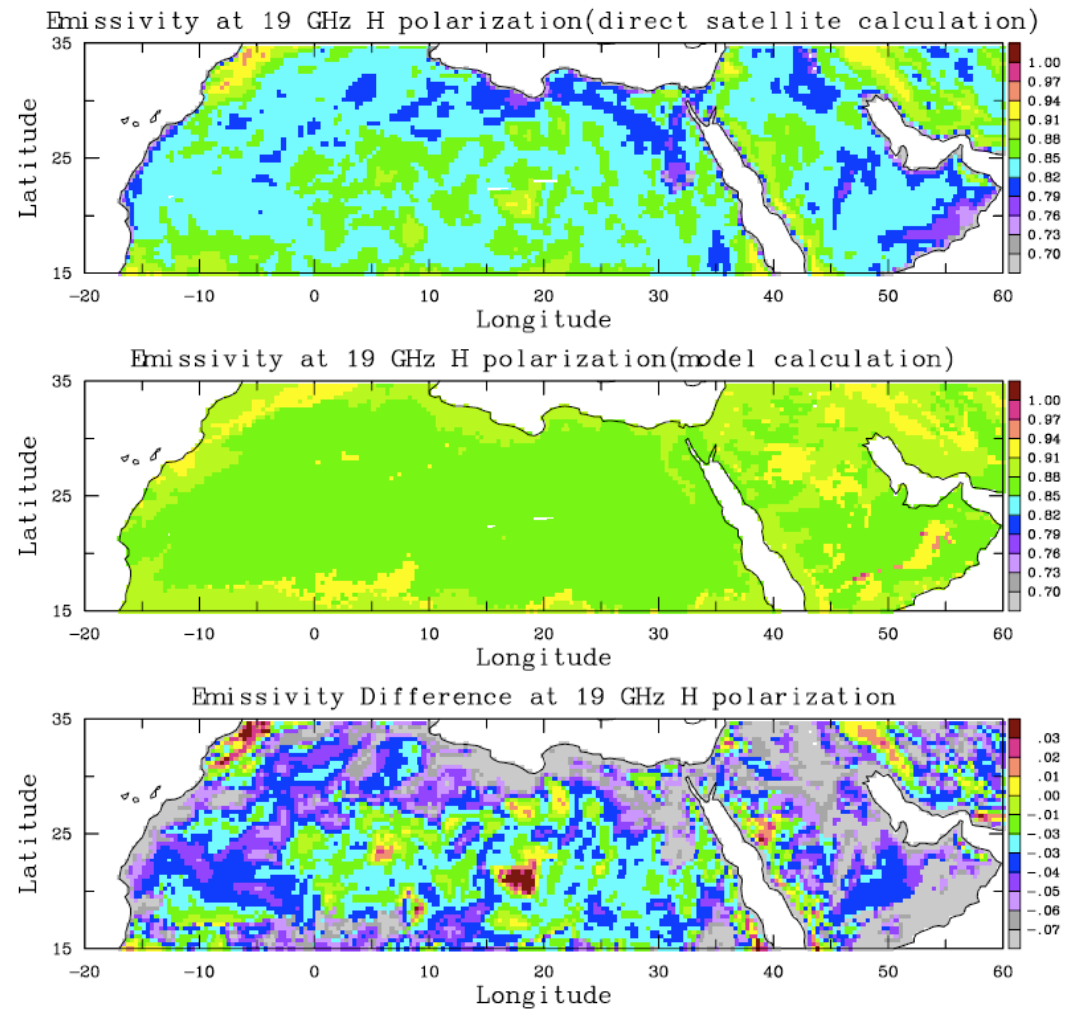- Very low variability generally assumed

However, large variability can be observed, especially over deserts

- In models, often one value assumed for one class of surface, i.e., only a few values for all deserts

INTRODUCTION

Example of differencies between satellite and model estimates in the MW

INTRODUCTION

A few studies in each wavelength range over deserts, but most of them at local scales

What we suggest:

A joint analysis of large scale satellite-derived emissivity datasets over arid and semi-arid regions in the IR and in the MW:
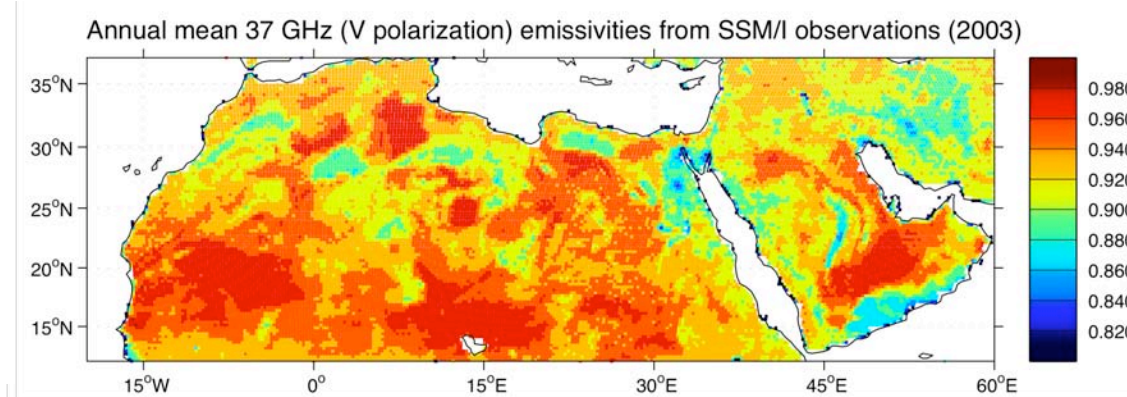
- to better understand the relationship with surface properties

- to check the consistency of the two data sets and give insights on their quality

- to give guidance for a better specification of the emissivities in inversion problems and climate models.
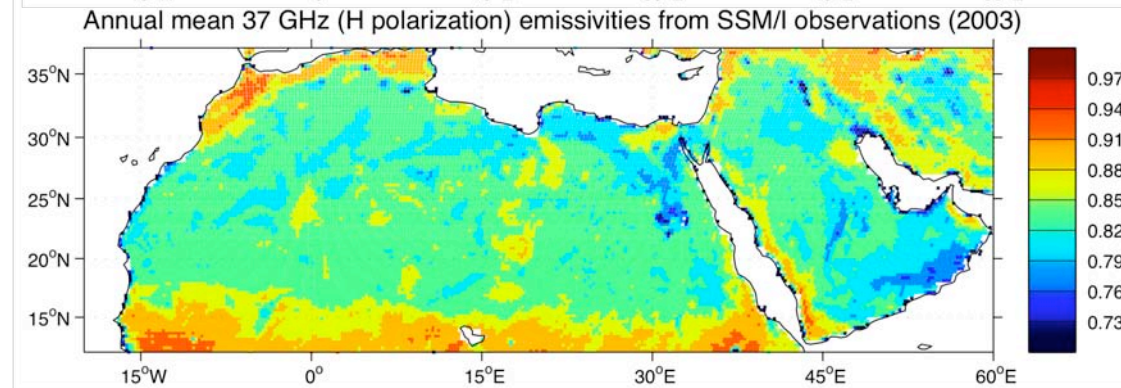
THE SATELLITE-DERIVED MW EMISSIVITIES
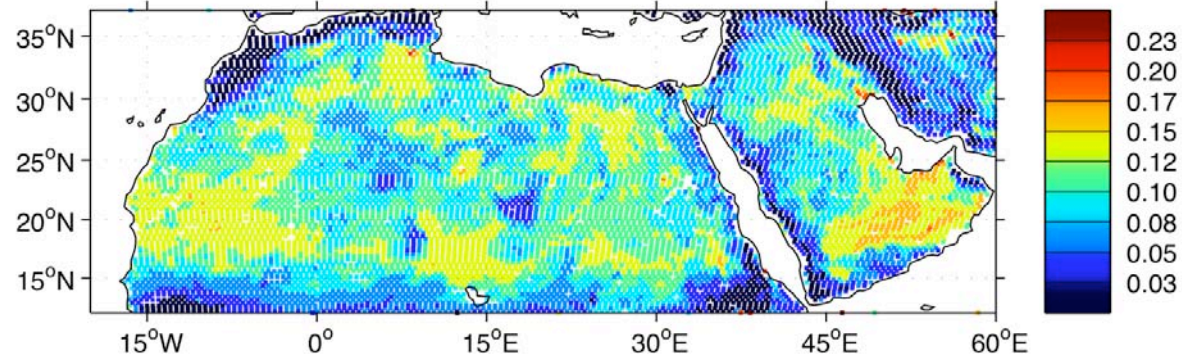
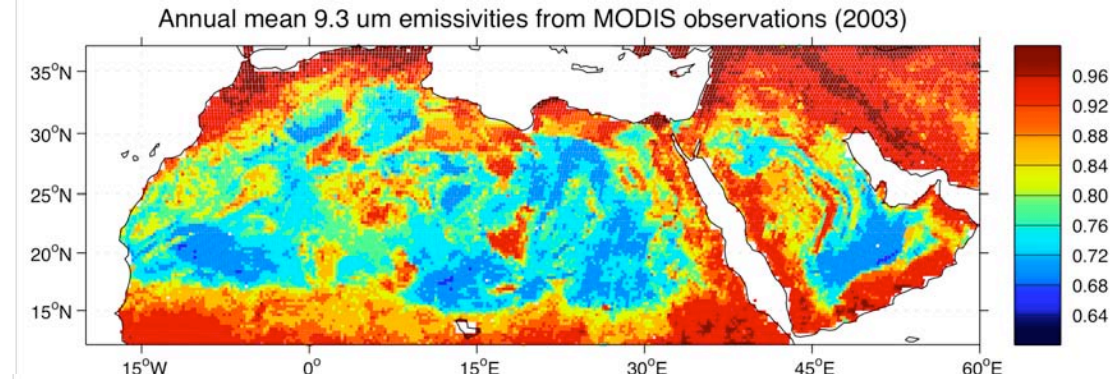See Aires et al. presentation

37 GHz H

37 GHz V

37 GHz V-H

THE SATELLITE-DERIVED IR EMISSIVITIES

See Borbas et al. presentation

9.3µm

10.8µm

14.3µm

Annual mean 9.3 um emissivities from MODIS observations (2003)

Annual mean 10.8 um emissivities from MODIS observations (2003)
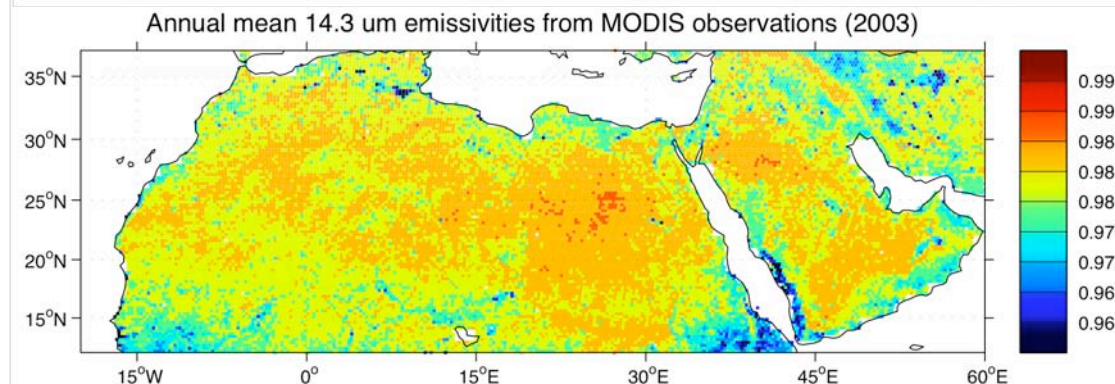
Annual mean 14.3 um emissivities from MODIS observations (2003)
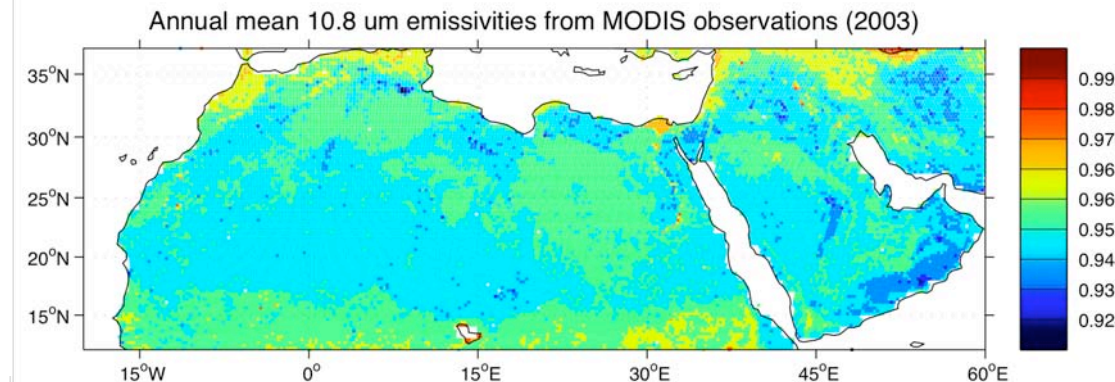
THE SATELLITE-DERIVED EMISSIVITIES

Very stable and contrasted signatures.

Some of the signatures are expected, some are not.

Cannot be noise (but could be artifacts of the retrieval methods…)
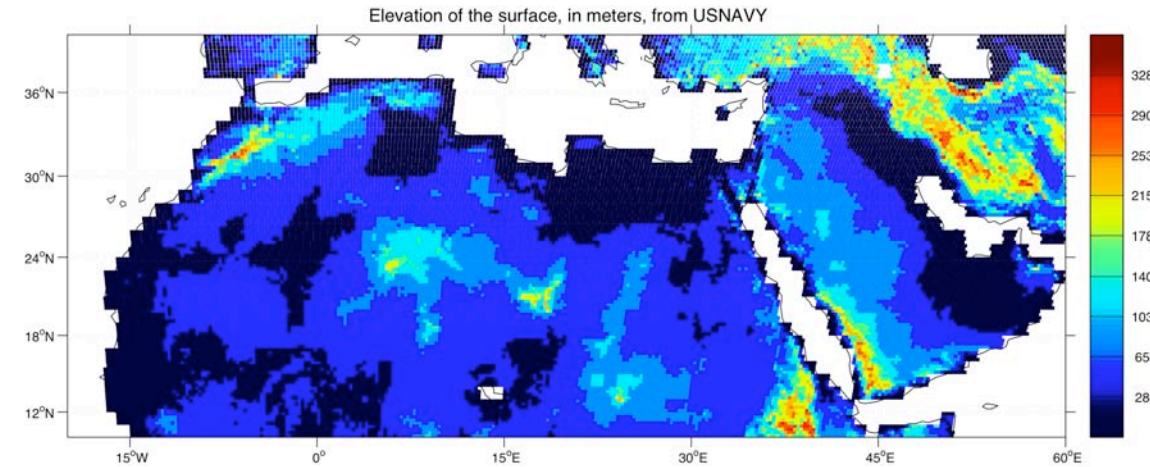
Can all the signatures be physically interpreted?

Some detective work…

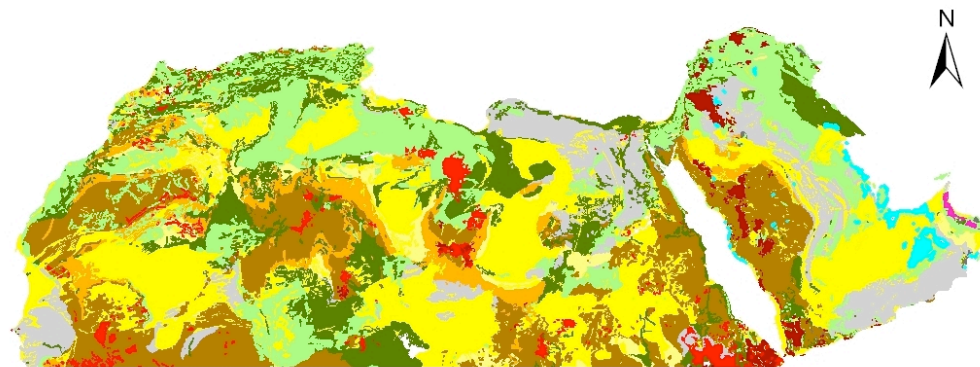# LAND SURFACE PROPERTIES OF THE REGION

Many sources of information analyzed. Not all relevant to our purpose

Topography

Elevation of the surface, in meters, from USNAVY

Lithography
(see poster by Catherinot et al.
for more details)

Legend

evaporite   carbonate siliceous and evaporite rocks

mix   siliceous rocks

ophiolite   siliceous argillaceous and carbonate rocks

intrusive rocks   siliceous argillaceous and evaporite rocks

volcanic rocks   siliceous and argillaceous rocks

carbonate rocks   Precambrian shield

With increasing roughness, decreasing polarization difference, as expected.
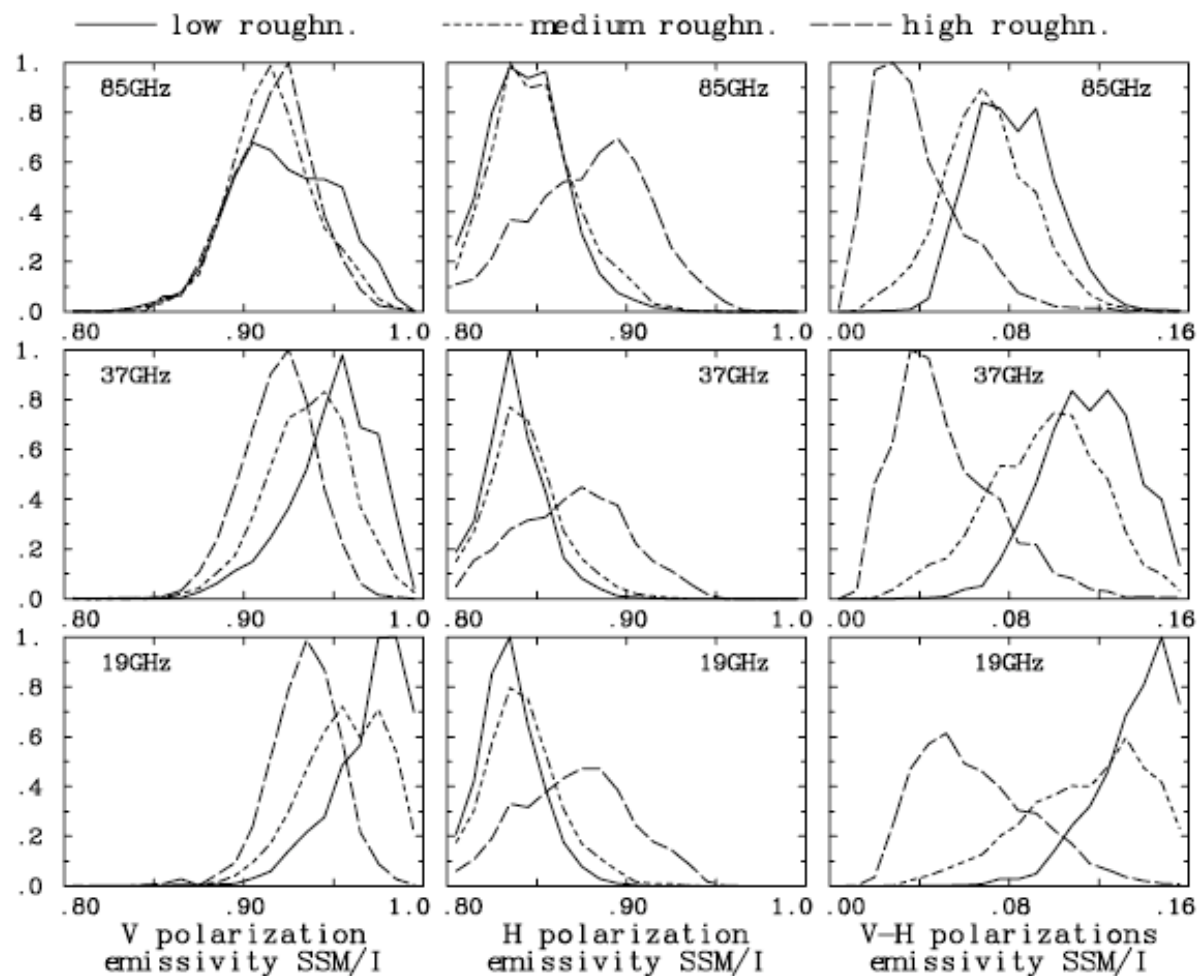
In some locations, reduced amplitude and shifted phase of the microwaves, compared to the IR. The lower the frequency, the larger the discrepancy.

=>Microwaves originate from below the surface, whereas IR measures skin temperature. The lower the frequency, the larger the penetration
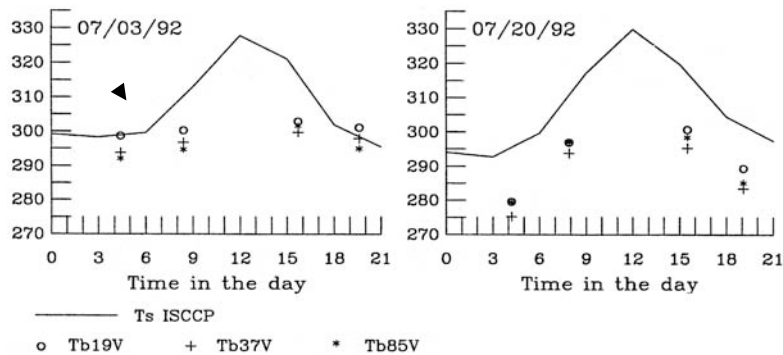

Time series of passive microwave SSM/I observations and IR surface temperature (ISCCP) at two locations in the African desert
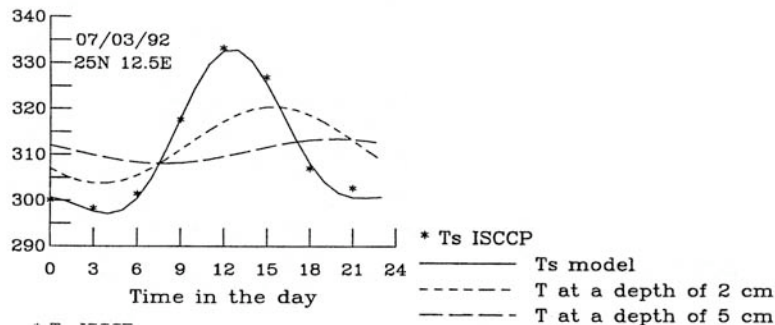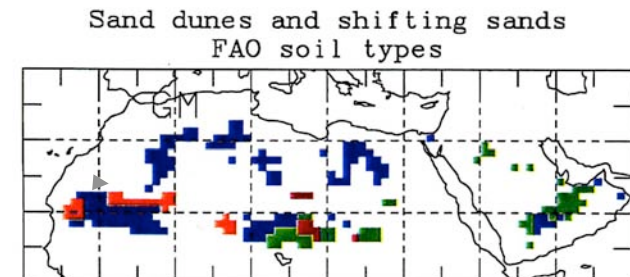

Temperature diurnal cycle at different depths from observations and heat conduction model

Estimate of the penetration depth using 8-times daily IR estimates of surface temperatures and a heat conduction model (thermal diffusivity of 0.002 cm2/s)
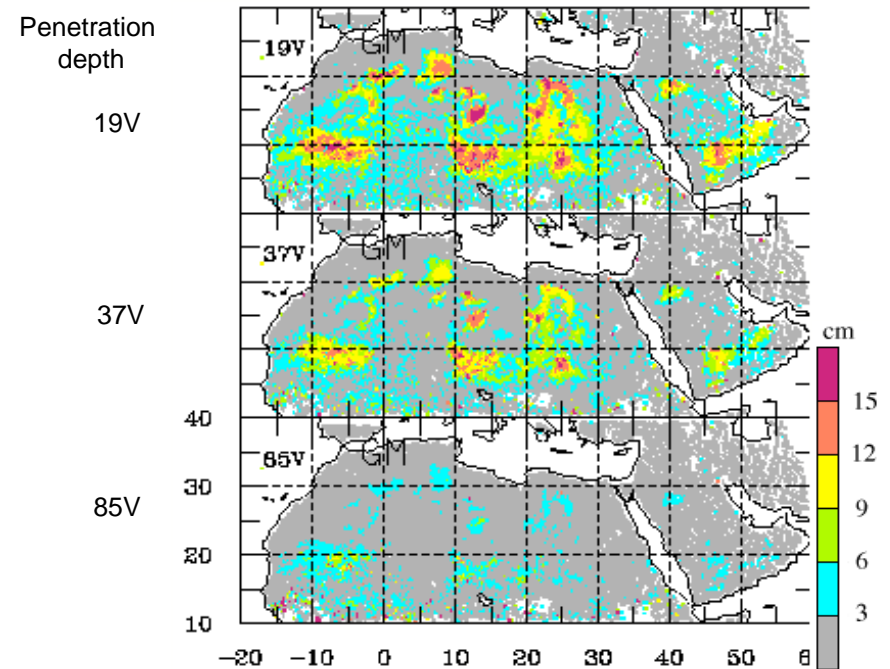
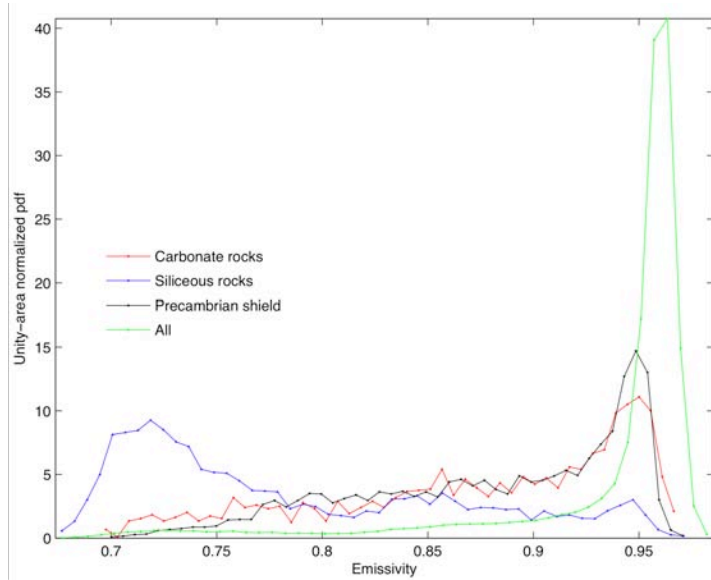Agreement between areas of large penetration depth and sand dunes
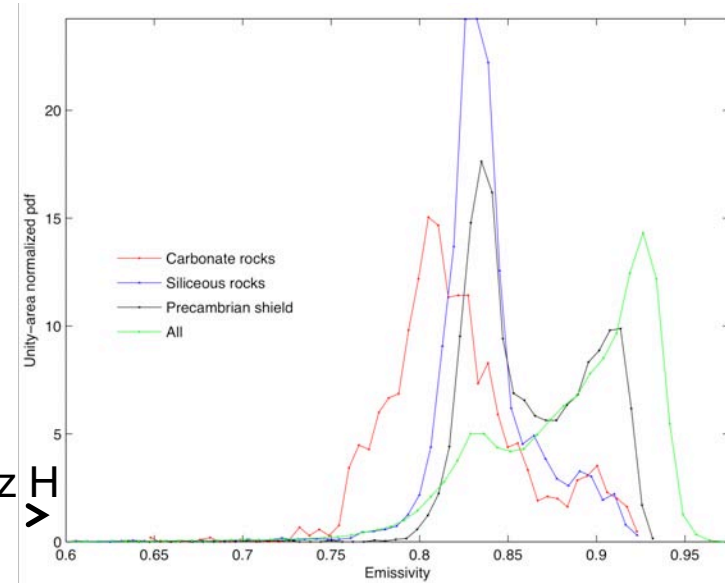

(Prigent et al., JGR, 1999)
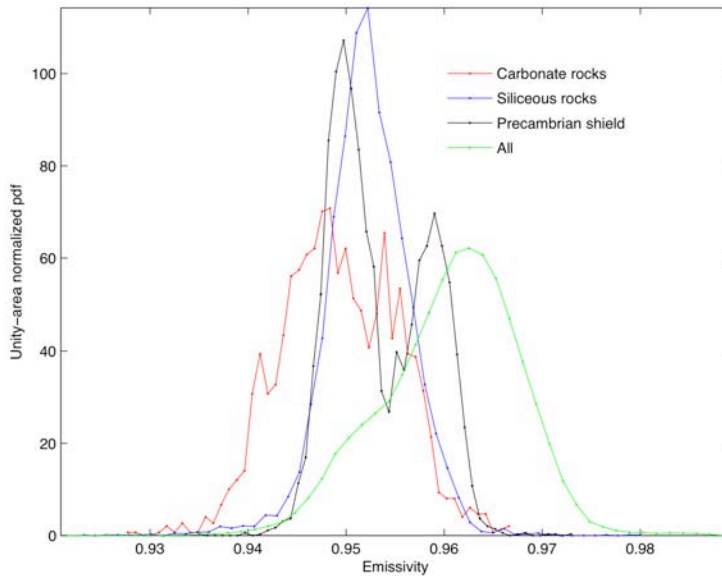
SENSITIVITY TO THE LITHOLOGY in the IR and MW

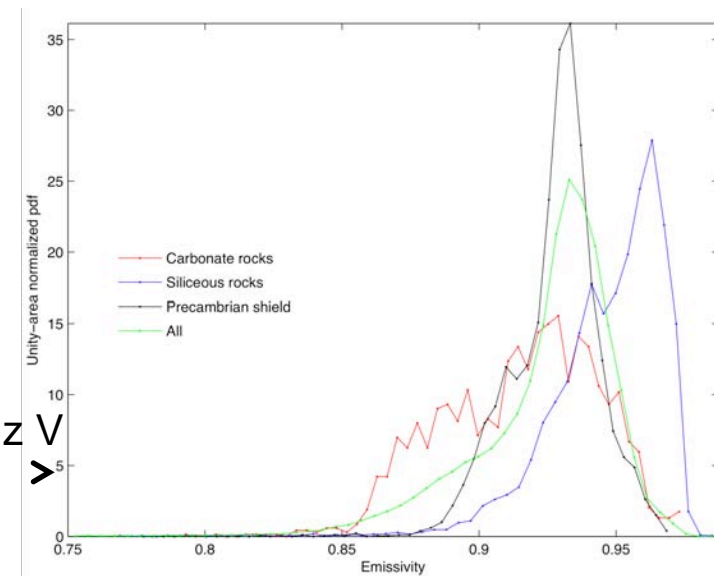Histograms of the emissivities for specific rock types
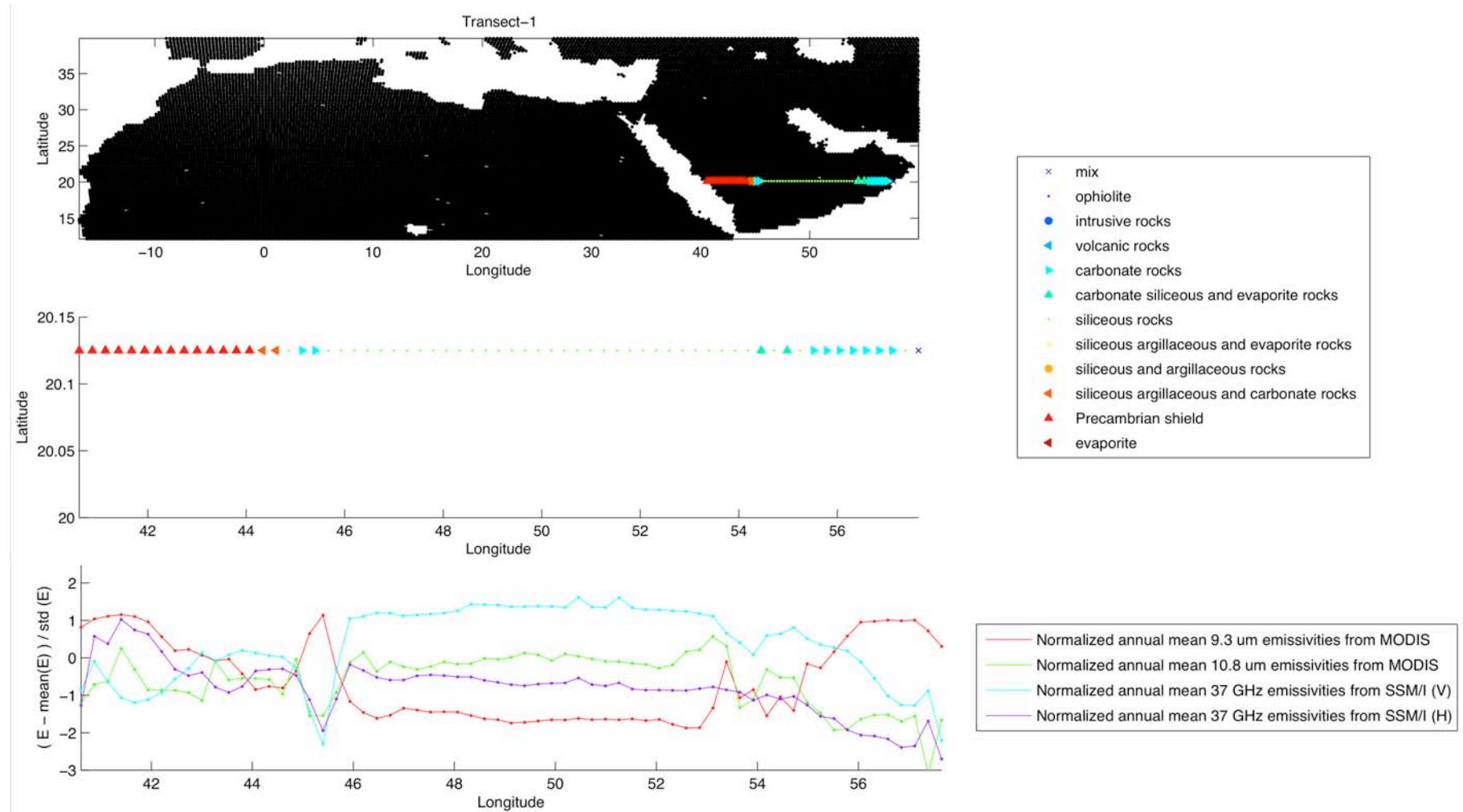

IR 9.3μm

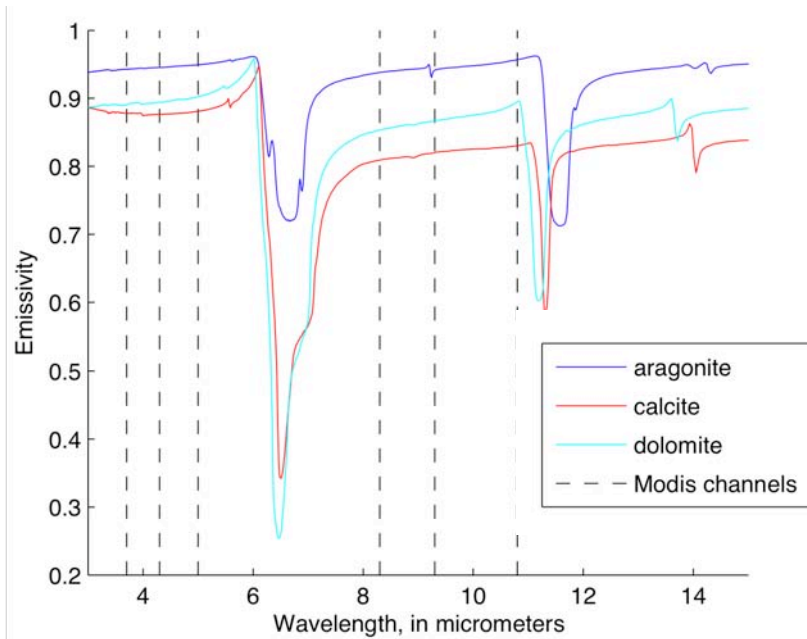MW 37GHz H

IR 10.8μm

MW 37GHz V
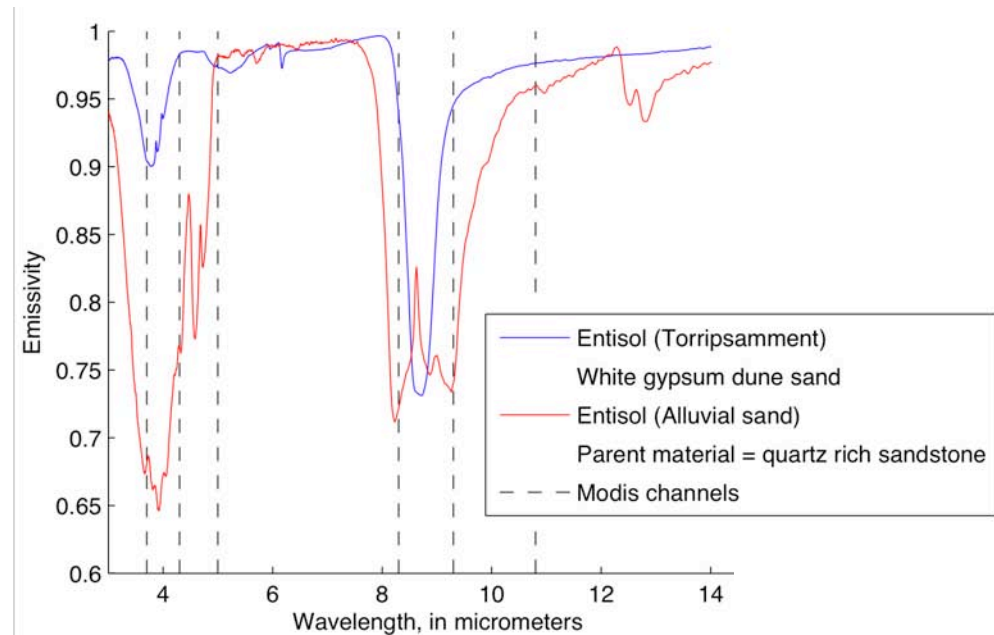
A TRANSECT OVER A SPECIFIC REGION

=> Spatial consistency of the microwave and infrared signatures, with the lithology

CORESPONDANCE WITH THE SPECTRAL PROPERTIES OF THE MINERALS

IN THE INFRARED, the ASTER database provides spectral information for many minerals and rocks

=> Rather weak signatures of the carbonates in the MODIS channels

=> Strong signatures of the silicates in the MODIS channels

* Note that all the spectra features not included in the initial IR spectral data base, although they show up in the IR emissivity data base
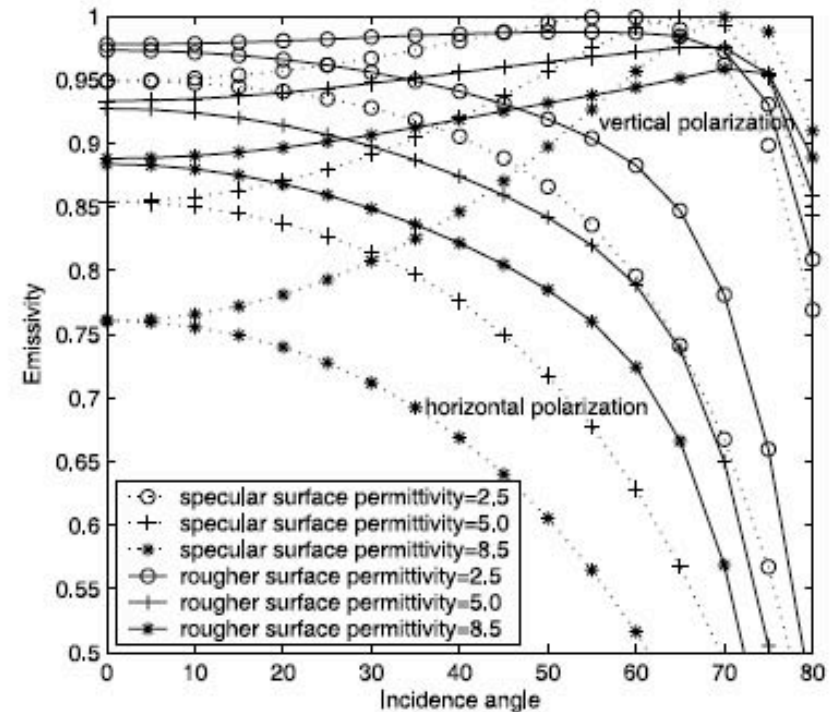
CORESPONDANCE WITH THE SPECTRAL PROPERTIES OF THE MINERALS

IN THE MICROWAVES, limited information in the literature.

Solid Rocks	Freq. (GHz)	ε '	ε "	References
Granites (average values)	0.45	5.47	0.08	Campbell and Ulrichs (1969)
	35	5.31	0.1	Campbell and Ulrichs (1969)
	170	5.31	0.197	Thomas (2004)
Basalts (average values)	0.45	7.79	0.2	Campbell and Ulrichs (1969)
	35	7.36	0.41	Campbell and Ulrichs (1969)
	170	7.67	0.45	Thomas (2004)
Carbonates (average values)	0.2	8.9	0.2	Thomas (2004)
	35	7.76	0.24	Thomas (2004)
	110	8.12	0.1	Thomas (2004)
	170	7.68	0.11	Thomas (2004)

Measurements performed in collaboration with C. Matzler, for specific materials. Not easy measurements…

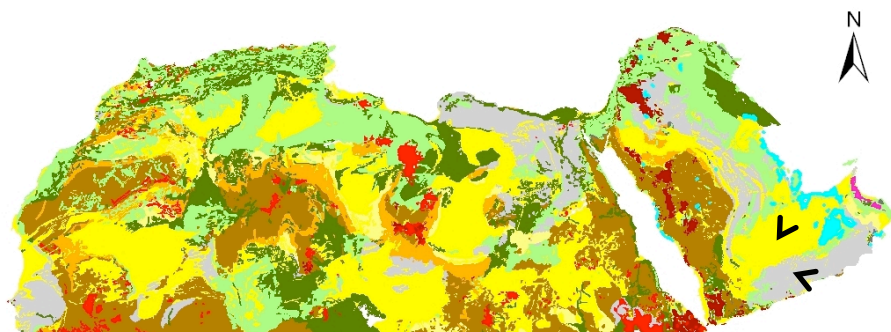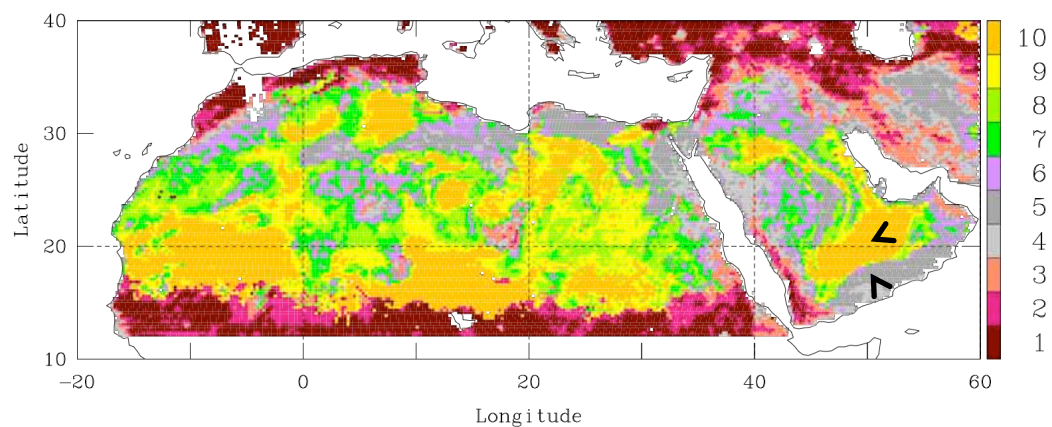⇒ Carbonated rocks usually have a higher permittivity

Simulations using the IEM model from Shi et al., 2002

⇒Higher permittivity induces lower emissivity

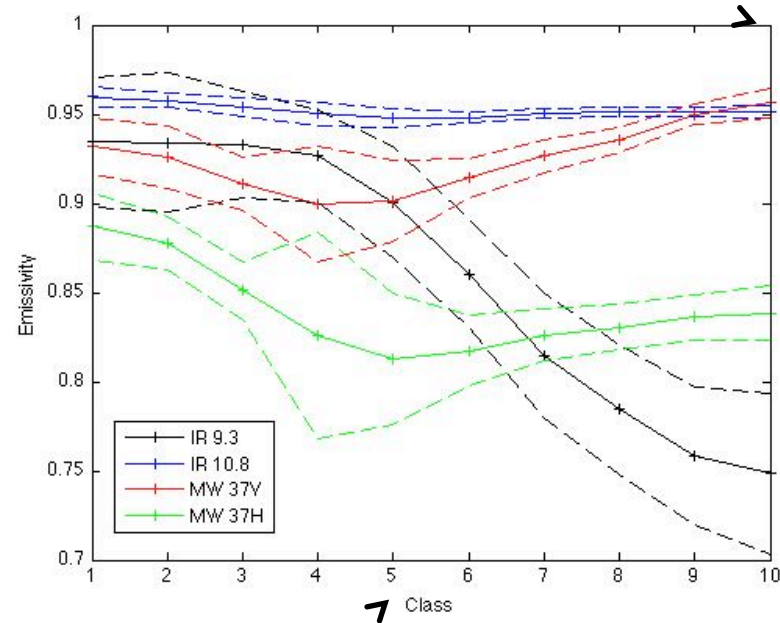# EMISSIVITY-DERIVED CLASSIFICATION OF THE REGION

silicates

carbonates

CONCLUSIONS

• High sensitivity of the IR and MW emissivities to the surface properties in deserts, with large variabilities as a function of topography, lithography, porosity

• Interest of the use of satellite-derived emissivity atlases in such environments that are very difficult to model.

• Sensitivity higher than expected of the MW to the presence of carbonated outcrops. Still to be physically explained.

• Systematic comparisons with visible observations (MODIS albedos, AVHRR, Parasol), thermal measurements (amplitude of the Ts diurnal cycle), microwave active observations (scatterometer and altimeter) under investigation. To constrain the physical interpretation of the satellite signals.

• Applications of the lessons learned with SSM/I to the analysis of SMOS data in these regions

See poster by Julie Catherinot et al. for additional analysis