Towards a calibration of SHARAD images

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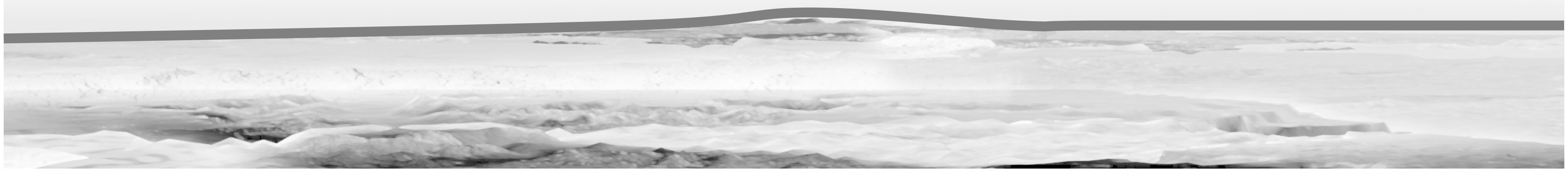


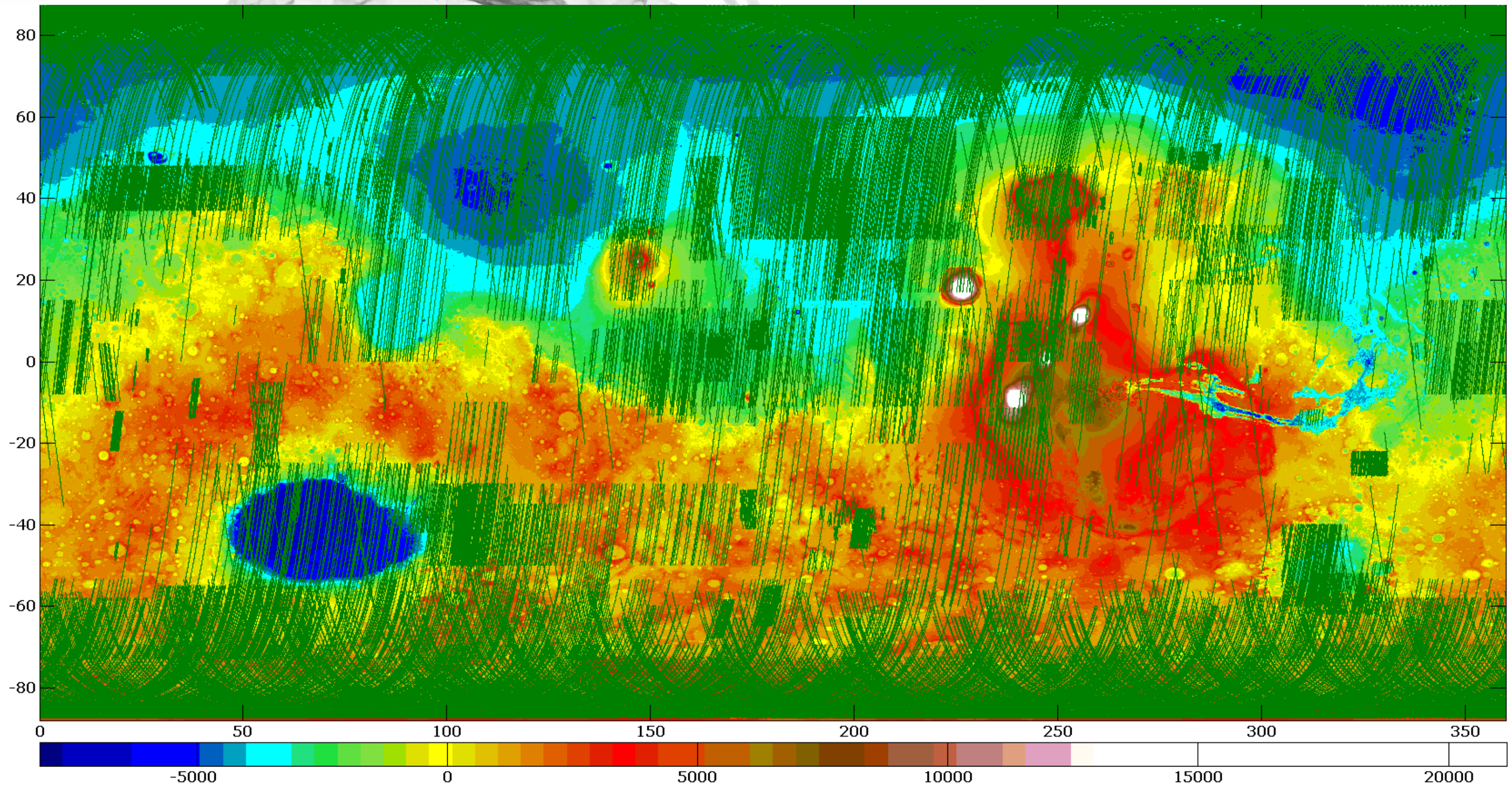
The approach

The goal is twofold:

- **to assess the “stability” of SHARAD measurements, to understand the influence of geometric and processing effects in order to calibrate the data;**
- **to assess the feasibility of estimating superficial relative permittivity directly from echo power;**

The approach

Method exploits full coverage of SHARAD data and, in principle, it would reach good accuracy from the great amount of possible data averaging

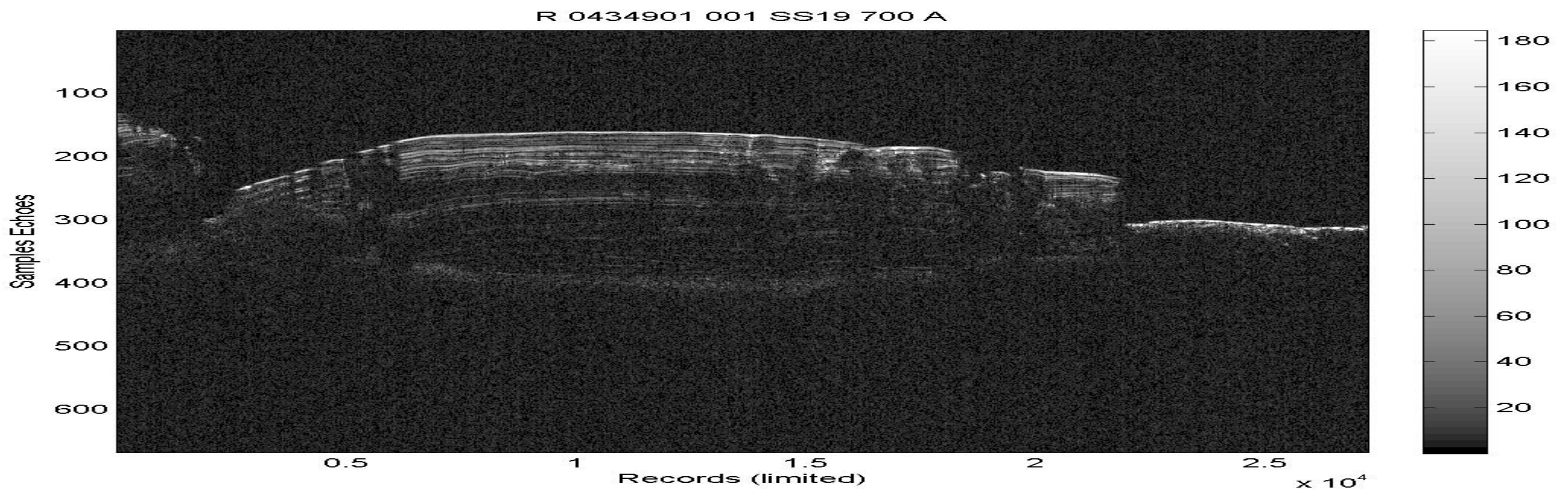


Radar Calibration

The final goal is to have a “calibrated” radargram where intensity variation would be related only to different dielectric properties of terrain

To this aim some kind of “reference signal” is needed

For this preliminary analysis the area of North Ice Cap has been selected



Radar Equation

Data should be corrected following a simple radar equation

$$P_r = \frac{P_t\, G^2\, \sigma_0\, A_r}{(4\pi)^2\, H^4\, L_{atm}\, L_{sys}}$$

Parameter	Definition	Evaluable from
P_r	Received Power	Sharad Scientific Data through Radar Calibration
P_t	Transmitted Power	Sharad System Definition
G	Gain of the Antenna	Sharad System Definition
σ_0	Radar Cross Section of the Target	Fractals Model
A_r	Effective Aperture of the Receiving Antenna	Geometrical Model
H	Distance from the Antenna to the Target	Sharad Ancillary Data
L_{atm} , L_{sys}	Atmospheric and System Losses	Radar Calibration

Backscattering Model

Planet's terrain is supposed to be a random rough process with fractal distribution (fBm)

In this way, a closed form for the backscattering coefficient can be derived under the Kirchhoff approach and the small-slope approximation

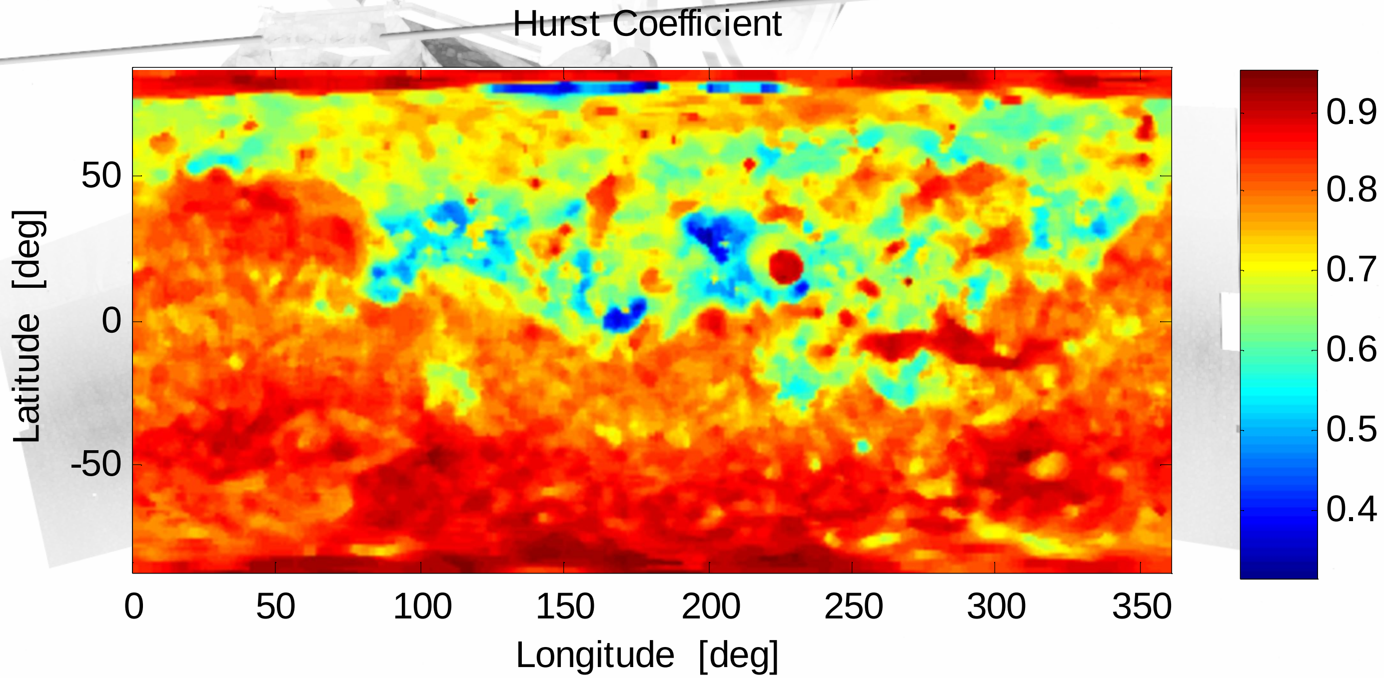
$$\sigma^0(\theta) = 2k^2\rho'(\theta)\cos^2\theta\int_0^\infty J_0\left(2k\tau|\sin\theta|\right)\exp\left(-2s^2k^2\tau^{2H}\cos^2\theta\right)\tau d\tau$$

$$s = T^{(1-H)}$$

ε_r

Backscattering Model

Using MOLA data, a map of H and T has been produced for the whole planet



Map Resolution: 1°x 1°

Useful Area for Fractals Estimation: 128 Km x 128 Km

Radar Calibration

Calibration consists in the comparison between generic signal power wrt "reference power", i.e. evaluated over North Ice Cap

$$\frac{P_r}{P_{r,ice}} = \frac{\alpha\, Echo}{\alpha_{ice}\, Echo_{ice}} = \frac{\dfrac{P_t\, G^2\, \sigma_{0,norm}\, R^2\, A_r}{(4\pi)^2\, H^4\, L_{atm}\, L_{sys}}}{\dfrac{P_{t,ice}\, G_{ice}^2\, \sigma_{0,norm,ice}\, R_{ice}^2\, A_{r,ice}}{(4\pi)^2\, H_{ice}^4\, L_{atm,ice}\, L_{sys,ice}}}$$

$\alpha = \alpha_{ice}$ is the generic conversion factor from DN to Watts

$$\frac{Echo}{Echo_{ice}} = \frac{\dfrac{G^2\, \sigma_{0,norm}\, R^2\, A_r}{H^4}}{\dfrac{G_{ice}^2\, \sigma_{0,norm,ice}\, R_{ice}^2\, A_{r,ice}}{H_{ice}^4}}$$

Radar Calibration

Over Ice it is possible to evaluate a sort of calibration constant

$$K_{ice} = \frac{G_{ice}^2 \ \sigma_{0,norm,ice} \ R_{ice}^2 \ A_{r,ice} \ Z_{ice}}{Echo_{ice} \ \ H_{ice}^4}$$

The needed accuracy can be achieved through the great number of analysed records

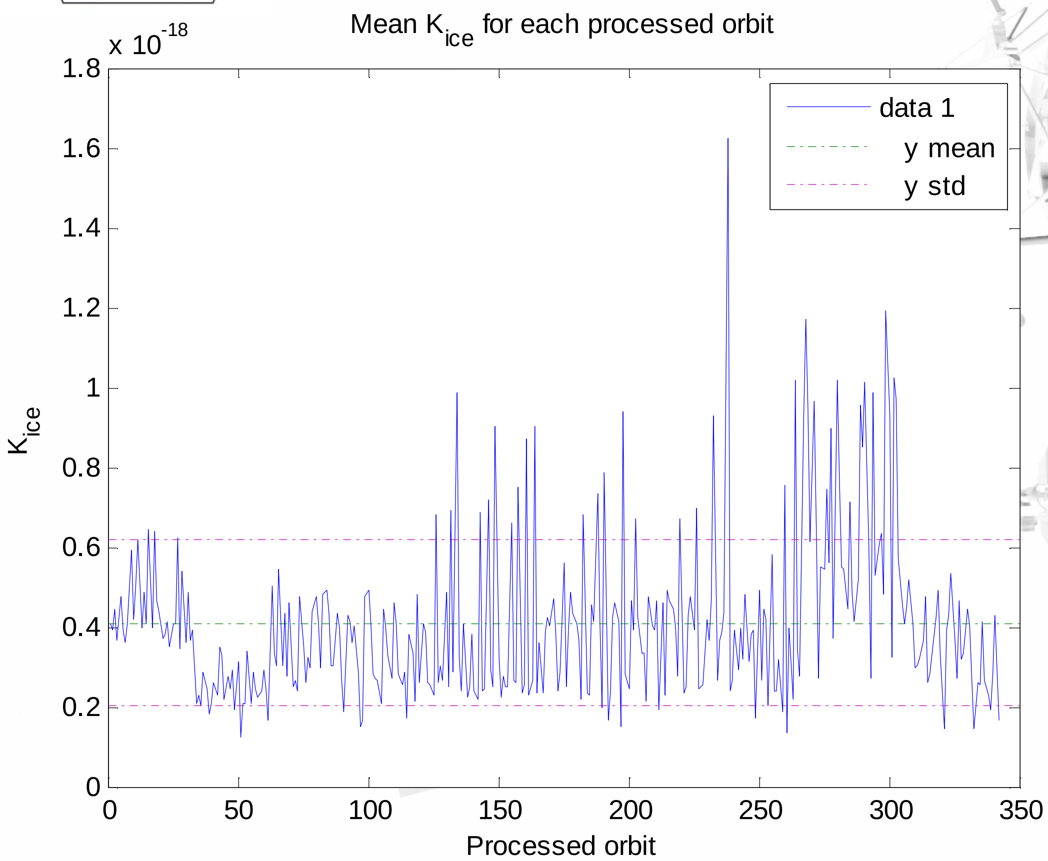
Kice Evaluation

Mean value of K_{ice} is evaluated under the following constraints:

- **Night acquisition to limit atmosphere ionization**
- **Latitude to process only North polar cap**
- **Signal to Noise Ratio to avoid weak echo processing**
- **Slope for flat areas processing**
- **Same operative mode (SS19)**

Parameter	Limit
Solar Zenith Angle	95° ÷ 175°
Latitude	= 85°N
SNR	= 8
Slope	= 1°

Kice Evaluation



Parameter	Value
Tot Products	342
Tot Records	611700 (reading skip = 7)
Post Zenith Filter	561639 (91.82%)
Post SNR Filter	478922 (78.29%)
Post Slope Filter	478678 (78.25%)
Mean	**4.30e-19**
Std	**2.08e-19**

Surface Relative Permittivity

From the evaluated Kice it is possible to retrieve Fresnel coefficient directly from signal power

$$R^2 = K_{ice} \frac{Echo\ H^4}{G^2\ \sigma_{0,norm}\ A_r\ Z}$$

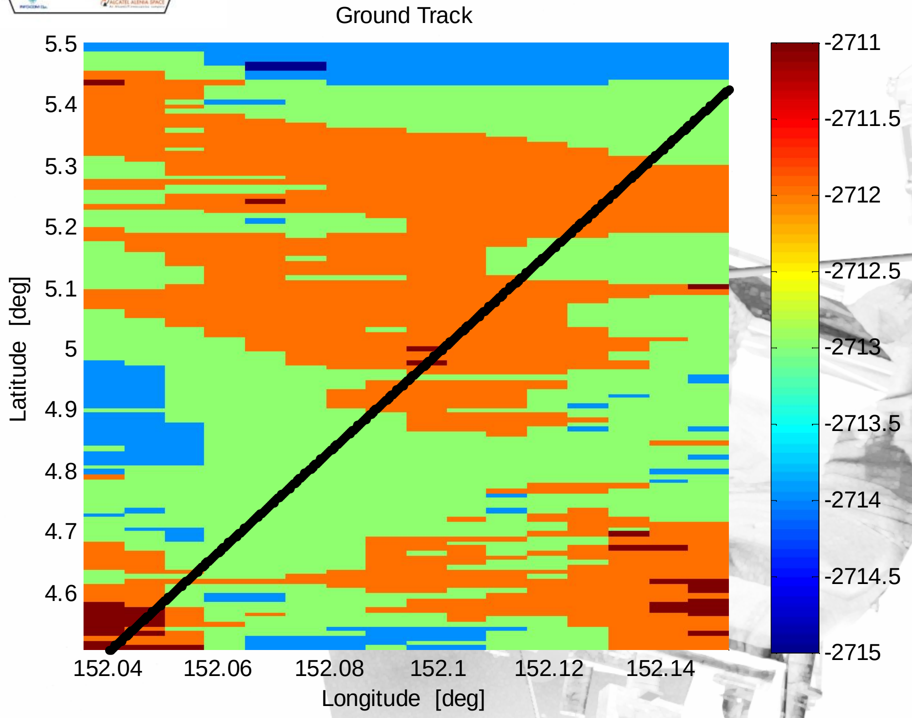
$$\varepsilon = \left[\frac{1+\sqrt{R^2}}{1-\sqrt{R^2}}\right]^2$$

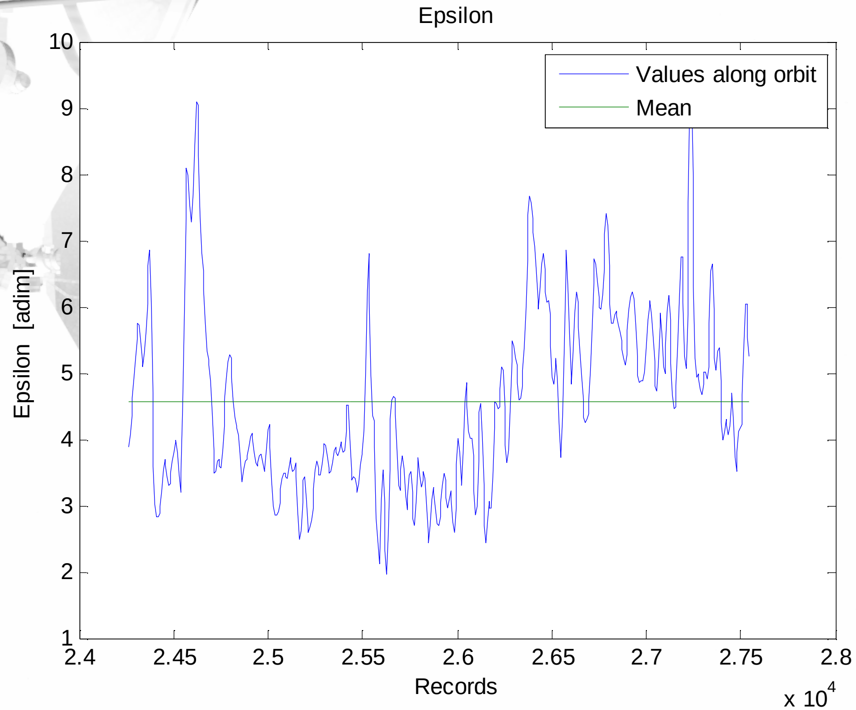
Permittivity retrieval

Analogous filtering criteria can be applied to the retrieval of Surface Relative Permittivity

Parameter	Limit
Solar Zenith Angle	100° ÷ 170°
SNR	≥ 8
Slope	≤ 2°
Epsilon	1 ≤ ε ≤ 100

Preliminary results

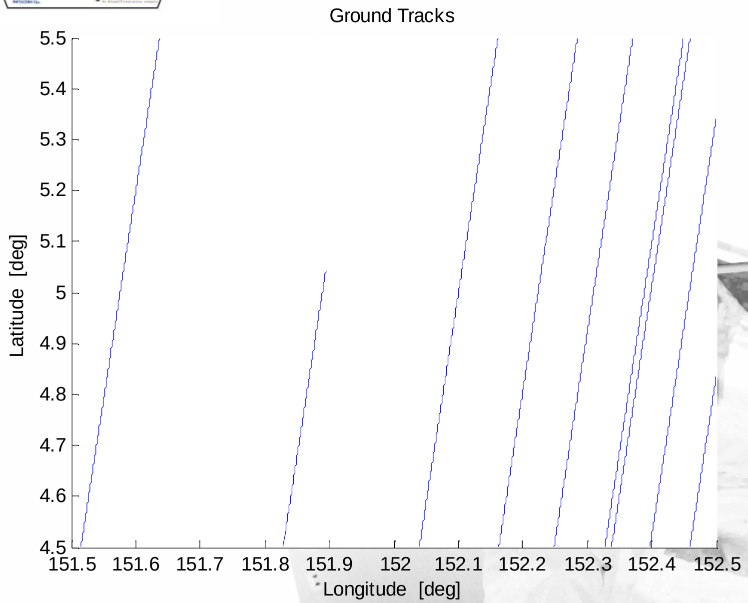


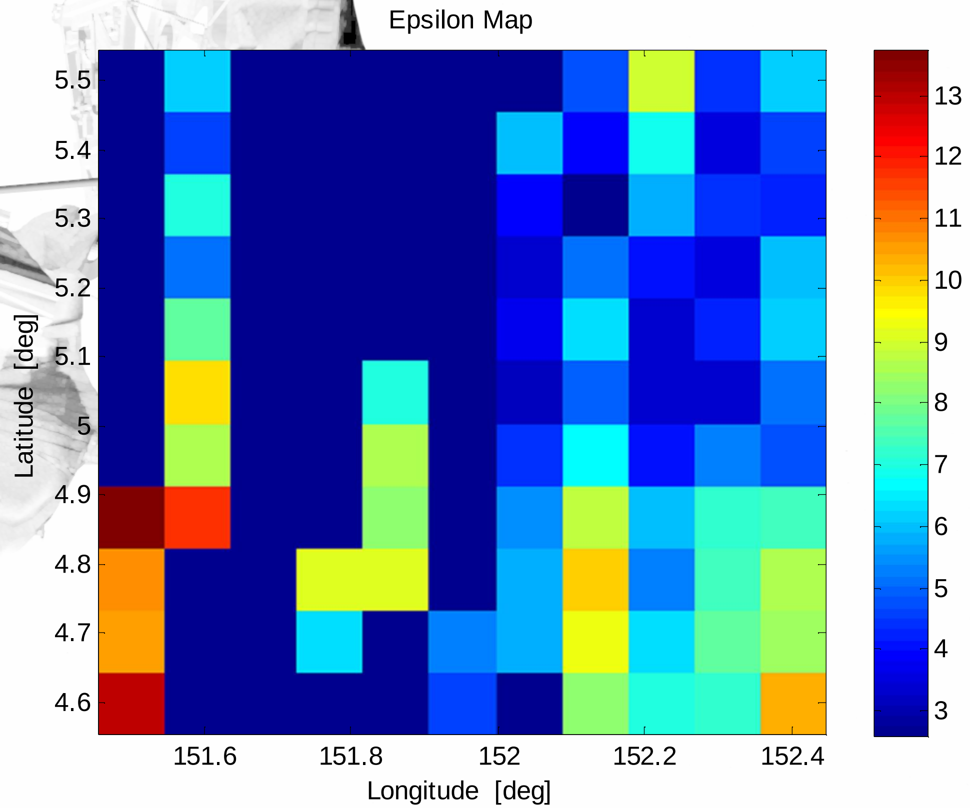


R_0264101_001_SS19_700_A (Frozen Sea)

Mean = 4.57

Preliminary results





Parameter	Value
Tot Products	9
Tot Records	3623 (reading skip = 7)
Post Zenith Filter	3623 (100%)
Post SNR Filter	3592 (99.14%)
Post Slope Filter	3592 (99.14%)
Post Epsilon Filter	3592 (99.14%)

Preliminary results

On the South Ice Cap few products with SS19 have been found