A simple technique to improve the AMSR-E spatial resolution

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Objective

To improve ground resolution of AMSR-E low frequencies (C-band) by using an approach based on multi-frequency data fusion techniques

Introduction & Background

- One of the problems of microwave radiometers operating from space is the **coarse spatial resolution** especially in the low-frequency range, which hampers a detailed analysis of the surface in variegated landscape territories.

- Early work on resolution enhancement goes back to 1990, with the work of Poe on SSMI data and before that to the Backus-Gilbert approaches (Stogryn A.,1978). Further research on this topic has been also carried out by Long and Daum (1998).

- All these methods offer a rigorous approach to the problem, however their implementation is not simple and requires the knowledge of additional parameters.

The proposed technique (SFIM)

- A simple technique for enhancing the spatial resolution of the lower frequency channels of microwave radiometers operating from space, using the corresponding high frequency images, is proposed here.

- It was derived from the Smoothing Filter-based Intensity Modulation technique (SFIM) proposed by Liu et al. (2004), which is commonly applied to enhance the Landsat Thematic Mapper resolution by using the SPOT Panchromatic

- **The fusion result preserves the information contained in the original low-resolution image.**

- The method has been applied to the AMSR-E C-band data collected on selected targets characterized by the presence of open waters surrounded by relatively homogeneous vegetation, with rivers, urban, and coastlines.

AMSR-E aquisition geometry

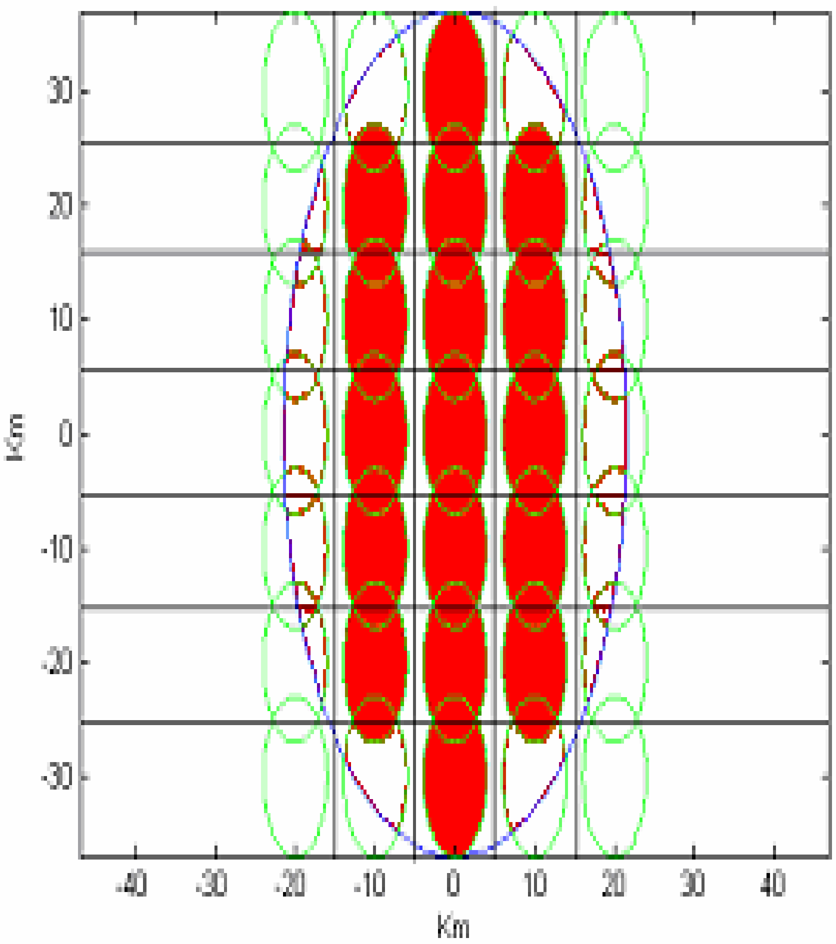
Main AMSR-E characteristics (source Jaxa)

CENTER FREQUENCIES (GHz)	**6.925**	**10.65**	**18.7**	**23.8**	**36.5**	**89.0**
BANDWIDTH (MHz)	350	100	200	400	1000	3000
SENSITIVITY (K)	0.3	0.6	0.6	0.6	0.6	1.1
MEAN SPATIAL RESOLUTION (km)	56	38	21	24	12	5.4
IFOV (km x km)	**74 x 43**	**51 x 30**	**27 x 16**	**31 x 18**	**14 x 8**	**6 x 4**
SAMPLING AREA (km x km)	**10 x 10**	**10 x 10**	**10 x 10**	**10 x 10**	**10 x 10**	**5 x 5**
INTEGRATION TIME (MSEC)	2.6	2.6	2.6	2.6	2.6	1.3
MAIN BEAM EFFICIENCY (%)	95.3	95.0	96.3	96.4	95.3	96.0
BEAMWIDTH (degrees)	2.2	1.4	0.8	0.9	0.4	0.18

- IFOV of the antenna is larger than the nominal spatial resolution, especially at the lower frequencies.

- If the IFOV contains targets that have extremely different emissions, the measured Tb disagrees with the expected values.

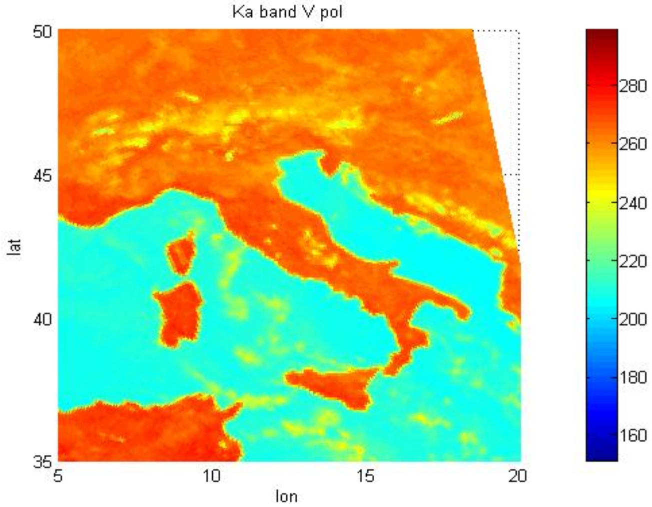
AMSR-E aquisition geometry

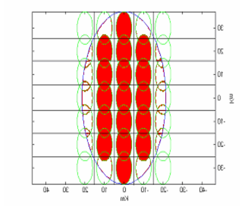


C-band IFOV

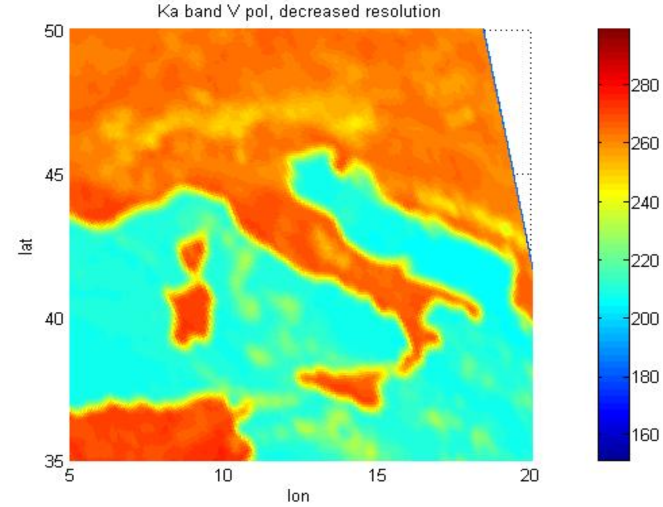
Ka band IFOV

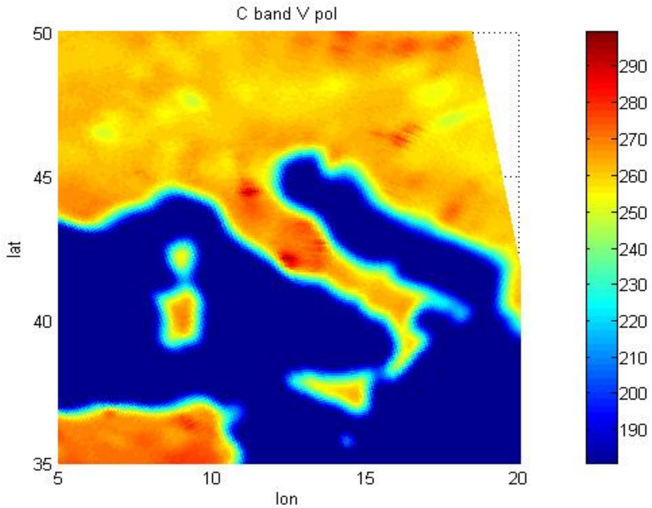
The Algorithm





Low Pass Filtering



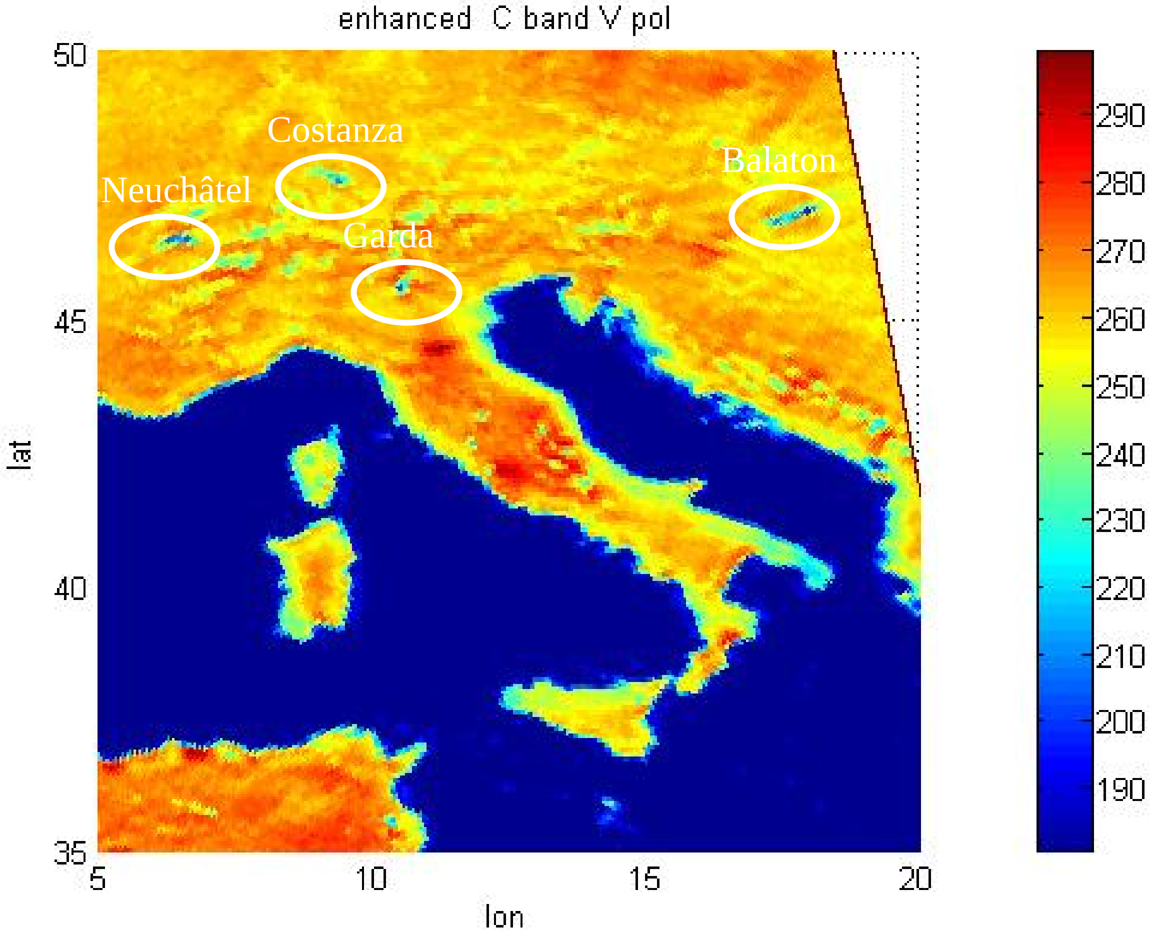


SFIM equation:

$$TbC_{Hres}=TbKa_{orig}/TbKa_{Lres}*TbC_{orig}$$

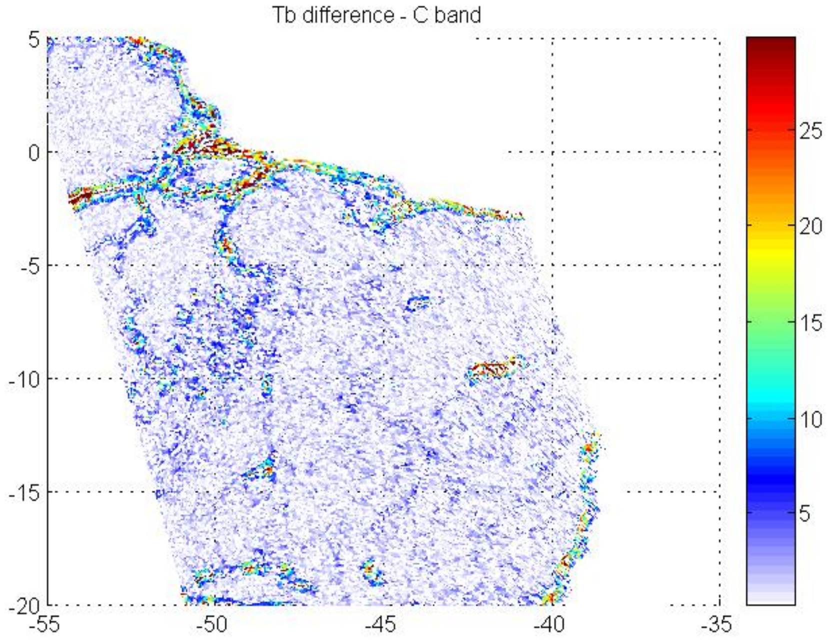
orig = original AMSR data
Hres =*data at enhanced resolution*
Lres =data at decreased resolution

The Algorithm 2

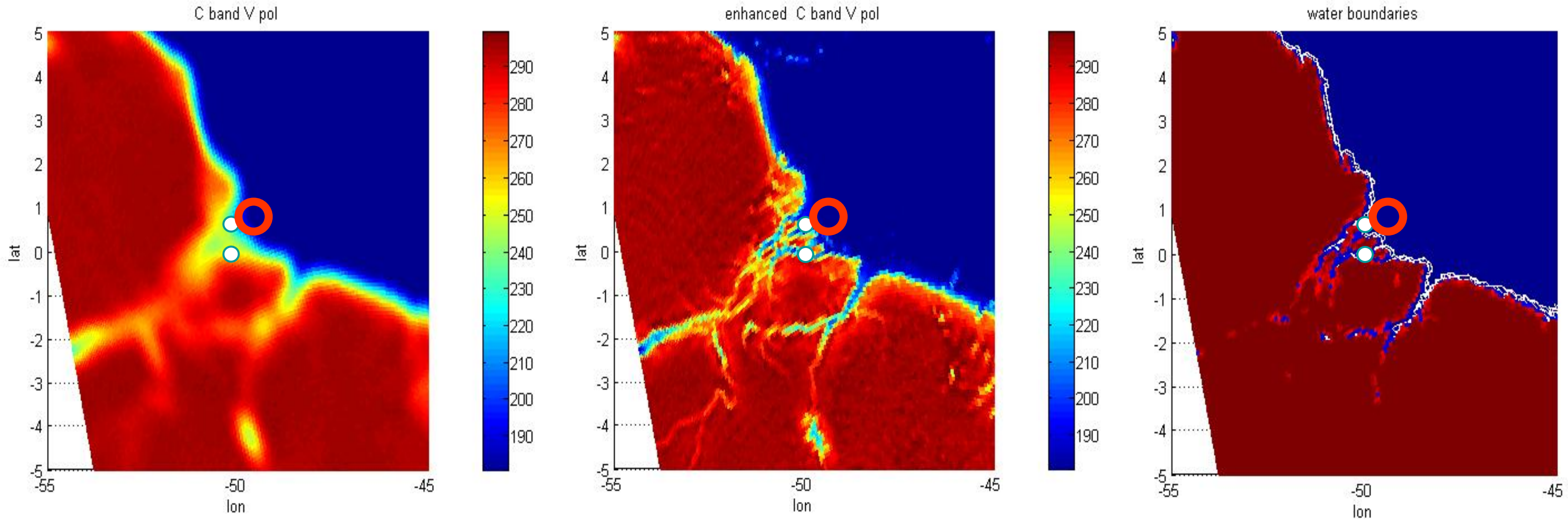


SFIM applications: Brazil

- Area coordinates: 35º W to 55º W and -20º N to 5º N
- large areas of equatorial forest surrounding open waters with rivers and coastlines
- the region has been the subject of previous studies (see Long and Daum, 1998)



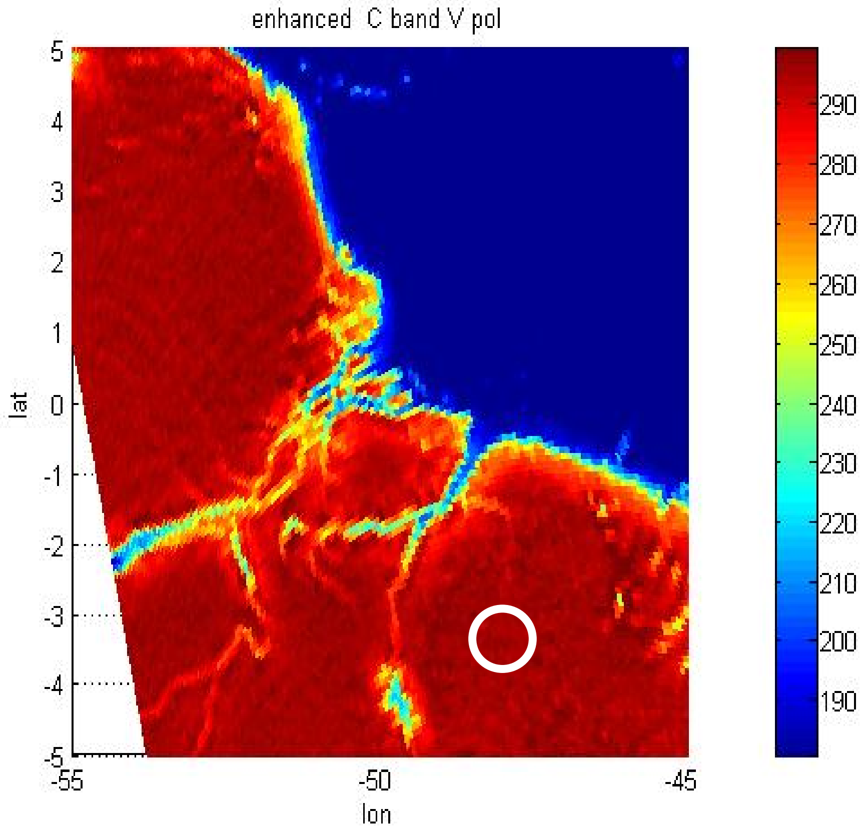
Open water



Area	LAT/LON	POL	TB AT C BAND (K)	TB AT C BAND ENHANCED (K)	OPEN WATER
1	0° N-50.2° W	V	205.85	177.23	177.51
1		H	137.10	95.21	96.91
2	0.5° N-49.9° W	V	213.65	178.90	175.67
2		H	147.00	102.94	96.91

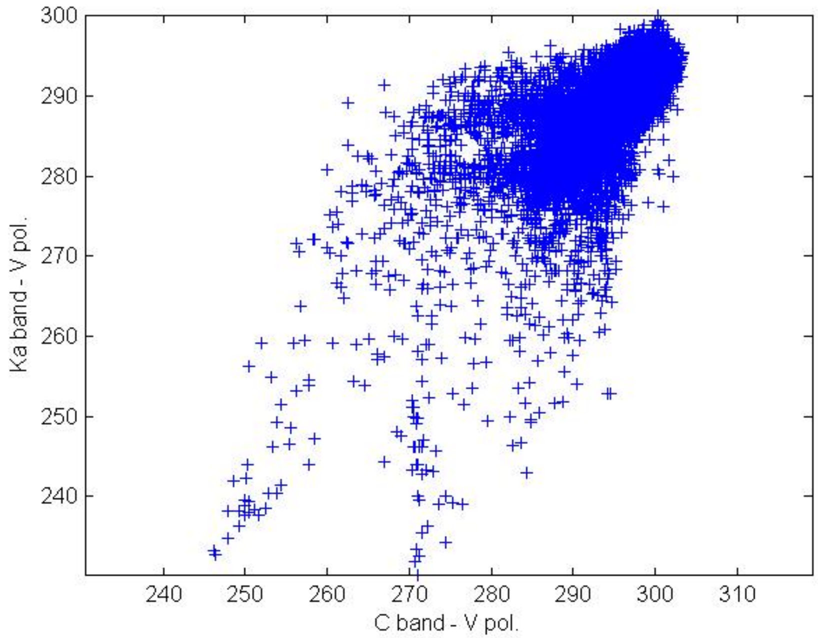
Equatorial forest

- An area uniformly covered by forest (> 95%), was selected by means of the Ecoclimap database. (http://www.cnrm.meteo.fr/gmme/PROJETS/ECOCLIMAP/pageecoclimap.htm).
- Area coordinates are: Lat –4.6⁰/–3.6⁰ N, lon 48.5⁰/47.5⁰ W
- The mean difference between the original values and the algorithm results was less than 0.5 K, with a maximum of 1.2 K



Equatorial forest: correlation effect?

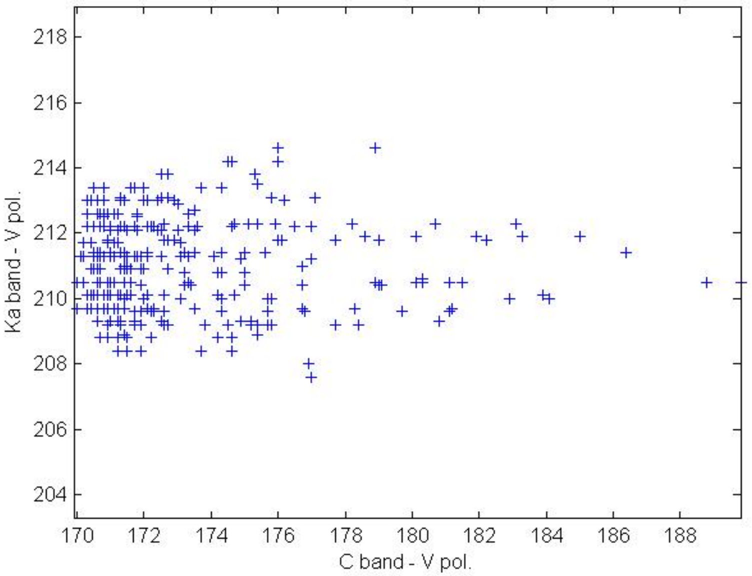
However the Tb at C and Ka bands are strongly correlated



Ka band vs C band on equatorial forest (R^2=0.71)

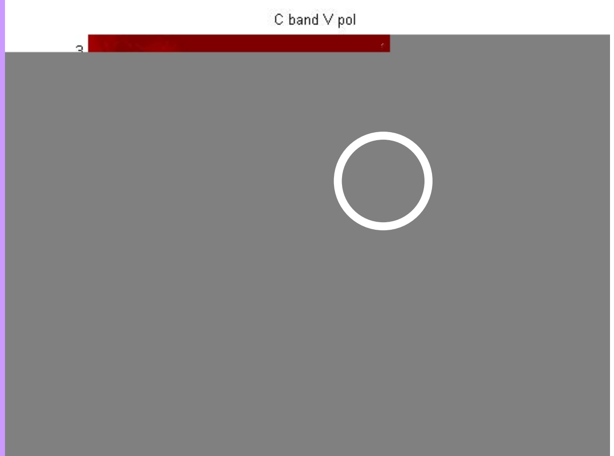
correlation effect: Victoria Lake

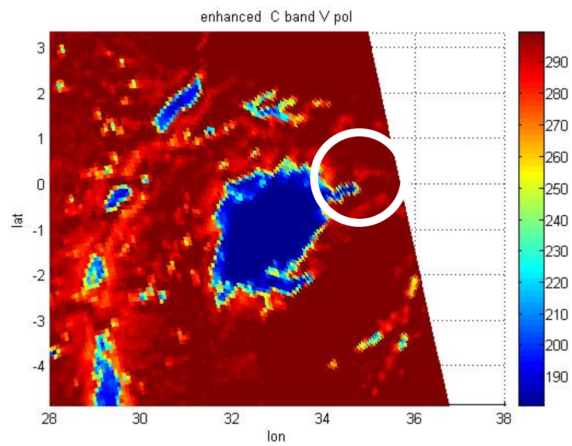
To verify if previous results are independent to the correlation between C and Ka bands, algorithm has been applied to data collected on Lake Victoria (South Africa)

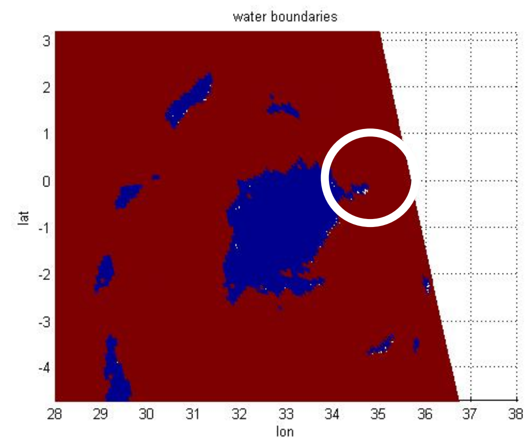


Ka band vs C band on Victoria lake (R^2=0.04)

Victoria Lake: resolution improvement

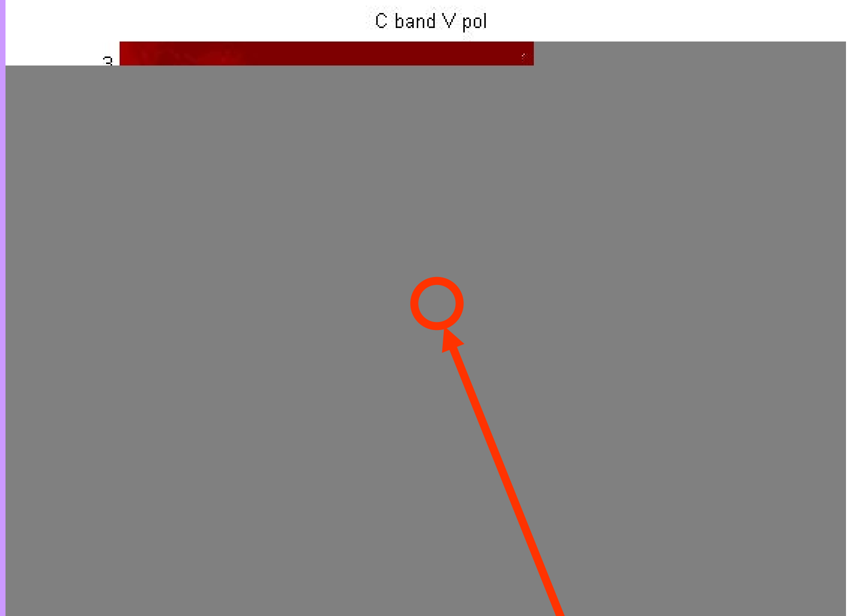


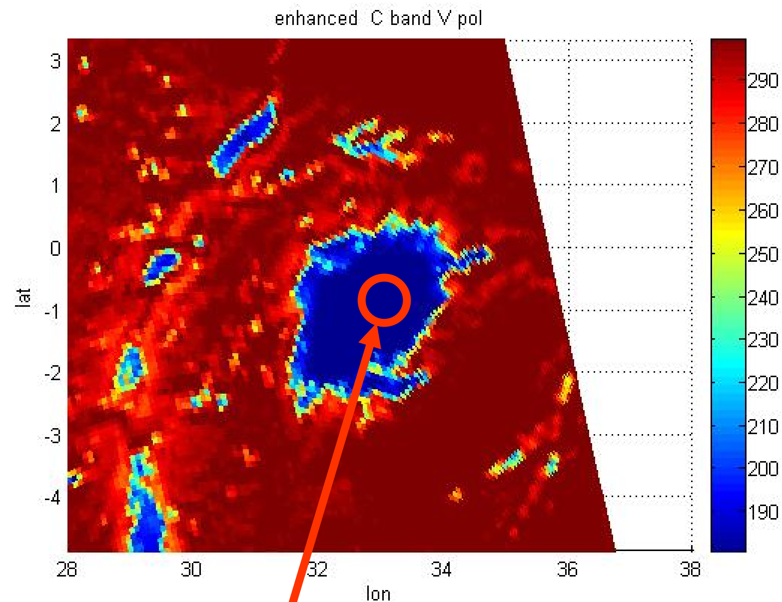




The Tb in V polarization decreases from 270.50 K to 176.36 K, which is a value close to the open water brightness of the central part of the lake

Victoria Lake: uniform targets





Comparison of data extracted on a portion of about 100x100 km, (-1.5^0 to -0.5^0 N and 32.5^0 to 33.5^0 confirmed that Tb from uniform targets are preserved

pol	C band (K)	C band enh. (K)	Ka band (K)	Δ Tb (K)
V	170.60	170.48	211.04	0.42
H	80.13	80.07	133.53	0.20

Application to the SMC retrieval

Application to the SMC retrieval: the algorithm

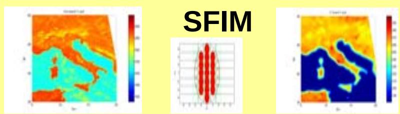
AMSR-E data in HDF format (JAXA or NSIDC)

↓

Tb extraction

↓

SFIM



↓

computation of FI and PI

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masking for snow dense veg., desert

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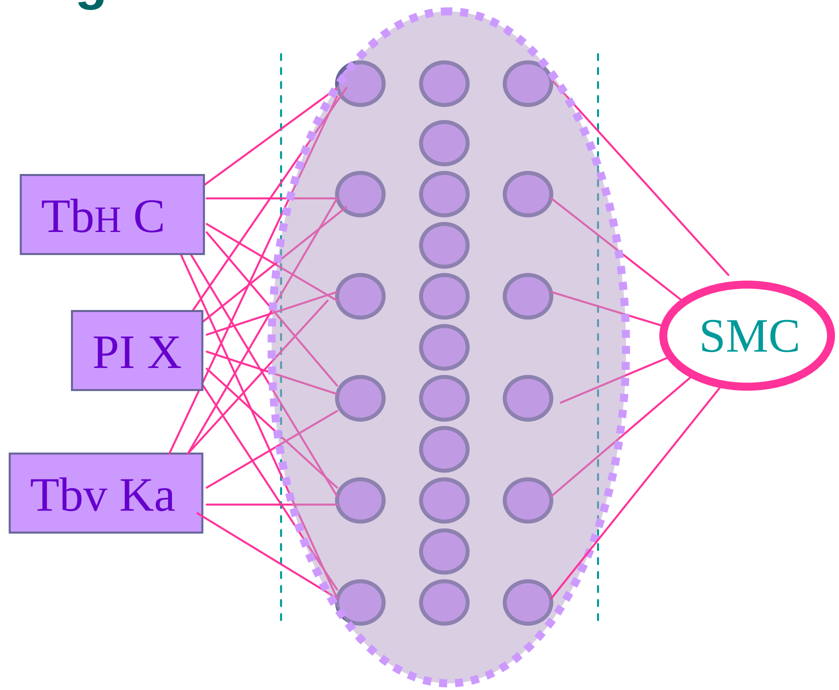
- Tb at C band, Hpol.
- PI at X band
- Tb at Ka band, V pol

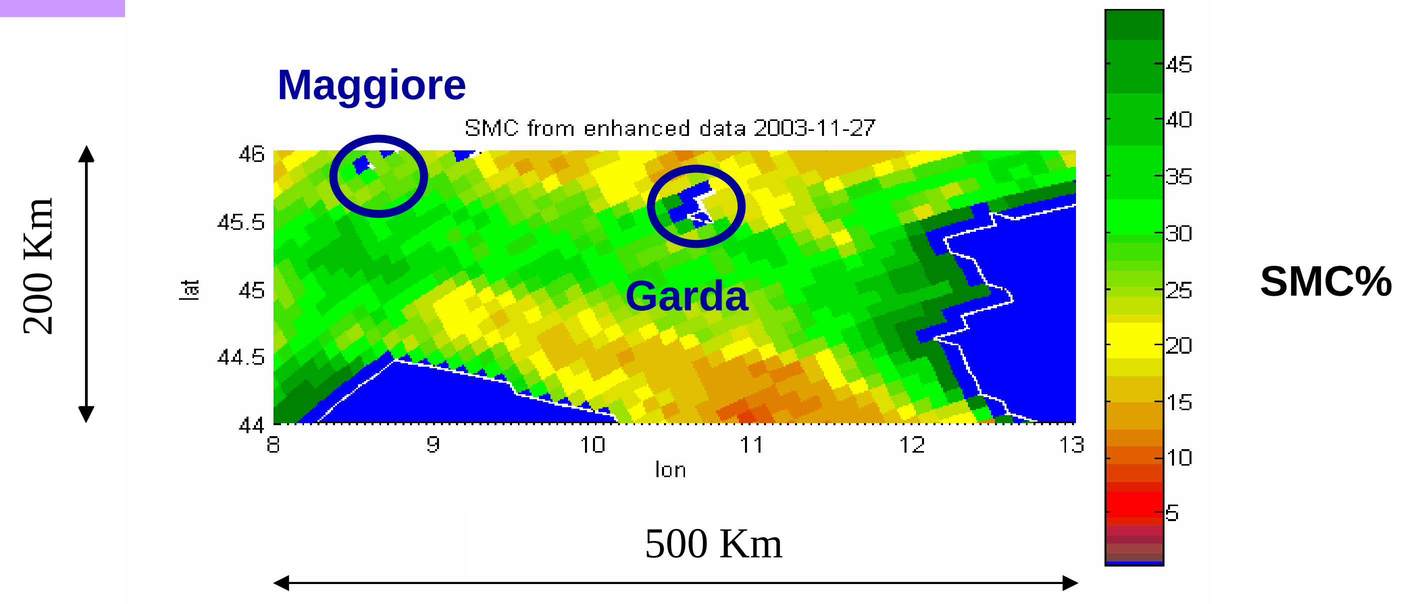
↓

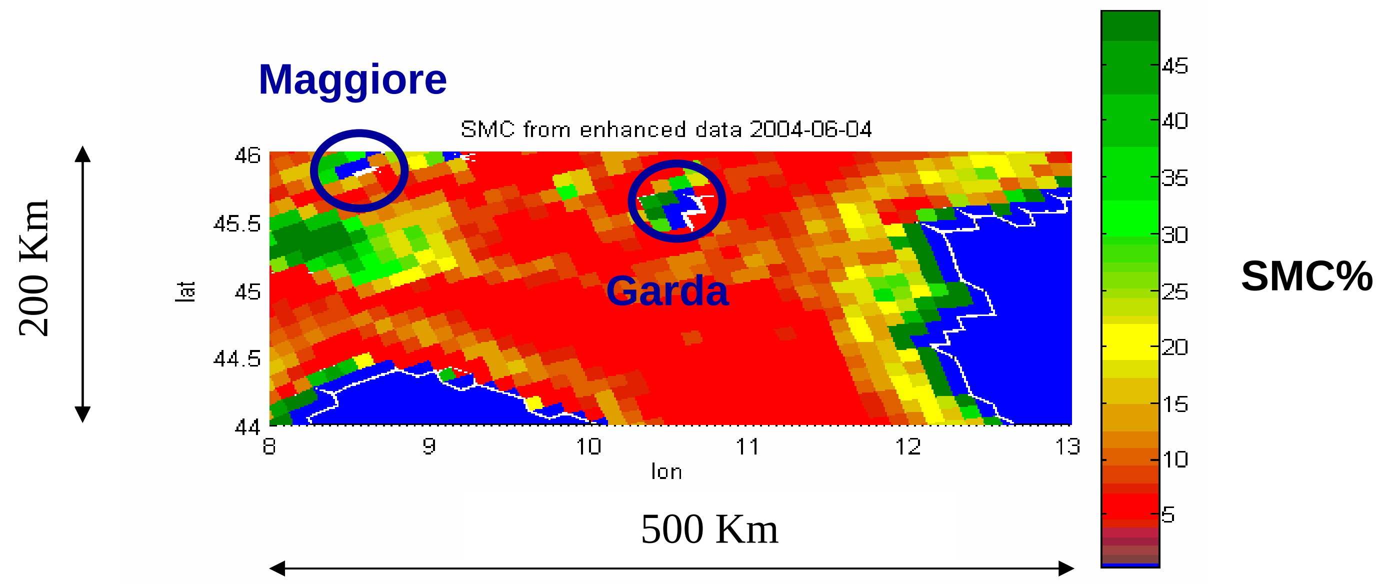
Inversion ANN → **SMC**



- Feed-forward multi-layer perceptron (MLP), with three hidden layers of neurons
- Trained by using the ω-τ model

Improvement in SMC retrieval: Po valley





Summary

- A simple method for enhancing the spatial resolution of the AMSR-E C-band channel has been implemented.
- The method is based on the SFIM technique and combines the C- and Ka-band brightness temperatures.
- The results obtained for natural targets demonstrated that this method is able to enhance the sensor spatial resolution, allowing a better separation between open water and vegetated surfaces in mixed pixels.
- Moreover, it preserves brightness temperature values collected over uniform areas, where no variation is expected.
- The method has been applied to the SMC retrieval allowing to obtain more detailed maps

Thank you for attention

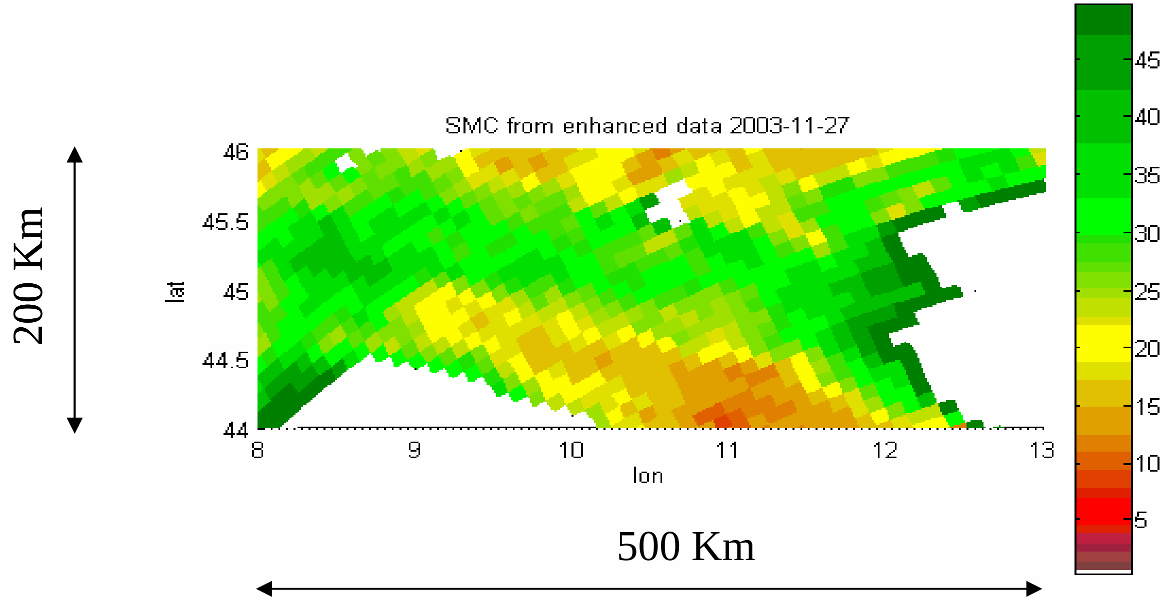
Check of calibration anomalies

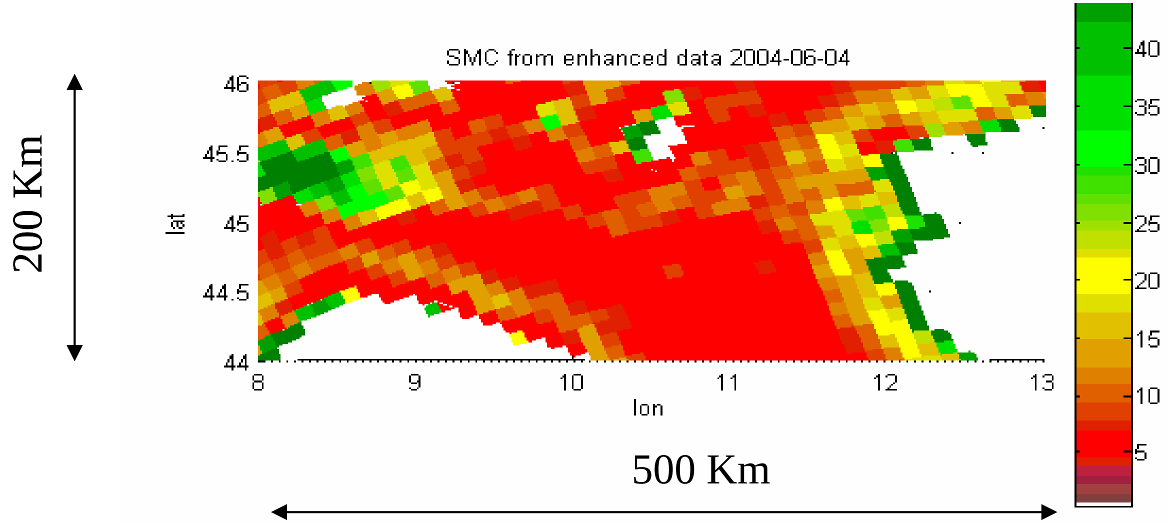
Linear recalibration of the C-band channel

- Daily measurements collected over reference targets:
  - Indian Ocean (45°-55° S, 115°-125° E) and
  - Brazil equatorial forest (4.00 S, 480 W)

have been compared with a two scale surface scattering model for the Ocean and data extrapolated from other satellites for the Forest

Improvement in SMC retrieval: Po valley





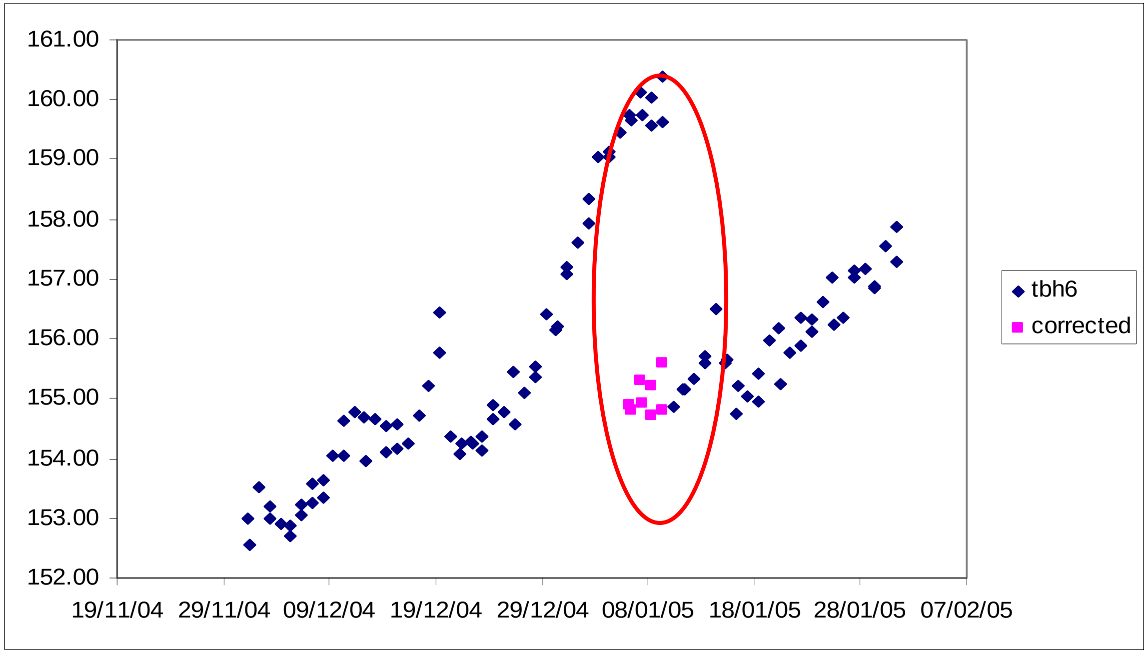
- Data extracted on the upper-right arm of the lake, which cannot be detected in the original image, confirm the resolution improvement.

Check of calibration anomalies

A test of calibration on the Antarctic Plateau

Results for Dome C

(123° E 75 S°)



C- and Ka-band IFOV comparison

AMSR-E aquisition geometry

- Over a period of 1.5 seconds, the spacecraft sub-satellite point travels 10 km. Even though the instantaneous field-of-view for each channel is different, active scene measurements are recorded at equal intervals of 10 km (5 km for the 89 GHz channels) along the scan.
- Therefore, the nominal spatial resolution at the 6 lower AMSR-E frequencies is of about 10x10 km, which corresponds to the sampling rate of the sensor.
- However, the IFOV of the antenna, intended as the ground area covered by the solid angle through which the detector is sensitive to radiation, is larger than the nominal spatial resolution, especially at the lower frequencies. The C-band IFOV is about 40x70 km.

algorithm description

The method is composed by two steps:

a) **the Ka-band image is degraded to the resolution of C-band using a two-dimensional low-pass filter. Filtering is based on a 7x3 sliding window, that has a value of "1" for all the Ka-band acquisitions that fall within each C-band IFOV, and "0" elsewhere. The output of the filtering procedure is a Ka-band image degraded to the resolution of the C-band channel.**

b) **The image is used for modulating the original C-band data, by applying the SFIM processing equation:**

$$Tb_{CHres}=Tb_{Kaorig}/Tb_{KaLres}*Tb_{Corig}$$

where *orig* indicates the original AMSR data, and *Hres* and *Lres* are the data at enhanced and decreased resolutions, respectively.

Mask for generating the Ka-band low-resolution image