CNR Short Mobility Program 2013

Relazione Scientifica del Dr. **Teodosio Lacava** in qualità di **Proponente** del

Dr. Marouane Temimi

National Oceanic and Atmospheric Administration - Cooperative Remote Sensing Science and Technology Center (NOAA – CREST), City University of New York – CCNY

Titolo:

Surface water extent and inundation mapping using observations from SUOMI/NPP sensors

Istituto CNR Ospitante:

Istituto di Metodologie per l'Analisi Ambientale (IMAA), Tito Scalo (PZ)

Durata:

10 giorni, dal 30 Settembre all'11 Ottobre 2013

Dr. Teodosio Lacava

Il Proponente

Introduction

Passive microwave observations from satellites have been commonly used for the monitoring of flooding and the delineation of inundated areas (Schmugge, 1998; Kerr, 2007). Starting from the radiometer onboard the Skylab space station a lot of sensors have been used for this kind of applications. In this direction, Special Sensor Microwave/Imager (SSM/I) data have been used so far to detect inundated areas within a multi satellite based global inundation dynamics study (Prigent et al., 1997; 2001). The same data have been also used to derive Water Surface Fraction (WSF) to improve flood forecasting in the Mackenzie River basin (Temimi et al., 2005), by combing the Basin Wetness Index (BWI – Basist et al., 1998) and rating curve equations. A similar WSF approach based on surface emissivity variations was used to observe the changes in surface water extent in Siberia (Grippa, et al 2007). Lacava et al. (2005) developed a qualitative method based on the Robust Satellite Technique (RST – Tramutoli, 2005) approach, to distinguish wet areas using Advanced Microwave Sounding Unit (AMSU) data. They proposed a Soil Wetness Variational Index (SWVI) based on the Soil Wetness Index (SWI) (Grody et al., 2000) which is computed as the difference of the brightness temperature measured in bands 16 (e.g. 89GHz) and 1 (e.g. 23GHz), SWI= BT89-BT23. Both the two indices (i.e. SWI and SWVI) have successfully been used to locate flooding in different parts of Europe (Lacava et al., 2005, 2006, 2012; Manfreda et al., 2011). The same approach has been also used to analyze Advanced Microwave Scanning Radiometer (AMSR-E) data developing a Polarization Ratio Variational Index (PRVI) from AMSR-E brightness temperature measurements, specifically the ones at 37 GHz, to assess the 2008 Iowa flooding in the U.S. (Temimi et al. 2011).

While SSM/I and AMSU sensors are still operational, AMSR-E stopped spinning and broadcasting data in October 2011, being replaced in July 2012 by its successor, the AMSRE-2 onboard the Global Change Observation Mission (GCOM). In addition, since the end of 2011 a new sensor, the Advanced Technology Microwave Sounder (ATMS) has been flying onboard Suomi National Polar-orbiting Partnership (Suomi/NPP) satellite.

During this activity the main goal is to investigate the potential of ATMS data for providing information on soil moisture and wetlands. Precisely the focus is on applying the same methodology already assessed with AMSU and AMSR-E data, the RST approach, for the multi-temporal analysis of historical series of ATSM data. Ultimately, an inundation mapping tool should be implemented operationally to routinely detect flooding events around the globe.

Sensor and data

Over the last decade NASA launched a series of satellites that offer an unparalleled view of Earth from space. That series which includes Terra and Aqua satellites, known collectively as NASA's Earth Observing System (EOS), has provided striking new insights into many aspects of Earth, including its clouds, oceans, vegetation, ice and atmosphere. However, as the EOS satellites age, a new generation of Earth-observing satellites are poised to take over. The Suomi/NPP (Figure 1) represents a critical first step in building this next-generation satellite system. It lifted off at 5:48 a.m. EDT on Oct. 28, 2011, to begin its Earth observation mission. Suomi NPP carries a diverse payload of scientific instruments to monitor the planet: the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), the Ozone Mapping and Profiler Suite (OMPS), the Visible Infrared Imaging Radiometer Suite (VIIRS) and the Clouds and the Earth's Radiant Energy System (CERES).

Figure 1: NPP satellite and sensors.

Like the long heritage of its predecessors, ATMS is a cross-track scanner, but it combines all the channels of the preceding AMSU-A1, AMSU-A2 and AMSU-B/MHS sensors into a single package with considerable savings in mass, power and volume. In particular, similarly to AMSU, 22 channels from 23 GHz to 183 GHz are included in ATMS (Figure 2 and Figure 3).

Ch	Center Freq. [GHz]	Pol	Ch	Center Freq. [GHz]	Pol
1	23.8	QV	1	23.8	QV
2	31.399	QV	2	31.4	QV
3	50.299	QV	3	50.3	QH
			4	51.76	QH
4	52.8	QV	5	52.8	QH
5	53.595 ± 0.115	QH	6	53.596 ± 0.115	QH
6	54.4	QH	7	54.4	QH
7	54.94	QV	8	54.94	QH
8	55.5	QH	9	55.5	QH
9	fo = 57.29	QH	10	fo = 57.29	QH
10	fo ± 0.217	QH	11	fo±0.3222±0.217	QH
11	fo±0.3222±0.048	QH	12	fo± 0.3222±0.048	QH
12	fo ±0.3222±0.022	QH	13	fo±0.3222±0.022	QH
13	fo± 0.3222±0.010	QH	14	fo±0.3222 ±0.010	QH
14	fo±0.3222±0.0045	QH	15	fo± 0.3222±0.0045	QH
15	89.0	QV	16	88.2	QV
AMSU-A			ATMS		

Exact match to AMSU
Only Polarization different
Unique Passband
Unique Passband, and Pol. different from closest AMSU channels

Figure 2: ATMS first 15 channels and main differences with AMSU.

MHS			ATMS		
Ch	Center Freq. [GHz]	Pol	Ch	Center Freq. [GHz]	Pol
16	89.0	QV	16	88.2	QV
17	157.0	QV	17	165.5	QH
18	183.31 ± 1	QH	18	183.31 ± 7	QH
19	183.31 ± 3	QH	19	183.31 ± 4.5	QH
20	191.31	QV	20	183.31 ± 3	QH
			21	183.31 ± 1.8	QH
			22	183.31 ± 1	QH

QV = Quasi-vertical; polarization vector is parallel to the scan plane at nadir
QH = Quasi-horizontal; polarization vector is perpendicular to the scan plane at nadir

Exact match to MHS
Only Polarization different
Unique Passband
Unique Passband, and Pol. different from closest MHS channels

Figure 3: ATMS last 8 channels (16-23) and main differences with MHS.

Generally speaking ATMS offers interesting improvements over the AMSU/MHS sensor, particularly in terms of sampling geometry and spatial resolution (Figure 4).

Beamwidth (degrees)

	ATMS	AMSU/MHS
23/31 GHz	5.2	3.3
50-60 GHz	2.2	3.3
89-GHz	2.2	1.1
160-183 GHz	1.1	1.1

Spatial sampling

	ATMS	AMSU/MHS
23/31 GHz	1.11	3.33
50-60 GHz	1.11	3.33
89-GHz	1.11	1.11
160-183 GHz	1.11	1.11
Swath (km)	~2600	~2200

Figure 4: ATMS vs AMSU/MHS in terms of beamwidth and spatial resolution.

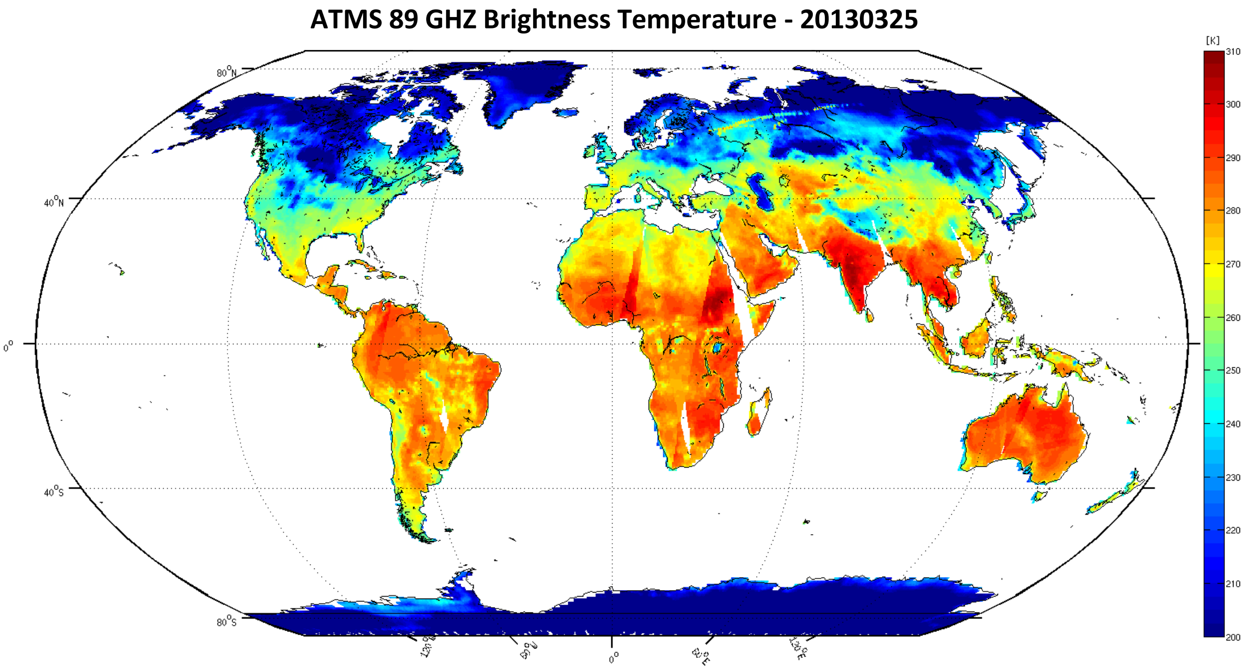
Considering the information just provided (Figures 2 - 4) it is clear that the interest in this study is to leverage on the AMSU legacy and integrate ATMS data in the flood detection techniques to make use of the improvement that the recent SUOMI NPP mission is offering.

To this aim, one day (February 25, 2013) of global ATMS data were downloaded from NOAA's CLASS website and processed to generate a daily global map, re-mapped on a regular grid of 35 km by 35 km. In particular, 163 Temperature Data Records (TDR) granules, each covering 8 minutes of acquisition, were analyzed, from the orbit 6880 to the orbit 6904.

The methodology and preliminarily results

As already said, ATMS could be considered as an evolution of the whole AMSU (A1+A2+B+MHS) system, so that, the same methodology already successfully applied to AMSU data (Lacava et al., 2005) was exported on ATMS data, trying to implement an operational inundation detection technique based on the integration of both the sensors.

The first step was the computation of the ATMS based Soil Wetness Index. In Figure 5 the global map of ATMS brightness temperature measured at 89 GHz (top) and 23 GHz(bottom) for the day of February 25, 2013, obtaining by processing and merging all the data above cited, are shown.



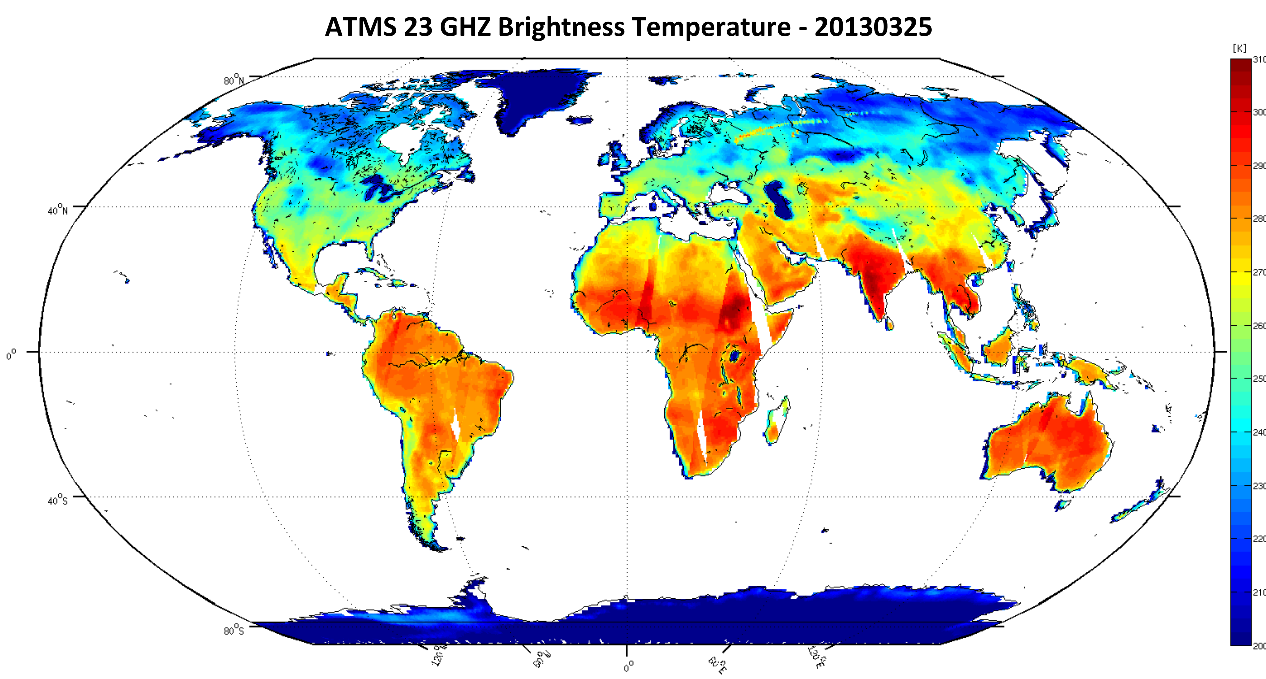


Figure 5: ATMS Brightness Temperature maps for February 25, 2013: on the top the one at 89 GHz and on the bottom at 23 GHz.

Once these data were available, the Soil Wetness Index map has been computed as the difference between them (Figure 6).

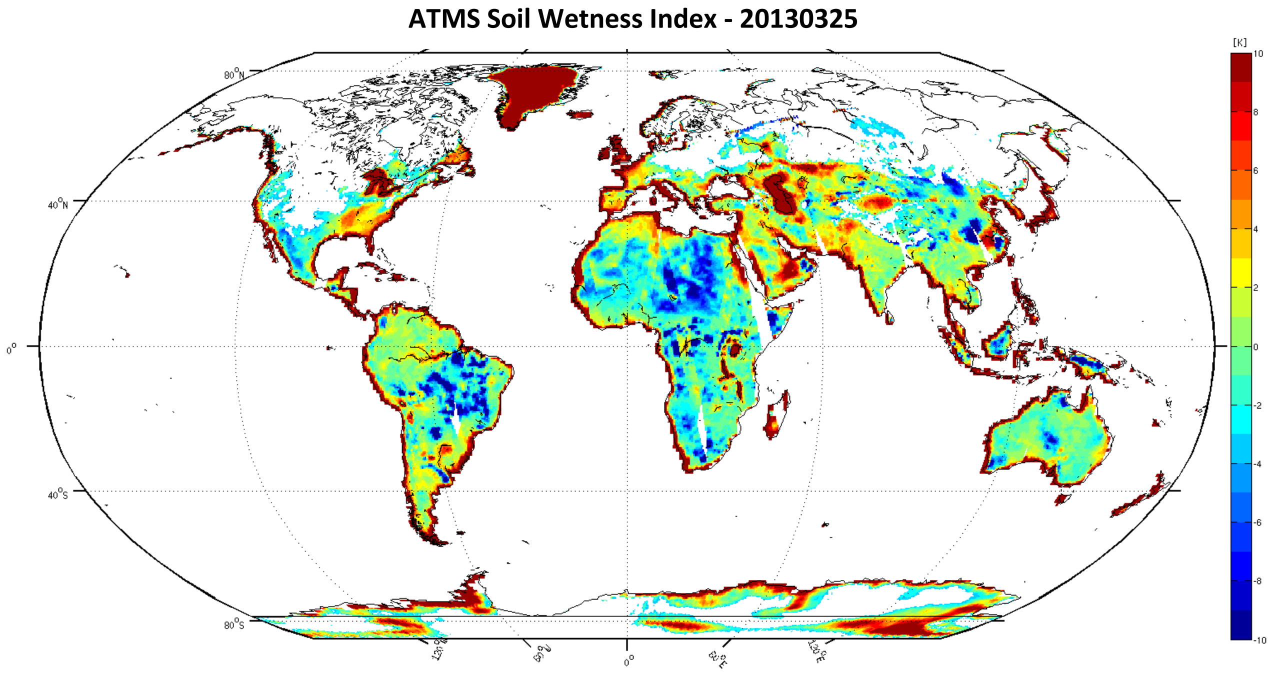


Figure 6: ATMS Soil Wetness Index map for February 25, 2013.

In this map, snowy/icy surfaces which are relatively noisy at the considered frequencies, have been masked out at this preliminary stage (Kongoli et al., 2004).

Looking at the map few first considerations may be done. First of all the almost total absence of gaps between all the considered orbits is evident. The 2600 km of swath of ATMS acquisition guarantees almost a three times daily acquisition over the same area, at least at medium latitudes. A first expected issue is observable along the coastline, where the presence within the coast pixels of water and land at the same time produces a “wet” effect. This problem as well as the one related to the presence of snowy/icy surfaces will be further investigated in the future. Anyway the SWI seems to be sensitive to the water presence: some of the larger worldwide rivers (Amazon River, the Danube River, etc…) were in fact detected at very high level of SWI.

One way to reduce the above cited “site effect” is the standardization of the SWI as proposed by Lacava et al. (2005) using AMSU data who implemented the RST approach to develop the Soil Wetness Variational Index (SWVI). SWVI is computed after analyzing multiyear time series of homogeneous (i.e. acquired during the same month and at the same overpass time) SWI maps devoted to characterize the signal, at pixel level, in terms of its normal behaviour (i.e. expected value, expressed in terms of temporal mean) and natural variability (i.e. statistical fluctuations, expressed by its standard deviation). One of the main requirements of RST is that almost 3 years of data have to be present to better identify the just mentioned “reference” fields (i.e. the temporal mean and the standard deviation). The limited data record from ATMS, because of its recent launch, makes the mean and standard deviation calculated using such data non suitable for SWVI analysis. Therefore, it is suggested that data from AMSU can be used to determine representative mean and standard deviation on a monthly basis for calculating SWVI with the ATMS data. Specifically, Suomi/NPP crosses the equator each afternoon at about 1:30 p.m. local time, almost the same time of the NOAA 19 (~1:38) which is flying since 2009. So that the reference fields at global level can be computed using AMSU-NOAA19 data as proxy of ATMS-NPP ones. This activity will be carried out during the next months.

Conclusion and future works

The first outputs generated after the ten working days, seem to indicate that ATMS can be effectively used for flood detection and monitoring at global scale. The ATMS based Soil Wetness Index confirmed the results already achieved by implementing it on AMSU data acquired in similar channels. Obviously further works have to be carried out to better investigate the dynamics of the proposed index in the spatiotemporal domain as well as to implement its standardization at global level. In particular, existing records of extreme flooding events around the globe will be used to verify the performance of the proposed technique.

An abstract on exploring the potential of the new ATMS sensor in flood mapping was submitted to the American Geophysical Union 2013 fall meeting (San Francisco, U.S.) by Dr. Temimi jointly with Dr. Lacava and accepted for an oral presentation. The preliminary results obtained during the visit and beyond will be included in the presentation at AGU and in a joint publication that is in preparation.

During the visit, in addition to advancing the joint work on the mapping of inundation globally, other lines of research were considered to enlarge the collaboration with CNR scientists who met Dr. Temimi during his seminar (Figure 7) and his visit.

Figure 7: Dr. Marouane Temimi during his seminar at CNR-IMAA.

Taking into account the new position that he has just started at Masdar Institute of Science and Technology of Abu Dhabi (UE) a particular interest was placed on the following ideas:

- Ocean color mapping;
- Dust mapping;
- Atmospheric conditions monitoring.

In this way a strengthening of the international cooperation among CNR, NOAA-CREST and Masdar Institute will be carried out in the future.

Acknowledgement

The CNR for founding the visit of Dr. Temimi in the framework of the Short Term Mobility Program – 2013.

References

Basist, A., Grody, N. C., Peterson, T. C., & Williams, C. N. (1998). Using the special sensor microwave/imager to monitor land surface temperatures, wetness, and snow cover. Journal of Applied Meteorology, 37(9), 888-911.

Brakenridge, G. R., Nghiem, S. V., Anderson, E., & Mic, R. (2007). Orbital microwave measurement of river discharge and ice status. Water Resources Research, 43(4). doi: 10.1029/2006wr005238

Ferrazzoli, P., Rahmoune, R., Moccia, F., Grings, F., Salvia, M., Barber, M., . . . Borro, M. (2010). The Effect of Rain and Flooding Events on AMSR-E Signatures of La Plata Basin, Argentina. Ieee Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 3(1), 81-90. doi: 10.1109/jstars.2010.2040584

Grippa, M., Mognard, N. M., Le Toan, T., & Biancamaria, S. (2007). Observations of changes in surface water over the western Siberia lowland. Geophysical Research Letters, 34(15).

Grody, N. C., Weng, F., & Ferraro, R. R. (2000). Application of AMSU for hydrological parameters, in: Microwave radiomemetry and remote sensing of the earth's surface and atmosphere, edited by: Pampaloni, P. and Paloscia, S., VSP, The Netherlands, 339–352.

Kerr, Y.: Soil moisture from space: where are we?, Hydrogeol. J., 15(1), 117–120, 2007.

Kongoli, C., Grody, N. C., & Ferraro, R. R. (2004). Interpretation of AMSU microwave measurements for the retrievals of snow water equivalent and snow depth. Journal of Geophysical Research; 109. doi: 10.1029/2004JD004836

Lacava, T., Cuomo, V., Di Leo, E. V., Pergola, N., Romano, F., & Tramutoli, V. (2005). Improving soil wetness variations monitoring from passive microwave satellite data: the case of April 2000 Hungary flood". Remote Sensing of Environment, Vol. 96-2, pp. 135-148.

Lacava, T., Di Leo, E. V., Pergola, N., & Tramutoli, V. (2006). Space-time soil wetness variations monitoring by a multi-temporal microwave satellite records analysis. Physics and Chemistry of the Earth, 31(18), 1274-1283.

Lacava, T., Brocca, L., Coviello, I., Faruolo, M., Melone, F., Moramarco, T., Pergola, N., & Tramutoli, V. (2012). Soil moisture variability estimation through AMSU radiometer, European Journal of Remote Sensing, vol. 45, pp. 89-97, doi: 10.5721/EuJRS20124509

Manfreda, S., Lacava, T., Onorati, B., Pergola, N., Di Leo, M., Margiotta, M. R., & Tramutoli, V. (2011). On the use of AMSU-based products for the description of soil water content at basin scale, Hydrol. Earth Syst. Sci., vol. 15, pp. 2839-2852.

Prigent, C., Rossow, W., & Matthews, E. (1997). Microwave land surface emissivities estimated from SSM/I observations. Journal of Geophysical Research, 102(D18), 21867-21890.

Prigent, C., & Aires, F. (2001). Joint characterization of vegetation by satellite observations from visible to microwave wavelenghts: A sensitivity analysis. Journal of Geophysical Research, 106(D18), 20665-20685.

Schmugge, T. J. (1998). Applications of passive microwave observations of surface soil moisture, Journal of Hydrology, 212-213, 188-197.

Temimi, M., Leconte, R., Brissette, F., & Chaouch, N. (2005). Flood monitoring over the Mackenzie River Basin using passive microwave data. Remote Sensing of environment, 98(2-3), 344-355.

Temimi, M., Lacava, T., Lakhankar, T., Tramutoli, V., Ghedira, H., & Khanbilvardi, R. (2011). A multi-temporal analysis of AMSR-E data for flood and discharge monitoring during the 2008 flood in Iowa. Hydrological Processes, Volume 25, Issue 16, pages 2623–2634, doi: 10.1002/hyp.8020.

Tramutoli, V. 2005. Robust Satellite Techniques (RST) for natural and environmental hazards monitoring and mitigation: ten years of successful applications. In The 9th International Symposium on Physical Measurements and Signatures in Remote Sensing, Shunlin Liang, Jiyuan Liu, Xiaowen Li, Ronggao Liu, Michael Schaepman (eds), ISPRS: Beijing (China); Vol. XXXVI (7/W20), 792–795. ISSN 1682–1750.