Atmospheric Research 134 (2013) 77–86

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

The 183-WSL fast rain rate retrieval algorithm.
Part II: Validation using ground radar measurements

Sante Laviola [a,*], Vincenzo Levizzani [a], Elsa Cattani [a], Chris Kidd [b]

[a] *CNR-ISAC, Bologna, Italy*
[b] *NASA-GSFC and Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD, USA*

ARTICLE INFO

Article history:
Received 12 November 2012
Received in revised form 28 May 2013
Accepted 1 July 2013

Keywords:
Microwave
Precipitation
Satellites
Validation
Radar
Winter

ABSTRACT

The Water vapor Strong Lines at 183 GHz (183-WSL) algorithm is a method for the retrieval of rain rates and precipitation type classification (convective/stratiform). It exploits the water vapor absorption line observations centered at 183.31 GHz of the Advanced Microwave Sounding Unit module B (AMSU-B) and of the Microwave Humidity Sounder (MHS) flying on NOAA-15/-17 and NOAA-18-19/MetOp-A satellite series, respectively. The characteristics of this algorithm were described in Part I of this paper together with comparisons against analogous precipitation products. The focus of Part II is the analysis of the performance of the 183-WSL technique based on surface radar measurements. The "ground truth" dataset consists of 2 years and 7 months of rainfall intensity fields from the NIMROD radar network, which covers North-Western Europe. The investigation of the 183-WSL retrieval performance is based on a twofold approach: 1) the dichotomous statistic is used to evaluate the capabilities of the method to identify rain and no-rain clouds and 2) the accuracy statistic is applied to quantify the errors in the estimation of rain rates.

The results reveal that the 183-WSL technique shows good skills in the detection of rain/no-rain areas and in the quantification of rain rate intensities. The categorical analysis shows annual values of the Probability Of Detection (POD), False Alarm Ratio (FAR) and Hanssen–Kuiper discriminant (HK) indices varying in the range 0.80–0.82, 0.33–0.36 and 0.39–0.46, respectively. The RMSE value is 2.8 mm h^{-1} for the whole period despite an overestimation in the retrieved rain rates. Of note is the distribution of the 183-WSL monthly mean rain rate with respect to radar: the seasonal fluctuations of the average rainfalls measured by radar are reproduced by the 183-WSL. However, the retrieval method appears to suffer during winter seasonal conditions especially when the soil is partially frozen and the surface emissivity drastically changes. This is verified by the discrepancy distribution diagrams where the 183-WSL performs better during the warm months, while during the winter time the discrepancies with radar measurements tend to maximum values. The stable behavior of the 183-WSL algorithm is demonstrated over the whole study period by an overall overestimation for rain rate intensities less than 1 mm h^{-1}. This threshold is especially crucial in wintertime when the classification of low-intensity precipitation regimes is difficult.

1. Introduction

A number of studies have tackled the problem of quantifying the accuracy of satellite-based rainfall estimation methods using ground measurements (gauges to radars) or the space borne Precipitation Radar (PR) onboard the Tropical Rainfall Measuring Mission (TRMM). As pointed out by Michaelides et al. (2009), the verification task must account for whether

---

DOI of original article: http://dx.doi.org/10.1016/j.atmosres.2010.11.013.

* Corresponding author at: CNR-ISAC, via Gobetti 101, I-40129 Bologna, Italy. Tel.: +39 051 6398019; fax: +39 051 6398132.

E-mail address: s.laviola@isac.cnr.it (S. Laviola).

0169-8095/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.atmosres.2013.07.013

general rainfall statistics or accurate location and timing are assessed. This is necessary for assessing satellite-based precipitation estimates for a wide variety of expanding applications (e.g., Kucera et al., 2013). Several methods proposed for the verification of these retrievals and an extended description can be found in Ebert (2007, 2011). For the purpose of this study it is worth noting the findings of recent validation studies. Lin and Hou (2008) showed that over land the AMSU-B rain retrievals are comparable in quality to those from conically scanning radiometers for instantaneous rain rates between 1.0 and 10.0 mm h^{-1}. Lin and Hou (2012) noted that for passive microwave sensors with pixel sizes ranging from 14 to 16 km the minimum detectable rain rates are about 1 mm h^{-1}. Zhou et al. (2008) found that satellite products over China are comparable to rain gauge data in revealing the spatial patterns of June–July–August (JJA) precipitation amount, frequency, and intensity, with pattern correlation coefficients ranging from 0.66 to 0.94. Tian et al. (2009) reported, among other things, that the satellite rainfall estimation methods in general miss a significant amount of light precipitation up to 40%. Shen et al. (2010) found that the performance of the satellite products varies for different regions and different precipitation regimes, with better comparison statistics observed over wet regions and for warm seasons. Finally, Kidd et al. (2012) conducted an extensive validation of high resolution satellite precipitation products over northwest Europe finding that they exhibit a seasonal cycle in correlation, bias ratio, Probability Of Detection, and False Alarm Ratio, with generally poorer statistics during the winter.

In Part I of this paper (Laviola and Levizzani, 2011) the retrieval design of the Water vapor Strong Lines at 183 GHz (183-WSL) method is described. The method is conceived for the Advanced Microwave Sounding Unit-B/Microwave Humidity Sounder (AMSU-B/MHS) sensors currently flying on the National Ocean and Atmospheric Administration (NOAA) and MetOp satellites. The detection of the rain systems and the retrieved rainfall rates were shown to be in qualitative agreement with the TRMM 2A12 (Kummerow et al., 1998) and the Goddard Profiling Algorithm (GPROF) (Kummerow et al., 2001) products. Laviola (2011) and Laviola et al. (2012) also presented a first validation of the 183-WSL estimation capabilities at mid-latitudes and over the Baltic Regions, where the experimental module for the snow cover detection was also tested.

The validation results are detailed over a 2 year and 7 month period (hereafter called "three years"). The analysis is based on the surface rainfall measured by the NIMROD radar network over North-Western Europe during 2006, 2007 and 7 months of 2008. The spatial domain covers various precipitation regimes, including light-intensity stratiform precipitation, snowfall during the winter storms, frontal rain bands, and orographic convection. The relatively long temporal extent of the analysis is thus exploited to investigate the algorithm sensitivity to the different types of precipitation and to explore the seasonal and intra-seasonal variations. The 183-WSL performance in terms of detection skill and rain rate quantification is assessed following a standard approach (e.g., Wilks, 1995): 1) categorical statistics used to evaluate the algorithm capabilities to discern rain from no-rain areas and 2) accuracy statistics to quantify the degree of reliability of the 183-WSL estimates by computing the numerical errors associated with the retrieved rain rates. The analysis is completed with the sensitivity evaluation to light rain rate regimes considering the threshold at 1 mm h^{-1}. Although the 1 mm h^{-1} threshold is often used to mark the accuracy threshold limit of the satellite-based rain retrieval methods, in this study it is adopted to separate light from moderate rain rates (e.g., Lin and Hou, 2012) in order to assess the algorithm skills in terms of total retrieved rainfall and rain type as classified by the 183-WSL modules for the detection of convective and stratiform rainfall.

2. Validation of the 183-WSL performances

In this section the validation methodologies and corresponding results of the comparison between the 183-WSL rainfall fields based on data from NOAA-15/16/17/18 and the NIMROD surface measurements used as ground "truth" (Sauvageot, 1994) are described. NIMROD is a European C-band radar network for weather analysis and nowcasting, which covers the United Kingdom, France, Germany, the Netherlands, and Belgium (Golding, 1998, 2000; Harrison et al., 1998). All measurements are calibrated and corrected for unrealistic rain values and spurious effects such as ground clutter, and are available for each radar location or as image composite every 5 or 15 min and at a nominal 1 or 5 km spatial resolution, respectively. The archive is managed by the British Atmospheric Data Center (BADC) and all measurements are archived in a binary format (UK Met Office, BADC: http://badc.nerc.ac.uk/data/nimrod). In this study the 15-min composite dataset at 5 km grid is used over the domain reported in Fig. 1; during the processing all data were averaged over a 16 km × 16 km grid to be compatible with the spatial resolution of the 183-WSL rain product.

2.1. Categorical statistics

The categorical statistics are applied to verify the ability of the 183-WSL algorithm to reproduce the precipitation spatial domain observed by radar measurements. Table 1 reports the number of rain/no-rain pixel pairs used in the analysis. Conditional indices representing the algorithm performance were calculated. The categorical verification data are presented in a 2 × 2 contingency matrix (Table 2) where all

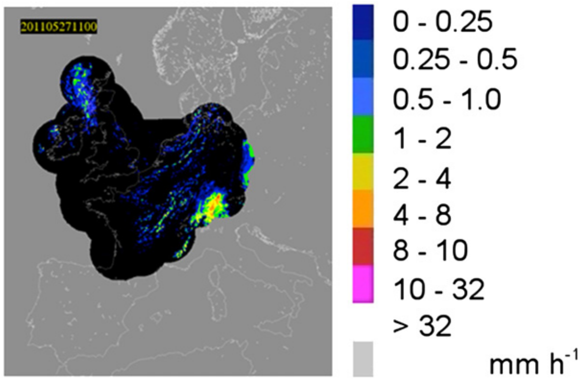

Fig. 1. NIMROD weather radar network spatial coverage and sample precipitation product.