Mediterranean Storms
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APPLICATIONS OF A RAINFALL ESTIMATION TECHNI UE BASED ON MW AND IR SATELLITE DATA ASSESSMENT OF RELIABILITY OF INSTANTANEOUS RAIN RATE MAPS IN THE MEDITERRANEAN

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ABSTRACT

Instantaneous rain rate maps are produced for the western Mediterranean area using Turk et al. (2000) combined passive microwave-infrared (PMW-IR) algorithm. Statistical brightness temperature - rain rate (T_B RR) relationships are generated from time-space coincident PMW and IR observations, and used to derive rain rate maps at the geostationary (GEO) time resolution. Depending upon how recently a given geographical region was imaged by an SSM/I or TMI overpass, some T_B - RR relationships may be several hours old and the onset of precipitating events could be completely missed by the method, leading to an underestimate of the total rain amount for the event. An application to the major flood occurred in Algeria at the beginning of November 2001 is presented, with the aim of assessing the method s performances in this particular environment. The statistics of the event are provided trying to determine the ability of the method in following the evolution of the precipitating clouds. In particular, some T_B - RR relationship are examined in view of understanding if they can be considered typical for strong precipitating events, perhaps depending on the geographical region. Operational TRMM/TMI products are used for comparison.

1 INTRODUCTION

The idea of using data from geostationary (GEO) satellites to produce rain rate (RR) maps over large areas of the globe has already been largely exploited using visible-infrared (VIS-IR) stand-alone observations or combining them with information from different sensors, especially passive microwave (PMW) instruments on polar platforms. At present, only GEO measurements have the spatial resolution (a few km^2) and repetition time (15-30 min) suitable to properly follow the rapid variations of the precipitation field. Moreover, the long history and the robust technology of such instruments prompts for the reanalysis of historical events and guarantees a timely and reliable release of calibrated data. VIS and IR measurements give only indirect information on the precipitation field (the precipitating hydrometeors do not interact directly with the photons collected aloft by space borne instruments at those wavelengths) and are liable to relevant uncertainties *per se*. Several methods have been thus developed that calibrate for example IR brightness temperature (T_B) data by using the more physically based rain estimates derived from PMW instruments. One of such blended techniques (Turk et al., 2002) is now being validated and shows a reasonable correlation with ground data. Especially when looking at mean or cumulated rainfall data, the correlation fairly increases and bias and root mean square (RMS) error decrease with increasing integration time (from a minimum of 1 hr up to 30 days) and spatial averaging of the data. The original operational set up of the software (global, automatic, real time, using a suite of PMW and IR observations) was adapted to the task of analyzing test case studies. The goal is to analyze the performances of the method in producing instantaneous rainfall maps that is to what extent the transfer of information from PMW to IR tracks the cloud evolution between two PMW calibrations.

2 THE HYBRID MW-IR METHOD

In the method of Turk et al. (2000), hereafter referred to as rapid update (RU) method, RR derived from the PMW measurements of the Special Sensor Microwave/Imager (SSM/I) (19.2 to 85.5 GHz) by means of the NOAA-NESDIS operational algorithm (Ferraro, 1997) are used to create global, geo-located RR-T_B relationships that are renewed as soon as new collocated data are available from both GEO and PMW instruments. The NESDIS algorithm derives rain rates at the A-scan resolution of the SSM/I (25 km) by means of non-linear relationships involving the instrument channels (vertical and horizontal polarization) that have been calibrated using large sets of ground reference data collected by several radar networks. The physical basis of such relationships are the scattering of MW radiation due to large ice particles above the freezing level occurring in precipitating clouds, and the emission due to liquid water. This latter phenomenon can be sensed only above oceanic surfaces, due to high and largely unknown emissivity of land surfaces in the MW spectral range. Relying on PMW measurements only (no need of large input data-base of physical properties) and on simple but well founded relationships, this algorithm is very robust and lends itself to global applications. To the end of calibrating IR measurements, the globe (or the study area) is subdivided in equally spaced LAT-LON boxes (2.5 2.5), and for each box space and time coincident IR and PMW measurements are collected. To form a meaningful statistical ensemble the method can look at older PMW orbit-IR slot intersections, until a certain box coverage is reached (say 75%) and a minimum number of coincident observations is gathered for a 3 3 boxes region. By means of this set of RR and corresponding T_B (these latter spatially averaged to the PMW rainfall resolution) the RR-T_B are derived by applying a probability matching method (Calheiros and Zawadski, 1987).

3 THE NOVEMBER 2001 ALGERIAN FLOOD

In early November 2001 a widespread frontal system and upper air trough from northeast Scandinavia to southwest Spain led to an extreme precipitation event in Algiers, causing a severe flooding and huge mudslides. More than 120 mm of rain fell in 12 hours during the night between 9 and 10 November and more than 130 mm during the next 6 hours on the mountains behind Algiers. This extreme event was characterized by unusually large rain rates and was reinforced by the cold maritime arctic air that picked up moisture crossing the warm Mediterranean waters and met initially maritime subtropical air. An intense orographic enhancement was caused by strong surface winds oriented towards the high mountains of the African coast (> 2300 m). The sudden onset of precipitation, the orographic complexity of the terrain, the vicinity to the coast are all elements that can introduce large errors and bias in PMW rainfall retrieval algorithms. Moreover, due to the short overall duration of the event (about 20 hours), the zone was imaged only a few times by PMW instruments. In such unfavorable condition, rapid update techniques are a powerful instrument to follow the evolution of the rain field. Because of the scarcity of validation data for this event, only the SSM/I derived RR fields were chosen for the calibration of the statistical relationships, and Tropical Rainfall Mission (TRMM) Microwave Imager (TMI) 2A12 operational rain product was retained as a source of comparison/validation data. In Table 1 the SSM/I and TRMM overpass time in the area of interest are summarized.

Satellite	Orbit and starting time (UTC)	Overpass time (UTC)
F13	20A 1620.15	1655 - 1700
F14	23A 1919.42	1955 - 2000
F15	24A 1958.33	2030 - 2035
TRMM	20011109.22741	0030 0035
TRMM	20011110.22742	0207 0212
F13	08D 0646.27	0655 - 0700
F14	10D 0803.55	0815 - 0820

Table 1. PMW instruments overpass for the selected area.

4 DATA ANALYSIS

The inspection of PMW rain maps (as example is give in Figure 1 for the orbit 1958, on November 9) revealed the following characteristics. The precipitation along the coast is missed altogether by the method. Starting from 50 km off the coast and coming ashore the NESDIS algorithm uses the land module, i.e. the precipitation in coastal environment is treated as it were occurring over land. In the present case very low precipitation is detected in most of rainfall maps. This is the most difficult zone to treat, because of the discontinuity in atmospheric conditions and of the mixed sea-land signal collected in the same field of view. One of the most prominent merit of hybrid methods is that they can eliminate these discontinuities and mitigate the problem of directly derive precipitation over the coast form PMW. By analyzing the terrain classification applied prior to the rain computation it appears that some small (precipitation) area is misclassified as snow. The largest part of precipitation over the Mediterranean sea in the area is derived by means of the scattering algorithm. Almost no precipitation is detected over the African continent, excluding light rain over the Algeria-Tunisia border. The strongest precipitation is detected over the Mediterranean off the coast of North Africa, and the values never exceeded 13 mm h^{-1}. Marked on the swath of the SSM/I instrument are the 2.5 2.5 boxes (and the 3 3 boxes region) in which the

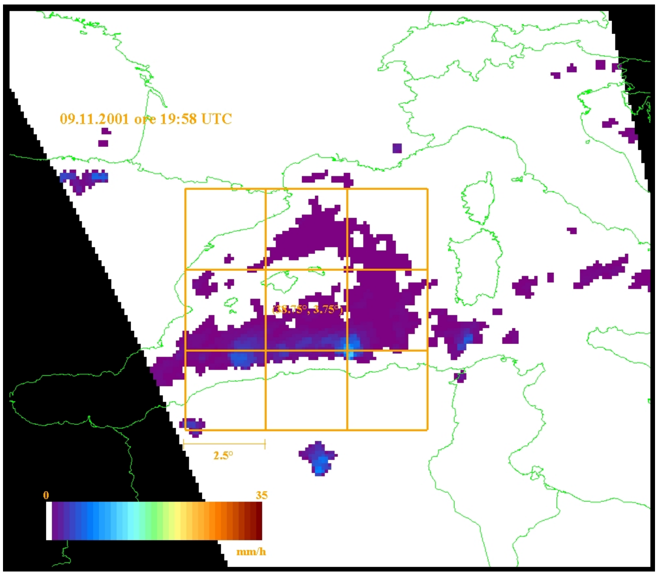

Figure 1. Rain map for the SSM/I orbit starting at 1958 UTC.

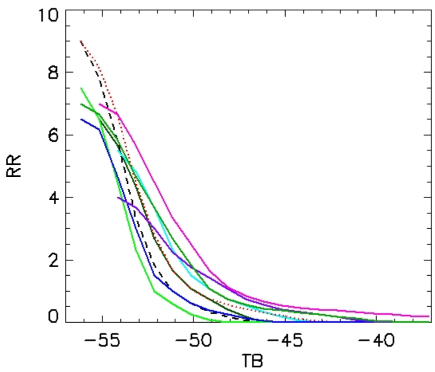

Figure 2. Brightness temperature-rain rate relationships for the 9 boxes of the histogram region shown in Figure 1. Black-dotted: Algiers box. Red-dashed: box over the sea North of town.

method geolocates the statistical RR-TB relationships. RR-TB curves for the 9 boxes in Figure 1 are plotted in Figure 2. These curves include the data derived by SSM/I orbit at 1958 UTC, i.e. the last calibration prior to the event. The heaviest precipitation appear to be associated with the Algiers box and the one to the North. The adjacent boxes reveal similar relationships, but with a reduced rain intensity. Note that the zero-rain threshold is always less than 40 C and the narrow range of temperatures giving rise to precipitation. Because of the lack of SSM/I overpasses after 1958 UTC in this area (the

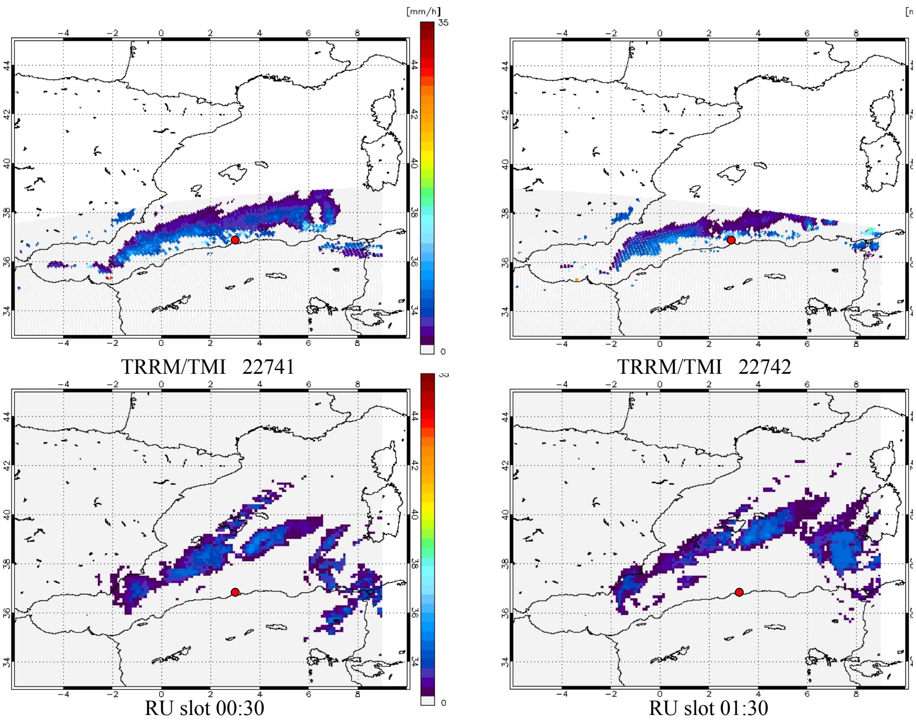

Figure 3. 10 November, 2001. Rain maps derived from TMI (top) and from the hybrid method (bottom).

successive orbit is on the day after at 0504 UTC) these relationships are used to derive the rainfall maps during the night. Heavy rain started falling after this overpass, so that the algorithm faced very critical data input conditions.

5 COMPARISON WITH TMI 2A12 RAIN PRODUCT

TMI (top) 2A12 rainfall maps are shown on top of Figure 3 and those from the RU method at the bottom. They refer to the central hours of the night, during the maximum of the event. The TMI data confirm that most of the precipitation over Algiers is missed, even if the product is derived by means of a completely different PMW algorithm (Goddard Profiling Algorithm, version 5). In general quite low precipitation is detected over the land. The rain rates do not differ very much between the two methods, but are in general lower for RU. In the RU maps the rain field appears shifted to the North, preventing a meaningful numerical comparison between the two, but the main features of the field seem fairly preserved, even 4 hours after the calibration. One interesting aspect is that RU is able to follow quite well the precipitation falling over East Algeria, but the zone of Algiers (red dot on the map) is still rain free. This implies that precipitation in this area have completely different characteristics with respect to the rest of the field. Since the RU is based on the IR T_B, METEOSAT IR images for the whole night were analyzed, considering a 1 1 box centered on Algiers. Note that IR T_Bs remained almost constantly > 50 C, and this explains why no precipitation is detected. The orography played a major role in the event, especially the relief south of town, giving rise to a precipitating system that, even if embedded on a larger field, was neither detected by PMW, nor by RU. Unfortunately, due to the low number of overpasses, the TRMM precipitation radar (PR) did not take measurements over the area of the disaster.

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