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A method for convective storm detection using satellite data

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RESUMEN

La humedad y la inestabilidad, en conjunto con un mecanismo de disparo, son las principales claves de iniciación y evolución de las tormentas de convección profunda. Los datos satelitales pueden proporcionar mediciones indirectas de la inestabilidad y la humedad de una amplia área en cortos periodos de tiempo. En este trabajo se estudia la utilización de un método objetivo basado en el uso combinado de técnicas de estimación de convección basadas en satélites. Este método se fundamenta en diferentes técnicas dispuestas en un enfoque multicapa de diferentes características convectivas, con el objetivo de estratificar un tope nuboso. Se investigan los canales infrarrojo (IR) de 10.8 μm y de vapor de agua de 6.2 μm de Meteosat segunda generación (MSG) junto con la temperatura de la tropopausa proporcionada por un modelo numérico. Se aplican el umbral, diferencias de brillo de temperatura y tendencias en el tiempo a la información disponible, de lo cual resulta un producto de cinco capas que destaca las áreas de diferentes actividades de convección. Este método de estratificación mostró gran capacidad para evaluar mejor la convección fuerte en comparación con las técnicas más simples como IR de falso color, y fue especialmente eficiente para identificar la célula de convección fuerte en un área grande con varios focos convectivos. Se llevó a cabo un análisis de validación utilizando datos de radar y de rayos, lo cual demuestra que este enfoque es muy útil para distinguir los casos fuertes de los débiles desde las primeras horas mediante la selección de patrones convectivos sutiles solamente presentes en tormentas severas. Los pequeños cambios en la evolución de la tormenta también se apreciaron mejor en los resultados arrojados por este método, lo cual facilita su identificación. Además se observaron algunas incertidumbres, probablemente debido al gran ángulo de visión, lo cual demuestra que la técnica derivada de las bandas espectrales del MSG tiene buena precisión para el estudio de los grandes sistemas convectivos en la región austral de Sudamérica.

ABSTRACT

Moisture and instability, along with a triggering mechanism, are the main keys of deep convective storms initiation and evolution. Satellite data can provide indirect measurements of instability and moisture of a wide area in short periods of time. This paper studies the use of an objective method based on a blended use of multiple satellite-based convection estimation techniques. This method is based on different techniques arranged in a several layers approach of different convective features, aiming to stratify a cloud shield. Meteosat Second Generation (MSG) infrared (IR) 10.8 μm and water vapor (WV) 6.2 μm channels are explored together with tropopause temperature information provided by a numerical model. Threshold, brightness temperature differences (BTD), and time trends are applied to the information available resulting in a five layers product, highlighting areas of different convective activities. This cloud shield stratification method showed a great ability to better evaluate strong convection when compared with simpler techniques such as IR false color, and was especially useful to better identify the strongest convective cell in a large area with several convective outbreaks. A validation analysis was conducted using radar and lightning data, showing that this approach is very helpful in distinguishing very strong cases from weaker ones by pointing out subtle convective patterns only present in severe storms. Also, small changes in storm evolution were more pronounced in the method output. Besides some uncertainties that were observed, likely due to the large viewing angle, techniques derived from MSG spectral bands displayed good accuracy in studying large convective systems in the South America southern region.

Keywords: Deep convection, satellite, mesoscale convection system.

1. Introduction

In severe weather forecasting, one of the most important steps is to identify existing convection and its evolution. Some features of convective clouds, such as rainfall initiation, are difficult to predict because of highly nonlinear dynamic processes occurring during short time scales over which convection evolves (Mecikalski and Bedka, 2006). Regarding the formation and evolution of deep convective storms, moisture and instability are the main keys followed by a lifting process that is connected to low-level convergence. The definition of conditional instability can be found in Emanuel (1994) or Glickmann (2000). Any tool used to evaluate deep moist convection must have these three key parameters present.

Although the contribution of radar systems to meteorology is clear, their efficiency and usage decrease with increasing range. In countries lacking satisfactory radar coverage or without a unified network (e.g., Brazil), other observations tools, among which satellites are the most important, remain to be the main data source to perform weather analysis. Satellite imagery allows extraction of valuable information of the atmosphere across a wide area and over short time intervals, and an automated analysis algorithm can more accurately identify deep convective storms of potential hazard.

As discussed by Doswell (1987), the problem of forecasting convection —in the context of large-scale processes— is in part due to the association between large-scale systems and mesoscale deep moist convection. A forecaster must be able to diagnose the structure of the troposphere and to forecast changes resulting from thermal and moisture advection, along with vertical motion fields (Johns and Doswell, 1992). Satellite data is the only operationally available dataset that provides an indirect measure of stability and moisture with high spatial resolution over a large domain (Roberts and Rutledge, 2003).

Multispectral satellite analysis has demonstrated an important role in increasing understanding of convective storm-top properties. Different infrared (IR) bands, and combinations between them, have been used to evaluate cloud phase, storm-top height and other features such as cold-U/V shape (Heymsfield and Blackmer, 1988; Schmetz *et al.*, 1997; Setvak *et al.*, 2010). Estimations of instability and moisture along with other deep convective storm characteristics are some of the features that can be assumed with different techniques applied to the whole Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI) water vapor (WV) and IR spectral bands.

Once the storm initiates, tracking and monitoring its features within the initial hours is crucial to minimize the related damage via increasing warning lead times. The problem is that traditional satellite instruments only observe the uppermost cloud tops, revealing no information about the internal structure of the storm (Setvak *et al.*, 2008). Taking full advantage of the high temporal sampling of MSG and its wide gamma of spectral channels, particularly the three channels 6.2, 7.3, 10.8 µm, may be viewed as a measure of convective activity.

This work had the objective to evaluate the usage of different techniques and variations to diagnose deep moist convection (such as mesoscale convective systems [MCSs]) formation and evolution over the southern South America region. An objective methodology, using different techniques arranged in