UPPER TROPOSPHERIC DIVERGENCE IN TROPICAL CONVECTIVE SYSTEMS FROM METEOSAT-8

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Abstract

The upper level wind field divergence in tropical convective cloud systems is directly inferred from satellite tracked Atmospheric Motion Vectors (AMVs) using successive images at 15 minute intervals in the water vapor channel (6.2 µm) of Meteosat-8. The use of radiances in the strongly absorbing 6.2 µm channel confines the feature tracking to the upper troposphere, enabling the derivation of consistent wind fields. A Lagrangian approach following the convective cloud systems throughout a day shows a pronounced diurnal cycle of the divergence with maximum values of 450 * 10^{-6} s^{-1}. A comparison with the ECMWF forecast system shows that the forecast does not depict the observed spatial structure and does not reach the maximum values of observed divergence at the scale of tropical cloud systems. However the forecast model performs reasonably well for divergences averaged over an area of 6° x 6° or larger.

1. INTRODUCTION

Deep convective cloud systems are commonly observed in tropical regions. Typically the convective systems undergo diurnal cycles and over land they attain activity maxima in the afternoon and evening (e.g. Hendon and Woodberry, 1993; Yang and Slingo, 2001). The diurnal cycle in tropical cloudiness and precipitation has been studied for several decades (e.g. Yang and Slingo, 2001 and references therein), because it is one of the most fundamental modes of variability in the global climate system due to the solar forcing. The novel aspect of this paper is the direct inference of upper tropospheric wind divergence in tropical convective systems from Atmospheric Motion Vectors (AMVs) and the analysis of its diurnal cycle. This is possible thanks to advances in the derivation of AMVs (Holmlund, 1998 and 2000) and the improved imaging performance of the European geostationary Meteosat Second Generation satellites, the first of which is Meteosat-8 (Schmetz et al., 2002). Meteosat-8 has an improved spatial sampling distance of 3 km and imaging intervals of 15 minutes which are key to the derivation of spatially dense AMV fields that capture the relevant spatial scales adequately. The paper presents a case study for convective cloud systems over tropical Africa and also shows a comparison with ECMWF forecast fields.

2. SUMMARY

This work has been published in the Geophysical Research Letters (Schmetz et al., 2005) and the interested reader is referred to this paper for details. The following only provides the conclusions.

The case study shows that atmospheric motion vectors (AMVs) derived from Meteosat-8 images at 15 minute intervals in the strongly absorbing 6.2 µm channel can be used to infer instantaneous divergence fields in tropical convective cloud systems. The case study has been performed over continental Africa and the main conclusions are:

- The diurnal cycle of upper tropospheric wind field divergence in tropical deep convective systems can be estimated directly from the satellite derived AMVs. The diurnal cycle of the divergence resembles previous results for tropical convective cloud systems (e.g. Yang and Slingo, 2001; Soden, 2000) in terms of phase. The diurnal cycle of divergence reaches maxima of about 450 * 10^{-6} s^{-1}. Those values are in agreement within a factor of 3 with maximum divergence values inferred from the area expansion of tropical convective cloud systems over Amazonia by Machado and Laurent (2004).

- A mean altitude of the observed divergence field, as defined by the mean height of AMVs near the location of the maximum of divergence, can be determined because the AMVs from the WV channel are well allocated to a consistent height range; in this case it is around 130 hPa with a standard deviation of 30 – 40 hPa. This altitude range remains fairly constant throughout the day and thus allows a comparison with divergence fields in atmospheric circulation models.

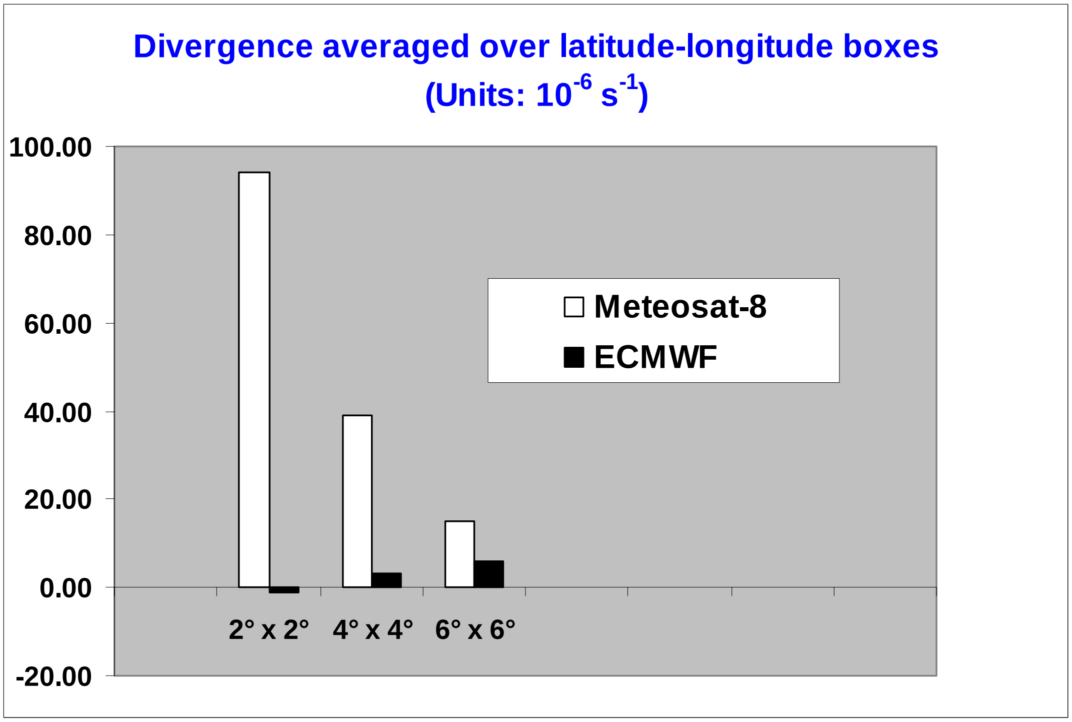

Figure 1: **Mean wind field divergence over Central Africa at 1200 UTC centered around the maximum divergence in a tropical cloud cluster (cluster 1 in Schmetz et al., 2005) for different size averaging boxes. Units of divergence are 10^{-6} s^{-1}. Values from ECMWF forecast model refer to a 12 h forecast and a level of 150 hPa. The choice of neighbouring pressure levels, the ECMWF forecast provides similar results.**

- A comparison with the ECMWF forecast shows that the forecast does not capture the strong divergence maximum values associated with the convective cloud systems, neither in magnitude nor in position. Area averaged divergence values over the full study area of about 1300 x 1400 km^2 agree within a factor of two, with ECMWF values being weaker. The ECMWF model forecast captures the increase of divergence during the day. Figure 1 shows how a spatial averaging over increasingly large areas improves the agreement. The area of averaging is centered around the maximum of divergence of the tropical cloud cluster as discerned by Meteosat-8. As the area of averaging is increased from 2° x 2° (latitude and longitude), over 4° x 4° to 6° x 6°, the agreement between forecast model and satellite derived divergence improves. It is within a factor of 2 – 3 for an averaging over 6° x 6°.

The satellite observed divergence field offers a useful diagnostic tool for testing convective parameterisations in atmospheric forecast/circulation models. An analysis of longer time series of observed divergence patterns will be a basis for climatological studies (e.g. Schmetz et al., 1995) which may address the relationship between the upper tropospheric humidity field and the large scale divergence.

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