USEFULNESS OF MPEF DIVERGENCE PRODUCT IN DIAGNOSING THE ENVIRONMENT OF DEEP CONVECTION

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I. INTRODUCTION

EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites generates the Upper-troposphere Divergence (DIV) product (EUMETSAT, 2005), which is hourly calculated at Meteosat Product Extraction Facilities (MPEF) from Meteosat Second Generation (MSG) channel 6.2 μm Atmospheric Motion Vectors (AMVs). There are two works on the use of these satellite data and the first one is the study of Schmetz et al. (2005) regarding the dynamics at the top of the tropical convective systems. A more recent one is on the MPEF DIV product as a diagnostic tool of convective environment in mid-latitudes by Georgiev and Santurette (2010). The quality of the MPEF DIV product was assessed by comparison with NWP model analyses of wind field as well as wind observations from upper-air soundings.

The MPEF DIV product has been disseminated to the user community since 2008 and there is no much experience in its operational use. The aim of this paper is to propose a relevant scheme for interpretation of the DIV product that enables inferring its information content over mid-latitudes as well as, based on examples for the summer seasons of 2010 and 2011, to show its usefulness in combination with relevant NWP fields and other meteorological data for deep convection forecasting.

II. VISUALISATION OF MPEF DIV PRODUCT

Two possible factors may affect the quality of the MPEF DIV product generation and might impose limitations in its visualisation and interpretation:

– The interpolation (Barnes, 1964) used as an intermediate procedure has the effect of smoothing out information horizontally.

– The input to the algorithm is all upper-level AMVs, which pass through specific quality control, derived by tracking cloud and humidity features in the 6.2 μm WV channel in the layer 100-400 hPa. This implies that the MPEF DIV values represent an atmospheric layer, rather than an atmospheric level.

While in the tropical convective cloud systems very high values of divergence, which can reach $450.10^{-6}s^{-1}$ (Schmetz et al., 2005) are observed, values below $-80.10^{-6}s^{-1}$ and above $+80.10^{-6}s^{-1}$ are not commonly seen over Europe in the MPEF DIV product (Georgiev and Santurette, 2010). Considering the effect of smoothing out information horizontally by the Barnes interpolation procedure, a specific colour palette (table 1) was introduced in the operational environment at NIMH of Bulgaria in June 2010 and then in Meteo-France that allows inferring the information content of the product for the purposes of upper-level diagnosis. In order to indicate the dynamic rate of the synoptic situations, the divergent values are shown in bluish shades with a light green colour showing little divergence in the range $[0 \div +20.10^{-6}s^{-1}]$ and the convergence values in the range $[-20.\ 10^{-6}s^{-1} \div 0]$ are not coloured.

Range of values ($10^{-6}\ s^{-1}$)	Colour/RGB
Convergence: below –120	255, 0, 80
Convergence: –120 to –100	255, 80, 80
Convergence: –100 to –80	255, 140, 140
Convergence: –80 to –60	255, 190, 190
Convergence: –60 to –40	255, 220, 220
Convergence: –40 to –20	255, 235, 235
Convergence: –20 to 0	248, 248, 248
Divergence: 0 to +20	220, 255, 235
Divergence: +20 to +40	235, 235, 255
Divergence: +40 to +60	220, 220, 255
Divergence: +60 to +80	190, 190, 255
Divergence: +80 to +100	140, 140, 255
Divergence: +100 to +120	80, 80, 255
Divergence: above +120	0, 0, 255
N/A	255, 255, 255

TABLE 1. Colour table for MPEF Divergence product.

An image of the DIV product over Central/Eastern Europe and Eastern Mediterranean visualised by using the colour palette from table 1 is shown on fig. 1a.

III. APPEARANCE OF THE UPPER-LEVEL DIVERGENCE AND ITS SIGNIFICANCE FOR THE SYNOPTIC DEVELOPMENT

In fig. 1b, the DIV product from fig. 1a is overlaid by the cloud top brightness temperature (BT) < –40 °C as derived from the Infrared (IR) 10.8 μm image. The areas of cloud top BT < –50 °C are coloured in yellow and those of BT < –60 °C in red. This visualisation scheme (that we simply call MSG DIV-IR composition) is proposed as an efficient interpretation scheme, which allows the user to assess the correspondence between upper-level divergence and development of deep moist convection. This visualisation composition for 18 June 2010 1645 UTC (fig. 1a) shows that all deep convective cells over the region are located within a large area of upper-level divergence in the range $[0 \div +80.\ 10^{-6}s^{-1}]$ as derived by the DIV product.

At the tropical convective systems, very strong upper tropospheric divergence (> $450.10^{-6}s^{-1}$) is generated through ascent, related to a strong convective development. According to Schmetz et al. (2005), inferring the divergence field in tropical convective clouds by MSG 6.2 μm WV channel data offers a useful diagnostic tool for testing convective parameterisations in NWP models.

For mid-latitudes, a divergent horizontal flow at the tropopause is a significant dynamic feature, which produces forcing of vertical motion at upper troposphere due to the high stratospheric stability aloft.

(a) (b)

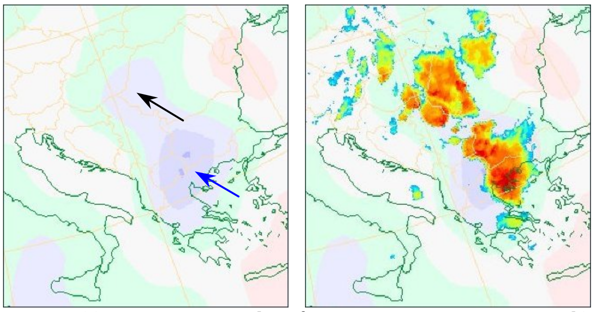

FIG. 1: (a) MPEF DIV product for 18 June 2010 1645 UTC (b) superimposed by the corresponding IR 10.8 µm channel image (only cloud top BT < –40 °C).

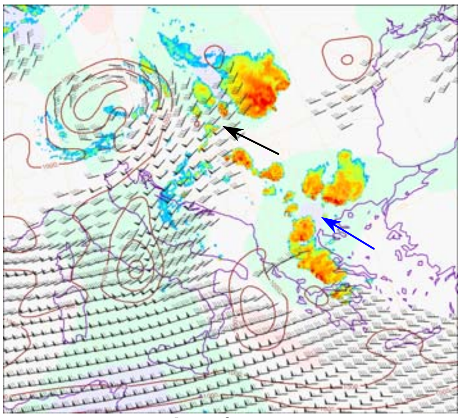

FIG. 2: MPEF DIV product for 18 June 2010 1245 UTC superimposed by IR 10.8 µm image (only cloud top BT < –40 °C) and nearest ARPEGE model analysis of heights of constant potential vorticity surface 1.5 PV-units (brown, only < 1000 dam) and wind vectors at 300 hPa (only > 30 kt).

Therefore at mid-latitudes the divergent (diffluent) flow near the jet is an essential ingredient of a pre-convective environment related to the upper-level dynamics. The possibility for upper-level diagnosis in this context by using the MPEF DIV product is illustrate in fig. 2, where in addition to the MSG DIV-IR composition for the case of fig. 1b at 1245 UTC, NWP dynamical fields are superimposed: heights of the constant potential vorticity (PV) surface 1.5 PV-units (brown, only < 1000 dam) and wind vectors at 300 hPa (only > 30 kt). Such a presentation allows distinguishing areas of upper-level divergence produced by the two possible mechanisms in mid-latitudes:

– Synoptic scale divergent flow, related to ageostrophic wind near the jet (at the black arrow in fig. 2).

– Convective developments with strong upper troposphere updraft in low rate of the upper-level dynamics (at the blue arrow in fig. 2).

The experience shows that usually for Europe, with these two possible mechanisms, the divergence derived by MPEF DIV product ranges between 20 and 80.10^{-6}/s that is much lower than the divergence derived by MPEF DIV product in the tropical convective systems (Schmetz et al., 2005). Some of the possible reasons for lower DIV values in mid-latitude Europe could be a weaker convective updraft compared with this at the tropical convective developments as well as a lower MSG resolution than this at the Central Africa that smoothing out information horizontally.

In order to assess the operational usefulness of the MPEF DIV product, a study of the relation between the DIV field and deep moist convection has been performed (Georgiev and Santurette, 2010). The convective cells are classified in 8 cases according to the location of their initiation and development regarding the values of the MPEF DIV product over the area. The limits of each one of the 8 cases are defined in table 2 and table 3.

Number of convective cells initiated at area of				
Divergence, $10^{-6}s^{-1}$		Convergence, $10^{-6}s^{-1}$		
> +20	+20 ÷ 0	0 ÷ –20	< –20	Total
114	781	266	13	1166
9.8%	66.5%	22.5%	1.2%	

TABLE 2. Initiation of deep convective cells (cloud top BT < –50 °C) regarding the areas of divergence/convergence as derived by the MPEF DIV product from 16 June to 22 July 2010.

Number of convective cells developed at area of				
Divergence, $10^{-6}s^{-1}$		Convergence, $10^{-6}s^{-1}$		
> +20	+20 ÷ 0	0 ÷ –20	< –20	Total
251	827	82	6	1166
21.5%	71.0%	7.0%	0.5%	

TABLE 3. Development of deep convective cells (cloud top BT < –50 °C) regarding the areas of divergence/convergence as derived by the MPEF DIV product from 16 June to 22 July 2010.

The results presented in table 2 and table 3 show that the initiation and development of deep moist convection over Europe is closely associated with the existence of upper-level divergence as derived by MPEF DIV product. For the period 15 June – 22 July 2010 the following figures were obtained:

– 76 % of all convective cells initiated at areas of divergence seen by MPEF DIV product (as in the case of fig. 2 to the northeast of the black arrow).

– 92 % of all convective cells developed at areas of divergence, which compared to the 76 % for the first category shows that at least

– In 15 % of the cases the upper-level divergence can be a result of the ascent associated with strong convective development (as in the case of fig. 2 to the northeast of the blue arrow).

The high persentage of deep convective cells initiated at positive DIV values suggests that the MPEF DIV product could provide useful information for assessing areas of upper-level divergence where strong convection preferable initiates. This relation can be helpful for convection forecasting by considering MSG DIV-IR composite images and dynamical parameters from NWP output. The satellite AMV DIV product may be useful as a nowcasting tool since in many situations divergence values are present in the images some hours before the initiation of deep convective cells especially in the areas of high rate of the upper-level dynamics, near jet streams (see Santurette and Georgiev, 2005, 2007). Over these areas the upper-level divergence, being an ingradient of the convective environment, significantly contributes to the develoment of deep convection as in the case at the black arrow in fig. 2.

IV. DIAGNOSING THE ENVIRONMENT OF DEEP CONVECTION

At mid-latitudes, severe convective events occur generally in areas where, in addition to the conditional instability of the atmosphere, there is a synoptic-scale upper-level forcing. A joint use of information for tropospheric instability and upper-level divergence is an efficient way to diagnose the environment of deep convection. In operational environment, analysis and forecast fields of tropospheric instability are usually available but it is not an easy operational task, considering only the instability, to anticipate where deep convection is going to develop. From an operational perspective, before starting a deep convective development, it is valuable to diagnose the upper-level divergence in the areas of instability. To illustrate this approach, the Lifted Index derived by using satellite data is shown in fig. 3a, while fig. 3b shows the NWP model analysis of convective available potential energy (CAPE) in black contours on 16 May 2011 1200 UTC, superimposed on the nearest MSG DIV-IR composition. The satellite and NWP instability products in fig. 3a and fig. 3b (black contours) indicate an area of instability northwest of Black sea (at the black arrow) and anotherone soth of Black sea (at the blue arrow).

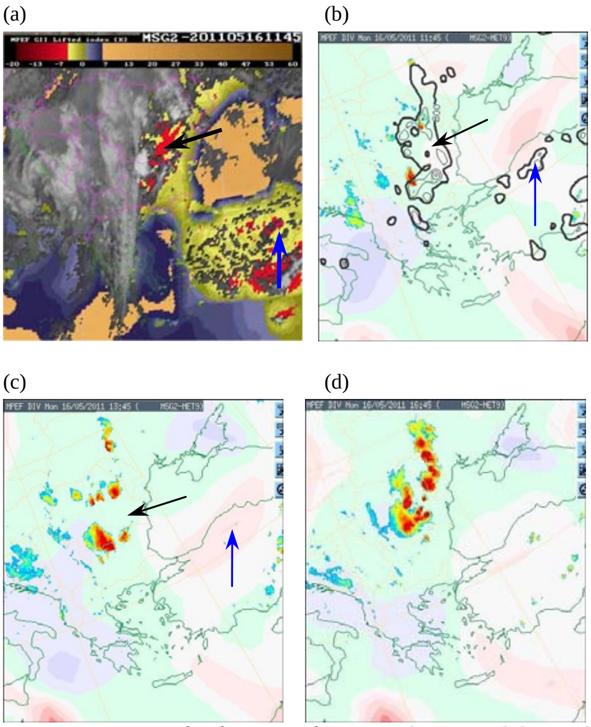

FIG. 3: Joint use of information for tropospheric instability and upper-level divergence on 16 May 2011: (a) MPEF Lifted Index, operationally derived from MSG data for 1145 UTC. MPEF DIV product superimposed by IR 10.8 μm channel image (only cloud top BT < –40 °C) for (b) 1145 UTC, overlaid by nearest ARPEGE analysis of CAPE (black, only > 800, interval 400 J/kg), (c) 1345 UTC and (d) 1645 UTC.

The sequence of images in figs 3b, 3c and 3d illustrate that the DIV product is useful to help recognising which of the areas of tropospheric instability diagnosed by NWP models or satellite data are not favourable for strong deep convection.

In areas of upper-level convergence as diagnosed by the MPEF DIV product, deep convection is not likely to develop, because the convective development is suppressed by the upper-tropospheric downdraft related to the upper-level convergence (at the blue arrow in fig. 3c). Fig. 3d shows that at the southern area (at location of the blue arrow), very few convective cloud top heights has hardly reached brightness temperature -40 °C that is at the lower limit of the MSG DIV-IR composition, which is used as an interpretation scheme of satellite data in deep convection analysis and forecasting.

At the same time, deep convection occurs in the area of pre-existing divergence seen by MPEF DIV product in the leading part of an upper-level trough at the black arrow in fig. 3, and the cloud top brightness temperatures are less than -60 °C over a large area of the convective system.

Among the others, this paper shows the benefit from the unique opportunity of the MSG 6.2 μm WV and other air mass channels to allow the derivation of advanced nowcasting products, which provide information for instability and upper-level dynamics. In the area of convective storm nowcasting, a combined use of complementary observation techniques and products is considered to be very beneficial and ensures the optimal use of the satellite data in an operational context.

Such applications may range from possibilities to pre-convective identification of potentially favourable environment to a characterisation of the deep moist convection development. Taking into account the significance of upper-level divergence/convergence for forcing/suppressing convection, the MPEF DIV product can help to anticipate the potential for severity of a certain convective development.

V. ACKNOWLEDGMENTS

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