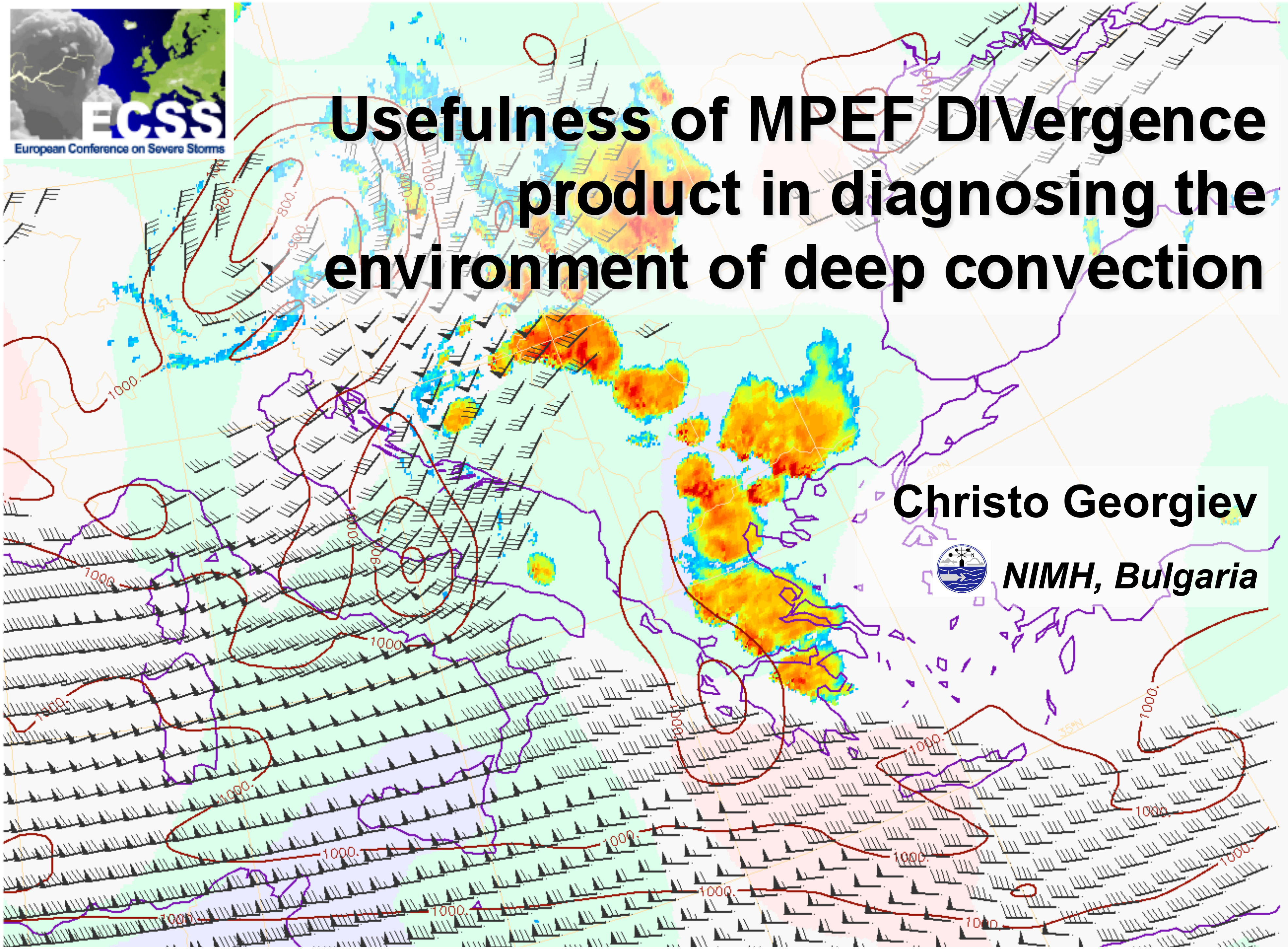
Usefulness of MPEF DIVergence product in diagnosing the environment of deep convection



Christo Georgiev

NIMH, Bulgaria

6th European Conference on Severe Storms (ECSS 2011) , 3 - 7 October 2011, Palma de Mallorca, Balearic Islands, Spain

Introduction

- **Basic experiance**

  EUMETSAT (2005). Upper Level Divergence Product Algorithm description. EUM/MET/REP/05/0163. EUMETSAT, 16 p.

  Schmetz, J., Borde, R., Holmlund, K., König, M., (2005). Upper tropospheric divergence in tropical convective systems from Meteosat-8. Geophys. Res. Lett., 32, L24804.

  Georgiev, C. G. and Santurette, P. (2010). Quality of MPEF DIVergence product as a tool for very short range forecasting of convection. Proceedings of 2010 EUMETSAT Meteorological Satellite Conference (Córdoba 20 – 24 September 2010). ISSN 1011-3932.

- **Appearence/significance of upper-level divergence**
- **Interpretation scheme and usefulness of MPEF DIV product**

GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L24804, doi:10.1029/2005GL024371, 2005

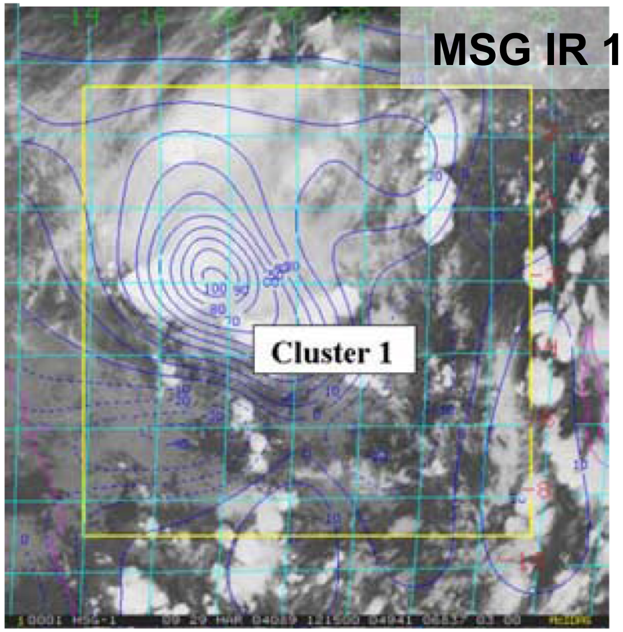
Upper tropospheric divergence in tropical convective systems from Meteosat-8

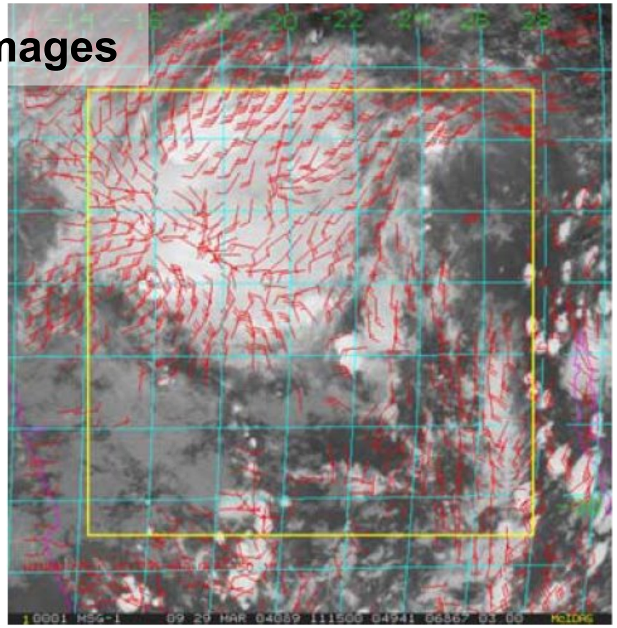
Johannes Schmetz, Régis Borde, Kenneth Holmlund, and Marianne König
EUMETSAT, Darmstadt, Germany

Divergence field at the top of a tropical convective cloud system.

The red contours represent wind field derived from atmospheric motion tracking in the Meteosat-8 WV channel at 6.2 μm.

MSG IR 10.8 images





Strong upper-level divergence is generated through ascent, related with a strong tropical convection.

Inferring the divergence field at the tropical convective clouds by MSG 6.2 μm WV channel data offers a useful diagnostic tool for testing convective parameterisations in NWP models (Schmetz et al., 2005).

Upper-level forcing of convection

At the mid-latitudes

Upper-level divergence of the flow can be an ingredient of a pre-convective environment related to the upper-level dynamics:

strong convective development can be forced by upper-level divergent (diffluent) flow near the jet

Upper-level Divergence ⇒ forcing of deep moist convection

Upper-level Convergence ⇒ depressing deep moist convection

DIAGNOSIS OF CONVECTION ENVIRONMENT

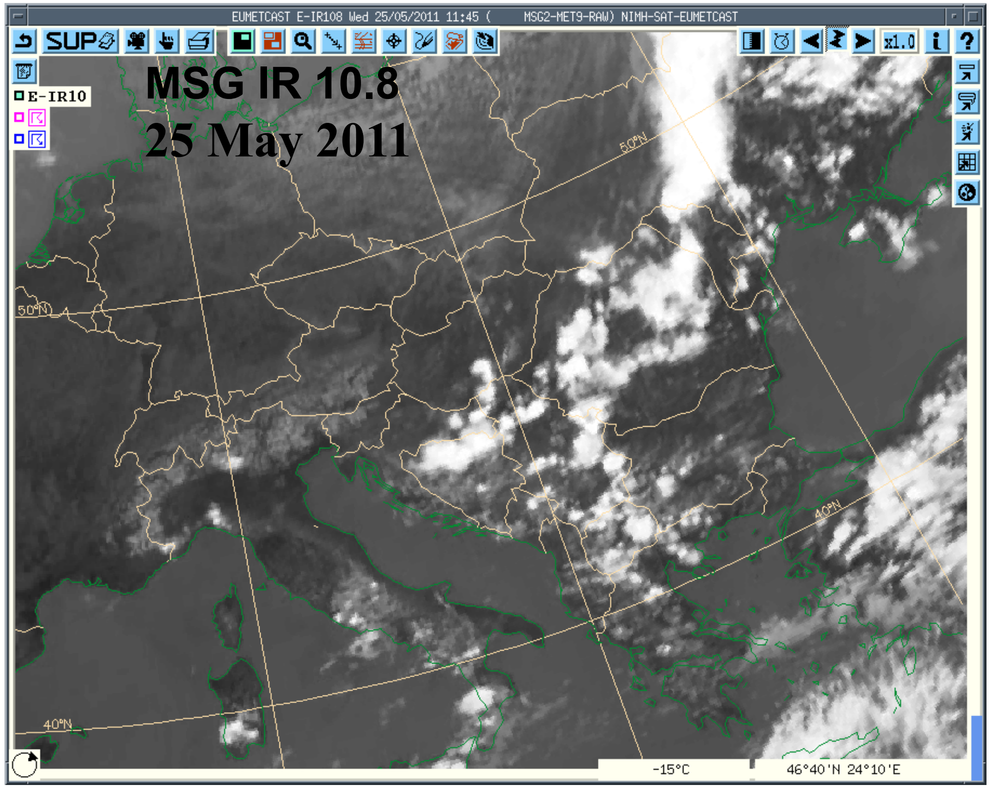
It is important for operational purposes to diagnose the upper-level divergence/convergence of the flow by WV images and/or

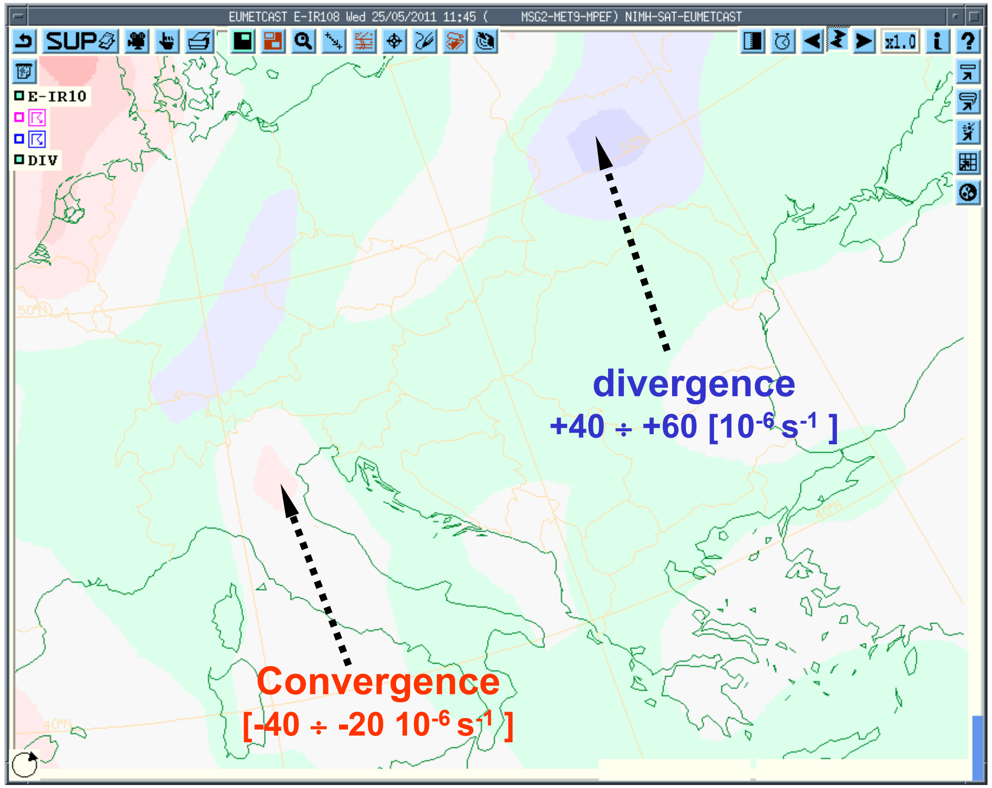
SATELLITE DIV PRODUCT

- EUMETSAT started to operationally disseminate the MPEF DIV product in 2008 via EUMETCast.
- There is no much experience in the operational use of the DIV product .

The input to the product algorithm is all upper-level AMVs, derived by tracking cloud and humidity features in the 6.2 μm WV channel in the layer 100-400 hPa.
Generally, the MPEF DIV values represent an atmospheric layer between 100-400 hPa, rather than an atmospheric level.

MPEF DIV PRODUCT VISUALISATION TEMPLATE





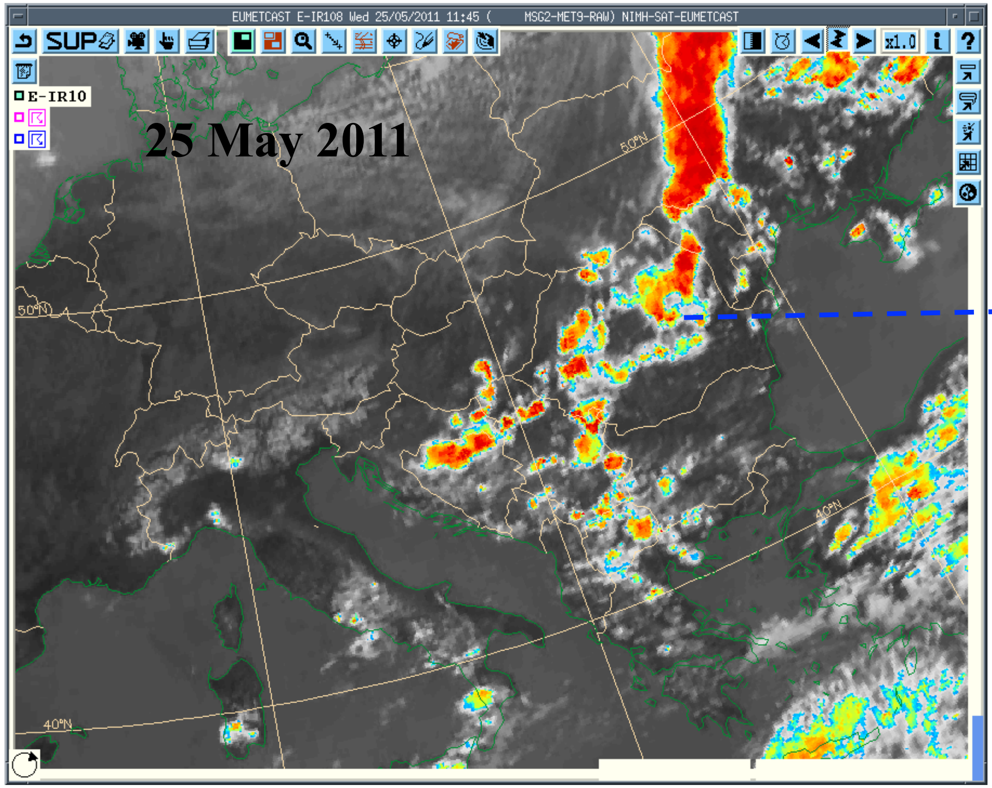
<u>MPEF DIV Visualisation template</u>, installed at the SYNERGIE Forecasting System at NIMH in 2010:

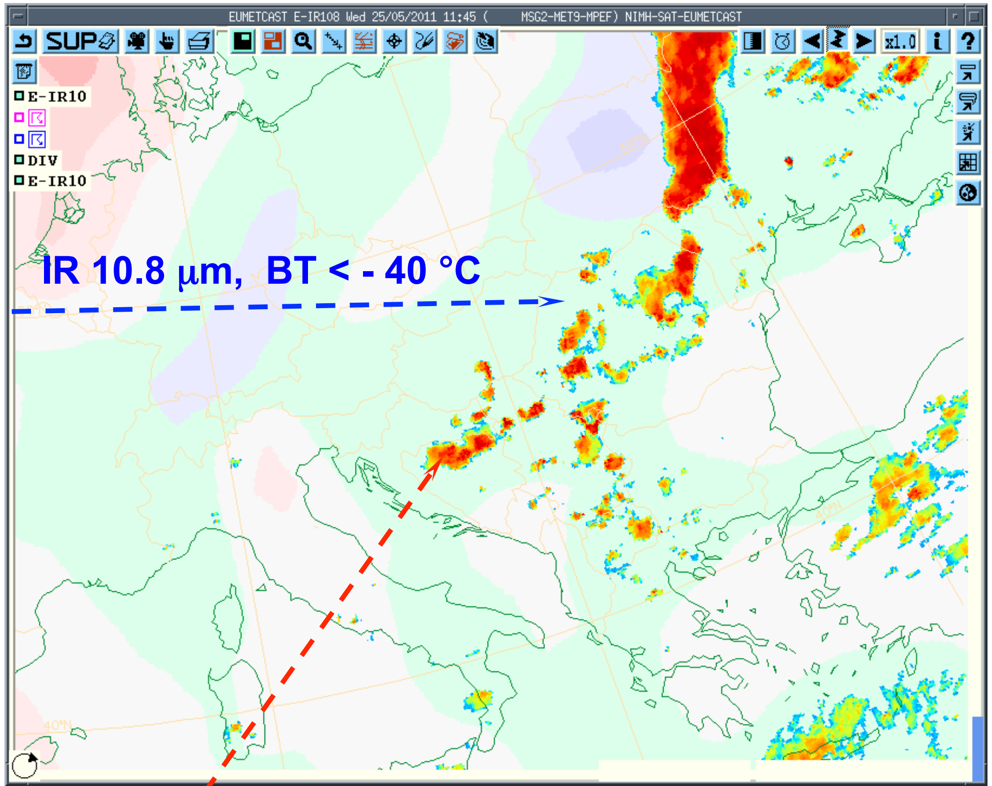
The upper-level convergence is coloured in reddish
The upper-level divergence is coloured in bluish
Light green colour shows values of little divergence in the range [0, $+20.10^{-6}$ s^{-1}]
The convergence values in the range [-20.10^{6} s^{-1}, $+0.10^{-6}$ s^{-1}] are not coloured.

NIMH 2010 Palette
Range of divergence values (10^{-6} s^{-1})

0 to +20	-120 to –100
+20 to +40	-100 to –80
+40 to +60	-80 to –60
+60 to +80	-60 to –40
+80 to +100	-40 to –20
+100 to +120	-20 to 0 [none]

MPEF DIV PRODUCT INTERPRETATION SCHEME





DIV product overlaid by IR 10.8 μm image,

colored only cloud top

brightness temperature (BT) < - 40 °C.

- cloud top BT < –50 °C in yellow;
  - BT < –60 °C in red shades .

Development of deep convective cells in relation to the upper-level divergence of the flow

NIMH 2010 Palette
Range of divergence values ($10^{-6}\ s^{-1}$)

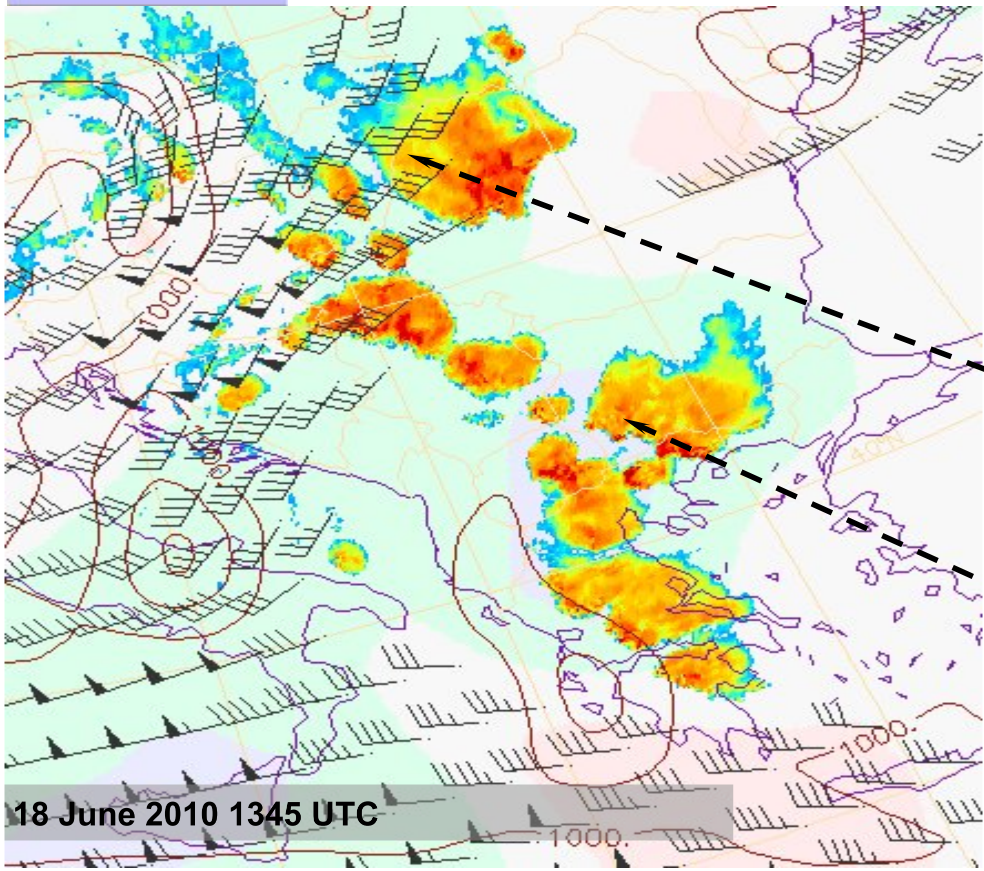
0 to +20	-120 to –100
+20 to +40	-100 to –80
+40 to +60	-80 to –60
+60 to +80	-60 to –40
+80 to +100	-40 to –20
+100 to +120	-20 to 0 [none]

Convective cloud systems over mid-latitude Europe

NIMH 2010 Palette Range of divergence values (10^{-6} s^{-1})
-40 to –20
-20 to 0 [none]
0 to +20
+20 to +40
+40 to +60
+60 to +80

Tropical convective clouds can produce very strong upper-level divergance, (about 450 * 10^{-6}/s, Schmetz et al., 2005**).**

MPEF DIV
IR 10.8 m (colored only BT < - 40 C)
300 hPa wind (only > 30 kt)
1.5 PVU surface height (only < 1000 hPa)

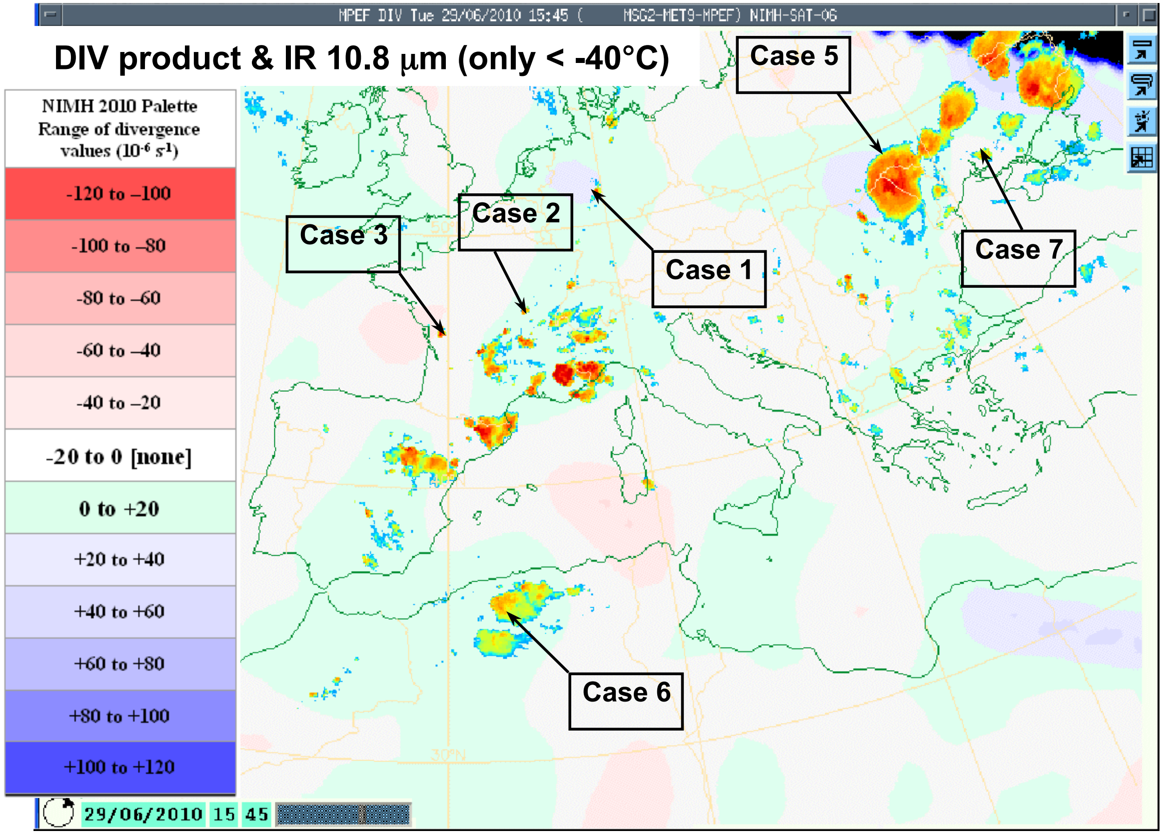


At mid-latitudes, the divergance as derived by MPEF DIV product is much lower, usually in the range +20 ÷ +60 * 10^{-6}/s, (Georgiev and Santurette, 2009),

including the two possible mechanisms, which act for producing upper tropospheric divergence:

- **Synoptic scale divergent flow, related to ageostrophic wind near the jet.**
- **Convective developments with strong upper troposphere updraft in low rate of the upper-level dynamics.**

MPEF DIV PRODUCT AS A TOOL FOR ASSESSING CONVECTIVE ENVIRONMENT

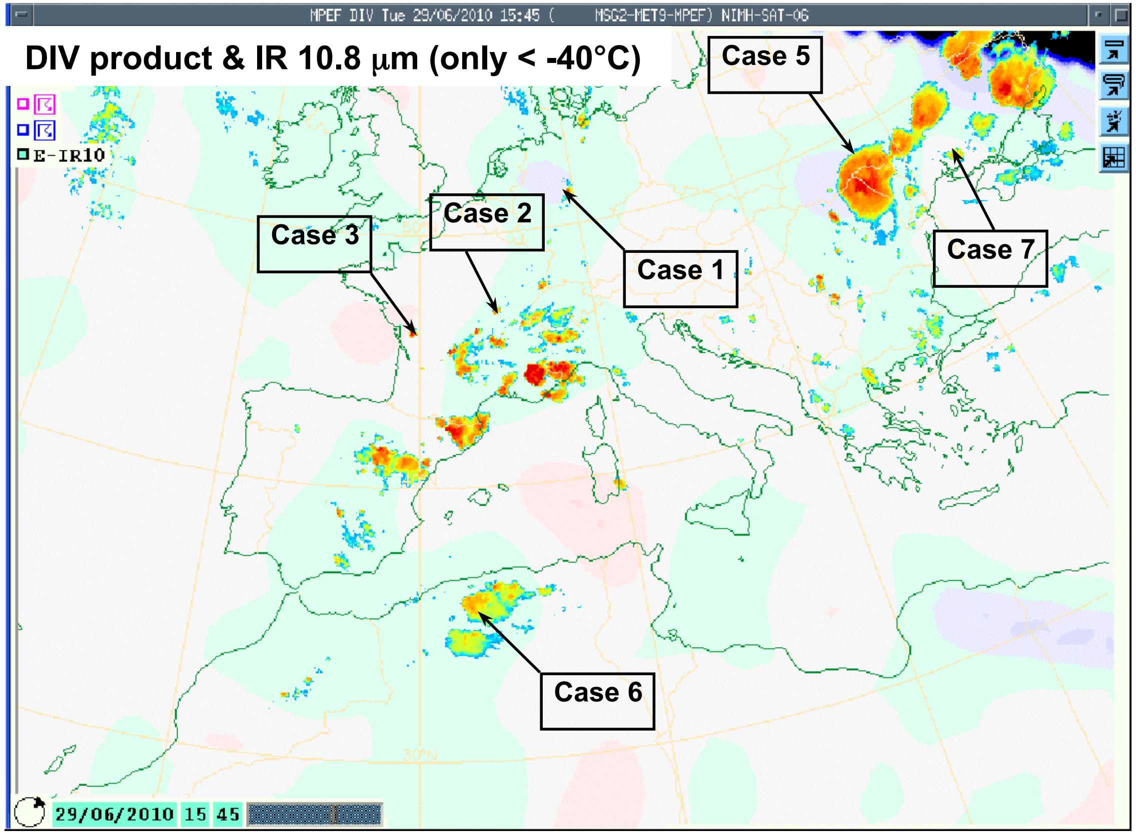


A study of the relation between the DIV field and deep moist convection.

The convective cells are classified in 8 cases according to the location of their initiation and development, regarding the divergence or convergence in the area as derived by the MPEF DIV product.

CASE 1	**Convective cells initiating**	**at an area of strong**	**Divergence**	**> +20 $10^{-6}s^{-1}$**
CASE 2	**at**	**weak**	**Divergence**	**[+20 ÷ 0 $10^{-6}s^{-1}$]**
CASE 3	**at**	**weak**	**Convergence**	**[0 ÷ -20 $10^{-6}s^{-1}$]**
CASE 4	**at**	**strong**	**Convergence**	**[< -20 $10^{-6}s^{-1}$]**
CASE 5	**Convective cells developing at**	**strong**	**Divergence**	**> +20 $10^{-6}s^{-1}$**
CASE 6	**at**	**weak**	**Divergence**	**[+20 ÷ 0 $10^{-6}s^{-1}$]**
CASE 7	**at**	**weak**	**Convergence**	**[0 ÷ -20 $10^{-6}s^{-1}$]**
CASE 8	**at**	**strong**	**Convergence**	**[< -20 $10^{-6}s^{-1}$]**

MPEF DIV PRODUCT AS A TOOL FOR ASSESSING CONVECTIVE ENVIRONMENT



- **76 % of the deep convective cells initiated at areas of divergence seen by MPEF DIV product.**
- **92 % of all deep convective cells developed at areas of divergence.**
- **In 15 % of the cases the upper-level divergence can be a result of a strong convective development: (15 % more convective cells in Case 3 than the cells in Case 7).**

Only 24 % of the deep convective cells initiate at areas of upper-level convergence seen by DIV product.

	Convective cells initiating at area of					Convective cells developing at area of				
	Divergence, $10^{-6}s^{-1}$		Convergence, $10^{-6}s^{-1}$		Total	Divergence, $10^{-6}s^{-1}$		Convergence, $10^{-6}s^{-1}$		Total
	> +20	+20 ÷ 0	0 ÷ -20	< -20		> +20	+20 ÷ 0	0 ÷ -20	< -20	
2010	**Case 1**	**Case 2**	**Case 3**	**Case 4**		**Case 5**	**Case 6**	**Case 7**	**Case 8**	
29/06/	1	40	9	1		7	43	1		
16/06 – 22/07	**114**	**781**	**266**	**13**	**1166**	251	827	82	6	1166
	9.8%	**66.5%**	**22.5%**	**1.2%**		**21.5%**	**71.0%**	**7.0%**	**0.5%**	

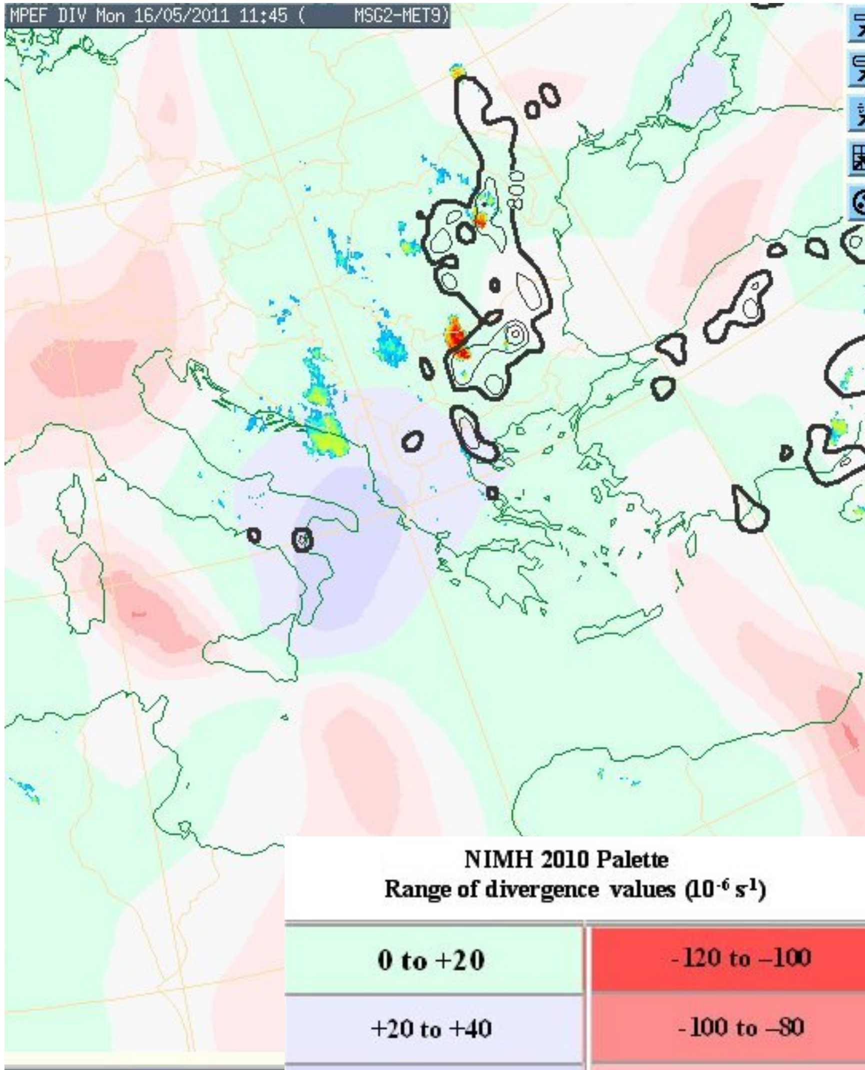
MPEF DIV PRODUCT INTERPRETATION SCHEME

The DIV product can help to recognise, where, among the areas of instability, the development of deep convection is not favourable regarding the upper-level conditions.

From Operational perspective, before starting a deep convective development it is valuable to diagnose the upper-level divergence in the areas of instability.

ARPEGE model-derived Cape is superimposed to show the instability analysed/forecasted by NWP (CAPE > 800 J/kg).

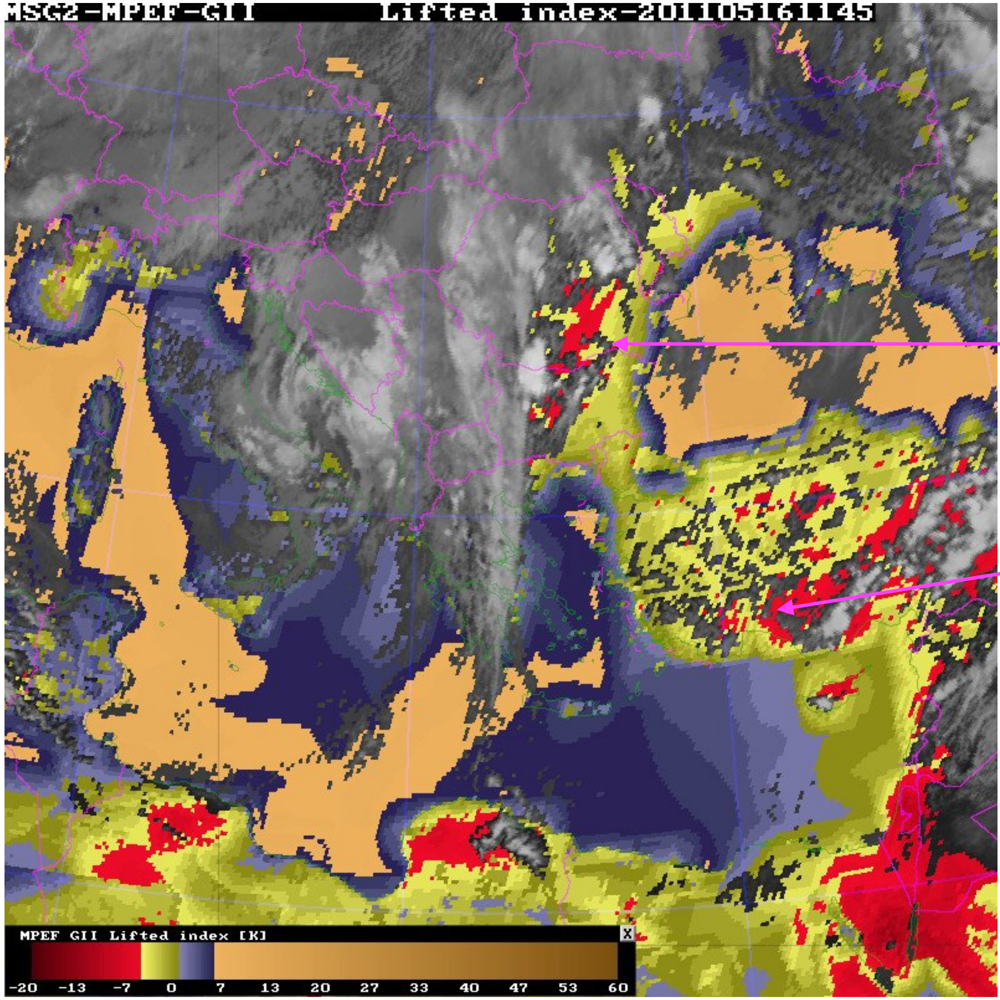
DIV product & IR 10.8 μm (only < -40°C)
ARPEGE NWP CAPE (only > 800 J/kg)



NIMH 2010 Palette
Range of divergence values (10^{-6} s^{-1})

0 to +20	-120 to –100
+20 to +40	-100 to –80
+40 to +60	-80 to –60
+60 to +80	-60 to –40
+80 to +100	-40 to –20
+100 to +120	-20 to 0 [none]

MPEF GII Lifted Index



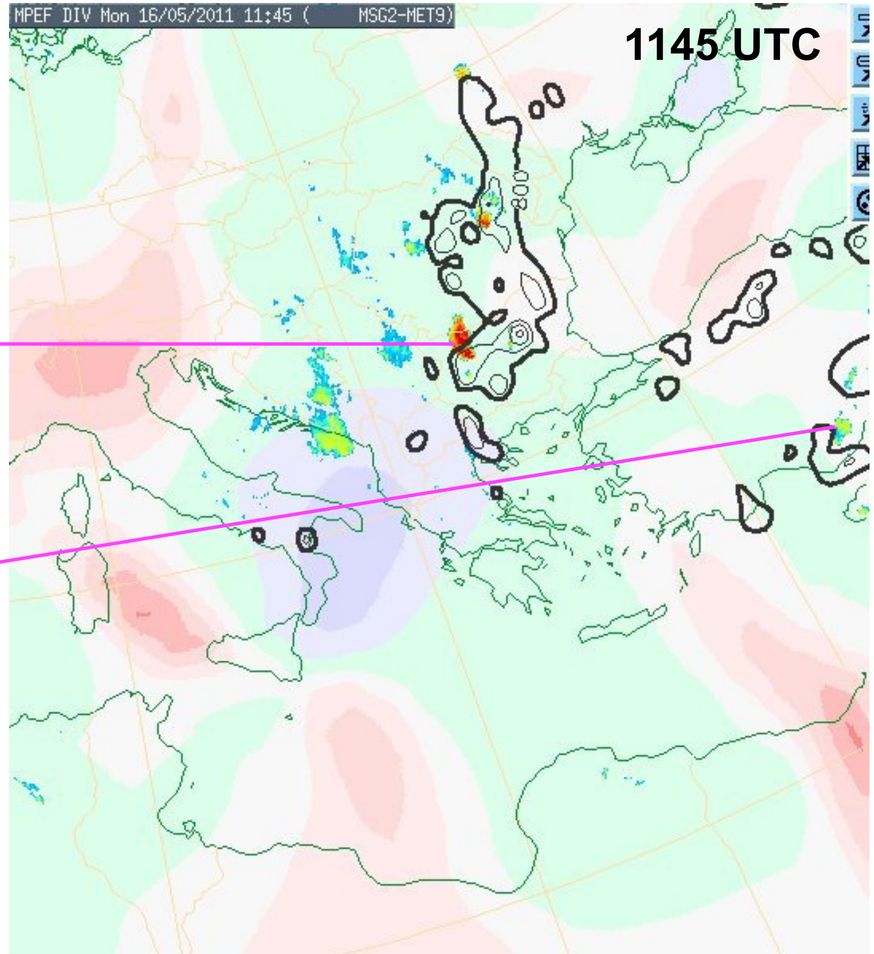
Lifted Index:

LI = Tobs - Tlifted from surface at 500 hPa

where Tobs is the observed temperature.

DIV product & IR 10.8 μm (only < -40°C)

ARPEGE NWP CAPE (only > 800 J/kg



Convection initiation at two areas of instability seen by

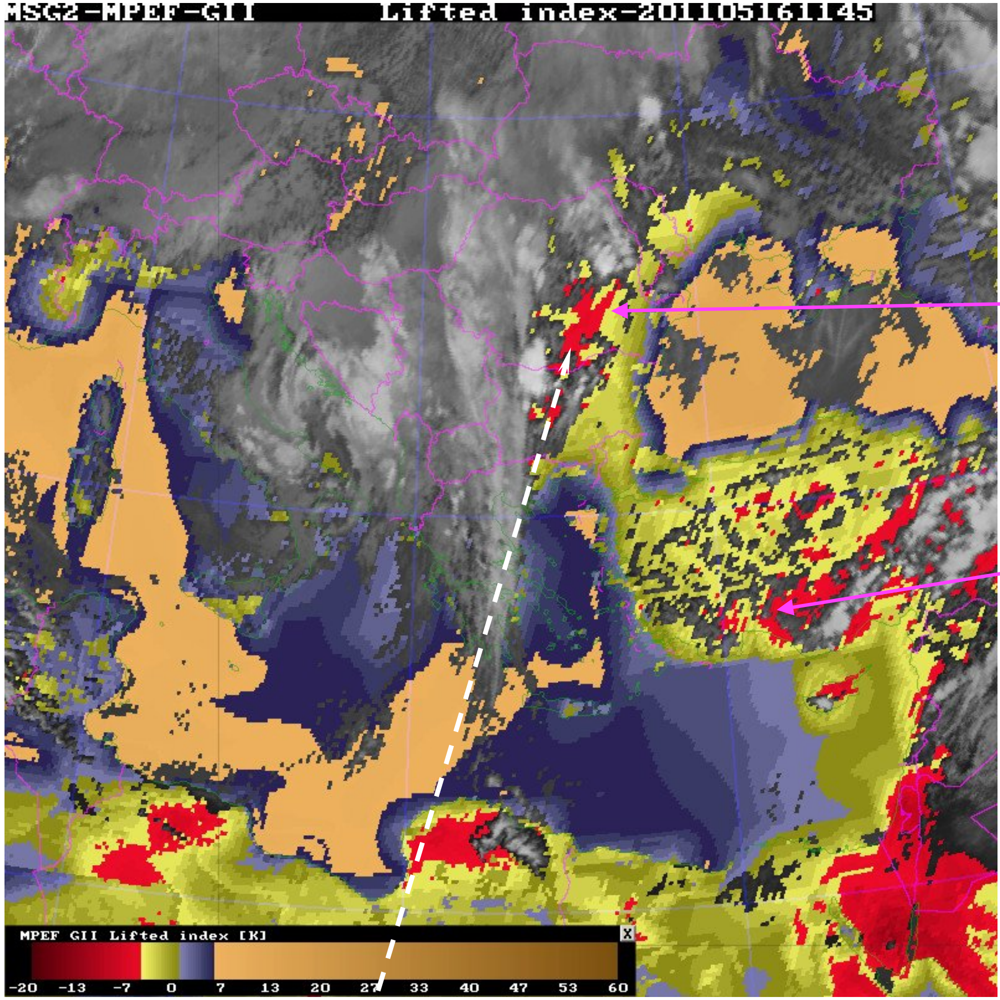
NWP model Cape

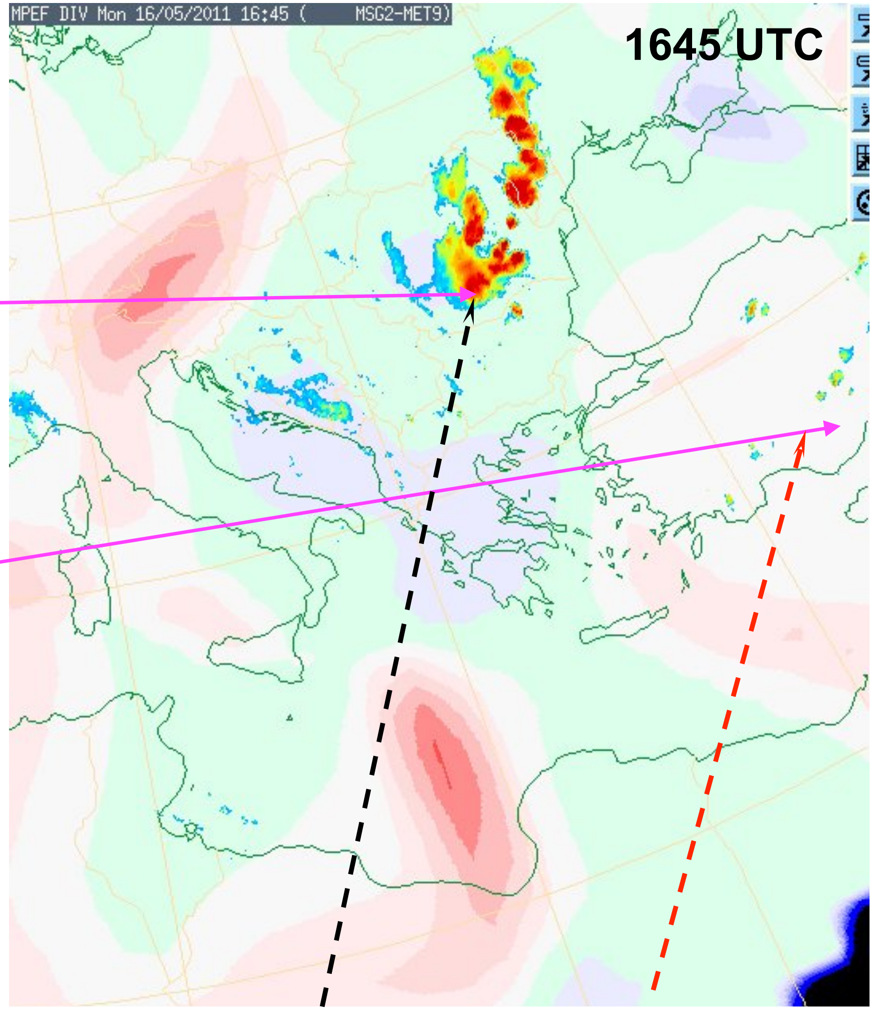
and

MPEF GII indexes

MPEF GII Lifted Index

DIV product & IR 10.8 µm (only < -40°C)

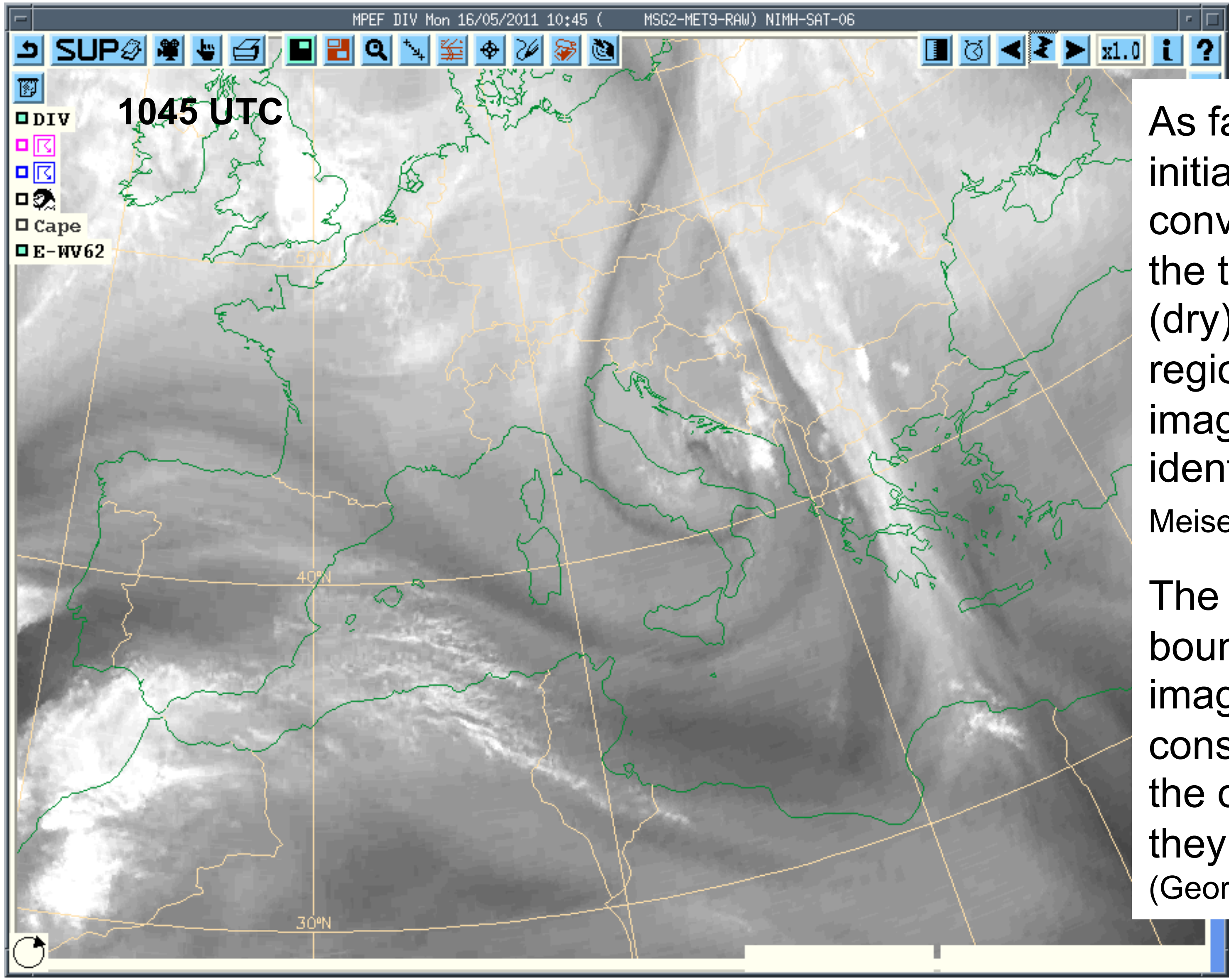




Strong convection further develops in the area of pre-existing Divergence seen by the satellite product

- Maximum development phase of convection at the divergence area over the Balkans
- No deep convective development over Turkey at the area of upper tropospheric convergence

Convection initiation as seen in WV imagery



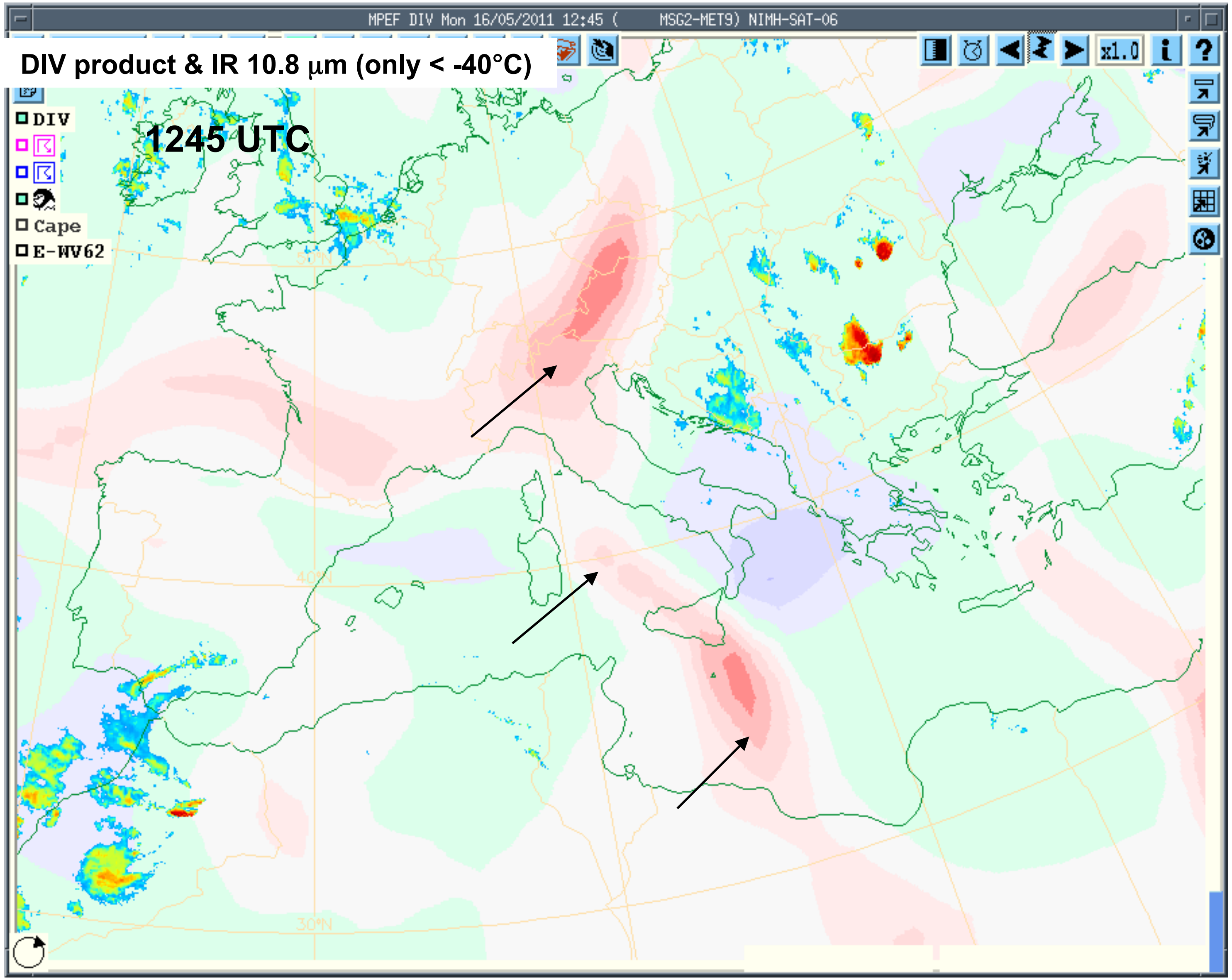
16 May 2011

As favoured areas for initiation of deep moist convection over Europe the transition zone of dark (dry) and light (moist) regions on Meteosat WV images have been identified Krennert & Zwatz-Meise, 2003); Ghosh et al., 2008).

The upper-level dry boundaries seen in the imagery should be considered with respect to the dynamic rate at which they are maintained (Georgiev and Kozinarova, 2009).

The DIV product is useful to recognise which of the moisture boundaries on the WV image are not favourable for deep convective development.

Operational use of MPEF DIV product



16 May 2011

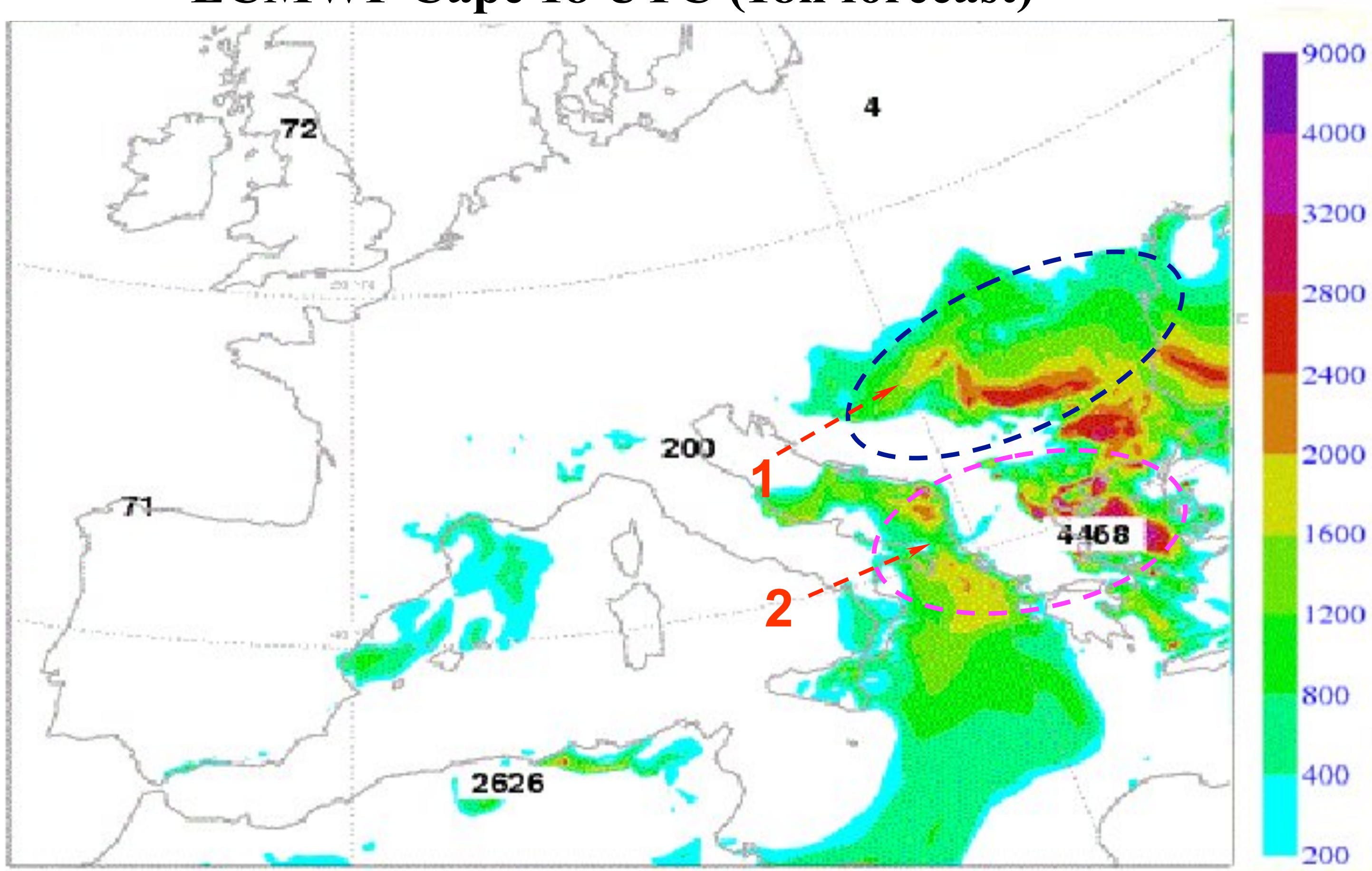
The upper-level convergence does not support deep moist convection.

The DIV product is useful to recognise which of the moisture boundaries on the WV image are not favourable for deep convective development.

Operational use of MPEF DIV product

Sever convection over the Northern Balkans 16 June 2010

ECMWF Cape 18 UTC (18h forecast)



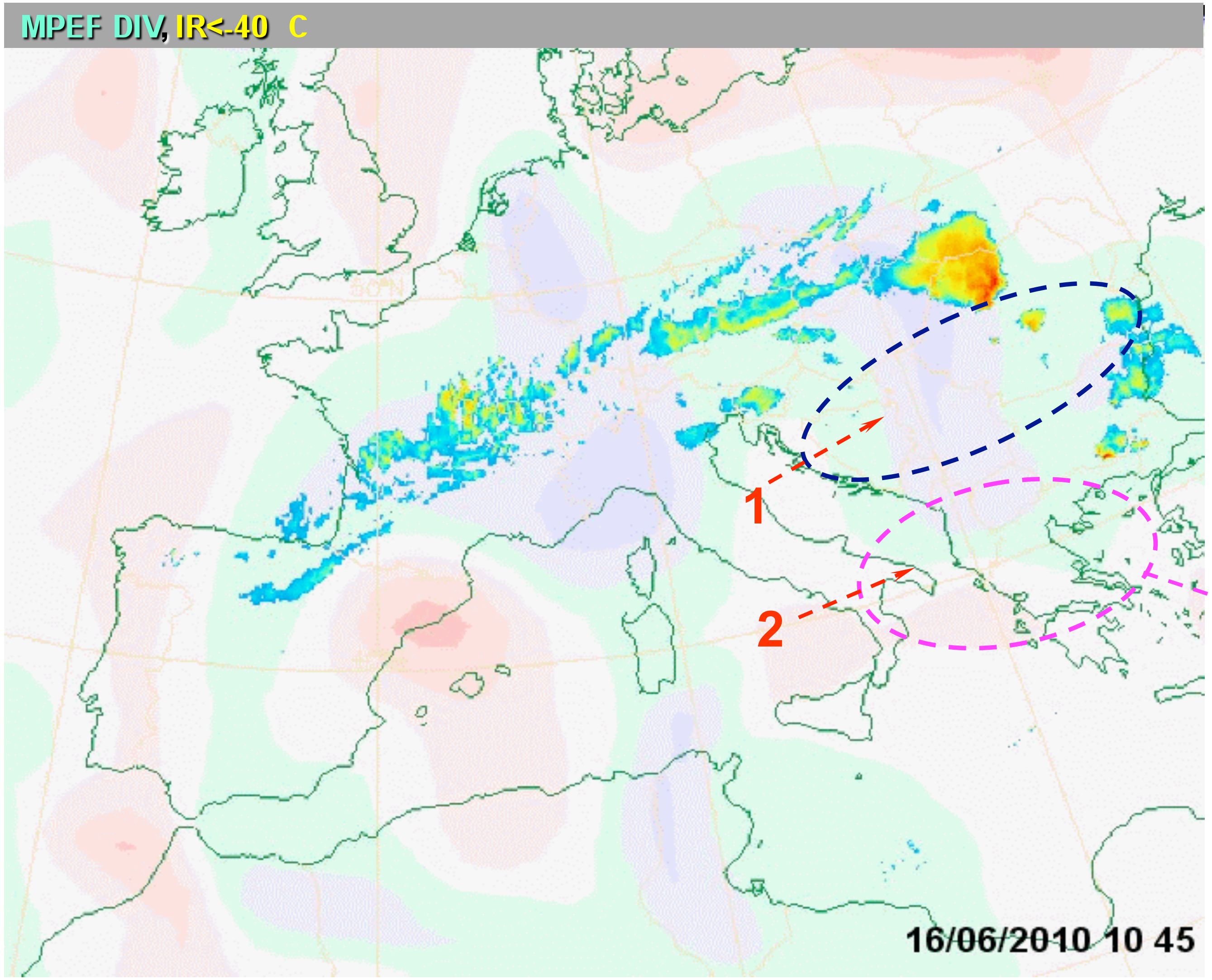
Two areas of tropospheric instability (as forcasted by NWP model),

Cape range: 1000 ÷ 1500 J/kg ,

at which of the two locations deep moist convection is most likely to develop?

Operational use of MPEF DIV product

Areas of instability (by NWP model Cape) and divergence/convergence (by the MPEF DIV)
at which of the two locations, deep moist convection is most likely to develop?

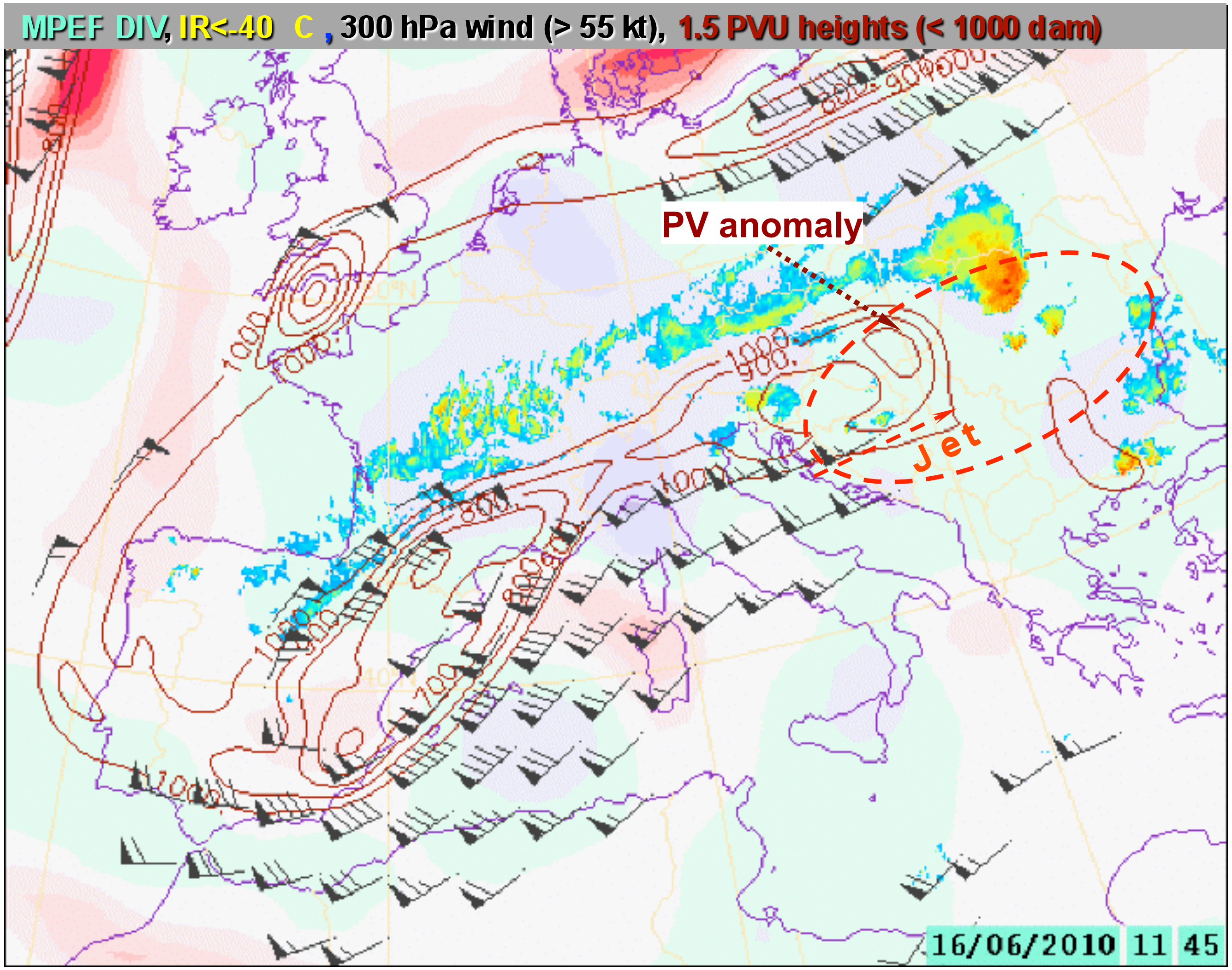


Deep convection initiates at an area of pre-existing divergence as seen by the MPEF DIV product: in the range [0 ÷ +20.10^{-6} s^{-1}].

The convective development is suppressed by the upper-level convergence.
The convective cloud top does not reach -40 °C level.

MPEF DIV PRODUCT INTERPRETATION SCHEME

DIV PRODUCT AS A FORECASTING TOOL



At high rate of the upper-level dynamics, the DIVERGENCE significantly contributes to formation of an environment of deep moist convection.

In the mid-latitudes high impact convective events often occur in areas where, in addition to the instability and low-level forcing mechanisms, there are upper-level forcing trough a divergent synoptic-scale flow.

For short-range forecasting of convection it is useful to consider MPEF DIV product in conjunction with other relevant information, e.g.:

- upper-level dynamical fields
- parameters of tropospheric instablity (NWP, GII)

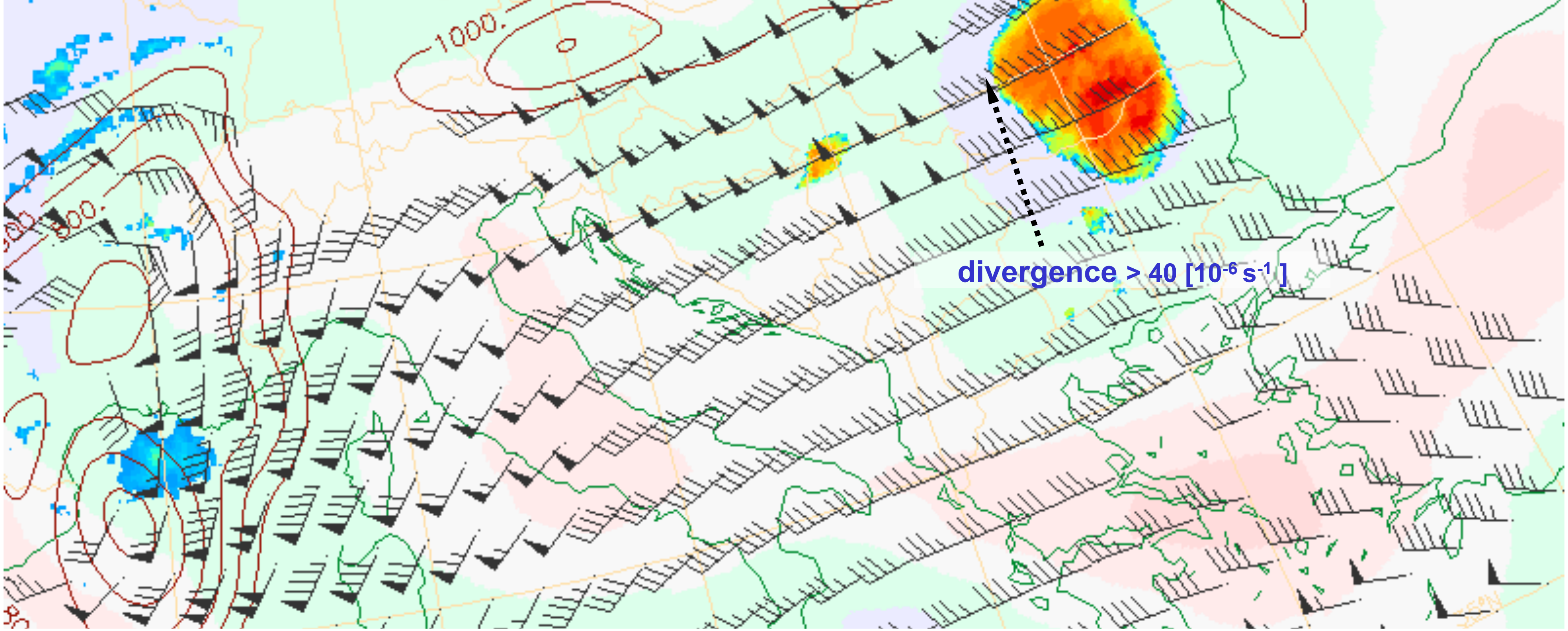
CONCLUSION
use of the MPEF DIV product in the operational context

- The DIV product is useful to identify which of the moisture boundaries on the WV image and areas of tropospheric instability are not favourable for deep moist convection. Only 24 % of the convective cells initiate at areas of upper-level convergence seen by MPEF DIV product.
- A good practice for diagnosing upper-level environment is by using the satellite DIV product in addition to the other relevant information :
  - Air mass instability from NWP models, from hyperspectral sounding indexes (as MPEF GII , RII) or from upper-air sounding data.
  - NWP upper-level dynamical fields.
- There is a potential for generation of DIV product on 15 minutes of half an hourly basis of Meteosat Rapid Scan Services. The quick repeat cycle of Meteosat Rapid Scan would help assessing the rate of upper-level dynamics at the onset of convective development.

Acknowledgments

The initial study on the usefulness of MPEF DIV product is performed in collaboration with Patrick Santurette through the Satellite Imagery cooperation Project of Météo-France and NIMH of Bulgaria. The author is grateful to Arthur de Smet from EUMETSAT for the helpful suggestions and comments regarding visualisation and interpretation of MPEF Divergence product.

Thank you!



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EUMETSAT (2005). Upper Level Divergence Product Algorithm description. EUM/MET/REP/05/0163. EUMETSAT, Germany, 16 p.

Georgiev, C.G. and Kozinarova, G. (2009). Usefulness of satellite water vapour imagery in forecasting strong convection: A flash-flood case study. Atmos. Res., 93 (2009), pp. 295-303.

Georgiev, C. G. and Santurette, P. (2010). Quality of MPEF DIVergence product as a tool for very short range forecasting of convection. Proceedings of 2010 EUMETSAT Meteorological Satellite Conference (Córdoba 20 – 24 September 2010). ISSN 1011-3932.

Ghosh, A., Loharb, D., Dasc J. (2008) Initiation of Nor'wester in relation to mid-upper and low-level water vapor patterns on METEOSAT-5 images. Atmospheric Research 87 (2), pp. 116-135.

Krennert, T., Zwatz-Meise, V., 2003. Initiation of convective cells in relation to water vapour boundaries in satellite images. Atmos. Res. 67-68, 353-366.

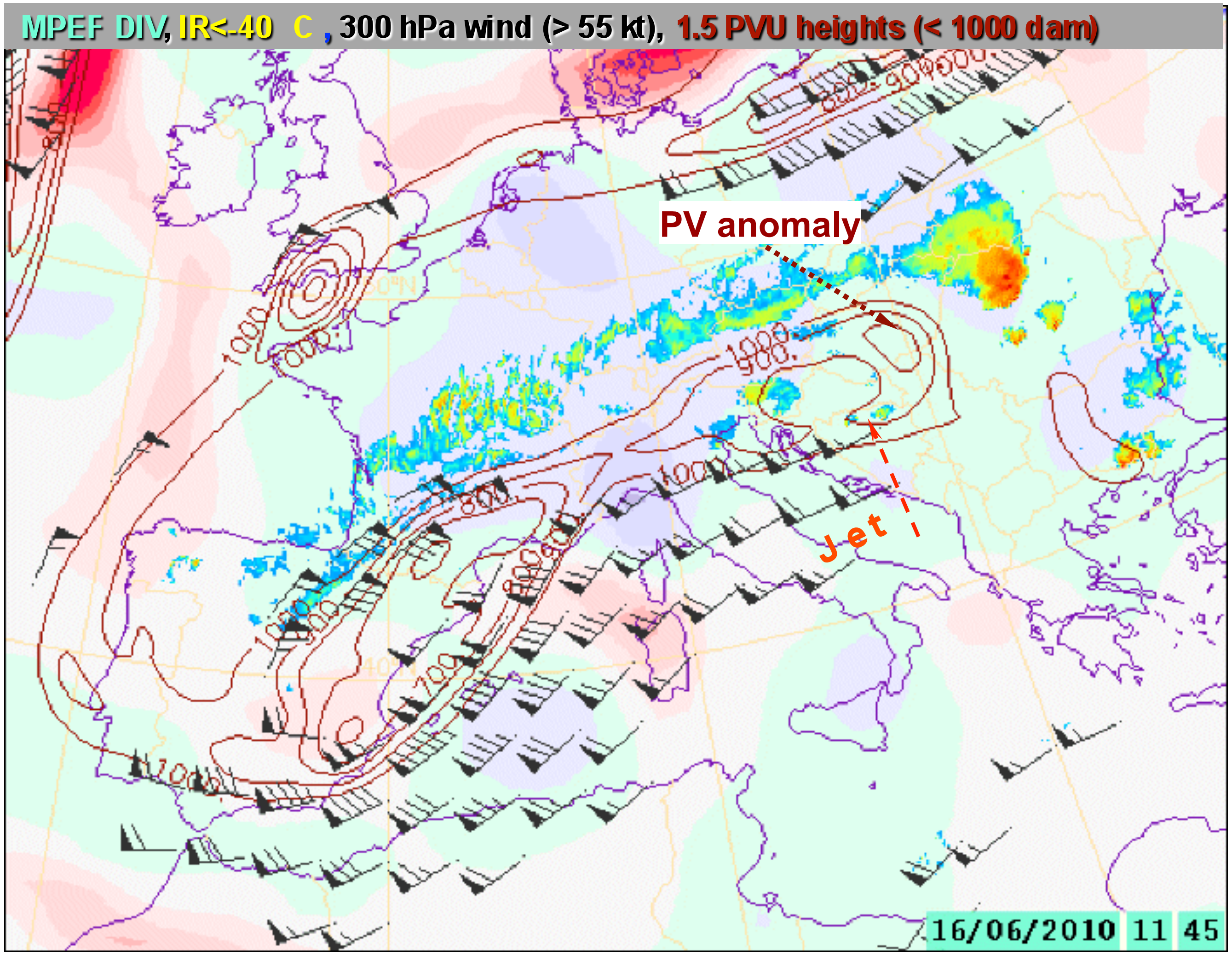
Schmetz, J., Borde, R., Holmlund, K., König, M., (2005). Upper tropospheric divergence in tropical convective systems from Meteosat-8. Geophys. Res. Lett., 32, L24804.

Santurette, P., Georgiev, C. G., 2005. Weather Analysis and Forecasting: Applying Satellite Water Vapor Imagery and Potential Vorticity Analysis. Elsevier Academic Press. ISBN: 0-12-619262-6, 200 pp.

16.06.2010

- http://bnt.bg/bg/news/view/31117/ljatna_burja_vyv_vidin

MPEF DIV PRODUCT INTERPRETATION SCHEME
DIV PRODUCT AS A FORECASTING TOOL



The deep convective cell initiated at the left exit of a jet and divergence seen by MPEF DIV product: in the range [+20.10^{-6} s^{-1} ÷ 0].

For short-range forecasting of convection it is useful to consider MPEF DIV product in conjunction with other relevant information, e.g.:

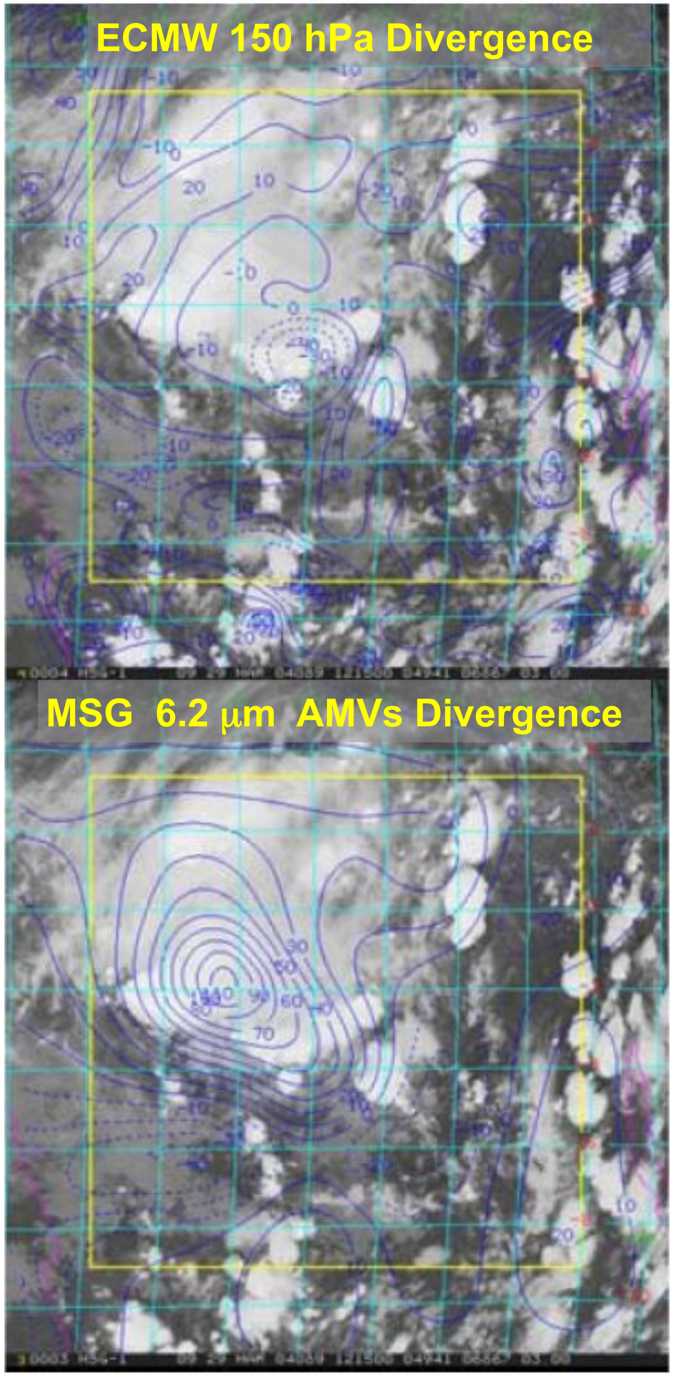
- upper-level dynamical fields
- parameters of tropospheric instablity (NWP, GII)

MPEF DIV PRODUCT VALIDATION

Two possible factors affect quality of the MPEF DIV product and might impose limitations :

- The Barnes interpolation (Barnes, 1964) used as an intermediate procedure as a necessary step. This has the effect of smoothing out information horizontally and the side effect is that small-scale features are suppressed.
- The input to the algorithm is all upper-level AMVs, which pass through specific quality control. They are derived by tracking cloud and humidity features in the 6.2 μm WV channel in the layer 100-400 hPa. Generally, the MPEF DIV values represent an atmospheric layer between 100-400 hPa, rather than an atmospheric level.

MPEF (DIV) Product over tropical Africa

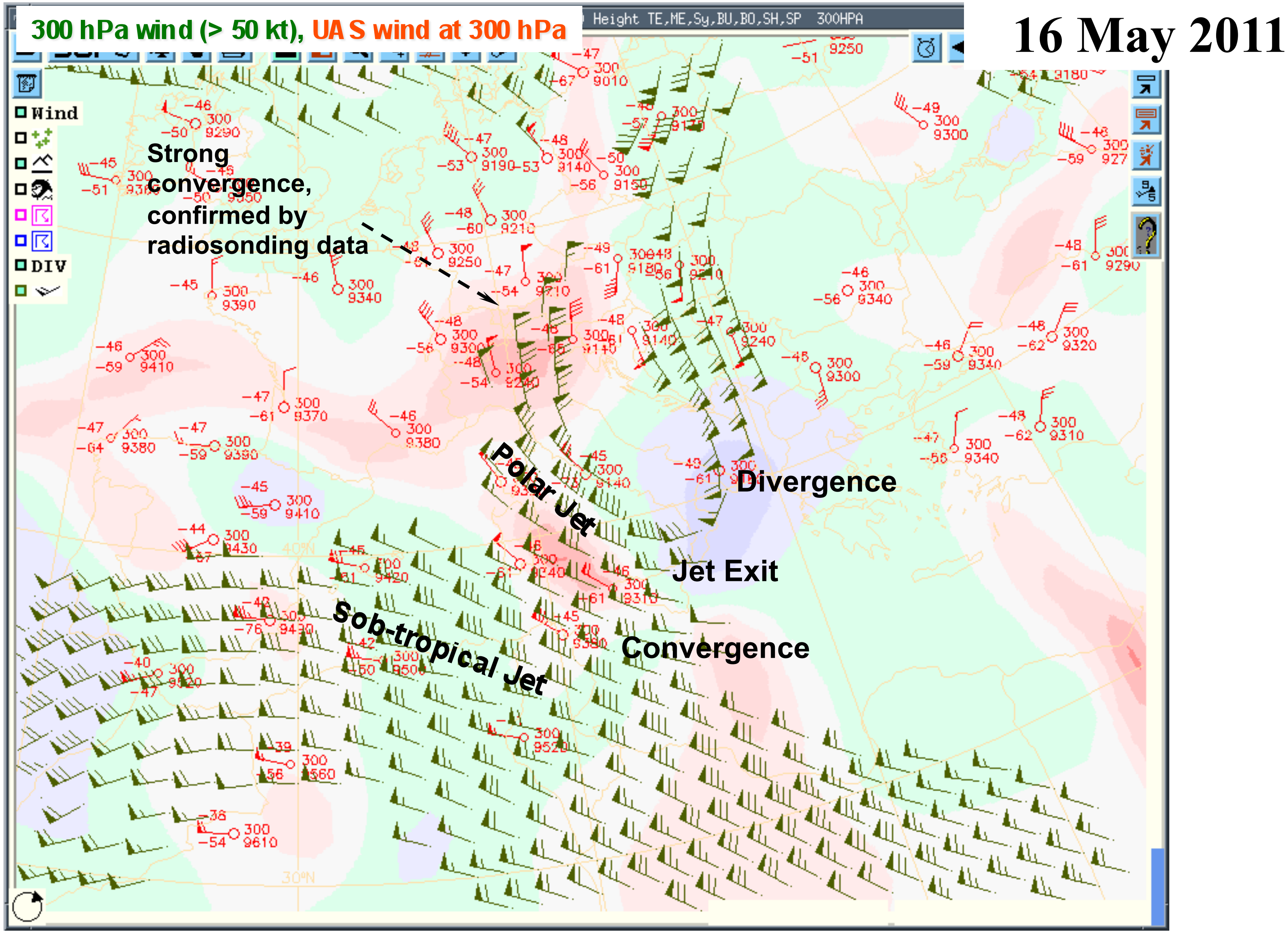


Schmetz et al. (2005) determined the mean altitude of the observed divergence field, as defined by the mean height of AMVs **at the top of the convective clouds**: In this case it was around 130 hPa with a standard deviation of 30–40 hPa.

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.

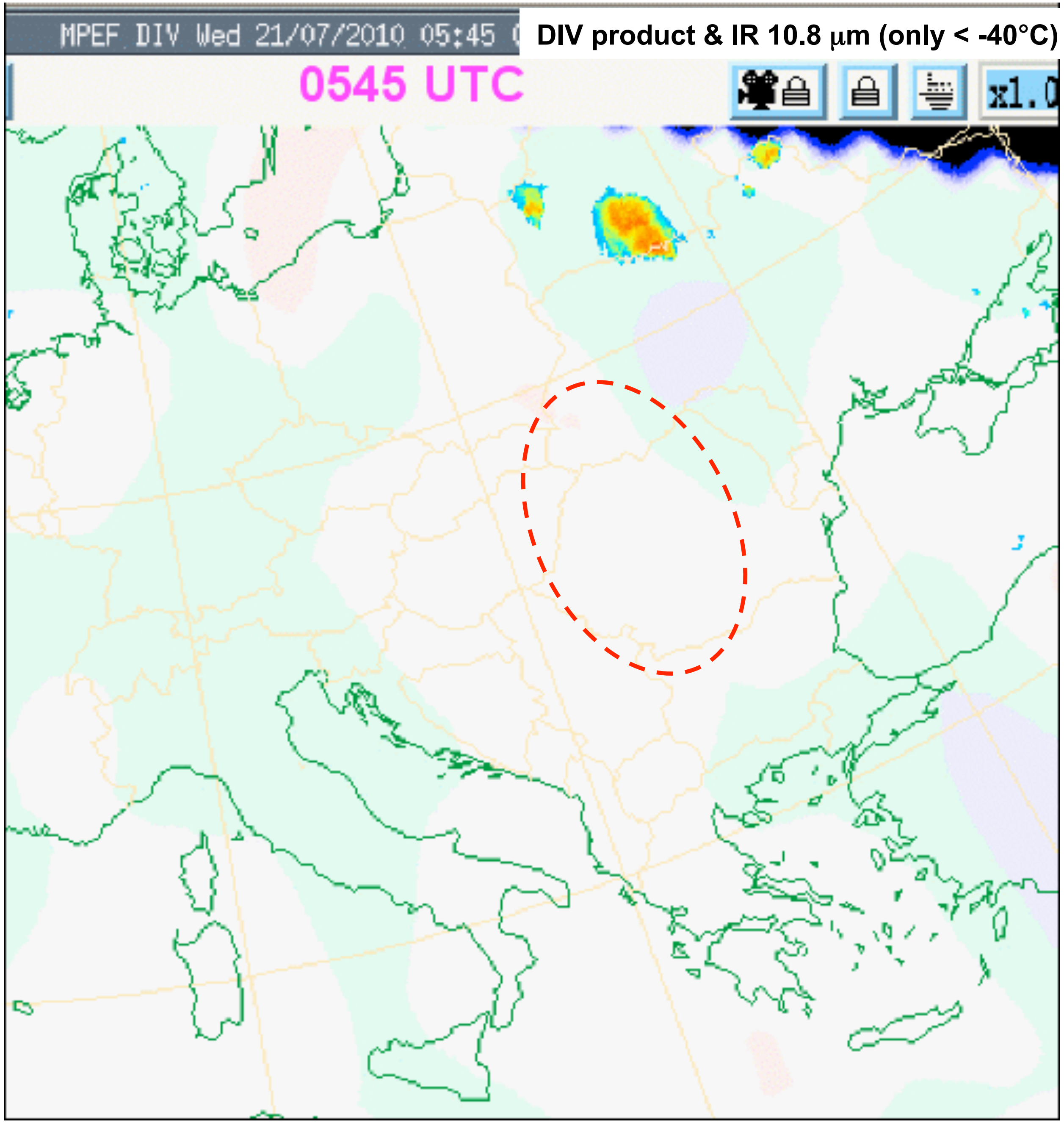
ECMWF wind field divergence at 150 h Pa (upper panel (forecast valid for 1200 UTC) and the corresponding satellite derived divergence field (lower panel), background are the 10.8 μm images Schmetz et al. (2005).

DIV Product validation at Mid latitudes



Validation of MPEF DIV product by comparing with 300 hPa wind from **upper-air sounding observations and NWP model analysis**

DIV Product validation at Mid latitudes



Sensitivity of MPEF DIV product to upper-level divergence resulting from ascent, associated with strong convective development at mid latitudes.

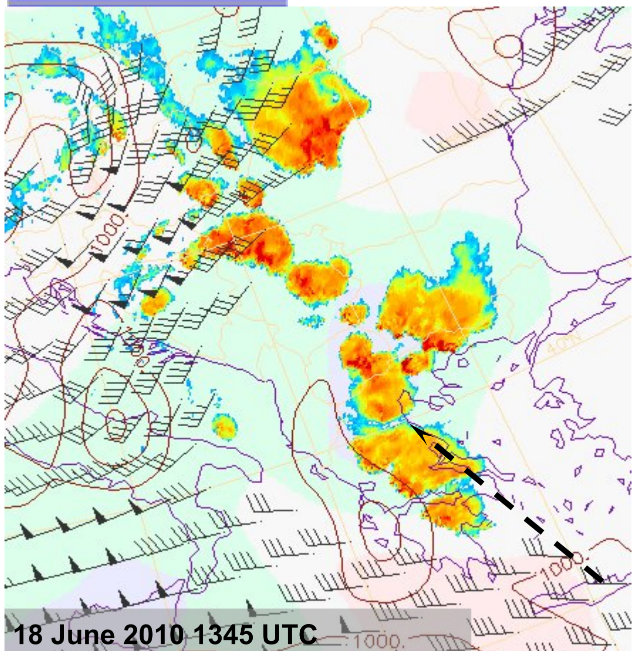
This effect causes sudden appearance of divergent values at such areas of striong convective developments in consecutive hourly images.

Convective cloud systems over mid-latitude Europe

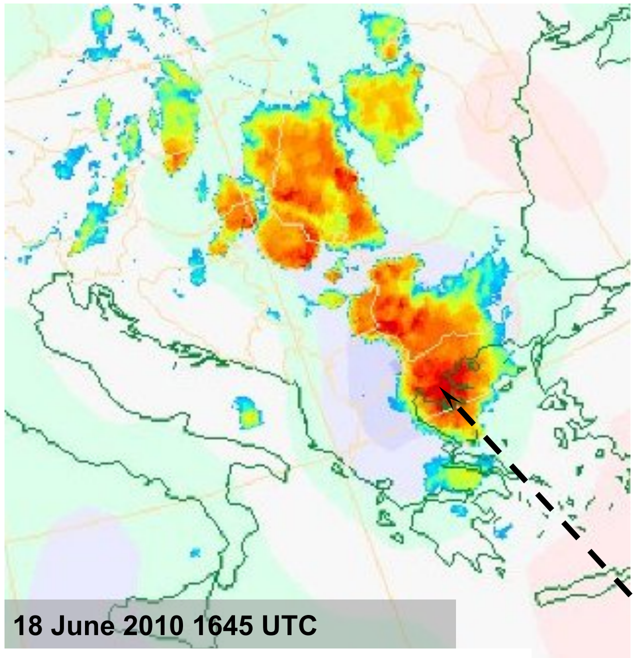
NIMH 2010 Palette Range of divergence values (10^{-6} s^{-1})
-40 to –20
-20 to 0 [none]
0 to +20
+20 to +40
+40 to +60
+60 to +80
+80 to +100

While the upper-level divergance in the tropical convective clouds can be very strong, (450 * 10^{-6}/s), it is much lower in the mid-latitude convective clouds (as seen in MPEF DIV ranging 20 – 60 * 10^{-6}/s) due to

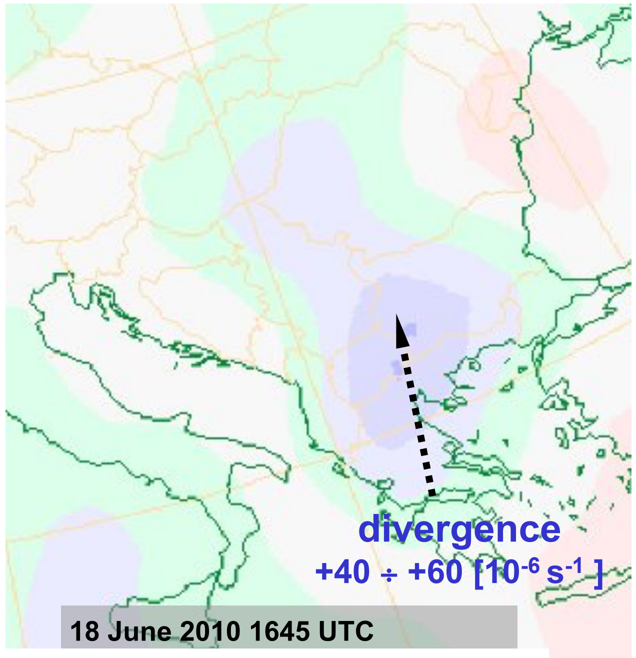
- **weaker updraft compared with this at the tropical convective developments.**
- **lower MSG resolution than this at the Central Africa that smoothing out information horizontally.**



MPEF DIV
IR 10.8 m, colored only BT < - 40 C
300 hPa wind (only > 30 kt)
1.5 PVU surface height (only < 1000 hPa)



MPEF DIV
IR 10.8 μm only BT < - 40 °C



MPEF DIV