INTERPRETATION GUIDE TO MSG WATER VAPOUR CHANNELS

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ABSTRACT

This paper is aimed to present a training material on the interpretation of data from the WV channels of MSG 6.2 μm and 7.3 μm. The training tool is guided through PowerPoint presentations by applying animation effects on images and detailed text explanations. The Interpretation Guide is illustrated by numerous examples including NWP models output, satellite imagery and conventional observations, taken from the forecaster's environment.

1. INTRODUCTION

Aiming to respond to the need of knowledge on the interpretation of data from the water vapour (WV) channels 6.2 μm and 7.3 μm of Meteosat Second Generation, a training material was developed. It is organised in two parts considering the problem of interpreting radiation measurements in WV channels from the two fundamental points of view (see Weldon & Holmes, 1991). The two parts are presented in Sections 2 and 3 of this paper respectively.

Part I concerns the interpretation approach addressed to the problem of using WV channel data considering each individual pixel on an image as a single value measured by the satellite that may provide information about the vertical distribution of humidity and temperature in the path of radiation. Based on real situations of specific image grey shades and brightness temperatures derived by satellite measurements, the response of the 6.2 μm and 7.3 μm channels to various cases of vertical moisture distribution is depicted. Attention is given to differences in moisture regime related to dynamical processes seen as light and dark image grey shades.

Part II illustrates the dynamical insight into the WV imagery interpretation during the evolution of significant synoptic-scale circulation patterns. The presented interpretation technique is referred to as Water Vapour Imagery Analysis: Many pixels over large areas are considered as patterns and features of grey shades on the image, and their interpretation relates these patterns and their changes with time to specific atmospheric circulation systems and processes. When using this approach, WV imagery serves operational forecasters with a valuable tool for synoptic-scale analysis.

The Interpretation Guide to MSG WV Channels is drawn on brief excerpts from Chapters 1, 2 and 3 and Appendix A of the book: Santurette & Georgiev (2005), published by Academic Press, Elsevier Inc. Chapter 4 of the book is unique in bringing together the interpretation of water vapour images, potential vorticity fields and model diagnostics as a guide to validating numerical model analyses or short period forecasts.

2. PART I: INTERPRETATION OF 6.2 AND 7.3 μm RADIATION MEASUREMENTS

Radiation effects from different moisture profiles

The thermal radiation, measured by the satellite, also referred to as “radiance” is converted to a brightness temperature or to an image grey shade. For IR split window channels this radiation will reach the satellite after no or very little absorption, so that the instrument can detect the temperatures of cloud tops, land and sea surface. For WV channels, the water vapour located anywhere in the troposphere will absorb some portion of the upcoming radiation and reradiate. Being commonly cooler than the earth’s surface or the cloud tops radiating from bellow, the water vapour usually radiates at a lower energy level. This effect produces differences in image grey shade and brightness temperature, derived by the WV channels.

The information content of MSG WV channel radiances is illustrated for various specific moisture profiles by considering images and corresponding data from operational upper-air soundings. An example is shown in Fig. 1.

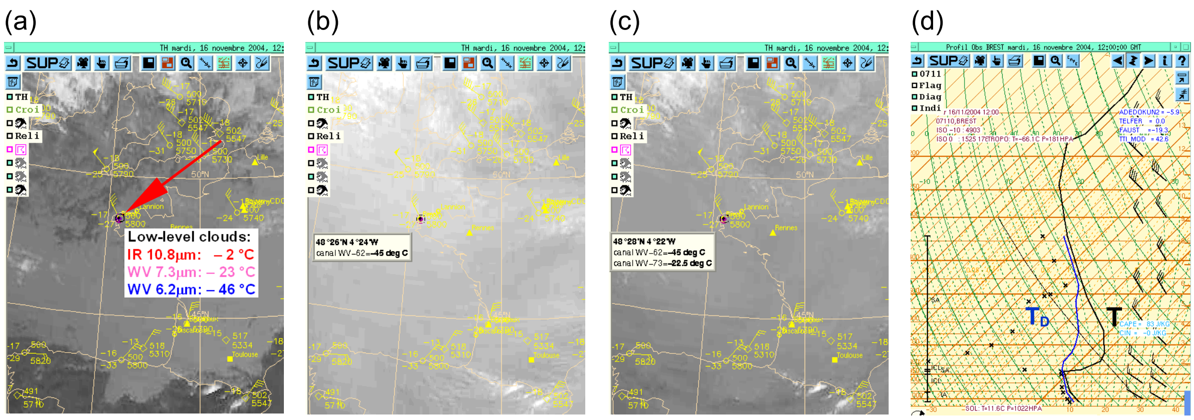

Fig. 1. Meteosat-8 images in: (a) IR 10.8 μm, (b) WV 6.2 μm and (c) WV 7.3 μm channels. (d) Upper-air sounding at Brest, T - air temperature (black curve), T_D – dewpoint (blue curve). Also shown the brightness temperatures derived from the three channels at location of the release point of the sounding shown in (d).

As seen in Fig. 1d, the considered upper-air sounding at Brest, France shows following features of the atmospheric moisture profile:

- Nearly saturated air at upper level.
- Extremely dry air in 800 - 500 hPa.
- Nearly saturated or saturated air below 850 hPa.

The IR 10.8 µm channel image in Fig. 1a shows brightness temperature – 2 °C, which is representative for the temperature of the cloud top, located, at 850 hPa (as seen by the sounding data in Fig. 1d). The WV channels radiances derived at the pixel representative for the moisture profile in Fig. 1d is described bellow.

- Medium grey shade in 7.3 µm (Fig. 1c) resulting from a brightness temperature of – 23 °C, which originates by the cloud top but does not represent it's physical temperature.
- Light grey in 6.2 µm (Fig. 1b), due to strong absorption by nearly saturated air at upper-level. The brightness temperature is – 46 °C, not representative for the temperature of the moist layer.

The Interpretation Guide to MSG WV Channels shows vertical cross-sections of relative humidity across specific patterns of image grey shades. Factors, which cause different moist layers at different vertical locations to produce large differences in brightness temperature derived by the two MSG WV channels are discussed.

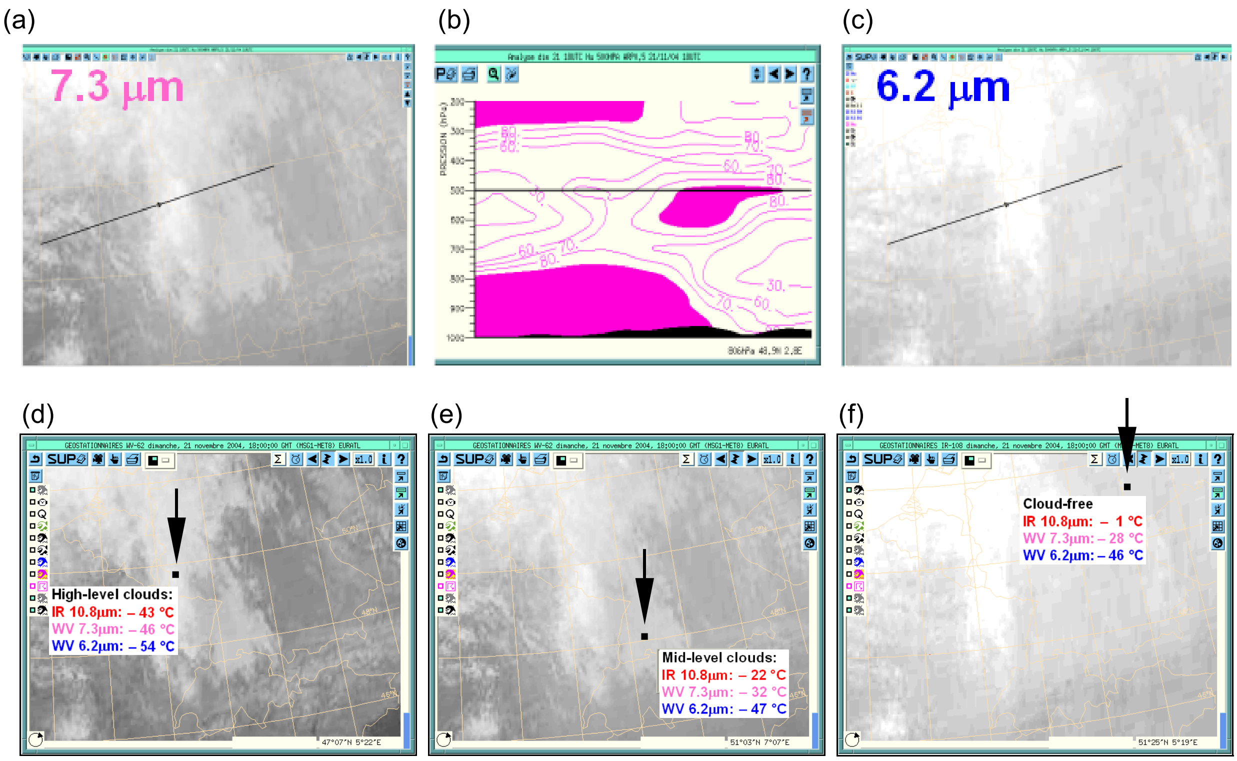

Fig. 2. Deep moist layers (200-1000 hPa) as seen in MSG WV channels (a) 7.3 µm image. (b) Vertical cross section (data from ARPEGE) of relative humidity (%) along the black line depicted in (a) and (c). (c) 6.2 µm image. Brightness temperatures derived by MSG

channels for the pixels indicated by the black points (arrows) in the Meteosat-8 images in (d) IR 10.8 µm, (e) WV 7.3 µm and (f) 6.2 µm.

These considerations are performed for various image patterns: Deep moist layers (200-1000 hPa); High-level moist layers (200-400 hPa); Mid-level moist layers (400-650 hPa); Low-level moist layers (650-800 hPa); Low-level to boundary moist/cloud layers (800-950 hPa). An example is shown in Fig. 2 for a case of a deep layer of high moisture content in cloud-free as well as in cloudy areas. Deep layers of high moisture content (cloudy or cloud free), shown in Fig. 2b, produce various grey shades of the WV images in 6.2 µm and 7.3 µm channels, as seen in Figs. 2a and 2c. The radiation effects responsible for the differences between the brightness temperatures in the IR 10.8, WV 7.3 and WV 6.2 channels shown in Figs. 2d, 2e and 2f may be summarised in two basic points as follows:

a. With the increasing of water vapour content, much of the radiation is absorbed and reemitted at lower energy levels at colder air, and therefore, the brightness temperature in WV channels decreases. The higher is absorption by water vapour above the clouds, the lighter WV channel images become.
b. For the less highly absorbed 7.3 µm radiation, the reduction of brightness temperature is less.

In the cases of high-level clouds, low- level clouds and cloud-free deep moist layer (at the black arrows in Figs. 2d, 3e and 3f respectively), the difference in brightness temperatures of WV 7.3 and WV 6.2 increases, because the 6.2 µm radiation is absorbed and reradiated in a longer path of troposphere to the satellite. Therefore, WV 6.2 channel is more sensible to detect deep moist layers.

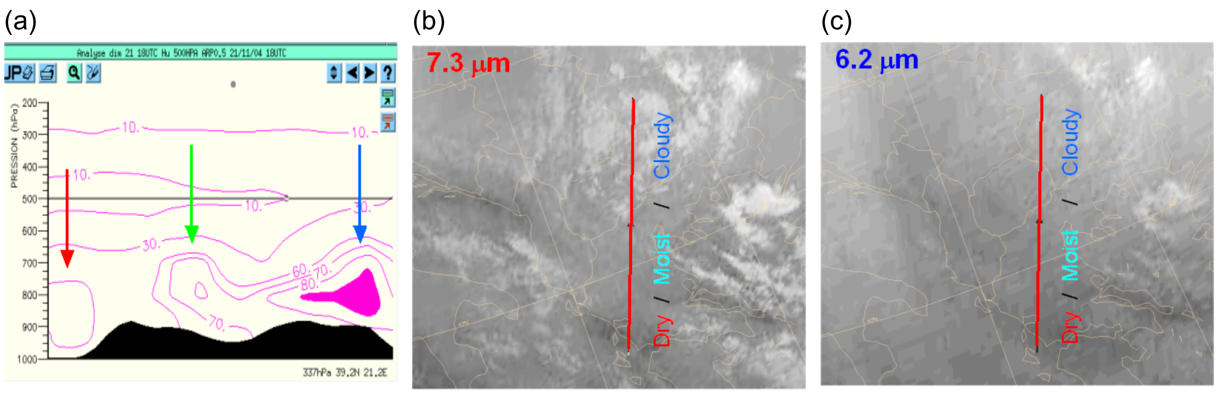

Fig. 3. Low-level moist layers (650-800 hPa) as seen in MSG WV channels. (a) Vertical cross section (data from ARPEGE) of relative humidity (%) along the red line in (b) and (c). Meteosat-8 images in (b) 7.3 µm and (c) 6.2 µm.

An example of a low-level moist layer (650-800 hPa) is shown in Fig. 3a. The dry, cloud-free, moist and cloudy areas of this layer appear in dark grey, medium grey and light shades of the 7.3 µm image (Fig. 3b) respectively. These features do not appear distinctly different in the image grey shades of the 6.2 µm channel (Fig. 3c). Therefore, low-level moist layers are detectable by the 7.3 µm channel and they are usually not visible in the 6.2 µm images. The 7.3 µm radiation is more sensible to detect differences in the water vapour content of the lower troposphere and may be useful for inspection of moisture commonly found there.

Differences in moisture regime related to dynamic processes as seen by WV imagery

Water vapour is accumulated in the troposphere from the earth's surface by vertical motions and wind regime of all directions. Therefore, the radiance in water vapour absorption band may be a source of information for atmospheric dynamics related to wind and the vertical motion. The Interpretation Guide is aimed to teach how to perform a dynamic interpretation of radiances in WV 6.2 and WV 7.3 channels for analysis of synoptic-scale perturbations in the atmosphere associated with large differences in humidity distribution and wind regime. Fig. 4 illustrates tools for applying this interpretation approach.

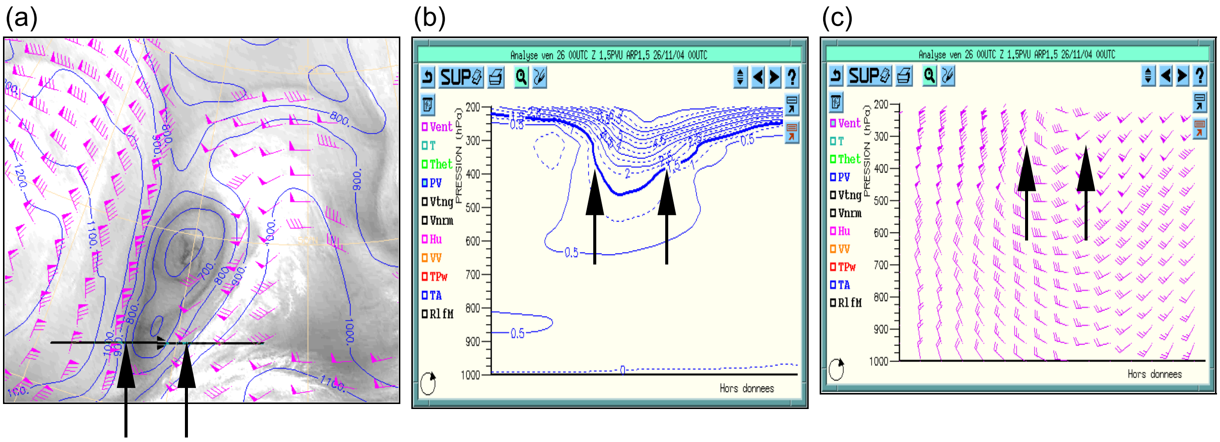

Fig. 4. Dynamic interpretation of radiances in MSG WV channels. (a) Meteosat–8 image in 6.2 µm superimposed by the 1.5 PVU surface heights. Vertical cross sections (data from ARPEGE) of (b) potential vorticity and (c) wind along the black line shown in (a).

The moisture boundaries produced by upper-level dynamics are distinctly seen in the 6.2 µm radiance (e.g. at the position of the black arrows in Fig. 4a). These boundaries between dark and light image grey shades are also transition zones between different upper-level wind regimes, depicted in Fig. 4c.

3. PART II: INTERPRETATION OF 6.2 µm CHANNEL RADIANCE IN IMAGE FORMAT

Based on the knowledge presented in Part I of the Interpretation Guide to MSG WV Channels, the training material in Part II provides pedagogy for understanding meteorological processes and interpreting 6.2 µm channel imagery as a tool for synoptic scale analysis.

WV imagery features related to synoptic dynamical structures

Aiming to provide with a quick and direct insight into the upper-level dynamics, the training material is developed in the view of the potential vorticity (PV) concept. On Fig 4a, the 6.2 μm WV image is overlaid by the geopotential heights of the constant surface of PV=1.5 PVU (1 PVU = 10^{-6} m^2 s^{-1} K kg^{-1}), this constant surface being defined as the dynamical tropopause (Santurette and Georgiev, 2005). Fig. 4b is a vertical cross-section of PV along the black line on Fig. 4a, the dynamical tropopause (1.5 PVU surface) being presented by the thick contour in Fig. 4b.

Dynamically active regions in the upper-troposphere circulation where cyclogenesis is going to develop are associated with close relationship between the PV distribution and WV imagery (see Santurette & Georgiev, 2005). Figs. 4a and 4b show the ability of WV 6.2 μm channel images to represent the upper-level dynamics.

- The changes in the field of tropopause height (blue contours in Fig. 4a), at the strong gradient zones, are well related to changes in moisture regime and upper-level wind.
- The moisture boundaries seen by the radiance in 6.2 μm channel (at the black arrows) well represent sloping areas of the tropopause (solid contour of the 1.5 PVU surface). The vertical distribution of potential vorticity (in Fig. 4b) depicts the folding of the tropopause, seen as a specific dark zone in the 6.2 μm image, this dark zone being produced by an intrusion of stratospheric air down to mid-tropospheric levels.

WV imagery features related to synoptic dynamical structures

The Interpretation Guide shows how to interpret MSG WV images in 6.2 μm channel for pattern recognition and analysis of important dynamical structures and synoptic-scale processes. Sequences of satellite images in 6.2 μm and 6.3 μm channels, other observation data and NWP model products are presented to highlight the practical use of WV Imagery as a tool for diagnosing evolution of the synoptic-scale circulation at mid and upper levels. Fig. 5 shows examples of some patterns considered and displayed in the training material by means of animation effects of the PowerPoint learning tool.

Typically, on a WV image, there are many well defined moisture boundary features, and some of them are associated with jet stream axes. Fig. 5a shows a 6.2 μm Meteosat–8 image overlaid by wind speed contours (blue) and wind direction (red) (only > 100 kt) at 300 hPa. The WV image boundary patterns related to the two branches of the jet stream are depicted: A jet stream branch coming from the upstream ridge (at location of the red arrow) and a jet stream branch on the forward side of the through (blue arrow).

Conceptual models for pattern recognition of kata- and ana-cold fronts are combined with schemes of layer moisture effects on 6.7 μm radiation adapted from Weldon & Holmes (1991). Examples from the Interpretation Guide are shown in Figs. 5b and

5c. By means of a joint interpretation of a 6.3 µm image and model fields (Santurette & Georgiev, 2005), important characteristics of the frontal system are depicted.

- The intrusion of very dry air rearward a kata-cold front (Fig. 5b) is identified by nearly black WV image shades. The low-level moist air at the surface cold front (SCF) that is capped by the dry-intrusion air above produces medium grey image shades, while the zone of convective clouds forward to the upper cold front appears nearly white.
- At the ana-cold front, the rising-warm air part of the transverse circulation generates a wide cloud band behind the SCF that overhangs the dry cold air. This cloud band produces nearly white WV image shades with dark- and light-grey shades rearward and forward respectively.

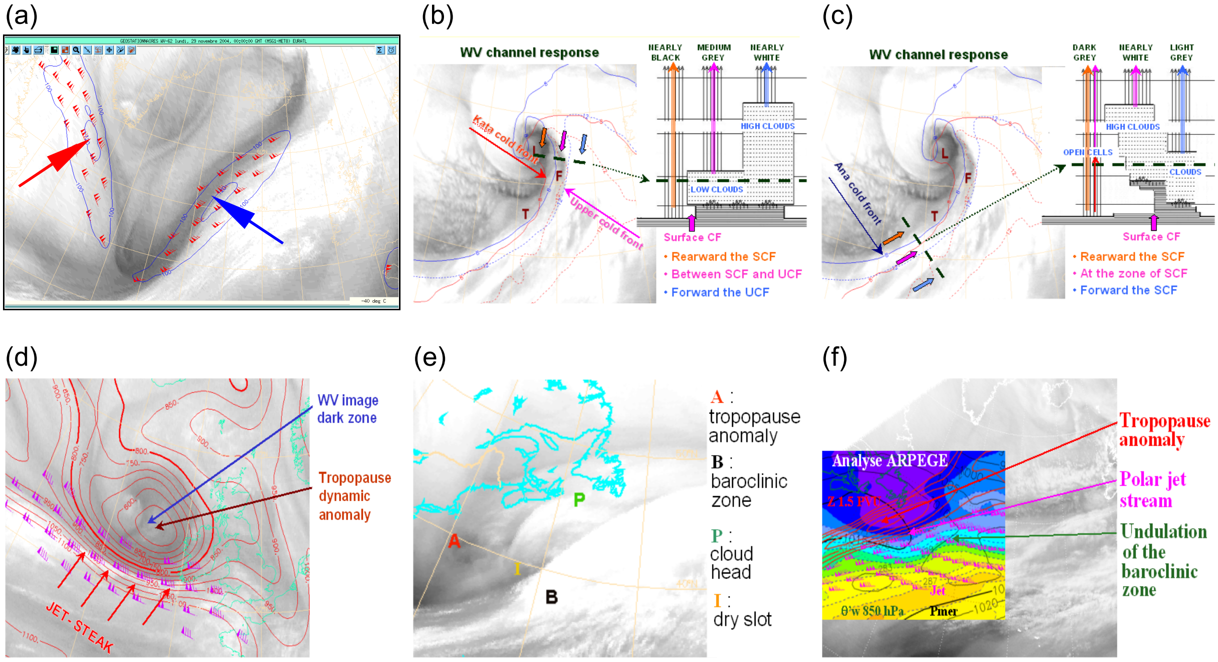

Fig. 5. WV imagery features related to synoptic dynamical structures. (a) Jet stream. (b) Kata-cold front. (c) Ana-cold front. (d) Tropopause (or PV) anomaly. (e) Upper-level precursors of cyclogenesis seen in WV imagery. (f) Ingredients of cyclogenesis seen in WV imagery and NWP model fields.

As discussed above, a synoptic-scale dark zone on the 6.2 µm channel image is consistent with an area of low tropopause heights that is referred to as tropopause dynamic anomaly or PV anomaly. WV imagery is a tool for observing PV anomalies and jet streams in the context of their interaction, which is critical for the evolution of synoptic situation. As seen in Fig. 5d, a jet-streak appears in the southern part of the anomaly (red arrows), associated with strong tropopause heights gradient.

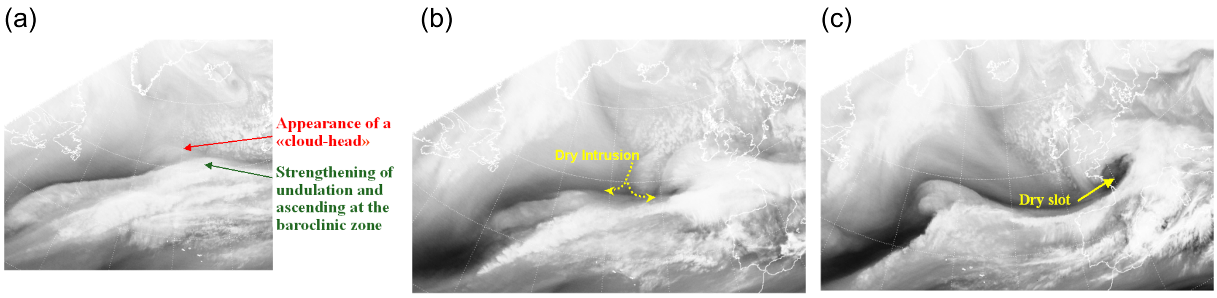

Fig. 6. A sequence of WV images showing characteristic patterns of upper-level dynamics of cyclogenesis (a) Cyclogenesis in its initial phase. (b) Strong development with distinct appearance of a cloud-head and dry intrusion features. (c) Severe cyclogenesis phase.

The use of MSG WV imagery in analysis of various representative features of mid-latitude cyclonic systems is considered. Cyclogenesis is often associated with a clear isolated tropopause dynamic anomaly—or positive PV anomaly—in the initial phase, which can be visible in the WV imagery. This cyclogenesis indicator as well as other upper-level precursors of cyclogenesis are shown in Fig. 5e. By applying joint interpretation of WV imagery and dynamical fields (e.g. Fig. 5f), the training material helps operational meteorologists to understand how to identify the main ingredients of a strong cyclone development. This technique is broadly considered in the Interpretation Guide since it provides with a basis of a set of methods for validating numerical model output and improving operational weather forecasts.

Sequences of WV images (Fig. 6) show the power of WV imagery in 6.2 μm channel as a tracer of the crucial elements responsible for occurrence of severe ciclogenesis. The usefulness of such an approach for improving short-range forecasts in an operational environment is considered in Santurette & Georgiev (2005).

4. CONCLUSION

The Interpretation Guide to MSG WV Channels provides with a step-by-step pedagogy for interpreting MSG WV channels' radiances as well as for using these data in understanding meteorological processes. The following principles in analysing WV imagery for operational forecasting purposes are considered:

- To look at an animation of WV images in order to see changes in the dynamical grey-shade features.
- To superimpose various fields of the forecasting environment onto the WV image to gain insight into synoptic ingredients of the atmospheric situation.
- By joint interpretation of WV imagery and dynamical fields, to identify mechanisms responsible for strong development leading to severe weather.
- To keep a critical mind when considering the model fields: Priority must always be given to the observational data and satellite imagery.

The training tool is developed through the Water Vapour Imagery Project of the bilateral cooperation between Météo-France and the National Institute of Meteorology and Hydrology of Bulgaria. It is submitted to EUMETSAT as a contribution of France and Bulgaria to the MSG Interpretation Guide.

5. REFERENCES

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