On the proper use of the satellite imagery for the manual synoptic analysis and diagnosis
-
still a topic of debate

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ABSTRACT

Although satellite images were extensively used for the manual synoptic work since they became available, and a lot of rules and conceptual models were developed in order to allow a physical correct interpretation of these data, there are also in the time being analyses distributed by Met Centres which are obviously based on a over-simplified use of the imagery. That refers especially to surface fronts which are often analyzed according to band-like structures in the imagery only and neglecting the typical signatures in the fields of temperature, pressure and wind by which fronts are physically correct defined. And there is still (or again) the tendency to argue with the satellite imagery alone when diagnosing synoptic features not only in upper levels, but also in the surface field. That is dangerous or even misleading since the baroclinic waves in the upper current which are mainly responsible for the cloud coverage in middle and high levels, often are not connected with surface features for a longer time, but show a distinct relative motion with respect to these features, approaching them, but also overtaking them and moving away. All this is reflected by the changing position of the cloud in the imagery, but cannot be recognized when applying too simple and rigid conceptual models of the relationship between clouds and synoptic systems. In the paper the described facts will be discussed with the aid of some typical examples.

The right way to use the satellite imagery in the synoptic analysis and diagnosis is therefore a continuous comparison of the images with all the other observations and the analyses or forecasts of the dynamically relevant parameters. In doing so, the imagery may provide the proof for the results of the diagnosis made with the aid of the other data, but can give also important hints with respect to inaccurate or even wrong analyses or forecasts.

1. Introduction

Since satellite images became available, they were extensively used for the manual synoptic analysis and diagnosis, especially in data-sparse areas. In doing so, it became obvious very soon that the correlations between the cloud structure and coverage shown by the imagery, with the synoptic features to be analyzed like fronts and pressure systems, are not as simple and unambiguous as suggested by some over-simplified conceptual models contained in the textbooks of Synoptic Meteorology. Therefore a lot of rules and refined conceptual models were developed in order to make the use of the imagery easier and to allow a physically correct interpretation of the satellite data (see, e.g., BADER et al. 1995).

On the other hand, there was the tendency to re-define well known structures like fronts with the aid of the satellite imagery alone. And also in the time being analyses of surface fronts are sometimes distributed by Met Centres which are obviously based solely on band-like structures in the satellite imagery and which are often not in agreement with the typical distribution in the fields of temperature, pressure and wind by which fronts are physically correct defined. In the following some typical examples of those wrong or at least questionable analyses are shown in order to discuss the reasons for the wrong interpretation of the satellite information and to define the way in which this information should be used for analysis and diagnosis.

2. Examples for wrongly analyzed surface fronts and other analysis problems when using the satellite imagery

2.1 A misleading upper cloud band

According to the well-known schemes of fronts, an active surface front should be connected with a cloud band parallel to the front and centred either ahead, above or behind of it. That is surely true for the majority of fronts especially with regard to lower clouds, but must not be valid for every case. Therefore it can be very misleading to infer the position of a surface front from band-like cloud structures in the satellite imagery alone.

As a typical example, Fig.1 shows an IR-satellite image of METEOSAT together with the numerical analysis of surface pressure and two analyses of the surface fronts.The upper analysis was distributed by an European Met Centre. It contains a frontal wave over UK and Ireland and a cold front running from Ireland to the Azores. This analysis, however, is not in agreement with the available surface observations and the model analyses of temperature and equivalent-potential temperature, resp., at 850 hPa. These data suggest a front position further in the west and connecting the two low pressure centres northwest of Ireland and north of the Azores as shown by the lower analysis.

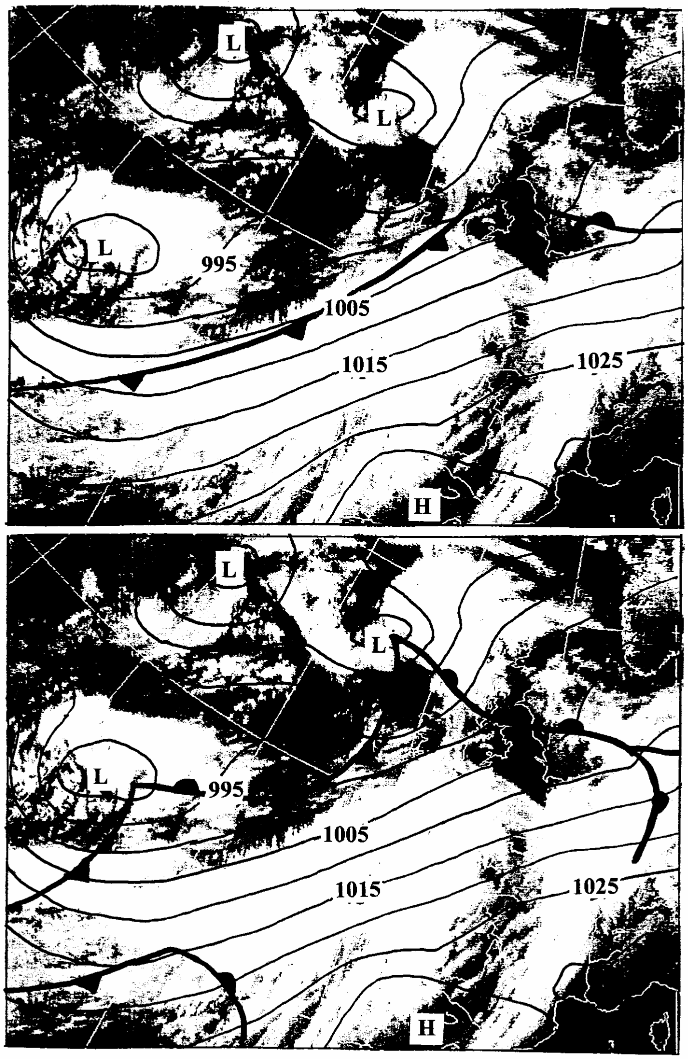

Fig. 1: IR-satellite image of METEOSAT for 12 Dec. 2000, 00 UTC with numerical analysis of surface pressure and two analyses of the surface fronts (see text).

The reasons for the wrong analysis become obvious when looking at the IR- image. It shows a broad cloud band at medium and high levels over the sea areas between Ireland and the Azores producing some rain as indicated by surface observations. The meteorologist responsible for the analysis obviously believed that this cloud band must be connected with a surface front. In spite of that, the fronts analyzed according to the temperature distribution were not connected with higher cloud at all places so that their position was not so clear using the image alone.

According to the numerical analyses, the cloud band can be traced back to a gentle ascent of warm and moist air in the southwesterly air flow in the mid and upper troposphere. The baroclinicity at the mid tropo-
sphere was maximized at the western edge of the band so that the upper jet stream had also its position there. The boundary of this air mass near surface was situated between the Azores and Portugal, i.e. near the southern end of the cloud band.

There was, however, no connection of this frontal zone with the fronts connecting the two low centres further west. Therefore also the normal correlation between surface fronts and the upper jet running distinctly displaced towards their cold side was not fulfilled in this case.The fronts belonging to the lows were rather shallow.

2.2 Misinterpretation of comma-like cloud structures in mid and upper levels

According to baroclinicity and the vertical shear of the tropospheric currents, the synoptic features like troughs and ridges at the different levels often show a different phase speed leading to the approach, but also the overtaking or moving away of an upper structure in relation to a system in the lower troposphere. That is reflected in the imagery by the different movement of the cloud belonging to the features concerned.

The approach of an upper trough or more generally: upper vorticity maximum to a lower frontal zone or already pre-existing wave disturbance may lead to a rapid and strong cyclogenesis. The approach is often made visible by the forward march of a tongue of dry air ("dry slot") aloft in direction of the surface front or low. The mature stage of the cyclogenesis is reached when the dry air arrives above the centre of the low and the inner part of the warm sector of the lower system. The cloud in middle and upper levels ahead of the dry tongue undergoes significant changes during this time and takes on a comma-like shape.

The monitoring of the movement of the dry slot relative to the surface low and the surface fronts is a very powerful tool for the nowcasting of strong cyclogenetic developments which eventually were not simulated by the NWP models (COST 78, 2001). The attempt to use the medium and higher cloud for the analysis of the surface fronts, however, would be very misleading since this cloud moves away from the lower frontal sytem near the centre of the surface low. In addition, the cyclonically bent far end of the cloud in higher levels could be misinterpreted as already existing occluded front whereas the warm sector of the real surface frontal sytsem is still open or the oxcclusion process has just started in this stage.

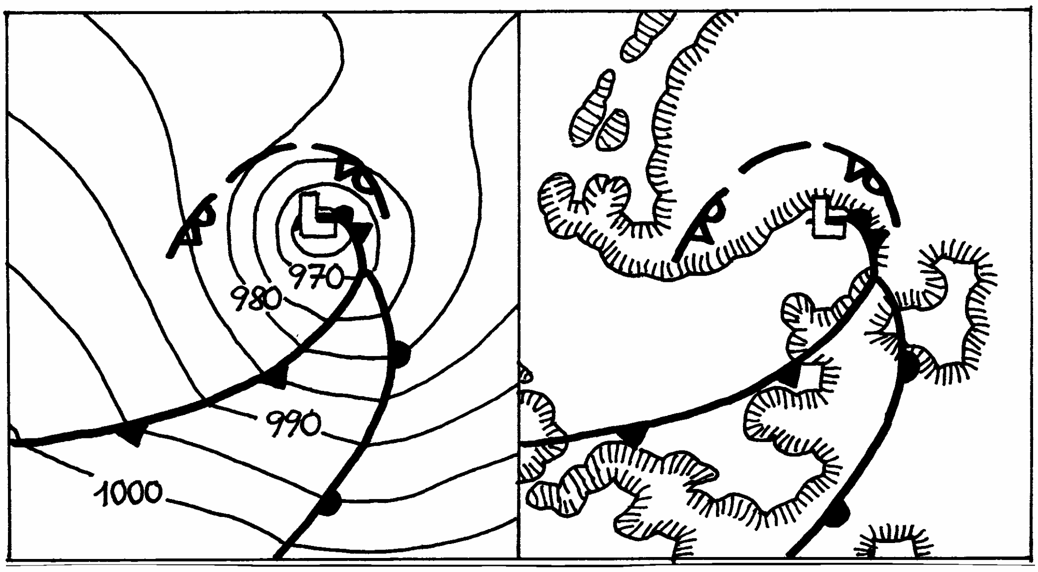

Fig. 2: Analysis of surface fronts from 26 Dec.1999, 06 UTC with isobars of surface pressure (left) and outline of the upper cloud according to the IR-image of METEOSAT (right)

This misinterpreatation has to stated, e.g., for some, meanwhile published surface analyses of the famous storm "Lothar" which hit northern France and southern Germany on 26 December 1999. This low had a position west of Brittany as warm sector cyclone at midnight and deepened by 30 hPa until 06 UTC while quickly moving eastwards towards northern France. During this time the warm sector shrank more and more and the occlusion process started. At the same time, however, a tongue of dry air aloft approached the surface low from northwest and reached the area above the centre and the occluded part of the frontal system in the morning as shown in Fig.2. Accordingly, the higher cloud has been moved away from the centre and showed a strongly cyclonically bent rearward edge north and west of it. This structure was misinterpreted as already existing occluded front wrapping round the centre of the low, but in an area without any indication of a frontal discontinuity in the surface parameters apart from precipitation.

2.3 Cloud structures of upper waves

In cases with strong temperature advection there is not only a change of the wind speed, but also of the direction in the vertical. Then short waves in the upper current may move with a distinct component across the lower air flow. In the case of warm advection in which normally the static stability is increased, these waves often have not much impact on the surface parameters, but they strongly influence the distribution of cloud and precipitation due to the vertical motions connected with them.

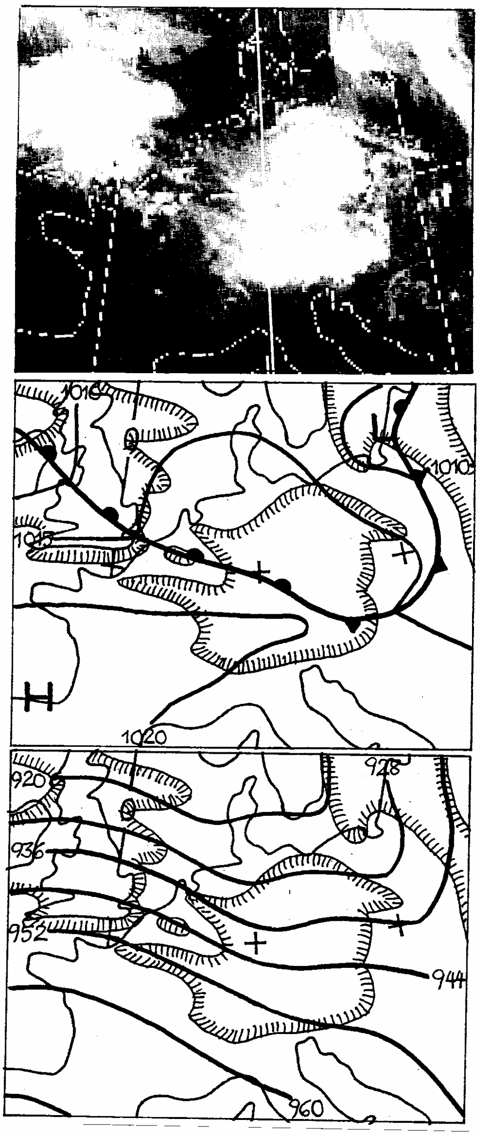

Fig. 3: IR-image of METEOSAT from 25 June 1991, 00 UTC (top) and outline of the higher cloud together with isobars of surface pressure (middle row) and isohypses of 300 hPa (bottom).

The satellite imagery is a very powerful tool to identify and monitor such waves and their behaviour. That is especially important in cases in which they were not really catched by the numerical analyses so that also the model forecasts may become doubtful. On the other hand, an interpretation of the cloud structures belonging to those waves in terms of surface fronts and surface pressure systems would lead to totally wrong analyses. That could happen, e.g., when performing an automatic classification with the aid of the imagery alone.

As a typical example, Fig.3 shows a medium-sized cloud area with some comma-like structure of the highest clouds above central Europe. The image alone could lead to the assumption that this cloud area would belong to a surface low and a partly occluded frontal system. In reality, however, the cloud had a position just above a ridge of high pressure between a low approaching Ireland and the UK and another low over eastern Europe. A surface front crossed the ridge from westnorthwest to eastsoutheast. This was true also for the frontal zone in the mid tropsphere so that the upper current showed the same direction. According to the upper air observations, but also the numerical analysis there was a short wave within this current with the vorticity maximum above northern Germany on the date shown. The comma-like shaped higher part of the cloud area can therefore be traced back to the ascent in the area of positive vorticity advection ahead of this maximum.

It can be shown that this upper wave developed 12 hours before above the region of warm air advection ahead of the warm front of the Atlantic low. According to its very short wave length, it travelled quickly eastsoutheastwards, leaving the area of the low and crossing the ridge downstream. In spite of its impact on the distribution of cloud and precipitation, its influence on the pressure field near surface remained small.

3. Conclusions

Also in the time being, surface analyses are sometimes distributed by Met Centres containing fronts which are obviously based on cloud structures in the satellite imagery, but which are not in agreement with the criteria in the fields of temperature, wind and pressure by which surface fronts are physically defined. These wrong or at least questionable analyses result from over-simplified conceptual models of the connections between fronts and cloud, but also from the general tendency to argue with the satellite imagery alone when diagnosing synoptic features not only in upper levels, but also in the surface field. That is dangerous or even misleading since the baroclinic waves in the upper current which are mainly responsible for the cloud coverage in middle and high levels, often are not at all connected with surface features like fronts or cyclones. If there is a connection, it changes with time, since the upper waves mostly show a distinct relative motion with respect to the surface features, approaching them, but also overtaking them and moving away. All this is reflected by the changing position of the cloud in the imagery, but cannot be recognized when applying too simple and rigid conceptual models of the relationship between clouds and synoptic systems.

The right way to use the satellite imagery in the synoptic analysis and diagnosis is therefore a continuous comparison of the images with all the other observations and the manual or numerical analyses or forecasts of the dynamically relevant parameters. In doing so, the imagery as a model-independent source of information may provide the proof for the considerations on the present physical state and the potential for development made with the aid of the other data, but can also give important hints with respect to inaccurate or even wrong numerical analyses or forecasts. As regards surface fronts, the surface parameters are, of course, decisive for their correct analysis and only the distribution of the lower cloud may be supportive for it.

4. References

BADER, M.J. et al., (1995) Images in weather forecasting, Cambridge University Press
COST 78: Meteorology - Improvement of nowcasting techniques, Final Report (2001), EUROPEAN COMMISSION EUR 19544