FORECAST OF DISPLACEMENT VELOCITY OF THE BASIC SITES OF LARGE-SCALE CYCLONIC CLOUD SYSTEMS AND FRONTAL SECTIONS FROM SATELLITE DATA

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ABSTRACT

The paper treats the automated methods for the calculation of the displacement velocity of the basic sites of large-scale cyclonic cloud systems and frontal sections using geostationary satellite data, suggested by the authors. The prognostic position of the cyclone centre, frontal line, as well as the front and rear edges of frontal clouds are computed. The original methods, provide for automatic frontal analysis whose results are coordinated with the traditional synoptic analysis is used. The relevant results of the investigation and the comparison with the charts of Offenbach and Bracknell Centers are presented. A possibility of calculating the prognostic location of frontal sections is stressed. The method under consideration for calculating the prognostic velocity takes into account the stage of the cyclonic cloud system development under different trajectories of its displacement. The method has been tested for a long time. The paper is supplemented with the demonstration of the working software version.

I. INTRODUCTION

The present work is dedicated to the problems of identification and short term forecast of the velocity of individual sections of large -scale cyclonic cloud systems from data of geostationary satellites. Two stages - analysis of synoptic objects and their forecasting - are isolated in operative synoptic practice.

Frontal systems and accompanying processes associated with cyclonic formations undoubtedly belong to the basic synoptic objects. These objects are often associated with the dangerous weather phenomena, and, therefore, their identification (especially automatic identification) is of importance. The first part of the work is dedicated to this problem.

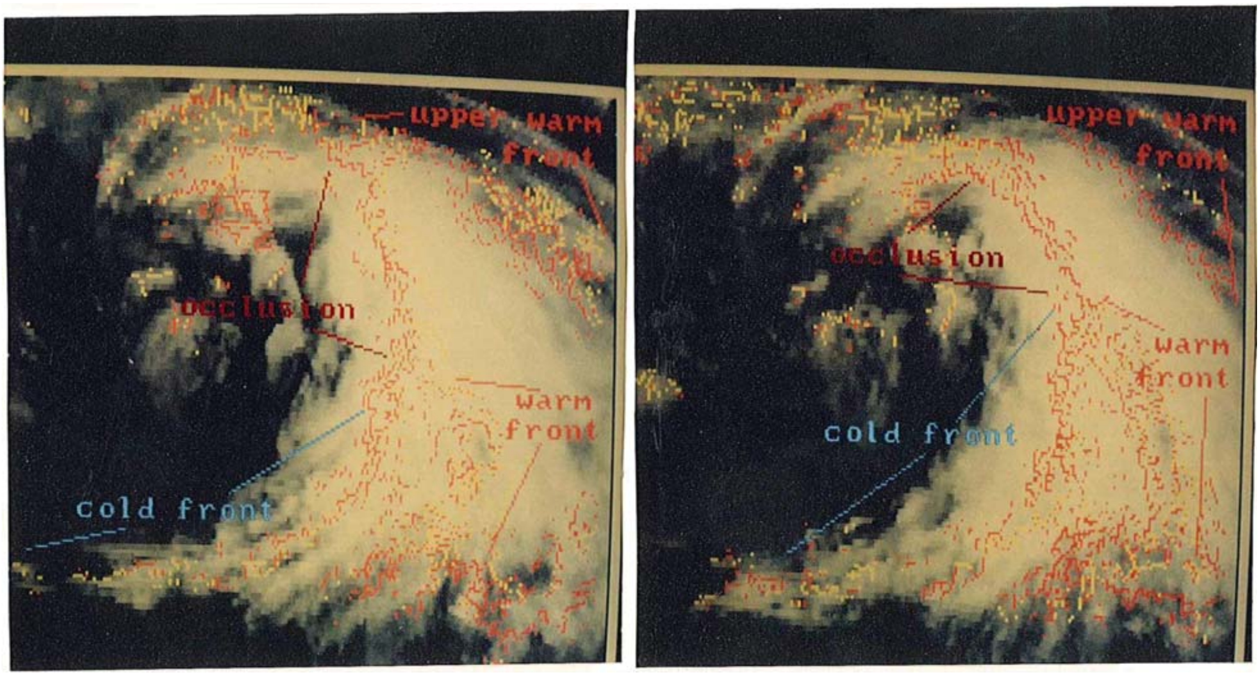
The second part treats the methods of forecasting the position and displacement velocity of individual sections identified in the process of automatic processing and videoterminal analysis of satellite information. Data on the comparison of the proposed methods with the results of the inertial forecasts for various types of frontal zones and individual parts of a cloud system are presented. It is noted the problem under consideration are a subject of routine daily operative synoptic practice.

II. DIAGNOSIS OF FRONTAL SECTIONS

Diagnosis of cyclonic cloud systems from satellite information is treated in a great number of works some of which are systematized and present in / 1 /. The result of these investigations are constantly used by forecasters in their operative work. For example, the characteristic features of cloud cover permitting the identification of frontal sections are described in / 1 /. However, all these methods are based to a great extent on the forecaster's experience. Frontal sections are plotted manually in all Meteorological Centers as before. The task of carrying out frontal analysis, which is solved by forecasters every day, remains complicated as indicated by frontal analysis diagrams set up at various Meteorological Centers and often suggesting different interpretations of one and the same synoptic situation.

The authors have suggested an approach to automatic identification of frontal zones the position of which is determined from multispectral information received from the geostationary satellite METEOSAT /2/. A comparison was performed of the position of frontal sections obtained using the suggested method with the maps of synoptic position analysis transmitted in operative mode from the RTH Offenbach and Bracknell Centers. It is established that the position of frontal zones built in an automatic regime using the new method corresponds to the position of fronts on the operative maps of the European Centers in different situations / 3 /.

The results presented in / 2 / and / 3 / were obtained by the authors with the use of WEFAX format METEOSAT information. However, the analogue WEFAX signal character makes further improvement of suggested method difficult. Therefore, the works were continued using the archive of digital METEOSAT information kindly granted to the authors by the Bracknell Centre. The result of automatic analysis of the frontal zone position from those data support the validity of the above conclusions. By way of example of identification of frontal zones from digital information present Fig. 1 a,b. Automatically identified position of warm and cold fronts, occlusion front and upper warm front are shown in the presented photographs. A comparison of the position of the warm and cold fronts relative to each other in Figure 1 demonstrates the rapprochement of these frontal zones, and, consequently, the process of occluding. Note that the result, obtained in METEOSAT digital data processing also point to a certain possibility to fix the mesoscale structure of the front: curvature of frontal zone, vortex structure, etc., which reflected in Fig la, lb. The use of additional filtering procedures made it possible to draw the form of presentation of the results closer to the routine method of presenting the front in the form of lines, used in meteorological practice.



a b

Figure 1. Result of the automatic frontal analysis of METEOSAT digital information for October 25 1992:
12:00 GMT (a) and 13:00 GMT (b).

Possibility of performing this automatic analysis at the frequency of satellite data receipt (i.e. practically every hour) is of prime importance. This makes it possible:

1. To formulate a new and extremely important problem of operative monitoring of the frontal zones development.
2. To organize the review of the results obtained in the "Movie -Loop" regime, i.e. to trace the dynamics of changes.
3. To use earlier elaborated methods of calculation and forecast of position and displacement velocity of the isolated sections of cyclonic cloud systems based on the study of the dynamic data change.

Evaluation of cyclonic cloud systems.

Processes occurring in the atmosphere constantly modify the cyclonic cloud system. This is reflected in the structure and content of multispectral satellite data and registered by the software of computer processing described in / 2 /. Second photograph presents the results of software operation in processing the digital METEOSAT information of high resolution. As a result, two areas of cloudiness activization and development (they are coloured red) and its destruction and degradation (they are coloured blue) present Fig 2. The coloured image obtained can be used for the qualitative evaluation of the supershort-range forecast of cyclonic cloud system development and displacement. This evaluation is used for the calculation of short-range forecasts.

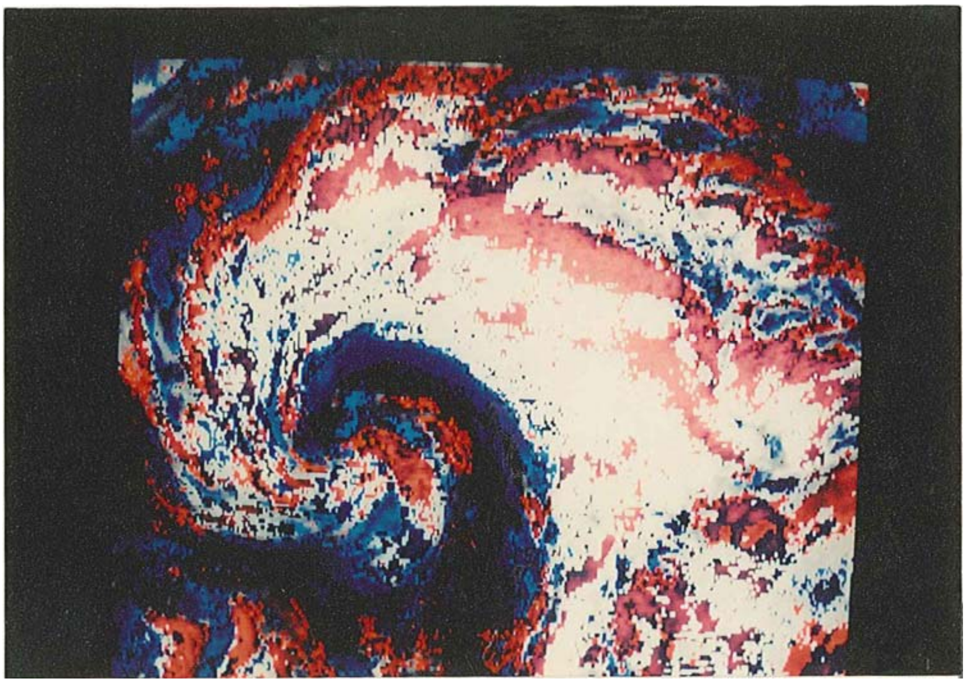


Figure 2. Result of METEOSAT digital information processing (March 8 1991). The area of activization and development (red cover); and destruction and degradation (blue cover) of cloudiness are noted.

III. FORECAST OF DISPLACEMENT VELOCITY OF THE BASIC SECTIONS OF CYCLONIC CLOUD SYSTEMS.

It is established in / 5 / that the displacement velocity of cyclonic cloud systems depends primarily upon the stage of cyclonic vortex development (the stages are described in WMO Technical Note No. 124 / 4 /) and the trajectory of its displacement. In the young cyclone, individual sections of a cloud system move with acceleration during the period of formation of its cloud spiral. The velocity at all sections of the cloud vortex decreases beginning with the stage of developed cyclone. The greatest slowing down of cloud system movement occurs in the filling cyclone, and the velocity decreases faster from the front of the cloud spiral that from its back. Regularities of changes in the velocity of the basic sections of cloud systems are reduced to an increase in the velocity in the frontal part of diving and southern cyclones at the initial stage of cloud system development, and to a considerable speed decrease from the stage of maximum development to the stage of filling up.

Velocity calculation is recommended to be carried out for the following sections of cloud systems: areas of the greatest curvature of the spiral and its frontal and back edges. These region have got certain synoptic meaning. The area of the greatest curvature mainly corresponds to the centre of cyclone at the 500 hPa level, while the frontal and back edges of the system correspond to the similar sections of frontal zone. Computation of the velocity of these sections is necessary for the time of the flowing of frontal cloudiness over the point of forecast and its moving away. It is found out that the most optimal time period between satellite data used for calculations amounts to 4 - 5 hour.

The authors have developed a specialized system of videoterminal processing of satellite data, realizing the procedure of calculating the velocity of the sections of cyclonic cloud systems in an intaractive regime. An example of the speed calculation and forecast position of the object of interest are shown in Fig. 3.

Forecast quality evaluation was carried out by way of comparison of the methodical velocity of cloud systems with the inertional method of velocity calculation. The result of comparison are presented in Tabl 1. Absolute and relative forecast errors for the velocity of frontal edge of cloud systems were found to be more than those for the back edge. Methodical forecast errors were, on average, by 30% less than those of the extrapolation one. The least absolute and relative errors were observed for occlusion fronts. For example, methodical forecast errors were by 35% less than those of the extrapolational one and account for 12h-forecast $\varepsilon = 0.50$ and $\delta = 6.0 - 7.7$ km/h. Extrapolational velocity forecast have got the greatest number of errors for cyclones moving from north ($\varepsilon = 2.2$) and less errors for western cyclones ($\varepsilon = 0.87$). Errors of the methodical forecasts of the velocity of these cyclones are by 25% less, on average.
Using inertial and methodical velocity, the time of cloud system approachment to Moscow was forecasted in operative regime. Comparison of the prognostic (tp) and actual (tf) values of the time periods computed as $dt = | tp - tf |$ (Tabl 2) made it possible to come to the following conclusions. Inertial forecast passage does not result in significant improvement. In forecasting the time period of warm front approach for the current day the consideration for the coefficients is insignificant, and in forecast for the coming night (for 24h) the introduction of the coefficients decrease dt by 3.0h to 1.4h. The inclusion of the coefficients is most important on outing the southern cyclones.

Tabl 1. Absolute (δ) and relative (ε) forecast errors of the inertial and methodical velocity for different sections of cloud systems, frontal cloudiness, and cyclonic cloudiness moving along different trajectories.

Tabl 1	forecast for 12 h				forecast for 24h			
	intertial		methodical		intertial		methodical	
	δ	ε	δ	ε	δ	ε	δ	ε
Cloud system part:								
frontal edge	12.0	0.80	6.7	0.51	11.1	0.76	8.7	0.61
rear edge	9.2	0.59	5.3	0.34	8.6	0.54	7.6	0.48
Kind of the front:								
cold	11.0	0.79	7.7	0.53	9.6	0.39	9.6	0.39
warm	12.0	0.78	7.7	0.50	10.1	0.75	6.5	0.49
occlusion	10.1	0.88	6.0	0.50	10.4	1.14	7.0	0.77
Cyclon trajectory:								
southern cyclone	11.1	0.92	8.7	0.72	5.6	1.90	0.33	0.11
western cyclone	10.3	0.87	7.4	0.62	8.7	0.75	7.08	0.53
northern cyclone	12.2	2.20	5.4	1.00	16.6	2.50	13.30	2.00

Tabl 2. Errors of the prognostic time of cloud system approach to the point of forecast for inertial (dti) and methodical (dtm) forecast.

Tabl 2	forecast for 12h		forecast for 24h	
	dti	dtm	dti	dtm
Part of Cloud system:				
frontal edge	1.8	1.3	3.1	2.7
rear edge	2.3	1.6	4.7	2.8
Kind of the front:				
cold	2.7	2.7	2.5	3.1
warm	1.5	1.2	3.0	1.9
occlusion	3.0	1.1	5.1	3.9
Trajectory of the cyclone:				
southern cyclone	3.4	1.4	2.0	0.7
western cyclone	1.8	1.9	3.5	3.3
northern cyclone	1.6	1.0	3.6	3.3

It should be noted that the forecast of velocity is more accurate for the rear edge of cloudiness than for frontal one. Inclusion of the coefficients specifies the cloud system edge approach to a point; this time differs from the actual one by 1.5h and by 2.8h in the forecasts for the current day and for the night, respectively. Forecasts of the velocity of displacement different fronts are equally reliable. Methodical forecasts improve the forecast of the time of passage of occlusion fronts and warm fronts. Vortices having westward trajectories are forecasted more accurately. Methodic forecast improves the extrapolational forecast of the cloud system displacement velocity by 33%, on average.

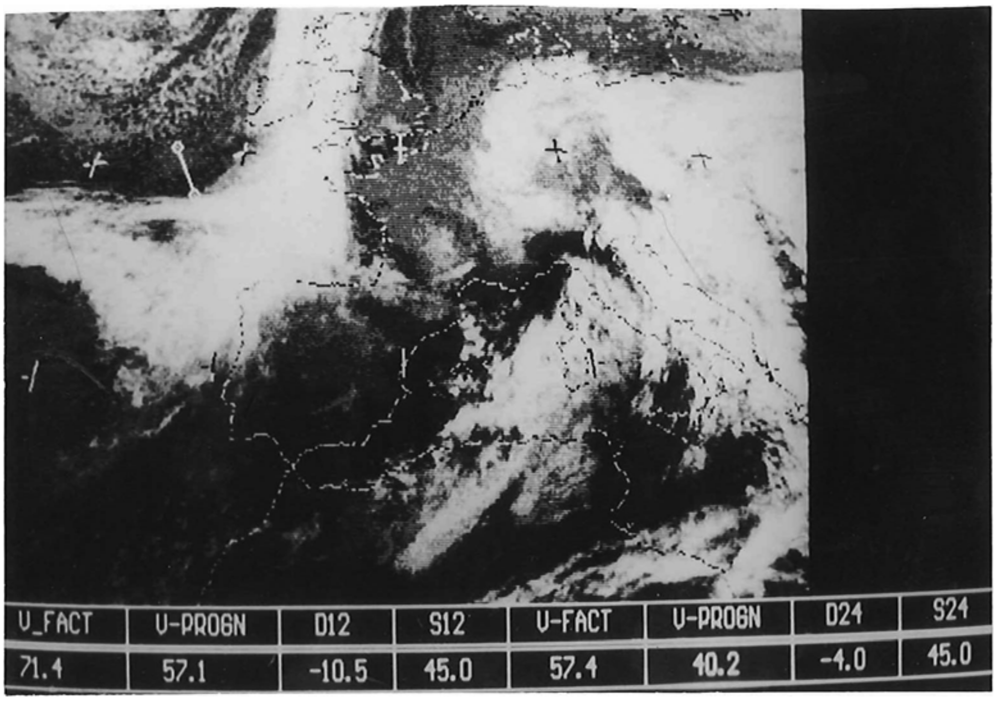


Figure 3. Result of calculation of the displacement velocity and position of the rear section of a cyclonic cloud system near the point of occlusion.

CONCLUSION

The suggested satellite data processing system makes it possible:
- to carry out the analysis with the purpose of automatic identification of frontal sections of cyclonic cloud systems and detection of the sections of activization and destruction of the cyclonic system;
- to prepare the short-range forecast of individual sections of cyclonic cloud systems and determine their prognostic position.

The authors also formulated the problem of organization of a system for operative monitoring of the frontal zones development. Considering this system extremely important in the scientific and practical aspects, the authors will be glad to study any remarks and to set forth their ideas on possible practical realization of such system.

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