CLOUD MOTION WIND EXTRACTION FROM GOMS DATA

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ABSTRACT

Satellite cloud motion winds (CMW) are planned to be operationally produced from sequential GOMS IR window images in the Hydrometeorological Centre (HMC) of Russia. This paper describes the technique for CMWs derivation. The interactive procedure for target cloud selection and the cross correlation method for calculation of target displacement are applied. The CMW height assignment is performed using measured and absolutely calibrated IR temperatures (which correspond to the cloud top temperatures) combined with "nearest" atmospheric temperature profiles from the HMC data base. There are two alternative approaches for absolute calibration of GOMS IR data: the first uses the absolutely calibrated NOAA (METEOR) IR measurements which are collocated with GOMS data; the second employs regression relation between measured GOMS counts and calculated radiances and is similar to known ESOC procedure. To improve the quality of CMWs the initial guess for them is extracted from HMC prognostic wind fields. The described scheme is realised on PC AT 486/50 and its efficiency is evaluated in experiments with real METEOSAT IR digital images. These experiments demonstrate the reliability of CMW estimates produced from METEOSAT images. The HMC will be implementing this scheme after the adjustment to real GOMS data.

1. INTRODUCTION

The Geostationary Operational Meteorological Satellite (GOMS) as the component of national observation space - based subsystem is planned and managed by the Russian Federal Service for Hydrometeorology and Environment Monitoring (ROSHYDROMET).

Technological research and development to ensure meeting of ROSHYDROMET environmental measurement requirements by GOMS spacecraft are implemented by All-Russia Research Institute of Electromechanics (VNIIEM). VNIIEM is also responsible for integration of on-board instruments and manufacturing the GOMS series of satellites. Following post launch checkouts ROSHYDROMET through its technological centres and institutions assumes responsibility for GOMS operations.

The major mission of GOMS is to provide continuous observations of the state of atmosphere and in particular the observations of atmospheric wind fields, which are used in the numerical weather-prediction. National plans envisage the development and operation of an integrated environmental satellite system by the end of 20th century comprising both low - orbit and geostationary satellites.

GOMS is designed as three - axis stabilized spacecraft and will be launched and located above the Equator at the approximate position 76° E in the nearest future. Its missions and services including the dissemination of output data products and relevant meteorological information to various domestic and foreign users will provide an input to the WMO Global Observing System and the World Weather Watch Programme.

The major technical characteristics of GOMS and its missions, services and products are described briefly in (Karpov,1991) together with the review of GOMS ground segments and cloud motion winds (CMW) derivation system outline.

The first version of the GOMS ground processing system and operational package (software) for CMW retrieval were developed on the basis of dedicated minicomputer complex used for imagery realtime ingest and preprocessing and on the ES mainframe computer combined with special minicomputer for interactive analysis and visualisation. To date these facilities are being replaced by distributed processing architecture including microcomputers.

This paper describes CMW extraction procedure from GOMS data which was developed in the Hydrometeorological Centre (HMC) of Russia. Section 2 of this paper describes the experimental CMW derivation system. Section 3 deals with the procedures for absolute calibrat ion of GOMS IR channel. The results of CMW extraction methods and calibration procedures testing in trials with real Meteosat IR images are discussed in section 4.

2. DESCRIPTION OF CMW DERIVATION SYSTEM

At present time cloud motion winds are produced routinely by satellite operators from NOAA, EUMETSAT, JMA, IMD, see (Merrill et al, 1991; Schmetz et al, 1992; Uchida, 1991). The winds at two levels are planned to be operationally produced from successive GOMS IR images at the HMC. The method of CMW derivation which will be performed, for CMW derivation is described in (Anekeeva et al, 1989).

Here we give some details of revised PC version of GOMS data processing system prepared for CMW derivation. The flowchart and basic processes of CMW derivation in PC processing package are as follows : manual selection of segments or target windows in IR image display for further processing; animation of time-sequential images; target cloud selection and tracking within search area for the determination of cloud-tracers coordinates on the pair of consecutive images; CMW values assessments; cloud top height assignment; quality control.

The procedure of CMW derivation is interactive. Three sucsessive IR and one VIS images are used for target cloud selection and tracking. The operator examines three successive IR images at 30-min intervals and selects target window and fixes a search area. The tracking of images is based on pattern-matching and utilizes the cross-correlation coefficients calculations for possible displacements of the target window (32*32 IR pixels array) in the larger search area (64*64 IR pixels array). The FFT technique is used for the acceleration of correlation coefficients calculations. For image navigation the predicted altitude and orbital data together with data on scanning geometry, data on land marks and Earth horizon data from IR full disk are used.

Cloud top height assignments are being made interactively. For the low-level winds the representative height is fixed. It will be determined by the operator on the basis of statistical fit between CMWs and radiosonde winds similar to (Uchida, 1991). Due to known difficulties in assignment of correct height for the high level winds especially when the target is semi-transparent cloud, two different procedures are implemented. In the first one, the derivation of low level wind heights is based on the a priori prepared statistical height assignment table.

Alternatively, the operator uses the forecast or analysis temperature profiles from HMC data base as ancillary data and determines the pressure at cloud top level by comparison between the IR cloud top brightness temperature and collocated temperature profile. Such procedure is routinely used for cloud top height assignment on the basis of the IR imagery from polar orbiting satellites. In the case of high semi-transparent tracers, the specific correction is performed in accordance with (Mosher, 1976).

Normally, the CMWs are subject to manual quality control and filtering. The quality of CMWs is estimated through several steps. First of all the two vectors produced from two pairs of adjacent images (with the image triplet) are compared with each other. All vectors are rejected for which the deviations in speed and direction exceed certain limit. After that the vectors are compared versus "true" values (the latest available wind field forecast or analysis from HMC database). The winds which are in 1arge disagreement with true values are removed.

3. CALIBRATION OF THE GOMS IR - WINDOW CHANNEL

Absolute calibration of the GOMS IR data is not performed onboard the satellite. In many meteorological applications (like CMW height assignment and SST estimation) the knowledge of measured IR quantities is required. Therefore the design of effective calibration procedure for the GOMS IR data is necessary.

Similar problems exist for METEOSAT, GOES, GMS radiometric channels. According to (Gartner, 1988; Schmetz, 1989) the current ESOC procedure of METEOSAT IR channels absolute calibration is based on the regression relationship between calculated radiances at the top of the atmosphere and associated onboard counts.

The calibration of GOMS IR data is foreseen utilizing two alternate approaches : the first one (procedure I) uses the absolutely calibrated NOAA (METEOR-3) IR measurements which are collocated with GOMS data; the second (procedure II) employs linear regression relationship between measured counts and calculated radiances similar to the ESOC procedure.

The theoretical background of procedure I (which is called isosecant method) is given in (Berio et al, 1982). The method is based on the similarity between radiances measured by IR radiometers on geostationary and polar-orbiting satellites due to the fact that spectral responce functions of some channels of both radiometers are sufficiently close to each other. The following measurements are supposed to be used in this procedure: the GOMS IR window channel and METEOR-3 IR radiometers channel 10.5-12.5 µm (the channel of NOAA HIRS-2 instrument).

The subsequent steps of isosecant method are as follows : derivation of regression relationship between radiances Rg from geostationary satellite and Rp from polar orbiting satellite in the form $Rg = A * Rp + B$ on the basis of synthetic measurements for the same scene; the determination of calibration relationship between radiances Rg and measured counts C in the form $Rg = D * C + E$ on the base of quasi-coincident and simultaneous isosecant observations from both satellites.

The second calibration procedure consists of the following : selection of cloud free sea surface fragments and fragments with cold clouds and a priori known cloud top temperatures and attribution of related counts on the IR image; calculations of theoretical values of radiances at the top of the atmosphere using fast radiative transfer scheme for selected fragments; formation of learning sample of pairs "calculated radiance - measured count"; determination of calibration coefficients; control of calibration quality.

The fast radiative transfer scheme from (Weinreb & Hill, 1980), spectral response function of IR channel (see fig.l) and temperature and humidity profiles from HMC database as ancillary data are used for radiance calculations. Two kinds of relationships are foreseen : $R = A * (C - C_0)$ and $R = B * C + D$ where R = measured radiance, C = measured count, C_0 = count at space view, A,B,D = calibration coefficients. The choice of suitable formulae depends on the learning sample. If we have some pairs related with cold c1ouds it is possible to use the second equation.

4. EVALUATION OF CALIBRATION PROCEDURES AND CMW EXTRACTION SCHEME

The described methods and software for GOMS data processing on PC-based equipment (AT 486/50) have been developed and evaluated in trials with real METEOSAT IR data. To receive high resolution IR images from METEOSAT the HMC experimental receiving station (PDUS type) has been exploited during the period November 1992 - July 1993.

For the validation of the procedure II the data for learning sample were collected on the basis of analysis of 7 IR image fragments (512 x 512 pixels) covering the Meditteranien Sea and Atlantic for 7 days in December 1992. The total number of collocations (R,C) in learning sample is 44. Theoretical values of radiances were computed with the radiative transfer mode 1 (Weinreb & Hill, 1980) and spectral response functions shown in fig.1 (Annexe to METEOSAT-5 calibration rep., 1991) using collocated temperature / humidity profiles from HMC database.

The results of performing the procedure II are shown in fig.2. Solid 1ine is the derived calibration equation with normalised calibration coefficient A = 0.664 (mW/(m*m*sr*cm^{-1})). The dashed 1ine shows current ESOC calibration line with A = 0.63076. The points in fig.2 depict the elements of learning sample. There are two sets of points with two centres of gravity related to sea surface and cold clouds.

The maximum difference between radiances computed with both calibration equations does not exceed 0.7 mW/(m*m*sr*cm^{-1}) that is not more than 1% of sample mean value of measured radiances. This experiment validates the procedure II as applicable to calibration of GOMS IR data.

With the described procedure the experimenta1 CMW extraction has been performed on the basis of three successive IR images from METEOSAT-5. Fig.3 shows an example of the CMW product as obtained for 23.09.1992 at 15.00 GMT and region of Atlantic. Comparison of CMW retrievals versus collocated wind field analysis data demonstrates the reliability of CMW estimates.

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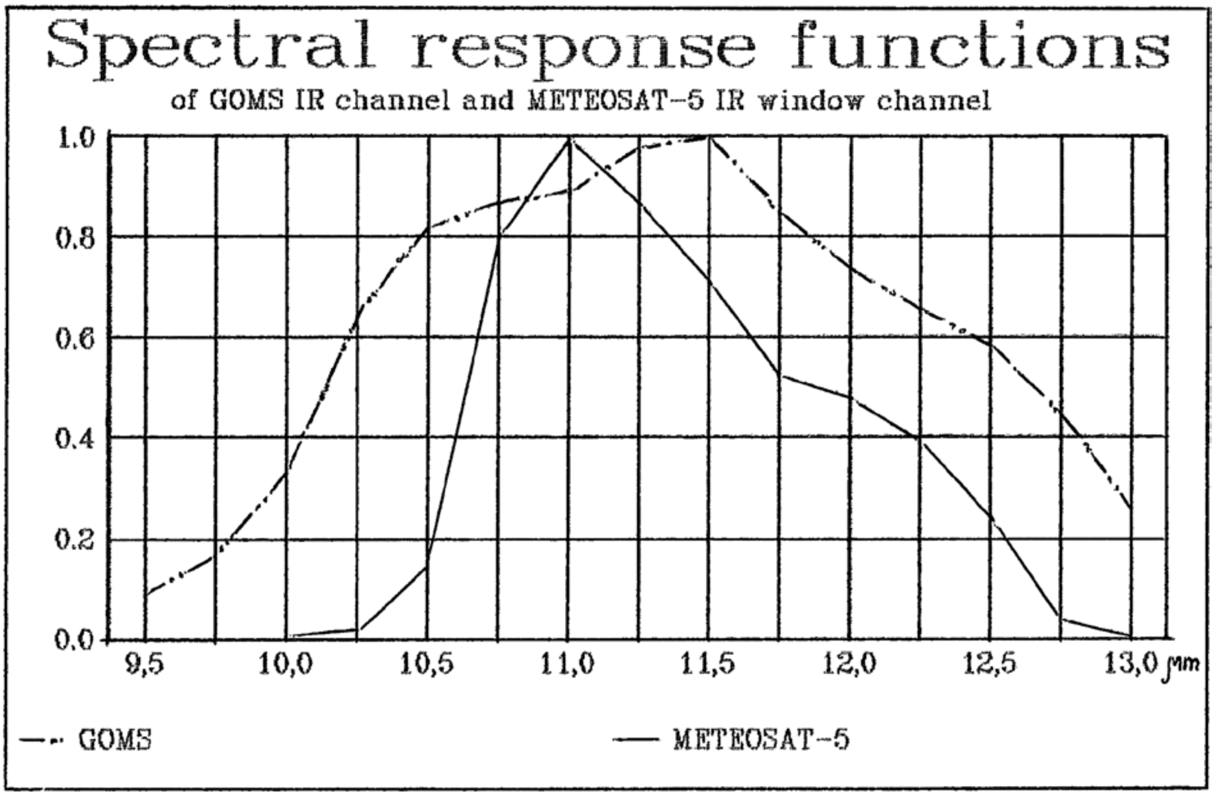
Spectral response functions
of GOMS IR channel and METEOSAT-5 IR window channel
1.0
0.8
0.6
0.4
0.2
0.0
9,5
10,0
10,5
11,0
11,5
12,0
12,5
13,0 μm
GOMS
METEOSAT-5

Fi g 1

THE RESULTS OF IR-WINDOW CHANNEL CALIBRATION (METEOSAT-5)

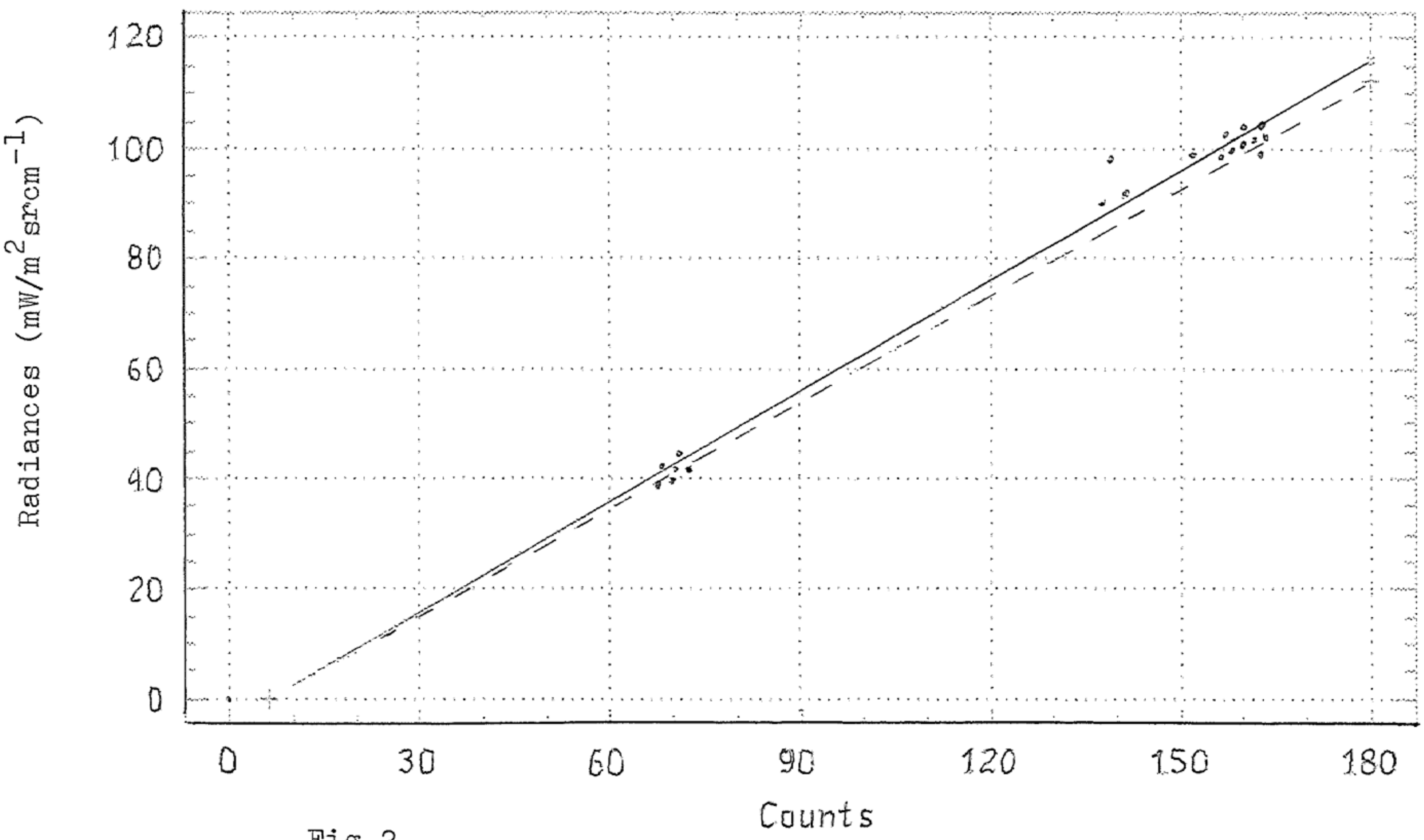

Fig 2

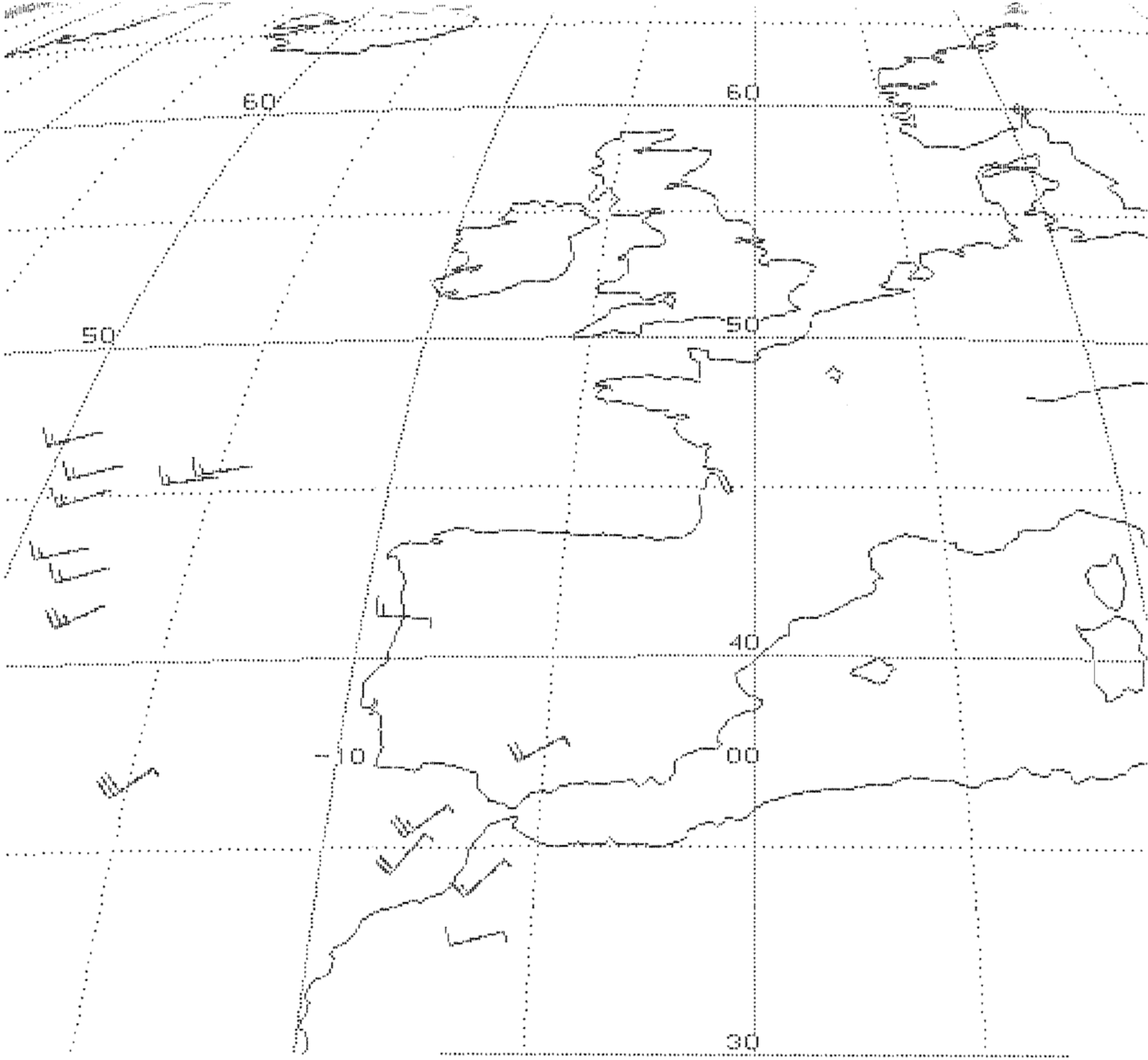

Fig. 3