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Use of aircraft remote sensing in marine chemistry and pollution research with particular reference to the dumping of TiO_2 waste solutions

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Summary

An experiment "chemical marine pollution" has been performed in the German Bight to investigate possibilities for determining chemical parameters from the sea surface. As an example, the continued dumping of waste solutions from titanium dioxide production northwest of Helgoland Island was taken. Here, distinct color variations in sea water can be observed. The relevant chemical processes have been monitored by Deutsches Hydrographisches Institut for a number of years now by means of research vessels. The flight campaign on 25 August 1976 is described, the results of simultaneous measurements at sea as well as pictures and data from remote sensing are presented, and examples for digital image processing are given. Experience from the experiment

can be taken as valuable input for future modified flight campaigns as well as basis for later satellite use. Shortly, a LANDSAT 1 satellite picture is discussed, where traces are discernible in the investigation area that may be related to the same dumping activities.

Introduction

For a number of years now, remote sensing has gained in importance in its application for monitoring environmental changes on earth. Particular progress resulted from the images transmitted by the US satellites LANDSAT 1 and 2 (formerly called ERTS). Preparative to the future utilization of the European SPACELAB, the German Bundesministerium für Forschung und Technologie (Federal Ministry for Science and Technology) has initiated and funded a project "Erdwissenschaftliches Flugzeug-Meßprogramm" (Geoscientific Aircraft Measuring Program). Within this program, selected test areas along the coasts and in interior parts of the Federal Republic were recurrently surveyed during 1975 and 1976, using a specially equipped research airplane. A substantial number of scientific teams had developed the experiments and carried out the necessary ground truth measurements during the campaigns (SCHROEDER 1974).

Design of Experiment

In the framework of its objectives for monitoring marine pollution attributed by federal legislation, Deutsches Hydrographisches Institut (DHI) participated in the "Flugzeug-Meßprogramm". For this purpose, a special experiment "chemical marine pollution" was designed and carried out by the author. Test object was the regular dumping of waste

solutions from the production of a titanium dioxide factory near Nordenham (Northern Germany). Starting May 1969, these solutions are introduced into the North Sea by two special tankers with a quantity of about 1800 t per day. The dumping area is a rectangle centred about 14 nautical miles northwest of Helgoland Island. The solutions contain mainly iron sulfate, sulfuric acid and titanium oxide sulfate. To obtain maximum initial dilution, the waste solutions are pumped directly into the propeller water of the tankers at medium speed. Under alkaline and oxidizing conditions prevailing in the sea water in this area, chemical reactions between the substances introduced and the water occur. These are characterized by conspicuous colors: the green divalent iron is oxidized to reddish brown trivalent iron, which then rapidly precipitates as colorful red-brown oxide hydrate, whereas dissolved titanium forms similar white colored oxide hydrate.

These processes seemed to offer a simple pathway for testing the suitability of presently available remote sensing techniques for determining chemical parameters from the sea surface. Any possibilities for future regular monitoring of this dumping area by means of remote sensing were also to be investigated.

Flight Campaign and Ground Truth

The flight campaign for this experiment was conducted on 25 August 1976, at very favorable weather conditions. During the dumping activities, the acid waste tanker was repeatedly and at different altitudes passed and surveyed by the research airplane. The aircraft was a DO 28 "Skyservant" operated by Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR, German Research and Testing Institution for Aeronautics and Spaceflight) from its Oberpfaffenhofen research center. The aircraft was equipped

with a number of multispectral cameras recording on black-and-white and false color film, a photogrammetric camera loaded with color negative film, and particularly with a eleven-channel-scanner. At the same time, the inorganic chemistry group of DHI was, together with other scientists, on board of Research Vessel "Gauss" of DHI working in the same investigation area to obtain the necessary "ground truth" data, i.e. to perform chemical and physical measurements directly in and near the sea water surface. Parameters determined were mainly dissolved and freshly precipitated iron, acidity (pH value), temperature and salinity. These parameters were determined continuously from the moving ship, taking advantage of a method for Fe and pH developed by WEICHART (1975) and relying on his previous results. For calibration, some water samples from the surface were also taken. The final goal of the investigation was to try to correlate these analytical data from sea water obtained by classical and more modern chemical procedures with the images from the sea surface recorded by photographic and scanning techniques with the aircraft. The eleven-channel-scanner was capable of producing eleven similar pictures of the same object at the same time using eleven channels with relatively narrow spectral bandwidth covering the visible and infrared region of the spectrum. By this way, the eleven individual pictures display differences in the spectral properties of the object.

Evaluation of Data and Digital Image Processing

Further scientific evaluation of data and pictures recorded in this experiment is presently underway. The images of the scanner are stored as digital picture element patterns (gray values according to lines and rows) on data tapes for the individual spectral channels. This makes them ideally

suited for further digital processing; for this purpose and within the Program, DFVLR has designed and assembled a special and advanced electronic computing system "DIBIAS" (digital image analysis system) in its research center at Oberpfaffenhofen. The system is designed for interactive use by the experimenters themselves who can not only digitally process their pictures but also display them on a color screen. Finally several different peripheral units are at hand for producing an output of images on paper or on slide, black-and-white or color.

A few examples for different digital processing capabilities with DIBIAS are to be presented *). The present aim was to test the computer programs available at Oberpfaffenhofen for their suitability for image processing in respect to the measurement of chemical data from the sea surface, particularly related to marine pollution phenomena. A first approach was to use combinations of seemingly natural colors taken from selected spectral channels, in order to display differences in spectral signature of the objects. Next, quotients between characteristic spectral channels were calculated, using formulas with suitably selected coefficients. Contrast enhancement was achieved by using stored or specially generated color wedges, thereby enabling the experimenter to better evaluate the pictures. The wake of Research Vessel "Gauss" repeatedly crossing the trail of the dumping tanker is very well visible in the thermal infrared

*) The presentation is mainly relying on large format color slides directly produced by DIBIAS. Owing to the very expensive duplication of color photographs, the author regrets not to have been able to include these pictures within this paper.

channel of the images. With adequate contrast enhancement, this secondary image is superimposed to the picture calculated first. This serves to a direct mapping of the course and path of "Gauss" at the time when the continuous measurements were taken. Sections of images from the low altitude surveys, when using optimal contrast enhancement by "function memory" programs, reveal a high degree of plasticity, with a very detailed fine structure of the fresh dumping trail. With these data, further investigations into the dynamics of the mixing process of waste solutions with the sea water may be interesting. Results of such studies are in turn needed for the purposes of international conventions on dumping. A program is available for micro-densitometry of the grey value distribution following an arbitrarily selected curved line in a suitably generated image. This can be used for simple and easy construction of profiles for correlation with continuous chemical measurements in sea water. Subtracting one channel from the other with subsequent display of the grey value distribution in the form of colored equidensites is well suited for enhancing the visible contrasts, particularly when applied to the images of the later stages of diffusion of the waste solution trails.

Satellite Imagery

Obviously, a search for imagery from LANDSAT 1 and 2 satellites depicting the same area northwest of Helgoland appeared to be of interest, to look for traces of the dumping of acid waste solutions. However, there seems to exist only a surprisingly small number of LANDSAT images from the North Sea and in particular the German Bight, some of them still less useful due to a high degree of cloudcover. At least two very suitable pictures did not show any trace

of the dumping; it was possible to show from the files of the dumping operations kept at DHI that in these cases, accidentally dumping had not taken place for that particular time and a few preceding days. One, partially cloud-covered image transmitted by LANDSAT 1 on 5 October 1973 displays some inconspicuous traces at the expected location. With some degree of speculation, these traces may be related to the titanium dioxide wastes dumping. A suitable section of the LANDSAT image was digitally processed by best possible means. From the files of DHI, evidence for several dumping operations during this period can be given.

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References

SCHROEDER, M. (Comp.), 1974: Missionsdefinition für ein erdwissenschaftliches Flugzeugmeßprogramm. Report, DFVLR, Oberpfaffenhofen

WEICHART, G., 1975: Untersuchungen über die Fe-Konzentration im Wasser der Deutschen Bucht im Zusammenhang mit dem Einbringen von Abwässern aus der Titandioxid-Produktion. Deutsche Hydrogr. Zeitschr. 28, 49...61