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Fast temperature changes in the upwelling area along the NW coast of Africa[1]

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Data from a scanning radiometer in the infrared and from a television camera which was sensitive in the visible part of the electromagnetic spectrum were applied to derive temperature patterns over cloud-free regions. Imageries from the Nimbus IV satellite were colour enhanced to detect patchiness and fast variations in the distribution of sea surface temperature.

The analysis of satellite information indicated very fast changes of sea surface temperature over large areas which could not be surveyed synoptically with conventional ship measurements.

Introduction

The purpose of this paper is to give a qualitative estimate of possible variations and the patchiness in sea surface temperature in the upwelling area along the NW Coast of Africa. The importance of such an investigation is demonstrated by the presence of very complicated surface structures of temperature, nutrients, and chlorophyll in the upwelling region (Weichert, 1970; Ballester, et al., 1972; Szekielda, 1972).

The fast response of sea surface temperature gradients over a large area to changes of the wind field was observed for the first time with the Nimbus II and III satellites in the upwelling region along the Somali Coast. Düing and Szekielda (1971) made a statistical comparison between the wind speed and the development of horizontal temperature gradients. As a result it was concluded that the response time of the development of surface currents onto the wind stress is in the order of 2–4 days, which is a surprisingly fast response of the vertical transport onto the wind. Unfortunately, almost no data are available to estimate the surface temperature changes as a function of the wind systems along the NW Coast of Africa.

Data treatment

Temperature patterns in the test site along the NW Coast of Africa were detected with the Temperature Humidity Infrared Radiometer (THIR) from the Nimbus IV satellite. A period between 18 April and 6 May, 1970, was selected when noise level of the instrument was low. Also the cloud coverage showed a minimum at this time, resulting in a repeated coverage for the temperature in the upwelling area. Temperature was recorded in the atmospheric window channel at 10·5 µm and 12·5 µm. The ground resolution at the subpoint was 8 km from an altitude of 600 nautical miles. The water vapour at 6·7 µm was also used to give qualitative information about the moisture content of the upper troposphere and stratosphere as well as the location of jet streams and frontal systems.

Cloud-free conditions were detected with the Image Dissector Camera System (IDCS) flown on the same satellite. The daytime pictures were taken simultaneously when THIR recorded temperature patterns. A complete timing cycle of one frame needed 208 s (Werner and Branchflower, 1970) and consisted of 800 scan lines per one entire image dissector video frame.

The ground resolution from the IDCS was approximately 2 nautical miles at the nadir with a decrease to 5 nautical miles near the edges of the field of view. This indicated that the IDCS in connection with the THIR is a good qualitative indication of whether a structure in the infrared data is produced by the sea surface temperature or by cloud features.

Results and discussion

The area covered in the following analysis lies between the Canary Islands at 28°N and Cape Verde (Dakar) at 15°N. Typical samples of the original black and white infrared image and the television picture are displayed in Figures 1 and 2. The colour enhancement was made from the black and white

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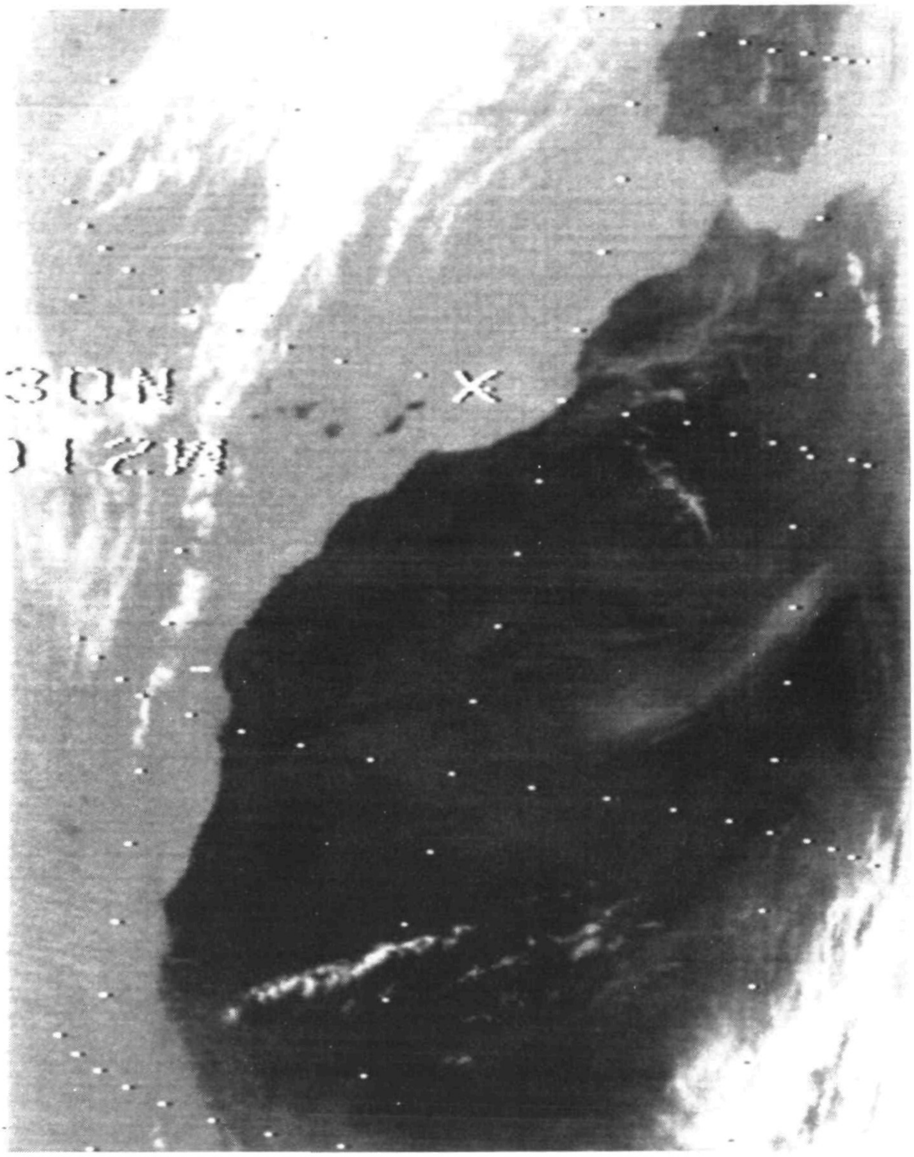

Figure 1. Infrared recorded imagery along the NW Coast of Africa between 30°N and 5°N. The continent and the Cape Islands appear black. Clouds are displayed in white. Data obtained with Nimbus IV Temperature Humidity Infrared Radiometer (THIR) on 16 April 1970, in the atmospheric window at 11·5 μm.

pictorial display of the IDCS and THIR with a density slicing machine where grey levels were displayed in colour on a television screen. The colour scale, black–purple–orange–yellow–green–blue–white showed the black body temperature from warm (black) to cold (white). The low albedo was enhanced to be black in the television image and high albedo was displayed in white.

Figure 3 shows the IDCS picture and the infrared image from 18 April, 1970. In the IDCS picture extremely low albedo was measured along the coast of NW Africa as indicated by the dark area. Rio de Oro is visible by the coastal region displayed in blue, green, and yellow. Slight gradient in the albedo was measured offshore as indicated from the colour change purple to yellow. However, no sharp gradients are visible in the albedo, indicating cloud-free conditions.

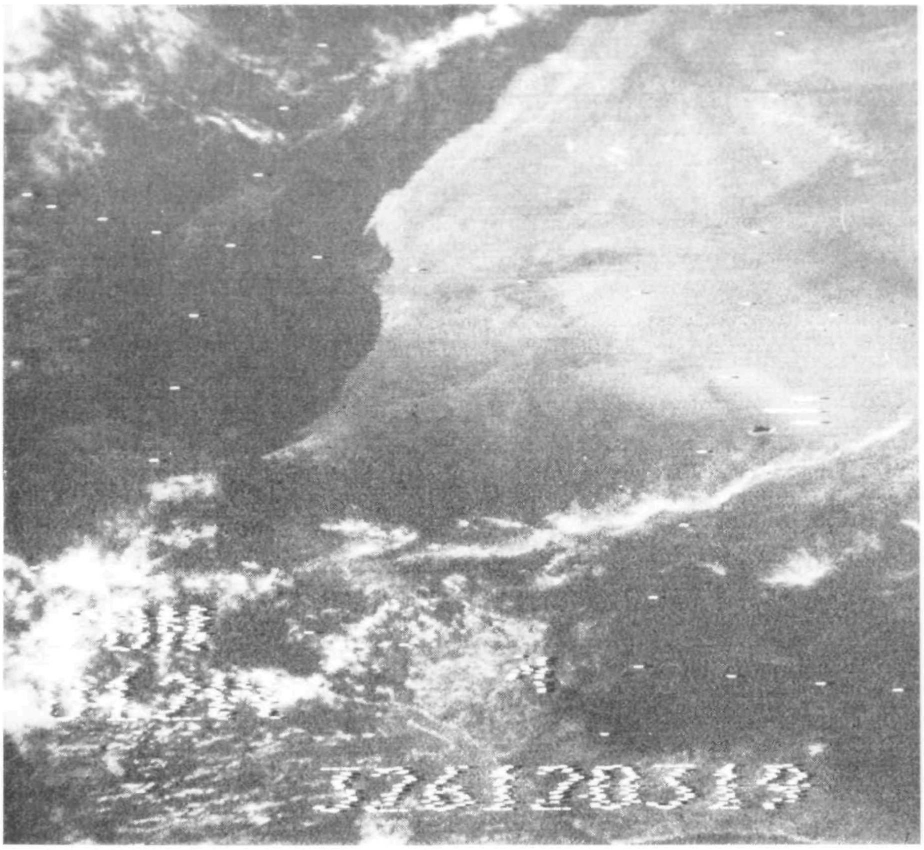

Figure 2. Data obtained with the Image Dissector Camera System (IDCS) on Nimbus III between 10°N and 35°N.

The corresponding infrared image shows the continent and islands in black according to their high black body temperature during the daytime. From the Canary Islands, Lanzarote, Gran Canaria, Tenerife, and Gomera are visible. In the southern portion of the display San Antao and Sao Vicente are visible as part of the Cape Verde Islands.

The structure in the distribution of the infrared data and the albedo level as detected with the camera system show that slight cloud contamination occurs only in the small portion of the northern part of the recordings. That means that the meandering and patchiness as shown in the infrared data is at the sea surface. From earlier experiments (Szekielda and Mitchell, 1972) we established that each colour step in the enhancement corresponds to approximately 2°C. Therefore, a temperature gradient of about 8°C in the surface water appears through the horizontal plane of the enhanced imagery.

On 20 April 1970, cloud-free conditions were detected with the IDCS between 8°N and 24°N (Fig. 4). According to the albedo measurements the region close to Cape Blanc shows an extremely dry and cloud-free atmosphere. Toward Cape Verde an increase of aerosols is indicated by the increased albedo levels. Small portions over the continent are cloud contaminated. They are displayed as a light blue pattern. The corresponding enhanced image from the black body temperature recordings with THIR showed the coldest water in green. The analysis indicated that upwelled water is limited to a very narrow band parrallel to the coast. It covered the area between 25°N and 16°N and had width of about thirty miles. The high radiation of about 11°N (as displayed in dark red) shows the southern limit of cold surface water.

According to the geostrophic circulation (Fedoseev, 1970) a cyclonic gyral with the centre to the South Coast of Cape Blanc is a permanent feature. For the spring season considerable eddy formation has been reported, especially south of Cape Blanc. This is not reflected in the surface radiation on 20 April because

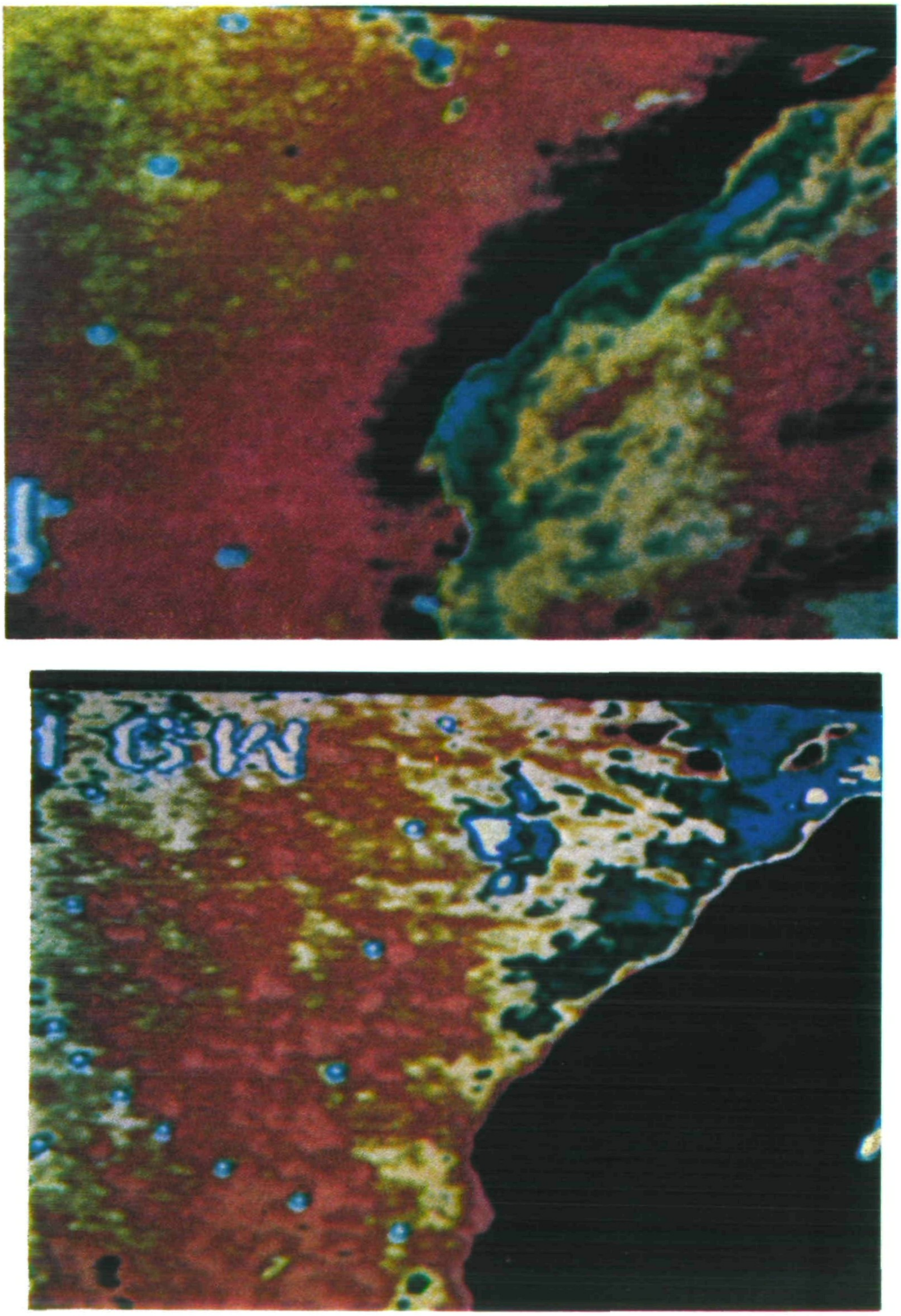

Figure 3. IDCS picture (above) and infrared image (below) taken on 18 April 1970. For explanation see text.

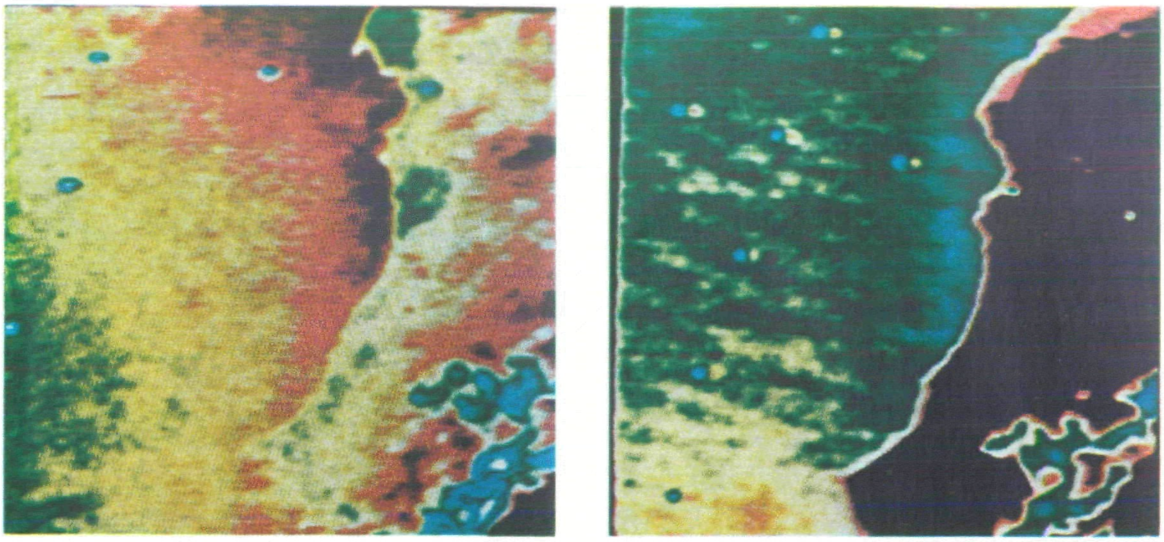

Figure 4. IDCS picture (left) and infrared image (right) taken on 20 April 1970. For explanation see text.

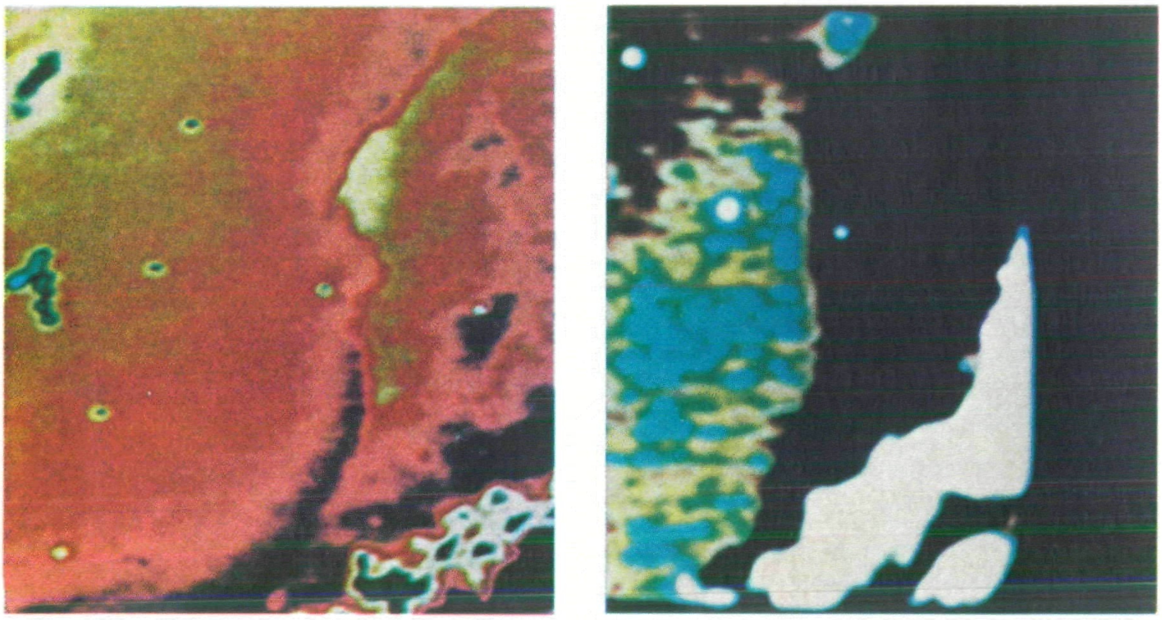

Figure 5. IDCS picture (left) and infrared image (right) taken on 22 April 1970. For explanation see text.

only high temperatures were recorded in the South.

On 22 April 1970, the image obtained with the IDCS again indicated cloud-free conditions between 25°N and 14°N along the NW Coast of Africa (Fig. 5). The corresponding enhanced infrared image shows that the structure in surface temperature patterns changed drastically if compared to previous recordings. Relative warmer black body temperatures were measured in the north as indicated by the dark and purple colours over the ocean. The building of separated cold water patches (enhanced in greenish-blue) indicated a startling change in the surface parameters.

A similar analysis was made 25 April 1970, with

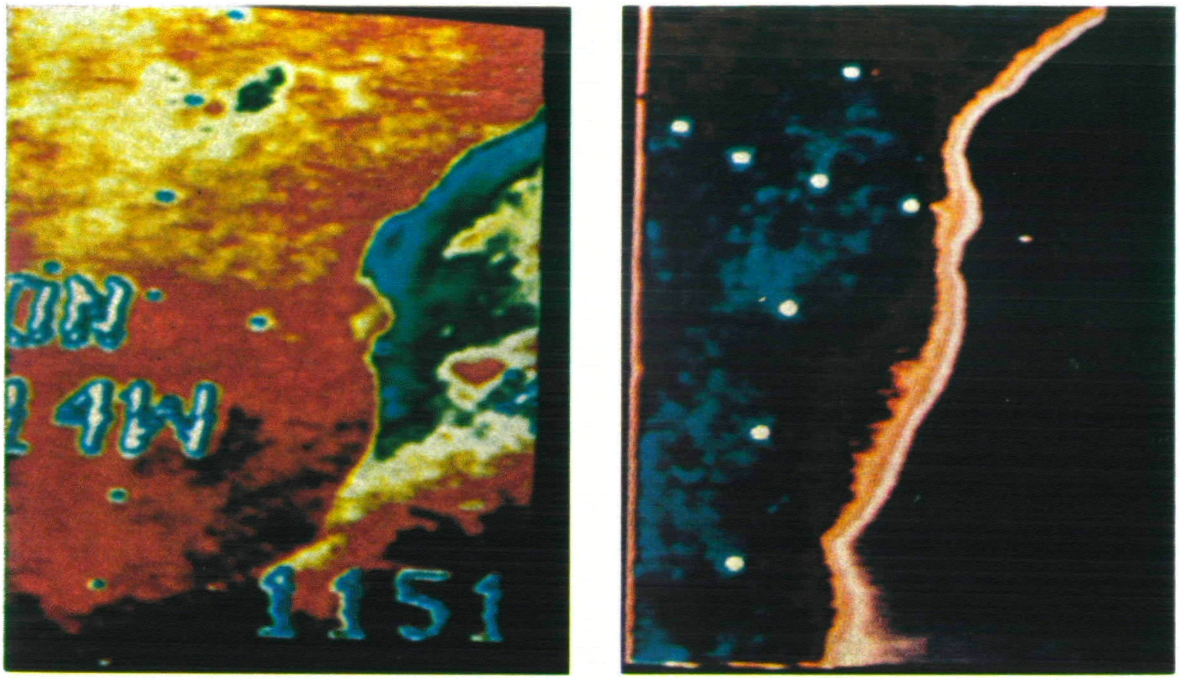

Figure 6. IDCS picture (left) and infrared image (right) taken on 25 April 1970.

the IDCS and THIR (Fig. 6). The infrared data show a patchiness in temperature with two cold centres between Cape Blanc and Cape Verde. Near coastal areas had relatively warmer temperatures.

This situation is in agreement with the geostrophic circulation of surface waters as reported by Fedoseev (1970). In April the Canary Current normally has a decreased intensity, and turns into a cyclonic water movement at about 25°N to the African Coast. The centre of another cyclonic gyre has its position at about 20°N and could explain the separated colder water mass found with THIR. Tomczak (1970) reported data on temperature variations of maximal 1·4°C in the upper 30 m. In near surface waters the changes are expected to be higher.

The fast changes in remotely sensed sea surface temperature as observed over a four day period does not mean necessarily that the main circulation changed completely. But we can conclude from this observation that other surface features might change very quickly. This has to be considered if biological and chemical parameters in the surface waters are discussed. This is especially important if only discrete sampling is applied in upwelling regions.

Fast changes in surface temperatures can be best detected in near coastal areas with high horizontal temperature gradients. Recent analysis of remotely sensed temperature data indicated that offshore regions also undergo a fast change with respect to surface temperature, although the change is less pronounced.

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