The National Centre for Environmental Data and Surveillance

EXAMINATION OF HOMOGENEITY OF COASTAL WATER SITES SELECTED FOR PROPOSED BUOY DEPLOYMENT

ENVIRONMENT AGENCY

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Executive Summary

Measurement of temporal variability of water quality in coastal waters is hampered by the ability to provide temporally representative sampling. External review of spatial surveys carried out as part of the Environment Agency National Coastal Baseline Survey (Reid *et al.* 1997) noted the frequency of sampling was insufficient to represent temporal variability. Proposed refinements to the coastal water quality monitoring strategy include the packaging of continuous water quality instrumentation aboard moored platforms. This development will continue from the development of the estuarine water quality monitoring buoy, Proteus.

Mooring of instrumentation on platforms in coastal waters is hazardous, with much instrumentation being either lost or removed. The strategy proposes that the platforms used are Trinity House Buoys which are large and relatively stable, whilst being legally protected from tampering.

These moored platforms must be located within areas of low spatial variability. To this end, data from the National Coastal Baseline Survey has been used to select potential locations for buoy deployment. The results of this analysis are described here.

Prior to deployment of instrument packages at these sites recommendations are made for further technique development. Firstly, the quality control of telemetered data from the buoy must be investigated, in particular the variation in sensor readings between calibrations. Secondly, the logistics of packaging the estuarine instrumentation on a Trinity House must be investigated. Finally, the physical robustness of the instrument packages when mounted in the coastal environment must be assessed.

EXAMINATION OF HOMOGENEITY OF COASTAL WATER SITES SELECTED FOR PROPOSED BUOY DEPLOYMENT

1. INTRODUCTION

1.1 This report outlines analysis carried out to identify homogeneity in regions of the coastal zone in which the deployment of long term monitoring buoys is being considered. The purpose of these buoys is to measure the temporal variability of the coastal environment necessitating their deployment away from areas of high spatial variability.

1.2 The analysis has involved the use of data collected in the National Coastal Baseline Survey from both ships and aerial platforms. Further data have been collected specifically to reinforce the initial findings and to fill in where no data were available.

1.3 The report first gives a background to the work, before describing the analysis carried out. Finally recommendations are given on the suitability of two of the buoy sites for such temporal monitoring and ways forward for the further assessment and repositioning of others.

2. BACKGROUND

2.1 The National Coastal Baseline Survey was commissioned in 1993 to allow the collection of water quality data of comparable analytical quality around the coastline of England and Wales within the three nautical miles zone of responsibility of the then National Rivers Authority. The Survey took an hierarchical approach to coastal monitoring with spot water quality samples being put into spatial perspective by continuous underway data, which in turn was made representative of the full width of the coastal zone by aerial remote sensing. The Survey has continued within the Environment Agency, although routine collection of aerial imagery has now ceased, and the Survey has in recent years carried out twice per annum, as opposed to the original four times.

2.2 In 1996 the Survey was subject to review with a number of case studies being carried out in order to allow refinement. One case study, carried out by external review (Reid *et al.*, 1998), looked at the spatial and temporal sampling of the Survey and concluded that the temporal frequency was wholly insufficient to reflect the changes in water quality seen within the dynamic coastal zone. Moreover, many of the original sampling sites were positioned so as to reflect estuarine influences as opposed to true integrated coastal water quality. This review recommended the development of *in-situ* water quality monitoring systems to be placed at intervals within the coastal zone away from estuarine influences.

2.3 A revised coastal baseline strategy has therefore been proposed which includes the population of the coastline with a series of water quality monitoring instrument packages. These are to be attached to buoys made available under an agreement with Trinity House which will provide the necessary stability and security for the placing of equipment within the coastal zone. The instrument package will be based on that developed for the Proteus estuarine buoy system (R&D Contract 523), making use of the telemetry techniques developed in this R&D project. Further R&D will be carried out to investigate the packaging of this instrumentationonto a Trinity House Buoy, in addition to investigating the quality control of data from the buoy system.

2.4 The siting of these buoys must be optimised to remove as far as possible estuarine effects within the coastal zone, so that the measurements are representative of the integrated effects of estuarine and offshore processes. Initially the coastline has been divided into the eleven littoral cells (HR Wallingford, 1993). These cells represent homogeneous sectors of coastline in terms of sediment flow which closely mimic the flow of water within the coastal zone. Cell boundaries are either drift divides, which tend to occur at physical features such as headlands, or sediment sinks. Within each cell there are a number of sub-cell boundaries. Variation within the cells will not be assessed by the buoy systems with surveillance techniques being used to detect the presence of different water bodies.

2.5 Deployment of instrument packages within the coastal zone is hazardous for two major reasons. Natural turbulence may result in small platforms being damaged, whereas larger

platforms may prove attractive to other users of the coastal zone, resulting in parts being removed or tampered with. The packing of the instruments onto an existing Trinity House Buoy will provide the size and stability required, whilst being better protected from tampering or removal by law. Due to the nature of the Trinity House buoys the majority are located close to estuarine sources, as these are the major shipping routes. Thus from the very large number of buoys only a small number have been selected for further investigation of suitability for the measurement of temporal variability.

2.6 This investigation will make use of the data collected as part of the National Coastal Baseline Survey (1993-1997) to investigate the homogeneity of waters around the proposed buoys. Data used in the investigation will be provided by underway continuous measurements of temperature, salinity, fluorescence and transmission, each being a parameter to be measured by the proposed instrument package. Airborne imagery, specifically CASI and thermal imagery collected as part of the baseline in 1994 and 1995 will also be investigated to show variation in both suspended matter and temperature.

2.7 The revised baseline proposes a phased deployment of instrument packages at the rate of two per annum over five years. The first two buoys to be deployed have been investigated in greater detail, with the collection of further CASI and thermal imagery This imagery was collected at predetermined tidal states, to allow a thorough analysis of variability to be carried out. Statistical software has been used to determine the variability in these images at varying distances from the buoy site.

3. INVESTIGATION OF PAST DATA FOR INITIAL SITING OF BUOYS

3.1 Investigation of continuous data

3.1.1 The buoy sites were selected to be within the centre section of the littoral cell, upon a Trinity House buoy and away from any major estuarine sources. This led to the following eleven buoy sites being proposed (Figure 1).

3.1.2 Continuous data from the 1995 and 1996 National Coastal Baseline Survey were investigated for each of the buoy sites. The data did not in all cases pass close to the position of the buoys with some sites located further offshore than the ship track. The data available showed no large scale variability in temperature, salinity, transmission or fluorescence around these sites. None of the sites were within the influence of estuarine plumes on these surveys, although not all tidal states were investigated.

3.2 Investigation of past CASI imagery of potential buoy sites

3.2.1 Imagery of each of the proposed buoy sites, collected as part of the National Coastal Baseline Survey in 1995 has been investigated for large scale variability, such as the presence of estuarine plumes, coastal fronts and other distinct water bodies.

3.2.2 Littoral Cell 1 - Saltscar Buoy. There were two images collected in 1995, both when there was a southerly tidal stream. Neither image showed the Tees Estuary outflow to be affecting the buoy site, with estuarine influence stopping upstream of this. The imagery showed the typical sediment banding seen on the north-east coast, with higher suspended sediment close to the shore. The inner leg of the box will be within this higher sediment water. This site has been selected for the first phase of deployment with further data collection being carried out in 1997. Further interpretation is shown in Section 4.

3.2.3 Littoral Cell 2 - Canada and George Buoy. The two images collected over Canada and George off the Humber represented different tidal states, with slack water on the first and a northerly flow of Humber derived sediment on the second. The position of the buoy was such as to be located outside the influence of Humber sediment, although there may be some effects as the location is very close to the boundary. At slack water the buoy is not affected. The Humber Estuary marks a significant divide in water quality and it is accepted that the water quality measured here will not be indicative of water quality to the south of the estuary. The water quality to the south of the estuary may, however, be considered to be non-representative of coastal waters being so heavily influenced by the Humber Estuary outflow.

3.2.4 Littoral Cell 3 - East Barnard Buoy. Two images were collected over East Barnard, one when the flow was to the south and the second when there was a clear offshore flow. The imagery collected when the tidal stream was to the south showed very low variability, with no apparent sediment affects at the buoy site. However, the site was clearly under the influence of near coastal suspended sediment when the flow was offshore. The effects were such that all buoys in the region would be under the same influence. This site was surveyed in July 1997 as a box survey and data from this showed a clear increase in transmission towards the shore, indicative of higher sediment (Wilson, *pers comm.*).

3.2.5 Littoral Cell 4 - Royal Sovereign Buoy. This buoy lies outside the three mile limit with no imagery having been collected of this in the past. Before deployment of a buoy in this region it would be necessary to collect both *in-situ* and aerial data of this site. In-situ box surveys carried out in July 1997 indicated low variability around the site, which is a good preliminary indication of suitability (Wilson, *pers comm*).

3.2.6 Littoral Cell 5 - Fairway Buoy. This littoral cell is highly variable being dominated by the presence of the Solent Estuary. Thus positioning of a buoy which would be representative of the entire cell is difficult. The Fairway Buoy has been selected as it is located outside the East Solent which is the smaller of the two outflows, but there is still great potential for this buoy being influenced by estuarine flow. Data must be collected of this site prior to deployment of a buoy.

3.2.7 Littoral Cell 6 - James Eager Lay Buoy. This site has been selected for the initial buoy deployment and further data collected in 1997 will be analysed in Section 4. Past data for this site shows no apparent effects from the Tamar Estuary. The first flightline was collected when there was a westerly flow and the second at slack water conditions, and so it can be assumed that the effects would be less marked when the flow is towards the East.

3.2.8 Littoral Cell 8 - Helwick Buoy. This buoy is very close inshore and therefore shows some influence of high suspended sediment, particularly in the images collected when there was a strong westerly flow. There may also be residual effects from Swansea Bay.

Much lower variability is seen in the second image which was collected when there was a slight easterly flow. Further data collection, including *in-situ* data, should be carried out before a buoy is deployed at this site.

3.2.9 Littoral Cell 10 - Ethel Rock Buoy. CASI imagery shows high variability in suspended sediment linked with flow around the many rocks here. This buoy is the most offshore of those in this cell and shows the least variability within this area. Imagery collected at slack water shows lower variability. Practical problems for data gathering around this site have been raised by boat crews, and trial data collection is being carried out.

3.2.10 Littoral cell 7 - Horseshoe Buoy, littoral cell 9 - Bwch Buoy and littoral cell 11 - Selker Buoy. These proposed buoy sites all lie outside the old baseline coverage, with no aerial or *in-situ* data have been collected in the past. These buoy sites should be subject to more intensive data collection exercises prior to deployment of instrument packages.

4. INVESTIGATION OF DATA FOR FIRST PHASE DEPLOYMENT

4.1 Littoral Cell 1 - Saltscar Buoy

4.1.1 Imagery was collected from this buoy site in September 1997 in a series of three sorties separated by three hours each. This allowed a change in tidal state and a corresponding change in the flow direction of material from the Tees Estuary, the major potential source of variability in this region. The image data were of high quality and selected images have proved suitable for the application of statistical analysis to determine the degree of variability.

4.1.2 Figure 2 shows example imagery from this buoy site. Figure 2a is a CASI true colour composite image comprising the three image channels upon which variability was calculated. It is apparent from visual inspection of the data that the area is homogeneous in terms of both water colour (CASI) and temperature (thermal).

4.1.3 The statistical analysis applied calculates the mean and standard deviation in both the radiance measured in the series of concentric boxes around the actual position of the buoy. The box size is sequentially increased from 25 pixels to 1089 pixels, representing a series of boxes of area $50m^2$ to $330m^2$ at the resolution flown. In order to compare the variability in different channels and between the CASI and thermal systems the variability is calculated as the standard deviation as a percentage of the mean. Those sites which show little increase in % variability as the size of the box increases may be considered to be homogeneous. The results for the imagery collected of the Saltscar Buoy are shown in Table 1.

Image number	Image time	CASI % variability			Thermal % variability
		Channel 2	Channel 4	Channel 7	
3454	11:12	1.4 - 2.1%	1.4 - 1.5%	2.3 - 2.6%	-
3455	11:18	2.1 - 1.9%	1.2 - 1.6%	1.4 - 2.4%	-
3458	13:16	1.6 - 1.8%	1.4 - 1.3%	2.8 - 2.2%	-
3462	15:41	3.9 - 4.5%	2.4 - 2.6%	3.2 - 3.5%	0.2 - 0.2 %

Table 1: Variability in imagery around the Saltscar Buoy site

4.1.4 Each of the images were collected perpendicular to the shore allowing a wide area around the buoy site to be examined. Only one of the images, 3462, shows a significant variability in the CASI imagery, with this being evident from the smallest size. The thermal imagery collected simultaneously with the CASI was examined in the same way, and very low thermal variability was observed. This image was collected at 15:41 GMT on 29 October 1997, and the variability in the CASI imagery may be explained by the low light levels encountered at this time which may result in more noise in the data. Figure 3 shows the increase in % variability for this site graphically.

4.1.5 The imagery collected from this site indicates the suitability of this buoy site for deployment of a long term monitoring package. The continuous track water quality data collected in 1995 also supported this conclusion.

4.2 Littoral Cell 6 - James Eager Lay Buoy

4.2.1 Imagery was collected of this buoy using the same sortie regime as described above on 30 October 1997. The imagery represents conditions of strong tidal flow both to the East and the West and allows the influence of the Plymouth Sound input to be assessed in both conditions.

4.2.2 Imagery was collected both parallel and perpendicular to the shoreline allowing changes in lighting conditions to be potentially assessed. Imagery was again of high quality, as shown in Figure 4 and allowed application of the above statistical analysis. Results are shown in Table 2 for a selection of the images flown.

Image number	Image time	CASI % variability			Thermal % variability
		Channel 2	Channel 4	Channel 7	
3472	11:57	2.8 - 2.9%	1.3 - 1.7%	3.1 - 3.2%	-
3473	12:02	1.8 - 2.7%	1.0 - 1.6%	2.2 - 3.3%	-
3475	13:31	2.2 - 2.6%	1.5 - 2.5%	2.9 - 4.2%	1.1 - 1.3%
3476	13:22	3.1 - 10.0%	3.5 - 10.0%	6.6 - 12.6%	-
3478	15:02	3.5 - 5.8%	2.3 - 5.1%	4.9 - 7.9%	-
3481	15:22	4.3 - 3.9%	2.4 - 2.2%	4.8 - 4.4%	-

Table 2: Variability in imagery around the James Eager Lay Buoy site

4.2.3 This imagery showed higher variability than encountered at Saltscar. Two images, 3476 and 3478 showed very high variability, up to 12%. Investigation of the imagery showed that the buoy was located close to the edge of the image in these cases which explains the variability seen. Image 3475 shows the highest variability for those flightlines shown perpendicular to the coast and encompassing the buoy site within the main body of the image. The variability in temperature was calculated for this image and was again found to be small, although greater than that noted at Saltscar. The results for this image are shown graphically in Figure 5.

4.2.4 This site shows low variability within both the CASI and thermal imagery, indicating its potential suitability for the deployment of a monitoring package. The main potential source of water quality changes from Plymouth Sound are shown to impact further offshore, as indicated in the imagery (Figure 6). There is a clear front in both temperature and water quality which represents the flow of Plymouth Sound waters offshore.

5. RECOMMENDATIONS

5.1 The two buoy sites which have been proposed in the first phase of the revised coastal baseline strategy have been assessed in terms of the variability around the sites. Both sites show low variability in water colour and temperature, with no indication of major water quality features from past continuous monitoring data. Buoy deployment can be recommended at these sites.

5.2 The instrument package developed within the National Centre as part of the Proteus R&D Project has been tested in Poole Harbour. This deployment proved that the telemetry systems worked successfully and that the instruments gathered data over an extended period without maintenance. However, the quality of the data gathered has not been assessed, in particular the degradation of sensor quality subsequent to calibration. This must be rigorously verified prior to deployment of the instrumentation.

5.3 The Poole Harbour deployment has tested the instrumentation, however the robustness of this when operating in the coastal environment has not been evaluated. Problems such as turbulence, movement of the instrumentation within the water column and lack of horizon for telemetry signals may possibly occur. Validation of the technique of mounting the instruments on a Trinity House Buoy should be carried out prior to deployment of the instrument package.

References

HR Wallingford, 1993. Coastal Management: Mapping of Littoral Cells, J.M. Motyka and A.H. Brompton. January 1993.

Reid, P.C., Planque, B and Thomson, S. 1997 Investigation of Spatial Homogeneity of Coastal Waters. Sir Alister Hardy Foundation for Ocean Science. October 1997.

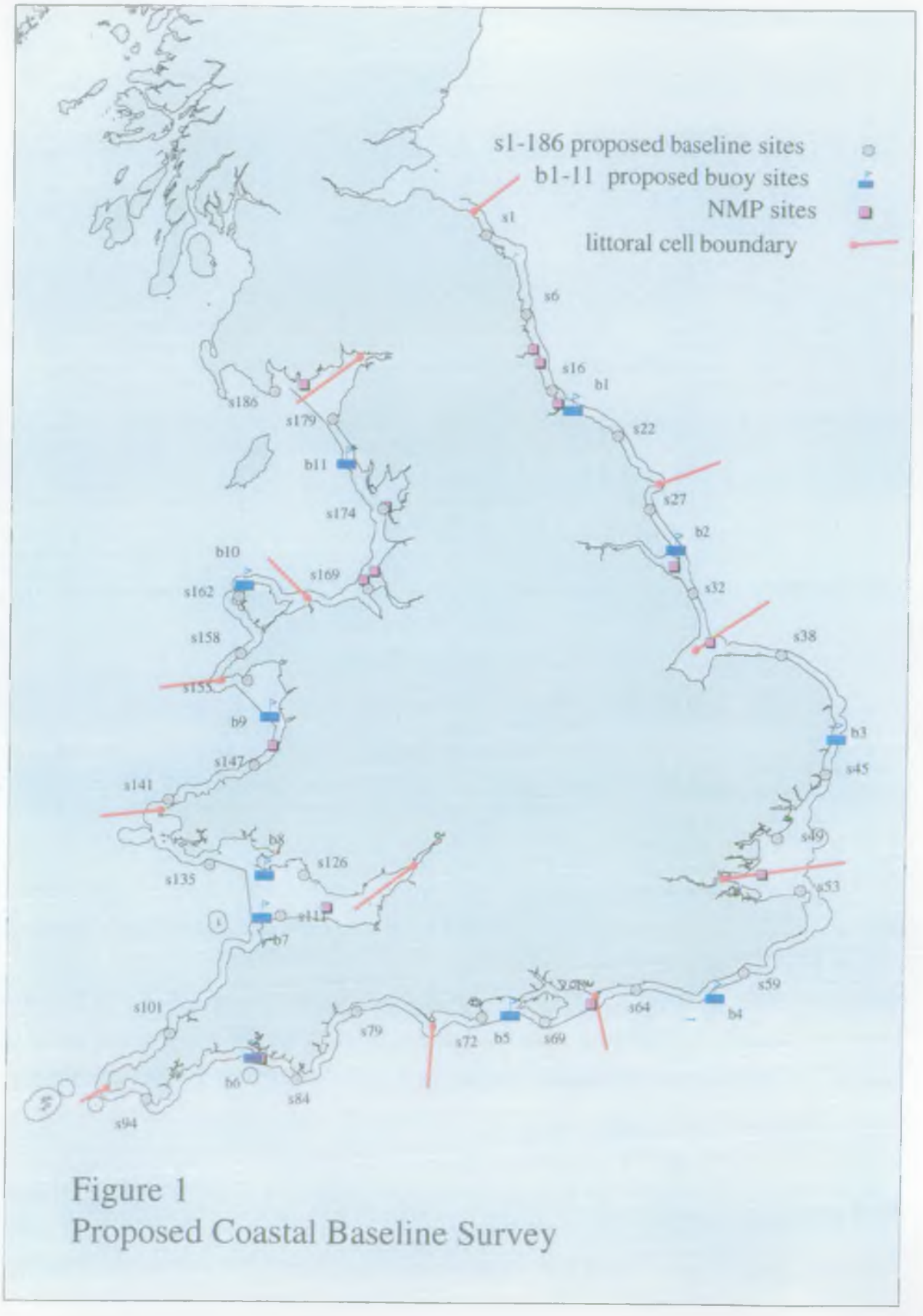


Figure 1
Proposed Coastal Baseline Survey

Figure 2a : CASI true colour composite image of Saltscar buoy site showing homogeneity of water colour in this region. Buoy site marked as red dot.

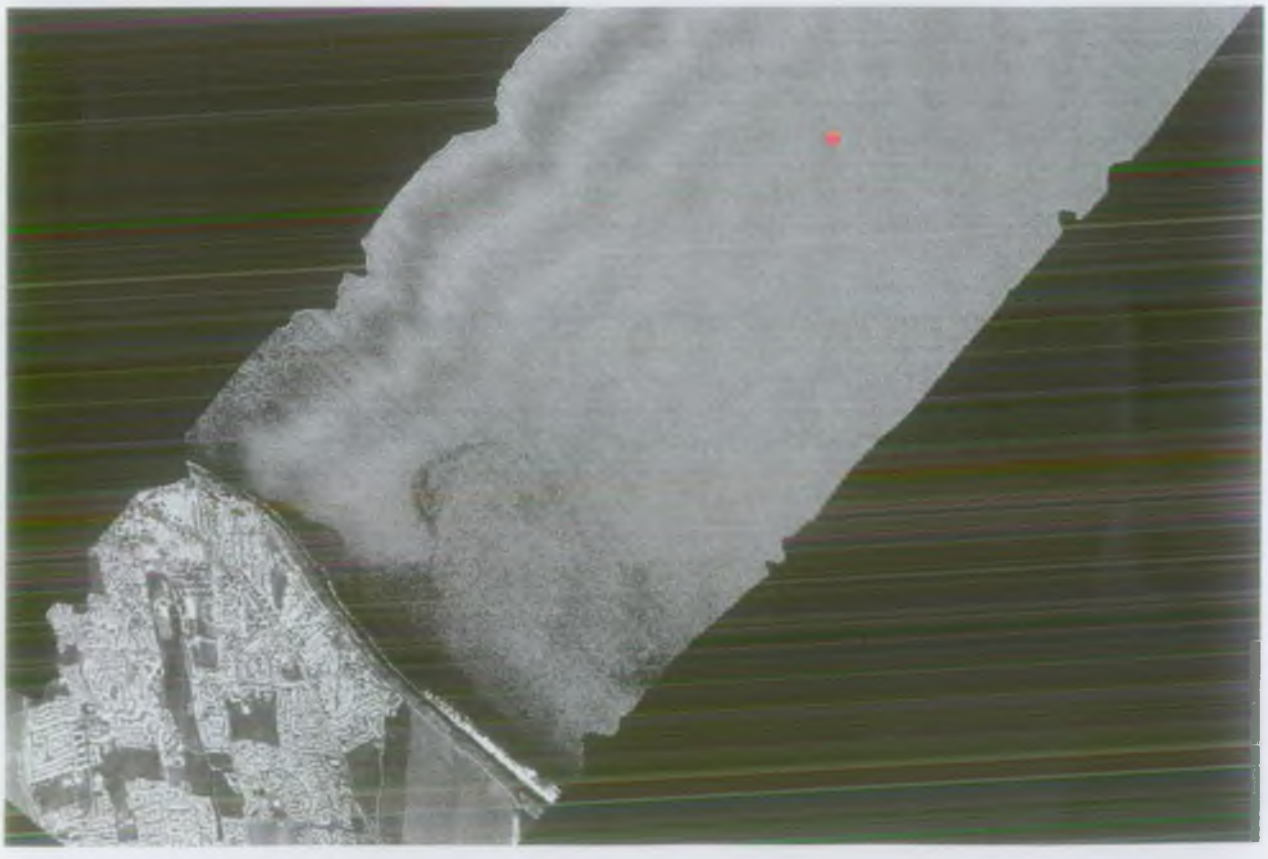
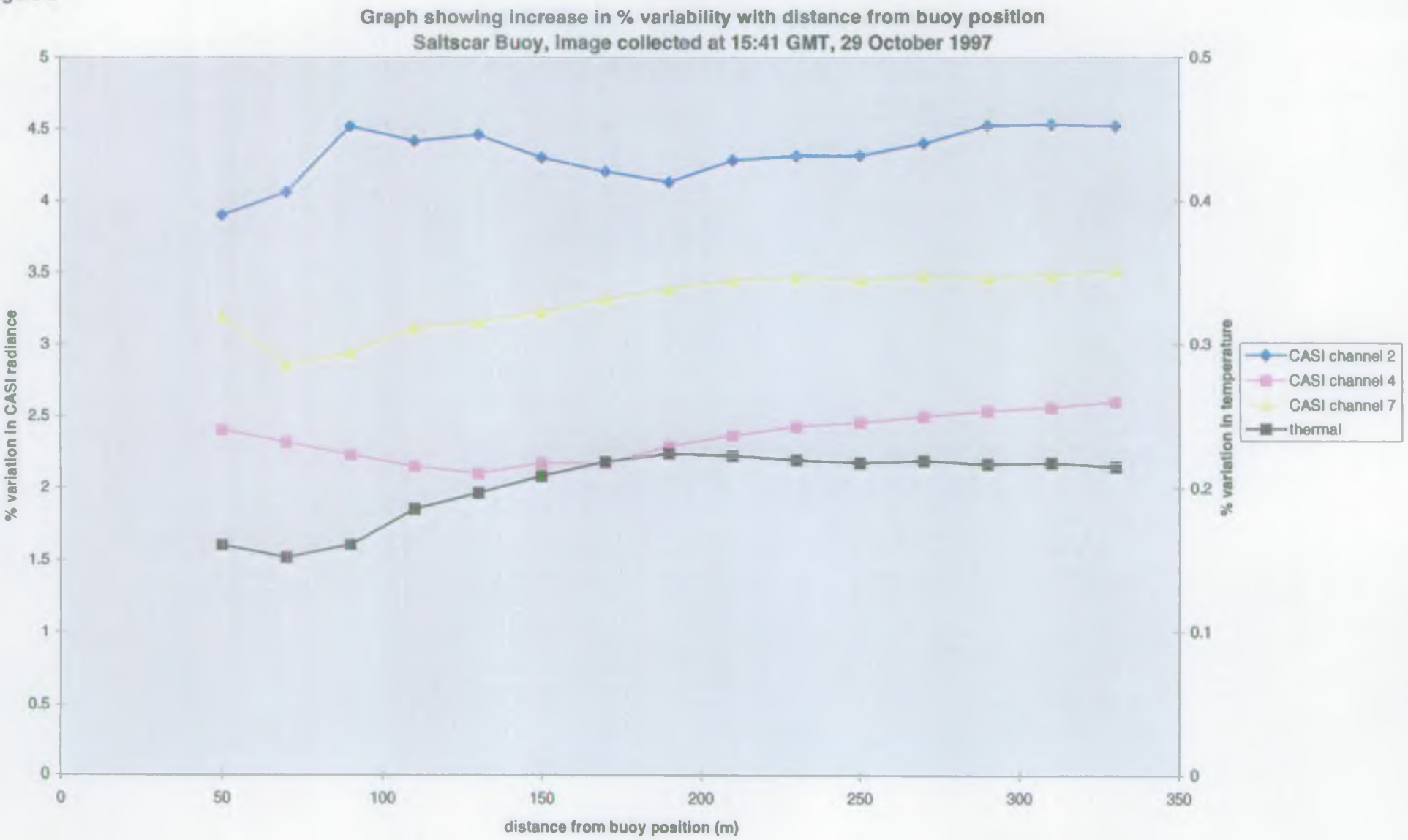


Figure 2b :Thermal image of Saltscar buoy site showing homogeneity of water temperature in this region. Buoy site marked as red dot.

Figure 3


Graph showing increase in % variability with distance from buoy position
Saltscar Buoy, Image collected at 15:41 GMT, 29 October 1997
% variation in CASI radiance
% variation in temperature
distance from buoy position (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
350
CASI channel 2
CASI channel 4
CASI channel 7
thermal

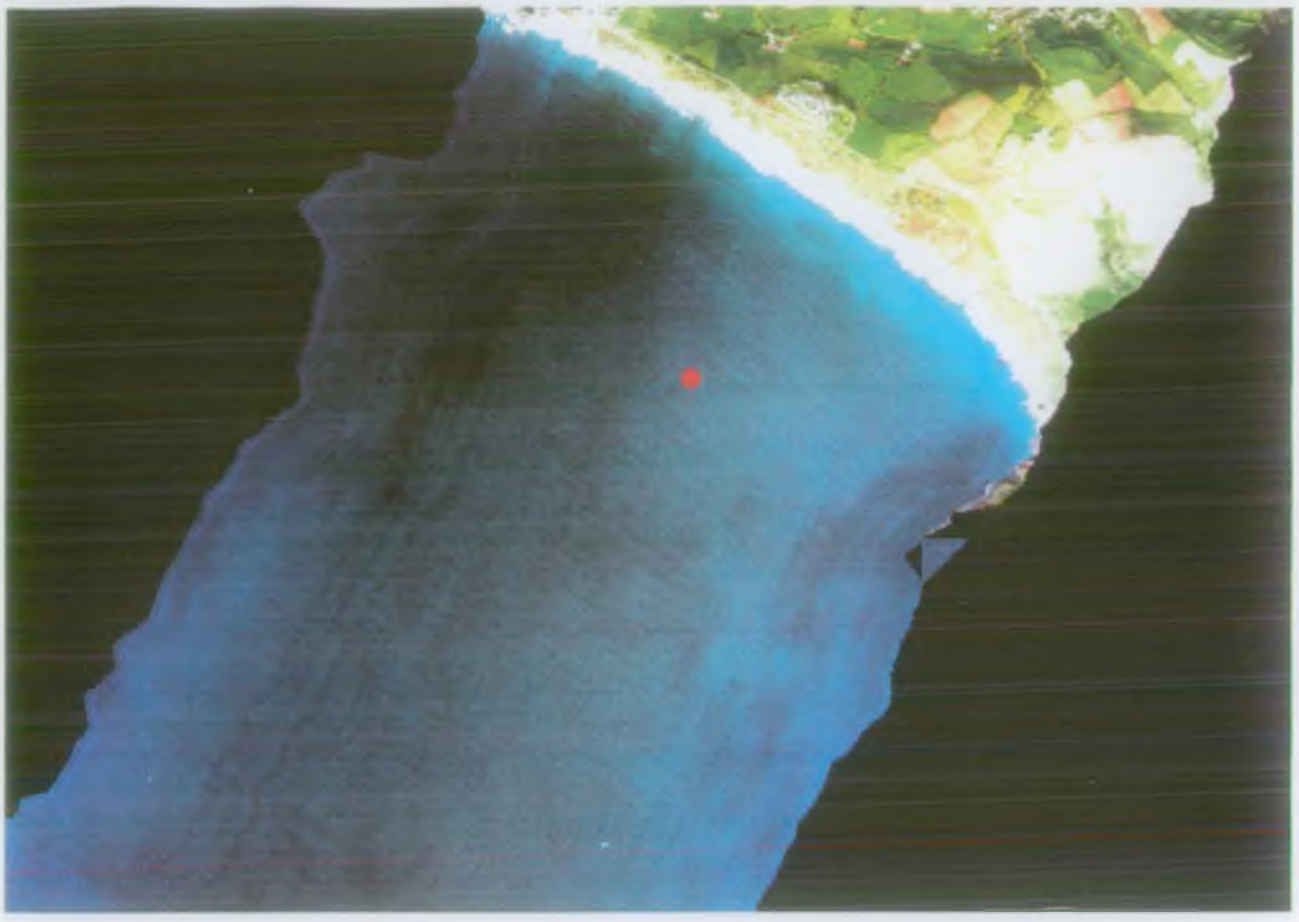


Figure 4a : CASI true colour composite image of James Eager Lay buoy site showing homogeneity of water colour in this region. Buoy site marked as red dot.

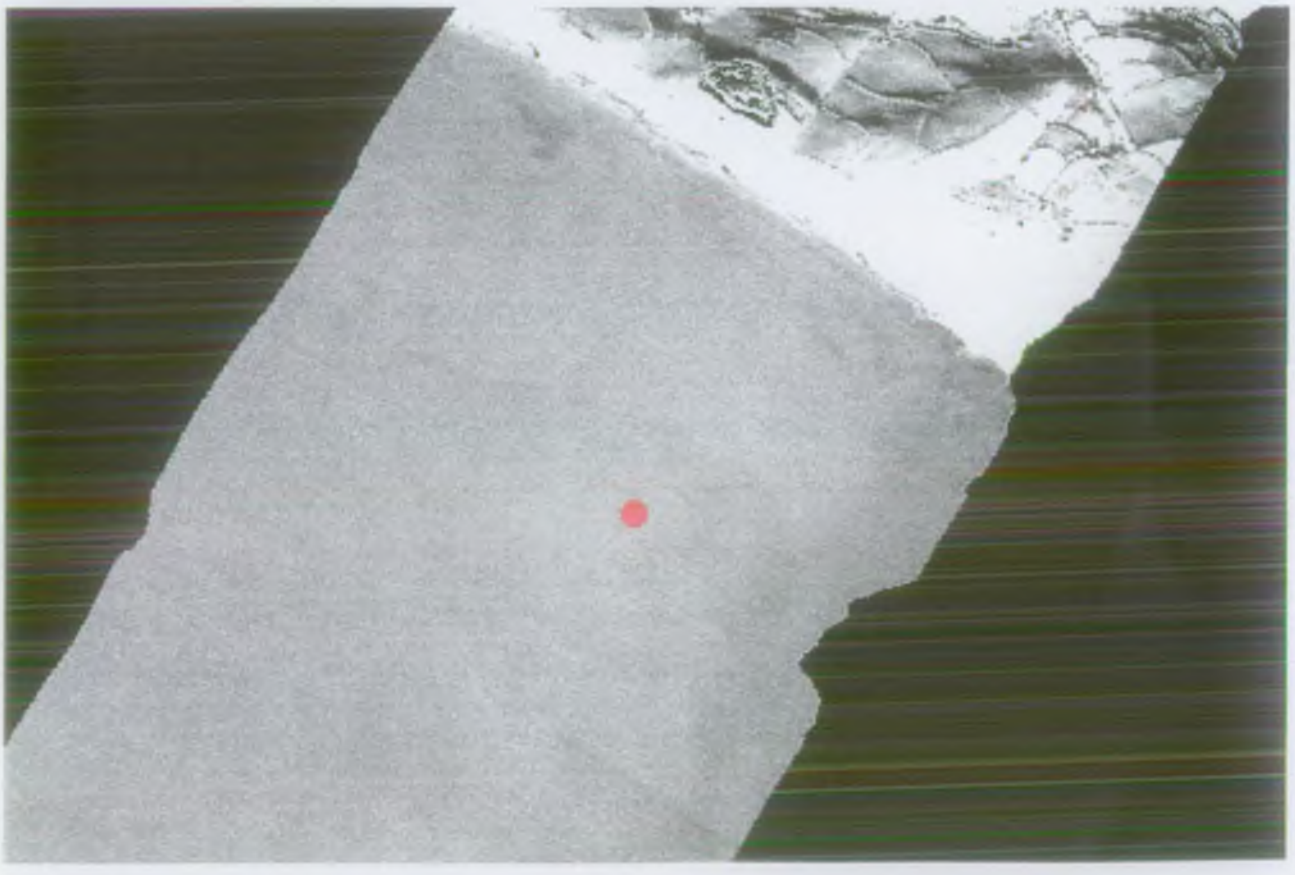
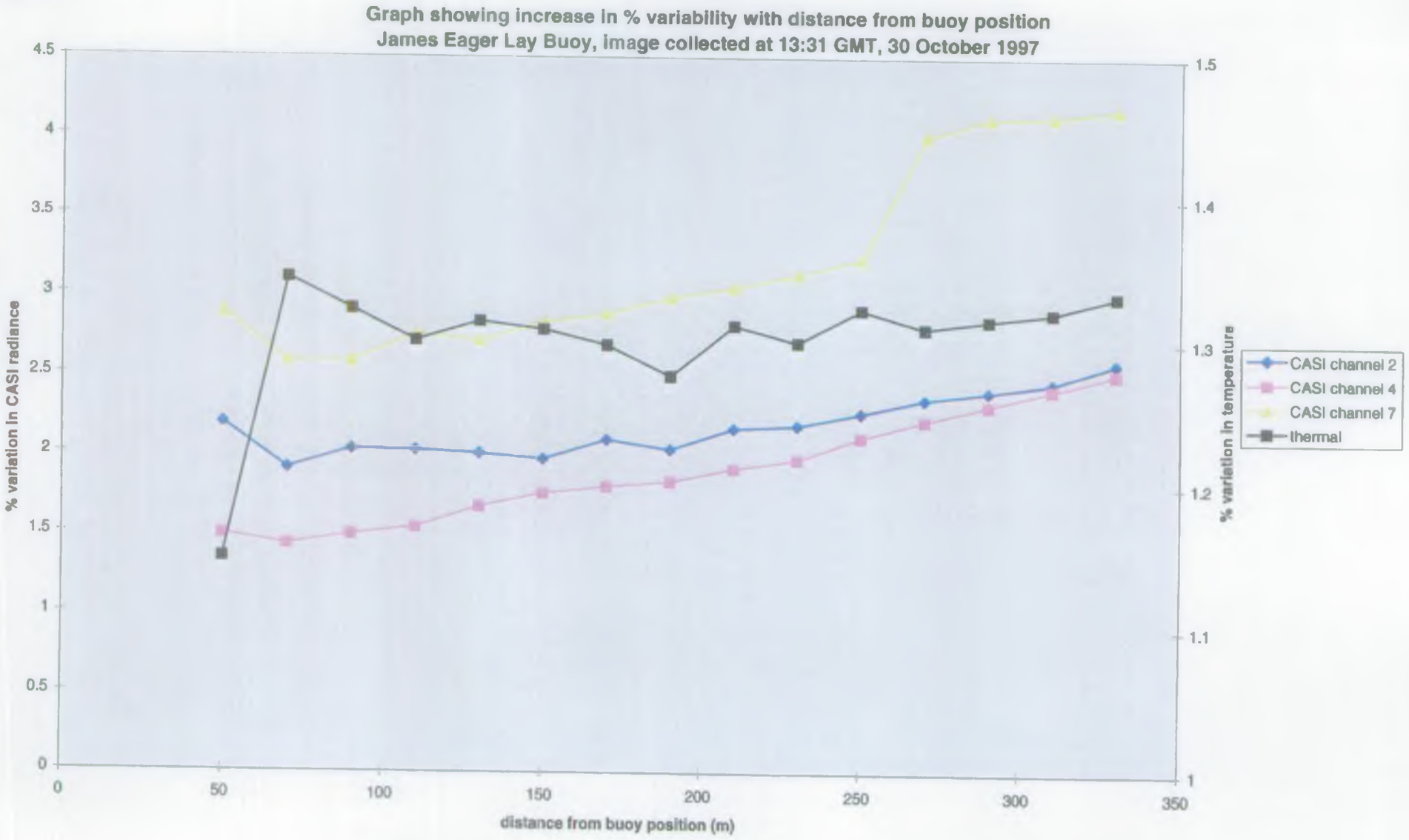


Figure4b : Thermal image of James Eager Lay buoy site showing homogeneity of water temperature in this region. Buoy site marked as red dot.

Figure 5


Graph showing increase in % variability with distance from buoy position
James Eager Lay Buoy, image collected at 13:31 GMT, 30 October 1997
% variation in CASI radiance
% variation in temperature
distance from buoy position (m)
CASI channel 2
CASI channel 4
CASI channel 7
thermal
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1.5
1.4
1.3
1.2
1.1
1
0
50
100
150
200
250
300
350

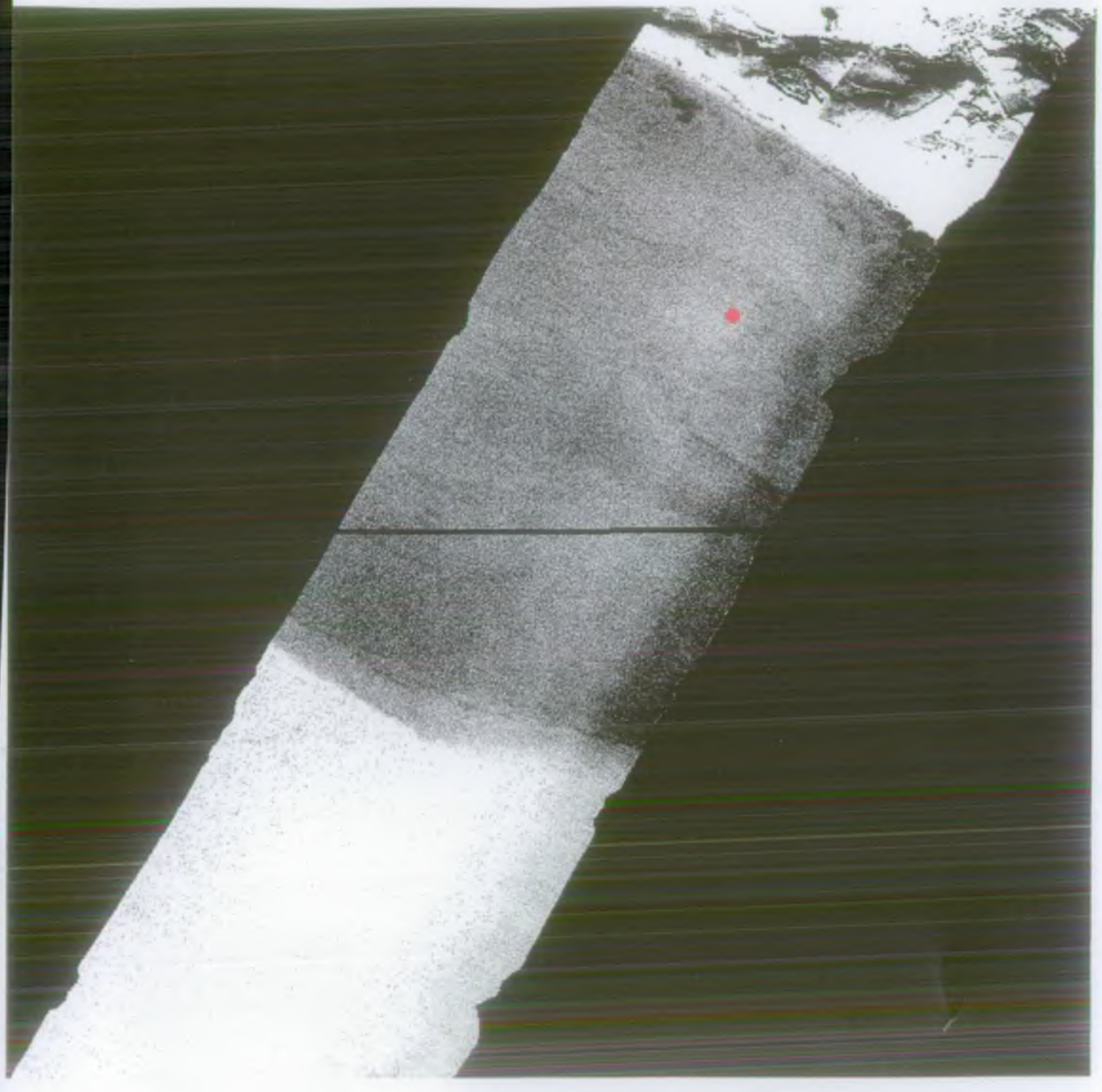


Figure 6 : Thermal image showing warmer water from Plymouth Sound held offshore of buoy site by coastal front. Buoy site shown by red dot.