Sea Surface Temperature Mapping near Kudankulam Nuclear Power Plant, Tamil Nadu, India; A Thermal Remote Sensing Approach

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Abstract: The effluents discharged from the power plants and factories into streams, rivers, lakes and oceans cause physio-chemical and biological changes in the sources. It leads to increase in the surface temperature of the water sources, which ultimately affects the native flora and fauna of that particular area1. Thermal Remote Sensing is one of the best tool for deriving the Land Surface Temperature (LST) and Sea Surface Temperature (SST) and its spatial and temporal variations. The present study focused on LST and SST temperature variations for Pre and Post operations of Kudankulam Nuclear Power Plant (KKNPP) located in Tirunelveli districts of Tamil Nadu, India through Remote Sensing and GIS. For this analysis, thermal data from Landsat ETM+ 2001, 2010, December 2014, 2015 of January, February and March have been freely downloaded and utilized for LST and SST analysis. However, only SST has been concentrated more on this present study. KKNPP's commercial operation was started on 31 December 2014, therefore, pre operational satellite data sets such as 2001 and 2010 have been used for the LST changes and correlation study with post operational data of December 2014, 2015 January, February and March. The results obtained from pre operational data mainly indicates the temperature variation pertaining to land use land cover change type and there was no much of variations in the Sea Surface Temperature. LST and SST ranges varies for 2001 and 2010 (9.91-28.35C; 2001, 21.32-33.02: 2010) Further, post operational data have been analyzed and resulted with huge variations in SST with increasing trend of about 5 to 7°C. Based on visual interpretation, it is observed that the hot water released in to the sea are clearly seen over an area of 3 to 5 sq km. SST for the period of 2014, 2015 January, February and March shows gradual increases in temperature, however the weather data for that particular period from the nearby station shows not much variations in the maximum temperature range. This pilot study around KKNPP suggest that the area requires suitable remedies to minimize the hot water being released in the sea to protect the ecosystem.

Keywords: Thermal Hazard, LST, SST, Landsat and KKNPP

INTRODUCTION

Thermal (heat) is one of the seven major categories of environmental pollutant. Thermal pollution is any change in natural water temperature which badly affects the aquatic environment. Nuclear and Thermal Power Plant may contribute significantly towards economic growth but they may bring associated harms of environmental pollution (Dr. Gulshad Mohammed, internet). Temperature is a crucial environmental factor affecting marine organisms and ecosystems. It affects the distribution of populations on both small and large geographical scales (Wilson, J.G., 1981), it determines the structure of communities and ecosystems by affecting the physiological processes and behaviour of fish species (Dembski, S., et al, 2006). Reefs and marine ecosystems around the world are exposed to the effects of thermal phenomena such as global warming, El Niño and localized thermal pollutants5. Heated effluents discharged to the marine environment may induce dramatic and unpredictable effects, depending on the amount and temperature of discharged material, as well as the climatic, hydrological and biological features of the local environment (Lardicci, C., Rossi, F., Maltagliati, F., 1999). Fish are mobile and mostly can migrate to safe areas when chronic low levels of heat pollution. However, many of their food sources like corals, sponges, macro algae, etc. are sessile, which may be adversely affected. Most importantly, changes in water temperature caused by power station's thermal discharge affect fish assemblages by decreasing species richness (Rong-Quen,et al., 2001).

Nuclear Power Corporation of India Limited (NPCIL) has constructed the Kudankulam Nuclear Power Plant (KKNPP) in collaboration with Russian organization—Atom Story Export (ASE). The Kudankulam site is located along the coast of the Gulf of Mannar, which is about 25 km NE of Kanyakumari in Radhapuram Taluka, Tirunelveli Kattabomman district of Tamil Nadu. The nearest town is Nagercoil, which is about 35 km west of KudanKulam village. The civil construction work has commenced on March 2002 and was expected to achieve first criticality in the year 2007–2008, however it was happened during the year 2014. KKNPP was first synchronized to grid at 2:45 am on 22 October 2013. Power generation from first nuclear reactor started on the same day. Unit 1 was operating at 73% capacity (680 MW) by April 2014. Unit 1 attained its maximum capacity of 1,000 MWe at 1:20 pm on 7 June 2014 and started commercial operation from 31 December 2014. Unit 1 was shut down in June 2015 for refuelling and annual maintenance. Based on this information, pre and post operation of KKNPP data set whichever freely available has been downloaded through USGS Earth Explorer website and used for this study (Kudankulam Nuclear Power Project web site, internet) Figure no 1.

Remote Sensing and GIS are the effective tools for change detection analysis. It has been used for pre and post Nuclear Energy production in Kudankulam Power Plant and mainly concentrated on the effluent released to the sea environment. The largest use of water in Kudankulam Power Plant is mainly for cooling purposes and vast quantities of heated water discharged into natural bodies of water. Thermal pollution due to heating water is bound to have harmful effects on the hydrography of the receiving waters. The large quantity of water released from the plant has high temperature when compare to the normal sea surface temperature that has been studied in this paper thoroughly.

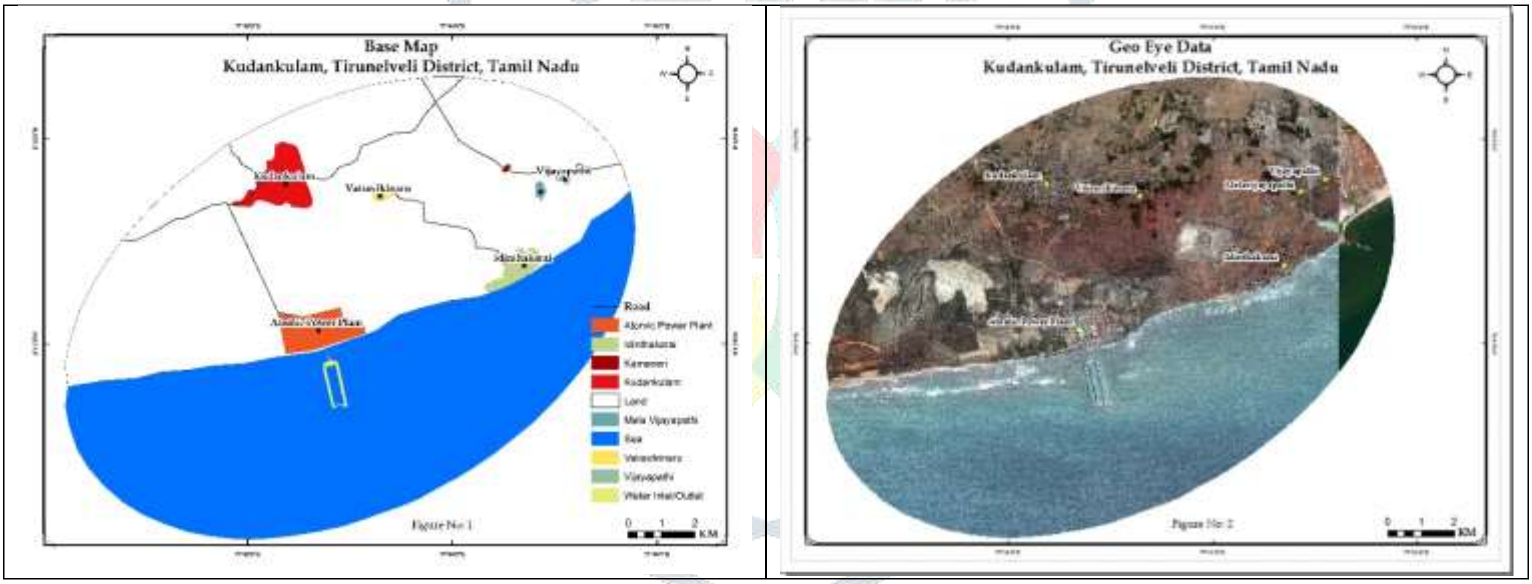
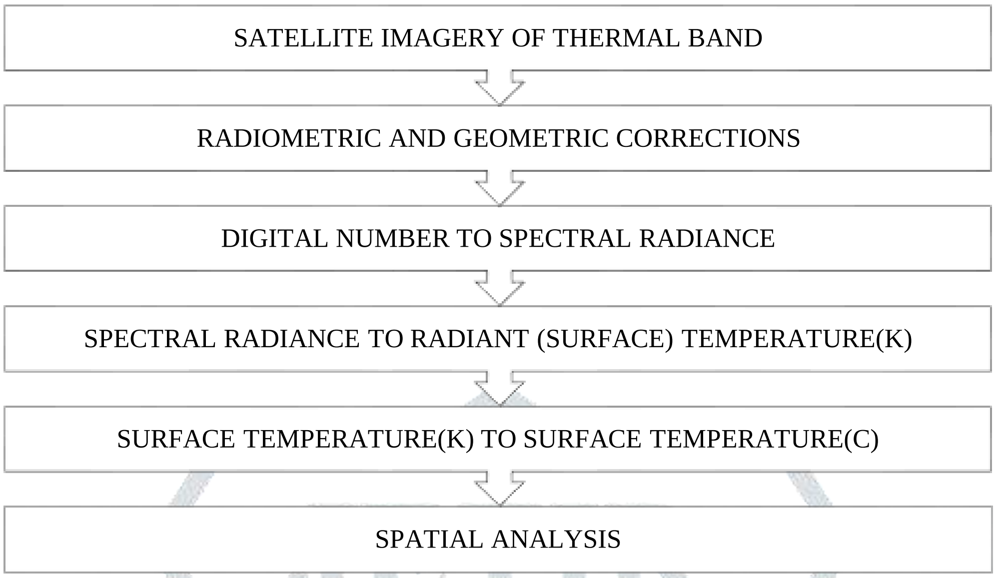


Figure 1: Base and Geo Eye Map of the study area

METHODOLOGY AND DATA PRODUCT USED

Flowchart



The data collected for the present research include Remote Sensing data of Landsat 7 ETM+ SLC on and off and falls in the path143 and row54 from which a small buffer zone around the KKNPP has been taken up for the present study. The Landsat Enhanced Thematic Mapper Plus (ETM+) comprises thermal bands 61 and 62 that captures the thermal temperature and store the information as digital number (DN) between the ranges 0-255. Freely downloaded thermal data has been used for LST and SST estimation and it's change detection, however, the present study mainly focused on the sea surface temperature change. The procedure adapted to calculate the LST/SST, generation of temperature color map, and identification of spectral profile for the effluent released is as follows.

Temperature calculations is simply made by converting the DN value to spatial radiance followed by spatial radiance into temperature in Kelvin and finally Kelvin to Celsius in temperature. Conversion of DN value to Radiance (W/m2*sr*µm) for Landsat ETM+ band 61 which captures the radiant thermal energy between 10.40 and 12.50 was taken in to ENVI directly to calculate the sea surface temperature using Landsat calibration option in the preprocessing option under basic tools. Further, bandmath from basic tool in ENVI has been used to convert surface radiance to temperature kelvin and kelvin to degree Celsius.

ETM+ thermal band data converted to spatial radiance, which is a more physically useful variable. Assuming surface emissivity =1 (USGS, 2001), the following equation is used to convert radiance to temperature Kelvin:

$$T = \frac{k_2}{[(k_1 \div L_\lambda] + 1}$$

Where, T= Temperature in Kelvin, Lλ= Spectral Radiance, The ENVI formula used for the above equation is (1260.56)/(alog(607.76/b1+1)). Further, the temperature in Celsius was calculated using the equation8, T (°C) = T-273.13, Where, T (°C) = Temperature in Celsius, T= Temperature in Kelvin, 273.13= Zero Temperature Kelvin

CONSTANTS(UNITS)	K1, (W/m2* sr * µm)	K2, j (Kelvin)
L7 ETM+	666.09	1282.71

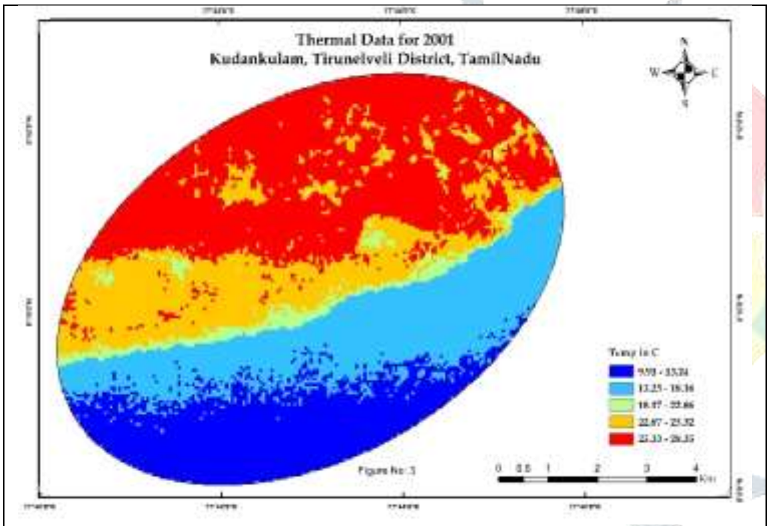
RESULT AND DISCUSSIONS

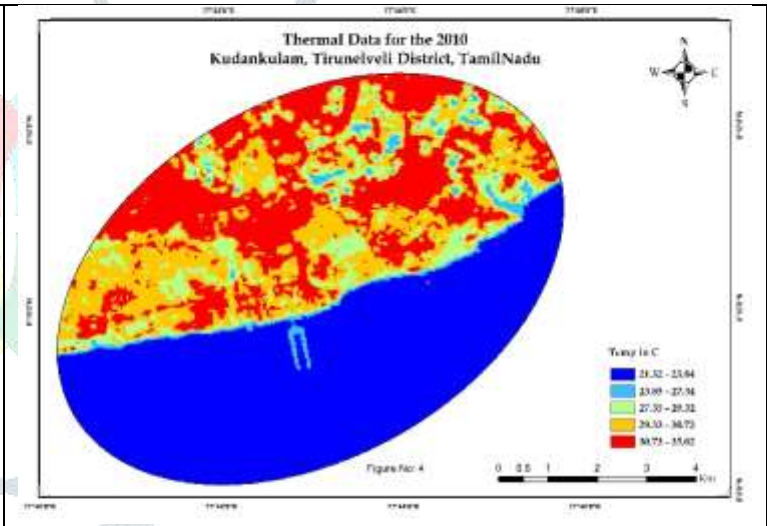
The SST for pre and post Atomic Power Production for the period 2001, 2010, 2014, 2015 January, 2015 February and 2015 March data have been prepared with the help of ENVI and ARC GIS software. The year 2001 thermal imagery shows that the construction was not started (Figure No 3). 2010 imagery clearly shows the inlet out let pipeline for coolant, in this plant sea water being used as coolant (Figure No 4). December 2014 imagery resulted the commercial production of electricity, and the year

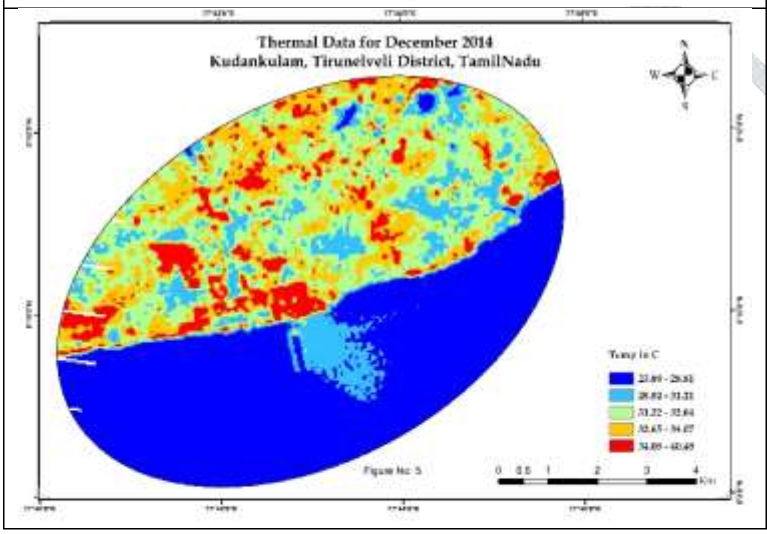
2015 January, February and March data shows continues production of electricity.

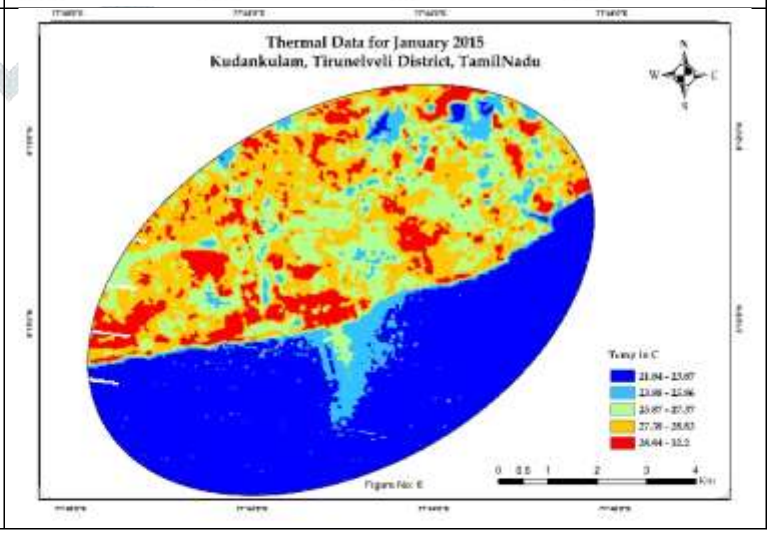
Visual interpretation has been made for the processed thermal data to point out the significant variation in the sea surface temperature. During the production of electricity in the atomic power station, coolant is used to maintain the boiler temperature. For this, the sea water has been circulated around the boiler and the same has been released to the sea with enhanced temperature. This temperature always higher than the sea surface temperature has been mapped using thermal remote sensing technique. During the month December 2014, it was noticed up to 5 degree variation with the surrounding sea surface temperature which is clearly shown in the figure no 5. To know the variations exactly, a profile (Figure No: 5a) has been drawn across the effluent discharged which shows peak temperature changes where the coolant inlet outlet construction area located.

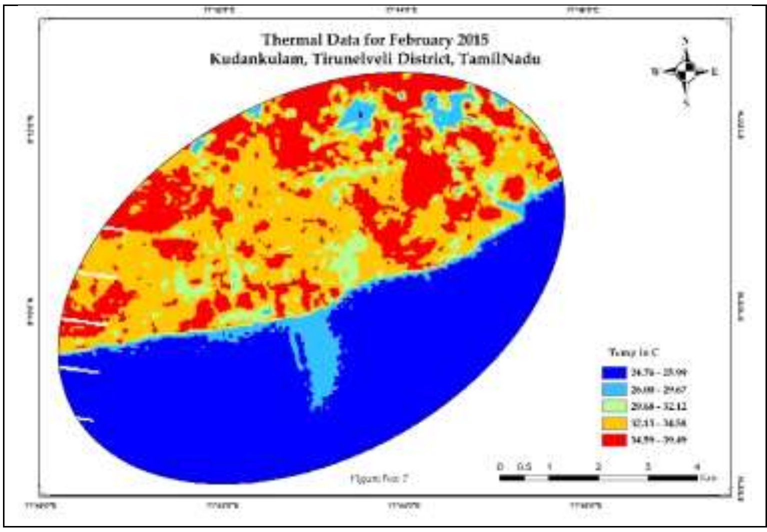
January, February and March data of the year 2015 shows progressively increasing trend in the temperature range and also in the areal extent (Figure No: 6, 7 & 8). Effluent spread for the month of January 2015 is about 3 sq km which is increased about 5 sq km during the month of March 2015. It was also noticed that the temperature range increased from 23.88-27.37°C in 2015 January to 27.76-33.94°C in March 2015. The analysis shows that the temperature is increased about 5 to 7°C where the hot water effluent has released. Higher temperature are recorded near the zone where the hot water is released to the sea and radially temperature reduced with the distance increases. It indicates that the temperature rise directly related to the amount of heat water released from the atomic power station. Profiles 6a, 7a and 8a has been drawn across the inlet/outlet zone where the effluent is discharged shows clear cut information about the sea surface temperature rise. Sky blue colour noticed in the figure number 5 to 8 are the area of effluent discharged by KKNPP where the section lines were drawn (Fig No: 8b) to differentiate the temperature variations spatially as well as temporally.











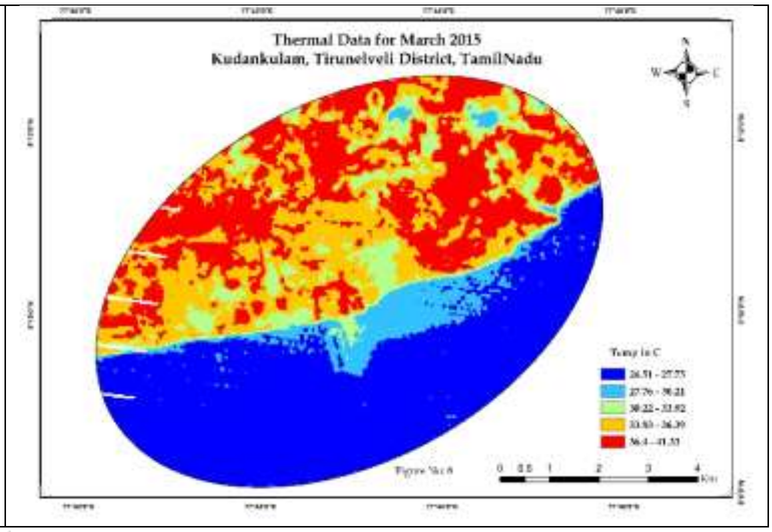


Figure No: 5a-Profile across the Effulent Released during December 2014

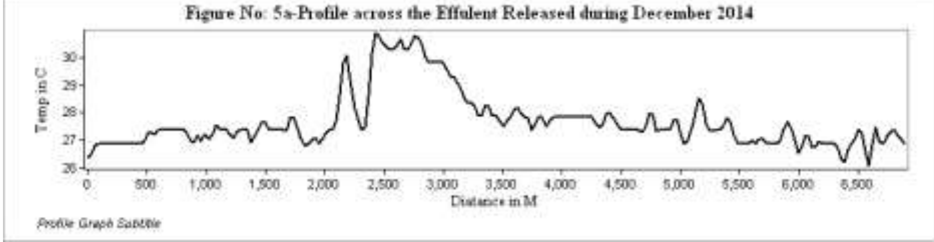


Figure No: 6a - Profile across the Effuluent released during January 2015

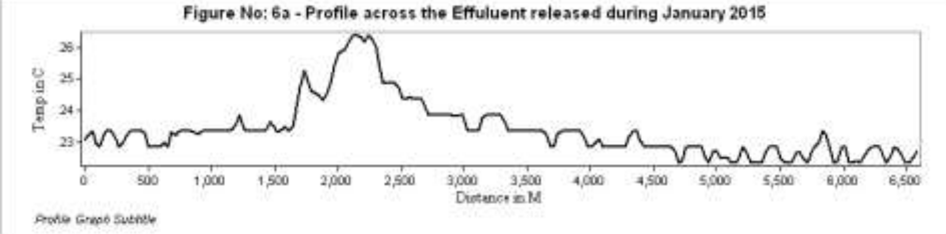


Figure No: 7a- Profile across the Effuluent released duirng February 2015

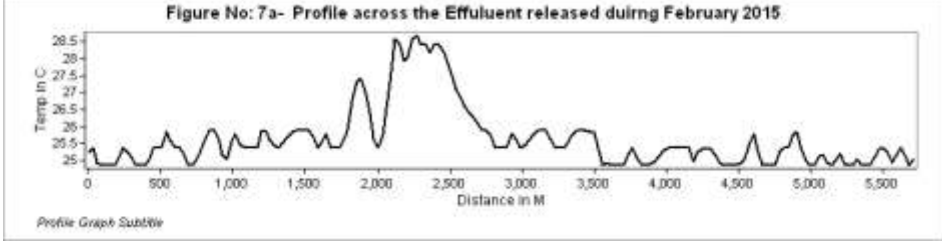
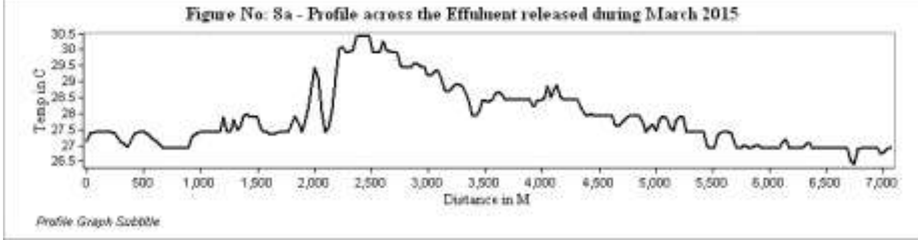
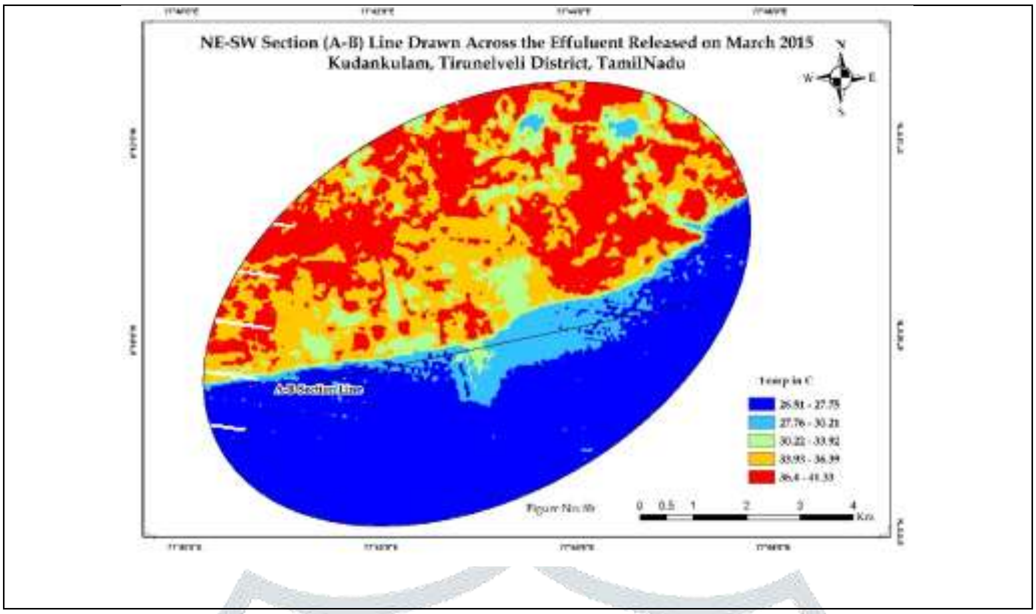


Figure No: 8a - Profile across the Effluent released during March 2015





WEATHER DATA

Weather data for the month of January, February and March for the year 2015 has been derived from the website and listed in the table given below. The temperature data shows not much variations in the weather during this period. The average temperature noticed in this region are 28.61°C, 30.28°C and 29.72°C for the month of January, February and March respectively. This information strongly support that the temperature rise in this field is not due to climatic change and it is directly related to the hot water released to the sea.

Table-2, 2015 Temperature data

Month	Temp. Min C	Temp. max C	Avg. Temp in C
January	25.56	31.67	28.61
February	26.67	33.89	30.28
March	25.56	33.89	29.72

CONCLUSION

The present work brought to light significant temperature rise about 5 - 7°C in the Sea Surface due to release of hot water from the Atomic Power Plants. Temperature is a major factor in the metabolism of living organisms. It controls chemical reactions which affect the synthesis of enzymes which in turn determine the general state of the organism, including growth rates and reproductive success. Temperature also determines the geographical distribution of most organisms. Therefore, temperature change in this region definitely will lead to ecosystem change in that particular area9. Besides, from this study it is observed that thermal remote sensing and GIS are the effective tool for estimating sea surface temperature and it's related spatial and temporal variations. It is also believed that these observations would form a base for further studies related to damage of marine ecosystem due to release of thermal effluents.

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