Analysis of Lateral Heat Flow of Surface Geothermal Manifestation Based on Temperature Distribution in Pine Forest Park, Tomohon North Sulawesi

by Cyrke Bujung

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Abstract: ***The presence of geothermal energy resource subsurface is reflected on the surface by the appearance of geothermal manifestation, i.e. hot spring, hot mud, fumaroles, etc. Existence of surface geothermal manifestation occurred as consequence thermal propagation from subsurface by fractures as geothermal fluid medium to surface.***

This research describes the surface temperature distribution to know lateral heat flow direction of surface geothermal manifestation based on temporal and spatial analysis at pine forest park, Tomohon North Sulawesi. This research using the remote sensing methods with thermal infrared channel recorded in years 2013, 2014, and 2015. The result of research shows that thermal anomaly, and lateral heat flow direction of geothermal manifestation at pine forest park trend toward northeast.

Index Terms*: *Keywords: Heat Flow, Geothermal Manifestation, Surface Temperature.

I. INTRODUCTION

The rapid increase of human population makes energy demand also increasing. The need for increased energy causes the usual energy reserves we use fossil energy is reduced. Therefore, it takes alternative energy such as solar energy, wind energy, water energy and so on including geothermal energy to help meet the world's energy needs. Geothermal energy is one of energy that is quite efficient and environmentally friendly. Until now it has proved successful able to support and help the fulfillment of world energy needs.

Approximately 40% of geothermal potential is in Indonesia. This is because Indonesia is located on the path of the world's volcano, but it is unfortunate that its utilization is still around 4%. Whereas in some areas such as North Sulawesi geothermal energy can contribute about 40% of its electricity needs.

To optimize the utilization of geothermal energy in North Sulawesi required exploration activities through geological, geochemical and geophysical studies. One of the exploration activities that can be done is to analyze the direction of openings of geothermal manifestations in the Lahendong region. Such as the manifestation of the Lahendong Pine Forest.

As for analyzing the direction of a manifestation opening a region should monitor every change and development of the area for a certain period, for example during the last 3 years. But with direct research methods, it is too difficult and time consuming. Because of the remote sensing method that can monitor the changes in a short time.

In this study the authors use remote sensing method, where through analysis of Landsat image data we can see the pattern of distribution of surface temperature of an area, in this case the manifestation. Supported also by a paragraph in the ebook read by the author, who said that a satellite would circle the earth and record the same place in a period of time. The length of time a satellite takes to re-record the same position on earth is called the temporal resolution. The higher the temporal resolution, the more data can be collected from somewhere within a period of time. Multi temporal data is very useful for land monitoring and land change review. Utami & Soetoto (2001) also explained that remote multi-sensing imagery helps to observe thermal changes occurring on surfaces that are not usually easy to observe directly in the field. Thus, by temporally analyzing the surface temperature distribution of a region of manifestation, more or less we can predict where the direction of the manifestation opening in the area will be. This research aims to mapping the surface temperature and knowing the direction of lateral heat flow of the Lahendong Pine Forest area

II. LITERATURE REVIEW

Attributes to search for with TIR remote sensing are related to high heat flow anomalies, excess vertical temperature gradients, and surface thermal manifestations. Some surface features above geothermal reservoirs are obviously hot, such as geysers, hot springs, fumaroles, and mud pools. Less obvious surface attributes of geothermal fields amenable to TIR remote sensing include locally elevated temperatures, geobotanical characteristics (e.g., thermally stressed vegetation), bare altered ground, host rock permeability and topographic relief, and the presence of certain rock types and minerals (Mariana Eneva, 2006).

Thermal property of a material is representative of upper several centimetres of

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the surface. As in thermal remote

sensing we measure the emitted radiations, it proves to be complementary to other remote sensing data and even unique in helping to identify surface materials and features such as rock types, soil moisture, geothermal anomalies etc. The ability to record variations in infrared radiation has advantage in extending our observation of many types of phenomena in which minor temperature variations may be significant in understanding our environment. Thermal remote sensing reserves immense potential for various applications (Anupma P).

Thermal remote sensing data needs to be treated differently from other remote sensing data, most important are the laws of Planck, Boltzmann, Kirchhoff and Wien (Kuenzer).

The spectral anomaly of the reflectance of the manifestation of the geothermal surface occurs at wavelengths below 0.7 µm. Temperature manifestation of the earth surface of Mount Patuha that exist between 304,88^{0}K up to 308, 34^{0}K. The degree of wetness and greenness is not significantly significant in temperatures of geothermal surface manifestations (Bujung, 2010).

Landsat 8 TIRS image can be used to find thermal anomalies caused by geothermal manifestation activities (Paruntu, 2014).

Through Landsat 7 ETM + image, on thermal infrared wave channel, can be identified temperature distribution of a geothermal prospect area (undap, 2015).

III. METHODOLOGY/MATERIALS

In this study the authors use remote sensing method with Landsat 8 TIRS imagery data recorded in 2013, 2014, 2015. Landsat 8 TIRS Image have two thermal infrared bands that are bands 10 and 11, but in research used only thermal infrared bands is band 10. However, according to Paruntu (2014) Landsat 8 TIRS band 10 has better ability than band 11 to identifying high temperature areas, so band 10 is far more effective in identifying thermal anomalies caused by geothermal manifestations. Therefore the authors use only Landsat 8 band 10 image data in this study. Image data for 3 years later was corrected geometric and radiometric. After being corrected the next step is resampling, which is the stage to restrict the area of study, in this case only Lahendong Pine Forest area. The resampling result will produce a map with digital information. According to Ekadinata (2008), digital imagery is constructed by a two dimensional structure of an image element called pixels. Each pixel contains information about the color, size and location of part / an object. Color information on pixels is called a digital number (DN). DN describes the size or intensity of light or microwaves captured by the sensor. However, since the DN value represents only the visible color in the image, it must be converted to the spectral radiance value. The value of spectral radiance is the value of the wavelength to the sensor. Based on the Law of Wien Shift, objects with different thermal conditions emit different wavelengths. Thus, through radiation of irradiated waves the surface temperature can be known. In ilwis processed by equation (1).

$$L = \frac{L_{max} - L_{min}}{Q_{calmax} - Q_{calmin}}(DN - Q_{calmin}) + L_{min} \qquad (1)$$

where :

L = Spectral Radiance [W / (m2sr-1µm)]

Lmax = Scaled Spectral Ratio for $Qcalmax$ [W / (m2sr-1µm)]

Lmin = Spectral Radiance scaled to $Qcalmin$ [W / (m2sr-1µm)]

Qcal = Digital value

Qcalmax = The maximum calibrated pixel value

Qcalmin = The minimum calibrated pixel value

Lmax, Lmin, Qcalmax, Qcalmin values are obtained from metadata.

Satellite sensors not only capture only thermal wavelengths, non-thermal wavelengths will also be recorded. Basically, each wavelength has a different spectral radiance. Using spectral wavelength spectral radiance can be calculated temperature on satellites. Then, the next step is to convert the spectral radiance value to the satellite temperature. This conversion is done in the whisper by inputting the equation (2)

$$T_s = \frac{K_2}{\ln(\frac{K_1}{L} + 1)} \qquad (2)$$

where:

Ts = Satellite Temperature

K1 = calibration constant = 666.09

K2 = calibration constant = 1282,71

L = Spectral Radiance [W / (m2sr-1µm)]

The values of K1 and K2 are derived from metadata

The satellite temperature value is the temperature value that has not been calibrated by the atmospheric factor so it has not been able to represent the value of surface temperature. But the satellite temperature value is required to obtain the surface temperature value. Therefore, after the satellite temperature value is obtained, the emissivity level is corrected so that the surface temperature is obtained with the value of surface temperature. The emissivity correction is done by equation (3).

$$T_p = T_s\left(\varepsilon^{\frac{1}{4}}\right) \qquad (3)$$

where:

Tp = Surface temperature in units of Kelvin

Ts = Satellite Temperature

ε = Emissivity (0.95)

The temperature value at Tp is the temperature in Kelvin, so to change it in Celsius can be done by equation (4)

$$T_c = T_p - 273 \qquad (4)$$

where:

Tc = Surface temperature in Celsius unit

Tp = Surface temperature in units of Kelvin

The above step is done

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equally to the three image data used are image data in 2013, 2014 and 2015. In the end we will get 3 maps of surface temperature distribution, where in analyzing the map we see the color that represents each temperature value with the division per pixel. From the values and colors given how can the surface temperature distribution in the Lahendong Pine Forest area. Furthermore, by analyzing the three maps are obtained changes in the distribution of surface temperature in the Lahendong Pine Forest area, is there an increase or decrease. In addition, on each map will get the point with the highest value, which is meant area with the highest surface temperature. It can also be seen more widespread areas that have higher surface temperatures than the surrounding area. Find and use points with high values on each map, can be seen the direction of movement of the point. The displacement of these points can be a basic reference in looking at the direction of the manifestation openings in the area. It is also supported by changes in the area that has a higher temperature than the surrounding area. Based on these two analysis is where to go where the manifestation aperture in the area.

IV. RESULTS AND FINDINGS

A. Surface Temperature Distribution of Lahendong Pine Forest

The geothermal manifestation of the Lahendong Pine Forest area is constantly evolving. This indicates the development and increase in surface temperatures in the Lahendong Pine Forest area, which is believed to be influenced by manifestations in the area. Because according to Paruntu (2014) anomalous increase in surface temperature of an area influenced by human activity and / or geothermal manifestation.

Basically, geothermal systems occur due to heat transfer of a heat source by its conduction and convection surroundings, and in convection heat transfer occurs cycle (Saptadji, 2006). These cycles that make geothermal manifestations constantly develop like temperature increases.

These developments, greatly affect the surface temperature in Lahendong Pine Forest area. See on the map surface. distribution produced in 2013 its highest temperature is 24.70^0C and the surface area with high temperatures around 2025 m^2 By 2014 high-aligned area about 4050 m^2 with the highest temperature $30,07^0C$ and in 2015 reach 34.33^0C with wide area high temperatures of about 6250 m^2. An increase in surface temperature of the manifestations can also be seen in Fig. 1.

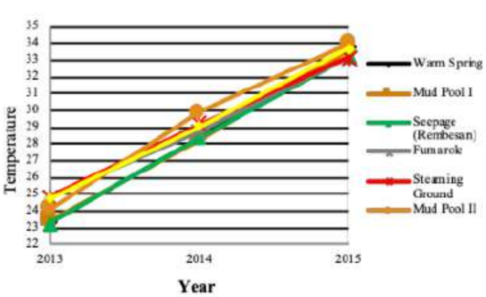


Fig. 1. Temporal changes in surface temperature of the geothermal manifestations

The authors correlate Landsat image data with field data. Some coordinates of manifestation in the Lahendong Pine Pine area are inputted into the map distribution of surface temperatures of 2013, 2014 and 2015 generated. In analyzing the data, the author also compares with the value of manual measurements in the field as a comparison. The temperature of the geothermal manifestation will be compared with the value of Landsat image processing result. Therefore the measurement was done in 2015, the image data used only the last recording year data is the Landsat thermal infrared image data of 2015. Field measurement data can be seen in Table I.

Table I. Table of temperature measurement results of geothermal manifestations

Mata Air Hangat	702849	142313	48
Mud Pool (I)	702831	142293	90.7
Rembesan	702896	142312	36
Fumarole	702655.3	141932.7	97.2
Tanah Beruap	702662	141932	96.9
Mud Pool (II)	702763.6	141924.6	95
Kolam Air Panas	702690	141923	98.1

Table I. points to an increase in the value of surface temperature manifestations in the Lahendong Pine Forest. The author represents every manifestation in the Lahendong Pine Forest area. Seen in Table I there are 6 types of manifestations, where the authors give 2 points for the mud pool because the Lahendong Pine Forest area is dominant with the manifestation.

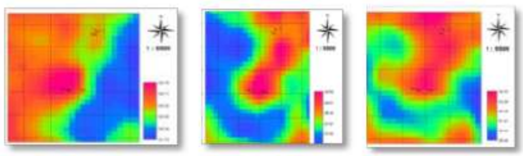
B. Lateral heat flow of surface Geothermal Manifestation in Pine Forest Area.

In addition to the increase in temperature of geothermal manifestation development in Lahendong Pine Forest area is also marked by the increasingly wide pink color in the area. The wider pink color in the map of the surface temperature distribution of the Lahendong Pine Forest area signifies the more open manifested land in the area. This is supported by the explanation from Fanita (2012) in his proceedings which says that one of the factors affecting the distribution of surface temperature of a region is the change of land cover area to become wake land. Since the field observation in the Lahendong Pine Forest area indicates that there is no settlement / land to be built then the only one that influences the increase of the surface temperature of the area is the manifestation of its manifestation. Analyzing the direction of the manifestation in the area, get directions to the Northeast (North East).

The author has also done a comparison with the appearance of google earth Lahendong Pine Forest area and surrounding areas. It was found that Lahendong Pine Forest was on the path of a manifestation opening from Soputan mountain to Mahawu mountain, past the old crater of the mountain of love hill and

Lahendong Pine Forest, and its direction was to the north east. Also supported by the discussion of Bujung (2015) in its proceeding and Undap (2014) in its journals that the direction of the manifestation openings in Mahawu mountain is to the northeast.

Fig. 2 shows the surface temperature distribution of the Lahendong Pine Forest area in 3 years. Also seen in this figure that the direction of lateral heat flow of geothermal manifestation towards to Northeast.



2013 2014 2015

Fig. 2. Surface Temperature Distribution of Lahendong Pine Forest for 3 Years.

V. CONCLUSION

The distribution of surface temperature in the Tomohon Pine Forest area increases annually and ranges from 21^{0}C to 34^{0}C. The surface temperature distribution pattern is influenced by the increasing of area with high surface temperature 2013 is about 2025 m^2, in 2014 about 4050 m^2 and in 2015 around 6250 m^2. Lateral heat flow direction of geothermal manifestation at pine forest park trend toward northeast.

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