UNIVERSITI TEKNOLOGI MARA

STUDY ON ACTIVE REGION STRUCTURE AND ITS RELATIONSHIP WITH SOLAR FLARE EVOLUTION AND CLIMATE CHANGE

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ABSTRACT

The study of the structure of the active region in triggering various classes of solar flare events is necessary to understand the relationship between the magnetic field and solar activity. This association has been the most interesting topic among researchers for nearly a century due to the reason that the Sun is not a stationary object and can cause changes in the magnetic complexity in the active region. These changes will lead to a variety form of solar flares phenomenon and also the amount of magnetic energy that will be released per day. Generally, most previous studies indicated that solar flares event is closely related to the large active region. Therefore, the structure of the magnetic class in the active region that triggered the evolution of powerful solar flares was determined as the first aim of this study. This aim completed the classification of the active region based on the Mount Wilson classification scheme, which contains line-of-sight magnetogram and the atmospheric imaging assembly 171 angstrom (Å) data provided by the Solar Dynamics Observatory's Helioseismic during the impulsive phase. This method was beneficial since it provides information regarding the physical processes occurring in the inner layer of the Sun such as its instability and magnetic activity during the impulsive phase. Here, it was found that the βγ of magnetic class in AR 12877 releases the highest magnetic energy amount of $21.40 \times 10^{15}\ erg$ and the releasing of powerful solar flares depended more on the number of sunspots and the amount of magnetic energy than the magnetic class. The higher the number of sunspots, the higher the amount of magnetic flux that the solar flares will release via a magnetic reconnection process. Then, this study followed with the calculation of the range of the time series of the solar flare event according to the flux as the second aim of this study. The result shows the βγ of magnetic class in AR 12887 released the X1 and M1.5 solar flares event in the range of 31 minutes and 73 minutes which is longer compared to β and βγδ. The result also gives an overview where the duration of the flare did not have a relationship with the class of solar flare events. It was believed that the magnetic class of the active region played a crucial role in this case of study. The third aim is to analyze the radiation of these solar activities regarding the climate change phenomena by applying a Pearson correlation technique. The sunspot numbers have been generally used as a reliable parameter of the Sun, while the thermosphere climate index as the Earth parameter. The data covers three years from 2019 until 2021 which is during solar minimum. Regarding climate change observation, it is found that sunspot number and TCI have a positive correlation, r = 0.59 as both of the variables showed an increasing pattern that related to each other's. The magnitude of TCI is classified as low levels along with fewer sunspot numbers from 2019 until 2021 which resulted in the thermosphere cooling off since a small amount of plasma penetrated the atmosphere. One of the benefits of this study is that it can develop other researchers' knowledge for future work on climate change studies.

Keywords: Active region, Magnetic class, Solar flare, Climate change

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

The Sun, the main solar system, continuously emits various eruptive solar events, such as solar flares, which can cause changes in the Earth's climate. The release of huge amounts of powerful-energy radiation across the electromagnetic spectrum accompanied by other phenomena mainly ejected the atmosphere above the active region. Active regions are the appearance of strong magnetic fields on the solar surface where these magnetic energies will be released with different values of magnitudes via a magnetic reconnection process (Priest & Forbes, 2002). Thus, a solar flare is an interesting phenomenon since it is a huge explosion of magnetic energy in the Sun that originates within the sunspot group or the solar active regions (ARs) with different magnetic complexity, shape, and sizes (Howard, 1989). As the production of the solar flare is related to the sunspot group, a scheme known as Mount Wilson classification is an effective method to figure out precisely the type of sunspot group that will release a variety class of powerful solar flares along with the temporal evolution.

Most previous studies have used the magnetic complexity of active regions to measure solar activity (Cortie, 1901; McIntosh, 1990; Moon et al., 2016). In 1919, the Mount Wilson (or Hale) classification was introduced by Hale et al. (1919), which was categorized according to the distribution of magnetic field topology. However, there are only three major complexity classes that were introduced at the beginning, which consist of: unipolar (α), bipolar (β), and multipolar (γ). Then, in 1960, a new class of magnetic complexity, δ, was introduced (Künzel, 1960). Therefore, the latest version of the Mount Wilson classification for the active region was divided into five major groups, which are: α, β, γ, $\beta\gamma$, and δ as stated by (van Driel-Gesztelyi & Green, 2015). This mechanism was widely used in the research field since it was an effective method to study the behaviour of ARs according to its simplest classification (Ireland et al., 2008; Stenning et al., 2013; Tang et al., 1984). These ARs also can appear with one or more combinations of two major classes, for example, β or $\beta\gamma\delta$ as to trigger solar activities.