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Analysis of Extreme Weather Causes of Flooding in Manado, North Sulawesi (Case Study: 27-28 January 2023)

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ABSTRACT

On January 27 and 28 2023, Manado City was hit by heavy rain which caused several areas to experience significant flooding. The high intensity of rain during that period reached extreme levels, resulting in the inundation of several areas and submerging hundreds of residents' houses in 22 villages or sub-districts and 7 sub-districts in Manado. In studying this event, this research investigates the factors that influence extreme weather in Manado, observing sea surface temperature data, streamlines, air observations, the Southern Oscillation Index (SOI), and the Indian Ocean Dipole (IOD). The analysis shows that the positive SOI and negative IOD phenomena significantly impact extreme weather in the region. Cumulonimbus (Cb) clouds drove the atmospheric conditions formed on January 27 and 28 2023 and air flows from the Indian Ocean which brought wet air masses into Indonesian territory. High sea surface temperatures, reaching 28-29°C, also play a role in the intensive growth of rain clouds. Based on atmospheric conditions seen from radiosonde observation data, the stability index value shows that unstable conditions trigger heavy rain which causes flooding.

Keywords: extreme weather, convective, disasters, floods

INTRODUCTION

Rainfall is the amount of rainwater that falls within a certain period of time and measures the amount of rainwater that falls on a flat surface in millimeters (mm) over a certain period of time (daily, weekly, monthly or annually). In other words, rainfall can be defined as the height at which rainwater collected on a flat surface does not evaporate, seep or flow.

The National Disaster Management Agency (BNPB) reported that a flood occurred in Manado City, North Sulawesi on January 27 to 28 2023, causing around 400 housing units to be submerged, resulting in fatalities. The Meteorology, Climatology and Geophysics Agency (BMKG) noted that the rainfall that occurred in this case accumulated on January 27 2023 reaching 237.8 mm and on January 28 2023 reaching 216.7 mm. This is included in the category of rainfall of more than 150mm/day which is included in the extreme rain criteria based on the BMKG rainfall intensity category obtained from BMKG Head Regulation Number KEP.009 of 2010 [8].

The importance of conducting research into the causes of floods is one of the efforts to overcome the consequences of these floods. Based on the background above, the researcher aims to analyze the extreme weather that causes flooding in Manado City by utilizing data from Wyoming University data, Himawari-8 Satellite data, Berau Of Meteorology (BOM) data which is an Australian executive agency as a weather service provider for Australia and its surroundings and sea surface temperature data from the National Oceanic and Atmospheric Administration (NOAA) website. Brings up a GAP Analysis from the research

you conducted. At the end of the introduction, describe the aim of your research and the hopes you want to achieve from your research.

METHOD

Research Data

The data used in this research is data from 27 – 28 January 2023. This data includes:

a. Sea surface temperature (SST) data obtained from the NOAA website.
b. Streamline data, Indian Ocean Dipole (IOD), and southern oscillation index (SOI) data taken from the BOM website.
c. Upper air observation data at 00.00 UTC from the station obtained from the Wyoming weather website.

Methodology

The research methodology used in this case is:

a. Analyze the conditions of sea surface temperature, southern oscillation index, and Indian Ocean Dipole in the Indonesian region in general, and the Manado region in particular to determine the global factors that influence extreme weather events in Manado.
b. Analyzing upper air conditions is carried out by processing data from the Temp code with the Raob 5.7 application. The interpretation results of upper air conditions are displayed in accordance with existing classifications to determine upper air stability.
c. Analyze wind patterns using streamline maps.

Research sites

This research examines the Manado City area, which is located in North Sulawesi Province. Geographically, Manado City is located between 1°25'88"-1°39'50" North Latitude and 124°47'00" - 124°56"00" East Longitude.

RESULT AND DISCUSSION

Southern Oscillation Index (SOI) value

The Southern Oscillation Index (SOI) is an index used to measure differences in air pressure in tropical regions in the western and eastern Pacific Ocean. In other words, SOI is calculated based on the difference in atmospheric pressure between Tahiti and Darwin Invalid source specified.. Positive SOI indicates that the air pressure in the western region is higher than the eastern region, while negative SOI indicates that the air pressure in the western region is lower than the eastern region .

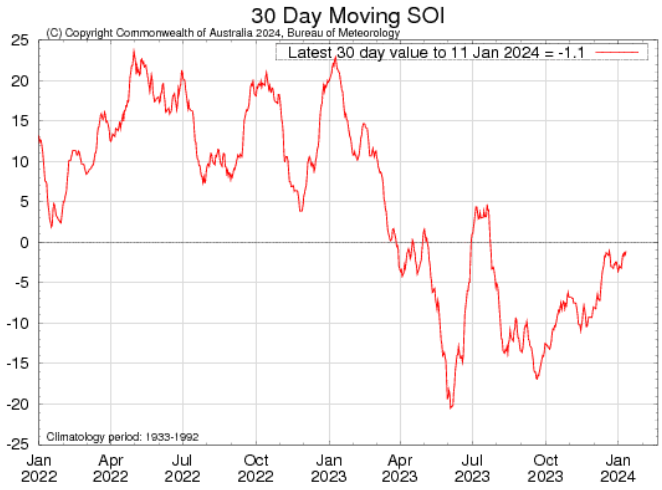

Figure 1. Southern Oscillation Index (SOI) graph for the last 12 months

From Figure 1, it can be seen that from the Southern Oscillation Index (SOI) graph, the SOI value in January 2023 is in the positive range, namely +11.8. A positive SOI indicates that the air pressure in the

western region is higher than the eastern region, while a negative SOI indicates that the air pressure in the western region is lower than the eastern region.

La Niña is a climate phenomenon characterized by cooling sea surface temperatures in the central and eastern Pacific Ocean. This phenomenon causes air pressure in the western region of the Pacific Ocean to be higher, while air pressure in the eastern region is lower. This causes winds in the western region of the Pacific Ocean to move towards the eastern region. The wind moving towards the eastern region brings wet air masses from the western region to the eastern region, including into Indonesia. This wet air mass causes higher rainfall in Indonesia. Therefore, a positive SOI can be an early indicator of La Niña.

Indian Ocean Dipole (IOD)

The Indian Ocean Dipole (IOD) is a climatic phenomenon characterized by the difference between sea surface temperatures in the western and eastern Indian Ocean. This IOD phenomenon involves interactions between the ocean and the atmosphere, which can have an impact on decreasing or increasing rainfall Invalid source specified.. A positive IOD indicates that the sea surface temperature in the western Indian Ocean is higher than the eastern part, while a negative IOD indicates that the surface temperature The sea in the western Indian Ocean is lower than the eastern part.

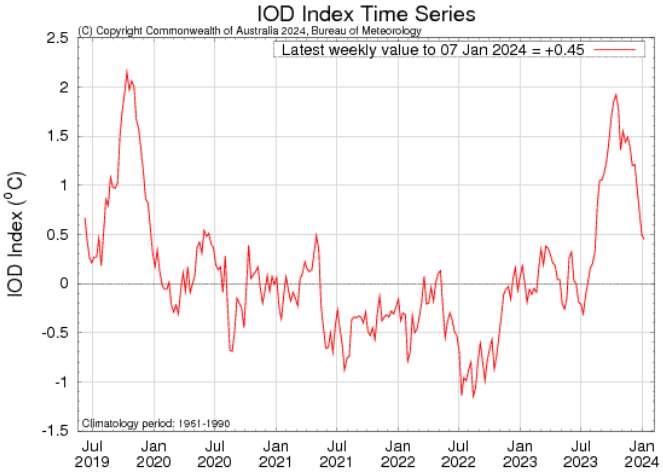

Figure 2. Indian Ocean Dipole (IOD) graph for the last 12 months

On January 27 and 28 2023, the IOD is in positive condition. The IOD on January 27 2023 reached a value of 0.26, while the IOD on January 28 2023 reached a value of 0.28. A positive IOD value indicates that the sea surface temperature in the western Indian Ocean is higher than the eastern part. This causes the winds in the western Indian Ocean to move eastward. The wind moving eastward brings wet air masses from the western region to the eastern region, including Indonesia. This wet air mass carried by the wind causes higher rainfall in Indonesia. This could be one of the factors causing the flash floods that occurred in Manado, North Sulawesi on 27-28 January 2023.

Streamline Analysis

A streamline is a line that connects points with the same speed and direction. Streamlines can be used to describe air flow in the atmosphere. Streamline is also defined as the condition of the blowing wind current which is then drawn based on a tangent line or parallel to the wind data in the area where they are located. Invalid source specified.

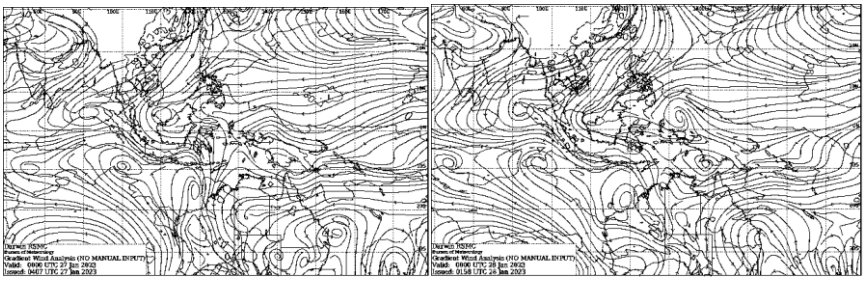

Figure 3. Graph of average monthly normal rainfall for 30 years

On January 27 and 28 2023, the streamline in Indonesia shows an air flow pattern that leads to Indonesian territory. This air flow originates from the Indian Ocean and Pacific Ocean. Air flows from the Indian Ocean bring wet air masses to Indonesian territory. This causes higher rainfall in Indonesia, including Manado.**Sea Surface Temperature (LST) Analysis**

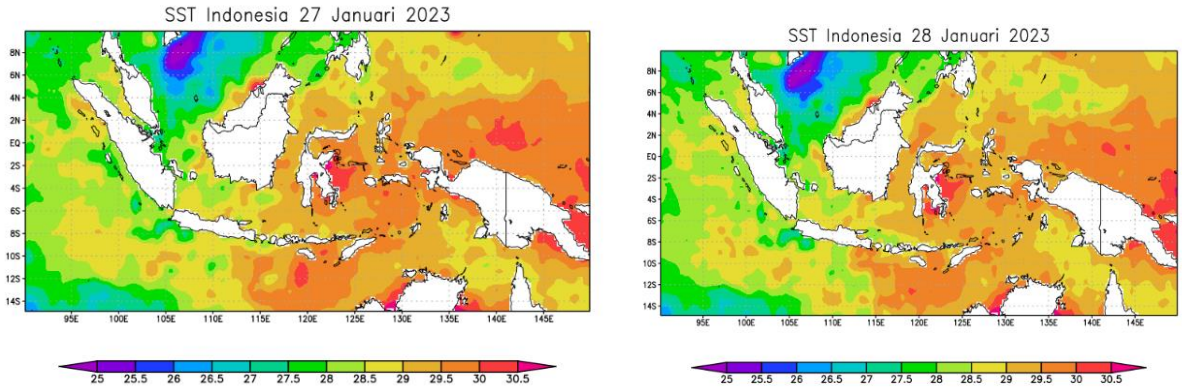

Figure 4. Indonesian SST conditions on January 27-28 2023

Based on the image above, it can be seen that the sea surface temperature (SST) in the Manado area is in the warm category with a value of 28-29°C. Based on the analysis of Indonesian SST on 27 and 28 January 2023, it can be concluded that sea surface temperatures in western Indonesia, especially around the North Natuna Sea, Java Sea and Banda Sea, are in warmer conditions. The warm SST in western Indonesia is caused by air flow from the Indian Ocean which brings wet air masses into Indonesian territory. This wet air mass contains a lot of water vapor, which can cause an increase in sea surface temperatures. This value interprets that sea surface temperatures in the Manado region, on January 27 and 28 2023, have the potential to be in conditions with convective processes that are strong enough to increase the formation of rain-producing convective clouds.

Upper Air Stability Analysis

Figure 5 is the result of processing radiosonde observation data at the Sam Ratulangi Manado Meteorological Station on January 27 2023 at 12.00 UTC and January 28 2023 at 00.00 UTC. From the results of this processing, data is obtained as in table 1. Table 1 shows the atmospheric stability index values consisting of the Showalter Index (SI) as a measure of the possibility and intensity of thunderstorms, the Lifted Index (LI) which shows the convective potential and the magnitude of cumulonimbus cloud formation, K Index (KI) as an indicator to see the potential for thunderstorms, Total Total Index (TTI) as a measure of the potential for extreme weather, Severe Weather Threat (SWEAT) index as an indicator to monitor the potential for dangerous storms and CAPE as a measure of convective potential energy in the atmosphere.

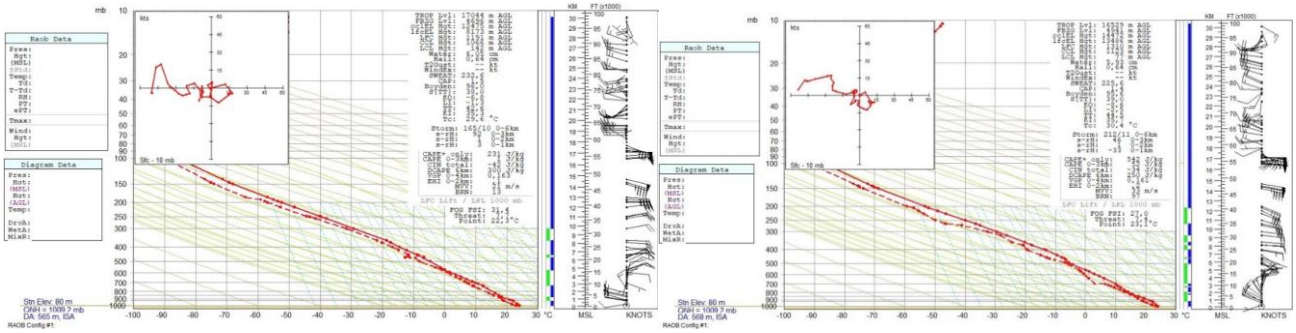

Figure 5. Results of rason data processing on 27 January 2023 at 12.00 UTC and 28 January 2023 at 00.00 UTC

On January 27 2023, the SI value is 1.3, which represents the possibility of a thunderstorm with moderate potential. An LI value of -1.3 indicates that there is a chance of moderate intensity thunderstorms occurring. A KI value of 35.3 means the potential for moderate thunderstorms is also 50-70%. A TTI with a value of 42 indicates moderate convective activity but also has the potential to trigger local lightning. A SWEAT index of 232.6 allows thunderstorms with moderate potential to occur. The CAPE index of 231 J/kg shows that convection is in the weak category. Meanwhile, the stability index on January 28 2023 has a value that is not much different, but several stability indices tend to increase, such as the CAPE value which has increased to 542 J/kg, but the convective processes shown are still relatively weak.

Table 1. Atmospheric Stability Index Values from Radiosonde Processing

Time	SI	LI	KI	TTI	SWEAT	CAPE
27 January 2023 At 12.00 UTC	1,6	-1,3	35,3	42	232,6	231 J/kg
28 January 2023 At 00.00 UTC	1,3	-2,5	35,7	44,5	225,6	542 J/kg

Cloud Top Temperature Time Series

Figure 6 is a time series graph for 27 January 2023 – 28 January 2023 which shows that the cloud temperature in Manado City has not changed significantly, namely only around 10°C to -50°C. The lowest temperature occurred at 04.00 UTC on January 27, which was around -52°C then gradually warmed up. At 06.00 UTC on January 28, it was around -50°C, which then warmed up again with several temperature drops that tended to stabilize.

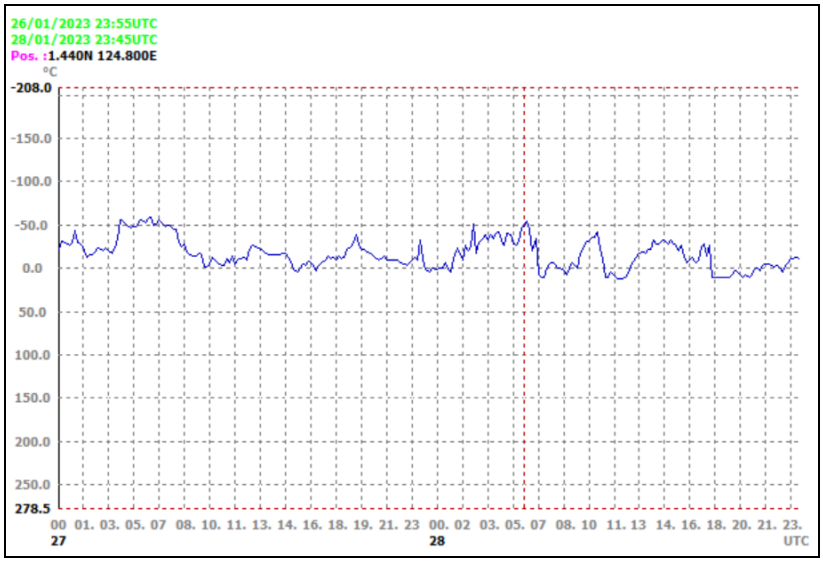

Figure 7. Time series for 27 January 2023 – 28 January 2023

CONCLUSION

The flooding that occurred in the Bireun Regency area on January 27 and 28 2023 was a phenomenon caused by extreme rainfall. Based on data from the Meteorology, Climatology and Geophysics Agency (BMKG), the accumulated rainfall on January 27 2023 reached 237.8 mm and on January 28 2023 reached 216.7 mm. Analysis of 2 global scale phenomena, namely SOI and IOD, shows that there is an influence on the formation of convective clouds that produce heavy rain. From the cloud time series graph, it can be seen that the temperature reached its highest peak at 04.00 UTC on January 27, namely around -52°C.

This rain event is also supported by Sea Surface Temperature (SST) conditions in western Indonesia, especially around the North Natuna Sea, Java Sea and Banda Sea, which are in warmer conditions caused by air flow from the Indian Ocean which carries mass. wet air to Indonesian territory. This wet air mass contains a lot of water vapor, which can cause an increase in sea surface temperatures. Apart from that, the atmospheric conditions shown in upper air observation data tend to be unstable, which greatly influences convective activity in the days before the flood disaster.

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