Utilization of surface meteorological data, Himawari-8 satellite data, and radar data to analyze landspout in Sumenep, East Java, Indonesia (case study of 20 November 2017)

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Abstract. One of the extreme weather that happened in Indonesia is landspout. Landspout is virtually a tornado that forms from a thunderstorm that is not a supercell. On November 20, 2017 at 08.00 UTC there was a landspout in the village of Kertasada, Kalianget District, Sumenep Regency of Madura, East Java, Indonesia which caused damage to dozens of houses and many shops and warehouses. The study was done to determine the differences condition of the atmosphere before, during, and after the phenomenon based on synoptic analysis, atmospheric instability analysis, satellite image analysis, and radar image analysis. The results of the synoptic analysis of two weather parameters, pressure and temperature, also supported the occurrence of landspout phenomenon. Pressure and air temperature for two days before the occurrence of the landspout had a relatively similar pattern, but the average pressure appeared higher on the day of the incident. Temperature patterns showed a decrease from one hour before the incident, which was 3.2°C. The surface wind analysis showed wind speed during the day of the incident was higher than the previous two days, with a difference of 6 m s⁻¹. The analysis of atmospheric instability when the incidence of the Lifted-Index (LI) values indicates the 'unstable atmosphere and possible thunderstorm criteria. K-Index (KI) shows the possible to become moderate convective' The total index (TT) showed a stronger convective, local lightning potential and a value were higher than the previous two days. Severe Weather Threat Index (SWEAT) showed the potential of lightweight thunderstorm with greater instability value than the previous day while the Convective Avalilable Potential Energy (CAPE) index showed a large and potentially stormy energy. Then, in this research used Himawari-8 satellite and Radar C-band to detected convective clouds. According to Satellite Animation and Interactive Diagnosis (SATAID) satellite data, there is a Cumulonimbus (cb) cloud clump in the Sumenep region of Madura, which is meant to be potentially a landspout.

1. Introduction
Entering the transition season as in November, the potential for extreme weather is quite high, especially strong winds and landspout. A landspout is defined as high winds that spin out of cumulonimbus (cb) clouds with wind speeds of more than 34.8 knots or equivalent to 64.4 km/hr [1]. A landspout has become an extreme weather phenomenon that needs to be watched out by the public. Bluestein [2] mentions that landspout or Puting Beliung in Bahasa is a new type of tornado that was not as easily detected by radar, since they are not associated with a mesocyclone, or even an intense radar echo [2].
This phenomenon is caused by strong winds gusts that come out of the cloud base Cumulonimbus (cb) that occurs at the stage of the cloud extinction. Landspout phenomenon occurred in the afternoon or evening with a short duration and is very damaging for the areas that are passed [3]. One of BMKG’s tasks is to give information and early warning of the occurrence of potentially dangerous weather phenomena for the public, including information about landspout [4].

Based on reports from the local mass media, on November 20, 2017, there was a landspout in the Sumenep area, East Java, Indonesia which happened at 08.00 UTC. The landspout hit four villages located in Sumenep district and one in the Saronggi Sub-district. The five villages are Kertasada Village, Marengan Laok, Karang Anyar, Kalimo’ok, and Nambakor. The landspout caused about 20 houses to be damaged and a citizen was injured [5]. Landspout has a kind of extreme weather with local characteristic this phenomenon did not mean unpredictable but difficult to predict [6].

To estimate the weather, it is insufficient to pay attention to weather parameters on a regional scale, but it also needs parameters in local scale as utilizing data of sounding observations from Juanda meteorological station. Station data used in this study were data from Kalianget meteorological station. Local scale was used to find out areas of vertical cloud growth [7]. Wilson and Scoggins (1976) said that a weather expert must pay attention to the index of air instability to understand convective weather patterns [8]. If the air is unstable, then the tendency of the air will be quite moist. Otherwise, if the air is in a stable condition, the tendency of the air is not so humid. The formula used by Wilson is known as SWEAT Index (Severe Weather Threat) [8].

To identify landspout can be supported by the SATAID (Satellite Animation and Interactive Diagnosis) application which can interpret meteorological parameter data and satellite imagery and use radar to see the cloud growth during landspout. The benefit of this research is to provide information to the public about how the character of a landspout and what kind of atmospheric conditions indicate the occurrence of a landspout so that it can be taken into consideration in making the forecast of a landspout.

2. Materials and methods
This research was conducted in the area of Sumenep, East Java, Indonesia (4.91 – 7.4 S and 113.5 – 116.2 E) on November 20, 2018. This area is our location for researching landspout. The data used in this research was surface meteorological data from Kalianget Meteorological Station, C-band radar data from Juanda Meteorological Station, upper air data from Wyoming University, and satellite data from BMKG remote sensing at the time of the phenomena.

Himawari-8 satellite data used IR channel displayed by SATAID to know cloud top temperature [9]. The data were as support data to analysis landspout. Surface meteorological observation data used were air temperature, relative humidity, air pressure and wind direction and speed data. Observations radiosonde used several instability indices such as K Index (KI), lifted index (LI), shower index (SI), Convective Available Potential Energy (CAPE) [3].
The methods used in this research was an analytical descriptive analysis to look at the characteristic of landspout and atmospheric conditions during landspout. Synoptic data were processed into graphical forms. C-band radar data were processed by Rainbow 5.49 application [10]. Upper air data were used to analysis atmosphere instability.

Based on satellite imagery, the meteorological data interpretation method were processed using the SATAID GMSLPD which is an extended version of GMSLPW (GMS Loop for Windows) with specialized functions for Dvorak analysis [11].

3. Result and discussion

3.1. Synoptic analysis

Based on figure 2 (a), it shows the pattern of surface 82 pressure on November 20, 2017 which was different from the pressure pattern two days before the incident. On the pressure chart, on the day there was increase pressure from 07.00 UTC to 08.00 UTC. While based on figure 2 (b), the observations of surface air temperature, on November 20, 2017 indicated a decrease in temperature from 1 hour before the landspout occurred that was at 07.00 to 08.00 UTC, with a decrease in temperature of 3.2°C.

![Surface temperature and air surface temperature on November 18-20, 2017 at 05.00 to 11.00 UTC.](image)

3.2. Upper air analysis

Based on the results of upper air sounding the air instability analysis of some instability indexes on November 18-20, 2017. The table showed an increase in the Lifting index (LI) showing the high instability value which was \(-1.62\). In addition, the surface air temperature required for convective air

| Time/Date | 18 Dir | Speed (m s\(^{-1}\)) | 19 Dir | Speed (m s\(^{-1}\)) | 20 Dir | Speed (m s\(^{-1}\)) |
|-----------|--------|----------------------|--------|----------------------|--------|----------------------|
| 05.00     | 080    | 1.5                  | 320    | 2.5                  | 180    | 4.5                  |
| 06.00     | 330    | 3.5                  | 000    | 0.0                  | 180    | 3.5                  |
| 07.00     | 300    | 2                    | 340    | 2.5                  | 120    | 4                    |
| 08.00     | 310    | 2                    | 290    | 3.5                  | 250    | 11.5                 |
| 09.00     | 000    | 0.0                  | 130    | 1                    | 000    | 0.0                  |
| 10.00     | 000    | 0.0                  | 130    | 1                    | 000    | 0.0                  |
| 11.00     | 000    | 0.0                  | 120    | 1                    | 000    | 0.0                  |
parcel lifting in the TC index value on November 20, 2017 was 32.7 °C, whereas in the previous two
days it was 19.9 °C and 21.9 °C. KI index used to identify potential convective showed a higher value
on November 20, 2017 which was 37, which means a strong convective potential on the day. And the
total index (TT) on November 20, 2017 was 45.4 °C, meaning that it was higher than the previous two
days. The research showed the total index value (TT) on November 18-19, 2017 was 43.6 °C and 44.2
°C. Therefore, it can be interpreted that the value of the total index (TT) on November 20, 2017 occurred
strongly convective and had local lightning potential.

### Table 2. Indexes of KI, LI, and TT on November 18-20, 2017 at 00.00 and 12.00 UTC.

| Date | Time | LI   | KI   | TC (celsius) | TT   |
|------|------|------|------|--------------|------|
| 18   | 0    | -0.55| 33.9 | 18.6         | 41.9 |
|      | 12   | -1.99| 31.5 | 21.1         | 44.2 |
| 19   | 0    | -1.15| 34.7 | 19.7         | 43.2 |
|      | 12   | -2.74| 36   | 20.9         | 43.6 |
| 20   | 0    | -1.72| 34.6 | 19.9         | 43.4 |
|      | 12   | -1.62| 37   | 21.9         | 45.4 |

### Table 3. The CAPE and SWEAT Index on November 18-20, 2017 at 00.00 and 12.00 UTC.

| Date | Time | CAPE | SWEAT |
|------|------|------|-------|
| 18   | 0    | 135  | 187.6 |
|      | 12   | 365.7| 218.8 |
| 19   | 0    | 152  | 204.4 |
|      | 12   | 995.3| 213.1 |
| 20   | 0    | 206.4| 193.5 |
|      | 12   | 194.8| 246.8 |

Based on the SWEAT and CAPE index values, there was no convective, but the SWEAT value was
higher on November 20, 2017 than the previous two days.

### 3.3. Satellite imagery analysis

Himawari-8 satellite imagery used the IR channel on November 20, 2017 was processed by the SATAID
version of GMSLPD application through the tropical cyclone analysis process. Analysis of satellite
imagery showed strong convective cloud growth which had the potential to become a landspout in the
Sumenep area starting at 7:30 UTC. In figure 3 above at 7:30 UTC, there was a cloud forming in the
Sumenep area. In the image, from 7:40 a.m. to 7.50 UTC, the cloud was formed which had the potential
to become landspout that had already formed the circle pattern. The circle pattern was shown by the
black color around the white color. At 8:00 UTC, the clouds above the Sumenep area increasingly
formed a perfect circle pattern. At 8:10 a.m., the clouds above Sumenep were perfect in forming a
circular pattern. At 8:20, the cloud had a circular pattern indicating the presence of a tornado. While at
8:30 UTS, the cloud pattern above Sumenep started to be oval.

The figure 4 (a) presents a cloud contour on November 20, 2017 showing a cloud core with a peak
temperature of -72.5°C. While figure 4 (b) shows a graph of the cloud peak temperature from 7:30 a.m.
to 8:30 UTC above the Sumenep area. From the graph, there is a decrease in cloud peak temperature.
The cloud peak temperature decreased up to -78°C, indicating the formation of strong convective clouds
that have the potential to become a landspout. In the conditions of decreasing the temperature of the
cloud tops, the landspout also has the potential to occur, if the conditions of cold clouds form a formation
like in figure 4.
3.4. Radar imagery analysis

HWIND is a product that displays horizontal surface wind data at an altitude. HWIND aims to determine wind patterns in a particular area [12]. Based on the image of HWIND products with a height of 0.5 km, which was at 08.00-08.30 UTC, it could be seen that the wind which blew on November 20, 2017 had a speed of 20-30 knots. At 08:30 UTC, the average wind speed was 25 knots, and this was supported by the analysis of satellite imagery.

CAPPI products displayed are products that come from a height near the surface. CAPPI product used in this analysis was CAPPI at 0.5 km of altitude [13]. Based on CAPPI product image analysis at 0.5 km of height, it could be seen that the hook echo pattern and reflectivity value were still observed from 08.10 to 08.20 UTC. The maximum reflectivity value was most clearly seen at an altitude of 0.5 km at 08.10 UTC with an intensity of 45 dBZ. This paper related to Satriyabawa and Pratama [14] about
landspout in Surabaya, East Java using weather radar imagery and WRF-ARW Model showing similar hook echo pattern with 45 dBZ reflectivity.

![Figure 5](image1.png)

**Figure 5.** HWIND product analysis on November 20, 2017 T 08.00 – 08.30 UTC.

![Figure 6](image2.png)

**Figure 6.** CAPPI Product Analysis on November 20, 2017 T 08.00 – 08.30 UTC.

4. **Conclusion**

Based on the results of analysis, it can be concluded that on November 20, 2017 there was landspout that occurred in Sumenep. The presence of a high temperature drop at 07.00 and 08.00 UTC on the day of the incident indicates that there is a strong surface cooling process before the occurrence of pickaxe. The condition of atmospheric lability based on upper air analysis shows that the lability will trigger the occurrence of pickaxe. Analysis of satellite imagery and radar images also supports, this is indicated by
the process of convective cloud growth in satellite imagery and reflectivity analysis on radar imagery which shows the echo hook pattern on CAPPI products with a maximum intensity of 45 dBZ.

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