Abstract: Extreme events related to heat waves have been increasing day by day in recent years over India. To achieve this, we took the help of the satellite data. In this paper, we analysed maximum temperatures of the heat wave episode which happened during 23 – 26 May, 2015 over Andhra Pradesh. Five stations such as nandigama, Kavali, Darsi, Rajamundry and Bapatla were selected and presented in this paper. The reason for selecting these five stations was due to high death rate in this episode. On comparing the both satellite and automatic weather station(AWS) temperature data, the correlation coefficient was 0.80. There was a sudden increase in the temperatures of about 8 – 130°C in the morning hours. Almost 8 – 10 hours with temperatures above 400°C lasted causing people expose to high temperatures causing more deaths.

Keywords: Heat wave, automatic weather station, satellite, INSAT-3D, Temperature.

I. INTRODUCTION

In recent times, heat waves have been considered as one of the major natural hazards of our country. Heat wave is refered as a period of abnormal high temperatures, which is more than the normal maximum temperatures. This period occurs during summer season i.e March to May. These extreme temperatures and prevailing atmospheric conditions affect the people lives. Globally, many human deaths occur due to heat waves [1]. Some of the heat wave events mentioned below indicates the heat wave impact on human deaths. In 2003, 70,000 people were dead due to heat waves [2]; In 2010, 11,000 people were dead in Russia whereas 1718 people were dead in japan [3]. The heat wave deaths in India are 1425, 1393, and 2500 during 2003, 2013, and 2015 respectively. In these deaths, majority of human loss occurred in Andhra pradesh. Out of 2500 deaths, 2320 deaths alone took place in the regions of Andhra Pradesh and Telangana. So, the two regions account for 92.8% of the total deaths.(http://indianexpress.com/article/india/india-others/8-of-10-heat-wave-deaths-in-andhra-pradesh-odisha/). In those 2320 deaths, 1735 deaths occurred in Andhra Pradesh whereas 585 deaths were recorded in Telangana. According to National Disaster Management Authority report(NDMA 2016), there are 305 deaths occurred over Prakasam district, 197 over Guntur district, 158 over East Godavari district, 102 over Nellore district and 66 over Krishna district. Study by Venkata B. Dodla and Satyanarayana. G.Ch et al. 2017 have discussed briefly about the occurrence of heat wave over India in 2015 and the related thermo dynamics behind it. They also explained that a sudden rise in temperatures in mid May month have caused more deaths in AP.

According to some recent studies by Kunkel et al. 2009 and Larsen 2006 [4-5], the phenomenon of heat waves will increase in future and deaths may even double in the next decade. The occurrence of heat waves differ globally. In 2003, European heat wave lasted for 3 months of June, July, and August [6-7] whereas the american heat wave lasted for few days of july in 1995 and 1999 [8-9]. Usually heat waves occur for few days [10]. Studies by [11-13] have shown the heat wave genesis and its impacts on Indian region. The Application of satellite in heatwave events has shown better indication of risks caused by heat stress and high temperatures [14]. INSAT-3D is an advanced weather satellite of India which was designed and launched by the Indian Space Research Organisation. It has 6-channel imager and a 19-channel sounder. It is used in search and rescue information.

There are four seasons in India. (a). winter season(December - February), (b). summer season or pre-monsoon (March - May), (c). rainy season or South-west monsoon (June - September) and (d). post-monsoon season (October–November). Out of all months, May month frequently records maximum temperatures more than 40 °C. Most of the Heat waves that occur over India take place in the month of May. Andhra Pradesh & Telangana regions are mainly exposed to these heat waves. In 2015, Andhra Pradesh experienced high temperatures more than 44 °C during May 23-27. So we have taken these dates for our study. In this paper, we analysed maximum temperatures of the heat wave episode which happened during 23 – 26 May, 2015 over Andhra pradesh. Five stations such as nandigama, Kavali, Darsi, Rajamundry and Bapatla were selected and presented in this paper. The reason for selecting these five stations was due to high death rate in this episode. The location of this stations as give below in Table 1. Later, we have collected automatic weather stations (AWS) data every hour at the same station. We tried to compare the both satellite and AWS temperature data and calculated the statistical metrics for both the datasets.

II. DATA & METHODOLOGY

The present study was carried out over the area covering Andhra Pradesh extending from 12-20 N and 75-85 E. The following data sets were used for analysis.
1. The data from INSAT-3D satellite are collected at http://www.mosdac.gov.in/.
2. The IMD- AWS data is purchased and collected at

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III. METHODOLOGY:

Statistical metrics comprises of correlation coefficient (CC), the root mean-square error (RMSE), mean absolute error (MAE), root-mean-square error (RMSE), index of agreement (IOA) and BIAS. These were computed to evaluate the INSAT-3d satellite performance with WRF model performance in the prediction of thunderstorms during the period of study. formulae (Wilks, 2006) are as follows:

BIAS = \frac{1}{n} \sum_{i=1}^{n} (o_i - f_i)

(1)

MAE = \frac{1}{n} \sum_{i=1}^{n} |f_i - o_i|

(2)

CC = \frac{\sum_{i=1}^{n} (f_i - \bar{f})(o_i - \bar{o})}{\sqrt{\sum_{i=1}^{n}(f_i - \bar{f})^2 \sum_{i=1}^{n}(o_i - \bar{o})^2}}

(3)

RMSE = \sqrt{\frac{\sum_{i=1}^{n} (f_i - o_i)^2}{n}}

(4)

IOA = 1.0 - \frac{\sum_{i=1}^{n} (f_i - o_i)^2}{\sum_{i=1}^{n} (|f_i - \bar{f}| + |o_i - \bar{o}|)^2}

(5)

where $o_i$ and $f_i$ correspond to observations and forecast values.

IV. RESULTS & DISCUSSIONS:

The results explain the maximum temperatures of the heat wave episode which happened during 23 – 26 May, 2015 over Andhra pradesh. Five stations such as Nandigama, Kavali, Darsi, Rajamundry and Bapatla were selected and presented in this paper. The reason for selecting these five stations was due to high death rate in this episode. The location of these stations as give below in Table 1.

The Time series analysis of mean maximum surface temperature for May, over the 5 stations was computed using INSAT-3D daily 0.10 temperature data at every 30 minutes time interval for the period 23 – 26 May, 2015. Later, we have collected the automatic weather station data for the same 5 stations. We have made an attempt to compare the INSAT-3D satellite data and AWS data. Results of the five stations are presented as follows:

1. Nandigama station:- It is present in Krishna district. From 23rd - 26th May, shown in Figure 1 there was almost 8-9 hours (from 3UTC to 12UTC) recording temperature greater than 40°C. The maximum temperature from AWS was 45.3°C where as from INSAT-3D it was 47.3°C. The minimum temperature from AWS was 29.7°C while as from INSAT-3D it was 28.5°C. When we have calculated statistical metrics for two datasets, the CC was 80% which is reasonable good. The BIAS value was -1.96. The RMSE was 3.05.

2. Rajamundry station:- It is present in East Godavari district. From 23rd - 26th May, shown in Figure 2 there was almost 8-9 hours (from 3UTC to 12UTC) recording temperature greater than 40°C. The maximum temperature from AWS was 45.3°C whereas from INSAT-3D it was 44.7°C. The minimum temperature from AWS was 28.5°C whereas from INSAT-3D it was 29.7°C. When we have calculated statistical metrics for two datasets, the CC was 80% which is reasonable good. The BIAS value was -0.31. The RMSE was 1.67.
3. **Kavali station**: It is present in Nellore district. From 23rd - 26th May, shown in Figure 1 there was almost 9 hours (from 6UTC to 14UTC) recording temperature greater than 40°C. This temperature has created discomfort for the human lives. The maximum temperature from AWS was 44.8°C where as from INSAT-3D it was 43.3°C. The minimum temperature from AWS was 32.5°C where as from INSAT-3D it was 28.9°C. When we have calculated statistical metrics for two datasets, the CC was 68% which is reasonable good. The BIAS value was -2.9. The RMSE was 3.5.

Figure 3: Time Series plot of Temperature plotted from AWS & INSAT 3D satellite data for May 23rd to May 26th 2015 over Kavali Station.

4. **Darsi station**: It is present in Prakasham district. From 23rd - 26th May, shown in Figure 1 there was almost 7-8 hours (from 6UTC to 14UTC) recording temperature greater than 40°C. This temperature has created discomfort for the human lives. The maximum temperature from AWS was 44°C where as from INSAT-3D it was 43.4°C. The minimum temperature from AWS was 34.6°C where as from INSAT-3D it was 29.1°C. When we have calculated statistical metrics for two datasets, the CC was 87% which is reasonable good. The BIAS value was -1.73. The RMSE value is 1.87.

Figure 4: Time Series plot of Temperature plotted from AWS & INSAT 3D satellite data for May 23rd to May 26th 2015 over Darsi Station.

5. **Bapatla station**: It is present in Guntur district. From 23rd - 26th May, shown in Figure 1 there was almost 10 hours (from 5UTC to 14UTC) recording temperature greater than 40°C. This temperature has created discomfort for the human lives. The maximum temperature from AWS was 45°C where as from INSAT-3D it was 43.9°C. The minimum temperature from AWS was 30.5°C where as from INSAT-3D it was 31.2°C. When we have calculated statistical metrics for two datasets, the CC was 84% which is reasonable good. The BIAS value was -1.36. The RMSE was 2.12.

Figure 5: Time Series plot of Temperature plotted from AWS & INSAT 3D satellite data for May 23rd to May 26th 2015 over Bapatla Station.

<table>
<thead>
<tr>
<th>Station</th>
<th>District</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darsi</td>
<td>Prakasham</td>
<td>15.78°N</td>
<td>79.65°E</td>
</tr>
<tr>
<td>Bapatla</td>
<td>Guntur</td>
<td>15.92°N</td>
<td>80.49°E</td>
</tr>
<tr>
<td>Rajamundry</td>
<td>East godavari</td>
<td>17.10°N</td>
<td>81.62°E</td>
</tr>
<tr>
<td>Kavali</td>
<td>Nellore</td>
<td>14.91°N</td>
<td>79.99°E</td>
</tr>
<tr>
<td>Nandigama</td>
<td>Krishna</td>
<td>16.77°N</td>
<td>80.28°E</td>
</tr>
</tbody>
</table>
Satellite and AWS Based Scrutiny of Heat Wave over A.P

Table-2 Statistical metrics.

<table>
<thead>
<tr>
<th></th>
<th>BIAS</th>
<th>MAE</th>
<th>RMSE</th>
<th>CC</th>
<th>IOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>23-May</td>
<td>-0.93</td>
<td>1.9</td>
<td>2.67</td>
<td>0.84</td>
<td>0.91</td>
</tr>
<tr>
<td>24-May</td>
<td>-1.73</td>
<td>2.9</td>
<td>3.06</td>
<td>0.85</td>
<td>0.84</td>
</tr>
<tr>
<td>25-May</td>
<td>-1.4</td>
<td>2.11</td>
<td>2.4</td>
<td>0.9</td>
<td>0.81</td>
</tr>
<tr>
<td>26-May</td>
<td>-0.31</td>
<td>1.48</td>
<td>1.77</td>
<td>0.94</td>
<td>0.97</td>
</tr>
</tbody>
</table>

V. SUMMARY AND CONCLUSIONS:

In this paper, we analysed maximum temperatures of the heat wave episode which happened during 23 – 26 May, 2015 over Andhra pradesh. Five stations such as nandigama, Kavali, Darsi, Rajamundry and Bapatla were selected and presented in this paper. The reason for selecting these five stations was due to high death rate in this episode. We tried to compare the both satellite and AWS temperature data and calculated the statistical metrics for both the datasets as shown in Table-2. On comparing the both satellite and AWS temperature data, the correlation coefficient was 0.80. Out of all four days, 25th & 26th May temperatures have shown good correlation between AWS and INSAT-3D. There was a sudden increase in the temperatures of about 8 – 13°C in the morning hours. Almost 8 – 10 hours with temperatures above 40°C lasted causing people expose to high temperatures causing more deaths.

This study reveals the possibilities of increased utilisation of satellite data especially from INSAT 3D for heatwave analysis over Andhra pradesh.

ACKNOWLEDGMENT

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