

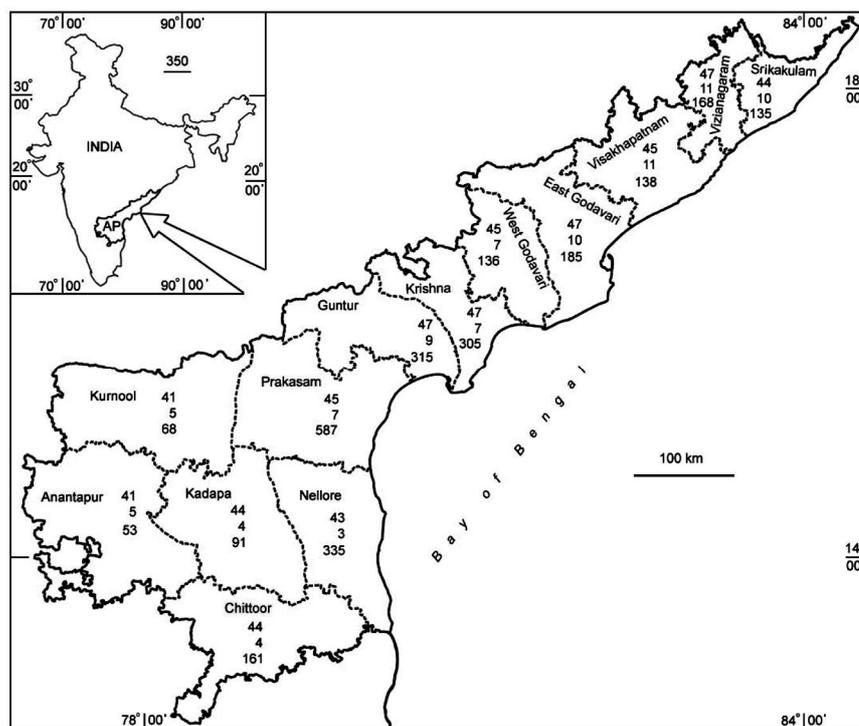
## Severe heat wave during May 2015 in Andhra Pradesh

Summer heat waves are increasing in intensity during recent years<sup>1</sup>, leading to excess human mortality<sup>2</sup>. In India, 14,129 heat-wave deaths occurred during 1979–2013. The heat waves largely occur in central India, but have intensified in the east coast region, especially in Andhra Pradesh (AP) and Odisha during the last two decades<sup>3,4</sup>. AP is one of the worst affected states in the recent past. During May, a semi-permanent trough usually prevails over Odisha to Tamil Nadu across coastal AP, associated with hot dry winds blowing from north/northwesterly along with significant rise in temperature leading to heat-wave conditions. The heat wave that occurred over the east coast during 19 May–10 June 2003 with maximum temperatures soaring over 45–49°C (ref. 5) killed 1421 people in (undivided) AP alone<sup>6</sup>. The year 2015, the hottest ever on record proved to be even worse as the heat wave during 22 May–1 June, triggered by a persistent deep trough along the east coast during the period associated with advection of hot and dry winds from northwest India, claimed 2677 lives.

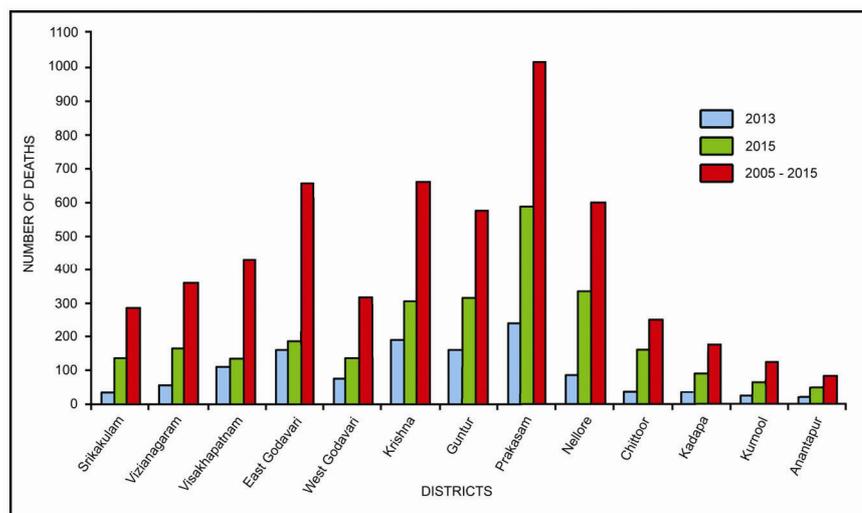
AP spread over 160,205 sq. km along the east coast of the Indian peninsula (Figure 1) is home to ~50 million people. Nine out of its 13 districts, facing the Bay of Bengal constitute the semiarid coastal region (annual rainfall 943 mm; temperature range 22.6–31.6°C) and the remaining 4 districts constitute the interior Rayalaseema region, which is more on the arid side (rainfall 683 mm; temperature range 22.2–30.4°C). May is the hottest month (mean temperature 31°C), while December records the lowest temperatures (22.4°C). Data on the daily maximum temperature recorded at 13 stations, each representing a district in the state, ranged from 42°C to 47°C showing deviations of 3–11°C from the climatic normal during 22 May–1 June 2015 (Figure 1). The daily maximum temperatures showed an increasing trend from about 36–45°C on 22 May to 44–47°C by 25 May in the coastal districts. Subsequently, the temperatures showed a progressive decrease to 37–38°C by 28 May in the five northern coastal districts (Srikakulam to West Godavari), but continued to be higher at 44–47°C in the four southern coastal districts (Krishna to Nellore). However, the maximum tem-

peratures were more or less consistent at 41–44°C on most days in the four Rayalaseema districts (Chittoor to Anantapur). Generally, heat wave and severe heat wave are classified as conditions when

the temperature departures are 5–6°C and ≥7°C respectively, for stations where the normal maximum temperature is ≤40°C, and 4–5°C and 6°C or more respectively, for stations where the maximum normal



**Figure 1.** Map showing the 13 districts in Andhra Pradesh (AP). Numbers in each district indicate maximum temperature (°C; top), maximum temperature anomalies (°C; middle) and heat-wave related deaths (bottom) during 22 May–1 June 2015. Inset shows location of AP in India.



**Figure 2.** District-wise heat-wave related deaths in Andhra Pradesh during 2013 (blue), 2015 (green) and 2005–15 (red).

temperature is  $>40^{\circ}\text{C}$  (ref. 7). The positive anomalies of maximum temperature were  $7\text{--}9^{\circ}\text{C}$  on many days and even reached  $10\text{--}11^{\circ}\text{C}$  at some stations, indicating heat wave to severe heat wave conditions almost throughout the 11-day period over the coastal AP region (Figure 1). The four Rayalaseema districts and the adjacent Nellore district in the southern part of the coastal region also experienced heat wave, despite the temperature departures being below the required criteria, since the maximum temperatures in this region were  $>40^{\circ}\text{C}$ , which indicates heat wave conditions for the plains<sup>7</sup>. Thermal stress on a person is based on ambient temperature, humidity, exposure to sunlight, wind, clothing and level of activity, as well as age, gender and state of health<sup>8</sup>. Ideally, assessment of heat-wave related deaths should consider all these variables as elucidated by Dash and Kjellstrom<sup>7</sup> in a review of various indices involving several of these variables. However, due to non-availability of such detailed data, we used temperature and relative humidity (RH) to derive the heat index (HI), or heat stress on the human body. The daily HI was above  $41^{\circ}\text{C}$  at all the stations during the period and even higher than  $54^{\circ}\text{C}$  on a number of days at many of the stations, with a maximum value of  $127^{\circ}\text{C}$  in Vizianagaram district on 24 May 2015. A HI value between  $41^{\circ}\text{C}$  and  $54^{\circ}\text{C}$  indicates 'Danger' and  $>54^{\circ}\text{C}$  indicates 'Extreme Danger' in relation to the health risk of heat stroke (<http://www.srh.noaa.gov/ffc/?n=hichart>). Apparently, with the computed HI values in the 'extreme danger' category during most of the days in the study period, the 2015 heat wave has taken its toll in AP claiming 2677 lives. The highest number of 587 deaths occurred in Prakasam district, followed by 335 in Nellore, 315 in Guntur and 305 in Krishna district (Figure 1).

However, the overall correlation coefficient between HI and mortality is poor

in all the districts, probably because the deaths might have occurred on subsequent days after the victims were subjected to heat stroke. Moreover, there is no linear relationship between HI and mortality among the districts. In the five north coastal districts where the HI values were consistently higher ranging from  $54^{\circ}\text{C}$  to as high as  $127^{\circ}\text{C}$ , the total death toll was relatively low at 762 than in the four south coastal districts where the HI values were relatively low ( $40\text{--}59^{\circ}\text{C}$ ; with some exceptions) but the mortality was relatively high at 1542. In the four Rayalaseema districts where the HI values were more or less similar to that of the south coastal districts, the heat-stroke deaths were much lower (373 persons) during the period. Therefore, while temperature and RH may be the key factors for estimating the intensity of the heat stress, other variables such as overexposure to the sunlight through outdoor activity, lack of awareness of the health threat of heat waves, socio-economic conditions and delayed or no medical treatment perhaps play a more important role in the human mortality to heat waves. This can be conjectured from the enormity of the death toll in Prakasam district during the May 2015 heat wave, despite the prevalence of relatively lower HI values than in several other districts. A similar situation prevailed during May 2013, as Prakasam district accounted for a maximum 242 casualties out of the total 1249 heat-wave deaths in AP (Figure 2). In fact, our compilation of data on heat-wave deaths during 2005–15 showed that the south coastal districts, Prakasam district, in particular, accounted for 1012 out of the total 5531 deaths in the state (Figure 2). Therefore, in-depth studies are necessary to understand not only the weather phenomena, but also the socio-economic and working conditions among the vulnerable sections of the people that lead to heat-wave related deaths in areas such as Prakasam district in AP.

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## Meteorite fall at Komargaon, Assam, India

A single piece of meteorite weighing approximately 12 kg and dimension  $10'' \times 9'' \times 8''$  fell at Komargaon town (lat.  $26^{\circ}39'N$ ; long.  $93^{\circ}46'E$ ), Golaghat district, Assam, India on 13 November 2015 (12:00 h, IST). We report here

eye-witness accounts and a preliminary description of the sample which includes macro- and microstructures and a tentative petrologic-chemical classification. According to local villagers, it was a bright sunny day with a clear sky. They

were startled by a thunderous sound and on searching they found a burning piece of material which might have traveled the sky and finally hit the ground hard. The celestial object landed on a soft ground mainly ploughed for plantation of