

# Weather Files for India: Documentation

This Web page describes the set of India weather files developed by NREL for use with the System Advisor Model ([SAM](#)). Paul Gilman and Mary Anderberg prepared the page with information from Ray George and comments from Shannon Cowlin.

SAM is a performance and financial simulation model that calculates the energy output and cash flow of renewable energy power generation projects. For solar energy projects, the model requires a weather file describing both the solar resource and weather conditions at the project location. A SAM weather file includes direct normal, diffuse horizontal, and global horizontal solar radiation data and weather data describing ambient conditions, including temperature, humidity, pressure, and wind speed.

## Data Sources

The SAM weather files for India combine solar resource data and weather data from two different sources.

The solar resource data are from the hourly data set available on the [India Solar Resource Maps](#) website, which contains hourly global horizontal, direct normal, and diffuse horizontal data for all of India, divided into approximately 10 km by 10 km square grid cells. The solar resource data were developed from satellite imagery using a numerical model developed at the State University of New York (SUNY). For a description of the SUNY method, see A New Operational Satellite-to-Irradiance Model ([PDF](#)).

The weather data are from the Integrated Surface Database (ISD) maintained by the U.S. National Oceanic and Atmospheric Administration (NOAA). The weather data include hourly values for air temperature, dew point temperature, atmospheric pressure, wind direction, and wind speed. For a description of the ISD, see the [Integrated Surface Database](#) web site.

## Location Selection

Although hourly solar resource data are available for all locations in India, ISD weather data are available for only 87 stations. The ISD stations shown in Table 1 were selected from the 87 stations to represent a range of climate zones where solar projects may be of interest in India. For those locations, solar resource data was combined with the ISD weather data to create the SAM weather files.

**Table 1. List of locations with Integrated Surface Database (ISD) station name, number and coordinates, SUNY grid cell coordinates, and years for which SAM weather files were prepared**

Location Name	ISD Number	ISD Station		Center of SUNY Grid Cell		Available Years
		Lat. (°N)	Long. (°E)	Lat. (°N)	Long. (°E)	
Amritsar	420710	31.633	74.867	31.55	74.85	2002-2008
Jaipur/Sanganer	423480	26.817	75.8	26.95	75.85	2004-2008
Lucknow/Amausi	423690	26.75	80.833	26.85	80.85	2002-2008

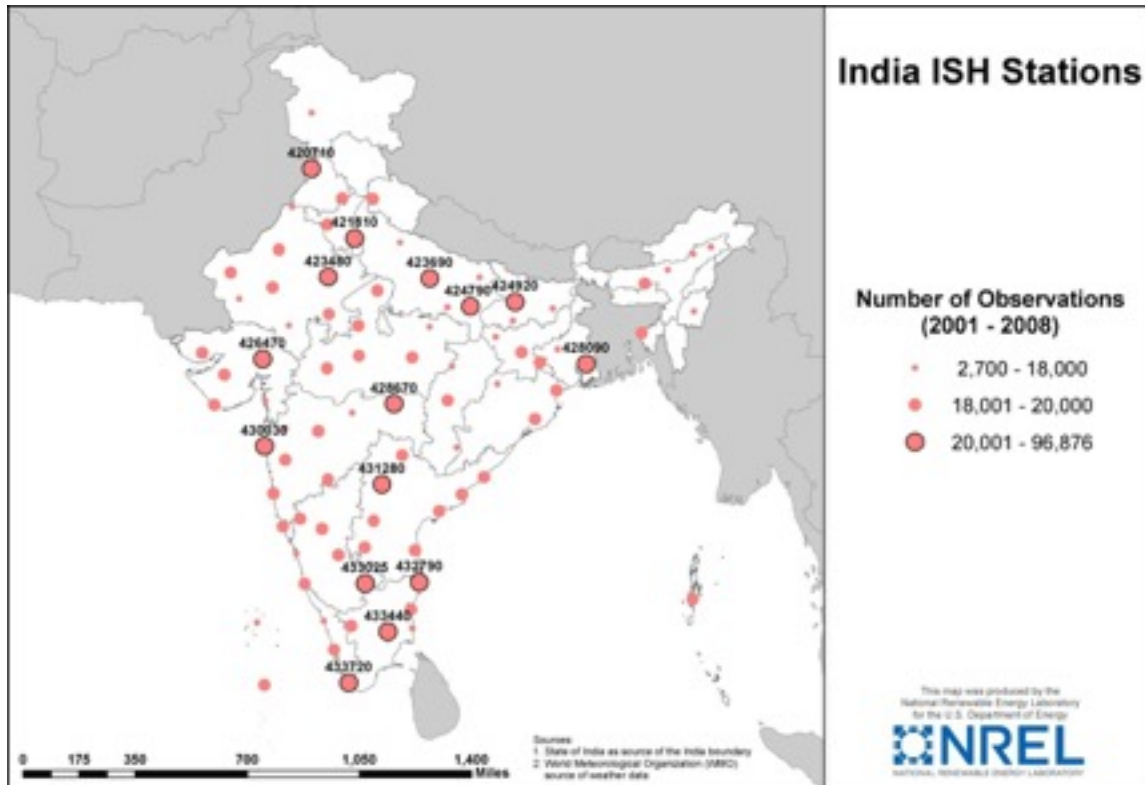
Varanasi/Babatpur	424790	25.45	82.867	25.55	82.85	2002-2008
Ahmadabad	426470	23.067	72.633	23.25	72.75	2002-2008
Calcutta/Dum Dum	428090	22.65	88.45	22.55	88.45	2002-2008
Nagpur/Sonegaon	428670	21.1	79.05	21.25	79.05	2004-2008
Begumpet Airport	431280	17.45	78.467	17.35	78.65	2002-2008
Tiruchchirapalli	433440	10.767	78.717	10.75	78.75	2002-2008

For most locations shown in Table 1, a SAM weather file is available for each year in the range 2002 through 2008. For Nagpur/Sonegaon and Jaipur/Sanganer, there were insufficient data for 2002 and 2003, so for those two locations, files are only available for 2004 through 2008.

The following selection criteria were used to select stations from the 87 ISD stations:

- Measured data available for a measurement period of 2002 to 2008 to match the dates for which SUNY solar radiation data.
- Data available for at least 20,000 hourly observations over the measurement period.
- Location with sufficient open land space to develop a large-scale solar power project. For example, New Delhi was excluded.
- Location away from coast to avoid climate effects of large bodies of water. For example, Bombay was excluded.

Figure 1 shows the 87 ISD stations. The size of each circle indicates the number of observations available at the station. Circles with black borders indicate the fifteen stations that met the minimum criteria of 20,000 observations. Numbers next to circles are ISD station numbers.



**Figure 1. Map of India showing location of 87 ISD weather stations**

For each of the nine ISD stations that met the above criteria, the land surrounding the station was examined to find parcels suitable for potential solar projects. Parcels meeting any of the following criteria were excluded:

- Protected areas such as national parks
- Bodies of water
- Major urban areas
- Agricultural land
- Slope greater than 5%
- Continuous land area less than 0.3 square kilometers

The remaining parcels were then visually examined in Google Earth for proximity to tall buildings, large population centers, rice paddies, river flood plains, or any other characteristics that would make them unsuitable for a large solar project.

Of the suitable parcels, for each ISD station, the parcel nearest the station was chosen (in most cases). To create the SAM weather file, solar resource data for the SUNY grid cell containing the parcel was combined with the weather data from the ISD station to create the SAM weather file for each year. Table 1 shows both the coordinates of center of the

SUNY grid cell and the coordinates of the ISD station used to create each file. Maps showing the relative positions of the ISD station and one or more sample parcels can be seen in Figures 2- 10, at the end of this document.

Note that the SUNY grid cell coordinates are used in the weather file so that SAM's sun angle calculations are based on the solar resource data.

## **File Format**

The SAM weather files for India are in the TMY3 file format, which is a comma-delimited text format. The standard TMY3 format requires the following data:

- Header data with the location name, time zone, latitude and longitude
- A header row of data element names and units
- Date and time stamps
- Solar radiation data for each of the 8,760 hours in one year
- Weather data for each of the 8,760 hours in one year
- Flags providing information about the source and quality of the data

For details about the standard TMY3 file format, see the [TMY3 User's Manual](#).

SAM simulations do not require all of the data elements included in a standard TMY3 file. The SAM weather files include hourly data for the following subset of elements in the standard format:

- Dry bulb temperature
- Dew point temperature
- Wet bulb temperature
- Percent relative humidity
- Wind velocity
- Wind direction
- Atmospheric pressure
- Global horizontal radiation
- Direct normal radiation
- Diffuse horizontal radiation
- Latitude
- Longitude
- Site elevation

- Time

For the remaining data elements not used by SAM, the value -9900 indicates a null value. SAM requires that each data element have a value regardless of whether it is used during simulations.

## Typical Meteorological Year and Single Year Data

The SAM weather files for India do not contain typical meteorological year data. Each file contains hourly data for a single year at a given location.

A typical meteorological year file contains data for a single year that represent the solar resource and weather over a period of many years. Thirty years of data are generally considered necessary to develop a typical meteorological year file that accounts for regular climate patterns at a given location. Because only six years of solar resource data were available for India, it was not possible to create typical meteorological year files based on this data.

For more information about typical meteorological year data, see the TMY3 User's Manual referenced above, and Chapter 5 of Concentrating Solar Power: Best Practices Handbook for the Collection and Use of Solar Resource Data ([PDF](#)).

## Time Stamp

The solar data in the SUNY data set are in Local Standard Time (LST) for GMT+5.5 hours and "time shifted" so that each hourly value represents the average value from the previous hour. See [About the data](#) for details.

Note that the time stamp for the ISD weather data is on-the-hour GMT. The weather data time stamp was adjusted to match the solar data time stamp based on the GMT +5.5 time zone.

## Missing Data

The solar data sets are complete with no missing data: For each grid cell and year, the data file contains solar radiation values for each of the 8,760 hours of the year.

The hourly weather data sets from the ISD were not complete. Gaps in the weather data were filled using the method developed for filling gaps in the U.S. National Solar Radiation Database (NSRDB) 1991-2005 update.

The ISD data do not include relative humidity values required by SAM. Those values were calculated based on the temperature and atmospheric pressure values included in the data set, and using the method used for filling gaps in the NSRDB 1991-2005 update.

For a discussion of the methods used to fill missing data in the NSRDB update, see the National Solar Radiation Database 1991-2005 Update User's Manual ([PDF](#)).

For three of the original locations selected, the number of gaps exceeded the number that could be filled by the algorithm. No weather files were generated for Patna (WMO #424920), one of the ten original candidate sites, because there large gaps in the data over the entire seven year period. For Nagpur/Sonegaon and Jaipur/Sanganer, there were too many gaps to fill in 2002 and 2003, so a SAM weather file is not available for 2002 or 2003 at those locations.

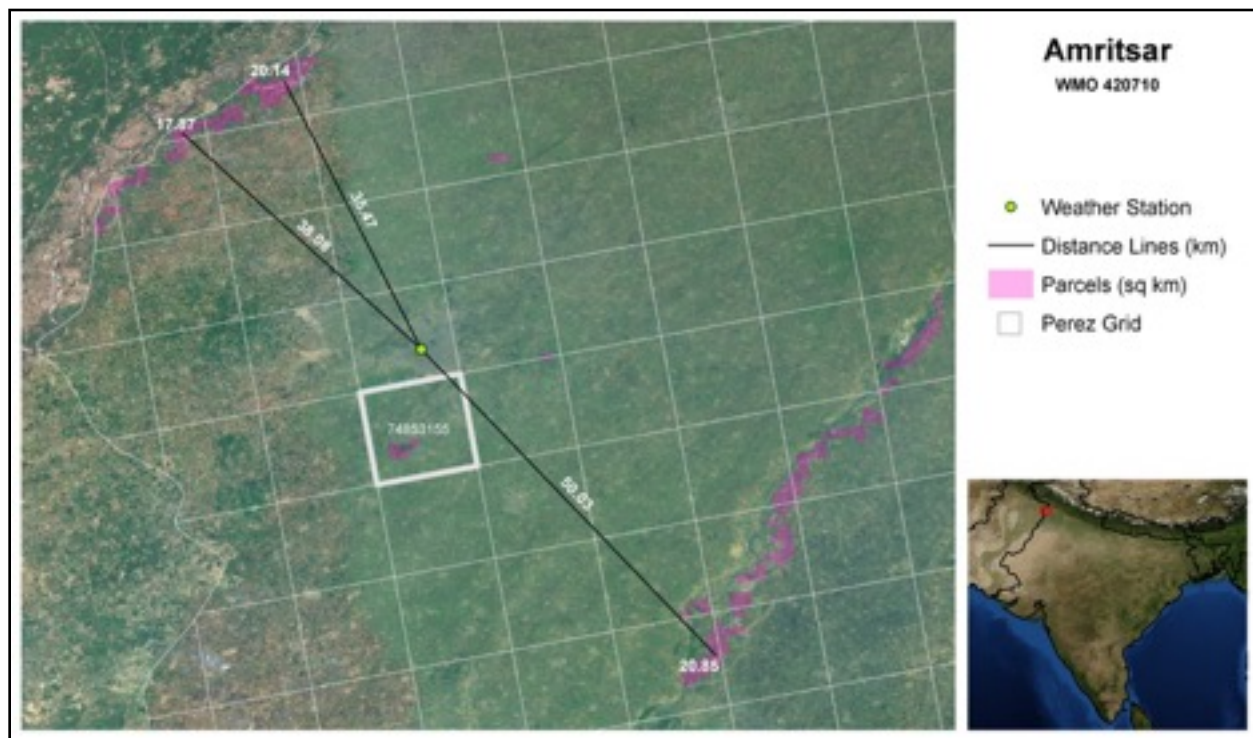
## Using the Weather Files in SAM

For simulations of a system's performance, the SAM weather files for India will provide reasonable estimates of hour-by-hour values for each of the years. For example, simulating a PV or parabolic trough system using 2006 weather file for Jaipur will give a reasonable estimate of the system's hourly electrical output, module conversion efficiency, and other technical metrics for that system in 2006, but not over a longer period.

SAM's financial models assume a multi-year analysis period, so using a single-year weather file does not produce results representing the full analysis period. For example modeling a 30-year utility-scale PV or parabolic trough project using the 2006 weather file for Jaipur will not give reasonable estimates of levelized cost of energy, internal rate of return, or other financial metrics.

One approach to financial modeling with specific-year weather files is to run the model for each of the years, and then aggregate the metrics of interest to provide some insight into the effect of year-to-year variation on the metrics of interest.

For a discussion of this topic, see Concentrating Solar Power: Best Practices Handbook for the Collection and Use of Solar Resource Data ([PDF](#)).

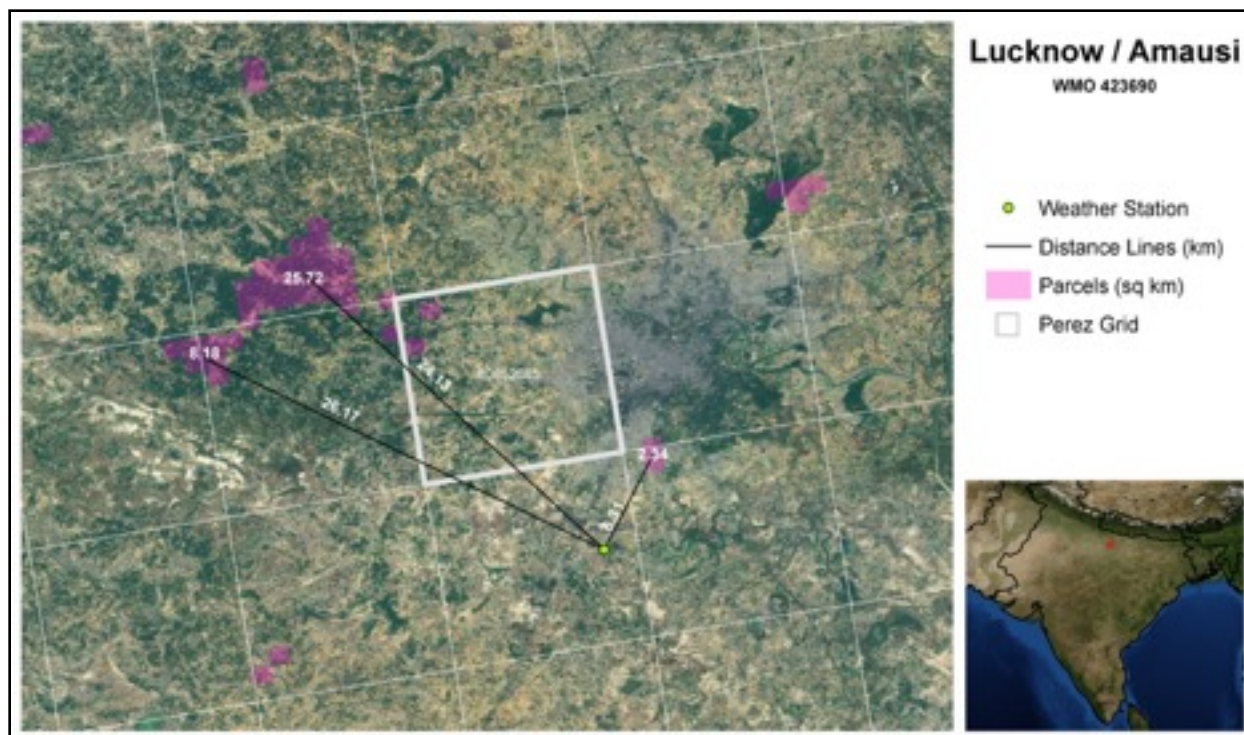


**Figure 2. 420710 Amritsar ISD weather station and selected grid cell.**



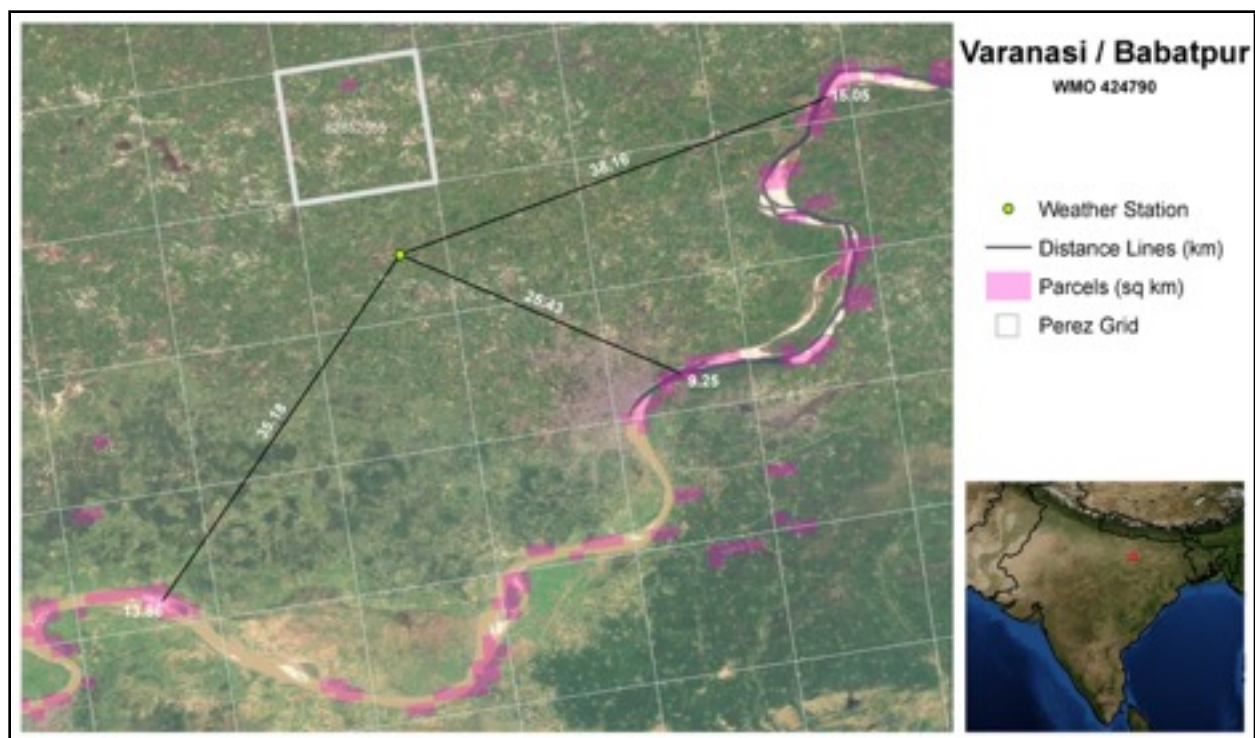


**Figure 3. 423480 Jaipur/Sanganer ISD weather station and selected grid cell.**



**Figure 4. 423690 Lucknow/Amausi ISD weather station and selected grid cell.**



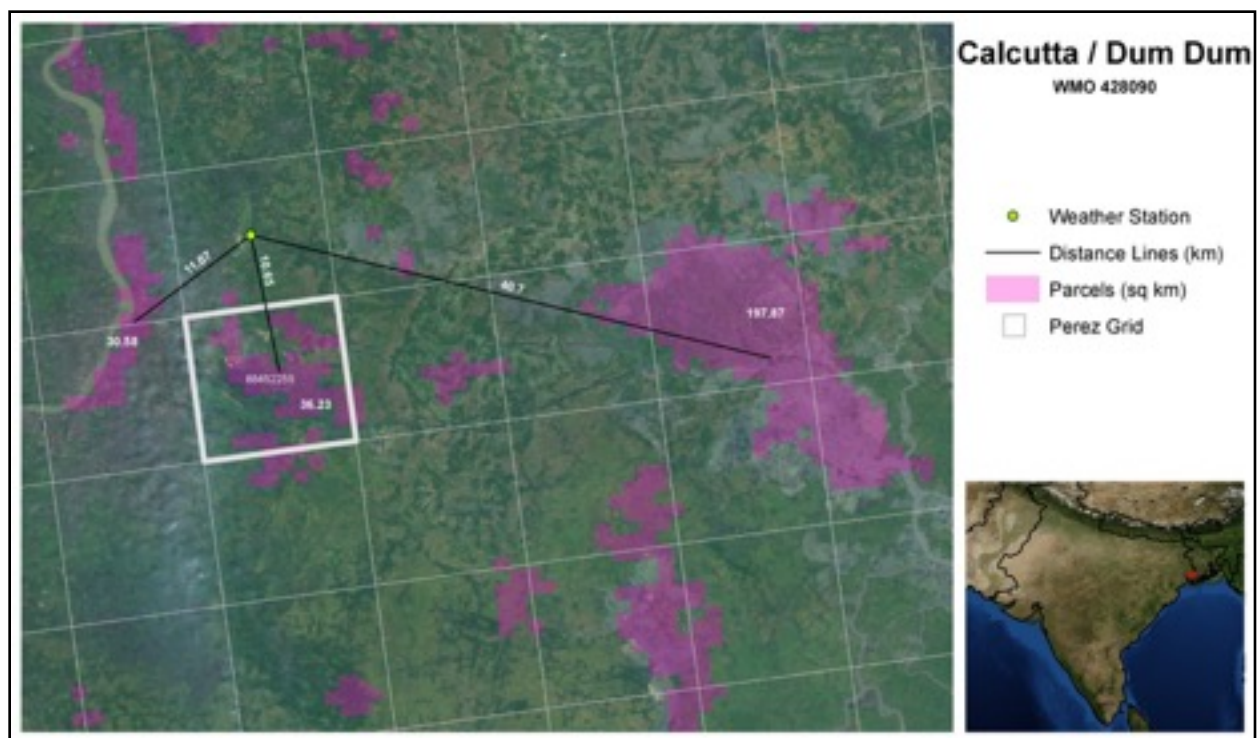


**Figure 5. 424790 Varanasi/Babatpur ISD weather station and selected grid cell.**



**Figure 6. 426470 Ahmadabad ISD weather station and selected grid cell.**





**Figure 7. 428090 Calcutta/Dum Dum ISD weather station and selected grid cell.**

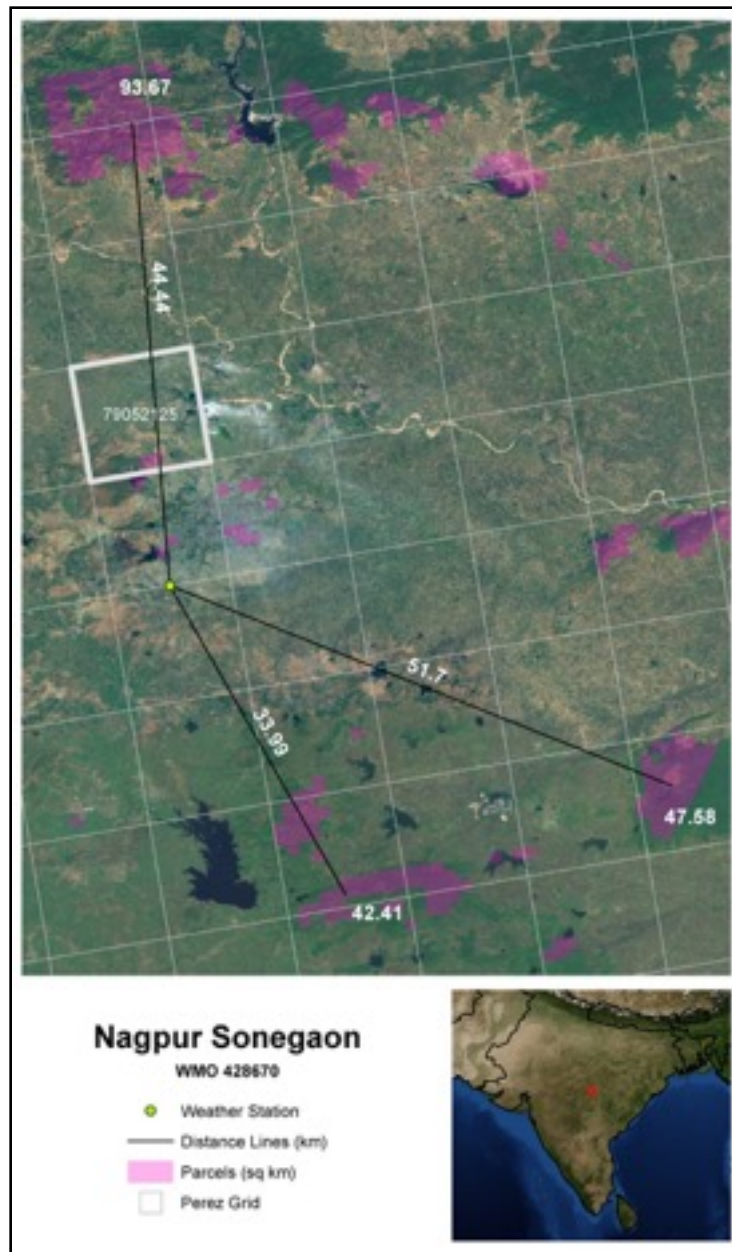
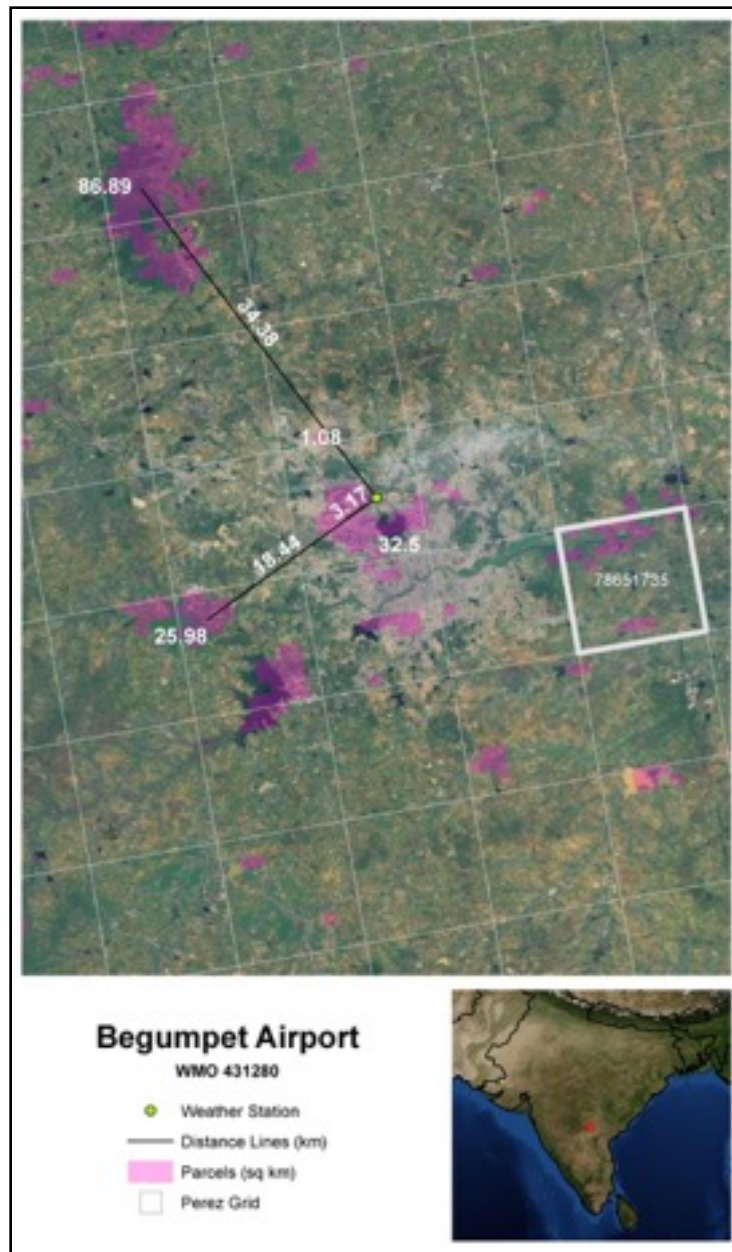
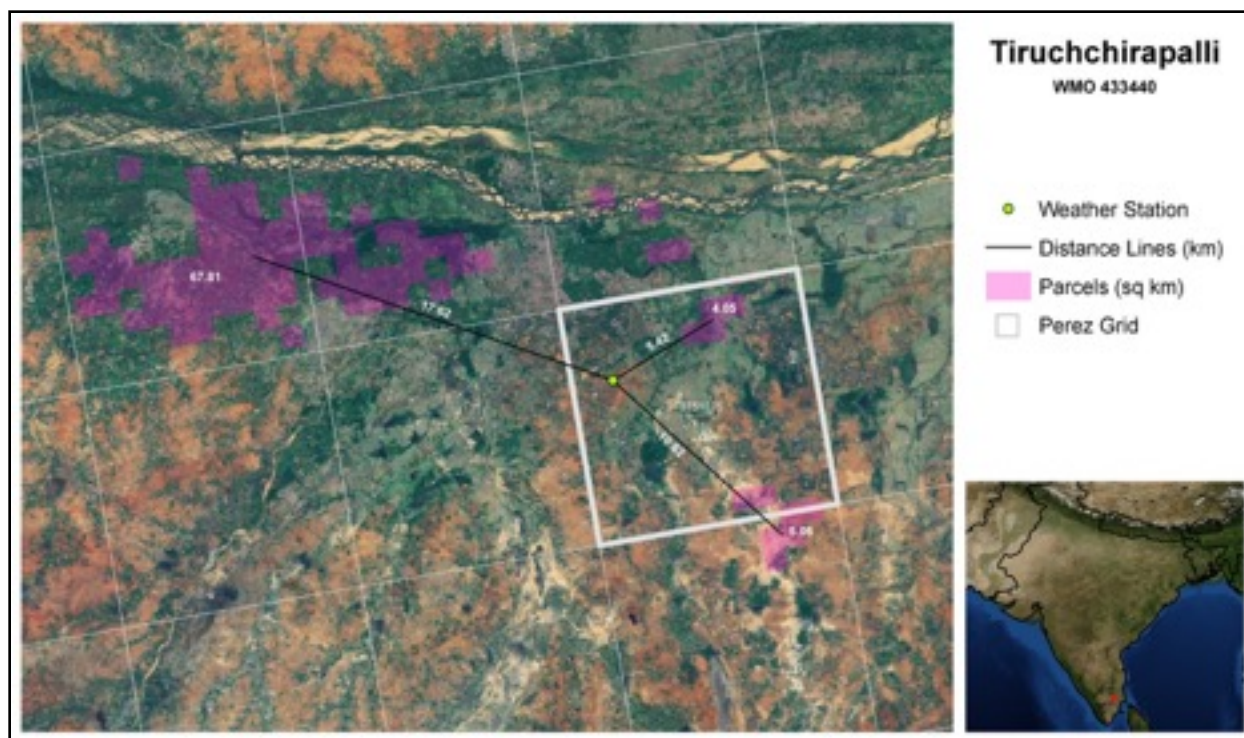


Figure 8. 428670 Nagpur Sonegaon ISD weather station and selected grid cell.



**Figure 9. 431280 Begumpet Airport ISD weather station and selected grid cell.**



**Figure 10. 433440 Tiruchchirapalli ISD weather station and selected grid cell.**