UGC Approved Journal

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 4, Issue 7, July 2017

Spatially Distributed Extrapolation of Ground Station Logged Temperature Time Series using Satellite Data based Digital Elevation Model

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Abstract: Time series of spatial distributed ambient air temperature data sets is used as the main driving variable to estimate snowmelt in temperature index models. However, extreme climatic conditions and prohibit establishment, maintenance and operation of metereological stations in the logistically challenging of catchment of Sutlej river in Nari Khorsam province of Tibetian Highlands. Remote sensing based land-surface temperature data are also not very useful for snow-covered areas. In the present study ASTER Digital Elevation Model is used for dividing the river basin area in five elevation zones. Time series of Daily maximum and minimum temperature data logged at weather station in Kaza are extrapolated to various elevation zones using the temperature lapse rate for obtaining spatially distributed temperature data sets.

Keywords: Extrapolation, Temperature, Digital Elevation Model, Rugged Tibetan Terrain, Elevation Zones, Temperature lapse Rate.

INTRODUCTION

The Land Surface Temperature / Air Temperature is widely used in a large number of science disciplines concerned with evapo-transpiration, climate change, hydrological cycle, vegetation monitoring, urban climate and environmental studies, among others (Arnfield, 2003; Bastiaanssen et al.1998). Understanding the spatial distribution of temperature in mountainous areas is utmost important for hydrological modelling. In the snow covered areas, ambient air temperature is the main factor to partition liquid from solid precipitation is used as the main driving variable to estimate snowmelt in temperature index models. Hence there is a lot of interest in satellite remote sensing for retrieving the temperature of earth surface.

Since 1978 microwave sounding units (MSUs) on National Oceanic and Atmospheric Administration polar orbiting satellites have measured the intensity of upwelling microwave radiation from atmospheric oxygen, which is related to the temperature of broad vertical layers of the atmosphere. Satellites may also be used to retrieve surface temperatures in cloud-free conditions, generally via measurement of thermal infrared from the Advanced Very High Resolution Radiometer. Weather satellites have been available to infer sea surface temperature (SST) information since 1967. For example, changes in SST monitored via satellite have been used to document the progression of the El Niño-Southern Oscillation since the 1970s. Various satellite based instruments are available which provide land surface temperature data sets. Among these the Landsat Thematic Mapper, Moderate Resolution Imaging Spectroradiometer (MODIS), and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensors are important. All these data sets have relative advantages over each other. For example, Landsat data has an advantage over MODIS in that L5-TM provides a spatial resolution of 120 m as compared with 1,000 m for the thermal band of MODIS. However, a repeat image is available after a gap of 16-days, compared with 1-day repeatability for MODIS. The ASTER imagery is available at 60 m spatial resolution is not available free of charge.

Over the land the retrieval of temperature from radiances is harder, because of the inhomogeneities in the surface. Due to the strong heterogeneity of land surface characteristics such as vegetation, topography, and soil, the Land Surface Temperature / Air Temperature changes rapidly in space as well as in time (Neteler, 2010; Prata et al., 1995). Retrieving LST is still a challenging task since the LST retrieval problem is ill-posed. Satellites do not measure temperature. They measure radiances in various wavelength bands, which must then be mathematically inverted to obtain indirect inferences of temperature.

Satellite-based thermal infrared (TIR) data is directly linked to the Land Surface Temperature through the radiative transfer equation. To better understand the Earth system at the regional scale LST must be retrieved at an accuracy of 1 K or better (Kustas and Norman, 1996; Moran and Jackson, 1991). However, direct estimation of LST from the radiation emitted in the TIR spectral region is difficult to perform with that accuracy, since the radiances measured by the radiometers onboard satellites depend not only on surface parameters (temperature and emissivity) but also on

DOI10.17148/IARJSET.2017.4736

atmospheric effects (Li and Becker, 1993; Prata et al. 1995). Therefore, besides radiometric calibration and cloud screening, the determination of LSTs from space-based TIR measurements requires both emissivity and atmospheric corrections (Ottle and Stoll, 1993).

The most crucial issue with use of satellite derived LST is it's accuracy and representativeness of the ground-truth LST at the satellite pixel scale (Johnson 2009). For this satellite derived LST must be calibrated and validated using adequate ground truth based data sets. Although ground-based validation is considered to be the most reliable validation technique, measurements of the ground-truth LST are limited by the by the difficulty and associated costs of sampling over high altitude rugged mountainous landscapes (Zhao et al.2013),

In the Nari Khorsum area within the Tibetan highland area, the meteorological stations network is sparse. Moreover the ground based data sets are not easily accessible as the region is administratively controlled by the Government of China. Hence for present circumstances it is prudent to use temperature data logged at a representative weather station on the Indian part of the catchment and interpolate or extrapolate it.

Objective

The object of present study is extrapolation of ground station logged temperature data time series in a spatially distributed fashion using satellite data based digital elevation model for the extremely rugged logistically challenging catchment of Sutlej river in Nari Khorsum province of Tibet.

MATERIAL AND METHODS

Spatial interpolation is widely used to obtain air temperature estimates at any point of interest (Ishida and Kawashima, 1993; Hudson and Wackernagel, 1994). In mountainous areas, air temperature is controlled by different factors related to location and topography (Hudson and Wackernagel, 1994). Therefore, the use of interpolation methods generate substantial errors and biases (Willmott et al., 1991). Conventionally, the method of altitudinal lapse rate is used to estimate temperatures at different elevations (Dunn and Colohan, 1999; Singh and Singh, 2001).

In troposphere, temperature declines with an increase in altitude at the rate of 9.8*C/km. This decline, known as temperature lapse rate, is controlled by the balance between heat convection from the surface and radiative cooling. However, lapse rates vary with: altitude, season, latitude, and interactions between topography and weather (e.g. dry versus moist air and inversions). The lapse rate method (LRM) takes the maximum air temperature observed at a reference station and extrapolates that value over the entire basin via a functional relationship between air temperature and elevation data. This method assumes a linear relationship between air temperature and elevation.

For the present study temperature data loggesd at Kaza, sub-divisional headquarter of Lahaul and Spiti district of Himachal Pradesh is used. Kaza is located at an elevation of 3650 m above the mean sea level and is representative of the cold arid conditions prevailing in the catchment of Sutlej in Tibet.

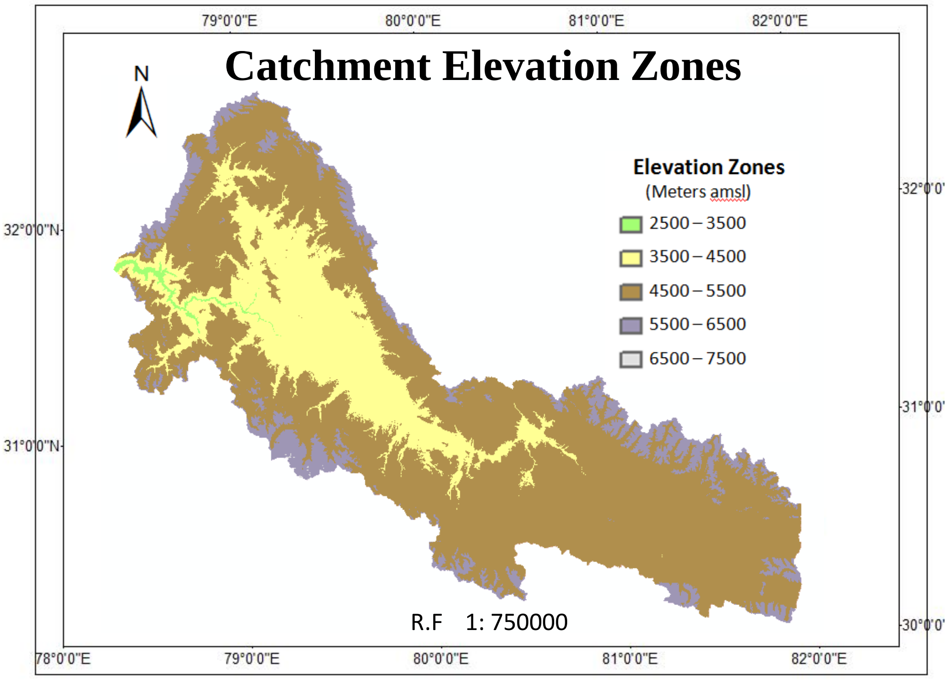


Figure 1: Elevation Zones in the Catchment.

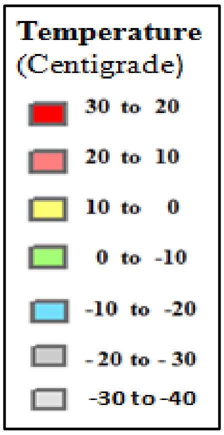
DOI10.17148/IARJSET.2017.4736

The maximum, minimum and average temperature data logged at a daily time step are used for extrapolating in the entire catchment using the temperature lapse rate as the method. ASTER senser derived Digital Elevation model is used for dividing the entire catchment into five elevation zones:

- Zone 1: 2500 - 3500
- Zone 2: 3500- 4500
- Zone 3: 4500 – 5500
- Zone 4 5500 – 6500
- Zone 5 6500 – 7500

RESULTS

The maximum, minimum and average temperature data sets were extrapolated for each day for the period starting from 1st march 2000 to 28th February 2003. The choice of the month of March is based on the assumption that snowmelt begins some time during month of March. The maps of spatially distributed Monthly Maximum Temperature, derived by extrapolating the data logged at Kaza station to mean elevation of each of the five DEM derived elevation zones are presented for showcasing the successful achievement of the objectives of this chapter. The maximum temperature ranges from a high of 32* Centigrade in August to a minimum of -35* Centigrade in March. Following color ramp key is used to interpret the maximum temperature profile.



Temperature (Centigrade)	
🟥	30 to 20
🟥	20 to 10
🟨	10 to 0
🟩	0 to -10
🟦	-10 to -20
⬜	- 20 to - 30
⬜	-30 to -40

Figure 2: Maximum Temperation range interpretation key.

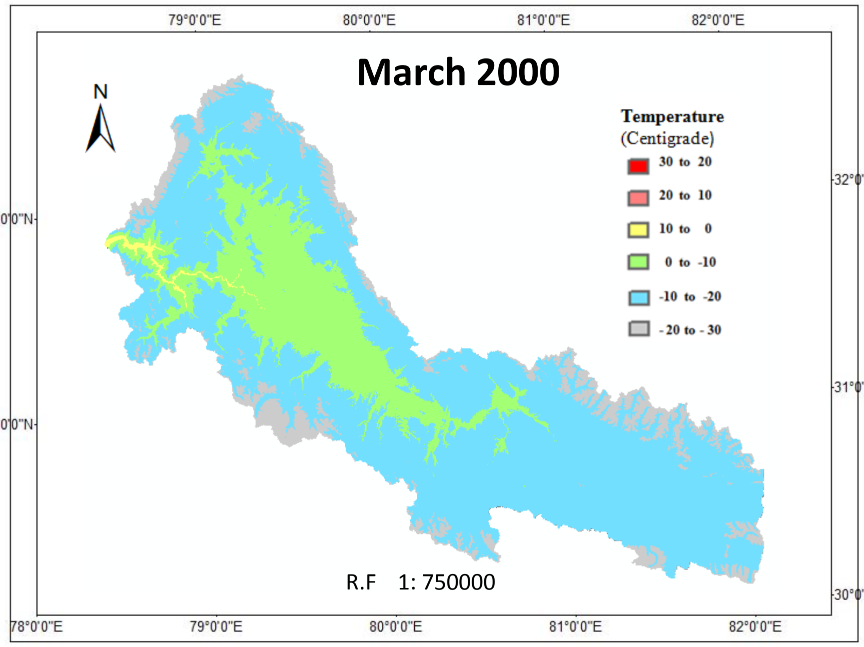


Figure 3: Monthly Maximum Temperature (March 2000) in the Sutlej Catchment in Tibet.

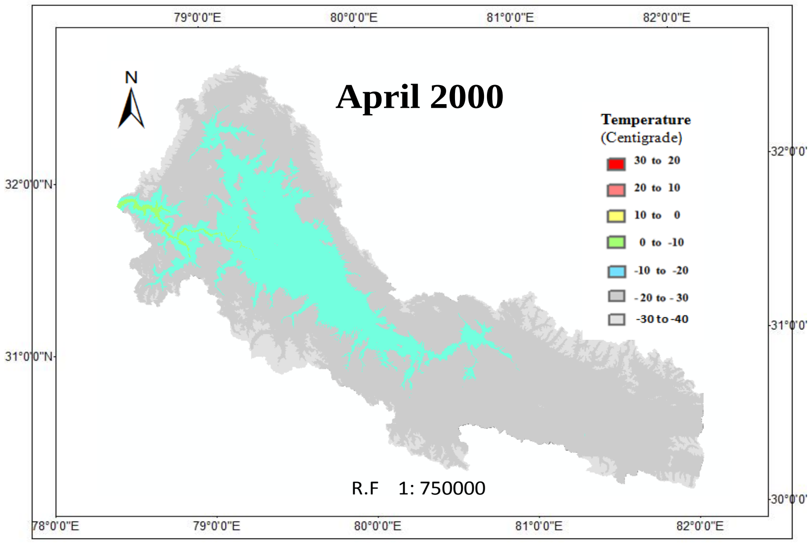


Figure 4: Monthly Maximum Temperature (April 2000) in the Sutlej Catchment in Tibet.

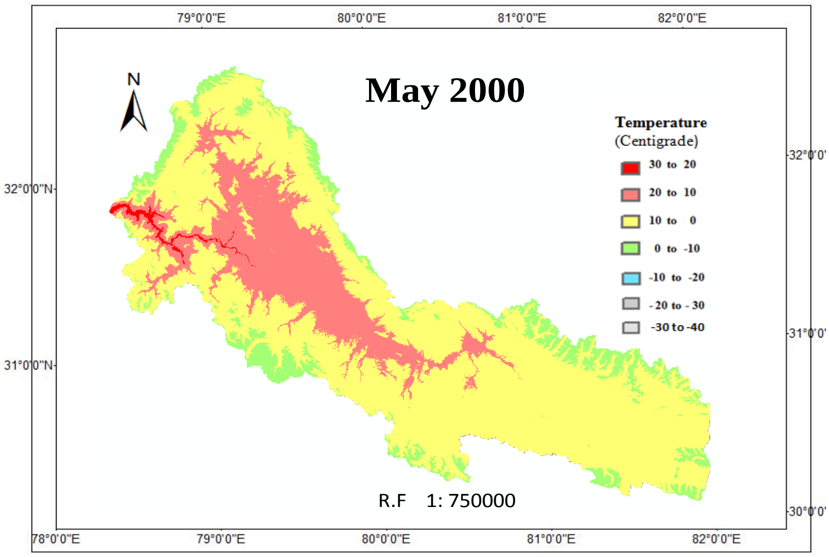


Figure 5: Monthly Maximum Temperature (May 2000) in the Sutlej Catchment in Tibet.

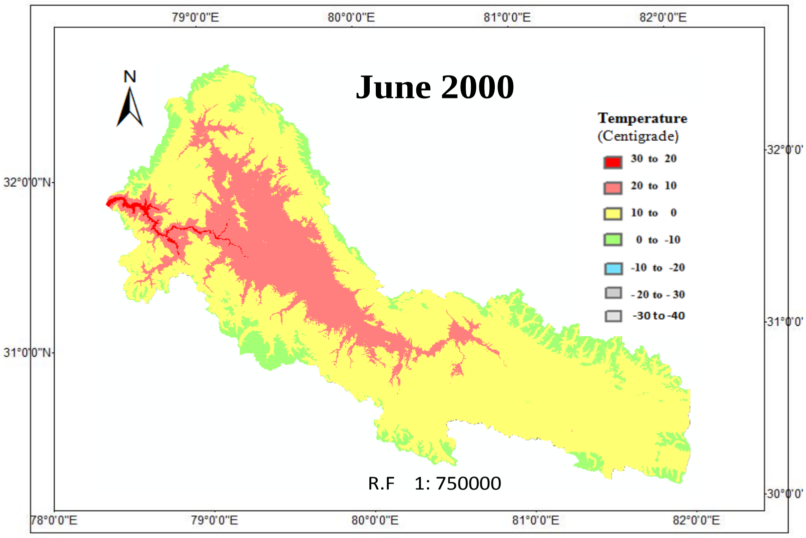


Figure 6: Monthly Maximum Temperature (June 2000) in the Sutlej Catchment in Tibet.

DOI10.17148/IARJSET.2017.4736

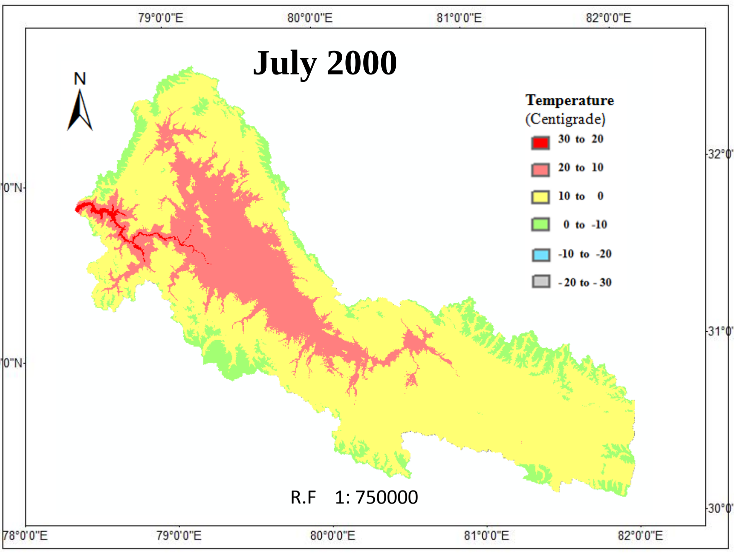


Figure 7: Monthly Maximum Temperature (July 2000) in the Sutlej Catchment in Tibet.

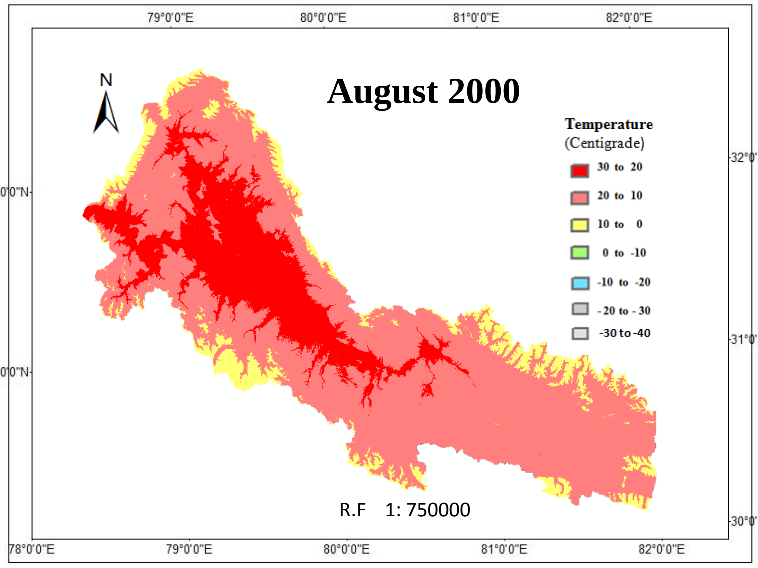


Figure 8: Monthly Maximum Temperature (August 2000) in the Sutlej Catchment in Tibet.

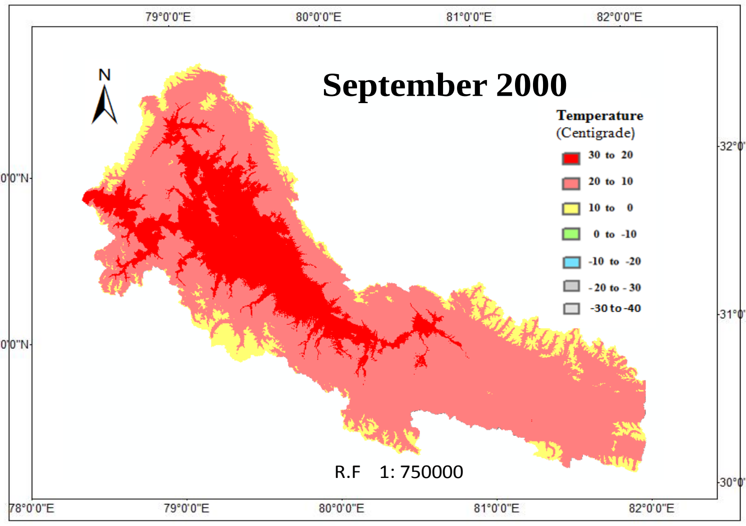


Figure 9: Monthly Maximum Temperature (September 2000) in the Sutlej Catchment in Tibet.

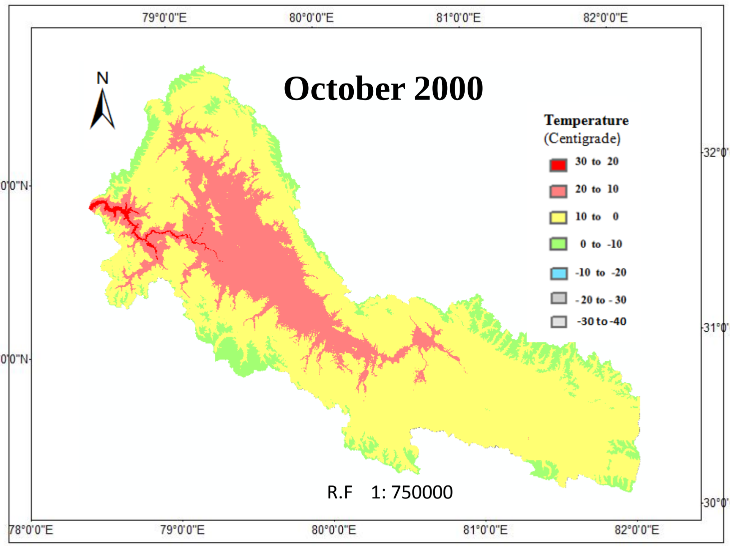


Figure 10: Monthly Maximum Temperature (October 2000) in the Sutlej Catchment in Tibet.

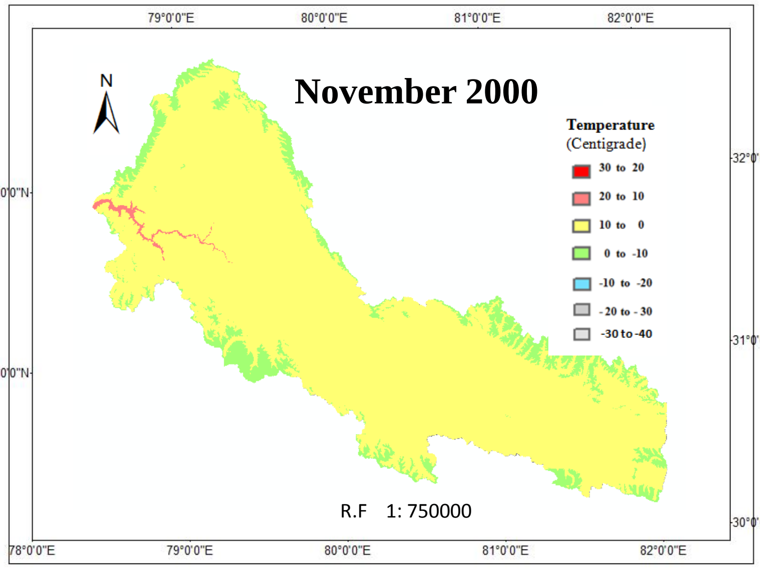


Figure 11: Monthly Maximum Temperature (November 2000) in the Sutlej Catchment in Tibet.

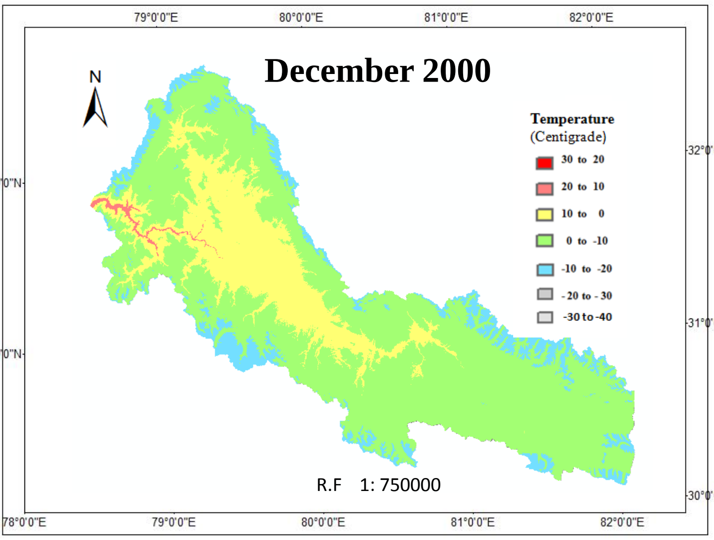


Figure 12: Monthly Maximum Temperature (December 2000) in the Sutlej Catchment in Tibet.

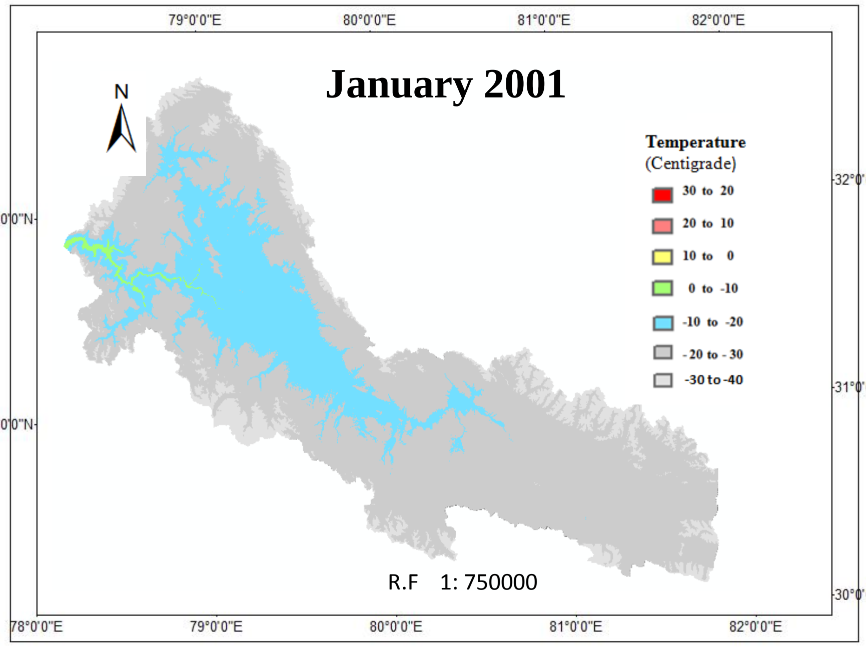


Figure 13: Monthly Maximum Temperature (January 2001) in the Sutlej Catchment in Tibet.

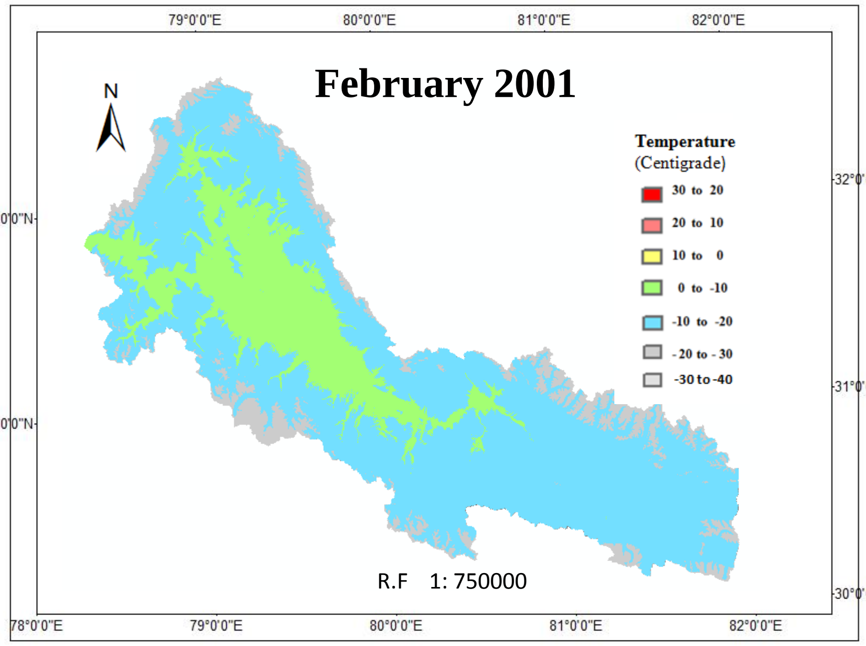


Figure 14: Monthly Maximum Temperature (February 2001) in the Sutlej Catchment in Tibet.

Similar information layers were created by extrapolating the Kaza station logged Minimum Temperature, Maximum Temperature and Average temperature the time period March 2000 to February 2003 using the ASTER Digital Elevation Model of Sutlej catchment in Tibet and temperature lapse rate methodology. These information layers were created at a daily time step.

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