THE APPARENT TEMPERATURE ANALYSIS OF PAKISTAN USING BIO-METEOROLOGICAL INDICES

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Abstract:

Concerning the importance of the study of human bio-meteorology we critically examine and analyze this interdisciplinary science for Pakistan using heat and wind chill indices. Climate research has indicated that, globally, temperature rises during the 20th century in the instrumental record. The calculations also show that Pakistan acquires serious heat index in its south eastern part. Chances of Heatstroke/sunstroke are much prominent in the peak summer days, especially in the areas of Sindh, south-eastern Baluchistan and southern Punjab. Precautionary measures have to be taken during summer outing in those days. Surprisingly in winter no effective wind chill is found throughout the country. This study does not cover mountainous areas of Pakistan. The aim of this paper is to promote substantial importance of human bio-meteorological research in Pakistan.

Key words: Bio-meteorology, Heat Index, Wind Chill Index.

Introduction:

Heat and Chill related mortality, evaluated mostly in terms of numbers of excess deaths during hot summer and cold winter periods, has been reported in many parts of the world. They include North America (e.g. Marmor 1975, Curriero et al. 2002, Davis et al. 2003), Europe (Keatinge et al. 2000), Australia (Guest et al. 1999), Japan (Bai et al. 1995, Nakai et al. 1999) and many other regions encompassing tropical (Kumar 1998), subtropical (Pan & Li 1995, Auliciems et al. 1997), mid-latitude (most studies) as well as high-latitude areas (Keatinge at al. 2000, Donaldson et al. 2003). The study of indices relating apparent temperature for Pakistan is rather unattended but a serious issue because it is directly related to human lives besides other lives existing on our Planet.

Bio-meteorology is that branch of ecology, which studies the interrelations between physical and chemical factors of the atmospheric environment and living organisms. Numerous bio-meteorological indices have been developed to account for the thermal stresses and chill hit encountered by the human body in varying ambient environments. The equations from which these indices have been devised are often based on fundamental physics and incorporate factors such as the fluxes of heat and moisture from bare skin, the influence of clothing on these fluxes, and the impacts of radiant absorption and metabolism. The resulting indices provide some measure of the relative level of comfort experienced by a modeled human body in a given environment. Examples include Physiological Equivalent Temperature, Perceived Temperature, and

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Predicted Mean Vote. Other measures, specifically designed for the purposes of examining human bio-meteorology, have also been widely applied in human comfort studies. In this paper, we examine two well-known indices that are commonly-used in human comfort studies i.e. heat index and wind chill index in the cities of Pakistan.

Comfort:

Comfort is a feeling state in which a subject has no wish to increase or decrease insulation or to adjust the ambient thermal environment. Most people are comfortable in bed with an air temperature under the bed-cloths of 30°C to 31°C. Similarly the air layer under street clothes maintains an average skin temperature of 31°C to 32°C (Steadman, 1994). It is possible to be comfortable, however, even though some parts of the body are at lower temperature than the average. The feet, hands, nose and ears are usually, during thermal comfort, several degrees below the temperature of the trunk. A sense of freshness is induced when the skin temperature is little lower than that for warm comfort and the feet in particular may reach temperatures around 25°C, and the hands and nose about 28°C, in the cooler range of the comfort zone.

Tropical people accept as comfortable considerably higher levels of air temperature and humidity than are accepted by temperate zone groups. Out door workers also tolerate higher temperatures than sedentary indoor workers. Adults at rest appropriately clothed for the environment and not exposed to solar radiation nor to relative humidity above 50% have the following model comfortable dry-bulb temperatures: cool temperate zone 17°C, temperate zone 23°C, subtropics 25°C, tropics 27°C. It appears that the tropical people accept some sweating as a component of comfort.

In general if the temperature is forecast to be above 32°C it is combined with humidity to calculate the apparent temperature. When the temperature is at or below 16°C it is combined with the wind speed to calculate the wind chill.

Heat Index (HI):

It is an index that combines air temperature and relative humidity to determine an apparent temperature to determine how hot it actually feels. The human body normally cools itself by perspiration, or sweating, in which the water in the sweat evaporates and carries heat away from the body. However, when the relative humidity is high, the evaporation rate of water is reduced. This means heat is removed from the body at a lower rate, causing it to retain more heat than it would in dry air. Measurements have been taken based on subjective descriptions of how hot subjects feel for a given temperature and humidity, allowing an index to be made which corresponds a temperature and humidity combination to a higher temperature in dry air.

Steadman (1979) quantifies the physiological effects of high heat and high humidity. The variables include heat generation and loss, fabric resistance, vapor pressure, wind speed, solar radiation, terrestrial radiation, proportion of body clothed, and other factors (Steadman 1984). When constants are input for these parameters, the index combines temperature and humidity into a single variable.

The formula for calculating the heat index in Fahrenheit/Celsius is given by

$$HI = \alpha_1 + \alpha_2 T + \alpha_3 R + \alpha_4 T.R + \alpha_5 T^2 + \alpha_6 R^2 + \alpha_7 T^2.R + \alpha_8 T.R^2 + \alpha_9 T^2.R^2$$

to within ± 1.3 oF (1.5 °C). It is useful only when the temperature is at least 80 oF (26.7 °C) and the relative humidity is at least 40%.

where

HI = Heat index
T = ambient dry bulb temperature
R = relative humidity (in percent)
α1 to α9 are constants and depend upon temperature scales

for Celsius there values are:

α 1 = 16.18754944
α 2 = 3.294368406
α 3 = 4.20936934
α 4 = -0.333784314
α 5 = -2.2154569 × 10-2
α 6 = -2.956469 × 10-2
α 7 = 3.9811176 × 10-3
α 8 = 1.420452 × 10-3
α 9 = -6.4476 × 10-6

Values of wind chill index verses impacts on human comfort are summarize in Table-1.

Wind Chill (WC):

Wind chill is the apparent temperature felt on exposed skin due to the combination of air temperature and wind speed. Generally (but not necessarily) except at higher temperatures, where wind chill is considered less important, the wind chill temperature (often incorrectly called the "wind chill factor") is always lower than the air temperature.

Wind chill is conceptionaly like thermal boundary layer. If one dives into the ocean and comes back out again, a thin layer of water will adhere to his skin. Human being live in an ocean of air, and air, like water, one be said to "wet" the skin or any other object that is immersed in it. Right at the surface of the skin, the adhering air is still. Because air has some internal stickiness (viscosity), there is drag between the adhering air and the air molecules farther away from the skin. As a result, near the skin or any surface there is a zone of relatively still air that may be several millimeters thick. This is the boundary layer.

The boundary layer insulates ones skin from the environment. If one blow on his arm, it can feel cool even though his breath is relatively warm because he has blown away the warm boundary layer air that was insulating the skin. If one do the same experiment in a hot sauna, instead of feeling cool, the spot he blow on can feel painfully hot, because he has blown away the boundary layer of sauna air that had been cooled by the skin and allowed the heat of the sauna to reach the skin more easily.

The concept of wind chill is of particular significance in very cold climate i.e. at high altitude, at high wind speeds, or in very high winds. It is of great importance to the survival of humans and animals, and can even affect machinery and heating systems.

The old wind chill formula was:

T_{wc} = 0.0817(3.71V0.5 + 5.81 -0.25V)(T - 91.4) + 91.4

On November 1, 2001, the U.S. National Weather Service and the Meteorological Services of Canada implement a new wind chill index i.e designed to more accurately how the wind and cold feel on human skin (Lutgens and Tarbuck 2004).

The new formula for wind speed in miles per hour (mph) and temperature in Fahrenheit is:

T_{wc} = 35.74 + 0.6215T - 35.75V0.16 + 0.4275TV0.16

The converted formula for wind speed in knot and temperature in Celsius is:

T_{wc} = 55.628 + 1.1187T – 21.572V0.16 + 0.7521TV0.16

Wind chill may be expressed as an equivalent temperature in Celsius, Fahrenheit or in power per unit area.

Twc may also express in kilocalories per square metre-hour (kcal·m-2·h-1), when T was air temperature in degrees Celsius and wind speed V was in metre per second. In Canada, wind chill factors are often reported as heat loss in watts per square metre. To convert this to the modern units of watts per square metre, which are used in Canada, multiply the result by 4184 J/kcal and 1 h/3600 s and 1 W s/J. (Note that 4184/3600 is about 1.162 and one can multiply by this number).

Values of Wind chill and its effects on Human comfort are summarized in Table 2.

Methodology:

To study examine heat impact on people of Pakistan Three parameters i.e. dry-bulb temperature, relative humidity and wind speed have been considered during study. Mean maximum temperature for heat index and mean monthly minimum for chill index has been taken. Mean monthly relative humidity has been calculated and used. This study have been presented on the data for the period of 1961 to 2004 inclusive, which is sufficiently long enough period of time to produce reliable and representative bio-meteorological indices for Pakistan.

The behaviour of heat and chill has been examined using heat index and chill factor formulae discussed above for summer and winter seasons of Pakistan and analysed according to Table-1 & 2 respectively which have been presented in degrees Celsius for convenience (see Figure-1-7)..

FINDINGS:

Heat Index:

Some important findings related to heat index analysis are as fallows.

In the month of April, Jacobabad, Lasbella and Pasni show the danger values (greater than 41°C, Figure-1). The highest index value for Nawabshah and Lasbela have been found 51.3°C and 52.0°C respectively.

In the month of May, 41.0°C isotherm moves northward and 54.0°C isotherm demark almost all Sindh except coastal belt of Sindh. Jacobabad and Lasbella show the highest index values greater than 54.0°C, (Figure-2) while Nawabshah acquires peak value (i.e. 66.0°C) in this month.

June is the month of largest covered area (Lower Punjab and Sindh-Baluchistan along Jacobabad, Sibi and Lasbella excluding Karachi) with the index value 41.0°C (Figure-3). The highest values appear for Sibi, Nawabshah and Lasbella, 67.3°C, 68.7°C and 69.2°C respectively.

Almost same area with same index value persists in the month of July as in June except excluding Badin and Karachi (Figure-4). Lasbella and Nawabshah remain possessing highest index values (64.2°C and 65.9°C respectively) which are relatively smaller than the previous month (i.e. June).

In the month of August same area along same index value persists as in July excluding Chhor and Hyderabad along Karachi and Badin. Padidan and Nawabshah acquired the highest values 60.0°C and 62.0°C respectively as shown Figure 3, 4 & 5.

In the month of September (Figure-6), highest heat index is observed over Padidan, Lasbella and Nawabshah 55.7 °C, 56.9 °C and 58.7 °C respectively.

In the month of October demarcation iso-line i.e. 54.0°C of heat Index disappears (Figure-7) but the 41.0°C isotherm still persists analogous to the month of April. It marks the Sindh and southern parts of Punjab and Baluchistan including Sibi and Jacobabad.

Chill Index:

Calculation and analyses chill index for the same period shows that there is no iso-line found greater than -13°C in any winter months. Figure-8 and Figure-9 are exemplary representation of chill index for the month of December and January. It is because of the fact that Pakistan lies in extra tropical area while the chill index found mostly in extra temperate areas.

Conclusion:

In May almost all Sindh along some parts of south-eastern and eastern Baluchistan and small area of southern Punjab adjoining to Sindh appears as in extreme danger zone. In June, July and August extreme danger heat index area expands to almost all Sindh and southern Punjab along with some parts of eastern Baluchistan. In September extreme danger heat index confined to only central Sindh. There may be chances of sunstroke, muscle cramps, and/or heat exhaustion to heatstroke or sunstroke likely to highly likely possible in aforesaid areas in the said month.

In the month of October situation in similar to the month of April in which danger heat index covers almost all Sindh and costal belt of Baluchistan and some part of southern Punjab. Chances of heatstroke or sunstroke are almost likely or highly likely to be happened.

The winter season in Pakistan is not so long as compared with summer. The Chill index values do not leave unpleasant impact of human comfort on people of Pakistan as found in the study (study is based on PMD data; collected at meteorological observatories situated throughout the country).

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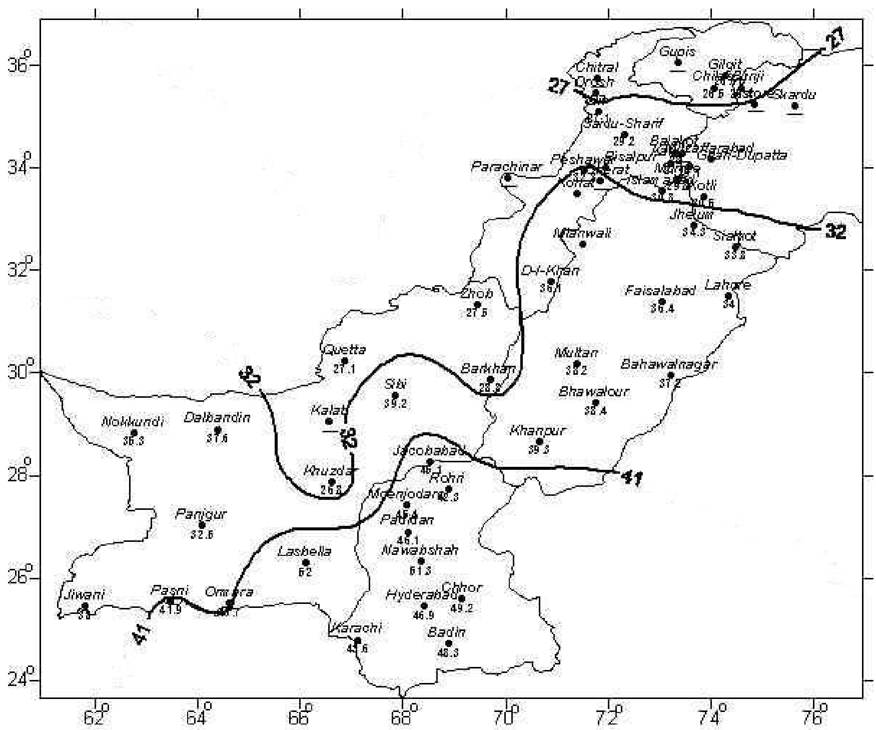

Figure-1: Mean Monthly Apparent Temperature in Celsius for the Month of April

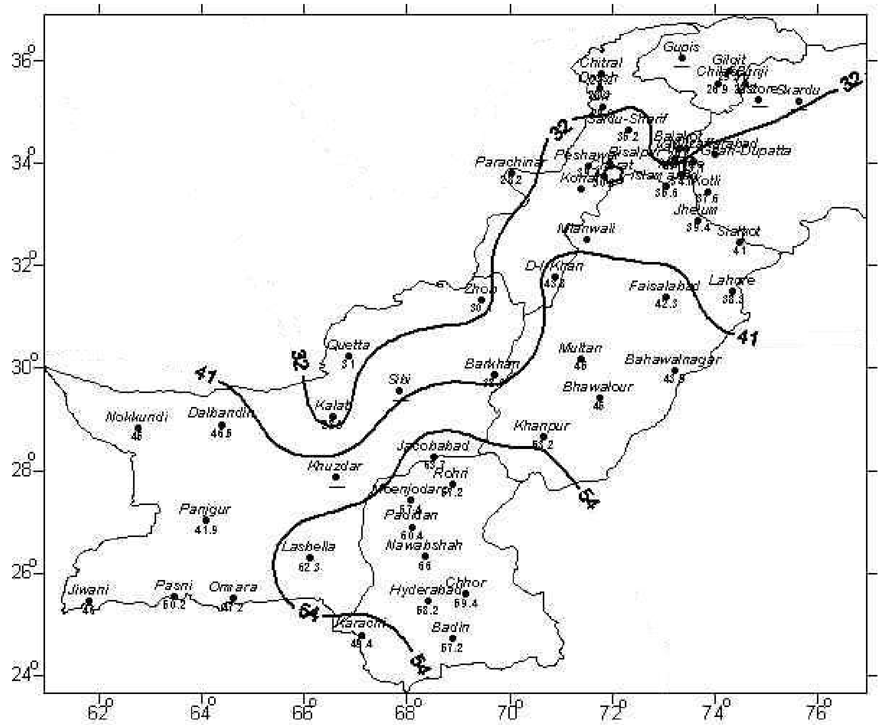

Figure-2: Mean Monthly Apparent Temperature in Celsius for the Month of May

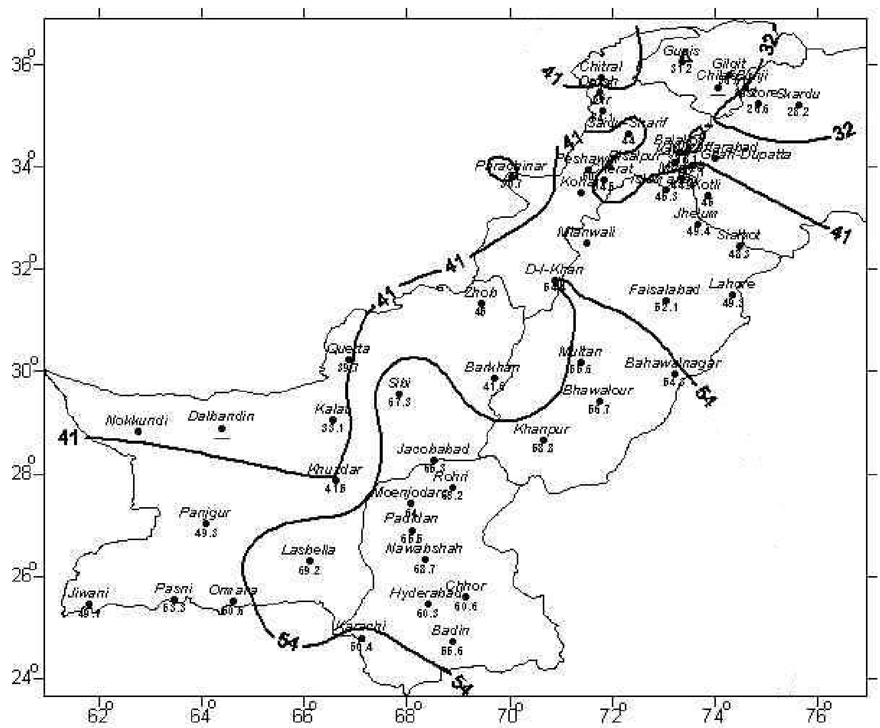

Figure-3: Mean Monthly Apparent Temperature in Celsius for the Month of June

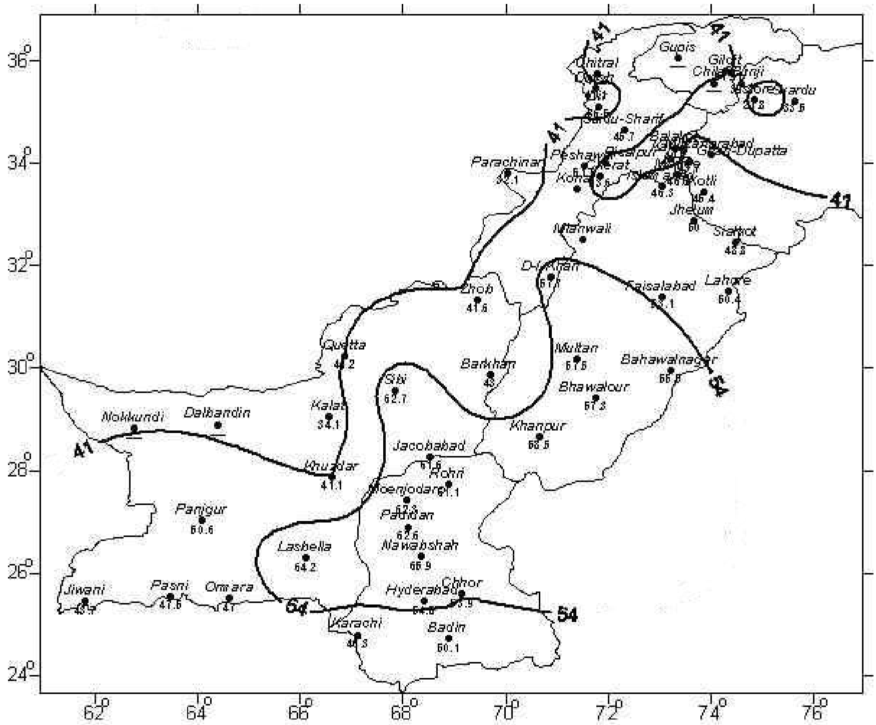

Figure-4: Mean Monthly Apparent Temperature in Celsius for the Month of July

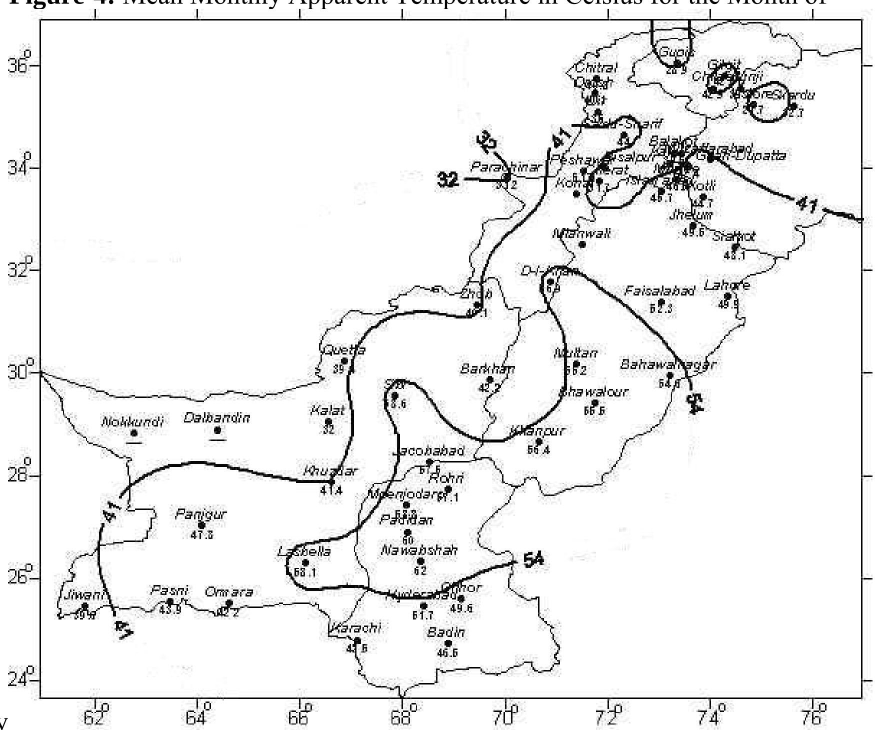

Figure-5: Mean Monthly Apparent Temperature in Celsius for the Month of August

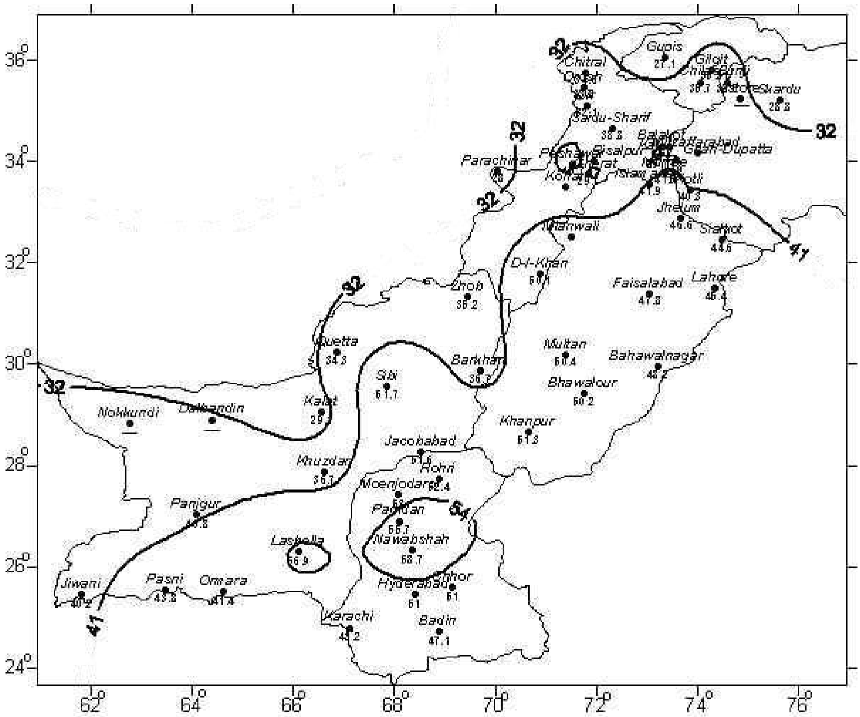

Figure-6: Mean Monthly Apparent Temperature in Celsius for the Month of September

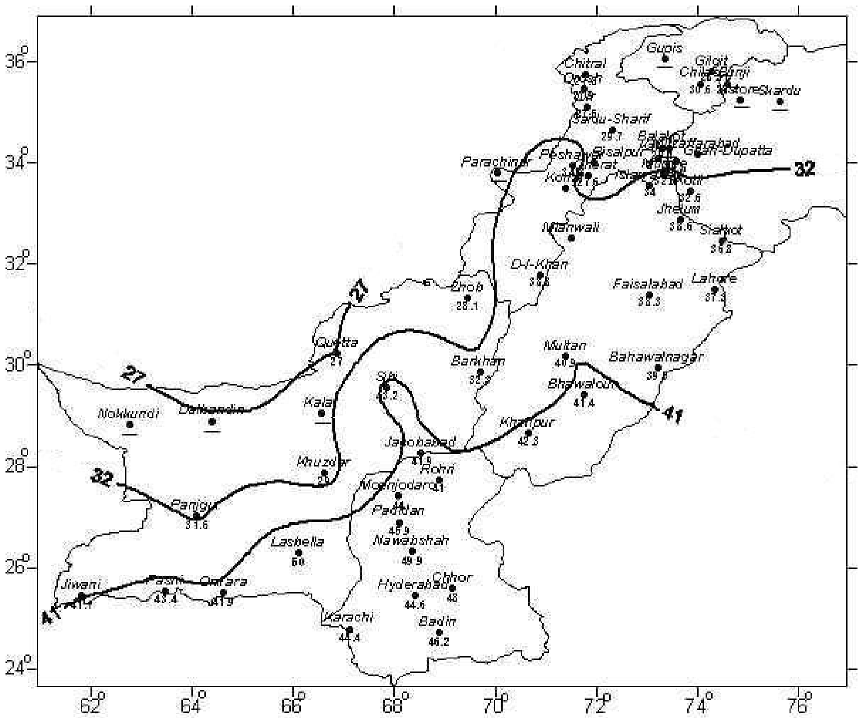

Figure-7: Mean Monthly Apparent Temperature in Celsius for the Month of October

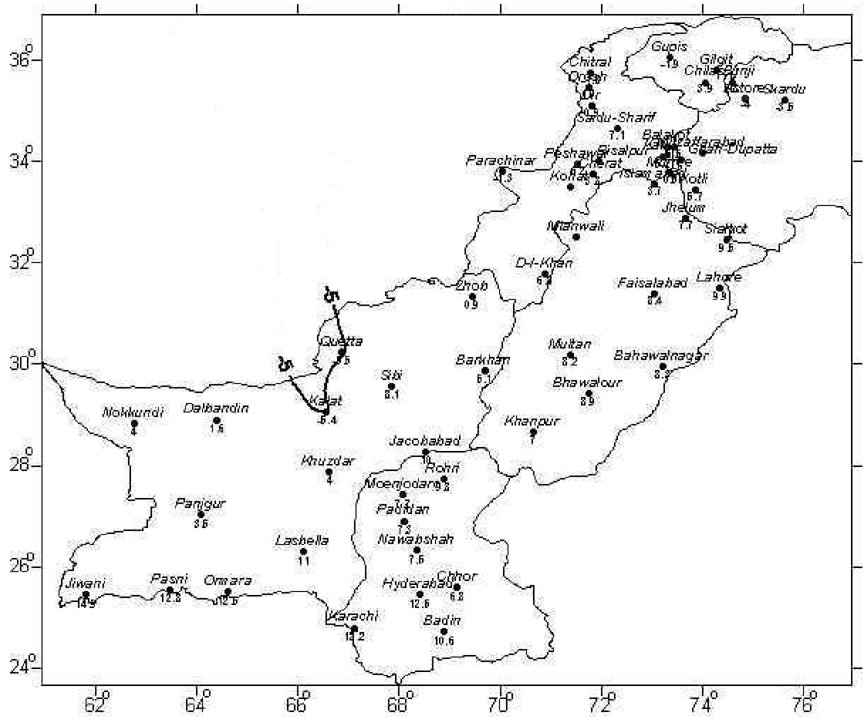

Figure-8: Mean Monthly Wind Chill in Celsius for the Month of December

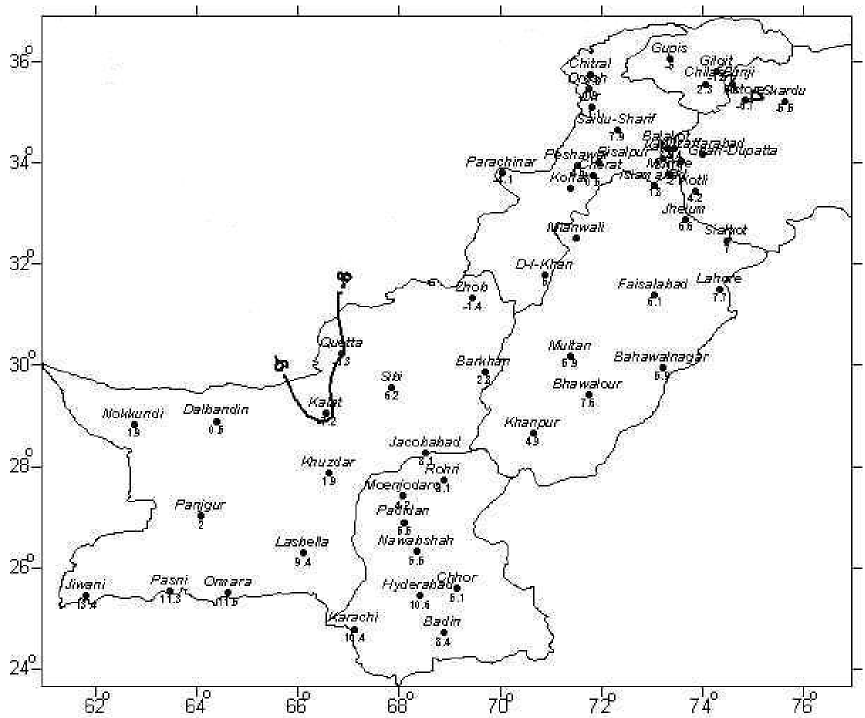

Figure-9: Mean Monthly Wind Chill in Celsius for the Month of January

Table-I: Heat Index and Human Sensitivity

Celsius	**Possible Impacts on human comfort**
27 to 32°C	Caution — fatigue is possible with prolonged exposure and activity
32 to 41°C	Extreme caution — sunstroke, muscle cramps, and/or heat exhaustion are possible
41 to 54°C	Danger — sunstroke, muscle cramps, and/or heat exhaustion are likely.
Over 54°C	Extreme danger — heat stroke or sunstroke are likely to highly likely.

Table-II: Wind Chill Index and Human Sensitivity

Celsius	**Possible Impacts on human comfort**
Above -13°C	None
-13°C to -24°C	unpleasant
-24°C to -33°C	Possible frost nip
-33°C to -50°C	Frostbite likely
Below -50°C	Exposed skin will freeze in 30 seconds