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Ancient science of weather forecasting in India with special reference to rainfall prediction

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ABSTRACT

The monsoon on the Indian subcontinent remains a seasonal occurrence that all inhabitants of the subcontinent desire. Modern scientific knowledge of methods of rain forecasting has originated recently. However, traditional indigenous wisdom is peculiar to our country. In the past, India had a magnificent scientific and technical legacy. Even today, it is common that village astrologers (pandits) are right in a surprisingly high percentage of their rain predictions. Scientists and local traditional farmers have a long history of astronomical research and treatises that predict rainfall. They use different methods to forecast rainfall conditions based on numerous *panchangs, almanac* bio-indicators (*Bhoum* method), non-bio-indicators (*Antariksh* method), and predict the likely behavior of climate in the planting season. Rainfall forecasting also aids in the planning of operations by agriculturists, builders, water supply engineers, and others. All mortals from the subcontinent have looked at it from their own perspective, and it continues to be the subject of intense multi-dimensional engagement. The monsoon has provided a means of life for numerous civilizations while also shaping the drainages and palaeo-geography of the subcontinent. The objective of this article is to document some indigenous knowledge for forecasting climate and environmental dynamics towards community resilience.

Keywords: Almanac, *Varahmihir*, *Brihatsanhita*, bio-indicators, *Nakshatra*, Indigenous knowledge, Weather forecasting.

Weather has always been an intriguing natural force, impacting our everyday lives and creating history. Weather forecasting has gone a long way, from ancient civilizations noting cosmic patterns to modern-day meteorologists employing advanced technologies. This article goes into the intriguing development of weather forecasting, tracing the path from ancient knowledge to cutting-edge technology which has transformed our understanding and prediction of weather patterns. Join us on this historical trip as we unearth the important milestones, strategies, and innovations that have changed weather forecasting into the accurate and vital discipline that it is today.

Meteorology may be traced back to prehistoric times in India. Early intellectual works from 3000 BCE, such as the *Upanishads*, contain significant debate of the mechanisms of cloud formation and rain, as well as the seasonal cycles induced by the earth's rotation around the sun. *Varahamihira*'s famous work, the *Brihatsamhita* (Iyengar, 2004) published approximately 500 B.C.E, gives unequivocal proof that a sophisticated understanding of atmospheric dynamics existed even at that time. It was recognized that rains flow from the sun (*Adityat Jayate Vrishti*) and that adequate rainfall during the rainy season was essential for abundant agricultural and food production.

Ancient literature is replete with reference to monsoon and the famines which occurred due to the failure of the monsoon for ex. *Yaska's Nirukta*, *Valmiki's Ramanyan*, *Jatak* series of *Buddhist* and *Chanakya's Arthasastra*. *Meghdoot* by famous scholar *'Kalidas'* is a legendary epic describing the Indian monsoon cloud and the onset of the monsoon over central India. Variability of rainfall and its impact on economy of India dates back to the *Kautilya's Arthasastra* in third century B.C. Greek philosopher Megasthenese an ambassador to the court of *Maurya* kings around 300 BC has description of Rain and Winds. Around 400 AD Fahsien a Buddhist scholar in his account to the monsoon winds which he observed in 100 BC, which has reference to these weather elements (Pant, 2002).

DIFFERENT ANCIENT TECHNIQUES OF WEATHER FORECASTING

There are many ancient techniques (not commonly used) of weather forecasting in *Vedic* astrology. During past millennium, most of these techniques went into disuse due to lack of state patronage. Another reason was deliberate secrecy due to threat to one's own state as a result of which many of the techniques were lost or forgotten. Many new short cut methods were devised during the medieval age, some of which neither any theoretical justification nor any connection with *siddhant* or *sanhita* and have been proven to be no more reliable than 50-60% cases.

Traditional weather forecast is issued in local *panchangs* (almanacs) based mostly on *Varahmihir's* (505-587 AD) approach as stated in *Brihatsanhita* (BS). This treatise treats the rainfall phenomenon in eight chapters on the lines which deal with conception, pregnancy and delivery of clouds, requiring a total time period of 195 lunar days and based on asterisms Rohini *Yoga, Swati Yoga, and Ashadha Yoga* (Seetaramayya *et al.,* 2002). The prediction of immediate rain from surrounding phenomena has also been given (Vaidya, 2016). The treatise also provides, meteorological information like halo around sun and moon, lines of clouds crossing the solar disc at rising and setting, winds, the red sky immediately before sunrise and after sunset, fanciful shape of clouds and of dust storms, thunder bolts, astronomical information on meteor falls etc.

The long range forecast as per BS is given in *shloka-*

Pause Mulad Bharanyantam Chandrakaren Garbhate
Ardradike Vishakhante Suryakaren Varshati

Meaning: In the month of *Pausa*, conception takes place when the moon moves through *Mula* to *Bharani* and rainfall takes place when the sun movers through *Ardra* to *Visakha* (note-invariably the moon passes through the asterism *Mula*, on the new moon day in the month of *Pausa*. The sun passes through *Ardra* in the month of *Asadha* (Seetaramayya *et al.,* 2002).

References about rain and weather are available in ancient literature such as *Rigveda, Shrimad Bhagvat, Parashar Sanhita, Panini's Ashtadhyayi* (500 BC) and *Meghmala* (800 AD). The literature in local languages includes local folklores and sounds related to rainfall pattern. Amongst this *Ghagh Bhaddari* in Hindi, *Bhadali Vakyo* in Gujarati and *SahadeoBhadali* in Marathi are quite popular.

Astronomy is a science of studying the motions of planets, Sun and stellar system, Hindu astrology rests on the *Nirayana* sputum (*i.e.* planetary places from the star *Revati*, affixed star of the first point of Aries) of the planets, and the modern tables give us the correct *Sayana* sputum (the planetary places from the Vernal Equinox), so that if the length of the *Ayanamsa* (the difference between *Sayana* and *Nirayana* sputum) is correctly known, it may be subtracted from the *Sayana* sputum and remainder will be the *Nirayana* sputum required. A comprehensive method of weather forecasting is to be found in ancient classics and they should be understood and applied through systematic investigation and research for excellent results. The study demands an urgent need to join together both the meteorologist and astrologers, to pursue the weather forecasting methods feasible for agriculturists in particular and the common man in general and help the country for its prosperity and development (Seetaramayya *et al.,* 2002).

There are mainly three methods for weather forecasting viz. 1. Bio-indicators (*Bhoum*), 2. Atmospheric observations (*Antariksha*) and 3.Mathematical method (*Divya*) (Joshi, 2004)

Weather forecast by using bio-indicators (Bhoum method)

Bhouma derived from *Bhumi* meaning Earth. Rainfall can be predicted fairly accurately by looking at the nature surrounding uxs. Kanani *et al.*, (2002) reviewed the various techniques of rainfall prediction based on observations taken by farmers.

The biological indicators of monsoon have also been well documented and are extensively used by local experts. Kanani *et al.* (1995) documented various tree species that have been used as indicators of monsoon by local communities. For example, the plant *Cassia fistula* flowers in abundance 45 days before the onset of monsoon. Pisharoty (1993) reported that the tree *Amaltas* or golden shower tree (*Cassia fistula*) is a unique indicator of rain. It bears bunches of golden yellow flowers in abundance about 45 days before the onset of monsoon. Kanani *et al.,* (2005) found that there was a difference of -3 to 7 days between actual date of onset of monsoon and that predicted at Junagadh based on flowering of *Amaltas* during 1996-2003. Appearance of good foliage of *Darbha* grass, *Pipal* tree (*Ficus religiosa*) indicate adequate monsoon. But good foliage of *Bael* (*Aegle marmelos*), *Khejro* (*Prosopis cineraria*) indicate drought condition.

Observations on the behavior of specific birds and animals have also been used as indicators of rain, as reported by Savalia *et al.*, (1991) and Golakia (1992). Sighting *chatura* (Dragon fly) means that monsoon is over. A Sparrow bathing in dust indicates good rain in coming season. If a chameleon climbs a tree and assumes black-white-red colors, immediate rain is sure to follow. If crows cry during night, severe drought is indicated. Kanani *et al.*, (2002) enlists the behavior of birds and animals indicating rainfall pattern. Mishra (1998) found that bio indicators are those living beings/biotic agents which change their behaviour with any change in the surrounding environment / weather.

Non-bio indicators are those non-living phenomena/ materials that change in response to the change in the surrounding environment. By watching those behavioral changes of the nature closely, people predict the present and future events like weather. These forecasting techniques along with weather folklore and proverbs have been invogue. These were identified and documented as following Table 1 and Fig. 1 (Ravi *et al*., 2008).

Weather forecast by using non- bio-indicators (Antariksha method)

The word *Antariksha* means sky. Thus, this method deals with observations to be made of the sky. *Bhadali* described ten 'chieftains' (variables) responsible for the development of 'ethereal embryo' of rains. i) Wind, ii) clouds, iii) lightning, iv) colour of sky, v) rumbling, vi) thunder, vii) dew, viii) snow, ix) rainbow and x) occurrence of orb around the moon and sun. Raman (1960)

Table 1: Explanation of natural bio-indicators for rain forecasting (Ravi *et al.*, 2008)

Indicator	Category	Type of Rain Forecasting	Explanation	Conformity
Movement of dragon flies	Bio Indicator	Short-range	Dragonflies migrate in swarms, signaling rain, a few hours before the humidity approaches saturation.	Sivanarayana (1993)
Flapping of ears by goats	-do-	Short-range	Increasing moisture causing uneasiness and sweating to goats, thereby flapping of ears.	Chhaganbhai (1992)
Movement of termites in rows	-do-	Short-range	If both atmospheric and soil surface humidity are high the termites are thought to be a rain indicator in the coming hours, as rain is typically associated with higher humidity levels. Because the larval ants don't yet have eyes or legs, worker ants may hold them thanks to the hook-like form of their hair.	.
Movement of black ants in a row	-do-	Short-range	The hair is shaped like a hook,enabling worker ants to carry larvae ants as they do not have eyes and legs at this stage. This process is observed with thousands of ants moving in a stream, there by indicating rain.	Selvanayagum (1991)
Peacock making sound early in the morning, late in the evening	-do-	Short-range	Sometimes cool breeze along with nearly saturated atmospheric humidity co-exist. Therefore, peacocks play and move in a rhythmic manner, suggesting that rain may be on the way.	
Squeaking of owls	-do-	Short-range	Owls are blind to light but sensitive to humid conditions. The fear of increasing humidity and heat released by clouds instigates restlessness among owls. The peculiar squeaking sound of owls has been attributed to be an indicator of rain.	
Number of seeds in the fruits of *Butea monosperma*	-do-	Short-range	Petiole of *Butea monospermous* is sensitive to changes in the humidity. As a result, the length of the fruit it bears varies. Typically, each fruit contains three seeds. Farmers think that if the fruit's seed base matures to full size, showers will fall early in the season. If the center seed matures, heavy rains will fall in the middle of the season. Rains fall near the end of the season when the seed is at the top of the fruit. If all three seeds fully mature, then excellent rainfall with uniform distribution is forecast throughout the season. As a result, when the monsoon winds blow, the seed near the petiole (first seed) grows fully in a short period of time. If the winds continue to be strong, middle seed develops. The same is true for third seed development.	Sivanarayana (1993)
Positioning of nest by weaver bird nest by weaver bird	-do-	Long-range	If the nest is formed toward the bottom of the well, it serves as a signal of poor well recharge owing to weak monsoon. In contrast, if the nest is erected on top of the well, it signals a good monsoon. Furthermore, it is probable that this bird studies the clouds and sky conditions and weaves its nest just above the water level in the well in anticipation of anticipated excellent rain.In contrast, if the nest is erected on top of the well, it signals a good monsoon. Furthermore, it is probable that this bird studies the clouds and sky conditions and weaves its nest just above the water level in the well in anticipation of potential excellent rain.	

Movement of Dragon flies

Positioning of nest by weaver bird

Flapping of ears by goats
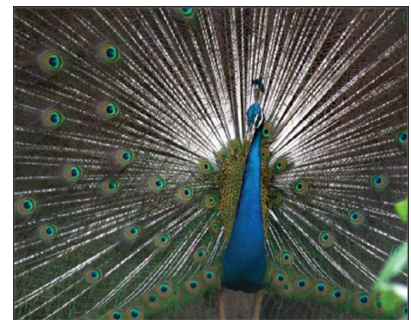

Flocking of Sheep

Butea monosperma tree

Movement of Termites in rows

Movement of ants in rows

Squeaking of Owls

Peacock singing

Fig. 1:   Natural bio-indicators for rain forecasting (Ravi *et al.,* 2008)

identified general atmospheric situations as indicators of a healthy conception of 'ethereal embryo'.i) Gentle and agreeable wind from the North, North-east and East; ii) Clear sky; iii) Soft, white halo around moon or the sun; iv) Dark colored sky- as dark as crow's egg; iv) Sky over cast with huge, bright dense clouds; v) Needle shaped or sword shaped clouds; vi) Blood red clouds; vii) Rainbow in the morning and evening; viii) Low rumbling of thunder; ix) Lightning; x) Appearance of 'mock sun'; xi) Planets and stars shining in full and with soft light. Similarly, Golakia (1992) collected local beliefs regarding occurrence of drought based on meteorological observations.

1.   If the sky acquires a faint yellow colour, there is less hope of rain.

2.   If crow colored clouds are observed throughout the day while night sky remains clear, a drought is indicated.

3.   If the velocity of wind is not high during *Mrigshirsh* constellation and high heat is not experienced during *Rohini* constellations a drought can be expected to follow.

4.   If it does not rain in *Ardra* and no winds occur in *Mrigshirsh* then drought would occur.

5.   If the wind blows from East during the month of *Shravan* and from Southwest during the month of *Bhadrapad*, a serve drought could be experienced.

6.   Occurrence of wind with velocity on the fifth day of the first fortnight of *Shravan* month is indicative of severe drought.

7.   Occurrence of rain in the presence of sunshine is an indicator of poor rainfall in the near future. Thus, occurrences of these phenomena on particular day are indicative of rainfall on succeeding days. Some of the indicators of conception of embryo of rain are gentle wind from north, north-east and east, soft, white halo around sun or moon, rainbow in morning or evening, needle or sword shaped clouds, lightening, etc. If any of these things appear in the sky, then rain is assured 192/193 days afterwards.

Some more local beliefs (Ravi *et al*., 2008) are non-bio indicators

Table 2: Natural Non-bio-indicators for rain forecasting (Ravi *et al.*, 2008)

Indicator	Category	Type of Rain Forecasting	Explanation	Conformity
Halo around the moon	- Non-bio-indicator	Short-range	Halo around the moon is formed due to high moisture content in the atmosphere. As the night wears on, the halo becomes more visible.	Verma (1998)
Pink coloured sky in the evening	-do-	Short-range	Mie scattering along with high relative humidity (more than 90) and low temperatures in the evening results in short duration high Intensity rains.	Sivanarayana (1993)
Red cloud sat sunrise,sunset	-do-	Medium range	Clouds reflect long wave radiation (Red colour and above) when they are dark and water bearing. Hence the possible occurrence of rain.	Selvanayagum (1991)
Sky with fish skin appearance		Medium range	Cyclone clouds (Altocumulus and Altostratus clouds) that bear rain	
Lightning Straight over head	-do-	Short-range	The rolling of stratocumulus clouds in the sky causes modest to moderate thunderstorms.As a result, rain is conceivable within a day via nimbus clouds generated by stratocumulus clouds.	
Dark rolling clouds	-do-	Short-range	(dark colour) form into stratus and nimbostratus in East direction in a short span of time resulting in rain.	
Rainbow in sunny weather	-do-	Short-range	This is due to high relative humidity. Water vapour becomes saturated because of copious amounts of water vapour entering into that area, resulting in rains. When rain is occurring rainbow also appears because, within its vicinity clouds are absent. This means there will be no more rain.	
Lightning in the East direction	-do-	Short-range	Cloud sat a long distance, which results in onset of rains after a gap of 7- 8 hours.	
Clouds in N-W direction(S-W Monsoon)	-do-	Short-range	Slow moving clouds are typical of the S-W monsoon, which brings rain.	Gupta(1993)
Northern winds with rain bearing clouds	-do-	Short-range	Rains due to N-E monsoon	Selvanayagum (1991)
Rohini constellation of S-Wmonsoon.	Astronomical ideal for onset	Long-range	Low-pressure formation when temperatures range between38-42°C,hot winds blowing for15- 20days. This results in onset of monsoon	

(Table 2 and Fig. 2) are explained below;

1. If the sky acquires yellow colour there is less hope of rain

2. Occurrence of rain in presence of sun-shine indicates absence of rain in near future.

3. Determination of wind direction on *Akshay Trutiya* day (which falls on 3rd day of *Vaishakh* month) and on *Holi* day also helps in weather forecasting.

As many as 500 ancient beliefs (of atmospheric observations and some bio-indicators) have been documented by Adhvaryu (1974) and Trivedi (1986). Kanani *et al.,* (2005) studied eight beliefs based on folklores from *Bhadali Vakyo* in Saurashtra and found that out of eight beliefs seven were found valid in prediction of rainfall. The study on wind direction on *akshaytrutiya* day and rainfall observations from farmers of seven districts of Saurashtra. They developed regression equation between rainfall prediction as dependent variable and 4 independent variables as direction of wind and number of farmers reported by largest number of farmers, direction of wind and number of farmers reported by second largest number of farmers on *akshayatrutiya* reported by number of farmers from Saurashtra. The predictability reported was 95%.

Halo around the Moon	Halo around the Sun	**Lightning in South-East**	Dark rolling clouds
Rainbow in sunny weather	Rainbow in the West	Lightning straight over the head	Red clouds at sunset
Lightning in the East	Lightning in North-East	Sky with fish skin appearance	Red clouds at sunrise

Fig 2: Natural non- bio-indicators for rain forecasting (Ravi *et al*., 2008)

According to *Varahmihir*, if we observe specific symptoms of rain conceptions in sky, there will be delivery of rain after 192± 1 calendar days (195 lunar days), in analogy with human gynecology. Vaidya and Kale (2014) recorded 17 symptoms (*viz.* Rainy Clouds, Blood Red Color before Sunrise approximate 15 to 20 minutes at East, Blood Red Color 15 to 20 Minutes after Sunset, Squalls, Wind Blowing Direction, Roaring Clouds, Lightening, Gusty Weather, Rain –Trace amount, Rainbow, Ants-Black or Red carrying eggs, *Patang* flying (Flying insects), Halo around Moon, Halo around Sun, Hot – Humid weather, Haze and Dew) of atmosphere (including 2 bio-indicators) and predicted rainfall at Barshi, Solapur district (MS) (for monsoon season of 2004 to 2013) (10 years at Barshi, Dist. Solapur (MS). The overall average Yes/No skill score for rainfall prediction was 78.34%. The lowest skill score of 74.5% was found in year 2007 and the highest skill score of 86.2% was found in the year 2006. Scientifically it is proved that the results of Yes/No skill score of rainfall prediction made for Barshi by RCRD theory is nearly 78.34% which is far better by all standards as compared to daily rain prediction by other methods like astro-meteorological method, modern methods like synoptic method of short range forecasting (2-3 days) or by location specific Numerical Weather Prediction method (valid for five days) by using Super Computers (Vaidya, 2013).

Mathematical method (Divya method)

Under mathematical method, the rainfall or weather forecasting is based on the science of astrology and astronomy. Earth is the part of solar system, which has five planets viz., Mars, Mercury, Jupiter Venus and Saturn. *Rahu* and *Ketu* are the pseudo planets, while Moon is a sub-planet revolving round the earth. All these planets and earth along with its moon are revolving round Sun. Earth is inclined at an angle of 23.5° and revolves round its own axis also. This spinning motion around its own axis creates day and night, while revolutionary motion around Sun creates seasons. There are group of stars called constellations (*Nakshatra*), which are stationary and they are 27 in number. Planets exert gravitational force on earth, which influences earth-atmosphere system. Similarly, *Nakshatra* also exerts resultant gravitational force on earth-atmosphere system, while planets pass through the space occupied by *Nakshatra*. These studies were made by Indian sages (scientists) (*Saptarishis*) *viz.*, *Krutu, Pulah, Pulatsya, Atri, Angira, Vashista and Mareechi*. The path of the earth around sun is elliptic and sun lies on one of the foci.

The plane containing sun and earth is called as Ecliptic. This Ecliptic is divided in 12 equal parts of 30°, which are called as *Rashis* or Zodiac *viz*., Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Acquarius and Pisces. There are 27 *nakshatras* for the purpose of astro-meteorology. Apart from these, the 28th *nakshatra "Abhijit"* is also allotted a space towards the end of *Uttarashadha* (No. 21) (Varshneya, 2007). The planetary chart of time and date of *Chaitra Pratipada* is laid, which indicate overall weather pattern for the year. Such planetary charts are prepared for the time when sun enters each constellation (*Nakshatra*) and its each quarter (*nakshatra charan*), prediction for that *Nakashtra* is based on this planetary chart. Actual predictions

are estimated using place of each planet and its angle with reference to other planets. For each location horoscope is drawn in which first house starts with *"Lagna"* and houses are placed anti-clockwise. Second horoscope is generated at the time of entry of Sun into particular *nakshatra* and planets in 7 to 12th house are noted for giving quick appreciable results till Sun is in same constellation. Based on this, planet position will indicate possibility of high wind speed damages, rise in temperature and fall in temperature.

Most important part of these methods is interpretation of the astrological/astronomical position in terms of weather systems. Some refinement was made by preparing horoscopes for *nakshatra* and to predict the daily rainfall. Such approach has been used in Maharashtra (Varshneya *et al.*, 2002) and for Gujarat (Varshneya *et al.,* 2008). Such forecasts have also been validated for different locations of Gujarat. The *Varsha Vigyan Mandal* of Junagadh used to invite all astrologers to give prediction and it has been found useful for farmers. However, most of the astrologers work out seasonal prediction by using their own wisdom and some knowledge of astrology.

In *panchang* (almanac) the prediction of probable dates of rainfall are given on *nakshatra* basis. Every province or region has its own *panchang* or almanac which gives seasonal rainfall prediction. The following principles are given for the prediction of rainfall:

Principle No. 1:- When the Sun and the Moon are in neutral asterisms there will be winds; when they are in feminine asterisms there will be lightning and phosphorescence; and when the Sun occupies a feminine asterism, and the Moon a masculine asterism, or vice-versa there will be rains (Varshneya, 2007). *Ashwini, Krittika, Rohini, Purvabhadra, Uttarabhadrapada, Anuradha, Shravana, Punarvasu, Pushya* are masculine; *Bharani, Hasta, Chitra, Swati, Vishakha, Purva, Uttara, Ashlesha, Magha, Jyeshta, Ardra, Dhanishta, Purvashadha*and*Revati* are feminine; *Satabhisha, Mrigasira*and *Moola* are neutral.

Principle No. 2:- When many planets are in one *rashi*, preferably in one *nakshatra*, it affects the weather. When many planets gather in one *rashi* with Mars and Sun joining them and Mars is with *Rahu*, there can be a terrible downpour, even if it is not regular monsoon season. When there is concentration of planets in one *rashi*, the weather begins to fluctuate and if moon joins them, there will be heavy downpour. Cancer, Pisces and Capricorn are full watery signs; Taurus, Leo and Aquarius are half watery signs; Aries, Libra and Scorpio are quarter watery signs while Gemini, Virgo and Sagittarius are not watery signs. Moon and Venus are full-blown watery planets. During Winter solstice (*Dakshinayana*) malefic planets (Saturn, Sun, and Mars) transiting through the *Amrita, Jala* and *Neeranadis*, would give rise to ordinary rains. If benefic planets transit the above constellations, there will be plenty of rain.

Principle No. 3:- Whatever may be the season, there must be weather–fluctuation when Moon joins Venus or when Moon is fifth or ninth from Venus in the rainy season, it causes good rain unless there are factors preventing rains.

Principle No 4:- When Mars transits from one *Rashi* into another within two days there is a perceptible change in weather and in the rainy season there must be a good rainfall. Mars is the most powerful planet causing rainfall.

Principle No. 5:- Similarly when a major planet (such as Jupiter, Saturn, *Rahu* and *Ketu)* is into a fiery, earthy, watery or airy sign) changes a *rashi*, it causes momentous events. In case of weather, it must cause a very noticeable change in weather.

Principle No. 6:-When planets retrograde and on the days when they begin direct motion, there is a change in temperature, humidity and what the meteorologists describe as disturbance causing rainfall etc.

PREDICTING DATES OF RAINFALL OCCURRENCE

The following principles are used to predict the dates / occurrence of rainfall in India.

a)   After the sun has entered *Mrigshirsha nakshatra* towards the end of May the south west monsoon begins to strike Kerala coast. When Sun enters *Ardra* (22nd-23rdJune) every year monsoon enters in Gujarat.

b)   When sun reaches and crosses six degrees in Gemini, the monsoon arrives in North India (around June 22) and when Sun reaches ten degrees in Virgo on 26 September, the monsoon begins to withdraw in North India.

c)   If the rains occur on 2nd & 5th day of *ashadh* month, there will definitely be more rain during the 2nd fortnight of *ashadh* & first fortnight of *shravan* month respectively. It was found to be true (1990 – 2001), except for 1995, in Gujarat (Kanani *et al.,* 2005).

d)   If the 11th day of first fortnight of *ashadh* (*dev-paudiekadashi*) falls on Sunday, Saturday or Tuesday, excess rainfall may occur, causing food grain prices to shoot up. It was found true (1990 – 2001), except 1995 and 1997, in Gujarat (Kanani *et al.,* 2005).

e)   When the Sun enters *Swati* it causes some occasional rain otherwise the south-west monsoon withdraws totally. In Indian tradition there is reference to the bird called *chatak* which supposedly waits for the rain-drop of *Swati*.

f)   The moon, in certain, '*nakshatras'* joining, with other planets or when aspected by them can cause or hinder rain. Planets will be placed in the *nakshatras* given in the *Sapta-Nadi Chakra*.

g)   There will be rain when Mercury transits Cancer and join Venus in the north India after August. h) The presence of Jupiter and Venus together in *Rohini* star shows torrential and untimely down pour of rains. Mars and *Rahu* together aspected by Saturn causes lightening and cloud bursts.

i)   Cyclones on the Andhra Pradesh coast are likely to occur close to periods of sunspot maxima when the planets Jupiter, Saturn, *Rahu (Ketu)* and Uranus form even loose aspects of *Kendra* (square) and *yuti* - conjunction between themselves. These indications are strengthened whenever either Virgo or the 12th

from it are afflicted.

ASTRO-METEOROLOGICAL METHODS

The solar system consists of one star (the Sun), the nine principal planets, their satellites and lesser bodies such as asteroids, comets and meteoroids, plus a vast amount of thinly-spread interplanetary matter. The Sun contains more than 99% of the mass of the system, and Jupiter is more massive than all the other planets combined. The center of gravity of the solar system lies just outside the surface of the Sun, due mainly to the mass of Jupiter. The solar system is divided into two parts. There are four relatively small, rocky planets (Mercury, Venus, Earth and Mars), beyond which come the asteroids, of which only one (Ceres) is over 900 km in diameter. Next come the four giants (Jupiter, Saturn, Uranus and Neptune) plus Pluto, which is smaller than our Moon and has an unusual orbit which brings it at times closer in than Neptune. However, Pluto does seem to be in a class of its own, and in size is intermediate between the smallest principal plane (Moore, 2000). The time required by planets to complete one revolution around Sun is Mercury in 88 days, Venus in 224 days, Mars in 686 days, Jupiter in 4332 days and Saturn in 10,759 days. The time taken by the Sun to complete one round along the ecliptic is a fixed period (365.2568 days) which is called as Sidereal year. Although according to modern Astronomy there are nine planets *viz.,* Sun, Moon, Mars, Mercury, Jupiter, Venus, Saturn, Uranus, Neptune and Pluto, but Hindu astrology recognizes only the first seven.

Riske (1997) in her book entitled 'Astro-meteorology' has advised to consider 1st, 7th, 4th and 10th position in *kundali* (planetary chart) of a given place and time. She has recommended to consider a *kundali* for the time of Sun's entry into zodiac, Sun and Moon position at 0, 90, 180 and 270° and planets in 1, 7, 4 and 10th house in addition to North and South half, East and West half of the *kundali*. She has classified the aspects into 3 classes negative, positive and neutral and has mentioned specific effect of these combination aspects of particular planet on weather. She has given guideline to predict wind, thunderstorms and hailstorms, tornadoes, hurricanes, floods, heat and cold wave, drought and snowfall in respect to USA.

Table 3: Name of *Nakshatra*

Nakshatras			
1. Ashwini	8. Pushya	15. Swati	22. Abhijit
2. Bharani	9. Ashlesha	16. Vishakha	23. Shrawan
3. Krittika	10. Magha	17. Anuradha	24. Dhanishtha
4. Rohini	11. Purva	18. Jyeshtha	25. Shat-taraka
5. Mruga	12. Uttara	19. Mula	26. Purva-bhadrapada
6. Ardra	13. Hasta	20. Purvashadha	27. Uttara-bhadrapada
7. Punarvasu	14. Chitra	21. Uttarashadha	28. Revati

Ramanathan (1987) states that the asterisms (*Nakshatras*) according to our ancient *rushis* are distributed in the zodiac is a belt of 48° with a spread of 24° on either side of celestial equator. The planets also move within this belt. Initially they had 28

asterisms, later *Abhijit*, which was assumed to be located partly in *Uttarashadha* and partly in *Shravana* was dropped leaving 27 asterisms (*Nakshatras*) (Table 3) covering the zodiac. In order to identify the *nakshatras* the ancients first developed the idea of group of stars having shapes of animals, birds, men etc. In each group they identified one bright star which was called *yog tara*. The asterism *Ashvini, Bharani etc.* were located with the help of *yogtara*.

The influence of *nakshatras* and planets on rainfall process after attributing the quality of *soma* or *agni* or related qualities to them especially when they have been taught by the *Vedic* seers that *agni* and *soma* are the two basic things which have given rise to everything that we witness in this universe. Though initially this art of rainfall forecasting was practiced by few experts like *Garga, Parasara, Narada, Devala, Vashistha, Bhrugu, Druhina, Rajputra, Kashyapa, Varahmihir* etc. Later in the light of careful observation covering more regions the number of experts increased and naturally the thumb rules also increased in number. Many of these rules handed down the generations and they have been incorporated in local *panchangs* and folklores or proverbs (Ramanathan, 1987).

The different workers got different planetary combinations for occurrence of rainfall based on their area or experience and gave certain rules for wet spell and dry spell or drought occurrence.

Astro-meteorological computations

The astronomical parameters like Conjunction (*yuti*), Opposition (*pratiyuti*), parallel (declination – *Krantiyuti*) and *Kranti Pratiyuti* is explained in literature with figures are given. The Earth rotates round the Sun, but if we observe from Earth, the Sun appears to move round the earth. During this motion, the path Sun traces in the sky is known as Ecliptic. Similarly, if we extend Earth's equator in the sky, the path it traces is known as Celestial Equator. The angle between the Celestial Equator and Ecliptic is 23.5° which is due to inclination of Earth's axis. The Celestial Equator and Ecliptic intersect at two points which are known as Vernal Equinox and Autumnal Equinox. All the planets appear to move in a fixed path which is very close to the Ecliptic. To find the position of planets on the Ecliptic, a perpendicular is drawn from the planet to the Ecliptic. Suppose this perpendicular meets ecliptic at point 'a', the angle made by the arc V_e – a to the center of the earth is longitude of the planet. So, in this Fig. 3 is the longitude of the planet traditionally called as *bhoga* which is used in defining *yuti* and *pratiyuti*.

As seen from the earth, if two planets have same longitude then these planets are said to be in Conjunction (Fig. 4). Similarly, if two objects are 180 degrees away from each other with respect to *Bhoga* coordinate then they are said to be in *Pratiyuti* (Opposition) with each other (Fig. 5). To know *Kranti* (declination) of planet, if a perpendicular is drawn from the planet to the Celestial Equator, the angle made by this perpendicular at center of the earth is *Kranti* (declination) of the planet. When two objects have same *Kranti* with same sign, they are in *Kranti-Yuti*, and if they have same magnitude of *Kranti* but different signs, they are said to be in *Kranti-Pratiyuti* (Fig. 6.).

Mangaonkar (1979) studied 36 planetary combinations in relation to weather. He gave three major groups of planetary
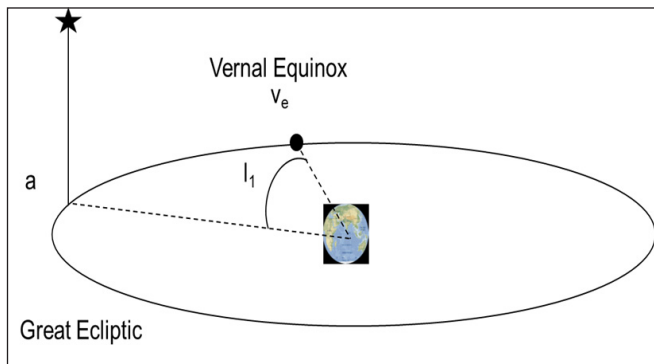
Fig. 3: Right ascension (*Bhoga*) angle from Vernal equinox to planet
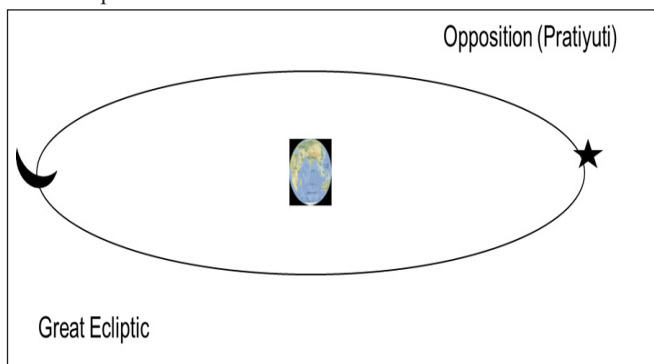

Fig. 4: Conjunction between Moon and planet

Fig. 5: Opposition (*Prati-yuti*) between Moon and planet
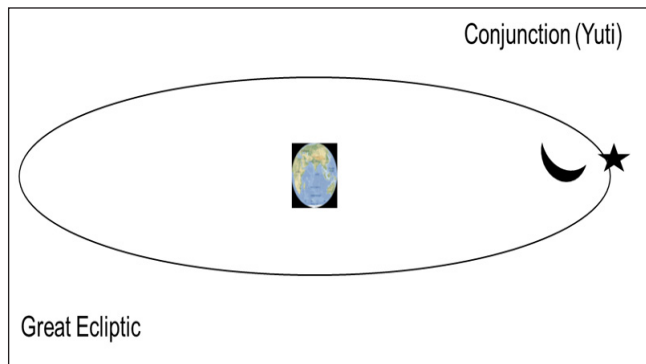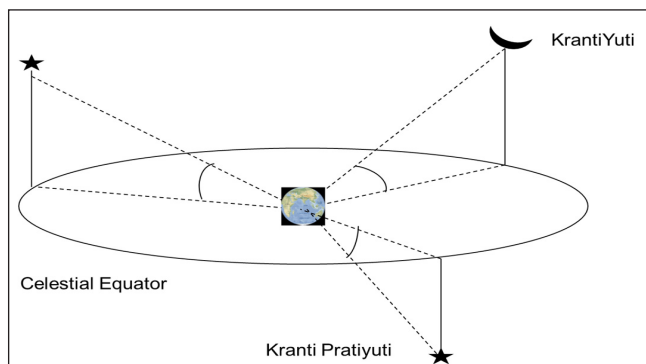

Fig.6: *Kranti yuti* and *Kranti Prati-yuti* between moon and planet

aspects conjunctions (*yuti*), opposition (*pratiuti*) and Parallel (*Samakranti*) between planets. The planetary combinations have different periodicity to occur and hence influence pattern of weather like cloud formation, cyclonic activity, thunderstorms, heavy downpour and dry spell *etc*. His study revealed that out of total 36 combinations 11 important combinations found relation to rainfall. He gave combinations responsible for rainy spells as below Sun–Moon (Conjunction), Sun-Mercury (Conjunction), Sun-Jupiter (Conjunction), Sun-Venus (Conjunction), Sun-Uranus (Conjunction), Sun-Neptune (Conjunction), Moon-Mercury (Conjunction), Moon-Jupiter (Conjunction), Moon-Venus (Conjunction), Mercury-Venus (Conjunction), Mercury-Mars (Conjunction), Mercury-Uranus (Conjunction), Mercury – Neptune (Conjunction). He elaborated various planetary combinations responsible for rainfall.

Dube (1986) enlisted the following planetary aspects favorable for rainfall occurrence:- Mercury-Venus (Conjunction), Mercury-Jupiter (Conjunction), Venus-Jupiter (Conjunction), Moon-Venus (Opposition), Moon-Saturn (opposition), Moon-Mercury (Opposition), Moon-Jupiter (Opposition), Venus-Venus (Opposition), Jupiter – Neptune Conjunction is favoring rainfall. Sun-Mercury *krantiyuti* is favorable for rainfall. The *krantiyuti* and conjunction between Mercury-Uranus, Mercury-Neptune, Venus-Uranus, Venus-Neptune is favorable for rainy events. Moon-Saturn-Sun, Saturn-Mars (Conjunction) creates cyclonic situation with heavy rainfall. If it is aspected with moon it is causing destructive rainfall. He also stated that Sun-Jupiter opposition is aspect which is not favorable in rainfall. Jupiter-Mars Opposition is also not

favoring rainfall.

Ramanathan (1987) gave the planetary combination rules as below

1. During the rainy season if Mars moves ahead of Sun, there will be drought, if Venus is ahead of Sun there will be rains, if Jupiter is ahead of the Sun weather will be hot and if Mercury is ahead of Sun, winds will occur.

2. Conjunction of Sun and Mars, Saturn and Mars, Jupiter and Mars results in drought. Conjunction of Mercury and Venus, and Jupiter and Mercury give rains.

3. Venus, Mercury and Jupiter in conjunction and influenced by other planets is indicative of heavy rains.

There is influence of eclipses of the Sun and the Moon, comets, the relative position of various planets with respect to Sun and the Moon *etc.* do influence the rainfall and forecaster should formulate rules accordingly (Ramanathan, 1987). Venugopal *et al.,* (2002) studied the effect of interplanetary conjunctions on weather systems such as depression, land depression, deep depression, cyclonic storm, severe cyclonic storm, very severe cyclonic storm, super cyclonic storm and super cyclonic storm with hurricane winds during 1990-2000 over Indian sea and neighborhood. In this study they established linkage through i) Solar influence ii) lunar influence and iii) planetary influence. He found parallels between these phenomena and different planetary conjunctions. Astronomical phenomena coincident with the periods of the cyclonic disturbances were identified. Majority of cyclonic events seems to play an active

role, either during a period of disturbance or few days before that. Lele (2002) have extensively given the astrological method of rainfall prediction for Maharashtra. He used to write rainfall prediction in very popular *'Date Panchang'* of Solapur (MS). He gave Moon, Venus and Neptune as full watery planets. He reported that when Jupiter is in aspect with Moon, Venus or Neptune gives heavy rainfall. He gave rainfall favoring planetary aspects like Sun with Moon and Venus, Mercury-Venus, Jupiter with Venus *yuti* and Moon-Jupiter, Moon Neptune, Moon-Venus and Moon-Neptune *yuti*is favorable for rainfall.

Role of planets on occurrence of rain or flood

1. When the Sun is overtaking Mars, there will be heavy downpour of rains, causing flood in rivers.

2. If the Moon is in the 7th from Venus and within view of benefic planets (Jupiter, Neptune and Mercury), or be in the 5th, 7thor 9th house from Saturn there will be immediate rain.

3. When Venus is in constellations of *Swati, Vishakha and Anuradha*, unprecedented rainfall results in heavy floods.

4. Heavy rain results when Jupiter is in Pisces while Venus is in Cancer.

Role of planets on occurrence of drought or famine

1. When Sun is between Venus and Mercury there is a break in monsoon in the sense that for some days there is dry spell.

2. Sun being behind Mars in the rainy season, there will be poor rain or rain is delayed or will create dry spells.

3. Rain will not be timely when all quadrants being occupied by malefic planets (increasing dryness planets like Sun, Mars, Saturn and Pluto).

4. Mars, affected by other malefic, will create dry spells till August.

5. If Jupiter and Mars are within 30 degrees (thirty degrees) of each other it prevents rains.

6. Famine will break out for want of rains when Venus is in one of constellations from *Jyestha* to *Shravana*.

7. There will be drought condition when Venus sets in or retrogrades in *Magha* or *Uttarashadha*.

8. Clouds become scattered and rainfall disturbed, when the Sun, Mars and Venus transit the same sign. If Jupiter joins the above combinations, clouds will deliver rains in plenty.

9. When Jupiter retrogrades in *Rohini*, the year will have less rainfall.

10. Droughts are noticed when Saturn is un-aspected in Aries, Leo or Sagittarius.

11. When Mars and Saturn are in conjunction there will be very low rainfall.

Lele (2002) gave prediction at least a year before commencement of rainfall. He has given major clues for rainfall prediction as below.

1. Sun is the major planet (star) for all weather we experience on earth, so he considers planetary positions such as conjunction, opposition, trine with sun and other planets. The movement of all planets in various constellations, *rashis* (Zodiacs), their rise and setting time and the conjunction of declinations are considered for rainfall prediction.

2. He has divided all planets, Zodiacs and constellations according to their character as Hot, Cold, Watery and Non-watery.

3. The Sun's entry in *Mesha, Vrishabh, Mithun, Vrishchikrashi and Asvini to Swati* constellations.

4. The year comes under which *'Mandala'* is considered.

Shah (2002) in his study of effect of planetary aspects and rainfall prediction for Saurashtra found that

1. The declination of Mercury in the end of May to June determines onset of monsoon in Saurashtra region. The position of Mercury determines cloud formation in Arabian Sea.

2. Venus has effect on cloud formation in Bay of Bengal. The position of Venus has effect on onset of monsoon in Pune and also effect on the trend of monsoon activities on the eastern part of *Ghat* area.

• Certain positions of Sun/Mercury, Sun/Saturn/Mercury have effect on Cyclone.

• Jupiter and Saturn when they are in conjunction or opposition in longitude (degree) and declination for longer period, cooling effect of weather is observed as under

    a. If this occurs in November, December, January cold wave is felt.

    b. If this occurs in April/May monsoon cycle is disturbed and possibility of less rainfall during monsoon.

    c. If this occurs in July, August, there is possibility of i) widespread and ii) satisfactory rain and iii) sometimes prolonged wet spells during monsoon.

• If Mars is moving ahead of Sun, Mercury and Venus continuously in June and July, the monsoon cycle is delayed hence, less rain or drought can be anticipated in Saurashtra region.

Certain position of moon with Jupiter /Saturn brings scattered but heavy showers. As per verification of forecast given by Shah for Pune and Saurashtra for year 1993 to 2001 recorded 66.7 and 65.4% average accuracy on the Yes/No basis (Shah ,2002).

Bhat *et al.,* (2002) examined the effect of planets on temperature. He found that when planet Jupiter is at aphelion (at longest distance from the Sun) there is more dampness and cold

weather than usual is felt. Planets responsible for cool weather are Mercury, Saturn, Uranus, and Jupiter when in opposition. Position of the Sun at times of New Moon i.e. Season change will give clue to the type of weather during the period. Position is referred in reference to *Nadi* and *Mandal*. Planets responsible for windy weather are *Ketu* and Mercury. Planets responsible for hot weather are Sun, Pluto, Rahu, Mars and Jupiter when in union. Planets responsible for moist weather are Moon, Venus and Neptune. Bhat *et al.,*(2002) states that the planetary position responsible for cold weather in winter is same as those responsible for giving rain in monsoon season.

Varshneya *et al.,* (2002) designed *Nakshatra-Varsha* almanac which predicted onset and withdrawal of monsoon and rainfall distribution based on astrology for five regions of Maharashtra. Varshneya *et al.,* (2008) prepared Monsoon Research Almanac which predicted daily rainfall for different districts of Gujarat state by casting the *kundali* at the time of sun's entry into each *nakshatra* for each district. The validation of rainfall forecast given in Monsoon Research Almanac on Yes/No basis indicated that average accuracy varied between 37% (2008) to 71.3% (2010) for state as a whole. Overall state average skill score was 58.8% (Vaidya, 2013). Daily rainfall (quantitative) was predicted for the first time in AAU Monsoon Research Almanac-2007 and has been predicted every year till 2012. From the year 2007 to 2012 the average error was -7.9% for state as a whole which was below 10%. The most accurate prediction was done for 2010 monsoon with only 1.1% error followed by 2007 monsoon prediction with 4.6% error. Average error was the lowest in Middle Gujarat (1.92%), while it was the highest in Saurashtra (-17.98%).

Desai *et al.,* (2015) gave methodology for predicting daily rainfall for Pune location. Their astrological prediction involved preparation of different planetary charts (*kundali*/horoscope) for Pune. The latitude-longitude of Pune was considered. In the beginning the when the sun enters into *Ashwini nakshatrai.e. Varsh Pratipada (Gudhipadawa), kundali* was prepared, it usually reflects the overall weather pattern of the year ahead. Such planetary charts (horoscopes) were prepared for each time when the sun entered in each constellation (*nakshatra*) starting from *Rohini to Swati* and its each quarter (*Nakshatra charan*). The *kundalies* of *amavasya, pournima*, *pratipada* of each fortnight, solar and lunar eclipse in this period were accounted while predicting rainfall. Besides *Tithi* of the day, *Chandra nakshatra* of the day, relative planetary positions like Sun, Moon, The Uranus, Neptune, Pluto, *Rahu* (North node) and *Ketu* (south node) were considered while predicting.

Pande (2014) gave the planetary aspects as per *Varahmihir* favorable for rainfall is Moon-Venus (Opposition), Jupiter – Venus (Opposition), Moon-Venus (Conjunction), Mercury-Venus (Conjunction), Mercury-Jupiter (Conjunction), Jupiter-Venus (Conjunction).

SEASONAL RAINFALL FORECAST

Parashara (4th century BC) wrote book *Krishi Parashar* having 243 verses out of which nearly 69 verses that relate to prediction of rainfall have strong astrological content. If we take *adhaka* (measure of rainfall) as equal to 1.6 cm or 16.0 mm

(Balkundi, 1998), then according to verses 27 and 28, the annual rainfall could vary between 800 mm (50 *adhakas*) and 1600 mm (100 *adhakas*) (Sadhale, 1996). *Parashara* has mentioned several methods for predicting rainfall in the whole year or part of the year and sudden showers. *Parashara* gave qualitative rainfall prediction model, as every year has (a particular planet as) a ruler, (another planet as) a minister, a particular cloud, and (depending on that) an amount of rainfall can be estimated qualitatively (Balkundi, 1999). The planet, which is fifth from the ruler planet, indicates the minister planet of that year. The minister planet of the year is Venus as it is the fifth from the Sun. The Moon indicate heavy rains, Mars indicate scanty rains, and Mercury indicate good rains. Each model however was so simple that an ordinary farmer with basic knowledge of *saka* calendar could learn it easily by memorizing verses. In today's time also farmers in rural areas of India speak in terms of planets and stars in relation to not only rainfall predictions but also many other farm operations (Sadhale, 1999).

Iyengar (2009) studied year to year variation of Indian monsoon rainfall as described qualitatively in some ancient *Sanskrit* texts. Interestingly, these are cyclic with periods of 3,5,7,18 and 60 years. Time series analysis of actual seasonal rainfall data shows that at very near the above periods the spectrum has significant peaks. The Venus visibility portent stated in the *Arthasastra* appears to be a proxy for the near three year fluctuation cycle in the rainfall. *Kautilya* mentions that rainfall for the season depends on the visibility of Venus. He expects good rainfall if Venus were to be sighted in the eastern sky during the monsoon season. Ramanathan (1987) also mentioned a method to estimate monthly rainfall pattern based on hypothesis like four pots filled with water are placed in four direction beginning with month and are named after the months beginning with *Shravana* in the order. These pots are kept on the day when moon passes through *Rohini* in the dark half of *Aashaadha*month. The amount of rainfall will have to guess from the quantity of water left in the pots at the end of 15 days. The first measurement of amount of rainfall with the help of rain gauge were made India as early as fourth century BC and continued to be practiced until the end of tenth century AD (Srinivasan, 1976). Bedekar (2002) have reviewed the various time scales of Earth, Sun, Jupiter, Saturn, and the names given to each time series. Particularly 5 circles of Jupiter (12 yr. each), two circles of Saturn (30 yr. each) completes the 60 years cycle. The separate name is given to each year of 60 yr. cycle known as *'Samvatsar'*. Each name of the *'Samvatsar'* is having different meaning. The effect of various time scales (circles) on monsoon need to be studied. He has also mentioned various *'Vahana'* of *Nakshatra* and accordingly rainfall prediction can be given.

Varahmihir's model for prediction of seasonal rainfall

Iyengar (2004) studied the *Varahmihir's* (VM's) text of *Bruhat Sanhita* (BS) edited by M. Ramakrushna Bhat (1981). *Bruhat Samhita* devotes 8 chapters to discuss rainfall including measurement and forecasting. In *"Pravarshan"adhyay* which is 23rd chapter of BS, Shloka 6-9, there is a statement on amount of rainfall to be forecasted for season, depending on the first rainfall in the month of *Jyestha*. The prediction of amount of rainfall according to *Chandra nakshatra* of first rainy date after *Jyestha*

pournima. The area of rainfall predicted is mentioned as 10 *yojan* (*i.e.* 80 miles), but according to *Garg, Parashar and Vashishtha, Varahmihir* explains area to be 12 *yojana* (96 miles). *Varahmihir* is categorical that rainfall measurement should start after the full moon in month of *Jyestha*. *Varahamihira* evolved a technique in which after the occurrence of the full-moon day (*Pournima*) of the month of *Jyestha* (approximately coinciding with June), *nakshatra* of the day on which the first rainfall is received should be noted. The predicted amount of the season's total rainfall for each *nakshatra* is also mentioned in the works of Ramanathan (1987) and Bhat *et al.,* (2005). Ramanathan (1987) gave the seasonal rainfall prediction based on asterism of moon on first rainy day after *Jyeshth Pournima* given in *Brihatsanhita* (BS). There are 10 classes of rainfall amount mentioned based on moon's asterism on first rainy day. The amount of rainfall recorded on that day has no significance. Modern meteorology defines a rainy day as a day on which a rainfall of 2.5 mm or more has been recorded in 24 hours.

Vanadeep *et al.,* (2012) conducted study in Tirupati (AP) revealed that the annual rainfall predicted based on planetary ruler of year (in local *panchang* of Tirupati in AP) and qualitative rainfall prediction was compared with actual observed annual rainfall at Tirupati. The percent of agreement for South-west monsoon season ranged from 10.6% to 72.8% with mean value of 37.5%.

Thus, *Varahmihir* appears to have been particular about the onset of monsoon, which he has placed after *Jyestha pournima* spread for next 27 days (Iyengar, 2004). He estimated the probability distribution of rainfall mentioned in BS and found mean value of 15.59 *Drona* and SD of 5.73 *Drona* with CV of 37%. This value is close to present day variability in western part of Madhya Pradesh (MP) including Ujjain. He compared rainfall mentioned in *Brihat Sanhita* with actual rainfall of Ujjain with 1 *Drona* = 6.4 cm = 64 mm as mentioned by Balkundi (1998). During ancient times some part of Rajasthan and Gujarat were included in Geo-political region of Avanti/Ujjain. The coefficient of variation increases as one proceeds from Ujjain towards Jaipur in Rajasthan. Thus, *Varahmihir* model is consistent with the present day understanding of rainfall distribution.

CONCLUSION

The traditional weather and climate knowledge type of hybrid knowledge co-production will allow the development of a system that benefits from both the local relevance of indigenous approaches and the greater precision and efficiency of contemporary procedures. Furthermore, knowing the scientific foundations of the diverse plant and animal species modifications in anticipation of weather and climate change may give crucial insights into the science of ecology and climate change. With rapid climatic changes and global warming, drastic variations in weather phenomena have been a common occurrence in recent decades. This is why numerous weather prediction models have frequently failed to perform as expected. This predicament applies to all the traditional scientific texts and treatises, including the *Panchangam, Varahmihir* and *almanac.* With climate trends becoming more volatile by the day, the usefulness and efficacy of all traditional, indigenous, and modern scientific approaches must be re-examined and re-evaluated. In the current circumstances, it will soon be necessary to integrate the traditional knowledge that our ancestors left us as an invaluable inheritance with the newest decorative technological advancements to create a meteorological monitoring and forecasting mechanism that is suitable, complete, and aesthetically pleasing.

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