Chapter-3

CLOUD FORMATION, PRECIPITATION AND ITS MEASUREMENT

Precipitation is one of the three main processes (evaporation, condensation, and precipitation) that constitute the hydrologic cycle, the continual exchange of water between the atmosphere and Earth's surface. This chapter discusses various processes such as cloud formation, interaction between Sun and ocean and earth surface, condensation and precipitation, as described in the ancient Indian literature. The chapter also sheds lights on the techniques used for precipitation measurement in ancient India.

Seasons and Clod Formation

The Rig Vedic Aryans had keenly and carefully demarcated the variation in seasons and divided the whole year into six such divisions as the verse indicates:

उतो स मह्यमिन्दुभिः षड्युक्तो अनुसेषिधत्।
गोभिर्यवं न चर्कृषत्।। R.V., I,23.15 ।।

The Sun was clearly known to the Rig Vedic Aryans as determinant of seasons and the seasons were formed for the benefit of the earthly creatures.

त्रीणि जाना परि भूषन्त्यस्य समुद्र एकं दित्येकमप्सु।
पूर्वामनु प्र दिशं पार्थिवानामृतूत्प्राशासद्वि दधावनुष्ठु।। R.V., I,95.3 ।।

Figure 3.1 shows the general cloud formation and associated processes, as understood in modern times. The knowledge about cloud formation is also present in the Rig Veda.

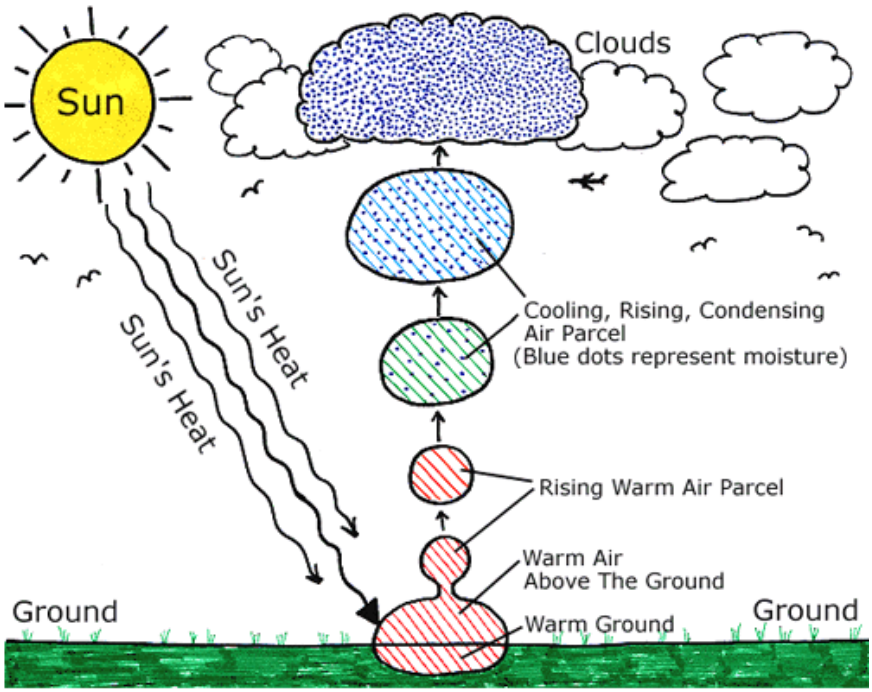

Figure 3.1: The process of Cloud Formation
(Source: https://climate.ncsu.edu/edu/CloudFormation)

Radiation, convection currents and rainfall as their effect, are described in the Rig Veda (I,164.47, VII, 70.2 and I,161. 11-12) through following verses.

उद्वत्स्वस्मा अकृणोतना तृणं निवत्स्वपः स्वपस्यया नरः।
अगोस्यस्य यदसस्तना गृहे तद्घोदमृभवो नानु गच्छथ।। R.V., I,161.11 ।।

संमील्यं यद्भुवना र्प्यसर्पत क्व स्वत्तात्या पितरा व आसतुः।
अशपत यः करस्नं व आददे यः प्राबवीत्प्रो तस्मा अबवीतन।। R.V., I, 161.12 ।।

कृष्णं नियांन हरयः सुपर्णा अपो वसाना दिवमुत्पतन्ति।
त आववृत्रन्त्सदनादृतस्यादिद्धृतेन पृथिवी व्युघते।। R.V., I, 164.47 ।।

These above verses of the Rig Veda also state that the rays of the Sun are the cause of the rains, and that the clouds are constituted of various elements. Some verses of Rig Veda (I,27.6; I,32.8; I,32.14; I,37.11; II, 24.4; V,55.3) describe the formation of cloud by evaporation of water by Sun and wind and then rainfall, and there is no other cause of rainfall other than Sun.

विभक्तासि चित्रभानो सिन्धोरूर्मा अपाक आ।
सधो दाशुषे क्षरसि।। R.V., I, 27.6 ।।

नदं न भिन्ममुया शयानं मनो रूहाणा अतिं यन्त्यापः।
यश्चिद्वत्रो महिना पर्यतिष्ठत्तासामहिः पत्सुतः शीर्बभूव।। R.V., I,32.8 ।।

The above verses explain that all that water goes to the sky with wind by the heat of Sun rays and gets converted to clouds and then again after the penetration by Sun rays, it rains and gets stored in rivers, ponds, ocean etc. The clouds are said to be leaders for replenishment of water. The verse V 55.3 of the Rig Veda explains the simultaneous formation of mighty clouds which are co-dispensers of moisture.

साकं जाताः सुभवः साकमुक्षिताः श्रिये चिदा प्रतरं बावृधुर्नरः
विरोकिणः सूर्यस्येव रश्मयः शुभं यातामनु रथा अवृत्सत।। R.V.,V,55.3 ।।

During Rig Vedic times the seasonal variation of rainfall was known, which is depicted through following verses (RV.VI,20.2 and VI,30.3) saying that the Sun extracts water from Earth during eight months and then this water rains during rainy season of four months.

दिवो न तुभयमविन्द्र सत्रासुर्यं देवेभिर्धायि विश्वम्।
अहिं यत्दृत्रमयो वव्रिवांसं हन्नृजीषिन्विष्णुना सचानः।। R.V.,VI,20.2 ।।

Verse I, 79.2 of the Rig Veda states that the Sun rays strike against moving clouds. Thus, the black shedders of rain roar. After this, the shower comes with delightful flashes of lighting. The rains then descend, and finally the clouds thunder.

अ ते सुपर्णा अभिनन्तं एवैः कृष्णो नोनाव वृषभो यदीदम्।
शिवाभिर्न स्मयमानाभिरागात्पतन्ति मिहः स्तवयन्त्यभ्रा।। R.V.,I,79.2 ।।

Following two verses (V.54.2 and V55.5) of the Rig Veda explain the cloud-bearing winds as the cause of rainfall, viz.

प्र वो मरुतस्तविषा उद्न्यवो वयोवृधो अश्वयुजः परिज्रयः।
सं विधुता दधति वाशाति त्रितः स्वरन्त्यापोइवना परिज्रयः।। R.V.,V,54.2 ।।

Meaning: "O cloud-bearing winds, your troops are rich in water, they are strengtheners of life, and are your strong bonds, they shed water and augment food, and are harnessed with steads

(waves) that wander far and spread every-where. Combined with lighting, the triple-group (of wind, cloud and lightning) roars aloud, and the circumambient waters fall upon the earth".

उदीरयथा मरुतः समुद्रतो यूयं वृष्टिं वर्षयथा पुरीषिणः।
न वो दस्त्रा उप दस्यन्ति धनेवः शुभं यातामनु रथा अवृत्सत।। R.V. V,55.5 ।।

This verse explains that the cloud-bearing winds uplift water from ocean and charged with water shower down the rain. Similarly, instrumentality of winds in the causation of rainfall can be easily read in verses I,19.3-4; I, 165.1, and their relationship with clouds in I, 19.8 of the Rig Veda, as follows:

ये महो रजसो विदुर्विश्वे देवासो अद्रुहः। मरुद्मिरग्न आ गहि।।
या उग्रा अर्कमानृचुरनाधृष्टास ओजसा भरुद्भिरग्न आ गहि।। RV.I,19.3-4 ।।

अ ते तन्वन्त रश्मिभिस्तिरः समुद्रमोजसा।
मरुद्भिरग्न आ गहि।। RV.I,19.8 ।।

Both of the above verses reveal the cause of rain, who commands the rain to come down and execution of eternal laws.

The following hymn (I,38.7) of the Rig Veda reveals how the moisture leaden winds bring some scanty rainfall in desert region also.

सत्यं त्वेषा अमवन्तो धन्वञ्विदा रुद्रियासः।
मिहं कृण्वन्त्यवाताम्।। R.V.I,38.7 ।।

From verse V,53.6-7 of the Rig Veda, we also come across the knowledge of Rig Vedic Aryans about the positive effect of yajna's (यज्ञ), forests and large reservoirs, causing rainfall.

आ यं नरः सुदानवो ददाशुर्षे दिवः कोशमचुच्यवुः।
वि पर्जन्यं सृजन्ति रोदसी अनु धन्वना यन्ति वृष्टयः।।
ततृदानाः सिन्धवः क्षोदसा रजः प्र सस्त्रुर्धेनवो यथा।
स्यन्ना अश्वा इवाध्वनो विमोचने वि यद्वर्त्तन्त एन्यः।। R.V.V.,53.6-7।।

The following hymn from the Rig Veda (V, 53.17) indicates that there are sixty-three types of winds. However, their climatological and meteorological implications are still unraveled and they are mostly treated as merely mythologies.

सप्त मे सप्त शाकिन एकमेका शता दुदः।
यमुनायमधि श्रुतमुद्राधो गत्यं मृजे नि राधो अश्वयं मृजे।। R.V.V,53.17 ।।

No clear cut mention of the monsoon is to be found in Rig Veda but the Marut hymns give satisfactory descriptions. Monsoon is, however, clearly referred to in the later period in the Yajurveda Samhita as सलिलवात (Taithriya IV.4.12.3).

वर्च इदं क्षत्र सलिलवातमुग्रम्।।
धर्त्री दिशां क्षत्रमिदं दाधारोपस्थाशानां मित्रवदस्त्वोजः।। T.S,4.4.12.3 ।।

However, a better reference to rain bearing winds is provided in the Rig Veda (R.V. X. 137.2 and I,19.7).

द्वाविमौ वातौ वात आ सिन्धोरा परावतः।
दक्षं ते अन्य आ वातु परान्यो वातु यद्रपः।। R.V.X,137.2 ।।

In versa, VIII,7.4 of the Rig Veda, the word मिहं is explained to mean mist, with which one cannot differ easily, if the content is taken into account, though at other places मिहं signifies rainfall.

वपन्त मरुतो मिहं प्र वेपयन्ति पर्वतान। यद्यामं यन्त वायुभिः।। R.V.VIII,7.4 ।।

The importance of yajna to purify environment and causation of rainfall has also been described in the Rig Veda (RV.X,98.4; x,98.6/12; x.98.7 and x,98.11) as below:

आ नो द्राप्सा मधुमन्तो विशान्त्विन्द्र देह्याधिरथं सहस्त्रम्।
निषीद होत्रमृतुथा यजस्व देवान्द्रे वाये हविषा सर्प्य।। R.V.X.98.4 ।।

अस्मिन्त्समुद्रे अध्युत्तरस्मन्पो देवोभिर्निवृता अतिष्ठन्।
ता अद्रवन्नाष्टिंणेन सृष्टा देवापिना प्रेषिता मृक्षिणीषु।। R.V.X.98.6/12 ।।

These hymns clearly describe that the water collected by Sun rays kept in kept in the sky safely, and to create rain, one should take help of knowledgeable priests, who will do appropriate yajna

(sacrifice) for rain. This implies that the precipitation is the result of weather and cloud formation. The three other Vedas, namely Sama, Yajur and Atharva Veda furnish some additional information on climatology and meteorology which we do not come across in the Rig Veda. Since these three Vedas chronologically belong to a later period, it can be easily seen that during the later Vedic period the water science further progressed to a considerable extent.

That the rain is a phenomena of ocean, wind and moisture, is proved to be clearly known by later Vedic times. Verse from the Tiathriya says "from the Ocean, O Maruts ye make (the rain) to fall, O Ye that are rich in moisture (TS.II,4.8.2)".

वृष्टयः उदीरयथा मरुतः समुद्रतो दूयं वृष्टिं वर्षयधा पुरीषिणः।
सृजा वृष्टिं दिव अद्रिभः समुद्रं पृण।। TS.II,4.8.2 ।।

In Taithriya, it is also very clearly mentioned that the air circulation plays a definite role in the causation of rainfall. It is stated thus: "Verily becoming of like hue he (wind) causes Parjanya to rain (TS, II 4.9.I).

मारुतनसि मरुतामोज इति कृष्णं वासः कृष्णंतूषं परि धत्त् एतद्वै
वृष्टये रुषं सरुप एव भूत्वा पर्जन्यं वर्षयति रमयत मरुतः श्येनमायिनमिति पश्चाद्वातं
प्रति मीवति पुरोवातमेव जनयति वर्षस्यावरुद्धयै वातमामानि जुहोति वायुर्वे वृष्टया ईशे
वायुमेव स्वेन भागधेयेनोप धावति स एवास्मै पर्जन्यं वर्षयस्य ष्टौ।। TS.II,4.9.1 ।।

West wind and the rain bearing monsoon or east wind are spoken of in above lines – "Stay O Maruts, the speeding falcon (with these words), he pushes back the west wind: verily he produces the east wind, to win the rains. He makes offering to the names of the wind, the winds rules the rain (TS.II,4.9.1).

During the Rig Vedic time, probably it was also known to the Aryans that plants (or forests) had some influence on the causation of rainfall.

सौभययैवाह्त्या दिवो वृष्टमव रुन्धे मघुषा सं यौत्यपां वा एष ओषधीनां रसो
यन्मध्वभदय एवौषधीभयो वर्षत्यथो अद्भय एवौषधीभयो वृष्टिं नि नयति।। TS.II,4.9.3 ।।

Like RigVeda, the Yajur Veda also tells about the influence of yajna (sacrifice) in purifying air, water and environment as a whole, which helps in causation of rainfall. Hymn I,12 of the Yajur Veda reads as follows:

पावत्रे स्थो वैष्णव्यौ सवितुर्वः प्रसव उत्पुनाभयाच्छिदेण पवित्रेण सूर्यस्थ रश्मिभिः।
देवीरापो अग्रेगुवो अग्रेपवो ग्र इममघ यज्ञ नयताग्रे यइपतिं सुधातु यज्ञपतिं देवयुवम्।। YV.I,12 ।।

This mantra (hymn) states that the substances like water, air etc. get polluted and if they will be broken into minute articles by fire (with the help of yajna) they will get purified and pure rainfall will occur. The hymn VI.10 of the Yajur Veda states that the materials used in yajna get divided into minute atomic forms due to attraction of Sun and ascend to sky. This causes plenty of rain fall. Likewise hymns VI – 16 and XIII – 12 of the Yajur Veda also reveal the same fact as:

अपां पेरुरस्यापो देवीः स्वदन्तु सवात्तं चित्सद्देवहविः।
सं ते प्राणो वातेन गच्छर्तो समङ्गानि यजत्रैः सं यज्ञपतिराशिषा।। YV.VI,10 ।।

In the Vedas at several places, the mist has been given the appellation of नीहार (Vajasaneyi Samhita 17.31) as:

न तं विदाथ य इमा जजानान्यघुष्माकमन्तरं बभूव।
नीहारेण प्रावृता जल्पा चासृनृप उक्थशासश्चरन्ति।। VS.XVII,31 ।।

The Yajur Veda knew about the immense concentration of mist or fog on water bodies and oceans “thou are ocean full of mist”. It was also known that pure waters purify all things through rain “May waters, like mother purify our bodies (YV.IV.2-3).

आपो अस्मान्मातरः शुध्रयन्तु घृतेन घृतप्वः पुनन्तु।
विश्व हि रिप्रं प्रवहन्त देवीः।

उदिदाभयः शुचिरा पूत एमिदीक्षातपसोस्तनूरसि
तां त्वा शिवा शग्मा परि दधे भद्रं वर्ण पुष्यन्।। YV.IV.2 ।।

The Sun was known to be the disperser of clouds and cause of rain “O Sun, thou bring rain on different parts of the earth”

महीनां प्योसि वचोदा असि वर्चो मे देहि।
वृत्रस्यासि कनीनकरचक्षुर्दा असि चक्षुर्मे देहिं।। YV.IV,3 ।।

The Sam Veda gives more emphasis on wooing Rain God. It clearly says that the eternal power of Sun penetrates the clouds and thus causes rain (SV. Previous II. 179). It also reveals that the Sun pours rain water on moving earth with the help of wind (SV. Previous II. 148) as;

यदिन्द्रो अनयाद्रितो महीरयो वृषन्तपः।।
तत्र पूषा भुवत्सचा।। SV.Previous II.179 ।।

इन्द्रो दधीचो अस्थभिर्वृ त्राण्यप्रतिष्कुतः।
जधान नवतीर्नव।। SV. Previous II. 148 ।।

The other verses of Sam Veda (V.562; final V.906; and final X.1317) discuss the kindness and greatness and power of God along with the process of rain. Verse SV. Final, XX.1802 clearly mentions the creation of oceans, rivers etc. due to the heavy rain by God.

असावि सोर्मो अरुषो वृषा हरी राजेव दस्मो अभि गा अचिक्रदत्।
पुनामो वारमत्येष्यव्ययं श्येनो न योनि घृतवन्तमासदत्।। SV. Previous,V.562 ।।

आ पवमान सुष्टुति वृष्टि देवोम्यो दुवः।
इषे पवस्व संयतम्।। SV.Final,V.906 ।।

त्व सिन्धू खासृजोधराचो अहन्नहिम्।
अशत्रुरिन्द्र जज्ञिसे विश्वं पुष्यसि वार्यम्।
तन्त्वा परि ष्वजामहे नभन्तामन्थकेषां ज्यांका अधिधन्वसु।। SV.Final,XX.1802 ।।

In Atharva Veda we come across the similar concepts and hydrologic knowledge as contained inthe other Vedas. Verse (I,4.3), for example, states as:

अपो देवी रुपं ह्वये यत्र गावः पिवन्त नः।
सिंन्धुभयः कर्त्व हविः।। AV.I,4.3 ।।

This verse reveals the concept of evaporation due to heating by Sun rays and subsequently life giving rainfall. The Prithvi Sukta of the Atharva Veda (XII,1.51) speaks of a violent dusty storm which uprooted trees and calls it as मातरिश्वा:

यां द्विपादः पक्षिणः संपतन्त हंसाः सुपर्णाः शकुना वयांसि।
यस्यां वातो मातरिश्येयते रजांसि कृण्वंच्यावयंश्च वृक्षान्।
वातस्य प्रवामुपवामनु वात्यर्चिः।। AV.XII,1.5 ।।

The various hymns of the Rig Veda indicate that the Vedic literature mythically describes the Indian atmospheric phenomena, especially those of the monsoons and rainy season, and the violent thunderstorms by which they are usually accompanied.

Following the Rig Veda, the Satpatha Brahmana also recognizes sixty three winds (SB Part I, 2.5.1.13). The same text calls hoar frost as पृश्वा.

त्रिः प्रष्टत्वा मरुतो वावृधाना उस्त्रा इव राशयो यज्ञियासः।
उप त्वेमः कृधि नो भागधेयं शुष्मं त एना ह्विषा विधेम।। RV.VIII,96.8 ।।

The Taithiriya Aranyaka (I.9.8) says that there are seven types of air currents or winds in the atmosphere which produce seven types of clouds of the same appellation. These are (1) वराह्व (2) स्वतपस (3) विधुन्महस (4) धूपम (5) श्वापय (6) गृहमेघ and (7) आशिमिविद्विष. The वराह्व creates circumstances which are responsible for condensation and good rainfall. The स्वतपस is that whose temperature condition is little affected by the insolation or Sun and perhaps occurs at a higher altitude and is responsible for precipitation. The actual text of the mantra is as follows:

तातनुक्रमिष्यायः वरावस्स्वतपसः	।	विघुन्मय सो धूपयः।।
श्वापयो गृहमेघाश्वेत्येते	।	पे चेमेशिमिविद्विपः।
पर्जन्यास्सप्त पृथिवीममि वरषन्ति	।	वृष्टभिरति।। Tai.Ara.,I,9.8 ।।

The विघुन्महस gives rise to thunderstorm; the धूपय possesses some latent property or aroma which it imparts to the objects with which it comes in contact, expanding quickly and the गृहमेध affects the humidity or moisture content of the atmosphere. Theses six belong to a single genus and have

a single or similar region of activity. The आशिमिदिद्विष belongs to another genus and its geographical realm or region is different from the preceding six; however, it is highly favourable for agricultural purposes. These seven classes of clouds bring rainfall with seven types of winds. In verse I.10.9 of the Taithiriya Aranyaka, two more types of clouds are mentioned (Tai,Ara,I,10.9). These are: (1) शम्बर or शाम्बर and (2) बहुसोमगी. The former is responsible for profuse rainfall, and the later is identified to be "the moving nimbus fall of water". Thus, total nine types of clouds with their properties, have been identified in the Taithiriya Aranyaka.

सवितारं वितन्वन्तम्। अनुवध्नाति शाम्वरः । आपपूरषम्ब्रश्वैव।
सवितारेपसोभक्त।। I,10.8 ।। त्यं सुतप्तृं विदित्वैव।
बहुसोमगीरं वशी।। अन्वेति तुयोवाक्रियां तम्। आ यसूयान्श्सोमतृप्सूषु।। Tai,Ara,I,10.9 ।।

On the similar lines, during the age of epics we get information regarding clouds, rainfall, evaporation, snow, storms etc. Verse VII.4.3 of Ramayana speaks of three kinds of clouds - ब्राहम (Produced from Brahma), अग्नेय produced from fire and पक्षज (produced on a mountain flank). White, red, blue and grey clouds are also referred to in the epic (V.1.81) as:

पाण्डुरास्णवर्णानि नीलमाज्मिष्ठकानि च।
कपिना कष्यमाणनि महाभ्राणि चकाशिरे।। Ramayana V,1.81 ।।
हरितास्णवर्णानि महाभाणि चकाशिरे।। Ramayana V,57.7 ।।

Climatic vagary or absence of rainfall is referred to in Ramayana (I.9.9) as:

अनावृष्टिः सुघोरा वै सर्वलोकभयावहा।। Ramayana I,9.8 ।।
अनावृष्ठयां तु वृत्तायां समानीय प्रवक्ष्यति।। Ramayana I,9.9 ।।

Here, it speaks indirectly of atmosphere free from dust, fog, frost and mist. Similarly, the condition of nocturnal sky (the moon from नीहार or mist) is alluded to in Ramayana (I.29.25), as:

शशीव गतनीहारः पुनर्वसुसमन्वितः।। Ramayana I,29.25 ।।

Mist and its disappearance through diurnal rise of temperature is referred to in I,55.25 verse of Ramayana, mist and severe cold in III, 16.12, cold western wind made still colder due to the effect of him (frost) in III, 16.15, very dense mist in the vicinity of earth surface in III, 16.23,

water vapour hanging on the surface of the river structure in III.16.24, dew formation on the sandy margins of the bank in III,16.24 and snowfall in III,16.25. These verses are given here as:

वदतौ वै वसिष्ठस्य या भैरिति मुहुर्मुहुः।
नाशायाम्यघः गाधेयं नीहारमिव भास्करः।। Ramayana I,55.25 ।।

निवृत्ताकाशशयनाः पुष्यनीता हिमारुणाः।
शीतवृद्वतरायामास्त्रियाना यान्ति साम्प्रतम्।। Ramayana III,16.12 ।।

प्रकृत्या शीतलस्पर्शो हिमविद्वश्च साम्प्रतम्।
प्रवाति पश्चिमो वायुः काले द्विगुणशीतलः।। Ramayana III,16.15 ।।

अवश्यायतमोनद्वा नीहारतमसावृताः।
प्रसुप्ता इव लक्ष्यन्ते विपुष्या वनराजयः।। Ramayana III,16.23 ।।

वाष्पसंक्षन्नसलिला रुतविज्ञेयसारसाः।
हिमद्रिवालुकैस्तीरैः सरितो भान्ति साम्प्रतम्।। Ramayana III,16.24 ।।

तुषारपतनाच्चैव मृदुत्वाद् भास्करस्य च।
शैत्यादगाग्रस्थमपि प्रायेण रसवज्जलम्।। Ramayana III,16.25 ।।

Verse IV,1.15 of Ramayana states about the mountain winds. In another Verse (VI, 78.19) we read about dusty, dry and gusty wind. Later on violent storm or tornado is also mentioned in Ramayana (VI,106.21, वाता मण्डलिनस्तीवाः).

शैलकंदर निष्क्रान्तः प्रगीत इव चानिलः।। Ramayana IV,1.15 ।।

Like the Ramayana, the epic Mahabharata also contains valuable information related to hydrosciences. In the twelfth skanda of the epic, atmosphere is divided into seven regions (skanda, sphere, XII,328.31) and are discussed in considerable detail as "that wind which is the first in above number and which is known by the name of प्रवह drives, along the first course, masses of clouds born of smoke and heat. Thus, during this time, the constituents of cloud were also predicted. This wind passes through the sky and comes into contact with water in the clouds (MB.XII,328.36) as:

पृथिव्यायन्तरिक्षे च यत्र संवान्त वायवः।
सप्तैते वायुमार्गा वै तान् निवोधानुपूर्वशः।। MB.XII,328.31 ।।

प्रेरयत्यभ्रसंधातान धूमजांश्चोष्मजांष्व यः।
प्रथमः प्रथमे मार्गे प्रवहो नाम योनिलः।। MB.328.36 ।।

The second wind called आवह, blows with a loud noise (MB. XII329.37). The wind which drinks up water from the four oceans and having sucked it up, gives it to the clouds, presents them to the Gods of rain, is the third in number and is known as उत्दह (MB. XII328.38-39-40).

अम्बरे स्नेहमम्येत्य विधुदभयश्च महाघुतिः।
आवहो नाम संमवाति द्वितीयः श्वसनो नदन्।। MB.XII,328.37 ।।

उदयं ज्योतिषां शश्वत सोमादीनां करोति यंः।
अन्तर्देहेषु चोदानं यं वदान्त मनीषिणः।। MB.XII,328.38 ।।

यश्चतुभर्यः समुद्रेभयो वायुर्धारियते जलम्।
उद्वत्याददते चापो जीमूतेम्योम्बरे बिल।। MB,XII,328.39 ।।

योदिभः संयोज्य जीमूतान पर्जन्याय प्रथच्छति।
उत्दतो नाम बंहिष्ठस्तृतीयः स सदागतिः।। MB,XII,328.40 ।।

The winds which support the clouds and divides them into various parts, which melts them for pouring rain and once more solidifies them, which in perceived as the sound of roaring clouds, is known by the name संवह. Fifth layer is called विवह and the sixth is referred to as परिवह. The seventh called परावह (MB.XII.328.41-42-43-47-48) refers perhaps to some cosmic region.

समूहयमाना बहुधा येन नीताः पृथक घनाः।
वर्षमोक्षकृतारम्भास्ते भवन्ति घनाघनाः।। M.B.XII,328.41 ।।

संहता येन चाविद्वा भवन्ति नदतं नदाः।
रक्षणार्थाय सम्भूता मेघत्वमुपयान्ति च।। M.B.XII,328.42 ।।

यो सौ वहति भूतानां विमानानि विहायसा।
चतुर्थः संवहो नाम वायुः स गिरिमदिनः।। M.B.XII,328.43 ।।

दारुणोत्यातसंचारो नभसः स्तनयित्नुमान।
पञ्चमः स महावेगो विवहो नाम मारुतः।। M.B.XII,328.48 ।।

षष्ठः परिवहो नाम स वायुर्जयतां दरः।। M.B.XII,328.45 ।।

येन स्पृष्टःपराभूतो यात्येव न निवर्तते।
परावहो नाम परो वायुः स दुरतिक्रमः।। M.B.XII,328.52 ।।

Here, at five places, the term wind used, actually implies a sphere or layer. These five names also occur in Puranas and other later literature. The epic gives another classification of clouds also giving four classes of clouds. The four types of clouds are संवर्तक, वलाहक (MB,VIII,34.28), कुण्डधार (XII 271.6) and उतंक (MB XIV 55.35-36-37). The वलाहक clouds are formed in the विवह layer of atmosphere (described before). The clouds brining rainfall in desert area are called उतंक. These classification of clouds are different from those enumerated in Ramayana and Puranas.

सोथ सौम्येन मनसा देवानुचरयन्तिके।
प्रत्यप्श्यज्जलधरं कुण्डधारमवस्थितंम्।। MB,XII,271.6 ।।

तदा मरौ भविष्यन्ति जलपूर्णाः प्योधराः।
रसवच्च प्रदास्यन्ति तोयं ते भगुनन्दन,
उत्तक्ड़मेघा इत्युक्ताः ख्याति यास्यन्ति चापि ते।। MB,XIV,55.36 ।।

Around 600-700 BC, Kanada in his Vaisesika Sutra referred to the process of condensation and dissolution of water (Vais. Sutr.V,2.8). He remarks “condensation and dissolution of water is due to the conjunction with fire or heat”. About the phenomena of thunder, he observes that the “rolling of thunder is a mark of the ingress of the light of the sky (Vais. Sutr.V,2.9)”, i.e. it is the pealing of thunder which warrants the inference. He again says (Vais. Sutr. V, 2.11) that the rolling of thunder results from conjunction with water and disjunction from a cloud. Here, it is fully evident that the great sage knew that thunder is caused due to impact of positively and negatively charged clouds.

अपां सङ्घातो विलयनञ्च तेजः संयोगात्।। Vais. Sutr.V,2.8 ।।
तत्र विस्फूर्ज थुर्लिङ्गम्।। Vais. Sutr.V,2.9 ।।
अपां संयोगाद्विभागाच्च स्तनयित्नोः।। Vais. Sutr.V,2.11 ।।

Discussing the falling of raindrops and flowing of streams, he further presents causes of falling of water resulting from gravity in the absence of conjunction (Vais. Sutr.V,2.3) i.e. falling of water in the form of rain, has gravity as its non-coinherent cause.

अपां संयोगाभावे गुरुत्वात् पवनम्।। Vais. Sutr.V,2.3 ।।

In the verse V, 2.4, it has been said that the distant progression of the stream or great aqueous whole composed by mutual conjunction of the fallen waters or raindrops, is produced by fluidity as its non-coinherent cause and by gravity as its efficient cause.

द्रवत्वात स्यन्दनम्।। Vais. Sutr.V,2.4 ।।

The phenomena of evaporation, cloud formation, classification of clouds and their relationship with winds or regions of atmosphere (वातस्कन्ध) are also quite satisfactorily discussed in several Puranas (Vayu Chapter 51, Linga Vol.I, Chapt. 36, Matsya Vol.I, Chapt. 54). Describing the general genesis of clouds, the Vayu Purana (51.22-25) says that there is moisture content in all the movable or immovable objects of the world and due to insolation or Sun's rays, evaporation of that humidity takes place, and this process produces clouds. viz.

आर्क तेजोहिभूतेभयोहयादत्ते रश्मिमर्जलम्।। Vayu,51.23 ।।

मेघानां पुनरुत्पत्तिस्त्रिविधा योनिरुच्यते।
अग्नेया ब्रह्मजाश्चैव वक्ष्यामि पृथाविधाः।
त्रिधा घनाः समाख्यातास्तेषां वक्ष्यामि संभवम्।। Vayu 51.28 ।।

अग्नेयास्त्वर्णजाः प्रोक्तास्तेषां तस्मात्प्रवर्तनम।
शीत दुर्दिनवाता ये स्वगुणास्ते व्यवस्थिताः।। Vayu 51.29 ।।

जीमूता नाम ते मेघा येभयो जीवस्य संभवाः।
द्वितीयं प्रवहं वायु मेघास्ते तु समाश्रिताः।। Vayu 51.36 ।।

The above verses say that those clouds which give or sprinkle water are called मेघ and which do not bring any rainfall are known as अभ. There are three types of clouds (1) आग्नेय (2) ब्रह्मज (3) पक्षज. These are connected with cyclonic (thermal and insolational), convectional (occurring in northern continents, Siberia and equatorial regions) and orographic (occurring and proceeding

from mountain flanks) types of rainfall respectively. According to above mentioned Puranas, आग्नेय occurs in the winter season and it is devoid of lightening and thunder and is of immense expanse and found in the mountain foots also. It brings rainfall within a radius of a mile or two. This description approximates most to the Nimbus of modern days. The Brahmaja (ब्रह्मज) clouds are produced due to convection currents. In precipitation they cover an area of radius of nearly a yojana (five or eight miles). Most probably these are cumulonimbus. The Puskara-Vartaka (पुष्करावर्त) clouds originate from or in the wings of mountains (पक्षसंभवा). They assume various forms and produce deep rumbling sound. They are full of profuse water and bring excessive rainfall which is extremely destructive. This description conforms to a large extent to the modern class of altostratus.

The Matsya Purana (Vol.I, Chap.54) furnishes still more elaborate and scientific information regarding clouds. It says that the clouds जीमूत is the cause of life. These clouds remain suspended on the air called Avaha. They change shape and goes up a yojana, from there form into rain hence they are called the source of rain (Verse 10). If the shlokas 17,18 and 19 are interpreted symbolically, they give other four classes of clouds expressed by the nomenclature गज, पर्वत, मेघ and भोगी. Then in the Verse 17 can be recognized further four classes of गज clouds.

विषुवद्गहवर्णश्च सर्वमेतद ध्रुवेरितम्।
जीमूता नाम ते मेघा यदेभयो जीव सम्भवः।। Matsya,I,54.9 ।।

द्वितीय आवहन वायुर्मेघास्ते त्वभिसंश्रिताः।
इतोयोजनमात्राच्च अध्यर्द्धविकृताअपि।। Matsay,I,54.10 ।।

तेषामप्यायनं धूमः सर्वेषामविशेषतः।
तेषां श्रेष्ठश्च पर्जन्यश्चत्वारश्चैव दिग्गजाः।। Matsya,I,54.17 ।।

गजानां पर्वतानाज्च मेघानां भोगिभिः सह।
कुलमेकं द्विधाभूतं योनिरेका जलं स्मृतम्।। Matsay,I,54.18 ।।

Parjanys (पर्जन्य) and दिग्गज rain in the season of हेमन्त and they are very useful for agricultural growth is spoken in the verse below:

पर्जन्यो दिग्गजाश्चैव हेमन्ते शीतसम्भवम्।
तुषारवर्ष वर्षान्ति वृद्वां ह्यन्नविवृद्वये।। Matsya,I,54.19 ।।

Process of condensation and precipitation on hygroscopic nuclei are very carefully described in a nutshell in the Matsya Purana (I,54.33) as:

नियच्छत्यापो मेधेभवः शुक्लाः शुक्लैस्तुरश्मिभिः।
अभ्रस्थाः प्रयतन्त्यापोवायुनासमुदीरिताः। Matsya,I,54.33 ।।

Meaning: "the waters from the (vapours) of the clouds when brought into contact with the wind (namely hygroscopic content of the air) fall in the shape of rain".

The Vishnu Purana (II,9.11-12) very scientifically enumerates the four sources of atmospheric moisture, "the glorious Sun, O Maitreya, exhales moisture from four sources, namely – seas, rivers, the earth and living creatures,". viz.

अभ्रस्था प्रपतन्त्यापो वायुना समुदीरिताः।
संस्कारं कालजनितं मैत्रैयासाघ निर्मलाः।। Vishnu,II,9.11 ।।

सरत्ससमुद्रभौमास्तु तथापः प्राणिसम्भवाः।।
चतुष्प्रकाश भगवानादन्ते सविता मुने।। Vishnu,II,9.12 ।।

The celebrated poet Kalidasa (100 B.C.) also knew a lot about clouds and the allied phenomena. He defines cloud thus "it is an assemblage of smoke, electricity, water and air" (Purvamegha Verse 5). At other places (Purvamegh, Verse 6) the poet names two types of clouds namely पुष्कर and आवर्तक

धूमज्योतिः सलिलमरुतां सन्नपातः व्क मेघः।
सन्देशार्था व्क पटुकरणैः प्राणिभिः प्रापणीयाः।। Meghadutam,Purvamegha.5 ।।

जातं वंशे भुवनविदिते पुष्करावर्तकानां जानामि त्वां प्रकृतिपुरुषं कामरुपं मघोनः।। Purvamegha Verse 6 ।।

The Mricchakatika (600 AD) refers to a kind of cloud द्रोण (X.26) from which the rain streams forth as from a bucket. In another context, the famous drama refers to a special type of rain द्रोणवृष्टि streaming forth as from a trough (X.39) viz.

कोयमेवंविधे काले कालपाशास्थिते मयि।
अनावृष्टिहते सस्ये द्रोणमेघं इवोदितः।। Mricchakatika, X.26 ।।

केयमभयुघते शस्त्रे मत्युवक्त्रगते मयि।
अनावृष्टिहते सस्ये द्रोणवृष्टिरिवागता।। Mricchakatika,X.39 ।।

Four types of clouds in all have been spoken of by Kalidas. They are आवर्त, संवर्त, पुष्कर and द्रोण. The Avarta brings no rainfall; the Samvarta gives an abundance of rain, the Puskara causes flood of rain and the Drona is most congenial to agriculture and mankind. This is stated in nutshell in the following lines –

आवर्तो निर्जलो मेघः संवर्ततश्च वहूदकः।
पुष्करो दुष्करजलो द्रोणः शस्यप्रपूरकः।।
Kalidas Granthavali, Abhidhan Kosh, P.154 ।।

In the library (Saraswati Bhavan Pustakalaya) of Sampurnand Sanskrit University, Varanasi a manuscript treatise entitled as मेघमाला is available. As the very name suggests, it is a work on climatology and more specifically science of clouds. On the basis of content and style of dialogue Tripathi (1969) tried to establish that Meghamala is a part of रुद्रायमालतंत्रम् (around 900 AD around). मेघमाला has 11 chapters. The first chapter of मेघमाला opens with the enquiry

मेघस्तु कीदृशादेव कथं विद्युत्प्रजायते।
कीदृशं वर्णरूपं तु शरीर तस्य कीदृशम्।।
(Meghamala, Manucript No. 37202, Sampurnand Sanskrit University, Varanasi)

The first chapter deals with what are clouds, how lightning is produced, what are nature, texture, ingredients and colours of clouds. Later in the Verse 20,21,22 is expressed, in their conventional Indian style, that the mountains control clouds. From Verses 32 to 68 we gather that there is a larger division of clouds comprising twelve species and designated as 1. सुबुध 2. नन्दशाला 3. कन्यद 4. पथुश्रवा 5. वासुदी 6. तक्षक 7. वकर्त 8. सारवत 9. हेमकाली 10. जलेन्द्र 11. वज्रदंष्ट and 12. विष्णुप्रभ. But no scientific detail of these is furnished. The Chapter II enumerates various types of years, refers to their rainfall and discusses the economic characteristics or conditions of each of them. The IIIrd chapter dwells on astrological influence on rainfall, climatology and economic condition of people, state of plenty and scarcity and production of various crops. VIIIth chapter aspires to

discuss the nature of rainfall and other meteorological conditions in the twelve months of the year. About the Kartika (October – November) the author says that during this month scattered clouds of varied colours occur. In Pausa (December – January) if sky is over cast with clouds, it is a very good symptom. If the month of Magha (January – February) is not normally cold (or has no frost) there occurs scanty rainfall in Phalaguna (February – March) northeast wind brings good downpour.

मासि मासि कथं देवि कीदृशं गर्भलक्षणम्।
किं वातं किं घनं युक्तं कस्य कालेन वर्षति।।

कार्तिके शुक्ल नन्दायां पज्चरुपाणि यो भवेत्।
अभ्राणि श्वेतवर्णानि रक्तर्णानि यो भवेत।।

पतिवर्णानि यो मेधा हि कृष्णवर्णश्च भवेत्।
कांस्यवर्णो भवेघस्तु ताम्रवर्णस्तथा भवेत्।।

न माघोपतितं शीतं ज्येष्ठे मूलं न वृष्टिकृत्।
नार्दायां पतितं तोयं दुष्टकालस्तदा भवेत्।।

तदा देवि भविष्यन्ति सुभिक्षं क्षेमवेव च।
पूर्वोत्त्रजवातेन रात्र्यन्ते जलमुत्तम्।। Meghmala, Page 14-38 ।।

In the chapter IX of Meghmala there is discussion on clouds, winds and lightning. Firstly, it discusses the correlation of rainfall with different shapes and directions of lightning. Then we are told that north-east wind is conductive to prosperity, southerly does good to people, south-west wind causes misery, westerly is much beneficial for the higher production of rice, northerly is also favourable to the good of people, and it produces a condition of plenty.

पूर्वे विधुत्करामेघा अग्नियां जलशोषिणी।
दक्षिणे रौरवं घोरं नैऋत्यां तापमादिशेत्।।

शुभिक्षं पूर्ववातेन जायते पात्र संशयः।
दक्षिणे तु क्षेमकरो नैऋत्यां दुः खदो भवेत।।

वारुण्यां दित्यंधान्यानि वायत्यांवायुखे भवेत्।
उत्तरे शुभदो देवि ऐशान्यां सर्वसम्पदः।। Meghmala, Page 47-48 ।।

The chapter X of Meghmala deals with the propitiation of clouds and apart from repeating the twelve species of clouds, already mentioned, adds another classification of the same comprising seven species designated as अम्बुद, गोलक, गिरि, आरोपक, सपर्वत, खिखिन्द and कोटिवार.

The encyclopedic Tantrik literature also does not lag behind in supplying information on hydrology. From the Tantraloka of Abhinavagupta, we can find out some important climatological and meteorological facts. In its Ahnika designated as देशाध्वप्रकाशन are described winds, clouds, track of winds and the allied phenomena (Vol. V of the Tantraloka) (Tripathi, 1969). It refers to ten air channels (वायुपथ) which are perhaps peculiar to only this text. Those ten air channels are 1. वितव 2. ऋतार्द्धि 3. वज्राइक, 4. वैद्युतं 5. रैवत 6. विषावर्त (दुर्जय) 7. परावह 8. आवह 9. महावह and 10. महापरिवह (Vol. V,121.138). These are arranged in space according to increasing height. The outstanding Tantrik work recognized ten types of clouds 1. मूकमेघ 2. प्राणिवर्षो 3. विषवारिवर्षी 4. स्कान्द 5. संवर्त 6. ब्राहम 7. पुष्कर 8. जीमूत 9. ईशकृत, and 10. महेशिकृत (कपालोत्थ). These types also occur according to the increasing height. It is perhaps for the first time in Indian literature that establishes the height of clouds. It reveals that different clouds occur at different level in the atmosphere.

The Jain literature also made a considerable contribution in the field of meteorology. The 'Prajnapana' and 'Avasyaka Curnis' provide outstanding references to the various types of winds (Tripathi, 1969). The Avasyaka Curnis furnish a list of fifteen winds (9-7/913) as: 1. प्राचीनवात (easterly) 2. उदीचीन (northerly) 3. दक्षिणवात (southerly) 4. उत्तर पौरस्त्य (northerly blowing from the front) 5. सवात्सुक (undefined) 6. दक्षिण पूर्वतुंगर (southerly strong wind) 7. अपरदक्षिणबीजाय (blowing from the south-west) 8. अपरबीजाय (westerlies) 9. अपरोत्तगर्जन (north-westerly hurricane) 10. उत्तरसवात्सुक (unknown) 11. दक्षिण सवात्सुक 12. पूर्वतुंगर 13. दक्षिण and पश्चिम बीजाय 14. पश्चिमगर्जभ (western storm) 15. उत्तरीगर्जभ (northern strom). Later in the same continuation tornadoes are referred to as कालिकावात. This vocabulary had influenced the Arabian geographers and navigators and they readily absorbed several of these Indian technical terms in their own language (Motichandra, 'Sarthavaha' (Hindi), P.202).

The 'Prajanapana' also refers to snowfall (हिम) and hailstorm (करक) (I.16). The 'Trilokasara' (Passage 679, P.280) of Nemichandra says that there are seven types of कालमेघ (periodic clouds). They rain for seven days each in the rainy season. Then there are twelve species of white clouds

designated as द्रोण. They also bring rain for seven days each. Thus, the season of rainfall extends over 133 days in all.

The Buddhist literature also throws significant light on meteorology. In the narrative of the first Jataka, named 'Apannaka', several climatological facts are described. In 'Migalopajataka (Cowel, Eng. Trans. Vol.III, P.164.), two violent storms are mentioned as कालवात (black wind) and बेरम्बरात (Tripathi, 1969). The latter is said to belong to the upper air (Samyutta Nikaya, Eng. Trans. XVII. 1-9, P.157). The Sumeru mountain was frequently visited by a violent hurricane (उत्पाटनवात or हरणवात) (Mahamorajataka No. 491, P.333; Harit Jataka No. 431, P.497). It resembled whirlwind in movement. In 'Milinda Panho' hot wind or Loo is spoken of as वातातप (Eng. Trans. Vol.II,IV,6.35, P.86). 'Aryasura' names four types of winds नियतानिल (Monsoon), चण्डानिल (tempest), उत्पातवात (hurricane) and पश्चात्यवायु (westorlies) (Jatakamala, ed. by H. Kern, 10.29, P. 90, 127, 133). In the 'Vinaya Pitaka' (III, V.9.4,P.85), whirlwind is called वातमण्डलीका. The Divyavadana' speaks of some kinds of hurricane as कालिकावात (Vol.II,P.41), and of storm accompanied by rain as वातवर्षम (Vol.II,P.163).The 'Milindapanho' (IV.1.36) says that there are four types of rainfall: 1. of rainy season 2. of winter season, 3. of the two months आषाढ़ and श्रावन (July and August), and 4. rain out of season. At a glance, it can be seen that the classification is fully scientific.

The Buddhist literature refers to two general classes of clouds as: कालमेघ (monsoon cloud) and अकालमेघ (storm clouds or accidental ones) (Mahavastu Vol.II, P.34, Tripathi, 1969). The Samyutta Nikaya classifies clouds into five categories (Vol.III, Book XI, 32.1.1, P.200), 1. शीतवलाहक (cool clouds),2. ऊष्णवलाहक (hot clouds) 3. अभ्रवलाहक (thunder clouds, it can be identified with cumulus), 4. वातवलाहक (wind clouds – perhaps clouds formed due to the activity of convection current in the atmosphere) and 5. वर्षवलाहक (rain clouds – most probably cumulonimbus which brings copious downpour of rain).

Thus, we see that the Jain and Buddhist texts (before 400 B.C.) have a very scientific classification of clouds and winds that can be compared with the modern meteorology. So much of subtle observation at such an early date is a golden achievement of ancient times.

Variation of Rainfall

According to the Matsya Purana, to the north and south of the snow-clad mountains (हिमवत) occurs the पुण्ड्र cloud which greatly increases the stock of rain. All the rain formed there converts itself into the snow. The wind on the हिमवत draws by its own force those snow flakes and pours them on the great mountains. Beyond the हिमवत there occurs little rain (Matsya, I,54.22-25).

शकीरान सम्प्रभुज्वन्ति नीहार इति स मृतः।
दक्षिणेन गिरिर्योसौ हेमकूट इति स्मृतः।। Matsya,I,54.22 ।।

उदगहिमवतः शैलस्योत्तरे चैव दक्षिणे।
पुण्डं नाम समाख्यात सम्वगवृष्टि विवृद्वये।। Matsya,I,54.23 ।।

तस्मिन प्रवर्तते वर्ष तन्तु षारसमुद्रभवम्।
ततो हिमवतो वायुर्हिमं तत्र समुद्रभवम्।। Matsya,I,54.24 ।।

आनयत्यात्मवेगेन सिज्वियानो महागिरिम्।
हिमवन्तमतिक्रम्य वृष्टिशेषं ततः परम्।। Matsya,I,54.25 ।।

Thus, there is a reference to a very important geographic fact of scanty rainfall or arid condition of the Tibetan plateau. The study and knowledge of this fact is really creditable on the part of those ancient Indians. The Linga Purana (Vol. I,36.38.39 and 49) says "it is the प्रवह wind or air current which makes the clouds produced by smoke and thermal activity full of water, so that the clouds Puskara (पुष्कर) and पक्षज give copious rainfall".

दन्दह्ययमानेषु चराचरेषु गोधूमभूतास्त्वथ निष्क्रमान्ति।
या या ऊर्ध्व मारुतेनेरिता वै तास्तास्त्वभ्रांयाग्निनावायुना च।। Lings,I,36.38 ।।

अतो धूमाग्निवातांनां संयोगस्त्वमुच्यते।
वारीणि वर्षतीत्यभ्रमभ्रस्येशः सहस्त्रदृक्।। Linga,I,36.39 ।।

विरिचोच्छ वासताः सर्वे प्रवहस्कंधजास्तः।
पक्षजाः पुष्कराघश्च वर्षाति च यदा जलम्।। Lings,I,36.49 ।।

Modern meteorology tells us that polar winds actually never bring any rainfall in the year in the region under their influence – flanking poles or Tundra, and only scanty summer rain occurs in those areas due to the sweeping of strong westerlies. The same fact is stated in the Puranic line,

ध्रुवेणाधिष्ठितो वायुर्विष्टिं संहरते पुनः।। Matsya,Vol.I,54.36 ।।

Meaning: the air from the Pole drives away the rain,

The Vrhat Samhita and Mayuracitraka by Varahamihira are two very important treatises which are replete with climatological and meteorological information. Although they abound in astrological guesses, they contain sufficient scientific facts also. In the Vrhat Samhita, there are three chapters (21st, 22nd, and 23rd) on climatology and meteorology and they treat the subject in their own ancient conventional style. Here only the salient features of the chapters are being presented.

The verses 23 and 24 of the chapter 21 of Vrhat Samhita state that extremely white or dark clouds resembling aquatic animals like huge fish, shark or tortoise and seen before the rainy season are a source of abundant rainfall viz.

मुक्तारजतनिकाशास्तमालनीलोत्पलज्जनाभासः।
जलचरसत्वाकारा गर्भेषु घनाः प्रभूतजलाः।। Vr.S.21.23 ।।

तीव्रदिवाकरकिरणाभितापिता मन्दमारुता जलदाः।
रुषिता इव धाराभिर्विसृजन्त्यम्भः प्रसवकाले।। Vr.S.21.24 ।।

The verse 31 discusses the conditions or meteorological ingredients which determine the spatial expanses of rainfall, though it appears to be of little value from modern meteorological point of view.

पञ्चनिमिन्तैः शतयोजनं तदर्द्धार्द्धमेकहान्यातः।
वर्षति पञ्जनिमित्ताद्रूपेणैकेन यो गर्भः।। Vr.S.21.31 ।।

From chapter 22, it is gathered that fleecy and thick clouds give abundant rainfall which is very congenial to agriculture. Again, if clouds situated in the east, south and north sail towards south, west and north respectively, they cause fine and copious rainfall.

रविचन्द्रपरीवेषाः स्निग्धा नात्यन्तदूषिताः।
वृष्टिष्तदापि विज्ञेया सर्वसस्यार्थसाधिका।। Vr.S.22.7 ।।

मेघाः स्निग्धाः संहताश्च प्रदाक्षिणगतिक्रियाः।
तदा स्यान्महती वृष्टिः सर्वसस्याभिवृद्वये।। Vr.S.22.8 ।।

In the Mayuracitraka, it is stated that scattered clouds devoid of lightning are harmful to people and those of red and white silken or golden or Kraunca bird's hue, embedded in the atmosphere and fleecy in texture are always beneficial to the people. Causation of fog or mist in Pausa (December–January) is conductive to good rainfall. (Sampurnanand Sanskrit University, Library, Manuscript No. 34332, Page 36-37).

पौषस्य कृष्णसप्तम्यां नभो विमलतारकम्।
स्वात्यां तुषारपातःस्यात श्रावणे तत्र वर्षणम्।।

Discussing the conditions determining rainfall, it says that if there is no frost in Magha (January–February), no vigorous wind in Phalguna (February – March), no clouds in Chaitra (March–April), no hailstorm in Vaisakha (April–May) and no scorching heat in Jyestha (May–June), there is insufficient rain in the rainy season (Above manuscript, Page 17 -18), viz.

माघे हिमं न पतति वाता वान्ति न च फाल्गुने।
न च धूमायितं चैत्रे घनैर्नभस्ततं न तु।।

कारका मोच न वैशाखे शुक्रे चण्डातपो न हि।
तदातितुच्छा वृष्टिः स्यात् प्रावृष्टकाले न संशयः।।

If Sun is hot in the morning, its light during the day is of yellowish hue and clouds are fleecy and dark-coloured, the conditions result in good rain. Similarly, if the Sun is hot in the morning or at the time of rising and scorching at noon and clouds have a pigment of molten gold, rain occurs during the very day (above manuscript, Page 18).

प्रावृटकाले यदा सूर्यो मध्यान्हे दुः सहो भवेत्।
तद्दिने वृष्टिदः प्रोक्तो भृशं स्वर्णसमप्रभः।।

If water appears to be dull, clouds are of the shape of mountain, quarters are clear, the sky is of the hue of crow's egg, there calm in the atmosphere and aquatic animals like high and others disappear in the bottom and grogs make loud noise, very fine and copious rainfall comes soon (Manuscript No. 34332, Page 18). Further, if the texture of the clouds resembles the wings of a Partridge, rainfall occurs.

यदा जलं च विरस गोनेत्र सन्निभिः।
दिशश्च विमलाः सर्वाः काकाण्डाभं यदा नभः।।

न यदा वाति तपनः पवनः स्थलं यदा।
शब्दं कुर्वन्ति मण्डूकास्तदा स्याद् वृष्टिकत्तमा।।

Thus, it is evident that Mayuracitraka has attempted to formulate principles for forecasting rainfall variation through the observation of natural phenomena and the synchronization and co-relationship of the two. The symptomatic synchronization in the realm of nature is often governed by laws having mathematical accuracy in which intuition of the animate (birds and the animals) and scientific cause and effect relationship of events form the accurate base, provided the observation has been made very carefully. In those ancient days, when advanced meteorology and its complicated computations, computers and other cybernetics and servo-mechanic contrivances were unknown, this was of special significance and most probably the only method.

Measurement of Precipitation

The amount of precipitation in the form of rain is usually determined from the accumulation of water collected in a rain gauge; and several types of recording instruments are routinely employed for the purpose. There are strong proofs to establish that the system of measuring rainfall was introduced by the Mauryan rulers in the Magadha country (south Bihar) in the fourth or third century B.C. and they are credited with the establishment of first observatory. The system was continued to be practised effectively by the succeeding rulers until the end of the sixth century A.D. (Srinivasan et al., 1975).

During the Mauryan period, the raingauge was known as वर्षामान. Kautilya describes its construction in these words "In front of the store house, a bowel (Kunda) with its mouth as wide

as an aratni (24 angulas = 18" nearly) shall be set up as raingague (वर्षामान) (Arthasastra, Book II, Chapt. V, P.56 Shamasastry). A schematic of the modern raingauge is shown in Figure 3.2. By comparing the dimensions of the ancient Indian and Symon's raingauge, one can easily infer about the level of knowledge possessed during that period.

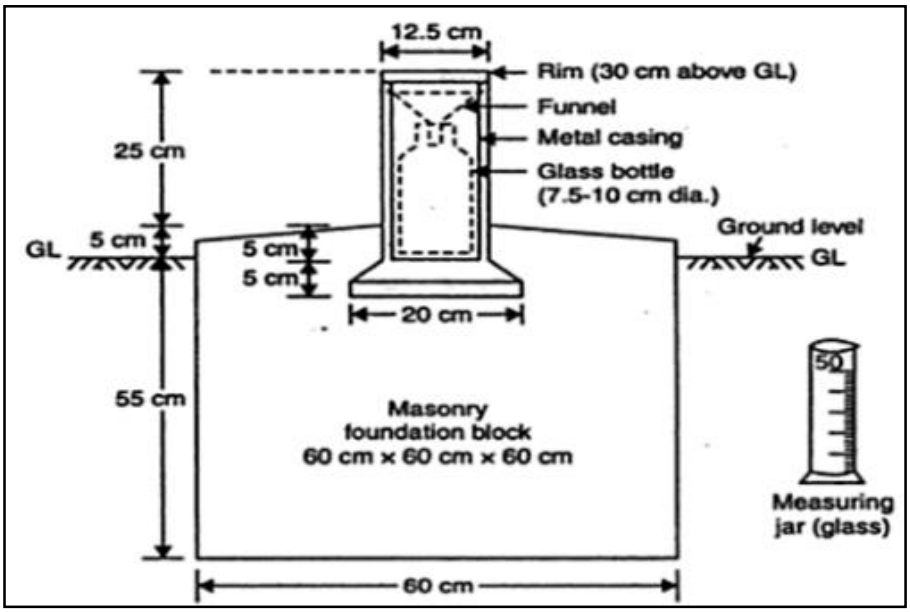

Figure 3.2: The Symon's raingauge (Modern raingauge) (Source: Raghunath, 2006)

The distribution of rainfall in various areas was well known at that time. A reference from Kautilya's Arthshatra can be cited here as: "'The quantity of rain that falls in the country of *jangiila* (desert countries or countries full of jungles)is 16 *dronas;* half as much more in *anupanam* (moist countries); as the countries which are fit for agriculture *(desavapanam)*; 13.5 dronas in the countries of *asmakas* (Maharashtra); 23 *dronas* in Avanti (probably Malwa); and an immense quantityin *aparantanam* (western countries, the countries of Konkan); the borders of Himalayas and the countries where water-channels are made use of in agriculture". Kautilya's method of classification of rainfall areas in relation to the annual average quantity is indeed remarkable and he is the only classical author who treats this aspect in a nutshell covering almost the whole of the Indian subcontinent (Srinivasan, 1975). From this, it is evident that the spirit of the methodology of the measurement of rainfall given by Kautilya is the same as we have today, the only difference is that he expresses it in weight measures (Arth. Chapt.XXIV, Book II, P.130) while we use linear measure nowadays. Discussing the further geographical details of rainfall, he observes "when one-third of the requisite quantity of the rainfalls, both during the

commencement and closing months of the rainy season, and two third in the middle, then the rainfall is considered very even (सुषुमारुपम्).

As can be easily expected out of the agricultural necessity, the science of forecasting the rains had also come into existence and must have been developing empirically. It is further mentioned in the book Arthshastra that "*A forecast of such rainfall can be made by observing the position, motion and pregnancy (garbhadhan) of Jupitar, the rising, setting and motion of Venus, and the natural or unnatural aspects of the Sun. From the movement of Venus, rainfall can be inferred".*

Discussing the classification of clouds and interrelationship of rainfall and agriculture, it is further added that "there are clouds which continuously rain for seven days; eighty are they that pour minute drops; and sixty are they that appear with the Sun shine". When rain, free from wind and unmingled with sunshine falls, so as to render three turns of ploughing possible, then reaping of good harvest is certain.

The author of Astadhyayi, Panini (700 B.C.) refers to the rainy season as प्रावृष (IV, 3.26; VI, 3.14) and वर्षा (IV 3.18). The former was the first part of the season. These two parts were known as पूर्व वर्षा and अपरवर्षा (अवयवादऋतोः VII 3.11). He also refers to वर्षप्रमाण (III, 4.32) as:

वर्ष प्रमाण अलोपश्चास्यान्यतरस्याम्।। Astadhayai,III,4.32 ।।

Citing examples for measurement of rainfall Panini further writes गोष्पदप्रं वृष्टो देवः (rain equivalent to depression created by hoof of cow), सीताप्रं वृष्टो देवः (rain equivalent to fill the furrow created by indigenous plough). It is evident that the गोष्पद was the measure of the lowest rainfall.

Like Kautilya, Kanad and other precursor authorities such as Varahamihira also describe the device of the father of the raingauge and tell us how to measure rainfall from it. In Verse 2 of chapter 23, he states that constructing a circular bowl (कुण्डकम्) measuring one cubit, one should tell the amount of rainfall, viz.

हस्तविशालं कुण्डकमाधिकत्याम्बुप्रमाणनिर्देशः।
पज्चाशत्पलमाढ़कमनेन मिनुयाज्जलं पतितम्। Vr.S.23.2 ।।

For calculating rainfall he adopts weight measures of pala, drona and adhaka (4 आढ़क = 1 द्रोण = 200 पल, and 1 आढ़क = 7 lbs. nearly). For measurement, rain water received in the bowl during the actual falling should be measured. The distribution of the rainfall according to time is discussed in the verses 6,7,8 and 9. These verses of Vrhat Samhita specify the amount of rainfall in various lunar mansions as:

हस्ताप्यसौम्यचित्रापोष्णधनिष्ठासु षोडश द्रोणाः।
शतभिषगैन्द्रस्वातिषु चत्वारः कत्तकासु दशः।। Vr.S.23.6 ।।

श्रवणे मघानुराधाभरणीभूलेषु दश चतुर्युक्ताः।
फज्गुन्या पज्चकृतिः पुनर्वसो विशंतिद्रोणाः।। Vr.S.23.7 ।।

ऐन्द्राग्न्याख्ये वैश्वे च विशंति सार्पभे दश त्र्यधिका।
आहिर्बुध्न्यार्यम्णप्राजापत्येषु पज्चकृतिः। Vr.S.23.8 ।।

पज्चदशाजे पुष्ये च कीर्तिता वाजिभे दश द्वौ च।
रौद्रेष्टादश कथिता द्रोणा निरूपद्रावेष्वेते।। Vr.S.23.9 ।।

In chapter XXXV, he says that phenomenon of rainbow is the result of spectro analysis of Sun's rays through clouds in the atmosphere. (XXXV.1)

सूर्यस्य विविधवर्णाः पवनेन विघाट्टिताः कराः साभ्रे।
वियति धनुः संस्थाना ये दश्यन्ते तदिन्द्रधनुः।। Vr.S.35.2 ।।

Parasara knew the contrivance of primitive raingauge and method of measuring the quantity of rain received (Vrhat Samhita, Chapt. 21, Garbhlakhsnadhyaya). viz.

आढ़काज्श्चतुरो द्रोणानयां विघात् प्रमाणतः।
धनुः प्रमाणं मेदिन्यां विघाद द्रोणाभिवर्षणम्।।

चतुर्विशाड्. गुलानाहे द्विचतुष्काड. गुलोच्हिते।
भाण्डे वर्षाम्बुसंर्पूर्णे, ज्ञेयमाढकवर्षणम्।। Vr.S.between 21.32 and 21.33 ।।

Epilogue:

From the various discussions presented in this chapter, we note that the knowledge related to cloud formation, precipitation and its measurement was of outstanding order in ancient India.

Condensation of evaporated water which is facilitated by the presence of dust particles etc. (which acts as nuclei as per modern meteorology), effect of yajna (यज्ञ), forests, reservoirs etc. on the causation of rainfall and the classification of clouds alongwith their colour, rainfall capacity etc. are thoroughly described in ancient Indian literature like Vedas, Puranas, Vaisesika Sutra, Astadhyayi, Arthasastra and Puranas. The forecasting of rainfall on the basis of natural phenomena like colour of sky, clouds, lightening, rainbow etc. was noteworthy. The instruments for measuring rainfall were developed and the principles were same as that of modern hydrology except that weight measure of Drona, Pala etc. were used instead of modern linear measurement.

The Indus civilization was able to find the seasonal variations in rainfall and methods to check the Indus floods. During the Mauryan period, it was possible to describe the distribution of rainfall in different areas of India and they are credited with the installation of first observatory worldwide. Modern meteorological facts like arid region of Tibetan rain shadow area and no rainfall due to polar winds are fully advocated in Puranas. The Jain and Buddhist works guessed the actual height of clouds. Knowledge of monsoon winds and their effects as conceived by ancient Indians is in accordance to modern hydro-science. These facts show that there was enriched knowledge of water science and associated processes, including meteorology during ancient times in India, which is at par to the modern water science.