Al-Bīrūnī's Meteorology in its Context

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1 Abstract

This paper investigates the meteorological conceptions of the esteemed scholar al-Bīrūnī, with a focus on weather forecasting, particularly the solar-based anwā system, as opposed to the lunar-based system prevalent in the meteorological and astronomical tradition of the Arabs. Additionally, the study touches on al-Bīrūnī's understanding of the water cycle, precipitation origins, and climatology. An analysis of various works by al-Bīrūnī reveals his dedication to the subject, showcasing both his originality and a coherent framework of thought that connects his views to the wider fields of cosmology and physics. Given the absence of a dedicated meteorological text (the Kitāb al-anwā is lost), the study relies on passages found in other sources such as the Kitāb al-āār al-bāqiya, Kitāb al-Tafhīm, Kitāb al-Jamāhir, and so forth. From this analysis, several interconnected key principles emerge. The importance of geography and orography in understanding the meteorology and climatology of various regions is emphasized, highlighting the central role of mountains in these processes. First, al-Bīrūnī's conception of the water cycle closely resembles the modern understanding, as he describes an exogenous cycle that contrasts with the continuous generation of water in the Aristotelian tradition. He also demonstrates an understanding of vapor as dispersed water in the air, recognizing water as a finite natural resource bound to perennial renovation. By examining al-Bīrūnī's work, this paper presents a broad understanding of his meteorological thought, situating it within the broader context of his cosmological and physical ideas. Despite the absence of a dedicated meteorological

text, the ample evidence found in his other works enables a thorough analysis of al-Bīrūnī's innovative contributions to the field. In conclusion, this study offers valuable insights into al-Bīrūnī's meteorological conceptions and their relationship to his broader intellectual framework. By doing so, it highlights the importance of geography, orography, and an exogenous water cycle, emphasizing al-Bīrūnī's originality and coherence in his approach to understanding the natural world. Further avenues of research are suggested in the conclusion.

2 Keywords: Meteorology, Climatology, Water Cycle, Physics, Weather Forecasting

2.1 Article

This paper explores al-Bīrūnī's comprehension of meteorology, a captivating subject that reveals the author's outlook on the environment and human interactions with it. The definition of meteorology in premodern science is a matter of debate, which will be discussed briefly in what follows. While this is not the first examination of al-Bīrūnī's meteorological ideas, the subject has not received significant recent attention. In 1922, Eilhard Wiedemann, a German physicist and historian of science, published a brief article [1] outlining the meteorological content of al-Bīrūnī's Kitāb al-āār al-bāqiya. This four-page work primarily serves as a reference for the existence of such material in al-Bīrūnī's works, valuable for reconstructing the history of meteorological knowledge.

Forty years later, Hamidullah Hasan Hasanov published a more extensive, preliminary article demonstrating that numerous meteorological passages can be found in al-Bīrūnī's extant works [2]. Regrettably, his Kitāb al-anwā seems to have been lost. Hasanov's preliminary collection of Birunian passages showcases the scientific ingenuity and autonomy of the Khwarazmian author and the impressive advancements that his vast knowledge and methods of inquiry permitted. One interesting passage noted by Hasanov, by way of example, pertains to al-Bīrūnī's observation that dew does not cross a certain altitude [2: 13]. Nonetheless, Hasanov's article is still a preliminary work, and he concludes his paper with following comment:

"The scientific assessment of Beruni's "Meteorology and Climatology" is not limited to what has been presented. We hope that in the near future, other works of the scholar will become available to a wider audience to gain a deeper understanding of the geographic legacy of our fellow countryman, the immortal Abu Rayhan Beruni." [2: 14]

In this paper, I aim to make a small but valuable contribution towards fulfilling his wish by examining a few meteorological passages in al-Bīrūnī's extant works

and discussing the broader picture that emerge from them.

Meteorology in the premodern period is a vast and at times vague field. Its scope may vary from author to author. For example, the Milky Way may or may not fall within the boundaries of meteorology, depending on whether a given author adheres to Aristotle's belief that the Milky Way is a sublunar phenomenon or, like astronomer al-Qūhī, considers it supralunar [3]. Furthermore, Aristotle's Meteorologica has a wide-ranging scope and has been extensively received and elaborated upon in the dār al-islām [4], resulting in several subjects that we do not currently consider meteorologically relevant being included in the field by some premodern authors, such as earthquakes or shooting stars.

Here, I will concentrate on the intersection between modern and premodern meteorological knowledge, focusing on topics that are more relevant to the wider natural world or creation, as understood by authors such as al-Bīrūnī. Hence, I will discuss passages concerning weather forecasts, general climatology and the water cycle.

Given that the what seems to have been the primary work addressing meteorological inquiries by al-Bīrūnī, the Kitāb al-anwā, appears to be lost, any investigation of this subject must commence with an examination of his principal works. Wiedemann and Hasanov have demonstrated that the Kitāb al-āār al-bāqiya encompasses numerous passages with meteorological relevance. Predominantly, these passages can be found in chapters concerning the rūmī calendar and lunar stations, or anwā, among others. Within these chapters, al-Bīrūnī delineates a distinction between weather forecast methodologies, which he elucidates in the introduction to the systematic discussion of the rūmī days. According to al-Bīrūnī, weather forecasts can be categorized into two primary groups: those based on the solar year and those reliant on the setting and rising of fixed stars.

The latter methodology has a substantial and rich history throughout the Arabo-Islamic period [5], [6]. Without delving into excessive detail, these forecasts are founded on the setting of fixed stars, accompanied by the corresponding rising of another fixed star in conjunction with lunar stations. Such astronomical events indicate the commencement of a specific naw, traditionally associated with a particular meteorological pattern. Just to give an example, as al-Bīrūnī writes in the Kitāb al-āār al-bāqiya, "when the moon stands in opposition to the Pleiades, the sun stands in the middle of Scorpio, and that time is the beginning of the cold season" [7: 337]. It is important to note, however, that al-Bīrūnī firmly rejects the idea, that seems to have been held by at least some among the Arabs, that the stars are the cause of meteorological phenomena [7: 338]. Conjunctions and oppositions, it seems, should only be understood as time-reckoning tools, useful to track meteorological patterns.

Weather forecasts derived from the solar calendar adopt an almanac-like struc-

ture, providing a general meteorological tendency for each day or a set of days. In the Kitāb al-āār al-bāqiya, al-Bīrūnī cites meteorological tendencies from several sources. Most of them are classical authors,[1] but al-Bīrūnī frequently reports the opinion of the Copts, and, in a few instances, the anwā by Sinān b. ābit b. Qurra. According to J. Samsó, these anwā mostly reproduce the Kitāb al-anwā composed by Sinān for the Abbasid caliph al-Mutaḍid and the content follows the Phaseis of Ptolemy. Only in a handful of cases Sinān diverges from Ptolemy's record [8: 38–39]. When al-Bīrūnī has to refer to his sources collectively, he refers to them as the aṣḥāb al-anwā, which proves even further that he does not see the term naw as limited to the lunar and Arab tradition.[2] However, the anwā provided for each day are not the only meteorological element in the chapter. Al-Bīrūnī completes them with several digressions and personal comments based either on his personal experience, or on the work of Arabo-Islamic authors, as we will see.

In line with the well-documented aptitude for accommodating opposing perspectives in premodern Islamic culture, al-Bīrūnī engages with both methodologies, the solar and the lunar. He concurs with Sinān's viewpoint that, whenever feasible, both methodologies should be simultaneously considered to yield a more robust forecast.[3] In contemporary terms, al-Bīrūnī ascribes a probabilistic nature to weather forecasts. This aspect connects to the broader discourse on weather forecasting developed by al-Bīrūnī in the Kitāb al-āār al-bāqiya, wherein weather forecasts are not absolute, irrespective of the methodology employed, because meteorological phenomena are influenced by more than just celestial movements and/or the impact of the Sun. In the same introduction al-Bīrūnī specifies that for both the lunar and solar methodology one should consider the geographical and climatic specificities [7: 242] and the peculiarities of a given year:

"Each of these theories, regardless of which one you believe to be accurate, is accompanied by specific conditions that determine the correctness of the anwā. These conditions enable the prediction of the year, season, and month's characteristics, such as whether it will be dry or moist, and whether it will meet the expectations of people or not. The prognostication is accomplished through various signs and evidence found abundantly in astronomical meteorology texts." [7: 243]

Geographical specificities play a crucial role in al-Bīrūnī's comprehension of

[1] The names referenced by al-Bīrūnī in the chapter under discussion are Eutecmon, Philippus, Callipus, Hipparchus, Dositheus, Metrodorus, Democritus, Caesar, Conon, Meton, Ptolemy.

[2] See for instance the entry for the first day of *Kānūn al-Awwal*: "for the first of its days the *aṣḥāb al-anwā* do not indicate anything" [7, p. 250]. Sachau translates the term as Parapegmatists [9, p. 239]

[3] "Sinān b. ābit advises that we should consider whether the Arabs and Persians concur on a Nau. If they do agree, its probability is reinforced, and the event is certain to occur; if they do not agree, the opposite is true." [8: 243].

weather systems, and he explicitly concurs with Sinān's assessment that some anwā are only valid for the region from which they originated. Nonetheless, the most overt acknowledgment of geography's role in shaping meteorological and climatic conditions can be found in the chapter on rain stones in the Kitāb al-jamāhir. Al-Bīrūnī is, at the very least, highly sceptical about the miraculous properties attributed to rain stones. This scepticism is not uncommon, as his doubts regarding what he perceives as folk superstitions also emerge in the Kitāb al-āār al-bāqiya [10: 176–7].

Rain stones are purportedly employed in invoking rain, and al-Bīrūnī recounts that a Turk presented one such stone to him. In keeping with his well-known empirical inclinations, al-Bīrūnī requests a test of the stone's capabilities, which inevitably fails to produce the anticipated rain, resulting in the humiliation of its owner and the amusement of the scientist. Al-Bīrūnī is perplexed by the widespread belief in such stones, even among scholars. He states that these scholars argue that perhaps the efficacy of rain stones is tied to specific locations, suggesting that a rain stone may only work in the lands of the Turks, no stone could evoke rain in Egypt, and the crushing of garlic might induce rain in Tabaristan.

Al-Bīrūnī appears almost wearied in highlighting that the disparate climatic conditions of these regions should not be attributed to different rituals, but rather to "the situation of the mountains, their structure, the blowing of the winds, and the passage of sea clouds" [11: 357–60]. The importance of the different orographic configurations in shaping climatic and meteorological outcomes is deeply connected and coherent with al-Bīrūnī's conception of the hydrologic cycle.

Al-Bīrūnī's perspective on the continuous renewal of freshwater on dry land is most explicitly articulated in the Kitāb al-jamāhir:

"All praise is for the Sustainer of the world, Who from the beginning to the end is Unique, Who has ordained the survival of islām which destructs ills and misfortunes, and [brings about] health and tranquility, Who has distributed food and fixed morality, Who has made struggle the source for food in the same way in which he has made the Sun and the Moon as the actors that uplift water towards the heaven. So, when the clouds are filled and laden with rain, winds drive them towards dry land and flood it with the blessing of water. Then, the earth generates plenty which for man is wealth and for animals sustenance. Moreover, this very same water returns to the slopes and [then] the oceans. He knows what comes to the earth, what comes out of it, and what comes down from the heavens and ascends towards them. Verily, he is the Knower, and He has issued commands out of his infinite wisdom." [11: 75]

The notion that precipitation, such as snow and rain, is solely attributable to atmospheric phenomena and that water ultimately exists as a fixed quantity circulating through a cycle of precipitation, return to the sea, and evaporation

may seem evident to contemporary readers. However, this was not the prevailing understanding in the eleventh century when the majority of scholars adhered, in varying degrees, to the Aristotelian doctrine of subterranean water generation. According to Aristotelian philosophers both in Europe and the dār al-islām,[4] the cycle of evaporation and precipitation was supplemented by subterranean processes in which air, trapped deep within the Earth, was continuously transformed into water under the influence of coldness and pressure. This concept resembles the manner in which vapor, perceived as an intermediate state between water and air, can be compressed and cooled back into water on land [4: 120–156].

Al-Bīrūnī drew upon the teachings of the Sabian mathematician and scientist ābit b. Qurra, to reject the idea of subterranean water generation, and instead, attributed a crucial role to mountains in the production of water precipitation. This concept is explored in passages from two of his works, namely, the Kitāb al-āār al-bāqiya and the Kitāb taḥdīd al-amākin.

Al-Bīrūnī, following the ideas of ābit b. Qurra as outlined in his Risāla fī manāfi al-ğibāl, explained that mountains are the areas with the highest precipitation. Even though ābit b. Qurra's risāla is lost, a summary preserved in al-Tawḥīdī's Kitāb al-hawāmil wa al-šāwāmil indicates that al-Bīrūnī refers to the role of mountains in obstructing winds and clouds, compressing and cooling them, leading to precipitation in the form of snow or rain [12: 354–6]. This process allows mountains to retain a significant portion of the precipitation, either as snow or as water seeping into their cavities, which is then released during the dry season, depending on the latitude and structural characteristics of the mountain ranges.

However, it is important to note that al-Bīrūnī did not subscribe to the commonly held belief that vapor represents an intermediate state between water and air. In the Kitāb tafhīm, the Khwarazmian polymath outlines his perspective on the subject in simple terms that align with his understanding of the water cycle:

"[Water] becomes mixed with air , and as a result of the intimate contact becomes suspended in the air . When the air [that was trapped] escapes to the outside, the water regains its natural state in the same way a s rainfalls from the clouds." [13: 124–5]

Hence, al-Bīrūnī maintained that vapor is not a continuous phase in the transformation of water into air and vice versa. Instead, it is a thin dispersion of water particles in the air. This understanding of vapor and evaporation processes distinguishes him from most of his contemporaries, primarily because he rejected the idea of subterranean air-to-water transformation. He expressed his scepticism about this idea in his famous correspondence with Ibn Sīnā, where he questioned the philosopher's opinion about the possibility of air transforming into water, ar-

[4]While we a few scholars in the premodern *dār al-islām* going beyon the Aristotelian doctrine on the hydrologic cycle, this will not be the case in Western Europe until the enlinghtement.

guing that it may very well be possible that "[water] particles spread out until they become invisible to the sight so that one cannot see these separate particles" [14: 146–7].[5] Evidently, al-Bīrūnī maintained the same theory throughout his life, as he relies on it in the later Kitāb tafhīm, despite Ibn Sīnā's argument against it in his own response.

Al-Bīrūnī's conceptualization of vapor as a dispersion of water in the air, rather than an intermediate state between two humid elements, aligns with the conception of the hydrologic cycle, which views water as a fixed quantity in the world continuously flowing in a cycle of regeneration. Al-Bīrūnī notes in the Kitāb al-jamāhir that regardless of the amount of pollution humans disperse in mountain sources, their waters will regain cleanliness [11: 359].

Orography plays a significant role in the divinely ordained mechanism of atmospheric water circulation. The meteorological importance of mountains and ranges influences the general climate of all earth's regions. Bīrūnī adheres to the ancient Greek practice of dividing the world into seven zones or "climes" when discussing astronomical geography [16]. These climes are defined by half-hour increments in the length of the longest day, and, although al-Bīrūnī also recognizes Indian and Iranian tradition, he considers the former less developed than the Greek one and the latter more of a political subdivision according to kingdoms and divergent customs than a geographical one [17: 102–3].

It is important to note that climes do not fully encompass the scope of climatology found in al-Bīrūnī's extant production since they are only one of the factors in defining the climatic conditions of a particular region or city.

"These things [i.e. such climatical differences] are due to the characterics of the place and its location, whether it lies in the mountains or on the sea, whether it is a place of great altitude or a low country, and also to the degree of northern or southern latitude of the place." [7: 246]

"When the latitude is the same and only the longitude differs, the time difference between them is the only factor affecting sunrise and sunset, with earlier times occurring in the eastern location proportional to the longitude difference. Unless there are other factors at play, such as proximity to the sea, mountains, sandy desert, or a difference in elevation, the climate of both locations will be similar." [13: 215–8]

As we have observed, weather forecasts are specific to particular regions within a given clime, rather than applicable to the entire clime. For example, in Iraq and Syria, a forecast for annual rainfall may be determined on November 7th based on the rising and setting of Venus, But, al-Bīrūnī points out, "This phenomenon

[5]The complete set of letters has been provisionally translated into series by Muzaffar Iqbal in the journal *Islamic Sciences* (formerly known as *Islam and Science*) from 2003 to 2007. For a broader discussion of the divergence between al-Bīrūnī and Ibn Sīna on cosmology and the fundamentals of natural philosophy see [15].

is unique to the climate of Iraq and Syria and not observed in other countries. In fact, it often rains in Khwarazm even before this time." In the same way, the abundant rains of Jurjan are due to high peaks of Tabaristan, since "the closer a region is to Tabaristan, the more humid its air and the greater the amount of rainfall it receives" [7: 245–6].

In these passages, al-Bīrūnī implicitly distinguishes between climes as zones and climate as the general meteorological conditions. The term used to refer to the latter is "air" (Ar. hawā), but this should not be interpreted as merely indicating air, as the characteristics of the air in a particular region are due to a complex interplay between clime and orography, rather than air itself.

To conclude, although there is no organized work in al-Bīrūnī's extant production devoted entirely to meteorology, meteorological statements are widespread throughout his works. The examples presented in this paper illustrate how al-Bīrūnī's meteorology forms a vast and deeply coherent system, reflecting the originality of his thought. Furthermore, al-Bīrūnī's meteorology is a critical component of his overall worldview, particularly since he did not view the sublunar and supralunar realms as subject to entirely different natural behaviours, as demonstrated by M. Mirza [15].

Moreover, the examples provided in this paper do not fully encompass the scope of meteorology in al-Bīrūnī's thought. For instance, al-Bīrūnī's understanding of winds,[6] which significantly shape climatological conditions and have consequential effects on both civilization and individual well-being, is still awaiting comprehensive treatment.

2.2 References

[1] E. Wiedemann, 'Meteorologisches aus der Chronologie von al Bîrûnî', Meteorologische Zeitschrift, vol. 39: 199–203, 1922.

[2] H. H. Hasanov, 'O "Meteorologii i klimatologii" Beruni', Nauchnye trudy Tashkentskogo gosudarstvennogo universiteta im. V.I. Lenina, vol. 193: 11–14, 1962.

[3] R. Rashed, 'Al-Qūhī: from meteorology to astronomy. (Résumé: Al-Qūhī: de la météorologie à l'astronomie.)', Arabic Sciences and Philosophy, vol. 11, no. 2: 154-155;157-204, 2001.

[4] P. Lettinck, Aristotle's Meteorology and its Reception in the Arab world, with an Edition and Translation of Ibn Suwār's Treatise on Meteorological Phenomena and of Ibn Bājja's Commentary on the Meteorology. Leiden: Brill, 1999.

[5] D. M. Varisco, 'Anwā', Encyclopaedia of Islam, THREE. Nov. 01, 2007. Accessed: Jan. 09, 2020. [Online]. Available: https://referenceworks.brillonline.com/

[6] An intersting annotation by

entries/encyclopaedia-of-islam-3/anwa-SIM_0222

[6] C. Pellat, 'Dictons rimés, anwā et mansions lunaires chez les Arabes', Arabica, vol. 2, no. 1: 17–41, 1955.

[7] A. R. M. al-Bīrūnī, Kitāb al-āār al-bāqiya an qurūn al-āliya. Leipzig: Otto Harassowitz, 1923.

[8] J. Samsó and J. Blas Rodríguez, 'Las "pháseis" de Ptolomeo y el "Kitāb al-Anwā" de Sinān b. Tābit', Al-Andalus, vol. 41: 15–48, 1976.

[9] A. R. M. Al-Bīrūnī, The Chronology of Ancient Nations: An English Version of the Arabic Text of the Athar-ul-Bâkiya of Albîrûnî. or 'Vestiges of the past'. London: W. H. Allen & Co., 1879.

[10] M. Borroni and V. Boselli, 'Hydraulics and Hydrology in a Passage of the Kitāb al-Āār al-Bāqiya by al-Bīrūnī', Arabic Sciences and Philosophy, vol. 31, no. 2: 159–182, Sep. 2021, doi: 10.1017/S0957423921000059.

[11] A. R. M. ebn-e A. al-Biruni, Al-jamāher fi al javāher. Iran: Scientific and Cultural Publications Co., 1995.

[12] Abū ayyān al-Tawḥidī, Kitāb al-hawāmil wa al-šawāmil. Cairo: Laǧnat al-Talīf wa al-Tarǧama wa al-Našr, 1951.

[13] M. ibn A. Bīrūnī, The Book of Instruction on the Elements of the Art of Astrology. London: Lund Humphries & Co., 1933.

[14] al-Bīrūnī and Ibn Sīnā, al-As'ilah wa'l-ajwibah: including the further answers of al-Bîrûnî and al-Masûmî's defense of Ibn Sînâ. Paris: Dār Bībliyūn, 1995.

[15] Mahan Mirza, 'Believing is Seeing: The Universe in the Eyes of al-Bīrūnī and Ibn Sīnā', in Light upon Light: Essays in Islamic Thought and History in Honor of Gerhard Bowering, J. J. Elias and B. Orfali, Eds. Leiden: Brill, 2019: 366–382. doi: 10.1163/9789004410121_016.

[16] D. Pingree, 'Bīrūnī, Abū Rayḥān IV. Geography', Encyclopædia Iranica. 2000. [Online]. Available: https://www.iranicaonline.org/articles/biruni-abu-rayhan-iv

[17] A. R. M. Al-Bīrūnī, The Determination of the Coordinates of Positions for the Correction of Distances Between Cities. Beirut: National Lebanese Printing, 1967.