Medieval weather prediction

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Meteorological practices that developed in the first millennium did not die in the Middle Ages but were radically improved with an international science of weather forecasting.

Observations of clouds, sunbeams, and birds—like those seen in this photo taken in Salisbury, UK—were important elements of classical weather forecasting. (Image courtesy of Peter Lawrence.)
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In August 1861 the London-based newspaper *The Times* published the world’s first “daily weather forecast.” The term itself was created by the enterprising meteorologist Robert FitzRoy, who wanted to distance his work from astrological “prognostications.” That story has led to a widespread assumption that weather forecasting is an entirely modern phenomenon and that in earlier periods only quackery or folklore-based weather signs were available.

However, more recent research has demonstrated that astronomers and astrologers in the medieval Islamic world drew widely on Greek, Indian, Persian, and Roman knowledge to create a new science termed astrometeorology. Central to the new science was the universal belief that the planets and their movements around Earth affected atmospheric conditions and weather. It was enthusiastically received in Christian Latin Europe and was further developed by Tycho Brahe, Johannes Kepler, and other astronomers. The drive to produce reliable weather forecasts led scientists to believe that astrometeorological forecasting could be more accurate if they used precise observations and records of weather to refine predictions for specific localities. Such records were kept across Europe beginning in the 13th century and were correlated with astronomical data, which paved the way for the data-driven forecasts produced by FitzRoy.¹

Islamicate astrometeorologists were the first to replace the ancient practice of observing only short-term signs, such as clouds and the flight of birds, to predict weather. They based their action on the hypothesis that weather is caused by the movements of planets and mediated by regional and seasonal climate conditions. Improved calculations of planetary orbits and updated geographical and meteorological information made the new science possible and compelling.

The body of scientific material being translated from Arabic continued to grow in the 12th and 13th centuries. During that time, rising populations spurred increases in urbanization, long-distance trade, and wealth. With improved forecasting, rulers were better able to address practical societal concerns, such as military strategy and food supply, both of which were heavily affected by weather. Bankers and traders were willing to pay for such valuable information. As a result, astrometeorology continued to develop during the 14th and 15th centuries and reached ever-growing audiences in the 16th and 17th centuries. It only fell from favor in the 18th century when forecasters began to view astrology with scorn.

**How astrometeorology worked**

Hellenistic scientists, particularly Ptolemy of Alexandria, made major advances in the field. Ptolemy produced geometrical and mathematical models of planetary movements based on observations recorded over centuries and new observations that he carried out himself. His fundamental works—generally known in the medieval period as the *Almagest* and *Tetrabiblos*—provided the means to calculate planetary positions and guidelines to interpret the data.

In astrometeorology, each planet had specific qualities that influenced related phenomena on Earth. Saturn—characterized as distant, slow-moving, and cold in...
color — was associated with the cold, dry element of earth. Mercury, being small, fast-moving, and usually close to Venus and the Moon, was associated with the warm, moist element of air. Exactly how planetary qualities influenced weather was disputed by philosopher-scientists, but the most widely accepted argument was that the planets emitted imperceptible rays that carried the qualities of the emitting planet to Earth.

The Sun and the Moon were the most significant astronomical bodies. The Sun’s effect on weather and climate through its light and heat was long established, and the Moon’s influence over ocean tides, bodily fluids, and plant growth was also widely recognized, at least by the educated. Astrometeorologists thought that the Sun and Moon were so powerful that they could even modulate the influences of weaker planets.3

The first step in making a forecast was for the astrometeorologist to calculate the positions of all the planets on a chosen date in relation to the zodiac belt and the ecliptic — the apparent path of the Sun around the heavens. Both were envisaged as circular, and the zodiac was divided into 12 equal sectors or signs, as shown in figure 1. Ptolemy systematized the portions of the heavens and explained that each had its own characteristics, which acted on any planet passing through the sectors.

Astrometeorologists noted that the angular relationships between planets were important for determining their mutual effects. Planets facing one another across the zodiac were negatively related; an angle of 45° was also problematic and likely to produce an atmospheric disturbance. However, planets at 60° or 120° would interact more positively and produce more moderate weather. When planets were close together, the intensity of their effects would increase depending on the natures and placements of the planets involved. Forecasters needed to also account for the climate zone of the chosen place and the current season. For example, an increase in atmospheric heat would have one set of effects in summer near the equator and another in winter near the Tropic of Cancer. An apparently simple set of principles required forecasters to make judgments as to the outcomes of all the factors at play.

The calculations for a forecast depended on the achievements of Islamicate astronomers, who had built accurate and updated models and tables of celestial structures and motions. That work in turn drew on advances in mathematics and the improvement in scientific tools and instruments. Astronomers tested and revised Ptolemy’s instructions for making weather forecasts, and many of them produced their own treatises on the subject. Those specialist works not only provided guidance for the basic techniques but also drew on the updated planetary data and new cosmological models. The result was a sophisticated, enticing, and complex body of material.

Rise of the expert forecaster

The scientific advances being made in the Islamicate world were first recognized in Latin Europe in the 11th century and stimulated curiosity and emulation rather than rejection. For example, figure 2 highlights an English astrolabe predicated on an Islamicate one. Territorial conquests by northern European forces in the Iberian peninsula of al-Andalus made librarians, scholars, and translators available to the new Christian rulers. Thus was born one of the greatest movements for scholarly translation and cultural assimilation in European history, and astrometeorology texts had an honorable place in that effort.

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clear explanation of the specific causes of heat, cold, drought, and rain and how their interactions in the atmosphere produce weather.

Al-Kindi’s conceptual framework and the central idea in his treatises, that the driving force for weather is heat generated by planetary movements, was Aristotelian. The concept was linked to the idea of four elements that compose the sublunar zone—earth, air, fire, and water—and their intrinsic connections to the primary qualities of hot, cold, dry, and moist. Astrologers believed that the planets and the fixed stars, including those making up the constellations to which the houses of the zodiac were linked, had special affinities with individual elements and qualities. Those qualities determined the nature of the effects each planet would have on the terrestrial world as it moved through the heavens.

The first step in al-Kindi’s forecasting method, as typical in astrometeorology, was to calculate the relevant planetary positions and directions. Next, forecasters would start their interpretation of the weather with the position and strength of the Sun. In al-Kindi’s model, the Moon had particular power over the elements of earth and water, both of which would be modulated on any given day by its position relative to the Sun. Forecasters needed to assess that interaction to predict winds because they believed the joint influence of the Sun and Moon determined whether the air in a particular region would be hot or cold. They then considered the other five known planets and calculated the factors affecting each one individually before incorporating the planetary groupings and interactions.

The techniques in al-Kindi’s method required that forecasters confidently judge which factors would have the greatest effects and for how long, and they accepted that experience was crucial in making a successful prediction. Experts put their trusted methods on record for the benefit of others. Especially influential was al-Kindi’s application of the concept known as “opening of the doors.” The treatises do not explain the phrase, but it hints that rain was caused by an almost physical change in the atmosphere, driven by specific combinations of planets and their movements in relation to one another.

The timing and extent of rainfall was sufficiently important in the Islamicate world that treatises on weather forecasting were frequently referred to as “books of rain.” Another valuable addition to the basic Ptolemaic model was the concept of “mansions of the Moon.” Credited to Indian astrologers, they were based on 28 fixed stars or star groupings, each of which occupied a sector of the Moon’s path through the zodiac. Each mansion was characterized in terms of its degree of humidity, which would affect the Moon.

The effect of the mansion currently occupied by the Moon was especially influential for the weather four times per month. The general monthly pattern of weather could be forecast by drawing up charts for each of the four occasions. If the Moon was in or moving into a wet mansion, for example, then the outcome would normally be rain. However, a significant interaction of the Moon and Saturn would modify the outcome considerably. Similarly, the disruptive influence of Mars would make storms, thunder, and hail more likely. The factors would diminish in power as the Moon traveled in its orbit and would be supplanted when the next key point was reached.

The spread of astrometeorology

Interest in Latin treatises on astrometeorology continued to grow after the 13th century and was unaffected by religious concerns. Theologians viewed weather forecasting differently from the making of personal astrological predictions for individual clients. The latter was fraudulent at best and heretical and dangerous at worst because of its clash with important teachings on free will. But an important endorsement for weather forecasting came from the great 13th-century theologian Thomas Aquinas. In his *Summa Theologiae*, he wrote of the power of the stars over earthly things and cited St Augustine’s statement that the heavenly bodies can cause physical effects on Earth. Because Aquinas viewed weather forecasting as an application of knowledge drawn from observation and experience, many theologians didn’t condemn it as demonic or divinatory.

For students, especially in Paris, the authoritative, contemporary survey of all forms of astrology was *Speculum astronomicum* (Mirror of Astronomy). The work by 13th-century theologian Albert the Great praised the value of knowing how variations in heavenly bodies can cause changes in earthly things, including the weather. Rather than rejecting astronomical weather forecasting as foreign and suspect, *Speculum astronomiae* endorsed the practice. Technological developments helped disseminate the new science. Most notably, the printing press, which arrived in northern Europe in the 15th century, made it possible for long-term weather forecasts, calendars, and predictions of health and political trends to be published as annual almanacs.

Almanacs grew out of the predictions and forecasts privately commissioned from renowned scientists and holders of university chairs in astronomy. Demand appeared almost as
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soon as the new meteorology reached Latin Europe. An early example was that of the astrologer Guido Bonatti, who advised Guido da Montefeltro, ruler of Urbino, and other leaders in the 13th century. Bonatti recorded his trusted techniques for weather forecasting in a long section of a book that was widely copied for the next two centuries and later printed when the technology was available.

Rulers made impressive investments in universities across Europe in the 13th and 14th centuries in no small part because of astronomy, astrology, and meteorology. The demand for expert astronomers and astrologers is illustrated by the career of Georg Peurbach, who studied in Italy, France, and Germany before becoming a professor of astronomy at the University of Vienna. He worked for Ladislaus V of Hungary and Bohemia and the Holy Roman Emperor Frederick III. Forecasts and predictions for powerful rulers were private, but university department chairs were often required to provide public guidance. Those predictions were given to university members and patrons in the form of annual prognostications, which included forecasts of seasonal weather. Examples survive from the early 15th century, and they were likely a matter of civic pride because the custom quickly spread.

The prognostications of Peter of Monte Alciano, who lived in Pavia, Italy, seem to have been especially sought after. His forecasts for 1419, 1421, 1430, and 1448 survive and reached not only the Holy Roman Empire but also France and England. Perhaps the most influential forecaster was Joannes Vesalius—the great-grandfather of the more famous Andreas Vesalius, the physician and author of the famous anatomy book De humani corporis fabrica (The Structure of the Human Body). Joannes Vesalius took a position at the University of Louvain in 1429 before becoming an adviser to Duke Philip the Good of Burgundy. The city council of Louvain commissioned a prognostication for 1431, which Vesalius duly read to an invited audience at the end of 1430. When Louvain’s first printer, Jan van Westfalen, arrived, he promptly issued annual prognostications modeled on those of Vesalius.

Strikingly, the University of Bologna employed two professors of astronomy and astrology in the 15th century. One was required to compile an annual almanac that showed the positions of all seven planets on a daily basis for the coming year and tabulate the angles of the planets to the Moon and to one another. The other professor was to use the data to produce a prog nostication.9 Printed almanacs today continue to follow the same formula.

Much of the time-consuming work of calculating the planetary positions was alleviated by the contribution of the astronomer Regiomontanus, pictured in figure 3. He produced a calendar and Ephemerides, or book of astronomical tables, both of which were made available in print beginning in 1476. The large volumes provided not only full planetary data but also guidelines for their interpretation and a table of corrections to apply when adjusting the coordinates for a particular city or region in Europe. The powers of the planets in each sign and each aspect were tabulated in numerical form, and the lunar mansions were included in a table.

Regiomontanus provided rules for producing prognostications, with the first section addressing weather forecasting. The rules applied standard procedures of the time and appear to be how Regiomontanus conducted his own practice. He identified specific planetary occurrences as especially influential. For example, an opposition of the Moon and Jupiter, when occupying the fire sign of Aries and the water sign of Scorpio, will generate clouds. If the Moon is moving toward Mercury, the forecast will include what Regiomontanus called an opening of the doors of the winds. But for traditionalists, he appended a section after his rules that offered the ever-popular weather forecasting according to al-Kindi.

In the time of scientific revolution

High demand for Regiomontanus’s works meant that multiple printed versions rapidly appeared, many of them pirated. He was acclaimed as the greatest astrologer of his time: Cardinal Bessarion and King Matthias Corvinus of Hungary employed him, and his work was used by Christopher Columbus to calculate the dates of coming storms.10,11 Besides Regiomontanus, several well-known early-modern scientists espoused astrometeorology, including Tycho Brahe and Johannes Kepler. The growing acceptance of a heliocentric universe failed to shake the belief that celestial bodies affected the atmosphere, Earth’s
weather, and the health of the human body. Indeed, the ongoing refinements to the rules for making weather forecasts by practitioners reinforced astrometeorology’s place in scientific and popular culture.

The supporting trend for astrometeorology appeared in several locations beginning in the mid 14th century. From about 1340, astronomers and scientists working at Merton College in Oxford, England, including the prominent John of Ashenden, showed a particular interest in the practice. Ashenden composed an enormous summa on astrology, and astrometeorology dominated its long second section. He became famous for having predicted the Black Death of 1348–49, and his weather forecasts for 1368–74 emphasized the major planetary conjunctions of 1365 and 1369. The conjunctions suggested that a period of heavy rain and floods would be followed by three years of drought and, consequently, crop failures and food shortages.

Parallel with Ashenden’s work were more local studies of weather, and predictions were recorded in treatises and presented to Merton College by William Reed, the bishop of Chichester from 1369 to 1385 and a fellow of the school. One treatise was entitled Rules for the Forecasting of Weather by Master William Merle. The rules were accompanied by detailed weather observations for 1337–44, made mostly in Lincolnshire but also in Oxford. The central aim seems to have been to correlate astrometeorological factors with actual weather notes to establish which factors proved most significant for making predictions. The research was perhaps inspired by the pioneering work of the Franciscan friar Roger Bacon, who conducted his studies in Oxford in the late 13th century. Among a collection of his scientific treatises is a calendar with daily planetary positions and weather notes.

A similar, separate project to the Bacon one was undertaken by Eyno of Würzburg, whose treatise on astrometeorology was supported by the inclusion of weather notes from 1331 to 1355. Like the Oxford group, Eyno placed a special emphasis on predicting advance warning of damaging weather; he records with some pride, for example, that he successfully forecast heavy snow on three separate occasions.

A volume of uncertain origin belonging to the Dominicans of Basel records comparable work from 1399 to 1406. The volume includes rules for astrometeorological prediction accompanied by sets of weather records and observations. The notes identify which astrometeorological factors would match the recorded weather. For example, 7 April 1400 was reported as cloudy with short sunny intervals and a strong west wind. A note indicates that the Moon moved away from the beneficent planet Jupiter, out of an air sign, and toward Mercury, a planet that was thought to cause air disturbances.

The argument that weather research was intended to improve and sharpen astrometeorology rather than to challenge it is supported by the expansion of science in the 15th and 16th centuries. The 16th century, for example, saw the production of treatises that amateur scientists could use to carry out their own forecasts and the publication of an ever-increasing number of annual almanacs and prognostications.

Books for nonexperts were published in local languages rather than the Latin found in theoretical works. Those in English are striking for the long-lived vocabulary they deployed. For instance, Thomas Buckminster’s An Almanacke and Prognostication for the Year 1598 indicates that the start of April would see “fair” and “fresh” weather. The Moon’s first quarter...
on 3 April saw a change to cloudy, cold weather that would become “raw” on 6 April. At the full Moon on 11 April, the weather was predicted to become “clear” and “fair.” A page from Buckminster’s almanac of 1590 is shown in figure 4.

Tycho’s work provides further evidence for the ongoing value placed on astrometeorology. He devoted a surprising amount of space to the subject in his 1572 treatise on a new star that appeared in Cassiopeia. Tycho gave his own observations and calculations on meteorology and supported the publication of daily weather forecasts. He acknowledged the inaccuracy of the predictions, but he argued that keeping weather records would strengthen astrometeorological practice.[14]

Tycho’s pupil, Kepler, followed his advice and made daily records of weather. His published Ephemerides and calendars included his weather observations and forecasts. Like other practitioners before him, Kepler identified what he believed to be the most important factors for weather prediction—in his case, planetary aspects.

Such distinguished support for medieval meteorology shows that it was hardly the result of superstition and ignorance. The updated and corrected observations of planetary movements that scientists like Tycho and Kepler produced made it possible to improve the planetary tables used by astrometeorologists. The accurate recording of the weather and its strengthening of forecasting techniques was perhaps the greatest legacy of astrometeorology to its modern successor.

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REFERENCES
1. A. Lawrence-Mathers, Medieval Meteorology: Forecasting the Weather from Aristotle to the Almanac, Cambridge U. Press (2020).
2. William of Conches, A Dialogue on Natural Philosophy (Dragmaconi Philosophiæ), I. Ronca, M. Curr, trans., U. Notre Dame Press (1997).
3. Ptolemy, Tetrabiblos, F. E. Robbins, ed. and trans., Harvard U. Press (1940), bk. 1, chap. 8.
4. J. al-Khali, The House of Wisdom: How Arabic Science Saved Ancient Knowledge and Gave Us the Renaissance, Penguin Press (2011).
5. E. Grant, in The Cambridge History of Science: Volume 2, Medieval Science, D. C. Lindberg, M. H. Shank, eds., Cambridge U. Press (2013), p. 436.
6. Al-Kindi, G. Bos, C. Burnett, Scientific Weather Forecasting in the Middle Ages: The Writings of al-Kindi, Kegan Paul International (2000).
7. T. Aquinas, Summa Theologiae, 2nd ed., Fathers of the English Dominican Province, trans. (1920).
8. P. Zambelli, The “Speculium Astronomiae” and Its Enigma: Astrology, Theology and Science in Albertus Magnus and His Contemporaries, Kluwer (1992), pp. 214, 230, 250.
9. S. Vanden Broecke, The Limits of Influence: Pico, Louvain, and the Crisis of Renaissance Astrology, Brill (2003).
10. D. Hayton, Centaurus 49, 185 (2007).
11. E. Zinner, Regiomontanus: His Life and Work, vol. 1, E. Brown, trans., Elsevier (1990), p. 120.
12. W. Merle, Merle’s MS: Considerationes temperiei pro 7 annis . . . The Earliest Known Journal of the Weather . . ., G. J. Symons, ed. (1891).
13. L. Thorndike, Isis 32, 304 (1940); 57, 90 (1966).
14. T. Brahe, De nova stella, Hauniæ (1901).