well as in making accurate predictions around a whole range of key issues. These include when and where to observe twilight, predicting seasonal and latitudinal variations, understanding and extrapolating those variations in terms of angular solar depression, and avoiding both false positive and negative observations. It is acknowledged that some of this was taken into consideration even in classical times – certainly by the great astronomers, but to a lesser extent in the folk astronomy practised by jurists and time-keepers. However, it must be conceded the nature of the scientific advancements over the last hundred years is such that medieval works on the subject need to be re-evaluated in their light.

Two undeniable facts remain: much of what was cutting-edge astronomy in the 12th century is now routinely studied at school, and determination of the prayer times was and still is predicated primarily on actual observation of the phenomenon of twilight. A bullet point summary of this chapter's conclusions will be found below for ease of reference.

Understanding Twilight [4.2]

» Twilight is the illumination of the atmosphere by residual scattered sunlight before sunrise or after sunset. The timings of the fajr and isha prayer, as well as that of the fast, depend on observation of the beginning of morning twilight (dawn) and the end of evening twilight (night). It is critical to note that it is observation that establishes prayer times, not the actual position of the Sun.

» Despite the importance of twilight, the phenomenon is not well understood by many modern Muslim scholars, and errors in understanding the science can lead to faulty legal conclusions being drawn. This topic is poorly covered in most modern works on this subject.

» The night sky is never completely dark, but at a certain point, the Sun's position is far enough beneath the horizon that no scattered sunlight reaches the human eye. When precisely this is perceived to happen depends on a number of related factors. Some are connected to latitudinal variation, some to

celestial conditions (like moonlight), whilst others are related to terrestrial light pollution.

» Twilight is the interaction between sunlight, the atmosphere, relative Sun-earth positions and the human optical system (which includes the eye and the brain). It is variability in each of these factors that produces variability in observation of the twilight phenomena that affect prayer times [4.4].

» 'Scattering' refers to the deflection of 'rays' of light by their 'bouncing off' atmospheric particles. When sufficient particles 'bounce' into the eye, light is perceived despite the Sun still being below the horizon. This occurs most in late dawn and early dusk, but exponentially less so in early dawn and late dusk. Blue wavelengths of light scatter the most, and red wavelengths the least [4.4.3].

Sun-Earth Position and Effect on Twilight

» The Sun appears to orbit the earth in a tilted elliptical orbit, which when combined with the earth's yearly orbit of the Sun, brings about seasonal variations in length of day and night. The higher one's latitude (the distance of a location from the equator), the more pronounced those variations are, thus far northern countries like the UK have very long summer days and very short winter ones [4.4.4].

» The length of twilight is linked to both the depth and shallowness of the Sun's passage beneath the horizon during the night. It can extremely lengthy in summer – up to 3 hours long – because of the shallowness of this lower transit, compared to 90 minutes in spring. In comparison, twilight lengths in mid-latitude countries only vary by about 20 minutes through the year. This makes fixing a duration for twilight impossible [4.4.5].

» Also, because the eye reacts to changes in intensity of light (see below), and changes in intensity relate to the gradient of the Sun's passage below the horizon, twilight may be detected later than expected in the morning and fade later than expected in the evening. This may be expected to vary through the seasons [4.4.7].

» Persistent twilight – where evening and morning twilights merge without an intervening true night – occurs at most latitudes of the UK during summer, posing legal challenges with regards to establishing the isha prayer, as well as setting a time for the commencement of the fast. A less well-recognised factor is that the week before and after persistent twilight is marked by drastic changes to the beginning and end of twilight that can significantly alter prayer and fasting times [4.4.5.4].

» The atmosphere is historically the least studied variable relating to twilight, but crucial in determining when first and last light will be seen. The atmosphere over northern latitudes differs from mid-latitudes in terms of height, density and quantity of large particles, all of which may delay observation of first light [4.4.6].

» These fundamental differences in the parameters of twilight in far northern latitudes makes extrapolation based on mid-latitude observations and calculations unfeasible and possibly incorrect. Muslims in these areas require their own banks of observational data upon which timings may be extrapolated [4.4.5.2].

The Optical System [4.4.7]

» The perception of twilight is an interaction between light reaching the eye, the retina and the brain's synthesis of sensory inputs. The optical system is dynamic, reacting to changes in light intensity rather than the mere presence of light. The faster the rate of change of light intensity, the sooner the optical system will detect 'light' on the horizon.

» Perception of 'red, yellow and white' twilight is primarily a function of the eye rather than the light itself. The eye has different receptors for low-light (which are monochrome) and bright-light (which give detailed colour vision). The disappearance of the red twilight in the evening (which marks the onset of isha according to the majority) is therefore due to the shutting down of colour vision because of low levels of illumination.

» Cameras operate in a fundamentally different way to the human eye, primarily because they do not have a brain that advances

some sensory inputs and discards others. A camera is thus unlikely to accurately capture what the eye sees, and in fact can provide widely differing observations of twilight depending on what settings one chooses.

» Relying on photographic evidence of the onset of dawn or the end of dusk – even if it were considered legally acceptable – is thus fraught with logistical challenges in determining, agreeing and enforcing particular settings over others. It should also be noted that photographs of early twilight may not reflect what the eye perceives at that time. Light meters, which provide a quantitative measurement of the brightness of the sky, pose similar problems – neither are a direct substitute for the human eye, which is what is legally required to determine prayer times.

» Nonetheless, if it could be demonstrated that a particular camera or light meter, utilising specific settings, could accurately replicate the phenomenology perceived by the human eye in different settings and conditions, a good argument could be made for 'automating' the process of dawn and dusk observation, allowing for a significant expansion of the bank of observation data.