Determine a Good Observatory Location

YU-CHIEH HSU
ujfiderciah20120512@gmail.com*

July 22, 2021

A good observatory to observe the night sky depends on many factors. Under ideal conditions, the best place to see sky objects lies in "a good seeing", that is, a steady, transparent atmosphere (In general, seeing could be known via telescope guiding systems by computing the full width at half maximum (FWHM) and half flux diameter (HFD) of a selected star)[1][2]. However, in most places crowded and developed, which can cause a strong atmospheric disturbance, to have a nice seeing is almost as far as possible. Apart from anthropogenic factors, we can still rely on "weather conditions" to define the sky quality. The project will show a basic weather analyze of night sky take place in Zhongli from January 2016 to December 2020 to determine if Zhongli is a good option to build an observatory, by analyzing some common features.

1 Introduction

Things to consider when deciding where an astronomy observatory should be located : clear, dry, and dark. In addition to latitude and season, a clear night sky should be able to see the maximum stellar objects. Lunar and human activities may cause heavy light pollution, but an observatory for the general public to know the beauty of the night sky is not that impracticable. Since buildings cannot be destroyed, which is one of the atmospheric disturbance contributing factor, the last thing to consider is humidity, a place where is often rainy and cloudy could impact both the seeing and the apparatus. Notice that the dataset only contains a five-year data, since we all know the climate in an area "should" be about the same in all time (we will not consider the El Niño and La Niña cases which are unpredictable and shouldn't be a reason not to build observatories). According to Isaac Newton Group of Telescopes, one of

*Website: https://github.com/violetyaya169078

[1]Full Width at Half Maximum (FWHM) : The width of a spectrum curve measured between those points on the y-axis which are half the maximum amplitude, quality of an astronomical image based on how much the telescope and atmosphere have smeared a point source in an image over several pixels in the CCD, measured in arcseconds(").

[2]Half Flux Diameter (HFD) : The star size in an astronomical image, measured in pixels. Both FWHM and HFD should be as small as possible for a good seeing, it can also tell if the telescope is out of focus.

the observing conditions at the observatory is : 75% of nights are clear. Other conditions like extinction[3] depends alot on the sky background of a certain area, which is not what we will put in consideration now. Also, we will not introduce any type of telescope, that should base on the individual decisions, its not in our discussion.

2 Steps

Investigation of the site should start with the geographical environment, giving the first information of where the observatory stand. In the overall dataset, cloud coverage(<25%), wind speed(<15m/s or 34mph) and visibility are the critical parameters of defining a clear sky. The percentage of the relative humidity(<90%) could tell the environmental condition of setting up a telescope. Next, we should observe whether this place have a stable climate by looking at its temperature variation in different seasons. Finally, we will take a look at the photometric and spectroscopic nights[4] The last of last, we will take a look at the world dark scale map via Wikipedia and the Light Pollution Map to see how bright or how dark Zhongli is.

3 Geographical Environment

1. Location : Taiwan, Zhongli district
2. Coordinates : 24°57'25"N 121°13'25"E
3. Area : 76.52 km^2
4. Climate (Taiwan) : Marine tropical. The northern and central regions are subtropical, whereas the south is tropical and the mountainous regions are temperate. The rainy season is concurrent with the onset of the summer East Asian Monsoon in May and June. The entire island experiences hot, humid weather from June through September. Typhoons are most common in July, August and September. During the winter (November to March), the northeast experiences steady rain, while the central and southern parts of the island are mostly sunny.
5. Geology (Taiwan) : Convergent boundary between the Yangtze Subplate of the Eurasian Plate to the west and north, the Okinawa Plate on the north-east, the Philippine Plate on the east and south, and the Sunda Plate to the southwest.

[3]Atmospheric extinction : The reduction in brightness of stellar objects as their photons pass through our atmosphere.

[4]Photometric and spectroscopic night : A photometric night is a night where the sky is clear and transparent at least six hours or the whole summer night. A spectroscopic night can be a bit lighter and partial cloudy (extinction <0.5 magnitudes and obscuration <50% above 30 degree elevation).

6. Topography : Plateau

Located at the north west of Taiwan, Zhongli has an estimated population 397,083 in January 2017, and it's one of the most multicultural cities due to its convenience and proximity to Taipei (easy to commute). With the eight biggest but least populated villages on the western side of the district while the eastern side is occupied by industrial factories (belonging to electronic, metal, chemical, mechanical, food, textile and plastic manufacturers) and the heart of the metropolitan area. Surrounded by shopping districts and night markets (daily, usually from 6 p.m. to 1 a.m.).(Wikipedia)

4 Parameters Definition

Parameters in this dataset :

1. Date time
2. Temperature
3. Precipitation
4. Wind Speed
5. Visibility
6. Cloud Cover
7. Relative Humidity
8. Conditions
9. Year
10. Month
11. Visibility Scale
12. Fraction

• Visibility (miles) : Measure of distance at which an object or light can be clearly discerned, varies from the direction and angle of view, and the height of the observatory, affected by the presence of fog, cloud, haze and precipitation (Scales from 0 (poor) to 11 (pure)).
• Cloud cover : Percentage of the cloud coverage, it can't represent the layer of the cloud.
• Conditions : Sky conditions, depend on cloud cover, include 'Clear', 'Partially cloudy', 'Overcast', and 'Rain'.
• Fraction : Percentage of nights which are better to observe.

5 Basic Standards

5.1 Cloud Coverage

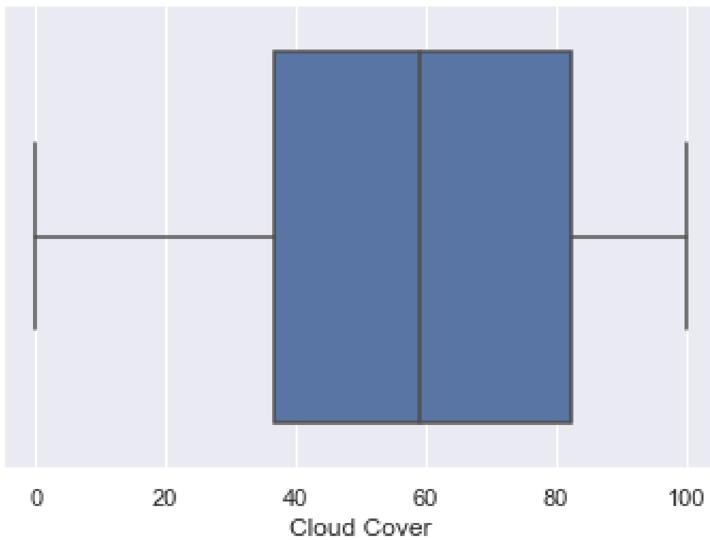

Figure 1: Cloud coverage from 2016 2020

Over 75% of all nights don't have their cloud coverage less than 25%, which doesn't meet our requirements of a clear sky.

5.2 Relative Humidity

Although there were many nights with humidity less than 90%, this can only represent the worst case when the telescope must be taken away, any percentage of the humidity is a harm to the apparatus. Thus, the dehumidification of an observatory is essential. Taiwan is an island surrounded by oceans, water can be easily carried by the wind.

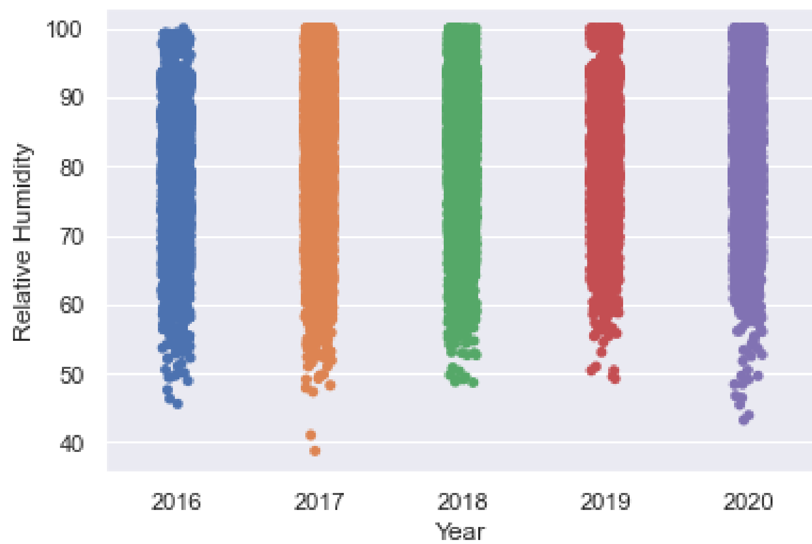

Figure 2: Relative humidity from 2016 2020

5.3 Windspeed

The ideal windspeed of a better observing night should lay below 15 meters per second(34 miles per hour).

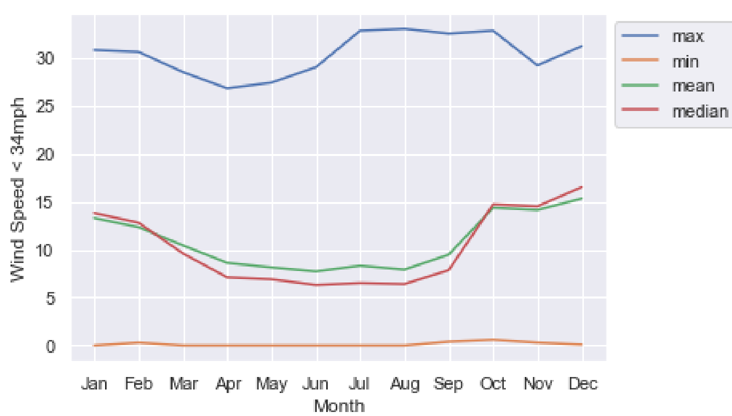

Figure 3: Windspeed of all months

Most of the time, the windspeed is at an acceptable range, which means the wind in Zhongli won't impact our observing difficulty. Still, we can see the wind in winters were higher than other months, showing that there are chances we might not be able to observe. We can also know that low windspeed might not have the ability to blow away the clouds, which may impact the cloud coverage and visibility indirectly. The height and structure of the observatory is also one of the factor that could be influenced by the wind, the stability of the telescope determine whether the photo is in focus.

5.4 Visibility

Defining different visibility conditions and see how the sky look like in the months of years. The sky should be as clear as possible for a good seeing condition.

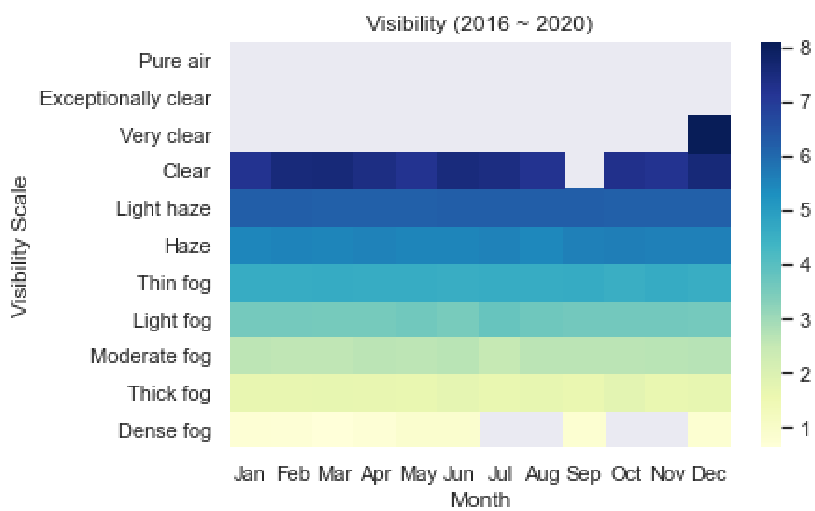

Figure 4: Visibility of all months

Visibility is an indicator of the air quality. Two possible reasons for why the visibility is so poor should take into account. PM2.5 is the main cause of the poor visibility in winters, influenced by the sandstorm brought from Siberia. The northeast monsoon is blocked by the central cordillera, lead to the retention of the sandstorm occupying the western Taiwan. Due to the high pressure, days without sandstorm could give a clear night to some degree. The poor visibility in springs and autumns, also in summer days without strong convection stem from Ozone, the emission from factors and vehicles. Stronger the ultraviolet, higher the concentration is. Typhoon and plum rain in summers can refresh the air, but the clouds and water could bring the observation to a halt. As one of the crucial conditions in astronomical observations, the visibility here is absolutely worse.

5.5 Temperature

We chose four random days from different seasons in 2018, and see how the temperature varies after their astronomical twilights at night. We expect the differences of the temperature between hours not to change a lot.

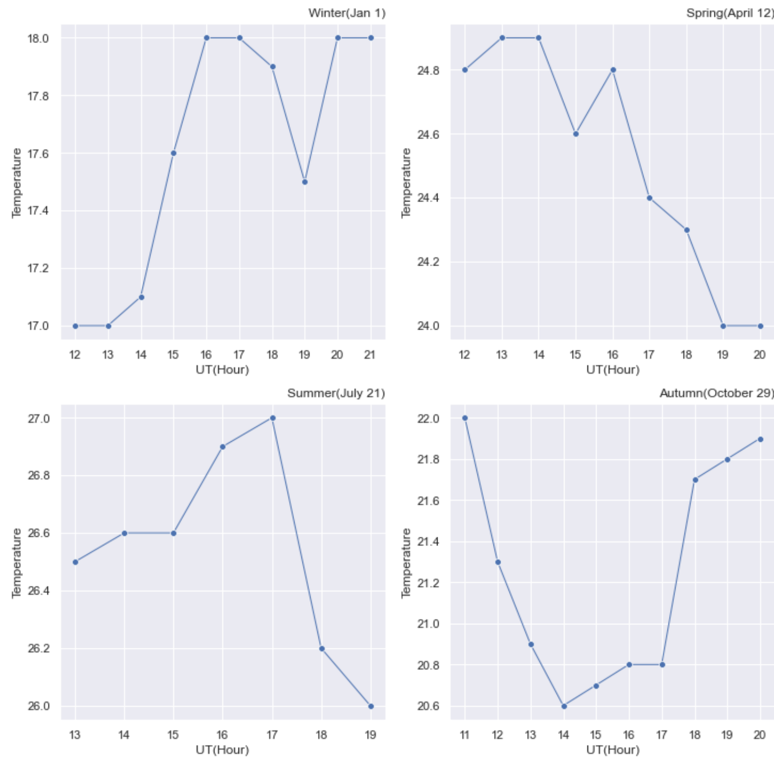

Figure 5: Temperature of night from each season

Only the temperature in spring met our expectations while temperatures of other seasons fluctuated one or two degrees. Besides the average temperature, the differences among indoors and outdoors is what really matters. The outcomes of telescopes impacted by dramatical temperature differences are disturbance, fogging and deformation, which needs appropriate thermal equilibration to adjust them.

5.6 Photometric Nights and Spectroscopic Nights

Generally speaking, the quality of our observation can be roughly classified into photometric nights and spectroscopic nights, which presents the overall situation of our observing nights. The following graph shows the fraction of all photometric nights and spectroscopic nights by month in 2016 to 2020.

Figure 6: Nights for a good observation

Apparently, the useful nights in Zhongli are few and far between, the opportunity of having a decent night to observe is exceptionally valuable.

6 Summary

In summary, the conditions of observing in Zhongli is never a good idea, none of a year have a clear sky over 75 percent of all months. The sky above Zhongli is often covered with clouds and fogs, moisture comes from every direction. Its hardly to see most of the sky objects with naked eye, only the ones with higher magnitudes. The visibility during moments of using a telescope was poor in most of the time, and these were only based on the weather and its geographical conditions, not including other human negligences!

7 References

[1] Astronomical Observing Conditions at Xinglong Observatory from 2007 to 2014, Ji-Cheng Zhang and others, Publications of the Astronomical Society of the Pacific Vol. 127, No. 958 (December 2015), pp. 1292-1306.
[2] Procedures for location of astronomical observatory sites, Stock, J., Le choix des sites d'observatoires astronomiques (site testing) [IAU symposium no. 19] tenu a Rome (Italie) du 1er au 6 octobre 1962 avec le concours financier du Consiglio Nazionale delle richerche. Edited by Jean Rosch. International Astronomical Union. Symposium no. 19, Gauthier-Villars, Paris, p.36-40.

Class	Title	NELM[5]	Approx.SQM[6]	Color
1	Excellent dark-sky site	7.6–8.0	21.99–22.0	Black
2	Typical truly dark site	7.1–7.5	21.89–21.99	Gray
3	Rural sky	6.6–7.0	21.69–21.89	Blue
4	Rural/suburban transition	6.1–6.5	20.49–21.69	Green/Yellow
5	Suburban sky	5.6–6.0	19.50–20.49	Orange
6	Bright suburban sky	5.1–5.5	18.94–19.50	Red
7	Suburban/urban transition	4.6–5.0	18.38–18.94	Red
8	City sky	4.1–4.5	<18.38	White
9	Inner-city sky	4.0	<18.38	White

Table 1: Bortle Dark Sky Scale

Appendix

The Bortle Dark Sky Scale

The Bortle dark sky scale is a scale divided in nine levels to describe the night sky's brightness of a particular location, published by John E. Bortle in *Sky & Telescope* magazine(February, 2001). It quantifies the astronomical observability of celestial objects and the interference caused by light pollution to help people evaluate the darkness of an observing site. Secondarily, to compare the darkness of observing sites. The scale ranges from 1(Darkest sky) to 9(Inner city sky) and presents in 9 colors on a map. This section is not a part of the data analysis process, hence in the appendix.

Table 2: Bortle Dark Sky Description(Wikipedia)

Class	Description
1	• the zodiacal light is visible and colorful • the gegenschein is visible • the zodiacal band is visible • airglow is readily visible • the Scorpius and Sagittarius regions of the Milky Way cast obvious shadows • many constellations, particularly fainter ones, are barely recognizable amid the large number of stars • many Messier and globular clusters are naked-eye objects • M33 (the Triangulum Galaxy) is a direct vision naked-eye object • limiting magnitude with 12.5 in (32 cm) reflector is 17.5 (with effort) • Venus and Jupiter affect dark adaptation
2	• the zodiacal light is distinctly yellowish and bright enough to cast shadows at dusk and dawn • airglow may be weakly visible near horizon • clouds are only visible as dark holes against the sky

	• surroundings are barely visible silhouetted against the sky • the summer Milky Way is highly structured • many Messier objects and globular clusters are naked-eye objects • M33 is easily seen with naked eye • limiting magnitude with 12.5” reflector is 16.5
3	• the zodiacal light is striking in spring and autumn, and color is still visible • some light pollution evident at the horizon • clouds are illuminated near the horizon, dark overhead • nearer surroundings are vaguely visible • the summer Milky Way still appears complex • M15, M4, M5, and M22 are naked-eye objects • M33 is easily visible with averted vision • limiting magnitude with 12.5” reflector is 16
4	• the zodiacal light is still visible, but does not extend halfway to the zenith at dusk or dawn • light pollution domes visible in several directions • clouds are illuminated in the directions of the light sources, dark overhead • surroundings are clearly visible, even at a distance • the Milky Way well above the horizon is still impressive, but lacks detail • M33 is a difficult averted vision object, only visible when high in the sky • limiting magnitude with 12.5” reflector is 15.5
5	• only hints of zodiacal light are seen on the best nights in autumn and spring • light pollution is visible in most, if not all, directions • clouds are noticeably brighter than the sky • the Milky Way is very weak or invisible near the horizon, and looks washed out overhead • when it is half moon (first/last quarter) in a dark location the sky appears like this, but with the difference that the sky appears dark blue • limiting magnitude with 12.5” reflector is 15
6	• the zodiacal light is invisible • light pollution makes the sky within 35$\circ$ of the horizon glow grayish white • clouds anywhere in the sky appear fairly bright • even high clouds (cirrus) appear brighter than the sky background • surroundings are easily visible • the Milky Way is only visible near the zenith • M33 is not visible, M31 is modestly apparent • limiting magnitude with 12.5” reflector is 14.5

7	• light pollution makes the entire sky light gray • strong light sources are evident in all directions • clouds are brightly lit • the Milky Way is nearly or totally invisible • M31 and M44 may be glimpsed, but with no detail • through a telescope, the brightest Messier objects are pale ghosts of their true selves • when it is full moon in a dark location the sky appears like this, but with the difference that the sky appears blue • limiting magnitude with 12.5” reflector is 14
8	• the sky is light gray or orange – one can easily read • stars forming familiar constellation patterns may be weak or invisible • M31 and M44 are barely glimpsed by an experienced observer on good nights • even with a telescope, only bright Messier objects can be detected • limiting magnitude with 12.5” reflector is 13
9	• The sky is brilliantly lit • many stars forming constellations are invisible and many fainter constellations are invisible • aside from the Pleiades, no Messier object is visible to the naked eye • the only objects to observe are the Moon, the planets, and a few of the brightest star clusters

The picture below is a screenshot of the brightness in Zhongli from the Light pollution map.

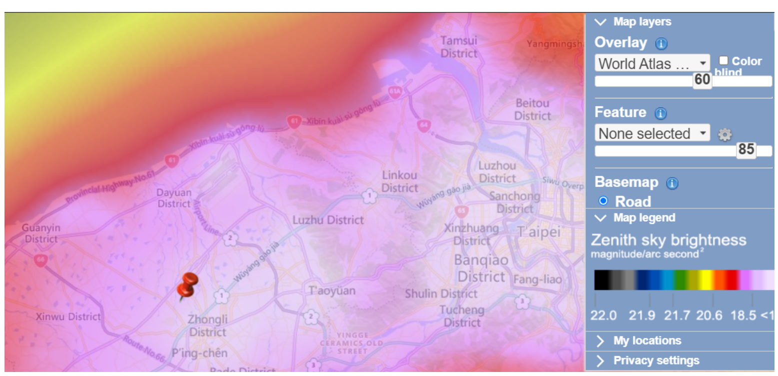

Figure 7: Light pollution of Zhongli(Light pollution map(2015))

Zenith sky brightness info (2015)
• Coordinates : 24.98370, 121.20000
• SQM : 18.57 mag./arc $\sec^2$
• Brightness : 4.03 mcd/m^2
• Artif. bright. : 3860 μcd/m^2
• Ratio : 22.6
• Bortle class : 7
• Elevation : 101 meters

The light scale where the pin located is at class 7, which is : **Suburban/urban transition**. From the information above, we can infer that Zhongli is too bright for celestial observations.

Types of Light Pollution

As one of the polluition people don't really regard with, some reasons that caused places like Zhongli to be so bright can sort out in five possibilities:

Type 1 : Light trespass : Poor control of outdoor lighting, occurs when unwanted light enters one's property.

Type 2 : Over-illumination : The excessive use of light, one of the common issues caused by the majorities.

Type 3 : Glare : Strong light or reflection that can cause blinding effect.

Type 4 : Light clutter : Excessive groupings of lights, for instance, street lamps, especially the ones without lampshades or wrong direction of irradiation.

Type 5 : Artificial satellites

Natural light pollution such as moonlight can also impact our observation, thus we won't choose the time after moonrise or the direction of the moon.