astronomy in a changing climate

Influences and Adaptation

Marrick Braam | January 2020

For ages, astronomy has been a science dedicated to the detection of the weakest of signals in the form of light[1]. To illustrate this weakness, imagine we are observing a distant galaxy. The inverse square dependence of flux on the distance to the galaxy tells us that doubling the distance from us would lead to a signal that is four times weaker. Moreover, recently astronomy has started detecting exoplanets (planets circling other stars than our Sun). The signals with which we detect these exoplanets are between a thousand and a million times smaller than the signal we receive from their host star [2].

In the past decades, improvements in technology and observing facilities have made it possible for us to detect these signals. These improvements are part of conquering the so-called instrumental effects and only form one half of the equation. The local state of the atmosphere at an observational site can be regarded as the other half. Although one may question the term natural effects, taking into account the influence of humanity in climate change, this article will stick to the term for historical as well as practical reasons. An in-depth discussion of the correctness of this statement could depend on how one would designate humanity's place in nature and is beyond the scope of this article.

The dependence of astronomical observations (at least in the optical and/or infrared part of the spectrum) on atmospheric conditions is threefold, namely through scattering, absorption and seeing.

Scattering

Light entering the atmosphere will be scattered by the collisions with large atmospheric particles, which are commonly known as aerosols. Astronomers usually try to mitigate this scattering by moving observatories to high altitude locations where the light has to cross a smaller part of the atmosphere to reach the telescope. Our polluting emissions are leading to an increase in aerosol content by for example smoke, dust from mining and contrails. Contrails are the condensation trails that are emitted by high flying aircraft and their presence can persist for several days [3]. Figure 1 shows the complexity of the atmospheric processes that involve aerosols. The aerosols will not only result in increased local atmospheric extinction and therefore more scattering of light from outer space, but it will also increase the scattering of light emitted from Earth's surface. Moreover, aerosols act as so-called cloud-condensation nuclei which could influence the process of cloud formation, leading to another degradation of observing conditions. The increasing content and effects of these particles have been known for years [4].

As a means to fight climate change, geoengineering of our climate through artificial delivery of sulphate aerosols has been proposed (see e.g. [5] for an overview). Obviously, this will lead to deteriorating observational conditions worldwide. Humanity should question whether this is desirable, even without taking the possible backlashes and ethical concerns of artificially modifying our atmosphere into consideration here.

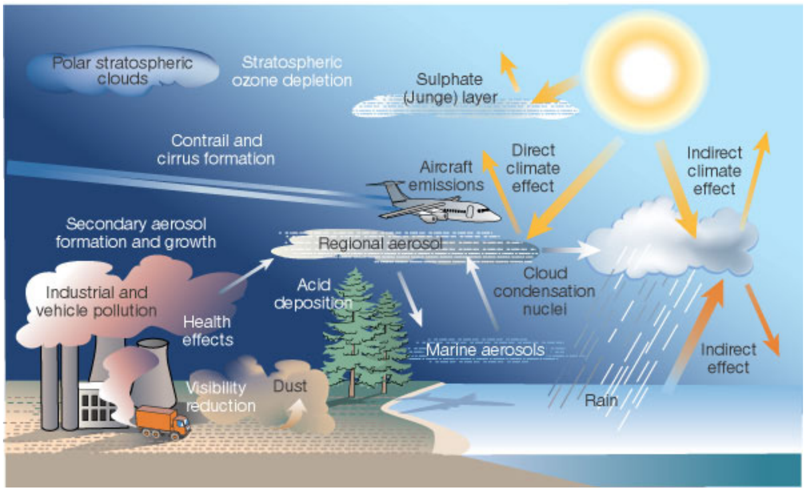

Figure 1: Illustration of the different effects caused by an enhanced content of aerosols in Earth's atmosphere.

Absorption

In parts of the electromagnetic spectrum, the light is absorbed by gases in the Earth's atmosphere. From Figure 2 it can be seen that most Gamma-ray, X-ray and UV light is absorbed, which is a necessary protection for life on the planet. Most of the visible light and radio waves are transmitted by the atmosphere, while the infrared part is partly transmitted. The wavelength of absorption is dependent on the specific gas. The primary gases responsible for atmospheric absorption are:

- H_2O (water): mostly absorbs in the infrared.
- CO_2 (carbon dioxide): mostly in the mid and far-infrared.
- O_3 (ozone): absorbs most of the damaging UV radiation.

Anthropogenic emissions enhance the amount of carbon dioxide (amongst others), causing increased absorption from these molecules. Although infrared astronomy is already preferably done by space telescopes, this might have negative consequences for ground-based telescopes such as the facilities at Mauna Kea Observatory at Hawaii.

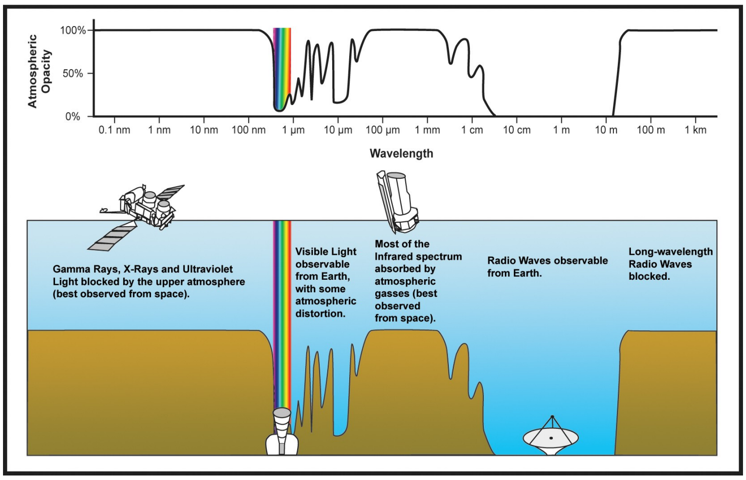

Figure 2: Illustration that shows the percentages of absorption of incoming light by atmospheric constituents (Image credit: NASA).

Seeing

The last effect considers the influence of turbulent motions caused by varying atmospheric densities in the atmosphere, which leads to distortion of images and alters positions of objects on the sky[1]. Heat pollution by for example urban areas deteriorates the seeing of many observatory sites. Moreover, the expected (and already observed) increase in the frequency of extreme weather worldwide contributes to this same process of deteriorating observations.

Climate change engagement

Astronomy does have to look at its own climate impact, as it is for example estimated that the work-related greenhouse gas emissions of the average Australian astronomer in 2019 are equal to 19 equivalent tonnes of carbon dioxide per year[6]. Since the average Australian had a footprint equal to 15.4 ton per year in 2014[1], it is evident that the astronomical community needs to implement measures to minimize the carbon footprint.

There are three possible ways towards this minimization. The first of these is already quite well implemented, this is namely the application of remote observing [7]. As of yet, this is done through the use of astronomical surveys, the willingness to make data publicly available and the reuse of archival data. This saves a lot of unnecessary travelling towards remote observatories and hence diminishes the carbon footprint. Secondly, the community should make sure that the energy used both at observational and computing facilities is produced out of renewable energy sources. Next to that code efficiency has to be an important factor in projects involving many CPU hours. Lastly, an often proposed solution for science in general is organising remote video conferences to reduce air travel [6]. However, the importance of connections that are made with other people during conferences is too valuable to give up in favour of video conferences. Therefore, it might be a better idea to organise more regional conferences and have only a

[1] https://data.worldbank.org/indicator/en.atm.CO2e.pc

limited amount of bigger conferences so that the total amount of flight kilometres will be reduced.

Climate change communication is an important component of our collective effort. Since astronomy and climate science are related, astronomers could take up roles to teach the basics of climate science in for example introductory astronomy classes [6]. This will help create awareness from a knowledge-based principle, which is favourable over messages only ventilating the doom scenarios (of which knowledge is nowadays well spread anyway). Another channel which is strongly incorporated in astronomy and can be used for communicating climate science is outreach. Aided by planetaria and the corresponding visualization techniques astronomers might be able to teach a wide audience about the scientific basis of our climate.

References

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