Other Environmental Issues

POLLUTION OF GEOPHYSICAL SITES

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ABSTRACT Astronomy in all wavelengths is not the only science to suffer from various causes of pollution. Sites in which geophysical research is being conducted are also in danger due to a variety of external causes. Among them, the following are described and discussed in addition to electromagnetic nuisances that are common to geophysicists and astronomers: heat production, magnetic disturbances, artificial vibrations in seismic observatories, chemical pollution in atmospheric studies, signal jamming, vandalism and site modifications around automatic stations.

INTRODUCTION

All environmental sciences, just as astronomy, suffer from different sources of pollution. In some way, one may even say that the objectives of these sciences being to study the natural properties of the environment, any artificial modification of some of its components is a degradation of the expected scientific results. In this particular presentation, I shall restrict myself to various ways one can physically study the Earth. Among the many facets of geophysics, the most sensitive to man's activity are magnetism, seismology, aeronomy and various atmospheric studies.

Man produces a series of signals that interfere with the natural signals that one wishes to study. The most conspicuous is the one that are well known to astronomers: electromagnetic radiations in all possible wavelengths. But in addition, he creates heat constant or variable magnetic fields, vibrations of different frequencies, he emits various chemical species in the atmosphere and, last but not least, mechanically modifies or destroys natural or artificial structures. Let us quickly describe what are the effects of each of these human activities on geophysics and also in some cases on astronomy.

POLLUTION BY ELECTROMAGNETIC RADIATIONS

Spectroscopy and photometry are the main tools used in order to study from the ground higher layers of our atmosphere. The natural glow produced in the mesosphere and ionosphere is some times very bright (as in the case of aurorae) but it exists at all latitudes, though generally much fainter. This glow has to be separated from the natural light coming from the outer space - and this

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is easy - but also from the parasitic not well defined artificial air-glow. Because of the absence of precise localization of this natural glow, a characteristic that it shares with the artificial one, one may say that it is even more difficult than to astronomers to eliminate it, so that the requirements for a non-polluted sky light are in some way even more stringent in this case than in astronomy. This is one of the reasons why sounding techniques using lasers in the visible spectrum or radio-emitters are more efficient since they can use a very well defined range of wavelengths. However it is not always possible to choose unpolluted regions of the spectrum, since one seeks to excite atoms or molecules of the higher atmosphere that respond in definite frequencies that should remain unperturbed. So in general, the conditions of protection are akin to those necessary for astronomers, but are more stringent: and increase of 10% of the night glow may mean a disturbance of 30 to 40% of the observed signal. Low pressure sodium lighting is the best in the case of specific atom excitations studies (except when mesospheric sodium is studied).

HEAT PRODUCTION

A source of heat produces air turbulence in its immediate environment. Although this does not seem to hamper geophysical observations, it is worth mentioning it, because it may significantly degrade astronomical seeing. Heating produces a modification of the surface boundary layer: it is shifted to a higher altitude and tilted in the direction of the wind. The turbulent region becomes more important and develops above the instruments at higher altitudes than the normal few meters in good locations. The effect is an increase of the instability of the images and an inclination of the layers above the boundary layer, provoking a possible abnormal refraction, a catastrophic situation for astrometry. Another application is the effect on observations of variation of the vegetation cover around observatories.

MAGNETIC FIELDS

Most of the geophysical observatories use proton magnetometers that are sensitive to a fraction of a nanotesla. In addition, magneto-telluric crust sounders used to study the first few kilometers of the Earth crust are very sensitive to periodic variations of the electromagnetic field, in particular to industrial 50-60 Hertz frequencies. Let us give two examples.

- A direct current line of 1000 amperes, used in some railway lines, produces a magnetic field inversely proportional to the distance, whose value is still 2 nanotesla at 10 kilometers.

- Measurements around 400 kilovolt electric lines at 50 Hertz show that the amplitude of the magnetic field is still of the order of 1 nT at 2 kilometers. The geophysical observatory of Garchy, in the center of France, has been partially ruined for its magneto-telluric research by the construction of such a line 2 kilometers from the site.

These examples show the importance of magnetic quietness and the difficulty to obtain the necessary protection. The French national magnetic observatory moved three times since the beginning of the century and its presently not fully satisfactory location is to be fiercely protected since no potentially better site seems to exist in the whole country (in particular because of the complex structure of the natural local magnetic field).

VIBRATIONS

Seismographs are widely used to record the seismic activity all over the Earth. It is very important to have dense networks, especially in those regions where the chances of earthquakes or volcanic activity are large. This means that there must exist a large number of seismologic sites in the world. The faint propagated vibrations of a distant earthquake are also very important to recognize since they are precious indicators of the structure of the inner parts of our planet. This signal is perturbed both by natural and artificial microseismic activity that have very a different spectrum. While natural microseismicity is essentially produced by oceanic waves and has frequencies of 0.1 to 0.4 Hertz, industrial vibrations are in the range of 1 to 60 Hertz. Generally this basic noise diminishes the sensitivity of seismometers that have therefore to be protected, which is rather a difficult problem since their small size make them particularly sensitive to such high frequencies.

The amplitude of industrial noise is of course very variable. Measurements made at 1.5 and 3 km distance from a quarry equipped with stone-crushers gave mean amplitudes respectively of 0.06 and 0.025 micrometer with peaks that can be 10 times larger. Such amplitudes are easily detected by standard seismometers.

High precision gravimeters are also affected by such a noise, which is one of the main limitations in their sensitivity since it is practically impossible to filter out all mechanical vibrations in a dynamical range of 1000. As an example, the accuracy of the most sophisticated absolute gravimeter, situated at the Bureau International des Poids et Mesures, Sevres, France, is essentially limited by this noise. Let us also remark that a jitter of amplitude of 0.05 micrometer corresponds to a motion of the astrometric image in a four meter focal length instrument of 0".1. This is of the order of the precision of the instrument and is not acceptable. For the extreme cases of precise astrometric instruments or interferometers in visual wavelengths, the artificial seismic noise should not have amplitudes larger than 0.02 micrometer.

CHEMICAL COMPOSITION OF THE AIR

Studies of the chemical composition of the atmosphere have a great importance particularly in climatology. It is necessary to evaluate the global composition of the whole Earth atmosphere or at least of very large regions. For this reason the stations monitoring the concentration of minor components must be particularly free of regional deviations due to local industrial or agricultural conditions. It is well known, for example, that the problem of the global content of carbon dioxide is a fundamental parameter in climatology. But there are many other minor constituents for which the same knowledge is important for ecological as well as for climatological reasons: ozone, SO2, NO and NO2, NH3, CO, hydrocarbon composites, etc... It is clear that this has to be measured in places where the presence of local providers of these gases is banned. This may be difficult, since highways are one of the main providers of CO, CO2, SO2 and hydrocarbon composites (various oil components and incomplete burning).

Of course, similar stations have to be installed in industrial and other polluted areas in order to help controlling the air composition under agreed upon norms. But for scientific purposes, when the global trend in atmospheric composition is the objective, the uncontaminated sites that exist should be systematically protected, particularly because, in order to be significant, measurements must remain comparable during many decades.

VANDALISM AND SITE MODIFICATIONS

There exists another very particular nuisance for some types of geophysical stations that has to be seriously accounted for: man. In many geophysical domains, it is necessary to have a great number of stations recording geophysical parameters and because they are many, they have to be automatic. Among these, one may quote :

- seismometers as part of seismic networks, in particular in sensitive regions,
- seismometers, chemical composition analyzers (presence of sulfur components) of the air, acoustic recorders, clinometers, etc... around active or potentially active volcanoes,
- magnetometers used to monitor the evolution of the Earth magnetic field and its local disturbances,
- gravimeters, horizontal pendulums and clinometers for Earth tides, generally set up in caves,
- atmospheric composition monitors in sensitive areas,
- geodetic fiducial point markers.

These stations are generally unguarded and vandalism has been recorded in many cases. But in addition simple modifications of the close environment not directed against the station may change seriously the results of magnetic and gravimetric measurements in a systematic way as for instance the construction of a wall or the accumulation of material whether metallic or not in an immediate vicinity. Similarly, modifications in the radio-electric environment with new radio stations or the installation of a high voltage electric transport line have in many occasions disturbed seriously the automatic transmission of records.

CONCLUSIONS

From the examples given in this presentation, several conclusions ought to be derived.

1. Astronomy is not the only science to be endangered by light pollution and radio interference. In several domains like aeronomy and outer atmosphere studies, similar complaints exist. Although geophysicists have not yet made their voice much heard (they are not yet as conscious of the danger as astronomers are), they are natural allies and their statements should be added to astronomers' complaints and may help in obtaining action against these nuisances.

2. Geophysicists have also to suffer from a number of other types of nuisances. Some of these actually are also lessening the observational capabilities

of astronomical observatories. In our fight to protect our observatories, let us not forget heat, vibrations and chemical air pollution. In some cases it might be just as difficult to obtain protection against them as against sky-glow and it may be desirable to try to obtain a package deal for all.

3. Geophysicists have, in addition, particular nuisances that seemingly do not affect astronomers, such as magnetic or electric field disturbances and most of the cases of chemical pollution. They also need protection of their automatic stations. Again, it may be of common interest to work hand in hand in order to obtain that the study of our Universe, planet Earth included, be considered as a major issue for man worthy to be protected as are human art productions, disappearing animals or special natural landscapes.

REFERENCES

Problems connected with the protection of geophysical sites are described in detail in "Rapport du groupe de travail sur la protection des observatoires astronomiques et geophysiques", November 1984, Academie des Sciences, 23 quai Conti, F-75006 Paris, France.