Remote sensing of earth objects from terrestrial photo imagery

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Abstract - *Ground based remote sensing of earth and atmosphere is an affordable and inexpensive method for observations that allows for great spatial and temporal resolution of the obtained data. Conventional terrestrial photography may be used as a practical remote sensing tool for the estimation of temporal and spatial variations of surface albedo on glacier and snow-covered mountain areas. We are interested in the possibility of evaluating the optical properties of clouds and atmosphere by visible images taken at ground level. Remote sensing of the earth objects either from the space or from ground-based observations encounters the problem of accounting for the influence of the atmosphere on the obtained data. Here we present a technique for evaluation of the transmittance of the atmosphere based on the attenuation of the contrast. The estimates of the optical parameters of the permanent gases are obtained using a model that also involves data on the horizontal visibility and other meteorological parameters. The contribution of the atmospheric constituents is additive, which allows for determining the current value of the volume scattering coefficient due to the presence of aerosols. This parameter is proportional to the concentration of aerosols either of natural or manmade origin. Thus, the considered tool is also useful for ecological monitoring.*

The use of terrestrial photography is an economic approach, complementary to satellite imagery. The combination of both techniques, satellite and ground-based photography, may enhance the quality of the satellite data (Corripio, 2004). The main problem in such an approach is the need to take into account the effects of scattering and extinction of radiation by the atmosphere. Here we study the possibility of determining the optical properties of atmosphere and clouds using ground based visible images.

The light that reaches detectors for remote sensing of the earth comes not directly from its sources but indirectly by means of scattering by atmosphere. Scattering is the process by which a elemental volume of matter in the path of an electromagnetic wave continuously abstracts energy from the incident wave, and reradiates that energy in all directions. Removing flux from a given beam of light leads to attenuation of the radiation due to the scattering. The amount of attenuation is determined by the optical thickness of the medium, which for a homogeneous path is the product of the total volume scattering coefficient and the path length. The transmitted radiation decreases exponentially with the optical thickness of the medium. Horizontal paths in the atmosphere are usually considered as homogeneous. For a horizontal line of sight, it is shown that the contrast between two adjacent objects decreases exponentially with the optical thickness of the atmosphere (McCartney, 1986). If C_o is the contrast seen close at hand, the apparent contrast C_R at distance R is attenuated to extent depending on the volume scattering coefficient of the atmosphere β:

$$C_R = C_0 \exp(-\beta R)$$

Pictures 1, 2 and 3 were taken in time interval of one hour on 22 February 2006 when the atmospheric conditions change fast. The mountains and the more distant high buildings are seen in a different way because of the current state of the atmosphere. In the first picture the Lozen mountain is not visible at all. In Picture 4 that is taken on 6 March 2006 under relatively clear atmosphere, the more distant Plana mountain is already outlined. Consequently, the images of appropriately chosen objects at known distance can be used for determining the optical properties of the atmosphere during the measurements. Because of the automatic regime of the available digital camera, settings as shutter-speed, aperture value and so on couldn't be controlled. The poor dynamic range of the amateur camera is smaller than the dynamic range of the scenes and some shadow and highlight details are lost. At this time a simple correspondence between the contrast in the image and the optical thickness of the atmosphere is not established.

In order to determine the optical properties of the atmosphere needed for including atmospheric corrections in remote sensing data we use the practical relation between the volume scattering coefficient and horizontal meteorological visibility: $\beta = 3.912/V$ (McCartney, 1986). In this reference we also find that the total volume coefficient of molecular scattering for the visible spectral range represented by the wavelength 0.55 μm for standard atmospheric conditions at sea level (temperature T_o=288.15^o K, pressure P_o=1013.25 hPa) can be taken 0.012 km^{-1}. After the necessary corrections for temperature and pressure at ground level according to the relationship: $\beta_m(0) = 0.012\frac{P}{P_\circ}\frac{T_\circ}{T}$, we find the molecular scattering coefficient of the permanent gases. The total volume scattering coefficient β of the atmosphere is the sum of the corresponding quantities for the atmospheric constituents - molecules and aerosols. Excluding the contribution of the molecular component β_m we obtain the total volume scattering coefficient of aerosols. The changes of the visibility are due mainly to the particular content of aerosols near to the ground level. The larger the concentration of aerosols, the lower the contrast, and the visibility is on the decrease. The needed meteorological parameters (visibility, pressure, temperature and so on) are taken from on-line data about the city of Sofia at website: http://bulgarian.wunderground.com/global/stations/15614.html. The visibility in the Pictures 1 - 4 is 1.6, 2.4, 7 and 10 km, correspondingly.

In general the directions of observations both from satellites and from earth surface are slant with horizontal and vertical paths being special cases. The corrections for altitude are made from model calculations referring to exponentially distributed atmosphere with molecular density scale height H_ρ equal to 9,3 km and that for aerosols taken as 1.2 km. Now the optical thickness of the atmospheric layer from ground level to altitude h is expressed by:

$$T_a(0,h) = \beta(0)\int_0^h \exp\left(-\frac{h}{H_\rho}\right)dh\,.$$

This approach is applied for atmospheric corrections in determination of the cloud optical thickness, which can be expressed by the measured brightness of the cloud base L_c in direction to the sun in the following way:

$$T = \ln\left(L_0/k\pi L_c\right) - \sec z_s T_a\,,$$

where the reference brightness L_o and constant k are determined from the energetic calibration of the camera (Bakalova, 2006), T_a is the vertical optical thickness of the entire atmosphere, and z_S is the zenith angle of the sun during the measurements. As a result we obtain that the optical thickness of the cloud in Picture 1 is 5.6 while in Picture 2 it is 7.7, and in Picture 3 the cloud optical thickness increases to 10.3. As far as the measurements are performed in one day, the change of the cloud optical thickness is indicative of the cloud evolution – the altitude of cloud base decreased.

Conclusions – In the present study the possibility of evaluating the optical properties of atmosphere and clouds from visible images taken at earth surface is discussed. A practical method for including atmospheric corrections in remote sensing data both from satellite and terrestrial measurements is proposed. The importance of atmospheric corrections in investigation of earth objects is illustrated by determination of cloud optical thickness. For example, the optical thickness of the atmosphere in Picture 1 is 5.4, i.e. completely comparable with the measured cloud optical thickness. While the natural aerosols give predominantly neutral spectral effects, some air pollutants may change the colour of the scattered light. Regular observation and detection of changes in brightness and colour contrast by means of visible images may be a useful tool for ecological monitoring.

Picture 1. Visibility 1.6 km – the distant high buildings are hardly discernable.

Picture 2. Visibility 2.4 km – the distant high buildings are shown clearly.

Picture 3. Visibility 7 km – the Lozen mountain appears behind the buildings

Picture 4.Visibility 10 km – the foot of the Plana mountain are also clear outlined

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