Lidars Combined with Sun Photometers Used for Atmospheric Correction of Earth Observation Images

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ABSTRACT

A new atmospheric correction method of earth observation images based on the combination of lidar data, sun photometer data and satellite data is proposed in this paper. Images of optical depth of the interested area processed by the in-site data and radiative transfer model is presented. Also issues to approach the final goal of this new atmospheric correction method are discussed.

1. INTRODUCTION

The earth observation Images by satellite optical sensors in the visible to inferred region are from the solar radiance reflected at the Earth's surface and scattered by the atmosphere. In this solar spectrum region, atmospheric gases and aerosols, as well as clouds, scatter and absorb solar radiation. Therefore, they modulate the radiance reflected from the target by attenuating it and introducing into the field of view radiation from solar radiance scattered in the atmosphere. As the ground-truth is the final goal of the earth observation activities, the remotely sensed images must be carefully corrected for atmospheric effects. These combined atmospheric effects vary in time and space, and the wavelength dependence causes raising difficulties to the atmospheric correction.

Numerous methods and algorithms have been proposed by various authors for moving the atmospheric effects from the earth observation images. The most commonly used correction procedures are based on the output of radiative transfer model, such as LOWTRAN, MORTRAN and 6S computer codes that provide atmospheric spectral radiance scattered by the atmosphere [1,2]. However, the accuracy of the output of these models depends on input atmospheric parameters. There is considerable evidence that the resulting atmospheric correction is more accurate by field measurement of the atmospheric parameters than by other means [3].

In recognizing of the above situation, we propose in this paper, that lidar and sun photometer combination is used to field-measure the atmospheric parameters that are important to the 6S model. And the field measured atmospheric parameters are used for the atmospheric corrections of the images taking during the satellite fly-over.

2. ATMOSPHERIC CORRECTION OF THE SATELLITE IMAGE

Assuming that E_0 is the radiation energy emitted or reflected from the sun by a target on the ground, and E_S is the radiation energy received by the sensor on the satellite from the target, we have,

$$E_S = E_0 \exp[-T(s,t,\lambda)] \qquad (1)$$

where, T(s,t, λ) is the atmospheric transmission between the satellite and the target which is determined by the scattering and absorption of the atmospheric constitutes, and is strongly space, time and wavelength dependant.

In the case of the target radiation energy is reflected from sunlight, the received radiation energy by the satellite sensor, E_S, should be,

$$E_S = E_0 \exp[-T(s,t,\lambda)] + E_A(s,t,\lambda) \qquad (2)$$

the last term E_A(s,t, λ) in the equation is the radiation energy from the sun scattered by the atmosphere. E_A(s,t, λ) appears as the background noise to the satellite image and is also space, time and wavelength dependant.

Form the above analysis, we could see that, the satellite image, as compared with its ground-truth, is not only attenuated in its intensity, but is also contaminated by the ground noise. These combined effects will greatly reduce the contrast and accuracy of the satellite image. Therefore, if the detailed information of the target, especially its biophysical properties, needed to be recovered from the satellite image, a proper correction to remove these atmospheric effects has to be conducted.

The atmosphere transmission T(s,t, λ) can be further expressed as,

$$T(s,t,\lambda) = \exp[-\tau(s,t,\lambda)] \quad (3)$$

where, τ (s,t, λ) is the optical depth of the atmosphere between target and satellite.

It is obvious that the atmospheric effects can be properly corrected only if the optical depth of the atmosphere is known accurately. In the visible and near to middle inferred optical range, the optical depth of atmosphere is mainly caused by the aerosol extinction and the ozone and water vapor absorption, with the first one is usually the dominant contributor. This leads to that, at least, the scattering and absorption properties of the aerosols and the contents of the ozone and water vapor of the atmosphere have to be measured in the field. Which allows an effective correction of atmosphere effects to be conducted in our proposed method.

3. LIDAR DESIGN AND DEVELOPMENT

To meet the requirements of multiple atmospheric parameter measurement, a multi-function lidar configuration is considered. Shown in Figure 1 is the optical layout of a multi-function lidar that we are planning to develop. Three transmitting wavelengths and six receiving channels will be its goal version. The wavelengths of 1064nm(~300mJ), 532nm(~200mJ) and 266nm(~100mJ) will be used for a multi-wavelength Mie scattering, and the wavelength of 266nm is also used to excite the O_2, N_2 and water vapor rotation-vibration Raman scattering. While the H_2O Raman at 294.6nm is used to measure water vapor content as a traditional Raman lidar [4], the O_2 and N_2 Raman at 277.5nm and 283.6nm, respectively, will be used to infer the ozone concentration working as a Raman/DIAL lidar. As the Raman wavelengths are in the solar blind region, the

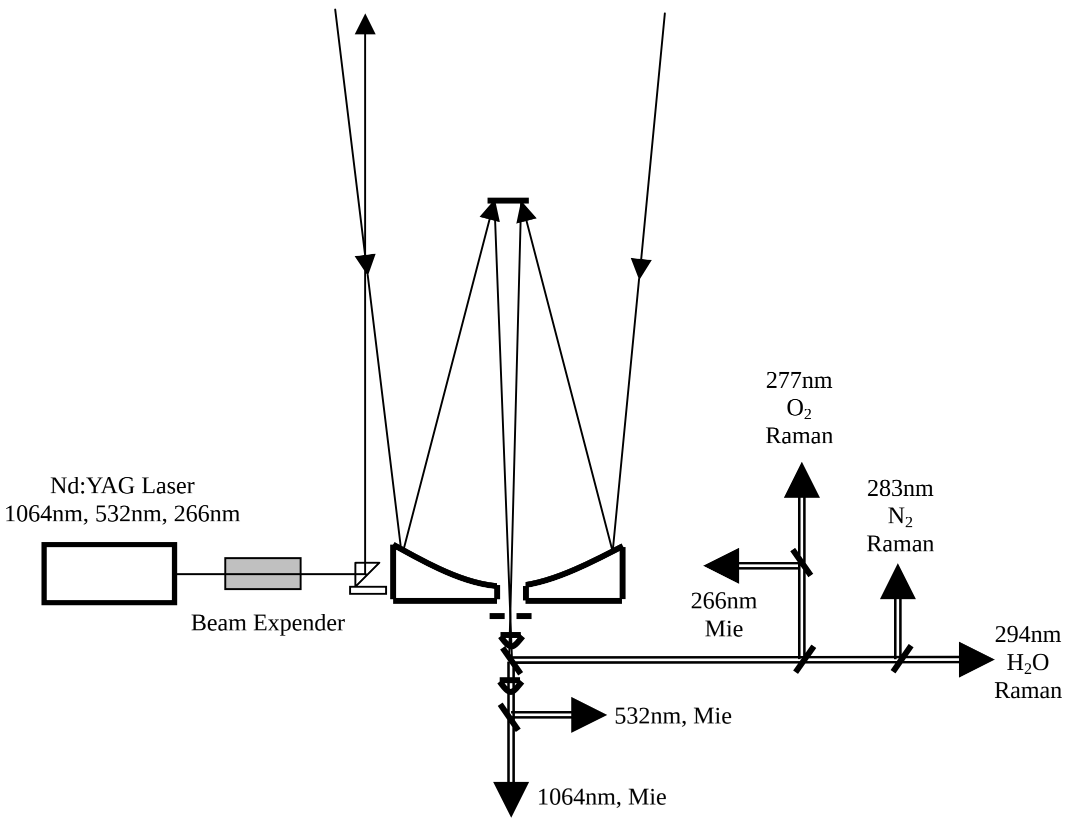

Figure 1. Optical Layout of Multi-Function Lidar

daytime operation of the Raman version can be expected. The planned detection range for the two Raman versions is in the boundary layer and the lower troposphere, and the Mie version could cover the troposphere. The receiving telescope will be the reflective type with the primary mirror diameter of 400mm. The PMTs will be used in all channels, except for the 1064nm where an enhanced APD detector will be used. Photon counting will be used in all three Raman channels, and the three Mie channels will work in the analog mode.

Figure 2. Mobile Scanning Lidar System Developed at Wuhan University

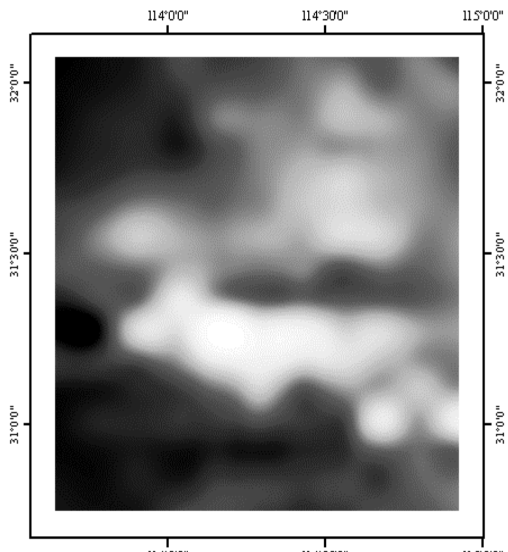

Figure 3. Aerosol optical depth distribution retrieved from discussed method

As the multi-function lidar has a relative complicated structure, the fixed vertical working mode is preferred. To compensate this inconvenient and also to develop a lidar equipment in our laboratory faster, we have constructed a simpler scanning Mie lidar for mobile applications. A photo of this lidar in Lab is shown in Figure 2. It is single wavelength (532nm, 200mJ) and a single Mie channel version, but a N_2 Raman channel at 607nm is adding in the lidar to help the Mie data retrival. The lidar will be installed in a minivan with an automatic sun photometer. By measuring the atmospheric optical depth and aerosol scattering using lidar and sun photometer around our region, the atmospheric correction of the satellite image fly-over can be performed on the basis of the field measurements of the atmospheric parameters.

4. ANALYSIS METHOD

Here, local meteorological data was applied. In this method, at first, we re-samples the MODIS 10km*10km resolution aerosol optical depth distribution to 5km*5km resolution. The second step is to calculate the difference between in-site data and MODIS data, and the difference data applied poly-fitting to obtain a curve equation. Finally, recalculate the aerosol optical depth values and feeds them into an improved 6S code for MODIS image atmospheric correction.

The research region lies in N29º58' ～ 31º22' and E113º41'～115º05', where the average altitude is about 0.05km. The inversion pixel resolution is 1km*1km. As the region lies in inner land of China, far away from the sea, so select continental aerosol model and urban aerosol model, respectively, to derive the aerosol optical thickness. At the same time, the observing time is from November 2005 to February 2006, so selects the mid-latitude winter atmospheric model. Figure 3 shows the distribution of aerosol optical thickness retrieved from in-site data and MODIS data.

5. CONCLUSION

In this paper, a new atmospheric correction method: combine lidar and sun photometer data into radiative transfer model, is introduced. The primary atmospheric correction system development is discussed. The development plans are presented.

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