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EXTRACTION OF OZONE AND CHLOROPHYLL-A DISTRIBUTION FROM AVIRIS DATA

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Data Basis and Preprocessing

The potential of airborne imaging spectrometry for assessing and monitoring natural resources is studied. Therefore, an AVIRIS scene of the NASA's MacEurope'91 campaign - acquired in Central Switzerland - is used. The test site consists of an urban area, the Lake Zug with its surrounding fields, the Rigi mountain in the center of the test site, and the Lake of Four Cantons. The region is covered by the AVIRIS flight #910705, run 6 and 7 of the NASA ER–2 aircraft resulting in an average nominal pixel size of about 18 m.

Simultaneous to the ER–2 overflight spectroradiometric measurements have been taken in various locations.Preselected reference targets were measured in the field with a GER Mark V spectroradiometer, and radiance measurements were taken on the lake using a Li–Cor LI 1800UW specroradiometer below and above the water surface [Itten et al., 1992].

A comprehensive meteorological data set was obtained by joining the POLLUMET experiment which carried out measurements to investigate the summer smog in Switzerland on the same day [Neininger, 1991].

The quality assessment for the actual data set can be found in detail in Meyer et al. [1993]. A parametric approach calculating the location of the airplane was used to simulate the observation geometry. This parametric preprocessing procedure, which takes care of effects of flight line and attitude variations as well as the pixel-by-pixel topographic corrections is described in Meyer, [1994].

Atmospheric Correction

The atmospheric correction is based on the radiative transfer code MODTRAN2. The correction itself is performed using a model proposed by Woodham [Woodham, 1985] and a pixel–by–pixel approach. The atmospheric profiles used, have been taken from radiosonde data. Where no data were available the standard midlatitude summer profile was used.

Another important factor was to estimate the visibility. The values obtained from the Swiss Meteorological network, and the estimations made in the field vary from 2–14 km for July 5th. Since small changes of the visibility have a siginficant impact on the output of the calculation in the radiative transfer code, a method to extract the visibility from AVIRIS data is tested. Two AVIRIS channels (53 / 71; 872 nm / 1045 nm) are selected. In these bands, the total attenuation of the radiance depends only on aerosol scattering. The meteorological visibility from this approach is estimated to be 5 km (eq. horizontal visibility of 3.85 km). The 5S code restricts however the horizontal visibility to 5 km, therefore this approach will have to be evaluated further also considering adjacency effects.

The pixel–by–pixel approach bases not on the reconstruction of the path through the atmosphere but relies on modelling the possible maximum and mininimum radiance at the sensor. Assuming that the objetct's reflectance is linear with the received radiance at the sensor, we did run the radiative transfer code twice for each pixel [Veraguth, 1994].

A comparison of two different corrections (visibilitiy decreasing with altitude and constant within the inversion layer) in a corrected AVIRIS scene using MODTRAN2 is shown in figure 1.

Extraction of Ozone

Ozone absorbs particulary in the ultraviolet and visible range of the spectrum. Hence, spectrometry is expected to be a promising tool to extract the ozone contents in a given air column by using the correlation between cumulative trace gas amount and absorption strength in the sensor channels located within the absorption bands. The following investigations were initiated to detect tropospheric ozone in the Chappuis-Band (500 - 700 nm), based on the POLLUMET data set, the AVIRIS specifications, and MODTRAN2 simulations.

Normally, the abundance of water vapor from imaging spectrometry data is usually determined by ratio methods [Frouin, 1990; Bruegge, 1990]. Two or more channels are combined to yield the total column water vapor abundance. The same method can be used to detect ozone.

First, the best channels within the Chappuis-Band have to be determined. It must be discriminated between 'Reference channels' which should not be affected by any absorbing gases including ozone and, on the other hand, 'Measurement channels' which should be sensitive to the change of ozone amount and not be disturbed by other absorbing gases. An empirical comparison of MODTRAN2 transmission calculations in the AVIRIS channels yielded a number of suitable AVIRIS ozone channels:

Measurement channel numbers:	22 (608nm), 23 (618 nm) ,17 (558 nm), 16 (549 nm)
Reference channel numbers:	1-12(< 515 nm), 28 (667 nm), 29 (677 nm), 40 (746 nm)

These selected channels could be combined both by three known splitting window techniques and by new approaches. To date, the following methods are used: Ratio of two channels [King, 1992], continuum interpolated band ratio (CIBR) using 2 reference channels [Bruegge, 1990] and the Narrow/Wide technique [Frouin, 1990] with two channels of different bandwith centered at the same wavelength. Two new approaches are introduced: The first is a quadratic interpolated band ratio (QIBR) which is analogous to the CIBR but which uses three reference channels. The second is a statistical approach (TOTAL) by ratioing several measurement channels by the same number of reference channels. Each of these five methods can be tested with different channel combinations, using the reference and measurement channels.

From radiosonde data and other POLLUMET in-situ measurements a reference atmosphere for July 5th (1991) was modelled, ending up in a complete profile of pressure, temperature, water vapor and ozone. The total ozone column in the different atmospheric layers was integrated with height and compared to standard atmospheric profiles. None of them represented the tropospheric ozone amounts in a satisfying manner; the ozone column was nearly twice as high as guessed by the tropical or the midlatidude summer model. This shows, that tropospheric ozone had a bigger influence on the total ozone signal than assumed.

In the evaluation of the methods, the influence of disturbing factors and the sensitivity to varying amounts of ozone were investigated. For this purpose the amount of the respective elements (aerosols, water vapor and ozone) were varied systematically in the atmospheric reference profiles. MODTRAN2 allows to simulate the corresponding radiance at the sensor channels and all the methods could be applied to the simulated radiance. A good sensitivity to ozone variations is obtained by the CIBR, the channel ratio and the TOTAL methods. The Narrow/Wide technique is only half as sensitive to ozone as the others. Changing visibility is proportional to the aerosol contents and affects especially the TOTAL and some of the CIBR-Methods. The Narrow/Wide and QIBR methods are not influenced that much. If tropospheric humidity is doubled, the influence on all investigated methods is only about one fifth of the change that is due to varying aerosol optical thickness. This evaluation step led to the elimination of most of the methods. The remaining ones were quantified using the ozone variation procedure described above. An absolute quantification was only possible for one CIBR (channels 10,28 and 22) and one Narrow/Wide ratio (channels 10, 28, 17 and 22). All the others yielded irrealistic high or low ozone contents. Finally the CIBR was selected because of the better sensitivity to ozone variations. However, the application to the AVIRIS scene (see figure 2) was only possible over water, which is due to the high sensitivity to changing ground response and the very low absorption in the Chappuis Band. The error which must be taken into account considering the disturbing factors is still about +/- 30% .

Extraction of Chlorophyll-a

During the overflight of the ER–2 aircraft, a wealth of limnologic measurements has been collected on the Lake Zug. For the results presented here, the measurements of chlorophyll concentrations using a two–filter method in various depths [Schanz, 1982] and the use of the Li–Cor 1800UW underwater spectroradiometer are of particular interest. Downwelling and upwelling irradiance measurements have been taken underwater as well as incident global radiation. The photosynthetically active radiation measurements of the solar irradiance are used to calculate the absorption coefficients.

The ER–2 overflight on July 5th 1991 was not during an algae bloom, hence very low chlorophyll concentrations were expected. In a first processing step, the AVIRIS radiance data are converted in upwelling irradiance data just below the water surface. Using MODTRAN2, the path scattered radiance was subtracted from the AVIRIS data and divided by the atmospheric transmission. Then the AVIRIS signal was transformed in upwelling radiance just unter the water surface. In the last step, the radiance had to be converted into irradiance data using a conversion proposed by Kirk [1983].

Different combinations of channels of the AVIRIS have been selected to extract chlorophyll-a. A CIBR method using the AVIRIS channels 26 / 29 / 31 (647 nm / 677 nm / 697 nm) shows promising results [Kurer, 1994] (see figure 3).

Conclusion

It is expected, that the presented applications to extract ozone and chlorophyll-a can be extended to many more environmentally sensitive parameters. Some efforts still have to be made in respect to adjacency effects and improvements of the atmospheric correction.

Acknowledgements

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References

C.J. Bruegge, J.E. Conel, J.S. Margolis, R.O. Green, G. Toon, V. Carrère, R.G. Holm and G. Hoover, "In-situ Atmospheric Water-Vapor Retrieval in Support of AVIRIS Validation." SPIE Vol. 1298, Imaging Spectroscopy of the Terrestrial Environment, pp 150 - 163, 1990

R. Frouin, P.–Y. Deschamps and P. Lecomte, "Determination from Space of Atmospheric Total Water Vapor Amounts by Differential Absorption near 940 nm: Theory and Airborne Verification". Journal of Applied Meteorology, Vol. 29, American Meteorological Society, pp 448 - 459, 1990

K.I. Itten, P. Meyer, K. Staenz, T. Kellenberger, and M. Schaepman, "Evaluation of AVIRISwiss'91 Campaign Data", In Summaries of the Third Annual JPL Airborne Geoscience Workshop June 1–5, 1992, Vol. 1 AVIRIS Workshop, ed. R. Green, Pasadena, pp. 108–111, June 1–5, 1992

M.D. King, Y.J. Kaufmann, W.P. Menzel and D. Tanré, "Remote Sensing of Cloud, Aerosol, and Water Vapor Properties from the Moderate Resolution Imaging Spectrometer (MODIS)." IEEE Transactions on Geoscience and Remote Sensing, Vol. 30, No. 1, New York, pp 2 - 27, 1990

J.T.O. Kirk, "Light and photosynthesis in aquatic ecosystems", Cambridge University Press, Cambridge, GB, 1983

U. Kurer, "Bestimmung der Chlorophyllkonzentration im Zugersee anhand von AVIRIS–Bildspektrometriedaten", Masters Thesis, Department of Geography, University of Zurich, p. 122, Zurich, 1994

P. Meyer, "A Parametric Approach for the Geocoding of Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Data in Rugged Terrain", Remote Sens. Environ., Vol. 48, pp. 1–25, 1994

P. Meyer, R.O. Green, and T.G. Chrien, "Extraction of Auxiliary Data from AVIRIS Distribution Tape for Spectral, Radiometric, and Geometric Quality Assessment ", In Proc. of the Fourth Annual JPL Airborne Geoscience Workshop, ed. R. Green, Washington, 1993

B. Neininger, "Field Phase Report der POLLUMET–IOP's–91", Project–Report, POLLUMET, Federal Instiute of Technology, Zurich, Switzerland, 1991

F. Schanz, "A fluormetric method of determining chlorophyll a and phaeophytin a concentrations", Arch. Hydrobiol. Beih. Ergebn. Limnol., Vol. 16, Stuttgart, Germany, pp. 91–100, 1982

D. Schläpfer, "Bildspektrometrie atmosphärischer Spurengase", Masters Thesis, Department of Geography, University of Zurich, p. 116, Zurich, 1994

S. Veraguth, "Die atmosphärische Korrektur von AVIRIS–Daten", Masters Thesis, Department of Geography, University of Zurich, p. 117, Zurich, 1994

R.J. Woodham and T.K. Lee, "Photometric Method for Radiometric Correction of Multispectral Scanner Data", In Canadian Journal for Remote Sensing, Vol. 8, No. 2, Ottawa, Canada, 1985

Figures

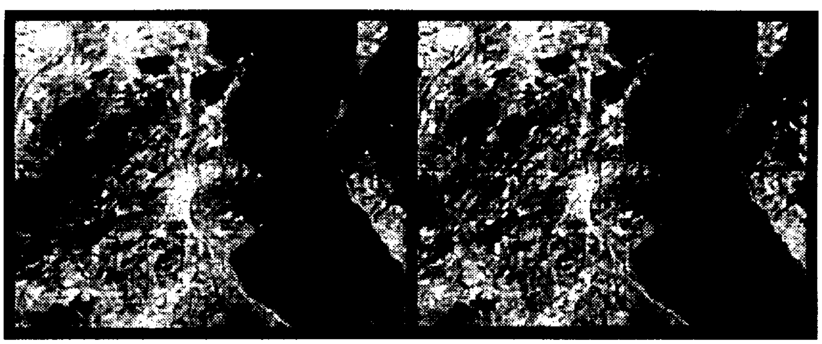

Figure 1: Atmospheric correction results by modelling the visibility decreasing with altitude (left), and constant within the inversion layer (right)

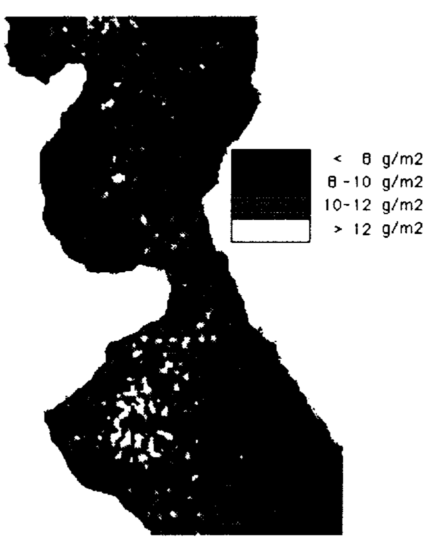

Figure 2: Total column tropospheric ozone distribution over Lake Zug

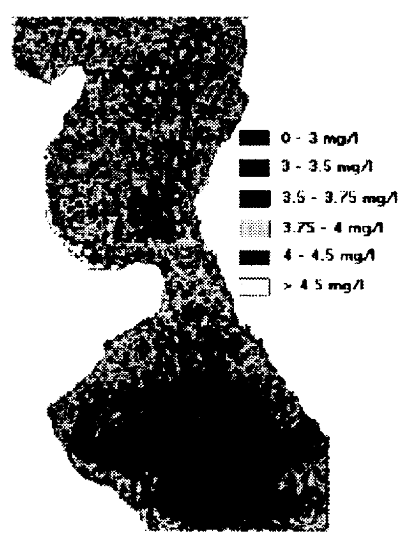

Figure 3: Chlorophyll-a distribution in Lake Zug