The Importance of Early Morning Local Overpass Times for BRDF Retrieval, Modeling of Spectral Reflectance and *fAPAR* Estimation

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Abstract - Blueprints for near-future moderate resolution satellite-borne sensor systems such as the VIIRS (Visible Infrared Imaging Radiometer Suite) sensor on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) do not include plans to ensure that land surface observations are made from an early morning (AM) orbit (07:30-08:30 local time) as well as in the afternoon (PM), and current spaceborne sensors designed to sample the bidirectional reflectance distribution function (BRDF) achieve this by off-nadir viewing with a small range of solar zenith angles (SZA). This may limit the utility of current and future systems in important Earth observation applications such as estimating the fraction of absorbed photosynthetically-active radiation (*fAPAR*). The lack of observations at 50° < SZA < 70° may only be partly offset by the 09:30 orbit foreseen for EUMETSAT's METOP satellite, to carry a third generation Advanced Very High Resolution Radiometer (AVHRR). Here existing AVHRR data are used to examine the likely impact of inverting models with observations at a small range of sun angles.

INTRODUCTION

Spectral reflectance values modeled using linear, semi-empirical, kernel-driven (LiSK) bidirectional reflectance distribution function (BRDF) models (amongst others) are subject to certain levels of noise depending upon the number and angular distribution of observations used in calibrating the model [1]. It has been shown from first principles that even if the physics of such a model are perfect, when adjusted against observations from a unique or a small range of solar zenith angles, model parameters and reflectance values are likely to contain an important error component [2]. It is useful to test this hypothesis with real satellite data, so that the extent of noise amplification and its likely impact on applications such as *fAPAR* retrieval can be appreciated. In [3] it is shown that geometries close to the sun at zenith and/or nadir viewing are undesirable for *fAPAR* retrieval since these maximize the contribution of the soil background relative to the canopy (an effect easy to visualize for semiarid environments). In [4] the sensitivity of the Carnegie-Stanford-Ames carbon cycle model's Net Primary Productivity (NPP) algorithm to foliage self-shading, solar and viewing geometry and aerosols was investigated (using afternoon orbit sun-target-sensor geometries taken from the Pathfinder-2 AVHRR Land data set) and it was shown that angular corrections must account for variations in both viewing and solar angles simultaneously and that for equatorial regions erroneous decreases in estimated monthly NPP of up to 45% are obtained as a result of variations in illumination and view angles and up to 86% as a result of varying sun-view geometry and aerosols combined. The question of accurate BRDF parameter retrieval thus has direct implications for the design and performance of future spaceborne moderate resolution remote sensing systems such as the NPOESS [5], slated for launch in 2005.

METHOD

The HRPT / LAC data set collected and processed for the NASA Earth Observing System Prototype validation Exercise (PROVE) campaign for the period May 10 – June 3 1997 was used to retrieve estimates of the BRDF over central-southern New Mexico and parts of Chihuahua, Mexico, by inverting a LiSK model composed of isotropic, LiSparseMODIS and RossThin kernels [6]. The reflectance estimates were derived from 17 orbits over a 25-day period at the end of dry season. The inverse matrix which provides the solution to the inversion problem was used to obtain noise inflation factors ("weights of determination"; see [1]) for reflectance predicted at viewing angles in the range ±60° for solar zenith angles of 0°, 30° and 60° in the principal plane. A reflectance image was modeled with a view zenith angle of 45° and a SZA of 60° in the principal plane, suggested as optimal for retrieval of the fraction of *fAPAR* in [3]. Noise is expected to be important where these factors exceed unity and where a much larger value is obtained the parameter or derived reflectance value is unlikely to be reliable.

RESULTS AND DISCUSSION

Typical results for a selected site in a grassland-shrubland transition zone are shown in Figure 1. This shows that when only PM orbits are available noise amplification is important at many geometries and especially for reflectance modeled at high solar zenith angles with weight of determination values > 10 for all viewing angles. When the PM data are augmented with data from a single early morning orbit (but maintaining the same total number of observations) there is a notable decrease in noise amplification, although the weight of determination is above unity for some geometries, particularly for reflectance modeled for a 60° solar zenith angle. When a larger number of morning scenes is available there is little noise amplification except at a single very extreme geometry (view zeniths > 50° at the solar zenith of 60°). This is because the target surface is viewed from many different directions and at both low and high solar zenith angles so extrapolation error is minimized. The implications for modeling reflectance at optimal geometries over large areas are that where a good angular sampling in both the solar and view zenith domains is not obtained, noise amplification will almost certainly pose an important problem.

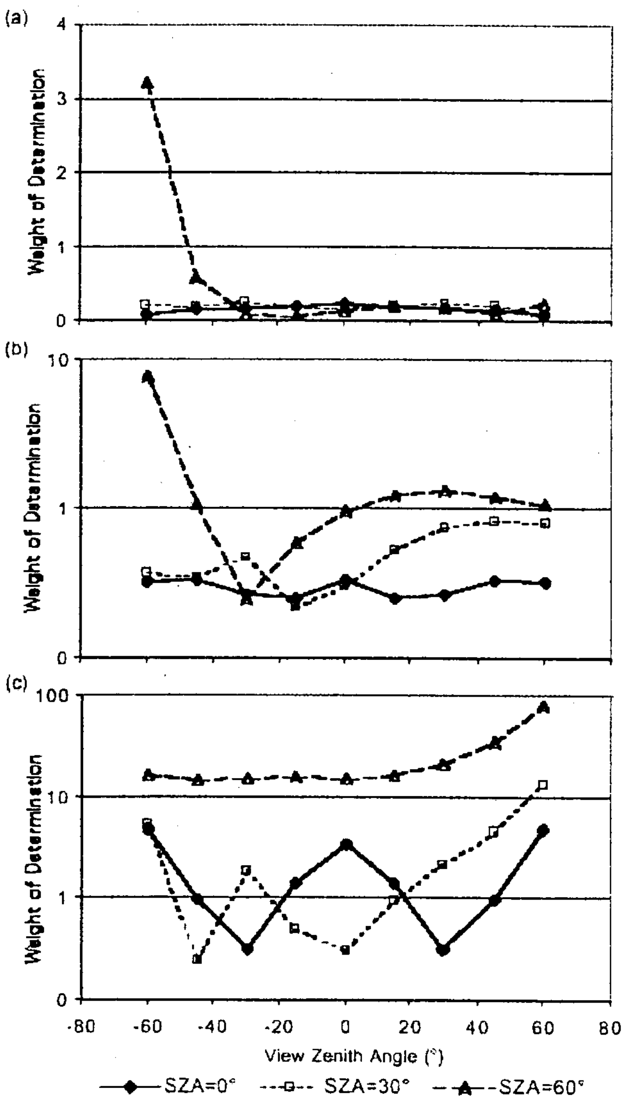

Fig. 1. Noise amplification in modeled principal plane visible channel reflectance over a grassland-shrubland transition zone: (a) 6 PM and 8 AM orbits (b) 5 PM and 1 AM orbit (c) 6 PM orbits. SZA=Solar Zenith Angle (°)

The results also show that even if weight of determination values are generally low (here with a mode of 0.19 but with a mean of 4.5 and standard deviation of 7.2), differences in the relative level of noise can impact on the spatial integrity of reflectance and parameter images. The reliability of the modeled values will thus vary from location to location as cloud and cloud shadow selectively remove observations, altering the angular sampling in unpredictable ways. Figure 2 shows the impact of these reductions on noise inflation: the lower numbers of observations correlate spatially with noise inflation and elevation but not with Root-Mean-Square-Error (RMSE) between modeled and observed reflectance. Including observations from an AM sensor presents some challenges: with long path lengths retrieval of surface reflectance ("atmospheric correction") is more sensitive to errors in the estimation of atmospheric parameters and particularly aerosol loadings; second, cloud shadows account for a larger proportion of the scene since they are not hidden underneath the clouds, although for semiarid regions this is offset by the lower probability of clouds in the early morning.

CONCLUSIONS

This study shows the potential extent of noise amplification in reflectance modeled at various geometries (including a suggested optimal geometry for *fAPAR* retrieval) when observations are not made in these regions of the angular domain and when the model is adjusted against real, "noisy" data from the AVHRR. This confirms expectations from previous theoretical studies and highlights the necessity for either injecting *a priori* knowledge into the model inversion procedure [7], or for including observations from both an early morning and an afternoon overpass, at a minimum. Thus far only relatively traditional approaches to land surface remote sensing appear to be anticipated for NPOESS: the Preparatory Project plans to develop only 5 land surface products with data from the VIIRS: albedo, land surface temperature, NDVI, snow cover/depth and surface type in 21 classes. Although the NPOESS VIIRS sensors will follow in the long heritage of POES and EOS sensors, as far as is known there are currently no plans to develop a BRDF retrieval algorithm, or even to consider the BRDF either as a source of noise or as an intrinsic part of land remote sensing. In view of the lessons learned over the last ten years from working with AVHRR visible and near-infrared data over land, this could leave an important void in the science and hinder progress in land remote sensing, impacting a wide range of applications from detailed and reliable land cover mapping to retrieval of accurate measures of albedo, fAPAR and NPP.

REFERENCES

[1] W. Lucht and P. Lewis, 2000, "Theoretical noise sensitivity of BRDF and albedo retrieval from the EOS-MODIS and MISR sensors with respect to angular sampling", International Journal of Remote Sensing 21(1) 81-89.

[2] X. Li, F. Gao, J. Wang, A. Strahler, W. Lucht, and C. Schaaf, 2000, "Parameter error propagation in BRDF derived by fitting multiple angular observations at a single sun position", in IGARSS 2000, 3142-3144.
[3] J-L. Roujean and F-M Bréon, 1995, Estimating PAR absorbed by vegetation from bidirectional reflectance measurements, Remote Sens. Environ. 51:375-384.
[4] G.P. Asner, 2000, "Contributions of multi-view angle remote sensing to land-surface and biogeochemical research", Remote Sensing Reviews 18:137-162.
[5] J. Cunningham, 2000, "Future Role of NPOESS in Earth Environmental Remote Sensing", at http://npoesslib.ipo.noaa.gov/Program/ProgramBrief_Spie_files/v3_document.htm.
[6] M.J. Chopping, 2000, "Large-scale BRDF retrieval over New Mexico with a multiangular NOAA AVHRR data set", Remote Sens. Environ., 74(1): 163–191.
[7] F. Gao, X. Li, A. Strahler, and C. Schaaf, 2000, "Acquiring a priori knowledge from ground and spaceborne BRDF measurements", in IGARSS 2000, 718-720.

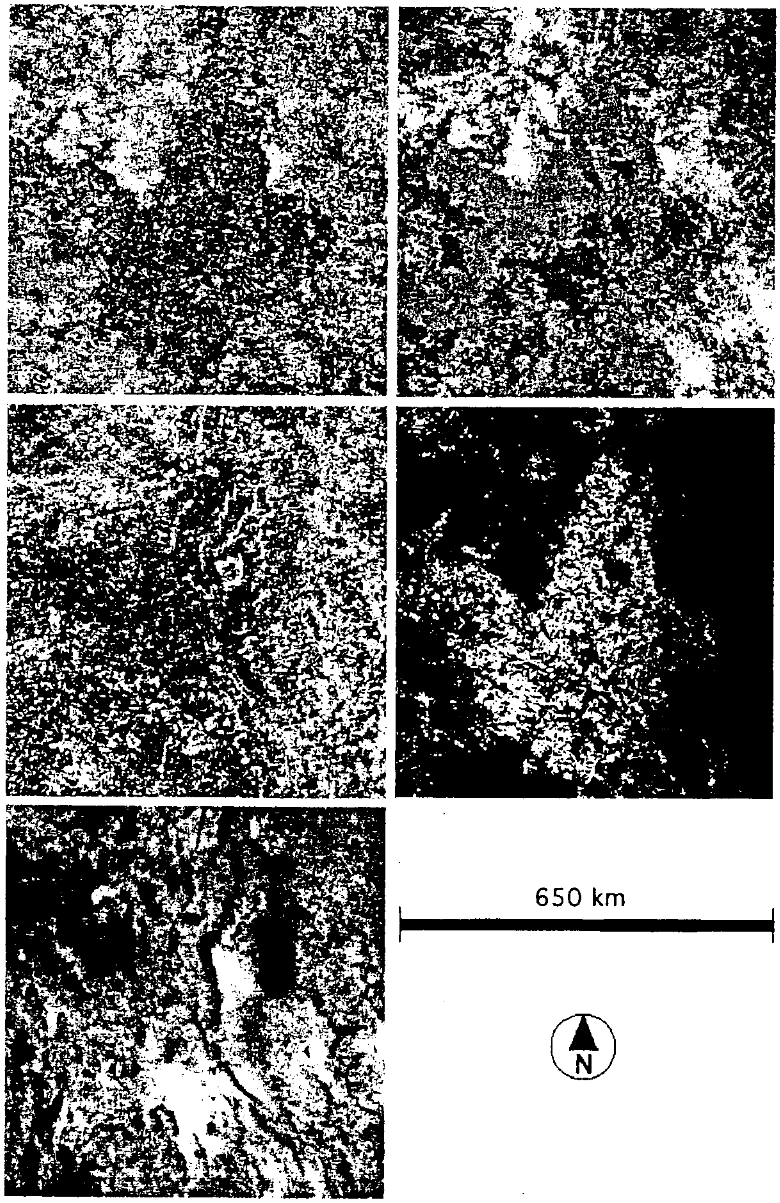

Fig. 2. 5°x5° images centered on S-Central New Mexico (in reading order): total number of clear-to-surface observations (5 - 14); number of AM clear-to-surface observations (1 - 8); absolute inversion RMSE (0.001 - 0.111) showing the perimeter of White Sands Missile Range near the center; noise inflation factors for visible wavelength reflectance at an optimal geometry for retrieval of *fAPAR* (SZA=60°, VZA=45°, RAA=0°; 0 - 25); isotropic visible wavelength reflectance (0.00 - 0.58).