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# The Green Vegetation as a Biosignature on Earth and Earth-like Planets

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**Abstract.** The vegetation signal measured from the integrated Earth reflectance visible spectrum derived from Moon Earthshine observations is compared with data from Earth-observing POLDER-1 satellite. The vegetation signal 24-h variation is computed from POLDER data for different Earth phases and observer positions (equator, pole).

## 1. Introduction

In June 2001, two groups (Arnold et al. 2002; Woolf et al. 2002) extracted the integrated reflectance spectrum of the Earth from Moon Earthshine spectra. They detected an increase ($\approx 0$ to 10%) of reflectance around 700nm attributed to the Earth green vegetation which reflectance significantly increases in the near infrared (the so-called Vegetation Red Edge, or VRE). This showed that vegetation, i.e. life, could be detected in a low resolution visible spectrum of an unresolved Earth. Here, we analyse the VRE obtained from Earth daily maps acquired by the POLDER-1 satellite (Deschamps et al. 1994) in June 1997 and compare it to Earthshine observations results.

## 2. Analysis of POLDER maps

The VRE is defined by the reflectance ratio $VRE = (r_I - r_R)/r_R$, where $r_I$ and $r_R$ are the near-infrared (NIR, 865nm) and red (670nm) reflectances, respectively

(Arnold et al. 2002). The VRE quantifies the reflectance variation between the red absorption peak and the NIR plateau from the vegetation reflectance spectrum. The NIR and red images are projected on a lambertian sphere to simulate the observed Earth phase. We do not take into account the anisotropy of the BRDF of the Earth surfaces (vegetation, deserts, oceans, clouds), nor add any specular Sun reflexion on the oceans.

## 3. Discussion: VRE from POLDER maps and Moon Earthshine

A desert Earth with all continents having the optical properties of the Sahara gives a POLDER-data-based VRE ranging from 8% (desert) to $-3\%$ (oceans). For a full desert planet or a full vegetation-covered planet, the POLDER-data-based VRE reaches 13% or 35%, respectively. But with vegetation, it is likely that oceans and clouds are present and decrease the VRE. We conclude 1) that in the extreme case of a planet with one hemisphere of water and the other one of desert, we would observe a VRE ranging from $-3\%$ to 13%, 2) that only two spectral bands are not sufficient to avoid a false negative detection (ocean+desert instead of ocean+vegetation), thus a full spectrum would be more consistent. When the Earth is seen from the North pole, the VRE reaches 12%: No vegetation is detected without ambiguity due to the high reflectivity of the Pole. June 2001 Moon Earthshine observations gave values of $7 \pm 3$ (evening) and $10 \pm 5\%$ (morning, Arnold et al. 2002), while June 12, 1997 POLDER maps give 6 and 11% respectively for the same simulated Earth and Moon configuration. Observations by Woolf et al. (2002) gave 6%, maybe only $\sim 3\%$ (Jucks 2002, private communication) while POLDER gives 6%. The VRE derived from POLDER seems in good agreement with the Earthshine observations, although Rayleigh scattering probably induces an underestimate of the VRE from POLDER data.

## 4. Conclusion

The results from POLDER data seem in agreement with the Earthshine results. For the Earth, the VRE estimator based on POLDER data indicates the presence of large oceans and lands covered by vegetation. A value $< 13\%$ would not allow a unambiguous detection of vegetation (ocean+desert or ocean+vegetation ?) and it is better to have a full spectrum to measure the VRE.

## References

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