A spectral signature of sand in GOME-2 observations at 400 - 500 nm

EUMETSAT 2011
Session 7, 132

A. Richter, F. Wittrock, and J. P. Burrows
Institute of Environmental Physics/Remote Sensing, University of Bremen,
FB 1, P.O. Box 330440, D-28334 Bremen, Germany
Email: Andreas.Richter@iup.physik.uni-bremen.de

A surface signal in nadir observations

Observations:

- usually, surface spectral reflectance is assumed to be smooth with wavelength in satellite UV/vis trace gas retrievals
- signatures from liquid water absorption and different vegetation types have been reported previously in satellite retrievals at wavelengths > 450 nm
- in a new fitting window for NO_2 covering 425 - 497 nm, unexpected large fitting residuals were found over deserts (see right)

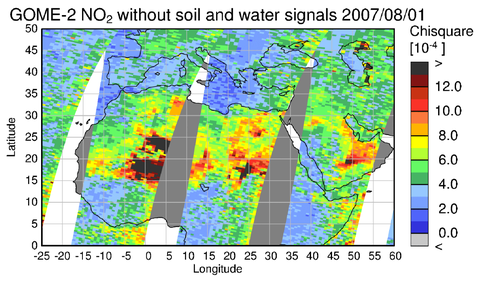


Figure: Fitting residual for an NO_2 retrieval at 425 - 497 nm without inclusion of the empirical sand signature

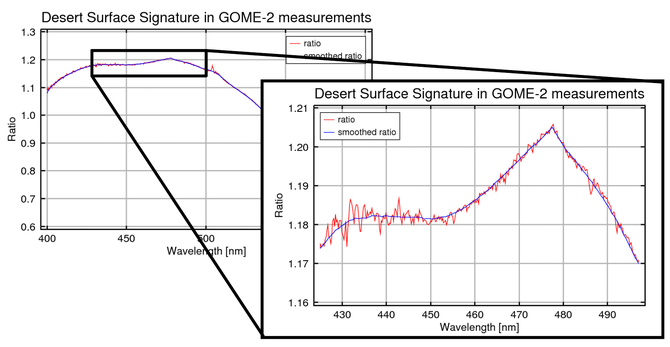


Figure: Logarithm of the ratio of two very close observations with different fitting residuals. Red is the original ratio with some residual Ring structures, blue the smoothed version used in the retrieval

Approach:

- two very closely co-located earthshine spectra were selected, one with a large fitting residual, the other one with a small one
- the ratio shows a pronounced spectral shape, in particular around 480 nm
- this strong spectral signature is systematically found in ratios from different deserts and different seasons
- the empirical signature is added in the retrieval as new parameter

Results:

- empirical signature is systematically found over all deserts
- some other bare soil regions e.g. in the Arctic in summer also show up
- estuaries of Amazon River and Rio Grande also visible
- no signal is found over ocean, clouds or snow / ice
- this seems to be a spectral property of sand and soil!

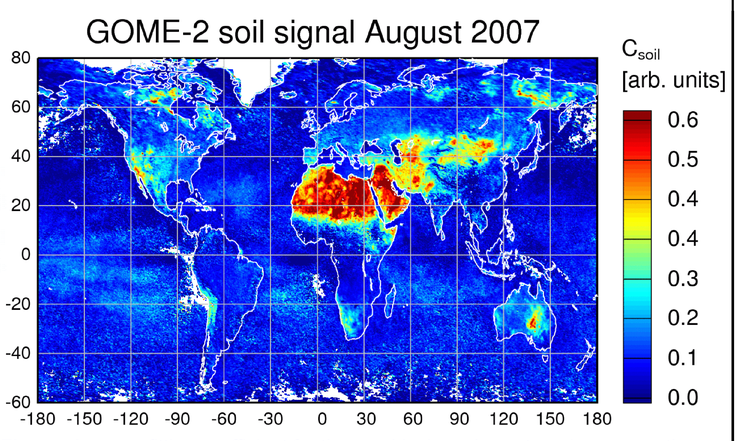
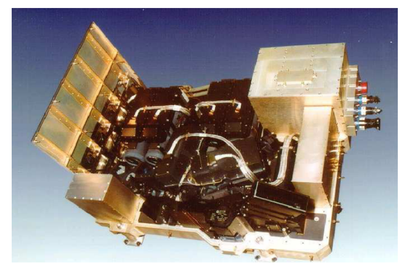


Figure: Average fitting coefficient for the empirical sand spectrum in one month of GOME-2 data. A cloud threshold of 20% has been used.

The GOME-2 instrument

GOME-2:

- launched on MetOp-A in October 2006
- data since January 2007
- 4 channel nadir viewing UV/visible spectrometer
- first in a series of three identical instruments
- 80 x 40 km^2 pixel size
- global coverage in 1.5 days
- 09:30 LT equator crossing



Verification with ground-based data

Figure: Experimental set-up on the roof of the IUP building with MAX-DOAS telescope on tripod and box with desert sand on the ground

Approach:

- Sand from the Sahara
- University of Bremen MAX-DOAS instrument alternatingly pointing to zenith-sky and sand covered surface for all of February 9, 2011
- Ratios taken between surface and zenith-sky measurements, high-pass filter applied

Results:

- high-pass filtered results are very similar to emiprical satellite spectrum
- peak at 480 nm is less pronounced
- low frequency contribution is different
- need for more measurements under better conditions

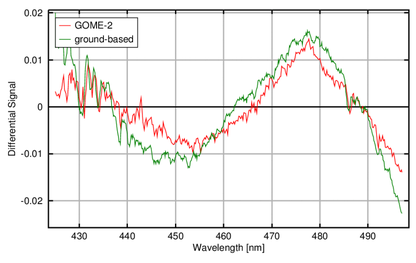


Figure: Comparison of satellite derived (red) and ground-based (green) sand signature

Sand signal and aerosols

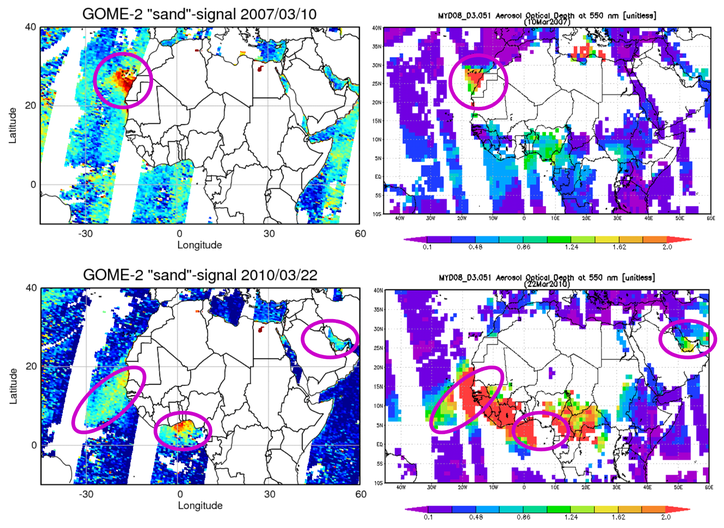


Figure: GOME-2 sand signal over the oceans (left) and MODIS AOD (right). Regions with enhanced sand signals are highlighted.

Observations

- on some days, clear enhancements of the GOME-2 sand signal are also observed over the ocean
- these signals are linked to desert dust export events as observed in MODIS AOD data

Implications:

- further support for the interpretation as sand spectral reflectance feature
- potential to identify different aerosol types from the reflectance signal

Possible interferences

As this is a signal so far not detected, and high frequency spectral features in sand spectra have not been reported before, interference by other parameters needs to be excluded:

Oxygen dimer (O_4)

- there is a similarity between the cross-sections of O_4 and the empirical sand signal around 480 nm
- over deserts, O_4 columns are larger
- changing O_4 cross-section doesn't change the signal
- over snow/ice, O_4 is large but the sand signal is small

=> not an O_4 interference!

Brightness

- desert areas are bright and the sand signal is found over bright surfaces
- no sand signal is found over clouds or snow and ice

=> not a brightness effect!

Liquid water absorption

- over regions where neither liquid water, nor sand signal are large, these two parameters are sometimes highly anti-correlated
- globally, the two parameters are not more anti-correlated then expected from their sources
- regions exist where only one of both is 0, as well as other areas, where both are close to 0

=> not a liquid water interference!

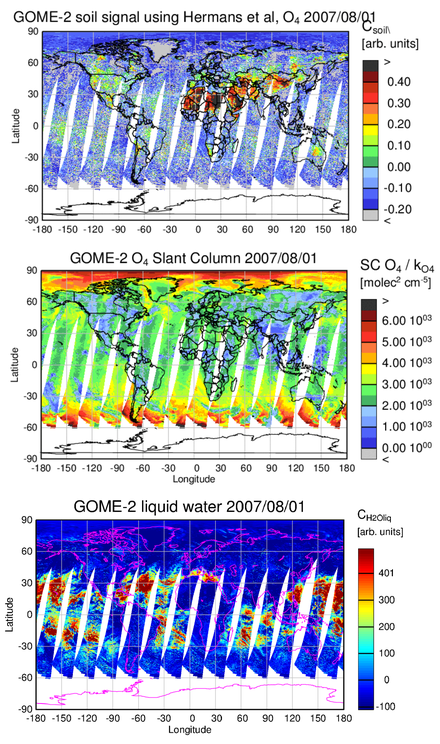


Figure: (top) One day of sand signal using an alternative O_4 cross-section and no cloud screening
(middle) the O_4 slant columns retrieved for the same day
(bottom) liquid water signal for the same day

Conclusions

- at wavelengths larger than 450 nm, surface spectral reflectance cannot be assumed to be smooth for DOAS type trace gas retrievals
- there is a clear sand signal in GOME-2 NO_2 fits at 425 - 497 nm which could tentatively be confirmed in ground-based measurements
- the sand signal has the potential of providing additional information on desert dust aerosol over the oceans

Acknowledgements

- GOME-2 radiances have been provided by EUMETSAT
- This project has been funded by the University of Bremen
- Provision of desert sand by Wolfgang von Hoyningen-Huene is gratefully acknowledged
- MODIS analyses and visualizations were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC

Selected References

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see also: www.iup.uni-bremen.de/doas