Atmospheric correction for Geostationary High Resolution ocean applications

(GSP 1-7084/12)

ESA contract 4000107111/12/NL/AF

Executive summary

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List of Tasks - Workpackages and associated deliverables of this study

WP-1000 Literature review	D1 : Literature review report
WP-2000 Forward modelling	D2 : Forward model description D3 : Synthetic database D4 : List of references cases and corresponding spectra
WP-3000 Sensitivity analysis	D5 : Sensitivity analysis report
WP-4000 Development onf an atmopsheric correction model for high air mass	D6 : Atmopsheric correction ATBD D7 : Verification and validation report D8 : Atmospheric correction model
WP-5000 Consolidation of missiuon requirements for GEO-OCULUS	

The objective of this study was to identify and implement solutions to the short comings of atmospheric correction schemes for geostationary satellites for ocean applications and consolidate the related Geo-Oculus requirements.

As stated in the Statement of Work (SOW), the main new challenge for atmospheric correction over ocean from the geostationary orbit is to provide accurate marine reflectances for conditions of high viewing zenith angle (VZA) and high sun zenith angle (SZA). According to the state of knowledge at the beginning of this activity, as described in the SOW, there was a particular concern about the limitations of the plane parallel atmosphere (PPA) assumption and a recommendation, following Ding and Gordon (1994), for using radiative transfer simulations based on the spherical shell approximation (SSA).

The literature review (Task 1) revealed a general lack of knowledge concerning atmospheric correction over oceans for high SZA and/or VZA. The conventional theory for ocean colour atmospheric correction algorithms was developed in preceding decades when the use of high zenith angles was unthinkable for remote sensing. For example, the operational processors for MODIS and MERIS data reject observations with SZA>70° and VZA is limited to 60° in the MODIS processing and about 40° by the design of the MERIS swath. The literature review, partially summarised in (Ruddick et al. 2013 (in press)), discussed many factors that become problematic at high SZA or high VZA, including the effect of the sphericity of the earth's atmosphere on the magnitude of molecular scattering in the atmosphere ("Rayleigh scattering"), but also including many other processes that need to be better treated in atmospheric correction algorithms including: general amplification of errors with increasing air mass, high reflectivity and lower transmissivity of the air-sea interface at high ZA, calculation of atmospheric attenuation for a spherical atmosphere, potential wave shadowing of the sea surface at high SZA (not mentioned previously) and the general increase in horizontal length scales for contamination of remotely sensed data by environmental adjacency effects.

Following the SOW focus on limitations of the PPA at high ZA, a large part of the planned activity therefore related to definition (Task 2) and use (Task 3) of a SSA-based radiative transfer code, including polarisation, to simulate top-of-atmosphere radiances for a variety of marine and atmospheric conditions. These simulations were analysed in detail: the phenomenon of reduced Rayleigh scattering in SSA for low SZA was characterised as function of VZA (process of reduced SSA path length for illumination of atmosphere in viewing direction) and the phenomenon of increased Rayleigh scattering in SSA for very high SZA (>80°) was characterised as function of SZA (reduced SSA path length for attenuation of light from sun to atmospheric scattering).

The POLYMER algorithm (Steinmetz et al. 2011) was refined and applied to perform an atmospheric correction for high airmass observations from MERIS (Task 4) as well as from the simulated dataset. For polar regions in summer there are multiple acquisitions from MERIS per day for very different air mass. By assuming invariance of the marine reflectance over the day (except for BRDF effects which are corrected) and taking as reference marine reflectance the observation with lowest air mass (provided this is less than 3) it is possible to analyse the performance of this atmospheric correction algorithm at high airmass. This methodology allows simulation of the performance of atmospheric correction algorithms for high air mass conditions similar to those that will be encountered from geostationary observations (except that only high SZA conditions can be tested in this approach). Crucially the method can be used without the need for in situ measurements and their associated uncertainties and can be used for a very large number of pixels even for a single image. The application of POLYMER to low and high air mass conditions found in MERIS imagery of the North Polar region proved to be scientifically very fruitful. An increase in atmospheric correction error was found for POLYMER (assuming the reference low air mass data to be perfectly corrected) which was linearly correlated with air mass and quite significant for air mass >5. Similar or larger biases were found with other atmospheric correction algorithms (MEGS, SeaDAS) and other sensors (MODIS, SeaWiFS), although not always of the same sign. Because of the many factors that may require special attention in an atmospheric correction algorithm at high SZA (as noted in the literature review of Task 1), it was difficult to isolate the cause of this bias although it seems that use of a SSA does not remove this bias. Results show that the Fresnel reflectance and transmittance needs to be particularly carefully treated at high SZA and the sensitivity to wind speed is critical. Moreover, the treatment of atmospheric transmittances including Rayleigh effects at short wavelengths (<450nm), ozone absorption for 550-650nm and potentially aerosol-related atmospheric attenuation, currently neglected by POLYMER, may require more attention at high air mass, or even at low and moderate air mass. These conclusions are not thought to be specific to the

POLYMER approach but are likely to be relevant for all atmospheric correction algorithms, perhaps *a fortiori* for those algorithms making a direct calculation of atmospheric path radiance. Similarly many of these effects (excepting the Fresnel effects), whilst amplified at high air mass, are likely to be relevant also for high precision atmospheric correction at low and moderate air mass.

The mission requirements for Geo-Oculus have been consolidated (Task 5) to take account of this study of atmospheric correction at high air mass.

Despite the many new findings arising from this study, it is felt that the atmospheric correction problem for high SZA and VZA is very far from solved and many of the results presented here are still far from being well-understood. This is a consequence of the large number of processes that become problematic for atmospheric correction at high ZA and the lack of previous scientific investigations of these effects, with the notable exception of the study of (Ding and Gordon 1994). Further research in this direction will benefit not only the exploitation of data from future geostationary ocean colour sensors such as Geo-Oculus (and NASA/Geocape and KIOST/GOCI-1 and -2) but will also be valuable for the exploitation of current and historical data from polar-orbiting ocean colour sensors such as MERIS, MODIS and SeaWiFS, particularly in polar regions. It is possible that future improvements in atmospheric correction algorithms for high ZA will allow geostationary observations to made for higher latitudes and that the ultimate limit for geostationary ocean colour will then be set by the degradation of spatial resolution with VZA rather than by the atmospheric correction errors.

References

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