IOCS 2019

Recommendations of Breakout workshop 9: Atmospheric correction under complex/extreme environments

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Objectives

Building on the earlier IOCS 2013 session about atmospheric correction ("Advances in atmospheric correction of satellite Ocean-Color imagery"), the goal of the present workshop was to review the recent progress achieved by the OC community for complex conditions frequently observed by satellites: atmospheric correction over optically-complex waters and under complex atmosphere (absorbing aerosol, NO2). Another topic relevant in complex environment was the provision of evolved level of confidence, such as per-pixel uncertainties, instead of binary flags.

Presentations and organization of the workshop – see slides of Breakout workshop 9 on the IOCS website.

Recommendations

1. Better understand the performance of AC algorithm

Many algorithms have been developed over the past years, covering a large range of forward models and inverse techniques. There is now a need to better understand their performance by answering the following questions: why do algorithms work or fail? What are their fundamental assumptions which explain their performance? Are there compensations in the errors (e.g. between marine and atmospheric modeling)? International validation/comparison exercises should be encouraged (such as the IOCCG working group "Intercomparison of Atmospheric Correction Algorithms over Optically-Complex Waters" or the CEOS Atmospheric Correction Intercomparison Exercise (ACIX-Aqua) activities) to provide guidance and recommendations to the users, but they have to go beyond a simple ranking and explain the root causes of the AC performance. To address this, the ACIX-Aqua will report performances as a function of water types, surrounding landcover, imaging geometry, and aerosol conditions.

2. Use the full spectral information

For complex environments, focus should be put on AC using the full spectral information (e.g. spectral matching algorithm), instead of the heritage NIR-based approach. This is important to get the proper spectral shape in the blue-green bands over complex waters. Because coupled approaches require a representative marine reflectance model, this requires to improve physical modelling (e.g. better knowledge of IOPs) or to go to statistical approaches.

3. Pay attention to pre-corrections

In general, AC algorithms start from the Rayleigh corrected signal. In complex conditions, this actual radiometry might not be accurate enough and degrade the theoretical performance of the AC itself. The following pre-corrections, although already part of the Level-2 processors, should get more attention:

- Effect of surface reflection (sun/sky glint), in particular for pushbroom technologies (Landsat-8, Sentinel-2).

- Gaseous corrections and out-of-bands. Water vapor is particularly crucial for OLCI bands in the NIR. NO_2 is also of most concern near industrial coastal area (see below).
- White-caps
- Rayleigh correction itself

4. Provide open code and open data

Understanding the performance of the AC algorithms and improving them requires a public access to their source code. This is the case of various codes (e.g. SeaDAS, POLYMER, ACOLITE…) but still not of the OLCI Level-2 processor. This should become a principle of funding agencies.

Simulated datasets should also be shared in the community (open data). In particular in complex/extreme environments, where there are little or non-optimal in-situ measurements. For instance, a new simulated dataset could represent events of absorbing aerosols.

5. Better exploit and extend validation datasets

Existing datasets (e.g. AERONET, AERONET-OC) are probably under-exploited when only used to get overall validation statistics on the retrieved marine reflectance or aerosol optical thickness. There is a need to investigate them in more details to understand the sources of failure of AC, based on physical analyses (e.g. discrepancies with respect to aerosol phase function).

It is highly recommended that the space agencies collaborate with operational water agencies/authorities benefiting from satellite data products to extend the validation network. This capacity building requires inter-agency effort to coordinate data collection. More importantly, using this new type of data requires further attention to the protocols and representativeness of the measurement.

A general recommendation about validation datasets is to maintain them in open access at international level, with inter-agency coordination. For complex environments, there is a particular need to gather data representative of situations expected to be acquired by satellite (for instance today UV measurements are lacking).

6. Address specifically the issue of absorbing aerosols

Absorbing aerosols are present over vast oceanic regions. They cannot be neglected as their impact can be 10 times larger than acceptable errors. AC based on NIR-SWIR only cannot handle the issue. Various solutions exist and should be analyzed in more details, notably for PACE, such as:

- Estimate the relevant optical properties (e.g., using multi-angle photo-polarimetry); still, it should be checked that accuracy of these properties is sufficient for the purpose of ocean colour.
- Use all the wavelengths with deterministic/statistical schemes, in particular bands sensitive to aerosol absorption, i.e., UV. With such approach, there is a need to study what would be the radiometric requirement in the UV, depending on the AC method (physic-based, spectral matching…). Another option is to consider the current capability in field radiometry in the UV and performance of existing UV sensors.
- Using multi-angle information (allows one to avoid determining separately the relevant variables). Feasibility for PACE (SPEX, HARP) should be investigated.
- Detect the presence of absorbing aerosols and, shift to a set of absorbing models in the standard AC algorithm.

To address the issue, agencies should encourage interdisciplinary collaboration between the modelling, atmospheric and the OC communities. For instance, global assimilated aerosol transport models could constrain the inversion; this solution could be implemented to past sensors to ensure continuity and to sensors from which we could not obtain a reliable AC.

The potential of hyperspectral inversion of the oxygen band should also be studied to get the vertical distribution of the aerosol. Experiment could be done with PACE and its 0.6 nm resolution programmable bands.

Last, using lidar for better describing the aerosol vertical column profile should be encouraged. This would help to select aerosols in a subset of models.

7. Take into account small scales variability of NO2

Small scale variability in tropospheric NO2 needs to be taken into consideration for coastal imagery. Effect can be as large as 50, 100 or 200% on remote sensing reflectance in the blue depending on Sun zenith angle. Diurnal variability impacts not only the amplitude of the signal but also its spectral shape.

The need for high-spatial and temporal resolution of atmospheric NO2 instead of current climatology could be achieved:

- From shipboard platforms, to integrate these measurements to atmospheric correction approaches
- From satellite observations of atmospheric NO2 (e.g., TEMPO, TROPOMI, GEMS, Sentinel-4, Sentinel-5) in operation.

The idea of using hyperspectral bands in the blue (400-450 nm) is challenging but should be investigated with PACE.

8. Derive uncertainties as part of the algorithm development

Deriving uncertainties should be a requirement when developing algorithm, especially in complex environments. It is found to be a rigorous approach to understand performance of the AC and list the various sources of errors (calibration, absorbing gas, sea state, aerosols…).

In complex environment, the target uncertainty in ocean colour radiometry should go beyond the historical 5% requirement defined over open ocean. Because of small signal, new requirements should be defined in radiometric unit, and could distinguish the water types. For the same reason, slightly negative reflectance should be kept (up to a given level) to not bias the statistics in the uncertainty assessment. Ideally the spectral error covariance should be also specified for appropriate use in the downstream ocean colour products.

Providing uncertainties of the ocean colour radiometry requires to characterize the input L1b uncertainties following metrology principles, both the pre-launch and post-launch. The full uncertainty structure is required: random & systematic components, temporal evolution, correlation (spectral, spatial). Agencies should provide in the Level-1b products the covariance matrix of the noise as well as the uncertainty of the calibration coefficients.