PhD proposal

Title

Opportunities offered by new generation geostationary weather satellite imagers for ocean colour observation in preparation for the Meteosat Third Generation programme.

Institute

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Main objectives, methods and workplan

Meteosat Third Generation (MTG) is EUMETSAT's future geostationary satellite programme that will succeed the Meteosat Second Generation (MSG) programme from 2022. MTG will consist of four imaging satellites (MTG-I) and two sounding satellites (MTG-S). The main mission of this programme is to provide usable data for nowcasting and numerical weather prediction.
However, the technical characteristics of the on-board sensors will allow many other applications in terms of observation of the atmosphere and continental/oceanic surfaces. Focusing on ocean surface observation, the Spinning Enhanced Visible and Infrared Radiometer (SEVIRI) sensor on-board MSG satellites is currently used to produce near-real-time sea surface temperature (SST) products at hourly time steps and with a nadir spatial resolution of 3km.
The Flexible Combined Imager (FCI), which will be carried on board the MTG-I satellites, is the successor to SEVIRI and offers major improvements in terms of spatial resolution and spectral acquisition bands. These improvements will allow, among others, some applications in the field of water colour observation.
The colour of water provides information on the organic and mineral suspended elements in the oceans. Observations of the oceans in the visible range by satellites can therefore provide information on the composition of the biomass, the concentration of sediments and thus help answer several current scientific questions in the context of climate change and the understanding of the carbon cycle, the air-sea interface energy balance or the evolution of marine ecosystems. The observation of water colour also allows numerous applications in operational fields such as the detection of Sargassum beds, the monitoring of coastal ecosystems and river outflow.
Today, sensors dedicated to the observation of water colour are almost exclusively embarked on polar-orbiting satellites and have characteristics that allow at best one or two measurements per day.
Geostationary satellites have a much higher frequency of observation, which makes them of obvious interest for the observation of phenomena with high variability, especially since water colour measurements from space are only possible under clear skies. The International Ocean Colour Coordination Group (IOCCG) published a report in 2012 [, IOCCG] dedicated to water colour observations from geostationary orbit sensors.

The objective of the PhD is to study the opportunities offered by the FCI instrument for ocean colour observation. Studies have already shown the capabilities, albeit very limited, of SEVIRI to observe water colour and in particular turbidity related to the presence of suspended matter in the Thames plume for example [Ruddick et al., 2014]. Nevertheless, there are still many issues that can be investigated in the exploitation of FCI data.

Regardless of the instrument, the greatest difficulty in estimating geophysical parameters of water colour (such as chlorophyll or suspended materials concentrations) is to convert the radiance measured by the instrument into radiance at the surface. This is done through what is commonly referred to as atmospheric correction [, IOCCG]. This removes atmospheric contributions to the recorded signal, in particular scattering due to atmospheric molecules (Rayleigh scattering), scattering due to the presence of aerosols and interactions between molecules and aerosols.

Algorithms for estimating geophysical parameters are then often based on radiance ratios at the surface. The two steps mentioned above present particularities for geostationary observations, notably related to the observation geometry with possibly high viewing angles, and to the lower signal-to-noise ratio than for instruments dedicated to the observation of water colour on lower orbit. The high repeatability of the measurements can nevertheless be an advantage in overcoming a low signal-to-noise ratio.

A recent study [Lavigne and Ruddick, 2018] has shown, based on fairly strong assumptions and radiance simulations, what possibilities the FCI sensor would offer.

The different steps of the proposed topic are the following:

1. Bibliography :
    - Bibliography on methods for retrieving water colour parameters.
    - Bibliography on atmospheric correction methods
2. Atmospheric correction methods for geostationary satellite data:
    - Review the classical atmospheric correction methods.
    - Apply them to geostationary data (based on existing SEVIRI or ABI data).
    - Identify their limitations for processing geostationary data.
    - Propose improvements/adaptations to these methods, for example by using a radiative transfer model.
    - Validate these modifications (e.g. based on an existing reflectance database).
    - Write a scientific paper.
3. Retrieving geophysical parameters :
    - Determine the needs in terms of geophysical products and compare them with the capabilities of existing instruments and the performance of atmospheric correction.
    - Propose suitable algorithms (taking advantage of the characteristics of geostationary observations: e.g. high temporal frequency) to restore geophysical parameters.
    - Select and study certain phenomena in particular (e.g. upwelling, tidal phenomena, etc.).
4. Write a scientific paper and the thesis manuscript.

The proposed PhD will be carried out within the CNRM/CEMS Ocean team, specialised in the restitution of ocean surface parameters from satellite observations. This PhD will be carried out with the support of the CEMS/SONDAGE radiative transfer model development team in order to perform atmospheric corrections using the RTTOV radiative transfer tool. This application is of great interest to the RTTOV development team as it will eventually lead to a first RTTOV-based atmospheric correction tool applicable to other more complex and reflective surfaces (land, snow surfaces).

Other collaborations will be envisaged with other CNRM colleagues, other French laboratories and the IOCCG communities.

Candidate profile

- Candidate must hold a master degree in either an environmental science domain (e.g. oceanography, meteorology) or in applied mathematics/signal processing.

- Knowledge in oceanography, remote sensing and data processing would be highly appreciated.

- Good level of written and spoken English.

- Python development skills is desirable (visualisation tools, data handling).

References

International Ocean Colour Coordinating Group (IOCCG). Atmospheric correction for remotely-sensed ocean colour products. Technical Report 10, IOCCG, 2010.

International Ocean Colour Coordinating Group (IOCCG). Ocean-colour observations from a geostationary orbit. Technical Report 12, IOCCG, 2012.

Héloïse Lavigne and Kevin Ruddick. The potential use of geostationary mtg/fci to retrieve chlorophyll-a concentration at high temporal resolution for the open oceans. *International Journal of Remote Sensing*, 39(8):2399–2420, 2018.

Kevin Ruddick, Griet Neukermans, Quinten Vanhellemont, and Dominique Jolivet. Challenges and opportunities for geostationary ocean colour remote sensing of regional seas: A review of recent results. *Remote Sensing of Environment*, 146:63–76, 2014.

To apply

To apply please send the following by email to jerome.vidot@meteo.fr and stephane.sauxpicart@meteo.fr before the 5th of July 2022:

- a detailed CV;
- a cover letter;
- one or two contacts of persons that could recommend you.