Utilisation de deep learning pour le changement d'échelle des données satellites d'observation de la Terre

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Requested background: Strong background in applied mathematics/physics. Good programming skills

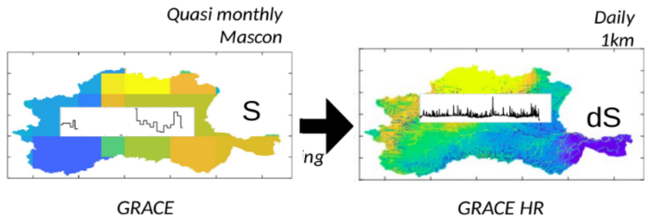
Type of subject:

Theory	~~not at all~~	medium	~~a lot~~
Numerical modeling	not at all	~~medium~~	~~a lot~~
Data analysis	~~not at all~~	~~medium~~	a lot

This internship could be followed by a PhD.

The observation of the Earth is essential for meteorology, climatology and environmental studies. Satellite instruments measure the radiances at the top of the atmosphere. Then, a complex algorithm solves an inverse problem to use these radiances to estimate quantities such as temperature, humidity, vegetation, surface emissivities, clouds, water presence, etc. These satellite observations can be at different wavelengths (infrared, visible, or microwave) depending on the type of applications: remote sensing of diverse geophysical variables over the continents, oceans or atmosphere. The wavelength of an observation changes its spatial resolution, this is why the size of observed pixels can range from 200 km for an instrument such as GRACE (for ground water storage monitoring) to 10 m for visible observations (e.g., for vegetation monitoring). However, it is convenient to have all the retrieved variables at the same spatial resolution, for instance for studying the water cycle, it is good to have all the components on the same grid (Pellet et al. 2021). Furthermore, spatial agencies encourage the development of satellite products with high spatial resolution for helping their societal use, and 1 km is the current goal for many global applications. The problem of the downscaling is therefore an essential issue for space agencies such as NASA, CNES or ESA. We propose here to investigate how artificial intelligence and deep learning can help improve the spatial resolution of satellite observations.

This research subject is truly multi-disciplinary, at the intersection of several disciplines: applied mathematics, physics, remote sensing, hydrology, climate, and artificial intelligence. Several approaches can be used to downscale satellite products. For instance, in (Pellet and Aires 2022), the 200 km GRACE measurements of ground water storage are downscaled to a 1 km resolution using an optimal interpolation technique with high resolution information from a physical downscaling (see Fig. below). Other statistical techniques have been used in the past, but a distinction needs to be made between methods that only intend to *interpolate* low resolution values (this does not really provide new information) and methods that actually do a *data-fusion* with other high-resolution information so that the downscaled product includes more information than the original low-resolution one.



We propose to use AI and in particular Neural Networks (NN) in order to perform such downscaling tasks. Our group has a 25-year experience in the use of NN and we recently developed a very original framework to perform such task, based on deep learning ideas. During this internship, we will implement this approach and test it in a very important application for weather forecasting: The goal is to estimate microwave surface emissivities over the continents, in particular linking them to vegetation, humidity and snow/ice properties. Obtaining such real-time emissivities is essential to assimilate satellite observations sensitive to the surface as this should improve the quality of weather forecast.

The steps of the internship will be 1) to build a database including surface emissivities in the microwave and surface properties such as vegetation and soil moisture; 2) develop a new NN framework for downscaling (both in time and in space); 3) analyze and evaluate the results; and 4) write a scientific paper to be submitted to an international scientific journal.

Bibliography:

- Pellet, Aires & Yamazaki (2021). Coherent satellite monitoring of water cycle over the Amazon. Total water storage change & river discharge estimation. *Water Ress. Res.*, 57.
- Pellet and Aires (2022). Downscaling of the GRACE total water storage over the Po region. To be submitted to J. of Hydrometeorology.