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ENHANCING CHANGE DETECTION AND SUPER-RESOLUTION WITH NIMBO DATA

Thomas Corpetti^{1,2}, Thomas Cusson², Antoine Lefebvre²

¹ CNRS, UMR 6554 LETG, Univ Rennes, Univ Brest, Nantes Université, F-35000 Rennes, France

² Kormap, 1137a Av. des Champs Blancs, Cesson-Sévigné, F-35510, France, <https://kormap.com/>

ABSTRACT

The Sentinel-2 (S2) satellite constellation offers new opportunities for monitoring the Earth. However, the raw data is difficult to use due to cloud cover and other limitations (10m resolution limited for analysis at fine scale, 16-bits representation that prevents from large scale visualization for example). As a consequence, several platforms have emerged to synthesize the data and offer easy-to-use products over the past years.

Among them, NIMBO is a free, cloud-based platform that provides users with access to monthly images of the entire Earth. The platform uses deep neural networks to remove clouds from satellite images, colorizing images and providing users with a clear view of the Earth's surface.

Providing homogeneous images makes it easier to develop large-scale tasks, in particular by creating reliable and robust datasets for various applications. This is illustrated in this paper, through two important applications: change detection and super-resolution.

Index Terms— Sentinel-2, large scale analysis, NIMBO platform, change detection, super-resolution

1. INTRODUCTION

The Sentinel-2 (S2) satellites represent a significant advancement in remote sensing data management due to their continuous acquisition process and high temporal resolution. Since S2's launch in 2015, numerous new use cases have been explored for a broad range of applications, including agriculture monitoring and gesture analysis [1, 2], imperviousness assessment [3], urban surveying (water areas [4], vegetation [5], mapping [6], human settlement [7] or Local Climate Zones for example [8]) or even water quality [9] and land cover classification [10].

However, because of cloud coverage, aerosols and other acquisition difficulties, S2 data are valuable but challenging to use. The challenges include the large volume of data, the multispectral nature of the data, and the rapidly evolving tools for processing the data. In response of these challenges, some global products have been developed to simplify access to this data, including user-friendly platforms for visualizing and acquiring global information on S2 data. These platforms



Fig. 1. Illustration of two NIMBO images acquired in one year interval over the Morat lake, Switzerland (april 2022 and april 2023)

may either be provided by public institutions like the French Theia Platform (cf. <https://www.theia-land.fr/>) or private companies like the NIMBO platform from Kormap (<https://nimbo.earth/>).

The NIMBO platform provides monthly-homogenized Sentinel-2 data over the entire Earth. To achieve this, a complete processing chain is developed to produce consistent data that can be easily compared from one month to the next. This allows for the creation of robust datasets for a variety of applications and facilitates the transfer of models developed for one date to other dates. In this article, we exploit this power of the NIMBO platform through two applications: change detection and super-resolution.

2. DESCRIPTION OF NIMBO DATA

To generate monthly cloud-free data over the world, all data available acquisitions are downloaded. Cloud are detected through a home made cloud detection product that extract cloud probabilities based on residual unet networks with attention modules [11]. Balanced interpolations over all bands are performed both on the basis of cloud presence probability and on the separation time on the 15th of the month (each synthesis being computed on the 15th of each month). Then, images are re-colored using a specific product based on residual networks presented in [12]. Some illustrations of monthly syntheses are visible in figure 1 for two different acquisition dates. Utilizing such homogenized data, we trained residual U-Net neural networks with attention modules that effectively

derive probabilities of urban areas, clouds, shadows, and vegetation regardless of the location or acquisition period. These products, accessible globally, are anticipated to be valuable for a wide range of applications, as illustrated in the two next sections.

3. APPLICATION FOR CHANGE DETECTION

Change detection is a critical task in Earth monitoring with a broad range of applications. Identifying changes in remotely sensed images is not a simple endeavor, as the definition of change fluctuates according to the specific application. Furthermore, due to the acquisition conditions (shooting angle, illumination, atmosphere, etc.), direct comparison of images is impractical. Additionally, traditional supervised deep learning models confront the challenge of procuring and processing a sufficient volume of labeled data for training.

Utilizing homogenized NIMBO images simplifies the task of change detection, as all spectral bands are comparable. Consequently, various differences can be simply be computed to identify changes in an unsupervised way, tailored to the specific application (image difference, NDVI difference, urban probability difference, VGG feature difference, etc.). In Figure 2, we showcase change information in two distinct scenarios: urban change identification based on the difference of urban probabilities at two different scales, and clustering of VGG feature differences to detect two types of changes. As evident, detected changes exhibit consistency in both situations (the two clusters in the bottom represent two different kind of changes).

4. APPLICATION FOR SUPER RESOLUTION

With NIMBO, we aim at providing large scale super-resolution images to evaluate the ability of S2 images to extract fine scale land cover statistics. The task of super-resolution is indeed of prime importance since in some applications, the 10m spatial resolution may be limited, especially for monitoring urban areas (where many patterns are below this resolution) or agricultural parcels where limits do not appear clearly in S2 images. Through some products exist (either to enhance the 60m bands to 10m [13, 14], to improve contour detection [15] or to improve the visualization [16]), these products generally require transfer learning or domain adaptation to be applied on the whole earth. To deal with this issue, we provide consistent datasets of low-high resolution images where low-resolution ones are issued from NIMBO and high-resolution ones are issued from ortho-images. To address the inconsistency issues between low-resolution and high-resolution images from different sources (NIMBO and orthophotos), we recolored the high-resolution images to make them consistent with the NIMBO images. To do this, a color transfer model was developed for each pair of 2.5m/10m images to correct the colorization. Special attention was paid to ensure

consistent colorimetry for high-frequency structures. This process enabled us to construct consistent datasets that allow us to learn super-resolution models that adapt to each part of the Earth and each date, making it easy to produce large-scale high-resolution data. In addition, high-resolution spectral values are consistent with Sentinel-2 ones, making the computation of high resolution spectral indexes (like NDVI) possible. Models are based on convolutional neural networks with content and style losses, and a low contribution of adversarial losses. Some illustrations are visible in figure 3

5. CONCLUSION

In this paper, we have illustrated the value of homogenizing Sentinel-2 data to simplify complex large-scale tasks such as change detection or super-resolution. Through a standardized process that creates monthly homogeneous composites, the resulting data can be inter-compared over time and space. To illustrate this value, we proposed two tasks: unsupervised change detection and super-resolution. The developed techniques can be applied to any location on the globe and at any period without adaptation. Such data are freely available on the NIMBO platform, <https://maps.nimbo.earth/>.

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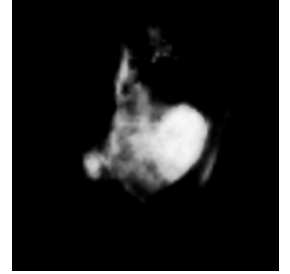
(a) Drome area (1), France, 2020



(b) Drome area (1), France, 2021



(c) Urban changes (scale 1)



(d) Urban changes (scale 2)



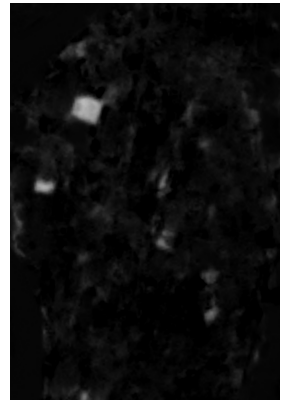
(e) Drome area (2), France, 2020



(f) Drome area (2), France, 2021



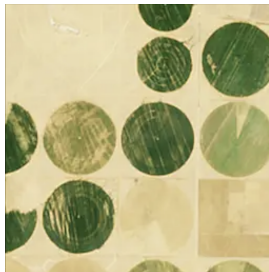
(g) Urban changes (scale 1)



(h) Urban changes (scale 2)



(i) : Egypt (west of Cairo), 2019



(j) : Egypt (west of Cairo), 2023



(k) : Clusters of change (blue and green)

Fig. 2. Illustration of change detection in two different situations: urban change identification (top) and change clustering (blue for subtle changes and green for more abrupt changes) based on VGG differences (bottom).

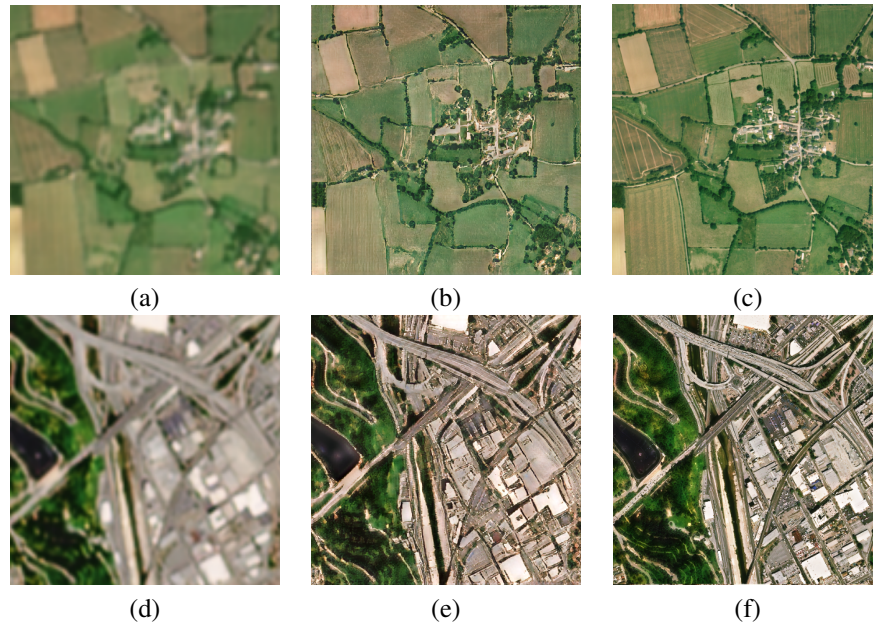


Fig. 3. Illustration of super-resolution on three different areas. (a,d): NIMBO images (10m); (b,e): estimated super-resolution (2.5m); (c,f): closest recolored real high resolution image for a localization in France (department of Loire-Atlantique) and USA (Los Angeles)

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