# On the fusion of Sentinel-1 and NPP/VIIRS imagery: a contribution for oceanographic monitoring

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**Abstract.** The method of IHS image fusion was tested over the ocean using Sentinel-1 and NPP/VIIRS imagery. The RBGs generated by pseudo-colors for Sea Surface Temperature and Chlorophyll-*a* Concentration data from VIIRS were fusioned to a fine resolution SAR grayscale image from Sentinel-1. The results are promising and reveal that the synergy between the two sensors may be explored through the IHS fusion approach for oceanographic monitoring. The method is easy to implement and may generate value-added products operationally, taking advantage of the unprecedented open policy distribution for Sentinel-1 data.

**Keywords:** Image Fusion, IHS, SAR, Sea Surface Temperature, Chlorophyll-*a*

## 1. Introduction

Historically, the oceanographic monitoring made by satellites has the ocean color (Visible) and sea surface temperature (Thermal Infrared) imagery as a major information source for operational analysis, as reviewed by Esaias et al. (1998). The general characteristics of such orbital data are the daily global coverage and spatial resolution from 250m to 4km, being capable to discriminate many oceanographic processes and features, such as ocean currents, fronts, and plumes. Other branch of satellite oceanography has been developed using , Synthetic Aperture Radar (SAR), an active sensor that operates in the microwave spectra. An extensive overview of SAR applications for oceanography was compiled by Jackson and Apel (2004). The SAR imagery has the unique capability of measuring the ocean roughness on a fine spatial resolution, although as stated by Holt (2004) “(...) The finely-detailed imagery of the ocean’s surface from a SAR is assuredly the most complex and least understood data set that is provided by a remote sensing instrument. What to make of the unprecedented two-dimensional views of waves, currents and eddies, slicks, surface manifestations of subsurface features, all brushed over by interactions with the boundary layer, have captivated and perplexed researchers for over three decades.”

The main objective of Earth Observation by Remote Sensing is the extraction of information about the surface structure by acquisition and interpretation of spectral measurements made at a distant location (Ghassemian, 2016). Following the author, the methods of multisensor data fusion enable the combination of different data sets and produce imagery with the best characteristics of each sensor. In order to help the analysis of SAR imagery, specially for oil spill monitoring, many authors (Brekke and Solberg, 2005) and monitoring systems have explored the synergy between SAR, optical and thermal imagery, mainly for separate true oil spills from false alarms. Kudryavtsev et al. (2010) presented the benefits of such synergy for studies of ocean dynamics and Liu et al. (2014) studied the tracking the internal waves.

Recently, a new paradigm for ocean monitoring has become possible with the operation of Sentinel-1 and the Copernicus system (Copernicus, 2016). For the first time the community has open access to global SAR imagery, enabling the use of such data to compose the traditional scheme of satellite ocean monitoring by whole user community. The objective of this article it to propose an operational approach of fusioning SAR, optical and thermal satellite imagery, using the IHS method, in order to easily provide a value-added product to contribute with ocean monitoring.

## 2. Methodology

### 2.1. Orbital Imagery

The data fusion scheme presented used orbital imagery acquired by Sentinel-1/C-SAR and Suomi-NPP/VIIRS over the Campos and Santos Basins, at the South Brazil Bight, in 03$^{rd}$ February 2016.

#### 2.1.1. Sentinel-1/C-SAR

Acquisition mode: Interferometric Wide
Product type: IW_GRD_HR
Polarization: VV
Incidence angle: 30.42º – 45.94º
Number of looks: 5 (range) x 1 (azimuth)
Resolution (m): 20
Pixel spacing (m): 10
Provided by: Copernicus Sentinel data 2016

The Sentinel-1 data was calibrated to sigma-zero and, then, the resulting mosaic of tiles over the AOI was resampled to a pixel spacing of 0.0004º (~44m). The resulting sigma-zero image was converted from linear range to decibels ($10*\log_{10}$).

#### 2.1.2. Suomi-NPP/VIIRS

The VIIRS (Visible Infrared Imaging Radiometer Suite) orbital sensor, onboard Suomi-NPP satellite, provides data within18 spectral bands in visible and IR range. The data used was obtained already at L2 processing level (geophysical parameters) as Sea Surface Temperature and Chlorophyll-*a* concentration variables.

- Sea Surface Temperature (SST)
  Processing Level: L2
  Resolution (m): 750
  Quality flags used: 0-2
  Provided by: Ocean Biology Processing Group (OBPG)/NASA

- Chlorophyll-*a* Concentration (Chl-*a*)
  Processing Level: L2
  Resolution (m): 750
  Algorithm: OCI
  Provided by: Ocean Biology Processing Group (OBPG)/NASA

Both SST and Chl-*a* data were map-projected, using a near-neighbor algorithm and then resampled to a pixel spacing of 0.0004º (~44m).

### 2.2. IHS image fusion

According to Ghassemian (2016), all the component substitution methods are based on the projection of a multispectral image into another color space using a transformation that separates the spatial structure from the spectral information in different components. Then, the component containing the spatial structure is replaced with the another image. Finally, by bringing the data back to the original space through the inverse transformation, the fusion process is completed. The transform of a RGB (Red-Green-Blue) composition into IHS

(Intensity-Hue-Saturation) projection separates the spectral information in H and S components from the spatial information, which is predominately represented by the I component (Chu and Zhu, 2008).

To achieve the objective of this article, the input RGB images were generated after the application of a pseudocolor pallet for SST and Chl-*a* imagery. The RGB compositions were, then, projected into the IHS coordinates. The spatial structure represented by the I component was substituted by SAR imagery and, to complete the image fusion, an inverse transformation was applied to RGB coordinates.

All the steps were executed using open-source softwares, namely *Geospatial Data Abstraction Library* (GDAL, 2016) and *Generic Mapping Tools* (Wessel and al., 2013) running under a *CentOS 7* Linux system.

## 3. Results and Discussion

Figure 1 presents the original input images used for IHS fusion method. Two distinct fusioning processes were performed using the SAR image as the high-resolution Intensity component after the transformation of the RGBs images (SST and Chl-*a*) with lower spatial resolution. One may note that some areas without valid SST and Chl-*a* data are due to cloud cover.

After performing the IHS fusioning method (Figure 2), one may observe the sharpening of original features seen on original SST and Chl-*a* imagery. It is interesting to observe that, differently from a traditional pan-sharpening fusion method, the fusion of SAR, SST and Chl-a not only may enhance the spatial structure information of the fusioned images but also promote the data synergy from distinct spectral regions.

Some details are revealed by Figure 3, where are noteworthy the sharpening of ocean current borders and some detailed features related to circulation and plumes over the continental shelf. The example presented showed that by incorporating SST or Chlorophyll-*a* data into the SAR images, some spatial patterns which sometimes are not easily seen in the SAR image may become apparent. The fusioned images also reveal their potential to support the oil spill monitoring, since they may help on discriminate the false alarms.

The running time of the entire fusion methodology has taken less than 5 minutes for each image and may became totally automatic, enabling it to be a promising operational product for oceanographic monitoring.

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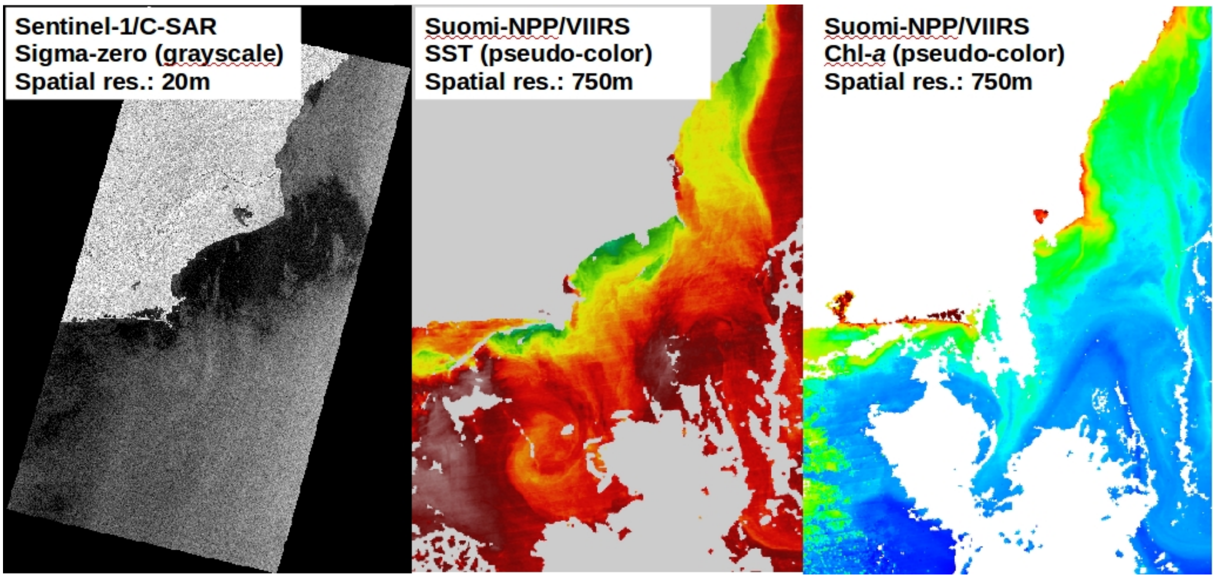


Figure 1: Original SAR, SST and Chl-*a* imagery, already geographically registered, used as input for the proposed IHS fusion method over the ocean.

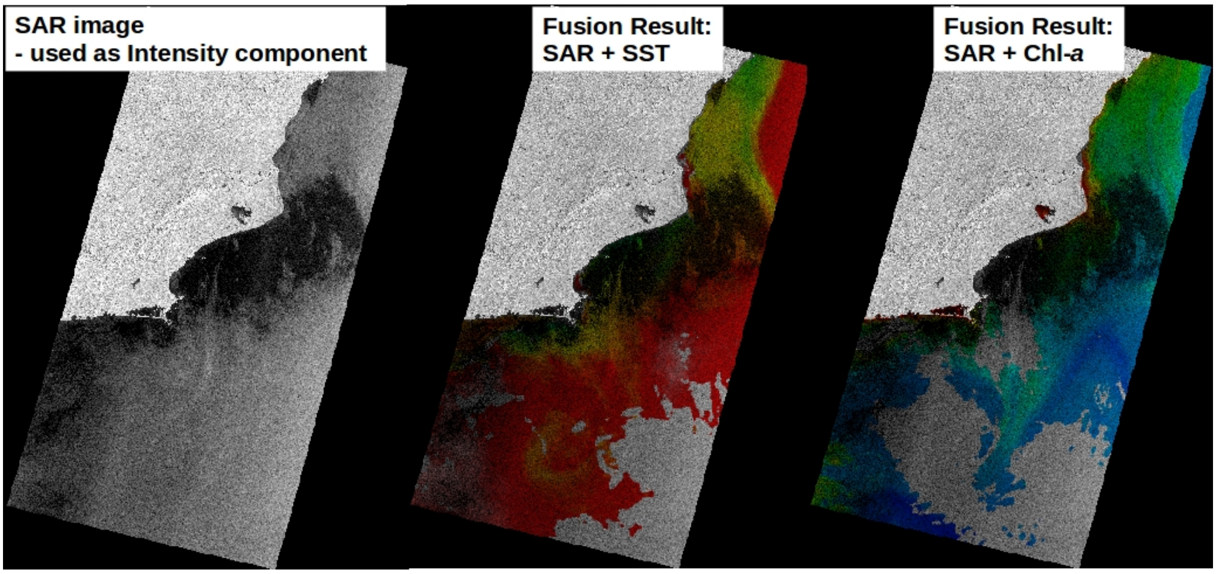


Figure 2: The results of IHS fusion of SAR+SST and SAR+Chl-*a* compared to the original SAR image, used as the Intensity component for the IHS fusion methodology.

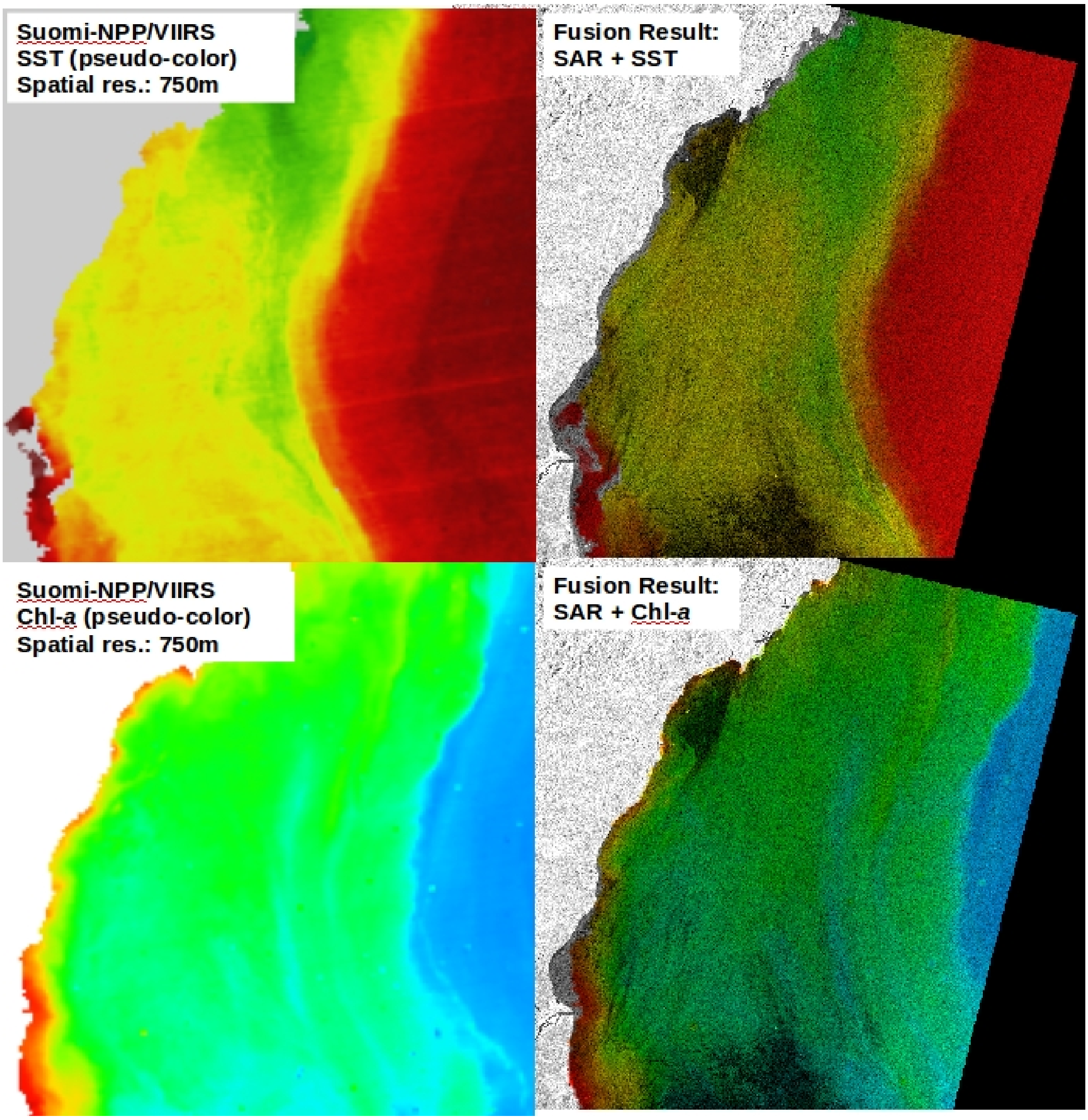

Figure 3: Details on the comparison between the original VIIRS imagery and the fusioned images.

## 4. Conclusions

The presented IHS fusion methodology was tested not for the usual pan-sharpening of optical sensors, but intended to explore the synergy between distinct orbital sensors which operate on different spectral regions. The orbital SAR depicts the ocean surface roughness in high-resolution, which is related to the variability of many oceanographic processes.

When the synergy between the SAR, SST and Chl-*a* imagery is explored, by the use of IHS fusioning, the oceanographic monitoring systems may take advantage of a value-added product which can depict sharpen features, surface circulation patterns, the nature of different plumes and help to identify oil spill from false alerts.

The unprecedented open policy distribution for Sentinel-1 data motivates the developing of operational products, combining the richness of SAR imagery to the traditional satellite oceanographic monitoring. The presented IHS image fusion methodology is a feasible option to achieve such objective.

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