Combined use of Sentinel-1, Sentinel-2 and Landsat 8 images for near-time forest change detection

R. Sonnenschein, C. Marin, C. Notarnicola
Institute for Applied Remote Sensing
EURAC.research
Bozen/Bolzano, Italy

M. Davidson
European Space Agency
ESTEC
Nordwijk, The Netherlands

***Abstract*—Our overall objective was to assess how accurate and timely forest changes can be detected by using a multi-source concept. Based on previous research activities, we further developed the continuous change detection approach (Zhu et al., 2012) and present a methodology that allows detecting near-real time mapping of forest changes using each Sentinel-1 or Sentinel-2/Landsat-8 image.**

***Keywords*—forest changes, Sentinel-1, Sentinel-2, Landsat-8, near-real time change detection**

I. Introduction

Earth observation has become the most important instrument for monitoring forest cover dynamics at high spatial resolution and across large areas. A large variety of change detection approaches has been developed which have been moved from bi-temporal change detection to annual change detection and continuous change detection approaches [1, 2, 3] mainly driven by the availability of free and consistent optical Landsat images. Despite the need of timely alerts about illegal logging activities or assessments of the spatial extent and impacts of disturbances caused by natural hazards, near-real time monitoring of forest disturbances has been restricted by the relatively low temporal resolution of the Landsat sensor and the presence of cloud cover. Fusion concepts combining Landsat and the daily MODIS images overcome the low temporal resolution but may miss small-scaled disturbances and furthermore, face similar limitations in areas with persistent cloud cover. Radar images allow forest change mapping in such situations but data access has been mainly restricted until now.

With the launch of ESAs Sentinel missions, earth observation monitoring capabilities have drastically increased by a series of satellite constellations offering complementary technologies and a free and open data access policy. Especially the Sentinel-1 C-band radar sensor and the Sentinel-2 multi-spectral optical sensor with a high spatial and temporal resolution are designed to provide detailed information on land changes over time. Yet, it remains unclear how the near-real time monitoring of forest disturbances benefits from the two Sentinel satellites, the synergies between them and the synergies with the Landsat-8 sensor.

II. Study Area and Datasets

A. Study area

South Tyrol, Italy is centrally located in the European Alps and covers an area of 7,400 km² (Figure 1). Topography is complex with elevation n ranging from 190 - 3890 m a.s.l. Forest is the most widespread land cover type (48%) of which 74% are coniferous tree species and 26% broadleaved species. Forest changes are predominantly driven by forest management activities that result in small-scaled clear-cuts while natural large-scale disturbances are uncommon.

Fig. 1. The location of South Tyrol (white outline) within the European Alps (red outline) and the footprints of Landsat and Sentinel sensors covering the area.

B. *Data*

We gathered all available Landsat-8 (surface reflectances), Sentinel-2 (radiances) and Sentinel-1 (ground range detected) data covering the study site. Due to the different spatial extents of the footprints of the sensors, we restricted the study area to the area of the Sentinel-2 footprint T32TPS. Additionally, we acquired the Copernicus High Resolution Layer: Forest Type at a scale of 20m [4].

III. METHODS

We converted Sentinel-2 radiances to surface reflectance values using the sen2cor tool. To exclude atmospheric effects, i.e. cloud, cloud shadows and haze as well as snow we used for Landsat-8 information from fmask, normalized difference snow index (NDSI) and illumination conditions while we used the classification scene layer for Sentinel-2. Similarly, we restricted Sentinel-1 data to local incidence angle values between 25°- 65° to avoid distortions by the sensor viewing geometry. Moreover, we only considered forested areas but excluded forest area under agricultural use (i.e. apple plantations).

We then fitted band-wise time-series models to each pixel through time considering data availability and temporal variability of the forest ecosystem. This step was only performed for Landsat-8 as well as for Sentinel-1 data for which longer time series were available. For each band, we derived measures of model fit (RMSE) and derived for each data source an integrated RMSE across all bands.

We then transferred the model from Landsat-8 to Sentinel-2 data by interpolating model coefficients (nearest neighbor) from 30m to 20m scale. Using this model, we predicted spectral values for each new acquisition date. Equivalently, we also predicted backscattering values for Sentinel-1 data. We flagged those pixels which considerable differed from the actual values using the modeling period as reference (mean RMSE). By integrating flagged pixels over time and across Sentinel-1 and Sentinel-2 sensors, we finally labeled pixels as forest change (= 3 subsequent flags).

Due to the lack of significant forest change events in the time period that is covered by the satellite data, we generated an artificial forest change data set. This data set was intended to capture the different factors that influence the temporal and spatial accuracy of the change product. As such the change plots should represent the influence of topography on illumination conditions and sensor geometry as well as data availability for both sensors. To represent different temporal conditions, the change plots were kept constant in space but were shifted to different point in times.

IV. PRELIMINARY RESULTS

Preliminary results show that for both, optical and radar data, a harmonic model that allows to model seasonal variability shows a good fit (Fig. 2).

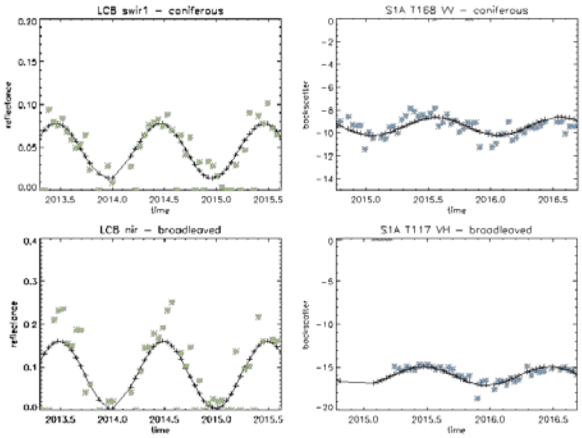

Fig. 2. Time series of surface reflectances and backscattering and their respective fittted time series models.

Surface reflectance values of Landsat-8 and Sentinel-2 data showed the same radiometric scale, yet, the noise level of Sentinel-2 was much higher than for Landsat-8 data which resulted in higher deviations of the predicted values.

Preliminary results show a high performance of the approach resulting in timely detection and spatially accurate delineation of the change plots. Yet, we will further test the application of our approach as well the transferability to other regions to be able to conclude our study.

ACKNOWLEDGMENT

This study was funded by ESA and performed in the frame of the SEOM project COMMONS (Land Cover Change Detection and Monitoring Methodologies based on the combined use of Sentinel-1 and Sentinel-2 for Natural Resources and Hazard Management).

REFERENCES

[1] Z. Zhu, C.E. Woodcock and P. Olofsson, “Continous monitoring of forest disturbance using all available Landsat imagery,” Remote Sensing Of Environmnet, 112, pp. 75-91, 2012.

[2] Z. Zhu and C.E. Woodcock, “Continuous change detection and classification of land cover using all available Landsat data,” Remote Sensing Of Environmnet, 144, pp. 152-171, 2014.

[3] Z. Zhu, C.E. Woodcock, C. Holden, Y. Zhiqiang, “Generating synthetic Landsat images based on all available Landsat data: Predicting Landsat surface reflectance at any time,” Remote Sensing Of Environmnet, 162, pp. 62-83, 2015.

[4] EEA: Copernicus High Resolution Layer: Forest Type, http://land.copernicus.eu/pan-european/high-resolution-layers/forests/forest-type”.