On the relationship between C-band interferometric coherence and crop phenology: case study of Metaponto plain (Basilicata, Italy)

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Abstract

In this paper we discuss the use of Sentinel-1 interferometric Synthetic Aperture Radar (SAR) coherence to study the crop phenology. This research activity has been proposed within the project "On Demand Services for Smart Agriculture" (ODESSA)", funded by the European Regional Development Fund (ERDF), Axis I Research and Innovation, Action 1B.1.2.1.

1 Introduction

Synthetic Aperture Radar (SAR) interferometry based on C-band images has known an increased interest in applications related to agriculture, thanks to the free access to Sentinel-1 data which are regularly acquired all over the world since 2014. In particular, for most of the European territory, the revisiting time of Sentinel-1 (A&B) is of six days. However, when combining different orbits, the updating frequency of information which can be provided by Sentinel-1 is less than one update every six days, thanks to the large size of Sentinel-1 image footprint and the overlaps among different footprint over the same area of interest.

Two recent applications of Sentinel-1 interferometric SAR data have shown their potential in agriculture. The first application is related to the remote measurement of soil moisture. Usually, this specific application of SAR data was based on the use of radar backscattering coefficient and, when possible, on scattering diversity provided by full-polarization images [1-5]. However, the main difficulties in applying this approach are the capabilities to distinguish the contributions of soil moisture and terrain roughness, as the radar backscattering depends on both quantities. Furthermore, in case of vegetated soils, a further problem is that of scattering of radar signal due to vegetation [6]. SAR interferometry (InSAR) has been also proposed to estimate soil moisture [7-11]. In particular, the use of phase triplets, i.e. phase difference of the three interferometric phase obtained by all InSAR combinations of a set of three SAR images acquired along the same orbit at different times, raised an interest in the SAR community working on soil moisture [7-9]. It was found that phase triplets is zero in case of terrain displacements and propagation delay in atmosphere and it could be related to the temporal changes of soil moisture. This relationship needs still to be investigated and validated with in-situ measurements. Actually, an experiment based on in-situ measurements and Sentinel-1 images showed that there is not correlation between phase triplets and soil moisture, while a clear correlation was found between interferometric phase and soil moisture in case of bare soils [12-14].

However, the application of this technique to real agricultural fields, characterized by a vegetation growth along the year is still an open issue. The problem a crop pheonology has been studied using TerraSAR-X images [15].

Recently, a methodology to use the information diversity of time series of Sentinel-1 coherence maps has been proposed for land cover mapping [16]. In particular, the application of a multivariate analysis to a time series of Sentinel-1 coherence maps of the same area has been used to classify agriculture fields based on the corresponding crops [17].

The aim of this work, carried out within the framework of the "On Demand Services for Smart Agriculture" (ODESSA)" project is to correlated time series of coherence maps with in-situ information on crops, using models for crop growth.

2 The project ODESSA

The ODESSA project has been funded by the European Regional Development Fund (ERDF), Axis I Research and Innovation, Action 1B.1.2.1. The whole research activity concerns the mapping of both soil moisture and crop phenology using SAR images acquired at X, C and L bands, to get information of soil moisture at different depths of the soil layer and to have a different sensitivity to the crop phenology based on the different penetration capabilities of SAR signals at the three frequency bands. The contribution of data acquired by the Hyperspectral PRecursor of the Application Mission (PRISMA), launched by the Italian Space Agency on March 2019, will also be investigated to characterize the soil properties and relate them to the SAR estimates of soil moisture.

3 Study area

The Metaponto plain (Basilicata, Italy) is chosen as study area. This plain is characterized by an intense agricultural activities. Furthermore, the morphological characteristics of the plain facilitates the correction of artifacts in the InSAR products, such propagation delay in atmosphere. The Basilicata region is also one of the sites selected for validation during the PRISMA mission of the thematic area of agriculture so increasing the availability of data. Figure 1 shows the geographic location of the study area and the footprint of Sentinel-1 images used in this study.

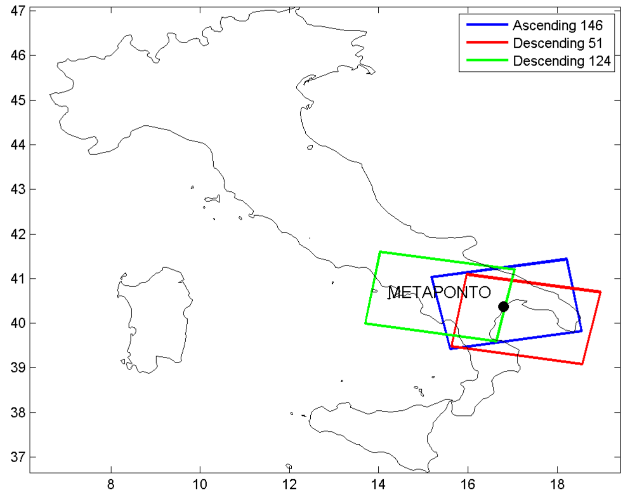

Figure 1. Study are with overlapped the fooprints of the Sentinel-1 images used in this study.

4 Image processing

Coherence maps are obtained by combining all Sentinel-1 images acquired over the study area during one year. The correlation between coherence values and the geometry of agricultural fields is obtained using the stack of NDVI index images computed along the year. The NDVI index was obtained using the bands four and eight of Sentinel 2 Level 2A images. This information is used to identify pixels on the coherence map to be correlated with the crop phenology. Figure 2 shows an example of both coherence and NDVI maps over the study area. A multivariate analysis is used to discriminate field based on the variance of coherence values along the year.

4 Conclusions

In this work we presented a methodology to use Sentinel-1 coherence maps to classify agriculture fields based on the corresponding crops and study their phenology. The coherence values obtained by combining all Sentinel-1 images acquired one year will be compared with the output of crop growth models.

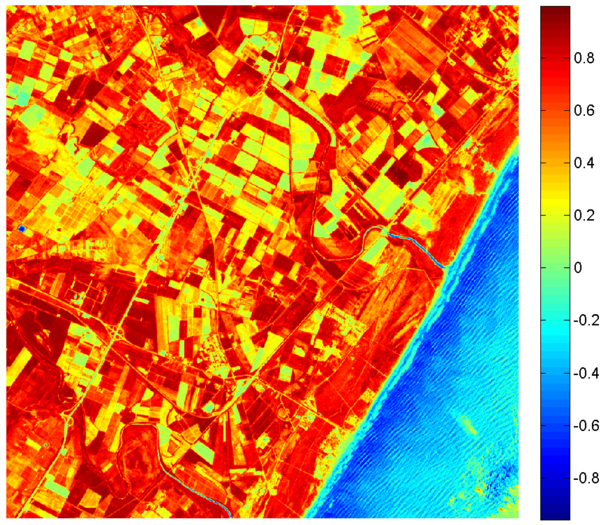

Figure 2. Map of NDVI index over the study area. The map has been obtained by Sentinel-2 image acquired on 5th May 2019.

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