Flood hazard monitoring in a transboundary reservoir-regulated River basin

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Motivation

Large or small reservoirs along rivers regulate downstream flows to generate hydropower but in many cases also store water for irrigation and urban sectors and contribute to flood control during intensive rainfall.
Floods due to failure in managing water storage of artificial lakes can pose a hazard to people and infrastructures in downstream plains. The potential flood hazard can have significant impacts, so it has to be monitored and assessed rapidly in order to mitigate impact and thus reducing the flood risk. Under climate change this task is even more important.

Reservoirs management therefore becomes critical, particularly for transboundary basins, where coordination between countries is needed but not always feasible.

"Floods are among the world's most frequent and damaging types of disaster and annually affect the lives of millions all over the globe. Over time and with population growth, climate related factors aggravated by urbanization and social, economic and political processes have massively increased and will continue to increase human exposure and vulnerability to floods. Nonetheless, vulnerability of societies to floods, whether transboundary or not, is still poorly understood."
***M. Bakker**, (2009) , Water Policy 11, 269–288*

Aim

In this study SAR images from ESA's Sentinel-1 satellite will exploit for monitoring the related water volume changes in the Kerkini Lake-reservoir during the period 2014 – 2015, and at the same time used for flood hazard mapping in the downstream of Strymon River (Serres basin, Northern Greece) which occurred in 2015
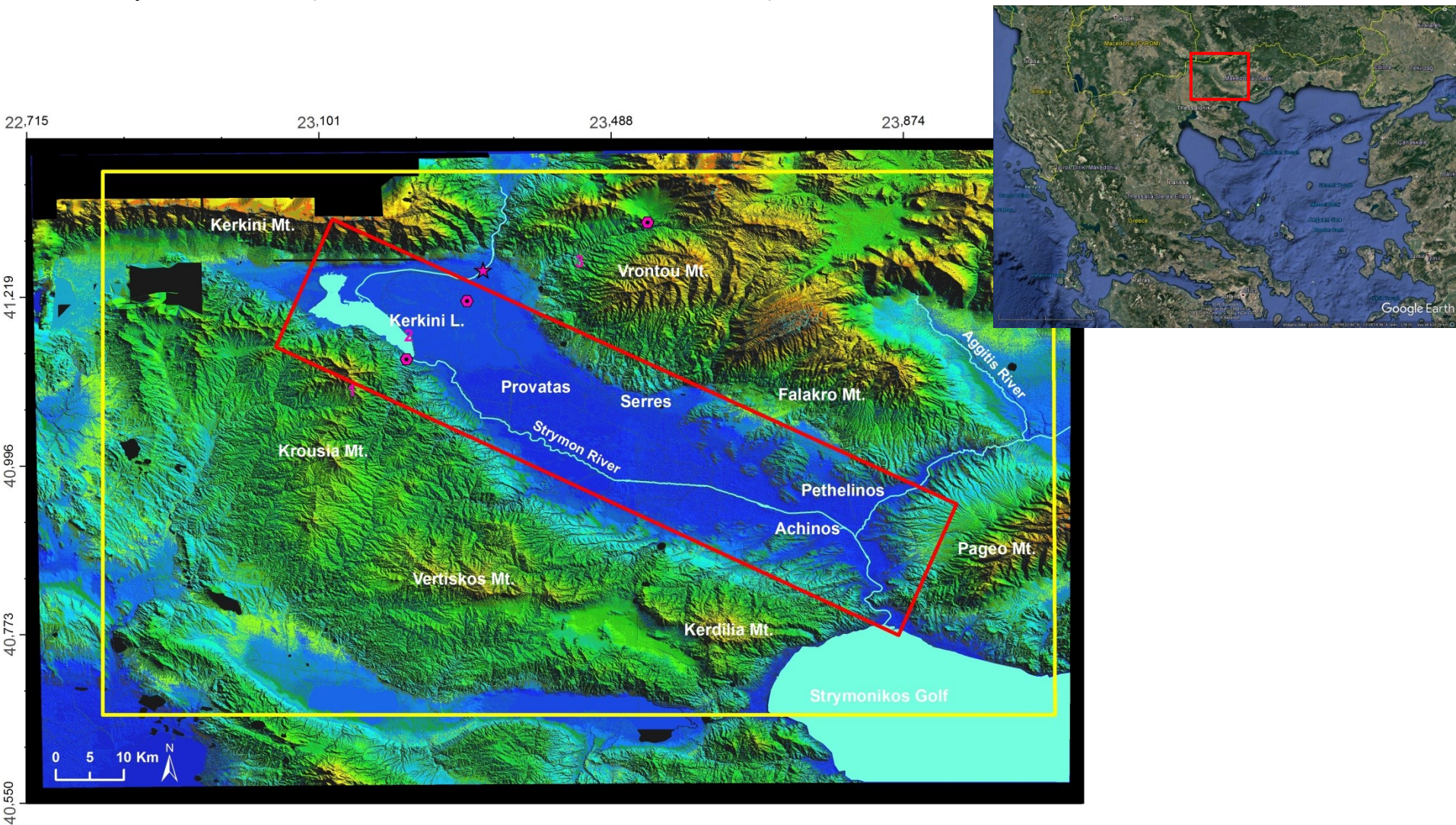
Geological-Geographical settings of the study area

The Strymon River catchment has a total area of 16,747 km2. It is a transboundary basin shared by Bulgaria (50.6%, 8,473 km2), Greece (35.8%, 5,990 km2), FYROM (9.8%, 1,641 km2) and Serbia (3.8%, 643 km2). It is fed by 58 tributaries of first and second order, 42 of which belong to Bulgarian territory and the remaining 16 to Greek territory.

In Greek territory, after a route of 25 km, Strymon River entering in the Serres Basin outflows into Lake Kerkini, which is an artificial lake, mainly used for irrigation purposes and flood. Maximum water volume in Lake Kerkini is 359.7x106 m3 at water level altitude of 36 m. Downstream to Lake Kerkini, Strymon River goes on for 77 km and keeps a direction from northwest to southeast before it outflows into Strymonikos Gulf.

There have been different bilateral (GR-BUL) holystic research projects concerning the Strymon basin management.

About active remote sensing sensors and flood mapping

Space based Earth Observation (EO) data can provide valuable and timely information in operational services for flood risk management. The use of optical imagery for flood mapping is limited by severe weather conditions, in particular by the presence of clouds. Active microwave sensors, such as Synthetic Aperture Radar, are independent on the Sun's electromagnetic radiation (EMR), provide their own illumination and record the amount of incident energy returned from the imaged surface.

 Parameters that affect and determine the response of the radar signal can be summarized to those who depend on (i) the system itself (direction of observation, frequency, wavelength, polarization), (ii) the landscape characteristics and properties (roughness, moisture) and (iii) environmental, climatic and anthropogenic factors (temperature, rain, fog, wind).


Antenna

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Difuse reflector   Specular reflector   Corner reflector
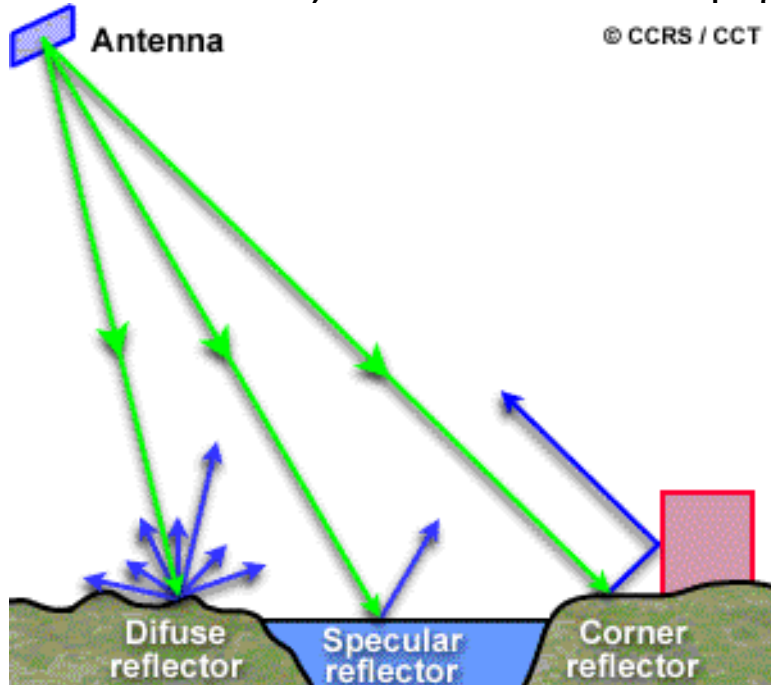
One of the major advantages of using SAR images corresponds to the way that the incoming microwave signal interacts with water.

Materials

Level 1 Ground Range Detected (GRD) **Sentinel 1A C-band scenes** were collected from Copernicus open Access Hub (https://scihub.copernicus.eu) on ESA's website. Level 1 GRD products concern SAR data detected, multi-looked and projected to ground range using an earth Ellipsoid Model and with an approximately square resolution pixel.

The mean monthly **accumulated precipitation** from three meteorological stations (Figure) were collected. As shown in Figure the rainfall is spread over the study period. Both the three meteorological stations show a maximum on December 2014 with an accumulated monthly rate about 145 mm. The second maximum value (maximum 100 mm) appears on March, and the third on June continuing the downward trend in rates (maximum 90 mm).

The **streamflow measurements** were collected from a single location of the Strymon river about 10 km before river's outlet to the lake Kerkini.
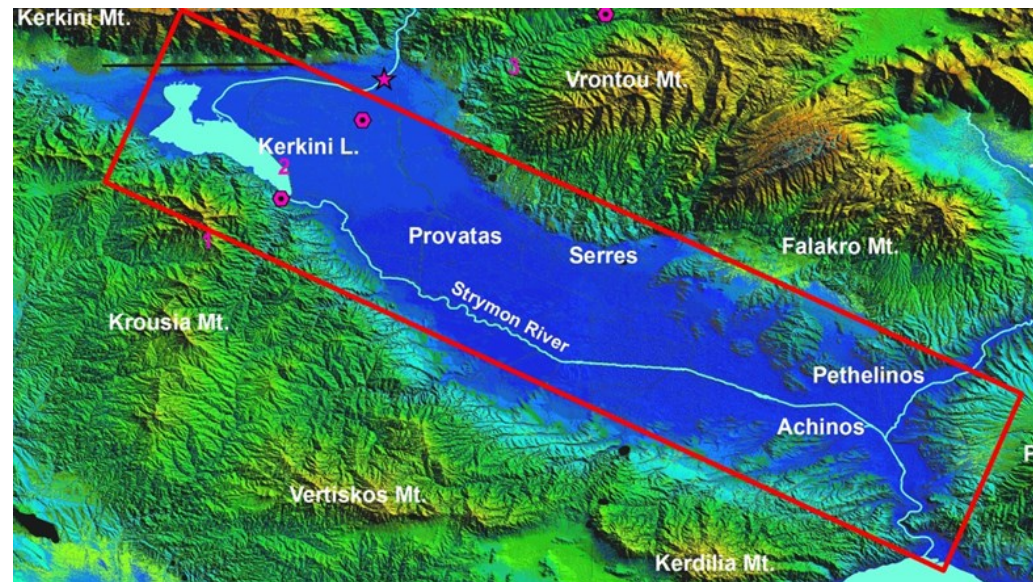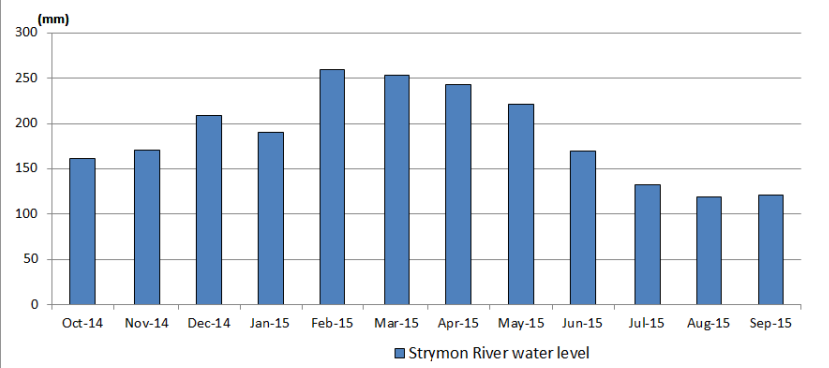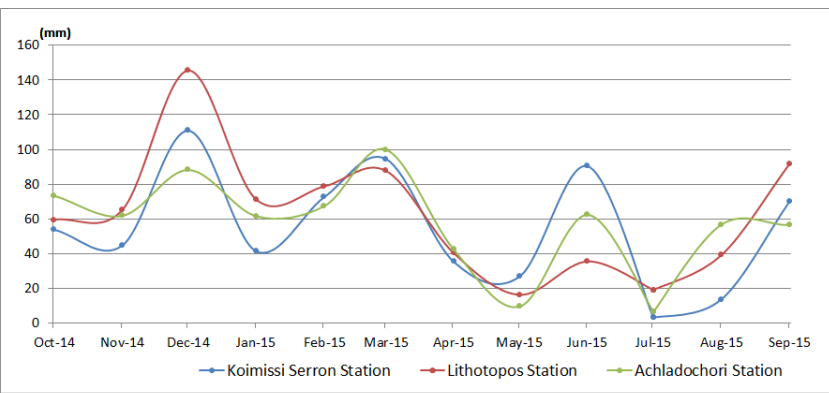
We directly read the zip file of a GRD image in the SNAP following File ⟶open image we open the subfolder band where normally we shall found two pairs of data amplitude and intensity in the two polarizations VV and VH. By double clicking on the amplitude VV we open the image. We are check the image focusing mainly in the area of our interest.

Starting with Open files

File / **Open Product View metadata, expand "Metadata"**.

1. The first step of the pre-processing is the "**Apply orbit**", in order to refine the initial orbit state vectors with the precise orbit files and provide accurate satellite position and velocity information. The orbit state vectors are updated in the metadata file. The refine vectors are downloaded automatically. Radar Apply Orbit file.

2. The second step concerns the **subset** of the image over the area of interest so we decrease the time processing and the volume of the image. Raster Subset. By zooming in the main window we can locate the area over where we want to work and make some minor corrections by selecting Geo-coordinates along long and lat. In our case we change the values as:

3. 41.238

4. 24.073

5. 40.814

6. 22.815

and then run without any other change. We check the result

3. Next step concerns **calibration**. This step aiming to provide the image pixels with values that are related to radar backscatterer of the scene and so to became also useful quantitative applications. Radar Calibration in processing parameters we select the VV image and sigma 0 as product. Run

4. Calibration is followed by **Speckle filtering**. Radar speckle filtering single product speckle filter. In the processing parameters now will be display only the amplitude VV image, the we select the G**amma Map** filter (test also other filters) with kernel size 5x5. We check the result and compare the initial subset image with the new filtered one.

5. Next step is the **Binarazation** which constitute the first real interactive process. On the left of the SNAP main window select Colour manipulation and then log10 then using grey triangle we try to estimate the threshold which based on the backscatterer signature (luminosity) separates water from the rest of the image (land). Normally the histogram is presented with two maximum frequencies the minimum value between the two maximum (curves) should ne the value-threshold. Some tests some times are required in order to obtain an image in which the land should be white (or almost) and the water black. Some problems are arise when an anaglyph is presented in the study area because in this case the shadow areas are black and thus are take in consideration by the system as water. At the last stage in a GIS we can eliminate these areas.

Anyway in the case that you should find the threshold and you have to "binarazing" the image. From Raster ➡**band-maths** and the window is open. In the name you must write water_ and the date of the image for example water_11_3_2015. Uncheck the Virtual…. Select edit expression and write the following expression:

255*(Sigma_0_VV<the value of the threshold)

for example 255*(Sigma_0_VV<2.94E-2) *be careful in threshold value could be -2 or -3* . The value is taken from the histogram when I move the grey triangle. Then press Run. The image water_11_3_2015 will be added at the bans of the last product (I mean generated after the speckle filtering).

6. Next step concerns the **geometric correction** of the water_11_32015 image. From Radar➡Geometric Terrain Correction➡ SAR simulation terrain Correction and the window is open. In the SAR simulation field I select water_11_3_2017 and in the resampling bilinear interpolation. For the moment don't save the layover and shadow mask. Then you have to go in the SAR Sim terrain Correction field and you change the image resampling to Nearest neighbor. At the write field check only that the data are going to store to the right folder and Run, it takes some minutes.
7. Then the result could be **enter to a GIS** for further manipulation and change the color of the water bodies and make transparent the land or you can import to Google Earth.
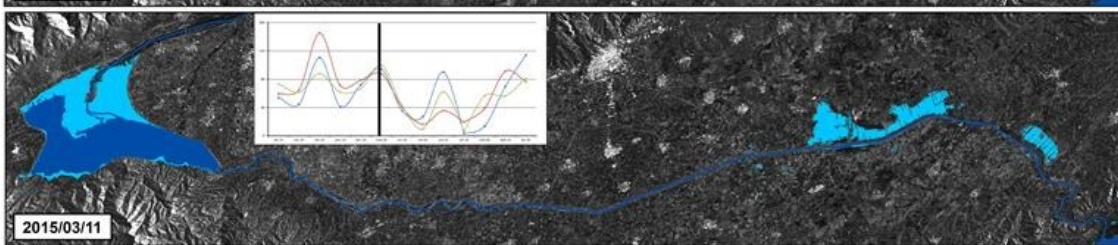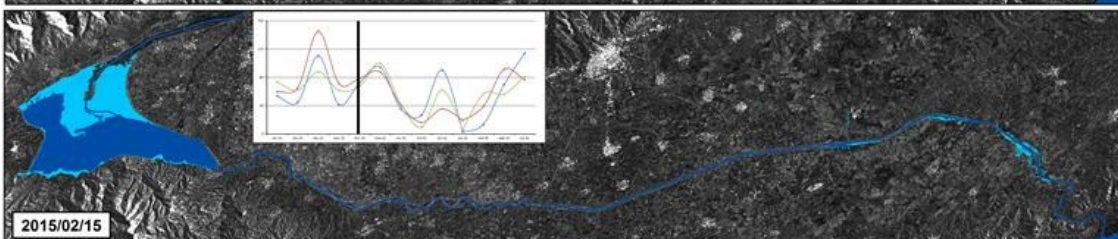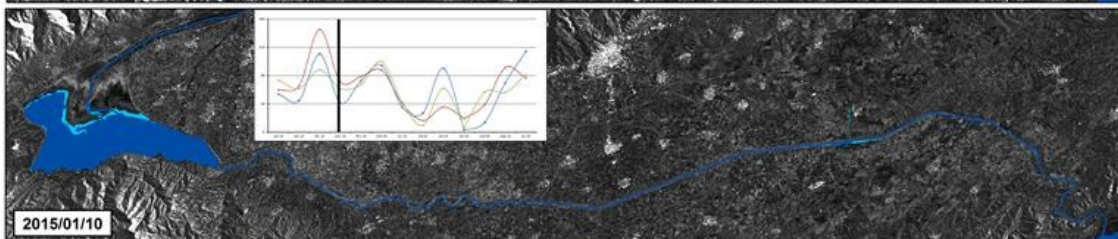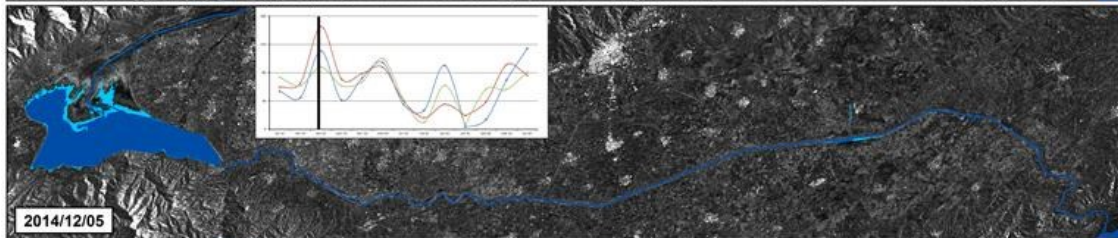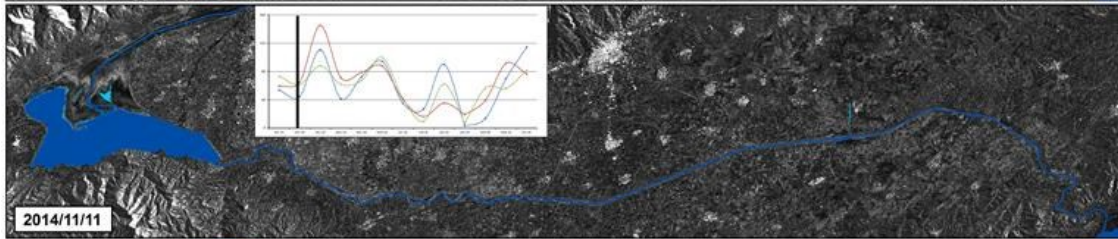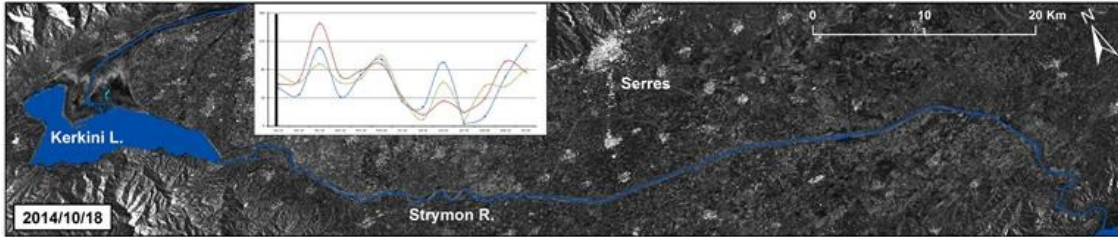
Binaration products water-nonwater
Dark blue= water during dry season
Light blue= water accumulation

"To visualize the water band in Google Earth, export it as a KMZ file; select on the Menu panel File --> Export --> Other --> View as Google Earth KMZ. The KMZ file can directly be imported to Google Earth.
Using the transparency tool in Google earth you can check the land cover type cover by the water.

In order to display solely the water pixels, you can do the following: unzip the KMZ file from SNAP; the resulting folder will include an overlay.kml file and an overlay.png; open the overlay.png in an image editor (e.g., **IrfanView**) and set the background color to transparent; optionally, you can change the white color to another color; override the overlay.png and import the overlay.kml to Google Earth. (Note: When using IrfanView, change the mask color via the Menu panel Image --> Replace Color. When saving the image as overlay.png, check Save Transparent Color, Save Transparency as Alpha channel, and Use main window color for transparency.)"

Multi-temporal SAR images

The above mentioned actions are considered as pre-processing steps (except binarization). In this study two main products were generated based on SAR data: (i) single SAR images products showing water and non-water areas over the study area and (ii) multitemporal SAR images combining two or three dates to show spatio-temporal occurrence and evolution of the flood event.
In several studies on various targets it has been demonstrated that color multitemporal SAR data offer more information than single scenes. It is based on the creation of a Temporal Differentiate Image (TDI), that consists of three SAR images associated with RGB color system.

The multitemporal image is simply the result of assigning intensity variations of three processed SAR images to each of the primary colours, to form an RGB image composition.
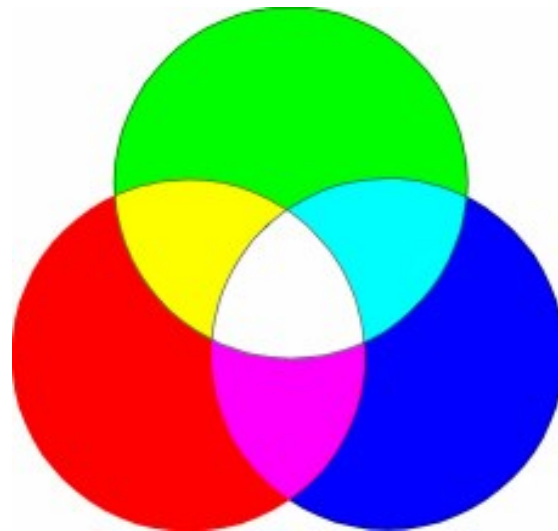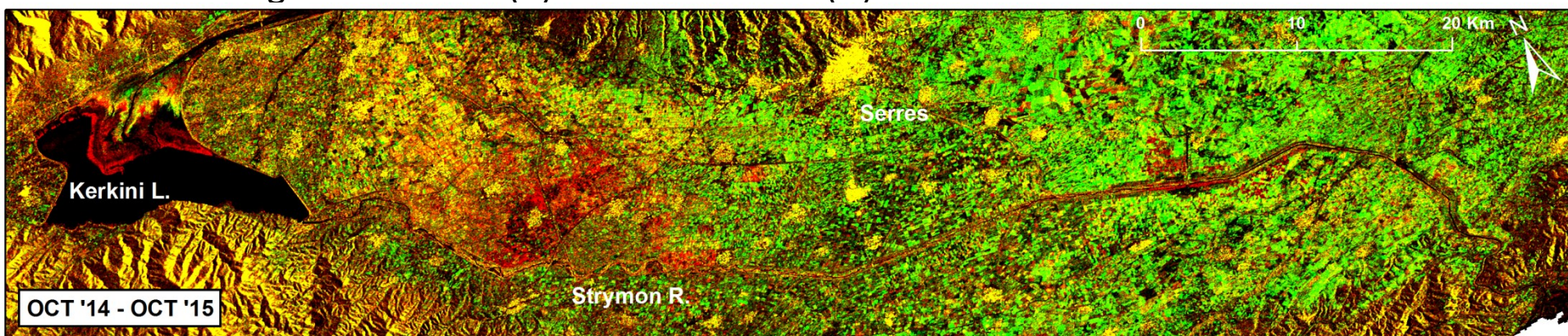

RGB color system

The scenes were firstly co-registered and stacked collocating the master and slave images into a single reference (master) geometry. As the spatial registration of the imagery is an essential requirement for effective change detection, the RMS value of the polynomial transformation of all pairs was decisively less than a pixel (0.05 of pixel).

For example:

A three-date image 11-11-2014 (**R**)/5-12-2014 (**G**)/10-1-2015 (**B**) (pre-event period)
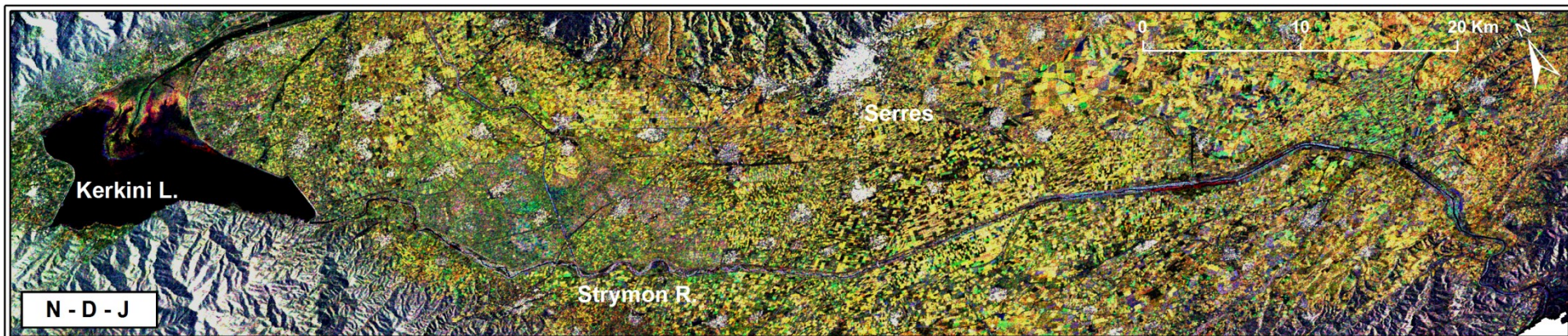
A two-date image 18-10-2014 (**R**) and 25-10-2015 (**G**)

Discussion