Detecting deep moist convection with Sentinel2

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Deep moist convection (DC) is associated with hazardous weather phenomena such as torrential rainfall and flash floods, severe convective wind gusts, large hail and tornadoes. The latent heat release inside deep convective clouds play a crucial role in several phenomena, for example, the intensification of hurricanes and cyclones in general. Several studies have shown that DC and overshooting cloud tops penetrate the lowest stratosphere and allow the exchange of gases from the troposphere deep into the stratosphere.

For all the aforementioned reasons, I believe the Sentinel constellation of satellites provide a unique opportunity to monitor DC around the globe, regardless the ground emissivity which is a major problem in other remote sensing techniques using the microwave and infrared spectrum. In addition, infrared channels from geostationary satellites may provide misleading information about the actual areas covered with DC due to high-level clouds (e.g., Cirrus canopy), let alone the lower spatial resolution compared to Sentinel.

I have developed a very simple script for detecting DC with the SENTINEL-2 L1C datasets which can be modified for the L2A and Sentinel3 datasets as well. I will describe the performance of the algorithm in a case study in Greece in April 2019. There is a potential for this script to be further optimized and evaluated in the near future and I would be interested to use external sources to provide the best possible results.

The main code of the script:

```
function S (a , b) { return a - b };

let gain = 2.5;

var MIDCL = S(B08, B09)
var DC = S(B10, B12)
var LOWCL = S(B11, B10)

return [MIDCL, DC, LOWCL].map(a => gain * a);
```

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with MIDCL representing mid-level cloudiness (cumulus congestus, altostratus, nimbostratus, etc) and thin cirrus, LOWCL showing low-level cloudiness (shallow cumulus, stratocumulus, stratus, etc) and DC showing areas with deep convective clouds at different stages. When we detect DC we expect heavy rainfall below, and high probability of severe weather (hail, severe winds and/or tornadoes).

I have chosen a case study (**Fig. 1 & 2**) for performing a simple verification of the algorithm by using the composite reflectivity of two ground radars in Greece on 14 April 2019 (**Fig. 3**).

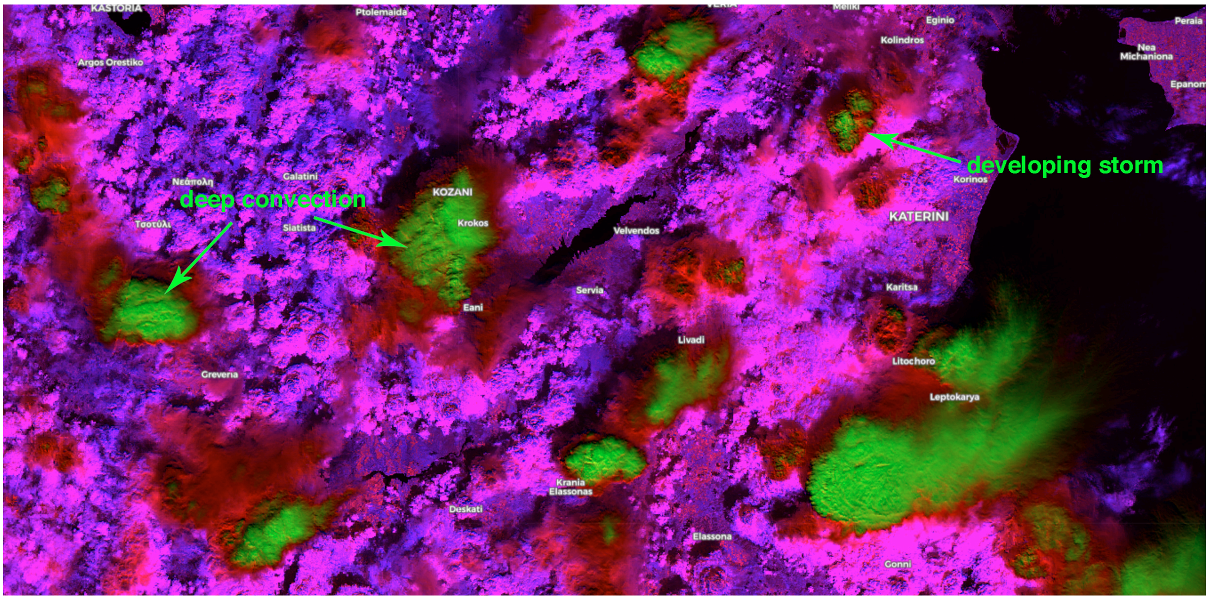

Fig. 1. The output of the DC algorithm for North Greece (lat=40.1961&lng=21.8860) on 14 April 2019 at 09:29 UTC, showing with green color the areas covered with deep convection (thunderstorms), with red mid-level clouds (precipitating or not) and with magenta/blue low-level cloudiness.

On 14 April 2019, the synoptic and thermal lift of unstable air masses over Greece created several thunderstorms, some of them producing excessive rainfall and hail. Sentinel 2 passed west of Greece at 09:29 UTC providing a good sample of the thunderstorms in North Greece (**Fig. 1 & 2**). In Fig. 3 the radars of 3-Δ company which is responsible for the hail suppression operations in Greece, showed high reflectivity values where DC was detected from Sentinel.

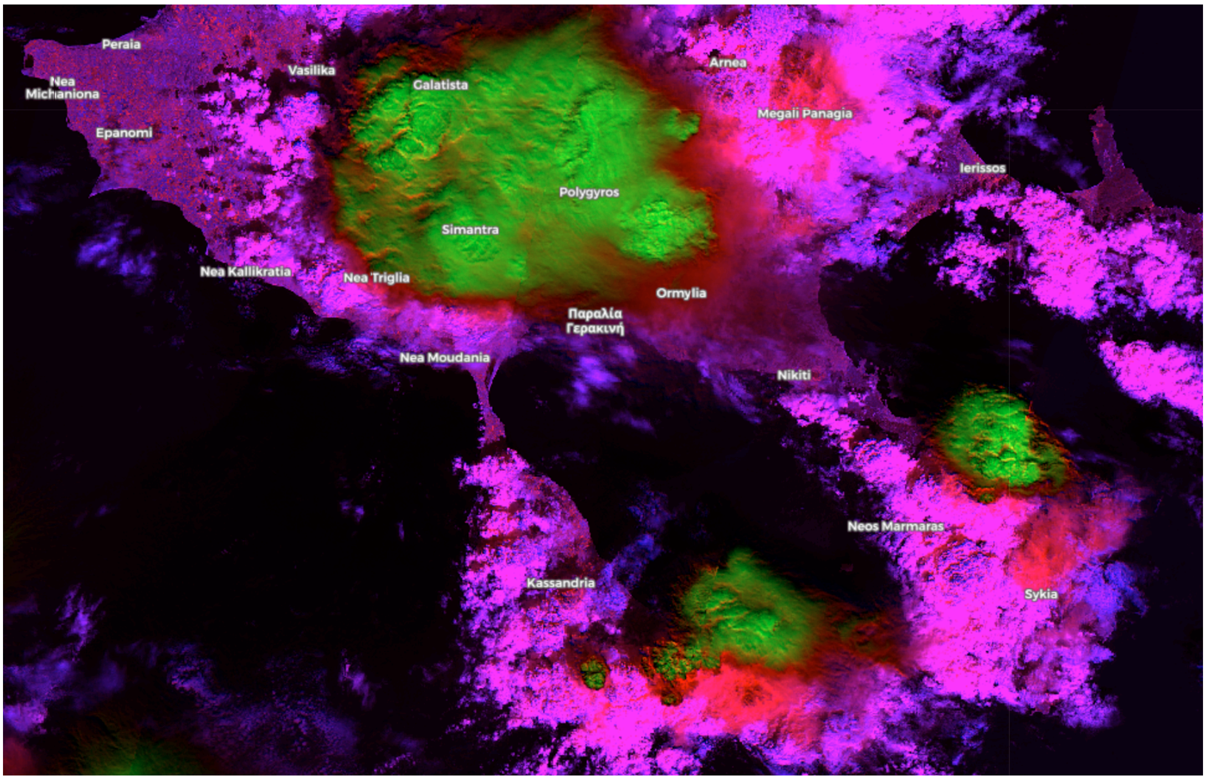

Fig. 2. The output of the DC algorithm for North Greece (Chalkidiki - 40.2486&lng=23.1576) on 14 April 2019 at 09:29 UTC, showing with green color the areas covered with deep convection (thunderstorms), with red mid-level clouds (precipitating or not) and with magenta/blue low-level cloudiness.

By using the difference between the channels B10 and B12 we can have information about DC and we can discriminate cirrus clouds at the cloud tops of thunderstorms from those developing elsewhere by using the difference between channels B09 and B08, which show also the middle-level cloudiness (**Fig. 2** – eg. Nikiti at the center of the figure). The B10 and B12 channels give information about very cold cloud tops in the upper troposphere, containing large quantities of ice, while the channels B09 and B08 give us information about both ice and snow in mid-troposphere.

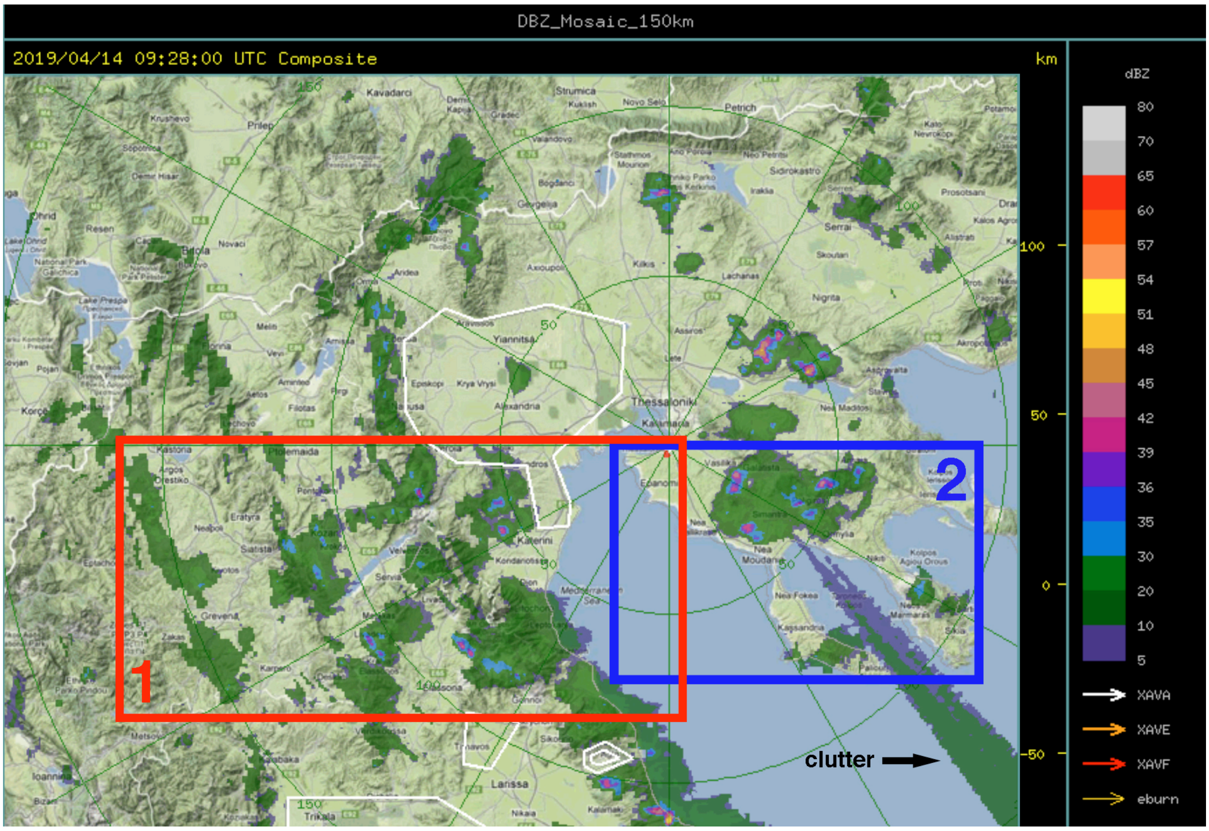

Fig. 3. Composite radar reflectivity (dBz) in North Greece on 14 April 2019 at 09:28 UTC, showing with green color precipitating areas (light rain/drizzle), with blue intense rainfall, and with orange/pink/red areas with heavy rain and/or hail. The red box corresponds to the domains in Fig. 1 and the blue box to the same domain in Fig. 2 with 1-minute lag.

If we only need to show DC, a mask is provided below with only the detected DC pixels (eg. Fig. 4):

```
function S (a,b) { return a - b };

let gain = 3.0;

var MIDCL = [0.8,0.1,0.1];
var DC = S(B10, B12)
var LOWCL = [1.0,0.2,0.4];

return [MIDCL, DC, LOWCL].map(a => gain * a);
```

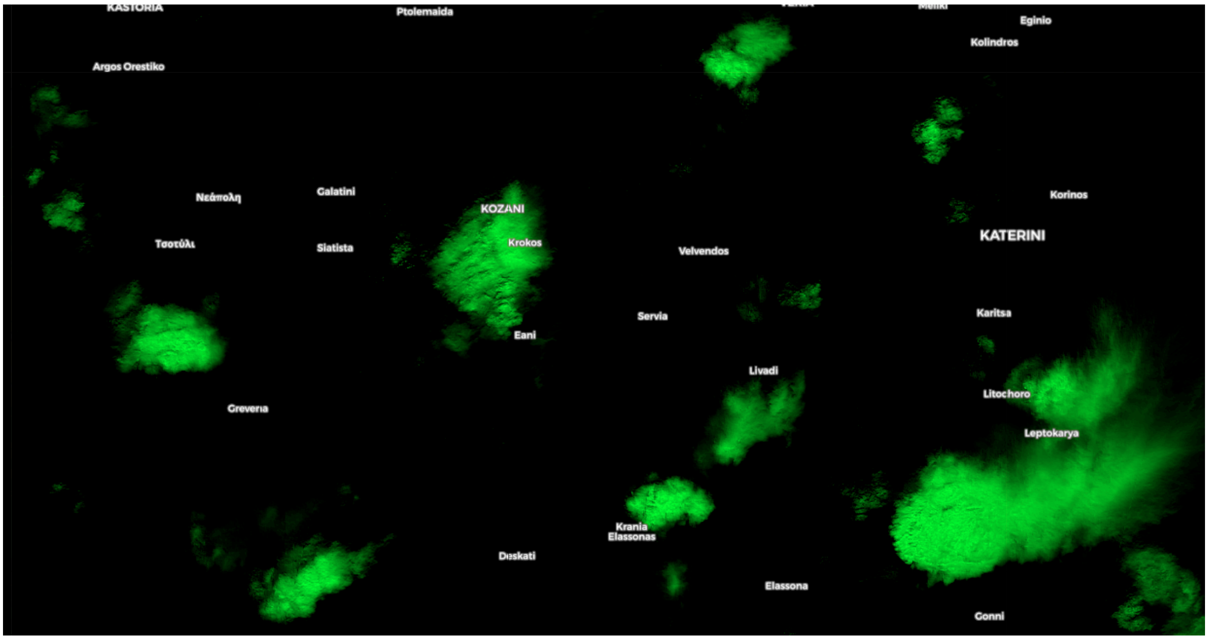

Fig. 4. A mask for the DC algorithm for North Greece (lat=40.1961&lng=21.8860) on 14 April 2019 at 09:29 UTC, showing with green color only the areas covered with deep convection (thunderstorms). The domain is almost similar as in Fig 1 and the red box in Fig. 3.

As mentioned earlier, there is a great potential to develop a more robust algorithm detecting DC and precipitating areas using Sentinel data. Such a product will be invaluable for nowcasting severe weather events and will complement other remote sensing datasets from spaceborne platforms which have much lower spatial resolution.

Thank you for taking my participation into consideration.