living planet symposium 2016

Let it snow - operational snow cover product from Sentinel-2 and Landsat-8 data

Manuel Grizonnet



CNES – Toulouse, France



Co-authors: S. GASCOIN (CNRS), O. HAGOLLE, C. L'HELGUEN, T. KLEMPKA

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Let It Snow in a nutshell @esa

- CNES and CESBIO are developing a snow cover product from Landsat-8 and Sentinel-2 data to provide the snow presence or absence at 20 m resolution every 5 days
- Algorithm is *simple* because the snow surface is quite straightforward to detect from high resolution optical imagery
- Challenge is typically to avoid the confusion between the snow cover and the clouds
- Take advantages of the availability of level 2A Product by CNES in the frame of the **THEIA initiative**
- Leverage research and development efforts

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THEIA Scientific Expertise Centres

The Scientific Expertise Centres (CES as for Centres d'Expertise Scientifique in French) are laboratories or groups of national laboratories leading research and developing innovative processes to use space data for "land surfaces" issues

CES's objectives

- Validate products provided by the Space Data Infrastructure
- Develop processes to use the data and demonstrate applications.
- Contribute to network and federate the scientific community at regional, national and even international levels
- Contribute to promoting the use of satellite data and associated analysis methods.

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CES Theia

- Surface reflectance CES : <u>Olivier Hagolle (Cesbio) (link sends e-mail)</u>
- Albedo CES : Jean-Louis Roujean (Météo France) (link sends e-mail)
- Land cover CES : Jordi Inglada (Cesbio) (link sends e-mail)
- Vegetation biophysics variables CES : <u>Frédéric Baret (Inra) (link sends e-mail)</u>
- Evapotranspiration CES : Vincent Simonneaux (IRD) (link sends e-mail) et Albert Olioso (Inra) (link sends e-mail)
- Irrigated surfaces CES : Valérie Demarez (Cesbio) (link sends e-mail)
- Digital soil mapping CES : <u>Philippe Lagacherie (Inra) (link sends e-mail)</u>
- Ground humidity CES : Yann Kerr (Cesbio) (link sends e-mail)
- Forest biomass and changes in forest cover CES : Thuy Le Toan (Cesbio) (link sends e-mail)
- Water levels of lakes and rivers CES : Jean-Francois Cretaux (Observatoire Midi Pyrénées) (link sends e-mail)
- Colours of the continental waters CES: Jean-Michel Martinez (IRD) (link sends e-mail)
- Snow-covered extent CES: <u>Simon Gascoin (Cesbio) (link sends e-mail)</u>
- Urbanisation / Artificialisation CES: <u>Anne Puissant (Université de Strasbourg) (link sends e-mail)</u> et <u>Eric Barbe (Irstea) (link sends e-mail)</u>
- Risks associated with infectious diseases CES : Annelise Tran (Cirad) (link sends e-mail) et Emmanuel Roux (IRD) (link sends e-mail)
- High frequency change detection CES: Pierre Gancarski (Université de Strasbourg) (link sends e-mail)
- Mapping and monitoring of water bodies CES : <u>Hervé Yesou (Université de Strasbourg) (link sends e-mail)</u>

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CNES Processing capacity

• CNES – MUSCATE Infrastructure

- To process automatically up to 3600 products a day (including reprocessing)
- Based on the mutualised CNES HPC center
- Use of CNES software: PHOEBUS (orchestration), SIGMA (orthorectification), and MACCS (conversion in surface reflectance)

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Cumulative Volume of MUSCATE data:



Snow cover detection from optical satellite images Solar

Pros

- Products: snow cover, albedo...
- Variety of sensors and resolutions (spatial, spectral and temporal)
- Weekly monitoring since 1966 and global monitoring since 1981

Cons

- Clouds, clouds, and again clouds...
- *Snow*-Vegetation interactions
- Incomplete (hydrology): , only the snow cover AREA is retrieved
- Trade-off between spatial and temporal resolution (Landsat vs. MODIS)

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Spatial vs Temporal resolutions @esa



Let it Snow in Theia operational ground segment Cesa



LIS algorithm

 The snow detection is based on the Normalized Difference Snow Index (NDSI) (Jeff Dozier (Rem. Sens. Env., 1989)):

$NDSI = \frac{Green - SWIR}{Green + SWIR}$

- The NDSI is based on the fact that only snow surfaces are very bright in the visible but dark in the shortwave infrared
- Computed on surface reflectance (with terrain effect correction!)
- Works for SPOT4/5, Landsat-8 and Sentinel-2 images since a shortwave infrared band near 1.6 μm is available
- For Sentinel-2 the index is computed at a resolution of 20 meters
- We want a robust and efficient algorithm to process large mountain regions with a reasonable computation cost
- Update cloud mask is mandatory

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Step 1

- Strict thresholds on the NDSI and red reflectance values
- Some lakes may also have a high NDSI value so we add a criterion on the red reflectance to remove them

snow1 = cloud1 is false and NDSI > N1 and Red > R1 (pass 1)

- Do not take the original L2A cloud mask as input -> very conservative
- Useful information for snow cover mapping is lost
- Allow the reclassification of some cloud pixels in snow or no-snow only if they have a rather low reflectance.
- Select only these potentially "dark clouds" because the NDSI test is robust to the snow/cloud confusion in this case
- Cloud flag is removed for these pixels unless they were flagged as a cloud shadow cloud1=(cloudL2A and pRed>Rc) or "cloud shadow" is true

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Step 2

- Estimate the lowest elevation of the snow cover in the image (*ZS*) using the SRTM digital elevation model.
- We perform another pass for the pixels located above the snowline elevation *ZS*, with different threshold values :

snow2=Z>ZS and cloud1 is false and NDSI>N2 and ρRed>R2



Bar plot of the snow cover area, cloud area and total area per elevation band after pass 1. The image is a SPOT-4 Take5 image in the High-Atlas of Morocco acquired on 27-03-2013

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Final result

- pass1 U pass2
- Background image is a RGB color composite (bands 421)
- Cloud mask is in black
- Snow mask after pass 1 is delineated in yellow
- Final snow mask in magenta



Snow and cloud mask in a SPOT-4 Take5 image in the High-Atlas of Morocco (27-03-2013)

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From R&D to operational product

- Matlab prototype developed by S. Gascoin (CNRS/CESBIO)
- Ported in Python and C++ based on open source software:
- OTB (open-source C++ library for remote sensing images processing)
- GDAL
- Python
- Compatible with SPOT4/SPOT5, Landsat-8 and Sentinel-2 products
- Iterative process
- Formats (metadata): followed guidelines from ESA SnowPEX initiative

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Going Big: Landsat-8 time seriesesa



Quicklooks of a Landsat-8 time series over the Pyrenees (the snow mask is drawn in magenta and cloud mask in green if you have good eyes)

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Revisiting the L2A cloud mask



Snow and cloud mask after processing by LIS (left) vs. L2A original cloud and snow mask (right). Clouds are marked in green, cloud shadows in black, snow in magenta

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Toward S2 snow product @esa

Alpes SPOT4-Take5 series

Snow fraction in elevation cells



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First Sentinel-2 snow map! esa





The Sentinel-2A image of 06-July-2015 (level 2A, tile 30TYN) and its snow mask. The snow mask is in magenta and the background image is a color composite RGB NIR/Red/Green

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First Sentinel-2 snow map @esa

- Snow mask computed from the Sentinel-2A image of 06-July-2015 is superposed to an aerial image of 2013 (IGN)
- In the Vignemale and Gavarnie area
- Persistence of snow patterns from one year to another
- It seems to work rather well!



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And now?

- CNES is implementing the operational version on the MUSCATE ground segment
- Hope to start distributing snow maps with Sentinel-2 in 2016
- Next step :develop an interpolation method to provide a 5-day gap-filled snow product



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And now?

- The accumulation of Sentinel-2 and Landsat data will enable to generate snow cover climatology at high resolution
- It will allow to better characterize the fluctuations of the snow cover in the mountains
- Develop services like web applications for winter tourism, support water managers decision-making in mountain regions
- Ski slopes in Alpe d'Huez and les 2 Alpes (From April to September)



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Perspectives

- Process Sentinel-2 sites from:
- Pyrénées (France, Spain, Andorra)
- French Alps
- Morocco Atlas mountain

and then the Alpine region up to Austria?

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Support/Help/Contribute @esa

- Source code : <u>http://tully.ups-tlse.fr/grizonnet/let-it-snow.git</u>
- CESBIO blog: <u>http://www.cesbio.ups-tlse.fr/multitemp</u>/
- Theia : <u>https://www.theia-land.fr/</u>



Thank you! Any questions? esa



Bassiès, Ariège (French Pyrénées)

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