Objectives of the project

Sentinel 2 is the first sensor which provides with high temporal repetitability a global coverage of the earth. Regions are observed every 5 days providing the most dense datasets ever available at this spatial resolution. These enhanced capabilities allowed a new era of earth observation applications in particular all those dealing with land use/land cover, vegetation evolution monitoring and phenology, biophysical variable estimation, etc. However, due to cloud presence, temporal profile of reflectances or variable of higher elaborated levels may not as dense as they should be. Images at some key dates might not be acquired, involving difficulties to have accurate predictions when real time applications are used. This is also the case in data reprocessing but in order to fill the gaps, several techniques could be developed.

We are exploring in this project a new promising one, called the Dynamic Time Warping (DTW).

Method description

2 steps to achieve the fusion:

• S2 time series consolidation
• Densification with L8/OLI time series

The two aspects of the products fusion are dealt with separately:
• Radiometric adjustment
• Geometric adjustment

Step 1 is performed using DTW method

The Dynamic Time warping is a distance measurement between two time series. It measures similarity between two time series, even the number of data is different.

For 1 pixel (x0,y0,t)

DTW is able to re align time series and fill gap. Distance is computed for all candidates

\[
d_{x0,y0,t} = \min_{\alpha, \beta} \sum_{t=1}^{T} (x_{\alpha(t)}, y_{\beta(t)}, t) - (x_{0}, y_{0}, t)^2
\]

Step 2 is performed chaining four steps:

• First, the pan-sharpening of the Landsat 8 products, it is required to significantly improve the Landsat 8 spectral band resolution.
• Secondly, the spectral adjustment using an approach relying on the sensor relative spectral response to project the Landsat 8 OLI acquired values onto the Sentinel 2 MSI sensor.
• Third, BRDF adjustments
• Finally, the resulting products should geometrically adjust to match the Sentinel 2 time series foot print.

Phase 2: Densification with L8/OLI

All steps have been applied (except BRDF corrections) allowing L8 time series to be merged with consolidated S2A time series. An example is provided hereafter for the Garderen test site.

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Test sites

• 6 sites selected for their landscape diversities
  • Toulouse (France)
  • Maricopa (USA)
  • Barrax (Spain)
  • La Crau (France)
  • Garderen (The Nederlands)
  • Ottawa (Canada).

Phase 1: Assessment of the performance of DTW

The results are assessed by statistical results and temporal profile analysis comparisons when two additional methods are used: Linear interpolation and Savitskly Golay smooth filtering.

Cost function use all 52 channels except B8, B9 and B10, and NDVI. The metrics are:

- Uncertainty (U) / Root Mean Square Error (RMSE)
- Accuracy (A) / Mean Absolute Error (MAE)
- Precision / Mean Precision (MPP)
- Recall

Consolidation assessment examples:

TOULOUSE site

GARDEREN site

Conclusion Phase 1

The profile analysis and statistical results over the tests sites confirm that the DTW provide the overall best results. The NIS is about twice smaller for the DTW than for any other methods. The individual results may vary depending on the diversity of pixel points available in the site. The second result of the sensitivity analysis is that the DTW provide better results than the other methods without depending on the test site and its content. But the absolute accuracy of the method may slightly vary depending on the diversity of pixel points available over the test site and the availability of reliable pixel candidate for the matching phase.