Simultaneous decomposition of multivariate images: Application to near infrared hyperspectral images of wheat

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PHENOME project

2012-2019

PHENOME is an infrastructure of **high-speed phenotyping** that will equip the French scientific community with a national network of platforms for studying the natural variability of a large collection of plant species under various environmental scenarios associated with climate change.

Objectives:

- Build platforms heavily instrumented at seven sites in France, meeting the needs of major agronomic species and to test the major environmental constraints.
- Develop hardware and software applications with technological advances with the development of new sensors, statistical analysis and database methods.
- Disseminate the techniques and methods to the French phenotyping community (seed companies, technical institutes, public research)
- Facilitate the emergence of French SMEs involved in the development of phenotyping methods.

Objectives

Cereal grains —**Imbibition,** Germination→ **Production of a new generation of plants**

↳ **Monitor the diffusion of water in single wheat kernels over time using NIR-HSI**

Find the infrared features common to different grains as well as to provide features specific to one or more grains.

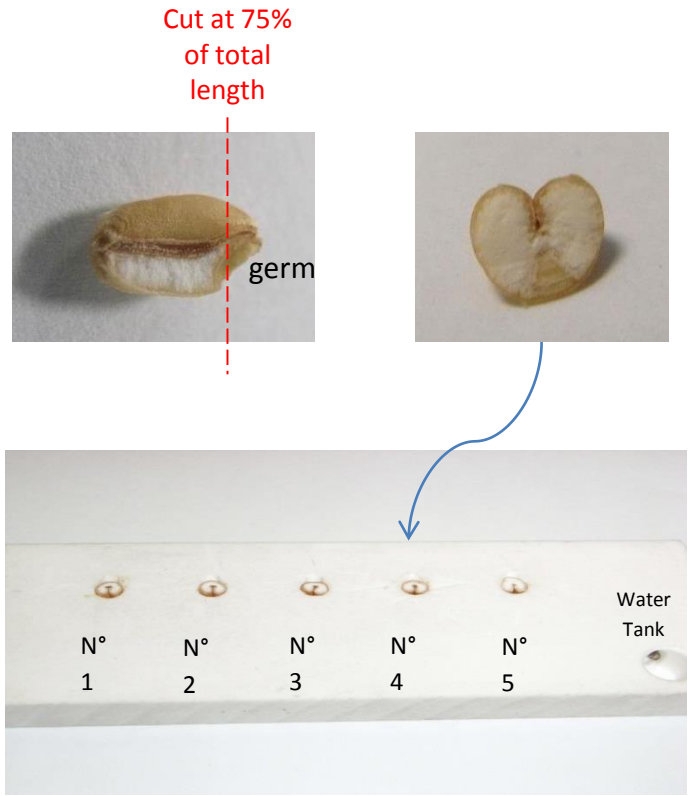
Use an algorithm based on the simultaneous spectral decomposition of the covariance matrices calculated for each NIR image

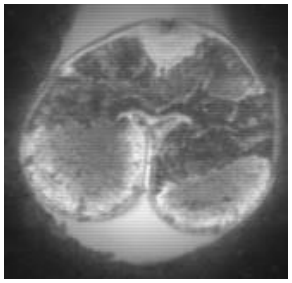
↳ **existence of common loading vectors that can be weighted differently for each multivariate image**

Material & Methods

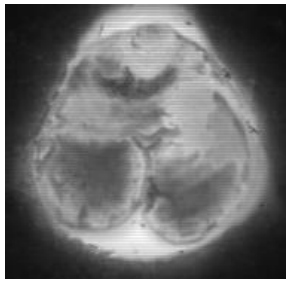
5 wheat kernels were cut transversely at 75% and placed in holes drilled in a Teflon holder, connected to a water tank.

- Acquisition of a NIR reference image of the surface of each seed
- Addition of water in the tank
- Acquisition of NIR images of the surface at different time intervals (0, 30min, 1h00, 5h00, 9h00, 24h00, 28h00, 33h00)





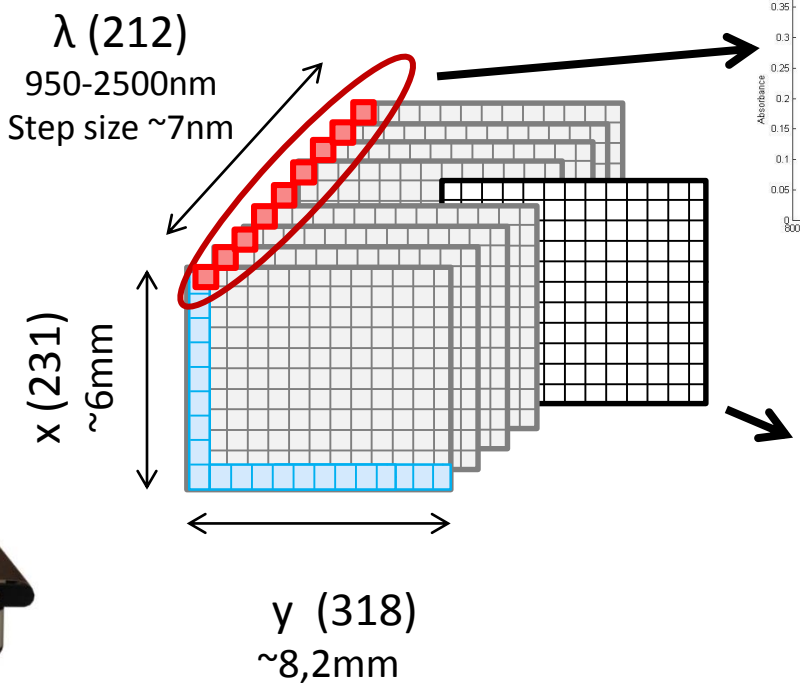
T=0



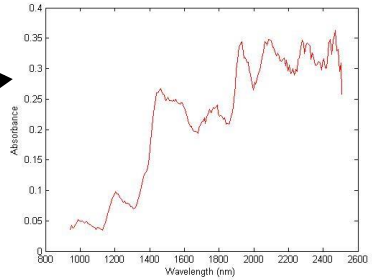
T=33h

Near-Infrared hyperspectral Imaging

HyperPro (BurgerMetrics)



Spectrum of a given point xy



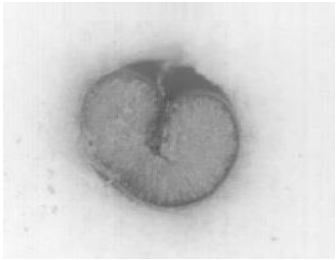


Image obtained at the selected wavelength

1min20s/image

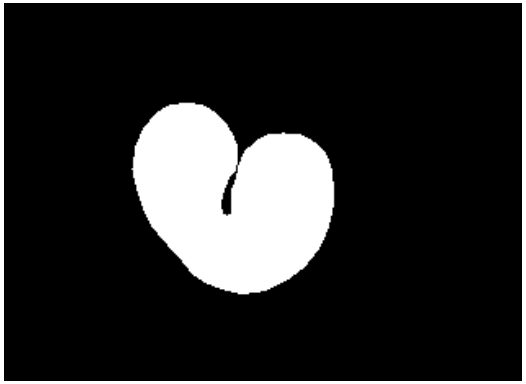
" Pushbroom" hyperspectral imaging system :

- Acquisition of an entire line (26µm spatial resolution)
- The belt advances along the y direction and a new line is acquired

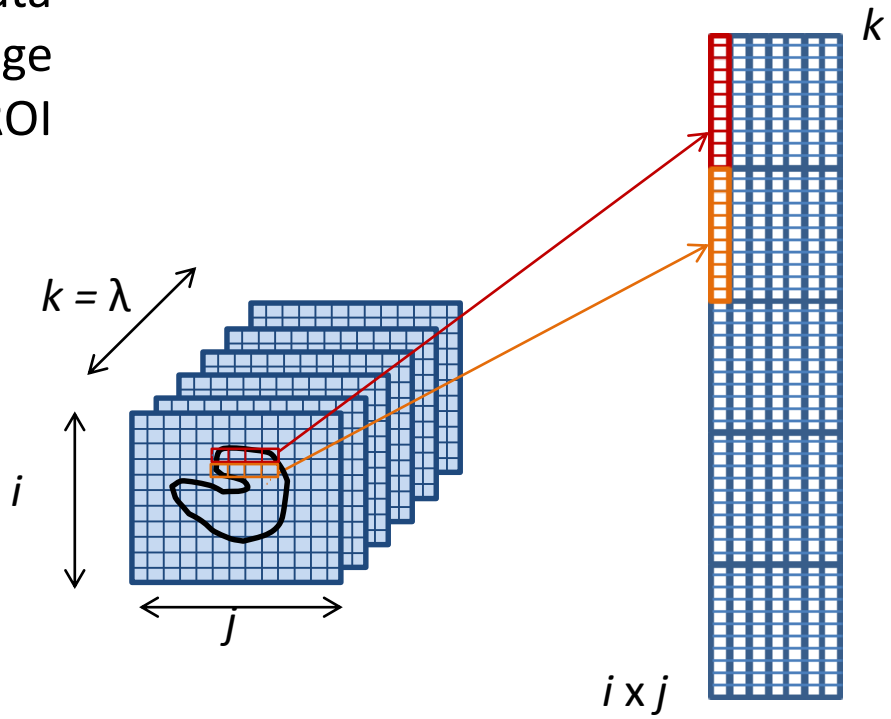
Data pre-treatments

ROI selection

A manual segmentation is performed on the averaged image for each data cube, resulting on a binary image (pixel values equal to 1 for the ROI and to 0 for the background



Hypercube unfolding



$\underline{\mathbf{X}}$
Multivariate image

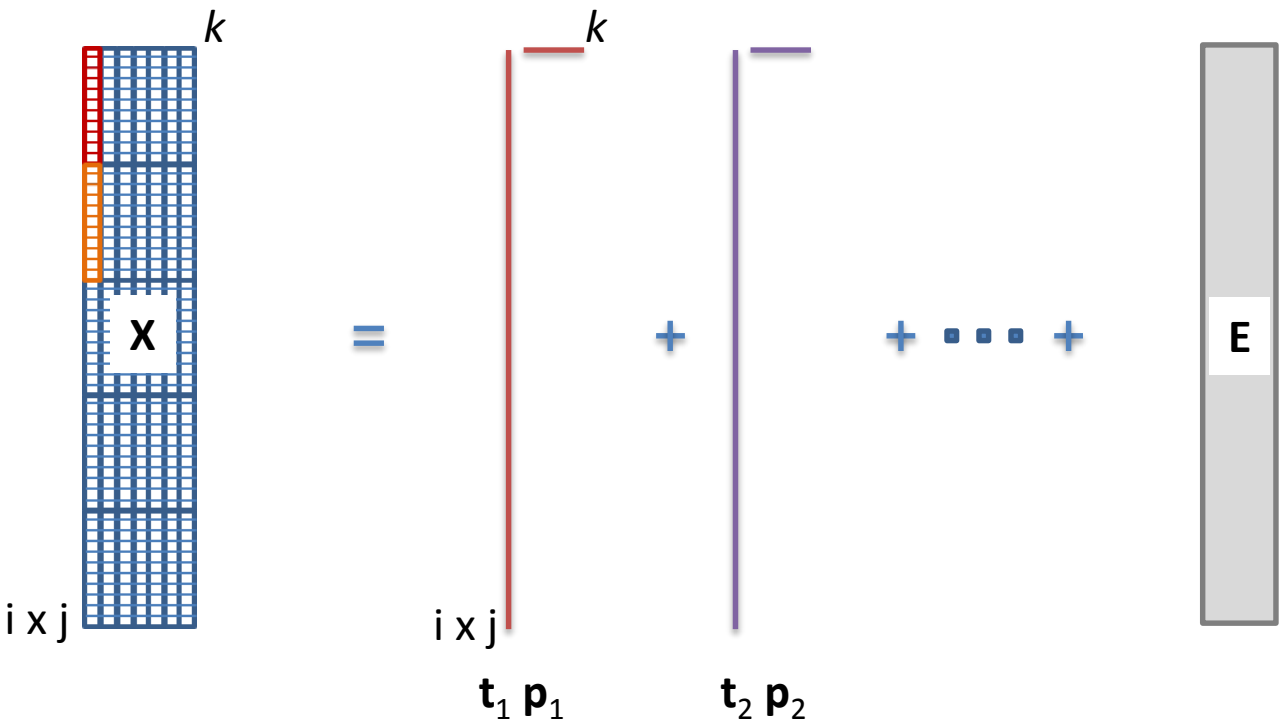
$\mathbf{X}$
Unfolded matrix $\mathbf{X}$

PCA of <u>one</u> multi-way image

$$\mathbf{X} = \sum_{a=1}^{A} \mathbf{t}_a \otimes \mathbf{p}'_a + \mathbf{E}$$

$\mathbf{t}_a$: score vector which can be reorganized as score image

$\mathbf{p}_a$: common loading vectors



Due to its high dimension, singular value decomposition (SVD) of **X** is <u>time consuming</u>

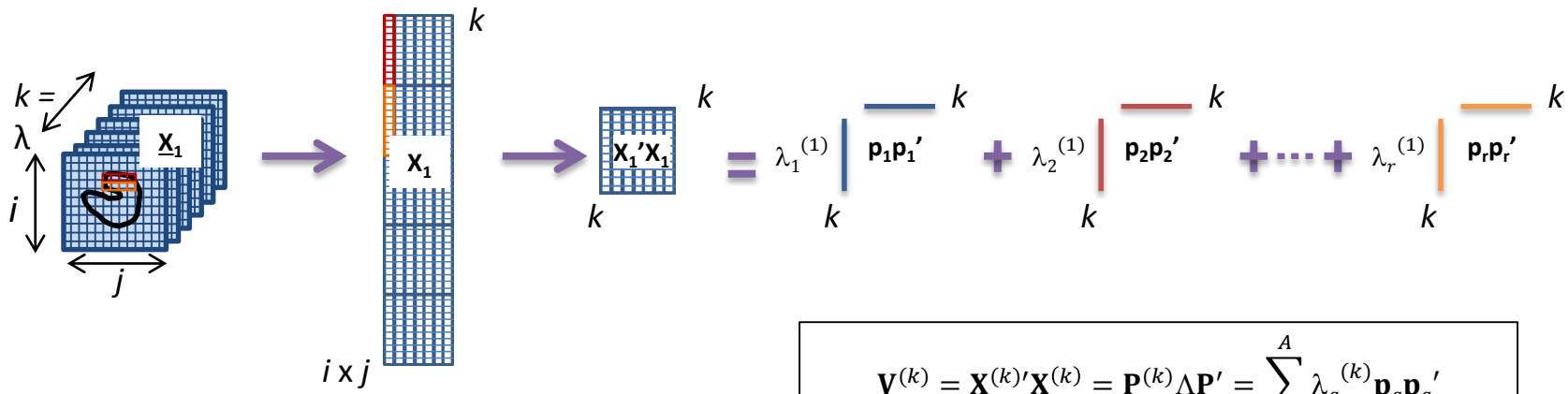
↳ loading vectors calculated by the SVD of the cross-product matrix $\mathbf{X}'\mathbf{X}$,

↳ With $\mathbf{V} = \mathbf{X}'\mathbf{X} = \mathbf{P}\Lambda\mathbf{P}'$ Λ: diagonal matrix of eigenvalues

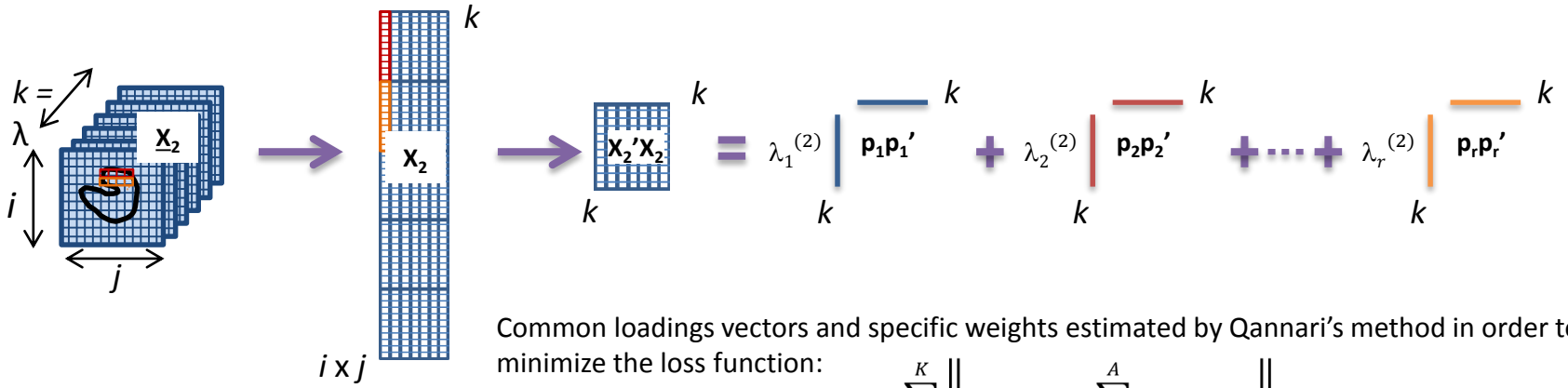
↳ and $\mathbf{T} = \mathbf{X}\mathbf{P}'$

PCA of several multi-way image

Multivariate images | Unfolded multivariate images | Covariance matrices | 1st dimension | 2nd dimension | rth dimension



$$\mathbf{V}^{(k)} = \mathbf{X}^{(k)\prime}\mathbf{X}^{(k)} = \mathbf{P}^{(k)}\Lambda\mathbf{P}' = \sum_{a=1}^{A} \lambda_a^{(k)} \mathbf{p}_a \mathbf{p}_a'$$

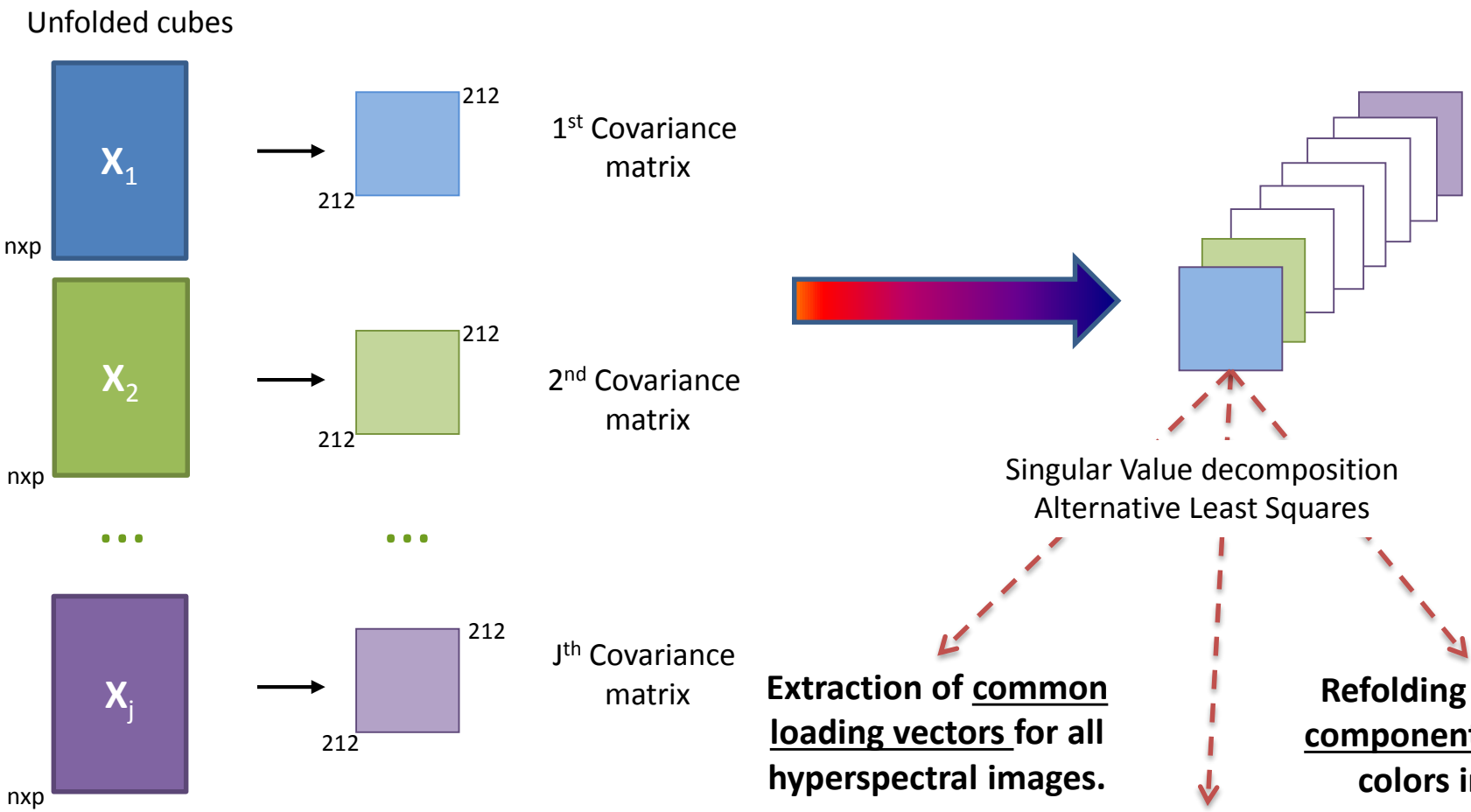


Common loadings vectors and specific weights estimated by Qannari's method in order to minimize the loss function:

$$L = \sum_{k=1}^{K} \left\| \mathbf{X}^{(k)\prime}\mathbf{X}^{(k)} - \sum_{a=1}^{A} \lambda_a^{(k)} \mathbf{p}_a \mathbf{p}_a' \right\|$$

Qannari et al. (2000) Food Qual. Pref., 11, 151-4.

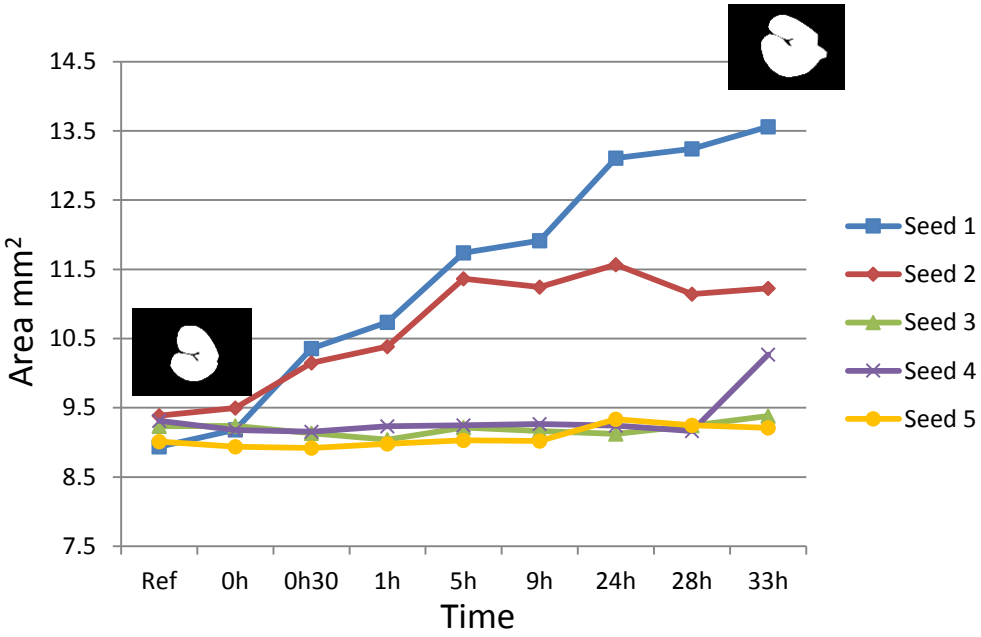
Simultaneous decomposition of multivariate images



SNV, center

Results

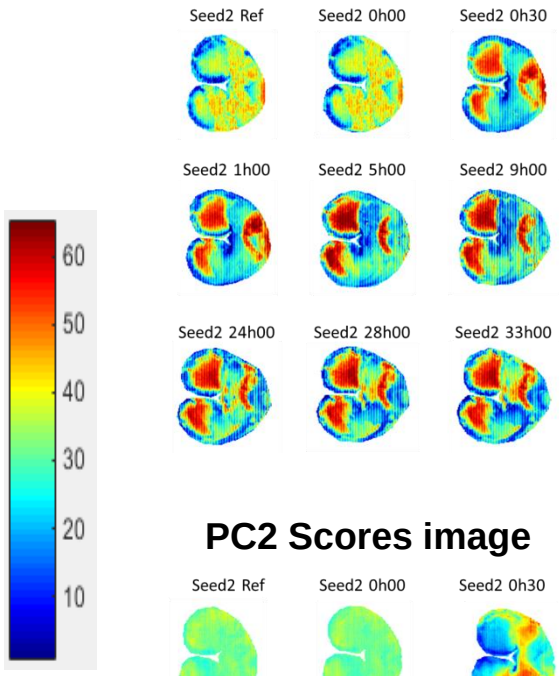
Area measurement:

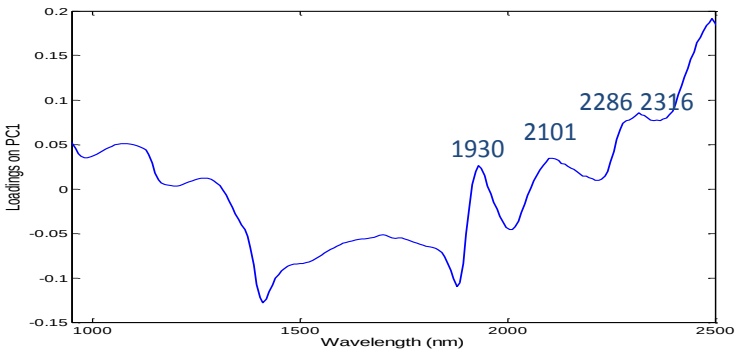


End of experiment, germinated seeds

Simultaneous decomposition for the seed N°2

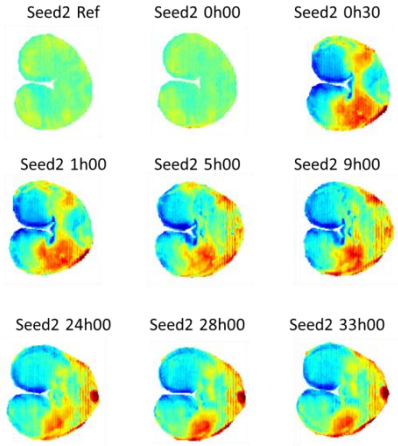
PC1 Scores image

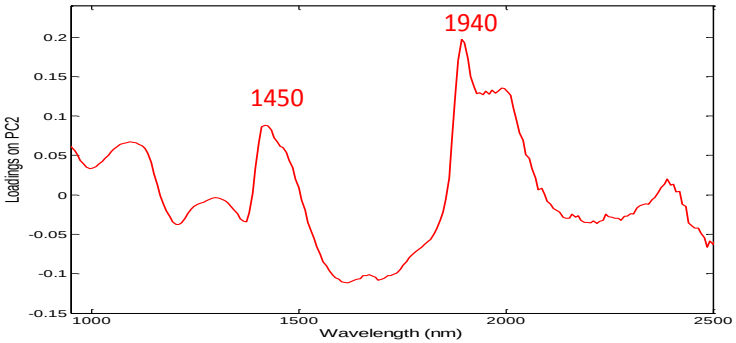




Starch

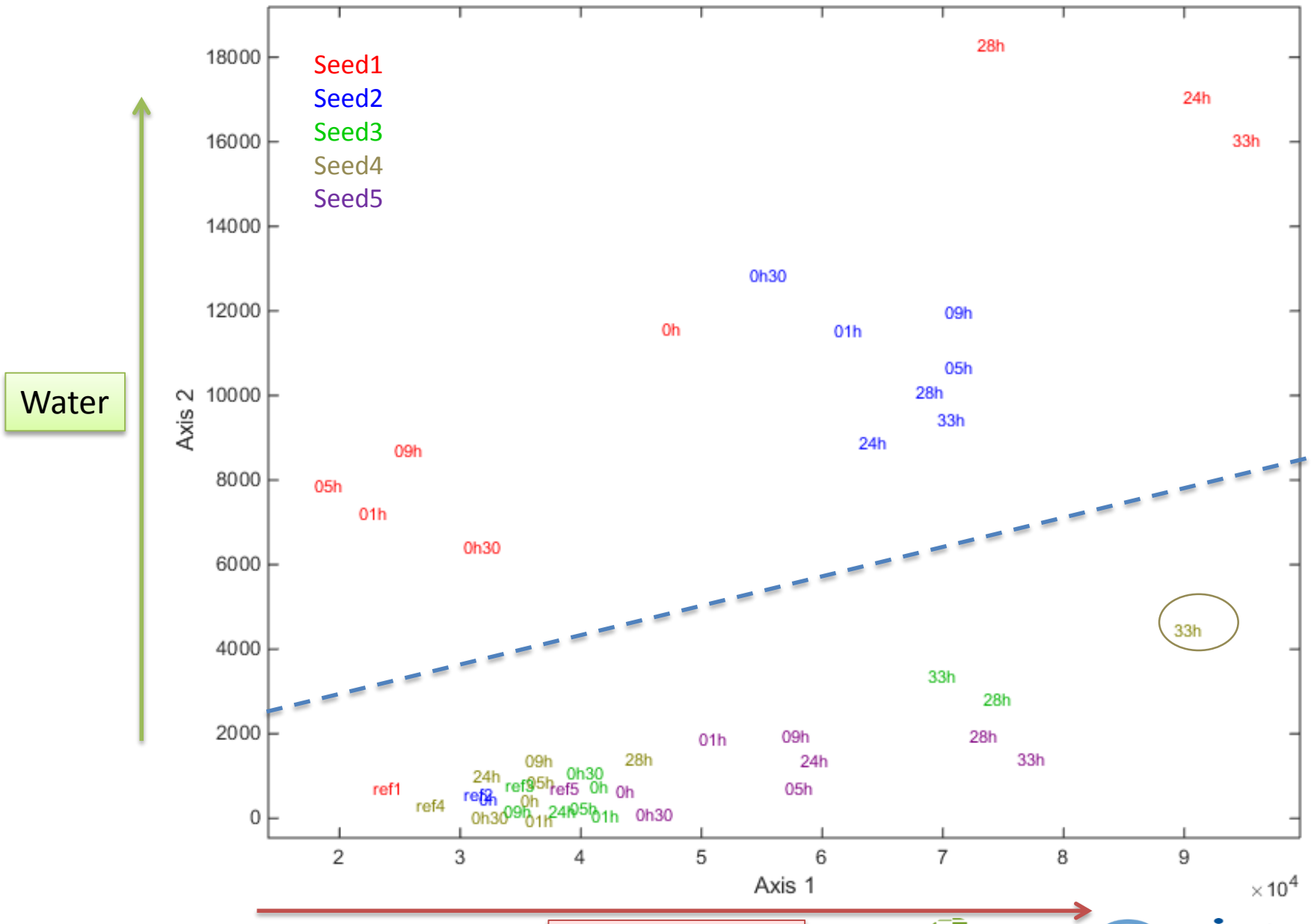
PC2 Scores image





Water

Projection of weights onto PC1-PC2



Conclusion

- A new approach has been developed to provide a detailed mapping of absorption and distribution of water in the tissues of the wheat grain using Near-infrared hyperspectral imaging and chemometrics.

- These results show that the kinetics of propagation of water are grain specific :
  - strong imbibition and germination
  - low imbibition and germination
  - no imbibition and no germination

- Beginning of imbibition process is sometimes extremely rapid (few minutes) but can also take hours. It depends on the dormancy release.

- Simultaneous decomposition are useful to obtain intensity images in false colors that bring out the spatial organization of the different components of the kernels.

Thanks for your attention

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