Temporal stability of Sentinel-2 information in tropical forests : influence of atmospheric correction method and implication for forest & biodiversity monitoring

Eric Chraibi, Nicolas Barbier, Gaëlle Viennois, Florian de Boissieu, Sandra Luque, Jean-Baptiste Féret

Living Planet Symposium 2022, May 23rd, Bonn

tetis
INRAE la science pour la vie, l'humain, la terre
AMAP
IRD Institut de Recherche pour le Développement FRANCE
Collège Doctoral Université de Montpellier
Université Montpellier
Ecole Doctorale GAIA Biodiversité Agriculture Alimentation Environnement Terre Eau
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Global biodiversity crisis

- Strong need for monitoring systems over all biomes
- 90% of deforestation between 1990-2020 occured in the tropics (FAO, 2020)
- Remote sensing holds strong potential for forest biodiversity monitoring
- Unprecedented amount of information collected from Earth observation systems

→ How can we get the most from satellite images of complex tropical systems?

ipcc
INTERGOVERNMENTAL PANEL ON climate change
Climate Change 2022
Impacts, Adaptation and Vulnerability
Summary for Policymakers

Global Biodiversity Outlook 5

LIVING PLANET REPORT 2020
BENDING THE CURVE OF BIODIVERSITY LOSS

Biodiversity loss risks 'ecological meltdown'

BBC, 10/09/2021

Estimating biodiversity from remotely sensed information

- Various dimensions of biodiversity: taxonomic, functional…
- Various types of sensors : multispectral, imaging spectroscopy, LiDAR, radar…
- Various methods, hypotheses and metrics to relate RS information to biodiversity

Remote sensing of terrestrial plant biodiversity

Ran Wang[a,*], John A. Gamon[a,b,c]

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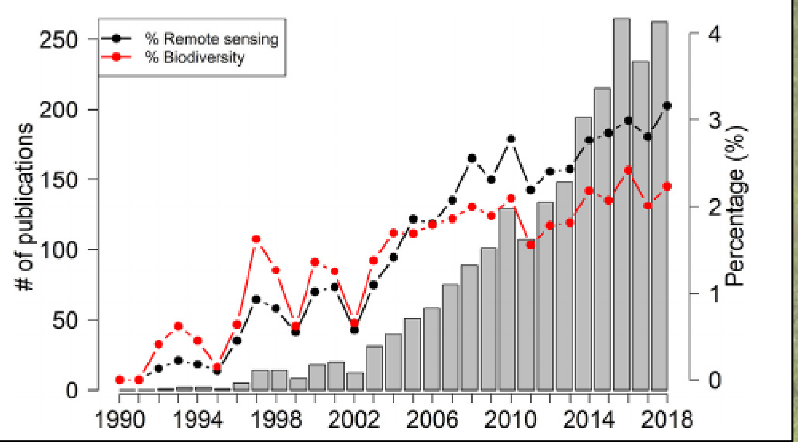
[b] *Department of Biological Sciences, University of Alberta, Edmonton, AB T6G 2E9, Canada*
[c] *School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE 68583, USA*

Wang and Gamon, Remote Sensing of the Environment 2019



ELSEVIER
Ecological Informatics
Volume 61, March 2021, 101195

From local spectral species to global spectral communities: A benchmark for ecosystem diversity estimate by remote sensing

Rocchini et al, Ecological Informatics 2021

Received: 18 July 2021 | Revised: 3 November 2021 | Accepted: 13 January 2022
DOI: 10.1111/avsc.12643
Applied Vegetation Science IAVS
SPECIAL FEATURE: REMOTE SENSING

About the link between biodiversity and spectral variation

Fabian Ewald Fassnacht[1] | Jana Müllerová[2,3] | Luisa Conti[4] | Marco Malavasi[4] | Sebastian Schmidtlein[1]

Fassnacht et al., Applied Vegetation Science 2022

Applied Vegetation Science
Conservation, restoration and survey of plant communities
IAVS
SPECIAL FEATURE: REMOTE SENSING | Open Access

Which optical traits enable an estimation of tree species diversity based on the Spectral Variation Hypothesis?

Michele Torresani, Hannes Feilhauer, Duccio Rocchini, Jean-Baptiste Féret, Marc Zebisch, Giustino Tonon

Torresani et al, Applied Vegetation Science 2021

ARTICLE
https://doi.org/10.1038/s41467-022-30369-6 OPEN

Plant beta-diversity across biomes captured by imaging spectroscopy

Anna K. Schweiger[1,2] & Etienne Laliberté[1]

Schweiger and Laliberté 2022, Nature Communications

Influence of atmospheric correction methods (ACMs) on forest monitoring

- Various ACMs available, method inter-comparisons exist
- Criterions of performance may not reflect suitability to specific applications land types

remote sensing MDPI

Article

Atmospheric Correction Inter-Comparison Exercise

Georgia Doxani [1,*], Eric Vermote [2,*], Jean-Claude Roger [2,3], Ferran Gascon [4], Stefan Adriaensen [5], David Frantz [6,†], Olivier Hagolle [7], André Hollstein [8], Grit Kirches [9], Fuqin Li [10], Jérôme Louis [11], Antoine Mangin [12], Nima Pahlevan [2,13], Bringfried Pflug [14] and Quinten Vanhellemont [15]

Doxani et al., Remote Sensing 2018

ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume V-3-2021
XXIV ISPRS Congress (2021 edition)

EVALUATING THE IMPACT OF LASRC AND SEN2COR ATMOSPHERIC CORRECTION ALGORITHMS ON LANDSAT-8/OLI AND SENTINEL-2/MSI DATA OVER AERONET STATIONS IN BRAZILIAN TERRITORY

Rennan F. B. Marujo [a,b,*], José G. Fronza [a,b], Anderson R. Soares [a], Gilberto R. Queiroz [a] and Karine R. Ferreira [a]

Marujo et al., ISPRS Annals 2021

Influence of atmospheric correction methods (ACMs) on forest monitoring

- Various ACMs available, method inter-comparisons exist
- Criterions of performance may not reflect suitability to specific applications land types
- Strong artefacts and differences between methods observed over tropical forests may compromise reliability of spectral metrics used to monitor biodiversity

remote sensing MDPI

Article

Atmospheric Correction Inter-Comparison Exercise

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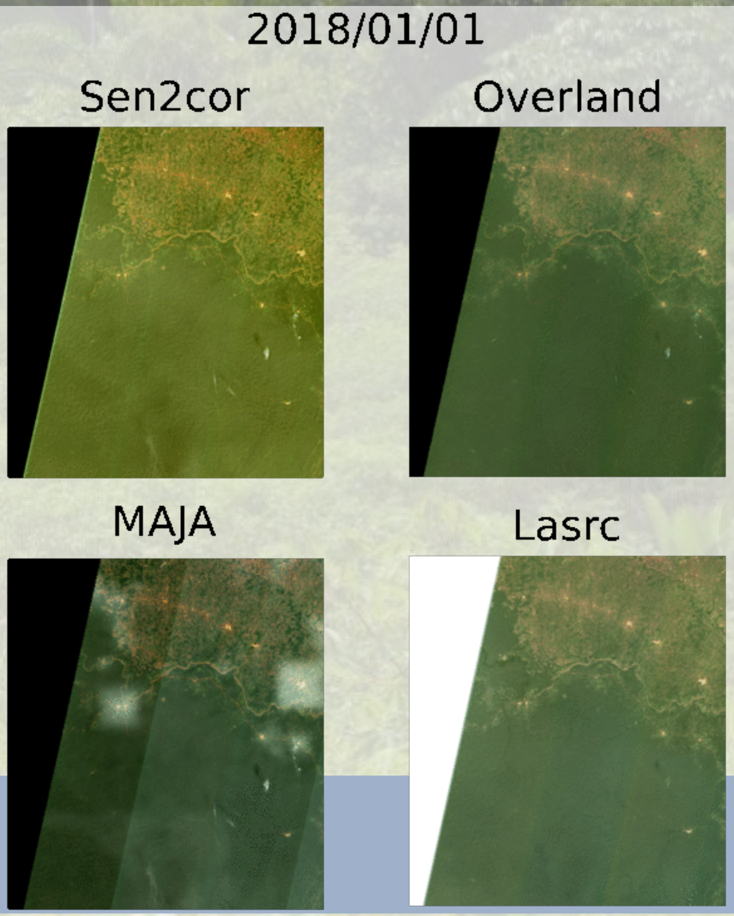
Marujo et al., ISPRS Annals 2021

Animation shows :

- Comparison of 4 ACMs applied on a **Sentinel-2 time series**
- One tile over tropical forest in Cameroon : T33NVE

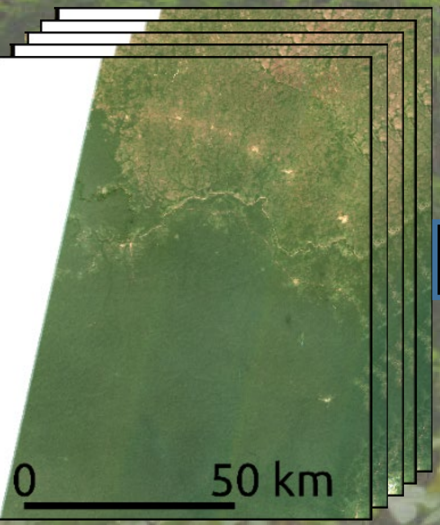
BOA reflectance of RGB bands with uniform color stretch (0-10%)



Overall description of our analytical framework

<u>Our objective:</u> assess the influence of ACMs on bottom of atmosphere reflectance and products derived from spectral information, in the context of dense tropical forest monitoring

S2 time series



Atmospheric corrections

- MAJA
- Sen2cor
- Overland
- LaSRC

RS products

- BOA Reflectance
- Spectral indices : NDVI, EVI, NDWI
- Spectral diversity metrics

Criterion for comparison

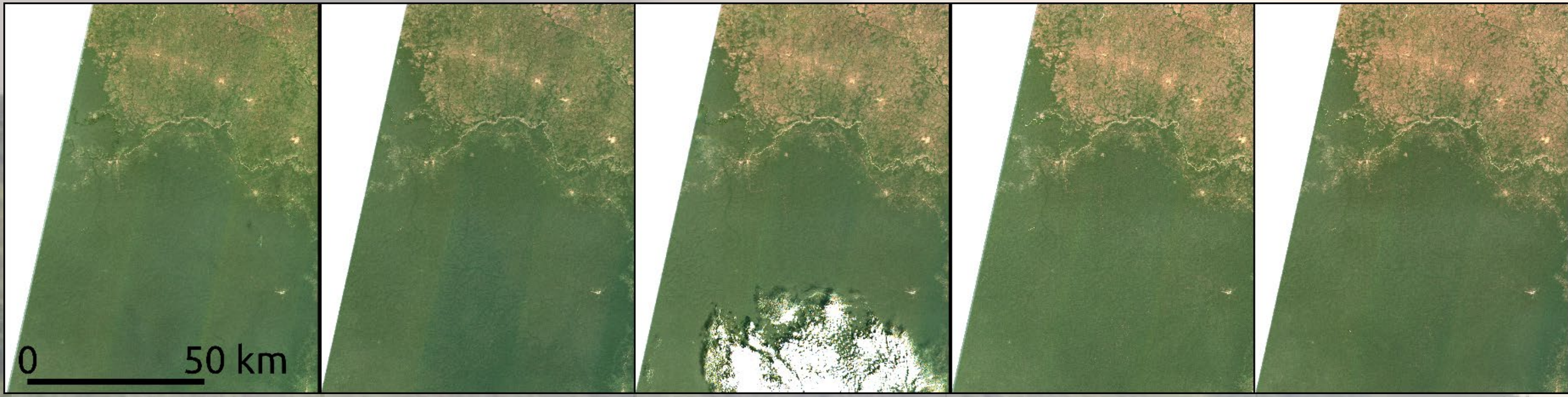
- Temporal stability of individual AC method
- Agreement between AC methods
- Upscaling Consistency

Materials: S2 time series identified for our study

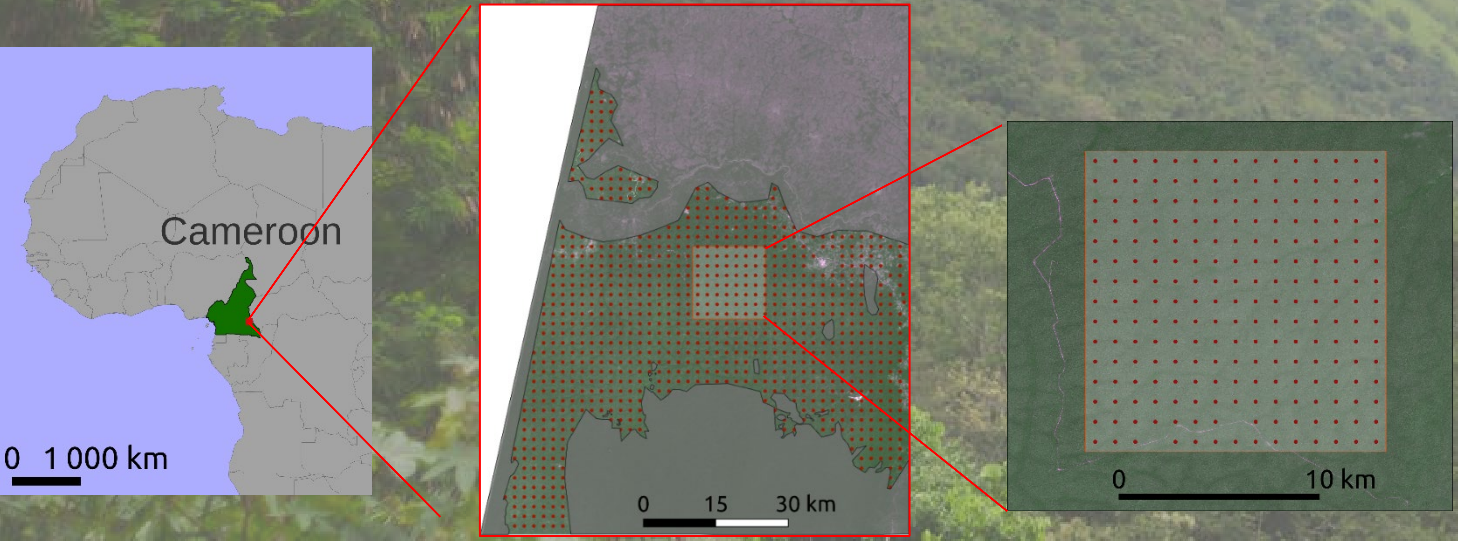
Hypotheses:

- Forests experience moderate changes during a relatively short period of time
- 'Stable' canopy reflectance expected

Selection of cloudfree/moderately cloudy S2 images for one tile over ~ 1 month



2018/01/01 | 2018/01/06 | 2018/01/26 | 2018/01/31 | 2018/02/05



Two spatial scales of analysis:

- **Full tile:** includes improperly masked clouds, non forest pixels, sensor artifacts…
- **Subset of dense tropical forest:** minimum environmental and sensor artifacts

Methods: computation of spectral diversity metrics with biodivMapR

Mapping tropical forest canopy diversity using high-fidelity imaging spectroscopy

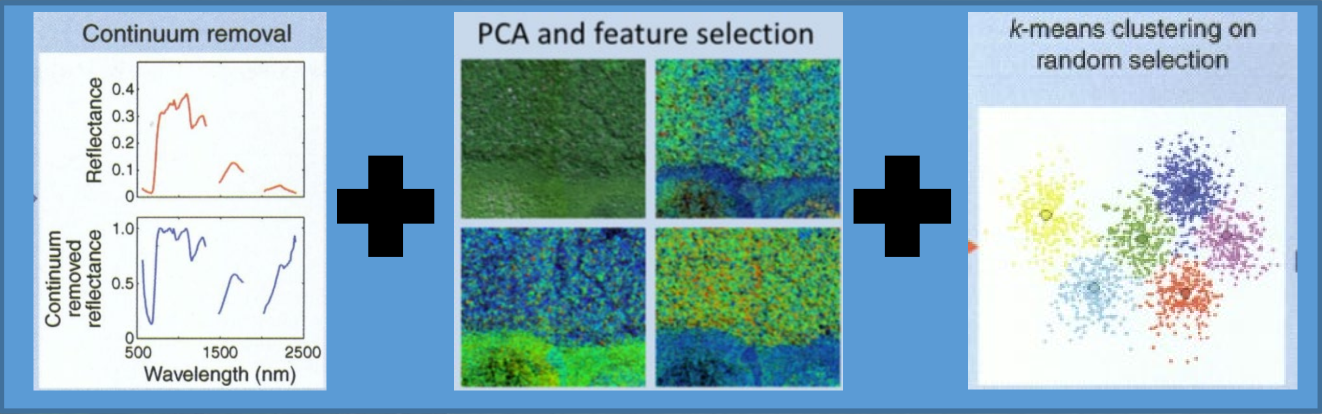
Jean-Baptiste Féret[1] and Gregory P. Asner

Féret & Asner, Ecological Applications 2014

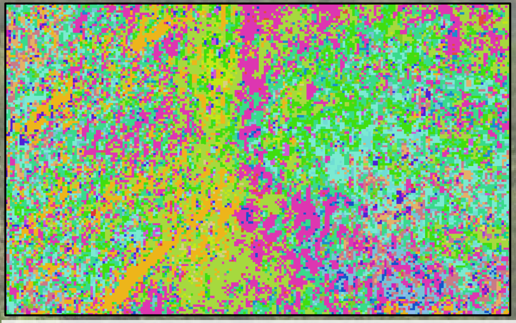
biodivMapR: An R package for **α-** and **β-**diversity mapping using remotely sensed images

Jean-Baptiste Féret, Florian de Boissieu

Féret & de Boissieu, Methods in Ecology and Evolution 2019

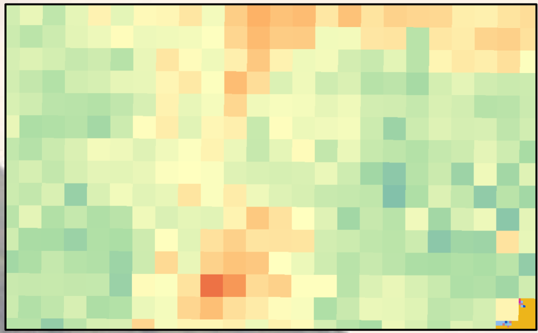


Sentinel-2 image

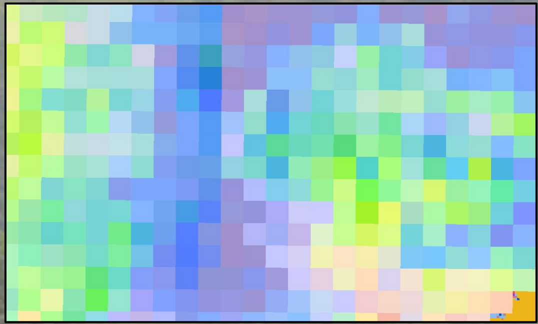


Clustering of transformed spectral space

Spectral diversity maps

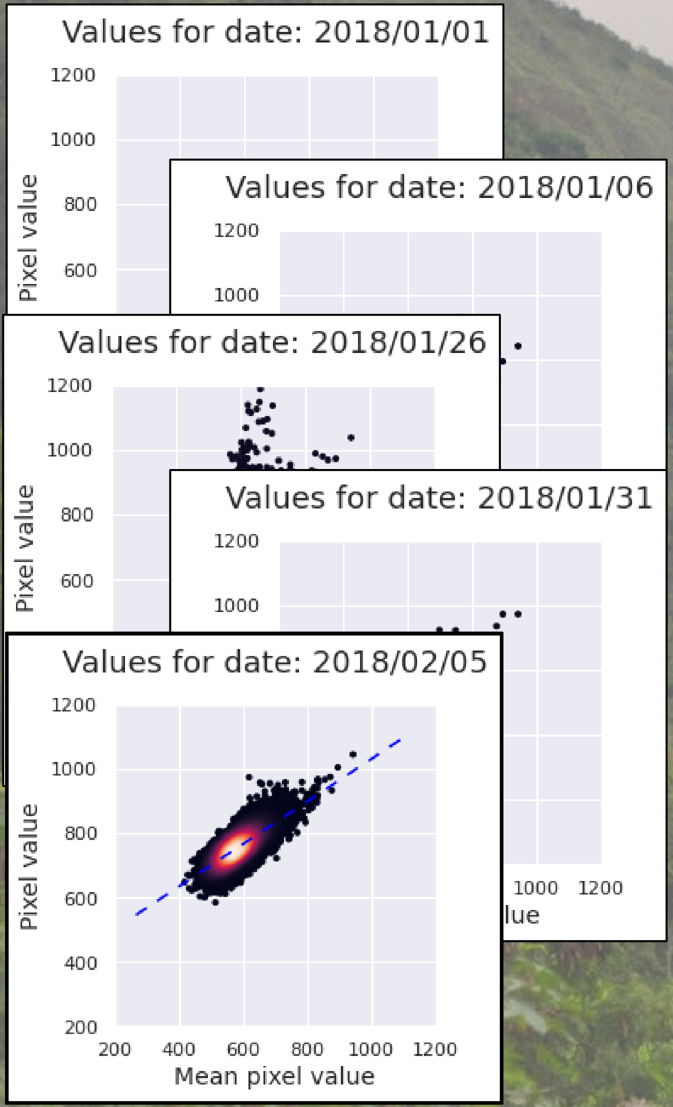


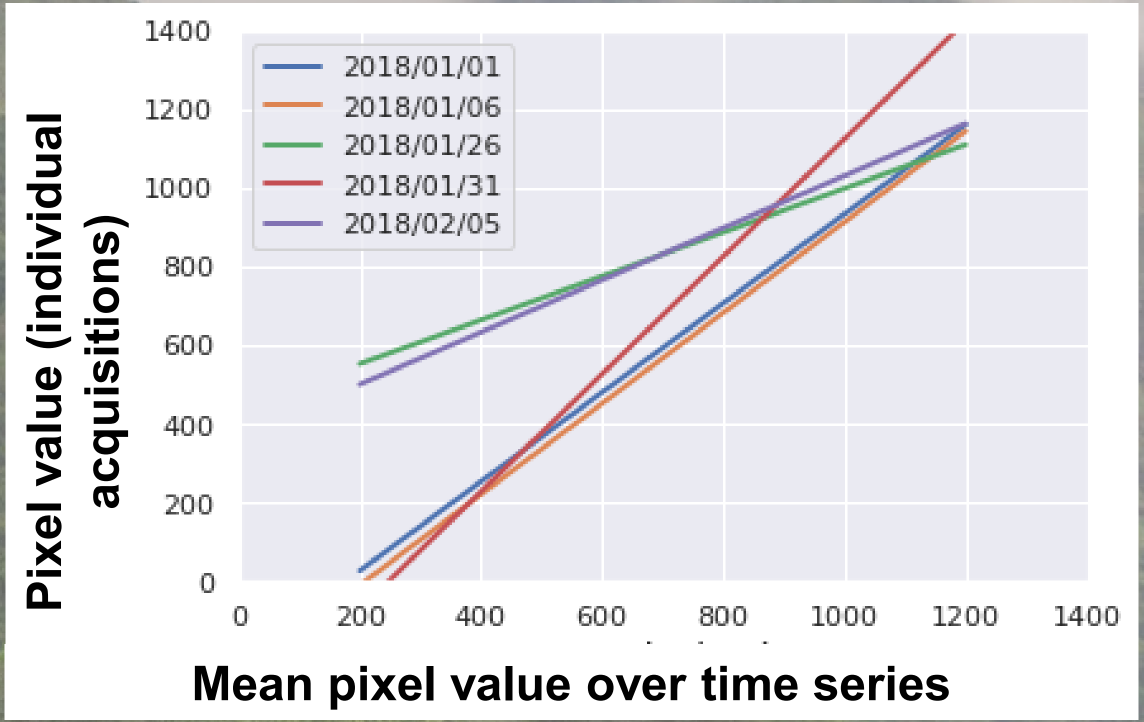
Alpha Diversity
Local diversity



Beta Diversity
Compositional difference between groups

Methods: Definition of the temporal stability of an ACM

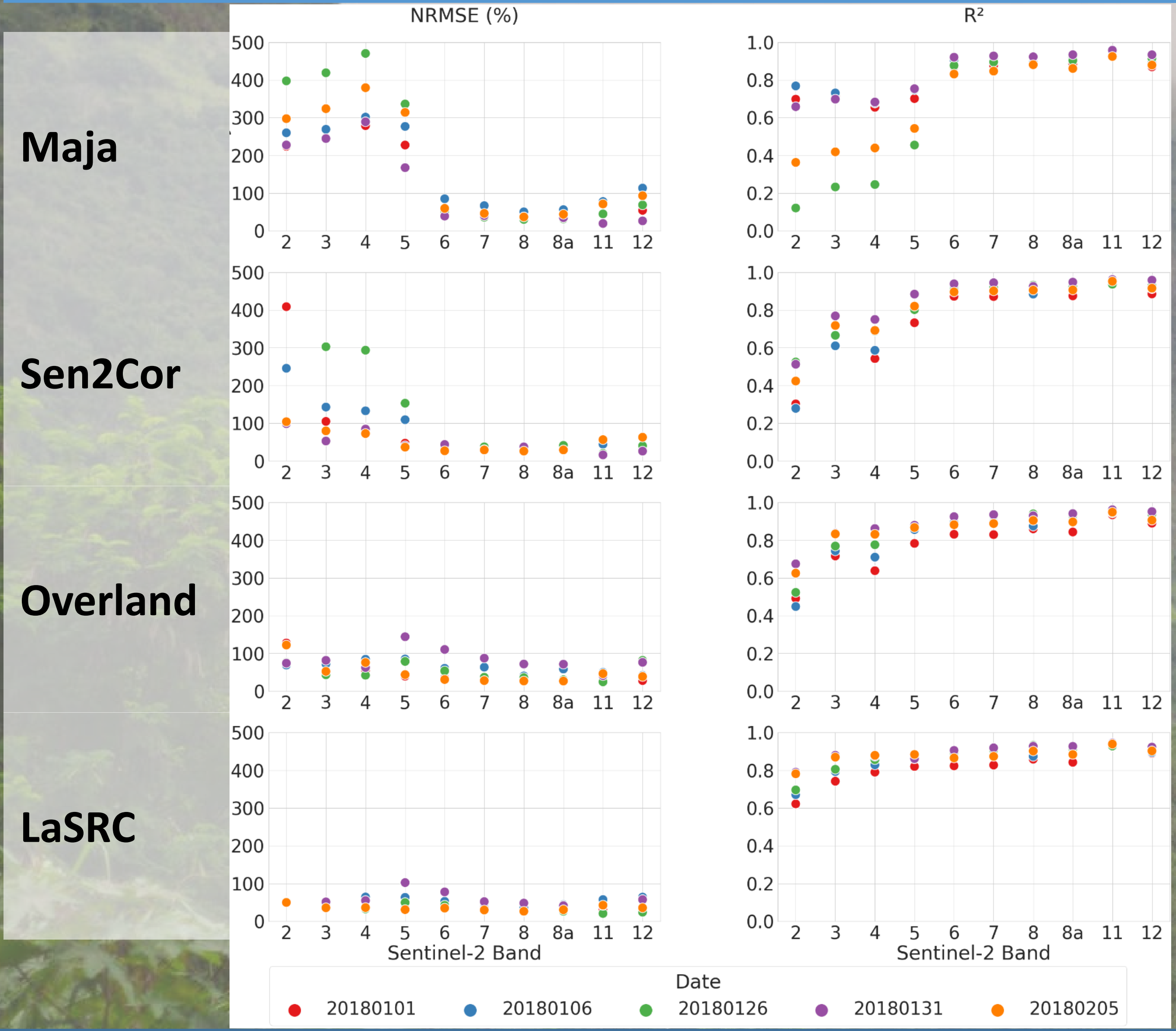




For BOA reflectance, spectral index & spectral diversity metrics :
R^2 and NRMSE between pixel value of individual acquisitions and value averaged over time series

Date	R^2	NRMSE (%)
2018/01/01	0.70	28
2018/01/06	0.75	33
2018/01/26	0.46	41
2018/01/31	0.75	20
2018/02/05	0.54	38

Temporal stability of S2 BOA reflectance

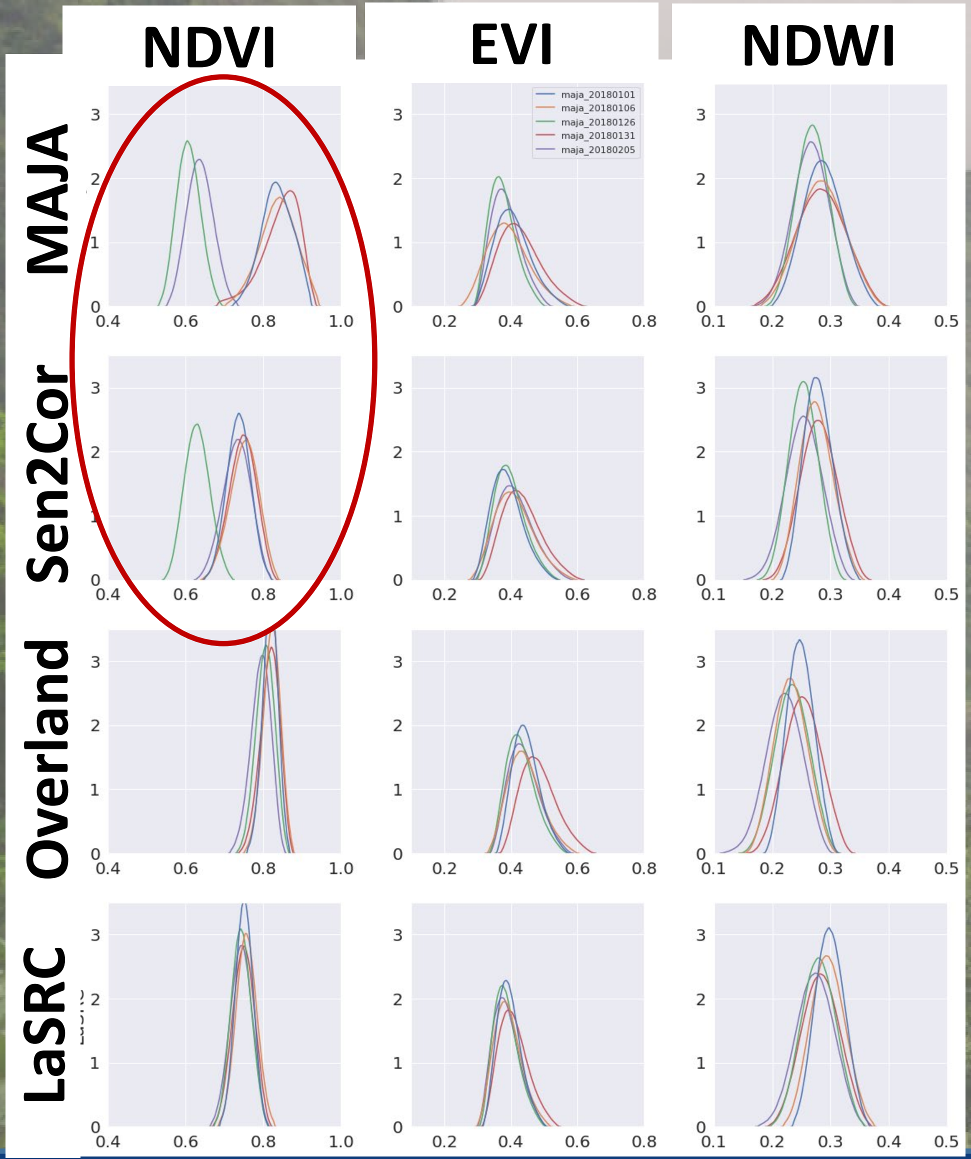


VIS and Red-Edge (B5) bands strongly vary between acquisitions for Maja and Sen2Cor

NIR & SWIR more stable for all methods

Overall, temporal stability of BOA reflectance produced over a time series with Overland and LaSRC is higher

Stability of spectral Indices over a time series



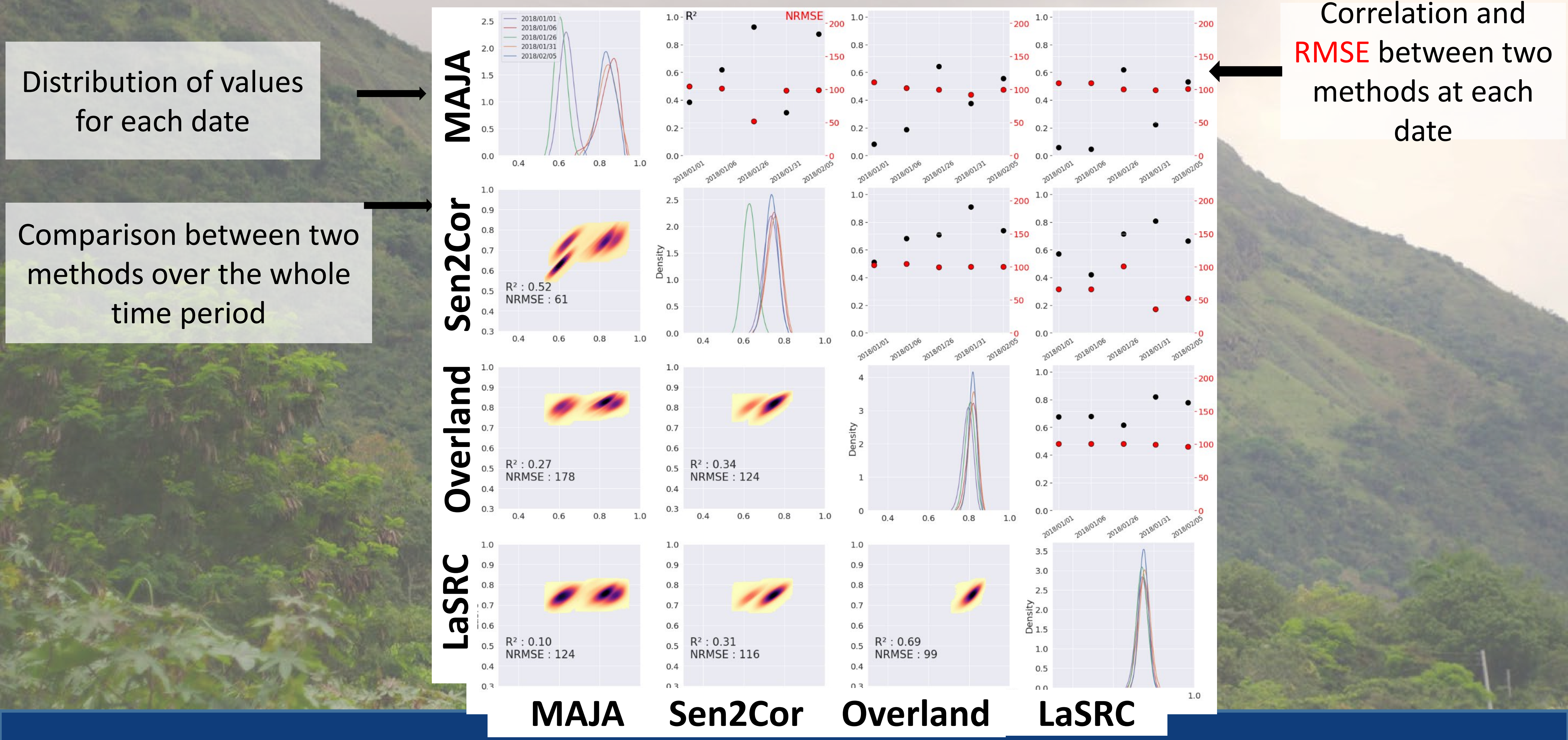
NDVI : important differences among acquisitions
→ Influence of VIS inconsistency across time

EVI : more stable despite using 2 VIS bands
→ Enhancement does its job !

NDWI: globally more stable
→ Stability of SWIR for all methods

LaSRC and Overland tend to be more consistent

Comparison between ACM : case of NDVI

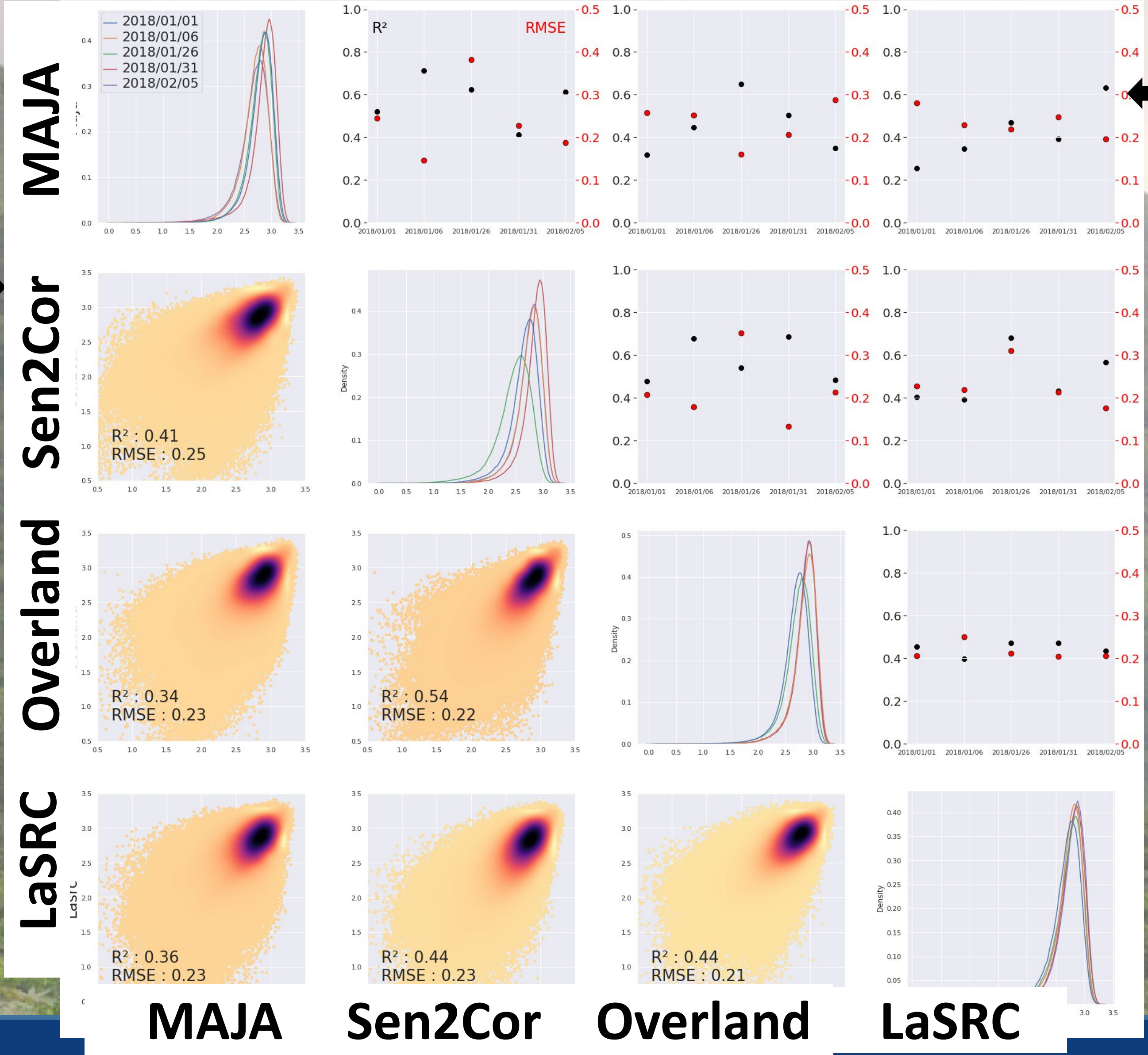


Comparison between ACM– Alpha Diversity (Shannon index)

Distribution of values for each date

Comparison between two methods over the whole time period

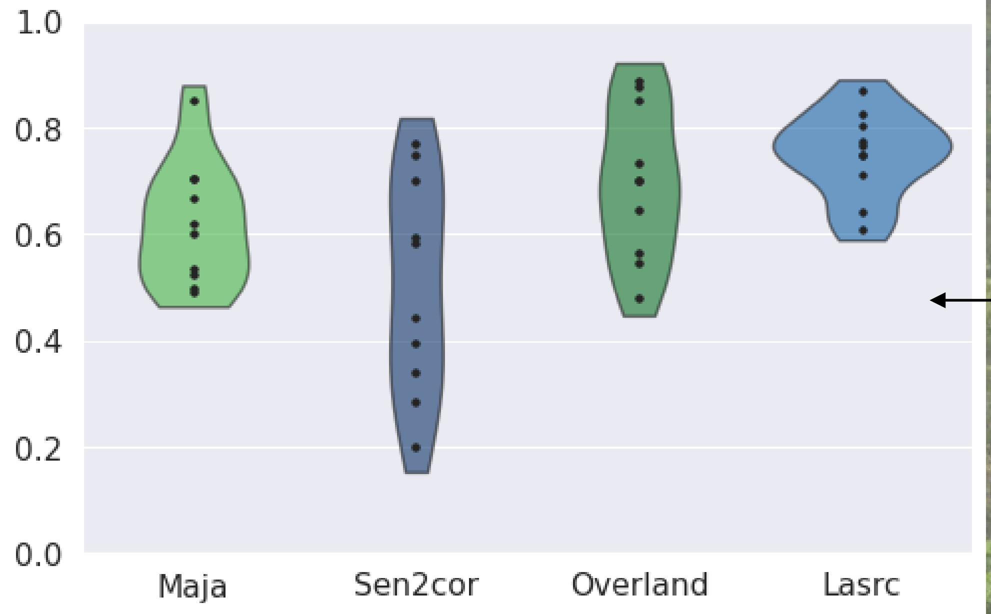
Correlation and RMSE between two methods at each date



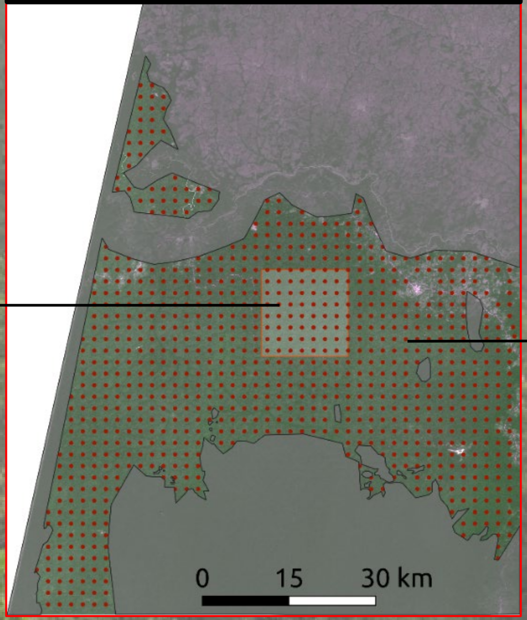
Stability of results– Beta Diversity (Bray Curtis dissimilarity)

- Spectral dissimilarity across space is influenced by spatial extent analyzed
- Relatively consistent spectral dissimilarity computed from subset with minimum artifacts
- Strong decrease in consistency of spectral dissimilarity for most ACMs when considering full tile

Subset – minimum local artifacts



Tile T33NVE



Full tile – sensor & environmental artifacts

Conclusions & perspectives

- Temporal stability of VIS Bands & NDVI over tropical forests varies depending on ACM
- NIR & SWIR bands are less affected
- LaSRC appeared as the most suitable ACM for tropical forest monitoring in our study
- Need to perform direct validation using in situ mesurements and forest inventories
- … This may not hold across land surface types (Temperate vs. Tropical, Forest vs . agricultural land vs. bare soil…)

	Temporal Stability							**Tile vs. subset**	
	BOA reflectance (S2 bands)		Vegetation indices			Spectral diversity		Spectral diversity	
	B02-B05	B06-B12	NDVI	EVI	NDWI	Alpha	Beta	Alpha	Beta
MAJA	−	✓	−	✓	✓	−	✗	✗	−
Sen2cor	−	✓	−	✓	✓	−	✗	✗	✗
Overland	−	✓	−	✓	✓	−	−	−	−
LaSRC	✓	✓	✓	✓	✓	✓	−	−	✓

Thank you
Questions?

We thank CNES & THEIA data & service center for MAJA, ESA for Sen2Cor, NASA for distribution of LaSRC, and Airbus for Overland

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Most data processings can be reproduced with open source packages, including :

https://jbferet.github.io/biodivMapR/

https://jbferet.gitlab.io/prosail/

https://jbferet.gitlab.io/preprocs2/

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