Remotely Sensing Functional Diversity – A Temperate Forest Case Study

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Future Earth Symposium: Global Biodiversity Monitoring

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Content

Introduction

A scaling based approach to remotely measure functional diversity change

Essential Biodiversity Variables and Ecosystem Services

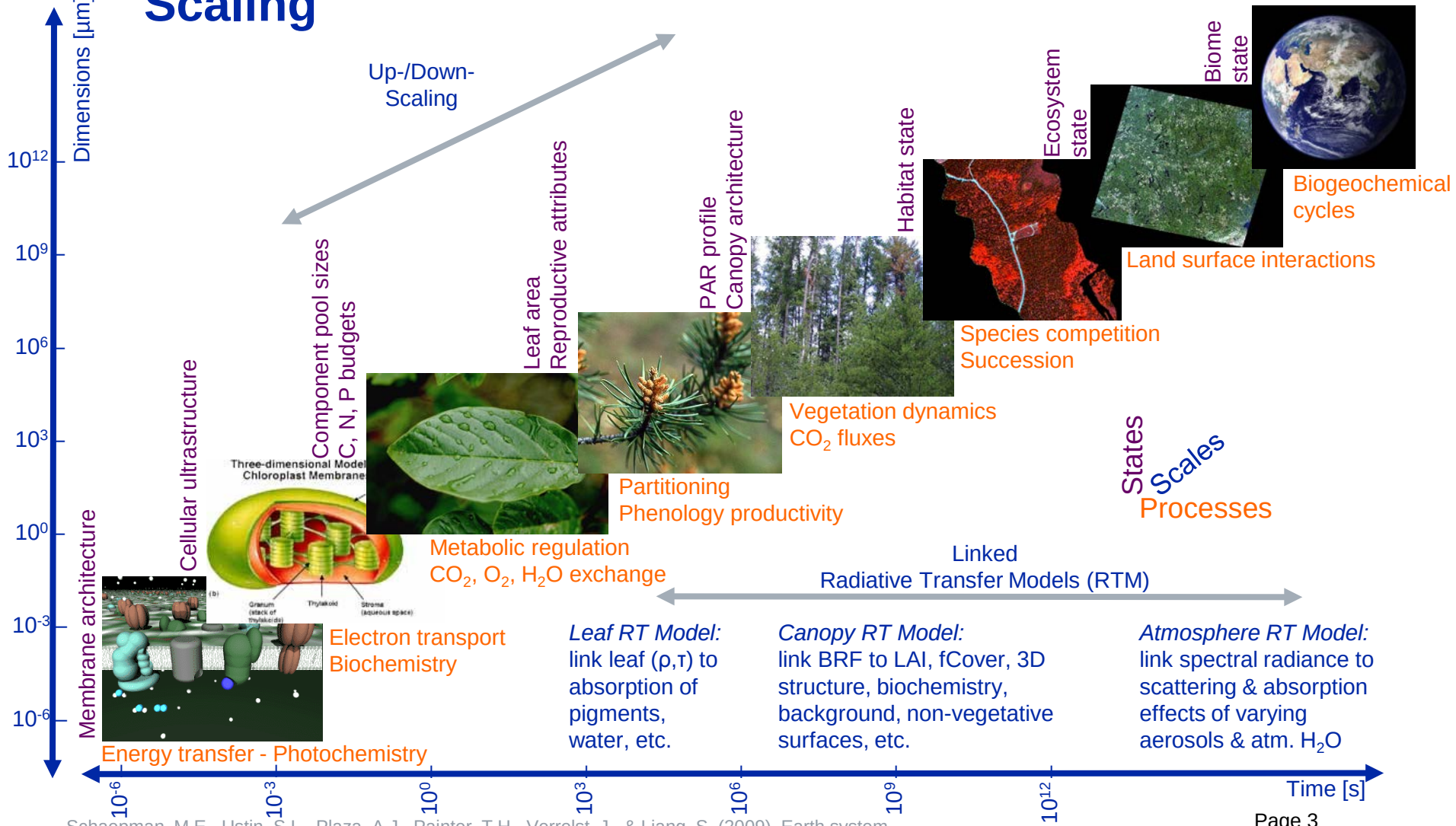
3D vegetation laboratory (aka ‘The Swiss Army Knife’ approach)

Latitudinal gradient of experimental systems

Coherent, globally derived Essential Biodiversity Variables and Constraints (Human Impact, Land Surface Phenology and Growth Limiting Factors)

Conclusions

Scaling



Schaepman, M.E., Ustin, S.L., Plaza, A.J., Painter, T.H., Verrelst, J., & Liang, S. (2009). Earth system science related imaging spectroscopy--An assessment. *Remote Sensing of Environment, 113*, S123-S137

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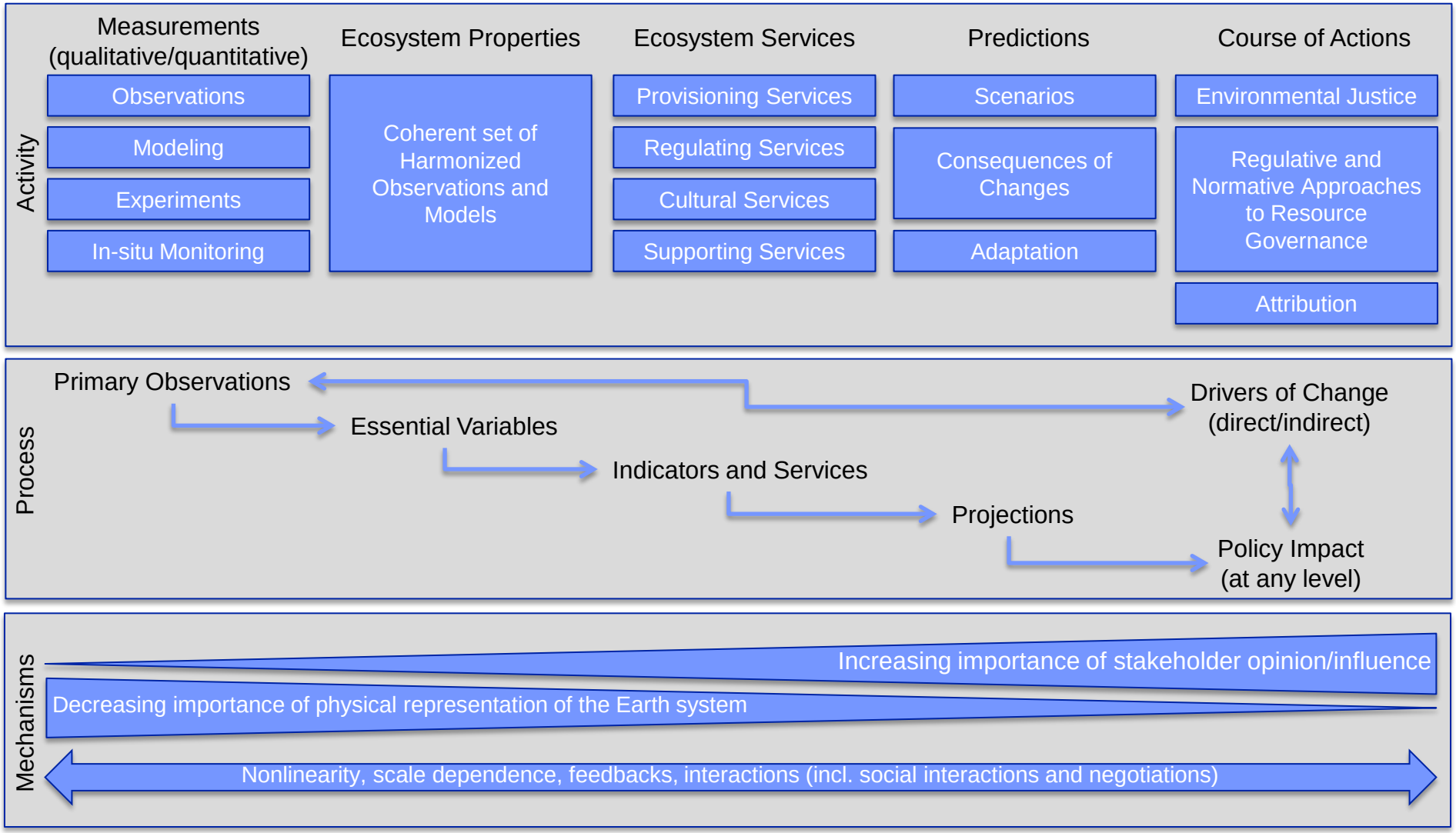


Schaepman, M.E., et. al. (2015 (in preparation)). Assessing the impact of global change drivers on biodiversity using mechanisms of feedback, interactions and scale. *Current Opinion in Environmental Sustainability*

3DVegLab: (Co-)Dominant Temperate Tree Species

	Species scientific name	Species common name
	*Abies alba*	Silver Fir
	*Picea abies*	Norway spruce
	*Pinus sylvestris*	Scots pine
	*Acer campestre*	Field Maple
	*Acer platanoides*	Norway Maple
	*Acer pseudoplatanus*	Sycamore
	*Carpinus betulus*	Hornbeam

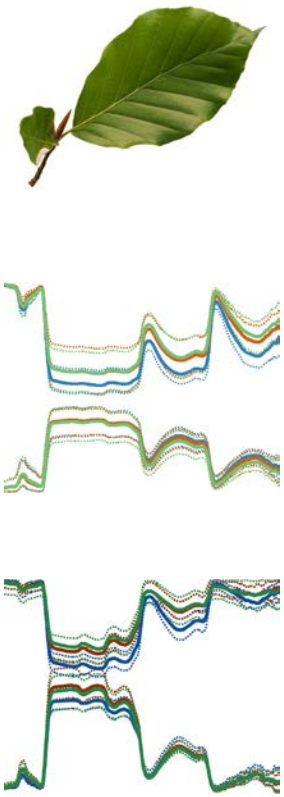
	Species scientific name	Species common name
	*Fagus sylvatica*	Beech
	*Fraxinus excelsior*	Ash
	*Quercus petraea*	Sessile Oak
	*Sorbus aria*	Whitebeam
	*Tilia platyphyllos*	Large Leaved
	*Ulmus glabra*	Wych Elm

3DVegLab: In-situ Measurements

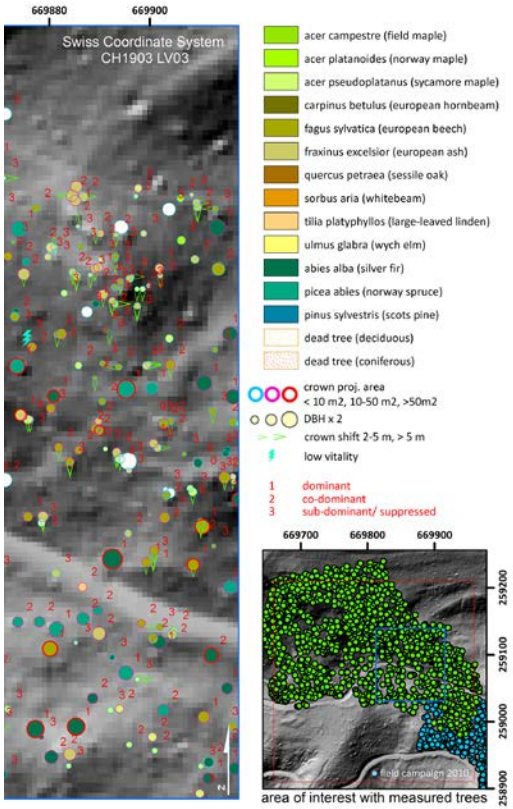
DHP

TLS

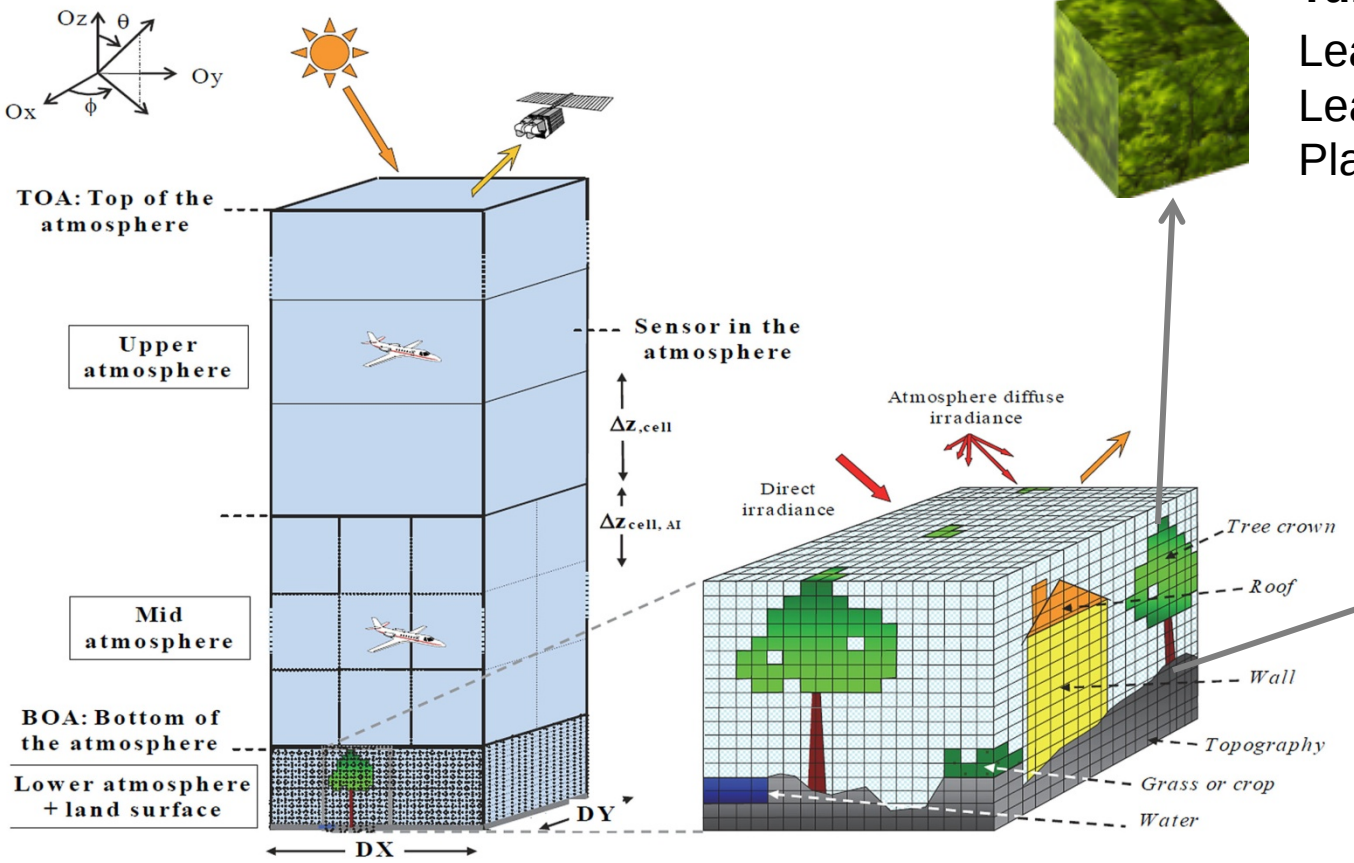
LOP



Forest inventory

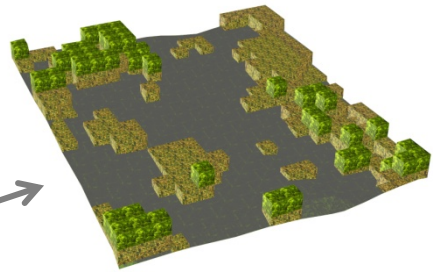


DART: Discrete Anisotropic Radiative Transfer



Turbid Medium

Leaf optical properties
Leaf angle distribution
Plant area index

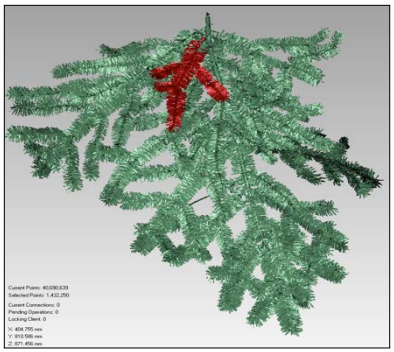


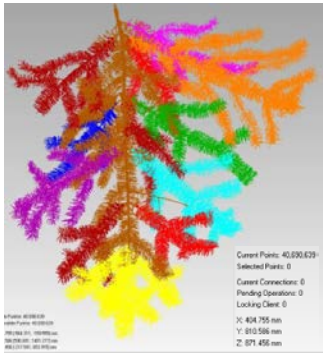
Canopy Background

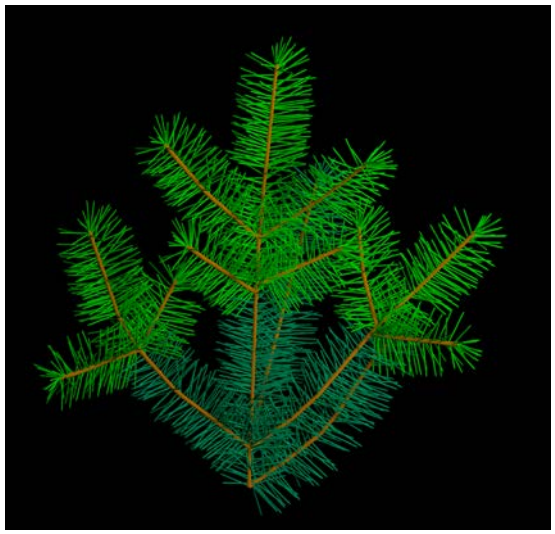
Digital terrain model
Understorey vegetation
Background plots

Gastellu-Etchegorry, J.-P., Grau, E., & Lauret, N. (2012). DART: a 3D model for remote sensing images and radiative budget of earth surfaces. In C. Alexandru (Ed.), Modeling and Simulation in Engineering, Chapter 2.

Shoot to Tree Reconstruction (LOP and Architecture)



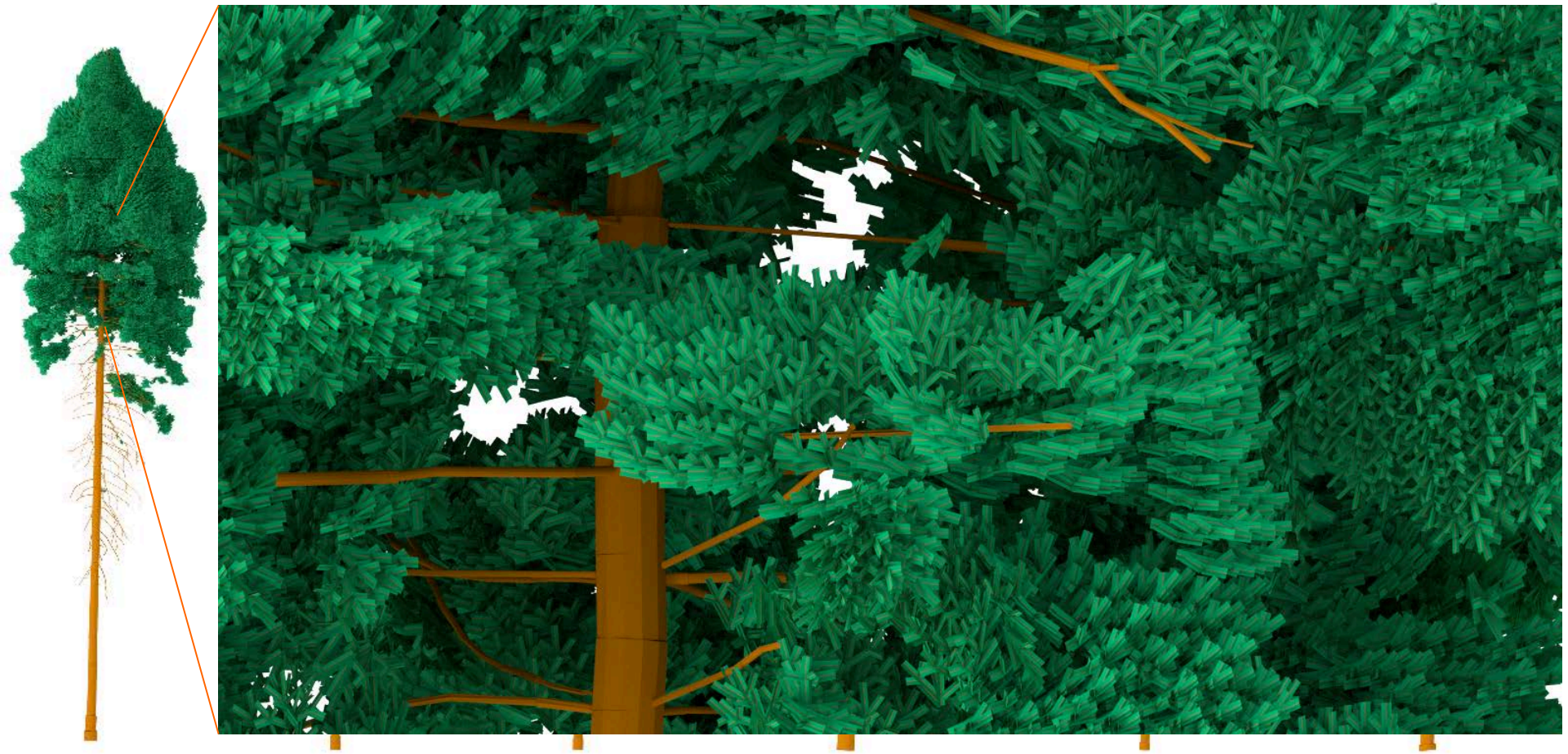




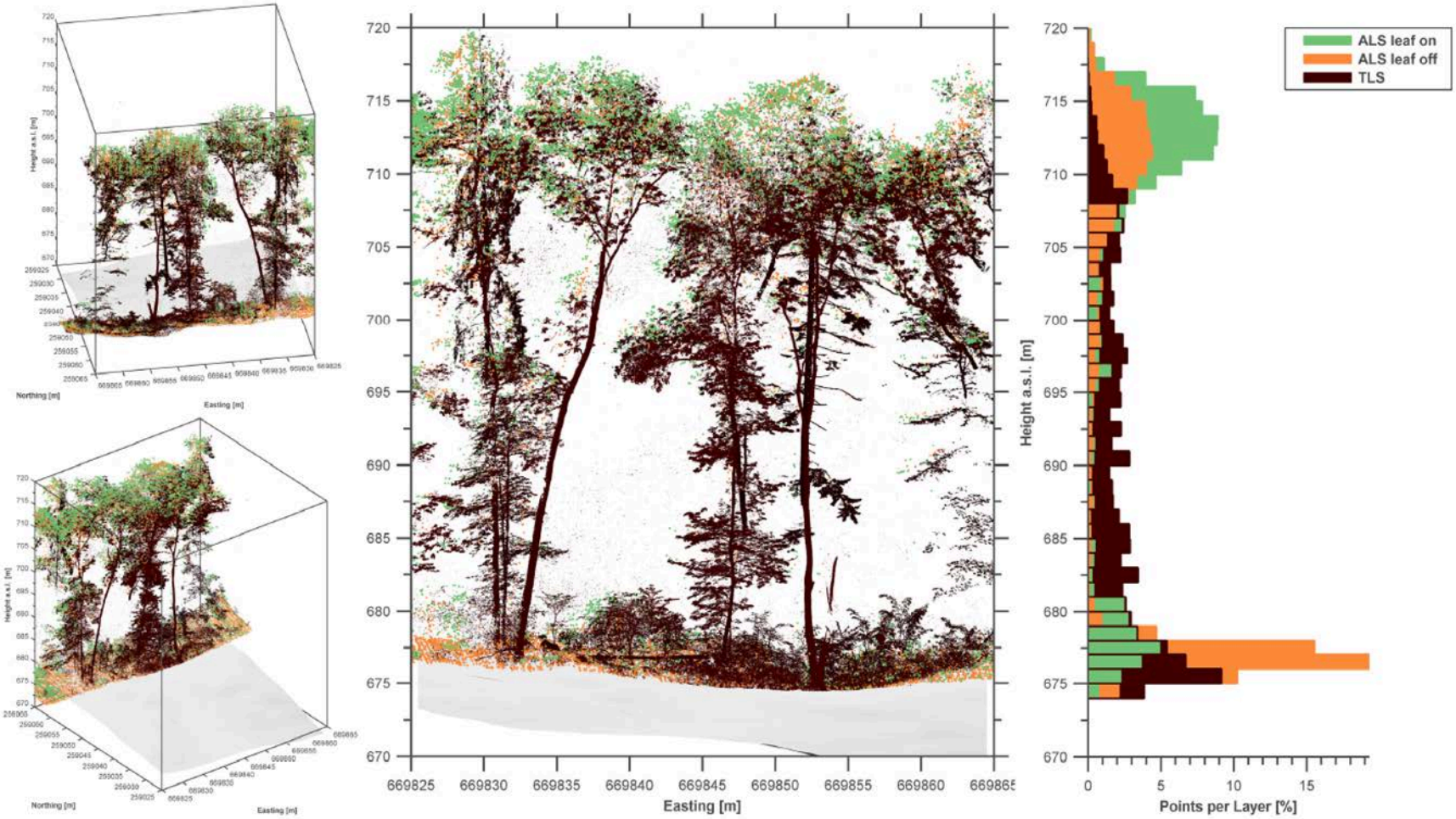
Yanez-Rausell, L., Malenovsky, Z., Clevers, J.G.P.W., & Schaepman, M.E. (2014). Minimizing Measurement Uncertainties of Coniferous Needle-Leaf Optical Properties. Part II: Experimental Setup and Error Analysis. *IEEE JSTARS, 7*, 406-420

Rautiainen, M., Mottus, M., Yanez-Rausell, L., Homolova, L., Malenovsky, Z., & Schaepman, M.E. (2012). A note on upscaling coniferous needle spectra to shoot spectral albedo. *Remote Sensing of Environment, 117*, 469-474

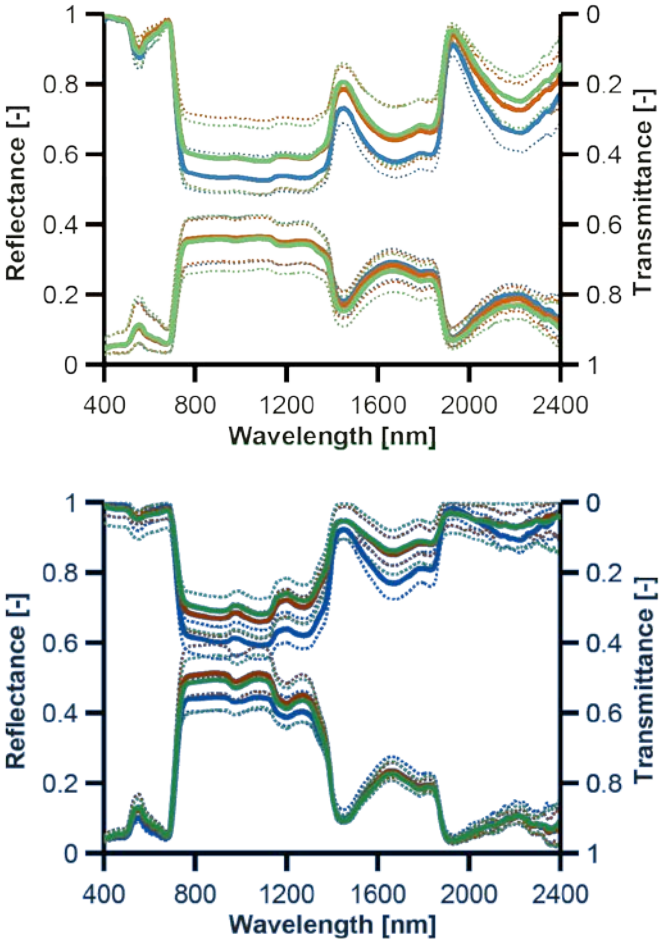
Reconstructed Needle Trees

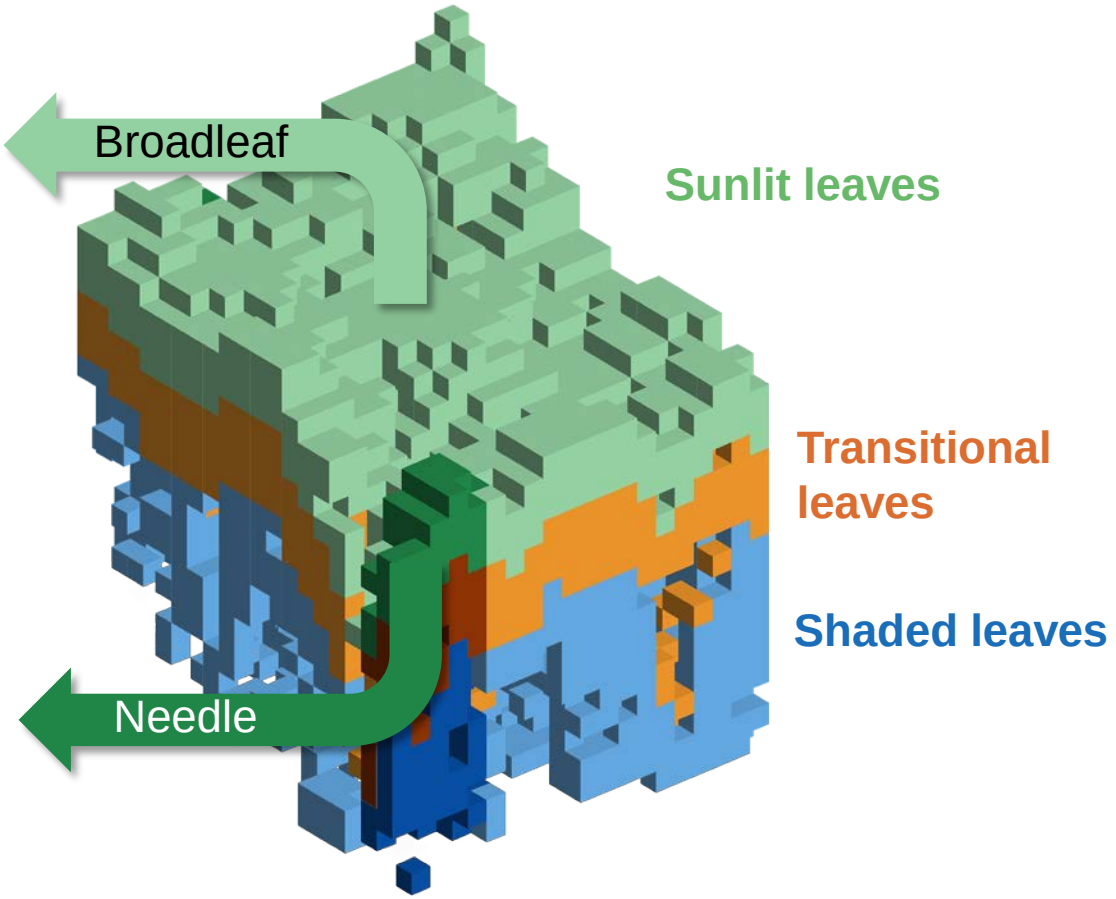


Airborne and terrestrial laser point clouds



3DVegLab: Leaf Optical Properties





Schneider, F.D., Leiterer, R., Morsdorf, F., Gastellu-Etchegorry, J.P., Lauret, N., Pfeifer, N., & Schaepman, M.E. (2014). Simulating imaging spectrometer data: 3D forest modeling based on LiDAR and in situ data. *Remote Sensing of Environment, 152*, 235-250

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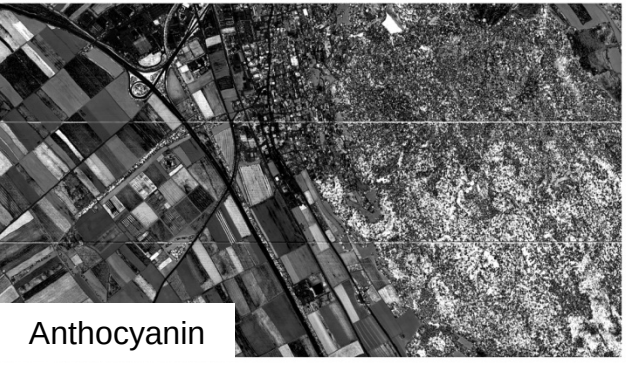
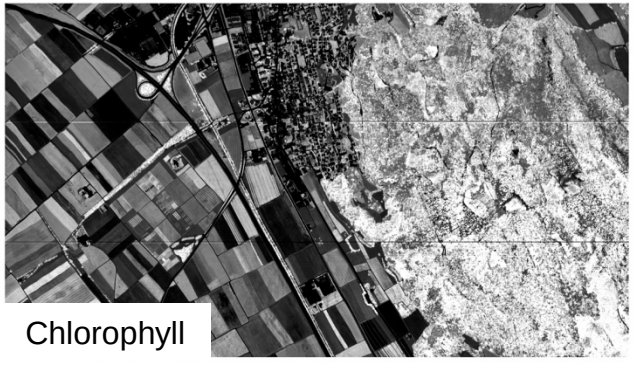
Pigment Retrieval

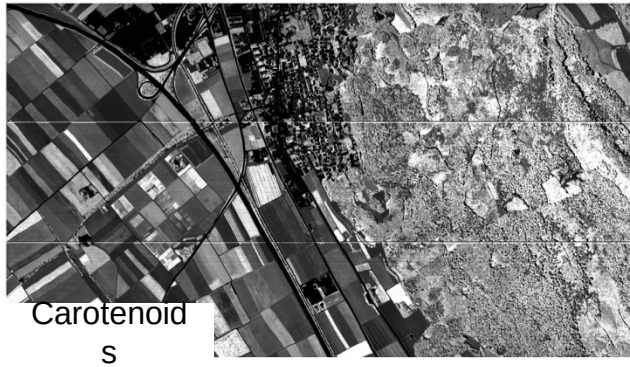
APEX-CIR



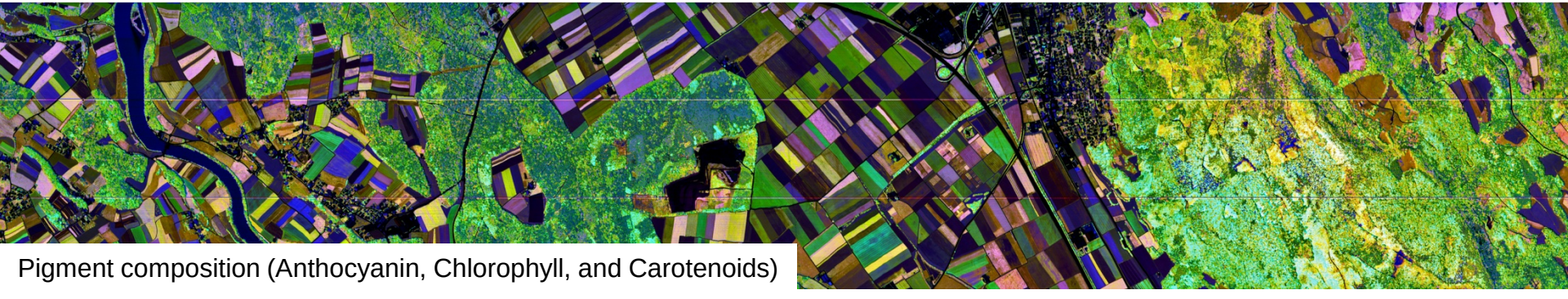
Anthocyanin



Chlorophyll

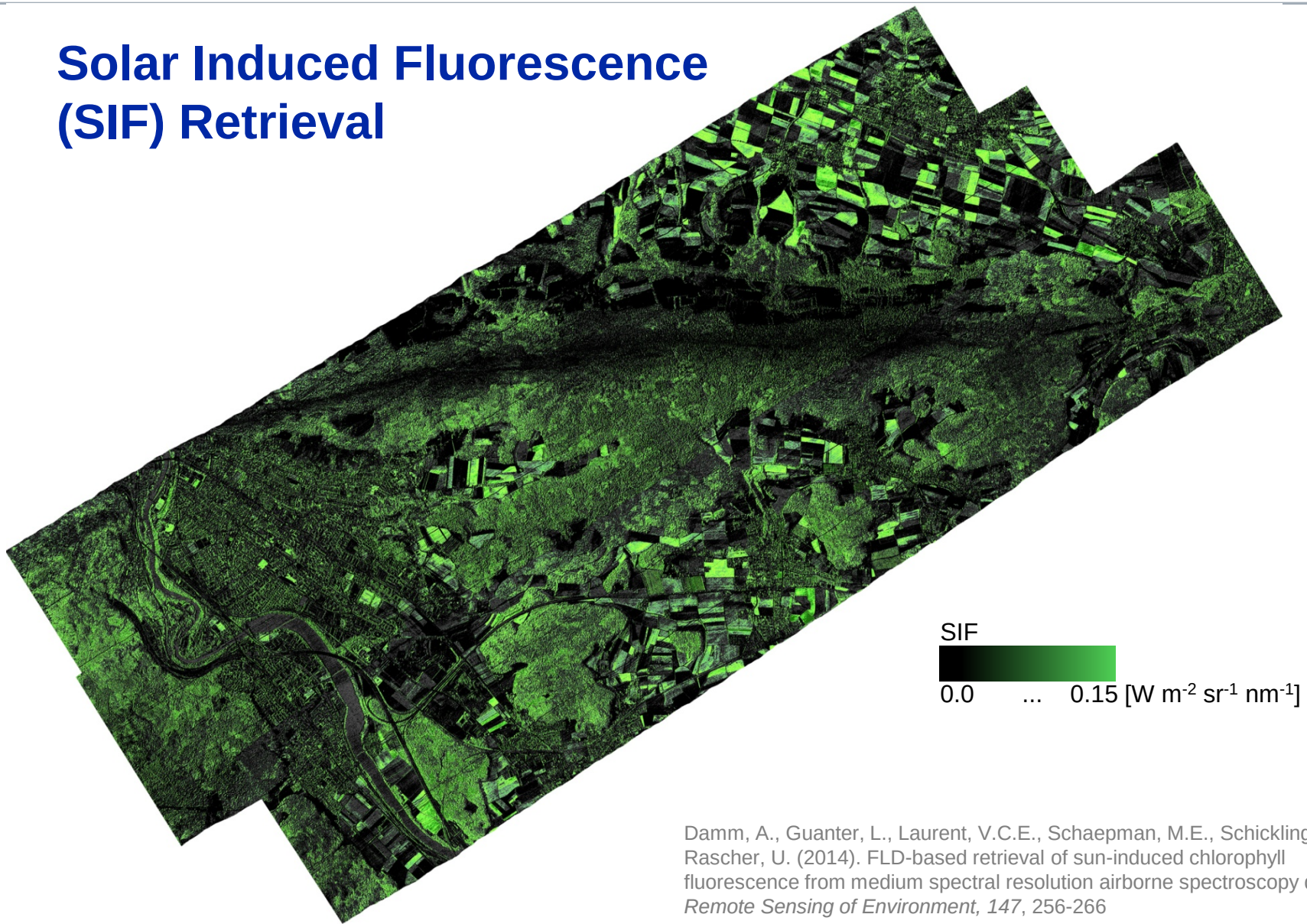


Carotenoids



Pigment composition (Anthocyanin, Chlorophyll, and Carotenoids)

Solar Induced Fluorescence (SIF) Retrieval



Damm, A., Guanter, L., Laurent, V.C.E., Schaepman, M.E., Schickling, A., & Rascher, U. (2014). FLD-based retrieval of sun-induced chlorophyll fluorescence from medium spectral resolution airborne spectroscopy data. *Remote Sensing of Environment, 147*, 256-266

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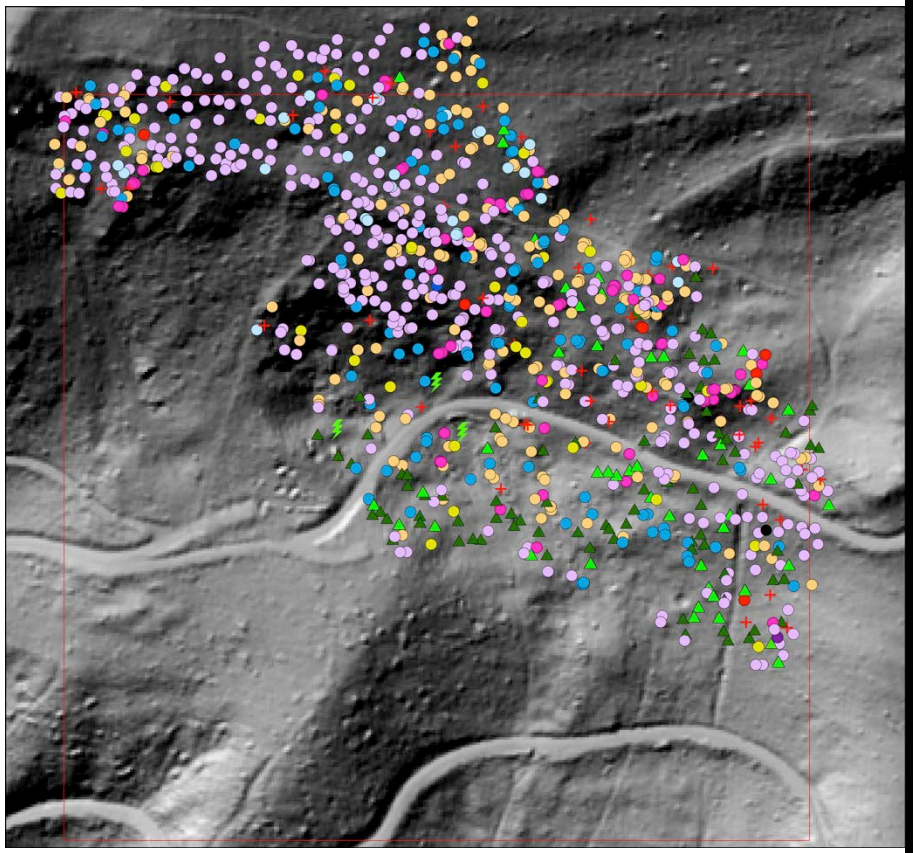
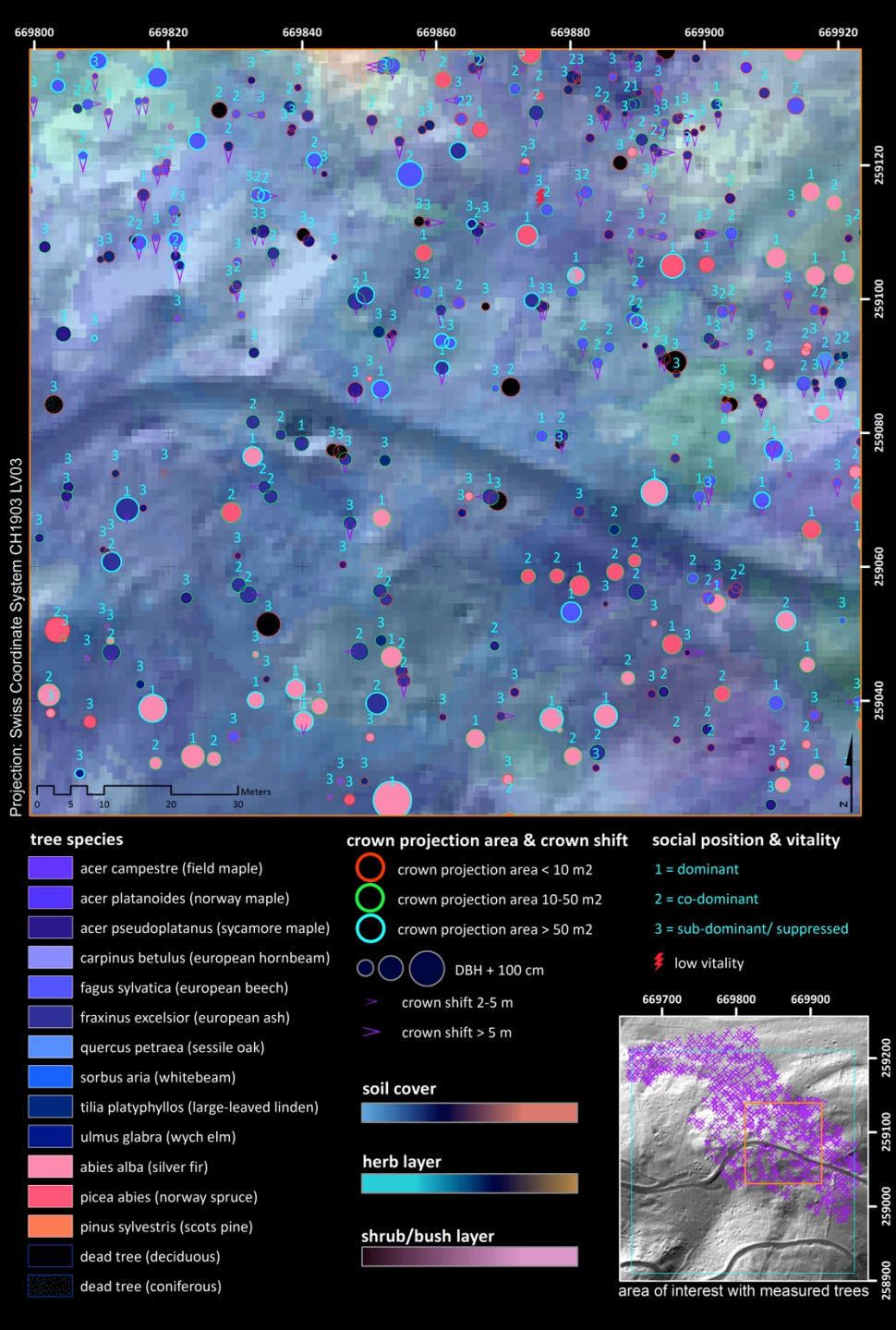
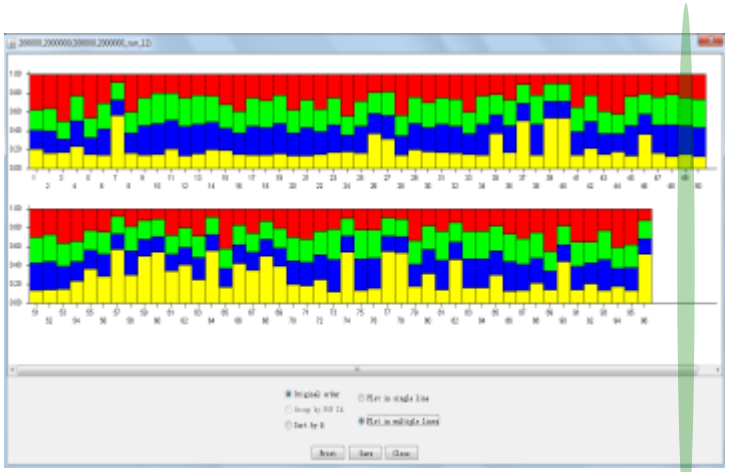
Field validation



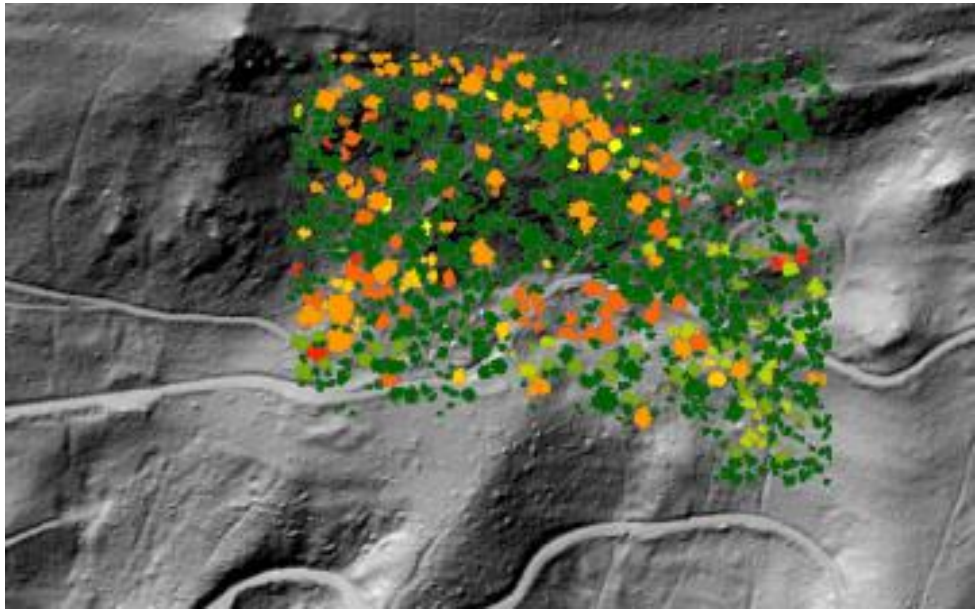


Within Species Variation using Microsatellite Markers

Mapping relatedness using genetic clustering structures defined by species and topography of the test site.

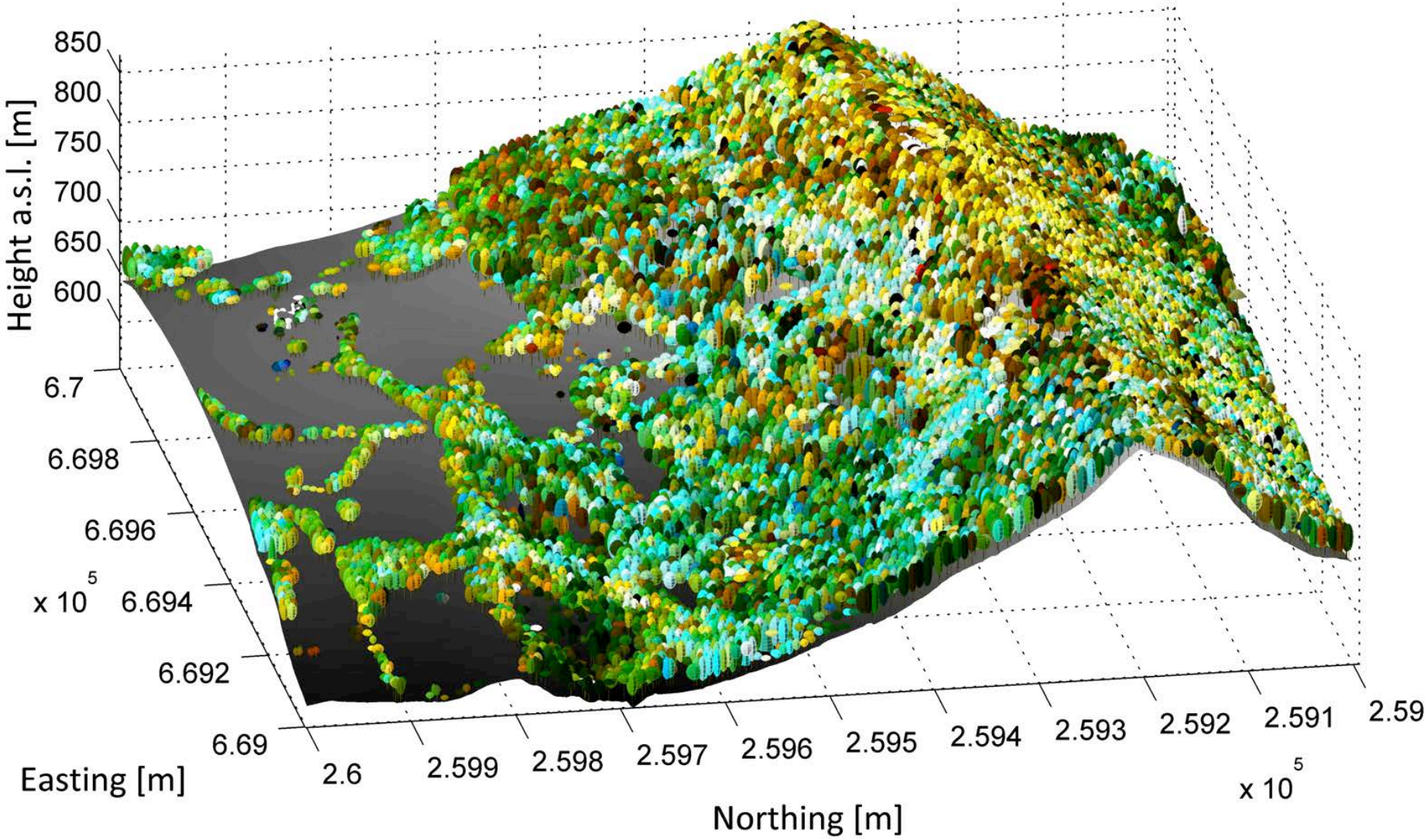


K=4

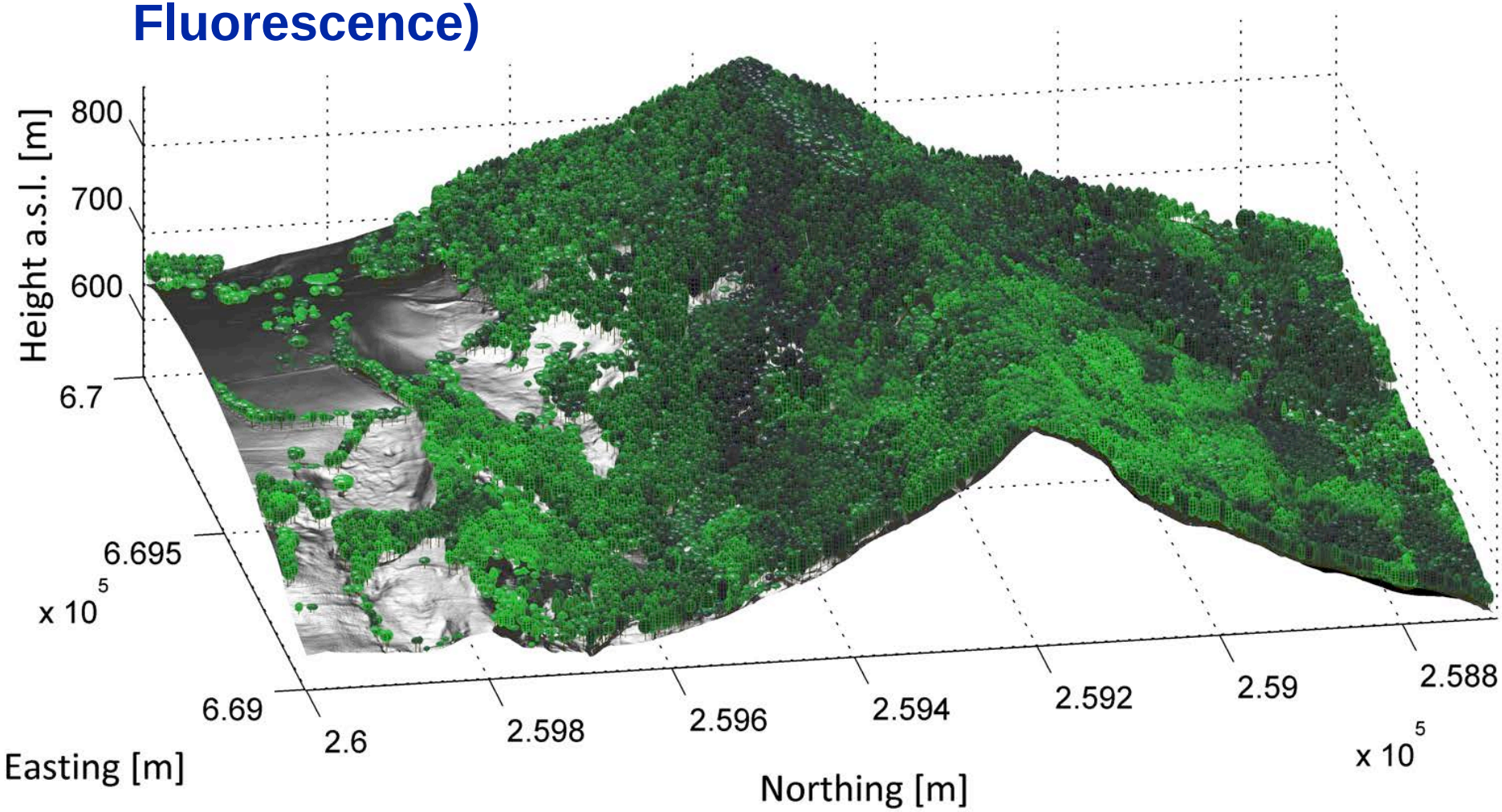


Guillen et al. 2015 in prep; He, 2014; Torabzadeh et al. 2015 in prep.

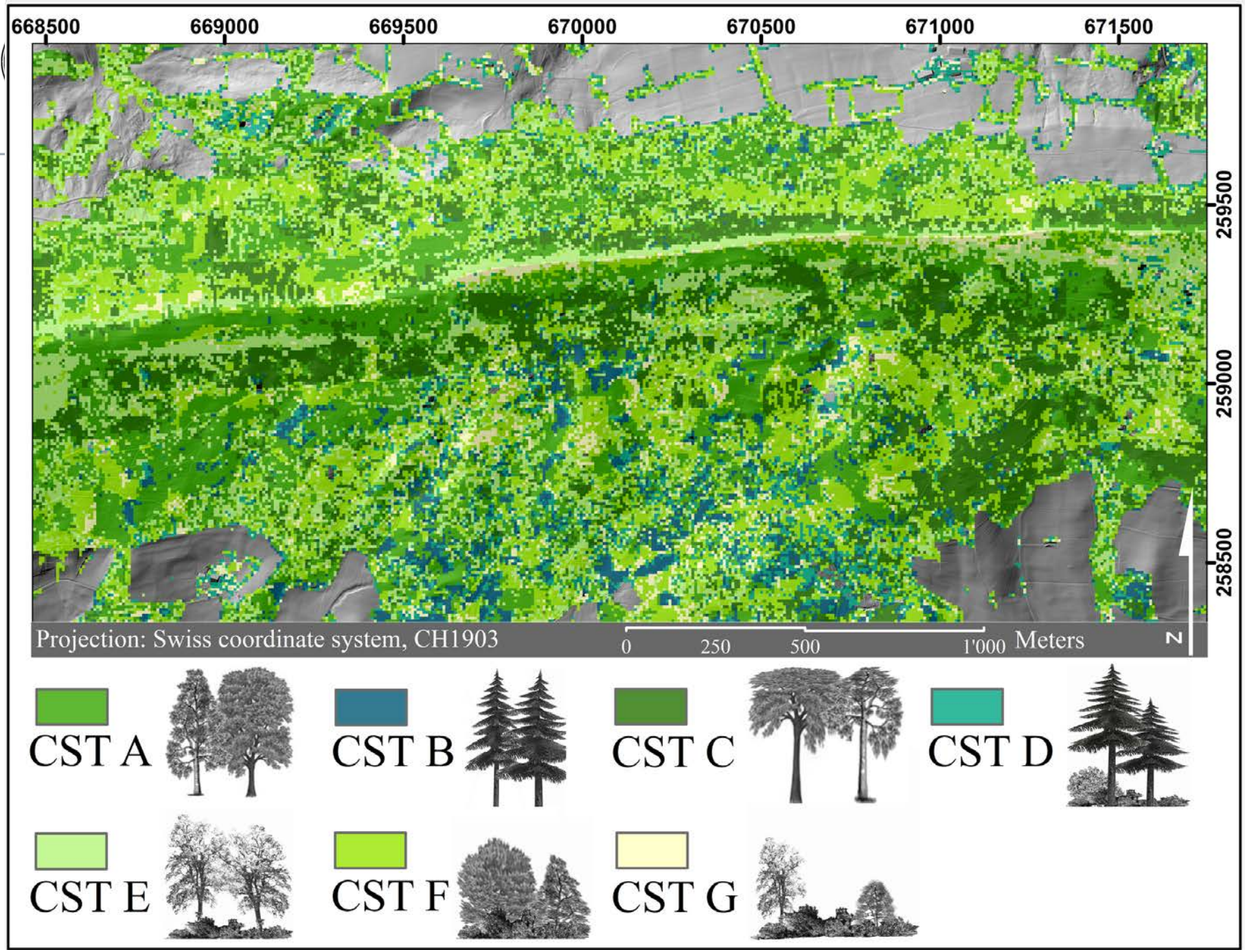
Functional Diversity (Growth Form and Pigments)



Functional Diversity (Growth Form, GPP/Solar Induced Fluorescence)

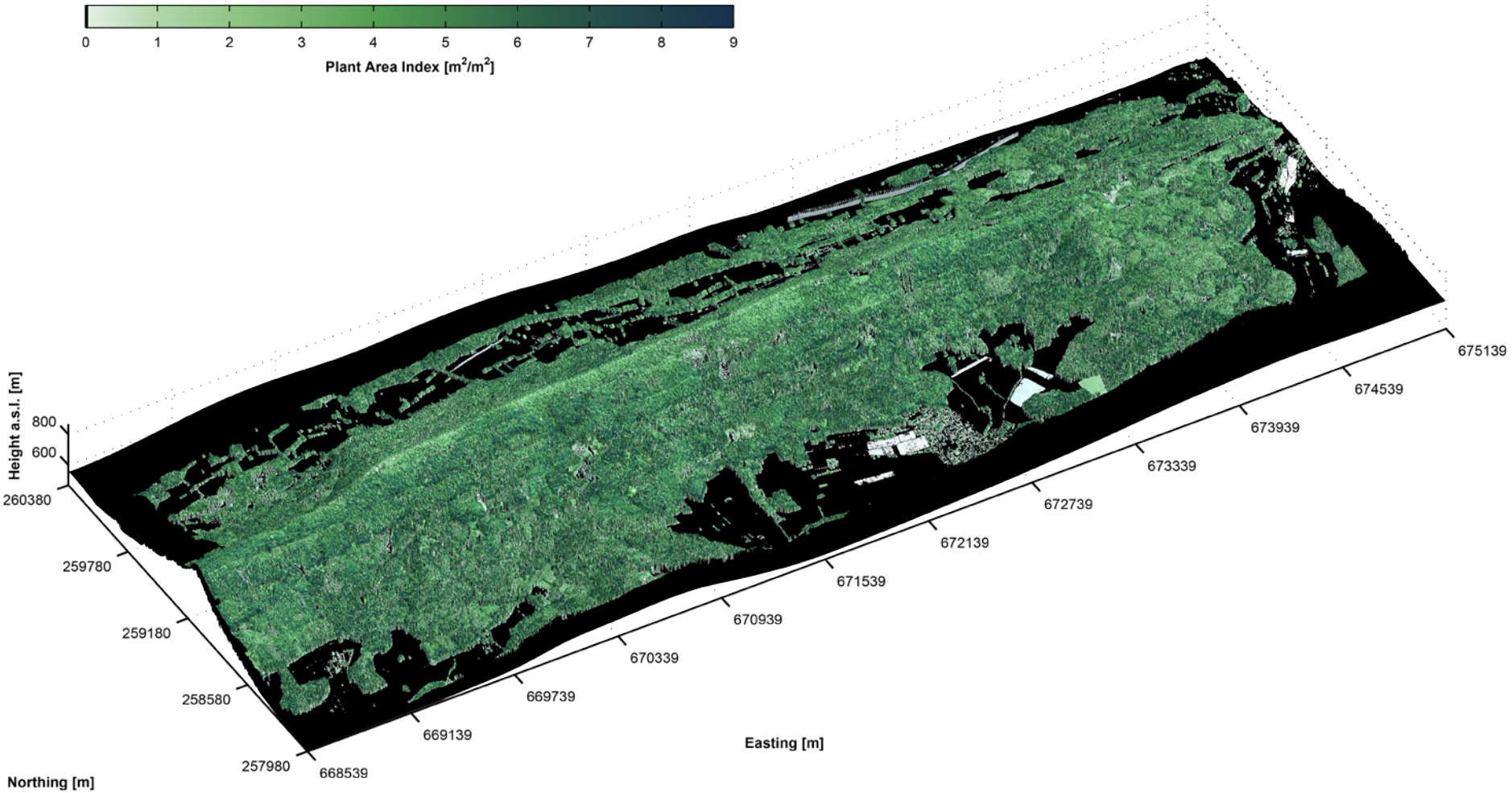


Damm et al. 2015, Far-red sun-induced chlorophyll fluorescence shows ecosystem-specific relationships to gross primary production: An assessment based on observational and modeling approaches. *RSE*, in revision



Leiterer, R. et al. (2015). Canopy strata characterization using multi-seasonal airborne laser scanning. *J ISPRS*, submitted

Scaling to Ecosystem Size



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NCEAS Working Group on Biodiversity from Space: Case Study

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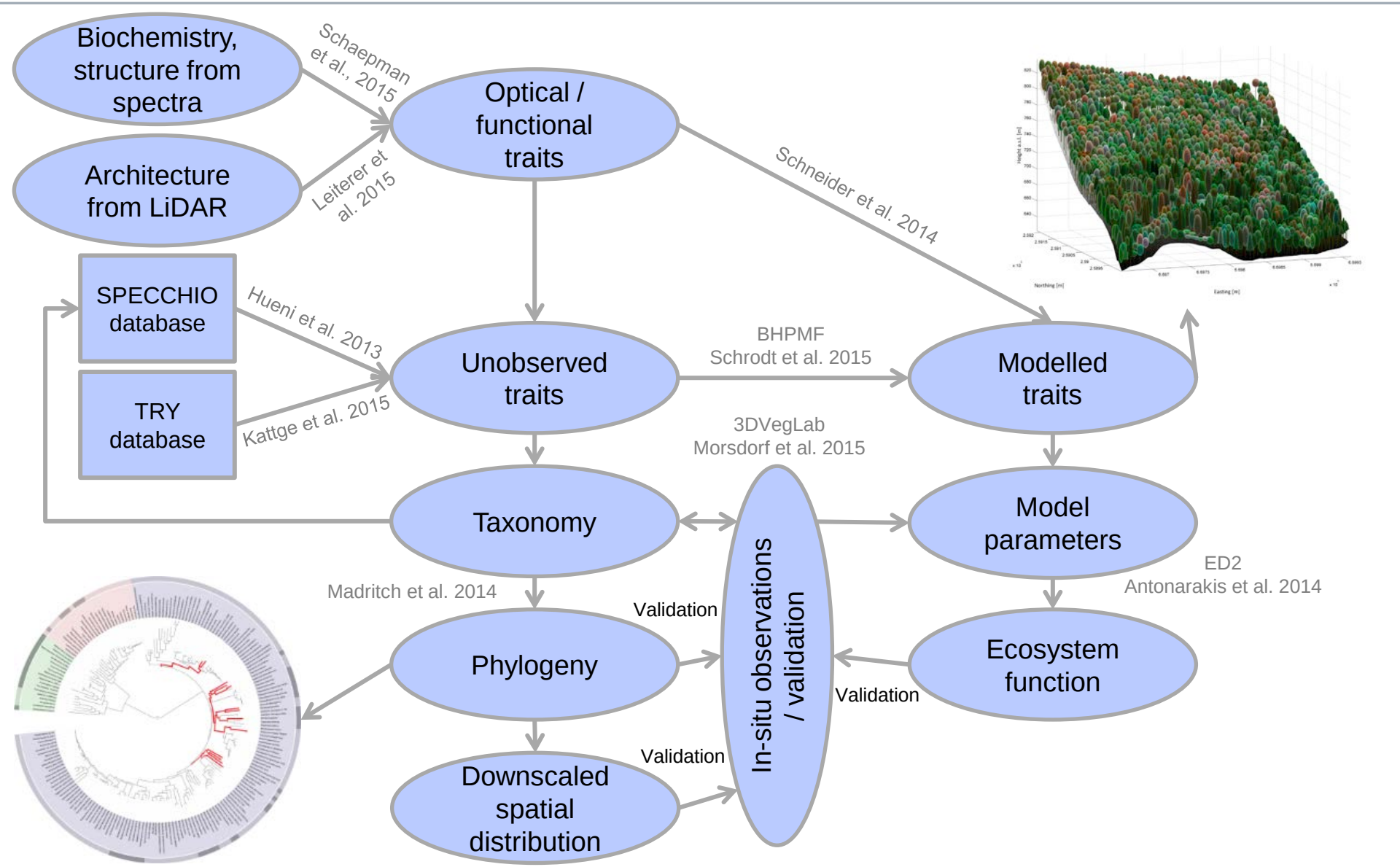

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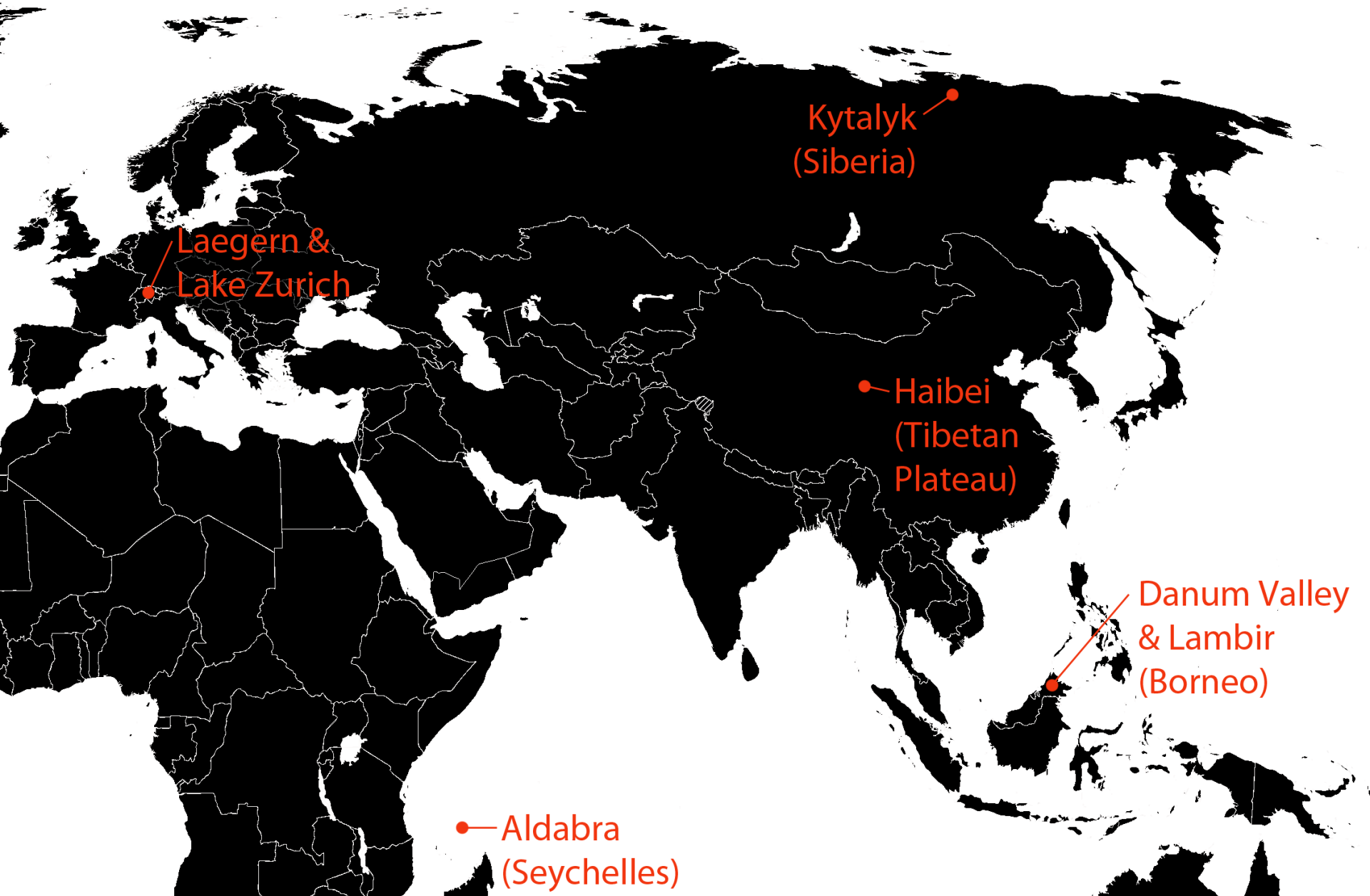

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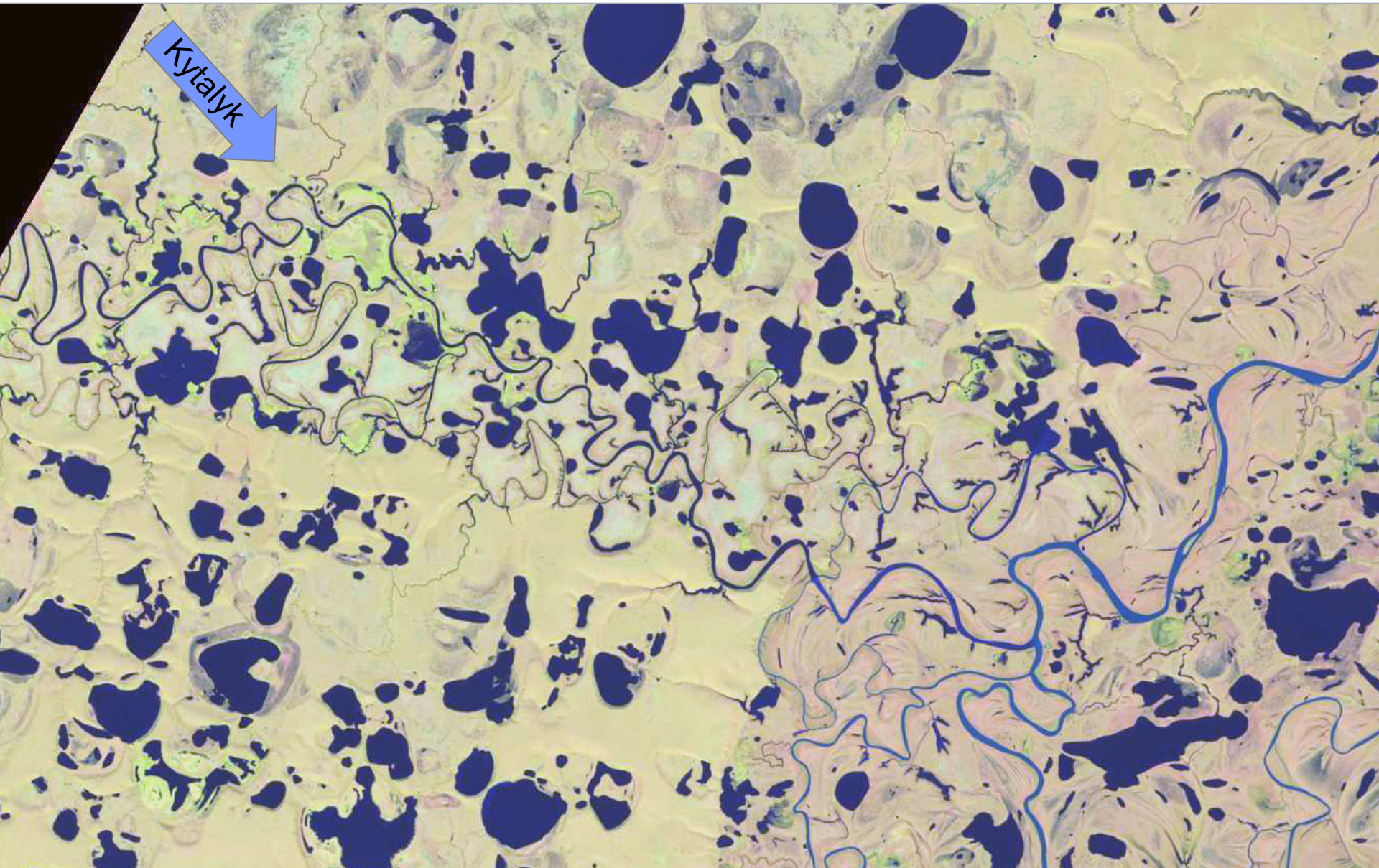
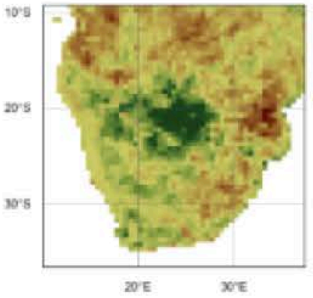



Photo MS July 2013

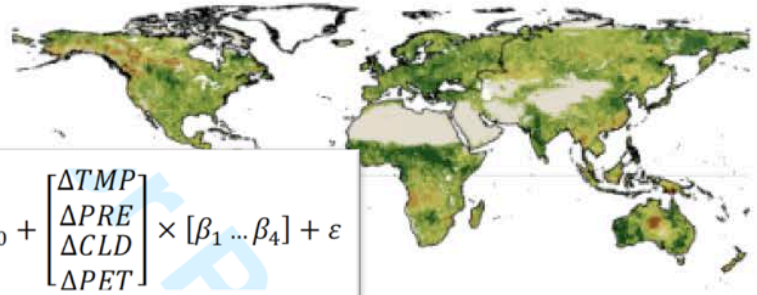
Quantifying Human Impact

- Trend in vegetation activity

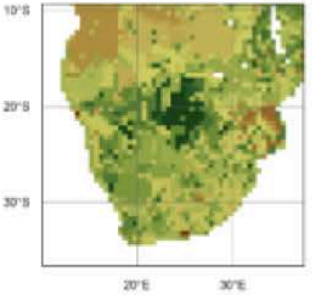
$$y_t = \alpha_1 + \alpha_2 t + \sum_{j=1}^{k} \gamma_j \sin\left(\frac{2\pi j t}{f} + \delta_j\right) + \varepsilon_t$$



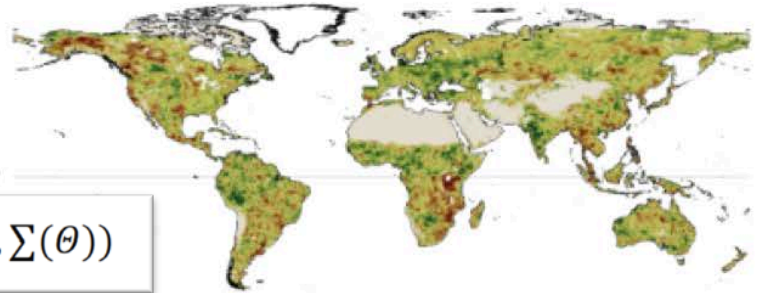
- Associated to climate (54%)



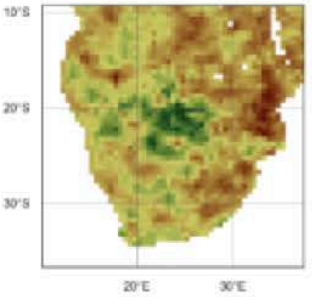
$$\Delta NDVI = \beta_0 + \begin{bmatrix} \Delta TMP \\ \Delta PRE \\ \Delta CLD \\ \Delta PET \end{bmatrix} \times [\beta_1 \dots \beta_4] + \varepsilon$$



- Non-associated (e.g. human)

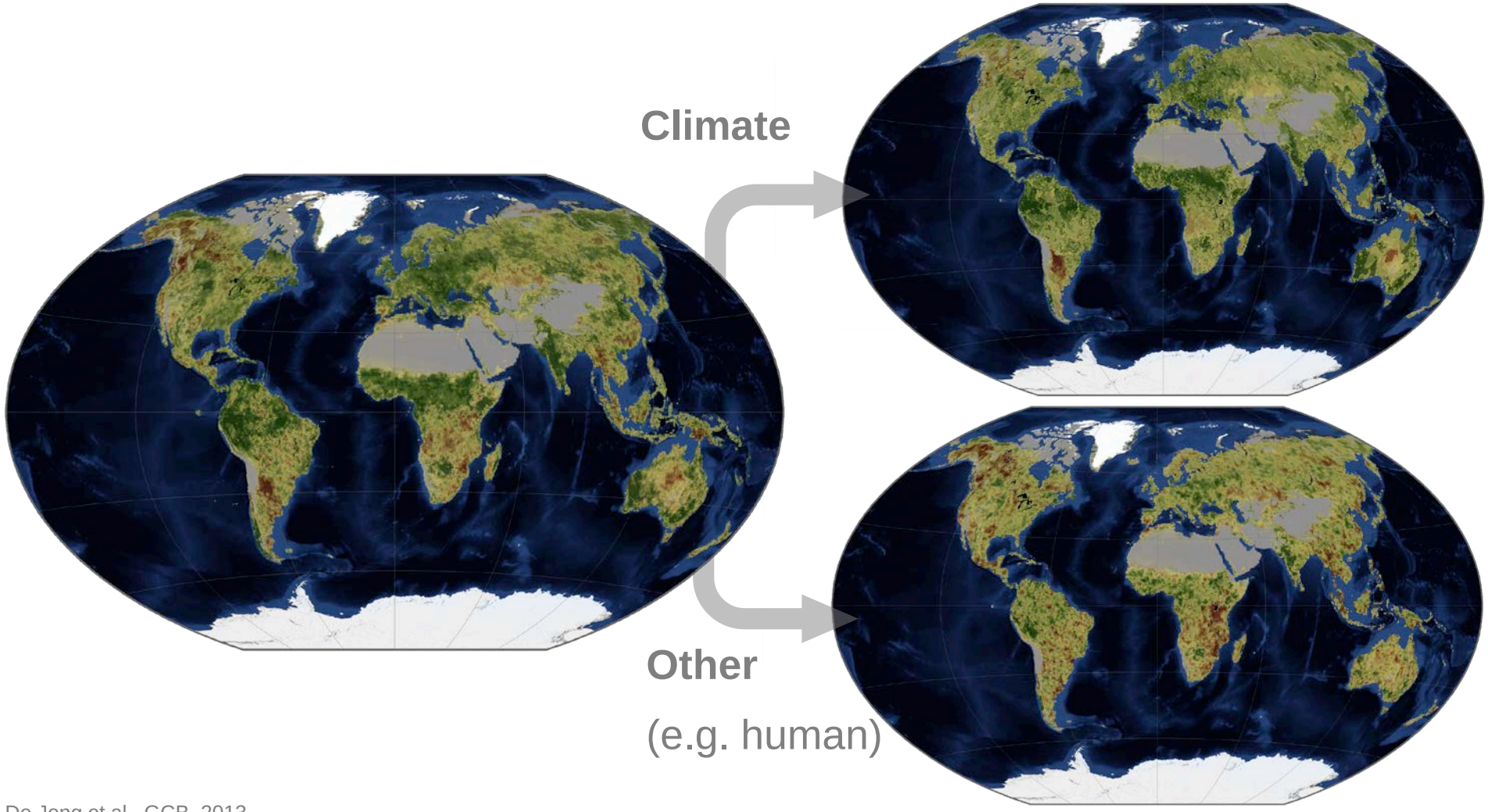


$$h \sim N(0, \sum(\Theta))$$



Additive deterministic and spatial random field

Attributing Climatic vs. Human Induced Change

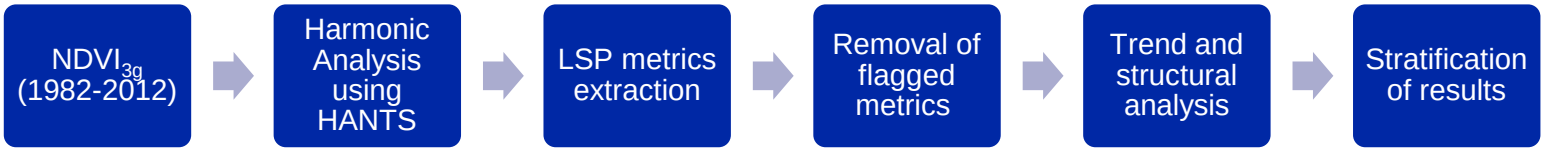


De Jong et al., GCB, 2013

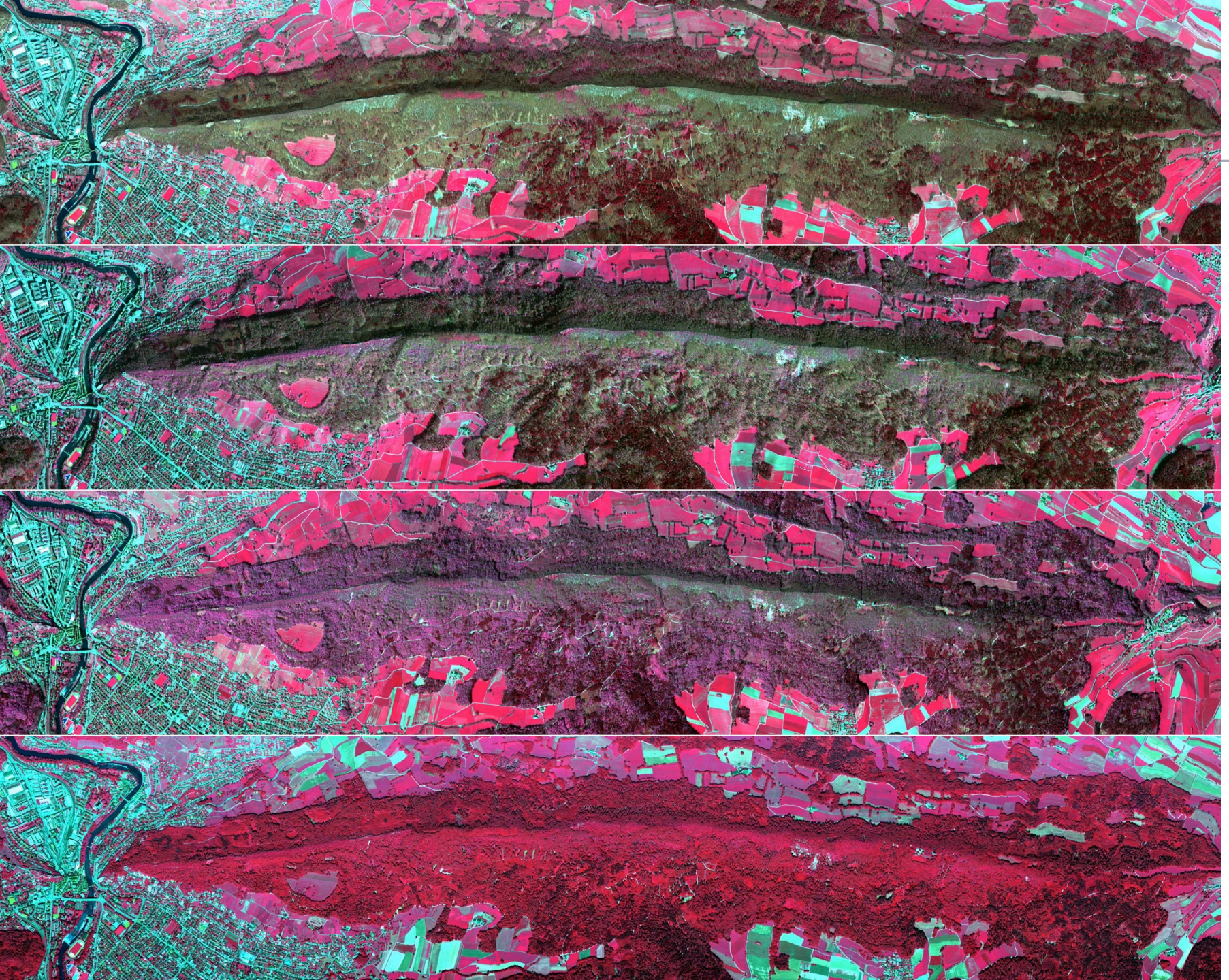
Phenology Combined with Growth Limiting Factors as an Essential Biodiversity Variable

Phenology is an indicator of plant response to changing conditions.

Scaling by coupling leaf phenology to land surface phenology (LSP) using a combination of satellite-inferred land surface phenology and in-situ observed leaf phenology (using PhenoCams).



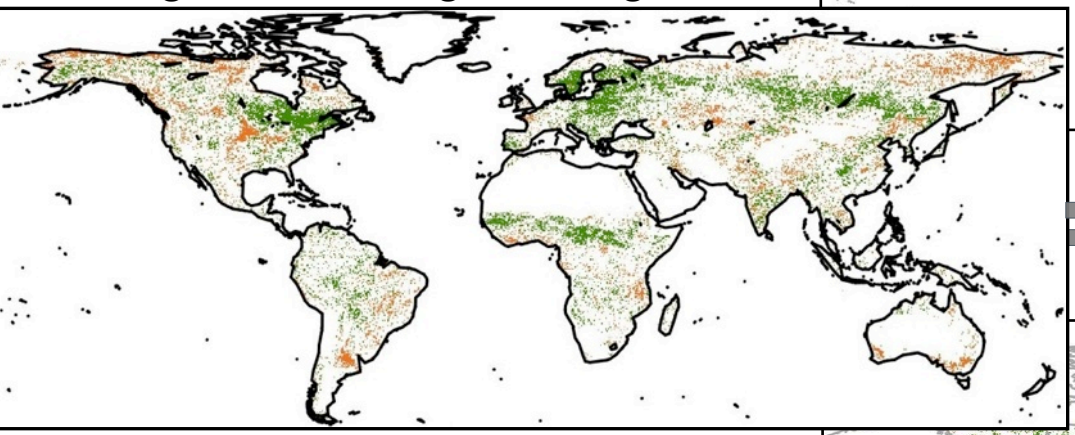
White et al., 2009; de Jong et al., 2013; Metzger et al., 2013; Garonna et al., 2014, 2015

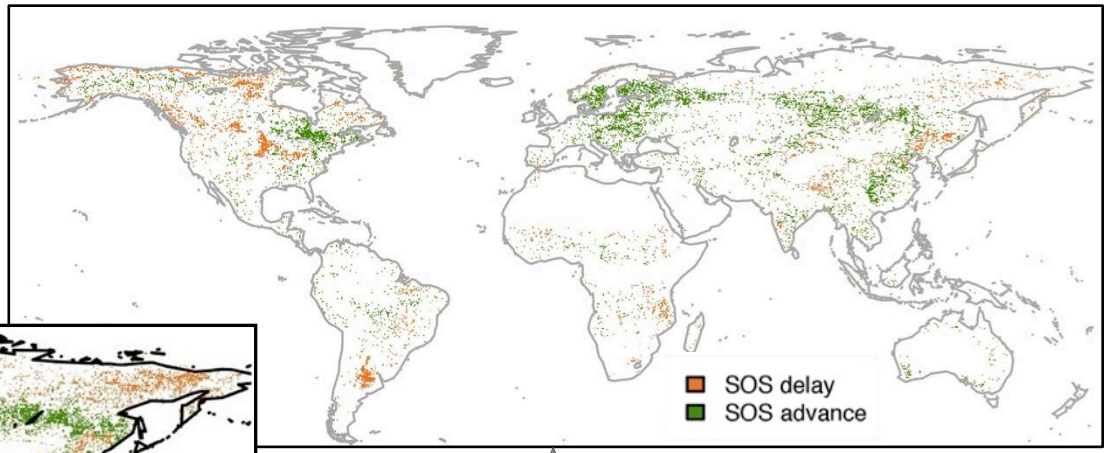


Relative Contribution to Growing Season Change

~13-19% of the terrestrial land surface shows significant GSL change.

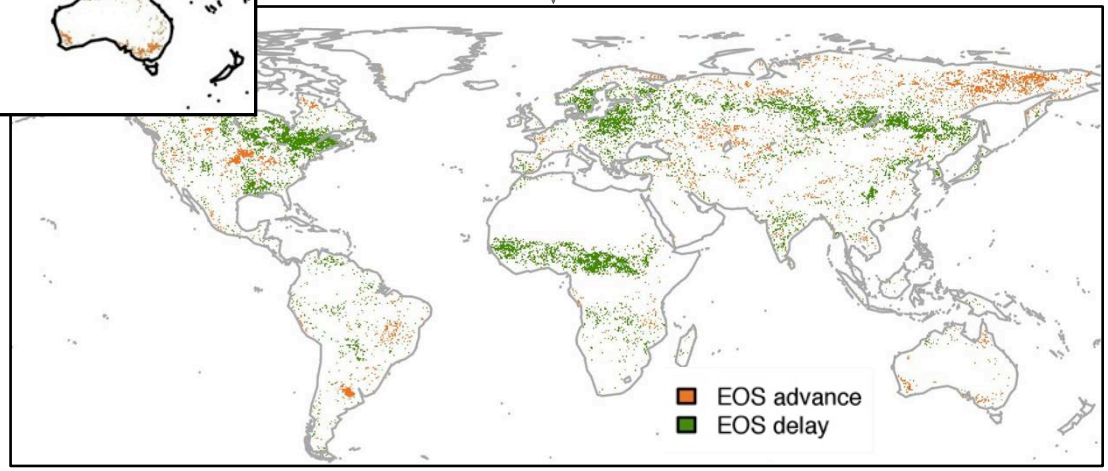
Growing Season Length Changes





Start-Of-Season

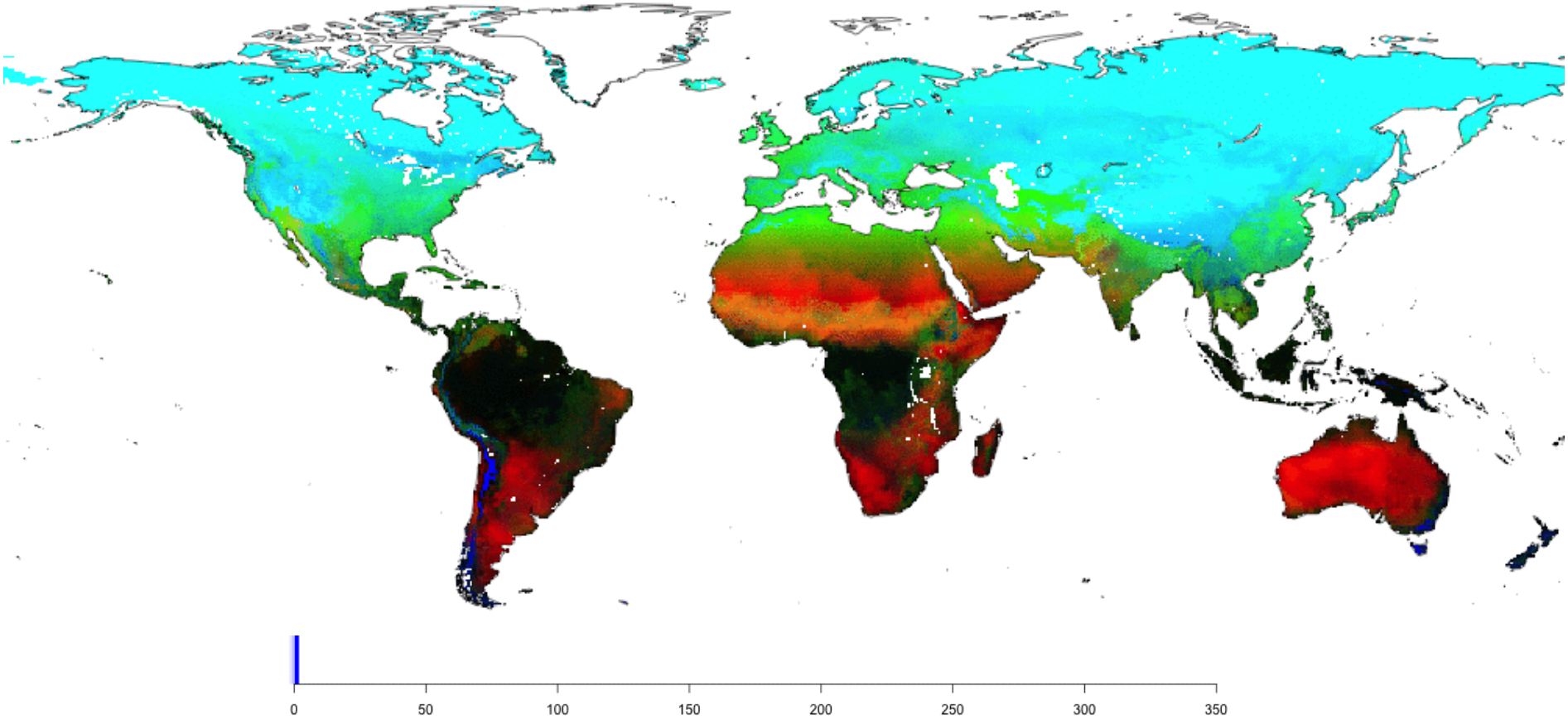
End-Of-Season



ΔGSL_{global} = +0.34 days/year
ΔSOS_{global} = -0.08 days/year
ΔEOS_{global} = +0.26 days/year

Garonna *et al.* (2015) *in prep.*

Daily Changes in Growth Limiting Factors



Garonna et al., 2015 in prep.

Conclusions

Regional scale retrieval of functional, α- and β-diversity from remote sensing has well progressed and is underway.

A coherent set of observation based, scale independent Essential Biodiversity Variables (EBVs) retrievable from Earth observation, model, and in-situ data does not yet exist. Prime challenge is for the 'land community' to agree a) on a set of variables and b) on their priorities (=essential)!

Equally important are globally coherent informative priors at relevant process length scales.

Dimensionality of diversity measurements derived from regional Earth observation does not yet scale with global requirements.

Thank you for your attention!

Phenology and Growth Limiting Factors as Essential Biodiversity Variables

Vegetation growth limiting factors (photoperiod, water pressure deficit, minimum temperature) are changing in an accelerated fashion.

Independent estimate of growth limiting factors without a priori knowledge on vegetation.

Foliar phenology in response to climate using a growing season index by Jolly et al. (2005).

Examine the inter-annual variability and trends of large-scale constraints to phenology at global scale.

Establish links between large-scale trends of LSP and climatic constraints to plant growth.

Nemani 2003; Jolly et al. 2005; Stöckli et al. 2011; Schimel et al., 2013; Garonna et al., 2015

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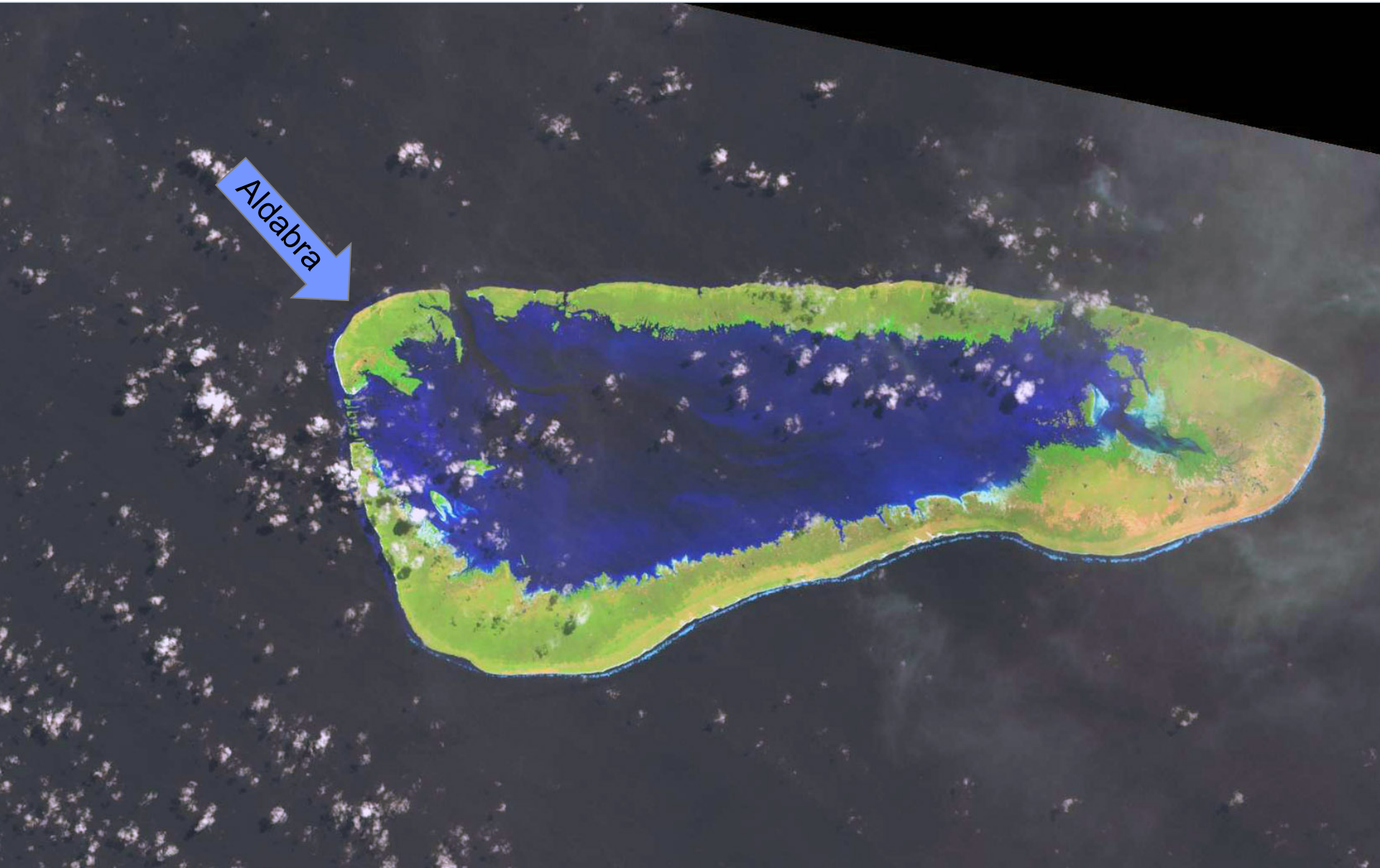

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