Processing satellite data

for land change and modification studies

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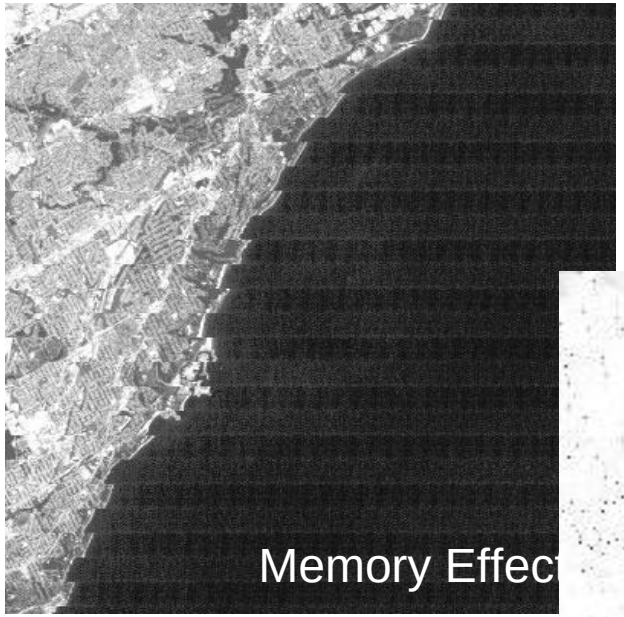
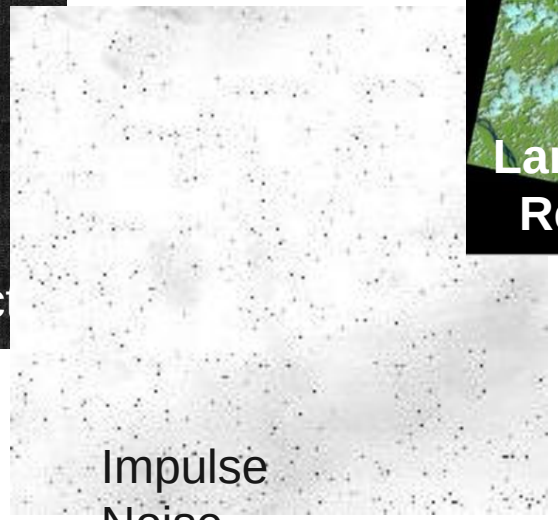
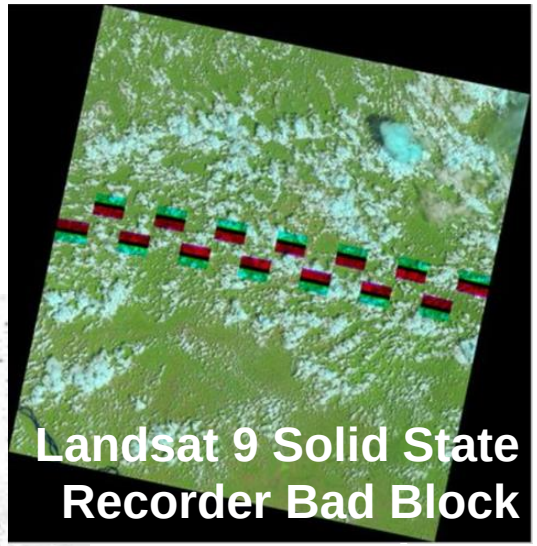
Earth Observation as key technology

https://www.opendatacube.org/

Raw satellite data are ugly and noisy







Banding: Affects Landsat 4-5 Thematic Mapper (TM) data.

Coherent Noise: Affects Landsat 5 TM and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data.

Coherent Noise Storm: Affected Landsat 7 data on May 29, 2003.

Data Loss: Affected Landsat 5 and Landsat 7 data mainly until 2006, although data loss can happen at any time.

Detector Failure: Affects Landsat 5 TM data, found once in Landsat 7 data.

Detector Ringing: Affects Landsat 7 data.

Detector Striping: Can affect data from all sensors.

Gimbaled X-Band Antenna (GXA): Affected Landsat 7 data from launch to April 2000.

Impulse Noise: Can affect data from all sensors.

Internal Calibrator (IC) Intrusion: Affected Landsat 7 data from launch to April 2007.

Lower Truncation Acquisitions: Affects Landsat 8 data.

Memory Effect: Affects Landsat 1-5 Multispectral Scanner (MSS) and Landsat 4-5 Thematic Mapper (TM) data.

Optical Leak: Affects Landsat 5 and Landsat 7 data.

Oversaturation: Can affect data from all sensors.

Scan Correlated Shift: Affected Landsat 4-5 MSS data.

Scan Mirror Pulse: Affected Landsat MSS data.

Shutter Synchronization Anomalies: Has affected Landsat 5 TM and Landsat 7 data.

Single Event Upsets: Has affected Landsat 7 data.

Solid State Recorder Bad Block Issue: Affects Landsat 9 data

Thermal Infrared Sensor Scene Select Mechanism Anomaly: Affected Landsat 8 Thermal Infrered Sensor.

https://www.usgs.gov/landsat-missions/landsat-known-issues

Cloud occurence

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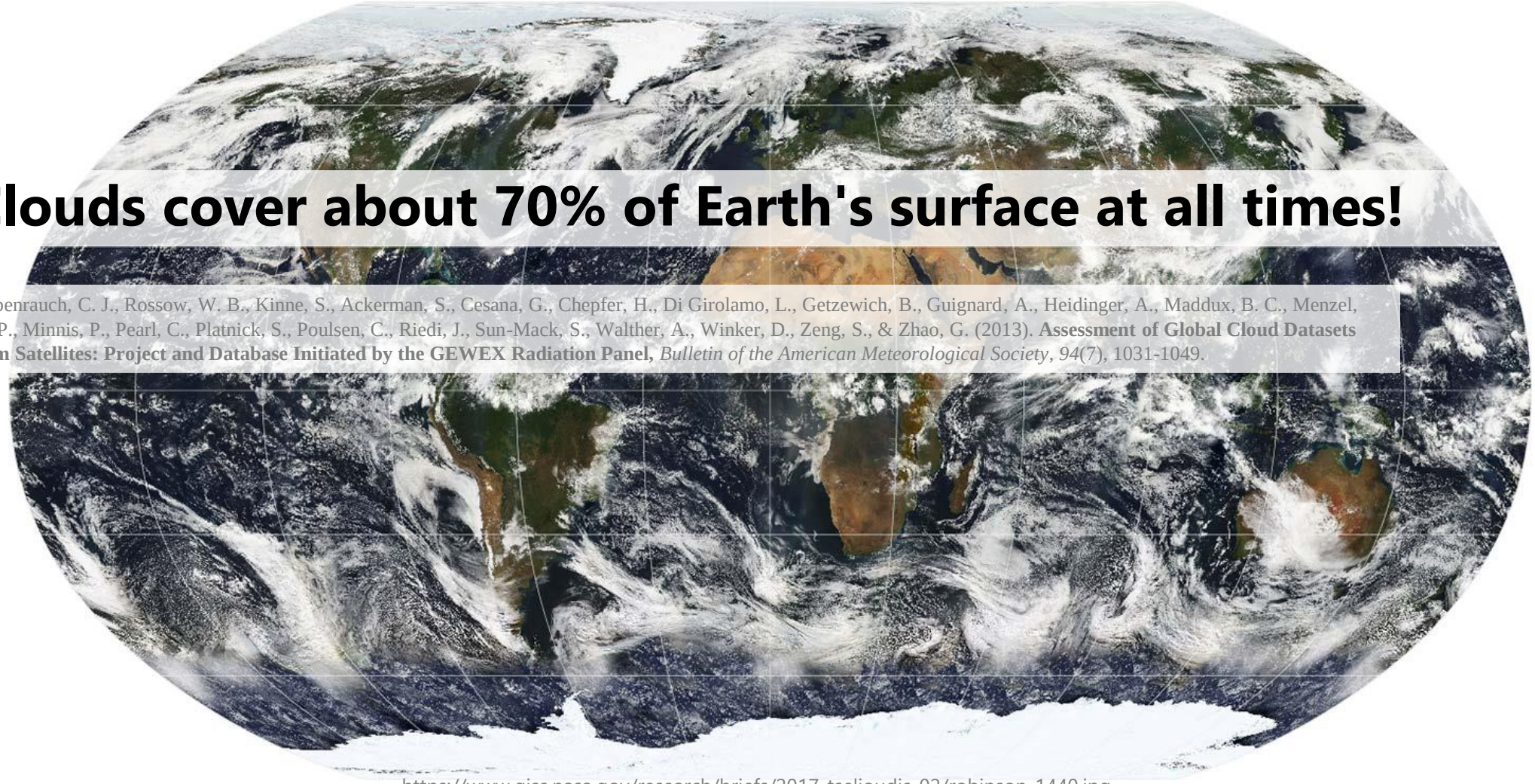
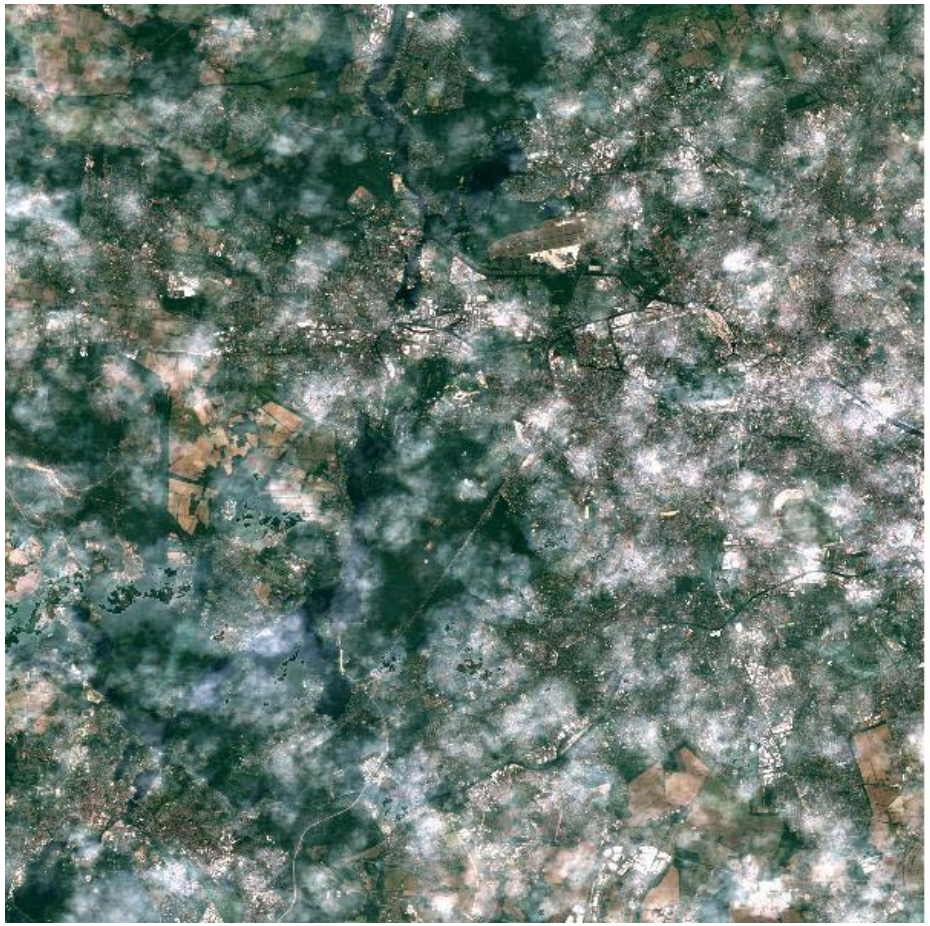
Clouds cover about 70% of Earth's surface at all times!

Stubenrauch, C. J., Rossow, W. B., Kinne, S., Ackerman, S., Cesana, G., Chepfer, H., Di Girolamo, L., Getzewich, B., Guignard, A., Heidinger, A., Maddux, B. C., Menzel, W. P., Minnis, P., Pearl, C., Platnick, S., Poulsen, C., Riedi, J., Sun-Mack, S., Walther, A., Winker, D., Zeng, S., & Zhao, G. (2013). **Assessment of Global Cloud Datasets from Satellites: Project and Database Initiated by the GEWEX Radiation Panel,** *Bulletin of the American Meteorological Society*, *94*(7), 1031-1049.



https://www.giss.nasa.gov/research/briefs/2017_tselioudis_02/robinson_1440.jpg

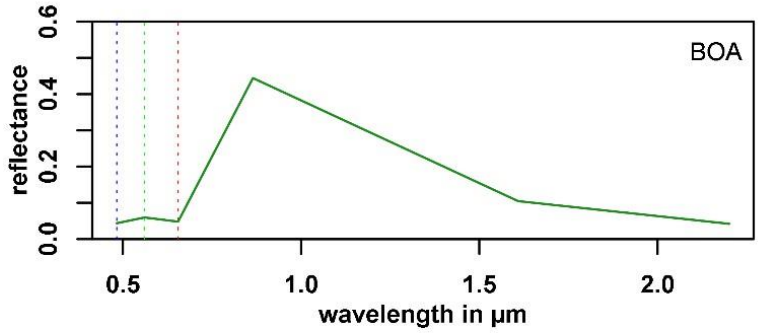
Cloud contamination



no cloud mask

good cloud mask

Atmospheric contamination



Different acquisitions

- Solar angles
- Viewing angles
- Air mass
- Aerosol concentration
- Aerosol size distribution
- Water vapor concentration
- Scattering
- Gas. Absorption
- Illumination (topography)
- Anisotropy
- …

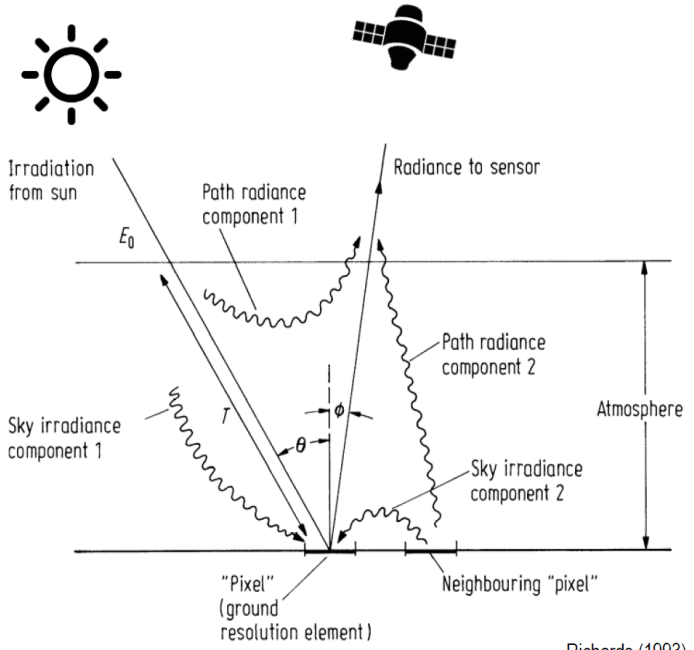
Atmospheric contamination

2018-08-06 **2018-08-03**

Different tree species?

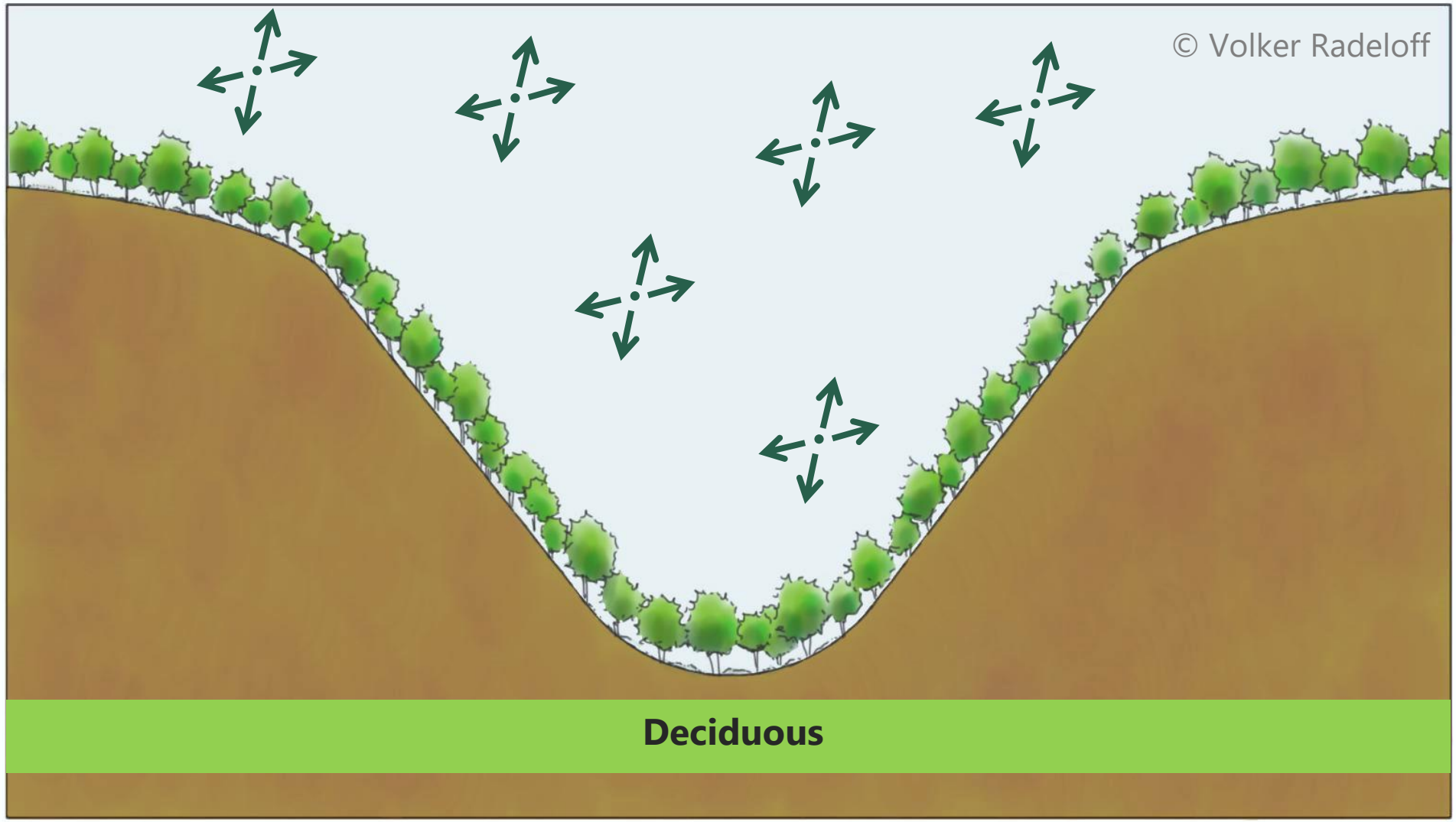
Different land surface characteristics?

Atmospheric correction!

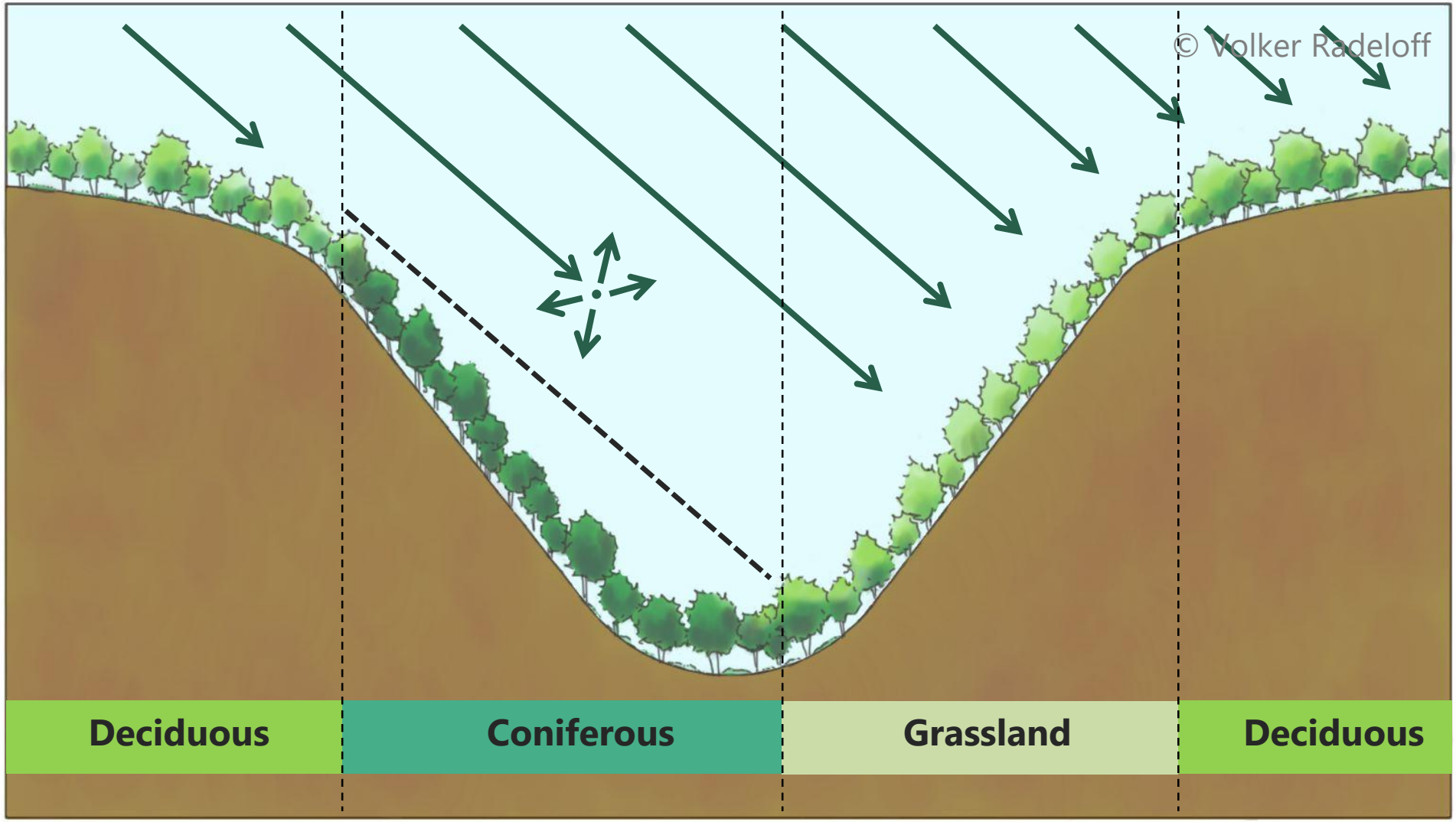


Richards (1993)

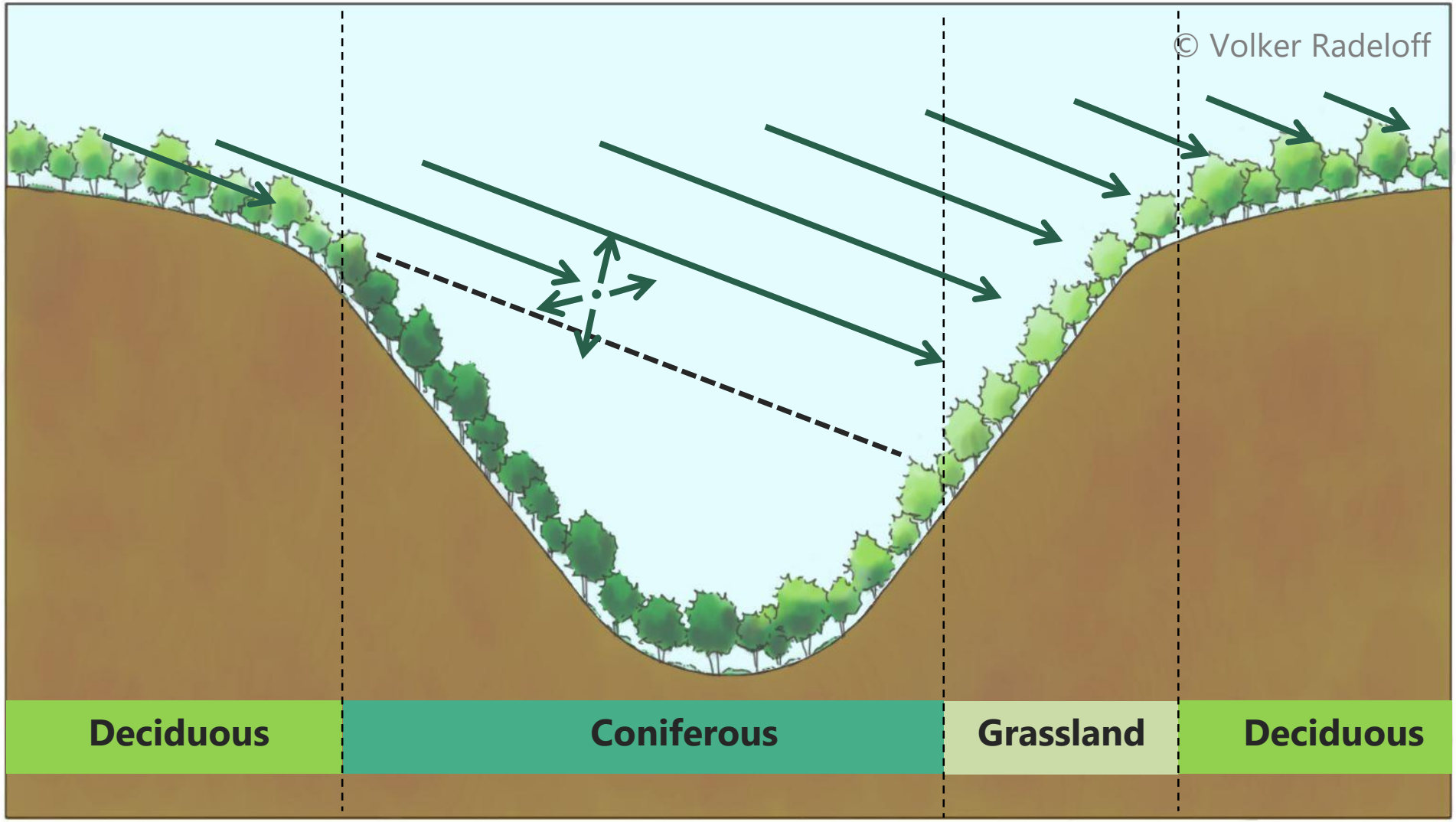
Illumination of sloped terrain



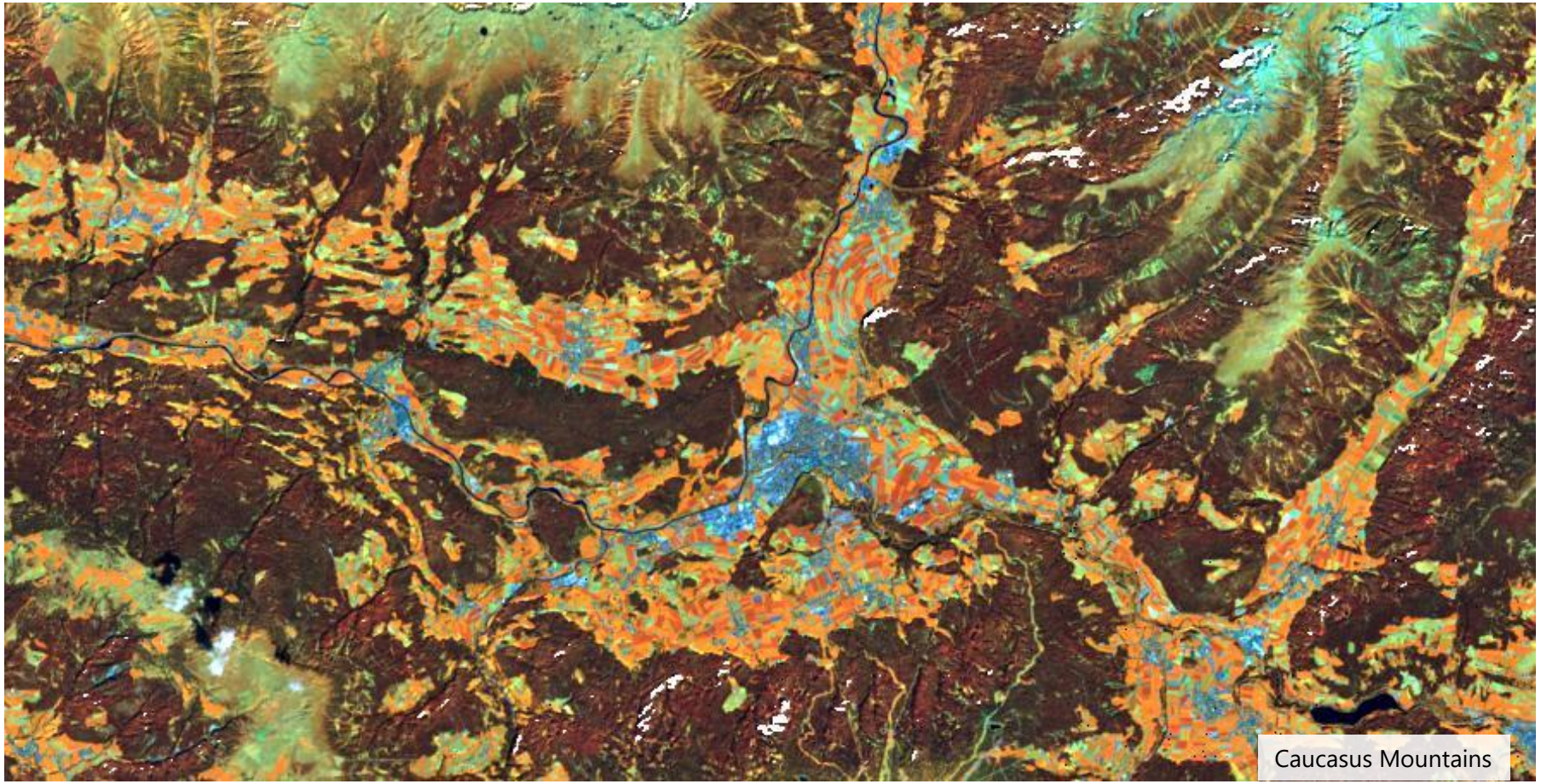
Illumination of sloped terrain



Illumination of sloped terrain



Topographic correction



Integrated atmospheric + topographic correction

- enhanced C-correction

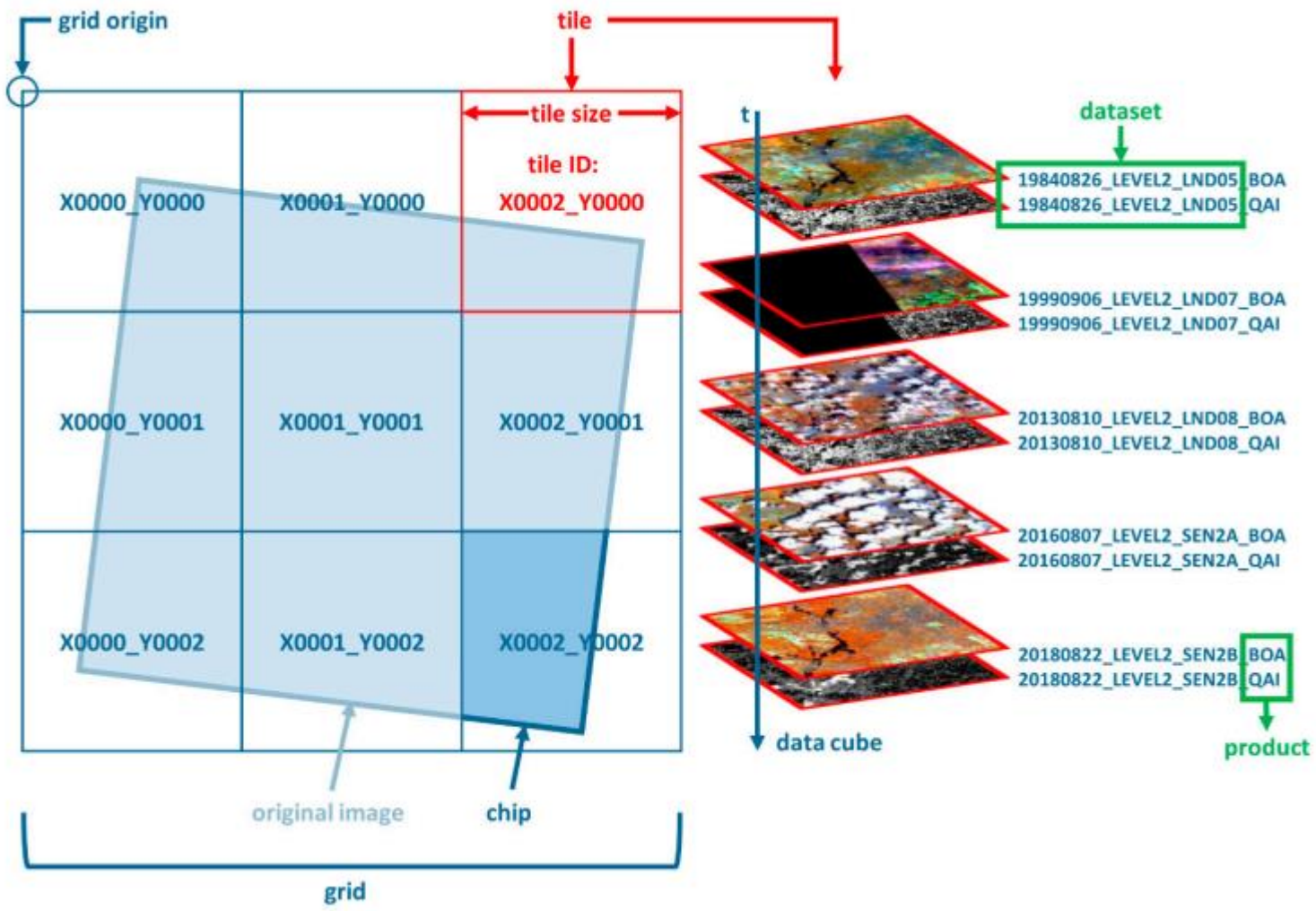
$$A_\lambda = (\cos \Theta_S + C_\lambda h_0^{-1}) / (\cos i + C_\lambda h_0^{-1} h)$$

white = deep shadows

Frantz, Röder, Stellmes, Hill (2016). An Operational Radiometric Landsat Preprocessing Framework for Large-Area Time Series Applications. *IEEE TGRS* 54

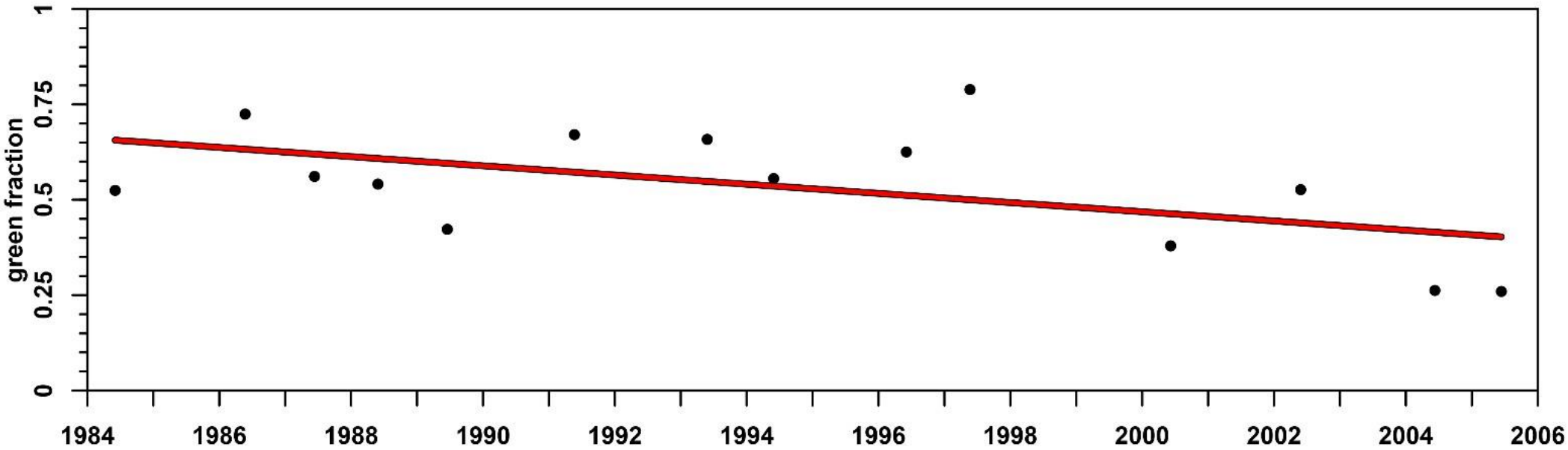
Buchner, Yin, **Frantz**, Kuemmerle, Askerov, Bakuradze, Bleyhl, Elizbarashvili, Komarova, Lewińska, Rizayeva, Sayadyan, Tan, Tepanosyan, Zazanashvili, Radeloff (2020): Land-cover change in the Caucasus Mountains since 1987 based on the topographic correction of multi-temporal Landsat composites. *Remote Sensing of Environment*

Data Cube



- Cloud detection = enabling of analyses
- Radiometric corrections = reducing uncertainty of analyses
- Data Management = increasing efficiency and simplicity of analyses

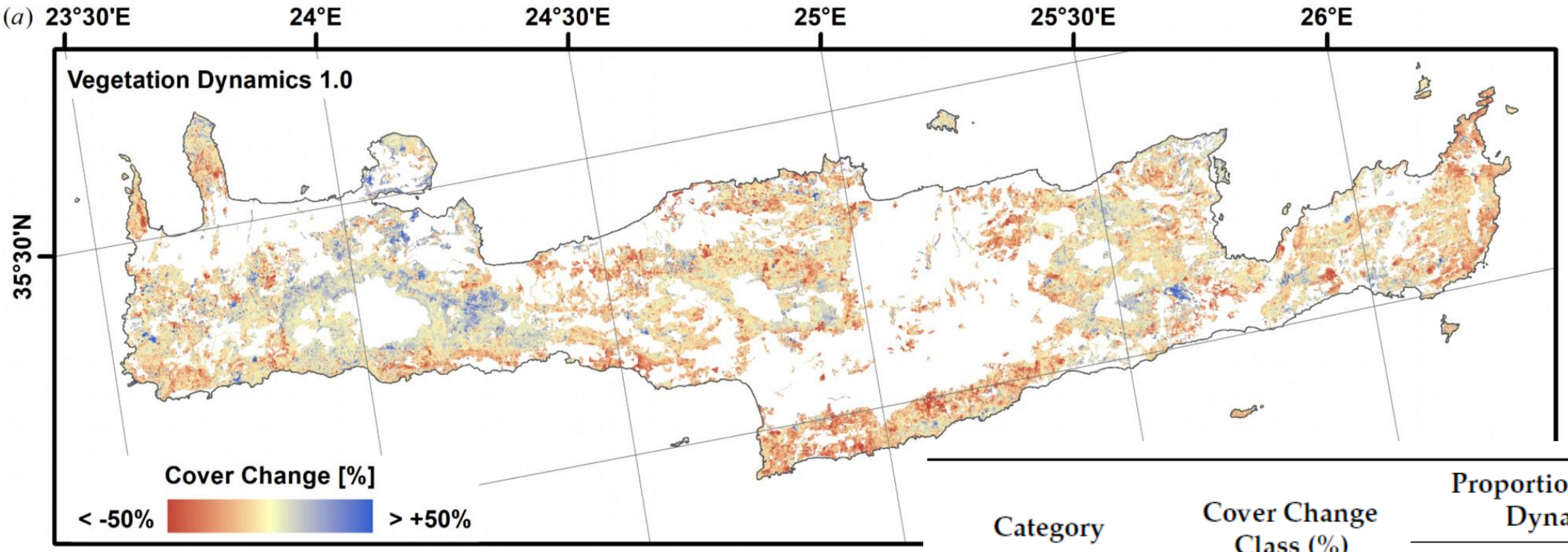
Long-term trend



Standard procedure

- generate annual composites
- Compute vegetation index
- Compute long-term trend

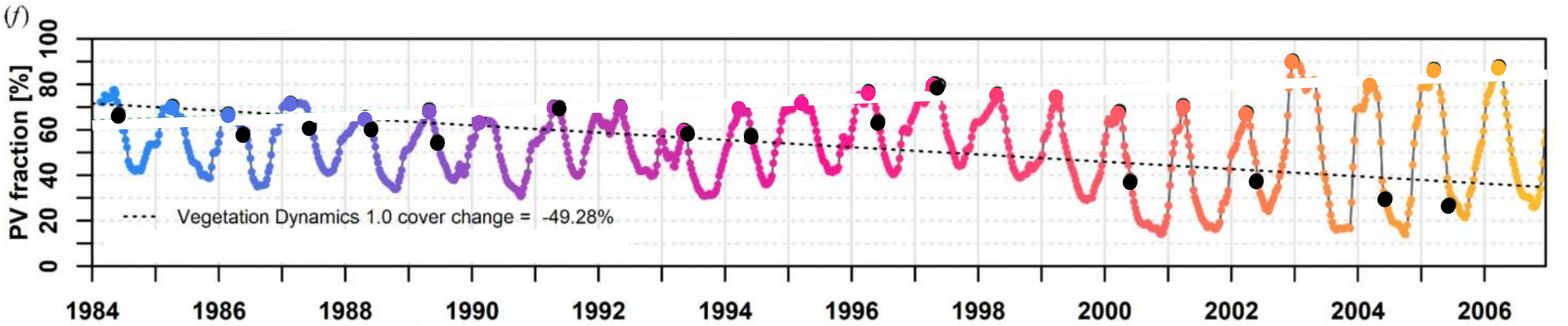
Land Change / Land Modifications



Reproduced from Hostert et al. 2003
Frantz et al. 2022 (https://doi.org/10.3390/rs14030597)

Category	Cover Change Class (%)	Proportion Vegetation Dynamics 1.0	
		(%)	(km^2)
Severe decrease	<−15	27.92	1212
Decrease	−15 to −5	21.88	950
Unchanged	−5 to +5	23.82	1034
Increase	+5 to +15	15.18	659
Strong increase	>+15	11.21	487

Observation bias

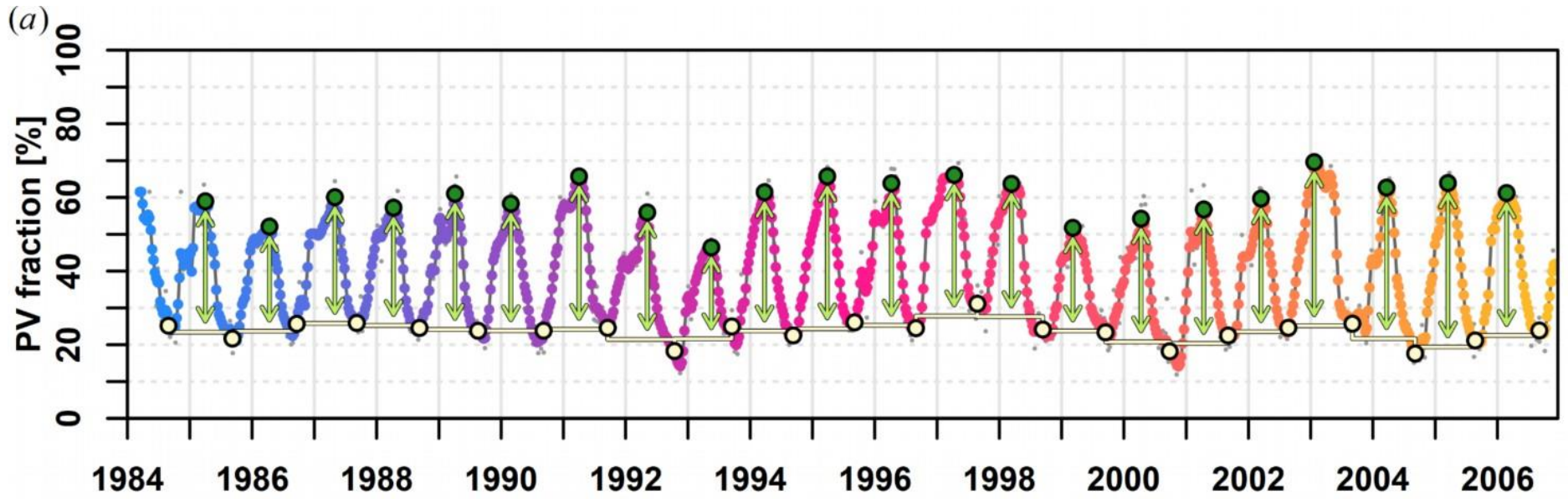


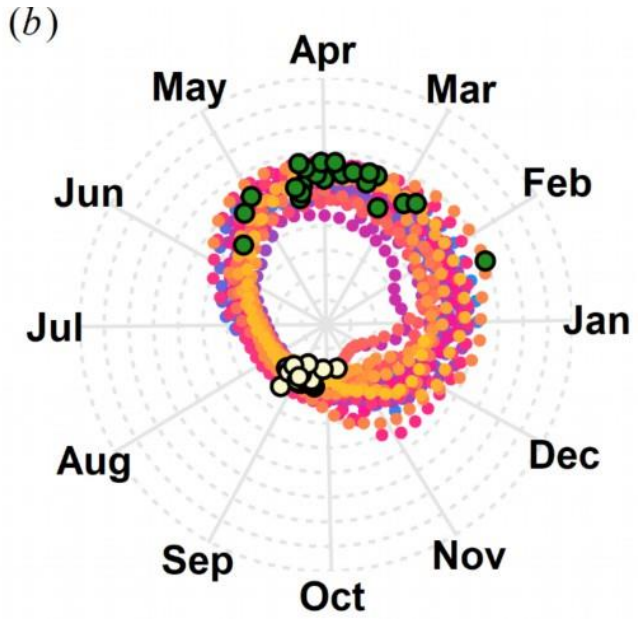
Not only reflectance needs to be standardized
The choice and method of the derived features has substantial impact on the final analysis, too

Static selection can easily introduce an observation bias if phenology has interannual variability or if a change results in a shift in phenology

Land Surface Phenology

Land Surface Phenology (LSP) can be meaured with annual LSP metrics a.k.a. „phenometrics“
→ Ecologically meaningful parameters that describe key aspects of the phenological cycle

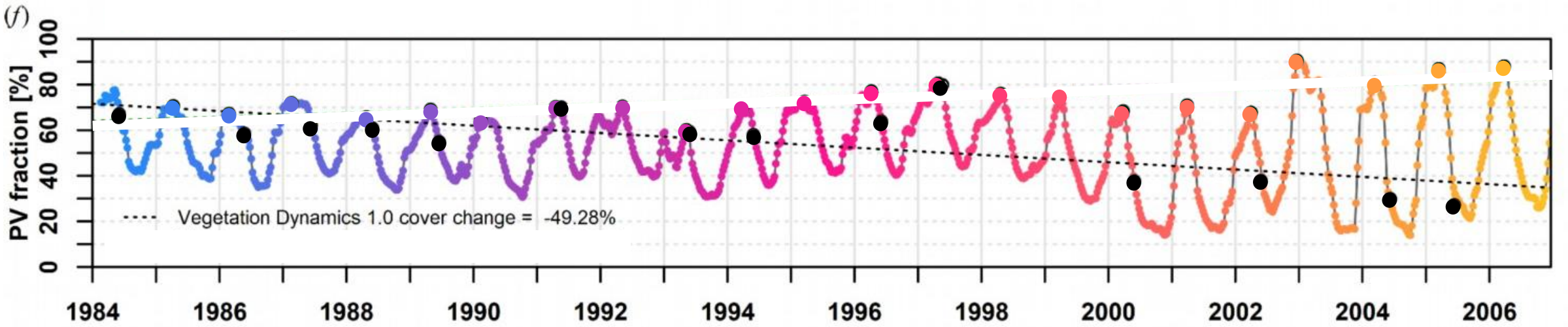




- Seasonal average vector
- Early and late minimum
- Length of season
- Base level

- Peak vegetation
- Seasonal amplitude
- Latent Integral (boxcar integral)
- …

Reducing the observation bias

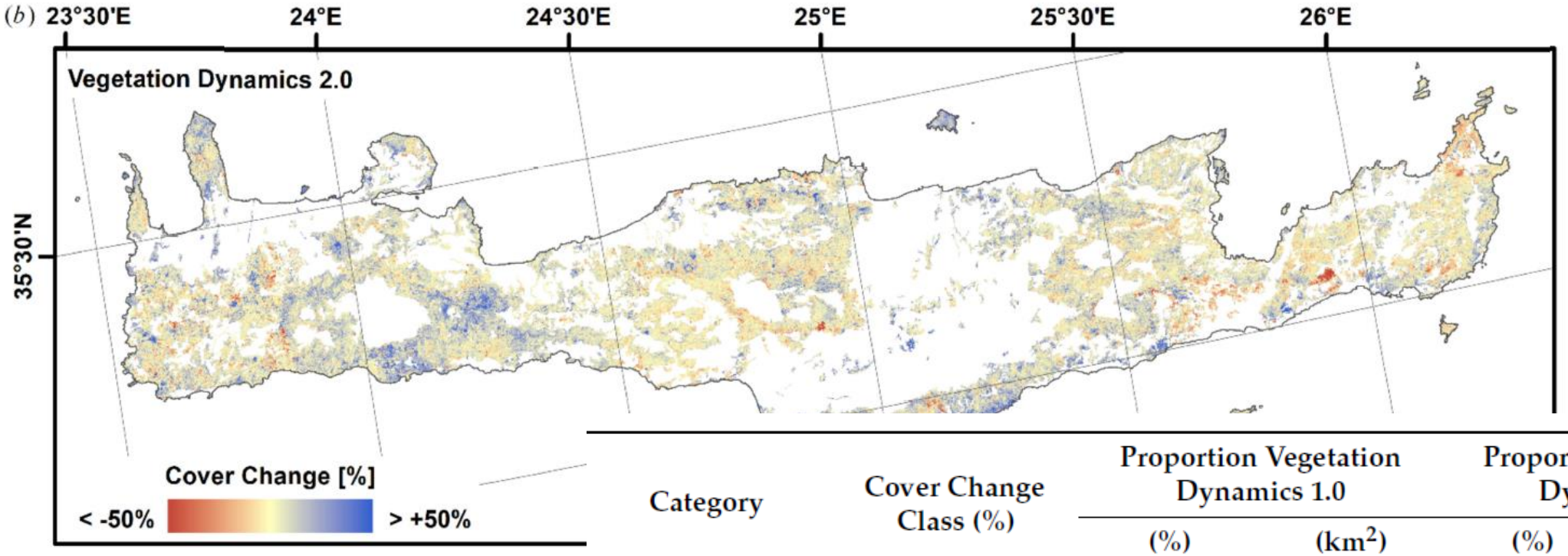


Static selection can easily introduce an observation bias if phenology has interannual variability or if a change results in a shift in phenology

Computing the trend on dynamically derived phenological parameters can reduce observation bias

Downside: increase in analytical complexity, high data availability required, no fits-all solution

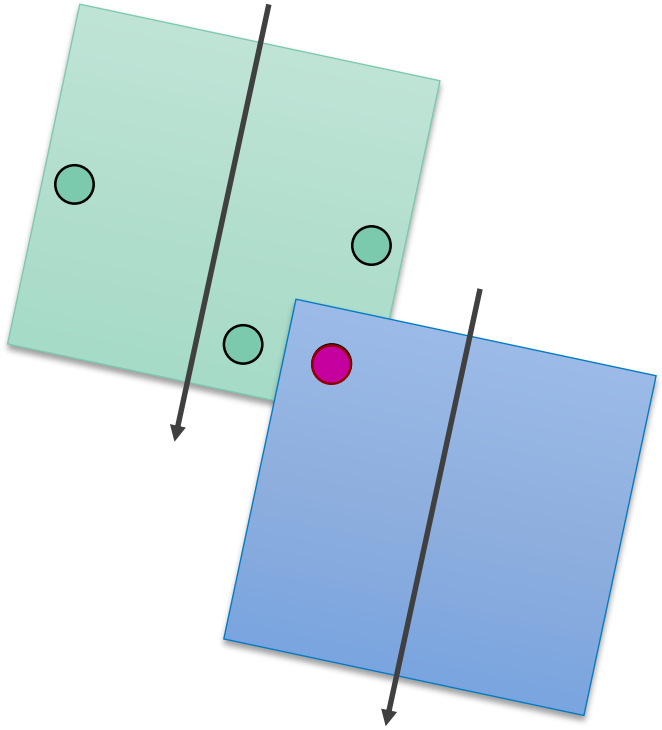
Trend for total vegetation (peak of season)



Frantz et al. 2022 (https://doi.org/10.3390/rs1403059

Category	Cover Change Class (%)	Proportion Vegetation Dynamics 1.0		Proportion Vegetation Dynamics 2.0	
		(%)	(km²)	(%)	(km²)
Severe decrease	<−15	27.92	1212	5.63	245
Decrease	−15 to −5	21.88	950	12.43	541
Unchanged	−5 to +5	23.82	1034	31.55	1373
Increase	+5 to +15	15.18	659	29.34	1277
Strong increase	>+15	11.21	487	21.05	916

Take aways



Goal

increase consistency and comparability through space and time to allow

- consistent usage across large areas
- consistent usage across time
- consistent usage across sensors

preprocessing

- comparison / trends on consistent phenological phases

data analysis

Questions?

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