Scaling photosynthetic light-use efficiency from canopies to landscapes

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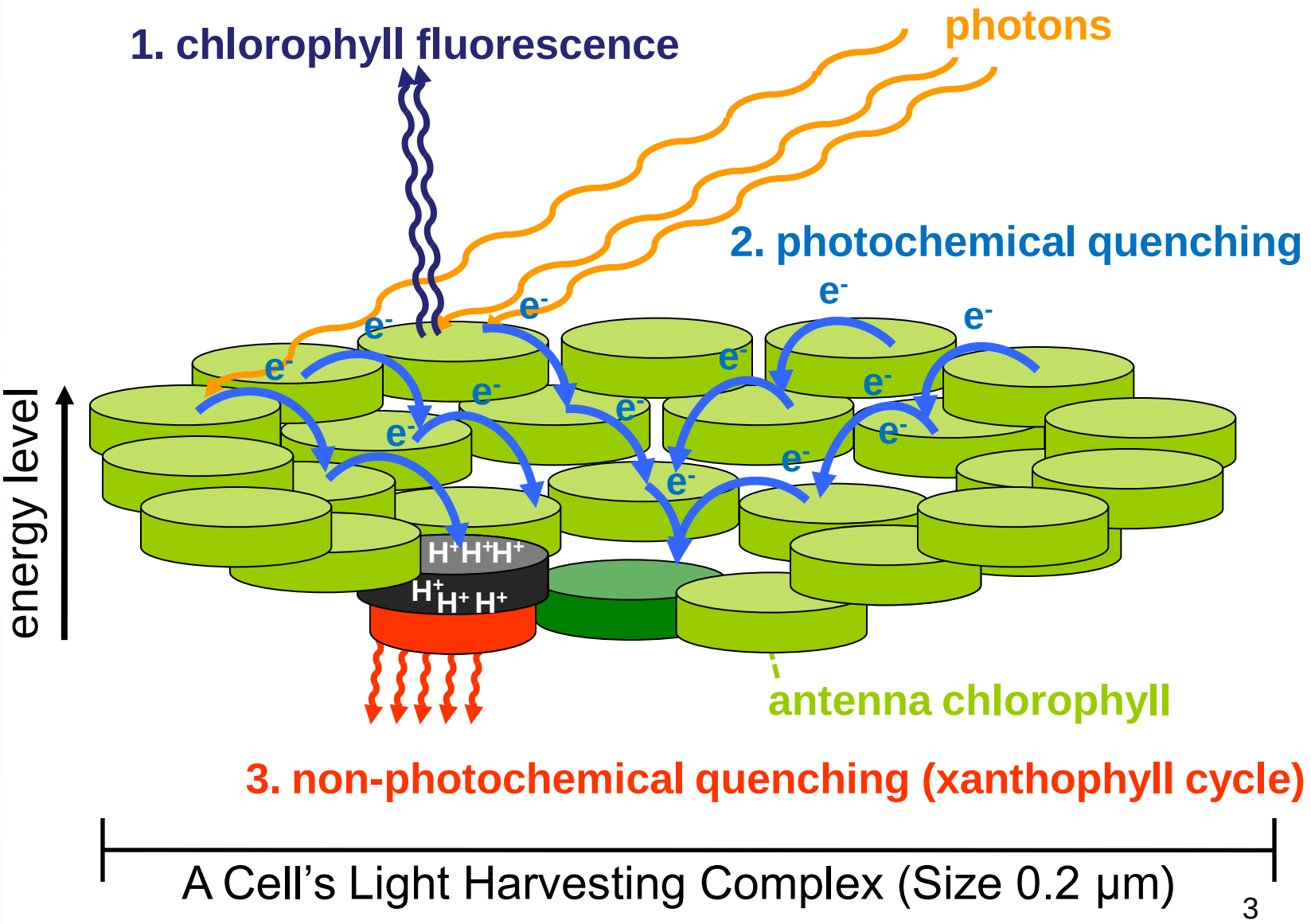
Remote sensing of Photosynthesis

Monteith (1972,1977):

$$GPP = \varepsilon \times f_{PAR} \times PAR$$

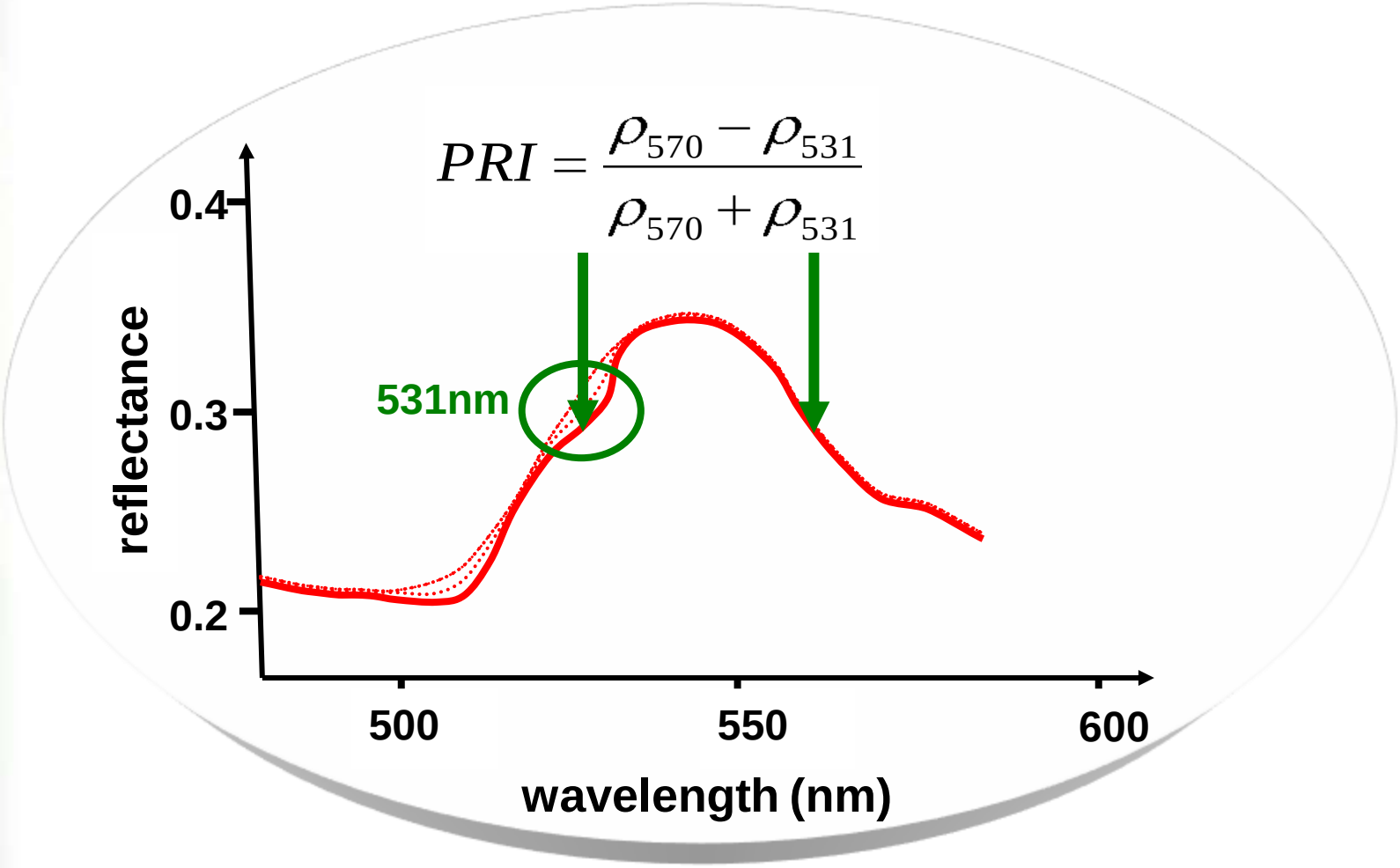
Light-use efficiency term ε

Photosynthetic Energy Pathways



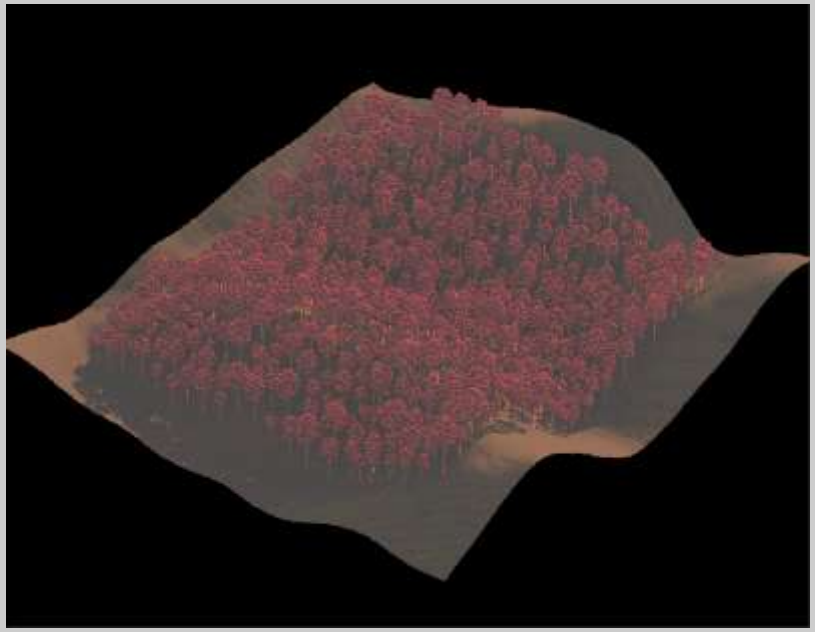
Hilker et al., Science of the Total Environment (2008)

Associated changes in reflectance

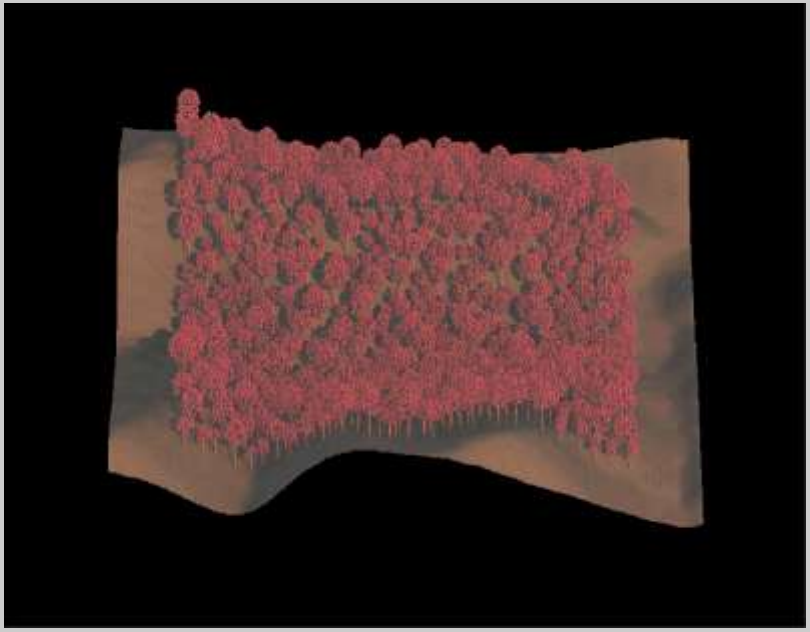


Effects of Structure on Remote Sensing of Photosynthesis

I. Physical effects



moving sun



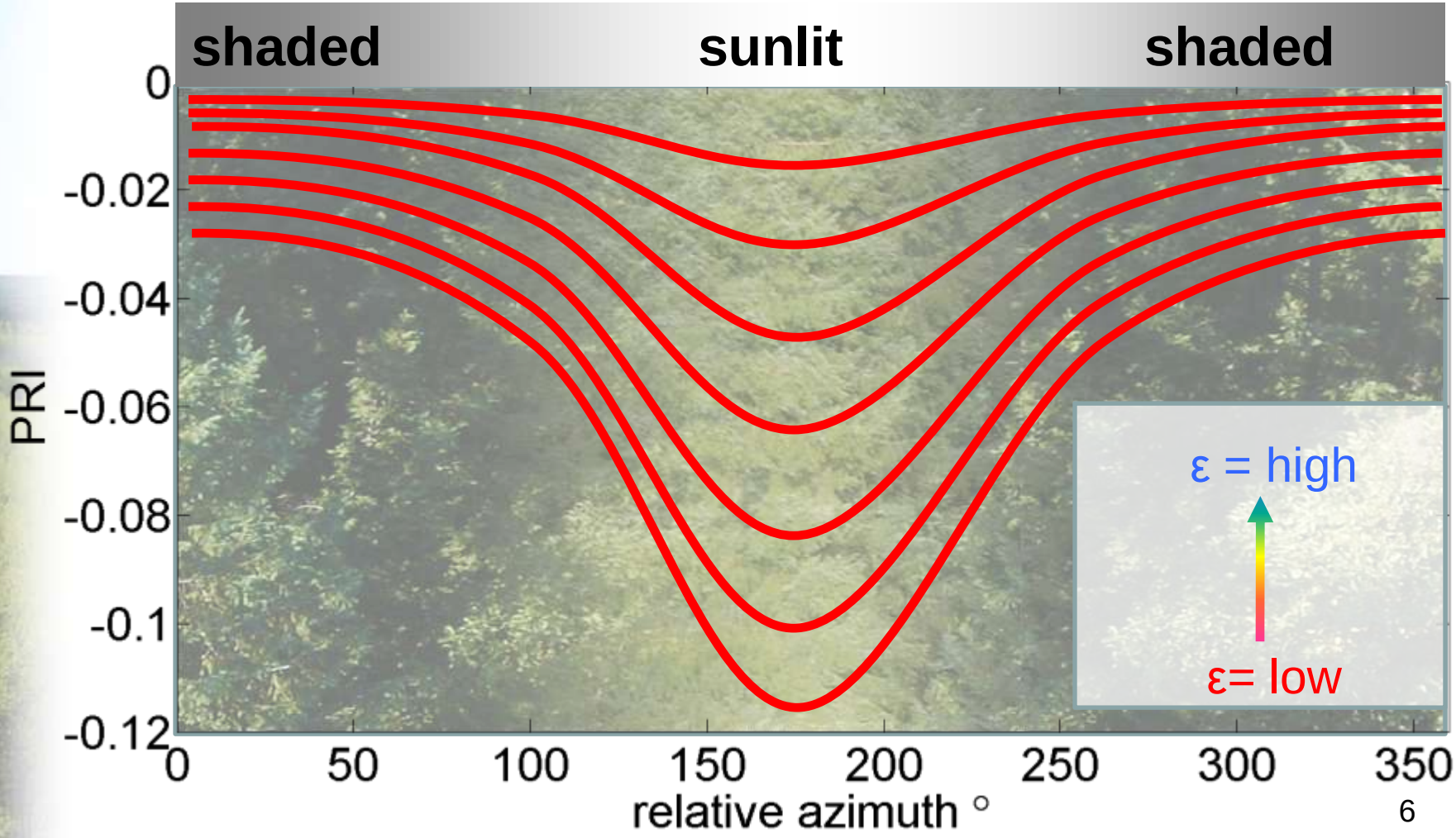
moving observer

Figure: D. Culvenor

Hilker et al., Journal of Geophysical Research(2008)

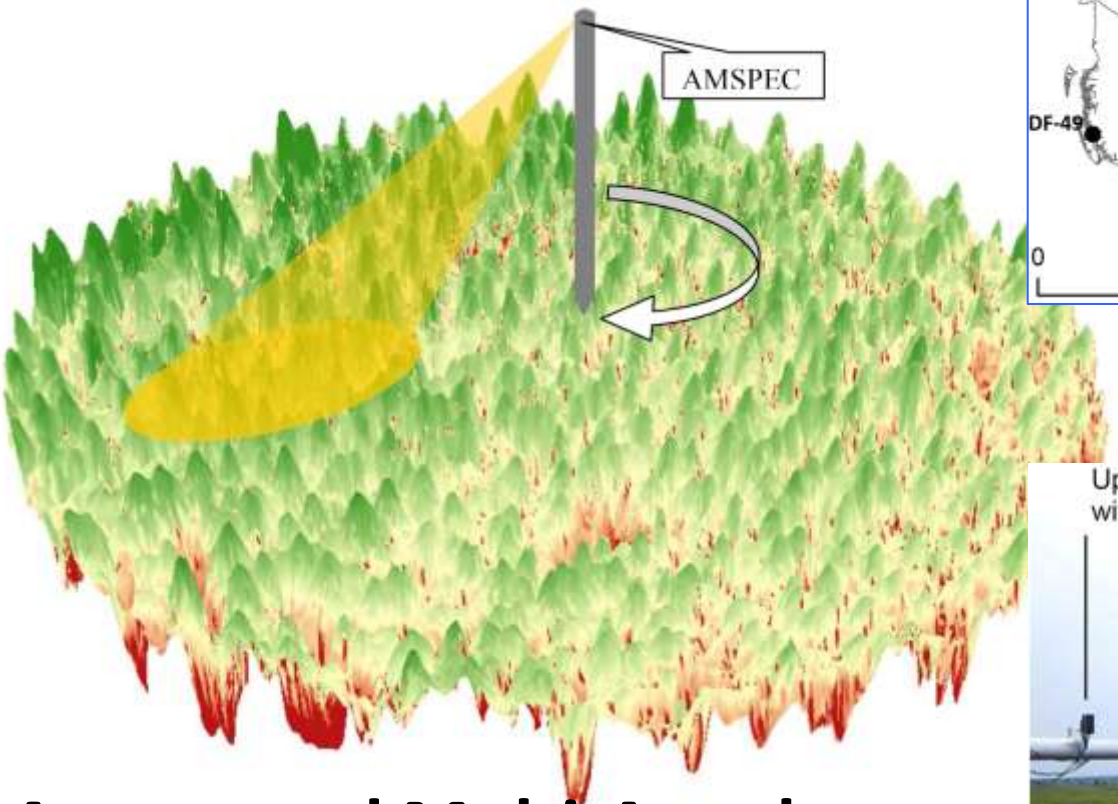
Effects of Structure on Remote Sensing of Photosynthesis

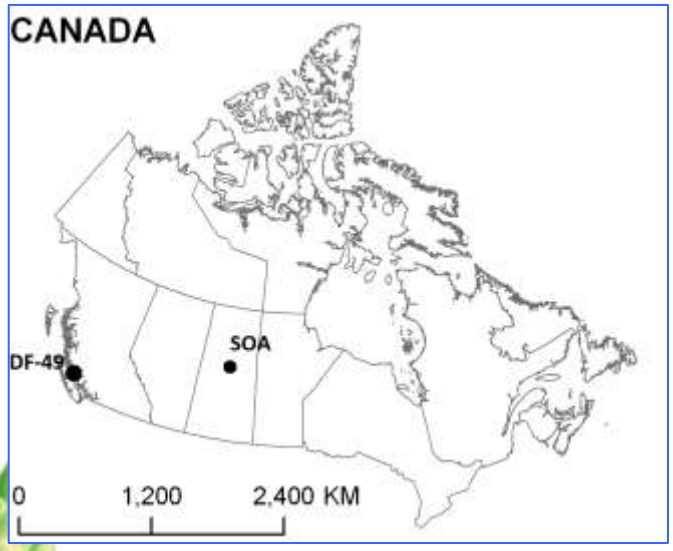
II. Physiological effects



Hall et al. Remote Sensing of Environment (2008)

Amspec

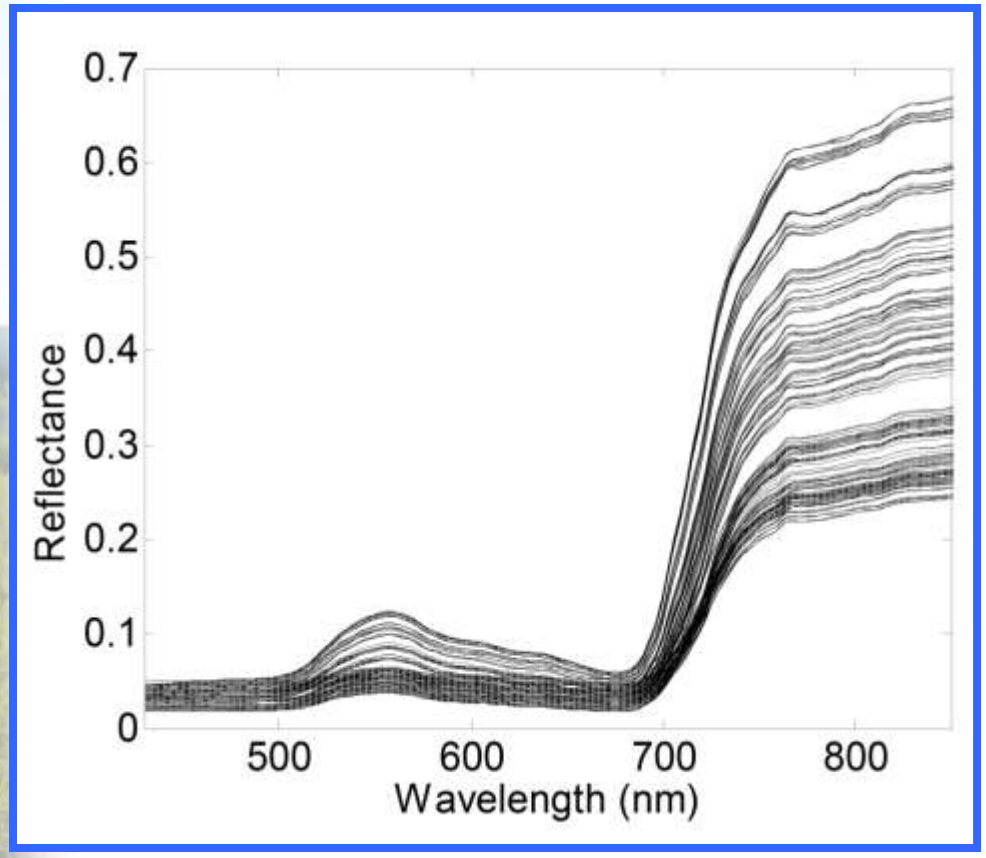




Automated Multi-Angular Spectroradiometer

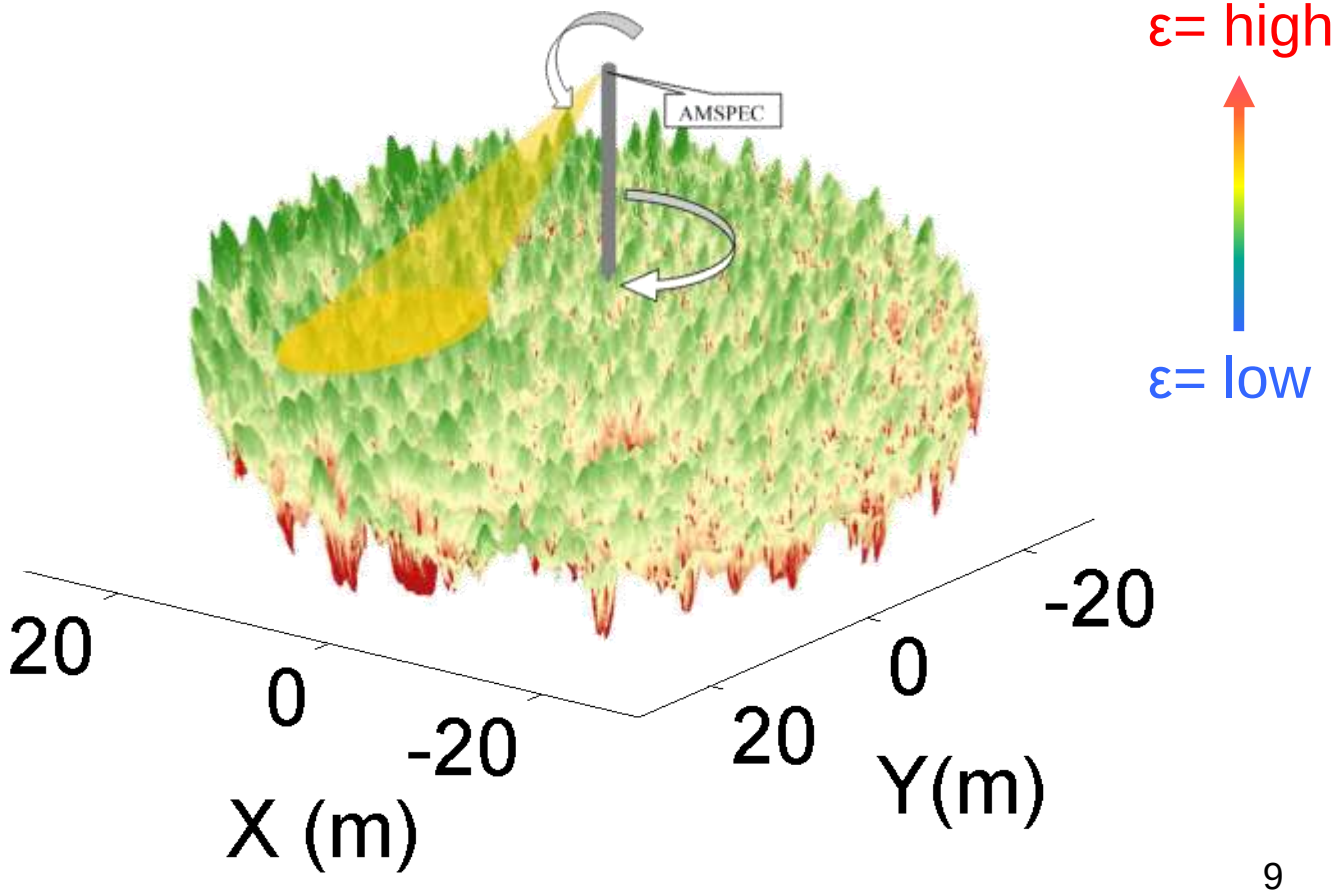
Hilker et al., Computers and Electronics in Agriculture (2007)
Hilker et al. Instrumentation Science and Technology (2010)

Amspec data



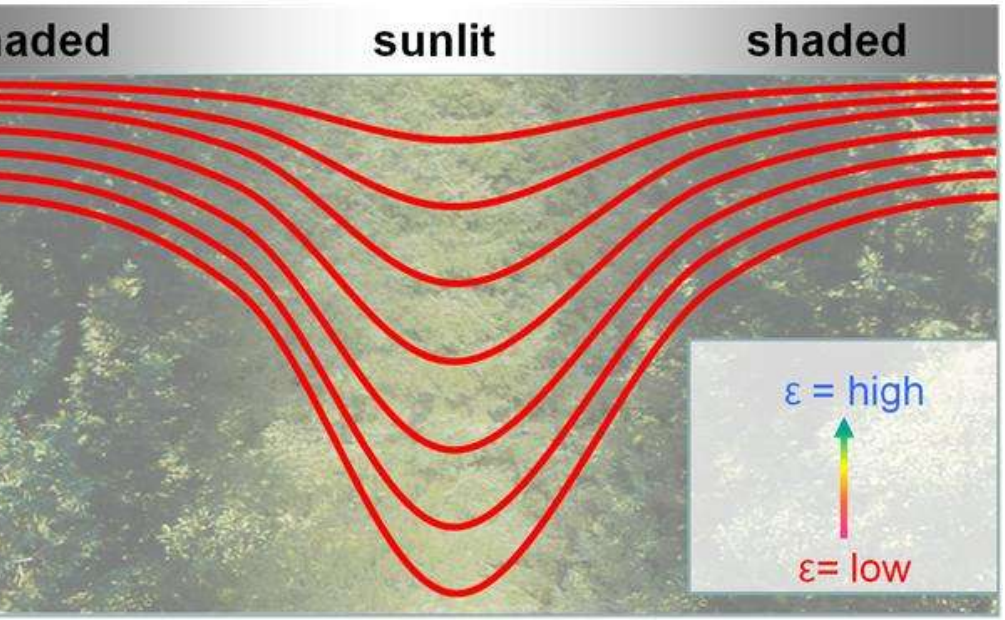
Hilker et al. Instrumentation Science and Technology (2010)

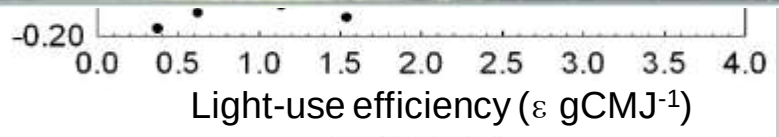
Combining Structure and Function: Inferring Photosynthetic Efficiency



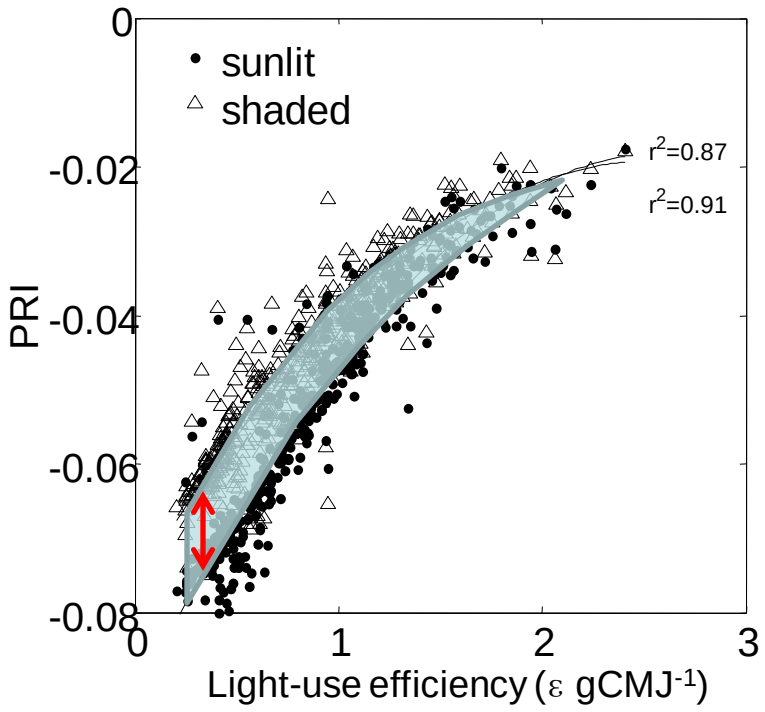
Hilker et al., Remote Sensing of Environment (2008)

RS of Photosynthetic Efficiency





not considering structure



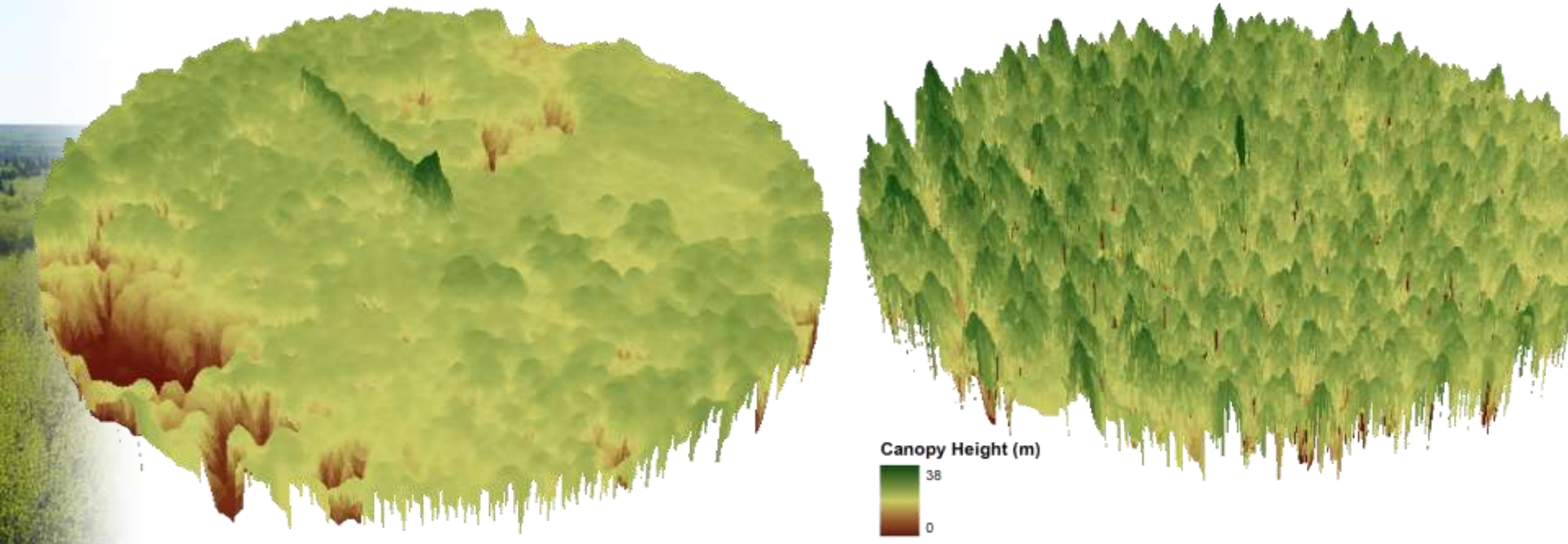
considering structure

Hilker et al., Remote Sensing of Environment (2008,2009)

Calculating shadow fractions (α_s)

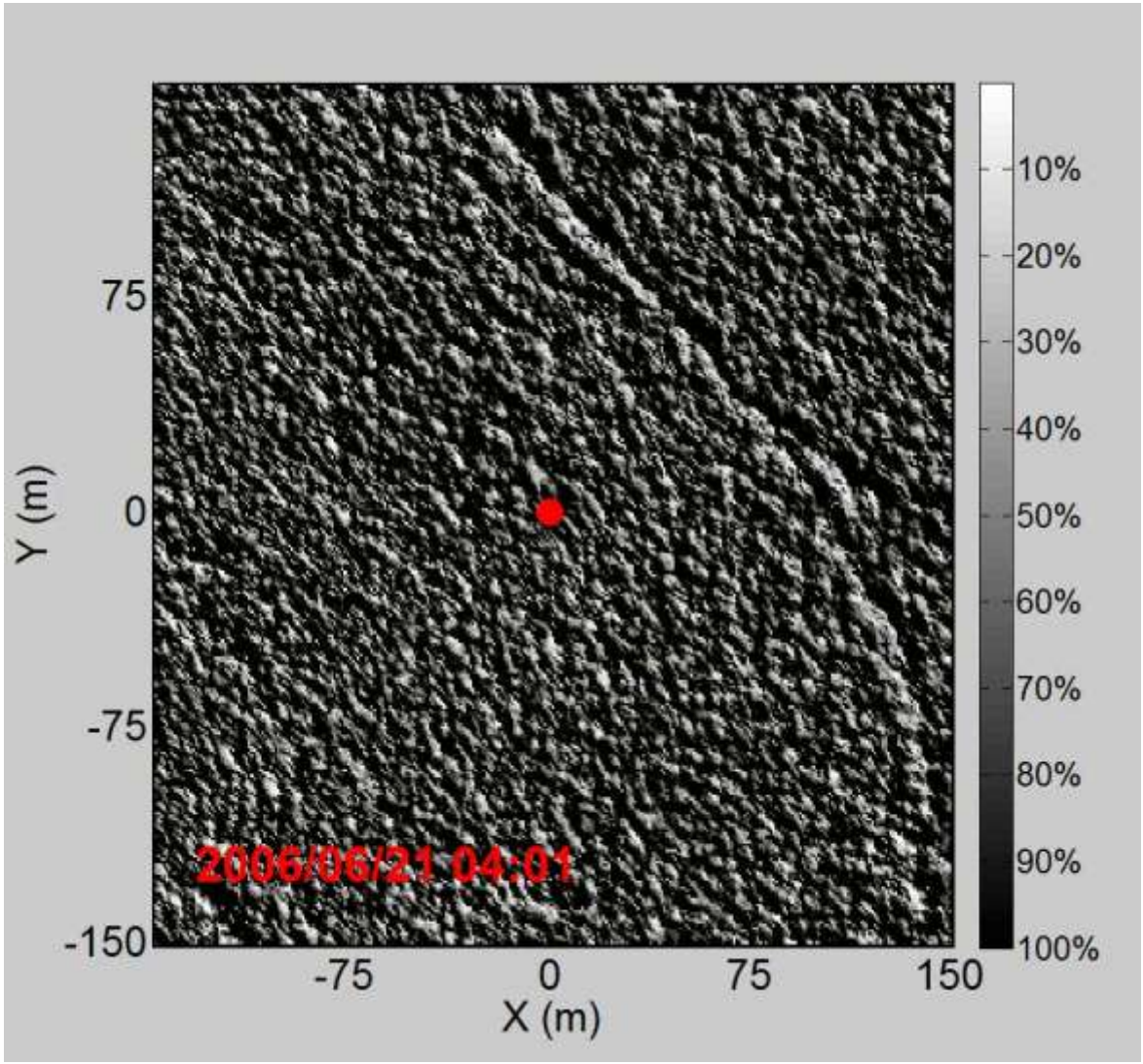
SOA

DF-49



Hilker et al., Remote Sensing of Environment (2010)

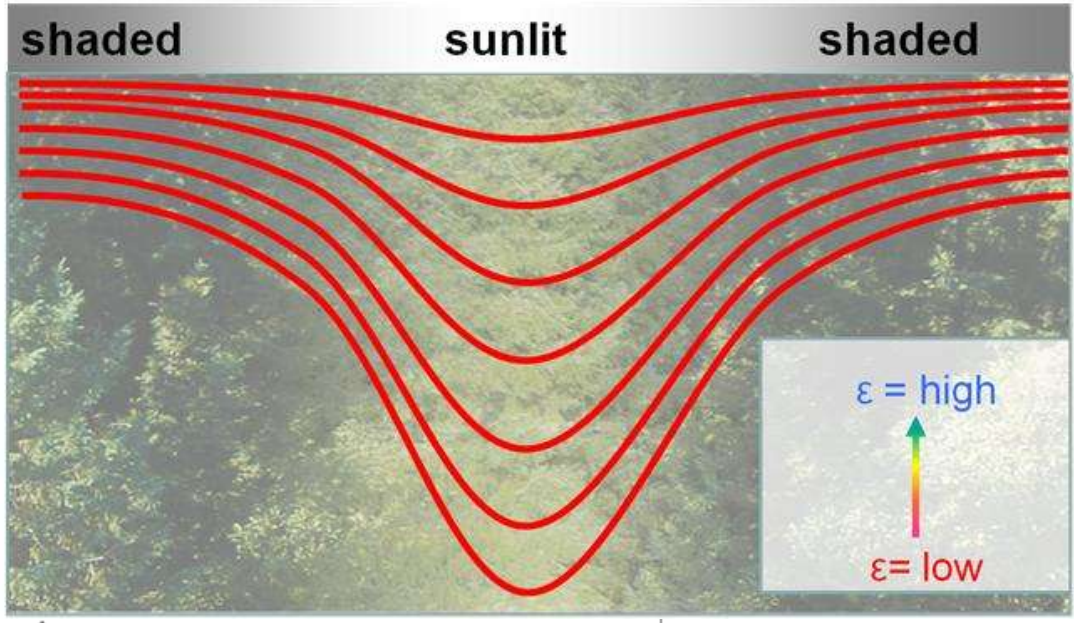
Calculating shadow fractions (α_s)

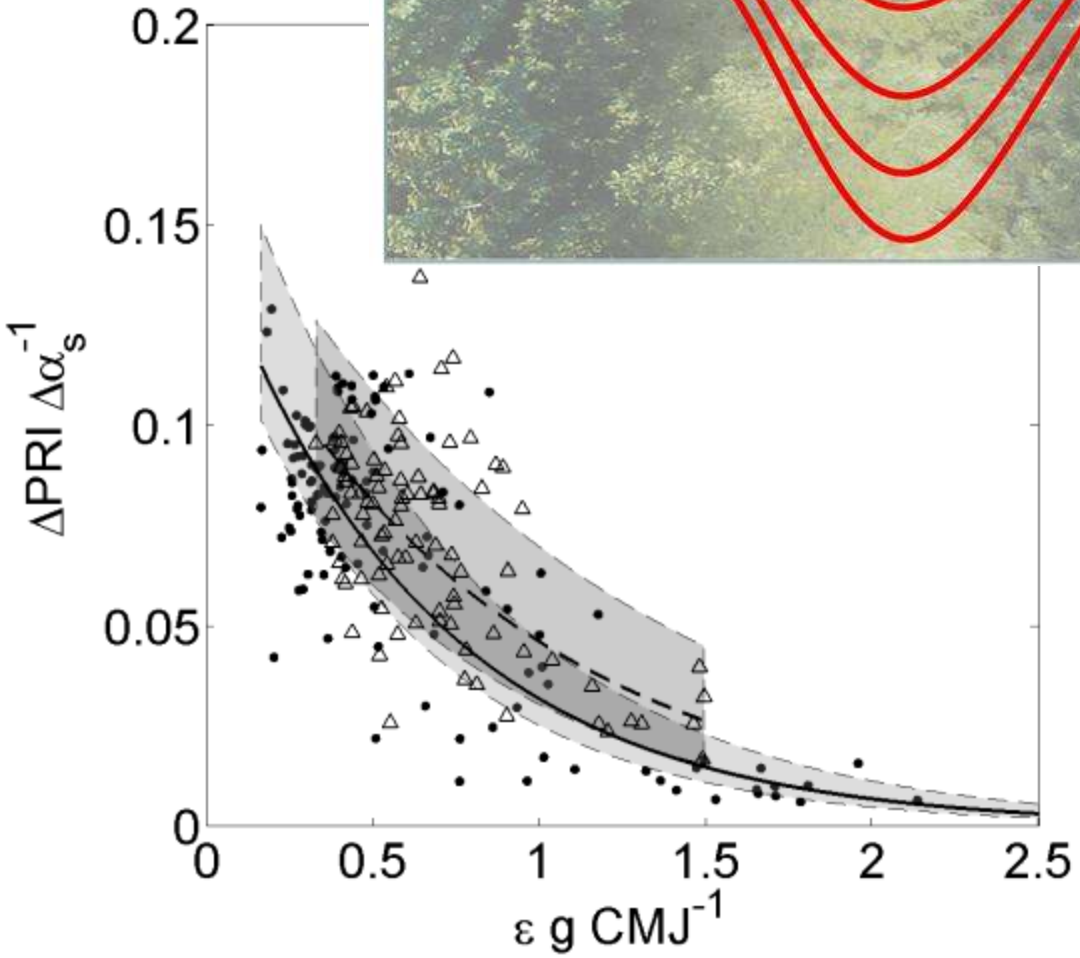


Hilker et al., Tree Physiology (2008)

Remote sen

1st derivat

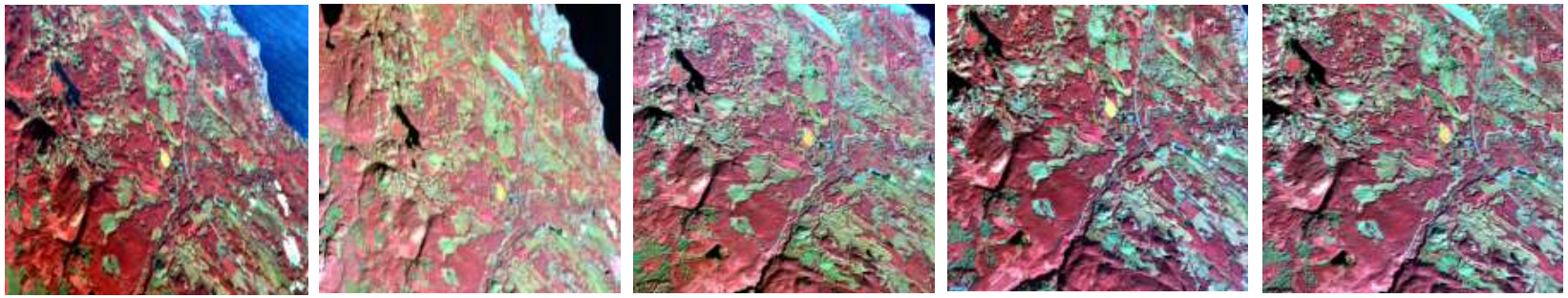




Hilker et al., Remote Sensing of Environment (2010)

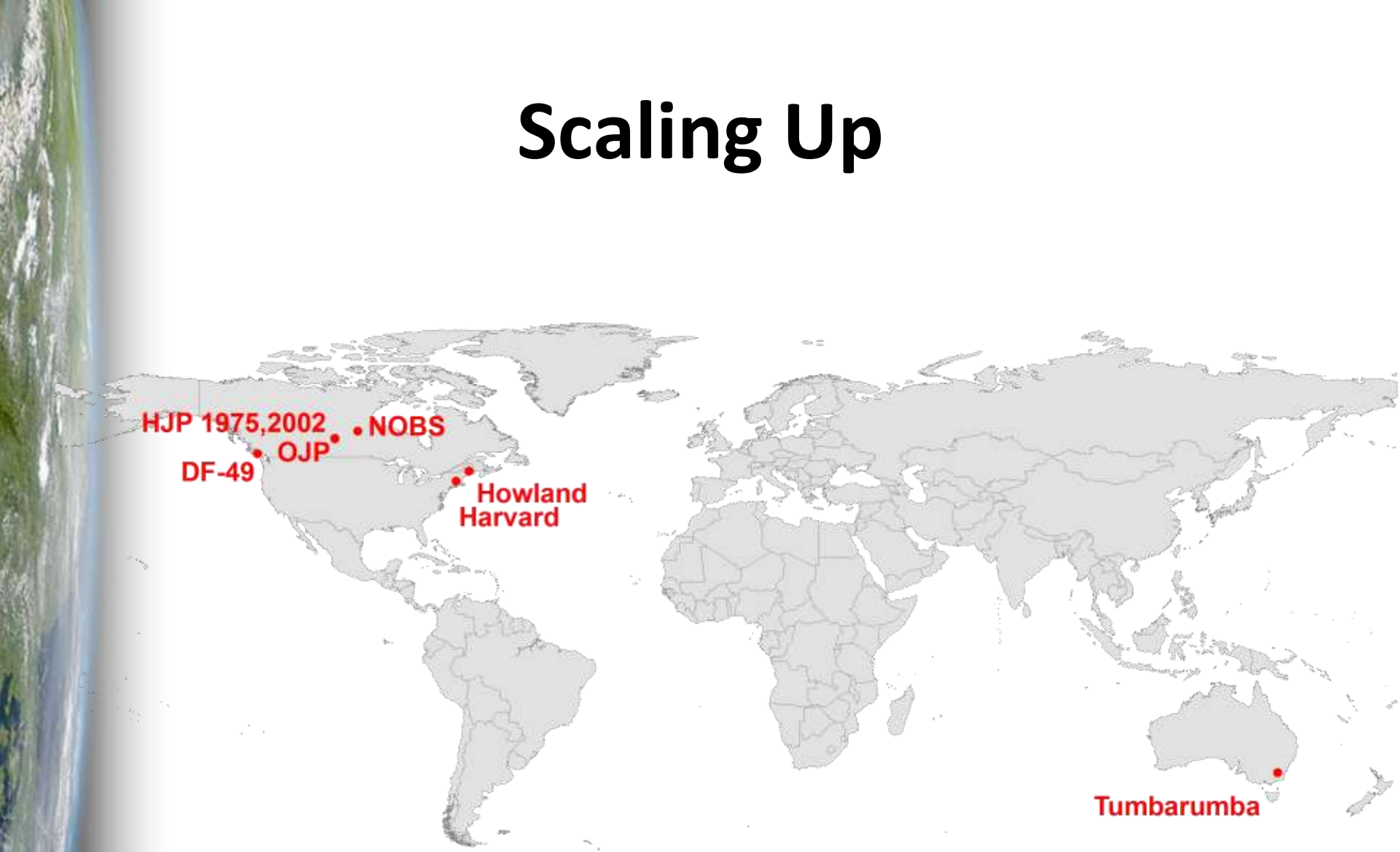
Scaling Up: CHRIS/Proba Satellite

Figure: UK Space Agency



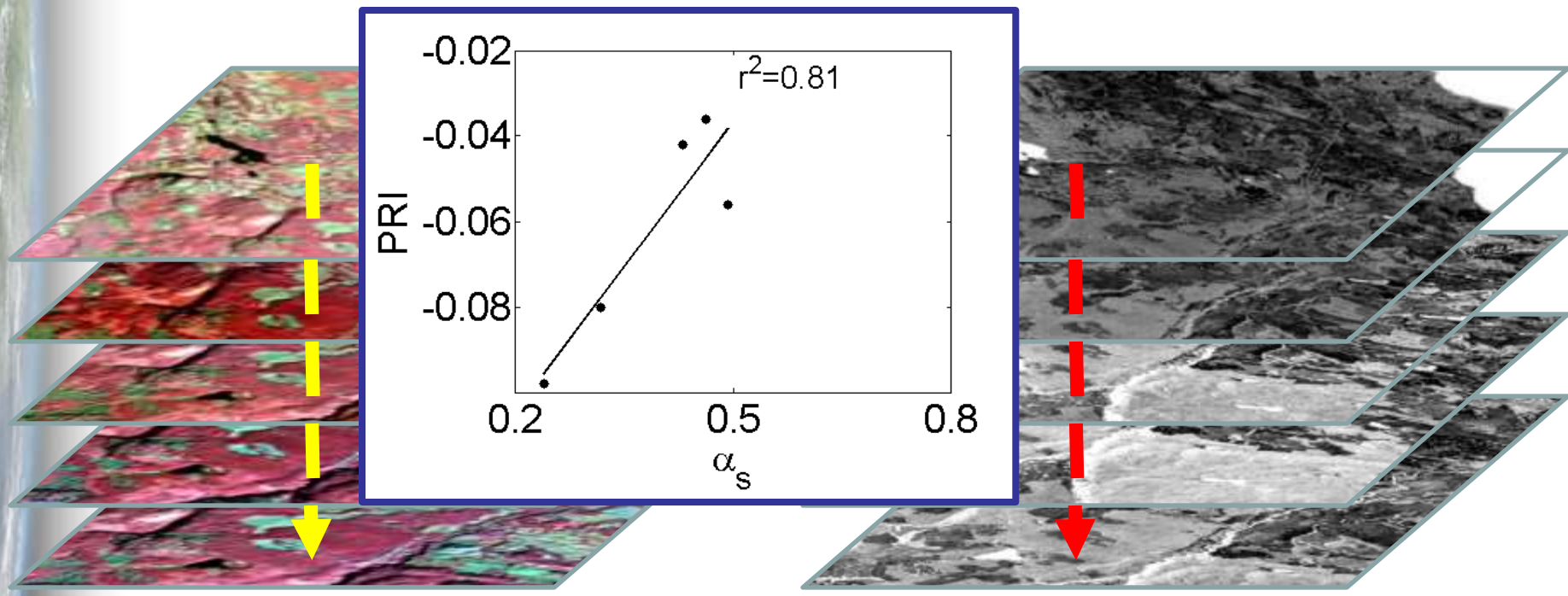
Hall, Hilker et al., Remote Sensing of Environment (in press)

Scaling Up



Hilker et al., Journal of Geophysical Research (in press)

Obtaining PRI and Shadow fractions from CHRIS/Proba



Reflectance for given overpass

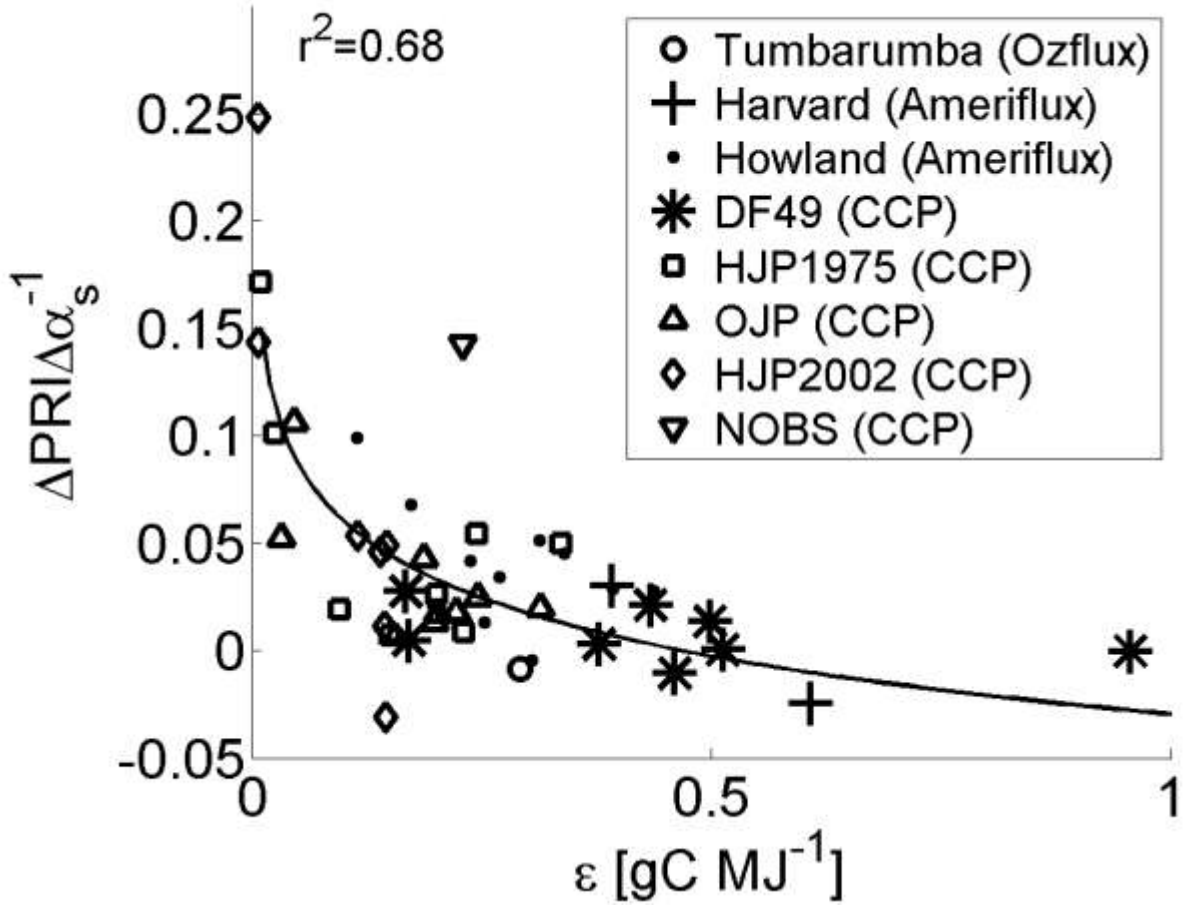
Corresponding Shadow fractions from spectral endmembers

Hilker et al., Journal of Geophysical Research (in press)

Structural Differences of Test Sites

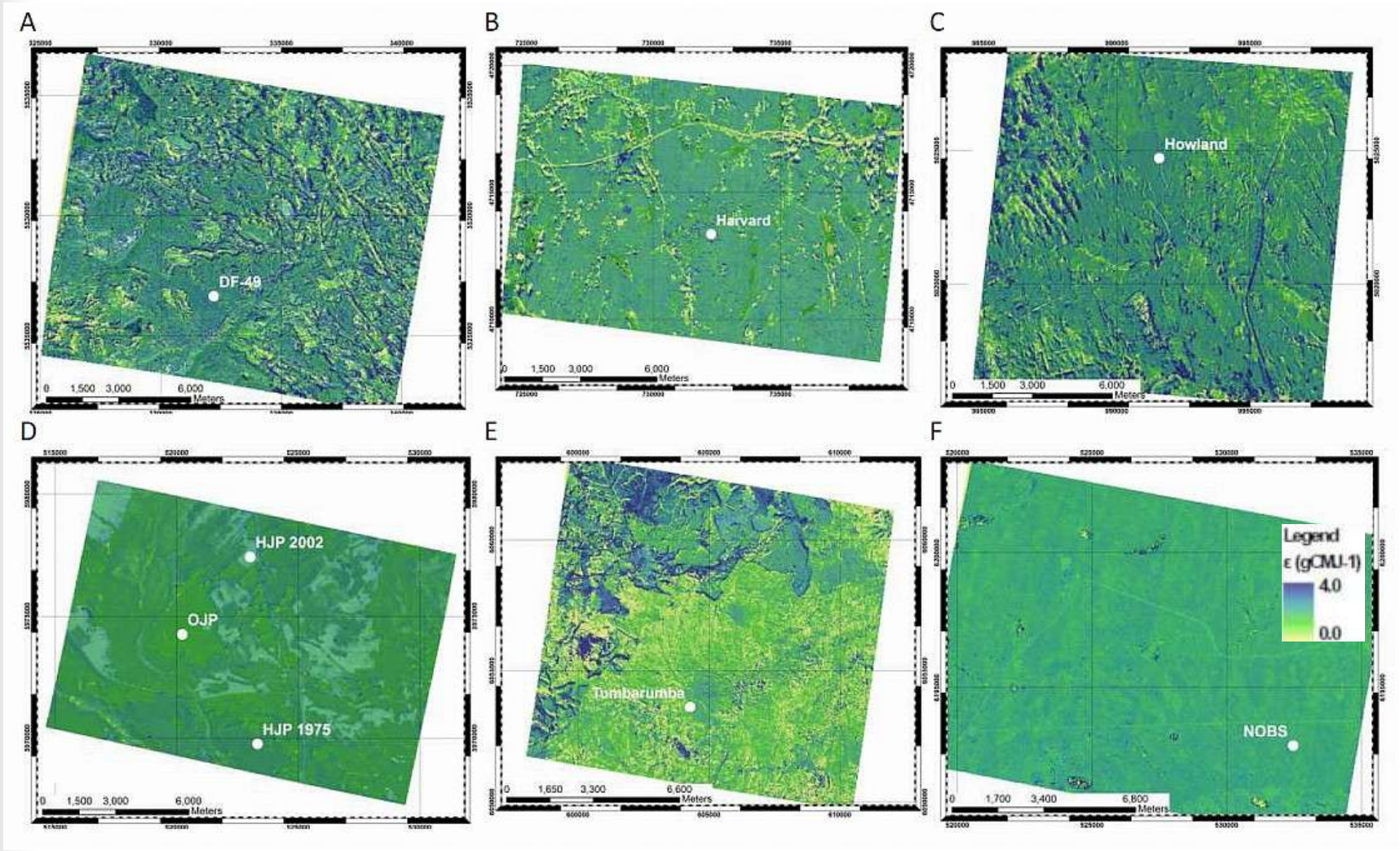
Hilker et al., Journal of Geophysical Research (in press)

Satellite-derived Photosynthesis



Hilker et al., Journal of Geophysical Research (in press)

Satellite-derived Photosynthesis

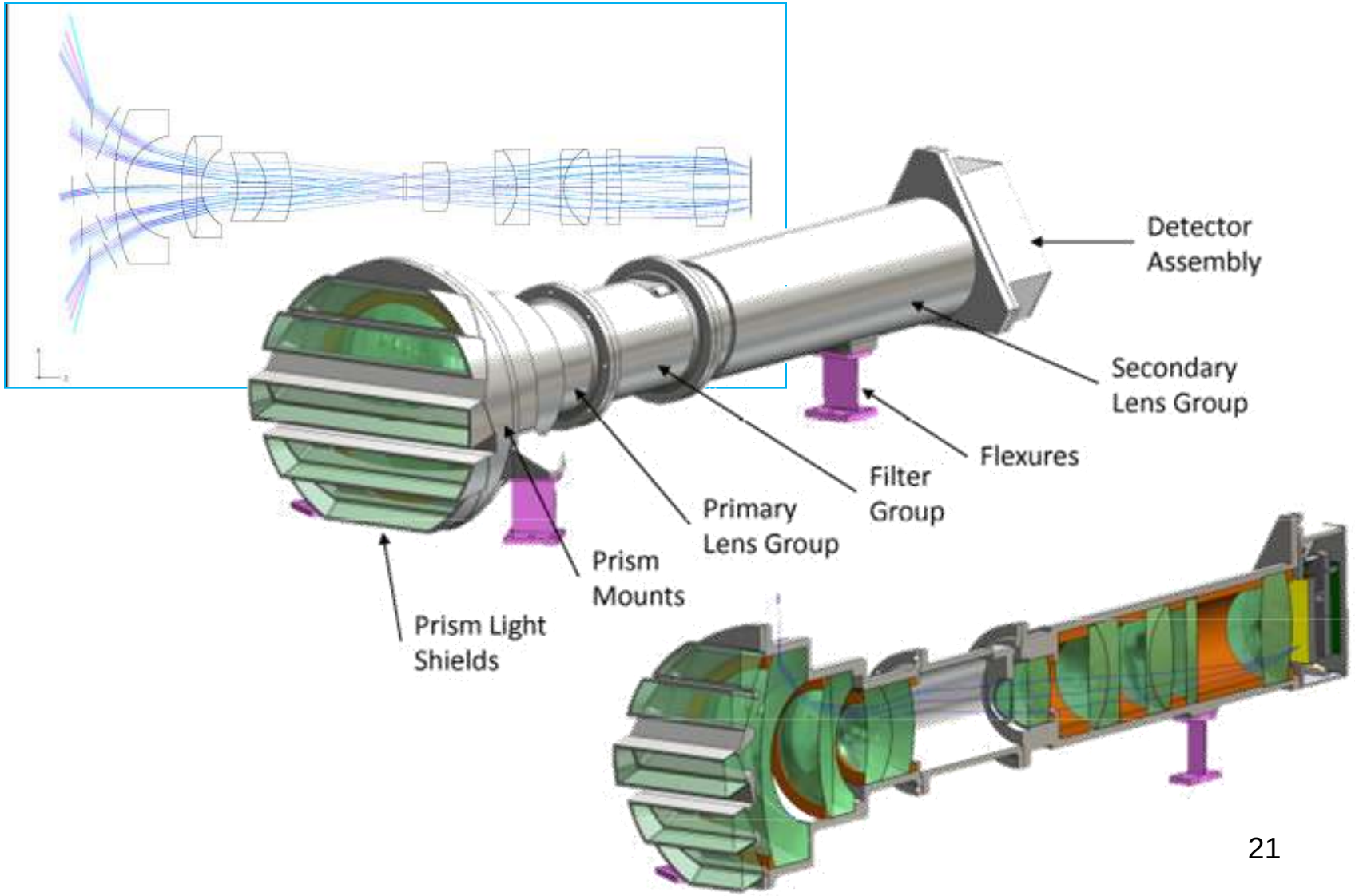


Hilker et al., Journal of Geophysical Research (in press)

Conclusions

1. Consecration of structure is essential for robust stand level sensing of function
2. Structure can be obtained from multi-angle spectral observations
3. ΔPRI $\Delta\alpha_s^{-1}$ can be used to infer instantaneous ε across different biomes
4. This relationship can be upscaled to space using an adequate sensor

PhotosynSat: Photosynthesis from Space



Thank you!!

For your attention!

Questions?

- Dominic Lessard, UBC, LFS
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- [illegible]um, UBC, LFS

For Sharing Data and Concepts:

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- Alexei Lyapustin, NASA GSFC
- Caroline Nichol, UED
- Alan Barr, NRCAN

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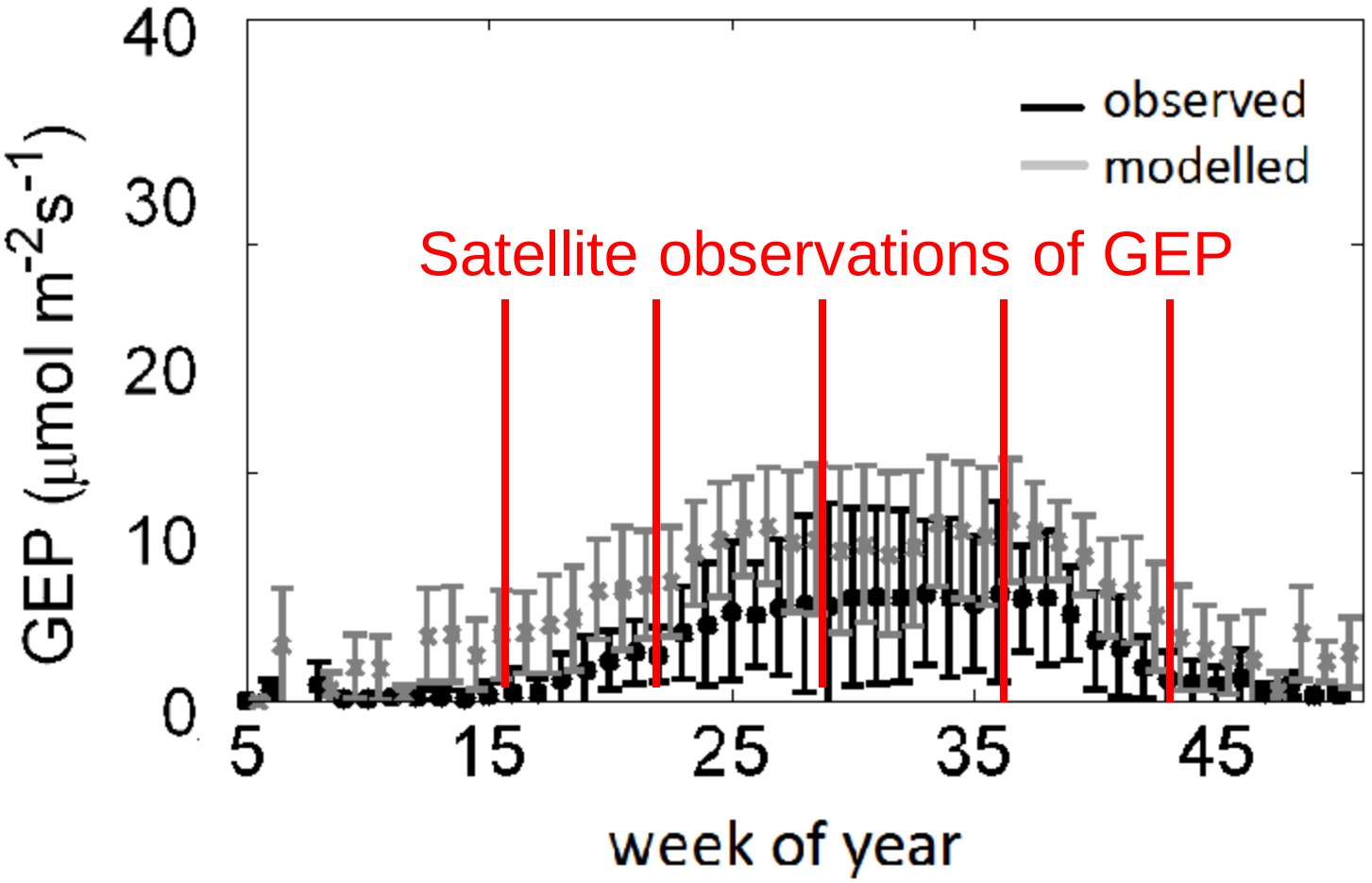
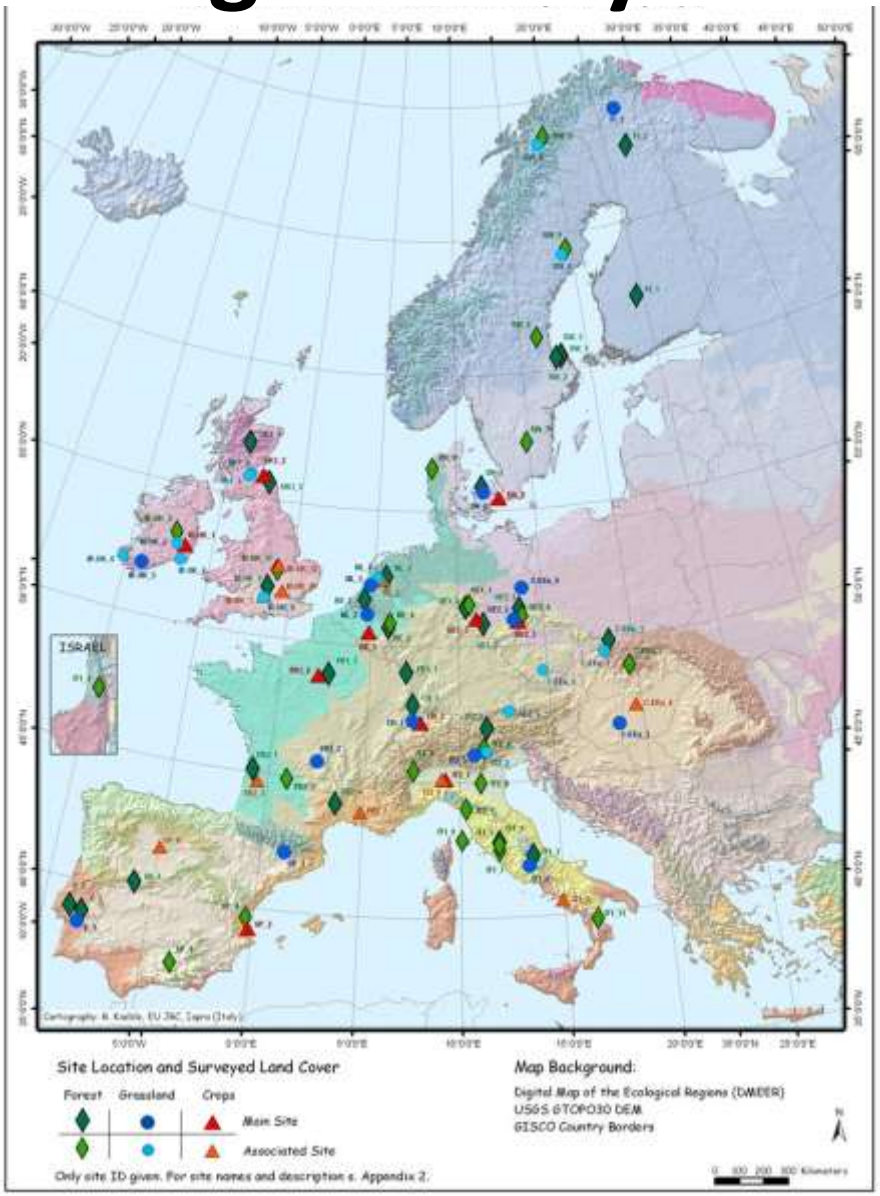
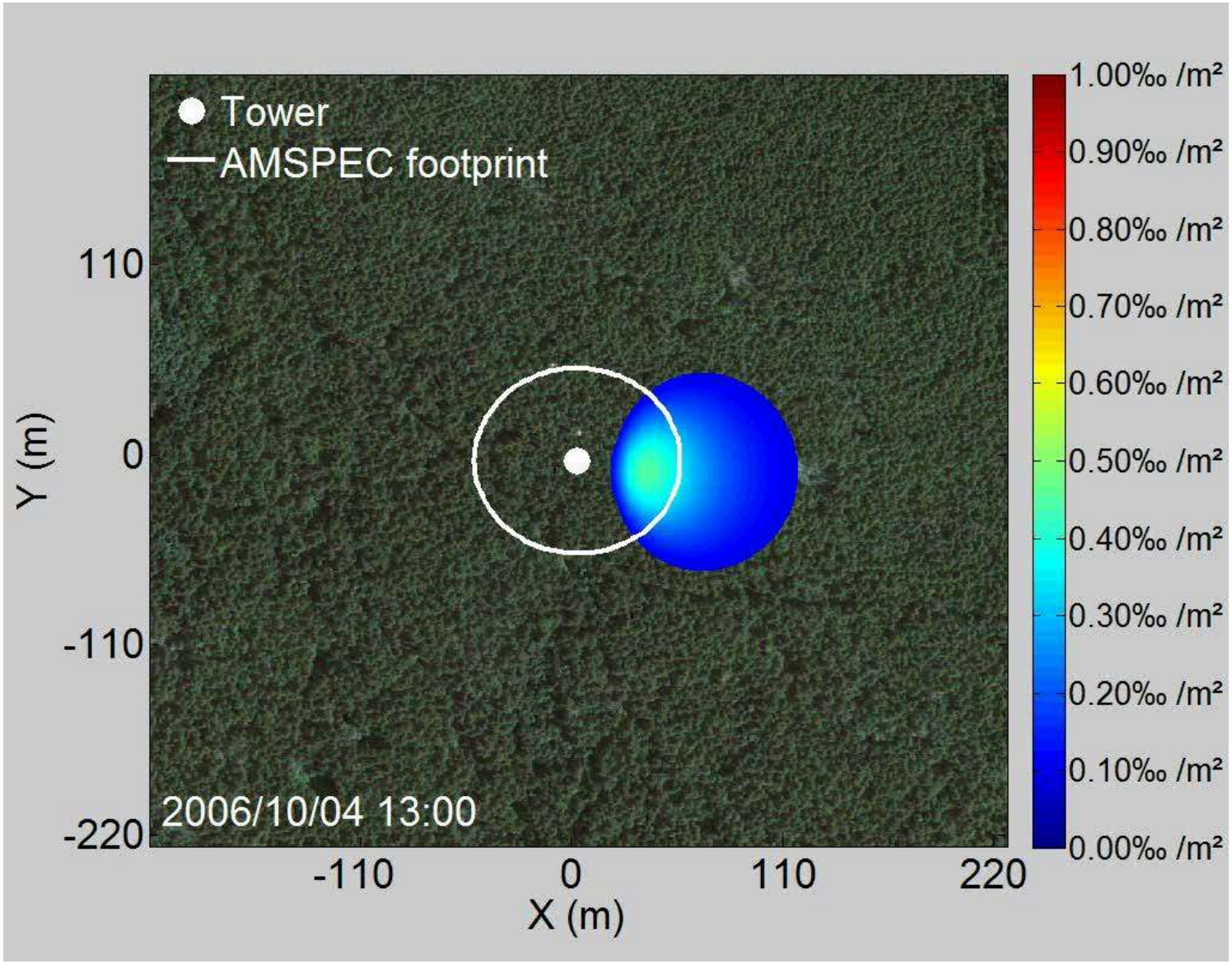
Integrating Remote Sensing and Carbon Models



Carbo Europe: Long-term monitoring of ecosystem change



Eddy covariance/AMSPEC footprint



Hilker et al., Journal of Geophysical Research(2008)

Flux footprint model: Chen et al. 2008

AMSPEC system

Range & Bandwidth:

400-1200 nm @ 10nm

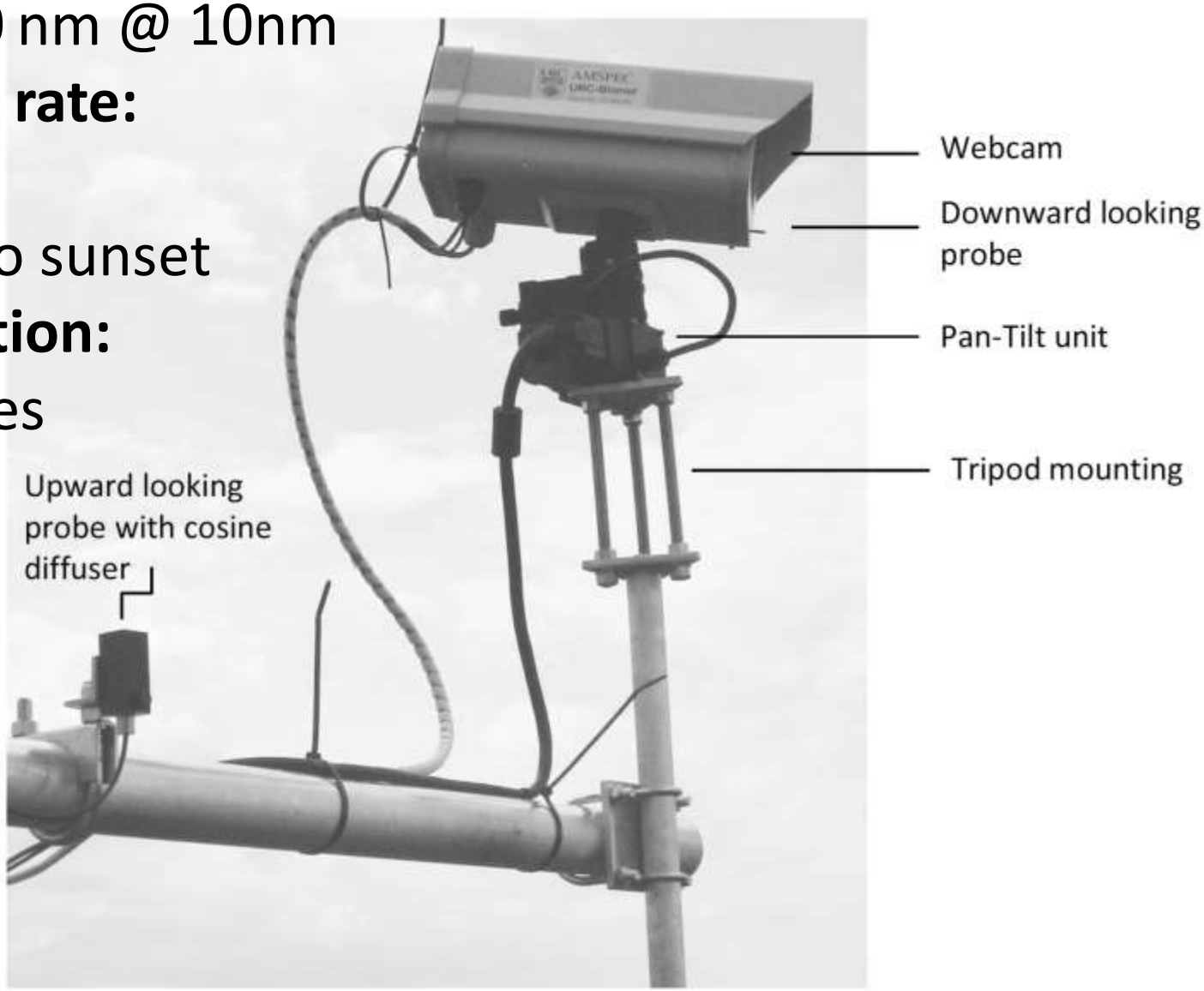
Sampling rate:

~ 5 sec

sunrise to sunset

Full Rotation:

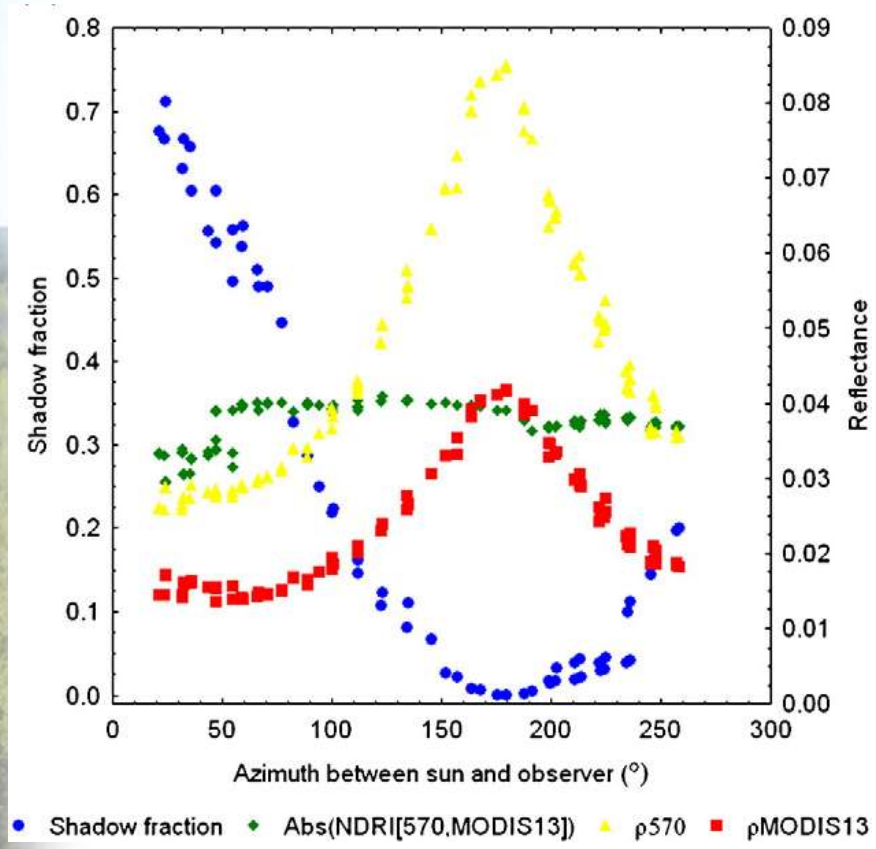
15 minutes



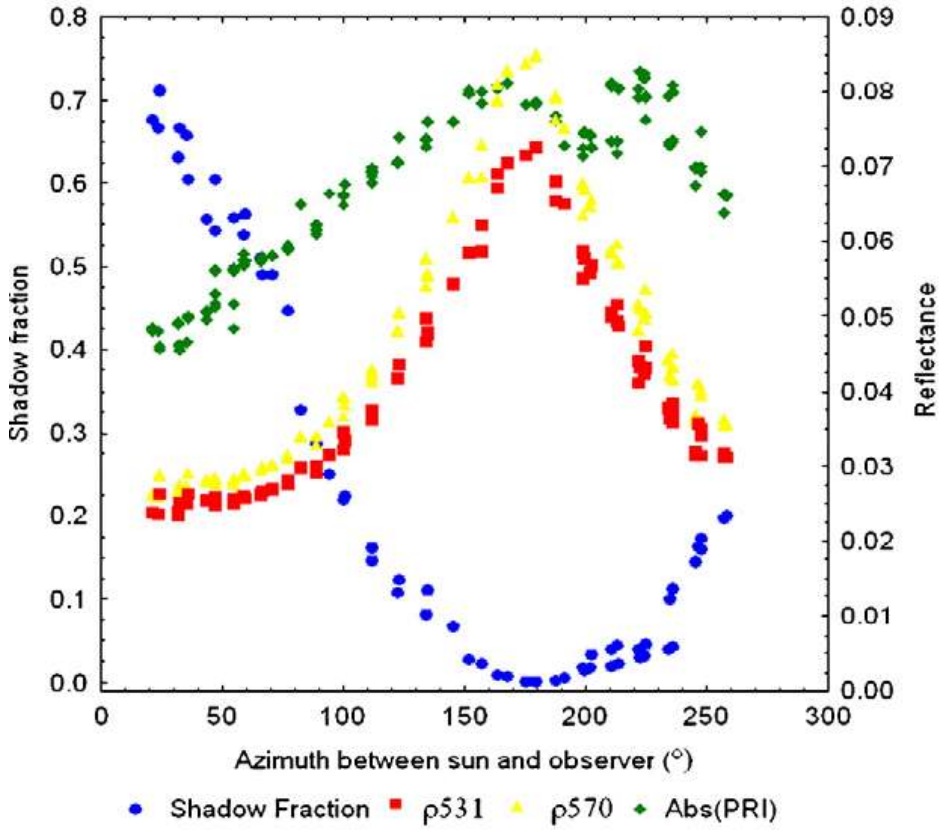
Sensitivity to shadow fractions

Stand level ε=const

NDRI

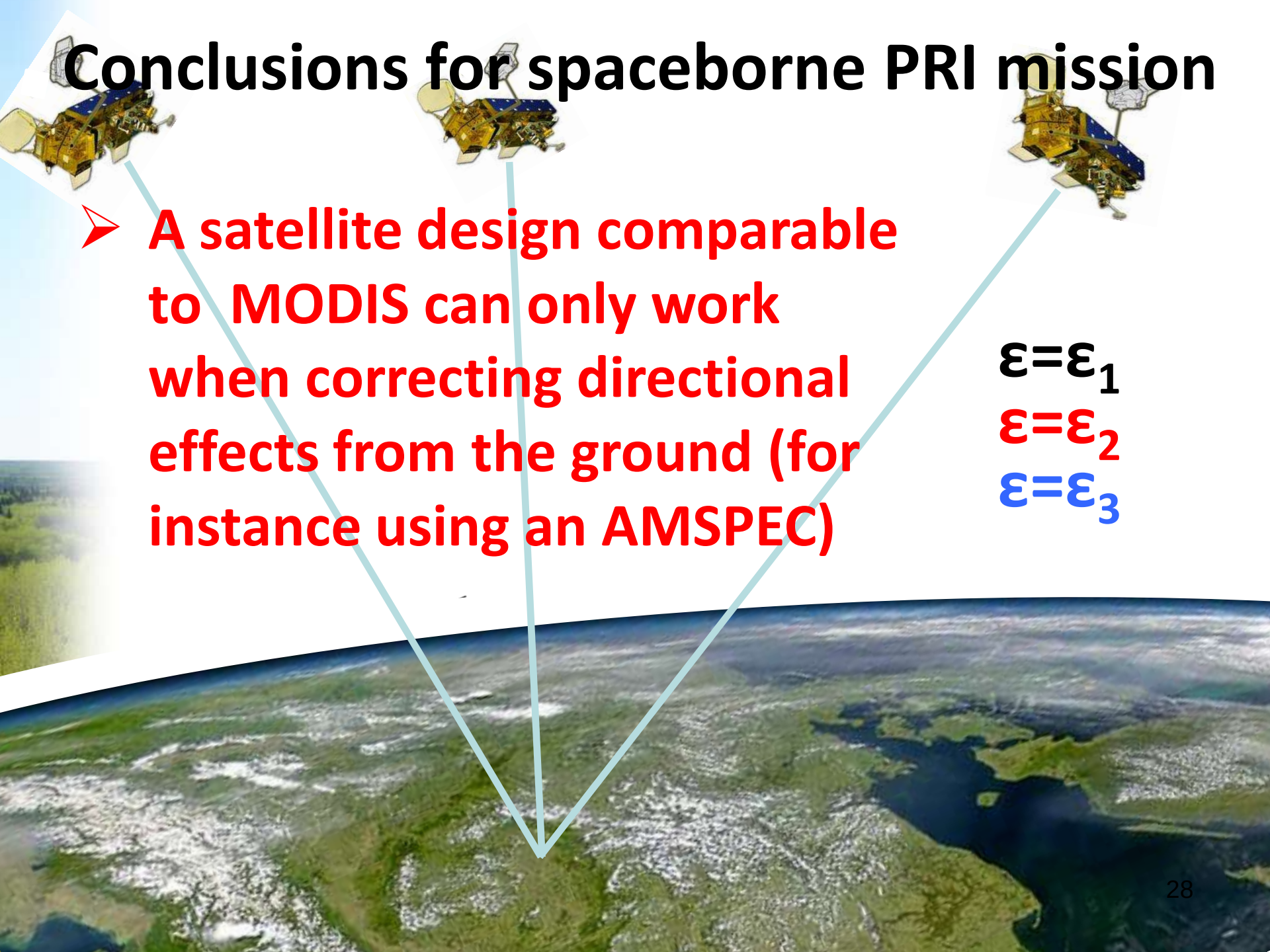


PRI



Hall et al., 2008, RSE

Conclusions for spaceborne PRI mission



- A satellite design comparable to MODIS can only work when correcting directional effects from the ground (for instance using an AMSPEC)

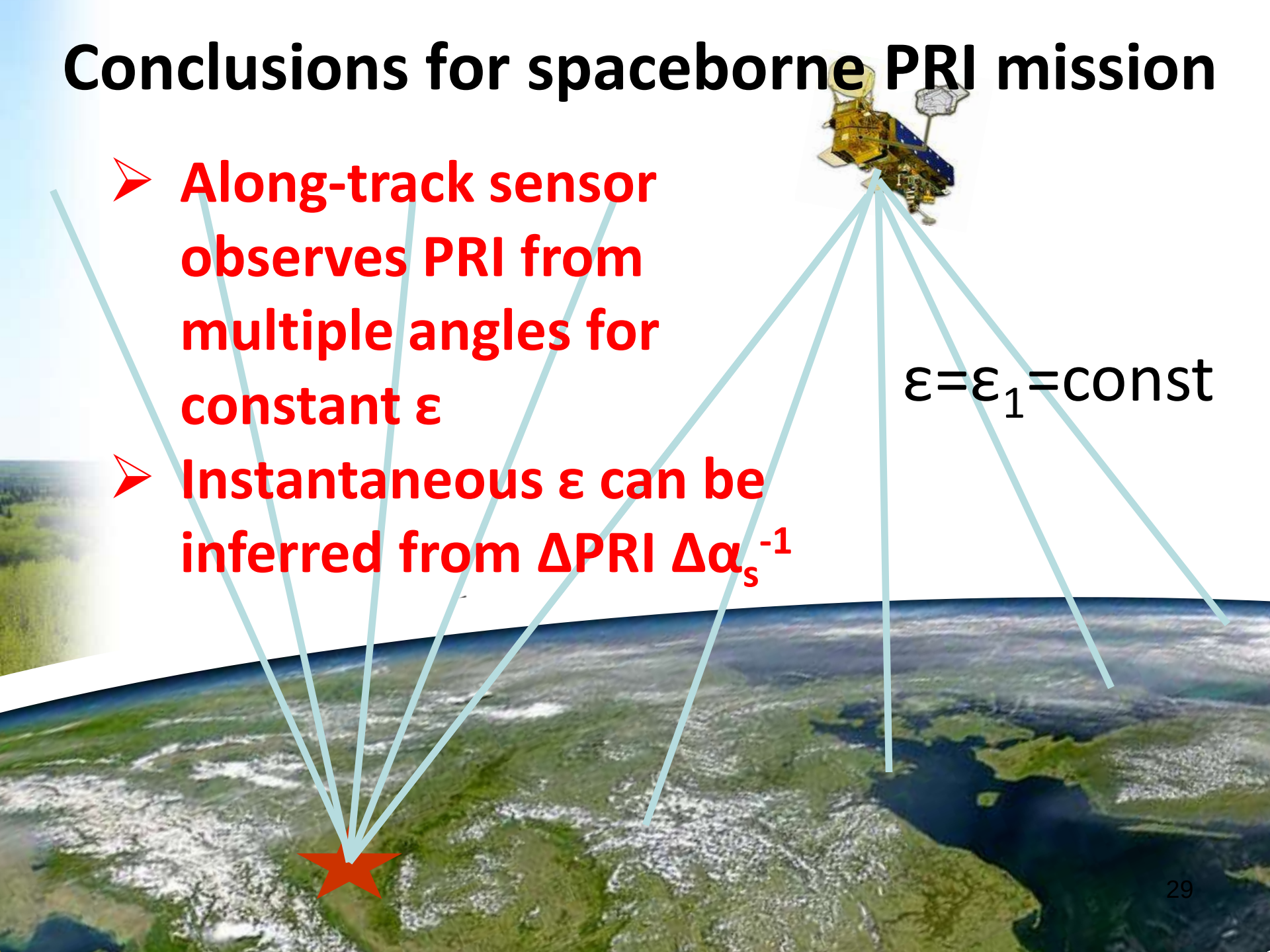
$\varepsilon=\varepsilon_1$

$\varepsilon=\varepsilon_2$

$\varepsilon=\varepsilon_3$

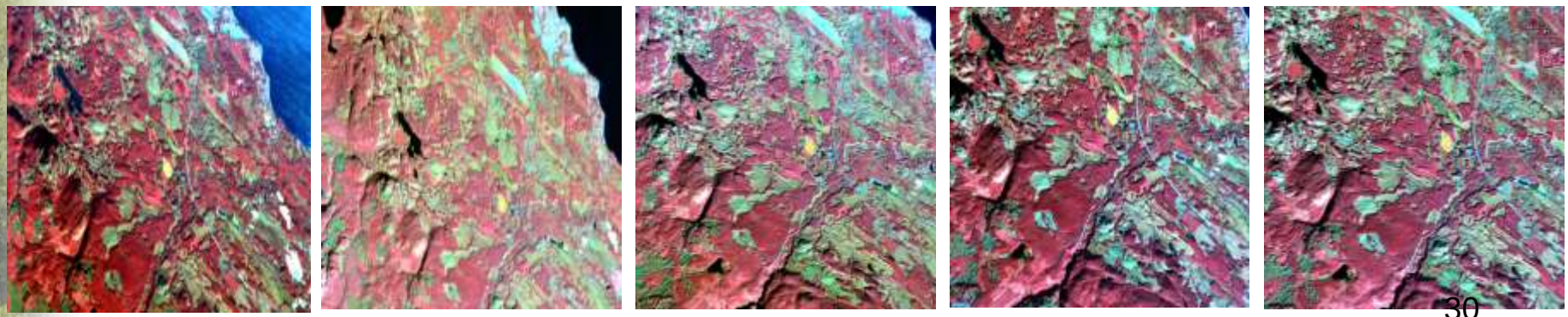
Conclusions for spaceborne PRI mission

- Along-track sensor observes PRI from multiple angles for constant ε
- Instantaneous ε can be inferred from ΔPRI $\Delta\alpha_s^{-1}$



Concept validation: CHRIS Proba

Operator: ESA (European Space Agency)
Date of Launch: 22 October 2001
Orbit Height: 615 km
Orbit Type: Sun-synchronous elliptical polar
Repeat Cycle: approx. 7 days
Resolution: 18 m (CHRIS)
Swath Width*:* 14 km (CHRIS)



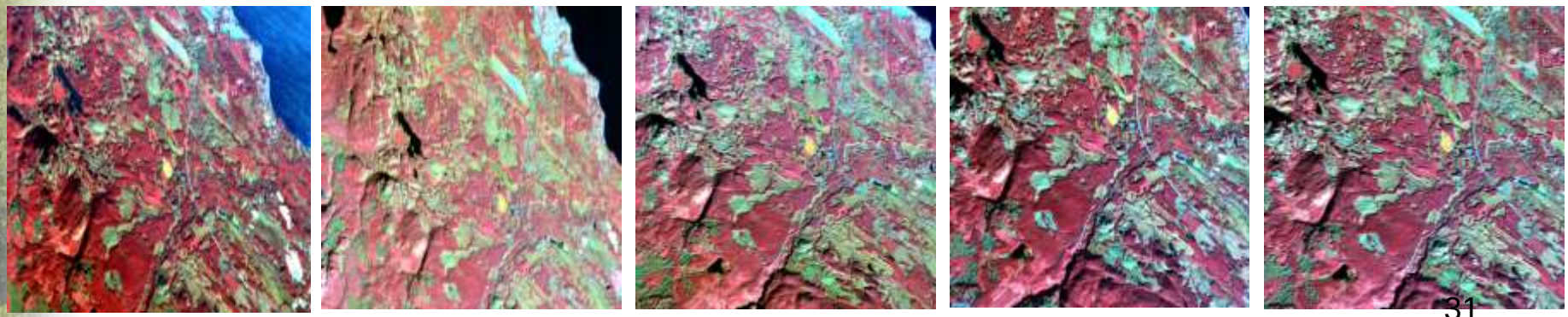
Concept validation: CHRIS Proba

Band	Cut-on Wavelength	Cut-off Wavelength	Central Wavelength	Bandwidth
1	419.4	422	420.7	2.6
2	437	447.4	442	10.4
3	484.1	495.6	489.8	11.6
4	523.8	535.3	529.5	11.4
5	544.4	557.2	550.7	12.9
6	564	574.6	569.3	10.6
7	623.6	637.6	630.5	14
8	652.4	668.1	660.1	15.7
9	668.1	679	673.5	10.9
10	690.4	702.2	696.2	11.8
11	702.2	708.3	705.2	6.1
12	708.3	714.5	711.4	6.2
13	733.8	747.3	740.4	13.5
14	747.3	754.2	750.7	6.9
15	768.4	790.9	779.5	22.5
16	857	884.3	870.5	27.4
17	884.3	903.1	893.6	18.8
18	903.1	912.9	908	9.7

up to 5 acquisitions per overpass

12 overpasses (@4-5 angles) for the DF-49 site during 2009

(Mode 3)



For Assistance and Support with Amspec:

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- Dominic Lessard, UBC, LFS
- Rick Ketler, UBC, LFS
- Andrew Hum, UBC, LFS

For Sharing Data and Concepts:

- Mike Wulder, NRCAN, CFS
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