

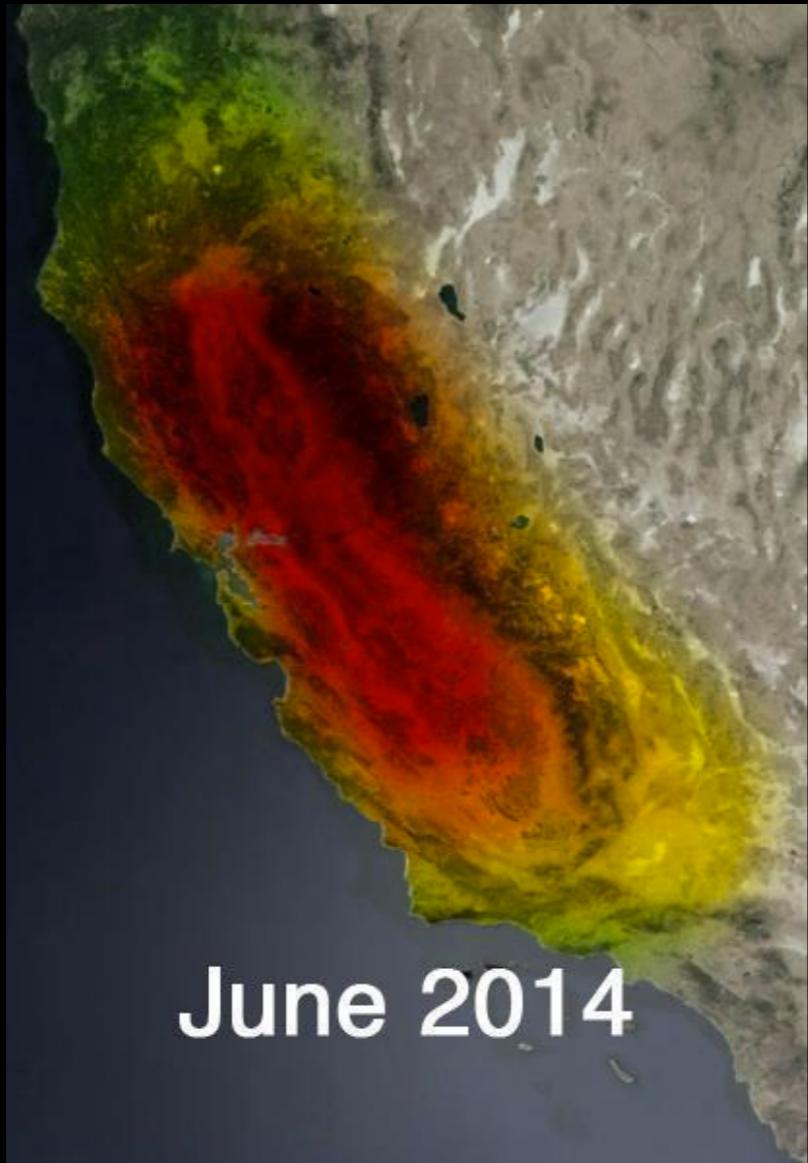
Advanced Topics in Remote Sensing

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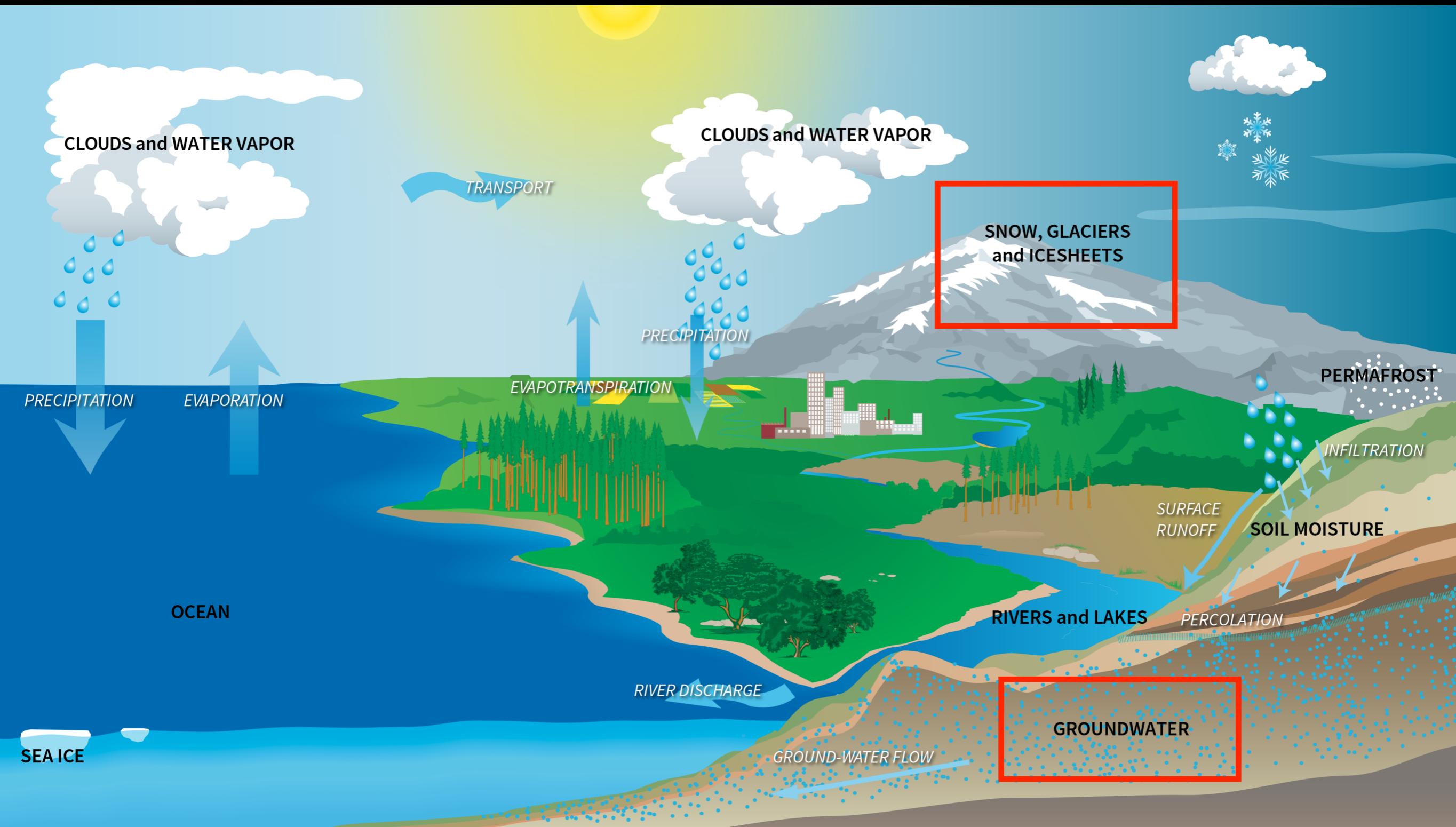
A tale of two cycles

Remote sensing of the water and carbon cycle



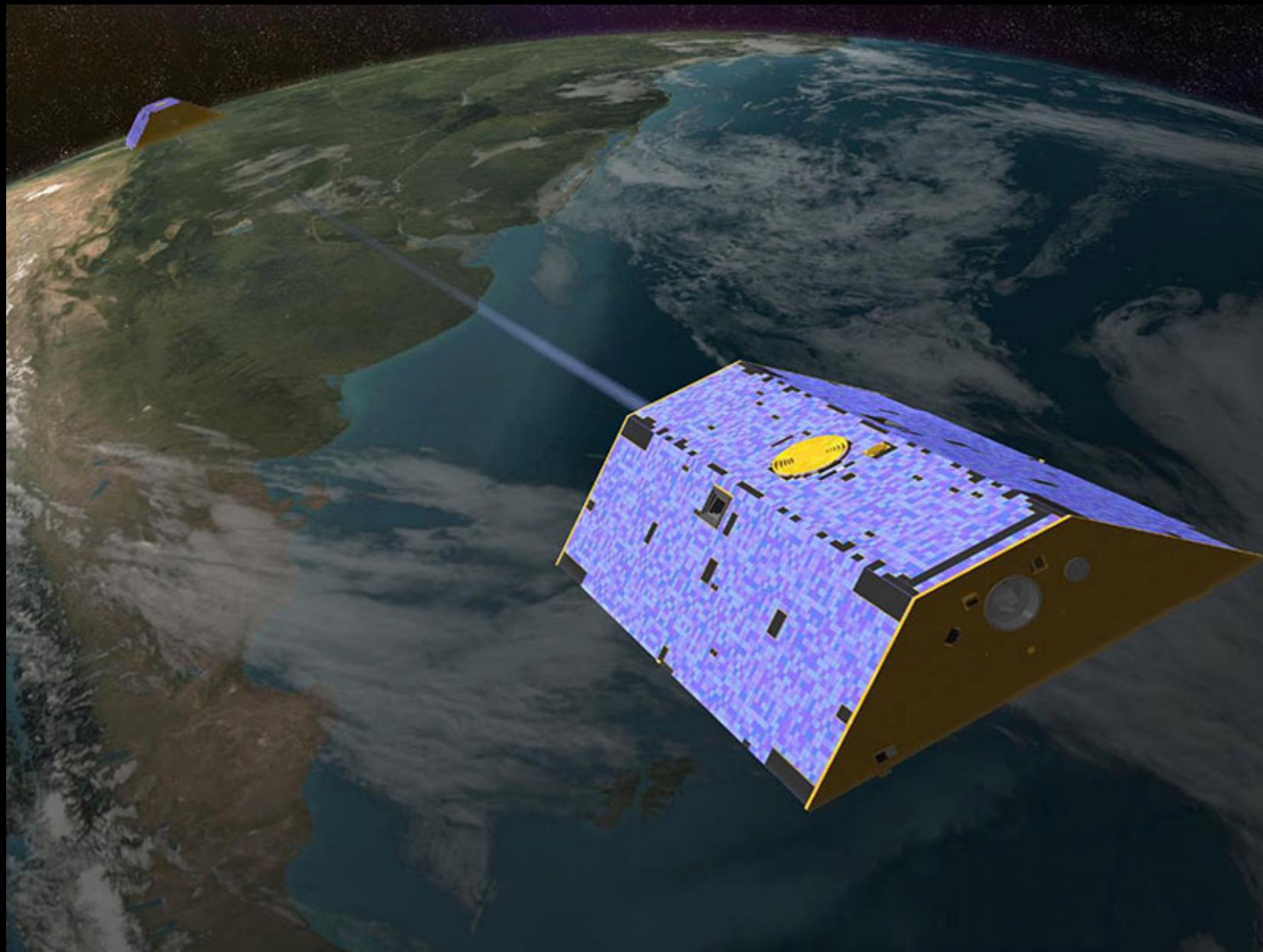
- Groundwater storage
- Photosynthesis

Global water cycle



GRACE

Gravity Recovery and Climate Experiment



- Launched Mar 17, 2002
- Collaboration between NASA and German space agency (DLR).
- Monthly data of Earth's gravity

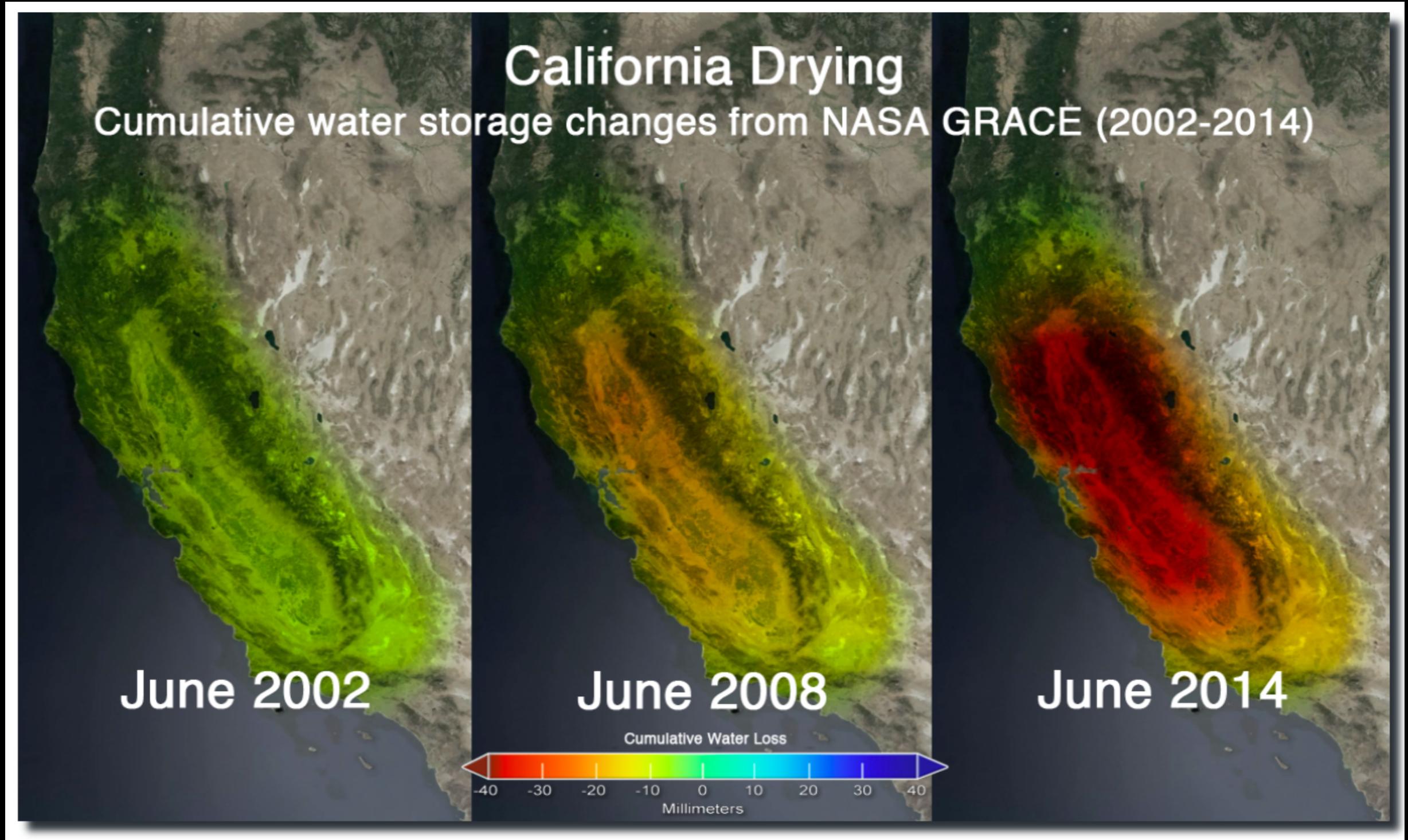
Earth's gravity field

Mapping the changes in glacier

Antarctic Mass Change from GRACE derived Gravity Observations



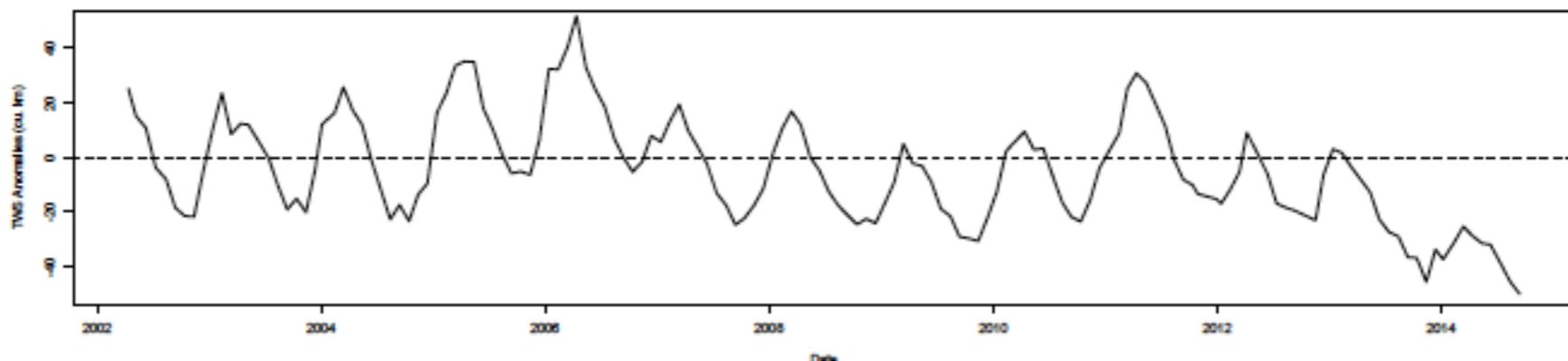
Groundwater depletion



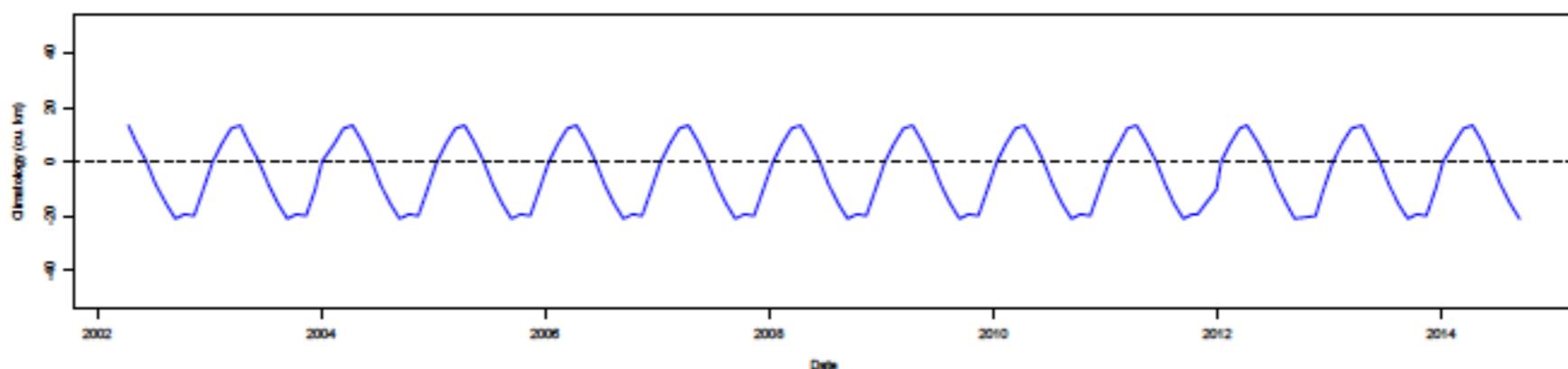
Terrestrial Water Anomaly = Groundwater at time i - groundwater storage baseline

California drought

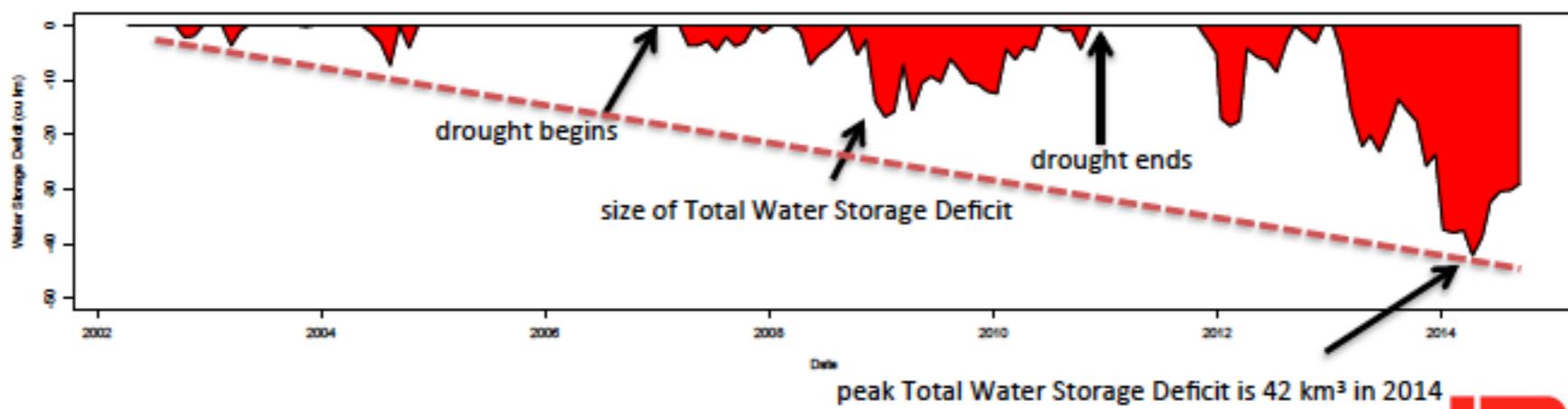
Actual monthly water storage variations



'Normal' range of monthly water storage variations



Differences from 'normal' dry conditions



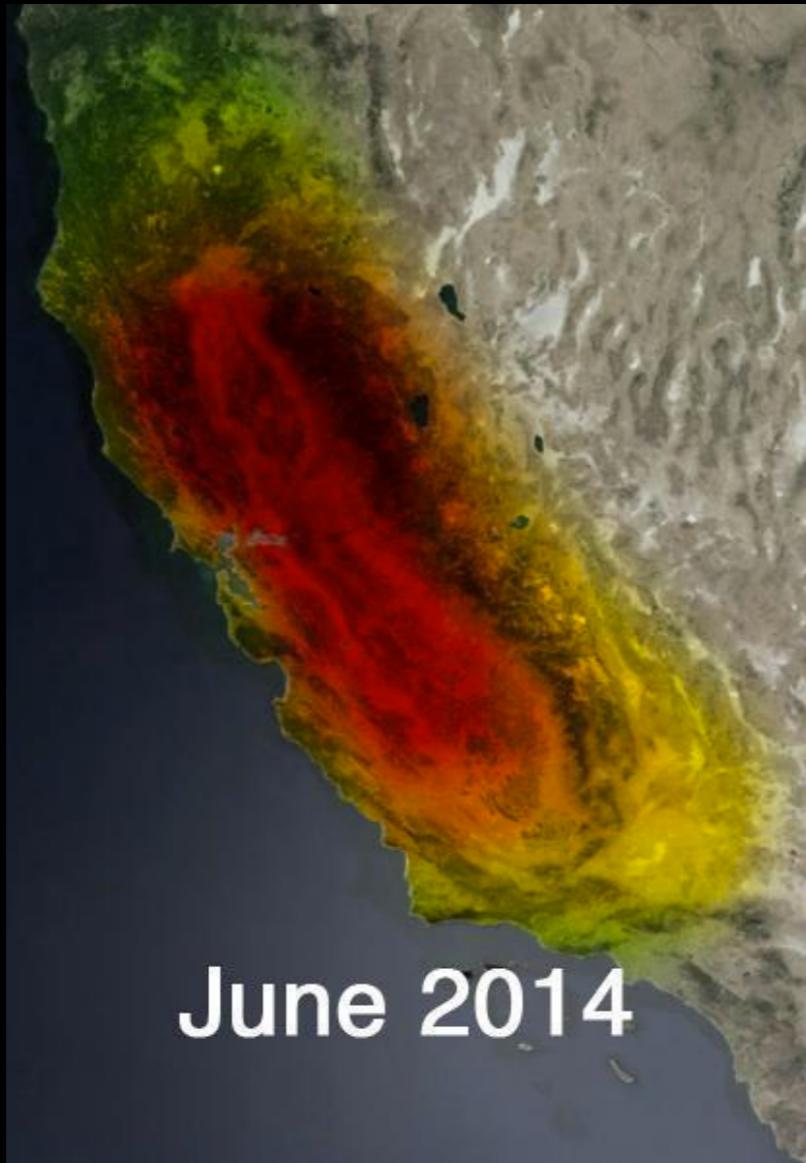
JPL

Credit: Jay Famiglietti

<http://theGracePlotter.com/>

A tale of two cycles

Remote sensing of the water and carbon cycle



- Groundwater storage
- Photosynthesis

The Holy Grail: the fate of anthropogenic CO₂ (2005-2014)

$33.0 \pm 1.6 \text{ GtCO}_2/\text{yr}$ 91%



Sources



$3.4 \pm 1.8 \text{ GtCO}_2/\text{yr}$ 9%

$16.0 \pm 0.4 \text{ GtCO}_2/\text{yr}$
44%

Sinks

$9.5 \pm 2.9 \text{ GtCO}_2/\text{yr}$
30%

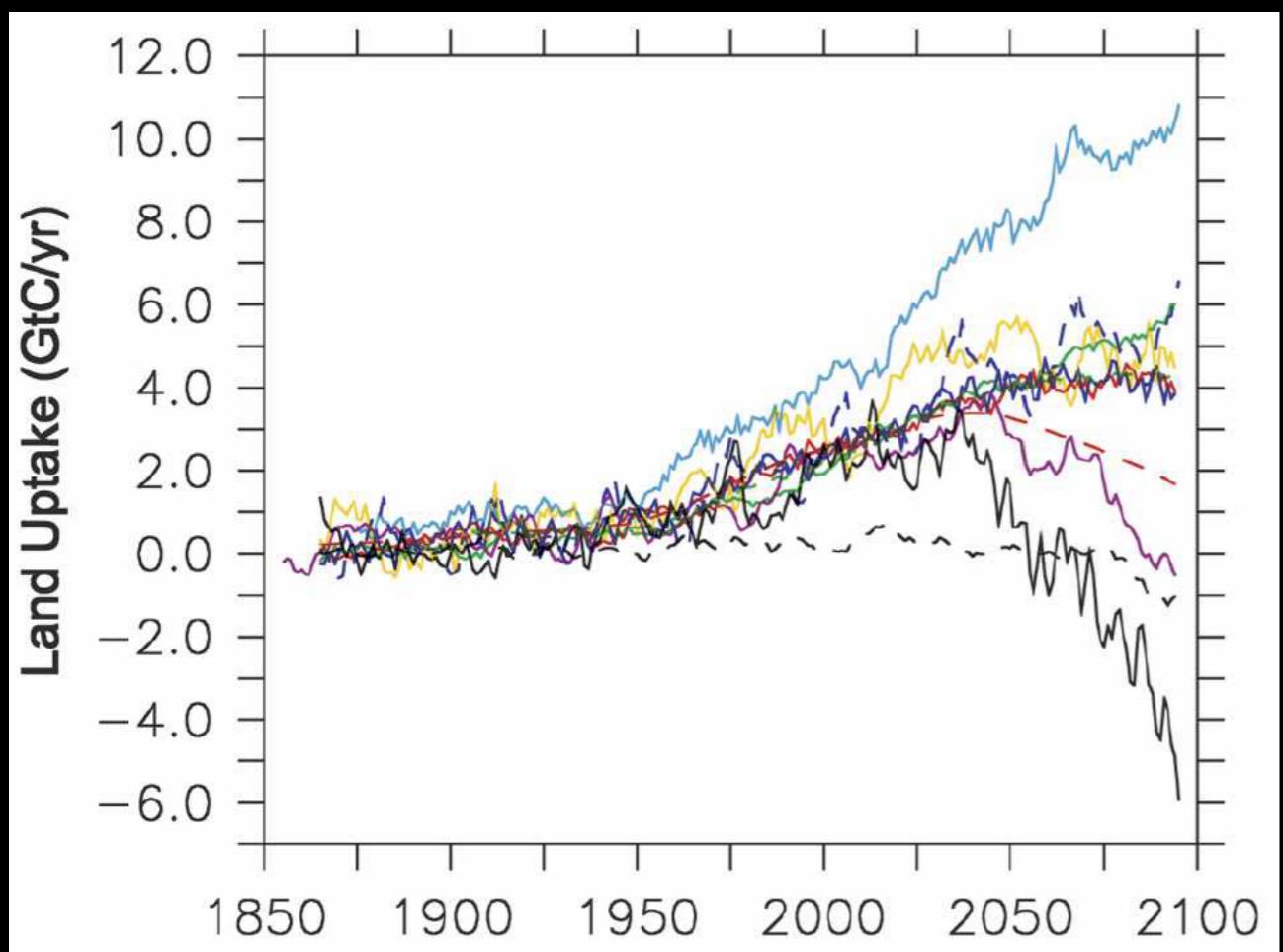


26%
 $10.9 \pm 1.8 \text{ GtCO}_2/\text{yr}$



The future of land sink is highly uncertain

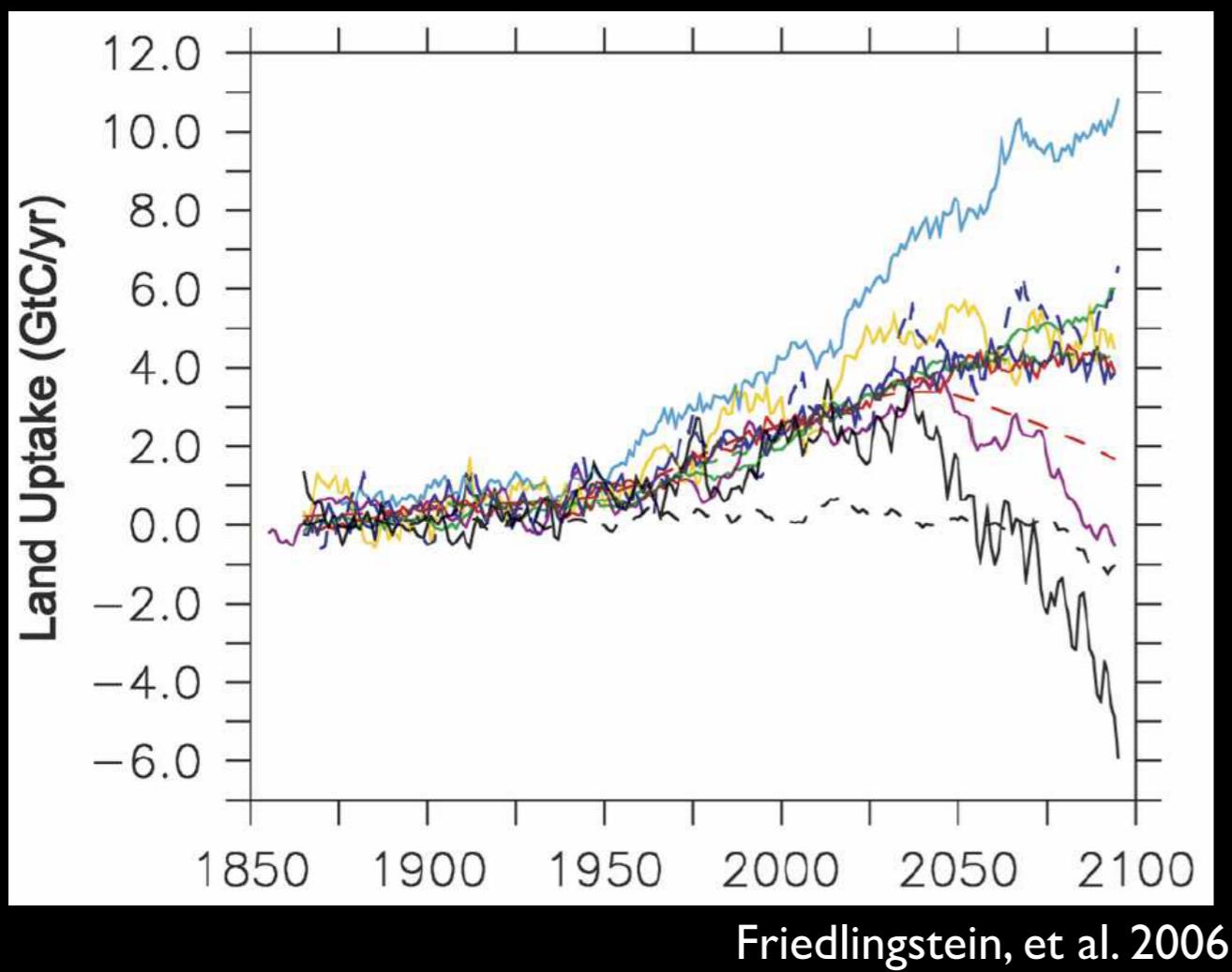
C⁴MIP simulations



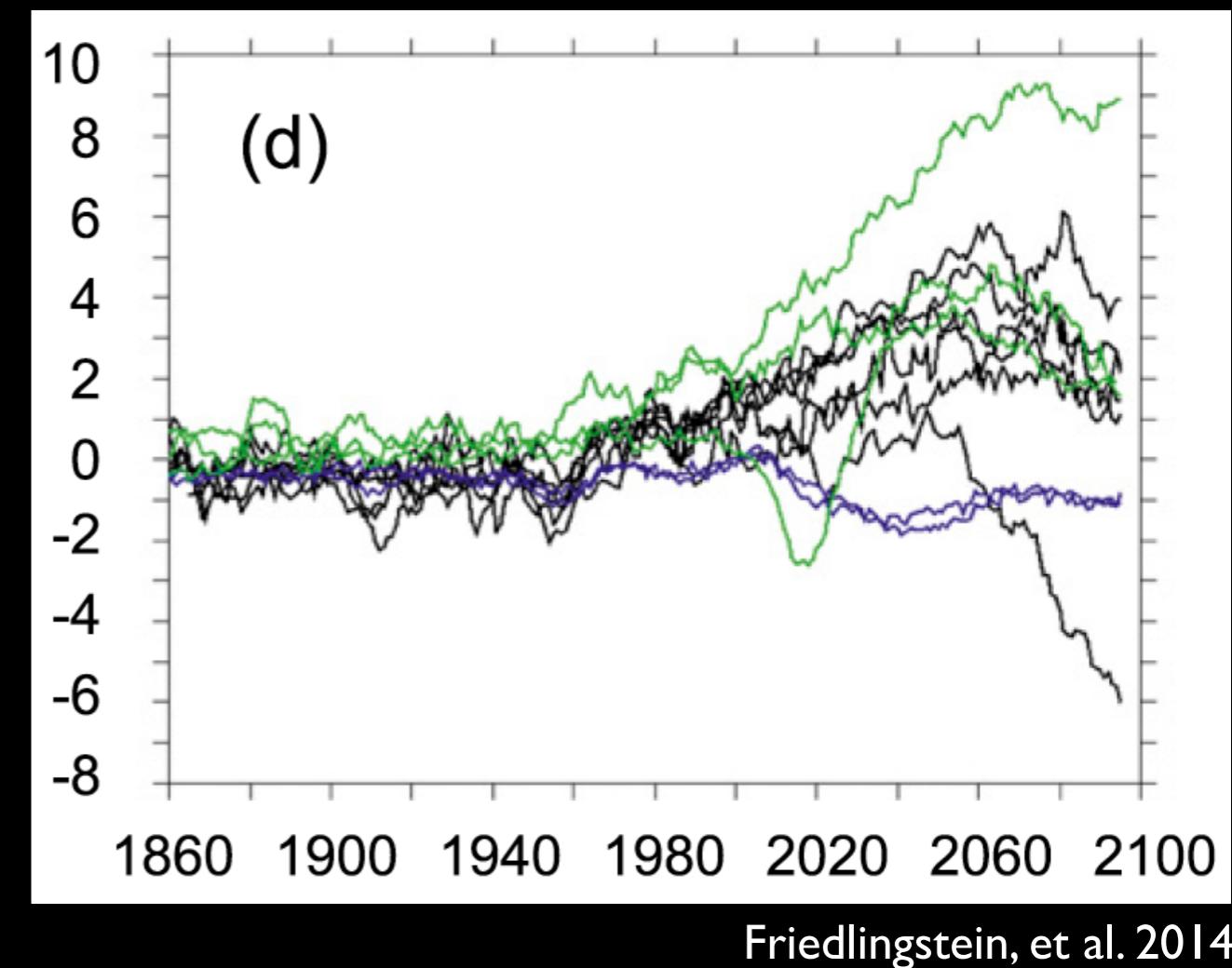
Friedlingstein, et al. 2006

The future of land sink is highly uncertain

C⁴MIP simulations

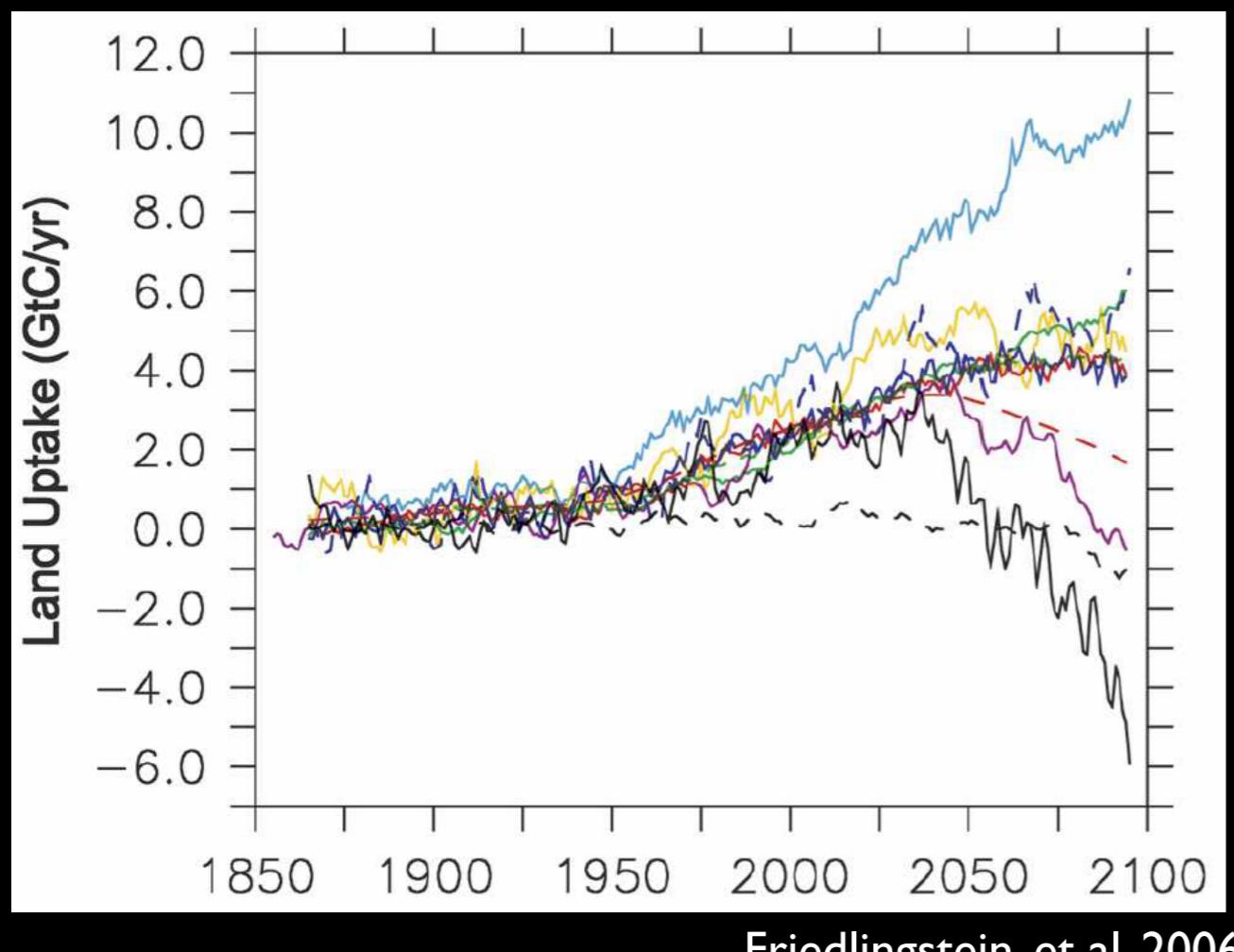


CMIP5 simulations

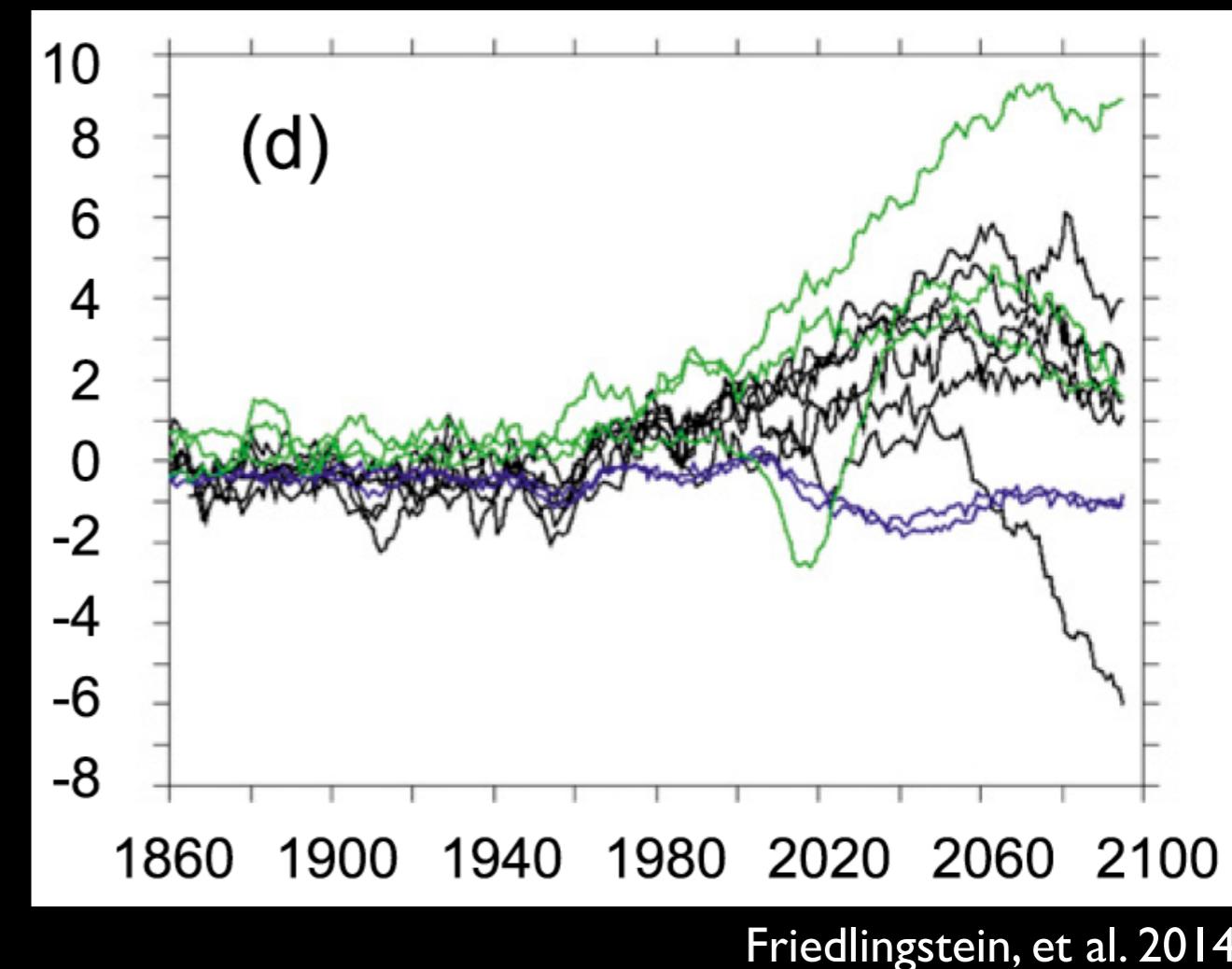


The future of land sink is highly uncertain

C⁴MIP simulations



CMIP5 simulations



Land sink = Photosynthesis - Respiration

4.3 Pg C/yr

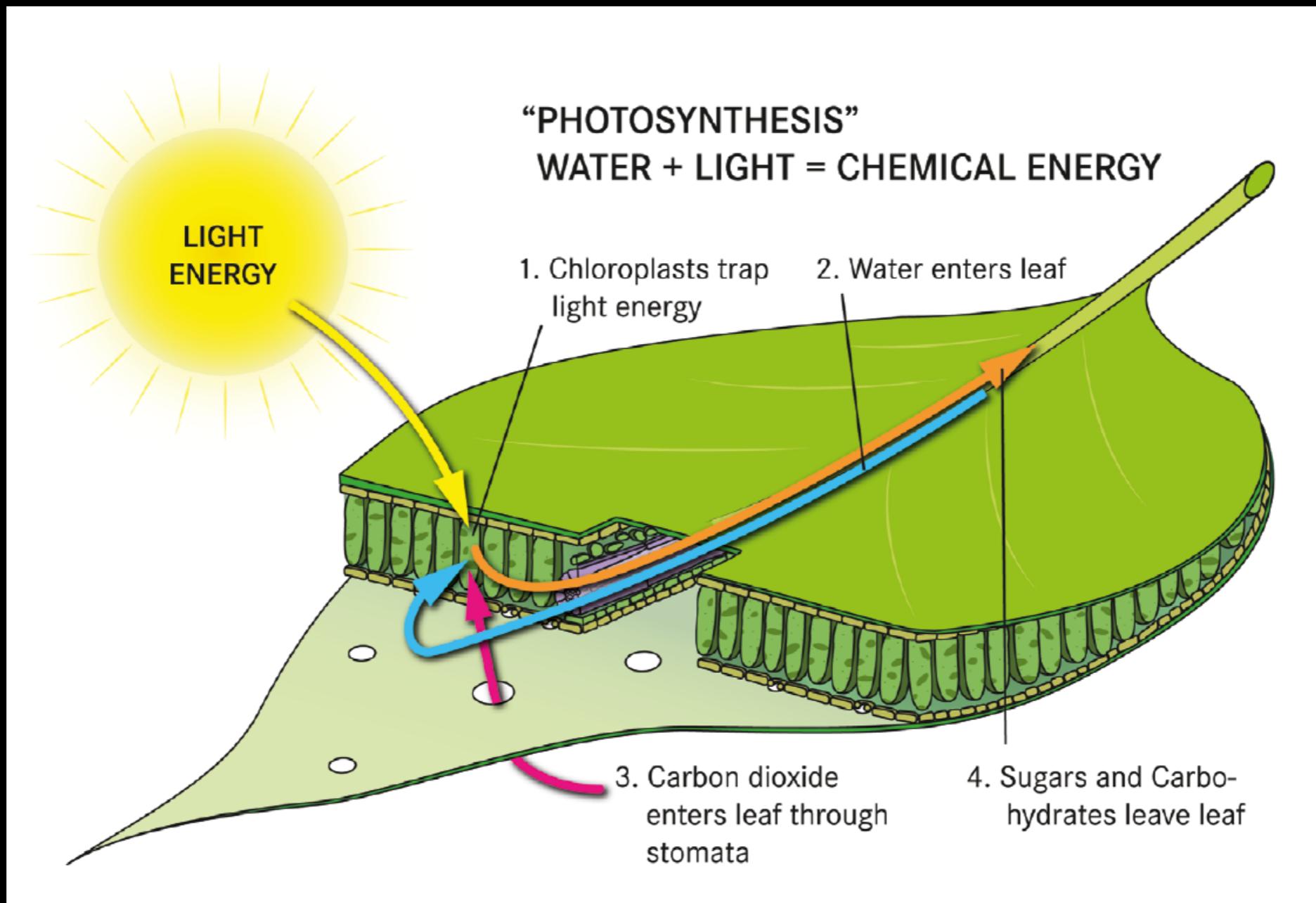
| 23±8 Pg C/yr

Beer et al., 2010

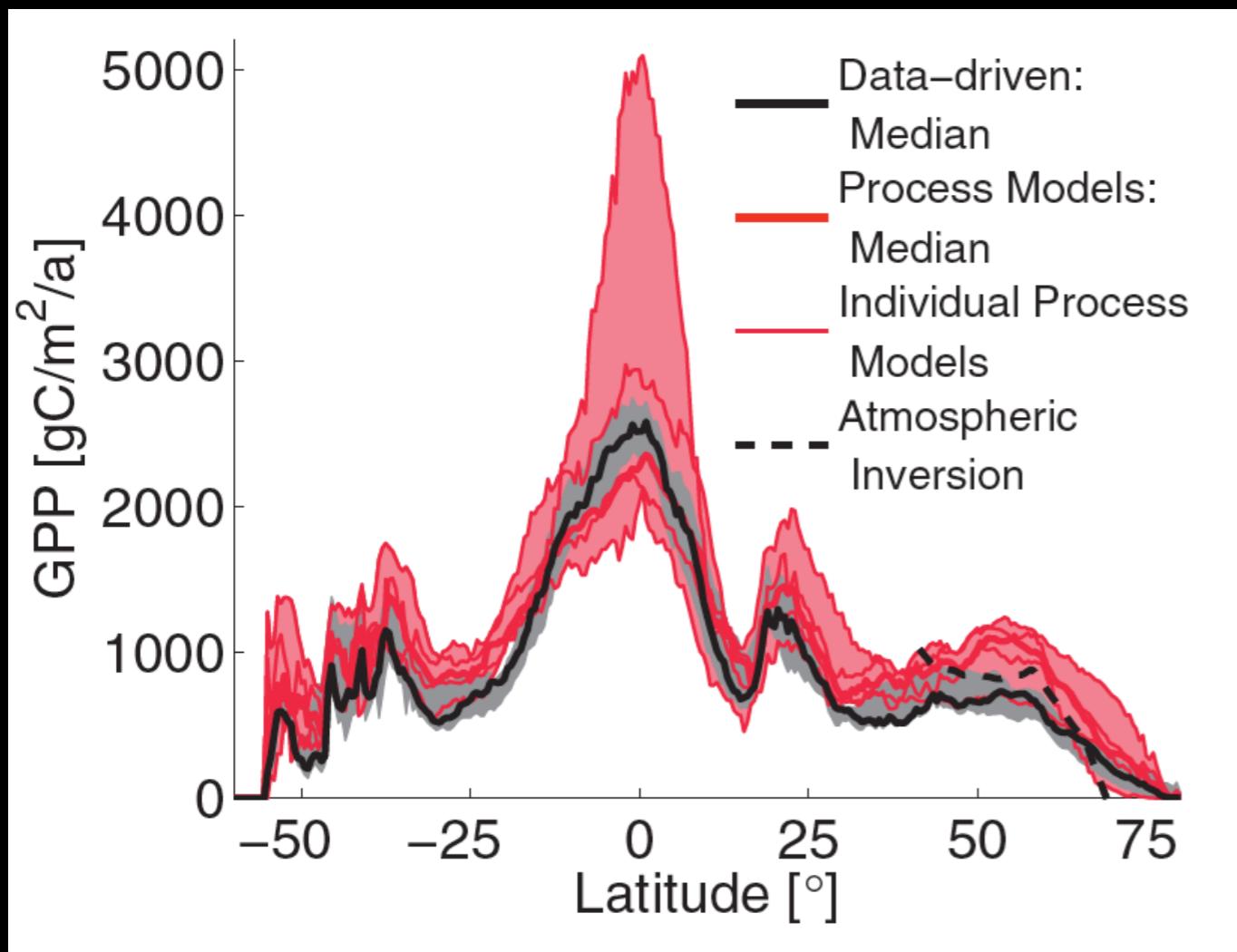
| 18.7 Pg C/yr

IPCC, 2014

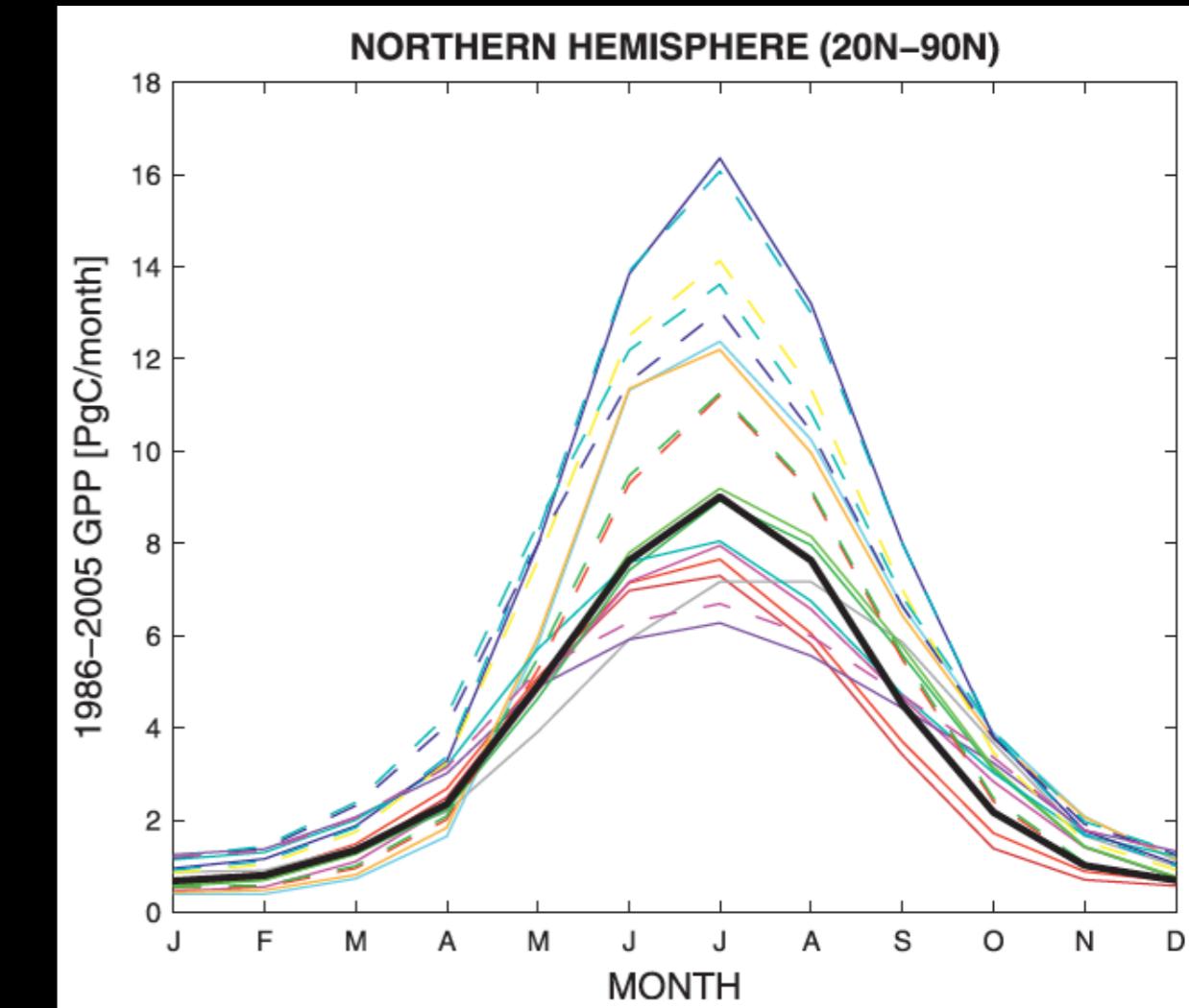
Photosynthesis (Gross Primary Productivity, GPP)



Three key uncertainties in estimating photosynthesis



Spatial uncertainty



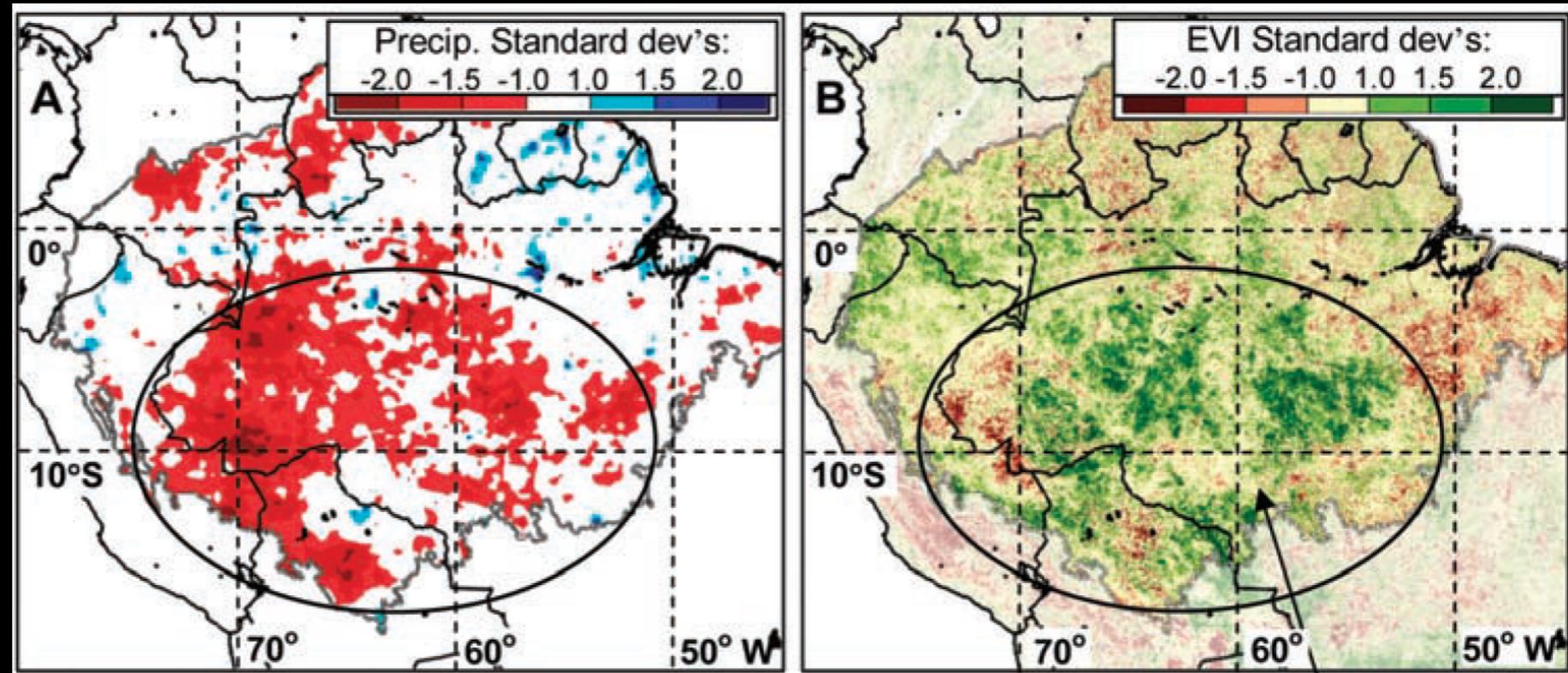
Temporal uncertainty

The Amazon Greenup debate

Amazon Forests Green-Up During 2005 Drought

Scott R. Saleska,^{1,*†} Kamel Didan,^{2*} Alfredo R. Huete,² Humberto R. da Rocha³

$$(\text{EVI}_{2005} - \text{EVI}_{\text{mean}}) / \text{SD}(\text{EVI})$$



Hot debate over remote sensing of photosynthesis

Large seasonal swings in leaf area of Amazon rainforests

Ranga B. Myneni^a, Wenzé Yang^{a,b}, Ramakrishna R. Nemani^c, Alfredo R. Huete^d, Robert E. Dickinson^{e,f}, Yuri Knyazikhin^a, Kamel Didan^d, Rong Fu^e, Robinson I. Negrón Juárez^e, Sasan S. Saatchi^g, Hirofumi Hashimoto^h, Kazuhito Ichii^h, Nikolay V. Shabanov^a, Bin Tan^{a,i}, Piyachat Ratana^d, Jeffrey L. Privette^{k,l}, Jeffrey T. Morisette^m, Eric F. Vermote^{k,n}, David P. Roy^o, Robert E. Wolfe^p, Mark A. Friedl^a, Steven W. Running^q, Petr Votava^h, Nazmi El-Saleous^r, Sadashiva Devadiga^s, Yin Su^a, and Vincent V. Salomonson^s

LETTER

doi:10.1038/nature13006

Amazon forests maintain consistent canopy structure and greenness during the dry season

Douglas C. Morton¹, Jyoteshwar Nagol^{2,3}, Claudia C. Carabajal^{1,4}, Jacqueline Rosette^{1,2,5}, Michael Palace⁶, Bruce D. Cook¹, Eric F. Vermote¹, David J. Harding¹ & Peter R. J. North⁵

LETTER
Sunlight mediated seasonality in canopy structure and photosynthetic activity of Amazonian rainforests

Jian Bi^{1,20}, Yuri Knyazikhin^{1,20}, Sung Ho Choi¹, Taejin Park¹, Jonathan Barichivich², Philippe Ciais³, Rong Fu⁴, Sangram Ganguly⁵, Forrest Hall⁶, Thomas Hilker⁷, Alfredo Huete⁸, Matthew Jones⁹, John Kimball⁹, Alexei Ilyapustin¹⁰, Matti Mõttus¹¹, Ramakrishna R. Nemani¹², Shilong Piao^{13,14}, Benjamin Poulter¹⁵, Scott R. Saleska¹⁶, Sasan S. Saatchi^{17,18}, Liang Xu¹⁷, Liming Zhou¹⁹ and Ranga B. Myneni¹

Amazon forests did not green-up during the 2005 drought

Arindam Samanta,¹ Sangram Ganguly,² Hirofumi Hashimoto,³ Sadashiva Devadiga,⁴ Eric Vermote,⁵ Yuri Knyazikhin,¹ Ramakrishna R. Nemani,⁶ and Ranga B. Myneni¹

Received 11 December 2009; accepted 26 January 2010; published 5 March 2010.

Uncertainties in the response to extreme climate events

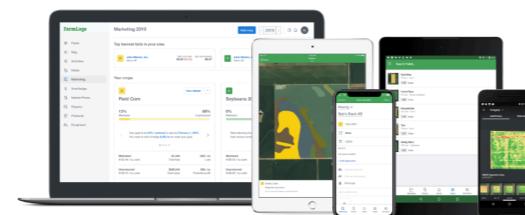
Precision Agriculture

Digital agriculture's leading farm software platform

Analyze your farm's data in one place with the Climate FieldView app

Get Started With FieldView

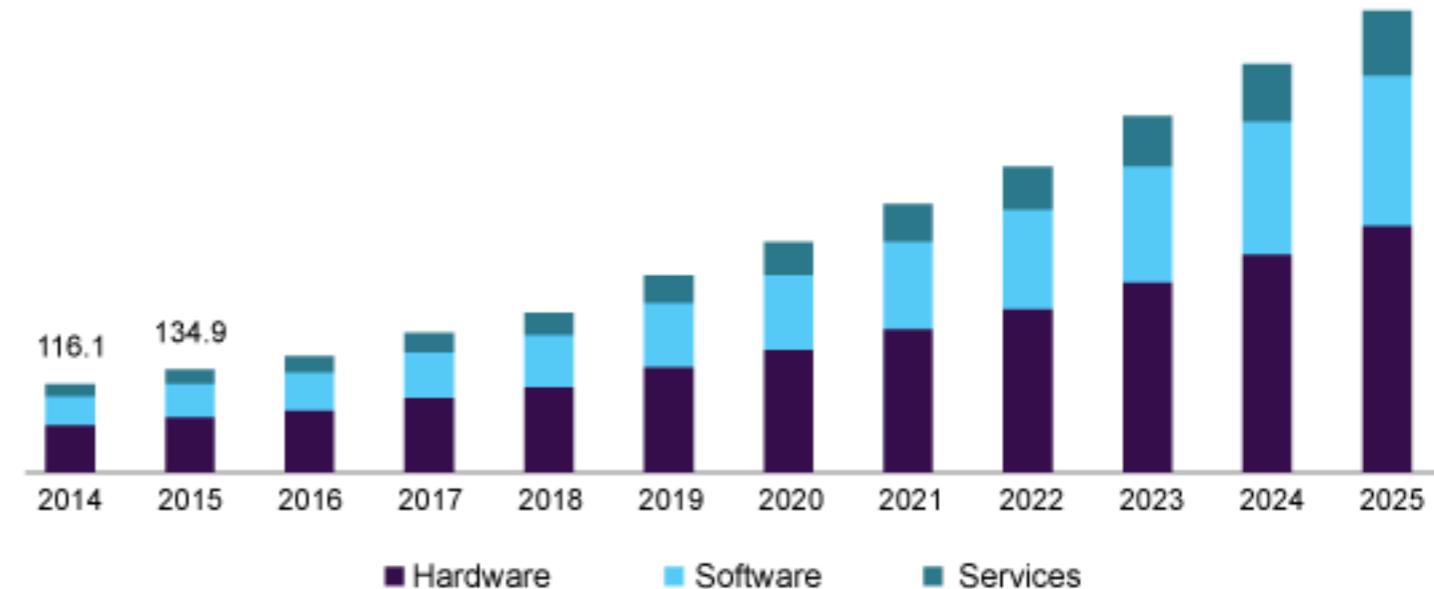
FarmLogs



With FarmLogs, you can:

- Monitor field conditions
- Plan and manage crop production
- Market your grain

Australia precision farming market by offering, 2014 - 2025 (USD Million)



How is photosynthesis estimated? — leaf scale



Portable
Photosynthesis System



Not-so-portable
Photosynthesis System

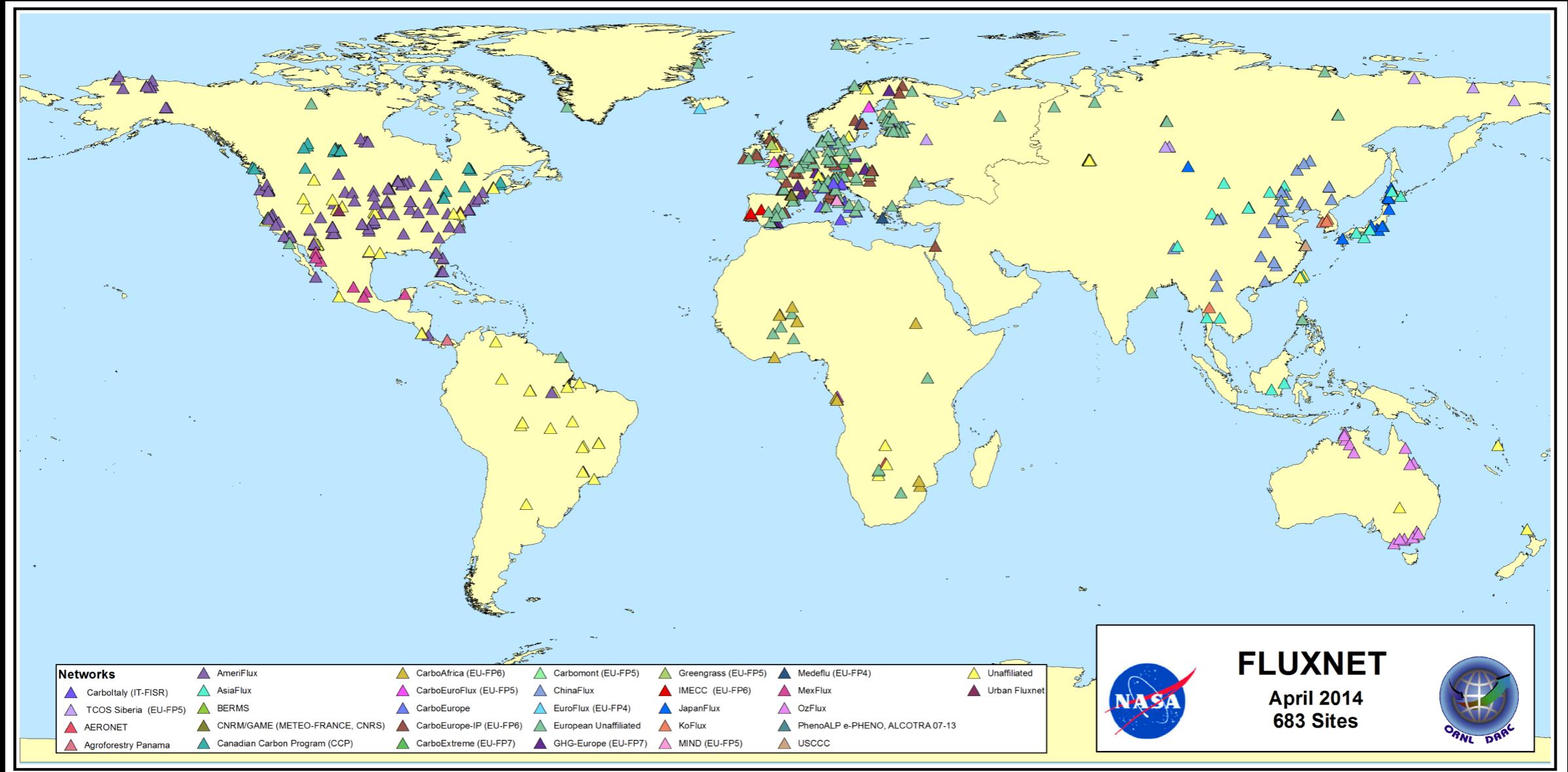
Credit: Li-Cor; Joe Berry

How is photosynthesis estimated? — eddy covariance



Net Ecosystem Exchange (NEE) = Photosynthesis - Respiration

FLUXNET: a net work of eddy covariance towers

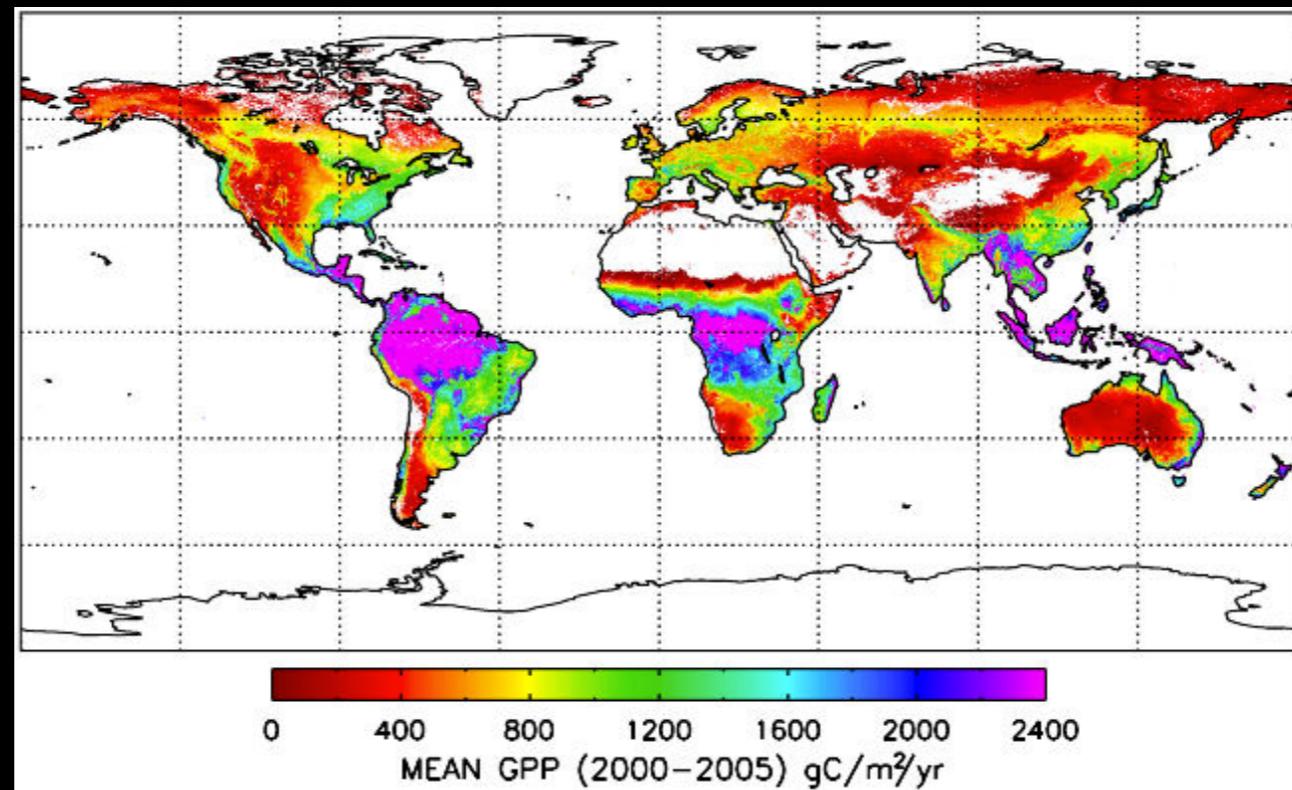


NEE(day) = Photosynthesis - Respiration

NEE (night) = Respiration

Credit:Li-Cor

How is photosynthesis estimated? — satellite remote sensing



$$GPP = PAR \times fAPAR \times \varepsilon_p$$

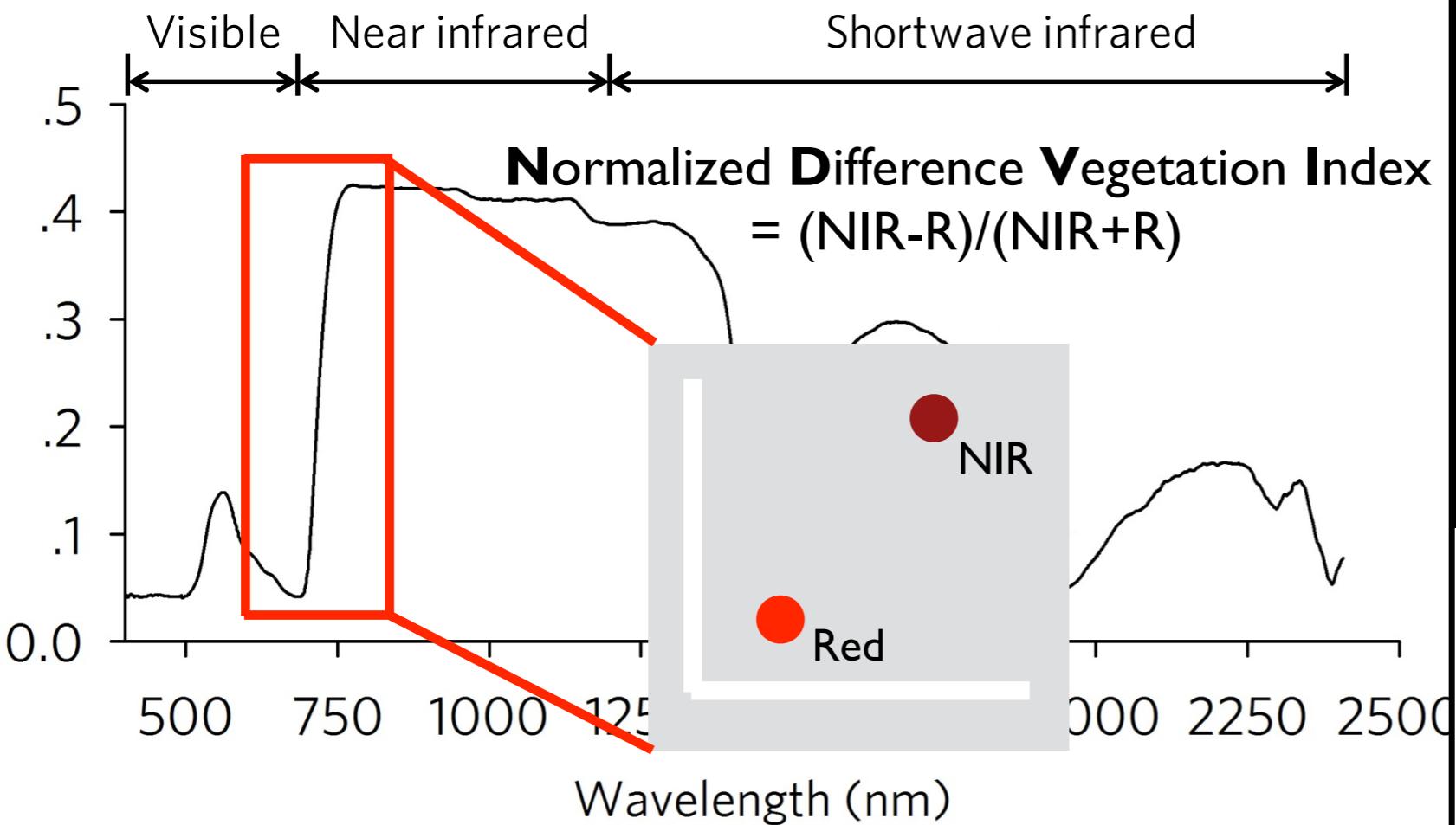
Vegetation Index

$f(\text{plant functional type, temperature, water})$

PAR: Photosynthetically Active Radiation

fAPAR: Fraction of PAR absorbed by leaves

The vegetation index is a measure of the “greenness” of tree canopy

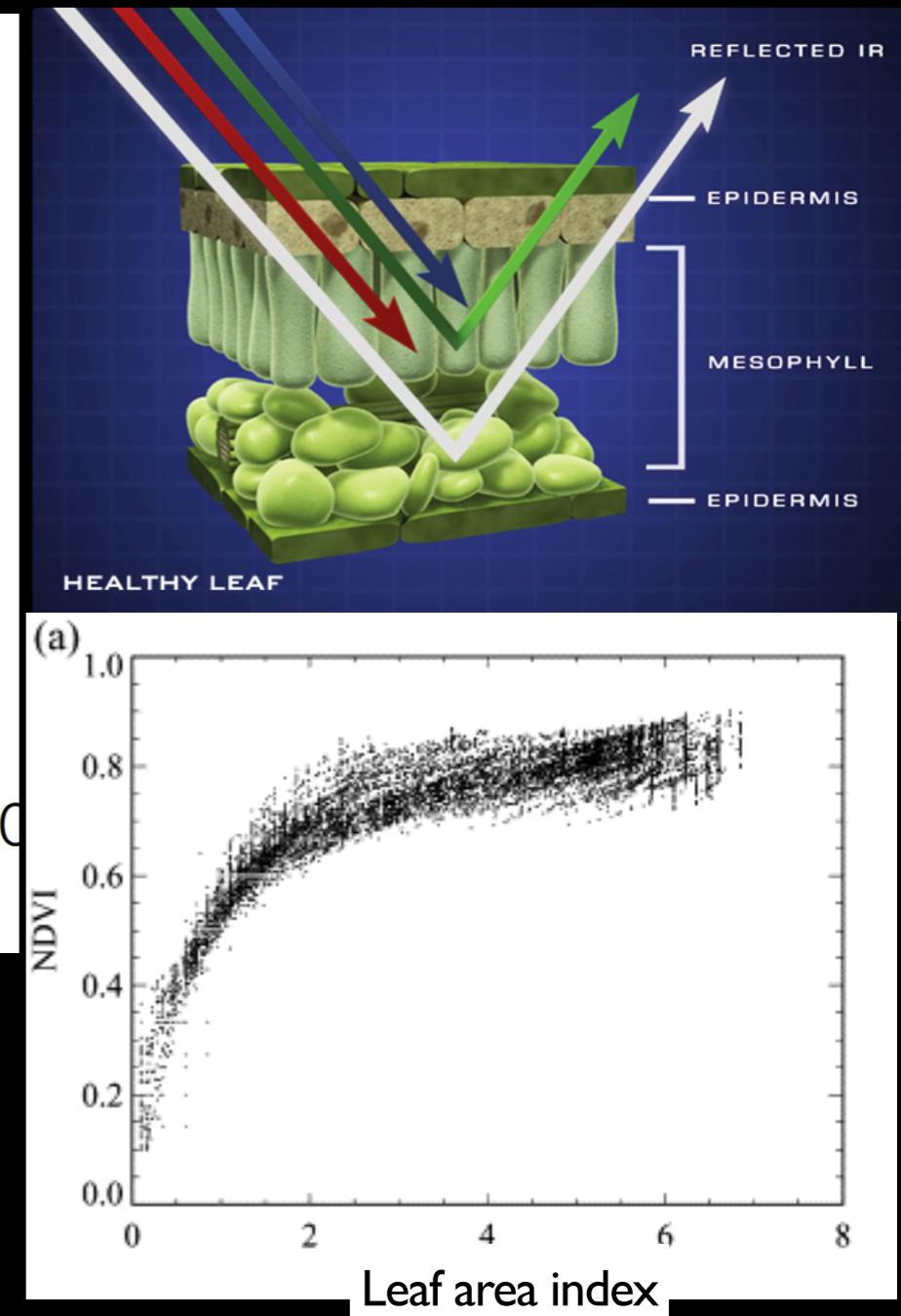


$$\text{GPP} = \text{PAR} \times \text{fAPAR} \times \varepsilon_p$$

Vegetation Index $f(\text{plant functional type}, \text{temperature, water})$

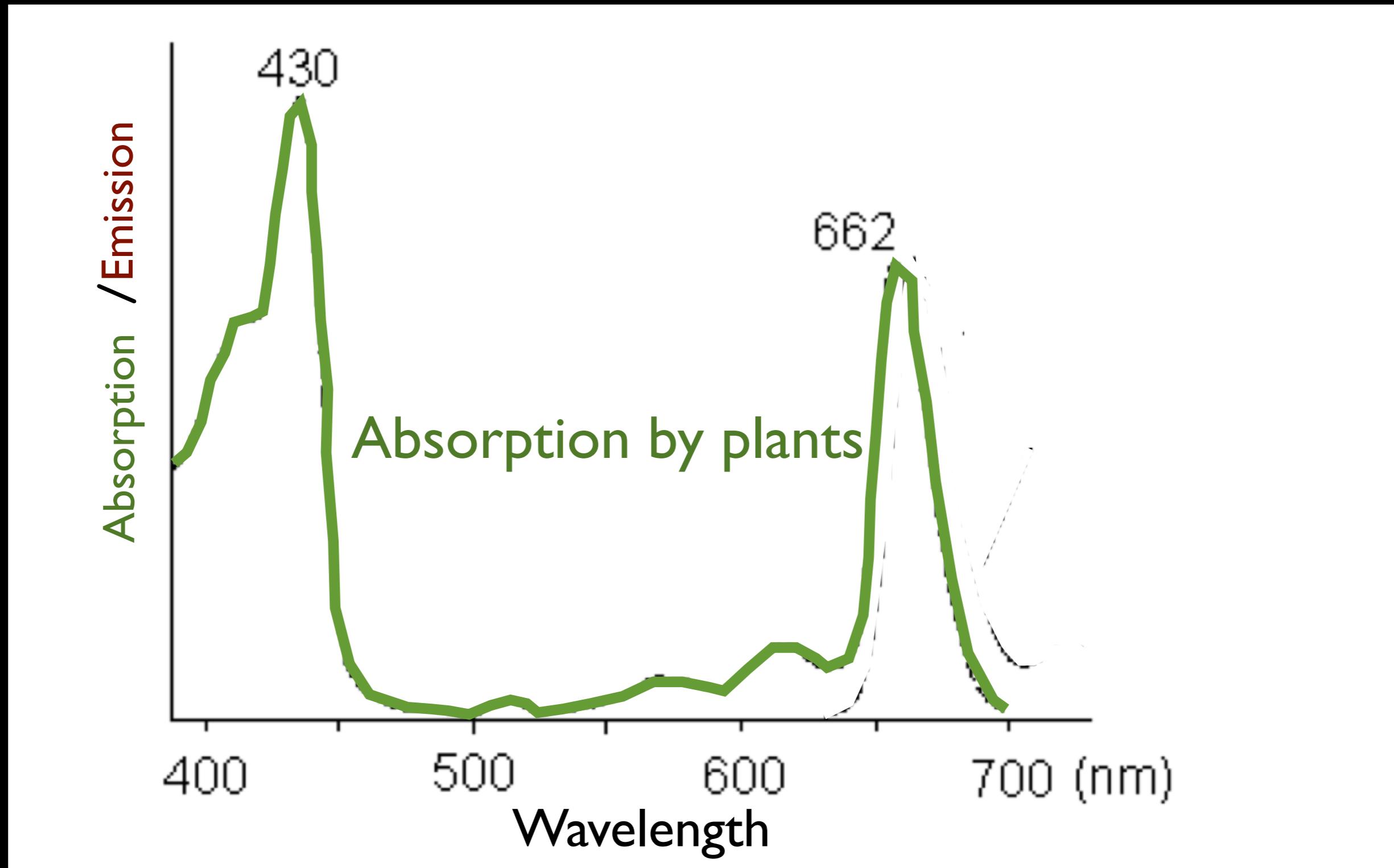
PAR: Photosynthetically Active Radiation

fAPAR: Fraction of PAR absorbed by leaves

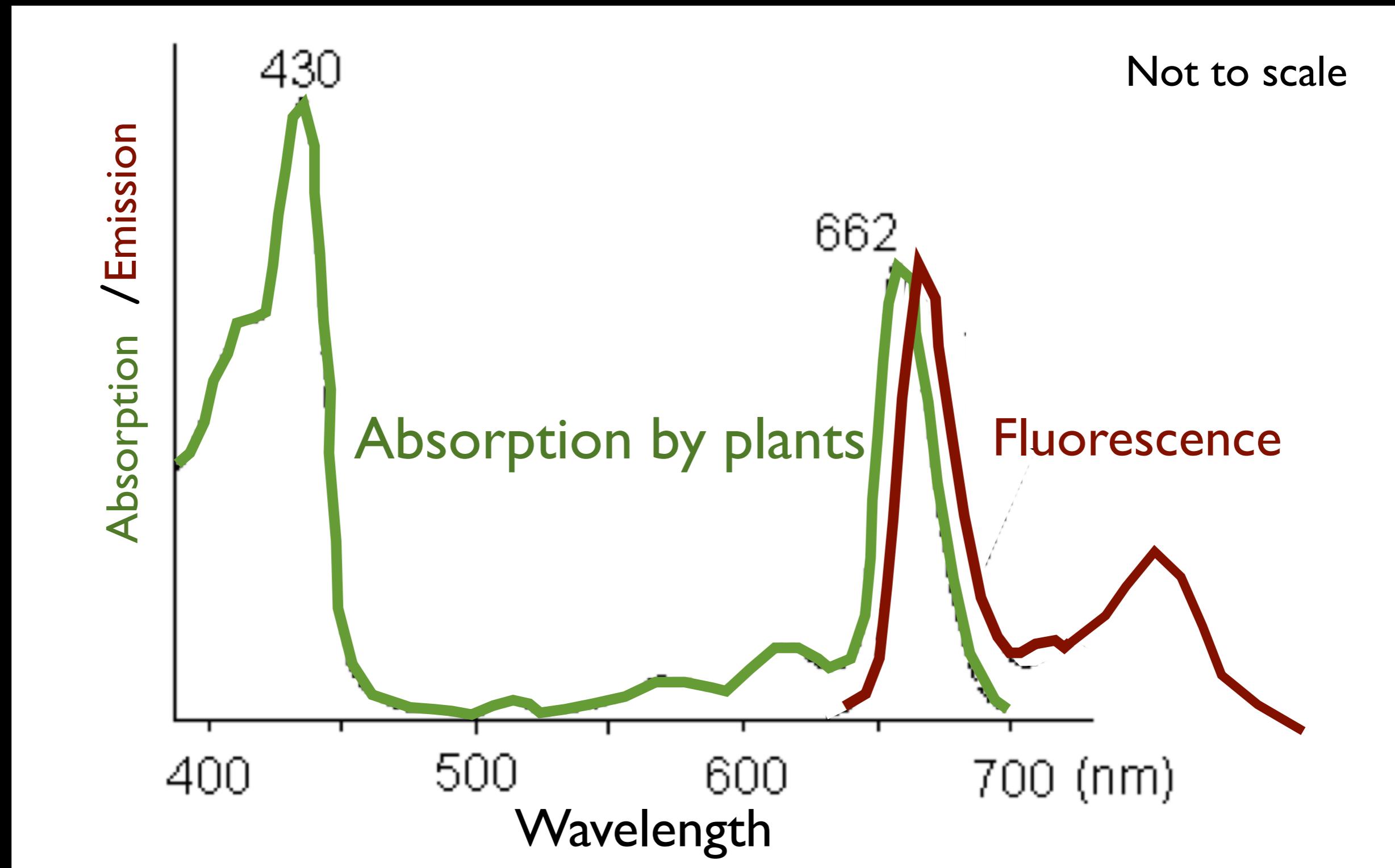


Myneni et al. 2002

Chlorophyll absorb mainly blue and red photons



Solar-induced fluorescence is emitted in a longer wavelength



one

EARTH FROM SPACE

[Home](#) [Episodes](#) [Clips](#) [Behind the scenes](#)

Cameras in space tell stories of life on our planet from a brand new perspective, revealing new discoveries, incredible colours and patterns, and just how fast it is changing.

On iPlayer

This programme will be available shortly after broadcast

Next on

NEW SERIES**EARTH
FROM SPACE**

A New Perspective

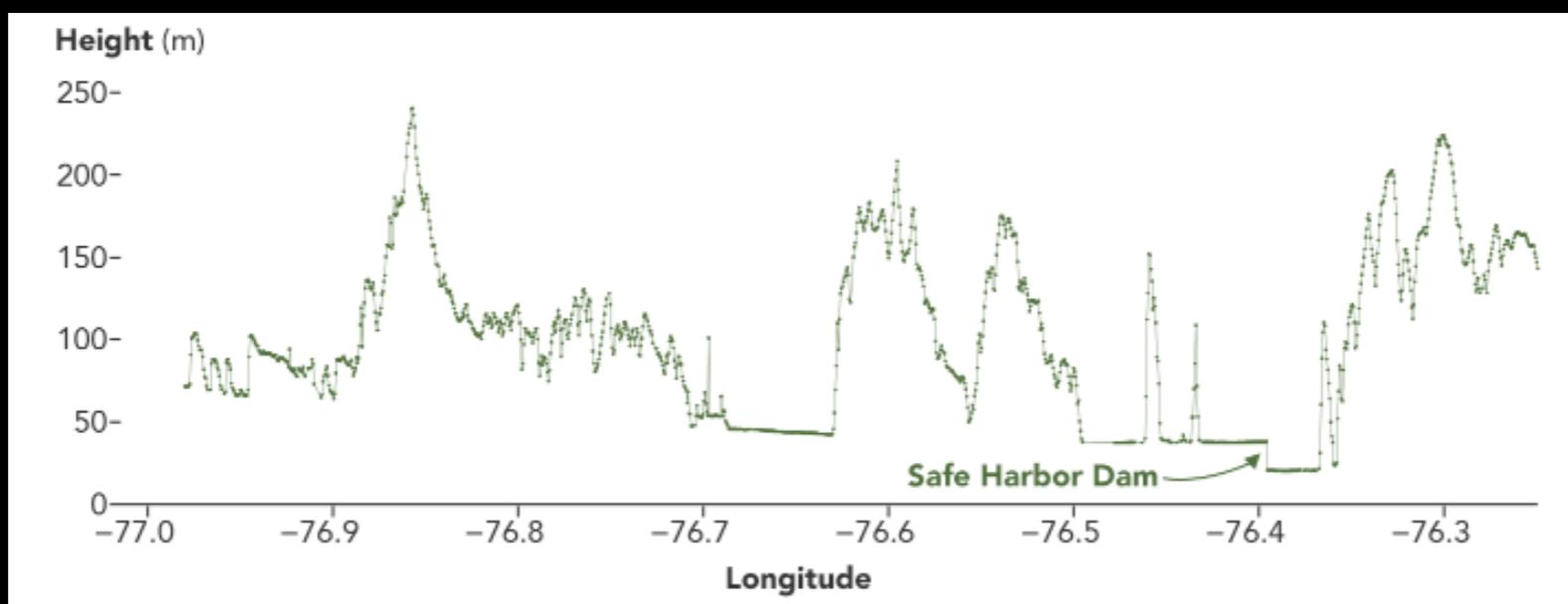
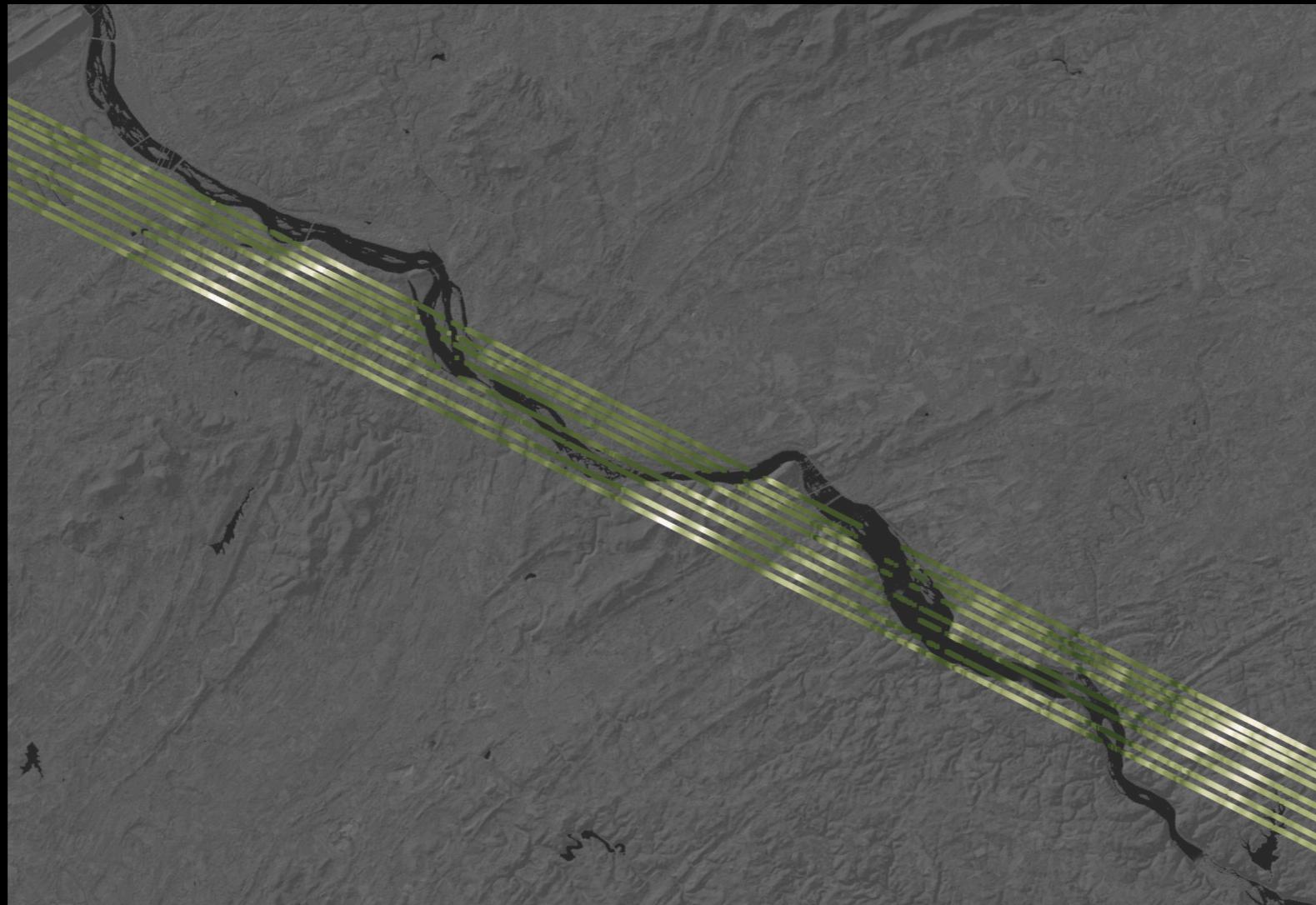
Series 1

TOMORROW 21:00

BBC ONE EXCEPT**SCOTLAND & SCOTLAND HD**



GEDI: first data available

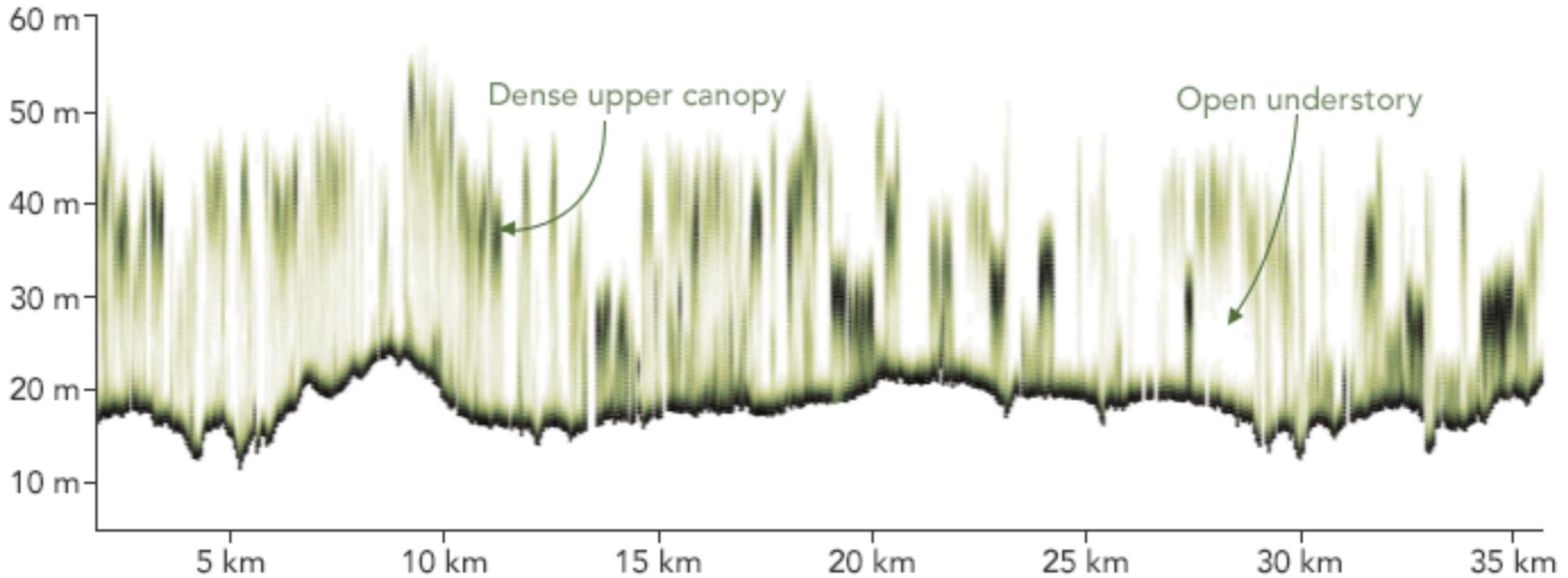




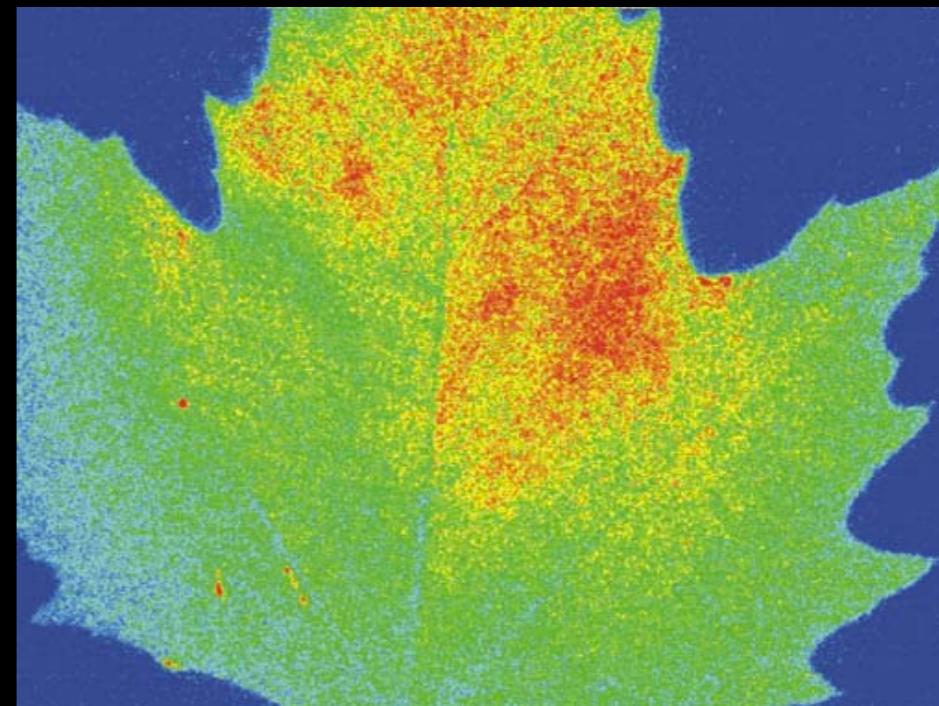
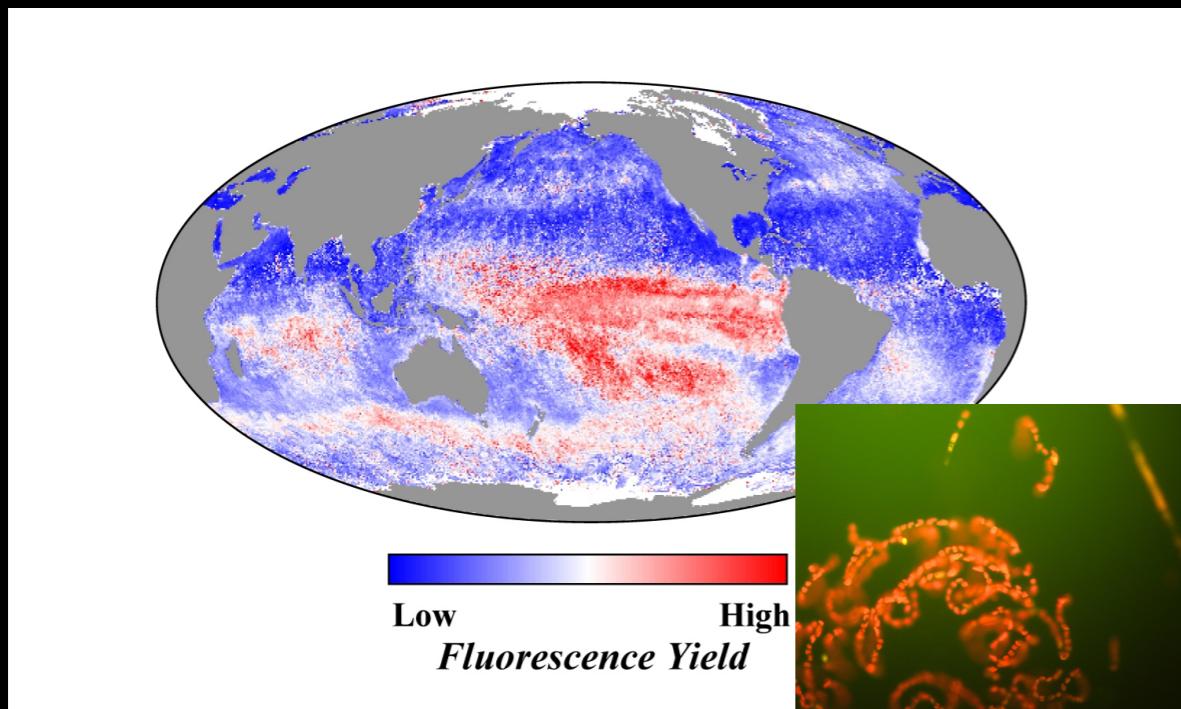
GEDI: first data available

GEDI sees to, and through, the trees in South Carolina

Surface Elevation

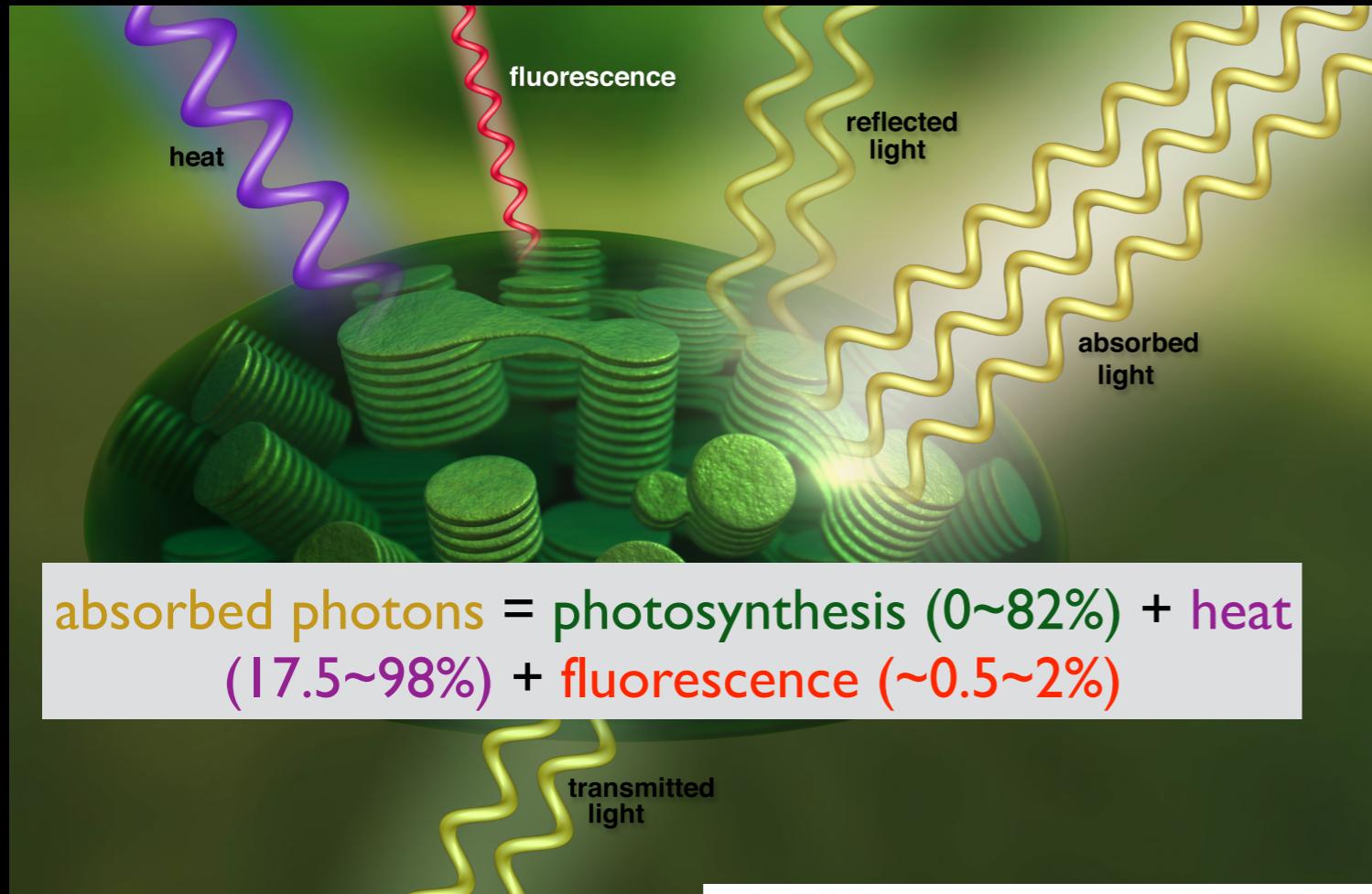


Fluorescence in nature

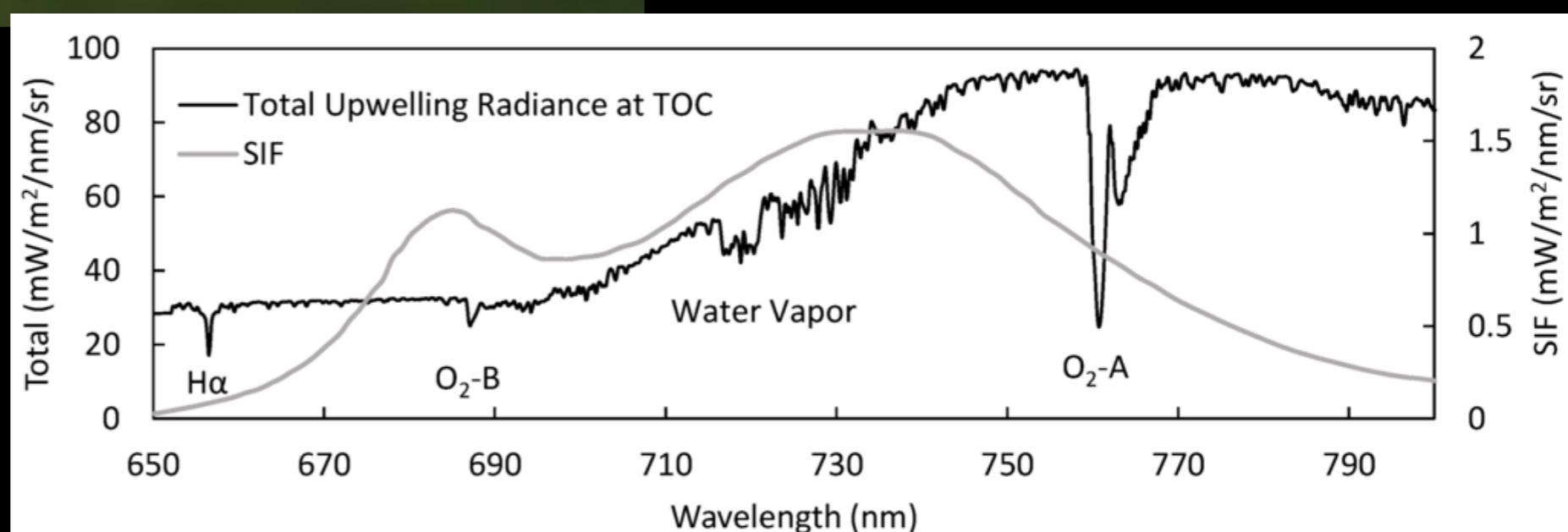
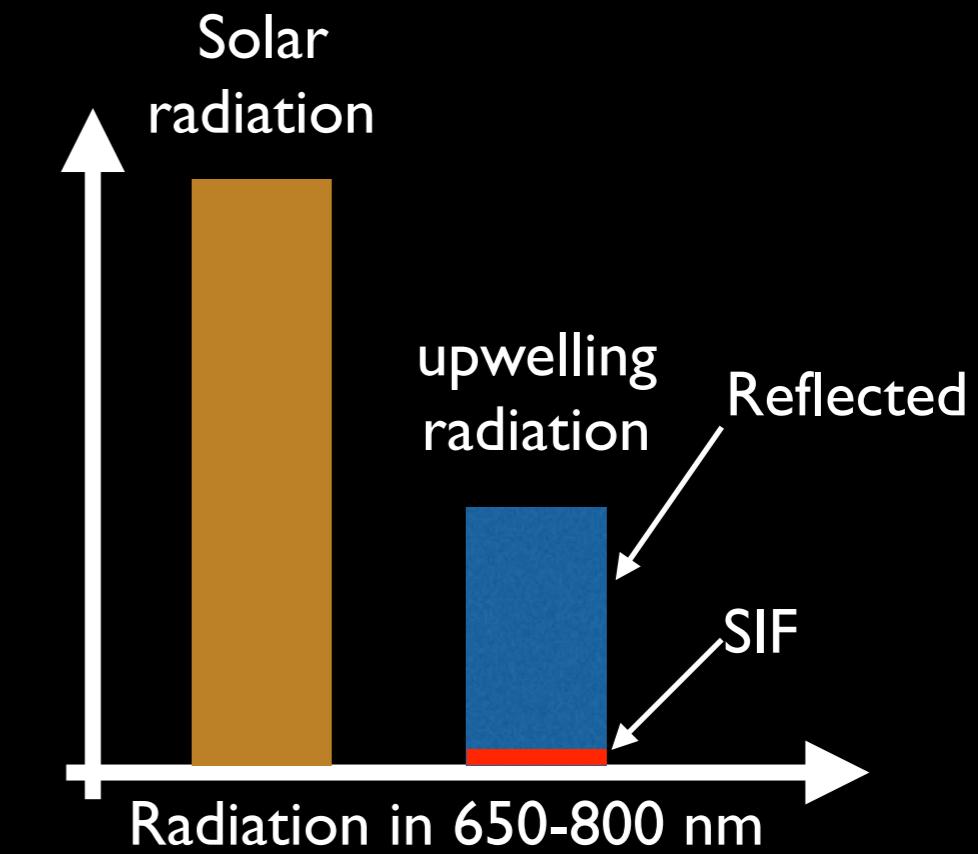


Source: Matt Reinbold; Wikipedia; NASA

Solar-induced chlorophyll fluorescence (SIF) is a small fraction of reflected light

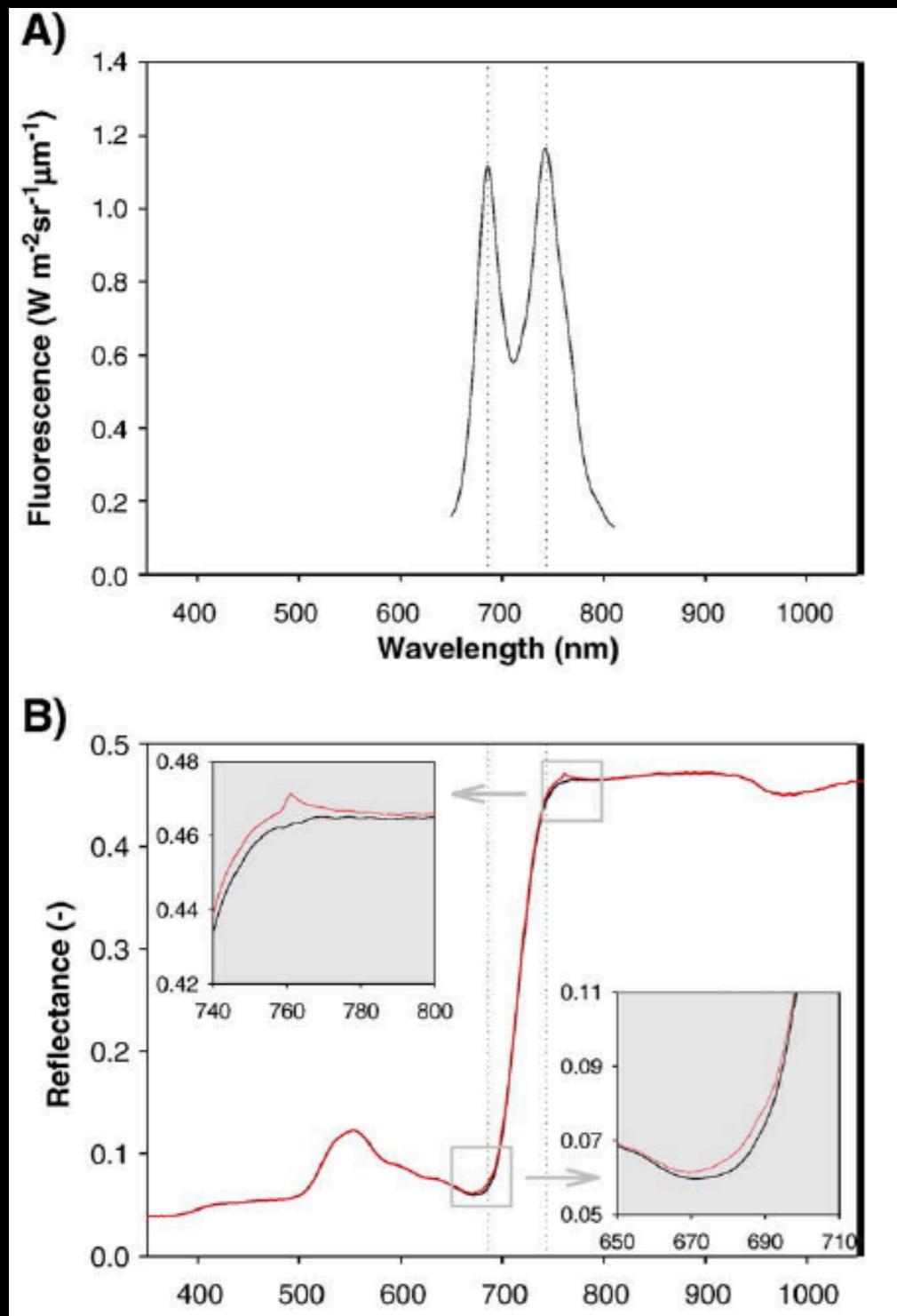


Credit: NASA

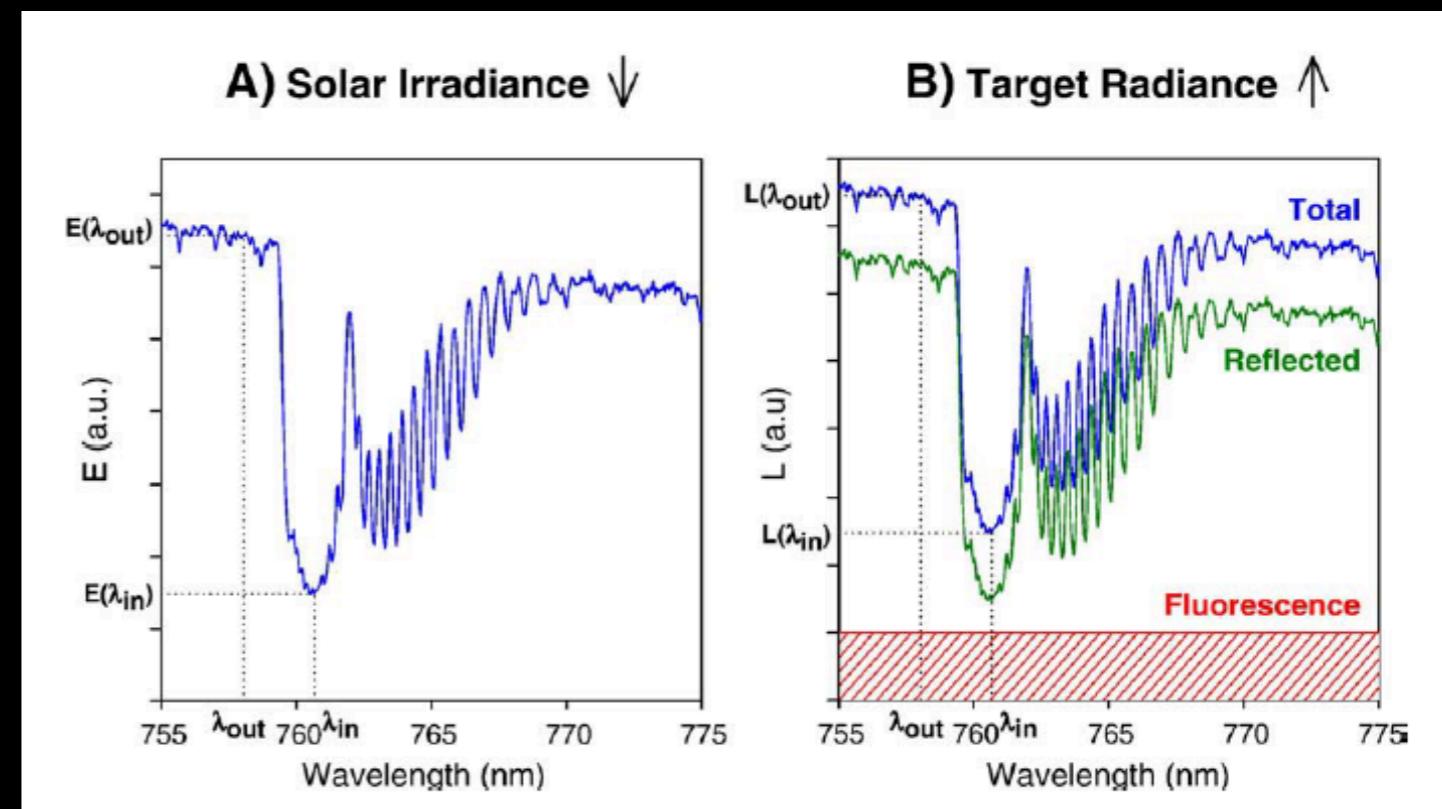


Liu et al., 2014

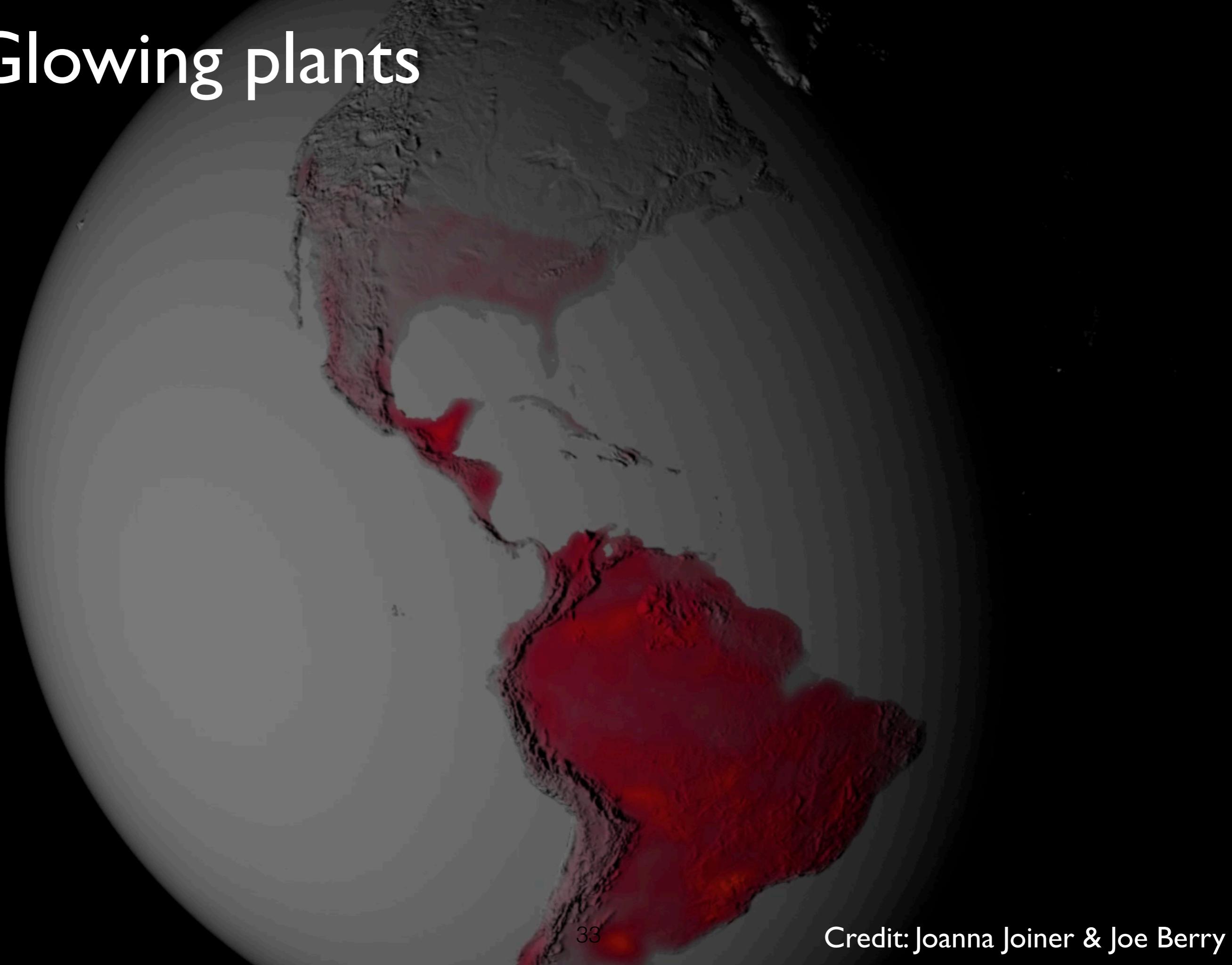
How to extract SIF?

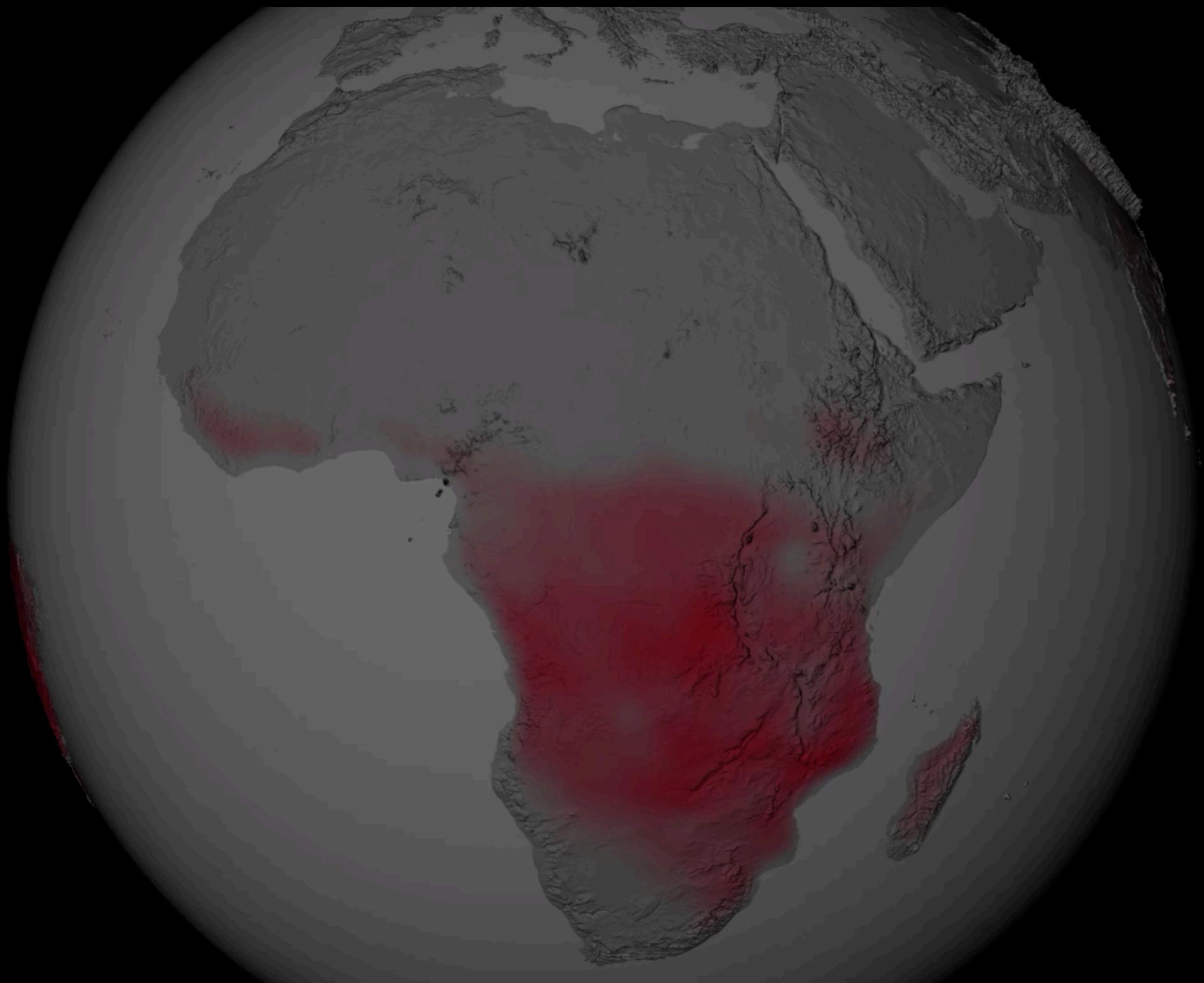


$$L(\lambda) = \frac{r(\lambda)E(\lambda)}{\pi} + F(\lambda) \quad [\text{W m}^{-2} \text{sr}^{-1} \mu\text{m}^{-1}]$$



Glowing plants





Jan 01

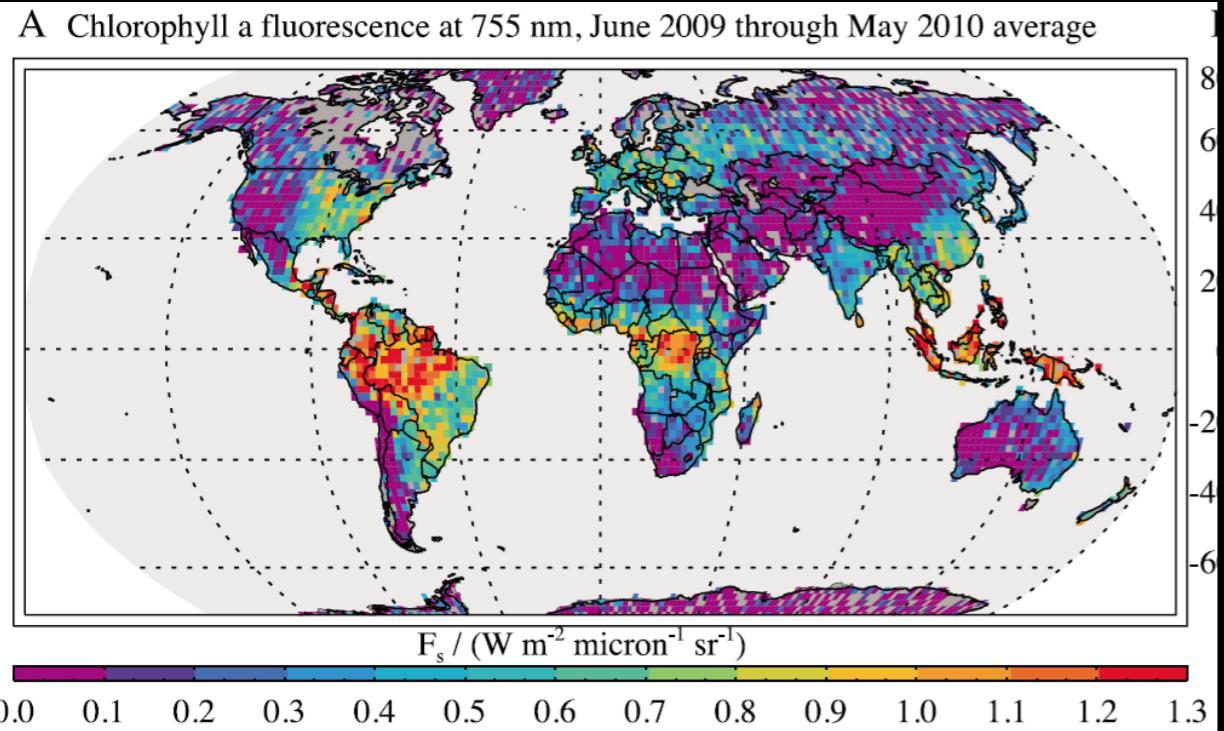
Jan 01



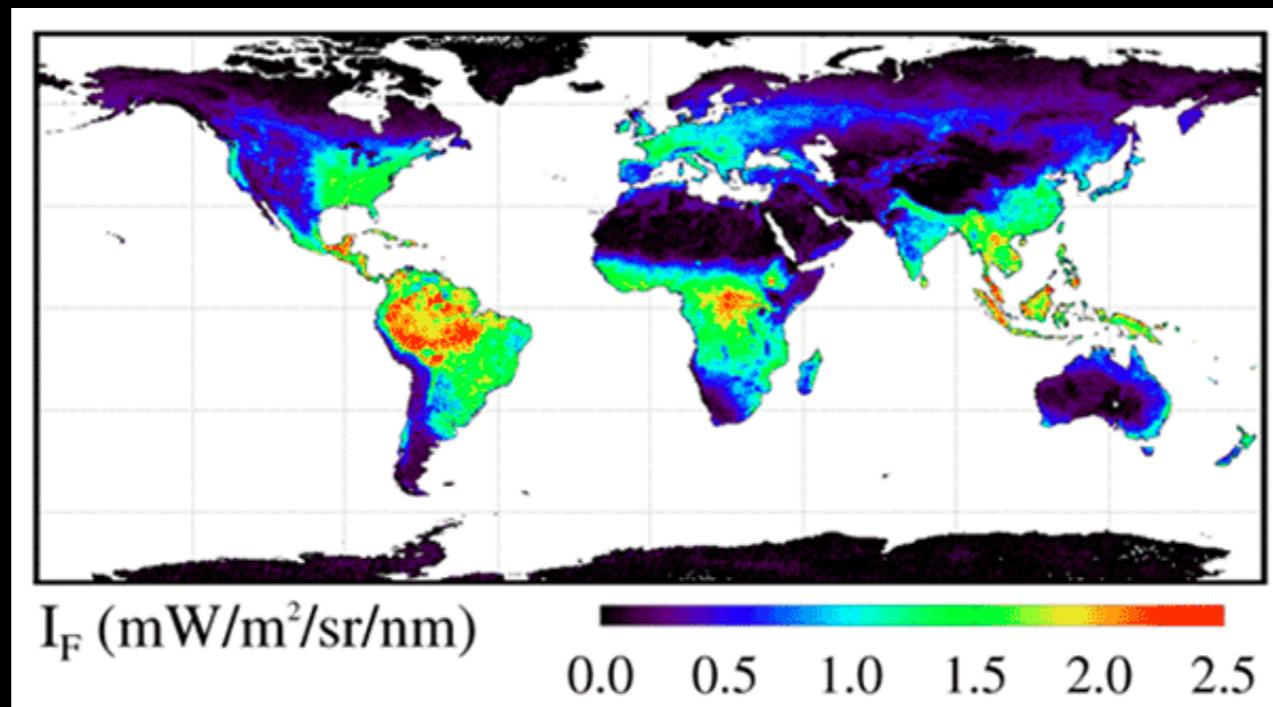


Satellite measurements of SIF

SIF from GOSAT



SIF from GOME-2

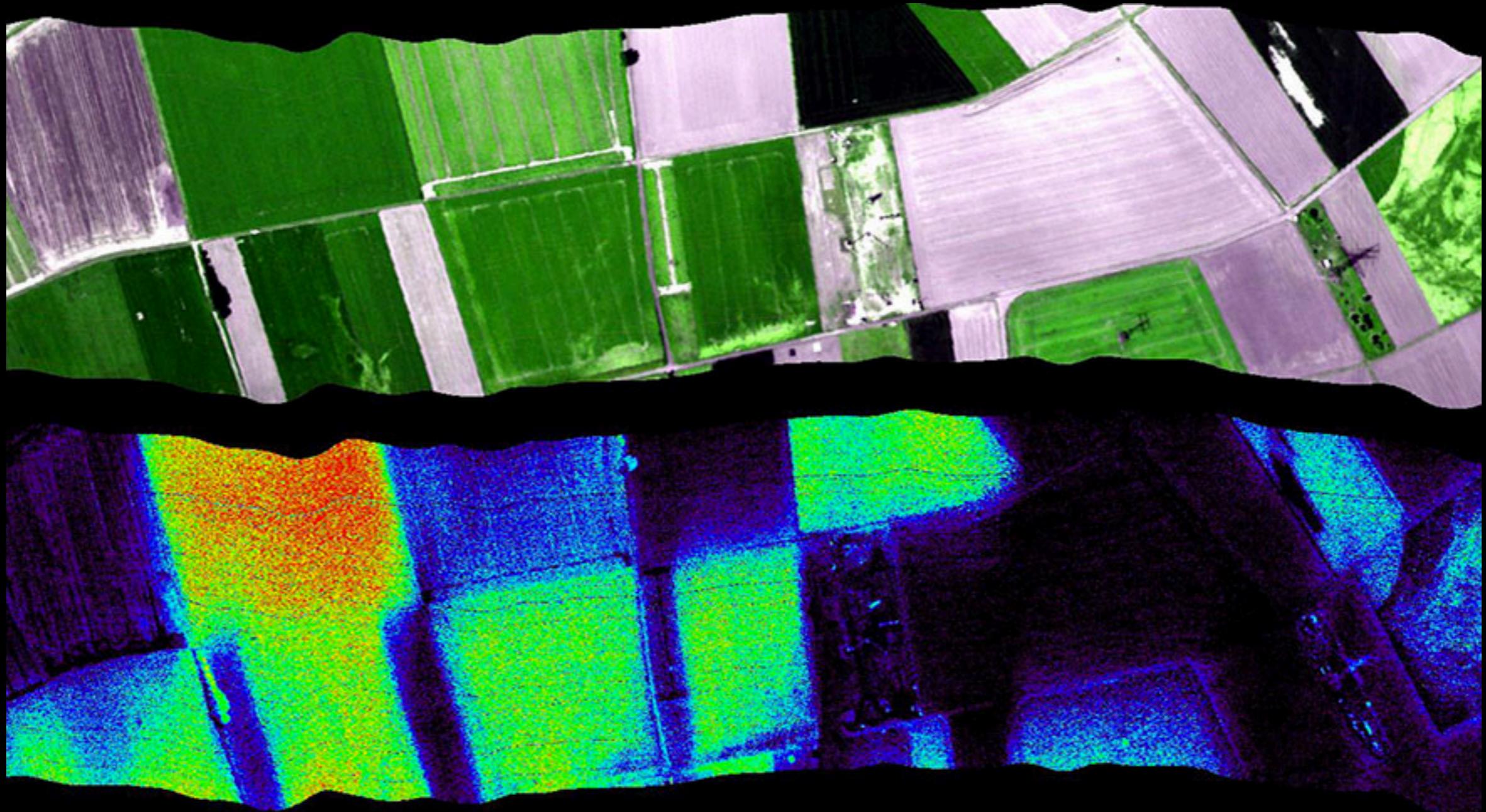


Satellite
SCIAMACHY

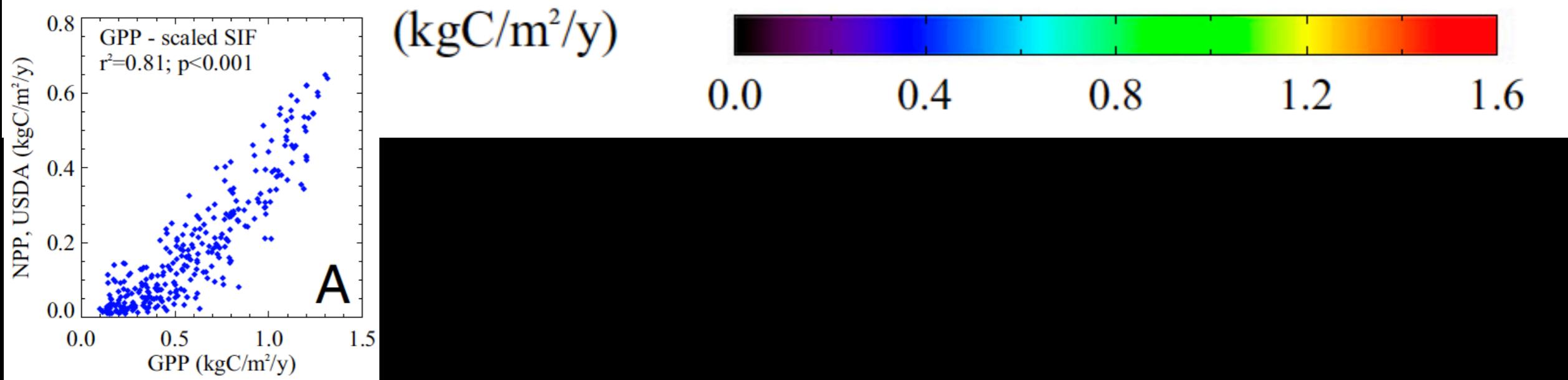
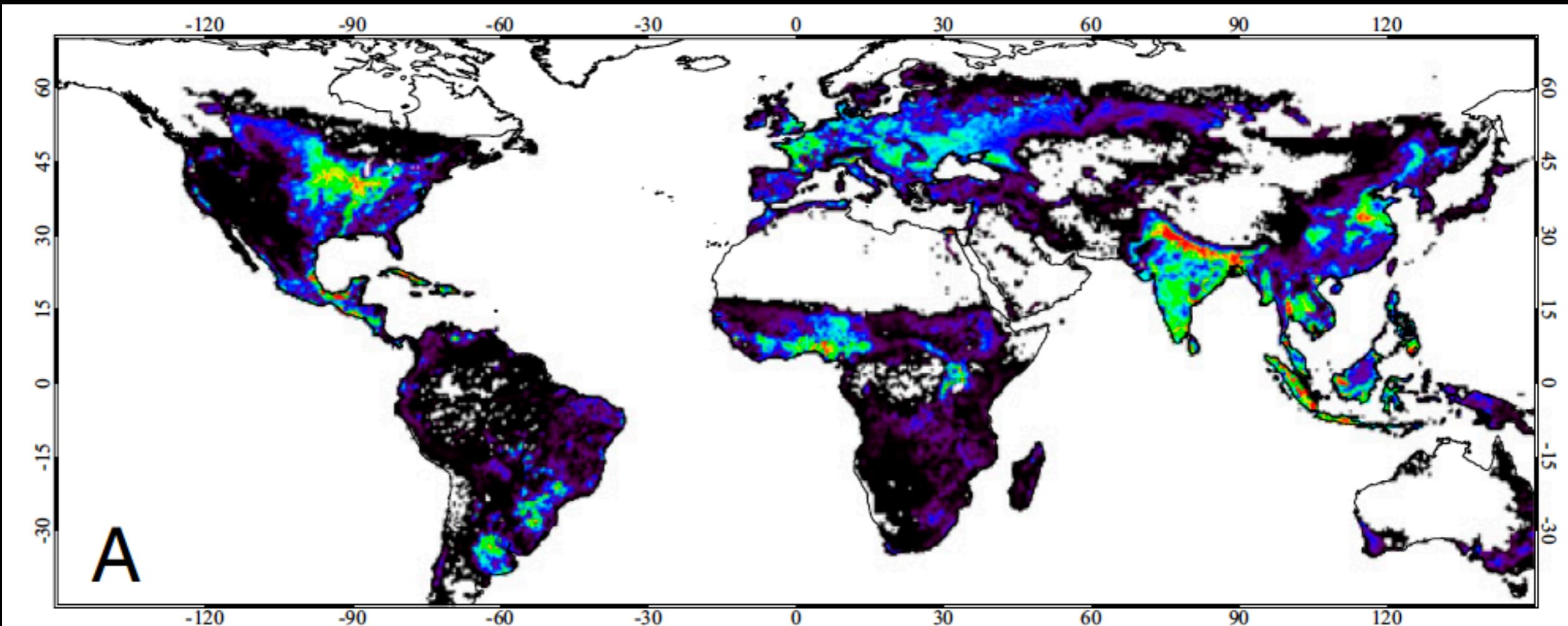
OCO-2
TROPOMI
GOSAT
GOSAT-2
TanSat

OCO-3
GEOCarb
FLEX

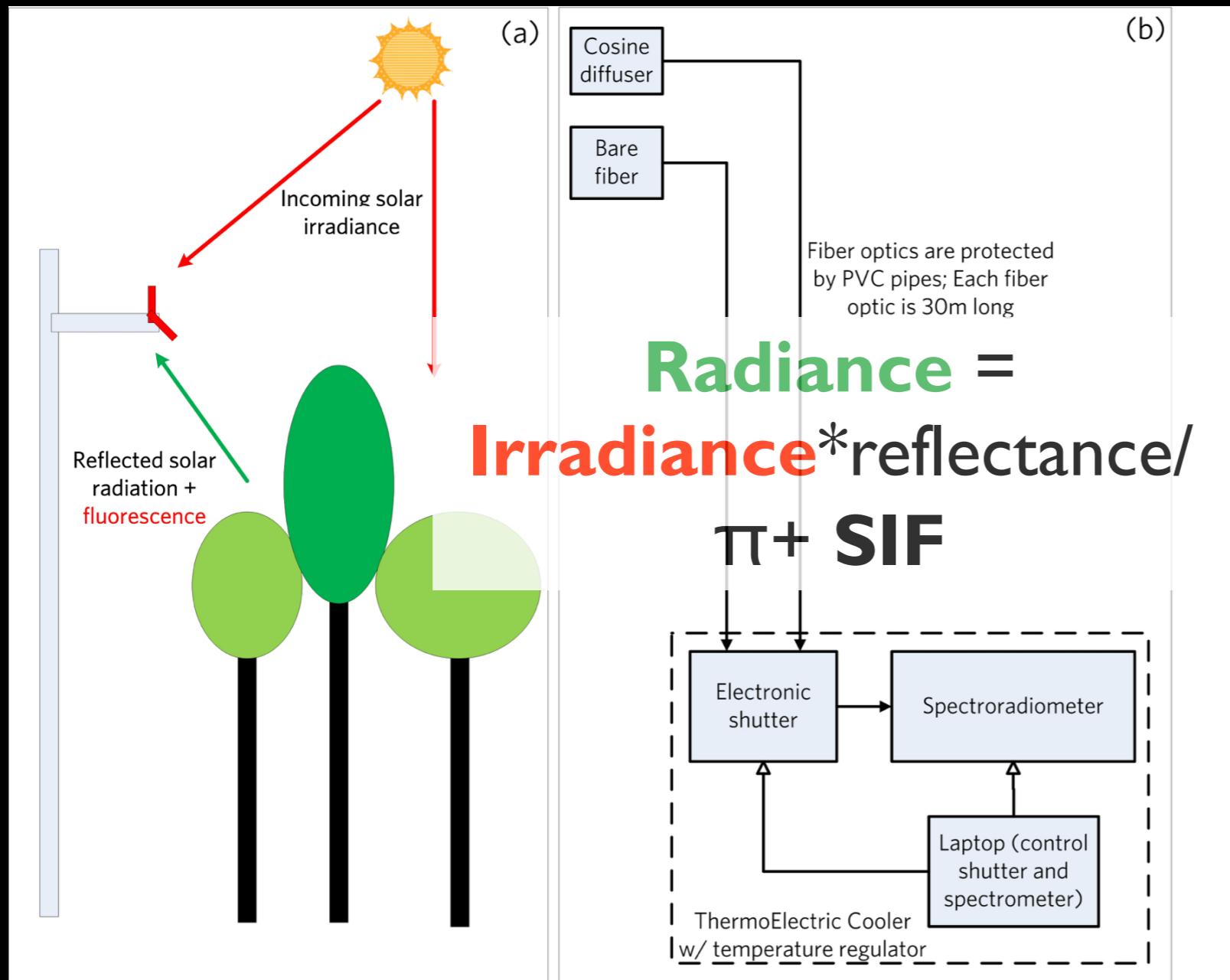
European Space Agency: FLEX mission



SIF for crop monitoring

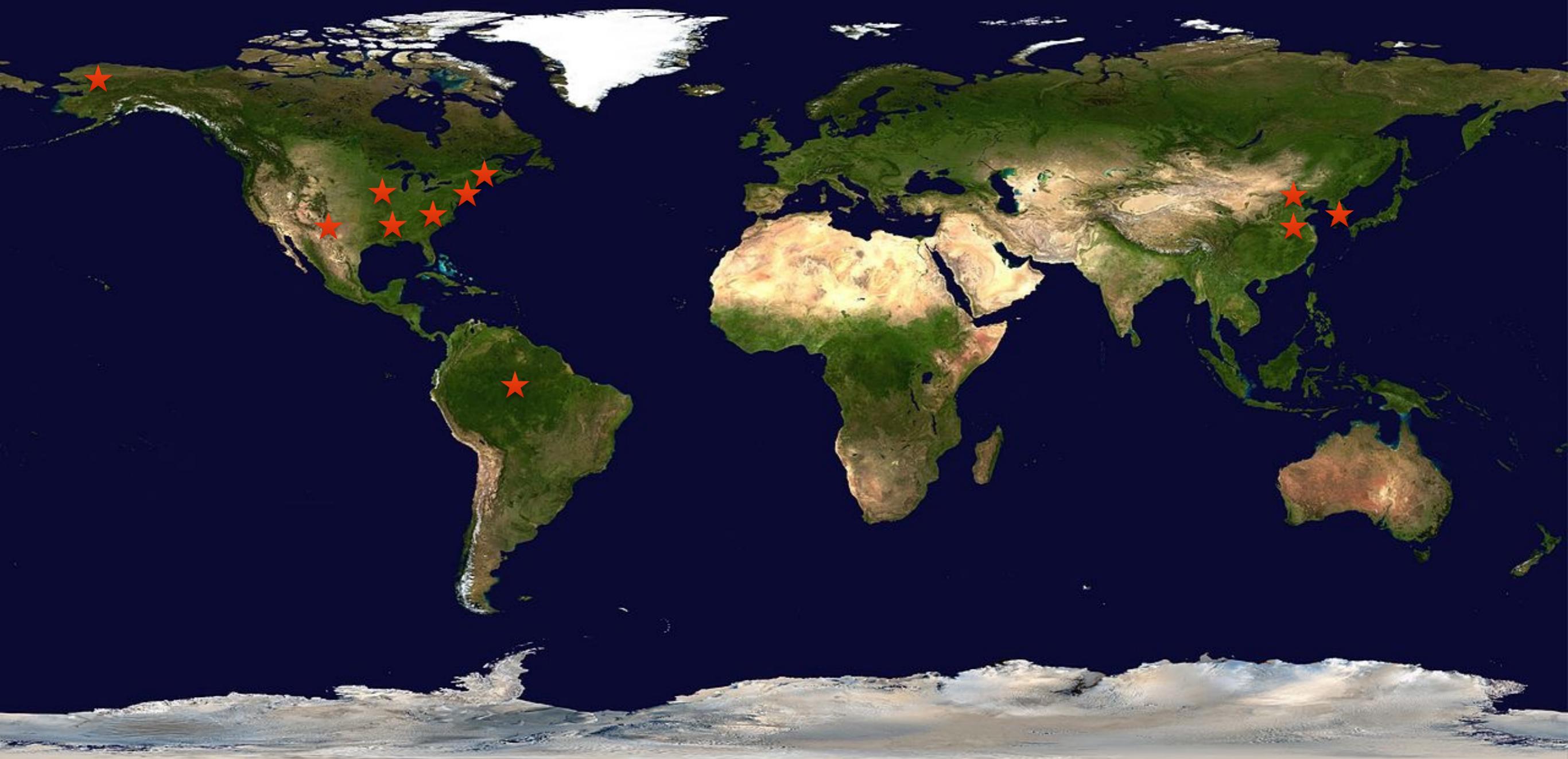


FluoSpec: an automated system for SIF



FluoNET:

a network of continuous measurements of vegetation photosynthesis



Recap

- Solar-induced fluorescence (SIF) is the radiation emitted by plants in the red and near-infrared wavelengths.
- The magnitude of SIF is small and can be detected by ultra-high resolution spectrometer.
- This is the future of remote sensing!