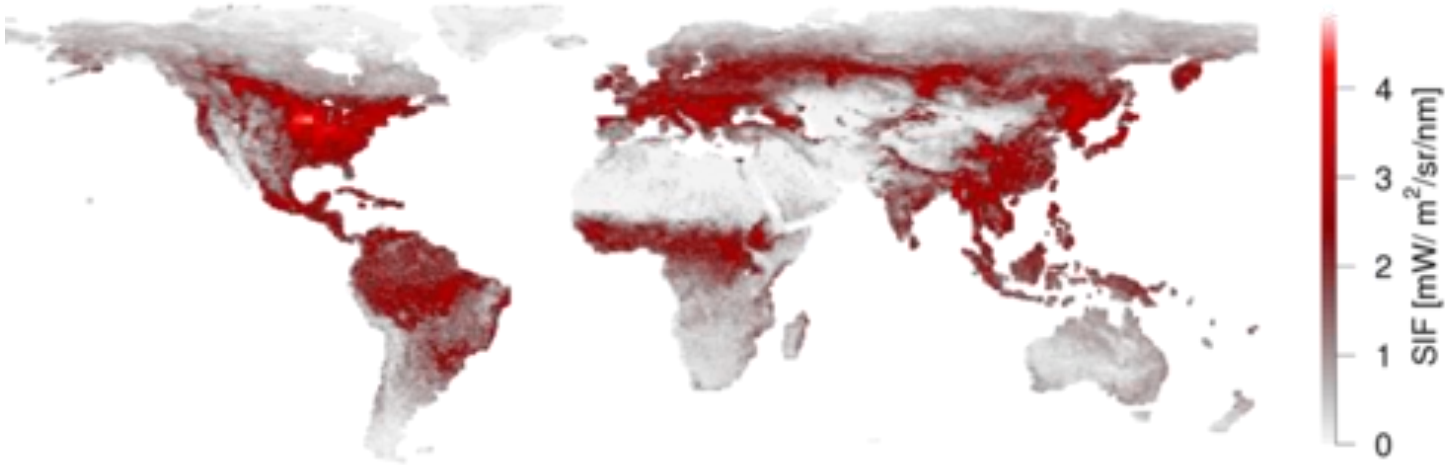


Assessing the potential of S5P/TROPOMI for global monitoring of terrestrial chlorophyll fluorescence

L. Guanter[1], I. Aben[2], P. Tol[2], J. M. Krijger[2], A. Hollstein[1], P. Köhler[1], A. Damm[3], J. Joiner[4], C. Frankenberg[5], and J. Landgraf[2]

[1]German Research Centre for Geosciences (GFZ), Helmholtz Centre Potsdam, Germany

[2]SRON Netherlands Institute for Space Research, Utrecht, the Netherlands

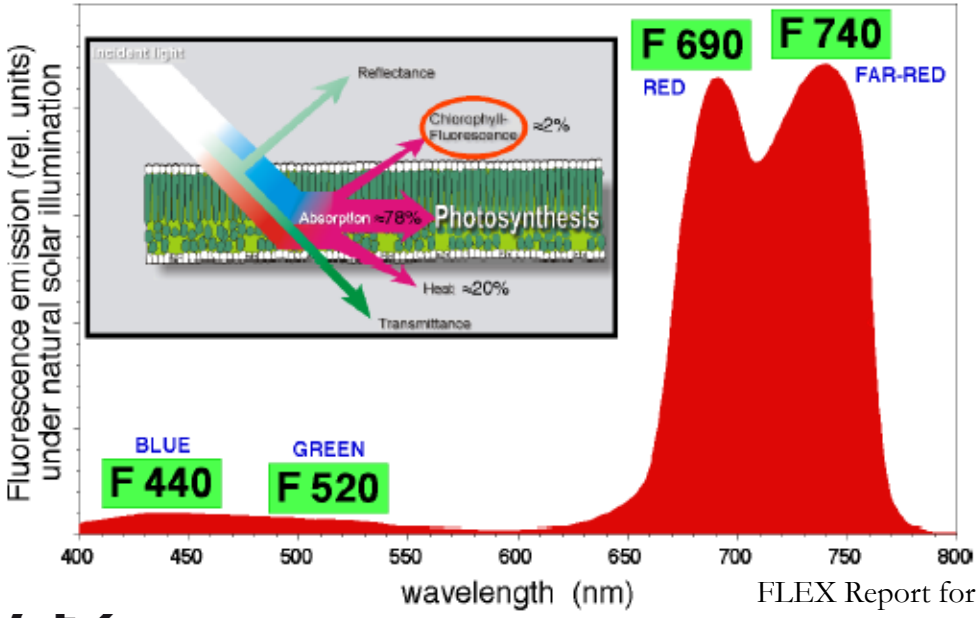
[3]Remote Sensing Laboratories, University of Zurich, Switzerland

[4]NASA Goddard Space Flight Center, USA

[5]Jet Propulsion Laboratory, California Institute of Technology, USA

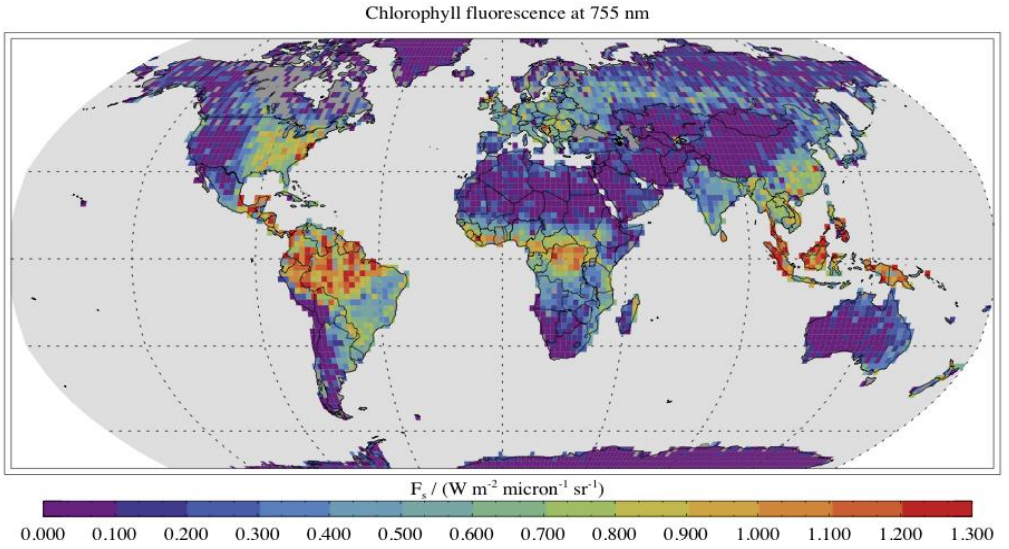
Monitoring of sun-induced chlorophyll fluorescence (SIF)

- **Chlorophyll fluorescence is an electromagnetic signal emitted by the photosynthetic machinery of green plants** and that can be linked to instantaneous photosynthesis.
- **First global measurements of SIF achieved in late 2011** from GOSAT TANSO-FTS spectra (Frankenberg et al., Joiner et al.).
- **Retrieval** based on in-filling of red and NIR solar **Fraunhofer lines** by SIF.

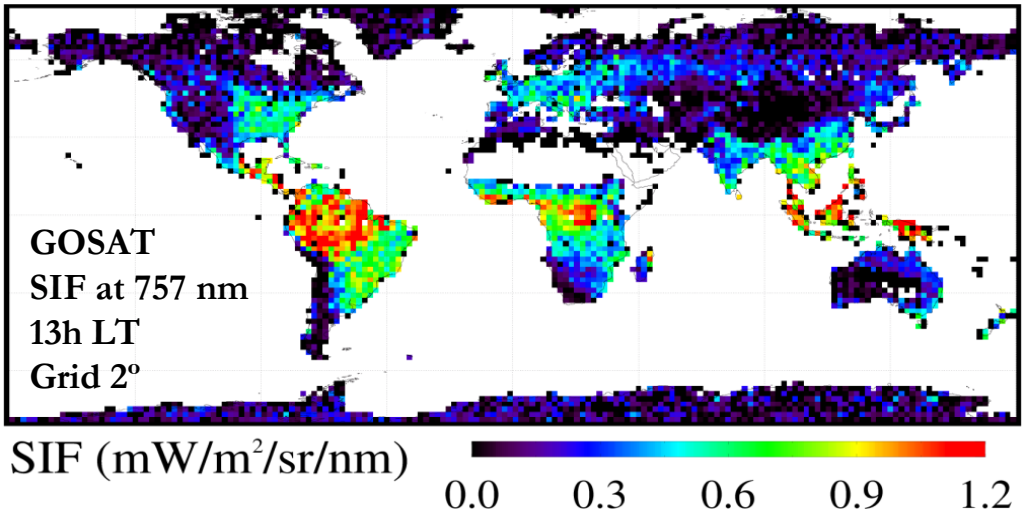


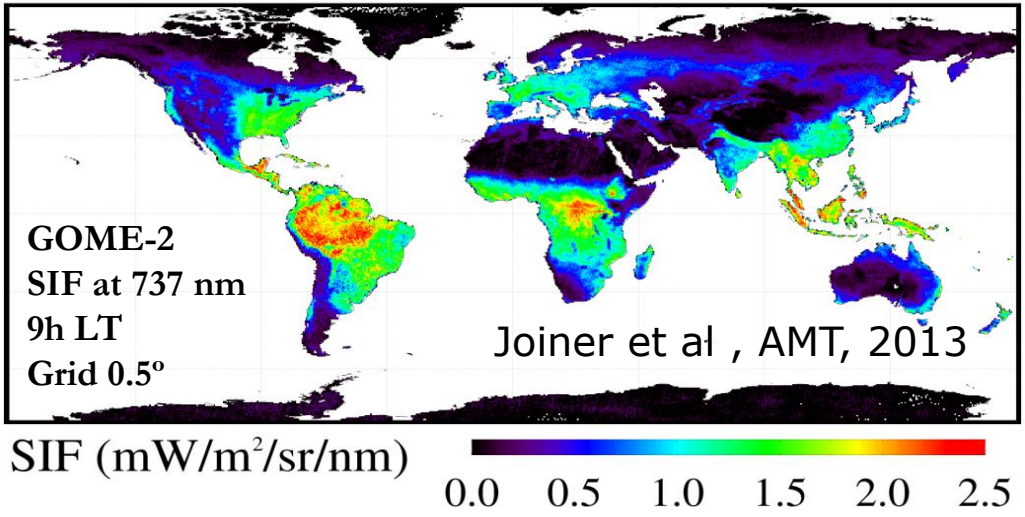
FLEX Report for Assessment (2008)

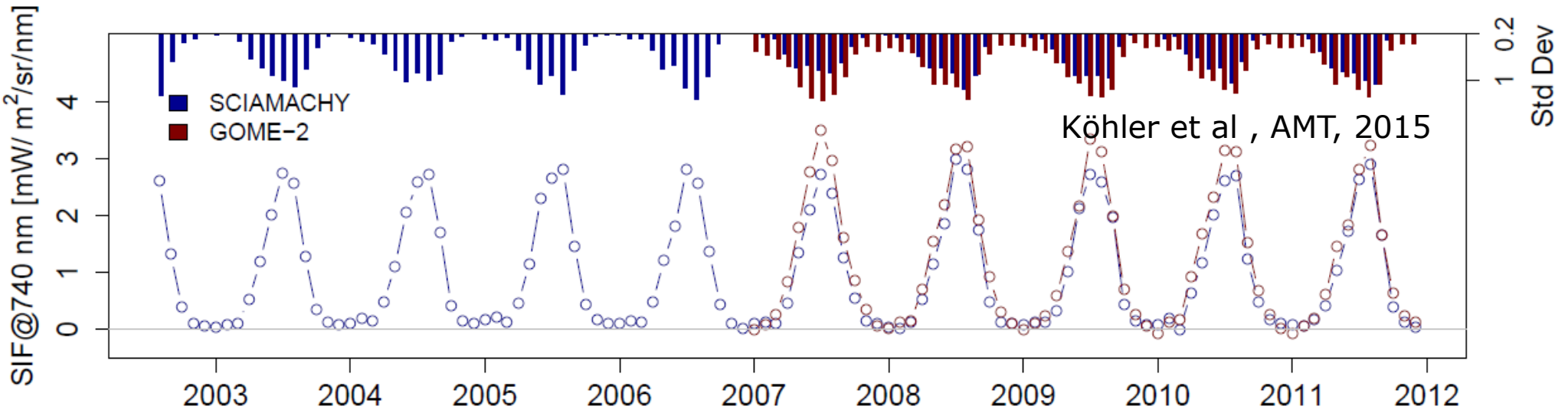
Frankenberg et al. (2011)



Global SIF data sets (from GOSAT, GOME-2, SCIAMACHY, OCO-2)



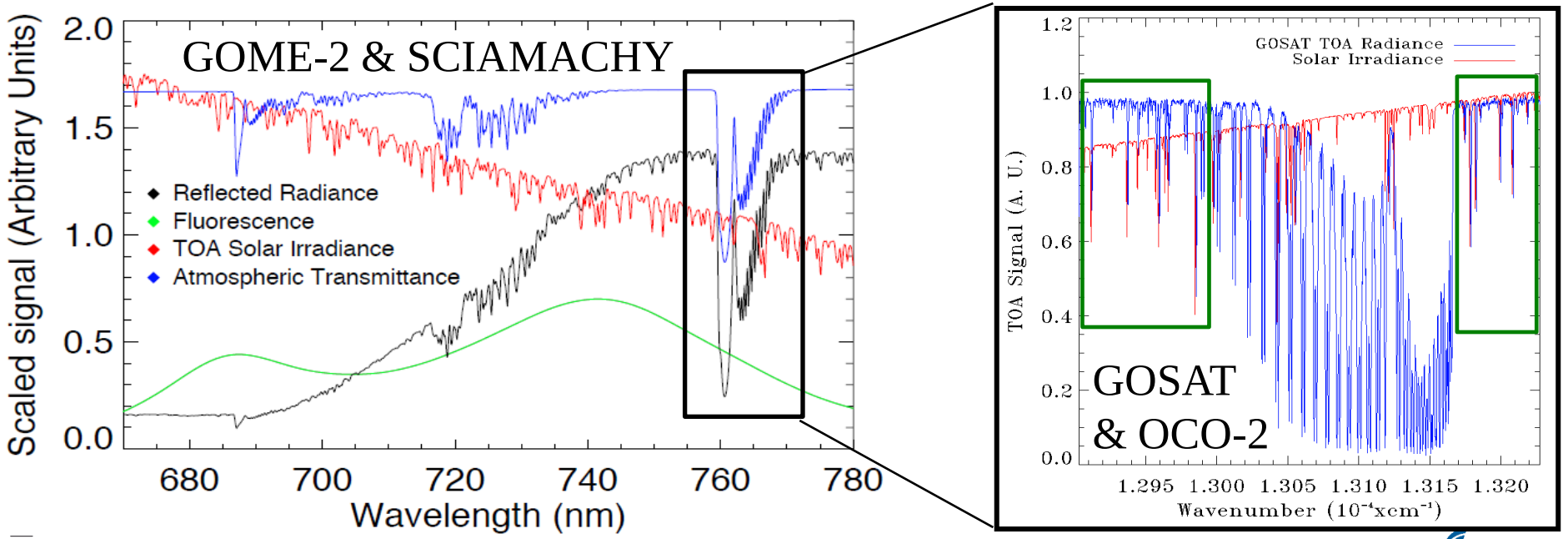


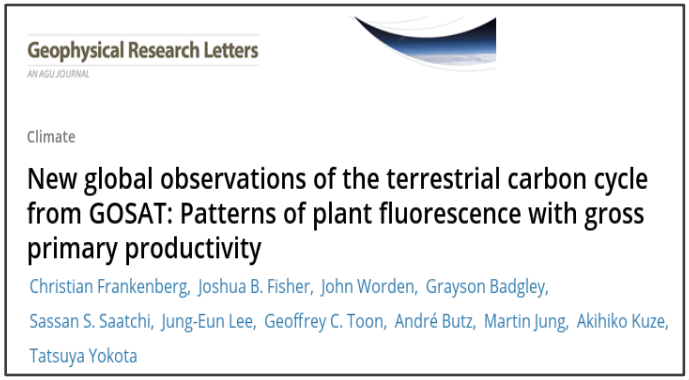


croplands between 100-80 W, 35-50 N

SIF retrieval from space

- **Challenge:** to decouple SIF from the solar radiation reflected by the surface and the atmosphere.
- Evaluation of the **fractional depth of solar Fraunhofer lines** → not affected by atmospheric scattering, simple modelling.
  - GOSAT & OCO-2, FWHM~0.05 nm – narrow fitting window (single lines)
  - GOME-2 & SCIAMACHY, FWHM~0.5nm – wide fitting window (red-edge)




Geophysical Research Letters
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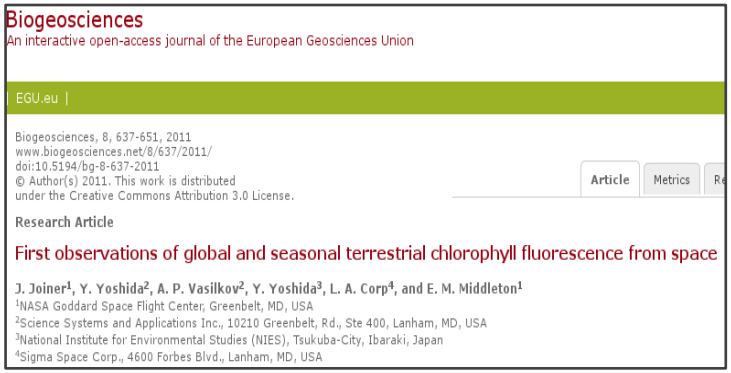
Climate

New global observations of the terrestrial carbon cycle from GOSAT: Patterns of plant fluorescence with gross primary productivity

Christian Frankenberg, Joshua B. Fisher, John Worden, Grayson Badgley, Sassan S. Saatchi, Jung-Eun Lee, Geoffrey C. Toon, André Butz, Martin Jung, Akihiko Kuze, Tatsuya Yokota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Biogeosciences, 8, 637-651, 2011
www.biogeosciences.net/8/637/2011/
doi:10.5194/bg-8-637-2011
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Research Article

First observations of global and seasonal terrestrial chlorophyll fluorescence from space

J. Joiner[1], Y. Yoshida[2], A. P. Vasilkov[2], Y. Yoshida[3], L. A. Corp[4], and E. M. Middleton[1]
[1]NASA Goddard Space Flight Center, Greenbelt, MD, USA
[2]Science Systems and Applications Inc., 10210 Greenbelt, Rd., Ste 400, Lanham, MD, USA
[3]National Institute for Environmental Studies (NIES), Tsukuba-City, Ibaraki, Japan
[4]Sigma Space Corp., 4600 Forbes Blvd., Lanham, MD, USA


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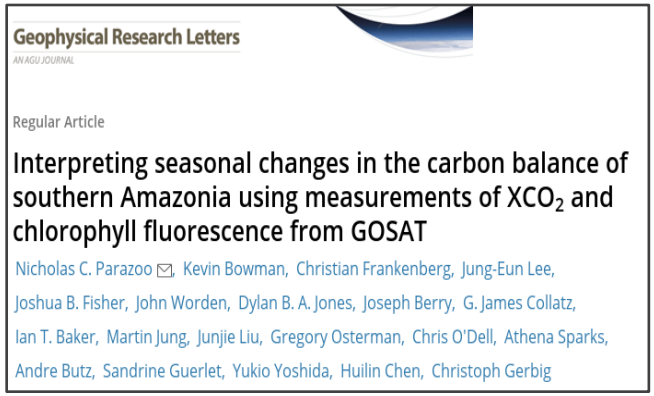
NATURE GEOSCIENCE | LETTER

Photosynthetic seasonality of global tropical forests constrained by hydroclimate

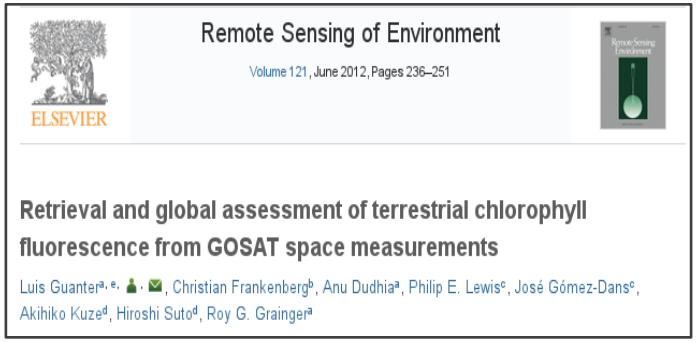
Kaiyu Guan, Ming Pan, Haibin Li, Adam Wolf, Jin Wu, David Medvigy, Kelly K. Caylor, Justin Sheffield, Eric F. Wood, Yadvinder Malhi, Miaoling Liang, John S. Kimball, Scott R. Saleska, Joe Berry, Joanna Joiner & Alexei I. Lyapustin


Geophysical Research Letters
AN AGU JOURNAL

Regular Article

Interpreting seasonal changes in the carbon balance of southern Amazonia using measurements of XCO_2 and chlorophyll fluorescence from GOSAT

Nicholas C. Parazoo, Kevin Bowman, Christian Frankenberg, Jung-Eun Lee, Joshua B. Fisher, John Worden, Dylan B. A. Jones, Joseph Berry, G. James Collatz, Ian T. Baker, Martin Jung, Junjie Liu, Gregory Osterman, Chris O'Dell, Athena Sparks, Andre Butz, Sandrine Guerlet, Yukio Yoshida, Huilin Chen, Christoph Gerbig

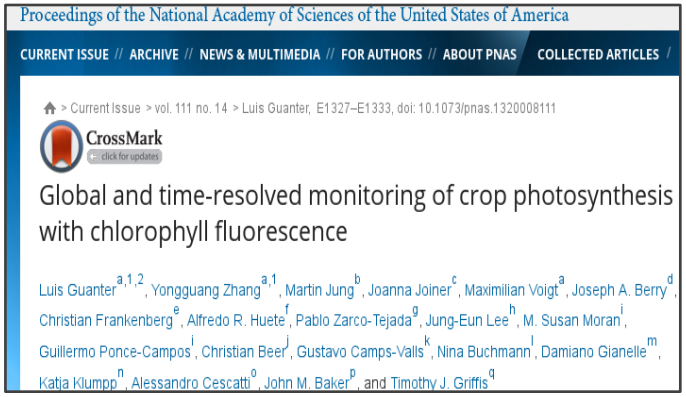

ELSEVIER

Remote Sensing of Environment

Volume 121, June 2012, Pages 236–251

Retrieval and global assessment of terrestrial chlorophyll fluorescence from GOSAT space measurements

Luis Guanter[a, e], Christian Frankenberg[b], Anu Dudhia[a], Philip E. Lewis[c], José Gómez-Dans[c], Akihiko Kuze[d], Hiroshi Suto[d], Roy G. Grainger[a]


Proceedings of the National Academy of Sciences of the United States of America

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> Current Issue > vol. 111 no. 14 > Luis Guanter, E1327–E1333, doi: 10.1073/pnas.1320008111

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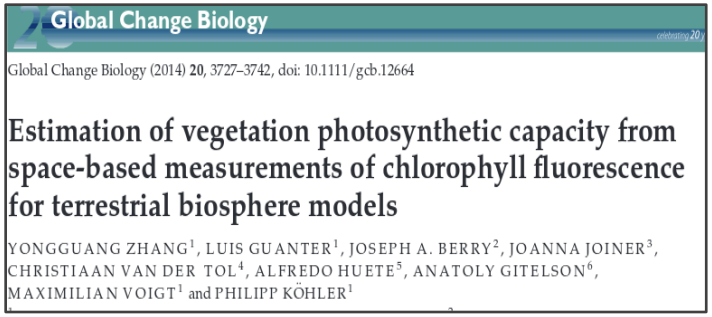
Global and time-resolved monitoring of crop photosynthesis with chlorophyll fluorescence

Luis Guanter[a,1,2], Yongguang Zhang[a,1], Martin Jung[b], Joanna Joiner[c], Maximilian Voigt[a], Joseph A. Berry[d], Christian Frankenberg[e], Alfredo R. Huete[f], Pablo Zarco-Tejada[g], Jung-Eun Lee[h], M. Susan Moran[i], Guillermo Ponce-Campos[i], Christian Beer[j], Gustavo Camps-Valls[k], Nina Buchmann[l], Damiano Gianelle[m], Katja Klumpp[n], Alessandro Cescatti[o], John M. Baker[p], and Timothy J. Griffis[q]


Global Change Biology

Global Change Biology (2014) **20**, 3727–3742, doi: 10.1111/gcb.12664

Estimation of vegetation photosynthetic capacity from space-based measurements of chlorophyll fluorescence for terrestrial biosphere models

YONGGUANG ZHANG[1], LUIS GUANTER[1], JOSEPH A. BERRY[2], JOANNA JOINER[3], CHRISTIAAN VAN DER TOL[4], ALFREDO HUETE[5], ANATOLY GITELSON[6], MAXIMILIAN VOIGT[1] and PHILIPP KÖHLER[1]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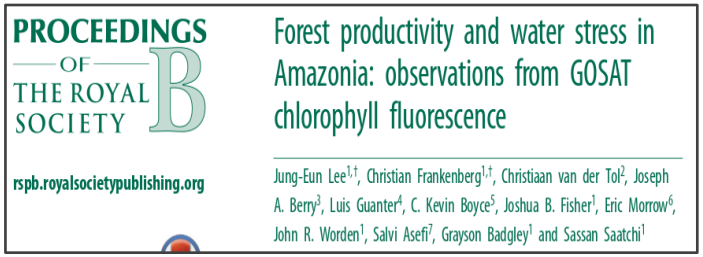
NATURE | LETTER

日本語要約

Agricultural Green Revolution as a driver of increasing atmospheric CO_2 seasonal amplitude

Ning Zeng, Fang Zhao, George J. Collatz, Eugenia Kalnay, Ross J. Salawitch, Tristram O. West & Luis Guanter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Forest productivity and water stress in Amazonia: observations from GOSAT chlorophyll fluorescence

Jung-Eun Lee[1,†], Christian Frankenberg[1,†], Christiaan van der Tol[2], Joseph A. Berry[3], Luis Guanter[4], C. Kevin Boyce[5], Joshua B. Fisher[1], Eric Morrow[6], John R. Worden[1], Salvi Asefi[7], Grayson Badgley[1] and Sassan Saatchi[1]

- Global SIF data used on a number of carbon cycle studies
- Bottleneck: low SNR & spatial resolution

Potential of S5P/TROPOMI for SIF retrieval

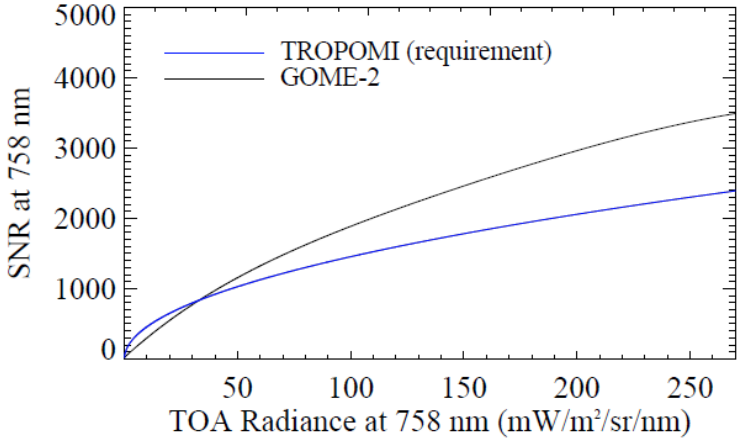
	GOME-2	TROPOMI
Data since/from	Jan 2007	Mid 2016
Overpass time	Morning	Midday
Red/NIR spectral coverage	650–790 nm	675–775 nm
Spectral resolution at 750 nm	~0.5 nm	~0.5 nm
Type of spatial sampling	Continuous	Continuous
Spatial resolution of single measurements	$40 \times 80\ km^2$	$7 \times 7\ km^{2*}$
Typical resolution of global composites	0.5°	0.1°*
Approx. number of NIR clear-sky observations over land per day	2800	~544 300*

Guanter et al., AMT, 2015

Sensitivity Analysis – Potential of TROPOMI for SIF retrieval

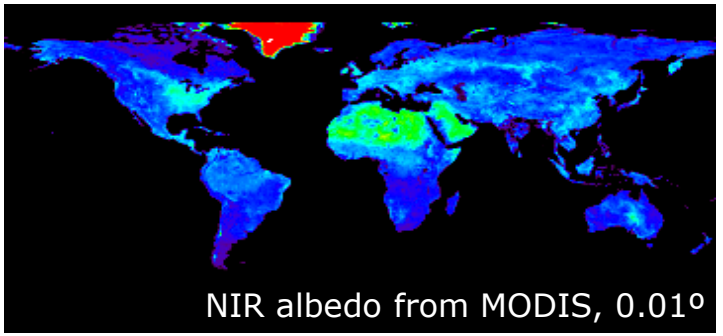
1) Spectrum-based end-to-end simulations to evaluate retrieval accuracy & precision

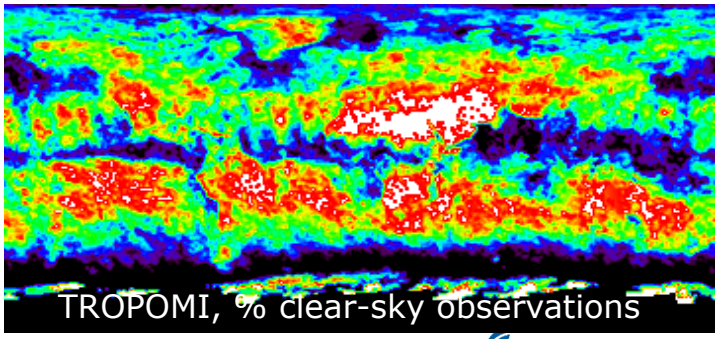
- Ensemble of atmospheric and vegetation conditions
- FWHM=0.5nm, SSD=0.1nm (TROP) / 0.2nm (GOME-2)
- Specific SNR-radiance curves for each instrument
- (Linear) Forward model based on Köhler et al. (2015)



2) Precision of spatio-temporal composites of SIF

- For each grid cell, 1-σ SIF errors converted to standard errors as a function of # of clear-sky observations
- Grid cells of 0.1º for TROPOMI and 0.5º for GOME-2
- 735-758 nm fitting window
- Cloud statistics, albedo and SIF (EVI) from MODIS





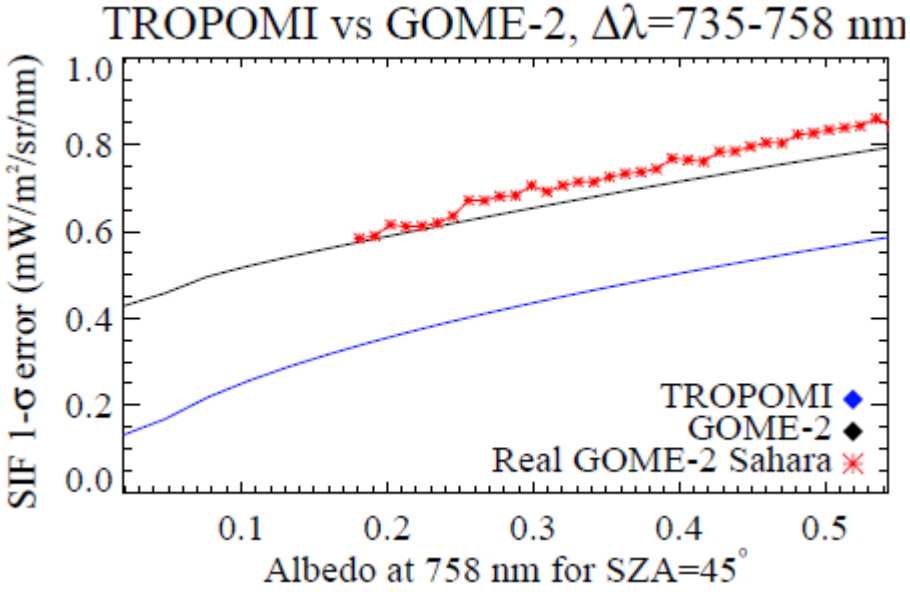
Guanter et al., AMT, 2015

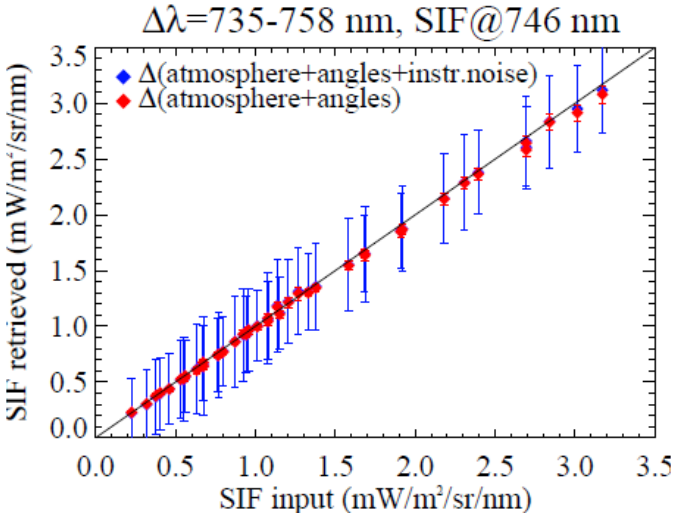
Single-retrieval simulations

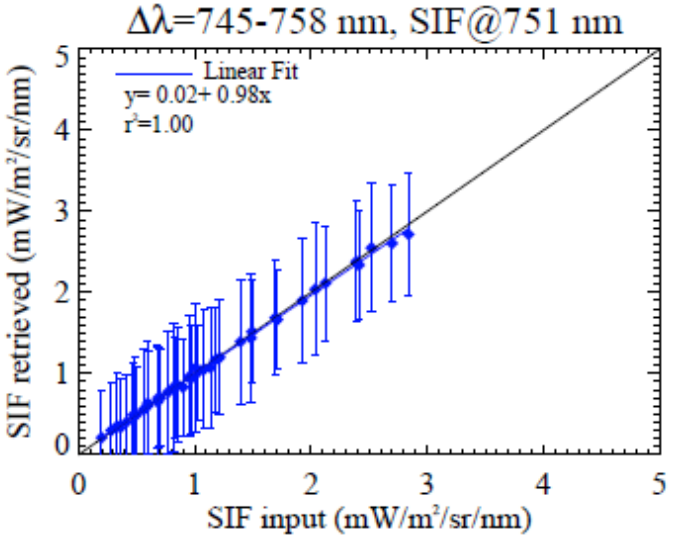
(1) TROPOMI higher retrieval precision than GOME-2

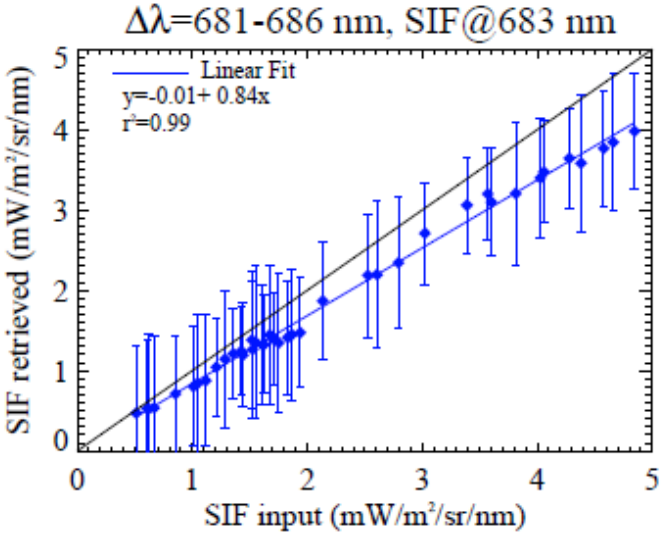
(2) End-to-end simulations show consistent retrievals at different wavelengths

(3) Instrumental noise, main error contribution



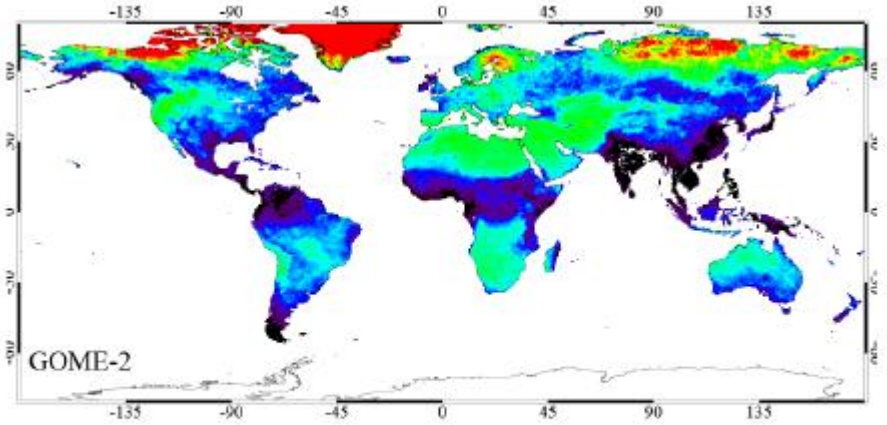


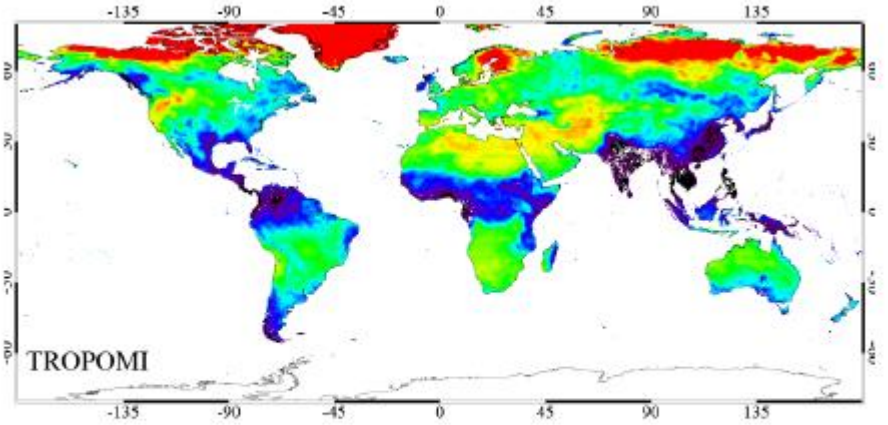


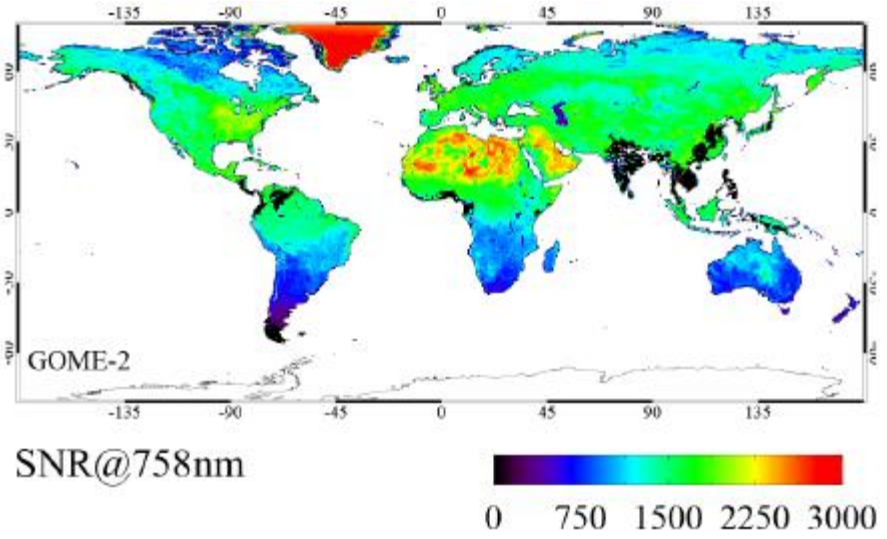


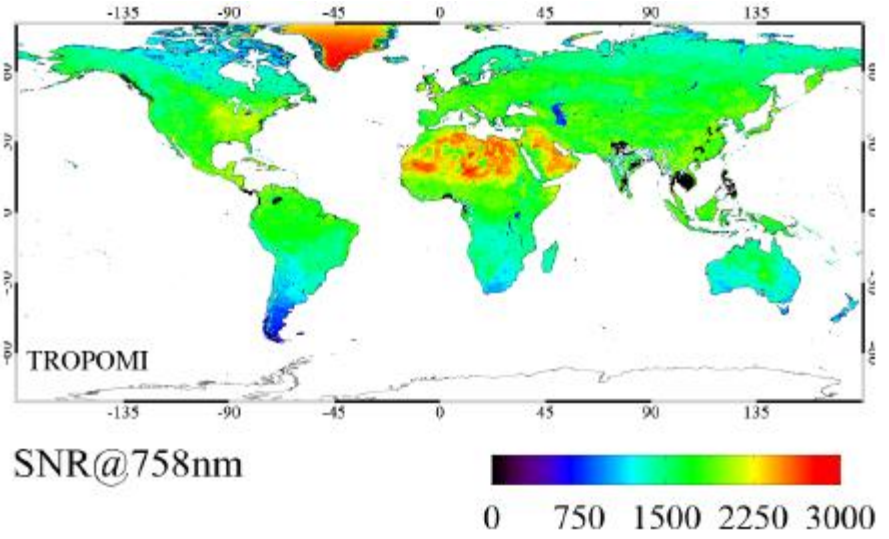
Precision of spatio-temporal composites of SIF

July, 7-day composite, cloud fraction<50%



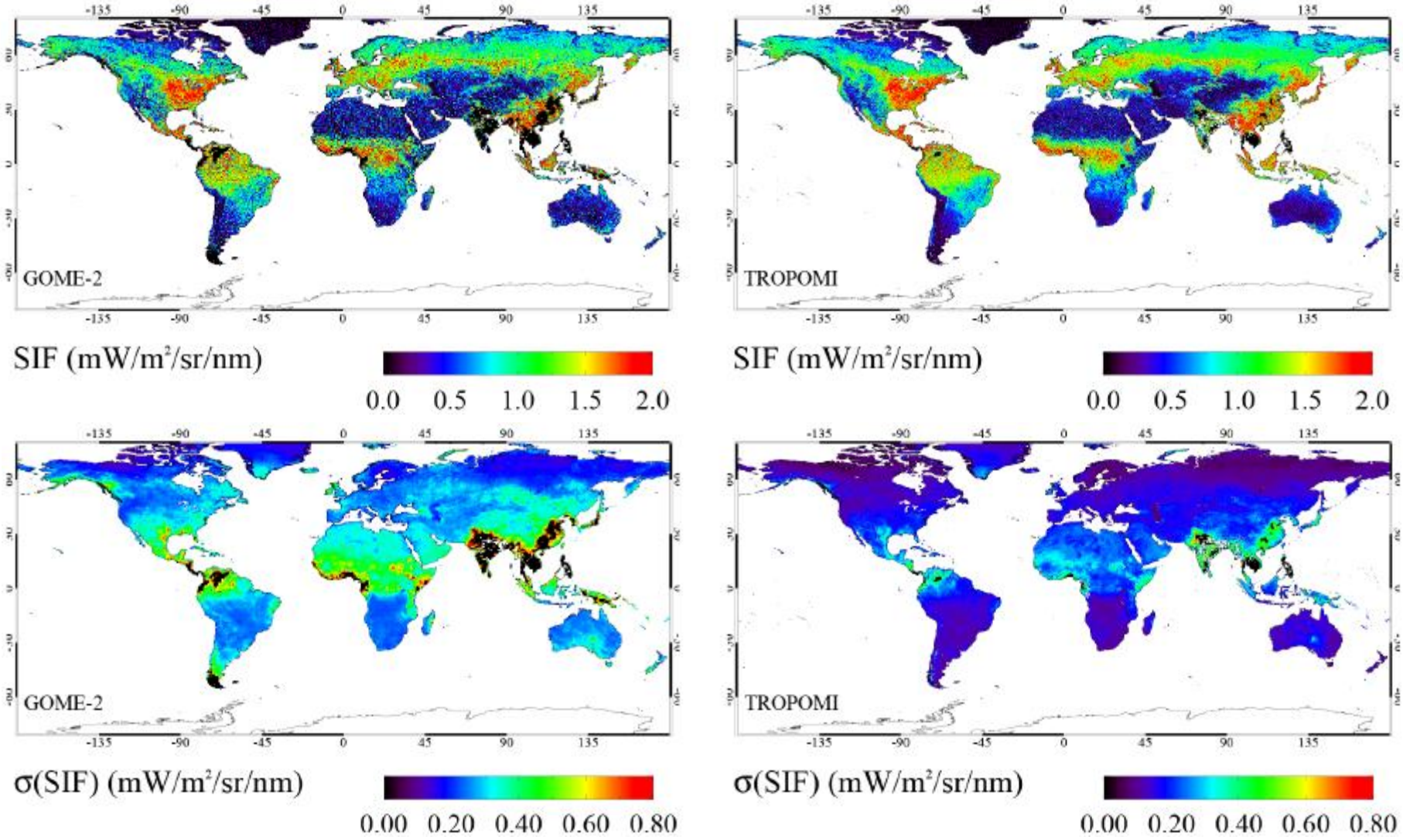






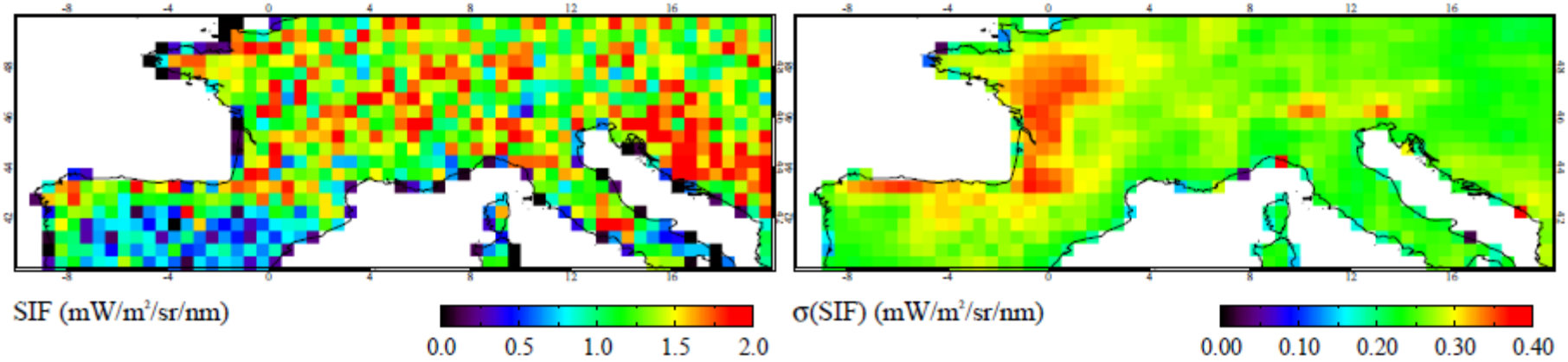
Precision of spatio-temporal composites of SIF

July, 7-day composite, cloud fraction<50%

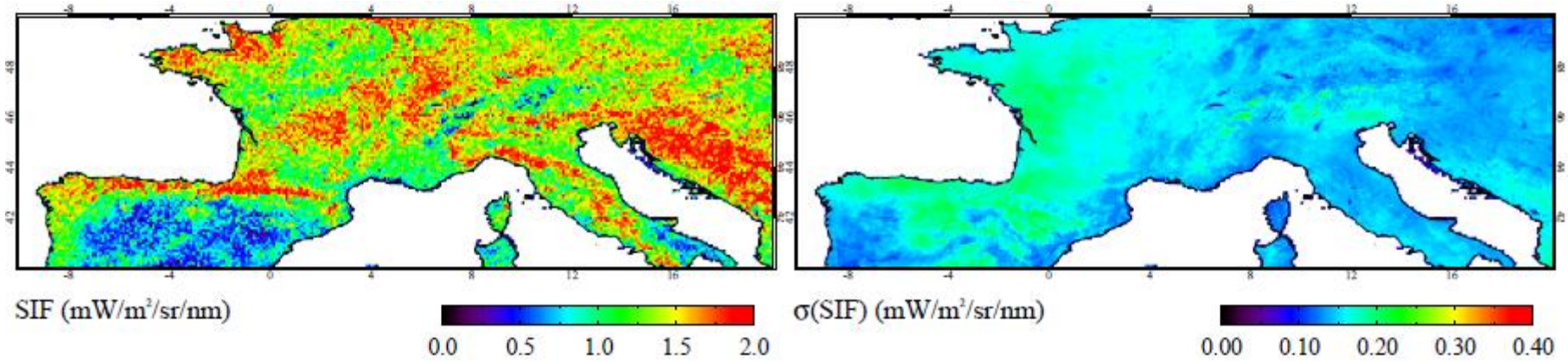


Precision of spatio-temporal composites of SIF

GOME-2, July, 7-day composite, cloud fraction<50%

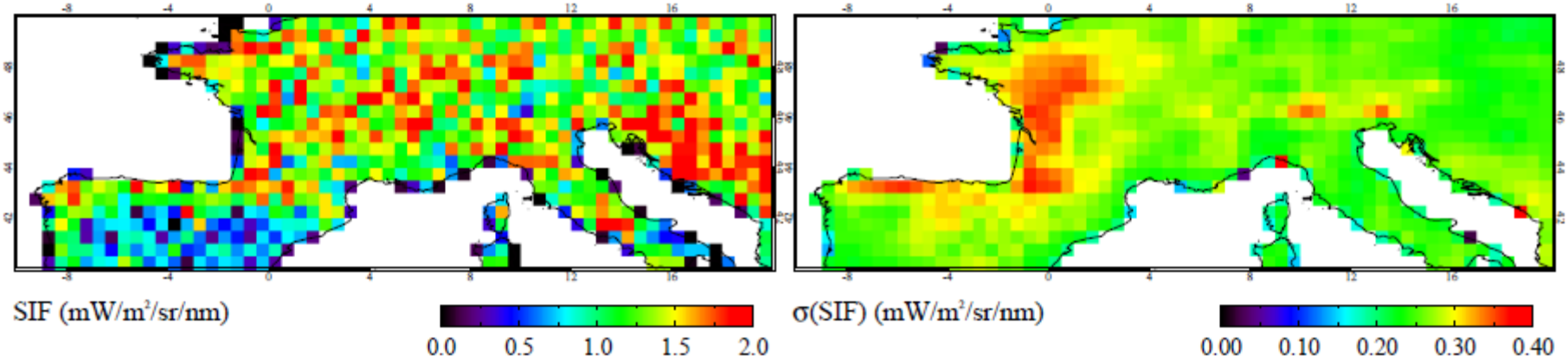


TROPOMI, July, 7-day composite, cloud fraction<50%

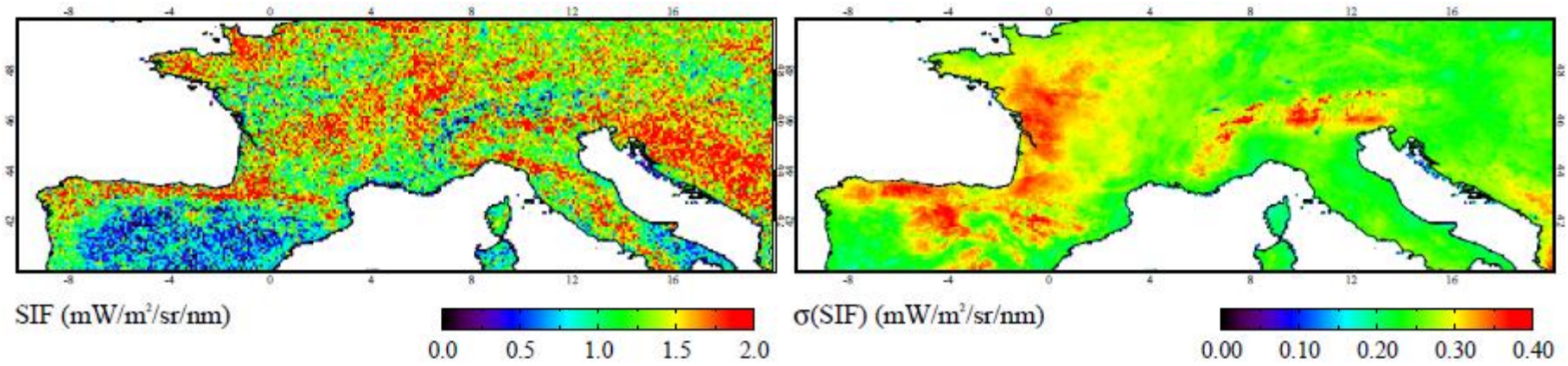


Precision of spatio-temporal composites of SIF

GOME-2, July, 7-day composite, cloud fraction<50%



TROPOMI, July, 3-day composite, cloud fraction<20%



Summary

- **Sun-Induced Chlorophyll Fluorescence (SIF):** a new data stream to look into the terrestrial carbon cycle.
- **Bottleneck**: coarse spatial resolution of existing data sets.
- **Sensitivity analysis confirms great potential of TROPOMI** because of (i) better single-retrieval precision, (ii) higher spatial resolution, and (iii) higher number of clear-sky observations.
- **Instrumental errors** (straylight…) still to be evaluated.
- Also **exciting opportunities for SIF monitoring with Sentinel-5 and Sentinel-4** (analysis of diurnal cycles).

Thank you for your attention!