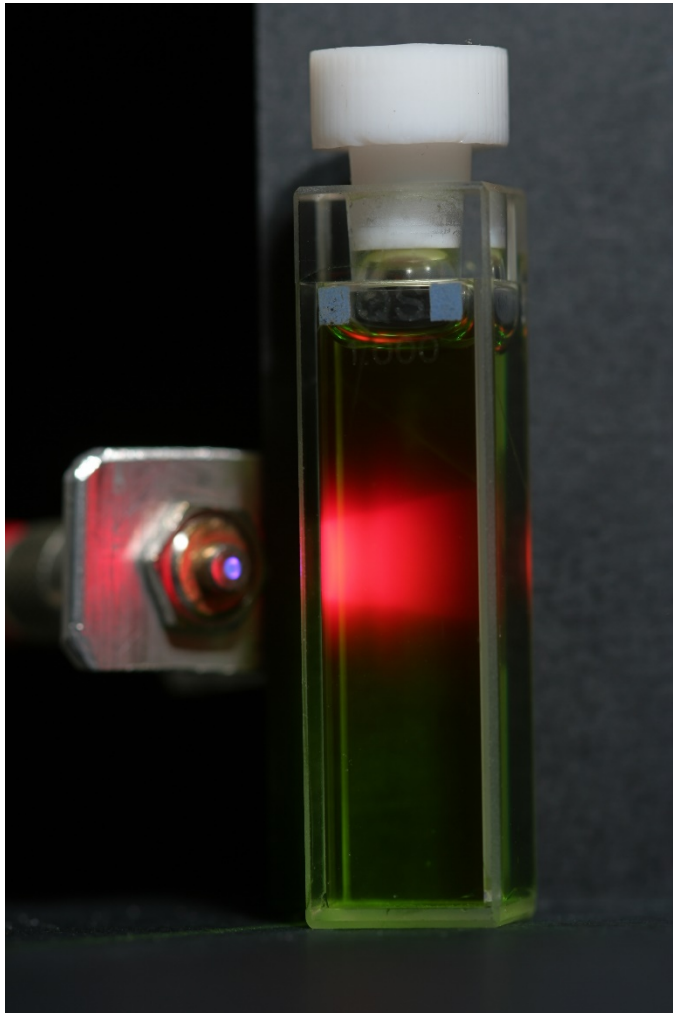


# **Directional partitioning of vertical Solar-induced fluorescence emissions for estimating ecosystem photosynthesis in a cool-temperate deciduous broadleaf forest in Japan**

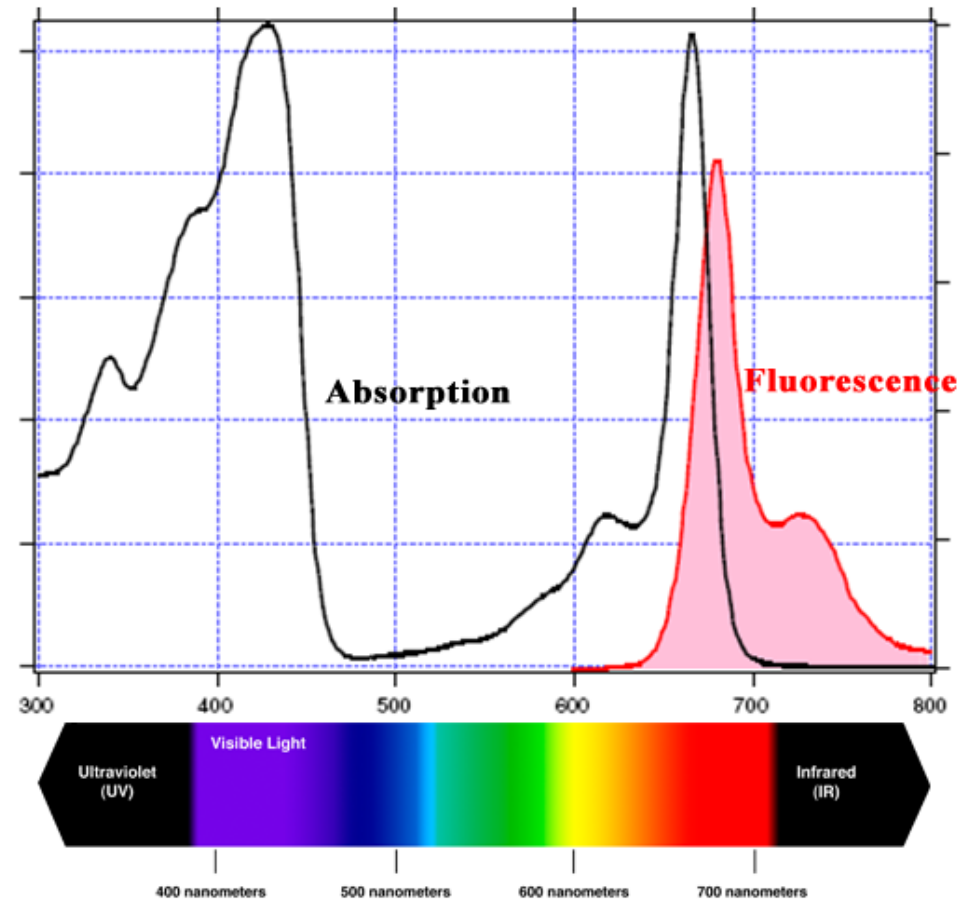
**Kato T <sup>1\*</sup>(tkato@cen.agr.hokudai.ac.jp), Sakai Y<sup>1</sup>,  
Tsujimoto K<sup>1</sup>, Nishida-Nasahara K<sup>2</sup>, Akitsu T<sup>2</sup>,  
Murayama S<sup>3</sup>, Noda H<sup>4</sup>, Muraoka H<sup>5</sup>**

**<sup>1</sup>Hokkaido Univ, <sup>2</sup>Univ of Tsukuba, <sup>3</sup>Nat Institute of Adv Industrial Sci Tech, <sup>4</sup>Nat Institute for Env Stud, <sup>5</sup>Univ of Gifu**

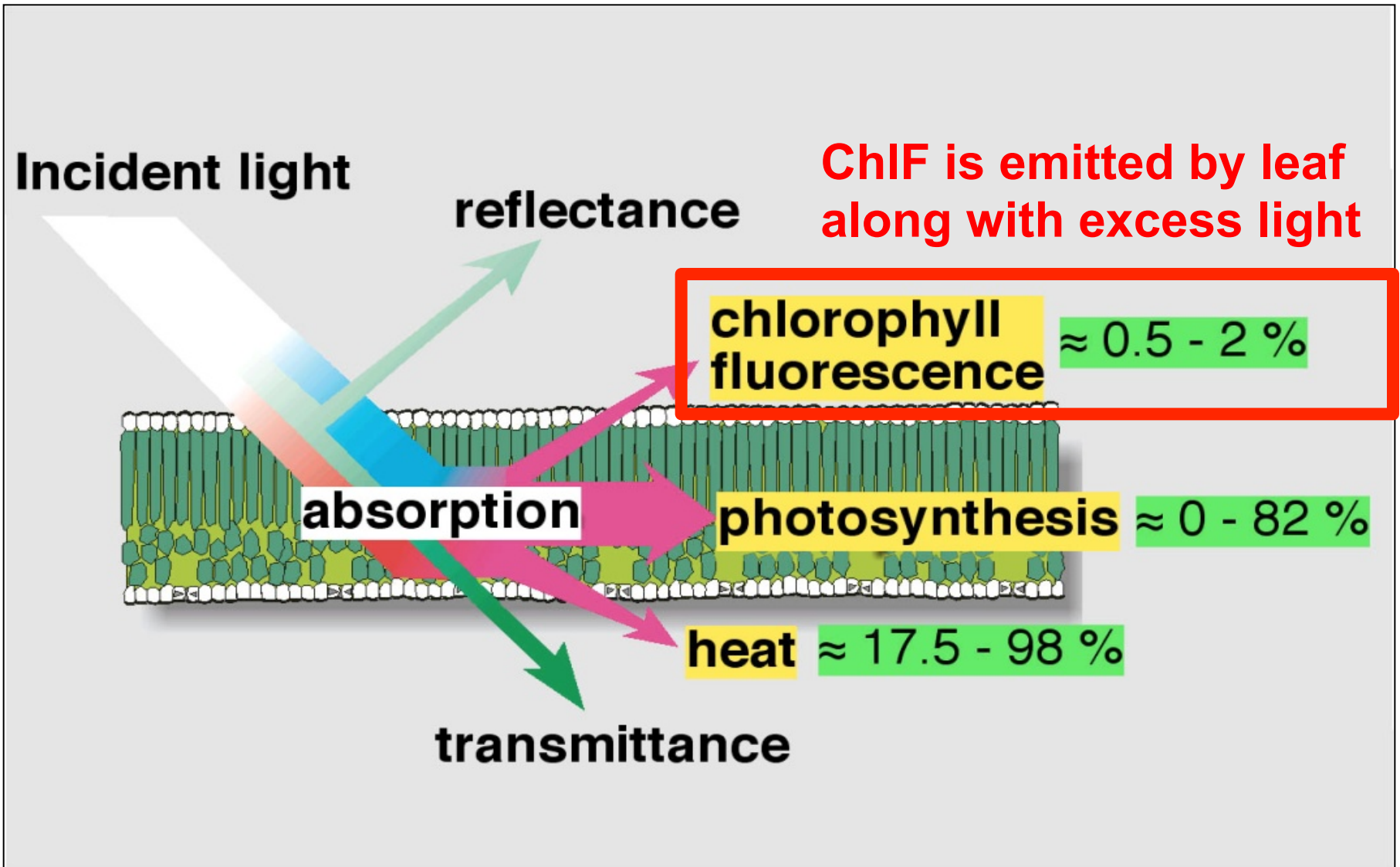
# Chlorophyll Fluorescence (ChIF)



ChIF = Red light from leaf



# Chlorophyll Fluorescence (ChlF)



# Detection of ChlF and SIF



Walz Pam series

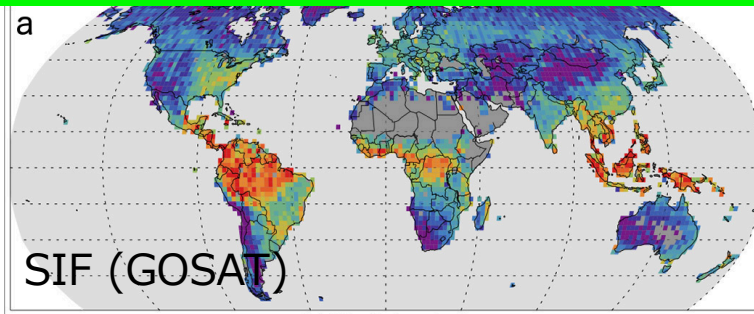
ChlF has been used for the estimation of stress under the strong flash light (Active measurement)

Recently, Passive measurement of ChlF induced by Sunlight (**SIF: Solar Induced Fluorescence**) from Satellite

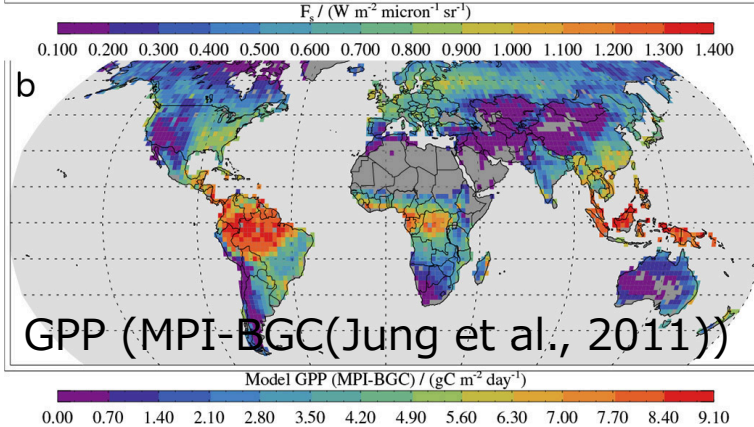


GOSAT (JAXA)

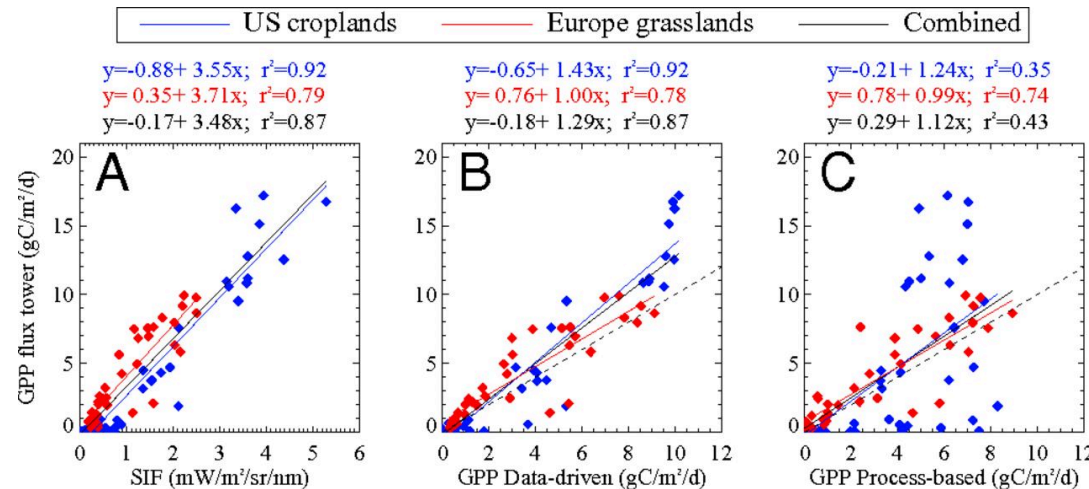
# SIF represents GPP on large scale



Guanter L et al. PNAS (2014)



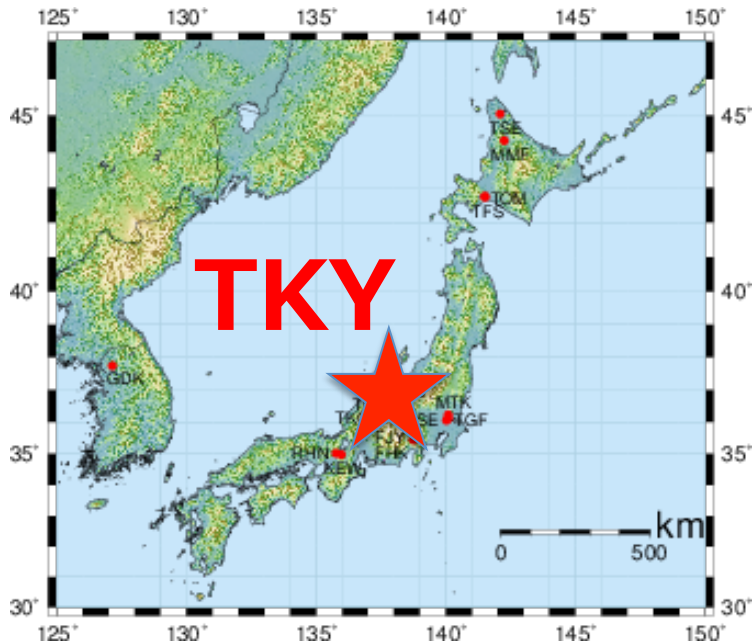
Frankenberg et al. (2011)



- Sun-Induced Fluorescence (SIF) from satellite strongly relates to the GPP on large scale ( $2^\circ \times 2^\circ$ , monthly)
- However, SIF should be more investigated its availability on finer spatio-temporal scale.
- Moreover, the contribution of lower layer in Forest ecosystems to SIF (thus, Photosynthesis) is totally unknown



# Japan has a PEN!!



Phenological Eyes Network  
(PEN)



HSSR (Hemi Spherical Spectro-Radiometer;  
MS700 spectrum radiometer (EKO) + rotater  
(Hayasaka Rikoh)

## Major sites for SIF detection

<b>TKY(Takayama)</b>	<b>Dec Broad For</b>	<b>2003-</b>
MSE(Mase)	Paddy field	2005-
TGF(Tsukuba)	Grassland	2003-
FHK(Fuji)	Dec Nd For	2006-
TKC(Takayama)	Eve Nd For	2007-
To be added .....		

**Aim: To evaluate how the different vertical layers would contribute SIF emission and potentially production in forest ecosystem**

# Deciduous Broadleaf Forest(TKY)



## Site info:

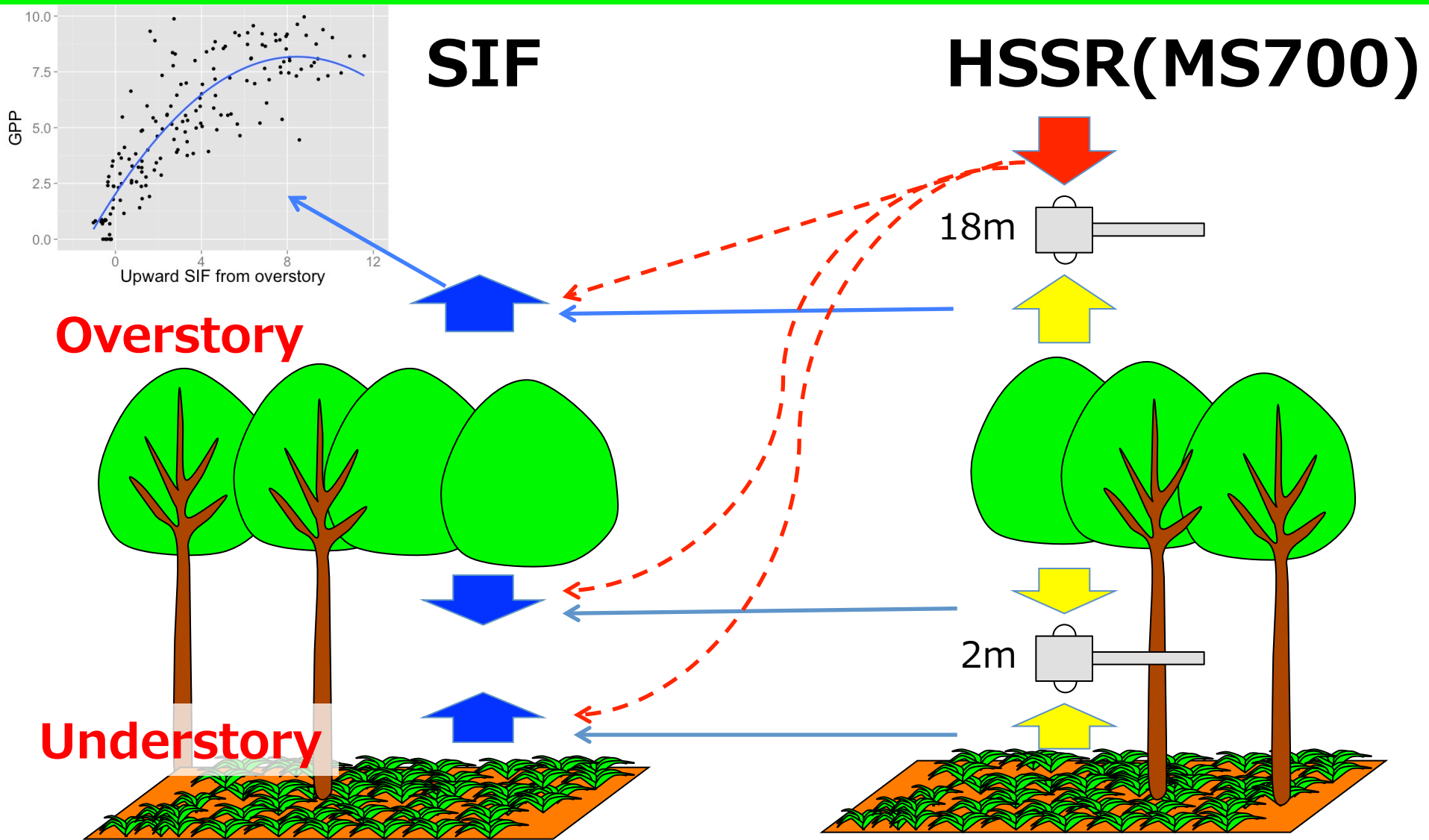
36°08' N, 137°25' E  
1420 m a.s.l.  
Mean  $T_{\text{air}}$ : 12.5 °C  
Prec: 2275 mm/yr  
LAI: 5-7 (max)



## Spectrum data info:

Range: 300-1150nm  
Interval: 3.3nm  
FWHM: 10 nm  
Rotate interval: 10 mins  
Target: O<sub>2</sub>-A band  
SIF calc: aFLD method

# Multi-directional SIF detection



**Assumption: Ref/Trns/Abs ratios are horizontally same**

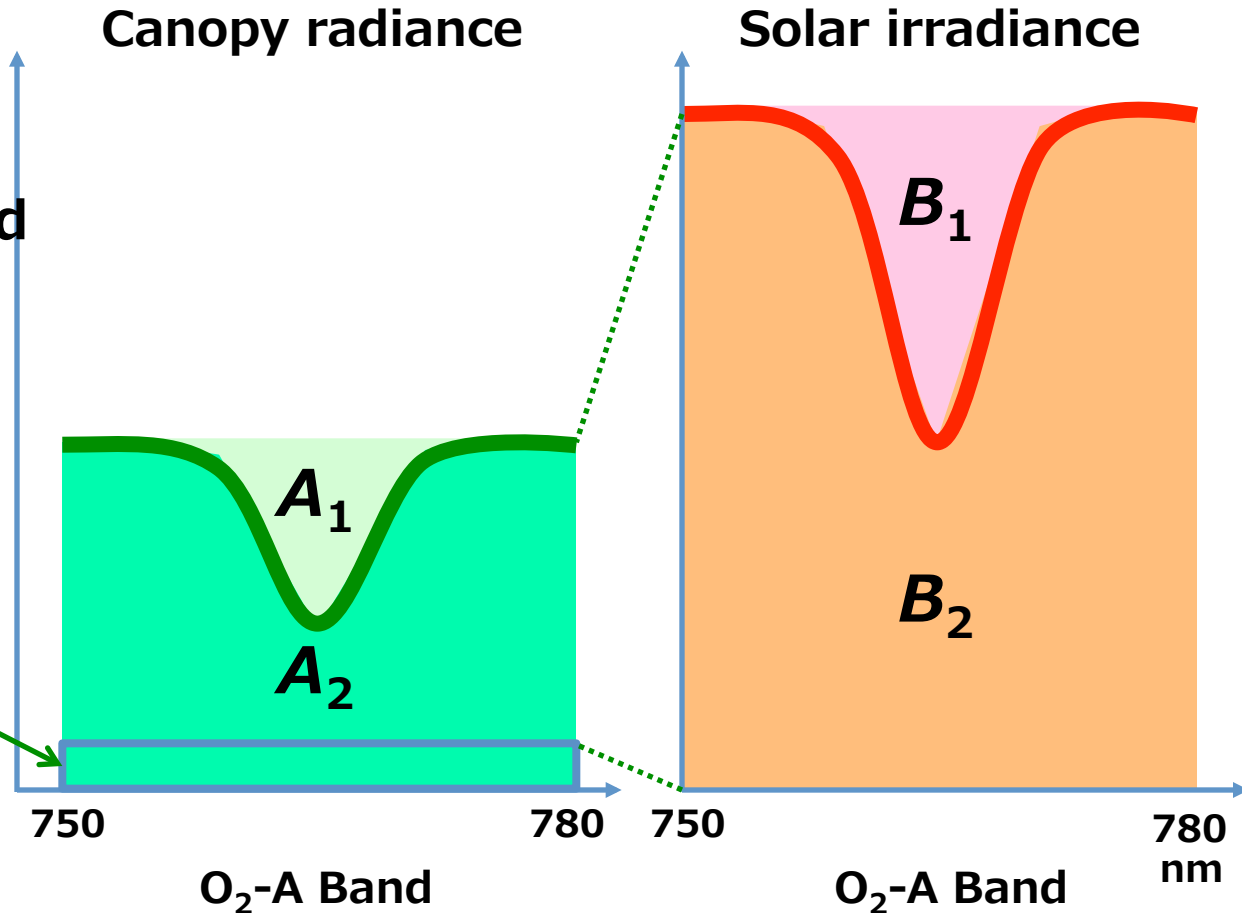


# Area-ratio Fraunhofer Line Discrimination (aFLD) method

To overcome the moderate precision on spectrum detection by HSSR, aFLD was applied newly here to SIF calc

**SIF**

$$SIF = A_2 - \frac{A_1}{B_1} \cdot B_2$$



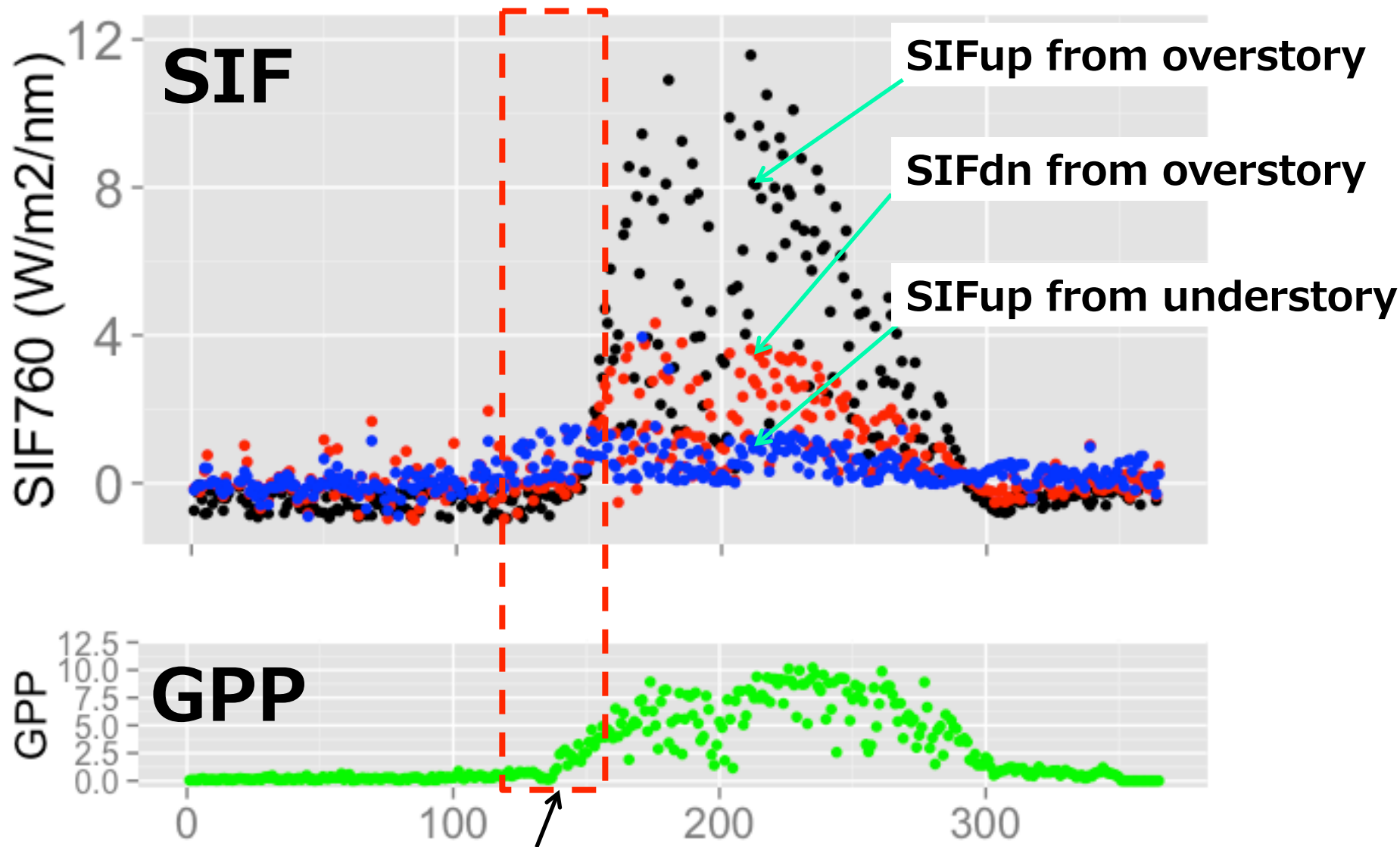
Kato, Tsujimoto, et al. in prep

SIF: Chlorophyll Fluorescence

$A_1, A_2$ : Area of upper and lower parts for canopy radiance around O<sub>2</sub>-A bands

$B_1, B_2$ : Area of upper and lower parts for solar irradiance around O<sub>2</sub>-A bands

# Seasonal Trend in SIF<sub>760</sub> (2006)



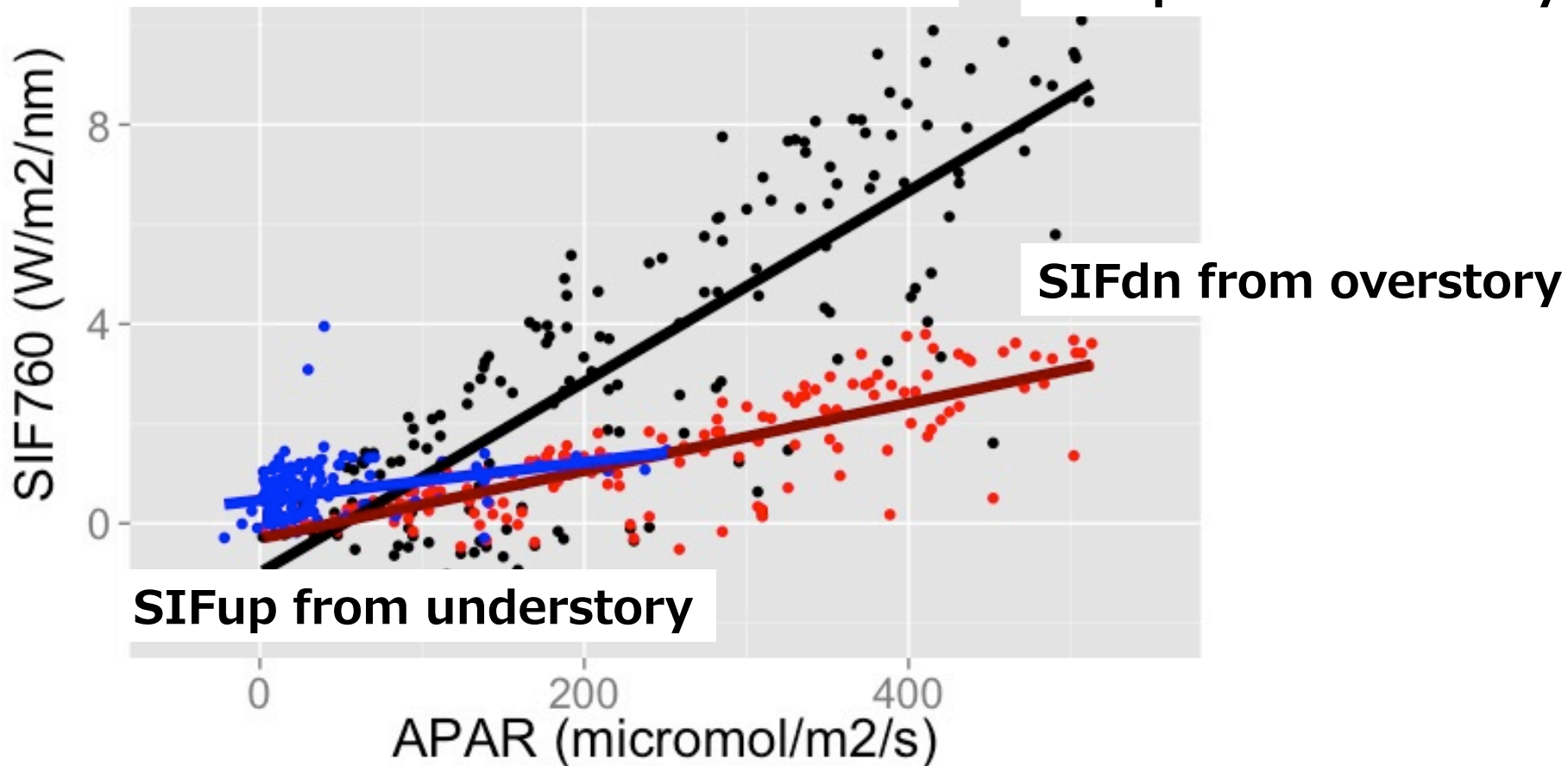
**Early onset of SIF from understory supported onset of GPP in May**

# SIF<sub>760</sub> vs. APAR ( $T_{\text{air}} > 10^{\circ}\text{C}$ , 2006)

$$\text{SIF} = -1.59 + 19.39 * 10^{-3} * \text{APAR}, r^2 = 0.69$$

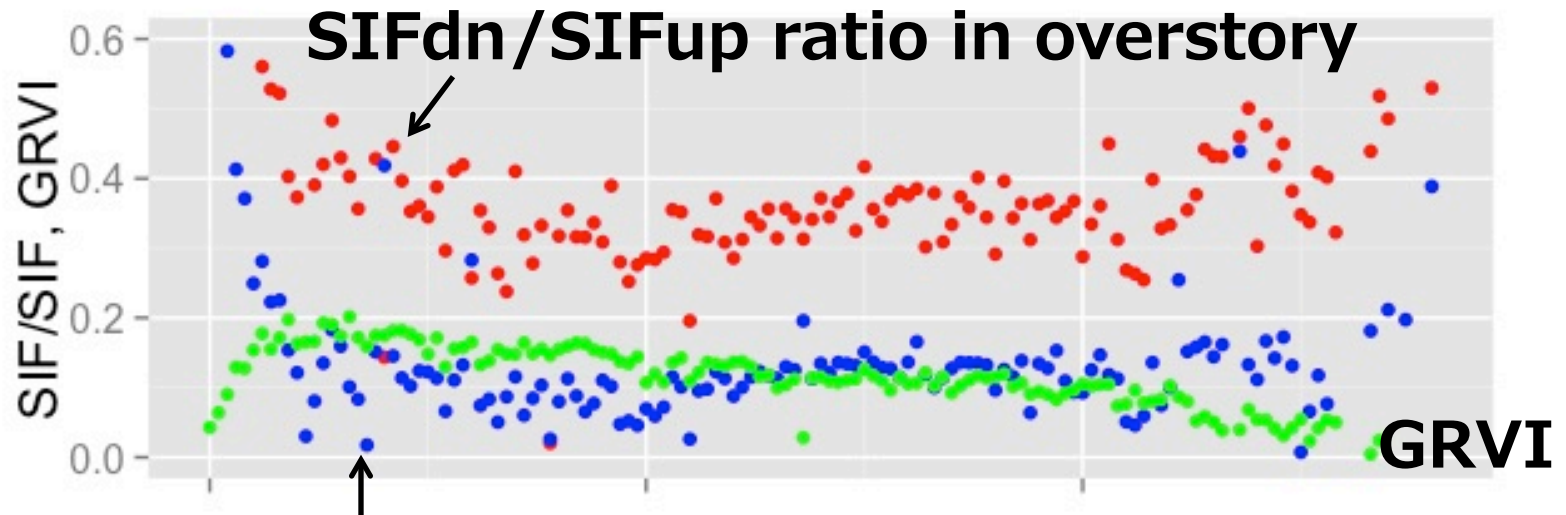
$$\text{SIF} = -0.316 + 6.86 * 10^{-3} * \text{APAR}, r^2 = 0.72$$

$$\text{SIF} = 0.466 + 3.81 * 10^{-3} * \text{APAR}, r^2 = 0.10$$

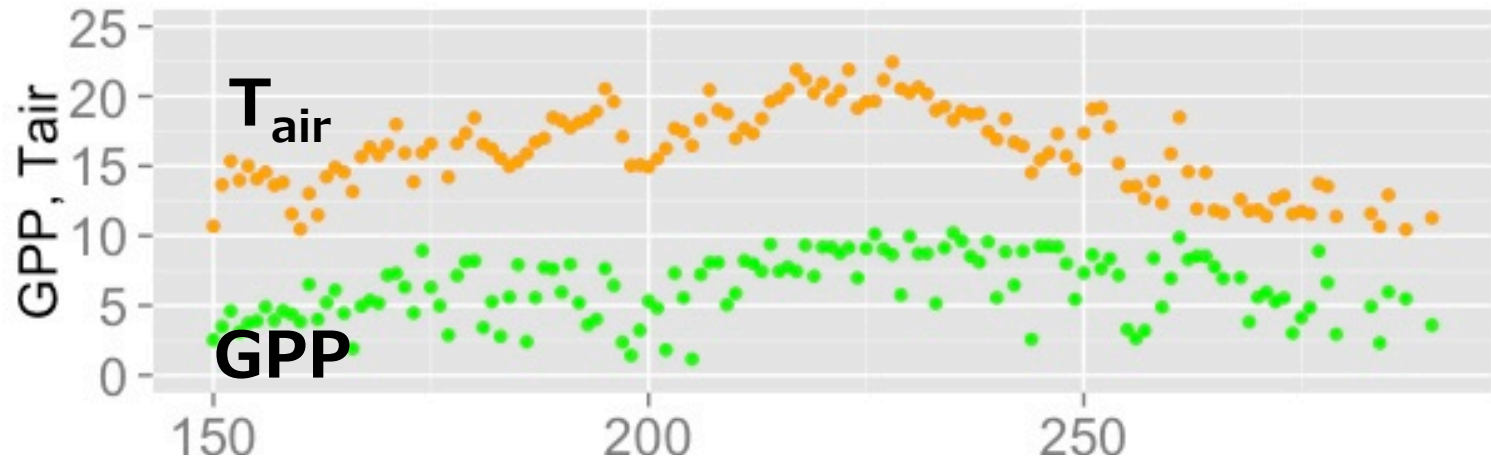


**Steeper slope of upward SIF in overstory:  
Stronger photoinhibition in top-canopy & sunlit side**

# Vertical SIF ratio in GS



**Understory/Overstory ratio in SIFup**



**Seasonal change in multi-dir. SIF ratio may reflect phenological shift in foliage chemistry**



# Overstory vs. Understory

	This study (2006)				Ohtsuka et al. (2007) Ecosystems	
	SIF <sub>760</sub>		APAR		NPP (Biometric)	
	W/m <sup>2</sup> /nm	%	μmol/m <sup>2</sup> /s	%	MgC/ha/yr	%
Overstory	<b>0.78</b> (up) 0.54 (dn)	70 ---	156.0	82	5.4	83
Understory	0.34 (up) --- (dn)	30 ---	35.0	18	1.1	17
Total	1.12 (up) --- (dn)	100 ---	191.0	100	6.5	100

- **43% higher upward SIF from overstory showed high contribution of sunlit tissue and leaves in top canopy**
- **Large contribution of understory in upward SIF may indicate less photoinhibition relatively to overstory**

# Summary

- **Multi-directional SIF<sub>760</sub> observation depicts the role of downward SIF emission from overstory and upward SIF emission from understory in Forest for the first time.**
- **Relative contribution of SIFs could reveal the physiological and phenological change in foliage chemistry and photosynthetic activity.**
- **Further investigation should be made by both field measurement and modeling**

# **Thank you for your attention!!**

**·This study is supported by**

**JSPS Kaken-hi Grant-in-Aid for Exploratory  
Research No. 15K12182**

**JSPS Kaken-hi Grant-in-Aid for Scientific  
Research (B) No. 16H02948**

**SUISHIN-HI of the Ministry of the  
Environment (MOE) of Japan, No. 2RF-1601**