An Automated Chamber Network for Evaluation of Carbon Budget of Asian Terrestrial Ecosystems

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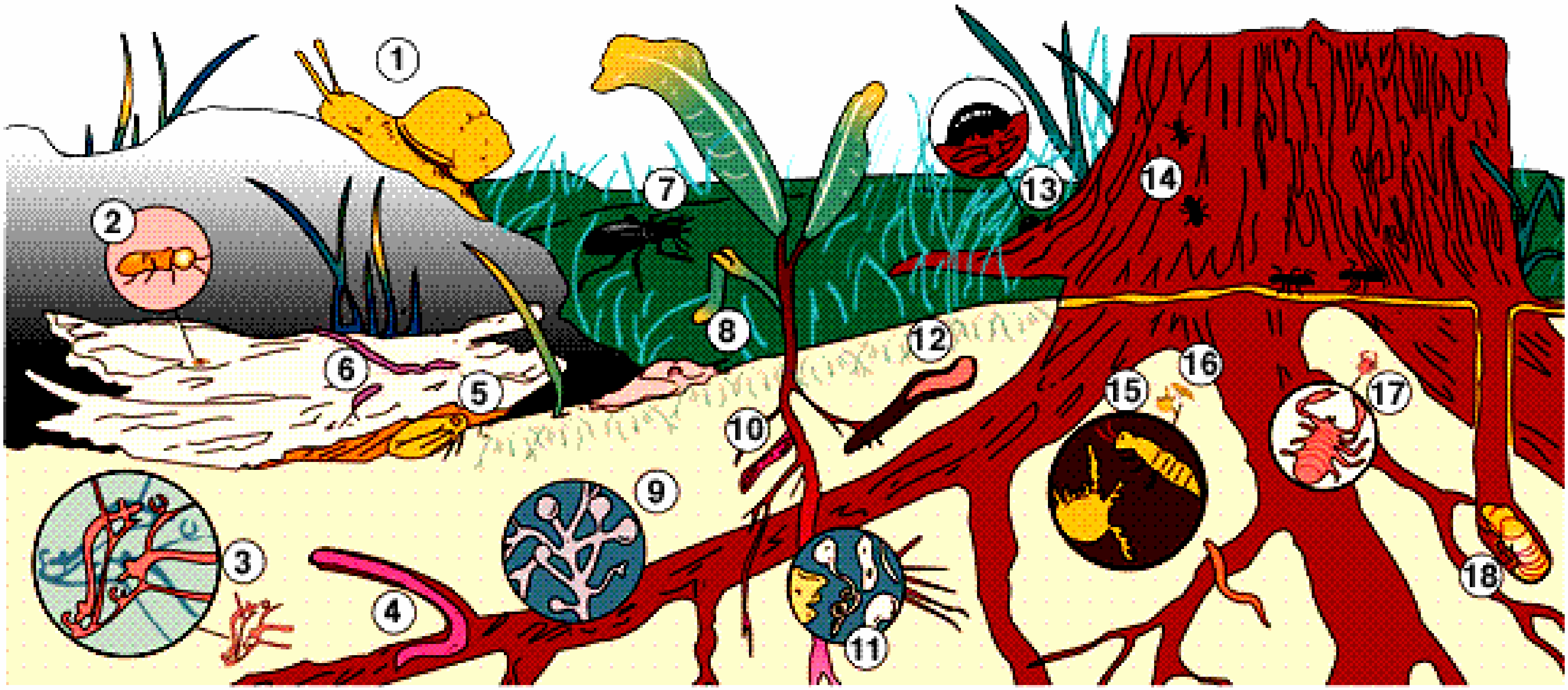
Outline

1. **What (is soil respiratio (Rs))**
2. **Why (study on Rs)**
3. **How (chamber network)**
4. **Find (results)**
5. **Future (plan)**

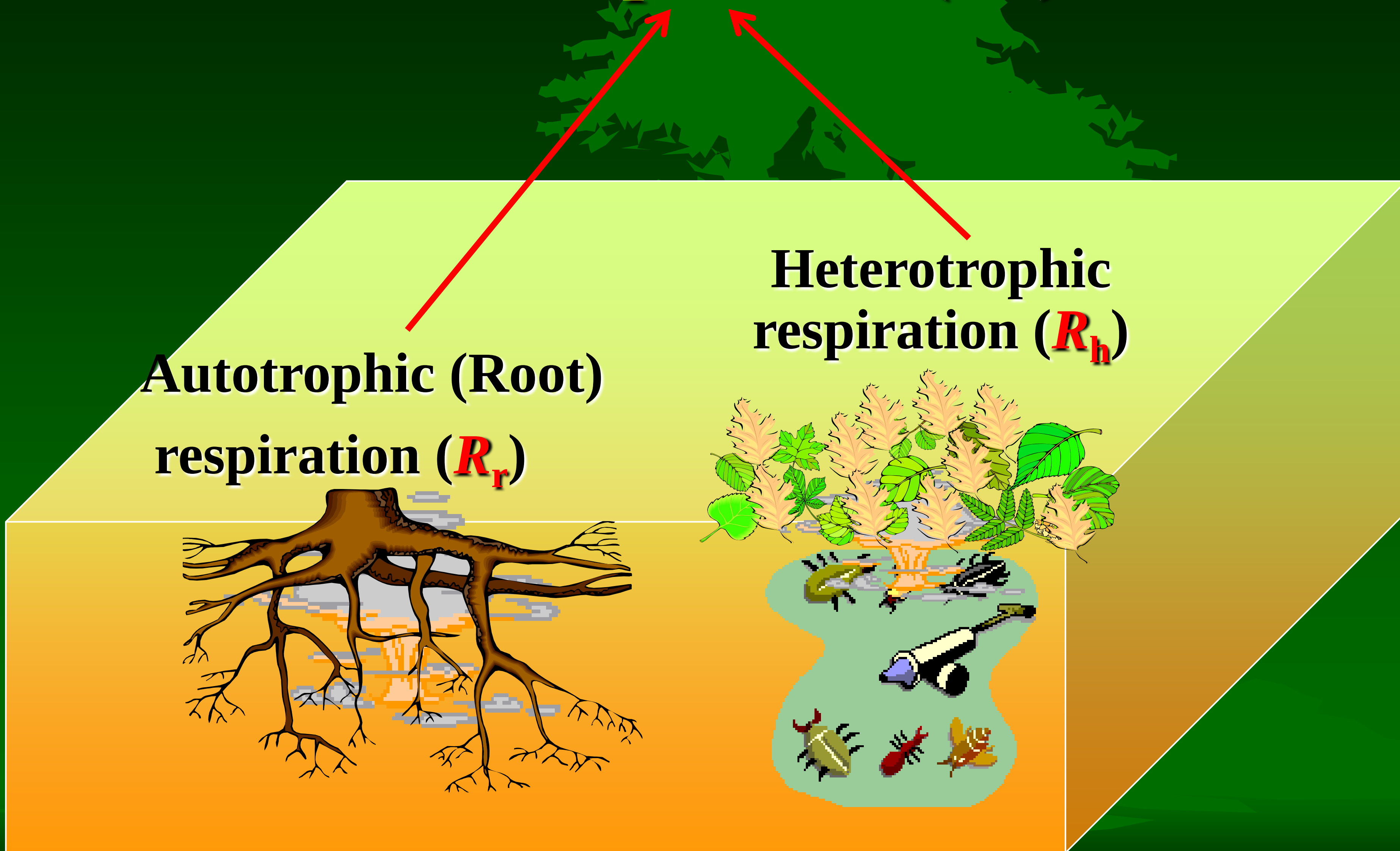
Soil Ecosystem

includes roots and numerous consumer organisms



Cunninghum & Caigo, 1999. Environmental Science: A Global Concern, 5e

Soil Respiration (Rs)



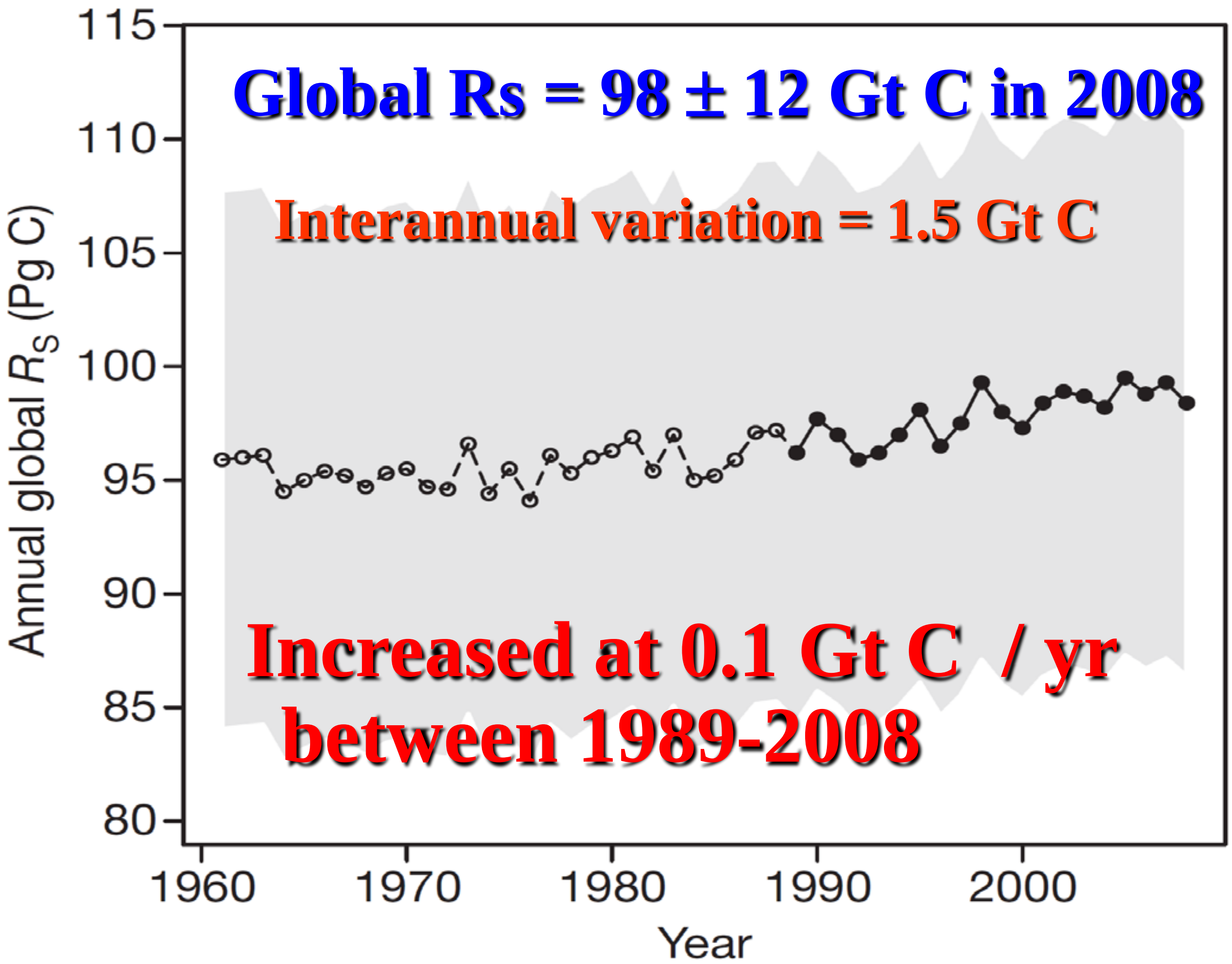


Figure 2 | Estimated annual global R_S. The dashed line indicates results outside the time period covered by main data set, S1 (1989–2008), but within the period covered by the entire R_S database, S0 (1961–2008), and should be considered speculative. The grey region shows the standard deviation of the Monte Carlo simulations ($N = 1{,}000$). **Nature, 464: 579-582 (25 March 2010)**

Global Heterotrophic Respiration (Rh)

Potter & Klooster 1998 (*GBC*); IPCC2007

by CASA model

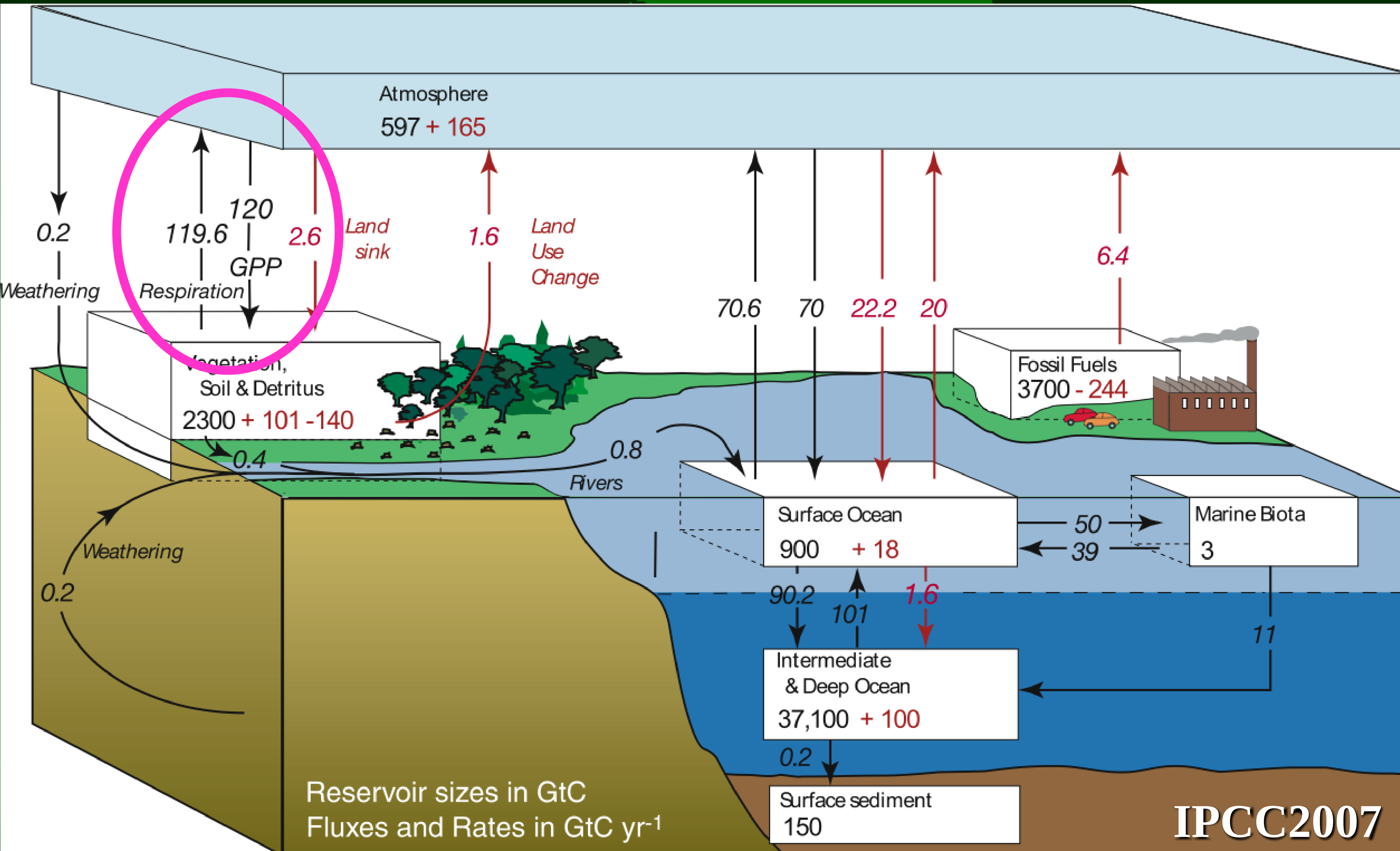
Global Rh = 71% of Rs (69.6 Gt C y^{-1})

10 times of fossil fuel emission (7.2 GtC y^{-1})

30 times of land C sink (2.6 GtC y^{-1})

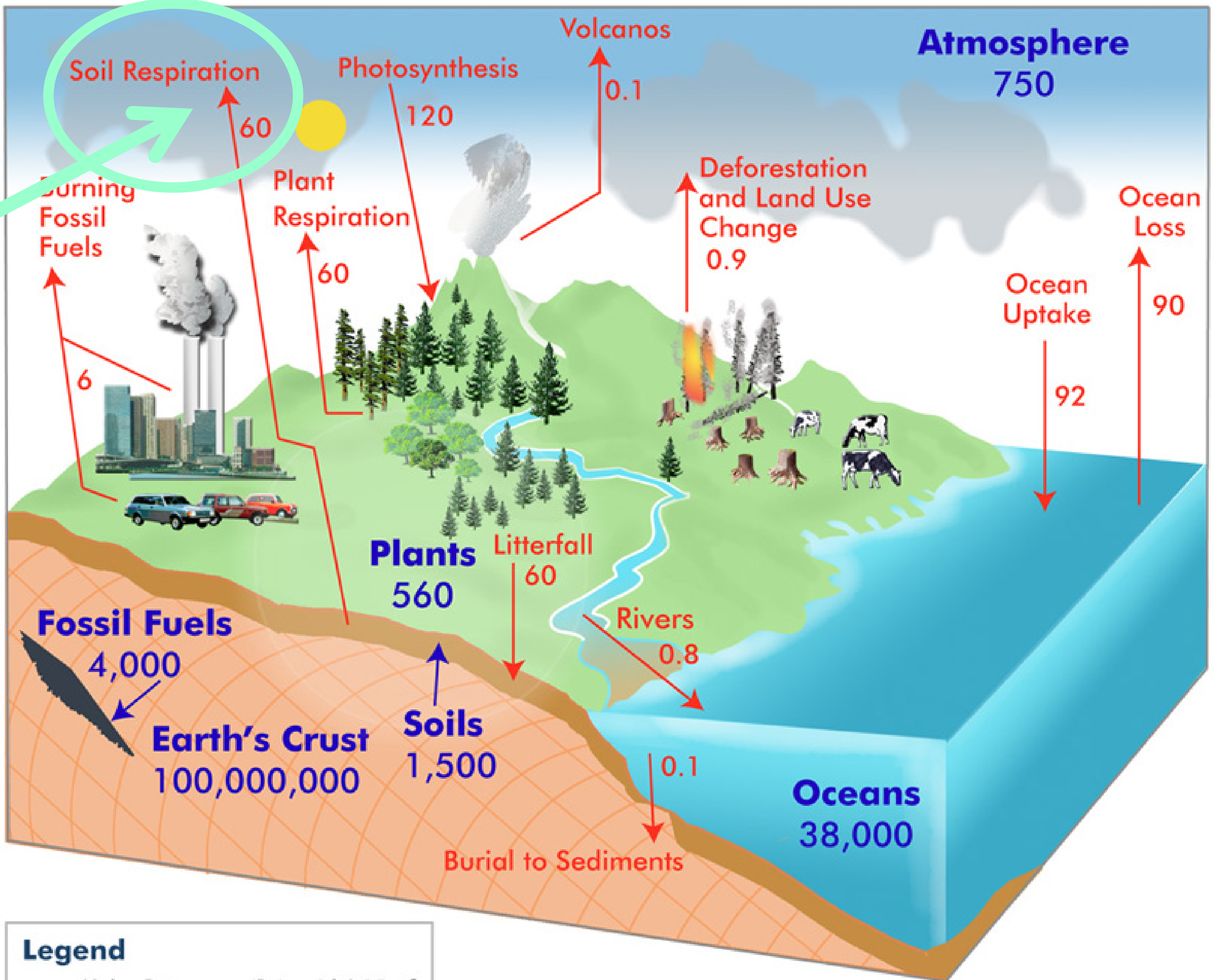
☞ **Plays a key role in global carbon cycle**

Global Carbon Balance



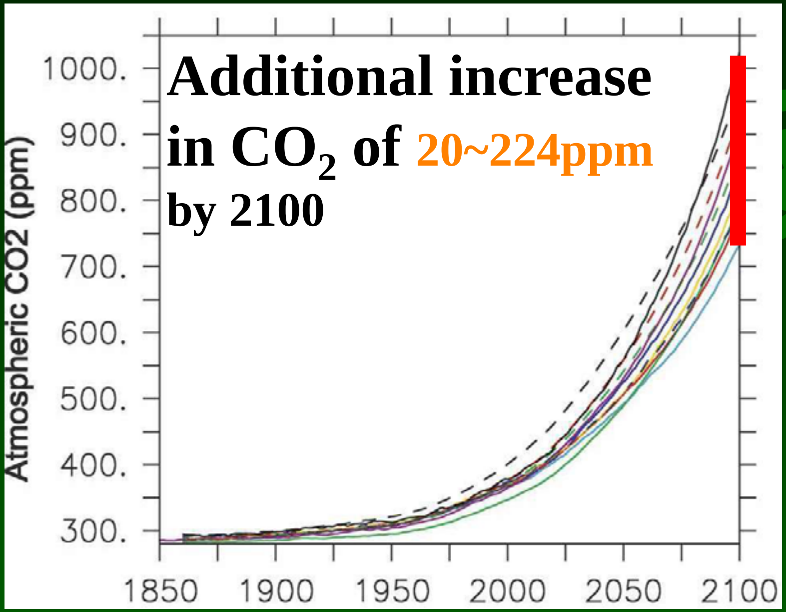
Global Carbon Cycle

Rh = 70



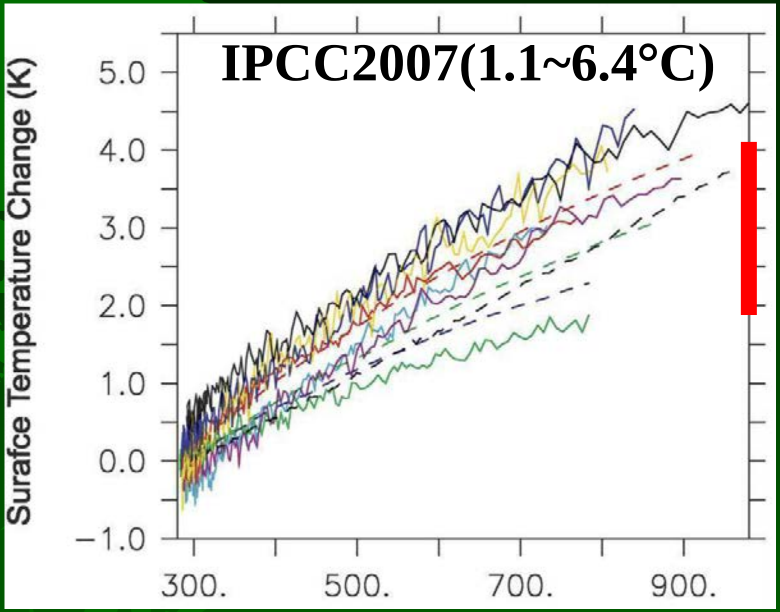
Feedback of Heterotrophic Respiration to Global Warming

(Friedlingstein et al. 2006; IPCC 2007)



Vicious cycle

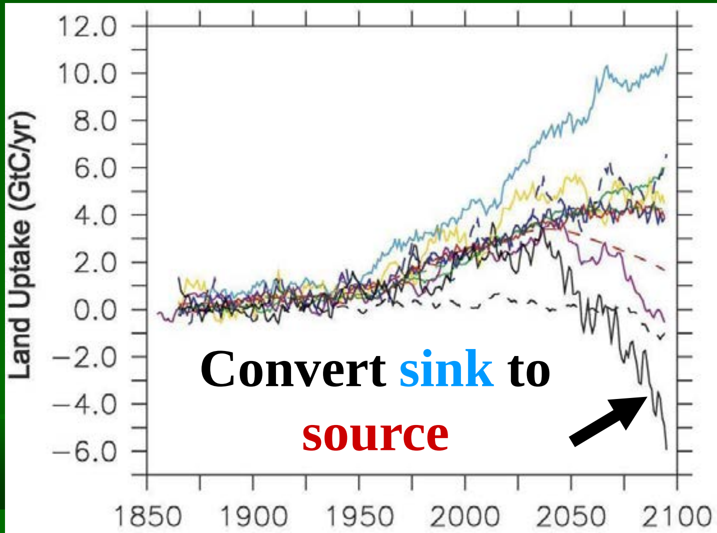
0.1~1.5°C



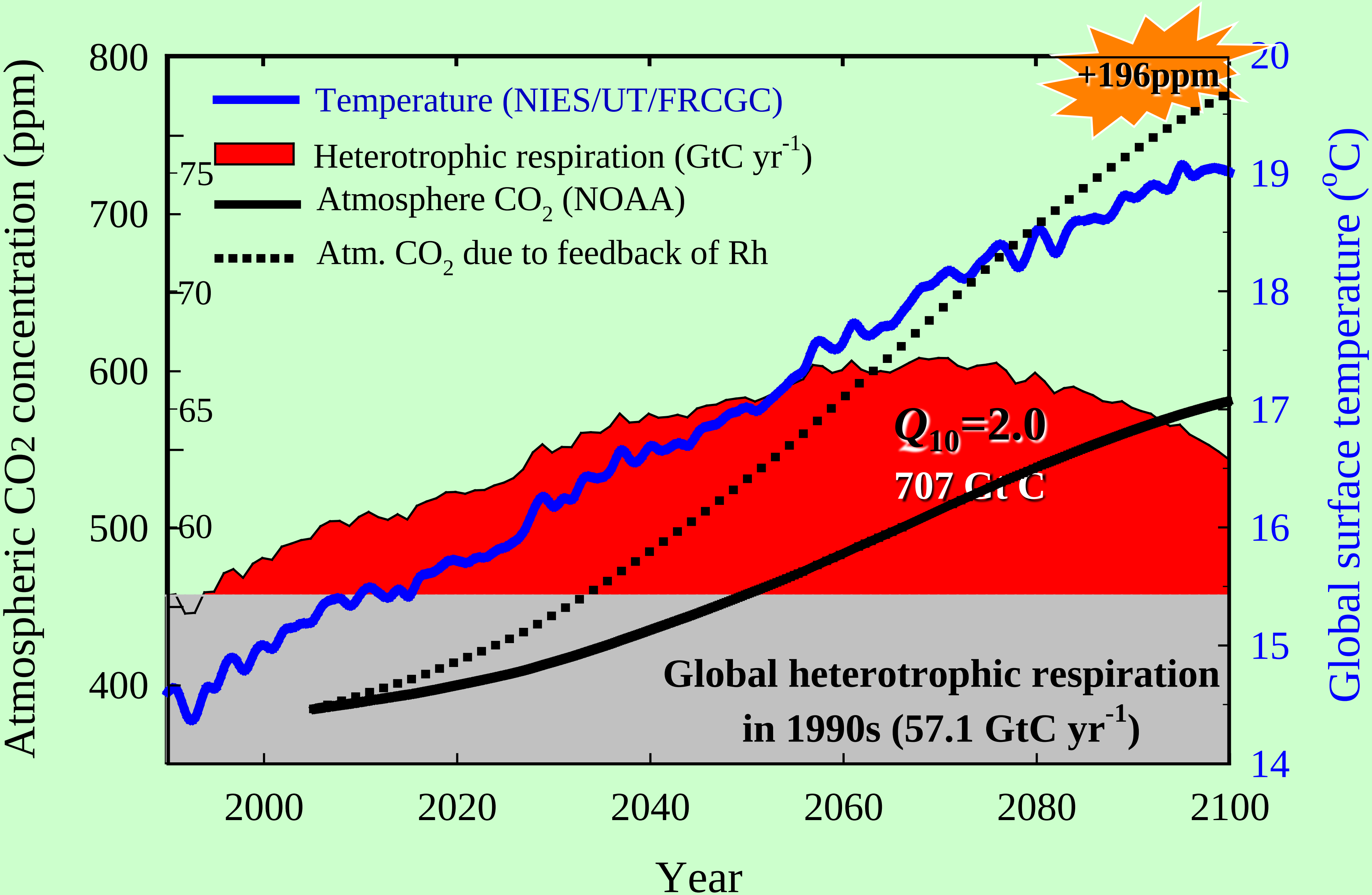
Heterotrophic respiration

Q_{10}=1.1~2.2

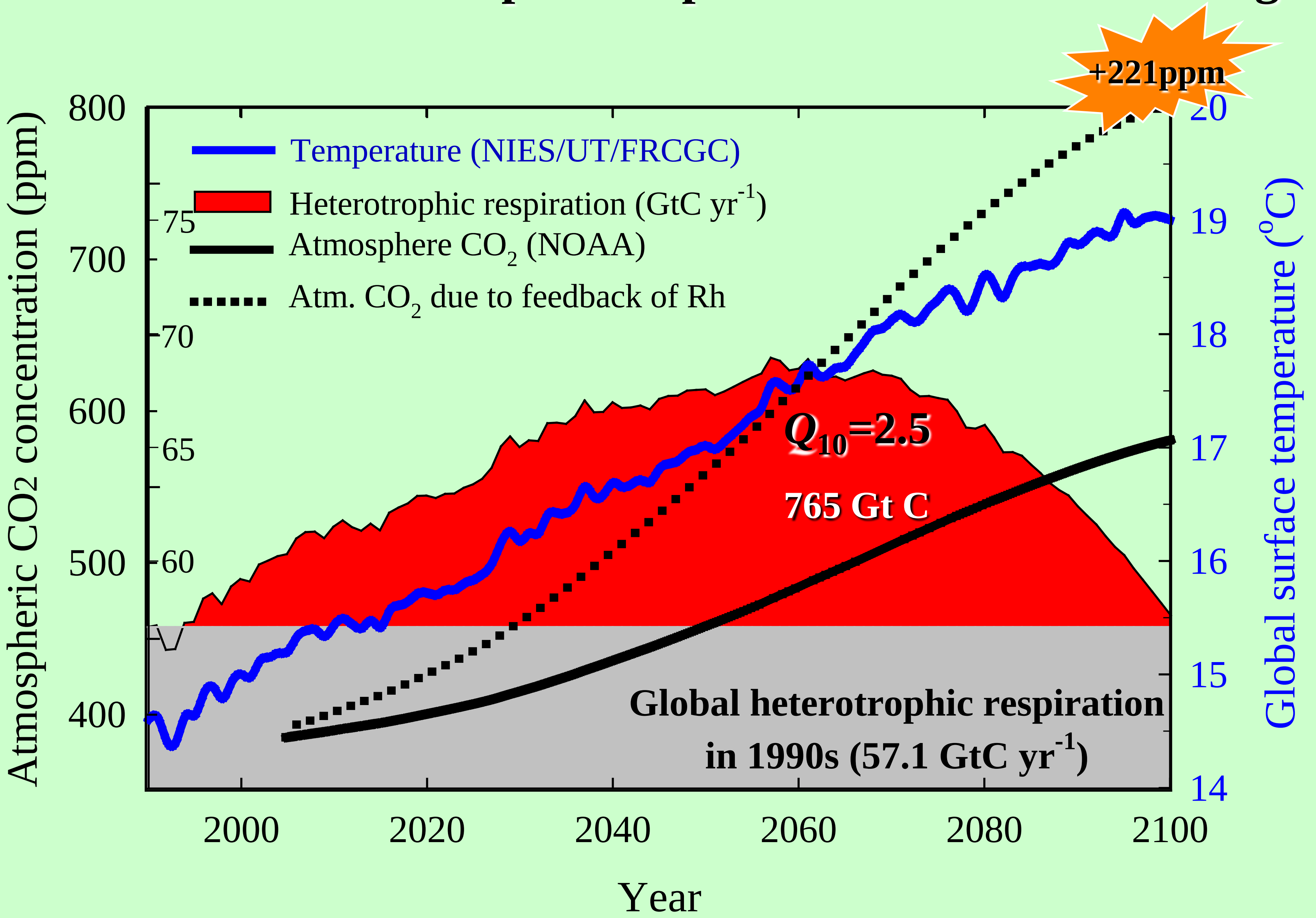
Positive feedback



Feedback of Heterotrophic Respiration to Global Warming



Feedback of Heterotrophic Respiration to Global Warming



Open Questions

- **With global warming, will Asian terrestrial ecosystems continuous be carbon sink?**
- **or potentially convert to carbon source?**

Eddy Covariance for Soil Respiration

Bare soil site

Eddy Covariance

- Daytime: underestimation
- Nighttime: overestimation

Chamber Methods

- **Static Chamber**
  - Alkali Soda lime
  - Syringe
- **Dynamic Chamber**
  - Steady state
    - Open-top
    - Closed-top
  - Non-steady state
    - Commodity

Static Chamber Technique

Alkali Absorption Method

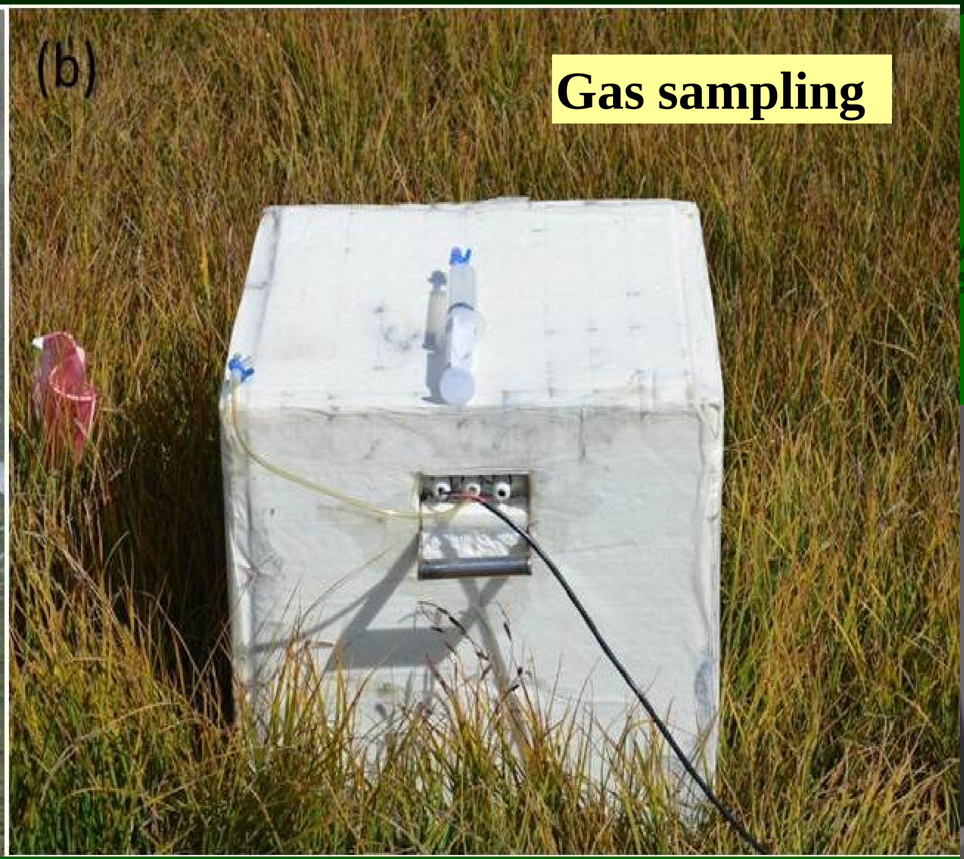
Science Camp for High School Students

July 27-29, 2004 in Tomakomai

ChinaFlux


阜康站
内蒙古站
老山
三江站
长白山站
沈阳站
海北站
禹城站
盐亭站
东湖站
常熟站
桃源
千烟洲站
鼎湖山站
鹤山站
西双版纳站
Eddy
Chamber site

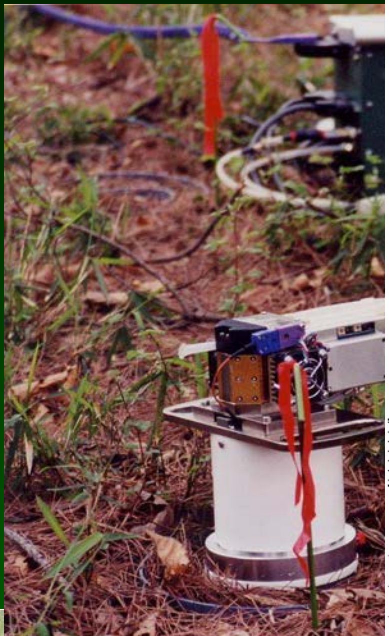
Manual static chamber-GC method



Sampling frequency: once a week

Time: 9:00-12:00

Co ent



御　見　積　書

No, INO-094

年　　月　　日

独立行政法人
国立環境研究所　御中

下記の通り御見積申し上げます。

会社

製造会社名 ：　　　　　株式会社
納　　　期 ：　受注後　　日の予定
御支払条件 ：　現金払
御見積有効期間 ：　６０　日

4-2323
9-0811
0-7702
8-0561

御見積金額合計　¥17,662,890._

型式　品　名	数　量	価格 単　価	価格 合　計
LI-8100　全自動土壌呼吸測定システム	1 台	35,000._	2,850,000._
LI-8150-16　マルチプレクサー（LI-8100用）	1 台	12,000._	3,400,000._
8100-104/16　ロングタームチャンバー16個セット	1 セット	11,200,000._	11,200,000._
小　計			17,450,000._
値　引			- 628,200._
合　計			16,821,800._
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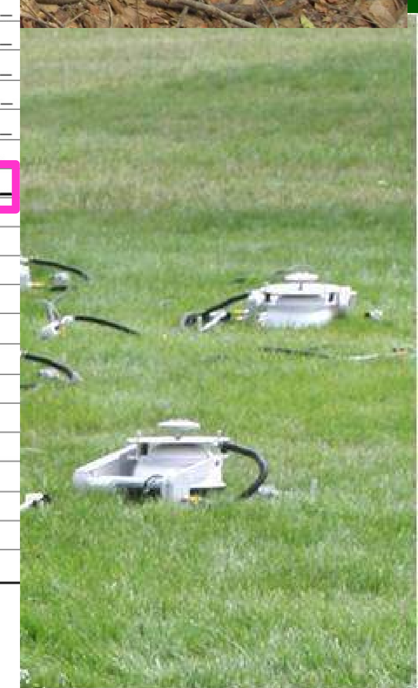
総　計			¥17,662,890._

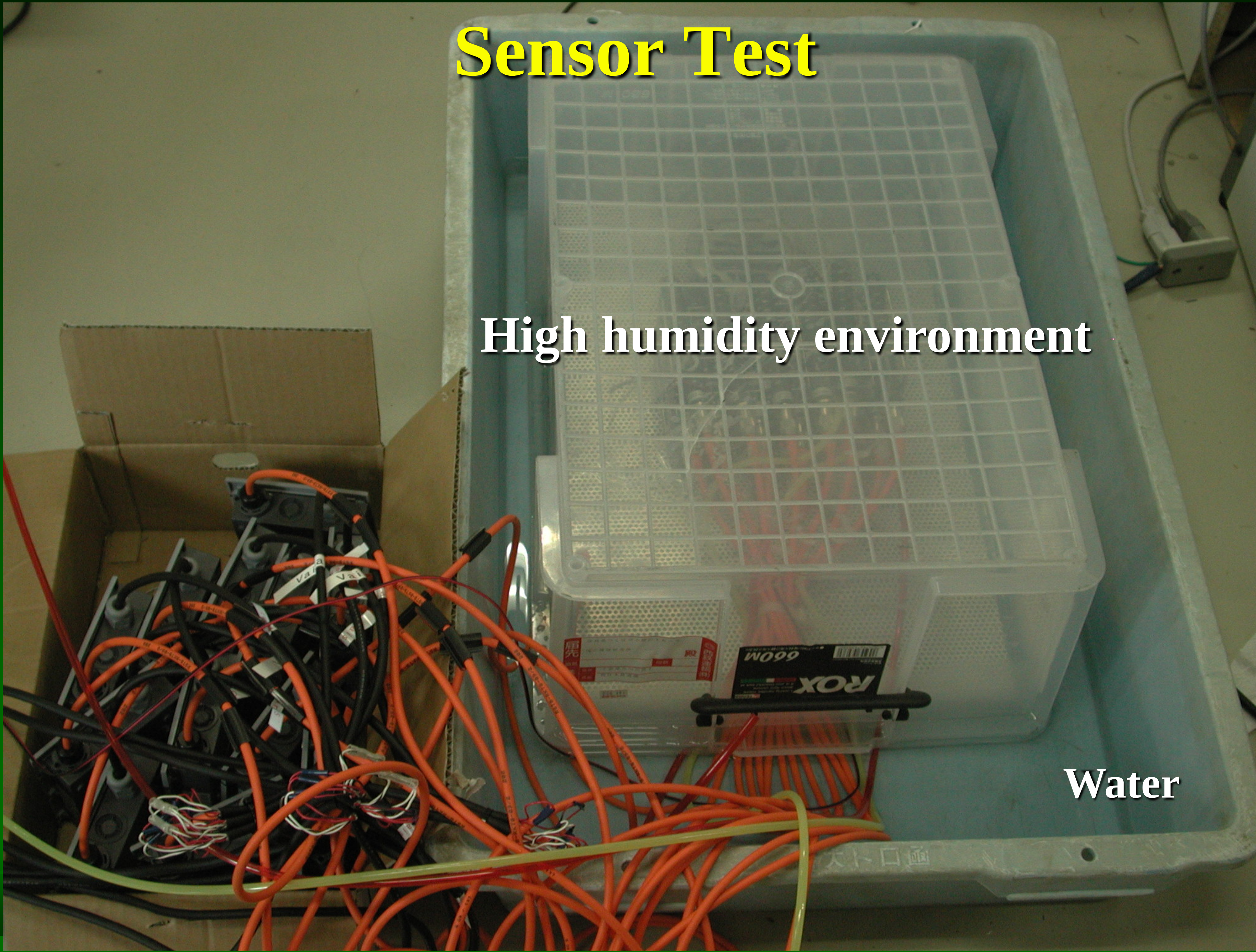
上記見積中には据付、試運転、整備又は調整等に関する費用は原則として含まれて居りません。
御契約に際し下記による訂正御承認賜り度御願い申し上げます。

担当者

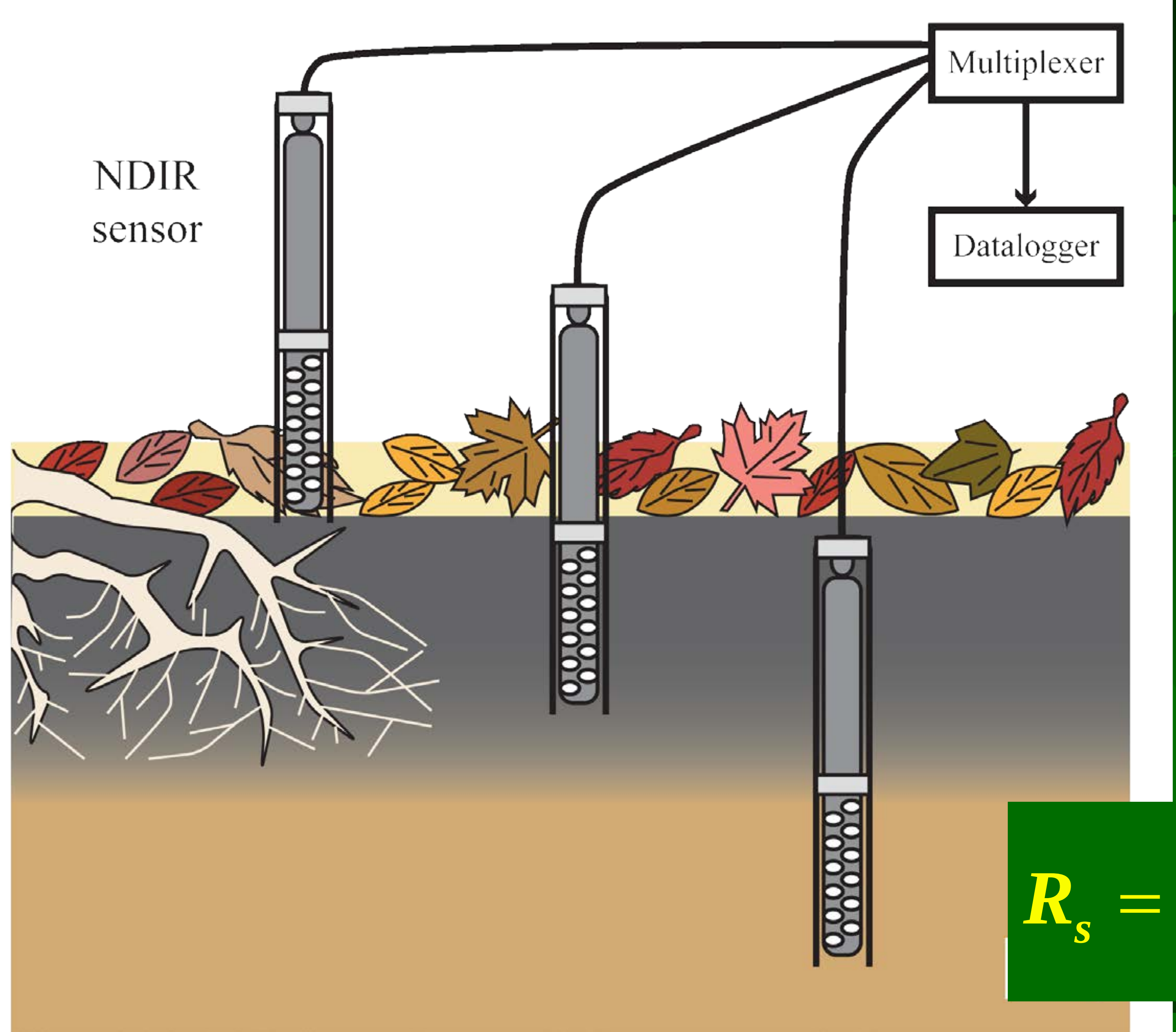


Soil CO_2 Gradient Technique

Sensor Test

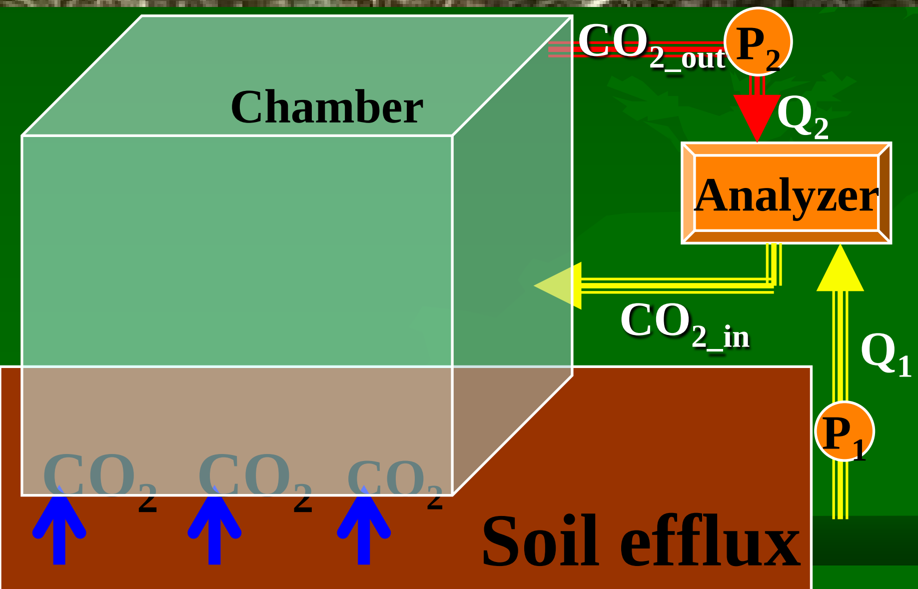


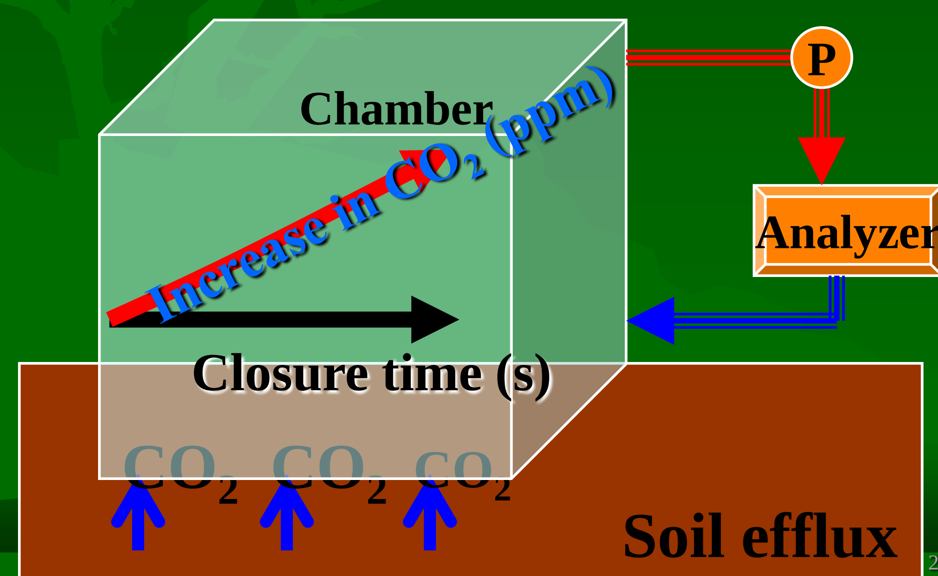
Soil CO_2 Gradient Technique

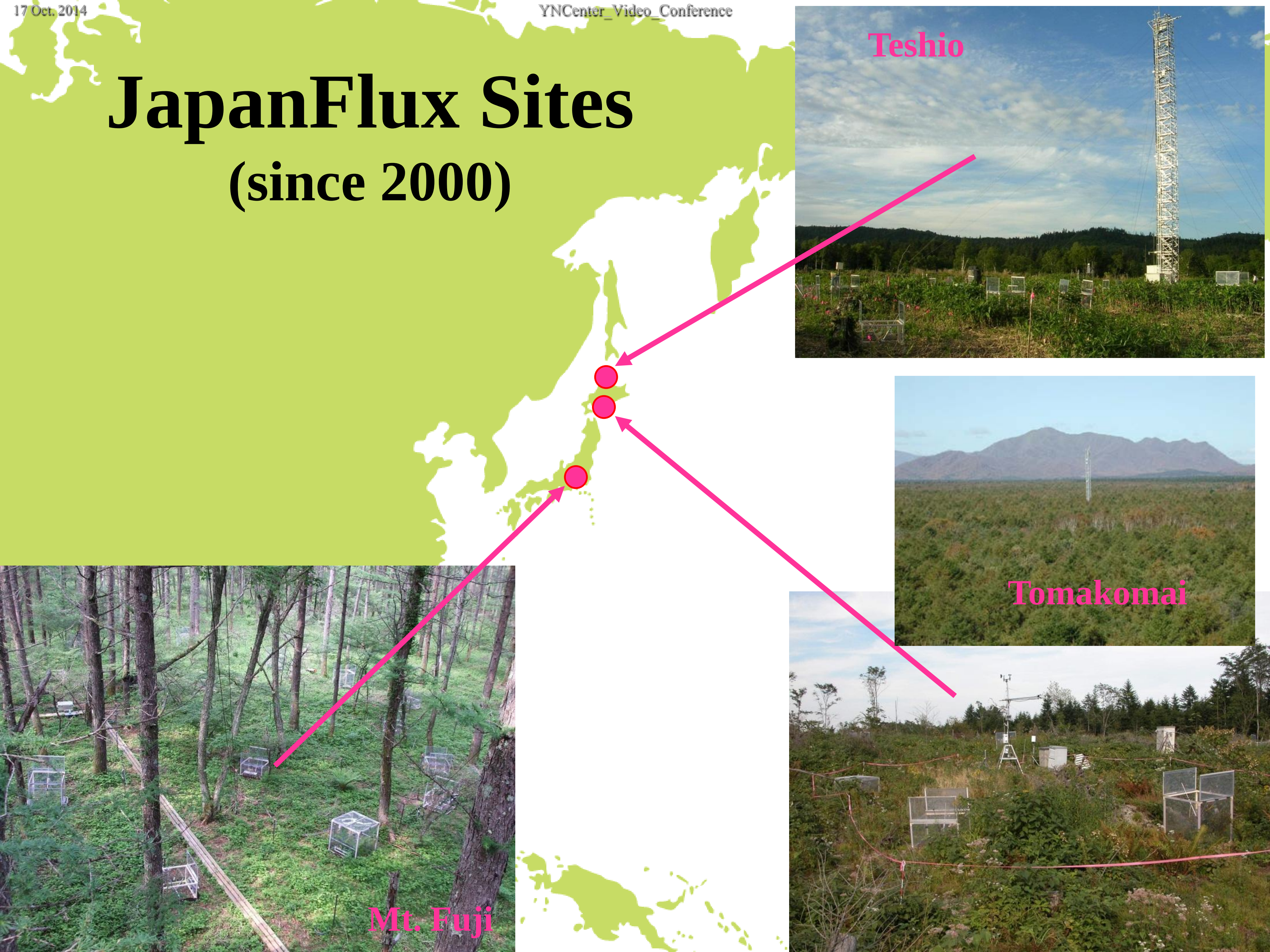


$$R_s = -D\frac{\partial C}{\partial X}$$

Automated Chambers for AsiaFlux

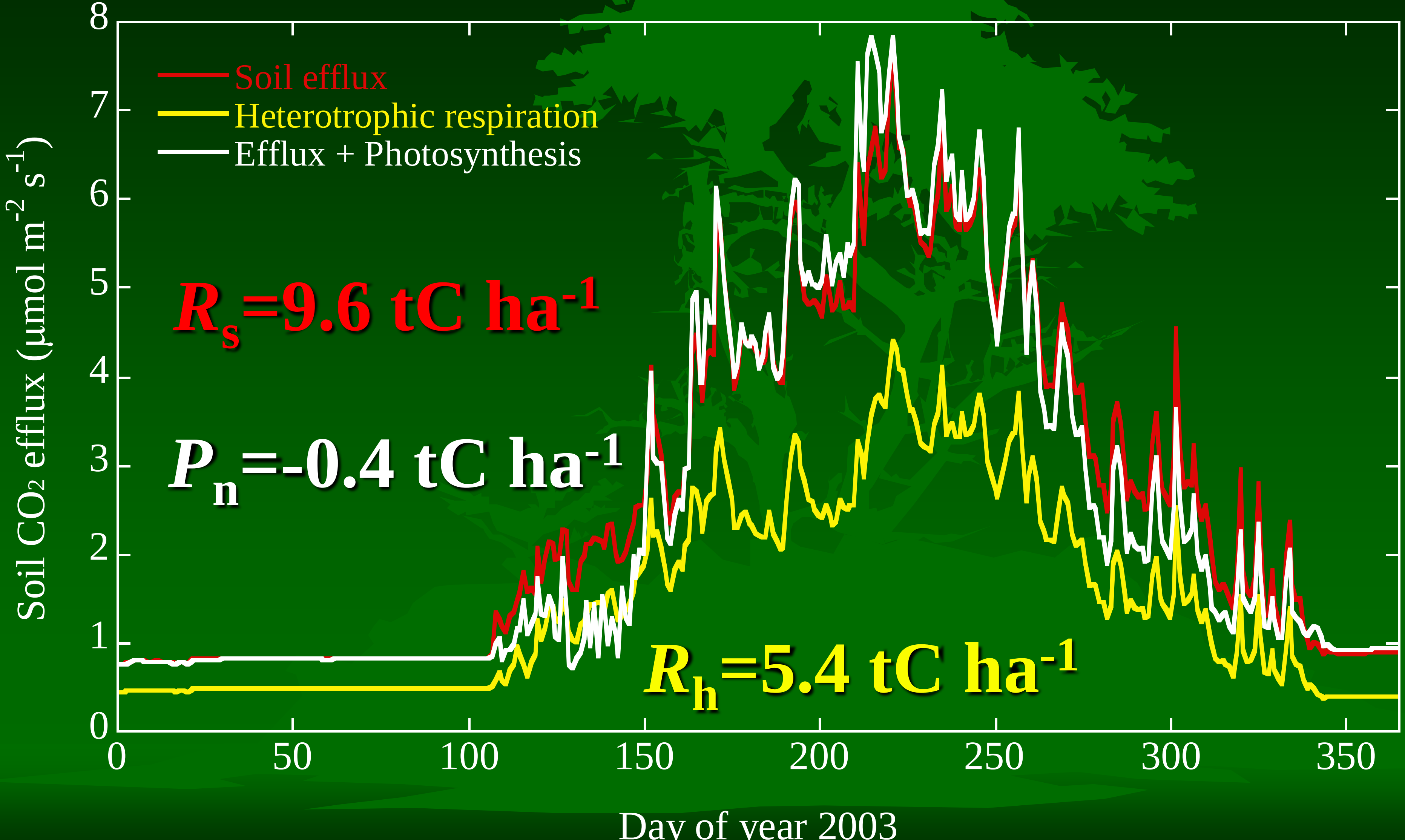





JapanFlux Sites
(since 2000)
Teshio
Tomakomai
Mt. Fuji

Tomakomai Flux Site Before Tyhoon Disturbance (2000-2004)

Soil Efflux, Heterotrophic Respiration, Understory Photosynthesis at Tomakomai



High temporal & Spatial Variations

N. Liang et al. / Agricultural and Forest Meteorology 123 (2004) 97–117 111

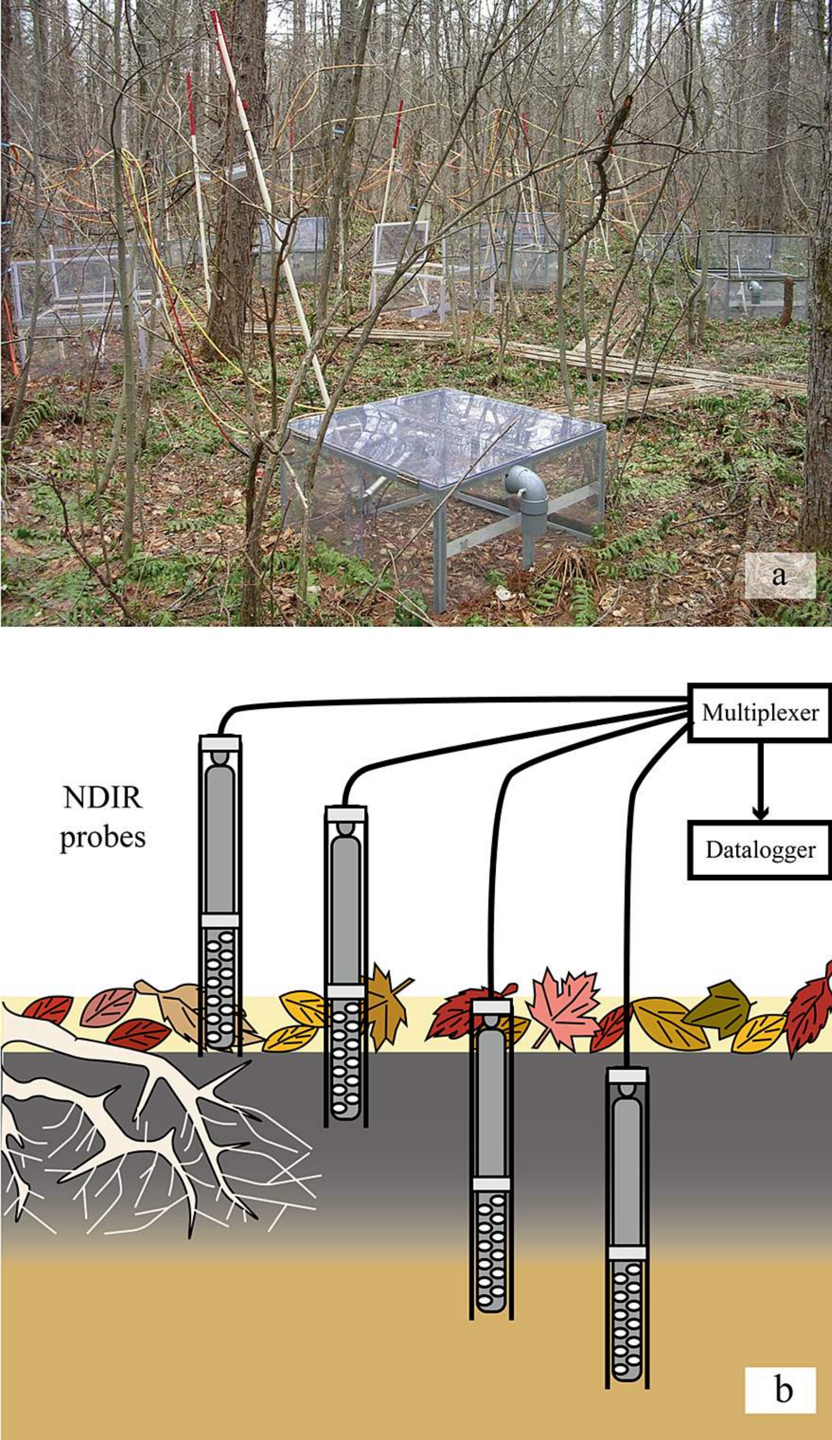
Table 1
Number of sampling points required for the automated chamber, open-top chamber, and LI-6400 chamber approaches to achieve different degrees of precision (within ±10% to within ±20% of the full sample mean) with 95% confidence interval

Chamber type	No. of sampling points actually measured	CO_2 efflux (mean + S.D.) (mg C m^{-2} h^{-1})	No. of sampling points required for measurements	
			Within ±10%	Within ±20%
Automated	16	126 ± 20	18	5
Open-top	9	118 ± 35	65	16
LI-6400	20	202 ± 90	355	89

Calculation is based on results averaged for the entire measurement period.


Chamber size: 90L×90W×50H cm
113 times of LI-6400-09
25.8 times of LI-8100
Automated Soil Efflux Chamber

Control Unit



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www.biogeosciences.net/7/3447/2010/
doi:10.5194/bg-7-3447-2010

Soil CO_2 efflux of a larch forest in northern Japan

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Revised: 15 October 2010 – Accepted: 29 October 2010 – Published: 5 November 2010

Abstract. We had continuously measured soil CO_2 efflux (R_s) in a larch forest in northern Japan at hourly intervals for the snow-free period in 2003 with an automated chamber system and partitioned R_s into heterotrophic respiration (R_h) and autotrophic respiration (R_r) by using the trench method. In addition, we applied the soil CO_2 concentration gradients method to continuously measure soil CO_2 profiles under snowpack in the snowy period and to partition R_s into topsoil (O_a and A horizons) CO_2 efflux (F_t) with a depth of 0.13 m and sub-soil (C horizon) CO_2 efflux (F_c). We found that soil CO_2 effluxes were strongly affected by the seasonal variation of soil temperature but weakly correlated with soil moisture, probably because the volumetric soil moisture (30–40% at 95% confidence interval) was within a plateau region for root and microbial activities. The soil CO_2 effluxes changed seasonally in parallel with soil temperature in topsoil with the peak in late summer. On the other hand, the contribution of R_r to R_s was the largest at about 50% in early summer, when canopy photosynthesis and plant growth were more active. The temperature sensitivity (Q_{10}) of R_r peaked in June. Under snowpack, R_s was stable until mid-March and then gradually increased with snow melting. R_s summed up to 79 gC m^{-2} during the snowy season for 4 months. The annual R_s was determined at 934 gC m^{-2} y^{-1} in 2003, which accounted for 63% of ecosystem respiration. The annual contributions of R_h and R_r to R_s were 57% and 43%, respectively. Based on the gradient approach, R_s was partitioned vertically into litter (O_i and O_e horizons) with a depth of 0.01–0.02 m, topsoil and sub-soil respirations with proportions of 6, 72 and 22%, respectively, on an annual basis. The vertical distribution of CO_2 efflux was consistent with those of soil carbon and root biomass.

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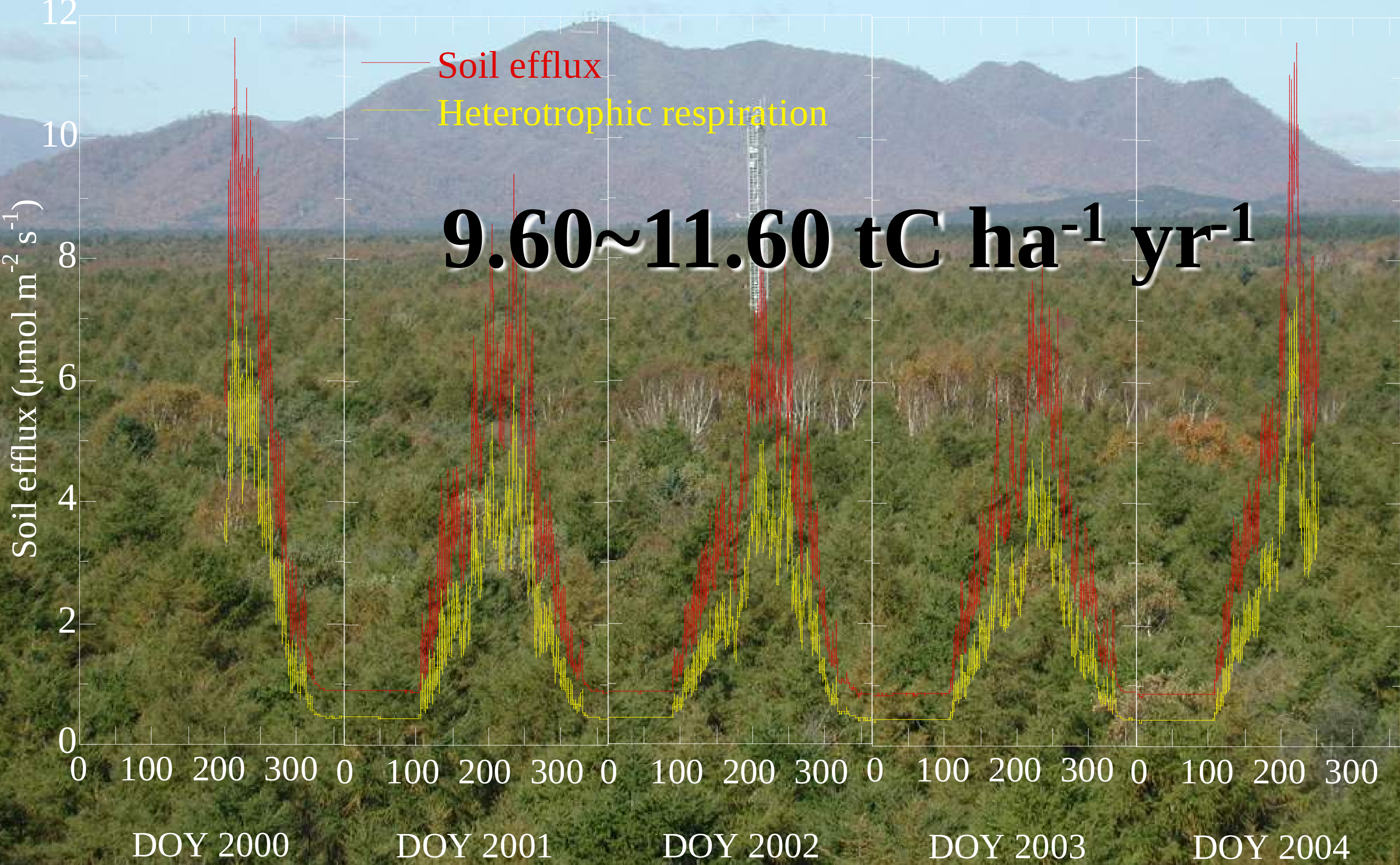
1 Introduction

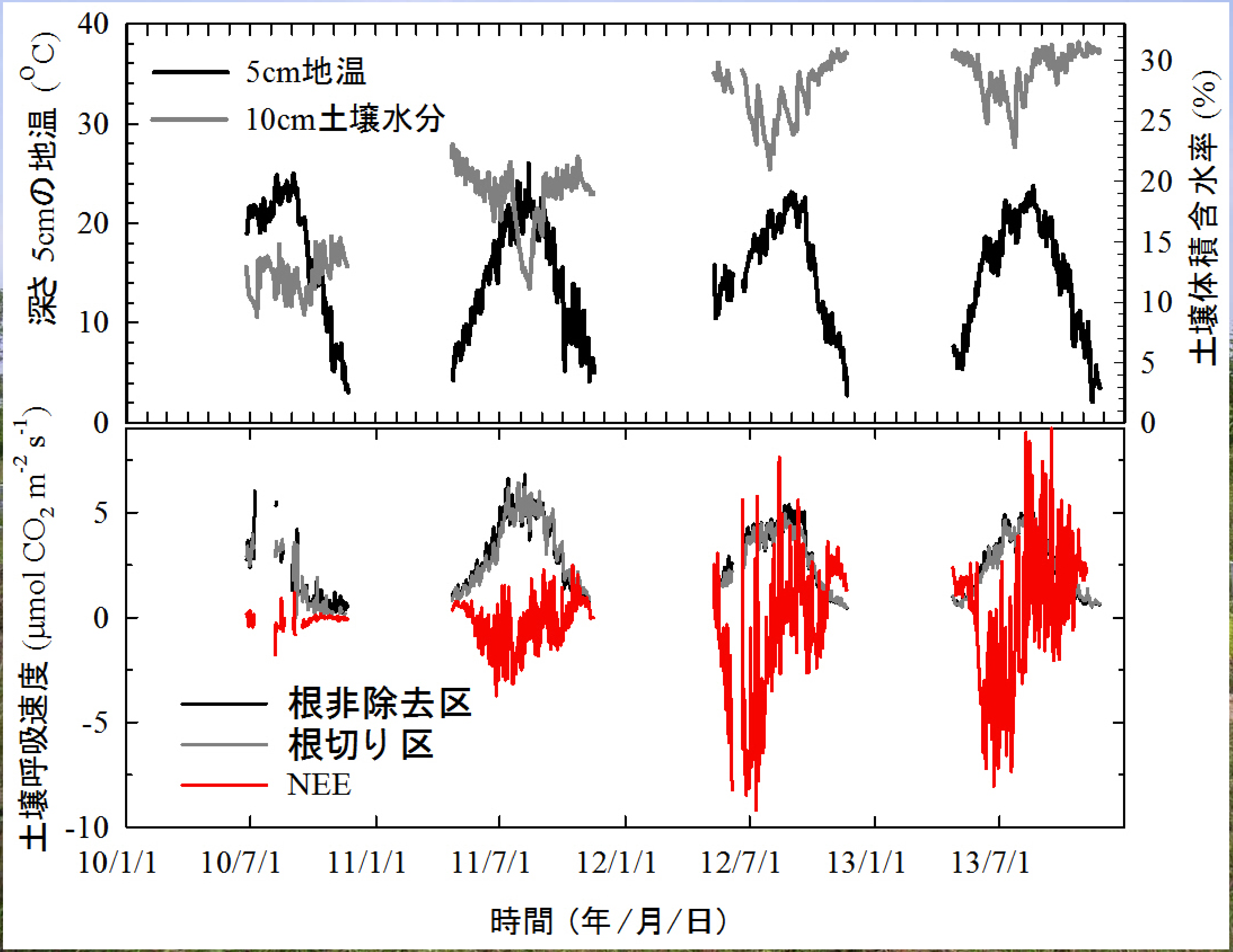
The world's soils contain about 1550 Pg of organic carbon, which is more than twice the amount in the atmosphere (IPCC, 2007). Forests worldwide contain about 45% of the global carbon stock, a large part of which is in the forest soils. Recently, Bond-Lamberty and Thomson (2010) estimated that the global soil CO_2 efflux, widely referred to as soil respiration (R_s), was about 98 Pg C y^{-1} in 2008 based on a five-decade record of chamber measurements, which is more than 13 times the rate of fossil fuel combustion (IPCC, 2007), indicating that 20–40% of the atmospheric CO_2 circulates through soils every year. Overall, R_s is the largest component of ecosystem respiration (RE) and the second largest flux in the global carbon cycle after gross primary production (GPP). R_s is therefore a key process that is fundamental to our understanding of the terrestrial carbon cycle (Davidson and Janssens, 2006). A relatively small change in the carbon flow into or out of soils can strongly influence the global carbon cycle. For example, it was reported that the global R_s increased by 0.1 Pg C y^{-1} between 1989 and 2008 (Bond-Lamberty and Thomson, 2010), and that the positive feedback from this enhancement of R_s by global warming would further raise atmospheric CO_2 concentration by 20-224 ppm by 2100 and resulting higher CO_2 levels would lead to an additional temperature increase ranging from 0.1 to 1.5 °C (Friedlingstein et al., 2006; IPCC, 2007).

In forest ecosystems, micrometeorological studies (i.e., eddy covariance) have shown that, on average, about 80% of GPP is respired back to the atmosphere (Law et al., 2002), and R_s has been estimated to account for 60-90% of RE, with marked temporal as well as spatial variations (Law et al., 1999; Janssens et al., 2001a, b; Liang et al., 2004). Therefore, R_s has recently received much attention from researchers and its accurate measurement is critical for developing a reliable model of carbon exchange in forest ecosystems (Jassal et al., 2007; Zhou et al., 2009).

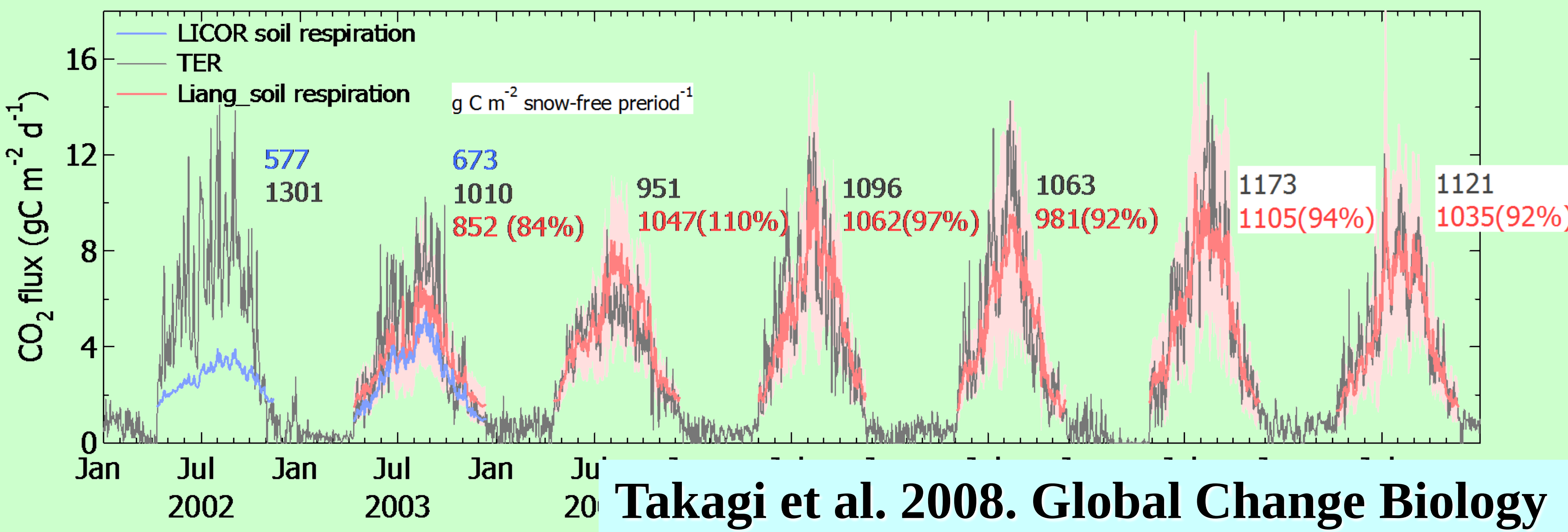
Inter-annual Variation of Soil Efflux at Tomakomai



苫小牧の台風跡地

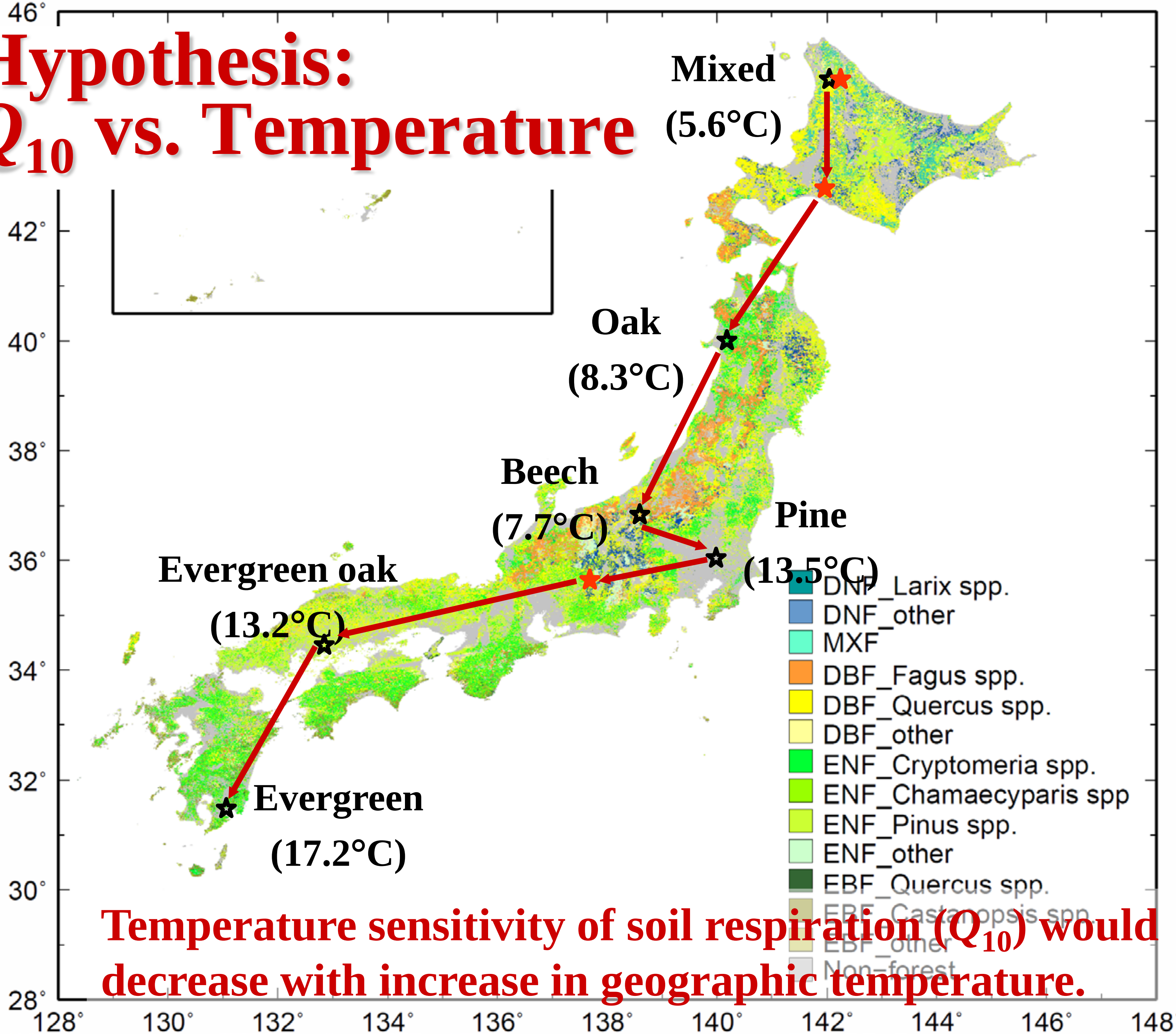

40
30
20
10
0
深さ 5cmの地温 (°C)
5cm地温
10cm土壌水分
30
25
20
15
10
5
0
土壌体積含水率 (%)
5
0
-5
-10
土壌呼吸速度 (μmol CO2 m-2 s-1)
根非除去区
根切り区
NEE
10/1/1
10/7/1
11/1/1
11/7/1
12/1/1
12/7/1
13/1/1
13/7/1
時間 (年/月/日)

Teshio CC-Lag Site

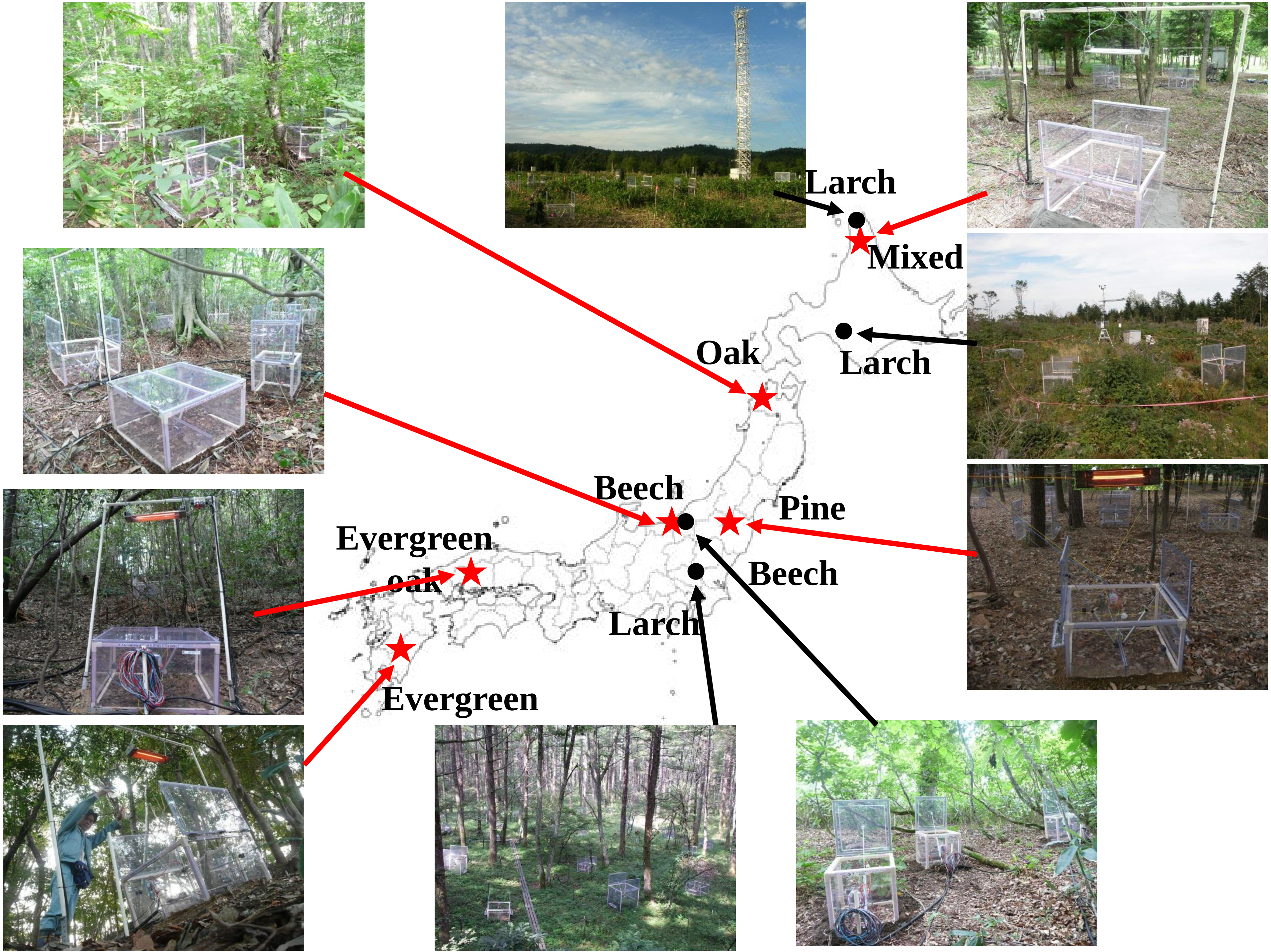


Takagi et al. 2008. Global Change Biology

Hypothesis: Q_{10} vs. Temperature



Temperature sensitivity of soil respiration (Q_{10}) would decrease with increase in geographic temperature.


Larch
Mixed
Oak
Larch
Beech
Pine
Evergreen
oak
Beech
Larch
Evergreen

Experiment Designing

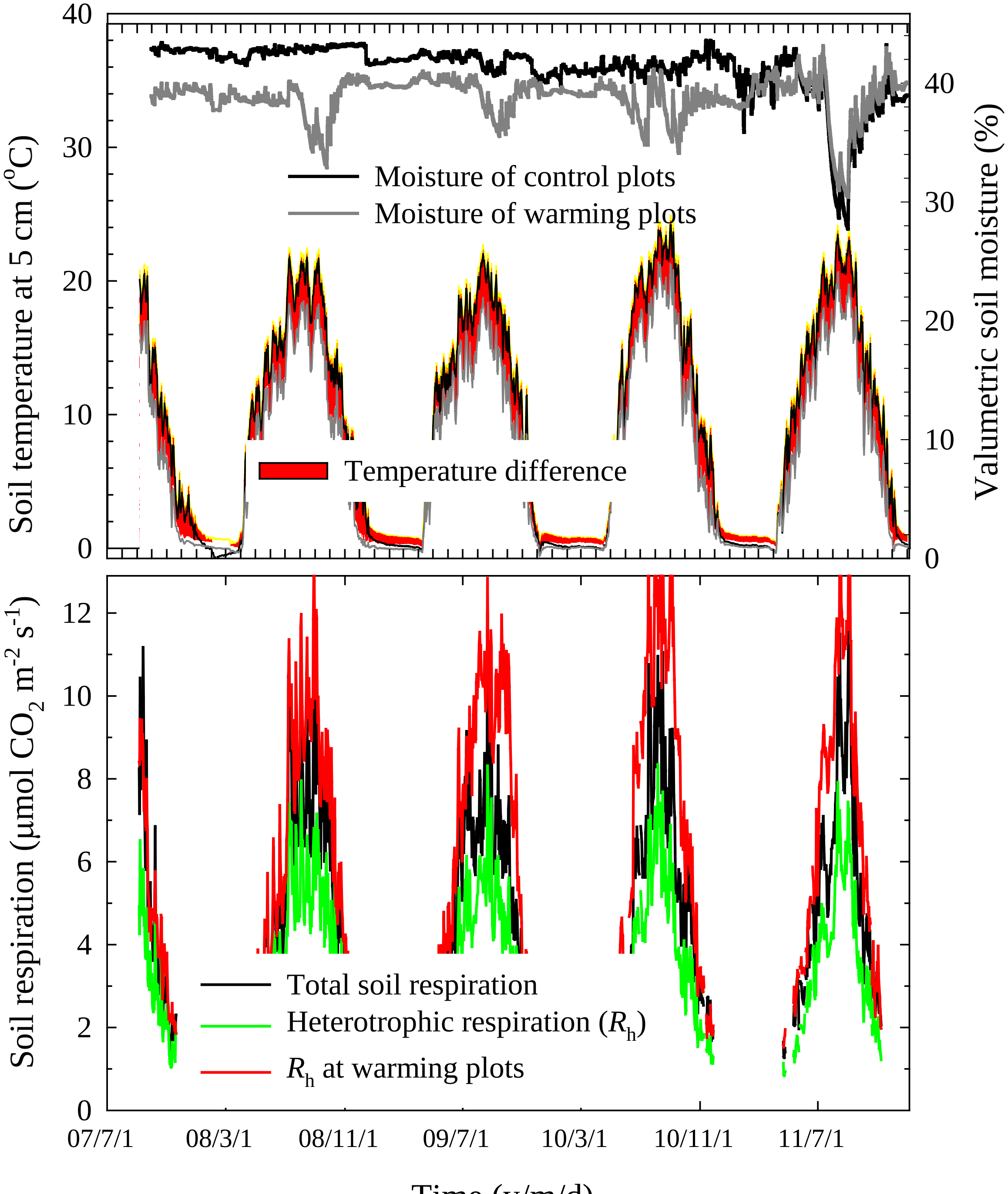
15~24 chambers (90×90 × 50 cm)

5 heterotrophic plots

10 trench plots

5 warming plots

Cool-temperate mixed forest in northern Hokkaido



Warming:

↑ 3.0°C Tsoil at 5-cm

Effect:

Rh↑ 20% per °C

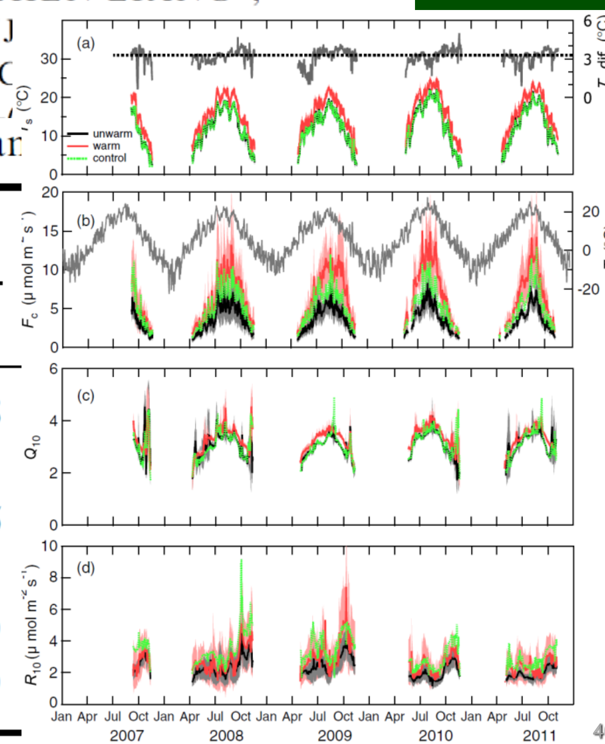
Tellus SERIES B CHEMICAL AND PHYSICAL METEOROLOGY
PUBLISHED BY THE INTERNATIONAL METEOROLOGICAL INSTITUTE IN STOCKHOLM

Sustained large stimulation of soil heterotrophic respiration rate and its temperature sensitivity by soil warming in a cool-temperate forested peatland

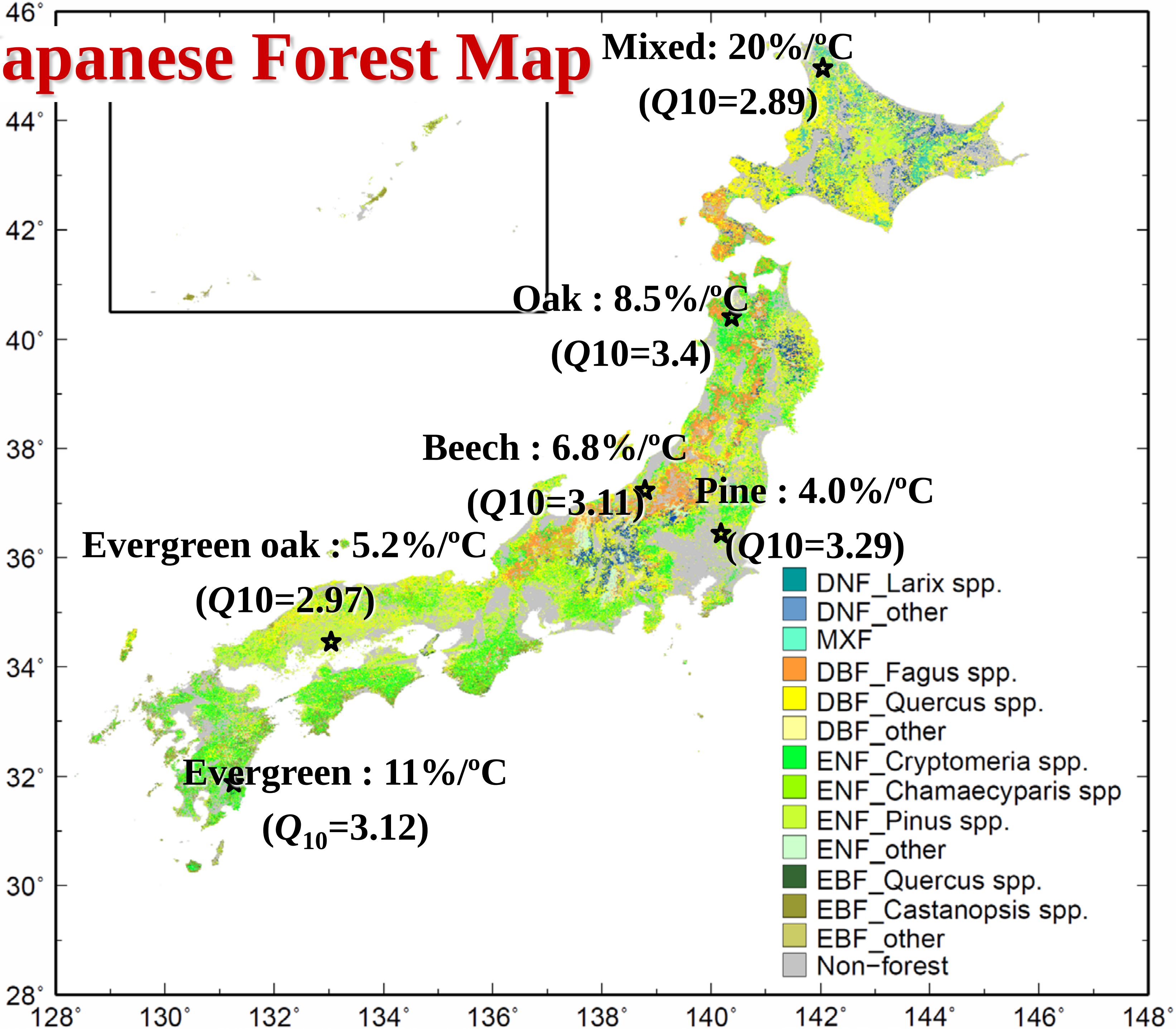
By MARICAR AGUILOS[1], KENTARO TAKAGI[2]*, NAISHEN LIANG[3], YOKO WATANABE[2], MUNEMASA TERAMOTO[3], SEIJ... YOSHIYUKI TAKAHASHI[3], HITOSHI MUKAI[3] and KAIC...
[1]Graduate School of Environmental Science, Hokkaido University, Sapporo 060-...

Table 4. Seasonal average (each measurement period for each year) and star...

Year	Q_{10} Unwarmed	Q_{10} Warmed	Q_{10} Control
2007	3.15 ± 0.35	3.18 ± 0.32	2.99 ± 0.18
2008	3.06 ± 0.24	3.27 ± 0.10	3.04 ± 0.11
2009	3.00 ± 0.04	3.15 ± 0.09	3.00 ± 0.05
2010	3.17 ± 0.06	3.47 ± 0.11	3.25 ± 0.11
2011	3.16 ± 0.19	3.33 ± 0.03	3.16 ± 0.09
Four seasons	3.10 ± 0.08	3.31 ± 0.06	3.11 ± 0.09

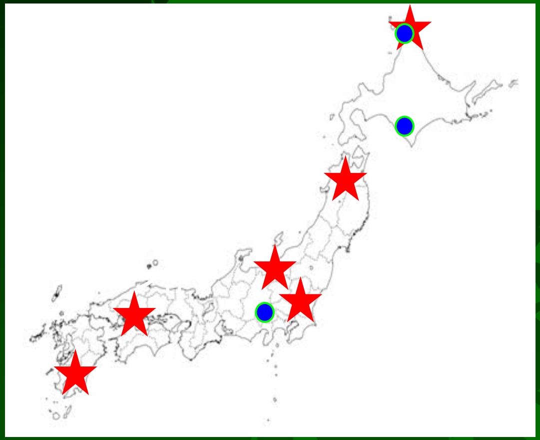


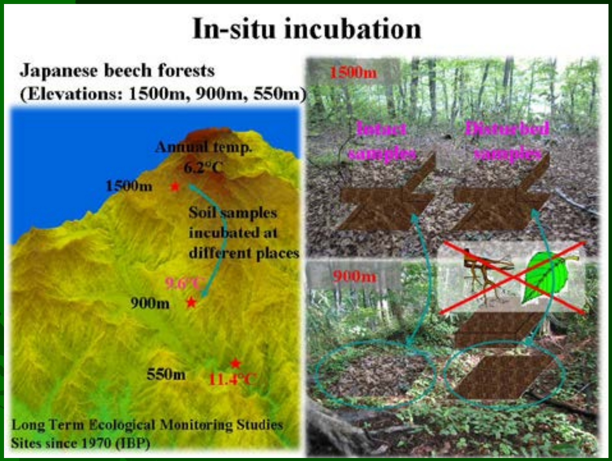
Japanese Forest Map



On-going Project

Warming Experiments





Evaluation of effects by short-term climate change, natural disturbance and human disturbance

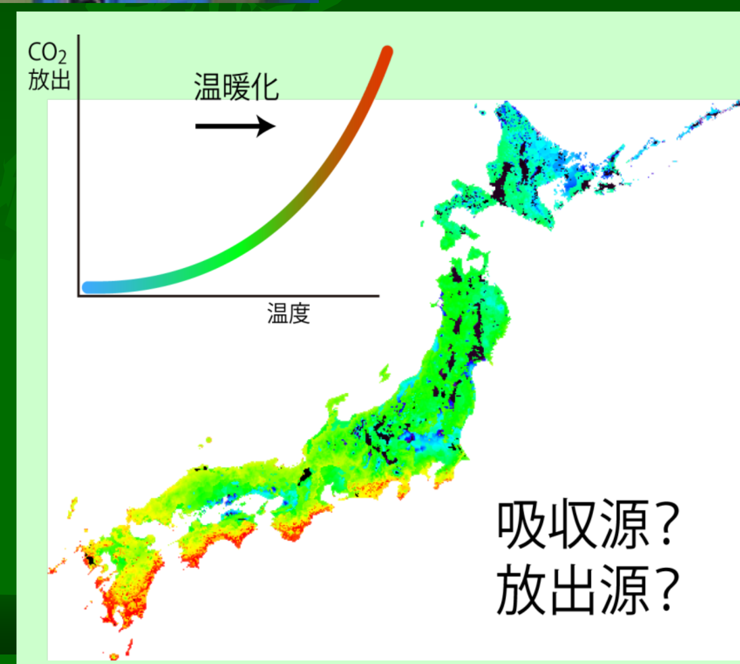
On-going Technology

Understanding mechanisms

Answering questions:

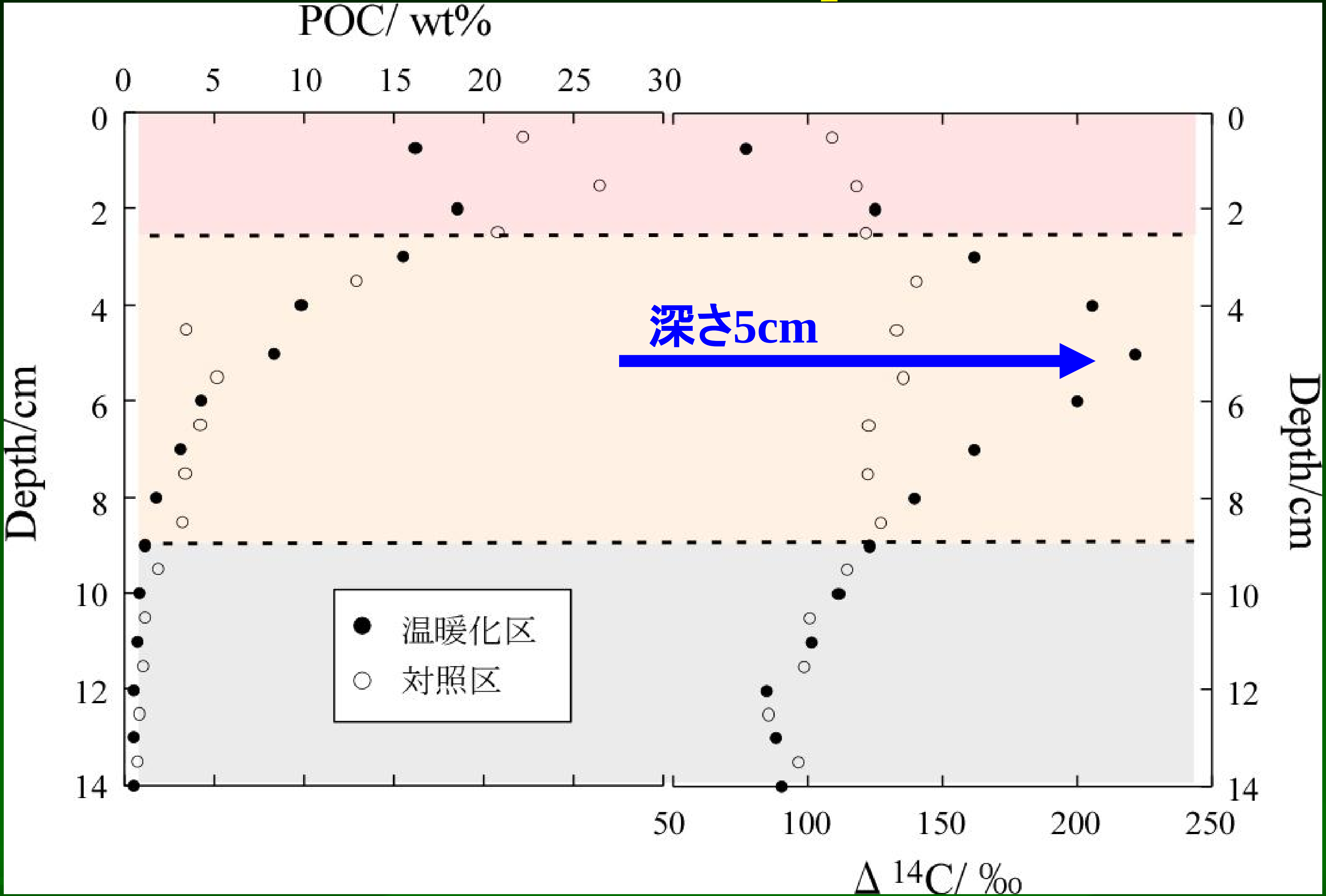
Carbon sink?

source?



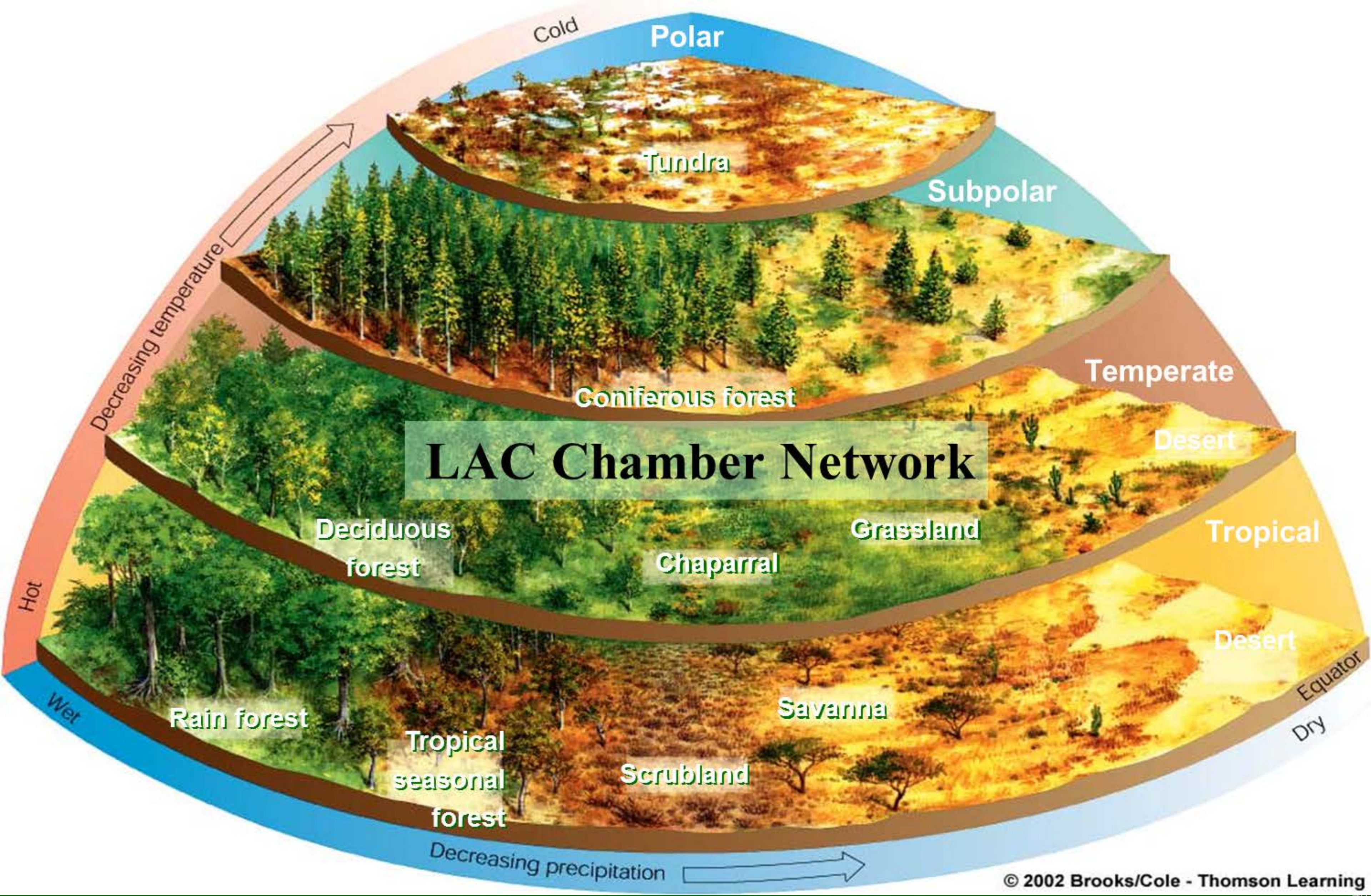
Sampling for Soil ^{14}C

Profiles of POC & $\Delta^{14}C$ of Japanese Forest Soil

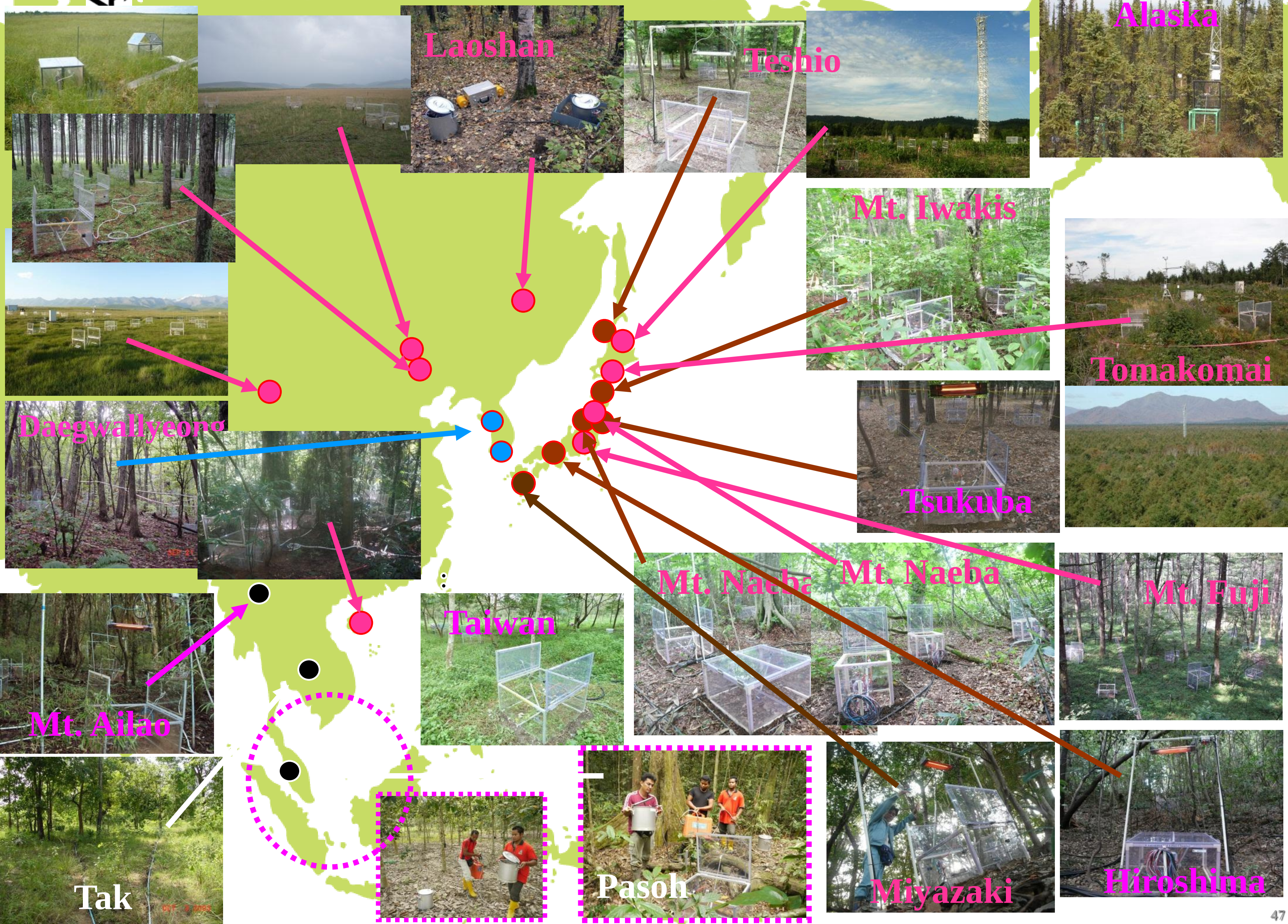


Older SOC seems more sensitive to temperature than that of new SOC

Ecosystems (Biomes) in Asia



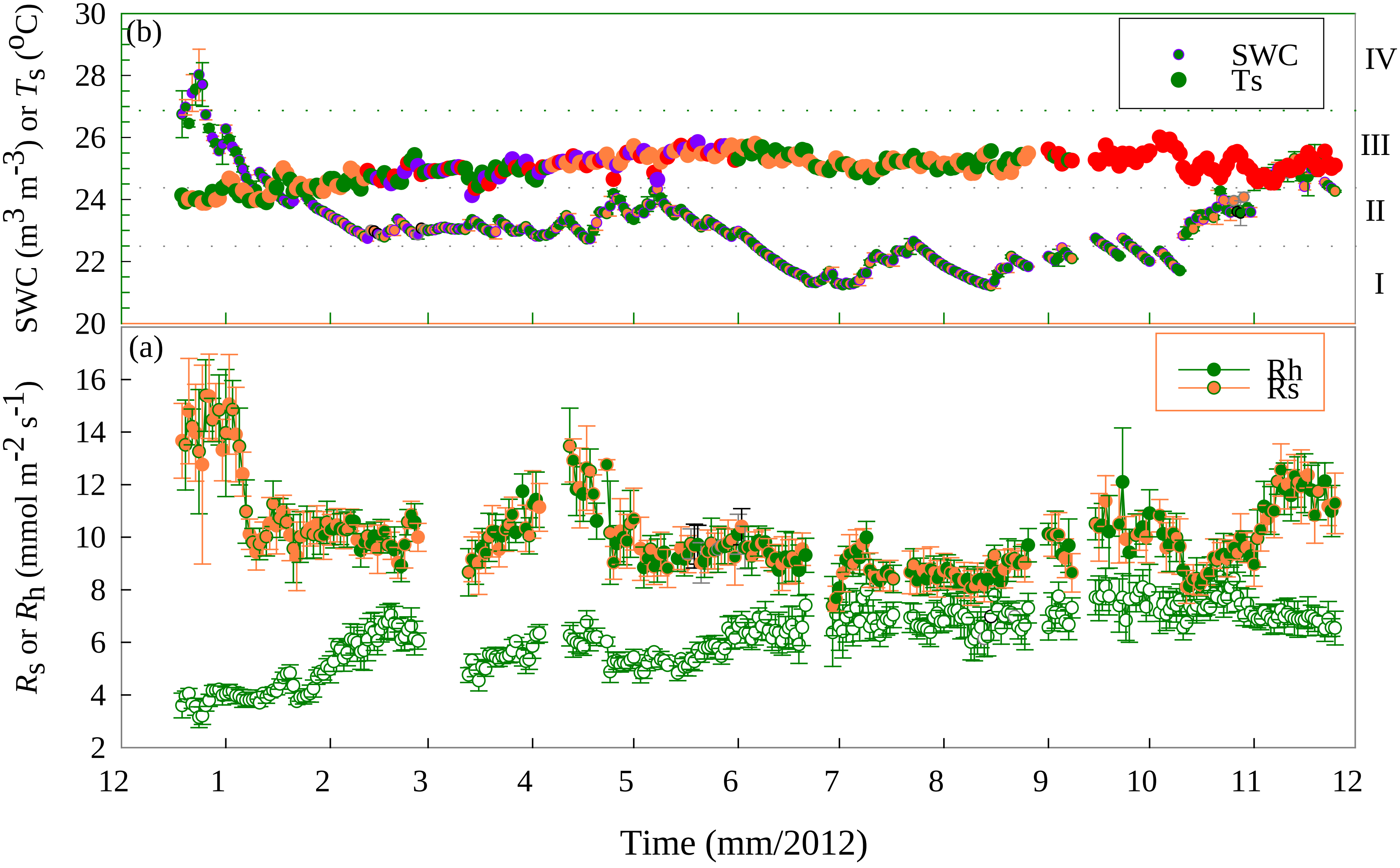
Automated Chamber Networks



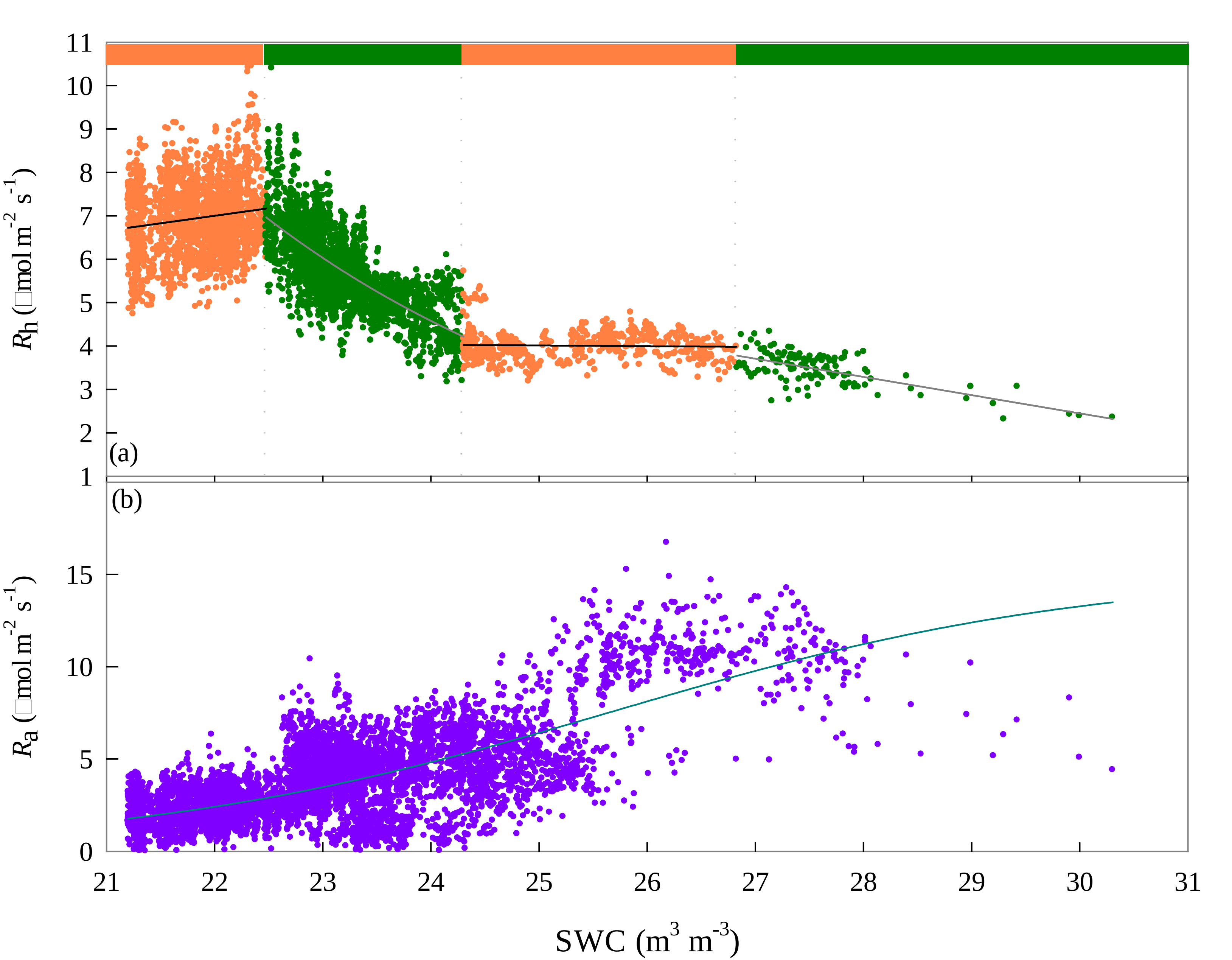
Continuous Measurement Rs at Malaysian Tropical Rainforests

http://www.nies.go.jp/biology/pasoh/English/index.html

Seasonal Changes in Soil Efflus at Pasoh Tropical Forest

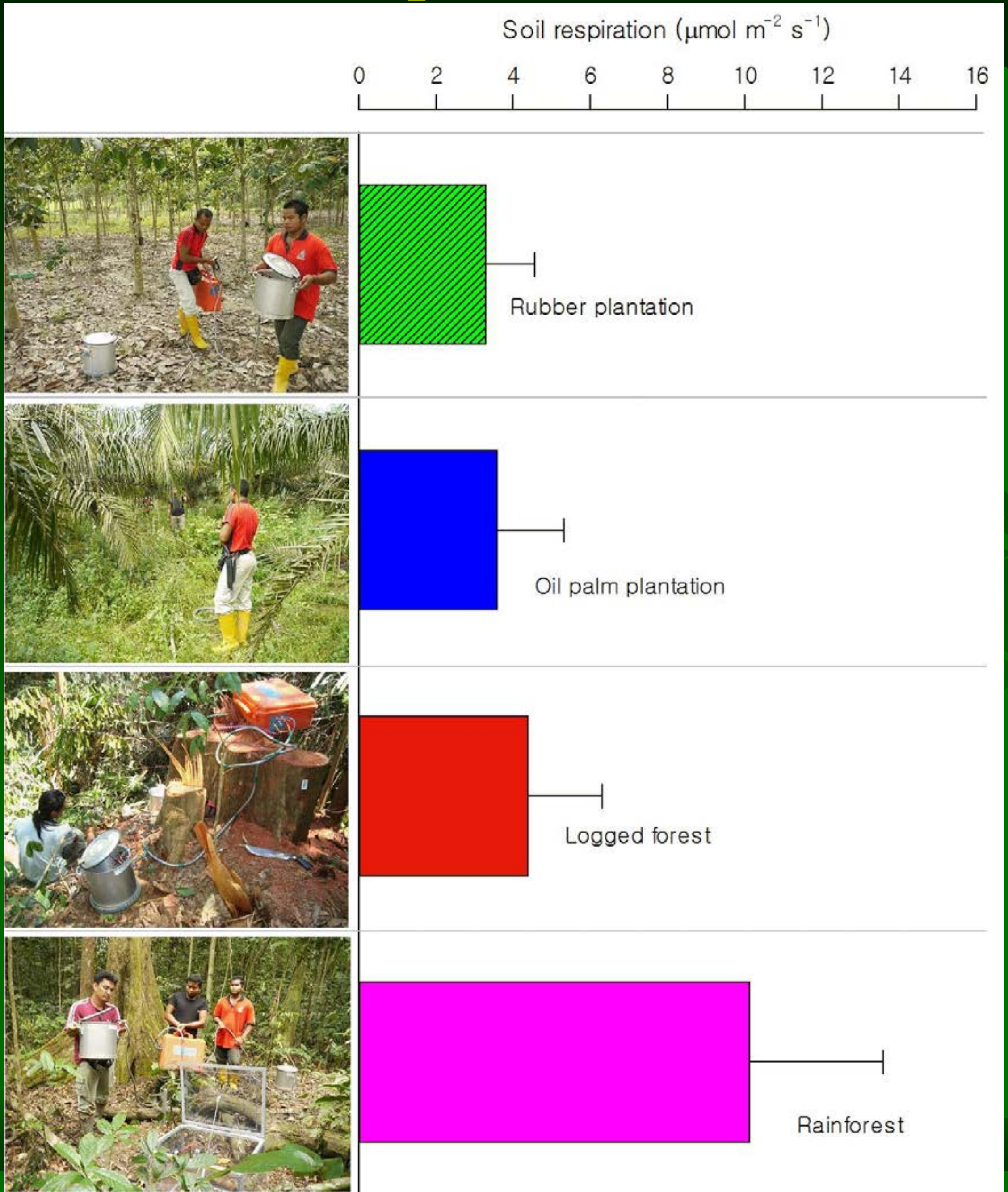


Soil Moisture Response of Auto- & Heterotrophic Respiration



Soil Respiration vs. Land Use Change

Soil Respiration at Different Land Use Types



Land use changes caused soil degradation (土壤退質(劣化)

Logging site

Decomposition of harvest residue

Monitor & control by mobile phone

Soil CO_2 Efflux vs. REDD Credit

With 30% of logging intensive (low-impact logging):

- T_2 = 23.5ºC + 1.5ºC (soil temperature increase)
- C = 38 tC/ha (harvest residue: AG=21, BG=17)
- d = 13% (decomposition ratio of CWD)
- $ = 15 US$/tC

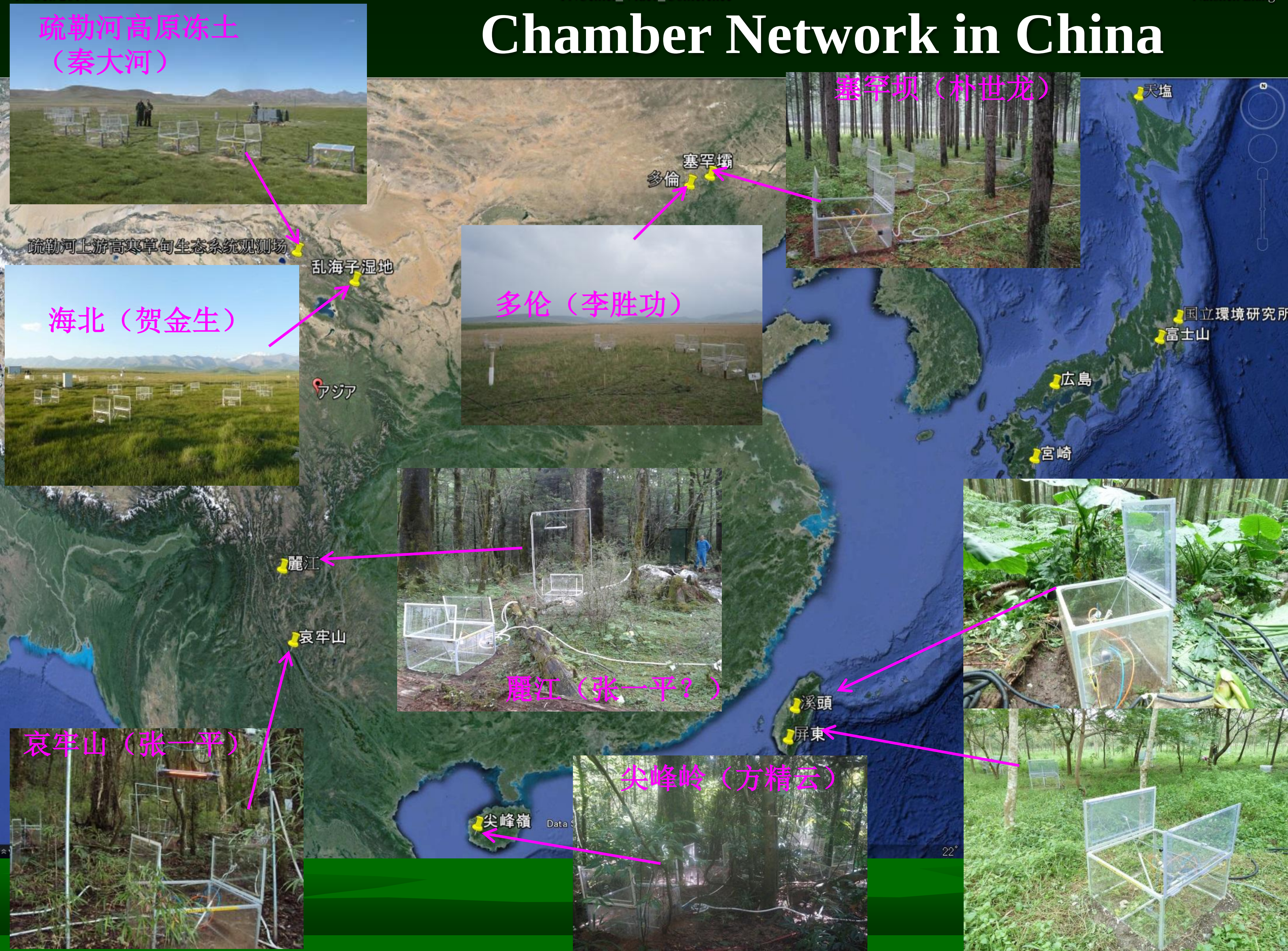
Total carbon lost at the first year after the logging:

$$\sum \$ = (3.32 + 5.70) \times 15 = 135 US\$ / ha$$

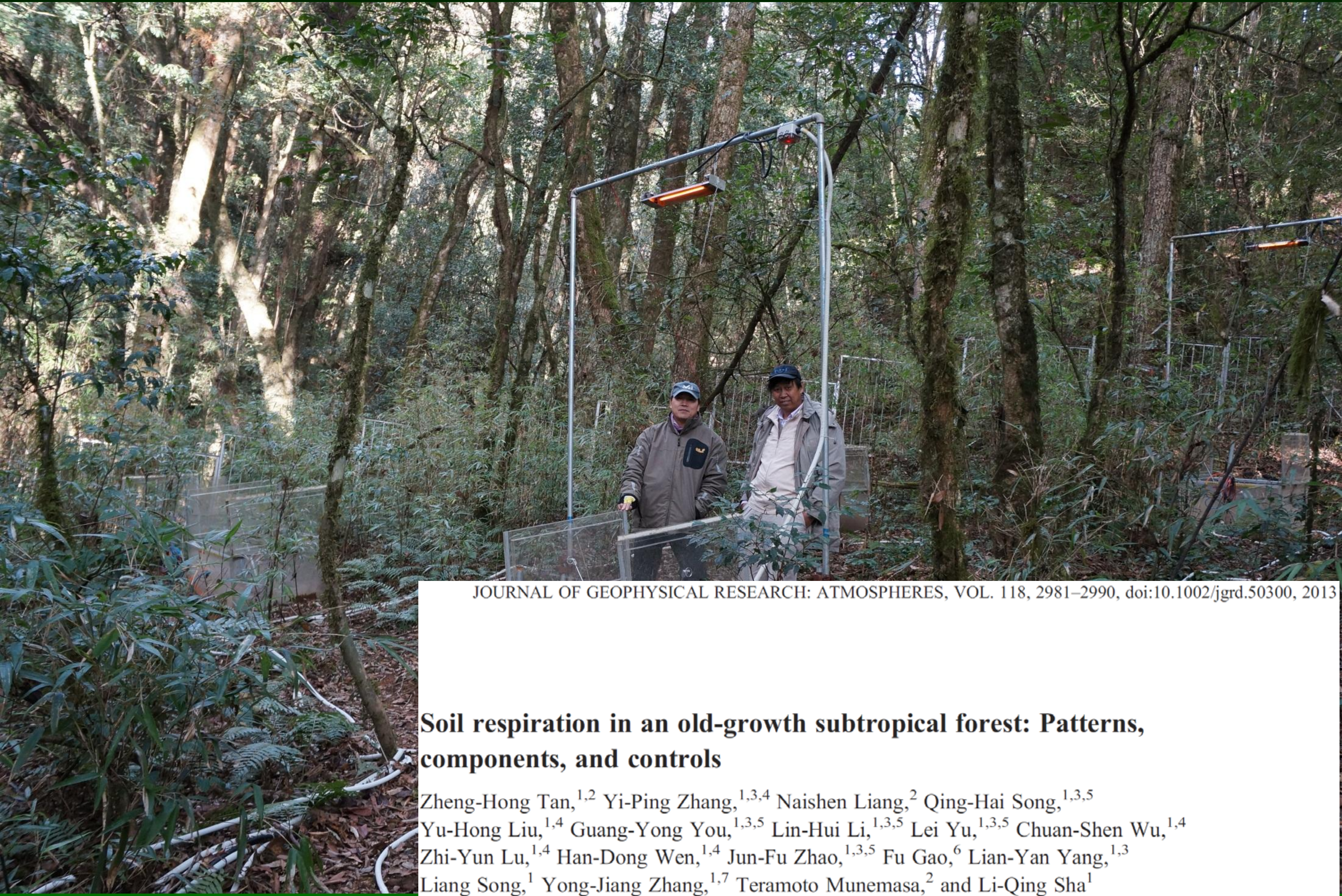
REDD credit = 247 - 135 = 112 US$ / ha

Low Power Consumption

Chamber Network in China



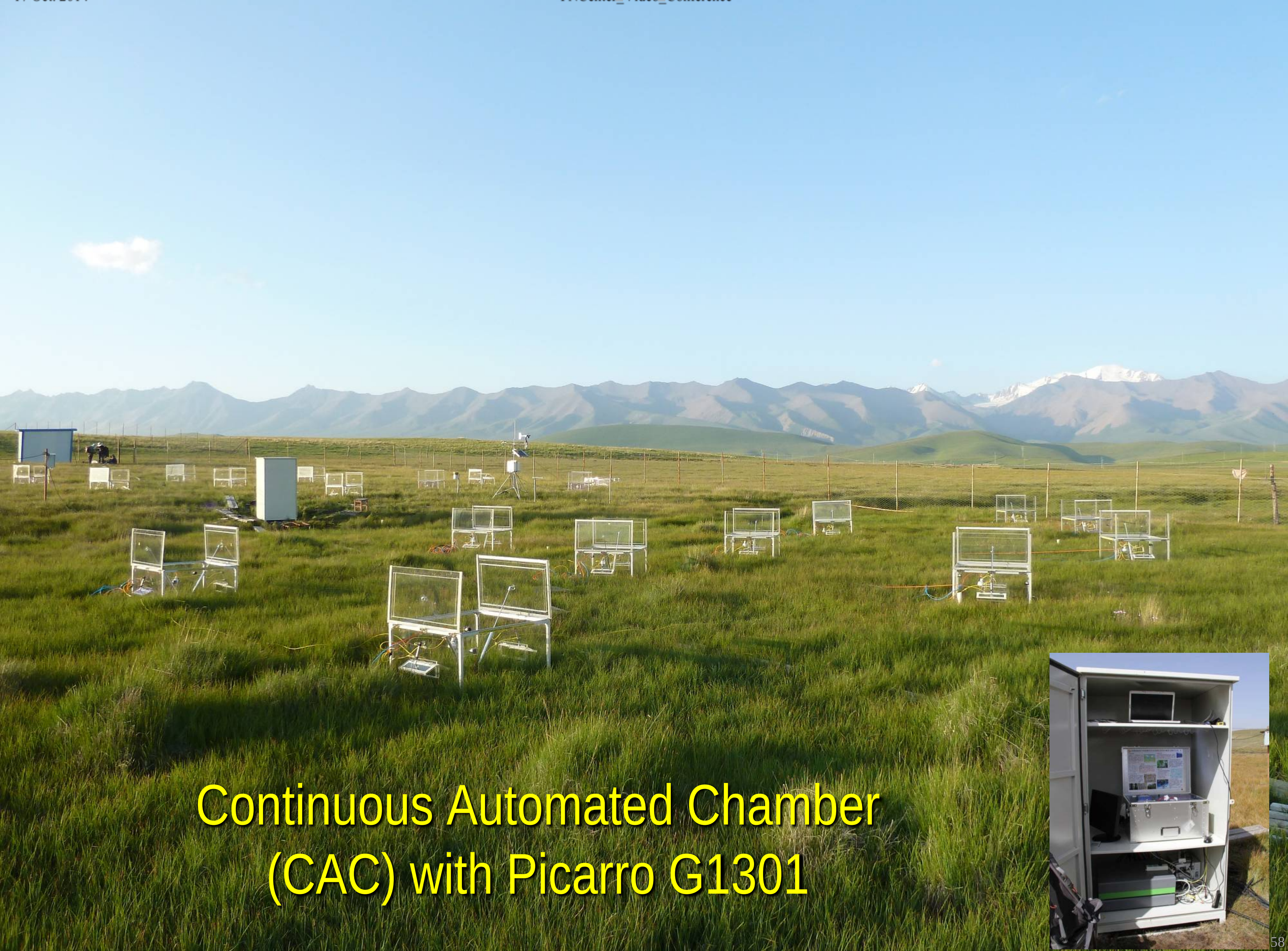
Subtropical Broadleaf Forest at Mt. Ailao



JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES, VOL. 118, 2981–2990, doi:10.1002/jgrd.50300, 2013

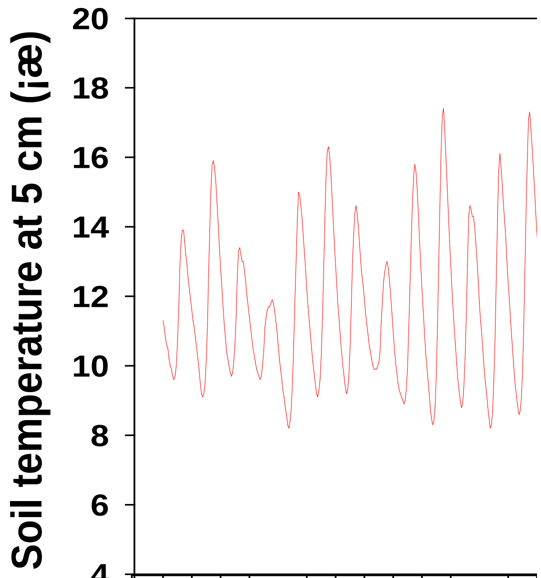
Soil respiration in an old-growth subtropical forest: Patterns, components, and controls

Zheng-Hong Tan,[1,2] Yi-Ping Zhang,[1,3,4] Naishen Liang,[2] Qing-Hai Song,[1,3,5] Yu-Hong Liu,[1,4] Guang-Yong You,[1,3,5] Lin-Hui Li,[1,3,5] Lei Yu,[1,3,5] Chuan-Shen Wu,[1,4] Zhi-Yun Lu,[1,4] Han-Dong Wen,[1,4] Jun-Fu Zhao,[1,3,5] Fu Gao,[6] Lian-Yan Yang,[1,3] Liang Song,[1] Yong-Jiang Zhang,[1,7] Teramoto Munemasa,[2] and Li-Qing Sha[1]



Continuous Automated Chamber (CAC) with Picarro G1301

Seasonal Variation of Soil Temperature and CH_4 Flux



Environmental Pollution 181 (2013) 81–90

Contents lists available at SciVerse ScienceDirect

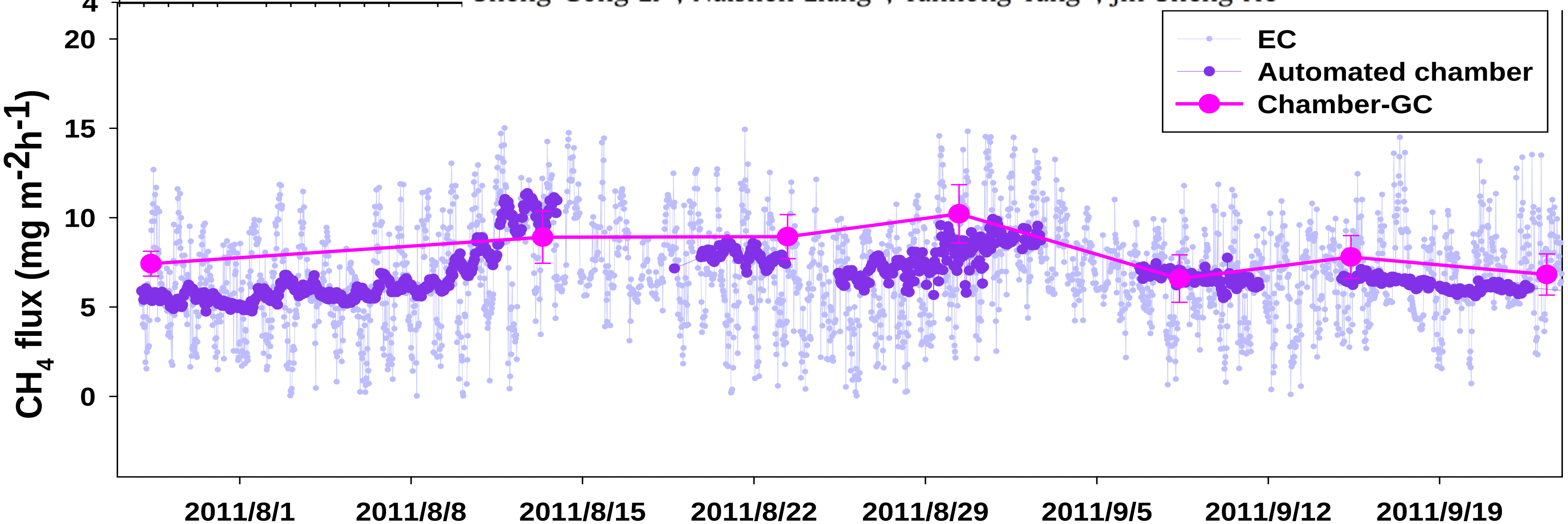
Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

ELSEVIER

A comparison of methane emission measurements using eddy covariance and manual and automated chamber-based techniques in Tibetan Plateau alpine wetland

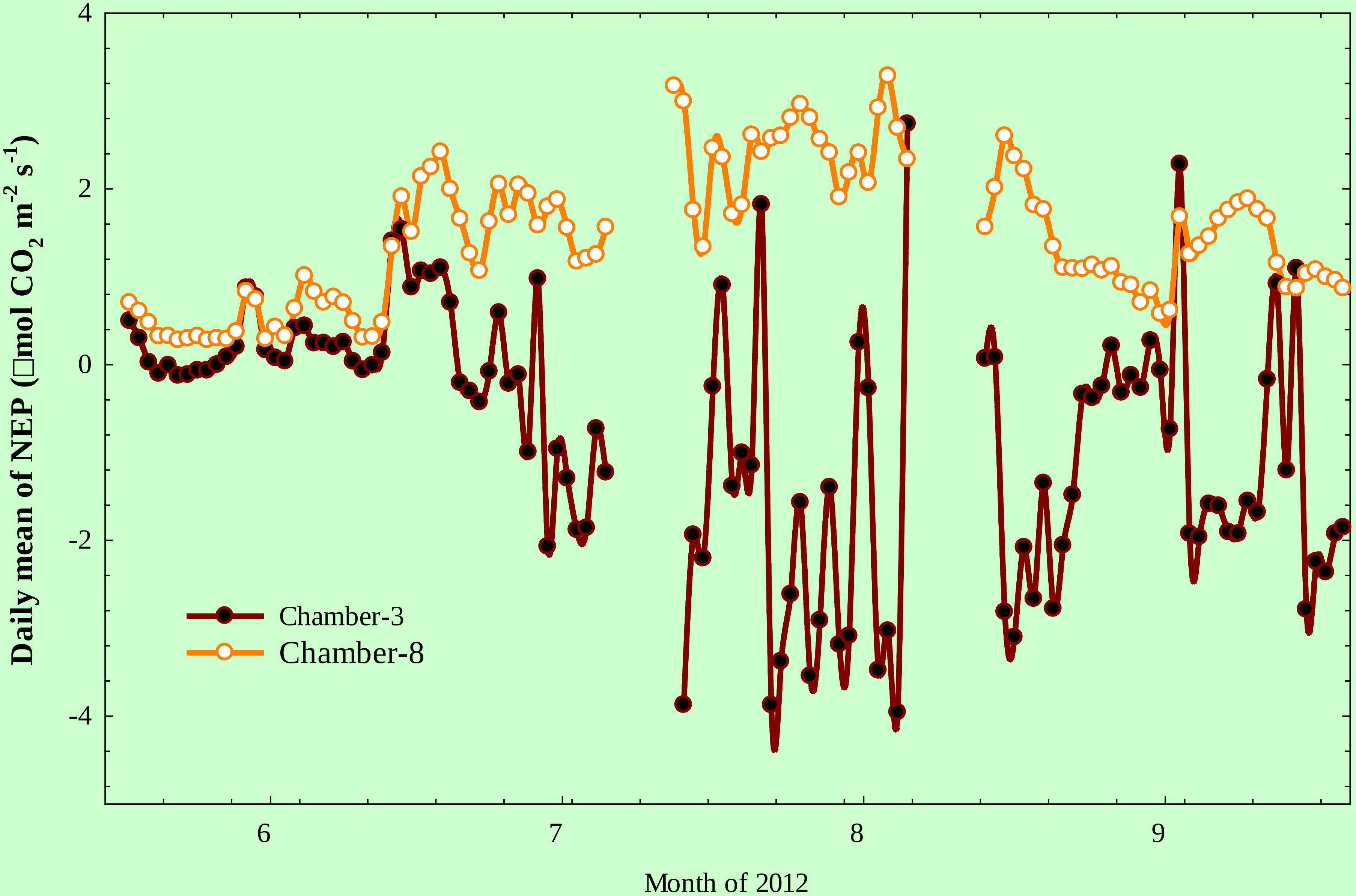
Lingfei Yu [a], Hao Wang [b], Guangshuai Wang [b], Weimin Song [a], Yao Huang [c], Sheng-Gong Li [d], Naishen Liang [e], Yanhong Tang [e], Jin-Sheng He [a,b,*]



Inner-Mongolian Grassland

A3 Foresight Program

Seasonal Change in NEP & Rs at Duolun Grassland Ecosystem



塞罕坝落叶松林生态系统

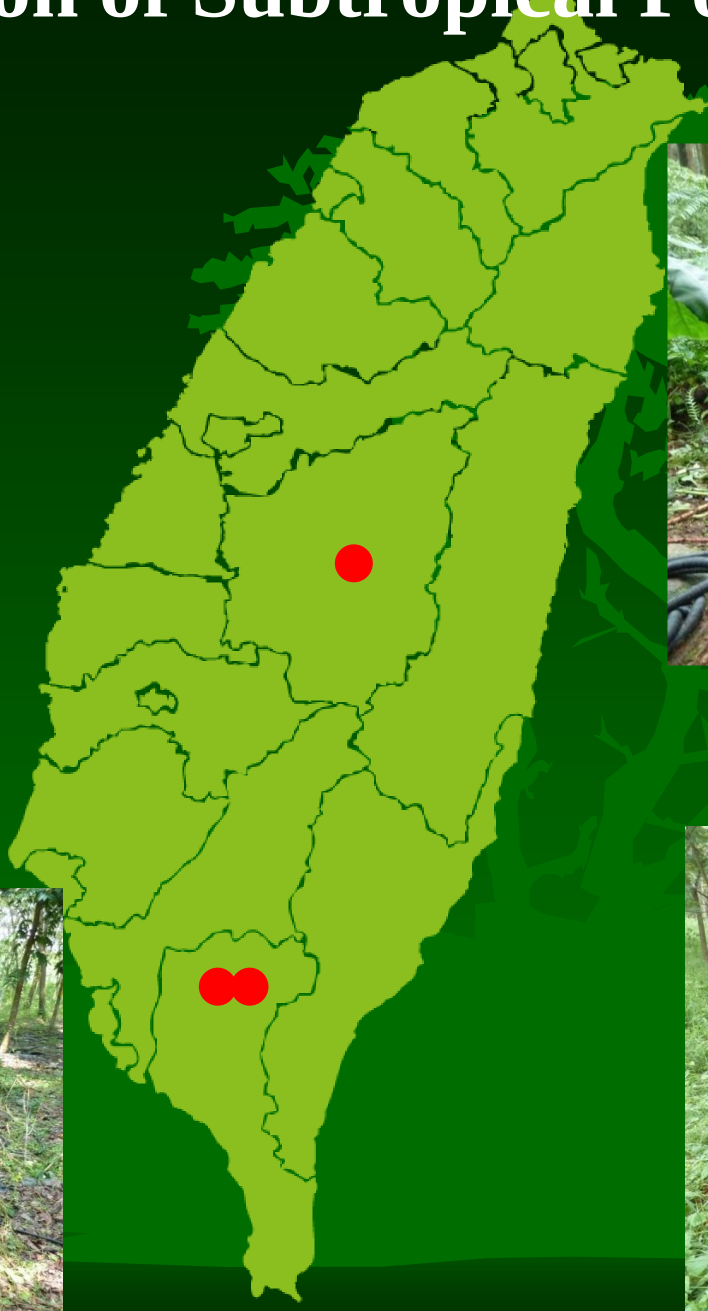
尖峰岭热带季雨林生态系统

麗江高山針葉林生態系統土壤呼吸增溫實驗

疏勒河上游高原凍土草甸生態系統

Seasonal Permafrost meadow, 4100m, Tibet Plateau

Soil Respiration of Subtropical Forests

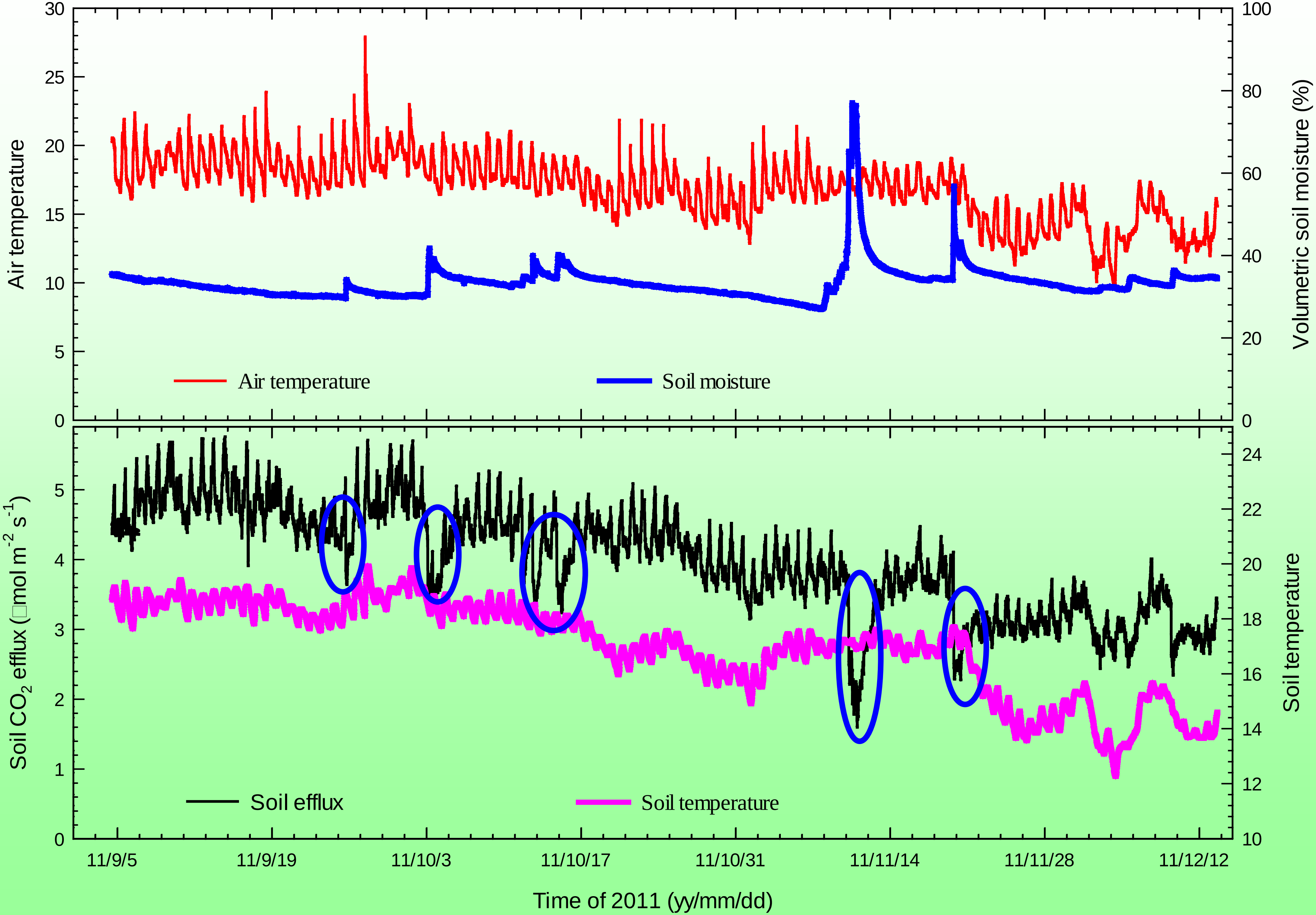


Xitou Flux Site

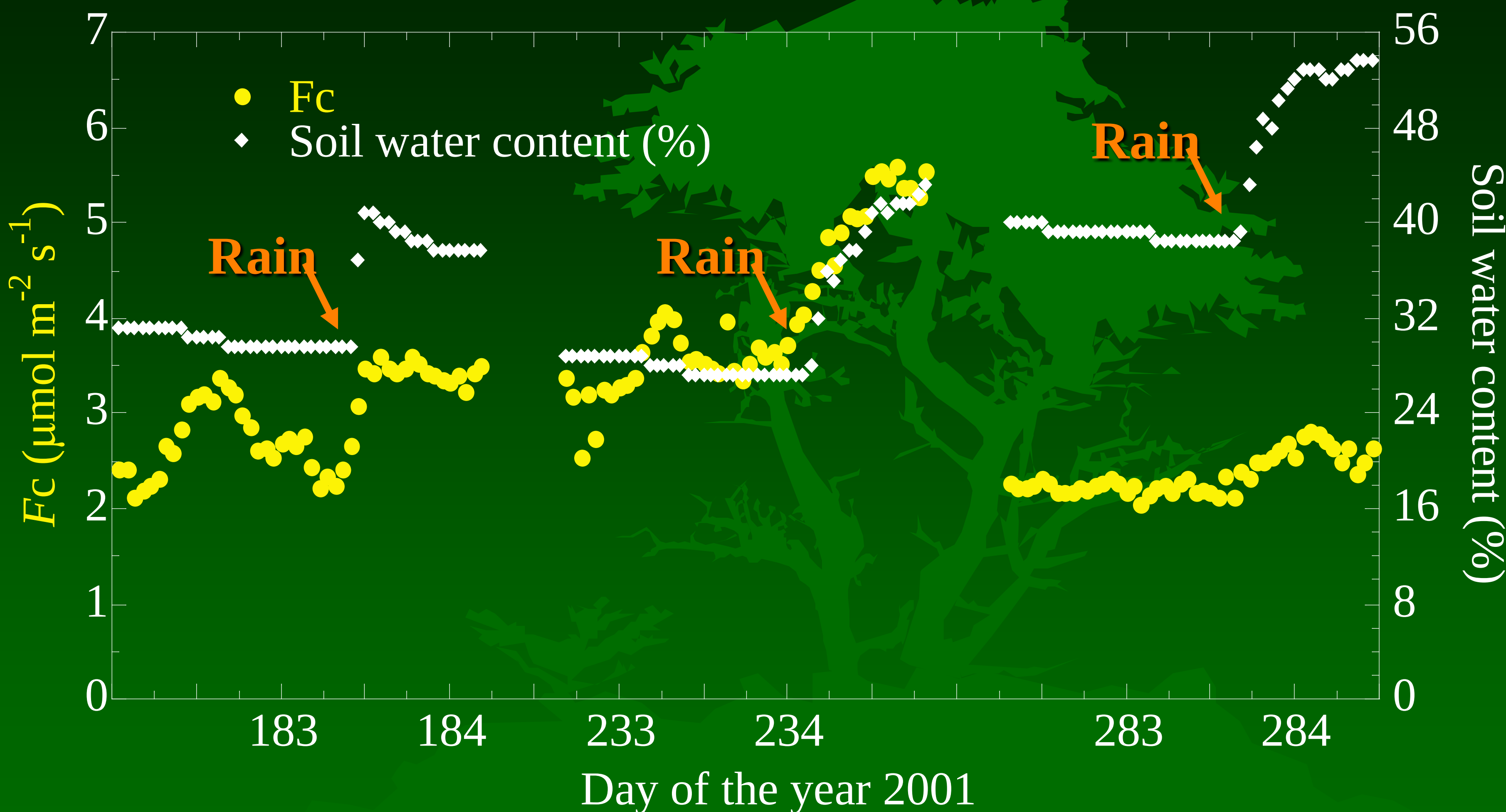
Pingdong Flux Site

Pingdong Flux Site

Seasonal Changes in Soil CO_2 Efflux at Xitou Flux Site



Is soil respiration regulated by surface soil water content?



Following rainfall, soil respiration increased immediately to a high value. However, the rate had returned to the general lower level by the next day.

Wood Respiration

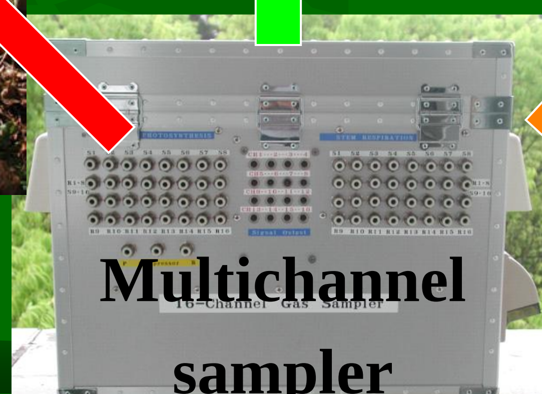

24 Automated Branch Chambers
Weight: < 200g

Multichannel Automated Chamber Systems

Photosynthesis

Soil efflux

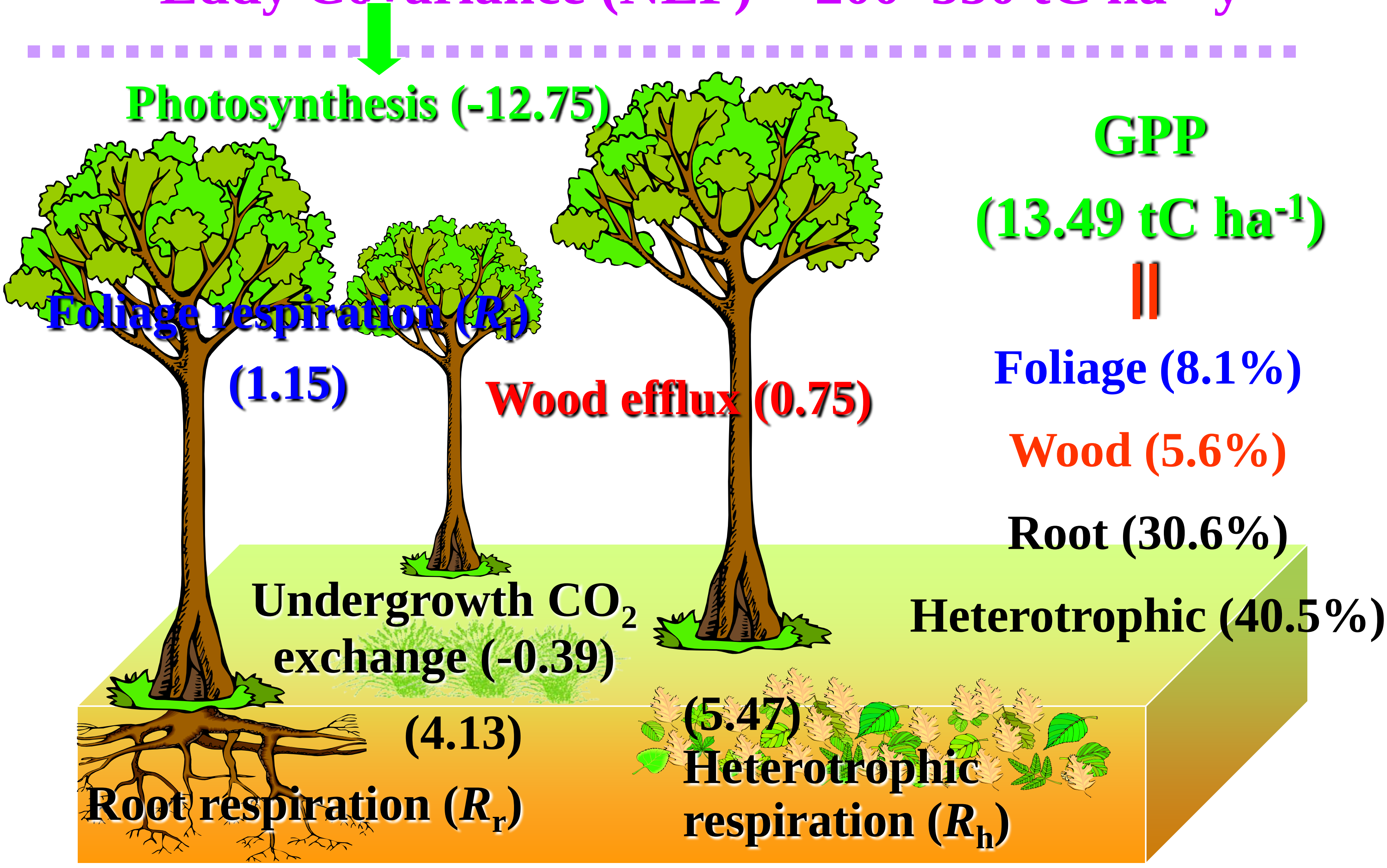
Stem efflux



Multichannel sampler

Larch Forest Carbon Balance

Eddy Covariance (NEP) = 200~550 tC ha^{-1} y^{-1}



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Liang et al. 2004. Agr. For. Meteorol.

Liang et al. 2005. Phyton

Liang et al. 2005. J. Agr. Meteorol.

Takahashi & Liang. 2007. Geochem. J.

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東 ら. 2013,北海道の農業気象

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Aguilos et al. 2014, AFM

阿部 ら. 2014, 関東森林研究



Thank you for attentions!