界面过程尺度化与试验研究

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一、生态界面的内涵

界面概念源于物理学

—— 物相之间的分界面

—— 显著的几何性

—— 可视性

物理世界无处不在 —— 宇观、分子水平

分子（CO_2）热运动

大气物理 —— **扩散过程满足波尔兹曼分布**

生态学界面问题

Surface

Interface

Boundary

Edge effect

Ectone

生态学意义下的界面

- 概念抽象和模糊

生态界面

（１９８５熊文愈）

与植物体表接触空气薄层

界面生态学

１９９０马世骏

发展方向：农业界面生态学

叶片尺度

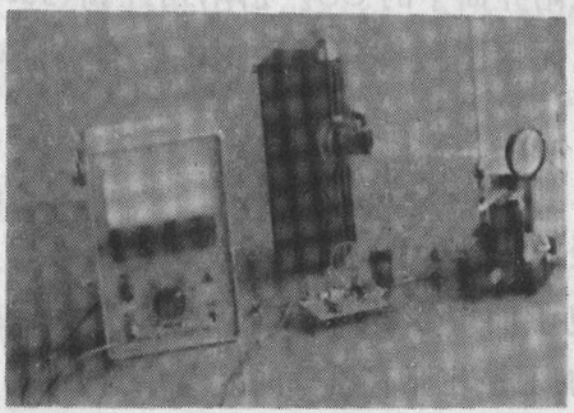


图 1.3.1-2　微环境测湿仪

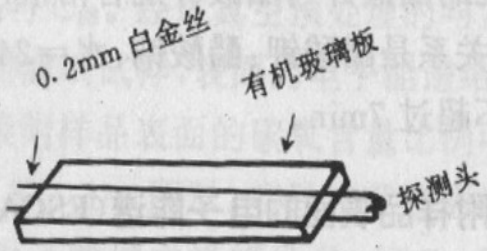


图 1.3.1-3　探头设计

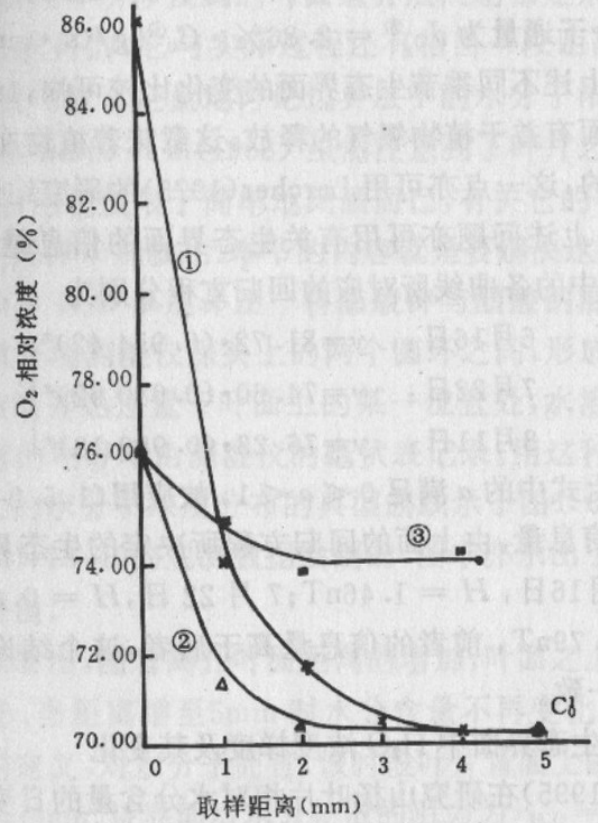
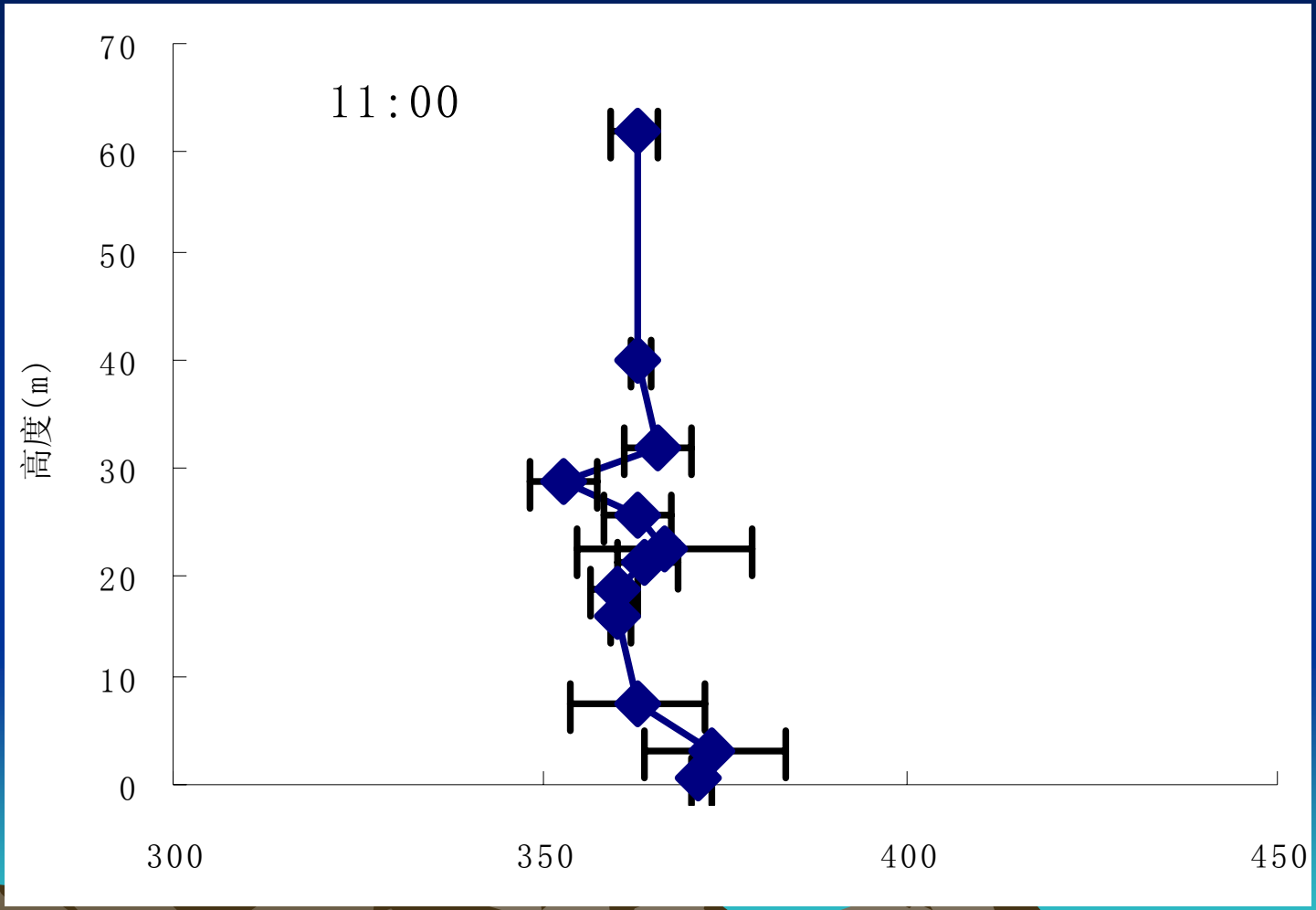


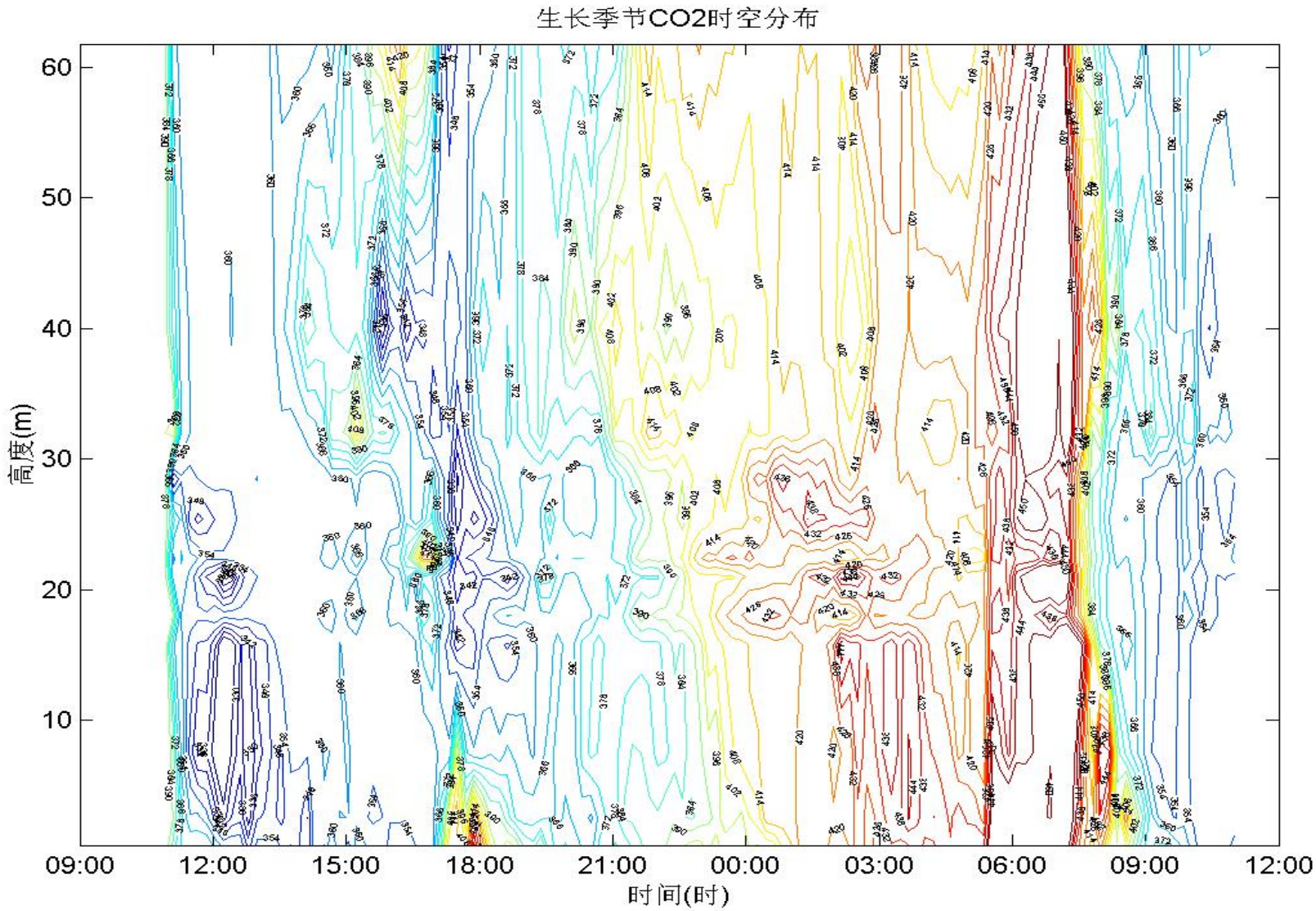
图1.6.2.2-2　生态界面的季节变化

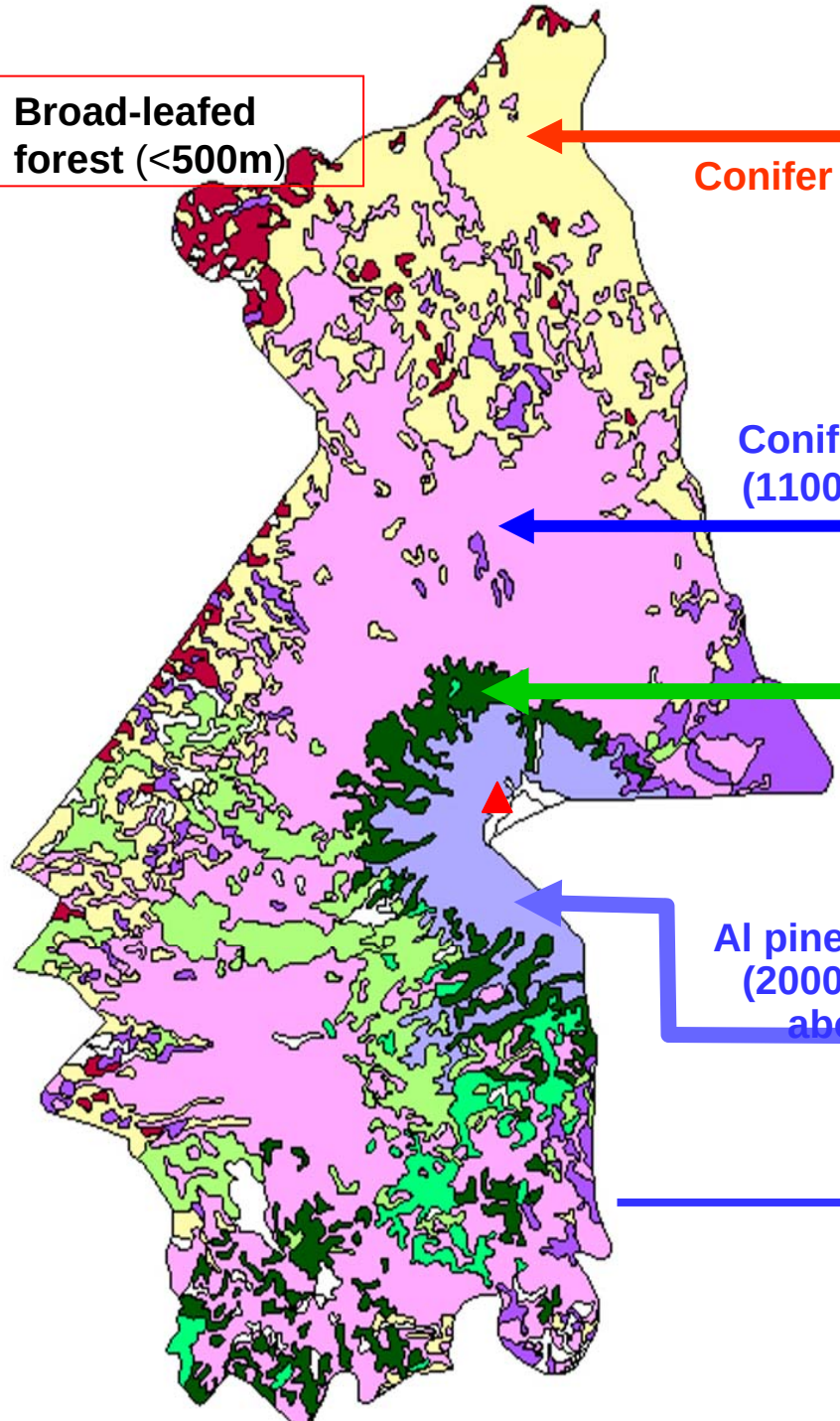
① 6月16日；　② 7月22日；　③ 8月11日

树木个体之间的界面

林冠-大气界面




生长季节CO2时空分布
高度(m)
60
50
40
30
20
10
09:00
12:00
15:00
18:00
21:00
00:00
03:00
06:00
09:00
12:00
时间(时)



Broad-leafed forest (<500m)

Conifer & Deciduous Mixed Forest (500-1100m)

Conifer forest (1100-1700m)

Betula ermanii Forest (1700-2000m)

Al pine Tundra (2000m and above)

Vegetation changes along elevation

界面的特性

- 梯度
- 信息、物质、能量流密集

$$F = \frac{\Delta V}{\Delta z}$$

$$F = \frac{\Delta V}{\Delta t}$$

生态界面的功能

如“关卡”、“门闸”，起着过滤、选择、调节和平衡作用

- 生态界面是生物与环境之间生态流通道
- 生态界面是生物系统的保护层
- 生态界面状况对生态系统状况有重要指示作用

生态界面的科学抽象

- **最初界定的局限性**

熊文愈教授（1985）：与植物器官接触的空气薄层，只关注界面的空气相。

- **对称思维的科学性**

在生态学意义下，异质物相分界及其与该分界毗邻的、反映物质能量或信息的活跃区域的总合。

“毗邻”指分界的两侧

“活跃区”指物质和能量的梯度分布

“总合”强调能量与物质梯度分布是环境强迫与生物调节作用的耦合。 **该定义可以普遍适用于不同尺度的界面过程**

表 1-1 不同类型生态界面的空间尺度和刻画方法

生态界面类型	尺度范围(m)	刻画方法
器官生态界面	0.001~0.01	吸附法、电子探针、闪烁仪、微照相法
冠层/大气生态界面	1~100	微气象学梯度观测，动量、感热交换通量
群落生态界面	10~1000	种群学、生境分析
景观生态界面	10^3~10^6	景观生态学法

界面生态过程试验研究实例

- 红松碳过程对于CO2浓度倍增响应的开顶箱模拟
- 长白山阔叶红松林碳交换研究

Simulation of response to 2XCO2 using

Open-Top-Chambers

Focus on:

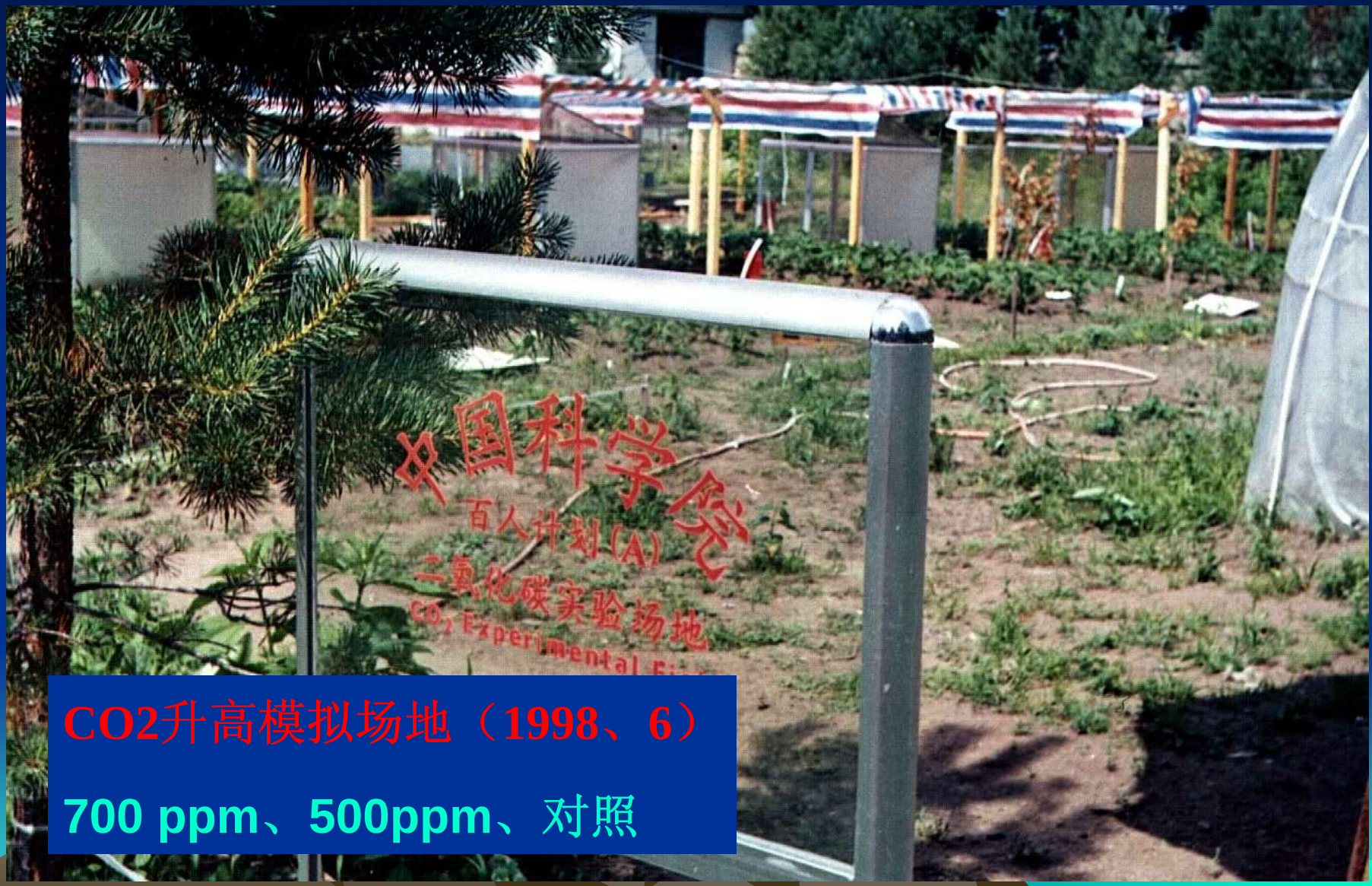
- **Acclimation of trees after long-term exposure to elevated CO_2**
- **The capability or potential of CO_2 assimilation in the future**
- **The carbon balance between above- and below-ground parts**

Experimental facility: Hexagonal Open Top Chambers/ automatically controlled

Experimental materials: *Pinus koraiensis*, *Pinus sylvestriformis*, *Quercus mongolica*

CO_2 concentration: 500 μ mol mol^{-1}/ 370

Treatment time: since 1999/growing season (from May to October)/$24h^{-1}$

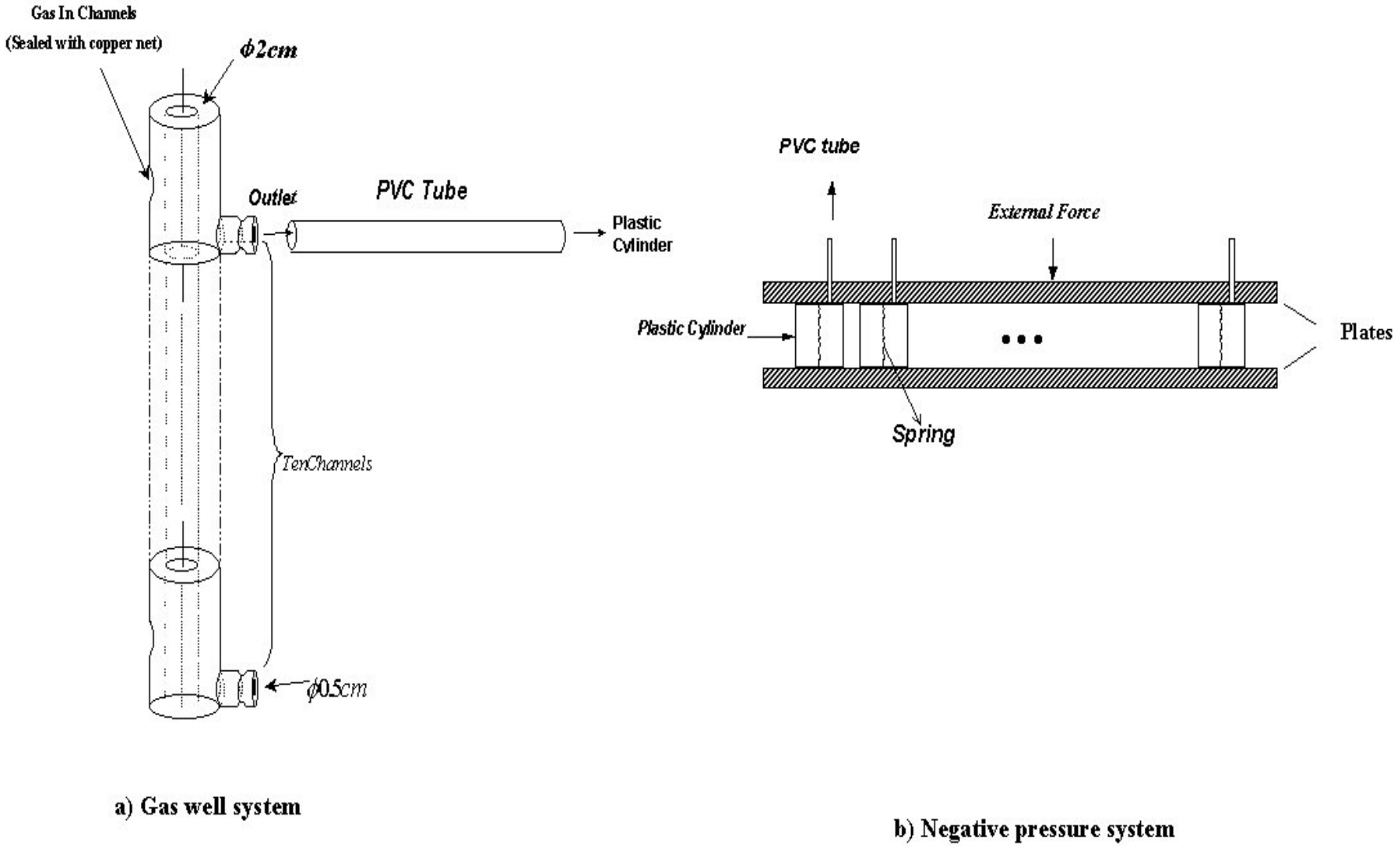


CO2升高模拟场地（1998、6）

700 ppm、500ppm、对照

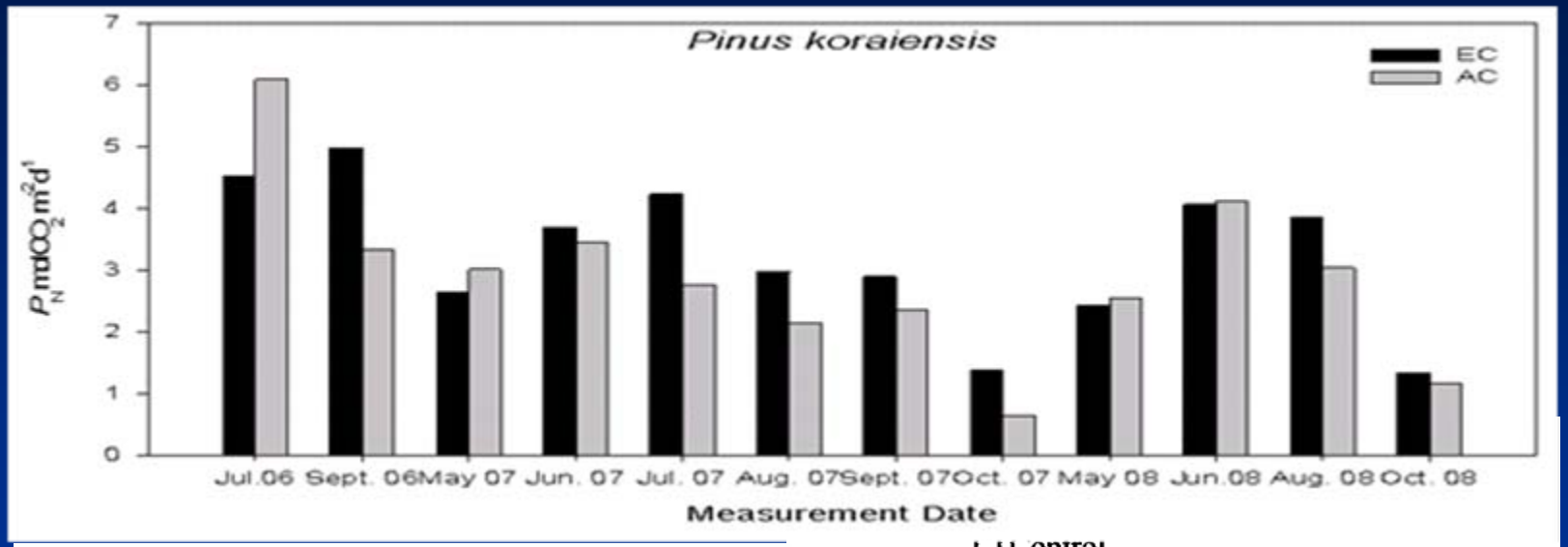

FACE

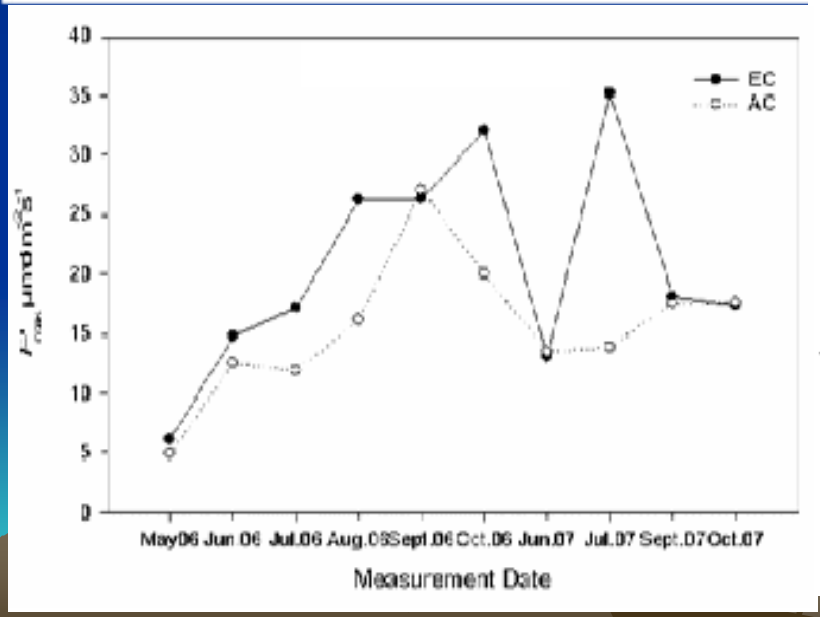
国家基金（青年/面上/重点）国家重大基础研究专项支持

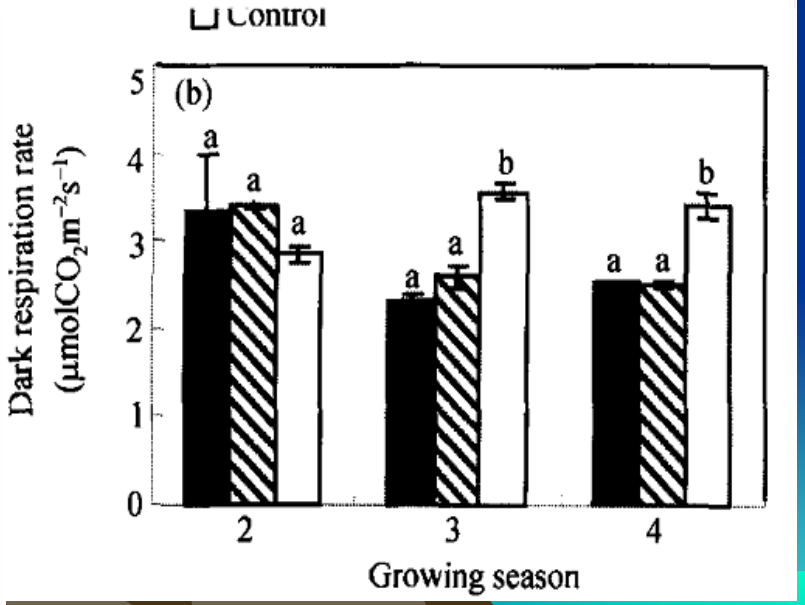


Gas sample collection system

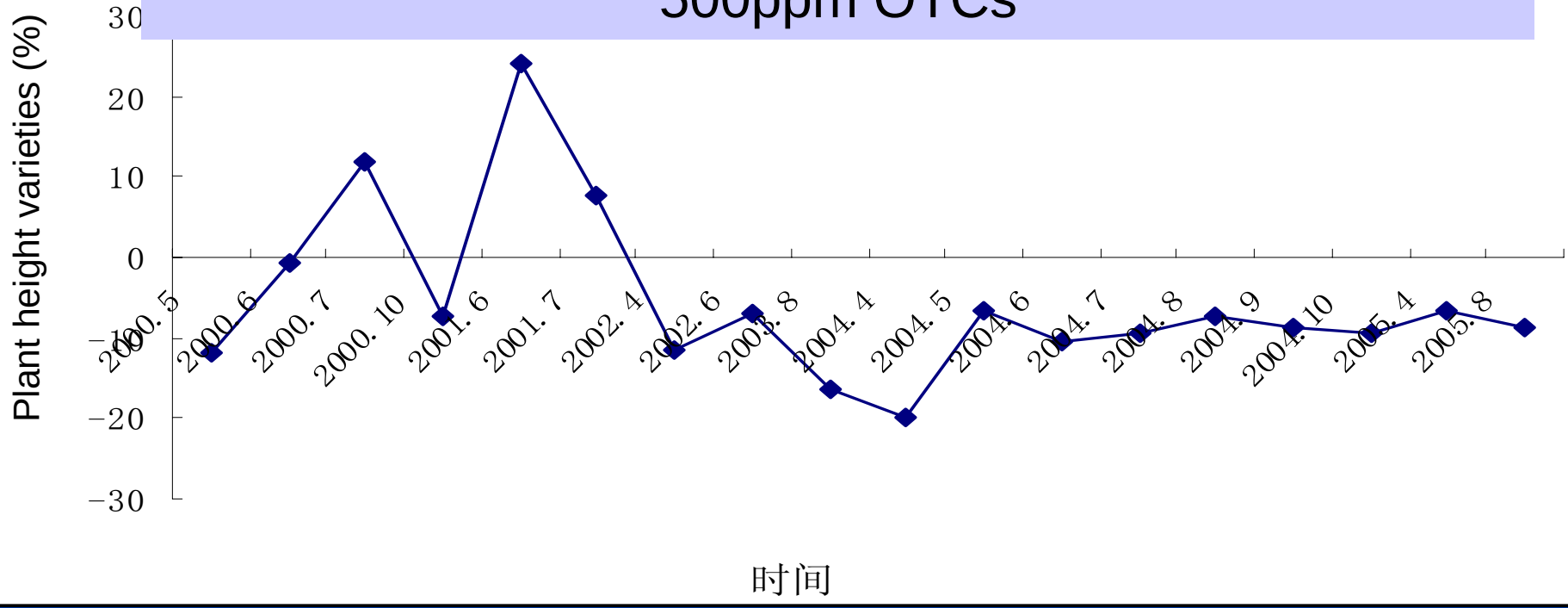
Net photosynthesis





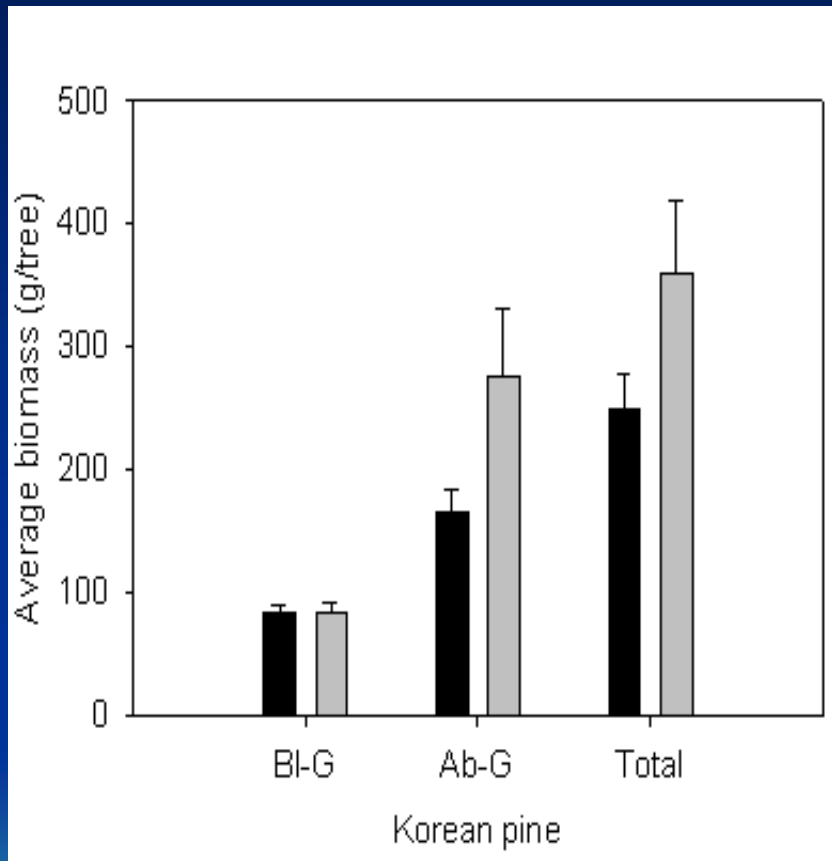


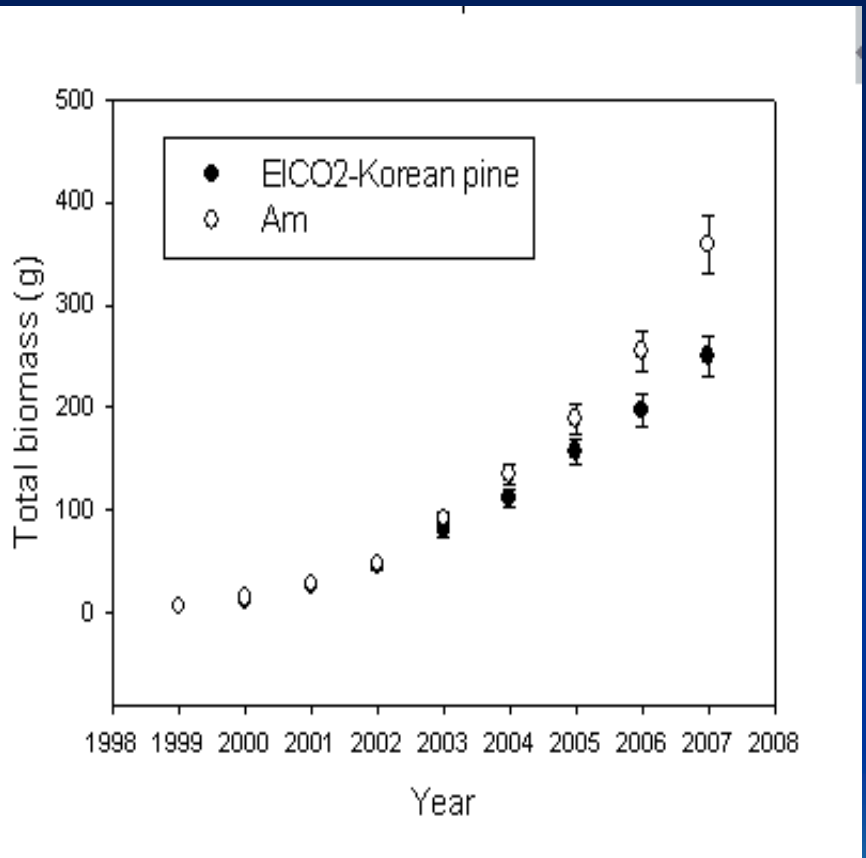
Tree height varieties of Korean Pine seedlings in 500ppm OTCs



High CO2 treatment restrained tree height growth, except the initial seasons

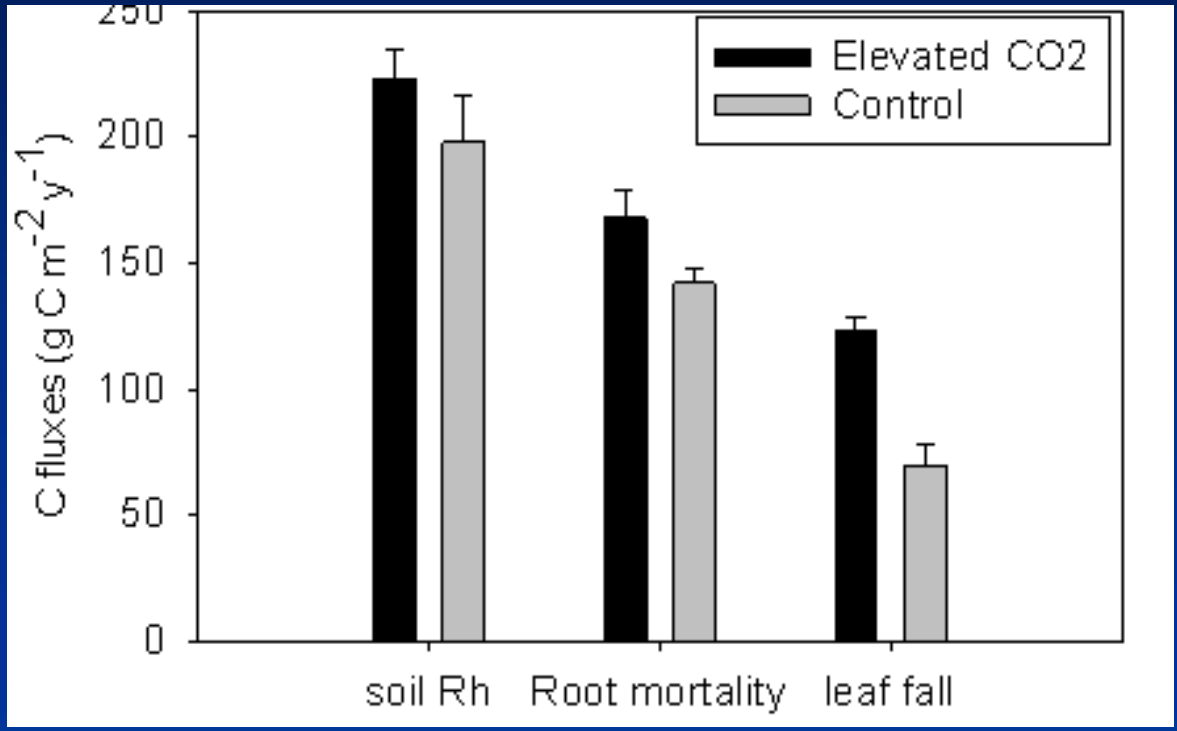
ANPP was retained





Exposure to high CO_2 inhibited total biomass increment and induced more assimilation allocated into roots of 2 tree species. Inhibition became more obviously as age increased

Soil carbon sequestration increased

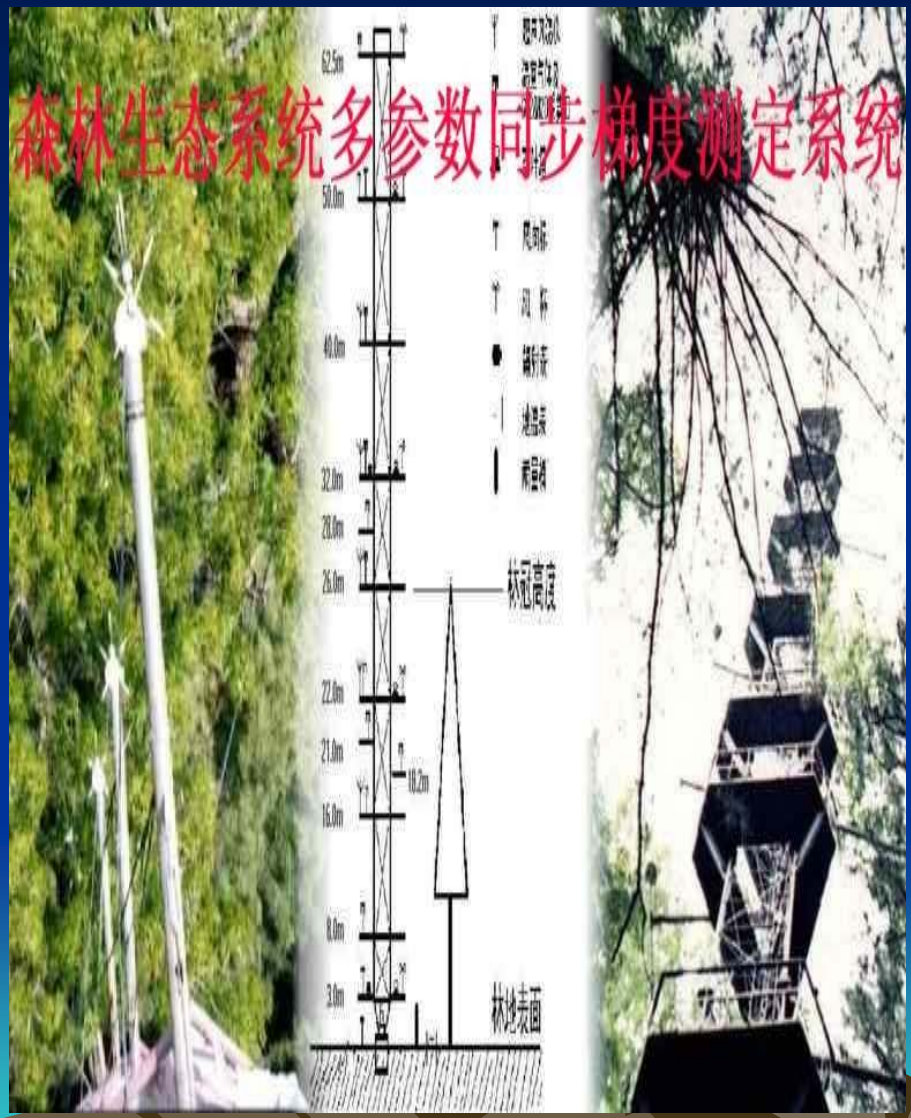


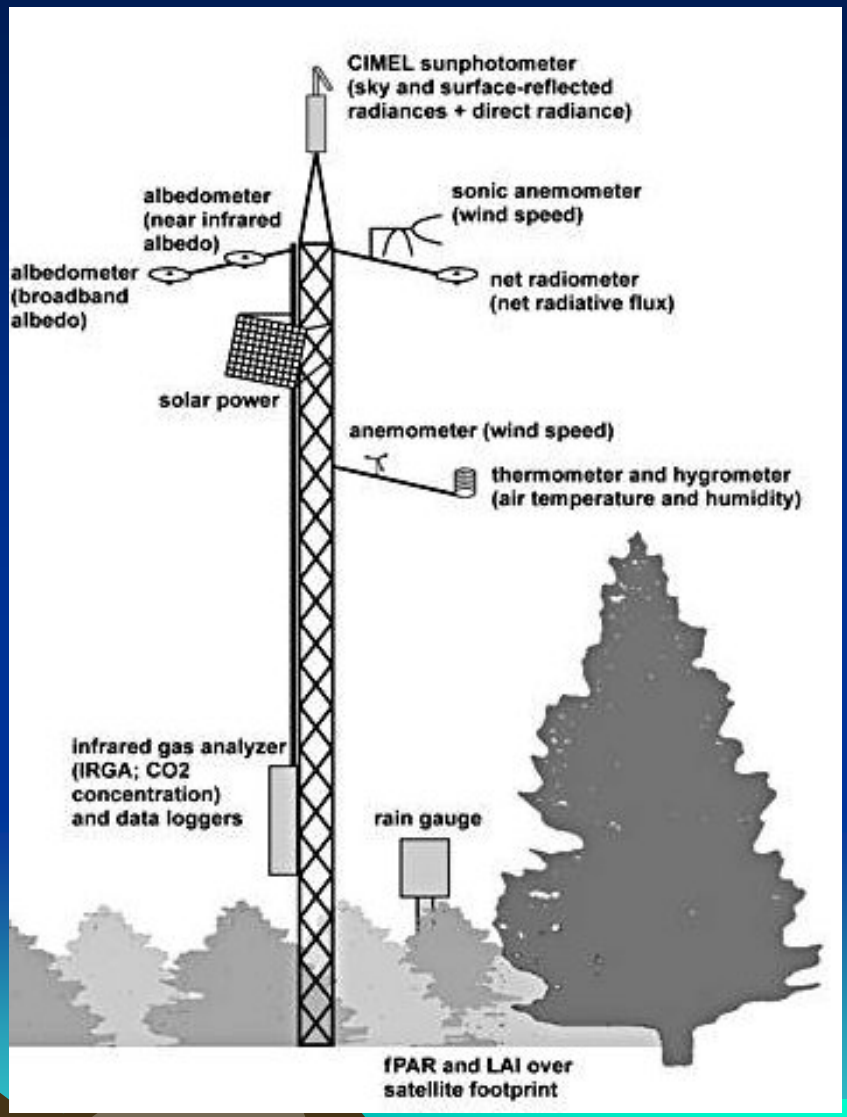
Long-term exposure to high CO_2 resulted significant increase in fine root turnover, product and fine root biomass. improved the stability of soil organic matter. Soil ROC, TOC and TOM were increased significantly

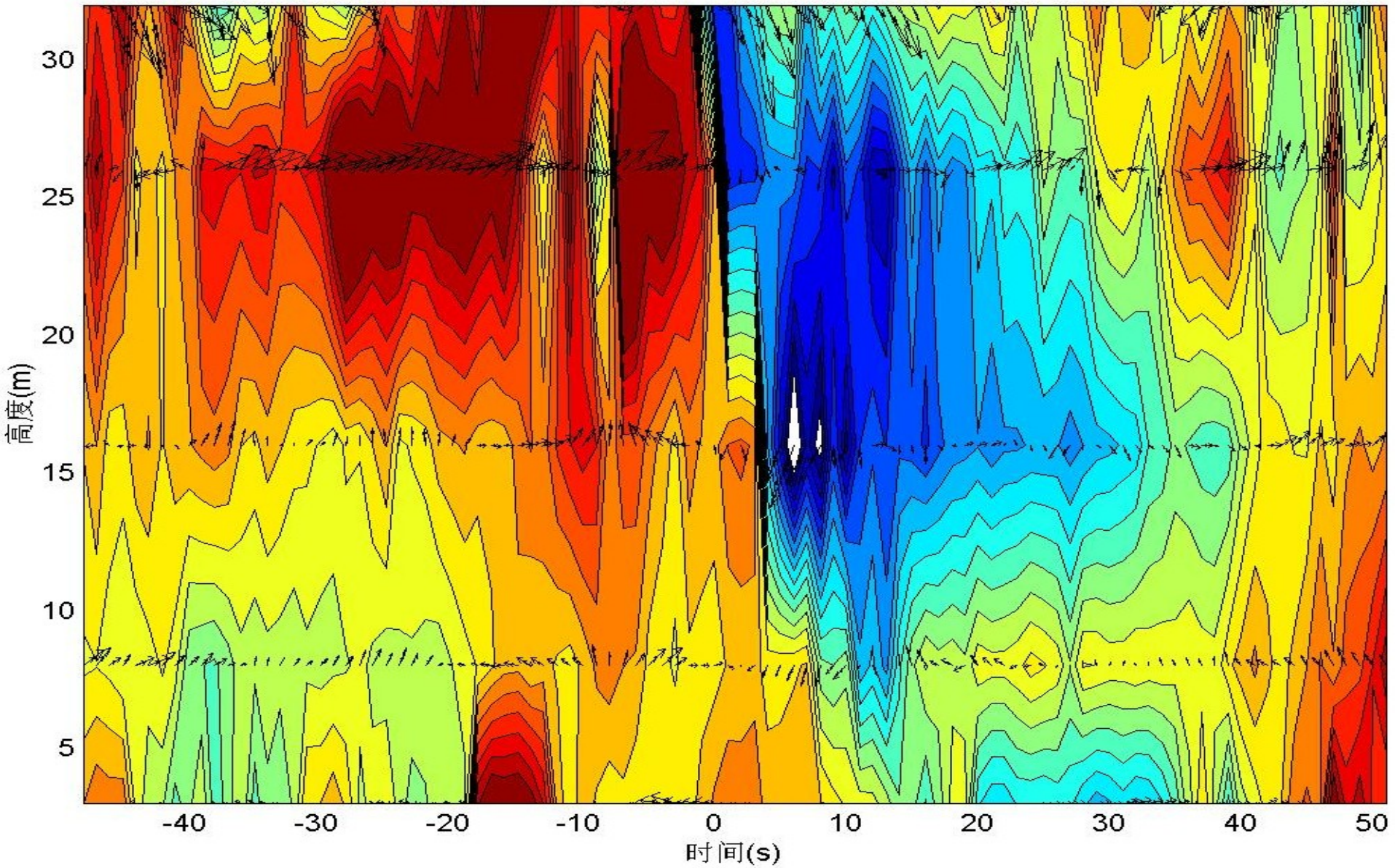
NOTE

- **Korean pine captured more and allocated even more carbon to respiration and below ground and then increased soil carbon sink capacity under 2xCO_2**

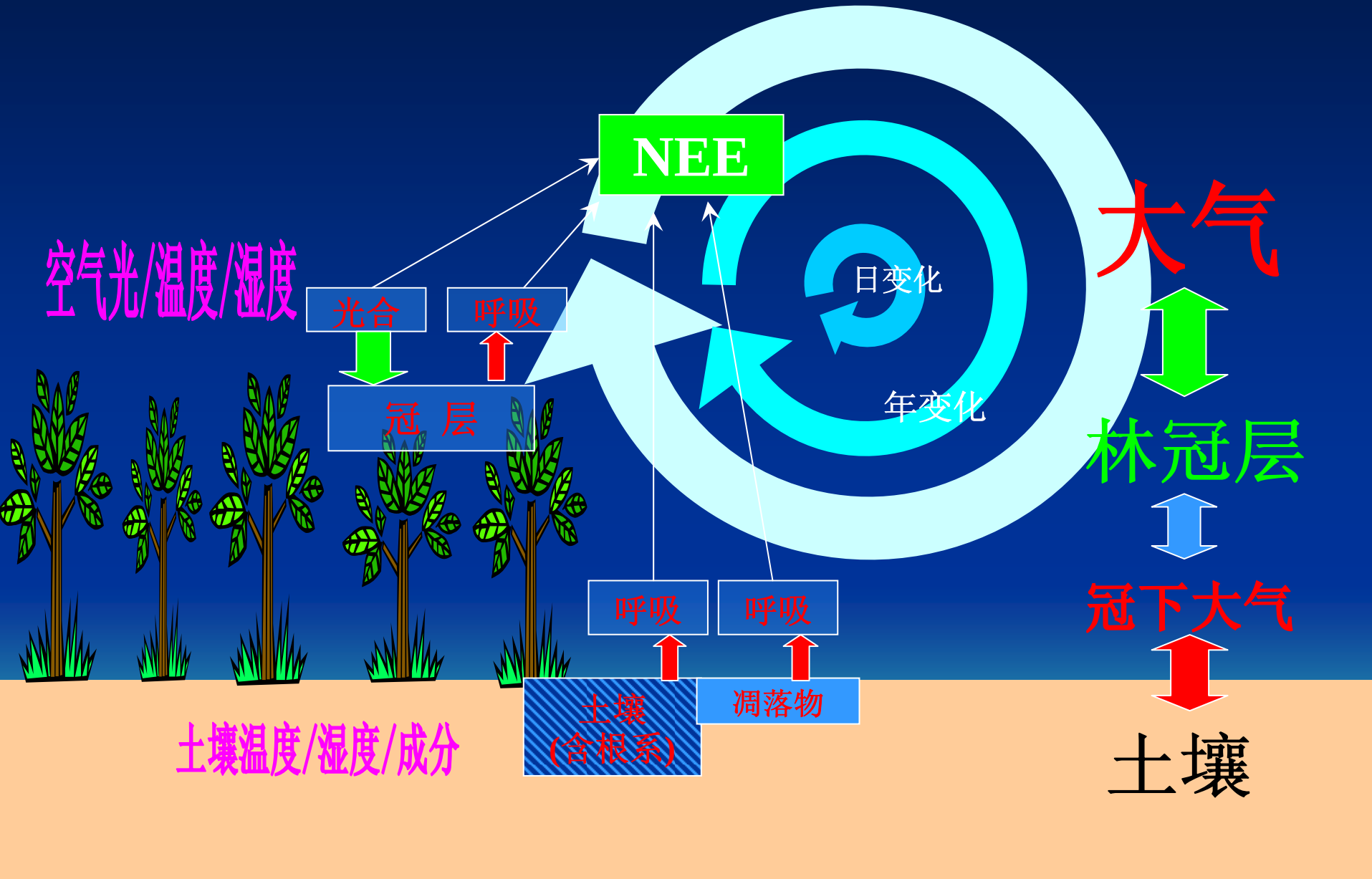
长白山阔叶红松林碳交换研究

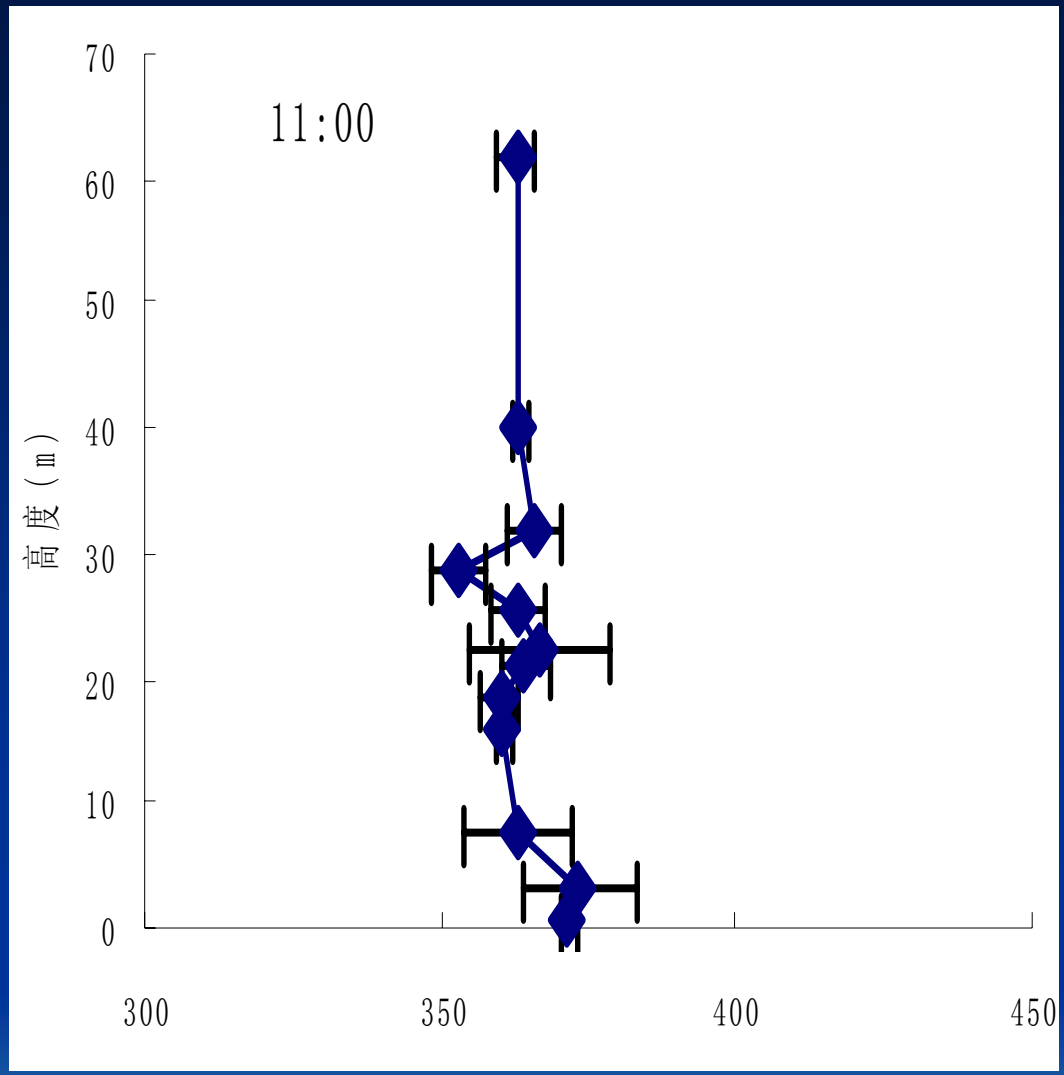




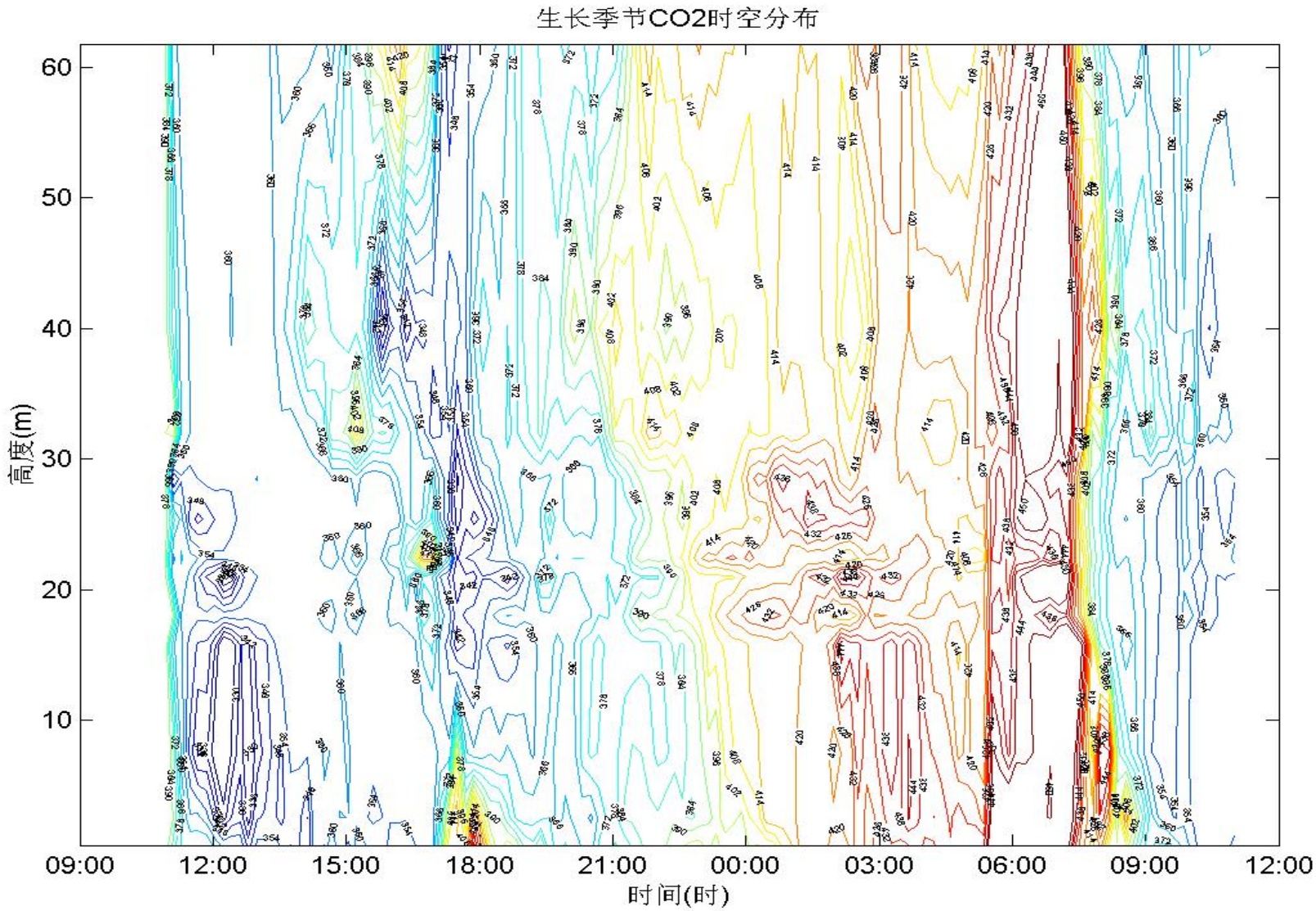

30
25
20
15
10
5
高度(m)
-40
-30
-20
-10
0
10
20
30
40
50
时间(s)

森林生态系统碳收支的界面过程





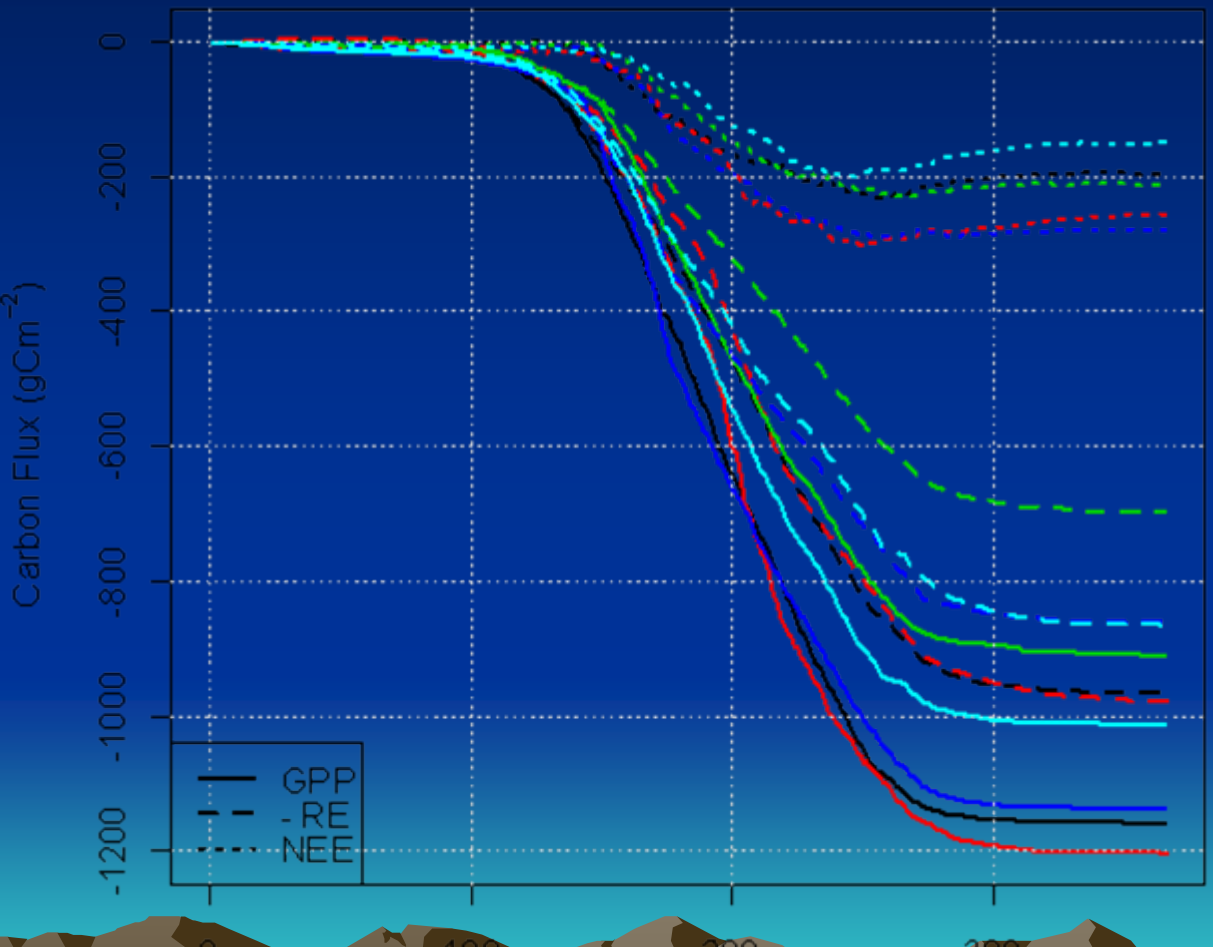
- 光合时段δ薄；午夜δ趋于无限大
- 生态界面是太阳辐射驱动下的耗散结构


生长季节CO2时空分布
高度(m)
60
50
40
30
20
10
09:00
12:00
15:00
18:00
21:00
00:00
03:00
06:00
09:00
12:00
时间(时)


大气


冠下大气
林地

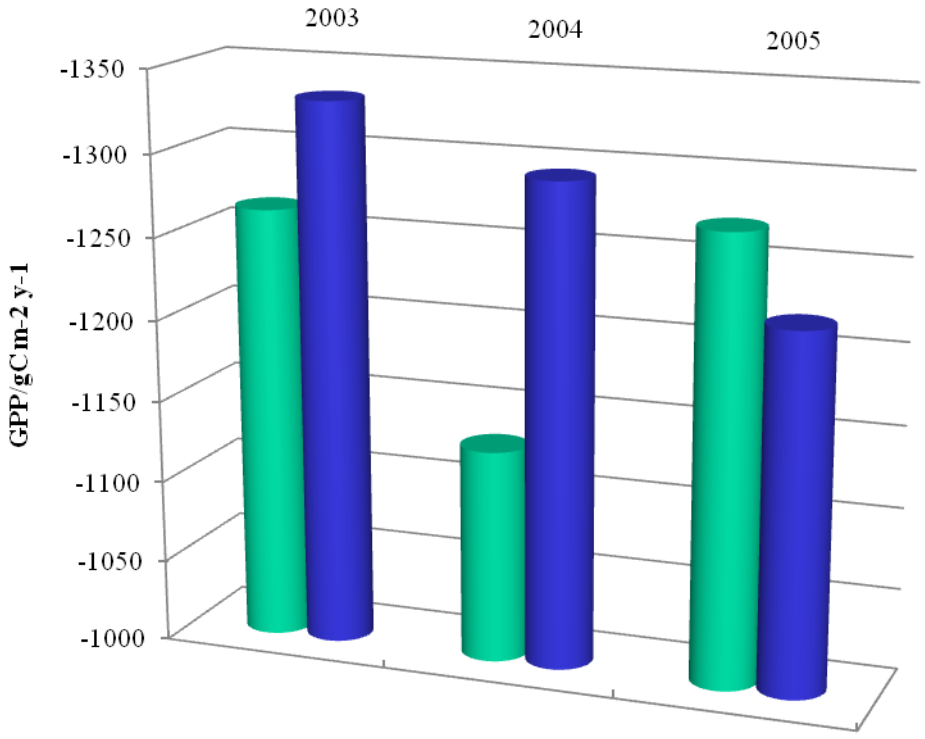
长白山阔叶红松林是一个碳汇



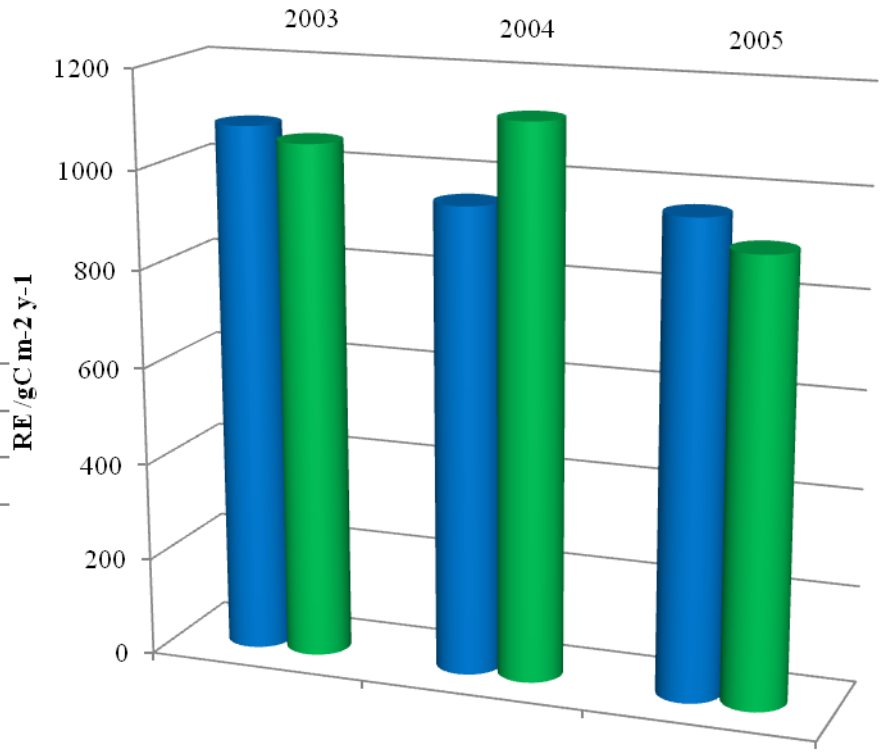
与国际同类研究的比较

涡度相关（1998-）	NEE（C g $m^{-2}year^{-1}$）	NPP（C g $m^{-2}year^{-1}$）	GPP（C g $m^{-2}year^{-1}$）
北美温带森林	585	944	1725
北方森林	68	517	963
长白山阔叶红松林	278 - 171		1332 - 1294

GPP、RE与人工林相当，且稳定性好；



	2003	2004	2005
落叶松人工林	-1265	-1130	-1272
阔叶红松林	-1332	-1294	-1219



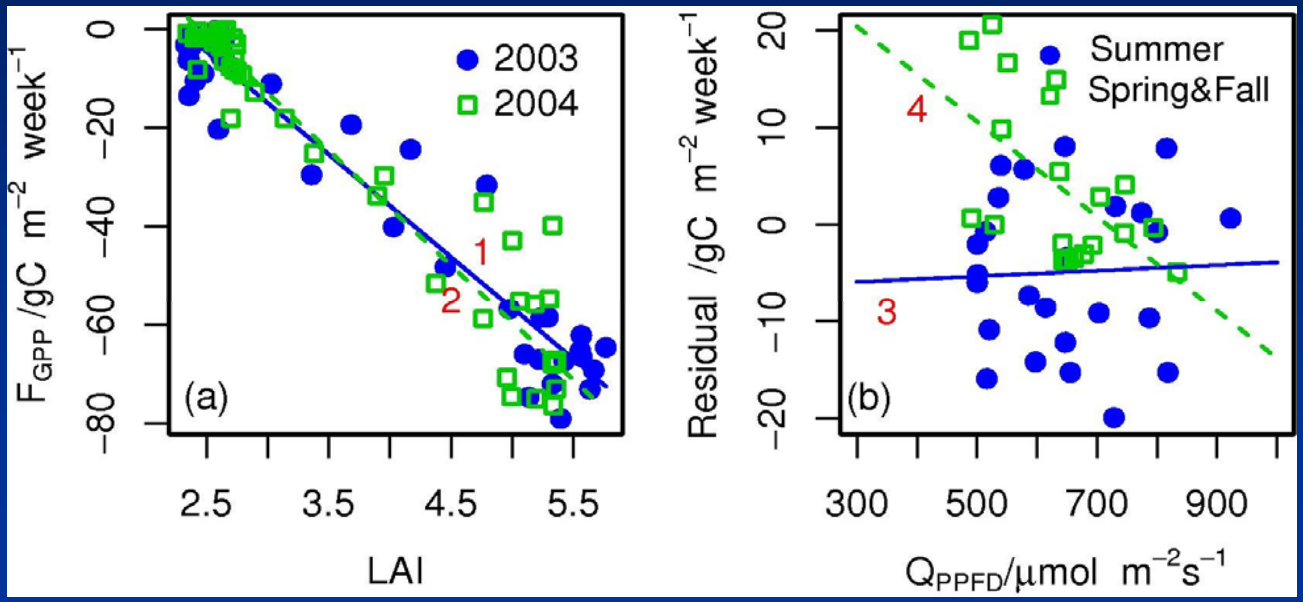
	2003	2004	2005
落叶松人工林	1082	953	963
阔叶红松林	1054	1124	902

- 长白山原始林(200a)和老山人工林(40a)碳通量比较

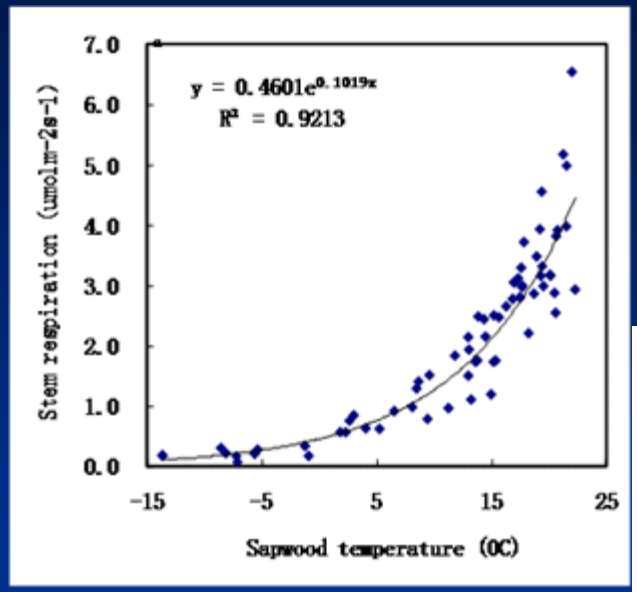
Where the carbon gone

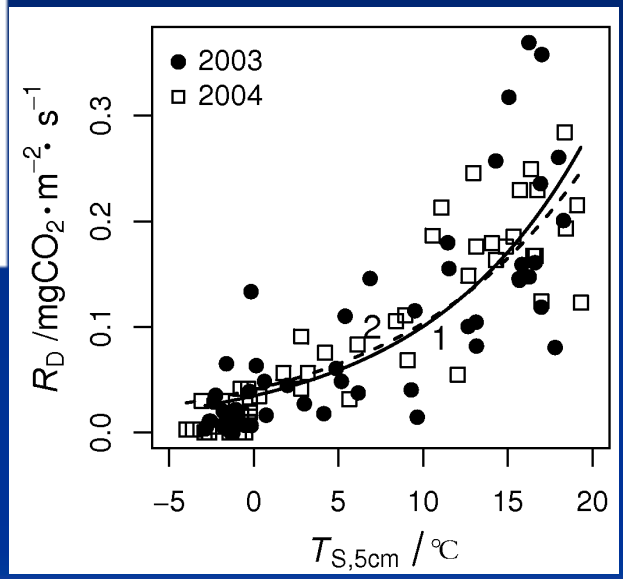
Carbon pools	Annual increment
	Soil
Respiration	-406±28
Litter-fall	225±23
Dead fine roots	258±12
Fallen woods	22±13
SOM	121±76
	Trees
ANPP	228±28
Coarse roots	55±7
	Shrub
ANPP	2.7
Coarse roots	1.3
Grass etc	
	Total
339±111	

Environmental Regulations

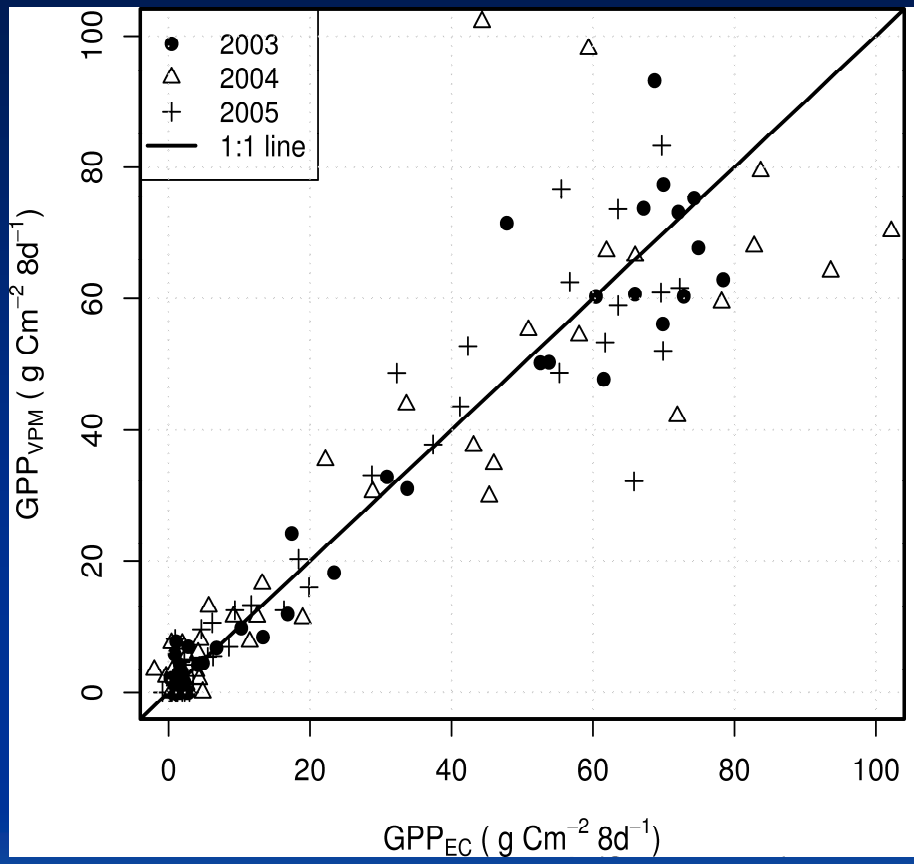


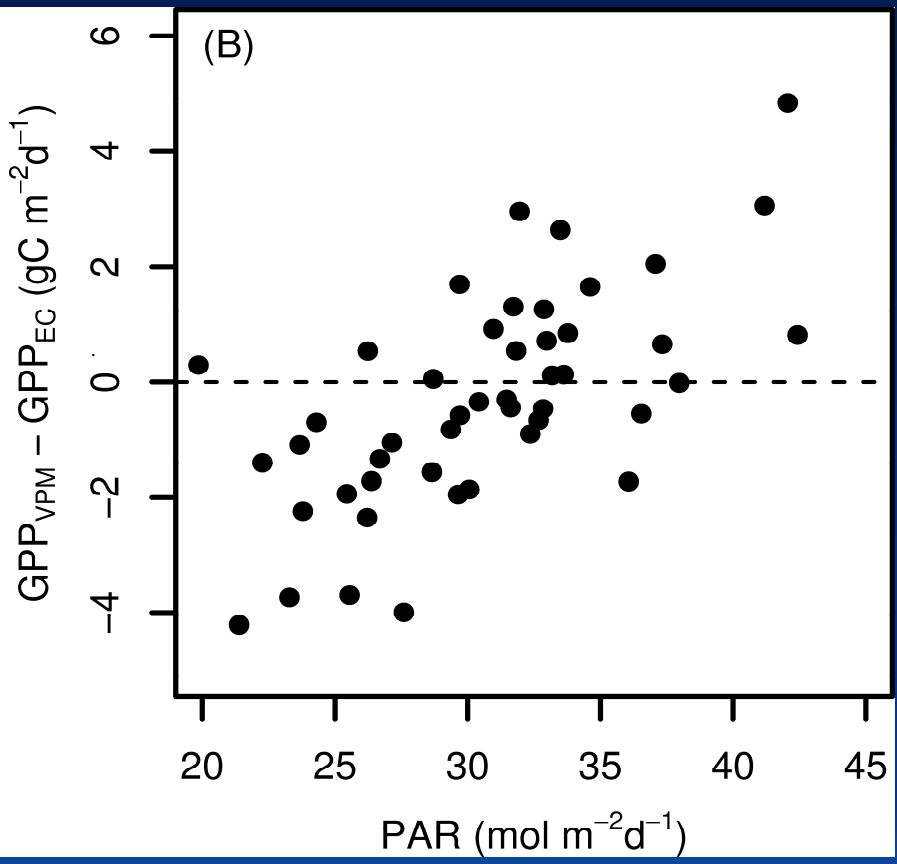
At seasonal scale, LAI is the most significant factor controlling F_{GPP}(P < 0.001).



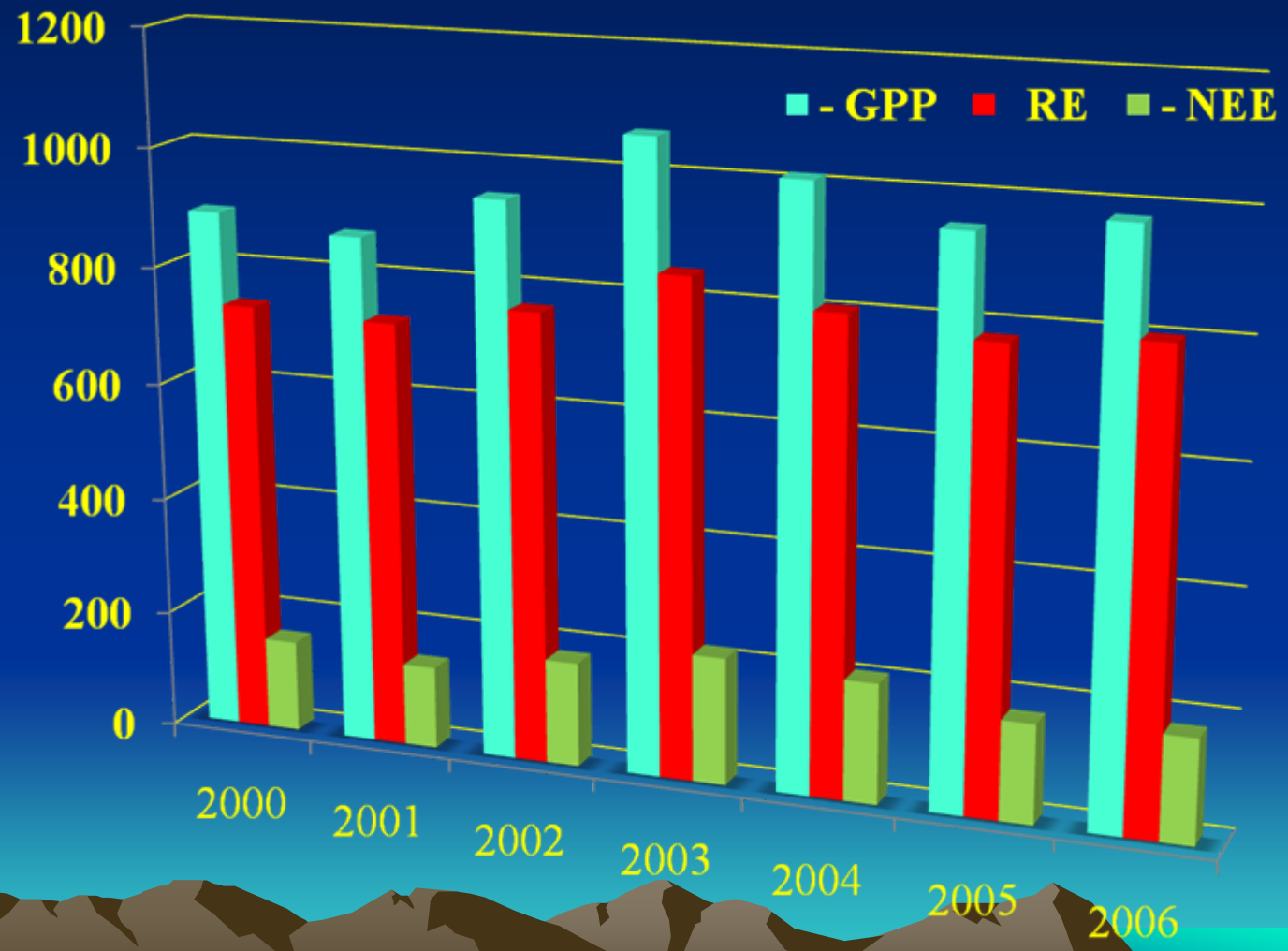


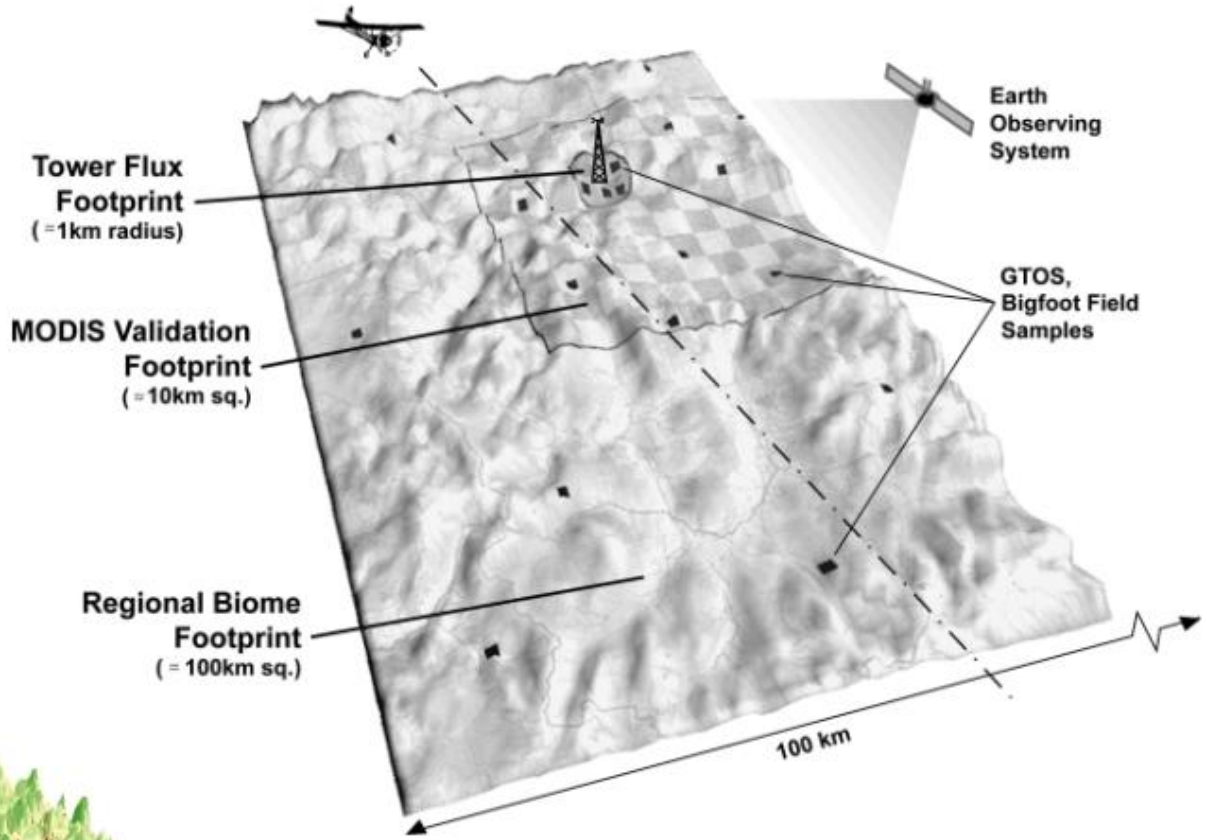
Soil temperature is the most significant factor controlling R_E(P<0.001).


2003
2004
2005
1:1 line
GPP_VPM (g Cm^-2 8d^-1)
GPP_EC (g Cm^-2 8d^-1)
0
20
40
60
80
100


(B)
GPP_VPM – GPP_EC (gC m^-2d^-1)
PAR (mol m^-2d^-1)
−4
−2
0
2
4
6
20
25
30
35
40
45

构建基于MODIS的长期碳收支





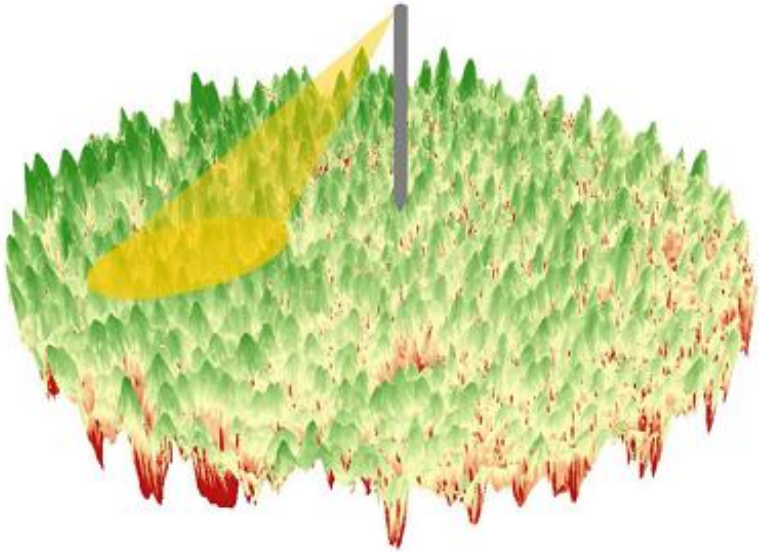
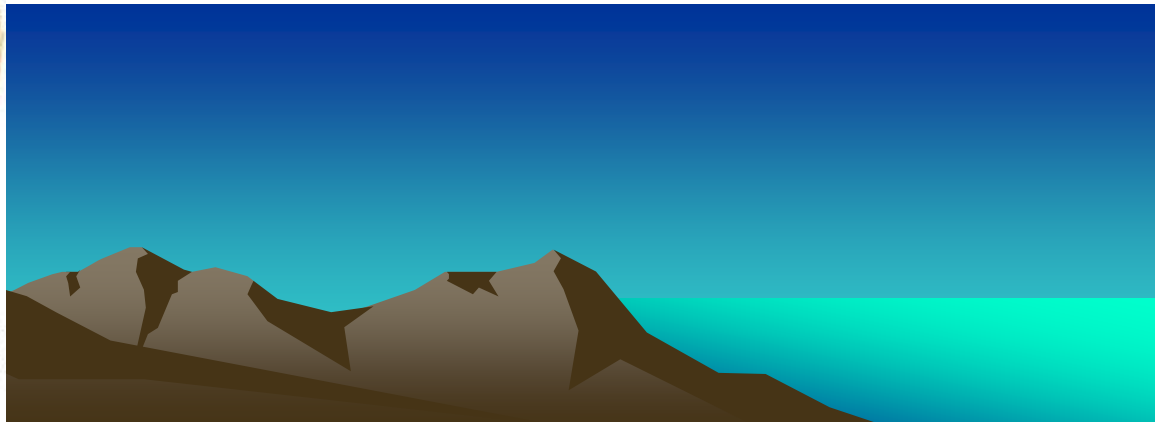


Fig 2: AMSPEC observes the forest canopy around the flux tower every 15 minutes; one scan is taken every 5 seconds. Data were collected over a one year period

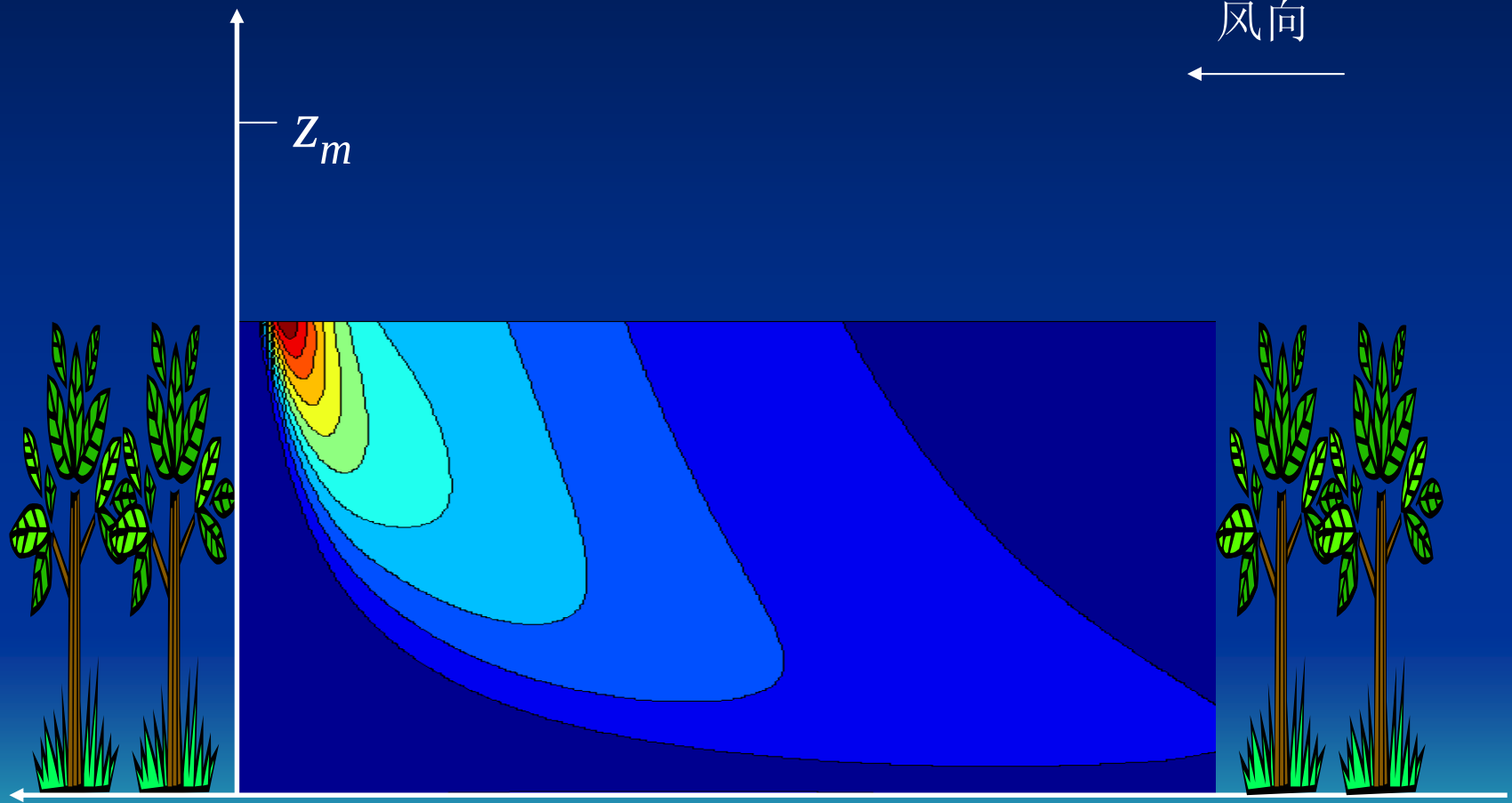


集成试验研究-经验

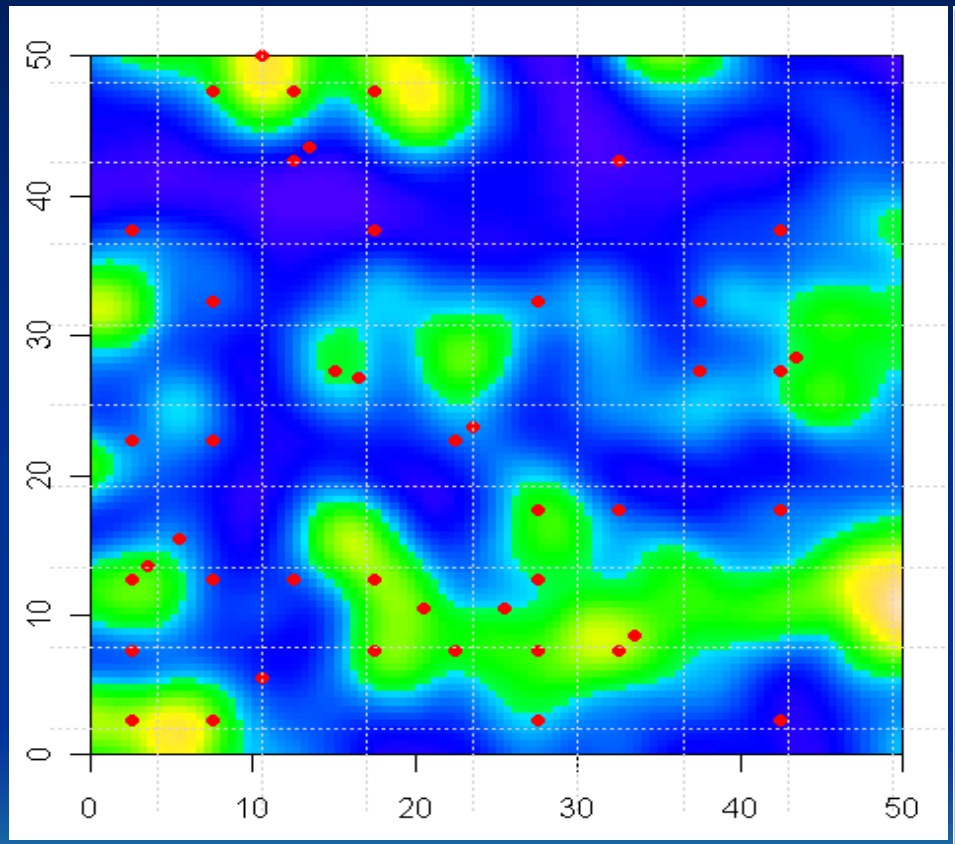
时空尺度的匹配

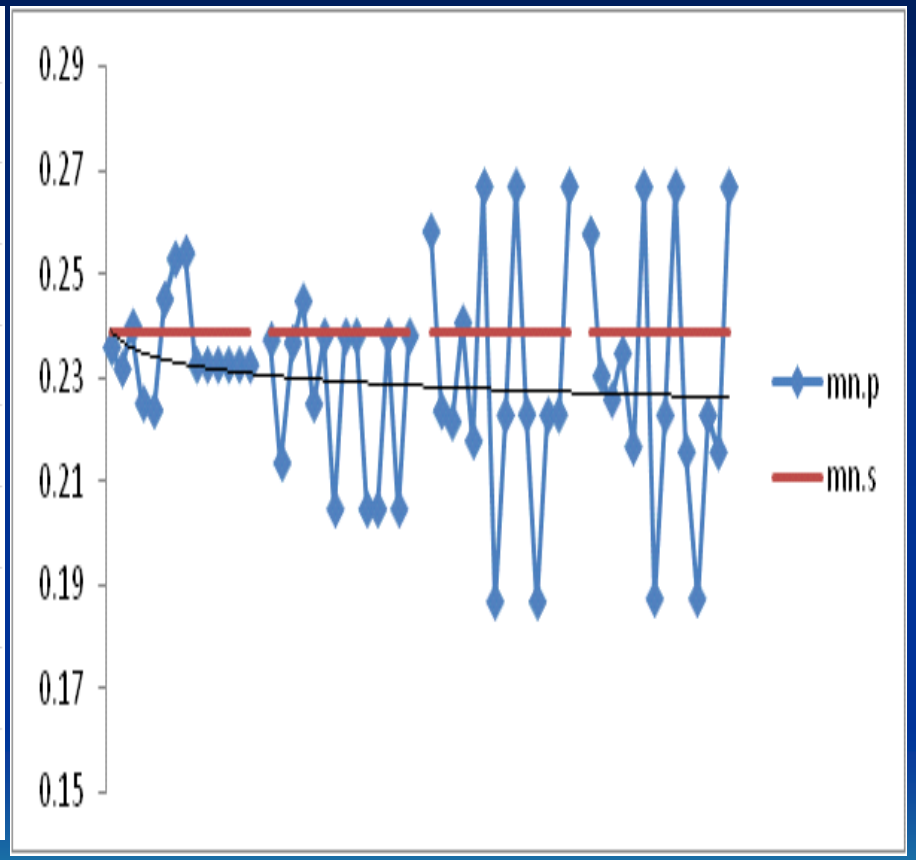
1. **Eddy-covariance up scaling? Quick bird, MODIS or NOAA?**

2 Where to measure soil respiration?



3 How many points should I sample?






谢谢