Introduction of Three-dimensional digital analysis of aerial photographs and Phenology monitoring camera system

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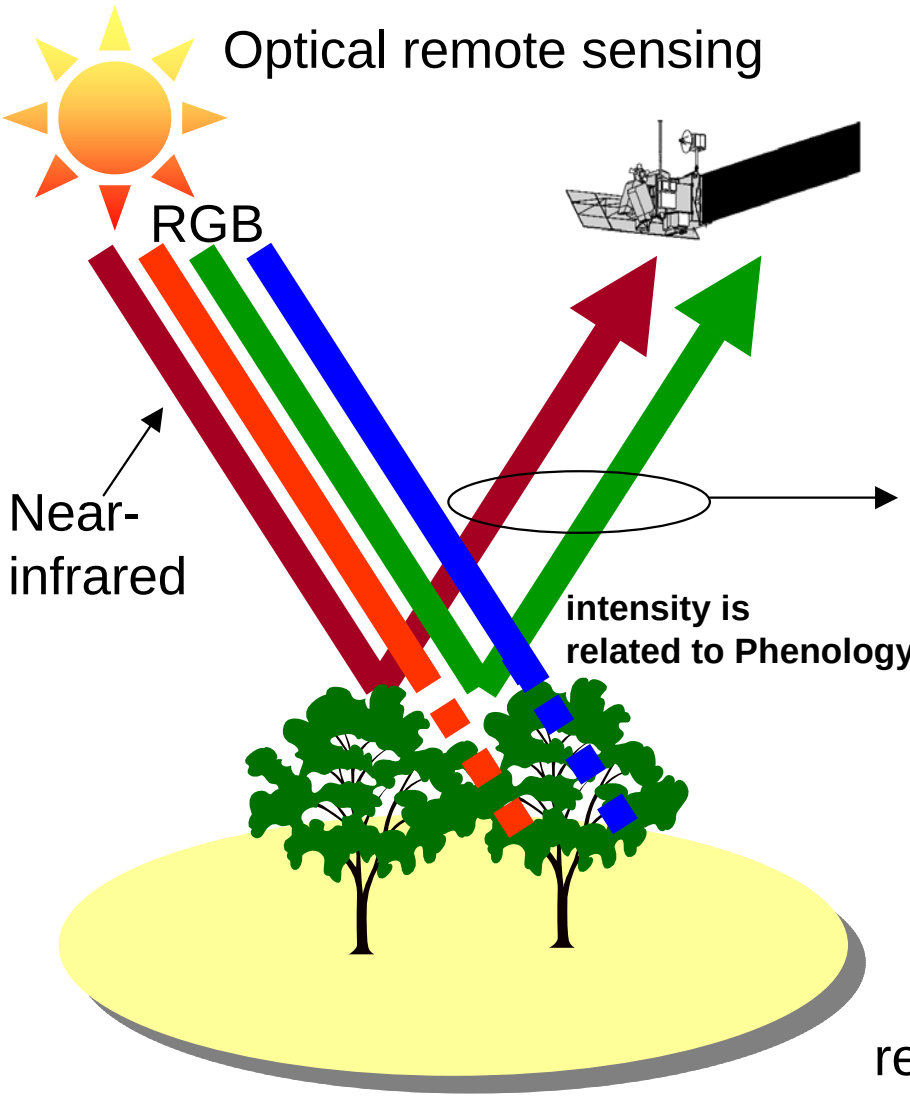
On site scale remote sensing;

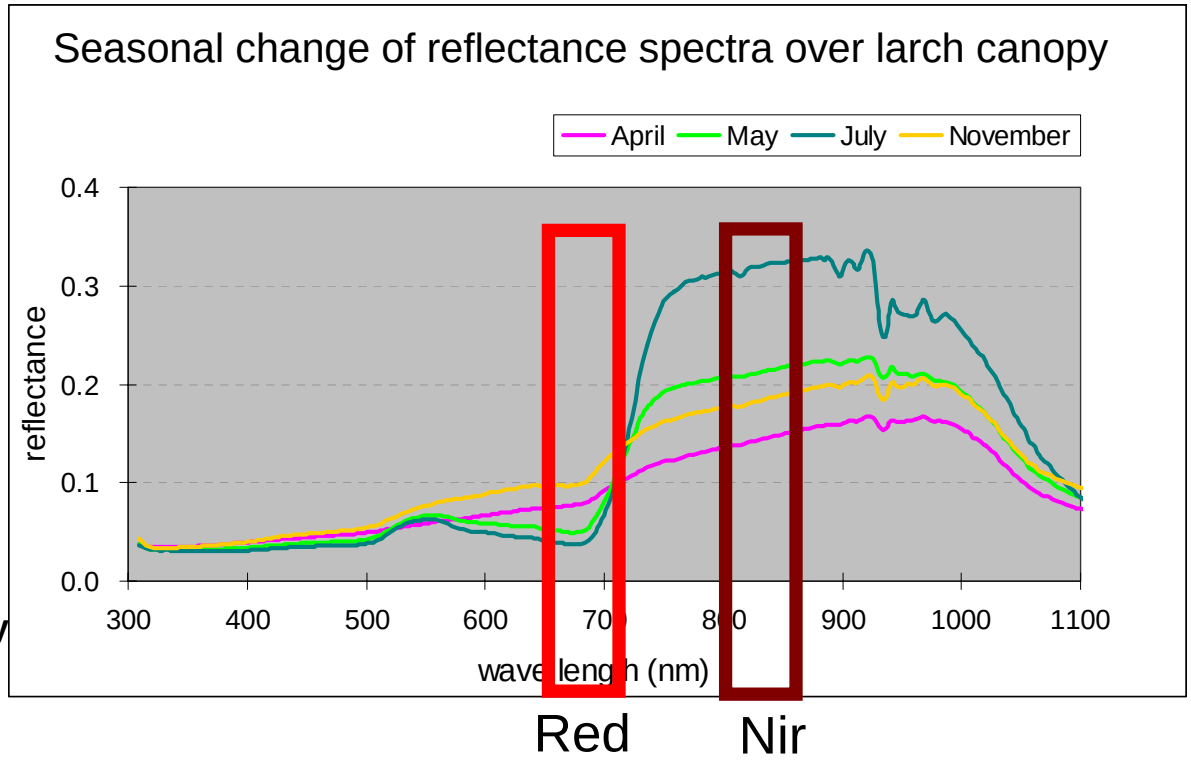
1. ***Phenology monitoring by spectral observation***

2. ***Three-dimensional digital analysis of aerial photographs***

Reflectance of vegetation canopy



red and blue light are
absorbed for photosynthesis

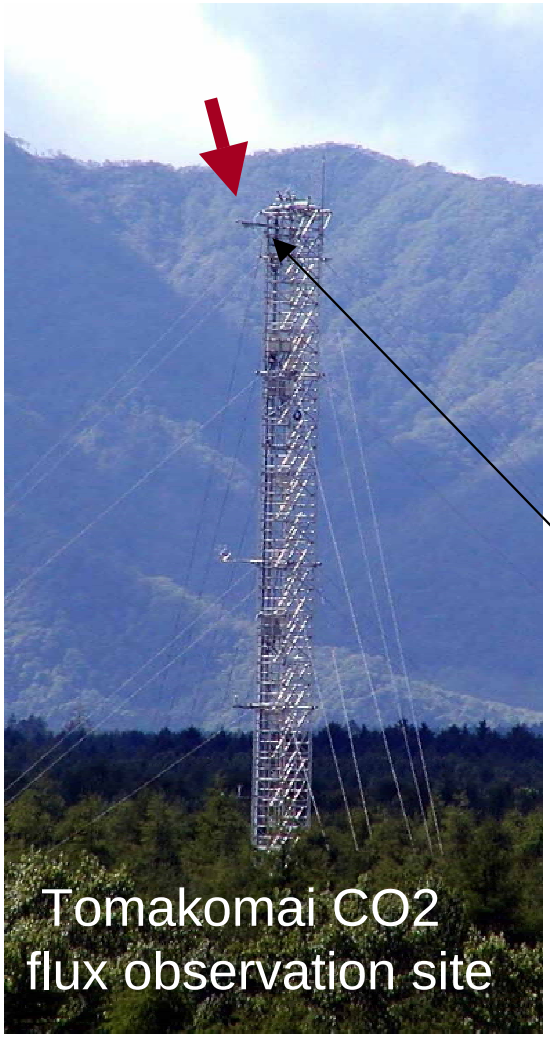


NDVI: Normalized Difference Vegetation Index

$$=(Rnir-Rred)/(Rnir+Rred)$$

related to the content of chlorophyll, LAI and fAPAR

Spectrum measurement by Hemispherical Spectro-radiometer and camera

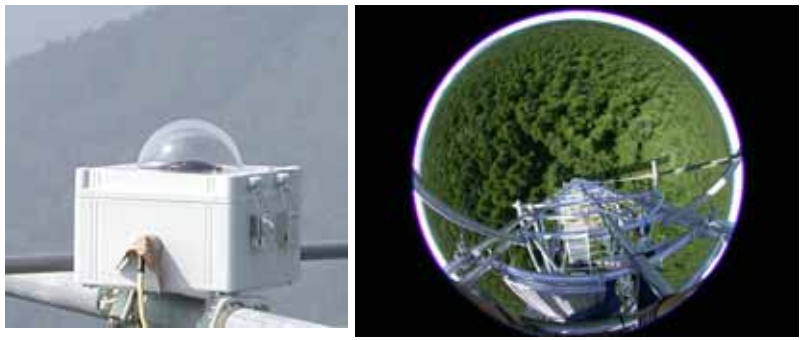


- development of a new algorithm
- verification of vegetation products obtained from earth observation satellite

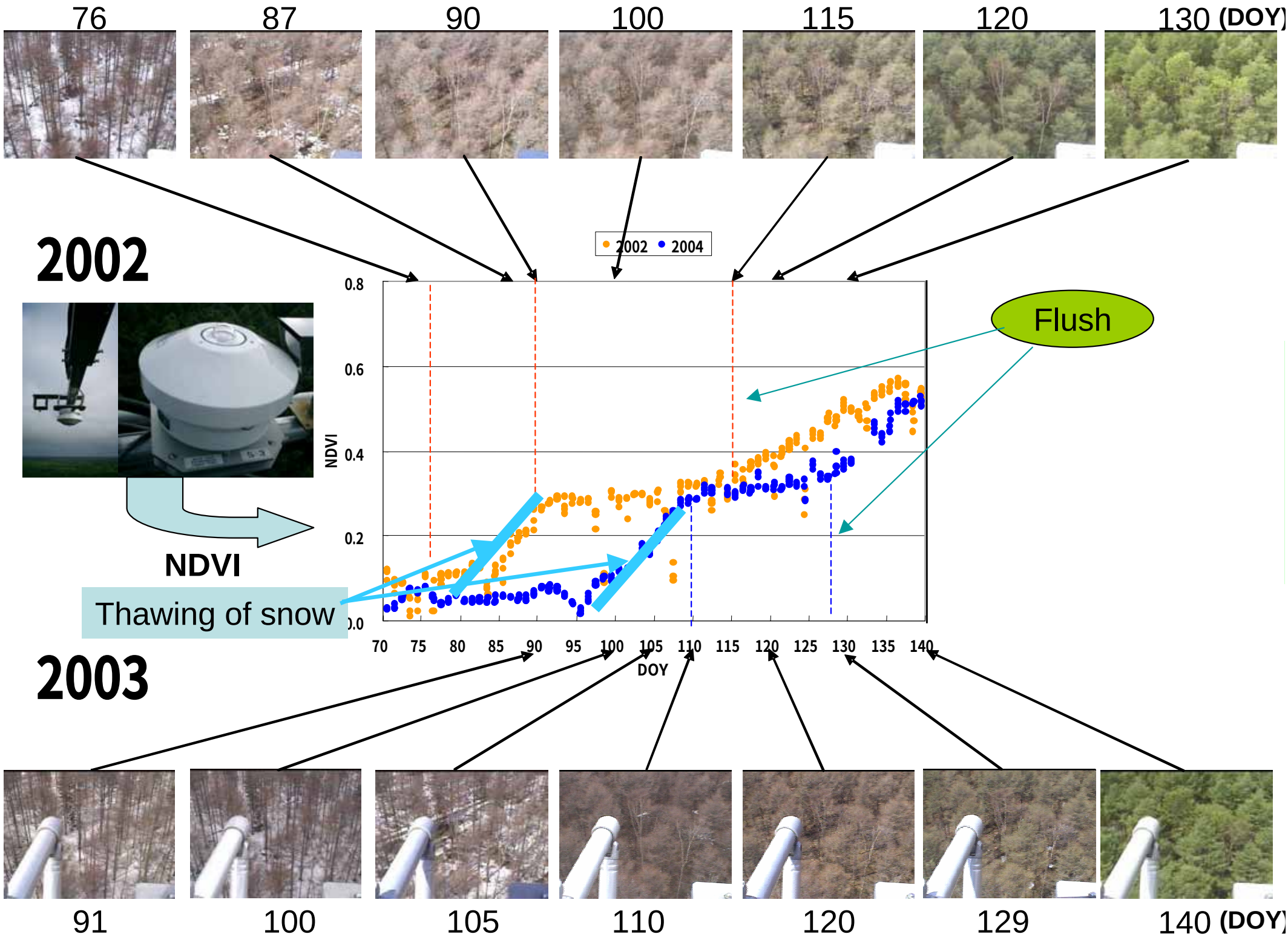
MS-131 (2000～2002)

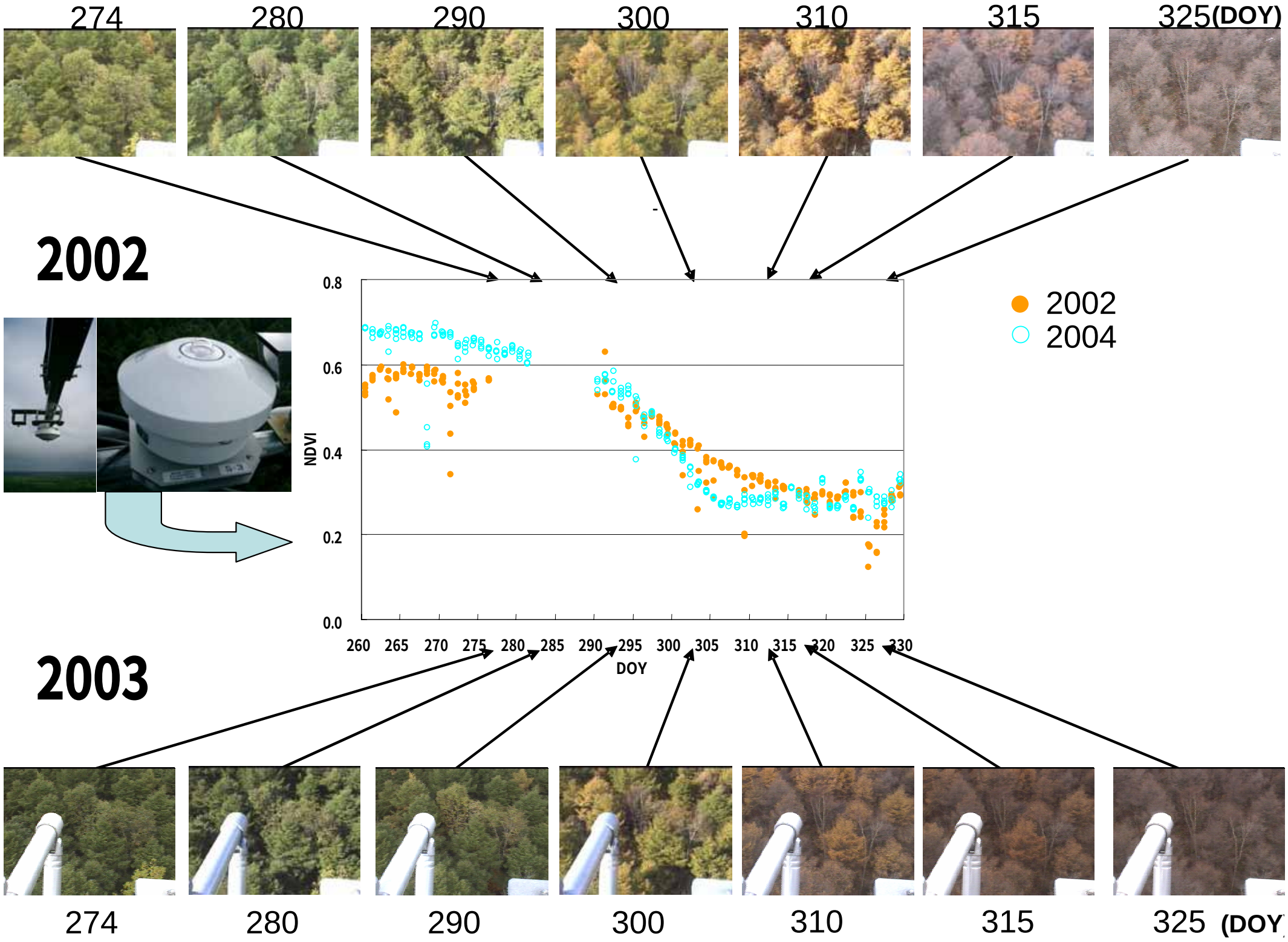
MS-700 (2003～)

CCD video camera

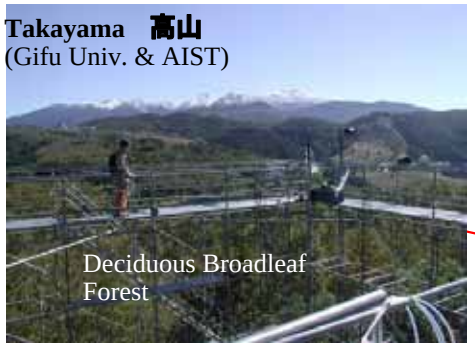


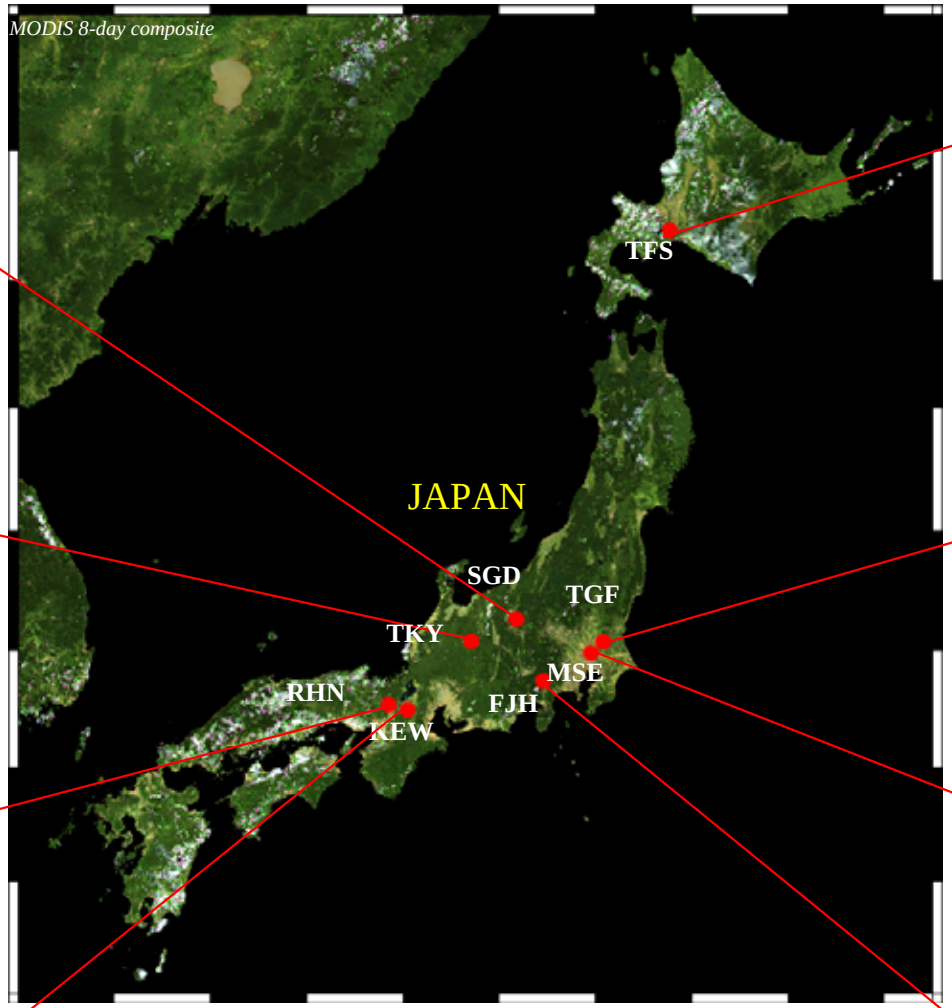
ADFC (automatic digital fish-eye camera)

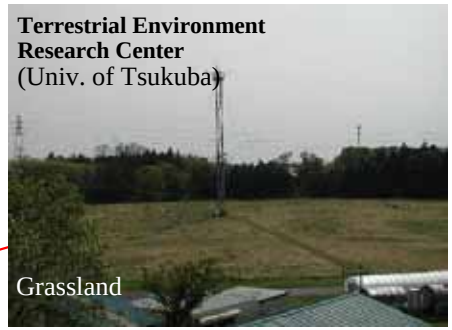

76
87
90
100
115
120
130 (DOY)
2002
2003
2002
2004
NDVI
0.8
0.6
0.4
0.2
0.0
70
75
80
85
90
95
100
105
110
115
120
125
130
135
140
DOY
Flush
Thawing of snow
91
100
105
110
120
129
140 (DOY)


274
280
290
300
310
315
325(DOY)
2002
2003
0.8
0.6
0.4
0.2
0.0
NDVI
260 265 270 275 280 285 290 295 300 305 310 315 320 325 330
DOY
2002
2004
274
280
290
300
310
315
325 (DOY)

PEN Phenological Eyes Network



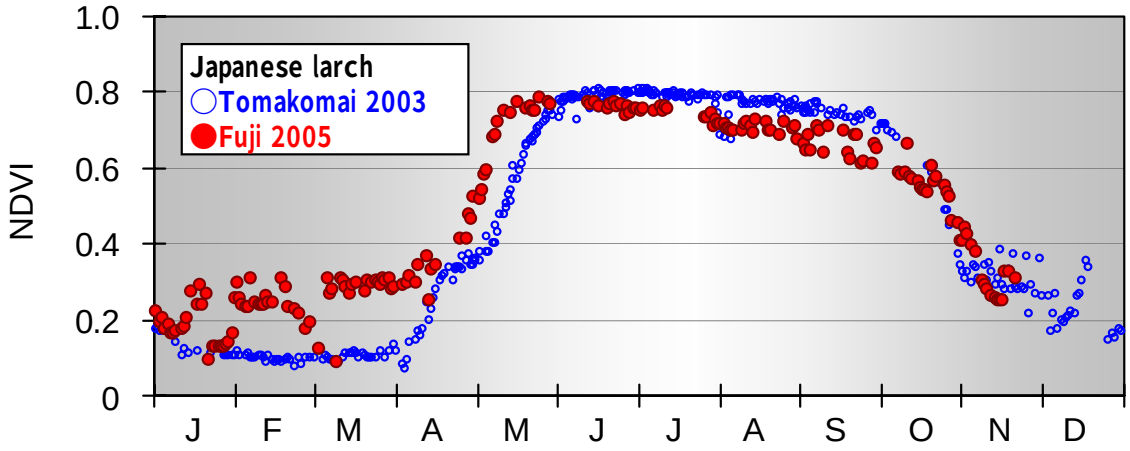




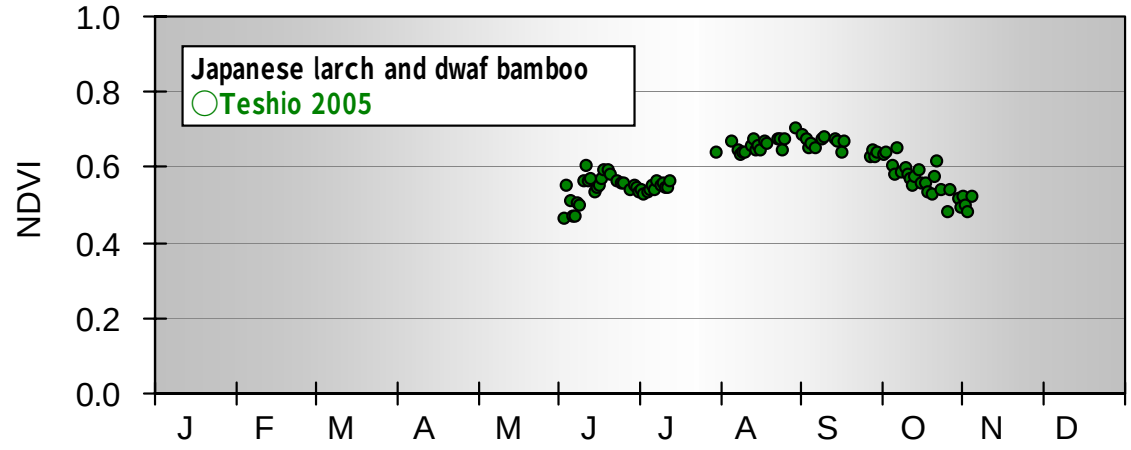
Most of the PEN sites are located at the AsiaFlux sites. AsiaFlux is a monitoring network of carbon, water and energy fluxes between ecosystems and the atmosphere.

* TFS and RHN stopped operation in September, 2004 and February 2006, respectively.

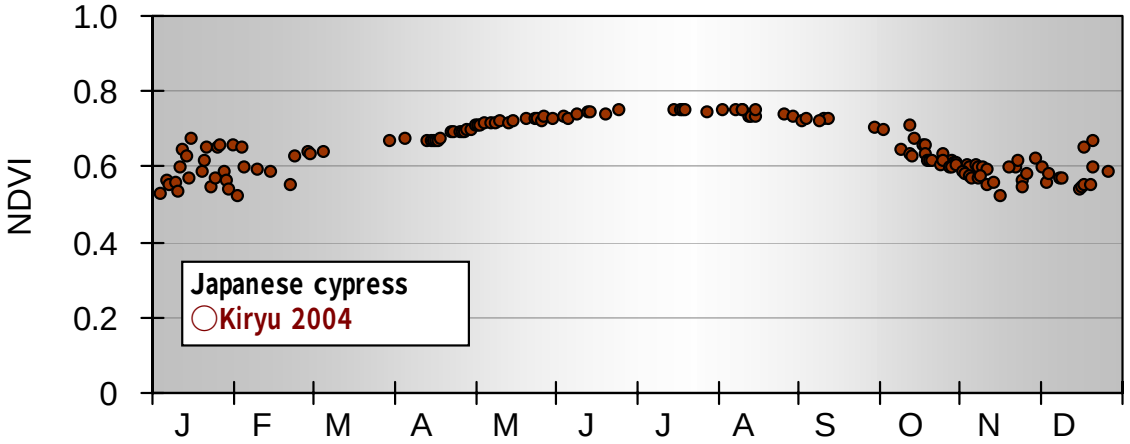
Seasonal variation in NDVI at the PEN site



Japanese larch

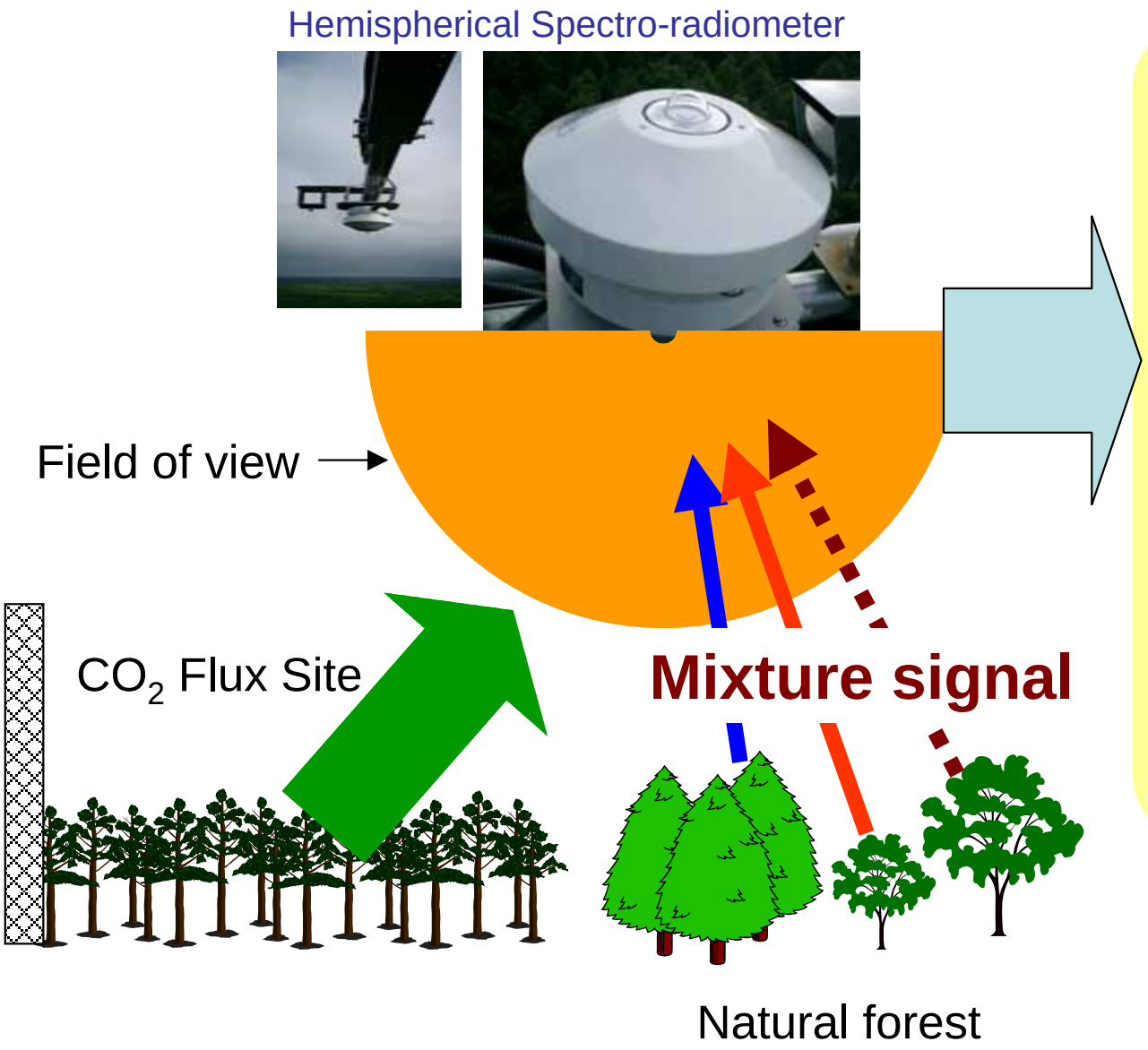


Japanese Larch and dwarf bamboo



Japanese cypress

Development of Spectral Imager

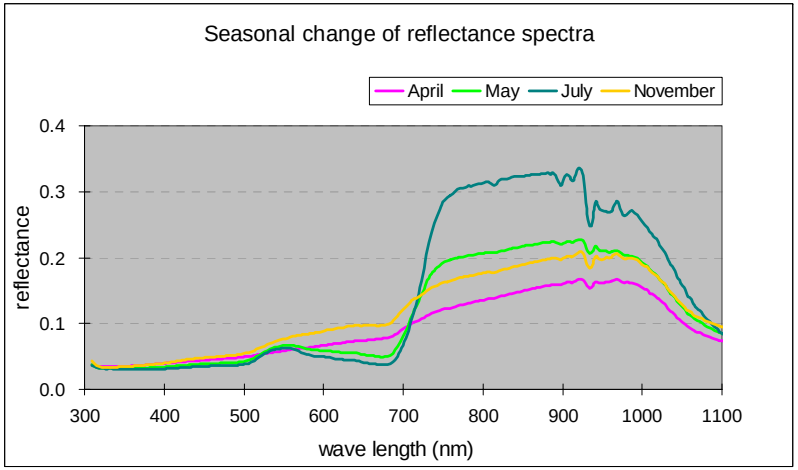


- All weather
- Low cost
- Easy operation
- Battery or Solar battery operation

Phenology Camera is required

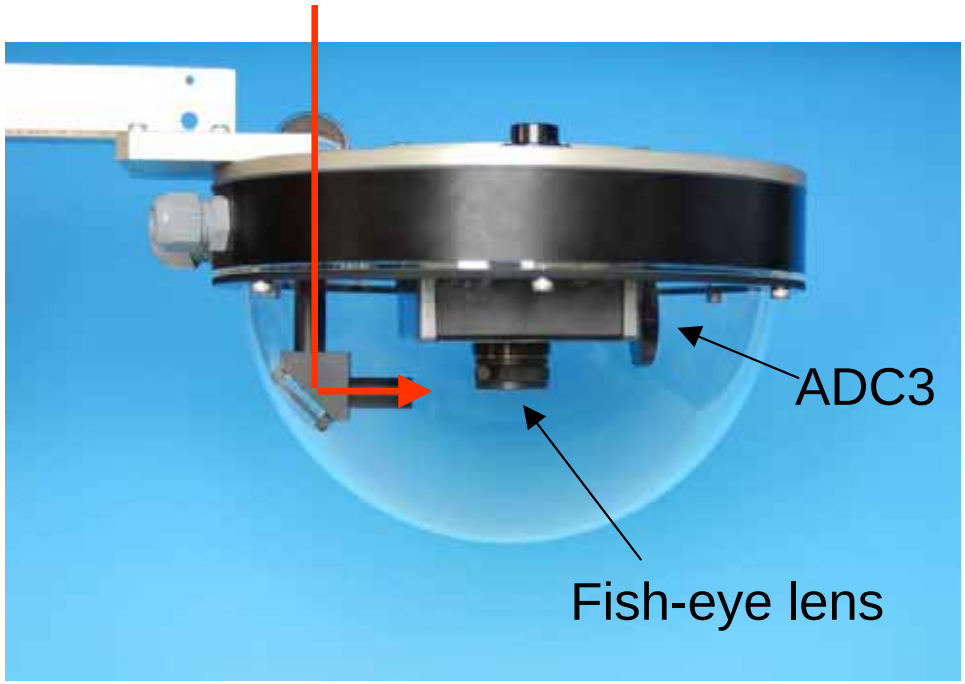
Multi Spectral Phenology Camera (Prototype)

Tetracam ADC3



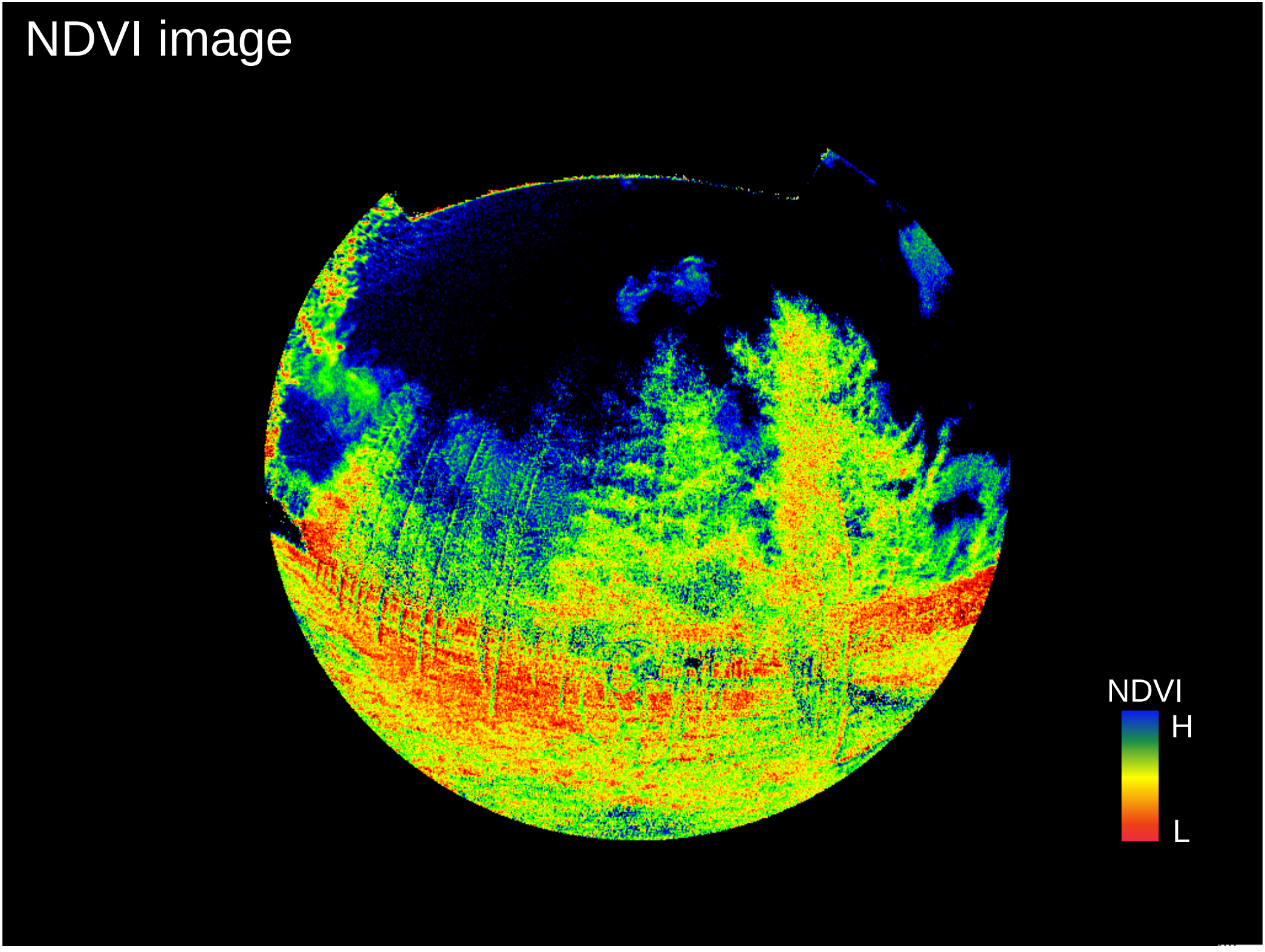
Normal digital camera

Tetracam ADC3

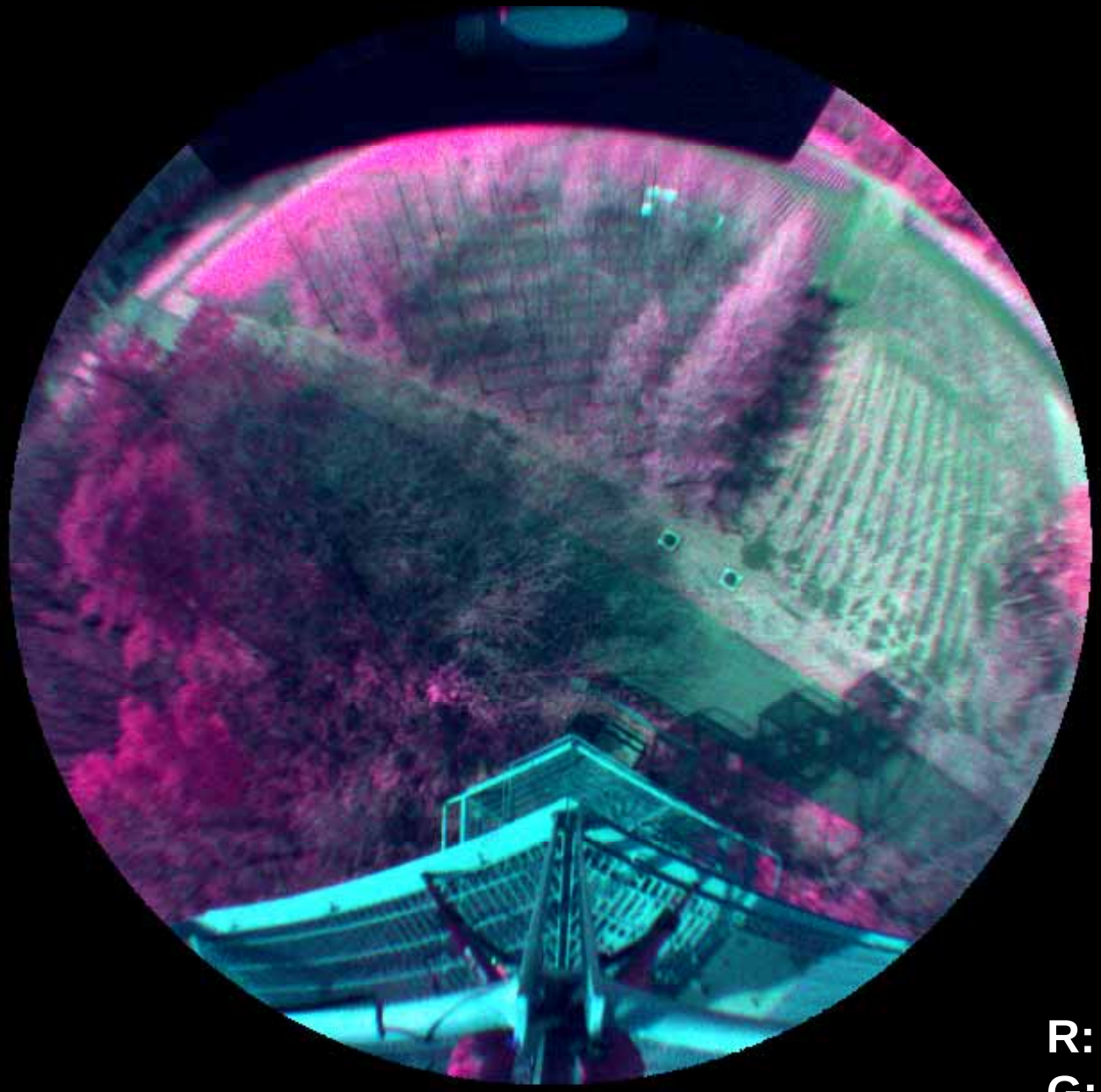


False color image

R: Near-infrared
G: Red
B: Green

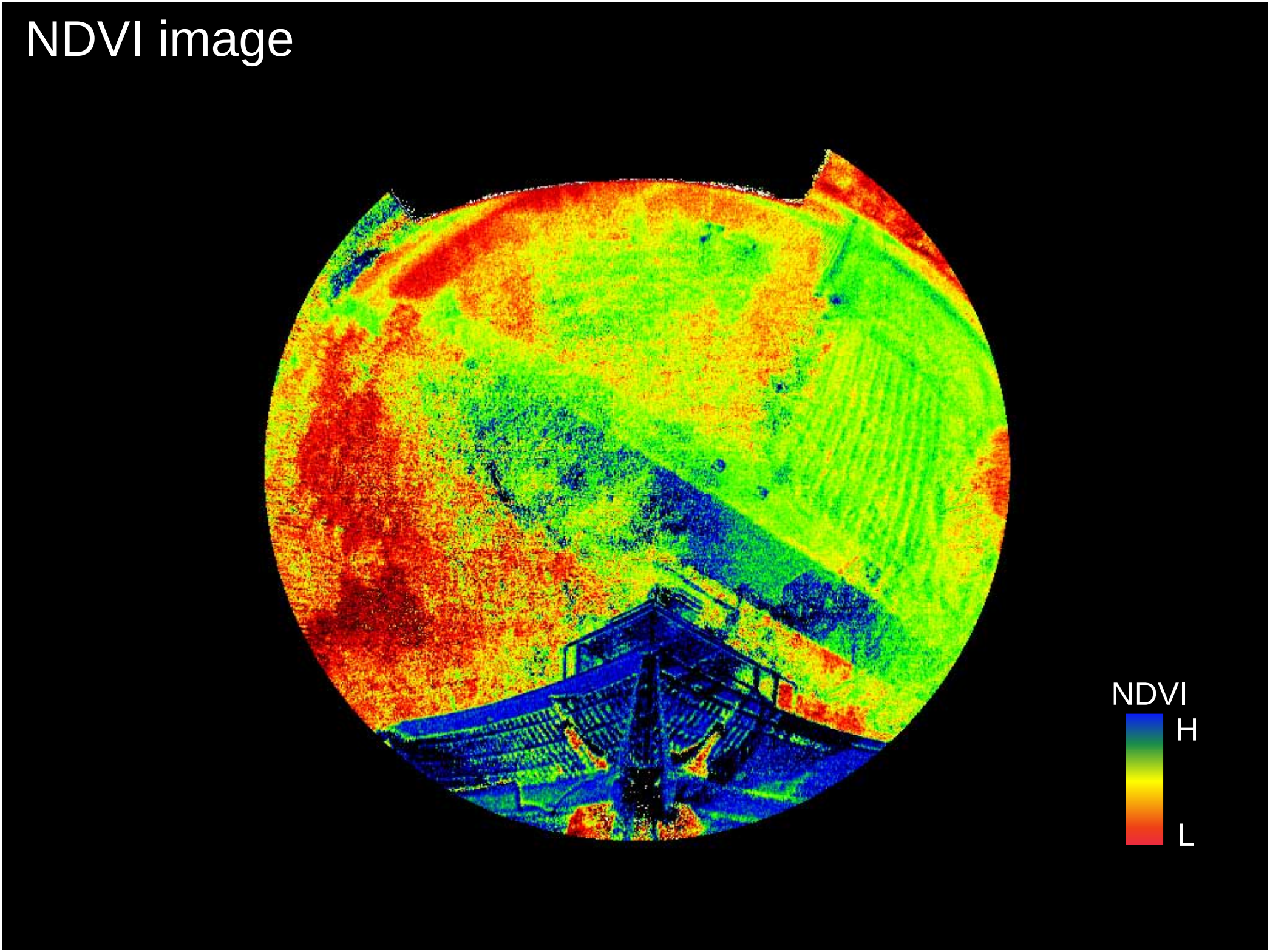

NDVI image
NDVI
H
L

False color image

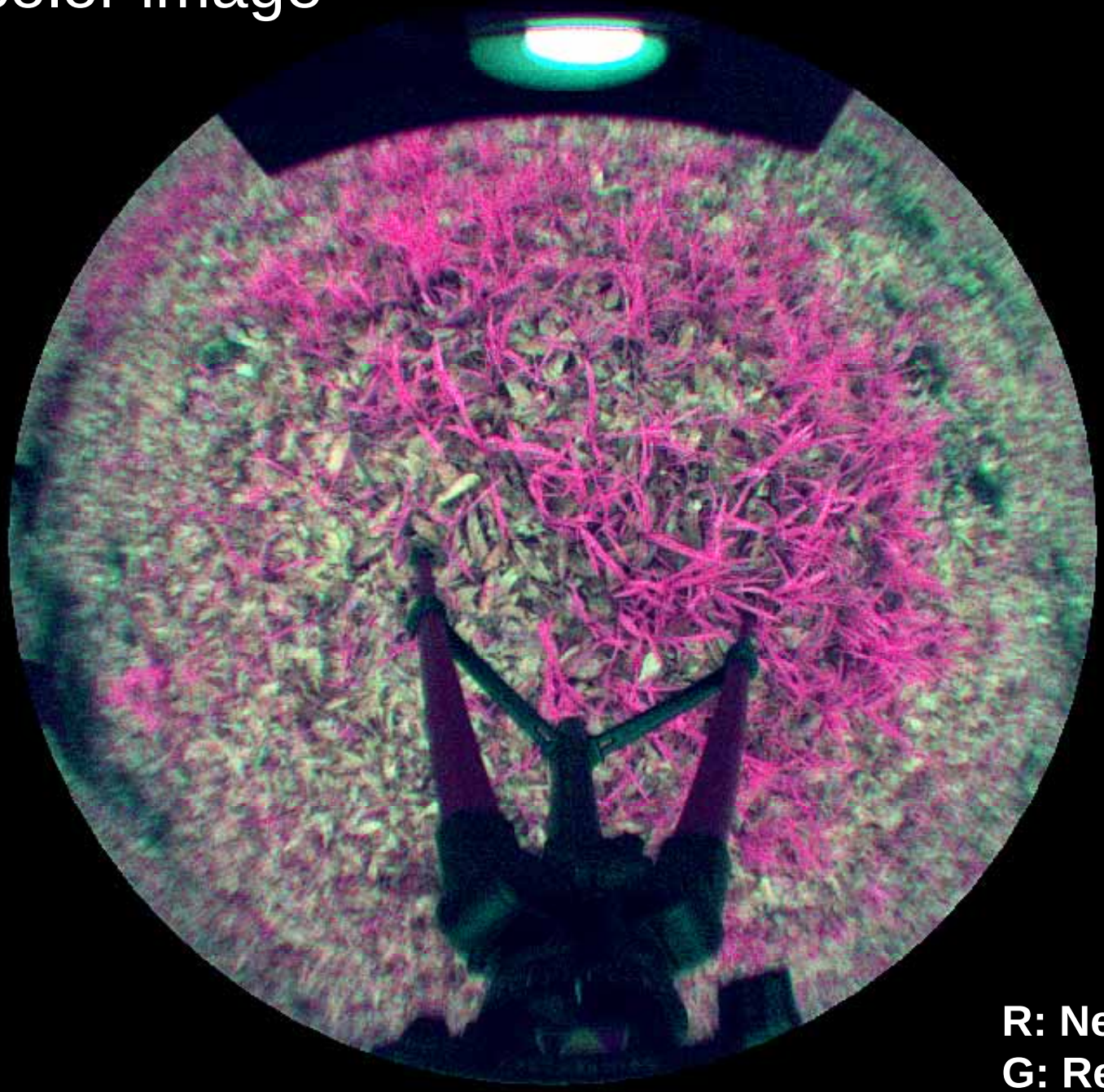


R: Near-infrared
G: Red
B: Green

NDVI image

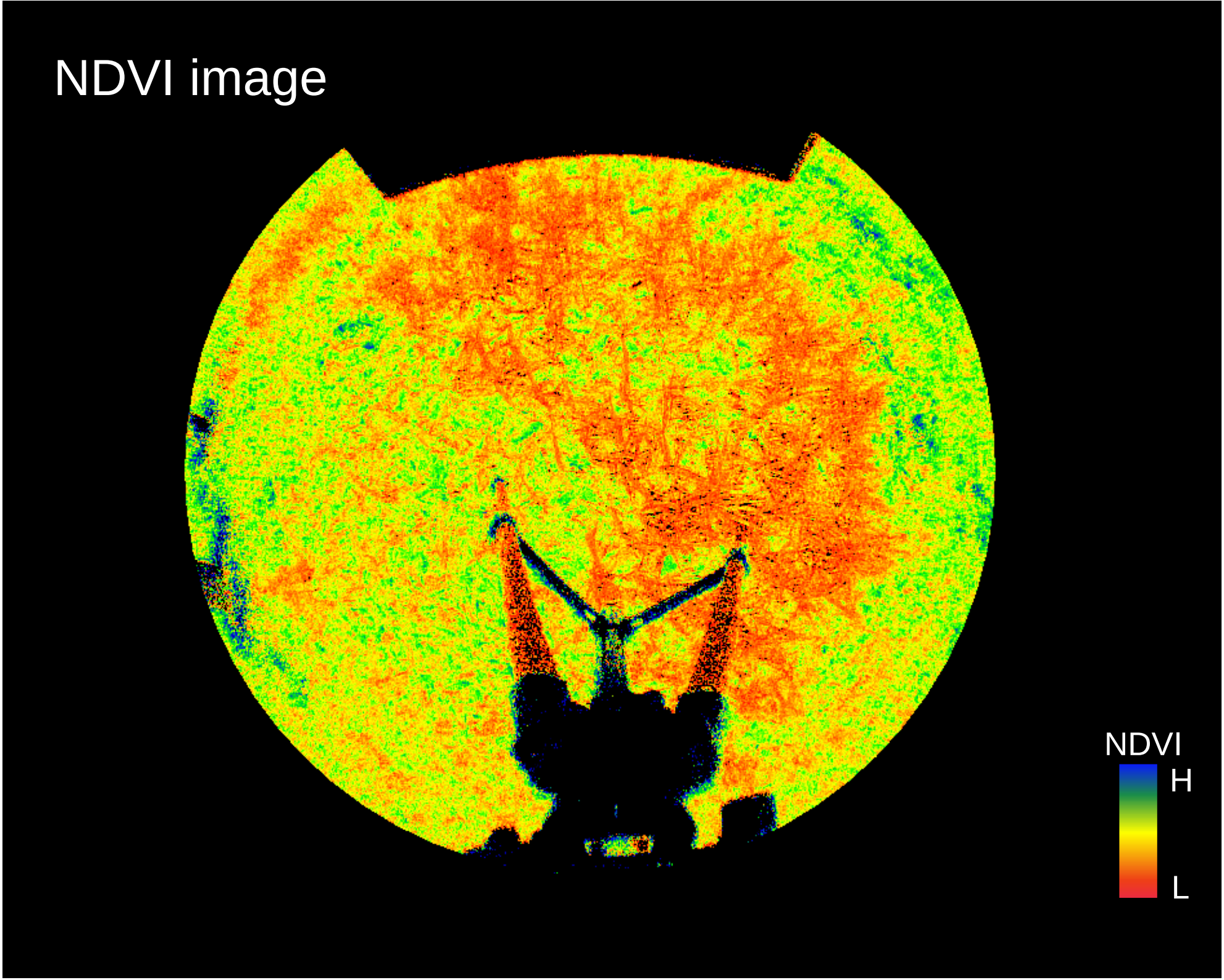


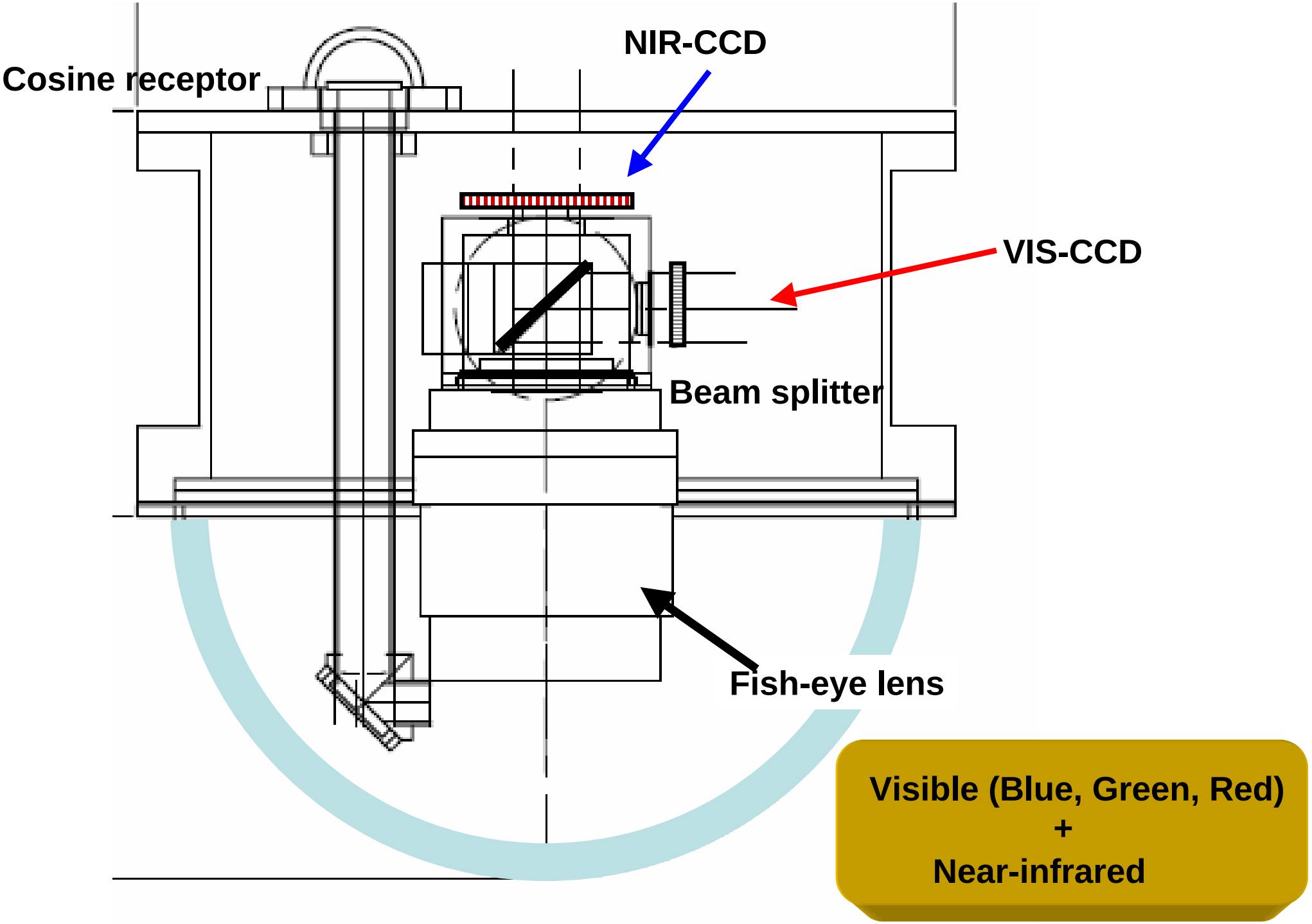
False color image



R: Near-infrared
G: Red
B: Green

NDVI image

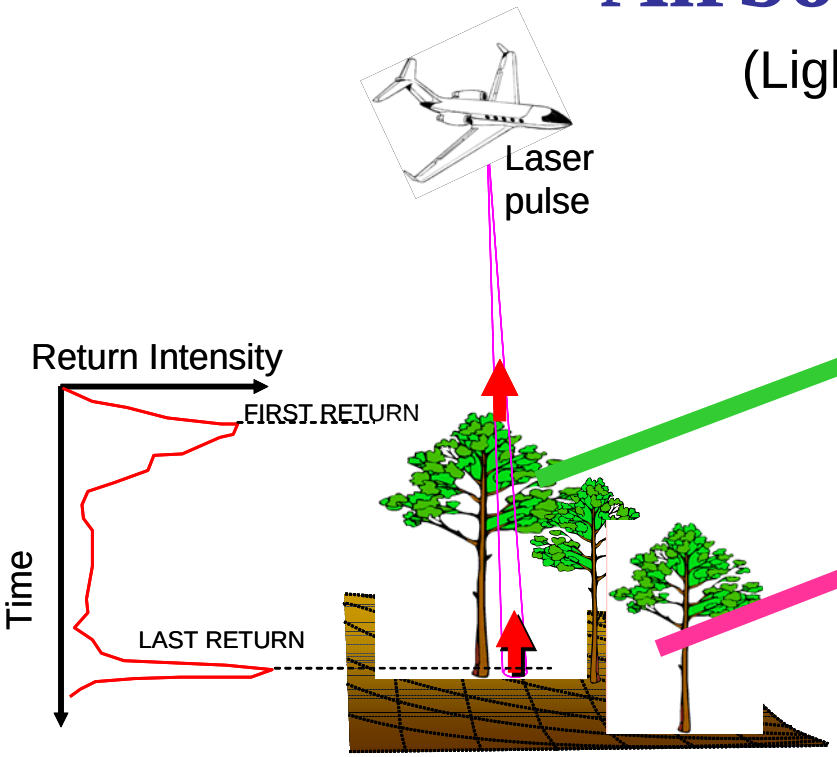



Cosine receptor
NIR-CCD
VIS-CCD
Beam splitter
Fish-eye lens
Visible (Blue, Green, Red)
+
Near-infrared

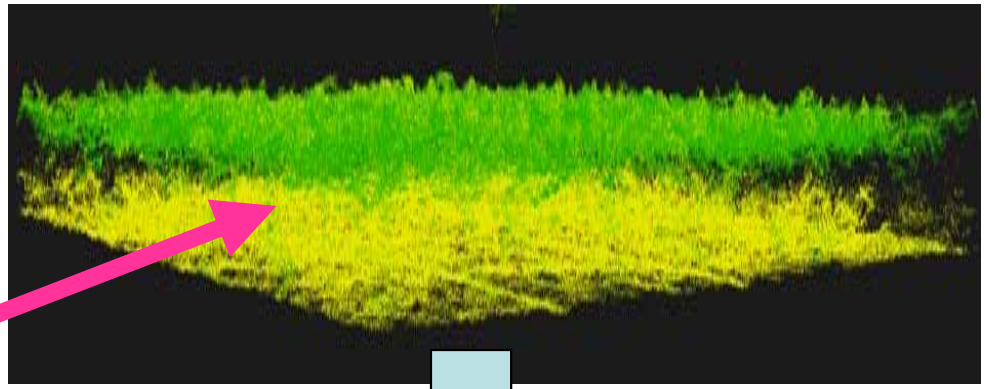
Three-dimensional digital analysis of aerial photographs

Airborne Lidar Systems

(Light Detection And Ranging)



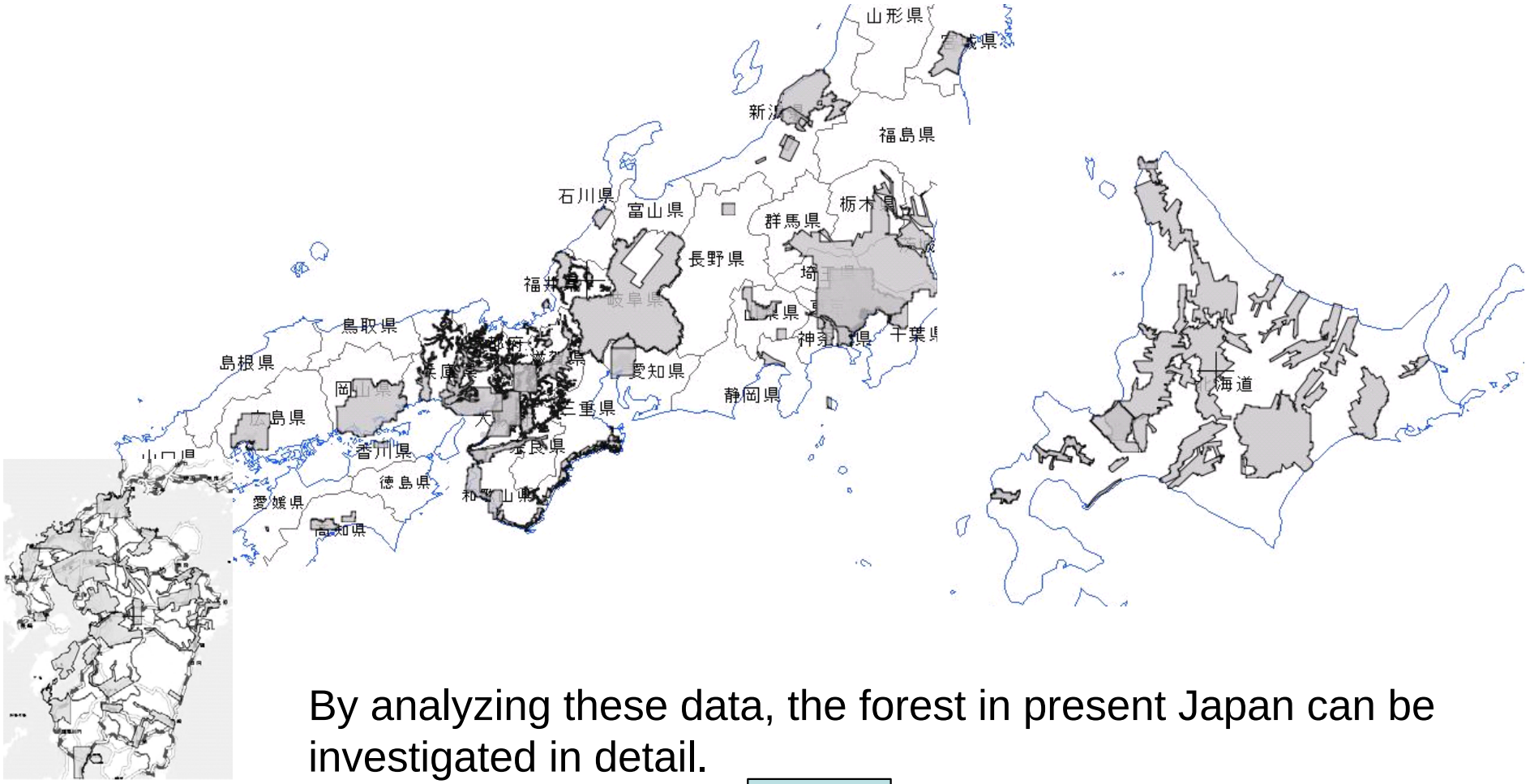
Raw point cloud (x,y,z coordinates)



Larch tree

Tomakomai CO_2 Flux research site

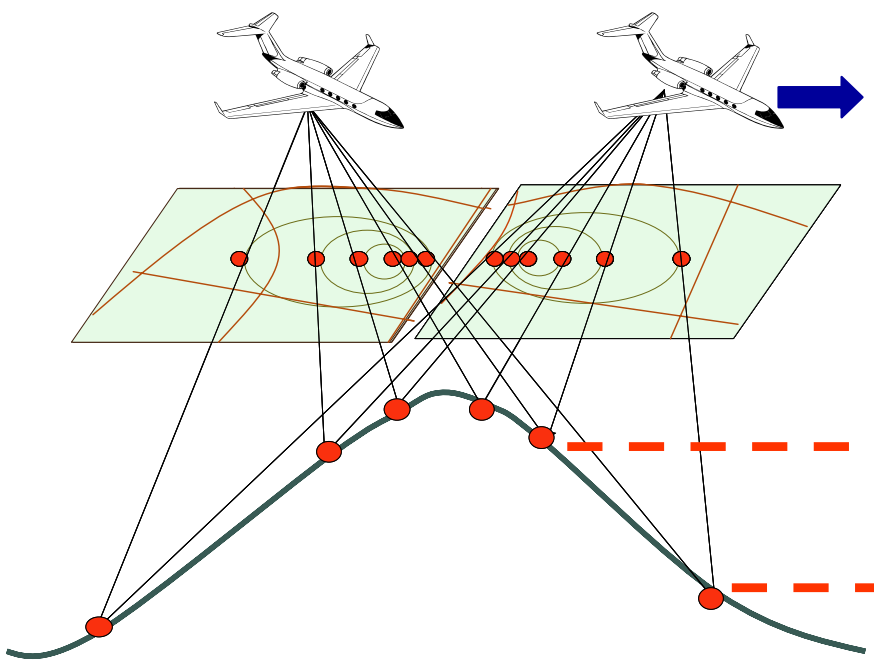
Observed area with airborne LiDAR in Japan

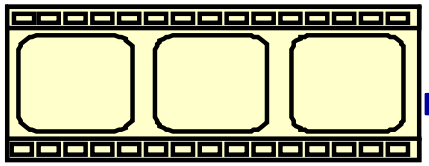


By analyzing these data, the forest in present Japan can be investigated in detail.

How can we get to understand the state of the past forest?

Three-dimensional digital analysis of aerial photographs

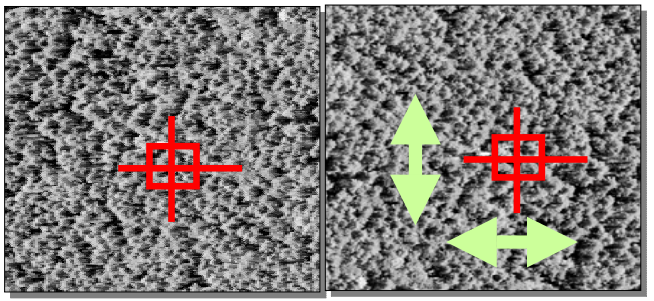




film

Scanner

Scanned digital data in the 10-micron pitch

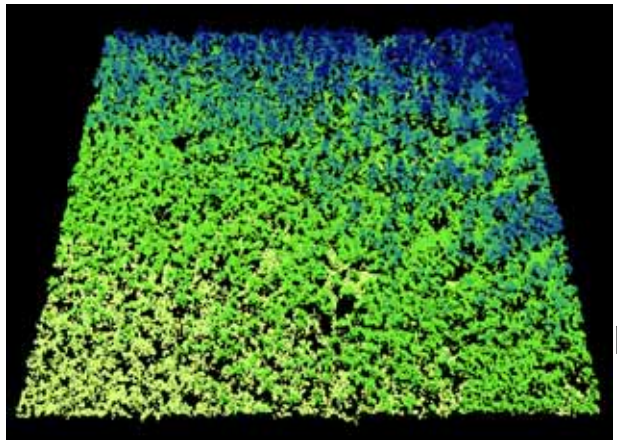


The software searches for the same target photographed from the different angle

Calculation of three dimension coordinates

Conventional method

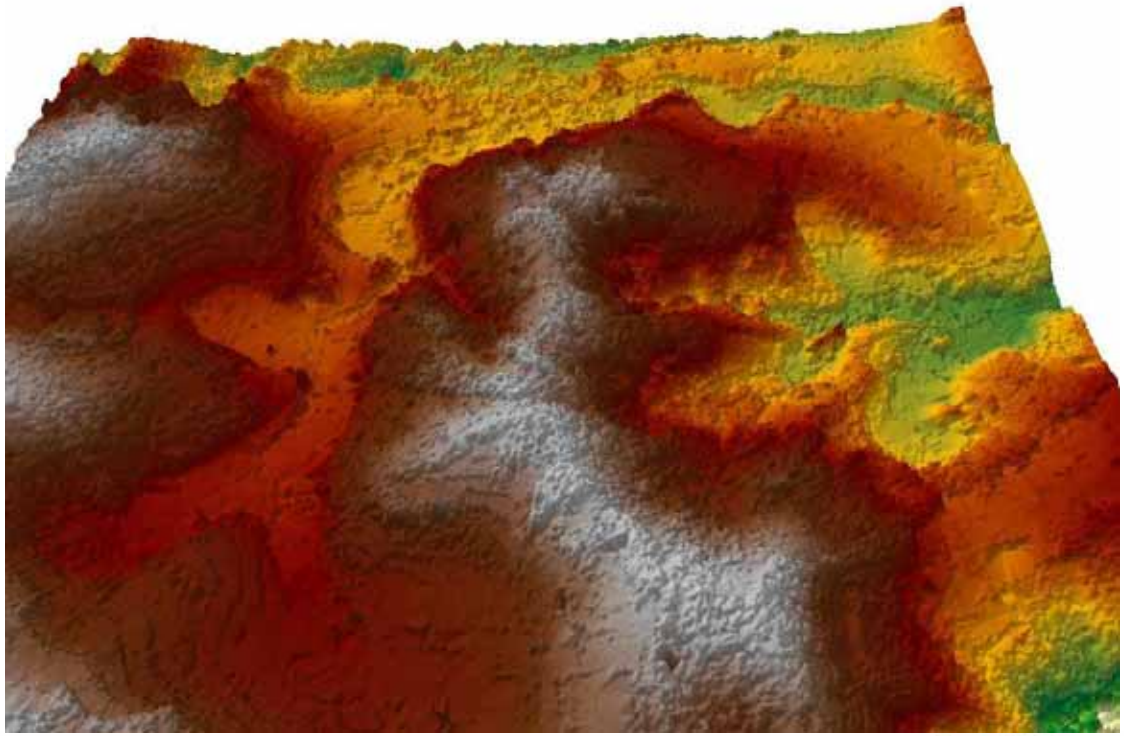
Requirements;
・Skills
・Time ・・・



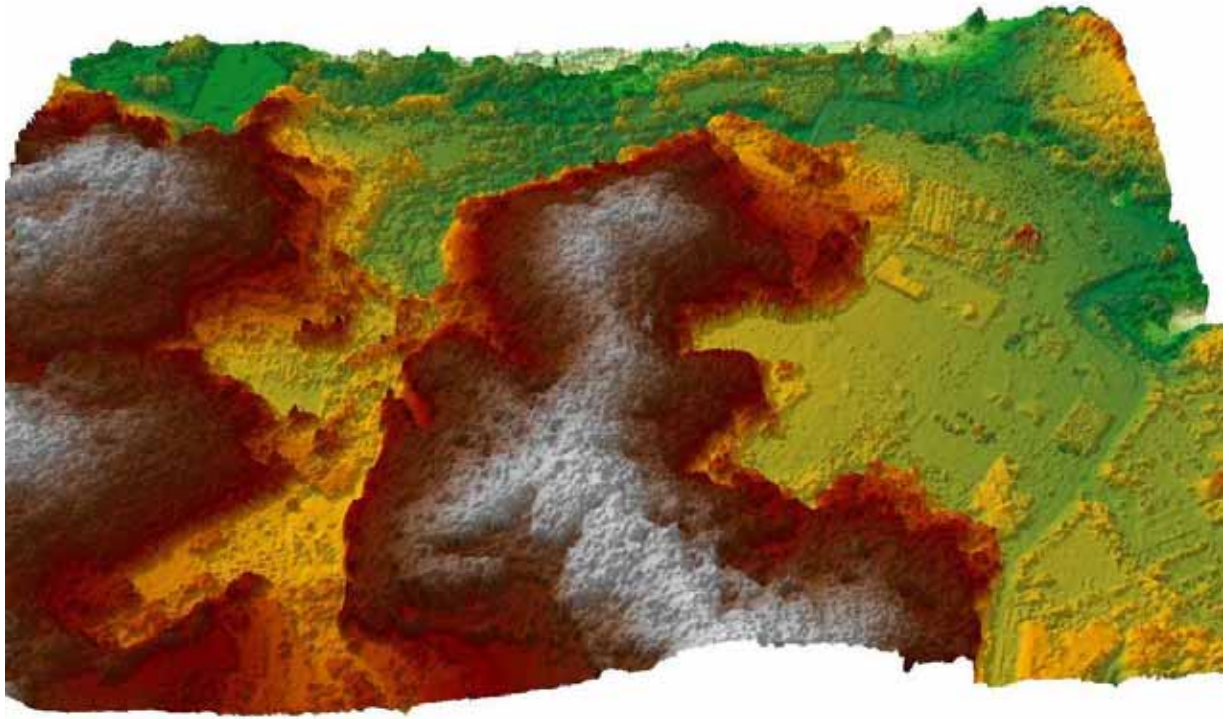
Digital surface model

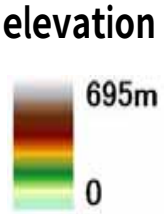
Digital Surface Model (DSM) produced from the aerial photograph of one pair

1967



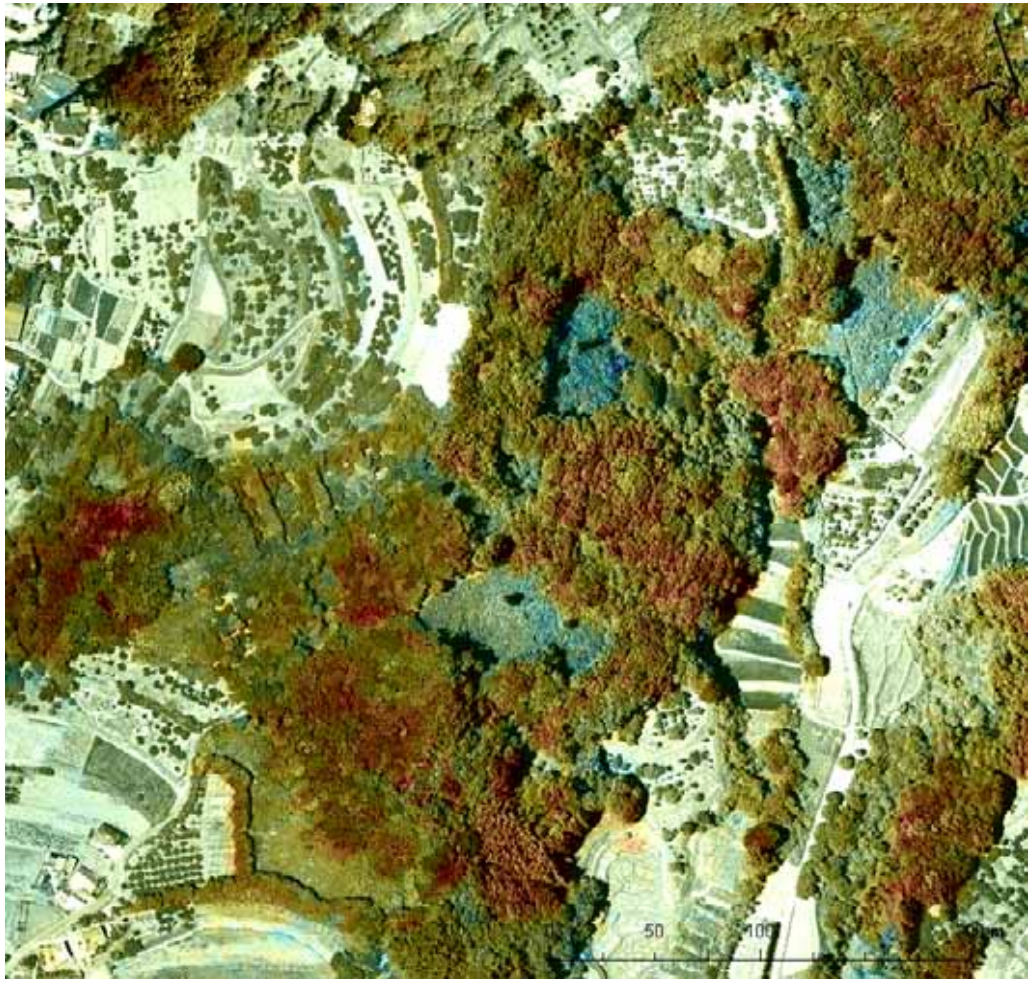
2002





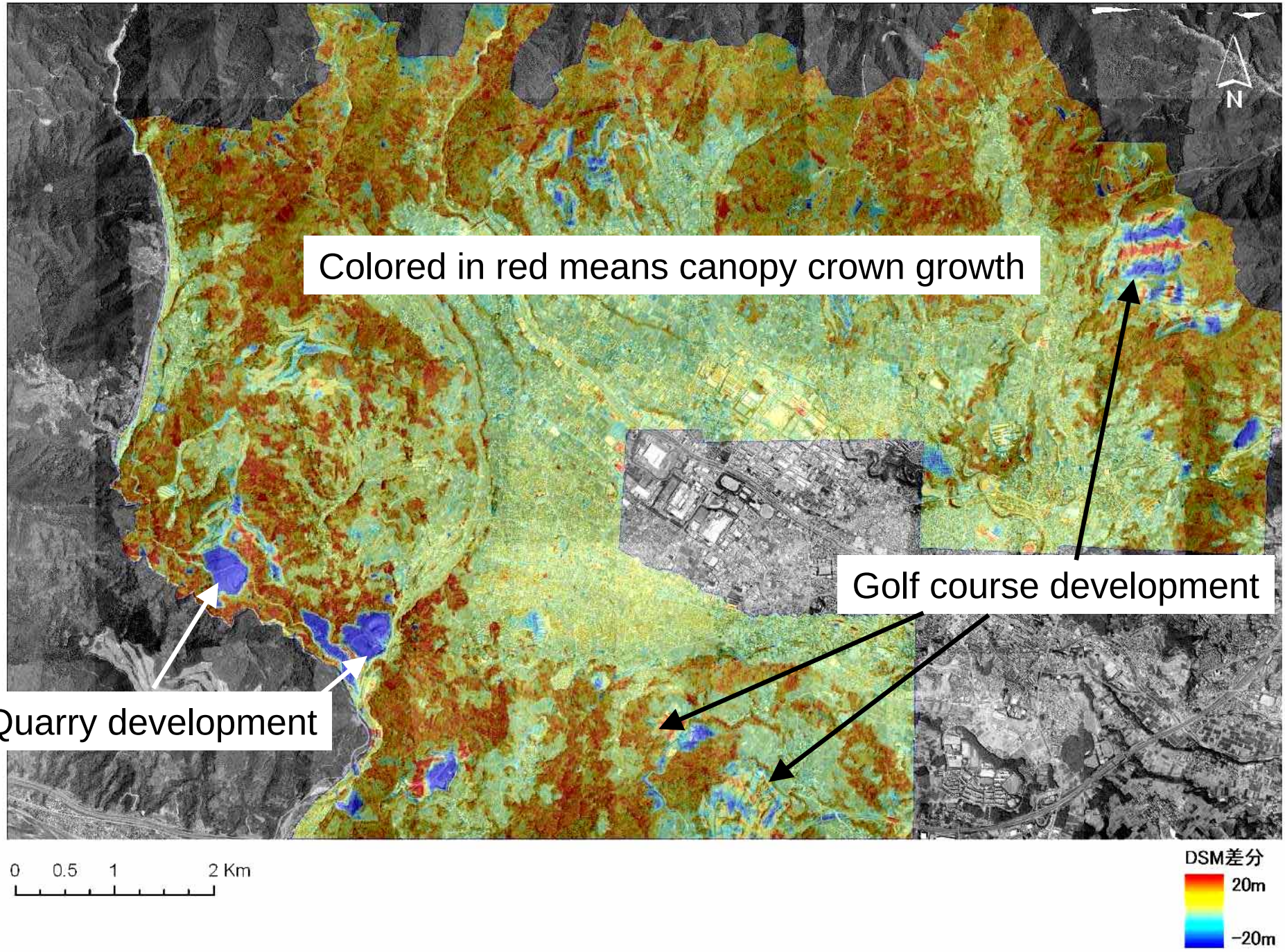
Extraction of the change of DSM in Satoyama-Village forest

DSM_{2002}-DSM_{1967}

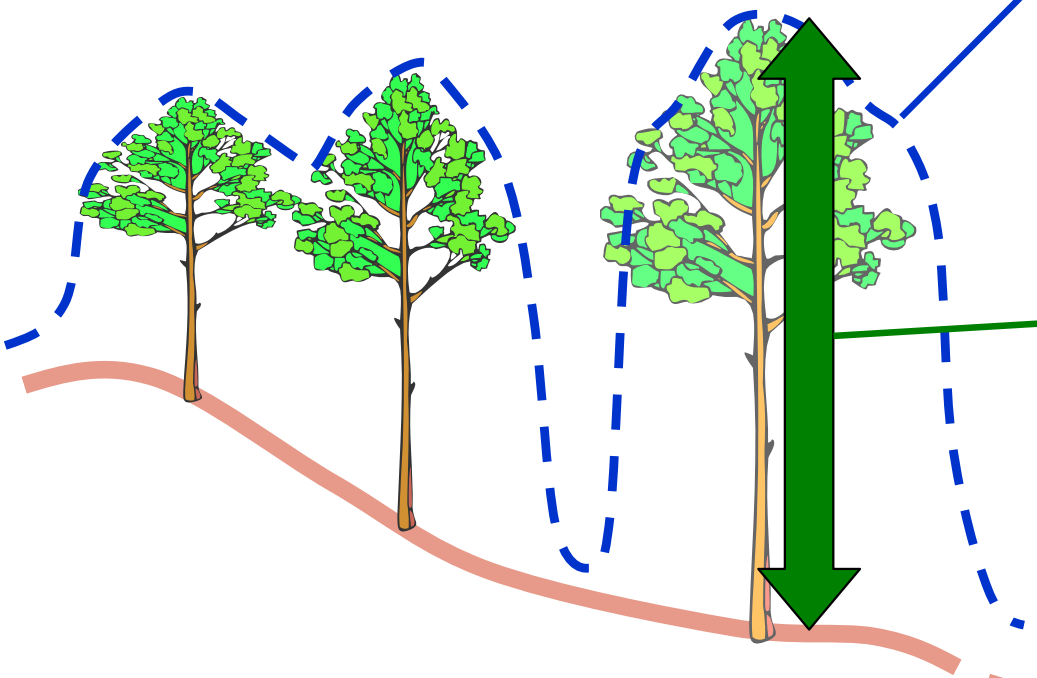


Red shows canopy crown growth and blue shows deforestation

Difference between 2002 and 1967 of DSM



The method of DCHM (Digital Canopy Height Model) calculation



DSM (Digital Surface Model)

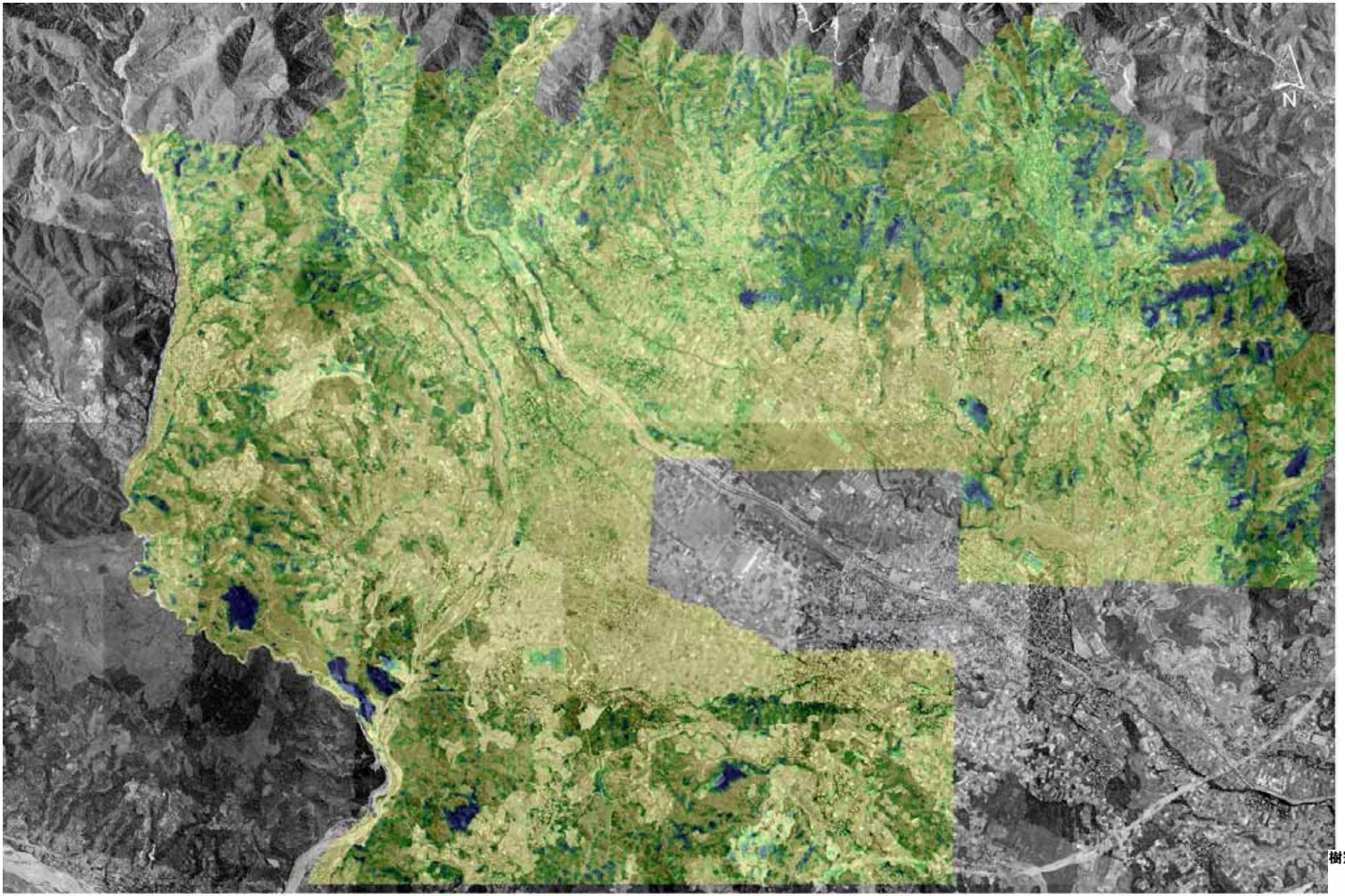
provided by aerial photograph analysis

DCHM (Digital Canopy Height Model)
＝DSM－DTM

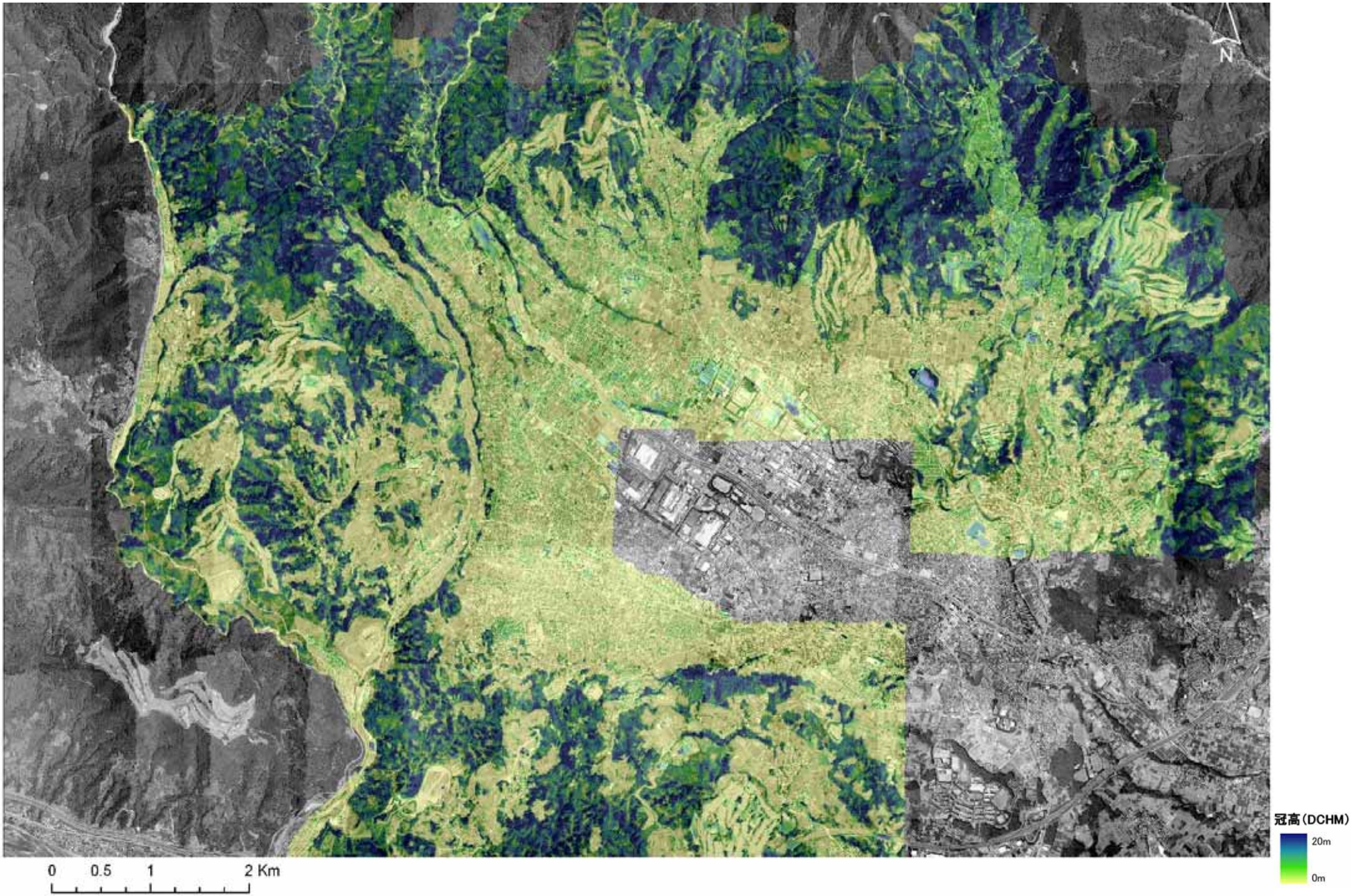
DTM (Digital Terrain Model)

provided by Geographical Survey Institute
or LiDAR survey

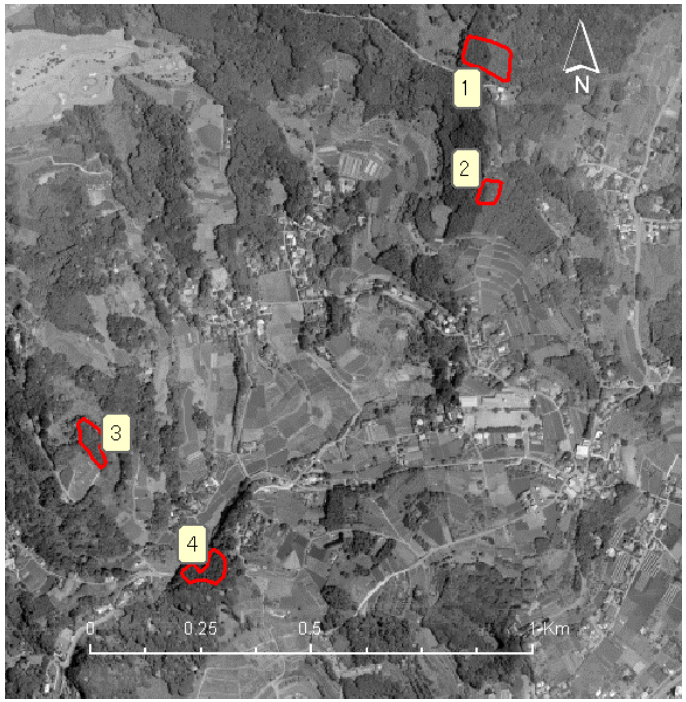
DCHM image in 1967

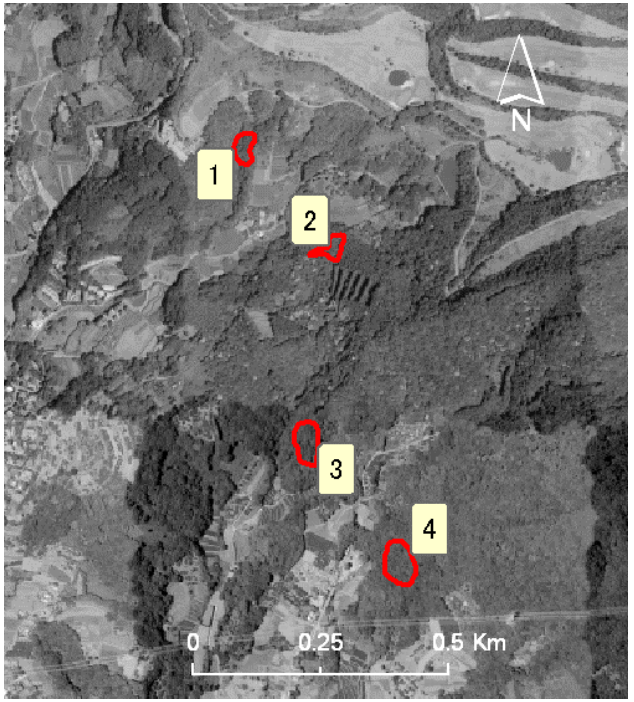


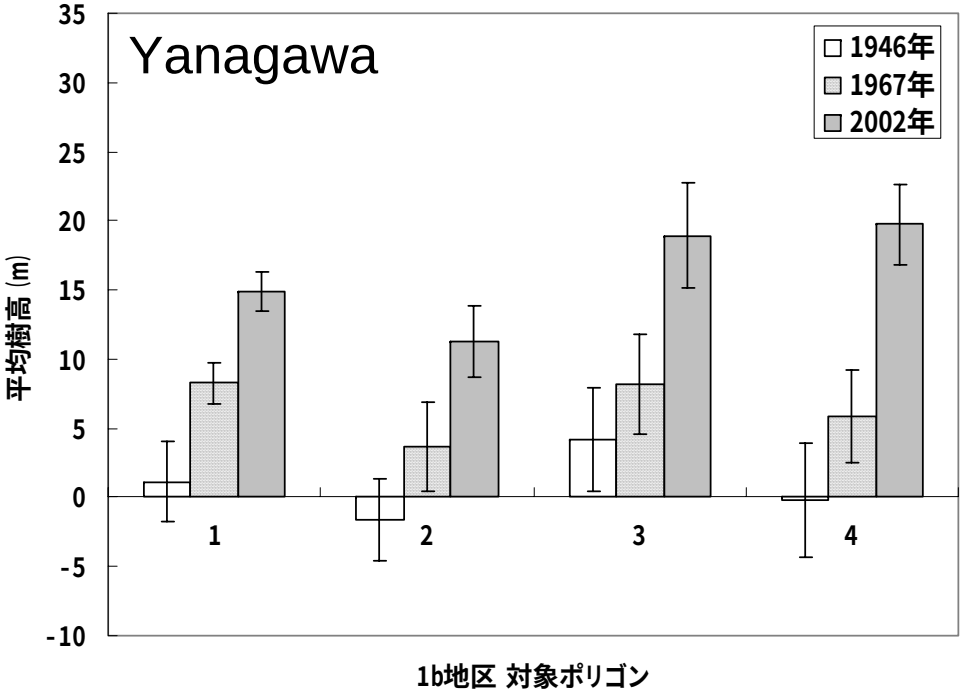
DCHM image in 2002

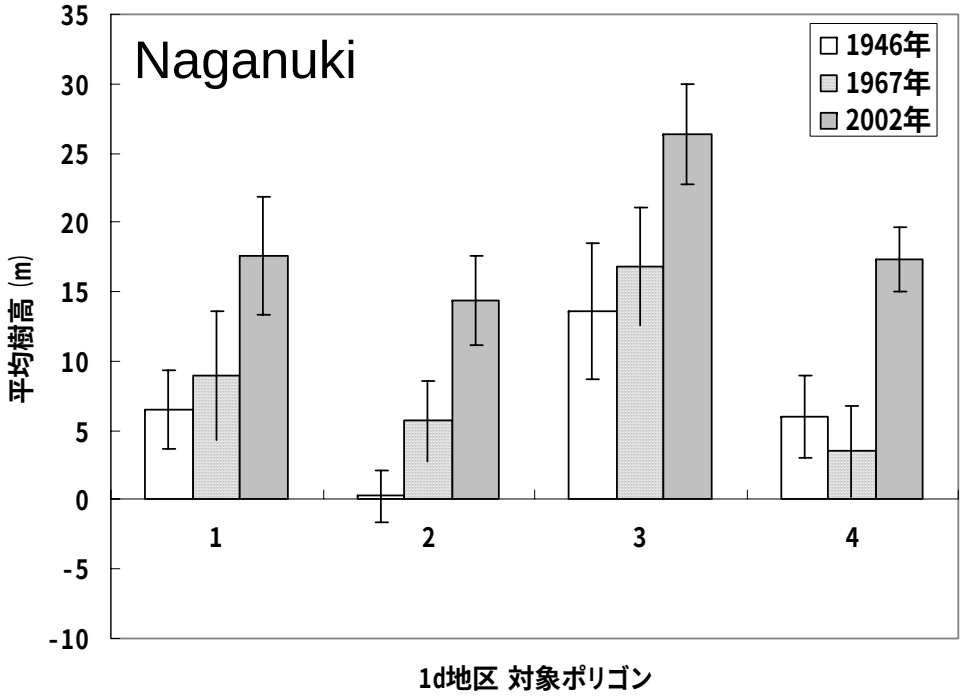


Canopy height change from 1946 to 2002

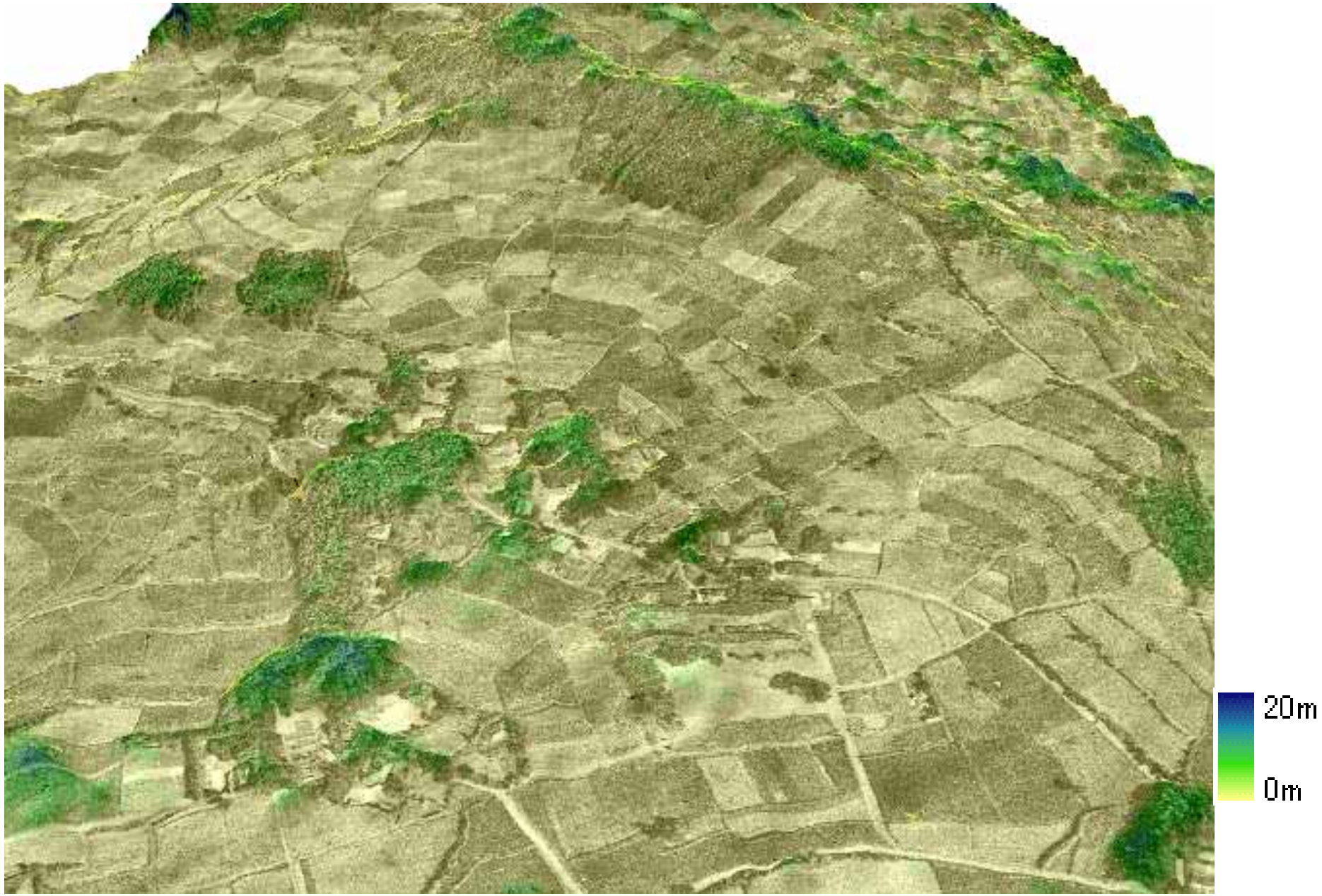








Colored image by DCHM in 1946



Colored image by DCHM in 1967

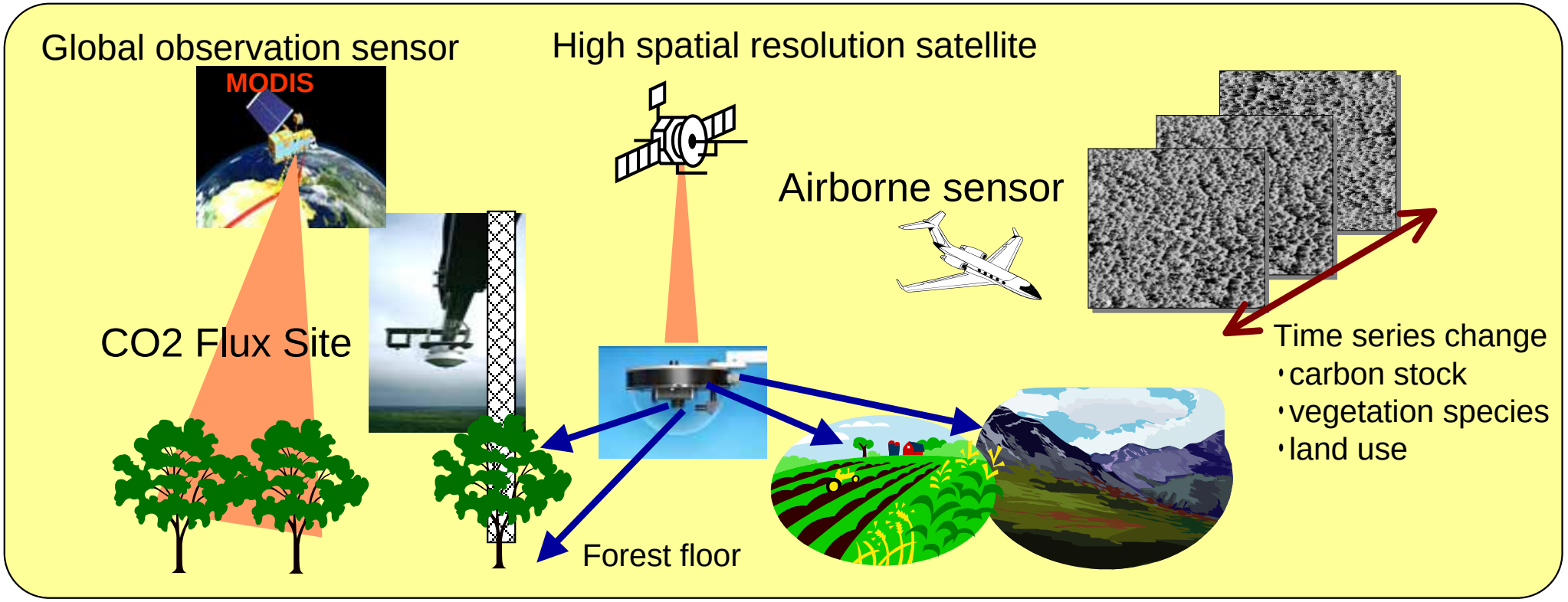
Colored image by DCHM in 2002

Conclusion

•The Multi Spectral Phenology Cameras of Prototype will be installed in several JaLTER sites, and be checked their usefulness.

•The new phenology camera which can photograph both true visible color and near-infrared will be developed.

•Precise DTM is required in order to calculate change of the canopy height from the past more correctly.

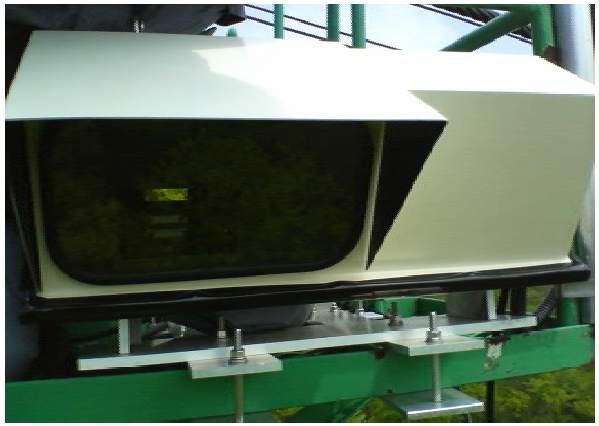


苫小牧タワーサイトにおける分光・熱画像観測

サーマルカメラ

NEC TH3100

視野角: 約15 °
最小検知温度：0.08℃
測定精度：±1.2℃
測定波長域 8〜13 μm



ハイパースペクトルカメラ

Specim ImSpector V10

視野角: 30 °
波長幅: 400〜1000 nm
サンプリング幅: 4.4 nm

2地点の画像情報を連続撮影

(2007年6月〜)

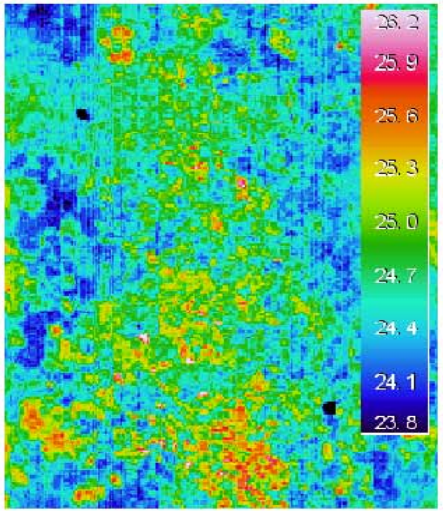
対照区

地温上昇区

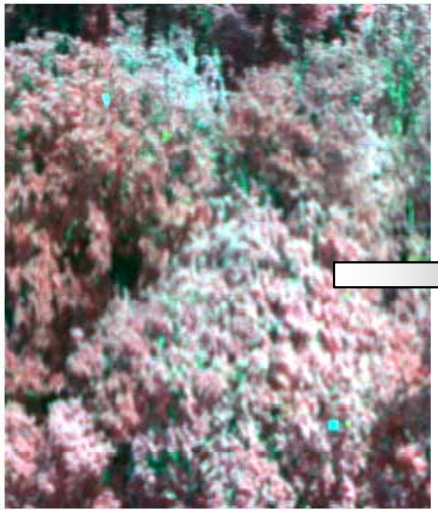
可視～近赤外域の分光反射情報と葉の生理機能

ミズナラ測定木

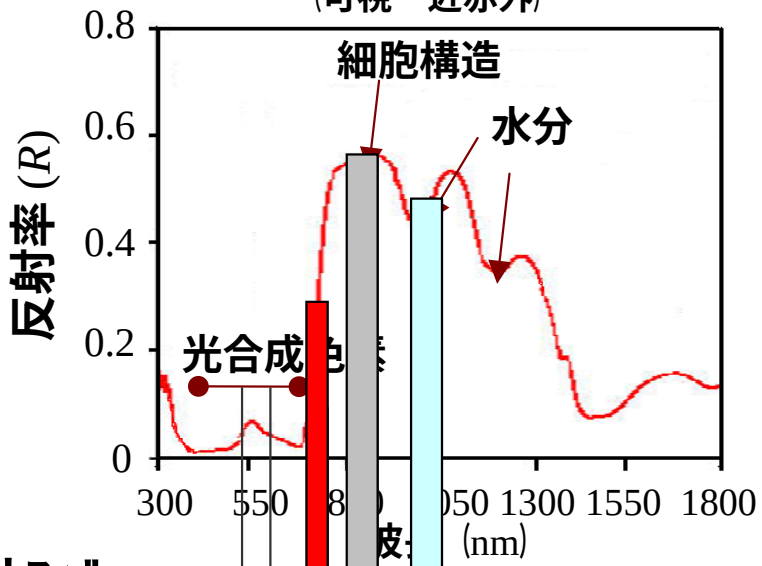
熱赤外画像



可視-近赤外合成画像 (2007/7/2)



葉面の反射スペクトル
(可視－近赤外)



光合成応答 **PRI**: Photochemical Reflectance Index $= \frac{(R531-R570)}{(R531+R570)}$

エポキシ化率、PSII活性、光利用効率

← キサントフィル サイクル

葉量変化 **NDVI**: Normalized Difference Vegetation Index $= \frac{(R_{NIR}-R_{RED})}{(R_{NIR}+R_{RED})}$

光吸収率 fAPAR、LAI

← クロロフィル・組織発達

色素量変化 **CCI**: Canopy Chlorophyll Index $= \frac{D720\ (720nm一次微分値)}{D700\ (700nm一次微分値)}$

葉内クロロフィル濃度

← クロロフィル

水分状態 **WI**: Water Index $= \frac{R970}{R900}$

水分量 (重度の乾燥など)

← 水分

※ 表面温度は蒸散や水分状態と関連があるかもしれない

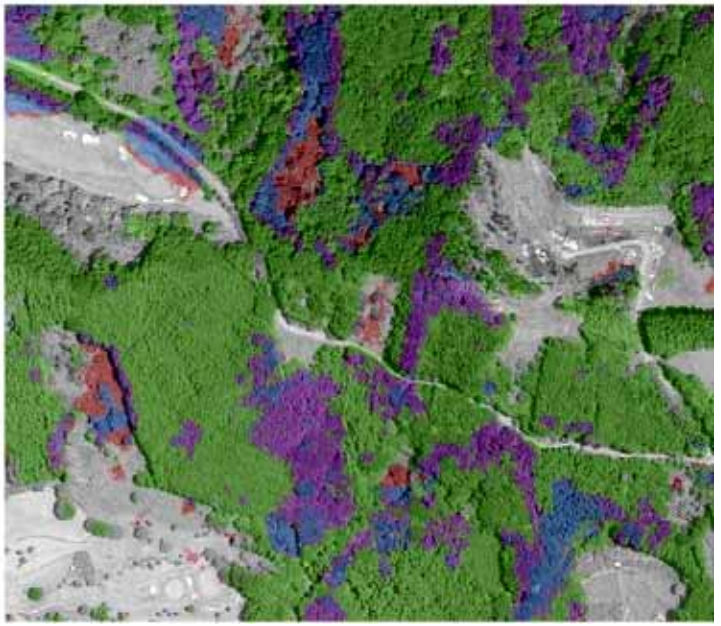
DCHM変動パターンによる土地被覆変遷の抽出手法の開発

土地被覆分類のルール

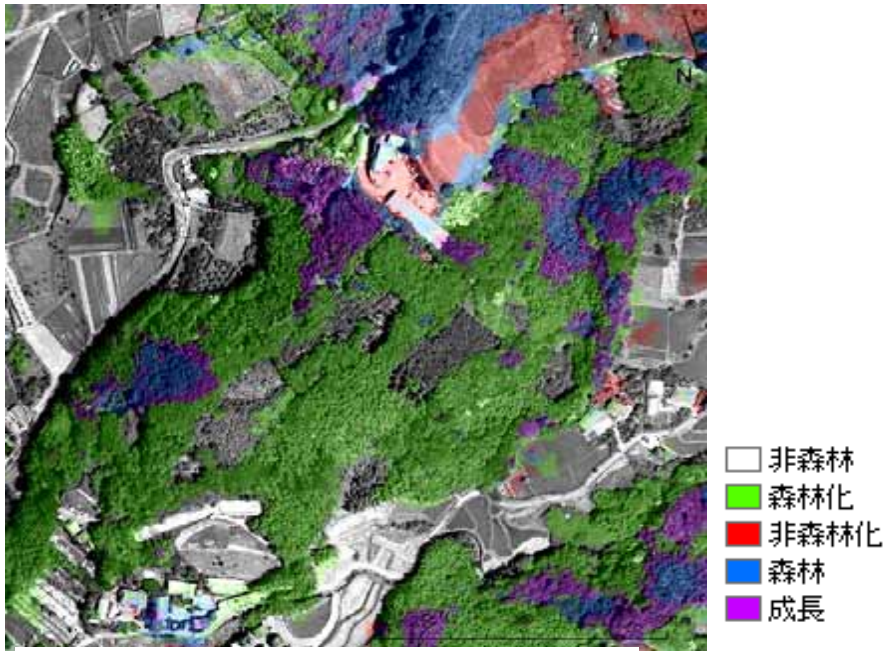
DCHMを算出し、

- ー5m以下を凹地/エラー
- ー5～5mを平地
- 5m～10mを低木林
- 10m以上と高木林

1967,2002年における
被覆変化をクラス分け

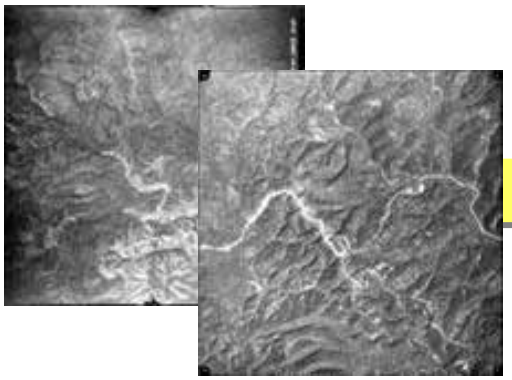


期首（1967年）クラス	期末（2002年）クラス	色	意味
凹地/エラー地	凹地/エラー地		非森林
	平地		非森林
	低木		森林化
	高木		森林化
平地	凹地/エラー地		非森林
	平地		非森林
	低木		森林化
	高木		森林化
低木	凹地/エラー地		非森林化
	平地		非森林化
	低木		森林
	高木		成長
高木	凹地/エラー地		非森林化
	平地		非森林化
	低木		森林
	高木		森林



DCHM変化を元にした土地利用変遷図

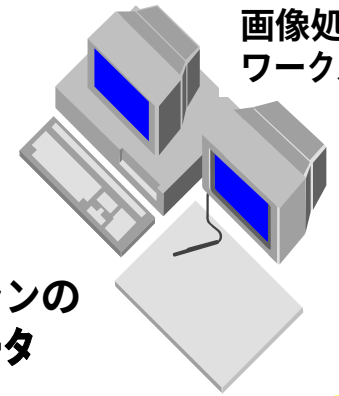
航空写真の三次元解析における従来手法とデジタル解析の比較



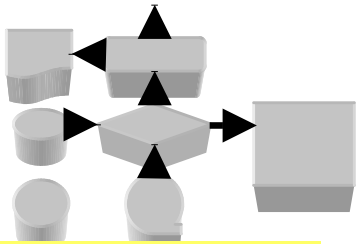
デジタル処理

専用スキャナ

10μmスキャンの
デジタルデータ



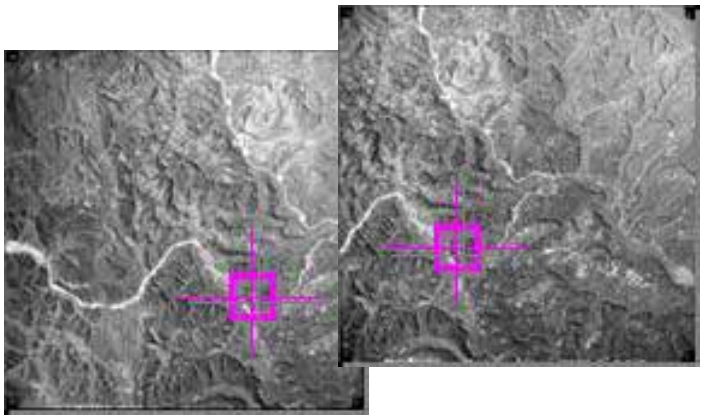
画像処理
ワークステーション



処理手法の新規開発

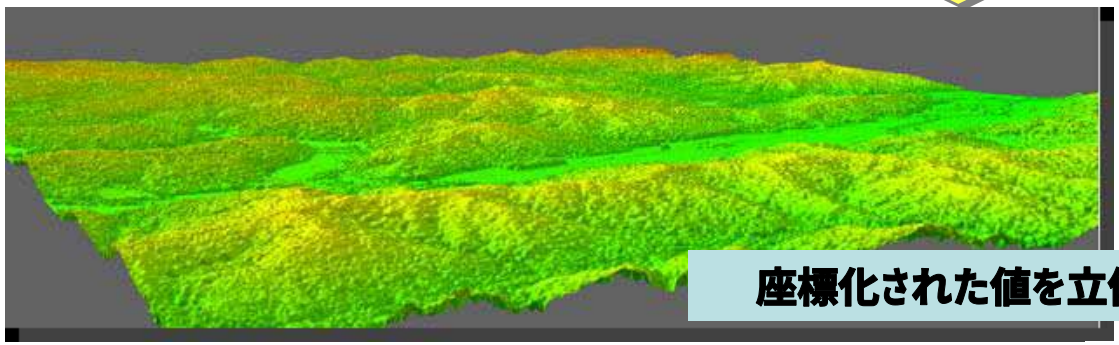
アナログ処理

解析者が立体視を行い
座標を読み取り記録



ステレオペアの写真から、同じ対象が写っている部分を自動探索
(**数百万点**以上のポイントを抽出)

2枚の写真の視差をデジタル値で再現し座標化

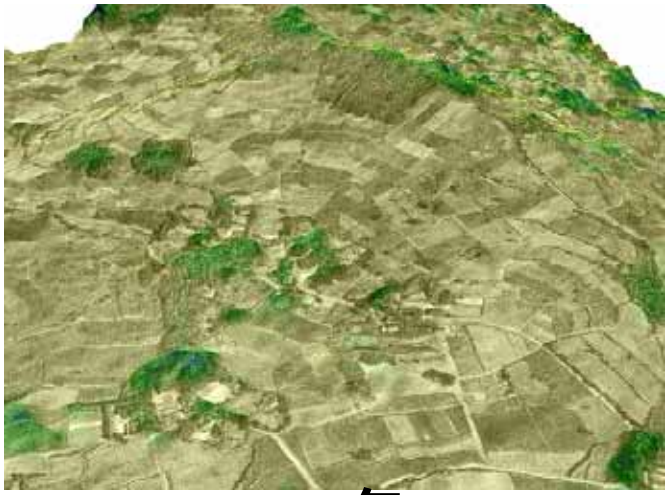


座標化された値を立体図化

景観再生の試み

名古木

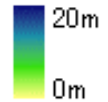
各年次のオルソ画像を三次化し、更に各年次の樹高値を算出し、
樹高の高低を緑→黄によってカラー化した画像



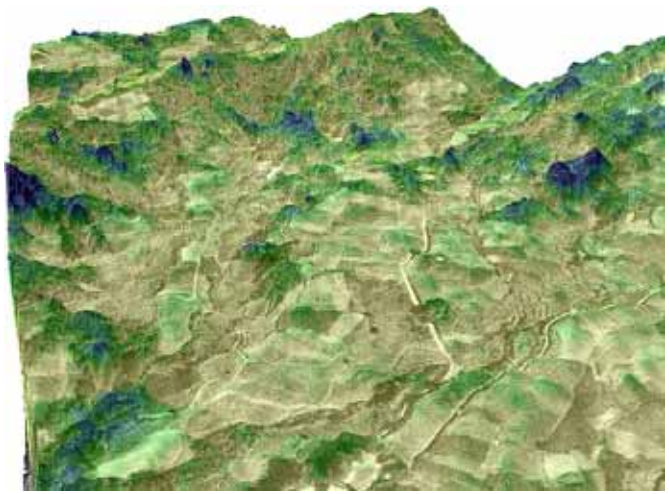
1946年

1967年

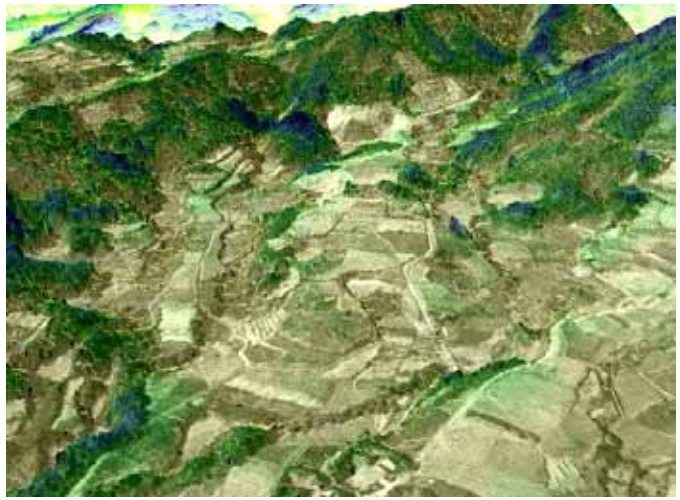
2002年



柳川

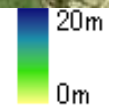


1946年

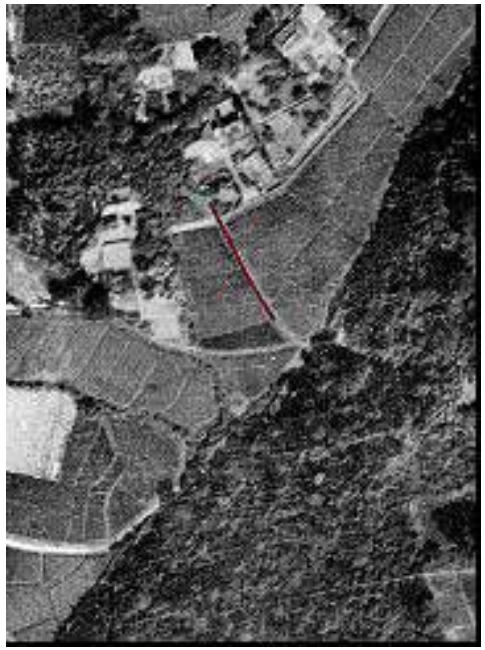


1967年

2002年

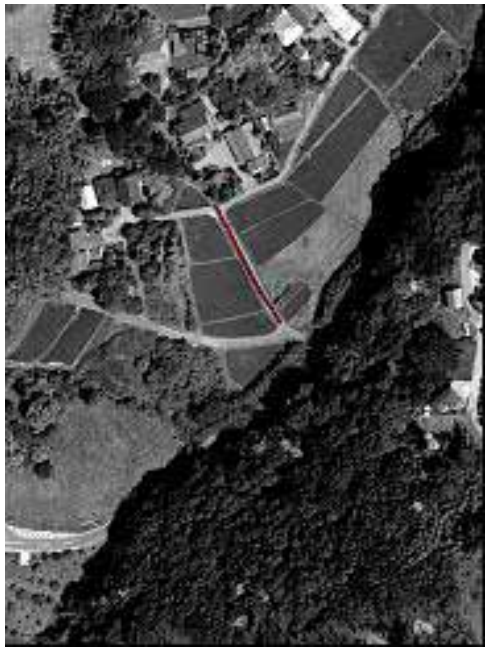


三次元化データの精度検証 (平地)

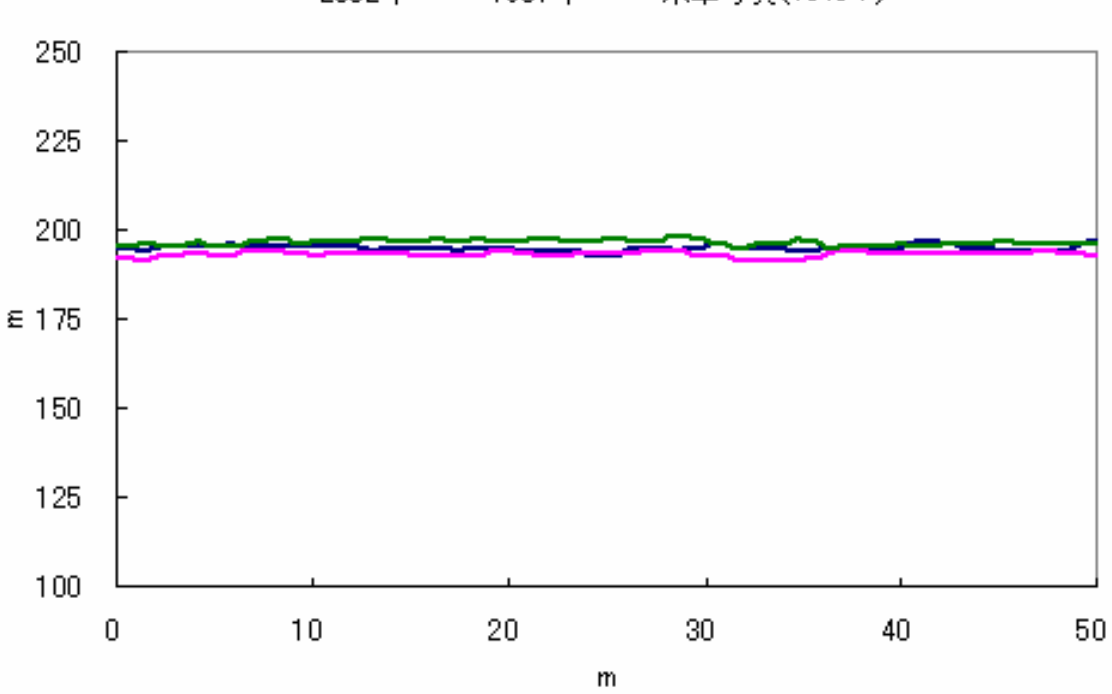


1946年

1967年



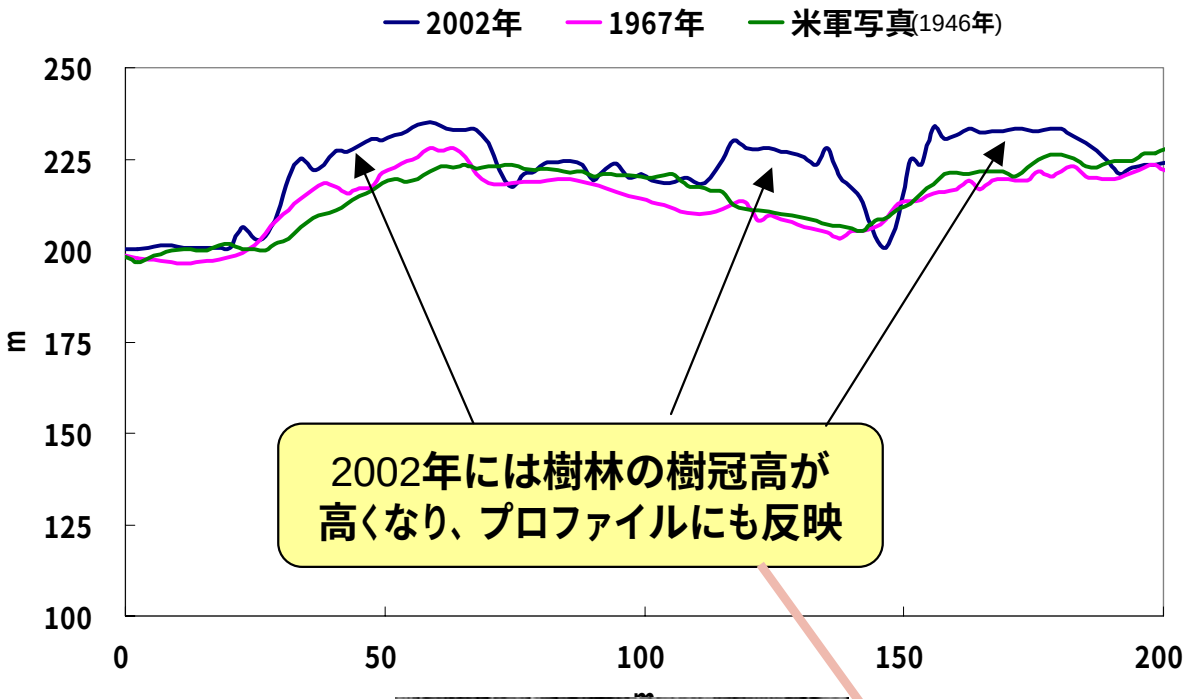
2002年

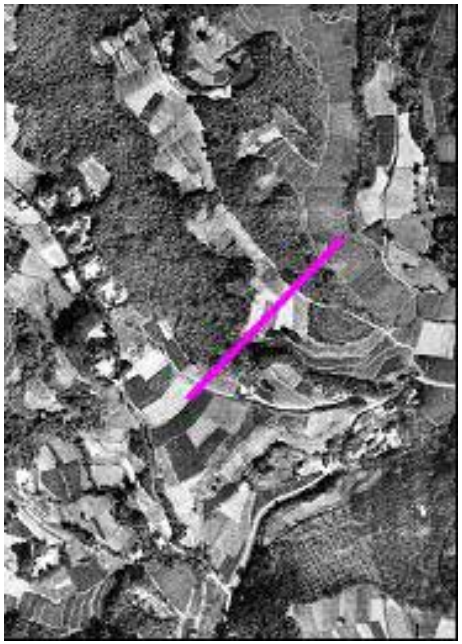


土地被覆の変化の無い場所を判読により特定 (図に示す道路)

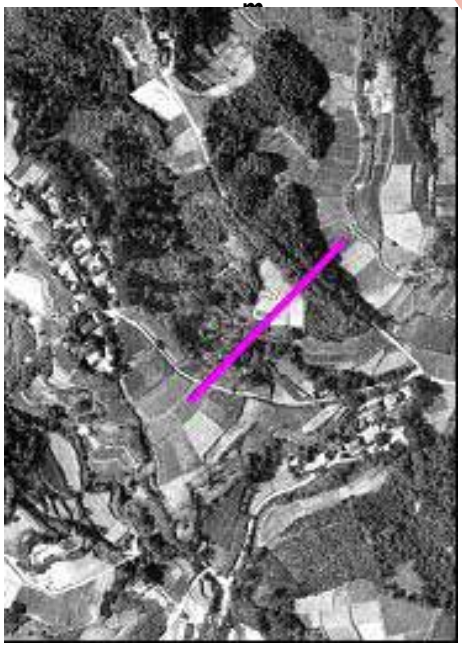
高さのプロファイルを求め、標高値が変化していないことを確認

三次元化データの精度検証 (林地)

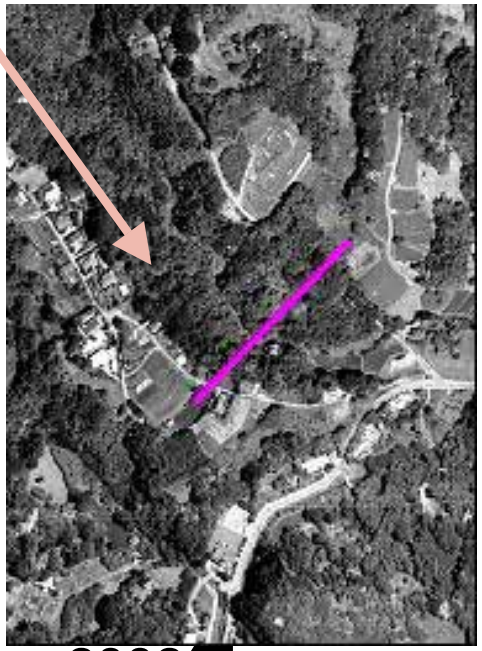




1946年



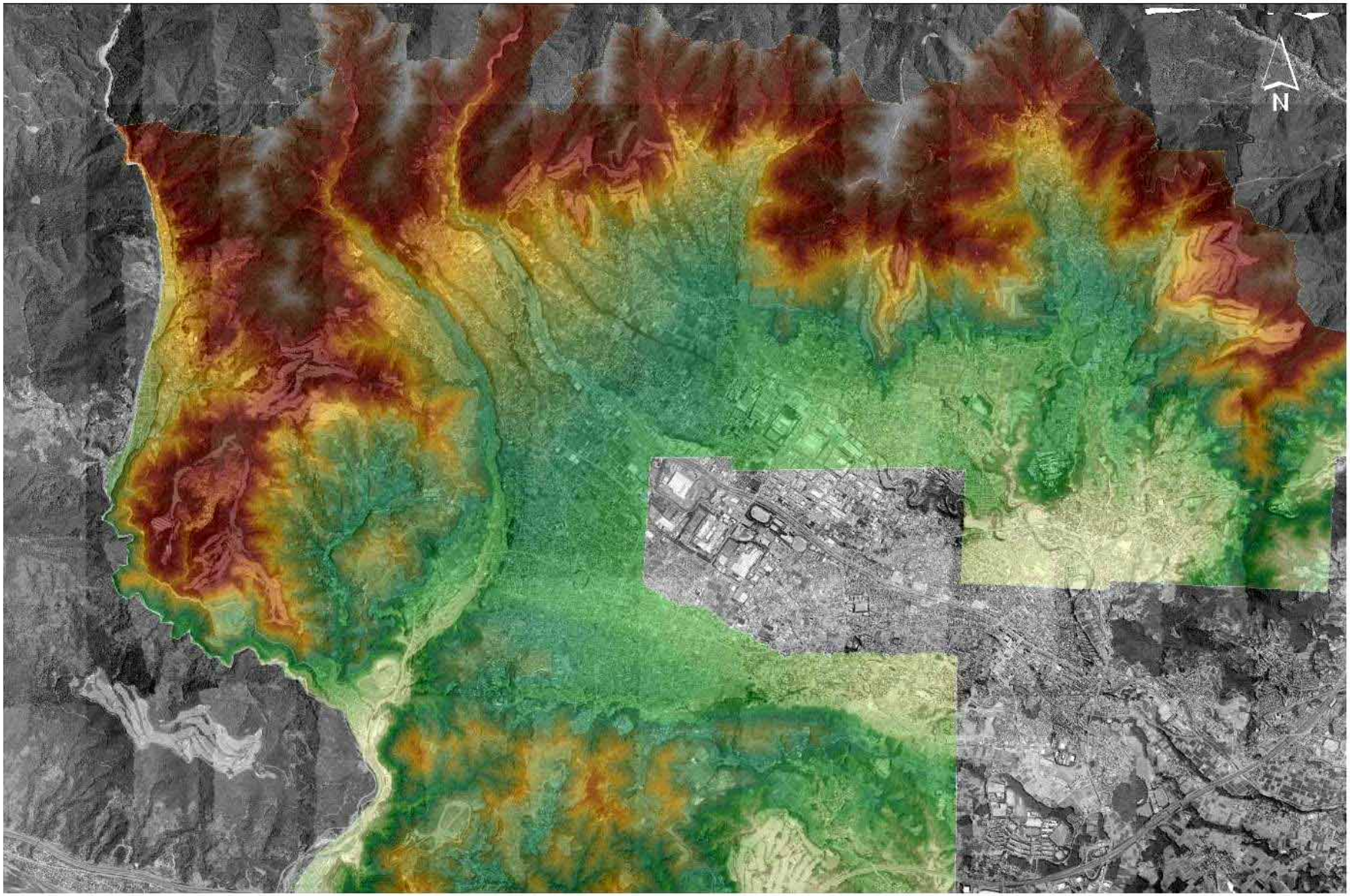
1967年



2002年

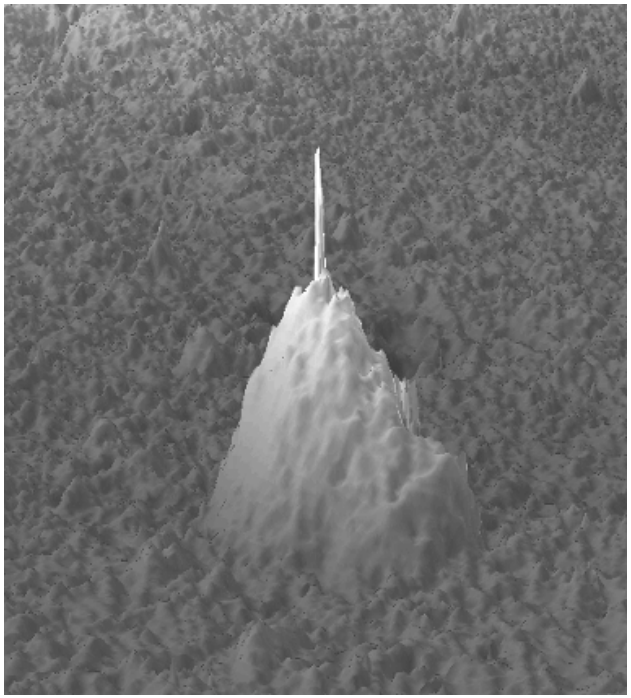
NIES-CGER Hiroyuki Oguma

2002年の秦野盆地全域のDSM（Digital Surface Model：表面高）



NIES-CGER Hiroyuki Oguma

ステレオマッチングのエラー
(汎用ソフトは万能ではない)

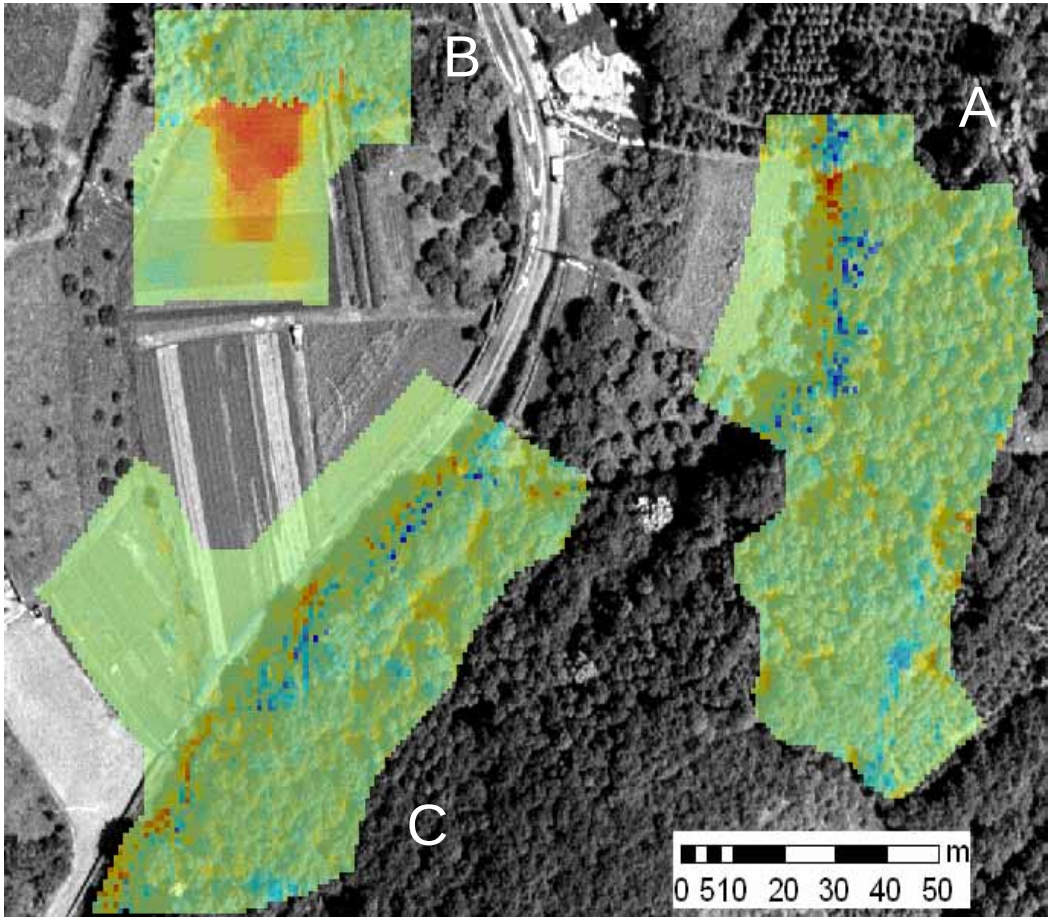


- マッチングパラメータの最適化、自動選択
- 複数のステレオマッチング結果の自動選択
- エラーの検出

写真解析技術としての研究課題

解析図化機による検証

2002年



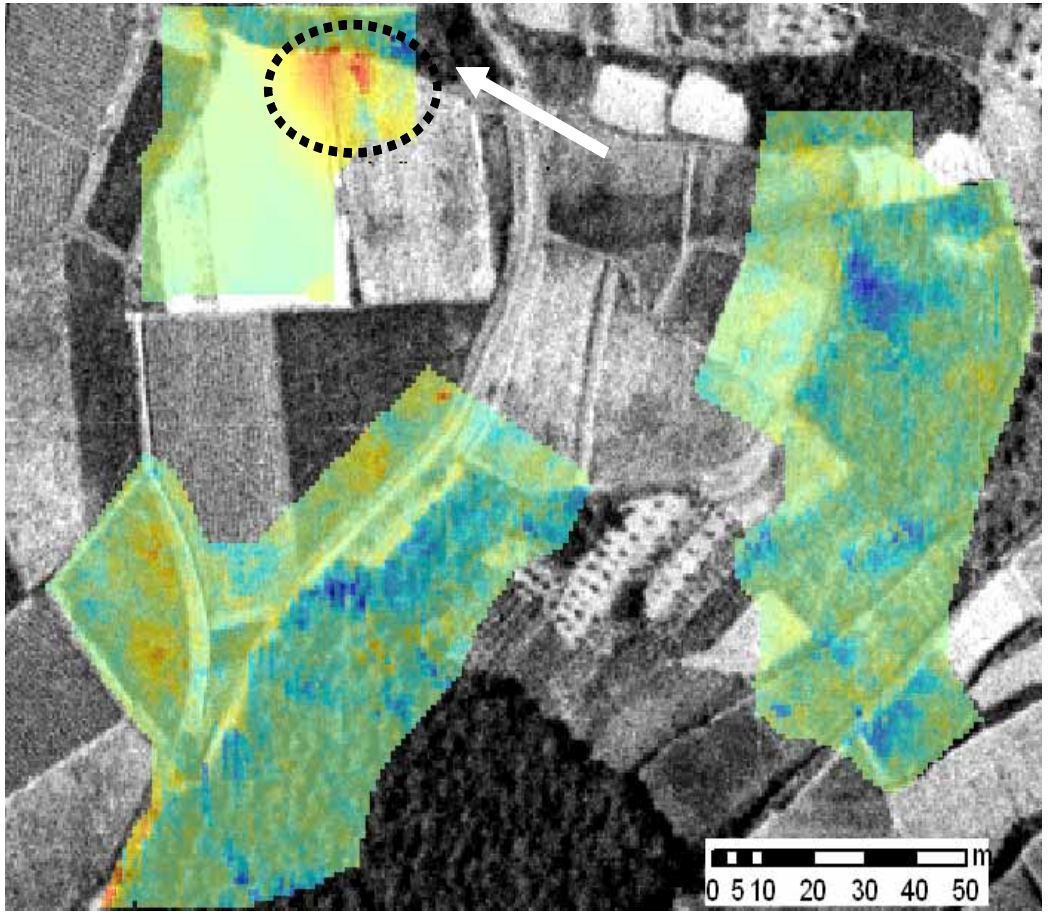
D-DSM$_{2002}$－A-DSM$_{2002}$

高：15.000000(m)

低　：-15.000000

サイト	最大差分(－m)	最大差分(＋m)	平均(m)	標準偏差(m)
A	-19.8	15.1	0.01	2.3
B	-7.7	15.2	2.2	4.2
C	-20.1	12.3	0.2	2.0

1967年



D-DSM$_{1967}$ － A-DSM$_{1967}$

高：15.000000(m)

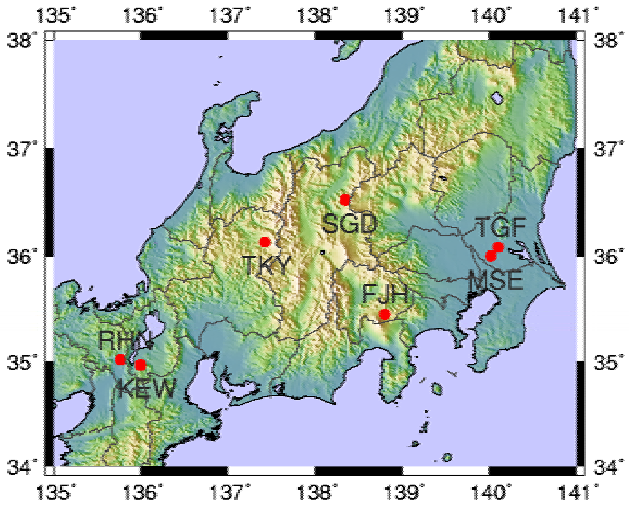
低　：-15.000000

サイト	最大差分(－m)	最大差分(＋m)	平均(m)	標準偏差(m)
A	-14.7	6.7	-1.3	2.4
B	-13.5	17.3	0.9	3.2
C	-14.4	13.9	-1.0	2.8

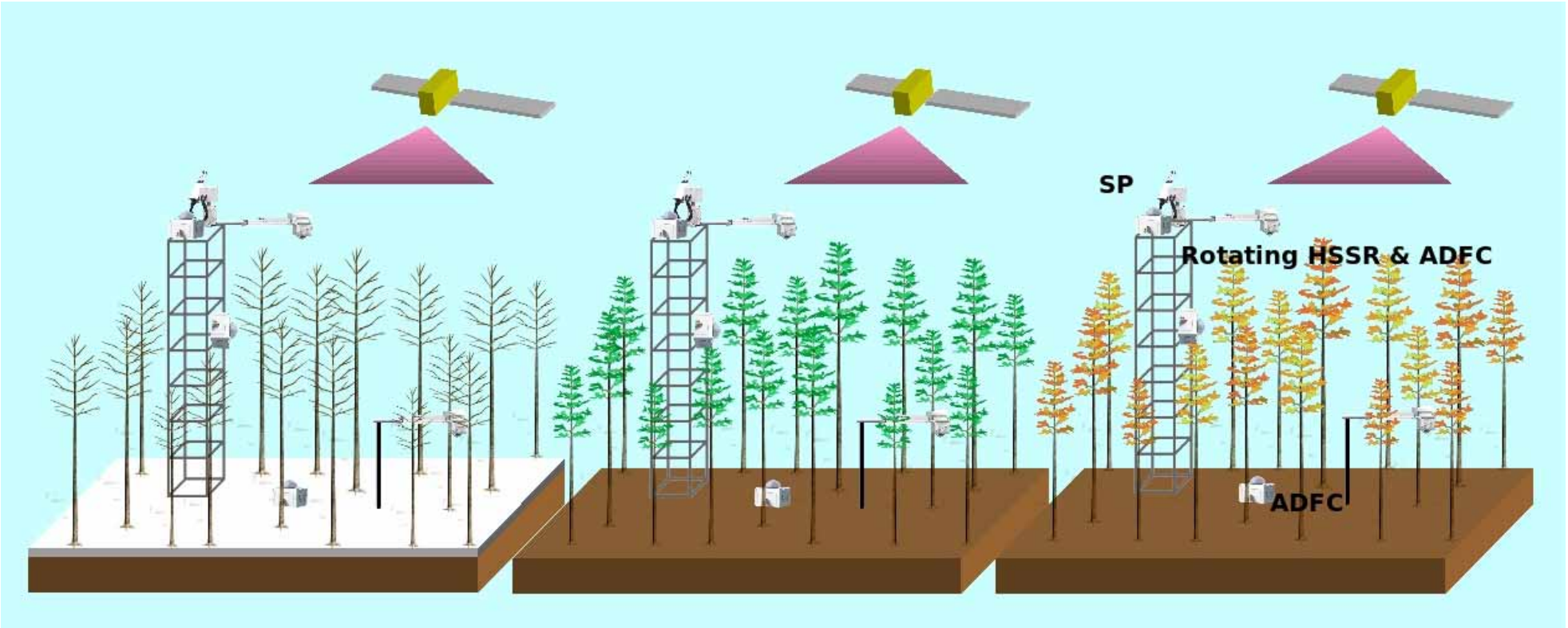
Phenological Eyes Network (PEN)

PEN

Phenological Eyes Network

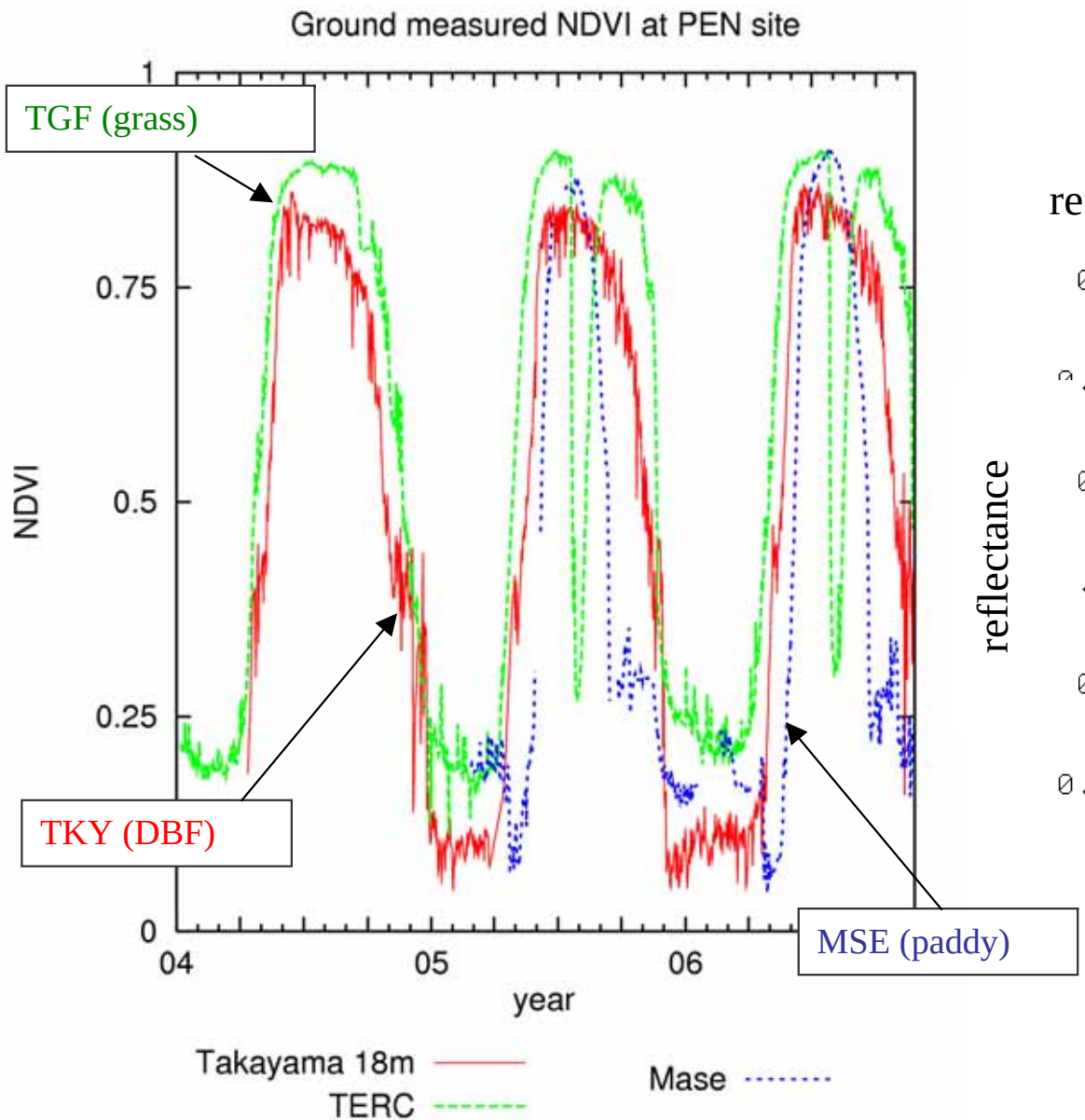


Phenology, carbon & water flux, aerosol (yellow sands etc.), spectral reflectance, leaf area (LAI), PAR, FPAR, etc.

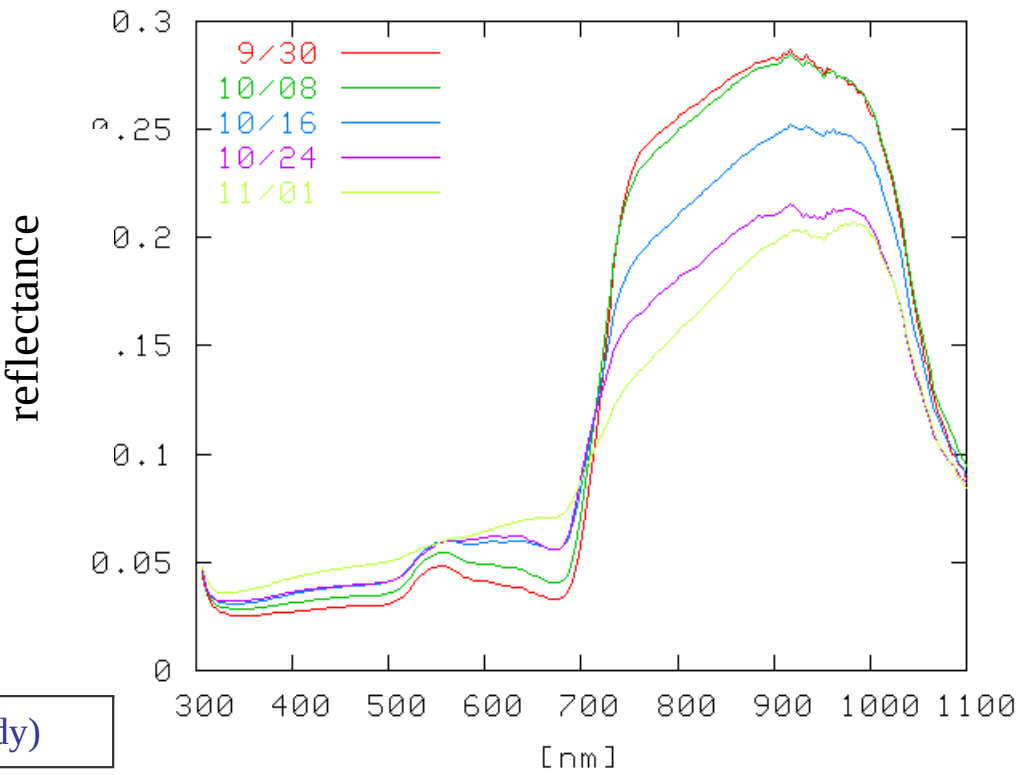


Phenological Eyes Network (PEN)

HSSR (hemispherical spectro-radiometer)



reflectance spectrum (Takayama site)



Phenological Eyes Network (PEN)

ADFC (automatic digital fish-eye camera)

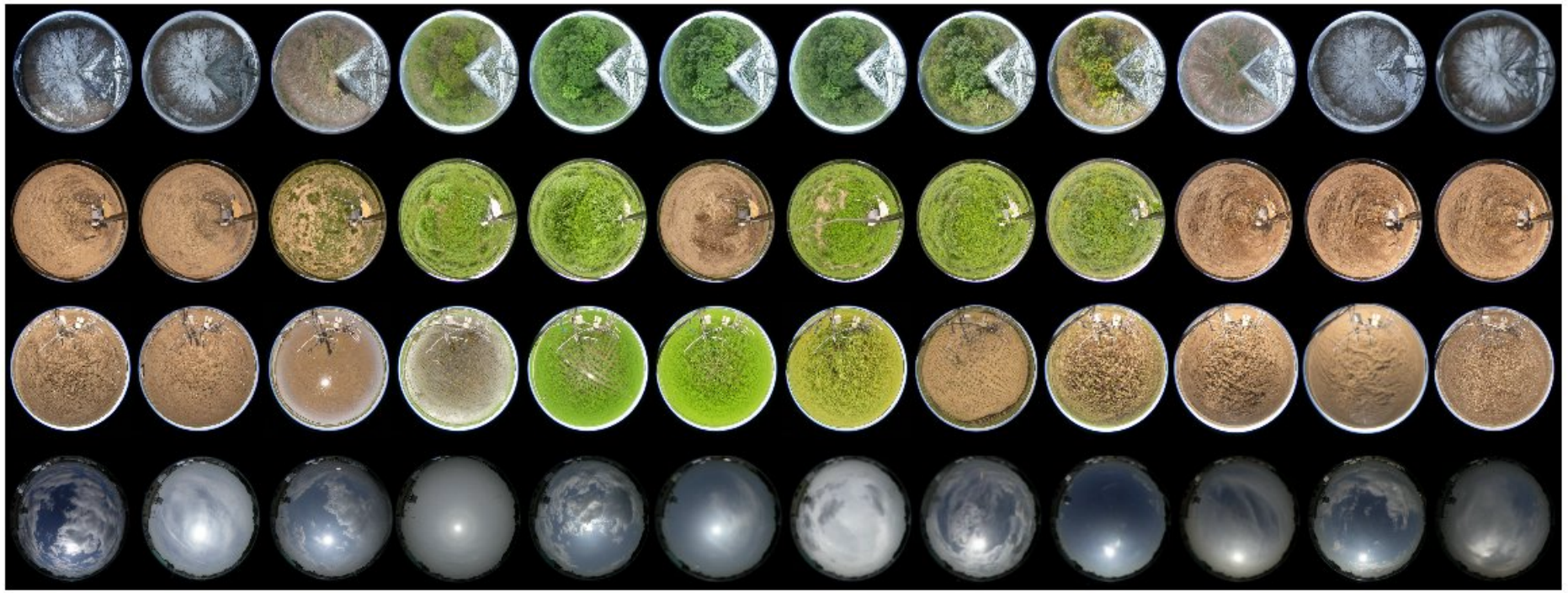
month: 3 4 5 6 7 8 9 10 11 12 1 2

TKY

TGF

MSE

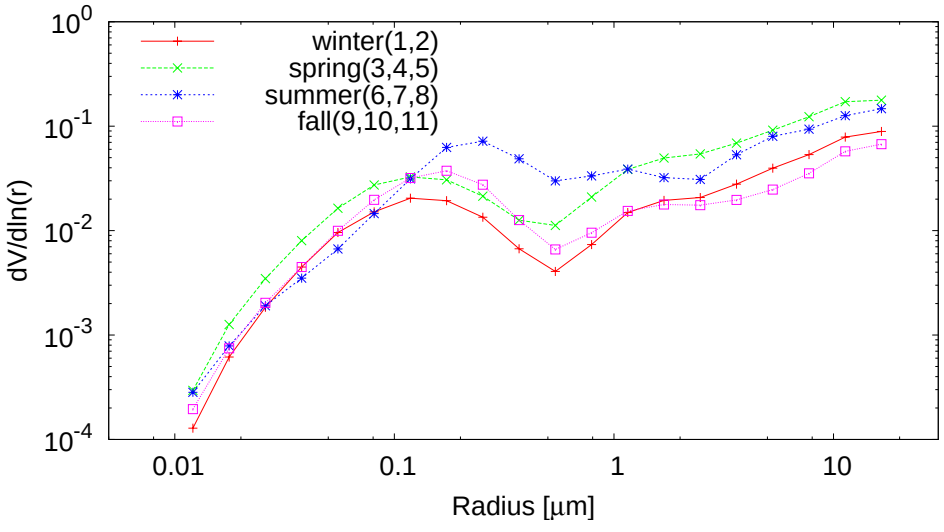
RHN



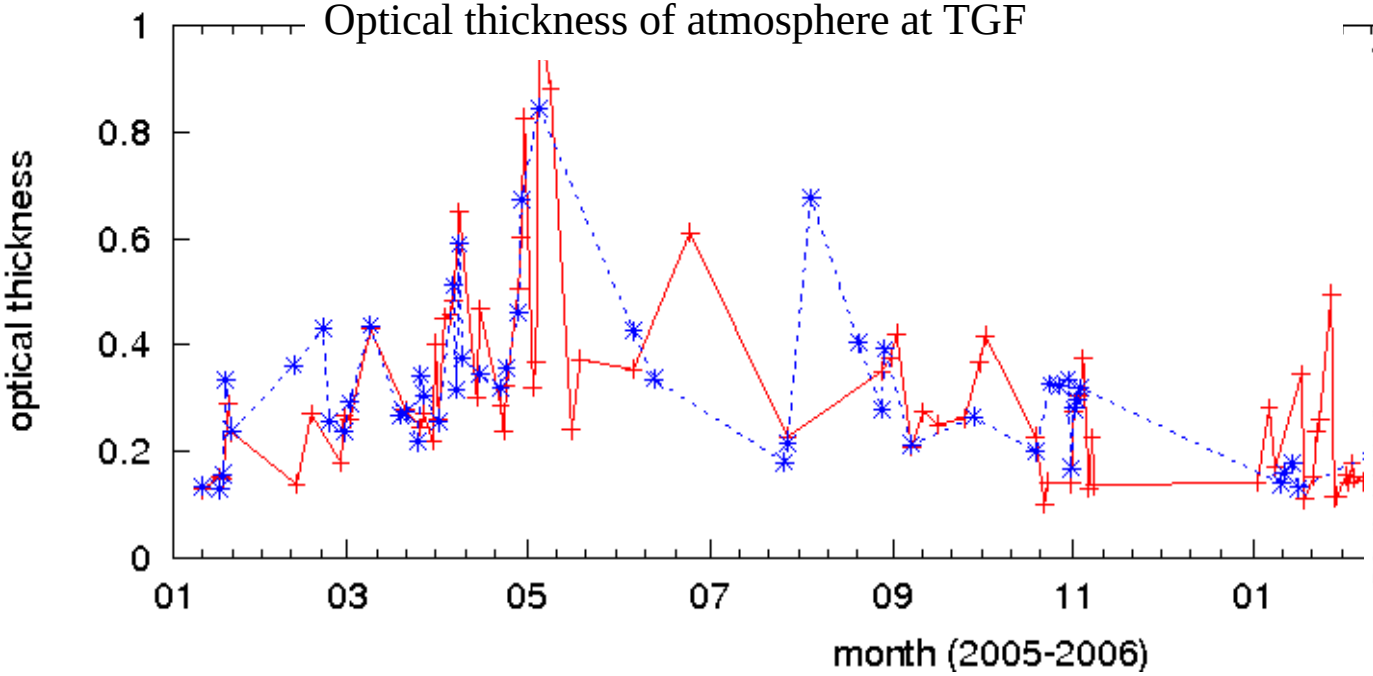
Phenological Eyes Network (PEN)

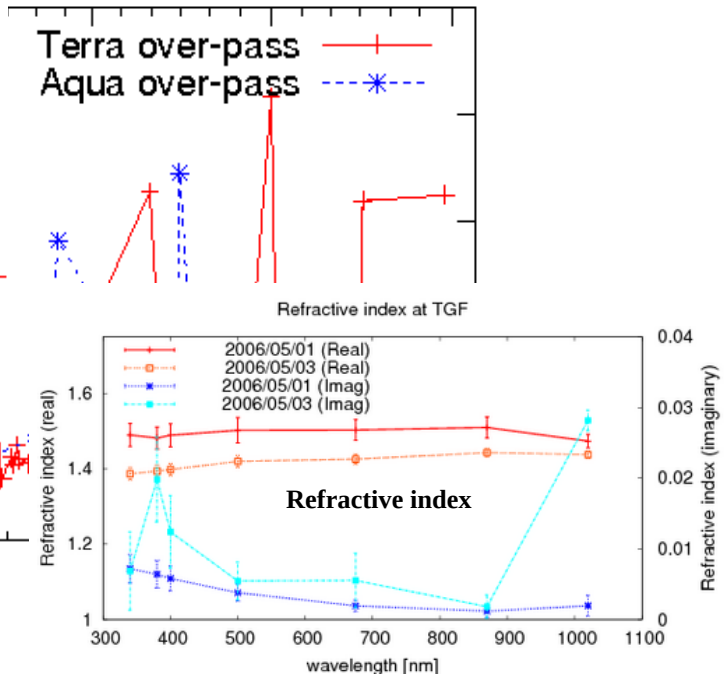
Skyradiometer (sunphotometer)

aerosol particle size
at TGF (2005)



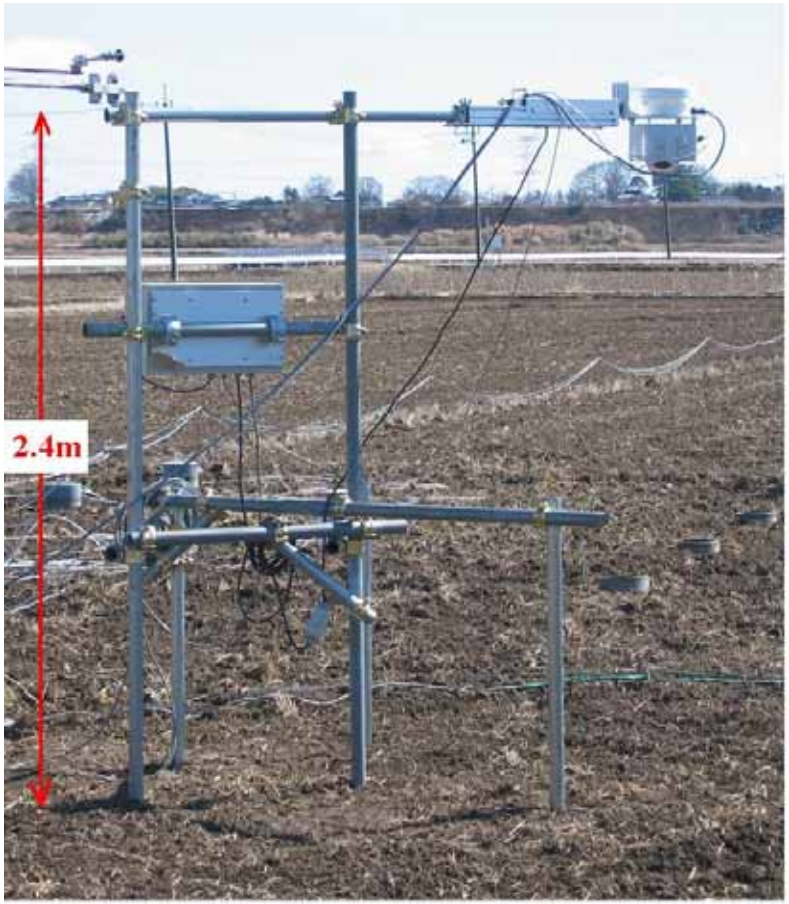
Optical thickness of atmosphere at TGF





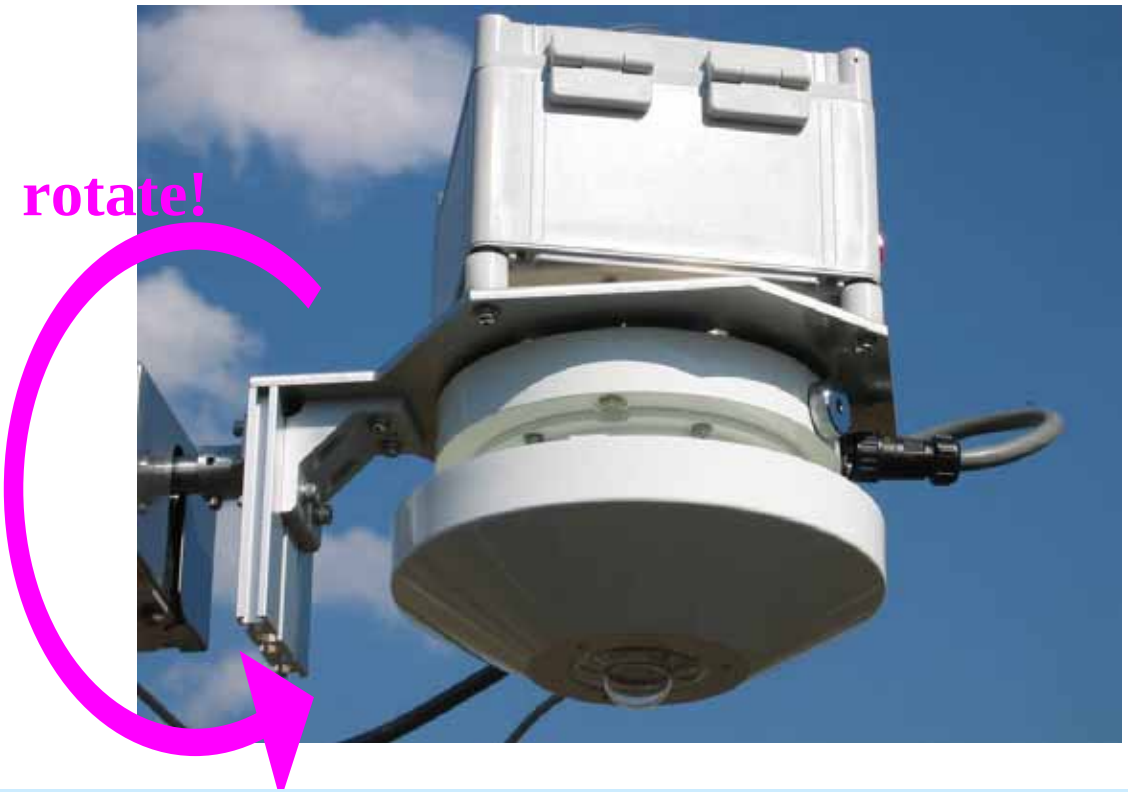
Phenological Eyes Network (PEN)

Installation in MSE



Automatic-capturing Digital Fish-eye Camera (ADFC)

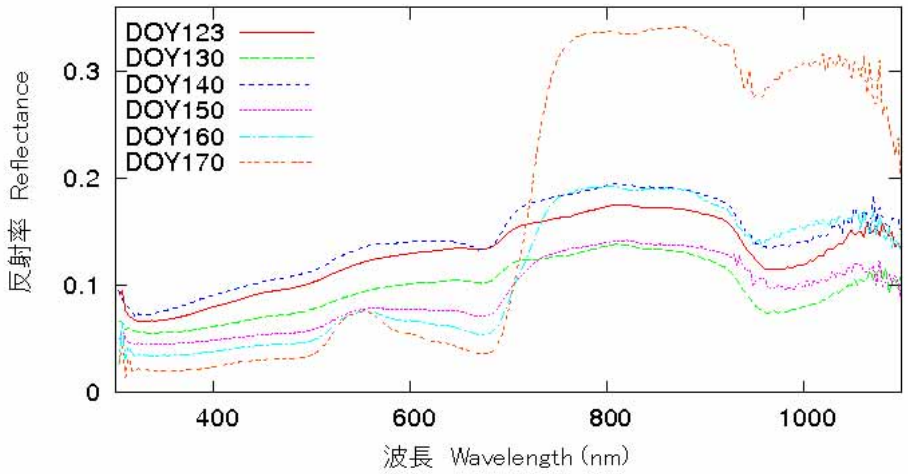
(NIKON Coolpix4300 + FC-8 Fisheye Converter)

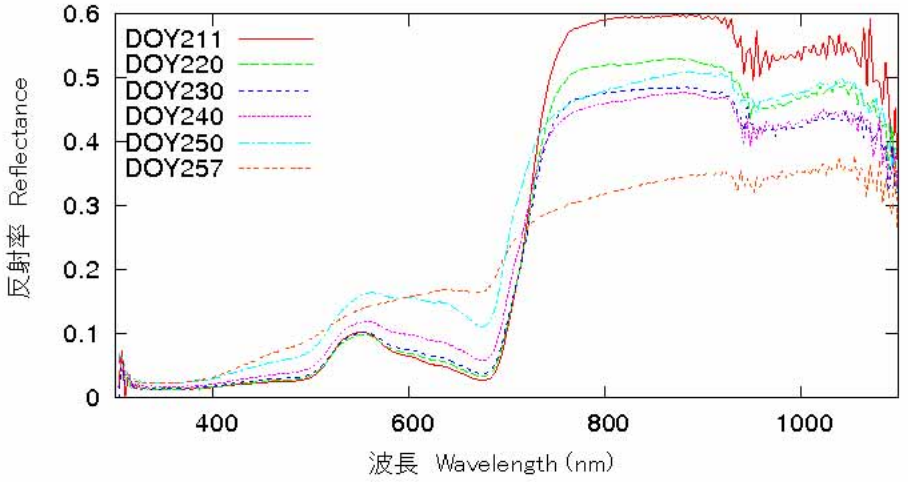


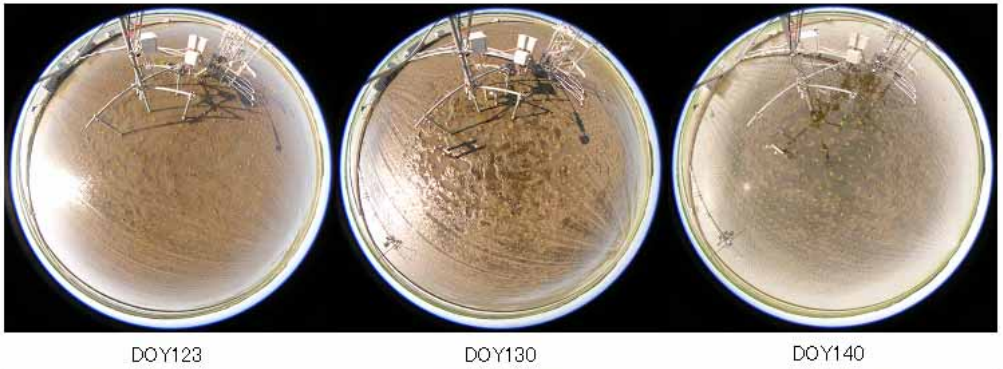
Hemispherical Spectro-radiometer (HSSR)

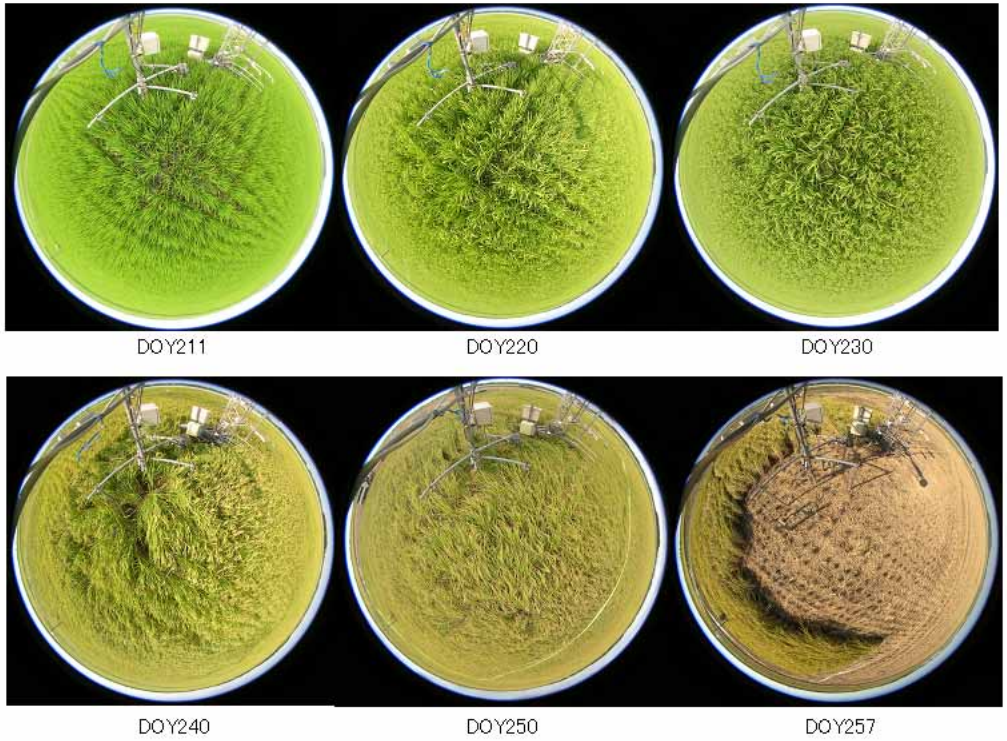
(Eko MS-700; 350nm-1100nm; 256bands)

Example: Mase site (paddy), 2005

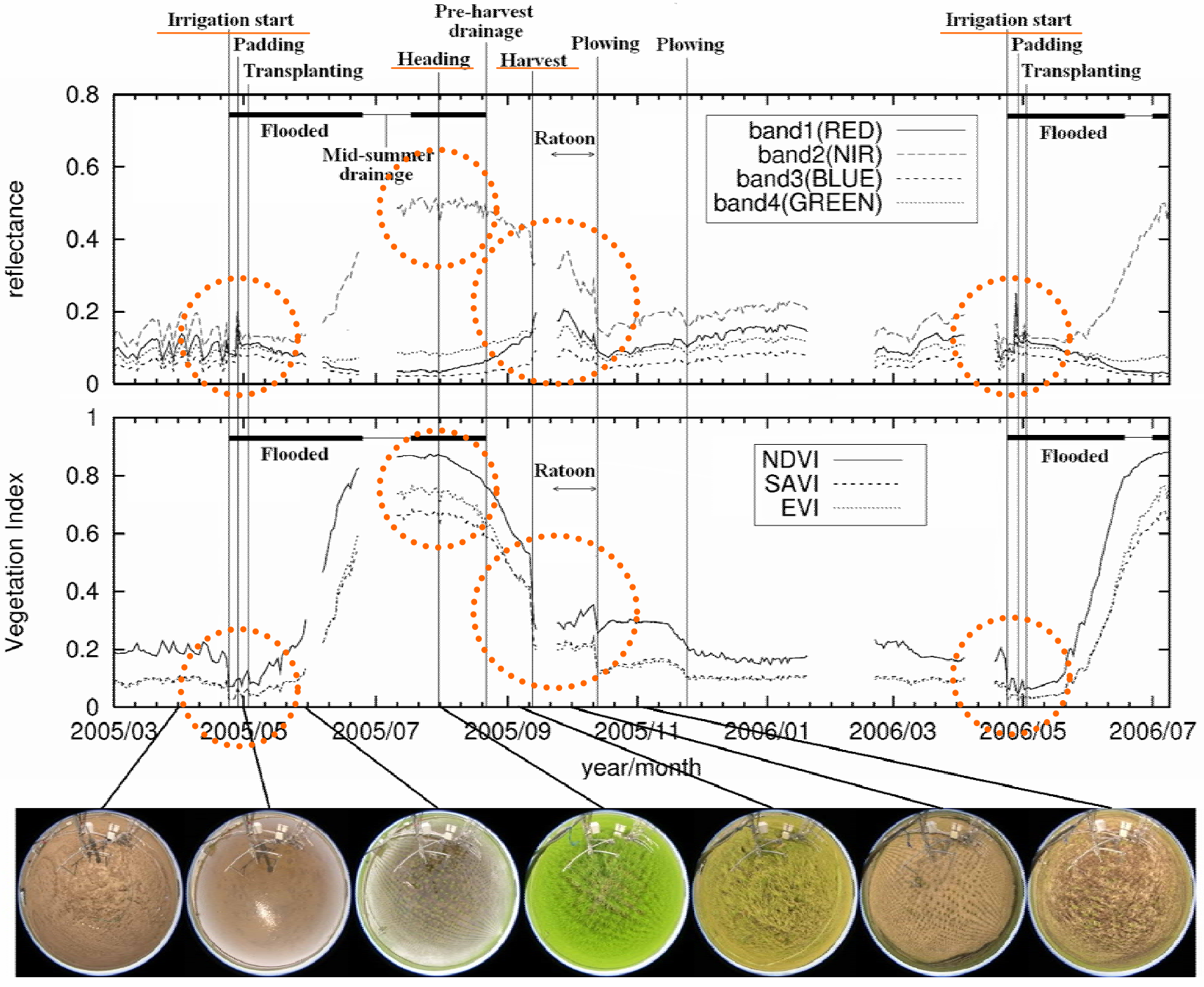




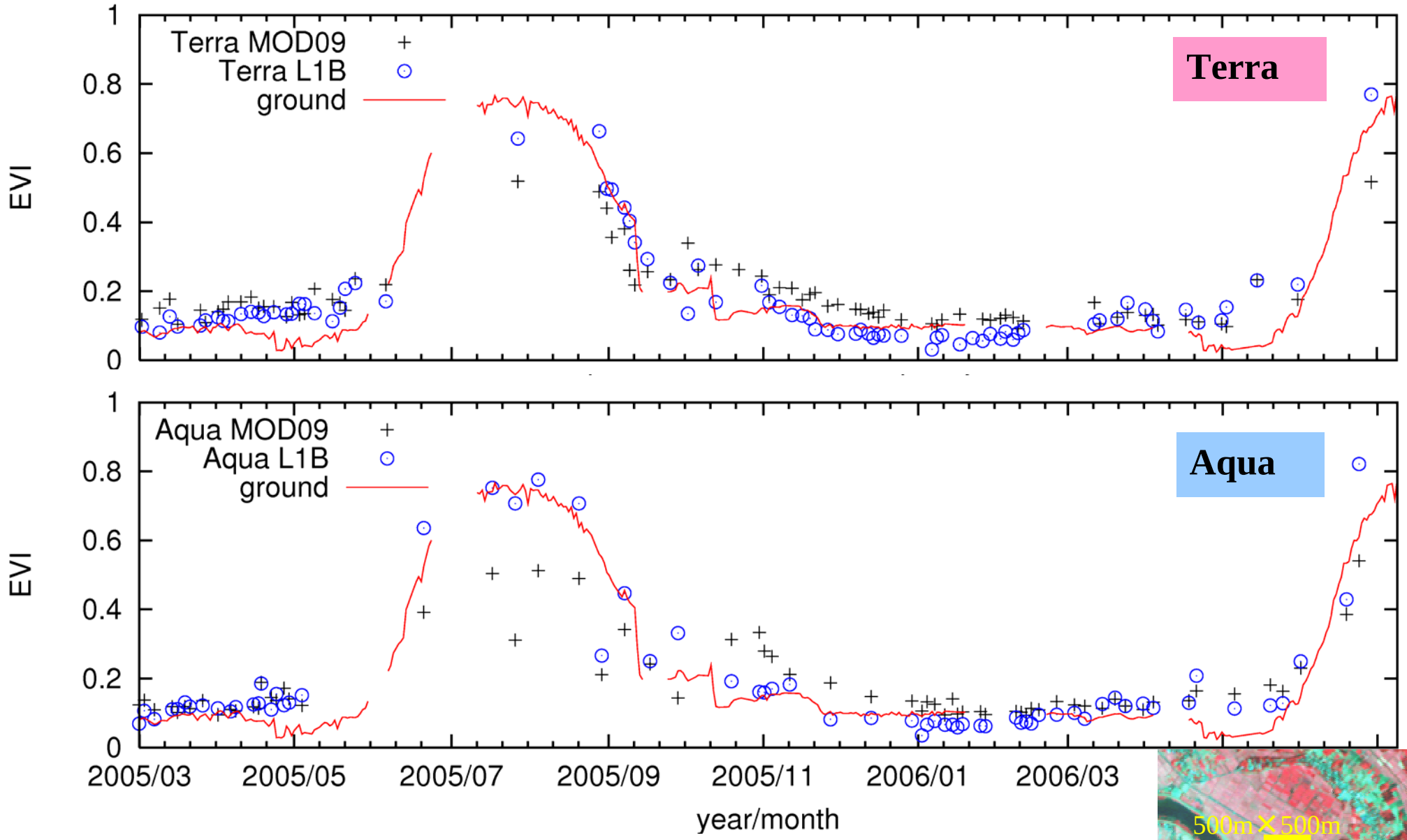


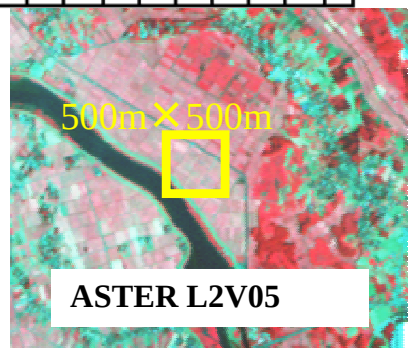


Example: Mase site (paddy), 2005-2006

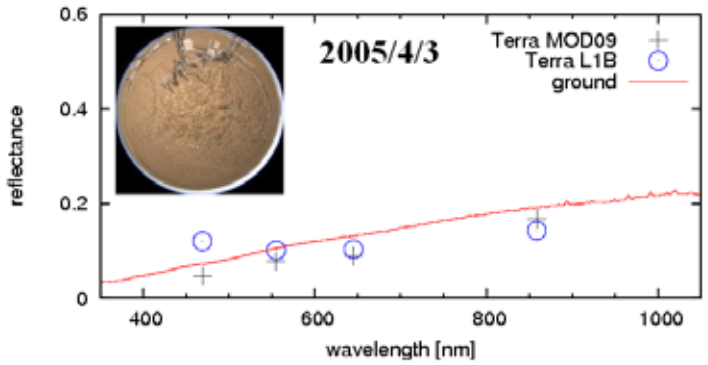


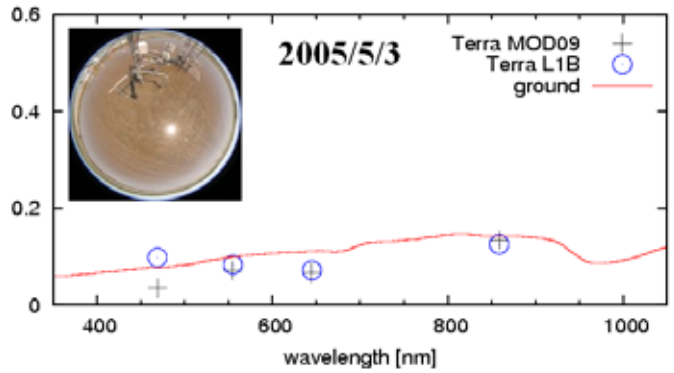
Example: check of satellite index at Mase site (paddy)

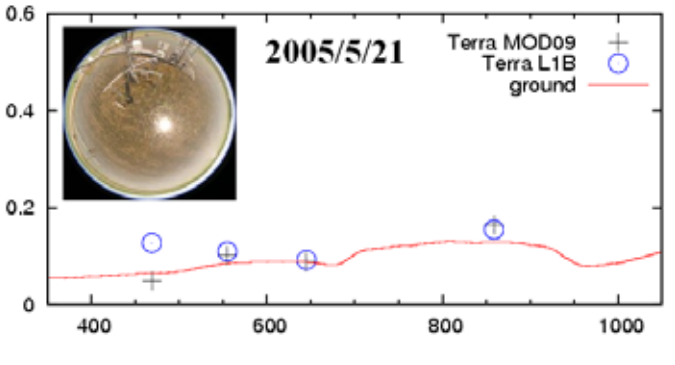


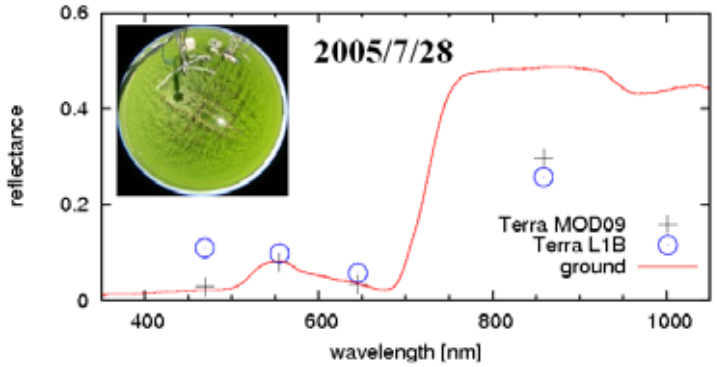


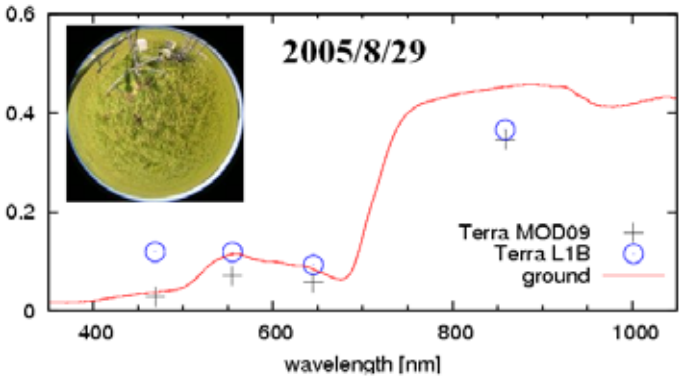
MODIS data vs. ground data: spectrum

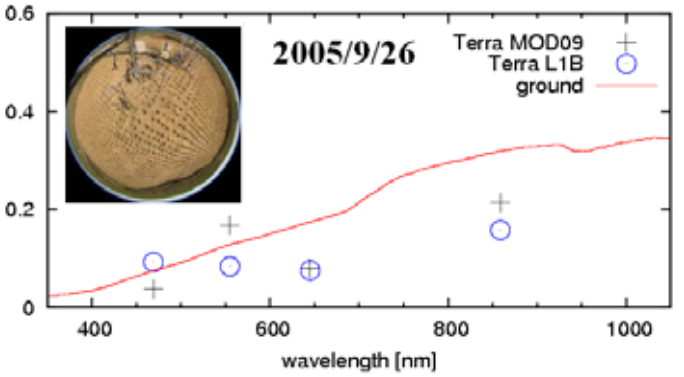


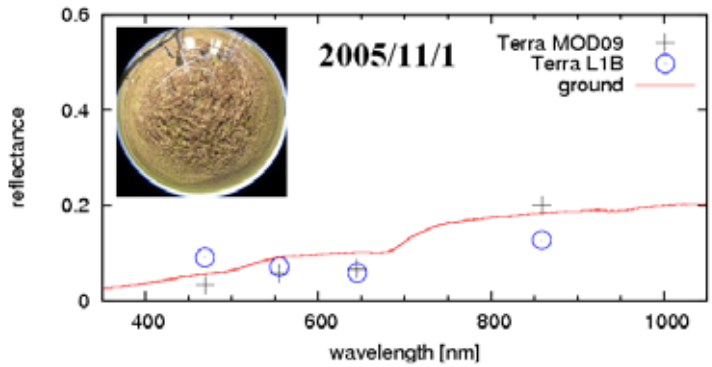


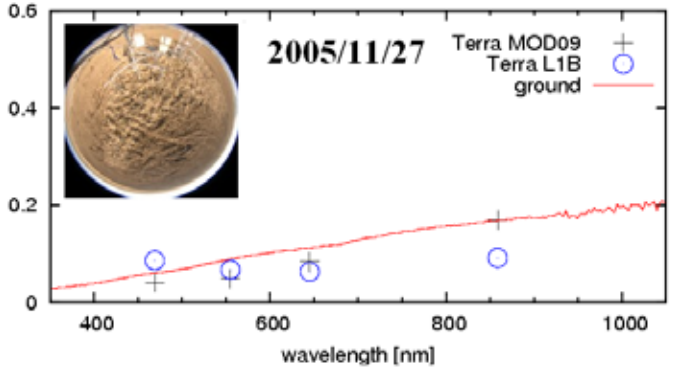












Manual observations

Leaf area index (LAI):

litter traps

LAI-2000

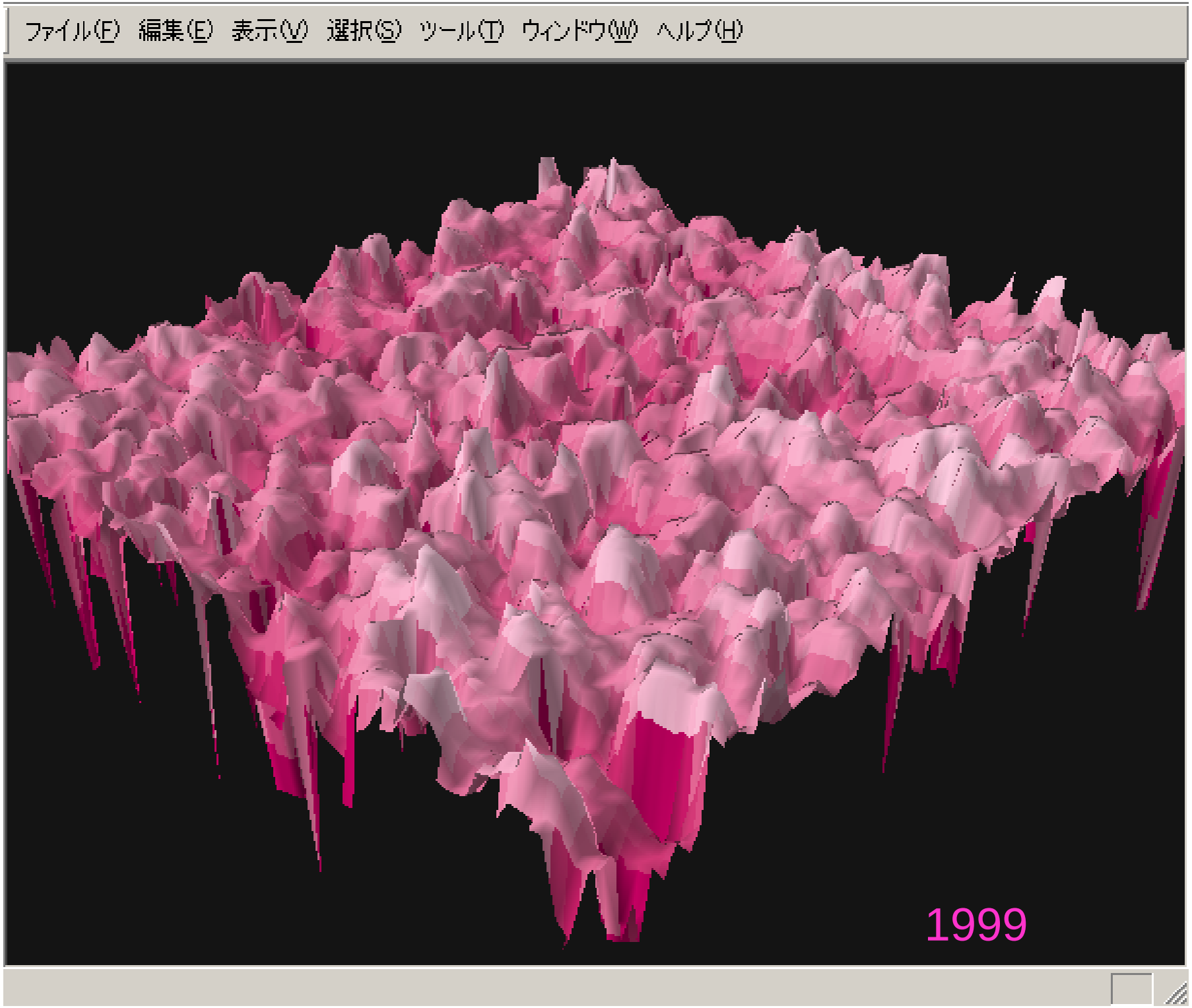
TRAC

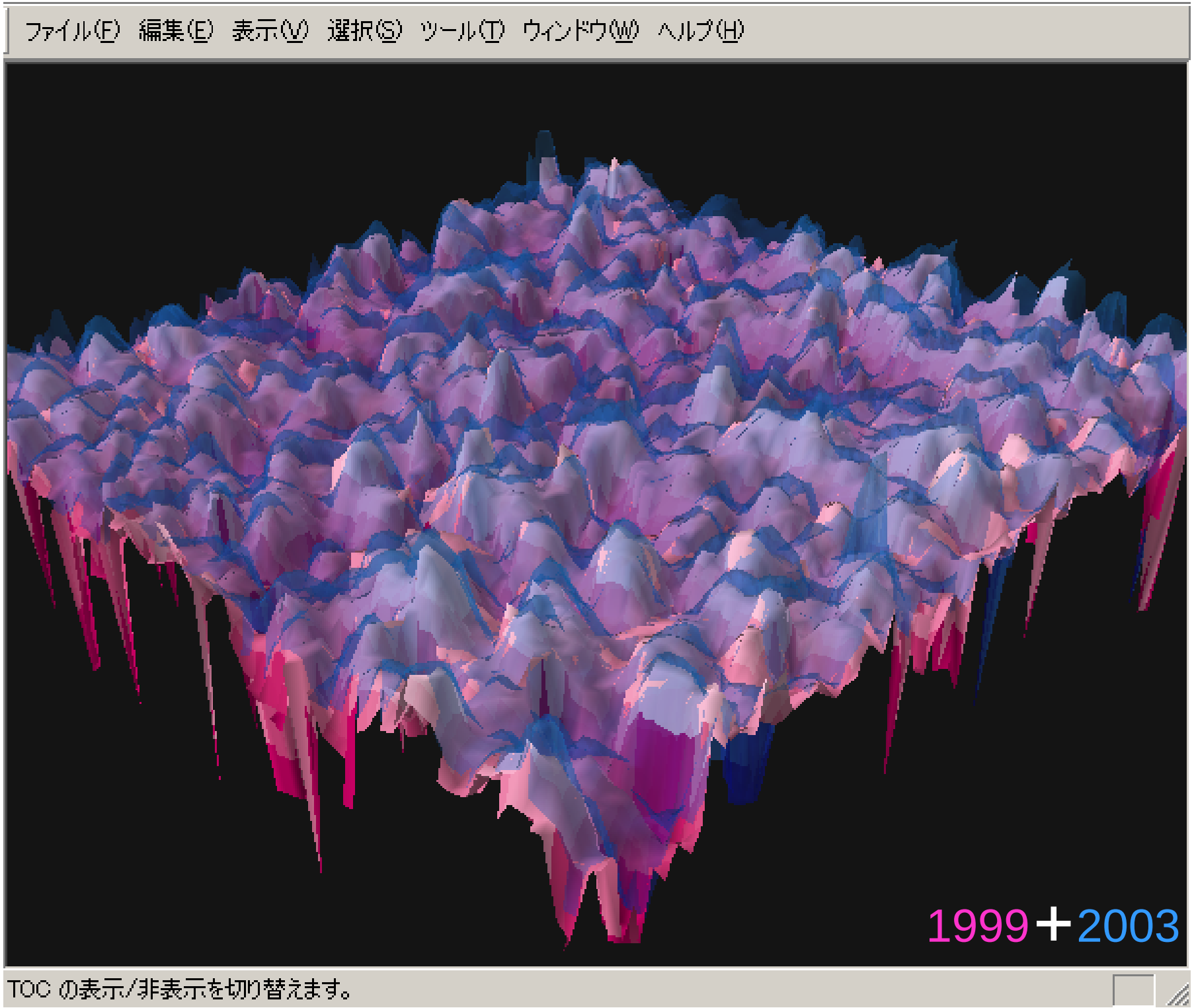
Monitoring of shoots and leaves

phenology

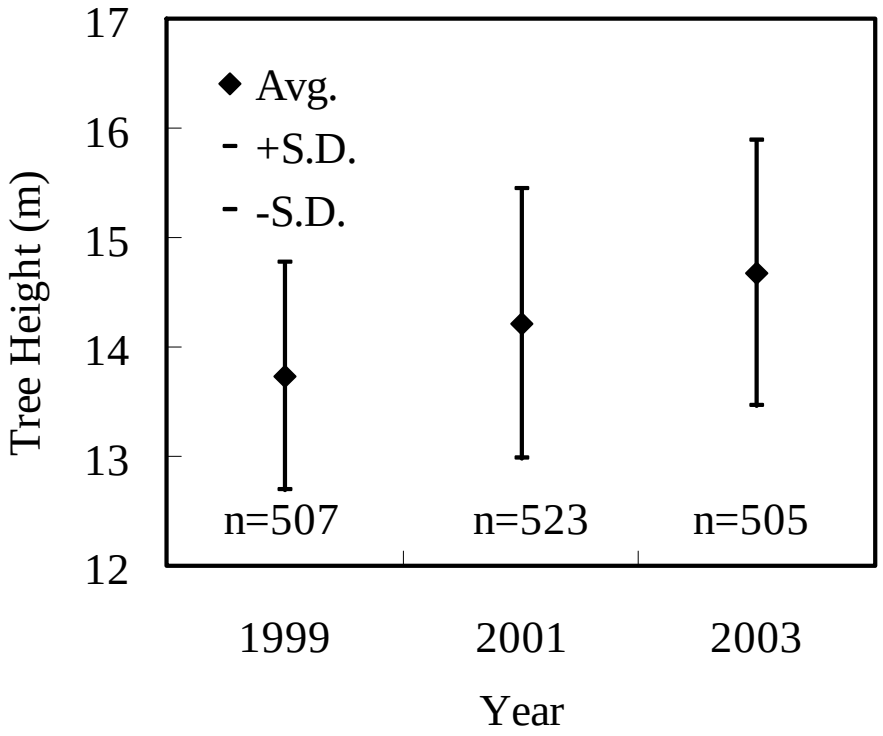
leaf spectrum

leaf physiology


ファイル(F) 編集(E) 表示(V) 選択(S) ツール(T) ウィンドウ(W) ヘルプ(H)
1999


ファイル(F) 編集(E) 表示(V) 選択(S) ツール(T) ウィンドウ(W) ヘルプ(H)
1999+2003
TOC の表示/非表示を切り替えます。

Tree Height Monitoring by LiDAR



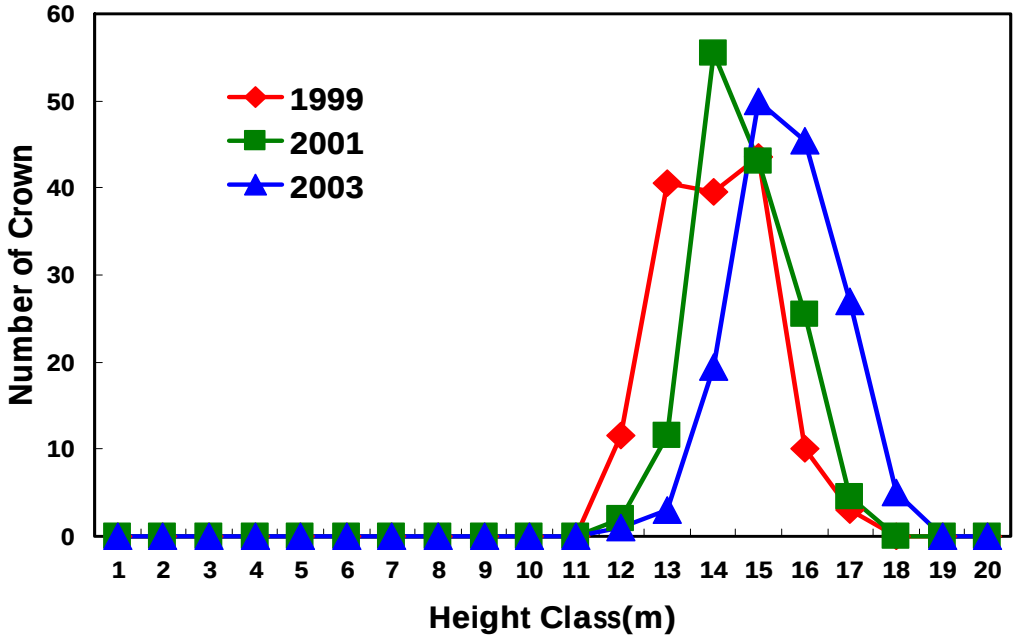
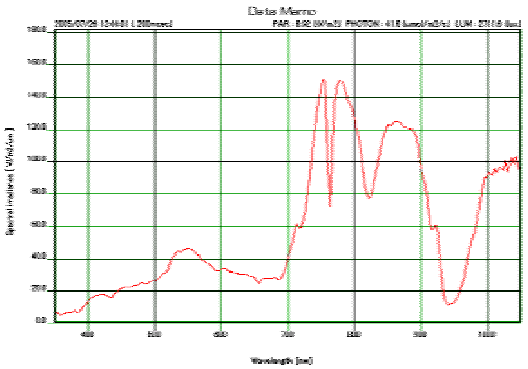


Fig. Histogram of number of crown

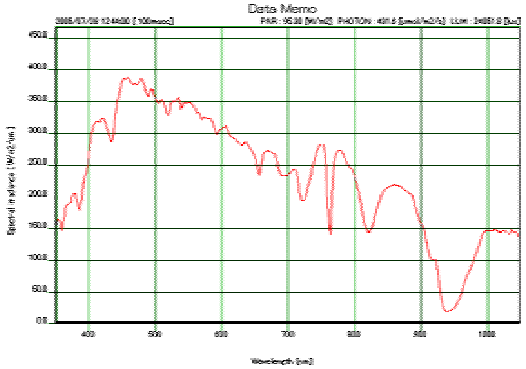
Average (left) and Histogram (right) of tree height obtained by laser survey

分光反射率の算出方法

反射光の分光放射量



全天分光放射量

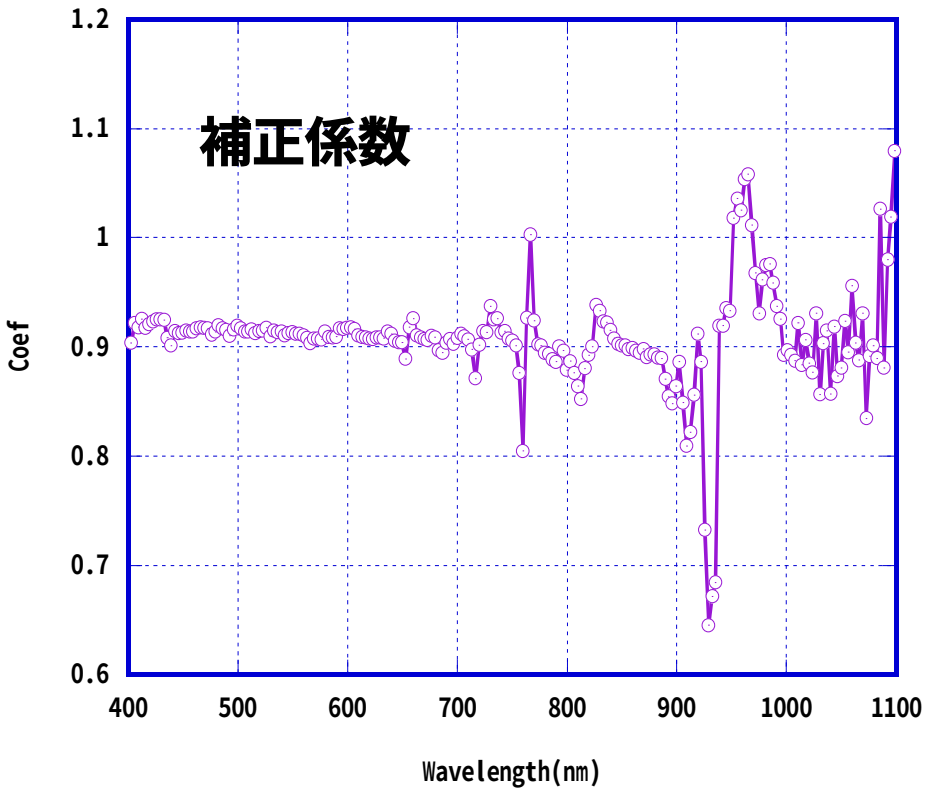


植生からの反射

両者の比を取ることにより
分光反射率を算出

上向き、下向き放射を同時測定
する必要性

1. 上下向きに2台の分光計を設置



2.

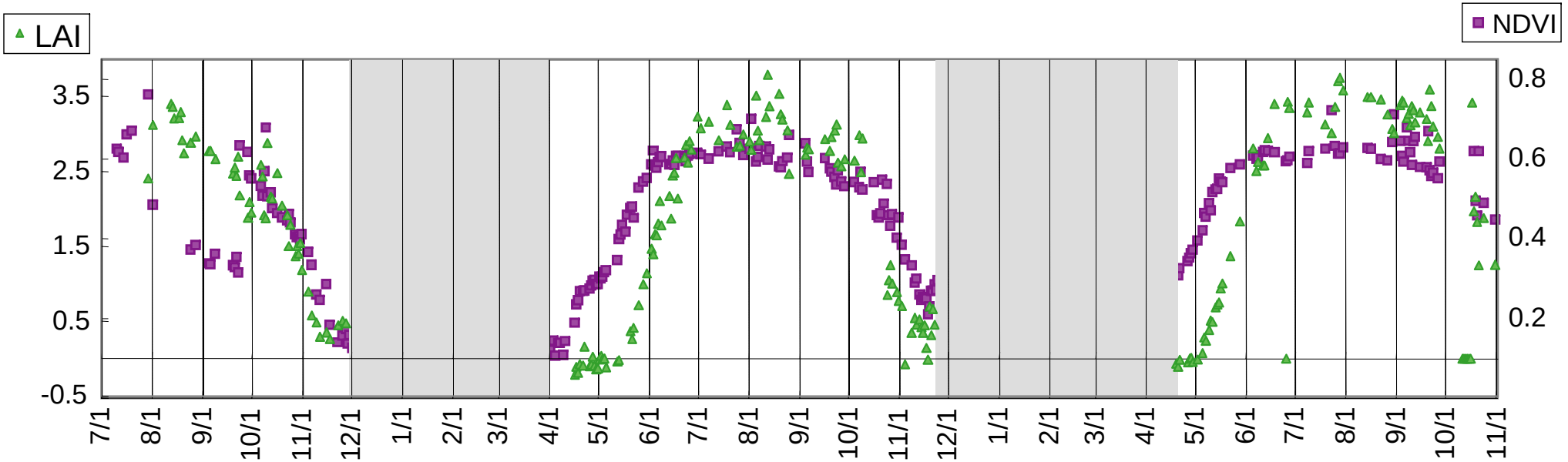
・同じ
・機差

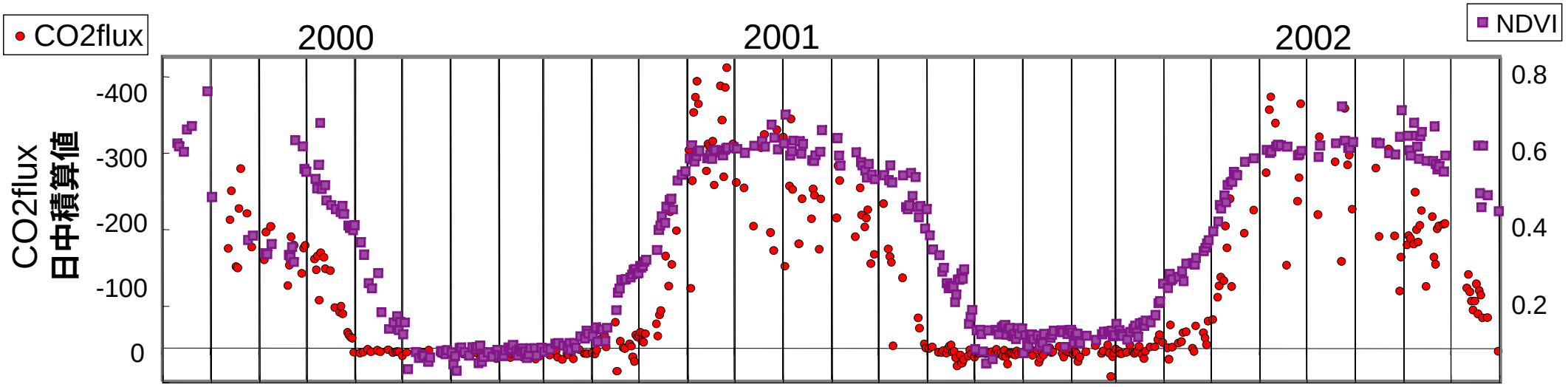
・上下
・位置
・重量

対象エリア

- 里地里山保全再生モデル事業対象地（環境省）
- 地理院撮影の150mmレンズ
- 土地被覆が多様（傾斜地、平地、農地、都市・・・・）

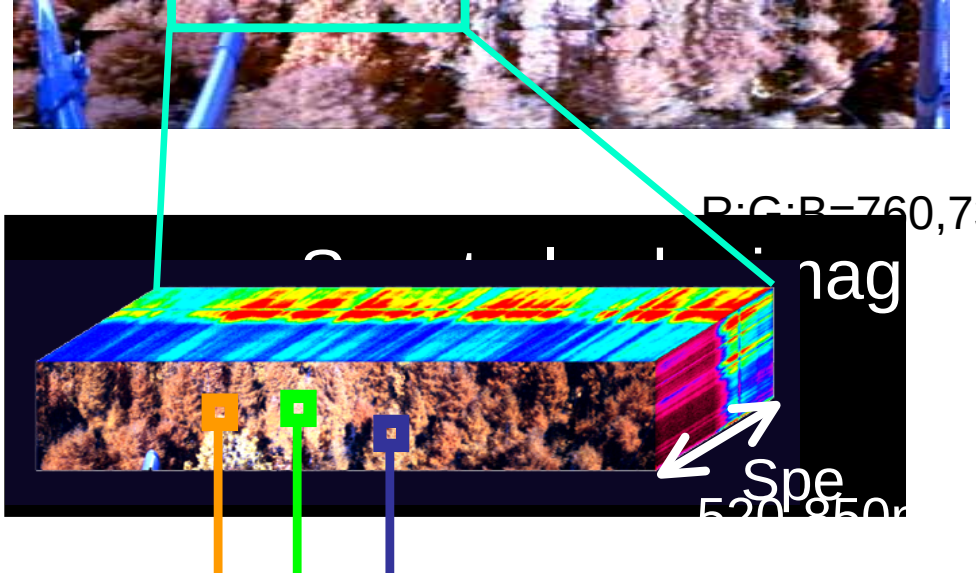
NDVIの変動が表すパラメータは？

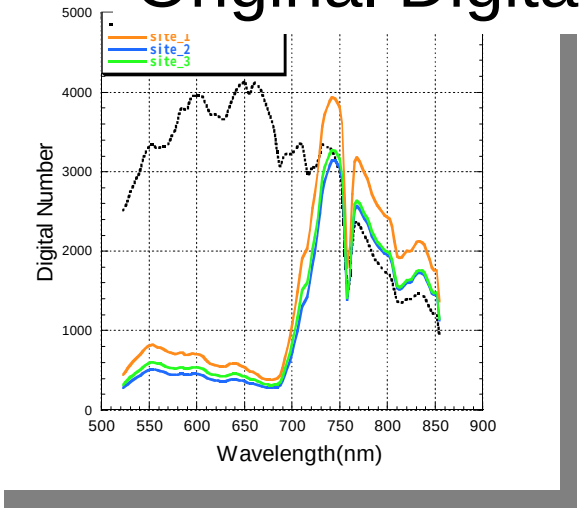


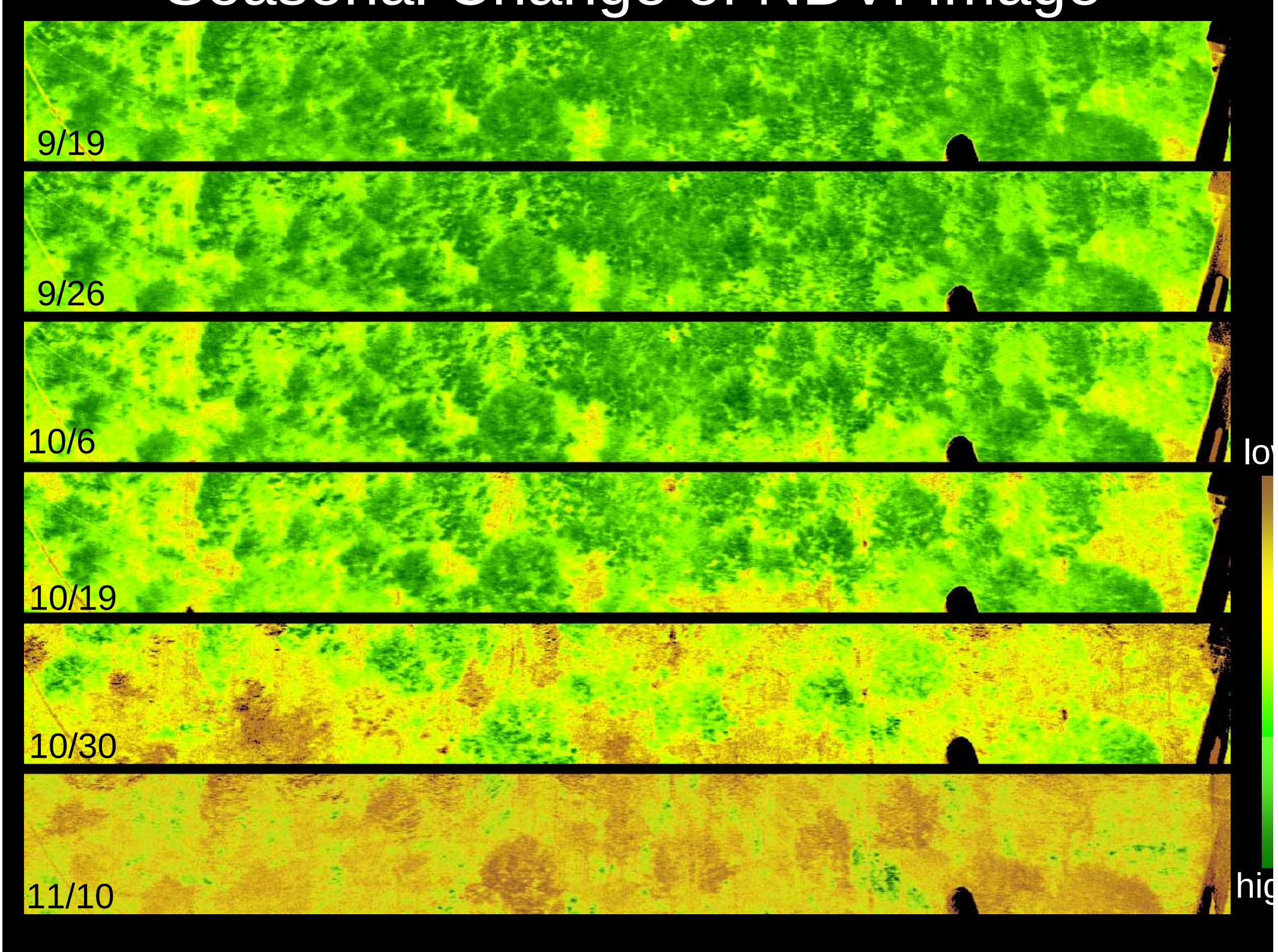


苫小牧フラックスリサーチサイトにおけるカラマツ樹冠上分光計測結果
(2000年～2004年)

苫小牧フラックスリサーチサイト (北海道)
北緯42**度**44**分、東経**141**度**31**分**
○対象
ニホンカラマツ(Larix kaempferi Sarg.)
樹高;18～20**m、樹齢**;**約**45**年**

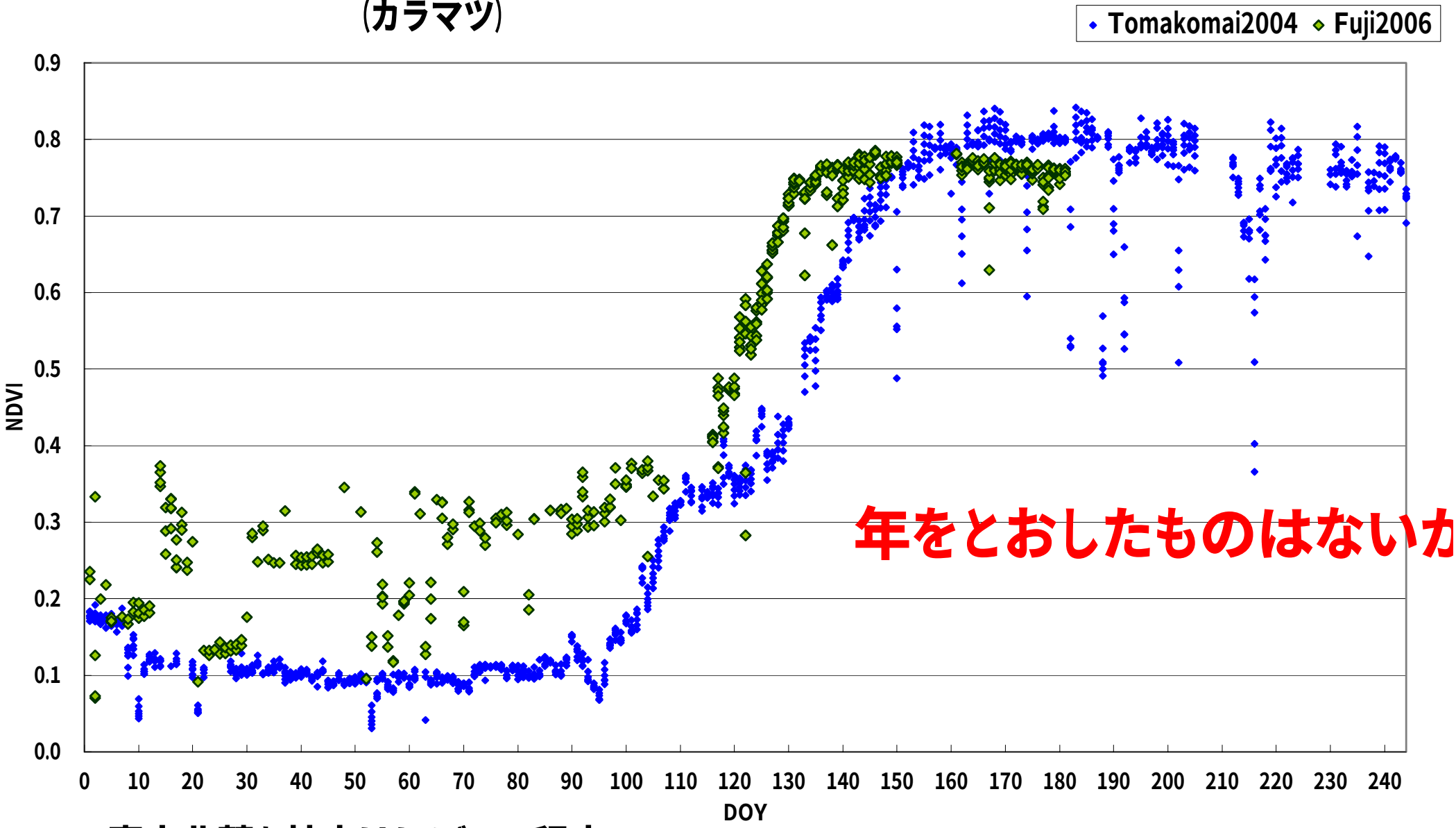

R:G:B=760,730,69
nag
Spe


Original Digital Number
site_1
site_2
site_3
Digital Number
Wavelength(nm)
0
1000
2000
3000
4000
5000
500
550
600
650
700
750
800
850
900


Seasonal Change of NDVI Image
9/19
9/26
10/6
10/19
10/30
11/10
low
high

NDVI　Fuji & Tomakomai　1/1-9/1　11:00-13:30

(カラマツ)

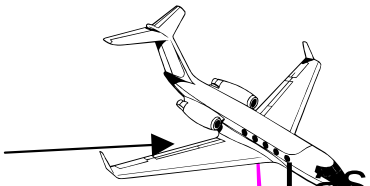


富士北麓も林床はほぼ0．3程度

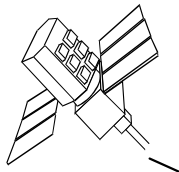
積雪時のみ0．1まで低下；苫小牧とほぼ同じ傾向

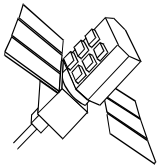
Airborne Lidar Systems

(Light Detection And Ranging)



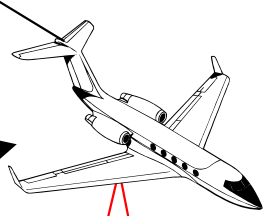
Laser pulse

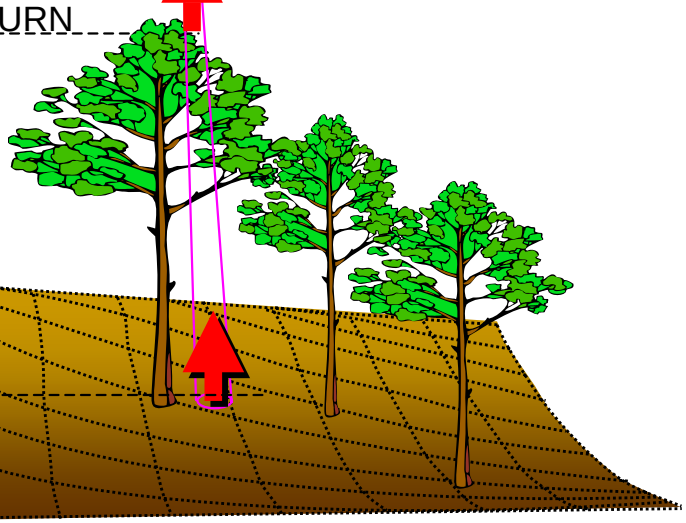




GPS SATELLITE

D-GPS: Position of the sensor systems
INS (Inertial navigation system): Orientation



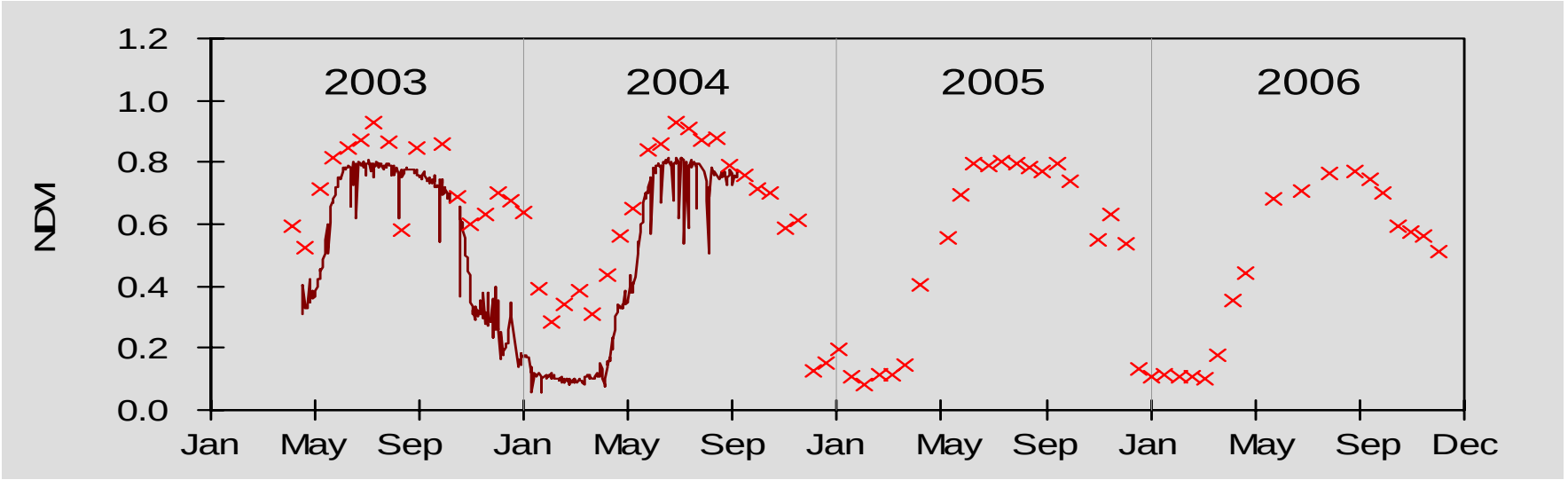


GPS
Grand Station

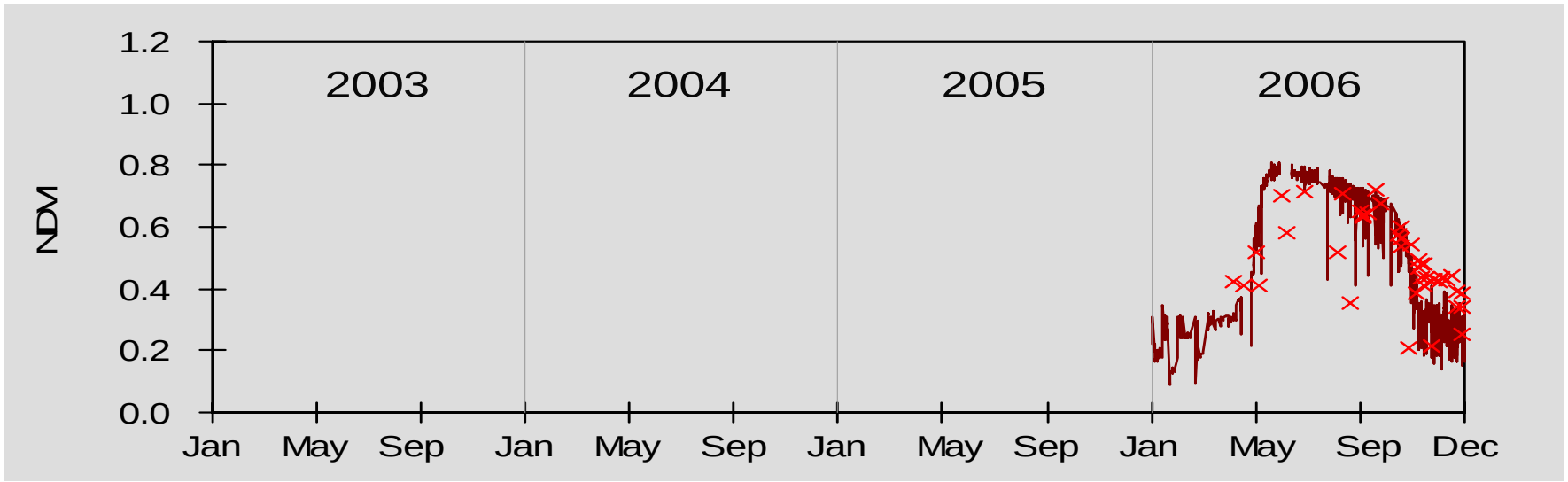
600～
3000m

Ground measured NDVI and MODIS NDVI

TOMAKOMAI



FUJI

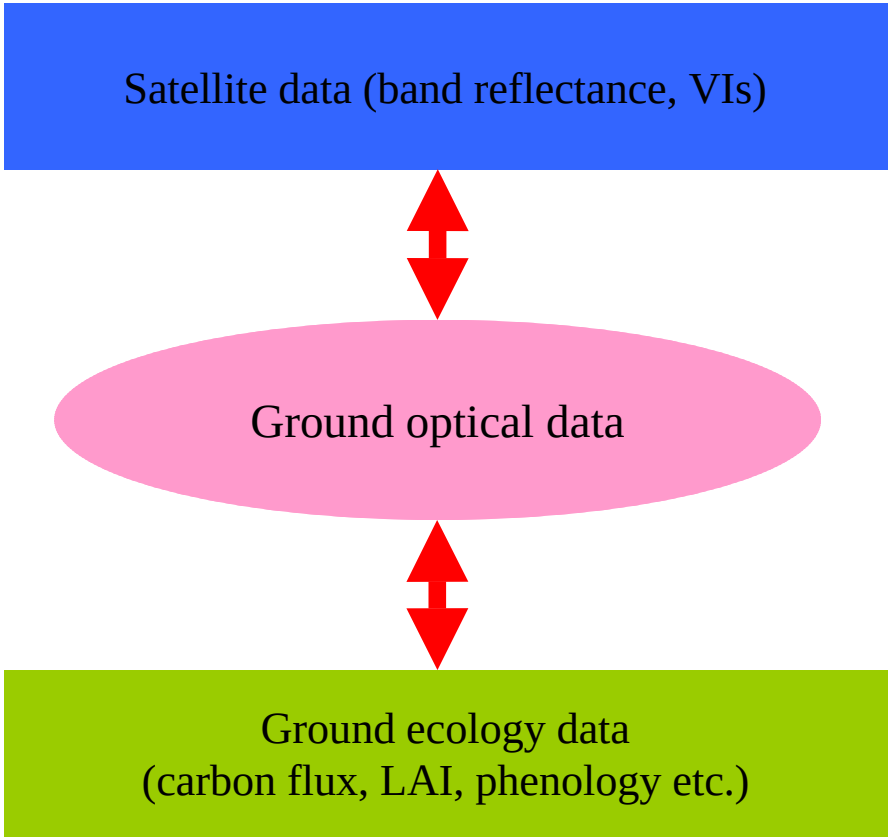


神奈川県秦野市の里山の変化(寺山地区

1946→1967→1983→1988→2002年

Phenological Eyes Network (PEN)

We need ground data for validation of ecology remote sensing.



Systematic error due to cloud, aerosol, sensor angle, sun angle, etc., within a single satellite sensor.

Difference in overpass-time, band setting, etc. among multiple sensor.

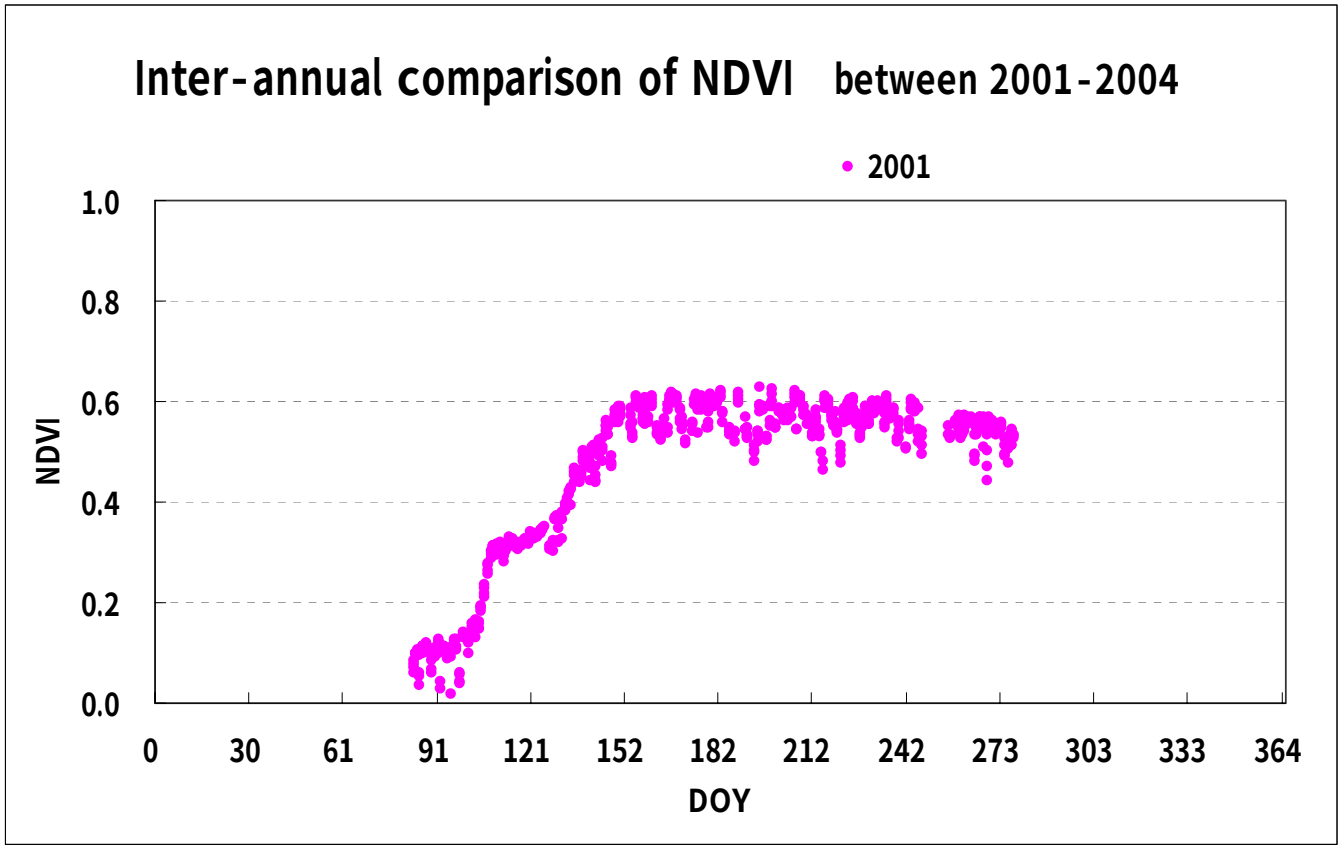
We need stable, long-term, multi-site ground datasets to mitigate these problems.

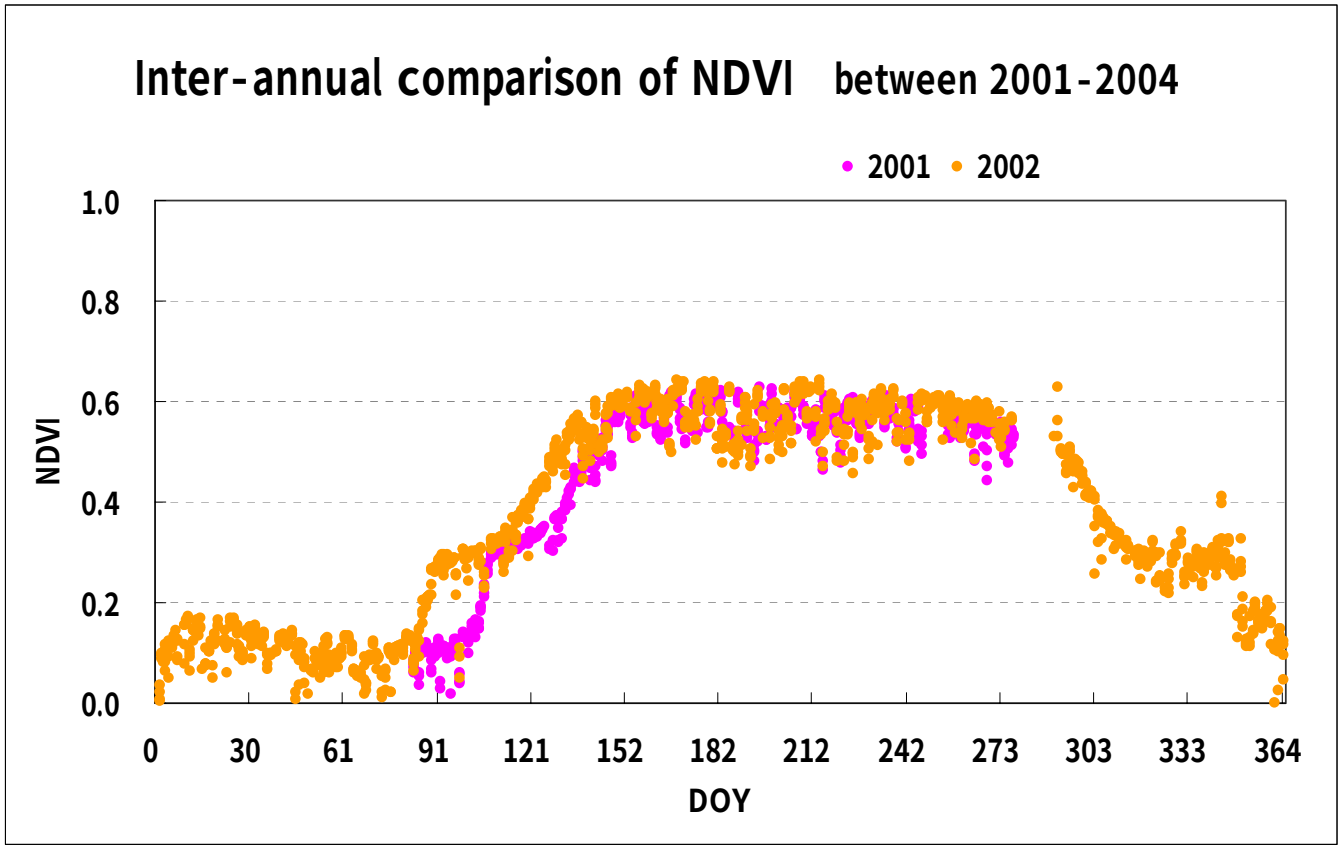
Because ecosystem is always changing!

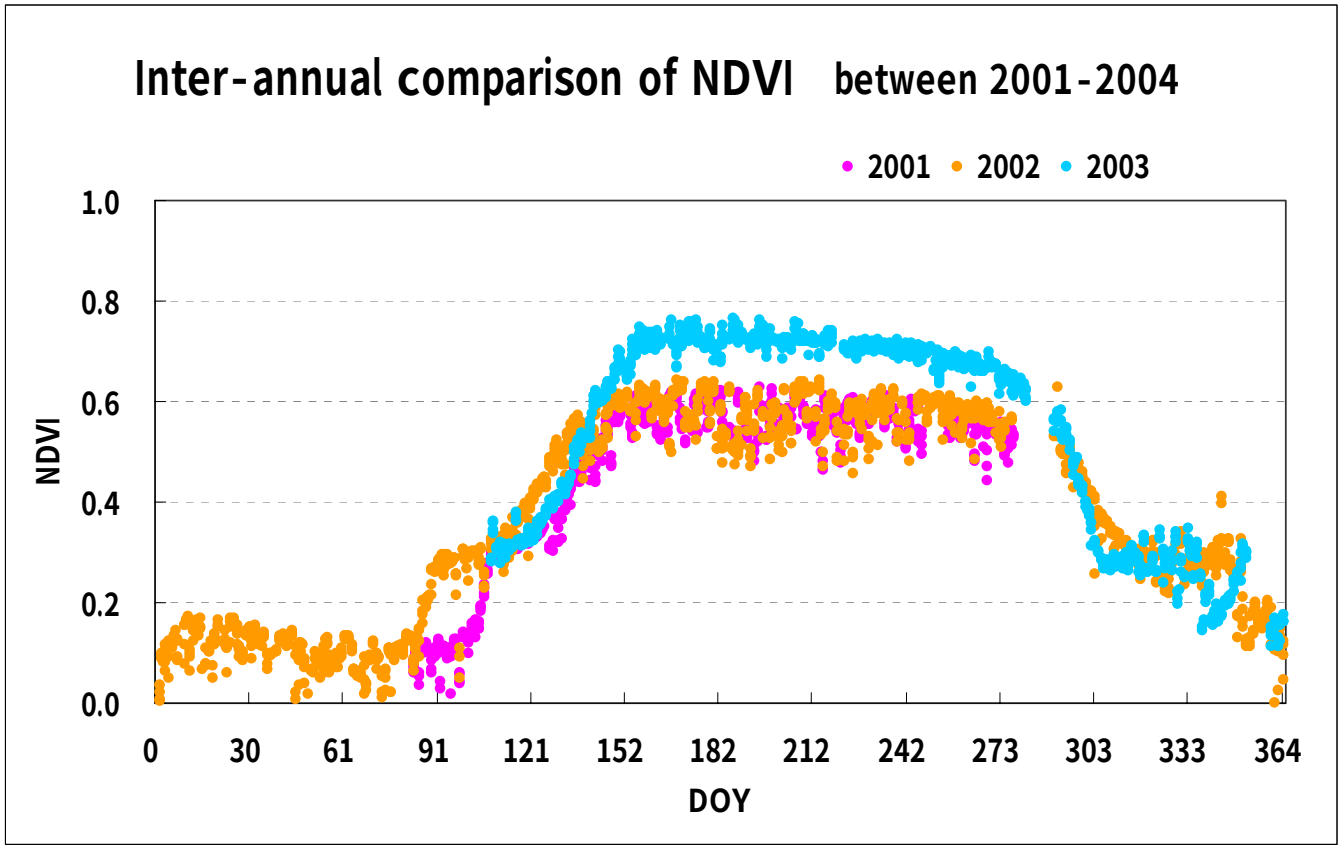
A network of the ground sites for data collection of these purposes:

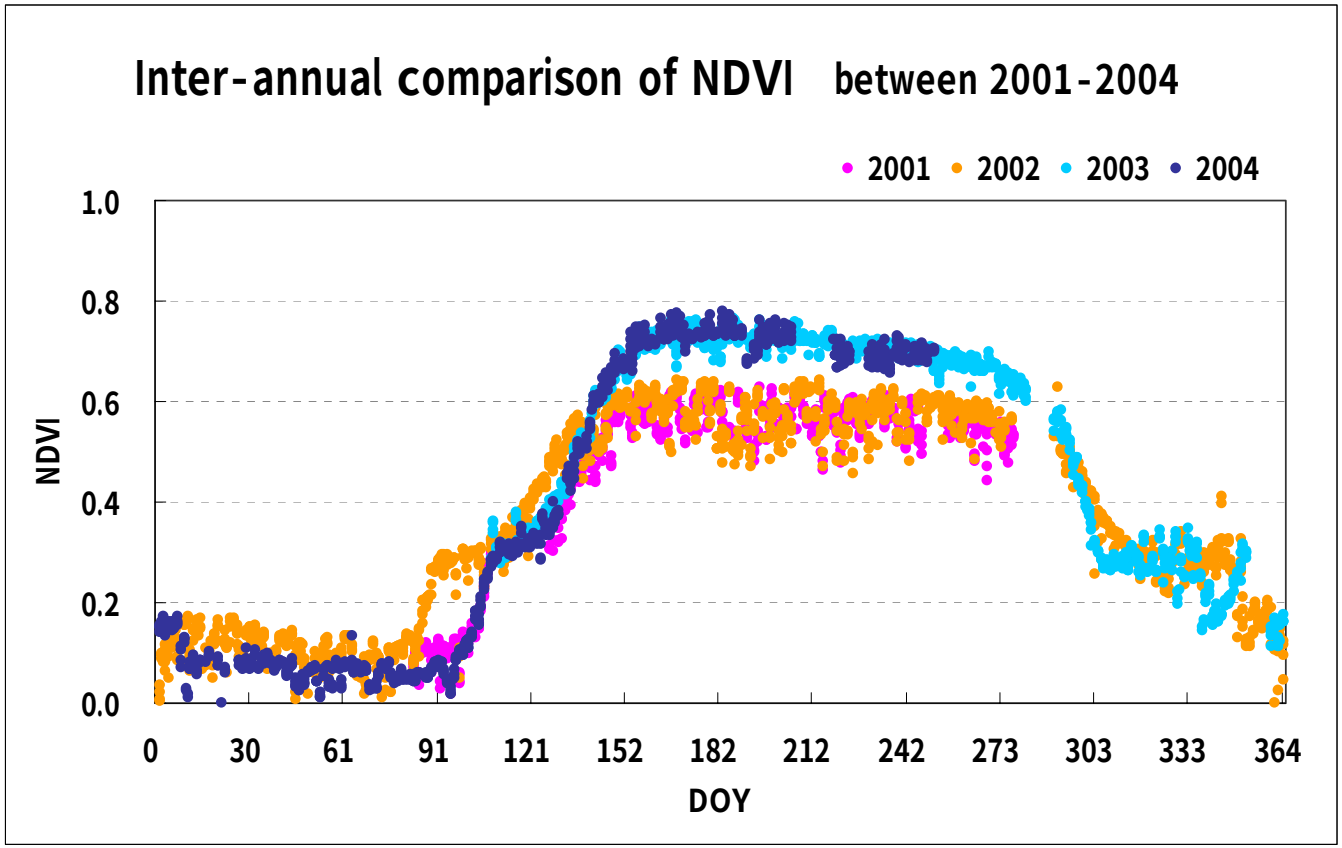
||

"***Phenological Eyes Network (PEN)***"


Inter-annual comparison of NDVI between 2001-2004
2001
1.0
0.8
0.6
0.4
0.2
0.0
NDVI
0
30
61
91
121
152
182
212
242
273
303
333
364
DOY


Inter-annual comparison of NDVI between 2001-2004
2001
2002
1.0
0.8
0.6
0.4
0.2
0.0
NDVI
0
30
61
91
121
152
182
212
242
273
303
333
364
DOY

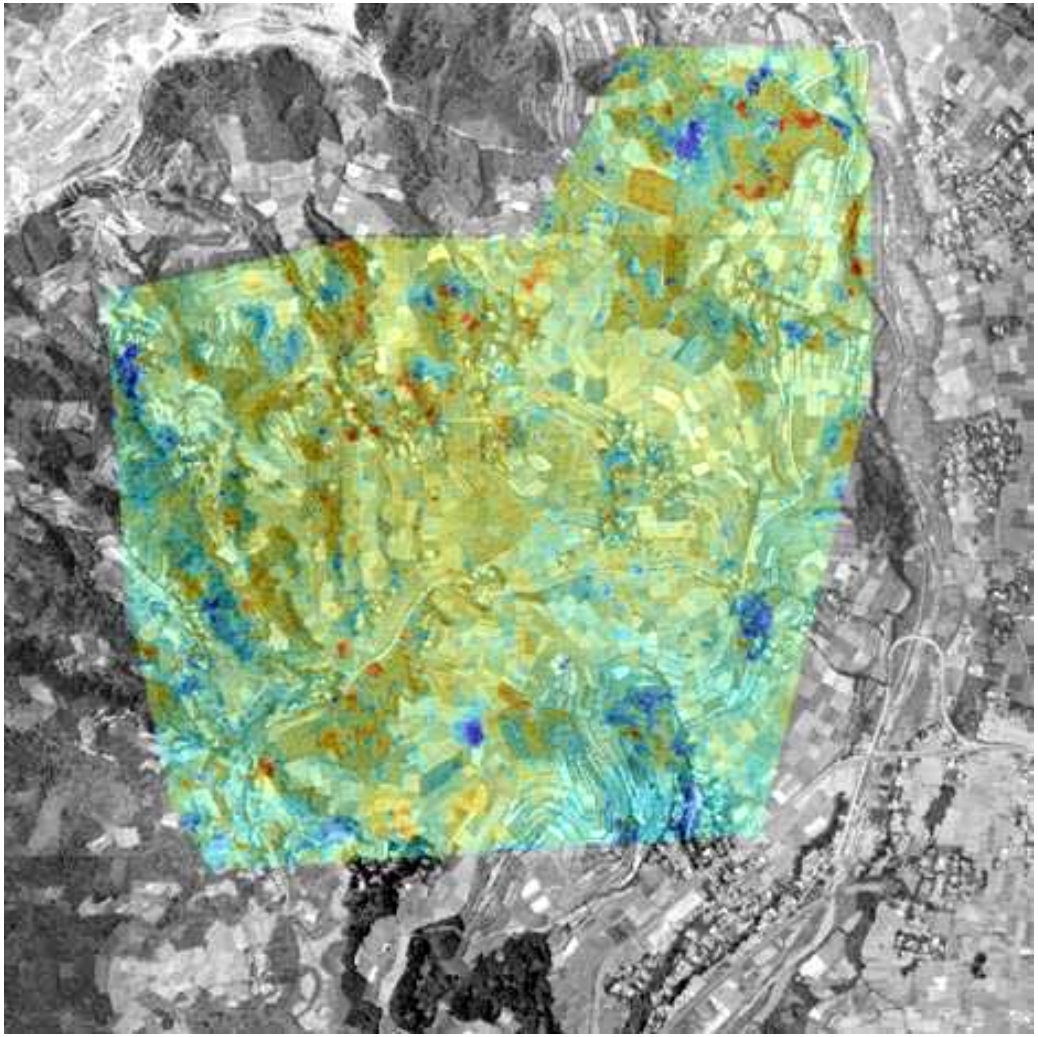

Inter-annual comparison of NDVI between 2001-2004
2001
2002
2003
NDVI
1.0
0.8
0.6
0.4
0.2
0.0
0
30
61
91
121
152
182
212
242
273
303
333
364
DOY

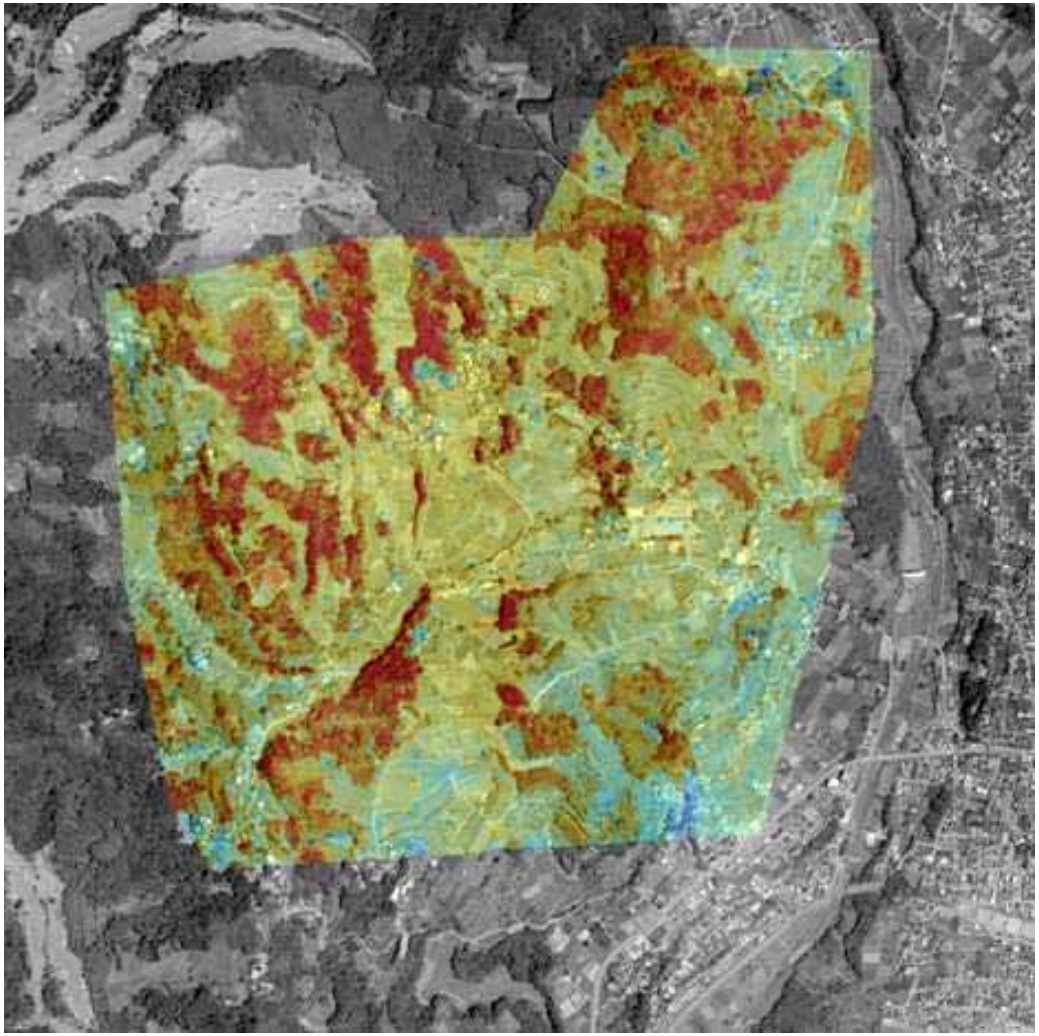

Inter-annual comparison of NDVI between 2001-2004
2001
2002
2003
2004
1.0
0.8
0.6
0.4
0.2
0.0
NDVI
0
30
61
91
121
152
182
212
242
273
303
333
364
DOY

Change of DSM for 50 years

1946→1967

1967→2002





The aerial photograph in 1946 was taken by the U.S. Forces.