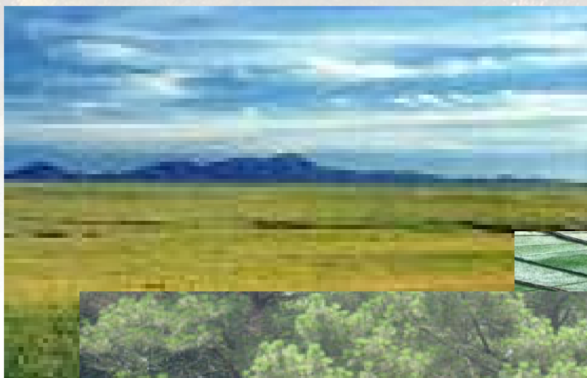
ESA - MOST Dragon 2 Programme

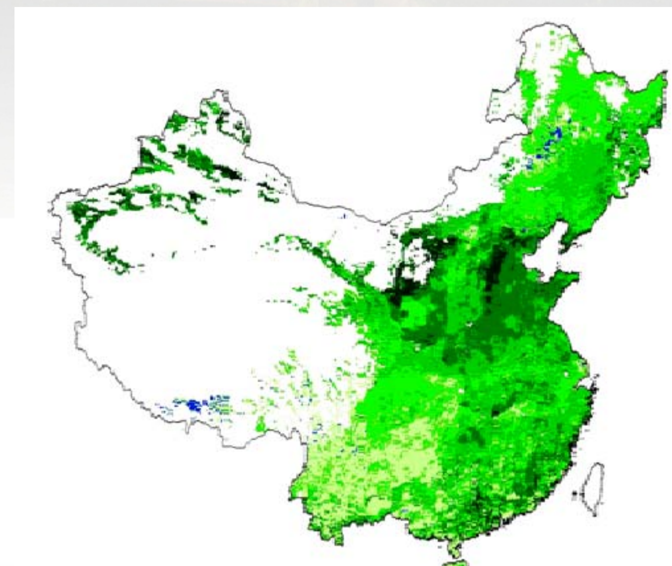
2011 DRAGON 2 SYMPOSIUM

中国科技部-欧洲空间局合作 “龙计划”二期

“龙计划”二期2011年学术研讨会

The role of croplands and grasslands in the carbon budget of China





20 - 24 June 2011 | Prague | Czech Republic

捷克 布拉格 2011年6月20-24日

Project team

Huang Yao , Zhang Wen, Sun Wenjuan

Laboratory of Vegetation and Environmental Change CAS, Beijing, China

Thuy Le Toan , Nicolas Delbart*, Ludovic Villard

CESBIO, Toulouse, France

Tan Bingxiang (CAF, Beijing, China)

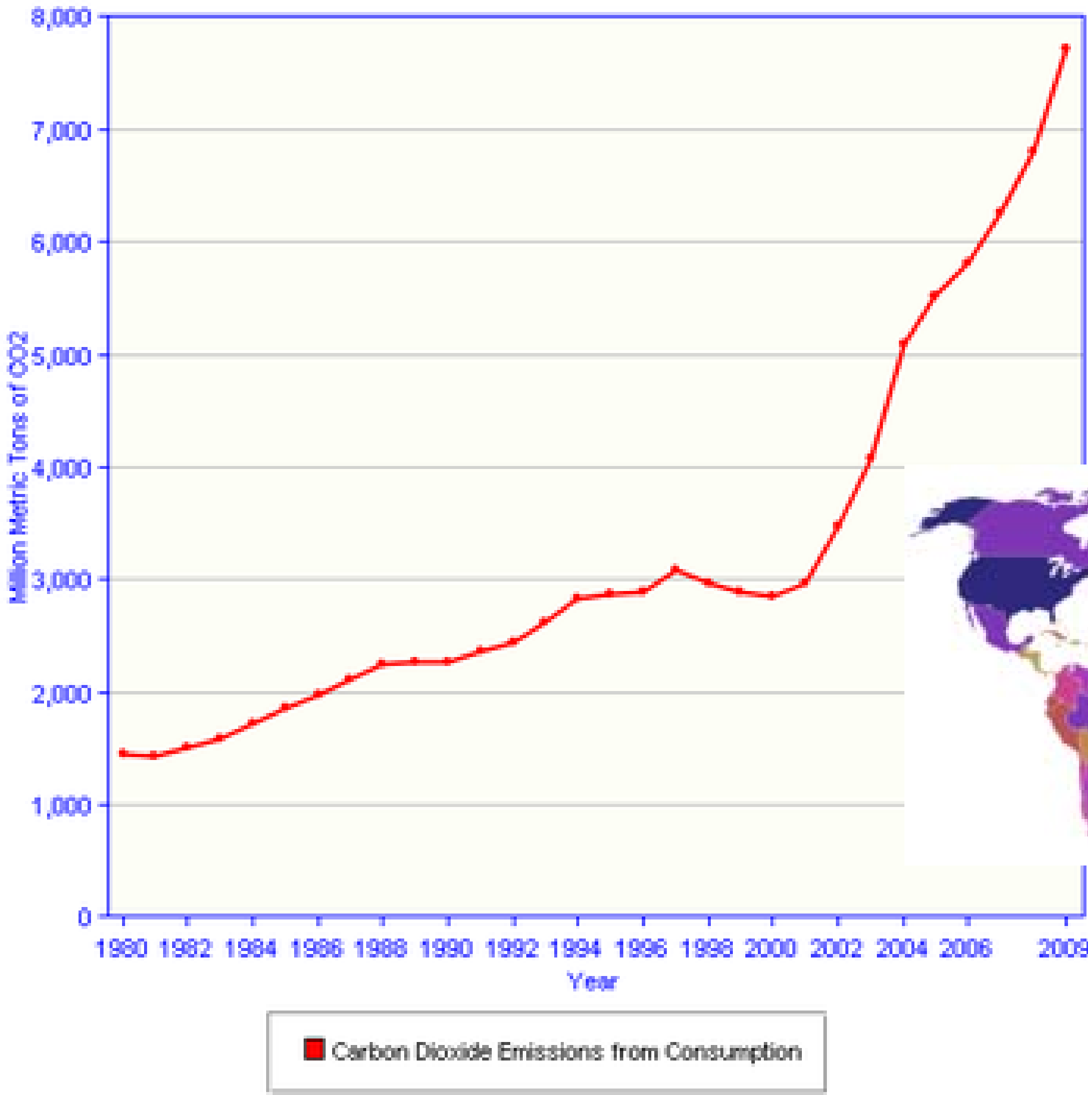
Wang Xiaoqin (Fuzhou University, Fuzhou, China)

He Guojin (Center for EO and Digital Earth, CAS, Beijing, China)

Alberte Bondeau (Potsdam Institute for Climate Research, Germany)

Michael Buchwitz (University of Bremen, Bremen, Germany)

Background



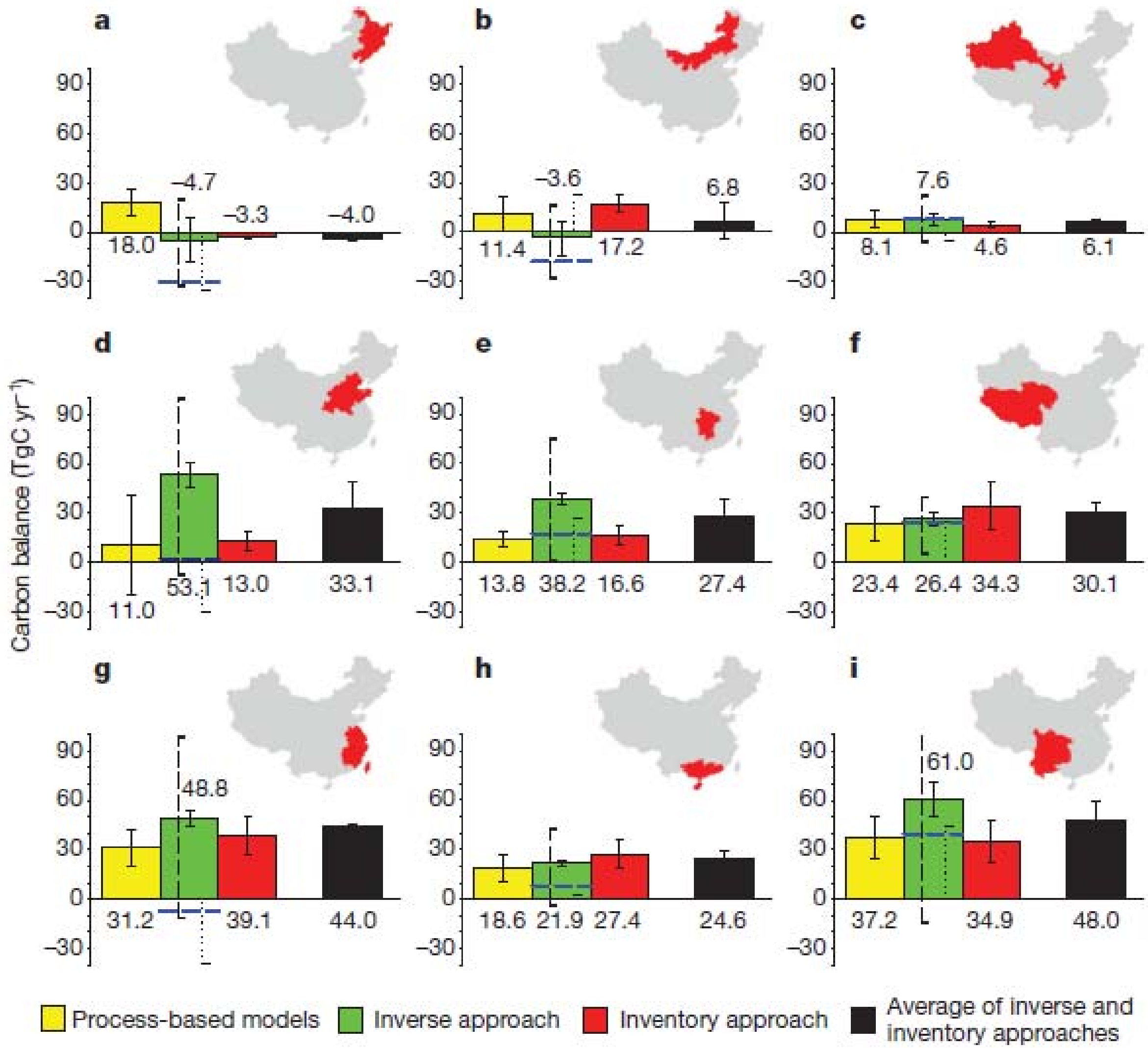
China CO2 emission per Mega tons from 1980 to 2009.

22.30% of global emissions

The carbon balance of terrestrial ecosystems of China

Piao et al., 2009, Nature

Net Carbon Sink by terrestrial ecosystems in China (1980s - 1990s) :
0.19-0.26 PgC / yr
(28-37% of fossil carbon emissions)



- ecosystem models
- atmospheric inversions
- biomass and soil carbon inventories extrapolated by satellite

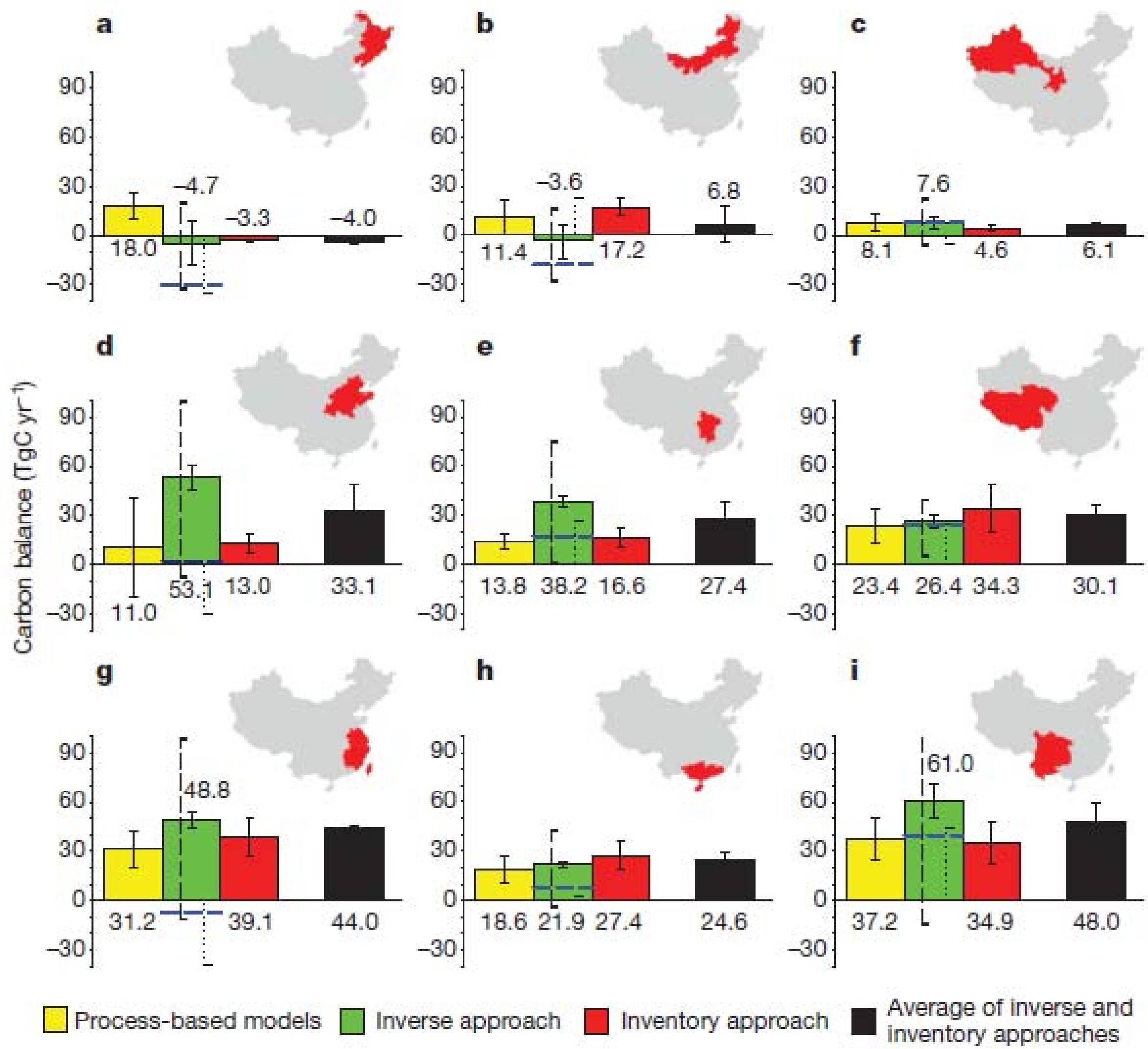
The carbon balance of terrestrial ecosystems of China

Piao et al., 2009

Northeast China: a net source of CO_2 to the atmosphere (overharvesting and degradation of forests).

Southern China: more than 65 per cent of the carbon sink: regional climate change, large-scale plantation programmes active since the 1980s, shrub recovery.

However,
cropland and grassland excluded in model and inventory calculations



Background

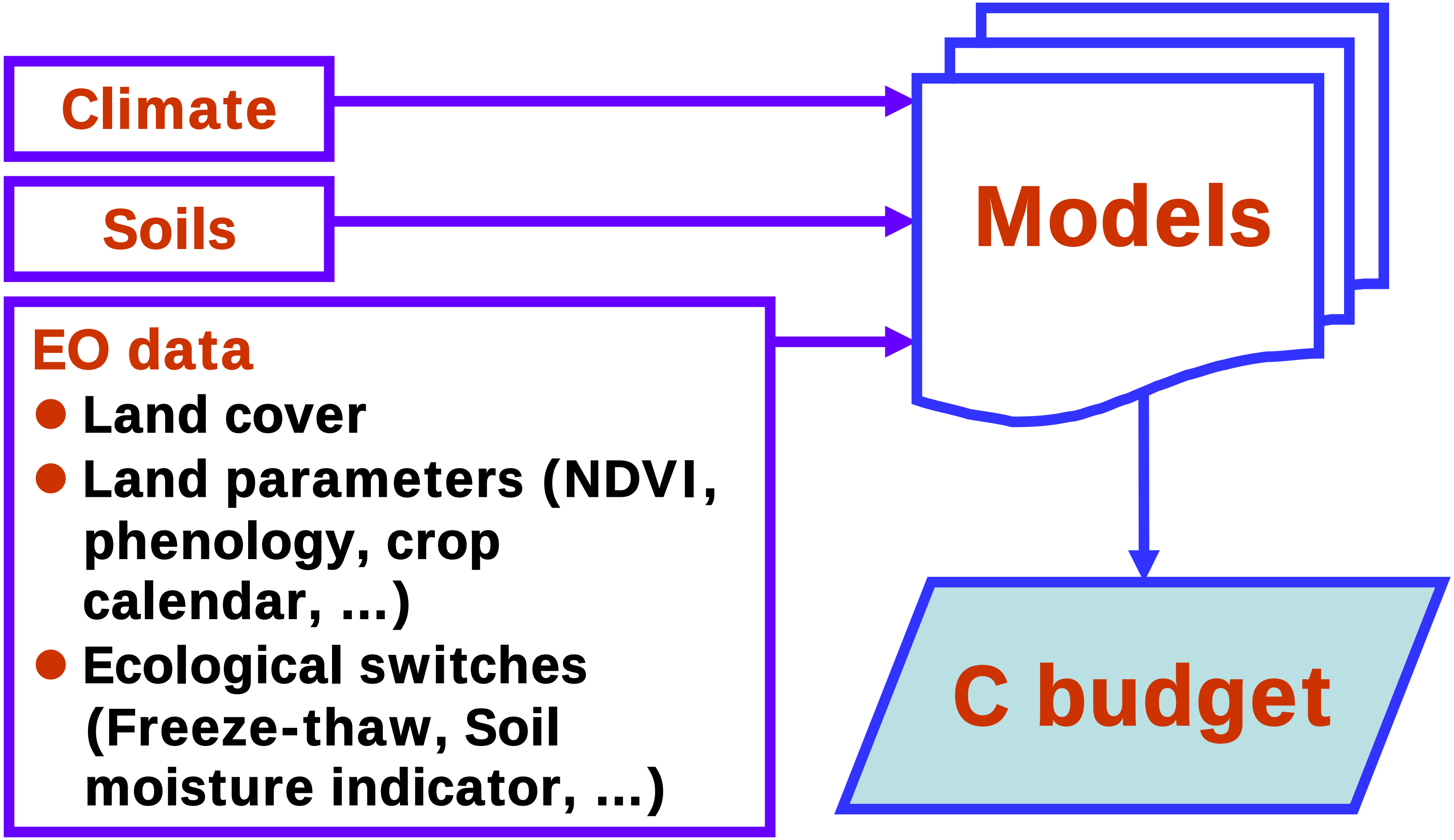
- Cropland and grassland are not included in Piao and al., 2009 study

- However, it is recognized that management of cropland and grassland can play an important role in mitigation climate change, by increasing carbon storage in soils and reducing emission (e.g.methane from rice cultivation).

Project Objectives

To contribute to better understanding the role of cropland and grassland in the C budget of China, by developing approaches that combine **models**, **in situ** and **EO data**, **for estimating regional and national Carbon budgets.**

Model estimates of C budget



Expected from EO data

Input for carbon models (CO2 and CH4)

- Land cover
- Photosynthetic indicators
- Phenology
- Soil moisture

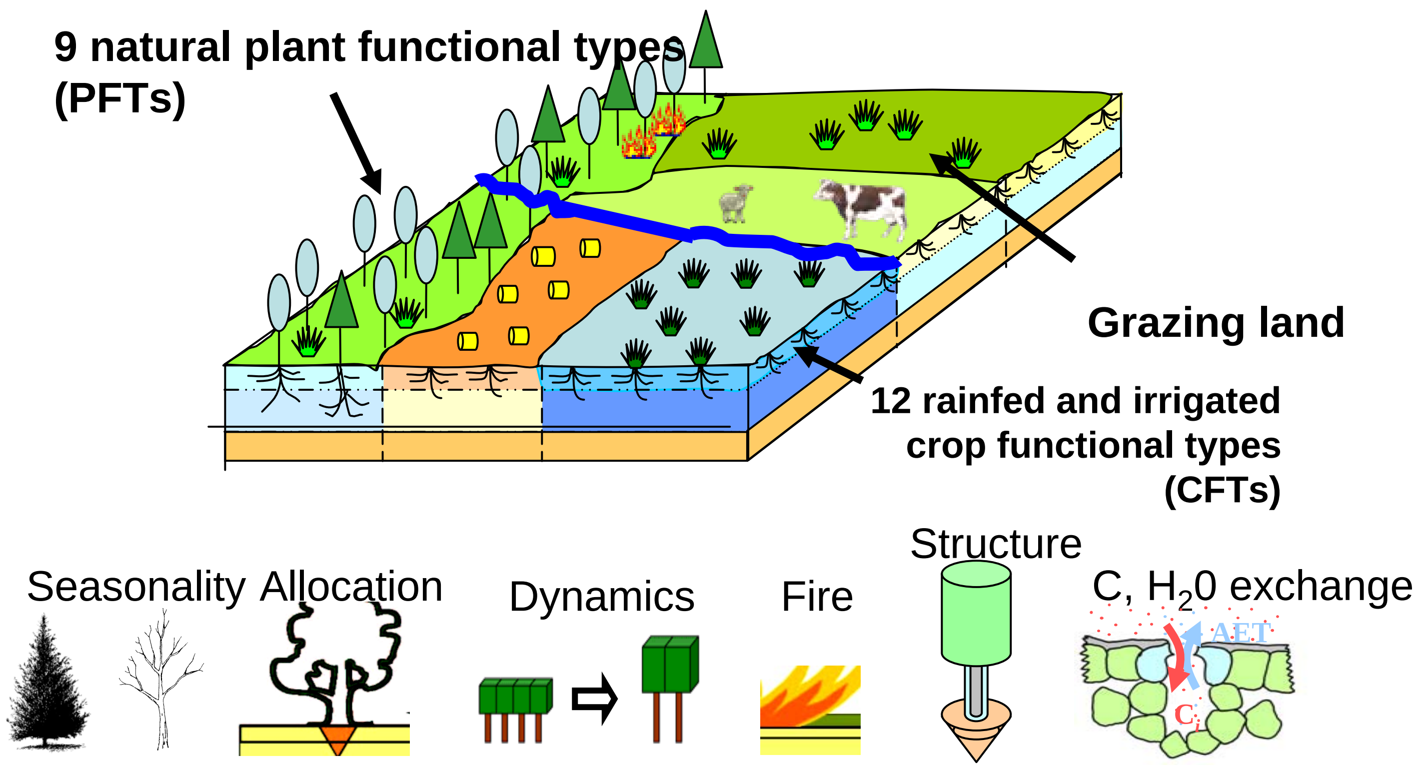
Input for methane models

- Rice mapping
- Irrigation state, rice varieties
- Wetland mapping

Comparison to model outputs

- Methane (column-averaged)
- CO_2 (column-averaged)

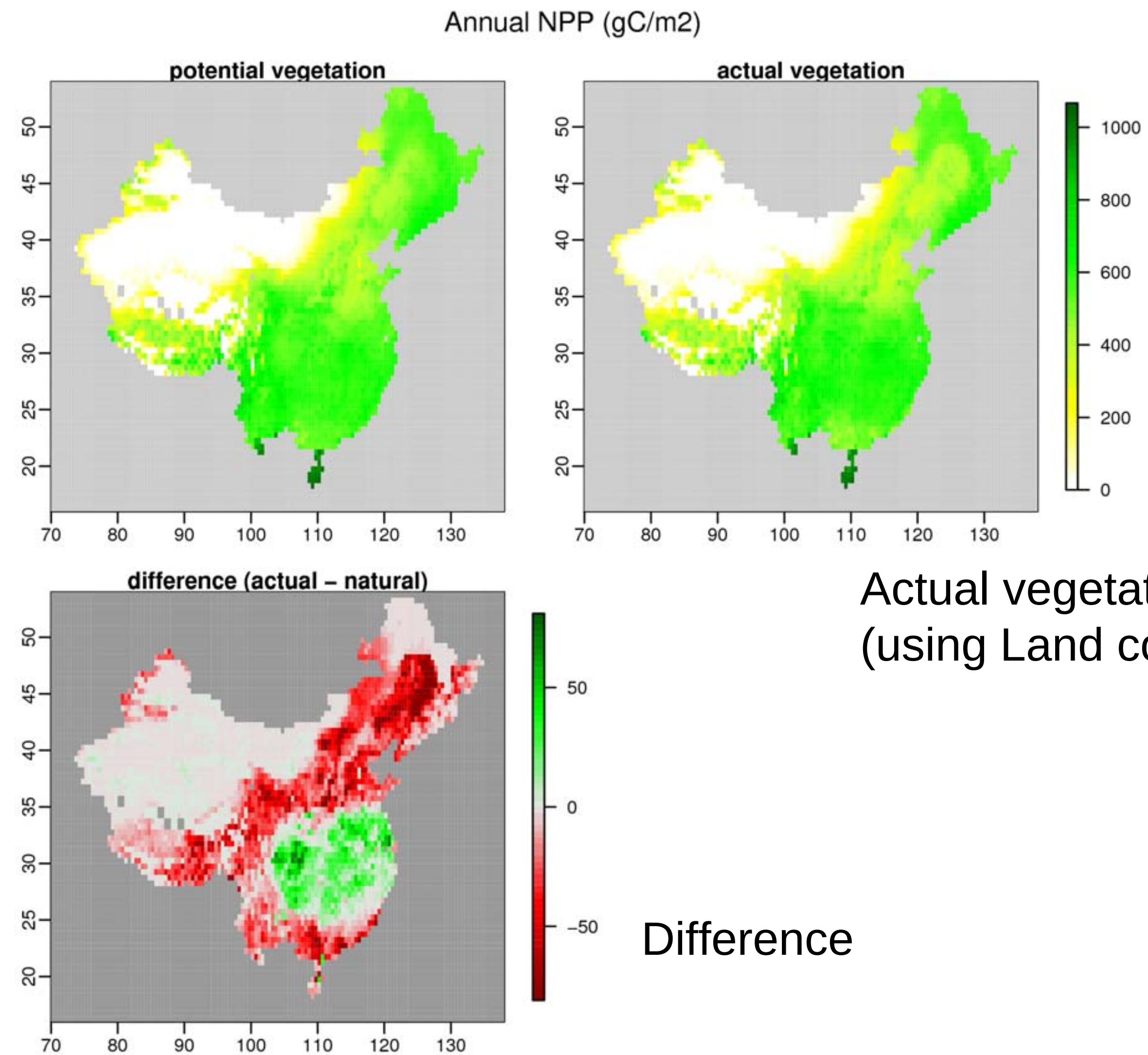
LPJmL dynamic vegetation and water balance model



Sitch et al 2003; Gerten et al. 2004; **Bondeau et al. 2007**

LPJmL Carbon Fluxes

Potential vegetation



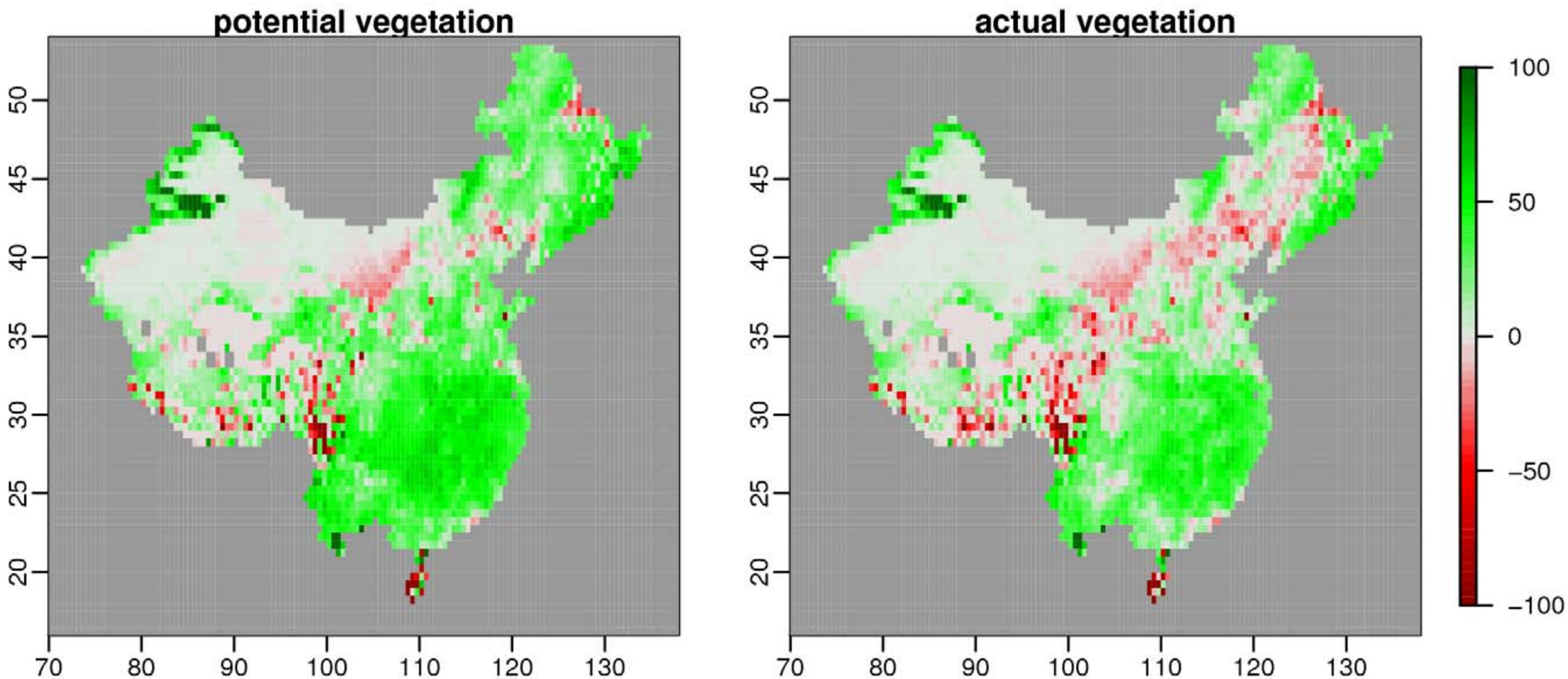
Actual vegetation
(using Land cover map)

Difference

LPJmL Carbon Fluxes

C balance for China:

Annual NBP (gC/m2)



0.18 PgC/yr

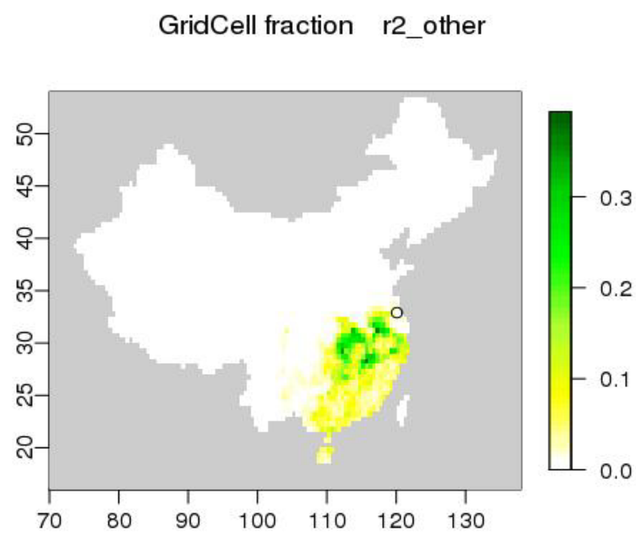
0.10 PgC/yr

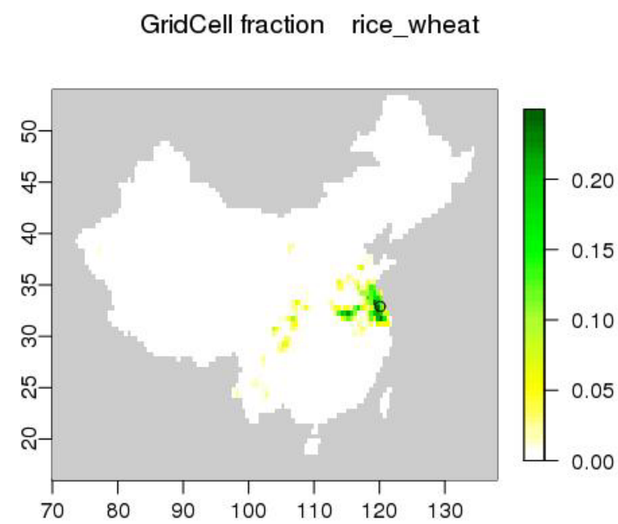
(Piao et al., 2009: Ecosystem models (no crop): 0.17 PgC/yr)

Need of more/better model constraints

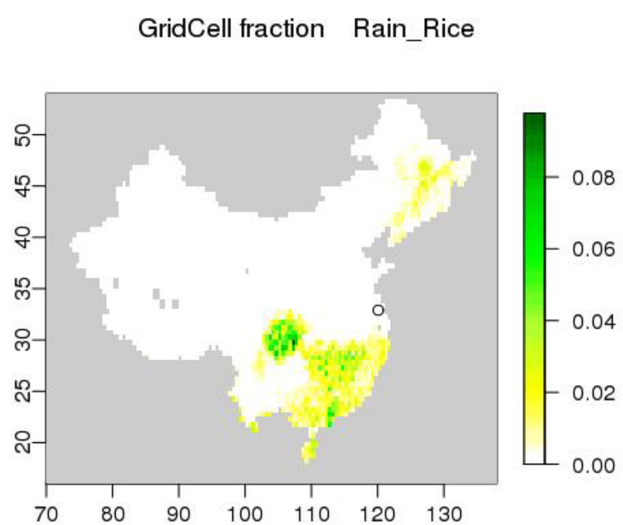
Different land use data sets used in models:

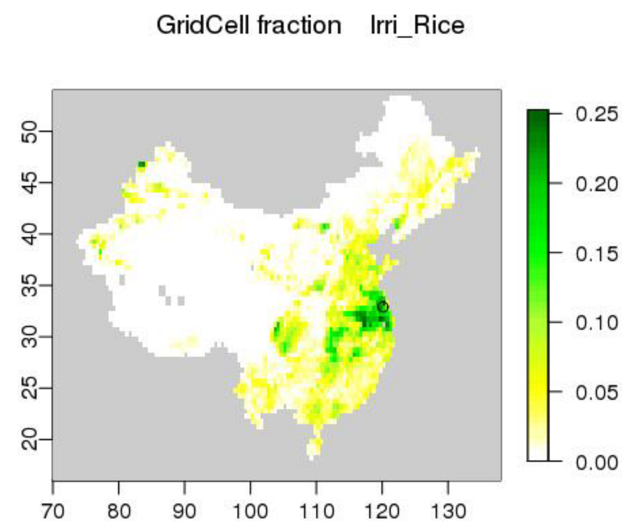
1) Fraction cover of each rotation (Frolking et al. 2002)





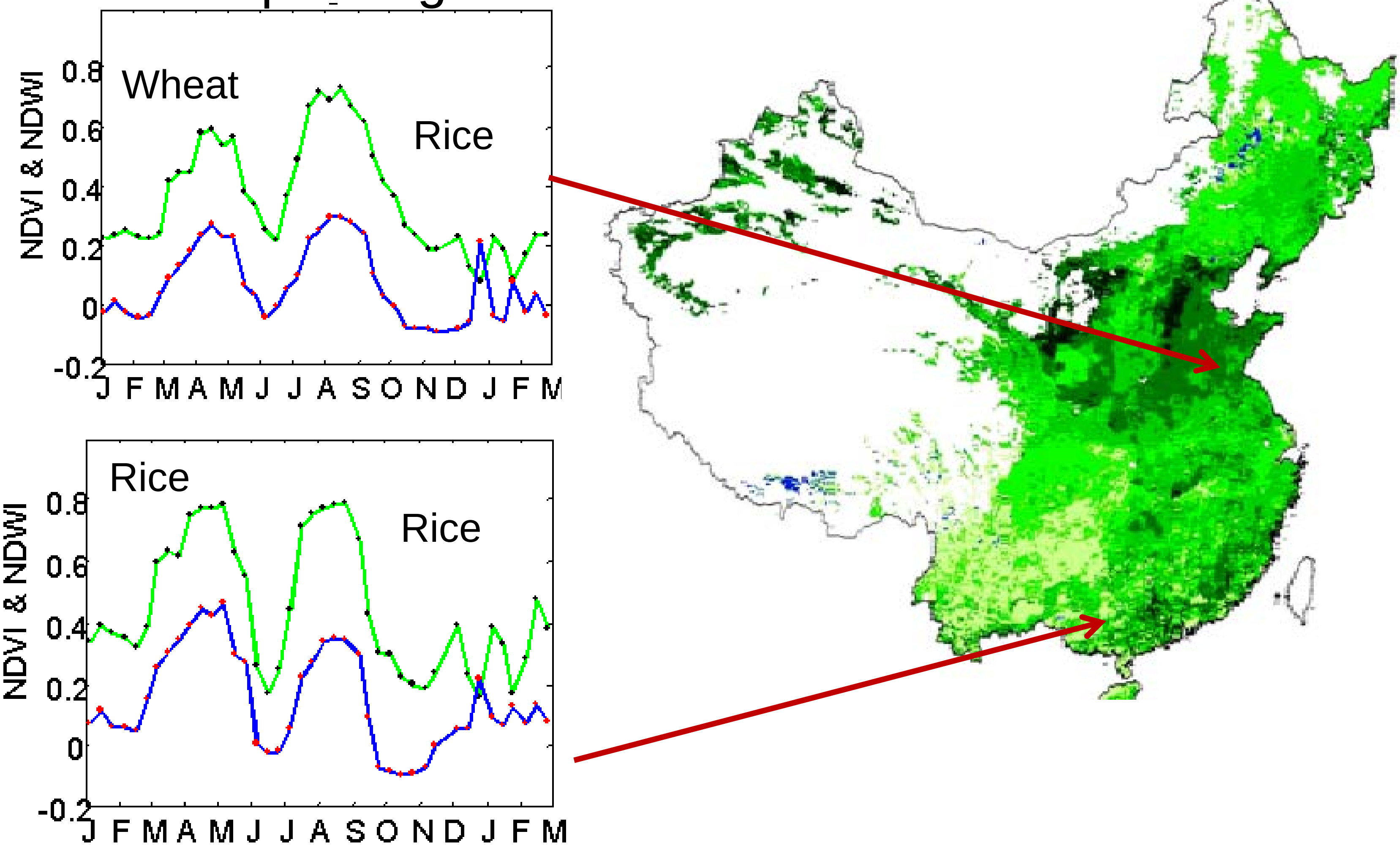
2) Rainfed & irrigated fraction cover of the different crops (Fader et al.) derived from: Siebert et al. 2007, Monfreda et al. 2008, Ramankutty et al., 2008,.



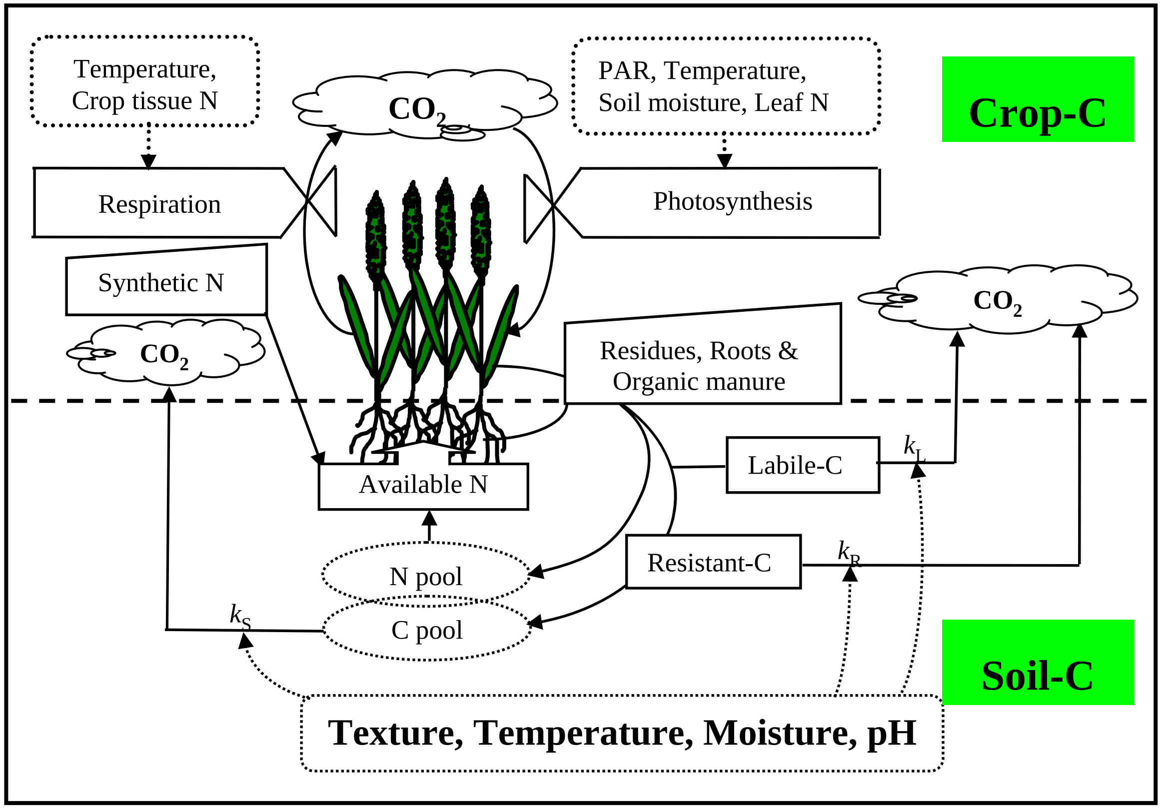


Crop rotation from remote sensing

From Spot Vegetation



Agro-C model for C budget of croplands



$$dW_i = GPP_i - RA_i$$
$$= GPP_i - (RG_i + RM_i)$$

$$W_{root} = \sum_{i=1}^{n} PR_i \times (GPP_i - RA_i)$$

$$W_{residue} = (W_i - W_{root}) \times (1 - HI)$$

$$dC_j^{(i)} = -k_j \cdot F_{Ts}^{(i)} \cdot F_W^{(i)} \cdot F_{Clay} \cdot F_{pH} \cdot C_j^{(i)}$$
$$(j = l,\ r,\ s)$$

$$RH_i = \sum_j dC_j^{(i)}$$

$$NEE_i = (RA_i + RH_i) - GPP_i$$

Conceptual explanation of Agro-C

(Huang Y, Yu YQ, Zhang W *et al*., 2009, *Agr. Forest Meteorol.*)

Soil organic carbon

Modeling interannual variability of global soil respiration from climate and soil properties

$$Rs = R_0 \cdot e^{Q \cdot T} \cdot \frac{P}{P + K}$$

(Raich *et al*. 2002)

Soil respiration (Rs)

Mean air temperature (T)

$$Rs = R_0 \cdot e^{Q \cdot T} \cdot \frac{P}{P + K} \cdot \frac{SOC}{SOC + M}$$

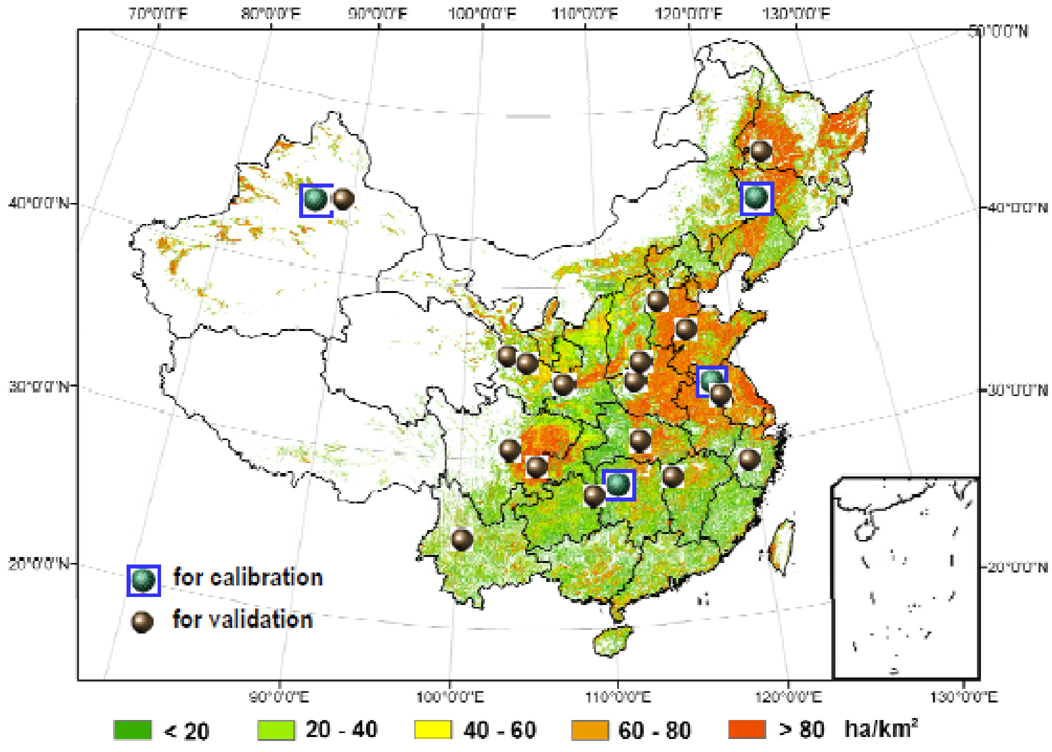
(This study)

Soil organic C (SOC)

Reference respiration (R_0)

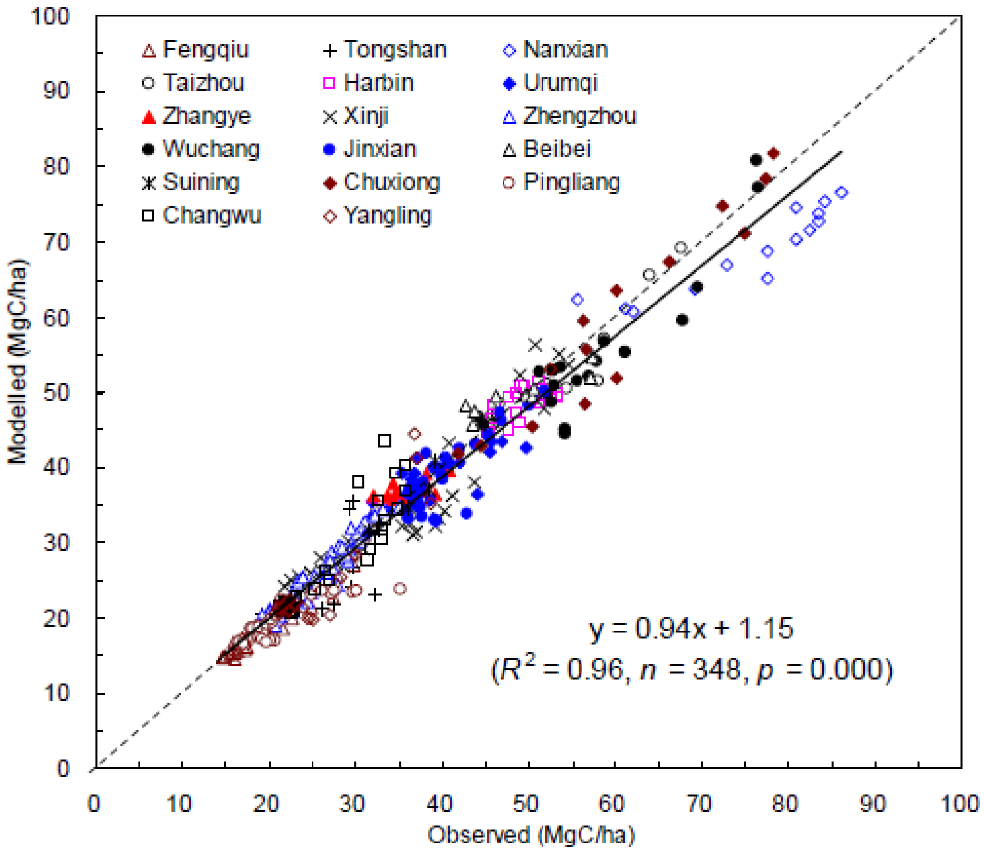
Annual precipitation (P)

Agro-C: model calibration & validation



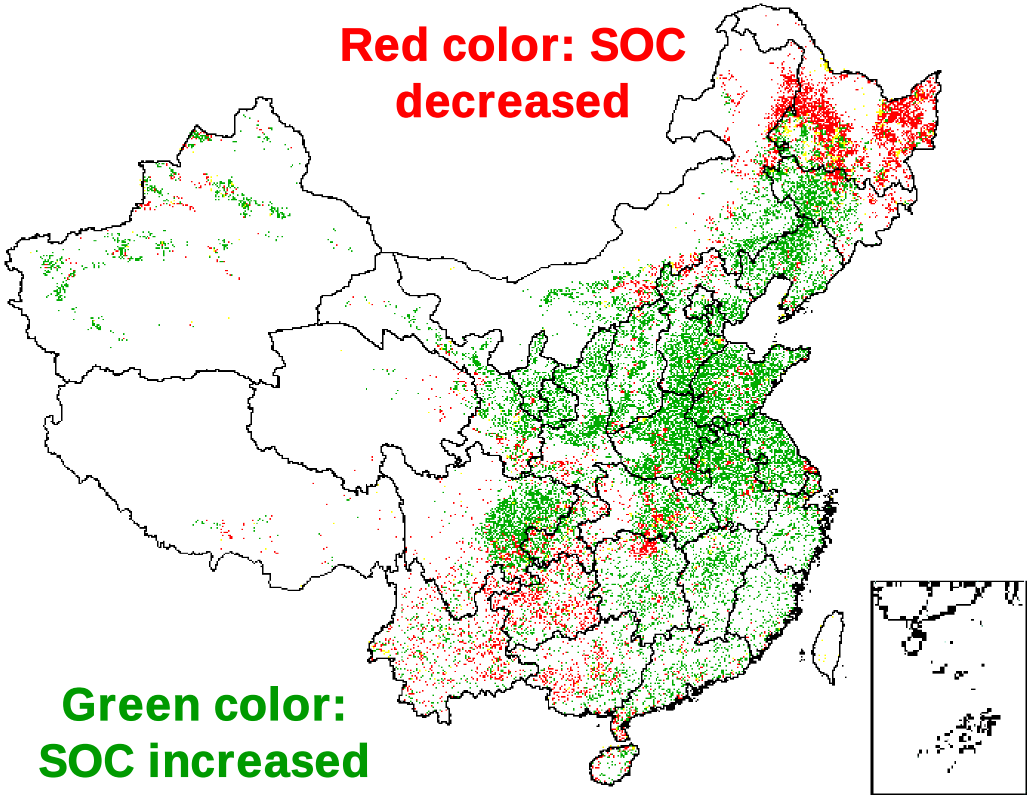
Long-term experimental sites for calibrating and validating Agro-C model

Agro-C: Model validation



Modelled vs. observed SOC

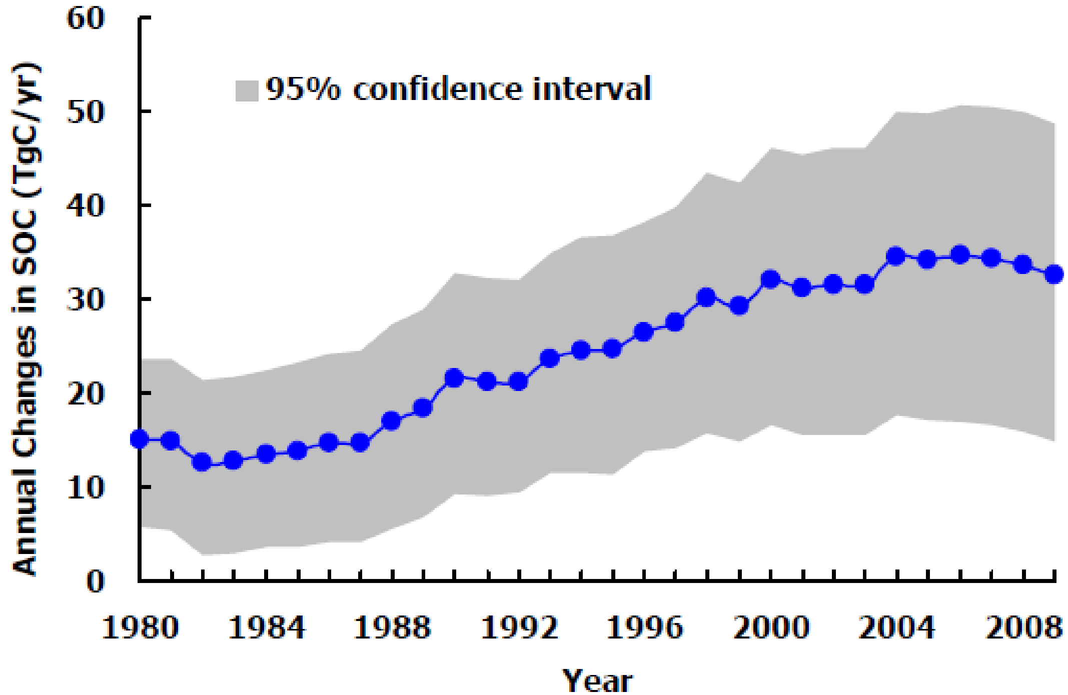
Model AGRO-C: change in SOC



Simulated changes in soil organic carbon between 1980 and 2000 by using Agro-C

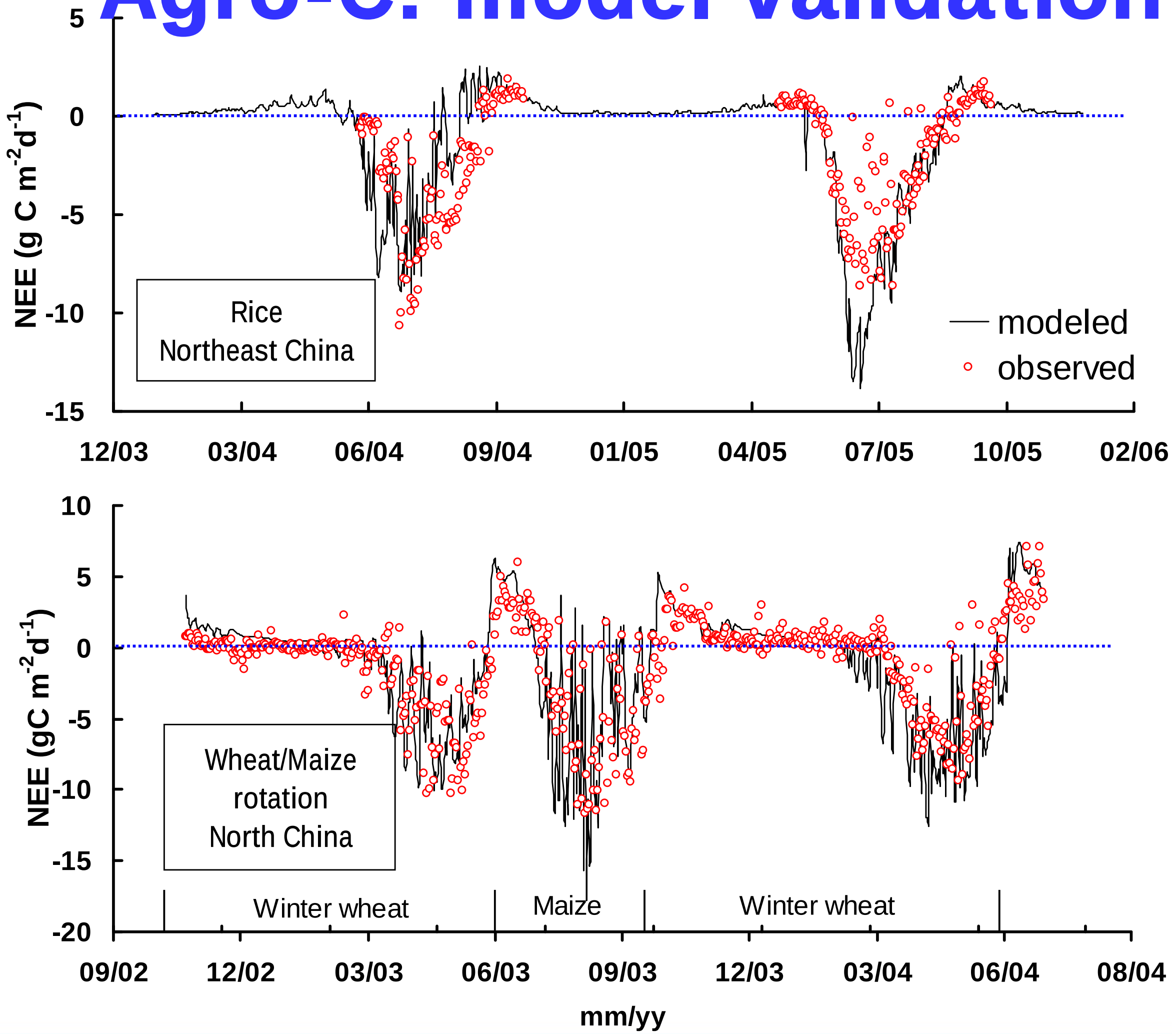
- **SOC increased in 71%–76%, decreased in 22%–25% and stabilized in 3%–5% of the national croplands.**
- **An overall increase was estimated to be 23±4 TgC/yr.**

China's croplands sequestered 730 (329 to 1095) Tg C from 1980 to 2009

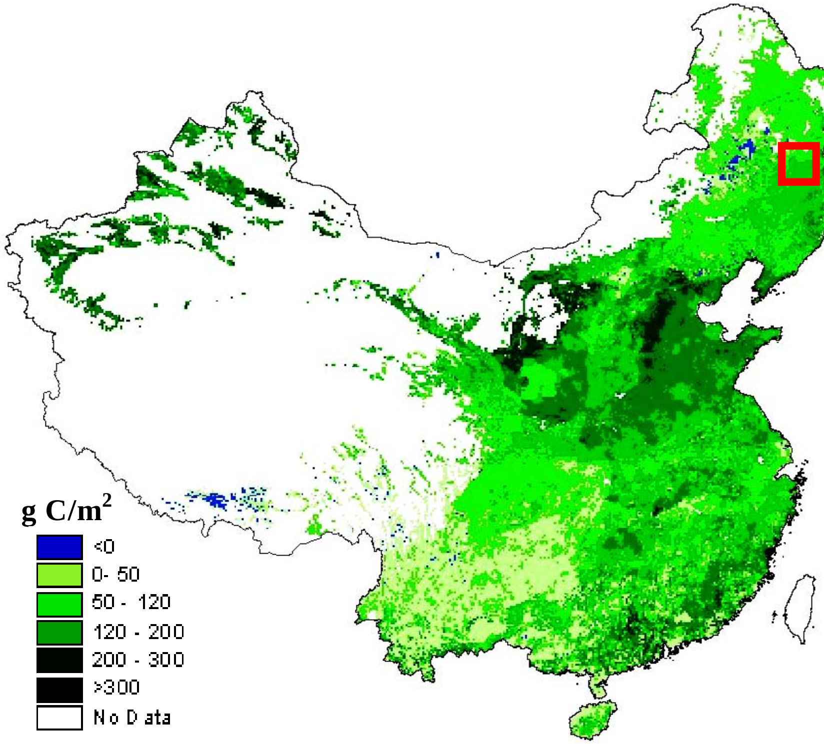


Simulated changes in SOC of China's cropland by using Agro-C

Agro-C: model validation



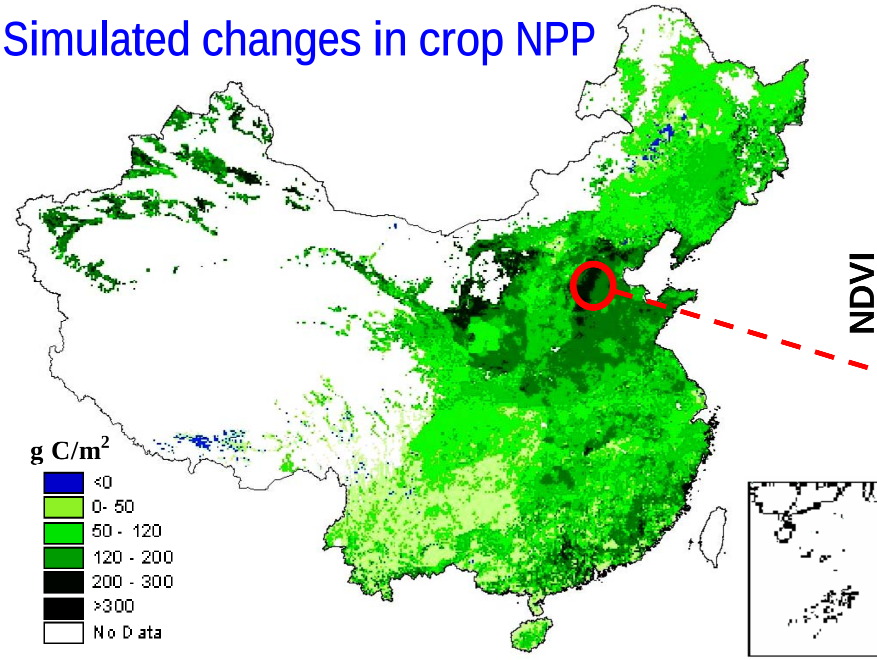
Simulated changes in crop NPP between 1980 and 2000 by using Agro-C

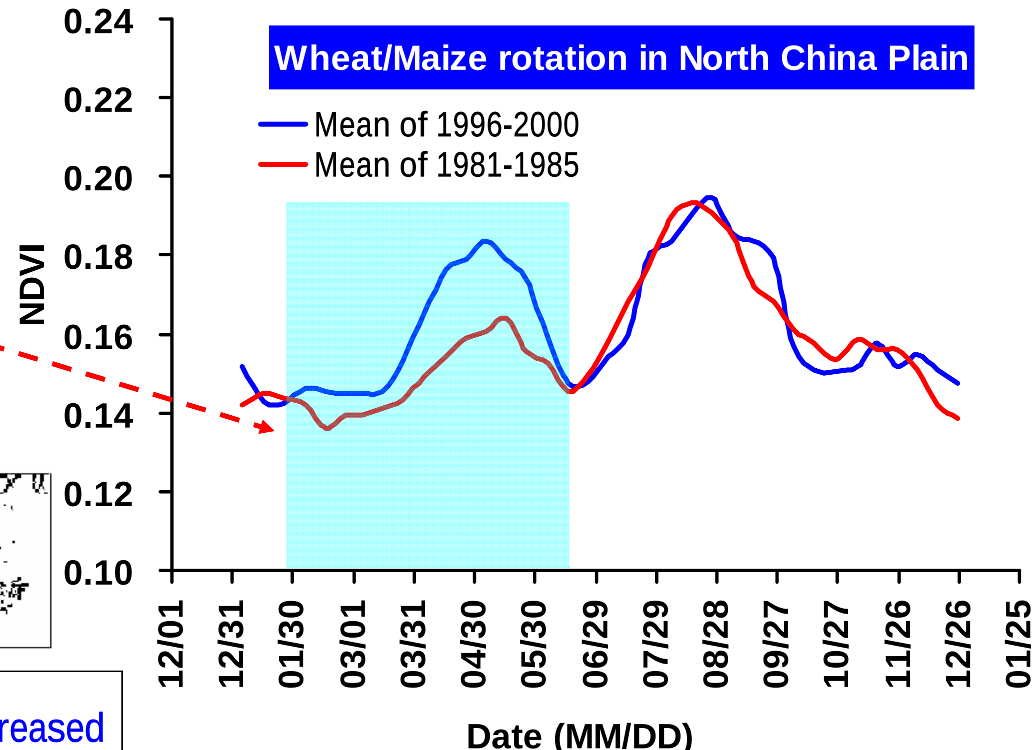


Heilongjiang Province	Mean of 1981-1985	Mean of 1996-2000	Increased
Accumulated >10° T (℃·d)	2704	2847	143
Rice area (Mha)	0.28	1.46	1.18
Rice NPP (tC/ha)	3.3	5.5	2.2

Global warming has resulted in a significant northward expansion of rice planting in northeast China.

Simulated changes in crop NPP

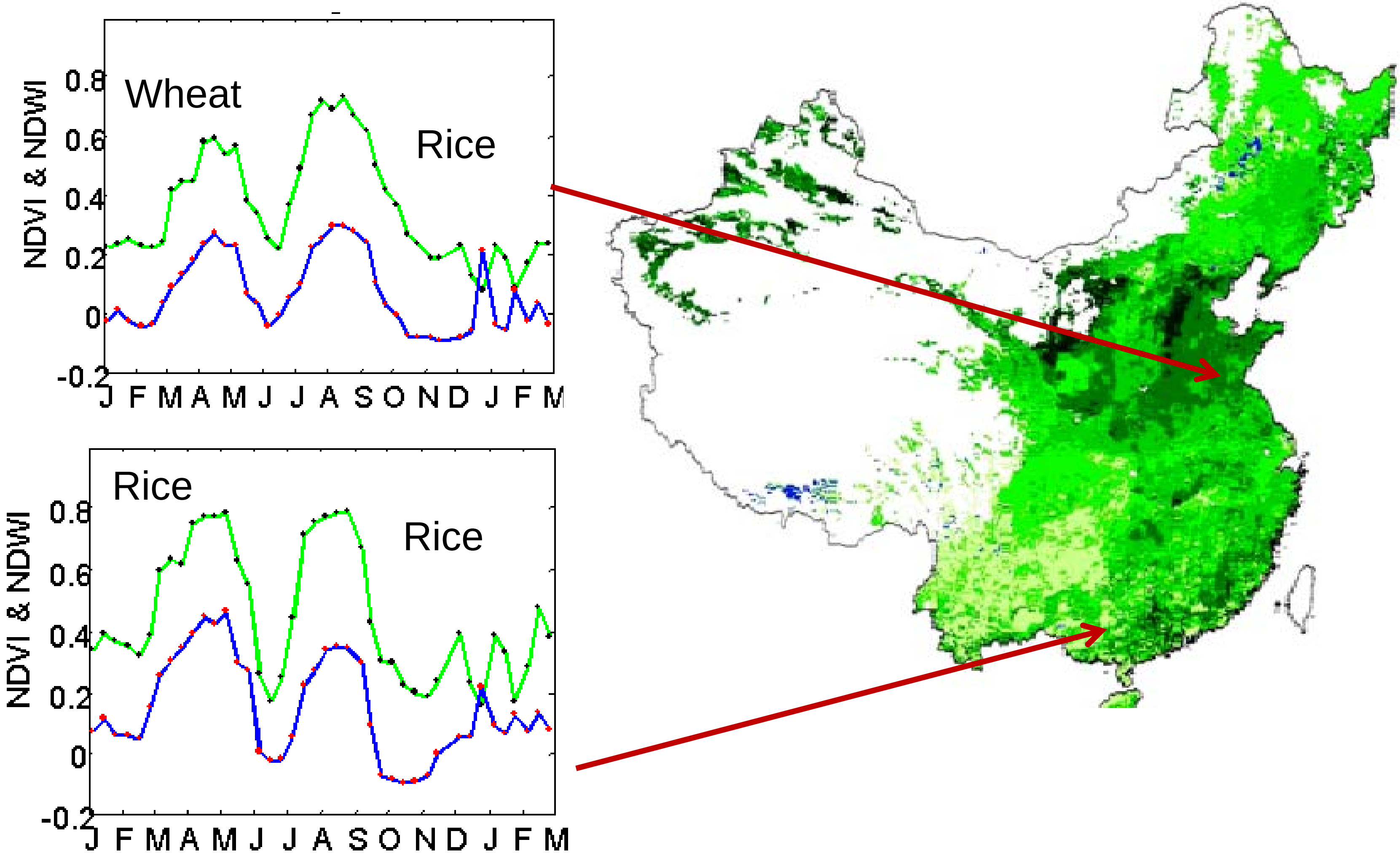




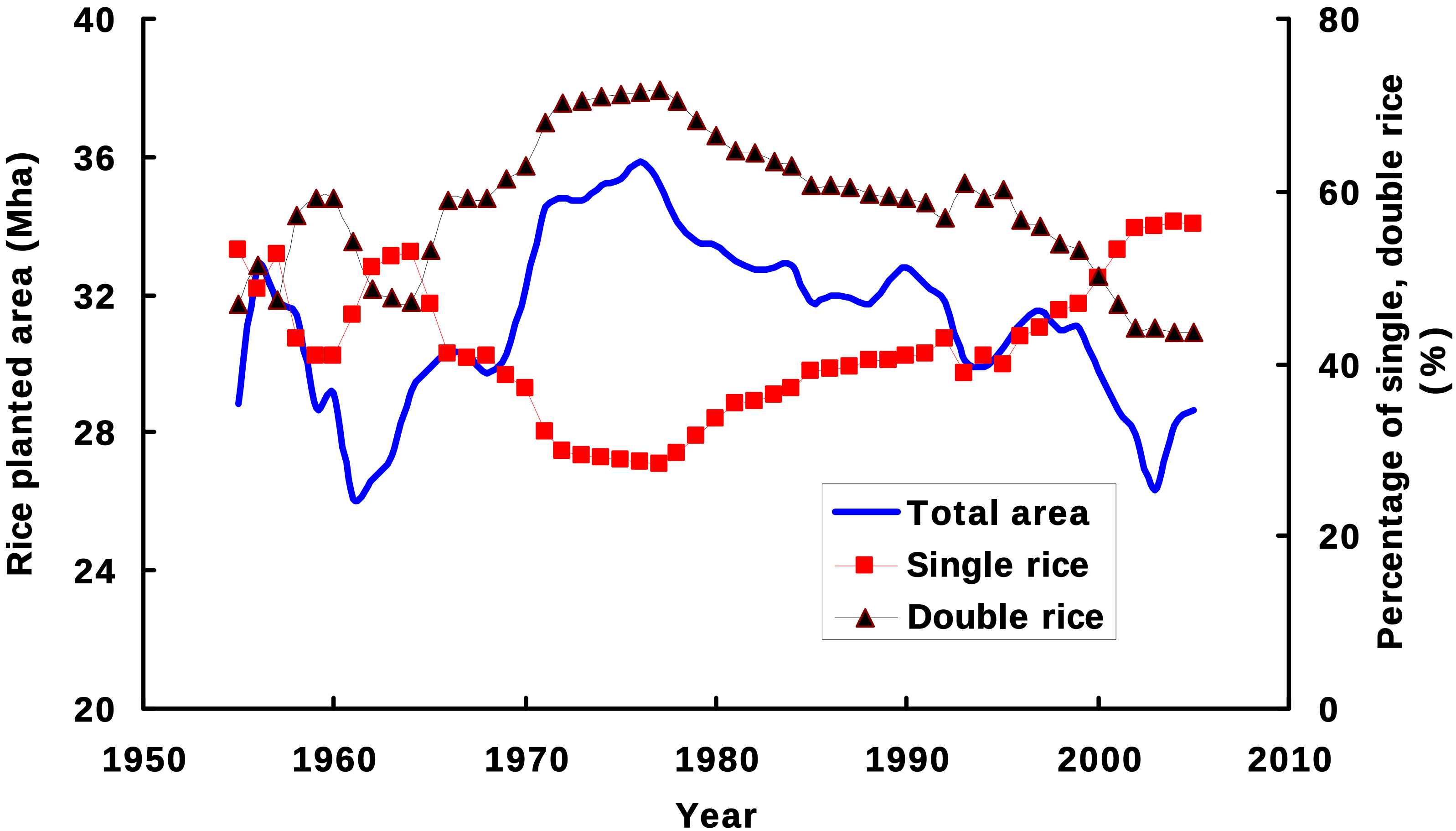
Hebei Province	Mean of 1981-1985	Mean of 1996-2000	Increased
Accumulated >10° T (℃·d)	4561	4742	181
N for wheat (kg/ha)	105	198	93
Wheat NPP (tC/ha)	3.35	4.66	1.31

Increase in N use promoted NPP production

Model AGRO-C: Progress and primary results

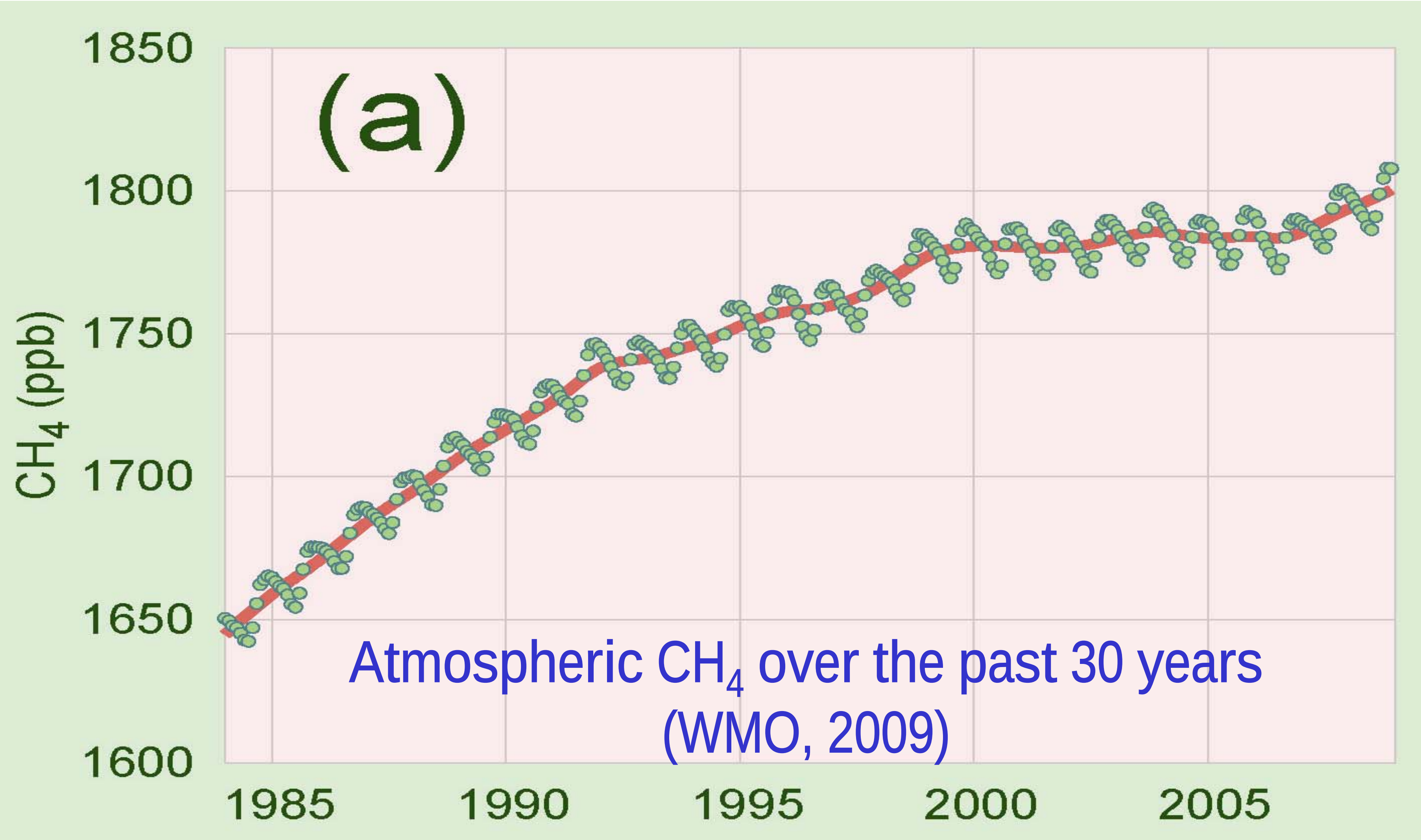


Trends in rice cropping

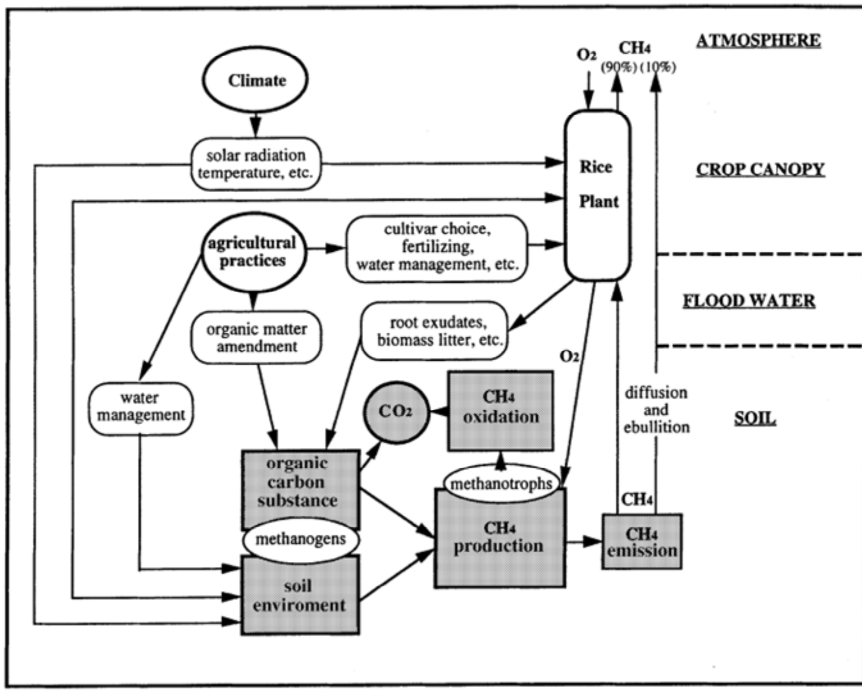


Changes in rice planted area over 1955-2005

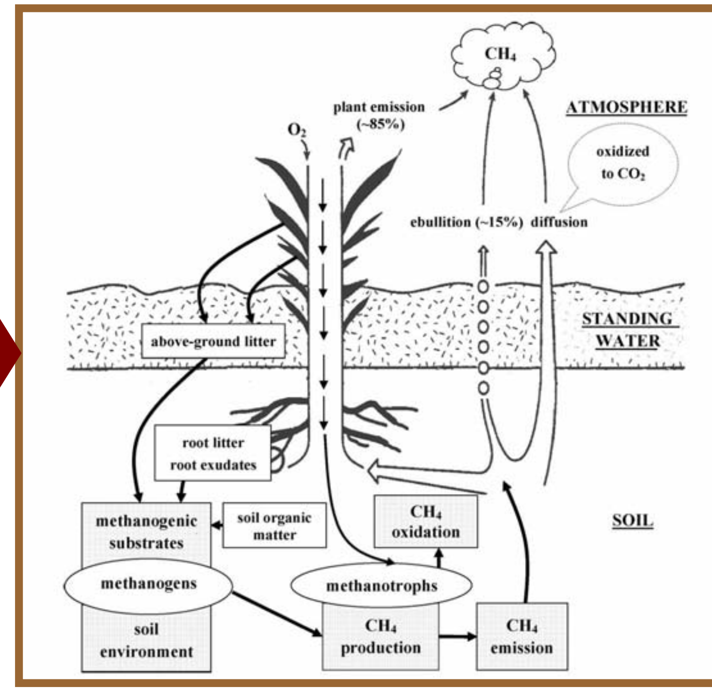
Trends in atmospheric CH_4



Modelling CH_4 emissions from rice paddies (CH4MOD) and from natural wetlands (CH4MODwetland)

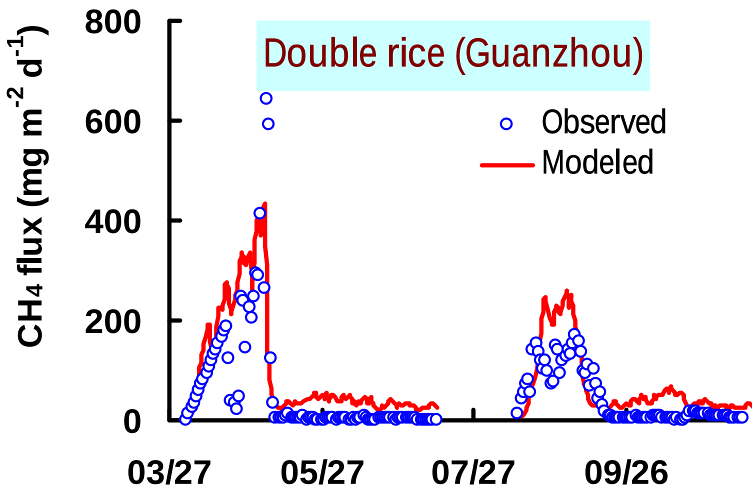


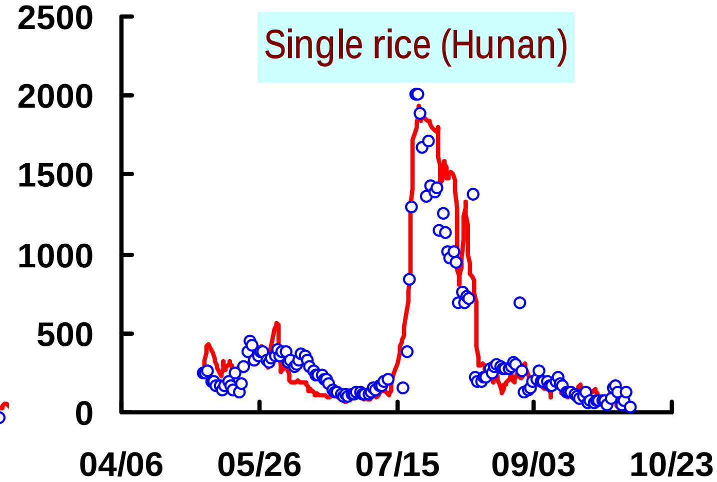
CH4MOD (Huang Y *et al*., 1998, *Global Change Biology*,; Huang Y, Zhang W, Zheng X *et al*., 2004, *J. Geophysical Research*)

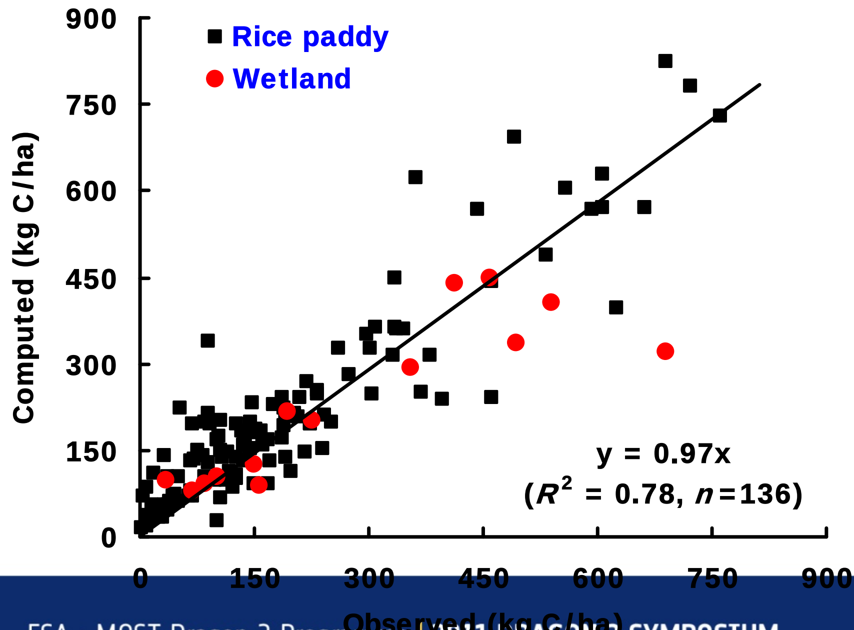


CH4MODwetland (Li T, Huang Y, Zhang W *et al*., 2010, *Ecological Modelling*)

Model CH_4: Validation

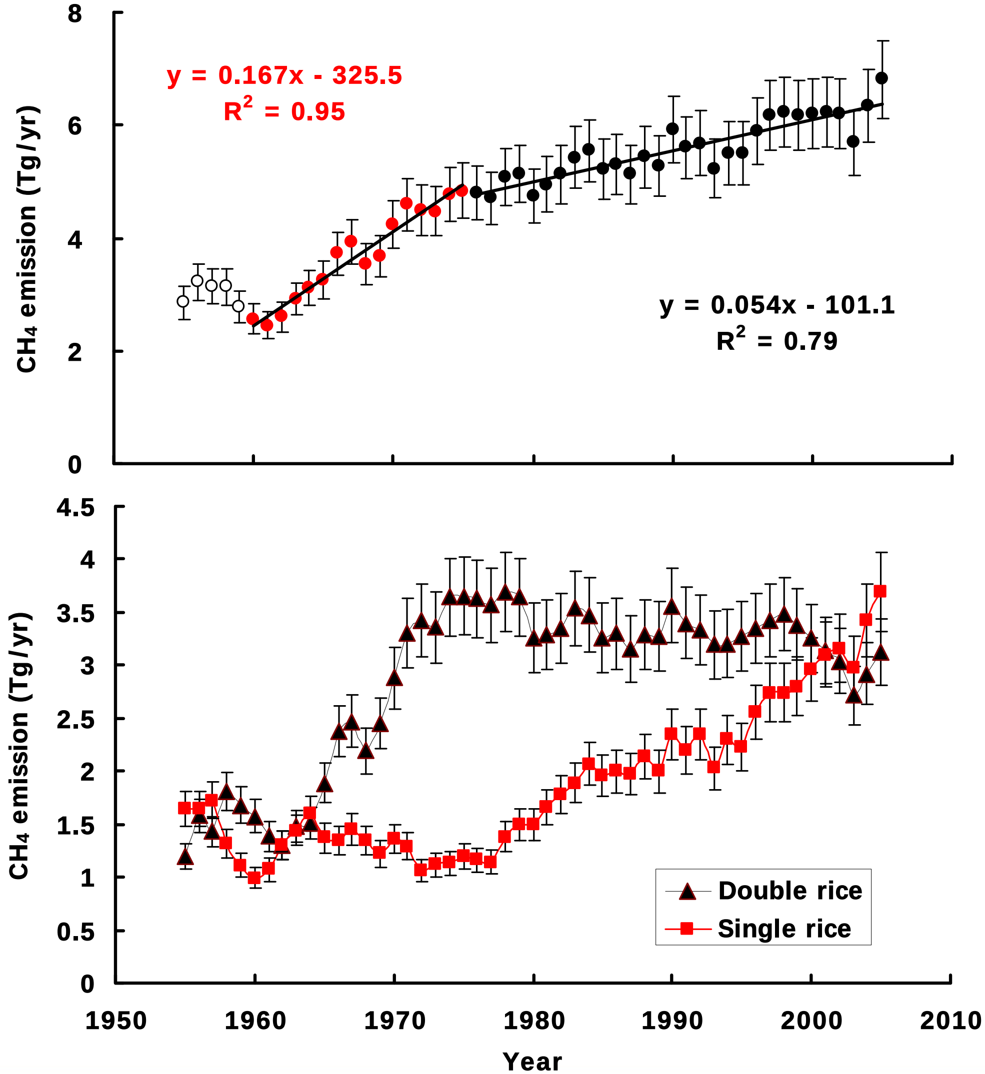






Model validation against independent measurements

Model CH_4: Trends in CH_4 emissions



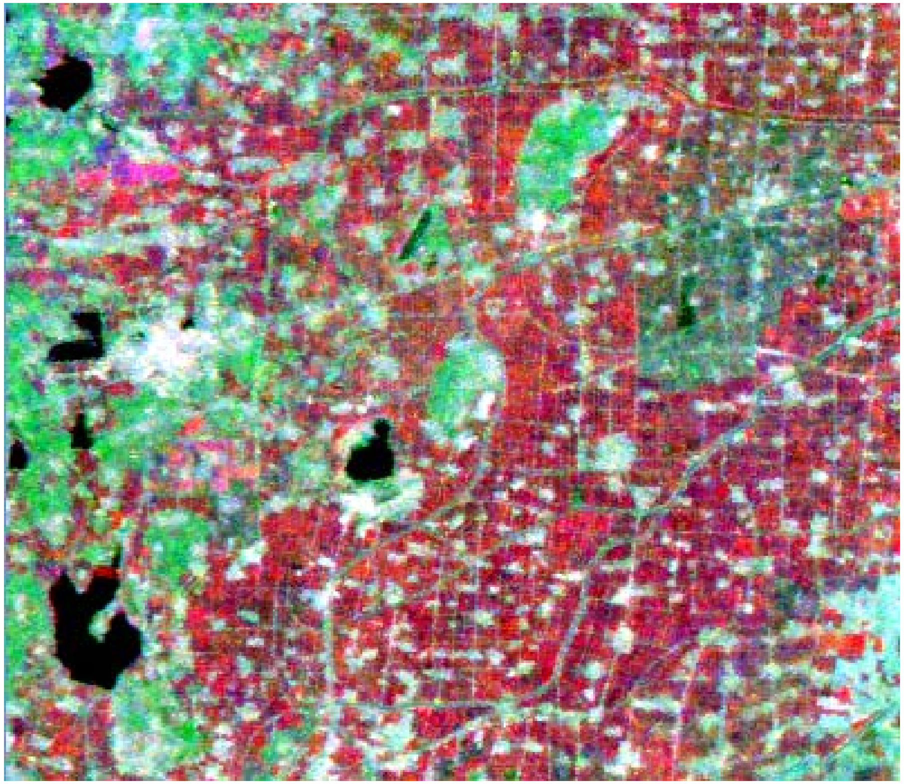
CH_4 emission from Chinese rice paddies China increased in general, but the growth rate has decreased since the mid 1970s.

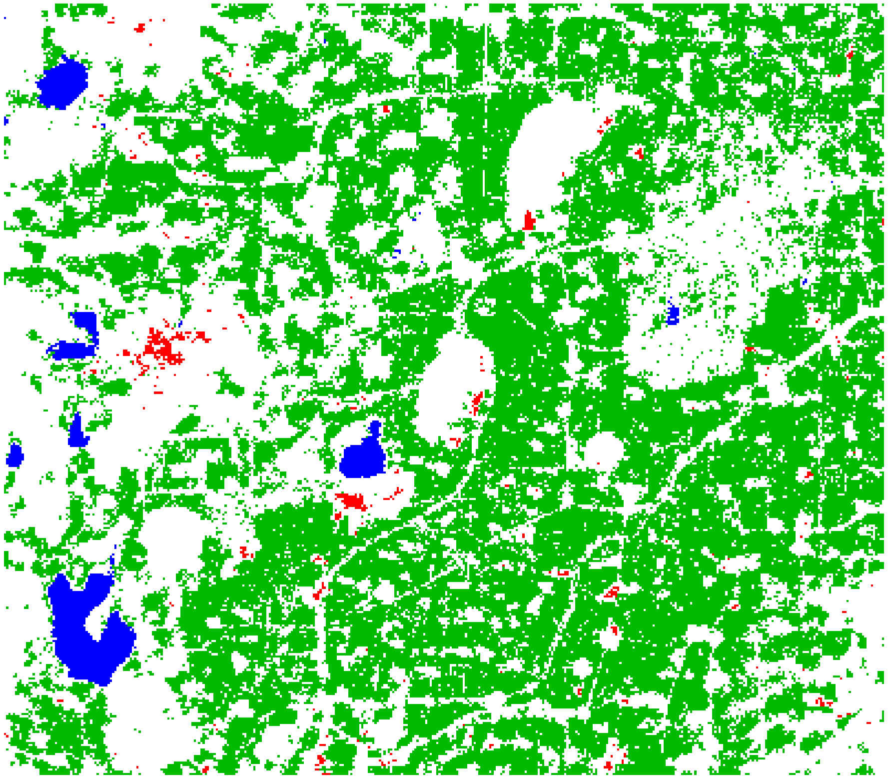
(Wang P, Huang Y, Zhang W, *Adv. Clim. Change Res.*,2009)

Better model constraint by EO
Irrigated rice mapping

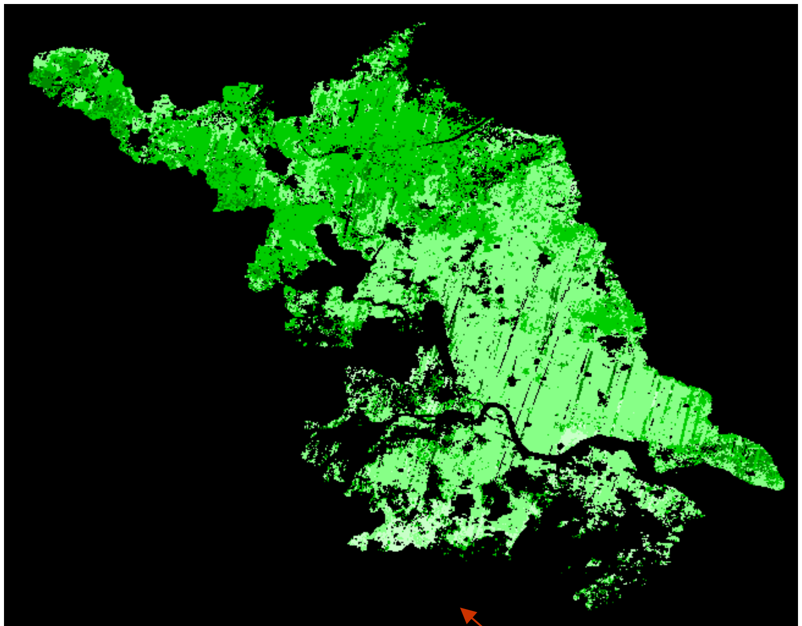
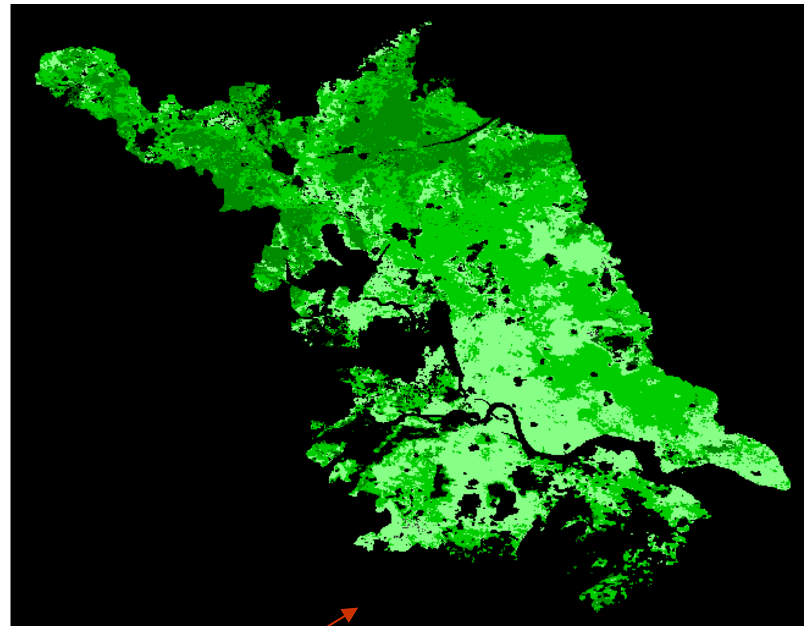
Rice mapping using ASAR WideSwath

Rice map from ASAR WSM





Better model constraint by EO Crop Calendar

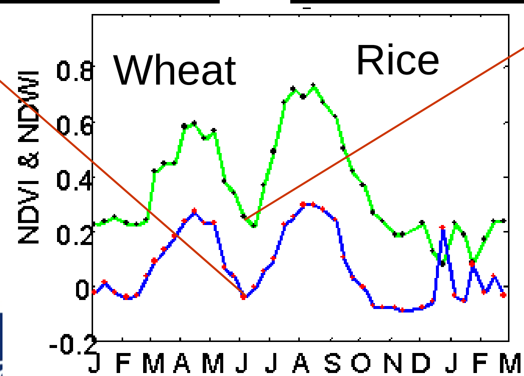
Flooding date	Transplanting date
	

White: 21-31 May

Light green: 1-10 June

Green: 11-20 June

Dark green: 21-30 June



Using SPOT VGT

Jiangsu

Better model constraint by EO Irrigation status

Mapping of mid season drainage (ASAR WideSwath VV)

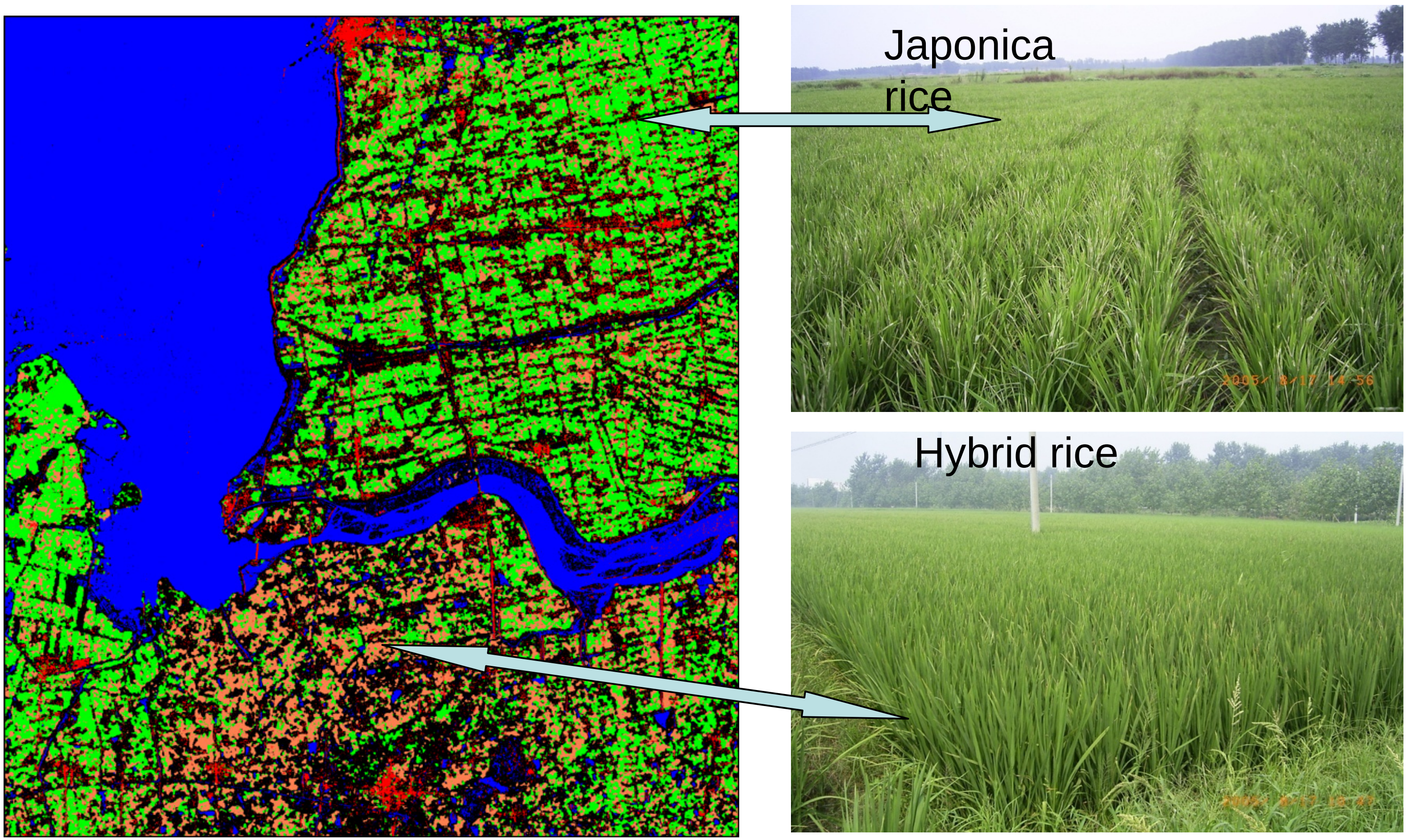
Magenta: 20060702 Green: 20060806

Magenta: 20060705 Green: 20060809

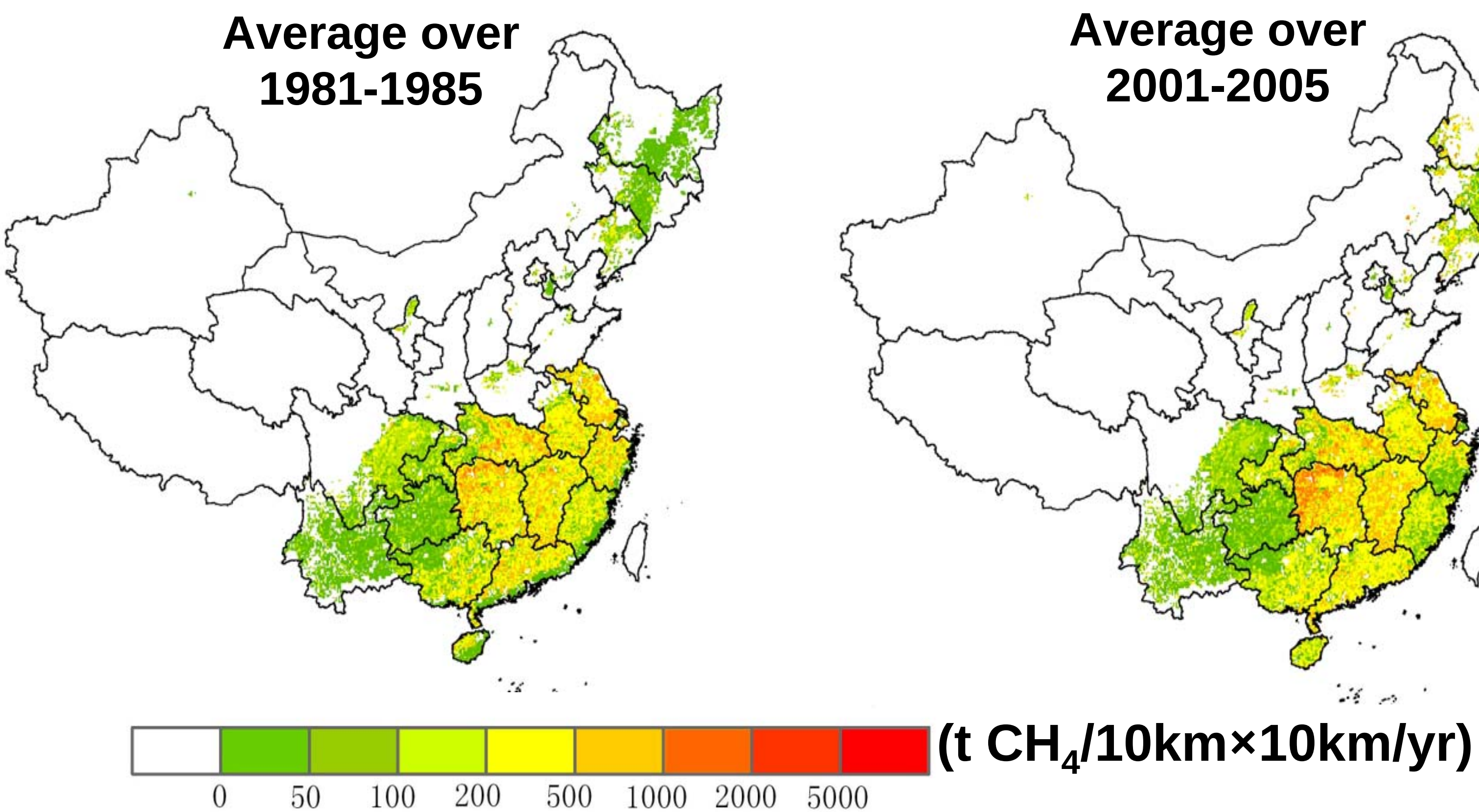
Magenta: flooded rice fields
Green: fields with temporary drainage

Better model constraint by EO
Varieties mapping

Mapping of rice varieties

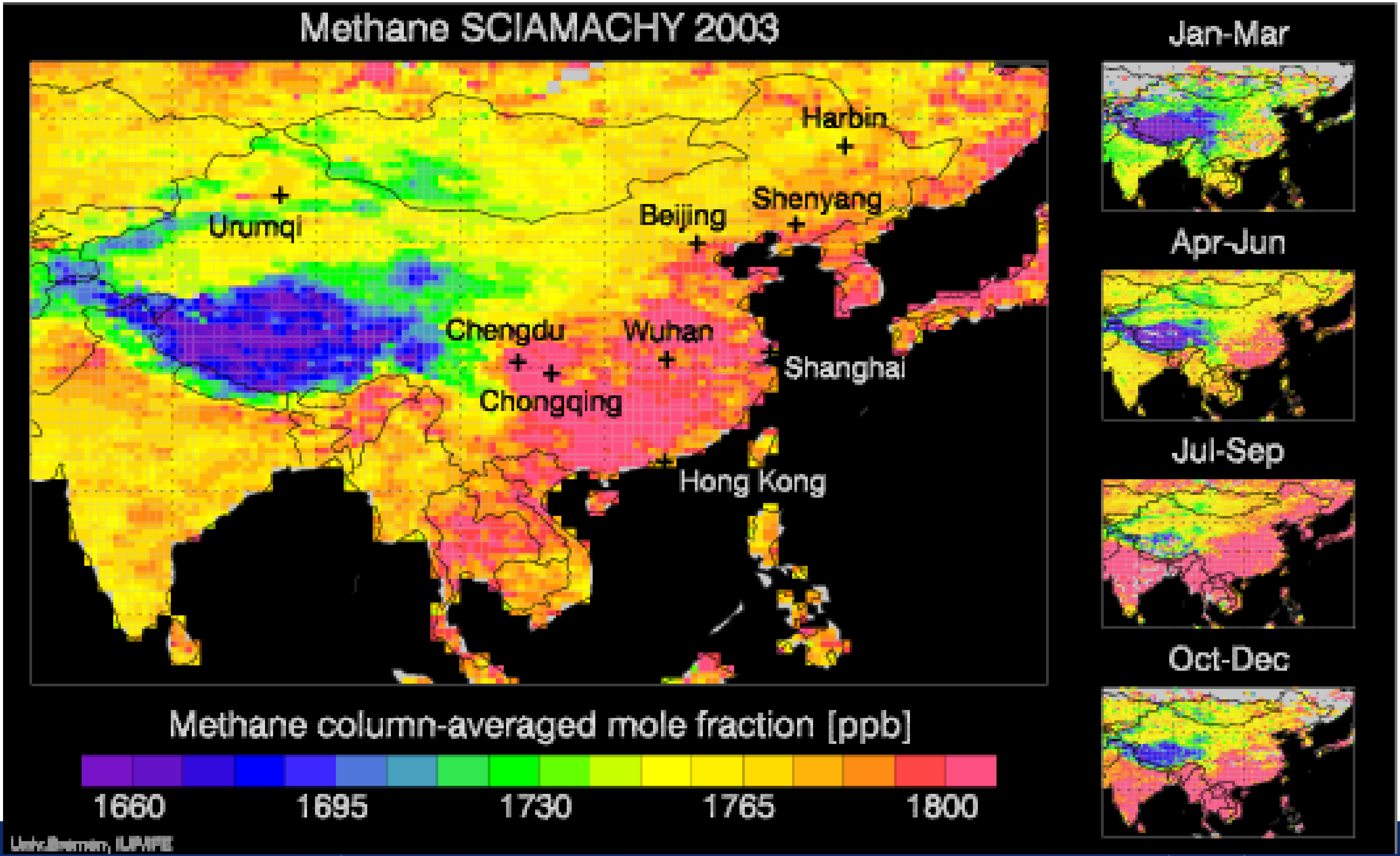


CH4 emissions from China

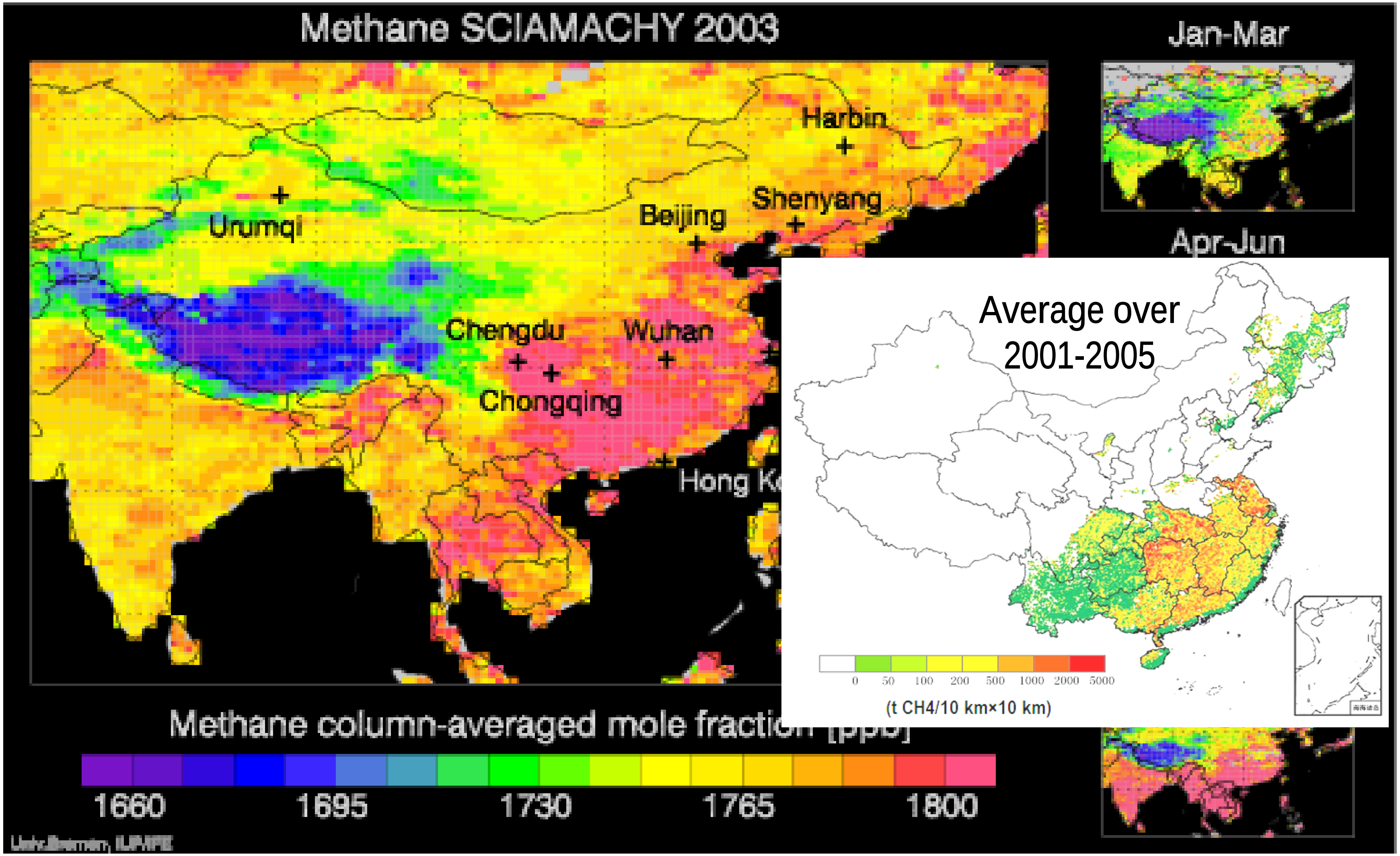


Spatial distribution of CH_4 emission did not change much over the last 50 years. Higher CH_4 emission occurred in Hunan, Hubei, Jiangxi, Guangdong, Guangxi, Jiangsu and Anhui Province, ~73% of the national total.

EO:Methane (column-averaged) from Sciamachy



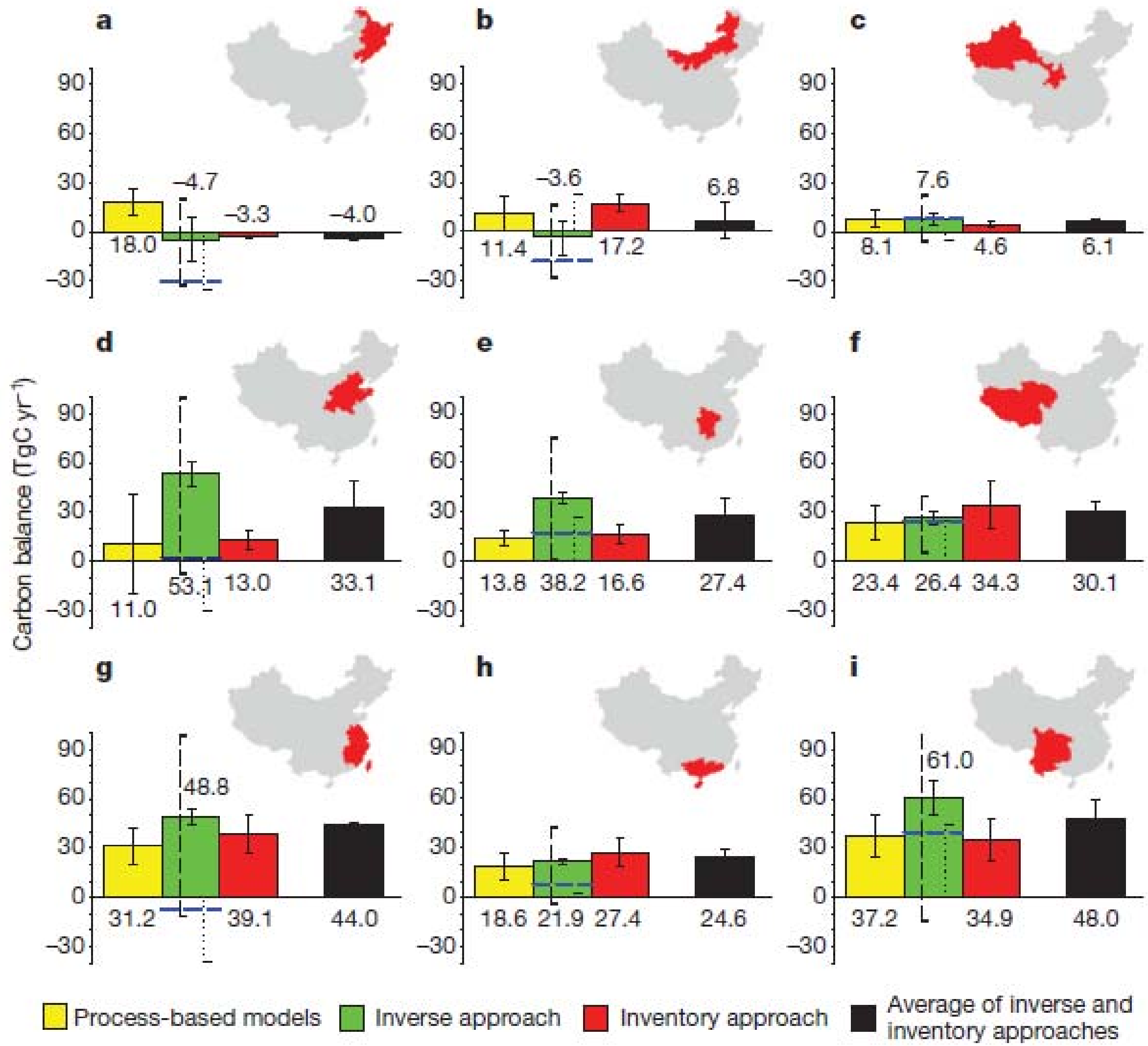
SCIAMACHY CH_4 and modelled rice paddy CH_4



Study of Grassland

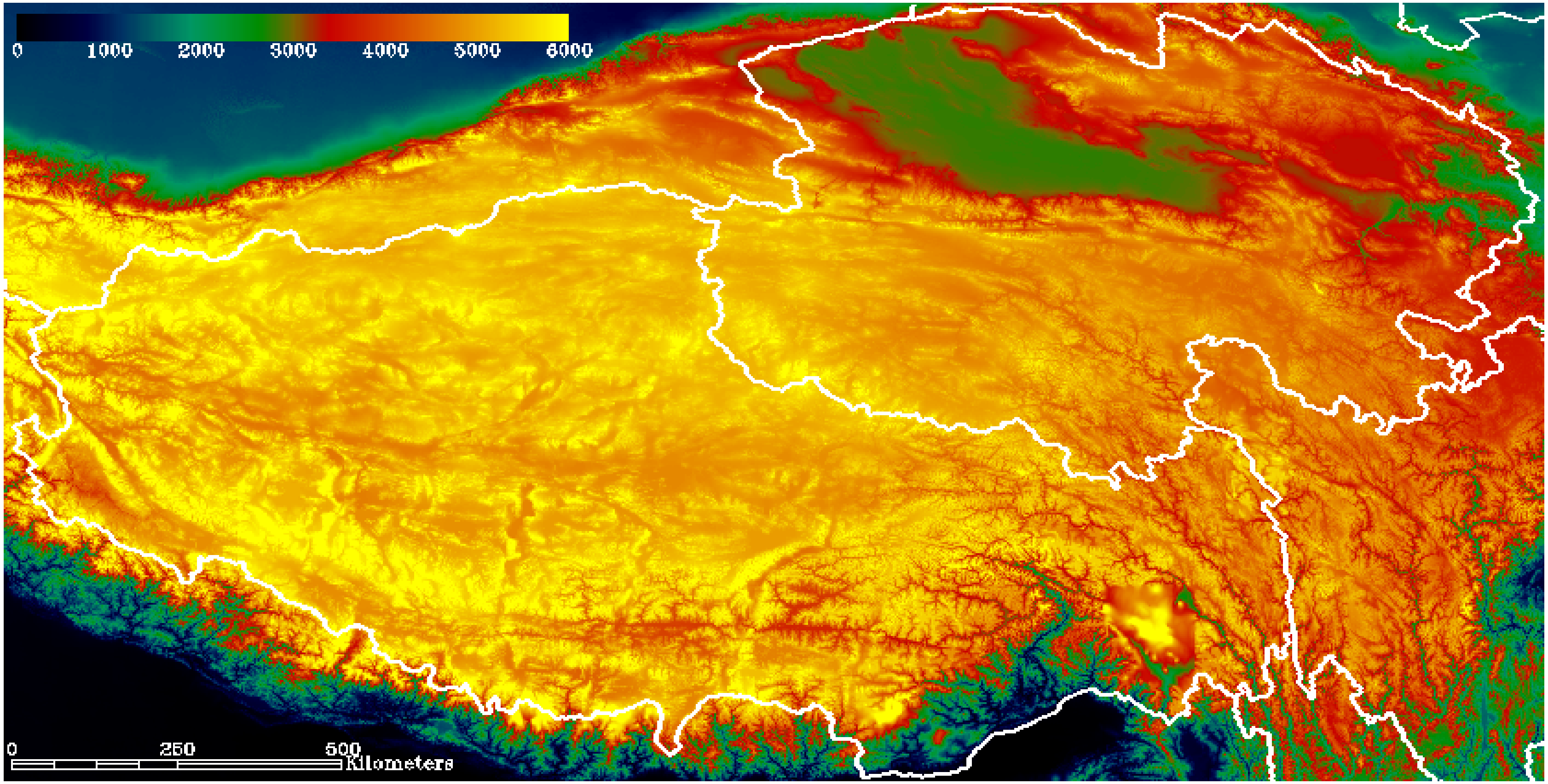
- ❑ Phenology in Qing Hai Tibet plateau
- ❑ Trend in Inner Mongolia

Carbon budget in Qing Hai-Tibet



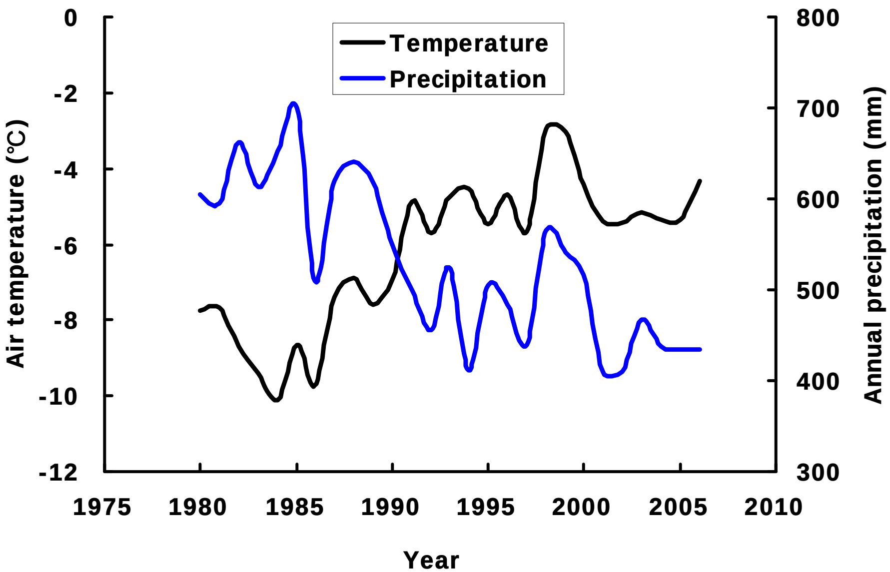
- **1.6 Mkm^2,**
  with ~75% of grasslands
  Increase of 1.8°
  over 2 decades

The Qing Hai-Tibet plateau

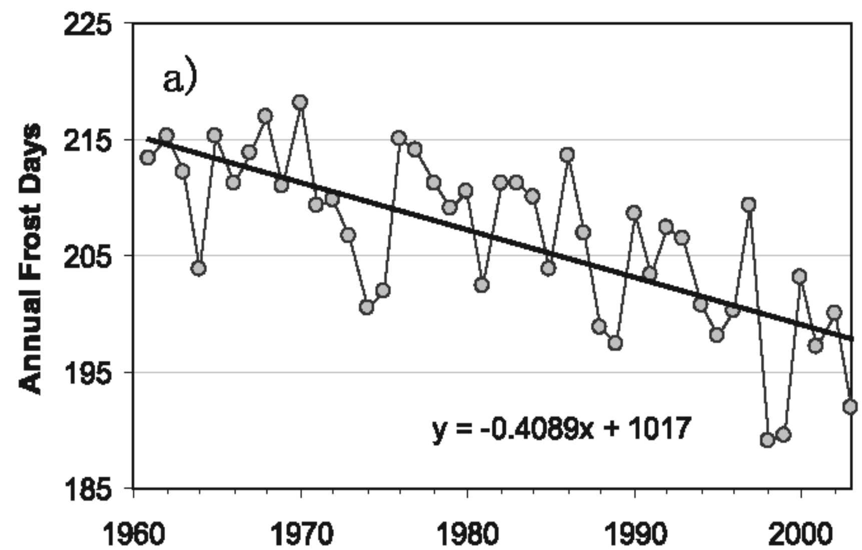


Topography, GTOPO 30

Climate change in Qinghai-Tibet Plateau



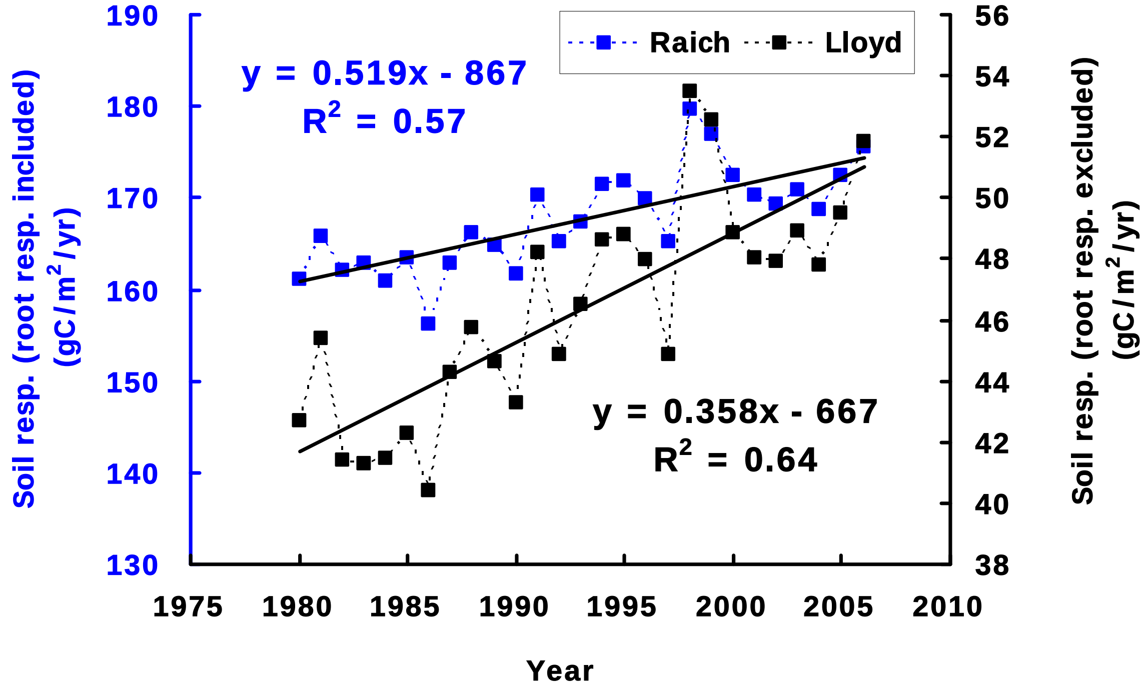
Temperature increased, precipitation decreased



Frost days decreased (Liu *et al*., 2003, JGR)

Soil respiration

Estimates of soil respiration in Qinghai-Tibet Plateau



Soil respiration increased

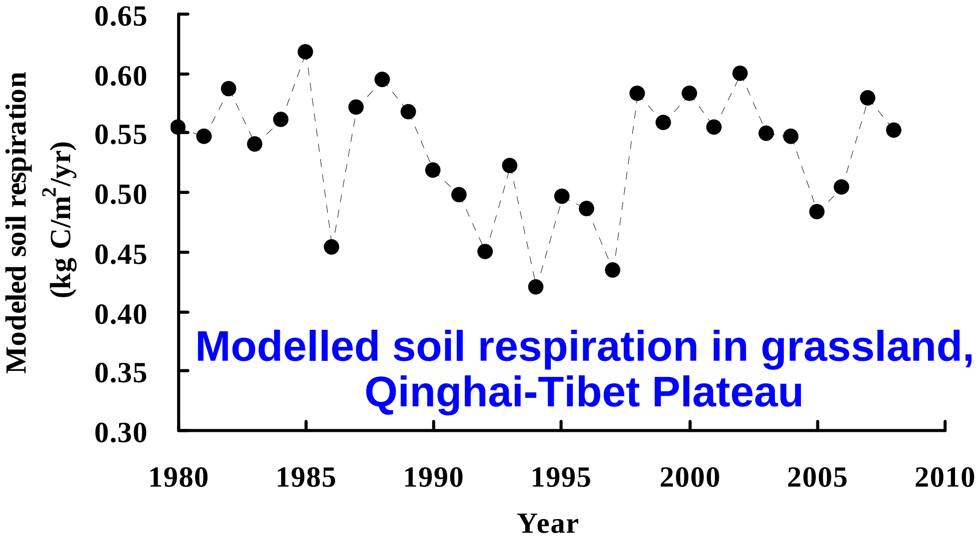
$$R_s = 1.25e^{0.05452T_a} \times \frac{P}{4.259 + P}$$

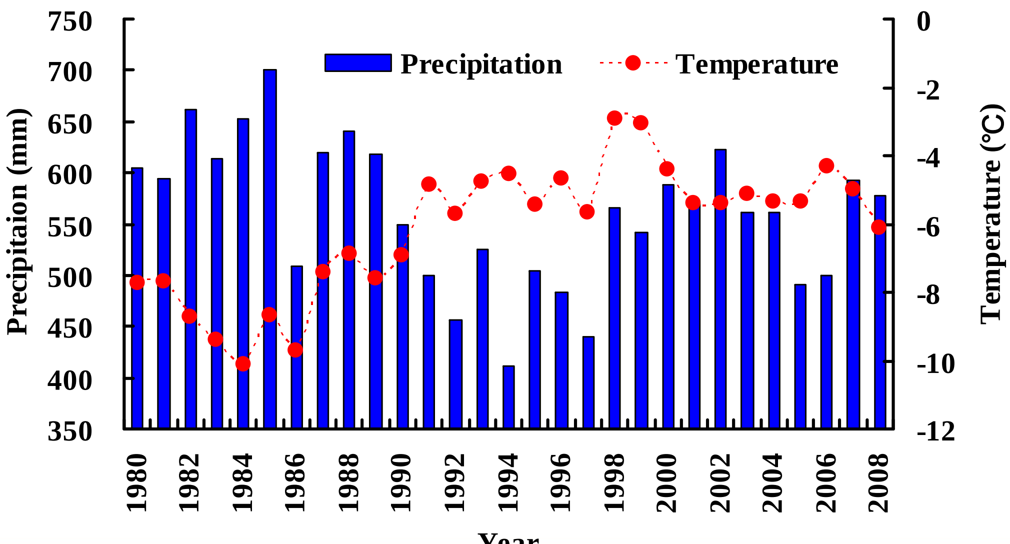
(Raich *et al*., 2002, *Global Change Biology*)

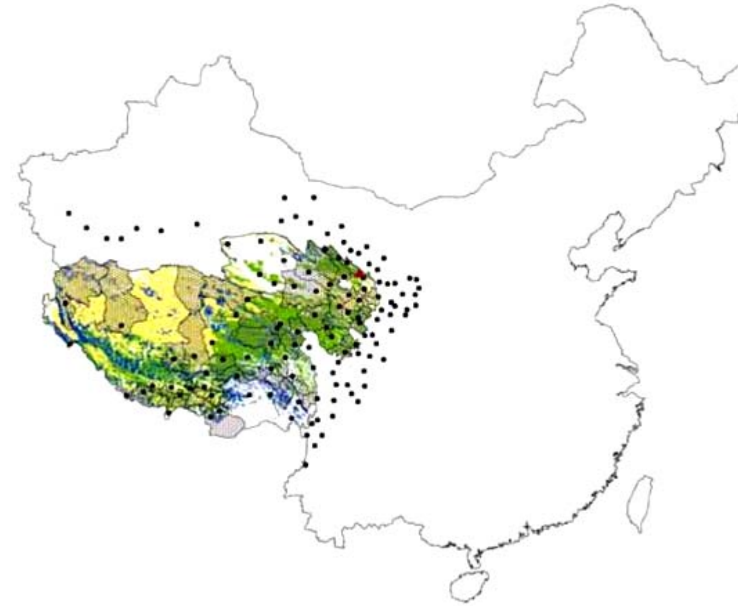
$$R = R_{10}\exp(308.56(\frac{1}{56.02} - \frac{1}{273.13 + T_a - 227.13}))$$

(Lloyd and Taylor, 1994, *Functional Ecology*)

Soil respiration: this study





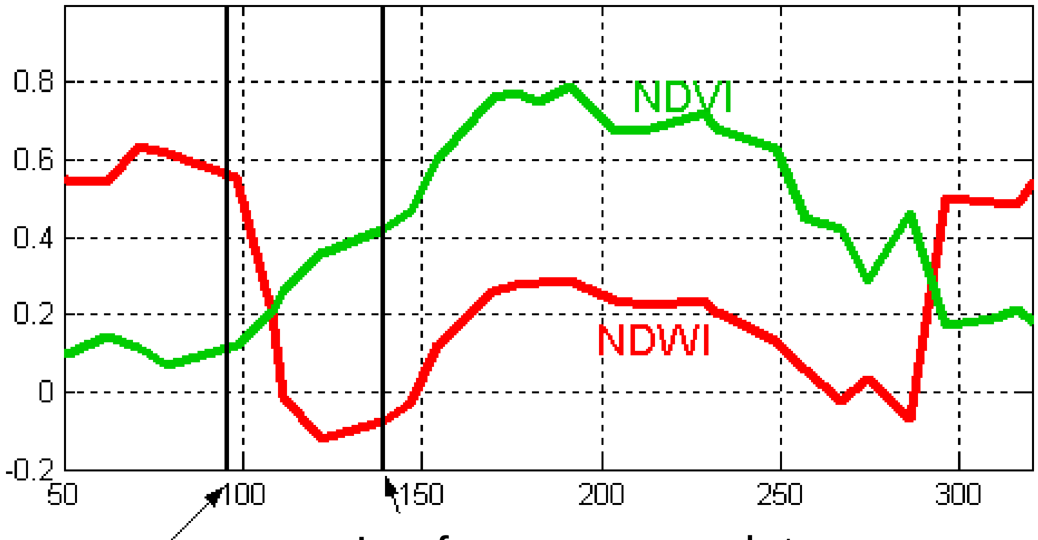


Limitation is the low density of meteorological stations in this area. Upscaling climatic parameters over this area would result in great uncertainty.

Earlier phenology in Qinghai-Tibet ?

Date of greening in cold regions

$$NDWI = \frac{NIR-SWIR}{NIR+SWIR}$$



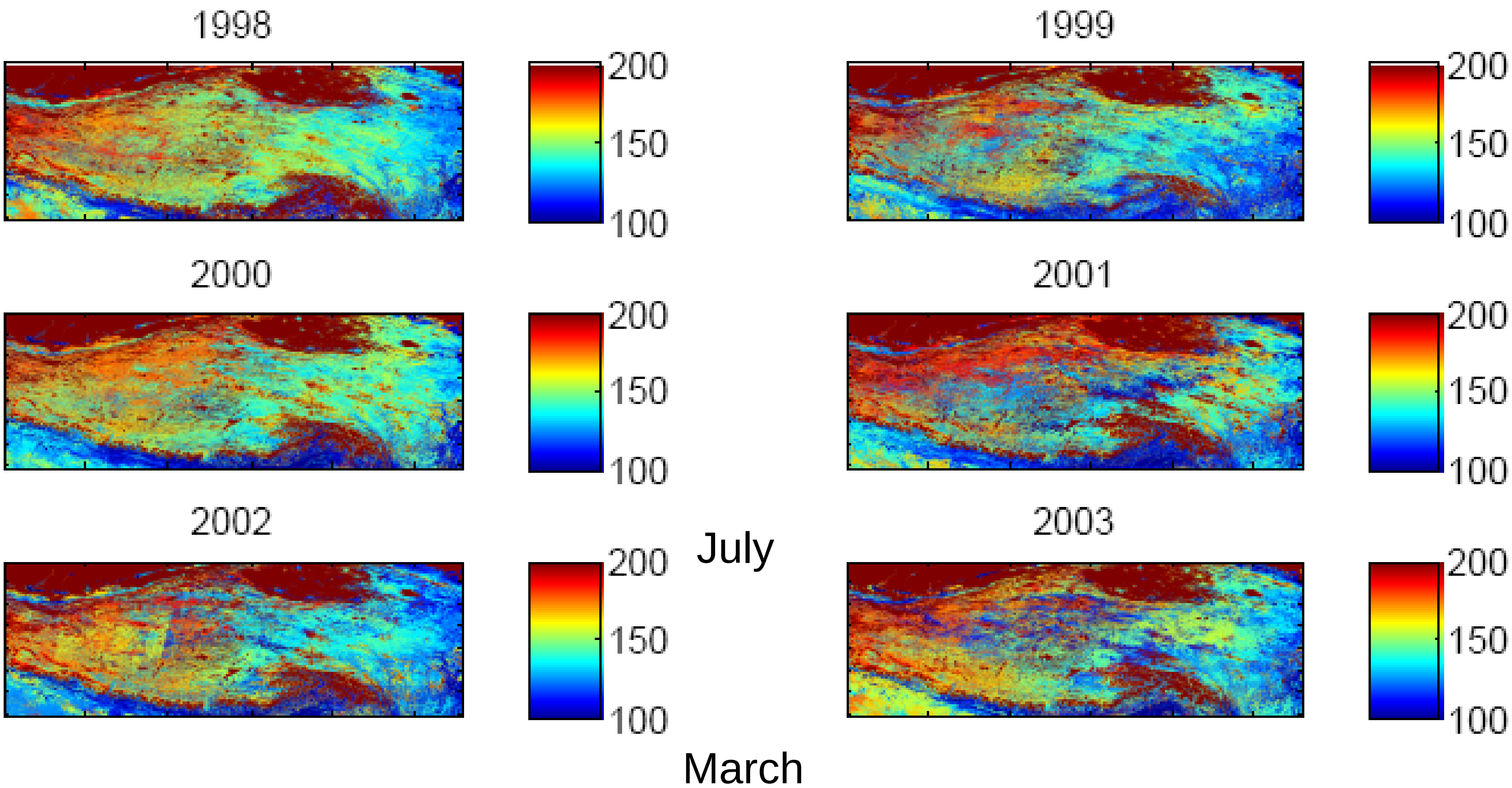
Snow melt date

Leaf appearence date

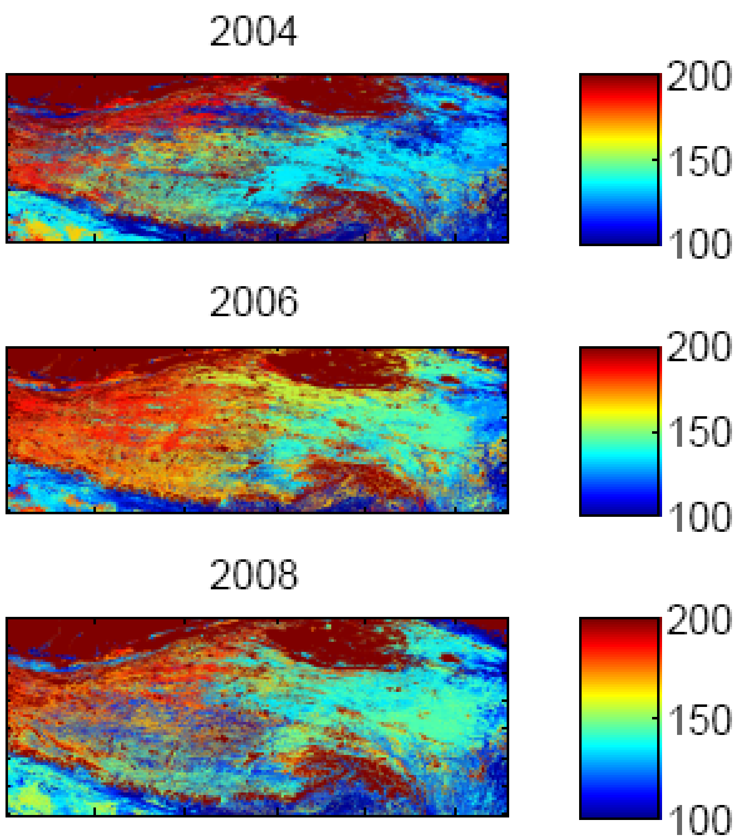
Delbart, Le Toan et al., RSE

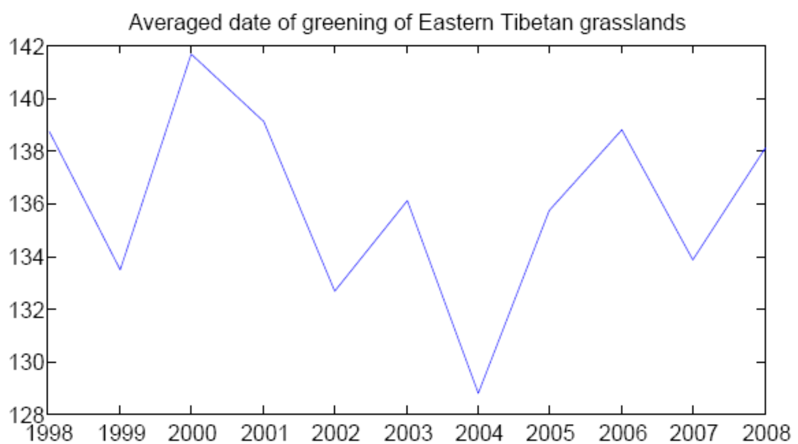
Leaf appearance = date when NDWI starts to increase

Dates of beginning of greening in Qinghai-Tibet



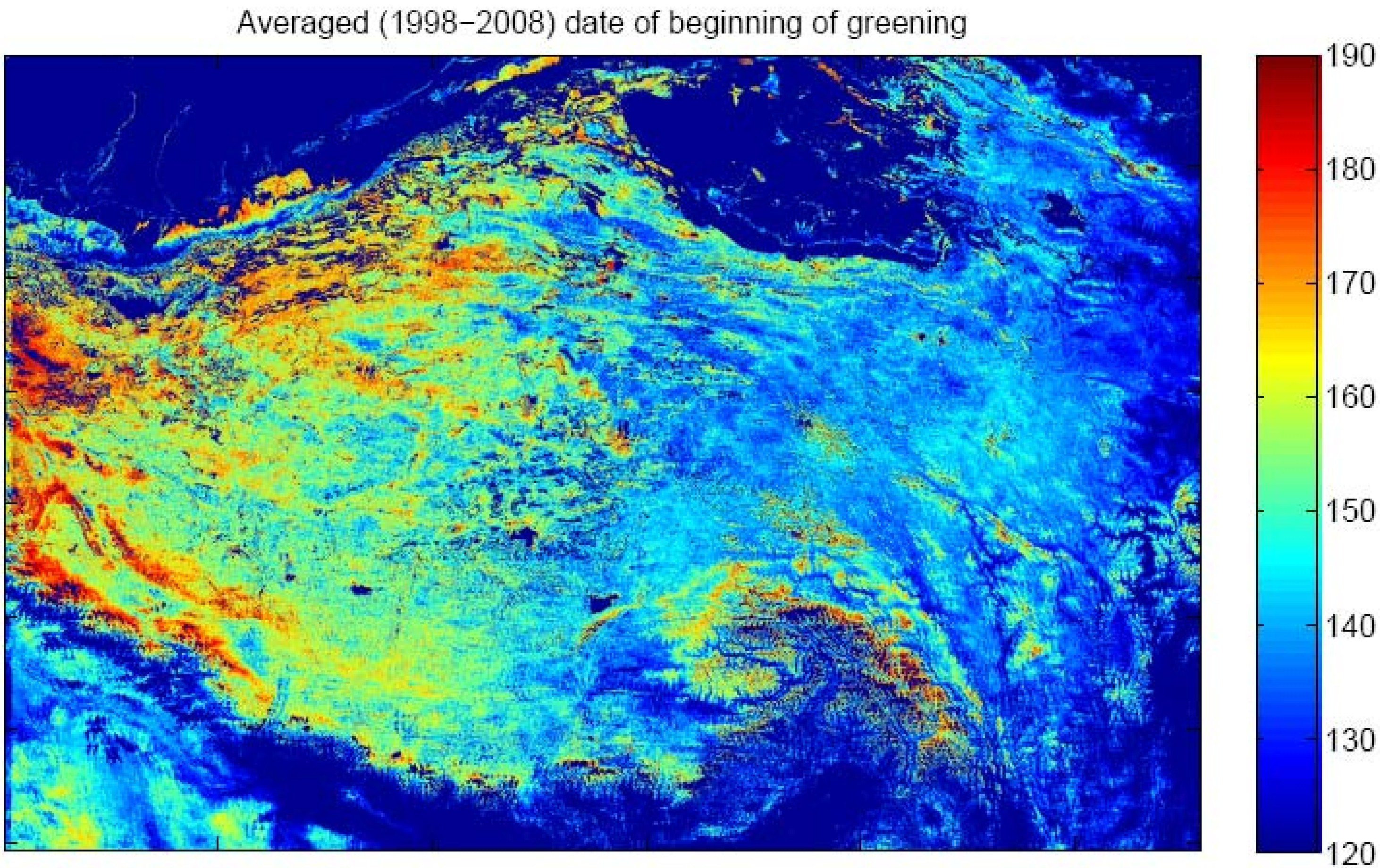
Dates of beginning of greening



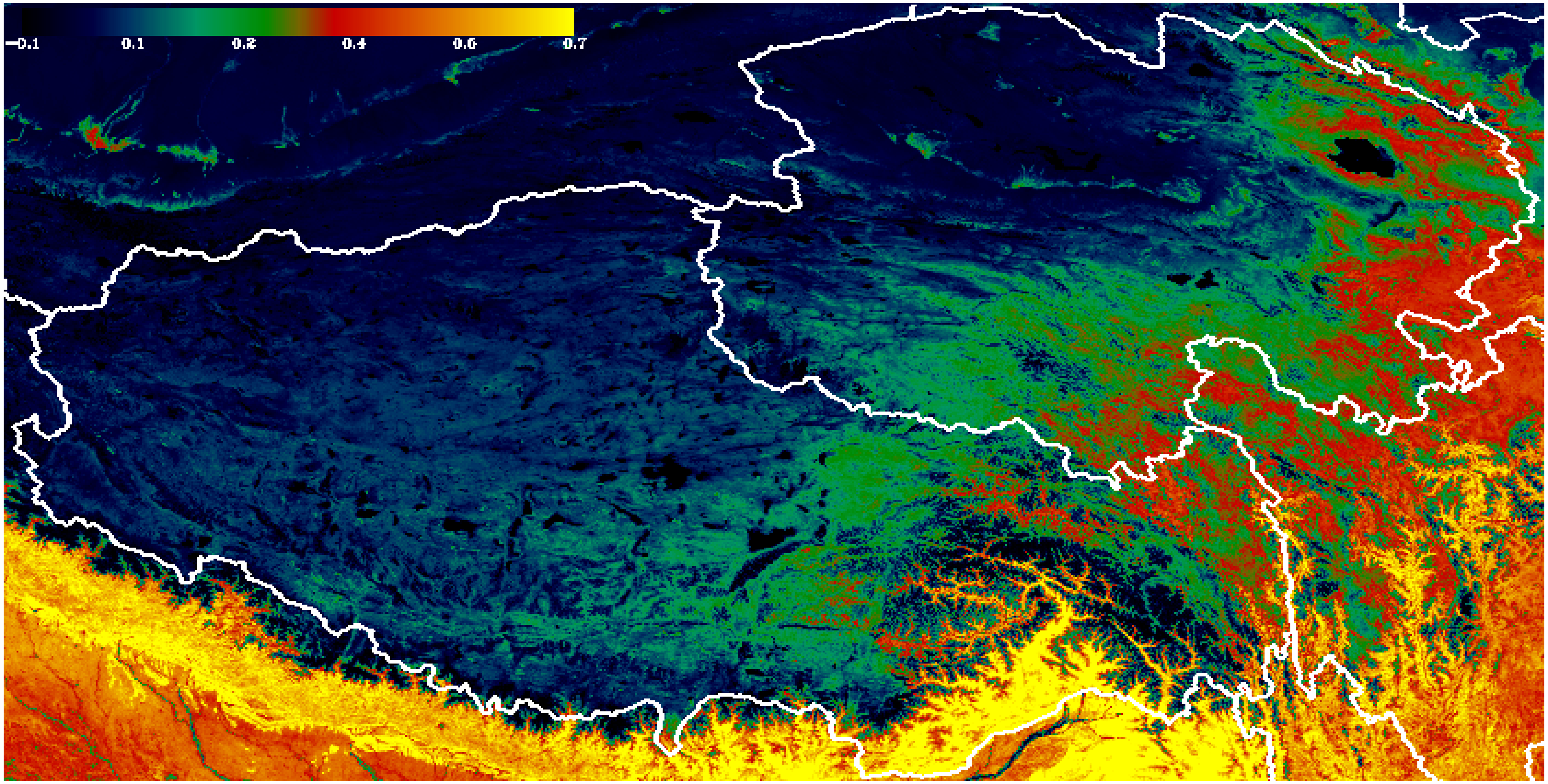


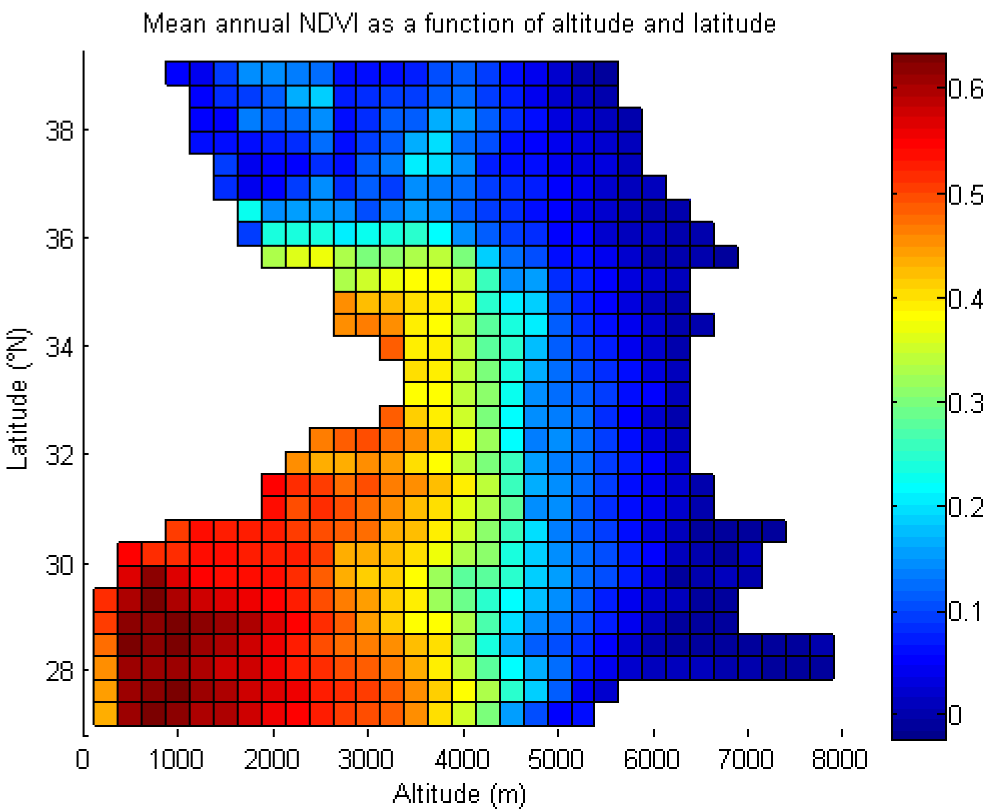
EO: phenology

Averaged (1998-2008) date of greening



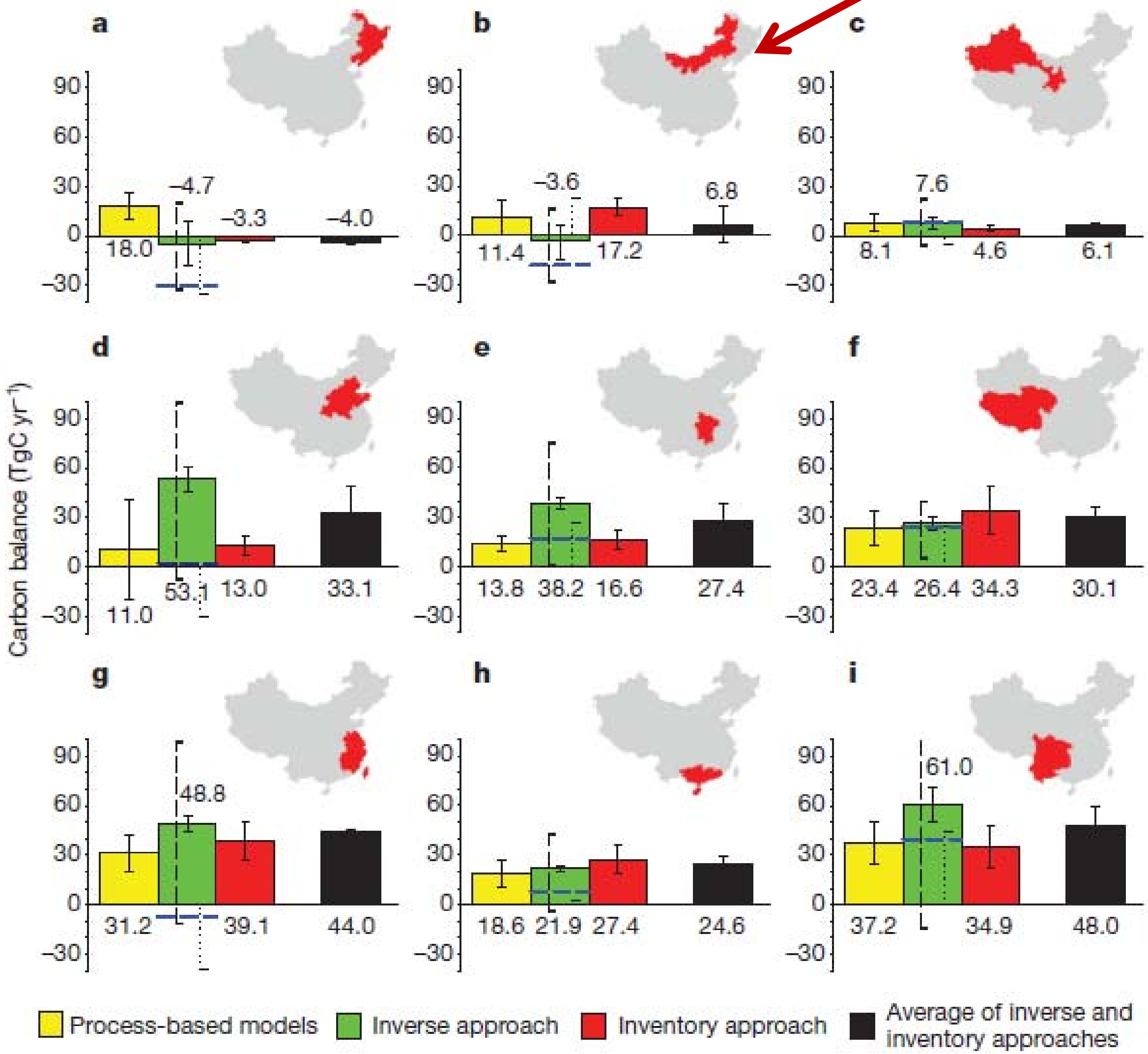
Mean NDVI 2007

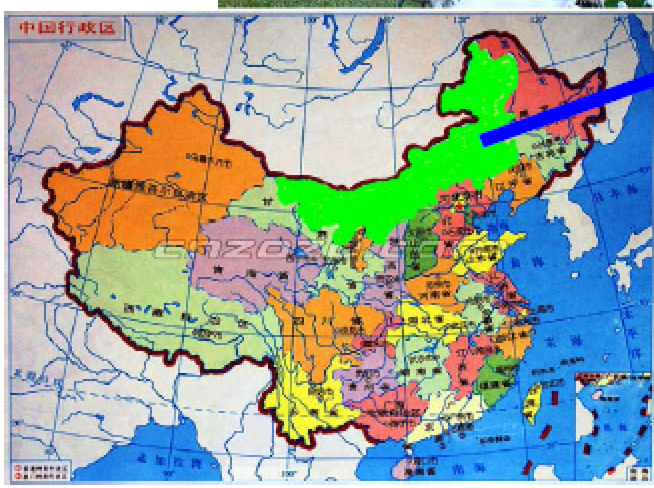


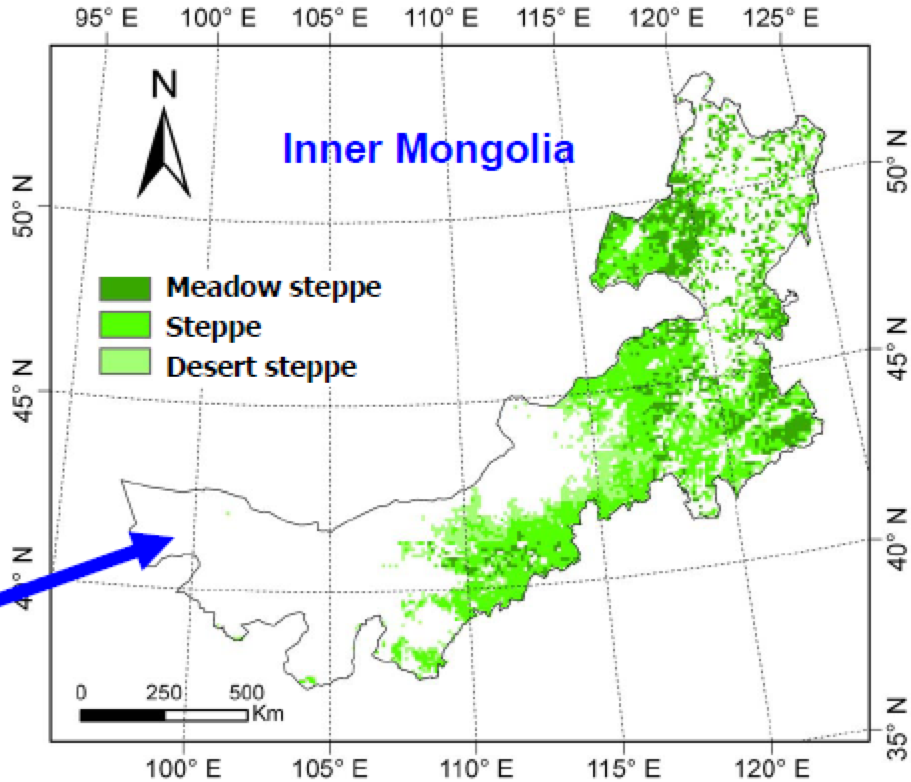


Mean annual NDVI as a function of altitude and latitude
Latitude (°N)
38
36
34
32
30
28
0
1000
2000
3000
4000
5000
6000
7000
8000
Altitude (m)
0.6
0.5
0.4
0.3
0.2
0.1
0

Grassland carbon budget in Inner Mongolia







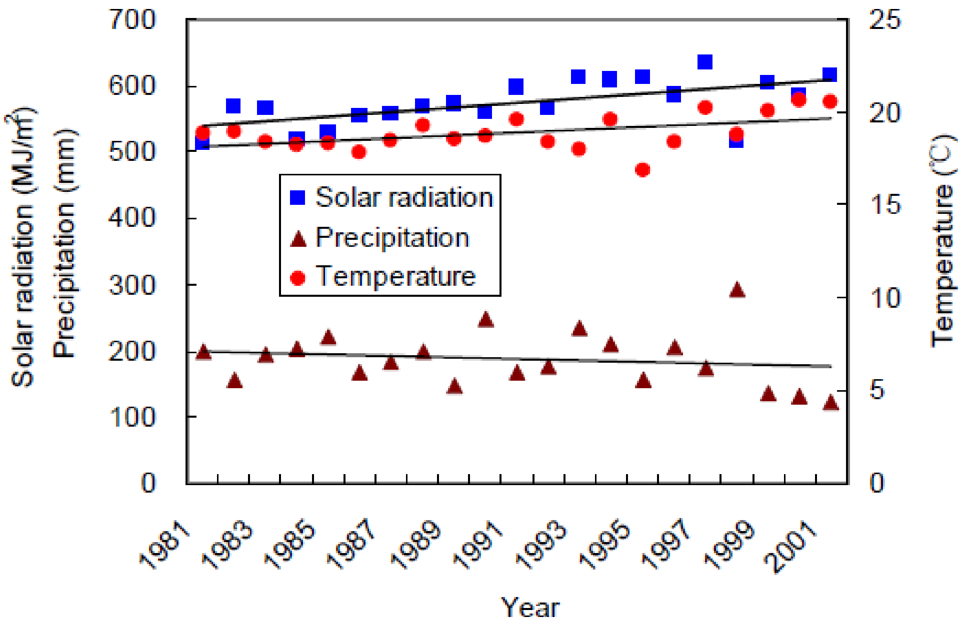
Inner Mongolia

~20% of the total grassland area in China

Grass NPP reaches maximum in mid July — mid August

Over the period 1981–2001 (July-August)

- **Solar radiation and temperature increased**
- **No significant trends in precipitation was detected**

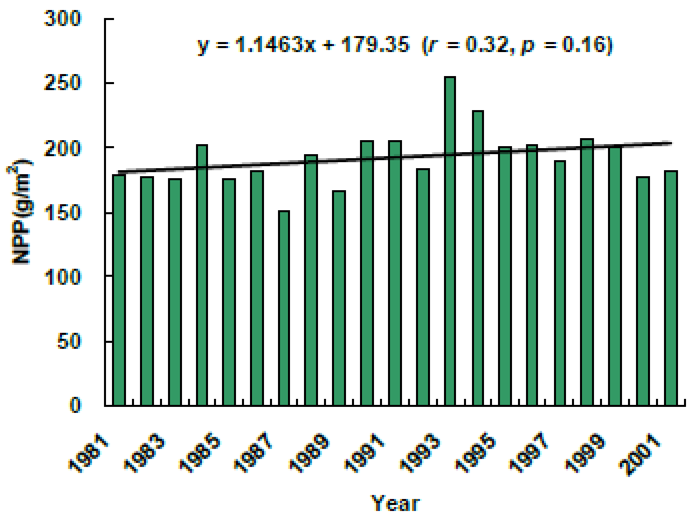


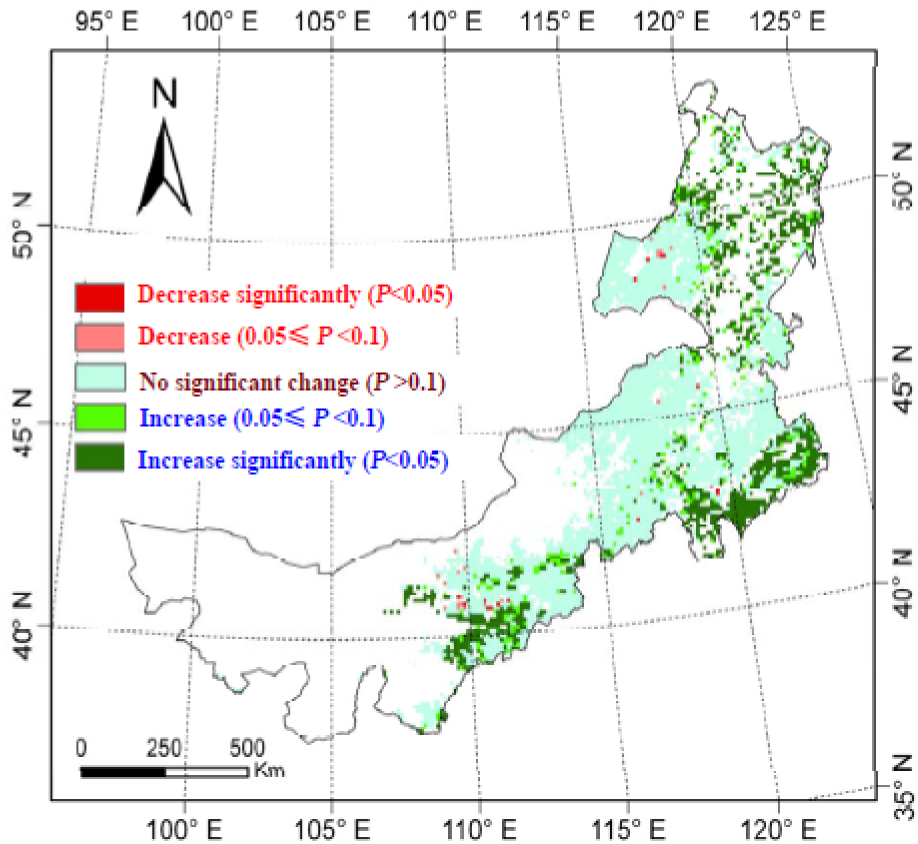
y (solar radiation) = 3.45x - 536 (r = 0.62, p = 0.003)

y (temperture) = 0.074x + 18 (r = 0.48, p = 0.024)

y (preciptation) = -1.17x + 200 (r = 0.18, p = 0.446)

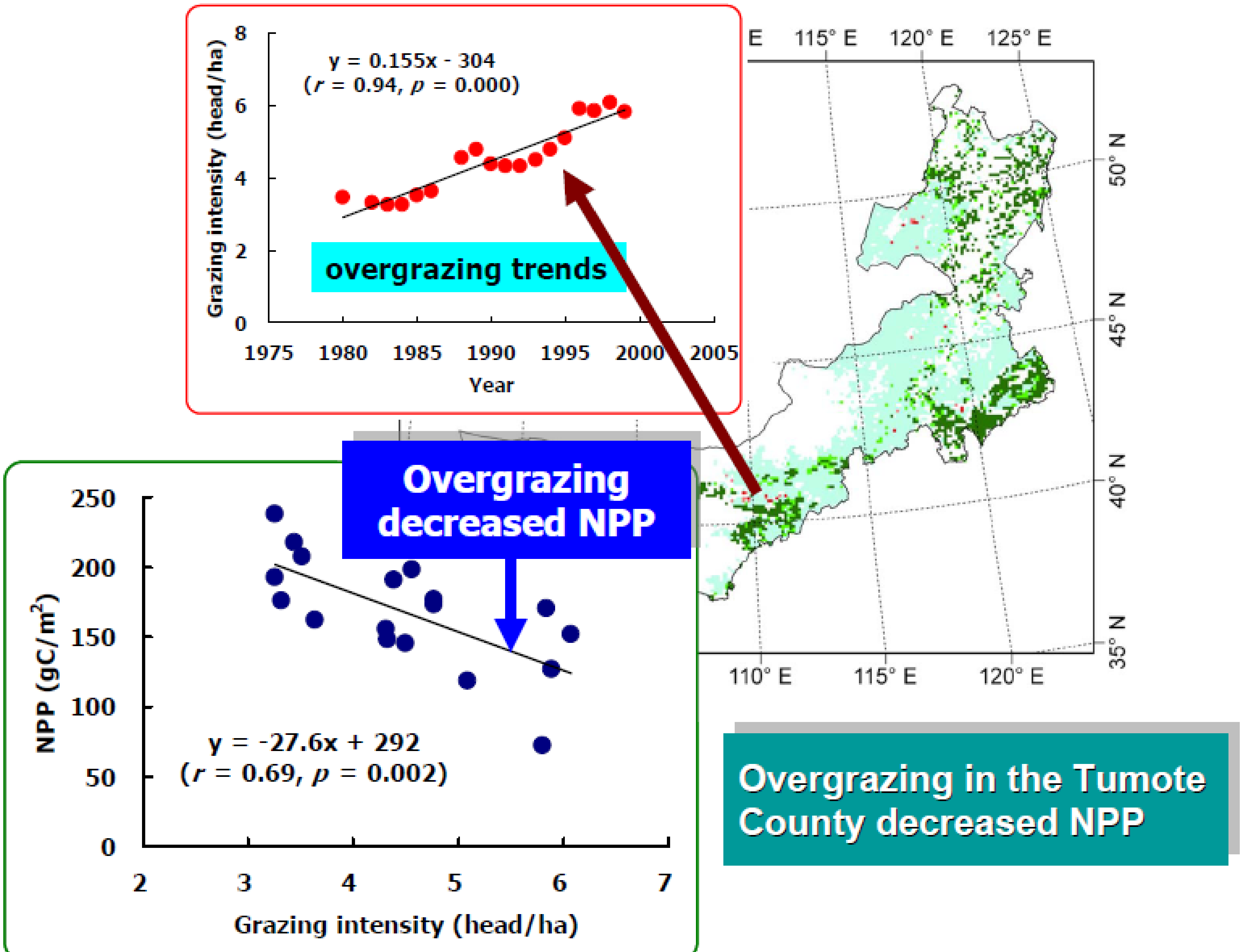
% of the total grassland		Significant
Increase	Decrease	
23.5	0.3	$P<0.05$
6.6	0.5	$0.05\le P<0.1$
45.4	23.7	$P\ge 0.1$





NPP from 1981 to 2001

- did not show significant changes in ~68% of the total grassland
- increased in ~24 % of the total grassland
- did not change as a whole


y = 0.155x - 304
(r = 0.94, p = 0.000)
overgrazing trends
Grazing intensity (head/ha)
Year
Overgrazing decreased NPP
y = -27.6x + 292
(r = 0.69, p = 0.002)
NPP (gC/m2)
Grazing intensity (head/ha)
115° E
120° E
125° E
110° E
50° N
45° N
40° N
35° N
Overgrazing in the Tumote County decreased NPP

Summary

The role of croplands and grasslands in the terrestrial Carbon budget of China
Is studied using models , in situ and EO data

- Dynamic Vegetation model LPJ-mL (from PIK): Carbon sink
  - 100 MtC/yr (forest+crop land)
  - 180 MtC/yr (potential vegetation)
  - 190-260 MtC/yr (forest), in Piao et al., 2009
- Soil carbon in crop/grassland: 700 MtC from 1980 to 2009 (24 MtC/yr)

- Increase of C uptake by Crop management (soil C sequestration, fertilization, multiple cropping)

- No significant change in the C budget of grasslands at 2 regions observed in the study

Summary (2)

❑ Remote Sensing data have been used
➢ As land cover maps
➢ As long time series in models for decade comparison (GIMMS since 1980)
➢ In detailed study using more advanced data (SPOT VGT since 1998)
➢ As demonstrators for advanced inputs in models (rice using ASAR)

❑ There is a big need for comprehensive/temporal datasets from remote sensing (e.g.rice and crop parameters from Sentinel 1, soil moisture from SMOS, ASAR GM, validated land cover maps)

Works to be done 2011-2012

- ❑ More integration of remote sensing data

- ❑ Synthesis of the different results on cropland and grassland

- ❑ Starting to introduce the forest ecosystem in the carbon balance

Collaboration required with
Forest ecosystems and Fire projects

Thank you


Photo-
synthesis
LAI
C & N
Leaves
Stems
Roots
Plant C & N
N
uptake
Litter
C & N