中国科学院地理科学与资源研究所
Institute of Geographic Sciences and Natural Resources Research, CAS

天地空一体化监测

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报告提纲

1. 天地空一体化监测的内容

2. 遥感和地面样方监测的耦合

3. 遥感和通量监测的耦合

4. 遥感和地面物候监测的耦合

5. 遥感和站点温度检测的耦合

天地空一体化解决的关键问题：

空间信息获取的一体化和智能化，
空间数据处理的自动化、定量化和实时化，
空间信息分发与应用的网格化，
空间信息服务的灵性化和大众化。

研究的核心

解决地球空间信息获取、处理、应用和服务中的基础理论问题。

空间信息网络技术和方法主要研究内容包括：
空天地一体化信息网络的资源共享；
海量空间数据压缩与传输控制；
卫星传感器组网与全球信息网络的集成，以及天地互联网的耦合等工作。

总体框架

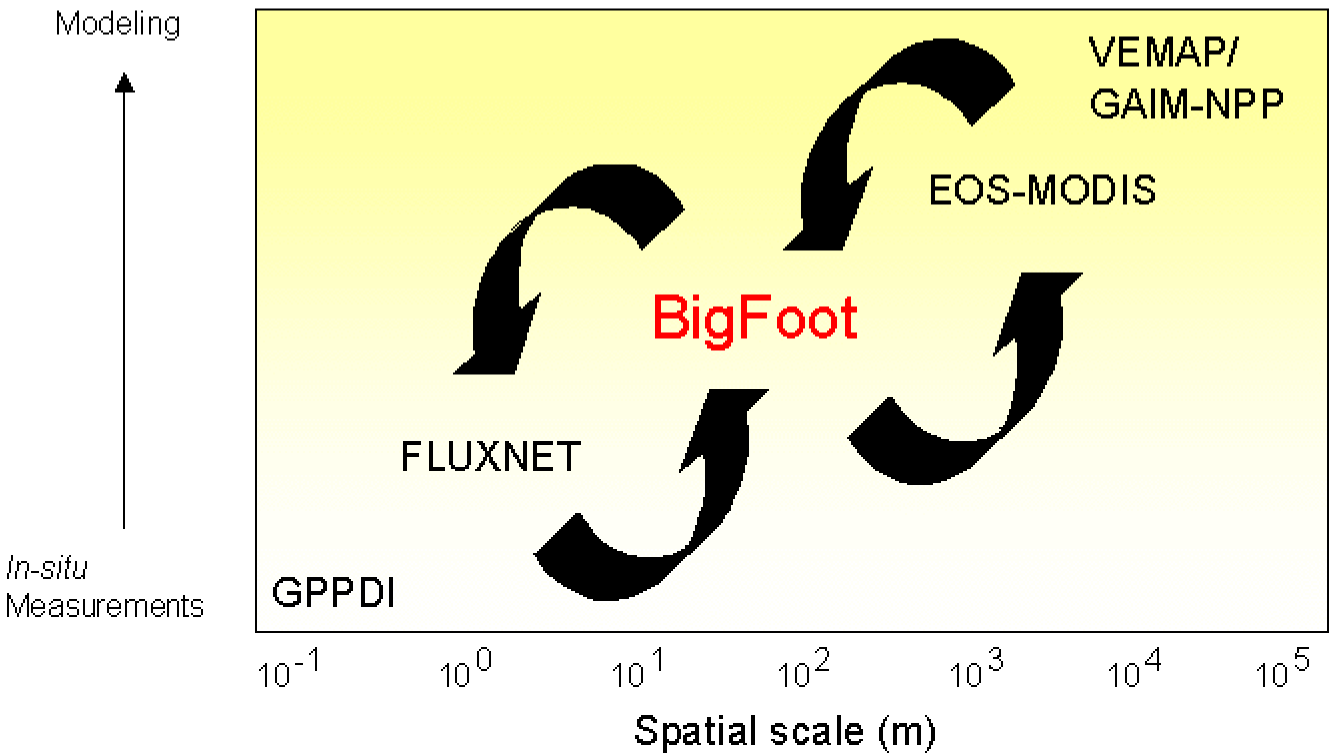
天”是要有较完善的卫星系统——天基系统，

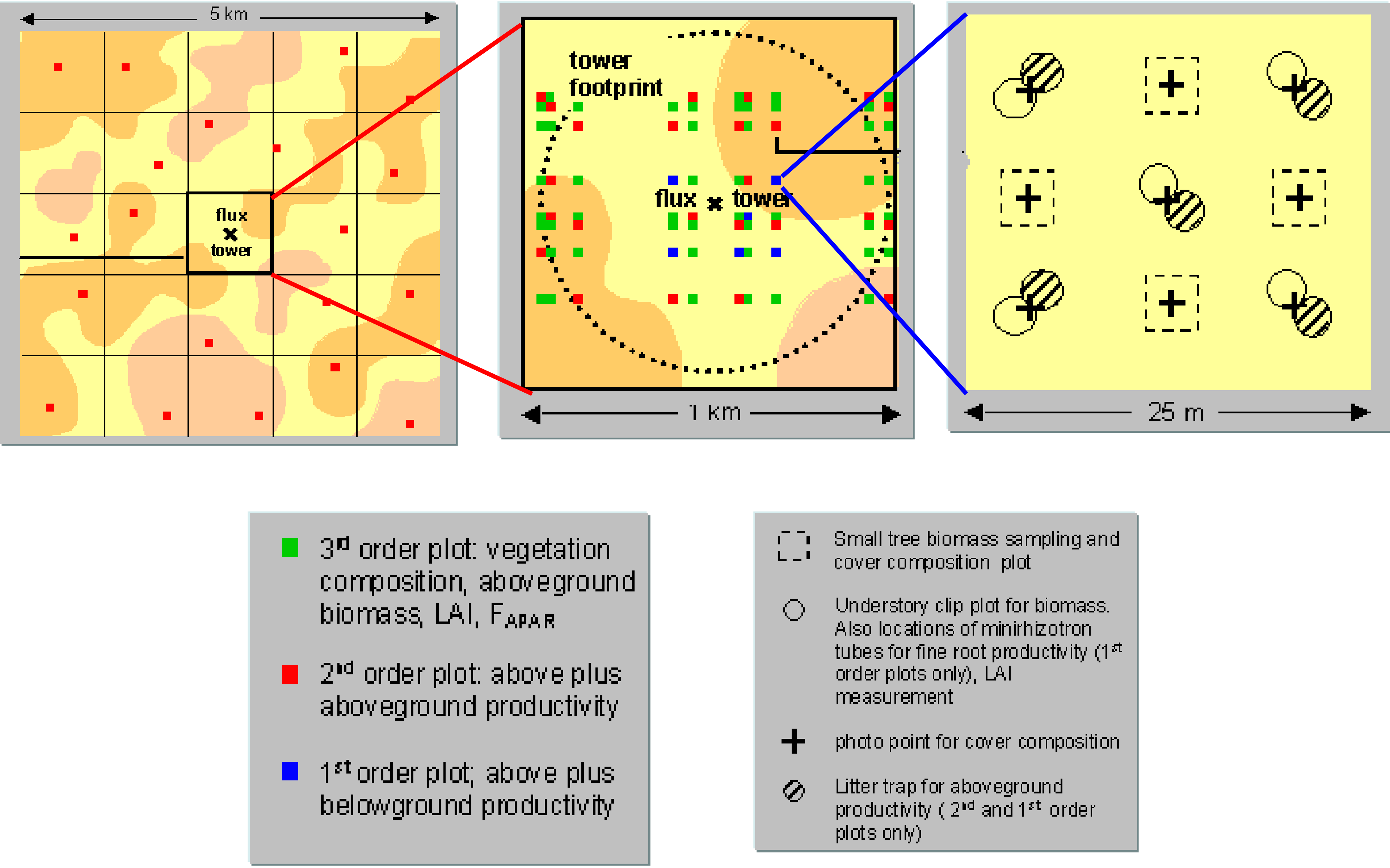
“空”是指空基系统，主要是具有遥感监测能力的飞机和飞艇，

“地”主要是地面监视系统。

Big foot

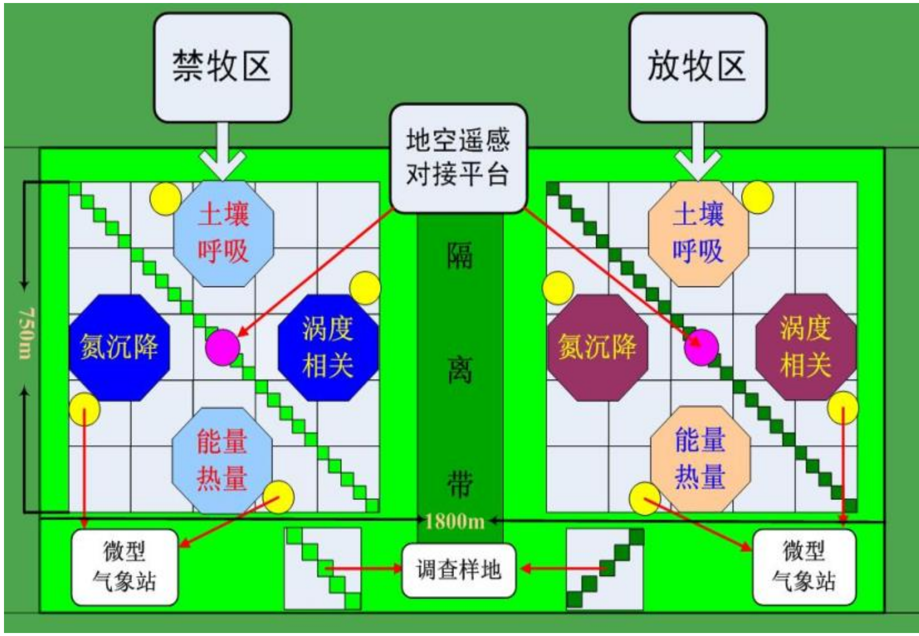
BigFoot is designed to provide that context using a combination of in situ ecological data, Landsat ETM+ data, and ecosystem models (Cohen and Justice 1999). Moreover, BigFoot maps land cover, LAI, fraction absorbed photosynthetic active radiation (f_{APAR}), and NPP over a 5 x 5 km area around an eddy flux tower at ETM+ resolution. This means we fully characterizes 25 MODIS cells around a given tower site, and are able to test a number of scaling factors that should reveal possible causes of MODIS mapping errors

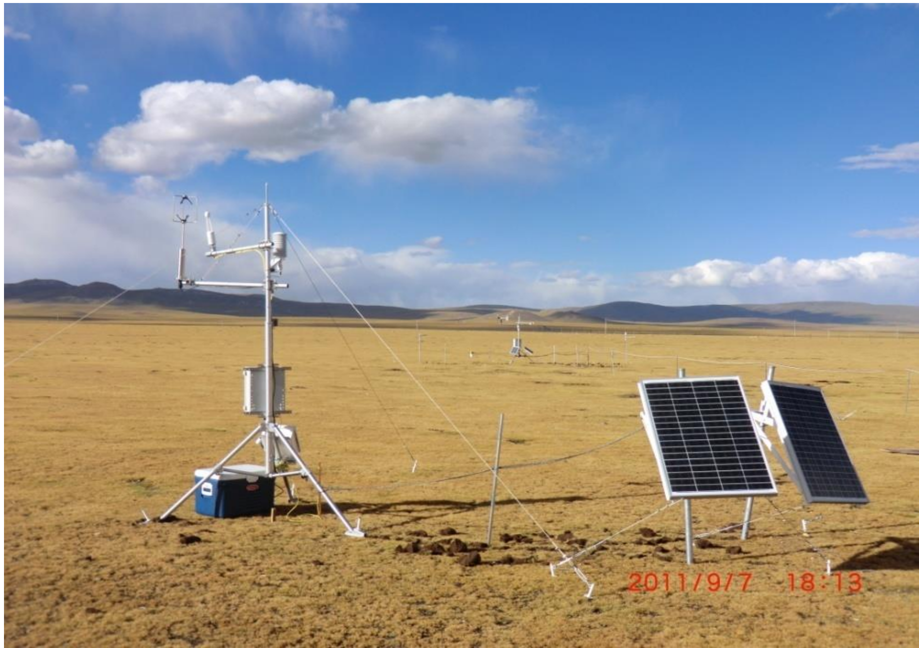

Modeling
In-situ
Measurements
VEMAP/
GAIM-NPP
EOS-MODIS
BigFoot
FLUXNET
GPPDI
10-1
100
101
102
103
104
105
Spatial scale (m)


5 km
flux
tower
tower
footprint
flux
tower
1 km
25 m
3rd order plot: vegetation composition, aboveground biomass, LAI, FAPAR
2nd order plot: above plus aboveground productivity
1st order plot; above plus belowground productivity
Small tree biomass sampling and cover composition plot
Understory clip plot for biomass. Also locations of minirhizotron tubes for fine root productivity (1st order plots only), LAI measurement
photo point for cover composition
Litter trap for aboveground productivity (2nd and 1st order plots only)

景观尺度


Google


禁牧区
放牧区
地空遥感
对接平台
土壤
呼吸
氮沉降
涡度
相关
能量
热量
隔
离
带
750m
1800m
微型
气象站
调查样地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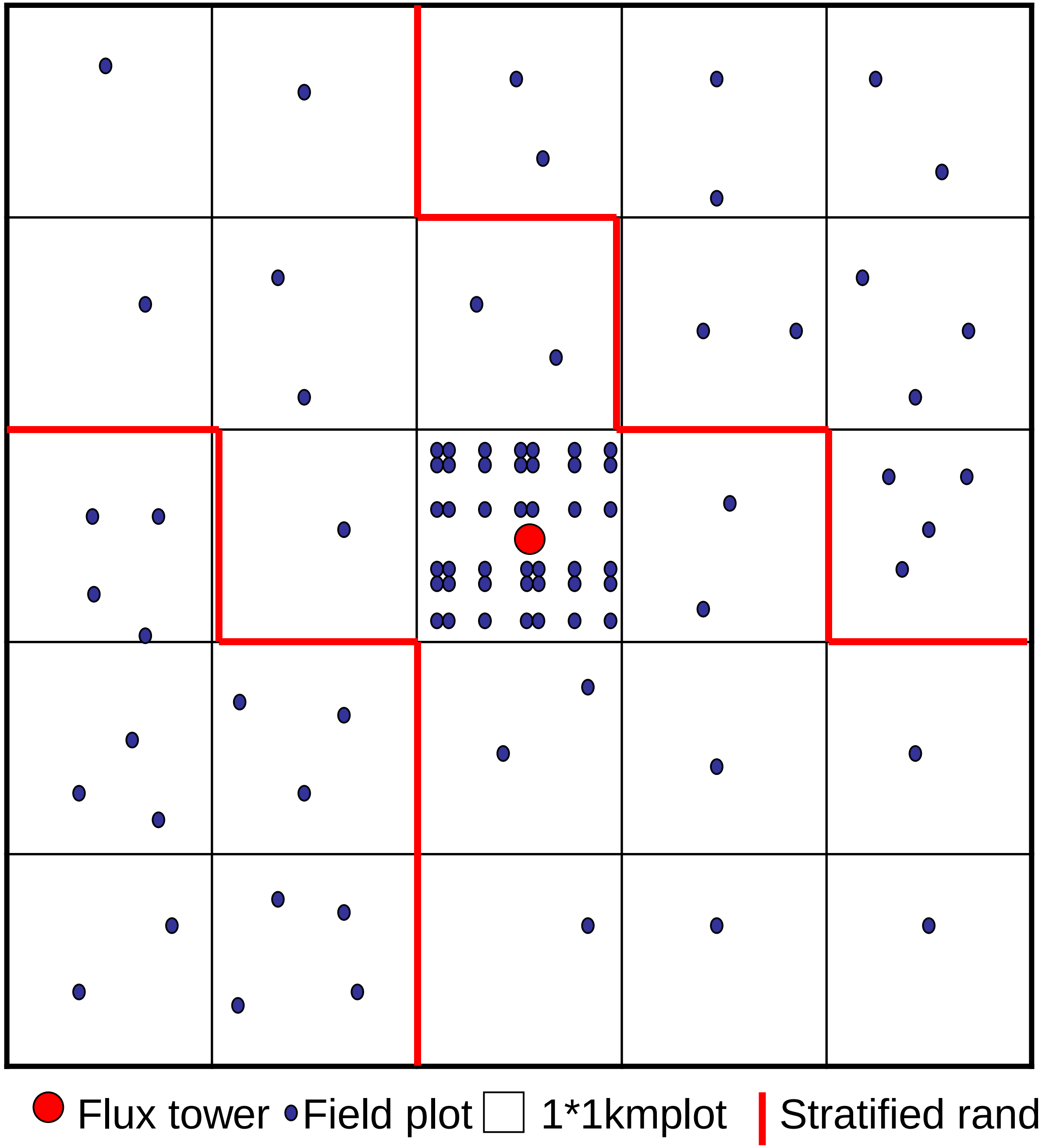
地面监测样点空间分布图



西藏草地地上生物量（AGB）

- 2011-2012年度共调查了90个样点，每个样点采集10个1m*1m样方的生物量
- 与采样同期的MODIS植被指数（250m）

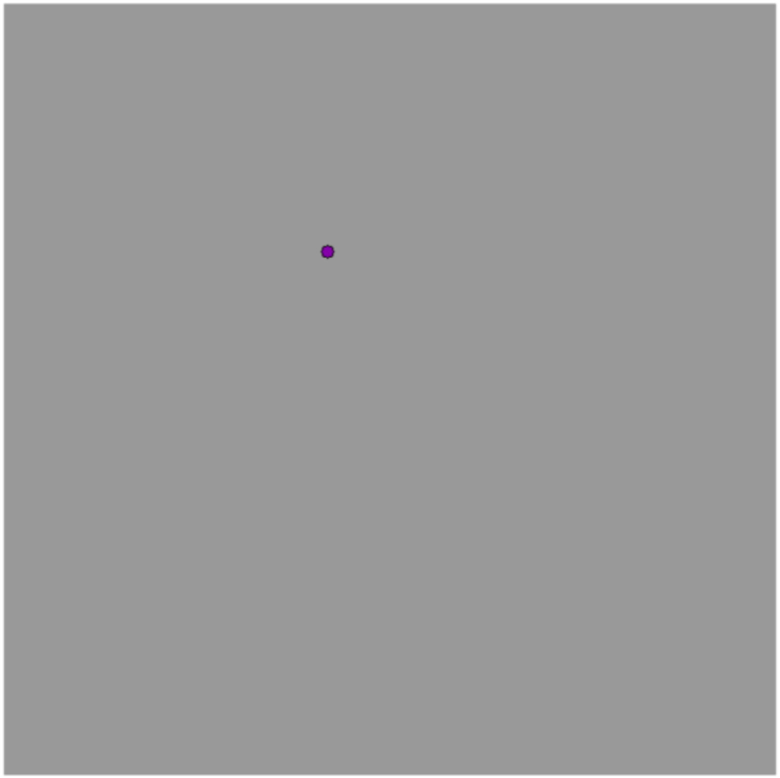
NDVI = $(\lambda_{NIR} - \lambda_R) / (\lambda_{NIR} + \lambda_R)$

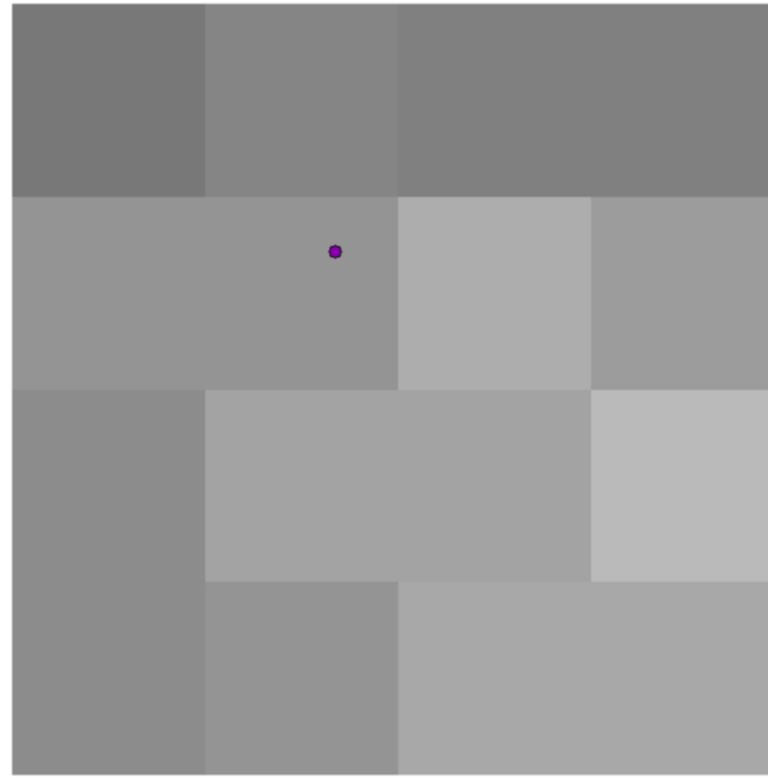
EVI = $2.5 (\lambda_{NIR} - \lambda_R) / (1 + \lambda_{NIR} + 6\lambda_R - 7.5\lambda_B$

MSAVI = $2 \lambda_{NIR} + 1 - ((2\lambda_{NIR} + 1) 2 - 8(\lambda_{NIR} - \lambda_R)) 0.5] / 2)$

NDWI = $(\lambda_{NIR} - \lambda_{SWIR}) / (\lambda_{NIR} + \lambda_{SWIR})$

西藏草地地上生物量（AGB）





MODIS Vegetation Indexes (VIs) of 1km and 250m

Four VIs: NDVI, EVI, MSAVI, NDWI

Three grassland types: alpine meadow, alpine steppe, desert steppe

西藏草地地上生物量（AGB）

不同草地类型与不同植被指数的回归系数比较

	NDVI		EVI		MSAVI		NDWI	
	250 m	1 km	250 m	1 km	250 m	1 km	250 m	1 km
Alpine meadow	0.237**	0.182*	0.179*	0.153*	**0.246****	0.191*	0.229**	0.225**
Alpine steppe	0.219**	0.242**	0.157*	0.208**	0.233**	0.247**	0.204**	**0.256****
Desert steppe	0.028	**0.231****	0.001	0.063	0.027	0.207**	0.004	0.013
Entire grassland	0.542**	0.532**	0.467**	0.485**	**0.553****	0.546**	0.500**	0.535**
Model	$AGB = -10.80 + 139.13\ MSAVI_{250m}$ $R^2_{boot} = 0.375\text{-}0.677$ $RSME_{boot} = 19.65\text{-}26.277$ $P_1 < 0.0001$ Moran's $I = 0.218$ ($P_2 = 0.03$)							

西藏草地地上生物量（AGB）

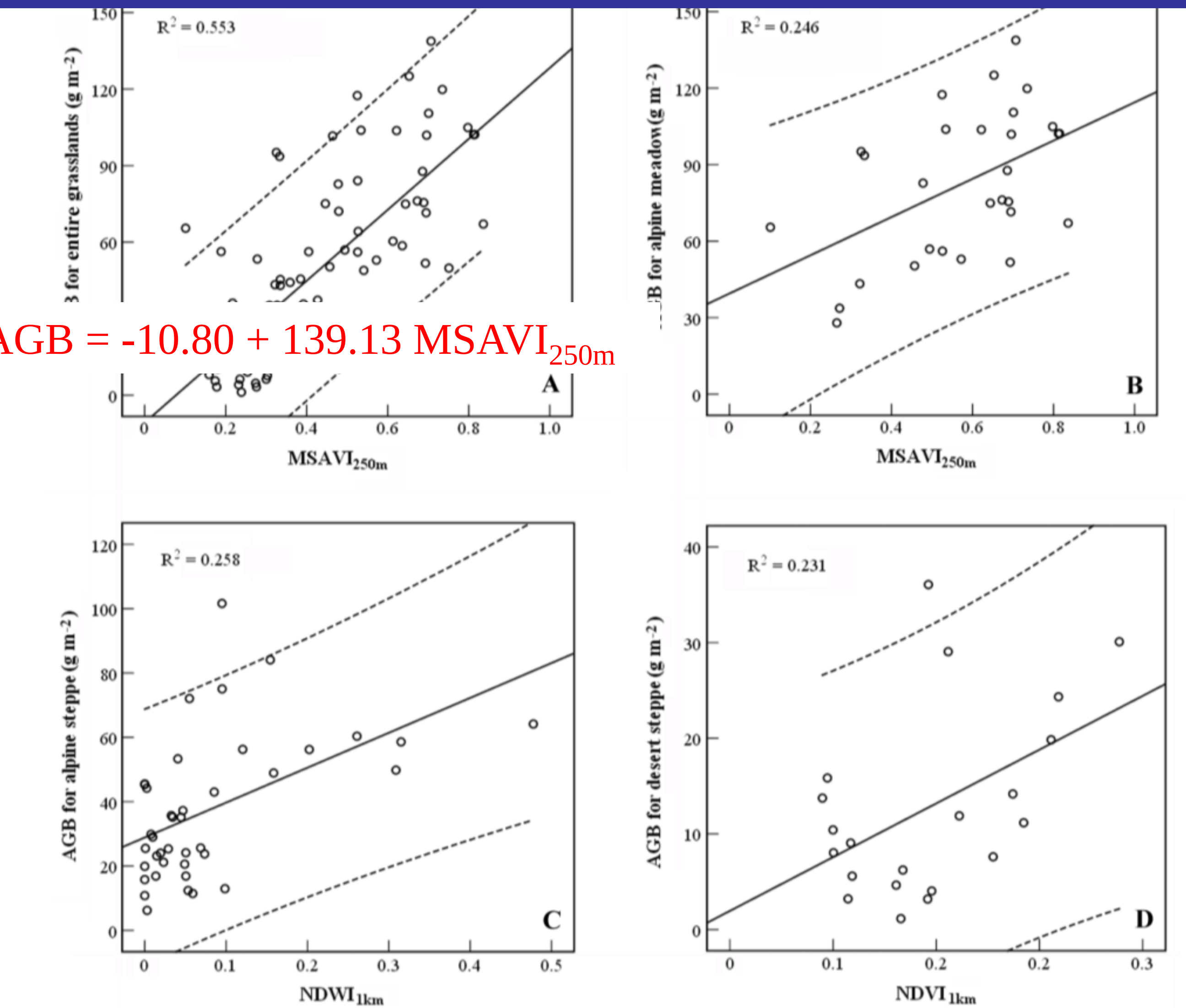
遥感影像分辨率变化对AGB-VI回归模型的影响

	R^2 – 250 m	R^2 – 1 km	*P*
VI			
NDVI	0.257 ± 0.213	0.297 ± 0.159	0.715[b]
EVI	0.201 ± 0.194	0.227 ± 0.182	0.273[b]
MSAVI	0.265 ± 0.217	0.298 ± 0.167	0.715[b]
NDWI	0.234 ± 0.204	0.257 ± 0.214	0.144[b]
Grassland type			
Alpine meadow	0.223 ± 0.030	0.188 ± 0.030	0.066[a]
Alpine steppe	0.203 ± 0.033	0.238 ± 0.021	0.068[b]
Desert steppe	0.015 ± 0.014	0.129 ± 0.107	0.068[b]
Entire grassland	0.516 ± 0.040	0.525 ± 0.027	0.465[b]

Paired Wilcoxon rank tests

差异不显著

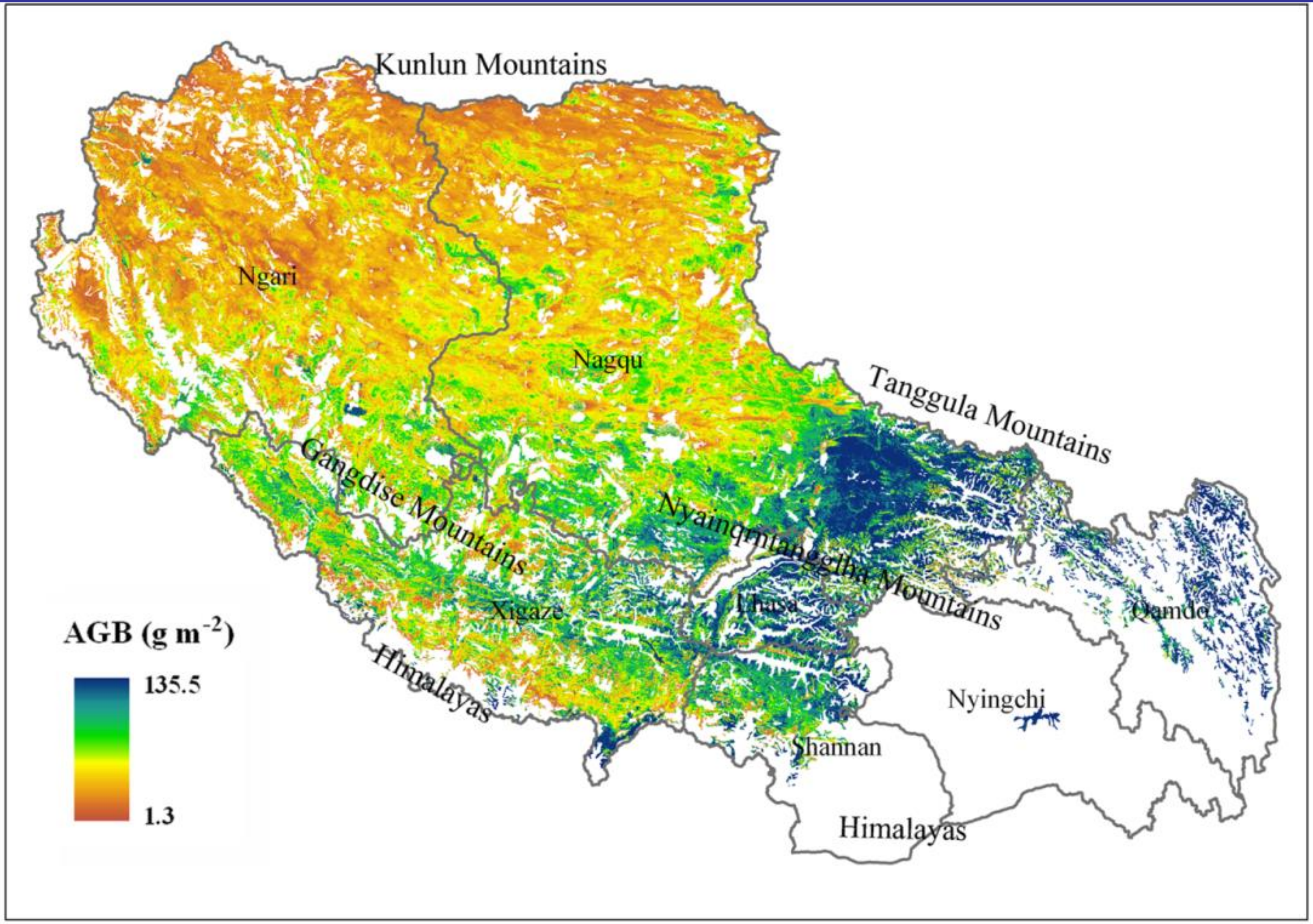
西藏草地地上生物量（AGB）



$AGB = -10.80 + 139.13\ MSAVI_{250m}$

不同草地类型与植被指数的最优回归关系

西藏草地地上生物量（AGB）



西藏草地AGB分布图

- 通量从local到区域的扩展

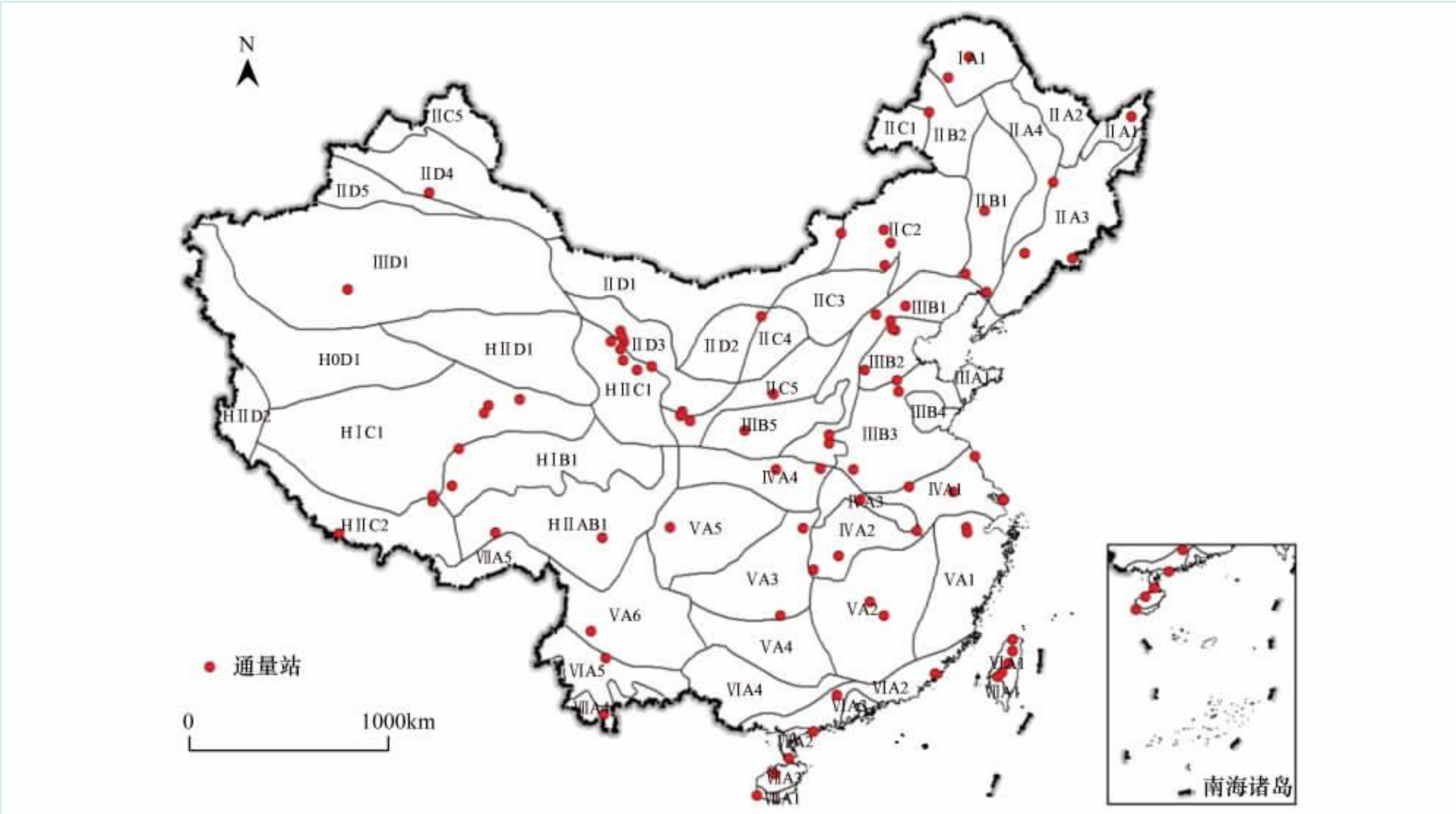
What makes up-scaling such a significant challenge is the nonlinearity between processes and variables and the spatial heterogeneity in surface and atmospheric properties.

Upscaling method:

1. Data-Driven
Data-driven approaches are based on empirical, statistical models and are trained with flux observations and various explanatory variables such as land cover, enhanced vegetation index (EVI), photosynthetically active radiation (PAR), and land surface temperature.

2. Data-assimilation approaches
simple ecosystem models and parameter estimation techniques. In this type of methods, flux observations are used to optimize the parameters of the models, and the optimized models are then used for the estimation of fluxes over broad regions.

通量站点在自然地理区划生态区中的分布

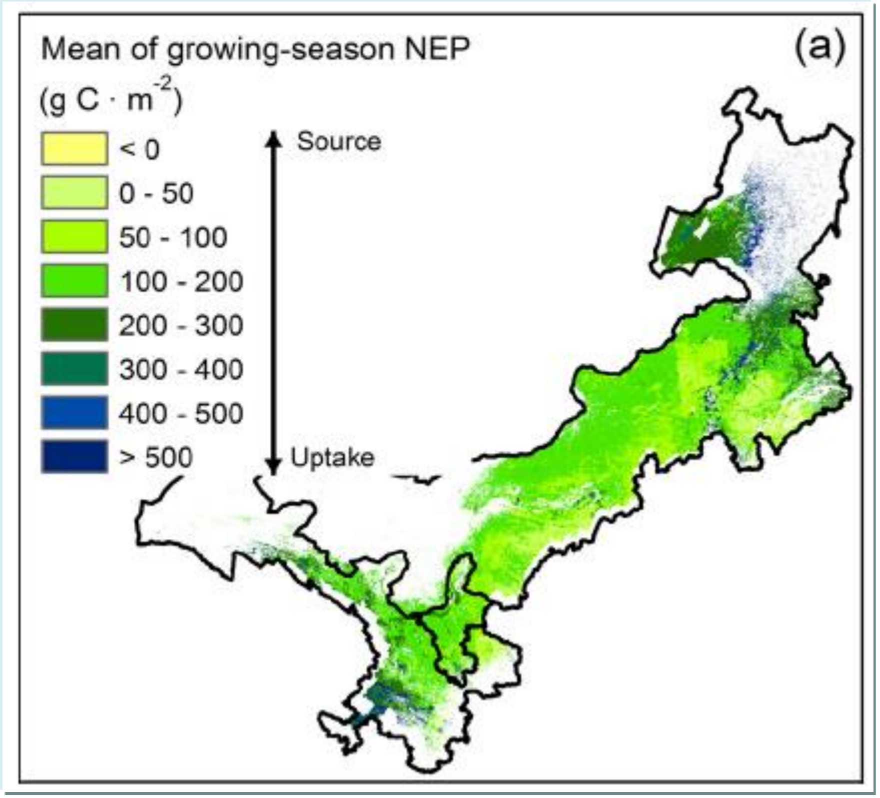


the half-hourly NEP data provided by flux-towermeasurements were integrated to the daily time scale, and thenaveraged over each 8-day period to match the 8-day compos-ite of the MODIS normalized difference vegetation index (NDVI)data.

Piecewise regression model

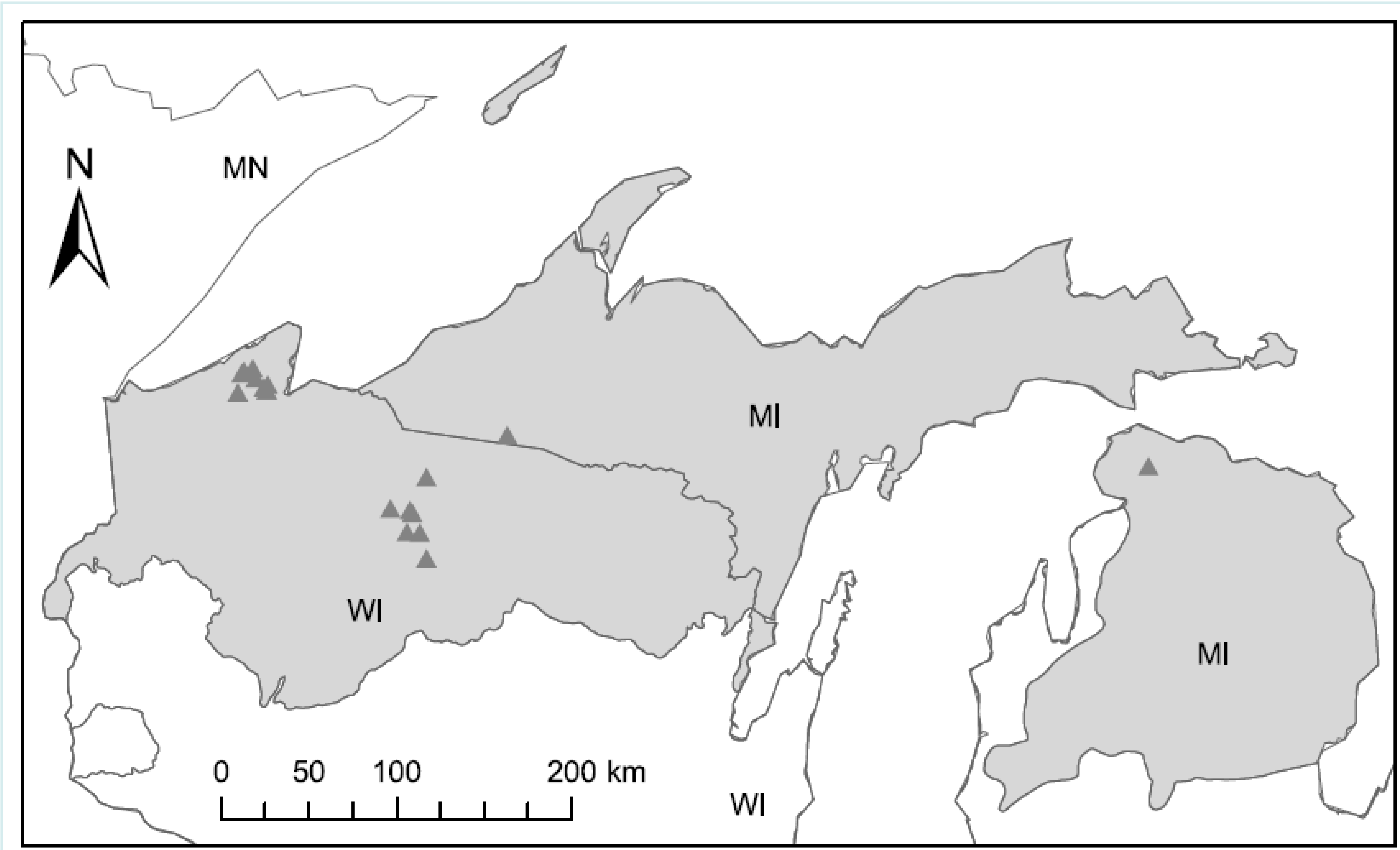
NEP = Remotely Sensed NDVI + phenological metrics + climate date (precipitation + temperature + PAR)

R can reach 0.97.



Zhang, et al., AFM, 2014

Chinese Grassland



3

Location and Site Characteristics of Eddy Covariance Flux Sites in the Chequamegon Ecosystem - Atmosphere Study (ChEAS)
Region Across Northern Wisconsin (WI) and Upper Peninsula of Michigan (MI)a

PFT	Site	ID	State	Lat	Lon	Data Period	Stand Age (years)	Dominant Cover	Reference
Evergreen forests (EF)	Intermediate Red Pine	IRP	WI	46.687	−91.153	2003	30	Red pine	*Noormets et al.* [2008]
	Mature Red Pine	MRP	WI	46.739	−91.166	2002–2005	70	Red pine, aspen	*Noormets et al.* [2008]
	Red Pine Clearcut	RPC	WI	46.649	−91.069	2005	7	Red pine	*Noormets et al.* [2008]
	Young Jack Pine	YJP	WI	46.619	−91.081	2004–2005	22	Jack pine	*Noormets et al.* [2008]
	Young Red Pine	YRP	WI	46.619	−91.081	2002	17	Red pine, jack pine	*Noormets et al.* [2008]
Deciduous forests (DF)	Intermediate Hardwood	IH	WI	46.730	−91.233	2003	26	Aspen	*Noormets et al.* [2008]
	Riley Creek	RC	WI	45.910	90.116	2005–2006	10	Aspen	This study
	Thunder Creek	TC	WI	45.671	90.053	2005–2006	7	Aspen	This study
	Willow Creek	WC	WI	45.806	−90.080	2000–2006	70	Sugar maple, basswood, green ash	*Cook et al.* [2004]
	Young Hardwood Clearcut	YHC	WI	46.722	−91.252	2002	13	Aspen, red maple	*Noormets et al.* [2008]
Mixed forests (MF)	Park Falls/WLEF	WLEF	WI	45.946	−90.272	2000–2005	~45	Northern hardwoods, aspen	*Davis et al.* [2003]
	Sylvania Wilderness Area	SWA	MI	46.242	−89.348	2001–2006	200	Eastern hemlock, sugar maple, birch	*Desai et al.* [2005]
	University of Michigan Biological Station	UMBS	MI	45.560	−84.714	2000–2003	79	Aspen, white pine, red oak, sugar maple	*Gough et al.* [2008]
Shrublands (Sh)	Pine Barren 1	PB1	WI	46.625	−91.298	2002–2003		Sweet fern, black cherry, willow, red pine	*Noormets et al.* [2008]
Woody wetlands (WW)	Lost Creek	LC	WI	46.083	−89.979	2001–2006	45	Alder-willow shrubs	*Sulman et al.* [2010]
Herbaceous wetlands (HW)	Wilson Flowage	WF	WI	45.817	90.172	2005–2006		Sedges and marsh grass	*Sulman et al.* [2010]
	South Fork	SF	WI	45.925	90.131	2005–2006		Sphagnum bog with Labrador Tea and LeatherLeaf	*Sulman et al.* [2010]

Modeling approach

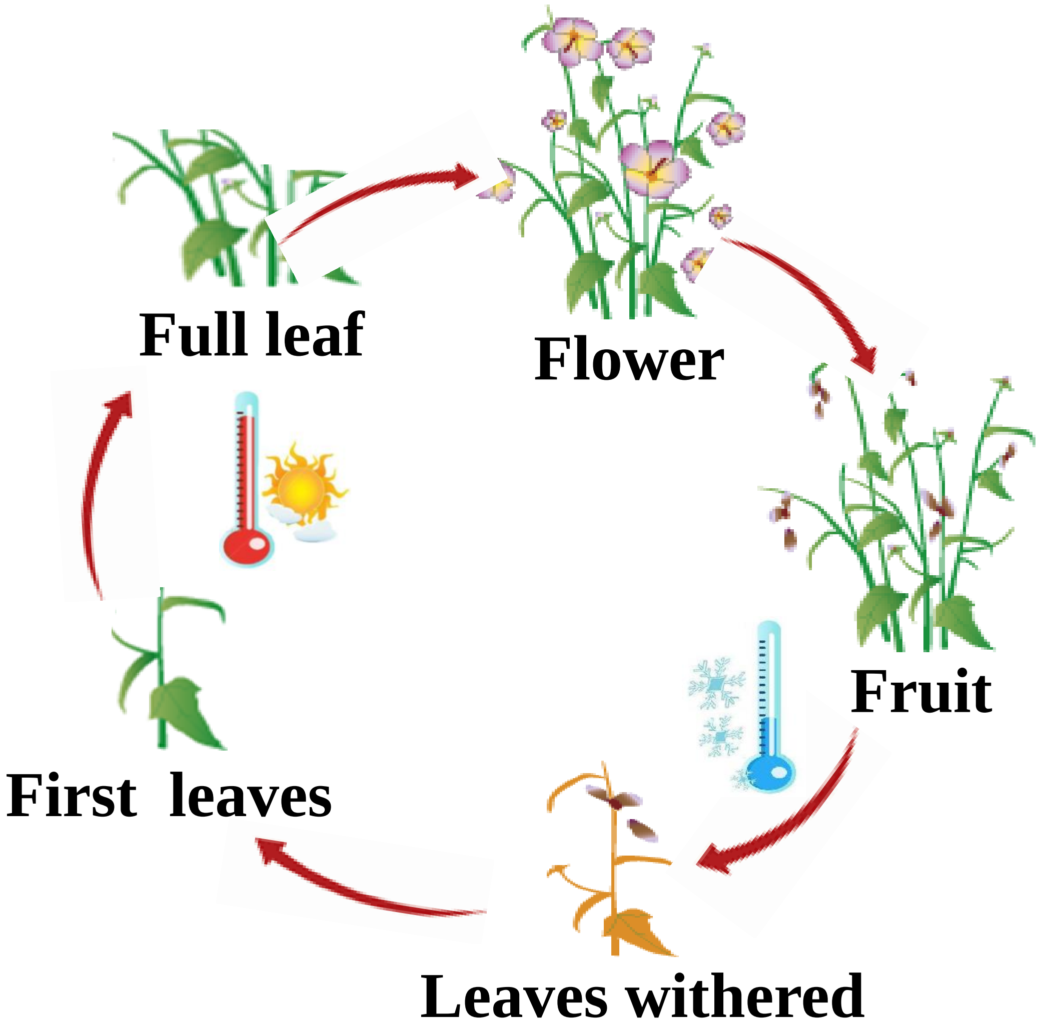
$$NEE = -\varepsilon_{\max} \times PAR \times fPAR \times W_s \times T_s + \left(R'_{ref} + \gamma \times AGB + \lambda \times GPP\right) \times e^{E_0\left(1/\left(T_{ref}-T_0\right)-1/(T-T_0)\right)}$$

ε max is the maximum light use efficiency (LUE)
PAR is the incident photosynthetically active radiation per time period
fPAR is the fraction of PAR absorbed by vegetation canopies,
Ws is the water scalar,
Ts is the temperature scalar,
R′ref is a parameter associated with the rate of respiration at the reference temperature,
Tref is the reference temperature,
E0 is an activation energy parameter that determines the temperature sensitivity,
T0 is a constant regression parameter.
Ws and Ts represent the limiting effects of water availability and temperature on GPP, respectively, and both scalars vary from 0 to 1.
Tref is set to 10° C, and T0 is kept constant at −46.02°

Xiao et al 2011, JGR.

物候定义

Phenology: the study of periodic plant and animal life cycle events and how these are influenced by variations in environment.



遥感能得出的四个物候阶段

1. Greenup: onset of photosynthetic activity
2. Maturity: plant green leaf area is maximum
3. Senescence: photosynthetic activity and green leaf area begin to rapidly decrease
4. Dormancy: physiological activity becomes near zero

Remote sensing way:

Remotely sensible phenological transition dates: the time at which the rate of change in curvature in the VI data exhibits local minima or maximums, or when the annual cycle transitions from one approximately linear stage to another.

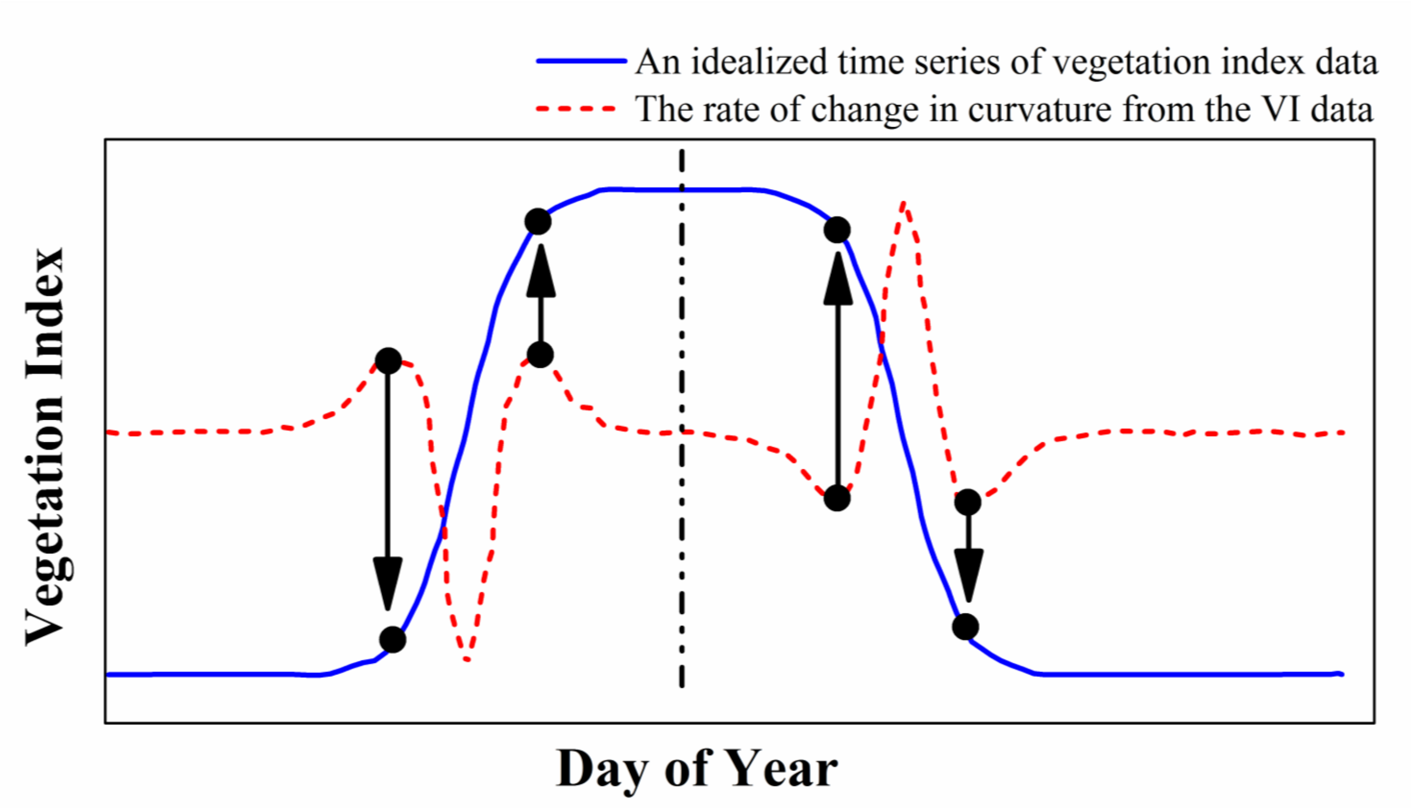
遥感能感出的地面相应的物候现象

DMA – First sustained flush of greenness

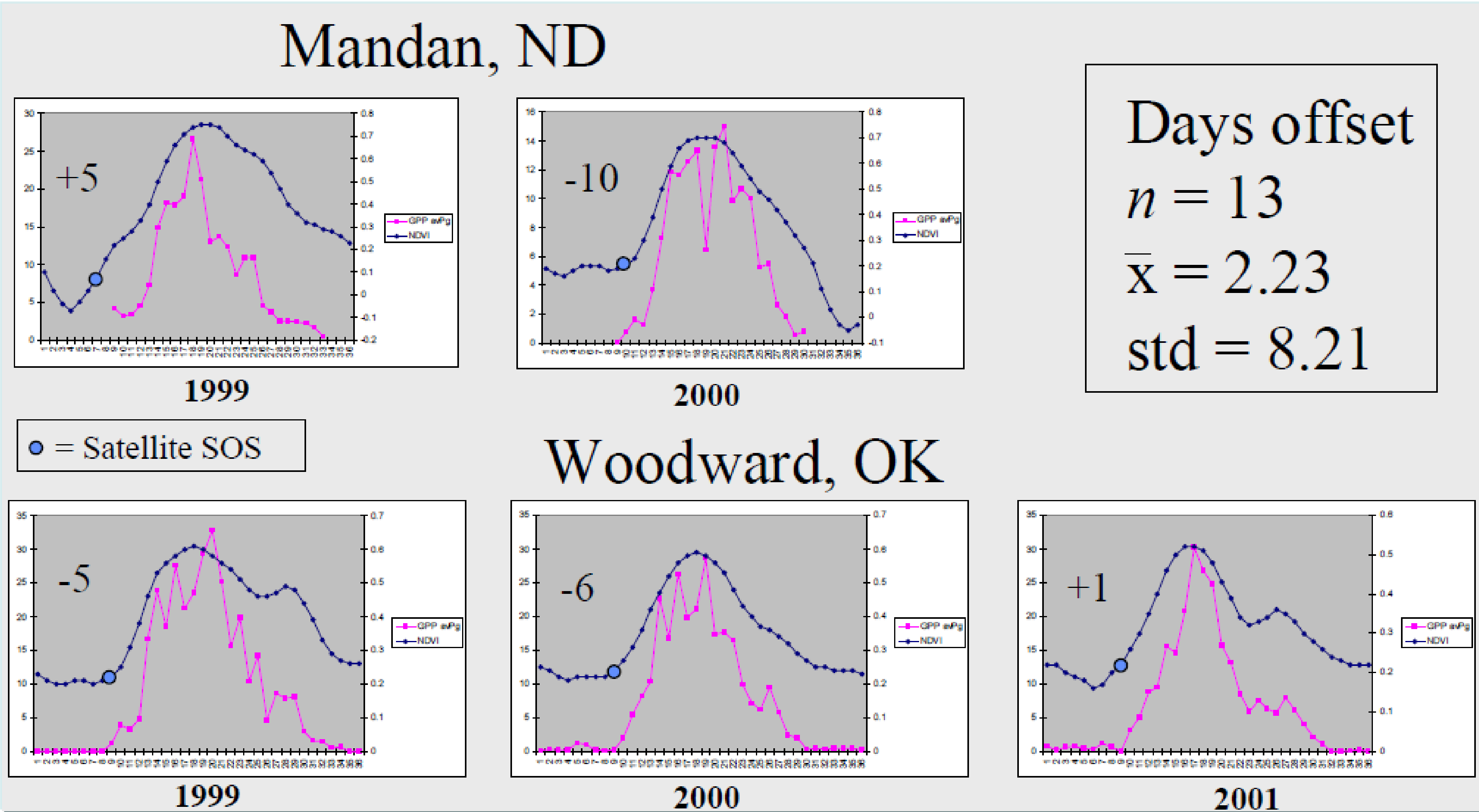
Half-max – Primary leaf expansion

Greatest increase – early season growth peak

Inflection point – environmental conditions preceding first flush



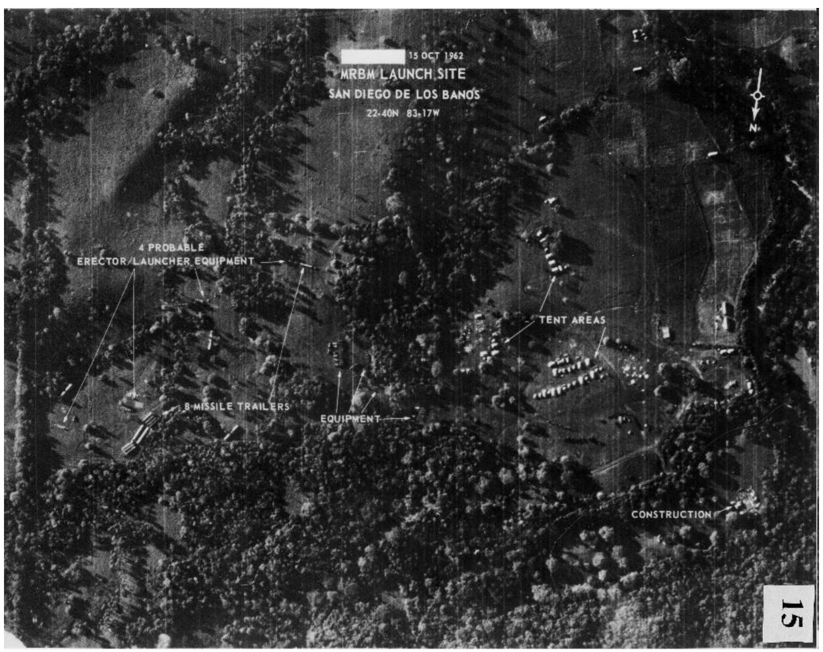
遥感的SOS时间，通量观测得出的GPP变化趋势

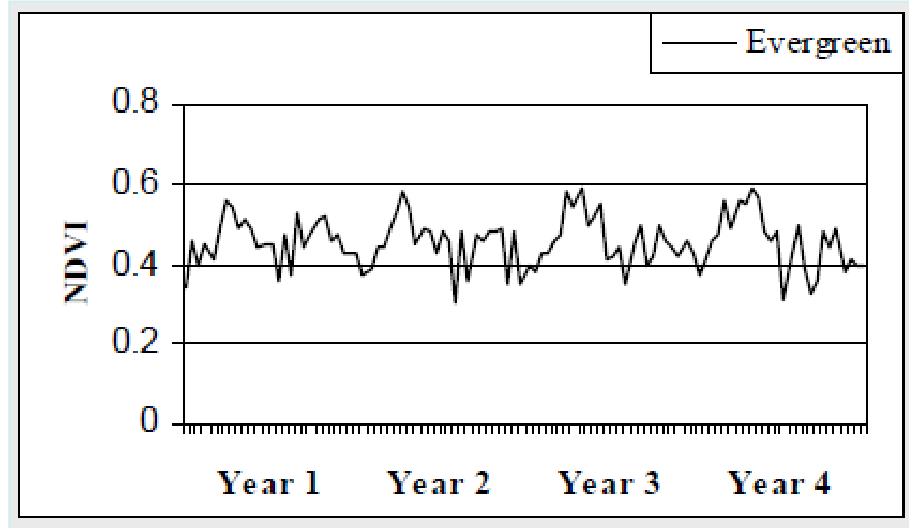


Reed, USGS, Sioux Falls, SD

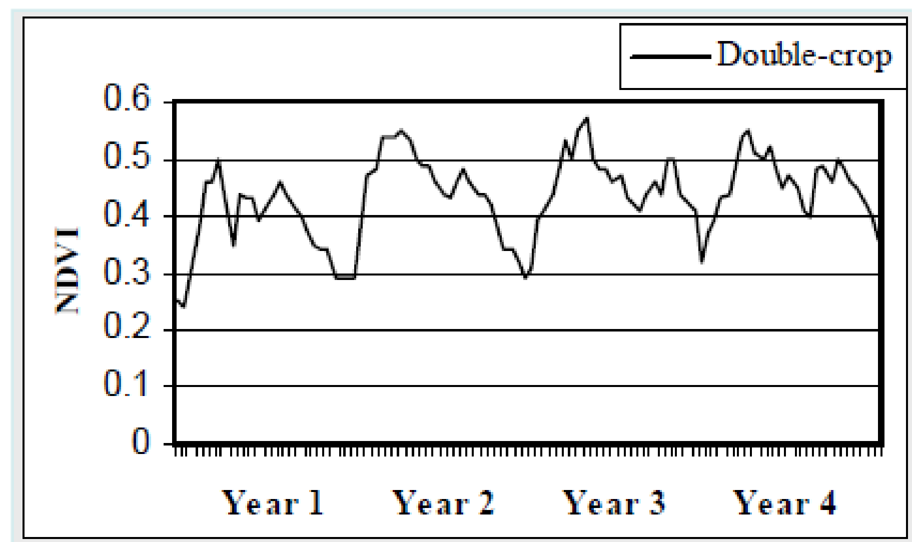
用遥感监测物候存在的问题

1. Variations in community composition
2. Micro- and regional climate regimes
3. Soil and land management
4. Traditional field measures are plant/plant type specific



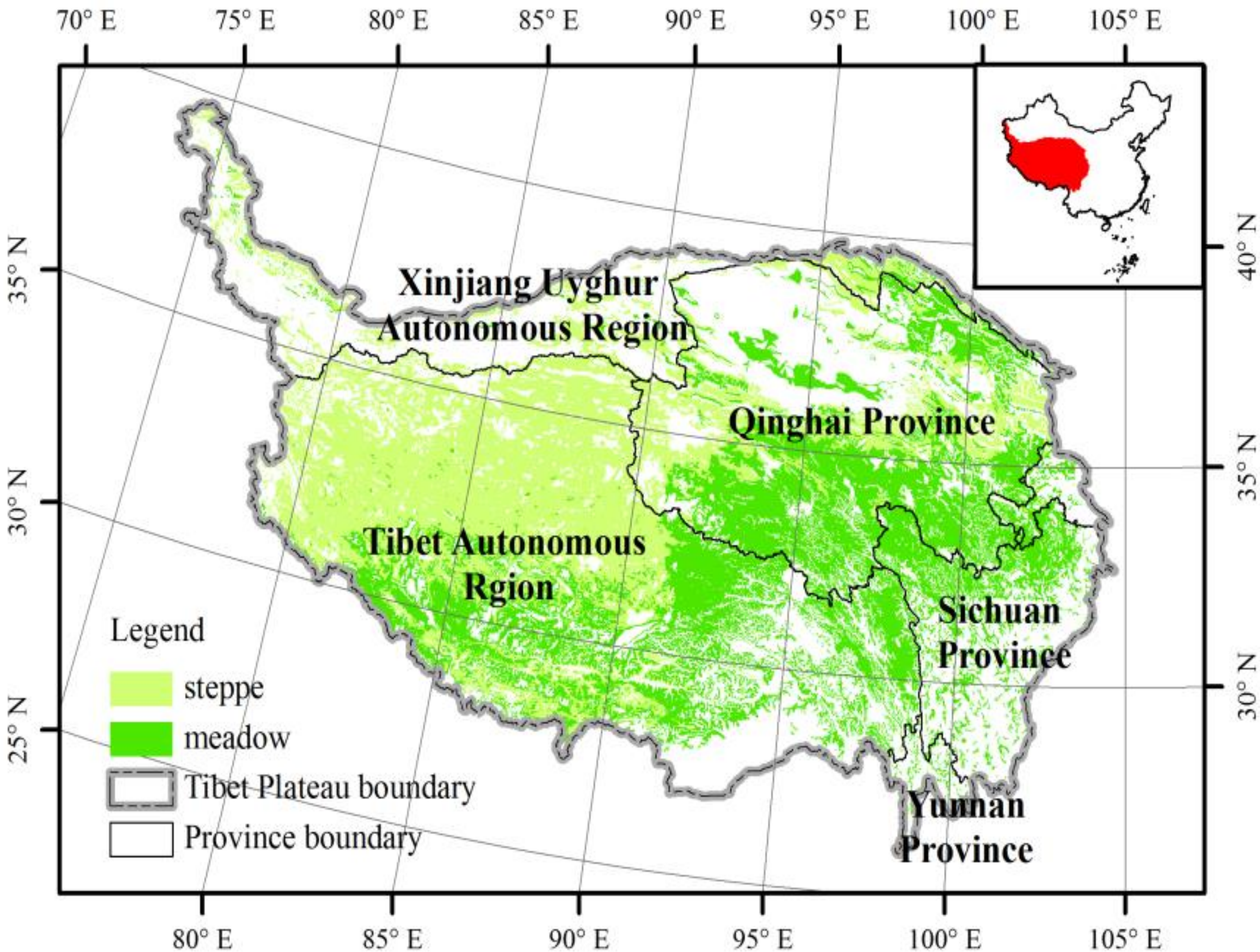


Bimodal growing seasons



Evergreen systems with differing seasonality

青藏高原草地的分布



70° E
75° E
80° E
85° E
90° E
95° E
100° E
105° E
35° N
30° N
25° N
40° N
35° N
30° N
Xinjiang Uyghur
Autonomous Region
Qinghai Province
Tibet Autonomous
Rgion
Sichuan
Province
Yunnan
Province
Legend
steppe
meadow
Tibet Plateau boundary
Province boundary
80° E
85° E
90° E
95° E
100° E
105° E

高空间精度遥感影像

◆Landsat

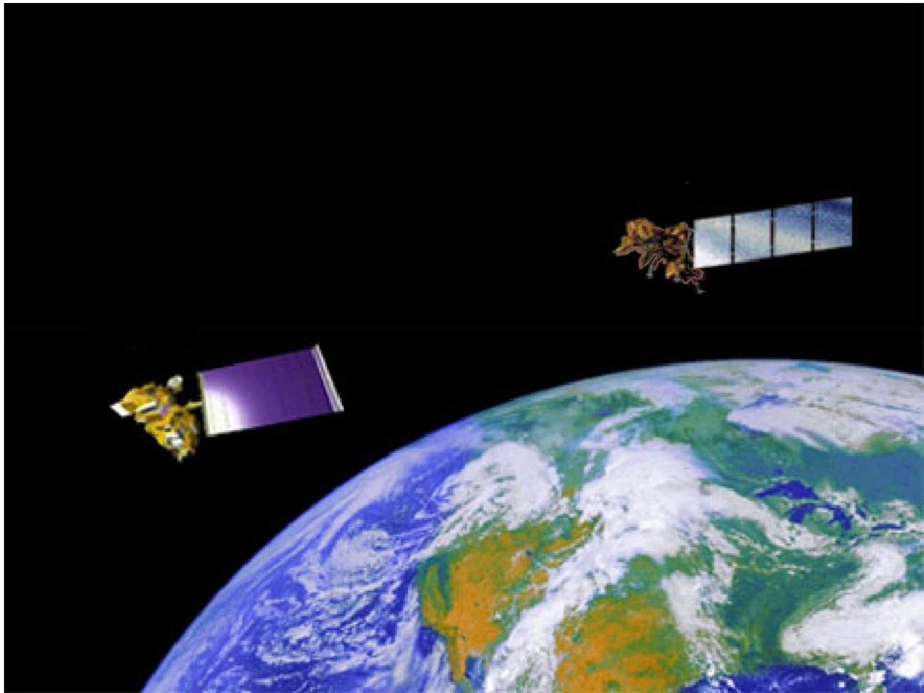
1972-present, 30-, 25- m resolution

◆SPOT

1986-present, 20m multispectral

◆IKONOS

1999-present, high spatial resolution, 4m multispectral



高时间精度遥感影像

- AVHRR
  - 1981-present, (8km) global coverage
  - 1989-present, (1km) conterminous US
- SPOT Vegetation
  - 1998-present, 1km resolution
- MODIS
  - 2000-present, 250m, 500m, 1km resolutions

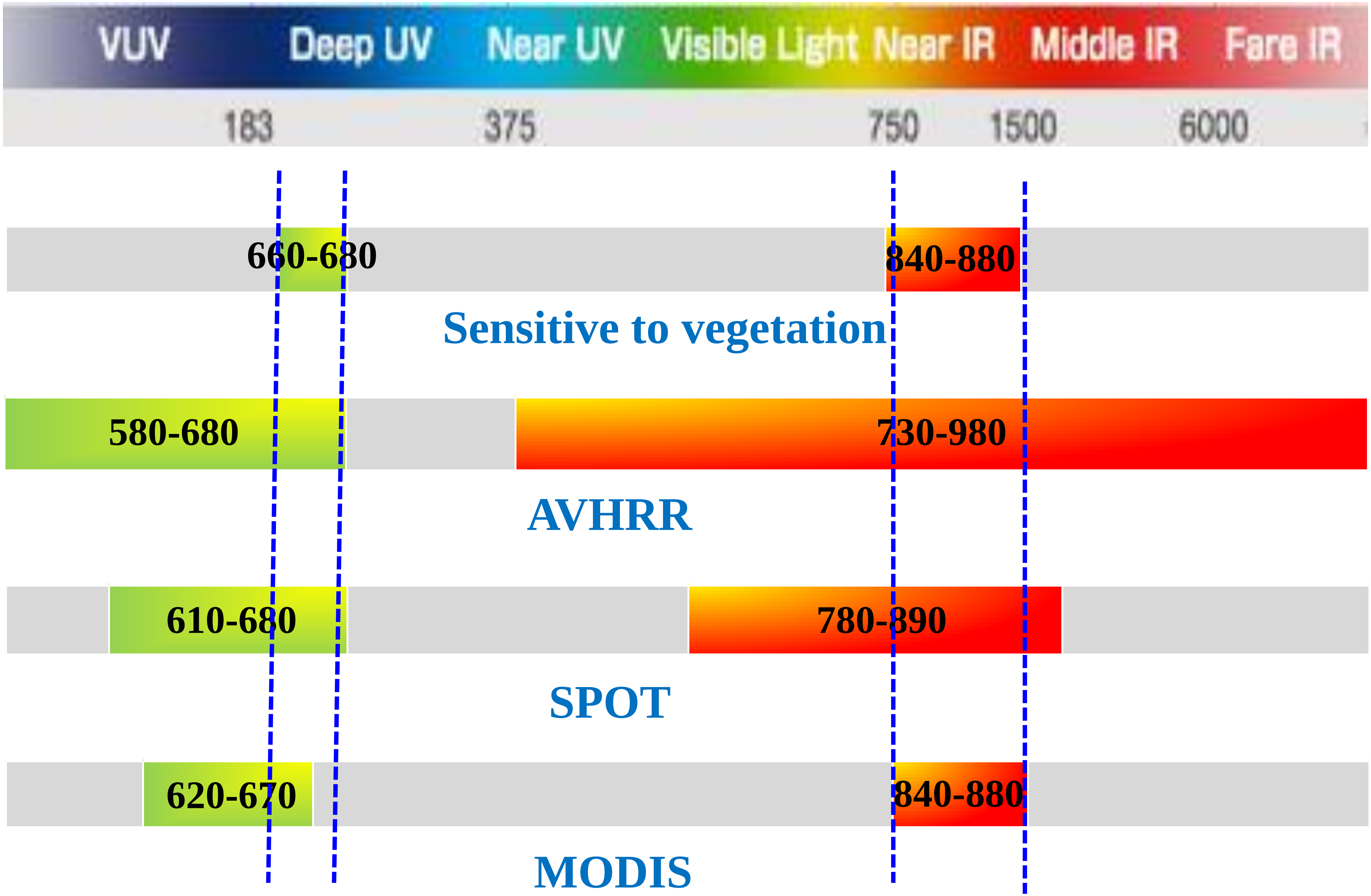
Keep in mind

The AVHRR sensors were not originally intended for vegetation study (Cracknell, 2001) using indices like NDVI (Rouse et al., 1973). When the potential and shortcomings of AVHRR for vegetation studies became a subject of research (Holben, 1986; Tucker et al., 1983)

modifications to optimise the sensor for vegetation studies were not prioritised due to data continuity considerations. Consequently, there are several aspects of AVHRR sensor design that are not ideal for vegetation trend studies (Steven et al., 2003; Teillet et al., 1997; van Leeuwen et al., 1999), such as post-launch degradation in sensor calibrations and drift in the satellite overpass times. The seasonal var-

Fensholt and Proud, 2011

各遥感数据红光和远红外波段分布



Unit: nm

AVHRR 用过的传感器

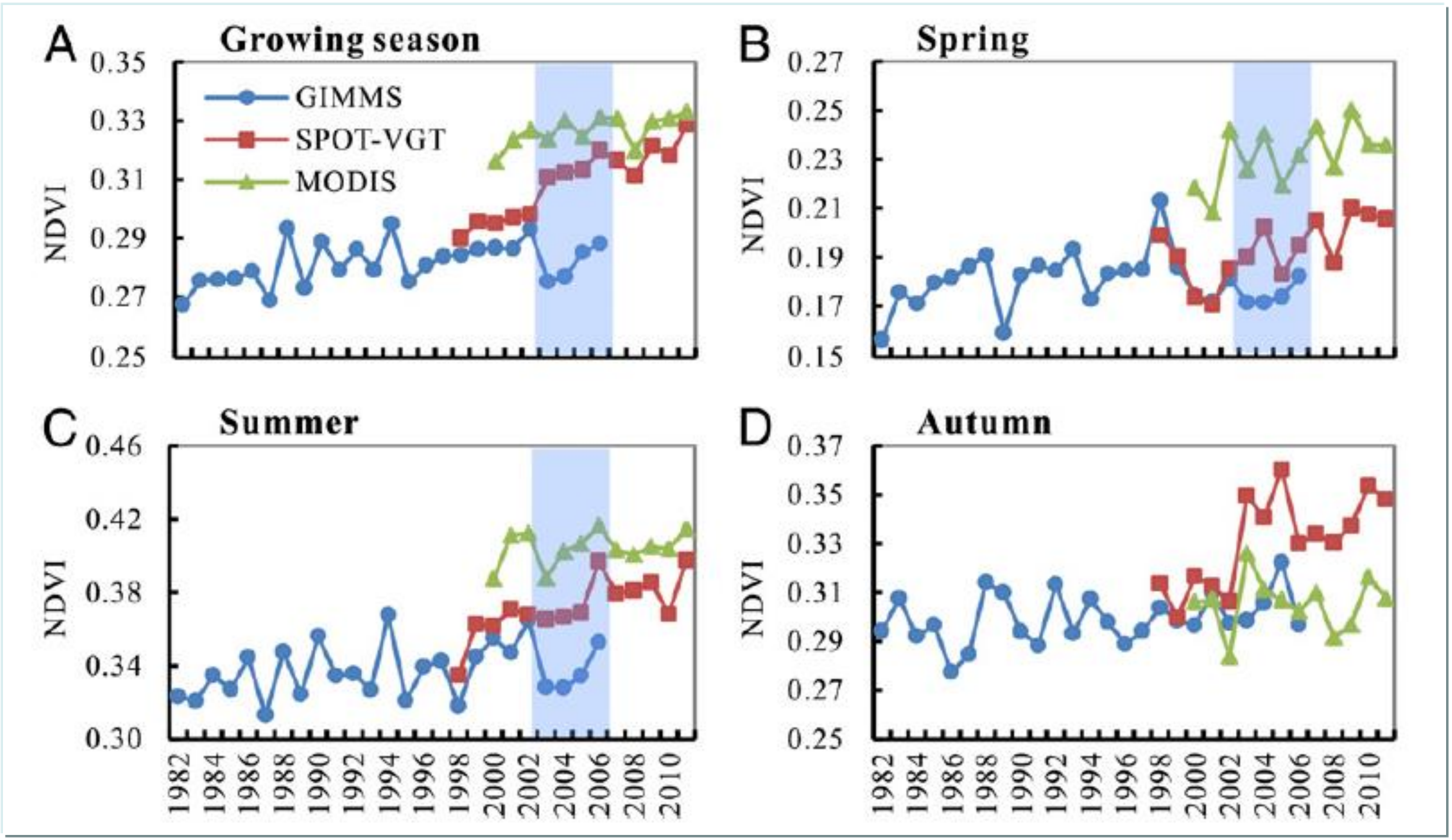
Period		Sensor
1985/01/21	1988/11/01	NOAA-9
1988/11/11	1994/10/21	NOAA-11
1995/01/11	2001/01/11	NOAA-14
2001/01/21	2002/12/21	NOAA-16
2003/01/01	2005/12/12	NOAA-17
2006/01/01	2009/12/21	NOAA-18
2010/01/01	2011/12/21	NOAA-19

Sensor	VIS (nm)	NIR (nm)	Radiometric	Spatial
AVHRR	580-680	725-1100	0-1023	8km (1.1km)
MODIS	620-670	841-876	0-4095	250m
VIIRS	600-680	846-885	0-1023	375m

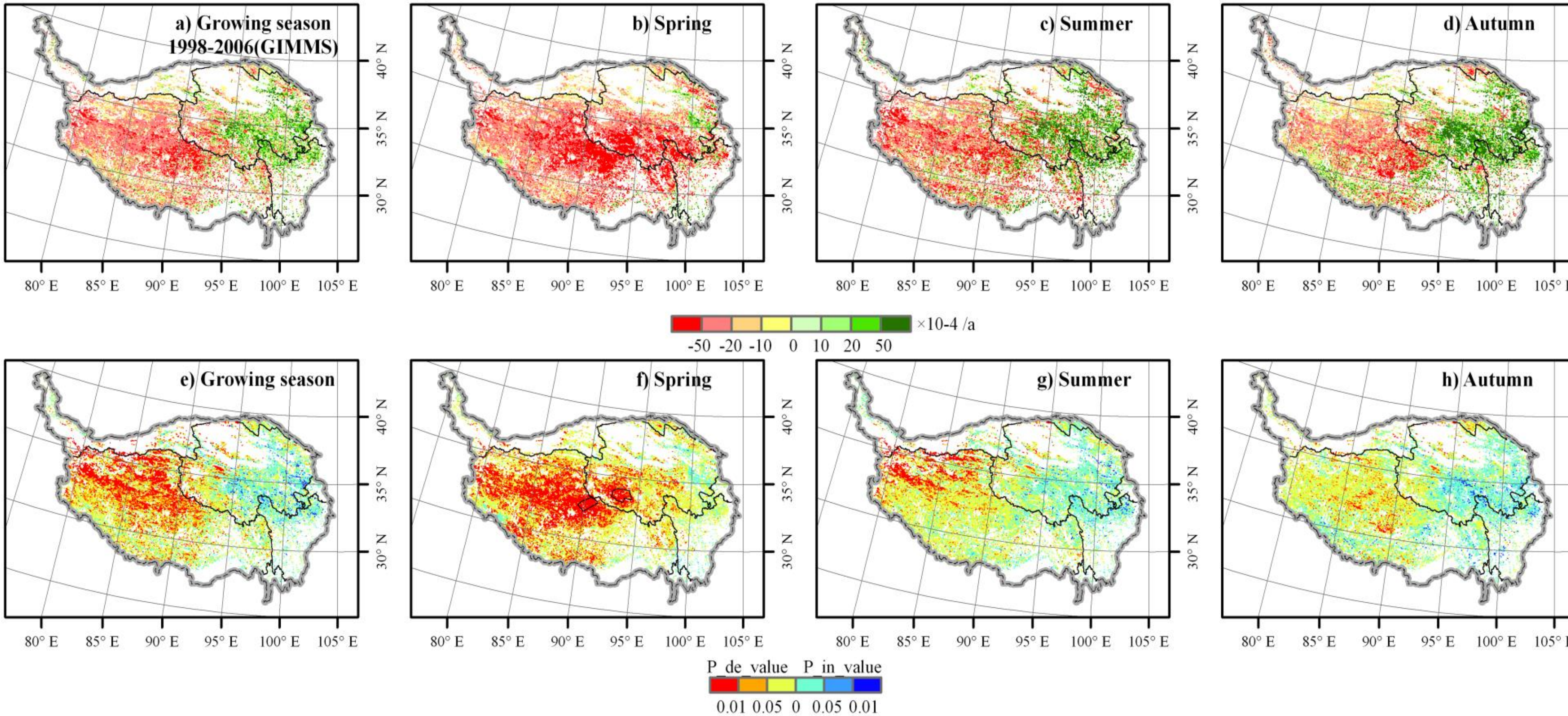
NDVI = (NIR-VIS)/(NIR+VIS)

Latifovic et al., 2012

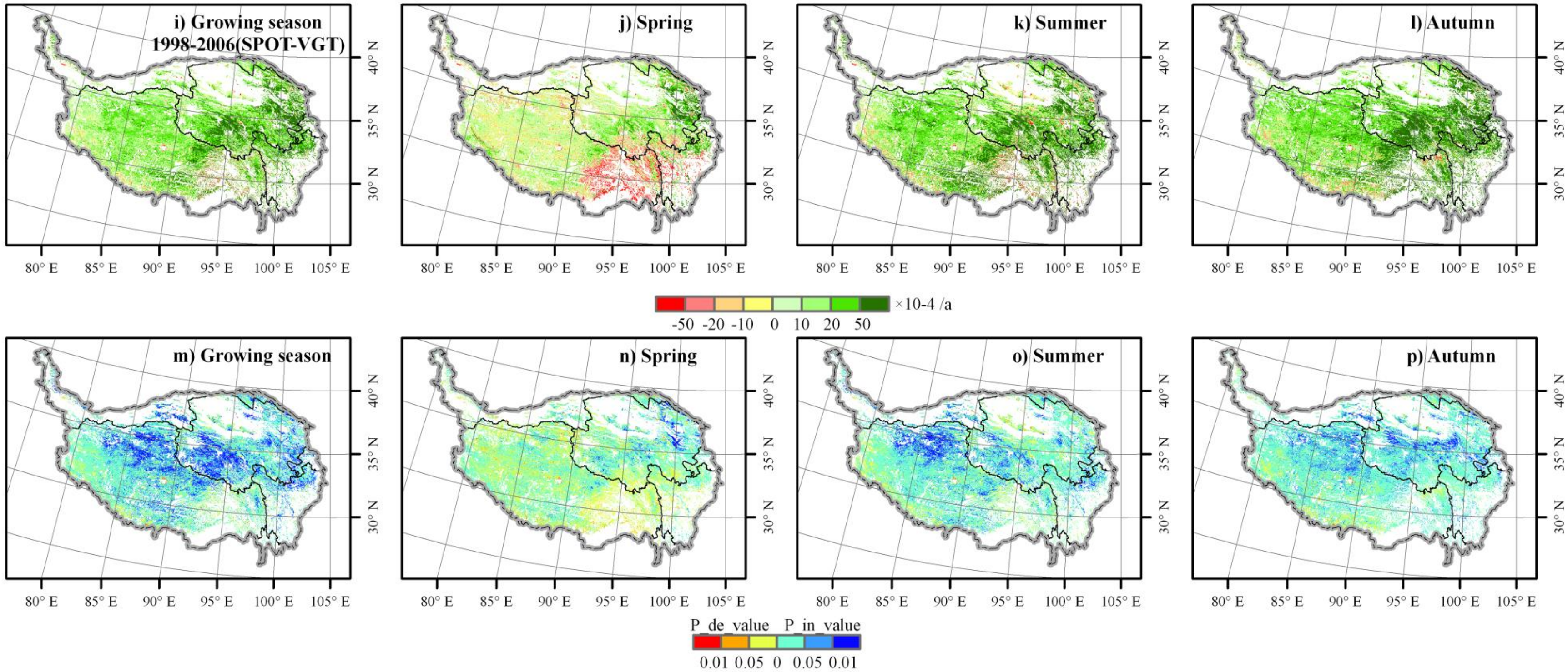
青藏高原NDVI变化趋势图



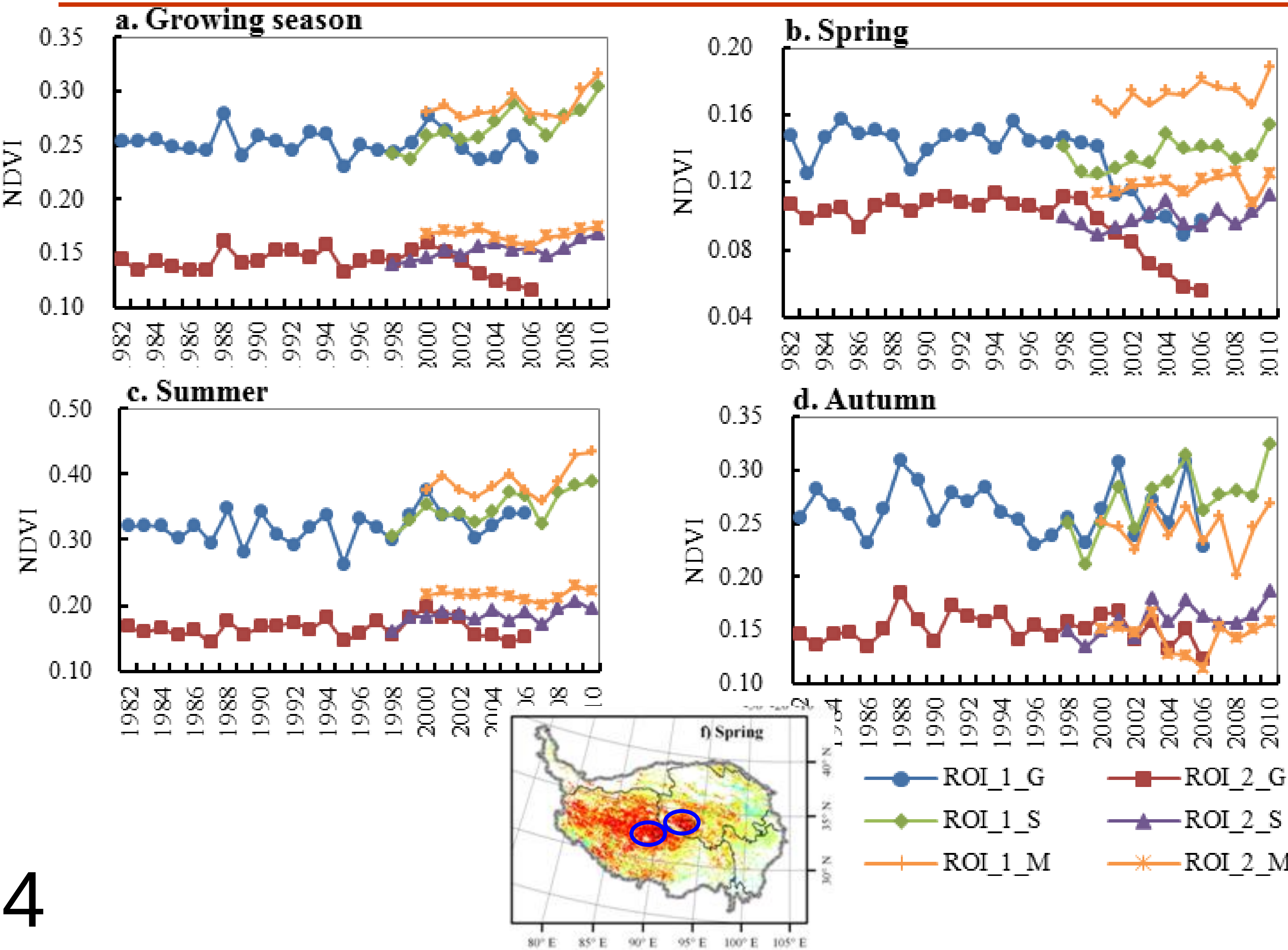
NDVI趋势（1998-2006）空间格局（基于GIMMS）



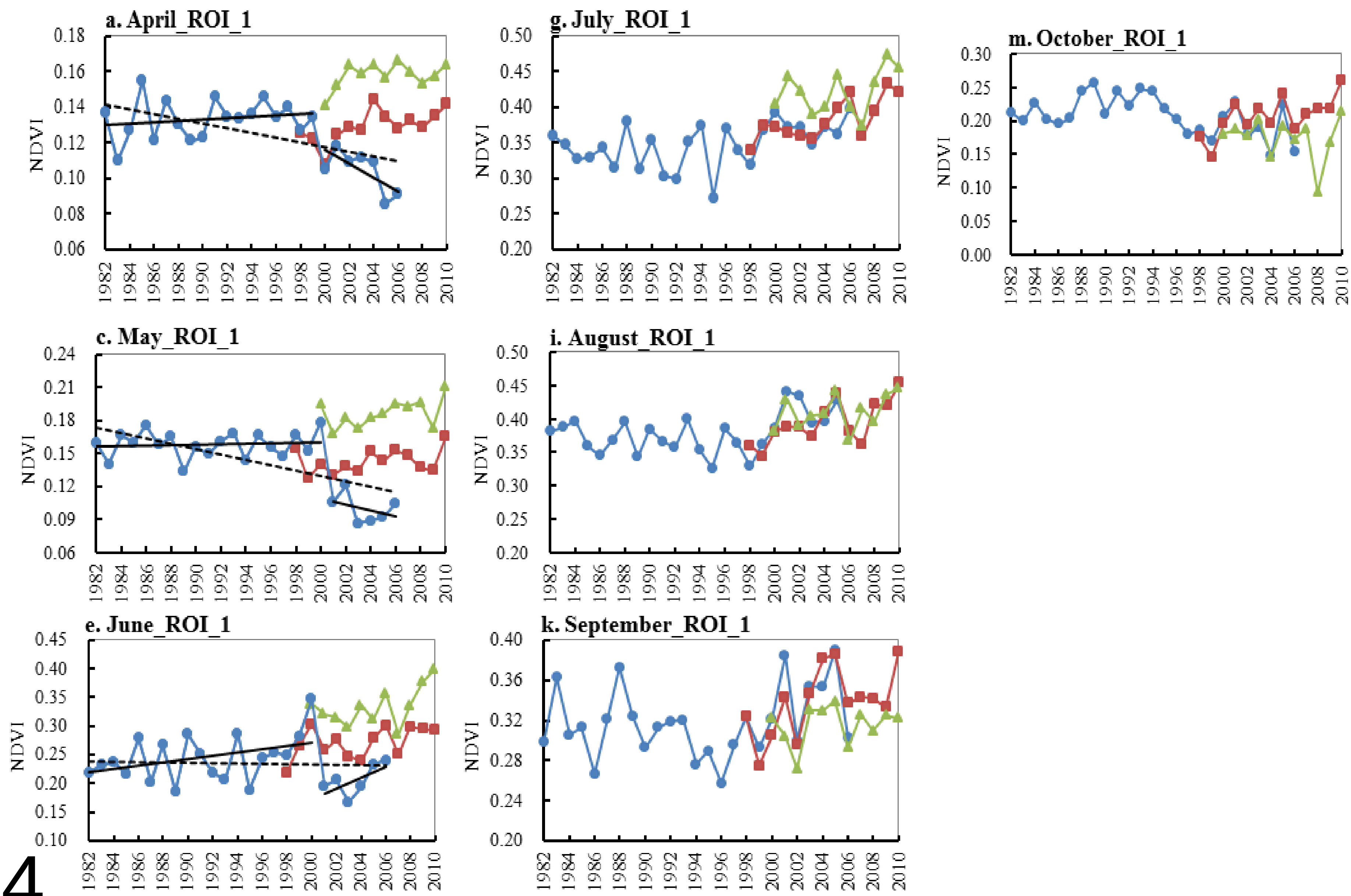
NDVI趋势（1998-2006）空间格局 （基于SPOT）



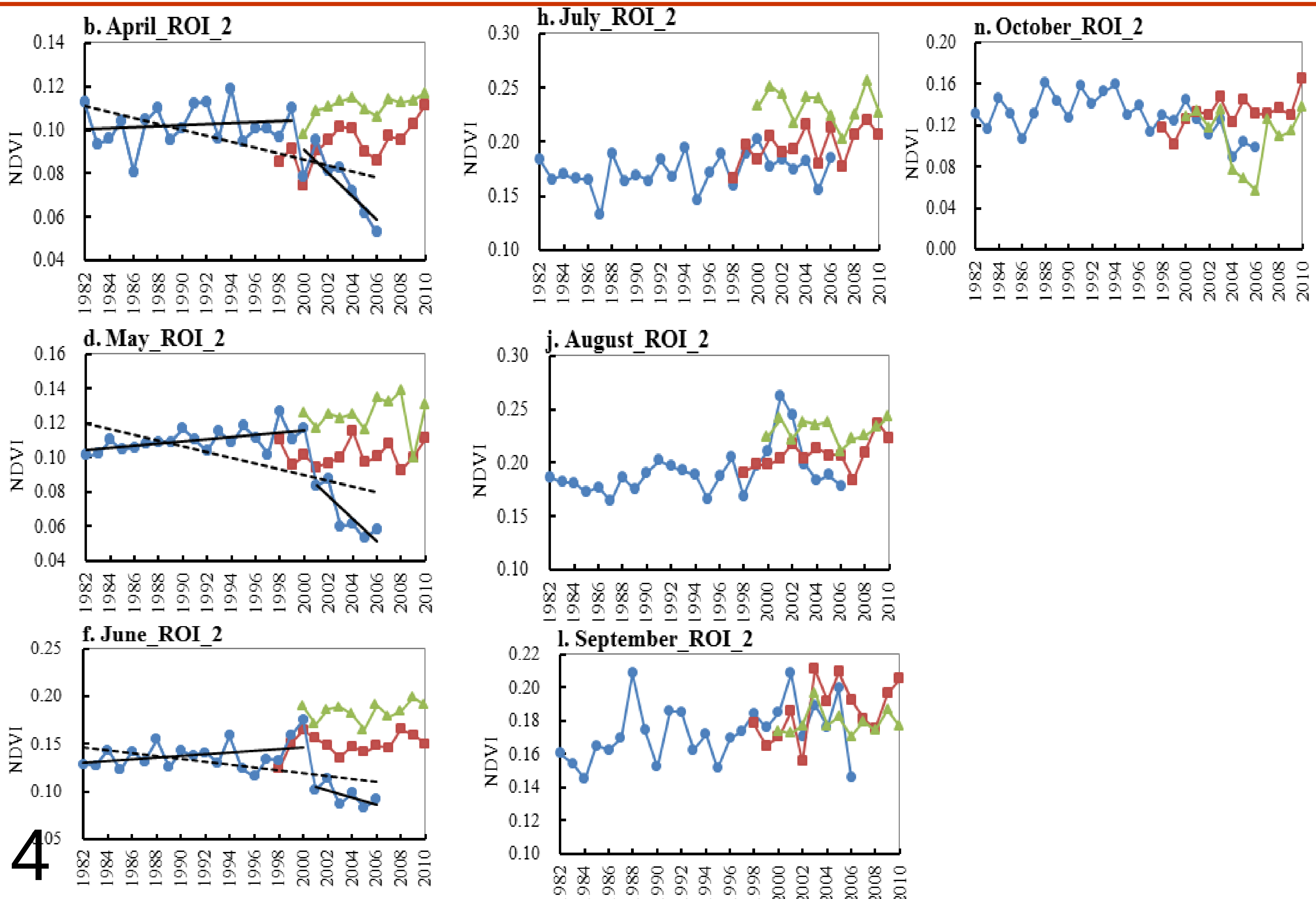
Area Of Interest (AOI) 内基于GIMMS, SPOT和MODIS数据NDVI变化趋势图（分季节）



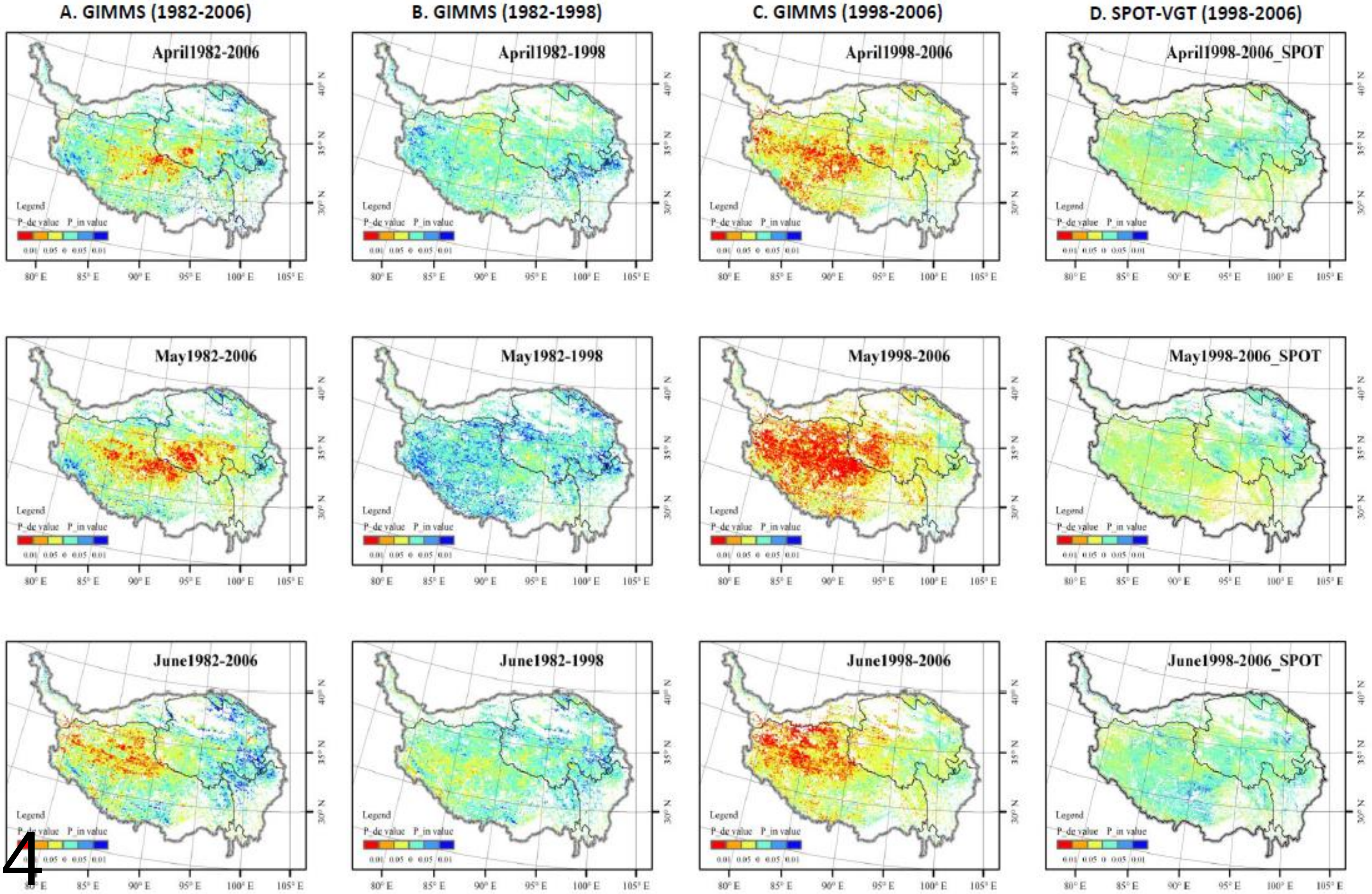
Area Of Interest (AOI1) 内基于GIMMS, SPOT和MODIS数据NDVI变化趋势图 （按月份）



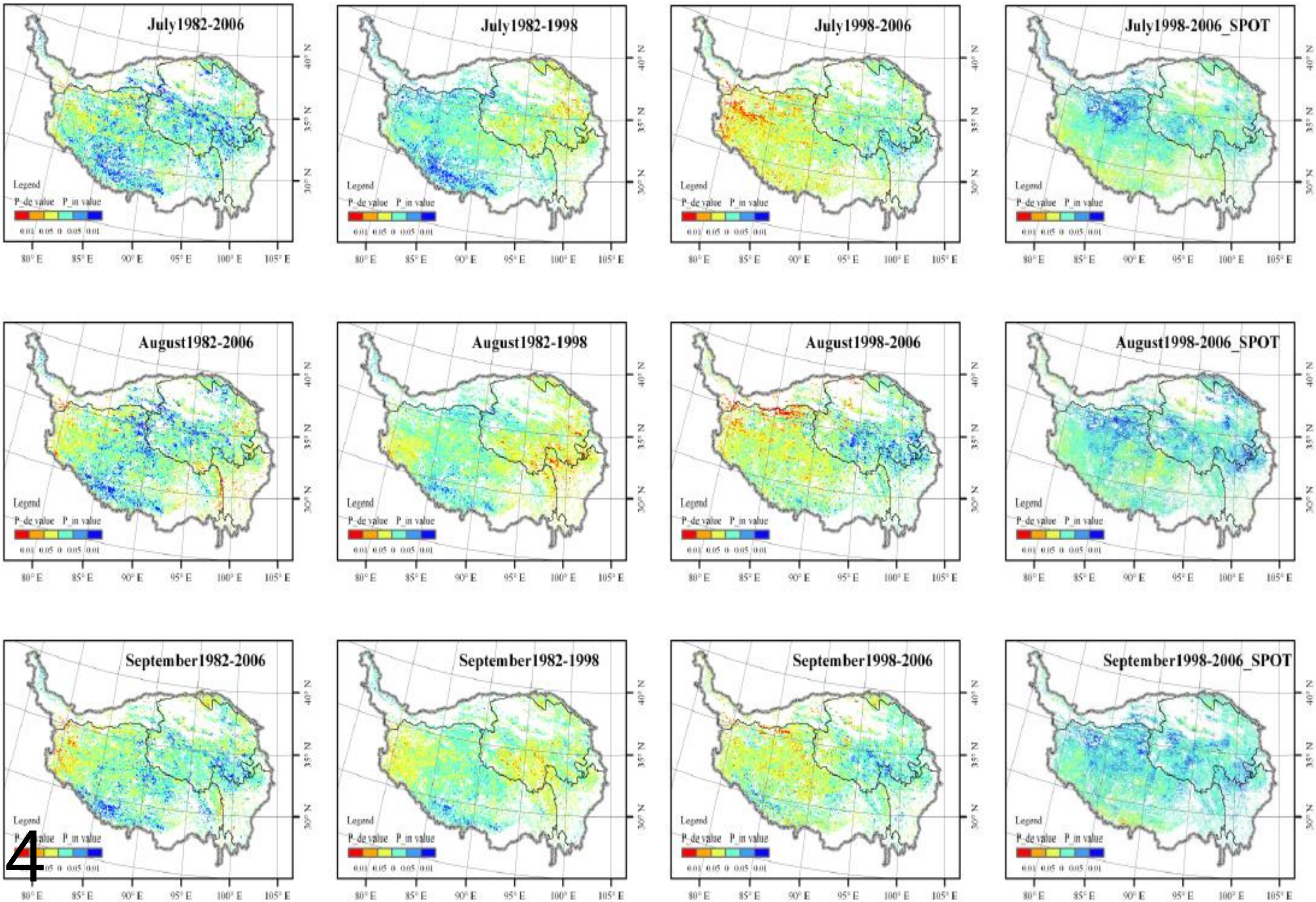
Area Of Interest (AOI2) 内基于GIMMS, SPOT和MODIS数据 NDVI变化趋势图 （按月份）



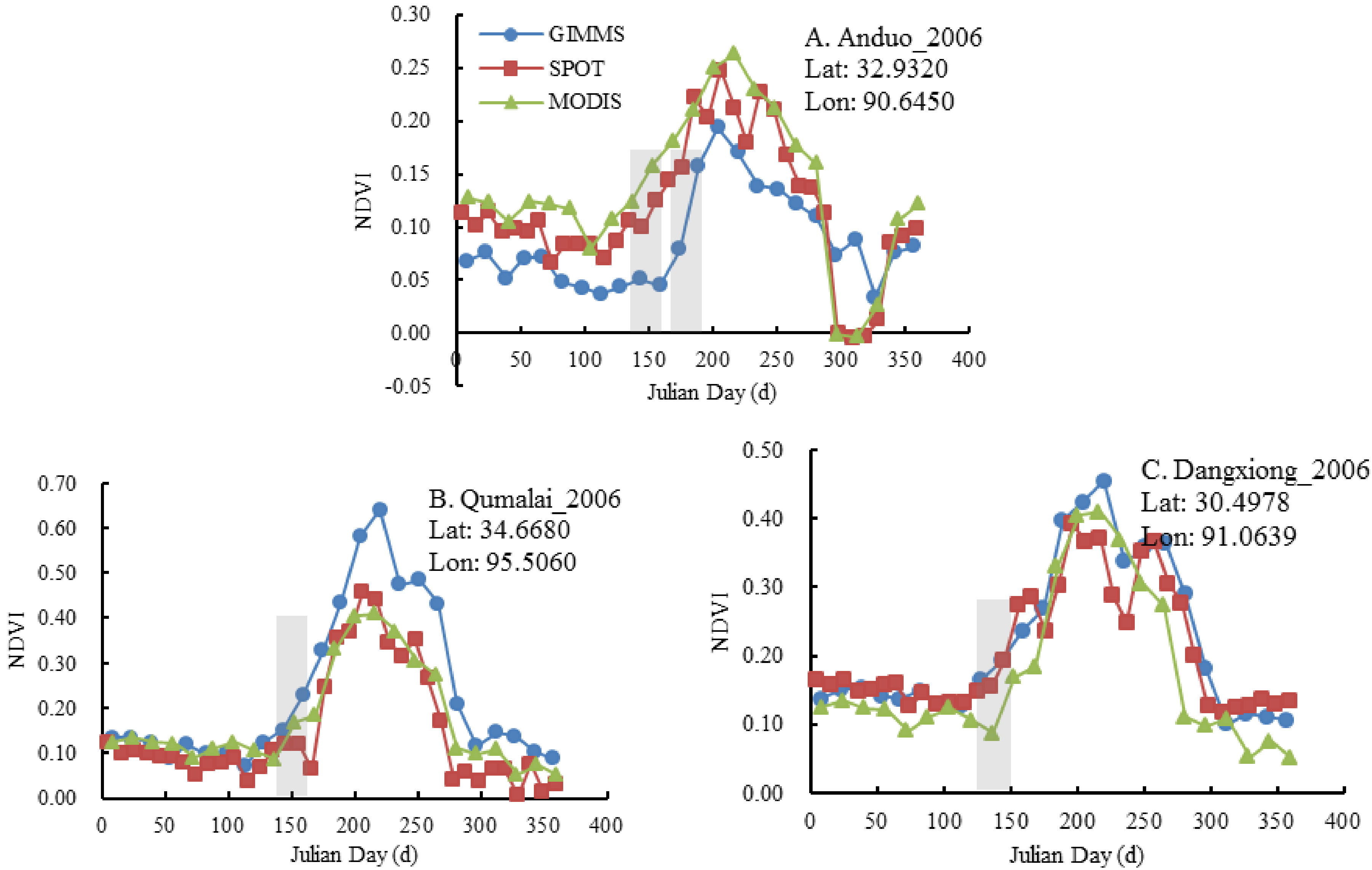
Monthly NDVI趋势显著性空间格局， 基于GIMMS （1982-2006, 1982-1998, 1998-2006）， SPOT （1998-2006）



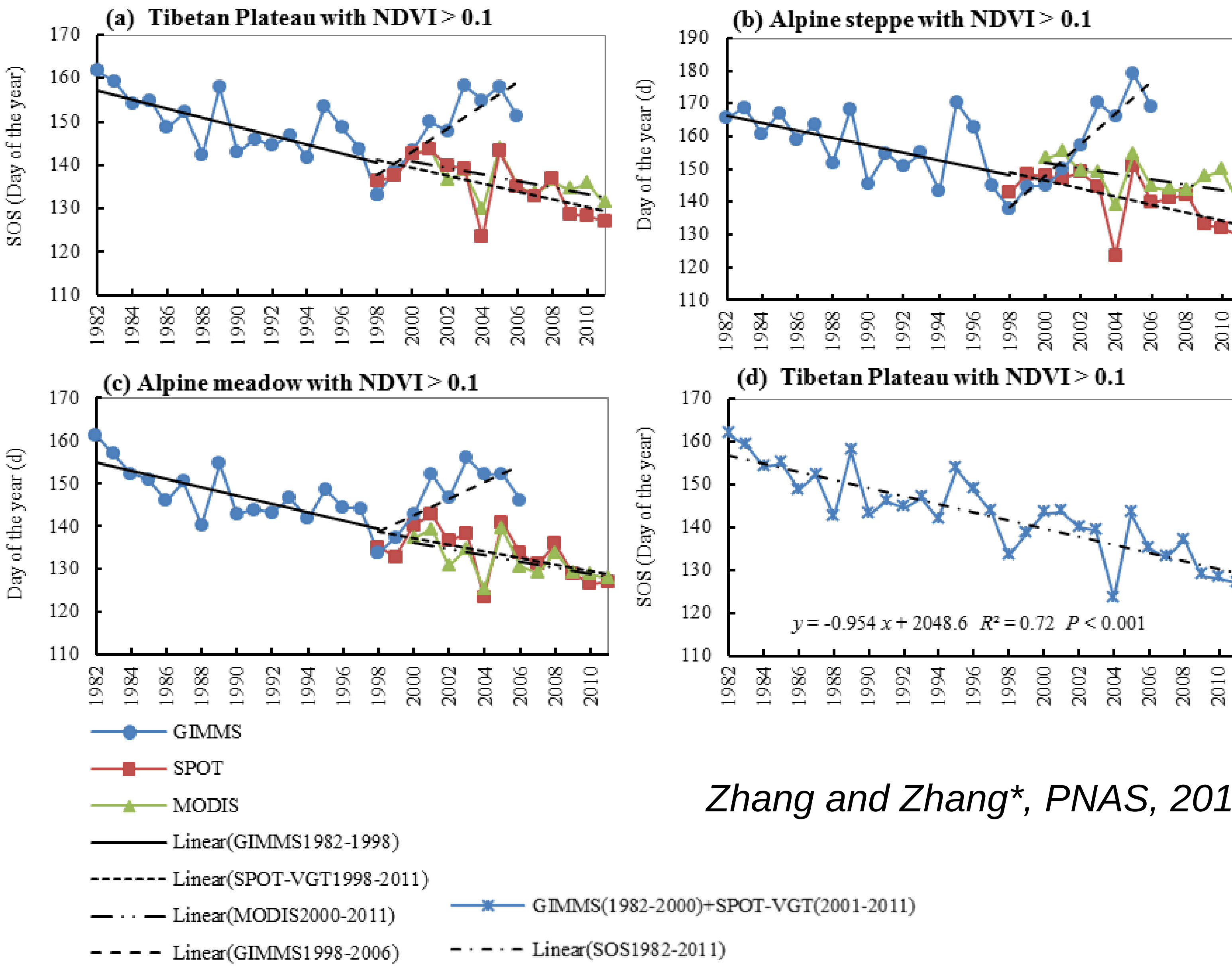
Monthly NDVI趋势显著性空间格局， 基于GIMMS （1982-2006, 1982-1998, 1998-2006）， SPOT （1998-2006）



基于GIMMS，SPOT，MODIS 在三个代表性样点(A.安多; B. 曲马来; C. 当雄） NDVI在2006年内动态变化

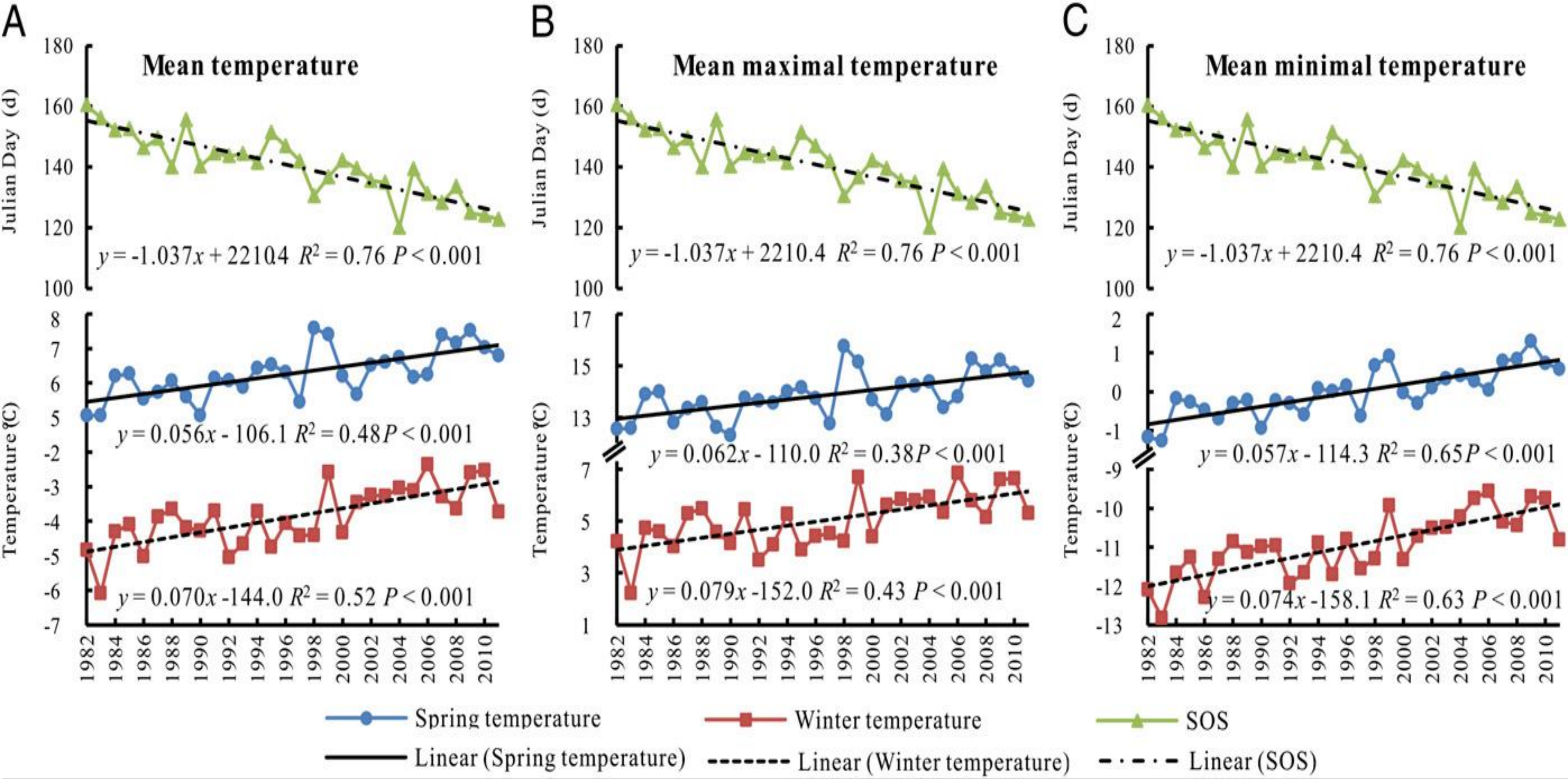


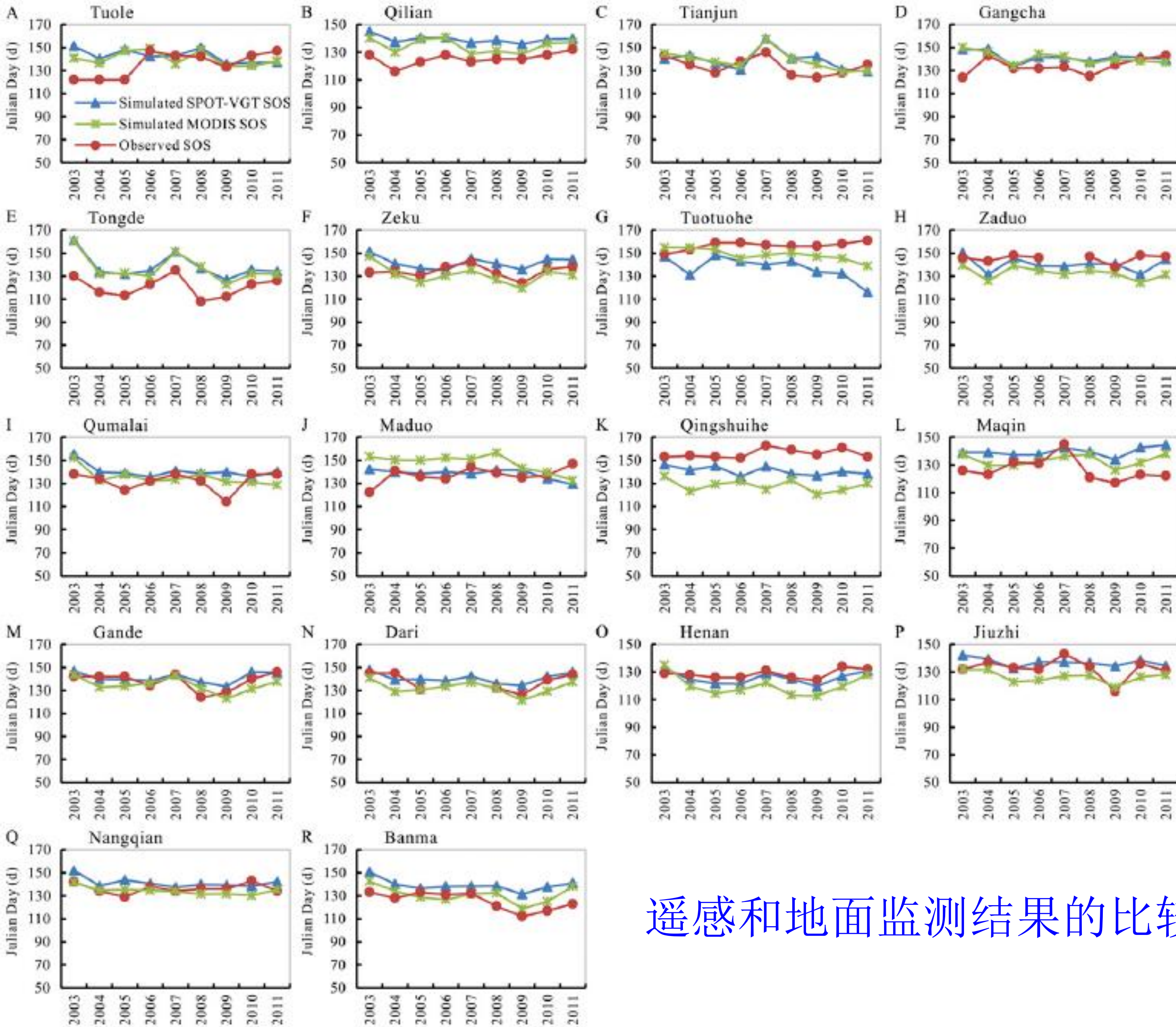
生长季开始期的动态变化



Zhang and Zhang, PNAS, 2013*

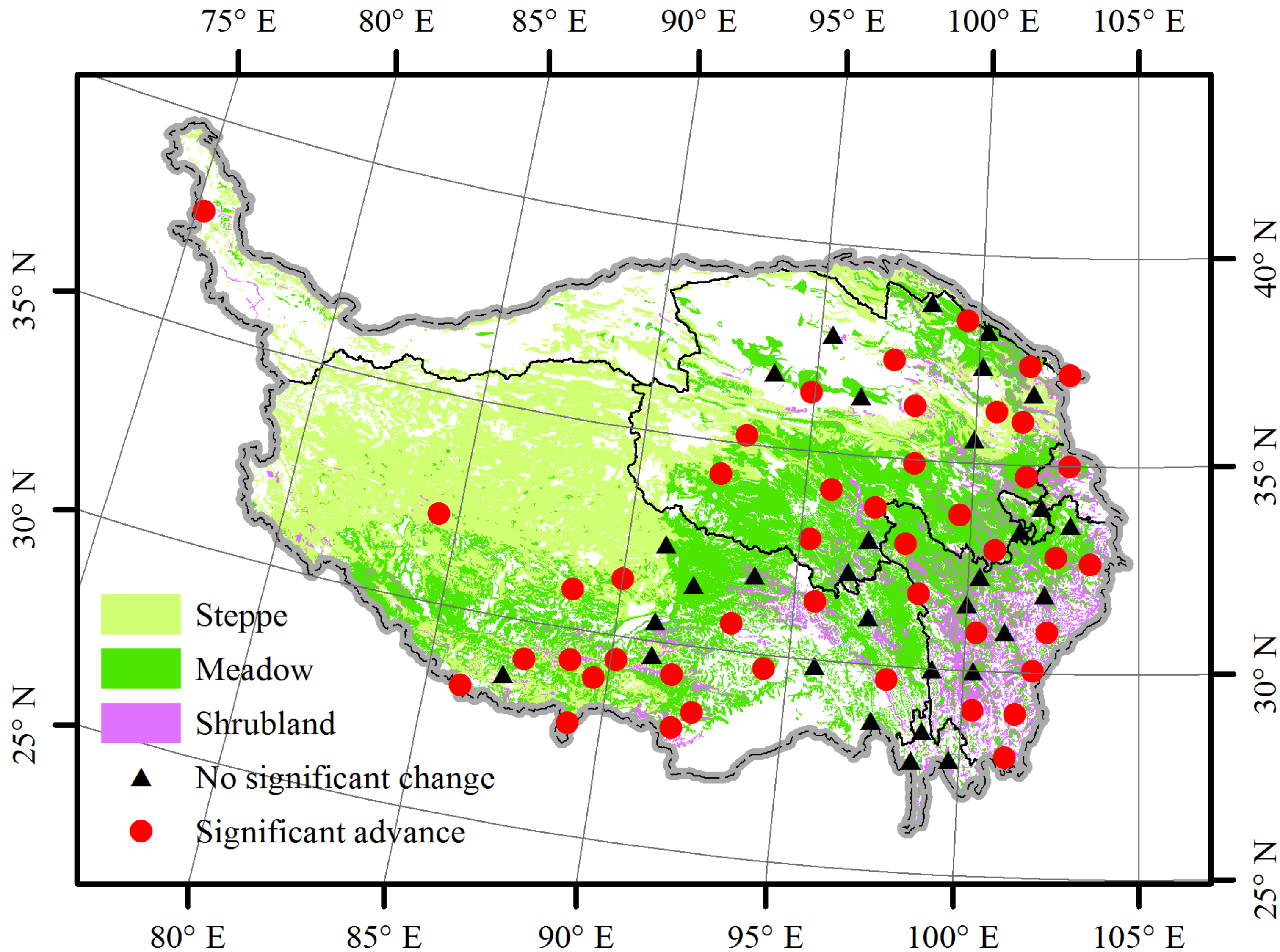
生长季开始期的动态变化和温度之间的关系



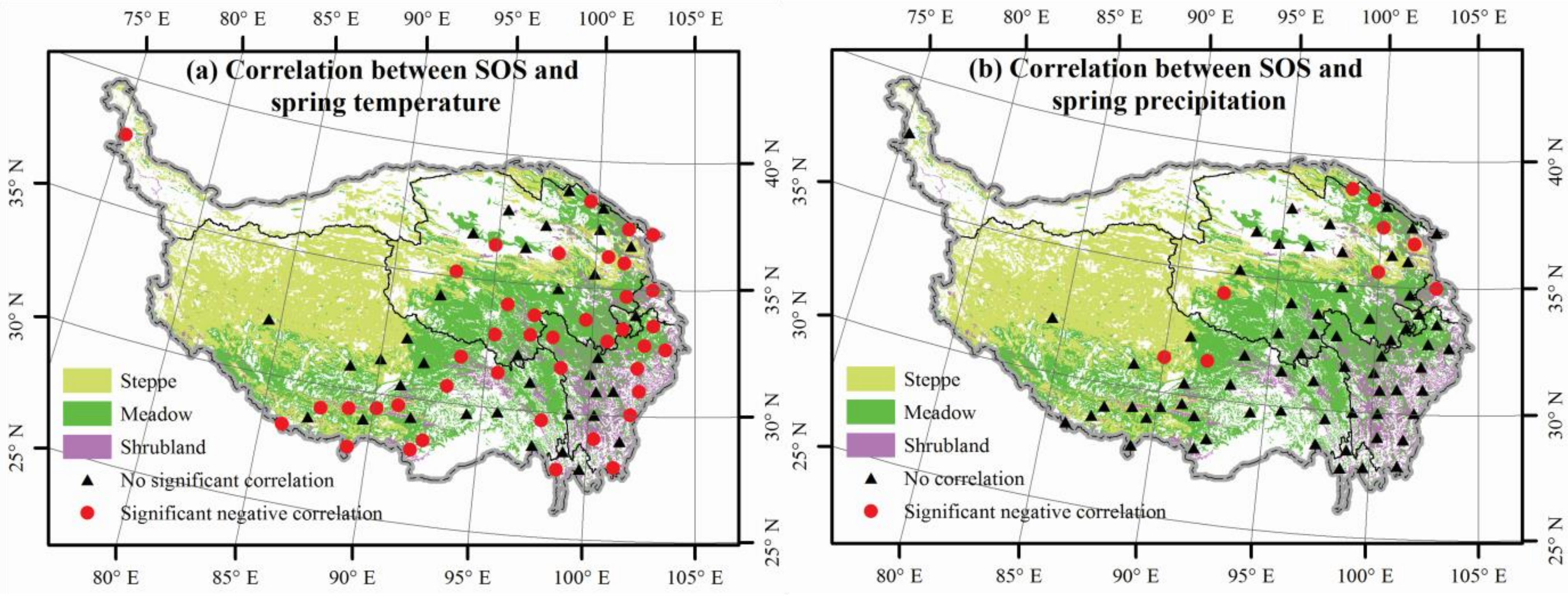


遥感和地面监测结果的比较

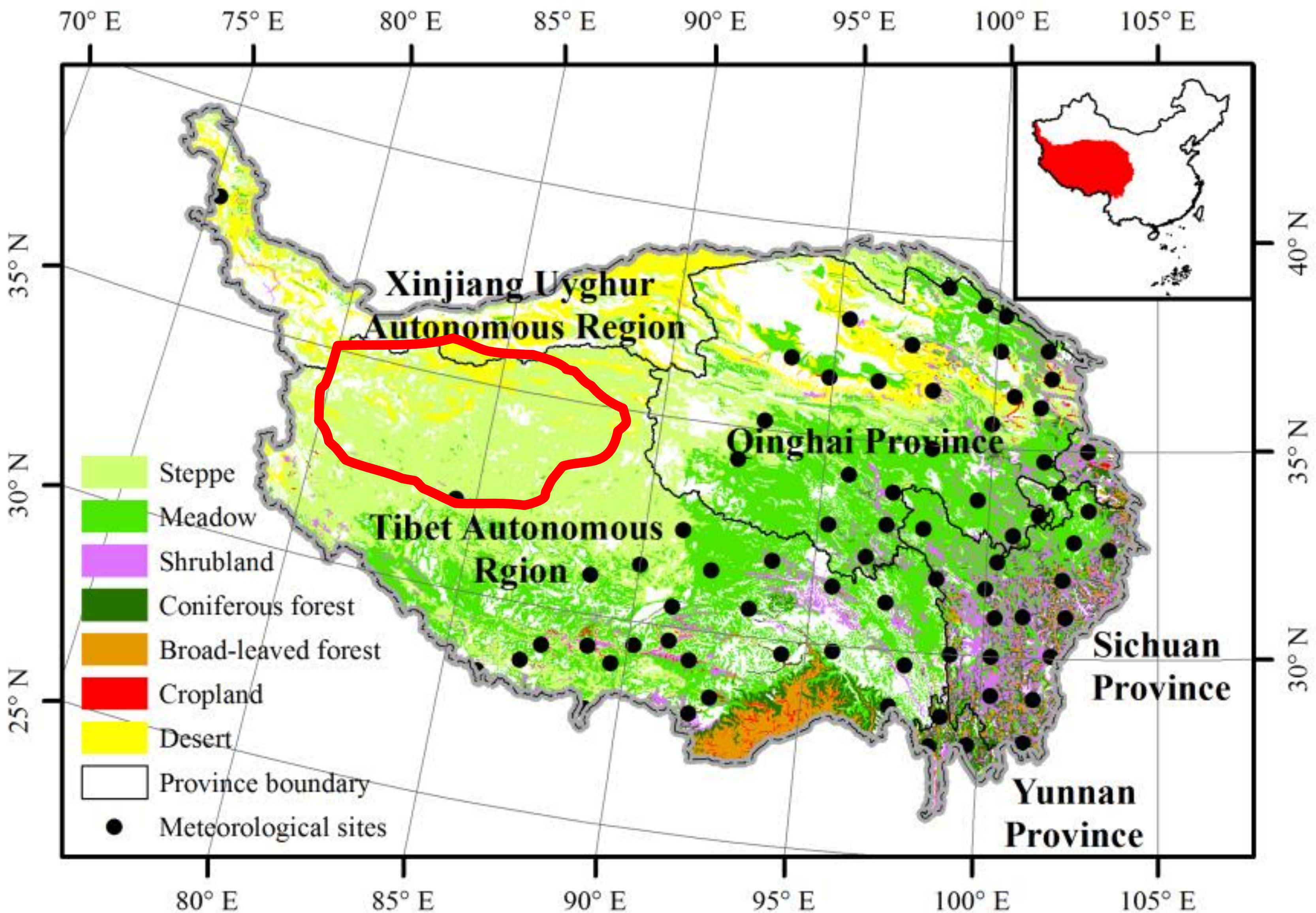
生长季开始期变化空间分布图



生长季开始期和气候因子的关系

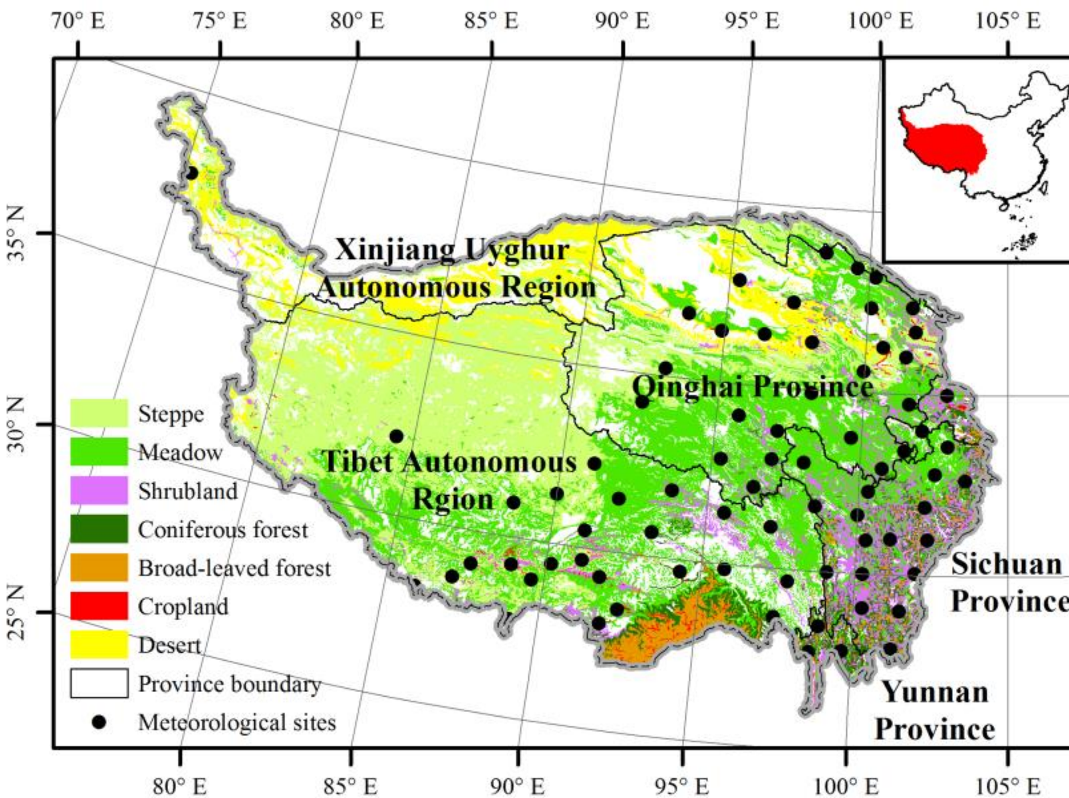


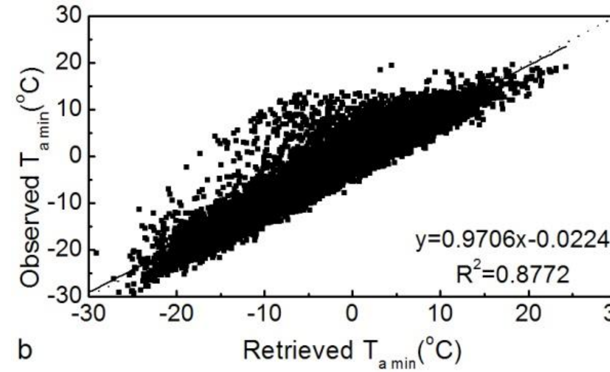
气象台站分布图

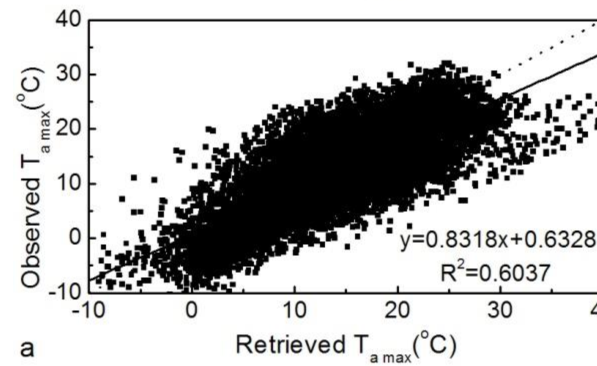


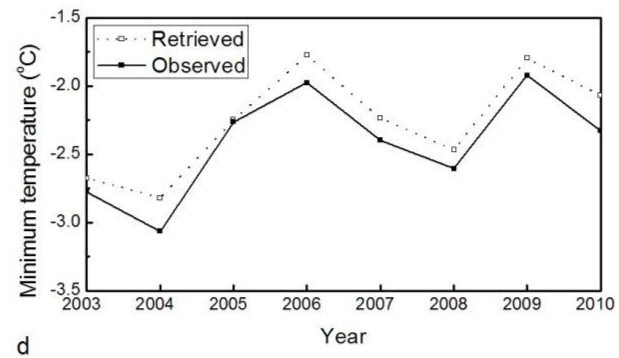
70° E
75° E
80° E
85° E
90° E
95° E
100° E
105° E
35° N
30° N
25° N
40° N
35° N
30° N
Xinjiang Uyghur Autonomous Region
Qinghai Province
Tibet Autonomous Rgion
Sichuan Province
Yunnan Province
Steppe
Meadow
Shrubland
Coniferous forest
Broad-leaved forest
Cropland
Desert
Province boundary
Meteorological sites
80° E
85° E
90° E
95° E
100° E
105° E

气象数据地面和遥感结果的比较

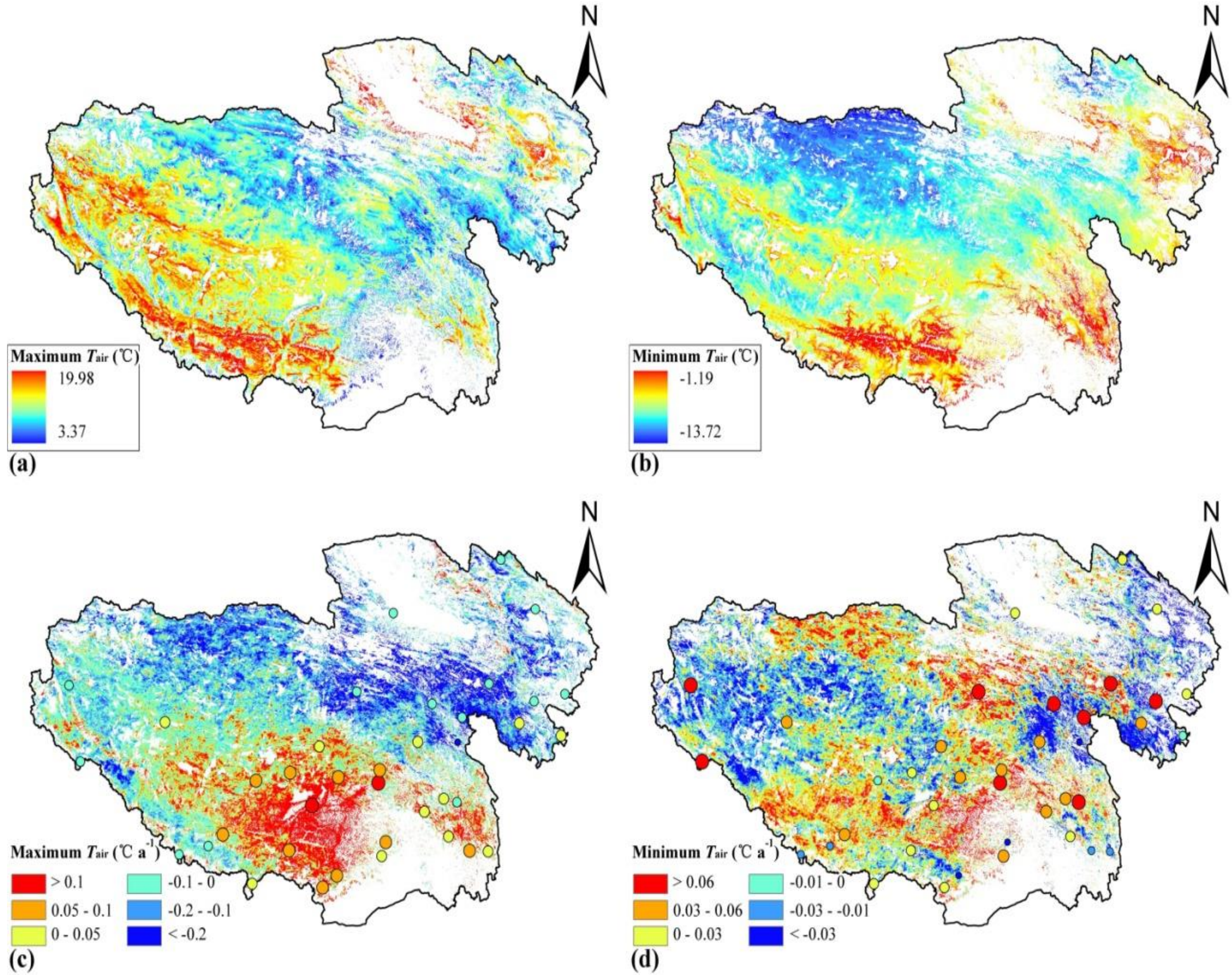




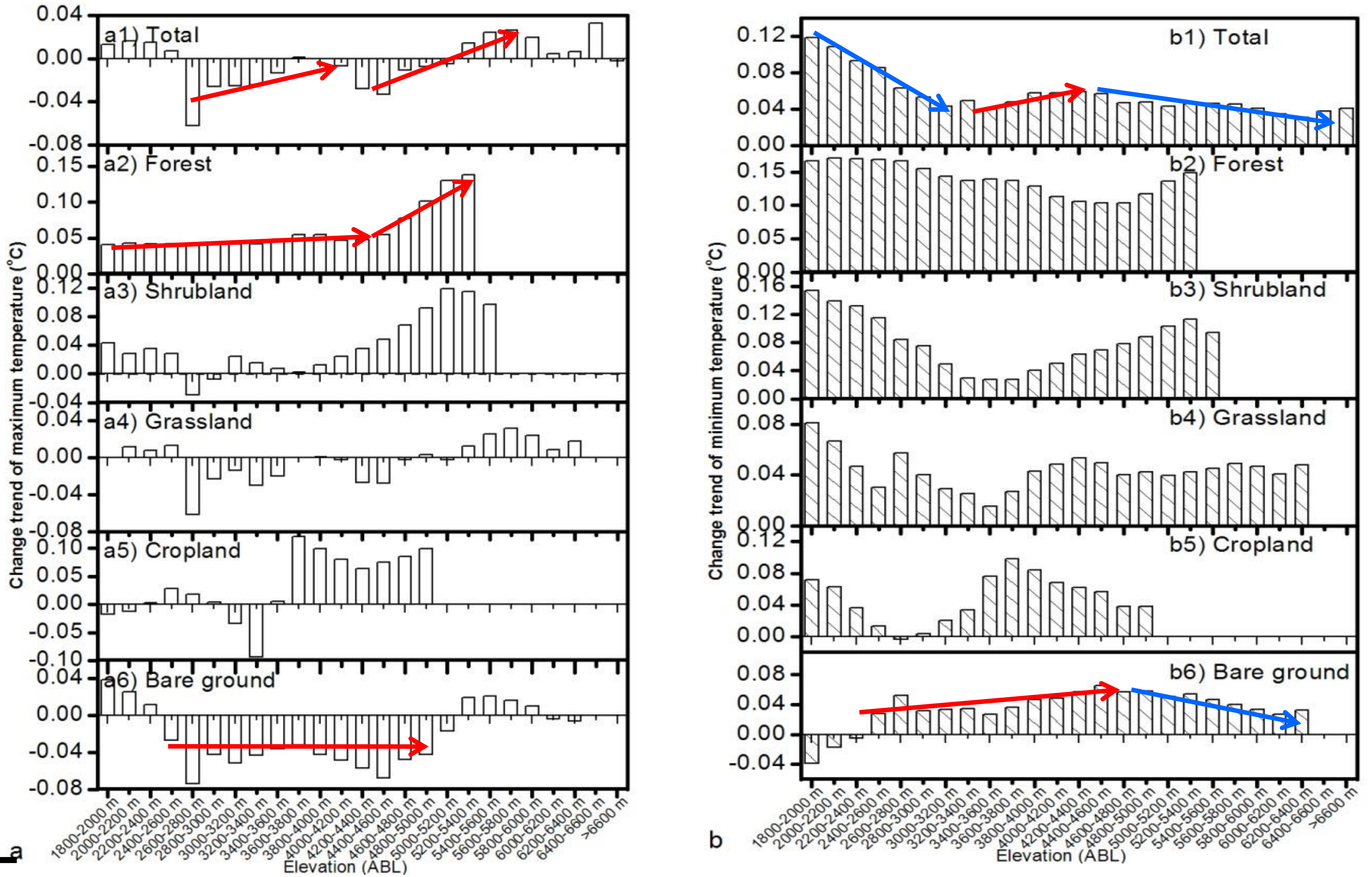




Spatial patterns of the multi-annual mean maximum (a) and minimum (b) T_{air} and their change trends



Altitude dependent temperature temporal trends



Tao and Zhang*, TAC, 2013


欢迎大家来指导工作及合作研究！