CLIMATE CHANGE & ECOLOGICAL CONSEQUENCES IN SOUTHEAST ASIA

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第六届现代生态学讲座

ISOMES VI - Nanjing, August 2-4, 2011

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CGCEO - Center for Global Change and Earth Observations

Our Mission Is:

To *specifically address the international aspects of the coupled social, land and climate systems in global environmental change studies using advanced geospatial tools, models, and observations*

Our Goal Is:

To improve our understanding of the interrelations among the human, land, and climate systems in the global context

Global to local scales

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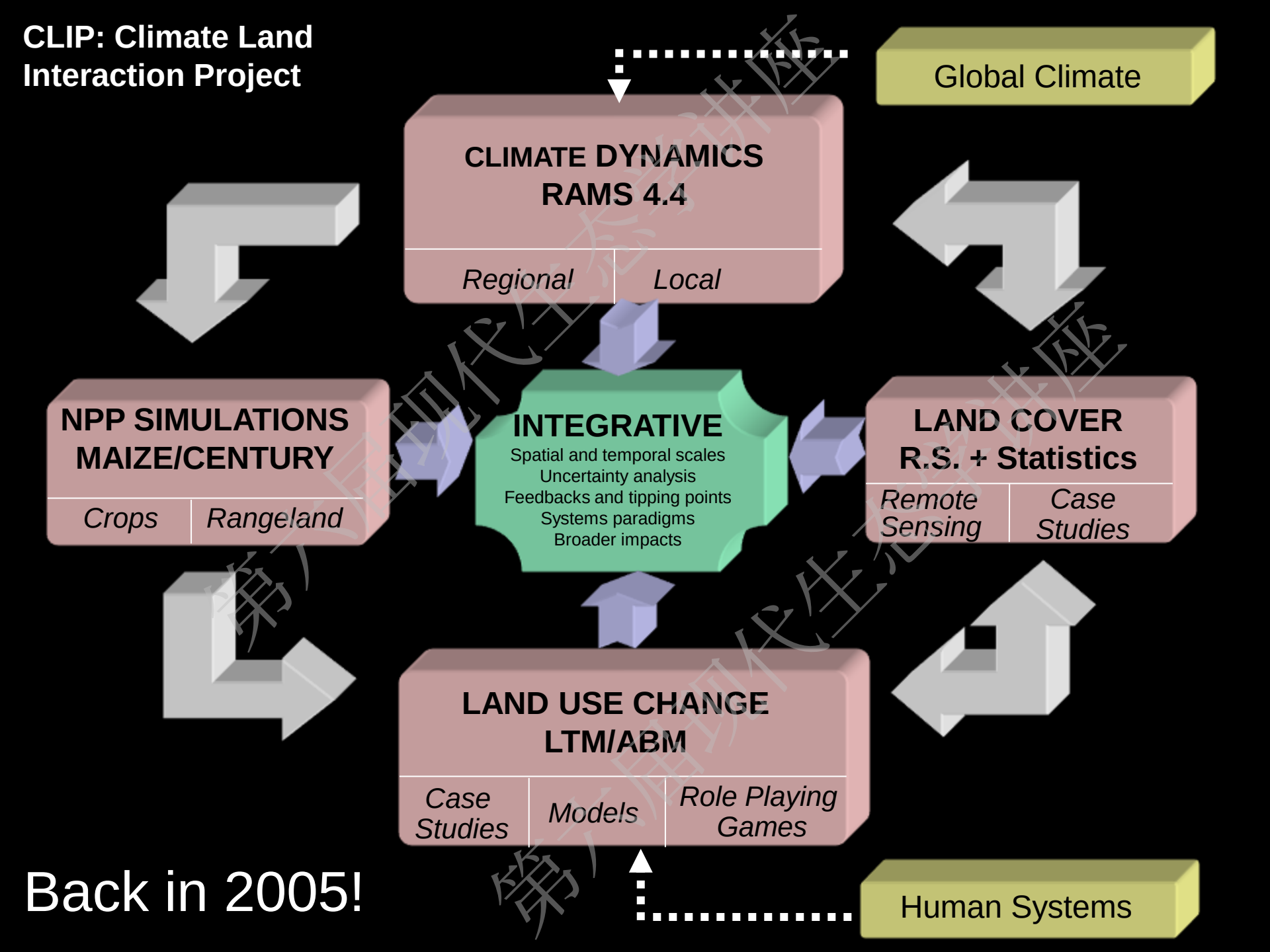
CLIP: Climate Land Interaction Project
Global Climate
CLIMATE DYNAMICS
RAMS 4.4
Regional
Local
NPP SIMULATIONS
MAIZE/CENTURY
Crops
Rangeland
INTEGRATIVE
Spatial and temporal scales
Uncertainty analysis
Feedbacks and tipping points
Systems paradigms
Broader impacts
LAND COVER
R.S. + Statistics
Remote Sensing
Case Studies
LAND USE CHANGE
LTM/ABM
Case Studies
Models
Role Playing Games
Human Systems
Back in 2005!

OUTLINE

- Climate Change - Known and unknown
- A System Approach
- Southeast Asia - Where and why
- One of the Pathways
  - Ecological Consequences

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Unit of Analysis & Scale

- Unit of analysis:
  - Representativeness is space and time?
- Scale:
  - Geographic areas
  - Time scale to capture true dynamics
- Interpretation of the results (yours and others!)

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Terms

- Various terms have been used but they mean different thing by different community and discipline!
  - Global change?
  - Climate change?
  - Global warming?
  - Climate variability?
  - Climate trend?
  - Climate forecastings?
  - Climate scenario?
  - Climate projection?

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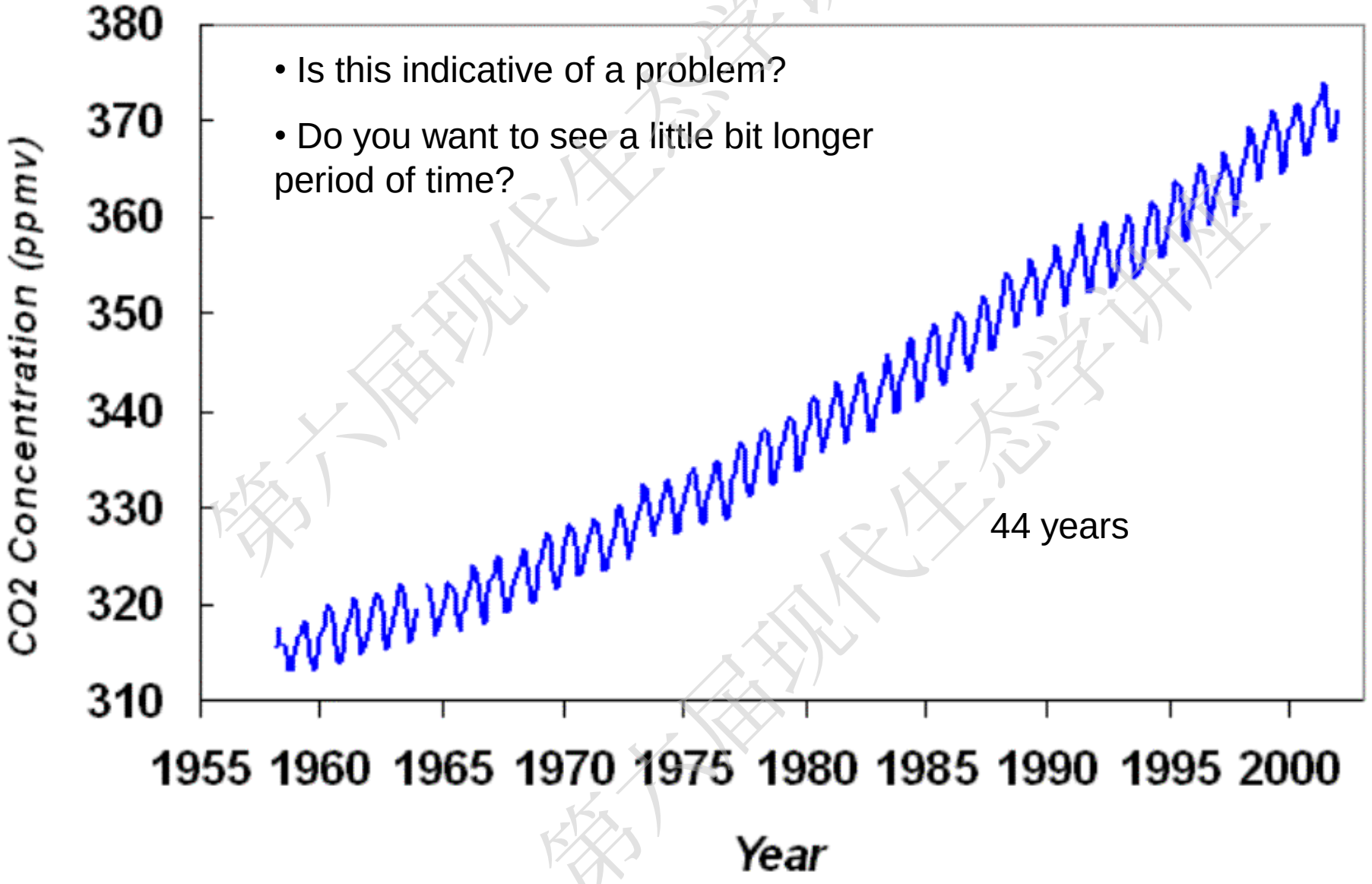
Atmospheric CO2 Concentration - Mauna Loa Observatory 1958 - 2002



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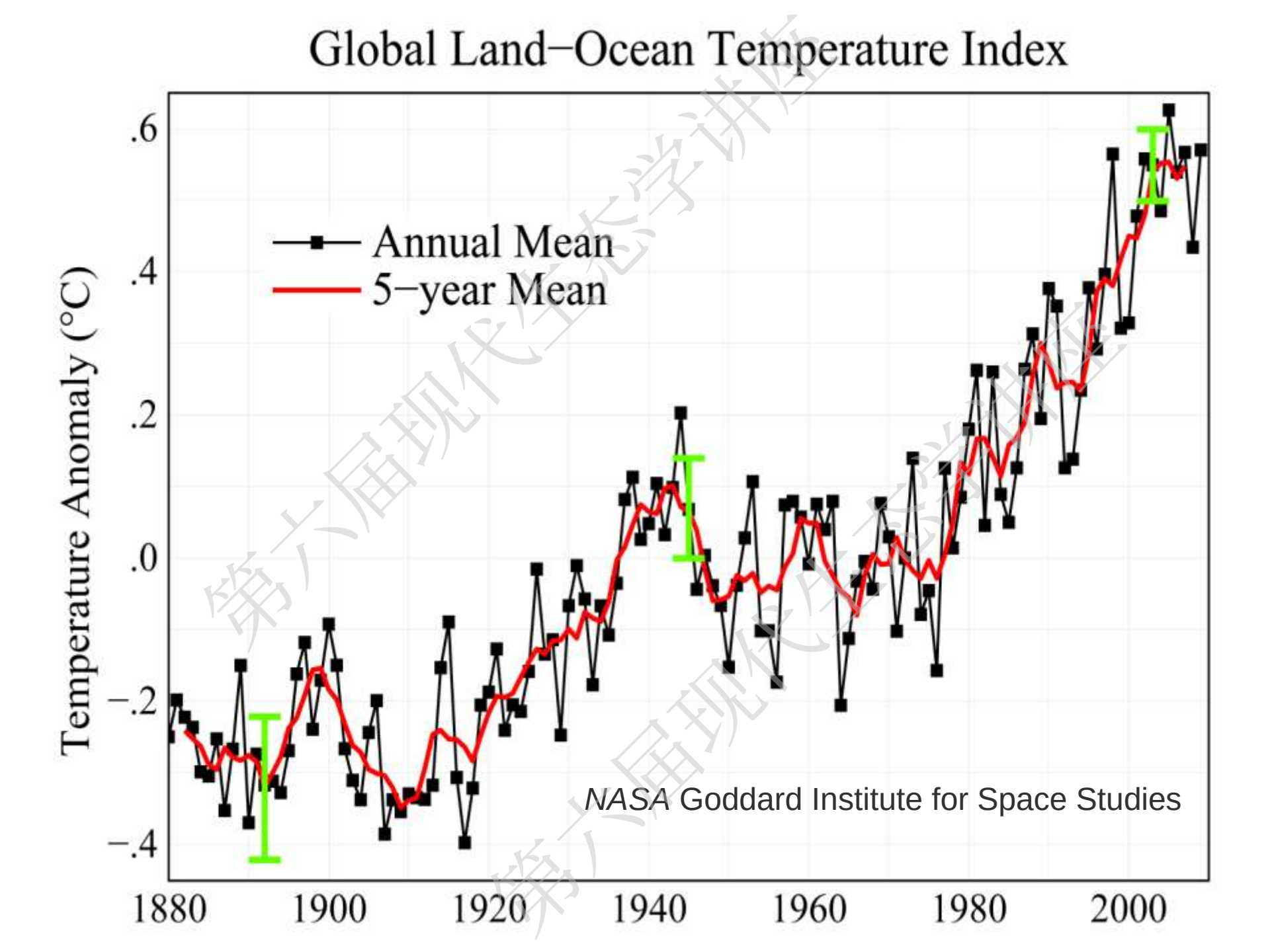
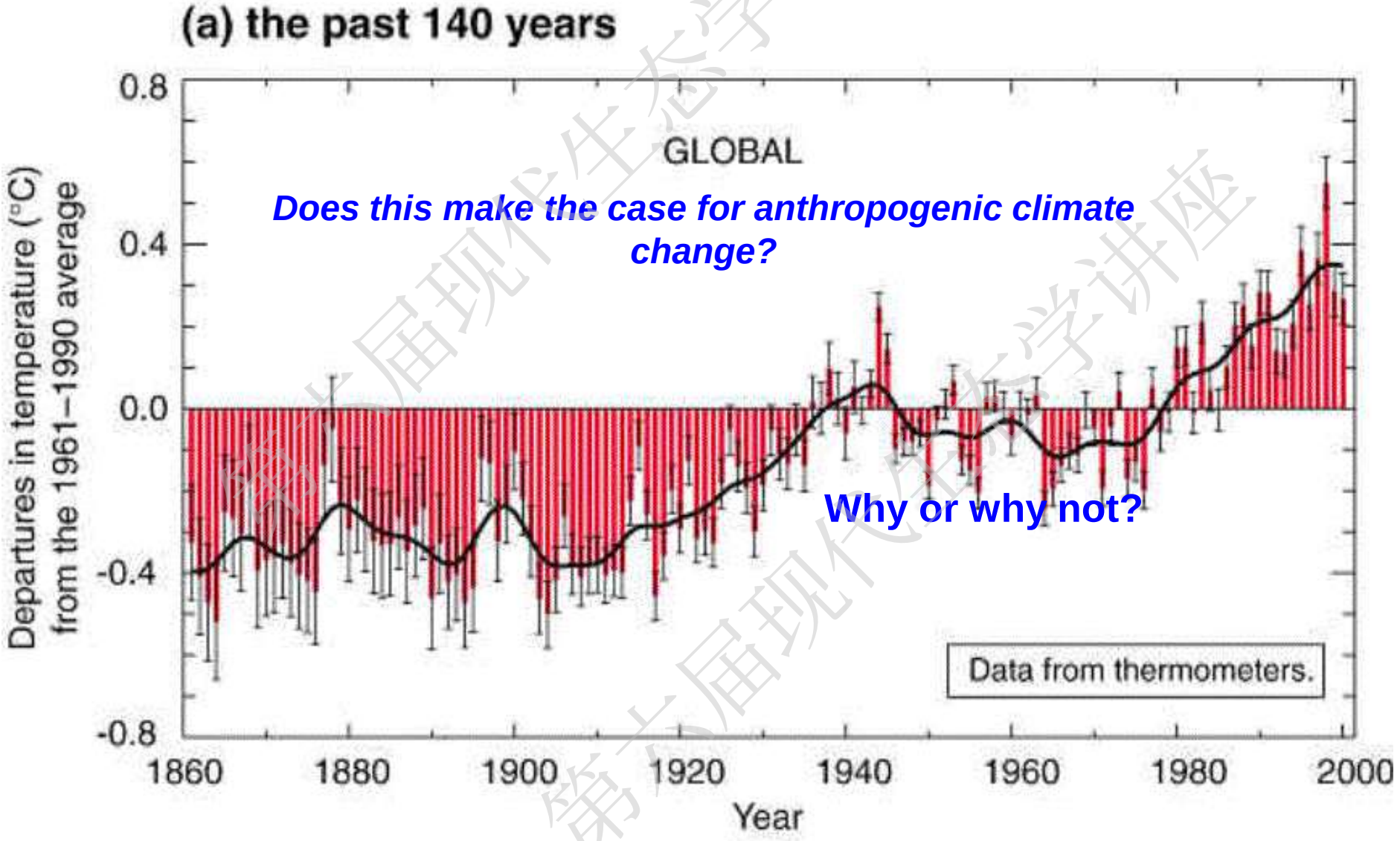

Global Land−Ocean Temperature Index
Annual Mean
5−year Mean
Temperature Anomaly (°C)
.6
.4
.2
.0
−.2
−.4
1880
1900
1920
1940
1960
1980
2000
NASA Goddard Institute for Space Studies

Climate Change



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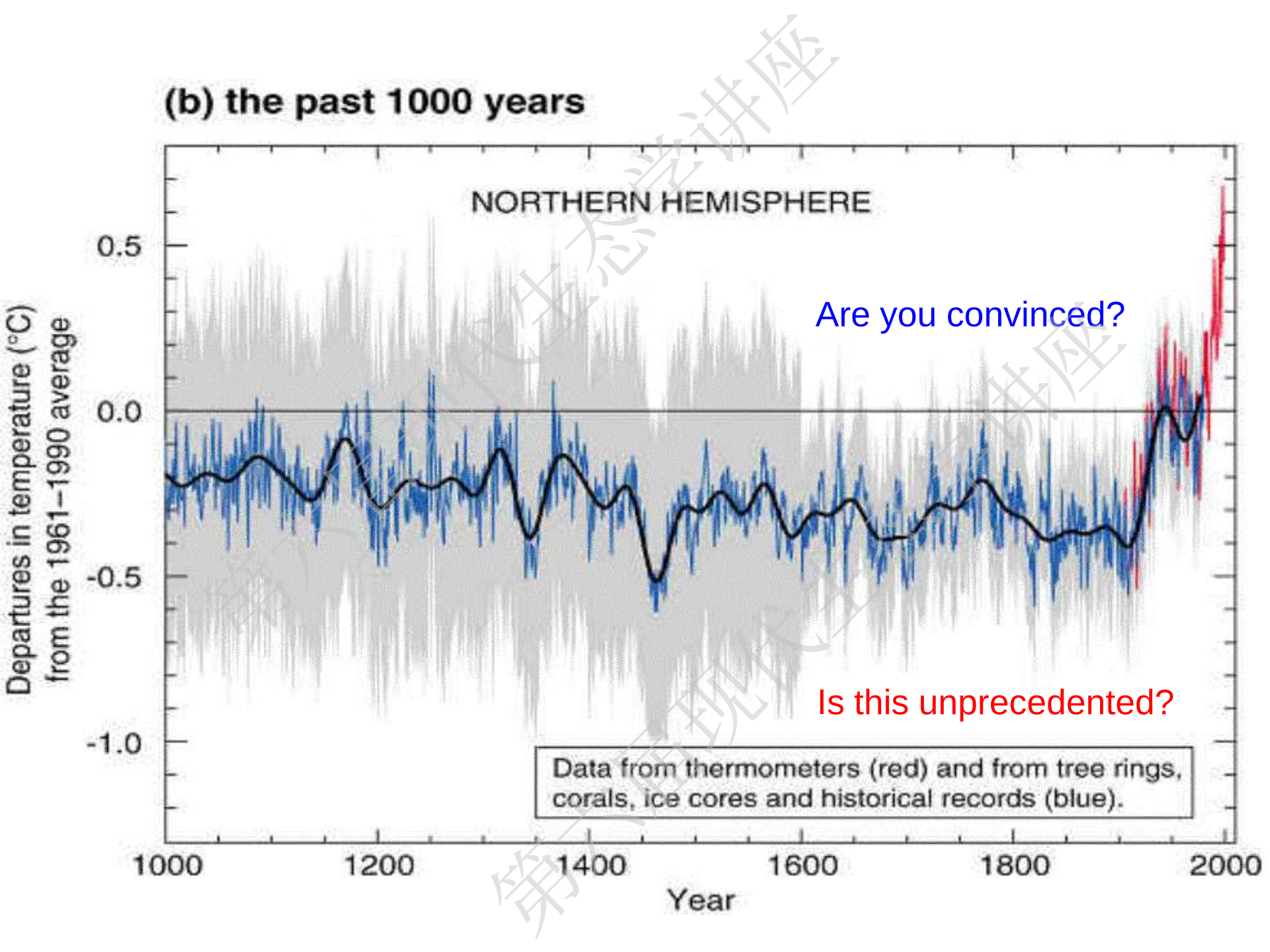
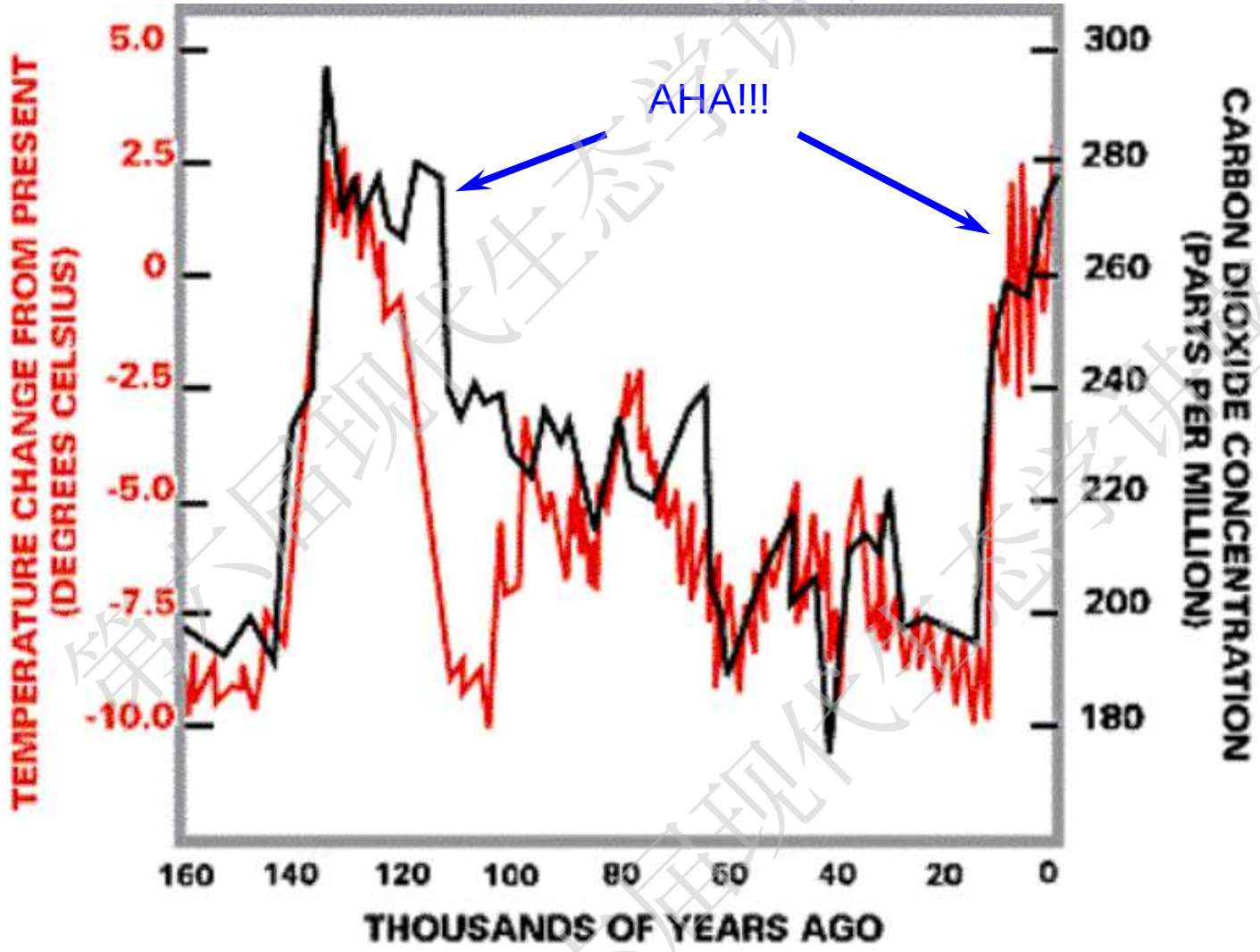
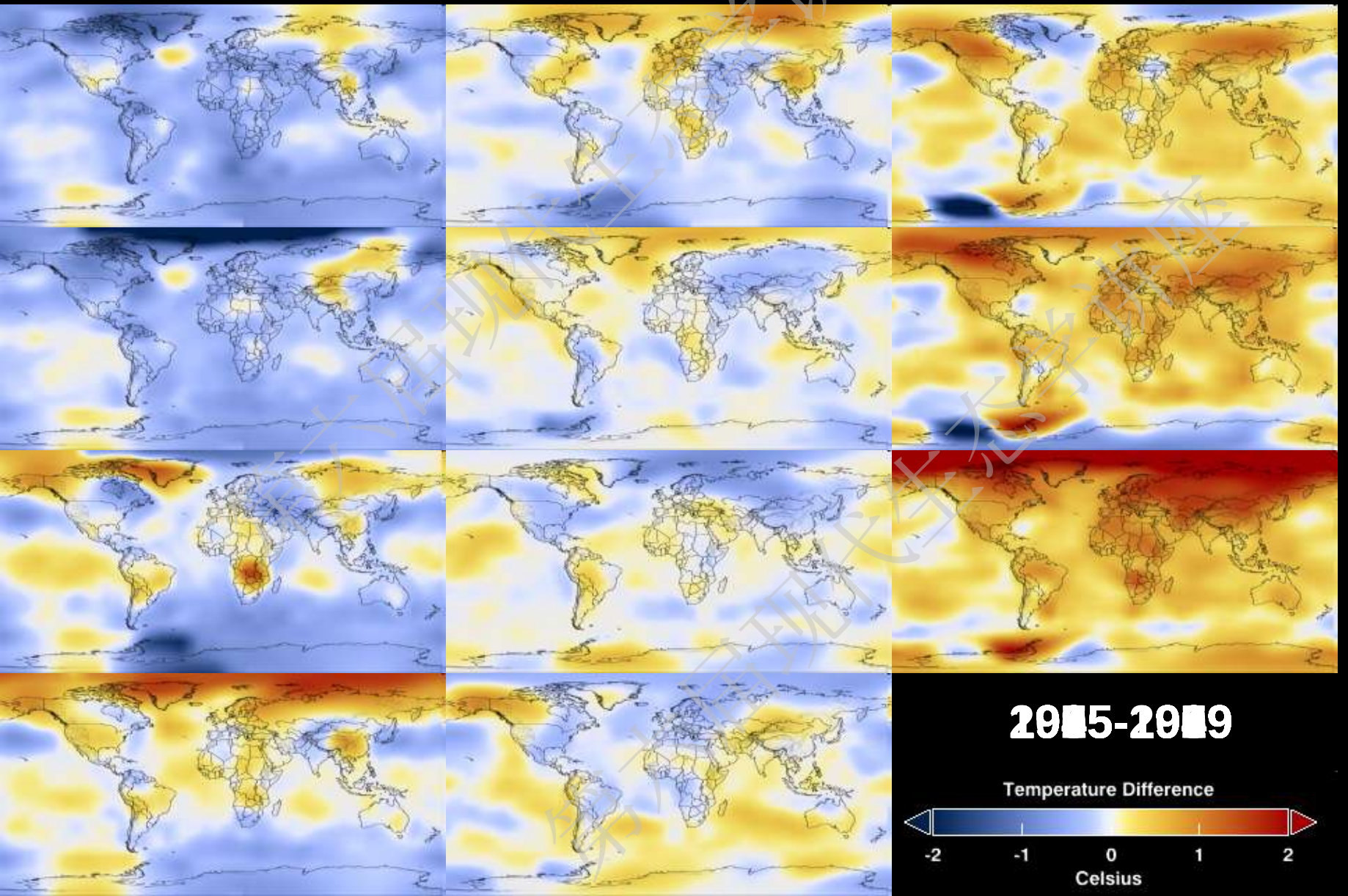

(b) the past 1000 years
NORTHERN HEMISPHERE
Are you convinced?
Is this unprecedented?
Data from thermometers (red) and from tree rings, corals, ice cores and historical records (blue).
Departures in temperature (°C) from the 1961–1990 average
0.5
0.0
-0.5
-1.0
1000
1200
1400
1600
1800
2000
Year



So we don't have to worry about global warming or do we?

Five-Year Average Global Temperature - Anomalies from 1909 to 2009



Who are the big players?

CO_2 emissions from land use change

Source : Climate Change Information kit, UNEP IUC, 1997.

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Known and Unknown

- Happening now
- Will continue
- Related to Us

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Known and Unknown

- Happening now
- Will continue, at least in the short term, say 50 years!
- Related to human activities, at least to a large degree!
- What is the magnitude due to human?

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Known and Unknown

- Some key issues are largely unknown:
  - Variability
    - Extreme events
    - Temporal frequency
    - Extent
  - Synchronization of temperature and precipitation
  - Forecasting in space and time!

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Known and Unknown

- Ecological and societal consequences are largely unknown:
  - Ecosystem services and functions
  - Resilience and adaptive capability
  - Thresholds and tipping points
- Adaptation Options are largely unknown
  - Conceptual framework proposed long time ago but implementation is largely unknown

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Recent NRC Report on "America's Climate Choices"

- **Research** to Improve Understanding of Human-Environment Systems:
  1. Climate *Forcings*, ***Responses***, *Feedbacks*, and *Thresholds* in the Earth System;
  2. Climate-Related Human *Behaviors* and *Institutions*
  3. *Vulnerability* and *Adaptation* Analyses of *Coupled* Human-Environment Systems
  4. Research to Support Strategies for *Limiting* Climate Change
  5. Effective Information and *Decision-Support* Systems
- **Tools and Approaches** to Improve both Understanding and Responses:
  1. Integrated *Observing* Systems
  2. Improved *Projections*, Analyses, and Assessments (both climate and impacts)

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A System Approach

One can not separate climate change from physical and socioeconomic processes!

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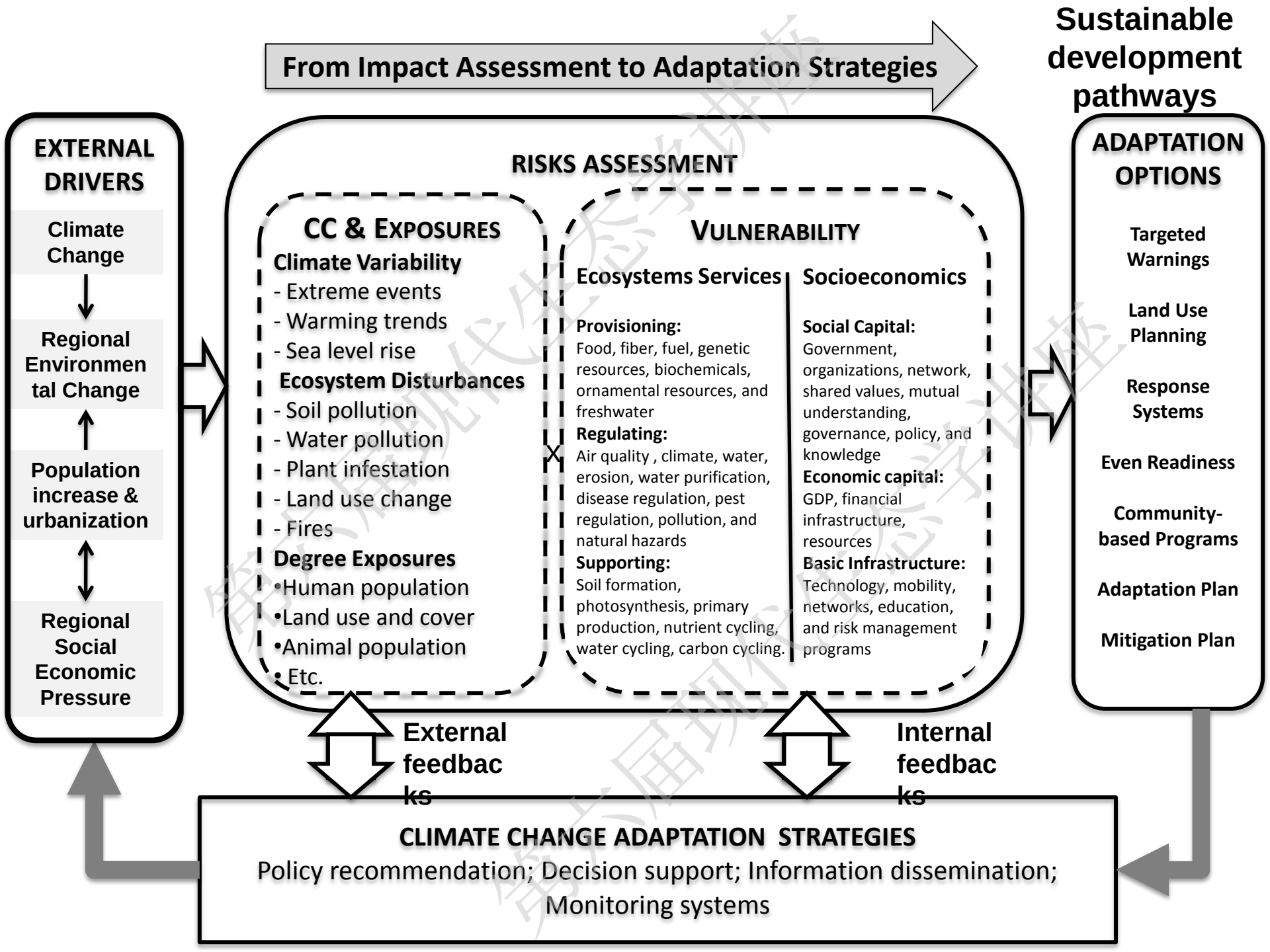
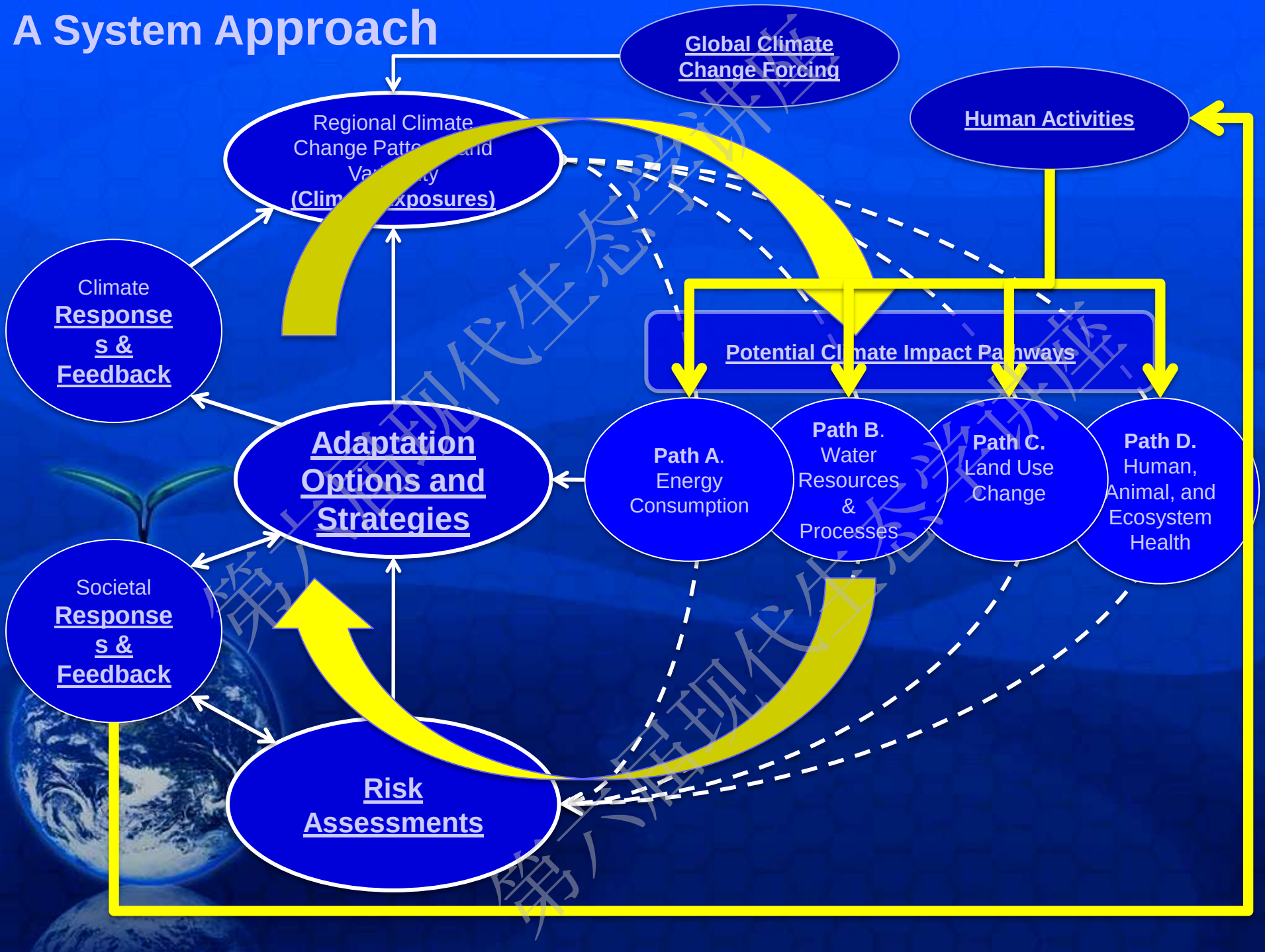

From Impact Assessment to Adaptation Strategies
Sustainable development pathways
EXTERNAL DRIVERS
Climate Change
Regional Environmental Change
Population increase & urbanization
Regional Social Economic Pressure
RISKS ASSESSMENT
CC & EXPOSURES
Climate Variability
- Extreme events
- Warming trends
- Sea level rise
Ecosystem Disturbances
- Soil pollution
- Water pollution
- Plant infestation
- Land use change
- Fires
Degree Exposures
•Human population
•Land use and cover
•Animal population
• Etc.
X
VULNERABILITY
Ecosystems Services
Provisioning:
Food, fiber, fuel, genetic resources, biochemicals, ornamental resources, and freshwater
Regulating:
Air quality , climate, water, erosion, water purification, disease regulation, pest regulation, pollution, and natural hazards
Supporting:
Soil formation, photosynthesis, primary production, nutrient cycling, water cycling, carbon cycling.
Socioeconomics
Social Capital:
Government, organizations, network, shared values, mutual understanding, governance, policy, and knowledge
Economic capital:
GDP, financial infrastructure, resources
Basic Infrastructure:
Technology, mobility, networks, education, and risk management programs
ADAPTATION OPTIONS
Targeted Warnings
Land Use Planning
Response Systems
Even Readiness
Community-based Programs
Adaptation Plan
Mitigation Plan
External feedbacks
Internal feedbacks
CLIMATE CHANGE ADAPTATION STRATEGIES
Policy recommendation; Decision support; Information dissemination; Monitoring systems

A System Approach



One of the Pathways:

Ecological Consequences:

Case Study in Southeast Asia

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Southeast Asia

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SEA

- Most dense population
- Largely developing
- Influenced most by climate change
  - Sea level rises - Many mega cities on shorelines
  - Tightly influenced by monsoon system
  - Glacier retreats - Mekong River recharge
  - Intensive human activities

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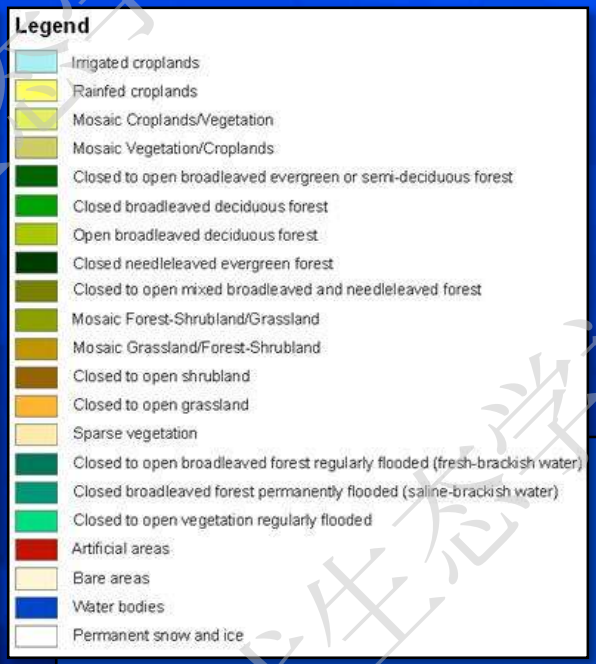
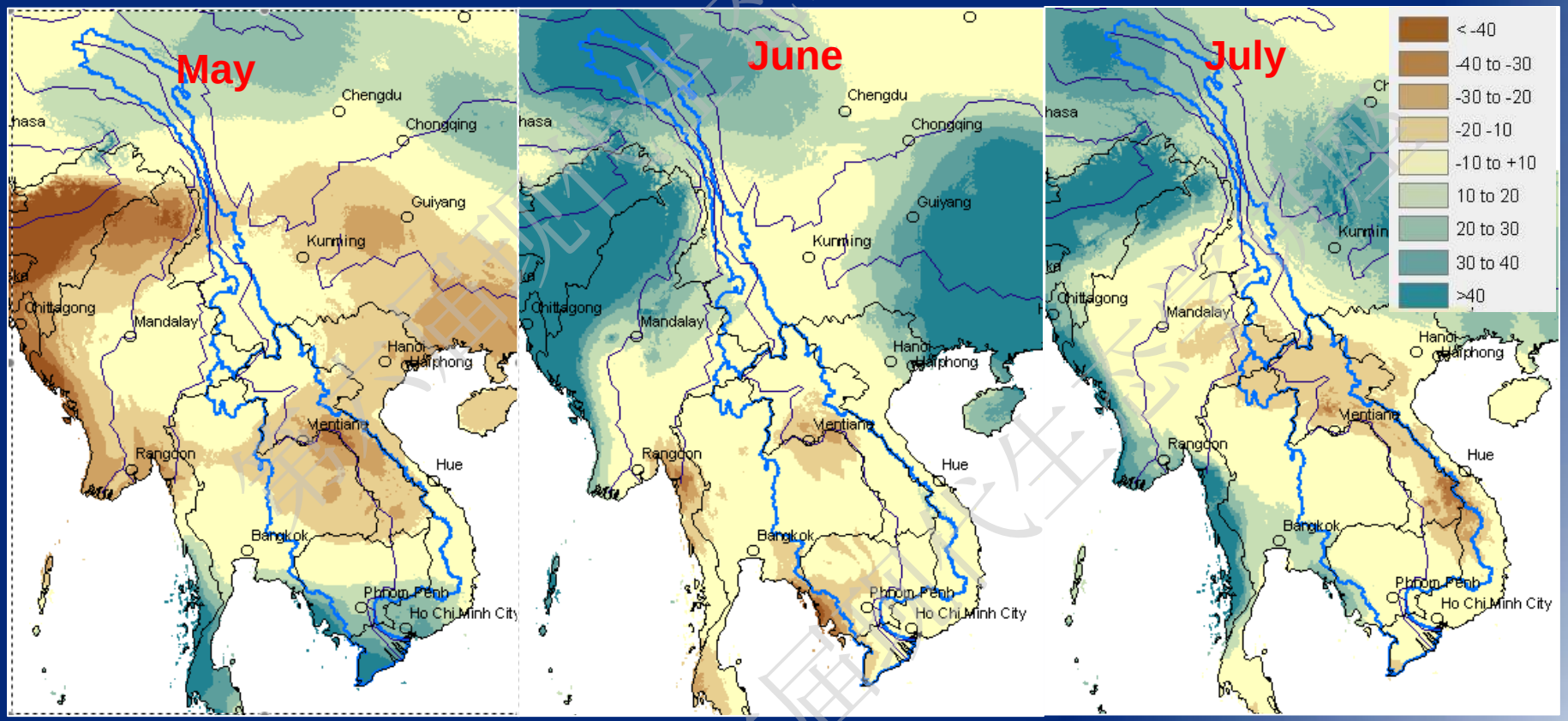
Land Use and Land Cover

Indochina & Japan



From the Global Land Cover 2005 v2.2 Product

SEA will experience significant climate change – variable



SEA Ecosystem Dynamics

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Ecosystems

- Ecosystems are temporally dynamic
  - Annual and inter-annual variability
  - Short and long term resiliencies to external disturbances
- Multiple ecosystem types interact and influence one another across broad spatial scales
- Important ecosystem attributes include: land cover composition, vegetation dynamics, climate, topography, and species diversity, among others
- Analysis of ecosystem dynamics requires continuous monitoring at large spatio-temporal scales

One Particular Attribute:
Vegetation Phenology

- The periodic biological events in the plant world or the timing of different stages of the vegetation seasonal cycle
- Influenced by the environment, especially temperature changes

- Emerging indicator of landscape and global environmental changes

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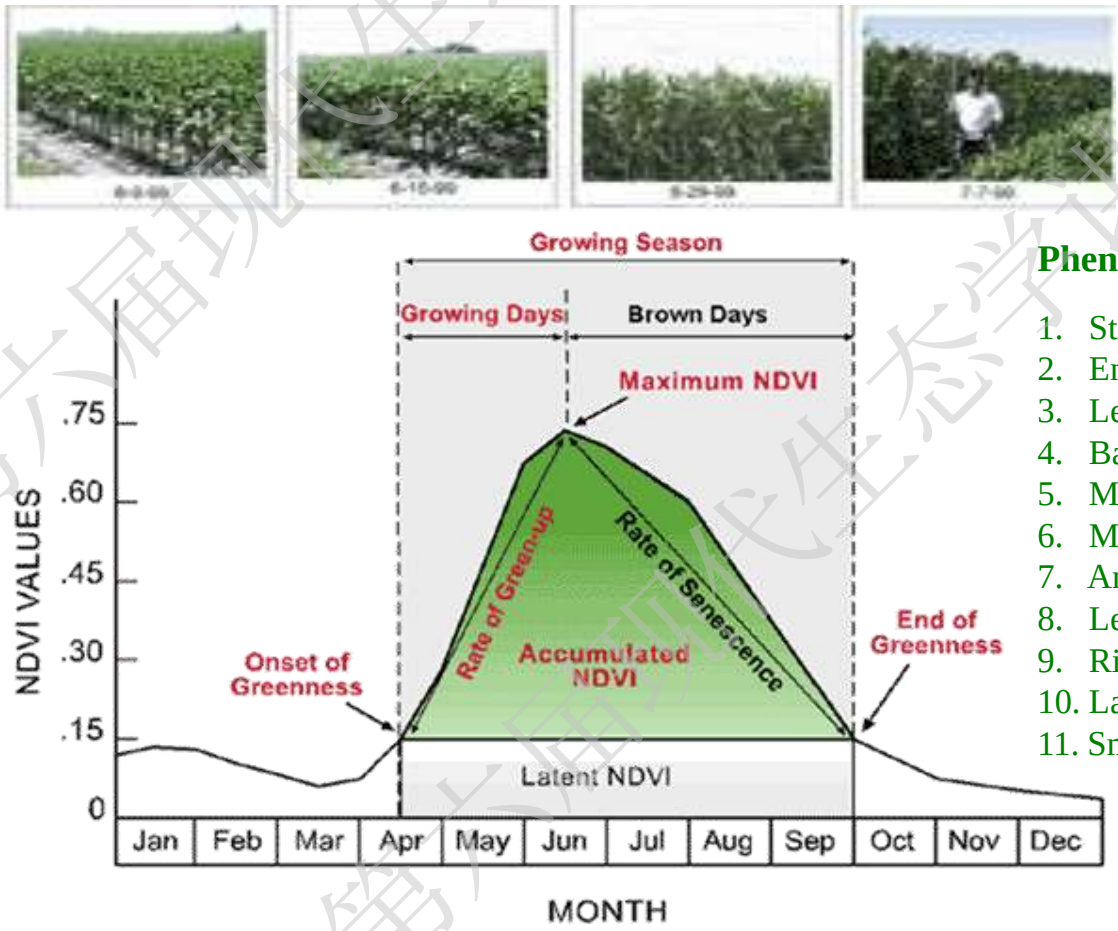
Phenology

The timing of different stages of vegetation seasonal cycle, such as leaf unfolding, first bloom, and leaf fall, as influenced by the environment (Schwartz, 2003)



Phenology Parameters

1. Start of season
2. End of season
3. Length of season
4. Base value
5. Middle of season
6. Maximum of data
7. Amplitude
8. Left derivative
9. Right derivative
10. Large integral
11. Small integral

Drivers of Ecological Change

- **Human Activities**
  - Population Growth
    - Agricultural Expansion & Intensification
    - Urbanization
  - Economic Growth
    - Infrastructure
    - Resource exploitation?
    - Deforestation

- **Climate Change**
  - Altered Temperatures & Precipitation Patterns
  - Increased Floods & Droughts

- **Ecological Impacts**
  - Ecosystem Degradation
  - Habitat Destruction & Fragmentation
  - Loss of Biodiversity
  - Species Migration
  - .....

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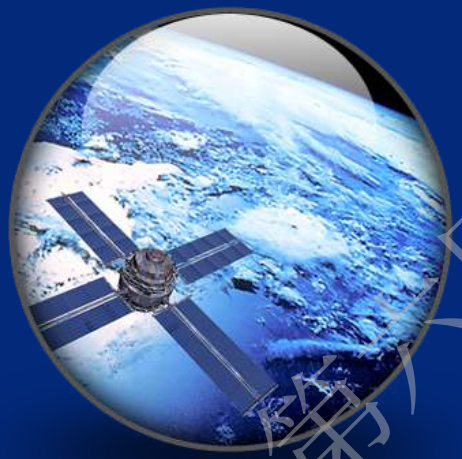
Specific Objective

Assess Large-scale Ecological Changes under Climate Change



- Develop effective methods for monitoring large-scale ecological change using moderate resolution satellite imagery and ground observations for Southeast Asia
- Quantify phenological attributes and their ability to provide unique ecological information about ecosystem dynamics
- Disseminate information via web-based tools to the general public and resource managers for effective ecosystem management

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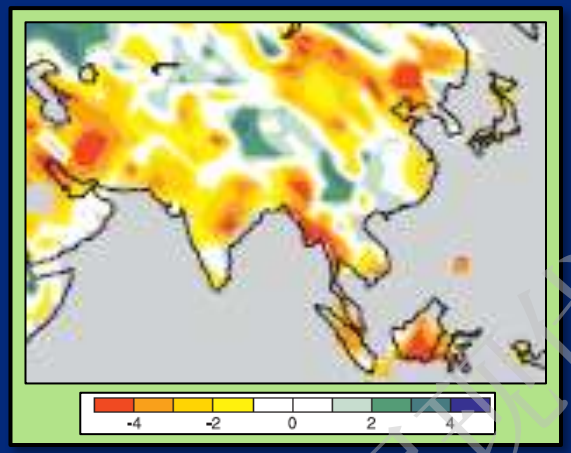
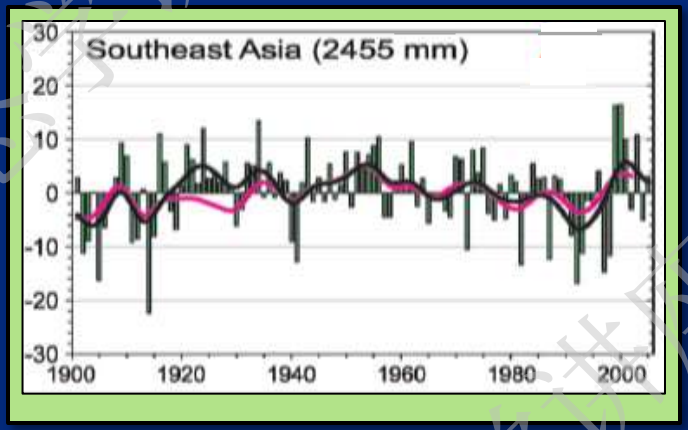
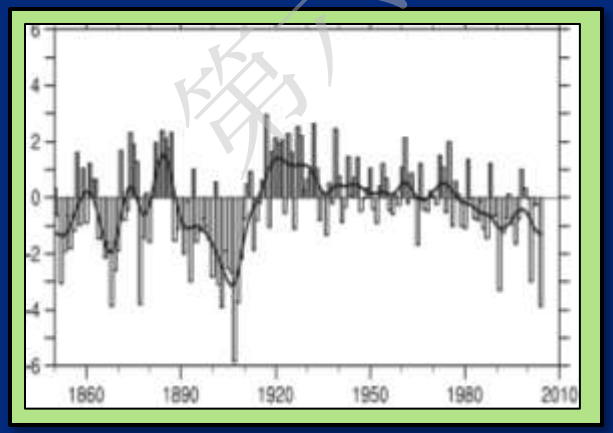
Climate Trends



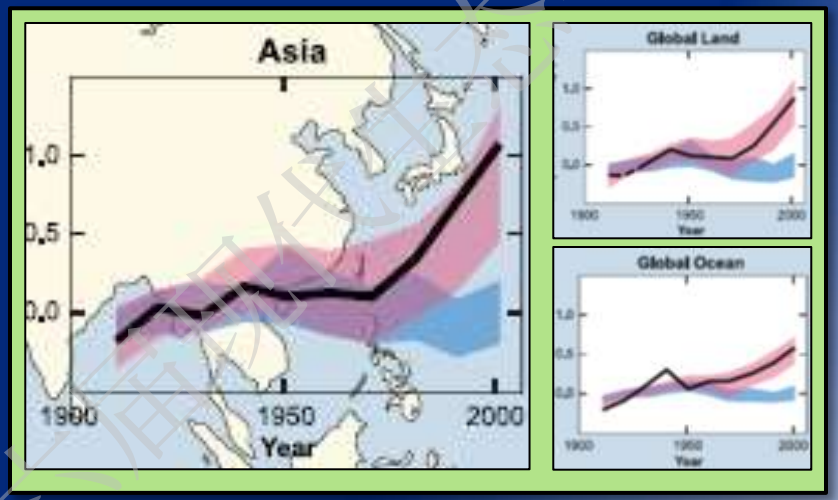
Palmer Drought Severity Index
(1900 – 2002)



Trend in Annual Precipitation



East Asia Monsoon Index



Temperature Anomaly °C

Source: IPCC Fourth Assessment Report

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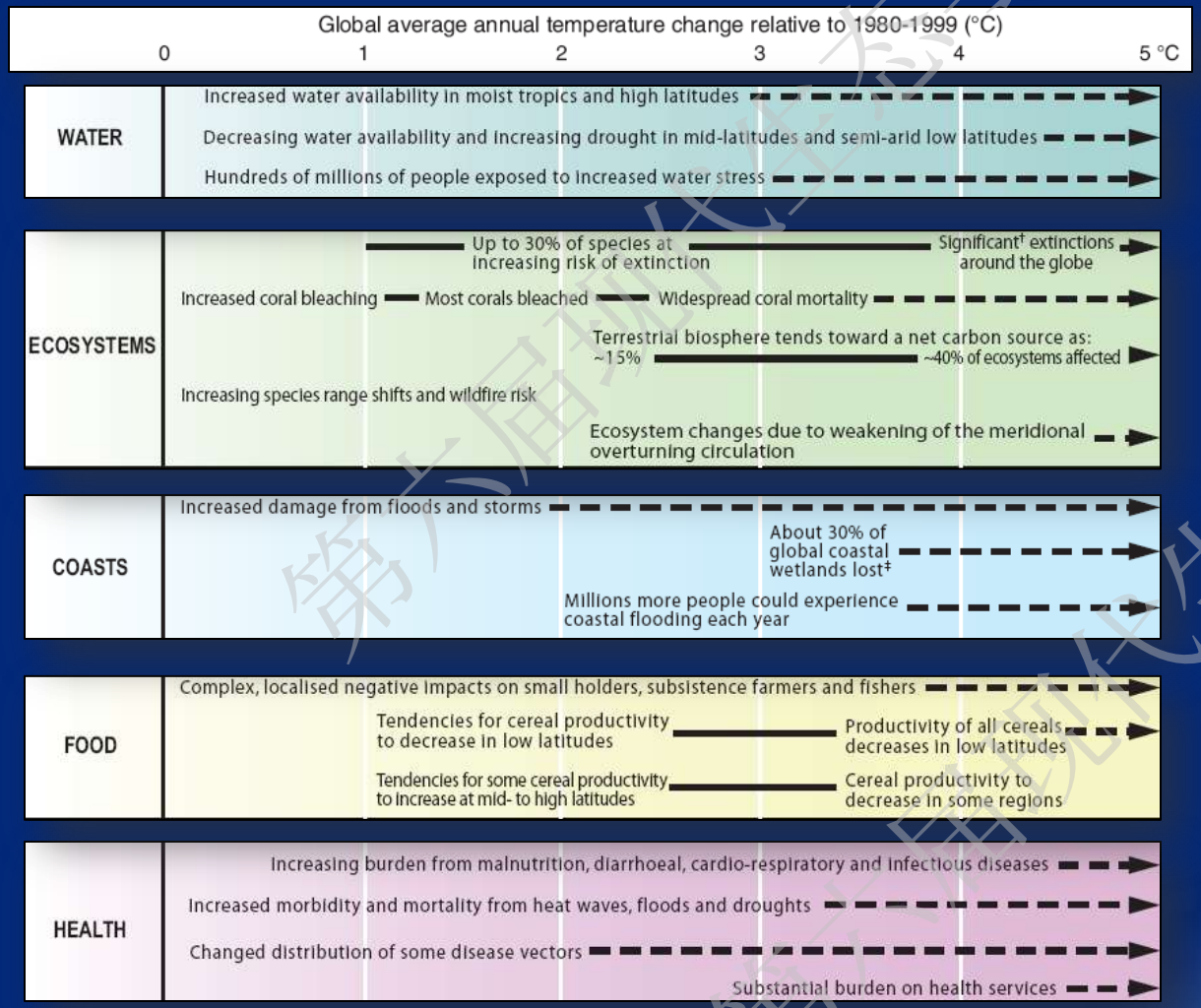
Potential Impacts of Climate Change

Source: IPCC Fourth Assessment Report



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Specific Methods

1. Observations
2. Phenology extraction
3. Change analyses
4. Eco-polygon mapping

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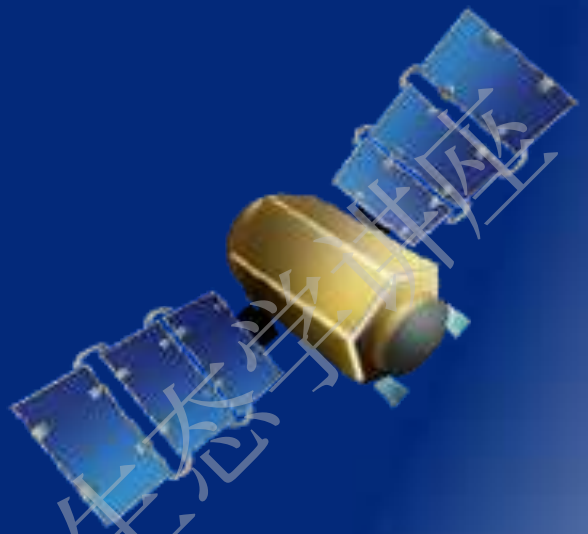
Satellite Observations

- MODIS EVI Products
- Time-series :2000-2008
  - 16-day composites
  - 250 m resolution
- DEM, soil, climate, and land uses



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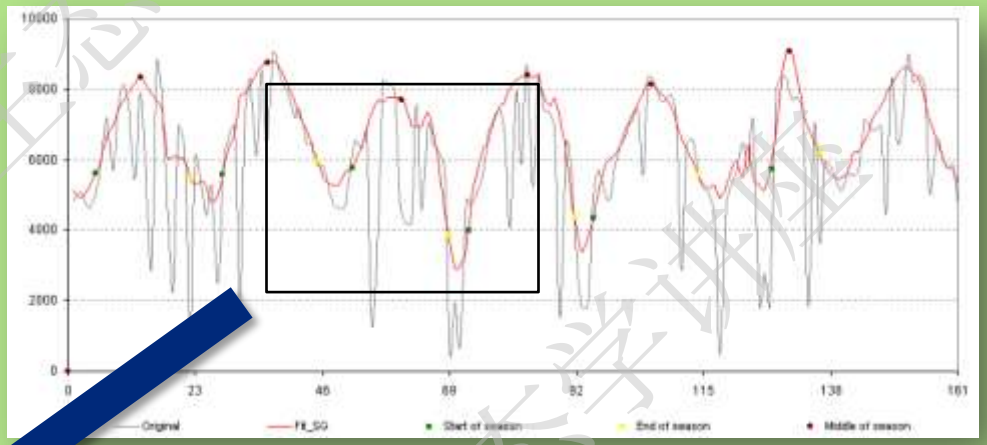
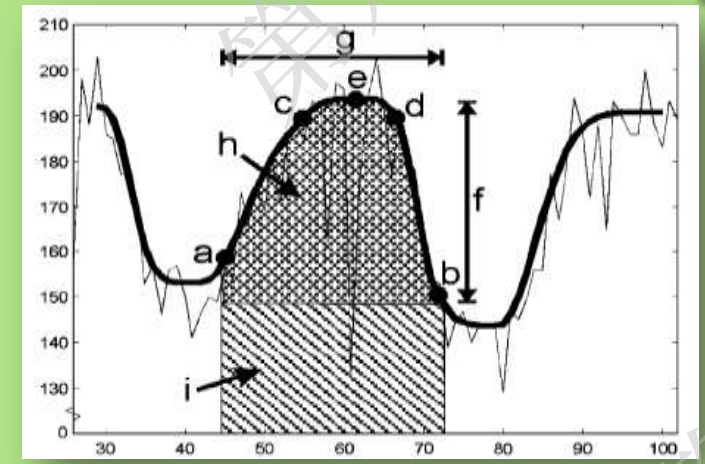
2000-2008 MODIS EVI Time-Series Images

Phenology seen from MODIS

MODIS 16-Day EVI Composites 2000 - 2008

EVI Seasonal Profiles and Phenological Parameters





Phenology Curve

PHENOLOGY PARAMETERS	DESCRIPTION
a) Start of the growing season	The first date which the value has increased
b) End of the growing season	The last date which the value has decreased
g) Length of the growing season	The number of days between the start and the end date
f) Amplitude of the growing season	The difference between the peak value and the start and the end date
i) Large integral	The total vegetation production
h) Small integral	The seasonally active vegetation

The Phenology Curve

- Fitted Curve Function: ***Savitzky-Golay Filter***
  - Least -squares polynomial regression for each point to fit curve
  - Adapts for upper envelope of EVI time-series profile
  - Preserves features of data distribution
  - Captures rapid phenology changes

$$Y_j^* = \frac{\sum_{i=-m}^{i=m} C_i Y_{j+1}}{N}$$

Y = original EVI value
Y^* = resultant EVI value
C_i = coefficient for the i^{th} EVI value of the filter
N = filter size ($2m+1$)
j = running index of the original ordinate data table
m = half-width of smoothing window
(Chen et al., 2004)

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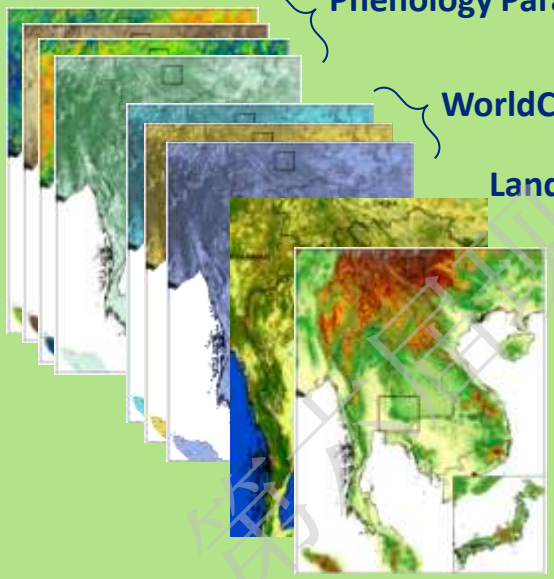
Ecological Mapping



Phenology Parameters 2000 - 2008

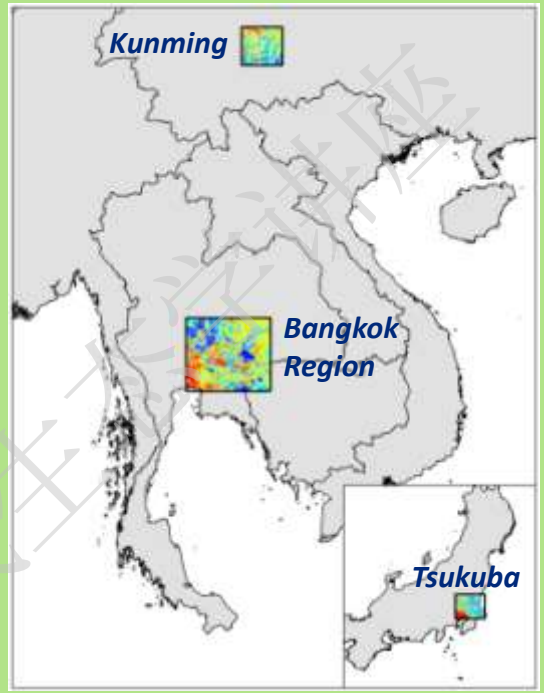
WorldClim Precip, Tmax, Tmin

Land Use/Land Cover

Digital Elevation Data

UNSUPERVISED CLASSIFICATION
OF 3 SELECTED TRAINING SITES

Eco-polygon Training Sites



Validation Components I & II

I : Field – Acquired GPS coordinates and field photos of eco-polygon training sites with GPS Camera

II: Collaboration with local scientists

PHENOLOGY & CHANGE ANALYSIS

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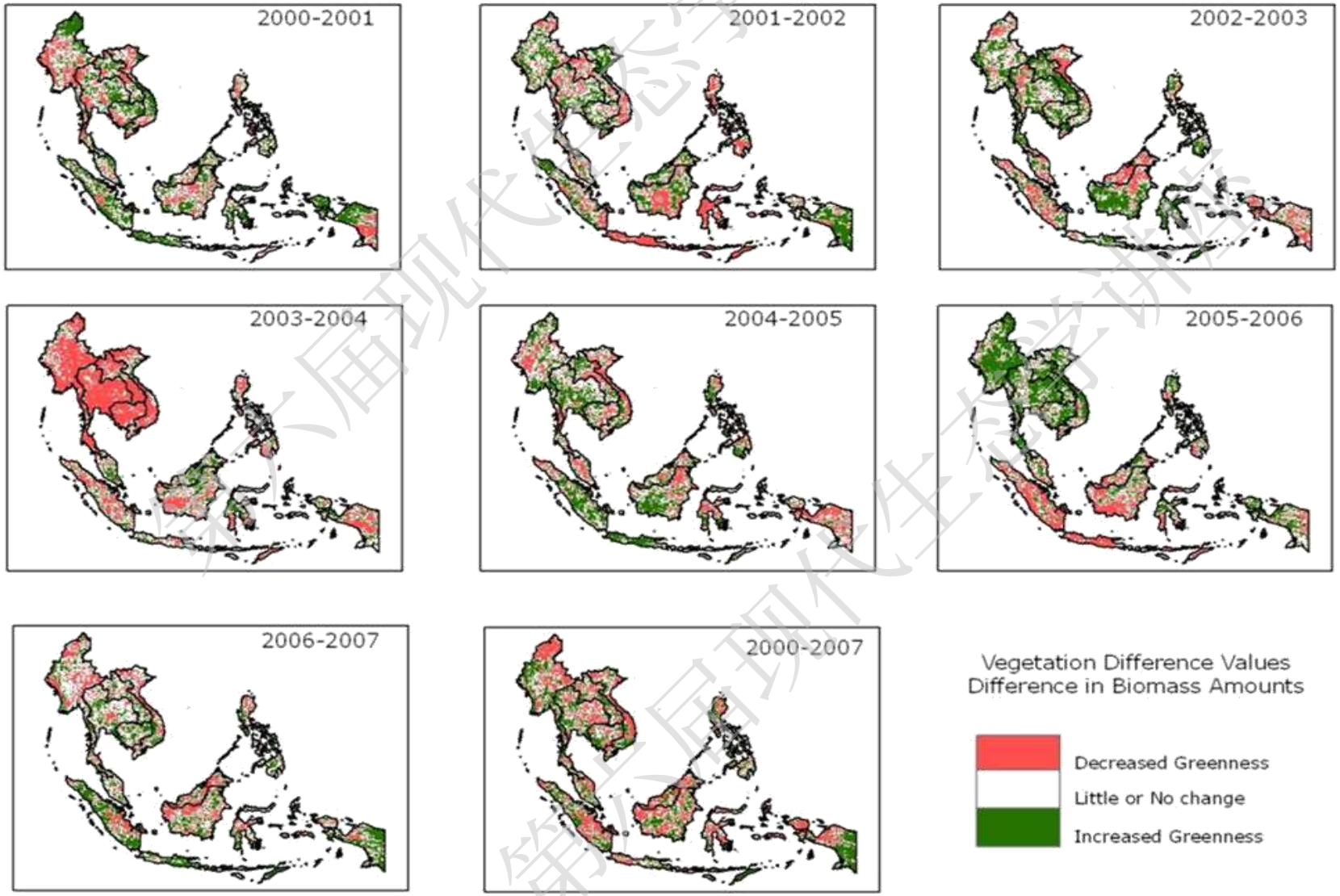
EVI Change Detection 2000-2007



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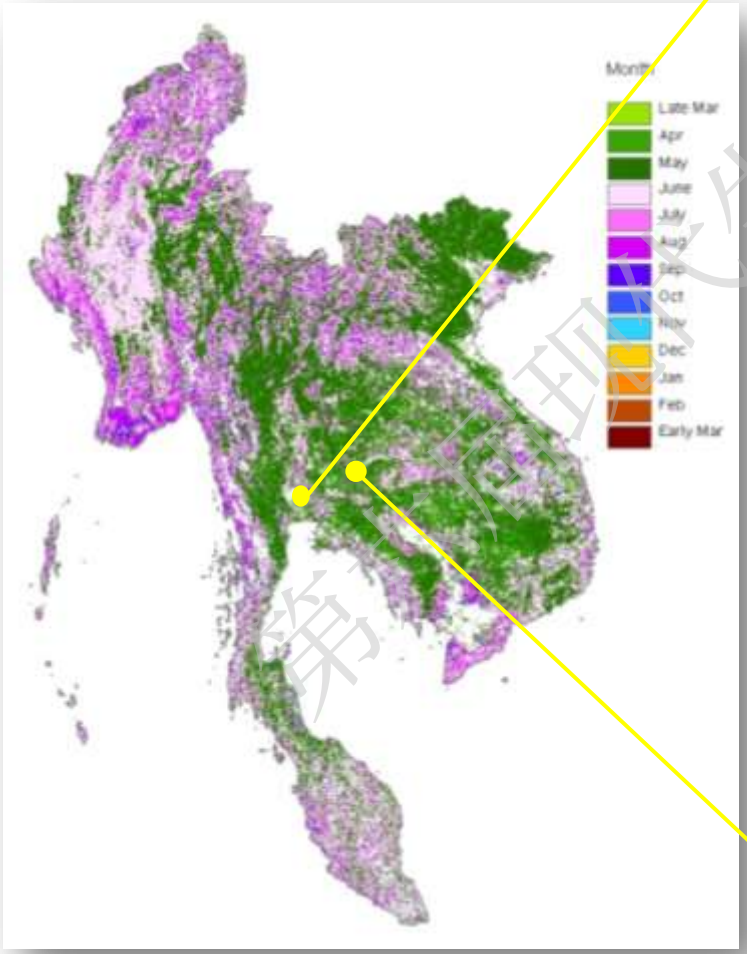
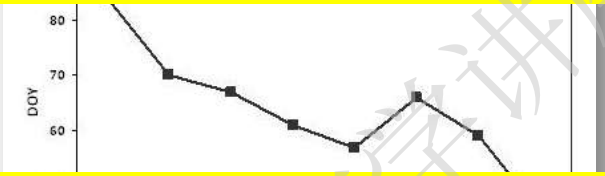
Start of Growing Season





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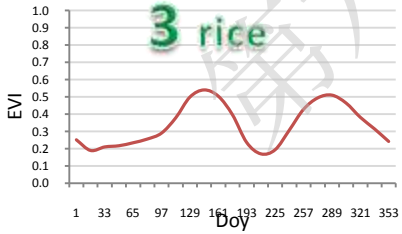
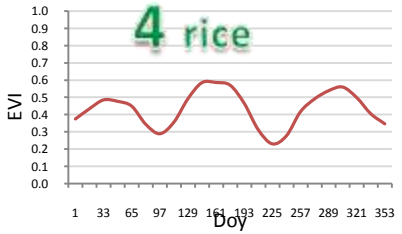
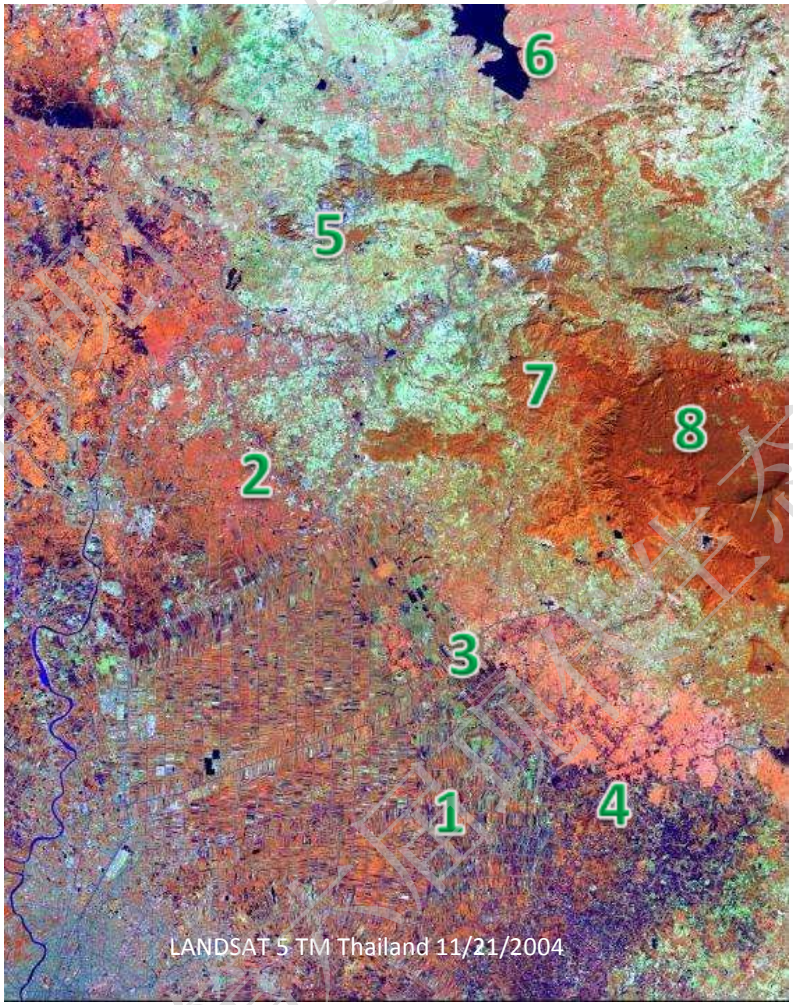
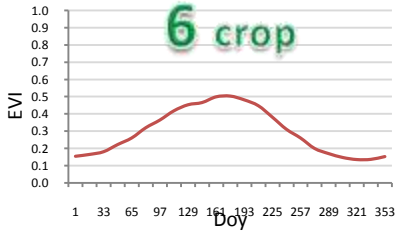
El Nino

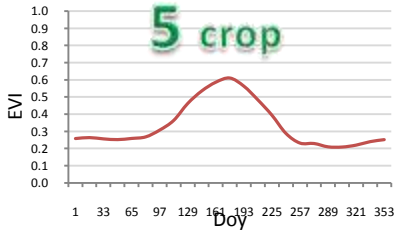
Seasonal Profile Patterns



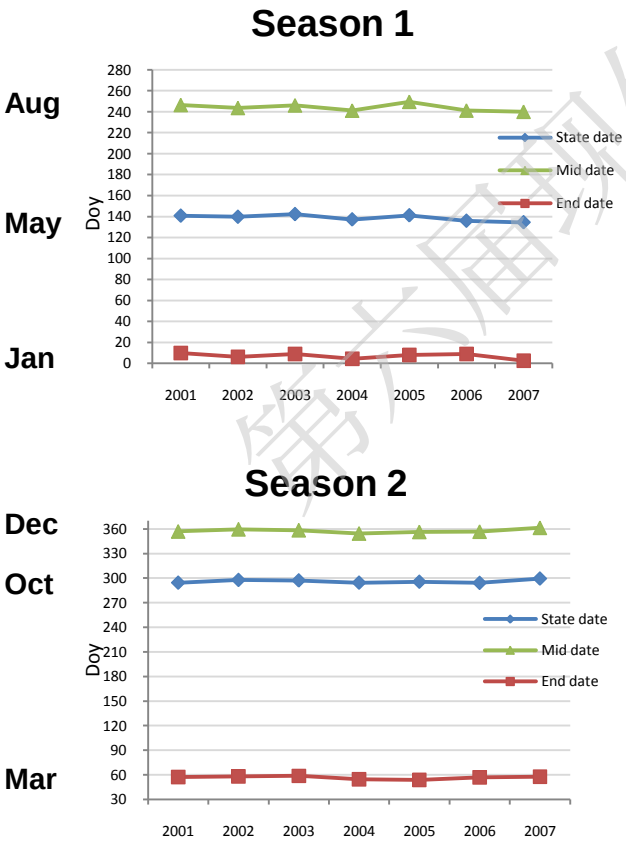


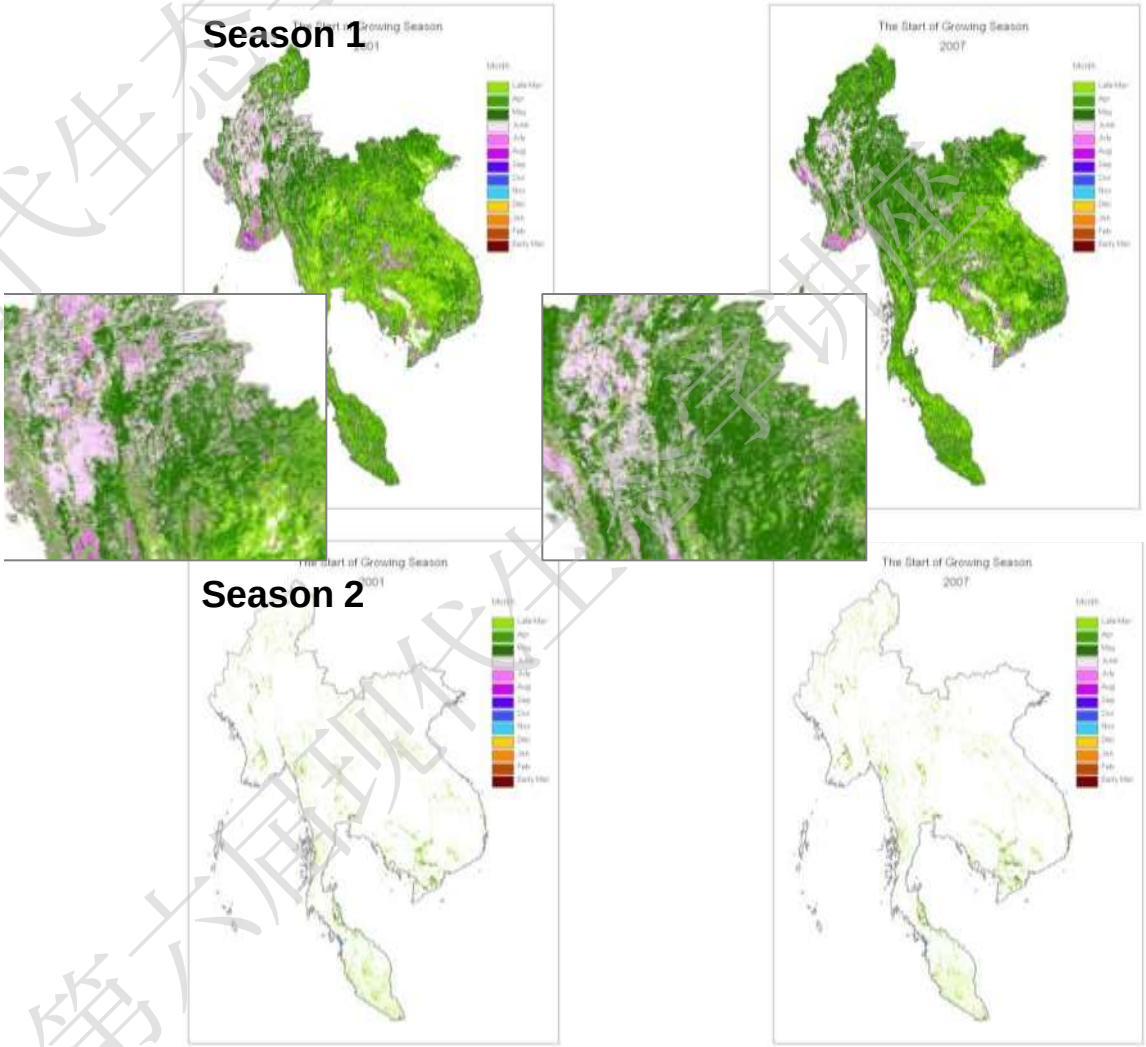






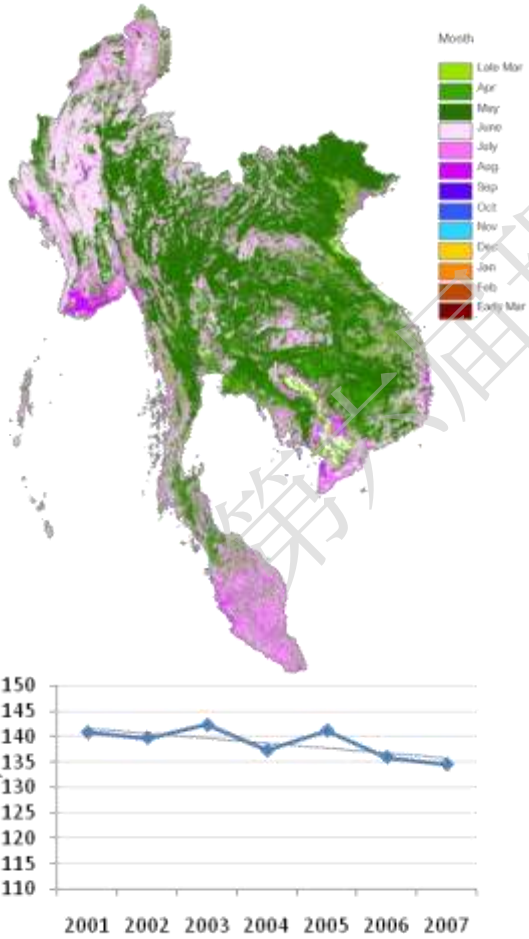
Number of seasons



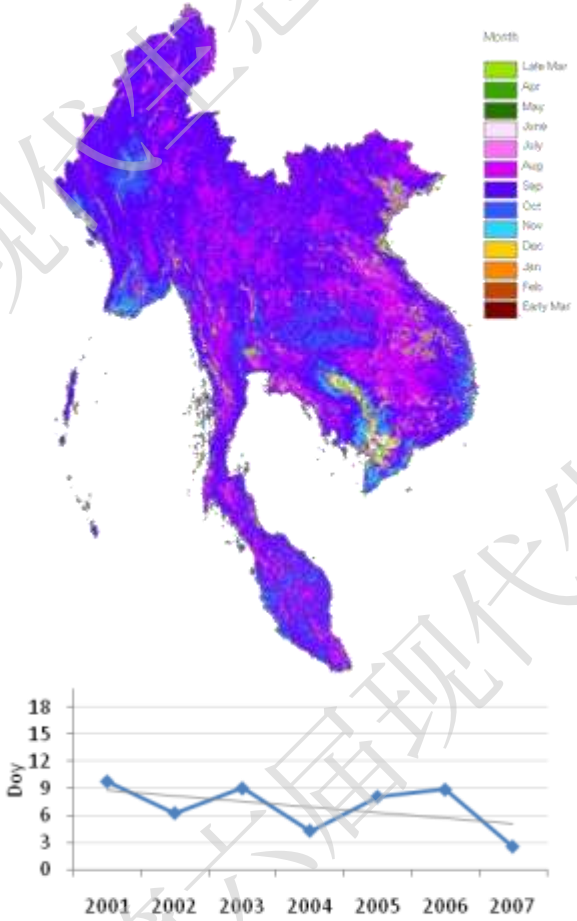


Planting Date

Start Date



Mid Date



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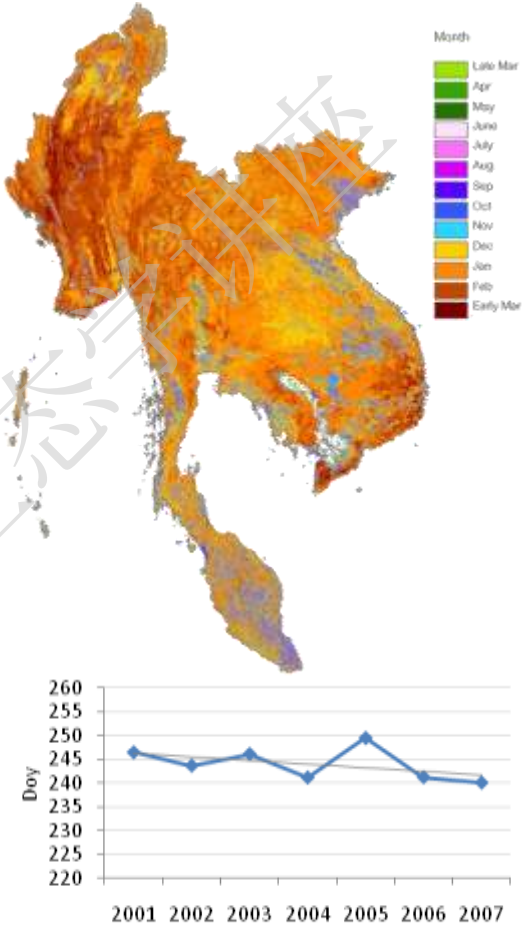
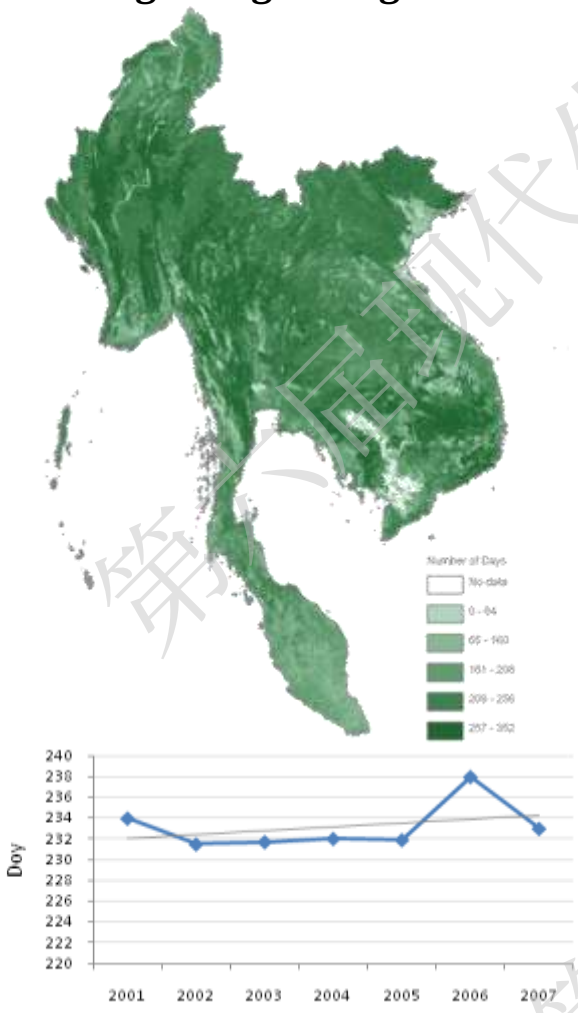


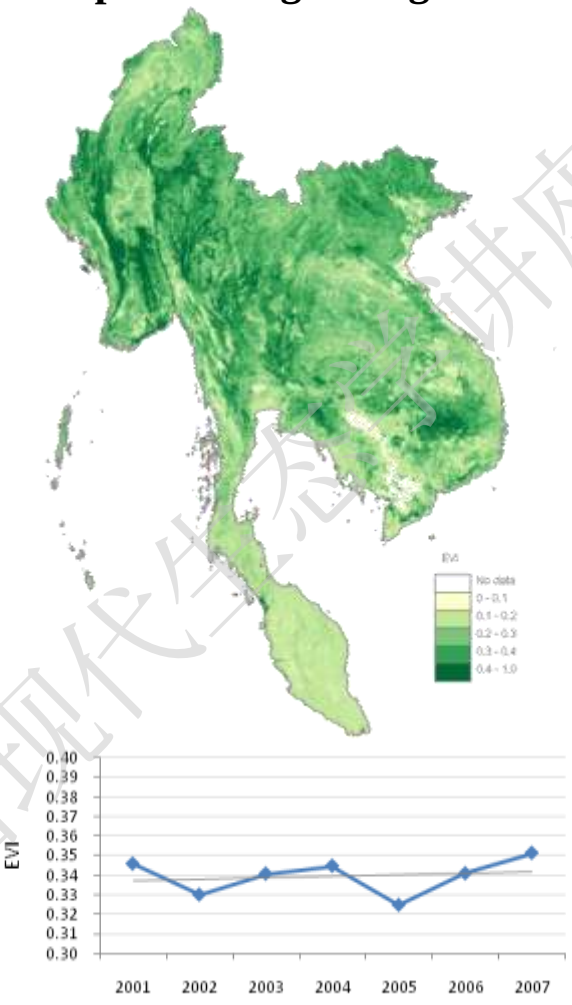
第六届现代生态学讲座

Planting Period and Peak Value

Length of growing season



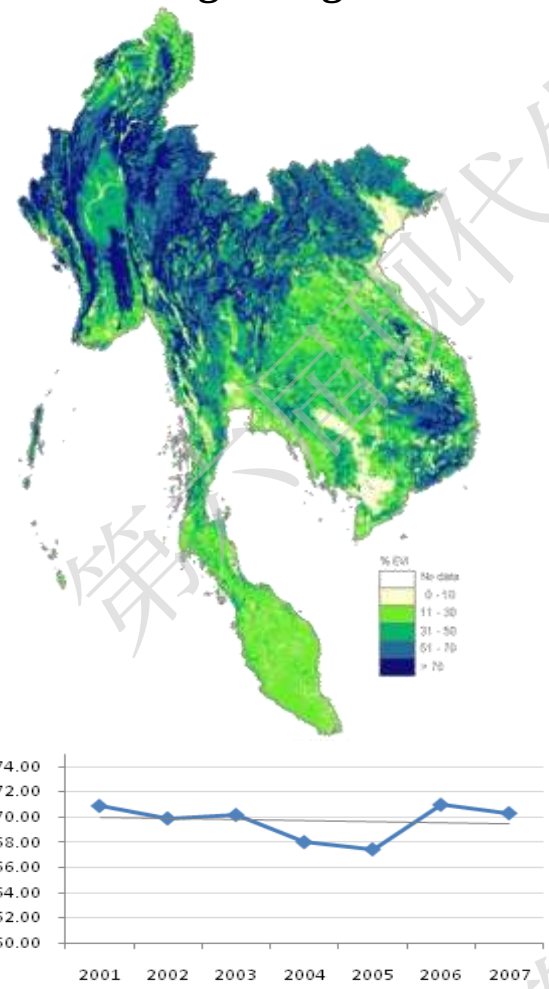
Amplitude of growing season



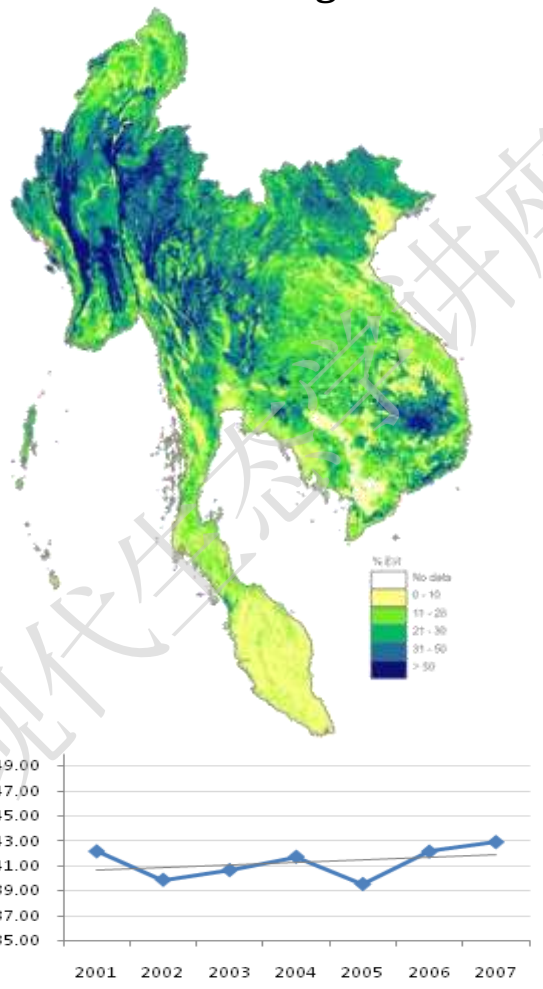
第六届现代生态学讲座

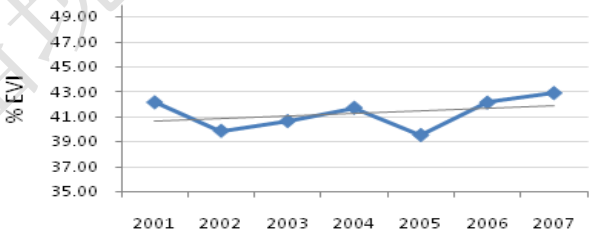
Planting Period and Peak Value

Large Integral



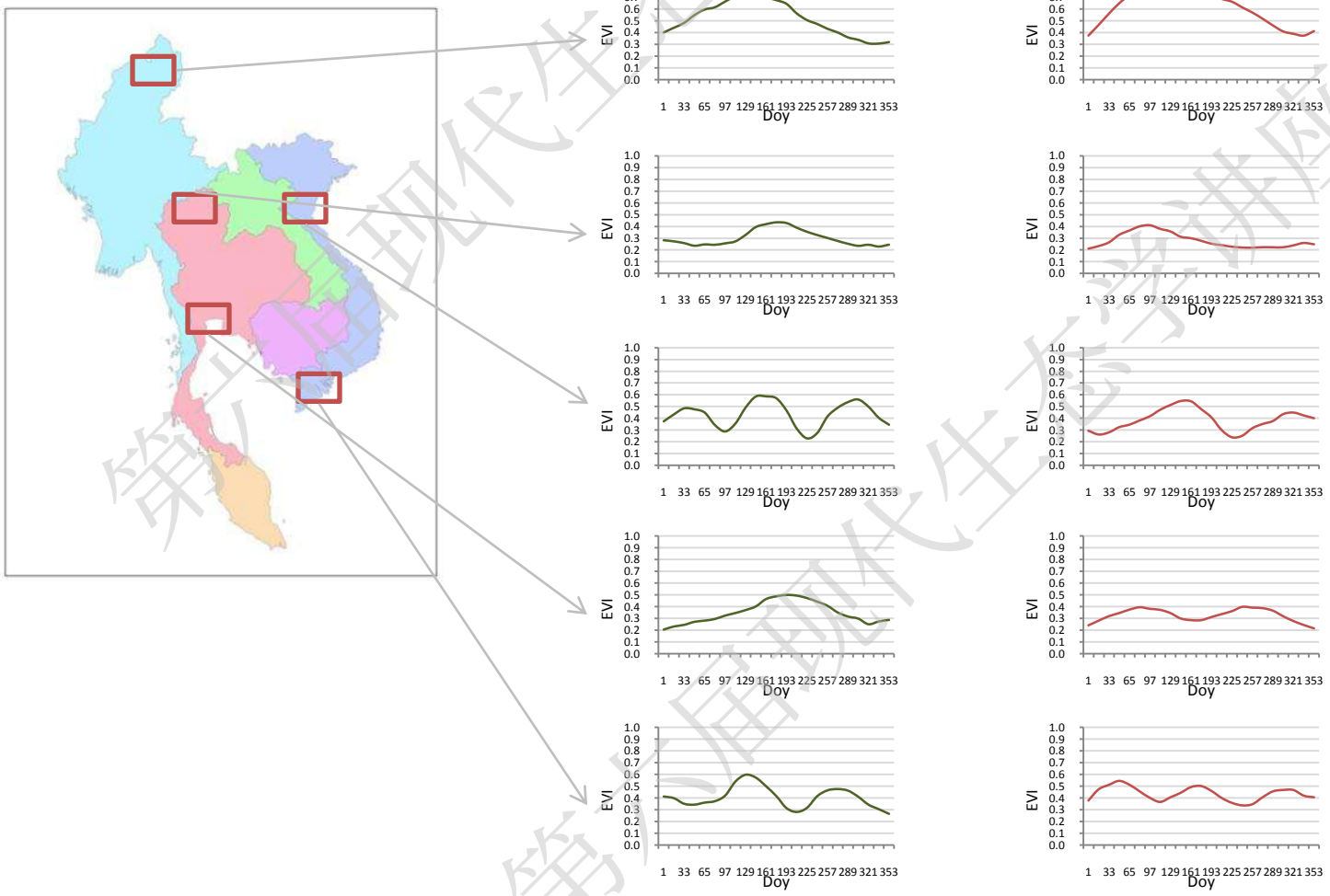
Small Integral





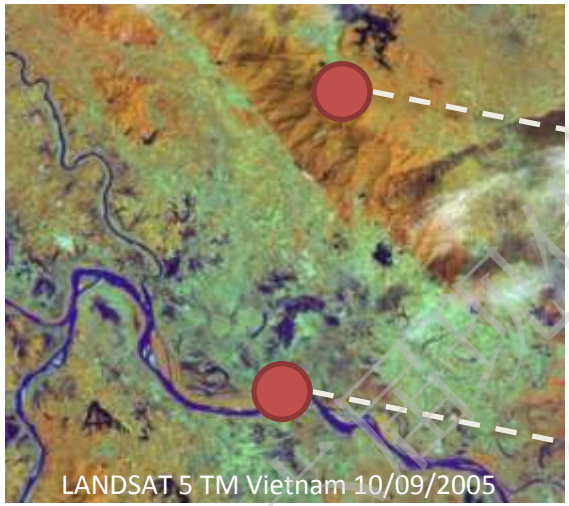
第六届现代生态学讲座

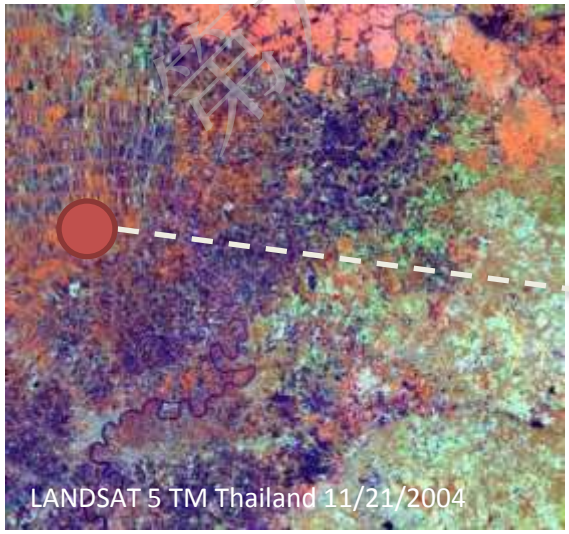
The number of season changes

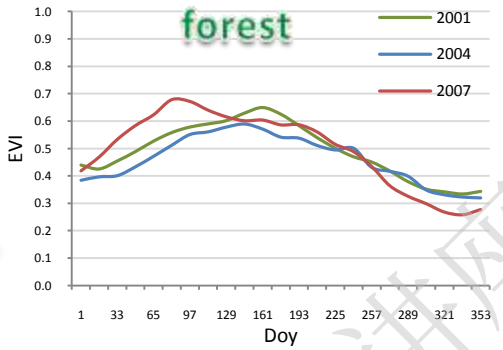


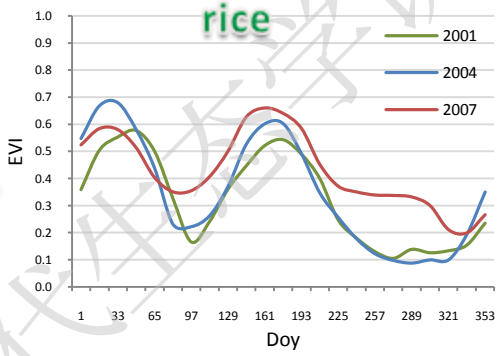
Results: Phenological Changes

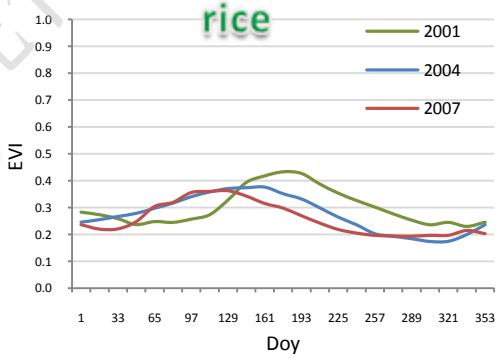
Growing season and the date changes











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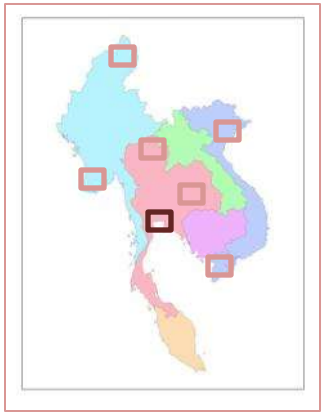
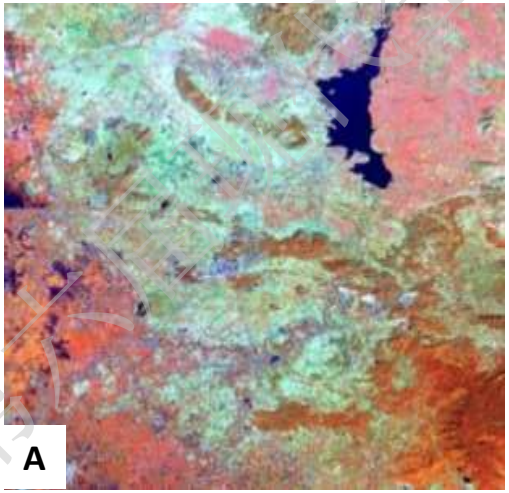
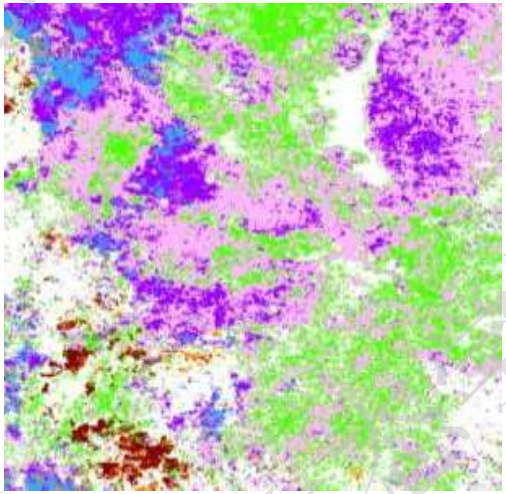
Comparison of Phenological Results and High Resolution Images



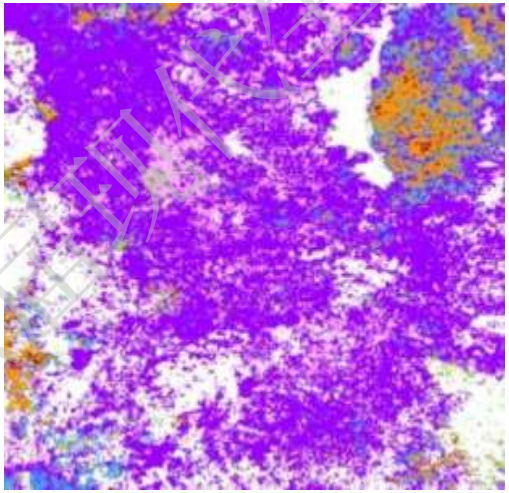


LANDSAT 5 TM Thailand 11/21/2004

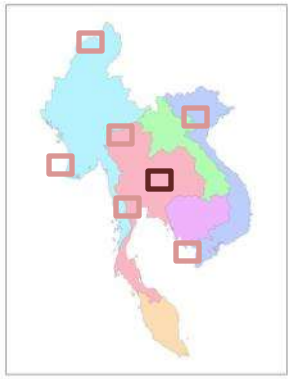
Start of the growing season 2004

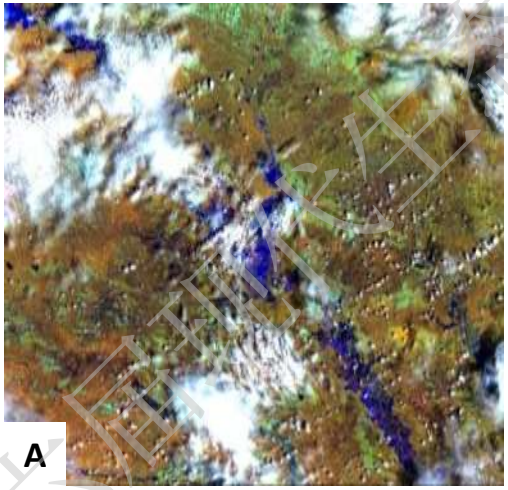


End of the growing season 2004

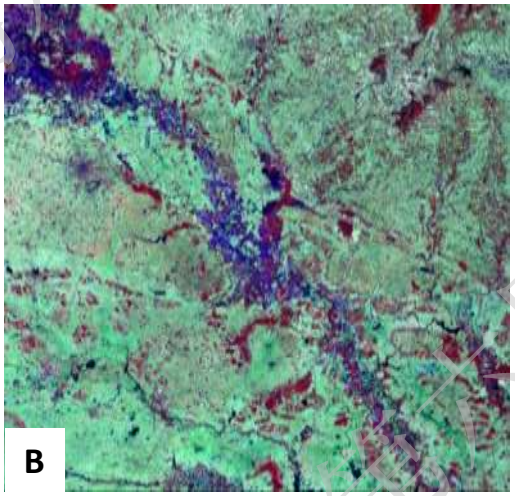


Comparison of Phenological Results and High Resolution Images



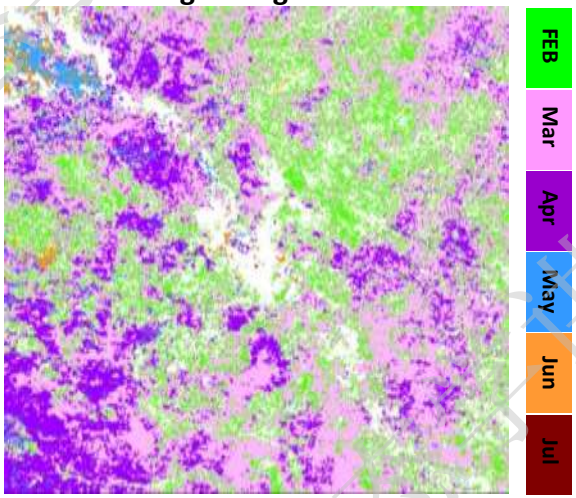


LANDSAT 5 TM Thailand 10/09/2006

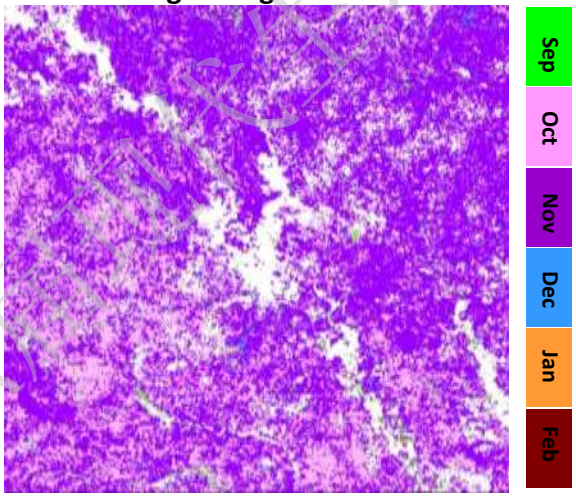


LANDSAT 5 TM Thailand 01/29/2006

Start of the growing season 2006

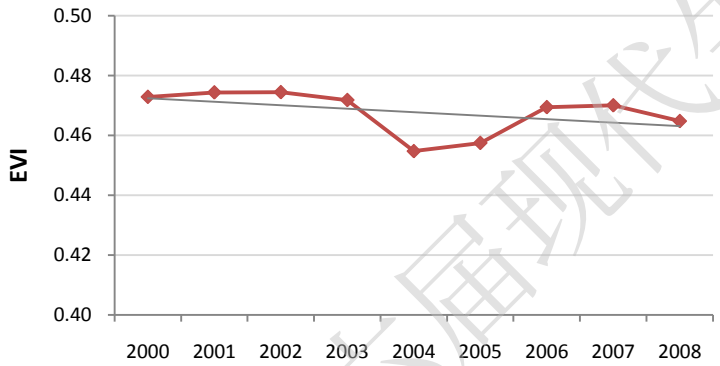


End of the growing season 2006

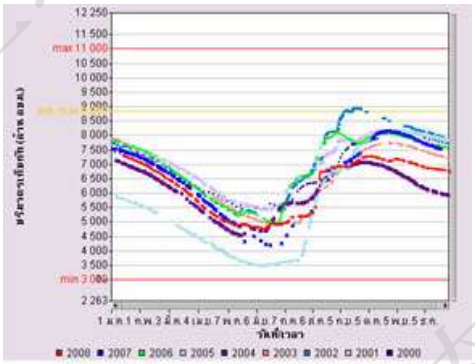


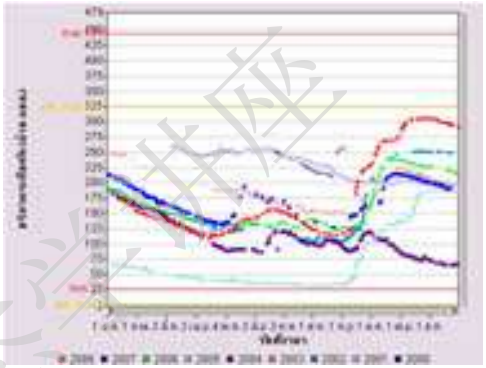
Results: Compare to rainfall data

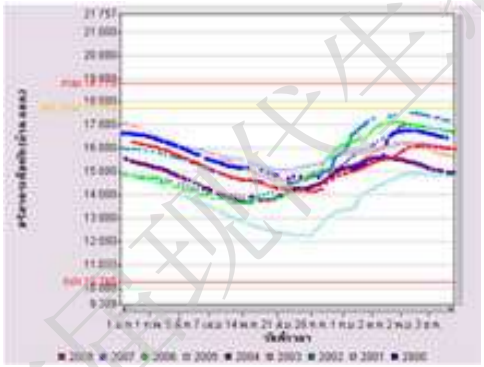
EVI Seasonal Profile



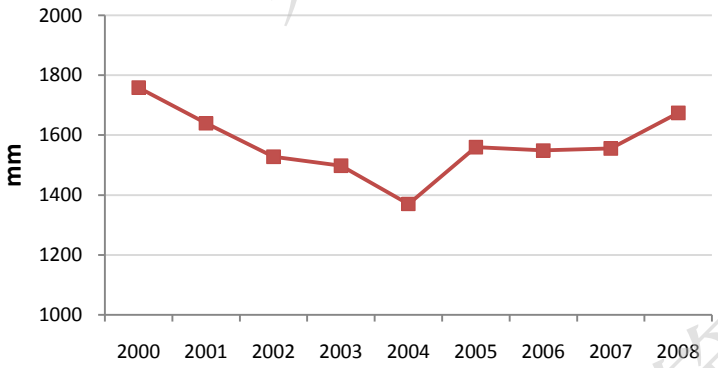
Volume and Water Levels in Dams







Average Rainfall Data



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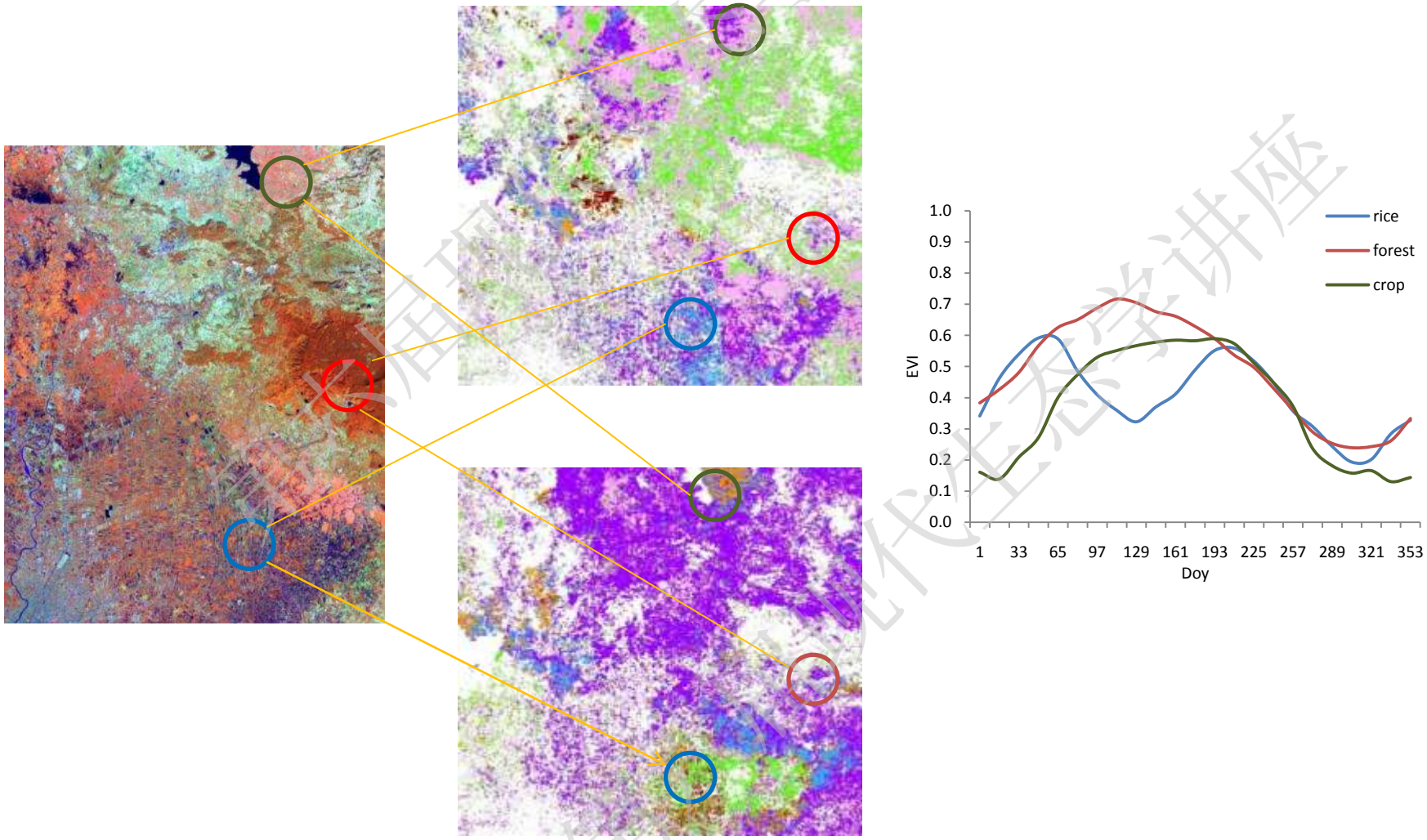
Different Vegetation Profiles and Phenology



UNDERSTANDING OF PHENOLOGY & CHANGES

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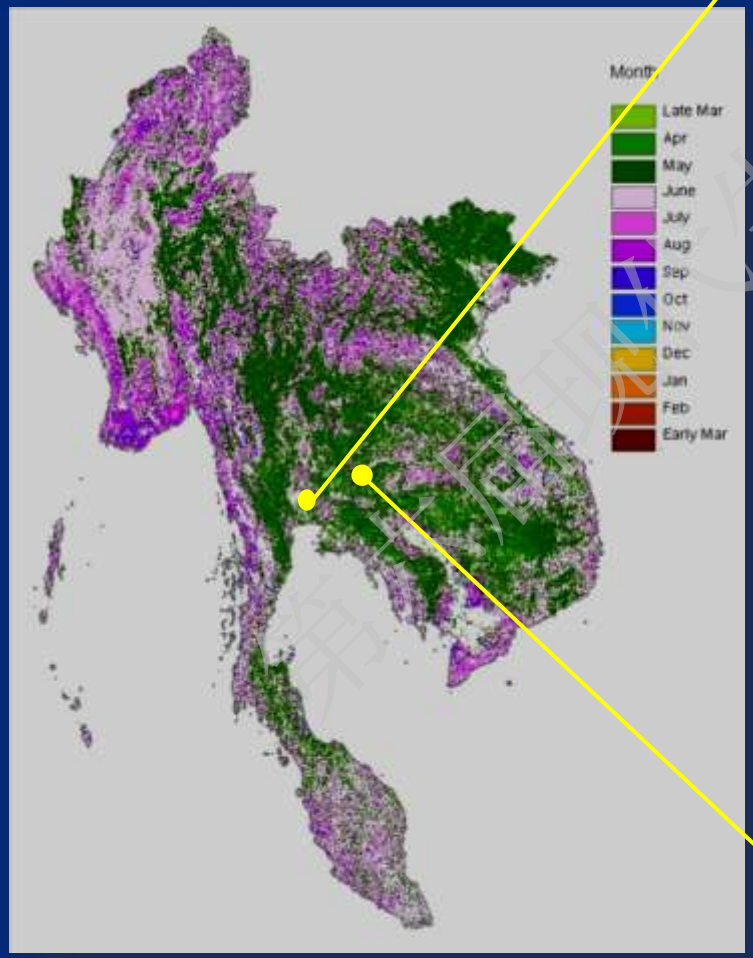
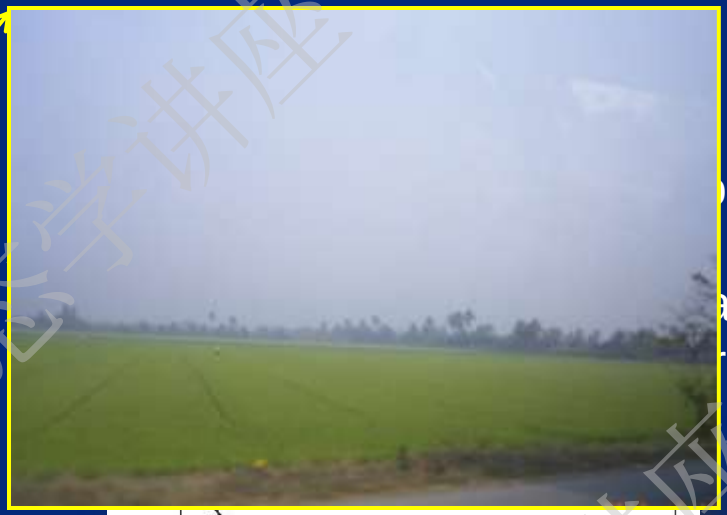
MICHIGAN STATE UNIVERSITY

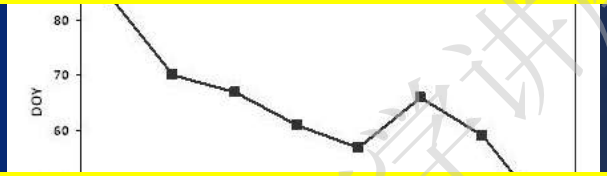
ISOMES VI - Nanjing, August 2-4, 2011

Center for GLOBAL CHANGE & Earth Observations Michigan State University

Start of Growing Season







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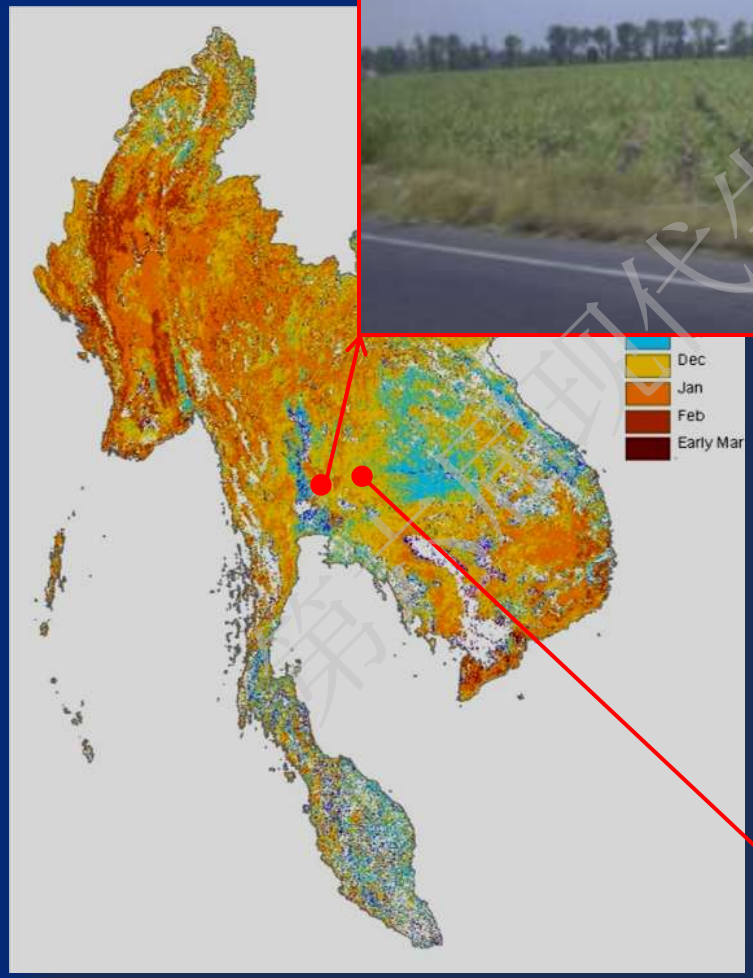
End of Grow



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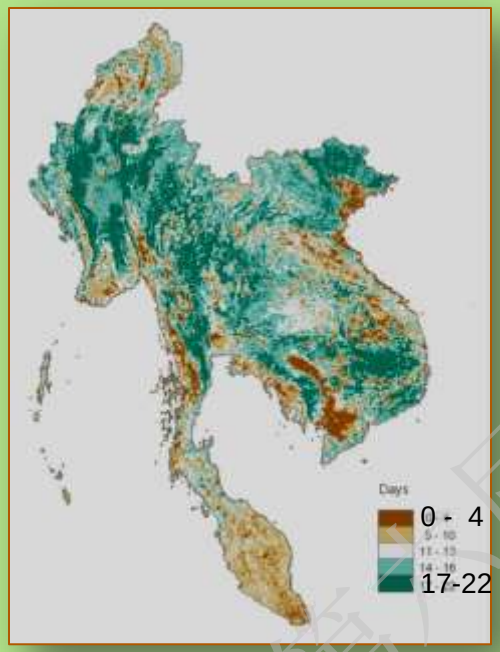
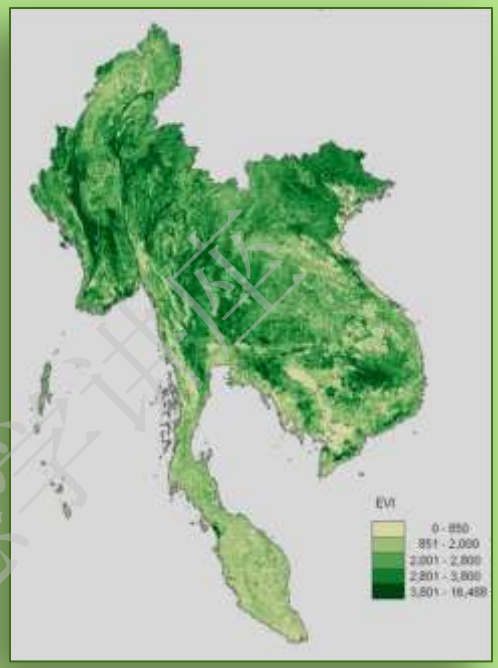
Length of Growing Season



- The growing season is generally longer in the northwest through the central portions of the Peninsula
- Likely due to moisture-rich environments, evergreen forests, and crops with longer growing seasons
- A large part of the eastern Peninsula experiences shorter growing season lengths
- This trend is supported by the general pattern of starting and ending dates

Amplitude of Growing Season

- Indicator of overall vegetation amount within the growing season
- Varies greatly across the Peninsula
- Relatively low amplitudes are found in the agricultural and dry areas in the eastern and central parts of the Peninsula
- The highest amplitudes are found in the north-northwest , where there is a mix of vegetation development and evergreen forests



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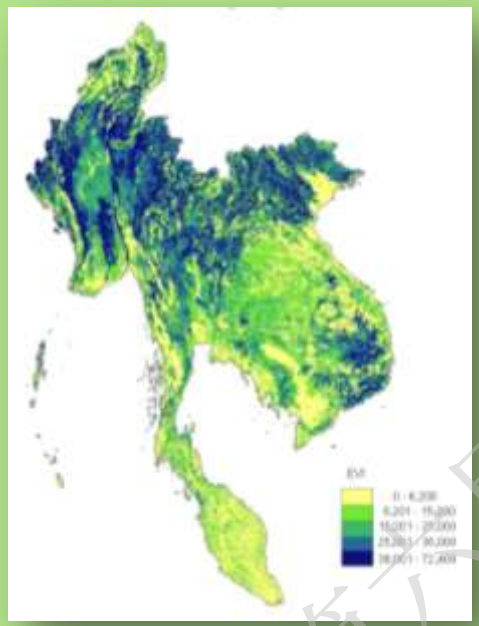
Large Integral

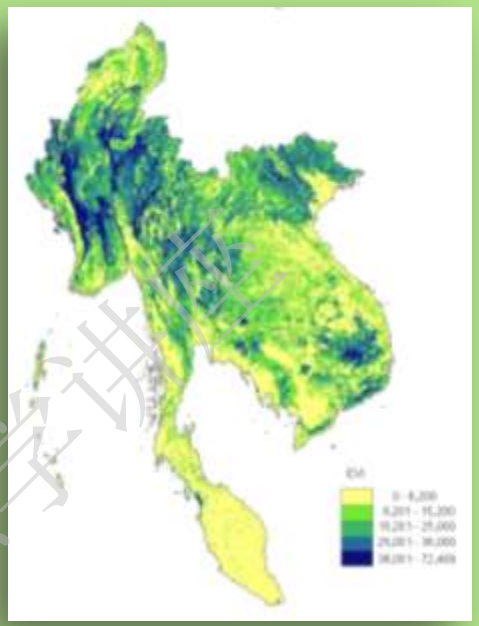


- Represents annual net primary production
- High production found in evergreen and deciduous forests in the north/northwest, East and the south represent low production

- The large integral is related with the amplitude of the growing season: ***areas with higher amplitude generally have higher values of total vegetation production***

Small Integral

- Indicates seasonally active vegetation or seasonal change in net primary production
- Also positively associated with large integral
- Some agricultural and dry areas have lower values which suggests low productivity (likely due to less rainfall)



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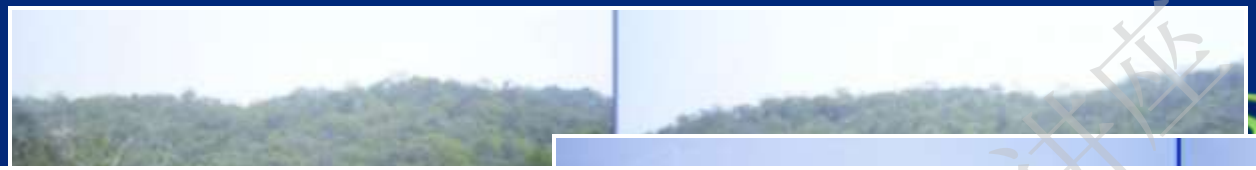

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Eco-Polygons

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CONCLUSIONS

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Conclusions

- A guideline for future ecological analyses:
  - An alternative method to assess phenology in Southeast Asia
    - Based on seasonal information
    - Identified phenology characteristics of multiple growth cycles
    - Identified vegetation dynamics that may be related to large- scale climate events (e.g., El Nino)
- A widely applicable framework
  - Extend study periods and/or areas

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Limitations & Future Directions

- Temporally limited data set (i.e., 9 years)
- Need for validation
- Need to understand ecosystem dynamics and disturbances for future adaptation strategy development in the region
- Integration with previous research to assess global climate change

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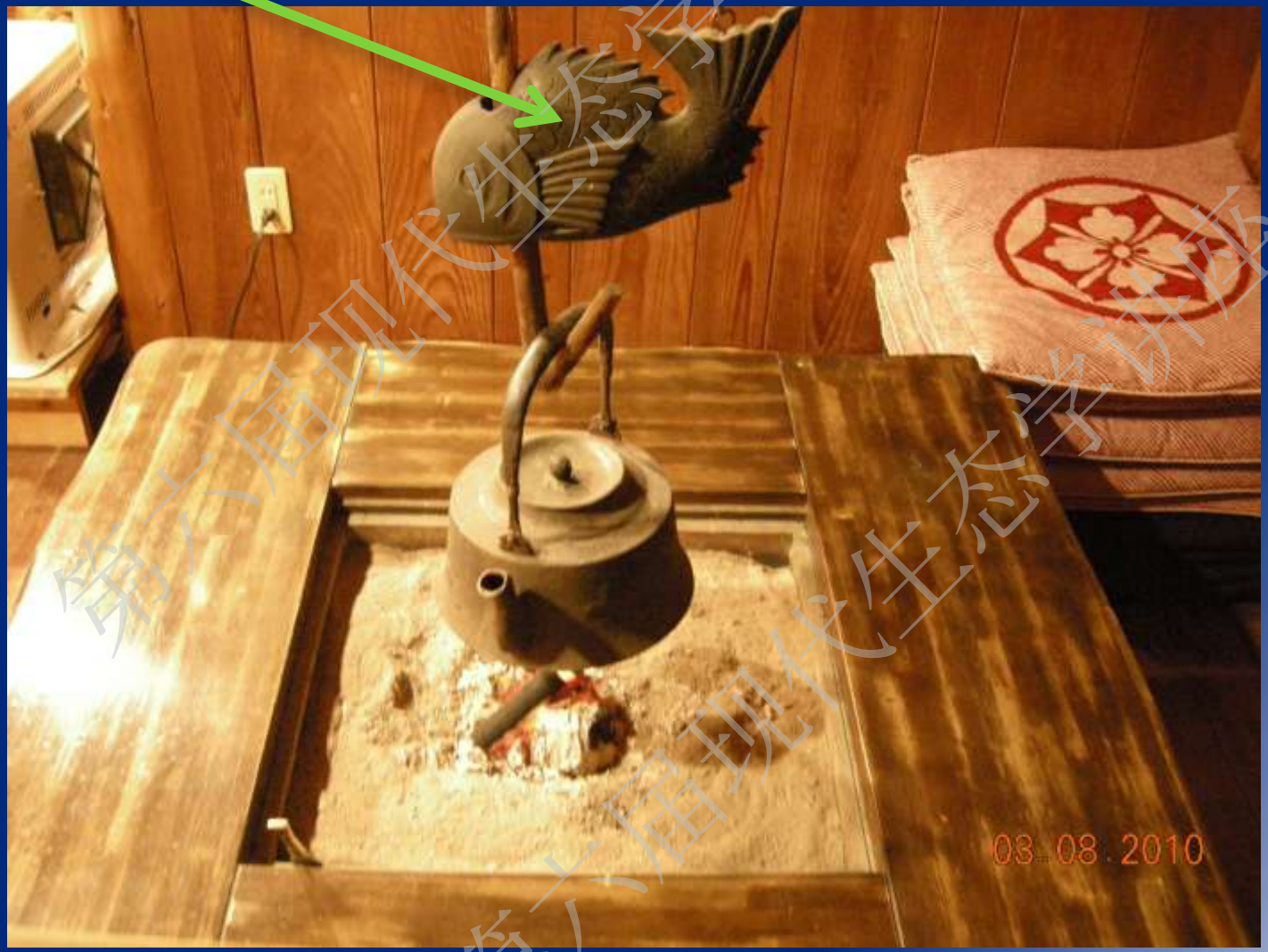
Look at the scale

Issues



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Mixed pixels!

Mixed pixels!

Thank you!
谢谢大家
qi@msu.edu
http://globalchange.msu.edu