水問題

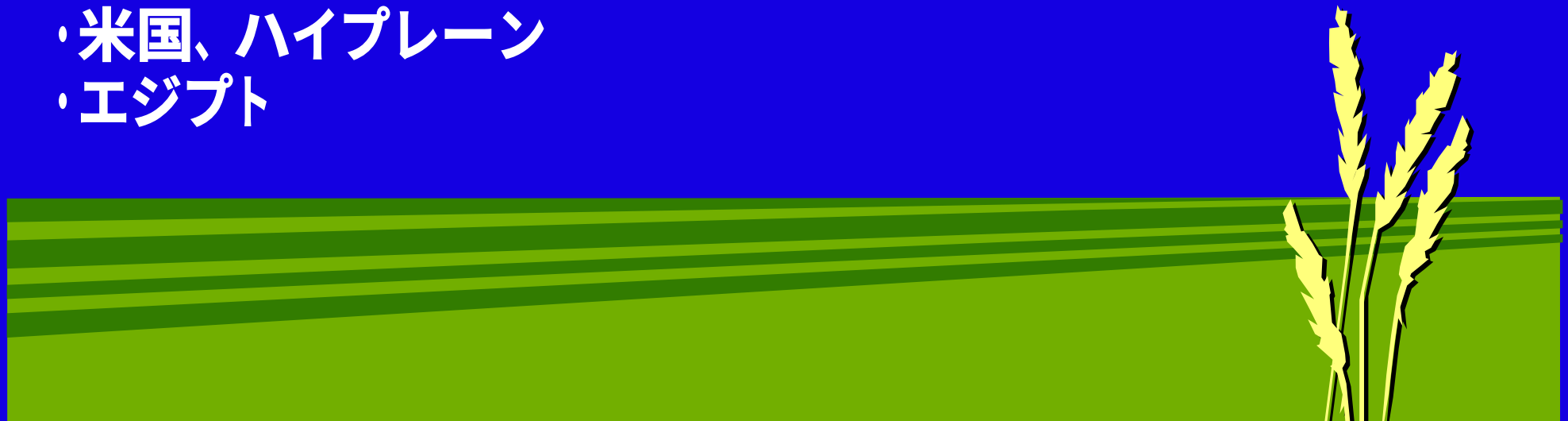
■水を巡る紛争

20世紀は石油を巡って戦争が起こったが、21世紀は水を巡る戦いが起こる

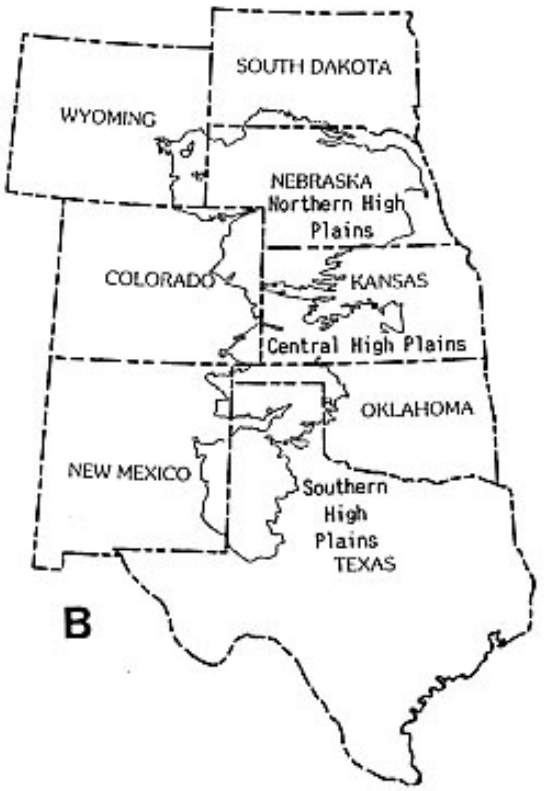
（紛争は増えてはいるが、それを上回る協調もある）

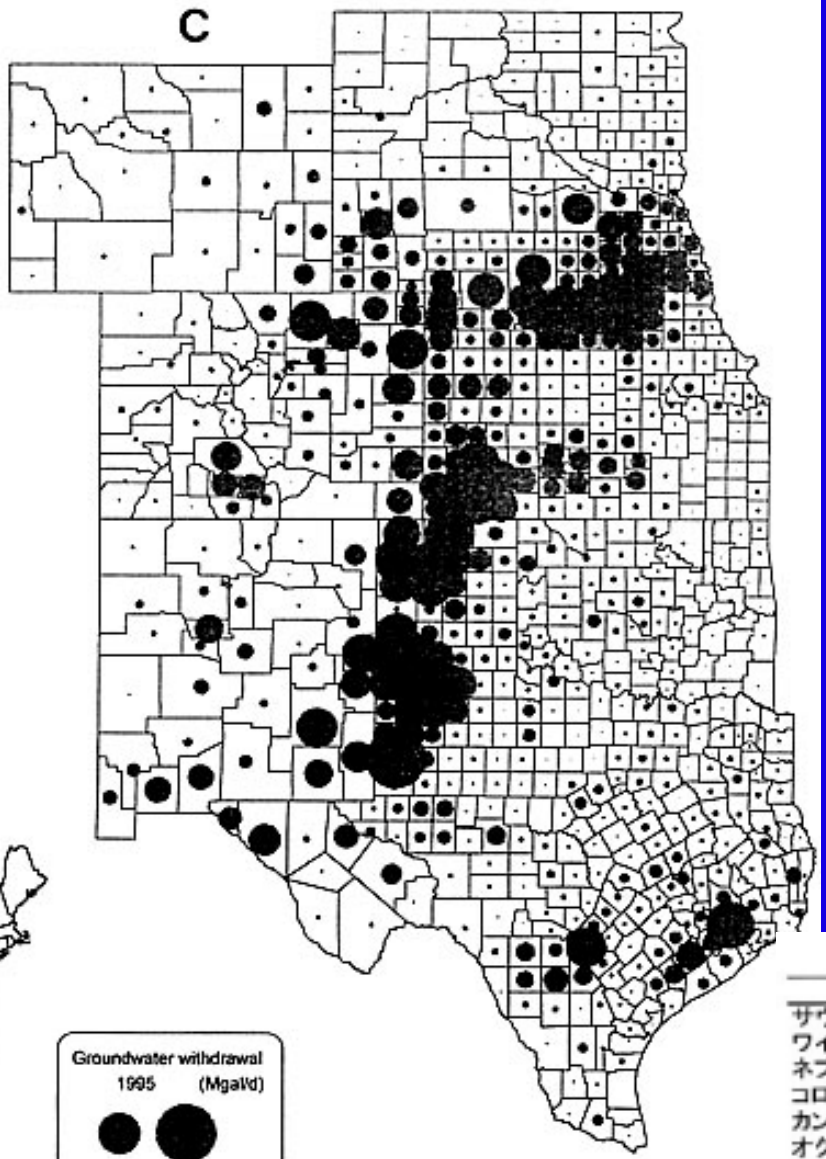
■２１世紀の地球環境問題

・グリーンウォーター
・黄河下流域
・米国、ハイプレーン
・エジプト



アメリカ・ハイプレーンズ地域の地下水利用の進展と課題





アメリカ西部、ロッキー山脈の東麓に広がるグレートプレーンズと呼ばれる**半乾燥地帯**は世界の食糧供給基地

いったい、ここで何が起こっているのだろうか？

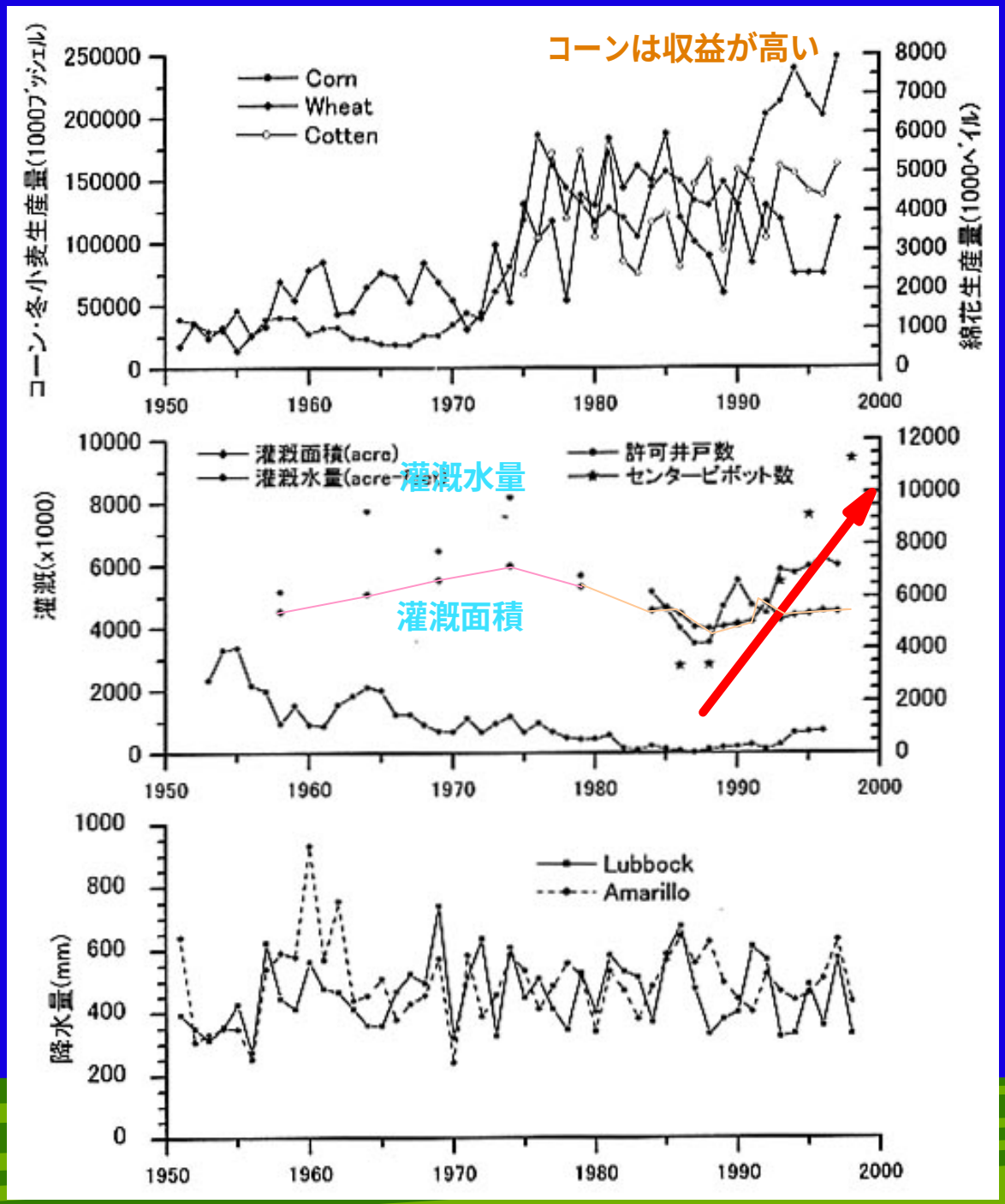
C：郡(county)別の地下水揚水量の分布(Mgal/d)　1gal=3.8l

表1　1997年の生産量における各州の全米順位

州	冬小麦	コーン	ソルガム	綿花	肉牛	豚
サウスダコタ		9	7		7	
ワイオミング						
ネブラスカ	6	3	3		2	6
コロラド	5				10	
カンザス	1	8	1		3	
オクラホマ	2		5		5	8
ニューメキシコ			9			
テキサス	4		2	1	1	

空白は11位以下を示す

地下水利用



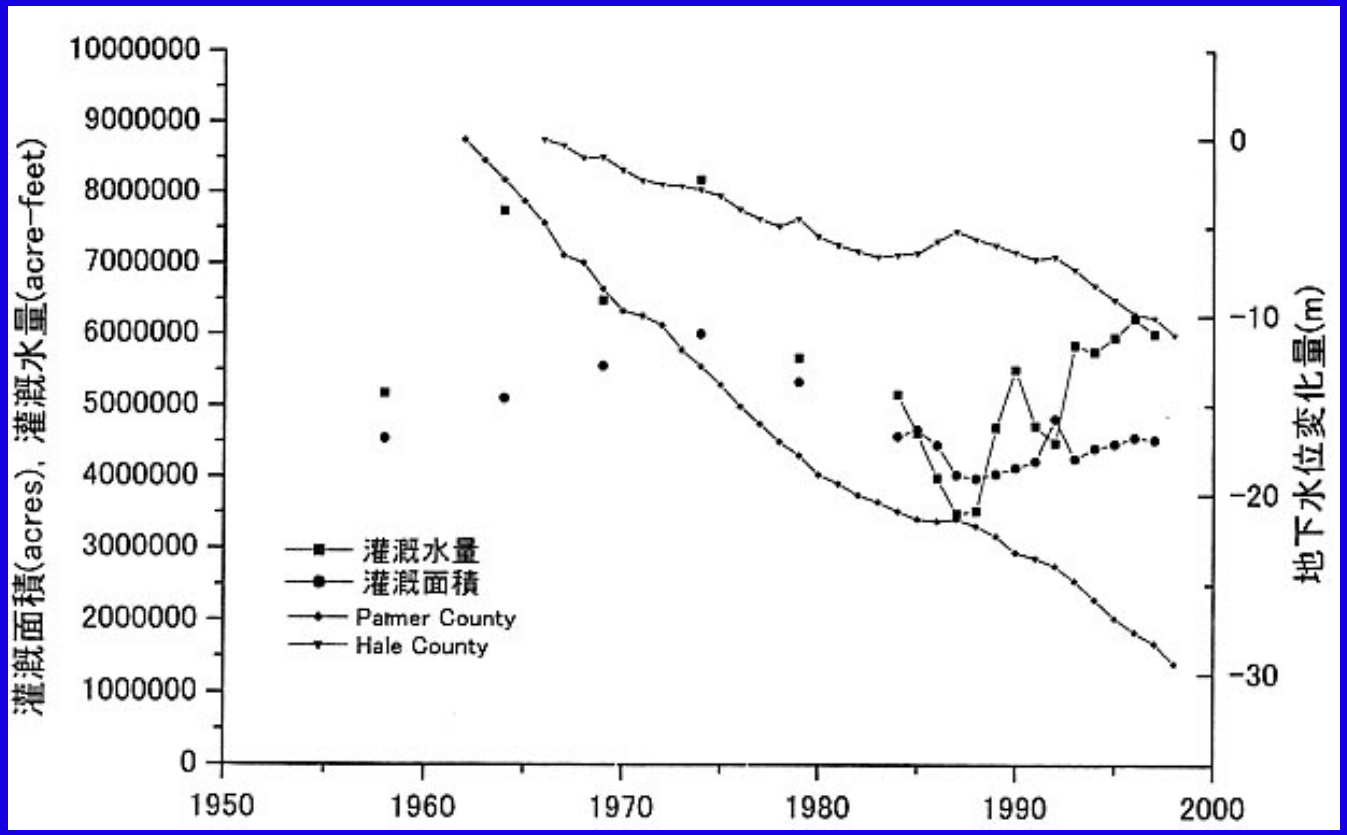
上：テキサス州におけるコーン、冬小麦、綿花の生産量

中：テキサス・ハイプレーンズ44州の灌漑面積・灌漑水量とハイプレーンズ地下水保全地区No.1における許可井戸数とセンターピボット数（→）

地下水揚水量は最近再び増加傾向にあるが、それはセンターピボットの増加と調和的である

下：LubbockおよびAmarilloの年降水量

灌漑と地下水位



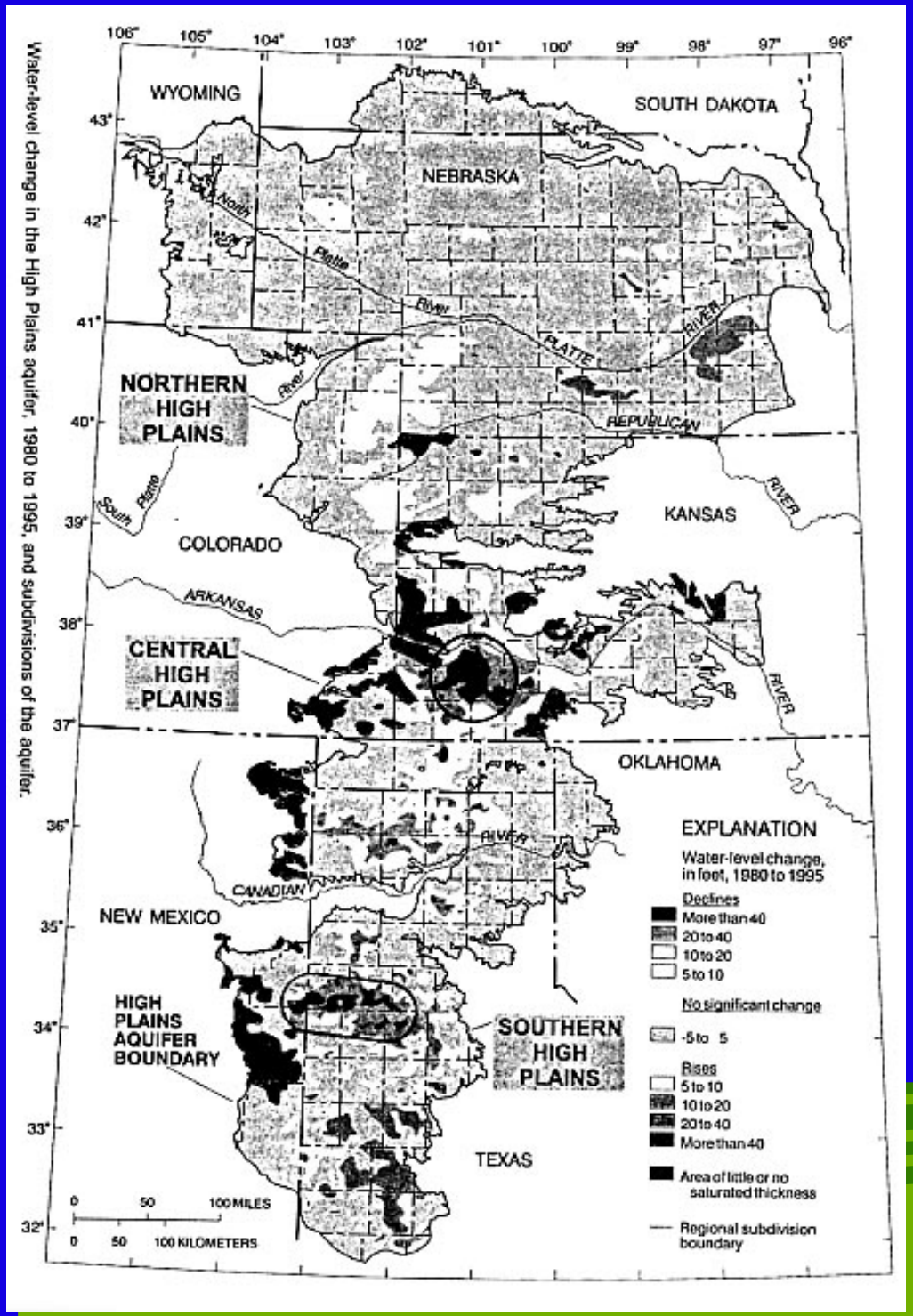
灌漑効率の高いセンターピボット方式→地下水揚水を促進

テキサス・ハイプレーンズ地域の灌漑面積、灌漑水量とParmer郡(1962年以降)、Hale郡 (1966年以降) における地下水位変化量

・揚水コストの増大
・穀物価格への転嫁

どのような対策がとられているか

・**節水農業**　センターピボット、ドリップ灌漑
・保全地域の指定による掘削井戸の許可性
・土壌保全保留計画 (政府が賃借料を負担し、10年間の休耕)
・様々な啓蒙活動



ハイプレーンス帯水層における地下水位変化

なぜ、改善できないのか？

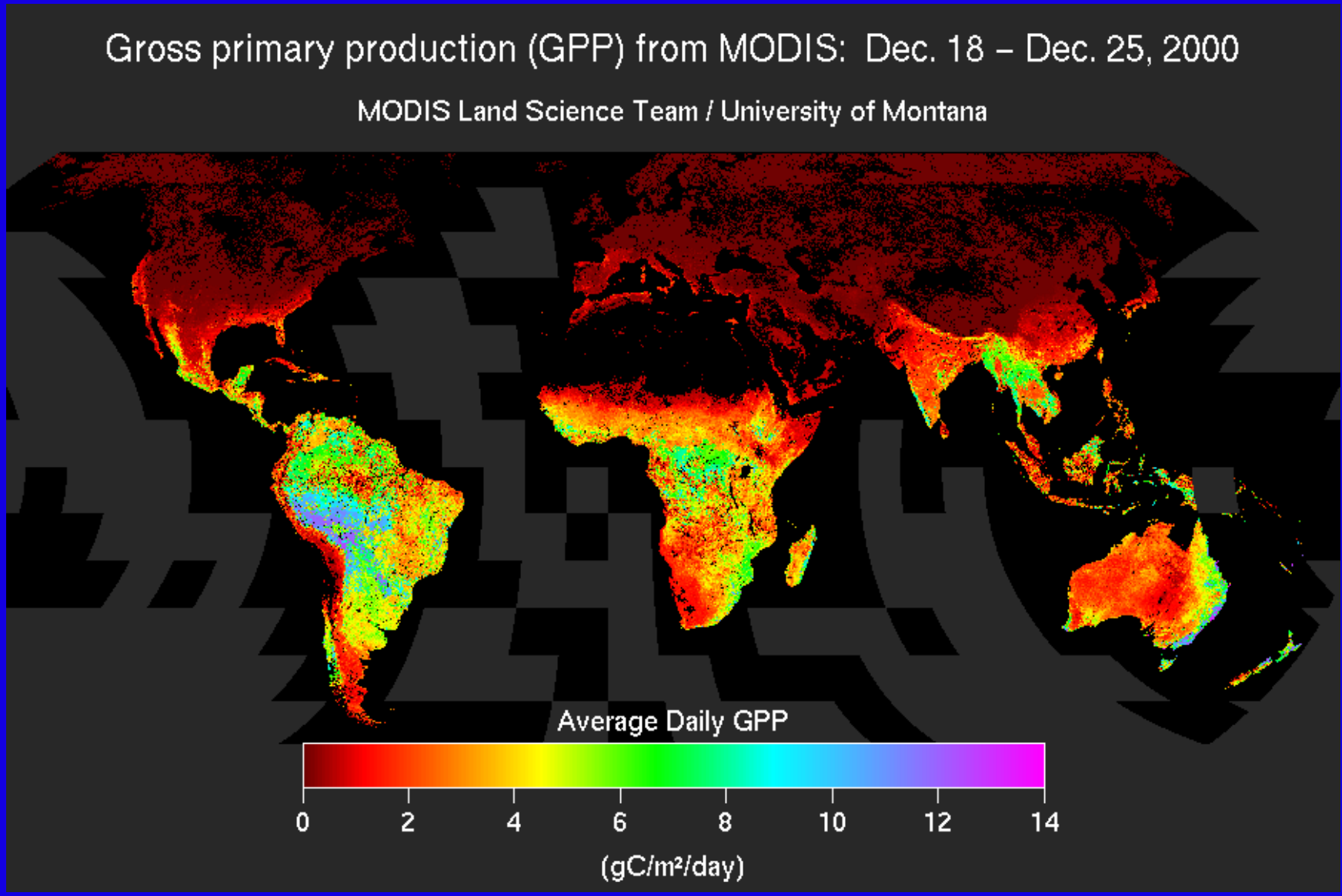
この地域を支える経済活動を止めることはできないから

・表流水の確保は不可能
・節水も最高レベルに達した

↓

自然の水循環を理解、強化して利用可能な水量の決定
ープラヤの機能

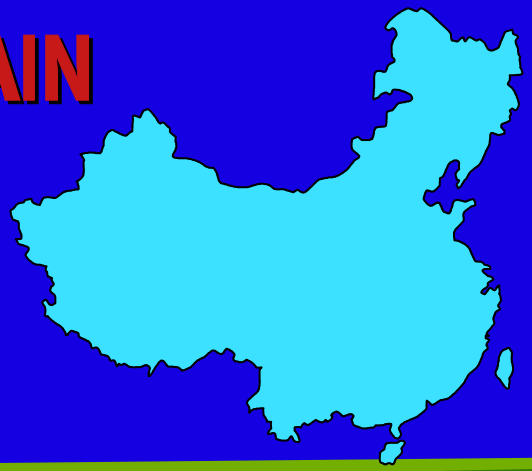
資料：田瀬則雄筑波大学教授（2000）、水資源セミナー講演集



衛星リモートセンシングで植物生産量、穀物生産量をモニターすることは可能である。ただし、その背後にある地域の事情を知らなければ社会に対して責任ある成果とすることはできない。千葉大学は食糧、水、社会経済、健康、リモートセンシング技術、等々様々な分野の研究教育が行われている総合大学である。普遍教育において様々な分野に接して、そこから複合的な視点を育んでほしい。

HYDROLOGICAL CYCLE AND CROP PRODUCTION IN NORTH CHINA PLAIN

Kondoh, A., Tang, C., Sakura, Y. and Shen Y.(Chiba University)
Tanaka, T. (Univ. Tsukuba)
Shindo, S. (Prof. Emeritus, Chiba University)
Liu, C. (Shijiazhuang Institute of Agricultural Modernization, CAS)
NCP 38N Project Group



Current status of Sino-Japan NCP 38N Project on Hydrological Cycle

２１世紀の地球環境問題

NEW GLOBAL ENVIRONMENTAL ISSUE
- WATER PROBLEM -

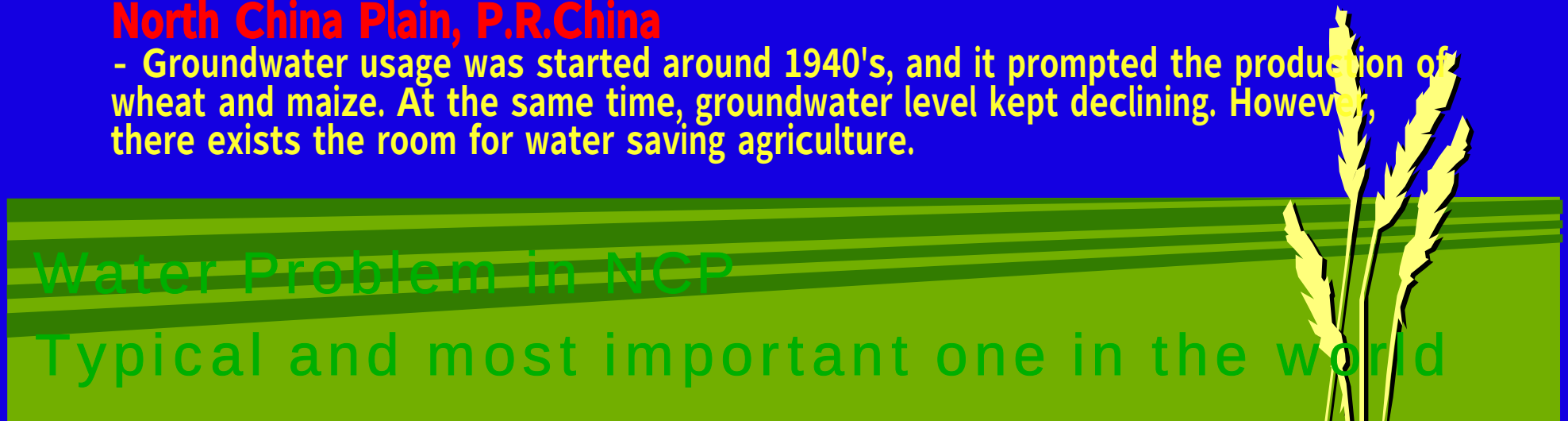
■ Problems appeared in the world with same background

- Progresses in irrigation technique promote crop production, however, the lack of knowledge on the renewal of water resources, especially groundwater, and the pursuit of short-term profit lead to the overuse of water resources.
- Import of grain is equivalent with that of water. It means the water problem is the one which go over the national boundary.

■ Well-known cases

Central Plain in USA -an extreme case-
- Over withdrawal of groundwater cause the decline of groundwater level. Saving water technique such as center pivot irrigation promoted further production.

North China Plain, P.R.China
- Groundwater usage was started around 1940's, and it prompted the production of wheat and maize. At the same time, groundwater level kept declining. However, there exists the room for water saving agriculture.



華北平原

China's Water Shortages Could Shake World Food Security

An abrupt decline in the supply of irrigation water to China's farmers has aroused growing concern in the world's capitals.

by Lester R. Brown and Brian Halweil

An unexpectedly abrupt decline in the supply of water for China's farmers poses a rising threat to world food security. China depends on irrigated land to produce 70 percent of the grain for its huge population of 1.2 billion people, but it is drawing more and more of that water to supply the needs of its fast-growing cities and industries. As rivers run dry and aquifers are depleted, the emerging water shortages could sharply raise the country's demand for grain imports, pushing the world's total import needs beyond exportable supplies.

food, because it can afford to pay more for grain. But low-income countries with growing grain deficits may not be able to pay these higher prices. For the 1.3 billion of the world's people who live on $1 a day or less, higher grain prices could quickly become life threatening. The problem is now so clearly linked to global security that the U.S. National Intelligence Council (NIC) the umbrella over all U.S. intelligence agencies, has begun to monitor the situation with the kind of attention it once focused on Soviet military maneuvers.

Brown and Halweil(1998)

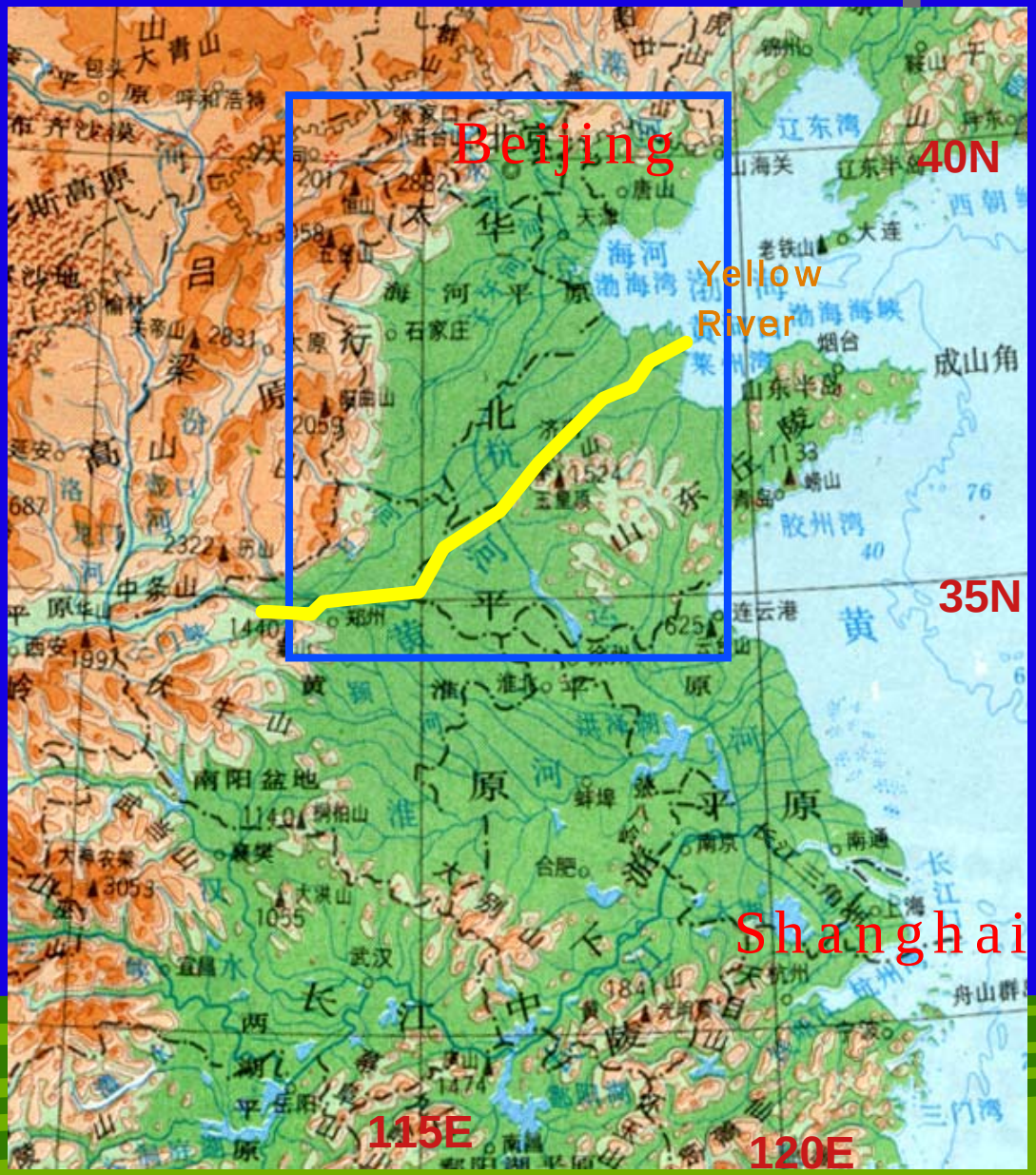
Topic 1

- **What is happening in NCP ?**
  - **Cutoff of the Yellow River**
  - **Decline of groundwater level**
  - **Salinization**
- **China's Water Shortages really shake world food security ?**

Topic 2

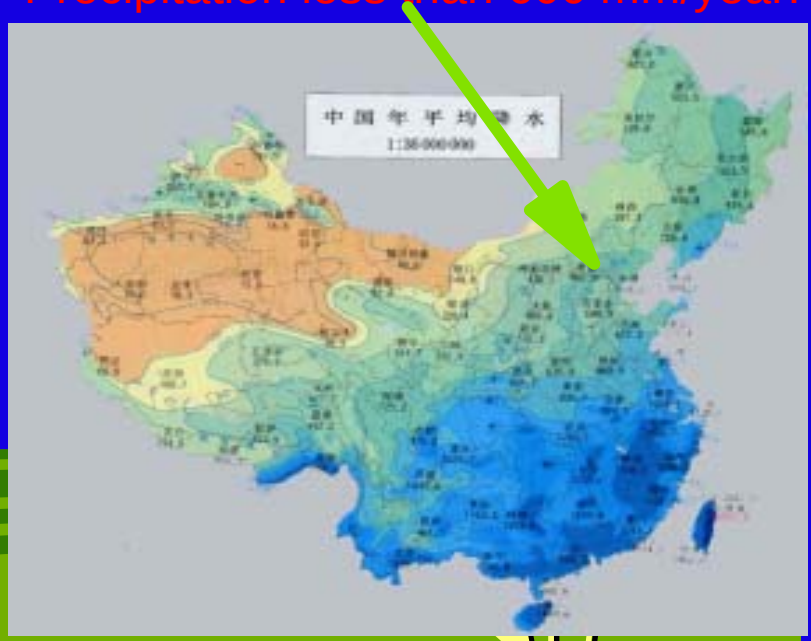
- **What can we do for the problems ?**
  - To recognize the actual condition of water cycle in NCP
  - To monitor surface conditions from the satellite
- **No countermeasures without real understandings of the Hydrological Cycle**

Where is the North China Plain ?



South of Great Wall, East of Taihang Mountains, North of Huaihe River. However hydrologist often refer NCP to the north of yellow river because of seriousness of water problem.

Precipitation less than 600 mm/year.



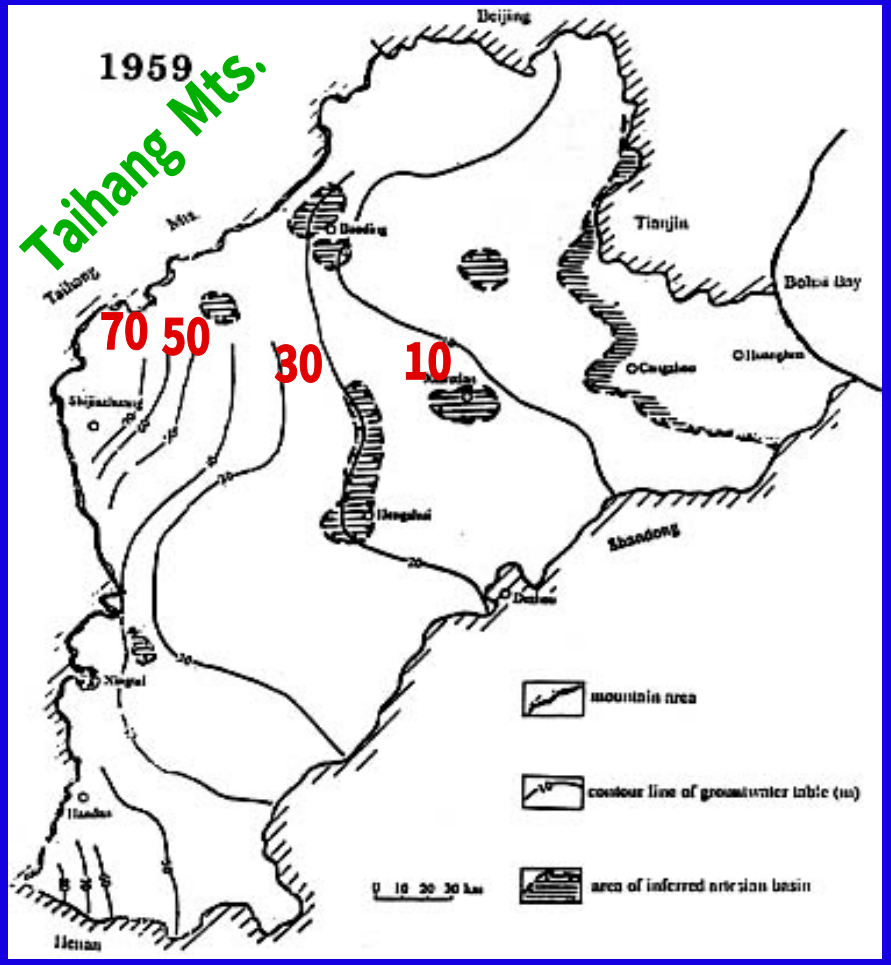
Cutoff of Yellow River

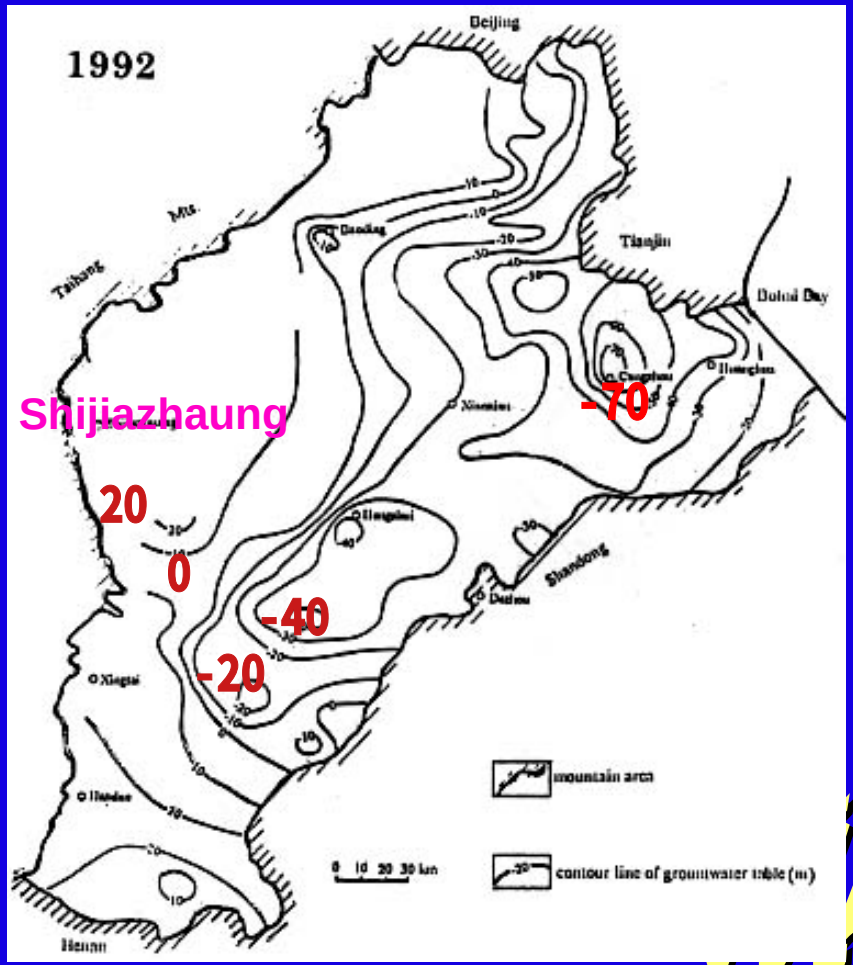
Sep., 2000 near 済南

Sluice for irrigation water

Sep., 1997 near 済南

Distributions of hydraulic head in confined aquifer

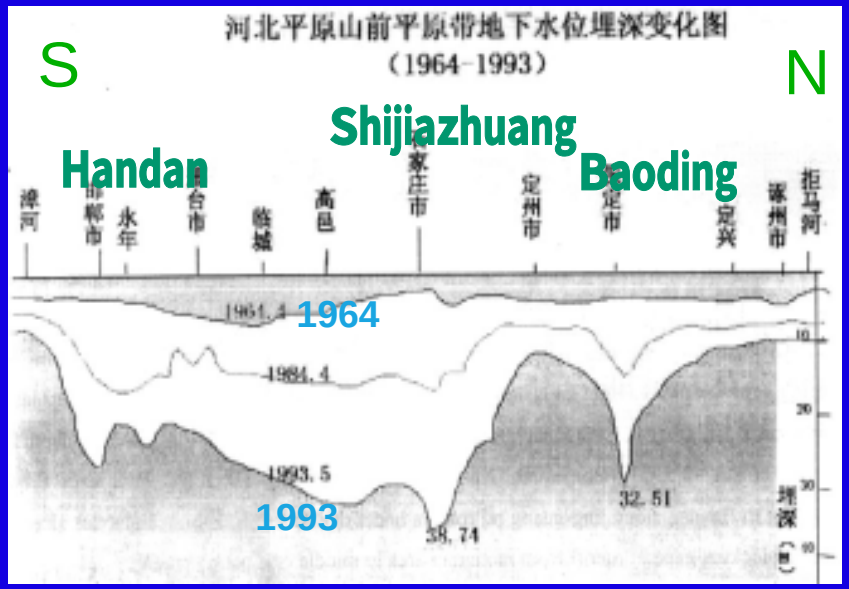


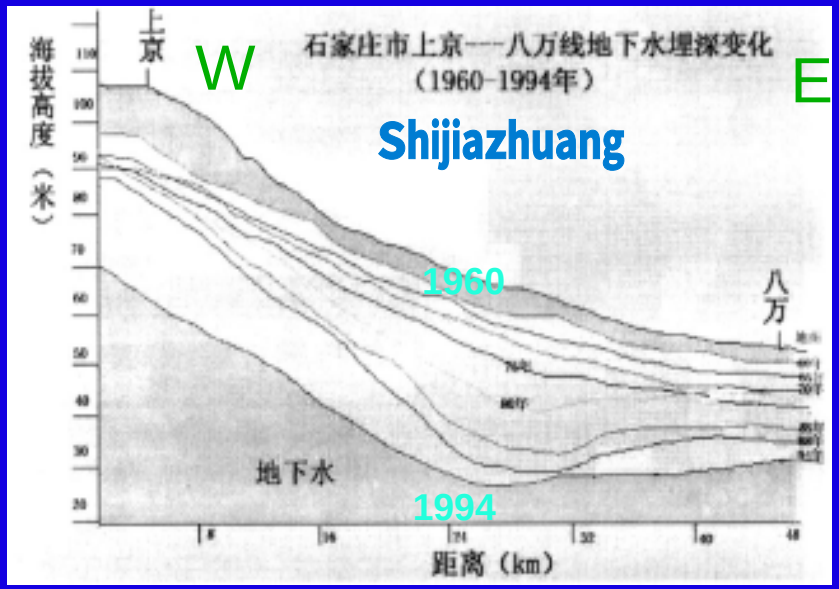


Regional subsidence cones

(Courtesy of Sun *et al.*(1998), Institute of Hydrogeology and Environmental Geology, CAS)

GWL Decline in Piedmont Area





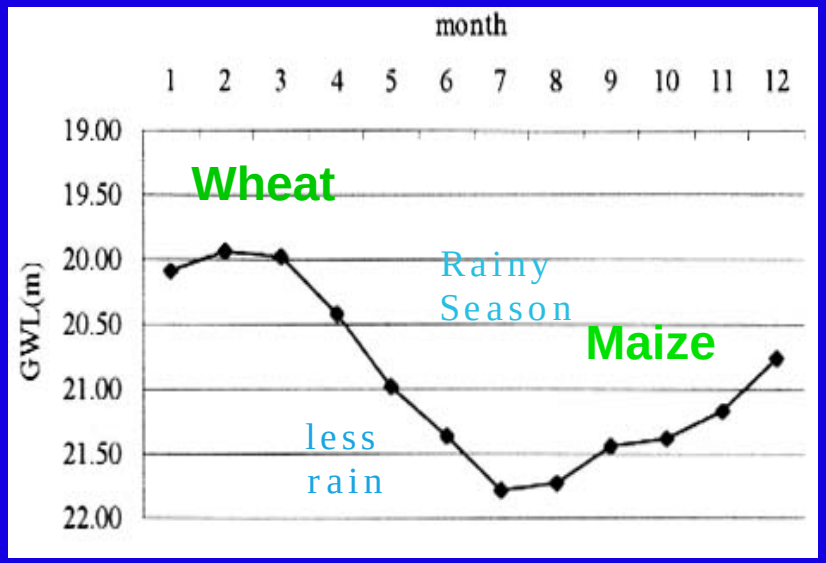
(after Tian *et al.*, 1998)

- Water transportation in NCP had its prosperous time in 1950's, however, the river reach possible for navigation became little in 1960's, and navigation had disappeared in 1970's. Dams built in Taihang Mountain retain water, and river water almost disappeared in the plain area.
- The acreage for wheat planting had increased since 1940's, and groundwater level had fallen simultaneously. Groundwater was used for not only agricultural purpose, but also industrious and domestic use. The rate of decline around Shijiazhaung City had reached 1.5 m/year.

Cost increase in GW withdrawal, land subsidence, water contamination, salinization, sea water intrusion, ...

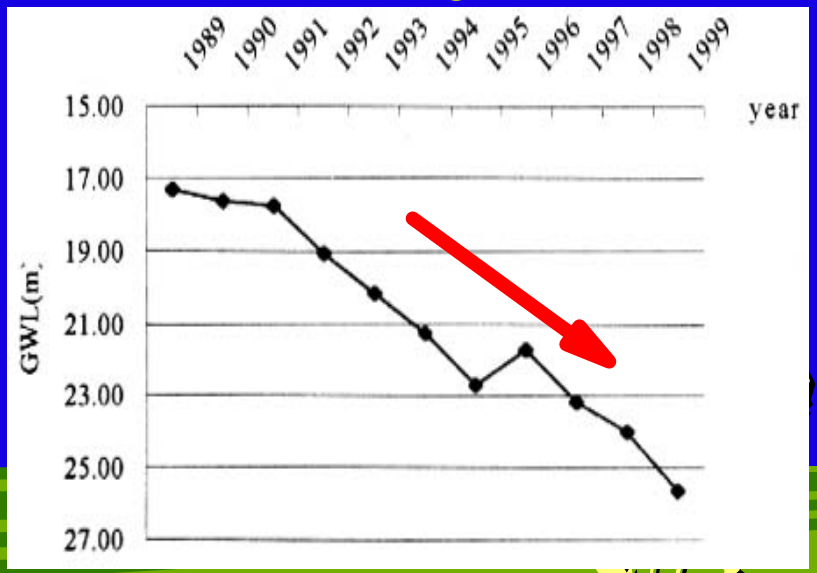
Sustainable Agriculture Possible ?

Fall of groundwater level at Luancheng



Seasonal change in GWL

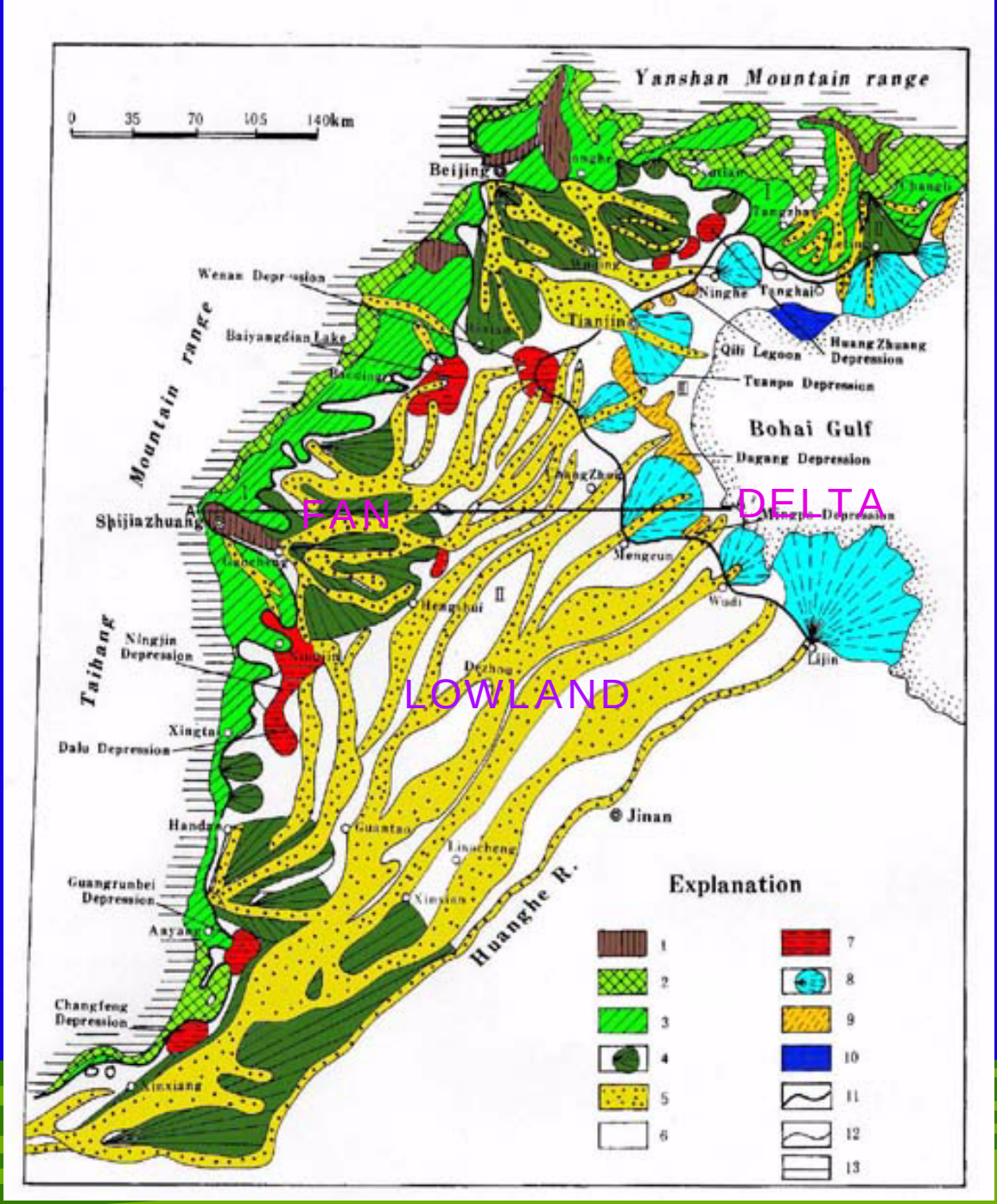
(Wheat field , May,2000)



Long time change in GWL

After Mao and Liu(2000)

Geomorphology of the NCP



LEGEND

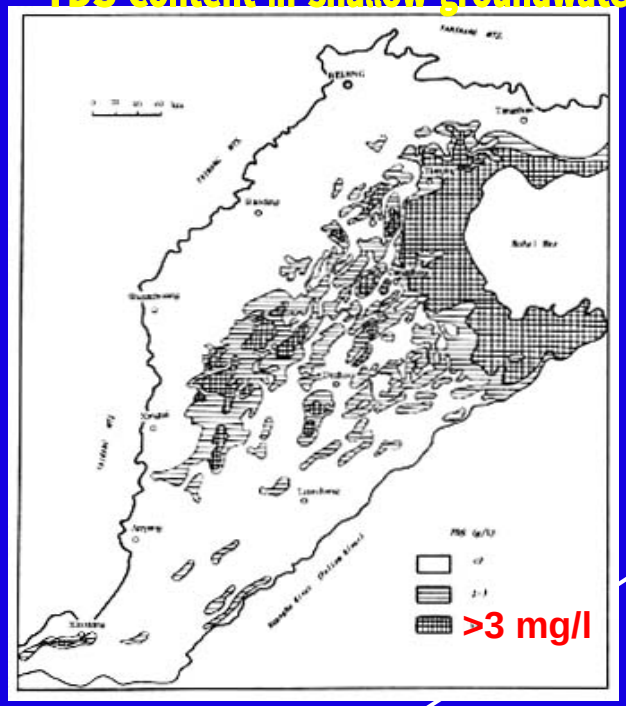
3(green): piedmont plain
4(green): fluvial fan
5(yellow): palaeochannel zone
7(red): depression at front edge of alluvial fan

Arrangement of geomorphological units creates local groundwater system

Wu *et al*.(1996): Palaeochannels on the North China Plain: palaeoriver geomorphology. *Geomorphology*, 18, 37-45.

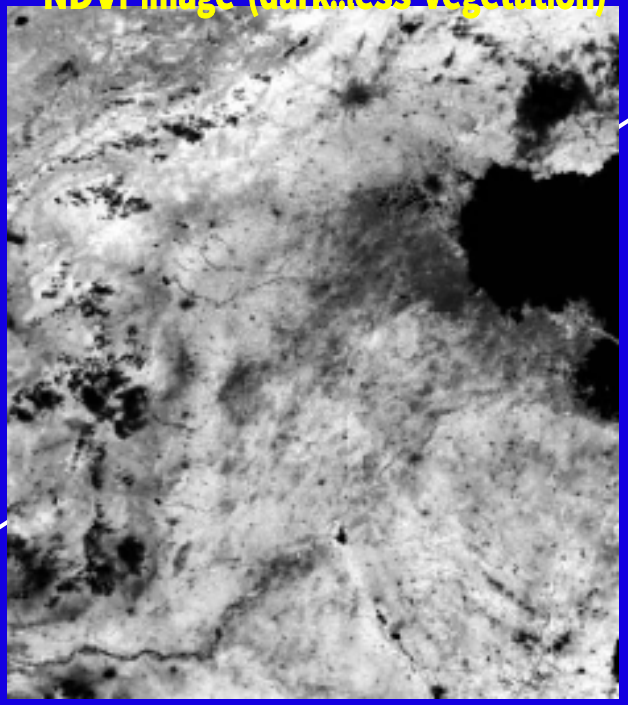
Subsurface Condition and Crop Production

TDS content in shallow groundwater



(After Fei, 1997)

NDVI image (dark::less vegetation)



WATER BUDGET

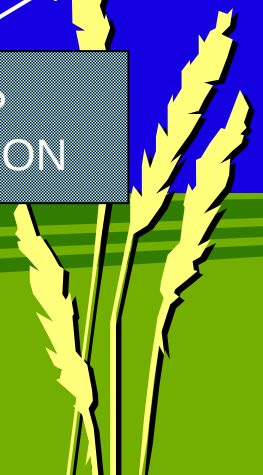
HEAT BUDGET FLUX

NDVI (Veg. Index)

GROUNDWATER FLOW SYSTEM (LOCAL TO REGIONAL)

SUBSURFACE CONDITION -High TDS -

CROP CONDITION



There is a close relationship between hydrological cycle and crop production, and it can be monitored from space.

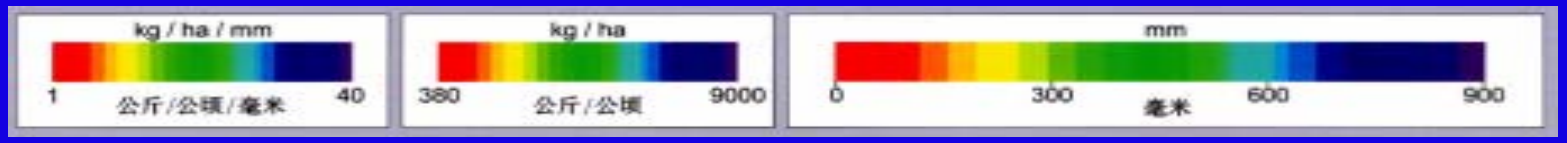
Production of Winter Wheat 1,Oct-15, Jun.

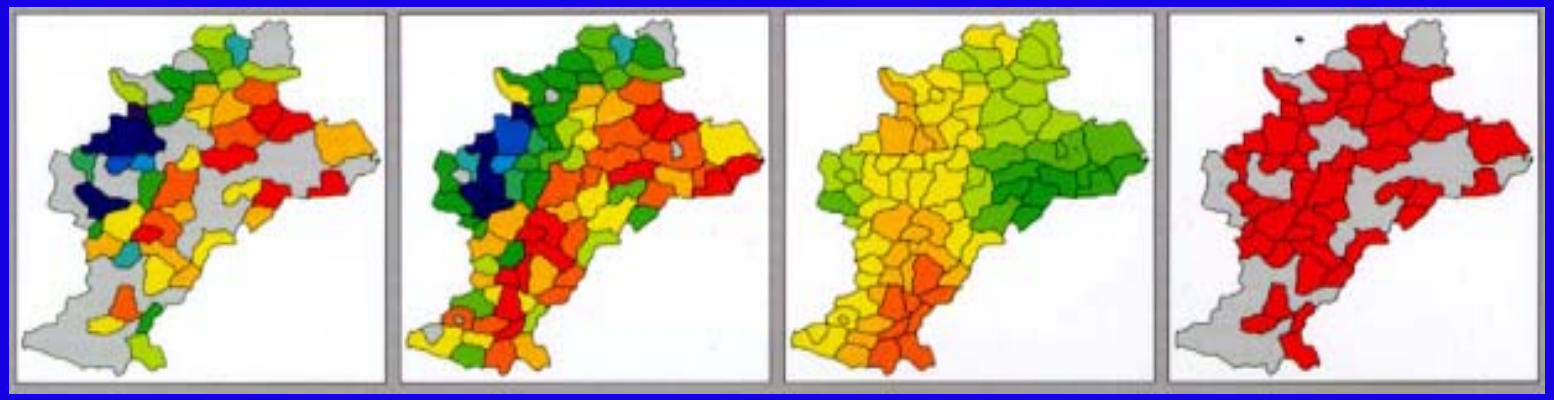
1992
Dry Year

1991
Wet Year

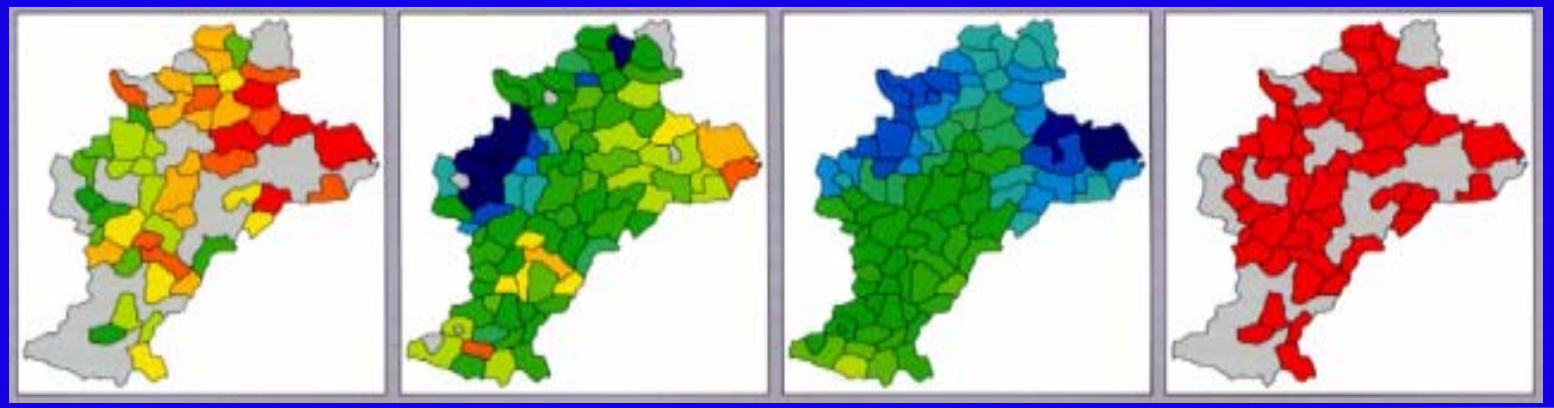
(Courtesy of Zhang Guangluo, Shijiazhuang Institute of Agricultural Modernization, CAS)

Production of Corn 16,Jun. - 30,Sep.





1992
Dry Year

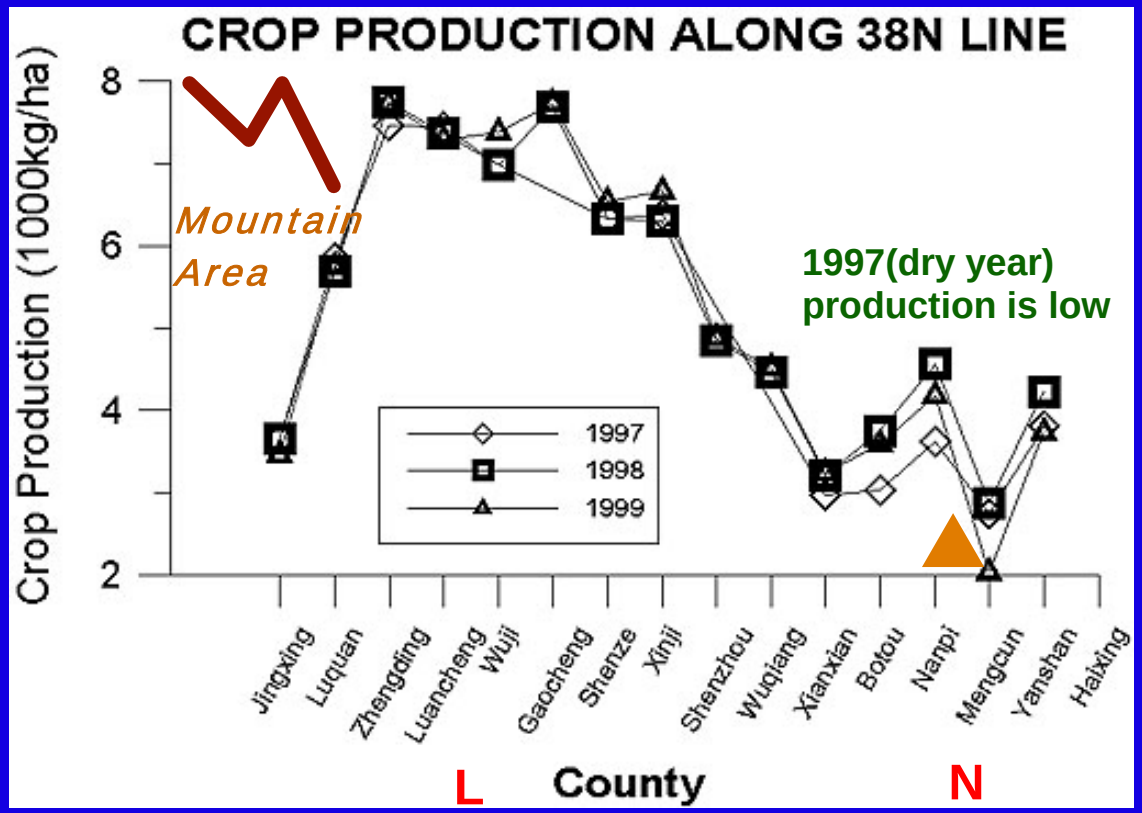


1995
Wet Year

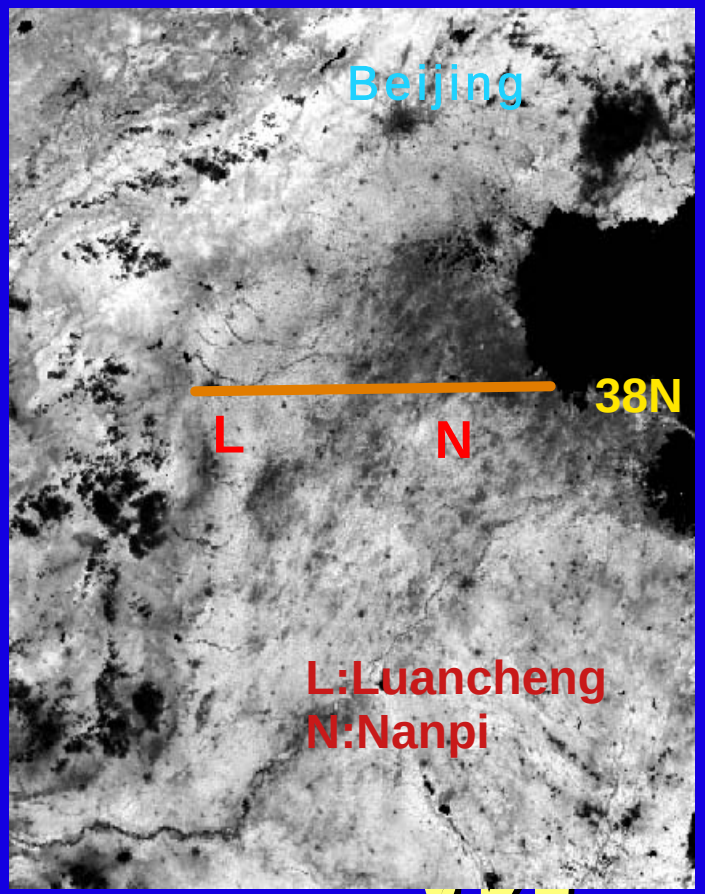
Hydrological regime affects the production of grains

Need for Hydrological Studies

CROP(wheat and corn) PRODUCTION ALONG 38N LAT. LINE



(Data from 河北省経済統計年鑑)

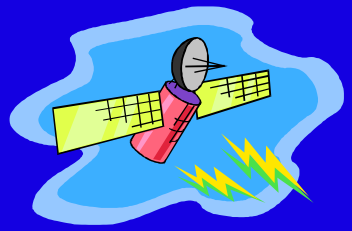


- Piedmont plain with high productivity, *less influenced by drought*
- Eastern part, around Nanpi, area is affected by salinization, *influence of drought is large*

Eastern part of Hebei Province, the usage of water from Yellow river is prohibited for irrigation.

General Perspective of the NCP 38N Project

Hydrological System in NCP



Taihang Mts.

Luancheng

Nanpi

Recharge exist or not ?

Et and its spatial & temporal variation

- Wheat, maize
- Surface wetness

Recharge from mountains?

Piedmont Plain

?

Evapotranspiration

Percolation, Withdraw

Water Usage, Contamination

Lowland Plain

Evapotranspiration

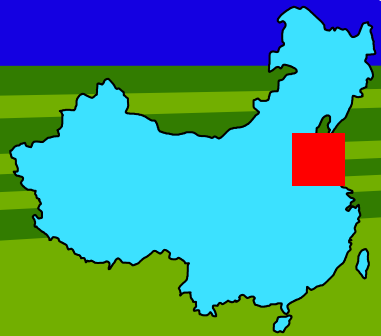
Salinization

Bohai Bay

Drawdown in Water Level

Deep Groundwater Flow

Its actual condition, residence time ?



Control of Et
W.Saving Agriculture
Groundwater Recharge

日本は何をすべきか

農水省統計で日本の食糧自給率（総合）は４０％以下
（穀物は３０％以下）　　注）食べ残し３５％？

グリーンウォーター（食糧の形で輸入する水）の増加

輸出国の水問題は顕在化しつつある

日本は金さえ出せばいいと思っているのか！
（国際世論の攻勢にさらされる危険性）

こんな時代が君たちの世代に来る可能性(-_-;)

North China Plain 38N Project
Flux Network

Three stations along 38N latitudinal line

観測站 Experimental Stations

太行山山地生態試験站 Taihang Mts.

[Observational Systems]

－15m Tower Air Temperature, Humidity, Wind Speed (6,9,15m),
Wind Direction (15m)

－Campbell Cooled Mirror System (3m height)

楽城生態農業試験站 Luancheng

[Observational Systems]

－36m Tower Air Temperature, Humidity, Wind Speed (4,16,32m),
Wind Direction (32m)

－Campbell Cooled Mirror System、CSAT-3

－Albedo Meter, PAR Sensor

－TDR, Automatic Tensiometer (Depth 5,10,30,60,90,120,200cm)

大気 Atmosphere
植生 Vegetation
土壌 Soil

南皮生態農業試験站 Nanpi

[Observational System]

－Campbell Cooled Mirror System

Taihang Experimental Station of Ecology
太行山山地生態研究站

Left photo shows 15m meteorological observation tower. Surroundings are pomegranate trees. Trees are planted along contour line in line like lower photo. The water trapped in the upslope area is used for plant growth.

Luancheng Agro-Ecosystem Experimental Station

栾城農業生態系統試験站

36 meteorological observation tower(left) and Bowen ratio system for flux measurements, albedo meter and PAR sensor system(right). Automatic tensioomater and TDR soil moisture sensors are installed in the subsurface. Photos are taken on 30 August, 2000.

Nanpi Station
南皮生態農業試驗站

Nanpi area is suffered by salinization problem, and production is low.

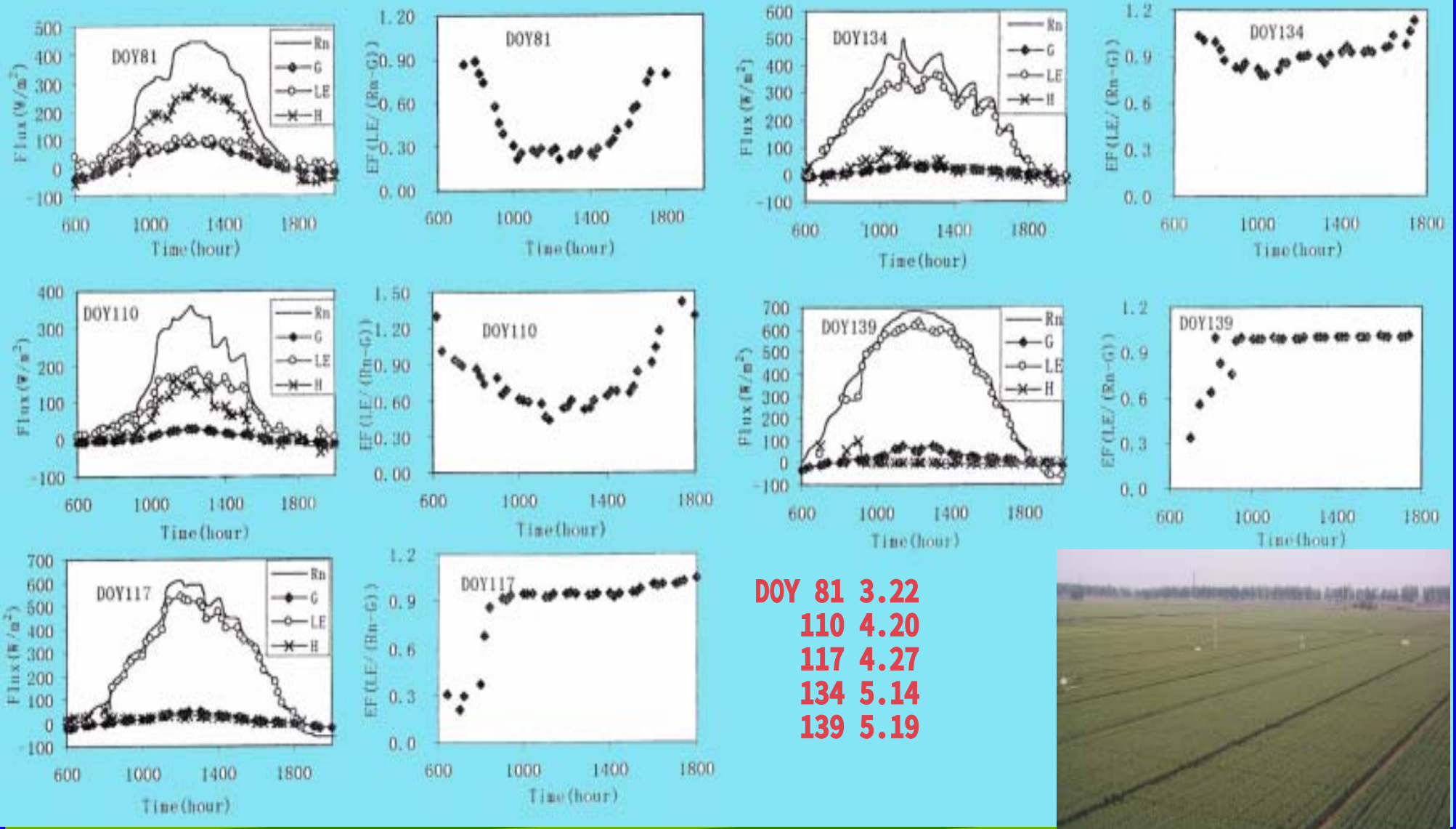
Photo shows characteristic style of agriculture around Nanpi area. Grains are planted within the line of fruit trees.

- Insurance for poor crop
- Control of evapotranspiration

Campbell Bowen Ratio System

Photo taken on 3 Sep., 2000. System is installed on the corn field, and it turns to wheat from October to June. Surroundings are fields of soybean, cotton, millet.

Diurnal Changes in Heat Budget in Luancheng Station in 1999



DOY 81 3.22
110 4.20
117 4.27
134 5.14
139 5.19

2000年5月20日の状況

LE/Rn become large with growth of wheat

Purposes of Flux Observation

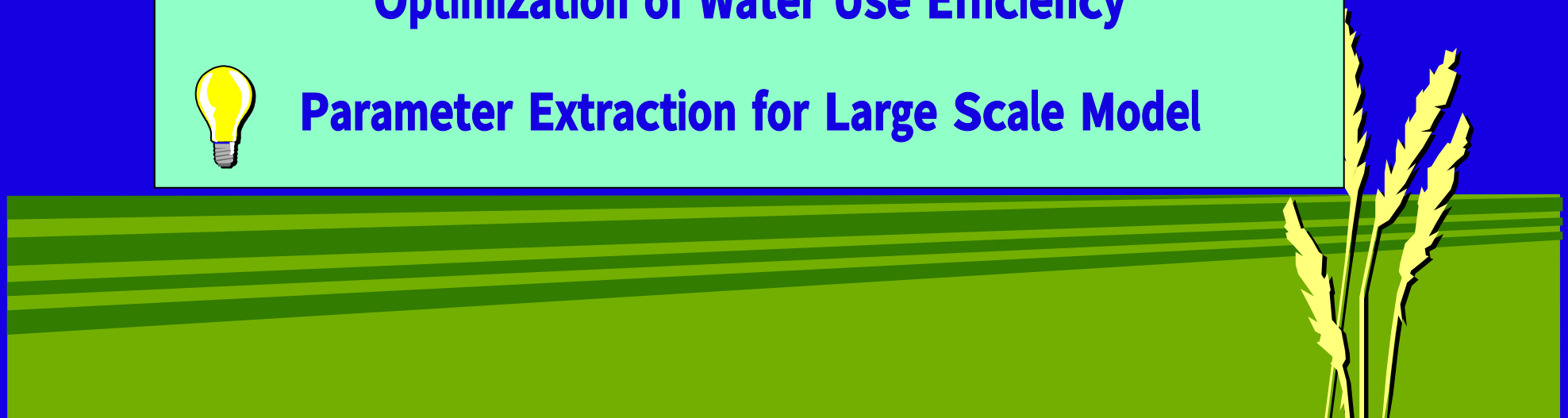
Understandings of diurnal, seasonal, and interannual changes in flux over winter wheat and summer maize fields, typical crops in NCP

Relationship with vegetation parameters such as LAI, production, fertilizer status and water stress condition, and so on.

One dimensional monitoring and modeling of water, heat, substances movements

Optimization of Water Use Efficiency

Parameter Extraction for Large Scale Model



Strategy to Regional Flux

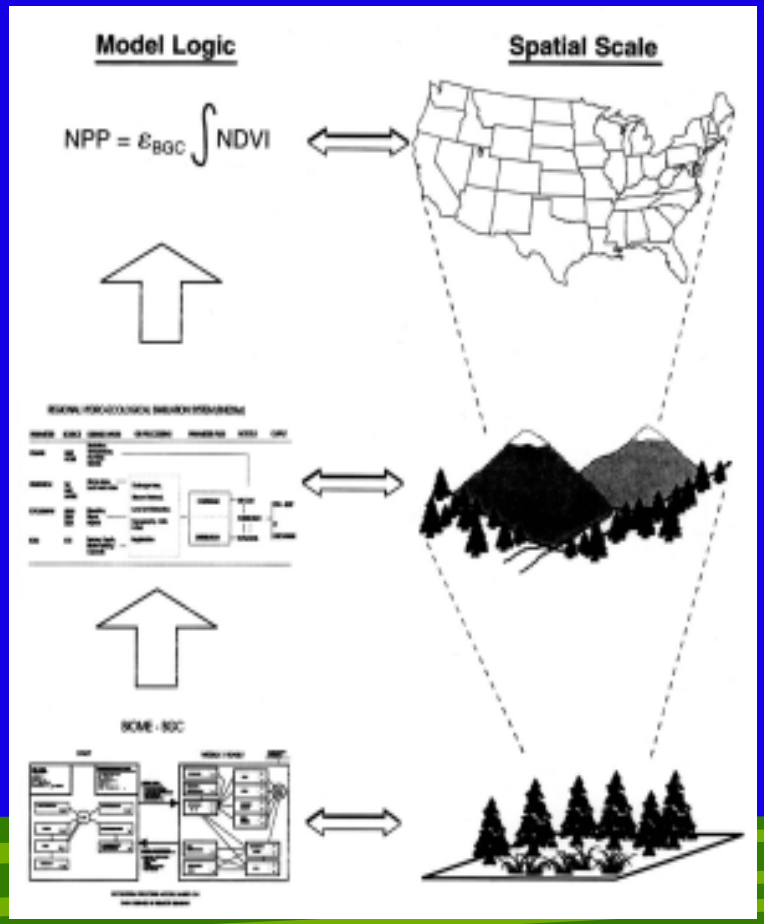
Flux observations at three stations

Wide Area

Satellite Remote Sensing

Tradeoff between accuracy, time resolution and long term observation, regional distribution

Simplification required in shifting from local to regional to continental scale flux analyses



(Waring & Running, 1998)

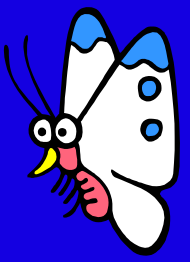
Target of this study

Find empirical relationships between surface flux and satellite data

ex) FLUX = a × f(sat) + b
a, b : constants or variables
f(sat) : Σ NDVI, length of growing season, peak NDVI, and so on

Flux measurements at the three stations in NCP along 38N line

Empirical Relationships between satellite data and surface parameters



(1) Relationship to NDVI

- Satellite Phenological Analyses
- NOAA/AVHRR

(2) Relationship to Surface Temperature

- Thermal Inertia : Retrieval of Surface wetness
- GMS5

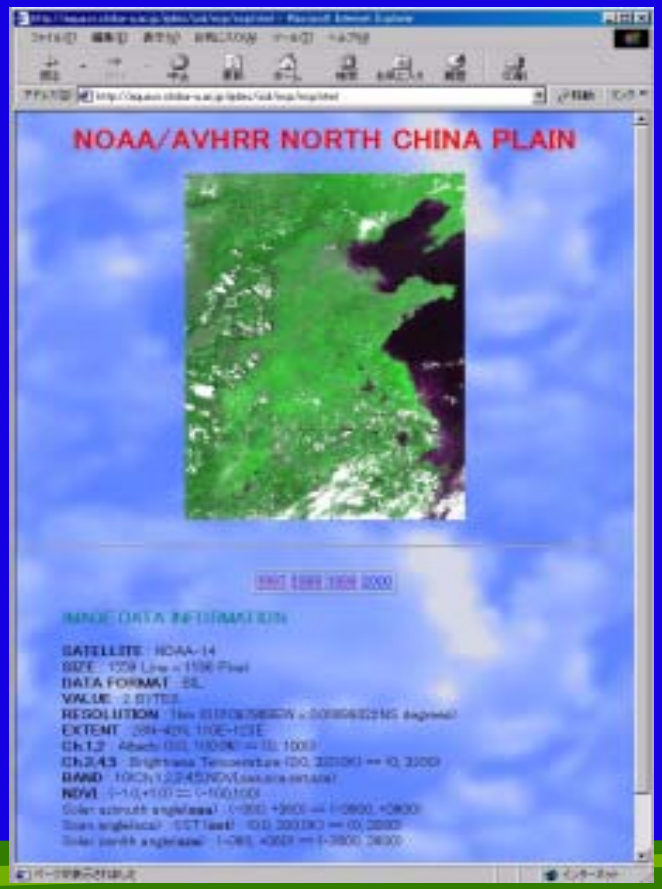
(3) Combination of NDVI and Surface Temperature

- VI-Ts method : Retrieval of Surface wetness
- NOAA/AVHRR

Of course, empirical relationships should be examined later for their physical background.

NOAA/AVHRR & GMS IMAGES ARE AVAILABLE

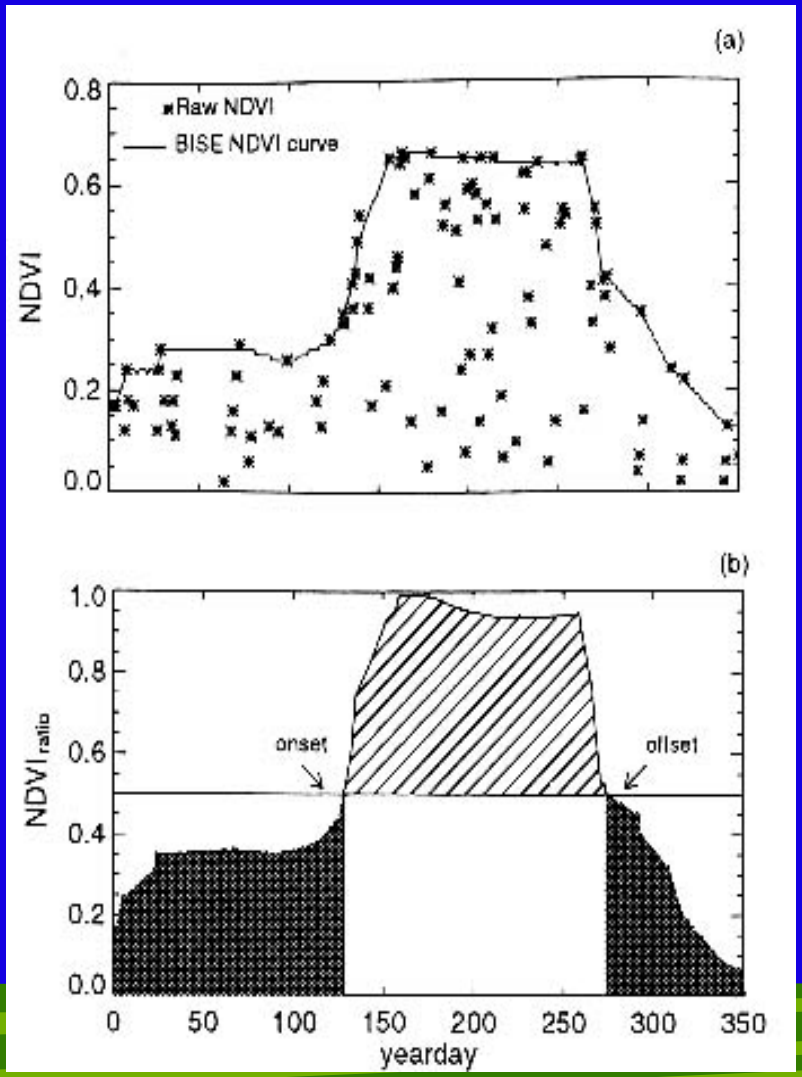
http://aqua.cr.chiba-u.ac.jp/gdes/sid/index.html



FTP site for browsed images and data

ftp://aqua.cr.chiba-u.ac.jp/receiver/

Importance of Satellite Phenology



Satellite Phenology
White et al.(1997)

Phenological parameters

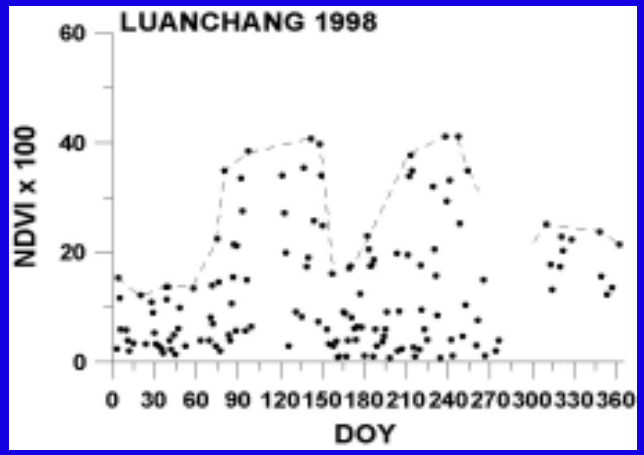
- Onset and offset date
- Annual integrated NDVI
- Duration of growing season
- etc.

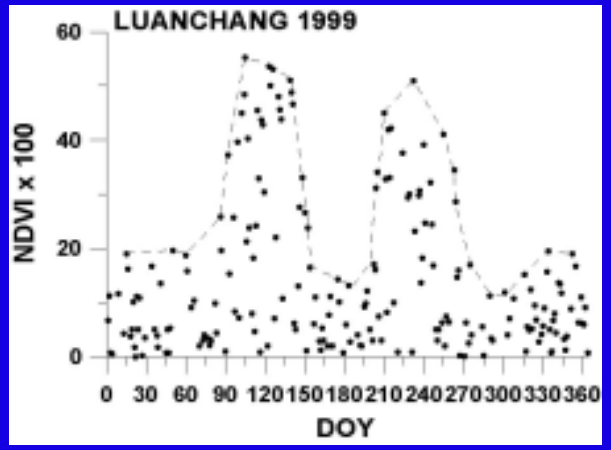
Examples

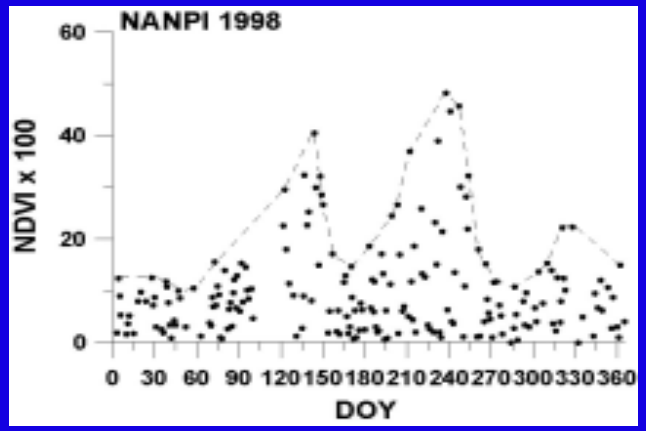
- NPP= $\varepsilon_{BGC} \int NDVI$ (Waring & Running, 1998)
- Flux=f(veg) $\int NDVI$
- Production =f(veg) $\int NDVI$

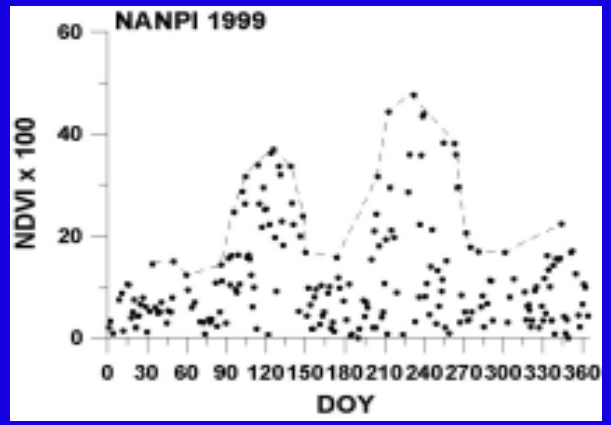
SATELLITE PHENOLOGY by NDVI

Examples of Luancheng and Nanpi



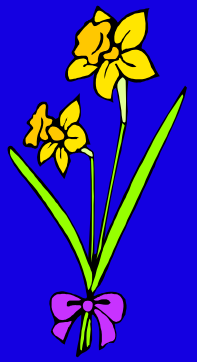






Phenological Parameters:

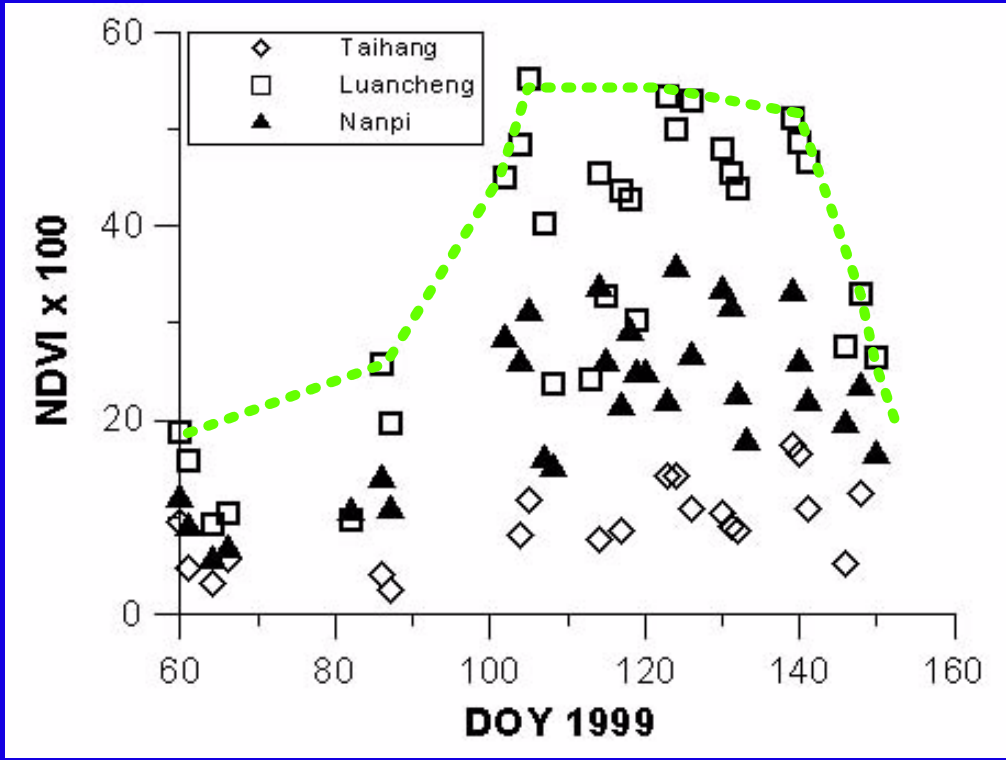
- Length of growing season
- Peak NDVI value
- Start date of growing season
- Sum of NDVI in growing season
- and so on.



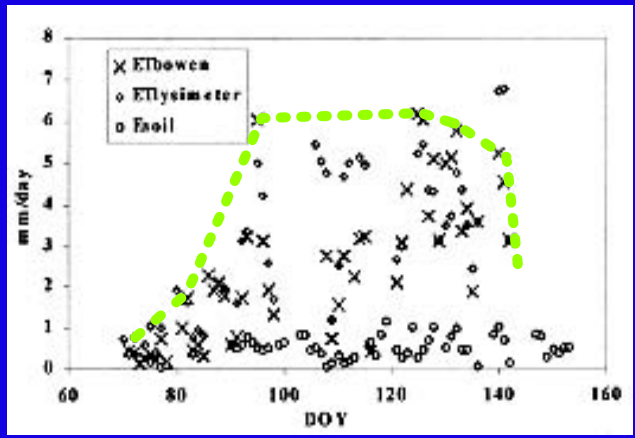
Extraction of crop production change due to climatic change

Changes in phenological parameters really reflect the flux variations ?

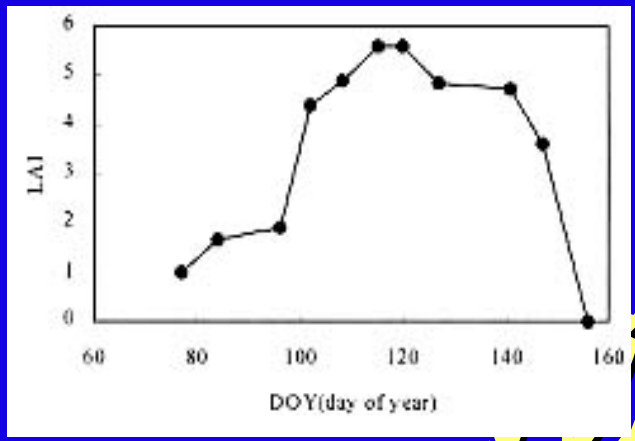
Changes in NDVI, Et, and LAI during 1999 winter wheat season (DOY60～160)



Changes in NDVI at Luancheng, Nanpi, and Taihang
- Excellent relationship among NDVI, Et, and LAI
- Difference in peak NDVI between Luancheng and Nanpi



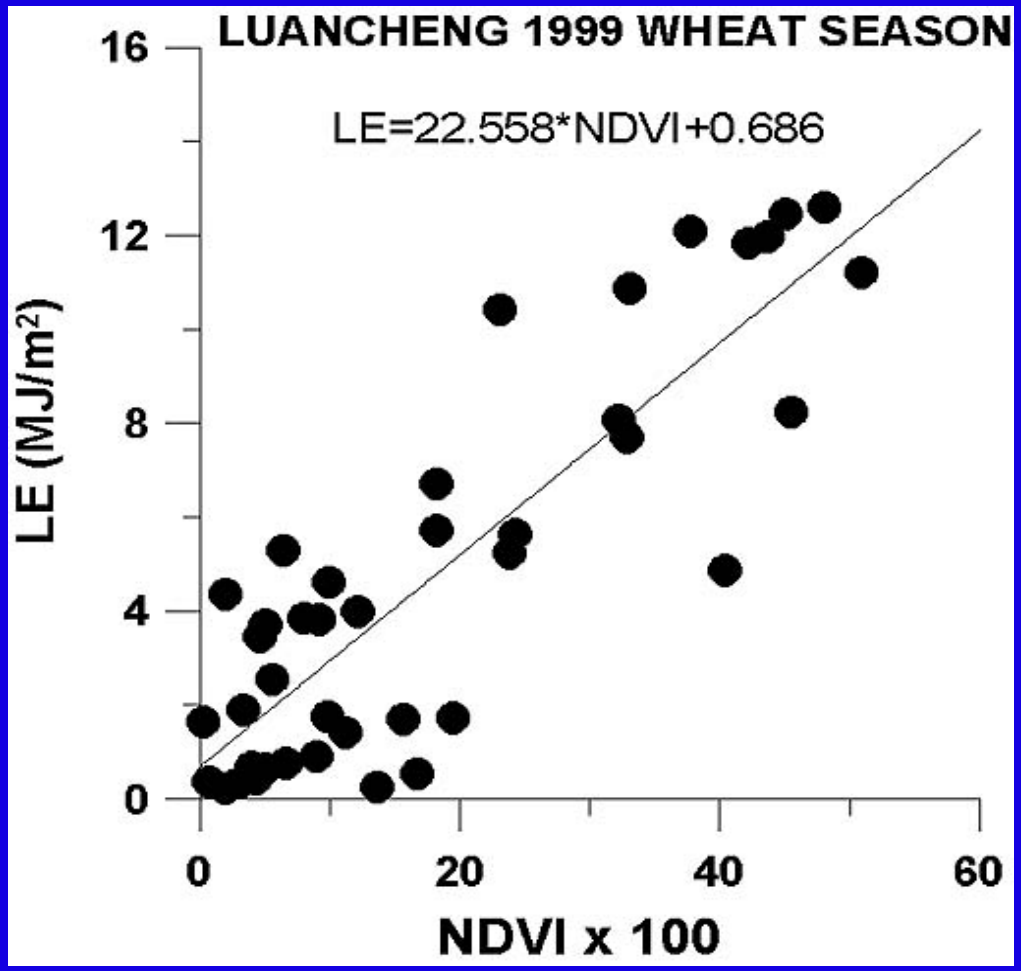
UP: Et, DOWN: LAI at Naipi



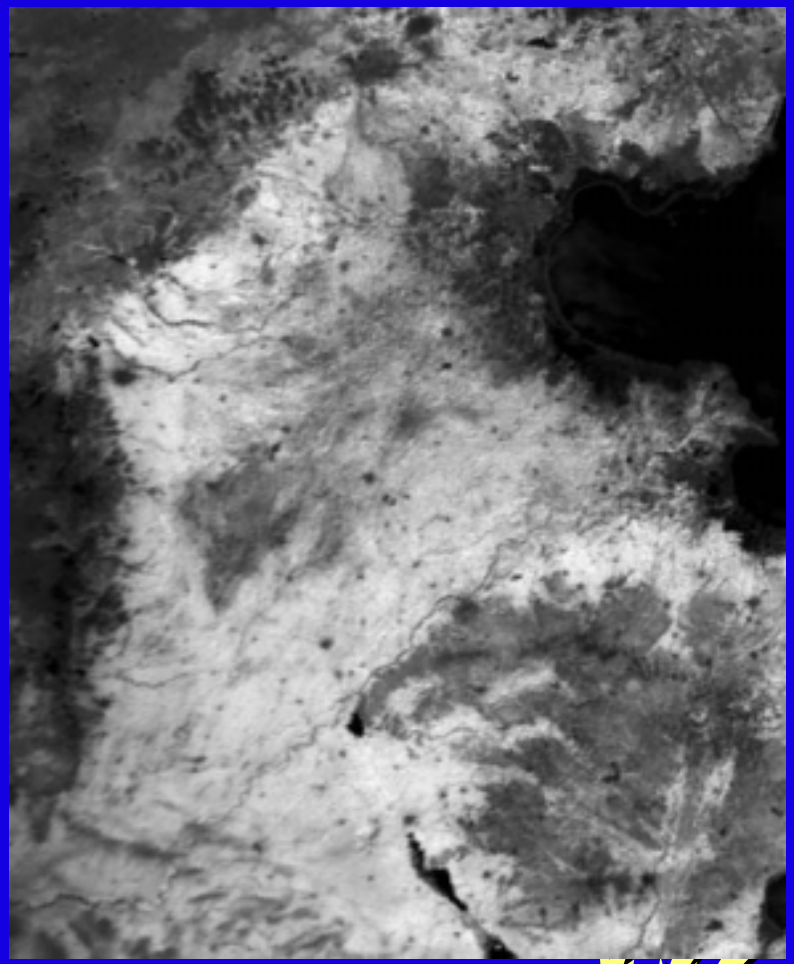
Good relationship between surface flux, LAI, and NDVI

Regional Evapotranspiration

*Preliminary result **



Relationship between NDVI and LE during 1999 wheat season in Luancheng



Distribution of LE(MJ/m²)
6 May, 1999
Gray Scale 0-255DN=0-15LE

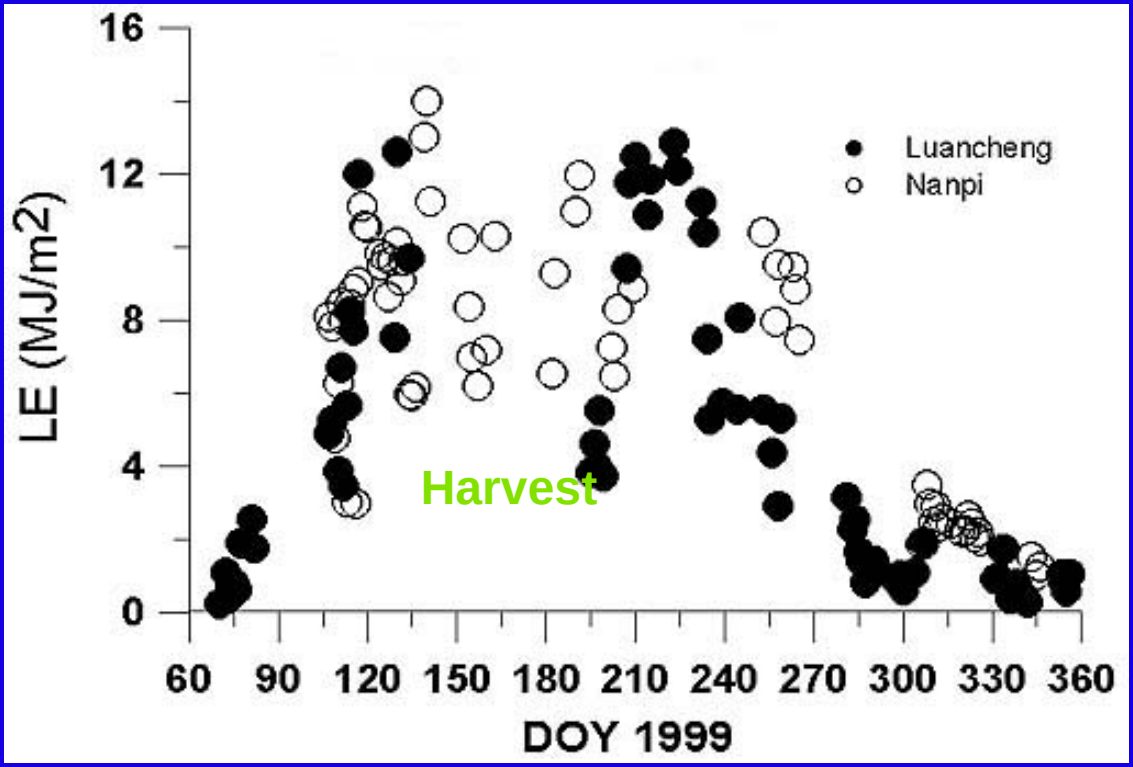
(* Images and data are not screend yet)

SKIP

Measured Latent Heat Flux at Luancheng and Nanpi

Preliminary result

Wheat Corn



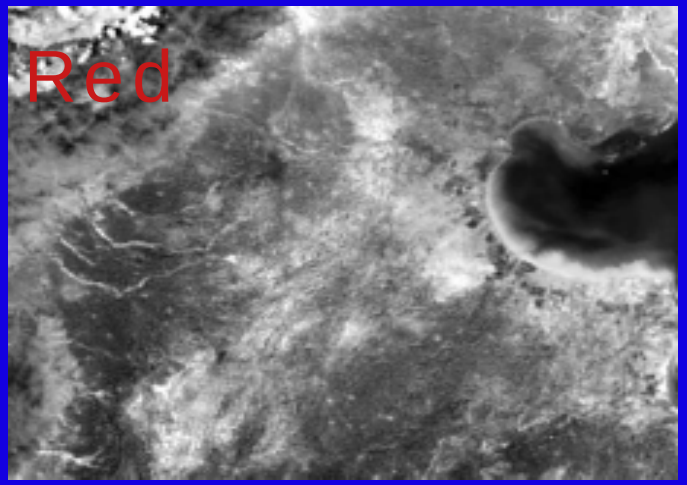
There is a difference in NDVI between Luancheng and Nanpi.

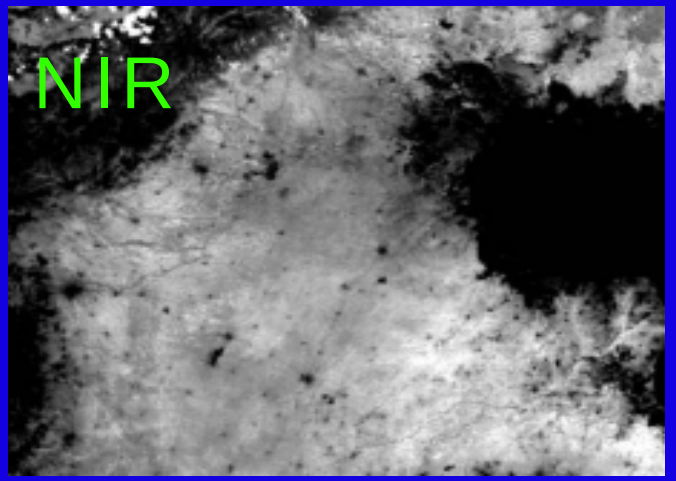
Is there a difference in LE ?

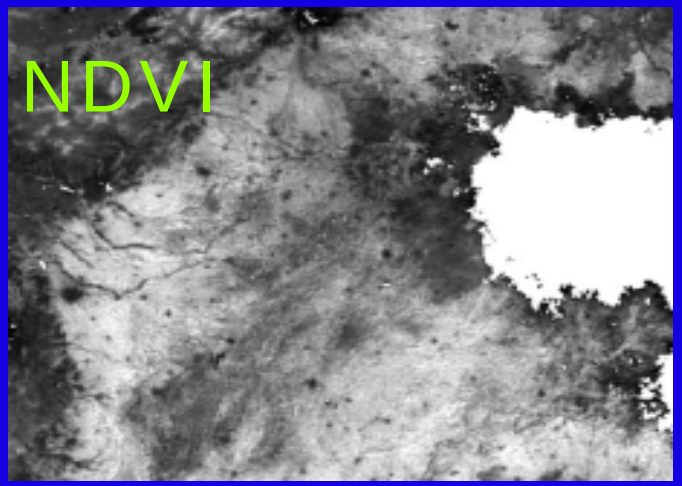
Correlation to crop production ?

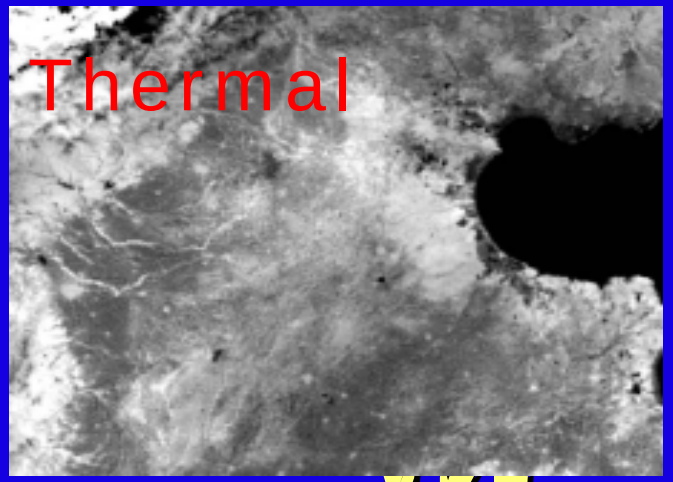
Surface features in NCP that influence surface flux

1999.5.12 AVHRR Channel Images









North China Plain has characteristic surface features.

There is low NDVI and high surface temperature area extending from northeast to southwest.

It means the heat budget is different, and it gives a key to expand point measurement to wide area.

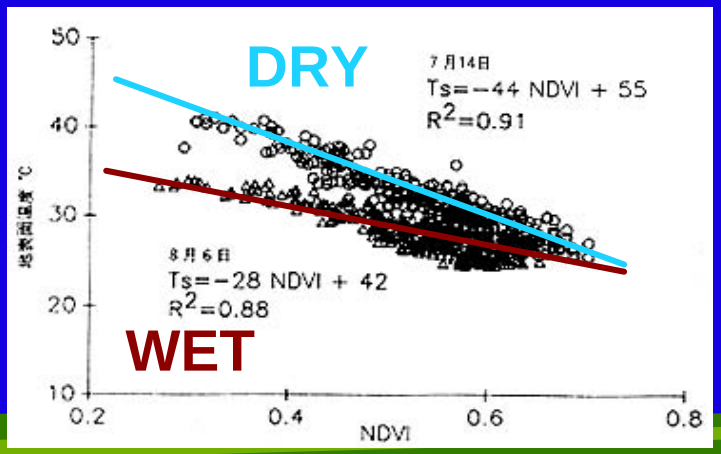
Need for the algorism combining the thermal bands

Key to expand wide area

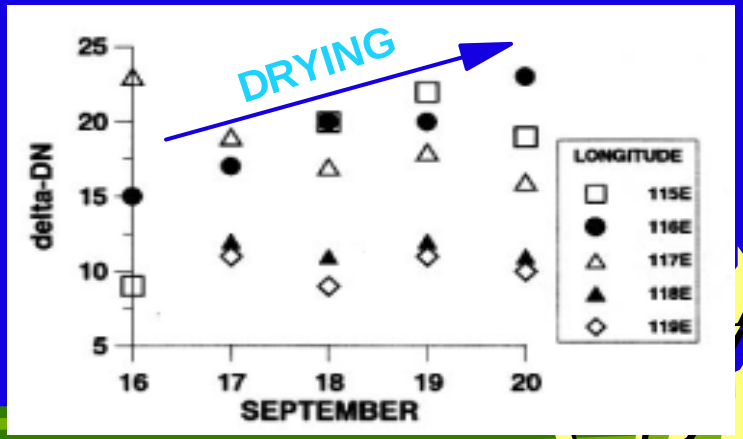
Surface temperature reflects the heat budget
Surface wetness governs the heat budget

Ts-VI method(Nemani and Running,1989)
- Slope parameter in scatterplot between brightness temperature(Ts) and vegetation index(VI)
- NOAA/AVHRR is available

ΔTs method(Wetzel et al., 1984)
- Increase in brightness temperature in morning time
- GMS/S-VISSR is available



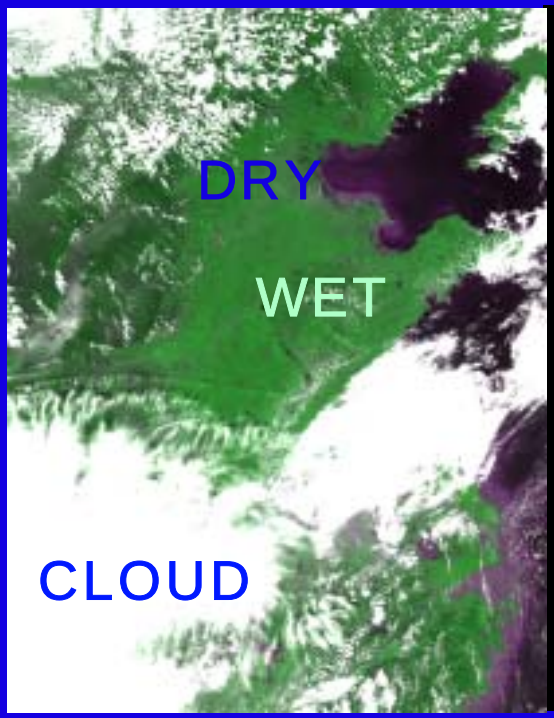
Nemani and Running, (1989)



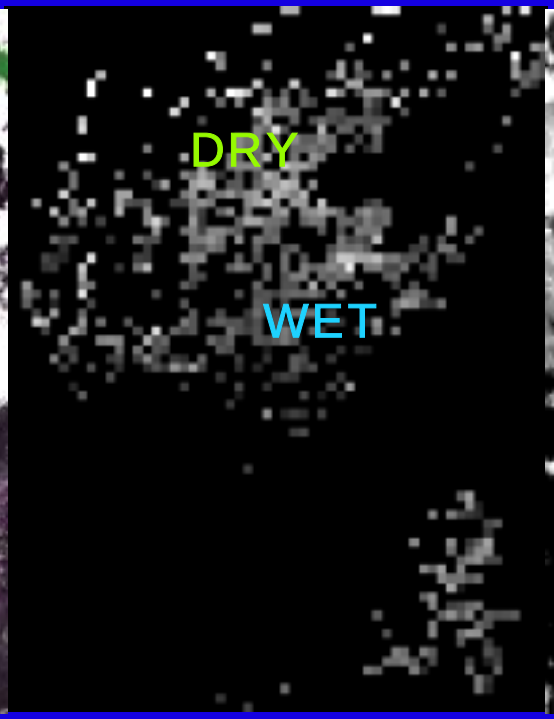
Time changes in d-Tb in NCP 38N

SURFACE WETNESS DISTRIBUTION

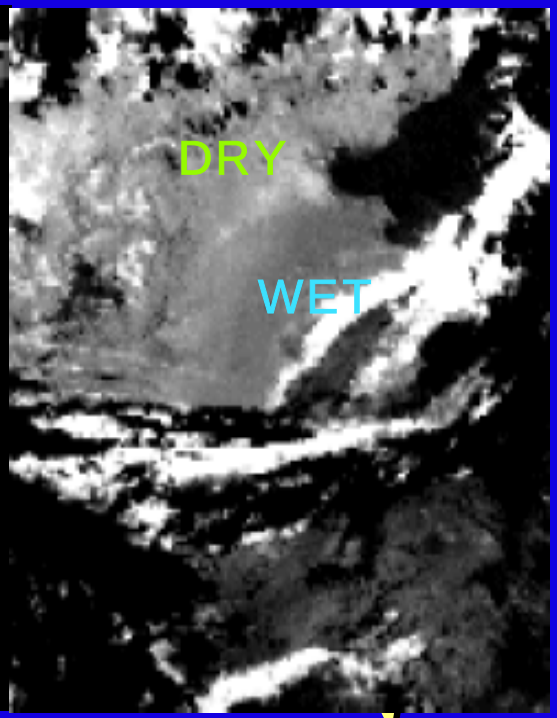
Example of 18 September 1997



False Color Image



Slope in Ts-Vi Relationship



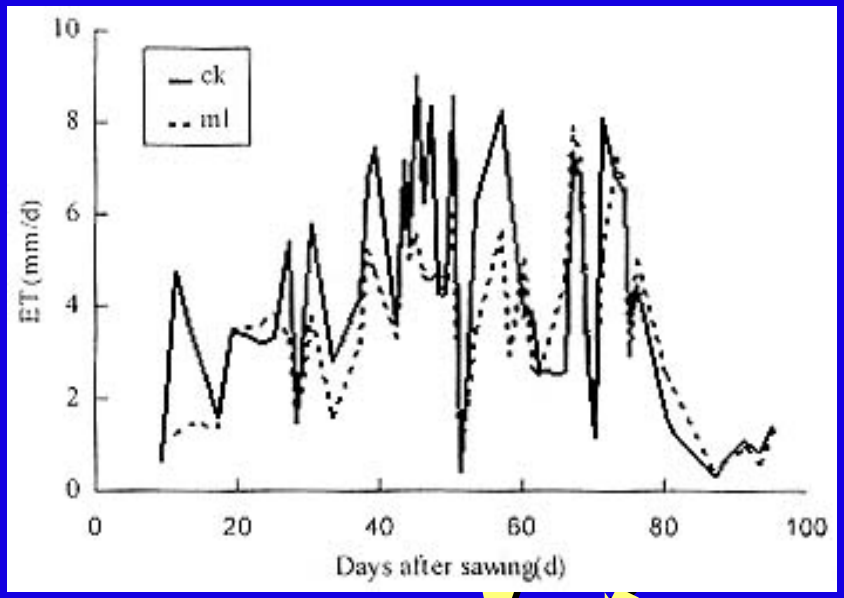
Tb Difference between 8 and 10LST

NOAA/AVHRR GMS/VISSR

Countermeasures

1. Water Saving Agriculture

1) **Irrigation scheduling** : Search optimum amount of water to maximize crop production
2) **Irrigation technique** : Spray, drip, infiltration irrigation instead of *flooding irrigation*
3) **Straw-multi** : Evaporation control
4) **Hoeing** : traditional measure to supress soil evaporation
5) **Alteration of crop** : convert winter wheat to grassland
6) **Windbreak forest** : evapotranspiration control
7) **Consciousness for water saving practice**
8) **Other measures** : chemical measures
   such as stomata regulator



Effect of straw-multi to evapotranspiration over winter wheat field in 1995 (Shen and Yang, 1998)

2. Water Harvesting

3. Water transfer from Changjiang(Yangtze) river

南水北調

Could water saving practices affect the water cycle ?

Final Remarks

- **Water problem is an important global issue in 21st century**
  Occurred everywhere in the world with same background. It is very important because it is directly connected to human life through food problem.
- **Measures are not created without real understanding on the problem**
  No countermeasures without real understandings of the Hydrological Cycle
- **Our project aims to explain hydrological cycle in NCP**
  Synthesized recognition of hydrological elementary processes is necessary
- **As a result from part of the project, outcome on flux are obtained**
  Characteristics of flux of wheat and corn, representative crops in NCP, become clear.
- **Observation will continue several years by the support of Nissan Foundation and MECSST**
  Understanding of the fluctuation of flux and crop production year after year
- **New satellite**
  Terra/ASTER will be available soon > Agricultural monitoring in the scale of field
- **Verification**
  Does remote sensing become the real tool for environmental science ?
  Feedback of scientific achievements to the region

Summary

- Current state of water problems in NCP
- Grain production and surface features
- Flux observation and its extension to wide area