An integrated water quality assessment model in response to climate change and land-use change

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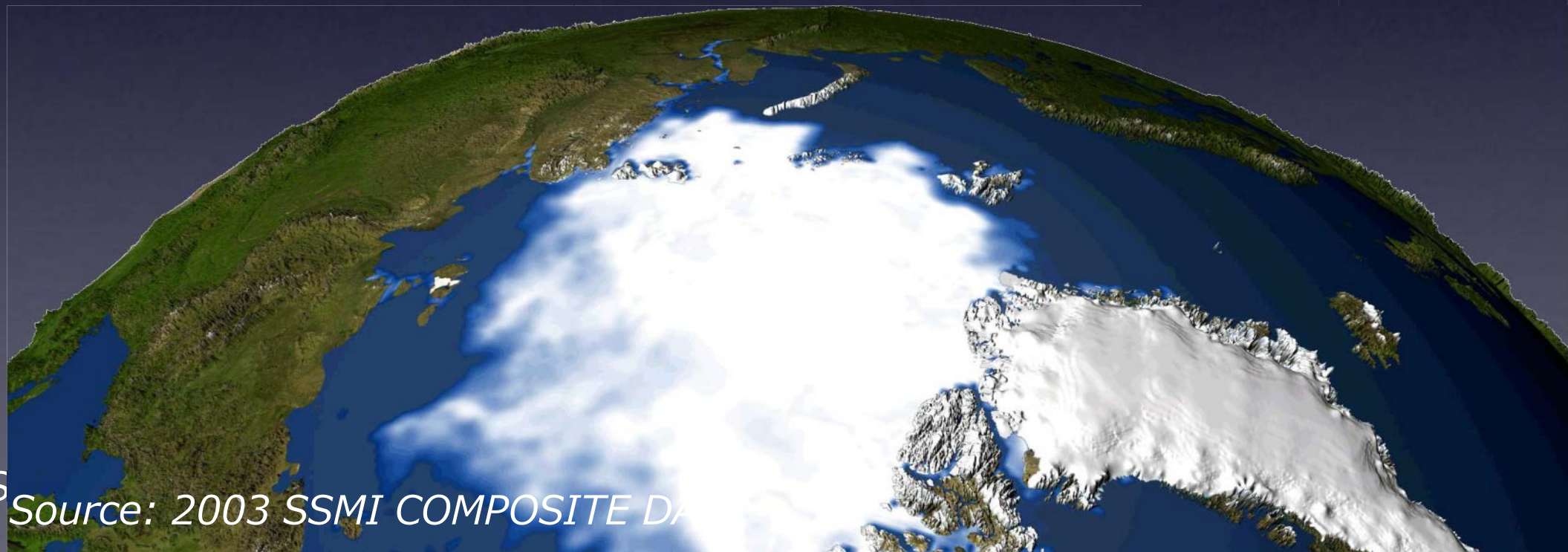
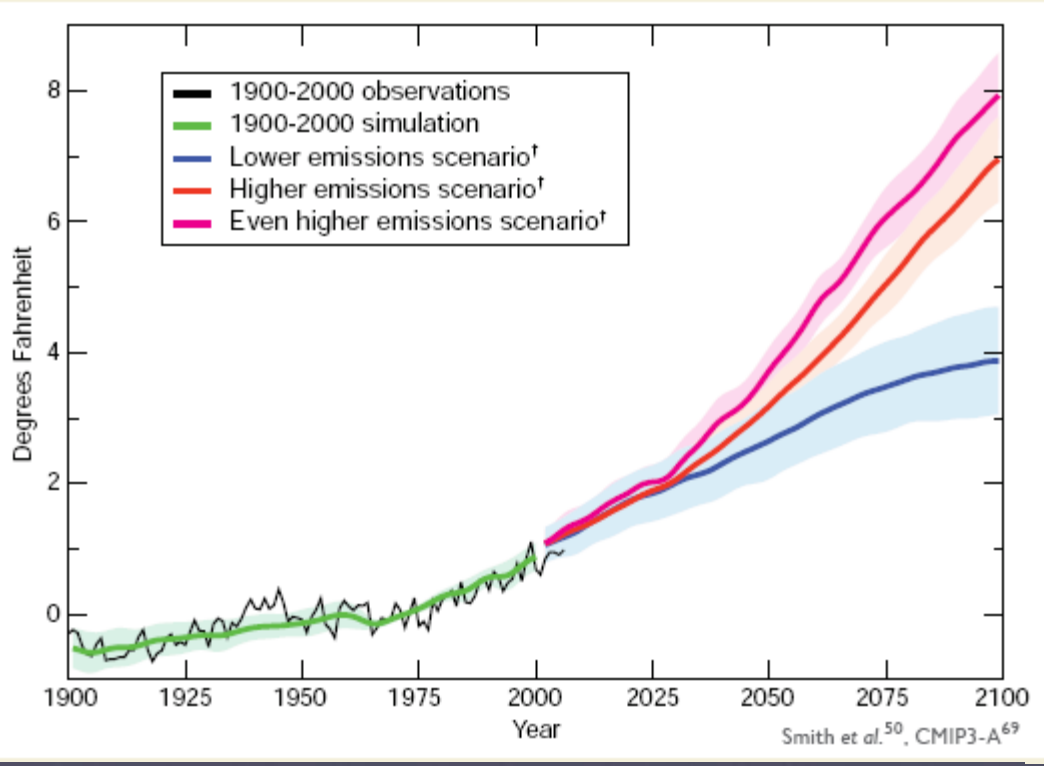
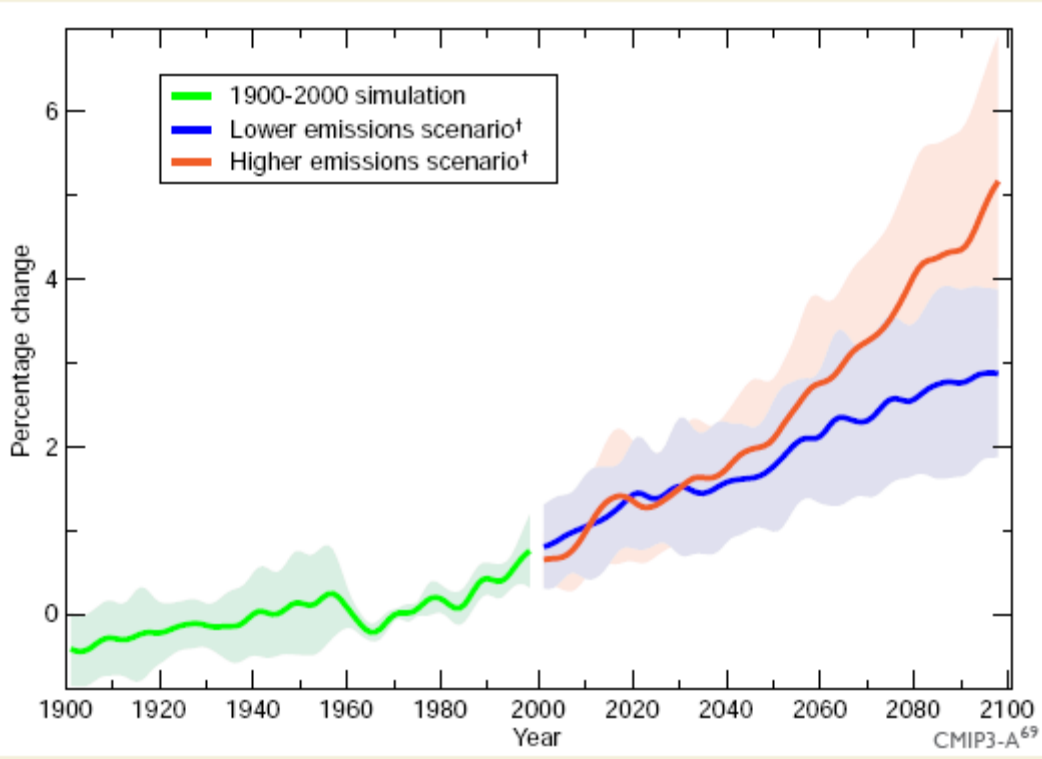


“The Climate is Changing & will Continue to Change”
Global Scale

Observed and Projected Global Average Temperature



Global Increase in Heavy Precipitation

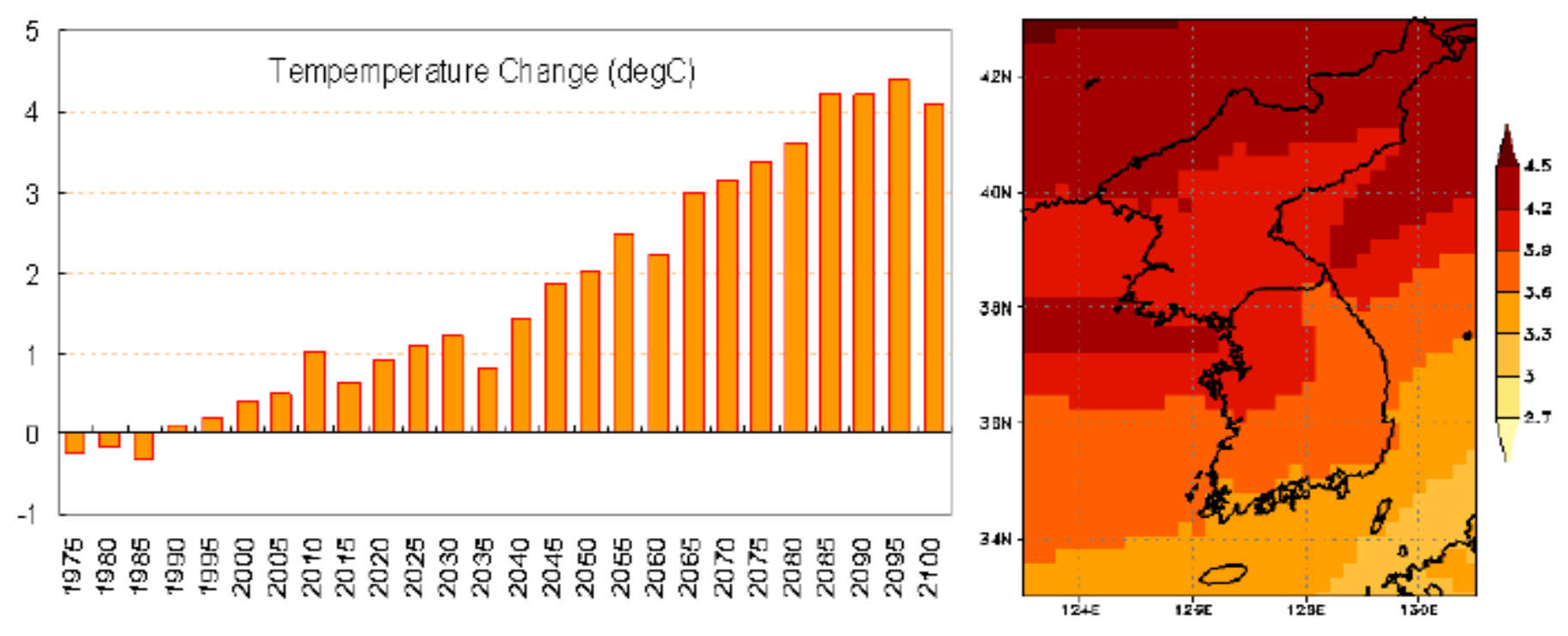


"We are already seeing the impacts from a changing climate"
especially in Arctic, Antarctic and mountain regions

Portage Glacier 2004

“ What about the South Korea region ?”

Observed and projected temperature change (SRES Scenario A1B)

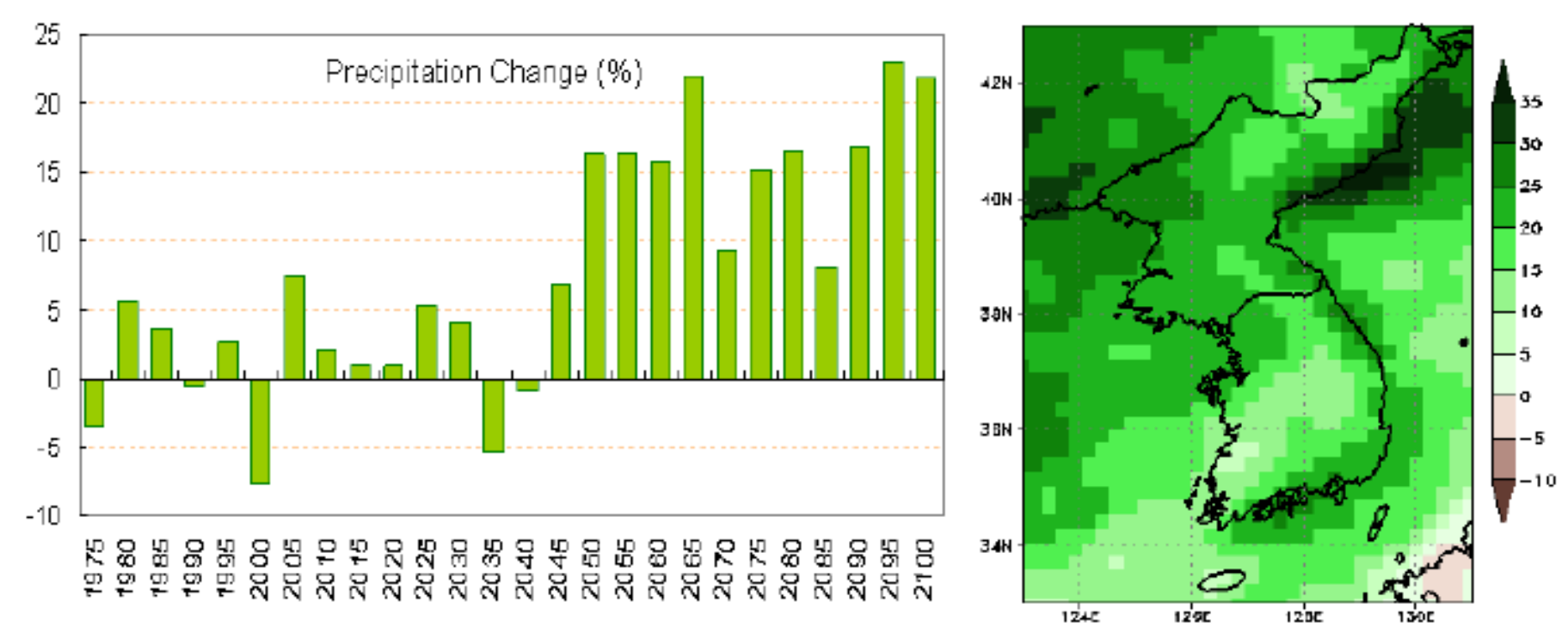


Korea Meteorological Administration, 2009

- Temperature has risen, especially in winter and spring
- Temperature will increase by ~4 ºC by the last quarter of the 21th Century, relative to the last quarter of the 20th Century
- The increases will be higher in the high latitude region

“ What about the South Korea region ?”

Observed and projected precipitation change (SRES Scenario A1B)

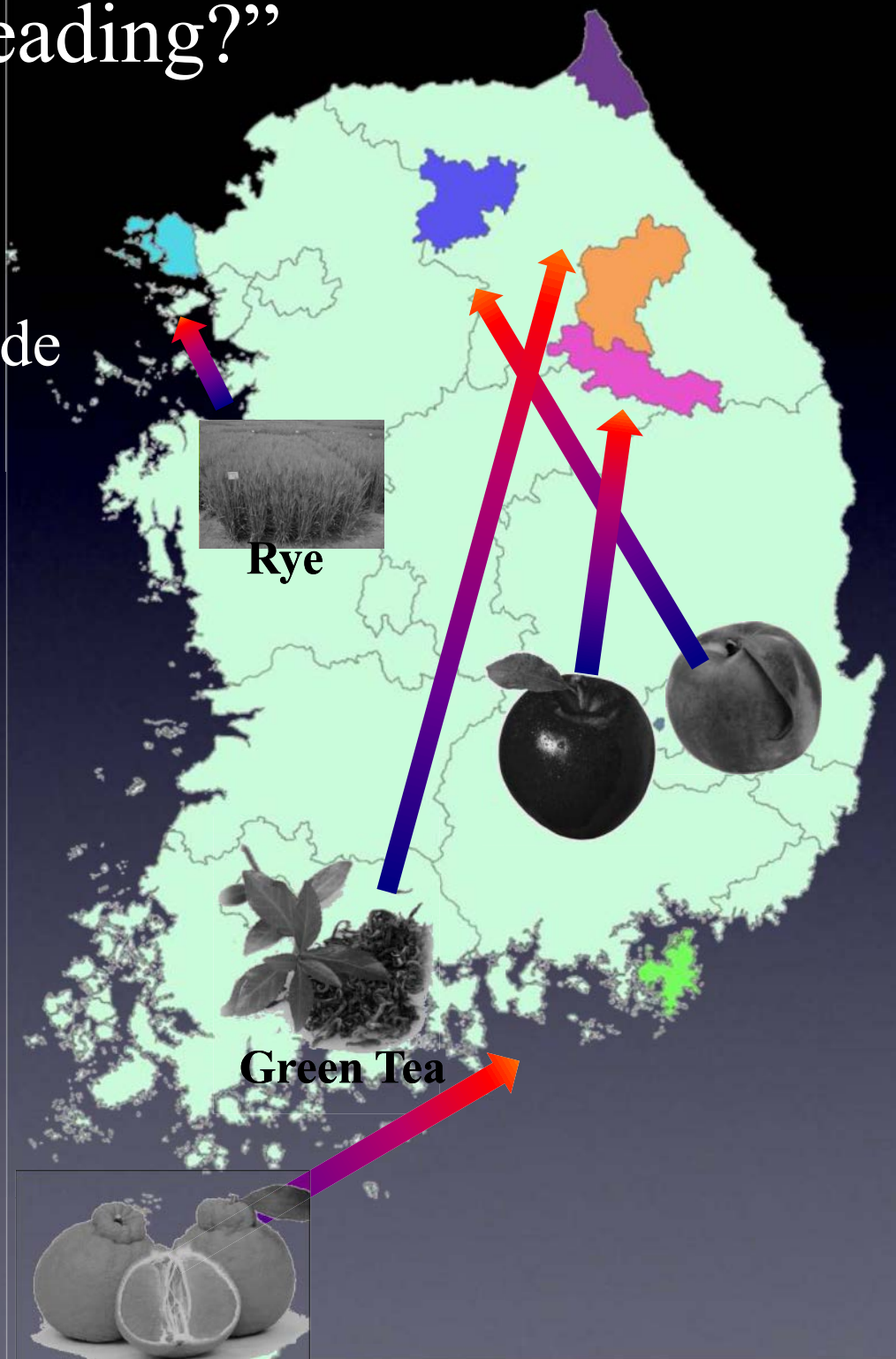


Korea Meteorological Administration, 2009

- Annual mean precipitation has increased, especially in Aug. and Sept.
- Precipitation will increase by ~17%
- Season variations in precipitation will become bigger by the last quarter of the 21th Century, relative to the last quarter of the 20th Century
- Extreme weather events are becoming more frequent

“ Where are South Korea heading?”

Cultivation of agricultural crops
has shifted to more northern latitude
in South Korea,
(e.g. mandarin, apple, peach,
rye, and green tea)

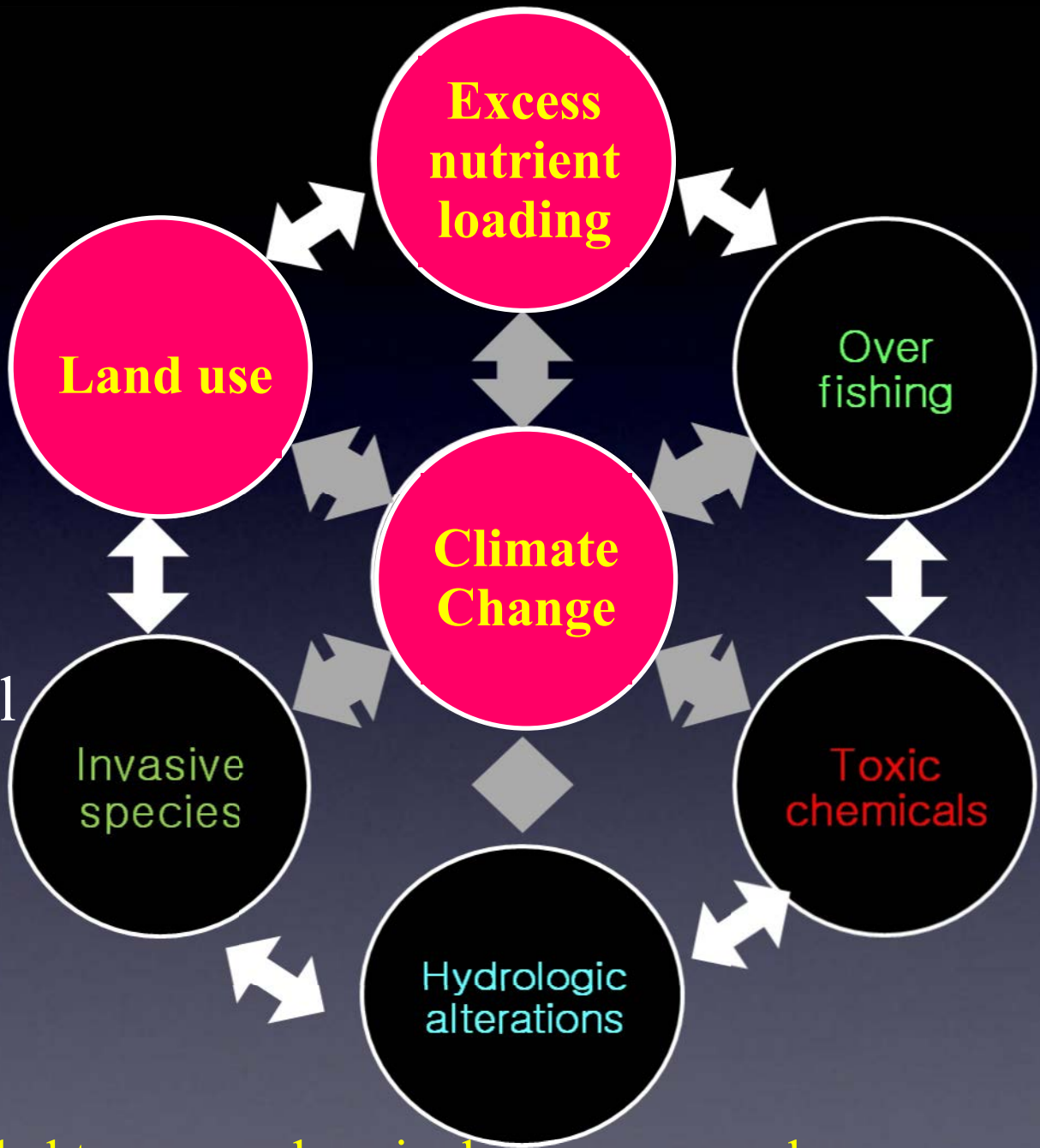


"Climate Change Impacts Will Not Occur in a Vacuum "

- Regional climate change will change the character of South Korea, especially in the aquatic ecosystems and water resources.

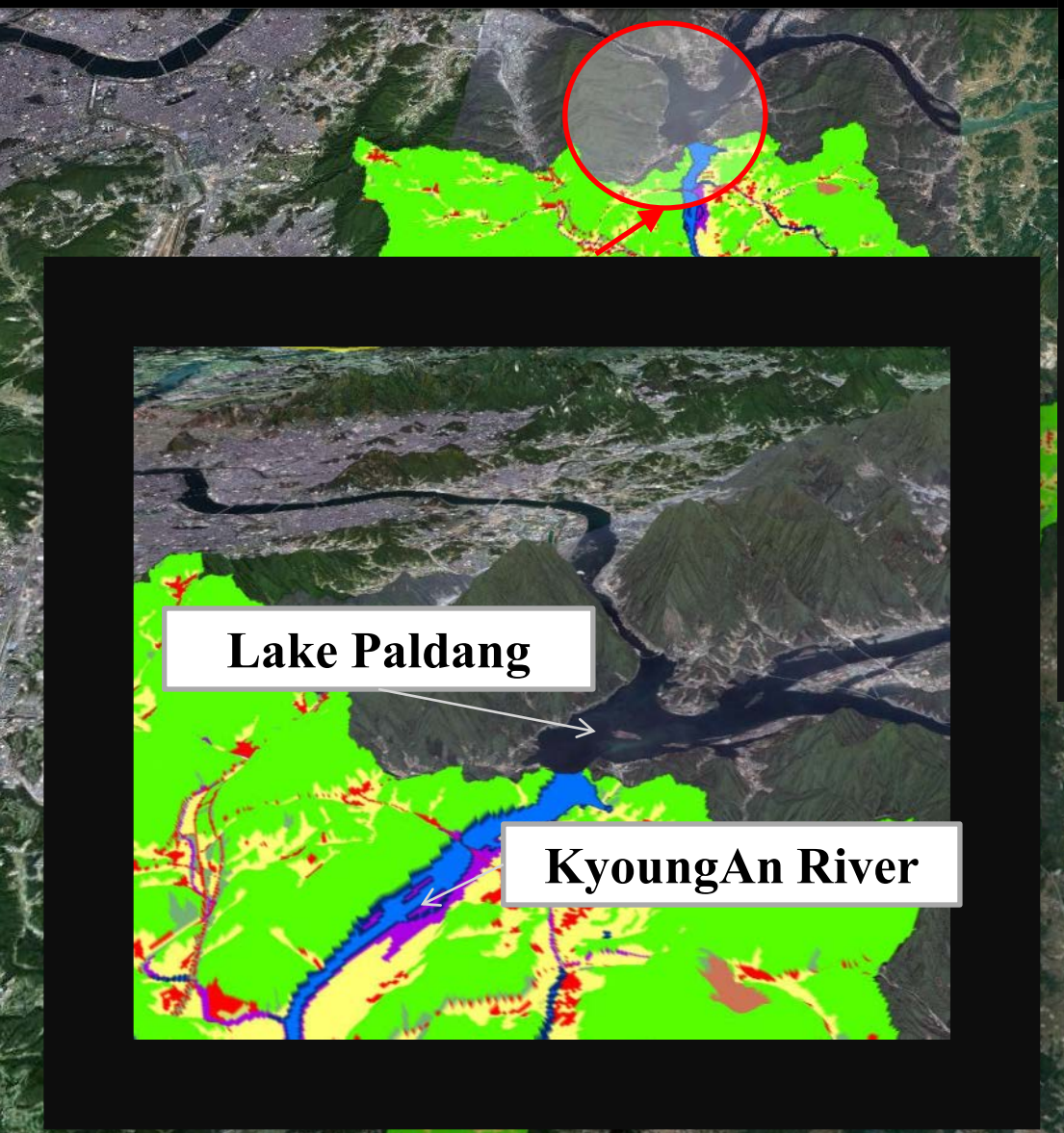
- Complex and synergistic interactions among global climatic drivers and regional non-climatic drivers

→Exacerbation of existing problems



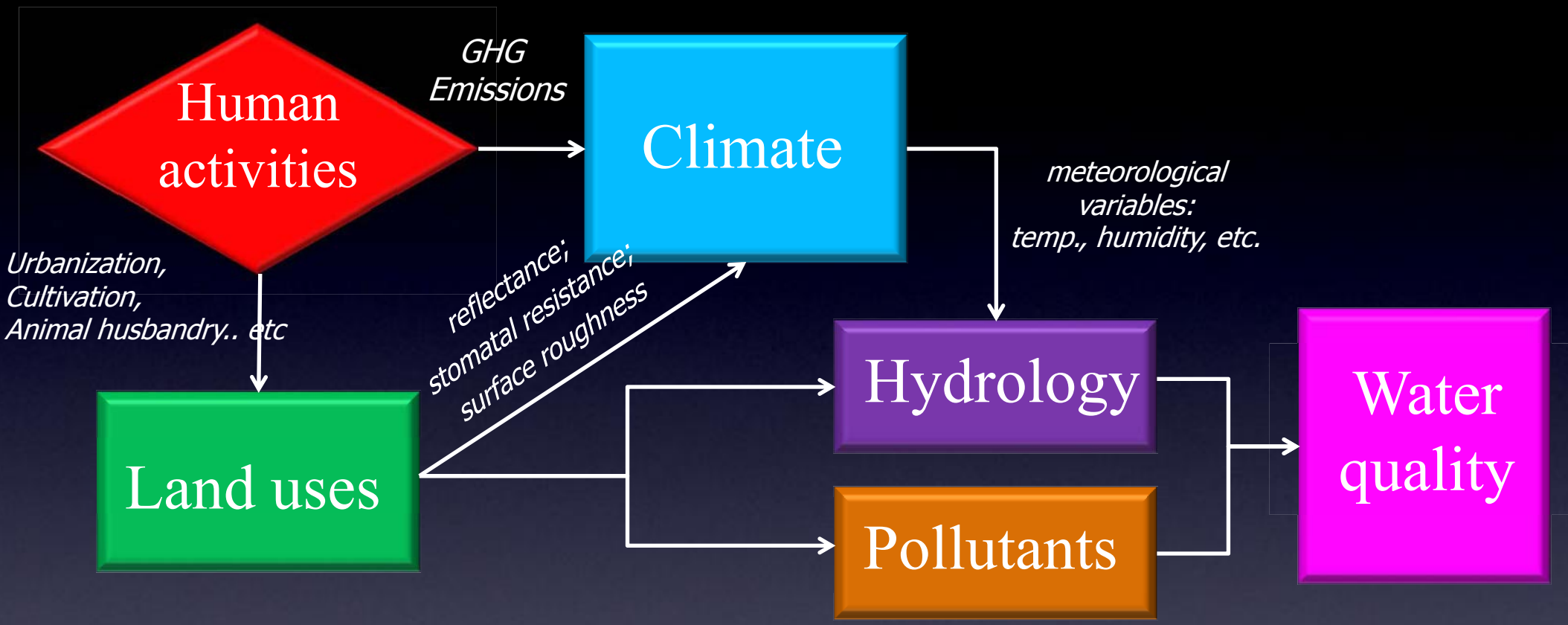
Integrated assessment is needed to comprehensively assess complex interactions across scales, processes, and activities

Case Study sites: Kyoung-An River Basin, South Korea

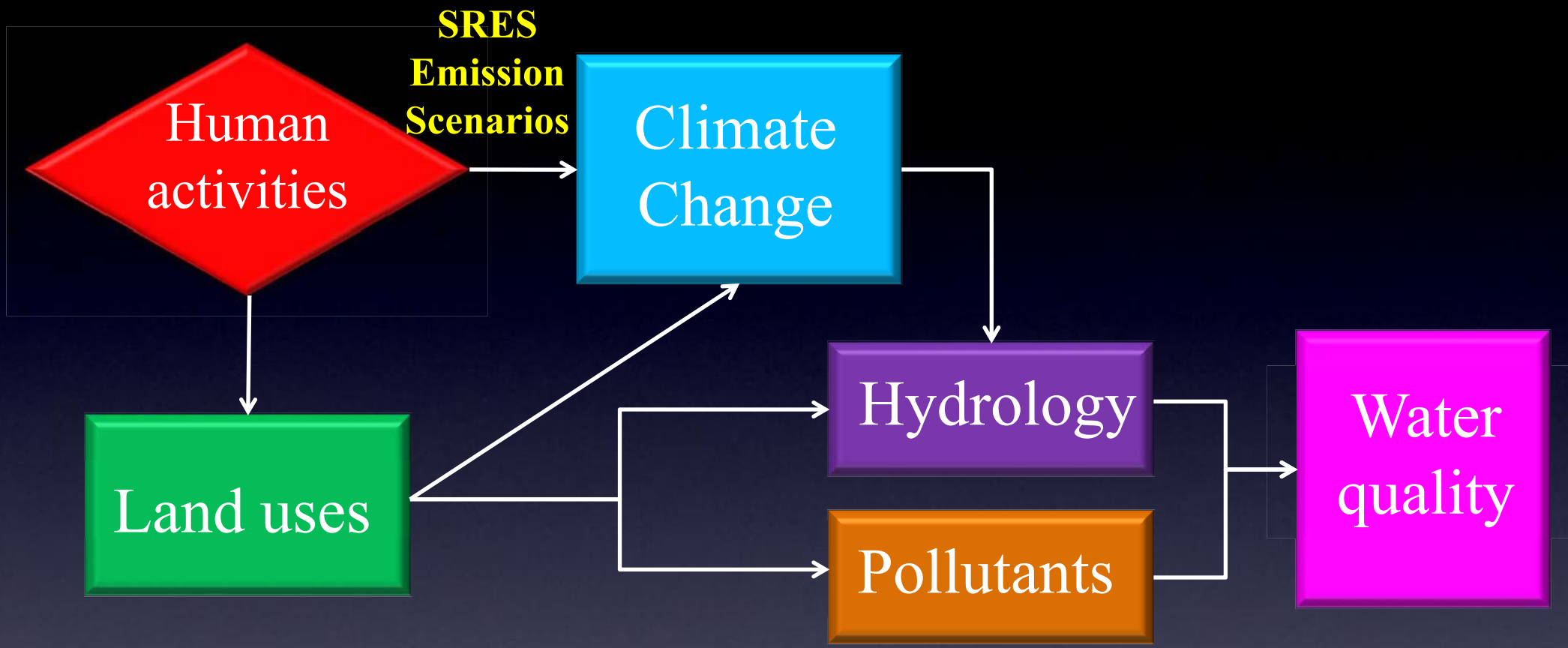


- Size : 560 km^2
- Disturbed landscape (~23% Agric, 12% urban, 65% forest)
- One of the upstream tributaries draining to Lake Paldang, which is the most important freshwater resource for the Seoul City

Relationships among climate change, land uses, and water quality

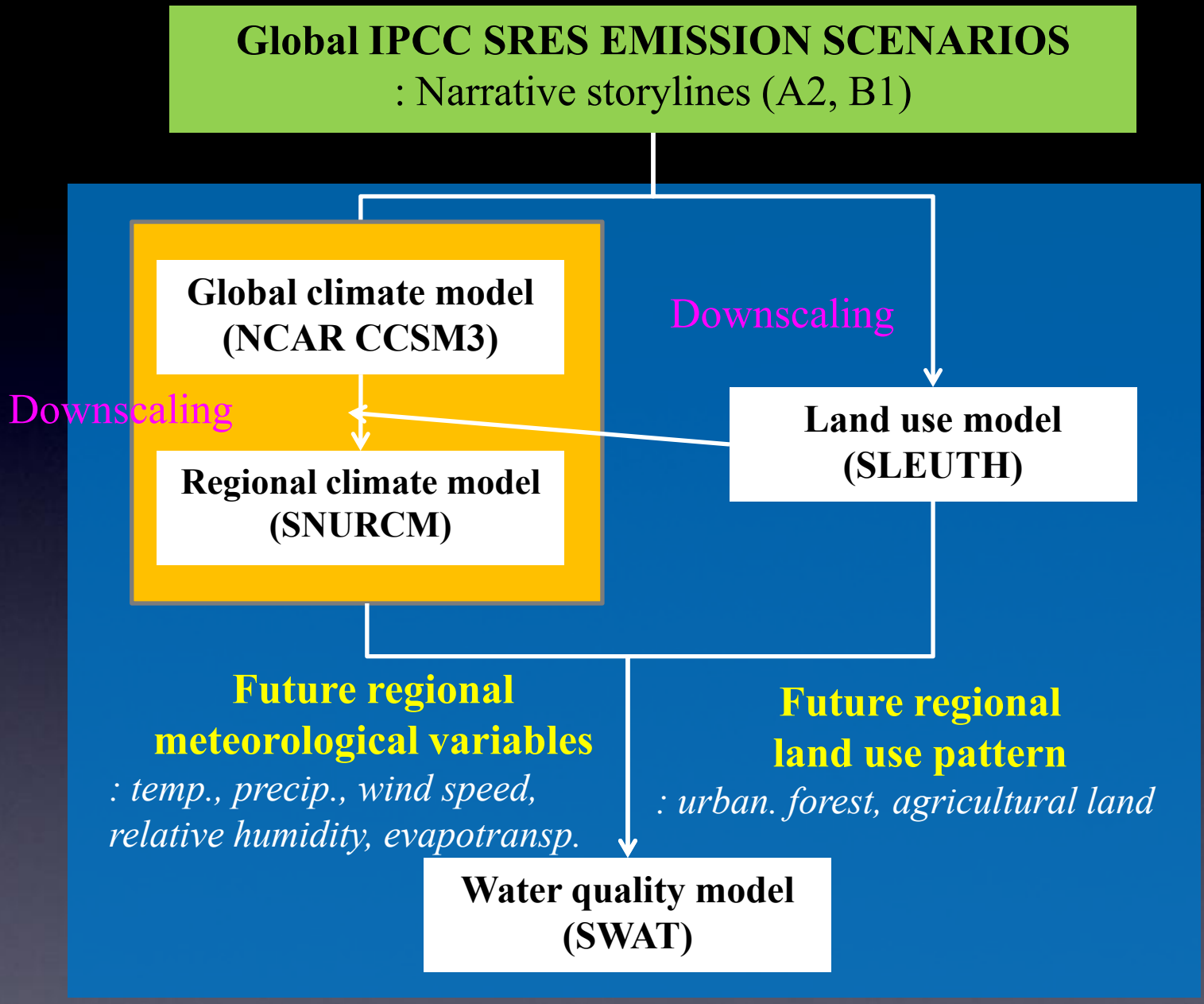


To provide the most consistent assessment of the impacts of climate change on water quality based on the SRES scenarios..

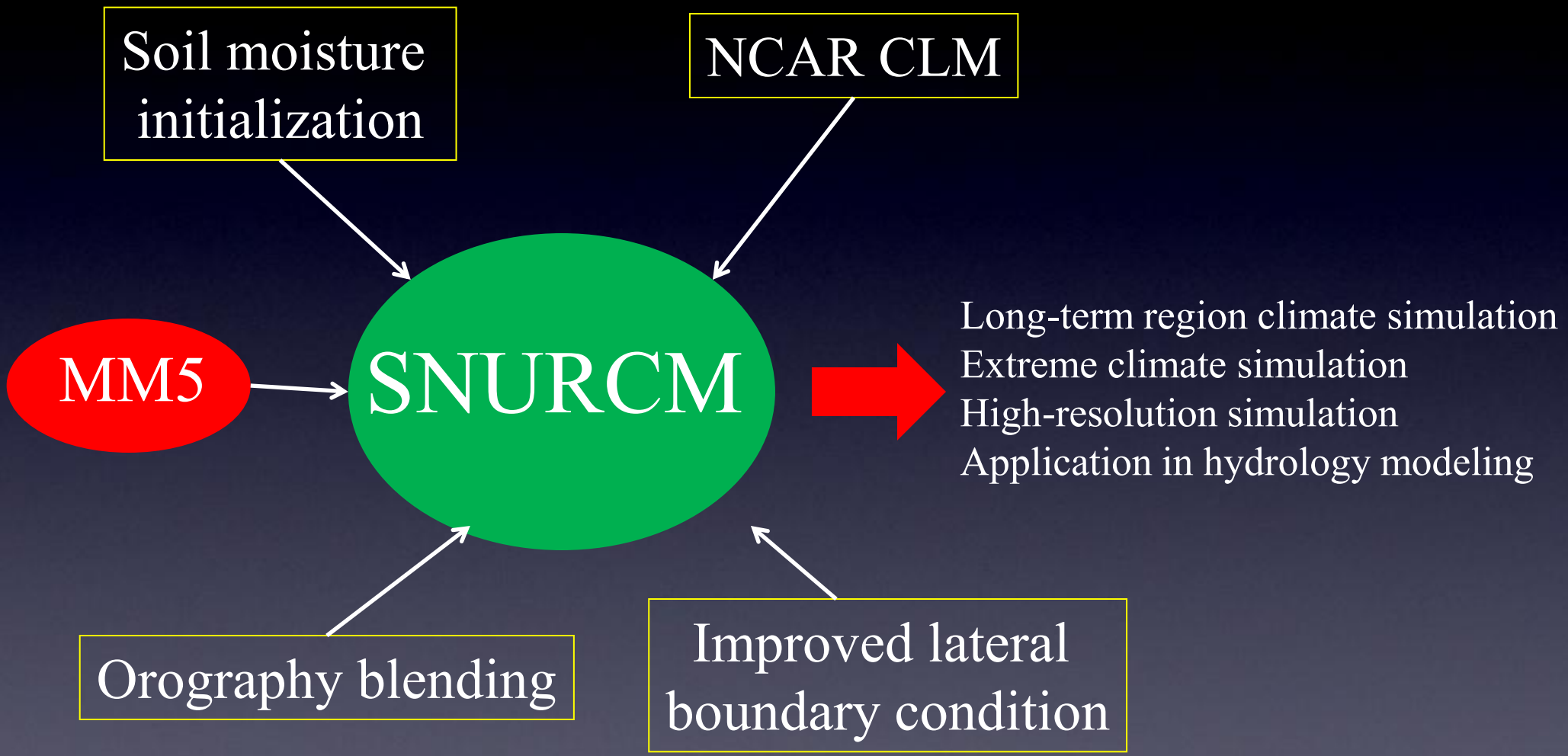


→ The climate associated with a given marker scenario should be superimposed onto the evolving land use scenarios consistent with the maker scenario

→ The narrative SRES storyline and their associated quantitative descriptors need to be downscaled at scales appropriate for impact assessments


Global IPCC SRES EMISSION SCENARIOS
: Narrative storylines (A2, B1)
Global climate model
(NCAR CCSM3)
Downscaling
Downscaling
Land use model
(SLEUTH)
Regional climate model
(SNURCM)
Future regional
meteorological variables
: temp., precip., wind speed,
relative humidity, evapotransp.
Future regional
land use pattern
: urban. forest, agricultural land
Water quality model
(SWAT)
Future runoff and nutrient loadings
: water discharge, SS, TN, TP

Seoul National University Regional Climate model (SNURCM)



(adapted from Lee et al. 2008)

SNURCM model configuration

MODEL CONFIGURATION	
MODEL	SNURCM (MM5, CLM, SP)
Initial boundary	NCAR CCSM3
Governing equations	Non-hydrostatic
Vertical layers (top)	21 sigma layers (70 hPa)
Horizontal grids	20km
Cumulus convection	Grell
Explicit moisture	Simple ice
PBL	YSU
Radiation	CCM2
Land surface	NCAR/CLM

Regional-scale land use prediction models

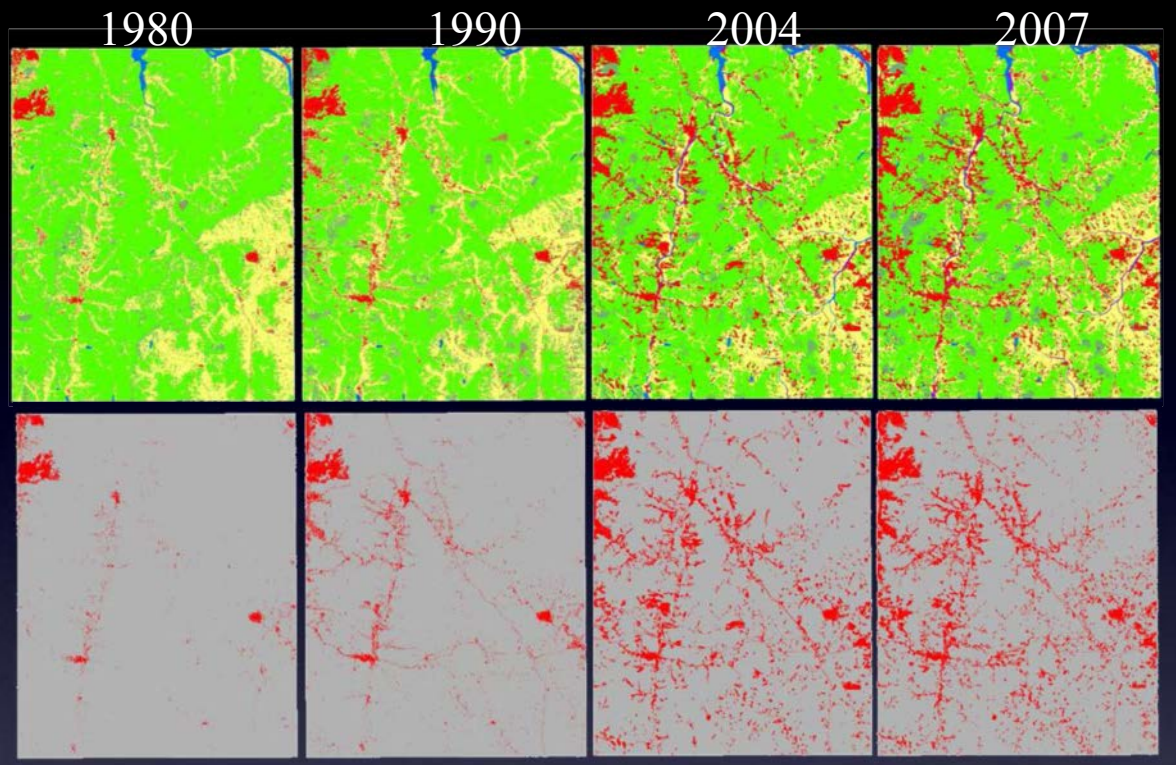
- A two-phase (nested scale) approach with an assessment of aggregate quantities of land use for the entire region, followed by downscaling procedure
- Examples of downscaling- methods to estimate regional from global scenario

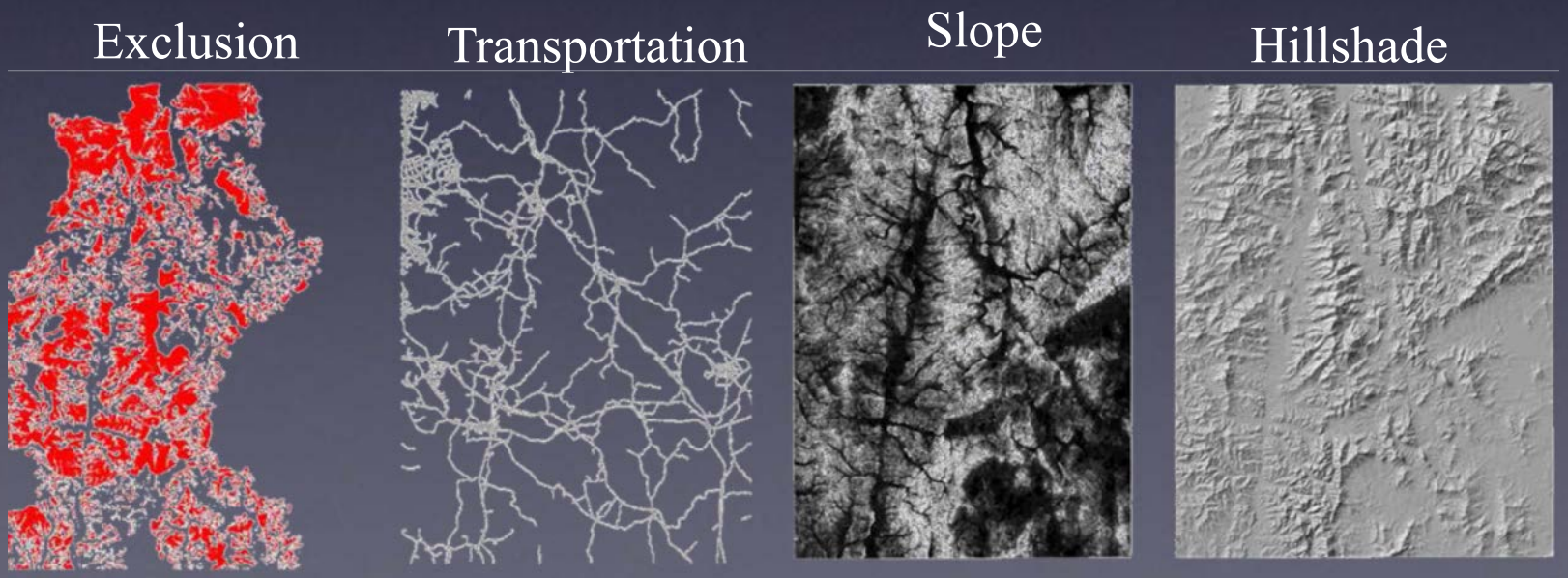
  - proportional approaches s (Arnell et al. 2004)
  - spatial allocation procedure based on rules (Rounsevell et al. 2006)
  - micro-simulation with cellular automata (Solecki and Oliveri, 2004)
  - regional-scale economic models (Fischer and Sun, 2001)
  - linear programming models (Holman et al., 2005)
  - empirical- statistical techniques (Verburg et al., 2006)
  - agent-based models (Alcamo et al., 2006)

SLUETH model (Clarke, 1998)

- SLUETH is one kind of model in the family of Cellular Automata
- Cellular Automata models are dynamic simulation models, where cell transitions are based on the state of the current cell and the states of neighboring cells
- SLUETH is an acronym for the input layers that the model uses in gridded map form: Slope, Land use, Exclusion, Urban extent, Transportation, and Hillshade
- Growth parameters: Dispersion, Breed, Spread, Slope, Road gravity
- Growth rules: Spontaneous growth, New spreading centers, Edge growth, Road-influenced growth

Input dataset used in this study





Downscaling SRES scenarios into the SLUETH model (Solecki and Oliveri, 2004)

Multi step process was developed to translate the SRES Scenarios into SLUETH defined modeling experiments

Step 1. Elaborate the broad narrative of each scenario within the context of urban growth and change in the target country settings

Step 2. Define specific growth parameters from the narratives

Step 3. Translate the scenario growth parameters into specific SLUETH program applications

Example: A2 scenario (Pessimistic future)

Broad narrative of A2

- Population: Continuously increased
- Governance: local-based, individualistic
- Energy: Higher reliance on fossil fuel
- Transportation: greater reliance on automobile ➔ Per-capita automobile vehicle miles ↑

Specific growth parameters of A2

- New growth center ↑
- New limited access highway loop road through the ex urban part of the region
- Road corridor growth and growth associated with new suburban and peri-urban employment centers↑
- Infilling in existing urban centers↓

SLEUTH modeling adjustments

- Breed and spread coefficients ↑
- New transportation layer with ring road added future
- Highways given increased weighting
- Dynamic exclusion layer increase percent exclusion around existing urban centers

Example: B2 scenario (optimistic future)

Broad narrative of A2

- Population: lower population growth than A2
- Governance: local-based, individualistic
- Energy: Conversion to alternative source of energy
- Transportation: less reliance on automobile ➔ Per-capita automobile vehicle miles ↓

Specific growth parameters of A2

- Growth along public transportation corridors ↑
- Spontaneous, leaf-frog sprawl growth ↓
- Infilling, compact growth, and edge growth ↑
- Protection of environmental resources ↑
- Active re-greening and afforestation ↑

SLEUTH modeling adjustments

- Highways given increased weighting
- Breed and dispersion coefficients ↓
- Dynamic exclusion layer increase percent exclusion around non-urbanized areas
- Percent exclusion of Protected areas in exclusion layer ↑

SWAT model

- SWAT is an acronym for Soil and Water Assessment Tool
- Long-term, continuous watershed simulation model (Arnold et al,1998)
- Assesses impacts of climate and management on yield of water, sediment, and agricultural chemicals
- Physically based including hydrology, soil temperature, plant growth, nutrients, pesticides and land management
- Inputs: Elevation map, Soil, Land use, Agricultural practice, Metrological data

SRES Scenarios

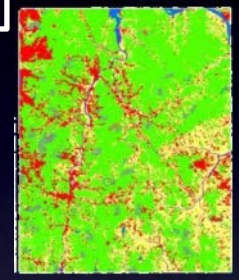
GCM

SLEUTH Model

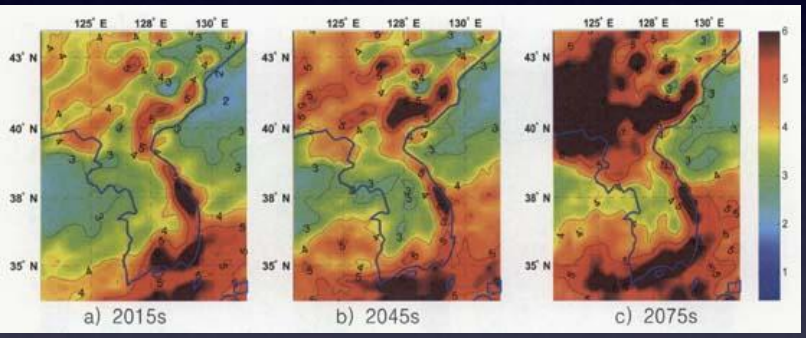
MM5

RCM

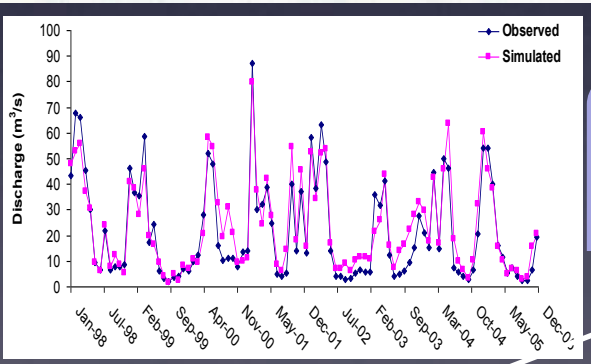
Future land use



Future weather data

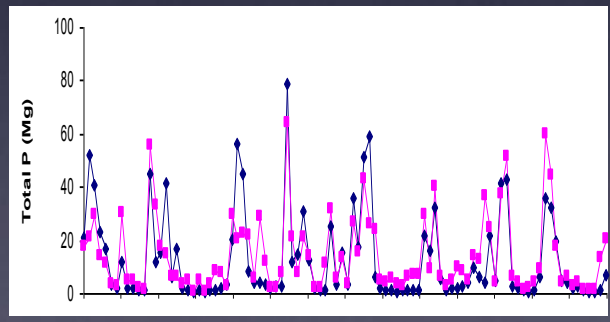


SWAT



Simulated Water discharge

Simulated Water quality



Observation

Future water quality

Observation

Conclusions

- Studies of the impact of climate change on water quality need to account for future changes in land uses and land cover
- This is because land use has a large influence on regional patterns of human activities and associated problems of aquatic environmental degradation and pollution
- There have been a small number of impact assessments that have used the climate changes resulting from the SRES emission scenarios, but very few that have also used the corresponding land use- change scenarios
- To provide the most consistent water quality impact estimates , the climate associated with a given marker scenario should be superimposed onto the corresponding future land use change as well as socio-economic and demographic characteristics of the storyline that drives that maker scenario
- Coupling GCM, RCM, SWAT, and SLEUTH models can provide an opportunity to provide a better integrated assessment of water quality in response to changes in climate and land uses

Thanks!!
Questions ??