United Nations Educational,
Scientific and Cultural Organization

UNESCO- **GRAPHIC** project

2004-

GRAPHIC: **G**roundwater **R**esources **A**ssessment under the **P**ressures of **H**umani**t**y and **C**limate Change

Makoto Taniguchi[1] and Alice Aureli[2]

1: Research Institute for Humanity and Nature

2: UNESCO-IHP

Global warming

Global Environmental Issues

Air pollution

Biodiversity

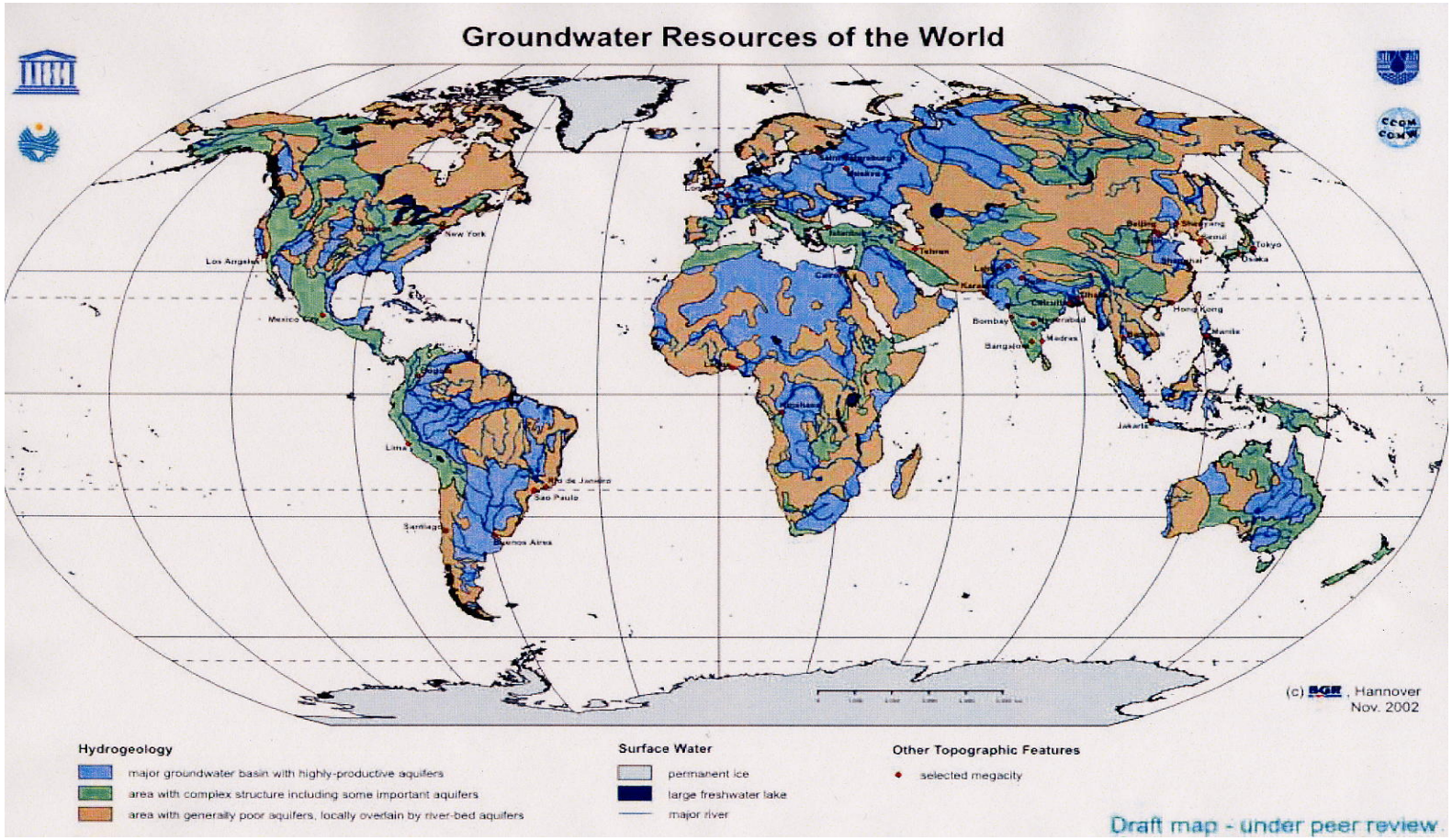
Seawater pollution

Increase in population

Subsurface Environments ?

Subsurface environmental issues are important for human life in the present and future, but have been largely ignored because of the **invisibility** of the phenomena and **difficulty** of the evaluations.

Global groundwater depression



Groundwater depression: 200km^3/year (Foster, 2000)

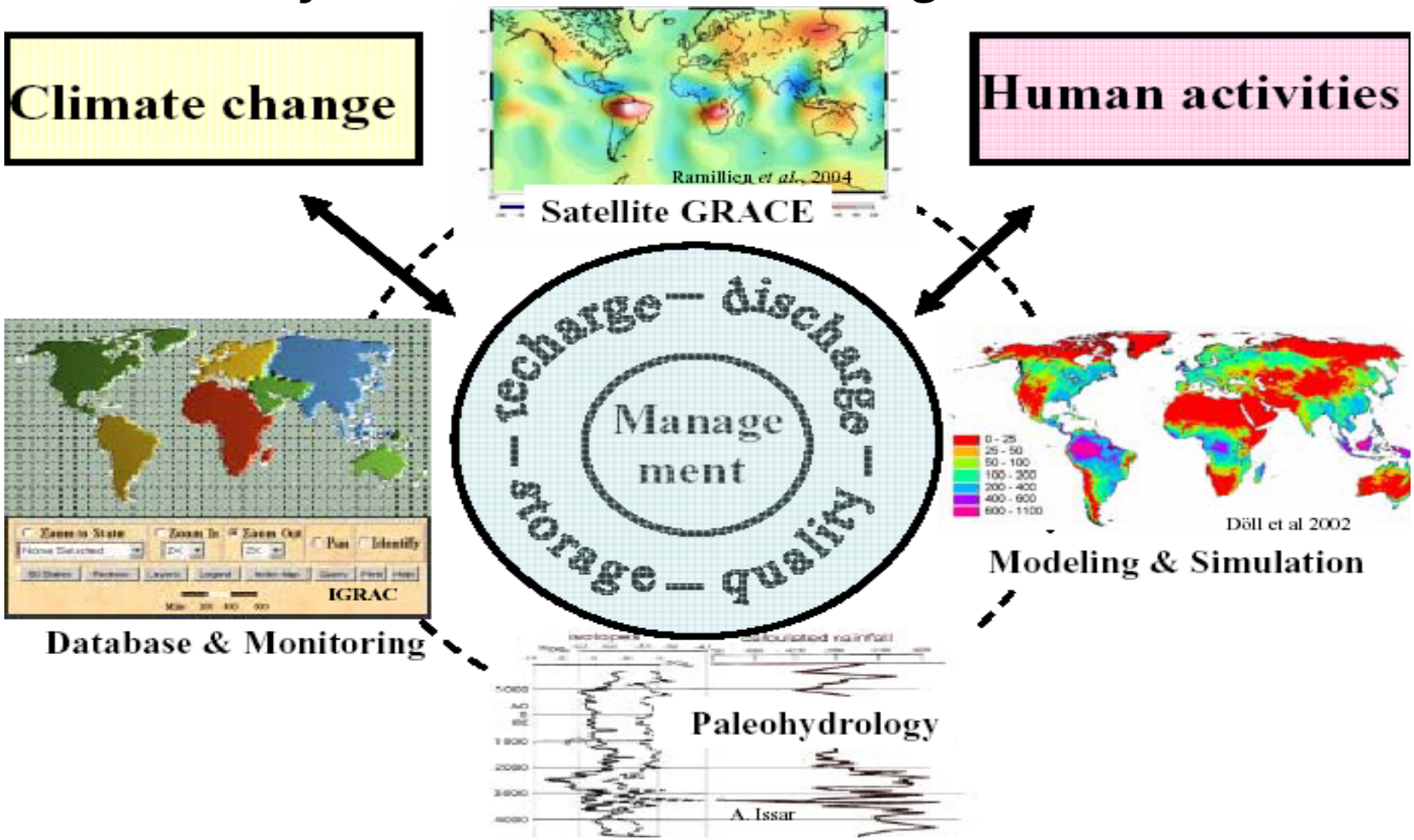
⇒1.2mm/year (per unit area of land)

Purposes of the GRAPHIC project

- **Groundwater** is an extremely important natural resource as a primary source for agriculture, domestic, and industrial water supplies in many countries.
- In order to maintain the sustainable uses of groundwater resources, **evaluations** of changes in (not only groundwater storage but also in) **groundwater fluxes** (recharge rates and discharge rates) and **quality** are necessary and important.
- This project will deal with groundwater resources assessment and future forecasting under the various pressures of **human activities** and **climate changes**.

Structure of GRAPHIC

To make the **GRAPHIC** project and its sub-elements manageable, the structure of the project will be divided into ***5 subjects***, ***4 methods*** and ***regions***.



Subject 1

Changes in groundwater recharge rates

Recharge enhancement

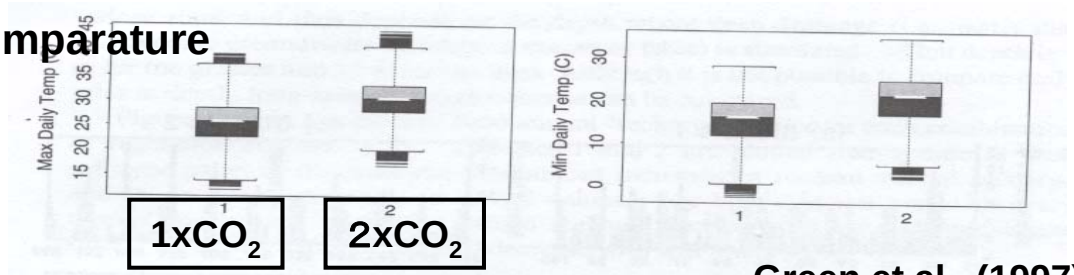
irrigation

deforestation

Artificial recharge

Land use changes
(e.g., permeable road,
no tillage agriculture)

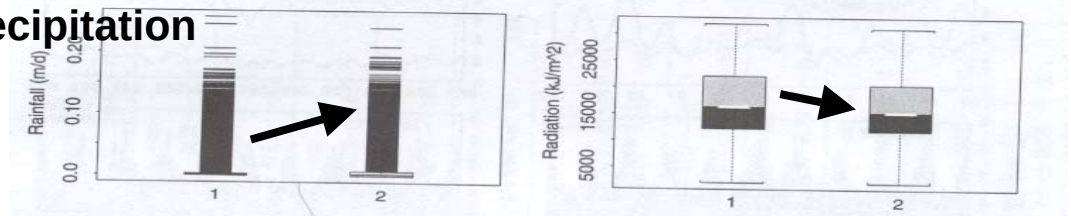
Temparature



1xCO_2 2xCO_2

Green et al., (1997)

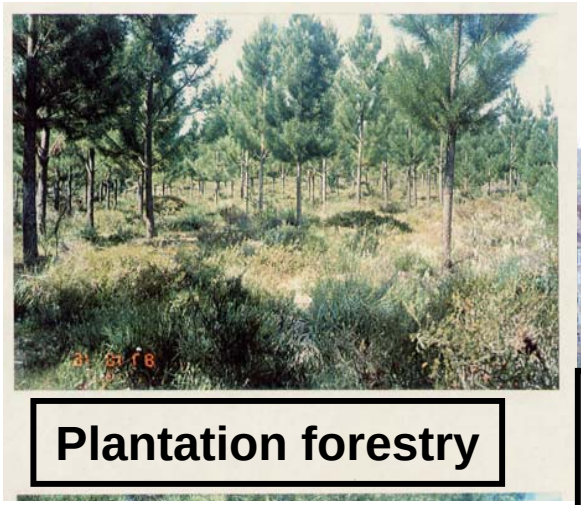
Precipitation



Climate change
(increased P)

Climate change
(decreased ET)

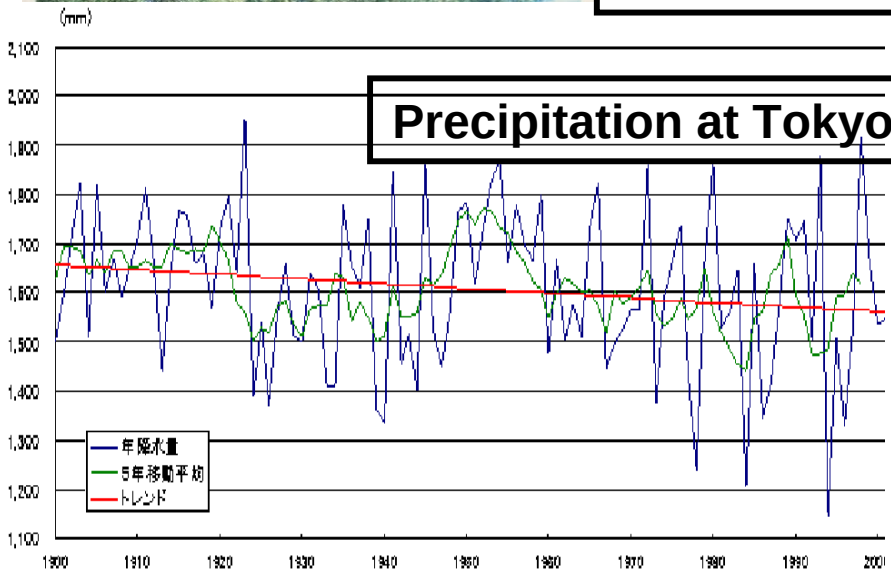
Recharge reduction



Plantation forestry

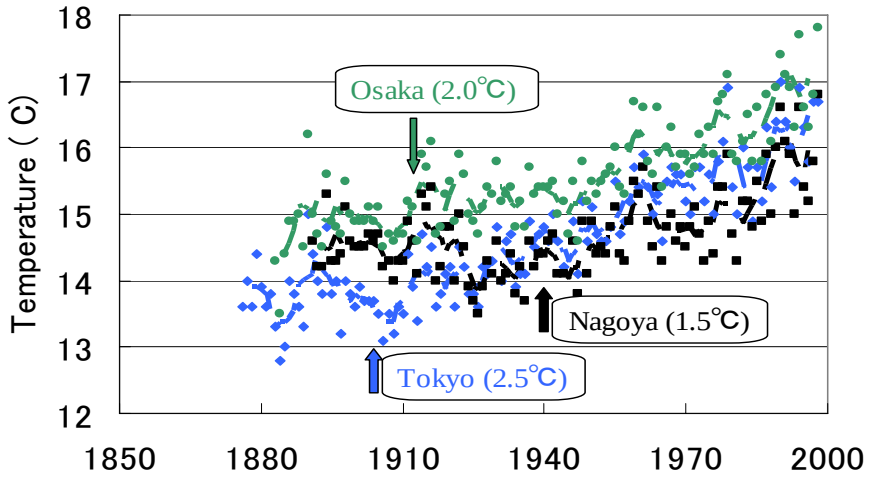
Urbanization (impermeable layer, etc.)

Mulching and precision agriculture –improved spatial soil water retention



Precipitation at Tokyo

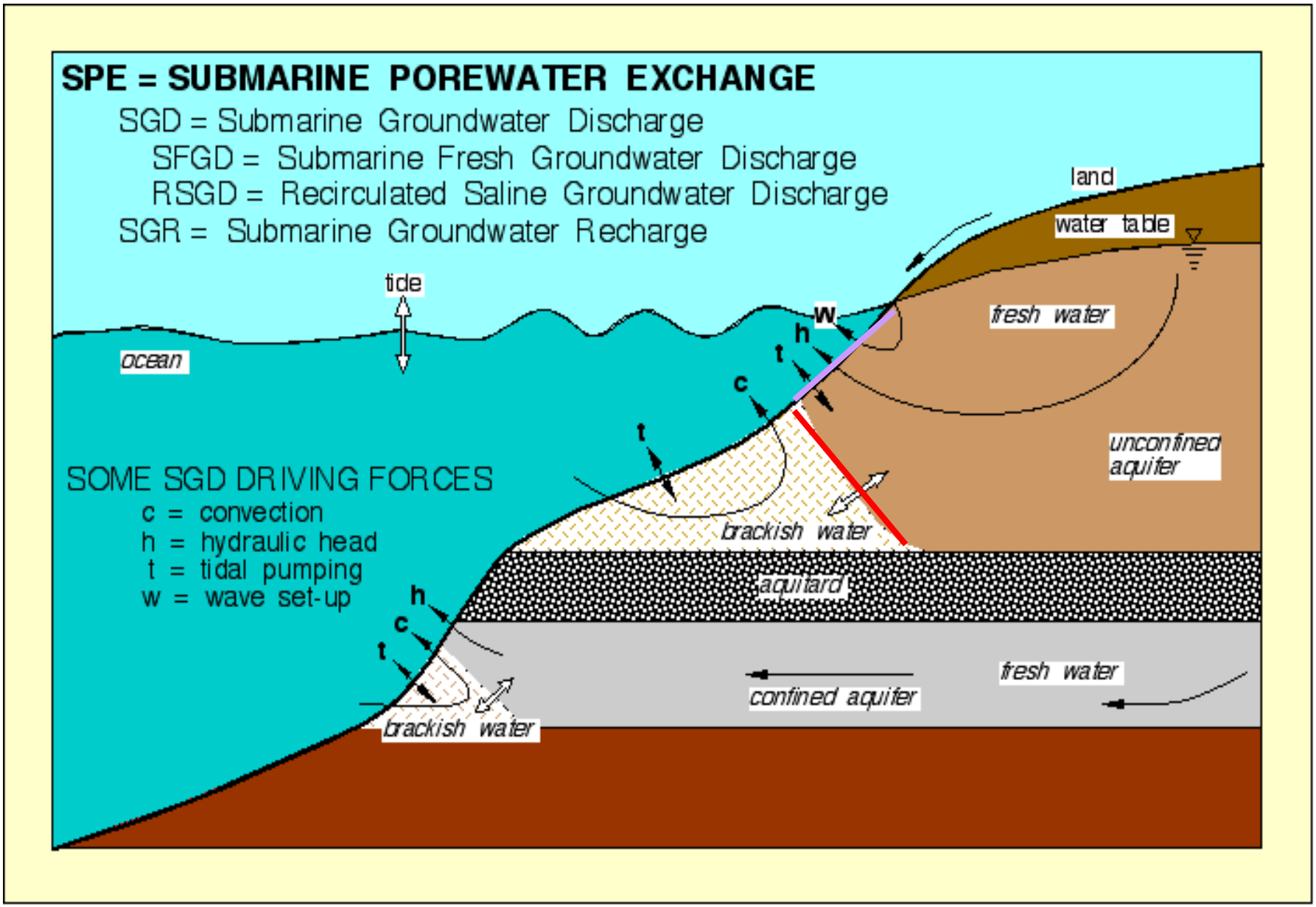
Climate changes (decreased precipitation)



Climate changes (increased ET due to warmer temperature)

Subject 2

Changes in groundwater discharge rates

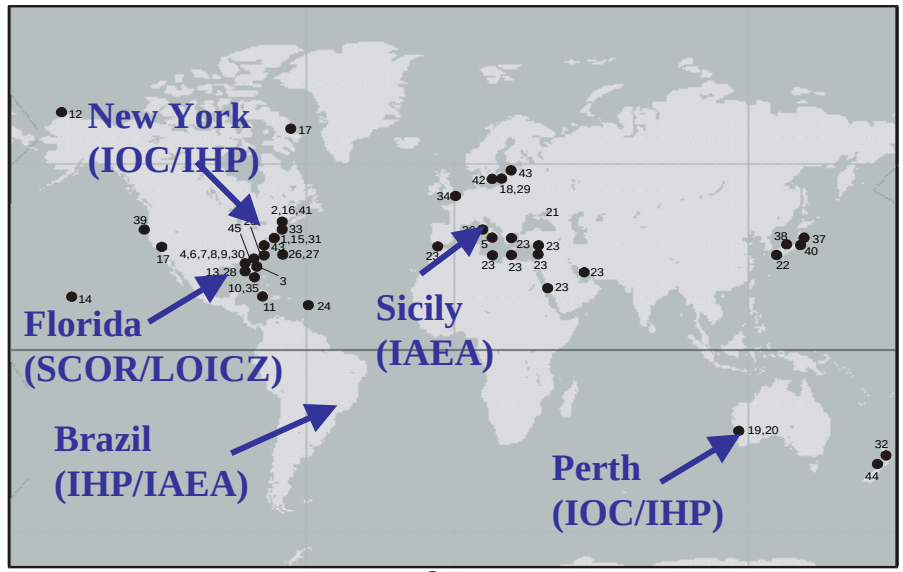


Freshwater-saltwater interface **SGD distribution**

Submarine Groundwater Discharge (SGD)

* SGD is about 8 % of total discharge from land to the ocean.
* Dissolved material transports by SGD is much important that SGD itself.
* SGD were found in continental scale, but quantitative evaluations were limited.
* Intercalibrations of SGD are needed by direct measurements, modeling and typology

Intercalibration at Florida (1999)



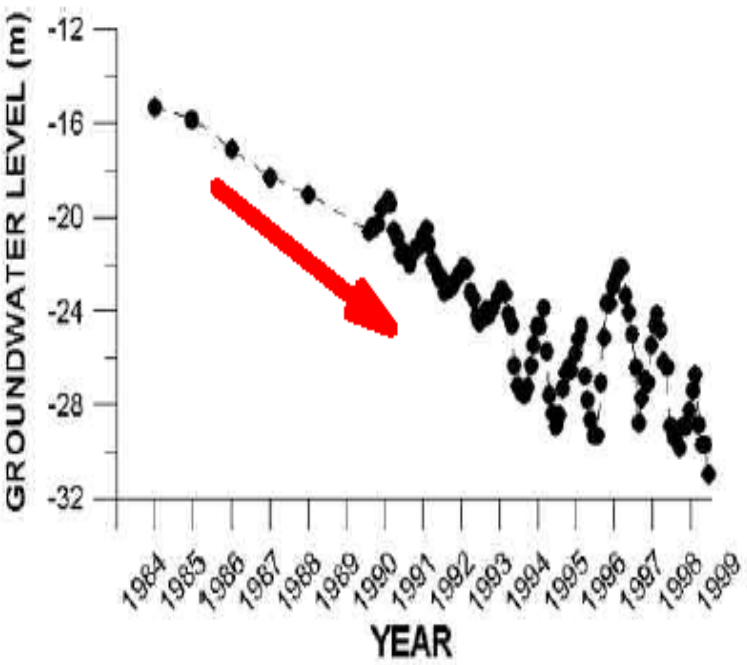
Locations of Intercalibration

Subject 3

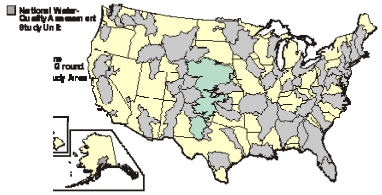
Changes in groundwater storage

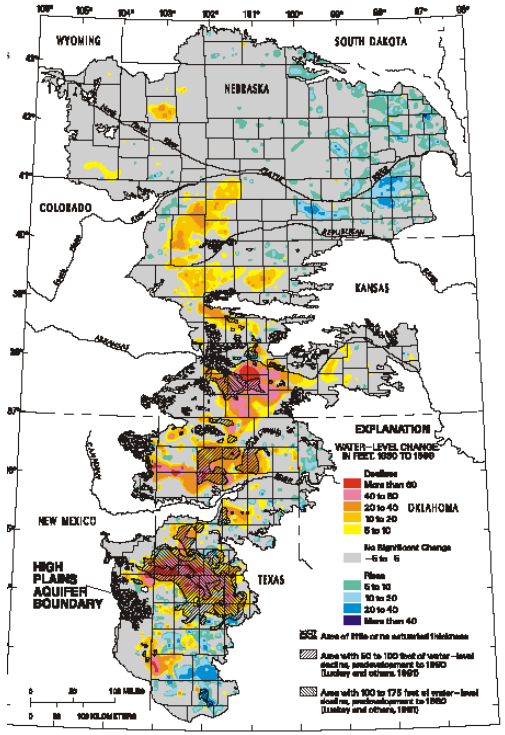
Reduction of Groundwater storage

Storage reduction



North of Yellow River, China



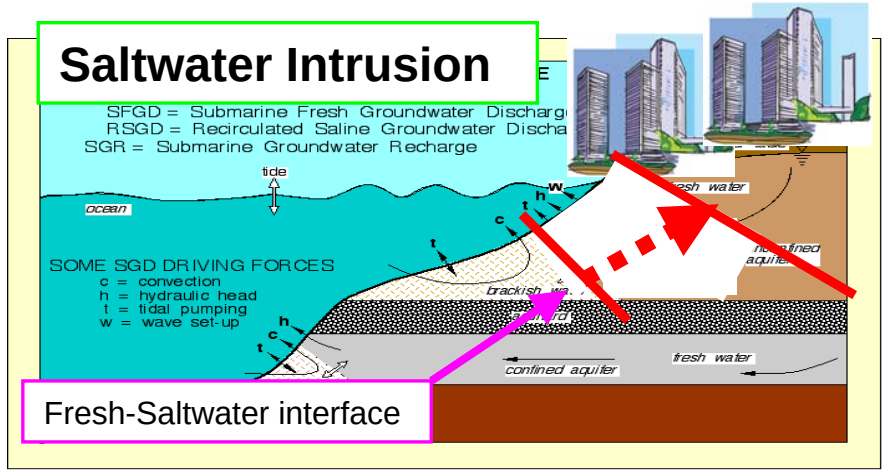


High Plain aquifer, USA

- Groundwater mining
- Negative balance between recharge and discharge
- Saltwater intrusion due to excessive pumping
- Saltwater intrusion by sea level rise due to climate change
- Groundwater contamination

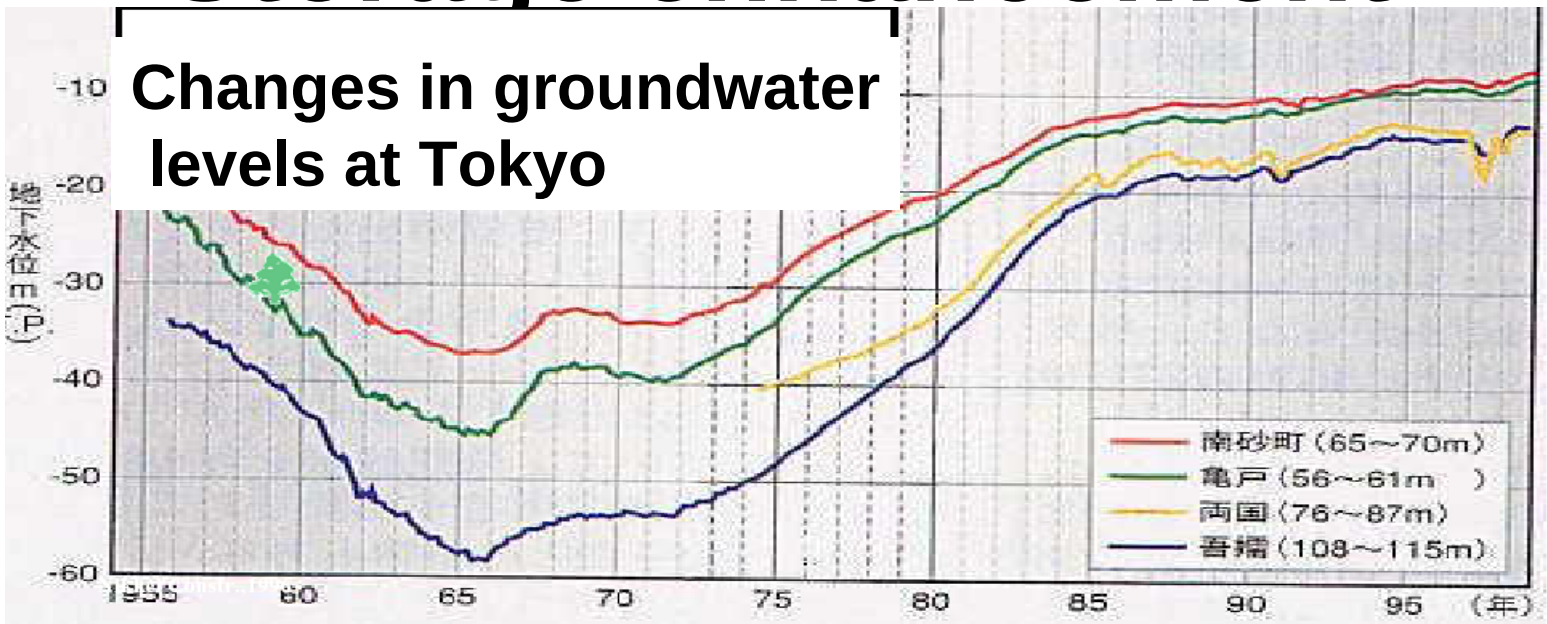
Disasters due to excessive groundwater use

subsidence



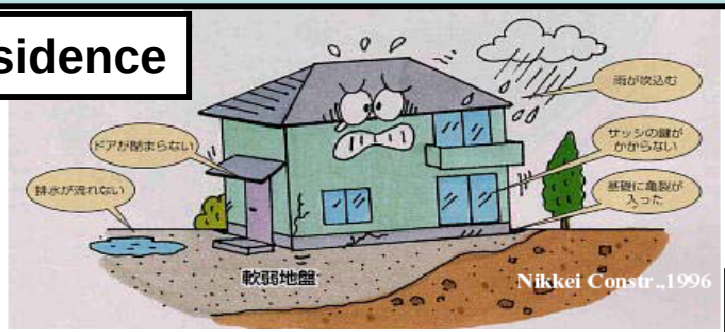
flooding

Storage enhancement



Pumping → subsidence → regulation → increased GL→ floating

subsidence

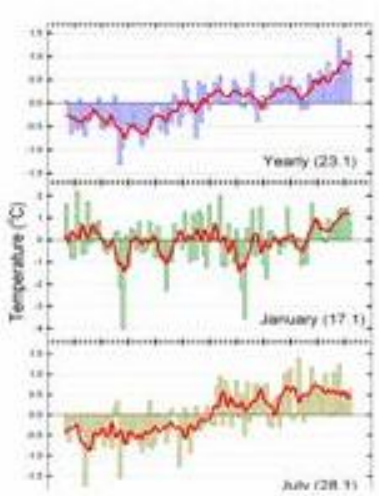


Steal weight

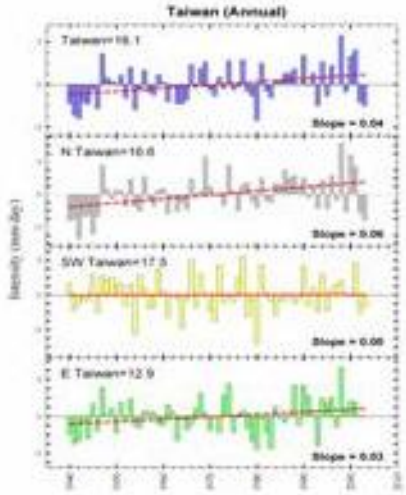
Subway station

- **Recovery of groundwater storage due to regulation of pumping**
- **Underground dam**
- **Positive balance between recharge and discharge**

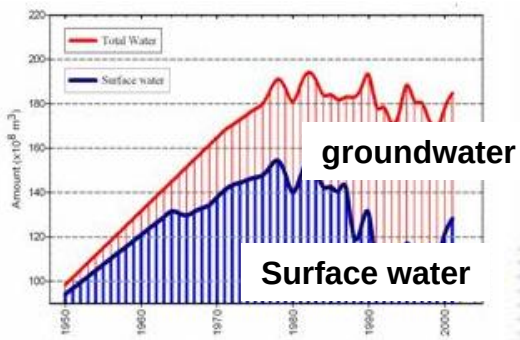
Climate change → Social reaction→ Subsurface environmental change



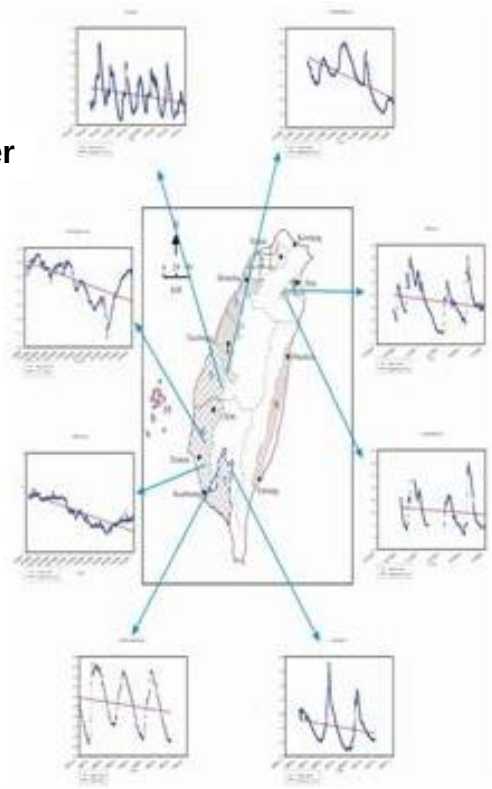
Global warming



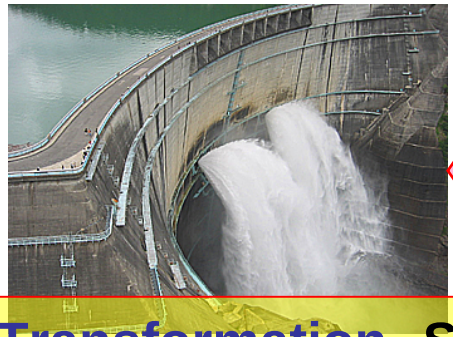
Increase in variability of Precipitation



Transformation of water resources (surface water → groundwater)



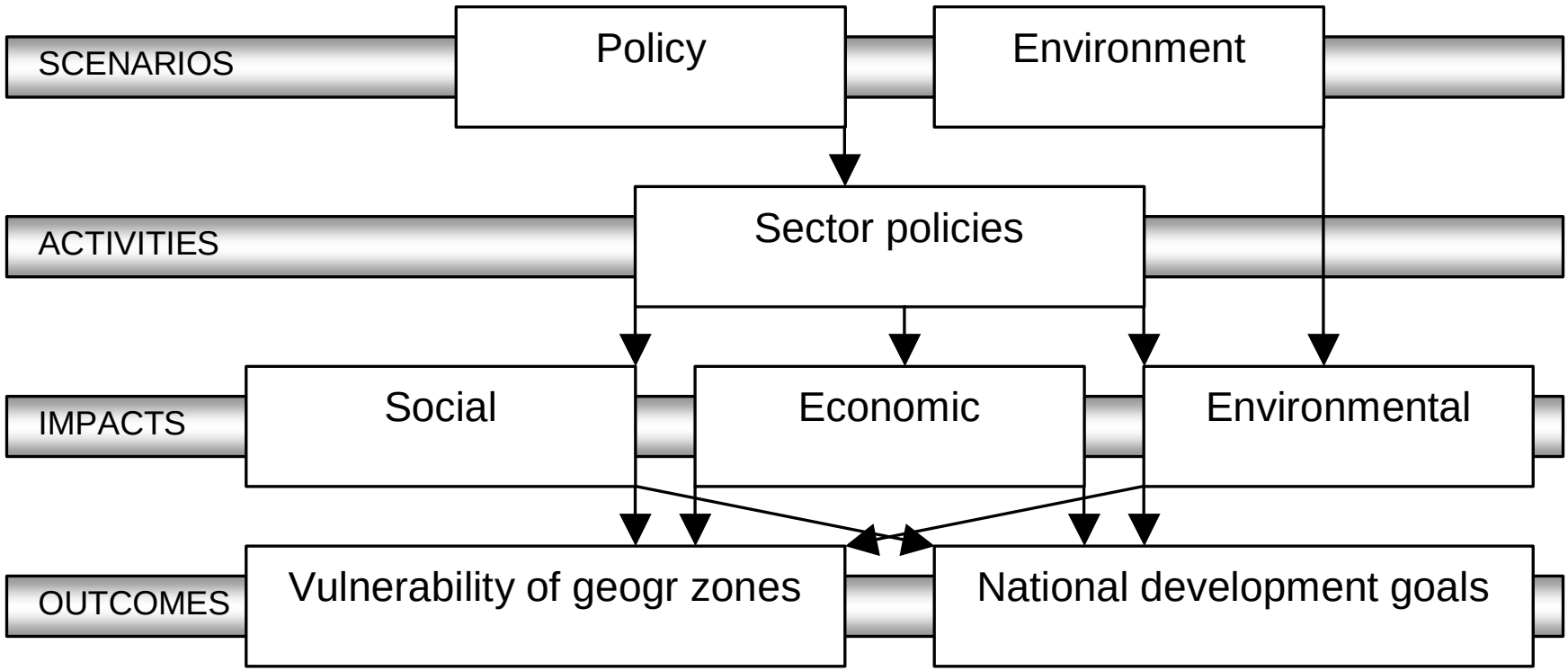
Decrease in groundwater level



Transformation Surface water ⇔ Groundwater

Subject 5

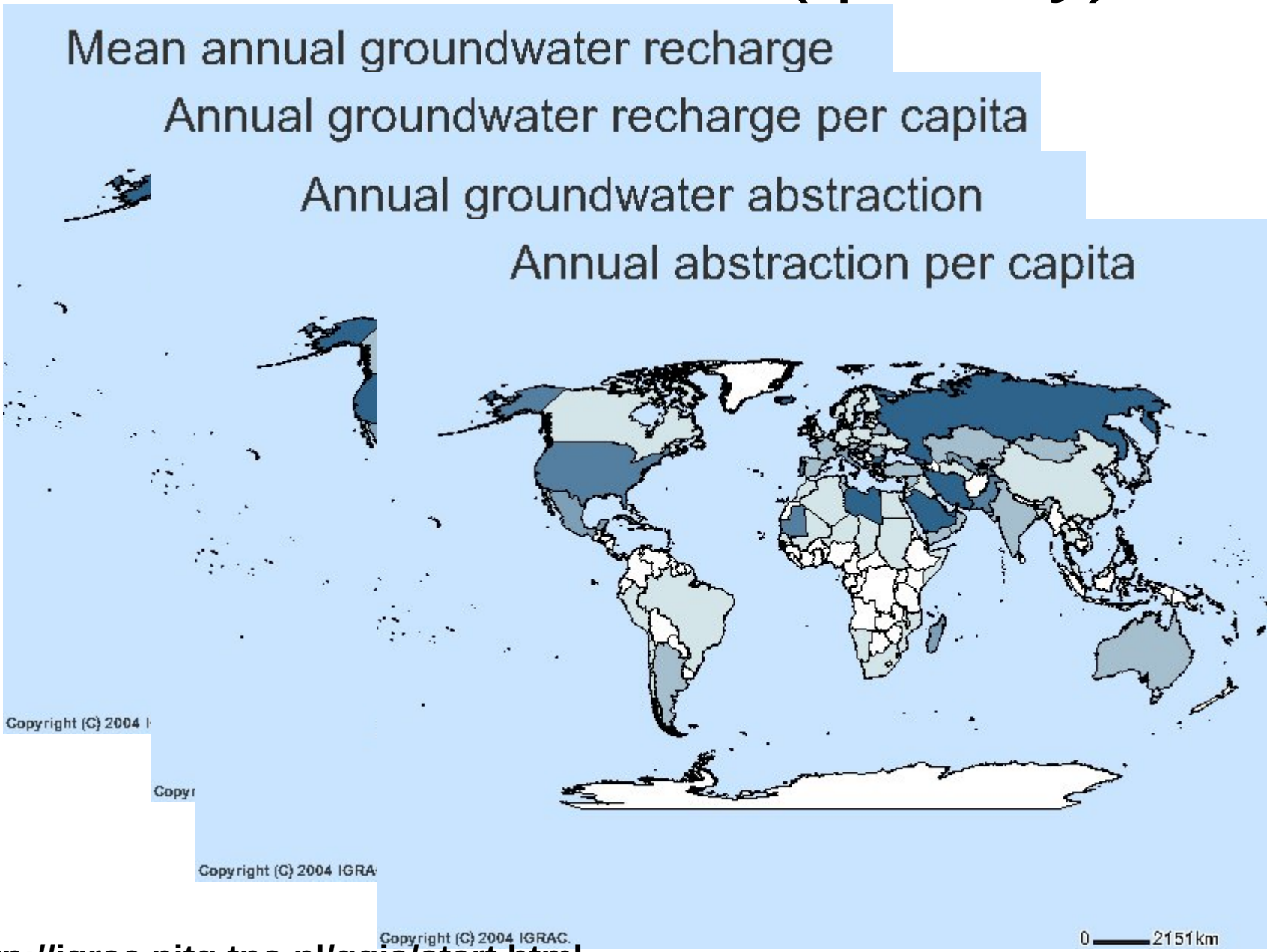
Managements


SCENARIOS
Policy
Environment
ACTIVITIES
Sector policies
IMPACTS
Social
Economic
Environmental
OUTCOMES
Vulnerability of geogr zones
National development goals

Method 1

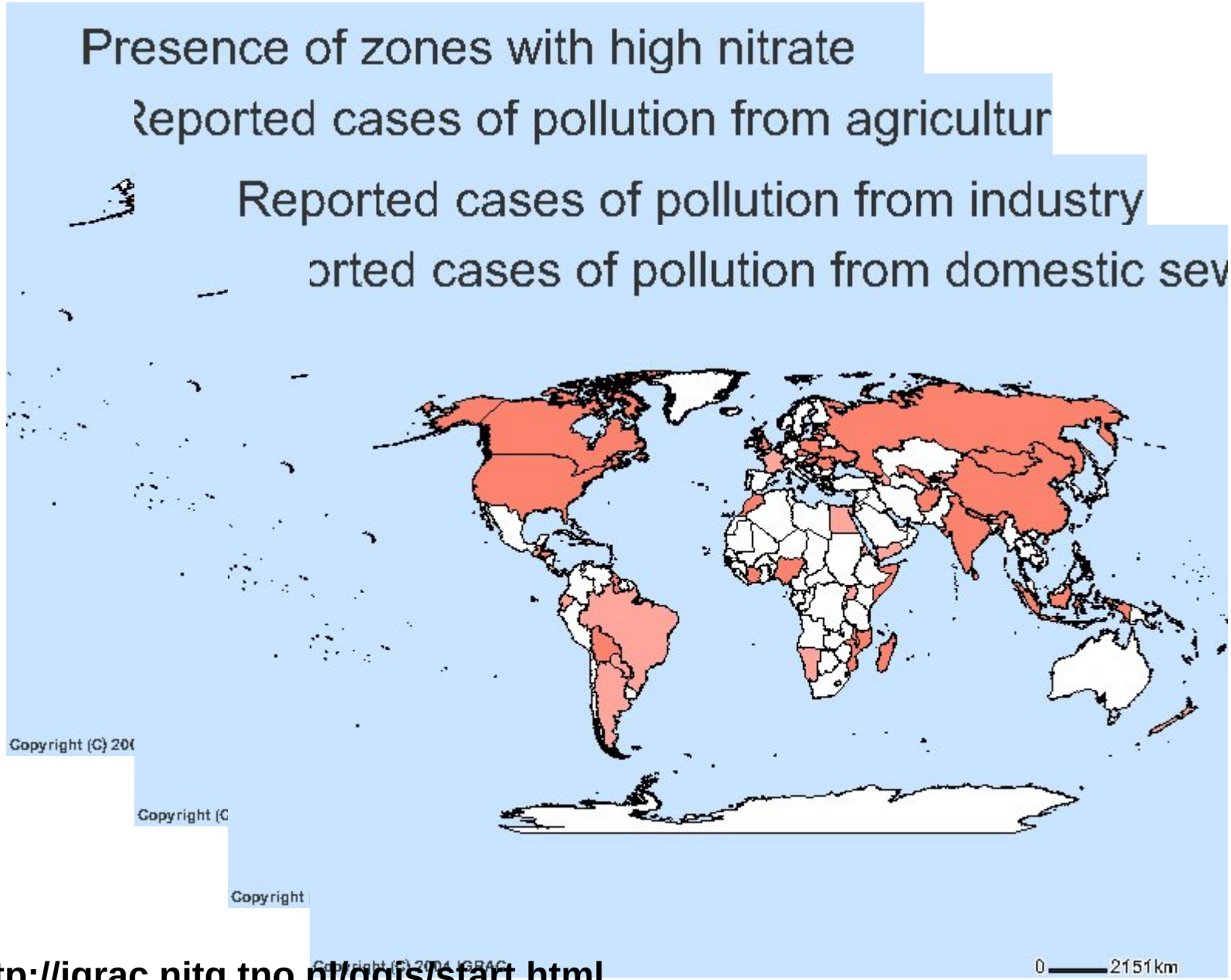
Database and monitoring

IGRAC database (quantity)



http://igrac.nitg.tno.nl/ggis/start.html

IGRAC database (quality)

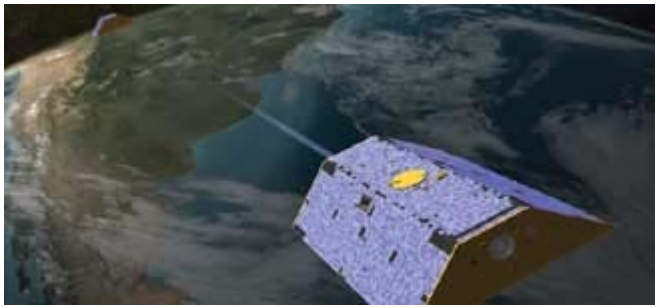


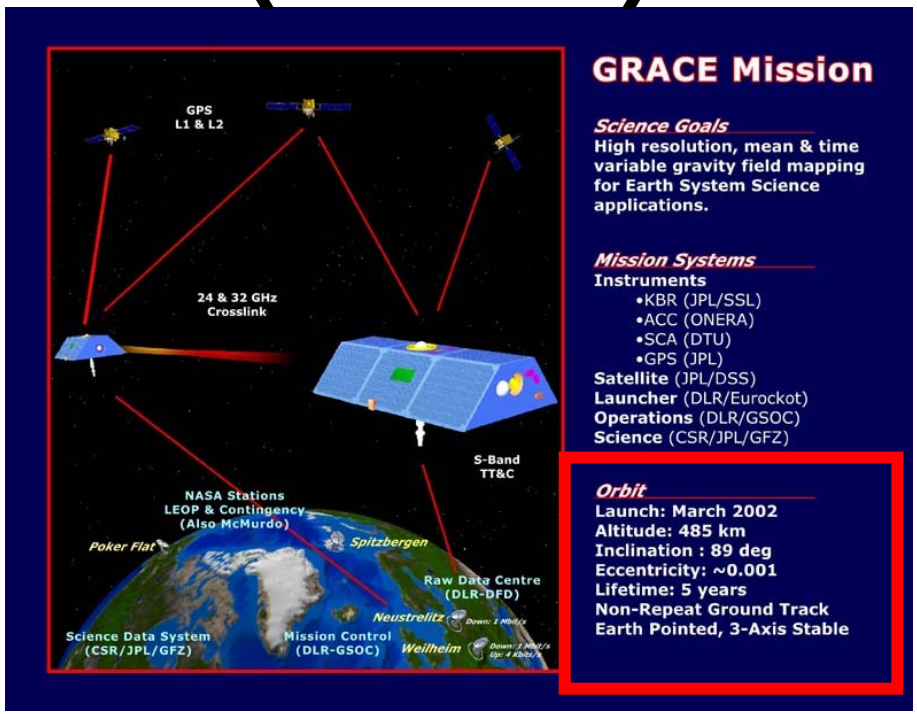
http://igrac.nitg.tno.nl/ggis/start.html

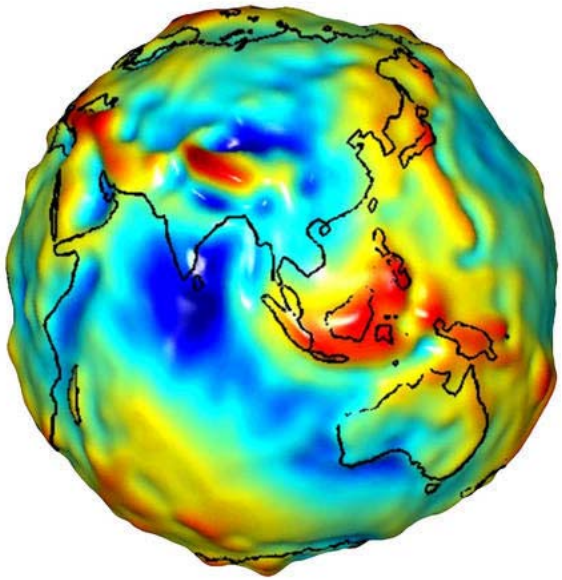
Method 2

Satellite GRACE

Gravity Recovery And Climate Experiment (GRACE)







Changes in gravity field are mainly caused by the changes in water storage on and in the earth including groundwater

High Plains Aquifer

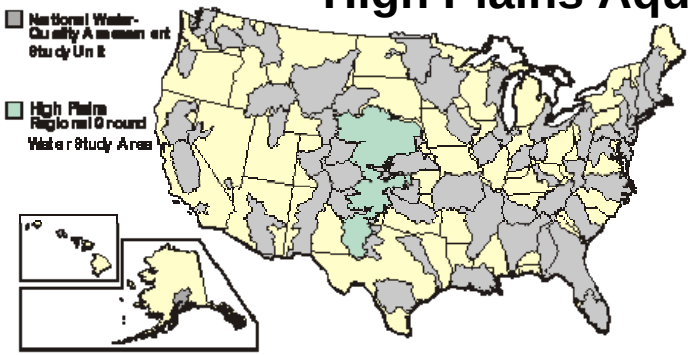
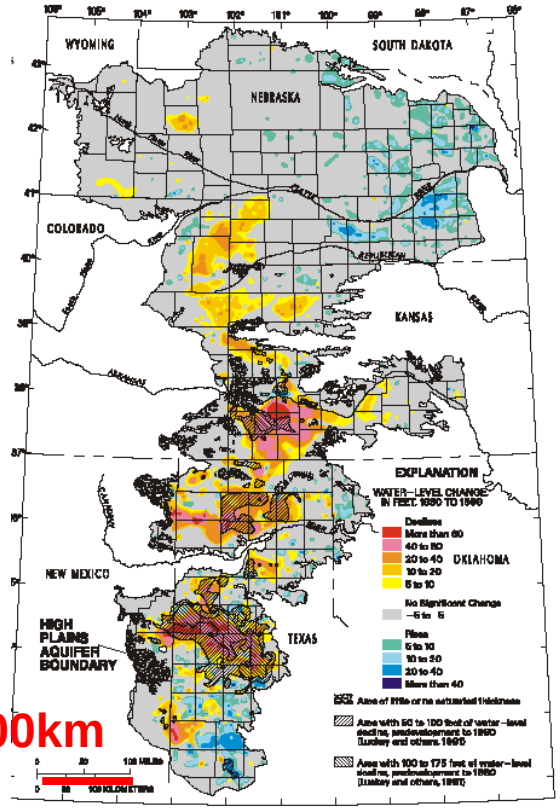


Figure 2. Areal photograph of irrigated cropland overlying the Ogallala Formation, Central High Plains aquifer.



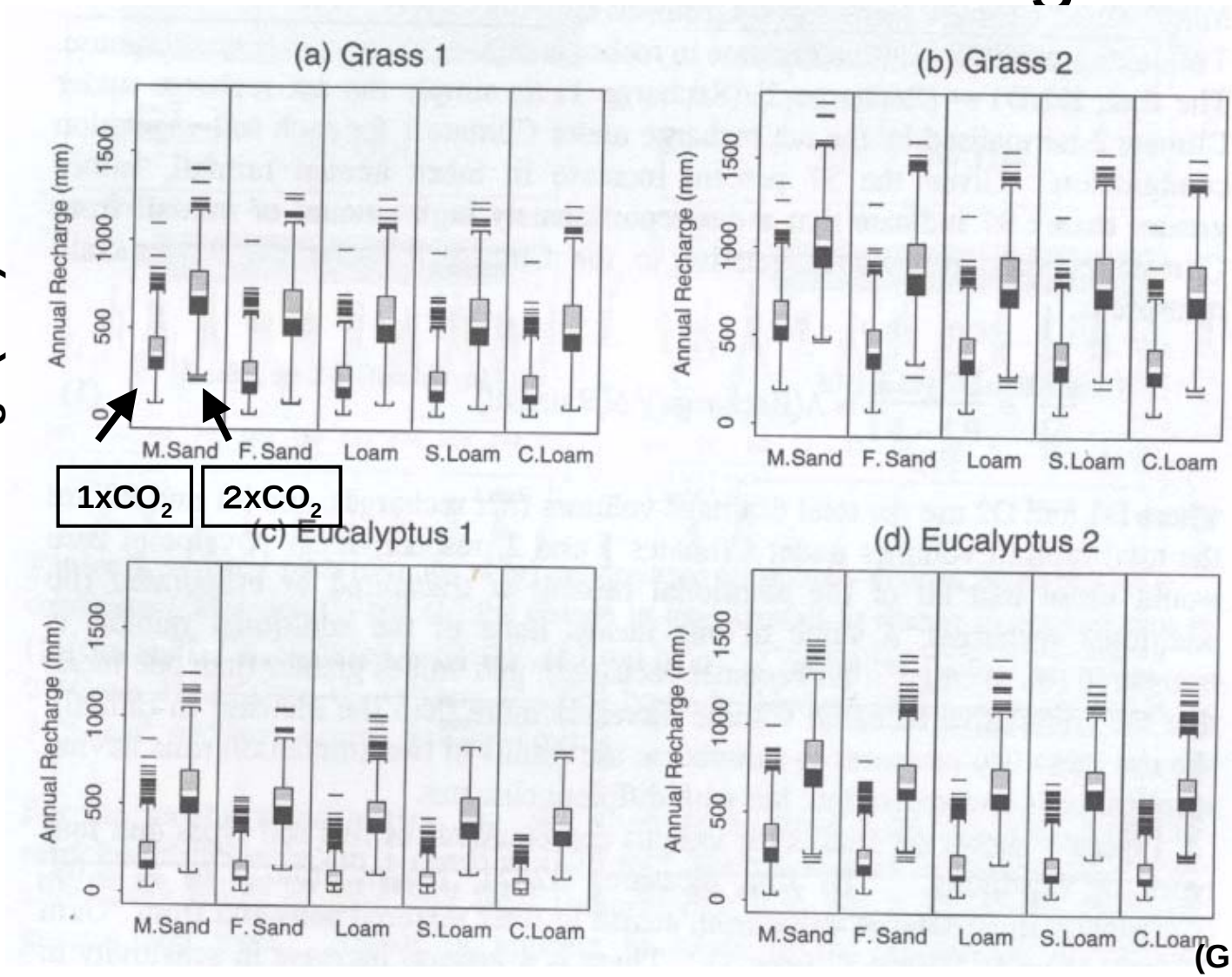
1980-1999 (Alley et al, 1999)

- Decreases in groundwater level by -19.8 mm/y ± 8.7 mm/y in High Plain Aquifer are detectable by **GRACE** (Rodel and Famiglietti, 2002)
- Monthly changes in water storage (P-E-R) with the amplitude of 40mm/month±7mm/month at Amazon basin are detectable by **GRACE**（Famiglietti and Rodel, 2003)

Method 3

Modeling and simulation

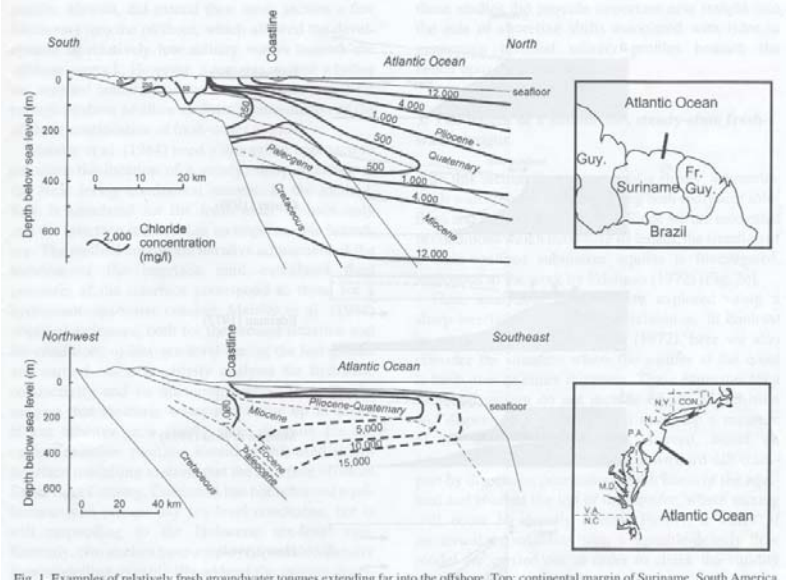
Groundwater recharge

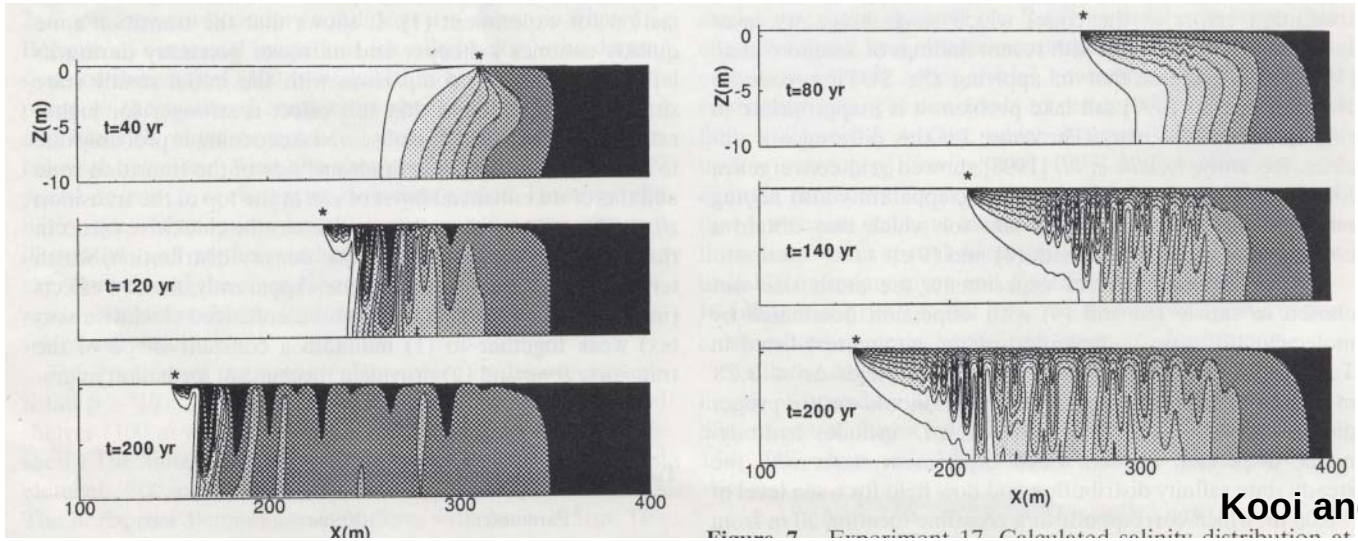


(Green et al., 1997)

Double CO_2 causes increases in groundwater recharge rates

Groundwater discharge

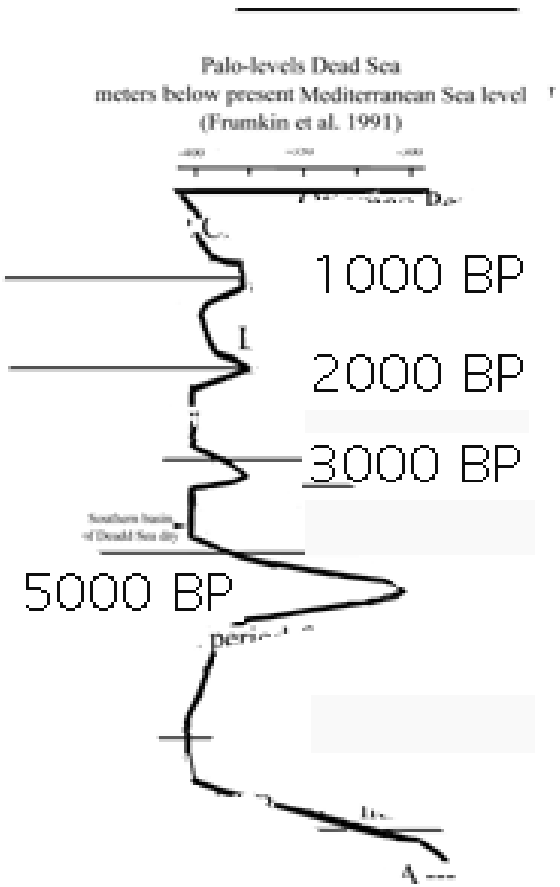




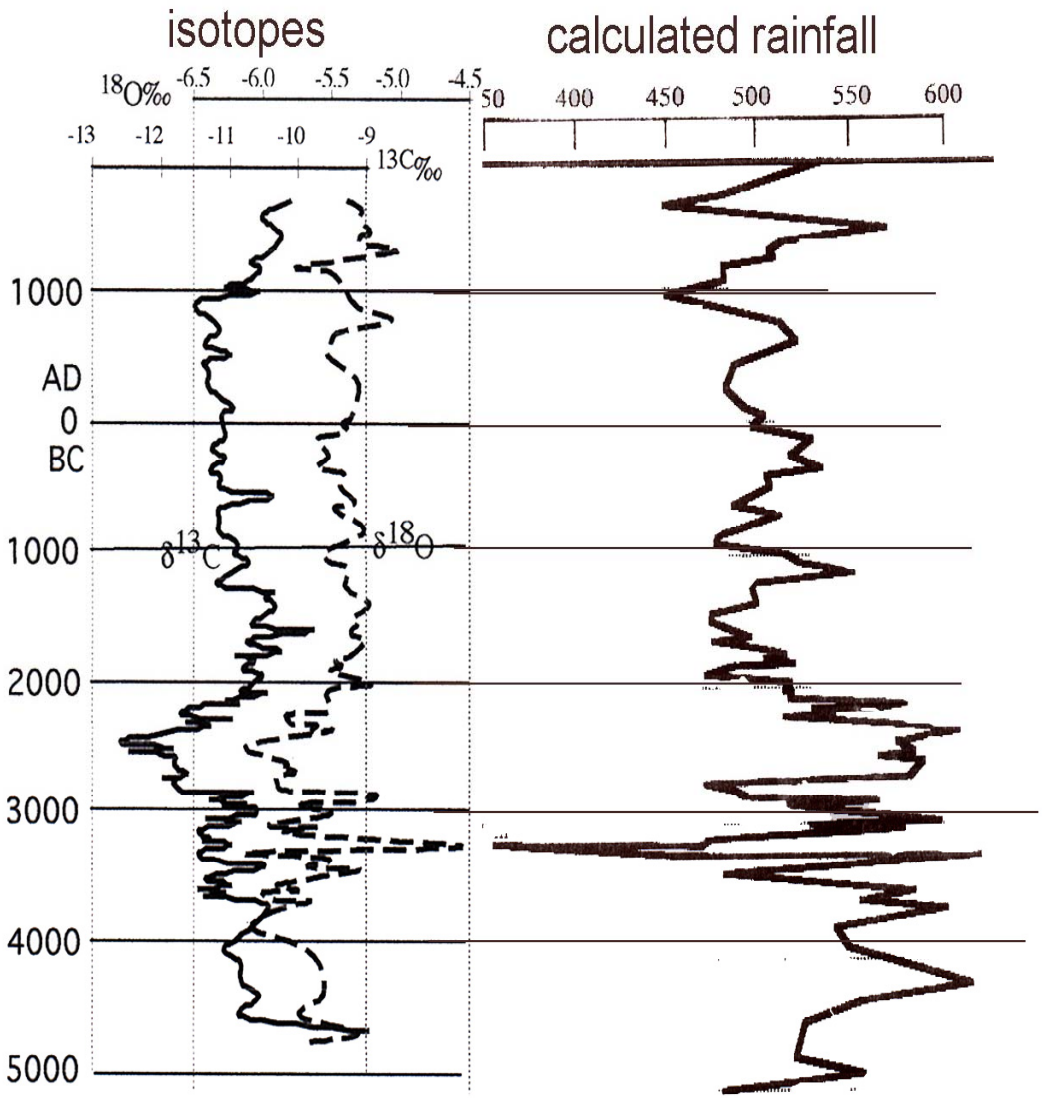
Kooi and Groen, 2000

Fresh groundwater under the seabed in the coastal zone (which was discharged during ice age) can be simulated

Method 4
Paleohydrology



- Levels of the Dead Sea during the last 5000 years, as could be deciphered from ancient sea levels in the caves in the salt plug of Mount Sedom



A. Issar

- **The first GRAPHIC meeting** was held at UNESCO-Paris on Mar. 2004

  Core members: **M. Taniguchi (Chair, RIHN**), A. Aureli (UNESCO-IHP), Jac van der Gun (IGRAC), T. Green (USDA), A. Issar (Ben Gurion Univ.), H. Kooi (Vrije Universiteit), O. Varis (U. Helsinki), J. Famiglietti (UC Irvine), G.Ramillien (Wanadoo)

- **The second GRAPHIC meeting will be held in England on Apr. 3-5, 2005**

- **Other related meeting**

  AGU(SF) Dec, 2004; GRAPHIC Session H21F

  IWRA, Nov 2005

***GRAPHIC*: Cooperation with research organizations and groups**

- **UNESCO/IHP** http://www.unesco.org/water/ihp/
- **IGRAC** http://igrac.nitg.tno.nl/homepage.html
- **WMO** http://www.wmo.ch/index-en.html
- **GWSP** (Global Water System Project) http://www.gwsp.org/
- **IAH** (International Association of Hydrogeology), Commission on “Hydrogeology and Climate changes” http://www.iah.org/
- **IAHS** (International Association of Hydrological Sciences), International commission on groundwater http://host.uniroma3.it/associazioni/iahs_icgw/
- **CUAHSI** (Consortium of Universities for the Advancement of Hydrologic Sciences, Inc.) http://www.CUAHSI.org/