GLOBAL WATER ISSUES

A Challenge for Earth System Science and Technology

Charles J. Vörösmarty and many colleagues
from CCNY and UNH

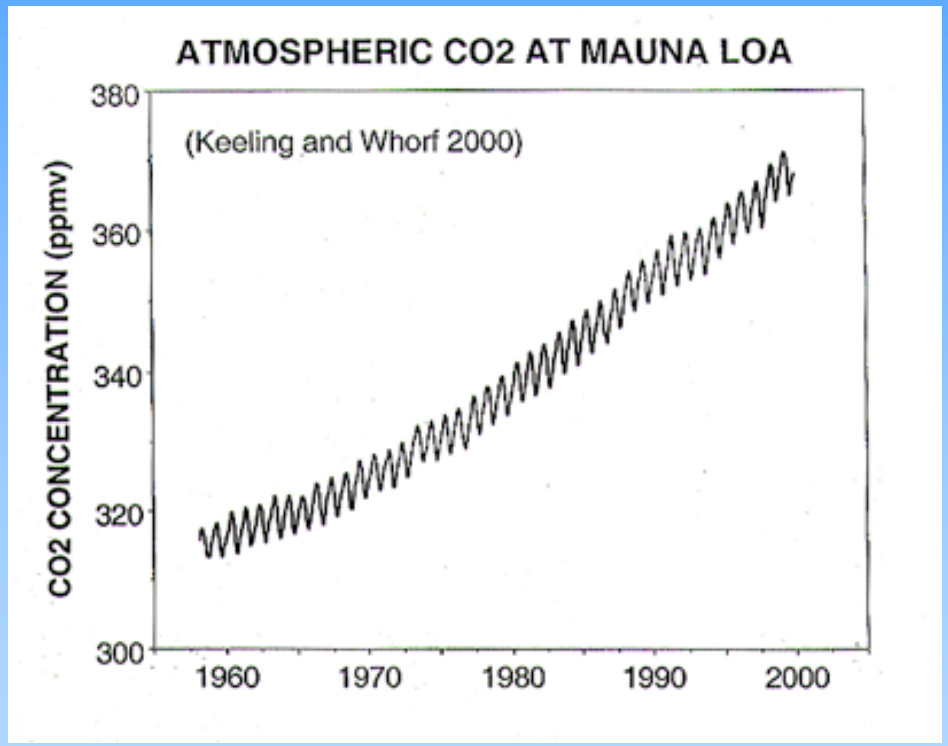
the City College of New York | CUNY The City University of New York

Water Resources in Developing Countries

ICTP, Trieste ITALY ***10 May 2009***

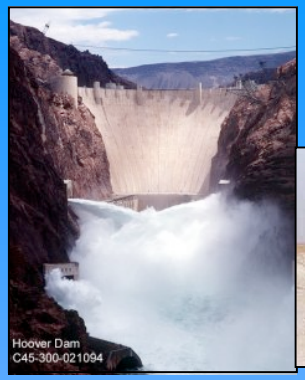
For the Global Climate Challenge

A Scientific Data Set That Has Mobilized the Politics of a Planet



Water as Friend and Foe

Sanitation and access to clean water



"Engineered" water

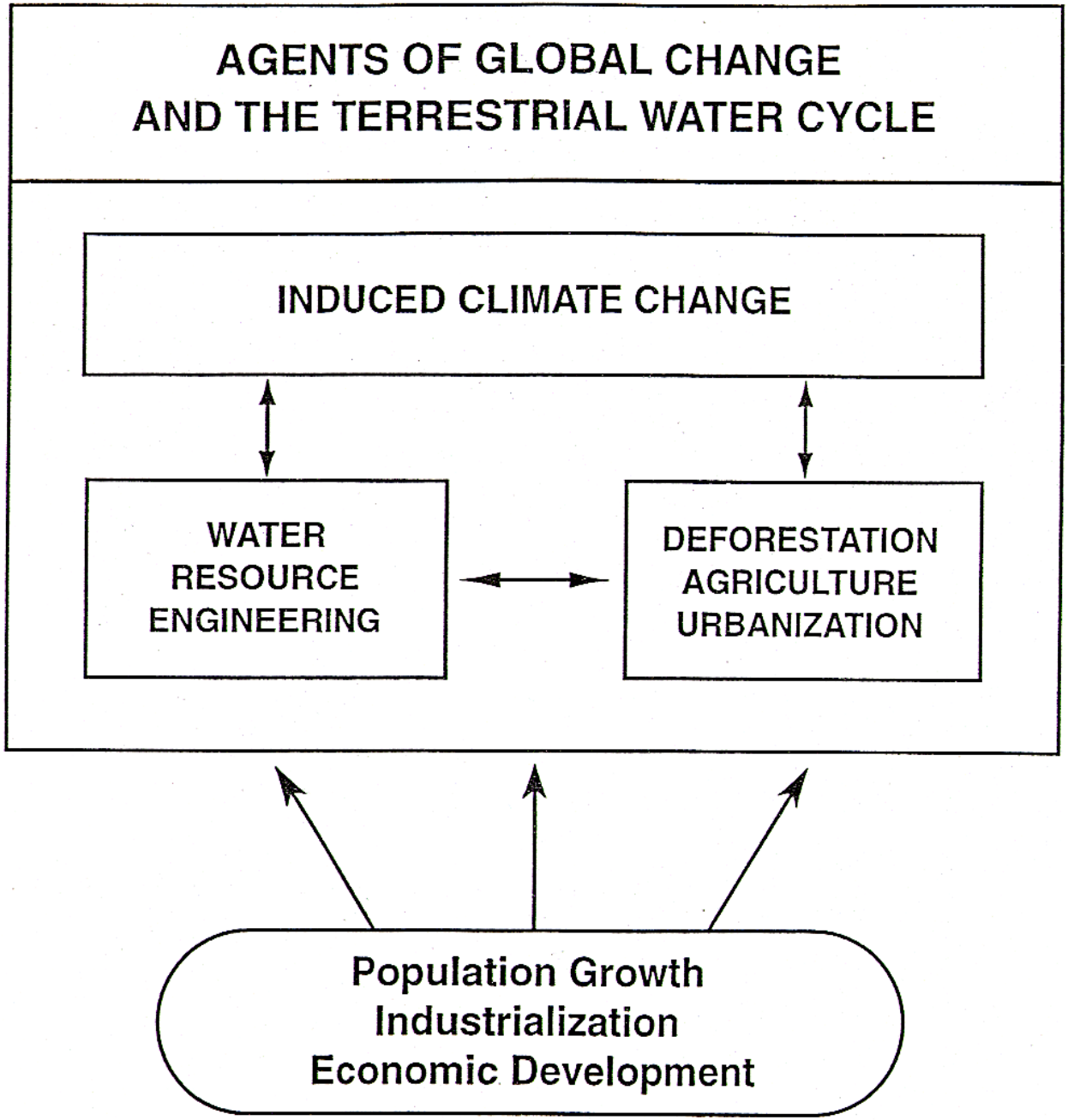
Water for development

Food security

Weather extremes

Maintaining aquatic ecosystem services

Pollution



State-of-the-Global Water System

- In the broadest sense…..

"Global Climate Δ"

≠

"Global Change"

Roadmap for This Talk

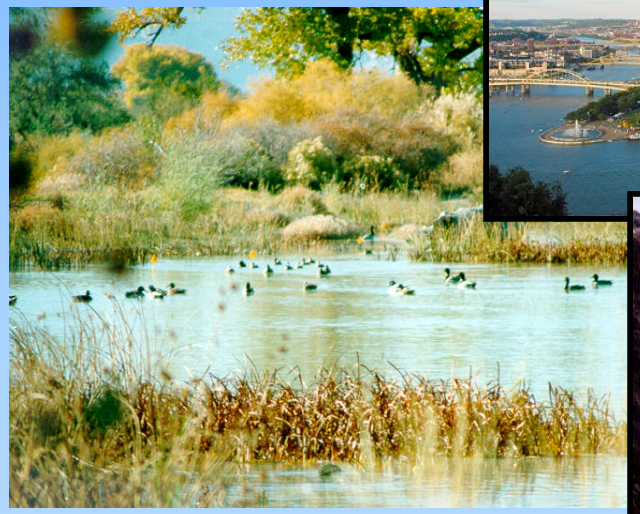
- The Nature of the Beast
  - What Are the Key Challenges?
  - How the Challenges Are Organized?
  - What Perspectives Are Needed to Address the Challenges…*today and into the future* ?

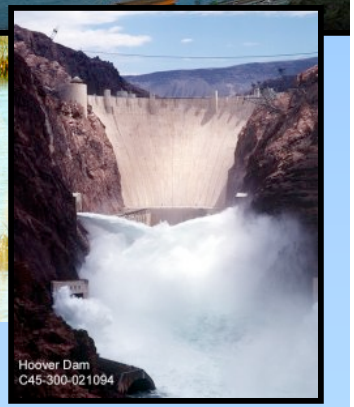
Major feature in the modern water system

Asymmetries between:

- Upstream/Downstream Users

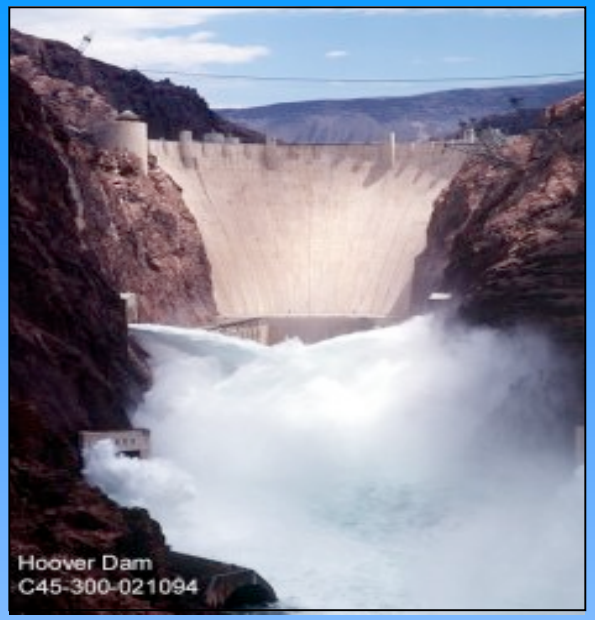
- Humans and Nature





...and both stressed by pollution, watershed mismanagement, poor engineering, biotic threats

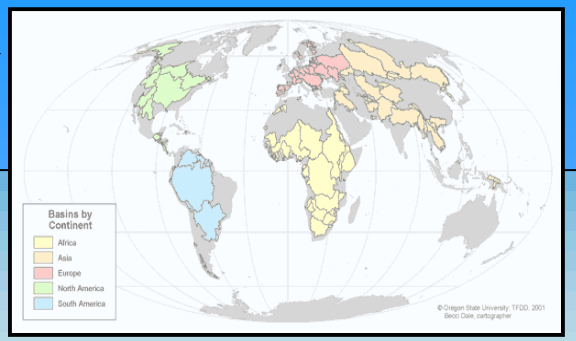
More People, More Development, Means More Water Engineering to Help Manage Asymmetries



- Widespread Hydrological Alterations Arising from
  - *Irrigation*
  - *Dams and Reservoirs*
  - *Interbasin Transfer/Flow Diversion*
- Benefits & Concerns
- Often These are Costly Supply-side Solutions

ASYMMETRIES IN WATER SUPPLY & USE DRIVE SOME OF THE CRISIS

261 Int'l Basins → *Source of conflict or* ***cooperation****?*



Water withdrawal and availability in the Aral Sea basin

Flow generation: water available in the country from rainfall and glacier melt

Water abstraction: withdrawal from surface water sources (rivers, canals and lakes)

Metres
3 000
2 000
1 000
500
200
0

km³ per year
60
50
40
30
20
10
0

UZBEKISTAN
TAJIKISTAN
KYRGYZSTAN
TURKMENISTAN
KAZAKHSTAN
RUSSIA
RUSSIA
ARAL SEA
LAKE BALKHASH
Syr-Darya
Amu-Darya
CASPIAN SEA
IRAN
AFGHANISTAN
PAKISTAN
CHINA

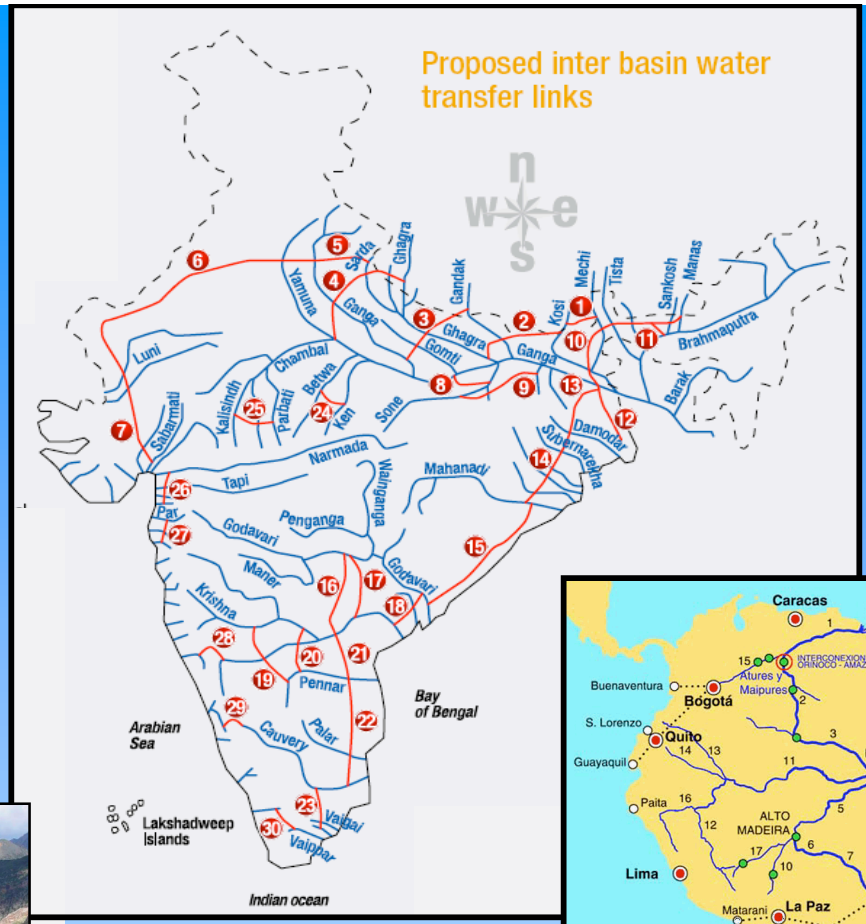
0 200 400 600 km

Source: Diagnostic Report on Water Resources in Central Asia, ICWC 2000.

MAP BY VIKTOR NOVIKOV AND PHILIPPE REKACEWICZ - UNEP/GRID-ARENDAL - APRIL 2005

Physical Re-Connection: Inter-Basin Transfers & Flow Diversions

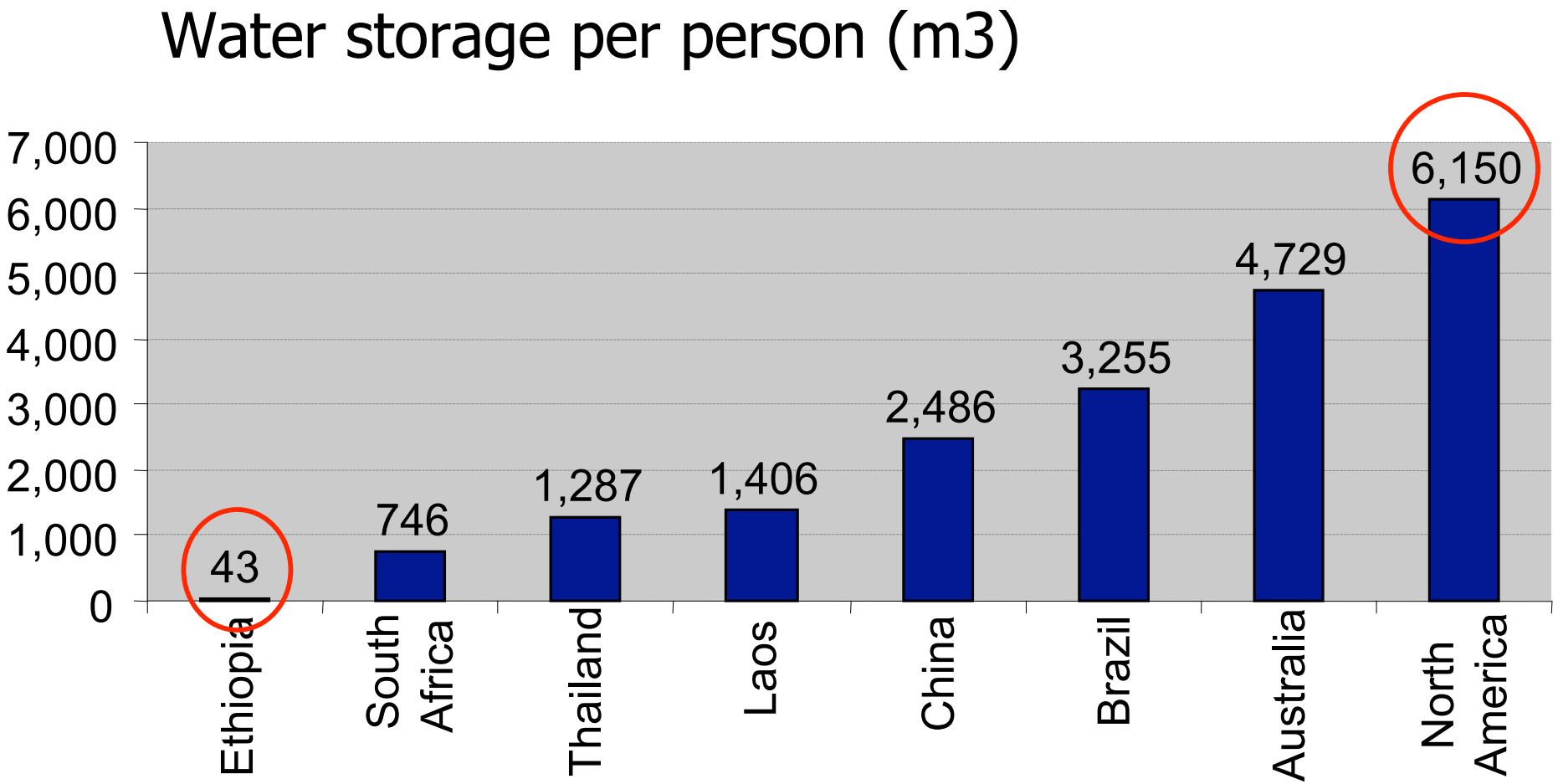
- Costly 'hard path'
- Engrain patterns of overuse
- Creates an asymmetry on both nature & human systems



Forced by food security issues

35,000 km of hydrovias…. direct links to globalization & food trade

Asymmetries in the Capacity to Control the Resource
Infrastructure gap: Reservoir water storage



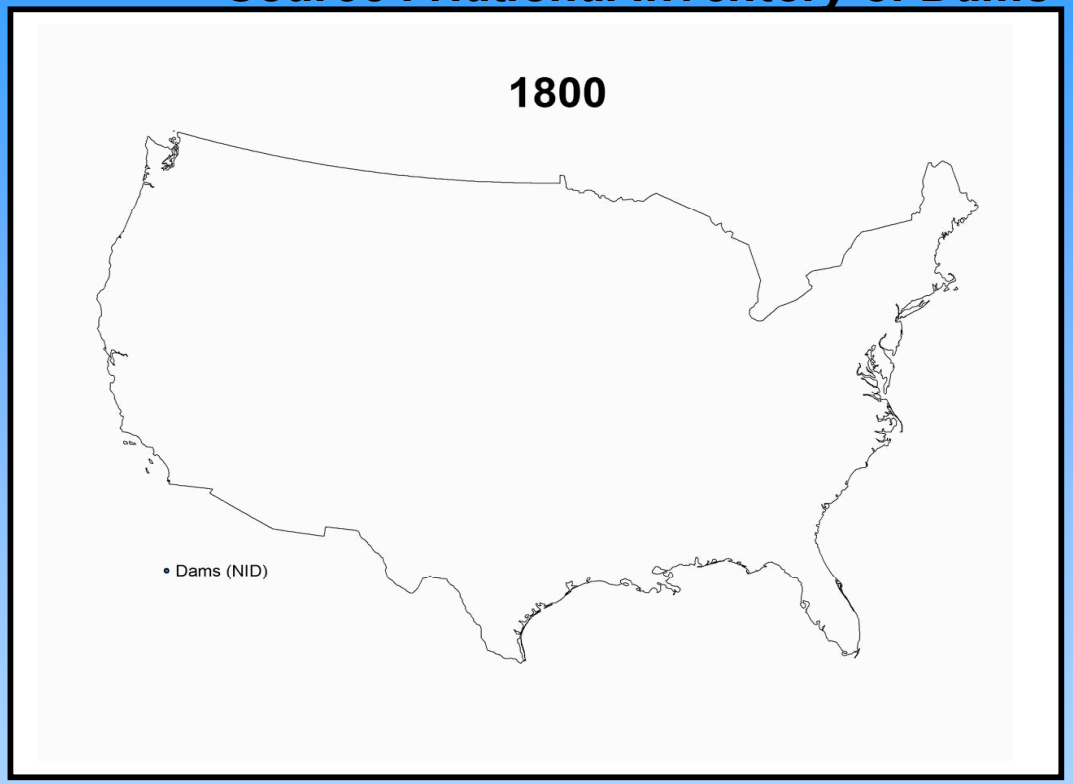
Trapping Water in Dams: *A hedge against space and time asymmetries*

17th - 19th Centuries

20th Century

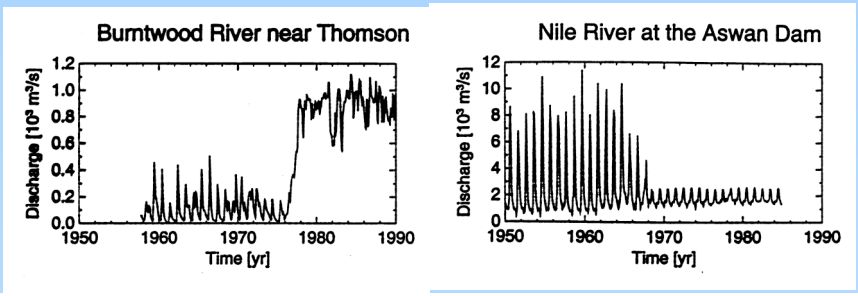
Changing Nature Of Water Engineering

Source : National Inventory of Dams



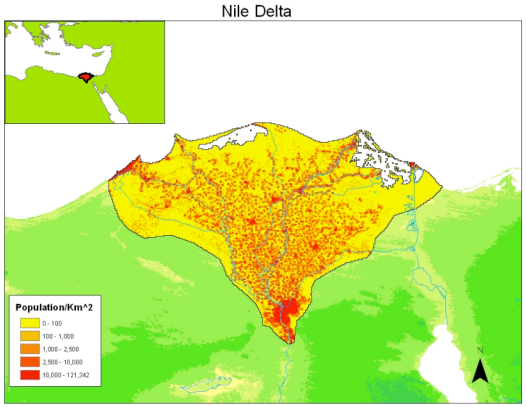
…emblematic of water development globally

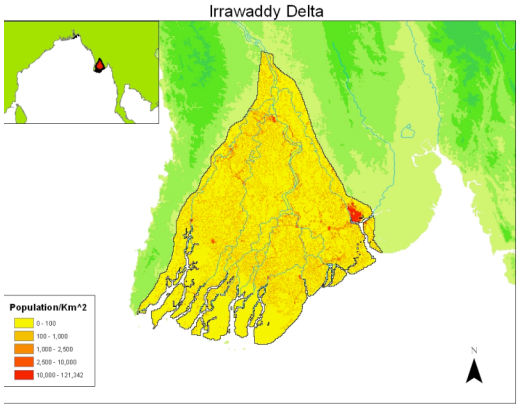
"Instant" control thru "instant" hydrograph distortion



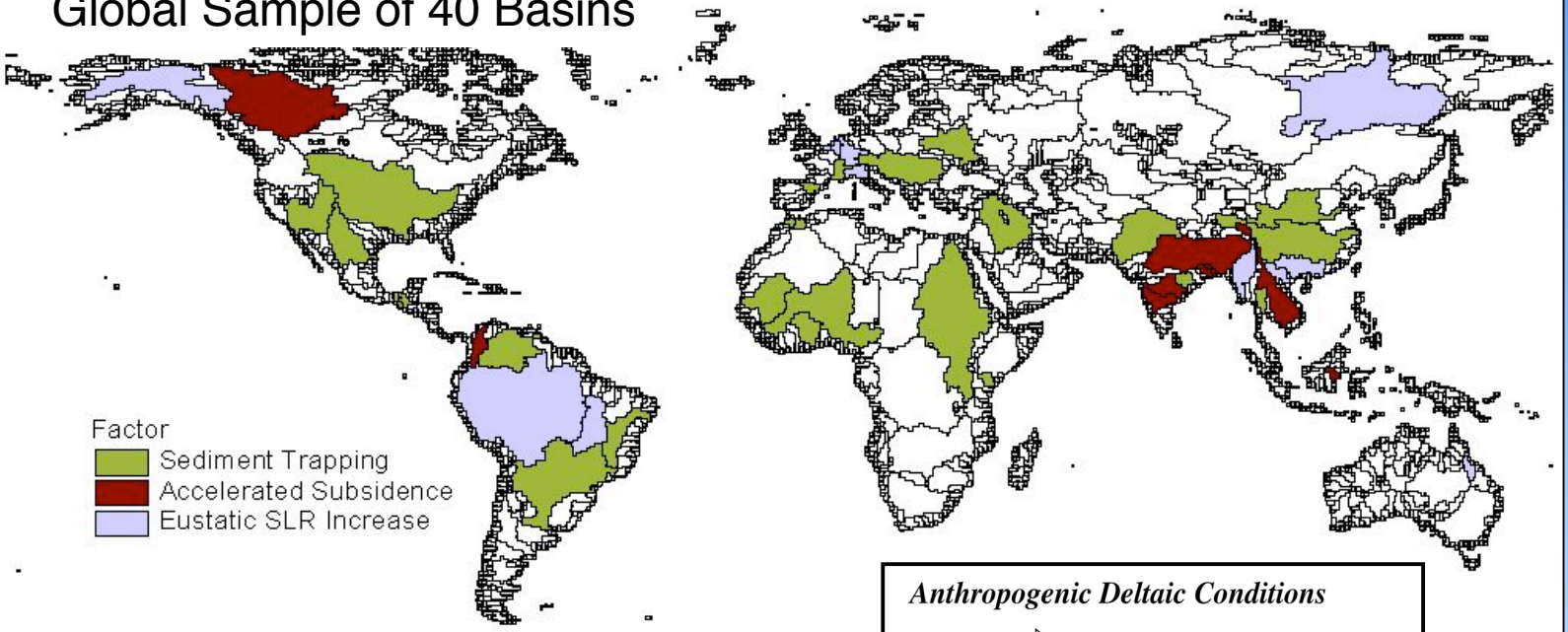
Deltas Under Threat

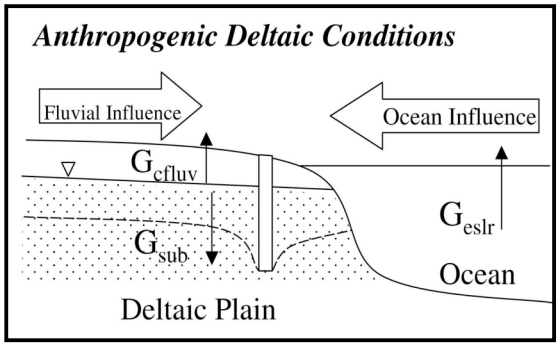
Basin Water Management Reverberates to Coastlines: *Eustatic/Steric Sea Level Rise Only Part of the Story*





Global Sample of 40 Basins





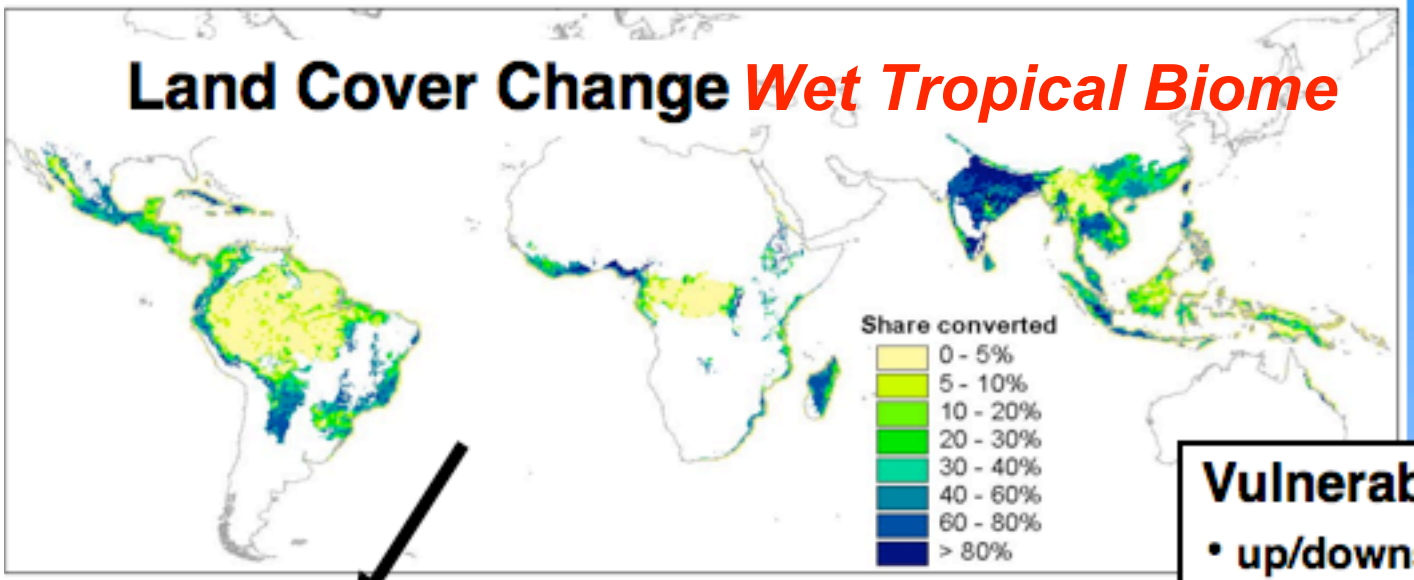
Sources of Change:

-- 5 Global Sea Level Rise
-- 8 Groundwater/petroleum extraction
-- 27 Upstream sediment trapping & diversion

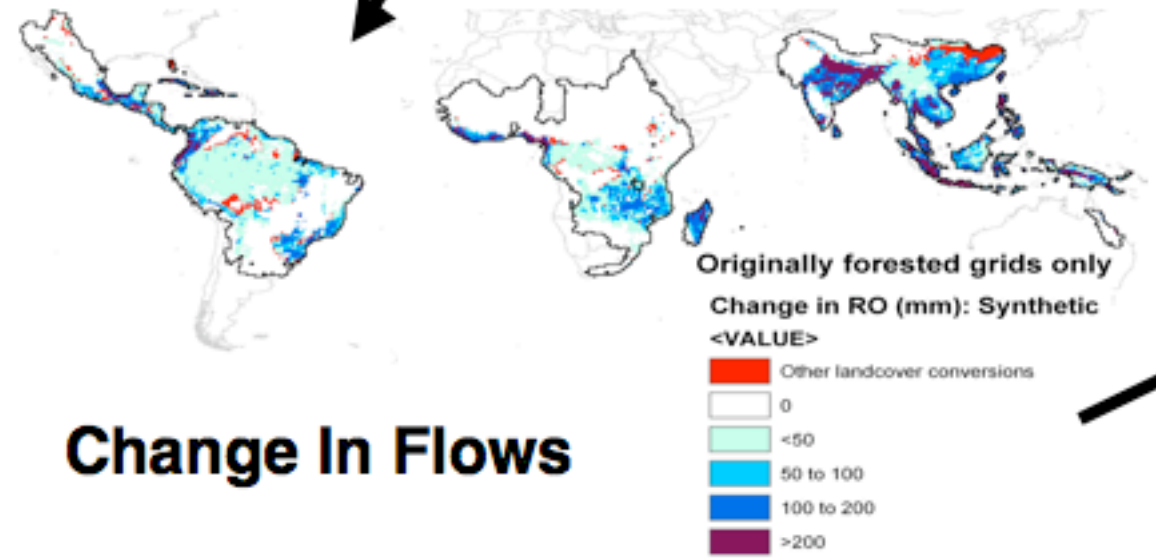
~0.5 Billion People Live on Deltas Worldwide

Ericson et al., 2006, *Global and Planetary Change;* Vörösmarty et al., 2009, *Bull. Atomic Scientists*

LANDSCAPE MANAGEMENT MATTERS
Upstream-Downstream Asymmetries



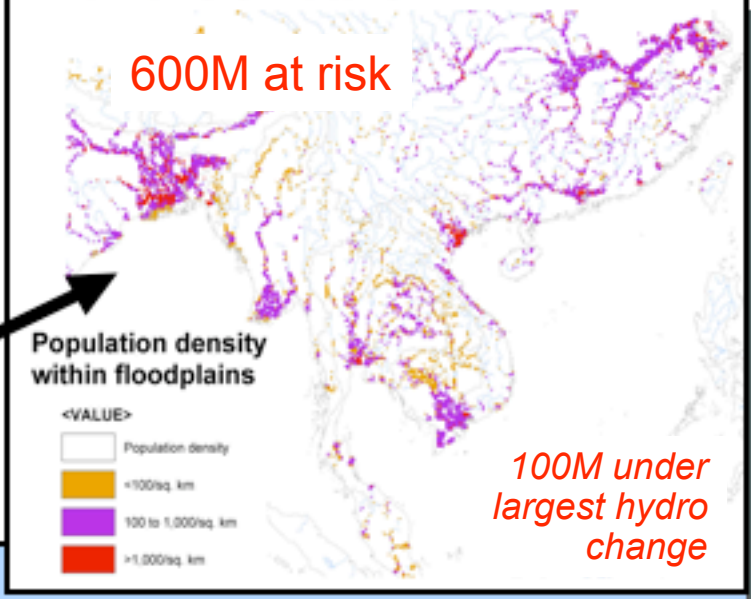
NEW CLASSES OF "teleconnections"



Change In Flows

Vulnerability Translated

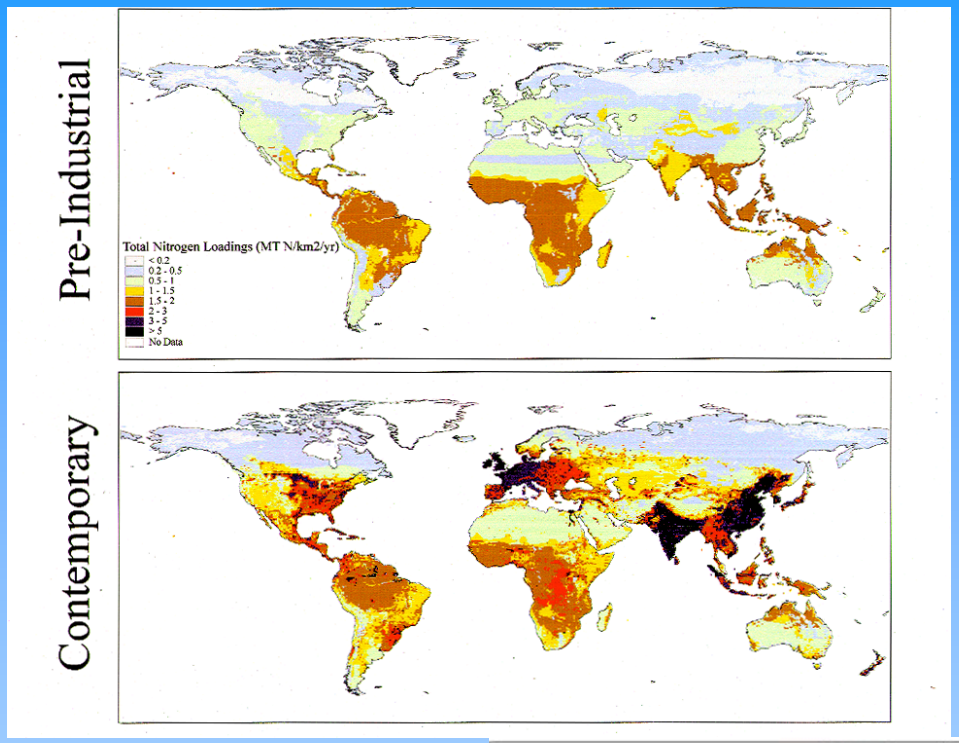
- **up/downstream stakeholders**
- **humans & nature**

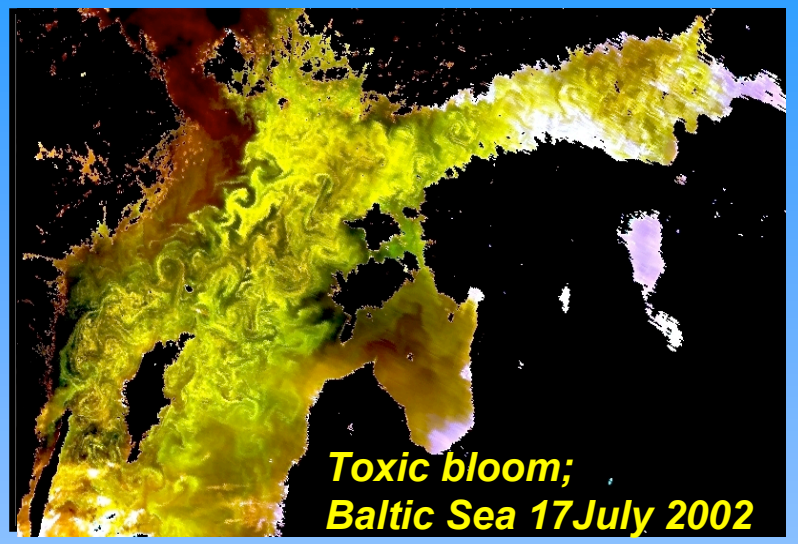


100M under largest hydro change

Douglas et al. 2007, WRM

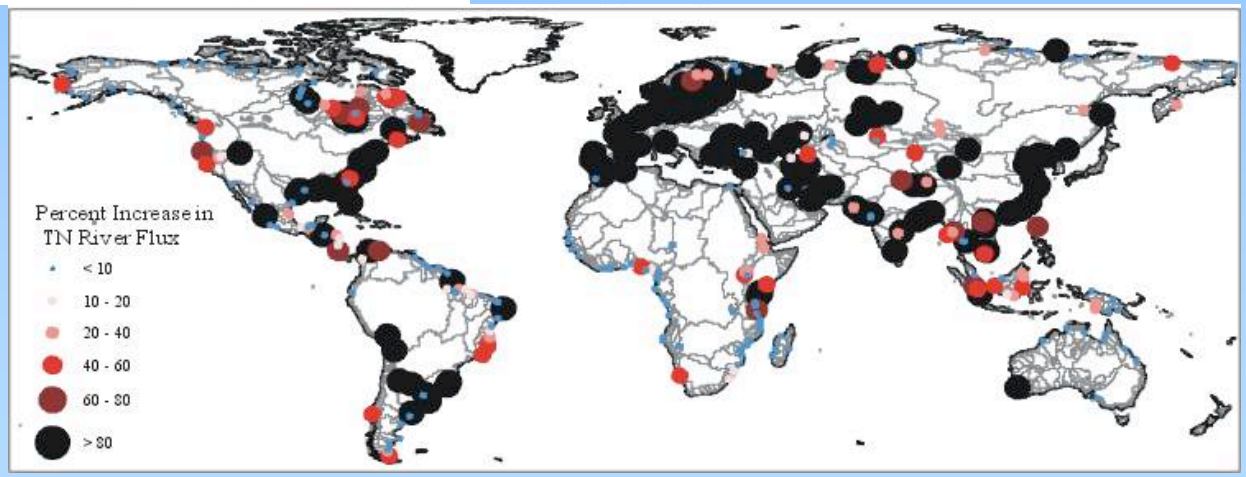
Chemical Asymmetry: Doubling of Global Nitrogen Pollution





Terrestrial Loading

% Change in River Fluxes

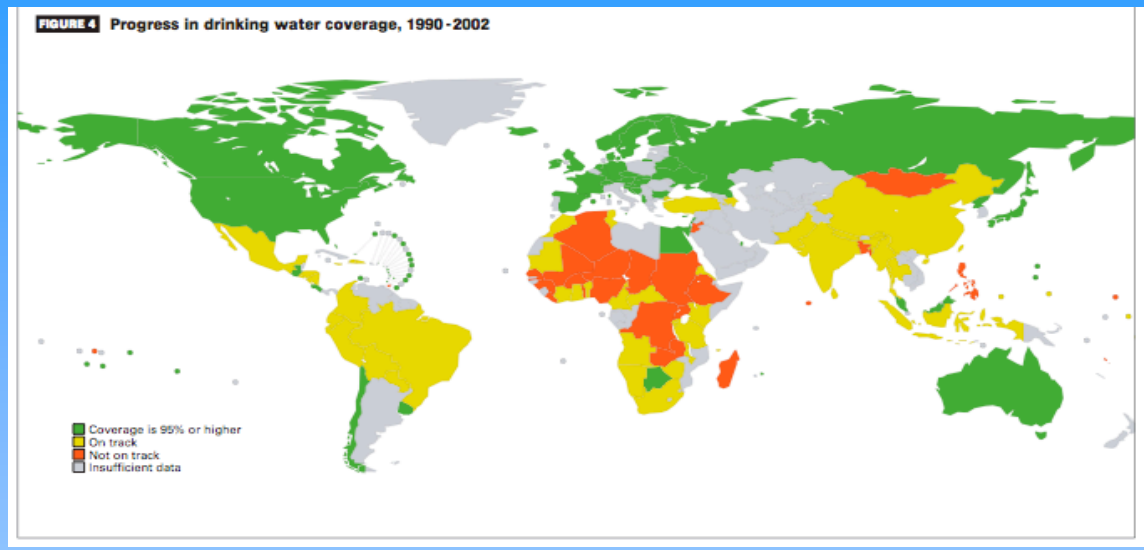


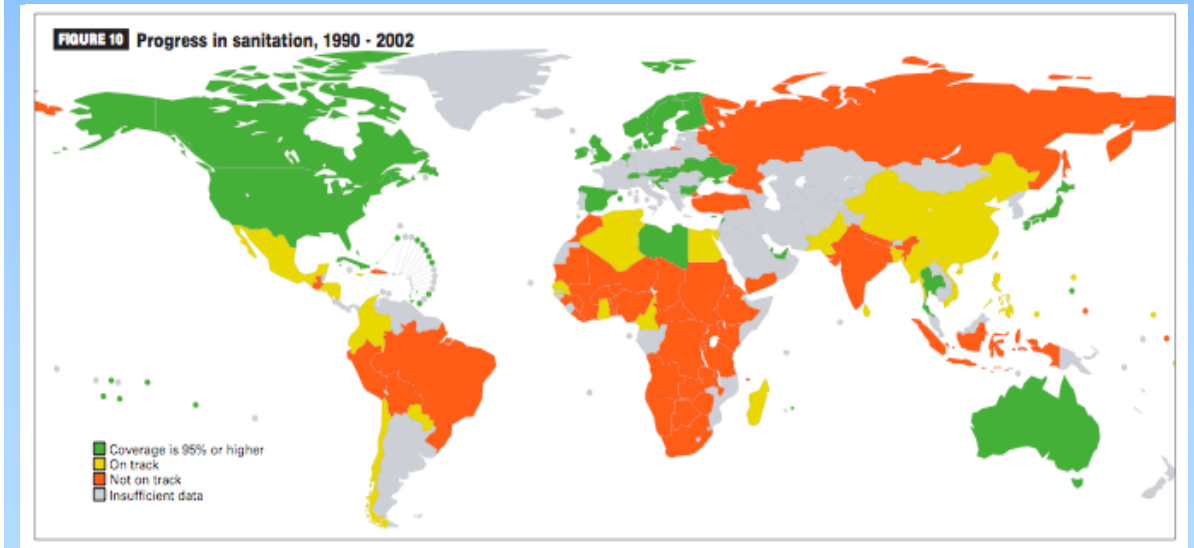
Green et al. 2004; Biogeochemisty

Asymmetry in Basic Provision of Clean Water & Sanitation:
A Millennium Development Imperative & Destabilizing Force

1.1 billion people lack clean drinking water

2.6 billion people lack basic sanitation





- 1.7M deaths from water-related diarrheal disease
- $100B? globally from health costs and decreased productivity
- Political not technical failure..no esoteric technology needed

WHO/UNICEF 2004

GLOBAL WATER ISSUES IN THE 21st CENTURY

The Future is Not What It Used to Be

Charles J. Vörösmarty, the Water Systems Analysis Group & many others

AAAS
ADVANCING SCIENCE, SERVING SOCIETY

Water Resources in Developing Countries

ICTP, Trieste ITALY 10 May 2009

Managing 21st Century Water

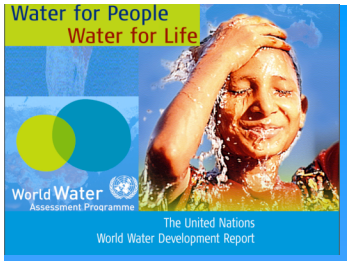
The Future is Not What It Used to Be

Charles J. Vörösmarty[1] for András Szöllösi-Nagy[2]

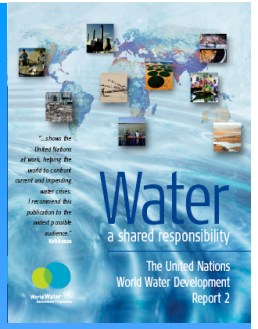
Environmental Cross-Roads Initiative

[1] City College of New York
City University of New York

[2] UNESCO International Hydrological Programme
and World Water Assessment Programme

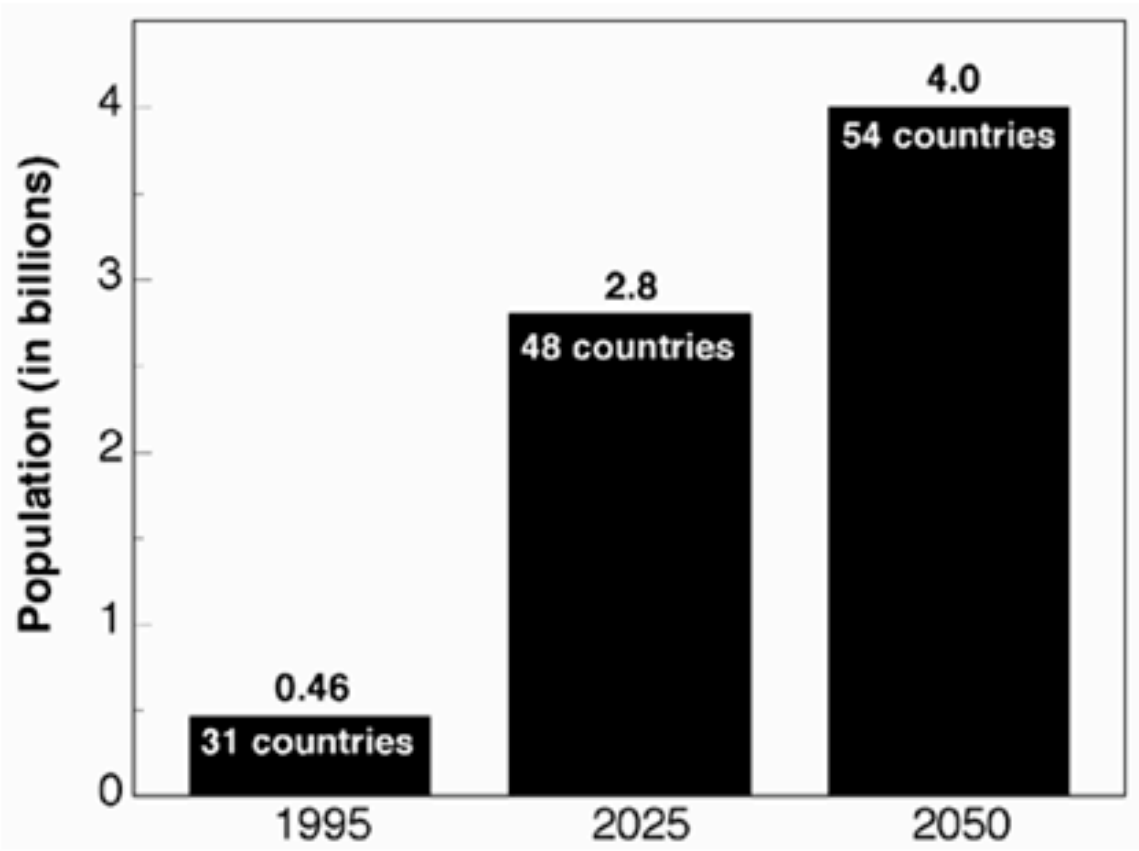


Water Crisis



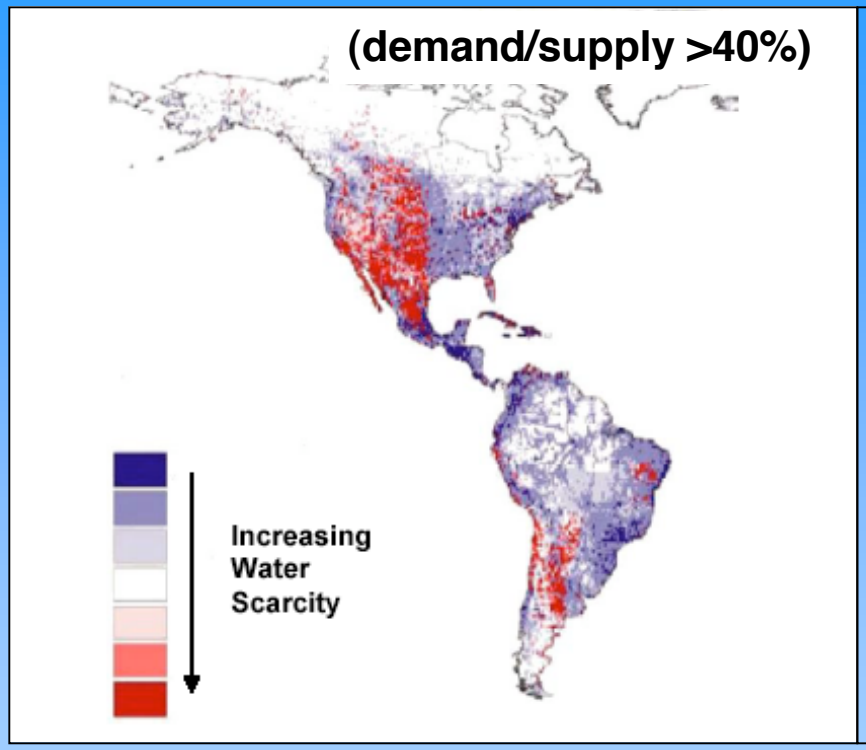
- WWDR1 and WWDR2 highlighted the fact that **we are in the midst of a water crisis, that will continue**

Sharp increase of population in water scarce and water stressed countries



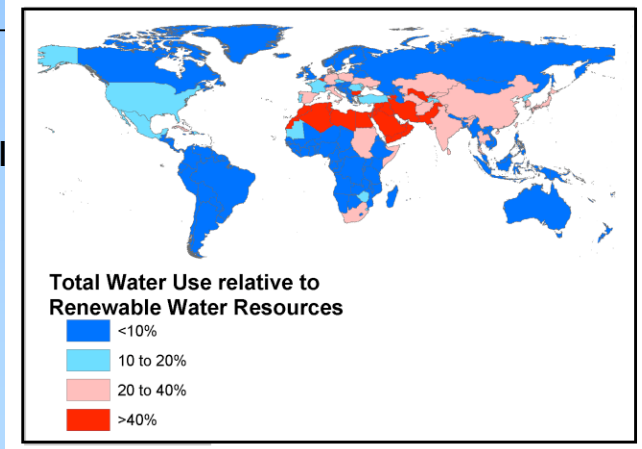
New Geospatial Approaches Raise Estimates of Scarcity

Contemporary and Future Population under High Water Stress



- Number highly sensitive to accounting unit
- Grid-based (30' lat/long) estimates (n > 60,000) capture spatial variability & show much higher numbers than country-level statistics (n ≈ 200)

		Total Population (billions)		
		Country-level		Grid-based
Water Stress	DIA/Q (unitless)	U.N.	Grid Sum	Full Resolution
Low	*<0.1*	1.72	1.95	3.16
Moderate	*0.1 to 0.2*	2.08	1.73	0.38
Med-high	*0.2 to 0.4*	1.44	1.54	0.37
High	*>0.4*	0.46	0.45	1.76



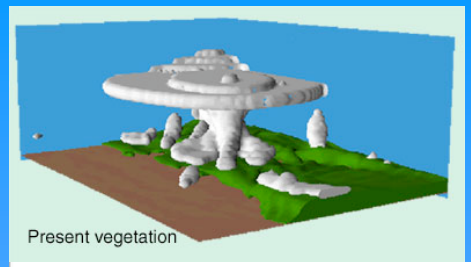
Vorosmarty et al. 2000

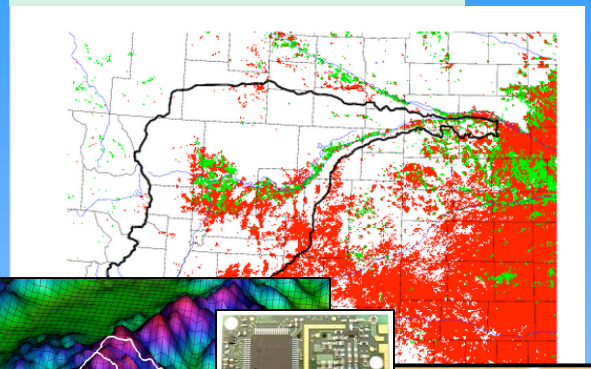
Contributions from Earth System Science

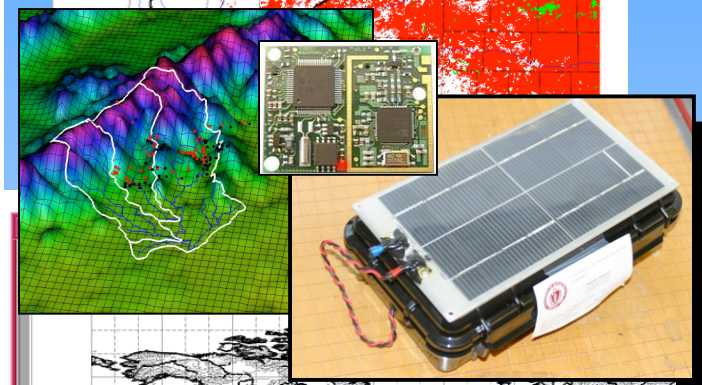
- Augmenting *in situ* networks in severe decline
- Operational satellite-based monitoring of the hydrosphere
- Simulation models and data analysis tools (NWP-4DDA, GCMs, RCMs, ESMs)
- Geo-referenced social science data

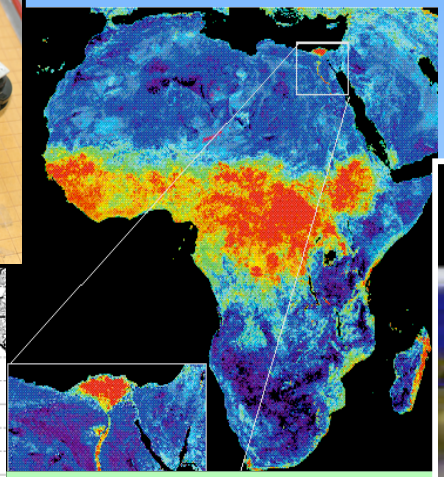
…are creating new ways to view the "global water crisis"

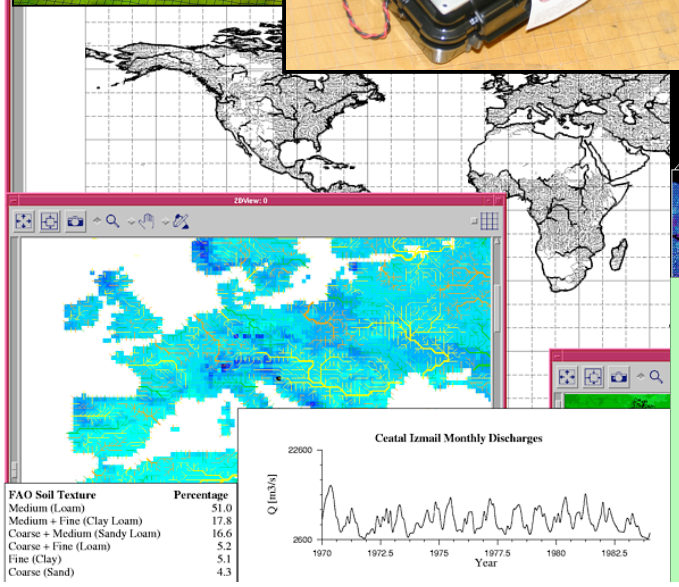
…to inform policy and improve management

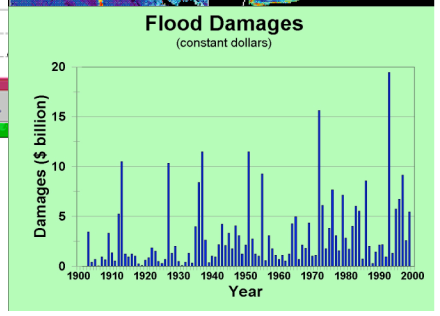


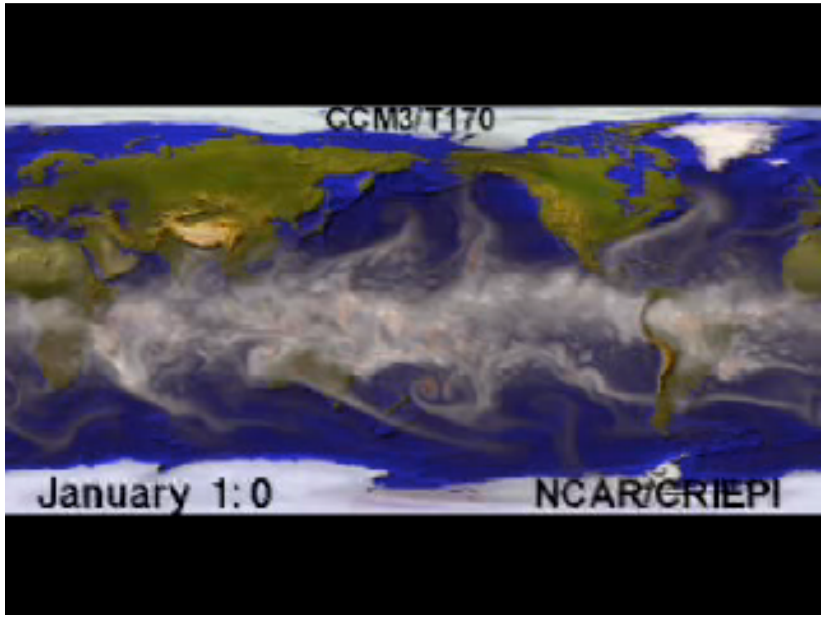




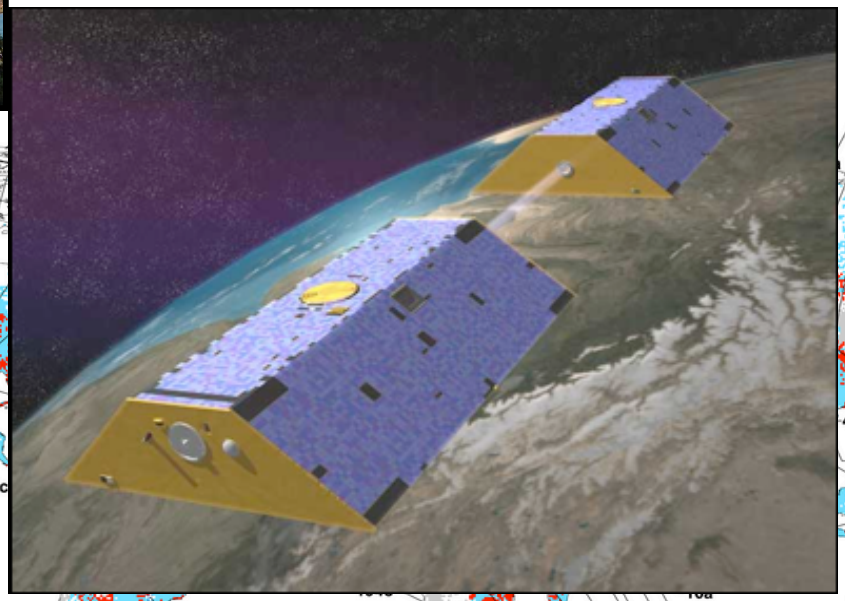




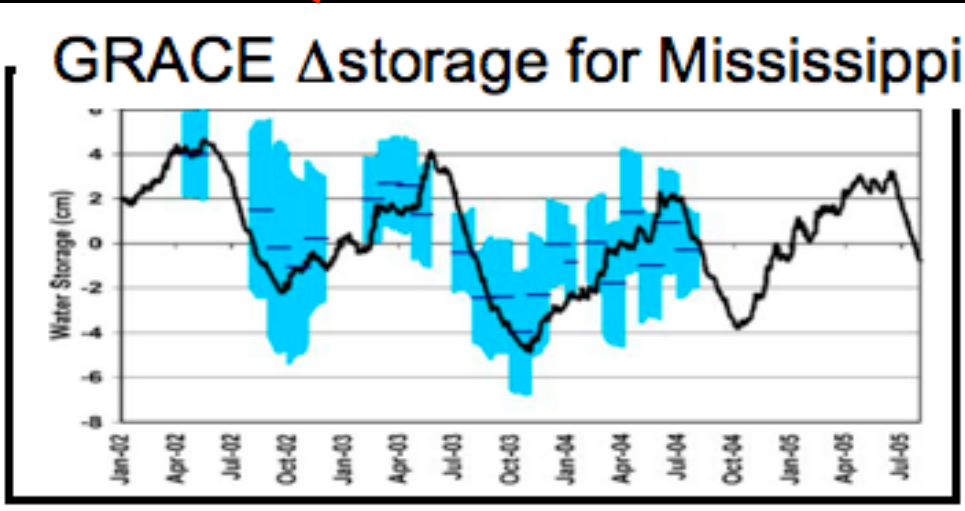


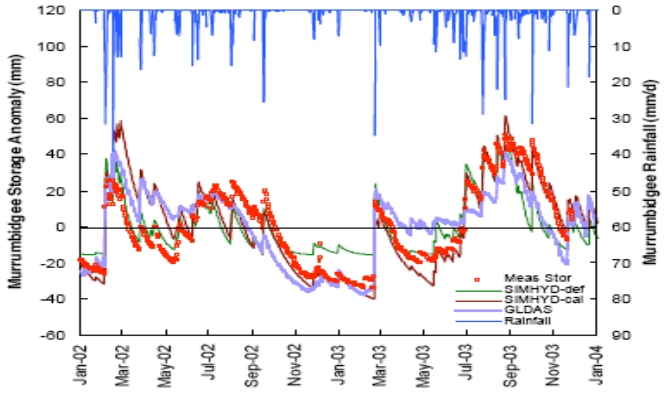


Irrigation & Urban Water Use in Excess of Sustainable Supplies

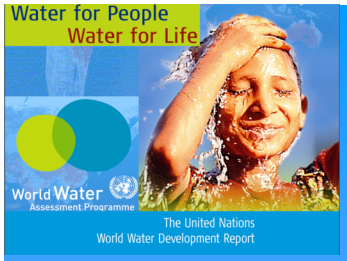


Documentary evidence and simulations now converging

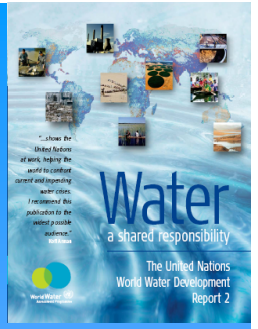




Tributary of Murray River: Ellett et al. 2005 MODSIM



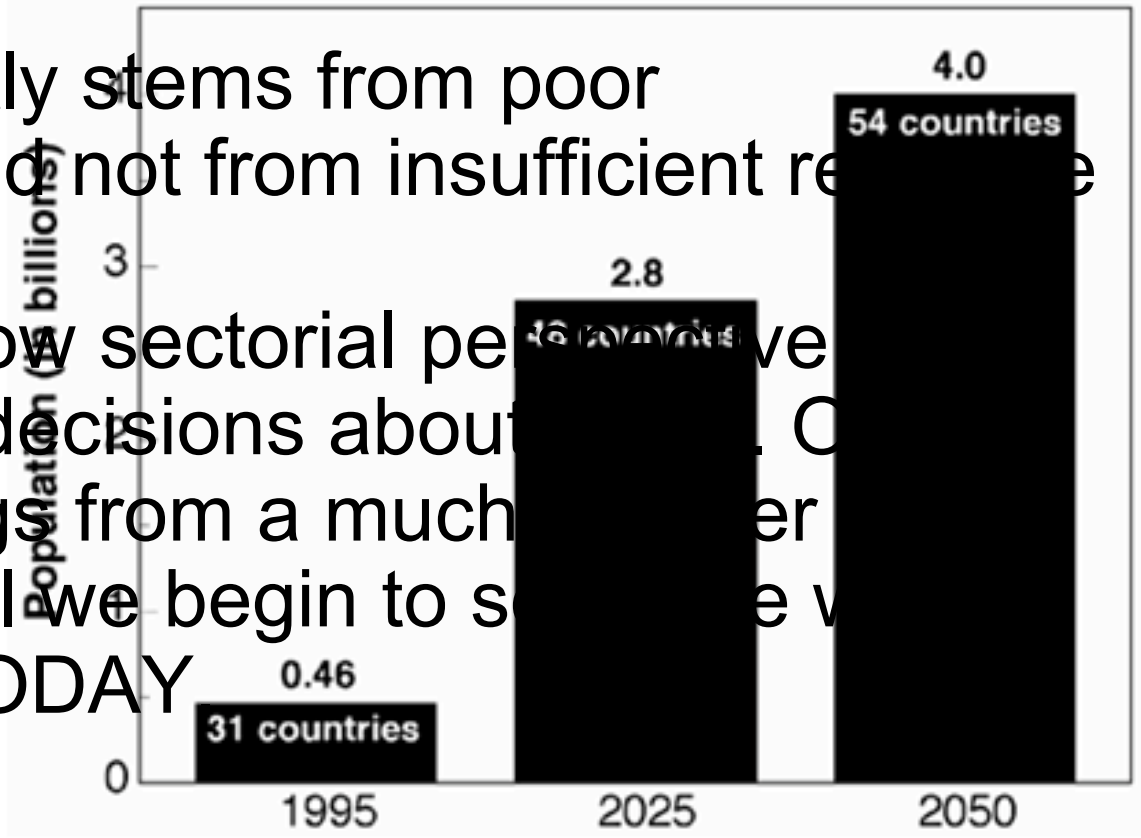
Water Crisis



- WWDR1 and WWDR2 highlighted the fact that **<u>we are in the midst of a water crisis, that will continue</u>**

Share
increase of
population in
water scarce
and water
stressed
countries

- The crisis mostly stems from poor governance and not from insufficient re e
- WWDR3: Narrow sectorial pe ve bfinded many decisions about . C looking at things from a much er perspective will we begin to s e v water crisis, TODAY



In Conclusion

- Nature of the Beast:

  Broad spectrum of global water challenges, linked over space, time, and theme

- Asymmetries abound:

  Upstream/downstream, nature/humans, rich/poor

- Multiple perspectives necessary to understand & formulate sound solutions: *Joint role for biogeosciences, human dimensions, and new technologies & engineering*

Some References

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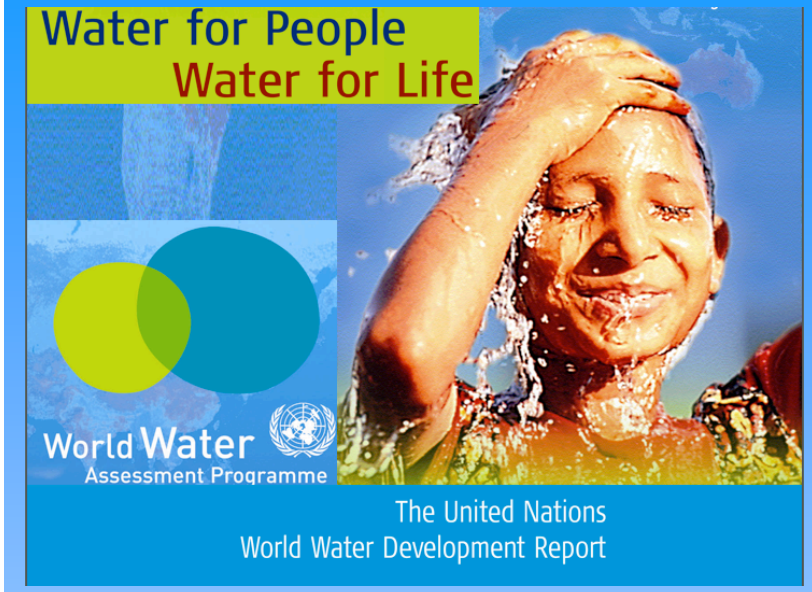
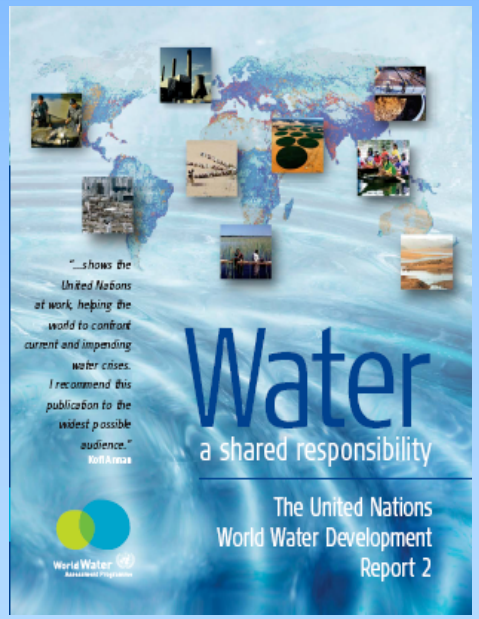
…..and now

….a few *advertisements*





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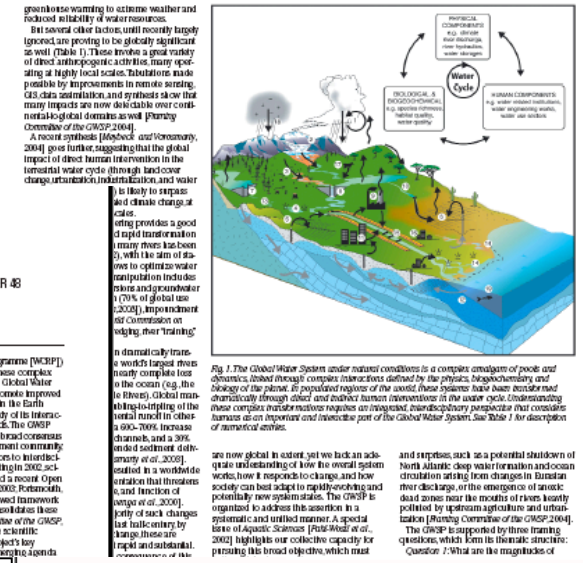
Humans Transforming the Global Water System

PAGES 509, 513–514

Fresh water figures prominently in the machinery of the Earth system and is key to understanding the full scope of global change. Greenhouse warming with a potentially accelerated hydrologic cycle is already a well-articulated science issue, with strong policy implications. A broad array of other anthropogenic factors—widespread land cover change, engineering of river channels, irrigation and other consumptive losses, aquatic habitat disappearance, and pollution—also influences the water system in

aquaculture depend. Domestic, industrial, hydropower, and recreational water use is crucial to a large and growing population that aspires to long-term improvements in well-being. Providing basic sanitation and clean drinking water services remains a major public health challenge. More than 1 billion people are without access to clean drinking water, 2.5 billion are without sanitation, and over 5,000 people, mostly children, die each day from water-related diarrheal diseases [*World Water Assessment Programme*, 2003].

and World Climate Research Programme [WCRP]) has been launched to study these complex issues. The primary aim of the Global Water System Project (GWSP) is to promote improved understanding of fresh water in the Earth system through integrated study of its interactions, feedbacks, and thresholds. The GWSP science agenda emerged from a broad consensus of the water science and assessment community, with more than 200 contributors to interdisciplinary planning meetings starting in 2002, science planning documents, and a recent Open Science Conference (October 2003; Portsmouth, New Hampshire). A peer-reviewed framework and implementation plan consolidates these deliberations [*Steering Committee of the GWSP*, 2004]. This article presents the scientific rationale for the GWSP, the project's key research questions, and an emerging agenda

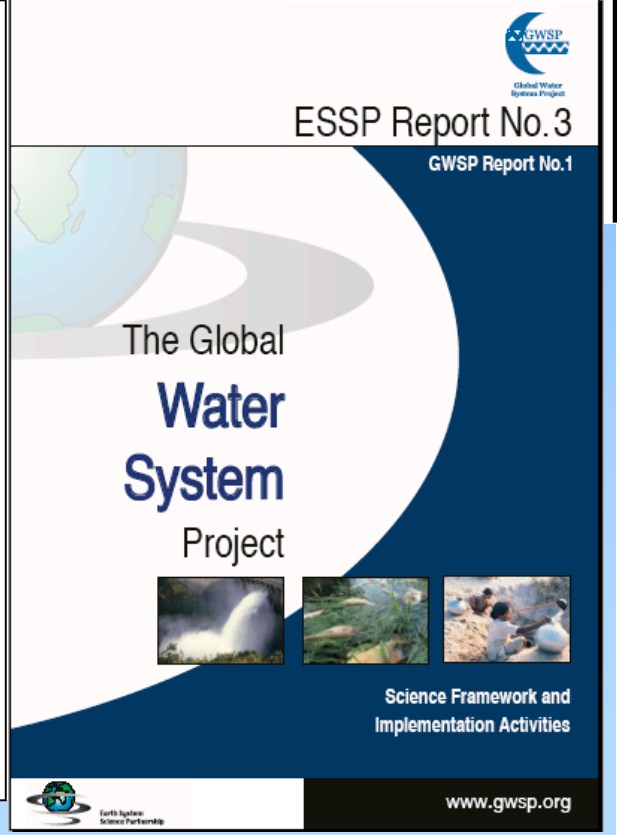


Mapping the Links between Water, Poverty and Food Security

Summary Report on the Water Indicators workshop held at the Center for Ecology and Hydrology, Wallingford, 16th to 19th May, 2005

Report authors[1]:
Caroline Sullivan, Charles Vörösmarty, Eric Craswell, Stuart Bunn, Sarah Cline, Claudia Heidecke, Adam Storygard, Alex Proussevitch, Ellen Douglas, Deborah Bossio, Dirk Günther, Anna Maria Giacomello, Dermot O'Regan and Jeremy Meigh

December 2005



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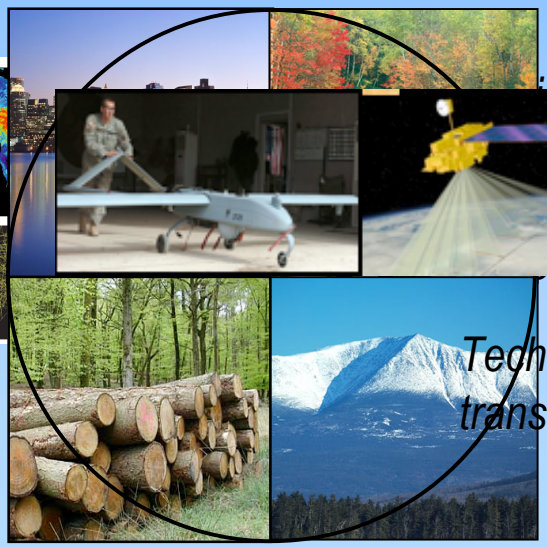
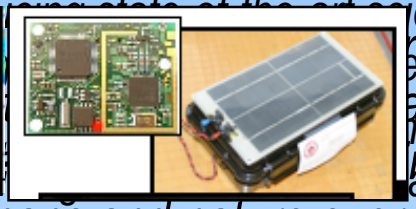
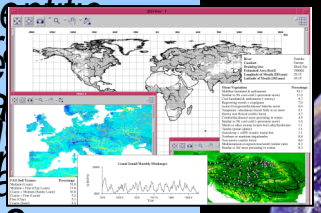
Our Mission

- *The CUNY Environmental Cross-Roads Initiative creates a major focal point for experts to join forces, dialogue, and jointly solve the major 21st century strategic environmental challenges facing the region, the Nation, the world.*

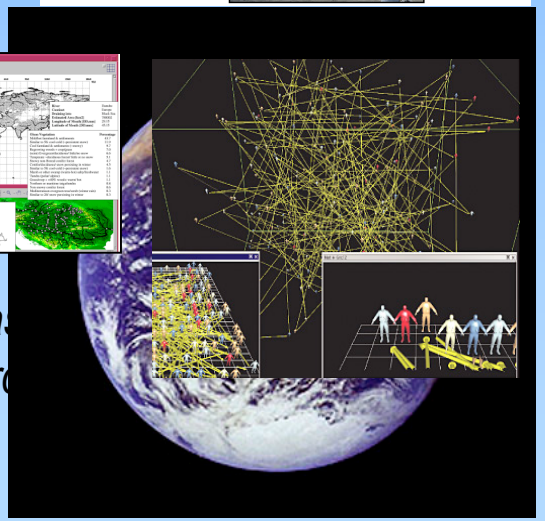




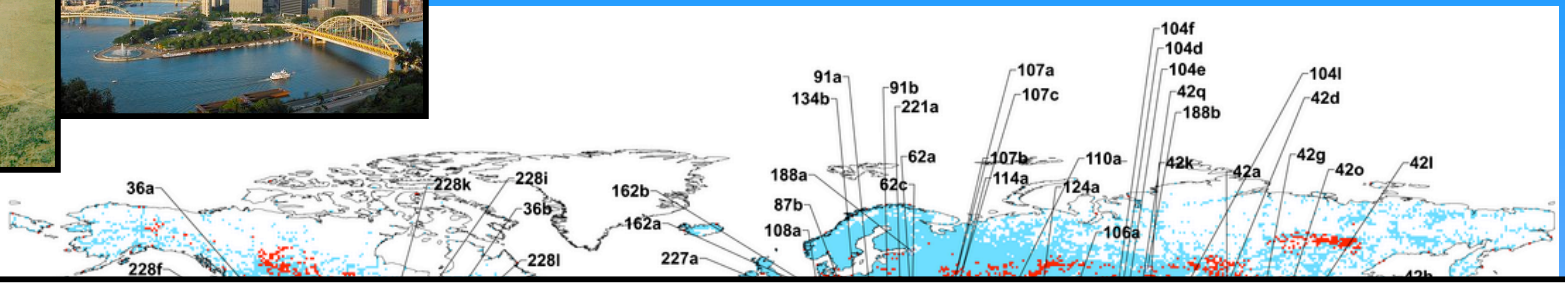


humans and nature over a millennial time horizon.

Technology is seen not merely as a tool but as a transformative force for environmental steward

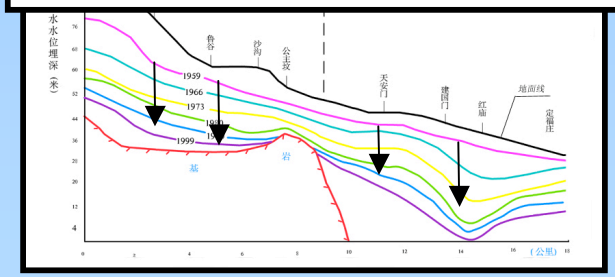


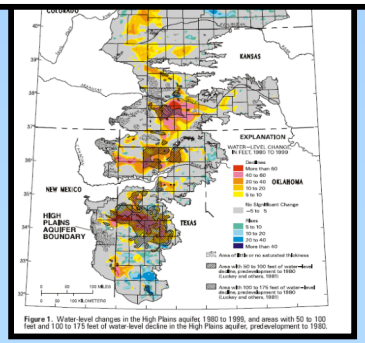
Irrigation & Urban Water Use in Excess of Sustainable Supplies



Help us in documenting these patterns: If you are aware of any overuse in your region, please contact me charles.vorosmarty@unh.edu

- Name of location/region
- Latitude/Longitude
- The Nature of the “Overuse”:
  - --groundwater over-abstraction?
  - --interbasin transfers required to meet demand
  - --depletion of river flows (navigation problems, lack of water to dilute pollution, ecosystem stress, etc.)





Western US Basin Transfers