Global Hydrology

Local Problems Move to Global Syndromes

C. Vörösmarty….and many colleagues

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

2011 CSDMS Meeting

Boulder, CO 30 October 2011

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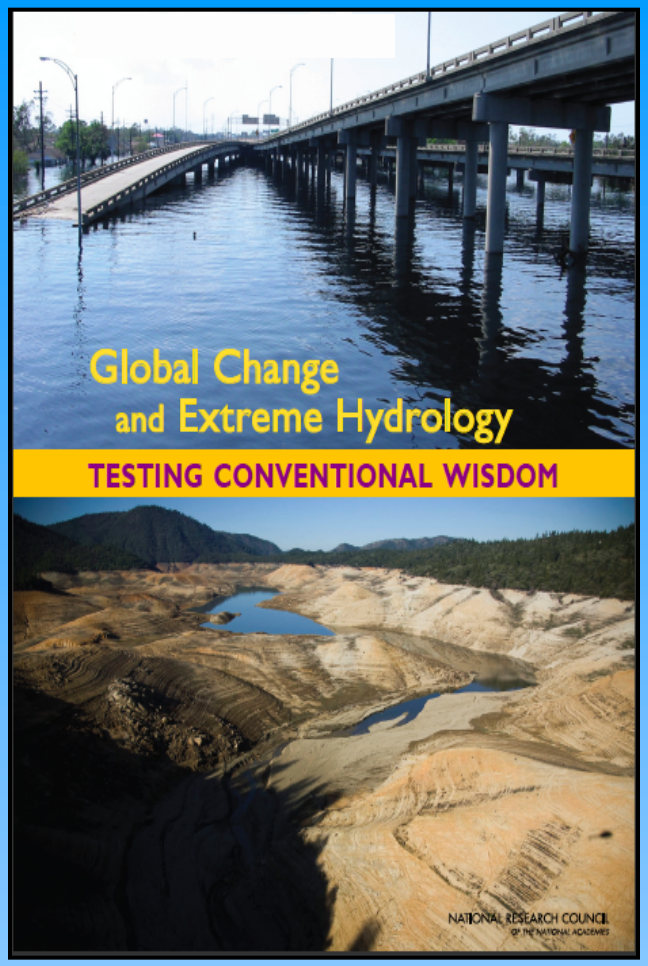
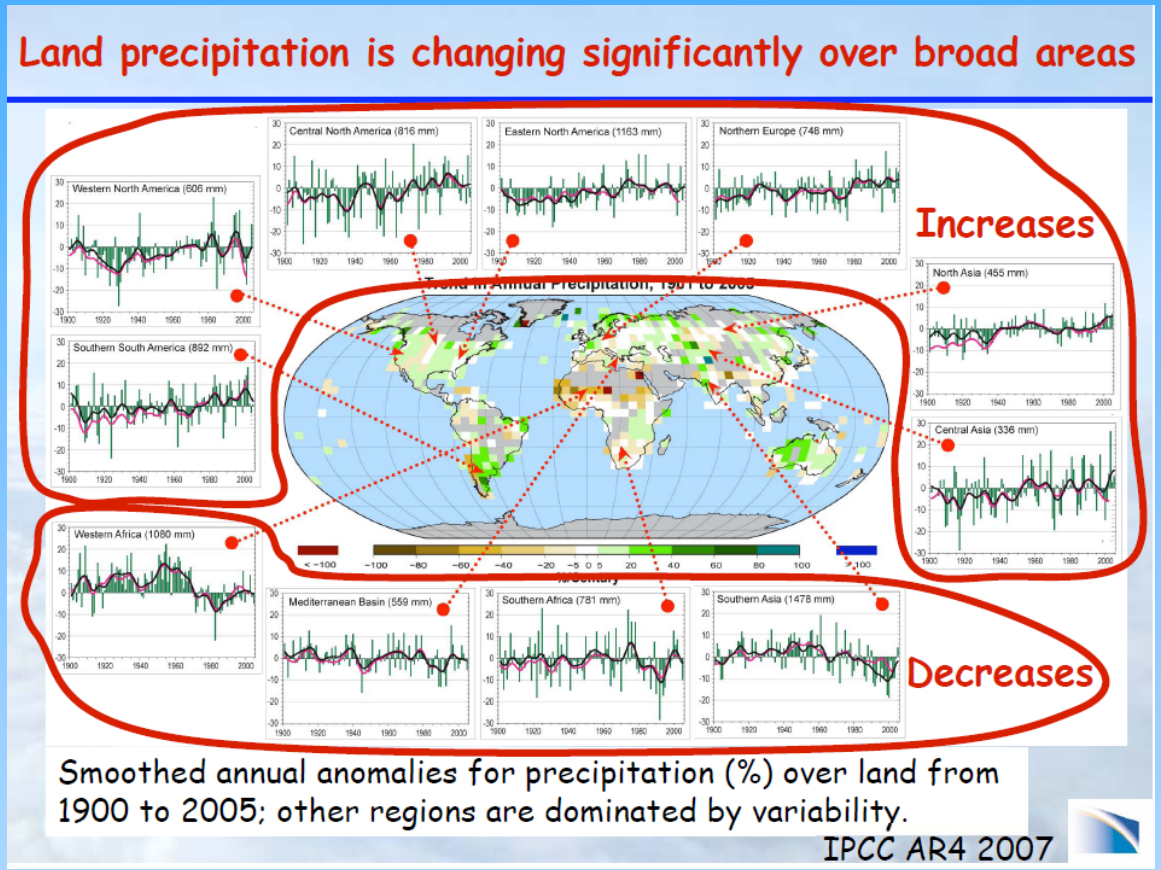


2011 NRC Committee on Hydrologic Sciences Report on Climate and Hydrology Extremes

- Mean land PPT ↑ 2-3% globally over last century
  - Winners/losers
    - Variability increasing



Major Findings

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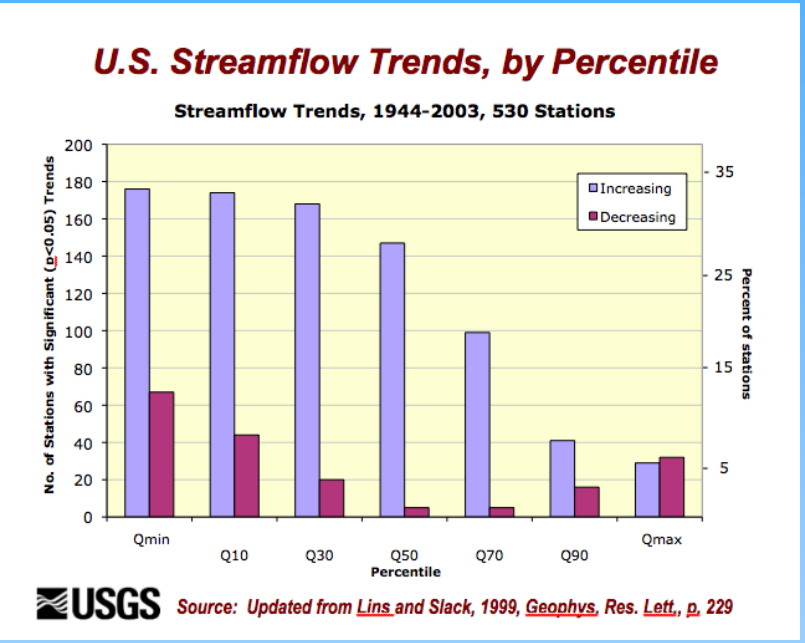
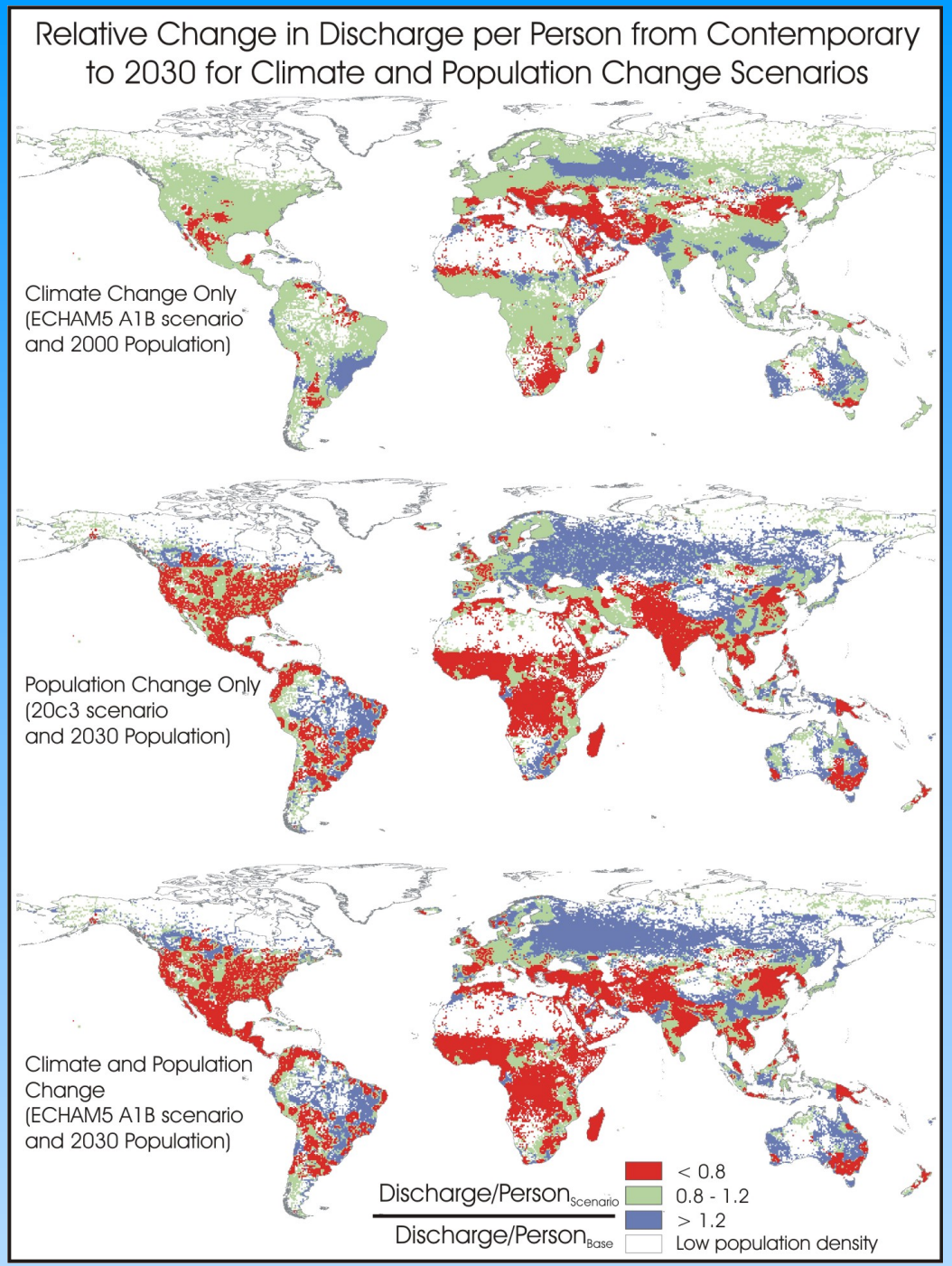
- Predictions made by climate science capture the reality that climate Δ is increasing PPT and other variables in observational record
- But…hard to translate into hydrologic signatures

…as a generally well, rapidly mixed atmosphere encounters hydrologic realities (slower processes, complex spatial patterns/processes including geology, biology, land use, engineering …scale mismatches also)



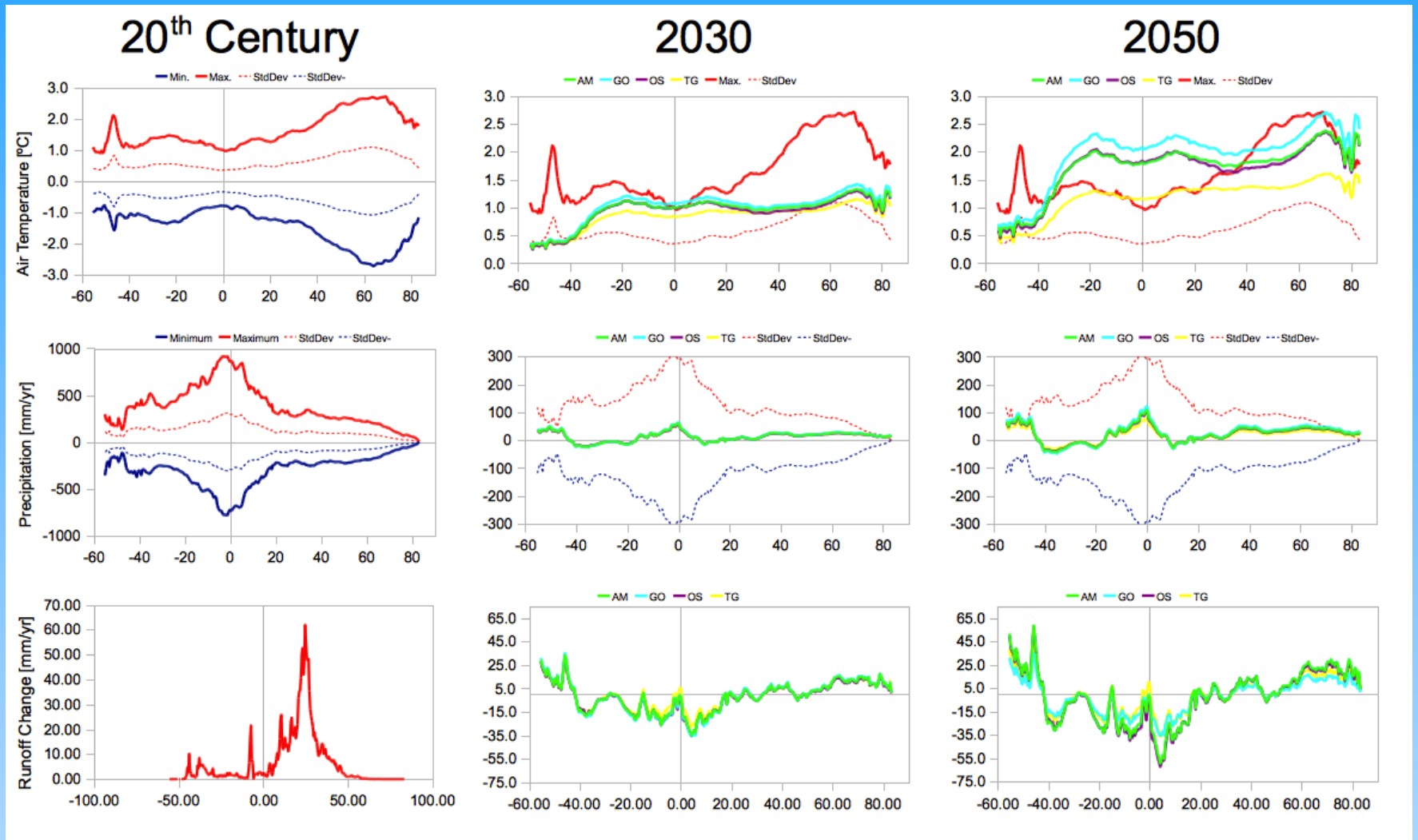
"WETTER BUT LESS EXTREME"

- Climate Change only part of our water resource worries
- Population growth and economic development another critical issue

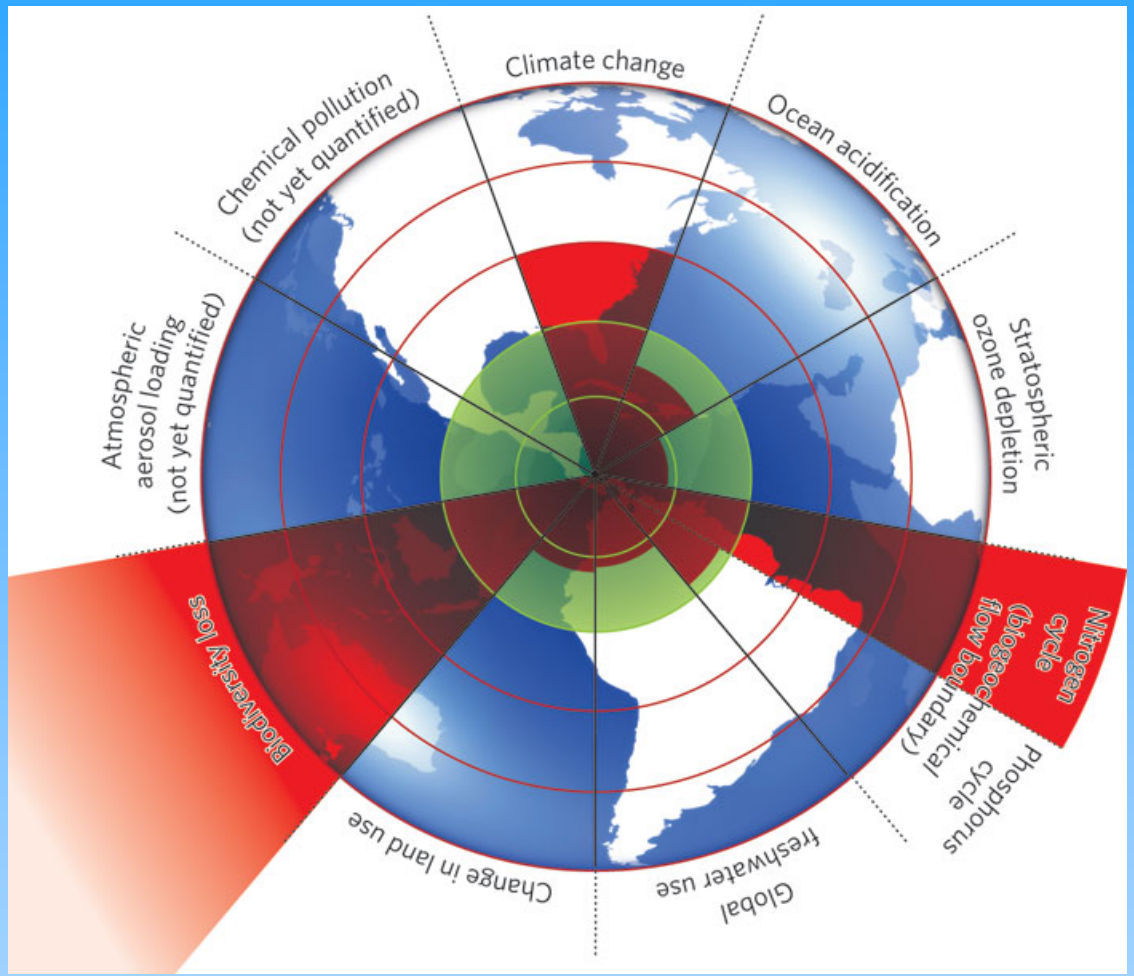


Vörösmarty, Levy, et al. --Recent work reported to National Intelligence Council

Climate Drivers and Runoff Responses

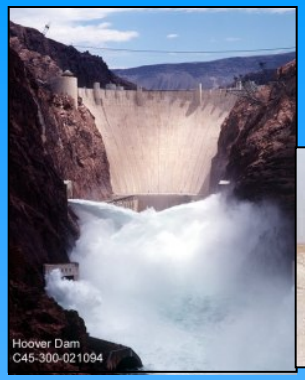


Planetary Boundaries



Rockström et al., Nature 2009

Sanitation & access to clean water



"Engineered"

> *"Water…a profoundly local resource"*
> *M. Muller (21 Sept.09)*

Urban waters

Water for development

Agriculture and Water

Climate change and its extremes

Ecosystem services

Water quality

Nature: September 30 issue

Can we capture the **full dimensionality** of this issue & move from local to regional to a fully global perspective?

…and thus be on par with the global climate change question

Visit: *www.riverthreat.net*

Major Sources of Threat to Inland Waters: Four *Themes*

Watershed Disturbance

- *Cropland*
- *Imperviousness*
- *Livestock density*
- *Wetland disconnectivity*

Pollutants

- *Soil salinization*
- *Nitrogen loads*
- *Phosphorus loads*
- *Mercury deposition*
- *Pesticide loads*
- *TSS loads*
- *Organic (BOD) loads*
- *Potential for acidification*
- *Thermal impacts*

Water Resource Development

- *Small dam density*
- *Large dam impacts (residency time Δ)*
- *River network fragmentation*
- *Consumptive use (loss/supply)*
- *Water crowding (population/supply)*
- *Cropland crowding (area/ supply)*

Biotic Threats

- *Invasion level (non-native fish)*
- *Non-native fish species richness*
- *Catch pressure*
- *Aquaculture*

N = 23 global data fields

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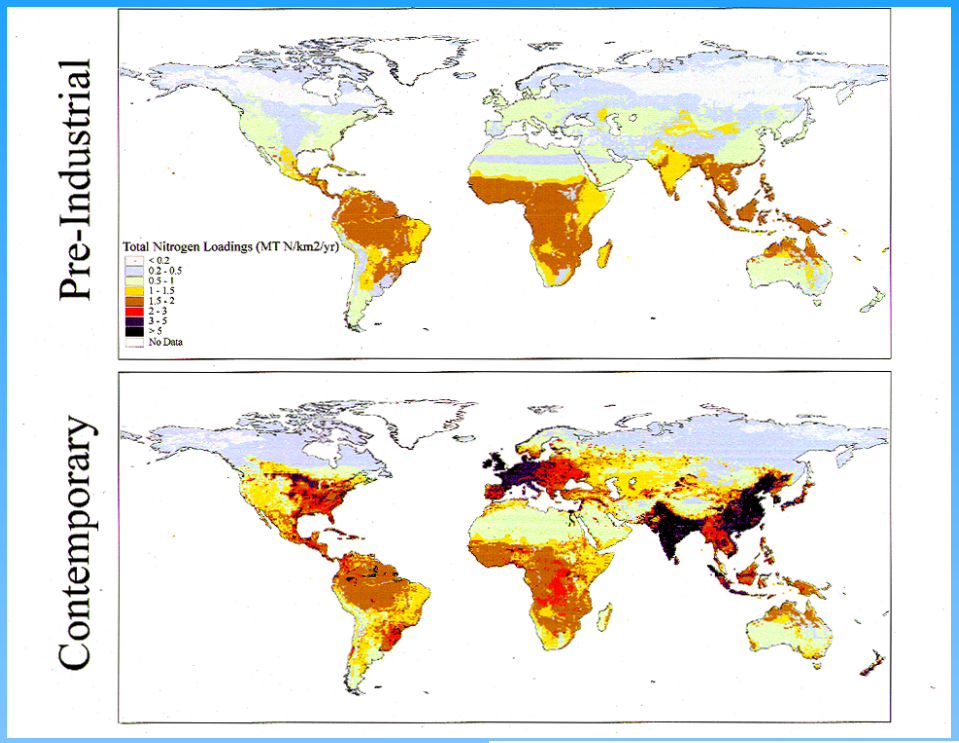
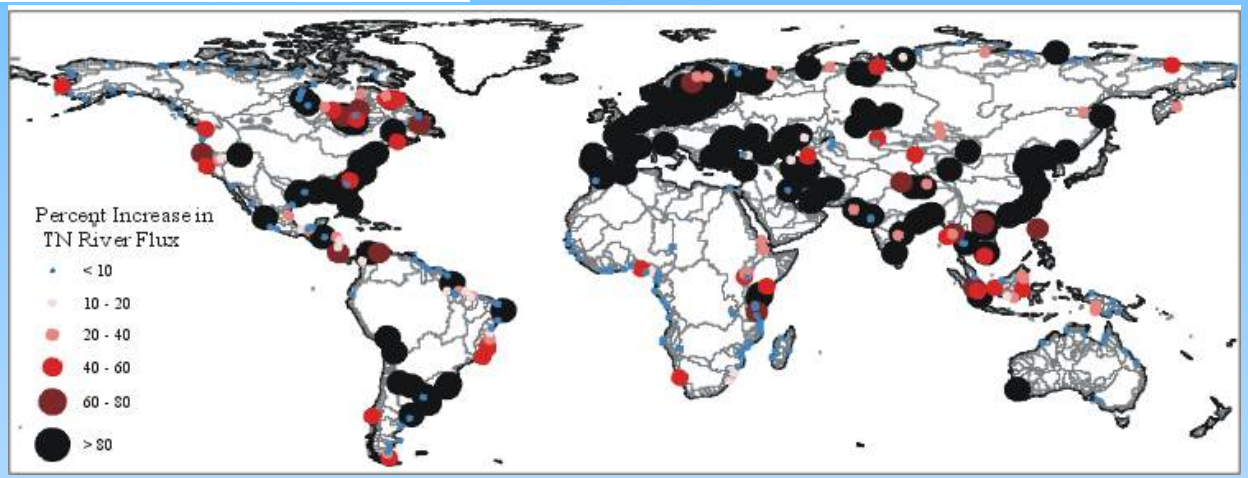
Water Supply-- Doubling of Global Nitrogen Pollution



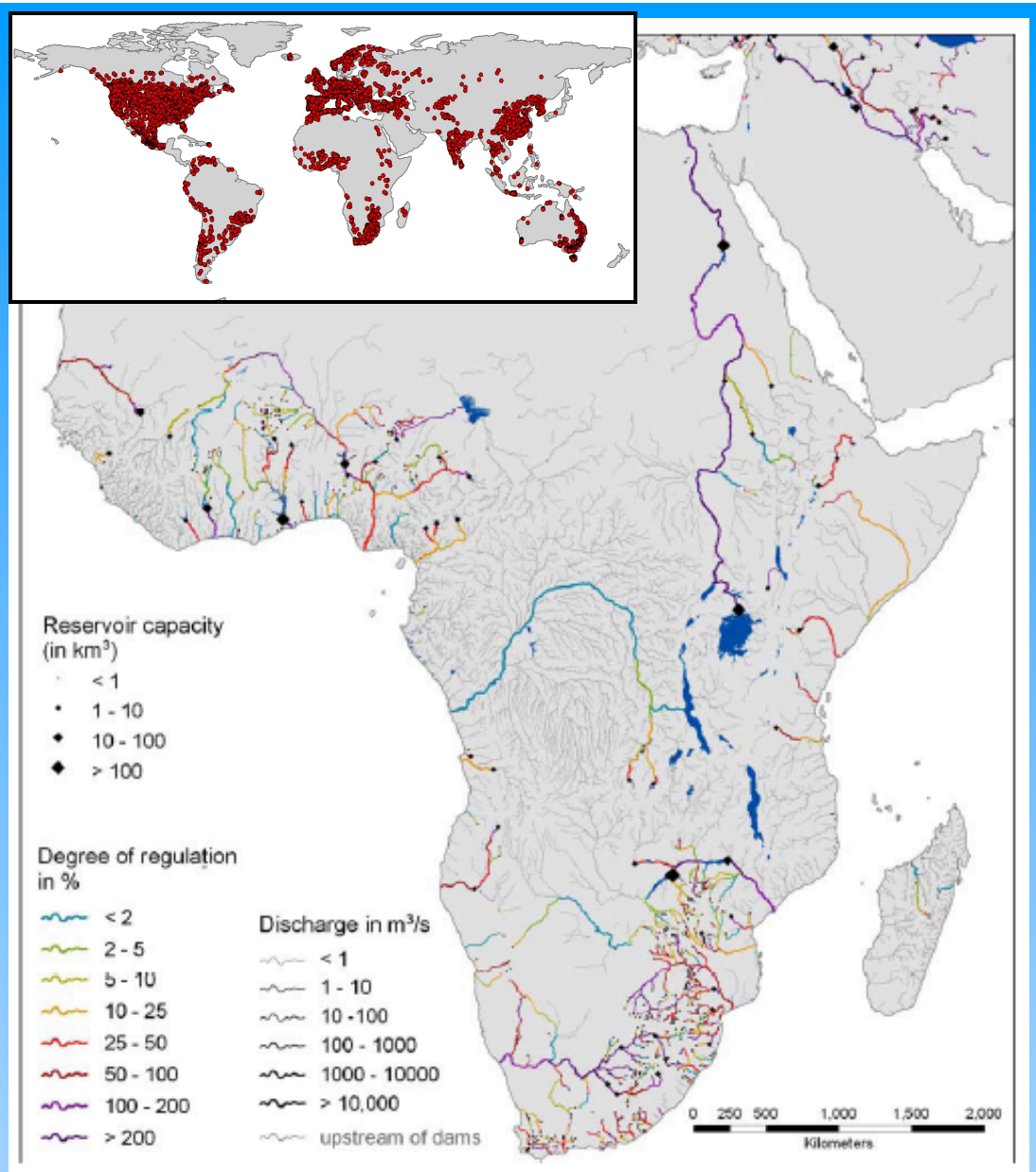
Terrestrial Loading

% Change in River Fluxes

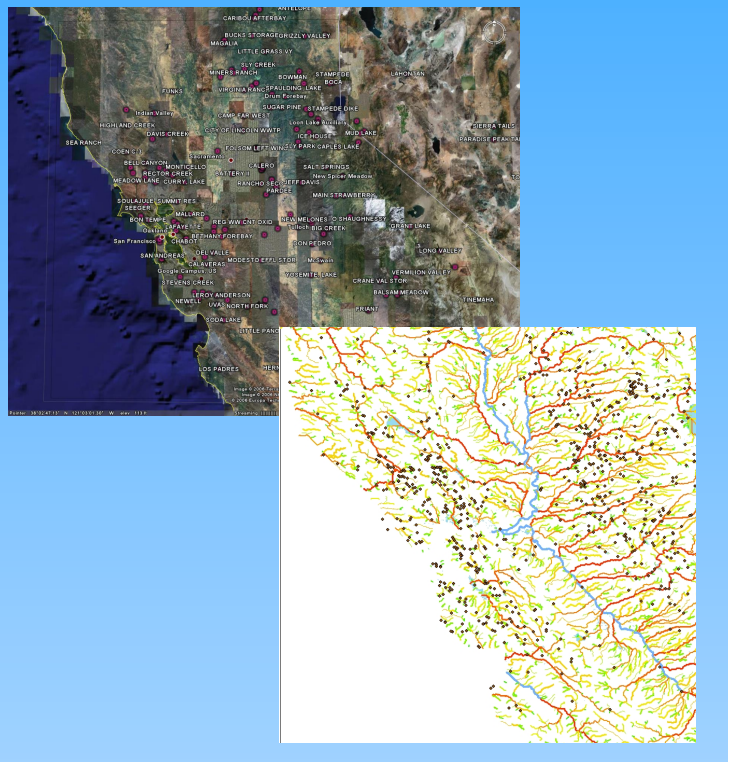


Green et al. 2004; Biogeochemisty

Impacts of flow regulation: New Global Reservoir and Dam (GRanD) database



WebFigure 3: Impacted river reaches downstream of GRanD reservoirs in Africa.



Lehner et al. *Frontiers in Ecology and the Environment* (in review)

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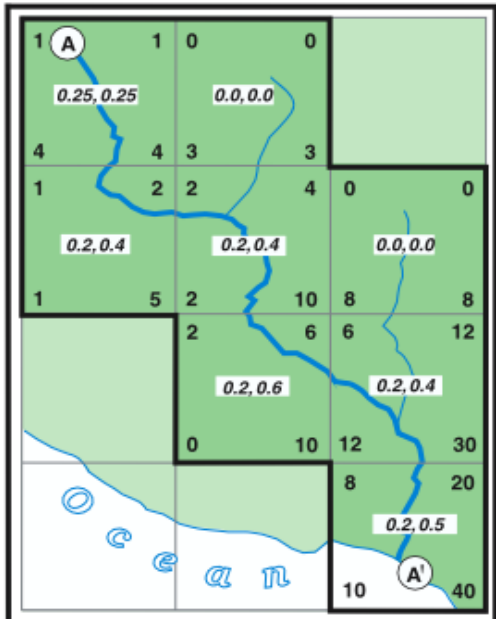
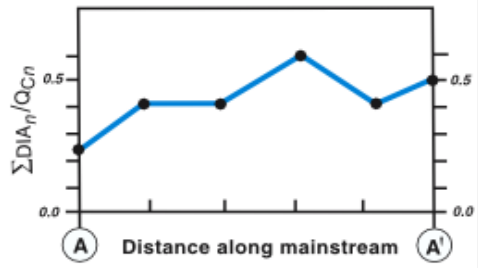




CALCULATION OF KEY WATER INDICATORS

DIA_n = domestic, industrial, agricultural water use ($km^3\ yr^{-1}$) in cell n

$\sum DIA_n$ = DIA in cell n plus all upstream cells ($km^3\ yr^{-1}$)
$= \sum_{i=1}^{n} DIA_i$

R_n = locally-generated runoff (mm/yr)

A_n = area of cell n (km^2)

$Q_{Ln} = 10^6 * R_n * A_n$ = locally generated discharge ($km^3\ yr^{-1}$)

$Q_{Cn} = \sum_{i=1}^{n} Q_{L_i}$ = river corridor discharge ($km^3\ yr^{-1}$)

DIA_n/Q_{Cn} = local relative water use (unitless)

$\sum DIA_n/Q_{Cn}$ = water reuse index (unitless)

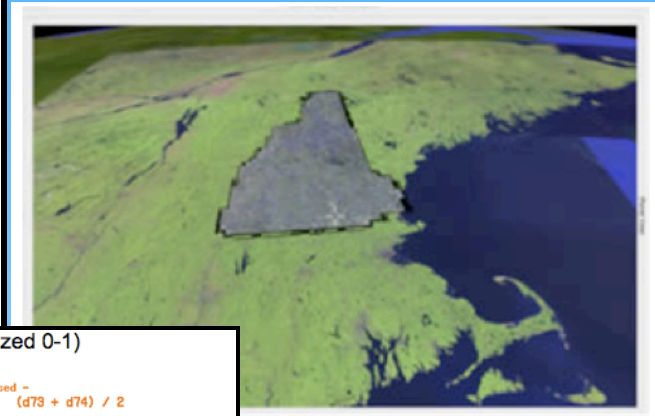
n = position of cell in river network
= total number of upstream cells plus cell in question

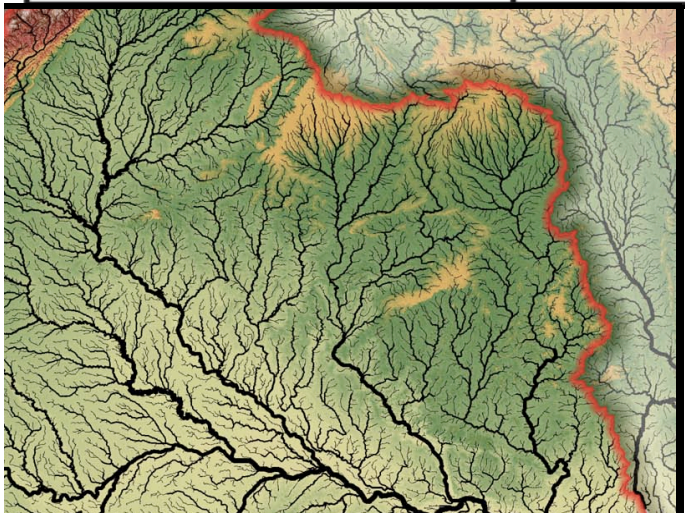
Key (cell n)

Global RIMS

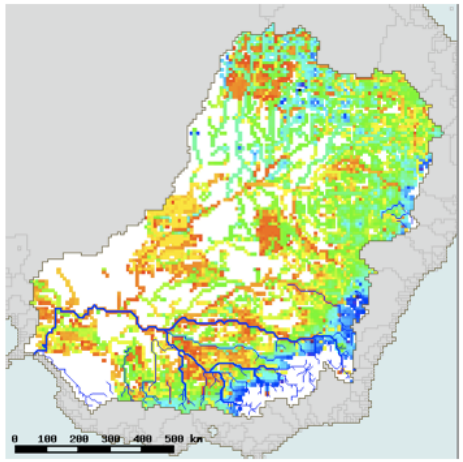
Global Rapid Indicator Mapping System for Water Cycle & Water Resource Assessment

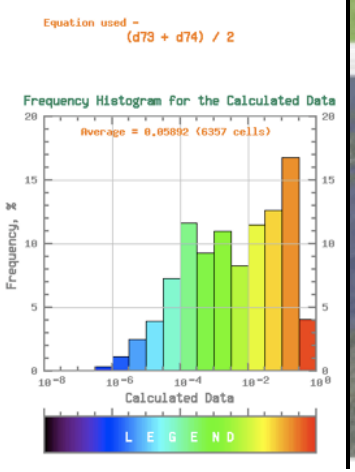
- *DEFINE WATERSHED STATE BASED ON LOCAL AND RECURSIVE INDICES*
- *GOOGLE AND OPEN MAP SERVERS*
- *MAP SYSTEM STATES OVER MULTI-SPACE & TIME SCALES*





Combined Indicator: N Pollution + Timing Shift (normalized 0-1)





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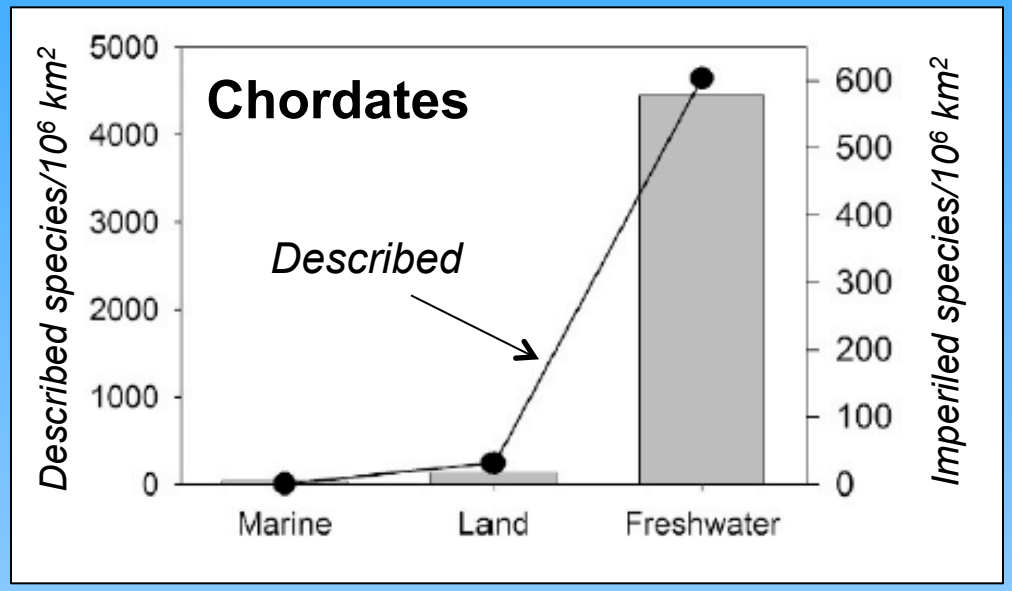
An Underpinning / Corroboration of BD Loss?

- Unusually high concentration of biodiversity: ~125,000 freshwater species described (~10% of known animal species) despite inland waters <1% of the Earth's area; high endemism…high risk



From: Strayer and Dudgeon (2010), J-NABS

- Globally 10,000-20,000 freshwater species are extinct or imperiled

- Have FW systems moved from the Holocene into the Anthropocene?

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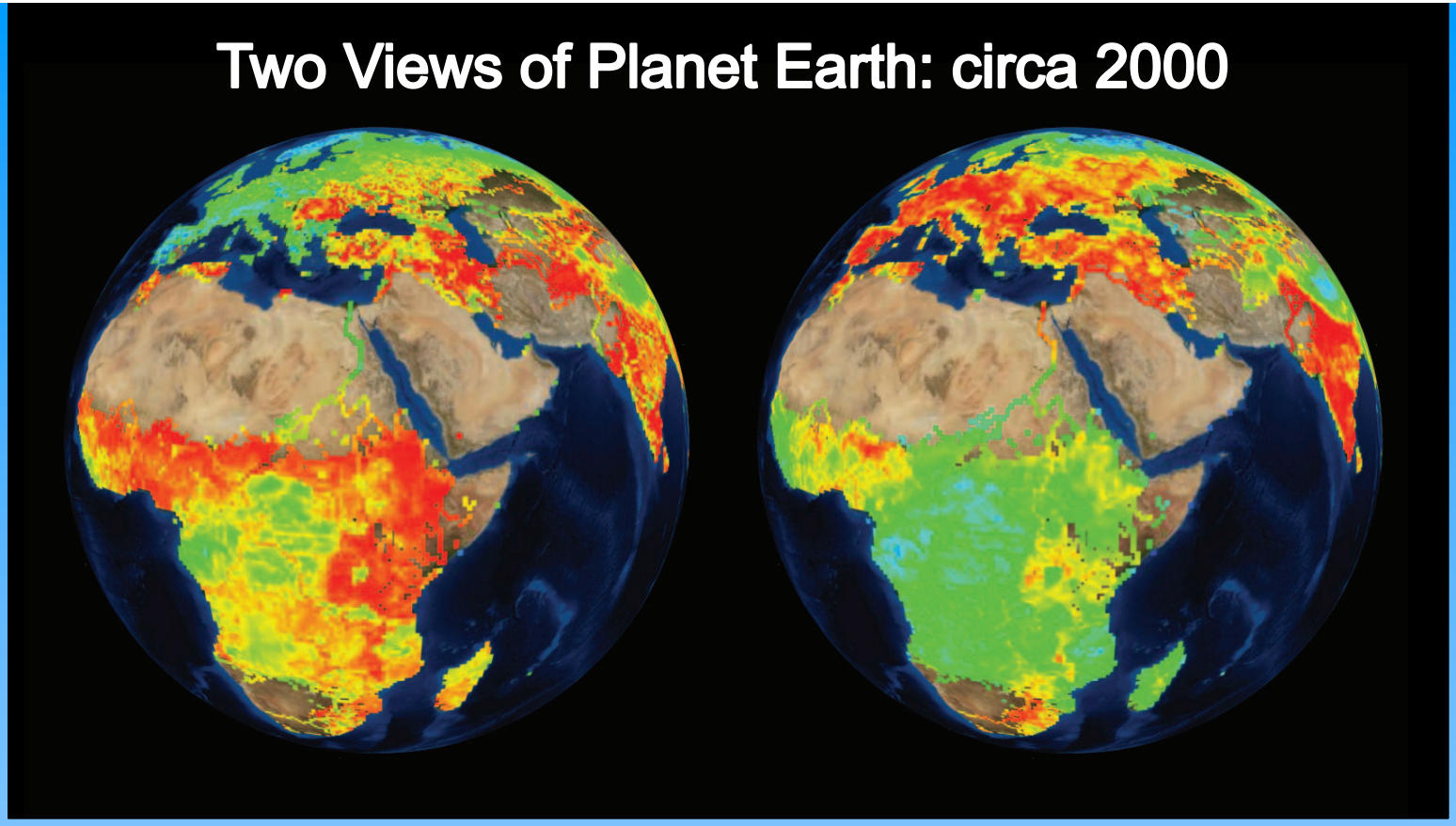
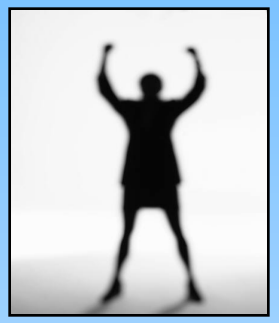
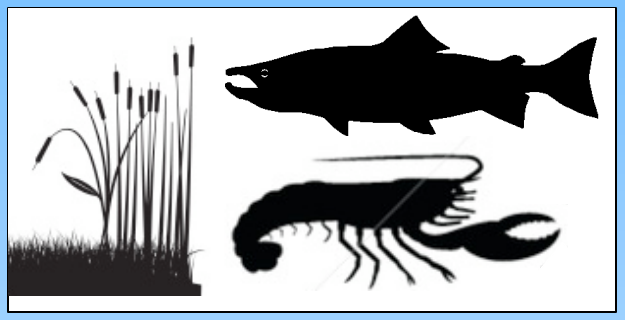
Two Views of Planet Earth: circa 2000







Why so different?

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"Haves & Have-Nots" in Provision of Clean Water & Sanitation:

A Millennium Development Imperative, Yet Still Unrealized

Almost 1 Bn lack clean drinking water

Over 2 Bn people lack basic sanitation

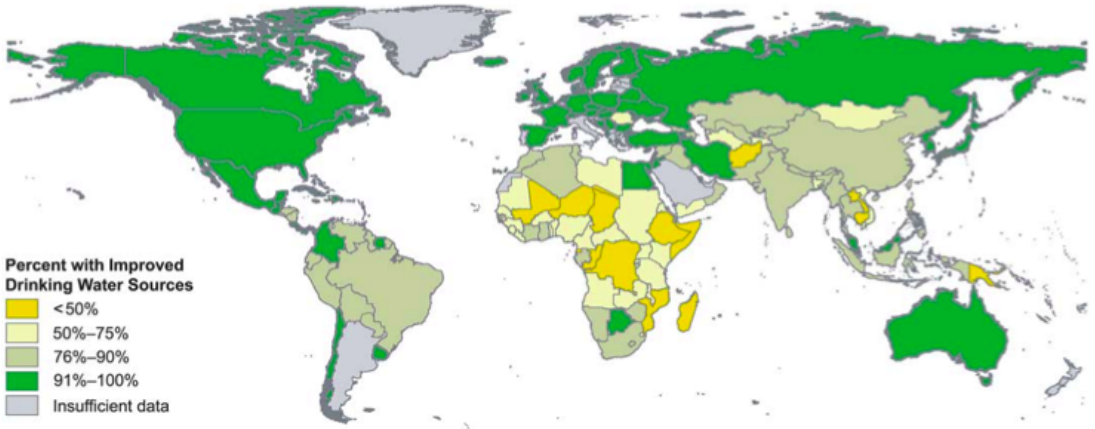


Figure 7.13. Proportion of Population with Improved Drinking Water Supply, 2002 (WHO/UNICEF 2004)

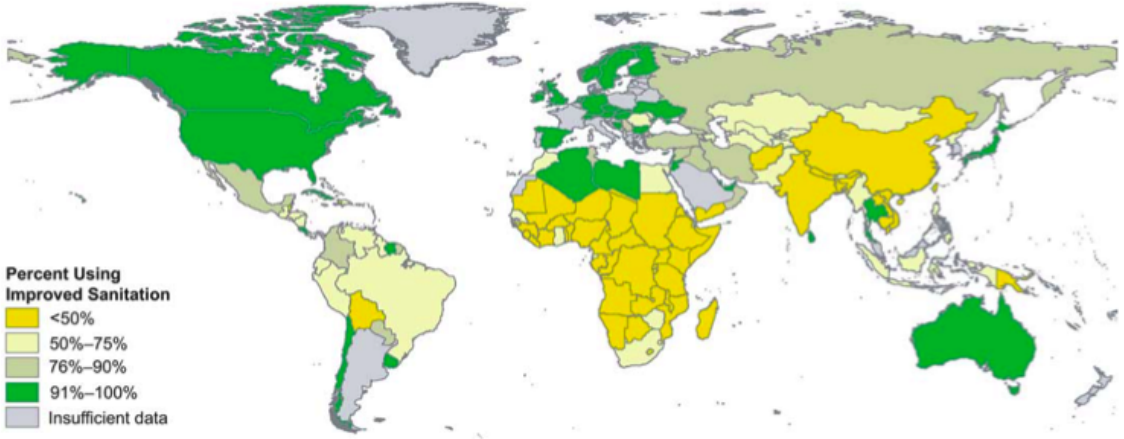
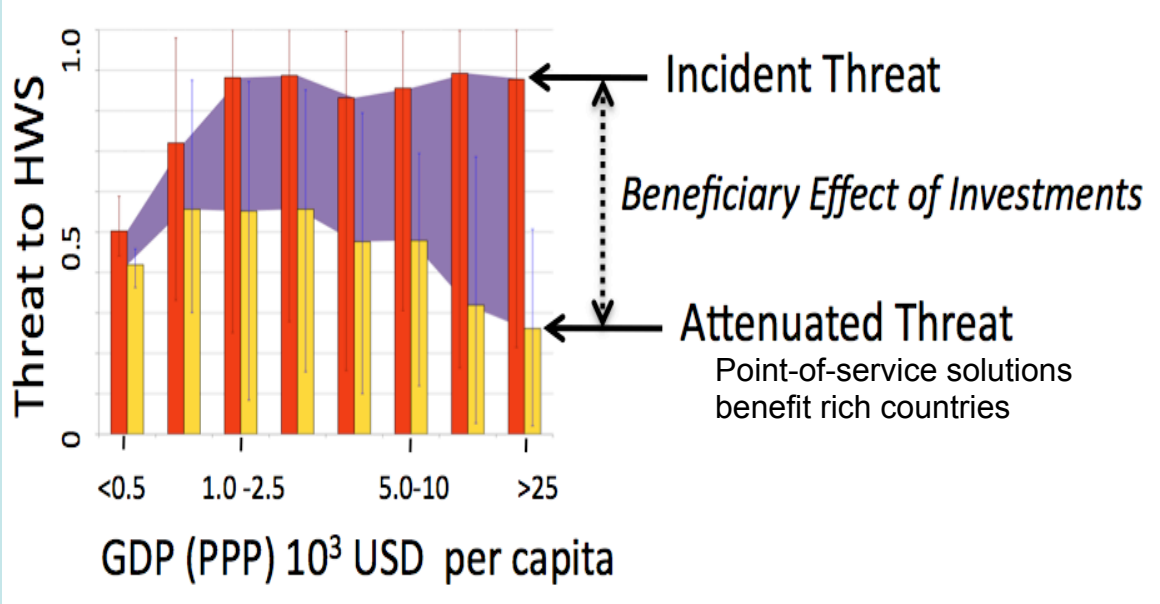


Figure 7.14. Proportion of Population with Improved Sanitation Coverage, 2002 (WHO/UNICEF 2004)

- 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, 2010

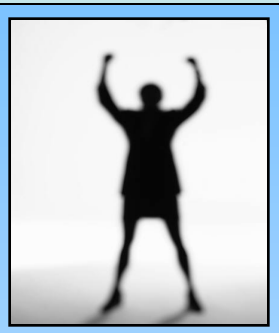
Human Water Security

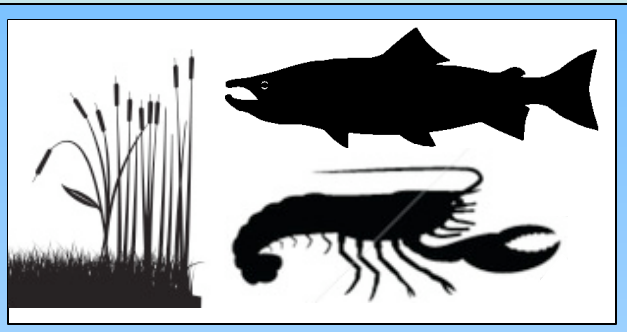


Large $$ & Energy Costs

- Treat symptoms rather than causes
- Strand poor & BD under high levels of threat
- Water management impacts (like from dams) impair BD and Ecosystem Services

Infrastructure investments are huge: $0.75Trillion/yr for OECD & BRIC alone by 2015





Why so different?

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In Conclusion

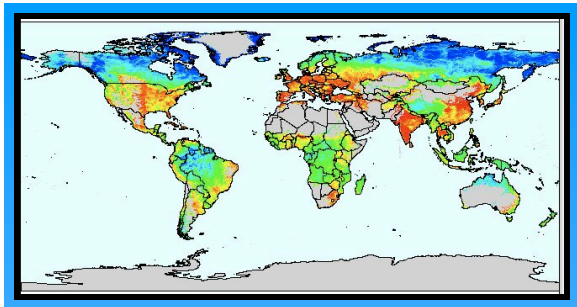
- Pandemic fingerprint of human-induced impacts on water systems…*local effects move to regional and global syndromes*
- *Human Water Security (HWS)* **and** *Biodiversity (BD)* at high levels of incident *Threat…persist into the future*
- Engineering interventions reduce *Threat* to *HWS* in developed world*….”stranding” developing world HWS and global BD in state of high Threat*

In Conclusion

- Integrated, ”soft path” and “ounce-of-prevention” alternatives can spare developing world the costly (in $$ & environmental terms) strategy of treating symptoms and not causes

…but we need interdisciplinary perspectives, technologies to monitor & simulate, and broad-thinking in policy-making & planning

…. “visioning” sustainable water futures requires insights from the past



Partners

- Charles Vörösmarty
- Mark Gessner
- Alexander Prusevich
- Stanley Glidden
- Caroline Sullivan
- Peter Davies
- Peter McIntyre
- David Dudgeon
- Pamela Green
- Stuart Bunn
- Cathy Reidy

OUTPUTS AND METHODOLOGY CAN BE FOUND IN*:*

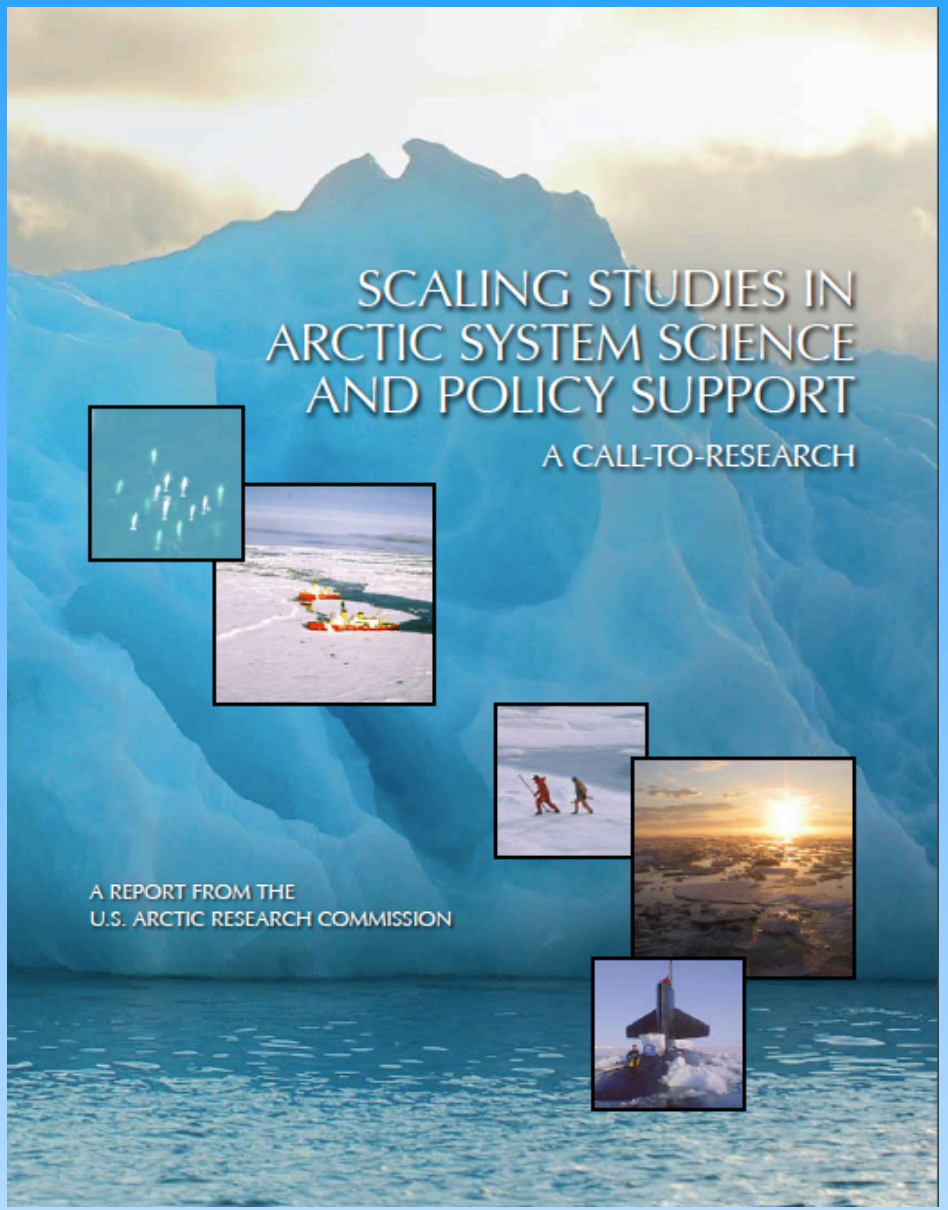
Vörösmarty et al. (2010) "Global threats to human water security and river biodiversity", *Nature* 467: 555-561 *(30 Sept. issue)*

For more information: www.riverthreat.net ; Email: contact@riverthreat.net

Main End-Product

Target audience:
Inter-agency committee (IARPC)

…plus
Individual agency program managers



Represents product of >20 researchers & practitioners (2008 Seattle Workshop)

SCIENCE

- Physical
  - –Weather and Climate Prediction
  - –Glaciers, Ice Caps, and Ice sheets
  - –Permafrost and Hydrology
  - –Arctic Ocean and Sea Ice
- Biology
  - –Marine Ecosystems
  - –Terrestrial Ecosystems incl. Freshwater
- Human systems
  - –Arctic human communities

Tipping Points & Feedbacks

Plus Inter-D Themes

Represents product of >20 researchers & practitioners (2008 Seattle Workshop)

SOCIETAL APPLICATIONS

- Human Health Research
- Climate Change Mitigation
- Public & Private Infrastructure Vulnerabilities
- Subsistence Harvest & Commercial Fisheries
- Non-renewable Resource Extraction
- Ice Navigation
- Oil Spill Preparedness, Response, Restoration

Key Findings

1: *Scaling issues and even the definitions of scale are so varied across individual disciplines that they hinder interdisciplinary research.*

2: *Scale incongruities among components of the Arctic system give rise to opportunities to study intermediate scales.*

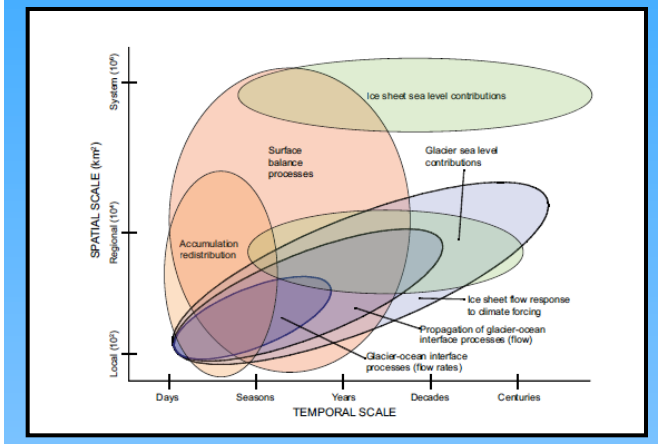
3: *Thresholds are scale-sensitive and important, yet prove difficult to detect, study, and/or predict.*

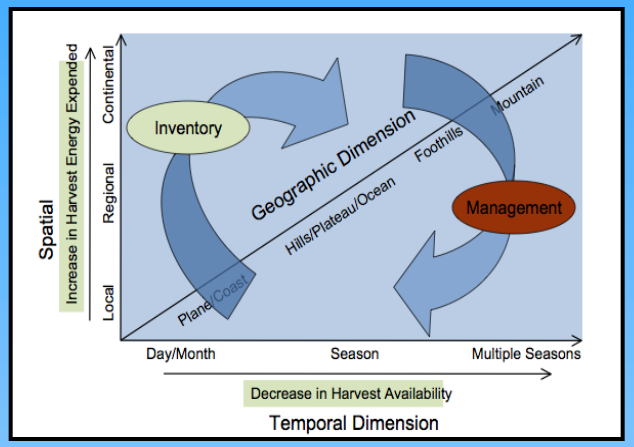
4: *Scales of human perception are much different than those associated with the study of natural systems.*

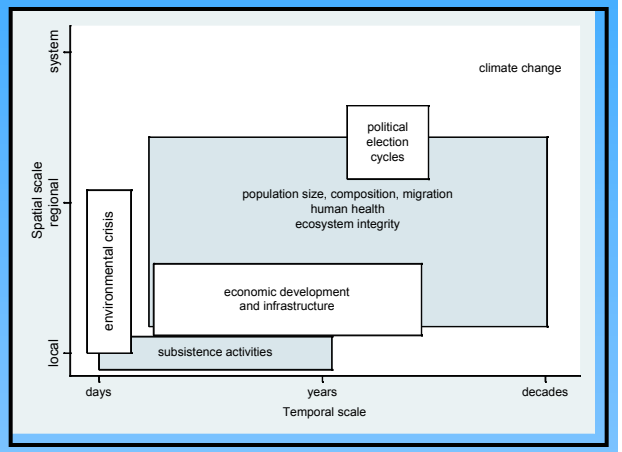
5: *Information has not been well structured to facilitate cross-scale studies.*

6: *Science conclusions and uncertainties require better translation into information for policymakers.*

Scale Means Very Different Things Across Disciplines…*Implications for Interdisciplinary Research & Assessments*







Glaciers and Ice Sheets

Wildlife Management

Social System Dynamics

Scaling Studies in Arctic Research

Questions?

For more information:
See: www.arctic.gov
Email: info@arctic.gov