Understanding the Global Hydrologic Cycle and Water Management Challenges

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P.H. Gleick, H. Cooley, J. Famiglietti, D. Lettenmaier, T. Oki,
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Research for People and the Planet

WCRP Community Position Draft Papers for Comment:

"Understanding the Global Hydrologic Cycle and Water Management Challenges"

P.H.Gleick, H.Cooley, J.Famiglietti, D.Lettenmaier, T.Oki, C.Vörösmarty, E.Wood

http://conference2011.wcrp-climate.org/documents/Gleick_hydrology.pdf

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Purely Scientific/Academic Point of View

- Understanding the complexity of the hydrological cycle and connections with global and regional climate is of paramount interest and central to our understanding of other planetary geological, atmospheric, chemical, and physical processes.

But water is more than that

- Water is key to some of the core economic, social, and political problems of our time such as poverty, environmental sustainability, human and ecosystem health, conflict, and economic prosperity.

Public Health

Infrastructure

Forestry

Water Resources

Energy

Agriculture

Environment

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Even without climatic changes, we have serious water resource challenges

- Billions without access to basic water services.
- Deteriorating natural ecosystems.
- Deteriorating infrastructure; lack of investment.
- Little public awareness of water problems.
- Ongoing disputes and violence over water.
- Few coherent international water policies.
- Few coherent national water policies.

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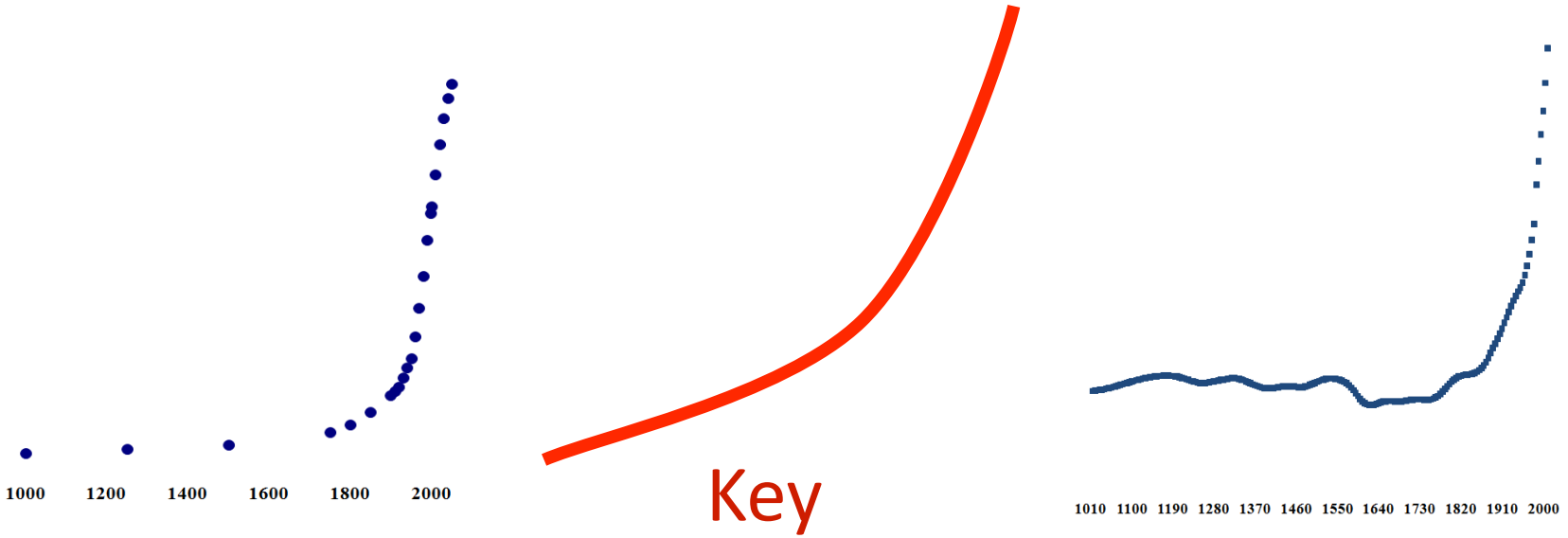
Human Influences are Growing

- Human influences on the character and dynamics of the water cycle are growing, often faster than our understanding of these influences and their ultimate consequences.



Gleick and Palaniappan 2010 ("Peak Water" *PNAS,* Vol. 107:2)

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We Need to Improve:

- Our systems for collecting, managing, sharing, and analyzing all kinds of water data.
- Our understanding of the local, regional, and global details of the water balance on timescales from minutes to millennia.
- Our ability to model and forecast aspects of both the hydrological cycle and the systems we put in place to meet human demands for water.

Hydrologists always want more and better data

- Without adequate data, understanding of existing conditions and dynamic processes will always be constrained.
- Without adequate data, the ability to develop more accurate models for forecasting and planning will be limited.
- The first recommendation in almost all past reviews of the hydrological sciences is to collect more geophysical, climatological, and hydrological data.

Key Areas of Discussion in Draft Paper

- Collect more comprehensive data on all aspects of the hydrologic cycle and human use of water, at enhanced resolution and increased precision;
- Improve management and distribution of these data;
- Improve representation of anthropogenic manipulations of the water cycle in the coupled land-atmosphere-ocean-cryosphere models at higher spatial and temporal resolution; and
- Expand research at the intersection of hydrological sciences and the technical, social, economical, and political aspects of freshwater management and use.

Important Data and Trends

Where are we?

Where are we going?

- Despite huge advances in data collection; management; monitoring; hydrologic sciences…
- There are vast gaps in our knowledge and data on water.

We don’t know where we are

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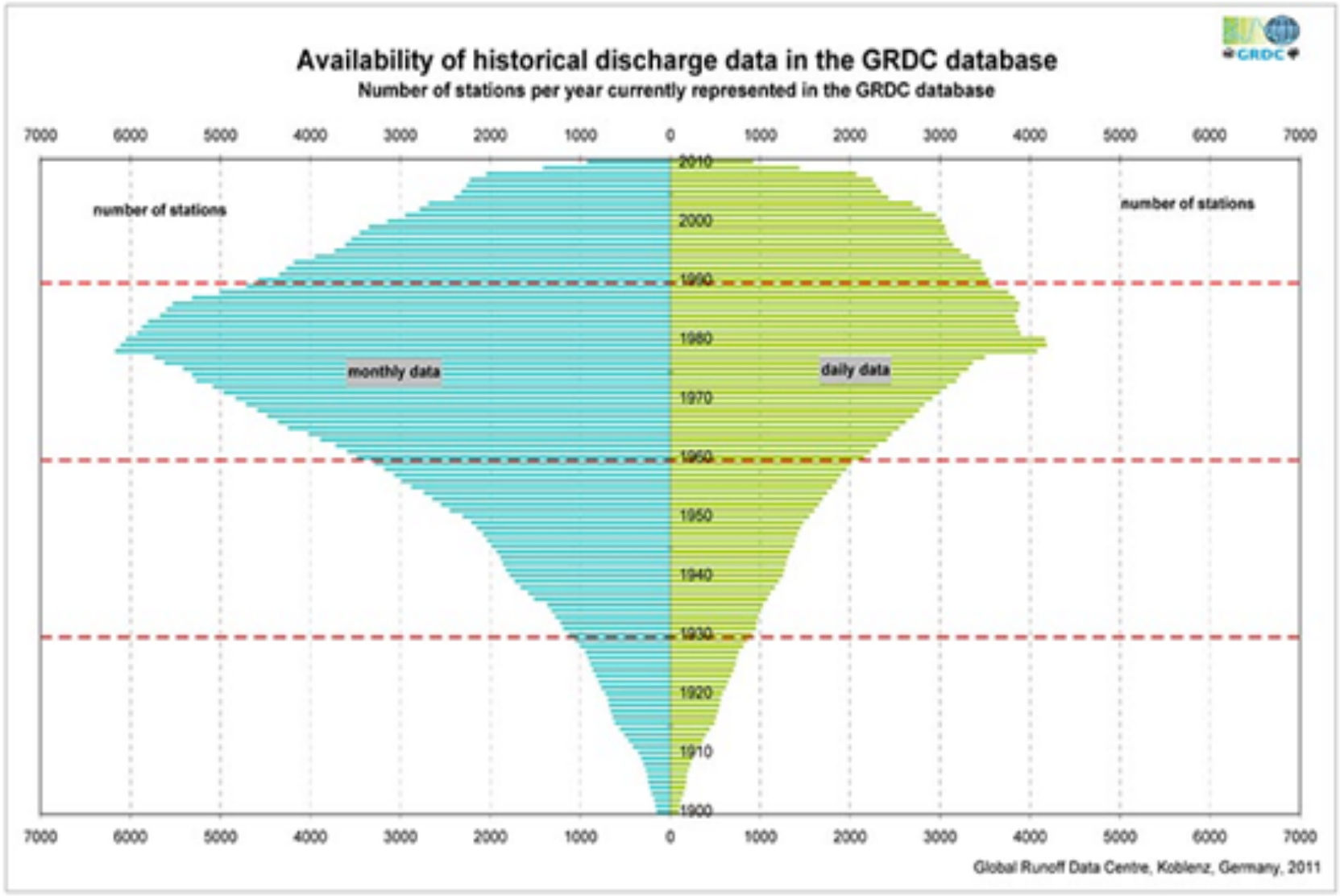
- We do not know how much water the world has.
- We do not know, accurately, the key components of the hydrologic cycle or the world's "water balance."
- We do not know how much water humans use.
- We do not know how much water ecosystems need for minimal levels of health.

Some data collection is going the wrong way



GRDC database on river discharge, 2011

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We don’t know where we’re going

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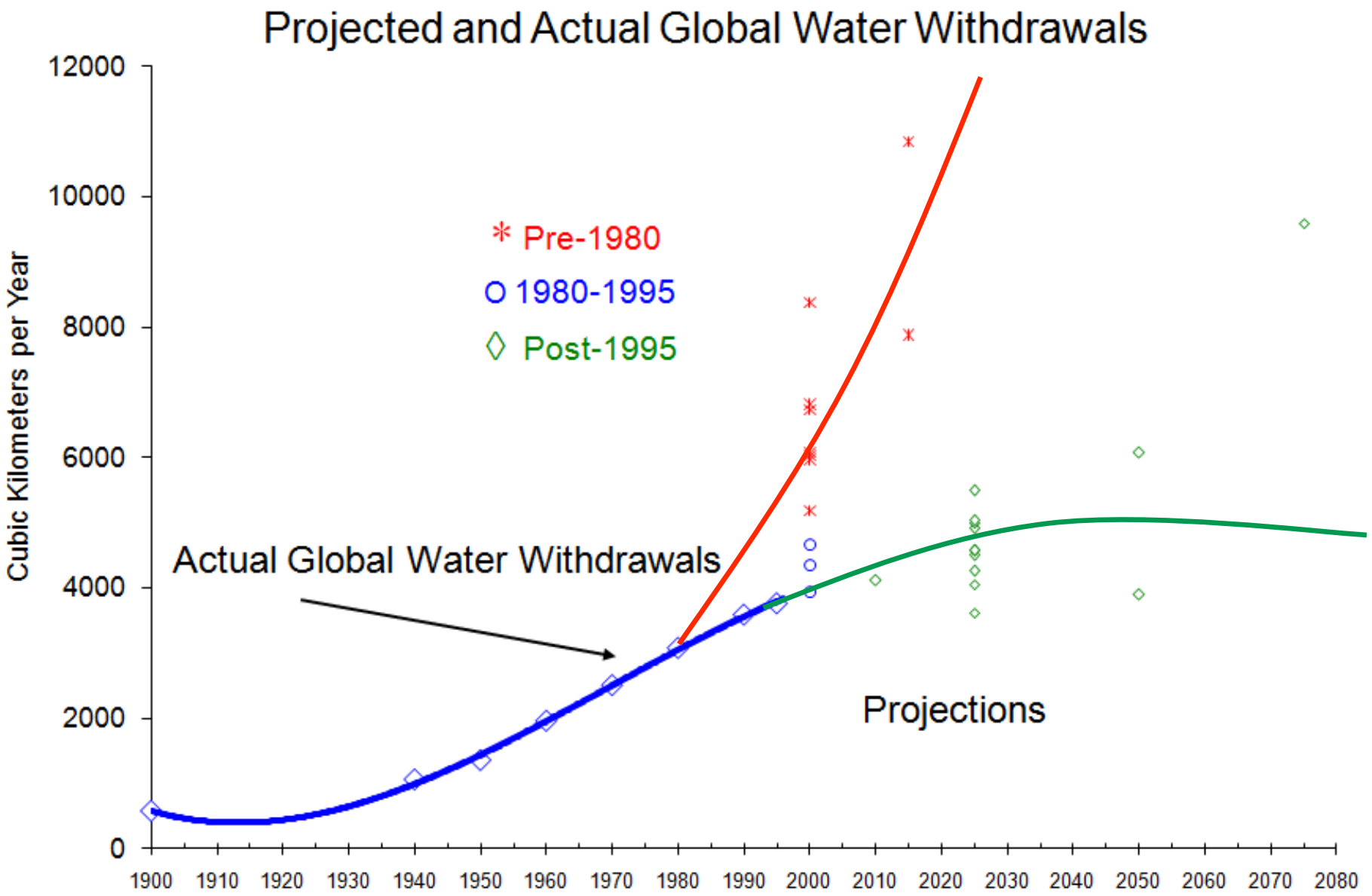

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And we have to be careful with the data we DO collect

Goldilocks data principle

We have too much,

We have too little,

We have just the right amount (but we don't use it properly)

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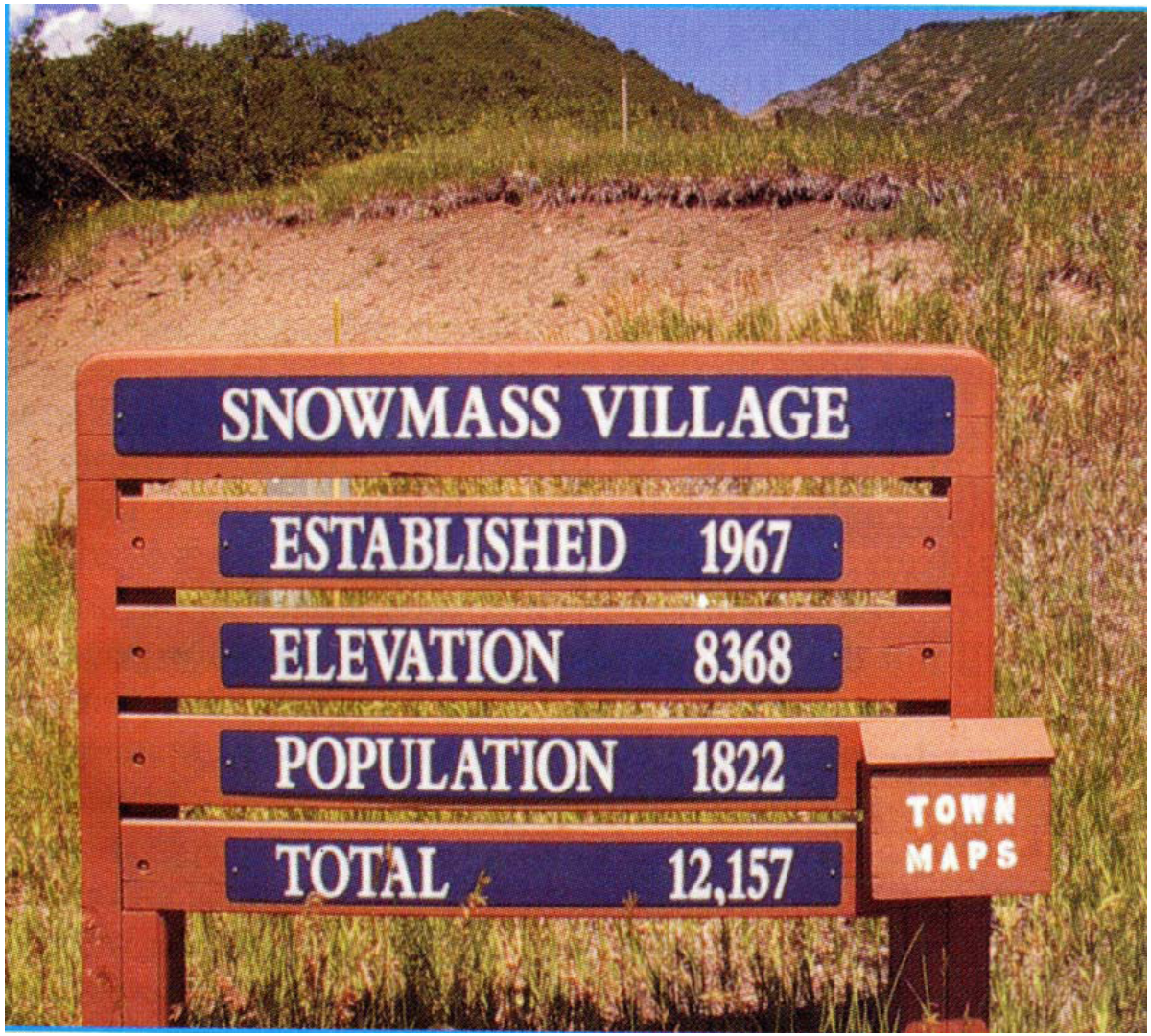
Data Errors or Misuse



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Just some key data needs?

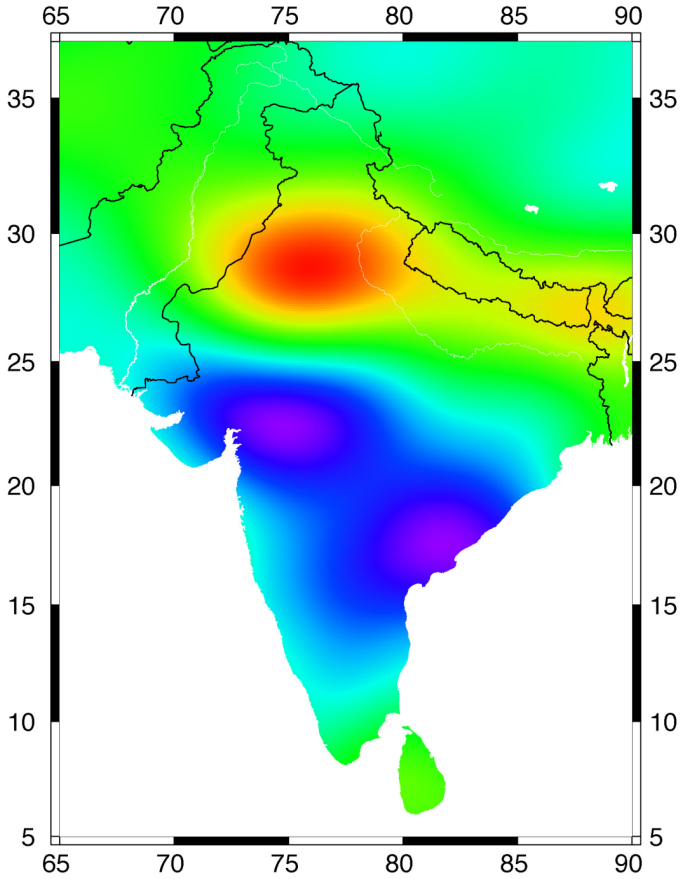
- New continental and global hydrometeorological data sets
- Transformed observations of streamflow into gridded (or equivalent) spatial fields over continental domains
- Gridded high-resolution precipitation data
- Improved evapotranspiration estimates at small and continental scales
- Expanded budget studies covering snow accumulation, melt, runoff, and evaporation of snow

Human interactions

- Water withdrawals, consumption, and reuse
- Redirection and transfers of water
- Disruptions of nutrient cycles and on contamination by human and industrial wastes
- Social and economic factors that influence water demand and use

Good data news

- We have unprecedented new capabilities in the form of technologies for in-situ and remote sensing data collection; and
- New approaches for embedded network sensing (ENS); and
- New techniques for visualization of data.



Groundwater changes in India, 2002-08, (GRACE, NASA)

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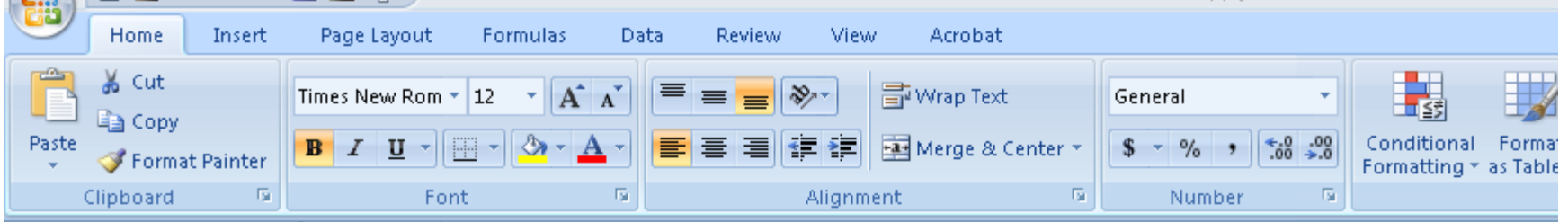
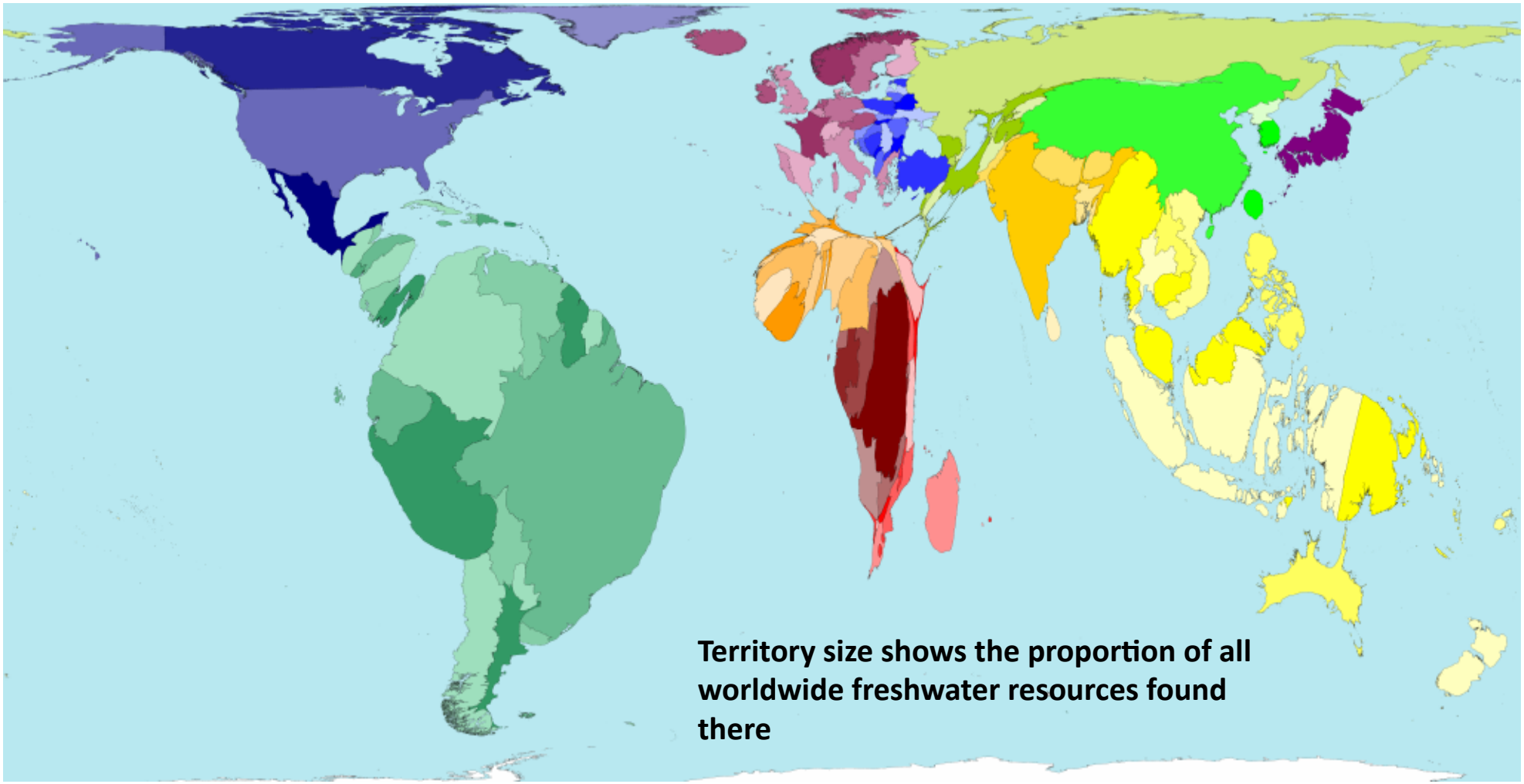


	A	B	C	D	E
1	**Table 1. Total Renewable Freshwater Supply, by Country (2010 Update)**				
2					
3	**Region**	**Country**	**Annual Renewable Water Resources (km^3/yr)**	**Year of Estimate**	**Source of Estimate**
4					
5	AFRICA	Algeria	11.6	2005	c
6		Angola	184.0	1987	b
7		Benin	25.8	2001	l
8		Botswana	14.7	2001	l
9		Burkina Faso	17.5	2001	l
10		Burundi	3.6	1987	b
11		Cameroon	285.5	2003	m
12		Cape Verde	0.3	2005	c
13		Central African Republic	144.4	2005	c
14		Chad	43.0	1987	b
15		Comoros	1.2	2005	c
16		Congo	832.0	1987	b
17		Congo, Democratic Republic (formerly Zair	1283	2001	l
18		Cote D'Ivoire	81	2001	l
19		Djibouti	0.3	2005	c

Water Resources (Worldmapper View)



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Bad data news

- These tools are not adequately utilized.
- The resources (and often the political will) for collecting data is limited.
- Too little money has been made available for building and maintaining adequate ground and remote-observing platforms
- Even those few in development are at high risk of delay or cancellation.
- We have many conflicting, overlapping, intersecting institutions/initiatives/efforts underway.

Alphabet Hydrological Soup: Organizations, Instruments, Satellites, Programs

- CLIVAR, GEWEX, CLIC, GRACE, GEO-CAPE, PATH, SMAP, SWAT, GPM, SWPP/NPOESS, GACM, GPSRO, DESDynI, ICESat-II, NWIS, ARM, AQUASTAT, GRDC, TRMM, IGRAC, CUASHI, GRDI, GLDAS, GFCS, CHyMP, JAXA/GCOM-W, CNES/ ISRO, EUMETSAT's MetOp, NOAA's POES, JPSS, DMSP, DWSS, GMI, DPR, ESA SMOS, USGCRP, GOOS, ICSU, IGBP, IHDP, ESSP, ESSI…
- FHSWTBCKTOAOTA

("for heavens sake, who the bleep can keep track of all of these acronyms?")

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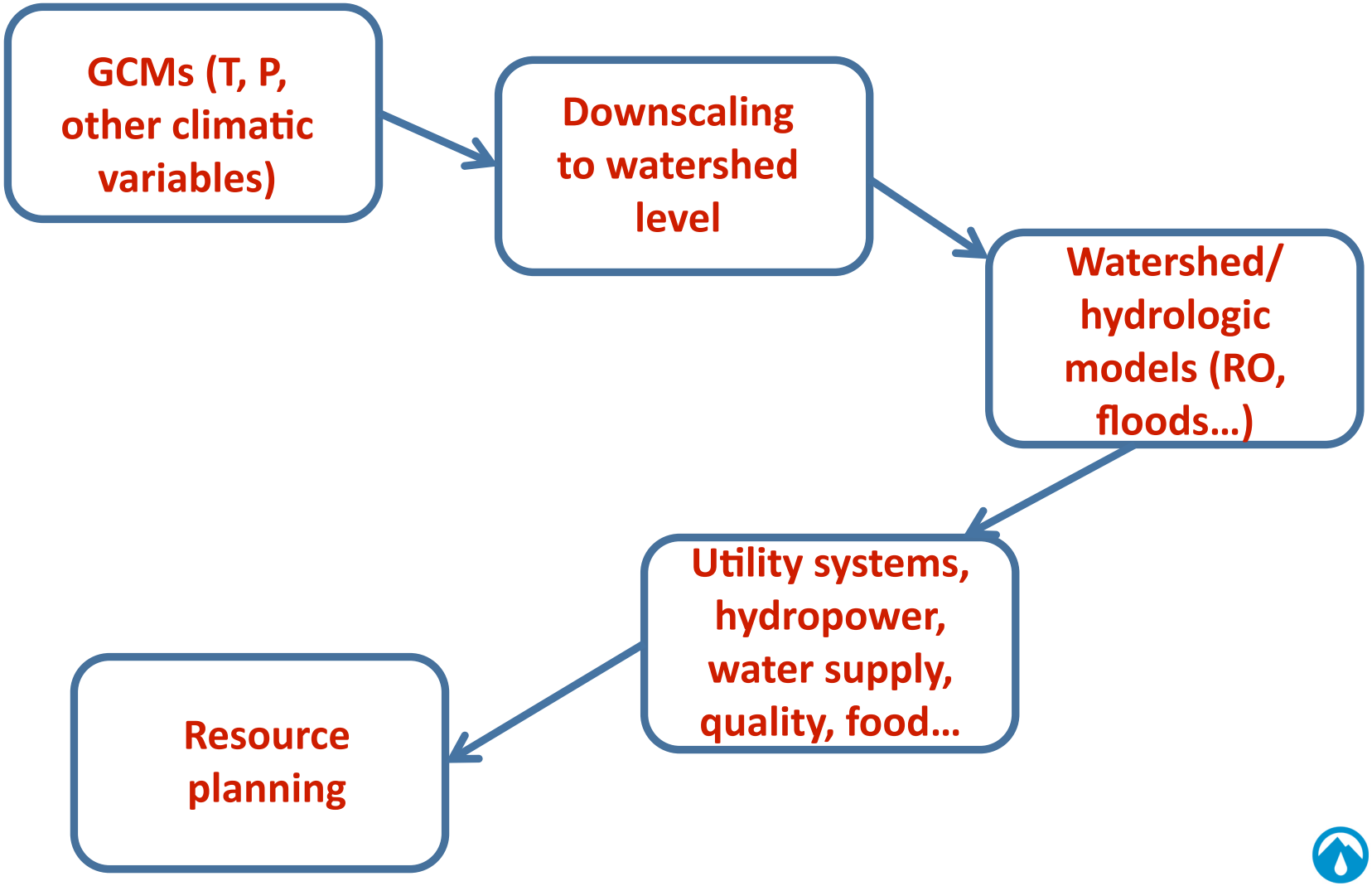
"Grand Modeling Challenge"

- To develop a new generation of "hyperresolution" hydrologic models that can exploit advances in computing power and improved access to data.
- Such models would be capable of representing the water cycle at a high spatial and temporal resolution, with improved surface and subsurface dynamics, land-ocean-atmosphere-cryosphere interactions.
- It would also permit modeling of human modifications such as dams and other artificial storage, groundwater withdrawals and recharge, alterations of nutrient flows, the impacts of urbanization, and much more.
- One example: the Community Hydrologic Modeling Platform (CHyMP)

Wood et al. (2011)

But there is also a practical need for better model integration



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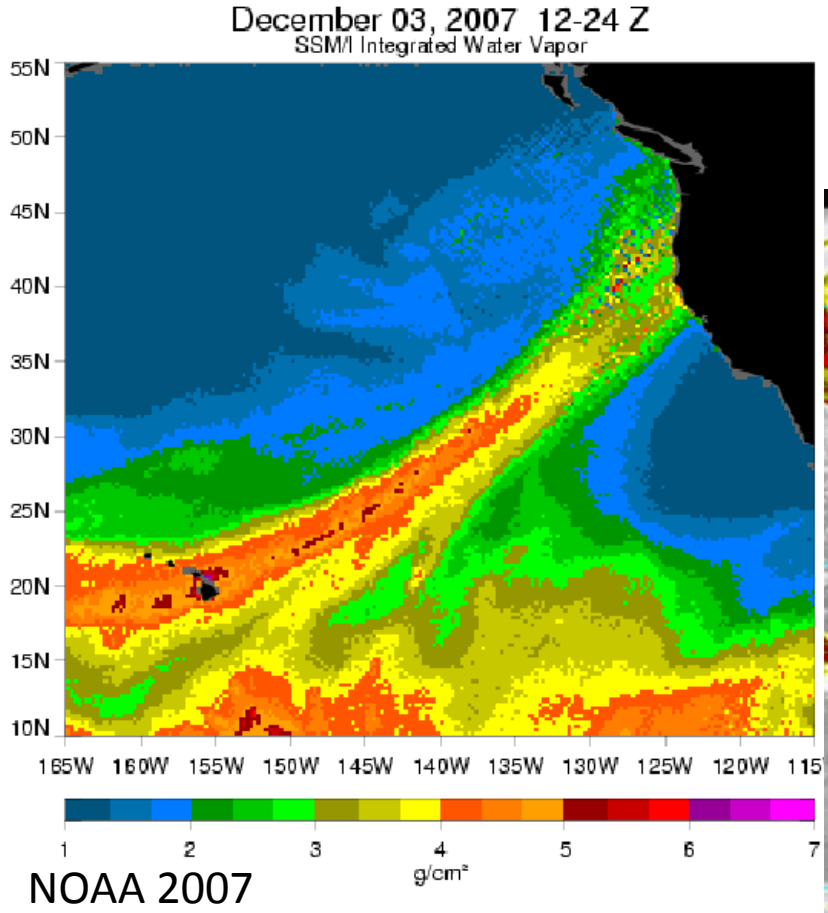
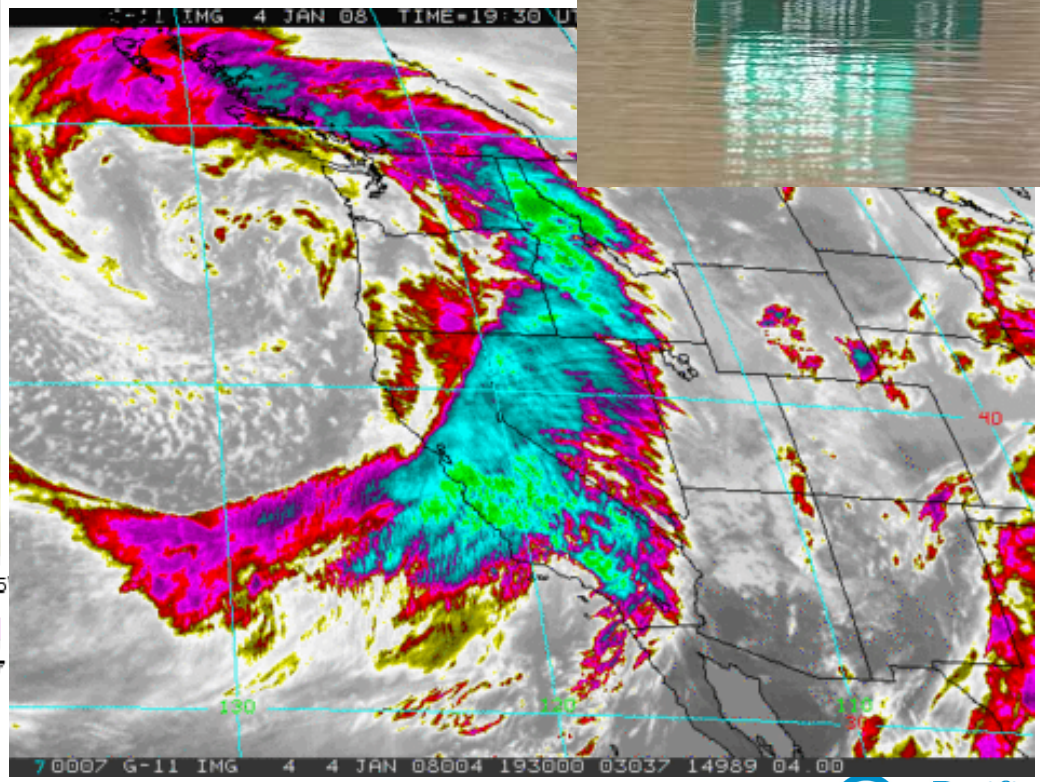
Improving understanding of extreme events is critical



NOAA 2007



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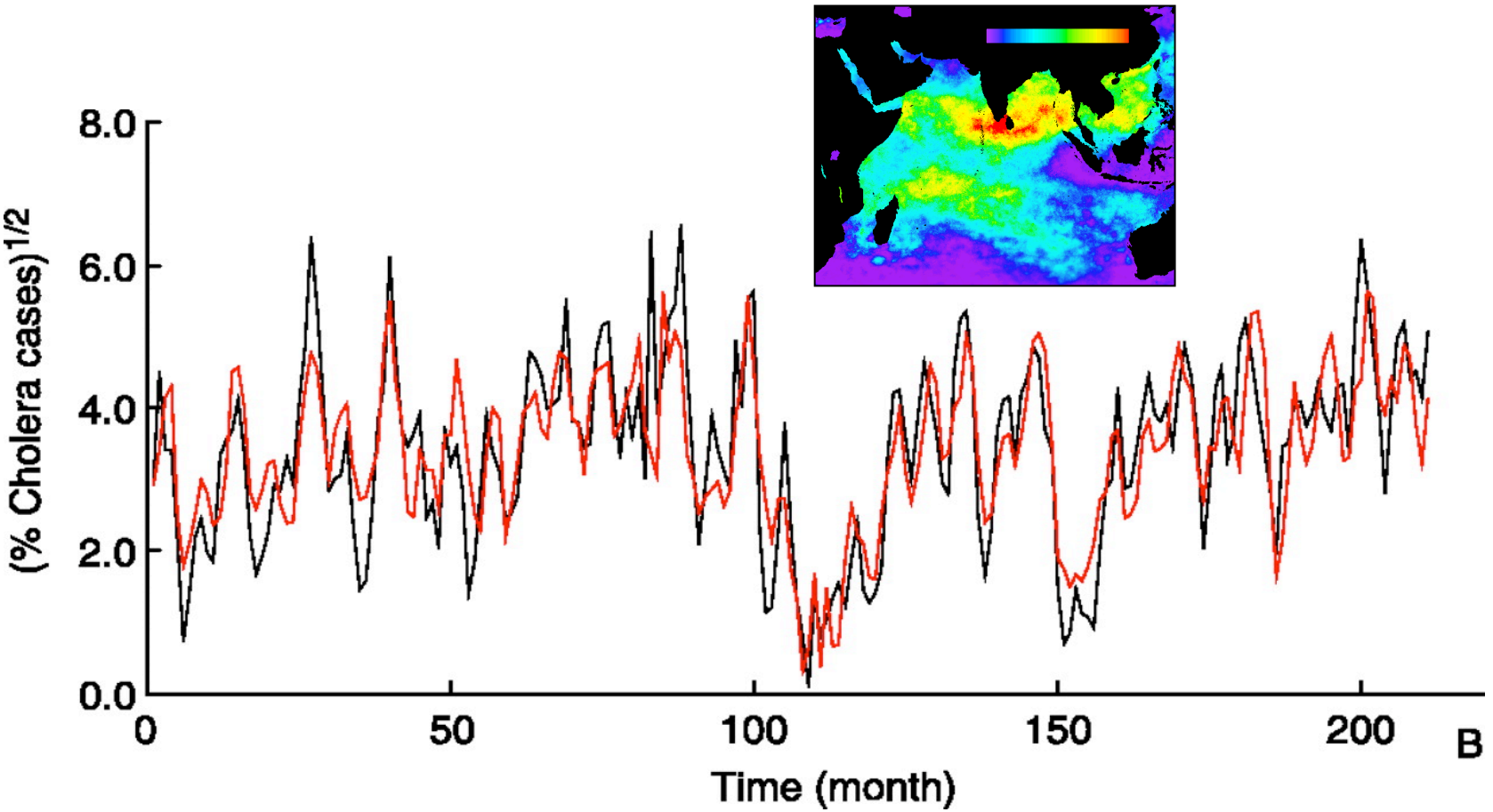
And a better understanding of unexpected connections is needed



The dynamics of cholera in Bangladesh (black line) are consistent with prediction including remote forcing by (lagged) ENSO (red line).

M Pascual et al. Science 2000; 289:1766-1769

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Summary/Conclusions

- Over the last decade there has been a transformation in the ways in which we view the hydrologic cycle at global, continental, and watershed scales.
- Water plays a central and complex role in human development and ecosystem health.
- Human activities are significantly and increasingly dominating the hydrologic cycle and are fundamentally tied to human-induced changes, especially climatic changes.
- We urgently need to improve investments in basic observational networks, basic scientific understanding, and modeling tools at all levels.
- We need to expand the next generation of researchers who can address these larger-scale challenges, with a broader perspective than provided by the traditional hydrologic science community.