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science for a changing world

Science and Technology in Support of Water for the People of Africa

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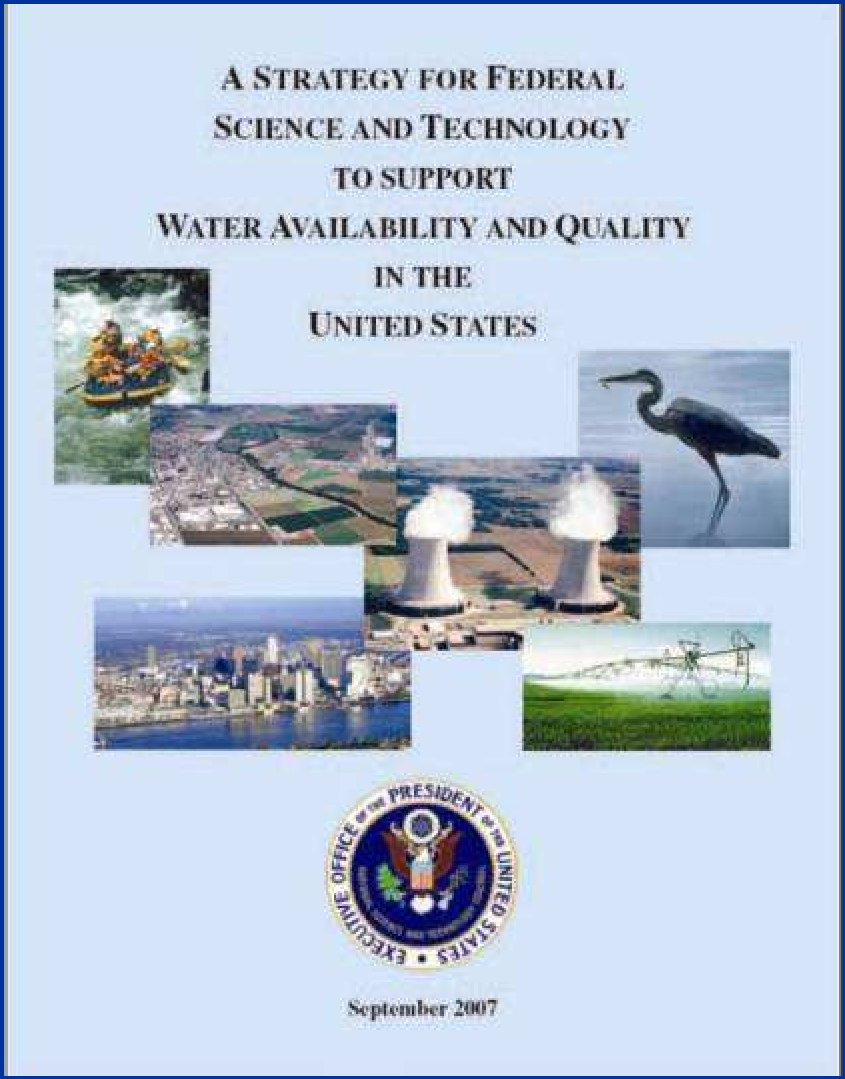
U.S. Department of the Interior
U.S. Geological Survey

SWAQ: Subcommittee on Water Availability and Quality

Recent publication of a strategy for science and technology related to water: primarily a domestic focus



USGS www.ostp.gov/nstc/html/_reports.html

Goals for the science and technology are the same across the globe

- Know the resource (measure and account for our water)
- Grow the resource (expand fresh water supplies while using existing supplies more efficiently)
- Manage the resource (predictive tools for improved water management)

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Know the Resource: You can’t manage what you don’t measure

- Identify and map the aquifers
- Monitor and report on the resource

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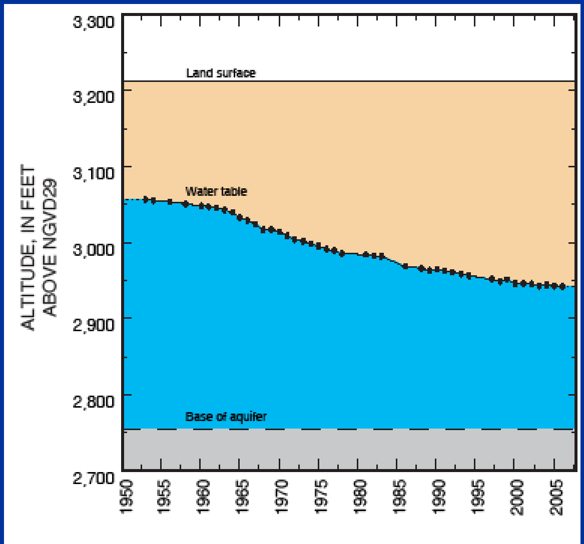
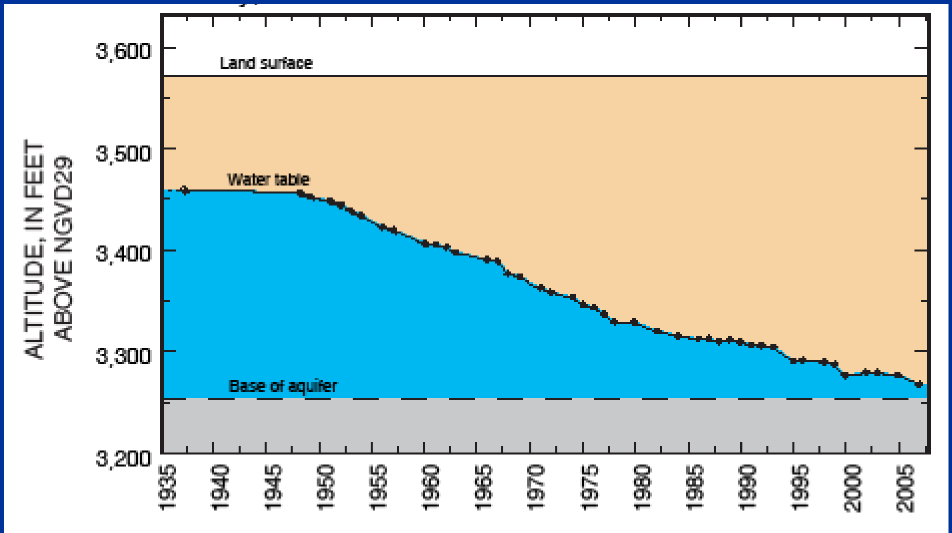
Ground-water depletion on the High Plains

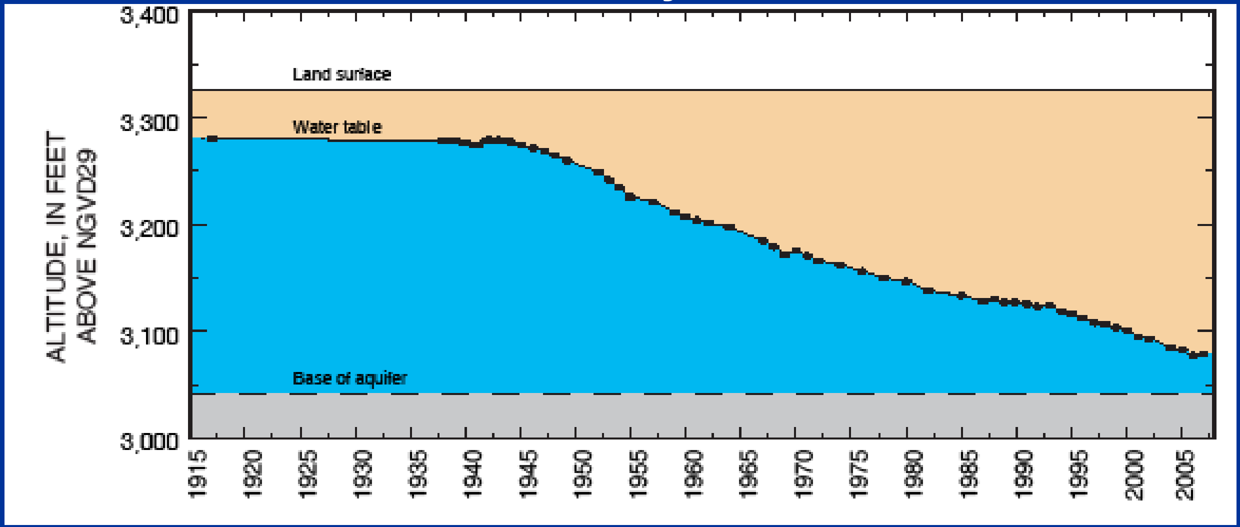
Hansford County, TX



Swisher County, TX



Hale County, TX



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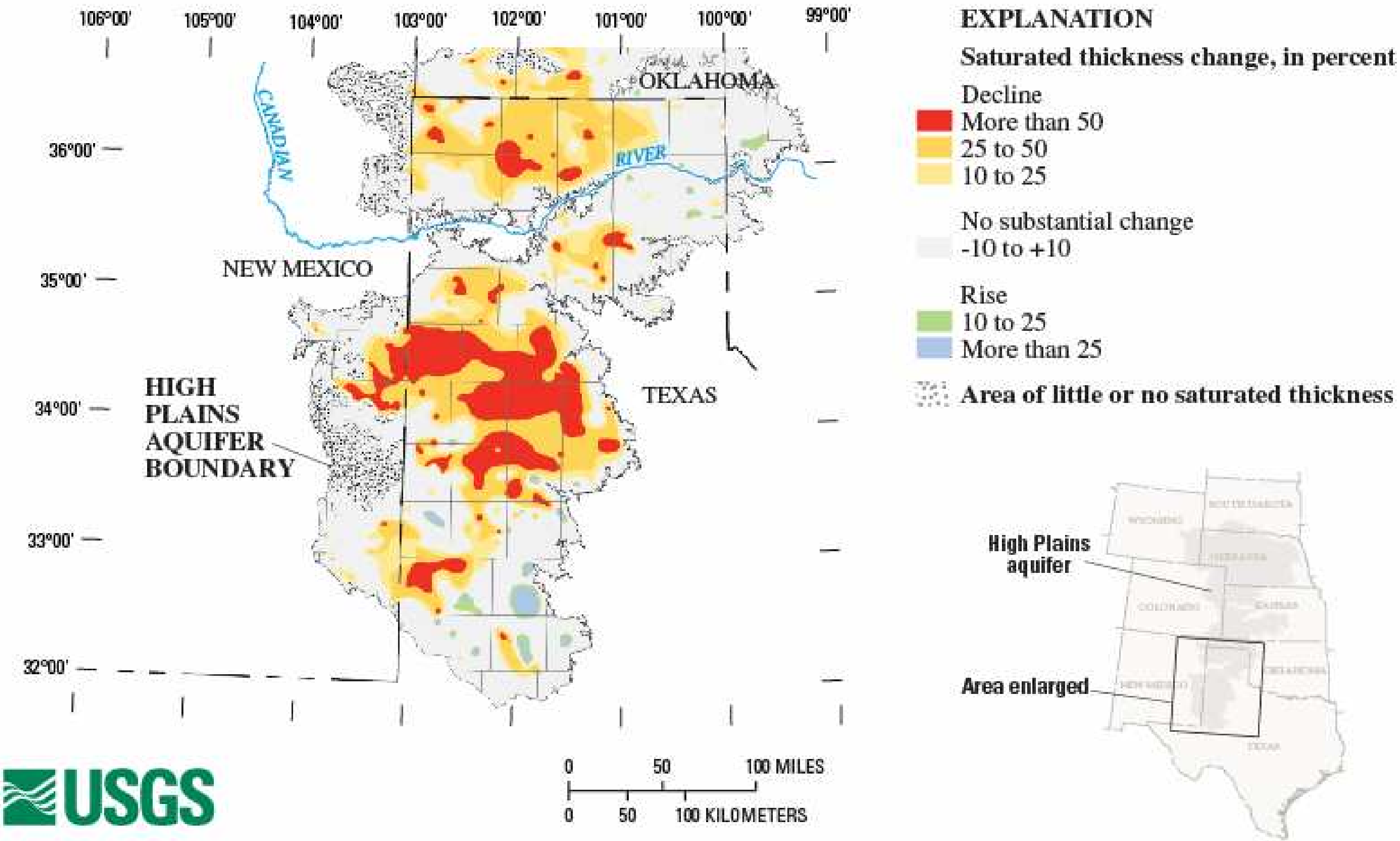
Percentage change in saturated thickness of the High Plains aquifer, predevelopment to 2005



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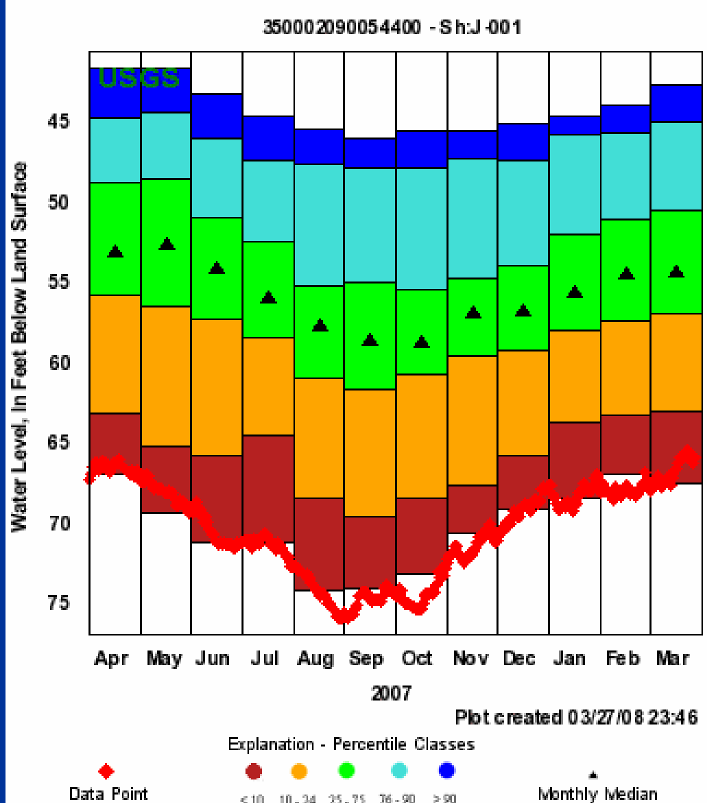
Ground-water level monitoring

Site Statistics



Most recent data value: 66.09 on 3/27/2008
Period of Record Monthly Statistics for 350002090054400
Depth to water level, feet below land surface
All Approved Continuous & Periodic Data Used In Analysis

Note: **Bold** values in the table indicate closest statistic to the most recent data value.

Month	Lowest Level	10th %ile	25th %ile	50th %ile	75th %ile	90th %ile	Highest Level	Number of Years
Jan	68.41	63.75	57.96	55.66	52.02	45.81	44.60	43
Feb	66.95	63.28	57.40	54.55	51.04	45.64	44.00	41
Mar	**67.44**	**63.05**	56.93	54.45	50.44	44.96	42.72	41
Apr	66.91	63.07	55.80	53.16	48.78	44.77	41.68	43
May	69.29	65.16	56.46	52.71	48.52	44.46	41.62	39
Jun	71.13	65.75	57.22	54.20	51.01	46.00	43.24	42
Jul	71.13	64.45	58.46	56.02	52.41	47.38	44.67	40
Aug	74.14	68.36	60.95	57.68	55.16	47.62	45.41	41
Sep	74.07	69.53	61.60	58.69	54.94	47.85	46.00	41
Oct	73.14	68.41	60.68	58.72	55.47	47.85	45.55	43
Nov	70.56	67.65	59.55	56.90	54.69	47.23	45.51	39
Dec	69.13	65.80	59.21	56.85	53.95	47.36	45.05	41

Statistics Options

View month/year statistics

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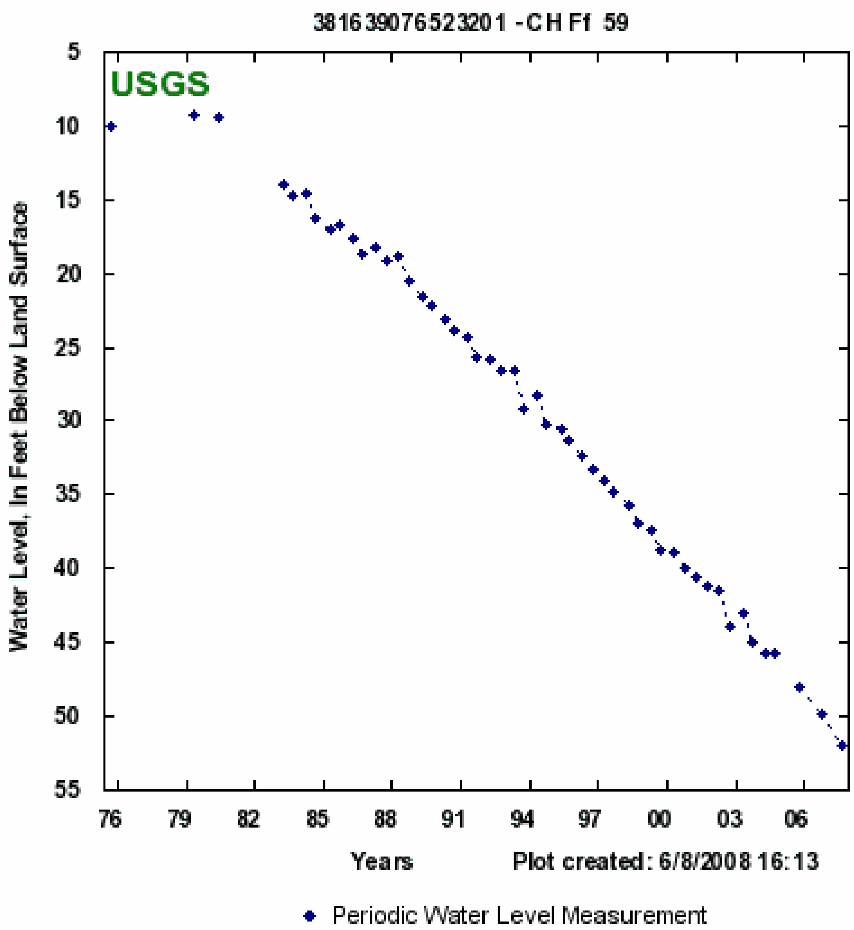
Documenting long-term water level declines An example from Charles County, Maryland

Periodic Ground-Water Data



Summary Statistics for Period of Record Periodic Water Levels		
Depth to water level, feet below land surface		
Approved Periodic Water Level Values		
Begin Date	**End Date**	**Number of Values**
09/02/75	09/06/07	50

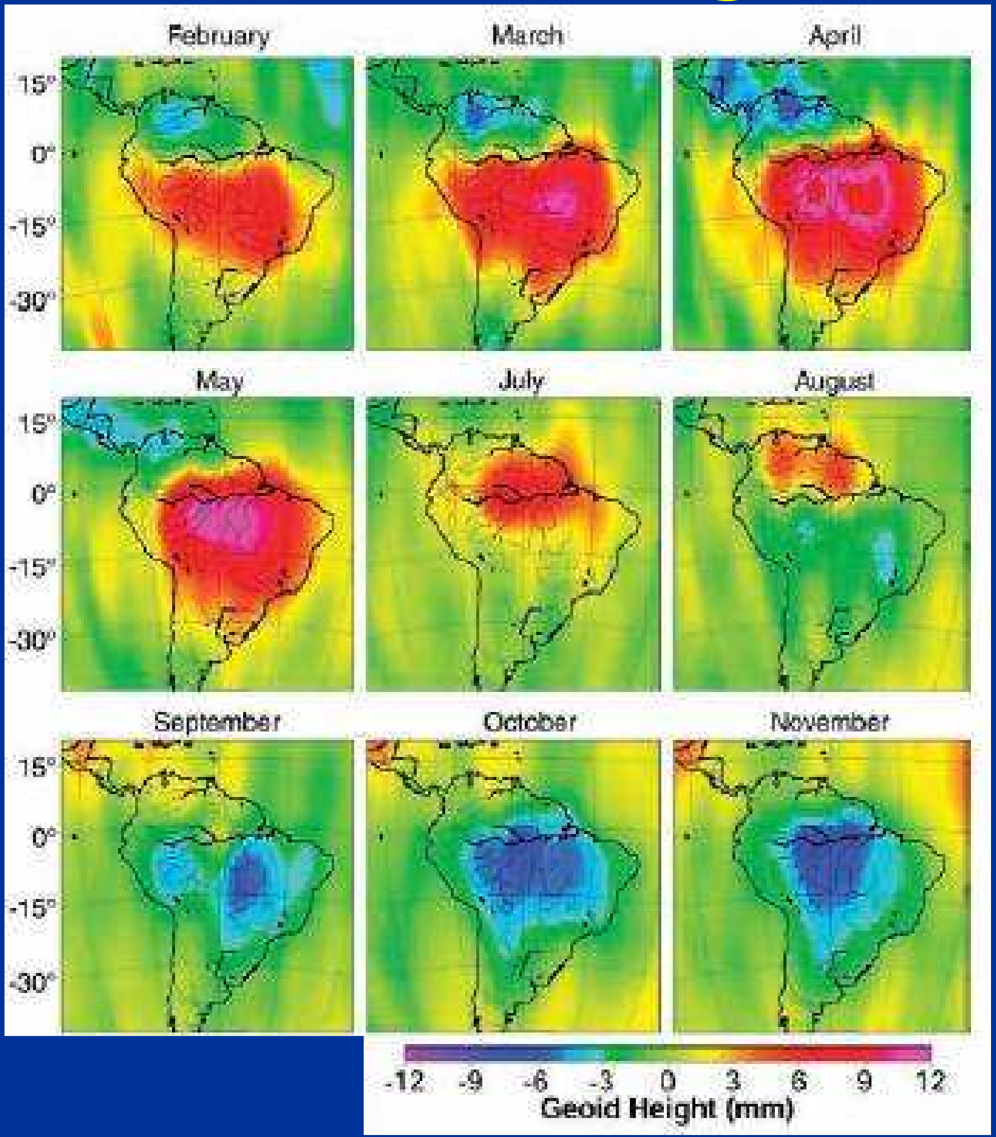
Highest WL	Date of Highest WL	Lowest WL	Date of Lowest WL
9.18	05/15/79	51.97	09/06/07

Ground-Water Levels Options

- View NWISWeb ground-water levels page
- View annual monthly statistics for all data types
- Download ground-water levels in text format

Use of gravity to estimate changes in water in storage

- From space: Grace mission
- From the land surface with micro-gravity meters



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Example from Africa
Water Exploration in Darfur-Sudan Using Remote Sensing

Dr. Alain Gachet
CEO of Radar Technologies France

Dr. Saud Amer
USGS

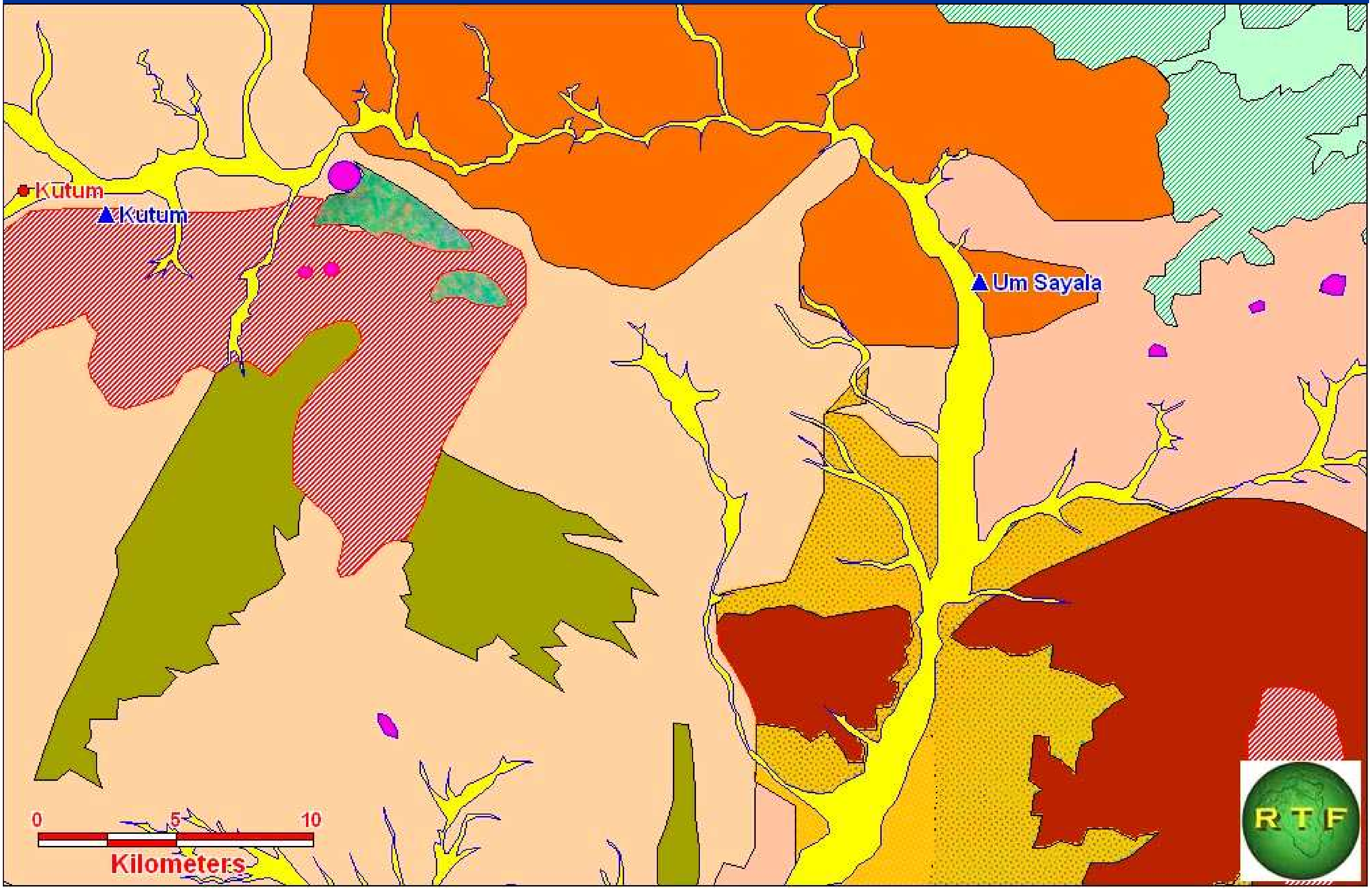
U.S. Department of the Interior
U.S. Geological Survey

www.radar-technologies.com

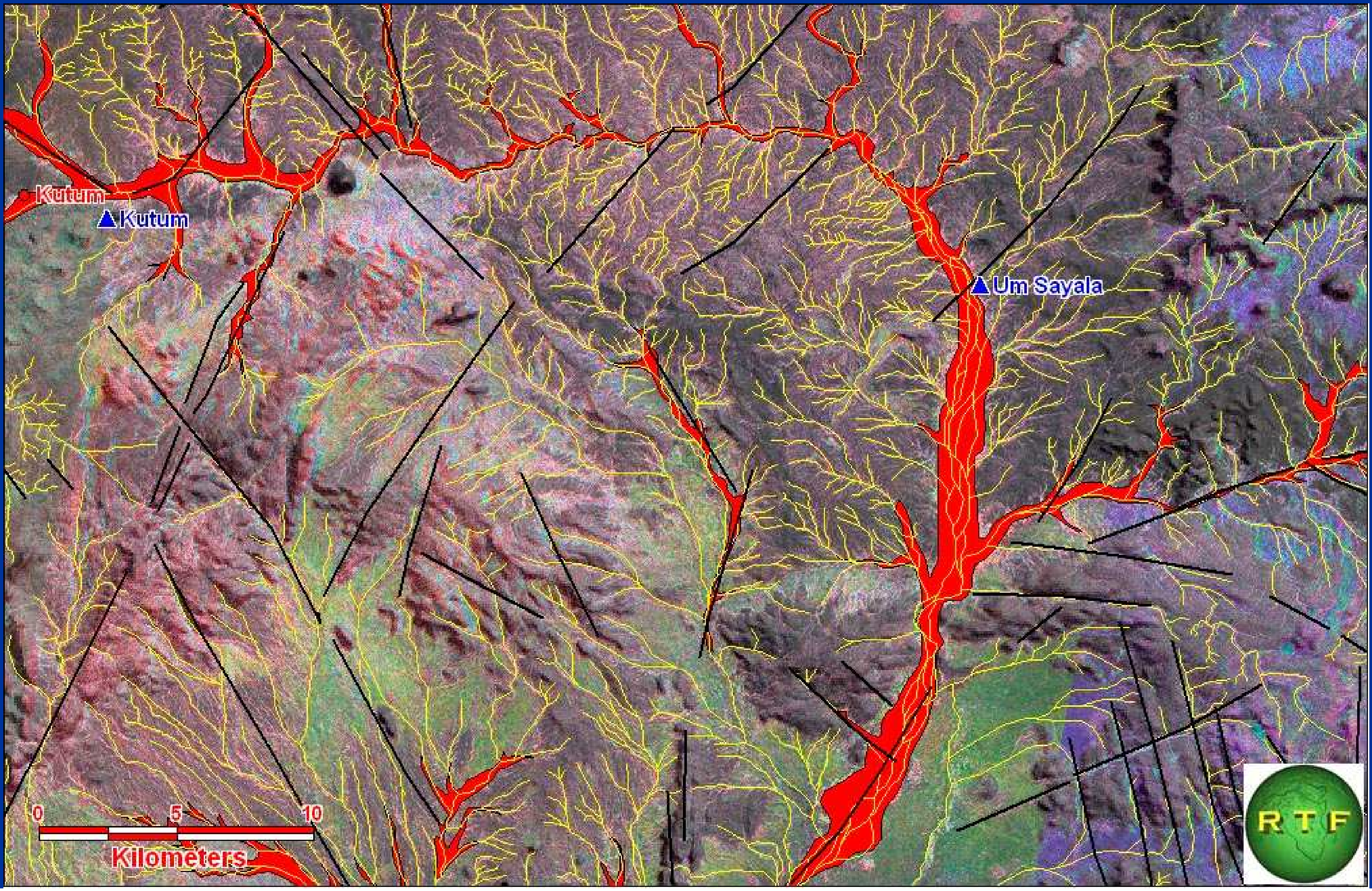
Refugees along the 650 km Chad-Sudan border

Photos Helene CAUX

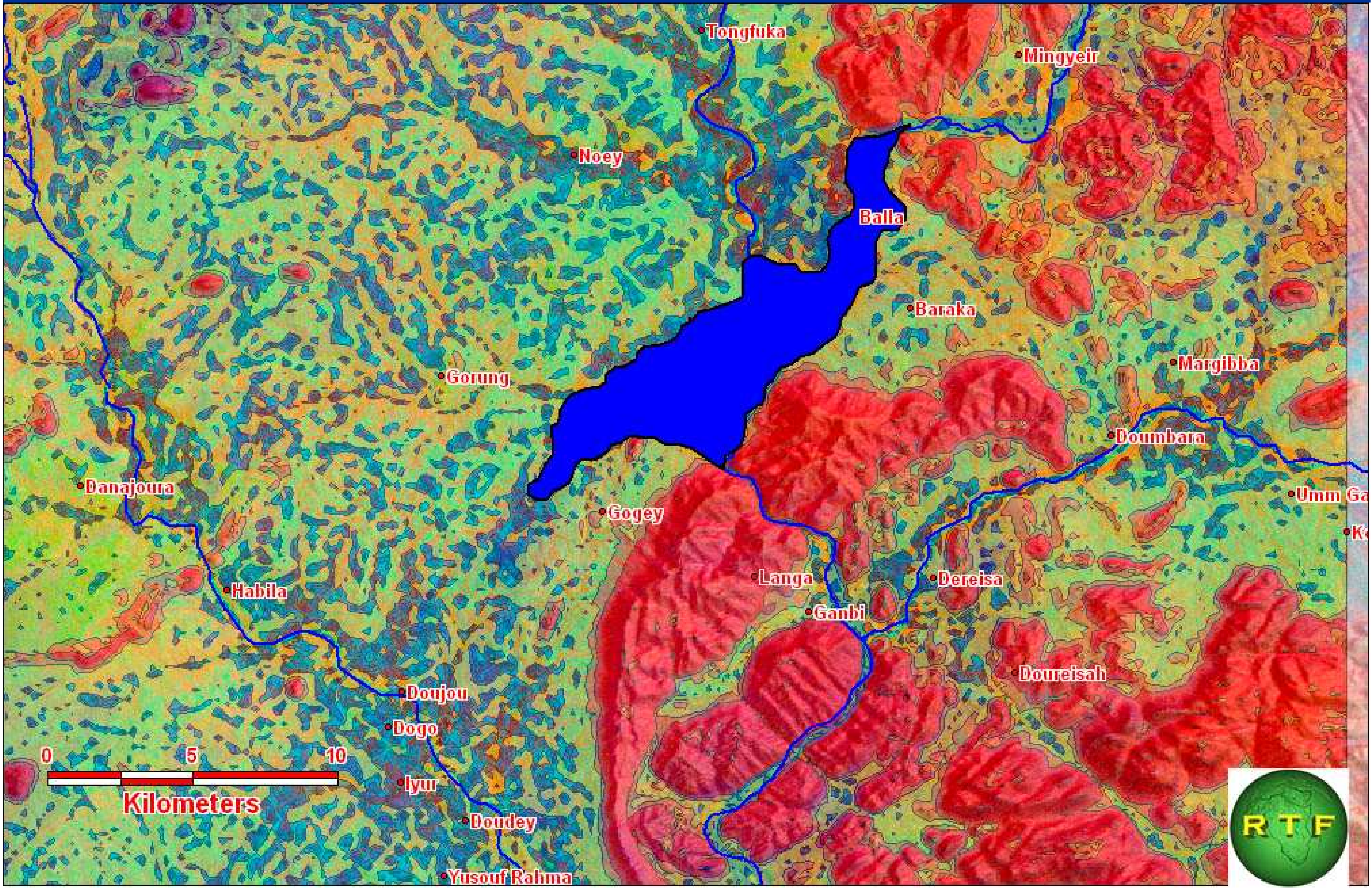
Geologic features extracted using Landsat



Radar techniques to detect and map potential aquifers



Identify micro-dam sites to recharge aquifers and provide water for agriculture and livestock



Accomplishments

- Identify water resources
- Provide precise drilling instructions
- Identify micro-dam sites for:
  - Aquifer recharge
  - Water storage
  - Agricultural use
  - Power generation
  - Reduction of soil erosion

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Know the Resource: You can’t manage what you don’t measure

- Streamflow
- Monitor and report on the resource
  - Know how it is changing over decades
  - Know conditions day to day, week to week
- Data are limited in Africa

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Monitoring streamflow and reporting in real time

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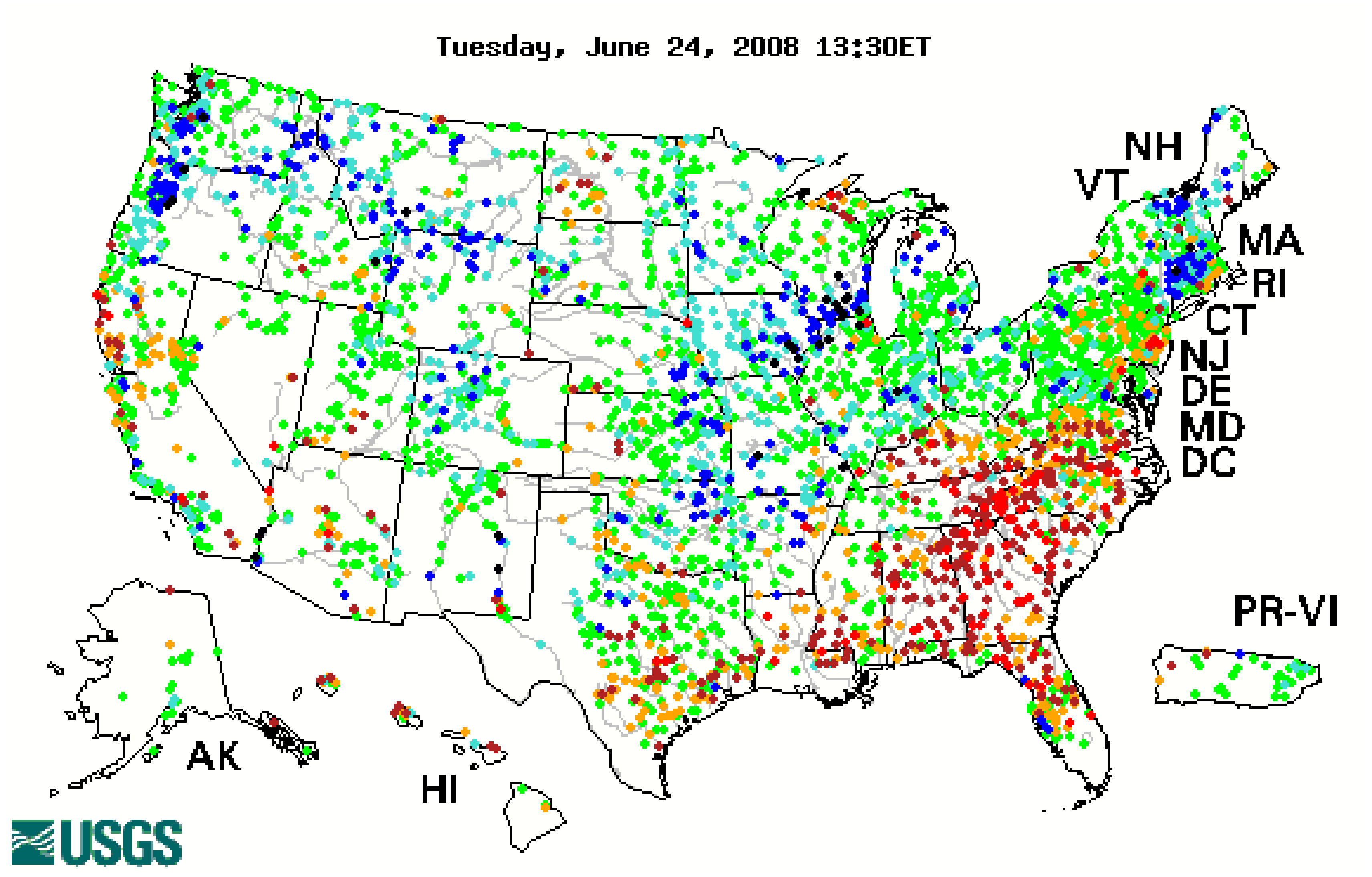
Waterwatch

A snapshot of streamflow conditions



Grow the Resource

- New treatment approaches, removal of salinity, pathogens, metals, etc.
- Reliable supply is a function of total supply and storage. Enhanced by:
  - New surface storage
  - Conjunctive use of surface and ground water
  - Artificial recharge and Aquifer Storage and Recovery

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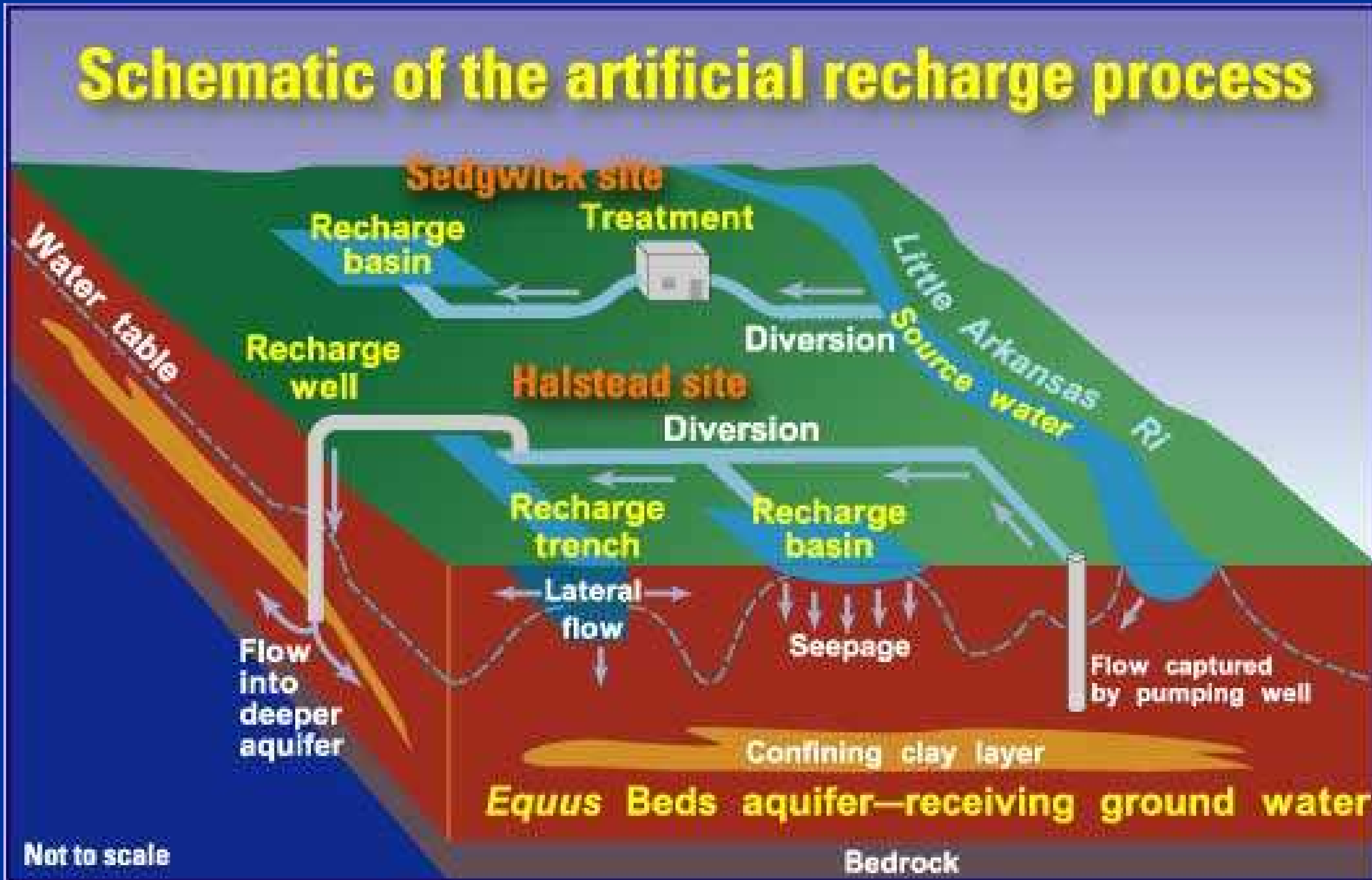
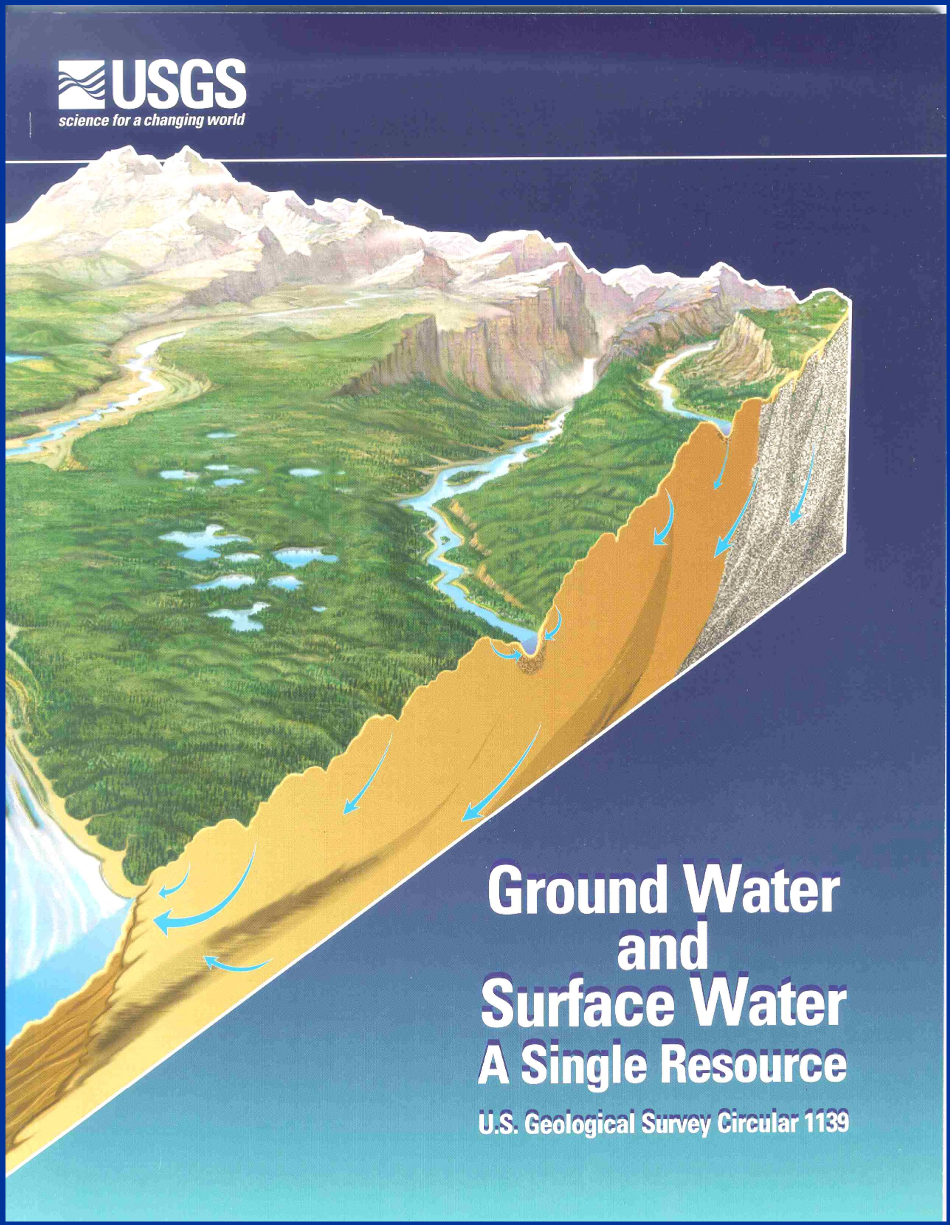


Equus Beds Recharge, near Wichita, KS

Ground water is vital to surface-water systems



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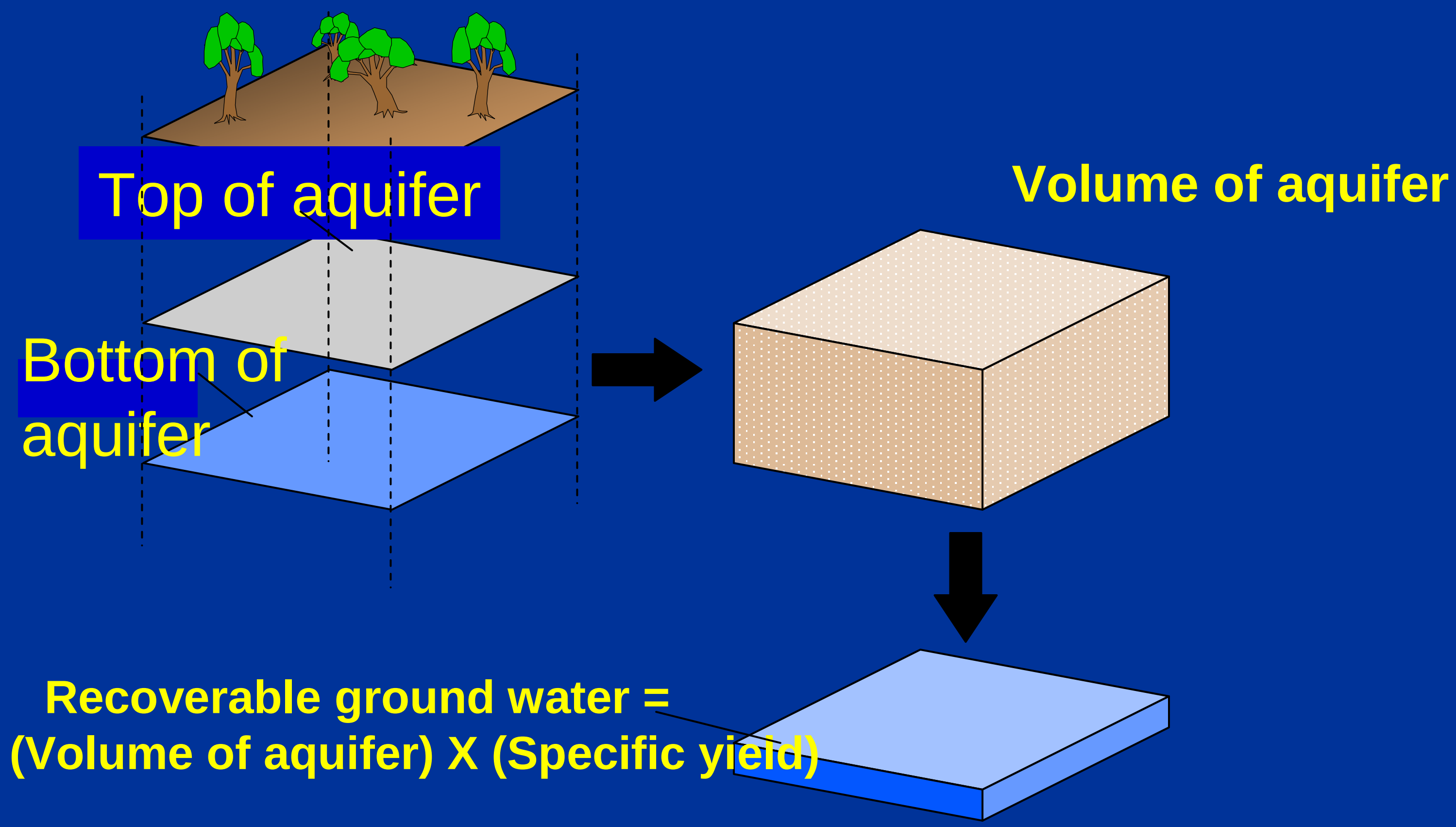
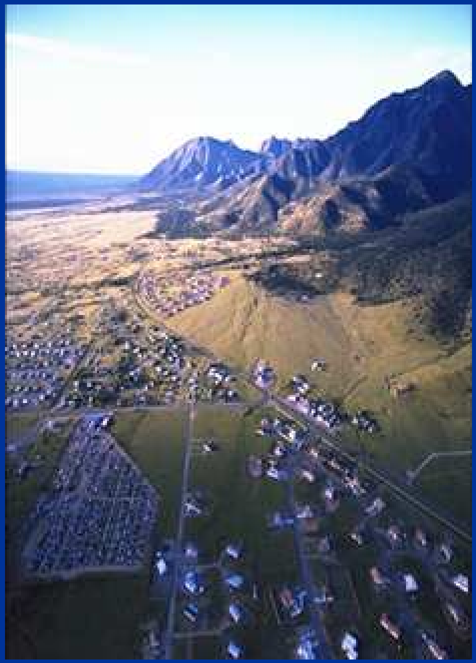
How much water do we have in the ground: The myth of recoverable ground water in storage



BUT: Depletion of a small part of the total volume of water in storage can have large effects on surface water, water quality, and subsidence which become limiting factors to development.



Upper San Pedro Basin, AZ

Houston, TX

Edwards Aquifer, TX

Republican River Basin, CO, KS, NE

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GW/SW Interactions

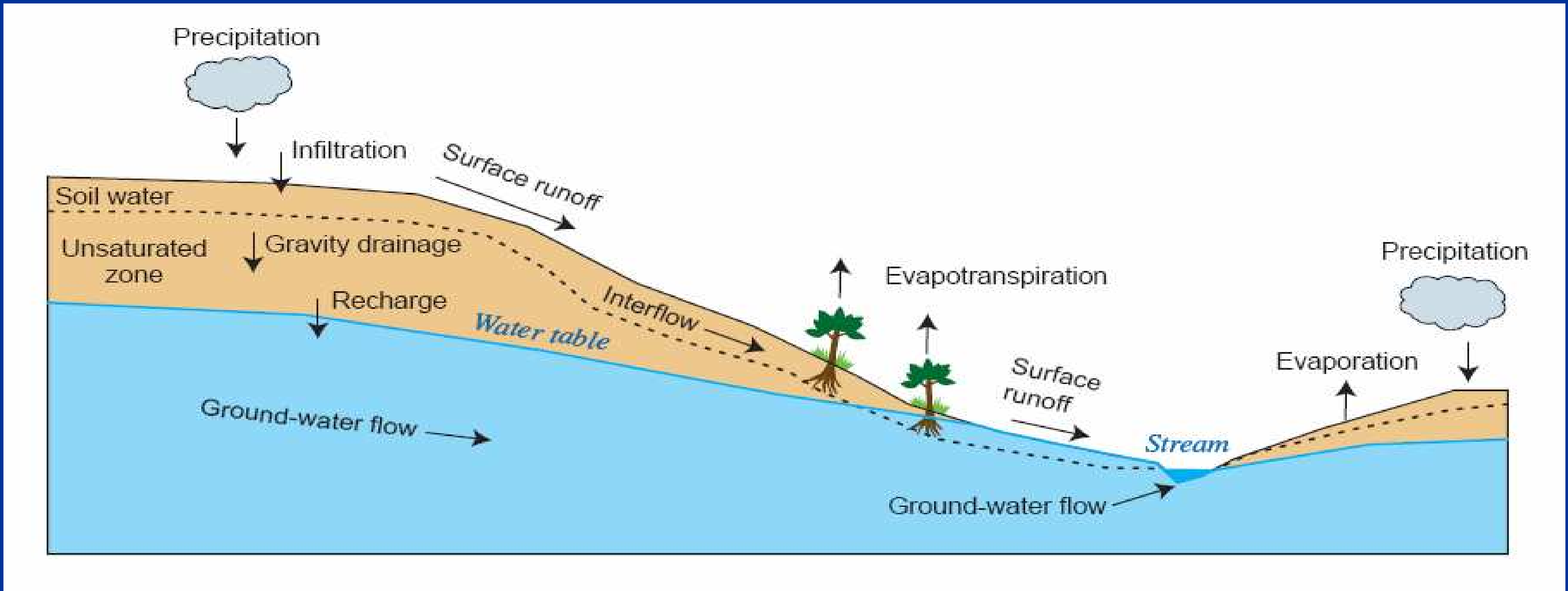
- ***Old paradigm***
  - **Small areas < 1 km**
  - **Time scales of weeks to years**
  - **Effect on streamflow**

- ***New paradigm***
  - **Tens of kilometers**
  - **Time scales of days to decades**
  - ***and*** **ecosystem and water quality issues**

Effective water management depends on understanding these interactions

GSFLOW—Couples the Precipitation-Runoff Modeling System (PRMS) with MODFLOW-2005

- **Simultaneous simulation of flow across the land surface, within saturated and unsaturated subsurface materials, and between terrestrial and surface-water domains (streams and lakes)**



Manage the Resource

- Predictive tools - for water supply and floods
- Prepare to adapt to changing climate
- Recognize the value of sharing sharing information and sharing management of the resource

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Flood early warning systems

- Floods are widespread
- Most of the human losses are in the tropics
- Growing population & urban development will increase the hazard
- Flood early warning systems can reduce the death toll
- Warning systems for Africa need to rely on satellite-based monitoring systems

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Example from Africa
Satellite Derived Rainfall Data for Flood Risk Monitoring

Guleid Artan[1], H. Gadain[2], C. Bandaragoda[3], K. Asante[1], and J. Verdin[4]

[1]SAIC TSSC Contract, U.S. Geological Survey Earth Resources Observation and Science (EROS), Sioux Falls, SD

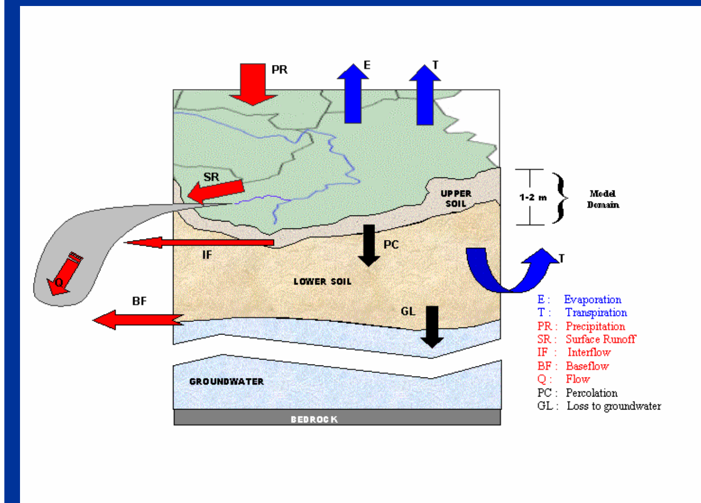
[2]UC Santa Barbara, Nairobi, Kenya

[3]Utah State University, Logan, UT

[4]U.S. Geological Survey, EROS, Sioux Falls, SD

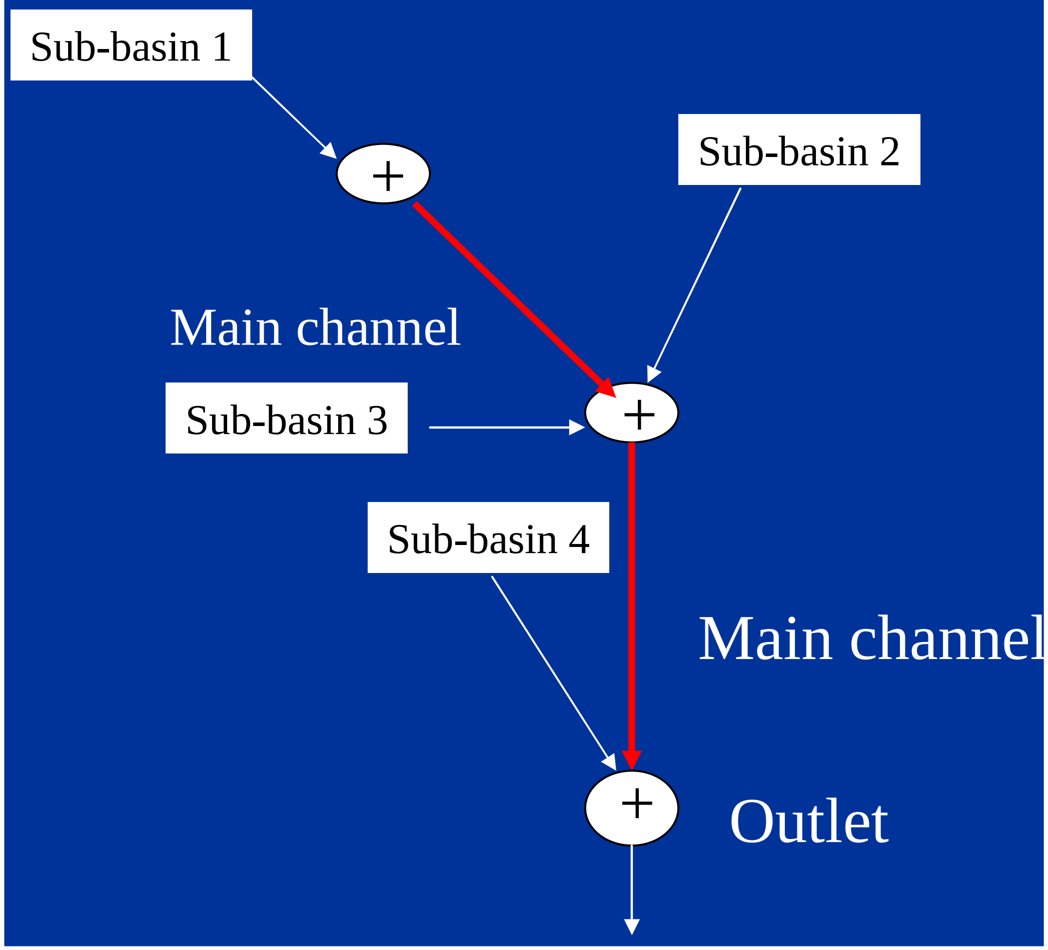
The Geospatial Stream Flow Model (GeoSFM)

Water Balance



Uses remotely sensed and continental-scale datasets, a parsimonious model

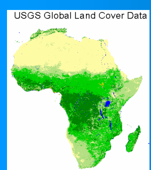
Routing



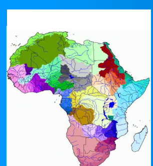
GeoSFM Database Components

Static Geographic Database

FAO Soil Data



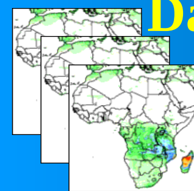
Land Use/ Land Cover



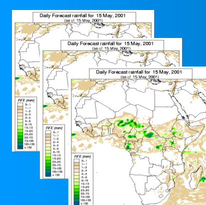
Elevation Data

Vector Data such as rivers, basins,gages…

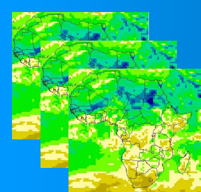
Dynamic Geographic Database



Gridded Rainfall

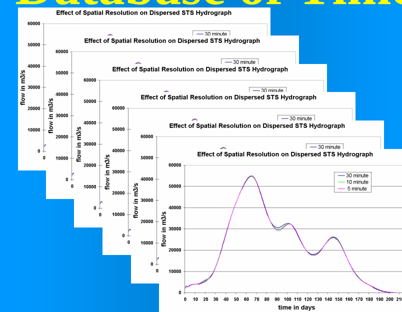


Gridded QPF



PET Fields

Relational Database of Time



1D time series of rainfall, PET, soil water, runoff and flow

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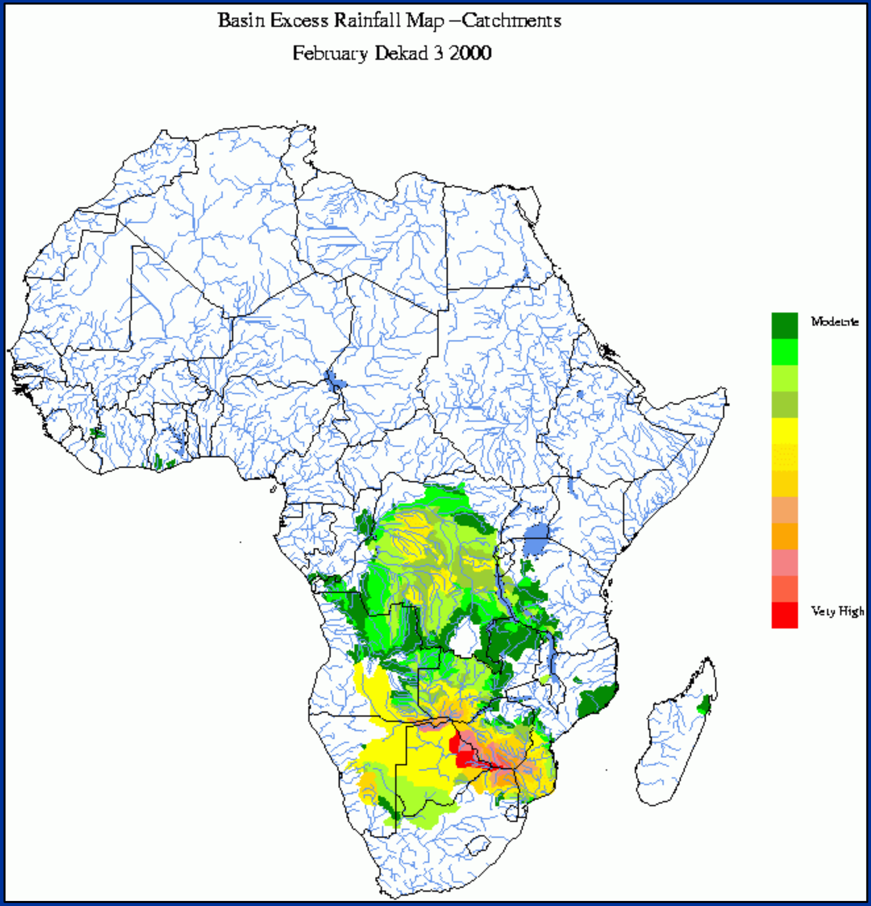
Basin Excess Rainfall Maps (BERMS)

BERMS provide a simple method for identifying areas subject to problems of flooding or excess moisture

Highlighting basins which are experiencing above-average rainfall in the previous three-day or ten-day period, and river reaches with potentially higher-than-average stream flow.



There are the high scores for the middle and lower Limpopo basin in Mozambique. The rainfall associated with the disastrous floods of February and March 2000 is clearly evident.

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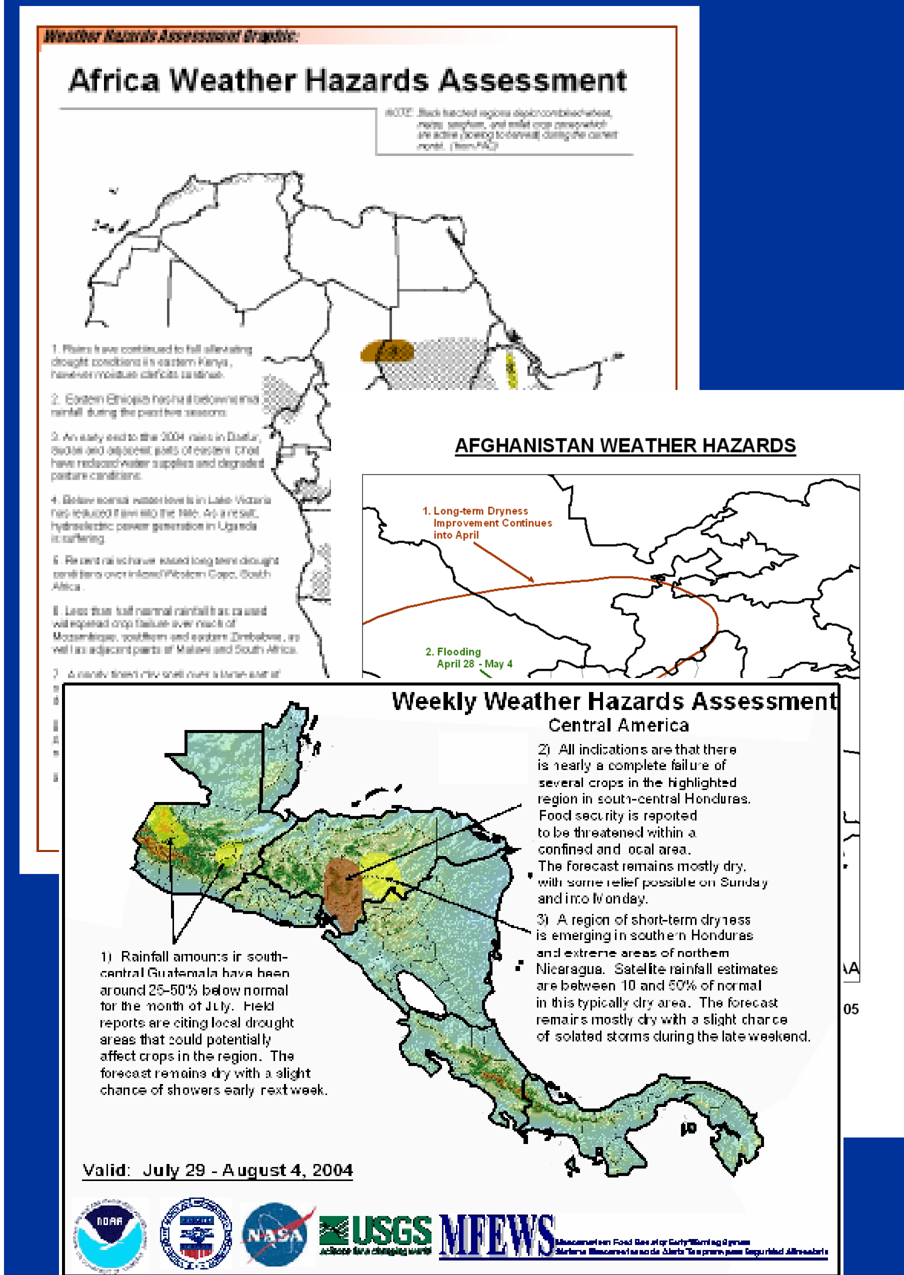
Weekly Weather Hazards Monitoring



- **A joint collaboration using resources from many organizations**
- **Inputs include field reports, model output, and meteorological and climatic analyses**
- **Recipients include national and regional agencies and NGOs.**
- **Adhoc flood/drought bulletins when severe events are forecast**

Thinking about climate change: recognize that it is one more possible stress factor along with

- Population growth
- Sanitation and waterborne disease
- Land use change (desertification, urbanization)
- Water use changes for agriculture, energy, industry

50 year evolution of our thinking about water and climate

- Starts with stationary paradigm – the future will look like the past

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50 year evolution of our thinking about water and climate

- Starts with stationary paradigm – the future will look like the past
- Recognized role of episodic but unpredictable changes in climate:
  - El Nino
  - Pacific Decadal Oscillation
  - Atlantic Multidecadal Oscillation

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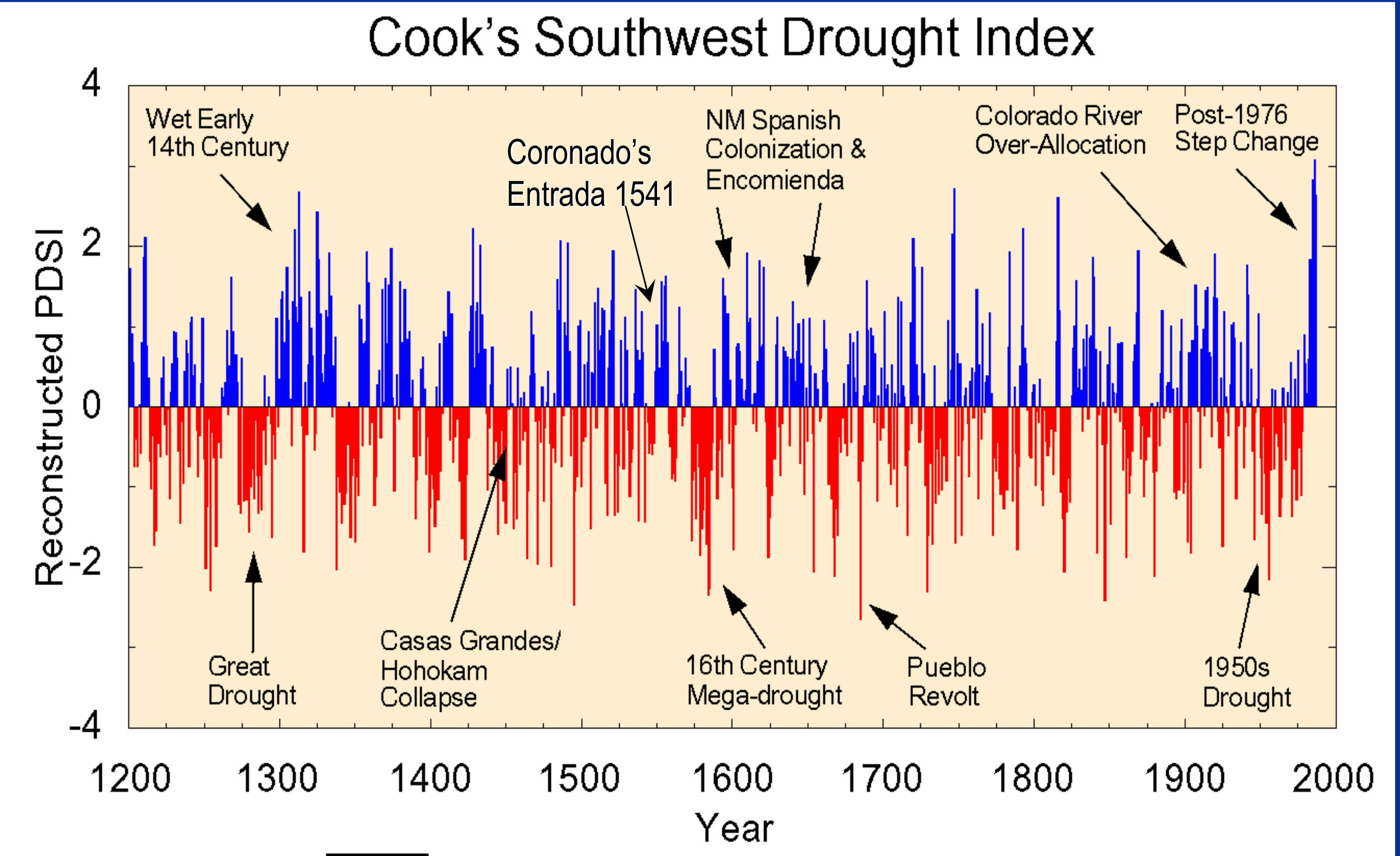
Persistent climate anomalies have had significant socio-economic impacts



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Significant Cultural Events

50 year evolution of our thinking about water and climate

- Starts with stationary paradigm – the future will look like the past
- Recognized role of episodic but unpredictable changes in climate:
  - El Nino
  - Pacific Decadal Oscillation
  - Atlantic Multidecadal Oscillation
  - Ice ages

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North America in the Ice Age

Significant climate change: why it started or why it ended—not well understood

![USGS]

50 year evolution of our thinking about water and climate

- Starts with stationary paradigm – the future will look like the past
- Recognized role of episodic but unpredictable changes in climate:
  - El Nino
  - Pacific Decadal Oscillation
  - Atlantic Multidecadal Oscillation
  - Ice ages
- Greenhouse gas induced warming

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What do we think we know about greenhouse gas induced warming?

- More evapotranspiration
- Changing circulation patterns
- Indications of longer dry periods
- Indications more rain per day on wet days
- More rain/less snow
- Sea-level rise

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Do we think the global models should be used to predict future hydrologic conditions?

- Let's try an experiment
- Use models to "hindcast" the 20th Century
- If successful: let's use the models to "forecast" the 21st Century
- (Nature, 2005, Milly et.al. of the USGS)

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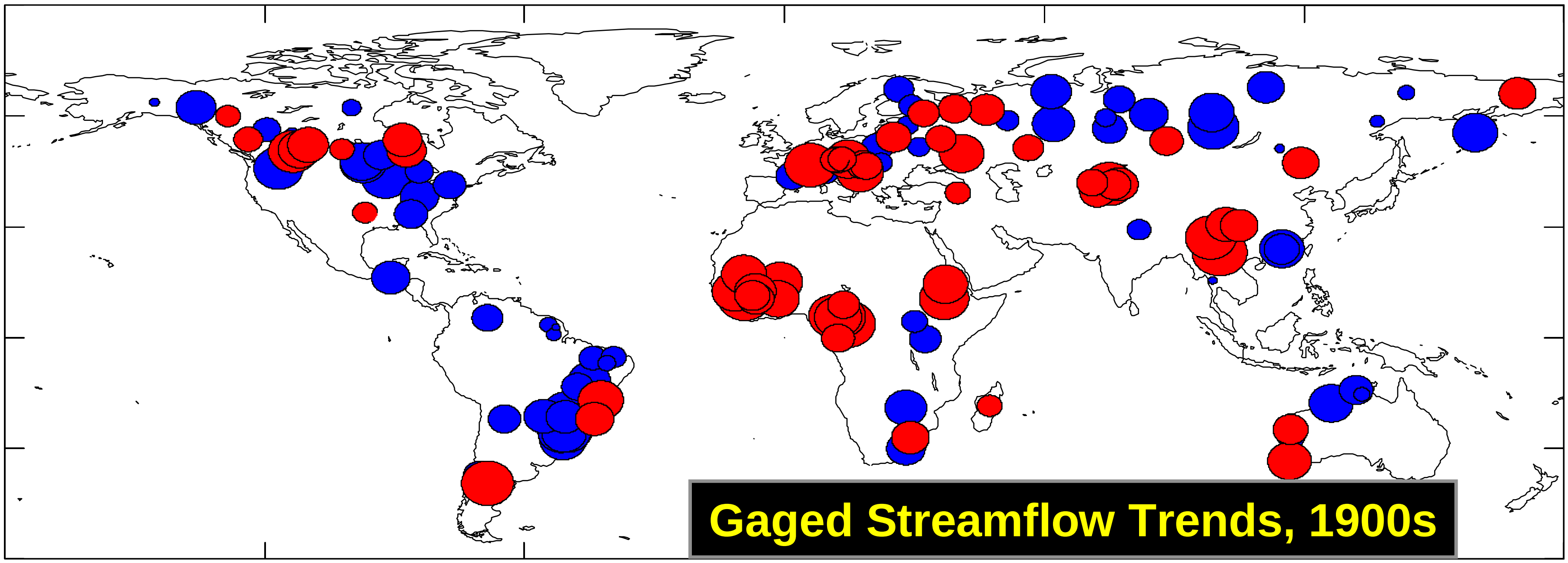
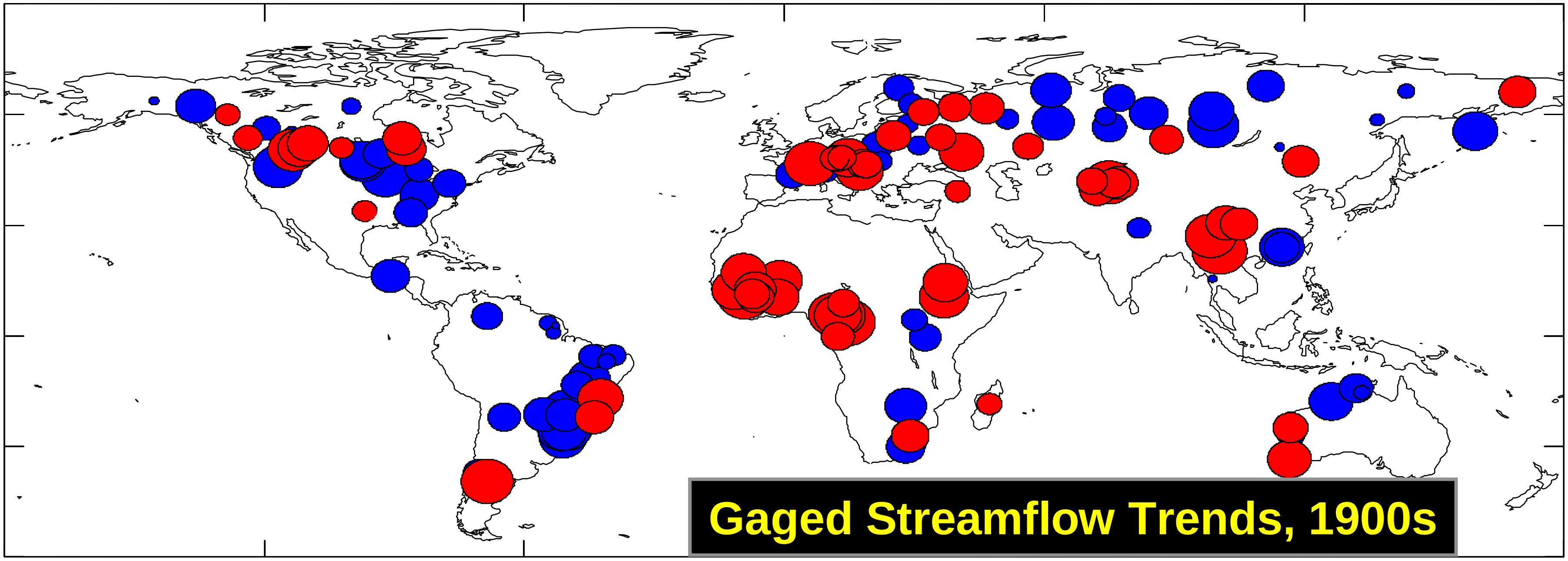
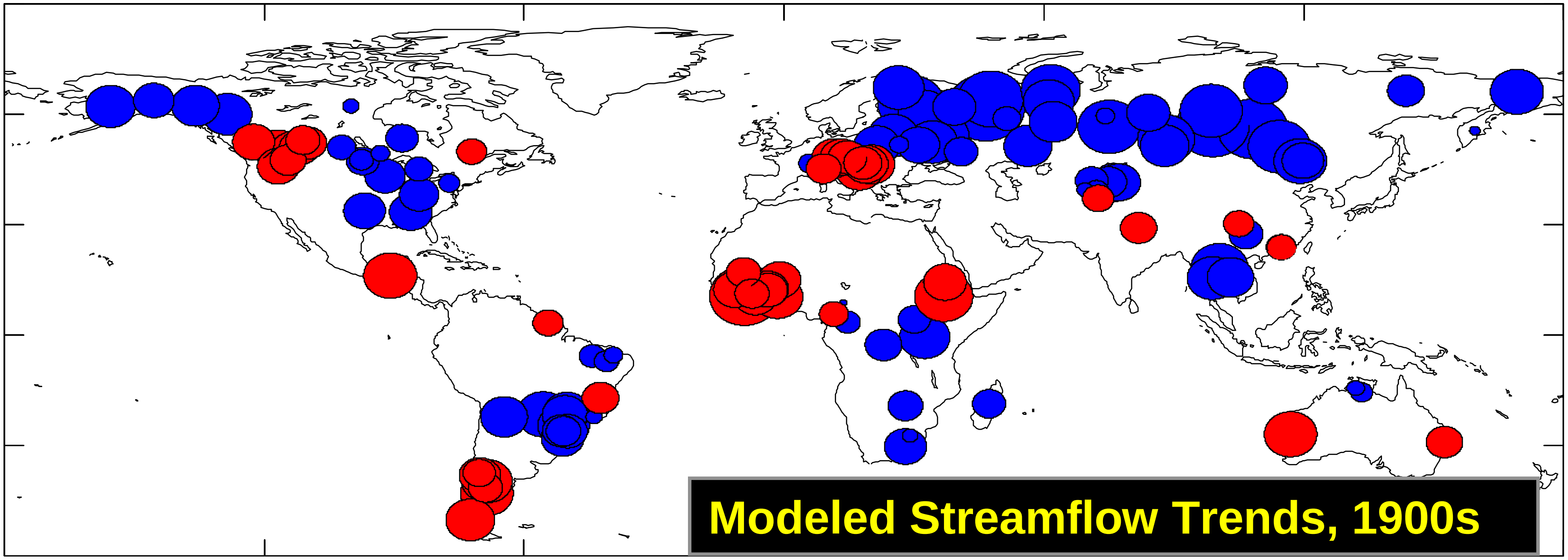

Gaged Streamflow Trends, 1900s

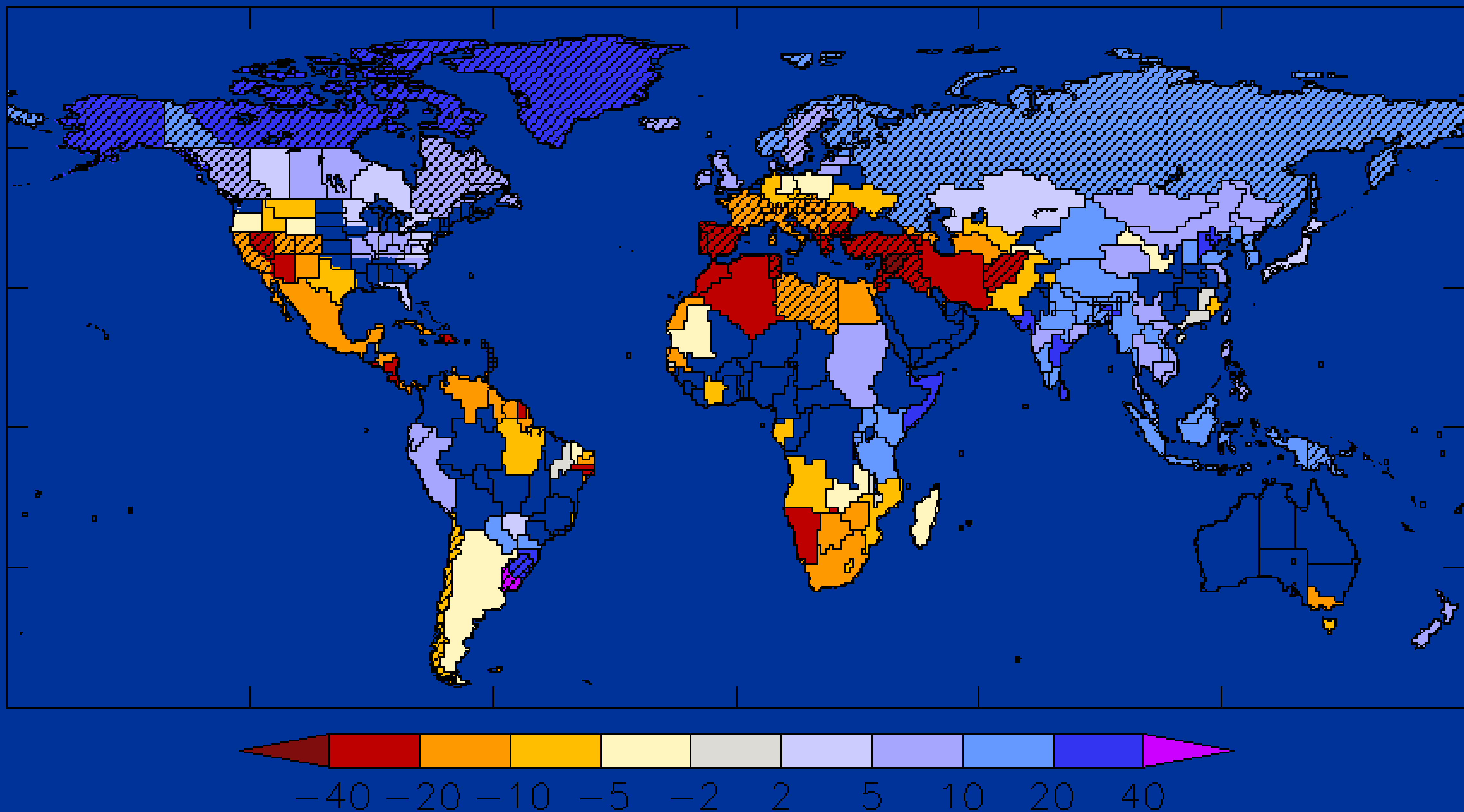

Gaged Streamflow Trends, 1900s


Modeled Streamflow Trends, 1900s

It now appears likely that a substantial part of global streamflow variability during the 20th century was not a random internal fluctuation of the climate system, but rather was caused by externally forced changes in climate.

Model-Projected Changes in Annual Runoff, 2041-2060

Percentage change relative to 1900-1970 baseline. Any color indicates that >66% of models agree on sign of change; diagonal hatching indicates >90% agreement.



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(After Milly, P.C.D., K.A. Dunne, A.V. Vecchia, Global pattern of trends in streamflow and water availability in a changing climate, *Nature*, **438**, 347-350, 2005.)

Science & Technology are crucial

- Know the resource
- Grow the resource
- Manage the resource wisely, in the face of many drivers (population, urbanization, agriculture, and climate)

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Science & Technology Capacity

- Development of African technical capacity is crucial - it starts with measurement and resource assessment

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