CUAHSI After 5 Years: Overview and Plans

CUAHSI

universities allied for water research

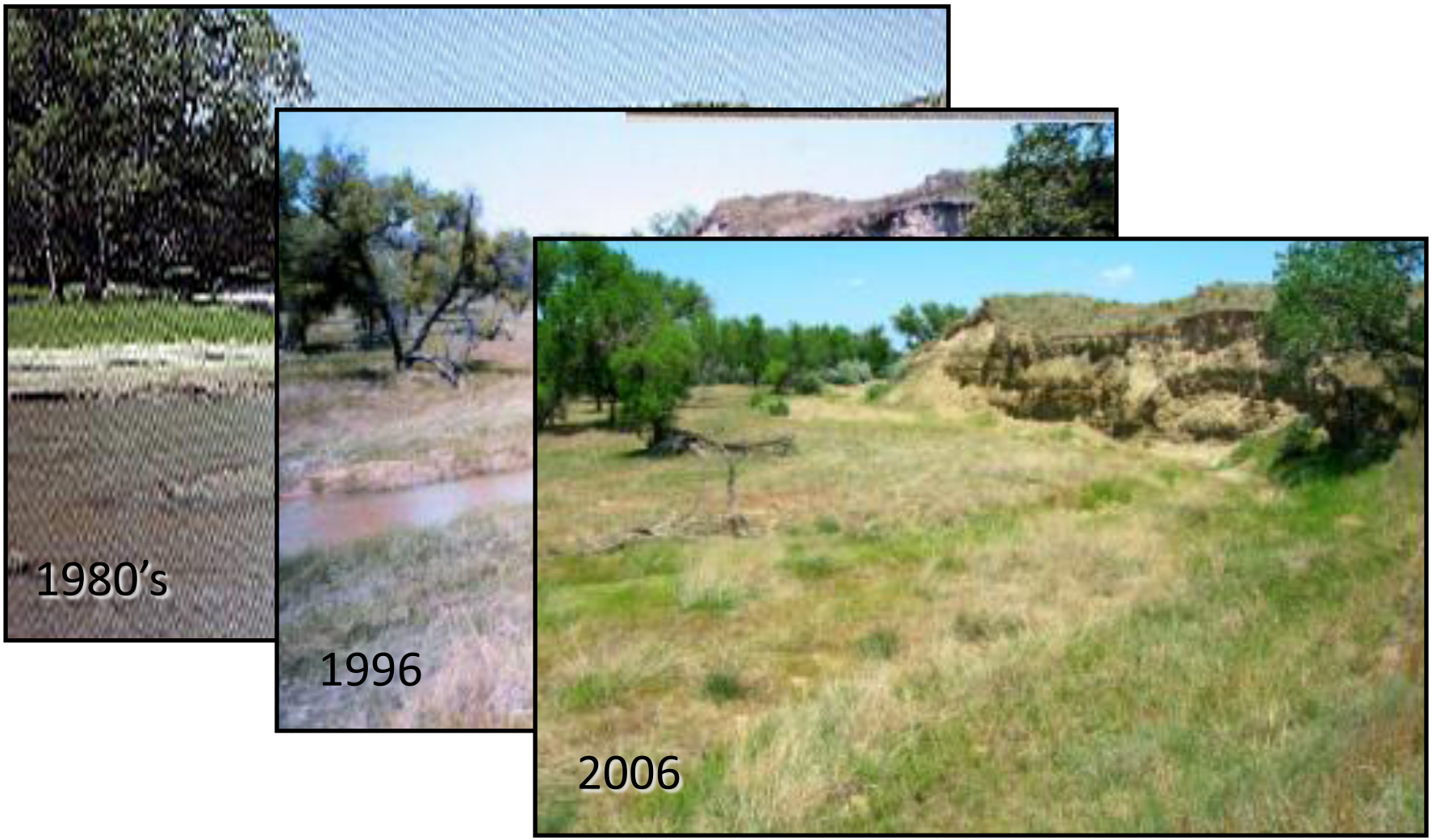
Frontiers of Hydrologic Science

- **Water and the Earth System.** Extend hydrologic theory to account for couplings among parts of hydrologic cycle and among water, rock, biota, and humans
  - Richer descriptions of water movement (flowpaths, residence time…)
  - Need for interdisciplinary research
- **Transcending place.** Establish generality of theory and improve predictive ability

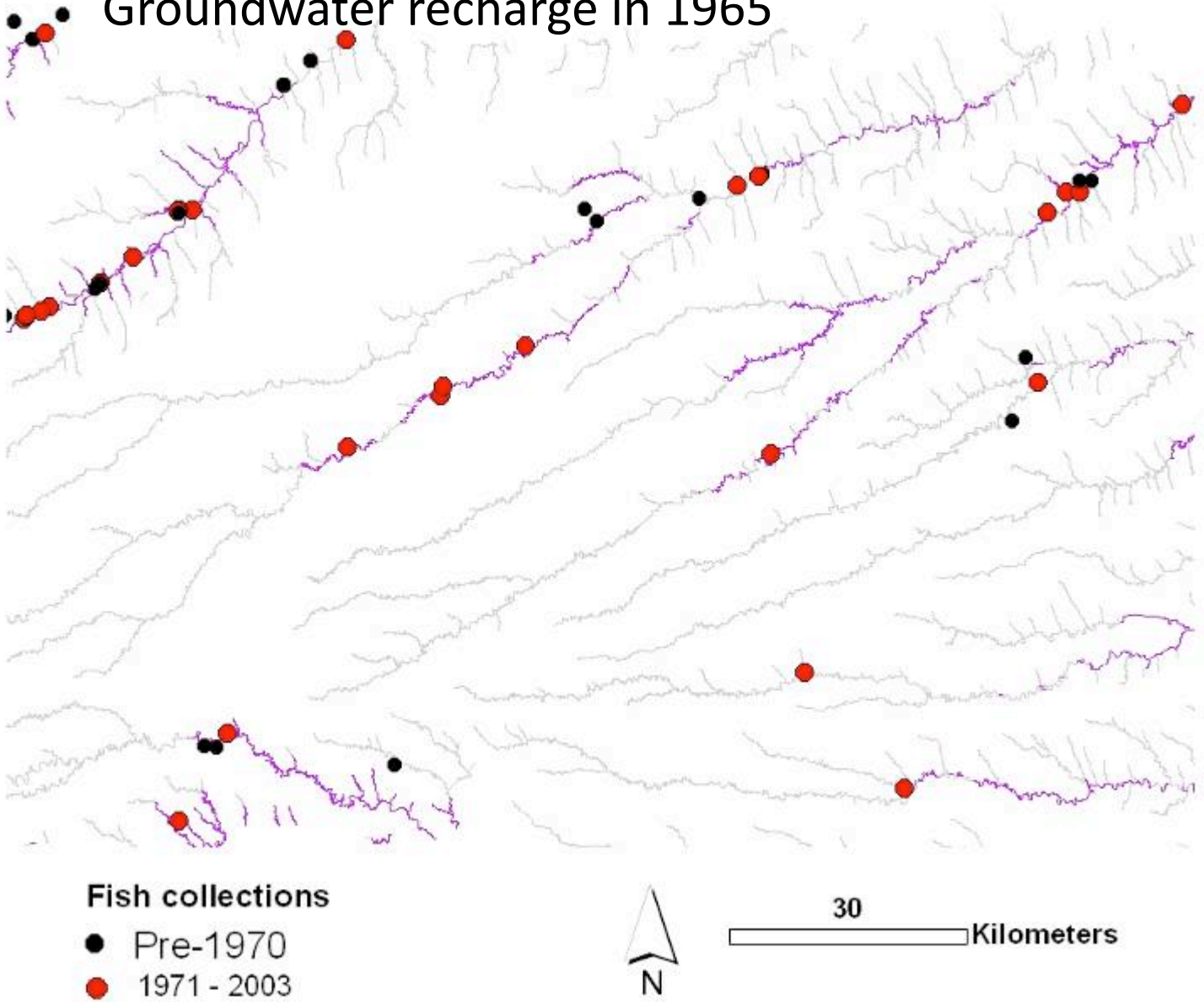
What is the role of tile drains in Iowa floods of 2008?

Arikaree River, Kansas

(courtesy of KDWP)



Groundwater recharge in 1965



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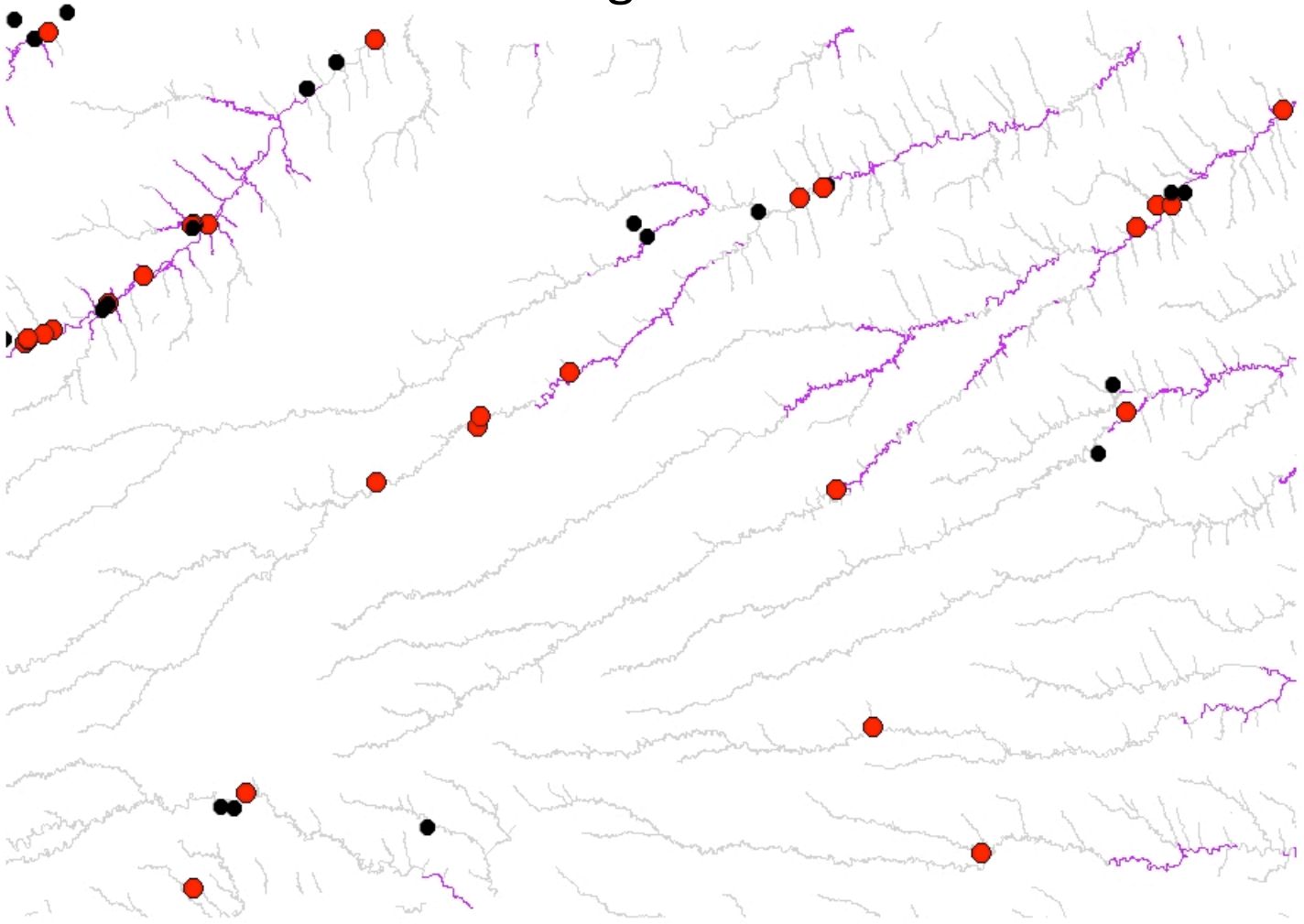
Groundwater recharge in 2005



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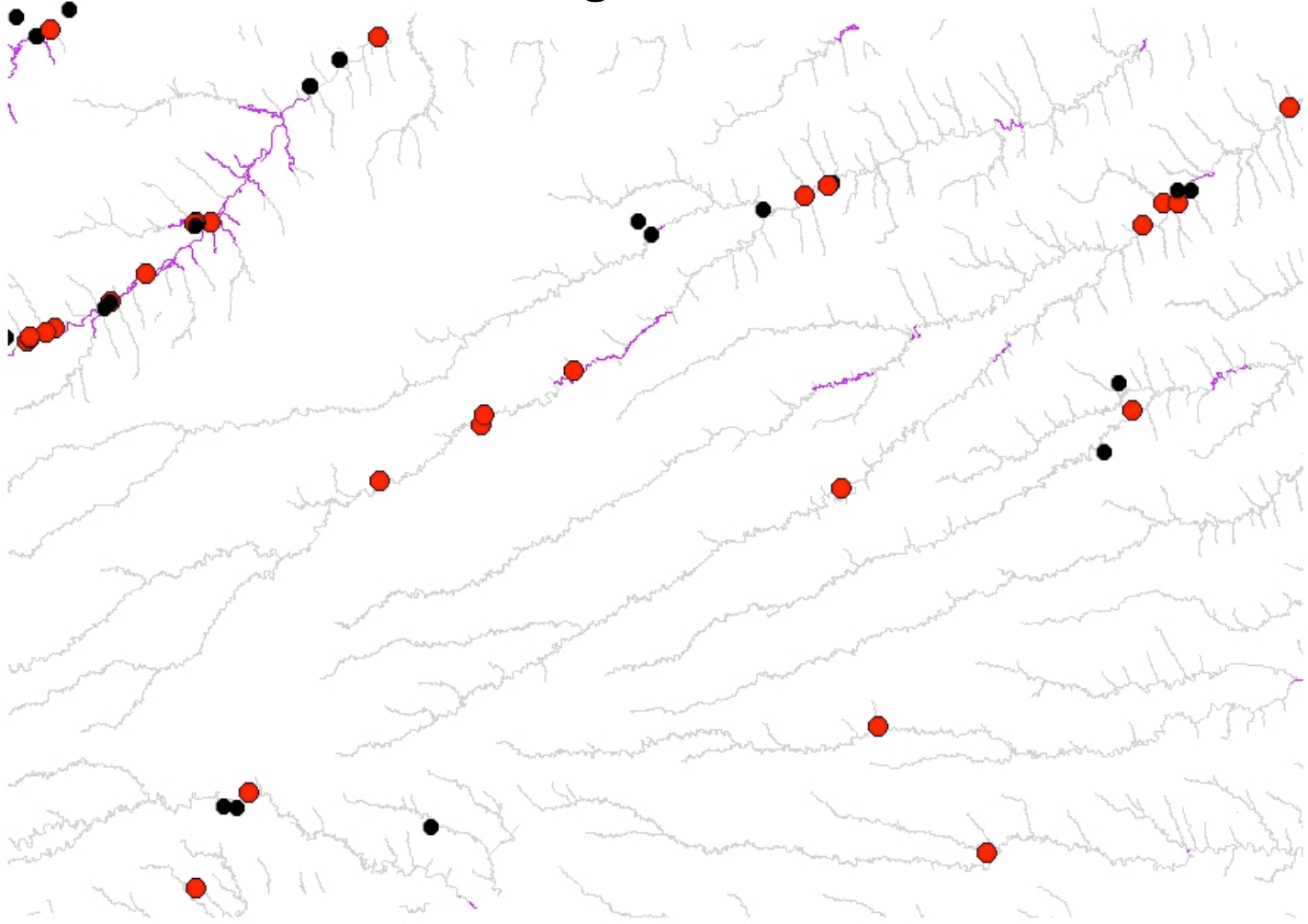
Groundwater recharge in 2020



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Hydrologic Science Today

- How does this place work? (Structure and organization, inference from holistic observation coupled with abiotic and biotic mechanisms)
- How is this place similar to and different from all other places? (Determining generality of inference)
- How does this place couple with the larger Earth system?

Technological Opportunities

- Web services for data access
  - Multiple sources, multiple scales
- GIS for spatial analysis
  - Interpretive context
- Fusion of data and models in space and time
  - Cutting edge of research
- High Performance Computing and Integrated Models
  - Mechanistic
  - Inferential through scaling patterns

Roles of CUAHSI

- **Organizer** of community activities
- **Provider** of tools and services to academic research community
- **Catalyst** for developing opportunities for individuals to pursue
- **Facilitator** between academic research community and federal government agencies

Goal 1: Systematic Inter-site Comparison

- CUAHSI Water Data Federation
  - Publication mechanism for academic researchers
  - Integrates with federal data holdings
- Workshop on Community Questions, e.g.,
  - What is storage of water [at beginning of water year] in gw, sw, soilwater, and vegetation?
  - How do stores compare with fluxes [=> turnover, residence time]?
  - What is relative sensitivity of stores to climate forcing [=>system resilience and adaptation]?
- Follow-up at CUAHSI Biennial Colloquium

Goal 2. Improve Integrated Water Cycle Models

- Fundamental goal of Community Hydrologic Modeling Platform (CHyMP)
- Improved accessibility of remotely sensed products (MODIS, GRACE, …)
- Development of Regional Models
  - Integrated water cycle models at regional scale
  - Use CUAHSI WDS and CHyMP
- Link GCM projections and Regional Models
- WRF-like community model

Vision: Where are we 5 years from now?

- Improved access for temporal and spatial data
- Tools for fusion of data and models in space and time
- Regional models of integrated water cycle that are interacting with GCM projections
- Hydrologic science actively contributing to policy debates

Other NSF-Funded Activities

- Meetings/Workshops
  - CUAHSI Biennial Colloquium (2010, 2012)
  - Dahlem-type conference (2011)
  - Instrumentation Training Workshops (annually)
  - Summer Synthesis Workshops (2009, 2010)
- Graduate Student Pathfinder Fellowships
  - Travel grants to enrich graduate experience by exposure to other fields sites or modeling groups

CUAHSI WATER DATA SERVICES

Web Services

A new perspective on data integration

Bringing Water Data Together

CUAHSI water data services

http://his.cuahsi.org

Government Water Data

Academic Water Data

SDSC SAN DIEGO SUPERCOMPUTER CENTER

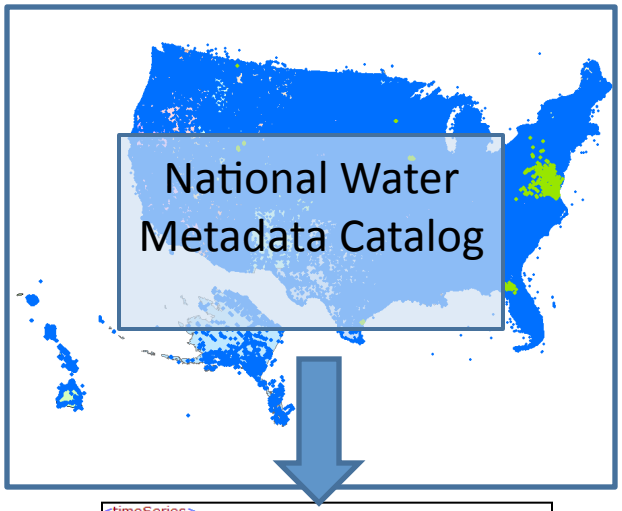
USGS science for a changing world — National Water Information System

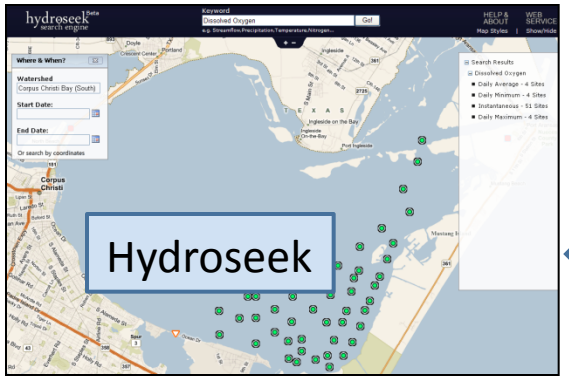
United States Environmental Protection Agency

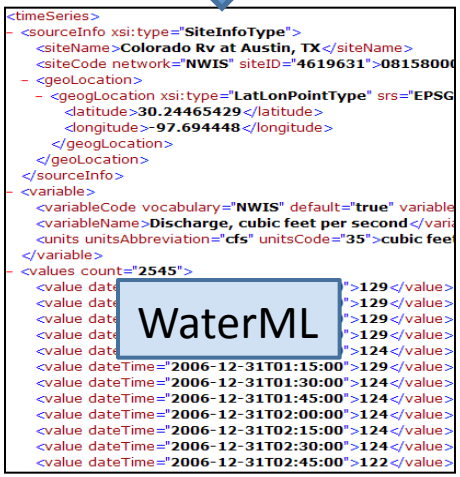
STORET

National Climatic Data Center

United States Department of Agriculture NRCS Natural Resources Conservation Service







UF University of Florida

The University of North Carolina at Chapel Hill

PennState

UMBC

Drexel University

The University of Iowa — Iowa City, Iowa

University of Minnesota

The University of Montana

UC Merced

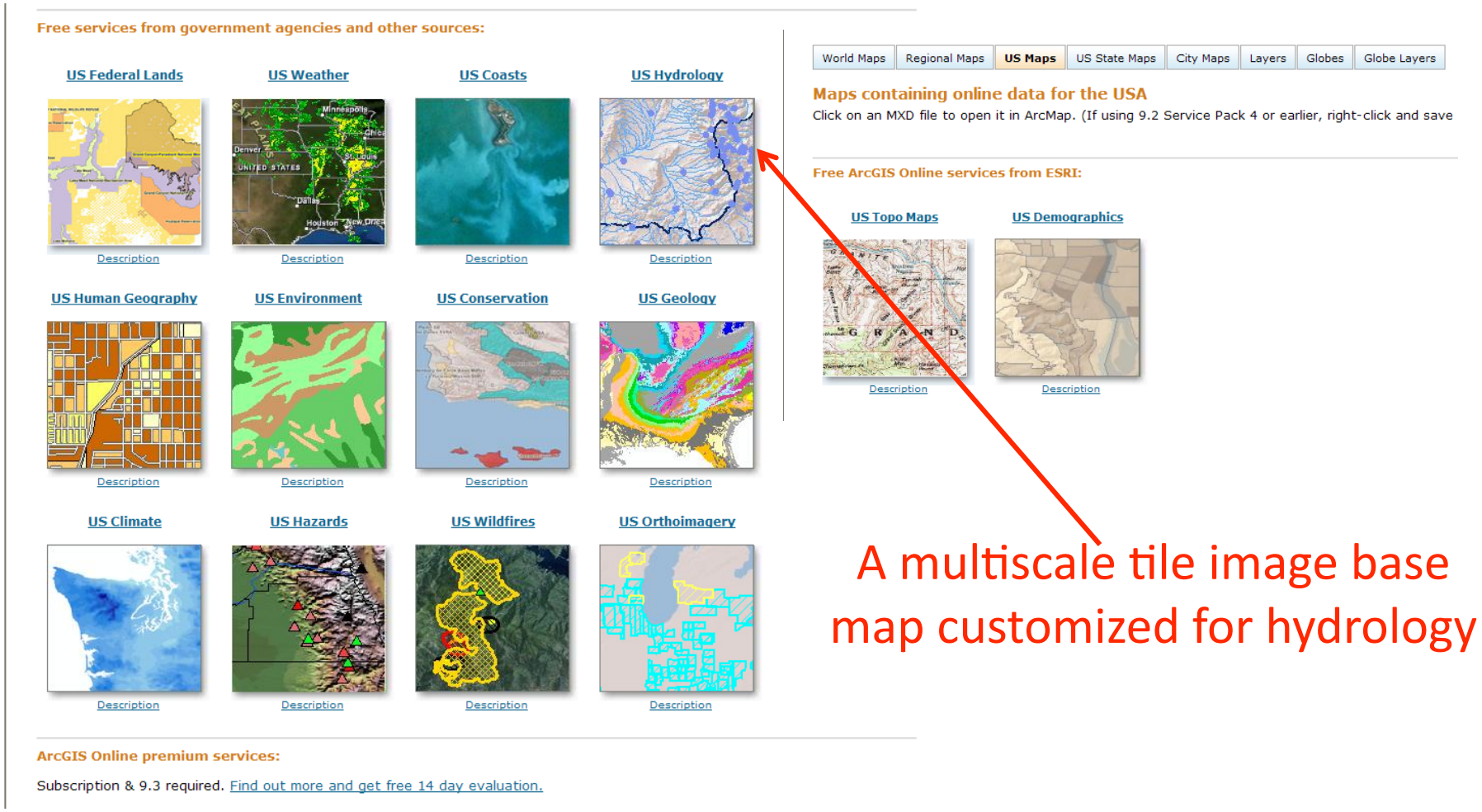
Utah State University

Texas A&M-Corpus Christi

Web Services in Space and Time

- Water Markup Language (WaterML) transmits time series data about one variable measured at one site by one organization as a web service (GetValues)
- Geographic Markup Language (GML) transmits spatial data about sets of geographic features as a Web Feature Service
- Combine these two services so that you can transmit water data in space and time

ESRI Hydrology Base Map



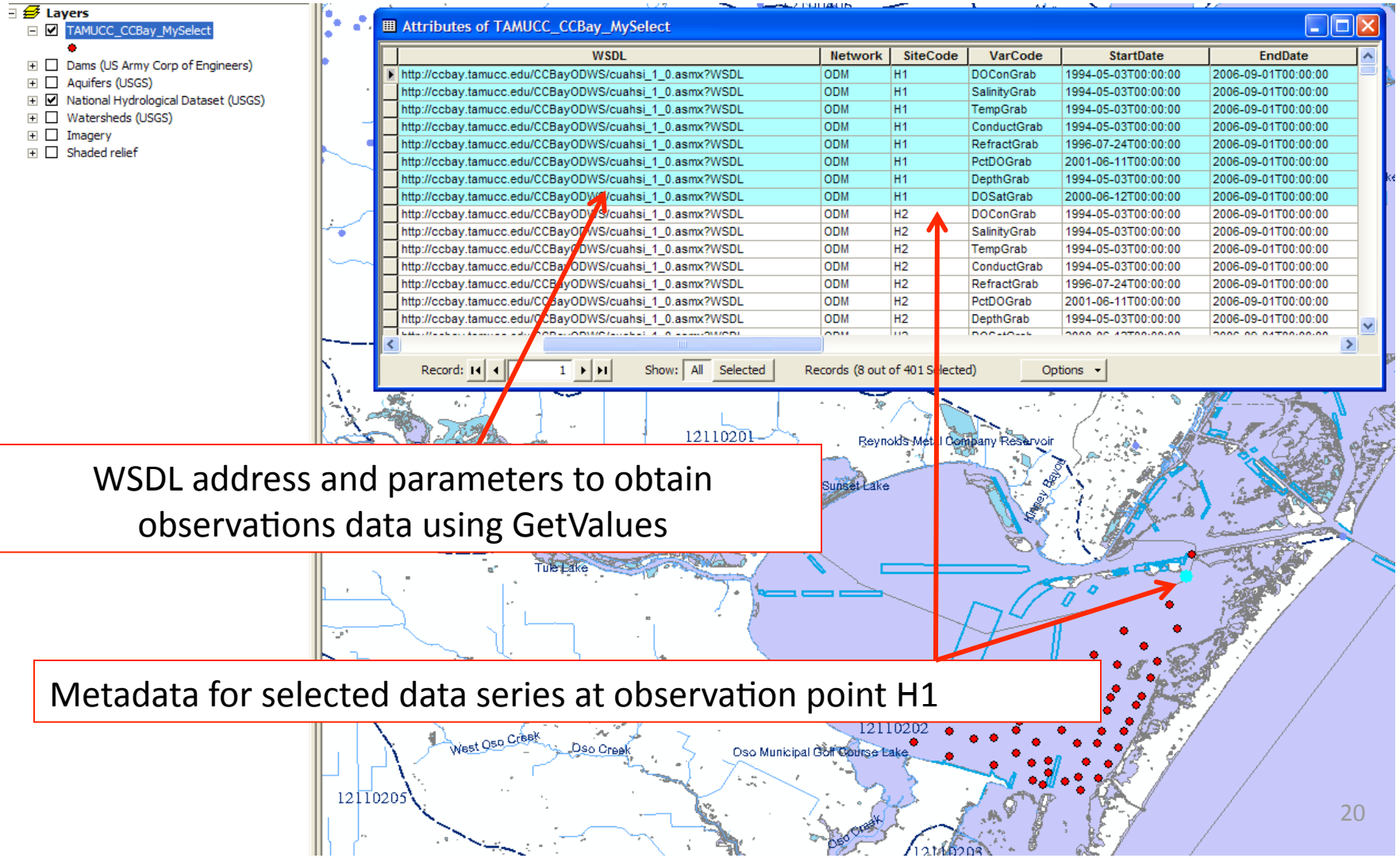
http://resources.esri.com/arcgisdesktop/index.cfm?fa=content&tab=US_Maps

Observations Data Layer for Dissolved Oxygen in Corpus Christi Bay

http://129.116.104.172/ArcGIS/services/CCBAY_MySelect/GeoDataServer/WFSServer

displayed over the US Hydrology Base Map from

http://downloads2.esri.com/resources/arcgisdesktop/maps/us_hydrology.mxd



Arc Hydro Groundwater Data for TWDB wells in Lubbock County

http://129.116.104.172/ArcGIS/services/Lubbuck_Wells/GeoDataServer/WFSServer

displayed over the US Hydrology Base Map from

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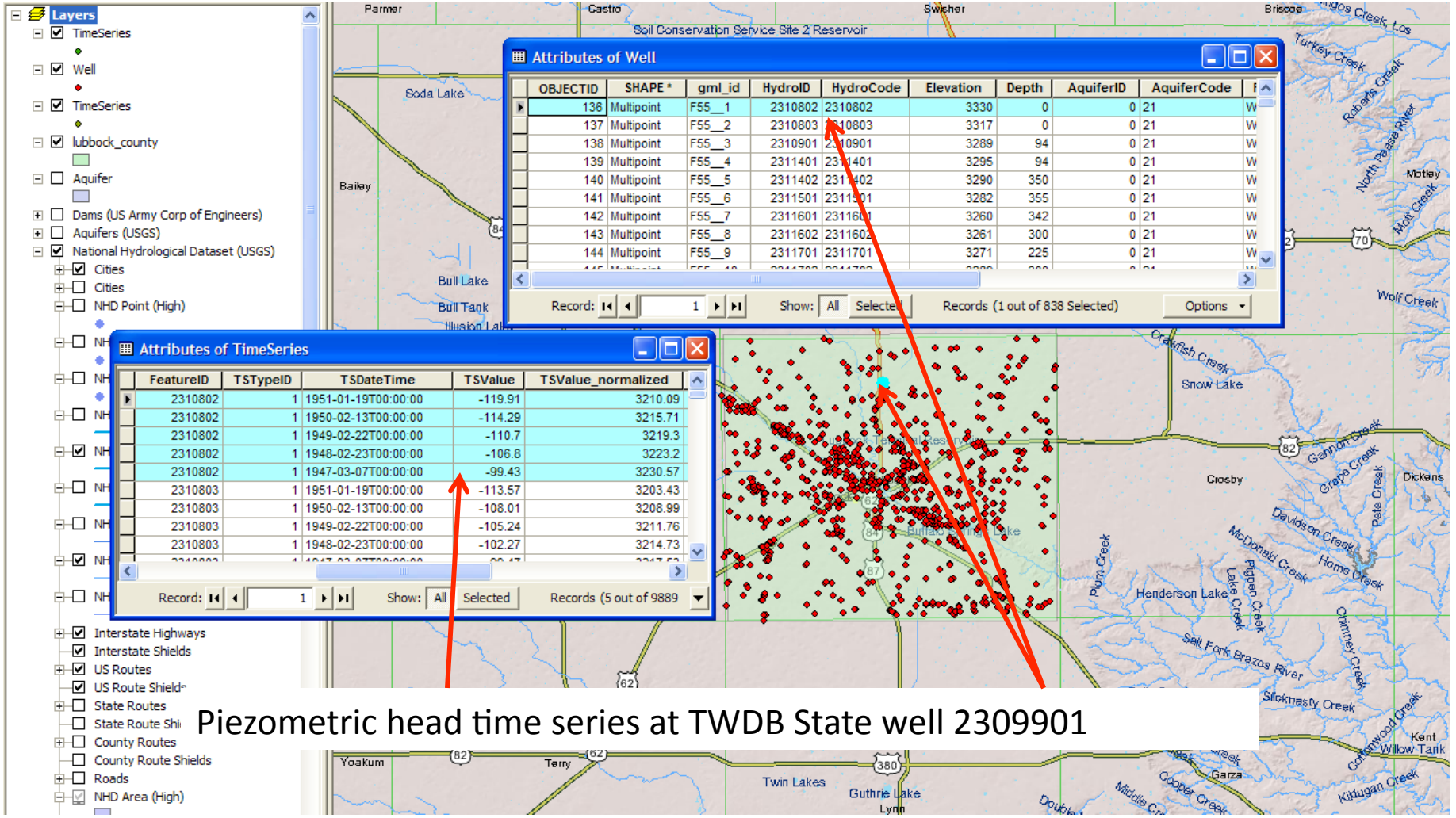

Arc Hydro Groundwater Data for the Edwards Aquifer

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displayed over the US Hydrology Base Map from

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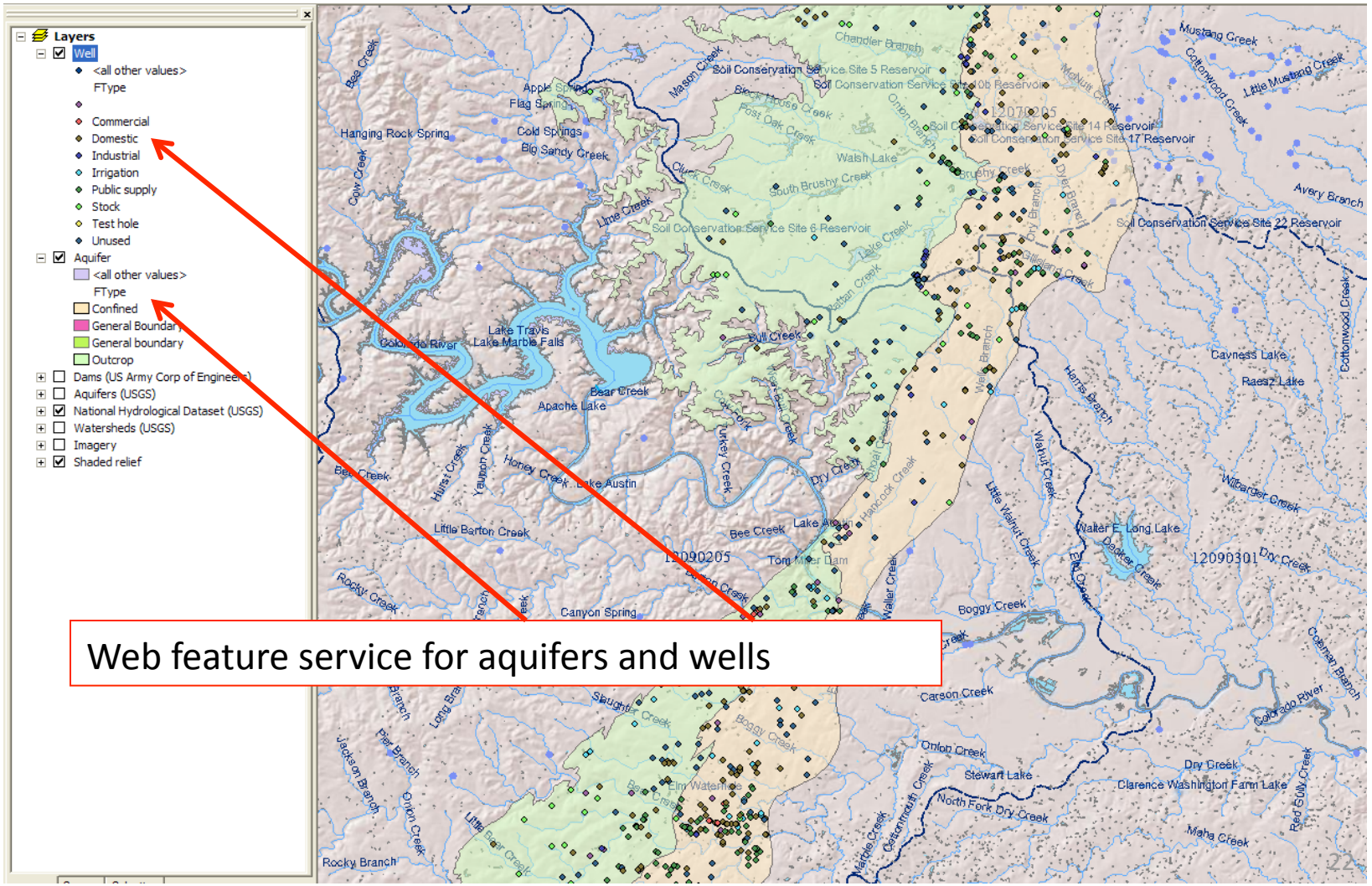
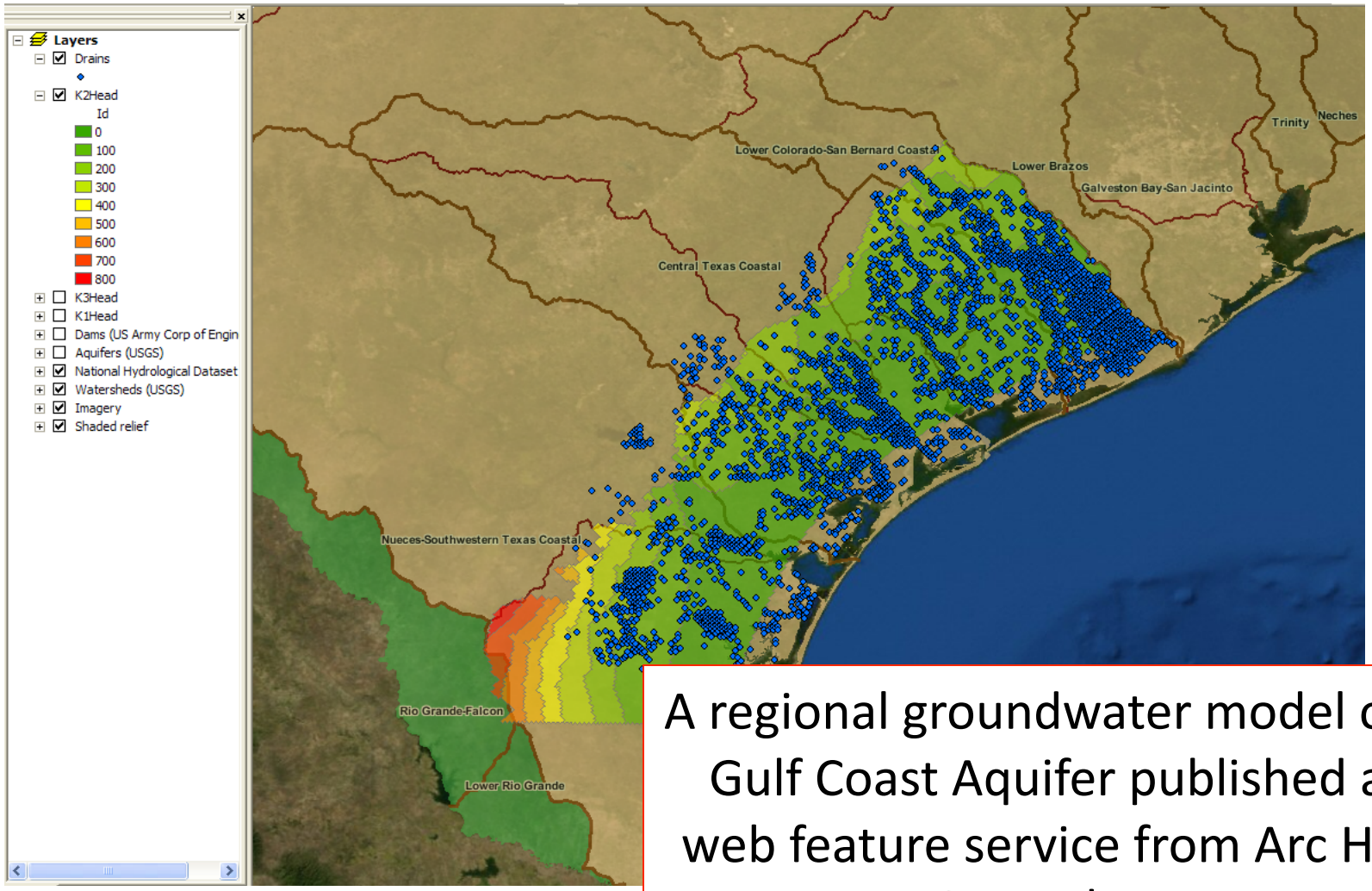


Gam ModFlow Data acquired from a Web Feature Service

http://129.116.104.172/ArcGIS/services/Gam_modflow/GeoDataServer/WFSServer



A regional groundwater model of the Gulf Coast Aquifer published as a web feature service from Arc Hydro Groundwater

Publishing Data Services

- Developing native web services for underlying databases using WaterML as transmission language (or other XML such as WQX)
- Reporting metadata to National Water Data catalog at SDSC
  - Manual dumps
  - OGC Web Feature Service standard for web service enables automatic retrieval
- Tagging variables to ontology

Potential Data Sets

- NRCS
  - Snotel and SCAN
  - Soil Pedon Data Set
- NASA
  - MODIS products
  - TRMM products
  - AMSR products
  - ….
- USFS
  - HydroDB/ClimDB
  - Individual EF's
- ARS
  - STEWARDS
  - Individual Sites
- USGS
  - NWIS UV, DV, IRR
  - WEBB Data Sets
- NCDC
  - ASOS
- DoE
  - ARM Sites
- NOAA/NWS
  - NARR
- EPA
  - STORET

Next steps: Campaigns

- Data limitations will become apparent
- Synoptic campaigns can provide comparable data, greater spatial coverage.
- Academic partners can provide labor

COMMUNITY HYDROLOGIC MODELING PLATFORM

The Need for Community Modeling in Hydrology

Community modeling: the development, distribution and technical support of common simulation software designed to serve the diverse needs of a community, and to be advanced through contributions from the community.

- Rich tradition in other disciplines, but less so in hydrology
- NCAR example enables a broad range of climate research, across spatial and temporal scales, for a variety of applications, and for *participation in international climate exercises such as the IPCC*
- A similar effort in hydrology will enable major advances in hydrological science that are *simply not possible in its absence*

Example science questions that require a community effort and an integrated hydrologic model

- How is fresh water distributed over and through the land surface, and how will this change over the next century?
- How does the space-time distribution of catchment water storage and flux influence patterns of ecosystem carbon and nutrient cycling
- How can water management best adapt to changes in the hydrologic cycle, and what are the feedbacks across scales?

The CHyMP effort proposes to significantly accelerate the development of advanced hydrological modeling capabilities in order to address complex water issues of the highest priority at the national and international levels

The Need for Community Modeling in Hydrology

- Eliminate repetition: stop 'recreating the wheel' and *spend more time on science*
- Enables *integrated modeling and new science* that cannot be done without it
- Can greatly *enhance integrated water management*, policy/ decision support

Without community hydrologic modeling, simulation tools will remain fragmented by and within disciplines or in the proprietary domain of the author.

CHyMP status report

- In the 'workshop' and community engagement phase
  - defining 'what is it' and determining 'why we need it'
  - identifying the needs and requirements and soliciting feedback through community engagement
  - articulating science and implementation strategies
- First CHyMP 'scoping' workshop, 26-27 March 2008, Washington, DC
- OpenMI Workshop, 7-10 April 2008, Wallingford, England
- CMWR2008 Session, 6-10 July 2008, San Francisco, CA
- STC pre-proposal for National Center for Hydrologic Modeling submitted, 14 October 2008
- AGU Fall Meeting 2008 Community Modeling session, 19 December 2008, San Francisco, CA
- Formation of CSDMS Hydrology Focus Research Group to advise and liaise with CSDMS
  - First meeting 20-21 January 2009, Boulder, CO
- Release of 'Rationale Report,' March 2009 (tentative)
- Second CHyMP 'science' workshop, 31 March – 1 April 2009, Memphis, TN
- Third CHyMP 'implementation' workshop and Science Plan, Implementation Plan to follow

Specific needs and issues

- Ties to and compatibility with other CUAHSI activities
  - Data Federation, HMF, Synthesis, E & O
  - Design for WATERS Network
- Engagement of other community modeling efforts such as CSDMS, ESMF, NCAR, USGS, NOAA, NASA, DoE, OpenWEB, etc.
- Links to other disciplines, e.g. ecology, climate, biogeochemisty, social sciences
- Portable to HPC/Scalable

Specific needs and issues

CHyMP effort

- Platform of modular components that can be linked together to form integrated water cycle models and implemented across scales

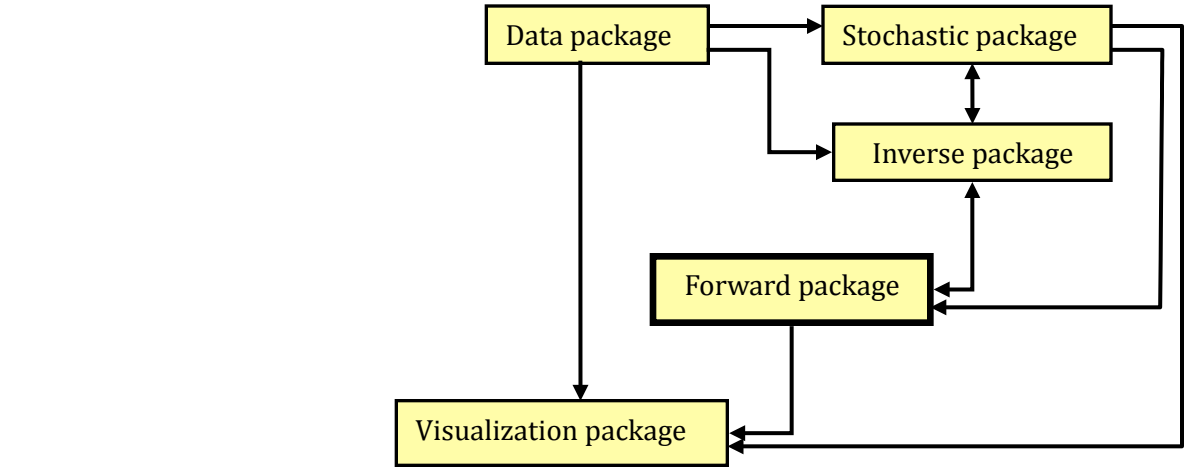
- Regional and National Integrated Water Models

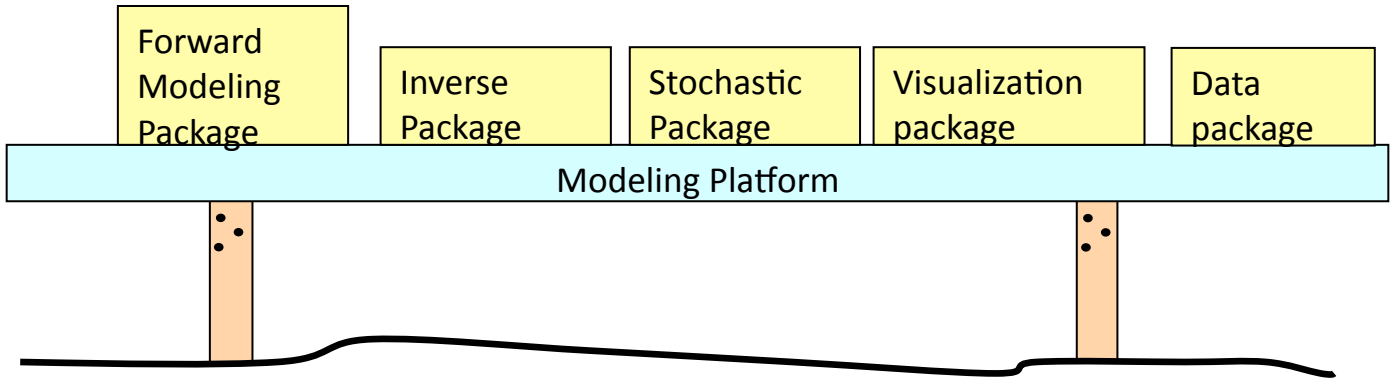
- Community engagement and input through working groups and annual meetings – NCAR model?

Specific needs and issues

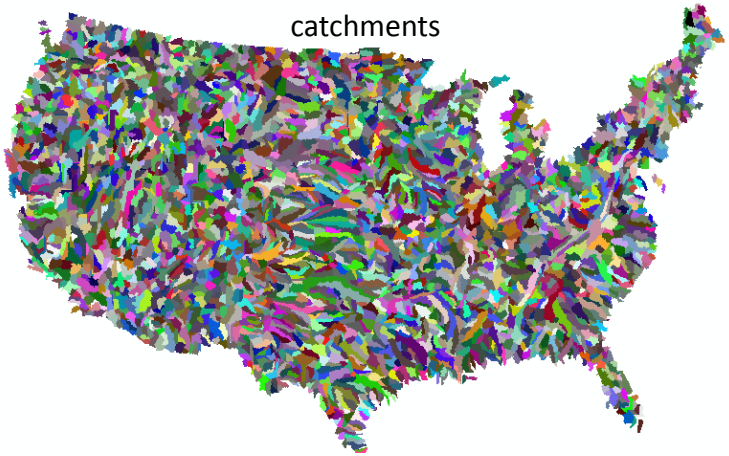
1. **Physics: Represent physics associated with all fresh water**
   Ground water, vadose, streams, lakes, estuaries, glaciers, snow, etc.
2. **Other Processes: Flexibility to represent many physical, chemical and biological processes**
   from biology, ecology, environmental engineering, geomorphology, economics, etc.
3. **Scale: Accommodate parameters and physics over a wide range of scales**
   Pores to continents; methods to up-scale and down-scale parameters.
4. **Other Domains: Couple with Ocean and Atmospheric Circulation Models**
   Entire hydrologic cycle
5. **Data: Exchange data with Hydrologic Information System**
   Get data for calibration, store results
6. **Calibration and optimization**
   Model parameters and uncertainty from large data sets, management strategies
7. **Stochastic: Include stochastic processes, data analyses**
   Parameter distributions, transition probabilities, networks, Monte Carlo, geostatistics
8. **HPC: Execute simulations on single, or many parallel processors**
   Middleware for seamless application
9. **Visualization**
   Display data to maximize insights
10. **Interface**
    Easy to use, learn, teach

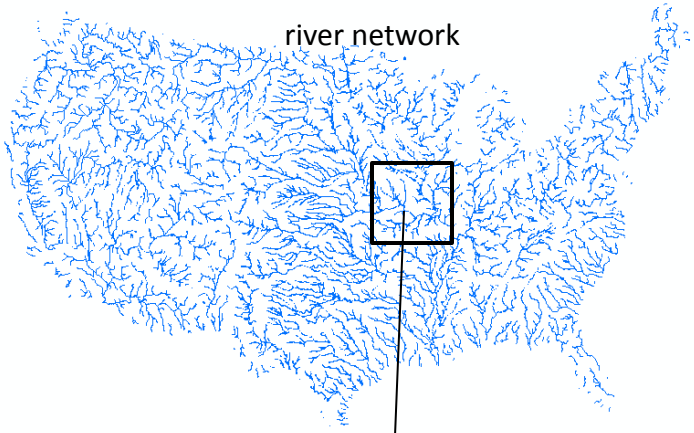
Specific needs and issues

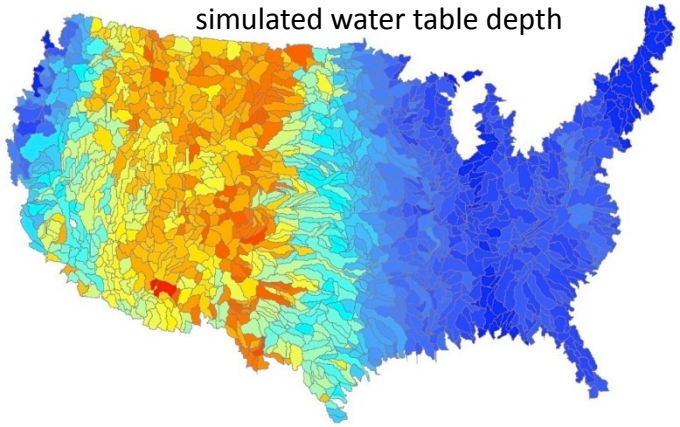


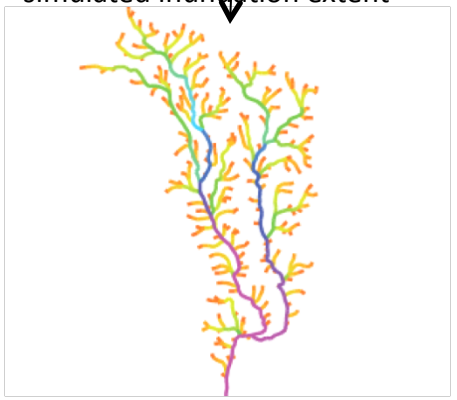


Towards a National Water Model









INTER-SITE COMPARISON

Approach for Inter-site Comparison

- Workshop to define “Community Questions”
  - Simple questions that are meaningful at any site (e.g., water storage)
  - Both answer to question and analysis process to derive answer important
- Publication of data sets using CUAHSI WDS
  - Long-term experimental watersheds data critical
  - Community engagement
- Basis for conceptualizing regional models
- Active participation with federal scientists
- Highlight contributions of agency long-term data sets

Conceptual Models
Water Distribution Example

Vegetation

Surface Water

Soil Water

Groundwater

How do we relate measurements in a complex landscape to one-dimensions stores?

Comparison of conceptual models will be useful as well as comparison of results.

Follow-on Activities

- Campaigns
- Development of Regional Models
  - Modeling of integrated water cycle
  - Use GCM projections
  - Feedback process representation to GCM's
- USGS "Water for America" Initiative
- NSF Water Initiative
- Linkage between water resources management and research