Water Data on the Web

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David is a specialist in surface water hydrology, and in particular in the application of geographic information systems to hydrology. In 2012, he received the Ray K. Linsley Award from the American Institute of Hydrology in recognition of his contributions in the field of surface water hydrology. In 2011 he received the Ven Te Chow Award from the American Society of Civil Engineers for notable contributions in water resources engineering, hydrology and hydraulic engineering, outstanding service to the profession through application of GIS in surface water and groundwater hydrology, authoring books and research papers in water resources engineering, and mentoring of young engineers. In 2011 he received the Distinguished Alumnus Award, Civil and Environmental Engineering Alumni Association, University of Illinois at Urbana-Champaign, "for significant and lasting impact on teaching, research and practice in the fields of hydrology and water resource engineering, including the pioneering of geographical information systems applications in hydrology and technologies that have been adopted by national and international institutions." In 2010 he received the AWRA Award for Water Resources Data and Information Systems, in recognition of his outstanding contributions to the application of Geographic Information Systems to water resources engineering and sciences. This award was also permanently renamed the David R. Maidment Award for Water Resources Data and Information Systems, in honor of his many contributions to the field and his furtherance of the mission of the American Water Resources Association.

I am very happy to be here and to learn more about what is happening in New Mexico. I have been in Texas for nearly thirty years, so I have looked upon you from a distance. Today I would like to begin by talking about the "cloud." I hear a lot about cloud computing and I obtained some slides from a colleague, Kristen Tolle, who is from Microsoft Research. She told me that she is permitted to say that Microsoft has more than ten but less than a hundred of the facilities that I am going to discuss.

When Microsoft started on this, which was about eight years ago, they began with moving computers to buildings and putting the computers in racks and then moving racks into buildings. After a while they asked, who needs buildings? We'll just put weather proofing around the racks and we'll move those instead. Figure 1 shows a rack that is actually on the back of a truck in Austin at the Dell facility, and it is being trucked across the country to Longmont, Colorado. When it gets to Longmont, a crane lifts it off the back of the truck and that is the cloud (Fig. 2). It looks like an RV park in Longmont, Colorado (Fig. 3). If you want to know where your iCloud is, it is in places like this. The interesting thing that has happened is that now the cost of moving information has gotten so low that the aggregation of information in facilities like this has become cost effective. Thus if you have a computer that works less than 40 percent of the time, it is cheaper to use one of these than to have your own computer.

Figure 1. Shipping a Rack

Figure 2. Modular Cloud Construction

Figure 3. Completed Cloud Computing Facility in Longmont, Colorado

So what does that mean for water? We collect lots of data on water such as measurements on rivers, rainfall, soil water, water quality, meteorology, and so on. Those are time series measurements at point locations. For a number of years, I was the leader of the Hydrologic Information System project of CUAHSI, which stands for the Consortium of Universities for the Advancement of Hydrologic Science, Inc. It is supported by the National Science Foundation for the advancement of hydrologic science in the U.S. We invented the WaterML language for transmitting hydrologic data through the internet. The U.S. Geological Survey (USGS) adopted it a few years ago and now they put out all of the information for their time series using WaterML. You can get information in this rather odd looking language that you see in Figure 4 from the USGS webpage (usgs.gov) or by going to waterservices.usgs.gov, which now means machines talking to machines. The USGS did this because they found out that 60 percent of the requests for information were coming from computers. Computers were being programmed to just get past the webpage. Now web **pages** deliver text and images and web **services** deliver data encoded in XML (Fig. 5).

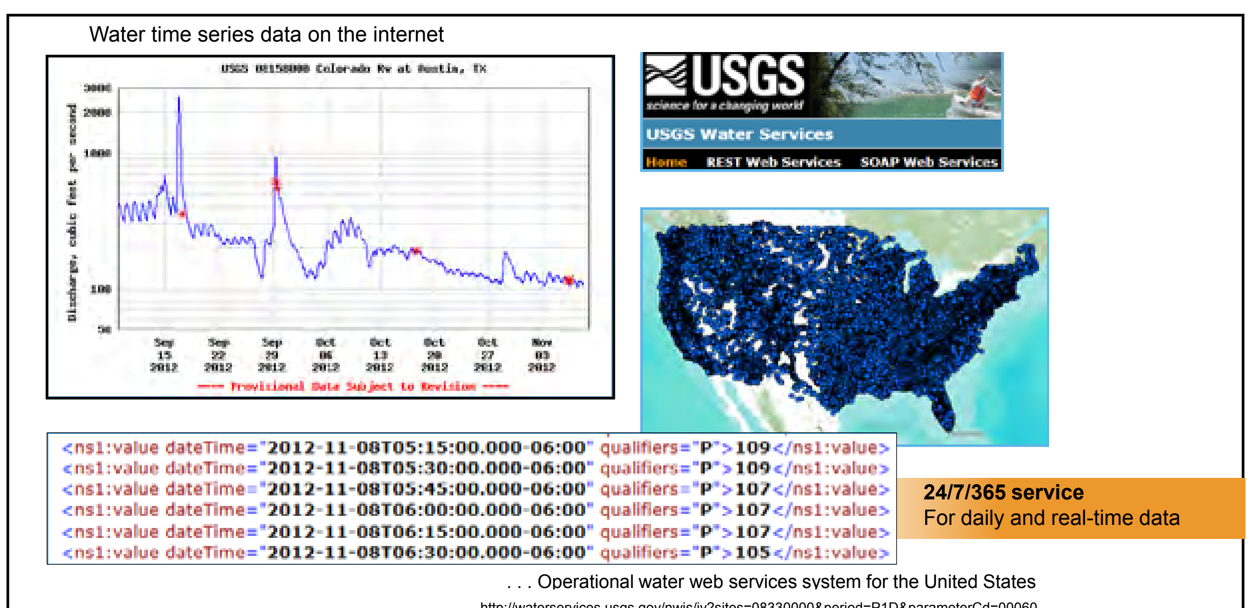

Figure 4. WaterML - the U.S. Geological Survey

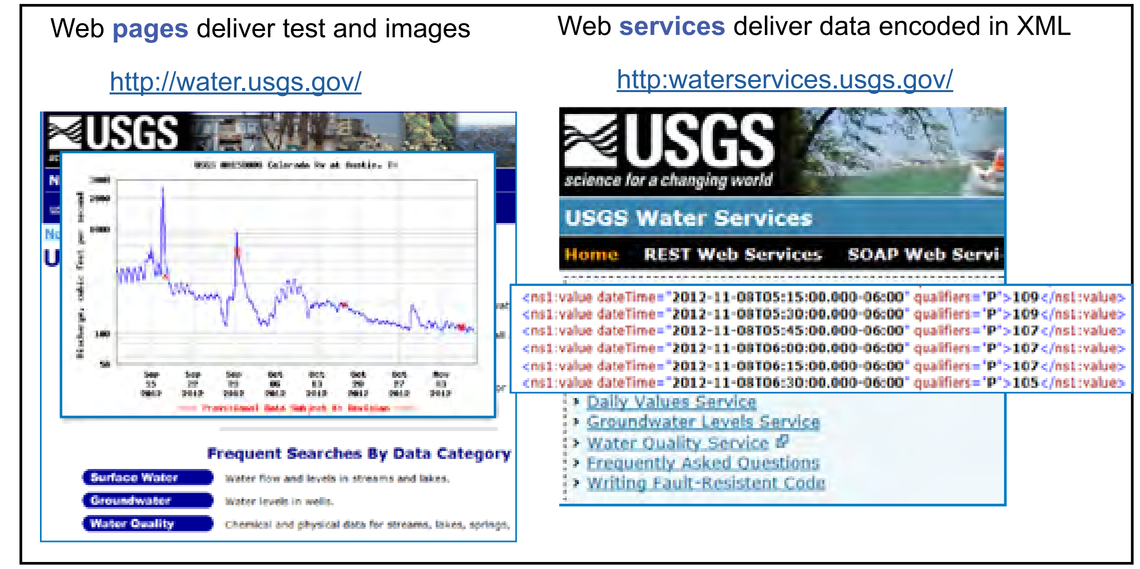

Figure 5. Web Pages and Web Services

By going to an archive and having direct machine access to that archive, you can have information downloaded in XML. I then asked myself, how do we institutionalize this so it can be applied across the world and not simply in the United States? An organization, the Open Geospatial Consortium, with over 400 companies and agencies, provides internet data standards for maps and observational data. In 2008, I proposed that there be an agreement between the Open Geospatial Consortium and the World Meteorological Organization to build an international system that would do this (Fig 6). This was legally concluded in 2009 and plenty of work has gone on since that time, like international experiments and so on. In 2012, a new international language was adopted as an OGC standard, WaterML2, which is now the first public standard for the exchange of water information across the Earth.

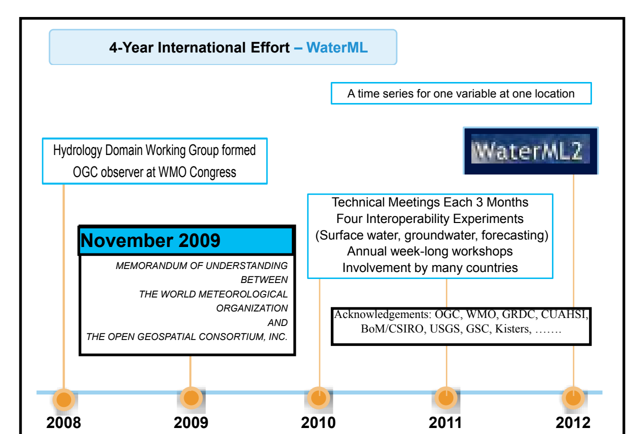

Figure 6. OGC/WMO Hydrology Domain Working Group

We have started setting up global observation systems and Figure 7 shows our network of streamflow observations. The yellow dots are locations where streamflow was recorded and housed at a global center, the blue dots are USGS data, and the green dots are from CNR in Mexico. Some others are located in other countries as well–quite a few in Italy. Just for fun, I got today's data at 8:00 a.m. for the Rio Grande at Albuquerque from the worldwide web services put out by the USGS (Fig. 8). I also checked on the Manawatu River at Teachers College, New Zealand (Fig. 9). Manawatu River at Teachers College has the longest flow record in New Zealand. I am originally from New Zealand. What you see at the bottom is the new international standard. So water data is being obtained simultaneously from far away New Zealand.

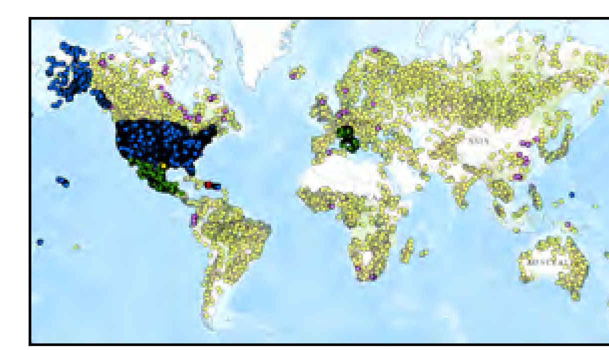

Figure 7. Global Streamflow Observations

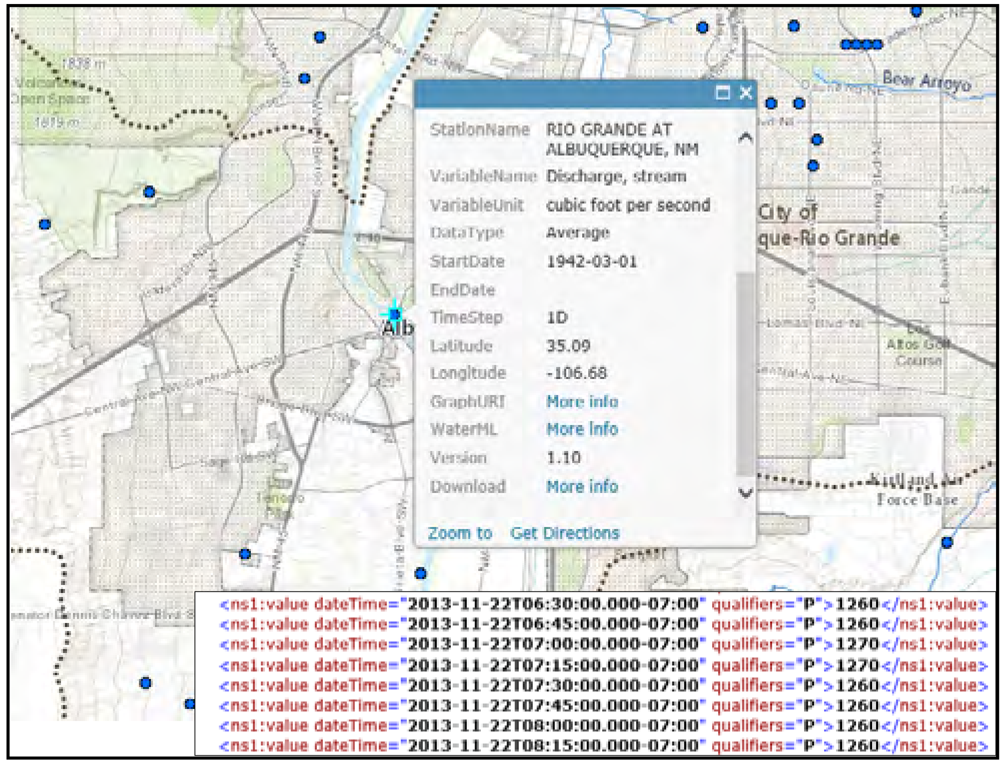

Figure 8. Rio Grande River at Albuquerque, NM

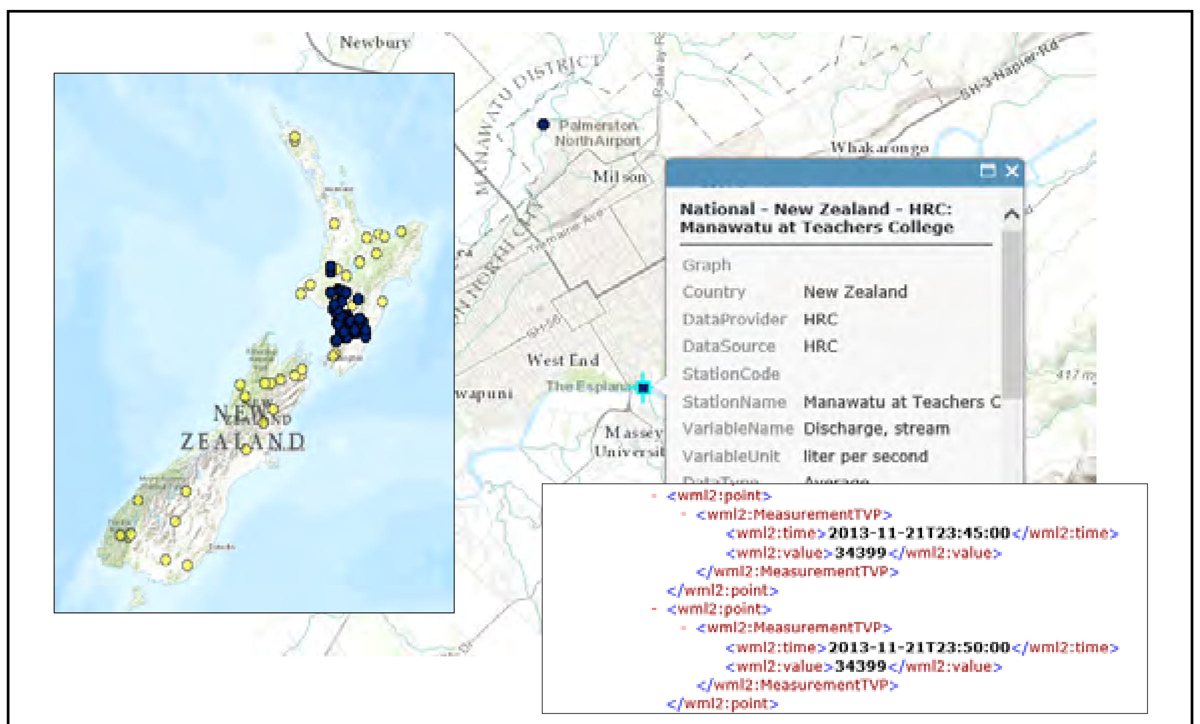

Figure 9. Manawatu River at Teachers College (New Zealand)

We now have a common language for water observations. What about water modeling? Figure 10 shows something that we are doing in the San Antonio and Guadalupe basins and with a little animation we can view the flow in the basin with calculations for every stream reach on a three-hour time scale. We are doing this in many other areas in city basins and other projects. The idea is that we have USGS coverage of the streams, and we can also have modeling of flow on every reach of the streams, not simply where the flow is being observed. If we can do that, we can start to optimize the operations of the water diversions on those streams.

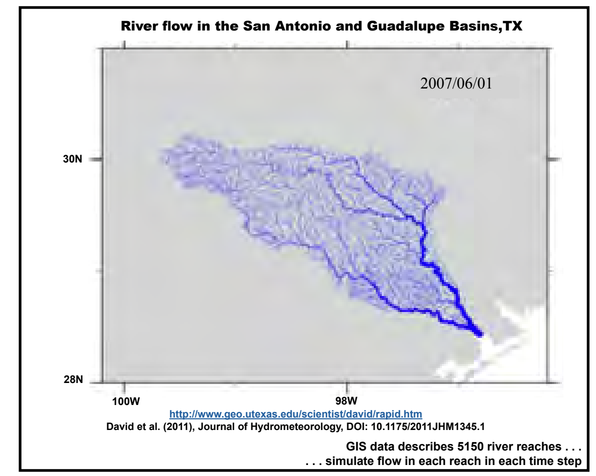

Figure 10. Flow in the San Antonio and Guadalupe Basins (RAPID model, June-September 2007, 3 hour time steps)

Figure 11 shows a project that we are cooperating on the Texas Commission of Environmental Quality Watermaster Program. The green dots are services that we are getting and are derived from USGS flow data; the triangles are water diversions in these basins, around 400 of them, some of which don't actually make diversions; and the purple dots are forecasts of flow that are being put out by the National Weather Service. The USGS does things in the present and the past while the National Weather Service does things in the future. We need to get information from the past, present, and future and aggregate all of this information into one place, which we have done in Austin. In Austin, we have a big data hub that is used as the base for this operation, and we can pinpoint the flow at any one of the 550 reaches within this basin. Thus the model becomes a service, the observations become a service, the diversions become a service, and we have an operating system that allows us to manage carefully the water in this basin.

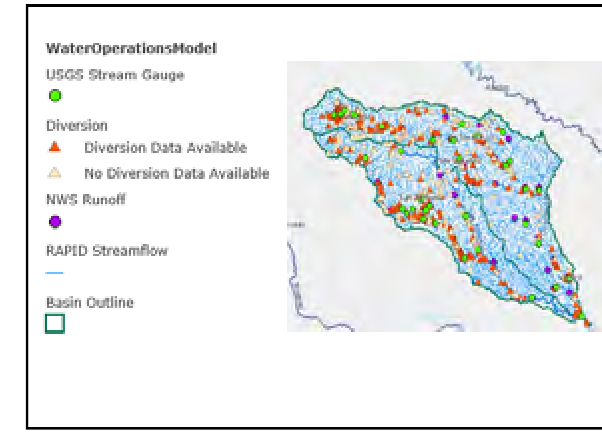

Figure 11. San Antonio — Guadalupe Water Operations Model

Another thing that is important when you start thinking about global water is that water is just kind of sloshing around the world. Figure 12 shows measurement of the water content of the Earth as measured by GRACE (Gravity Recovery and Climate Experiment). Two satellites fly about 500 km above the Earth and the distance between them is around 220 km. The color that you see in the figure represent the depth of water measured in centimeters. It turns out that water is heavy enough that its movement can be measured by satellites. This is sort of an eye in the sky measuring how much water there is. We can measure the water storage within our state of Texas. Figure 13 provides our current water situation, and you can see on the graph the average depth for the last ten years. From the 2011 drought through earlier this year, our water storage is about a hundred cubic kilometers down. That is equivalent to about 70 Lake Travises for those of you who are familiar with Lake Travis near Austin. What this says is that our state is very low on water, and since our state is next to New Mexico, I would imagine that New Mexico is low as well. This is one of the reasons that the flow in the Pecos River is so low—the whole water system is very low right now, and we can measure that from space. One of the things I am often asked is if this correlates to drought measure, and yes, it absolutely does. The top graph in Figure 13 is the U.S. drought monitor intensity measure, and you can see that the water usually drops as the drought increases.

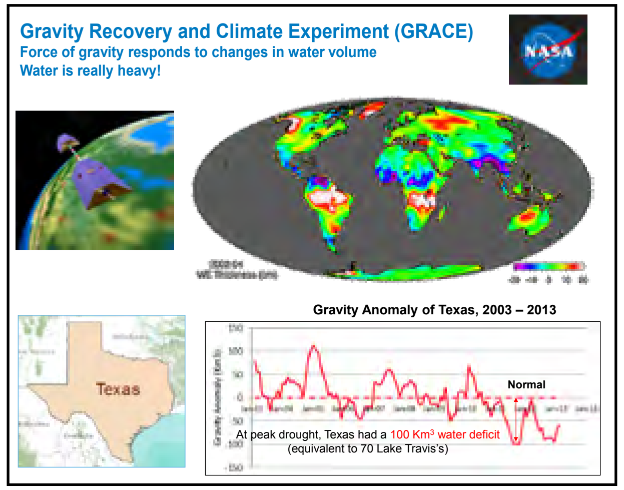

Figure 12. Gravity Recovery and Climate Experiment (GRACE)

The Texas Water Development Board compiles the records of the surface water reservoir system. We have 119 reservoirs accumulated and presented in Figure 14. You can see that the reservoir volume and GRACE anomaly are almost parallel lines. What that says is that our service water reservoir system is reacting as one huge system, and you can measure that with the GRACE satellite that is spinning around the Earth. It is quite remarkable when you really think about it.

It turns out that 90 percent of the water that we lost in the 2011 drought didn't come from the service water reservoir system–less than ten cubic kilometers came from that system. That means that the soil and groundwater systems are very critical. NASA is assessing this using the Land Data Assimilation System (LDAS) where they model the circulation of water around the U.S. in the atmosphere and the exchange between the land and the atmosphere. NASA does this atmospheric modelling on a 1/8 degree mesh (Fig. 15). Figure 16 is an example of what that information looks like for Travis County where I live. You can click on a point and, for example, get the soil moisture level in this county at that point.

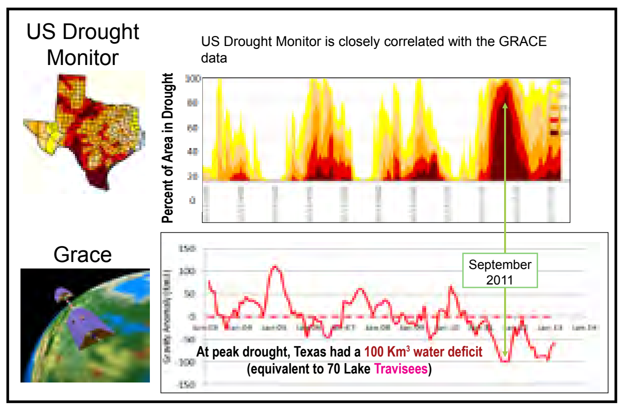

Figure 13. Drought and GRACE

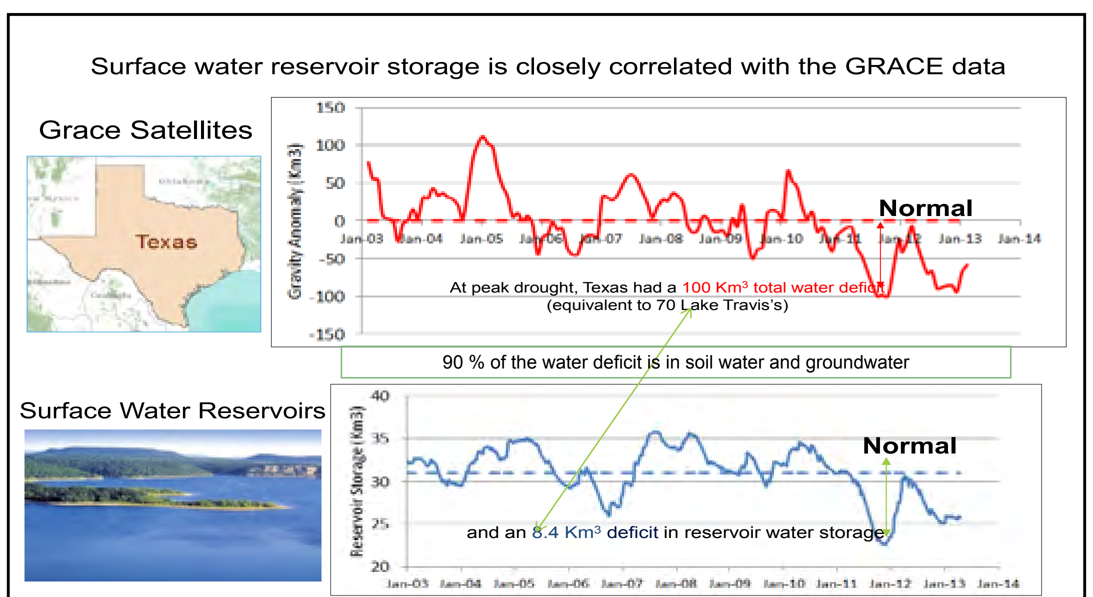

Figure 14. GRACE and Texas Reservoir Water Storage

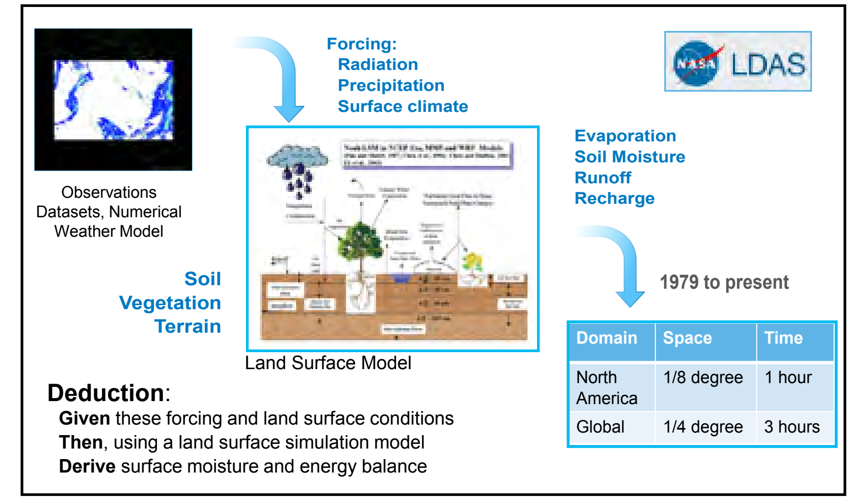

Figure 15. LDAS—Land Data Assimilation System

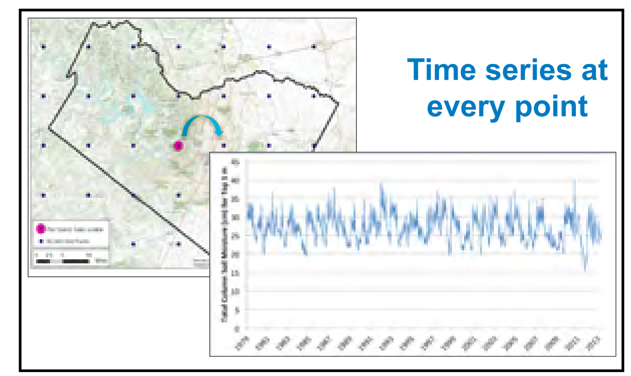

Figure 16. LDAS "Data Rods" project

We are also working with NASA on a project using time series data of soil moisture, evaporation, precipitation, and any data that can be used in this model. This information is useful when we compare a measurement today with the same time last year, or the same time the year before, and how they vary as compared to the average. In Figure 17, the red line is 2011, the purple line is 2013, and the green line is 2012. This is interesting because you can start to get a quantitative measure as to what exactly is happening. How dry is dry? How dry is it exactly relative to how dry it was last year or previous years?

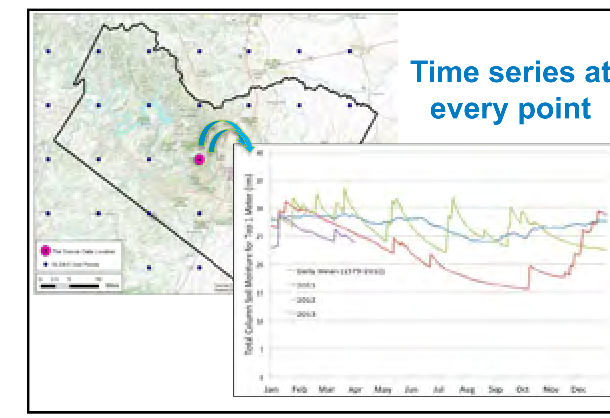

Figure 17. Current Soil Moisture Conditions

NASA has built these "data rods" for the whole country and Figure 18 shows the data rods for Texas. You now know how much water is being stored in the basin. I can ask myself, how much water do we have in soil moisture in Texas? It turns out that in the top one meter of soil, we have about 45 cubic kilometers of water that we lost during the 2011 drought. Nearly half of all the water that we lost was in the top one meter of soil, which is why there is a lot of discussion at this conference about soil moisture (Fig. 19). The soil is a crucial component of understanding what is going on in this situation.

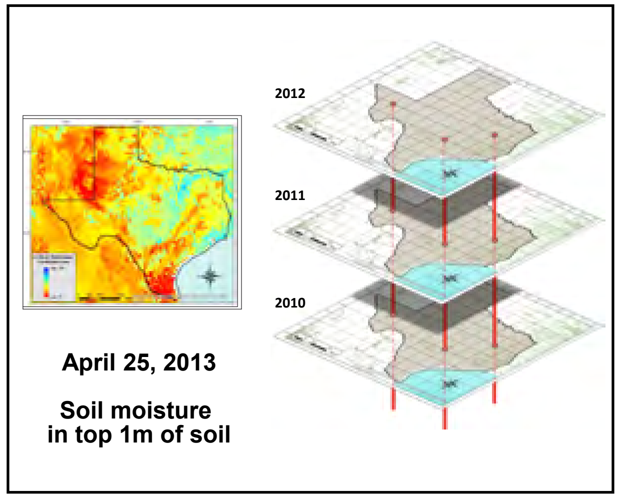

Figure 18. "Data Rods" for Texas

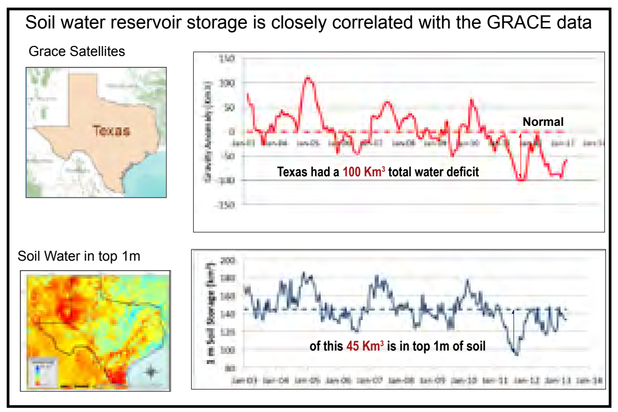

Figure 19. GRACE and Texas Soil Water Storage

What I envision in the future is something that I am going to call World Water Online that brings together water data across the whole Earth at all spatial scales linking data, modeling, maps, observations, and everything else on the web. I am going to dream here a bit (Fig. 20). I imagine that at the world scale, we would think about how we assess water and climate issues similar to what I was showing with GRACE. How are we going to understand drought and how it moves? At the national scale, we will think about the landscape and how much water we have. At the regional scale, we will solve aquifer and watershed management problems. At the local level, we will look at households and how households, individual wells, and so on, are affected.

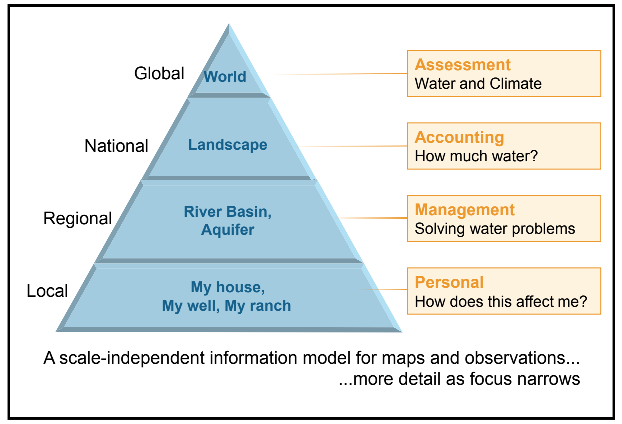

Figure 20. Scales of Application

Let's imagine that we could do this. To give one example of what is being done, Figure 21 shows Google Map images of rivers. It starts with a global map of all the rivers in the world–the Amazon is seven times larger than the next biggest river, so that is why the amazon looks big there. Then you have the rivers of the United States, and you can see the Mississippi. Then you have the rivers of Texas, and here are the rivers that surround my house where you can see a little stream that we call Panther Creek. You can do this similarly with any stream anywhere (Fig. 22). You can see any active watershed on Earth. It turns out that there is an active watershed right next to my house, and I didn't even know exactly where it was located.

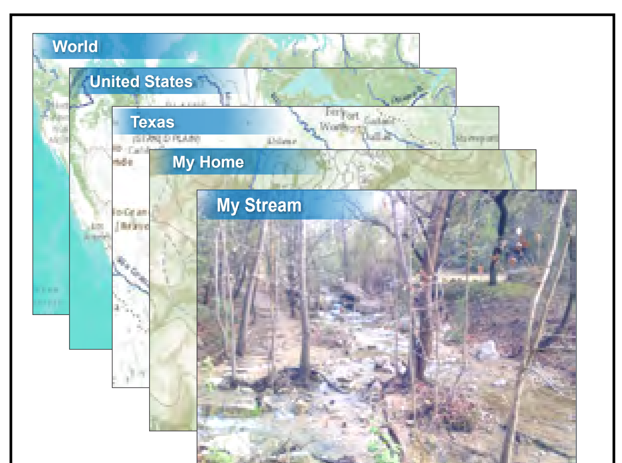

Figure 21. World Hydro Overlay Map

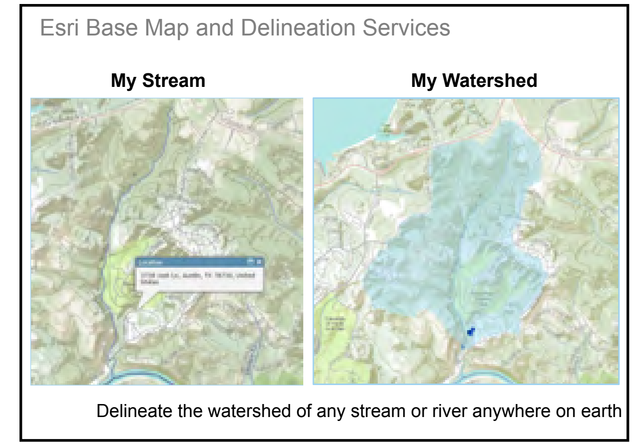

Figure 22. Watershed of My Stream

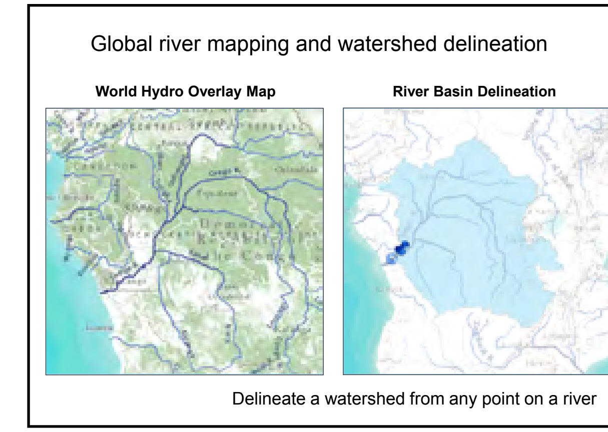

Figure 23. Congo River Basin

Figure 23 shows how we can delineate a watershed from any point on a river anywhere on the planet. This capability is already working in most places of the U.S. It is now being expanded to Africa and the figure shows a view of the Congo Basin. You can use this for the small stream by my house and at the same time use it for the rivers of the Congo without having to go get any data at all. This is all happening because something in Longmont, Colorado or somewhere else, is doing all the work. This is not happening on my computer at all. What is happening is that all of these computations and data are being housed at these huge facilities and processing happens on top of them. Figure 24 shows the precipitation across the Congo Basin. The idea is to link hydrologic processes with drainage areas. I would like to believe that we can build a World Water Online as a system to link people everywhere with water data, maps, and models.

Thank you.

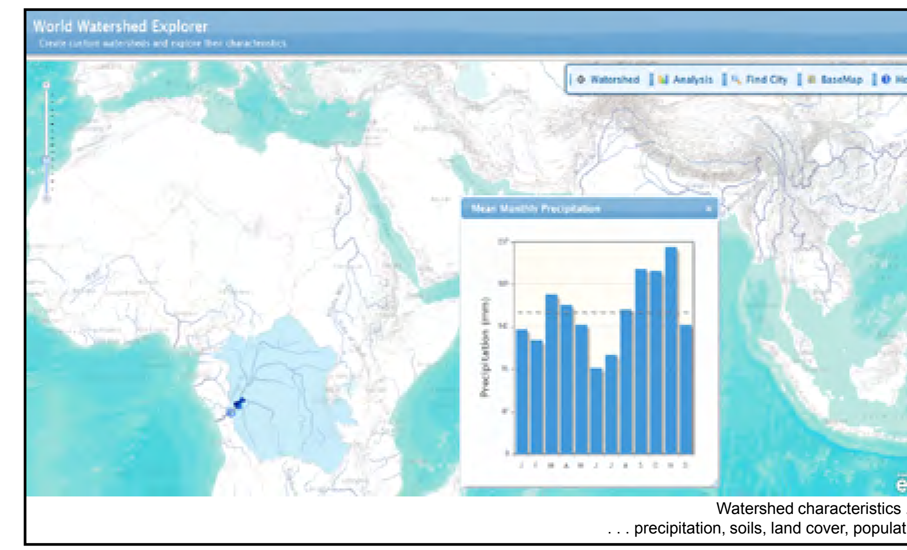

Figure 24. World Watershed Explorer—Congo Basin