

## UWRL Dam Model Saves the LCRA \$800,000



Researchers from Utah Water Research Laboratory are using scale models to help dam owners prevent future damage from flooding to a Colorado River dam.

## Guest Editorial



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## Upcoming Event

Western Snow Conference -- April 20-23, 1998.  
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## A Digital Water and Climate Atlas for Asia



## EDITORIAL



Dr. Gilberto Urroz specializes in erosion control, hydraulic structures modeling, and groundwater modeling

### In this issue . . .

We present articles emphasizing current research work at the Utah Water Research Laboratory, including a hydraulic model of scour below a dam, hydrologic time-series methods with specific examples, and the effects of vegetation on flow resistance. We also profile a post-doctoral researcher who is returning to his home country of Egypt after six years at Utah State University where he obtained his master's and doctoral degrees.

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Welcome to the first issue of the Utah Water Journal, an electronic journal that addresses the need for the exchange of information among water professionals, planners, water users, and other decision-makers in the State of Utah. My name is Gilberto Urroz, and I am the Editor-in-Chief of the journal and a faculty member at Utah State University.

The Utah Water Journal is the result of collaboration between Utah State University and state, local, and private institutions in the analysis of water-related issues. The use of an electronic format allows for timely

publications of articles of interest to our subscribers, as well as for the rapid feedback to authors on their contributions.

The Utah Water Journal is designed to be a forum where issues of water quantity and quality in the State of Utah can be presented and discussed. To better accomplish this objective, we are requesting submissions of articles, announcements, and comments on water-related issues of interest to the people of Utah. Collaborations on water-related issues at the national and international level that may impact Utah are also requested. Please see the Instructions to Authors page for more information.

For this first issue, we focused on research topics from the Utah Water Research Laboratory. However, we would like to feature articles from other organizations in future issues.

Upcoming issues of the Utah Water Journal will address problems of interest to water professionals in the State of Utah, including but not restricted to, past weather patterns and effects of El Nino Southern Oscillation (ENSO), groundwater studies in specific Utah locations, population changes in our state and their effects on water supply and demand, flood protection in low-lying areas, modeling of closed-basin lakes (e.g., the Great Salt Lake), policy issues, etc.

It is our desire that the Utah Water Journal serve as an effective forum for the exchange of ideas on water-related issues. Therefore, do not hesitate to contact us with your collaborations, critiques, or suggestions.

Dr. Gilberto E. Urroz  
Editor-in-Chief  
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### Related Information

Hydraulics Lab/Fluid Mechanics Program /  
news/09sep/04/dams4.htm Water Engineering at  
UWRL

By Leanda Hemphill  
UWRL

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In June 1997, a powerful rainstorm near Austin, Texas, forced officials to open all ten flood gates on the Wirtz Dam to pass the resulting floodwater through the reservoir. Within hours, the water had gorged out a significant hole in the granite rock near the base of the dam's spillway section.

Another unexpected flood could widen the hole and erode the bedrock under the dam gates. If the dam failed, communities would be threatened farther downstream on the Colorado River. Decisions about emergency repairs needed to be made quickly by the owners of the dam, the Lower Colorado River Authority (LCRA).

The LCRA decided to fill the 15 feet long, 25 feet wide, and 12 feet deep hole with concrete. Then they would pour three concrete pads at the toe of the spillway section to deflect water away from the dam structure.

But first, LCRA called in experienced engineers from the UWRL to verify the feasibility of the proposed modifications. Within one month, the engineers had built a 1:35 scale model of the Wirtz Dam and tested different structural scenarios. The UWRL model studies demonstrated that one of the pads was not necessary. This finding saved the dam owners \$800,000.

UWRL researchers are working with LCRA to investigate additional long-term options to minimize the potential for more scour holes downstream of the spillway section.

The UWRL offers a range of services for hydraulic structures including design, analysis, physical modeling, computer modeling, and field testing. These studies can increase the safety of the hydraulic structure by identifying and eliminating potential problems.



Wirtz Dam Model

# A Digital Water and Climate Atlas for Asia

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## 1. INTRODUCTION

A digital water and climate atlas has been created for agriculture interests. The World Water and Climate Atlas for Agriculture includes 10-day, monthly and annual precipitation totals as well as maximum, minimum and average temperatures. The data are shown at a 2.5 minute grid resolution. In addition, other calculated values are included such as precipitation probabilities, evapotranspiration, net evapotranspiration, days with rain, and moisture availability. These data and calculations may assist agricultural interests in planning and other purposes.

## 2. METHODS

Measured climatic parameters include only maximum and minimum temperatures and total precipitation. Other parameters presented in the Atlas are derived from reported temperature and precipitation. Parameters presented in the Atlas include: maximum, minimum and mean temperatures; total precipitation, days with precipitation and precipitation probabilities; evapotranspiration; moisture availability index; and net evapotranspiration.

A world digital elevation model (DEM), digital line graphs (DLGs) and digital cities data base from the United States Geological Survey were used in the mapping process. The DEM used was based on a 2.5 minute regular grid.

### 2.1. Interpolation Methods

Data do not exist at all locations and for all time periods. It was necessary, therefore, to interpolate among the data in space and time to derive estimates for specific places and times. Interpolation methods vary from sophisticated and complex to simple linear routines.

In our work we have found that interpolation techniques fall into three categories. We define the first as the "distance weighting" method that simply gives a computational weight to an observation depending

on how far the location of the observation is from other observation locations. The second method is the krigging and zoning types that interpolate well but tend toward instability when data are sparse. The third method is the minimum curvature and associated thin spline methods that need specific starting surfaces and boundaries. When there are sufficient data, nearly all interpolation routines provide like estimates. Where data are sparse, care must be taken in choosing the interpolation routine because it will introduce information not included in the original data. That information may or may not be acceptable in making estimates in data sparse regions.

### 2.2. Spatial Interpolation Techniques

Although errors often occur in weather and climatic data, contour maps are usually drawn so that the surface on which the contours lie, passes exactly through the observations. It is necessary to interpolate among the random observations in order to construct such a surface either manually or by machine. To facilitate machine computation, a regular, rectangular grid is usually constructed. The final grid is then easily contoured for presentation as contoured surfaces. The grid distribution is also available for specific observation estimates in space or time.

Our interpolation routine uses a derivative minimum curvature technique based on the work of Briggs (1974) and Webring (1981). In this process, the optimal properties of the spline fit can be obtained in two dimensions by solving the differential equation equivalent to a third-order spline. This describes the displacement of a thin sheet in two dimensions under the influence of random point observations. Finite difference equations are deduced from the principle of total minimum curvature. An iterative method is then used to derive the solution. Finding the solution set of difference equations is an extremely time-consuming process, even on very fast computers, but these conditions maintain the minimum curvature property in sparse data areas and cause the gridded surface to converge to the data.

The biharmonic difference equation is used to generate a smooth surface with the property of minimum total curvature. The curvature refers to the estimate of the second horizontal derivatives in x and y at each grid location. The specific algorithm developed by Briggs (1974) included randomly placed data values as boundary conditions for the difference equations. This requires that the grid be initialized by an independent

method and then the difference equations applied using a finite number of iterations. This has the disadvantage that the initialization method can introduce false trends, and therefore must be carefully administered. Advantages of the algorithm in spatial interpolation include its high degree of internal consistency, and the capacity to fit a surface to very large amounts of data without the use of potential, unstable matrix methods.

The initial surface used in development of the Atlas included only the best fitting data values. This surface was then relaxed, and additional data were added for computation of the finite difference equations and development of the final surface.

A technique, sometimes known as a “blind” process, was used to test the adequacy of the gridding interpolation method. With this technique a random observation is excluded from the interpolation process and a new surface is derived without the observation. The difference between the surface with the observation and the surface where the observation is excluded is then calculated. The differences are accumulated and statistics derived. These results imply how well the interpolation routine estimates missing observations and the reliability of the gridded surface.

### 2.3. Data and Databases

We tried to obtain as much measured temperature and precipitation data as possible for Asia. There are a finite number of observation stations. Although there are many data bases, those data sets are comprised of combinations of the same weather stations to meet certain criteria and the one we developed and used in the Atlas is just such a data base. For any particular weather station and specific time, at least one data value was available. Sometimes several conflicting data values were available for the same time and place. The values which best fit our Atlas project were used. Conflicting values were “flagged” and retained as part of the data base.

The climatological data sets that were used for the Asian phase of the project included the Global Daily Summary (1977-1990), the India Precip data set (1961-1970), the Kanpur, India Precip data set (1975-1984), the China Precip data set (1961-1982), the FAOCLIM World-Wide Agroclimatic data base, and the GHCN, (version 1). Monthly and annual values were readily available in the FAOCLIM World-Wide Agroclimatic and first version of the GHCN data bases. Daily values were taken from the Global Daily Summary (GDS).

Some additional data were made available for a small number of miscellaneous weather stations. This included a printed set provided for Sri Lanka.

Data considered correct for any weather station was used in the gridding process. This means that if data were available for only one day for a particular weather station, it was used for that day. It is difficult to determine how many stations were used in the gridding process. All stations had some missing data that ranged from a day to nearly the entire period of record. In all, over 17,000 weather stations were used in the creation of the Atlas for Asia, but the count differed on a day to day basis.

### 2.4. Quality Control

All data used in the Atlas had been through several quality control levels prior to use in the Atlas. The original, observed, raw data were not available. One objective in creating the Atlas was to derive average ten-day, monthly and annual estimates for the 1961-1990 period. Ten-day values were derived from an aggregate of daily values. However, all daily data were not available for every weather reporting station. Daily data were available from the GSD data set for the 1977-1982 and 1984-1990 for many stations. Although the data sets we obtained were previously quality controlled, errors and missing data also infested the data sets. Sometimes these data were flagged as questionable, but in most cases they were not. In addition, some data sets included several derived values for the same location and time. It was necessary to determine which of all the values reported for a location should be used for the Atlas.

The data were plotted at the latitude and longitude for the location given in the data base. Where the location appeared obviously incorrect, such as in the ocean or well beyond given country boundaries, the name of the city in the data base was compared with the location of the city as noted on our digital city location data base. Where possible, implausible weather station locations were corrected. This process was iterative in checking location and data values. When the location could not be verified, the station data are not used in the Atlas. When locations of two or more stations were located in a close proximity and their data values were inconsistent with each other, the data value most like other, nearby stations was used. When there were no close stations, an average of the inconsistent values was computed and used at the location. Stations where deviations could not be explained are excluded from the

final thematic mapping, but are included in a tabular data file for reference.

### 2.5. Temperature Estimates

Temperatures normally decrease with increasing elevation. This rate of temperature decrease is commonly referred to as the temperature “lapse rate.” The lapse rate can be calculated when there are two or more temperature recording stations in the same vicinity but at different elevations. A “standard” lapse rate is used regularly for atmospheric stability and thermodynamic calculations. The lapse rate also differs with changes in the moisture content of the air. Because we were computing average 10-day, monthly and annual estimates for a 30-year period, we used a standard linear lapse rate of 6.6 degrees Celsius for each 1,000 meters. We also converted the Celsius and Fahrenheit temperatures to Kelvin equivalents for ease in computation. Results are reported in degrees Celsius.

A “lapse-grid” was created to speed the computation process. This was done by dividing the lapse rate of 6.6 by 1,000 and multiplying the result by elevation value of each grid cell from the DEM.

The spatial interpolation estimates for temperature was computed by reducing the temperatures to sea level at a constant lapse rate, interpolating the values to grid locations, and then restoring the temperatures to the DEM topographic surface. The temperatures were reduced to sea level by multiplying the elevation of each weather station location on the DEM by 6.6, dividing the result by 1,000 and then adding that value to the temperature as recorded at the weather station. The sea level temperatures were then interpolated using the minimum curvature technique to compute a sea level temperature for each grid cell. The gridded sea level temperature was smoothed using the eight adjacent cells. The gridded sea level temperatures were then restored to the topographic surface by subtracting the lapse grid values from the computed sea level grid location values. The final result was spatially distributed temperatures for each grid cell for the Asia region.

### 2.6. Temporal Distributions

For each day, every data value was used for verified locations, and a spatial grid was created for that day. In this manner grids were created for each day for the period of available daily data. When missing values occurred for a particular location and day, those values were estimated for the grid cell at the particular location by the interpolation routine. The temperature

estimates were then smoothed through time using a low pass filter on the time series developed for each individual grid cell. These values were aggregated into 10-day averages and then monthly averages. The aggregated monthly averages were compared with monthly averages reported in the data bases. Ten-day values for the entire 1961-1990 period were derived by using a ratio from the aggregated daily, ten-day and monthly values with the monthly values from the data base.

The mean temperature was calculated as a unique surface for each day using the daily maximum and minimum temperature grids. The mean temperature for each grid point was computed as the sum of the daily maximum and minimum grid point temperatures, divided by 2.

Where daily temperatures were available, 10-day and monthly temperatures were computed by averaging each of the maximum, minimum and mean daily temperatures for the time period needed. That is, for each grid point, the ten daily map values were summed and divided by 10. Monthly and annual temperature surfaces were derived in the same manner. Monthly temperatures from the Atlas were compared with monthly data reported for stations in the various data bases. Differences in values were resolved or flagged for further research. The 1961-1990, 30-year summaries for temperatures and temperature derived parameters were calculated by summing the 30, 10-day, monthly or annual values and dividing the sum by 30.

### 2.7. Precipitation Estimates

The precipitation distributions developed in much the same way as were the temperature grids. The station locations were verified using the exact method as for temperature. A quality control process was then applied that used slope, aspect and elevation for each station location and compared the station location and precipitation amount with surrounding stations and observed values. Finally the precipitation values were spatially interpolated using the minimum curvature technique described above and the resulting surface is presented as the distribution of average 1961-1990, total precipitation for each 10-day, monthly and annual period.

Computed parameters include probability of precipitation at several levels, the moisture availability index, the net evapotranspiration index and the number of days with rain. These values were all computed on a grid cell by grid cell basis using estimates made from

the observed precipitation and temperature grids.

The number of days with rain were computed as the number of days with 1 mm or more of rain. These values were counted from the days in the daily precipitation record and used for the entire 1961-1990 period.

Precipitation probability was computed using the gamma distribution algorithm as developed by Hargreaves. This algorithm was used to compare computed estimates with values derived by Hargreaves (1974). The algorithm was not stable when computing probability amounts for bimodal distributions and it is replaced in the second version of the Atlas.

The probability of assured precipitation at the 75 percent level (P75) was calculated and used in determining both the assured moisture index (A75) and the net evapotranspiration (NET). The moisture availability index (A75) and net ETo, are compositions of reference evapotranspiration and assured rainfall.

### 3. RESULTS

Gridded surfaces in ArcInfo and ASCII format are available on the internet or from the authors. Resulting maps show temperatures, precipitation and calculated parameters. These maps are available at <http://atlas.usu.edu>. A descriptive help file is available with the viewing software. The gridded distributions were mapped at 2.5 minutes in latitude and longitude with no projection. In order to allow flexibility, the spatial distributions can be shown using any of several map projections available locally.

It is difficult to present maps of reasonable quality and resolution at several different scales. To make the results available to as many as possible, an Internet web site has been established. Maps for all parameters and in several formats can be obtained at <http://atlas.usu.edu>. In addition, the maps are available on compact disk format and can be ordered from the authors or through the Internet site.

The digital Atlas contains several tools that contribute to ease of use, and yet a significant amount of flexibility and power. These include user controlled automatic connections to the Internet with the capability to obtain recent data and maps. It also shows all available parameter distributions with the ability to select any or all.

A "polyclip" feature allows the user to define an area of interest with curved or straight lines. Once the area is selected, the average of any parameter for the

area is easily obtained. In addition, data and statistics for the area may be printed. A map showing the spatial distribution of a parameter may also be printed. For each parameter, default scales and colors have been chosen so that a particular color represents a specific numerical value for the parameter, regardless of location. This allows consistency for each parameter for the Atlas throughout the world. However, where there is little variation of the parameter in a chosen area, the parameter can be easily re-scaled using the high and low of the parameter in the area. The representative map is also re-scaled with the entire color pallet.

Point or spatial averages of any parameter can be quickly calculated and shown on the computer screen or printed. Tables of values may also be printed for points or user-specified areas.

Three types of maps result from derivation of the Atlas. The first type is a computer graphic or printed map that could be referred to as a "location" map. The second is a printed map that meets strict cartographic criteria. The third could be called a "science" map and might be presented as either a computer graphic or printed map. In addition, maps presented on computer screens must have highly visible, intense colors. Maps printed on paper, on the other hand, must have subtle colors and shading. Coloring of printed maps cannot be used for computer presentations, nor can the bright, intense colors necessary for computer screens be used for printed maps.

The first type includes maps that cover large areas and are presented as a small picture on a page or computer screen. All that is expected from such maps is a general impression of how a parameter is distributed spatially, and as a tool to navigate to smaller areas. For example, the first computer screen opened on the Atlas shows topography for the entire world, including the ocean areas, and is used as a tool to zoom to smaller areas.

The printed maps must be carefully prepared so that the parameter shown is emphasized. This means that the underlying base map must be downplayed and yet it must meet strict cartographic criteria in projection, amount and type of features shown, and color combinations. These maps are excellent to use for guidance, but scientists don't expect the maps to be exact, especially for specific points. As an example, the National Geographic magazine presents "location" maps within the pages of the magazine, but its printed maps are generally beautiful, color renditions for small

areas shown at specific projections and are presented on large, separate sheets, folded to fit within the magazine.

The third which we call a "science" map, can be presented as either a computer graphic or printed map. The distinguishing factor of these maps is that parameters presented on the maps, and even the very fine details, are expected to be scientifically correct. However, these maps tend to be very cluttered, crowded, and are not pleasing to the eye.

Our Atlas includes all three types of maps. The computer visualization program opens with a location map of the world. As the user "zooms" to smaller and smaller areas, resolution on the maps increases. Small area maps have been printed on large sheets for the measured and calculated parameters of the Atlas.

Additional useful parameters have been developed. Calculations of the ratio of the 75% probable precipitation (P75) and ETo, or the moisture availability index (A75) (Hargreaves et al., 1985, and Hargreaves, 1994), can be used to identify areas of rain fed agricultural potential and evaluate needs for irrigation and drainage. When A75 is 1.0, yields are 100% of potential. When A75 is 0.33, yields are about 40% of potential due to moisture stress. When the index is 1.33 or greater, water is 1.33 times or more than is necessary, and yields are about 80% of potential because of problems with aeration and the leaching of nutrients (Hargreaves, 1975).

The net ETo, or net evapotranspiration (NET) is similar to A75 and represents the difference between ETo and P75. When ETo is greater than P75, NET gives an indication of the required depth of irrigation necessary to achieve full crop production. When P75 is greater than ETo, the absolute value of NET is indicative of the potential surface runoff.

#### 4. FUTURE DEVELOPMENT

As far as we can determine, this represents the most comprehensive and best quality data set ever assembled for Asia. However, additional data will help refine and make the Atlas even better. We expect as the Atlas is used, additional data will become available and can be added. We welcome comments about data distribution and additional data. Data can be transmitted via the Internet or through traditional methods. We expect to derive better and better iterations of the Atlas for Asia as additional data, better techniques and new technology become available. We are presently eval-

uating new temperature lapse rates and precipitation distributions.

#### 5. CONCLUSIONS

The World Water and Climate Atlas for Asia uses data from over 17,000 weather stations. The Atlas includes 10-day, monthly and annual summaries for the 1961-1990 period. Averages and standard deviations are included for maximum, mean and minimum temperatures; precipitation totals and probabilities; number of days with rain; and reference evapotranspiration. The difference and ratio between precipitation and evapotranspiration are also given. The Atlas is published on CD-ROM and the Internet. Data are available by latitude and longitude and for user defined polygons. There are many direct uses for the Atlas in hydrology, planning and agricultural operations. It provides a ratio of the adequacy of precipitation for crop production; the amount of irrigation necessary for optimum crop production; the excess of precipitation that must run off, percolate into the soils, or be removed; and time series and spatial data necessary for use in crop yield models.

#### 6. ACKNOWLEDGEMENTS

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**WESTERN SNOW CONFERENCE**  
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Call for Papers

The Western Snow Conference (WSC) provides an international forum for individuals and organizations to share scientific, management and socio-political information on snow and runoff from any viewpoint. An aim of the WSC is to advance the snow and hydrological sciences. Membership is open to any person or institution having an interest in snow and runoff issues. The theme for this years conference is: Increasing western water supply demands and climatic extremes. Advances in data collection, forecasting, monitoring, water delivery and management.

The WSC meets annually in mid-April: for the presentation of 16 oral and 12 to 16 poster papers, with published proceedings. All Papers must adhere to the standards defined in the WSC Publication Policy (available upon author acceptance). Poster presentations will include a four page published manuscript. Papers are invited on research and applications in snow hydrology in the following areas:

- El Nino and Snowmelt Runoff
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- Long Range Forecasting
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- Data Collection/Monitoring
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Please submit abstracts (150 words or less) for consideration to the Technical Program Committee, no later than January 1, 1998. Notice of acceptance will be given by February 1, 1998. Graduate and undergraduate Papers are welcome: a \$250 James E. Church award and free registration to the Conference for the best student paper. Abstracts should indicate either 'oral' or 'poster' presentation, with the senior author's name, address, phone and fax numbers, and e-mail address.

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