Hydrological Forecasting Improvements

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Overview

High and low Great Lakes levels cause extensive flooding, erosion, and damage to shorelines, shipping, and hydropower. The Great Lakes community requires water resource nowcasts and 1- to 12-month probabilistic outlooks of lake supplies, lake levels, and connecting channel flows. These require careful tracking of moisture storage variables and heat storage variables. The products must be relevant to users and delivered in a clear and understandable manner that aids in planning and decision making. They must make maximum use of all available information and be based on efficient and true hydrological process models. The existing large-basin runoff models and large-lake thermodynamics and heat storage models provided an initial Great Lakes Advanced Hydrologic Prediction System (AHPS) development. It continues with process model development, data stream incorporation, and integrated data management. We built near-real-time data acquisition and use software to download meteorological data, reduce it, and use it in a daily hydrological outlook; the entire procedure has been completely automated. We implemented this system in demonstration and in the field to enable timely estimates of current conditions and hydrologic outlooks. As new distributed-parameter models for the atmosphere, lake thermodynamics, and land surface progress, they will be integrated. We will continue to serve a variety of present users, whose needs are satisfied with basin-wide outlooks based on GLERL's lumped-parameter models, while also servicing some of these and others with AHPS outlooks based on GLERL's developing distributed-parameter process models.

2001 Accomplishments

- All dynamic link libraries (DLLs) integrated into the GUI for the Advanced Hydrologic Prediction System (AHPS) were tested. NOAAPort was fully incorporated into AHPS, which involved redesigning the Thiessen weighting database management and the near-real-time data reduction used in AHPS to accommodate very large data networks. AHPS was installed, reinstalled, and updated at several field sites with the existing rudimentary back-end interface for monthly forecast products; as improvements are made, they are shipped to the field as well. Evaluations of AHPS and other extended Great Lakes level forecasts were made in which AHPS components and AHPS relative performance were determined, including separation of errors of modeling, sampling, observation, and weather forecasts.
- Recalibrations of the lake thermodynamic model were completed using meteorological and satellite water temperature and ice coverage data through 1995. The recalibrations will be added to both the forecasting (AHPS) and simulation model suites at GLERL.
- Recalibrations of the LBRM for the Great Lakes were continued; several lake basins are recalibrated but still require further checking. Documentation for use and calibration of the LBRM were updated and all software, worked examples, and input and output files were placed on CD for distribution (publication).

- Interface pieces were integrated for GLERL's AHPS to allow an operator to intuitively and easily download multiple data streams in a near-real-time manner and incorporate them into the AHPS data base, run evaporation and runoff models over the entire Great Lakes basin, compute appropriate biasing weights for matching weather forecasts with historical data, and prepare extensive forecasts of hydrology probabilities for the Great Lakes.
- Channel routing and lake-level regulation code was coordinated with the USACE and Environment Canada. Continued to work with the US-Canadian Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data as they consider GLERL's AHPS; reported AHPS developments to the committee and accepted their input.
- GLERL's AHPS operations were continued in house and research results were disseminated daily on the World Wide Web; see GLERL AHPS products. Agency assistance in making AHPS operational in their offices was continued.

2000 Accomplishments

Evaluation: Data acquisition began in preparation for an AHPS reevaluation and recomparison to be carried out in CY01. Monthly Great Lake water levels and net basin supplies (computed as a residual) were obtained from the US Corps of Engineers; monthly Great Lakes outflows, diversions, lake levels, and residual net basin supplies were obtained from Environment Canada; and monthly Great Lakes net basin supplies (computed as the sum of lake precipitation, lake evaporation, and surface runoff to the lake) were calculated anew at GLERL.

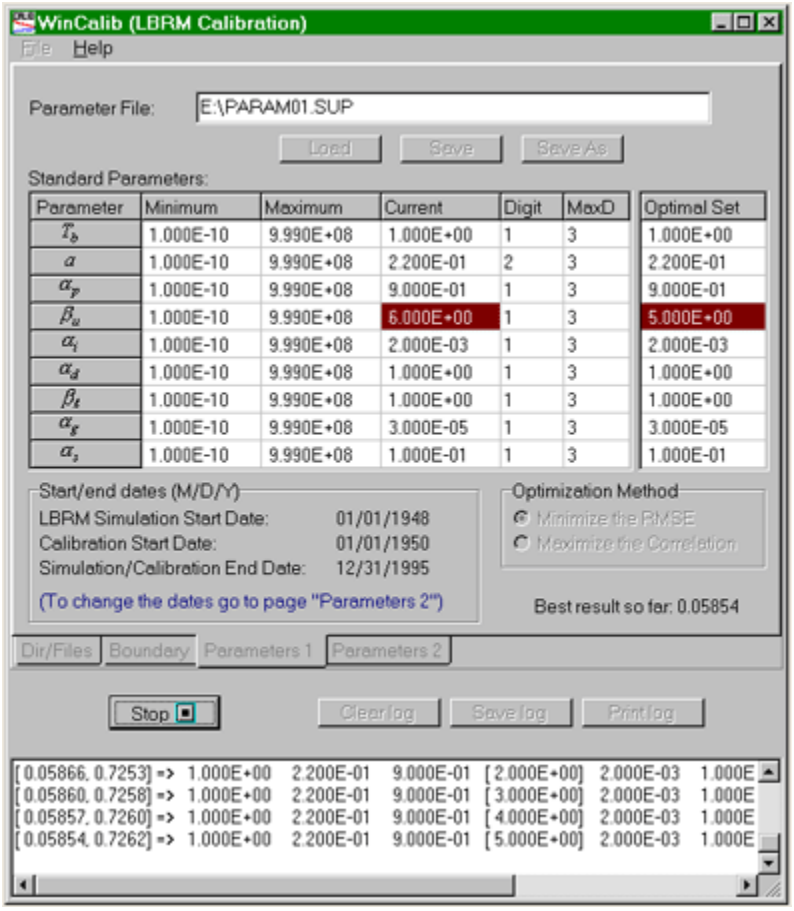
Data Streams: Continued incorporating the NOAAPORT data stream from GLERL's new satellite receiver, containing various meteorological data from water and land surfaces throughout the Great Lakes basin. NOAAPORT will provide GLERL's AHPS with much more data from stations that are not available from current sources (the Midwest Regional Climate Center Information System, a subscription near-real-time data stream). This includes many stations over the lake surfaces, not currently available otherwise. Modified AHPS software to accept the required format changes and data source changes, but have not yet actually integrated the NOAAPORT software into AHPS nor placed it into the field.

Software: Continued integration of an interface for GLERL's AHPS to allow an operator to intuitively and easily download multiple data streams in a near-real-time manner and incorporate them into the AHPS data base, run evaporation and runoff models over the entire Great Lakes basin, compute appropriate biasing weights for matching weather forecasts with historical data, and prepare extensive forecasts of hydrology probabilities for the Great Lakes. Converted all FORTRAN77 code for hydrological model simulations and forecast biasing to FORTRAN95 to make dynamic link libraries (DLLs) and integrated with the PASCAL code for the graphical user interface (to add to that already done for making provisional data updates). These efforts revealed that important FORTRAN error handling must be handled via written code.

Channel Routing: Continued building coordinated channel routing and lake-level regulation code with the USACE and Environment Canada. Added GLERL technical support to the workgroup, concerned with this, to take over development of the coordinated model. Continued to work with the US-Canadian Coordinating Committee on Great Lakes Basic Hydraulic and

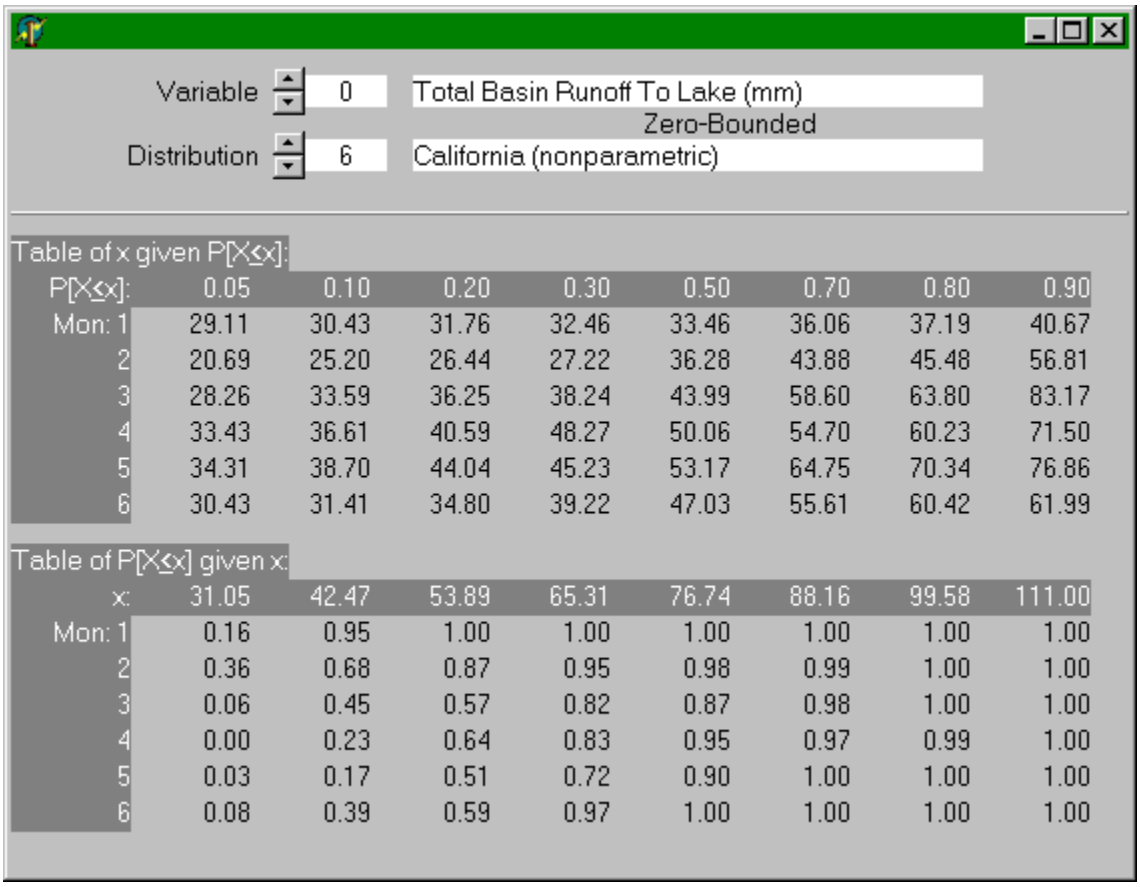
Hydrologic Data as they consider GLERL's AHPS; reported AHPS developments to the committee and accepted their input.

Model Updates: Looked at alternative snowmelt mechanics for the Large Basin Runoff Model (LBRM) and built the incorporation of boundary conditions into the model code so that they are easier to use. Translated all LBRM code into FORTRAN95 and restructured the code to make it modular, facilitating its use as a DLL. Built Windows application programs to serve as the interface for running and using the LBRM.



Built DOS and Windows application programs/interface for calibrating the LBRM. Documented the LBRM, constructing application/calibration examples. Started recalibrations of the LBRM for the Great Lakes; Superior is practically finished and the remaining lakes are recalibrated but still require further checking. The examples and all software for running and calibrating the LBRM are freely available from the GLERL over the World Wide Web at . Built new web sites to track requests for software products concerning the LBRM and Derivative Outlook Weights.

Graphical User Interface Development



Variable 0 Total Basin Runoff To Lake (mm)
Zero-Bounded
Distribution 6 California (nonparametric)

Table of x given P[X≤x]:

P[X≤x]:	0.05	0.10	0.20	0.30	0.50	0.70	0.80	0.90
Mon: 1	29.11	30.43	31.76	32.46	33.46	36.06	37.19	40.67
2	20.69	25.20	26.44	27.22	36.28	43.88	45.48	56.81
3	28.26	33.59	36.25	38.24	43.99	58.60	63.80	83.17
4	33.43	36.61	40.59	48.27	50.06	54.70	60.23	71.50
5	34.31	38.70	44.04	45.23	53.17	64.75	70.34	76.86
6	30.43	31.41	34.80	39.22	47.03	55.61	60.42	61.99

Table of P[X≤x] given x:

x:	31.05	42.47	53.89	65.31	76.74	88.16	99.58	111.00
Mon: 1	0.16	0.95	1.00	1.00	1.00	1.00	1.00	1.00
2	0.36	0.68	0.87	0.95	0.98	0.99	1.00	1.00
3	0.06	0.45	0.57	0.82	0.87	0.98	1.00	1.00
4	0.00	0.23	0.64	0.83	0.95	0.97	0.99	1.00
5	0.03	0.17	0.51	0.72	0.90	1.00	1.00	1.00
6	0.08	0.39	0.59	0.97	1.00	1.00	1.00	1.00

Developed software for distribution fitting and argument evaluation (and its inverse; i.e., both “y = F(x) given x” and “x = F-1(y) given y”). This allows “on-the-fly” building and reading of distribution values for any AHPS output forecast product. This software will be incorporated into the developing back-end AHPS interface module. Developed specialty versions of the AHPS back-end forecast products interface for alternate graphic depictions useful in selected presentations.

System Demonstration: Continued operating GLERL’s AHPS and disseminating research results daily on the World Wide Web; see Great Lakes Hydrology Outlooks or Great Lakes Net Basin Supply Forecast Model or GLERL Advanced Hydrological Prediction System Products. They are aided by ongoing field demonstrations at the Midwest Climate Center, the Army Corps of Engineers, and other agencies. Continued assisting agencies in making the AHPS operational in their offices. Handled several Y2K issues, some requests coming from the field. Presented and demonstrated the Large Basin Runoff Model, the Great Lakes Evaporation Model, and AHPS at the Great Lakes Advanced Hydrologic Prediction System Training Workshop, Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan, 17-19 July 2000.

Graphics: Designed and student intern constructed a multi-media training tutorial on the computer for use by others on the computer. Made it available on the World Wide Web with the software for using probabilistic meteorology outlooks; see Derivative Outlook Weights Software.

1999 Accomplishments

Began integration of an interface for GLERL's AHPS to allow an operator to intuitively and easily download multiple data streams in a near-real-time manner and incorporate them into the AHPS data base, run evaporation and runoff models over the entire Great Lakes basin, compute appropriate biasing weights for matching weather forecasts with historical data, and prepare extensive forecasts of hydrology probabilities for the Great Lakes. The graphical user interface (GUI) framework is in place (realized as "threads" in Windows programming); all FORTRAN77 code for making provisional data updates has been converted to FORTRAN95 to make dynamic link libraries (DLLs) that are suitable for interfacing with the PASCAL code for the interface; code conversion for the model simulations and forecast biasing has just begun. Multiple problems involved in threading and the interaction of threads in the interface caused delays and were resolved.

Dr. Zhu finished her postdoc work on 2-dimensional thermodynamics modeling of the Great Lakes and submitted a final report, which is on file. The resulting model is not really suitable for use in either a climate change study (as part of CHARM, under Dr. Lofgren) or a forecast setting (as part of AHPS). The model is too cumbersome for the latter as well as not offering any improvement in performance over the present 1-dimensional model currently used in AHPS. It would allow forecasts, not currently made, for locations on the lakes, but requires more work before it can be incorporated.

Began incorporating the NOAAPort data stream from GLERL's new satellite receiver, containing various meteorological data from water and land surfaces throughout the Great Lakes basin. NOAAPort will provide GLERL's AHPS with much more data from stations that are not available from current sources (the Midwest Climate Center Information System, a subscription near-real-time data stream). This includes many stations over the lake surfaces, not currently available otherwise. Acquisition and data preparation software was largely completed. Incorporation of the data stream automatically into the AHPS is beginning now.

Began building a user's manual with complete documentation on GLERL's AHPS . This manual will be in the form of an extensive hypertext help file (to be placed internal to GLERL's AHPS GUI) as well as in a conventional manual format. Activities began with 4 documents on file formats, internal to the AHPS, and the acquisition of software for building hypertext files. Incorporation of this material has begun. This will eventually include documentation of the AHPS GUI, mentioned above, but not until the GUI is finished.

Continued operating GLERL's AHPS package and disseminating research results daily on the world wide web. They are aided by ongoing field demonstrations at the Midwest Climate Center, the Army Corps of Engineers, and other agencies. Continued assisting agencies in making the AHPS operational in their offices.

1998 Accomplishments

The Great Lakes community requires water resource nowcasts and 1- to 12-month probabilistic outlooks of lake supplies, lake levels, and connecting channel flows. These require careful tracking of moisture storage variables and heat storage variables. The products must be relevant to users and delivered in a clear and understandable manner that aids in planning and decision making. They must make maximum use of all available information and be based on efficient and true hydrological process models. GLERL Advanced Hydrologic Prediction System provides probabilistic outlooks of many hydrological variables at weekly, seasonal, and interannual time scales throughout the Great Lakes by using, in order of user priority, the new long-lead extended-climate probabilistic meteorology outlooks from several agencies.

Most recently, GLERL (1) Compared GLERL's AHPS with existing US and Canadian deterministic forecasts to assess the effects of (a) considering residual vs. component lake supplies, (b) considering antecedent moisture and heat storage conditions (vs. not considering them), and (c) considering weather forecasts (vs. not considering them). (2) Initiated movement of AHPS computer software from DOS to Windows and created a graphical user interface for near real time data reduction; it is a working version transferred to two US Army Corps offices and the Midwest Climate Center. Forecasting programs, while not yet moved to Windows from DOS, have been adapted to run under Windows (in DOS) for both Windows 95 and Windows NT. (3) Rewrote channel routing and lake-level regulation code and incorporated Lake Superior regulation plan 1977 and mid-lakes routing into GLERL AHPS for daily modeling of lake levels, flows, and total lake supplies. We can now begin a full lake level forecast on any day and not just the beginning of the month. This is true for all lakes except Ontario, where we are still working on incorporating Lake Ontario regulation into the forecast procedures. (4) Built a graphical user interface for restructuring historical meteorology samples to match probabilistic meteorology outlooks in operational hydrology forecasting for a single area. It must now be extended for multiple (simultaneous) areas. (5) Instituted ongoing lakewide and regional demonstration of the Great Lakes AHPS. There are ongoing field demonstrations at the Midwest Climate Center. We also automated the posting of all AHPS results DAILY onto the World Wide Web for special use by the International Joint Commission.

Products

Croley, T. E., II, 2001. Large Basin Runoff Model. In Mathematical Models in *Watershed Hydrology* (V. Singh, D. Frevert, and S. Meyer, Eds.), Water Resources Publications, Littleton, Colorado, 56 pp. (in press).

Presentations and demonstrations of the Large Basin Runoff Model, the Great Lakes Evaporation Model, and AHPS at the Great Lakes Advanced Hydrologic Prediction System Training Workshop, Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan, 4-5 June 2001.

GLERL's Large Basin Runoff Model web package, with examples and all software for running and calibrating the LBRM, is freely available over the world wide web at Large Basin Runoff Model Software.

GLERL's Advanced Hydrologic Prediction System interim software package installed at GLERL is used daily to present extended probabilistic hydrologic outlooks on all of the Great Lakes and their basins; forecast products are available over the World Wide Web at GLERL AHPS Products. The package installations were updated this year at the Midwest Climate Center for weekly use (see Great Lakes Hydrology Outlooks and Great Lakes Net Basin Supply Forecast Model), at the US Army Corps offices in Detroit for monthly use, in the offices of Environment Canada in Cornwall for monthly use, and at Ontario Hydro and New York Power Authority for occasional use.

Croley, T.E., II, 1998. Great Lakes advanced hydrologic prediction system. *Proceedings, First Federal Interagency Hydrologic Modeling Conference*, Subcommittee on Hydrology of the Interagency Advisory Committee on Water Data, Las Vegas, 19-23 April, pp. 6-1 to 6-8.