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ANALYSIS ON PROGRESS AND FUTURE DIRECTIONS ONHYDROLOGIC MODELING

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ABSTRACT

An overview of hydrologic modeling's past and future is presented in this paper, which analyses the advances made in hydrologic modelling since computer technology was introduced. It is possible to track the advancements in hydrology by examining the changes in data collecting and processing, conceptual frameworks, interdisciplinary collaboration, computational and analytical methods, and models and the results produced by those models and those methods. New data gathering and computation methods are predicted to assist hydrology by increasing integration with technical and non-technical disciplines and by increasing the usage of information technology resources. That's why issues like food and water safety, energy security, public health, ecosystem stability, and sustainable development will all be impacted by hydrology in the twenty-first century.

1. INTRODUCTION

As long as we can remember, hydrology has been in existence (Biswas 1970). In spite of the fact that hydrologic modelling dates back to the 1850s, Mulvany (1850) developed a method for computing peak discharge, Darcy (1856) carried out experiments on flow-through sandy sands, and Fick (1858) developed Fick's first rule, which states that undisturbed groundwater flows in a straight line when it is not disturbed. Saturation and actual air vapour pressures are directly proportional to the rate of evaporation. This law of evaporation has been known since Dalton (1802). The development of evaporation physics was based on this law. Many revolutionary advances in hydrologic cycle modelling were accomplished over a span of more than a century until the 1960s. Mathematical physics, as well as laboratory and field experiments, contributed to some of these advancements. The pre-1960 developments in hydrologic research and engineering are largely responsible for where we are today in those fields of study. Hydrological advances up to the 1960s were covered in the Chow handbook of applied hydrology (1964), while the Maidment handbook of hydrology (1993) and the Hershey and Fairbridge encyclopaedia of hydrology and water resources (1998) covered advances that happened in the interim. There has been a long history of progress in hydrological cycle modelling, as described by Singh and Woolhiser (2002).

Hydrological modelling advanced dramatically after the invention of the personal computer in 1960. With its newfound computing power, the computer surpassed expectations. As a result, a new discipline of hydrology known as "digital" or "numerical" was born. The development of stochastic hydrology, which necessitates the analysis of massive volumes of data, also occurred. After that, a slew of noteworthy events transpired. As a result of the Stanford Watershed Model (Crawford and Linsley, 1966) and a slew of other watershed models constructed around the world in the years that followed (Singh 1995; Singh and Frevert 2002a, b, 2006). The foundation for reservoir and river basin simulations was built by the development of optimization or operations research approaches. There were also some of these methods used to calibrate water-flow modelling systems (Beven 2001; Duan et al. 2003). Second and third-dimensional modelling was made possible by advances in numerical mathematics. As a result, groundwater and soil water flow models, as well as two- and three-dimensional models, were constructed (Bear 1979; Pinder and Celia 2006; Remson et al. 1971). The real-time simulation of various flow phases, such as liquid and gaseous, was also done in order to model water and pollutant transport, as well as the movement of silt and pollutants (Bear and Verruijt 1987; Charbeneau 2000). Geographical and temporal modelling, such as the Mississippi River basin, was used in the fifth step (Molley and Wesse 2009; Sorooshian et al. 2008). Combining hydrology with other fields was only a matter of time before it became viable. To give just a few examples, it was possible to combine hydrology with climatology to model and forecast precipitation (Sorooshian et al. 2008), geomorphology to represent river basins geometrically (Baker et al. 1988; Bates and Lane 2002; Beven and Kirkby 1993), hydraulics to describe flow characteristics (Singh 1996), and soil physics to quantitate soil texture and structure (Bohne 2005; Guymon 1994; Miyazaki 2006, (Delleur 1999; Fetter 1980; Singh 2017a, b, c). Because of the link between hydrology and ecosystems, the field of ecohydrology was born (Eagleson 2002; Gordon et al. 2006; Rodriguez-Iturbe and Porporato 2004). The study of water resources is now influenced by changes in climate and rising temperatures (Arnell 1997). Singh provides a more in-depth look at the hydrologic cycle's various components (2013, 2014, 2015, 2017a).

During the next decades, as computing power increased dramatically, hydrology evolved and extended both vertically and horizontally (horizontally). The early twentieth century saw the incorporation of hydrology into fields like statistics, probability, and information theory (Bras and Rodriguez-Iturbe 1985; Clarke 1998; Gelhar 1993; Mays and Tung 1992; Singh et al. 2007; Tung and Yen 2005). This has resulted in the development of computer-based applications for data gathering as well as storage and retrieval (Croley 1980; Hoggan 1989). Remote sensing equipment, including radar and satellites, has made it possible to acquire spatial data for large areas (Engman and Gurney 1991; Hogg et al. 2017; Lakshmi 2017; Lakshmi et al. 2015). raster and vector data processing, like GIS, was built to manage enormous volumes of data (Maidment 2002). In the last two decades, artificial neural networks, fuzzy logic, genetic programming, and wavelet models have been developed (Kumar et al. 2006; Ross 2010; Sen 2010; Tayfur 2012). New ideas in hydrology were adapted from other disciplines. Entropy theory (Singh 2013, 2014, 2015, 2016, 2017b), copula theory (Singh and Zhang 2018), chaos theory (Sivakumar 2017), network theory (Sivakumar et al. 2017), and catastrophe theory (Sivakumar et al. 2017) are examples of these theories (Poston and Stewart 1978; Zeeman 1978). In the coming years, hydrologic modelling will increasingly incorporate these theories.

2. HISTORY OF HYDROLOGIC DEVELOPMENTS

Since the 1850s, there have been many advances in hydrology, and it will be difficult to include them all here. As a result, this article will only provide a brief overview of some of the most significant changes from the author's perspective. Topics, rather than dates, will be used to group these recent changes for convenient access.

Watershed geomorphology

Quantitative geomorphology was founded on Horton's empirical rules, which were developed in 1945. These were the laws of stream slopes, stream lengths, and stream numbers. Horton ordering is a system he devised for channel and basin ordering. Additionally, Horton (1932) defined overland flow length and drainage density. Overland flow was the primary source of landform formation and streamflow creation. Horton–Strahler ordering is the name given to Strahler's modification of Horton's channel network ordering mechanism. The law of stream areas was developed by Schumm in 1956. As Hack (1957) for mean annual discharge, Leopold and Miller (1956) and Gray and Wigham (1956) have shown, a law of discharge can be derived because discharge is highly associated with drainage area (1970). (1992). Strahler (1957) was the first to suggest the law of drainage basin similarity, although Gray (1961) found that not all basins were geometrically comparable. Smart and Surkan have also looked at the relationship between drainage area and length, as Gray (1961) did (1967). Shreve proposed a statistical law for channel numbers (1966). On the basis of the notion of minimal energy dissipation rate, Yang (1971) proposed the law of average stream drop. These pioneering initiatives have a considerable impact on the advancement of the next years. Geomorphological characteristics of watersheds have been researched, according to Fitzpatrick (2017). For calculating the hydraulic geometry of steady-state channels, Smith (1974) utilised conservation laws and sediment transport laws. The entropy of a given object can be calculated using entropy theory and the concept of the least energy dissipation rate. Upstream hydraulic geometry was developed by Singh and Zhang (2008a, b) and downstream hydraulic geometry was developed by Singh et al. (2003a, b).S Beven and Kirkby (1993) and Baker et al. (1995) discuss channel network applications and flood geomorphology, respectively (1988). A river basin's fractal geometry has been used to characterise it by Rodriguez-Iturbe and Rinaldo (2001). As a result, ungauged basins' runoff forecasting models rely heavily on watershed geomorphology (Bloschl et al. 2013; Wagner et al. 2004).

Hydraulic geometry

With regard to both hydraulic geometry at a station and down stream, the relationship between channels' diameters and discharges can be summarised as follows: It is (Wolman 1955). Leopold and Maddock (1953) were the first to derive hydraulic geometry relations of power form. This relationship has been studied extensively because of its practical usefulness in building stable channels, river flow control works, river rehabilitation works, and irrigation systems. Regime theory (Blench 1952), tractive force theory (Lane 1955), the minimum entropy production model (Leopold and Langbein 1962), the stability model, and the minimum variance t have all been used to arrive at this conclusion (Deng and Zhang 1964; Singh et al. 2003a, b; Singh and Zhang 2008a, b). Exponents for the exponents in the equations are affected by different theories of hydraulic geometry. When it comes to exponent stability, for example, Singh discusses how channel patterns, stream size, climatic and environmental factors and land use all affect exponent stability. He also discusses how drainage basins affect this stability, and how boundary conditions affect it (2003).

Surface runoff

For calculating peak discharge due to a rain event with uniform intensity and length equal to or greater than the period of concentration, Mulvany developed a method he named the logical approach in 1850. Up till now, this approach has been used to construct modest urban watershed drainage systems. Equations derived by St. Venant de (1871) to represent surface flow are today known as St. Venant equations. The equation for calculating flow velocity in open channels was derived by Manning two decades later, in 1895. There is a correlation between the peak of storm runoff and the amount of rain that falls, according to Imbeau (1892). Linear systems hydrology was founded on Sherman's unit hydrograph concept in 1932. Semi-empirical formulas for overland flow were derived by Horton (1939). Methods to separate hydrographs were devised by Barnes (1940). With hydraulic principles and a reduced momentum equation, Keulegan (1944) predicted overland flow with great accuracy. In 1944, Izzard experimented with overland flow on paved surfaces. Using a unit hydrograph, Clark (1945) came up with a method for calculating the rainfall–runoff hydrograph. Rainfall–runoff models now have both a conceptual and a physical basis because of these improvements. For these tactics to work, we needed to determine how much surface runoff there would be, and therefore how much more rainfall there would be.

The Soil Conservation Service (SCS) of the United States Department of Agriculture (USDA) developed a method known as SCS-Curve Number (CN) for calculating rainfall-induced runoff. Curve number is used to account for historical soil moisture conditions, land use and cover hydrologic conditions, and abstractions. Watersheds of all sizes, from small urban watersheds to rural watersheds, are still commonly utilised to estimate runoff and excess rainfall. The impact of runoff on the source area was researched by Nielsen et al. (1959), who came to the conclusion that it is a significant factor.

"Snow Hydrology," a book released in 1956 by the U.S. Army Corps of Engineers, established the groundwork for much of the subsequent research in the field. Everything you might ever want to know about the snow environment was covered in this one book. Snowmelt was first measured using the degree-day method proposed by Martinec (1960). An equation for the energy balance of the snowpack was devised and proven by Anderson (1968). Water percolation in snow and water movement in a stratified snowpack were developed by Colbeck (1972) and Colbeck (1975). This book is a must-read for everyone who wants to know more about snow and floating ice. The kinematic wave theory of snowmelt water vertical movement through a snowpack and saturated basal flow in a snowpack was developed by Singh et al. (1997a, b). Snowmelt runoff generation and simulation were thoroughly reviewed in Kuchment (2017). In 2011, Singh et al. (2011) created an encyclopaedia of snow, ice, and glaciers.

2.4 Interception and depression storage

As much as a quarter of the annual precipitation may be lost due to interception loss in watersheds with dense, humid vegetation. According to Helvey and Patrick (1965), the loss in such watersheds could be as high as 15 cm. For a range of vegetative coverings, Horton (1919) developed a series of empirical equations for calculating storm interception For calculating vegetation interception, Linsley et al. (1949) devised an exponential type model. The Horton model was tweaked by Merriam (1960). For calculating interception loss, Bultot et al. (1972) devised empirical relationships. When it comes to infiltration loss, seasonal variations in canopy structure can have a significant impact. The forest infiltration loss model created by Gash (1979) can be found here. Beech forest canopy and floor interception in a beech forest was studied by Gerrits et al. (2010).

Holtan and Horton (1939) empirically tested the preservation of depressive symptoms. For various antecedent situations, Turner (1967) generated time-dependent depression storage intensity curves. For hydrologic modelling, Ullah and Dickinson (1979a, b) used a digital surface model to examine the geometric features of depressions Interception and depression storage losses were taken into account in the SCS-CN model (1956) by the Soil Conservation Service (Mishra and Singh 2010c). For a given effective rainfall, Linsley et al. (1949) provided an exponential model for calculating surface depression storage. Impervious areas' surface storage and soil roughness and slope were explored by Borselli and Torri (2010), who proposed an empirical model.

3. DATA OBSERVATION AND TOOLS

There are many aspects of hydrologic systems that we may learn through actual data. There are a variety of data types needed for hydrologic modelling. These include hydrometeorological and physiographic data as well as geomorphic and pedological data. Research and fresh knowledge have been and continue to be generated using data collected by local, state and federal government entities over the years. In the previous 30 years, data collection technology has seen four major shifts. On top of everything else, more precise methods of data collection, such as acoustic Doppler velocimetry, are available (ADV). Direct discharge measurement, for example, was previously not possible but is today. A radar-based representation of the rainfall field can also be used to collect spatial data rather than point data, for example. As a result of the development of satellite technology, data may now be collected in previously unreachable areas.

Satellites and radar, as well as other remote sensing techniques, are becoming increasingly common (Engman and Gurney 1991). NASA's Earth Resources Technology Satellite (ERTS) and USGS's Landsat-1 (also known as Landsat-1) launched in 1972, and since then, six additional satellites have been launched and data have been collected on the land surface (Shen et al. 2013). The Landsat Data Continuity Mission (LDMC), a new generation of satellites, was put into operation in 2013. The NASA Land Measurement Portal (http://landportal.gsfc.nasa.gov) contains data products in four categories: radiation budget, vegetation characteristics, land cover/land use changes, and land hydrosphere. More precisely, data on meteorological inputs, soil and land use characteristics, water body inventory (such as lakes, reservoirs, rivers, etc.), snow cover and ice fields, and water quality parameters can all be obtained for hydrologic modelling purposes. Satellite sensors and missions have also been launched by other countries in the Asia-Pacific region (Japan, China, and India). Soil moisture and ocean salinity can be estimated using the Advanced Microwave Scanning Radiometer (AMSR) and the Soil Moisture and Ocean Salinity (SMOS) instruments; precipitation can be estimated using the Tropical Rainfall Measuring Mission (TRMM); vegetation can be determined using the Moderate Resolution Imaging Spectroradiometer (MODIS); surface water levels can be determined using the JASON-1 and JASON-2 instruments and the TOPEX-POSEIFON instrument; The terrestrial water cycle has been studied extensively by Lakshmi et al. (2015) using remote sensing methods. Remote sensing of hydrological extremes was edited by Lakshmi (2017) in a book.

Using weather radar, forecasters are able to map out rainfall patterns and predict the weather for the next 24 hours. Radars, both on the ground and in orbit, are employed. Radar rainfall data are typically scaled to match data recorded at rainfall gauging stations using bias correction techniques. However, despite the fact that radar rainfall data can be accessed online, it is recommended that they be used with quality assurance and bias adjustment in mind. Pathak et al. (2017) edited a special issue of Journal of Hydrologic Engineering on radar rainfall and operational hydrology that contains papers dealing with radar rainfall data estimation, improvement, and validation; application of radar rainfall data; and use of radar rainfall for flood forecasting.

3.1 Geographical information systems

This technology, known as Geographical Information Systems (GIS), may be used to store and analyse massive volumes of data (Singh and Fiorentino 1996). The x, y, and z coordinates of land surfaces described in a coordinate system are referred to as "geographic information" in this context. Because it is a data processing tool, GIS may deal with technologies that supply or record information, such as digital elevation models (DEMs), topographic surveys, and maps of land use and land cover (Maidment 2002). GPS and GIS can now be used in conjunction to generate more comprehensive data. It is possible to incorporate spatial, non-spatial, and auxiliary data into hydrologic models through the use of geographic information systems (GIS) (Mujumdar and Nagesh Kumar, 2012). GIS and its applications have been thoroughly addressed by Griffin et al. (2017).

CONCLUSIONS

In light of this research, we may say the following:

From humble beginnings in the 1850s, hydrologic modelling has progressed significantly. More and more advances are being made in modelling because of the rising availability of powerful computers, high-tech instruments, and advanced geospatial information systems (GIS). 2.Hydrology is progressively being integrated with related fields, and this trend will continue. Hydrology is becoming increasingly important as a result of global warming and climate change, as well as the increasing importance of water, food, and energy security. Hydrology is integrating information technology with little resistance. As new approaches in mathematics, statistics, and science are discovered, hydrology is eager to incorporate them into its work.

REFERENCES

1. Abbott MB (1976) Discussion of “Review of models of tidal waves,” by J.B. Hinwood and I.G. Walls. J Hydraul Div 102(HY8):1145–1148

2. Abbott MB (1979) Computational hydraulics: elements of the theory of free surface flows. Pitman, London, p 324

3. Ackers P, White WR (1973) Sediment transport: new approach and analysis. J Hydraul Eng ASCE 99(11):2041–2069

4. Anderson EA (1968) Development and testing if snowpack energy balance equations. Water Resour Res 4(1):19–37

5. Arnell N (1997) Global warming, river flows and water resources. John Wiley, Chichester, p 224

6. Bagnold RA (1966) An approach to the sediment transport problem from general physics. U.S. Geological Survey Professional Paper 422-I

7. Baker VR, Kochel RC, Patton PC (eds) (1988) Flood geomorphology. John Wiley & Sons, New York, p 503