Geography of international water conflict and cooperation: Data sets and applications

Shira Yoffe,[1] Greg Fiske,[2] Mark Giordano,[3] Meredith Giordano,[3] Kelli Larson,[4] Kerstin Stahl,[4] and Aaron T. Wolf[4]

Received 29 July 2003; revised 21 November 2003; accepted 16 December 2003; published 12 May 2004.

[1] The Transboundary Freshwater Dispute Database provides a framework for quantitative, global-scale explorations of the relationship between freshwater resources and international cooperation and conflict. Projects were designed to test common theories linking freshwater resources to cooperation and conflict, in particular within the context of geography and environmental security. The projects, which follow in sequence, consider three main hypotheses on the likelihood and intensity of water resource disputes. To test these hypotheses, a unique set of tools was created that links water-specific event data with a geographic information system (GIS) that meshes biophysical, political, and socioeconomic data sets at the river basin and other scales. There are three linked data sets: (1) an event data set documenting historical water relations, including a methodology for identifying and classifying events by their intensity of cooperation/conflict; (2) a GIS data set of countries and international basins, both current and historical; and (3) a spatial data set of biophysical, socioeconomic, and political variables, linked to the GIS. This paper describes the hypotheses, the above tools created to test them, and a methodological framework for utilizing the linked event and GIS data sets, providing three projects as examples: (1) indicators of international basins at risk of political tensions, (2) relationships between internal and international hydropolitics in three geographic regions, and (3) hydroclimatological variables and international water relations. *INDEX TERMS:* 6399 Policy Sciences: General or miscellaneous; 1833 Hydrology: Hydroclimatology; 9345 Information Related to Geographic Region: Large bodies of water (e.g., lakes and inland seas); 9399 Information Related to Geographic Region: General or miscellaneous; *KEYWORDS:* conflict, cooperation, event data, freshwater resources, geography, transboundary rivers

Citation: Yoffe, S., G. Fiske, M. Giordano, M. Giordano, K. Larson, K. Stahl, and A. T. Wolf (2004), Geography of international water conflict and cooperation: Data sets and applications, *Water Resour. Res.*, *40*, W05S04, doi:10.1029/2003WR002530.

1. Introduction

[2] The relationship between water and conflict is an area of continued interest and debate in both the policy literature and popular press [*Westing*, 1986; *Elliott*, 1991; *Gleick*, 1993; *Homer-Dixon*, 1994; *Remans*, 1995; *Butts*, 1997; *Elhance*, 1999; *Marty*, 2001; *Chatterji et al.*, 2002; *Wolf*, 2002]. The lack of global-scale, quantitative tools for evaluating interactions over shared water resources results in the facts that: most literature is based on individual case studies, and global evaluations are rare; existing work often consists of case studies from the most volatile basins and excludes examination of cooperation, spatial variability, and precise definitions of conflict; and, while this literature occasionally stresses various socioeconomic, political, or biophysical indicators for conflict, including proximity, government type, aridity, and rapid population growth, comprehensive methodologies for evaluating them are rarely offered.

[3] In order better to understand water's relationship to both cooperation and conflict throughout the globe, researchers at Oregon State University have been developing over the last seven years the Transboundary Freshwater Dispute Database (TFDD), a project of OSU's Department of Geosciences in collaboration with the Northwest Alliance for Computational Science and Engineering. TFDD is an electronic compendium of case studies of water conflicts and conflict resolution, international treaties, national compacts, and indigenous methods of water dispute resolution available online at www.transboundarywaters.orst.edu.

[4] This paper presents three specific hypotheses regarding water's relationship to conflict and describes three major components of the TFDD created to test them. These data sets, the Water Event Data Set, the International Basin geographic information system (GIS) data set, and the Spatial Variable Data Set, offer, for the first time, the possibility of linking instances of historical international water relations with biophysical, socioeconomic and political variables, using event data methodologies and a GIS. These data sets, especially as they are further linked for analysis through space and time, provide tools to systematically explore water cooperation and conflict throughout a range

[1]American Association for the Advancement of Science, Washington, DC, USA.
[2]Woods Hole Research Center, Woods Hole, Massachusetts, USA.
[3]International Water Management Institute (IWMI), Colombo, Sri Lanka.
[4]Department of Geosciences, Oregon State University, Corvallis, Oregon, USA.

0043-1397/04/2003WR002530

of spatial and temporal scales. This paper then provides an overview of the results of three research applications which took advantage of these linked data sets. Each application employs a different spatial and temporal focus and analytical approach, illustrating the potential range of applications to which these data sets may be applied: (1) Basins at Risk I: Indicators of International Tension provides a quantitative, global-scale exploration of the relationship between freshwater resources and international cooperation and conflict. (2) Basins at Risk II: Internal and International Relations examines the relationship between dynamics within a nation and that nation's international hydropolitical relations. (3) Hydroclimatology, Conflict, and Cooperation explores the links among hydroclimatology, climatic variability, and international conflict and cooperation.

2. Environmental Security and Freshwater Resources

2.1. Background

[5] The concept of environmental security considers links between the environment, natural resources, and violent conflict. The environmental security concept gained prevalence around the end of the Cold War, when several scholars began to consider the inclusion of environmental concerns in the concept of international security [*Ullman*, 1983; *Westing*, 1986; *Gleick*, 1989; *Mathews*, 1989; *Myers*, 1989; *Homer-Dixon*, 1991]. The literature links international conflict with resource scarcity, population growth, political instability, and conflict [e.g., *Gurr*, 1985; *Lipschutz*, 1989; *Homer-Dixon*, 1991]. A recurring theme in this literature is that of "resource geopolitics," that vital and scarce resources which cross political boundaries present sources of conflict. As scarcity increases, so too does the potential for conflict. More recent literature questions environmental security's emphasis on conflict.

[6] Much of the thinking about the concept of "environmental security" has moved beyond a presumed causal relationship between environmental stress and violent conflict to a broader notion of "human security," a more inclusive concept focusing on the intricate sets of relationships between environment and society. Within this framework, water resources, their scarcity, distribution, and quality, have been named as the factor most likely to lead to intense political pressures.

[7] Despite the growing literature on water and conflict, there currently is little quantitative, global-scale work being done to bolster any of the common conclusions being so widely reported. Many authors emphasize water as a source or cause of conflict [*Westing*, 1986; *Gleick*, 1993; *Remans*, 1995; *Samson and Charrier*, 1997; *Butts*, 1997; *Homer-Dixon*, 1994, *Toset and Gleditsch*, 2000]. At the same time, a much smaller body of work argues more strongly for the possibilities and historical evidence of cooperation between coriparians [*Wolf*, 1998; *Salman and de Chazournes*, 1998; *Turton*, 2000].

[8] Since global data sets of international basins simply have not existed until recently, researchers have had difficulty in applying their conclusions broadly. Problems which have arisen include the tendency: to use terms such as conflict, dispute, tensions, ar interchangeably; to lump together vastly dissimilar types of water-related incidents, such as water as a tool, weapon, or victim of warfare; to exclude cooperative events, leaving any tests of causality incomplete; to fail to consider spatial variability, defining variables at the country scale, rather than linking them to the basins being considered; and, to concentrate case studies on the most conflictive basins (e.g., Indus, Jordan, Nile, and Tigris-Euphrates), making it difficult to apply broader, more general conclusions.

[9] To move beyond the case study approach and gain a global-scale and quantitative perspective, we adopted an approach utilizing the political science concept of "event data", then linked these data with a GIS delineating international river basins, their riparian countries, and various biophysical, socioeconomic, and political indicator variables at the international river basin and other scales.

2.2. Theoretical Framework

2.2.1. Indicators of International Tension

[10] Little exists in the environmental security literature regarding empirical identification of indicators of future water conflict. Widely cited and commonly used measures, such as volume of water available per capita within a country (water stress index [*Falkenmark*, 1989]) have been critiqued on a number of grounds, in large part because they fail to account for spatial variability in water resources within countries and the technological or economic adaptability of nations at different levels of development. Although weighting the water stress index to account for "adaptive capacity" (e.g., weighting the index by a factor based on UNDP's human development index [*Ohlsson*, 1999]) attempts to address the latter concern, the spatial component remains absent. Moreover, both measures focus on implications for water resource management, rather than the geopolitical considerations of resource scarcity.

[11] One of the few authors to explicitly identify indices of vulnerability which might suggest "regions at risk" for international water conflicts is *Gleick* [1993], who suggested four variables considering physical components of water and energy, with the nation as the unit of analysis. None of the indicators were empirically derived or tested.

[12] Our approach considers two distinct aspects as to why nations may choose to dispute or cooperate. First, along with the authors cited above we look at the water resources themselves and various aspects of stress: supply versus demand, droughts, and changes in the physical system. Rather than the nation-state, we use river basins, the distinct physical units in which these changes take place, as our fundamental unit of analysis. In addition, we consider another side to the equation, related to the institutional capacity of a nation to absorb aspects of stress, either within a nation, between pairs of nations, or among all the nations of a basin. This institutional capacity is broader than a country's economic strength, although that certainly plays a major role. Other issues, such as general friendship/hostility over nonwater issues, the existence or absence of joint water management bodies or treaties, and stability and types of governments within a basin, are all components contributing to functional institutional capacity.

[13] The working hypothesis which we set out to test, then, regards the relationship between change in conditions in a basin and the attendant institutions. Hypothesis 1 is as follows: the likelihood and intensity of dispute rises as the

rate of change within a basin exceeds the institutional capacity to absorb that change (hereinafter referred to as H1).

2.2.2. Internal and International Relations

[14] There are many examples of internal water conflicts ranging from interstate violence and death along the Cauvery River in India, to California farmers blowing up a pipeline transporting water to Los Angeles, to much of the violent history in the Americas between indigenous peoples and European settlers. Despite a rich history of water related discord, however, the issue of water disputes within a nation's borders has rarely been assessed methodically. One barrier to such analyses is the intricate nature of the problem: intuitively, it stands to reason that, as scale decreases from the international to the internal, the dynamics become more subtle and complex. Water after all is related to almost all human activity, from basic human needs to agricultural production, economic development, environmental health, and even religion and aesthetics. Any risk to a safe, stable supply of water therefore threatens the very stability of society at all its levels. Following this logic, though, one runs the risk of falling into a rhetorical trap where, by equating water with stability, one comes to the axiomatic conclusion that poverty and instability cause strife, not a particularly useful contribution.

[15] The focus of this hypothesis, then, is the very specific instances of conflict and cooperation between at least two sets of actors within countries which are demonstrably and directly related to water resources as a scarce and/or consumable resource, or as a quantity to be managed – i.e., where water is the driver of the event. The primary question posed is whether or not relationships exist between internal (i.e., within a country) and international water cooperation and conflict, and how scale affects the type and intensity of conflict. In particular we are interested in understanding whether internal water issues drive international relations, if causality is reversed, or if a relationship exists at all. Hypothesis 2 is as follows: periods of conflict and cooperation at the international scale will correspond to similar periods at the internal (i.e., domestic) scale (hereinafter referred to as H2).

2.2.3. Hydroclimatology

[16] Natural water availability varies greatly around the globe and through time. Regions with limited water resources or times of water shortage are often intuitively associated with competition and hence dispute over water. In individual basins, long droughts have often caused tensions between the riparian countries of transboundary rivers. In heavily managed basins, negotiated discharges may not be met during times of drought, leading to difficult negotiations such as currently between Mexico and the United States in the case of the Rio Grande/Rio Bravo river basin [*Kelly and Chapman*, 2002]. At the continental scale, *Ashton* [2000] presents a map of Africa showing a correspondence between the distribution pattern of perennial rivers and lakes and the areas where some form of conflict over water has occurred. Beyond that, in a global framework, the link between hydroclimatology and political dispute has not been given much attention. While the tests of H1 included average precipitation and climate zones as indicators, subsequent research is carried out to shed light on the complex relationship. Here, we specifically look at intense conflict and strong cooperation, climatic variability and the role of scale, both temporal and spatial, when exploring the influence of climatic and hydrologic variables on conflict and cooperation. Hypothesis 3 is as follows: the likelihood of intense dispute rises as the average precipitation within a basin decreases or the variability of precipitation or discharge increases (hereinafter referred to as H3).

3. Methodological Approach: Data Compilation and Integration

3.1. Water Event Data Set

3.1.1. Event Data

[17] A number of political science data sets exist that document interactions among countries. These "event data" are widely used in quantitative political science analyses. Originally developed by Charles McClelland in the early 1960s, event data serve as a bridge from traditional diplomatic history to quantitative analyses of international politics. Unlike traditional foreign policy studies, which primarily use documents, histories, memoirs and other narrative sources, event data allow analysis in a statistical framework. As stated by *Schrodt* [1993], "Event data are generated by examining thousands of newspaper reports on the day to day interactions of nation-states and assigning each reported interaction a numerical score or a categorical code. . . . When these reports are averaged over time, they provide a rough indication of the level of cooperation and conflict between two states." Many of the existing event data sets were created under the Data Development for International Research (DDIR) project, which was funded by the National Science Foundation in the late 1980s and early 1990s. The goal of the DDIR was to provide empirical data that would facilitate understanding and predicting of international conflict [*Merritt et al.*, 1993]. Event data sets cover a number of interaction types (e.g., military, political, economic) and issue areas (e.g., trade, scientific exchange, border disputes). Many of them, however, focus only on crisis events or, more specifically, on military interactions among nations, and thus do not provide any information on cooperative events. Moreover, none of the existing event data sets code specifically for water resource issues, and many are limited by the small number of countries included or the time periods covered.

[18] The Water Event Data Set is an attempt to compile all reported instances of conflict or cooperation over international freshwater resources in the world from 1948 to 1999. We defined water events as instances of conflict and cooperation that occur within an international river basin; involve the nations riparian to that basin; and concern freshwater as a scarce or consumable resource (e.g., water quantity, water quality) or as a quantity to be managed (e.g., flooding or flood control, water levels for navigational purposes). Incidents that did not meet the above criteria were not included as events in the analyses, although the event data are available for other research purposes. Such incidents included, for example: use of water as a weapon, victim, or target of warfare; navigation or construction of ports; boundary or territorial disputes (e.g., control over river islands); purchasing and selling of hydroelectricity; third-party (i.e., nonbasin country) involvement; and, issues internal to a country (for details, see S. Yoffe and K. Larson, Basins at risk: Water event database methodology, as given by *Yoffe* [2002]).

Table 1. Water Event Intensity Scale[a]

COPDAB Scale	Recentered BAR Scale	Antilogged, Recentered Scale	Event Description[b]
15	−7	−198.3	*Formal Declaration of War*
14	−6	−130.4	Extensive War Acts causing deaths, dislocation or high strategic cost
13	−5	−79.4	Small scale military acts
12	−4	−43.3	Political-military hostile actions
11	−3	−19.8	Diplomatic-economic hostile actions. *Unilateral construction of water projects against another country's protests; reducing flow of water to another country; abrogation of a water agreement.*
10	−2	−6.6	Strong verbal expressions displaying hostility in interaction. *Official interactions only.*
9	−1	−1.0	Mild verbal expressions displaying discord in interaction. *Both unofficial and official, including diplomatic notes of protest.*
8	0	0.0	Neutral or nonsignificant acts for the internation situation
7	1	1.0	Minor official exchanges, talks or policy expressions-mild verbal support
6	2	6.6	Official verbal support of goals, values, or regime
5	3	19.8	Cultural or scientific agreement or support (nonstrategic). *Agreements to set up cooperative working groups.*
4	4	43.3	Nonmilitary economic, technological or industrial agreement. *Legal, cooperative actions between nations that are not treaties; cooperative projects for watershed management, irrigation, poverty-alleviation.*
3	5	79.4	Military economic or strategic support
2	6	130.4	Major strategic alliance (regional or international). *International Freshwater Treaty*
1	7	198.3	Voluntary unification into one nation

[a]See *Yoffe et al.* [2003].
[b]Italic type represents our modifications and water-specific actions.

[19] For each event, we documented the international river basin in which it occurred, the countries involved, the date, the level of intensity of conflict or cooperation, and the main issue associated with each event. The time period, 1948 to 1999, was chosen for its relevance to potential future instances of cooperation and conflict and for data manageability and availability. The global spatial coverage considers all international river basins, although event data were not found for all basins.

3.1.2. Water Event Data Sources

[20] To create the Water Event Data Set, we gathered event data from political science data sets, the International Crisis Behavior Project [*Brecher and Wilkenfeld*, 2000], the Conflict and Peace Databank [*Azar*, 1980] (data were obtained through Inter-university Consortium for Political and Social Research (distributor), http://www.icpsr.umich.edu/), the Global Event Data System [*Davies*, 1998], and the Transboundary Freshwater Dispute Database [*Wolf*, 1999], as well as historical analyses and case studies of international river basins. In addition, we obtained about half our event data from conducting our own primary searches of electronic news databases, primarily the Foreign Broadcast Information Service. See Appendix A for additional information on these data sources.

3.1.3. Water Event Data Set Structure and Coding of Events

[21] The incidents of conflict and cooperation over freshwater catalogued in the Water Event Data Set can be considered in two basic formats: (1) "interactions," in which incidents are broken out by the country pairs (dyads) and basins involved (which allows exploration of the relationship between incidents and variables at the country scale), and (2) "events," in which one entry is provided for each incident in a basin, regardless of the number of country pairs involved (allowing for exploration of the relationship between incidents and variables at the basin scale). The Water Event Data Set contains ~1800 events, which can be broken out into approximately 3300 country pair interactions. The data include events for 124 countries and for 122 out of 265 current and rical international basins. Further details regarding the spatial and temporal coverage of the water event data are given by *Yoffe* [2002] and *Yoffe et al.* [2003].

[22] The data set provides great flexibility in how incidents are grouped and sorted, allowing for a wide range of questions to be asked. Each incident in the Water Event Data Set includes the following information: (1) the date of the incident; (2) the riparian countries involved, including whether a country initiated an action, was the target or recipient of an action, or whether the action was mutual; (3) the international basin(s) with which the incident is associated; (4) a summary describing the incident, including additional locational information; (5) the intensity (or category) of the incident, based on the COPDAB scale of cooperation and conflict; (6) the main issue area of the event (water quality, water supply/development project, hydropower, navigation, fishing, flood control, economic development, joint management, and other); and (7) the source(s) of information from which the data were compiled.

[23] Each event is coded by its intensity of conflict or cooperation. The intensity of an event is largely determined by the actor and target of the action (e.g., governmental versus nongovernmental) and the nature of the action (e.g., verbal versus substantive). The coding is based on the 15-point International Cooperation and Conflict Scale developed by *Azar* [1980], but incorporates water-specific considerations and terminology (S. Yoffe and K. Larson, Basins at risk: Water event database methodology, as given by *Yoffe* [2002]). The 15-point "BAR scale" (for the Basins at Risk project, described below) ranges from +7, the most cooperative event (voluntary unification into one nation over water) to −7, the most conflictive (formal declaration of war over water), with 0 representing neutral or nonsignificant acts (Table 1). The Water Event Data Set contains no events at the extremes of the scale, as we found no instances of countries unifying into one nation, nor formal declarations of war, over water.

[24] Exponential and other transformations of data are common in event data analyses and a comparison of results using other mathematical transformations offers an area for

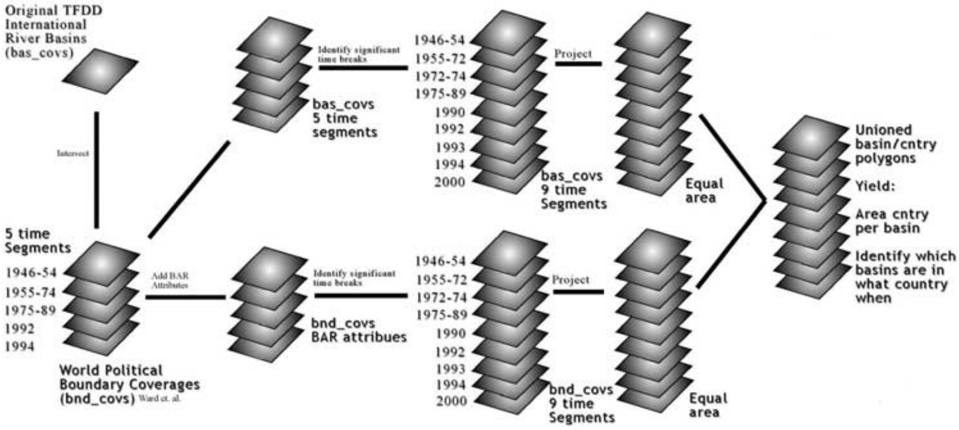

Figure 1. A basic model showing the steps taken in the creation of a temporal spatial data set for the Basins at Risk Project.

additional research. For the statistical analyses, we applied an exponential transformation to the BAR scale values (Table 1). The exponential transformation provides a numerical representation of the greater significance of the extremes of the BAR scale as compared to events toward the center of the scale, i.e., of the transition from, for example, small-scale military acts to extensive war acts (Categories −5 and −6) as compared to the transition from mild to strong verbal hostility (−1 to −2).

[25] Applying a conflict/cooperation scale is a useful method for exploring a wide range of research issues and applications. It is not only possible to extract and analyze events with particular intensities, such as the extremes, but having chosen a transformation, aggregated measures of conflict/cooperation can be calculated for a range of spatial and temporal scales (e.g., basin, region, country, year, etc.). While basin-specific projects may prefer to consider individual events, for analyses comparing data by year, the BAR scale values of conflict/cooperation for all events in that year should be averaged to filter the noise in the data. For analyses spanning the entire time period of the study, the average of the annual averages provides a good overall picture of international water relations.

3.2. International Basin Geographic Information System Data Set

[26] GIS offers powerful tools for compiling, visualizing and analyzing potential indicators of international water resource conflict, because it has the capability to incorporate biological, physical and socioeconomic data. While there has been substantial work in mapping the physical aspects of watershed systems, much less work has been done to incorporate these physical systems with socioeconomic data. Nevertheless, in many circles GIS technology has been praised for its potential to bring policy and science together and to facilitate integration, analysis, mapping and presentation of spatial and nonspatial information in the understanding and managing of natural resources.

[27] The idea of analyzing political, socioeconomic, and biophysical elements via watershed boundaries is relatively new in the field of political geography. For many years the dominant polygon for the display, and hence the output of manipulated data, has efined by national borders. Water data often are readily available only at the country level [*Brunner et al.*, 2000]. This fact has limited studies exploring spatial aspects associated with international water conflict. Geomorphologists have long considered the river basin to be a natural framework of study when considering the physical aspects of water resources [*Leopold et al.*, 1964]. The same consideration holds true when considering the relationship of freshwater to international conflict and cooperation.

[28] The GIS allowed us to conduct analyses at a range of spatial scales, including country, region, and basin-country polygon (a country's territorial share of an international basin). The key unit of analysis, however, was the international river basin, which comprises all the land that drains through a given river and its tributaries into an ocean or an internal lake or sea and includes territory of more than one country. The term "riparian" here refers to countries whose territory includes part of an international river basin.

[29] Our GIS data set delineates 263 current international basins, two historical basins, and their riparian countries from 1948 to 1999 (G. Fiske and S. Yoffe, Use of GIS for analysis of indicators of conflict and cooperation over international freshwater resources, as given by *Yoffe* [2002]). The GIS facilitated creation of the Water Event Data Set by enabling us to determine: whether a particular basin was international in a given year; what specific countries shared that basin; and, whether a specific event occurred in an international basin, as many events we researched turned out to be related to intranational (i.e., within a country), rather than international waters and as not all basins were international across the entire time period of the study. Creation of a tributary names database, in which tributary names are coded by the international basin with which they are associated, facilitated linking events to international basins.

[30] The GIS coverages that comprise the temporal portion of this study are divided into nine time segments (Figure 1), which were chosen to capture periods of significant world political boundary and polity changes. Dates of significant changes in boundary locations include, among others, 1990, East and West Germany united; 1990, North and South Yemen united; 1991, break up of the former Soviet Union; 1992, former Czechoslovakia break

Figure 2. Water availability per capita by basin [*UN Environment Programme and Oregon State University*, 2002].

up; 1992, break up of the former Yugoslavia; and 1993, independence of Eritrea.

[31] Compared with other forms of GIS data, finding coverages of historically accurate international political boundaries represent a much more involved treasure hunt. Historical GIS coverages are rare. While there is a large body of work, especially in political science and political geography, involving analysis of political boundaries [e.g., *Gleditsch and Ward*, 2000], these studies continue to be conducted without the use of GIS.

3.3. Spatial Variable Data Set

[32] With the establishment of updated basin boundaries and a reasonably correct estimate of international basin status (past and present), accurate aggregation of various data sets to the basin boundaries was possible. Aggregation of data at the basin level included approximately 100 layers of global and/or regional spatial data falling into one of three general categories: biophysical (e.g., topography, surface runoff, climate), socioeconomic (e.g., GDP, dependence on hydropower), and political (e.g., style of government, present and historic boundaries). Where possible, we backdated relevant parameters such that the data set is both uniformly formatted and historically accurate (e.g., 1964 boundaries coincide with 1964 GDPs and government types).

[33] Linking spatial data with the historical GIS enables incorporation of both temporal and spatial variability into analyses. It allows derivation of data, such as population, climate, and water availability, at the basin level (Figure 2) or other scales and exploration of correlations between these variables and the event data. This ability to explore factors associated with events, to ask why an event might have occurred, is a powerful f of the TFDD and directly addresses past criticisms concerning the utility of event data sets [*Lanphier*, 1975; *Andriole and Hopple*, 1984; *Laurance*, 1990].

4. Applications

4.1. Exploring Indicators of Water Conflict and Cooperation

[34] The unique tools created through the Transboundary Freshwater Dispute Database offer a wealth of data and resources for further research and comparative analyses. The GIS delineation of international river basins and their riparian countries, both current and historical, allows variables to be defined at the scale of a nation's portion of an international basin, basin, nation, or region, with the possibility for back-calculating variables at those scales for the years covered by the historical GIS. The spatial polygons of the GIS data sets are coded so as to link with the Water Event Data Set, allowing for analyses at multiple spatial scales.

[35] The structure of the Water Event Data Set allows information to be sorted and grouped, for example: by interactions (country pairs) or events; by individual countries, basins, or geographic regions; by macroevent (e.g., a whole series of events tied to a particular theme, such as the Gabčikovo-Nagymaros Dam dispute); and/or by the intensity of cooperation/conflict. In terms of time, the temporal grain of analyses may be structured as day-to-day interactions, monthly, annual, or multiple-year averages. Aggregated over time, statistics of the historical events have revealed interesting information for regional comparison and quantification of global-scale patterns in water relations and related indicator variables. Examples discussed by *Yoffe et al.* [2003] include overall percentage of events at different BAR scale values or for different issue areas, the temporal

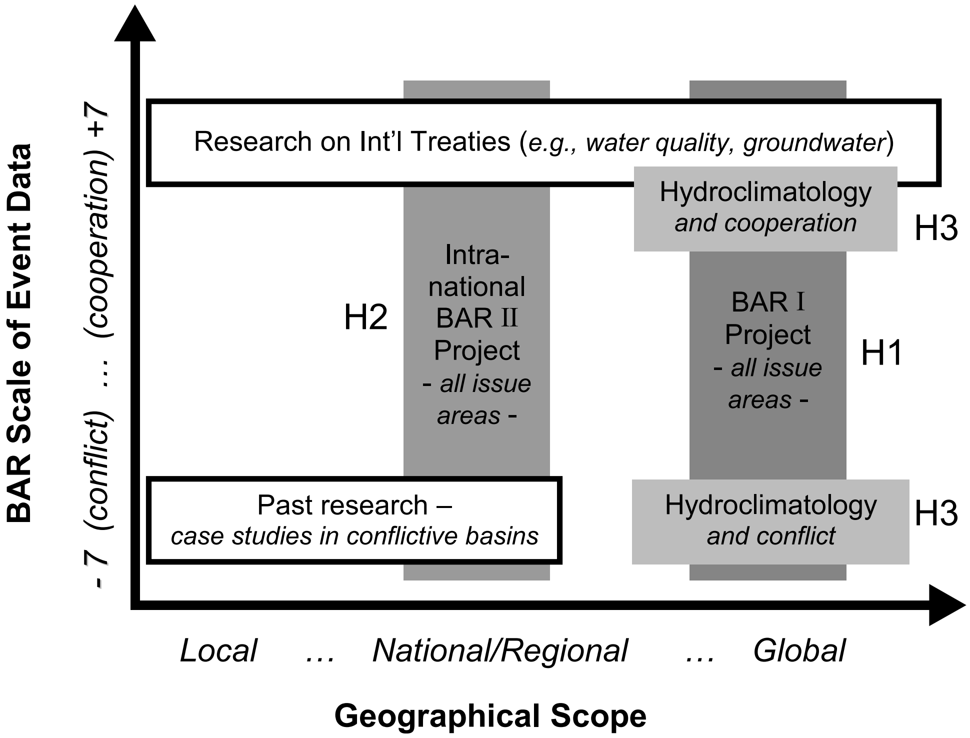

Figure 3. TFDD research applications (gray) and most previous research (white).

distribution of these percentages, and their spatial distribution worldwide.

[36] Given the structure and linkages among the data sets, one can explore historical water relations globally, going back fifty years, as was done in the Basins at Risk project (hypothesis 1), or one can focus on a specific basin, or set of basins, and choose to explore events at a decadal, annual, monthly, or even daily temporal scale. The methodological approaches used to create the BAR Water Event data set and GIS data set can be applied to other issue areas or modified to explore internal water events, as was done in the BAR 2 project (hypothesis 2). Rather than aggregate events over time, one can create a timeline of events for a specific basin and compare that history of water conflict and cooperation with other variables, such as extremes of floods or droughts. The individual basin may not tell a global story, but can provide insights into the role of water in that basin's political relations. The data sets can also contribute to case study research. The hydroclimatological research (hypothesis 3) compares results from analyses at multiple temporal scales and considers extremes of events, rather than averages as used in Basins at Risk. The three hypotheses are described below.

[37] Figure 3 represents the various ways TFDD data sets have been applied in terms of spatial coverage and exploration of the spectrum of conflict and cooperation. The results of three research applications, considering the three hypotheses discussed earlier and highlighted in shades of gray in Figure 3, provide examples of the range of potential applications of the BAR and TFDD data. These applications are summarized in the following sections: (1) Basins at Risk I: Indicators of Tension, for which much of these data resources were created; (2) Basins at Risk II: Internal/International Relations, which explored linkages between intra and international conflict and cooperation over freshwater resources in three countries; and (droclimatology, Conflict and Cooperation, which researched hydroclimatological variables and intense freshwater conflict/cooperation. Other projects also conducted include analyses of consideration of water quality issues in international freshwater agreements [*Giordano*, 2002] and the role of international treaties in addressing management of international groundwater resources [*Matsumoto*, 2002]. Figure 3 also illustrates differences between the three applications and conventional case studies, which have dealt mostly with selected and often highly conflictive basins.

4.2. Basins at Risk I: Indicators of International Tension (Hypothesis 1)

[38] In Basins at Risk I (BAR I), we conducted a series of quantitative and qualitative analyses on the relationship between freshwater resources and international cooperation and conflict. With the event and GIS data sets in place, we were able to assess the setting within which each event of conflict/cooperation took place. Hypotheses regarding various sets of parameters were tested using single and multivariate statistical analyses in order to identify significant indicators of international water conflict/cooperation. The results of this research and further details on the statistical analyses are given by *Wolf et al.* [2003b] and *Yoffe et al.* [2003].

[39] The BAR I project found that historical international relations over shared freshwater resources were overwhelmingly cooperative. Although conflicts over water occurred, violent conflict was rare and far outweighed by the number of international water agreements. International cooperation over water resources covered a wide range of concerns, including quantity, quality, hydropower, and infrastructure development. Conflict, especially acute conflict, centered on issues of quantity and infrastructure (e.g., dams and reservoirs).

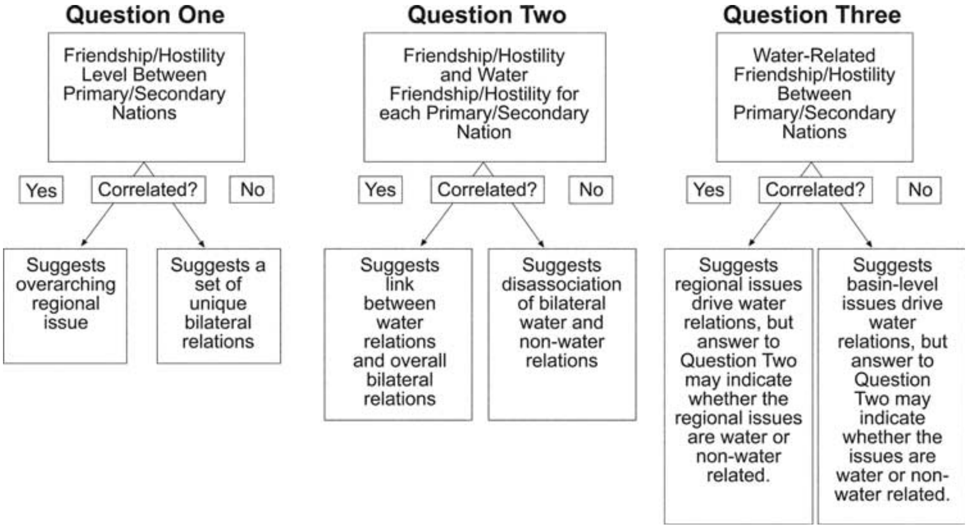

Figure 4. BAR II: Framework for analysis (modified from *Giordano et al.* [2002]).

[40] Many of the factors traditionally considered to be relevant indicators of international conflict, and of water conflict in particular, showed no statistically significant association with international water conflict or cooperation. Neither spatial proximity, average climate, basin water stress, government type, relative power, dams, nor dependence on freshwater resources for agriculture or energy showed a significant association with conflict over international freshwater resources. The factors that did show a slight association with conflict over freshwater resources included high population density, low per capita GDP, and overall unfriendly relations between countries. None of these indicators, however, explained more than a small percentage of the variability in the data.

[41] We had hypothesized that the likelihood and intensity of dispute rises as the rate of change within a basin exceeds the institutional capacity to absorb that change. We found that the relevant indicators appear to be rapid or extreme changes in physical or institutional settings within a basin (e.g., the building of large dams or the internationalization of a basin) and the presence of institutional mechanisms that mitigate uncertainty, international freshwater treaties in particular. Broadly defined, institutions and institutional infrastructure matter, perhaps because institutions provide a mechanism for mitigating or managing the uncertainty that theorists associate with a propensity toward international conflict.

4.3. Basins at Risk II: Internal and International Relations (Hypothesis 2)

[42] While one of the findings of the BAR I project was an overall correlation between general bilateral relations among nations and bilateral relations regarding water resources, the study did not clarify the direction of the linkage, whether the nature of the linkage is consistent across countries and regions, or if international issues drive domestic relations over water or vice versa. A follow-up study was thus undertaken to further examine the dynamics of water relations and the factors that may influence these relations in different geographic settings. The new study, termed BAR II, developed an analytical framework (Figure 4) w as applied to three geographically distinct case study regions, (the Middle East, South Asia, and southern Africa), in order to systematically examine the linkage between water and nonwater events from the international to the domestic scale and to evaluate the direction of the linkage. A full description of the study, methods, and results are provided by *Giordano et al.* [2002].

[43] The study focused on internal (i.e., domestic) and international conditions for one representative country (Israel, India, and South Africa), in each of the three regions. The specific questions addressed include the following: (1) What, if any, relationships exist between domestic and international water cooperation and conflict for each of the three countries? (2) If a relationship exists, is it similar across the three regions? (3) If the internal-external water relationships vary across regions, what factors might influence this variation, and how might we predict the variation? The principle analytical tool utilized in the study was event data: the nearly 1800 water related events covering the period 1948–1999 and over 300,000 nonwater related events between co-riparian states for the period 1948–1994 collected for the BAR I study, described above. In addition, 400 internal water-related events between and among governmental and nongovernmental actors over the period 1989 to 2000 were collected and coded.

[44] While full application of the analytical framework was hindered by certain data limitations, the results of the analysis provided valuable insights into the study of water conflict and cooperation. In general, the results suggested that while relationships do in fact exist between water and nonwater events at the international scale and that water events can be related between international and domestic scales, the nature and direction of these relationships vary considerably by region. For example, in the case of Middle East, the results suggested a linkage between international water relations and general international relations. In South Asia, on the other hand, water relations not only appeared to be independent from general foreign affairs issues, but the relationships seemed to vary by basin. These findings appear consistent with the results of more qualitative assessments. In the Middle East a connection between water and

Table 2. Hydroclimatic Parameters and Test Results

Hydroclimatic Variable	Parameter	Number of BCPs for Test Sample	High Probability: Most Conflictive Events (BAR −7 to −5)	High Probability: Most Cooperative Events (BAR 5–7)
Precipitation and evapotranspiration	Index of Aridity	134	arid semi-arid	arid
Precipitation	Annual Precipitation	134	dry	wet
Precipitation	Spatial Variability	134	high	–
Precipitation	Temporal Variability	134	high	–
Precipitation	Seasonality Index	134	high	low
Discharge	Specific Discharge	77	low	low
Discharge	Temporal Variability	79	–	high
Discharge	Seasonality	79	–	high
Discharge	River Type	79	ephemeral	ephemeral

nonwater events has clearly been demonstrated through the inclusion of water issues in regional peace agreements. South Asia, India and Pakistan have historically disassociated water and nonwater events and, as a result, the Indus Water Treaty has survived despite continued political hostilities between the two countries.

[45] In summary, the BAR II project found that relationships exist between water related events at varying geographic scales (e.g., domestic and international) and between water and nonwater relations. However, the nature of these relationships and the extent to which they are present appear to vary considerably by region. The results thus highlight not only the intricacies of hydropolitical dynamics and their variation across geographic space but also the need to consider the often distinct historical and political conditions within a region or basin for water relations to be well understood.

4.4. Hydroclimatology, Conflict, and Cooperation (Hypothesis 3)

[46] Ongoing research is considering more closely the role that climate and hydrology might play in conflict and cooperation over international waters. The initial findings of the BAR I study found no significant difference between most climate types and dispute levels and no consistent pattern for precipitation [*Yoffe et al.*, 2003]. The BAR analysis, however, utilized the international river basin as the primary spatial unit of analysis, and conflict levels for the basins were defined by averaging BAR intensity values of all events (cooperative and conflictive) within the period of the study. Different climatic regimes within the boundaries of basins and temporal changes in water availability may play an important role, which can only be identified in an examination of the systems at a finer scale than that utilized in BAR I.

[47] The geographic unit used in this study is a basin-country-polygon (BCP). The BCP used here is a portion of an individual country within an international river basin. The Climate Research Unit (CRU) 0.5 degree monthly mean precipitation [*New et al.*, 2000], the Tateishi Potential Evapotranspiration and Water Balance [*Ahn and Tateishi*, 1994] and all available at-station discharge data from the Global Runoff Data Center (http://www.bafg.de/html/internat/grdc/grdc.htm) were used to derive a variety of hydroclimatic parameters including aridity, spatial rainfall variability, interannual variability, intra-annual variability, and river type within e P. The new indices and the relative frequency of extreme events (cooperative and conflictive) were used to test whether the frequency of conflict or cooperation (grouped by BAR scale values) for BCPs characterized by particular hydroclimatic conditions (classes of aridity, spatial variability of precipitation, interannual and intra-annual variability, and river type) was different from any randomly chosen subset of BCPs of the same size. The test was carried out for the BCPs that had five and more political events of conflict and cooperation (for details, see *Stahl and Wolf* [2003]).

[48] Table 2 summarizes the parameters, the sample size of available BCPs, and some results. Here, we concentrate on the hydroclimatic classes for which the subsets of BCPs show an increased probability of most conflictive and most cooperative events. An increased probability for conflict was found for arid and semi-arid regions, dry and high-variability precipitation conditions, and ephemeral rivers. An increased probability of most cooperative events was also determined for arid regions, for regions with high precipitation and low seasonality, as well as for rivers with little and variable discharge. These results suggest that extreme conflicts but also strong cooperation are relatively frequent in regions with extreme climatic conditions characterized by high hydrologic variability. A high relative frequency of events on both sides of the conflict-cooperation intensity scale makes the basin appear moderate when averaging the scale of all events (as done in the BAR I study described earlier), thus concealing the more complex relationship with geographical indicators shown here.

[49] The relationship has political implications. As shown by *Wolf et al.* [2003a], there are indications of a temporal relationship as well: deteriorating water-related international relations in the Senegal river basin, for example, follow generally the climatic drying trend (Figure 5). In several water-scarce regions, treaties have been signed during a series of wet years or before major development projects. When water stress later rises during a series of dry years, tensions between the riparians of a shared river become likely. With the available data sets, this issue can now be investigated for many basins and future research will investigate such temporal patterns.

5. Conclusions

[50] In discussions of environmental security and research on international water relations, there has been a tendency in the past to focus on conflict. Case studies

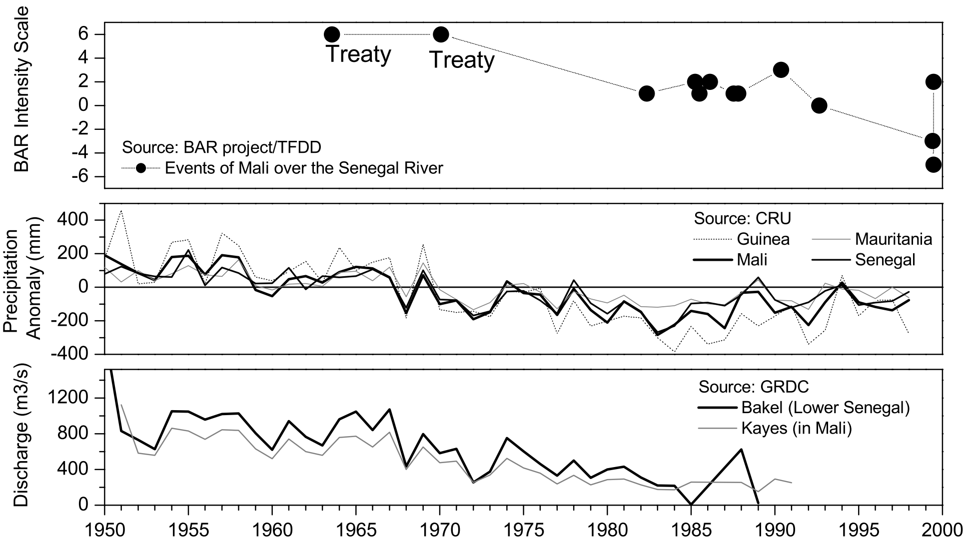

Figure 5. Time series of events of conflict and cooperation of Mali over the Senegal River, precipitation anomaly in the Senegal Basin portion of the four riparian countries, and annual mean discharge at two gauging stations along the Senegal River (modified from *Wolf et al.* [2003a]).

exploring international water relations often focus on high-profile regions such as the Middle East, and fail to provide a global view of international freshwater relations. The TFDD research team at Oregon State University provided a missing component, applying political science methodologies that quantify events between nations, as well as the tools offered by GIS, to develop a global-scale database linking historical and current international river basins, a catalogue of historical freshwater relations, and multidisciplinary variables to test potential indicators of water conflict and cooperation. This database is truly unique in its global-scale, quantitative approach, and incorporation of both conflictive and cooperative relations between nations over freshwater resources.

[51] The methodologies, data sets, and applications described above offer a substantial resource for research on the relationship between freshwater-related cooperation and conflict and numerous biophysical, socioeconomic and political variables at a wide range of spatial and temporal scales. Moreover, the coding of water events combined with the GIS also allows for various analyses that explore different issue areas (e.g., water quality, infrastructure development) and indicator variables (e.g., population, hydroclimate) in greater detail. The event coding also allows analyses of both cooperative and conflictive relations at a range of intensities.

[52] Thus far, the applications described in this paper have incorporated the TFDD data sets to explore different aspects of international water relations. The original Basins at Risk project provided a quantitative, global-scale investigation of numerous theorized indicators of conflict and produced a framework by which basins at potential risk for future conflict might be identified and further evaluated. The research considered the hypothesis that the likelihood and intensity of dispute rises as the rate of change within a basin exceeds the capacity to absorb that change. The study found support for that hypothesis and created a framework of indicators to identify and further evaluate basins at potential risk for future c over freshwater resources. A follow-up study, BAR II, quantitatively explored the linkages between internal and international water and non-water events for three specific regions (the Middle East, South Africa, and Southeast Asia). While this research found validity in the hypothesis considering correspondence between instances of intra and international water conflict and cooperation, as well as exploring linkages between water and nonwater events, the nature and direction of these relationships varied across the three regions and the direction of causality remains unclear. The last of the three applications described above provided a quantitative, global-scale study of various hydroclimatic variables and their relationship to cooperation and conflict, considering events at the extremes of the BAR scale. The results indicate that the hypothesized premise that the likelihood of intense dispute rises as the average precipitation within a basin decreases or the variability of precipitation or discharge increases is supported when specifically considering the relative frequency of the most conflictive events in a basin, while the relationship with cooperation still presents a complex picture. The research found that historically, extreme events of conflict were more frequent in marginal climates with highly variable hydrologic conditions, while the riparians of rivers with less extreme natural conditions have been more moderate in their conflict/cooperation relationship. The entire causal relationship between hydroclimatology and water-related political relations also depends on socioeconomic conditions and institutional capacity as well as the timing and occurrence of changes and extremes in a country and basin.

[53] The potential for further analyses utilizing TFDD resources is immense. Though the projects described above have largely focused on international relations at the global scale, applications extend beyond these to studies of specific nations or regions, as is evident from the BAR II project. Moreover, significant opportunities exist for more in-depth studies of particular indicators (e.g., as is seen in the hydroclimate study) and their relationship to conflict, cooperation, or overall water relations.

[54] We hope that others will build on the data sets we have created and the research we have undertaken thus far. For more information on the data sets and research projects described here, please visit the Transboundary Freshwater Dispute Database website at http://www.transboundarywaters. orst.edu.

Appendix A: Water Event Data Sources

[55] In order to create the Water Event Data Set, we drew from the following sources.

A1. Existing Event Data Sets

[56] The International Crisis Behavior Project (ICB) provides appropriate temporal and spatial coverage, along with textual summaries, of conflictive events. The Conflict and Peace Data Bank (COPDAB) and the Global Event Data System (GEDS) include cooperative as well as conflictive events, contain searchable event summaries, and provide broad spatial and temporal coverage. These three event data sets contain textual summaries and other coding that allowed us to distinguish whether an interaction between nations was related to freshwater resources. In cases where it was questionable whether or not an incident was actually water-related, we researched the original news article for clarification.

[57] The ICB data set was developed by *Brecher and Wilkenfeld* [2000] to aid investigation of interstate, military-security crises and the behavior of states under externally generated stress, from 1918–1988. Of the 412 crises identified by this data set, *Wolf* [1998] found only four disputes where water was, at the least, a partial cause.

[58] The COPDAB, created by Edward E. Azar, codes interstate and intrastate events for approximately 135 countries from the years 1948–1978 and contains 256,373 event records. Event information was derived from a wide range of U.S. and foreign news sources and includes event date, initiating actor, event target, information source, issue areas, brief event description, and a numeric code assigned from a 15-point categorical scale and ordered by the intensity of event conflict or cooperation. The data set does not include any water-specific coding, however the brief textual summary provided a guide to identify possible water-related events.

[59] Building on the COPDAB, the GEDS Project, directed by *Davies* [1998] at the University of Maryland, tracks day-to-day interactions among nation-states and other international actors using online news reports, such as Reuters. The GEDS database covers the years 1979 to 1994 and contains 82,778 event records. A limitation of the GEDS and COPDAB data is that coverage is not consistent for all countries for all years.

A2. Electronic News Databases

[60] About half of the event data compiled by BAR were gathered from news articles identified using electronically-searchable news databases. BAR researchers conducted keyword and subject searches of CD-Rom and online databases, identified and obtained potentially relevant news articles, and then coded and entered each article into the BAR Water Event Data Set. To ensure coding consistency, each article entered was double-checked by one or more BAR researchers. The pr news source was the Foreign Broadcast Information Service (FBIS), the current on-line version of which is called the World News Connection (WNC).

Table A1. Database Search Results

Database	Approximate Years Covered	Total Records	Initial Search Results	Number of Events	Number of Interactions
ICB	1918–1988	412	412	4	4
COPDAB	1948–1978	256,373	5,300	388	549
GEDS	1979–1994	82,778	9,500	144	225
TFDD	1874–2000	200	126	126	535
FBIS	1978–1995	n/a	1,817	439	770
WNC	1995–1999	n/a	9,589	321	629

[61] Developed by the U.S. Central Intelligence Agency as part of their responsibility to monitor and translate foreign news reports and government statements, FBIS contains translated broadcasts, news agency transmissions, newspapers, periodicals and government statements on events from nations around the globe. FBIS articles cover 1978 to 1995, are available on microfiche, and catalogued in a searchable CD-ROM index of titles and subject terms for individual foreign news articles. Full-text articles from October 1995 to the present are available on-line through the World News Connection (http://www.wncfedworld.gov). To identify relevant articles, we searched the database using a set of water terms (e.g., water resources, hydropower, etc.) and cooperation/conflict terms (e.g., dispute, war, agree*, treaty).

A3. International Freshwater Agreements

[62] One component of the Transboundary Freshwater Dispute Database Project (TFDD) is a compilation of the world's international freshwater agreements [*UN Environment Programme and Oregon State University*, 2002]. The TFDD treaties data set is a searchable database of summaries and/or the full text of, at this time, approximately 400 water-related treaties and international agreements, covering the years 1874 to 2002. Documents in the TFDD address the freshwater needs of the signatories and, for the most part, deal with water rights, water allocations, water pollution, principles for equitably addressing water needs, hydropower/reservoir/flood control development, and environmental issues and the rights of riverine ecological systems. All agreements entered into the Water Event Data Set (126 treaties from the TFDD) were coded at the same level of intensity of cooperation.

[63] Table A1 lists the number of events and interactions obtained from each of the event data sources described above.

[64] **Acknowledgments.** This paper draws on the work of a myriad of researchers, analysts, reviewers and students who have been involved at various stages of these projects over the last six years, and relies on the generosity of database managers from around the world. While all those who helped are too numerous to mention here (please see http://www.transboundarywaters.orst.edu for detailed acknowledgments for each project), we would like to mention specifically those agencies who supported our efforts, notably, the Oregon State University College of Science, the Carnegie Corporation of New York, the National Science Foundation Landscape Studies Fellowship, and the German Research Foundation. We are especially grateful to Ariel Dinar, this special section's Associate Editor, for his careful reads and detailed suggestions, as we are to two anonymous reviewers for their helpful advice.

References

Ahn, C.-H., and R. Tateishi (1994), Development of a global 30-minute grid potential evapotranspiration data set, *J. Jpn. Soc. Photogramm. Remote Sens.*, *33*, 12–21.

Andriole, S. J., and G. W. Hopple (1984), The rise and fall of event data: From basic research to applied use in the U.S. Department of Defense, *Int. Inter.*, *10*(3–4), 239–309.

Ashton, P. (2000), Avoiding conflicts over Africa's water resources, *Ambio*, *31*(3), 236–242.

Azar, E. E. (1980), The Conflict and Peace Data Base (COPDAB), *J. Conflict Resolution*, *24*(1), 143–152.

Brecher, M., and J. Wilkenfeld (2000), *A Study of Crisis*, Univ. of Mich. Press, Ann Arbor.

Brunner, J., et al. (2000), Water scarcity, water resources management, and hydrological monitoring, second world water forum, The Hague, Netherlands, March.

Butts, K. (1997), The strategic importance of water, *Parameters*, 65–83.

Chatterji, M., S. Arlosoroff, and G. Guha (Eds.) (2002), *Conflict Management of Water Resources*, Ashgate, Burlington, Vt.

Davies, J. L. (1998), The Global Event-Data System: Coders' manual, August revision, Cent. for Int. Dev. and Conflict Manage., Univ. of Md., College Park. (Available at http://geds.umd.edu/geds/)

Elhance, A. P. (1999), *Hydro-politics in the Third World: Conflict and Cooperation in International River Basins*, U.S. Inst. of Peace Press, Washington, D. C.

Elliott, M. (1991), Water wars, *Geogr. Mag.*, *63*, 28–30.

Falkenmark, M. (1989), The massive water scarcity now threatening Africa—Why isn't it being addressed?, *Ambio*, *18*(2), 112–118.

Giordano, M. (2002), International river basin management: Global principles and basin practice, Ph.D. dissertation, Oreg. State Univ., Corvallis.

Giordano, M., M. Giordano, and A. Wolf (2002), The geography of water conflict and cooperation: Internal pressures and international manifestations, *Geogr. J.*, *168*(4), 293–312.

Gleditsch, K. S., and M. D. Ward (2000), War and peace in space and time: The role of democratization, *Int. Stud. Q.*, *44*(1), 1–30.

Gleick, P. (1989), The implications of global climatic changes for international security, *Clim. Change*, *15*(1/2), 309–325.

Gleick, P. (1993), Water and conflict: Fresh water resources and international security, *Int. Security*, *18*(1), 79–112.

Gurr, T. R. (1985), On the political consequences of scarcity and economic decline, *Int. Stud. Q.*, *29*, 51–75.

Homer-Dixon, T. F. (1991), On the threshold: Environmental changes as causes of acute conflict, *Int. Security*, *16*, 76–116.

Homer-Dixon, T. F. (1994), Environmental scarcities and violent conflict: Evidence from cases, *Int. Security*, *19*, 5–40.

Kelly, M., and K. Chapman (2002), Sharing the waters, Americas Program investigative article, Interhemispheric Resour. Cent., Silver City, N.M., May.

Lanphier, V. A. (1975), Foreign relations indicator project (FRIP), in *Theory and Practice of Events Research: Studies in Inter-nation Actions and Interaction*, edited by E. Azar and J. D. Ben-Dak, pp. 161–174, Gordon and Breach, Newark, N. J.

Laurance, E. J. (1990), Events data and policy analysis: Improving the potential for applying academic research to foreign and defense policy problems, *Policy Sci.*, *23*, 111–132.

Leopold, L. B., M. G. Wolman, and J. P. Miller (1964), *Fluvial Processes in Geomorphology*, W. H. Freeman, New York.

Lipschutz, R. D. (1989), *When Nations Clash: Raw Materials, Ideology and Foreign Policy*, Ballinger, Cambridge, Mass.

Marty, F. (2001), *Managing International Rivers: Problems, Politics, and Institutions*, Peter Lang, Bern.

Mathews, J. T. (1989), Redefining security, *Foreign Affairs*, *68*(2), 162–177.

Matsumoto, K. (2002), Transboundary groundwater and international law: Past practices and current implications, M.S. thesis, Dep. of Geosci., Oreg. State Univ., Corvallis.

Merritt, R. L., R. G. Muncaster, and D. A. Zinnes (Eds.) (1993), *International Event-Data Developments: DDIR Phase II*, Univ. of Mich. Press, Ann Arbor.

Myers, N. (1989), Environment and security, *Foreign Policy*, *74*, 23–41.

New, M. G., M. Hulme, and P. D. Jones (2000), Representing twentieth-century space-time climate variability. Part II: Development of 1901–1996 monthly grids of terrestrial surface climate, *J. Clim.*, *13*, 2217–2238.

Ohlsson, L. (1999), Environment, scarcity, and conflict: A study of Malthusian concerns, report Dep. of Peace and Dev. Res., Goteborg Univ., Goteborg, Sweden.

Remans, W. (1995), Water and war, *Humantares Volkerrecht*, *8*(1), 6.

Salman, S. M. A., and L. B. de Chazournes (Eds.) (1998), *International Watercourses: Enhancing Cooperation and Managing Conflict*, *Tech. Pap. 414*, The World Bank, Washington, D. C.

Samson, P., and B. Charrier (1997), International freshwater conflict: Issues and prevention strategies, draft report, Green Cross Int., Geneva, Switzerland, May.

Schrodt, P. A. (1993), Event data in foreign policy analysis, in *Foreign Policy Analysis: Continuity and Change in Its Second Generation*, edited by L. Neack, P. J. Haney, and J. A. K. Hey, pp. 145–166, Prentice-Hall, Old Tappan, N. J.

Stahl, K., and A. T. Wolf (2003), Does hydro-climatic variability influence water-related political conflict and cooperation in international river basins?, paper presented at International Conference on Hydrology of the Mediterranean and Semi-Arid Regions, HydroSci. Montpellier Lab., Montpellier, France, 7–10 April .

Toset, H. W., and N. Gleditsch (2000), Conflict and shared rivers, *J. Polit. Geogr.*, *19*(8), 971–977.

Turton, A. (2000), Water wars in southern Africa: Challenging conventional wisdom, in *Water Wars: Enduring Myth or Impending Reality*, *Afr. Dialogue Monogr. Ser.*, vol. 2, edited by H. Solomon and A. Turton, pp. 9–34, ACCORD, Pretoria, South Africa.

Ullman, R. H. (1983), Redefining security, *Int. Security*, *8*(1), 129–153.

UN Environment Programme and Oregon State University (2002), *Atlas of International Freshwater Agreements*, UNEP Press, Nairobi, Kenya.

Westing, A. (Ed.) (1986), *Global Resources and International Conflict: Environmental Factors in Strategic Policy and Action*, Oxford Univ. Press, New York.

Wolf, A. T. (1998), Conflict and cooperation along international waterways, *Water Policy*, *1*(2), 251–265.

Wolf, A. T. (1999), The Transboundary Freshwater Dispute Database Project, *Water Int.*, *24*(2), 160–163.

Wolf, A. T. (Ed.) (2002), *Conflict Prevention and Resolution in Water Systems*, Edward Elgar, Northampton, Mass.

Wolf, A. T., K. Stahl, and M. F. Macomber (2003a), Conflict, cooperation, and university support for institutions in international river basins, *Water Resour. Update*, *125*, 31–40.

Wolf, A., S. Yoffe, and M. Giordano (2003b), International waters: Identifying basins at risk, *Water Policy*, *5*(1), 31–62.

Yoffe, S. B. (2002), Basins at risk: Conflict and cooperation over international freshwater resources, Ph.D. dissertation, Dep. of Geosci., Oreg. State Univ., Corvallis.

Yoffe, S., A. T. Wolf, and M. Giordano (2003), Conflict and cooperation over international freshwater resources: Indicators of basins at risk, *J. Am. Water Resour. Assoc.*, *39*(5), 1109–1126.

G. Fiske, Woods Hole Research Center, P.O. Box 296, Woods Hole, MA 02543-0296, USA.

M. Giordano and M. Giordano, International Water Management Institute (IWMI), P.O. Box 2075, Colombo, Sri Lanka.

K. Larson, K. Stahl, and A. T. Wolf, Department of Geosciences, Oregon State University, Corvallis, OR 97331-4501, USA.

S. Yoffe, American Association for the Advancement of Science, c/o Department of Geosciences, Oregon State University, Corvallis, OR 97331-4501, USA. (syoffe@mfire.com)