NOAA Scientific Publications Report

FEBRUARY 15, 2013

HIGHLIGHTED ARTICLE

A Unified Flash Flood Database over the U.S.

Labor capacity reduction from heat stress under climate warming

Post-Kyoto partner: Considering the stratospheric ozone regime as a tool to manage nitrous oxide

Billion-Dollar Fish: The Untold Story of Alaska Pollock

ADDITIONAL ARTICLES

Contributions of downstream eddy development to the teleconnection between ENSO and the atmospheric circulation over the North Atlantic

Use of Windsat to Extend a Microwave-based Daily Optimum Interpolation Sea Surface Temperature Time Series

El Niño impacts on seasonal U.S. atmospheric circulation, temperature and precipitation anomalies: the OLR-event perspective

OTHER REPORTS, BOOK CHAPTERS, & INTERNAL PUBLICATIONS

None.

HIGHLIGHTED ARTICLE

AUTHORS

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PUBLICATION DATE

Early Online Release: January 25, 2013

TITLE

A Unified Flash Flood Database over the U.S.

JOURNAL

Bulletin of the American Meteorological Society

SIGNIFICANCE

- It is anticipated that this database will be used for many diverse purposes such as evaluating tools to predict flash flooding, characterizing seasonal and regional trends, and improving understanding of dominant flood-producing processes.

SUMMARY

This study combines data from the US Geological Survey, the National Weather Service and vital witness reports to provide information for decision makers about flooding events. This study is the first of its kind to provide a cross-cutting database readily available to the public that could help improve flash flooding prediction and identify seasonal and regional flooding trends. The database uses three primary sources: 1) the archive of discharge observations from the US Geological Survey to describe individual flooding events, 2) flash flooding reports collected by the National Weather Service from 2006-present, and 3) witness reports obtained directly from the public during 2008 – 2010. This information, when combined, can improve our flood forecasts and provide decision makers important tools to be prepared for future flooding events. A major asset of the unified flash flood database is its collation of relevant information from a variety of sources that is now readily available to the community in common formats.

Response to flash floods in Summit County, CO

VISIT THE SCIENTIFIC PUBLICATIONS REPORT ARCHIVE

HIGHLIGHTED ARTICLE

AUTHORS

J. P. Dunne, R. J. Stouffer, and J. G. John (OAR/GFDL)

PUBLICATION DATE

Expected February 2013

TITLE

Labor capacity reduction from heat stress under climate warming

JOURNAL

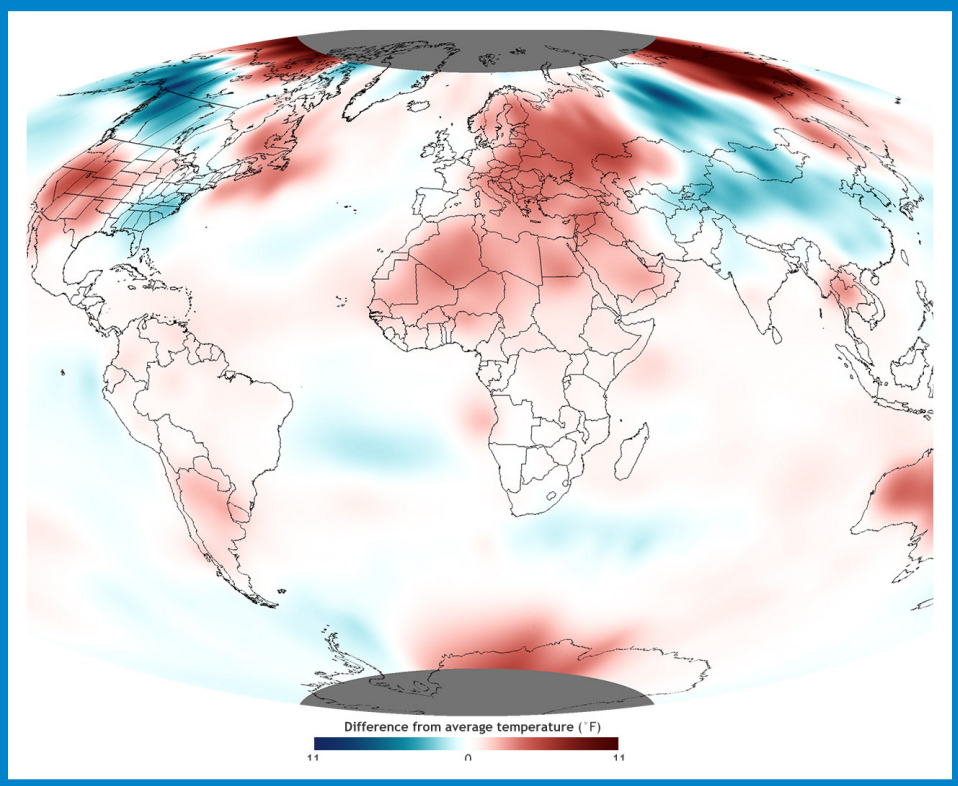
Nature Climate Change

SIGNIFICANCE

- This work represents a fundamental step forward in our ability to quantify the direct impact of climate warming on the global human population.
- Even under active mitigation of CO2 emissions, labor capacity reduction due to heat stress doubles by the middle of this century with severe reduction of labor capacity due to environmental heat stress inferred under continued highest emissions out to 2200.

SUMMARY

This paper explores climate change consequences to human activity under increased heat stress through wet bulb globe temperature (WBGT). The authors quantify historical and projected maximum environmental heat stress around the world and consequent reduction in labor capacity in the global population. The implications of these changes are measured through loss of an acclimated individual's occupational capacity to safely perform sustained labor under environmental heat stress (labor capacity) based on industrial and military occupational health thresholds for well-acclimated workers. The authors show that in the present day, peak months of heat stress reduce population-normalized labor capacity to about 90%. By mid-century, the labor capacity falls to about 80% during peak months. With an increase of 2C, labor capacity is reduced to 74% in peak months. In a high emission scenario of temperature increase of 5.6C, the labor capacity is reduced to 39% in peak months. In this much warmer world, many areas would not be able to sustain human labor without environmental control during the warmest months of the year.



November 2012 was the fifth warmest November since record keeping began in 1880

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HIGHLIGHTED ARTICLE

AUTHORS

D. Kanetr, D. L. Mauzerall, **A.R. Ravishankara (OAR/ESRL), J. S. Daniel (OAR/ESRL), R. W. Portman (OAR/ESRL),** P. M. Grabiel, W. R. Moomaw, and J. N. Galloway

PUBLICATION DATE

Likely early-mid February 2013

TITLE

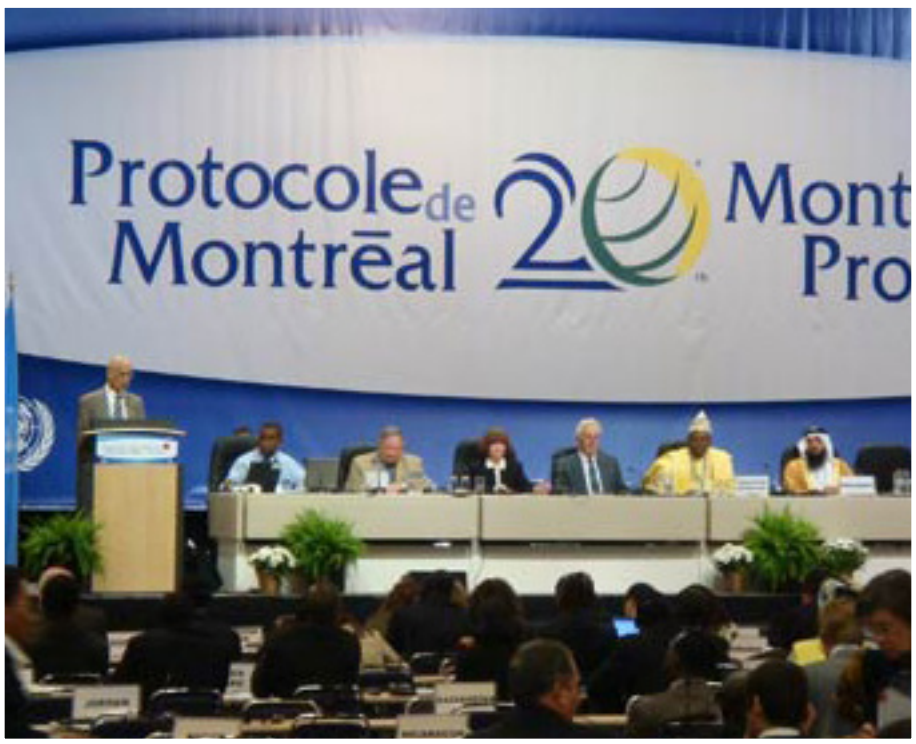
Post-Kyoto partner: Considering the stratospheric ozone regime as a tool to manage nitrous oxide

JOURNAL

Proceedings of the National Academy of Science

SIGNIFICANCE

- Nitrous oxide (N_2O) is both an ozone depleting gas and a greenhouse gas (GHG), but N_2O is only controlled by the Kyoto Protocol
- The authors discuss the potential pros and cons associated with controlling emissions of this GHG under the Montreal Protocol
- Inclusion of N_2O into the Montreal Protocol could provide a valuable mechanism to regulate N_2O emissions and to improve international efforts to codify regulations on these dual-threat gases



Montreal Protocol on Substances that Deplete the Ozone Layer

SUMMARY

Nitrous oxide (N_2O) is the largest known remaining anthropogenic threat to the stratospheric ozone layer. However, it is currently only regulated under the 1997 Kyoto Protocol due to its simultaneous ability to warm the climate. The threat N_2O poses to the stratospheric ozone layer, coupled with the uncertain future of the international climate regime, motivates our exploration of issues that could be relevant to the Parties to the ozone regime (the 1985 Vienna Convention and its 1987 Montreal Protocol) should they decide to take measures to manage N_2O in the future. There are clear legal avenues for the ozone regime to regulate N_2O, as well as several ways to share authority with the existing and future international climate treaties. N_2O mitigation strategies exist to address its most significant anthropogenic sources, including agriculture, where behavioural practices and new technologies could contribute significantly to reducing emissions. Existing policies managing N_2O and other forms of reactive nitrogen could be harnessed and built upon by the ozone regime's existing bodies to implement N_2O controls. The possible inclusion of N_2O in the ozone regime need not be viewed as a sign of the UNFCCC's failure to adequately deal with climate change. Rather, it could represent an additional valuable tool in sustainable development diplomacy.

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HIGHLIGHTED ARTICLE

AUTHORS

K.M. Bailey (NMFS, retired 1/3/13)

PUBLICATION DATE

Expected May 15, 2013

TITLE

Billion-Dollar Fish: The Untold Story of Alaska Pollock

JOURNAL

Book Published by University of Chicago Press

SIGNIFICANCE

- Alaska pollock is everywhere; its ubiquity has made pollock the most lucrative fish harvest in America
- In the last few years, the pollock population has declined by more than half, and some scientists are predicting the eventual collapse of the fishery.
- The author delves into the science, politics, and economics surrounding Alaska pollock in the Bering Sea, detailing the development of the fishery, the various political machinations that have led to its current management

Alaskan Pollock

SUMMARY

Prized for its generic fish taste, pollock masquerades as crab meat in California rolls and seafood salads, and it feeds millions as fish sticks in school cafeterias and Filet-O-Fish sandwiches at McDonald's. That ubiquity has made pollock the most lucrative fish harvest in America—the fishery in the United States alone has an annual value of over one billion dollars. But even as the money rolls in, pollock is in trouble: in the last few years, the pollock population has declined by more than half, and some scientists are predicting the fishery's eventual collapse. In *Billion-Dollar Fish,* Kevin M. Bailey combines his years of firsthand pollock research with a remarkable talent for storytelling to offer the first natural history of Alaska pollock. Crucial to understanding the pollock fishery, he shows, is recognizing what aspects of its natural history make pollock so very desirable to fish, while at the same time making it resilient, yet highly vulnerable to overfishing. Bailey delves into the science, politics, and economics surrounding Alaska pollock in the Bering Sea, detailing the development of the fishery, the various political machinations that have led to its current management, and, perhaps most important, its impending demise. He approaches his subject from multiple angles, bringing in the perspectives of fishermen, politicians, environmentalists, and biologists, and drawing on revealing interviews with players who range from Greenpeace activists to fishing industry lawyers. Seamlessly weaving the biology and ecology of pollock with the history and politics of the fishery, as well as Bailey's own often raucous tales about life at sea, *Billion-Dollar Fish* is a book for every person interested in the troubled relationship between fish and humans, from the depths of the sea to the dinner plate.

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ADDITIONAL ARTICLE

AUTHORS

Y. Li and N.-C. Lau (OAR/GFDL)

PUBLICATION DATE

TBD

TITLE

Contributions of downstream eddy development to the teleconnection between ENSO and the atmospheric circulation over the North Atlantic

JOURNAL

Journal of Climate

SIGNIFICANCE

- For this study, the authors examined the 2009/2010 winter season, which was characterized by unusual storminess over the U.S. — a signature of both El Niño and strong negative NAO conditions.
- The persistence and frequency of the types of episodes that drive El Niño winters and contributes to the prevalence of negative NAO conditions were determined.

SUMMARY

El Niño-Southern Oscillation (ENSO) is the dominant pattern of interannual climate variability, and has strong influence on the atmospheric circulation around the globe. North Atlantic Oscillation (NAO) is another prominent mode of interannual variability in the Northern Hemisphere extratropics, and exerts a strong influence on the climate of the North Atlantic basin and the surrounding land areas. The main purpose of this study is to describe and assess of the interactions between these two prominent teleconnection patterns of the interannual climate variability. El Niño winters tend to favor the persistence of a strengthened Pacific subtropical jet stream and a Pacific storm track shifting toward the equator. The wave packets that populate the storm tracks travel eastward through downstream development towards the western Atlantic, and synoptic-scale transient eddies reduce the pressure over the region. The more frequent and higher persistence of those episodes during El Niño winters contributes to the prevalence of negative NAO conditions.

ADDITIONAL ARTICLE

AUTHORS

V. Banzon (NESDIS/NCDC) and R.W. Reynolds
(Cooperative Institute for Climate and Satellites-NC)

PUBLICATION DATE

Accepted December 29, 2012

TITLE

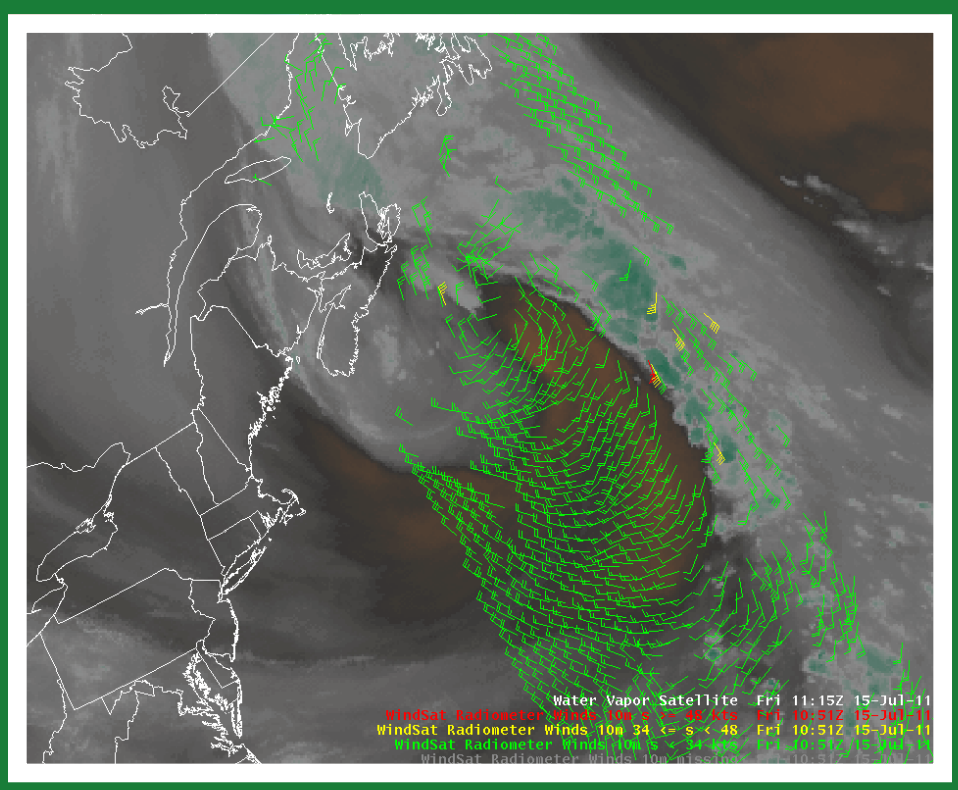
Use of Windsat to Extend a Microwave-based Daily Optimum Interpolation Sea Surface Temperature Time Series

JOURNAL

Journal of Climate

SIGNIFICANCE

- After the loss of AMSR-E data, WindSat SSTs can be used in order to continue the Daily Optimum Interpolation SST analysis (DO-ISST), a product used for weather prediction, climate studies, and other applications.
- However, the DOISST time series is consistent over this transition only if in situ SST measurements from ships and buoys are available to correct for significant biases between AMSR and WindSat due to their difference in overpass times.



Ascending WindSat Swath from 1051 UTC 15 July 2011, and GOES-East Water Vapor from 1115 UTC 15 July

SUMMARY

The NOAA 1/4° daily optimum interpolation sea surface temperature analysis (DOISST) is available either as a 31-year (from 1981 onward) time series based on Advanced Very High Resolution Radiometer (AVHRR) observations, or as a nine-year (2002 to 2011) time series that incorporates additional data from the Advanced Microwave Scanning Radiometer (AMSR) on the EOS platform. In October 2011, AVHRR+AMSR DOISST production was discontinued when the AMSR instrument lost its capability to collect daily, global-coverage data. SSTs from the follow-up AMSR2 instrument will not be available until mid-2013. To ensure an uninterrupted consistent long-term microwave-based DOISST time series, this study tested the feasibility of bridging the gap between AMSR and AMSR2 using WindSat Polarimetric Radiometer (WSAT) data. Comparison of WSAT and AMSR SST data during their period of overlap from 2004 to 2011 showed temporal gaps were common for WSAT, especially before 2009. The WSAT daily spatial coverage was slightly inferior to AMSR, but still far superior to AVHRR. When satellite SSTs were bias-adjusted with respect to in situ data, the resulting AMSR-only and WSAT-only analyses were very similar. Monthly zonal averages agreed to within 0.1 K, except when WSAT data were continuously missing for over three weeks. However, if satellite SSTs were not bias adjusted prior to analysis, seasonally-varying zonal average differences were observed, with maxima of ~0.3 K occurring at mid-latitudes. Thus, WSAT can be used to continue the microwave-based DOISST time series because the methodology compensates for the different equatorial crossing times of the two satellites.

ADDITIONAL ARTICLE

AUTHORS

D.E. Harrison (OAR/PMEL) and A. Chiodi (JISAO)

PUBLICATION DATE

Expected February 2013

TITLE

El Niño impacts on seasonal U.S. atmospheric circulation, temperature and precipitation anomalies: the OLR-event perspective

JOURNAL

Journal of Climate

SIGNIFICANCE

- Using the OLR characterization of El Niño years improves statistical seasonal weather forecasts over the continental United States.
- Improving the U.S. seasonal weather forecast skill would be economically useful for many NOAA user communities.

SUMMARY

If El Niño events are identified by their signature in outgoing long-wave (OLR) radiation rather than by sea surface temperature anomalies (like Niño 3.4) fewer years are identified as El Niño events, and much stronger seasonal weather anomaly associations are found. Those years identified by a conventional Niño 3.4 measure but not by the OLR measure are found to have very weak seasonal weather associations. Almost all of the anomaly patterns we associate with El Niño over the United States arise from the OLR events.

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METEOROLOGICAL
SOCIETY

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EARLY ONLINE RELEASE

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A Unified Flash Flood Database over the US

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3rd Draft

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PRELIMINARY ACCEPTED VERSION

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Abstract

Despite flash flooding being one of the most deadly and costly weather-related natural hazards worldwide, individual datasets to characterize them in the US are hampered by limited documentation and can be difficult to access. This study is the first of its kind to assemble, reprocess, describe, and disseminate a georeferenced US database providing a long-term, detailed characterization of flash flooding in terms of spatiotemporal behavior and specificity of impacts. The database is comprised of three primary sources: 1) the entire archive of automated discharge observations from the US Geological Survey that has been reprocessed to describe individual flooding events, 2) flash flooding reports collected by the National Weather Service from 2006-present, and 3) witness reports obtained directly from the public in the Severe Hazards Analysis and Verification Experiment during the summers 2008-2010. Each observational data source has limitations; a major asset of the unified flash flood database is its collation of relevant information from a variety of source that is now readily available to the community in common formats. It is anticipated that this database will be used for many diverse purposes such as evaluating tools to predict flash flooding, characterizing seasonal and regional trends, and improving understanding of dominant flood-producing processes. We envision the initiation of this community database effort will attract and encompass future datasets.

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1. Introduction

Flash floods are rapid surface water responses over normally dry land to intense rainfall or a sudden release of water from a dam break or ice jam, and have significant impacts on transportation, infrastructure, and human safety. While hydrometeorologists, in recent decades, have significantly advanced our comprehension of synoptic and mesoscale environments conducive to intense rainfall, tools used by forecasters to predict the hydrologic response, location, timing, and magnitude of the social impact have not progressed commensurately (Gourley et al. 2012). Predictability is determined by the development and refinement of a physical system model, and it is strongly dependent on the available data. In this case, data involve a unified observational dataset of flash floods, which holds great potential for advancing the science and predictability of flash flooding. This article serves the following purposes: 1) to announce a recently assembled US-wide database on flash flooding available in multiple, common formats to reach a wide range of users and 2) to encourage others to submit additional, related datasets that can be incorporated into the database.

There is no single source of information that holistically describes flash flooding in the US. Perhaps it is the diverse and discontinuous nature of flash-flooding impacts that makes them difficult to observe and subsequently catalogue in a consistent database. Flash floods differ from other weather-related hazards (i.e., tornadoes, hail) in that their impacts are strongly controlled by surface properties, infrastructure, and social exposure factors. Streamflow measurements operated and maintained by the US Geological Survey (USGS) benefit from automation and high temporal resolution, resulting in long-term, continuous records at each gauge site. These instruments require electrical power

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and road access for communications, regular instrument maintenance, and manual measurements to empirically establish a rating curve (i.e., the relationship between the measured stage and the desired discharge). The costs associated with these requirements (on the order of $10,000 per year) imply that automated streamflow measurements are relatively uncommon in small basins where flash floods occur (Gruntfest 2009).

Forecasters at local National Weather Service (NWS) offices throughout the US routinely collect reports of flash flooding from trained spotters, local authorities, and emergency management officials within their areas of responsibility. The NWS Storm Events Database is essential for evaluating and improving operational forecast products and procedures. Details contained in the reports, such as information about the meteorological environment, a dollar estimate of the damages, and number of fatalities, have yielded very useful information to the research community as well. Limitations of the database include subjectivity in the reported event locations defined by often imprecise, bounding polygons, times are often related to the meteorological event rather than the flooding impacts, they are dependent on a person to witness the event, and they provide little or no information about the site's societal exposure or antecedent conditions.

The third database considered in this study comes from the Severe Hazards Analysis and Verification Experiment (SHAVE), which was conducted across the US during the summers of 2008-2010 at the National Severe Storms Laboratory (NSSL) (Ortega et al. 2009). Student callers obtained details on the specific type of impact, magnitude, and frequency of flash flooding directly from members of the public who responded to a telephone-based questionnaire. This georeferenced, survey-based approach overcomes

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some of the imprecision noted with the NWS Storm Events Database, but it is based on unreliable reports from the general public. Also, NSSL researchers designed the SHAVE data collection methodology for high-resolution, storm-targeted reports, and, thus, the dataset does not encompass all events at a given time.

The assembly of the three aforementioned datasets into a unified, consistent database retains the inherent limitations associated with each one, yet the database combines the high-resolution details from SHAVE with the broad spatial coverage and event narratives from the NWS storm reports with the automated streamflow measurements from USGS to provide a more complete depiction of flash flooding across the US. The database is freely available to the public at http://www.nssl.noaa.gov/projects/flash/database.php, and we provide it in three different formats for a variety of users who may be interested in quick-and-easy plots, detailed spatial investigations, or statistical analysis using the raw data.

2. Data sources and processing steps

a. USGS discharge measurements

We obtained the USGS archive of instantaneous streamflow data from 10,106 gauges with records dating from Jul 1927 through Sep 2010 in a MySQL database format. The USGS maintains the instantaneous data for most stations beginning in the mid 1980's and with data intervals commonly ranging from 5-60 minutes. The public can directly access this archive at http://ida.water.usgs.gov/ida/. While applications such as calibrating and evaluating hydrologic models for water budget studies and water resources management require time series data, these data require additional processing in order to define when

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flooding events occurred and to determine the magnitude of flooding. NWS offices have defined stage heights associated to stream bankfull conditions, action, minor, moderate, and major flooding for 3,490 stream gauge locations. These thresholds were defined in coordination with the local emergency management and stakeholder community, and were based on impacts to lives and/or property. Often, the bankfull stage is the same as the minor flood stage (often referred to as the flood stage). However, in more rural areas, the flood stage may be greater than the bankfull stage due to the lack of infrastructure situated in close proximity to the streams.

We converted the USGS database to an "event-based" database for flood studies in the following manner. We identified all events that exceeded their pre-defined action stage for each station; this is most often the lowest stage height threshold defined by the NWS. According to the NWS Directive 10-950 - Hydrologic Services Program Definitions and General Terminology, action stage is "the stage which when reached by a rising stream, lake, or reservoir represents the level where the NWS or a partner/user needs to take some type of mitigation action in preparation for possible significant hydrologic activity" (http://www.nws.noaa.gov/directives/sym/pd01009050curr.pdf). In total, there were 98,668 events in the database that exceeded action stages at 2,948 of the gauges in the USGS archive (see Fig. 1); 665 of these gauges have catchment areas less than 250 km^2. For each event, we provide the following information: USGS Gauge ID, latitude (decimal degrees), longitude (decimal degrees), start time (UTC) at which the flow exceeded the action stage threshold, end time (UTC) when the flow dropped below the threshold, peakflow magnitude ($m^3 s^{-1}$), peak time (UTC) at which peakflow occurred (UTC), and the difference between start time and peak time (in hours).

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This latter variable, referred to hereafter as the flooding rise time, is a proxy for the time-to-rise and is plotted against basin catchment area in Fig. 2 for all 98,668 events combined. We see there is a clear relationship between the proxy "flashiness" of an event and catchment area. The spread, represented by the gray-shaded interquantile areas, results from different antecedent conditions, variable basin geomorphologies that impact their responses to rainfall, and events with rainfall that fell near the basin outlet. While there is no formal method to segregate flash floods from river floods, we recommend users apply a threshold to the flooding rise time rather than the catchment area. From the figure, we see that applying a threshold of 6 hr corresponds to a median basin catchment area of approximately 250 km^2, and is the recommended flooding rise time threshold for flash flood events.

Along with the events dataset, we supply metadata for each station containing static information about the USGS station's ID, latitude (decimal degrees), longitude (decimal degrees), hydrologic unit code (HUC), agency, degree of regulation, gauge name, drainage area (km^2), contributing drainage area (km^2), computed flows ($m^3\ s^{-1}$) for recurrence intervals for 2, 5, 10, 25, 50, 100, 200, and 500 yr, and computed flows ($m^3\ s^{-1}$) for action stage, minor, moderate, and major flooding. The USGS has previously computed flows for recurrence intervals (return periods) from 2-500 years using a Log-Pearson Type III distribution for those stations with at least 10 years of record and no significant changes in the record due to urbanization, diversion, or regulation. The degree of regulation field comes directly from USGS metadata for peakflow data and has values of either "Yes", "No", or "Undefined".

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Each station's event data and metadata are grouped by first-level, two-digit hydrologic unit code (HUC), which represents a basin scale at the regional level. We provide the processed USGS flood event database for HUC basins in the US and Caribbean in the following three formats: 1) comma-delimited text file, 2) GIS shapefile, and 3) kmz file for Google Earth™. Use of kmz files yields quick-and-easy displays, while the provision of shapefiles enables more in-depth spatial analysis using GIS software. The comma-delimited files can be read by a number of commonly available statistical software packages. Some users may also wish to access the text files directly for use in originally developed code and scripts. Data for Alabama, North Dakota, South Dakota, and Wyoming were not available when we obtained the database. Station data for these states will be added in future updates to the database (to be done on an annual basis).

b. NWS storm reports

We obtained all NWS reports of flash flooding from 01 Oct 2006 to 31 Dec 2011 from the database managed by the NWS Performance Branch. Prior to 01 Oct 2007, the NWS recorded storm reports by county; any instance of flash flooding yielded a recorded event for the county. Because counties are delineated primarily according to political, rather than physical, geographic boundaries and their sizes vary considerably across the US, this procedure lacks the necessary spatial resolution for meaningful hydrological interpretation. NWS forecasters now report the locations of impacted regions using bounding polygons defined by as many as eight vertices. There was a transitional period in implementing the new procedures, so it is not uncommon for polygons to have the

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same shape as a county or to be recorded as a point, especially from 2006-2007. In addition to the reports nominally being stored as a single county-wide point prior to 01 Oct 2007, there are also instances in which event locations were recorded with only two vertices. In the latter case, we converted the two points into a single polygon feature by assigning the vertices as the diagonal of a bounded rectangle.

According to the NWS *Storm Data* Directive, a recorded flash flood must have posed a potential threat to life or property and had a report of moving water with a depth greater than 0.15 m (6 in) or more than 0.91 m (3 ft) of standing water. Typical situations that meet these criteria include rivers and streams out of their banks, evacuations, rescues, road closures, and floodwaters in an above-ground residence (i.e., not a basement). Each report from the NWS database contains a unique ID, the three-letter abbreviation of the NWS forecast office (WFO) that reported the event, beginning and ending time of event (UTC), state, county, NWS region, direct/indirect fatalities and injuries (if applicable), a dollar estimate of property and crop damage (if applicable), details about the event including its cause (e.g., heavy rain), source of report (e.g., law enforcement), event and episode narratives, and vertex coordinates in decimal degrees of latitude and longitude as well as the range (mi) and azimuth (e.g., NE) from the nearest city. We used the entries in the vertex coordinate fields to create individual polygons for display and analysis in Google Earth™ and GIS software. In this conversion, we noted that the maximum allowable characters in the event and episode narrative fields were often exceeded for shapefile and kmz formats. In some cases, these narratives can be several sentences long. The full narratives are preserved in the comma-delimited format.

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Figure 3 shows the locations of all 19,419 flash flood reports contained in the NWS database. The limitations inherent in this database include poor precision and accuracy in both the timing and spatial extents of flash flooding. Often, the meteorological event timing is taken as flash flood timing. Regarding spatial extent, it's not clear that bounding polygons are appropriate for delineating impacted regions. Unlike rainfall amounts, flash flood impacts are often spatially discontinuous and may be associated to difficult-to-contour features such as road networks. Consistent with the processing of the USGS dataset, we segregated the NWS flash flood reports into regional, two-digit HUC basins. We provide files separately for point-based reports vs. polygons. The same file formats used for the USGS dataset (i.e., comma-delimited text, GIS shapefile, and kmz) are utilized for the NWS flash flooding reports.

c. SHAVE questionnaire responses

During the summers of 2008-2010, the NSSL employed 5-6 undergraduate meteorology students to collect unique details on flash-flooding impacts at very high resolution (Gourley et al. 2010). The experiment designers utilized WSR-88D-based warning products and flash flood warnings issued by the NWS and displayed them in Google Earth™ to guide the SHAVE callers where flash flooding may have just occurred. Students initiated calls if rainfall exceeded flash flood guidance, there was a NWS warning or advisory, or a survey response for a different hazard (i.e., hail) suggested flash flooding was a problem. Then, callers employed a purposeful sampling strategy to better refine the spatial extent of flash flooding. They used a georeferenced telephone database to call the public and initiate a questionnaire designed to obtain

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details about flash-flooding impacts, including the depth and movement of flood waters, lateral extent of water out of the stream, incidence of rescues and evacuations, start and end times of impacts, respondent-estimated frequency of event, and types of impacts. The callers also included detailed comments to assess the uncertainty and validity of the reports as well as to include other anecdotal responses that didn't readily fit into one of the survey questions. The SHAVE dataset was post-processed in order to better classify the impact types and to incorporate additional geographical attributes into each report, including land use, local terrain slope, contributing drainage area, compound topographic index (relates to dominant runoff process), and population density (Calianno et al. 2012). Future efforts planned for SHAVE in 2013 include the collection of social science data on human behavior prior to and during flash flooding events.

Figure 4 shows the spatial distribution of all 9,369 reports collected during SHAVE. SHAVE was operational only when undergraduate students were available on a full-time basis during the warm season from early May through the end of Aug in 2008-2010. The SHAVE database differs from the NWS storm reports in that it is storm-targeted and point-based. The NWS reports are meant to encompass all flash-flooding events across the US from 2006-2011, while the SHAVE reports are for specific storms. The SHAVE dataset provides for the assessment of false alarm rates (i.e., forecast of flood with no observed event) because it includes reports of "no flooding." In fact, this class comprises 73% of the total reports. Accounts from human reports, especially the untrained public, are subject to uncertainty due to perceptions and occasional embellishments, and must be used with caution. Users are encouraged to refer to the supplied metadata for additional information about each field. In concert with the other databases, we provide the

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SHAVE data in comma-delimited text format, kmz, and GIS shapefile format for each of the regional HUC basins.

d. Other candidate data sources

The second goal of this article is to reach out to other agencies, universities, and companies who maintain datasets related to the observation of flash flooding. For example, active and passive microwave sensors positioned on the ground and in space (e.g., 37 GHz channel onboard Tropical Rainfall Measurement Mission, Moderate Resolution Imaging Spectroradiometer onboard the Terra and Aqua satellites, Advanced Spaceborne Thermal Emission and Reflection Radiometer onboard Terra) have shown the potential for monitoring inundated areas near streams and provide reasonable estimates of surface water fluxes and depths (see e.g., http://oas.gsfc.nasa.gov/floodmap/) (Brakenridge et al. 2005). Local and regional networks of cameras or ultrasonic sensors mounted near bridges and tunnels can be very useful for detecting flash floods (Kim et al. 2008). There are also myriad networks of stream gauges and rain gauges, many of which are used by NWS offices, operated by cities, counties, districts, water boards, bureaus, private companies, and tribes. For example, CoCoRaHS observers are encouraged to report flooding along with their rainfall reports. In 2011, the Iowa Flood Center based at The University of Iowa developed and deployed over 100 fully automated and autonomous stream stage sensors on local bridges. NWS forecasters use these data in real time, and we plan to add the data to the US flash-flood database.

Post-event surveys serve as the primary basis for a flash flood database already built for Europe (Gaume et al. 2009). For instance, while the NWS storm events dataset

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generally contains surveyed events, further details from field investigations would certainly be useful to estimate peakflows (Gaume and Borga 2008). There is certainly a wealth of information on flash flood impacts that could be made available by insurance agencies. Thus far, social science data such as human exposure, behavior, perceived risks, and responses constitutes a significant missing component in the unified flash flood database. Once social science data are included in SHAVE, a planned activity for 2013, we will be able to gain a more comprehensive understanding of flash flood impacts through an end-to-end analysis of the physical and societal components. Social media have also been shown to provide potential for volunteer reporting by the public, including submission of georeferenced photographs of flooded lands (Xiao et al. 2011). Lastly, incorporation of long-term archives (decadal) of gridded rainfall datasets from WSR-88D-based products will be essential for understanding the role of the causative rainfall to the quickness and intensity of basin responses. We encourage those who maintain datasets like the ones described here to consider making them a part of the US unified flash flood database for freely accessible, community use.

3. Summary

This article describes the data sources and processing steps to create a unified database of flash flood observations across the US that is now available to the community here: http://www.nssl.noaa.gov/projects/flash/database.php. The database comprises streamflow observations maintained by the USGS, storm reports collected by the NWS from trained personnel, and public survey responses to a questionnaire developed for the SHAVE experiment. We have rigorously post-processed all datasets for consistency in

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terms of data formats, time formats, geographic projection, and units. The database will be updated once per year in order to include recent USGS streamflow data, storm reports from the NWS, and SHAVE.

We expect the announcement of this unified database will result in the inclusion of additional datasets relevant to flash flood observation, specifically those that provide social science data. The overall goal is to provide a comprehensive observational database on flash flood impacts, which will enhance the research community's understanding of the social, physical, and economic effects of flash flooding.

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List of Figures

FIG. 1. USGS streamflow stations (yellow dots) and their contributing drainage areas (outlined in green) for 2,948 gauges with flood events from Jul 1927 to Sep 2010. The time series data have been converted to event data based on flows exceeding their pre-defined action stages. In total, there are 98,668 events comprising the USGS component of the flood database.

FIG. 2. Quantile plot of flooding rise time (in hr), defined as the time of peak flow minus the time at which the action stage was reached, as a function of basin catchment area (in km^2) for all 98,668 events. The thick black line represents the median (50% quantile), the dark gray-shaded region represents the area between the 25% and 75% quantiles, the light gray-shaded region represents the area between the 10% and 90% quantiles, and the thin lines represent the 1% and 99% quantiles.

FIG. 3. National Weather Service reports of flash flooding from 01 Oct 2006 to 31 Dec 2011 from the Stormdat program. The database includes 19,419 flash flood reports.

FIG. 4. SHAVE reports of no flooding, non-severe flooding, and severe flooding obtained from the public during the summers of 2008-2010. In total, there are 9,369 reports contained within the SHAVE storm-targeted dataset.

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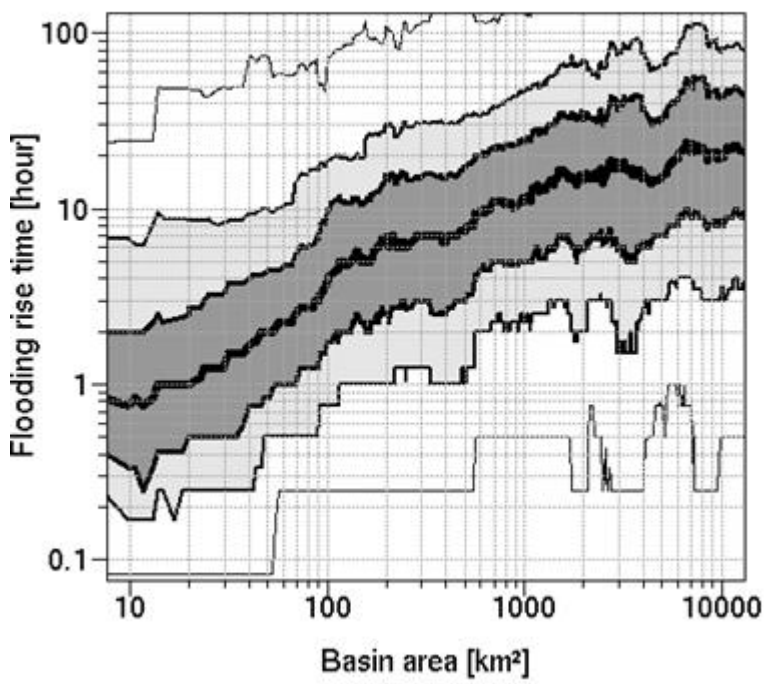

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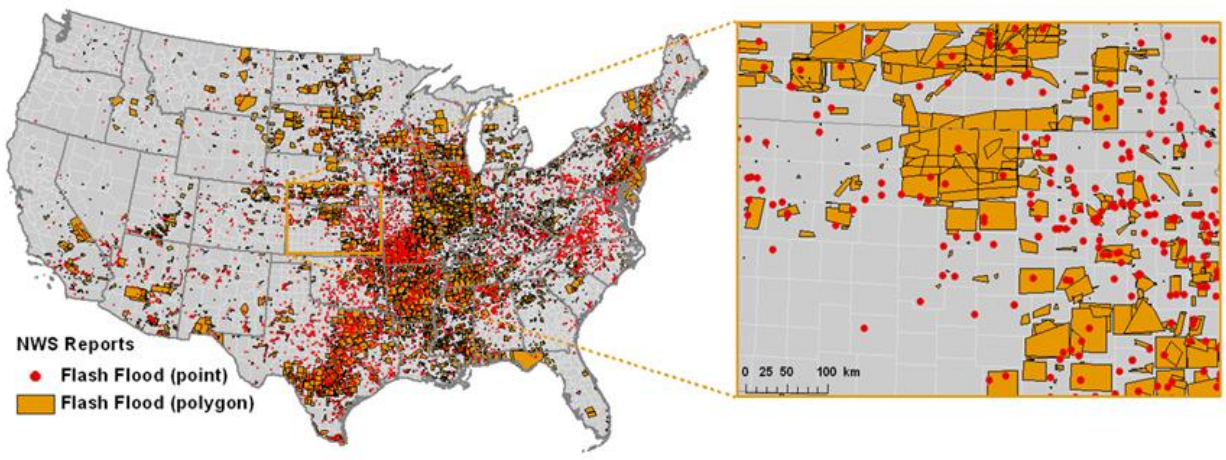

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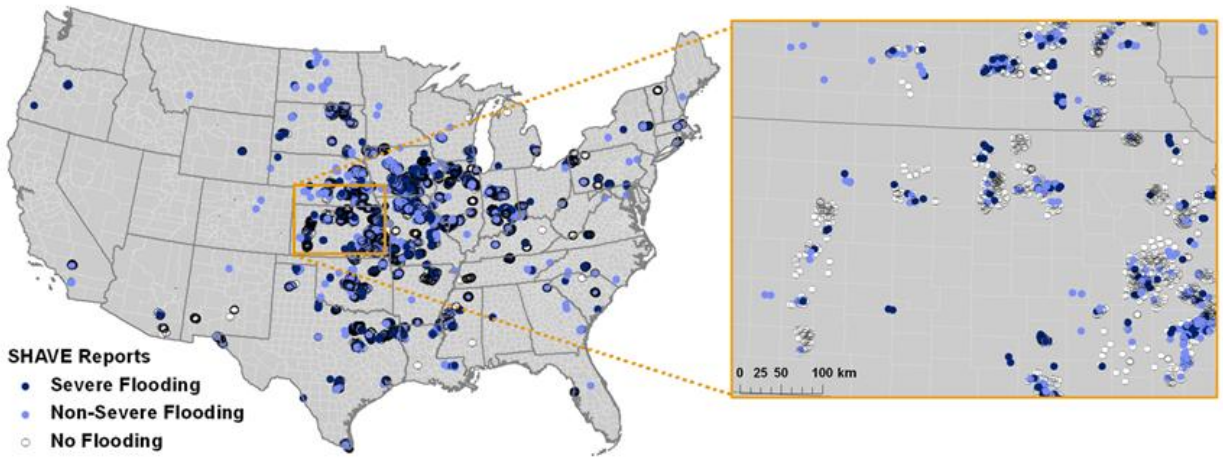

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