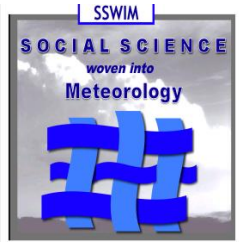

How Time is Considered in the Hazards Social Science Literature: An Annotated Bibliography August 2011

Prepared for the Warn-on-Forecast project
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I. INTRODUCTION AND MOTIVATION

The NOAA Warn-on-Forecast (WoF) project aims to increase tornado lead time from 10 to15 minutes to 1 to 2 hours by the year 2020. One of the big unknowns with this project is the question of how will officials and various segments of the population use the increased time?

Social scientists have approached the concept of time from multiple and varied perspectives, both implicitly and explicitly, and a review of this literature may benefit the WoF team of software developers and meteorologists. This annotated bibliography catalogs 116 articles from the literature that are related to time, with an emphasis on "warning time".

To highlight how social scientists have approached "time" related to hazards, a few examples are highlighted here. The examples are grouped into three categories that encapsulate some major time-related themes found in the social science literature:

1) passage of time
2) extended prediction/lead time, and
3) "ideal" tornado warning lead time.

These examples are not a comprehensive representation of all the articles or themes included in the annotated bibliography. They are summarized here to encourage discussion of the broader set of references. We are happy to discuss our findings with you individually or in an informal presentation to a group of WoF folks.

Passage of time

The passage of time is viewed across a spectrum between discreet phases or periods to a continuum where all moments are interconnected and phases overlap.

- Pingel et al. (2005), Carsell et al. (2004), and Schumacher et al. (2010) pose lead time as consisting of three discreet phases: data collection and evaluation, notification and decision making, and action (mitigation) time.
- Most articles consider warnings as a discreet period of time, posing the question of what actions, perceptions, and decisions are taking place within that period.
- Perry and Lindell (2003) and Tierney (1993) assert that preparedness is a continual process, while preparedness plans are a snapshot in time. They show that plans must be living documents that take into account changes in resources and vulnerability.
- Neal (1997) theorizes that the phases of disaster (mitigation, preparedness, response, and recovery) are not mutually exclusive categories, but rather form a continuum in which the phases overlap. Neal (1994) applied this theory to the response and recovery of a tornado impact, finding that the phases of response and recovery were not discrete moments in time, but blended together over the course of the event.

Extended prediction/lead time

The shift in tornado warning lead time proposed by WoF changes the context for tornado warnings, bringing forward a diverse variety of implications to be considered.

- Turner (1976) considered the multiple implications of an extended earthquake prediction of up to a year. Some factors they assessed were economic, political, legal, social, and behavioral.
- Nilson and Nilson (1981) considered at what point within the earthquake prediction the information should be released to the public.
- Turner (1983) conducted a longitudinal study of preparedness over the course of six years under an earthquake prediction. One relevant result is that there was a reduced urgency to the event.
- Letson et al. (2007) pose the possibility that dramatic changes in warning lead time for hurricanes and tornados will change the capabilities for response, which may result in entirely new response paradigms.

Ideal tornado warning lead time

It is uncertain as to if extended tornado warning lead times will benefit the public and other groups. Ideal lead time depends on the audience studied as well as the methodologies used by the researchers, whether that is through regression analysis or stated preference.

- Simmons and Sutter (2008) found that morbidity decreases in a linear fashion as lead time increases up until 15 minutes, where morbidity then increases.
- Hoekstra et al. (2011) found that the preferred lead time for the general public was approximately 34 minutes, with a majority of respondents reporting that an extended lead time of one to two hours would make the situation seem less life threatening.
- Ewald and Guyer (2002) found that the median lead time preferred by schools was 15 minutes, and 30 minutes by assisted living facilities.

II. HOW TO USE THE ANNOTATED BIBLIOGRAPHY

Our literature review shows that social scientists conceptualize time in many ways. This list is a non-comprehensive summary of time-related literature from multiple perspectives in the field of natural hazards and response. Although it does not include all time-related articles, it is an extensive review of time-related articles from a multi-hazard perspective. It includes both an annotated bibliography as well as a matrix. The matrix serves as a convenient reference tool, enabling the reader to quickly search for specific articles as well as compare and contrast among articles.

The matrix is comprised of 11 categories. They are:

- **Author(s)**
- **Year**
- **Methodology**
- **Hazard Type**
- **Lead-time:** warning lead time of actual event (if applicable) issued by the official government agency or perceived by the individual/group
- **Time of Action:** time the individual/group used/needed to take action before onset of hazard
- **Space of Action:** space in which action took place
- **Response:** type of study (actual event or hypothetical)
- **Key Words**
- **Stakeholder:** participant group(s) of the study
- **See Also:** related articles

For example, to find an article on earthquakes, search for earthquakes (EQ) under the Hazard Type category. To find something more specific, such as long term prediction of earthquakes, search for "long term prediction" under Key Words. To specify the duration of warning and response, look under the Lead-time or Time of Action categories. This will lead you to Turner (1976, 1983) and Nilson and Nilson (1981). Some boxes state VAR, usually meaning it is multi-hazard. The major annotated bibliography provides the full reference of the article, along with either the article's abstract, a brief summary written by the authors of this bibliography if no abstract is available, or a combination of the abstract and some of our additional comments.

Below are the categories, abbreviations and their meanings used to classify the range of bibliographic references.

Section	Abbreviation/Code	Meaning
Headings	HAZ TYPE	Hazard Type
	METH	Methodology
	LEAD-t	Lead Time
	T (ACTION)	Time for Action
	SPACE (ACTION)	Space for Action
Hazard Type	CYC	Cyclone
	EQ	Earthquake
	FFL	Flash Flood

	FL	Flood
	HUM	Human (terrorist, war)
	HUR	Hurricane
	MULTI-HAZ	Multi-Hazard
	SVR WX	Severe Weather
	SVRT	Severe Thunderstorm
	TECH	Technological (nuclear, explosion, chemical)
	TOR	Tornado
	TSU	Tsunami
	TYP	Typhoon
	WF	Wildfire
	WINT	Winter Storm
Methodology	ASSES	Assessment
	CBA	Cost Benefit Analysis
	COMP	Computation
	DA	Decision Analysis
	DOC	Document Analysis
	EXP	Experiment
	F-OBS	Field Observation
	FOC-G	Focus Group
	GIS	Global Information Systems
	INT	Interview
	LIT REV	Literature Review
	MOD	Model
	NS	Not Stated
	P-OBS	Participant Observation
	RA	Regression Analysis
	SIM	Simulation
	STATS	Statistical
	SUR	Survey
	THR	Theory
Lead Time	SEC	Second(s)
	MIN	Minute(s)
	HRS	Hour(s)
	DAY	Day(s)
	YRS	Year(s)
	OPEN	Open Time Window
	NA	Not Applicable
	NONE	No Time
	VAR	Various
Time for Action	SEC	Second(s)
	MIN	Minute(s)
	HRS	Hour(s)

	DAY	Day(s)
	YRS	Year(s)
	NA	Not Applicable
	NONE	No Time
	VAR	Various
	POST	Post Event
	CON	Continuous
Space for Action	EVAC	Evacuation
Response	PERCEP	Perceptions
	ACT ACTIONS	Actual Actions
	EXP ACTIONS	Expected Actions
	POS ACTIONS	Possible Actions
	LIT REV	Actions within Literature Review
	THR	Theoretical Actions

III. MATRIX

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Abe, K. and Kazama, R.	1985	SUR	FIRE	MIN-HRS	MIN-HRS	local	ACT ACTIONS	evacuation; sources of information; barriers to evacuation; rumors	general public of Japan	
Adeola, F.O.	2009	SUR F-OBS P-OBS	HUR	HRS	HRS	EVAC zones	ACT ACTIONS	Hurricane Katrina; social vulnerability; social disorganization; FEMA	general public in southern USA	
Ashley, W.S.	2007	STATS	TOR	MIN	MIN	nationwide	ACT ACTIONS	tornado fatalities; vulnerabilities; nocturnal tornadoes; demographics	general public in U.S.	
Averill, J.D. et al.	2005	SUR INT FOC-G	HUM	MIN	MIN	World Trade Center buildings (WTC 1 and WTC 2)	ACT ACTIONS	building fires; egress modeling; emergency communication; evacuation behavior; evacuation time	World Trade Center survivors	
Baker, E.J.	1979	STATS	HUR	HRS-DAY	HRS	EVAC zone	ACT ACTIONS	evacuation; predictors for response; multiple storms; recommendations for research	general public	
Baker, E.J.	1995	EXP	HUR	DAY	DAY	local	ACT ACTIONS	probabilities; warning; evacuation	general public of Southwest Florida	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Balluz, L. et al.	2000	SUR	TOR	MIN	MIN	local	ACT ACTIONS	USA; mitigation methods; population surveys	general public of Arkansas	
Barnes, L.R. et al.	2007	VAR	TOR MULTI-HAZ	MIN	MIN	local	PERCEP	false alarm rate; warning response; cry wolf	emergency managers, general public	Dow & Cutter 2006
Baumgart, L.A. et al.	2008	SIM SUR	SVRT	MIN DAY	MIN DAY	jurisdiction	ACT ACTIONS	decision making; model; information sources	emergency managers	League et al. 2010; Morss & Ralph 2007
Bourque, L.B. et al.	1971	SUR INT	EQ	NONE	NONE	local	ACT ACTIONS PERCEP	evacuation behavior; zero lead time; preparations	Los Angeles County residents	
Buckle, P., G. Mars, and S. Smale	2000	LIT REV THR	MULTI-HAZ	NA	vulnerability changing through time	vulnerability changing through space	NA	vulnerability; resilience; assessment	vulnerable populations, emergency planners	McEntire 2004
Burton, I.	1981	SUR	TECH	NA	POST	local	ACT ACTIONS	derailment; fires; explosions; evacuation behavior; official response	Mississauga residents	
Carr, L.J.	1932	THR	VAR	NA	Disaster Phases	NA	EXP ACTIONS	disaster phases (first appearance), cultural readjustment, social change	general public	Neal 1997

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Carsell, K.M. et al.	2004	THR CB	FLO	HRS	HRS	floodplain	EXP ACTIONS	flood forecasting; benefit cost ratios; California; rivers; tangible and intangible benefits; direct and indirect benefits; flood timeline	general public, floodplain managers	Pingel et al. 2005; Schumacher et al. 2010
Chiu, A.	1983	ASSES	HUR	HRS MIN	HRS MIN	local	ACT ACTIONS	disaster response and recovery; building damage; wind load provisions; hurricane-resistant buildings; FEMA	Hawaiins	
Cova, T.J. et al.	2009	INT THR	WF	VAR	"significant" "moderate" "little" "none"	local	EXP ACTIONS	fire hazards; public safety; evacuation; planning; shelter-in-place	general public, emergency response	
Cutter, S.L.	1987	CS	TECH	NONE	HRS	local	ACT ACTIONS	airborne chemical spill; evacuation; planning; timing	general public	
Czajkowski, J.	2011	MOD	HUR	HRS-DAY	HRS	EVAC region	EXP ACTIONS	evacuation; dynamic decision-making	general public in Gulf Coast	Regnier 2008
Dash, N. and Gladwin, H.	2007	LIT REV	HUR	NA	NA	household	LIT REV	evacuation; human factors; risk management; decision making	general public	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Dash, N. and Morrow, B.H.	2001	SUR	HUR	NA	DAY	EVAC route	ACT ACTIONS PERCEP	evacuation; return delays; hurricanes; barrier islands; risk assessment	general public of Florida	
Donner, W.R.	2008	INT	TOR FLO	MIN DAY	MIN DAY CON	local	PERCEP	emergency management; flooding; human ecology; Oklahoma; policy	emergency managers in Oklahoma	Rodriguez et al. 2010
Dow, K. and Cutter, S.L.	2002	SUR	HUR	DAY	HRS	EVAC route	ACT ACTIONS	evacuation; South Carolina; emergency services; preferred time window; decisions during evacuation	general public of South Carolina	
Dow, K. and Cutter, S.L.	2006	INT	HUR	DAY	DAY	community	ACT ACTIONS EXP ACTIONS	cry wolf; information sources; evacuation; repeat response	general public of South Carolina	Barnes et al. 2007
Drabek, T.E.	2000	INT	HUR FL	HRS-DAYS	NONE-DAYS	place of employment	ACT ACTIONS	evacuation; warning response; stress-strain; length of forewarning; organizational size; organizational mission	employees	Drabek 2001

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Drabek, T.E.	2001	INT SUR	HUR FL	DAY	DAY	work to home to shelter	ACT ACTIONS	evacuation predictive model; disaster and evacuation warning systems; policy recommendations	employees	Drabek 2000
Drabek, T.E.	2005	INT SUR STATS	MULTI-HAZ	VAR	CON VAR	community	ACT ACTIONS PERCEP	disaster response; effectiveness; managerial strategies; coordination strategies; social factors; predictive factors	emergency managers	
Duclos, P. et al.	1987	INT	TECH	NONE	MIN-HRS	EVAC zone	ACT ACTIONS	evacuation; transportation; warning messages; delays; public shelter; factors affecting decisions	general public in public shelter in Mississippi	
Etkin, D.A. and Myers, M.F.	1999	LIT REV	SVRT	MIN	CON MIN	local	EXP ACTIONS PERCEP	risk perception; mitigationand response; social dimensions	general public, state and local government, federal government	
Evans, D.L.	2003	INT	TOR	MIN HRS	MIN HRS	local	ACT ACTONS PERCEP	lead forecaster; instant messaging; Hazardous Weather Outlooks (HWO)	emergency managers, media, local residents in Eastern U.S.	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Ewald, R. and Guyer, J.L.	2002	SUR	TOR	MIN	MIN	local	EXP ACTIONS	ideal lead-time; warning response	schools, hospitals, assisted living facilities	Simmons & Sutter 2009
Fitzpatrick, C. and D.S. Mileti	1990	INT	EQ	MIN	MIN	local	ACT ACTIONS PERCEP	aftershock warnings; short-term impacts	general public, organizations, informants in San Francisco Bay area and Santa Cruz	
Fritz, C.E.	1957	INT	TECH EQ TOR	NONE-NS	NS	individual- local	ACT ACTIONS PERCEP	normalization of threat; comparative analysis; role of fore-warning in psychological stress	general public, observers of emergency operations	
Gigerenzer, G. et al.	2005	SUR	PRECIP	NA	NA	NA	PERCEP	probabilistic weather forecasts; numerical probabilities	general public in Amsterdam, Athens, Berlin, Milan, and New York	
Gladwin, H. et al.	2009	RECS	HUR	NA	VAR	NA	NA	warnings; forecasts; research needs; integration of social science; time scale dependency	general public, officials, institutions, businesses	Letson et al. 2007

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Glass, A.J.	1970	ASSES	MULTI-HAZ	VAR	VAR	VAR	EXP ACTIONS PERCEP	uncertainty; pre-impact phase; warning period; recoil period; post-impact phase; contingency response; military	general public	
Golden, J.H., and Adams, C.R.	2000	LIT REV THR	TOR	MIN	MIN	NA	EXP ACTIONS	warning communication; tornado response; weather warning partnership; emergency managers	general public, NWS, emergency managers, media, stakeholders	Mileti and Sorenson 1990
Gregg, C.E. et al.	2007	SUR	TSU	MIN-HRS	NONE-HRS	coast	PERCEP	alerts; warning system; sirens; environmental cues; Hawai‘i	students and adults in Hawai'i	
Gruntfest, E.C.	1977	INT DOC	FFL	NS	NONE SEC	local	ACT ACTIONS	warning response; behavior; recommendations	general public in Big Thompson Canyon	
Hammer, B. and Schmidlin, T.W.	2002	SUR	TOR	MIN	MIN	local	ACT ACTIONS	warning response; lead-time; fleeing	general public in OKC area	Hoekstra et al., 2011; Simmons & Sutter, 2009
Handmer, J.	1992	CS	FL	WKS	WKS	floodplain	ACT ACTIONS	long lead-time; informal warnings; media	forecasters, media, general public in Australia	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Hayes, J.L.	2007	INT	TOR	MIN	MIN HRS	local	ACT ACTONS PERCEP	lead time; NWS products and services; county-based warnings; storm-based warnings; radios	weather forecasters, media, emergency managers, general public in Southern Alabama and Georgia, Enterprise High School	
Hayes, J.L.	2009a	INT	TOR	MIN	MIN HRS	local	ACT ACTONS	lead time; assessment; NWS products and services; storm spotters; warning polygons	weather forecasters, media, emergency managers, general public in Southern U.S.	
Hayes, J.L.	2009b	INT	TOR	MIN-DAY	NONE-DAY	local	ACT ACTONS	lead time; assessment; NWS products and services; shelters	weather forecasters, media, emergency managers, general public in Oklahoma and Missouri	
Hayes, J.L.	2009c	INT	FLO	MIN HRS	MIN HRS	regional	ACT ACTIONS	electronic communication; river modeling; levees; precipitation prediction; societal factors	forecasters, emergency managers, flood and levee district staff, television stations staff in Central U.S.	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Hayes, J.L.	2010	INT	FFL	MIN HRS	MIN HRS	local	ACT ACTONS PERCEP	weather radios; real-time feedback; false alarms; night	weather forecasters, emergency managers, residents in Southeast U.S.	
Haynes, K. et al.	2009	INT	FFL	HRS	HRS SEC	local	PERCEP	flood fatalities; flood safety; shelter-in-place	emergency managers	Cova et al. 2009
Hodler, T.W.	1982	SUR	TOR	MIN	MIN	local	ACT ACTIONS	emergency warning system; disaster planning; human behavior	general public in Kalamazoo, Michigan	
Hoekstra, S. et al.	2011	SUR	TOR MULTI-HAZ	MIN	MIN	local	EXP ACTIONS PERCEP	lead-time; risk perception; behavior	general public	Ewald & Guyer 2002; Simmons & Sutter 2008
IACLEA	2007	FOC-G	HUR HUM	DAYS NONE	CON DAYS POST	campus	ACT ACTIONS	lessons learned; chronology; planning; equipment; staff; coordination; communication	officials at Gulf Coast universities, University of Oklahoma, and Georgia Institute of Technology	
Johnson, D.L.	2005	INT	TSU	MIN	MIN	regional	ACT ACTONS PERCEP	tsunami information bulletin (TIB); media; TsunamiReady program; outreach; false alarm	weather forecasters, emergency managers, media, residents of West Coast	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Johnson, D.L.	2006	INT	HUR	HRS	HRS	HUR zone	ACT ACTIONS	warnings; cone of uncertainty; software	general public, forecasters in Florida	
Kapucu, N.	2008	SUR DOC INT	HUR	VAR	CON VAR	statewide local	ACT ACTIONS	community coordination; disaster management; disaster response operations; public preparedness; repeated threats; pre-disaster activities	emergency managers in Florida	
Kirschenbaum, A. and Rapaport, C.	2009	SUR STATS	HUM	MIN	MIN	local	ACT ACTIONS	warnings; compliance; timing; social adaptation; compliance over time	general public of Israel	
Kirsher, T. et al.	1987	STATS	FFL	HRS	HRS SECS	local	ACT ACTIONS	evaucation; dams; trust; communication	town officials and general public in Essex, Connecticut	
Knocke, E.T. and Kolivras, K.N	2007	SUR	FL	HRS	HRS SECS	local	PERCEP	risk perception; flood knowledge and communication	general public of southwest Virginia	
Lachman, R. et al.	1961	SUR	TSU	HRS	MIN-HRS	EVAC zone	ACT ACTIONS	evacuation; warning recognition; delayed response	general public of Hilo, Hawaii	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
League, C.E. et al.	2010	FOC-G SUR	TOR	MIN	MIN	local	EXP ACTIONS	emergency managenet; tornado warnings; weather radar; spotters, user-centered system design; ideal lead time; frequency of information use	emergency managers in Oklahoma	Baumgart et al. 2008; Morss & Ralph 2007
Legates, D.R. and Biddle, M.D.	1999	SUR	TOR	MIN	MIN	statewide	ACT ACTIONS	field surveys; long-track tornado; shelter	general public in Oak Grove, Alabama	
Leik, R.K. et al.	1980	DOC	HUR TOR FL EQ	VAR	VAR	nationwide	EXP ACTIONS PERCEP	warning systems; response	general public	
Letson, D. et al.	2007	THR LIT REV	HUR	HRS-DAY	CON HRS-DAY	NA	POS ACTIONS	economic models; public safety; weather forecasting; risk management	individuals, businesses, society	Gladwin et al. 2009
Lindell, M.K.	2000	THR	TECH	HRS	MIN HRS	miles	EXP ACTIONS	emergency management; nuclear incidents; protective actions; warning response	emergency managers, nuclear plant personnel, local government, general public	
Lindell, M.K. et al.	2005	SUR	HUR	DAY	DAY	local	ACT ACTIONS	evacuation; traffic management; risk management	general public of Louisiana	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Lindell, M.K. and C.S. Prater	2010	INT RECS	TSU	NS	NA CON	local EVAC zone	ACT ACTIONS EXP ACTIONS PERCEP	emergency services, evacuation, risk management, communication, planning, warnings, preparedness, evacuation time estimates	emergency personnel, general public of Oregon	
Lindell, M.K. et al.	2007	THR LIT REV	HUR	DAY	HRS DAY	jurrisdiction EVAC zone	LIT REV	evacuation; traffic management; risk management; communication; emergency services	meteorologists, emergency managers, public	
Lindell, M.K. et al.	2002	MOD	HUR	NA	HRS-DAY	EVAC route	EXP ACTIONS	evacuation time ewtimates; empirically based; Texas	general public of Texas Gulf Coast	
Maximuk, L.	2006	INT	TOR	NONE	MIN	NWS county warning area	ACT ACTIONS	County warnings; effective use of time; radar; "sectoring"	NWS Forecasters in Rogers, Minnesota	
McEntire, D.A.	2004	LIT REV	MULTI-HAZ	NA	vulnerability changing through time	vulnerability changing through space	NA	vulnerability; resilience; assessment; hazards vs disasters	NA	Buckle et al. 2000
McGlown, K.J.	2001	FOC-G MOD THR	MULTI-HAZ	VAR	VAR	healthcare facility	PERCEP	evacuation; healthcare facilities; decision-making	healthcare officials	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Mileti, D.S. and Peek, L.	2000	THR	TECH	HRS	NA	local	EXP ACTIONS	risk; communication; warning response	detection, management, public subsystems	Lindell 2000; Mileti & Sorenson 1990
Mileti, D.S. and Sorenson, J.H.	1990	THR	MULTI-HAZ	VAR	VAR	VAR	EXP ACTIONS	decision-making; warnings; response; model	detection, management, public subsystems	Mileti & Peek 2000; Schumacher et al. 2010
Morss, R.E	2010	DOC INT	FL	NONE HRS MON	MIN HRS MON	flood zone	EXP ACTIONS	decision making; weather forecasting; natural disasters; emergency services; dikes; detention reservoirs; precipitation; lead time; previous experience	Public officials, individuals in Red River Basin, Grand Forks and Fargo, North Dakota, and Fort Collins Colorado	
Morss, R.E. and Ralph, F.M.	2007	P-OBS INT	WINT	HRS DAY	HRS DAY CON	WFO jurisdication local	ACT ACTIONS	forecasting process; lead time model; information use; researcher-user interaction	forecasters and emergency managers in California	Baumgart et al. 2008; League et al. 2010
Morss, R.E. et al.	2005	INT	FLO	NA	CON	floodplain	ACT ACTIONS	uncertainty; scientific information use; decision making	floodplain managers in Colorado	
Neal, D.M.	1994	INT	TOR	MIN	DAY	local	ACT ACTIONS	response; recovery; disaster phases; types of activity	general public, city officials, media, social services in Lancaster, Texas	Neal 1997; Neal 2004

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Neal, D.M.	1997	THR LIT REV	MULTI-HAZ	NA	"Disaster Phases"	NA	LIT REV	four phases of disaster; disaster research; life cycle approach	disaster researchers and practitioners	Carr 1932; Neal 1994; Neal 2004
Neal, D.M.	2004	F-OBS DOC INT	TOR	NA	disaster phases	local	ACT ACTIONS	response, recovery, disaster phases, types of activity; objective vs social time	emergency responders of Lancaster, Texas	Neal 1994; Neal 1997
Nilson, L.B. and Nilson, D.C.	1981	THR	EQ	DAY-YRS	NA	NA	THR EXP ACTIONS	early vs. delayed warnings; earthquake prediction; social, economic, and political aspects	general public	Stallings 1977; Turner 1976; Turner 1983
Parker, D.J.	1987	DOC INT	FLO	HRS	HRS	NA	ACT ACTIONS	warnings; inter-organization cooperation; public education	public officials, forecasters, police in Britain	
Parker, D.J. et al.	2007	SUR	FL	HRS	HRS SEC	local	ACT ACTIONS PERCEP	flood warnings; economic benefits; flood damage; damage savings; warning improvement	general public in England and Wales	
Paul, B.K. et al.	2003	INT	TOR	MIN	MIN	local	ACT ACTIONS	community size; warning response; lead-time	general public in Kansas, Missouri, and Tennessee	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Perry, R.W. and M.K. Lindell	2003	LIT REV REC	HUM MULTI-HAZ	NA	CON	community	NA	preparedness; planning; disaster response; coordination; training and drills	emergency management and responders	
Pingel, N. et al.	2005	COMP	FLO	HRS	NA	watershed	NA	flood forecasting; probabilistic methods; time factors	NA	Carsell et al. 2004; Schumacher et al. 2010
Phillips, B.D. and B.H. Morrow	2007	LIT REV	SVR WX	MIN	MIN	local	PERCEP	vulnerable populations; discrimination; socioeconomic status	general public, vulnerable populations	
Regnier, E.	2008	DA	HUR	HRS-DAY	DAY CON	EVAC zones	EXP ACTIONS	decision analysis; risk; natural systems; disaster planning; public evacuations; spatially dependent lead time	public officials	Czajkowski 2011
Rodriguez, H. et al.	2010	INT	MULTI-HAZ	MIN	NA	local	PERCEP	disasters; hazards; radar resources; technology; social sciences; emergency managers; population	emergency managers in Oklahoma	Donner 2008

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Ruin, I. et al.	2009	INT	FFL	HRS	HRS SEC	local	ACT ACTIONS	road users; uncertainty; hydrometeorological simulations; social vulnerability	general public of Gard Region of Southern France	
Ruin, I. et al.	2008	STATS	FFL	HRS	HRS SEC	local	ACT ACTIONS PERCEP	flash-flood; death circumstances; vulnerability; ungauged catchment; Mediterranean area	general public of Gard Region of Southern France	
Ruin, I. et al.	2007	GIS	FFL	MIN	MIN	local	PERCEP	motorists; flash flood perception; GIS; mental mapping	motorists	
Salmon, J.D.	1984	RECS	HUR	HRS	DAY	EVAC zone	NA	horizontal vs. vertical evacuation, time requirements, lead time, planning, politics, risk, convenience	emergency planners	
Schmidlin, T.W. and P.S. King	1995	SUR	TOR	MIN	NONE-MIN	local	ACT ACTIONS	survivors vs. fatalities; mobile homes; vehicles, warning systems; lead time; demographics	general public of Georgia and Alabama	Schmidlin & King 1997

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Schmidlin, T.W. and P.S. King	1997	SUR	TOR	MIN	SECS-MIN	local	ACT ACTIONS	survivors vs. fatalities; mobile homes; vehicles; warning systems; lead time	general public of Arkansas	Schmidlin & King 1995
Schmidlin, T.W. et al.	1998	SUR	TOR	MIN	MIN	statewide	ACT ACTIONS	field surveys; mobile homes; age; shelters; night tornadoes	general public of Florida	
Schneider, D.M.	1957	P-OBS INT	TYP	HRS	HRS	local household	ACT ACTIONS	non-western disaster response; supernatural and spirituality in disaster; use of time; chronic disaster; social meaning of disaster	population of Yap	
Schultz, D.M. et al.	2010	SUR	TOR	MIN	MIN	local	EXP ACTIONS	highway overpasses; false alarms; hypothetical cases	Austin, Texas floodplain residents	
Schumacher, R.S. et al.	2010	INT	TOR	MIN	MIN	local	ACT ACTIONS	warnings; lead-time	businesses, school and university officials, emergency managers in Colorado	Carsell et al. 2004; Mileti & Sorenson 1990; Pingel et al. 2005

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Schwartz, R.M.	2003	DOC F-OBS INT	TOR	NONE	NS	local regional	ACT ACTIONS	preparedness; response; communication; education; relationships	NWS; emergency responders	
Sherman-Morris, K.	2010	SUR	TOR	MIN	MIN	campus	ACT ACTIONS PERCEP	warnings; colleges; mobile emergency alert systems; risk communication	students and faculty of Mississippi State University	
Simmons, K.M., and Sutter, D.	2006	RA	TOR	MIN	MIN	NA	NA	tornado warnings; fatalities; injuries; Doppler radar	general public in U.S.	Simmons, & Sutter 2008
Simmons, K.M., and Sutter, D.	2008	RA	TOR	MIN	MIN	NA	NA	tornado casualties; lead-time; tornado warnings	general public in U.S.	Hoekstra et al. 2011; Simmons &. Sutter 2006; Simmons & Sutter 2009
Simmons, K.M., and Sutter, D.	2009	RA	TOR	MIN	MIN HRS	nationwide	NA	false-alarm effect; tornado casualties; regression model	general public in U.S.	Ewald & Guyer 2002; Simmons & Sutter 2008
Sinha, A.K. and Avrani, S.U.	1984	INT	CYC	HRS-DAY	HRS-DAY	local	ACT ACTIONS	Gujarat cyclone; disaster-warning systems; warning dissemination; environmental cues	emergency officials and general public of India	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Slovic, P.	1999	THR	MULTI-HAZ	VAR	VAR	VAR	PERCEP	risk perception; risk assessment; risk communication; risk management	general public	
Sorenson, J.H.	1991	SUR	TECH	HRS	HRS	local	ACT ACTIONS	model; evacuation; hazardous materials fire; warnings	general public of Nanticoke, Pennsylvania	
Sorenson, J.H.	2000	LIT REV THR RECS	MULTI-HAZ	VAR	VAR	VAR	EXP ACTIONS	warnings; long-term/short-term sustainability; warning integration; dissemination	officials, emergency managers, general public	Mileti & Sorenson 1990
Sorenson, J.H. and Mileti, D.S.	1988	LIT REV	MULTI-HAZ	HRS	SEC-HRS	VAR	ACT ACTIONS LIT REV	lead time; warning time; warning response; evacuation time; shadow evacuation; evacuation location	general public	
Spiegel, J.P.	1957	NS	FFL	NONE	SEC	household	ACT ACTIONS	disaster phases; flood response; warning systems; normalization of threat	general public, public officials of a small town in England	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Stallings, R.A.	1977	LIT REV	EQ	open time window	YRS	local	LIT REV	prediction; social, economic, preparedness constraints; timing; inequality	general public	Nilson & Nilson 1981; Turner 1976; Turner 1983
Sutter, D. and S. Erickson	2010	STATS	TOR	NA	"Man hours"	county vs storm based warning area	NA	warnings; economics; time	general public in U.S.	
Tierney, K.	1993	LIT REV	MULTI-HAZ	NA	CON	NA	LIT REV	preparedness; planning; warning response; disaster phases	general public (recognizing heterogeneity)	
Turner, R.H.	1976	THR RECS	EQ	YRS OPEN	YRS	EQ zone	THR	prediction vs warning; societal response; economic response; timing	general public, officials, economic insitutions	Stallings 1977; Turner 1983; Nilson & Nilson 1981
Turner, R.H.	1983	SUR	EQ	OPEN	YRS	EQ zone	PERCEP	earthquake prediction; long-term prediction; effect of waiting	general public in Southern California	Stallings 1977; Turner 1976; Nilson & Nilson 1981
Vogt, B.M. and J.H. Sorenson	1999	SUR	TECH	NONE	MIN-HRS	EVAC zone residence	ACT ACTIONS	evacuation; shelter in place; toxic airborne event; timing of warning and evacuation	general public in West Helena, Virginia	
Wallace, A.F.C.	1956	CS	TOR	NONE-MINS	NONE-MINS	local	ACT ACTIONS	lack of communication; environmental cues; informal warning; phases of disaster; time-space model	population of Worcester, Massachusetts	

AUTHOR(S)	YEAR	METHOD	HAZ TYPE	LEAD-t	t (ACTION)	SPACE (ACTION)	RESPONSE	KEY WORDS	STAKEHOLDER	SEE ALSO
Wolshon, B. et al.	2010	LIT REV THR	MULTI-HAZ	NA	HRS	EVAC zone	EXP ACTIONS	evacuation; evacuation tail; emergency planning; nuclear power plant; travel behaviour	evacuation tail	
Worth, M.F. and B.F. McLuckie	1977	INT SUR DOC	FFL	NONE-DAYS	NONE-DAYS	citywide eastern Colorado	ACT ACTIONS	warning system; warning process; time dimensions; warning phases	officials, organizations, general public in Colorado	
Zahran, S. et al	2008	STATS RECS	FLO	HRS	HRS	local	ACT ACTIONS	built environment; casualties; social vulnerability	general public ofTexas	

IV. ANNOTATED BIBLIOGRAPHY

For this section, each article is listed by the number that correlates to the matrix, full bibliographic reference, and an abstract. Abstracts written by the authors of the paper appear in black and abstracts written by the authors of this bibliography appear in red. Additional comments made by the authors of this bibliography appear in blue.

Abe, K. and R. Kazama, 1985: A psychological analysis of the evacuation behavior at the Great Sakata Fire. *International Journal of Mass Emergencies and Disasters*, **3(1)**, 133-146.

This research studied human behavior in the great Sakata Fire. The fire, fanned by a violent wind at the time, burned continuously in the center of the city for about 12 hours. Although it rained that night, the fire was massive and spread extensively. The research focus was on: 1) the recognition of the fire: about what time was it noted, how the fire was reported, and what were the early forecasts about it; 2) the behavior of people seeking refuge: the period of preparation for refuge, the state of the fire at the time, what people thought of doing and how; 3) information: the means used to obtain information about the fire, and rumor behavior; and 4) social disorganization: whether or not there was panic and looting behavior, details about it, and reasons why it occurred. The fire spread at a speed of about 100 m/h, which was rather slow in spite of the strong wind. This condition is considered as the reason for the relatively smooth evacuation of people, the lack of any great panic, and the few deaths and injuries.

Adeola, F.O., 2009: Katrina cataclysm does duration of residency and prior experience affect impacts, evacuation, and adaptation behavior among survivors? *Environment and Behavior*, **41(4)**, 459-489.

This study explores the extent to which people's prior experience of a natural disaster influenced subsequent behavior concerning the threats of a hydrometeorological disaster and if duration of residency in a disaster-prone landscape affects the extent of preparedness for an impending disaster. Mixed methods research strategies involving survey, field observation, and participant observations at several locations including rescue and evacuation centers in New Orleans, Louisiana, Austin, Texas, and Lawrenceville, Georgia, were used, during the immediate impact phase, emergency shelter phase, and postimpact and recovery phase of Katrina catastrophe. For the survey, a sample of 598 subjects completed a 15-page, 54-item questionnaire addressing various aspects of the Katrina flood in the New Orleans Metropolitan Area. The qualitative aspect consists of field observations of the event, interviews, and direct comments by the victims dispersed across the South. In the regression analysis performed, prior experience was found to be less important than friends' and family members' influence in determining evacuation behavior. However, duration of residency and prior experience were found to be slightly significant in predicting the odds of evacuation.

Ashley, W.S., 2007: Spatial and temporal analysis of tornado fatalities in the United States: 1880-2005. *Weather and Forecasting*, **22(6)**, 1214-1228.

A dataset of killer tornadoes is compiled and analyzed spatially in order to assess region-specific vulnerabilities in the United States from 1880 to 2005. Results reveal that most tornado fatalities occur in the lower–Arkansas, Tennessee, and lower–Mississippi River valleys of the southeastern United States—a region outside of traditional “tornado alley.” Analysis of variables including tornado frequency, land cover, mobile home density, population density, and nocturnal tornado probabilities demonstrates that the relative maximum of fatalities in the Deep South and minimum in the Great Plains may be due to the unique juxtaposition of both physical and social vulnerabilities. The spatial distribution of these killer tornadoes suggests that the above the national average mobile home density in the Southeast may be a key reason for the fatality maximum found in this area. A demographic analysis of fatalities during the latter part of the database record illustrates that the middle aged and elderly are at a much greater risk than are younger people during these events. Data issues discovered during this investigation reveal the need for a concerted effort to obtain critical information about how and where all casualties occur during future tornado and hazardous weather events. These new, enhanced data, combined with results of

spatially explicit studies exploring the human sociology and psychology of these hazardous events, could be utilized to improve future warning dissemination and mitigation techniques.

Averill, J.D., D.S. Mileti, R.D. Peacock, E.D. Kuligowski, N. Groner, G. Proulx, P.A. Reneke, H.E. Nelson: 2005. Appendix C: Causal Modelling. "Predicting Evacuation Delay in the World Trade Center," Pp. 217-228. Occupant Behavior, Egress, and Emergency Communications: Federal Building and Fire Safety Investigation of the World Trade Center Disaster. NIST NCSTAR 1-7. Washington, D.C.: U.S. Department of Commerce, National Institute of Standards and Technology.

This project analyzed the factors (variables) and social processes (the major paths of causal links between variables) that influenced people delaying the initiation of their evacuation out of the two World Trade Center buildings (WTC 1 and WTC 2) on September 11, 2001. Evacuation delay was defined as the number of minutes that passed from when a person first became aware that something was wrong until they began their evacuation. In order to understand what factors impacted the overall evacuation time of the average occupant in World Trade Center WTC 1 or WTC 2, two primary dependent variables were predicted: how long an individual delayed initiating their evacuation, where initiation is defined as entering a stairwell or elevator with the intention of exiting the building; and how long an individual spent traversing the stairwells. The sum of these two times was the total evacuation time. Multivariate regression modeling was utilized to rigorously establish factors which contributed to increasing the overall evacuation time. Environmental cues, floor, and perceived risk were the major factors resulting in people to obtain further information on the situation and what actions to take, increasing evacuation delay.

Baker, E.J., 1979: Predicting response to hurricane warnings: A reanalysis of data from four studies. *Mass Emergencies*, **4(1)**, 9-24.

In a reanalysis of four studies about three hurricanes (Carla, 1961; Camille, 1969; Eloise, 1975), predictors for evacuation are examined through χ^2 analysis and a Goodman and Kruskal τ_b tests. Multiple predictors were analyzed, including sources of information, evacuation orders, storm monitoring, belief that the storm would hit, damage estimation, weather forecast confidence and recall, education, previous experience, length of residence, characteristics of the home, and demographics. The largest predictor is home elevation, meaning that those most at risk are those most likely to evacuate. Length of forewarning, time monitoring the storm, and time of day were not significant predictors. Belief that the storm will hit was only slightly significant, and only at short times before landfall. The author makes suggestion for future research because of the limitations in evacuation research in 1979.

Baker, E.J., 1995: Public response to hurricane probability forecasts. *Professional Geographer*, **47(2)**,137-147.

Interviewers presented 400 residents of Pinellas County, Florida, with sets of hypothetical hurricane threats to assess the effect of hurricane probability forecasts and other risk indicators on public response to the threats. Evacuation notices from local officials were more important than other threat variables, and hurricane probabilities did little to modify that effect. Respondents appeared to comprehend and use the probability information reasonably: Evacuation behavior in actual hurricane threats is consistent with the survey findings.

Balluz, L., L. Schieve, T. Holmes, S. Kiezak, and J. Malilay, 2000: Predictors for people's response to a tornado warning: Arkansas, 1 March 1997. *Disasters*, **24(1)**, 71-77.

On 1 March 1997, powerful tornadoes touched down in Arkansas (USA) on a Saturday afternoon. Twenty-six fatalities and 400 non-fatal injuries were reported. We performed a population-based cross-sectional study to determine factors associated with appropriate responses to tornado warnings.

Of 146 survey participants, 140 (96 per cent) knew the difference between 'tornado watch' and 'tornado warning' and were aware of when the warning was announced. Of those 140 participants, 64 (45.7 per cent) responded to the warning by seeking shelter, and 58 (90.6 per cent) of those 64 acted within five minutes of hearing the warning. Four factors were positively associated with those seeking shelter: having graduated from high school (OR = 4.2, 95 per cent CI =1.1−15.5); having a basement in

one's house (OR = 3.8, 95 per cent exact CI=1.1−17.1); hearing a siren (OR = 4.4, 95 per cent CI = 1.3−18.9); and having prepared a household plan of response when tornadoes occur (OR=2.6, 95 per cent CI = 1.1−>6.3).

On the basis of these findings, we recommend: first, that people who live in tornado-prone areas have a personal plan of action to help them respond immediately to warnings; second, public-health education officials in areas with frequent tornadic activity should do more to educate the public about what they can do to protect themselves from a tornado; and third, that emergency-management officials planning protection measures for vulnerable communities should consider that most people have limited time (our study documented five minutes) in which to respond to a tornado warning. Thus, shelters in tornado-prone areas should be quickly accessible by residents.

Barnes, L.R., E.C. Gruntfest, M.H. Hayden, D.M. Schultz, and C. Benight, 2007: False alarms and close calls: A conceptual model of warning accuracy. *Weather and Forecasting*, **22(5)**, 1140-1147.

The false alarm rate (FAR) measures the fraction of forecasted events that did not occur, and it remains one of the key metrics for verifying National Weather Service (NWS) weather warnings. The national FAR for tornado warnings in 2003 was 0.76, indicating that only one in four tornado warnings was verified. The NWS's goal for 2010 is to reduce this value to 0.70. Conventional wisdom is that false alarms reduce the public's willingness to respond to future events. This paper questions this conventional wisdom. In addition, this paper argues that the metrics used to evaluate false alarms do not accurately represent the numbers of actual false alarms or the forecasters' abilities because current metrics categorize events as either a hit or a miss and do not give forecasters credit for close calls. Aspects discussed in this paper include how the NWS FAR is measured, how humans respond to warnings, and what are alternative approaches to measure FAR. A conceptual model is presented as a framework for a new perspective on false alarms that includes close calls, providing a more balanced view of forecast verification.

Baumgart, L.A., E.J. Bass, B. Phillips, and K. Kloesel, 2008: Emergency management decision making during severe weather. *Weather and Forecasting,* **23(6)**, 1268-1279.

Emergency managers make time-sensitive decisions in order to protect the public from threats including severe weather. Simulation and questionnaires were used to capture the decision-making process of emergency managers during severe weather events. These data were combined with insights from emergency manager instructors, National Weather Service (NWS) forecasters, and experienced emergency managers to develop a descriptive decision-making model of weather information usage, weather assessments, and decisions made during severe weather. This decision-making model can be used to develop better decision support tools, improve training, and to understand how innovative weather information could potentially affect emergency managers' role of protecting the public.

Bourque, L.B., L.G. Reeder, A. Cherlin, B.H. Raven, and D.M. Walton: 1971. The Unpredictable Disaster in a Metropolis: Public Response to the Los Angeles Earthquake of February, 1971. University of California, Los Angeles: Prepared for the Defense Civil Preparedness Agency, Washington, D.C., 20301, UCLA Survey Research Center.

At 42 seconds after six on Tuesday morning, February 9, 1971, the Los Angeles metropolitan area was jolted by southern California's most severe earthquake since the Long Beach Quake of 1933. The quake registered 6.4 on the Richter scale, A second shock of similar intensity followed almost immediately, and within five minutes, four additional aftershocks occurred. Within three hours, 68 aftershocks had occurred, the epicenter, located in the San Bernadino Mountains, was approximately 10 miles east of Newhall and nine miles northeast of San Fernando on the northern fringe of the sprawling Los Angeles metropolitan area, Major damage and injury was centered in the Sylmar-San Fernando area in the northern San Fernando Valley. However in areas such as the central city, --where the intensity of the quake was significantly less, but where buildings are generally older--its effect on people and property was still substantial. This report focuses on the interface between social structural systems and the individual psychological system. It is hypothesized that knowledge of an individuals relation to his community and the wider social system and identification of the characteristics of his environment at the

moment of impact in a disaster increases our ability to predict both his immediate and long-range emotional reactions and social behavior.

There is a vast literature on disasters including journalistic accounts, case histories, extensive descriptive surveys, and theoretical surveys, However, it is our impression that the San Fernando earthquake of 1971 provides an unique perspective on disasters. First, an earthquake is a natural disaster which, to date, provides no opportunity for warnings to be transmitted to its potential victims. Second, unlike a majority of disasters studied in the Ifnited States, this disaster occurred on the periphery of one of the largest metropolitan areas in the world--an area which contains a highly sophisticated communication system and the California Institute of Technology, one of the major centers for the seismological study of earthquakes. Third, the disaster occurred at a time of day, 6:00 a.m., when almost everyone was at home in bed. Consequently, for persons living in a family unit, no lag time existed in determining how other family members fared during the quake.

Buckle, P., G. Mars, and S. Smale, 2000: New approaches to assessing vulnerability and resilience. *The Australian Journal of Emergency Management*, **15(2)**, 8-14.

Different perspectives on how resilience and vulnerability may be assessed are illustrated because lack of understanding often constrains the effective practice of emergency management. Incorporated into a coherent framework and understanding of vulnerability and resilience will help to integrate it with other disciplines such as community development, social psychology, community economics and environmental management.

This article recognizes that assessments of vulnerability tend to be based in a single point in time, while conditions which make a group vulnerable are not static. It makes the recommendation that new vulnerability assessment techniques need to be developed, and changes across time and space are part of these new recommendations.

Burton, I. 1981: The Mississauga Evacuation: Final Report. Toronto, ON: Institute of Environmental Studies, University of Toronto.

On November 10, 1979, a train in Mississauga derailed, causing several fires and explosions from derailed propane cars and chlorine leakage. The city was closed for almost a week and all residents were evacuated. A team of researchers from the Emergency and Risk Research Group designed a questionnaire that they disseminated to 1,000 residents who were evacuated. The survey focused on public response to the evacuation, societal impacts of the hazard, costs of the event, and official response. A major finding pertaining to time in particular was that the creation of an “evacuation alert” stage prior to the actual evacuation may increase the likelihood that people respond in a quick fashion.

Carr, L.J., 1932: Disaster and sequence-pattern concept of social change. *American Journal of Sociology*, **38(2)**, 207-218.

Social change is much broader than cultural change and includes also populational changes, relational changes, and catastrophic changes. Study of catastrophic changes supports the hypothesis that all social change tends to follow a definite sequence- pattern: (i) a precipitating event or condition; (2) adjustment-dislocation; (3) individual, interactive, and cultural readjustments. As a working hypothesis this means that episodic views of social change must be given up: no single event in the series can be called the change to the exclusion of the rest. Applied to statistics this suggests the value of selective sampling to describe the cycle. Other research problems include the search for possible analogues of cultural lag in relational and populational changes and for techniques for identifying the precipitating event to facilitate the study of con- temporary social process.

This article is cited by Neal (1994, 1997) as the first use of phases in disaster research. For further works on disaster phases see the review by Neal (1997).

Carsell, K.M., N.D. Pingel, and D.T. Ford, 2004: Quantifying the benefit of a flood warning system. *Natural Hazards Review*, **5(3)**, 131-140.

A flood warning system yields direct and indirect, tangible and intangible benefits. To achieve this, the system includes hardware, software, plans and procedures, and personnel that work in an integrated manner to increase the mitigation time available prior to the onset of flooding. This mitigation time increase is a consequence of a reduction in the time required to collect data, to evaluate and identify the flood threat, to notify emergency personnel and the public, and to make decisions about the appropriate response. The direct tangible benefit—the inundation damage reduction—can be computed with standard expected damage computation procedures, using modified depth-damage functions that include mitigation time as an independent variable and accounting for improvements to the efficiency of response due to the implementation of the flood warning system. This proposed method is applicable for benefit evaluation for any flood warning system; it is illustrated here with an example from the Sacramento River basin of central California.

Chiu, A. 1983. "Hurricane Iwa, Hawaii, November 23, 1982." Washington, D.C.: National Academy of Sciences.

Hurricane Iwa was the most costly storm ever to strike Hawaii, although it was not the most severe. This storm caused many complications, including damage to buildings and other structures, lifelines, and disaster response and recovery efforts. Basically, everything went wrong when it came to public and official response to the storm. This report has many components, including an array of important conclusions. A major finding pertaining to time is that the more time available between the awareness of possible danger to the actual onset of a disaster, the less likely a person is to respond and take protective action.

Cova, T.J., F.A. Drews, L.K. Siebeneck, and A. Musters, 2009: Protective actions in wildfires: Evacuate or shelter-in-place?. *Natural Hazards Review*, **10(4)**, 151-162.

The decision of whether to evacuate or shelter-in-place SIP in a wildfire poses a significant challenge for emergency managers and residents in fire-prone areas. Events such as the 2007 Witch Creek Fire and 2008 Tea Fire in California highlight the option and viability of SIP, as well as the conflict that can occur between first-responders and residents in protecting life and property. In general, anecdotes abound of people choosing SIP over evacuation in wildfires using a variety of means of refuge e.g., structure, safe area, and water body. We propose a typology of wildfire protective actions that includes all viable forms of in-place shelter and discuss heuristics that have been proposed to guide people through the options. A key distinction is drawn between SIP as a backup plan when evacuation is perceived as too risky and SIP to improve structure survivability. Regardless of the form that SIP takes, the need for this strategy is growing as the wildland-urban interface expands. The paper concludes with a discussion of suggested areas for research and planning.

Cutter, S.L., 1987: Airborne toxic releases. *Environment*, **29(6)**, 12-17 28-31.

This article considers contingency planning for airborne toxic releases of both stationary and mobile storage of hazardous chemicals. It makes the argument that communities should make plans for toxic releases within their communities to facilitate effective response. It highlights the need for plans and the obstacles faced by public officials in making plans. To highlight this, the author considers four cases of toxic airborne releases, including the New York gasoline leak, the Mississauga train derailment, the Somerville tank car rupture, and the Taft chemical tank explosion. The article ends with lessons learned from these case studies and concludes that successful response is contingent upon notification, chemical danger, preparedness, and geographic characteristics.

In terms of time, the article considers the amount of time taken during each event for response. These times ranged for 2.5 hours to 24 hours. Additionally, the time of the event played a role in successful response since early morning events meant families were at home together, aiding in a quicker evacuation.

Czajkowski, J., 2011: Is it time to go yet? Understanding household hurricane evacuation decisions from a dynamic perspective. *Natural Hazards Review*, **12(2)**, 72-84.

To better understand household hurricane evacuation decisions, this paper addresses a limitation to existing hurricane evacuation modeling aspects by developing a dynamic model of hurricane evacuation behavior. A household's evacuation decision is framed as an optimal stopping problem in which every potential evacuation time period prior to the actual hurricane landfall, the household's optimal choice is to either evacuate or to wait one more time period for a revised hurricane forecast. We build a realistic multiperiod model of evacuation that incorporates actual forecast and evacuation cost data for our designated Gulf of Mexico region. Results from our multiperiod model are calibrated with existing evacuation timing data from a number of hurricanes. Given the calibrated dynamic framework, a number of policy questions that plausibly affect the timing of household evacuations are analyzed, and a deeper understanding of existing empirical outcomes in regard to the timing of the evacuation decision is achieved.

Dash, N. and H. Gladwin, 2007: Evacuation decision making and behavioral responses: Individual and household. *Natural Hazards Review*, **8(3)**, 69-77.

Researchers have examined a wide range of factors that affect evacuation decisions after people hear hurricane forecasts and other information. This review of the literature focuses on three broad areas of research that often overlap: warning, risk perception, and evacuation research. Whereas it is challenging to demarcate the literature along these lines, we believe each of these areas represents important dimensions of evacuation decision making. The literature on warning focuses to varying degrees on warning as a social process, rather than a simple result of hearing official warnings. Warnings by themselves do not motivate evacuation—people must perceive risk. The extensive literature on objective and subjective processes in risk perception has to be evaluated. The review concludes with a focus on some important work in modeling evacuation and evacuation decision-making. Finally, we present recommendations for future research that draws on the strength of earlier work while focusing more directly on risk, the information included in hurricane forecasts, and the timing of those forecasts.

Dash, N. and B. H. Morrow, 2001: Return delays and evacuation order compliance: The case of Hurricane Georges and the Florida Keys. *Environmental Hazards*, **2(3)**, 119-128.

Using interview data, we examine the effects of the heavily publicized delays in reentering the Florida Keys after Hurricane Georges on future evacuation intent. Of particular interest is the finding that the delays will have less influence on the future evacuation decisions of those who experienced them than on those who learned of them from secondary sources. Fear of return delays is only one factor in evacuation decision-making, albeit an understudied one. For this sample of evacuees, perceived risk is the most salient factor, and this risk assessment is not sufficiently diminished by the inconveniences, such as delays, associated with evacuation. For non-evacuees, however, the delay factor appeared to only increase their reluctance to evacuate the next time, despite their level of perceived risk.

Donner, W.R., 2008: Decision making as community adaptation: A case study of emergency managers in Oklahoma. *Disasters*, **32(2)**, 292-302.

This paper explores how emergency managers make judgments regarding long-term policy and offers a sociological account of organizational decision making within an ecological context. Discussions with emergency managers focusing on the relative merits of rainfall estimation and tornado detection served as data with which to address these issues. Among the 39 interviewees, a consensus emerged favoring tornado detection over rainfall estimation. From these findings, the paper attempts to understand why emergency managers prefer tornado detection to rainfall estimation and to develop theoretical generalizations explaining trends in these preferences. When developing long-term policy, analysis of transcripts revealed emergency managers to be most concerned with the relative uncertainty of hazards, the capabilities of technology in hazard mitigation, and how the public perceives environmental threats. Given the environmental, technological, and social concerns reflected in this reasoning, there appears to be a strong ecological context driving the need for tornado detection among emergency managers. Implications and concerns are presented in the final section.

Dow, K and S.L. Cutter, 2002: Emerging hurricane and evacuation issues: Hurricane Floyd and South Carolina. *Natural Hazards Review*, **3(1)**, 12-18.

A survey of coastal South Carolina residents addressed the role of household decisions in amplifying demand on transportation infrastructure during 1999's Hurricane Floyd evacuation. The evacuation rate averaged 65% ~64.2%! in coastal evacuation areas. Three major findings reveal that traffic problems are becoming a major consideration in whether people evacuate. How they evacuate is emerging as an issue for evacuation traffic planning. First, about 25% of households took two or more cars. Nearly 50% of evacuees left in one 6-h period. Major traffic pressure developed on the Interstate system, particularly Interstate-26. Second, while the majority of respondents carried road maps, only 51% of that group used them to determine their route. Many decided to stay on the nterstate despite the congestion. Finally, the majority of South Carolinian residents traveled distances greater than necessary for safe sheltering and more than in past hurricanes. Transportation issues will become more important in coastal evacuations as traffic problems impinge on peoples' ability to get out of harm's way and ultimately influence their decisions to evacuate.

Dow, K. and S.L. Cutter, 2006: Crying wolf: Repeat response to hurricane evacuation orders. *Hazards, Vulnerability, and Environmental Justice*, S.L. Cutter, Ed., Earthscan, 209-225.

This chapter from *Hazards, Vulnerability, and Environmental Justice* examines the theory of "crying wolf" for hurricane evacuations, or the repeat response to evacuation orders when previous hurricanes did not occur. The authors looked at three communities which were ordered to evacuate for Hurricanes Bertha and Fran in 1996. Through the use of survey style interviews, the investigated evacuation rates, information used to make decisions, what made people decide to evacuate, and stated expectations about whether people would evacuate again given that the communities were not impacted by either storm. They found that the decision to evacuate is based on multiple factors and information sources and that repeat response to evacuation orders is based on the situation, such as the severity of the coming storm and probability of impact.

Drabek, T.E., 2000: Pattern differences in disaster-induced employee evacuations. *International Journal of Mass Emergencies and Disasters*, **18(2)**, 289-315.

When people are at work and they learn that disaster is imminent, what are their responses? To what degree are there pattern differences in their response profiles because of event variations or structural features of the business firm for which they work? Interviews with employees (n = 406) of 118 businesses impacted by one of seven different recent disasters provide the first answers to these questions. While there were many interdependencies among three areas of constraint, analyses documented that many, but not all, aspects of employee evacuation behavior were patterned significantly by: (1) length of forewarning; (2) organizational size; and (3) organizational mission.

Drabek, T.E., 2001: Disaster warning and evacuation responses by private business employees. *Disasters*, **25(1)**, 76-94.

When people are advised that their place of employment is threatened with disaster, how do they respond? Interviews with employees (n = 406) of 118 businesses affected by one of seven recent disasters provide the first answers to this question. Multivariate analyses document the key variables that best predict variation are: 1) emergent perceptions of risk; 2) time of evacuation from work; 3) time of evacuation from home; 4) multiple evacuations; and 5) tension between work and family commitments. When warned of impending disaster, most employees initially responded with denial. Gradually, however, emergent perceptions of risk intensified especially among those living in communities in which the least amount of disaster planning had occurred or who resided in a mobile home or apartment. Highest levels of work and family tensions during these evacuations were reported by racial minority employees who had children living at home. Policy implications for these and other findings are discussed so as to pin-point changes business managers should make that will enable them to provide the leadership and compassion expected by employees.

Drabek, T.E., 2005: Predicting disaster response effectiveness. *International Journal of Mass Emergencies and Disasters*, **23(1)**, 49-72.

What social factors best predict the relative effectiveness of community disaster responses? This question is explored through interview and questionnaire data obtained from 62 local emergency managers whose communities were impacted by some type of disaster event. Various coordination strategies used in the year prior to the event and during the response were assessed first. These and numerous other potential sources of constraint were used in regression analyses to determine predictors of response effectiveness (both as perceived by the local emergency manager and through ten evaluative criteria). Results indicated that both measures of response effectiveness were predicted by seven factors: 1) high level of domain consensus; 2) use of more coordination strategies by the local emergency manager during the response; 3) more lengthy period of forewarning; 4) more frequent disaster training activities and actual responses during the prior two years; 5) more frequent participation by local emergency manager in local service organizations; 6) high community growth rate; and 7) use of more managerial strategies by the local emergency manager during the prior year.

Duclos, P., L. Sanderson, F.E. Thompson, B. Brackin, and S. Binder, 1987: Community evacuation following a chlorine release, Mississippi. *Disasters*, **11(4)**, 286-289.

On 7th September 1986, four miles north of Collins, Mississippi, a train transporting chlorine derailed. Two cars ruptured and gas escaped. As a result, 100 families were evacuated. To study the evacuation process, we conducted person-to-person interviews with sixty-two families staying in the evacuation center. Only 52.5% of the families received their first directive to evacuate directly from police or other officials. Delays in evacuating tended to be shorter when people were warned by the police and were told the reason for evacuating. Lack of personal transportation and preexisting health problems resulted in delays in evacuation. Concerns about evacuation included fear of looting, lack of a place to go, lack of transportation, difficulty in moving with children and elderly persons, and the need to take care of pets. One third of the intervieweves reported feeling panic. Community evacuation procedures would be improved if: (1) officials contact all households directly; (2) the warning message addresses people's concerns; and (3) transportation is provided

Etkin, D.A. and M.F. Myers, 1999: Thunderstorms in a social context. *Storms: Volume II*, R. Pielke Jr. and R. Pielke Sr., Eds, Routledge, 43-59.

This chapter describes the social aspects of thunderstorms, including lightening, high winds, hail, and tornadoes. It considers the climatology and formation of thunderstorms and myths about thunderstorms. It provides a brief overview of risk perception, social dimensions, and mitigation and adaptation to thunderstorms, including insurance, forecast and warning systems, and relief systems. The chapter concludes with considerations for future research, including studies about vulnerable populations and the realities of decision making.

Evans, D.L. “Veterans Day Weekend Tornado Outbreak of November 9-11, 2002.” National Weather Service. March, 2003.

During the Veterans Day weekend of November 9-11, 2002, tornadoes struck 17 states from the Mississippi Valley to the Atlantic Coast and from the Gulf Coast to the Great Lakes. From Saturday afternoon, November 9, to the early morning hours of Monday, November 11, 2002, 76 tornadoes touched down. Twelve of these tornadoes killed 36 people in five states. Due to the magnitude of this event, a service assessment team was formed to examine the warning and forecast services provided to emergency managers (EMs), government agencies, and the public. Service assessments provide a valuable contribution to ongoing efforts to improve the quality and timeliness of our products and services. Findings and recommendations from this assessment will improve techniques, products, services, and the information provided to the American public. The interaction between the NWS and local governments and businesses during this case was excellent.

Ewald, R., and G. L. Guyer, 2002: The ideal lead time for *tornado* warnings- A look from the customer's perspective. Preprints, *21st Conf. Severe Local Storms*, San Antonio TX, *Amer. Meteor. Soc*.

This study sought to pinpoint the ideal lead-time from the perspective of large populations, including schools and hospitals and assisted living facilities (HALs). The authors sent out surveys to both populations, with questions such as the minimum time to take shelter, the ideal lead time to take shelter, sources of weather information used, and actions taken. The most important and relevant result of this study is that the median ideal lead time preferred by schools was 15 minutes, and 30 minutes for HALs. 100% of both populations had an action plan for severe weather, they knew where the safest locations were for their area, and the majority used NOAA weather radios as their primary means of notification.

Increasing the amount of lead time all while decreasing the false alarm rate is an ongoing mission for the National Weather Service. This study is one of the first to investigate whether or not there is an ideal lead time for larger populations. The authors do recognize, however, that this is preliminary work and its complexities will not be resolved solely from the results of this study.

Fitzpatrick, C. and D.S. Mileti, 1990: Perception and Response to Aftershock Warnings During the Emergency Period. Pp. 75-83 in The Loma Prieta Earthquake: Studies of Short-Term Impacts, Monograph No. 50, edited by R. Bolin. Boulder, CO: University of Colorado, Institute of Behavioral Science, Natural Hazards Research and Applications Information Center.

This study focused on analyzing the perceptions of earthquake aftershock warnings by interviewing people living in the San Francisco Bay area and Santa Cruz. Among those who were interviewed were the general public, organizations, and informants. The topics included perceptions and response, and communication of the warning to the public. Because an earthquake is such a rapid event with no warning, any warnings issued for aftershocks were found to not be that useful since they often got lost in the media coverage. Pertaining to time, the public is less likely to hear a warning depending on what stage of hazard response they are in; the researchers found that if they are in the middle of a disaster response, they are less likely to hear a warning. Familiarity and habituation also were found to cause someone to be less likely to respond to a warning.

Fritz, C.E., 1957: Disasters compared in six American communities. *Human Organization*, **16(2)**, 6-9.

By combining and comparing data from six disasters ranging in type from explosions, airplane crashes, earthquakes, and tornadoes, the authors propose some generalities regarding the psychological effects of disaster. These include causes of psychological disturbance, normalizing the disaster, spatially personalizing disaster, perceptions of disaster, and the general qualities of those who rise to leadership positions. With regards to time, those disasters which have some degree of fore-warning are less psychologically disruptive than sudden onset disasters.

Gigerenzer, G., R. Hertwig, E. van den Broek, B. Fasolo, and K.W. Katsikopoulos, 2005: "A 30% chance of rain tomorrow": How does the public understand probabilistic weather forecasts? *Risk Analysis*, **25(3)**: 623-629.

The weather forecast says that there is a "30% chance of rain," and we think we understand what it means. This quantitative statement is assumed to be unambiguous and to convey more information than does a qualitative statement like "It might rain tomorrow." Because the forecast is expressed as a single-event probability, however, it does not specify the class of events it refers to. Therefore, even numerical probabilities can be interpreted by members of the public in multiple, mutually contradictory ways. To find out whether the same statement about rain probability evokes various interpretations, we randomly surveyed pedestrians in five metropolises located in countries that have had different degrees of exposure to probabilistic forecasts— Amsterdam, Athens, Berlin, Milan, and New York. They were asked what a "30% chance of rain tomorrow" means both in a multiple-choice and a free-response format. Only in New York did a majority of them supply the standard meteorological interpretation, namely, that when the weather conditions are like today, in 3 out of 10 cases there will be (at least a trace of) rain the next day. In each of the European cities, this alternative was judged as the least appropriate. The preferred interpretation in Europe was that it will rain tomorrow "30% of the time," followed by "in 30%

of the area." To improve risk communication with the public, experts need to specify the reference class, that is, the class of events to which a single-event probability refers.

Gladwin, H., J.K. Lazo, B.H. Morrow, W.G. Peacock, and H.E. Willoughby, 2009: Social science research needs for the hurricane forecast and warning system. *Bulletin of the American Meteorological Society*, **90(1)**, 25-29.

Hurricane disasters are, in part, social constructs as evidenced by the losses in 2004 and 2005 despite strong forecasts and warnings. The authors provide recommendations for the integration of social science into improvements made to hurricane warnings and forecasts. They suggest four main overarching themes that should be considered: warning process, decision making, evacuation behavior response, and societal impacts and valuation. Along with each theme are a series of examples.

With attention to time, the authors point out the lack of available research on decision making over the temporal and spatial scale of the hurricane threat. They also argue that these scales will differ with the varying institutions. Time is also of critical importance when considering evacuation behavior, and the authors argue the need to include subjective and objective elements across varying spatial and temporal scales into evacuation modeling.

Glass, Albert J., 1970. "The Psychological Aspects of Emergency Situations." *Psychological aspects of stress.* Ed. Harry S. Abram. Springfield, IL: Charles C. Thomas Publishing. Print.

This chapter discusses the four phases of response during emergency situations. They are the pre-impact phase, the warning period, the recoil period, and the post-impact phase. It's only during the pre-impact phase when one can influence behavior during the later phases; it is impossible during the later phases to alter one's actions due to the short duration and severity level of the warning phase, for example. The best type of response according to the author during the pre-impact phase is a contingency response, rather than exhibiting a "fight" or "flight" response. A contingency response refers to an individual who is educated of the signals indicating that danger is near, allowing them to make the most appropriate actions during the warning period. This is an issue when it comes to severe weather warnings, however, as people who are not as educated on what to do during a warning may not feel as prepared during the pre-impact phase as those who are educated on the situation. For example, during severe weather season, those who know what actions to take during a tornado warning and who have a predetermined shelter may be less stressed during an actual event than those who are not as familiar with appropriate tornado warning behavior. The author defines the warning phase as "a brief time period which usually permits only the implementation of a preconceived plan or effort, e.g. hospitals having an emergency plan (66)."

Golden, J.H., and C.R. Adams, 2000: The tornado problem: Forecast, warning, and response. *Natural Hazards Review*, **1(2)**, 107-118.

Research on tornadoes over the last 20 years has been conducted by a combination of universities, research institutions, federal agencies, and more recently by private meteorological companies. Recent advances in scientific technologies and computers have led to an explosion of knowledge in the last decade. This is evidenced by increased accuracy in the detection and prediction of tornadoes as well as increased warning lead time before tornado formation. Most of the research in this area has focused on the physical sciences and technology portion of the warning process. Far less attention has been spent on the warning communication process, behavioral response, and epidemiology of tornadoes. The translation of improved technologies into better tornado forecasting and warning services must also involve the incorporation of physical and social science. This is necessary to develop improved warning communication and coordination processes that will lead to the further reduction of tornado related injuries and fatalities.

Gregg, C.E., B.F. Houghton, D. Paton, D.M. Johnston, D.A. Swanson, and B.S. Yanagi, 2007: Tsunami warnings: Understanding in Hawai'i. *Natural Hazards*, **40(1)**, 71-87.

The devastating southeast Asian tsunami of December 26, 2004 has brought home the destructive consequences of coastal hazards in an absence of effective warning systems. Since the 1946 tsunami that destroyed much of Hilo, Hawai'i, a network of pole mounted sirens has been used to provide an early public alert of future tsunamis. However, studies in the 1960s showed that understanding of the meaning of siren soundings was very low and that ambiguity in understanding had contributed to fatalities in the 1960 tsunami that again destroyed much of Hilo. The Hawaiian public has since been exposed to monthly tests of the sirens for more than 25 years and descriptions of the system have been widely published in telephone books for at least 45 years. However, currently there remains some uncertainty in the level of public understanding of the sirens and their implications for behavioral response. Here, we show from recent surveys of Hawai'i residents that awareness of the siren tests and test frequency is high, but these factors do not equate with increased understanding of the meaning of the siren, which remains disturbingly low (13%). Furthermore, the length of time people have lived in Hawai'i is not correlated systematically with understanding of the meaning of the sirens.

An additional issue is that warning times for tsunamis generated locally in Hawai'i will be of the order of minutes to tens of minutes and limit the immediate utility of the sirens. Natural warning signs of such tsunamis may provide the earliest warning to residents. Analysis of a survey subgroup from Hilo suggests that awareness of natural signs is only moderate, and a majority may expect notification via alerts provided by official sources. We conclude that a major change is needed in tsunami education, even in Hawai'i, to increase public understanding of, and effective response to, both future official alerts and natural warning signs of future tsunamis.

While not directly about time in the problem statements it tests, this article is interesting from the perspective of time in that the recommendations made by the authors is that the most timely response may come from the observation of natural cues and warning signs versus an official warning prior to a tsunami in Hawai'i.

Gruntfest, E.C., 1977: What people did during the Big Thompson Flood. Working Paper 32. Institute of Behavioral Science, University of Colorado. 62pp.

The Larimer County Sheriff's Department and several canyon residents estimate that more than 2500 people were in the Big Thompson Canyon the night of the flood, July 31, 1976. These included 600 full-time residents, approximately 1200 part-time residents, and many tourists. One hundred thirty-nine people died in the flood and several are still missing.

The purpose of this study is to analyze the behavior patterns which were adopted at the time of the flood, and to apply that knowledge to the improvement of warning system design for Front Range communities vulverable to flash flooding. Comparisons are made between the actions of the survivors and non-survivors and the warned and non-warned populations. Variables which influenced the choice of action are examined. These variable include location prior to the flood, action taken, group context, location in the canyon, kind of warning received (if any), and number of people in a group. Warning characteristics such as source, mode, number and content are also discussed.

Information was obtained through informal interviews with canyon residents, county officials, relief agency personnel and out-of-state residents who were visiting the canyon at the time of the flood. Additional information was available in newspaper accounts, government agency reports and in literature on flash floods and warning systems.

The results indicate that climbing the canyon wall was the best action to have adopted, and that doing nothing different or taking no action at all were the worst in terms of survival chances. Those who were driving alone through the canyon ran the highest risk.

Recommendations for avoiding such a catastrophe in the next flash flood include the installation of signs through canyons with specific instructions for action in the event of a flash flood warning, high water or heavy rain, and improved public education for heightening awareness of flash flood potential and possible adjustments to the hazard.

Hammer, B., and T.W. Schmidlin, 2002: Response to warnings during the 3 May 1999 Oklahoma City tornado: Reasons and relative injury rates. *Weather and Forecasting*, **17(3)**, 577-581.

Residents of homes that sustained F4 or F5 damage in the deadliest of the 3 May 1999 tornadoes were surveyed to determine their responses to the tornado warning, reasons for their

responses, and relative injury rates. There were 190 people in 65 surveyed houses at the time that warnings were issued. Television was the most commonly cited source of the warning (89%), followed by a telephone call (37%), sirens (37%), and AM/FM radio (25%), and 55% received the warning from more than one source. Nearly one-half (47%) of the residents fled their homes before the tornado struck. Of those who fled, 65% went to a tornado shelter, of whom 70% ran to the shelter (median distance 30 m) and 30% drove to the shelter (median distance 4.8 km). About one-half (53%) of those who fled their homes left in a vehicle. None of those who fled their homes, by foot or by vehicle, were injured. Of those who stayed in the home, 39% sought shelter in a bathroom, 38% in a closet, 9% in a hallway, and 15% in other rooms. Reasons for not leaving included believing the storm would not strike their house, believing it was too late or too dangerous to leave, having no transportation available, or having no alternative shelter available. Thirty percent of those who remained in their homes were injured and 1% killed. The rate of serious injury was not significantly different for those in a closet (14%), hallway (20%), or bathroom (23%). Tornado preparedness and warning programs should recognize that long tornado warning lead times and street level television coverage allow residents to make reasoned decisions to minimize risk and that those decisions may include driving out of the path of the tornado.

Handmer, J., 1992: Can We Have Too Much Warning Time? A Study of Rockhampton,Australia. *Inspiration: Come to the Headwaters. Proceedings from the Fifteenth Annual Conference of the Association of State Floodplain Managers*. Denver, CO, 155-159.

In a case study of a 1988 flood in Rockhampton, Australia, the author investigates the effect of a lead-time of over one week. The author found that the official sources of warning information were competing with unofficial sources of warning information, such as long time residents, who were receiving significant media attention. The unofficial warning sources largely agreed with the official warnings, but the media attention created a heightened sense of risk which may have been problematic. Additionally, there was concern that errors in a forecast made so long in advance would reduce credibility of the official channels.

Hayes, J.L. “Service Assessment: Tornadoes in Southern Alabama and Georgia on March 1, 2007.” National Weather Service. November, 2007.

During the afternoon and evening of March 1, 2007, deadly tornadoes moved across southern Alabama and Georgia. In a 14-hour period beginning at 12:30 p.m. CST, 31 tornadoes occurred, resulting in 19 fatalities across the two states. Eleven of the tornadoes were classified as strong (EF2-EF3) on the Enhanced Fujita Tornado Intensity Scale and two were classified as violent (EF4).
Due to the magnitude of this event, a service assessment team was formed to examine the warning and forecast services provided to key decision makers and the public. In keeping with the NOAA goals of developing hazard-resilient communities, the team was also tasked with trying to identify possible reasons for the large loss of life during this event, in light of the overall high quality of services provided by the National Weather Service.

The findings and recommendations from this assessment are offered with the goals of 1) improving the quality of warning and forecast products and services, and 2) enhancing the ability of the National Weather Service (NWS) to increase public education and awareness regarding issues associated with tornado safety. The ultimate goal is to help meet the NWS mission of saving lives and property and enhancing the national economy.

Hayes, J.L. “Service Assessment: Super Tuesday Tornado Outbreak of February 5-6, 2008.” National Weather Service. March, 2009a.

In response to the Super Tuesday tornado outbreak of February 5-6, 2008, which killed fifty-seven people in four states, the National Weather Service conducted a service assessment to review the services provided during the outbreak. Most people were satisfied with the outlooks, watches, and warnings provided by the NWS prior to the storms. The storm was forecast four days in advance, tornado watches had an average of two hours lead time, and warnings had an average of 17 minutes of lead time. This advanced notice allowed the NWS, media, and emergency managers to prepare for the outbreak in

advance. The NWS service assessment makes sixteen recommendations to improve NWS services and products.

Hayes, J.L. “Service Assessment: Mother’s Day Weekend Tornado in Oklahoma and Missouri, May 10, 2008.” National Weather Service. October, 2009b.

Mother’s Day Weekend, May 10-11, 2008, brought severe weather to many sections of the county. The greatest impact was in the northeast Oklahoma and southwest Misouri. A tornado, rated EF4 on the Enhanced Fujita scale, moved southeast from the town of Picher, Oklahoma, into southwest Missouri. The tornado caused 21 fatalities. The areas affected by this tornado were covered by a tornado watch and multiple tornado warnings. The average lead time was longer than the goals established by the Government Performance and Results Act.

The National Weather Service formed a six-member service assessment team to evaluate its performance during this event. The team focused on the societal responses and impacts of this event. The team tried to determine why there were so many fatalities despite the timely watches and warnings that were issued by the National Weather Service.

Hayes, J.L. “Central United States Flooding of June 2008.” National Weather Service. December, 2009c.

During June 2008, record or major flooding occurred across large areas of the central United States. The flooding had devastating impacts, with 11 people losing their lives. Damages have been estimated at over $5 billion. The states most severely affected were Illinois, Indiana, Iowa, Missouri, South Dakota, and Wisconsin. Also, heavily impacted were Kansas, Michigan, Minnesota, Nebraska, and Oklahoma. In all, 143 National Weather Service river forecast locations experienced major flooding, with 73 of these locations establishing records. Because of the severe impact of the flooding, the National Weather Service of the National Oceanic and Atmospheric Administration formed a Service Assessment Team to evaluate National Weather Service performance during the event. Special attention was given to National Weather Service coordination with other Federal, state, local, and private entities. The recommendations from this assessment will lead to improvements in the quality of National

Weather Service products and services and enhance the public’s ability to make more informed decisions associated with flood events. The ultimate goal of this report is to further the National Weather Service mission of protecting lives and property and enhancing the national economy.

Hayes, J.L. “Southeast United States Floods, September 18-23, 2009.” National Weather Service. May, 2010.

Copious moisture drawn into the southeastern United States from the Atlantic and Gulf of Mexico produced showers and thunderstorms from Friday, September 18, through Monday, September 21, 2009. Rainfall amounts across the region totaled 5-7 inches, with locally higher amounts near 20 inches. The northern two-thirds of Georgia, Alabama, and southeastern Tennessee were hardest hit with the southeasterly low-level winds providing favorable upslope flow. Flash flood and areal flooding were widespread with significant impacts continuing through Wednesday, September 23, 2009. Eleven fatalities were directly attributed to this flooding.

Due to the significant effects of the event, the National Oceanic and Atmospheric Administration’s National Weather Service formed a service assessment team to evaluate the National Weather Service's performance before and during the record flooding. The findings and recommendations from this assessment will improve the quality of National Weather Service products and services and enhance the ability of the Weather Service to provide an increase in public education and awareness materials relating to flash flooding, areal flooding, and river flooding. The ultimate goal of this report is to help the National Weather Service meet its mission of protecting lives and property and enhancing the national economy.

Haynes, K., L. Coates, R. Leigh, J. Handmer, J. Whittaker, A. Gissing, J. Mcaneney, and S. Opper, 2009: ‘Shelter-in-place’ vs. evacuation in flash floods. *Environmental Hazards*, **8(4)**, 291-303.

This paper examines the circumstances in which a `shelter-in-place' strategy may be a viable alternative to evacuation during flash floods. While evacuation remains the dominant strategy for a range

of hazards, a review of the literature suggests growing awareness of the dangers associated with late evacuations and some limited consideration of shelter-in-place options. This study examines the feasibility of a shelter-in-place strategy for flash floods in Australia through: a review of literatures on evacuation, `sheltering-in-place' and flood fatalities; an analysis of Australian flash flood fatalities and injuries; and interviews with flood and emergency managers. The results demonstrate that the majority of flash flood fatalities (75.7 per cent) have occurred outside when people have entered flood waters in a vehicle or on foot for a range of reasons, including to continue their intended travel, engage in recreational pursuits, continue their work, and evacuate or carry out a rescue. Interviews with emergency managers confirm that while shelter-in-place may not be the preferred option, the strategy may need to be implemented for flash floods when, due to the limited warning times, evacuation is not possible.

Hodler, T.W., 1982: Residents' preparedness and response to the Kalamazoo tornado. *Disasters*, **6(1)**, 44-49.

A survey was conducted of individuals residing in the path of the tornado that hit Kalamazoo, Michigan, on 13th May 1980. The residents' tornado preparedness and response were examined in an effort to evaluate the city's emergency warning system. The system was adequate for people on the east side of the city and lacking for west side residents. Other factors pertaining to the storm event and human response were also evaluated.

Hoekstra, S., K. Klockow, R. Riley, J. Brotzge, H. Brooks, and S. Erickson, 2011: A preliminary look at the social perspective of Warn-on-Forecast: Preferred tornado warning lead time and the general public's perceptions of weather risks. Weather, Climate, and Society, forthcoming.

Tornado warnings are currently issued an average of 13 minutes in advance of a tornado (Golden and Adams 2000) and are based on a warn-on-detection paradigm (Erickson and Brooks 2006). However, computer model improvements may allow for a new warning paradigm, warn-on-forecast, to be established in the future (Stensrud et al. 2009). This would mean that tornado warnings could be issued one to two hours in advance, prior to storm initiation. In anticipation of the technological innovation, this study inquires whether the "warn-on-forecast" paradigm for tornado warnings may be preferred by the public (i.e., individuals and single families). Our sample is drawn from visitors to the National Weather Center in Norman, Oklahoma. During the summer and fall of 2009, surveys were distributed to 320 participants to assess their understanding and perception of weather risks and preferred tornado warning lead-time. Responses were analyzed according to several different parameters including age, region of residency, educational level, number of children, and prior tornado experience.

A majority of the respondents answered many of the weather risk questions correctly. They seemed to be familiar with tornado seasons; however, they were unaware of the relative number of fatalities caused by tornadoes and several additional weather phenomena each year in the United States. The preferred lead-time was 34.3 minutes according to average survey responses. This suggests that while the general public may currently prefer a longer average lead-time than the present system offers, the preference does not extend to the one to two hour time-frame theoretically offered by the warn-on-forecast system. When asked what they would do if given a one-hour lead-time, respondents reported that taking shelter was a lesser priority than when given a 15-minute lead-time, and fleeing the area became a slightly more popular alternative. A majority of respondents also reported the situation would feel less life threatening if given a one-hour lead-time. These results suggest that how the public responds to longer lead times may be complex and situationally-dependent, and further study must be conducted to ascertain the users for whom the longer lead-times would carry the most value. These results form the basis of an informative stated-preference approach to predicting public response to long (> 1 hour) warning lead times, using public understanding of the risks posed by severe weather events to contextualize lead-time demand.

IACLEA, 2006: Campus public safety preparedness for catastrophic events: Lessons learned from hurricanes and explosives. International Association of Campus Law Enforcement Administrators. http://www.iaclea.org/visitors/PDFs/LessonsLearnedReportFinal.pdf.

On March 21, 2006, IACLEA, the U. S. Department of Homeland Security (DHS), and the Federal Bureau of Investigation (FBI) convened a two-day listening session for campus public safety leaders from higher education institutions affected by Hurricanes Katrina and Rita. Hosted by McNeese State University in Lake Charles, LA, the purpose of this two-day session was to identify and share lessons learned that might be applied to planning for future catastrophes, whether natural or man-made.

In addition to attendees from the sponsoring agencies, representatives from numerous institutions were invited to participate in the conference, including:

- Centenary College,
- Delgado Community College,
- Dillard University,
- Georgia Tech,
- Jackson State University,
- Louisiana State University,
- McNeese State University,
- Nicholls State University,
- University of Oklahoma,
- Tulane University,
- University of New Orleans,
- University of South Alabama,
- University of Southern Mississippi, and
- Xavier University.

Participants were asked to present a summary of the most important issues they encountered leading up to and in response to Huriccanes Katrina and Rita. In addition, they were asked to provide written responses addressing their planning, command and coordination, communications, equipment and logistics, and staffing issues. The representative from Dillard University was unable to attend but submitted information in advance.

A selection of their challenges and lessons learned are compiled in the following chapters of the report. Additionally, the report concludes with lessons learned from incidents involving explosives at Georgia Tech and the University of Oklahoma in 2005.

While not a scholarly article, this paper presents the perspective of campus emergency officials on the response activities of their campus pre- and post-event. Each school representative presents a chronology of events, showing what each campus did up to 72 hours out from Hurricane Katrina and during the threat of explosives at OU and Georgia Tech. It also discusses the importance of pre-event preparedness and maintaining up-to-date preparedness plans.

Johnson, D.L. “West Coast Tsunami Warning, June 14, 2005.” National Weather Service. November, 2005.

On June 14, 2005, an earthquake measuring magnitude 7.2 occurred approximately 90 miles off the northern California coast, prompting NOAA’s West Coast and Alaska Tsunami Warning Center to issue a tsunami warning for the West Coast of the United States.

While no tsunami was generated by the earthquake, the event did prove to be, as one emergency manager put it, “an excellent test.” Processes and procedures were exercised, and in some cases, problems within the system were noted and are being addressed. Emergency managers received the information in a timely fashion, and many successfully exercised evacuations or other plans to protect life and property. Notification of the public at large, however, was less timely and efficient. Some equipment malfunctions were noted and some procedures require improvement. There was a degree of confusion about what to do when a tsunami warning is received and about the warning itself. While we encourage the public to listen and follow the direction of their emergency managers, citizens also need to understand what to do and to be prepared to respond immediately when a warning is issued.

This assessment evaluates the performance of the National Weather Service (NWS) during the event and provides recommendations to improve services in the future. It takes into consideration the affected audiences in the emergency management community as well as the public. Service assessments significantly enhance ongoing efforts to improve the quality and timeliness of NWS products

and services. Findings of this assessment will further NOAA's goal to serve society's needs for water and weather information.

Johnson, D.L. "Hurricane Charley: August 9-15, 2004." National Weather Service. January, 2006.

Hurricane Charley made landfall on August 13, 2004 at Cayo Costa, Florida after a change in track about three hours prior to landfall. Charley was a category 4 storm at landfall and the third most expensive hurricane in United States history at the time. Because the storm track was changed less than three hours prior to landfall, there was public criticism because the media and public perceived a lack of time for action. The area where landfall was made was within the cone of uncertainty, and the service assessment report recommends further education on the uncertainty inherent to hurricanes and improvements to the cone of uncertainty. The service assessment also details seventeen recommendations based on the event.

Kapucu, N. 2008: Collaborative emergency management: Better community organising, better public preparedness and response. *Disasters*, **32(2)**, 239-262.

Community coordination requires communication and planning of precautions to take when faced with a severe threat of disaster. The unique case of the four Florida hurricanes of 2004--Charley, Frances, Ivan, and Jeanne--is used here to assess community responses to repeated threats of hurricanes. The paper examines how effectiveness in coordinating community disaster response efforts affects future public preparedness. The findings suggest that pre-season planning, open communication between emergency managers and elected officials, and the use of technology all had a significant impact on community responses. The repeated threat scenario indicates that emergency managers must work vigilantly to keep residents informed of the seriousness of a situation. The study describes how emergency managers in Florida countered public complacency during four hurricanes in six weeks. The strategies identified as useful by public managers in the context of hurricanes are applicable to other natural and man-made disasters.

Kirschenbaum, A. and C. Rapaport, 2009: Disaster warnings and compliance: The impact of social process factors over time. *International Journal of Mass Emergencies and Disasters*, **27(3)**, 250-271.

Disaster warnings have proved to be only partially effective in bringing about behaviors that enhance survival. For disasters that are ongoing and associated with repeated warnings, determinants of compliance may change over time. To test this argument, a theoretical working model is developed and tested on the basis of data collected from a field survey of a national representative sample of Israeli households (814). Respondents were asked if they complied with the warning to enter a sealed room (i.e., shelter in place) at the initial and toward the end of a three month long ballistic missile attack on Israeli civilians during the First Gulf War. Compliance decreased with time. We then sought to generate a parsimonious model to explain the drop in compliance by focusing on a variety of factors that included "message" oriented and social process variables. Results of the logistic regression models demonstrated that compliance initially was determined by prior levels of preparedness whereas determinants of behavioral compliance three months later broadened to include gender, risk perceptions, and the source of knowledge for actions to the threat. These results strongly suggest that initial compliance with warnings depend on having available fundamental survival assets. With repeated warnings over time, social process variables significantly affected compliance decisions. Efforts to increase disaster survival should therefore consider the time continuum in terms of the impact of social process variables on complying with warnings.

Kircher, T., J. Nelson, and J. French, 1987: Avoidance of death and injury through monitoring of dams and flood evacuation in Essex, Connecticut, June 1982. *Disasters*, **11(2)**, 117-119.

During a period of heavy rainfall in Essex, Connecticut, on 4th and 5th June 1982, dams in the town along the Fall River were monitored for signs of breaks. The observation of water spilling over one of the dams at 10 p.m. in 5th June led to the decision to evacuate community residents. The notification

and evacuation process was conducted by the volunteer fire department over a two-hour period. At 12.30 a.m 6th June, the upper dam on the Fall River gave way, resulting in a rapidly moving flood wave which sequentially destroyed four additional dams along the river. Although there was extensive property damage, there were no serious injuries and no deaths. The responsible actions of the town officials in monitoring the dams during the period of heavy rainfall permitted the evacuation order to be given in sufficient time to evacuate the residents. The success of the evacuation was the result of good communication, trust, and co-operation between town officials and the community.

Knocke, E.T., and K.N. Kolivras, 2007: Flash flood awareness in Southwest Virginia. *Risk Analysis*, **27(1)**, 155-169.

Flash floods are one of the most dangerous weather-related natural disasters in the world. These events develop less than six hours after a rainfall event and create hazardous situations for people and extensive damage to property. It is critical for flash flood conditions to be warned of in a timely manner to minimize impacts. There is currently a knowledge gap between flood experts and the general public about the level of perceived risk that the latter has toward the powerful flood waters and how events should be warned of, which affects the communication capabilities and efficiency of the warning process. Prior research has addressed risk perception of natural disasters, but there is little emphasis on flash floods within flood-prone regions of the United States. This research utilizes an online survey of 300 respondents to determine the current state of flash flood awareness and preparation in southwestVirginia. Analysis of trends involved the use of chi-squared tests ($\chi 2$) and simple frequency and percentage calculations. Results reveal that a knowledge base of flash floods does exist, but is not advanced enough for proper awareness. Young adults have a lower understanding and are not as concerned about flood impacts. Increased exposure and perceived risk play a key role in shaping the way a person approaches flash floods. People do monitor flood events, but they are unaware of essential guidance and communication mechanisms. Finally, results suggest that the current method of warning about flash floods is not provided at an appropriate level of detail for effective communication.

Lachman, R., M. Tatsuoka, and W.J. Bonk, 1961: Human behavior during the tsunami of May 1960. *Science*, **133(3462)**, 1405-1409.

The Hawaiian city of Hilo was hit by a tsunami in 1960 in the middle of the night. This paper examined the behavior of the survivors of the disaster by conducting a survey. The study looked at whether sirens were understood, sources of information, when people chose to take action and why, where people were when the tsunami impacted the city, and how people were rescued after the impact. The survey found that most people heard the siren but not all understood what the siren represented, which was inferred from the action taken. 15% chose to continue with their routine, 32% evacuated immediately, and 44.5% waited for another signal, additional information, or an evacuation order. Of those who did not evacuate, most who took no action were asleep while those who waited remained awake, indicating that they were aware enough of the threat but may have required further direction to evacuate. 57% who did not evacuate were trapped under wreckage and 23% were injured. There is no evidence based on this study that education level impacted decisions but disaster experience had a slight significant impact of response.

League, C.E., W. Diaz, B. Phillips, E.J. Bass, K. Kloesel, E. Gruntfest, and A. Gessner, 2010: Emergency manager decision-making and tornado warning communication. *Meteorological Applications*, **17(2)**, 163-172.

Emergency managers (EMs) play a critical role in communicating severe weather and tornado warnings to the public, yet communicating the uncertainty of when, where or if a tornado may hit remains a great challenge for EMs. Focus group and survey data concerning weather product usage, weather observing spotter interaction, and decisions to warn the public were collected from Oklahoma EMs in order to characterize the communication processes EMs employ during severe weather outbreaks. These processes include: (1) acquiring weather information, (2) interpreting the information in order to make weather hazard threat assessments, (3) verifying the information, and (4) making time-sensitive warning decisions. The results indicate that while EMs use a variety of weather and radar products to acquire

information, weather observing spotters are key sources of verification data. With respect to warning the public about tornado threats, sirens are the primary method. These findings are related to the development of a new radar system being developed by the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA), so that this new technology can be designed to reduce uncertainty in the EM decision-making and warning communication processes.

Legates, D.R., and M.D. Biddle, 1999: Warning response and risk behavior in the Oak Grove-Birmingham, Alabama, tornado of 08 April 1998. *Quick Response Report #116,* Natural Hazards Center.

On 08 April 1998, a long-track violent tornado killed 32 people and injured 300 in Jefferson County, Alabama, near Birmingham. Within one week of the disaster, field surveys were collected from persons residing or working within the damage area (n=65) regarding their actions, and the actions of those in their care or company (n=232). Similar data were obtained for the fatalities (n=32). The purpose of the field operation was to collect spatial, demographic, behavioral, and attitudinal information from a sample of survivors, and to the fullest extent, for all victims. Morbidity and mortality data were analyzed for significant trends in warning access, source, compliance, and lead-time as well as shelter availability, cultural and architectural variables, hazard perception, and self-assessment of warning systems. Goals were to catalog significant differences between victim and survivor traits, to identify successful warning operations and media practices, and to characterize emergent risk factors for death, injury, and damage. Major risk factors for death included living in a wooden house, a house with walls not anchored to the foundation, becoming airborne, and being elderly. Risk factors for survival included taking shelter below ground, having access to, and consulting televised warning information, being aware of the tornado watch, and familiarity with sources of weather information in general.

Leik, R.K., M.T. Carter, J.P. Clark, S.D. Kendall, and G.A. Gifford, 1980: Community response to natural hazard warnings. Information for the Defense Community. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA099509

This project has focused on the nature and effectiveness of dissemination of and response to warnings of natural hazards. Two components of the project involved field studies of 31 communities, subject to one of four hazards: hurricane, flash flood, tornado or earthquake. One component studied selected organizations in the community regarding the adequacy of the dissemination network, and the other component studied samples of 200 households in each community regarding preparedness and response. A quasi-experimental design specified pre-threat studies to be followed by post-threat follow-up studies of the same organizations and households if a major threat occurred. A third component involved laboratory experimental simulation studies of the effects of message content, timing, prior experience, and social structure factors on response to warnings. A number of serious problems with existing dissemination mechanisms have been found, and critical factors affecting response to warnings have been identified. Laboratory and field data are in close accord. Results generally concur with and expand on previous knowledge. Twelve recommendations for improving dissemination and response are provided.

Letson, D., D.S. Sutter, and J.K. Lazo, 2007: Economic value of hurricane forecasts: An overview and research needs. *Natural Hazards Review*, **8(3)**, 78-86.

Hurricane forecasting is in part an economic problem, because it commits scarce resources to save lives, reduce injuries, and lessen economic impacts. New sensing, recording, and reporting technologies, as well as the increased number of clients and their changing needs, have heightened the need to economically justify the hurricane warning system. Estimating forecast value can help show if improved forecast provision and dissemination would offer more benefit to society than alternative public investments such as infrastructure or forecasts of other hazards. We review research that has estimated the economic value of the hurricane forecast and warning system and the value of improving forecast quality. We recommend developing a comprehensive theoretical understanding of economic value of hurricane forecasts to diverse stakeholders across all time scales. This improved, basic understanding

would involve a more in-depth discussion of the value of information as well as a broader knowledge of actual or created distinctions between adaptation, mitigation, and response to hurricane risks.

Lindell, M.K., 2000: An overview of protective action decision-making for a nuclear power plant emergency. *Journal of Hazardous Materials*, **75(2-3)**, 113-129.

Protection of the public in a nuclear power plant emergency requires decision-makers to balance the time requirements from two chains of events: the events associated with a radiological release and the events involved with the response to that release. The management of these events is distributed among personnel at the nuclear plant, in the local community, and in state and federal agencies. All of these parties must coordinate their response to the emergency to assure that timely and effective protective response can be made by the risk area population. This article describes the process by which protective action recommendations (PARs) are developed in nuclear power plant emergency exercises and provides recommendations from research on emergency response in other types of natural and technological hazards.

Lindell, M.K., J.C. Lu, and C.S. Prater, 2005: Household decision making and evacuation in response to Hurricane Lili. *Natural Hazards Review*, **6(4)**, 171-179.

This study collected data on the evacuation from Hurricane Lili to answer questions about households' reliance on information sources, the factors affecting their decisions to evacuate, the timing of their hurricane evacuation decisions, and the time it took them to prepare to evacuate. The results replicated previous findings on the sources of hazard information, evacuation concerns, and the timing of evacuation decisions. In addition, they provide new information about evacuation preparation times and the finding that household characteristics are uncorrelated with evacuation decision times or evacuation preparation times.

Lindell, M.K. and C.S. Prater, 2010: Tsunami preparedness on the Oregon and Washington coast: Recommendations for research. *Natural Hazards Review*, **11(2)**, 69-81.

This study sought to identify the research that is needed to improve tsunami emergency preparedness in the Pacific Northwest. A search of the archival literature yielded very few journal articles and technical reports on community preparedness for tsunami hazard in the United States. Consequently, we conducted interviews with 12 key informants within six coastal communities in four counties of Washington and Oregon. These two sources of information revealed a number of important deficiencies related to emergency response preparedness and risk communication. Based on this assessment, we propose a series of specific recommendations for research on agency notification and mobilization, protective action selection and timing, warning and evacuation, and risk communication and perception. Addressing research needs in these areas would improve coastal communities' ability to respond effectively to tsunami threat.

Lindell, M.K., C.S. Prater, and W.G. Peacock, 2007: Organizational communication and decision making for hurricane emergencies. *Natural Hazards Review*, **8(3)**, 50-60.

This paper reviews research and theory on the processes by which emergency relevant organizations communicate with each other and with the population at risk from hurricanes. The technology for hurricane forecast, warning, and protective action has made significant advances in the past 20 years, but there is a disturbing potential for hurricane strikes that could cause a large number of casualties in addition to the predictably large economic cost from property destruction. Consequently, social science research is needed to expand the existing knowledge base on the response of households, businesses, and special facilities to hurricane warnings. Available research suggests local officials need better information about evacuation time estimates, evacuation costs, and the potential loss of life in a late evacuation. They also need improved decision support systems that will facilitate the choice of appropriate protective actions when hurricanes threaten their jurisdictions.

Lindell, M.K., C.S. Prater, and J.Y. Wu, 2002: Hurricane evacuation time estimates for the Texas Gulf coast. Hazard Reduction & Recovery Center, Texas A&M University, 39pp.

This report describes the application of an improved method for developing hurricane evacuation time estimate (ETEs). In contrast to the procedure used in previous analyses, Lindell, Prater and Wu (2001) proposed an *Empirically Based Large-Scale Evacuation time estimate Method (EMBLEM)* that uses two empirical evacuation time components for the evacuating population- warning time and preparation time. This differs from the previous research procedure of adding an arbitrary three-hour time buffer to account for these activities. The empirically based estimates demonstrate that ETEs can be very long when warnings are slow or when evacuees must return home before evacuating. In addition, the EMBLEM procedure accounts for the effects of spontaneous evacuation. This can substantially increase the ETEs for hurricanes in Categories One and Two when inland risk areas are densely populated and their populations are prone to evacuate. Finally, the EMBLEM procedure accounts for the time required for evacuees to travel out of the risk area. For counties whose population centers are located well inland from the coast, addition of this component makes little difference. When a major hurricane is forecast to strike a county that has a significant number of people living on the coast or on barrier islands, the inclusion of response time can add as much as two hours to ETEs.

The EMBLEM procedure does not account for the evacuation of transit-dependent populations and special facilities. As is the case for other methods of evacuation analysis, ETEs for these population segments must be computer separately. Finally, these is uncertainty about the estimates for many of the input variables, so further analyses should be conducted to determine the extent to which any ETEs will be significantly affected by changes in the values of these parameters. In particular, these analyses should examine the effects of variation in the distributions of warning times and preparation times, the number of evacuating vehincles per household, the rate of warning compliance and spontaneous evacuation, and evacuee route choice as well as the effects of capacity changes such as lane reversals.

Maximuk, Lynn. “Service Assessment: Tornado in Rogers, Minnesota September 16, 2006.” National Weather Service. November, 2006.

On the night of September 16, 2006, a tornado formed in Rogers, MN at 9:52pm. No warning was released by the National Weather Service until 10:02pm. The reason for the delay was assessed by a National Weather Service assessment team. The reasons for the warning being issued well after touch down were the forecaster waiting for data from the WSR-88D radar, the time it took to create the warning, and the “sectoring” of the assignments at an inopportune time at the WFO. Recommendations are made to improve services provided by the NWS, including the recognition that storm-based warnings and improvements to radar in development at the time of the assessment would have increased the speed of warning release.

McEntire, D.A., 2004: Tenets of vulnerability: An assessment of a fundamental disaster concept. *Journal of Emergency Management*, **2(2)**, 23-29.

This article reviews academic findings on disaster vulnerability and provides 15 tenets about this fundamental concept. Research is taken mainly from sociologists but also include findings from other disciplines. The study uncovers what is known about vulnerability and stresses the importance of this concept for those interested in disaster reduction.

This article points out that vulnerability is dynamic, changing over space and time. It also points out how vulnerability is part of all phases of emergency management (mitigation, preparedness, response, and recovery.)

McGlown, K.J., 2001: Evacuation of healthcare facilities: A new twist to a classic model. *Natural Hazards Review*, **2(2)**, 90-99.

Disasters and their potential for damage are increasing in the United States and worldwide. Government officials warn that disasters will be occurring at an increasing rate and will worsen in the future. As these risks increase, the likelihood of evacuation of a health care facility grows. We know much about the role of hospitals in evacuation, yet little about how the decision to evacuate a facility is initially

made. This study compares two models from studies related to the evacuation process: Vogt's adaptation of Quarantelli's classic model examining organizational ability to cope, and McGlown's model from variables considered critical to health care executives in the decision to evacuate a health care facility. This study contributes to the literature on evacuation behavior of health care organizations by examining the variables perceived by decision makers as critical in their decision to evacuate their facility compared to variables identified in the literature. These findings may form the first constructive step toward the development of an empirically based decision framework for health facility evacuation.

Mileti, D.S. and L. Peek, 2000: The social psychology of public response to warnings of a nuclear power plant accident. *Journal of Hazardous Materials.* **75(2-3)**, 181-194.

This article reviews the process of public response to warnings of an impending nuclear power plant emergency. Significant evidence exists to suggest that people engage in protective action in response to warnings based upon the substance and course through which emergency warning information is disseminated. The three basic components of a warning system are defined, and the elements of public response to warnings are summarized. Popular myths about public response to warnings are outlined and dispelled based upon current research verification. The conclusion provides an overview and synthesis of the warning response process.

Mileti, D. S., and J. H. Sorenson, 1990: Communication of emergency public warnings: A social science perspective and state of-the-art assessment. Oak Ridge National Laboratory Rep. ORNL-6609, 145 pp.

More than 200 studies of warning systems and warning response were reviewed for this social science perspective and state-of-the-art assessment of communication of emergency public warnings. The major findings are as follows.

First, variations in the nature and content of warnings have a large impact on whether or not the public heeds the warning. Relevant factors include the warning source; warning channel; the consistency, credibility, accuracy, and understandability of the message; and the warning frequency.

Second, characteristics of the population receiving the warning affect warning response. These include social characteristics such as gender, ethnicity and age, social setting characterisitics such as stage of life or family context, psychological characteristics such as fatalism or risk perception, and knowledge characteristics such as experience or training.

Third, many current myths about public response to emergency warning are at odds with knowledge derived from field investigations. Some of these myths include the "keep it simple" notion, the "cry wolf" syndrome, public panic and hysteria, and those concerning public willingness to respond to warnings.

Finally, different methods of warning the public are not equally effective at providing an alert and notification in different physical and social settings. Most systems can provide a warning given three or more hours of available warning time. Special systems such as tone-alert radios are needed to provide rapid warning.

Morss, R.E., 2010: Interactions among flood predictions, decisions, and outcomes: Synthesis of three cases. *Natural Hazards Review*, **11(3)**, 83-96.

To complement other flood mitigation measures, hydrometeorological predictions are often used in decisions leading up to and during floods. Understanding the role played by predictions in flood events can help forecasters provide more useful information, and it can help decision makers use this information more effectively as part of broader flood loss-reduction strategies. This article examines the interactions among predictions, decisions, and flood-related outcomes by analyzing three cases of severe flooding in the United States: the Red River basin flood of April 1997 in Grand Forks and Fargo, N.D.; the Fort Collins, Colo. flood in July 1997; and the Pescadero Creek basin, California flood in February 1998. The floods occurred in different hydrometeorological and societal circumstances, had different types of predictive information available, and had different societal impacts, providing an opportunity to compare and contrast lessons learned. Issues explored include the interplay between the floods and their

hydrometeorological and societal context and the roles of predictions and predictive uncertainty in decisions and outcomes.

Morss, R.E. and F.M. Ralph, 2007: Use of information by National Weather Service forecasters and emergency managers during CALJET and PACJET-2001. *Weather and Forecasting,* **22(3)**, 539-555.

Winter storms making landfall in western North America can generate heavy precipitation and other significant weather, leading to floods, landslides, and other hazards that cause significant damage and loss of life. To help alleviate these negative impacts, the California Land-falling Jets (CALJET) and Pacific Land-falling Jets (PACJET) experiments took extra meteorological observations in the coastal region to investigate key research questions and aid operational West Coast 0–48-h weather forecasting. This article presents results from a study of how information provided by CALJET and PACJET was used by National Weather Service (NWS) forecasters and forecast users. The primary study methodology was analysis of qualitative data collected from observations of forecasters and from interviews with NWS personnel, CALJET–PACJET researchers, and forecast users. The article begins by documenting and discussing the many types of information that NWS forecasters combine to generate forecasts. Within this context, the article describes how forecasters used CALJET–PACJET observations to fill in key observational gaps. It then discusses researcher–forecaster interactions and examines how weather forecast information is used in emergency management decision making. The results elucidate the important role that forecasters play in integrating meteorological information and translating forecasts for users. More generally, the article illustrates how CALJET and PACJET benefited forecasts and society in real time, and it can inform future efforts to improve human-generated weather forecasts and future studies of the use and value of meteorological information.

Morss, R.E., O.V. Wilhelmi, M.W. Downtown, and E. Gruntfest, 2005: Flood risk, uncertainty, and scientific information for decision making: Lessons from and interdisciplinary project. *Bulletin of the American Meteorological Society*, **85(11)**, 1593-1601.

The magnitude of flood damage in the United States, combined with the uncertainty in current estimates of flood risk, suggest that society could benefit from improved scientific information about flood risk. To help address this perceived need, a group of researchers initiated an interdisciplinary study of climate variability, scientific uncertainty, and hydrometeorological information for flood-risk decision making, focused on Colorado's Rocky Mountain Front Range urban corridor. We began by investigating scientific research directions that were likely to benefit flood-risk estimation and management, through consultation with climatologists, hydrologists, engineers, and planners. In doing so, we identified several challenges involved in generating new scientific information to aid flood management in the presence of significant scientific and societal uncertainty. This essay presents lessons learned from this study, along with our observations on the complex interactions among scientific information, uncertainty, and societal decision making. It closes by proposing a modification to the “end to end” approach to conducting societally relevant scientific research. Although we illustrate points using examples from flood management, the concepts may be applicable to other arenas, such as global climate change.

Neal, D.M., 1995: Transition from response to recovery: A look at the Lancaster, Texas tornado. *Quick Response Research Report #79,* Natural Hazards Center.

In response to Neal (1997), which was being written at the time of this study, the author put his theory that the phases of disaster are fluid to an empirical test during the Lancaster, TX tornado of April 25, 1994. The author examined the transition from response to recovery phases and documented the time of actions that would be categorized as response activities and recovery activities. The author found that while the phases exist, the lines distinguishing between the two phases are blurry, with both response and recovery activities taking place 3-4 days after the event before a transition to largely recovery activities on day 5. This empirical evidence is used to support his hypothesis that the phases of disaster are not linear and distinct, but rather non-mutually exclusive, with the activities of one phase affecting the activities of the next.

Neal, D.M., 1997: Reconsidering the phases of disaster. *International Journal of Mass Emergencies and Disasters*, **15(2)**, 239-264.

The use of disaster phases (eg. preparedness, response, recovery, and mitigation) has assisted both disaster researchers and managers. Disaster researchers have used disaster phases to systematize and codify research results. Disaster managers have drawn upon disaster periods to organize their own activities. Yet, many problems exist with the current use of disaster periods. In summary, I find that the current uses of disaster periods lack conceptual clarity for improving scientific and practical use. As a result, I suggest ways the field can recast the use of disaster phases to improve the theoretical and applied dimensions of the field.

While very different from many other articles, this article provides a concise review of the breakdown of time phases throughout the history of disaster research and the ways these time phases are used to codify and process research and activities related to disaster management. It also points out the numerous problems with considering disasters as being divided into defined phases. The article suggests that the phases of disasters are actually overlapping, mutually dependent, multidimensional, and cyclical.

Neal, D.M., 2004: Transition from response to recovery after the Lancaster, TX, tornado: An empirical description. *Journal of Emergency Management*, **2(1)**, 47-51.

Disaster researchers and disaster managers have relied upon various depictions of disaster phases for their professional activities, but there has been little empirical examination of these phases. This paper looks at when response activities started and ended and when recovery efforts began following a tornado. The data indicate that the transition from response to recovery is not a discrete event; rather, soon after response activities were initiated within the community, recovery efforts were also started. Although disaster phases provide an effective way to organize data and actual events, they need much further empirical and theoretical examination if they are to be an important component of disaster research and disaster management.

Nilson, L.E. and D.C. Nilson, 1981: Resolving the “sooner vs. later” controversy surrounding the public announcement of earthquake predictions. *Disasters*, **5(4)**, 391-397.

This article considers the question of whether scientific predictions of earthquakes should be announced as they are made, possibly years in advance, or whether public warnings of earthquake hazards should be delayed until days before a predicted event. The authors pose a set of theories and hypotheses regarding the benefits and drawbacks of early announcement of earthquake predictions on society, the economy, and politics. They propose creating a color coded policy to indicate threats, including the appropriate uncertainty, and refraining from calling announcements made well in advance “predictions.” They hypothesize that this will provide officials with sufficient time to implement mitigation while avoiding alarming the general public. It also keeps information channels open for the public and maintains awareness of the hazard.

Parker, D.J., 1987: Flood warning dissemination: The British experience. *Flood Hazard Management*, J. Handmer, Ed., Geo Books, 169-190.

In this chapter of *Flood Hazard Management*, Parker (1987) considers the institutional limitations to flood warning dissemination. Through the use of document analysis and interviews with authorities, the chapter identifies weaknesses in the flood warning dissemination system and provides nine recommendations to improve the system based on warning system models. The nine recommendations include the role of forecasters and police, experience, publicity, message content, feedback and evaluation.

Parker, D.J., S.M. Tunstall, and S. McCarthy, 2007: New insights into the benefits of flood warnings: Results from a household survey in England and Wales. *Environmental Hazards*, **7(3)**, 193-210.

The flood defence agency in England and Wales has been pursuing a programme of flood warning system enhancement, engaging householders at risk in improving their warning responses. The immediate aim of this paper is to test and revise a model of economic benefits of warnings, but the survey data also generate insights into the constraints acting upon flood warning responses. Damage saving is less than previously anticipated: warning reliability and householder availability problems limit savings. Warnings are less likely to be received by those in lower social grades, and flood warning lead time is a factor in avoiding damage. The survey data indicate the complexities involved in improving flood warning response, and provide policy pointers.

Paul, B.K., C.T. Brock, S. Csiki, and L. Emerson, 2003: Public response to tornado warnings: A comparative study of the May 4, 2003, tornadoes in Kansas, Missouri, and Tennessee. *Quick Response Research Report #165,* Natural Hazards Center.

On May 4, 2003, a major storm system moved across the Midwest, spawning numerous tornadoes in the states of Kansas, Missouri, and Tennessee. These tornadoes caused heavy damage to both rural and urban communities. In an attempt to determine whether residents were sufficiently warned and able to seek shelter, survey were conducted in 18 communities of Kansas, Missouri, and Tennessee impacted by the May 4, 2003, tornadoes. This analysis of survey data reveals that tornado warnings were adequate and timely in large communities. The same is not true for small communities, particularly for rural areas, where tornado warnings also significantly differ across timing and sociological factors. Several suggestions are made to improve warning systems in smaller communities.

Perry, R.W. and M.K. Lindell, 2003: Preparedness for emergency response: Guidelines for the emergency planning process. *Disasters*, **27(4)**, 336-350.

Especially since the terrorist attacks of 11 September 2001, governments worldwide have invested considerable resources in the writing of terrorism emergency response plans. Particularly in the United States, the federal government has created new homeland security organizations and urged state and local governments to draw up plans. This emphasis on the written plan tends to draw attention away from the process of planning itself and the original objective of achieving community emergency preparedness. This paper reviews the concepts of community preparedness and emergency planning, and their relationships with training, exercises and the written plan. A series of 10 planning process guidelines are presented that draw upon the preparedness literature for natural and technological disasters, and can be applied to any environmental threat.

In writing about emergency preparedness, this article points out the distinction between preparedness and planning, and the major difference is embedded in the concept of time. Preparedness is a continuous process which changes over time as capabilities and vulnerabilities change. Planning is a snapshot of preparedness at one point in time and may not reflect the changes that have occurred. Thus, it points out the importance of an emergency plan being a living document that changes as community aspects change.

In the article's guidelines, the author also points out that quick response is not always the best response. The author points out that a quick response based on incomplete information may not result in optimal outcomes and may create an even more hazardous situation. Response should be based on accurate and complete information rather than emphasizing the speed in which response can be accomplished.

Pingel, N, C. Jones, and D. Ford, 2005: Estimating forecast lead time. *Natural Hazards Review*, **6(2)**, 60-66.

Flood warning systems (FWS), if properly designed and operated, reduce flood damages and save lives. For federally funded projects, the economic benefit of the FWS must be computed. That benefit must be greater than the project cost for the system to be implemented. The driving factor in the benefit computations is the duration of the lead time attributed to the FWS. In other words, how far in advance can a FWS forecast a threshold exceedence? We have developed a straightforward procedure to answer this question using standard-of-practice rainfall-runoff models. The result can be used with economic models to estimate the economic benefit of an FWS for project planning purposes.

Phillips, B.D. and B.H. Morrow, 2007: Social science research needs: Focus on vulnerable populations, forecasting, and warnings. *Natural Hazards Review*, **8(3),** 61-68.

This paper assesses the state of social science research specific to populations at risk vis-à-vis weather forecasting and warnings. At-risk populations are defined as groups historically disadvantaged by socioeconomic status; patterns of discrimination and exclusion, or both; a lack of political representation; or cultural distancing. These contexts marginalize some groups, leaving them less likely to receive, interpret, and respond appropriately to forecasts and warnings. We give an overview of key concepts from vulnerability research and suggest research topics emanating from the social science literature relevant to forecasting and warnings.

Regnier, E., 2008: Public evacuation decisions and hurricane track uncertainty. *Management Science*, **51(1)**, 16-28.

Public officials with the authority to order hurricane evacuations face a difficult trade-off between risks to life and costly false alarms. Evacuation decisions must be made on the basis of imperfect information, in the form of forecasts. The quality of these decisions can be improved if they are also informed by measures of uncertainty about the forecast, including estimates of the value of waiting for updated, more accurate, forecasts. Using a stochastic model of storm motion derived from historic tracks, this paper explores the relationship between lead time and track uncertainty for Atlantic hurricanes and the implications of this relationship for evacuation decisions. Typical evacuation clearance times and track uncertainty imply that public officials who require no more than a 10% probability of failing to evacuate before a striking hurricane (a false negative) must accept that at least 76%—and for some locations over 90%—of evacuations will be false alarms. Reducing decision lead times from 72 to 48 hours for major population centers could save an average of hundreds of millions of dollars in evacuation costs annually, with substantial geographic variation in savings.

Rodriguez, H., W. Donner, W. Diaz, and J. Santos-Hernandez, 2010: Emergency managers, allocation of resources, and policy implications: The intersection of weather hazards, population, and technology. *Journal of Emergency Management*, **8(2)**, 35-44.

This article explores the end-user community's knowledge and perception of severe weather events, warnings, and new radar technology. Particular attention has been paid to the advantages, problems, and limitations of current weather technology from the emergency manager's perspective. Specifically, the authors focus on end-users' recommendations regarding the allocation of the new radar resources that are being developed by the Engineering Research Center (ERC) on the Collaborative Adaptive Sensing of the Atmosphere (CASA), which is funded by the National Science Foundation (NSF). In-depth interviews were conducted with members (n = 50) of the emergency management community in Oklahoma and National Weather Service (NWS) meteorologists with diverse experiences in disaster mitigation, preparedness, response, and recovery. On the basis of the results from the in-depth interviews, the authors generated seven broad categories that include the recommendations or factors that emergency managers and NWS personnel reported should be taken into account in the allocation of radar resources, including: (a) nature of the hazard event, (b) potential impact and outcomes of the hazard event, (c) lead time, d) false alarm rates, (e) population issues, (f) infrastructure, and (g) availability of other resources. Our findings suggest that respondents generally agreed that the type of hazard, its severity, and the potential impact and outcomes of severe weather events should play a primary role in the allocation of radar resources. However, there were some conflicts or concerns regarding the role that population size should and could play in the allocation of such resources.

Ruin, I., J.D. Creutin, S. Anquetin, E. Gruntfest, and C. Lutoff, 2009: Human vulnerability to flash floods: Addressing physical exposure and behavioural questions. *Flood Risk Management*, 1005-1012.

Flash floods surprise people in the midst of their daily activities because they are sudden. They, particularly strike people traveling. For each catastrophe, up to half of the deaths are road users. Hydrometeorological research allows longer prediction lead-times and reduced uncertainty. However,

social vulnerability remains an outstanding focus. Experts call for a comprehensive integration of social and natural sciences to improve the understanding of public responses and target loss reduction. A first step in the direction indicated is to better understand the hydrometeorological circumstances of the resulting accidents as well as the behavior of the population during the crisis. The catastrophic September 2002 flash floods in Southern France took 23 human lives in 16 distinct sub catchments. Based on this experience, the authors combine analysis of the physical and human response to Mediterranean storms by using both the results of hydrometeorological simulations and qualitative research tools as interviews of flood victims.

Ruin, I., J.D. Creutin, S. Anquetin, and C. Lutoff, 2008: Human exposure to flash floods – Relation between flood parameters and human vulnerability during a storm of September 2002 in Southern France. *Journal of Hydrology*, **361(1-2)**, 199-213.

The aim of this paper is to investigate the detailed hydrometeorological circumstances that lead to accidental casualties, and to better understand the prominent physical factors of risk. Based on an event that affected the Gard region (Southern France) in September 2002, it is a first attempt to combine analysis of the physical and human response to Mediterranean storms. After details concerning the methodology (for meteorological, hydrological and casualty analysis), the local context and the event, the authors examine two points: the dynamics of the event (flash-flood and riverine-flood response to the storm) together with human exposure on the one hand, and scale as a critical problem affecting flood risk on the other. This investigation stresses the specificity of small catchments, which are more dangerous both in hydrological and human terms. Moreover, this contribution linking social sciences and geophysics constitutes an important step in what Morss, R.E. et al. (2005) call the “End to end to end” process.

Ruin, I., J.C. Gaillard, and C. Lutoff, 2007: How to get there? Assessing motorists’ flash flood risk perception on daily itineraries. *Environmental Hazards*, **7**, 235-244.

Flash floods are characterized by their suddenness, fast and violent movement, rarity, small scale but high level of damage. They are particularly difficult to forecast accurately and there is little lead time for warning. This makes motorists especially vulnerable. Assuming that these flash flood hazard specificities may be the significant factors leading to difficulties for drivers to perceive danger, we used cognitive mapping combined with GIS data processing to assess motorists’ flash flood risk perception on their daily itineraries. The analysis of 200 mental maps collected allows planners to have maps highlighting dangerous areas where risk perception is weak and to identify reasons for this.

Salmon, J.D., 1984: Vertical evacuation in hurricanes: An urgent policy problem for coastal managers. *Coastal Zone Management Journal*, **12(2-3)**, 287-300.

Evacuation inland (“horizontal evacuation”) is the traditional method of saving life in areas forecast as the site of hurricane landfall. But “high confidence” warning time is only 12 hours, while some coastal areas are now so densely populated that twice that time is required for evacuation. Coastal managers much therefore risk the ire of local citizens “unnecessarily” evacuated early, and the associated risk that several false alarms will reduce citizen compliance, *or* the risk that evacuation will be too long delayed.

The alternative of vertical evacuation (going upstairs in hurricane-proof buildings) is resisted by planners who are concerned that its risks are too high and that partial acceptance of the concept would vitiate compliance with the horizontal component. But in some areas there may no longer be a choice: prudent coastal managers must determine the potential need and capability for vertical evacuation in their areas. Effective integration of both vertical and horizontal evacuation will require development of new plans and policies.

Schmidlin, T.W. and P.S. King, 1995: Risk factors for death in the 27 March 1994 Georgia and Alabama Tornados. *Disasters*, **19(2)**, 170-177.

Field surveys were made one week after tornadoes killed 40 persons and injured over 300 in rural regions of Alabama and Georgia, USA, on 27 March 1994. Surveys were completed for samples of 20

persons who were killed and 31 persons who were in the paths of the tornadoes but survived to determine whether there were differences in personal characteristics, behavior or location between the two groups. Persons who died were significantly older than persons who survived, more likely to be in mobile homes or in rooms above ground with windows, less likely to be watching television before the tornado, and were aware of the approaching tornado for less time than survivors. There was no difference in gender, race, marital status, education, disability or previous experience with tornadoes between those who died and survivors.

The unique aspect of time for this article is that while the National Weather Service issued warnings with 10 to 20 minutes of lead time, a majority of participants did not know about the tornado warning until they heard or saw the tornado. Many of these participants had the radio or television on. The authors suggest that this may be because the day was a Sunday or because there were multiple warnings issued over eight hours that people did not hear the warnings in the background.

Schmidlin, T.W. and P.S. King, 1997: Risk factors for death in the 1 March 1997 Arkansas tornadoes. *Quick Response Research Report #98,* Natural Hazards Center.

Field surveys were made two weeks after tornadoes killed 26 persons in Arkansas, USA, on 1 March 1997. Surveys were completed for samples of persons killed (n=25) and persons in the paths of the tornadoes but survived (n=73) to determine whether there were differences in personal characteristics, behavior, or location between the two groups. Fourteen of the 25 deaths were in mobile homes, four in frame homes, two each in commercial buildings, vehicles, and outdoors, and one in a garage. Risk factors for death included being in an above-ground room with windows, being in a room where the roof, wall, or floor was blown away, and being hit by debris. Divorced persons formed a larger portion of deaths (22%) than of those who survived (1%). There was no significant difference between deaths and survivors in age, gender, race, education, disability, or time between first becoming aware of the tornado and the tornado striking.

Similar to Schmidlin and King (1995), while the NWS had lead times of 18-32 minutes, the first awareness of the tornado was often seeing the funnel cloud. This was because of the numerous warnings on the television which caused a "numbing."

Schmidlin, T.W., P.S. King, B.O. Hammer, and Y. Ono, 1998: Risk factors for death in the 22-23 February 1998 Florida tornadoes. *Quick Response Report #106*, Natural Hazards Center.

Field surveys were made in the week after tornadoes killed 42 persons in central Florida, USA, on 22-23 February 1998. Surveys were completed for persons killed (n=42) and a sample of persons in the paths of the tornadoes but who survived (n=86) to determine whether there were differences in personal characteristics, behavior, or location between the two groups. All but one of the deaths were in mobile homes or parked recreational vehicles.

Risk factors for death included advanced age, being in an above-ground room with windows, being in a room where the roof, wall, or floor was blown away, being hit by debris, and being unmarried. The well-known vulnerability of mobile homes is emphasized in these results. A lack of underground shelters or sturdy above-ground shelters for mobile home residents contributed to the high death toll. In addition, the midnight occurrence and lack of community sirens meant few people received warning of the approaching tornado, in spite of 10 to 24 minutes warning from the National Weather Service.

Schneider, D.M., 1957: Typhoons on Yap. *Human Organization*, **16(2)**, 10-15.

In an ethnographic study of the people of Yap, the author considers the response of the people to the chronic disaster of typhoons. Within this culture, the typhoon has taken on a social, cultural, and supernatural meaning, and the storms are brought about through the breakdown of social relations between the people and their chief. Because of this, the time spent before, during, and after the event is spent trying to repair these social relations through spiritual means. With hours of warning due to environmental cues, preparation for the storm is spent bringing in the canoes and performing spiritual and magical ceremonies within the house to repair and maintain relations with the ancestors. During the storm, cultural taboos are enhanced and the house is not abandoned until it collapses. And after the storm, the focus is on repairing social relations, with a particular focus on food supply, rather than

repairing homes. The author poses the idea that in the face of chronic threat, the disaster takes on a social meaning as well as a physical meaning, which will shape how response occurs.

Schultz, D.M., E.C. Gruntfest, M.H. Hayden, C.C. Benight, S. Drobot, and L.R. Barnes, 2010: Decision making by Austin, Texas, residents in hypothetical tornado scenarios. *Weather, Climate, and Society*, **2**: 249-254.

One of the goals of the Warning Project is to understand how people receive warnings of hazardous weather and subsequently use this information to make decisions. As part of the project, 519 surveys from Austin, Texas, floodplain residents were collected and analyzed. About 90% of respondents understood that a tornado warning represented a more serious and more likely threat than a tornado watch. Most respondents (86%) were not concerned about a limited number of false alarms or close calls reducing their confidence in future warnings, suggesting no cry-wolf effect. Most respondents reported safe decisions in two hypothetical scenarios: a tornado warning issued while the respondent was home and a tornado visible by the respondent while driving. However, nearly half the respondents indicated that they would seek shelter from a tornado under a highway overpass if they were driving. Despite the limitations of this study, these results suggest that more education is needed on the dangers of highway overpasses as shelter from severe weather.

Schumacher, R.S., D.T. Lindsey, A.B. Schumacher, J. Braun, S.D. Miller, and J.L. Demuth, 2010: Multidisciplinary analysis of an unusual tornado: meteorology, climatology, and the communication and interpretation of warnings. *Weather and Forecasting*, **25(5)**, 1412-1429.

On 22 May 2008, a strong tornado—rated EF3 on the enhanced Fujita scale, with winds estimated between 136 and 165 mi h21 (61 and 74 m s21)—caused extensive damage along a 55-km track through northern Colorado. The worst devastation occurred in and around the town of Windsor, and in total there was one fatality, numerous injuries, and hundreds of homes significantly damaged or destroyed. Several characteristics of this tornado were unusual for the region from a climatological perspective, including its intensity, its long track, its direction of motion, and the time of day when it formed. These unusual aspects and the high impact of this tornado also raised a number of questions about the communication and interpretation of information from National Weather Service watches and warnings by decision makers and the public. First, the study examines the meteorological circumstances responsible for producing such an outlier to the regional severe weather climatology. An analysis of the synoptic and mesoscale environmental conditions that were favorable for significant tornadoes on 22 May 2008 is presented. Then, a climatology of significant tornadoes (defined as those rated F2 or higher on the Fujita scale, or EF2 or higher on the Enhanced Fujita scale) near the Front Range is shown to put the 22 May 2008 event into climatological context.

This study also examines the communication and interpretation of severe weather information in an area that experiences tornadoes regularly but is relatively unaccustomed to significant tornadoes. By conducting interviews with local decision makers, the authors have compiled and chronicled the flow of information as the event unfolded. The results of these interviews demonstrate that the initial sources of warning information varied widely. Decision makers' interpretations of the warnings also varied, which led to different perceptions on the timeliness and clarity of the warning information. The decision makers' previous knowledge of the typical local characteristics of tornadoes also affected their interpretations of the tornado threat. The interview results highlight the complex series of processes by which severe weather information is communicated after a warning is issued by the National Weather Service. The results of this study support the growing recognition that societal factors are just as important to the effectiveness of weather warnings as the timeliness of and information provided in those warnings, and that these factors should be considered in future research in addition to the investments and attention given to improving detection and warning capabilities.

Schwartz. R.M., 2003: An examination of preparedness, response, and recovery for the La Plata, Maryland, tornado. *Journal of Emergency Management*, **1(3)**, 30-36.

The most severe tornado of spring, 2002, did not occur in Tornado Alley but in La Plata, MD. It was first classified as an F5 but then reclassified as an F4 on the Fujita Tornado Intensity Scale. This

paper examines preparedness, response, and recovery issues by studying the town of La Plata (a bedroom community south of Washington, DC), Charles County, Maryland, and the National Weather Service. Methods employed included a site visit, field observations, and interviews.

While this event had little to no warning lead time, the focus of this paper is on the importance of pre-event preparedness and planning, such as building relationships between forecasters and emergency responders, communication, and education.

Sherman-Morris, K., 2010: Tornado warning dissemination and response at a university campus. *Natural Hazards*, **52(3)**, 623-638.

An online survey was completed by 2,921 students and employees at a large university following a tornado near-miss that required taking shelter. During this event, the university's emergency alert messaging system was tested. The first alert message was received by over 66% of the sample within 15 min, and cell phones were the most common means of receiving this message—especially for students. Employees relied more on computer instant messaging than did students. Interpersonal communication was also important. The majority could correctly define tornado watch, tornado warning and shelter in place. Age and frequency of use of weather information were of mixed significance as predictors. Finally, over three quarters of respondents reported taking shelter during the event. Being female and being an employee made a respondent more likely to take shelter.

Simmons, K.M., and D. Sutter, 2006. Improvements in tornado warnings and tornado casualties. *International Journal of Mass Emergencies and Disasters*, **24(3)**, 351-369.

Doppler radar installation by the National Weather Service (NWS) improved tornado warning performance, raising the probability of detection and mean lead time while reducing the false alarm ratio. Research on tornado casualties has established that a warning reduces tornado injuries while lead times of up to fifteen minutes also reduce tornado fatalities. In this paper we estimate the decrease in tornado casualties attributable to the observed change in the distribution of warning lead times, and thus provide evidence on the benefit to society of weather warning systems. We find that increases in warning lead times accounts for 30-50 percent of the reduction in injuries but no more than ¼ of the reduction in fatalities which occurred with the installation of Doppler radar by the NWS. Future improvements in warning performance to further reduce tornado fatalities by 18 percent and injuries by 24 percent.

Simmons, K.M., and D. Sutter, 2008: Tornado warnings, lead times, and tornado casualties: An empirical investigation. *Weather and Forecasting*, **23(2)**, 246-258.

Conventional wisdom holds that improved tornado warnings will reduce tornado casualties, because longer lead times on warnings provide extra opportunities to alert residents who can then take precautions. The relationship between warnings and casualties is examined using a dataset of tornadoes in the contiguous United States between 1986 and 2002. Two questions are examined: Does a warning issued on a tornado reduce the resulting number of fatalities and injuries? Do longer lead times reduce casualties? It is found that warnings have had a significant and consistent effect on tornado injuries, with a reduction of over 40% at some lead time intervals. The results for fatalities are mixed. An increase in lead time up to about 15 min reduces fatalities, while lead times longer than 15 min increase fatalities compared with no warning. The fatality results beyond 15 min, however, depend on five killer tornadoes and consequently are not robust.

Simmons, K.M., and D. Sutter, 2009: False alarms, tornado warnings, and tornado casualties. Weather, Climate, and Society, **1(1)**, 38-53.

This paper extends prior research on the societal value of tornado warnings to the impact of false alarms. Intuition and theory suggest that false alarms will reduce the response to warnings, yet little evidence of a "false alarm effect" has been unearthed. This paper exploits differences in the false-alarm ratio across the United States to test for a false-alarm effect in a regression model of tornado casualties from 1986 to 2004. A statistically significant and large false-alarm effect is found: tornadoes that occur in an area with a higher false-alarm ratio kill and injure more people, everything else being constant. The

effect is consistent across false-alarm ratios defined over different geographies and time intervals. A one-standard-deviation increase in the false-alarm ratio increases expected fatalities by between 12% and 29% and increases expected injuries by between 14% and 32%. The reduction in the national tornado false-alarm ratio over the period reduced fatalities by 4%-11% and injuries by 4%-13%. The casualty effects of false alarms and warning lead times are approximately equal in magnitude, suggesting that the National Weather Service could not reduce casualties by trading off a higher probability of detection for a hihger false-alarm ratio, or vice versa.

Sinha, A.K. and S.U. Avrani, 1984: The disaster warning process: A study of the 1981 Gujarat cyclone. *Disasters*, **8(1)**, 67-73.

This paper reports on the channels through which warning of the impending disastrous cyclone of October-November 1981 was received and disseminated in the districts and villages of Gujarat in Northwest India. The process is slow and laborious, and efforts are in hand to improve the speed and efficiency of warning methods. Some of the problems likely to be encountered are discussed.

Slovic, P., 1999: Trust, Emotion, Sex, Politics, and Science: Surveying the Risk-Assessment Battlefield. *Risk Analysis,* **19(4)**, 689-701.

Risk management has become increasingly politicized and contentious. Polarized views, controversy, and conflict have become pervasive. Research has begun to provide a new perspective on this problem by demonstrating the complexity of the concept "risk" and the inadequacies of the traditional view of risk assessment as a purely scientific enterprise. This paper argues that danger is real, but risk is socially constructed. Risk assessment is inherently subjective and represents a blending of science and judgment with important psychological, social, cultural, and political factors. In addition, our social and democratic institutions, remarkable as they are in many respects, breed distrust in the risk arena. Whoever controls the definition of risk controls the rational solution to the problem at hand. If risk is defined one way, then one option will rise to the top as the most cost-effective or the safest or the best. If it is defined another way, perhaps incorporating qualitative characteristics and other contextual factors, one will likely get a different ordering of action solutions. Defining risk is thus an exercise in power. Scientific literary and public education are important, but they are not central to risk controversies. The public is not irrational. Their judgments about risk are influenced by emotion and affect in a way that is both simple and sophisticated. The same holds true for scientists. Public views are also influenced by worldviews, ideologies, and values; so are scientists' views, particularly when they are working at the limits of their expertise. The limitations of risk science, the importance and difficulty of maintaining trust, and the complex, sociopolitical nature of risk point to the need for a new approach-one that focuses upon introducing more public participation into both risk assessment and risk decision making in order to make the decision process more democratic, improve the relevance and quality of technical analysis, and increase the legitimacy and public acceptance of the resulting decisions.

In regards to time, much of Slovic's assessment of risk can be applied to the idea of longer tornado warning lead time. Slovic notes that when under time-pressure conditions, the individual is forced to resort to their intuition, or affective response, to make quick judgments. Consequently, a longer warning time may weaken this dependence on affective response since the individual now has more time for reflection. This in turn may increase the perceived risk as people deviate from what their intuition tells them to do and instead dwell on alternative possibilities and not take immediate action. This is only one way to interpret Slovic's assessment of risk in terms of time and hazards.

Sorenson, J.H., 1991: When shall we leave? Factors affecting the timing of evacuation departures. *International Journal of Mass Emergencies and Disasters*, **9(2)**, 153-165.

Very little work has been conducted on the dynamics of human behavior in evacuations. This paper documents what is known about the timing of departures in different emergency events. This is followed by an effort to model individual variations in warning receipt and evacuation departures in the Nanticoke, PA hazardous materials fire. Among the factors which are significantly related to the time of warning receipt are the mode of the first warning, the proximity of the site of the emergency and the type

of structure inhabited. The only significant variable related to mobilization time is the personalization of the warning. Perceived threat, age and family size were not related to the mobilization time. The variability of human behavior is evacuations.

Sorenson, J.H., 2000: Hazard warning systems: Review of 20 years of progress. *Natural Hazards Review*, **1(2)**, 119-125.

The United States has no comprehensive national warning strategy that covers all hazards in all places. Instead, public warning practices are decentralized across different governments and the private sector. Uneven preparedness to issue warnings exists across local communities; hence, people are unevenly protected from the surprise onset of natural disasters. Without changes in this situation, inequalities will grow larger, and the gains made in saving lives over the past decades may well be reversed. Since the first assessment of research on natural hazards was completed in 1975, there have been significant improvements in forecasts and warnings for some hazards but only marginal improvements for others. Forecasts for floods, hurricanes, and volcanic eruptions have improved most significantly, and public dissemination of warnings has improved the most for hurricanes. However, a 100% reliable warning system does not exist for any hazard.

Sorenson, J. H. and D.S. Mileti, 1988: Warning and evacuation: Answering some basic questions. *Industrial Crisis Quarterly 2*, **2(3 & 4)**, 195-209.

In this paper we address five questions that are frequently asked in the context of emergency planning for various accidents and disasters. These questions are commonly voiced by emergency managers or planners wanting a better basis for developing emergency response plans. The questions are frequently answered by people who have an image of how people behave in an emergency; often, however, their observations are inaccurate and misleading. The questions are as follows. First, how long does it take to warn a population about a crisis? Second, how many people evacuate in an emergency situation? Third, when do people evacuate? Fourth, do people evacuate unnecessarily? Fifth, where do people go when they evacuate?

The major findings are as follows. First, most emergency response systems, which typically consist of law enforcement, firefighting and other civic employees, and sometimes volunteers, coupled with emergency use of available electronic media, can issue an effective warning given three or four hours of lead time. In some situations, when the threat is urgent, a warning can be disseminated in a much more rapid fashion. In situations with less than one hour of available warning time, some, and perhaps a substantial portion of the population ill not receive a warning.

Second, the speed of warning dissemination, particularly in urgent situations, is increased by informal warning processes. People seek information following the receipt of the warning and one common way to do so is to contact friends, relatives or neighbors. In some of the situations studied, 50% of the initial warning was attributable to informal notification processes.

Third, when advised or ordered to take a protective action such as evacuation, few people respond instantaneously except when there is a recognized and immediate threat. The length of time it takes for people to respond is variable among events, depending on the available time to impact and the severity of the threat. In any event, people are unlikely to take action simultaneously; rather it will be spread out over time.

Spiegel, J.P., 1957: The English flood of 1953. *Human Organization*, **16(2)**, 3-5.

In an ethnographic study of a flash flood which affected a small town in England, the author describes the situation of the town prior to impact, during impact, and during recovery. The flash flood, produced by a cyclone, had no warning and people made spontaneous decisions to climb to the roof of their homes or porches to avoid the floodwaters. The lack of warning is attributed to the organization of flood detection systems and the time it took for the police constable to make a decision regarding warning the citizens of the town. Because he failed to make a decision in time, he himself became trapped by the flood waters. Post-impact, as people returned to their homes for recovery, tensions grew within the community because of a lack of morale and public support. The article provides no conclusions or recommendations.

Stallings, R.A., 1977: A review essay on Panel on the Public Policy Implications of Earthquake Prediction, *Earthquake Prediction and Public Policy*. *Mass Emergencies*, **2(4)**, 259-267.

This article reviews the *Earthquake Prediction and Public Policy* report (for an overview of the panel findings see Turner 1976) released by the Panel on the Public Policy Implications of Earthquake Prediction. It critiques the report on findings, focus, and implications, and compares the report to others on the same topic. It commends the report for recognizing questions of inequality when it comes to disproportionate losses to certain sectors of society and its use of previous literature on hazards and disasters for forming conclusions and recommendations. The review also points out that the panel report fails to take into consideration what happens as the science of earthquake prediction is developing, as the report jumps from mitigation to what happens once predictions are released.

Sutter, D. and S. Erickson, 2010: The time cost of tornado warnings and the savings with storm-based warnings. *Weather, Climate and Society*, **2(2)**, 103-112.

The authors examine the cost of time spent under tornado warnings issued annually by the National Weather Service (NWS). County-based tornado warnings imposed substantial costs on the nation: an average of 234 million person-hours spent under warnings annually between 1996 and 2004, with a value of $2.7 billion (U.S. dollars) per year. Counties are large relative to tornado damage areas; therefore, county-based warnings overwarned for tornadoes, warning many persons a safe distance from the storm and not in immediate danger. In October 2007 the NWS introduced storm-based warnings (SBW) for tornadoes, which are expected to reduce the area warned by 70%–75%. SBW consequently will reduce the time spent under warnings by over 160 million person-hours per year, with a value of $1.9 billion. The time spent under warnings does not measure the full cost to society because many people do not respond to the warnings. Adjusting for warning response, this study estimates that SBW might save 66 million person-hours actually spent sheltering a year with a value of $750 million. Sensitivity analysis indicates that the value of time spent sheltering saved by SBW exceeds $100 million per year with a probability of 0.95.

Tierney, K., 1993: Disaster preparedness and response: Research findings and guidance from the social science literature. *US-ROC Workshop on Natural Disaster Reduction*, Taipei, Taiwan.

This paper is a non-comprehensive literature review on the state of social science research on disasters, with particular focus on the phases of preparedness and response. From the research it provides guidance on the processes of planning, education, warnings, evacuations, and post-disaster response, based in empirical evidence from previous work. The synthesis provides a resource for further sources on disaster research.

In considering the aspect of time, this paper emphasizes the importance of preparedness being a continual process and plans being living documents, while also recognizing that preparedness is rare in households. It also considers the implications of repeat disasters in forming a “disaster subculture,” or disaster becoming an accepted way of life.

Turner, R.H., 1976: Earthquake prediction and public policy: Distillations from a National Academy of Sciences report. *Mass Emergencies*, **1(3)**, 179-202.

This article details some of the results of the Panel on Public Policy Implications of Earthquake Prediction. It provides a summary of the panel’s findings based on research conducted on other hazard types. It considers the implications of long term prediction and warnings for public response, prediction and warning issuance, economics, legal liability, and politics. Based on this review, the article details twenty recommendations for stakeholders and fourteen research recommendations to be conducted for further understanding of the effect of long term prediction of seismic hazards.

Turner, R.H., 1983: Waiting for disaster: Changing reactions to earthquake forecasts in Southern California. *International Journal of Mass Emergencies and Disasters*, **1(2)**, 307-334.

Several earthquakes near predictions in 1976 initiated a period of waiting in Los Angeles County for a great and destructive earthquake. Hypothesized negative effects of an extended period of waiting under an open-ended threat of disaster include (1) declining sense of urgency and vigilance, (2) disillusionment and disbelief, (3) accumulating anxiety and defensive denial of danger, and (4) resentment and scapegoating. Hypothesized positive effects include (5) familiarization, appreciated, and sensitization, and (6) symbolic and active rehearsal of responses. Interviews with five waves of adult County residents over a period of nearly two years, followed by a sixth wave immediately after a moderate but nondestructive earthquake, provided measures of change and stability of response to earthquake threat. Measures of fear, imminent expectation for a damaging earthquake, household preparedness, confidence in scientific earthquake prediction capability, suspicion that information was being withheld, attitude toward releasing uncertain predictions, focus on scientific as compared with unscientific forecasts, and preferred media source of information on forecasts tend to disconfirm the disillusionment, denial, and scapegoating hypotheses, to support reduced urgency and familiarization hypotheses, and to provide weak support for the rehearsal hypothesis.

Vogt, B.M. and J.H. Sorenson, 1999: Description of survey data regarding the chemical repackaging plant accident West Helena, Virginia. Oakridge National Laboratory, 57 pp.

Shortly after 1:00 p.m. on Thursday, May 8, 1997, clouds of foul-smelling smoke began pouring from an herbicide and pesticide packaging plant in West Helena, Arkansas. An alert was sounded, employees evacuated, and the West Helena fire department was called. As three firefighters prepared to enter the plant, the chemical compounds exploded, collapsing a solid concrete block wall, and killing all three firefighters. As the odorous smoky cloud drifted away from the plant, authorities ordered residents in a 2-mile area downwind of the plant to evacuate and those in the 2- to 3-mile zone to shelter in place. This study examines and compares the responses to a mail survey of those ordered to evacuate and those told to shelter in place. Among the variables examined are compliance with official orders and perceived warnings, threat perception, time and source of first warning, response times, and behavior characteristics for both populations. The findings indicate that 90% of those that were told to evacuate did so but only 27% of those told to shelter-in-place did so, with 68% opting to evacuate instead. The implications of these findings for emergency managers is that people will likely choose to evacuate when both warnings to evacuate and warnings to shelter are issued to residents in close proximity to each other. The findings on warning times closely resemble other findings from evacuations when chemical accidents occur and route notification is used for warning residents.

Time of response is measured in two ways for this report. The first is the time it took the community to receive the first warning. 74% of the community was completely warned within one hour, some taking action before a warning was received because of environmental cues. Time to evacuate was also measured, and similar to other studies, it was found that there was variation in the time it took to evacuate, with some leaving early, most taking a moderate amount of time, and some lagging behind.

Wallace, A.F.C., 1956: Tornado in Worcester: An exploratory study of individual and community behavior in an extreme situation. National Academy of Sciences- National Research Council Publication 392, 166 pp.

The Committee on Disaster Studies of the National Research Council, during the spring and summer of 1953, undertook to carry on a series of exploratory field studies of disaster. Some of these studies were conducted by members of the Committee staff, some by persons retained as consultants, some by organizations under contract. These studies involved many aspects of disaster: evacuation experiences, communications, rumor, panic, rescue and rehabilitation, etc.

Following the tornado which struck Worcester, Massachusetts, on June 9, 1953, several organizations sent personnel to study various phases of the disaster, particularly what happened during the rescue and rehabilitation period. The Committee itself sponsored or facilitated: a study of communications in Worcester and in Flint, Michigan (struck by another tornado the day before) by Irving Rosow, a graduate student at the Russian Research Center at Harvard; a study of the role of the Catholic Church, in Worcester and Flint, by a team from the
Catholic University of America, including Carroll Brodsky, John Muldoon, and Regina Flannery Herzfeld; two studies of medical care following the disaster, one by the Massachusetts General Hospital, and the

other by Jeannette Rayner of the Committee's staff; a study of the psychological and physiological effects of the stress of their tornado experience on a group of previously studied Worcester firemen and industrial employees; and a brief "horseback survey" by the writer aimed at identifying spatial and emotional dimensions of the disaster which would repay systematic analysis later in this or an analogous situation. Other studies made by a variety of persons and organizations are listed in the bibliography of this report.

These studies, and other sources of data, have been collated in the preparation of this report, which is an attempt to analyze the Worcester tornado disaster as an event, according to the categories of the theoretical model developed in the introduction. It is avowedly exploratory, as the sub-title indicates, in two senses: the conceptual formulations (the time -space model, the disaster syndrome, the counter - disaster syndrome, the isolation period, and the cornucopia theory) are intended to stimulate thought rather than to make converts to a system, and accordingly are not presented as a formal body of theory nor as a set of hypotheses verified adequately by the available Worcester materials; and the empirical data, almost entirely compiled by other observers with a variety of interests, are evidently uneven in quality, quantity, in representativeness, and in precision of reference to the matters I have chosen to emphasize. Furthermore, such generalizations as I have made or implied about disasters as types of event obviously will require the assembling of much comparative materials, both for general validation and for necessary qualification. With these caveats in mind, it is hoped that both the empirical data on the Worcester case, and the theoretical formulations which have been worked out to organize these data, will be of some use to scholars and administrators interested in disaster studies. The interpretations and opinions expressed are my own and do not necessarily reflect the views of the Committee on Disaster Studies.

Wolshon, B., J. Jones, and F. Walton, 2010: The evacuation tail and its effect on evacuation decision making. *Journal of Emergency Management*, **8(1)**, 37-46.

Over the past decade, several major incidents have occurred in the United States that have demonstrated the need for a better understanding of the behaviors, characteristics, and requirements of persons traveling during emergency evacuations. In addition to numerous emergency management and preparedness organizations, the agencies charged with the review and approval of plans for emergencies associated with nuclear power plants have also taken particular interest in these issues. Through their support of evacuation-related research, entities like the Nuclear Regulatory Commission and the Federal Emergency Management Agency are leading efforts to recognize and understand the lessons learned from evacuations associated with both natural and technological hazards so that they are not repeated in the future. One area of particular interest (and the one that is the focus of this article) is the segment of an evacuating population known as the “evacuation tail.”The evacuation tail is loosely defined as the last 10 percent of the population that departs during an evacuation. This group is of particular interest because the evacuees that make up the tail have been recognized to take a disproportionally longer amount of time to prepare and travel than the rest of the population. Depending on the specific characteristics of an emergency, such delays can put the tail population at a significantly elevated risk. In this article, the evacuation tail is described within the context of preevacuation activities and evacuee travel characteristics for the purpose of improving the overall evacuation process. It is thought that with this knowledge, the techniques and lessons learned from nuclear power plant evacuation planning can be applied to evacuations of any hazard type or location.

Worth, M.F. and B.F. McLuckie, 1977: Get to high ground!: The warning process in the Colorado floods June 1965. Disaster Research Center Historical and Comparative Disaster Series #3, 74pp.

In 1965, eastern Colorado was hit with flash flooding. This report compares the warning process of ten communities in the northeast and southeast quadrants of Colorado, including their institutional response and time of warnings and confirmation of those warnings for both official agencies and the general public. The comparisons are made between warning time, organizational preparedness, and response to similar flooding situations in each of the ten communities, with a great deal of variety in success between the differing towns. The case studies are examined using a theory of warning systems and processes, which breaks the warning process into three phases: evaluation, alert, and confirmation. For each of the cases, there was no phase of evaluation, but there were differing times between alert, confirmation, and initial flooding.

Zahran, S., S.D. Brody, W.G. Peacock, A. Vedlitz, and H. Grover, 2008: Social vulnerability and the natural and built environment: a model of flood casualties in Texas. *Disasters*, **32(4)**, 537-560.

Studies on the impacts of hurricanes, tropical storms, and tornados indicate that poor communities of colour suffer disproportionately in human death and injury.2 Few quantitative studies have been conducted on the degree to which flood events affect socially vulnerable populations. We address this research void by analysing 832 countywide flood events in Texas from 1997–2001. Specifically, we examine whether geographic localities characterised by high percentages of socially vulnerable populations experience significantly more casualties due to flood events, adjusting for characteristics of the natural and built environment. Zero-inflated negative binomial regression models indicate that the odds of a flood casualty increase with the level of precipitation on the day of a flood event, flood duration, property damage caused by the flood, population density, and the presence of socially vulnerable populations. Odds decrease with the number of dams, the level of precipitation on the day before a recorded flood event, and the extent to which localities have enacted flood mitigation strategies. The study concludes with comments on hazard-resilient communities and protection of casualty-prone populations.