Extreme Weather Forecasting

STATE OF THE SCIENCE, UNCERTAINTY AND IMPACTS

Edited by Marina Astitha and Efthymios Nikolopoulos

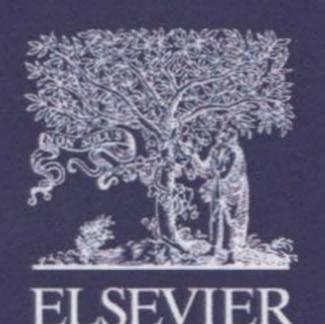
Extreme Weather Forecasting reviews current knowledge about extreme weather events, including key elements and less well-known variables to accurately forecast them. It covers multiple temporal scales as well as components of current weather forecasting systems. It also includes case studies on successful forecasting as well as the impacts of extreme weather predictability. This book is a comprehensive model agnostic review of best practices for atmospheric scientists and others who utilize extreme weather forecasts.

Key features:

- Reviews recent developments in numerical prediction for better forecasting of extreme weather events
- Covers causes and mechanisms of high-impact extreme events and how to account for these variables when forecasting
- Includes numerous case studies on successful forecasting, outlining why they worked

Dr. Marina Astitha is an associate professor and the associate department head at the Department of Civil and Environmental Engineering, University of Connecticut (UConn). Dr. Astitha's expertise lies in the areas of atmospheric numerical modeling (weather and air quality) from regional to global scales. She is leading the Atmospheric Modeling and Air Quality Group since joining UConn in 2013. Her research program focuses on improving the prediction of extreme weather events, wind prediction for wind farm facilities, and integration of multimedia modeling systems with machine learning to solve environmental problems. She is committed in supporting, mentoring, and inspiring the next generation of engineers to innovate, lead, and thrive in solving complex environmental problems and sustain a healthy, diverse, and equitable society in the years to come.

Dr. Efthymios Nikolopoulos is an assistant professor at the Department of Mechanical and Civil Engineering at Florida Institute of Technology. His research focuses on the integration of remote sensing observations with numerical and statistical modeling in order to advance understanding and predictability of water cycle components and weather-related hazards. Dr. Nikolopoulos has authored/coauthored 60 peer-reviewed publications and 8 book chapters in the areas of hydrometeorology, remote sensing of precipitation, flood hydrology, and landslide/debris flow prediction. He is an associate editor for the Journal of Hydrology and the recipient of the NASA Earth System Science Graduate Fellowship and the Marie Curie Postdoctoral fellowship.



9 780128 201244

Contents

List	of con	tributors		XI				
For	eword			XV				
Pre	face			xvii				
1.	Over	view of extreme weather events, impacts and						
	forec	asting techniques		1				
	1.1 D	Definition of extreme weather events		1				
	Marin	a Astitha and Efthymios Nikolopoulos						
	111	Extreme heat		3				
		Extreme cold—severe winter storms		3				
		Tropical and extratropical storms		5				
		Severe convective storms		5				
		Extreme rainfall		6				
	1.2 V	Veather forecasting		7				
	Marin	Marina Astitha, Linus Magnusson and Efthymios Nikolopoulos						
	-							
	13 F	xtreme weather forecasting in urban areas		14				
		I Tewari, Zhihua Wang, Dan Chen, Quang-Van Doan, uki Kusaka, Prathap Ramamurthy and Pallav Ray						
	1.3.1	Introduction		14				
		Urban heat island		15				
		Heat wave forecasting		18				
		Air quality modeling and prediction		22				
		Forecasting urban precipitation		26				
	1.3.6	Forecasting coastal urban flooding		29				
	1.4 V	Vildfires and weather		31				
		o Kosovíc, Timothy W. Juliano, Amy DeCastro, Maria Frediar	ni					
		nda Siems-Anderson, Pedro Jimenez, Domingo Muñoz-Espar						
		C. Knievel and Masih Eghdami						
	1.4.1	Introduction: wildfires and weather—a coupled system		31				
		1.4.1.1 Wildfire impacts		34				
		1.4.1.2 Wildfire severity and weather		35				
		1.4.1.3 Wind storms, droughts, and storm outflows		38				

		1.4.1.	4 Pyro	cumulus and pyrocumulonimbus clouds	41
		1.4.1.	5 Wild	fire emissions and transport	44
	1.4.2	Wildf	ire predi	iction and risk assessment	46
		1.4.2.	.1 Wild	fire prediction	46
		1.4.2.	2 Wild	fire risk assessment	50
	1.4.3	Data	requirer	nents and data quality	53
		1.4.3.	.1 Mete	eorological data	53
		1.4.3.	2 Fuel	data	54
		1.4.3.	.3 Fire	perimeter data	57
		1.4.3.	.4 Data	assimilation	60
	1.4.4	Wildf	ire predi	iction sensitivities and uncertainties	61
		1.4.4.	.1 Sens	itivity to weather forecast	61
		1.4.4.	.2 Sens	itivity to fuel characteristics	61
				itivity to ignition location and fire perimeter	63
				mble prediction for uncertainty quantification	64
	1.4.5			dfire modeling for improved wildfire preparedness	65
				collection, quality control, archiving, and standards	65
		1.4.5		fire spread parameterizations	66
		1.4.5	.3 Ope	rational wildfire prediction and risk assessment systems	67
	Refer	rences			68
2.	Ope	ration	al mult	tiscale predictions of hazardous events	87
	Linus	s Magn	usson, (C. Prudhomme, F. Di Giuseppe,	
	C. Di	Napol	i and F.	Pappenberger	
	2.1	Introdu	uction		87
	2.2	Examp	le case:	2015 European heatwave	90
	2.3	Key fac	ctors of p	predictability	94
		2.3.1	Europea	an heatwaves	95
		2.3.2	Europea	an cold spells	96
		2.3.3	Northwe	estern European windstorms	97
		2.3.4	Precipita	ation extremes due to North-Atlantic cyclones	98
		2.3.5	Precipita	ation extremes in southern Europe	98
		2.3.6	Severe o	convection	99
	2.4	Hazaro	d forecas	ting	100
		2.4.1 Hydrological processes and predictability of flood and droughts 10			
		2.4.2	Challen	ges	103
			2.4.2.1	Type of hydrological, floods and drought forecasting, mode	ls 106
			2.4.2.2	Improving usefulness of flood and drought forecasting	
				systems	107
			2.4.2.3	Hazard thresholds	107

		2.4.2.4	Impact forecasting	108	
		2.4.2.4	Seamless forecasting	109	
	2.4.3	Fire risk		110	
		2.4.3.1	Forecasting fire at different spatial and temporal scales	111	
	2.4.4	Heat str	ess	112	
		2.4.4.1	Hazard forecasting	113	
		2.4.4.2	Discussion	115	
2.5	Evalua	tion of h	nazardous events	116	
	2.5.1	Observa	ations for evaluation	117	
	2.5.2	Evaluati	on metrics	120	
2.6	Conclu	usion		121	
2.7	Summ	ary		121	
Refer	rences			123	
			eme weather events and associated impacts:		
Case	Stuc	lies		131	
3.1	Extrer	ne hea			
Mart	ina Ca	lovi, We	iming Hu, Laura Clemente and Guido Cervone		
3.1.1	Intro	duction		131	
	3.1.1	.1 Hea	t waves	133	
	3.1.1	.2 Soci	ial vulnerability	135	
	3.1.1	.3 Nun	nerical weather forecasting	139	
3.1.2	Data			140	
	3.1.2	.1 Nor	th American Mesoscale Forecast System	141	
	3.1.2	.2 Wea	ather Underground	142	
	3.1.2	.3 Soci	ioeconomic	144	
3.1.3	3 Methodology				
	3.1.3	.1 Ana	log Ensemble independent search	144	
	3.1.3		antages and disadvantages of the Analog Ensemble Inique	146	
	3.1.3	.3 The	Schaake Shuffle	146	
	3.1.3	.4 Bias	correction for rare events	148	
	3.1.3	.5 Spar	tiotemporal downscaling	148	
	3.1.3	6.6 Acc	essibility	149	
3.1.4	Resu	lts		151	
3.1.5	Con	clusions		165	
Acro	nyms			166	
Refer	rences			167	

3.2 Atmospheric rivers

Forest Cannon and Luca Delle Monache

3.2.1	Introduction				
3.2.2	Atmosp	heric river evolution	174		
	3.2.2.1	Mesoscale predictability challenges in atmospheric rivers	176		
	3.2.2.2	Precipitation generation in atmospheric rivers	177		
	3.2.2.3	Factors modifying hydrologic impacts during			
		atmospheric rivers	178		
3.2.3	Forecas	ting atmospheric rivers	178		
	3.2.3.1	Initialization	180		
	3.2.3.2	Parameterization	183		
	3.2.3.3	Grid resolution	184		
3.2.4	Regiona	al models	186		
3.2.5	Ensemb	le forecast systems	188		
3.2.6	Verificat	ion	193		
3.2.7	Decision	n support	195		
	3.2.7.1	Calibration of atmospheric river forecasts	195		
	3.2.7.2	Role of partnerships between forecasting agencies and			
		stakeholders	195		
3.2.8	Summa	ry	196		
Refere	ences		196		
3.3 T	he hvd	rological Hillslope-Link Model for space-time			
		on of streamflow: insights and applications at			
-		Flood Center			
Ricard	lo Manti	lla, Witold F. Krajewski, Nicolas Velasquez, Scott Small,			
		v, Felipe Quintero, Navid Jadidoleslam and Morgan Fonley			
3.3.1	Introduc	rtion	200		
4		ric set of ordinary differential equations to model water	200		
3.3.2		the landscape and the river network	204		
3.3.3		decomposition and model inputs for the implementation of			
		e-Link Model	210		
	3.3.3.1	Horizonal landscape decomposition	210		
	3.3.3.2	Configurations of hillslope-scale vertical and horizontal flows	210		
	3.3.3.3	Meteorological inputs	211		
	3.3.3.4	Streamflow gage stations	213		
	3.3.3.5	Automated flood forecasting system	214		
3.3.4					
		and horizonal fluxes at the hillslope scale	215		
	3.3.4.1	The simplest closure relationship: constant runoff coefficient	215		

	3.3.4.2	A variable runoff-coefficient model dependent on	
		top-layer soil moisture and ponded water storage	218
	3.3.4.3	A novel nonlinear parameterization for subsurface flows	220
3.3.5		and real-time applications of the Hillslope-Link Model	
	at the lo	owa Flood Center	222
	3.3.5.1	Effect of rainfall resolution and spatial randomness	222
		Propagation of hillslope scale oscillations	223
	3.3.5.3	A case study: real-time prediction of the September 2016 flood event along the Cedar River	225
3.3.6	Summa	ry and conclusions	233
3.3.7	Future	work and upcoming challenges	235
Ackno	wledgm	ents	235
Refere	ences		235
215	ocial in	npacts: integrating dynamic social vulnerability in	
		pacts. Integrating dynamic social vulnerability in passed weather forecasting	
Galate	eia Terti,	Sandrine Anquetin and Isabelle Ruin	
3.4.1	Drivers	of social impacts from extreme weather events	239
	3.4.1.1	What is the role of human exposure and vulnerability	
		in weather-related disasters?	239
	3.4.1.2	How is social vulnerability defined and measured?	241
	3.4.1.3	The space-time scales of human exposure: an intersection of the weather and vulnerability driving forces?	242
	3.4.1.4	How the concept of dynamic social vulnerability can support weather impacts prediction?	244
3.4.2	The nee	ed for integrated forecasting tools to anticipate social impacts	247
	3.4.2.1	Are hazard forecasts sufficient to improve early warning	
		systems?	247
	3.4.2.2	How to shift from hazard forecasts to impact-based	
		forecasts?	250
	3.4.2.3	How vulnerability metrics can complement hydrologic forecasts toward impact estimation?	252
3.4.3		of methodological advances in modeling the coupled	
		drometeorological system in high-impact weather events	255
	3.4.3.1	Examples of two aggregated and individual-based microscale interdisciplinary approaches	255
	3.4.3.2	Methodological comparison: strengths and weaknesses of the interdisciplinary modeling	261
3.4.4	Toward	operational decision-making in high-impact weather events:	
	insights	from a participatory role-playing experiment	264
3.4.5	Conclus	sion	268
Refere	ences		270

3.5 Landslides and debris flows

Dalia B. Kirschbaum and Sana Khan

3.5.1	Introduc	ction	278		
3.5.2	Data an	d methodology	280		
	3.5.2.1	Precipitation products	280		
	3.5.2.2	Methodology	281		
3.5.3	Results		282		
	3.5.3.1	Contiguous United States evaluation	282		
	3.5.3.2	Global evaluation	288		
	3.5.3.3	Case studies	292		
3.5.4	Discussi	ion	297		
3.5.5	Conclus	sions	301		
Ackno	wledgm		302		
Refere	ences		302		
3.6 V	Veather	-induced power outages			
Diego	Cerrai a	and Emmanouil Anagnostou			
3.6.1	Power	grid outages and severe weather	305		
3.6.2	Modelir	ng weather impact on the electric grid	307		
	3.6.2.1	Power outages during tropical storms	312		
	3.6.2.2	Power outages during extratropical rain and wind storms	315		
	3.6.2.3	Power outages during thunderstorms	318		
	3.6.2.4	Power outages during snow and ice storms	320		
Refere	References				
erword			327		
ex			329		