Changes in Mediterranean Climate Extremes: Patterns, Causes, and Impacts of Change

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A thesis submitted for the degree of Doctor of Philosophy
at the University of East Anglia, Norwich
December, 2006

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Abstract

The Northern Mediterranean region includes a wide range of climatic variability, and a spectrum of economies that have entered the EU at different times. This study attempts to increase understanding and predictability of both the Mediterranean climate and the potential for climate derived socio-economic impacts a selection of these economies may face. A methodology is detailed whereby the target region is assessed for the patterns and causes behind extreme climatic events (that may challenge current adaptation strategies), and the kinds of socio-economic outcomes that they may produce.

In order to explore the behaviour of floods, droughts, heatwaves, and cold snaps, across the Northern Mediterranean region (35°-45°N, –10°-30°E) with a selection of hemispheric circulation predictors (drawn from the NCEP/NCAR reanalyses), two differing models have been used. Orthogonal Spatial Regression (OSR) is an inversion of a dendroclimatology technique that relies on spatial variability, with Principal Components Analysis (PCA) at its core. Radial Basis Function Artificial Neural Networking (RBF ANN) is a machine-learning pattern matching approach, capable of non-linearity. The two have been applied as direct downscaling methods to the STARDEX (STAtistical and Regional dynamical Downscaling of EXtremes for European regions) indices of extremes, across the target area. Analysis suggests that there may be significant departures between regional and seasonal contrasts in extreme behaviour, and those evident for mean climate. In addition, where warming occurs, extreme high temperatures generally show a trend of greater magnitude than the mean. Modelled links between circulation predictors and extreme climate are consistent with these results, statistically significant, largely linear, and are (in many cases) stronger for extremes than the mean. Distinct circulation regimes have been identified, as described by groups of predictors (representative of Atlantic influence, for instance), each with effects that are relevant to a particular region, season, and type of Mediterranean extreme climate.

This thesis also explores direct relationships between extreme events (quantified by the indices of extremes) and socio-economic indicators (i.e., agricultural yield, energy consumption, and excess mortality). OSR and ANN are applied again, as

econometric upscaling models, between climate indices and socio-economic indicators, to provide the final link in a chain of potential predictability. Long-term (i.e., decadal) trends in the socio-economic indicators considered are consistent with non-climatic influences. However, regional variations in sensitivity to extreme climate have been identified (on a seasonal basis) that demonstrate both the advantages of using upscaling technique, and the use of station-scale predictors over spatially aggregated data. The model functions (e.g. linear, gaussian, or quadratic) most useful for modeling relationships are seen to vary between regions and seasons. Furthermore, regions that display strong trends in extreme behaviour and significant links to sensitive sectors of activity have been highlighted. This study suggests that Mediterranean climate extremes are changing over time, and that policy concerning the socio-economic impacts of those changes must be specified with regional concerns in mind.

Acknowledgements

I would like to thank my supervisors, Dr. Clare Goodess, and Prof. R. Kerry Turner for their diligence, rigour, and support. I would also like to thank Prof. Phil Jones for providing many insightful comments on the climate side of this thesis.

Various members of the Climatic Research Unit have provided invaluable advice and aid during my time here, in particular Jean Palutikof, Mike Salmon, Ian Harris, and my office mates - David Foxall, Carol McSweeney, Ali-Reza Massah, Amanda Townsend, and Kate Willet.

The data used for this thesis have been acquired from several sources. Daily climate data were compiled from sets provided by members of the STARDEX project, FIC, KNMI, the U.K. Met Office, and the Bosnian and Slovenian Meteorological Offices. Both NCEP/NCAR reanalysis data (Ian Harris), and the NAO index time series (Phil Jones) were provided by CRU. Fotis Panagiotopoulos supplied the Siberian High index data. Data regarding extreme climate events were acquired from Munich Re, and OFDA/CRED (the Em-dat database). The databases of Eurostat, the World Bank, the WHO, and the FAO were used to develop the socio-economic indicators in Chapter 6.

Phil Jones and Keith Briffa wrote the original Orthogonal Spatial Regression Fortran program developed here, Colin Harpham wrote the Radial Basis Function Artificial Neural Network C++ program, and Malcolm Haylock wrote the Indices of Extremes program (for the STARDEX project), used to calculate climate indices in Chapter 3.

In addition to the above I would also like to thank my kind and patient friends in both Norwich and parts distant, particularly for much needed opportunities to let off steam. Final mention goes to my family, who have provided essential assistance in times of trouble, endless encouragement, and most importantly, inspiration.

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List of Acronyms

AIR	All India Averaged Rainfall
ANN	Artificial Neural Networks
AYA	Agricultural Yield per
	hectare Anomaly
BLUE	Best Linear Unbiased
	Parameters
BOSR	Basin OSR
CAP	Common Agricultural Policy
CCA	Canonical Correlation
	Analysis
CDD	Cooling Degree Days
CLR	Classical Least-squares
	Regression
CO_2	Carbon Dioxide
CRU	Climatic Research Unit
DEFRA	Department for
	Environment, Food, and
	Rural Affairs
	Diurnal Temperature Range
DTR	East-Atlantic West-Russia
	pattern
EAWR	European Climate
	Assesment
ECA	ECA and Dataset
	Commerical Electricity
ECA&D	Consumption
ECC	European Centre for
	Medium-range Weather
ECMWF	Forecasting
	European Coal and Steel
	Community
ECSC	European Economic
	Community
EEC	Emergency Disasters Data
	Base
EM-DAT	Excess Mortality Index
	El Niño-Southern
EMI	Oscillation
ENSO	Empirical Orthogonal
	Function
EOF	ECMWF ReAnalysis
	Residential Electricity
ERA	Consumption
ERC	European Union
EU	

EU-ETS	EU Emission Trading
	Scheme
FAO	Food and Agricultural
	Organization
FIC	Fundación para la
	Investigación del Clima
GBF	Gaussian Basis Function
GCM	General Circulation Model
GDP	Gross Domestic Product
GNP	Gross National Product
HadCM	Hadley Centre Coupled
	Model
HadRM3	Hadley Centre Regional
	Model 3
HDD	Heating Degree Days
hPa	hectoPascals
HGT	Geopotential HeiGhT
IPCC	Intergovernmental Panel on
	Climate Change
ITCZ	Inter-Tropical Convergence
	Zone
JJA	June, July, August
KNMI	Koninklijk Nederlands
	Meteorologisch Instituut
LBF	Linear Basis Function
MAM	March, April, May
mb	millibars
MEI	Multivariate Enso Index
MICE	Modelling the Impact of
	Climate Extremes
MLP	Multi-Layer Perceptron
MO	Mediterranean Oscillation
MO(AC)	MO for Algiers and Cairo
MO(GI)	MO for Gibraltar and Israel
MPI	Mediterranean Pressure
	Index
MSLP	Mean Sea Level Pressure
NADW	North Atlantic Deep Water
NAO	North Atlantic Oscillation
NCAR	National Center for
	Atmospheric Research
NCDC	National Climatic Data
	Center
NCEP	National Centers for
	Environmental Prediction
NOAA	National Oceanic and
	Atmospheric Administration

NCPI	NSCP Index
NSCP	North-Sea Caspian Pattern
OLS	Ordinary Least Squares
OSR	Orthogonal Spatial Regression
PC	Principal Component
PCA	Principal Component Analysis
PDF	Probability Density Function
PDSI	Palmer Drought Severity Index
PF90	Fraction Of Rainfall Due To Wet Days Index
PINT	Rainfall Intensity Index
PN90	Number Of Days Classed As Wet Index
PQ90	Wet Days Index
PREC	Mean Total Daily Rainfall Index
PX5D	Five Day Maximum Rainfall Index
PCDD	Consecutive Dry Days Index
RBF	Radial Basis Function
RCM	Regional Climate Model
RMSE	Root Mean Squared Error
ROSR	Regional OSR
SRES	IPCC Second Assessment Report
SH	Siberian High
SHI	Siberian High Index
SHM	Specific HuMidity
SLP	Sea Level Pressure
SOI	Southern Oscillation Index
SON	September, October, November
SPI	Standardized Precipitation Index
SRES	IPCC Special Report on Emission Scenarios
SST	Sea Surface Temperature
STARDEX	STatistical And Regional dynamical Downscaling of Extremes for European regions
SVD	Singular Value Decomposition
TAR	IPCC Third Assessment Report
TAVG	Mean Temperature Index
TPF	Thin Plate spline basis Function
THC	Thermohaline Circulation
TMAX	Maximum Temperature Index
TMIN	Minimum Temperature Index
TNFD	Frost Days Index
TN10	Cold Nights Index
HWDI	Heat Wave Duration Index
TX90	Warm Days Index
UCTE	Union for the Co-ordination of Transmission of Electricity
UEA	University of East Anglia
UKMO	United Kingdom Met Office
UM	Unified Model
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organisation
USD	United States Dollars
WDCGG	World Data Centre for Greenhouse Gasses
WG1	Working Group 1 of the TAR
WMO	World Meteorological Organization
WHO	World Health Organization