EGU Session NH1.4: NBS for hydro-meteorological risk reduction

Evaluating nature-based solutions in a non-stationary climate with changing risk of flooding

OPERANDUM
OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks

GLOBAL CENTRE FOR CLEAN AIR RESEARCH
UNIVERSITY OF SURREY

Sisay E. Debele, Jeetendra Sahani, Silvia Maria Alfieri, Paul Bowyer, Nikos Charizopoulos, Michael Loupis, Massimo Menenti, Fabrice Renaud, Mohammad Aminur Rahman Shah, Christos Spyrou, Thomas Zieher, Silvana Di Sabatino, and Prashant Kumar

Introduction

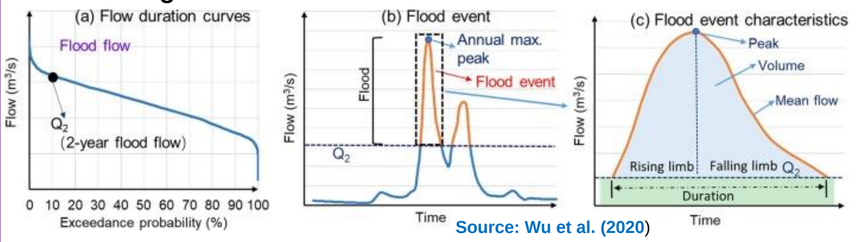
In a rapidly changing environment, analysis of risks linked with non-stationary hydroclimatic extremes has many important implications for resilient and sustainable water resources management, including the evaluation of risk for existing protection measures and the design of new measures (e.g., NBS). This study develops the non-stationary framework to better address various challenges associated with a rapidly changing environment.

Objective

- The aim of this study is to apply non-stationary flood frequency models using the generalized extreme value (GEV) distribution to model the changes in flood risk under two scenarios:
- without NBS in place and; and
- with NBS i.e. wetlands/retention ponds

Methodological framework

- **Extracting flood events**



Source: Wu et al. (2020)

GEV model: Parameter estimation: maximum likelihood estimation (MLE)

- **Probability density function of the GEV**

$$GEV(y;\mu,\sigma,k) = exp\left\{-\left[1+k\left(\frac{y-\mu}{\sigma}\right)\right]^{-1/k}\right\}$$ **Stationary model**

$$GEV\left(y;\mu(t),\sigma(t),k(t)\right) = exp\left\{-\left[1+k(t)\left(\frac{y-\mu(t)}{\sigma(t)}\right)\right]^{-1/k(t)}\right\}$$ **Non-Stationary model**

$$\mu(t) = \beta_0 + \beta * time$$
$$\sigma(t) = \beta_0 + \beta * time$$ **Trend parameters**

Data sources: Weather and Hydrological data

Weather data: Precipitation, temperature and evapotranspiration are obtained from regionally downscaled climate projections from the **EURO-CORDEX project.** The data covered the period from 1950-2100.

Regional climate model:SMHI-RCA4 (OAL-Greece &
KNMI-RACMO22E (OAL-Ireland)

Hydrological data: Lumped Variable Source Area Watershed Model is forced with precipitation, minimum & maximum temperature and evapotranspiration to simulate streamflow for 1950-2100.

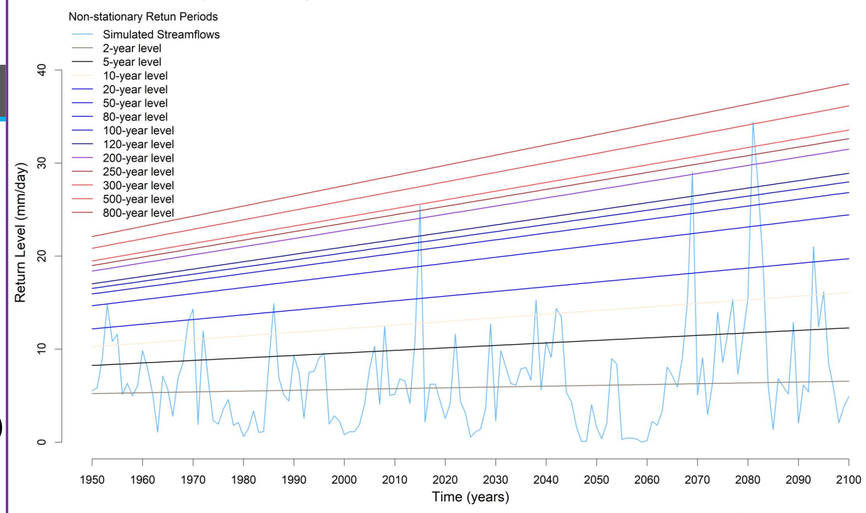
Preliminary Results

1). Statistical Model

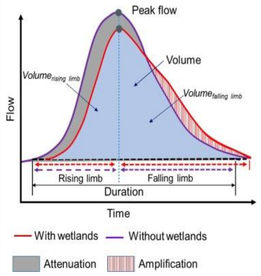
- **Stationary and Nonstationary Gumbel Models fitted to the Annual Flood Data of OAL-Ireland**

Fitted model	Estimated parameters	Log-likelihood	AIC	Test statistics (alpha = 5%)
Stationary Gumbel model	$\mu = 4.47\ \sigma = 3.9$	$\ell = -449.084$	902.168	$D = 8.6746$ $\chi^2 = 5.99$ p−value = 0.01307
Non-stationary Gumbel model	$\mu_0 = 4.24\ \mu_1 = 0.003$ $\sigma_0 = 2.66\ \sigma_1 = 0.0159$	$\ell = -444.7467$	897.4933	

- **Nonstationary return periods**



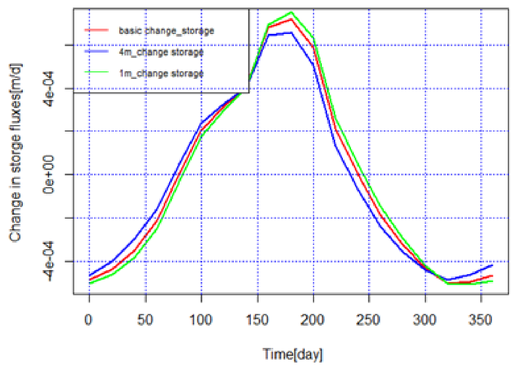
2). Hydraulic model: HEC-RAS: NBS - Wetlands and room for the river



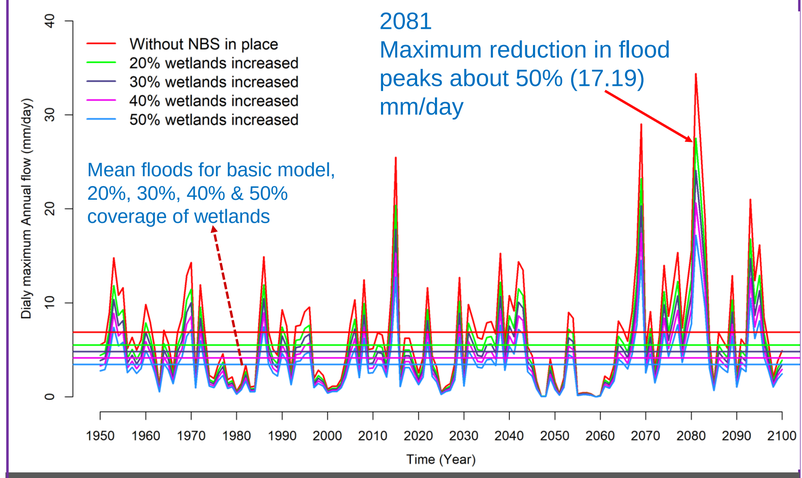
Source: Wu et al. (2020)

Graphical representation of how wetlands affect floods in terms of peak and mean flow, duration and flow volume.

- **Increasing bottom width of the river**
- Bottom width of basic model 2m
- **Scenario 1**: Bottom width increase double (100%) = 4m)
- **Scenario 2**: Bottom width decreased (50%) = 1m)



- **Efficiency analysis by increasing the percentage of wetlands by 20%, 30%, 40% and 50%**



Summary & Conclusions

- Non-stationary model results project a decrease in flood risk for OAL-Greece and an increase in flood risk for OAL-Ireland.
- Our modeling study shows that wetlands can attenuate flood peaks between 20% (6.88 mm/day) and 50% (17.19 mm/day) in the large river basin.
- The attenuation efficiency of these wetlands varied with their location and size in the basin, especially apparent on peak flow, mean flow and flow volume on the rising limb of a flood event
- Increasing the width/area of the river could decrease surface runoff/flow velocity and increase groundwater storage/recharge.

Acknowledgements

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Contact: s.debele@surrey.ac.uk, www.surrey.ac.uk/gcare,
https://www.operandum-project.eu/
@GCARE@AirPollSurrey; @firaol_SED; @OPERANDUM_EU