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ENERGY TRANSFERS IN ATMOSPHERE AND OCEAN

cen

Probabilistic assessment and projections of US weather and climate risks and economic damages

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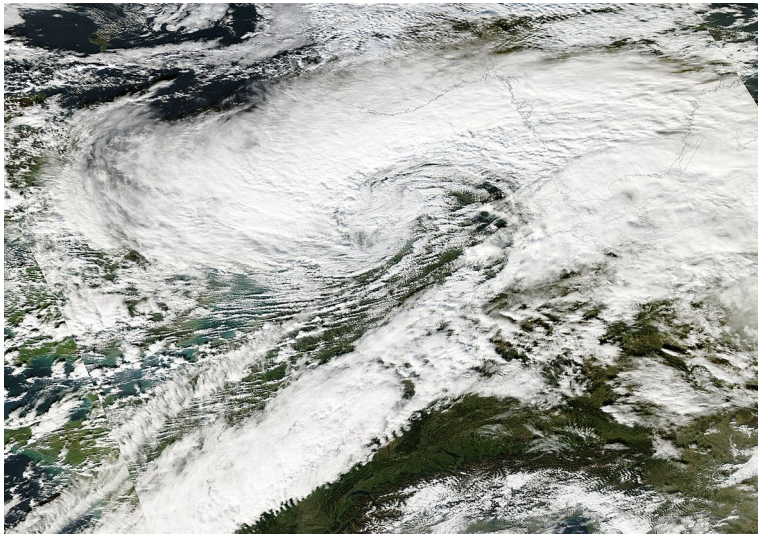
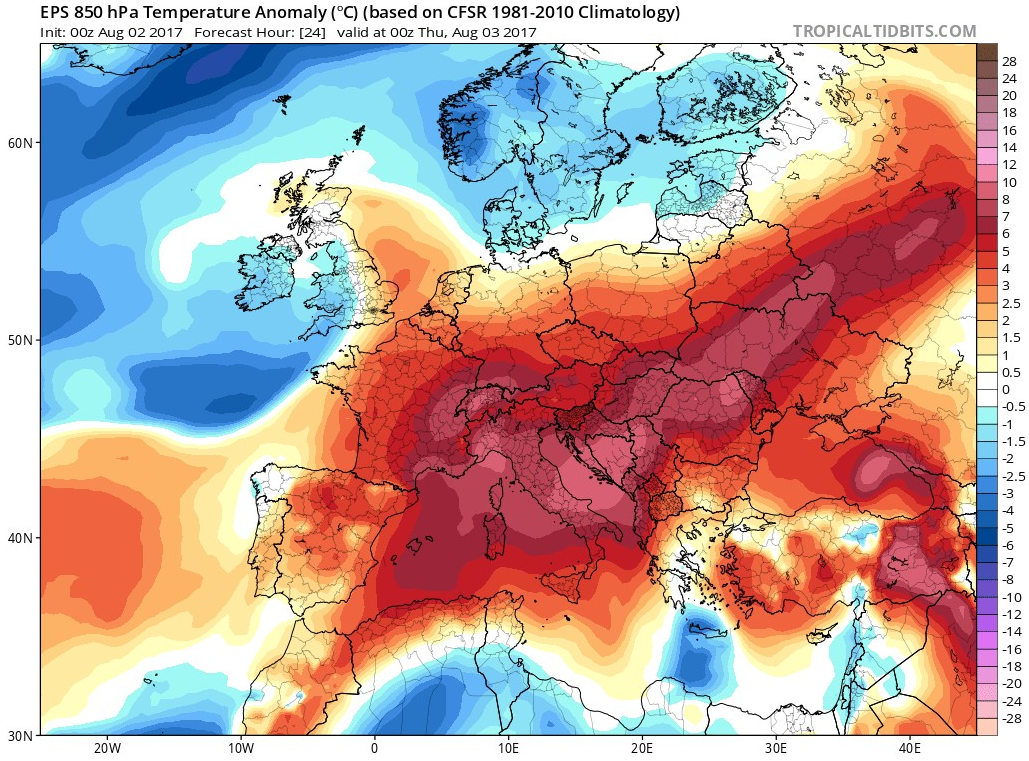
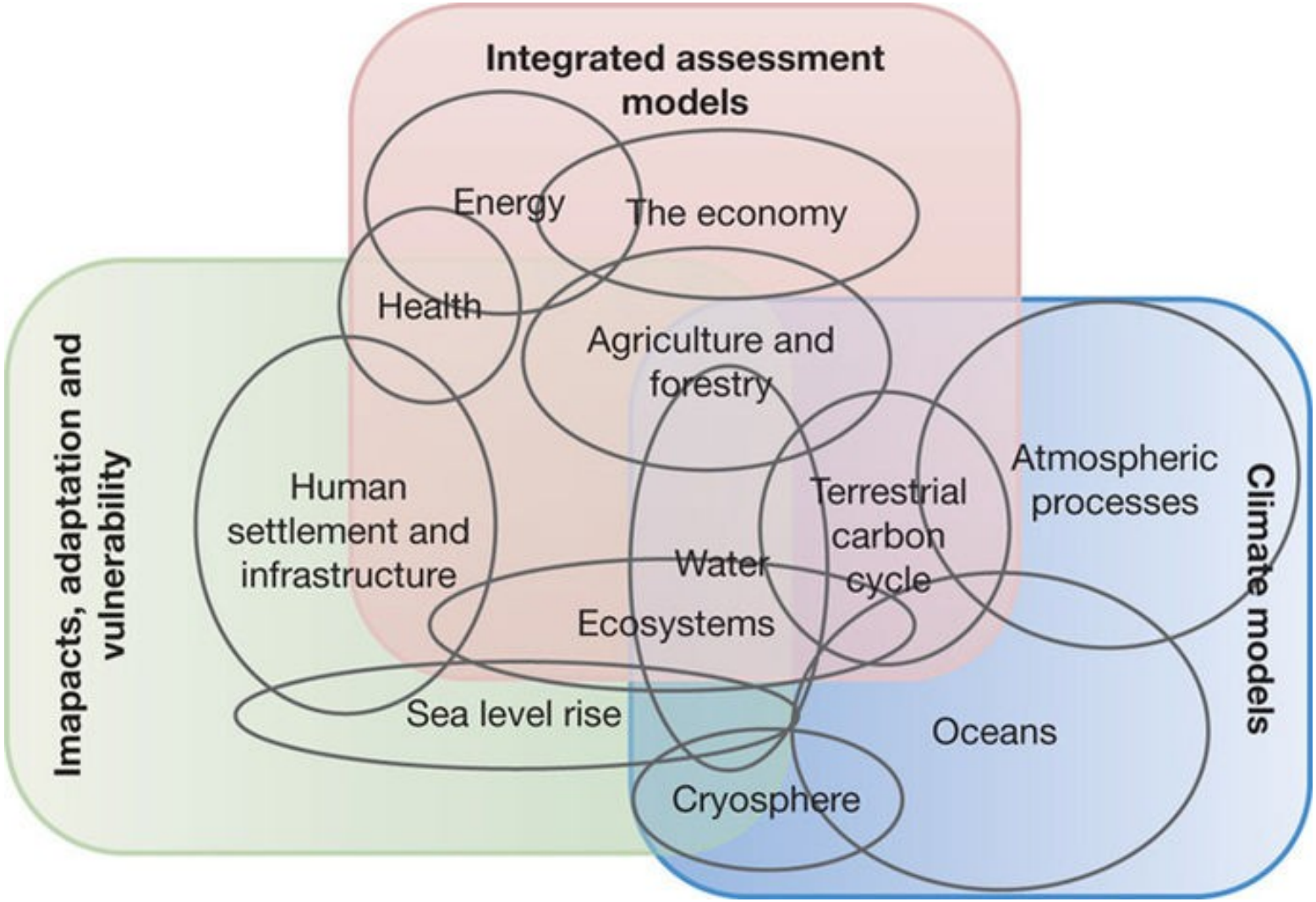
Introduction



Introduction

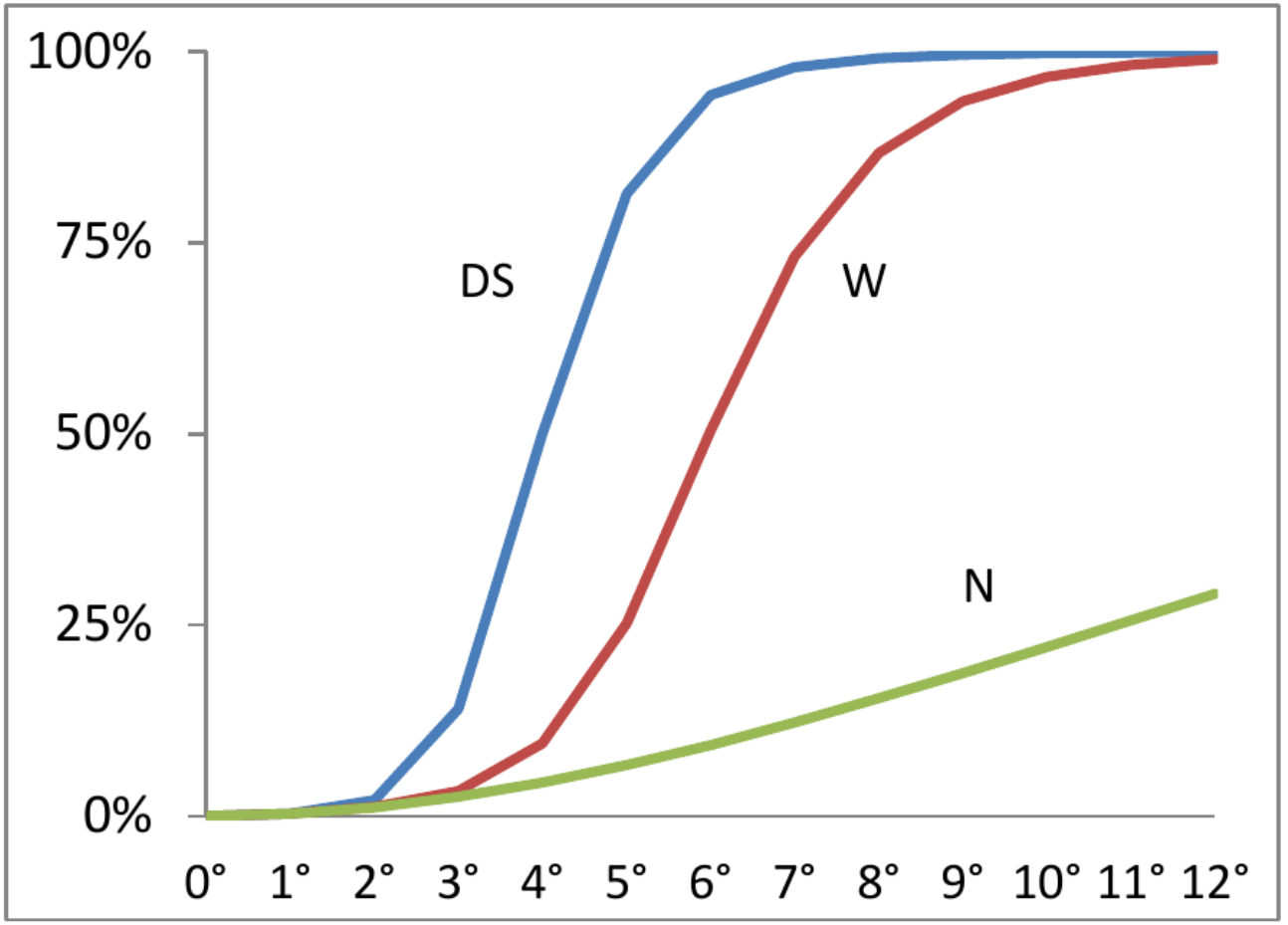


Integrated Assessment Models (IAM)



Moss et al. 2010

Climate Damage Functions in IAMs

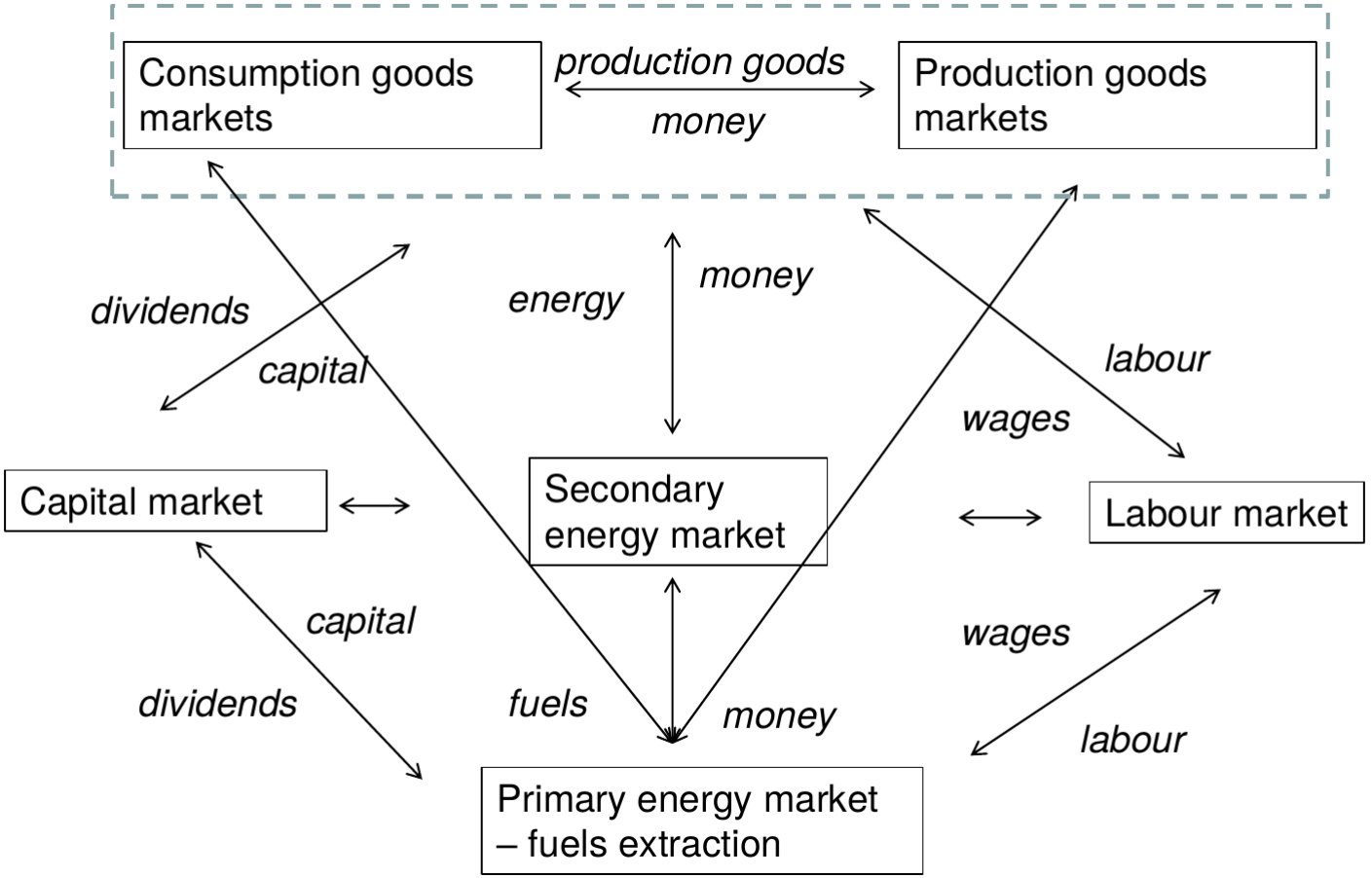


N: Nordhaus 2013
γ=0
W: Weitzman 2012
γ=1, β=6.1
DS: Dietz and Stern 2014
γ=1, β=4.0

$$Damage = 1 - \left(1 + \left(\frac{T}{18.8}\right)^2 + \gamma\left(\frac{T}{\beta}\right)^{6.754}\right)^{-1}$$

Covington and Thamotheran 2015

Agent-Based Model



Czupryna et al. 2019; in revision

Extreme Weather and Climate Events

Aims

- Damage function for extreme events
  - Fit extreme value distribution
- Identify covariates
  - Is global warming (GMST) increasing number of extreme events/economic damages?
- Probabilistic projections
  - Based on SSP, RCP & CMIP5

Definition of Disasters

Category	Cat-Class	Worldbank Income Groups				Number of fatalities
		High income	Upper middle income	Lower middle income	Low income	
		The threshold depends on the different stages of development				
Catastrophe	4	≥ 3.000	≥ 1.000	≥ 300	≥ 100	≥ 1,000
Major loss event	3	≥ 300	≥ 100	≥ 30	≥ 10	100 - 999
Medium loss event	2	≥ 30	≥ 10	≥ 3	≥ 1	10 - 99
Small loss event	1	≥ 3	≥ 1	≥0.3	≥ 0.1	1 - 9

Hoeppe 2016

Data

Centre for Research on the Epidemiology of Disasters
EM-DAT:
The International Disaster Database
http://www.emdat.be/

Definition of Disasters

EM-DAT Definition of Disasters:

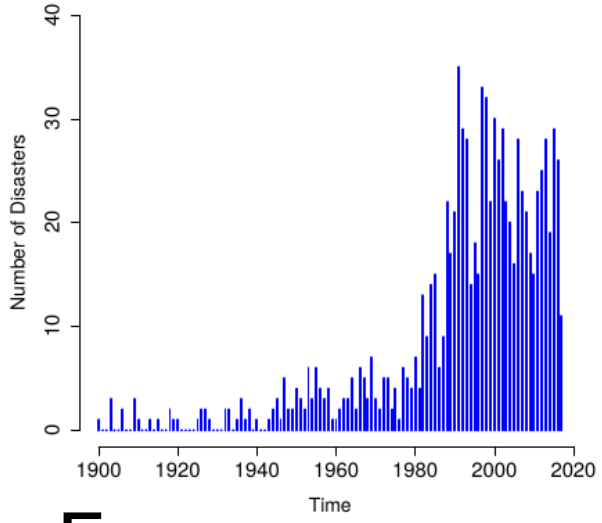
- 10 or more people dead
- 100 or more people affected
- The declaration of a state of emergency
- A call for international assistance

Natural Disasters

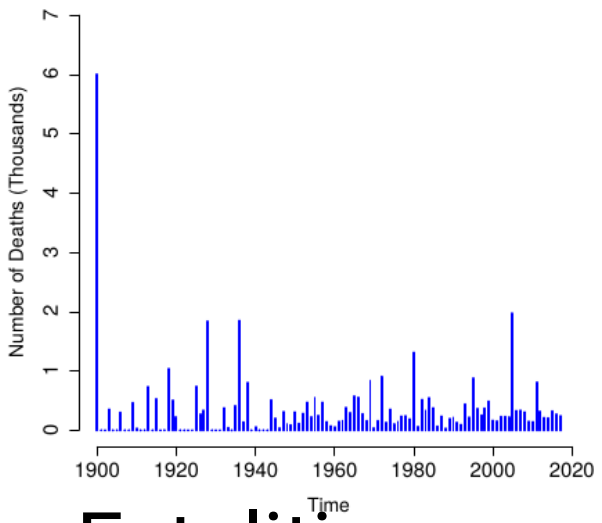
EM-DAT Sub-group: Natural Disasters:

- Climatological
- Meteorological
- Hydrological

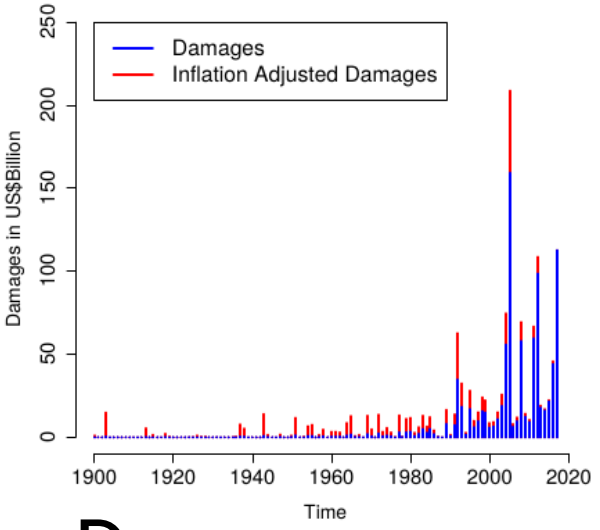
Weather-related Disaster Data



a) Frequency



b) Fatalities



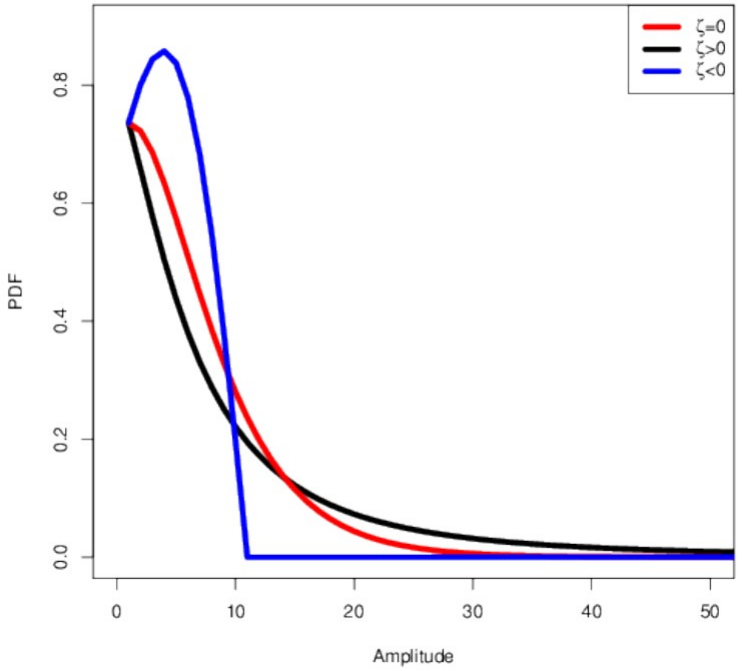
c) Damage

US Data (1900-2016)

Extreme Value Statistics

Generalized Pareto Distribution with Poisson Process

$$p(z) = \frac{1}{\sigma}\left(1 + \zeta\frac{x-\mu}{\sigma}\right)^{-(1+\frac{1}{\zeta})}$$



Non-Stationarity:

$$\zeta(t) = \zeta_0 + \zeta_1 COV_1 + \zeta_2 COV_2 + ...$$

$$\sigma(t) = \sigma_0 + \sigma_1 COV_1 + \sigma_2 COV_2 + ...$$

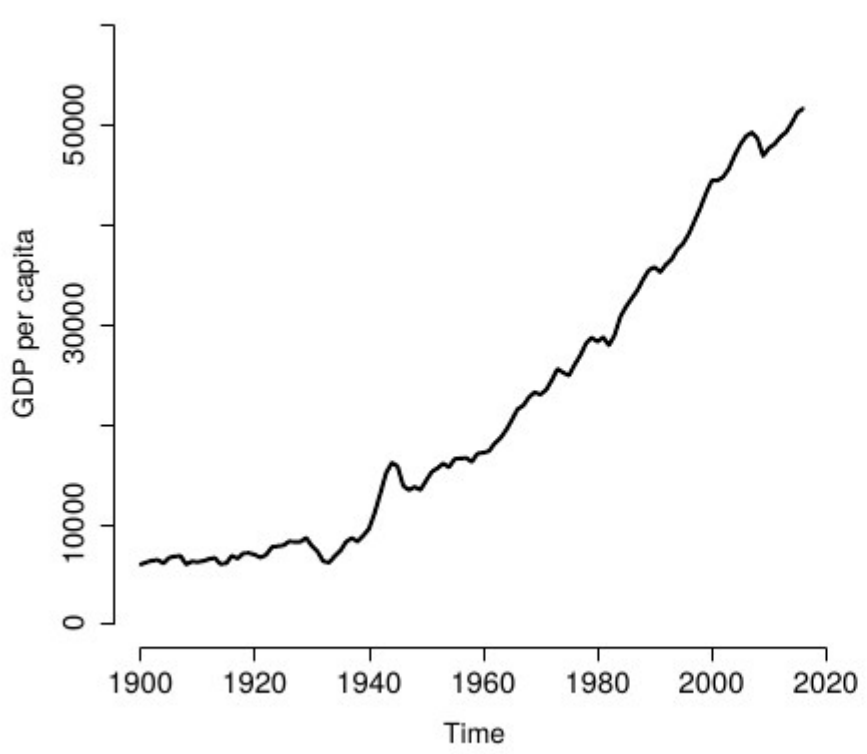
Covariates 1900-2016

- Global Mean Surface Temperature (GMST)
- Sea level
- ENSO3.4
- Atlantic Multidecadal Oscillation (AMO)
- Pacific Decadal Oscillation (PDO)
- Atlantic Accumulated Cyclone Energy Index (ACE)
- Atlantic Basin Monthly Hurricane Statistics (NTC)
- Population
- GDP per capita (GDPPC)

Data

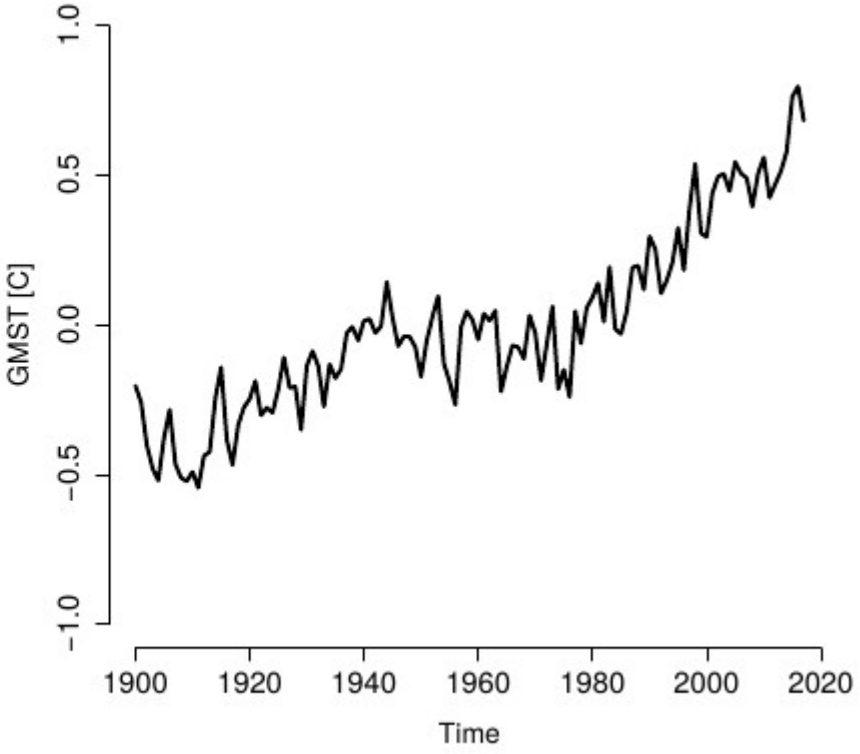
Covariates

GDPPC



a)

GMST

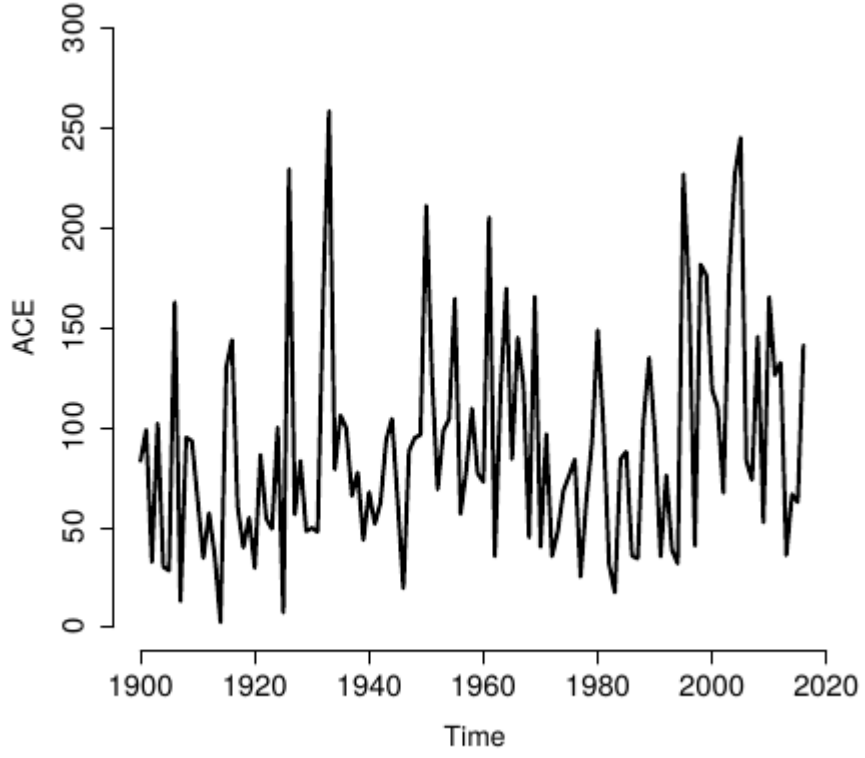


b)

Data

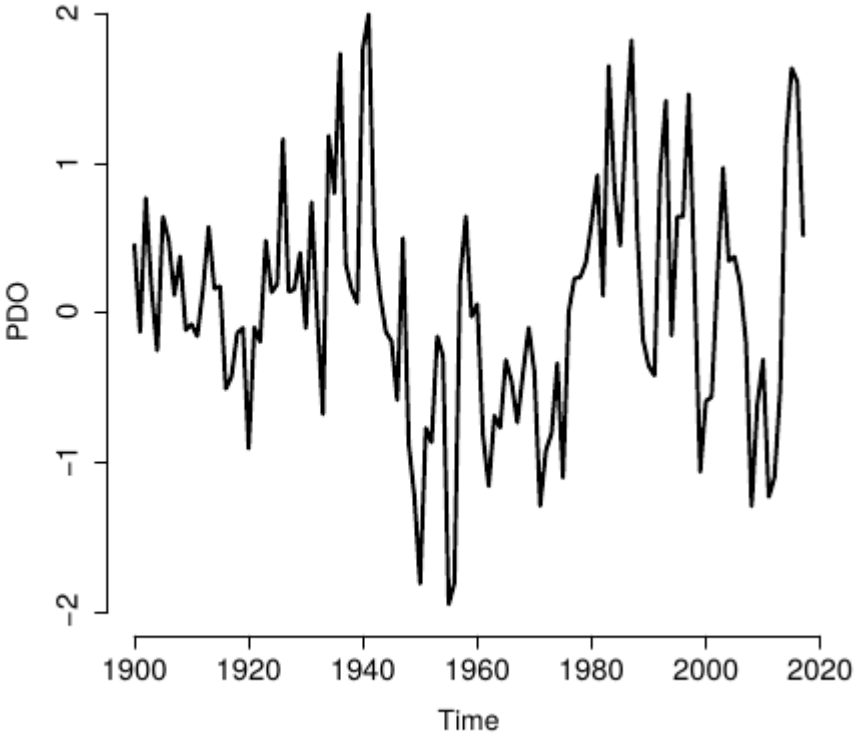
Covariates

Atlantic Hurricanes



c)

PDO

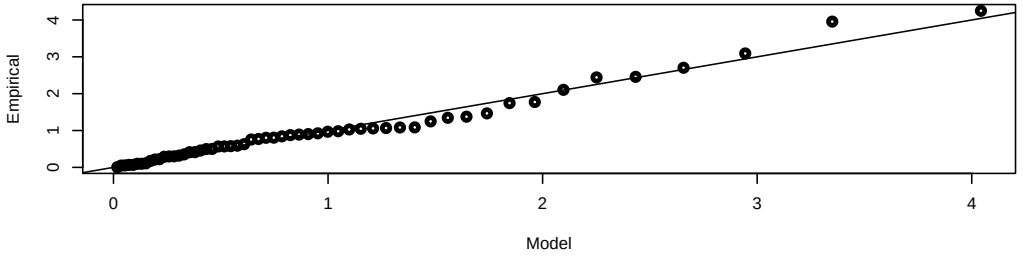


d)

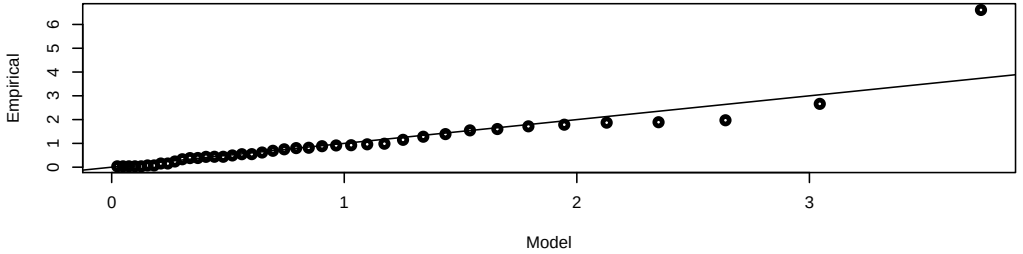
Results

Quantile-Quantile plots

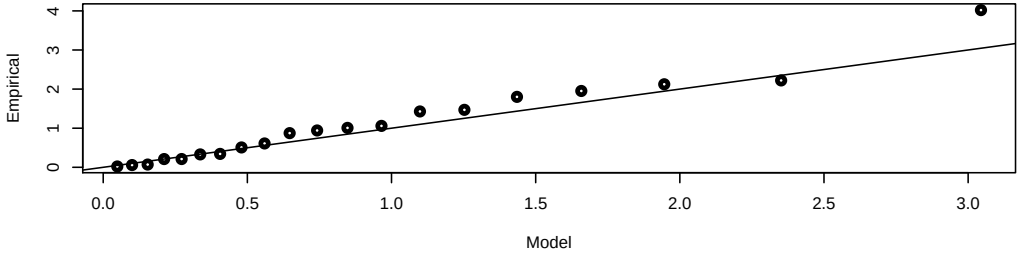
Frequence of occurrence



Fatalities



Damages



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Results

Model selection based on BIC

ΔBIC

Co-variates used	Damages	Occurrences	Deaths
Stationary	30.80	14.55	21.33
$\sigma(GMST)$	23.34	16.81	24.25
$\zeta(GMST)$	23.68	14.24	24.26
$\sigma(GMST)+\zeta(GMST)$	25.81	11.01	26.92
$\sigma(ENSO)$	31.37	12.18	24.12
$\zeta(ENSO)$	34.53	13.01	19.77
$\sigma(ENSO)+\zeta(ENSO)$	35.30	16.75	7.00
$\sigma(AMO)$	30.72	8.90	24.30
$\zeta(AMO)$	25.68	13.11	21.36
$\sigma(AMO)+\zeta(AMO)$	28.99	15.97	23.77
$\sigma(PDO)$	34.13	16.70	21.49
$\zeta(PDO)$	34.82	16.59	0.00
$\sigma(PDO)+\zeta(PDO)$	37.25	20.17	21.54
$\sigma(Sealevel)$	20.99	14.52	24.19
$\zeta(Sealevel)$	18.95	9.89	23.54
$\sigma(Sealevel)+\zeta(Sealevel)$	21.90	13.94	26.50
$\sigma(ACE)$	9.44	7.58	24.07
$\zeta(ACE)$	9.87	8.27	24.28
$\sigma(ACE)+\zeta(ACE)$	11.42	9.95	27.02
$\sigma(NTC)$	27.06	18.29	24.10
$\zeta(NTC)$	21.11	17.05	23.34
$\sigma(NTC)+\zeta(NTC)$	23.80	10.28	26.32
$\sigma(Population)$	8.03	9.25	24.26
$\zeta(Population)$	5.22	1.50	23.55
$\sigma(Population)+\zeta(Population)$	9.39	6.17	26.46
$\sigma(GDPPC)$	2.68	7.91	24.33
$\zeta(GDPPC)$	1.26	1.30	23.97
$\sigma(GDPPC)+\zeta(GDPPC)$	3.27	0.00	26.80
$\sigma(GMST+GDDPC)$	6.56	10.16	25.34
$\zeta(GMST+GDDPC)$	0.00	3.56	20.21
$\sigma(GMST+GDDPC)+\zeta(GMST+GDDPC)$	5.63	10.98	30.42

Franzke and Czupryna 2019, submitted

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Results

Best fit models:

- Frequency of Occurrence: GDPPC (ACE)
- Fatalities: PDO
- Damages: GDPPC & GMST

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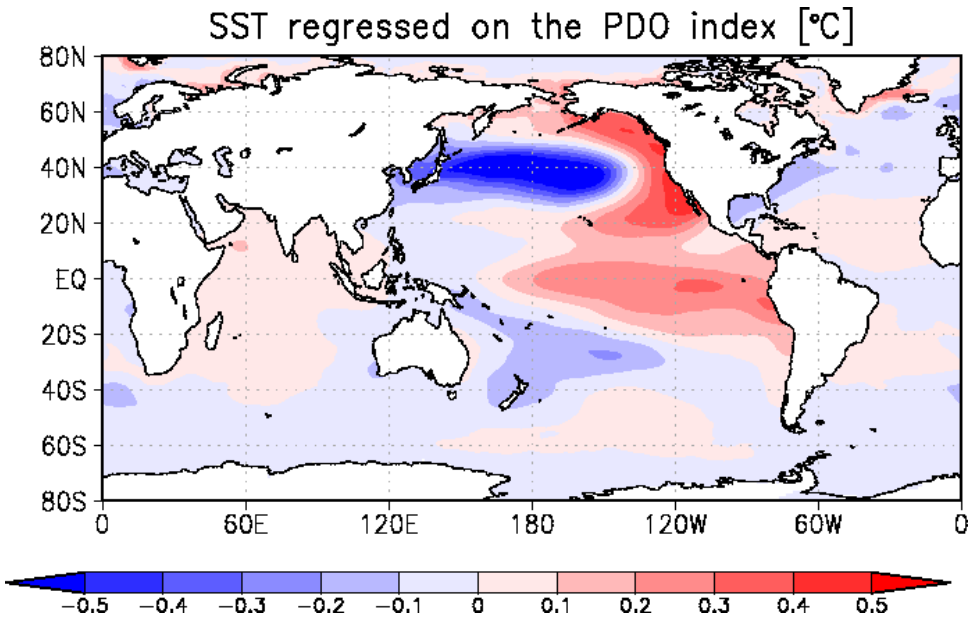
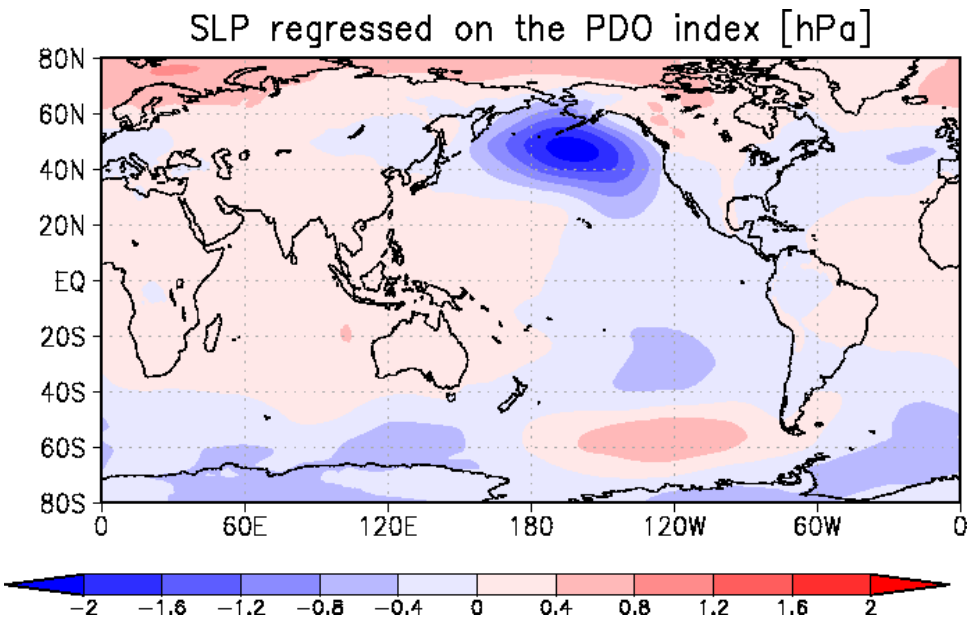
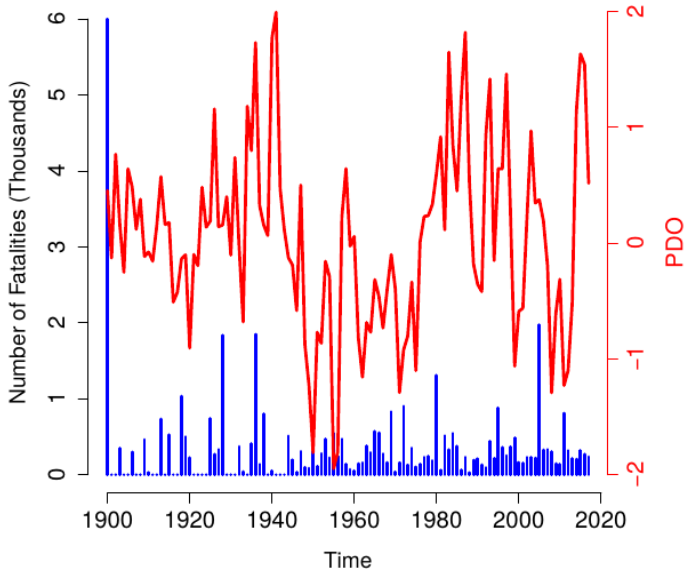
Pacific Decadal Oscillation







PDO	20-year effective return level	50-year effective return level
-1.5	733	1025
0.0	1263	2240
1.5	2417	5719

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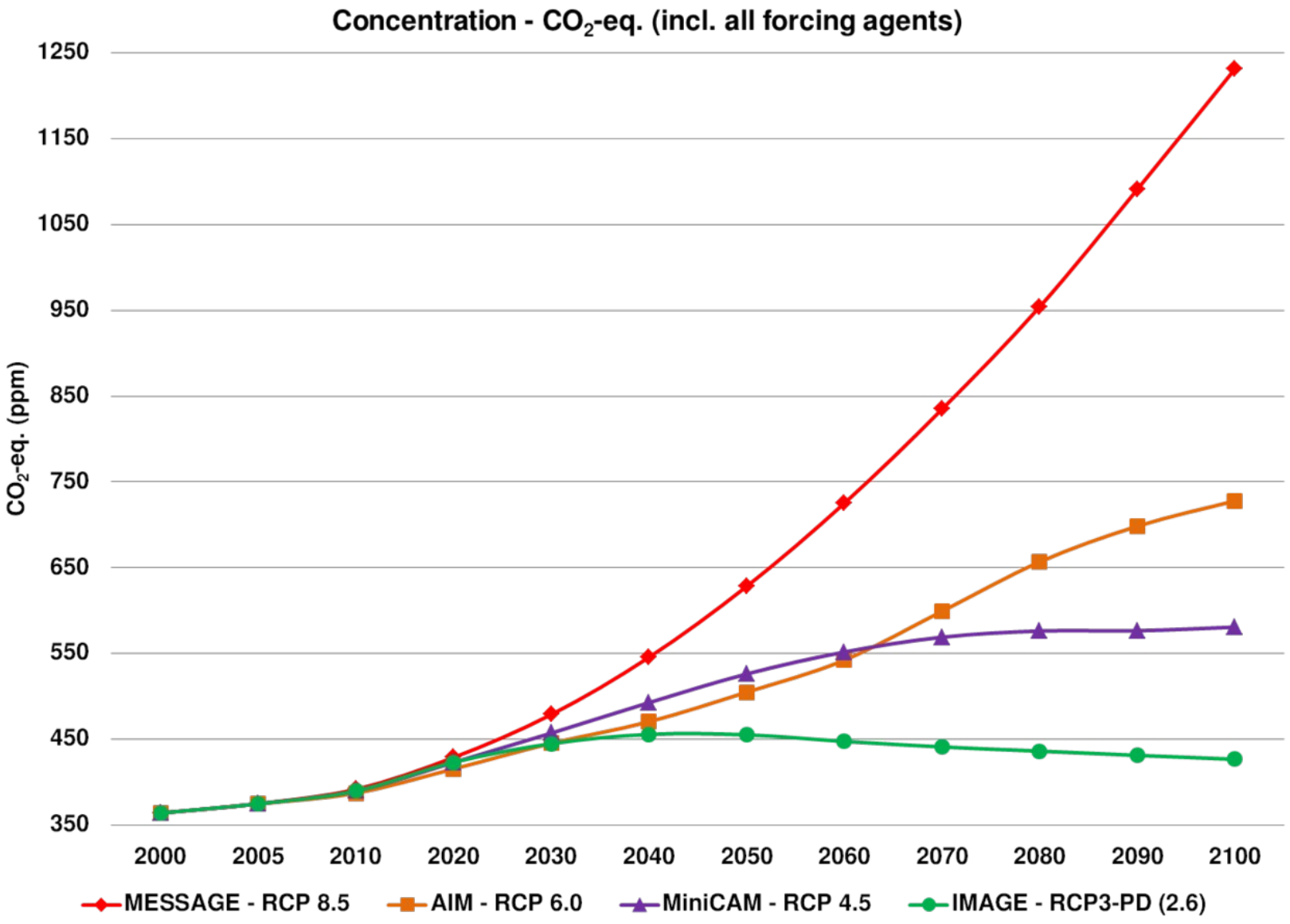
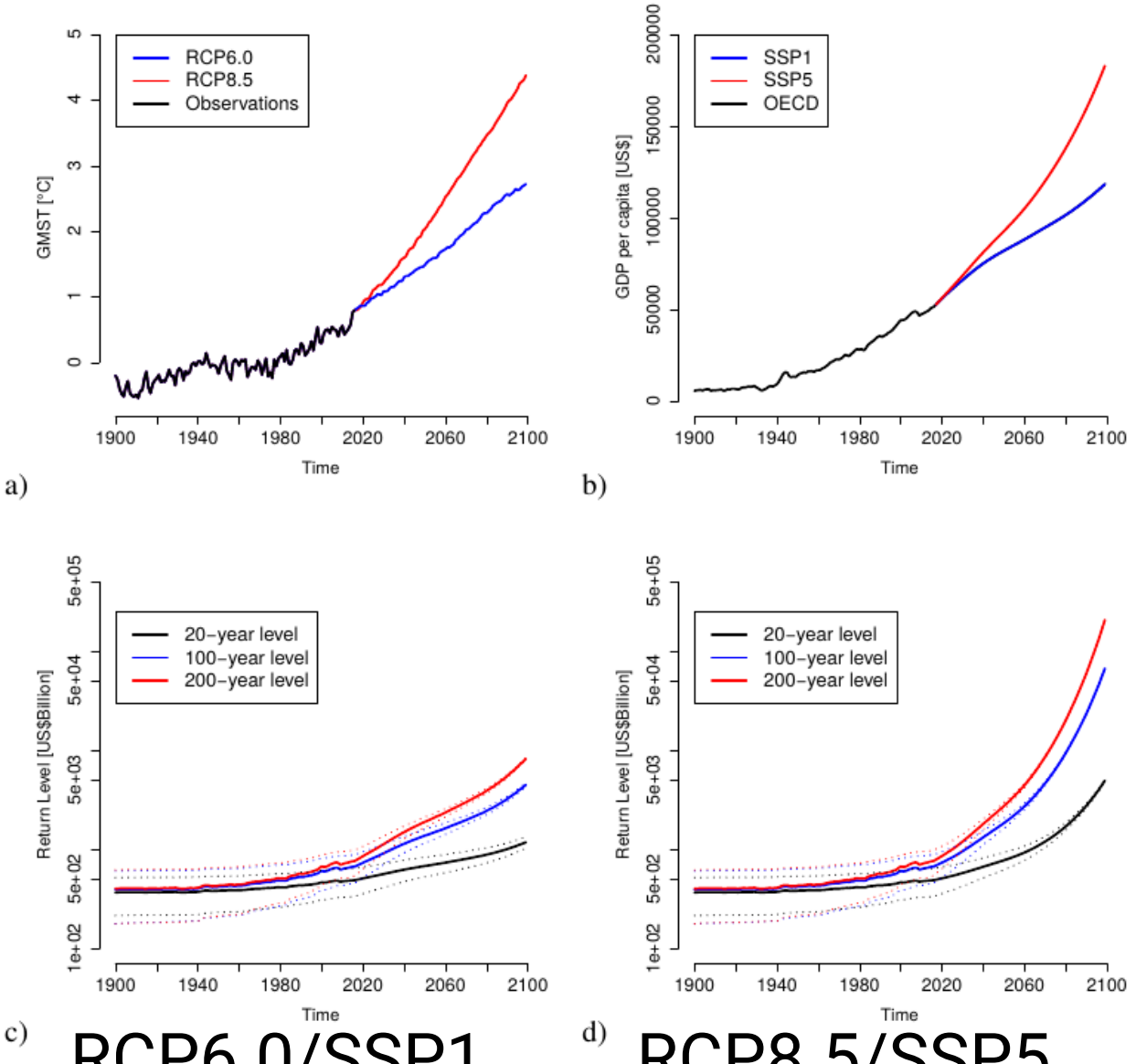
Future Projections



Future Projections



Franzke and Czupryna2019, submitted

Results

Future Projections (2060 & 2100):

Projection	20-year effective return level	100-year effective return level	200-year effective return level
In Year 2060			
RCP60/SSP1	317 (0.1% of GDP)	696 (0.27% of GDP)	998 (0.4% of GDP)
RCP85/SSP5	396 (0.15% of GDP)	1128 (0.4% of GDP)	1825 (0.7% of GDP)
In Year 2100			
RCP60/SSP1	1185 (0.1% of GDP)	4499 (0.4% of GDP)	8238 (0.6% of GDP)
RCP85/SSP5	4959 (0.4% of GDP)	66823 (5% of GDP)	205971 (16% of GDP)
In Year 2016	212	293	335

Increase in risks (2016 vs 2060): 3-5.4 times

2060: Costs 0.1-0.7% of GDP
2100: Costs 0.1-16% of GDP

Summary

- US disaster risk has been increasing over the last 100 years
- US Disaster risks follow *Generalized Pareto Distribution*
- US Disaster risks co-vary with GDPPC & GMST
- Hurricanes are increasing frequency of occurrence of US weather-related disaster risks
- PDO affects number of fatality risks

References

- Guha-Sapir, D., Hoyois, P., Wallemacq, P. and Below, R., 2017: Annual Disaster Statistical Review 2016
- Franzke, C., 2017: Impacts of a Changing Climate on Economic Damages and Insurance. Economics of Disasters and Climate Change, 1, 95-110.
- Franzke, C. and Czupryna, M., 2019: Probabilistic Assessment and Projections of US Weather and Climate Related Risks and Damages. In revision