Catastrophic Climate Risks and Insurance

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Actuarial Conference #62, December 2021

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@freakonometrics

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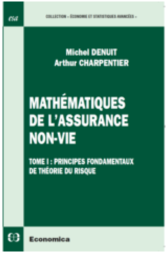
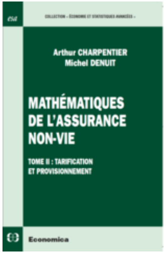
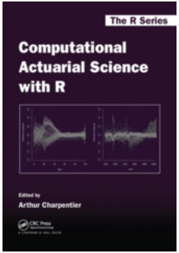
freakonometrics.hypotheses.org

- AXA JRI *unusual data for insurance*
- AXA training *data science for actuaries* (2015, Normandy, Istanbul & Singapore)
- +100 research papers

Predictive Modeling, Actuarial Science, Mathematical Economics, Risk, Inequalities, Econometrics, Statistics, Machine Learning Climate Modeling, Extremes, Fairness







Published & on-going work on climate related risks

- Flood (Hurst / Gumbel, 2008)
  doi: 10.1002/env.909
- Windstorm dynamics (2006)
  doi: 10.1007/s00477-005-0029-y
- Insurability of climate risks (2008)
  doi: 10.1057/palgrave.gpp.2510155
- Public intervention ? (2014)
  doi: 10.1016/j.jpubeco.2014.03.004
- Earthquake dynamics (2015)
  doi: 10.1007/s10950-015-9489-9
- Heat wave and return period (2011)
  doi: 10.1007/s10584-010-9944-0
- Floods & fairness (2020)
  doi: 10.1057/s41288-021-00233-7
- Subsidence & heat waves (2021)
  doi: 10.5194/nhess-2021-214
- 'Le Livre Vert 2022' (2021)
  isbn: 9782746523616
- Wildfires (2021)
- Public intervention with RL (2021)

Dynamics of Climate Events [1]

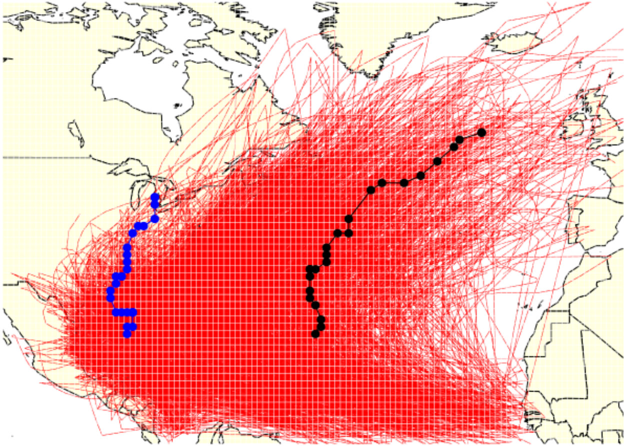
Joint work with David Sibaï (ENSAE) and several other (former) students.

- J.C. Bouette et al. "Wind in Ireland: long memory or seasonal effect?" In: *Stochastic environmental research and risk assessment* 20.3 (2006), pp. 141–151.
- A. Charpentier. "On the return period of the 2003 heat wave". In: *Climatic change* 109.3 (2011), pp. 245–260.
- A. Charpentier and M. Durand. "Modeling earthquake dynamics". In: *Journal of Seismology* 19.3 (2015), pp. 721–739.
- A. Charpentier and D. Sibaï. "Dynamic flood modeling: combining Hurst and Gumbel's approach". In: *Environmetrics* 20.1 (2009), pp. 32–52.

On the temporal occurrence of natural disasters...

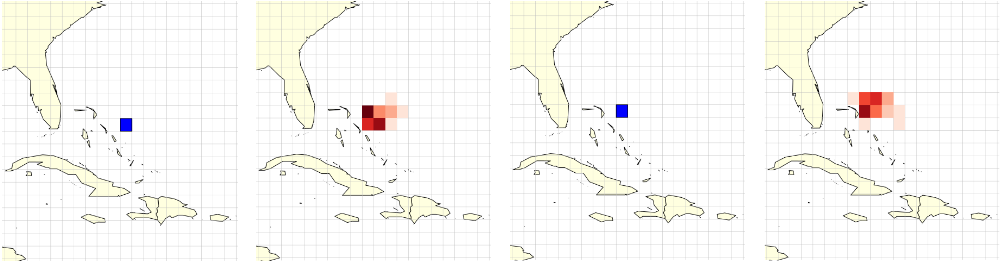
Dynamics of Climate Events [2]

Spatial models well documented in cat' software



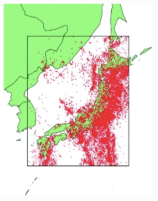
Dynamics of Climate Events [3]

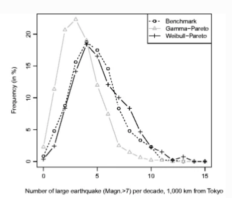
Spatial models well documented in cat' software

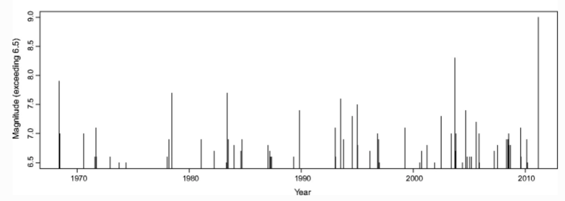


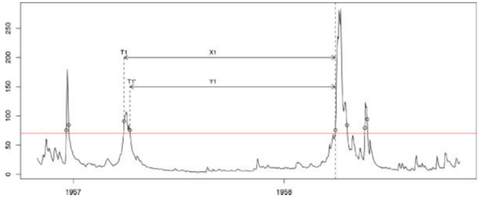
Dynamics of Climate Events [4]

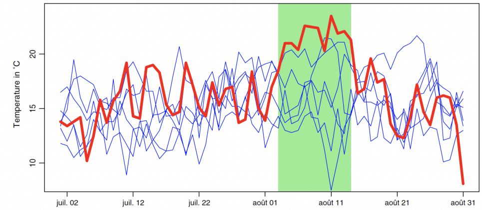
"*seismic gap hypothesis*" / dynamic of flood events / heat wave persistence











Flood Risk in France [1]

Joint work with Laurence Barry (PARI) and Molly James (EURIA / ACPR).

A. Charpentier, L. Barry, and M. James. "Insurance against Natural Catastrophes: Balancing Actuarial Fairness and Social Solidarity". In: *Geneva Papers on Risk & Insurance* (2021). DOI: 10.1057/s41288-021-00233-7.

On the fairness of the French "catastrophes naturelles" mechanism...

Actuarial fairness : a fair premium should be a function of the underlying risk
"*at the core of insurance business lies discrimination between risky and non-risky insureds*"
see also Maynard (1979), Boonekamp (1979), Landes (2015), Avraham (2017)

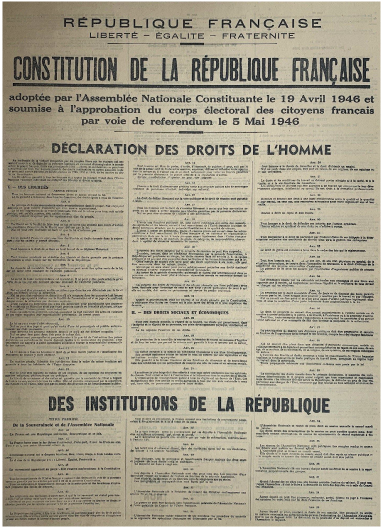
On fairness & solidarity

- French Constitution (1946)

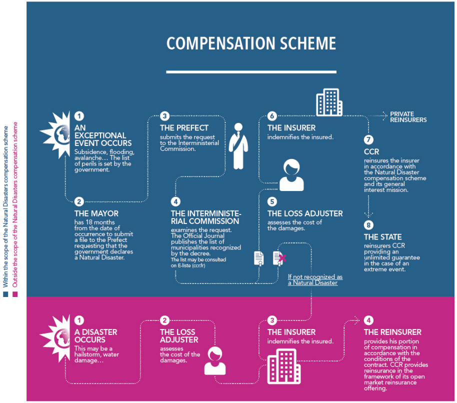
  12. *La Nation proclame la solidarité et l'égalité de tous les Français devant les charges qui résultent des calamités nationales.*

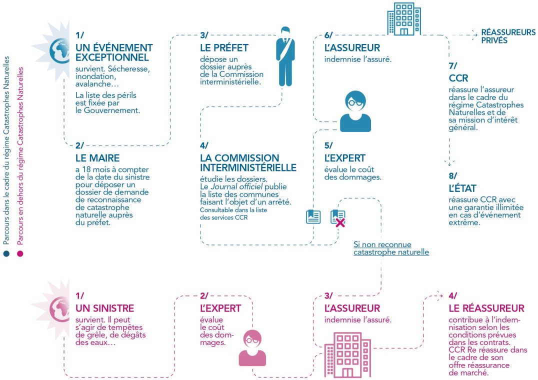
- 82-600 Law (1982)

  régime d'indemnisation des catastrophes naturelles



Flood Risk in France [3]



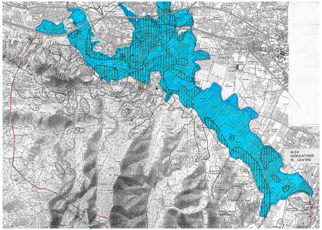


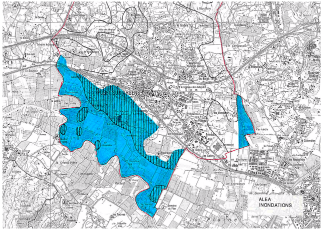
source: https://www.ccr.fr/en/-/indemnisation-des-catastrophes-naturelles-en-france

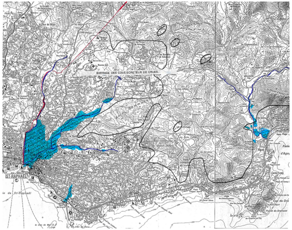
Flood Risk in France [4]

Two different flood perils : overflow vs. coastal

PPRIs (plan de prévention du risque inondation) in Roquebrune-sur-Argens, Puget and Saint-Raphaël. The plain area (in blue) is the risky area.



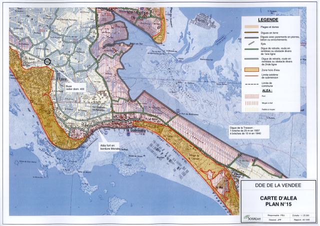


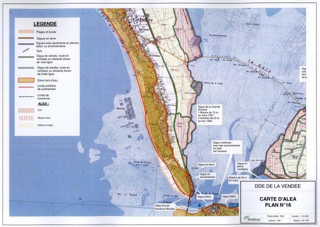


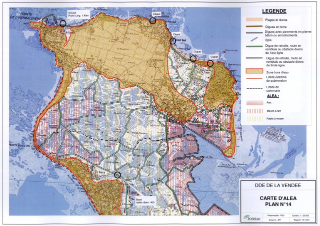
Areas clearly identified as risky, from documented (historical) floods.

Flood Risk in France [5]

PPRLs (plan de prévention des risques littoraux) in Vendée. The dashed area is the risky area. Areas with possible coastal risk.





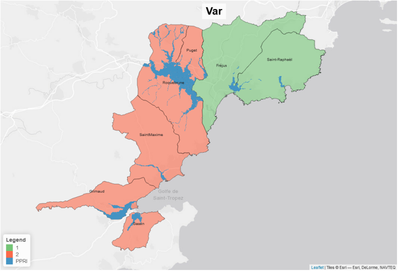


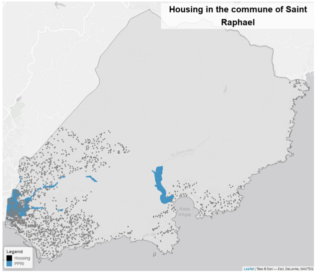
See https://github.com/freakonometrics/floods

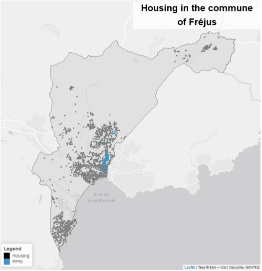
Flood Risk in France [6]

10% of households represent 73.6% of the losses... who lives in those risky areas ?

“ventes de biens fonciers” dataset, https://cadastre.data.gouv.fr/dvf, 2014-2018,



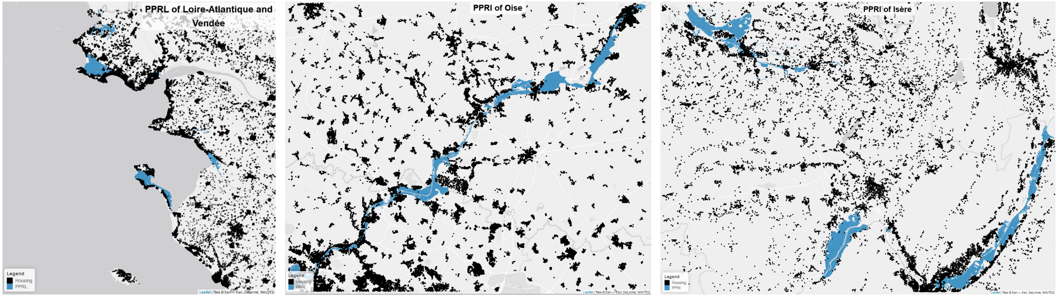




(possible bias on those 5-year notarial transactions...)

Flood Risk in France [7]

E.g. in 4 "departements" (Loire-Atlantique, Vendée, Oise, Isère)



- sold houses / apartments, ■ PPRI-PPRL areas

Flood Risk in France [8]

Table 1: coastal risk areas vs. Table 2: overflow / non-costal risk areas

			Average Price	Difference (%)	Maximum Price	Number	Proportion (%)	Welch t test
Vendée	Non risky	Apartments	4293		21840	329	9%	
		Houses	2928		65909	2795	74%	
	Risky	Apartments	3302	-23%	9773	39	1%	1.0
		Houses	10253	+250%	71483	637	17%	-60.1
Pays-Loire	Non risky	Apartments	4399		79913	8411	37%	
		Houses	3019		75472	12678	55%	
	Risky	Apartments	6784	+54%	68478	1001	4%	-8.6
		Houses	3245	+7%	22895	765	3%	-2.7

Table 1: Prices (€ per m^2) of houses sold (2014-2018) for Vendée - Western part of France, with PPRL (coastal risk). The *Difference* is the relative difference between average prices (per m^2) between the risky and the non-risky zones, either for apartments or houses.

Flood Risk in France [9]

			Average Price	Difference (%)	Maximum Price	Number	Proportion (%)	Welch t value
Var	Non risky	Apartments	5392			9874	53%	
		Houses	5957			6913	37%	
	Risky	Apartments	4190	-22%		1471	8%	6.4
		Houses	4172	-30%		226	1%	5.2
Haute Loire	Non risky	Apartments	2399		38333	3403	27%	
		Houses	1314		20625	8857	69%	
	Risky	Apartments	2163	-11%	28125	319	2%	1.6
		Houses	1247	-5%	7432	272	2%	0.9
Seine et Marne	Non risky	Apartments	6260		79710	82133	44%	
		Houses	3356		79167	98824	53%	
	Risky	Apartments	4333	-30%	40000	2177	1%	8.0
		Houses	2693	-20%	54096	1784	1%	7.5

Flood Risk in France [10]

			Average Price	Difference (%)	Maximum Price	Number	Proportion (%)	Welch t value
Isère	Non risky	Apartments	4960		79800	27982	52%	
		Houses	2429		69375	24600	45%	
	Risky	Apartments	3252	-3%	35714	885	2%	6.1
		Houses	2543	+5%	14067	435	1%	-1.2
Oise	Non risky	Apartments	6170		79963	24613	34%	
		Houses	3126		78214	44737	62%	
	Risky	Apartments	5725	-7%	50000	1385	2%	2.1
		Houses	2866	-8%	62184	1640	2%	4.6

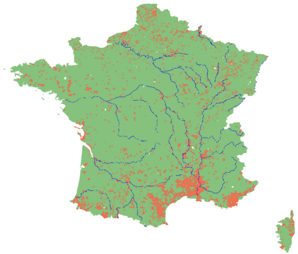
Table 2: Prices (€ per m^2) of houses sold (2000-2020) for several départements in France, with PPRI (overflow risk, or non-costal).

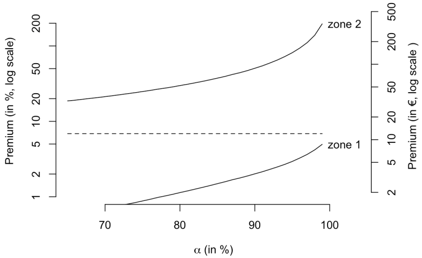
Flood Risk in France [11]

2 zone model, $\alpha \in [0\%, 100\%]$,

- zone 1, proportion α, less risky
- zone 2, proportion $1-\alpha$, more risky

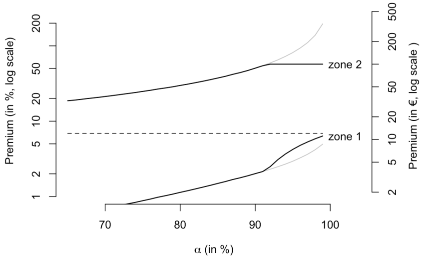
so called "*Will Rogers phenomenon*",
When the Okies left Oklahoma and moved to California, they raised the average intelligence level in both states.





$\alpha = 90\%$, less risky,
26.4% of losses, 3.5€

$1-\alpha = 10\%$, more risky,
73.6% of losses, 88.5€



Flood Risk in France [12]

		Uniform			Two-Zone Model		
		Country	Region	Municipality	$\alpha = 95\%$	$\alpha = 90\%$	$\alpha = 80\%$
Var	Frejus	12.0€	30.6€	15.7€	5.1€	3.5€	52.1€
	Grimaud	12.0€	30.6€	84.3€	142.3€	88.5€	52.1€
	Puget	12.0€	30.6€	133.0€	142.3€	88.5€	52.1€
Pays Loire	Assérac	12.0€	3.6€	6.7€	5.1€	3.5€	2.0€
	Mesquer	12.0€	3.6€	10.2€	5.1€	3.5€	2.0€
	Le Croisic	12.0€	3.6€	25.9€	5.1€	88.5€	52.1€
Vendée	Talmont-Saint-Hilaire	12.0€	10.7€	4.8€	5.1€	3.5€	2.0€
	Noirmoutier-en-l'Île	12.0€	10.7€	8.5€	5.1€	3.5€	2.0€
	La Faute-sur-Mer	12.0€	10.7€	275.1€	142.3€	88.5€	52.1€

Table 3: Comparing premiums, in €, in nine cities, in Var, Pays-de-Loire and Vendée.

Flood Risk in France [13]

		Uniform			Two-Zone Model		
		Country	Region	Municipality	$\alpha = 95\%$	$\alpha = 90\%$	$\alpha = 80\%$
Var	Fréjus	6.9%	17.5%	9%	2.9%	2.0%	29.8 %
	Grimaud	6.9%	17.5%	48.2%	81.3%	50.6%	29.8 %
	Puget-sur-Argens	6.9%	17.5%	76.1%	81.3%	50.6%	29.8 %
Pays Loire	Assérac	6.9%	2%	3.8%	2.9%	2.0%	1.1 %
	Mesquer	6.9%	2%	5.8%	2.9%	2.0%	1.1 %
	Le Croisic	6.9%	2%	14.8%	2.9%	50.6%	29.8 %
Vendée	Talmont-Saint-Hilaire	6.9%	6.1%	2.7%	2.9%	2.0%	1.5 %
	Noirmoutier-en-l'Île	6.9%	6.1%	4.9%	2.9%	2.0%	1.1 %
	La Faute-sur-Mer	6.9%	6.1%	157.2%	81.3%	50.6%	29.8 %

Table 4: Comparing premiums, in percent of the household premium, in nine cities, in Var, Pays-de-Loire and Vendée.

Flood Risk in France [14]

		Hierarchical Model $\gamma = 20\%$			Hierarchical Model $\gamma = 40\%$		
		$\beta = 10\%$	$\beta = 20\%$	$\beta = 50\%$	$\beta = 10\%$	$\beta = 20\%$	$\beta = 50\%$
Var	Fréjus	14.7%	13.7%	12%	12.7%	12.0%	10.7 %
	Grimaud	17.8%	21.5%	27.7%	15.1%	17.8%	22.5 %
	Puget-sur-Argens	20.1%	27.1%	38.8%	16.8%	22.0%	30.8 %
Pays Loire	Assérac	3.2%	3.4%	3.7%	4.1%	4.2%	4.5 %
	Mesquer	3.3%	3.8%	4.5%	4.2%	4.5%	5.1 %
	Le Croisic	4.0%	5.6%	8.1%	4.7%	5.9%	7.8 %
Vendée	Talmont-Saint-Hilaire	6%	5.6%	4.9%	6.2%	5.9%	5.4 %
	Noirmoutier-en-l'Île	6.2%	6.0%	5.8%	6.3%	6.2%	6.0 %
	La Faute-sur-Mer	18.3%	36.5%	66.7%	15.5%	29.1%	51.7 %

Table 5: γ: national, $(1-\gamma)\beta$: municipality.

Flood Risk in France [15]

- Tradeoff: risk vs. welfare / wealth
- Prevention cannot be done at the individual level, even cities...
- Hierarchical approach: city / region / country

A. Charpentier, L. Barry, and M. James. "Insurance against Natural Catastrophes: Balancing Actuarial Fairness and Social Solidarity". In: *Geneva Papers on Risk & Insurance* (2021). DOI: 10.1057/s41288-021-00233-7.

Subsidence Risk in France [1]

Joint work with Hani Ali (Willis Re) and Molly James (EURIA / ACPR).

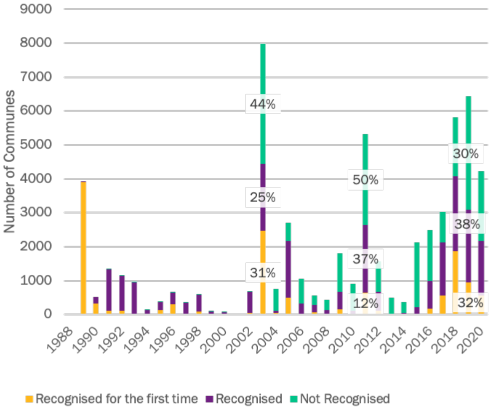
A. Charpentier, M. R. James, and H. Ali. "Predicting Drought and Subsidence Risks in France". In: *Natural Hazards and Earth System Sciences Discussions* (2021), pp. 1–27. DOI: 10.5194/nhess-2021-214.

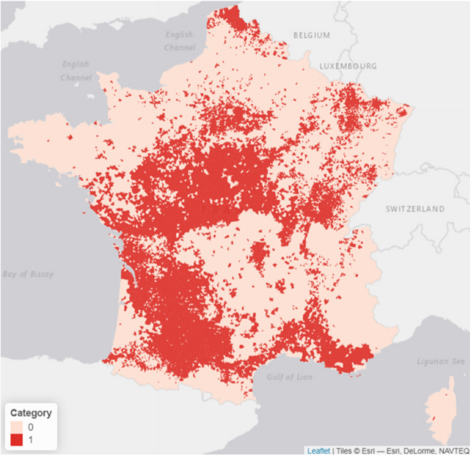
"*Subsidence is caused by the shrinkage and swelling of clay soils*"

- Geotechnical factor: Area of municipalities at medium or high risk $> 3\%$. (categories based on clay concentration in the soil and historical statements)
- Meteorological factor: Standardized soil moisture index (SSWI), if an indicator of the season is lower than a return period of 25 years, then the whole season is eligible for the commune concerned.

Subsidence Risk in France [2]

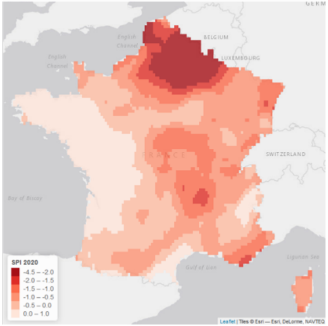
Data 1989-2018

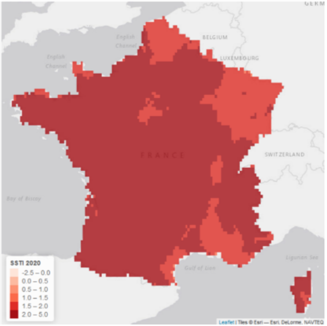


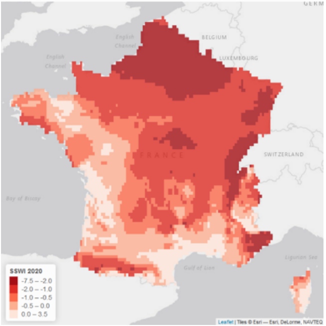


Subsidence Risk in France [3]

Indicators 2020: ESPI (precipitation) ESSTI (soil temperature) & ESSWI (soil humidity), ERA5-Land 9 km $\times$ 9 km



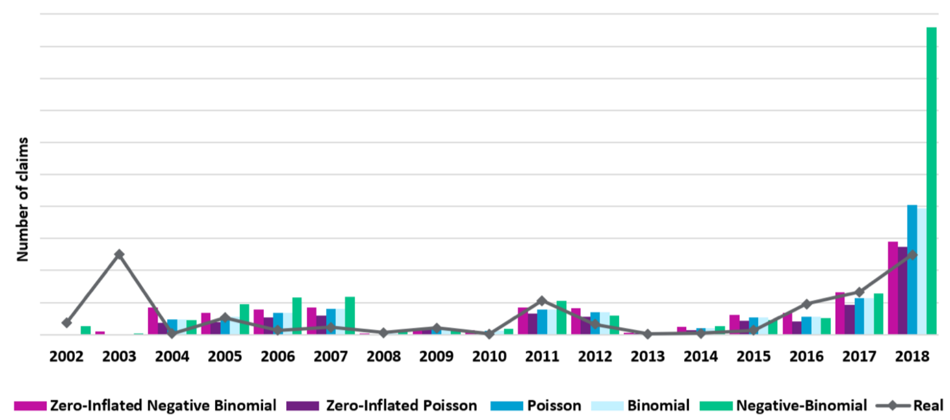




(via ESDAC (European Soil Data Centre) for soil concentration)

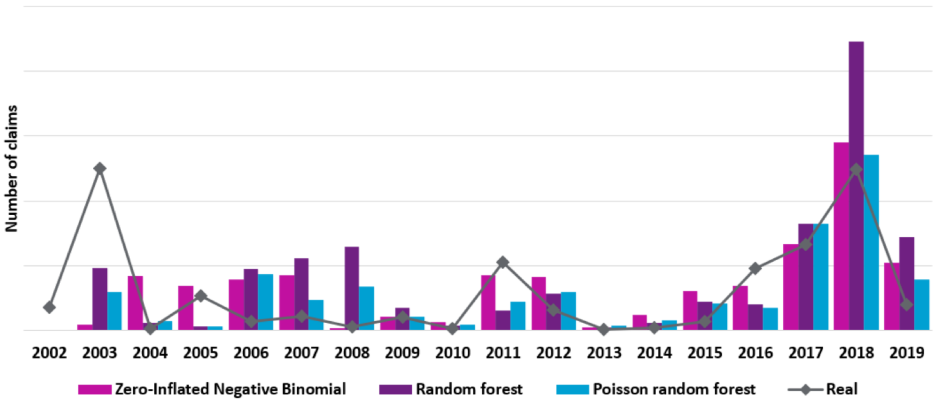
Subsidence Risk in France [4]

Regression models for frequencies: binomial, Poisson, negative binomial & zero-inflated Poisson, zero-inflated negative binomial,



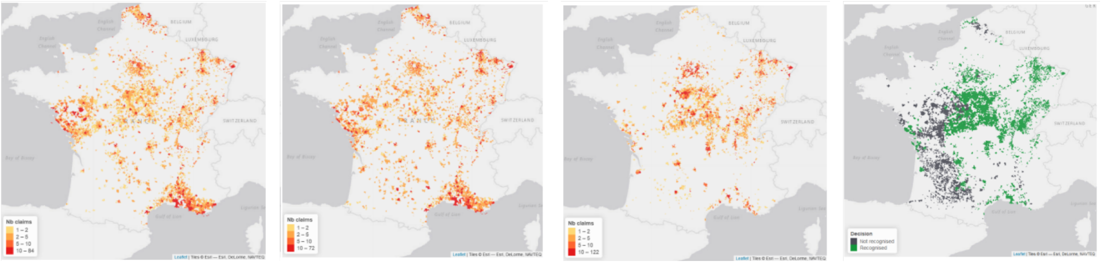
Subsidence Risk in France [5]

Random forest models for frequencies

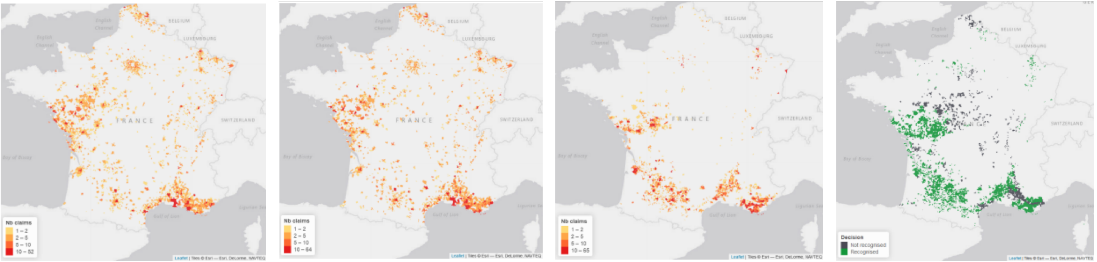


Subsidence Risk in France [6]

2017, random forest Poisson, zero inflated, observed, Nat Cat recognition

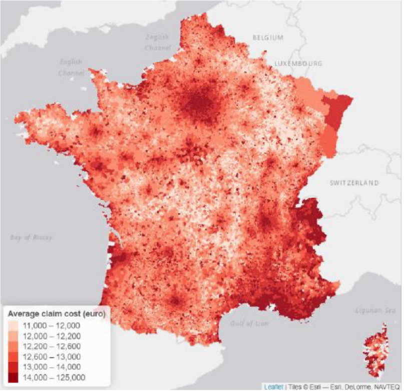


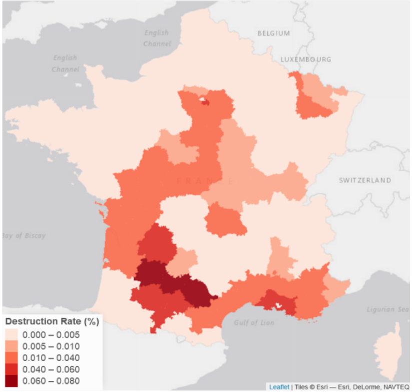
2018, random forest Poisson, zero inflated, observed, Nat Cat recognition



Subsidence Risk in France [8]

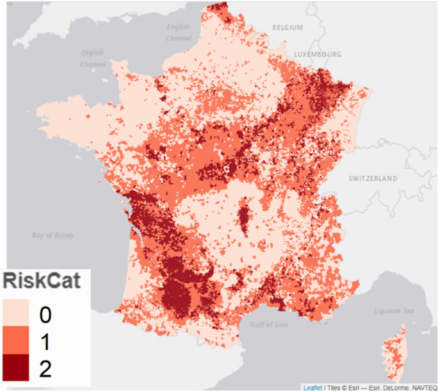
Models for costs and destruction rates





Subsidence Risk in France [9]

Risk map

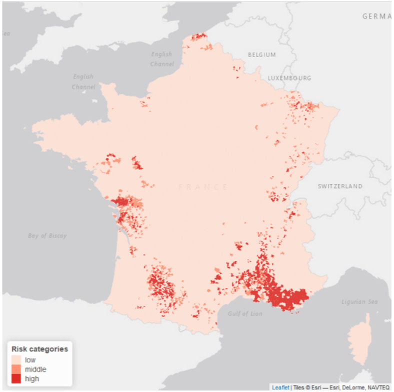


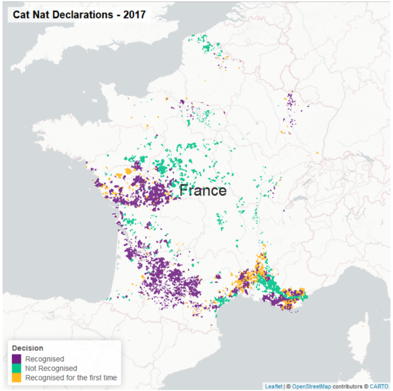
x

zone 0: 41% contracts, 0% losses
zone 1: 47% contracts, 67% losses
zone 2: 12% contracts, 33% losses

Subsidence Risk in France [10]

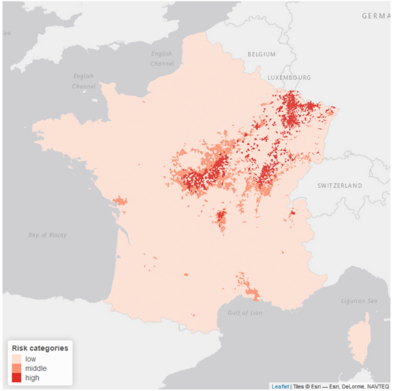
Risk map for 2017

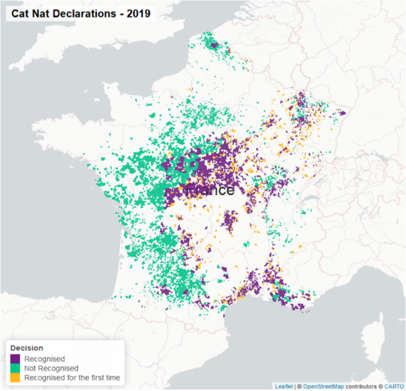




Subsidence Risk in France [11]

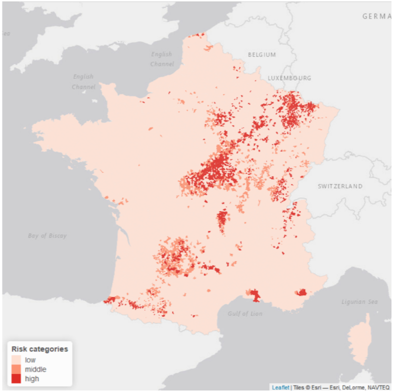
Risk map for 2019

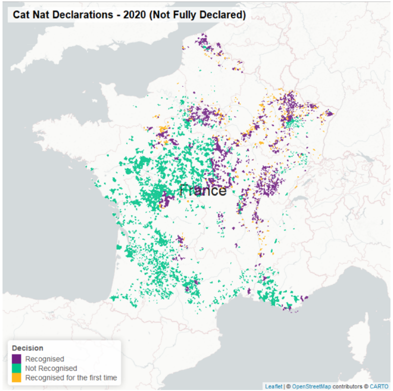




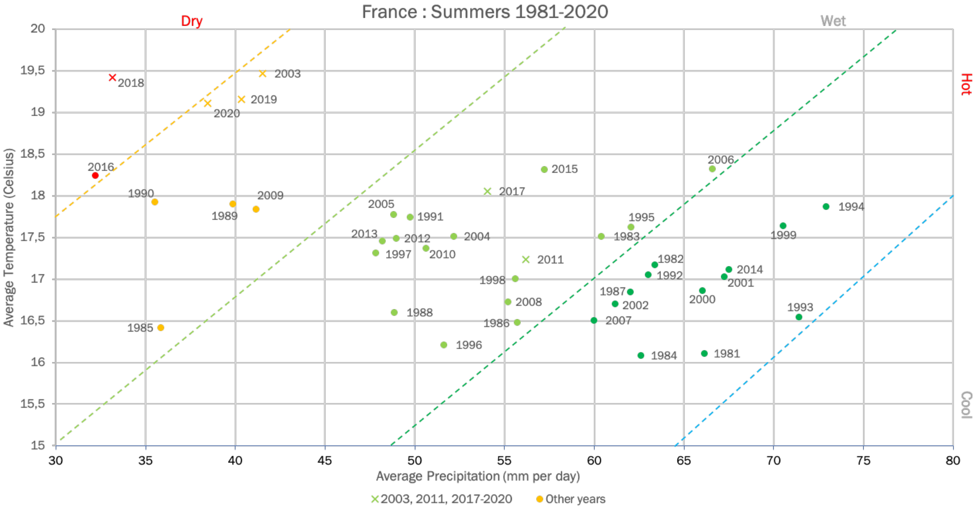
Subsidence Risk in France [12]

Risk map for 2020





Subsidence Risk in France [13]

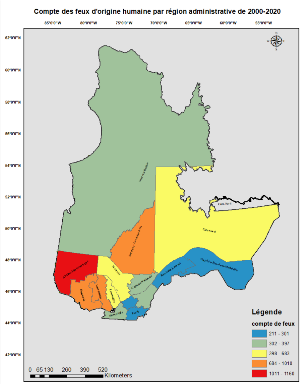


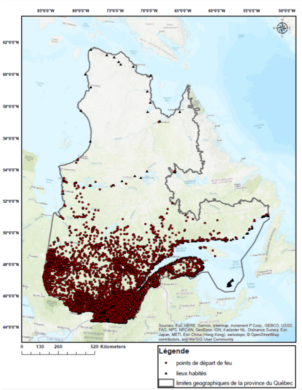
Subsidence Risk in France [14]

A. Charpentier, M. R. James, and H. Ali. "Predicting Drought and Subsidence Risks in France". In: *Natural Hazards and Earth System Sciences Discussions* (2021), pp. 1–27. DOI: 10.5194/nhess-2021-214.

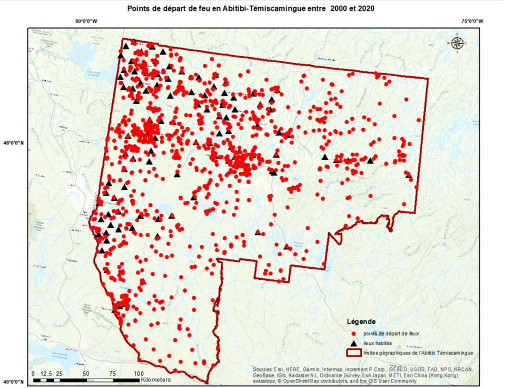
Wildfire in Québec (Canada) [1]

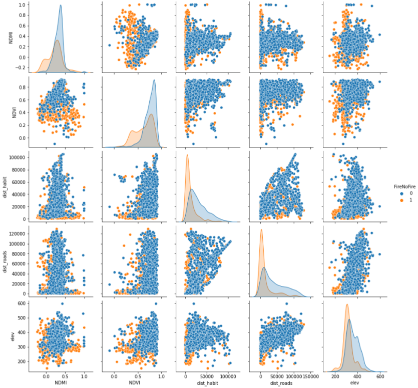
Joint work with Amirouche Benchallal (UQAM) and Yacine Bouroubi (Sherbrooke).





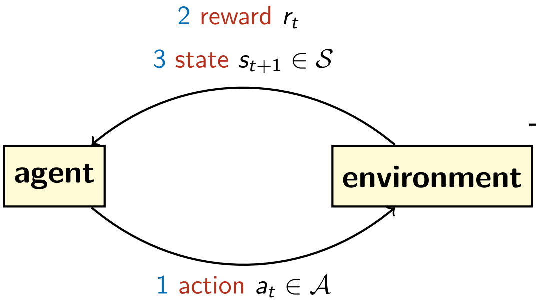
Wildfire in Québec (Canada) [2]

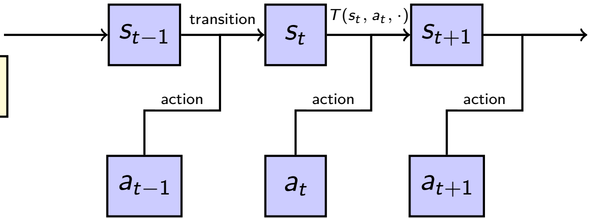




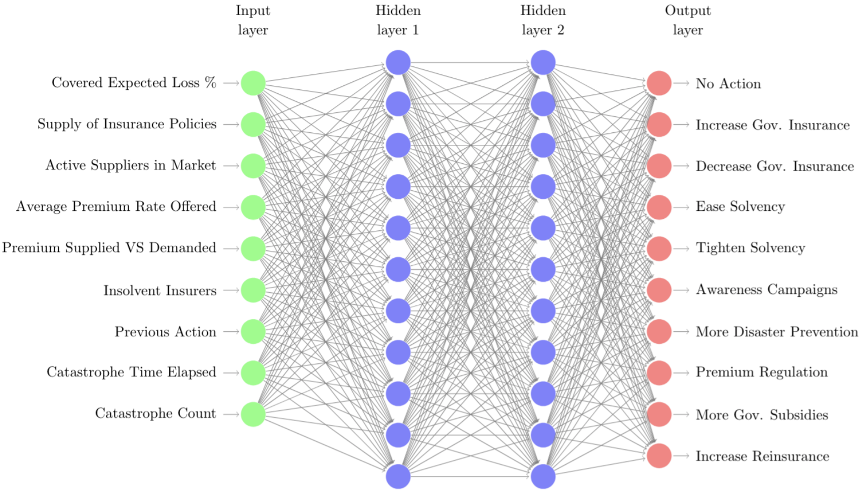
On Government Intervention [1]

Joint work with Nouri Sakr (Columbia) and Mennatalla Mohamed Hassan (American University in Cairo).



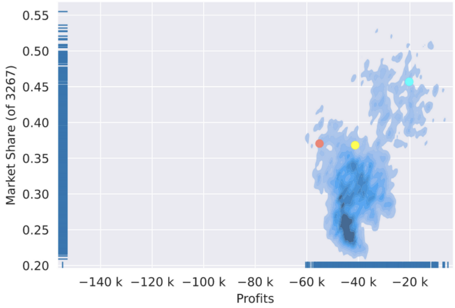


On Government Intervention [2]



To go further...

- https://freakonometrics.github.io/
- https://jridata.github.io/
- ILB (Institut Louis Bachelier) report on *Insurance: Bias, Discrimination & Fairness*
- AICrowd "Insurance Pricing Game" (2021)



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A. Charpentier, L. Barry, and M. James. "Insurance against Natural Catastrophes: Balancing Actuarial Fairness and Social Solidarity". In: *Geneva Papers on Risk & Insurance* (2021). DOI: 10.1057/s41288-021-00233-7.

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