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The genesis of clustered storms.

Marc Bagarry

Vincent Noel

Back to the roots!

- Find our common ancestor
- The discovery of ‘Lucy’, the first hominid skeleton, served as a clue to understanding hominid evolution!
- What about clustered windstorm genesis?

Objectives

- We observe many historical situations where **several storms occur consecutively in a narrow timeframe**: this is what we call “clustering”

- Our view of clustering is built on a **4-days proxy**: if two or more storms happen in less than 4 days, we consider that these storms are in a cluster

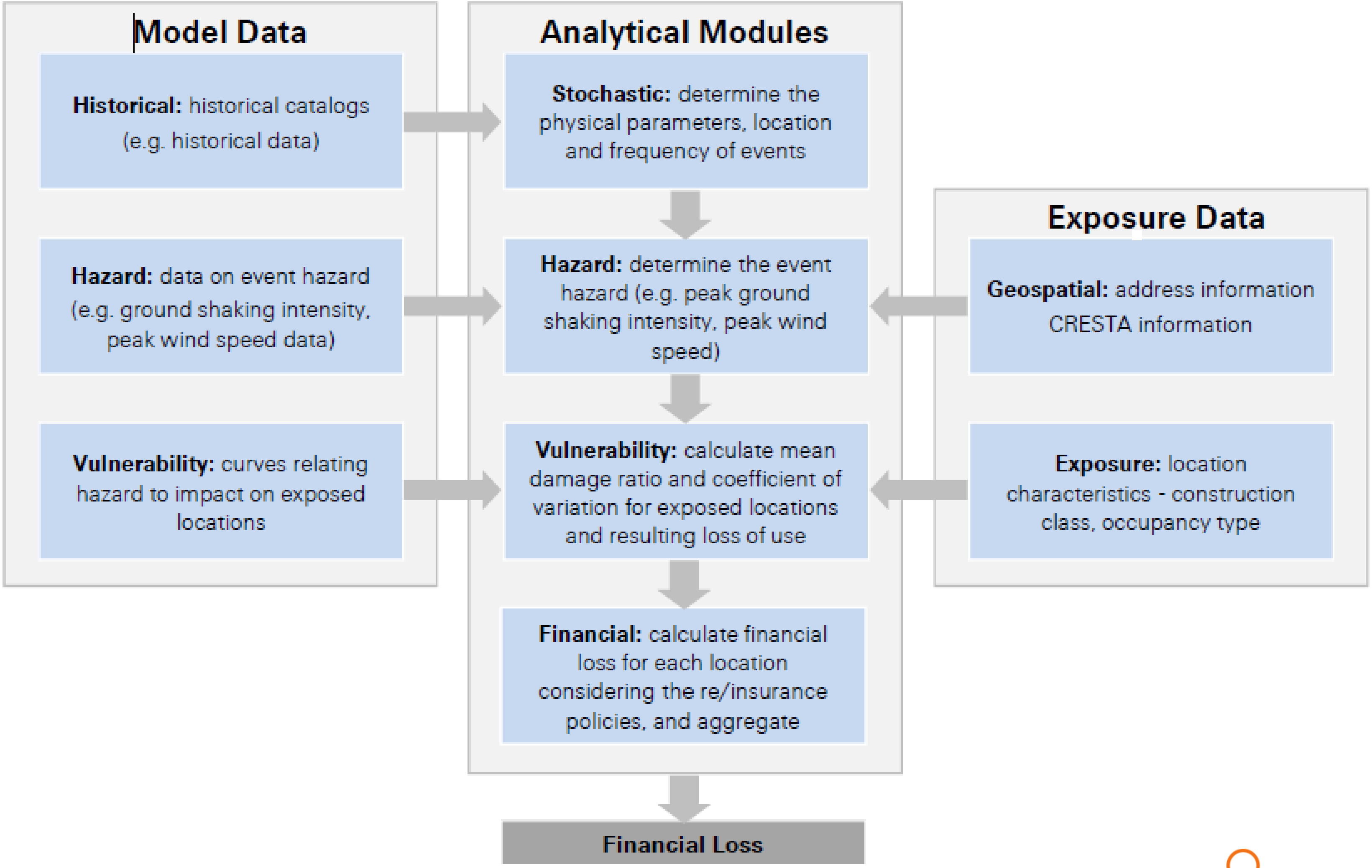
- Our goal is therefore to **prove the existence of an underlying phenomenon** that causes these clustering storms

Building a vision of risk

- This presentation is based on the work developed at Groupama in the context of actuarial thesis. The first is about the construction of criteria to score the models' ability to reproduce the phenomenon, the second aims to prove the existence of a generating event in clustering situations.
  - Storm clusters: which paradigm? Clémence Fauve, 2017
  - The genesis of storm clusters. Vincent Noel, 2019 (to be published)

- Groupama has built its risk vision since the issue of its first cat bond in 2007 and the approval of its internal model for solvency 2 by developing its own criteria for evaluating cat models and a change policy. It is the result of upstream work with many players: reinsurance brokers, modelling agencies, climatology research centres, reinsurers.

Principles of cat models



Model Data

Historical: historical catalogs (e.g. historical data)

Hazard: data on event hazard (e.g. ground shaking intensity, peak wind speed data)

Vulnerability: curves relating hazard to impact on exposed locations

Analytical Modules

Stochastic: determine the physical parameters, location and frequency of events

Hazard: determine the event hazard (e.g. peak ground shaking intensity, peak wind speed)

Vulnerability: calculate mean damage ratio and coefficient of variation for exposed locations and resulting loss of use

Financial: calculate financial loss for each location considering the re/insurance policies, and aggregate

Exposure Data

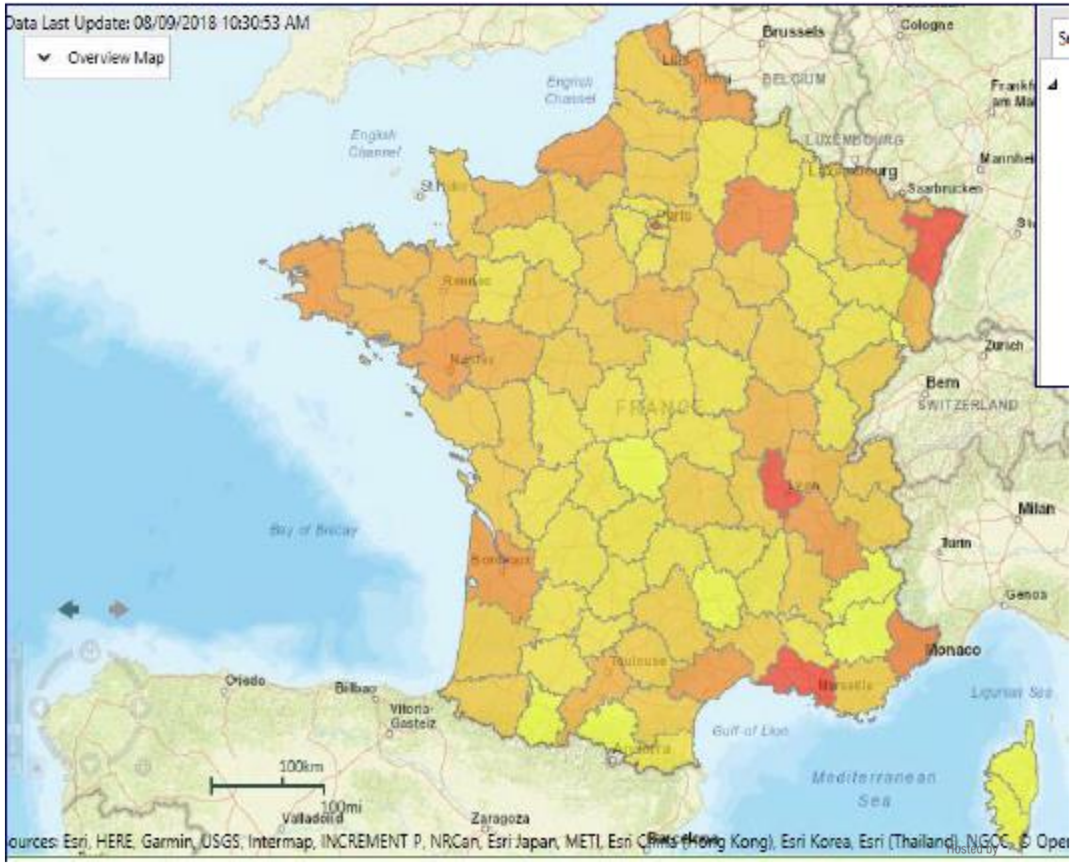
Geospatial: address information CRESTA information

Exposure: location characteristics - construction class, occupancy type

Financial Loss

Groupama exposures – as at end of 2018

- Strong positions in France and abroad
  - €14,3 billion in combined premium income
  - 19% of premium income generated abroad
  - 12 million cooperative members and customers
- In France:
  - No. 1 insurer of agriculture, public authorities, individual health
  - No. 2 insurer of home and protection
  - No. 4 insurer of motor
- Large representative portfolio thanks to a significant presence throughout France.



Keyword definitions…

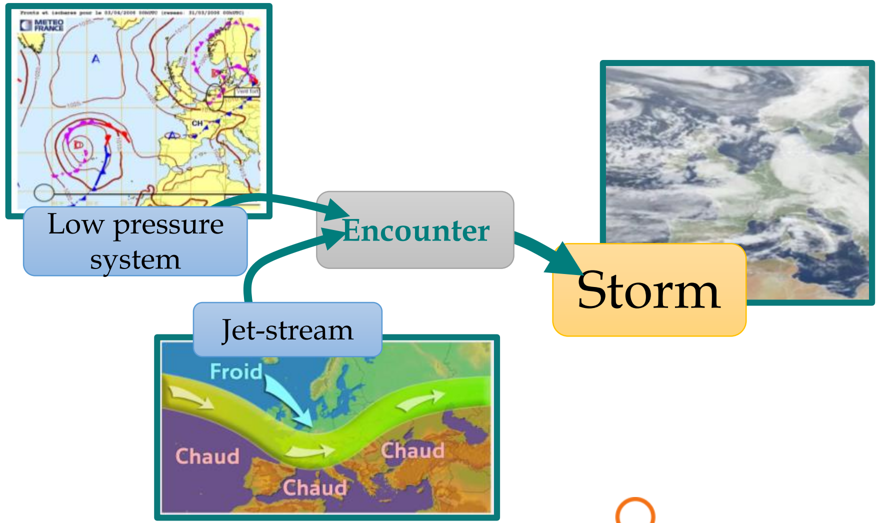
- Storm Severity Index: used to quantify the strength of a storm, calculated as **$SSI=V^3 \times A \times D$**, where
  - V is the maximum surface wind speed of the storm
  - A is the greatest area with damaging winds of the storm
  - D is the duration of the storm.
- Stormy hours and storms:

→ Stormy hours Thresholds: **surface windspeed** > 12 m/s, **affected territory** > 10%

→ Storms **A storm is characterized by consecutive stormy hours** (more than 12 consecutive hours)

- Jet-stream: fast flowing air currents near the altitude of the tropopause, with speeds up to 360km/h.

  When **a low pressure system encounters a jet-stream**, the winds around it accelerate and form a **storm over Europe**.



Low pressure system

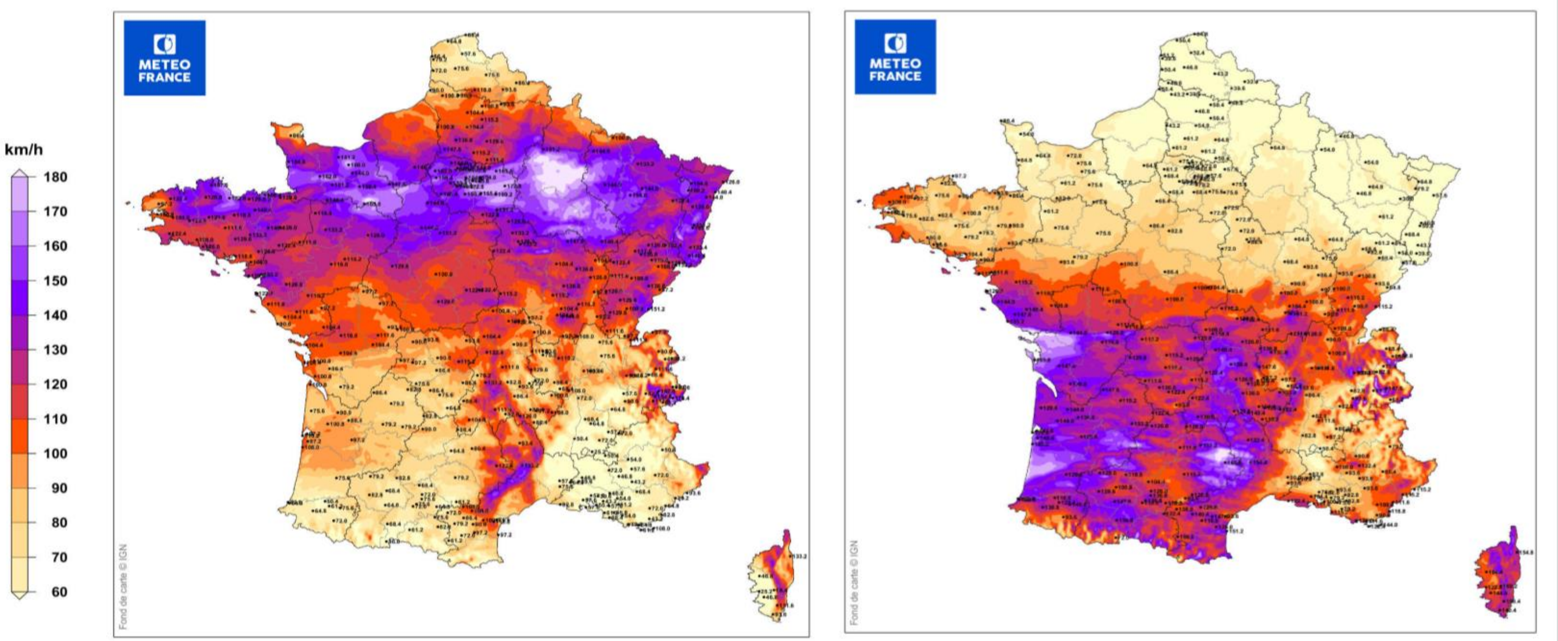
Encounter

Storm

Jet-stream

What is clustering?

- Clustering caracterizes the **occurrence of several storms in a limited time frame** (these storms cannot in general be considered independent): our view of clustering is based on a **4-days interval between consecutive storms**.



A clustering example: Lothar and Martin, 26th and 27th of december, 1999

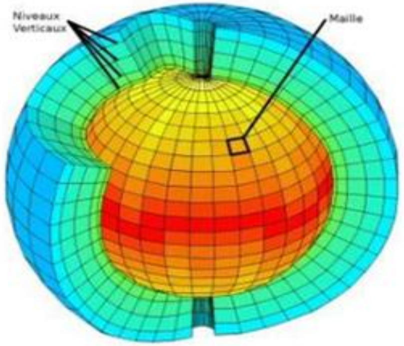
- Because of the specific atmospheric conditions over the Atlantic, **winter is the most prolific period for the birth of storms over Europe** (roughly from october to march).

Regional Climate Models data

Statistical studies on historical data have their limits:

→ Data history
  → Main issues: depth and quality of the historical data

→ Need for another source of data
  → **Climate Models** (both Global and Regional)



We therefore have enough homogeneous data for **significant statistical results**

There are many sources for these climate models:

For instance…

Météo-France:

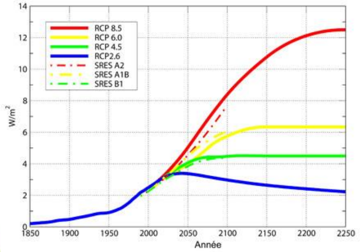
→ ARPEGE-Climat: data simulated on France
Hourly data: 200 years at current climate
+ 200 years at RCP4.5
+ 200 years at RCP8.5

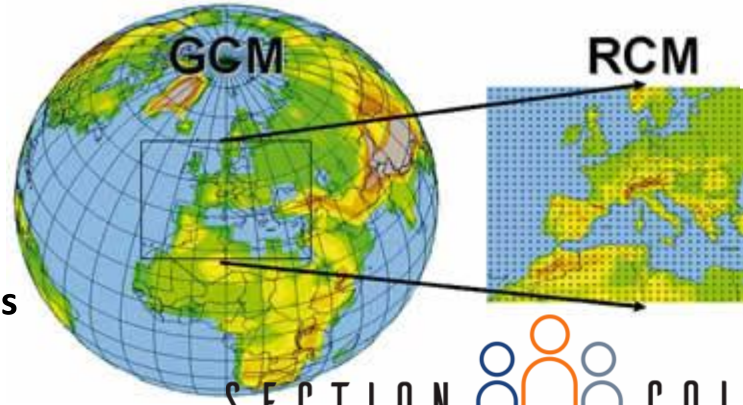
CORDEX:

→ an international coordinated experiment on climate models

Main objective of this initiative:
improving downscaling from Global to Regional Climate Models

6 hourly data: 35 years at current climate
+ 95 years at RCP4.5
+ 95 years at RCP8.5





It’s getting hot in here!

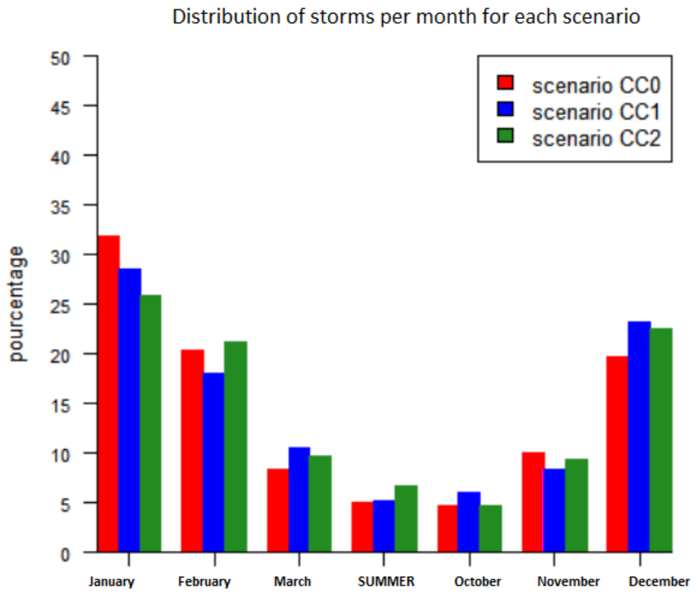
- Results of a study on french storms across three scenarios: CC0 (historical climate), CC1 (RCP 4.5), CC2 (RCP 8.5)

	Number of storms per meteorological year		
Scenario	CC0	CC1	CC2
Minimum	0	0	0
Maximum	6	8	6
Average	between 1 and 2	between 1 and 2	between 1 and 2
Quantile 75%	2	2	2

	Nb of meteorological years…		
Scenario	CC0	CC1	CC2
...without any storm	116	130	128
...with more that 3 storms	84	57	56
...with more than 4 storms	32	26	22

	Statistics on the severity of each scenario's storms		
Scenario	CC0	CC1	CC2
Average	744	793	803
Standard-deviation	556	570	559
Minimum	131	154	166
Q25	360	404	383
Q50	572	594	650
Q75	939	1008	1025
Maximum	3680	4185	3523

✚



No noticeable variation in:
- frequency…
- severity…
- number of clusters…

…related to climate change.

Myths and realities!

Time dependence

"**No clusters**, but years of more or less stormy weather."	X
"Modeling the gaps between 2 storms by a **iid random variables**"	X
"Modeling the annual number of storms by a **Negative Binomial**"	√

Dependency in severity

"Only storms of **high severity** occur in clusters"	X
"**Same severity** of cluster storms"	√

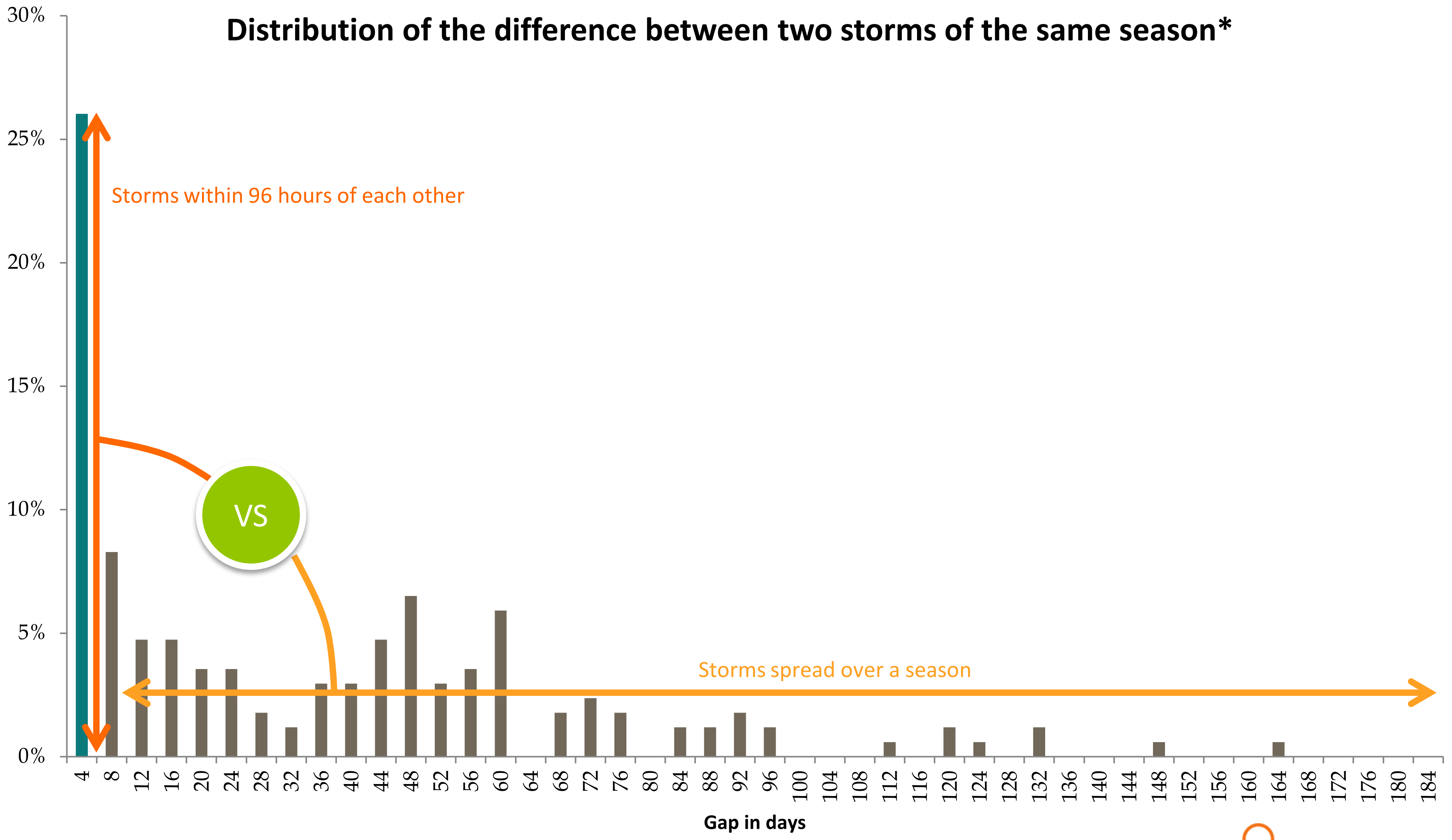
Spatial dependence

"**Same storm tracks** of a cluster"	√

Bicentennial years

"Characterized by the occurrence of an **exceptional storm**"	X
"Characterized by the **clustering effect**."	√
"Characterized by storms like **Lothar**"	√

Close encounters of the second storm



of the same season* (July to June)

Risk mitigation via reinsurance

- **Hour clause = aggregation of claims** related to a common underlying cause
- The hour clause is most appropriate to protect against clustering situations where several storms occur in a short period of time!

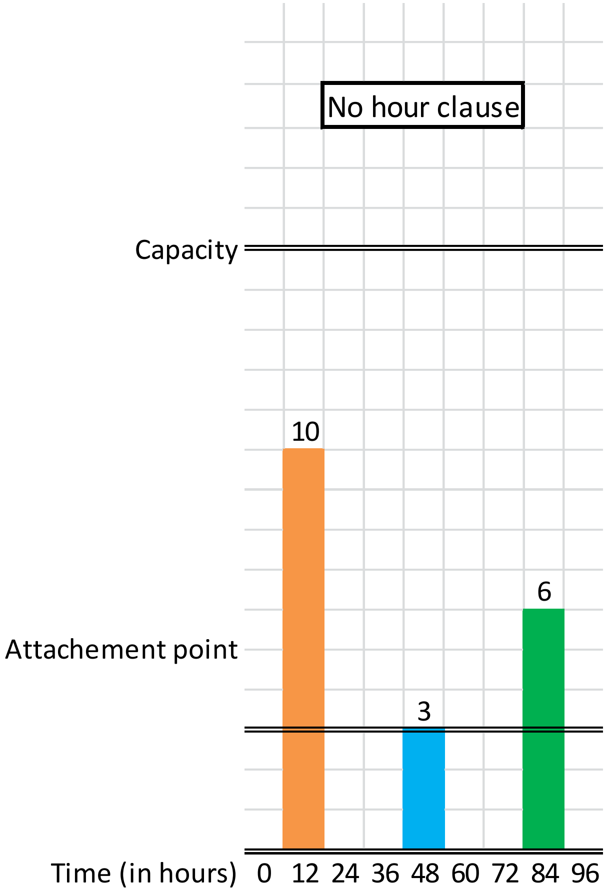
<u>Example for clause:</u> *"When several cyclones occur successively, claims produced by these cyclones are aggregated within a 72 hours timeframe."*

- The duration depends on the peril:

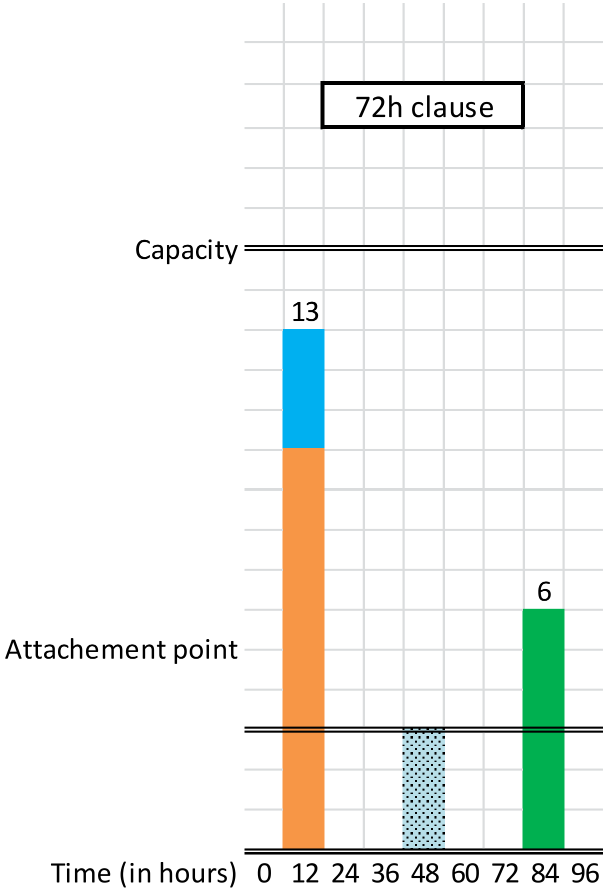
	Storms, cyclones, hurricanes	**Hail**	**Flood**	**Snow**	**Frost**	**Earthquake**	**Volcano eruption**	**Avalanche, landslide**	**Other**
Market benchmark	72h	72h	504h	504h	504h	168h	168h	168 h	168 h

- Due to the **reinstatement mechanism in reinsurance**, the actual coverage of **an insurer can widely depend on the hour clause definition**.
- Moreover, the duration of the hour clause can have a huge impact on the coverage (cf. next slide)

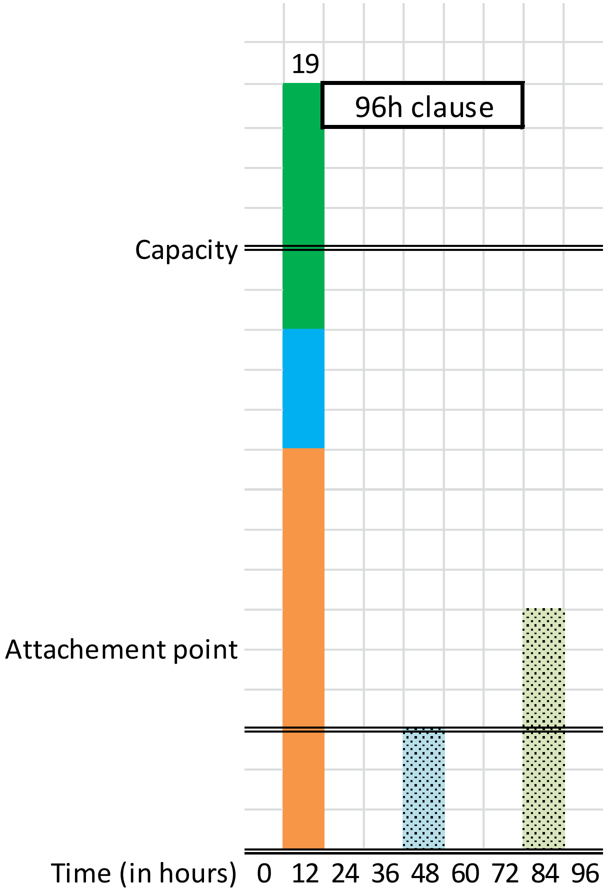
Hour clauses: an example



Loss to layer = 7 + 0 + 3 = 10

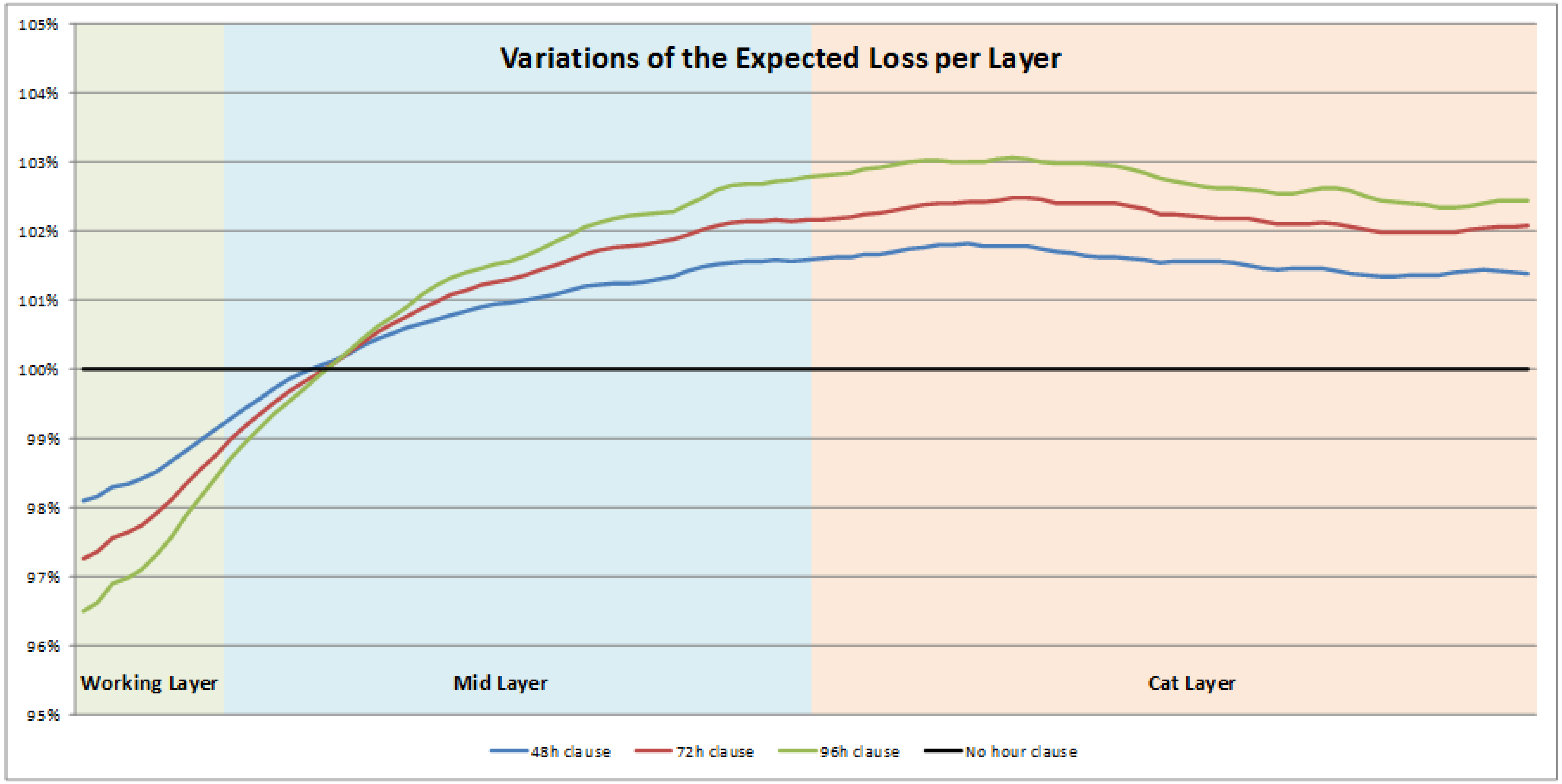


Loss to layer = 7 + 3 + 3 = 13



Loss to layer = 7 + 3 + 2 = 12

Risk transfer in a clustered world



In order to **observe the impact of the duration of the hour clause**, we first simulate claims across several years.

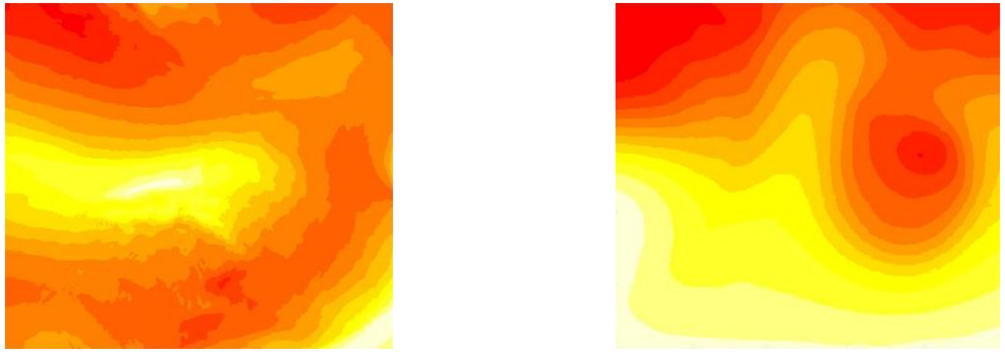
We then aggregate these claims using different durations for the hour clause, and we replicate a classic reinsurance structure (XS treaty).

The variability in the Cat Layer is due to the low number of events that activate this layer.

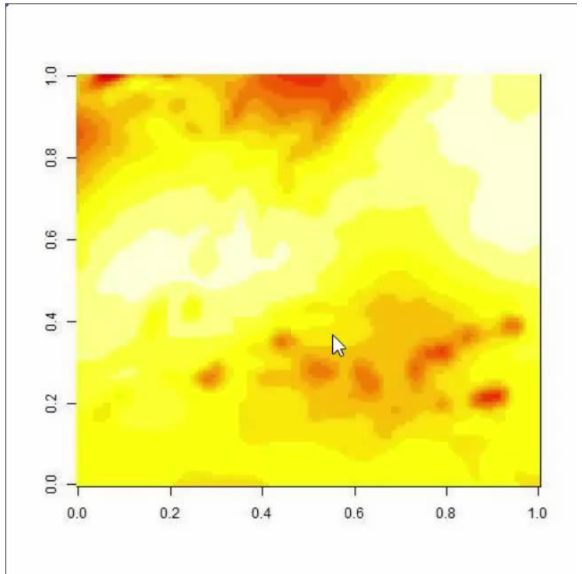
The genesis of storms

Using RCM (Regional Climate Models) simulations, we identified french windstorms and looked back at the **atlantic configurations up to 7 days before the occurrence of each storm**

Atlantic configuration = jet-streams + pressure systems



- We tried to track pressure systems by using a GOTURN-like neural network…

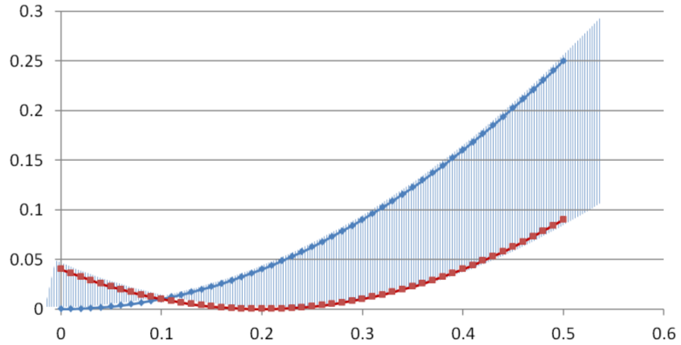


…but these pressure systems vary too fast for the neural network to catch up with them.

Defining atmospheric stability

We built two measures to quantify the stability of atmospheric configurations.

- **Intensity measure** (allows us to quantify the variations of windspeeds or pressure):



For each configuration, we first estimate the **distribution of the intensity** (windspeed of the jetstream, pressure,…). We then compute the absolute area between pairwise distributions of consecutive configurations (value of blue hatched area in the picture).

- **Space measure** (allows us to quantify the variations in the birth and development of jetstreams and pressure systems alike):

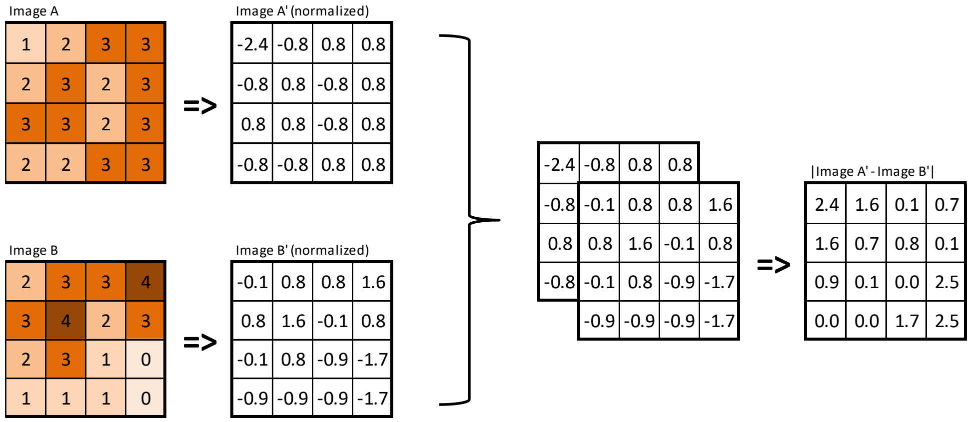


Image A

1	2	3	3
2	3	2	3
3	3	2	3
2	2	3	3

=>

Image A' (normalized)

-2.4	-0.8	0.8	0.8
-0.8	0.8	-0.8	0.8
0.8	0.8	-0.8	0.8
-0.8	-0.8	0.8	0.8

Image B

2	3	3	4
3	4	2	3
2	3	1	0
1	1	1	0

=>

Image B' (normalized)

-0.1	0.8	0.8	1.6
0.8	1.6	-0.1	0.8
-0.1	0.8	-0.9	-1.7
-0.9	-0.9	-0.9	-1.7

-2.4	-0.8	0.8	0.8	
-0.8	-0.1	0.8	0.8	1.6
0.8	0.8	1.6	-0.1	0.8
-0.8	-0.1	0.8	-0.9	-1.7
	-0.9	-0.9	-0.9	-1.7

=>

|Image A' - Image B'|

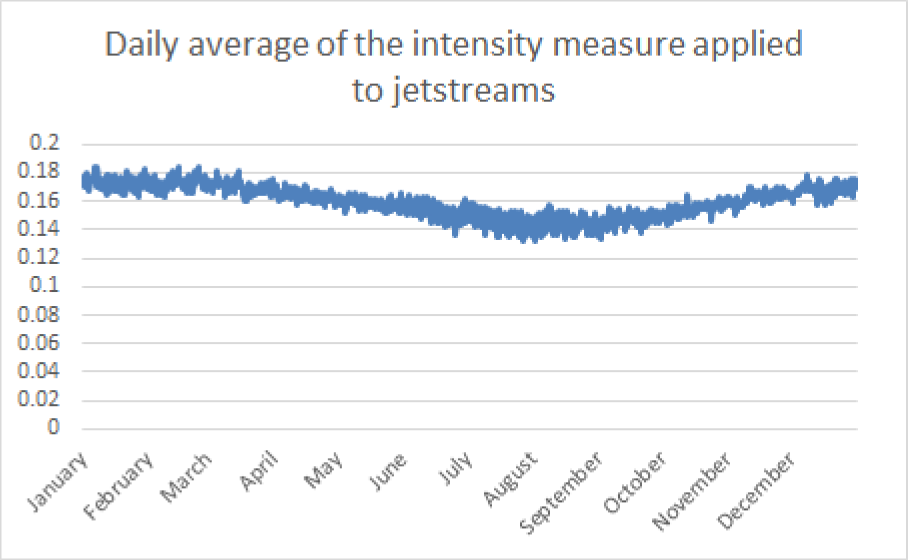
2.4	1.6	0.1	0.7
1.6	0.7	0.8	0.1
0.9	0.1	0.0	2.5
0.0	0.0	1.7	2.5

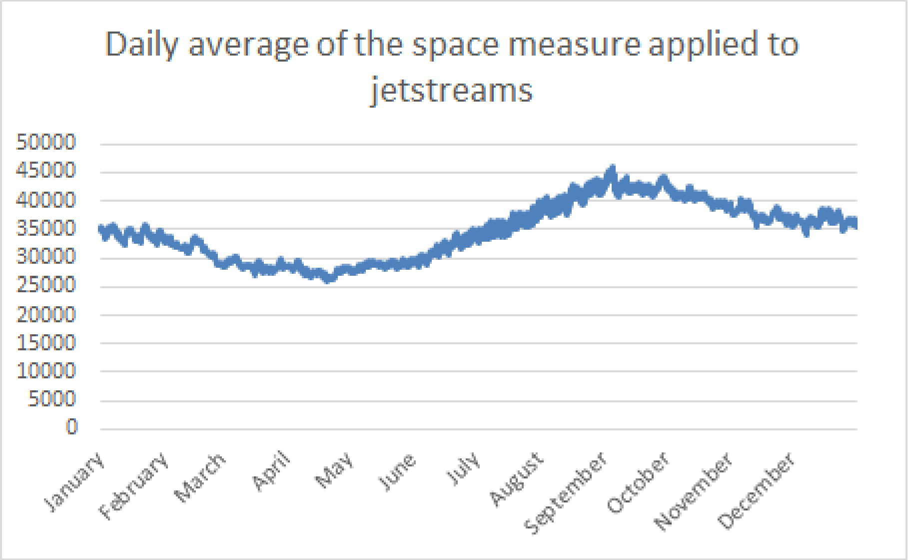
In order to avoid redundancy with the intensity measure, we first **normalize each configuration** by substrating the average of the picture's values, then dividing by the standard deviation.

We then compute the **sum of the elementwise absolute difference between consecutive configurations**.

Jet-streams stability:

When applied on jetstreams, we observe clear seasonalities for both measures (intensity+space).

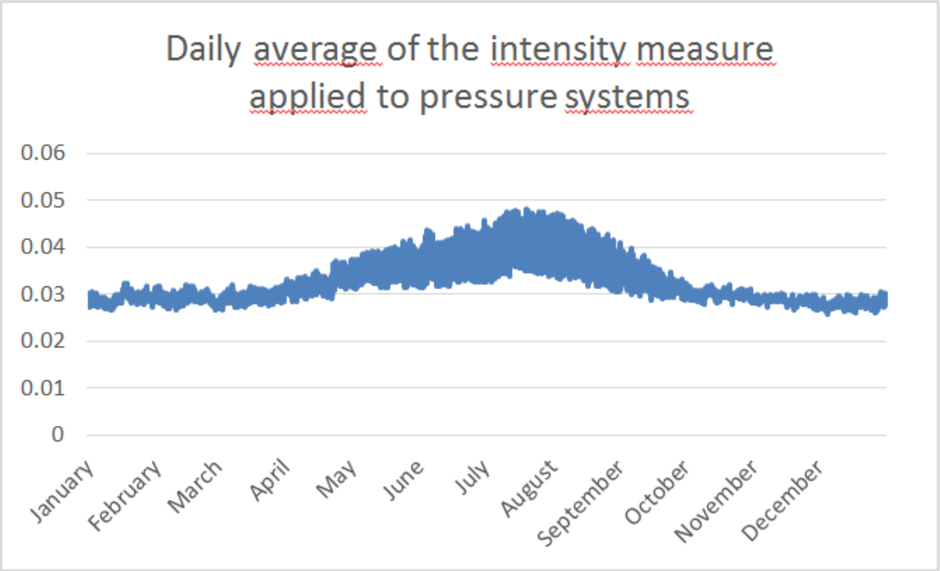


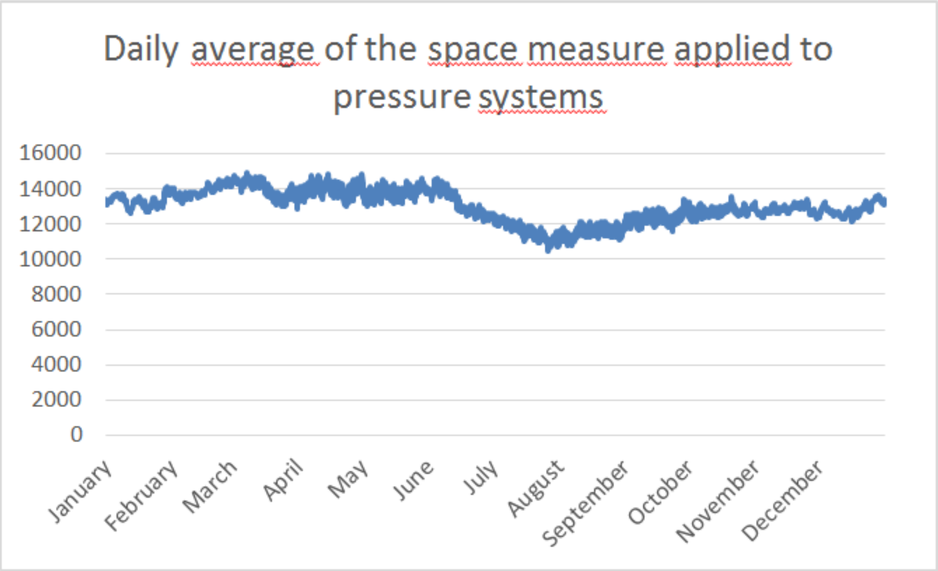


The intensity of jetstreams is **more stable in summer** (roughly: from june to october), while the position of jetstreams is **more stable in winter/spring** (roughly: from november to june).

Pressure systems stability:

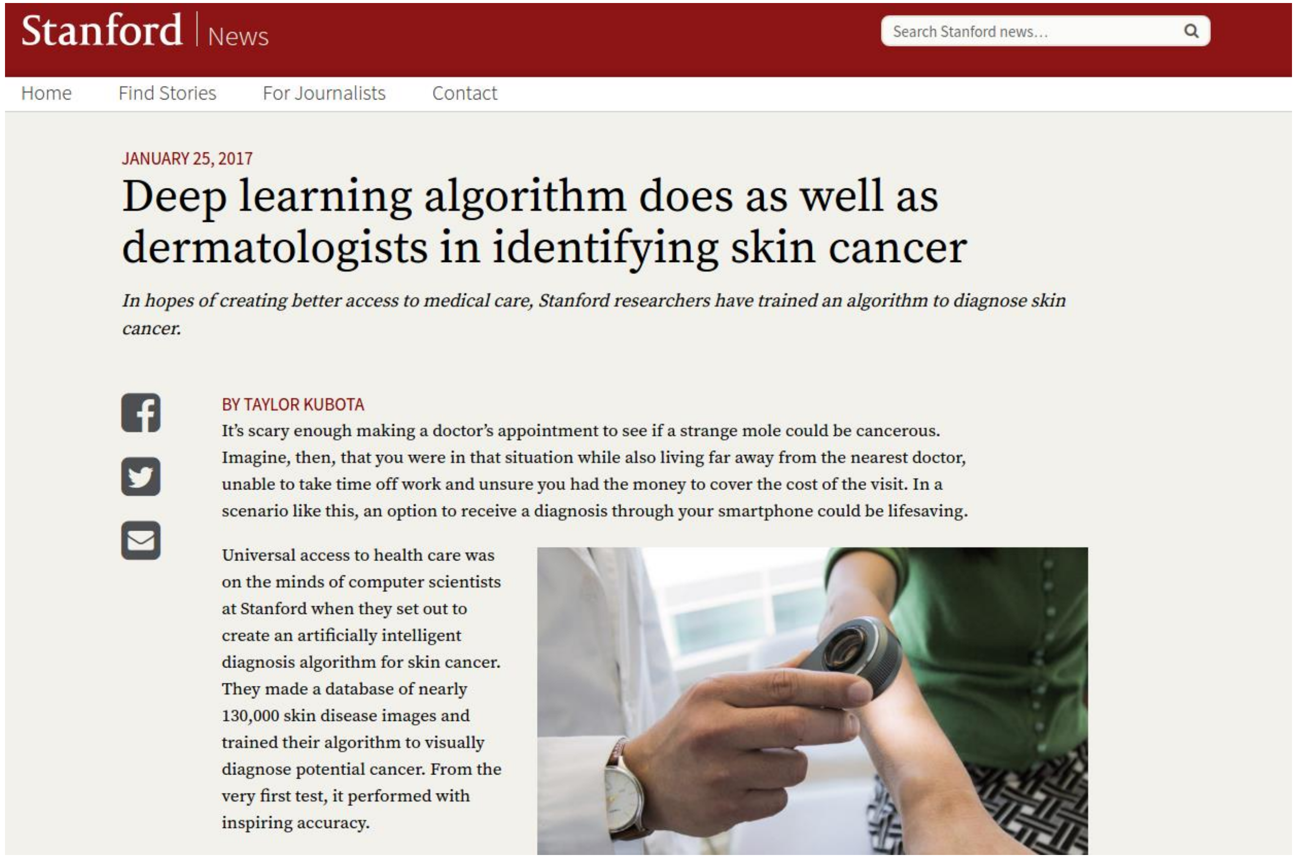
When applied on pressure systems, we also observe clear seasonalities for both measures (intensity+space).





The intensity of low pressure systems is **more stable in winter** (roughly: from october to april), while the position of low pressure systems is **more stable in summer/autumn** (roughly: from june to october).

Diagnostic tools



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JANUARY 25, 2017

Deep learning algorithm does as well as dermatologists in identifying skin cancer

In hopes of creating better access to medical care, Stanford researchers have trained an algorithm to diagnose skin cancer.

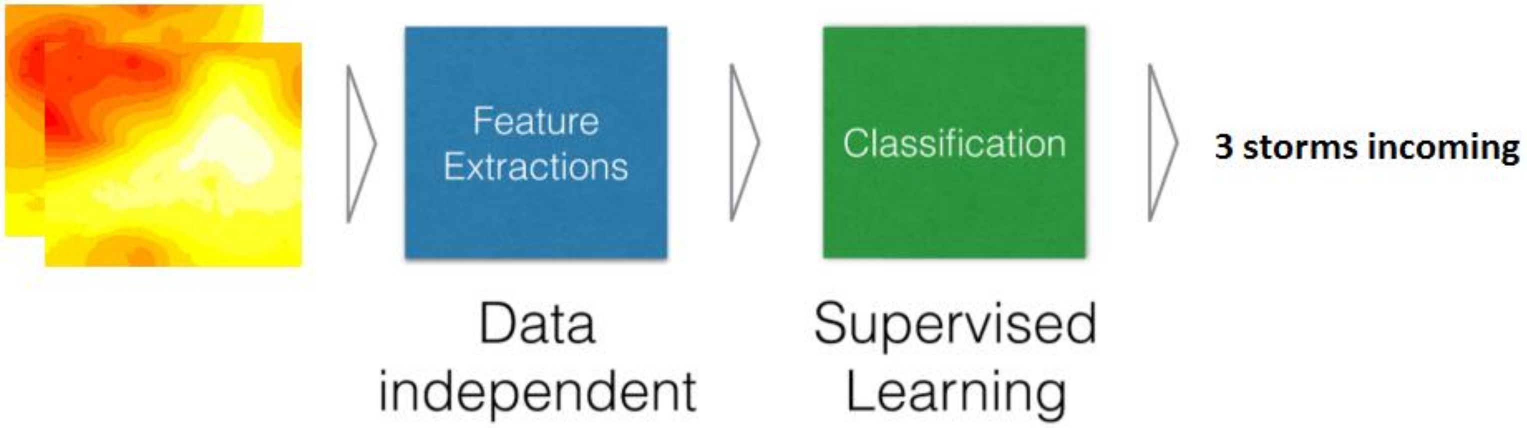
BY TAYLOR KUBOTA

It's scary enough making a doctor's appointment to see if a strange mole could be cancerous. Imagine, then, that you were in that situation while also living far away from the nearest doctor, unable to take time off work and unsure you had the money to cover the cost of the visit. In a scenario like this, an option to receive a diagnosis through your smartphone could be lifesaving.

Universal access to health care was on the minds of computer scientists at Stanford when they set out to create an artificially intelligent diagnosis algorithm for skin cancer. They made a database of nearly 130,000 skin disease images and trained their algorithm to visually diagnose potential cancer. From the very first test, it performed with inspiring accuracy.

- Diagnose the ability to generate a series of storms from an earlier satellite image view.
- using cartographic images of astmoshepric conditions in term of intensity and their evolution

Artificial intelligence for clustering



Feature Extractions

Classification

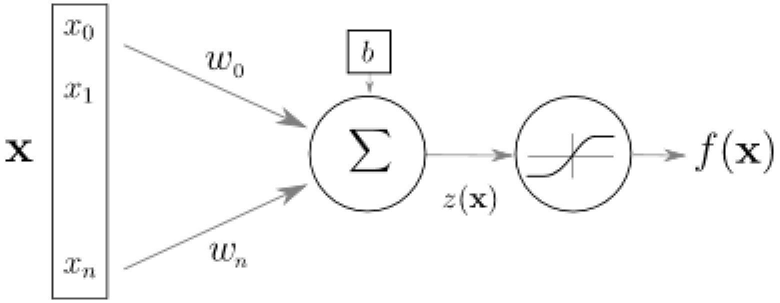
3 storms incoming

Data independent

Supervised Learning

- Estimate the number of storms that will happen in a given timeframe (e.g. 72 hours), using one image of the atmospheric configuration occurring 4 to 5 days before this timeframe (with a neural network)

Artificial neurone



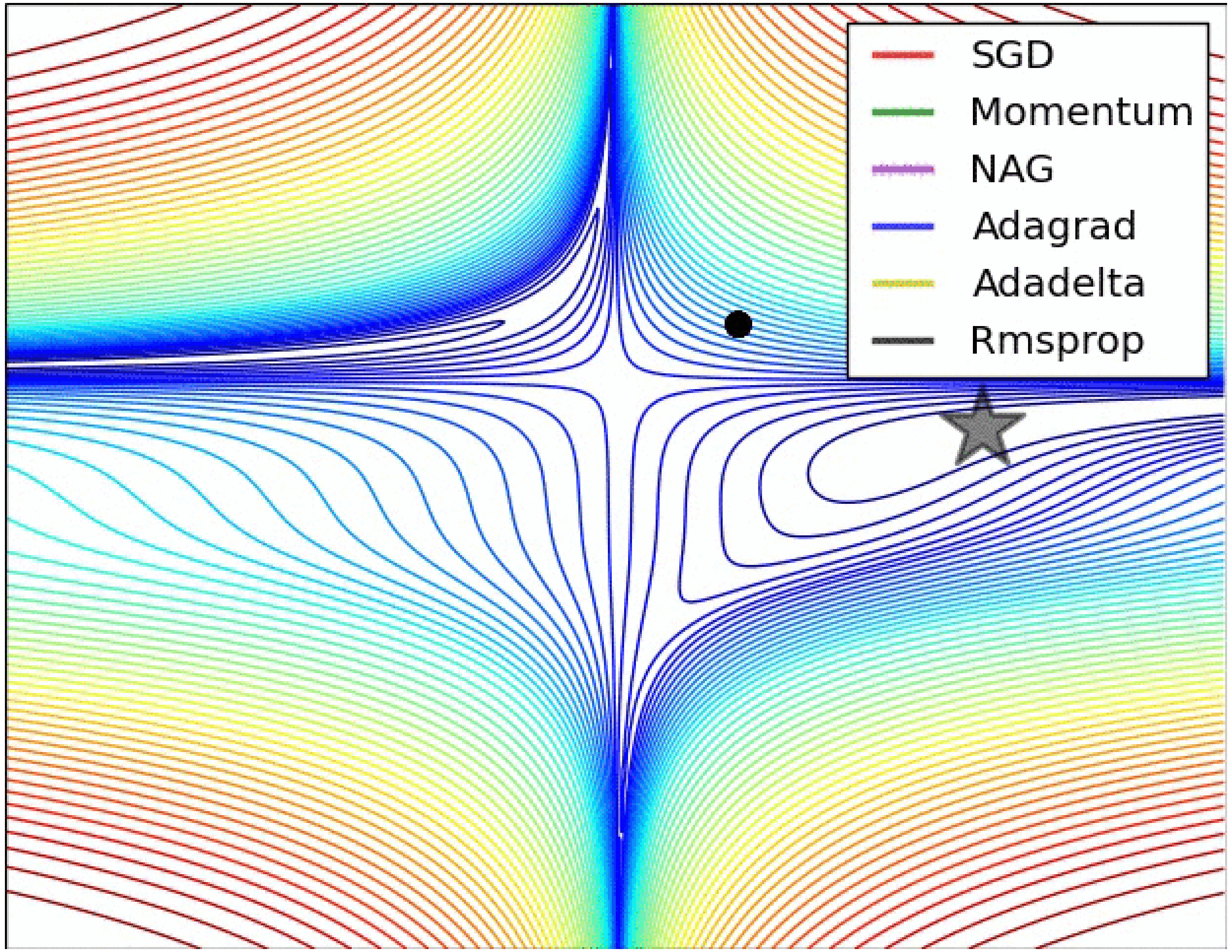
$$z(\mathbf{x}) = \mathbf{w}^T\mathbf{x} + b$$

$$f(\mathbf{x}) = g(\mathbf{w}^T\mathbf{x} + b)$$

- $\mathbf{x}$, $f(\mathbf{x})$ input and output
- $z(\mathbf{x})$ pre-activation
- $\mathbf{w}, b$ weights and bias
- g activation function

T	T+1	T+2	T+3	T+4	T+5	T+6	T+7
Observed image (jetstream+pressure systems)	▨				Number of storms occurring in this timeframe		

Stochastic gradient descent



Initialize θ randomly

For E epochs perform:

- Randomly select a small batch of samples $(B \subset S)$
- Compute gradients: $\Delta = \nabla_\theta L_B(\theta)$
- Update parameters: $\theta \leftarrow \theta - \eta\Delta$
- $\eta > 0$ is called the learning rate

Stop when reaching criterion

- nll stops decreasing when computed on validation set

Usual suspects

- Cluster embryo or pure coincidence?
- Is there anything recognizable in the images that would explain the course of the events?
- How many crimes ask the expert!

Conclusion

- Measure the ability of an initial image to create storm clusters. Follow predictive ability going up in the time scale.
- Determine what would need to be changed in the initial image to change the category of storm cluster category.
- Approach that requires a large volume of data also used for climate change studies. An insurer's initiative to proactively identify clues using artificial intelligence to question experts.

marc.bagarry@groupama.com

vincent.noel@groupama.com