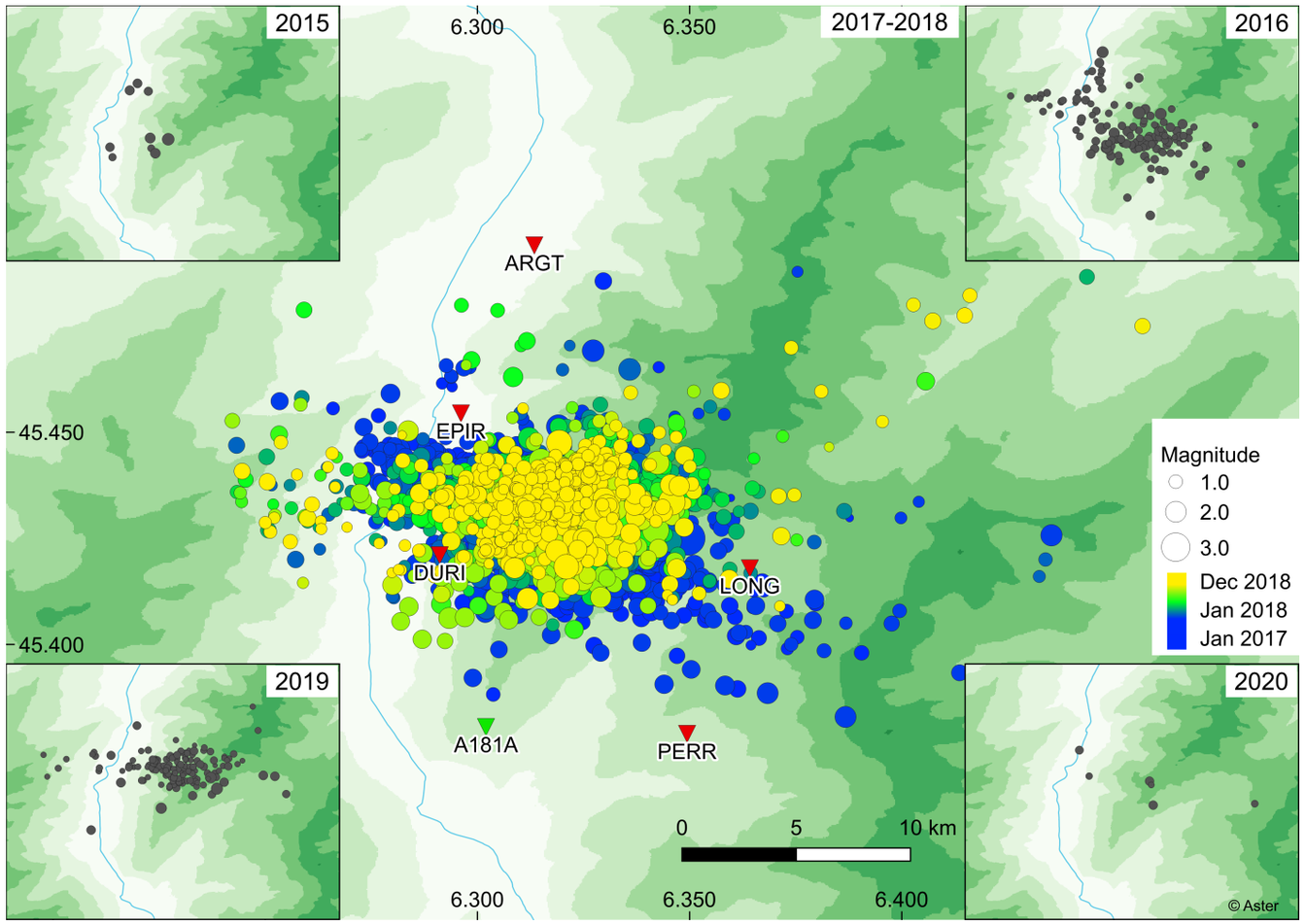
Essaim sismique dans la vallée de la Maurienne (2017-2019) observé par le réseau SISmalp : surveillance et gestion opérationnelles

Coralie Aubert, Svetlana Byrdina, Olivier Coutant, Cyrielle Dollet (PhD Student), Gael Janex, Stéphane Garambois, Philippe Guéguen, Agnès Helmstetter, Riccardo Minetto (PhD student), Mickael Langlais, Jérôme Nomade, Stéphane Schwartz, Benjamin Vial

Maurienne seismic activity

@SISmalp 1989 - 2020

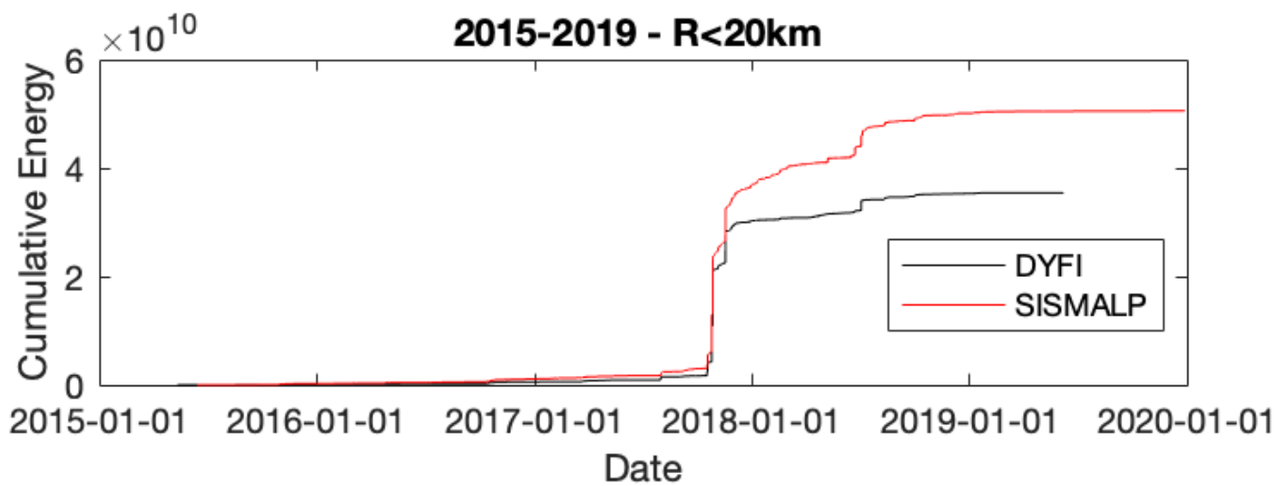


1989-2015 Very weak activity in the Valley
Oct. 2015 Seismic activity detected by SISmalp - Alertness
Oct. 2016 Stronger activity felt by population - 13 Oct. 5 EQK [1.2-2.1] / 24 Oct. 7 EQK [1.3-2.2]
July/Aug 2017 Increase of the activity 31 July M=2.3 - July 12 EQK - Aug 61 EQK - Sept 113 EQK)
Oct 17 / Oct 18 M 2.9 and M 3.1
Oct. 2017 Temporary stations installed (Code YW)

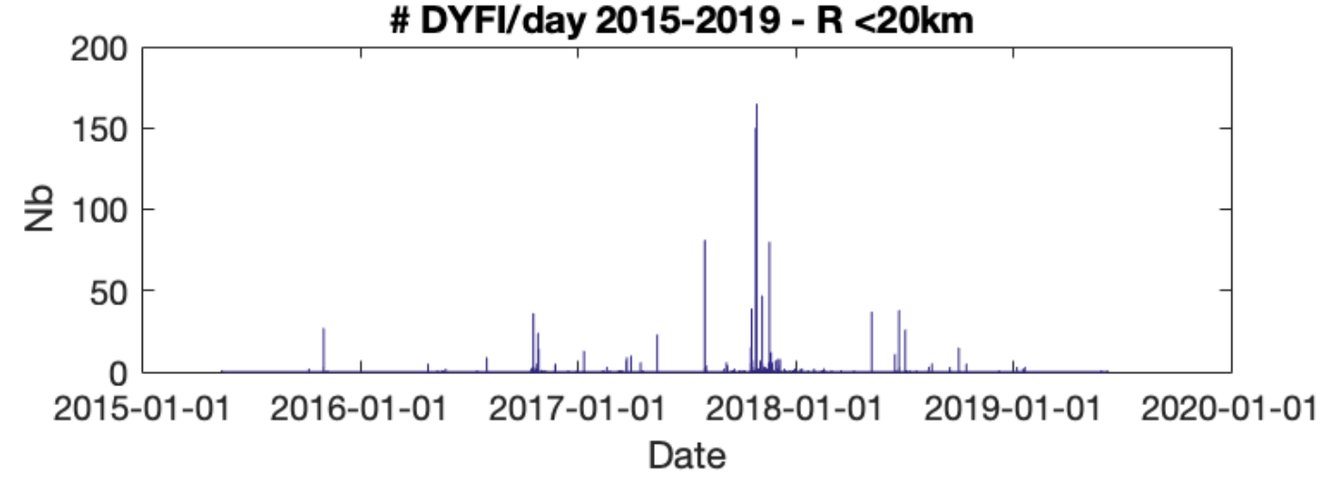
Maurienne swarm activity and perceptions

@SISmalp catalogue + BCSF Did You Feel It? (distance < 20km)

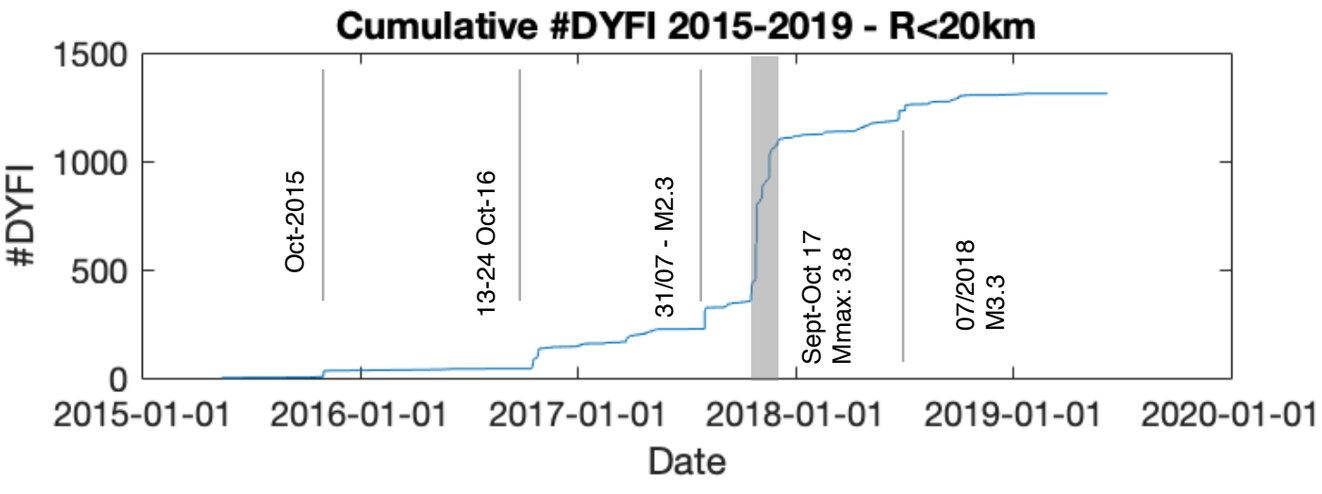
$\log_{10}(E_s) = 3/2\ M + 4.32$



Did You feel it?



Cumulative DYFI



Sequence timeline

2015 Sismalp détecte une augmentation de l'activité en 2015

Phase de Vigilance/Observation

Oct 2016 - Début de l'essaim - Premier contact avec le maire de La Chapelle

13 Oct: 5 séismes, 1.2< M_L <2.1 / **24 Oct:** 7 séismes, 1.3< M_L <2.2

July 2017 - Reprise de l'activité

31 Jul: M_L =2.3 - **July/Aug/Sep:** 12/61/113 séismes - **17 & 18 Oct** M_L =2.9 & 3.1

1. La population questionne le maire (pouvoir de police)

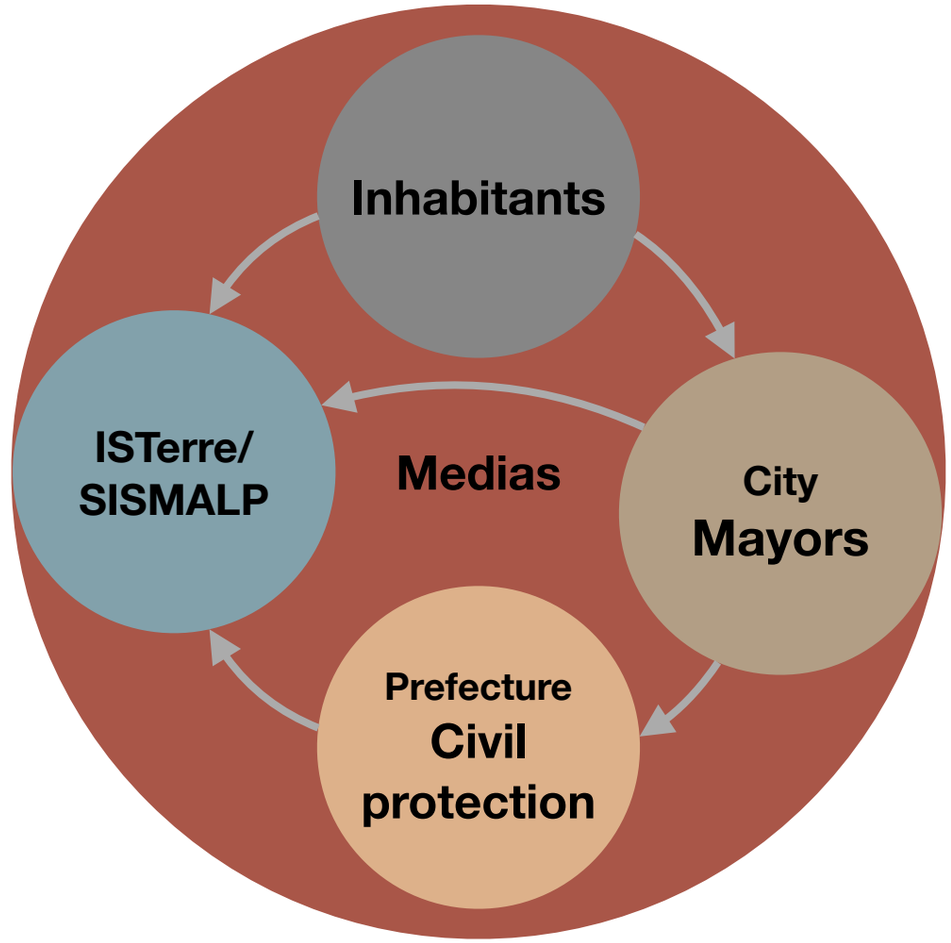
2. Les maires, démunis, cherchent de l'information:
que se passe-t-il?
Ils interrogent la Préfecture (Protection Civile)

3. Les maires et la protection civile se tournent vers ISTerre/Sismalp

Oct 2017 - Réseau temporaire

4. Les habitants se tournent directement vers ISTerre/Sismalp

5 Les Medias interrogent à leur tour ISTerre/Sismalp



…tout le monde se tourne vers ISTerre/SISMALP

Genesis of the SISM@LP-Swarm project

Xynthia 2010

2017 - Nantes Administrative Court:

The State (35%),
The Municipality (50%)
The ASVL (15%) are condemned "in solidum"

L'Aquila 2009

Séisme de l'Aquila: les sept scientifiques italiens acquittés

Condamnés en première instance à six ans de prison, les sept experts ont finalement été acquittés en appel ce lundi par la Cour d'appel de l'Aquila. En 2012, ils avaient été accusés d'avoir sous-estimé les risques sismiques avant le séisme meurtrier de 2009.

11/2014

Aquila: "Les sismologues ne possèdent pas la vérité absolue"

Au lendemain de la condamnation de scientifiques italiens à 6 ans de prison pour avoir sous-estimé les risques sismiques dans la région de l'Aquila en Italie, la communauté scientifique est sous le choc. La réaction de Robin Lacassin, directeur de l'équipe de tectonique à l'Institut de physique du globe.

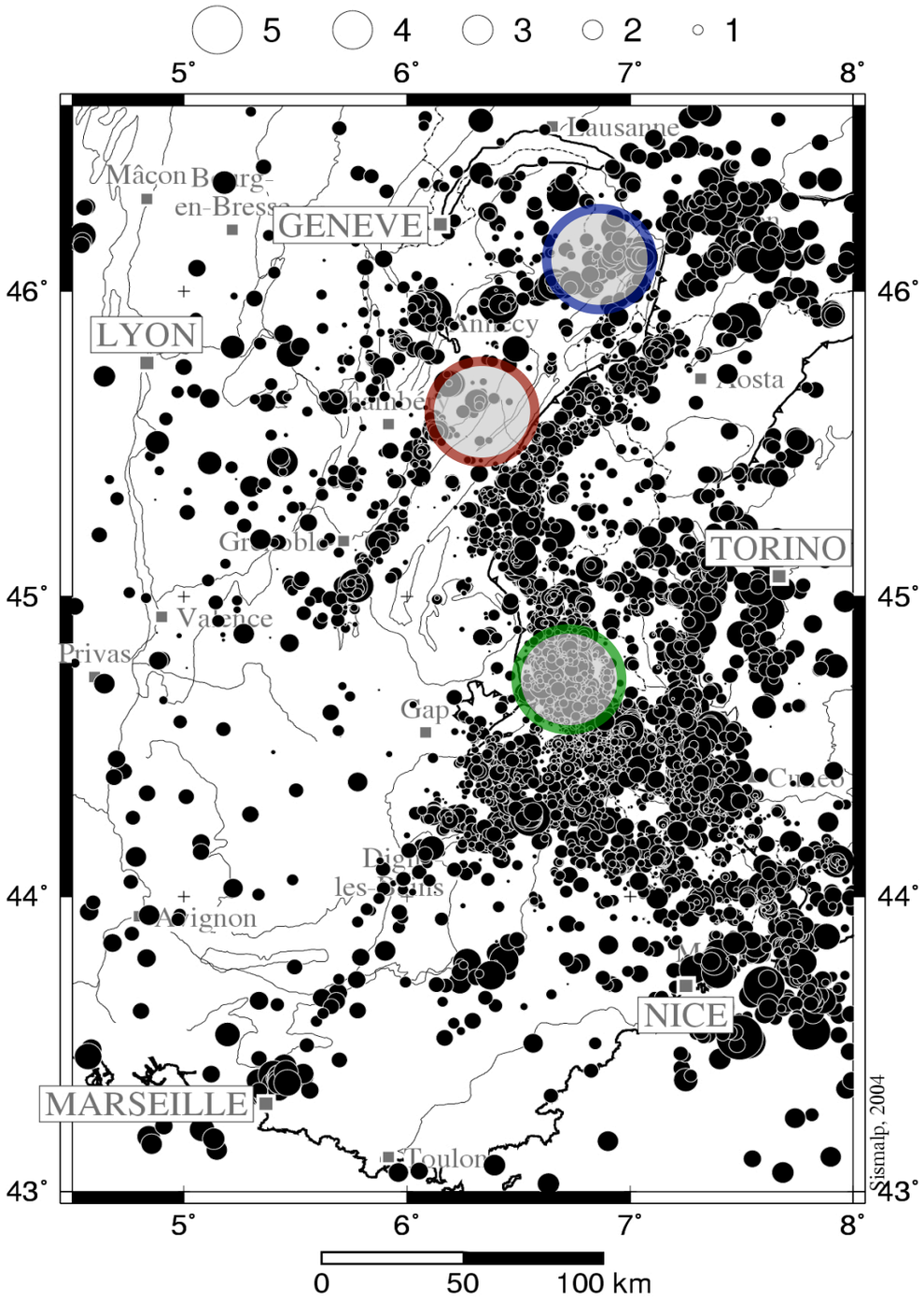
What information to communicate in uncertain times?

The responsibility of decision-makers? Scientists? State offices? Insurers?

SISM@LP-Swarm

Maurienne Swarm

Ubaye Swarm



Chamonix Swarm

SISM@LP-Swarm

Objective 1 : Improving knowledge on the physics of swarms

Objective 2 : Perception and non-structural damage

Objective 3 : Improving the flow of information from SISmalp in case of emergency

Objective 4 : Sharing knowledge and information

La Région Auvergne-Rhône-Alpes

RÉGION SUD PROVENCE ALPES CÔTE D'AZUR

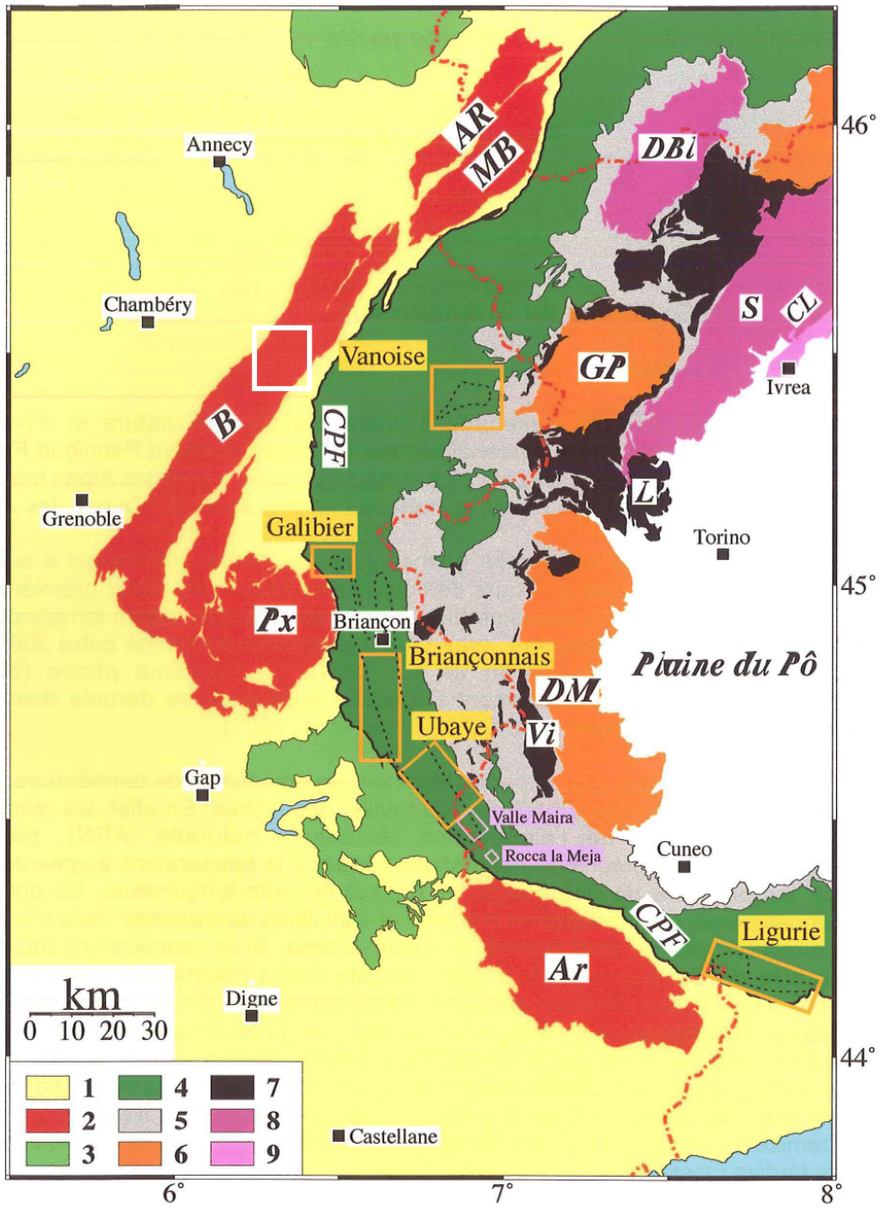
Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
MINISTÈRE DE LA COHÉSION DES TERRITOIRES ET DES RELATIONS AVEC LES COLLECTIVITÉS TERRITORIALES

AGENCE NATIONALE DE LA COHÉSION DES TERRITOIRES

l'Europe s'engage sur le Massif Alpin

UNION EUROPÉENNE
Fonds Européen de Développement Régional

Geology of the Maurienne Swarm



Localisation des zones d'échantillonnage. Les cadres orangés délimitent les cinq localités principales, les cadres mauves, deux zones d'études complémentaires.
Les pointillés noirs indiquent les zones d'affleurement du Marbre de Guillestre, du Galibier à la Ligurie, et les calcaires et brèches rouges du Jurassique-Crétacé de la Vanoise.
AR: Aiguilles Rouges; MB: Mont Blanc; B: Belledonne; Px: Pelvoux; Ar: Argentera; DBl: Dent Blanche; GP: Grand Paradis; DM: Dora Maira; S: Sesia; L: Lanzo; Vi: Viso;
CL: Ligne Canavèse; CPF: Chevauchement Pennique Frontal.
1: Couverture de la zone externe alpine; 2: Massifs cristallins externes; 3: Flysches; 4: Zone Briançon-naise; 5: Schistes lustrés; 6: Massifs cristallins internes; 7: Ophiolites; 8: Massifs cristallins internes; 9: Zone d'Ivrea

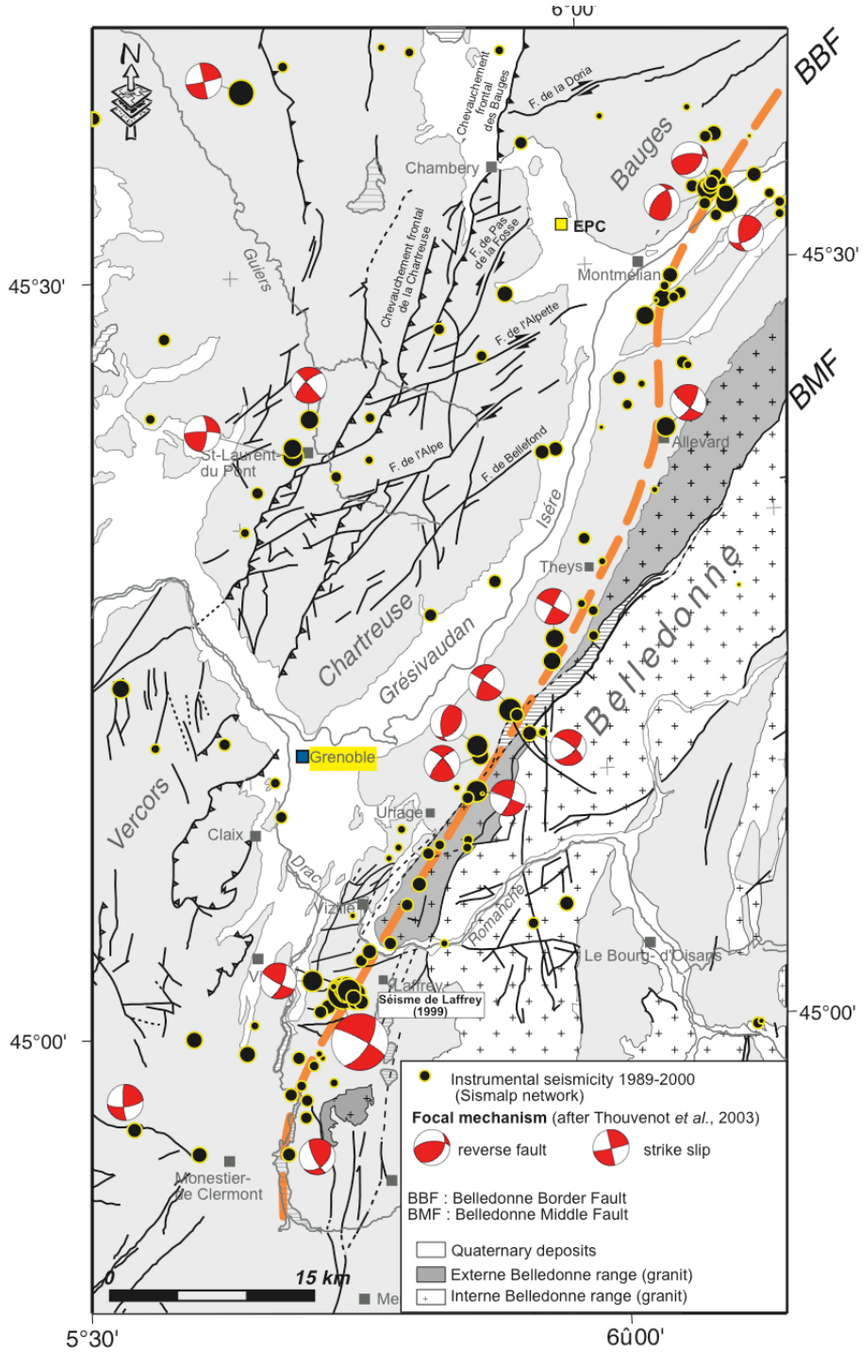
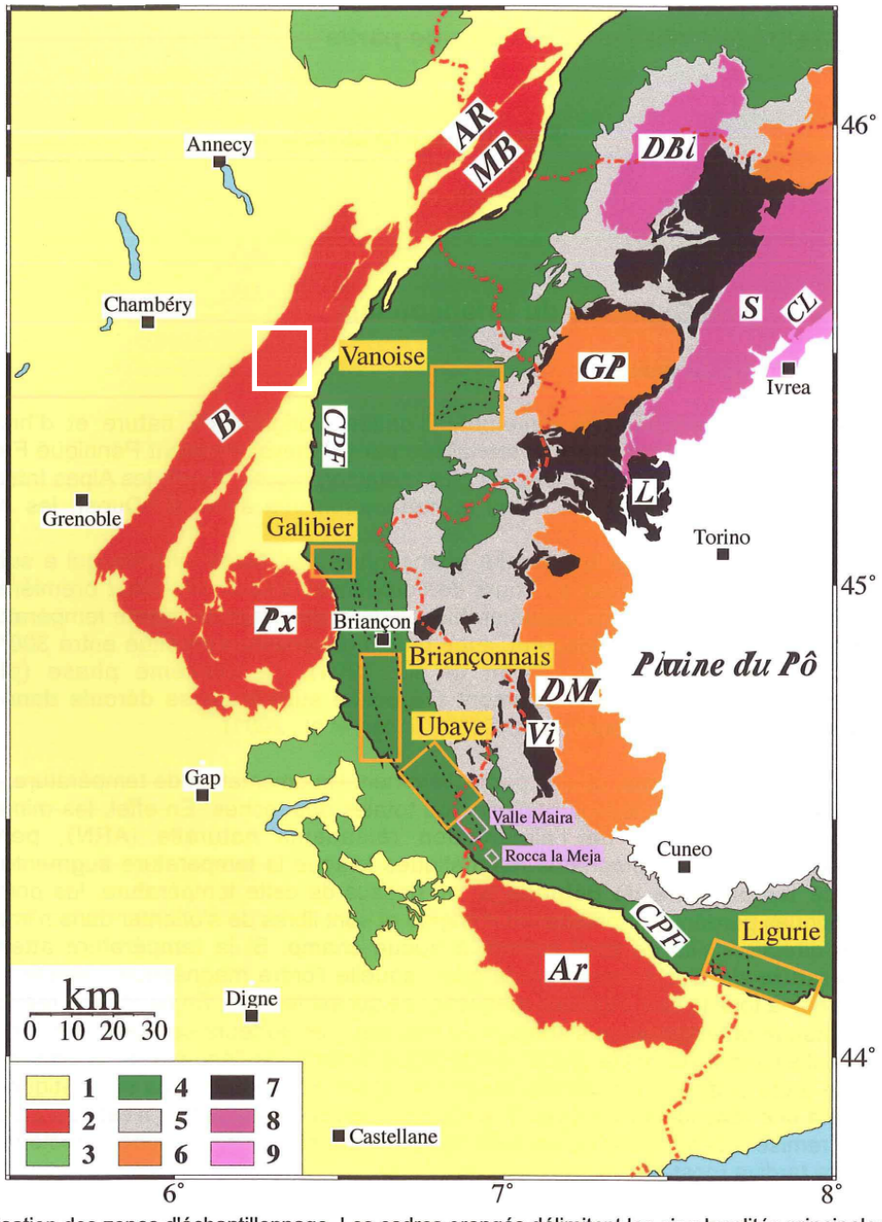


Fig. 2. Map of Grenoble and the main epicenters localized by the regional seismic network SISMALP (after Thouvenot et al., 2003).

Geology of the Maurienne Swarm



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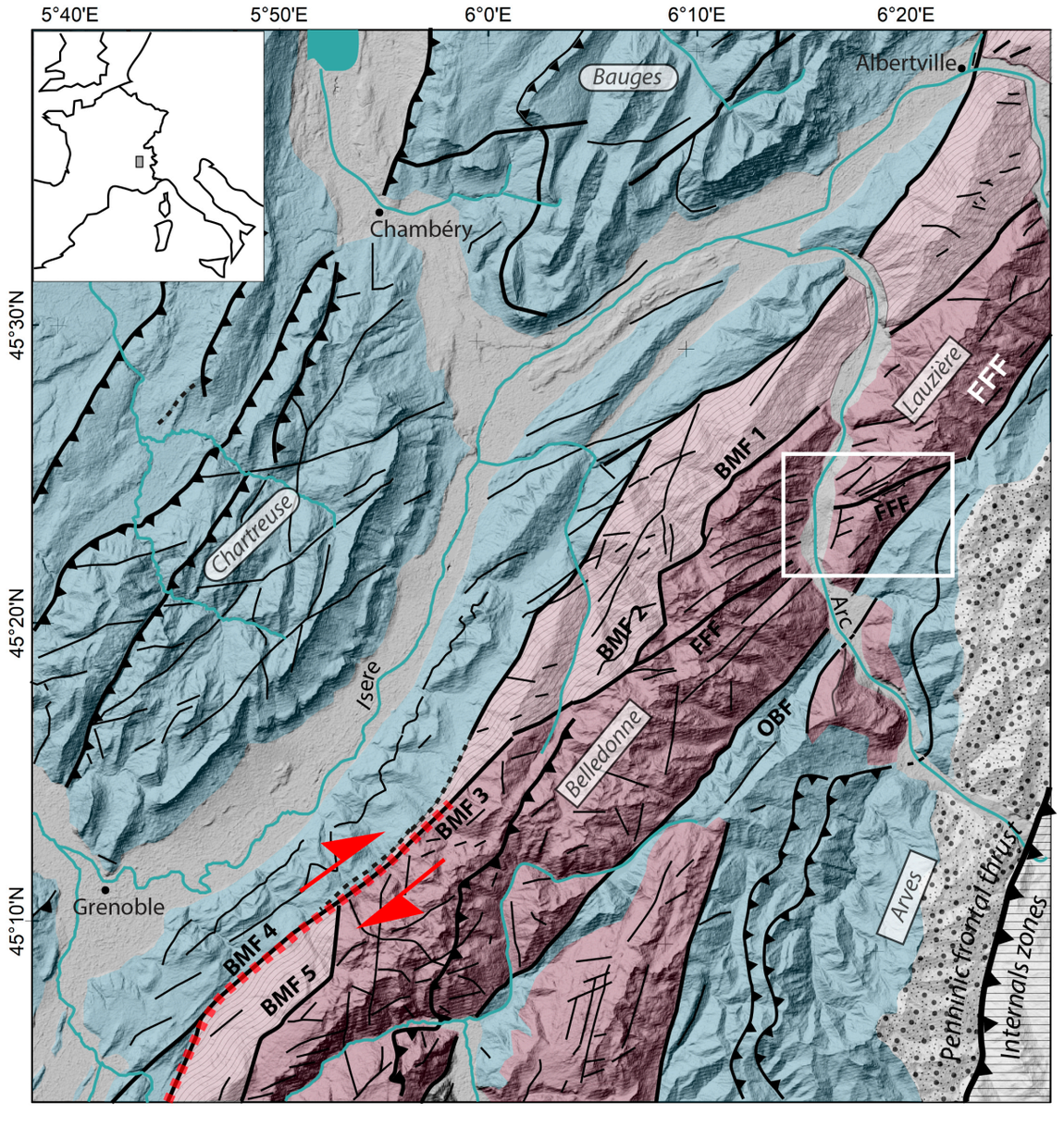
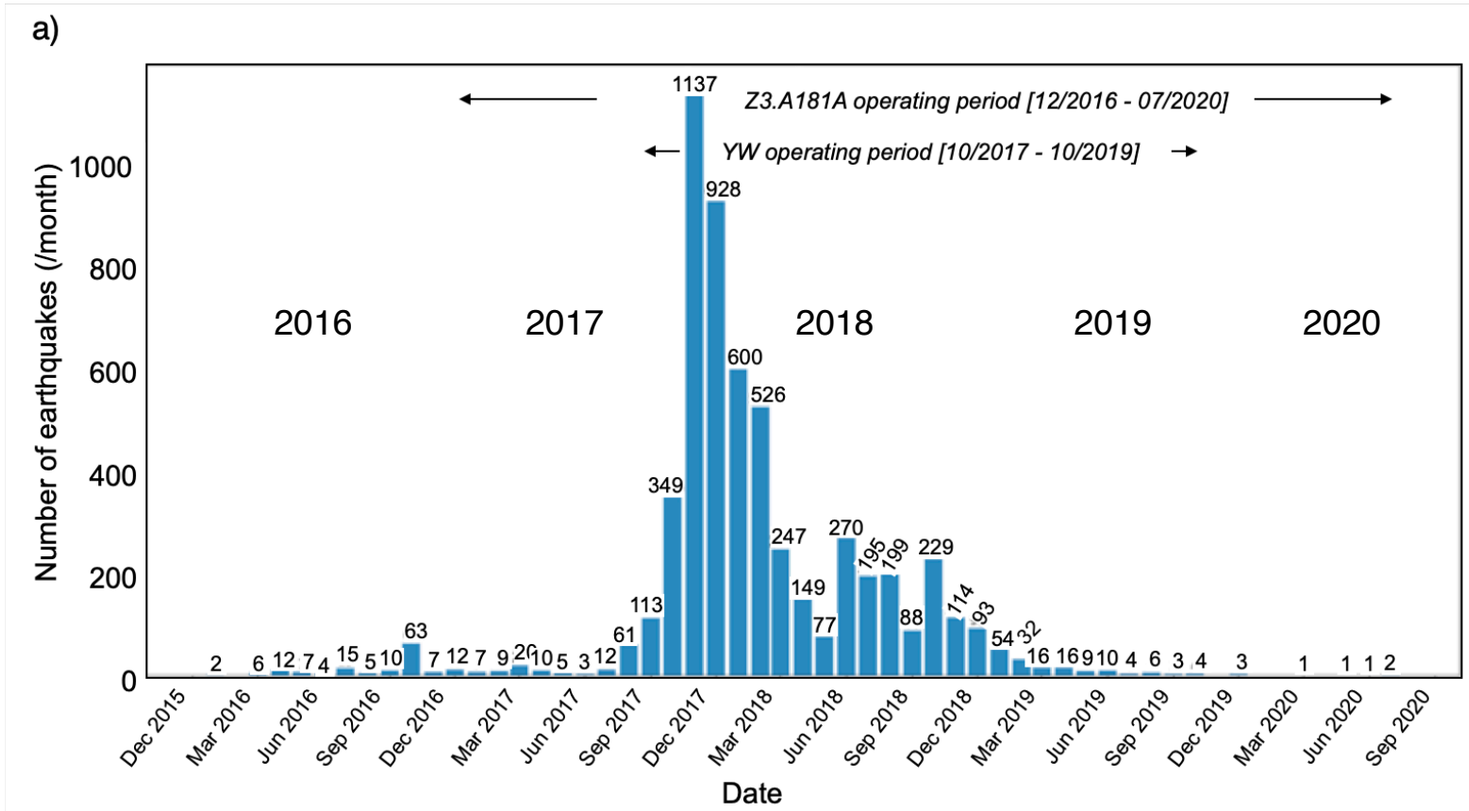


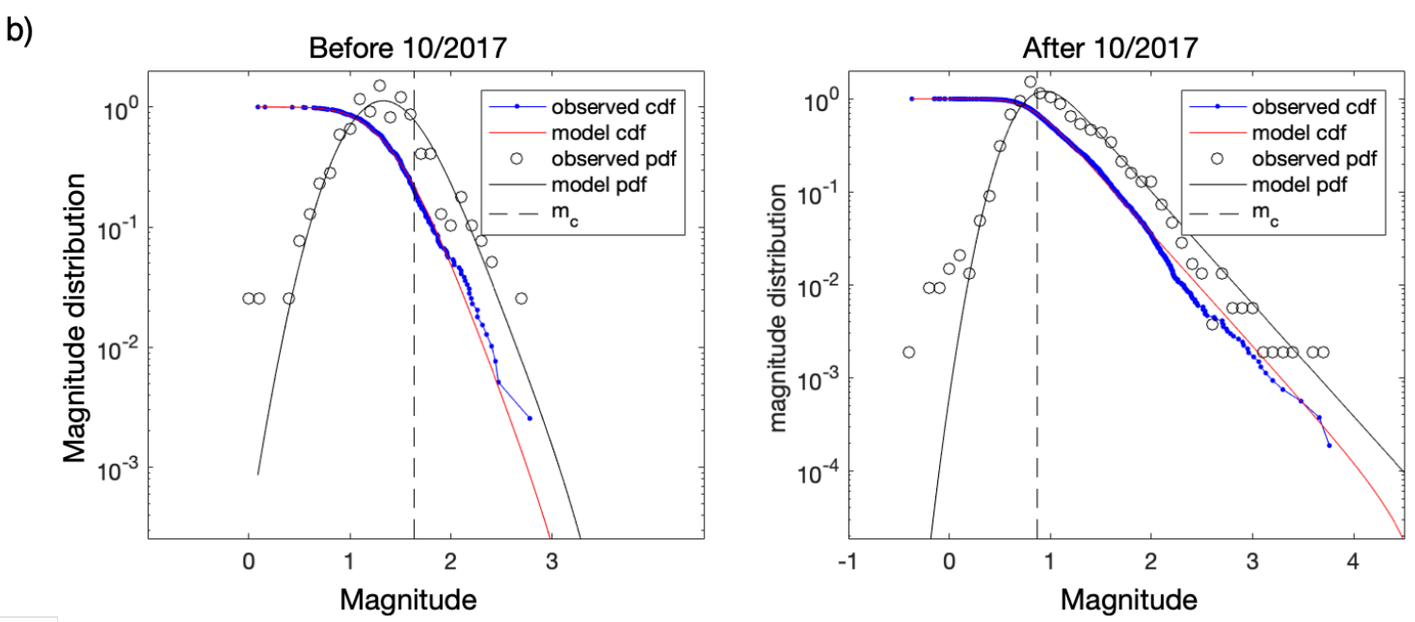
Seismology

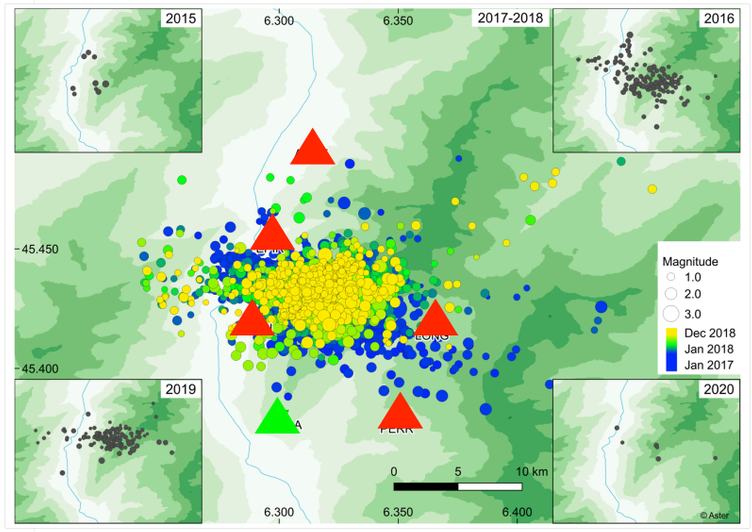


2015-2020:
5,744 events
Oct 2017 - Dec 2018:
5,201 events (91% - 11 EQK/day)
Mmax: 3.8 Oct, 27th 2017 (SISmalp)

Before Oct 2017
mc=1.635
After Oct 2017
mc=0.871

Not clear variation of the b-value
YW endtime: Oct 2019





Data processing
Based on Seiscomp3 instance

Semi-automatic procedure

Seiscomp instance considering temporary stations (Z3.A181A and YW) and FR+RA regional stations

Usual configuration: 6 validated phases to find a solution

==> **Home-made script** added to the configuration considering 3 phases on YW and Z3.A181A (for small events)

Event clustering: cross-correlation for each pair of events using waveforms at station Z3.A181A

—> assigned to the same cluster for CC>0.9 (92% of the original catalog)

—> #cluster: 157 - Largest cluster consist on 663 events

Relocalisation: hypoDD applied to the cluster with #events > 10

—> #cluster: 99 (83% of the original catalog)

Step 1: relocation of each cluster (one reference event) with SC phases

Step 2: relocation within each cluster by CC to find P and S arrival times based on P and S phase of the reference event - Ts-Tp for each pair produced cluster by cluster - Shift (if necessary) of the entire cluster

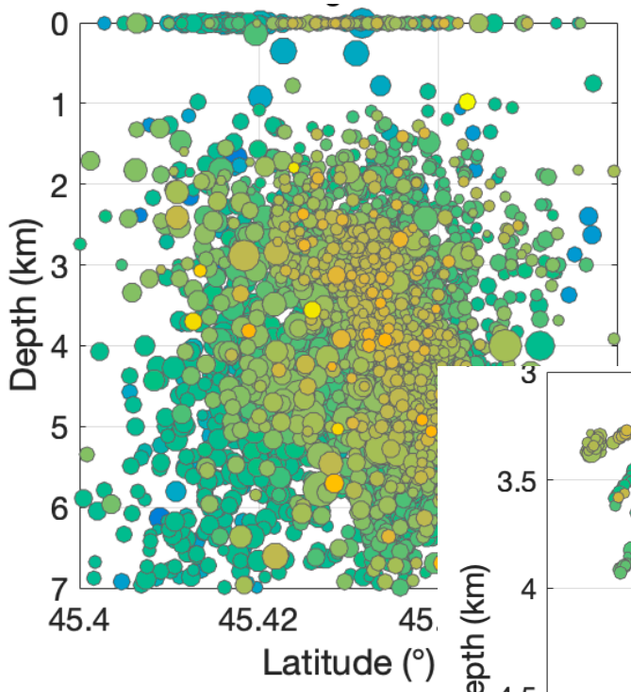
1D velocity model (Vp/Vs=1.73 - Paul et al., 2001)

Depth (km)	−1	0	2	3	4	5	6	10
V_p (km·s)	4.00	4.50	4.75	5.00	5.15	5.30	5.50	5.70

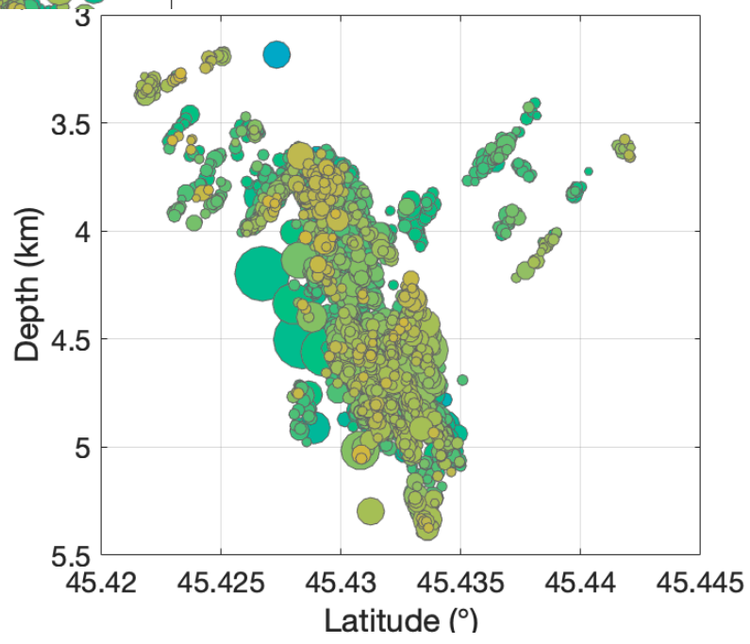
Data processing

Based on Seiscomp3 instance

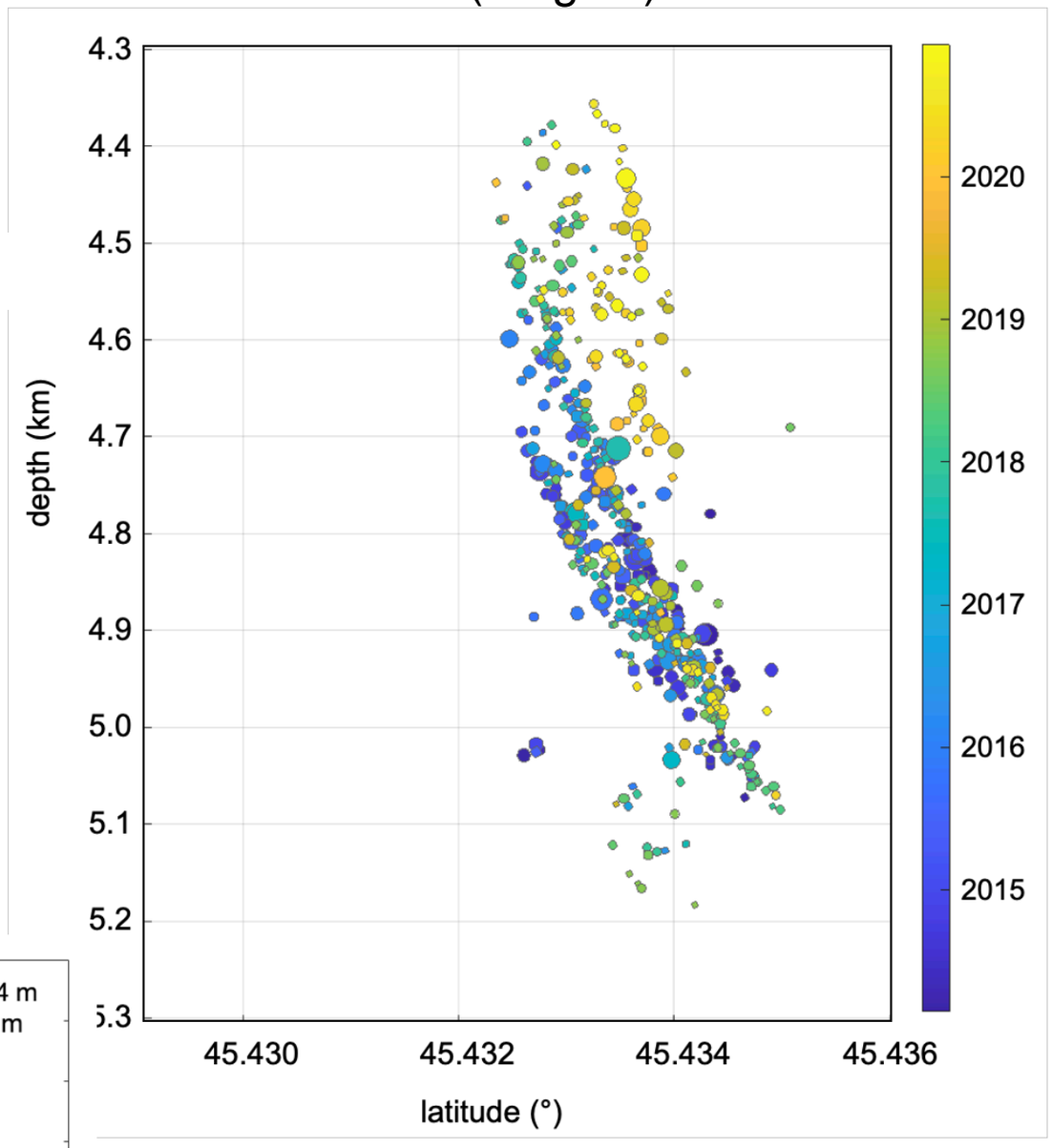
No cluster - No reloc



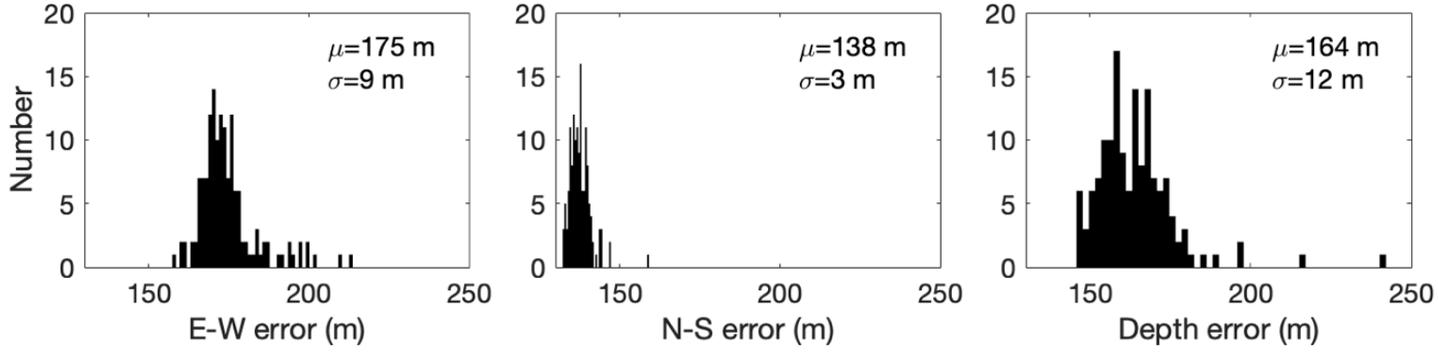
Cluster + Reloc



Cluster 8 (Largest)



Relative error ~150m

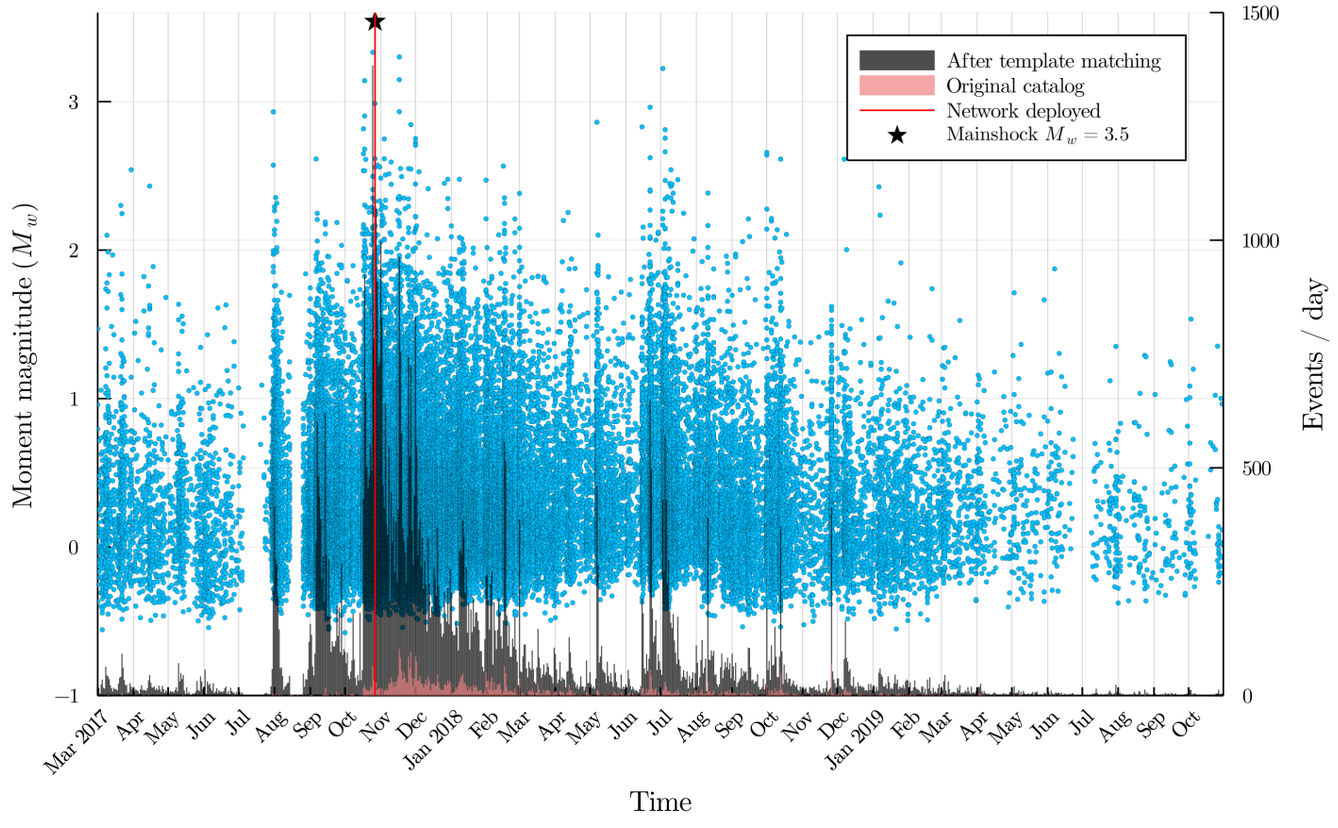


Data processing

Template-Matching+HypoDD

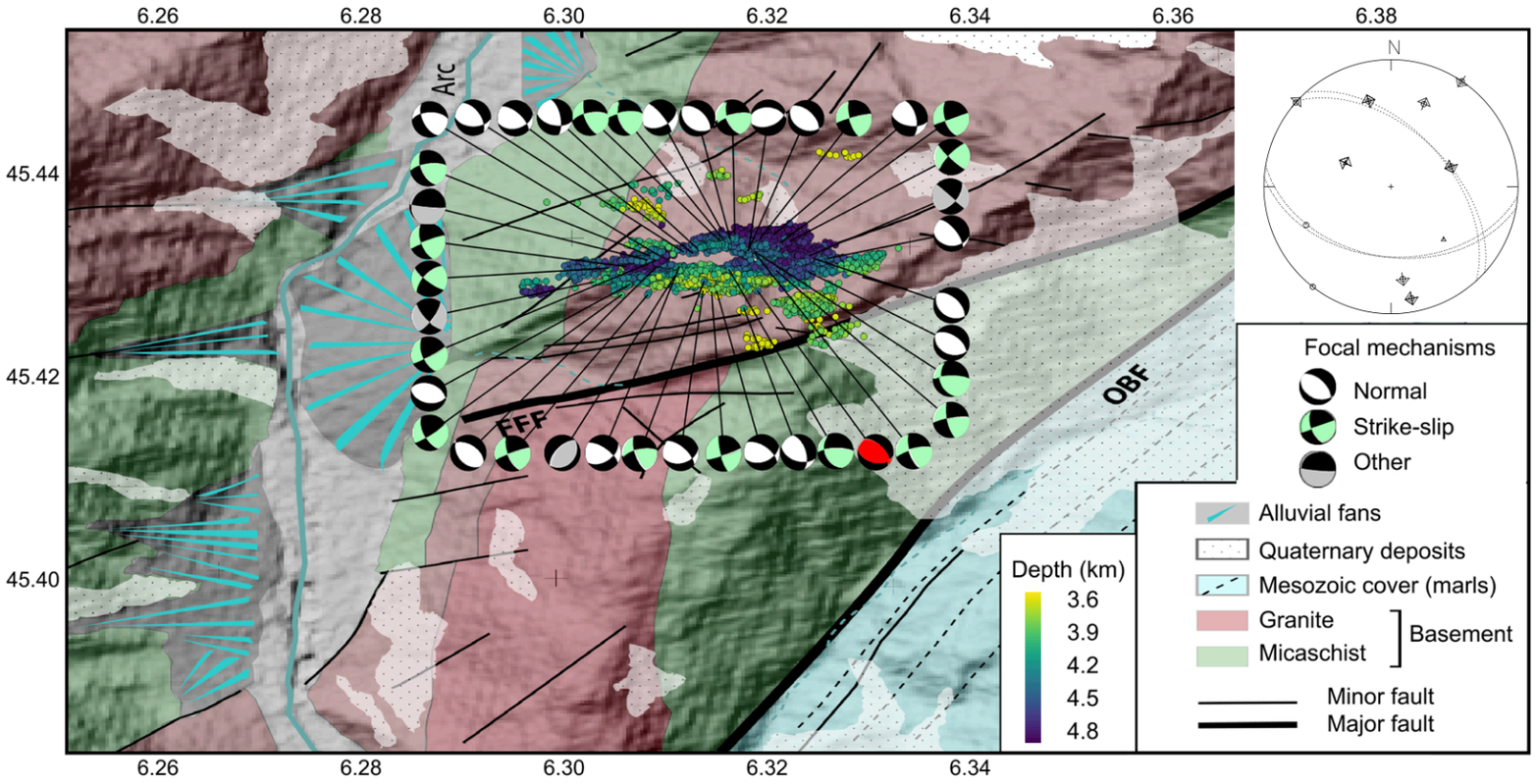
Minetto et al., submitted

79,503 events
Z3.A181A (AlpArray) station



- b-value variation in depth
- Migration appears to be driven by a self-controlled rupture process based on the interaction of seismic slip and fluid flow.

Conclusions 1



Swarm activity corresponds to a segment of the dextral **Fond-de-France Fault,** which outcrop clearly on the edge of the Lauzière massif

The epicenters show a **EW alignment,** while the most hypocenters define a faulting structure **dipping north at about 70°** between **2 and 6 kilometers (bsl)**.

Fluid/seismic interaction (Minetto et al., submitted)

Conclusions 2

Feedback from workshops with local authorities

WS 1: REX from the sequence

WS 2: Seismic swarm crisis management

WS 3: lack of information/flow of information

Irrational behavior of the population

- population leaving the valley
- fear of economic loss to the valley
- parents worried about their children at school
- Fake news !

Conclusions

1. Inadequate regulatory measures (PCS, DICRIM...)
2. the beneficial effect of the actions of the SISmalp team (betting on M after october 2017!)
3. The “lack” of previous seismicity introduced a bias on the seismic perception :

what would be the consequences in case of bigger earthquakes?

4. Territorial inequality (urban/rural) face to seismic risk and limits of the decentralization
5. Questioning the responsibility of stakeholders

Merci de votre attention

@SISMALP-Swarm website

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Guéguen, P., Janex G., Nomade J., Langlais M., Helmstetter, A., Coutant O., Schwartz S., Dollet C., 2021. Unprecedented seismic swarm in the Maurienne valley (2017–2019) observed by the SISmalp Alpine seismic network : operational monitoring and management , CR Geoscience, doi 10.5802/crgeos.70

Dollet C, Guéguen P. 2021. Global occurrence models for human and economic losses due to earthquakes (1967–2018) considering exposed GDP and population. Natural Hazards. doi : 10.1007/s11069-021-04950-z