

The French accelerometric strong-motion network for earthquake hazard and risk studies



OVERVIEW

The French accelerometric strong-motion network (RAP-RESIF, Réseau Accélérométrique Permanent, rap.resif.fr) aims at improving the knowledge on **earthquake strong ground motion** that could affect the **French territory (mainland and overseas territories)**, and its **effect on structures**. Accelerometers have the required sensitivity to record high amplitudes in the frequency range of interest to civil engineering. The RAP sets up its stations in regions of relatively high seismicity where earthquake hazard is the highest (West Indies, Alps, Provence and Pyrenees), but also in regions where seismicity rates are modest although not negligible (Fossé Rhénan, Ardennes, Massif Central, Massif Armoricain, Mayotte). One of the challenges is to install stations as close as possible to seismic sources in order to record strong motions at short distances (ideally within 20 km). The distribution and evolution of the network is therefore strongly dependent on the increasing knowledge of the French seismicity and potentially active faults. The RAP also aims to locate its stations in areas prone to seismic risk: specific geological sites where phenomena of wave amplification are expected, and urban areas with high human, economic or environmental stakes.

The RAP coordinates, manages, promotes and disseminates earthquake data recorded in France, with the help of regional networks that operate the **162** seismological stations on field. The RAP central site is based in ISTERre laboratory (University of Grenoble Alpes, OSUG observatory), where is also located the national datacenter of the research infrastructure RESIF (Réseau Sismologique et Géodésique Français, www.resif.fr), in which the RAP is in charge of the accelerometric part. The RAP central site collects the accelerometric data recorded by all the stations, updates and maintains the subsequent national database, improves the data quality control, provides a technical support to the regional networks, ensures technology intelligence and takes care of the renewal of the seismological stations. It also defines new technologies and equipment that will be deployed on the whole network.

Furthermore, the RAP is in charge of promoting the use of accelerometric data through its support to scientific research projects and to innovative experiments. The main scientific goal is to improve our understanding of the mechanisms involved in the generation of strong and destructive seismic motion. The supported researches relate to fault rupture processes (source effects), propagation and attenuation of seismic waves on the French territories, effects of local amplification due to geology (site effects), predictions of the expected ground motion in France, spatial variability of earthquake ground motion, adaptation of design spectra, dynamic response of structures and buildings for earthquake engineering (seismic vulnerability).

RESIF DATA PORTAL

Waveforms, station information and event catalogs. seismology.resif.fr

Open-access data

THE FRENCH PERMANENT SEISMOLOGICAL NETWORKS

2 complementary networks:

RLBP-RESIF code FR

Broadband seismometers (120 sites)

Regular distribution and uniform coverage

For imagery of superficial and deep geological structures + seismic sources studies

RAP-RESIF code FR/RA

Accelerometers (162 sites)

Located close to seismic sources and denser in some exposed urban areas

Also in French overseas territories

For ground-motion prediction + seismic behavior of buildings

Observatory services:

RENASS renass.unistra.fr

Earthquake location and magnitude in mainland France

BCSF www.franceseisme.fr

Instrumental and historical seismicity, Shakemaps, macroseismic surveys, mainland and overseas

LDG

Earthquake warning in mainland France

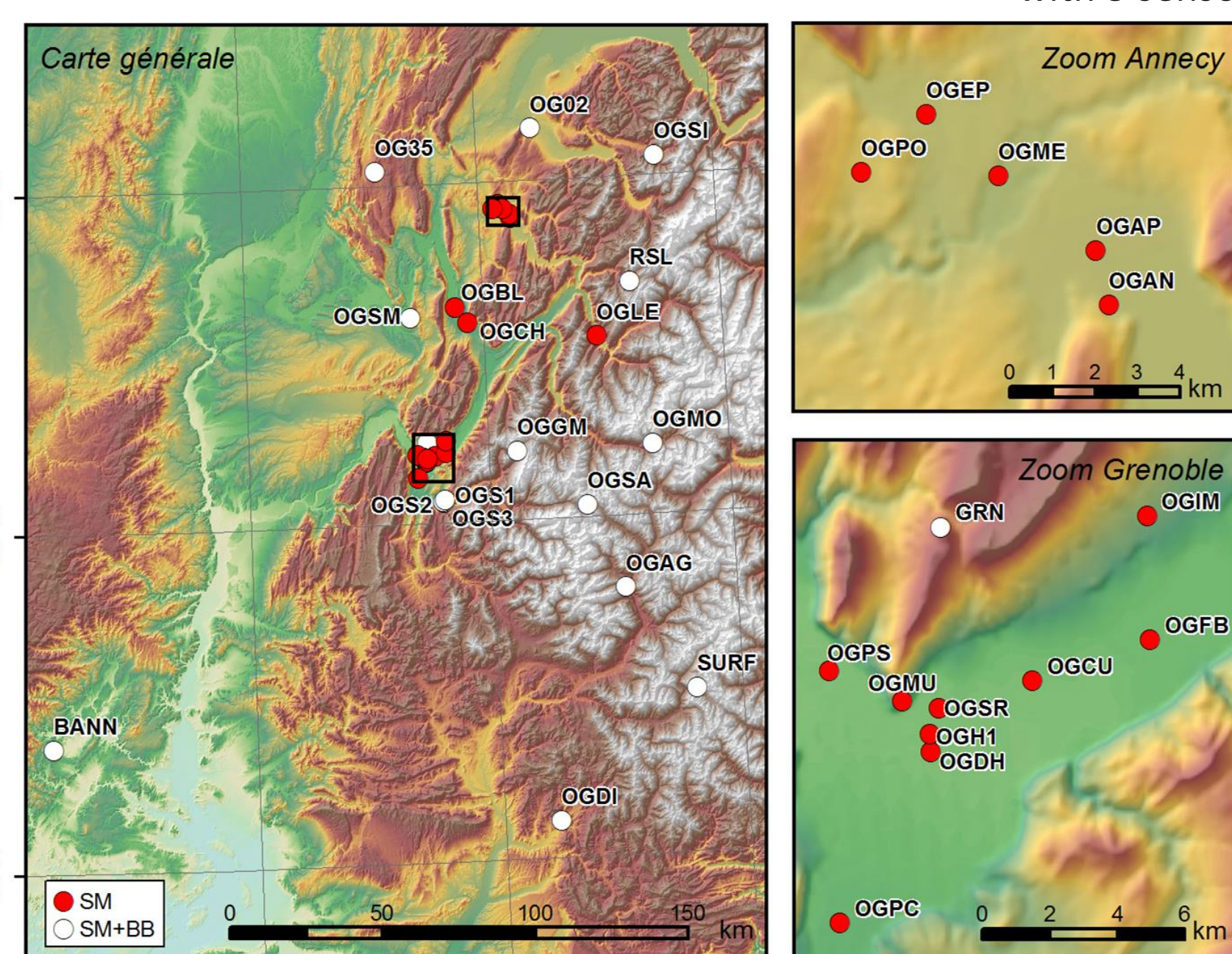
Installation and operating care of stations by regional observatories and partners

Earth Sciences Observatories: EOST (Strasbourg), OSUG (Grenoble), OCA (Nice), OMP (Toulouse), IPGP (Paris), OPGC (Clermont-Ferrand), OSUNA (Nantes), UBO (Brest) + IRSN, CEA/DASE, BRGM, IFSTTAR, CEREMA

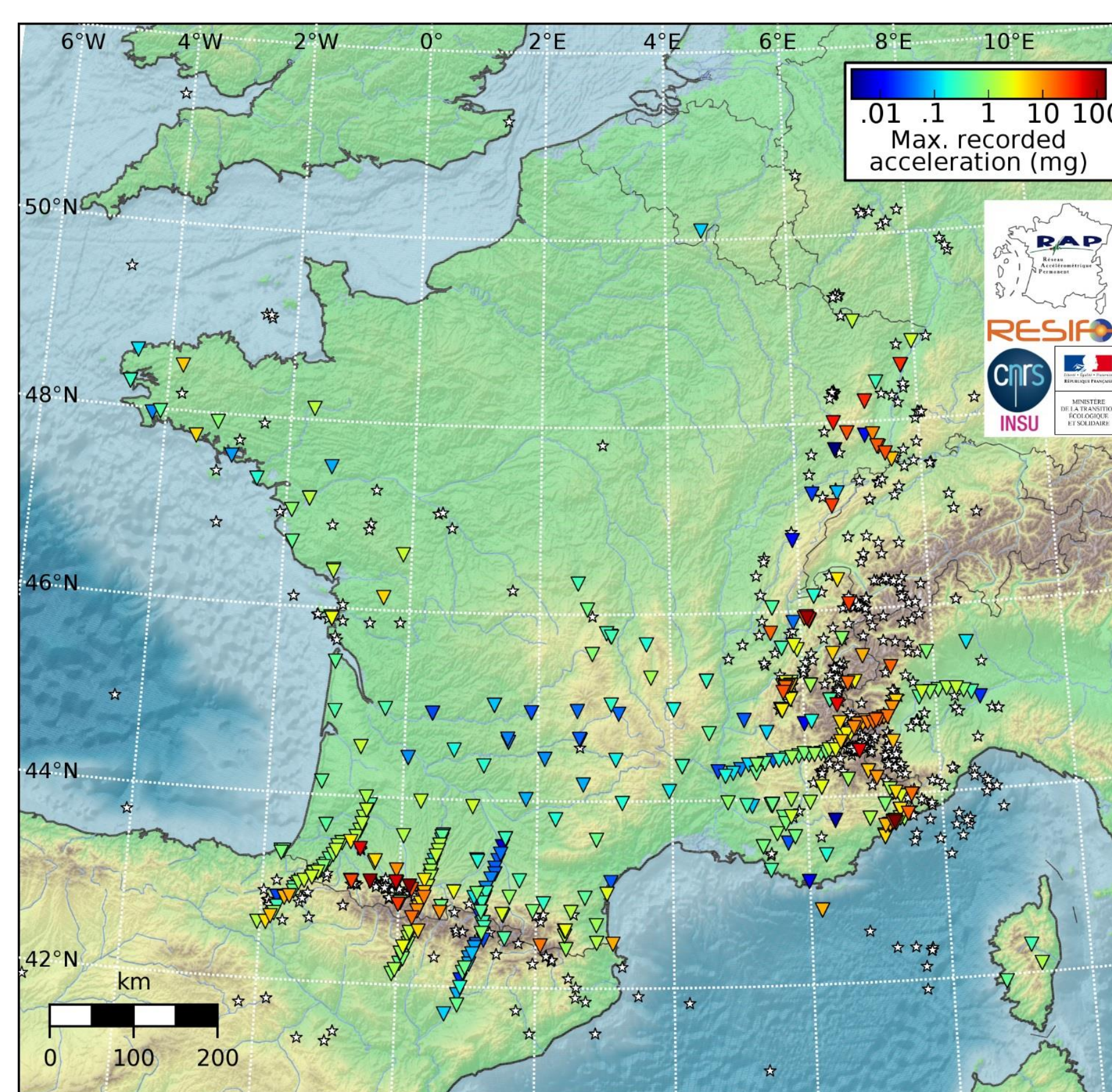
Example for the RAP-Alps regional network

42 accelerometers
16 BB+SM sites
18 SM sites

Including 2 arrays:
1 building with 7 sensors
1 deep borehole with 3 sensors

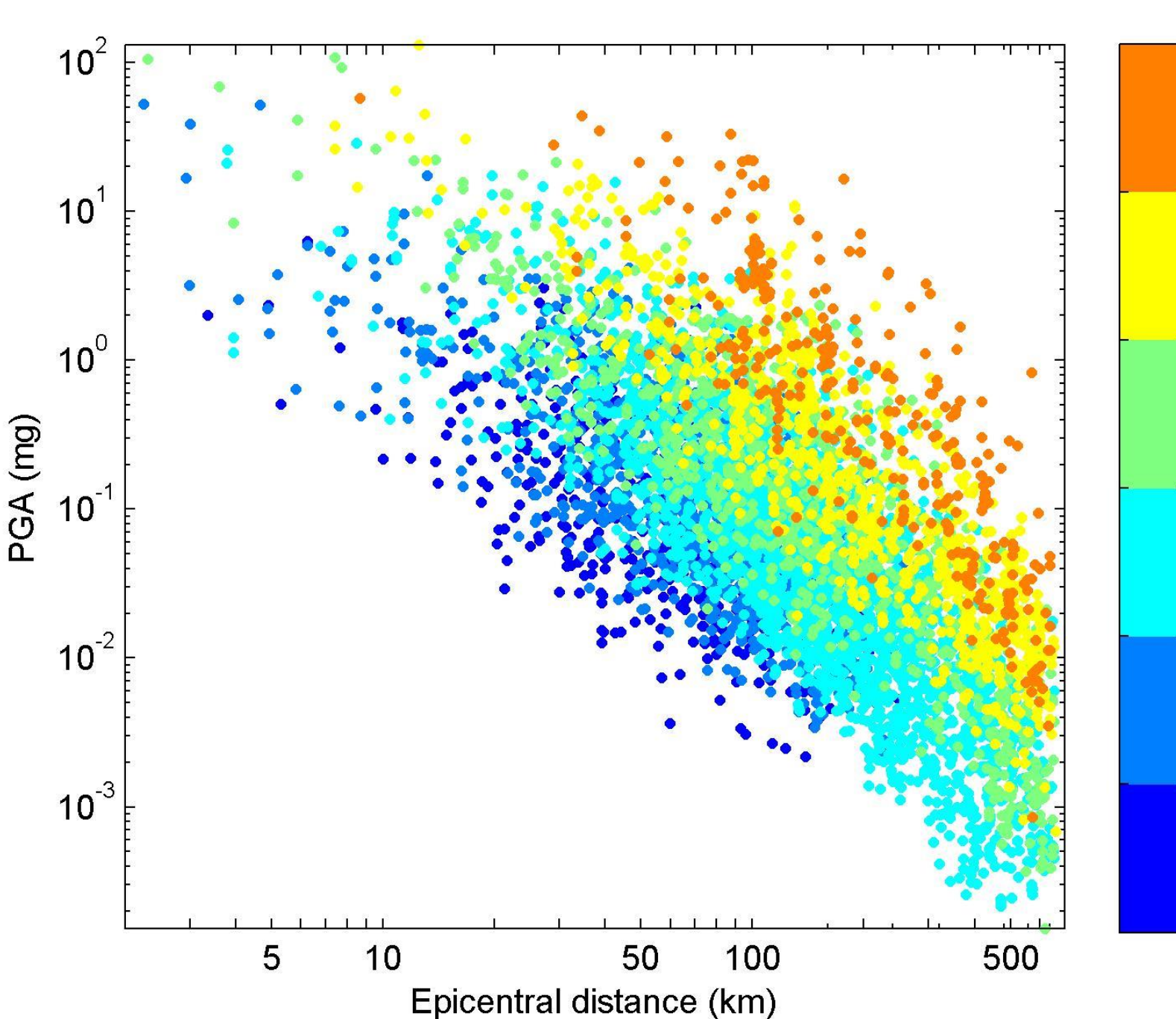


TWENTY YEARS OF EARTHQUAKE GROUND MOTIONS RECORDED IN MAINLAND FRANCE



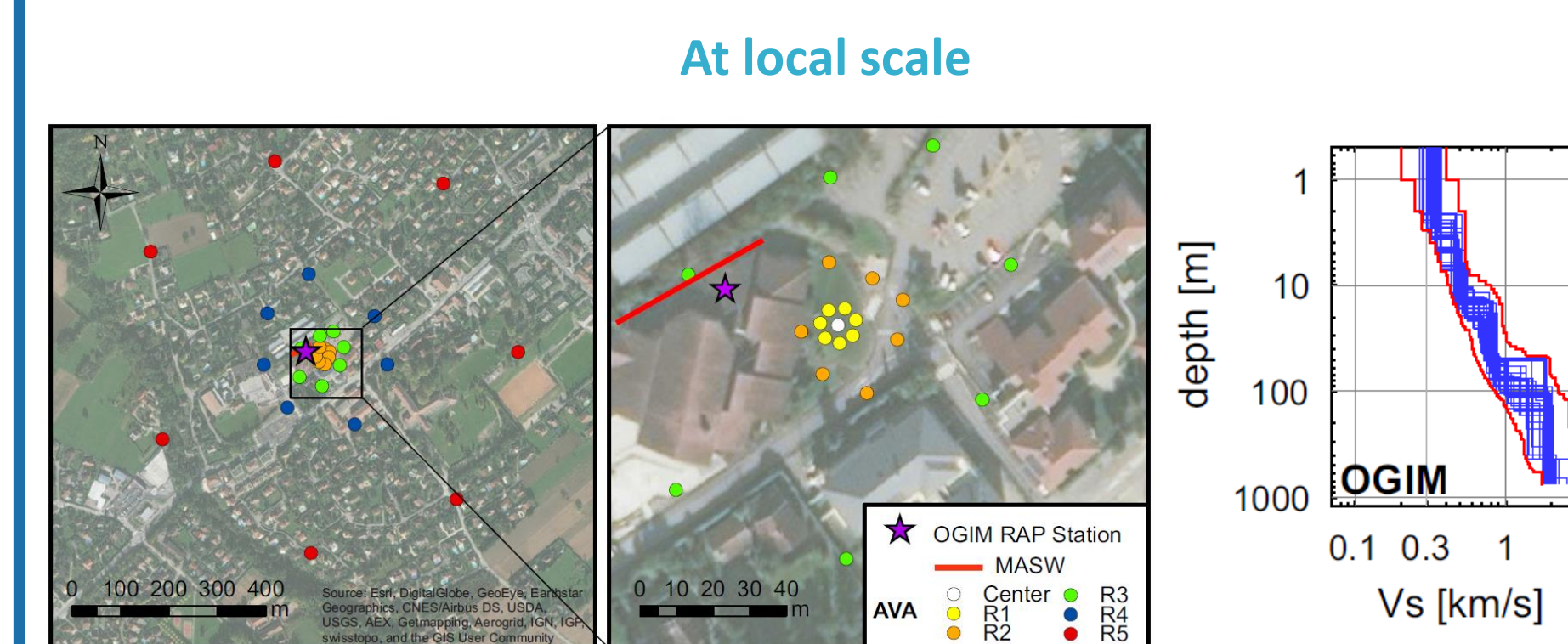
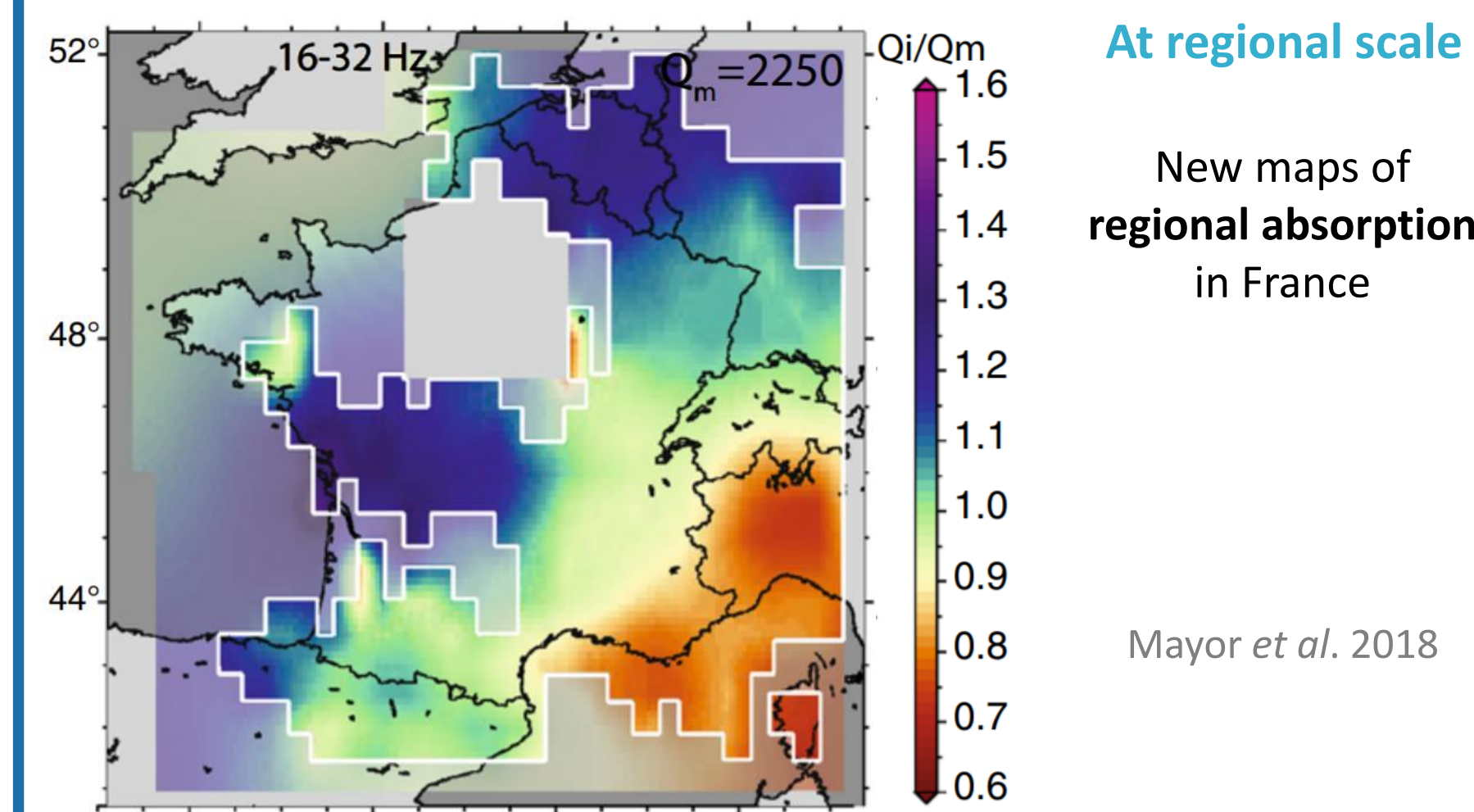
Twenty years of accelerometric and velocimetric recordings of earthquakes in mainland France (1996-2016) were necessary to produce this map of the maximum peak acceleration ever recorded at each station. This comes from a compilation of more than **6500 quality-checked records from 468 earthquakes recorded at 379 stations** (Traversa *et al.* in prep.). White stars show the epicenters of the considered earthquakes (magnitudes M_L 2.4 to 5.6). The installation duration of each station is variable, from twenty years for the oldest permanent stations (among 177 stations from RA and FR networks; ref. below), down to two years for temporary transect arrays (202 stations from YP and X7 networks; ref. below).

Product of the RAP WG Ground-motion prediction.



Compilation of more than 6500 peak ground accelerations (PGA) in mainland France as a function of epicentral distance, from the dataset of quality-checked records mentioned above. Flatfile from Traversa *et al.* in prep. Derivation of specific ground-motion models is in progress.

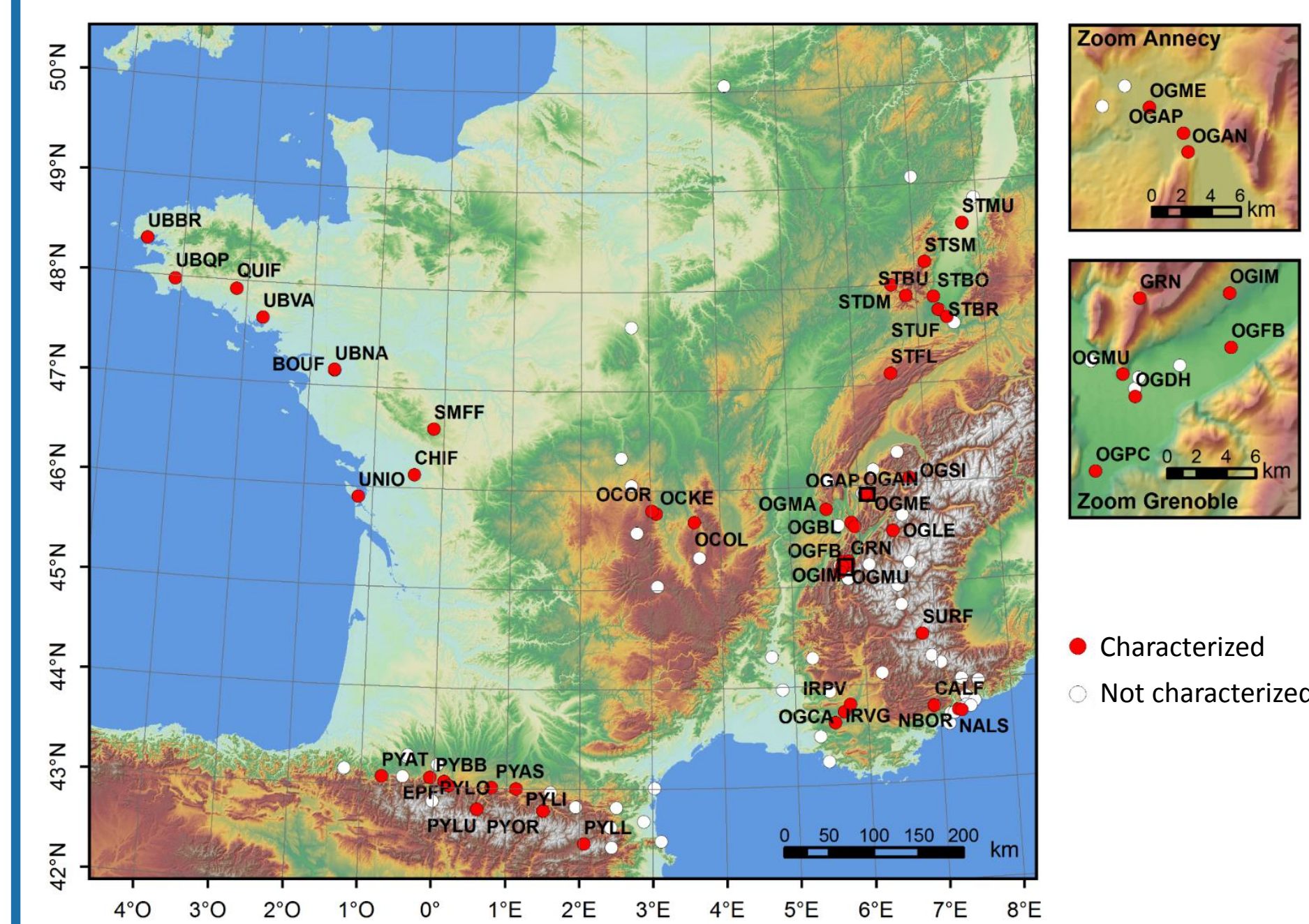
SPECIFIC STUDIES ON GROUND RESPONSE



Site conditions characterization and site effects from passive (AVA) and active (MASW) surface-waves methods

Hollender *et al.* 2018

ONGOING CHARACTERIZATION OF RAP-RESIF STATIONS



• Velocity profiles
• V_{530}
• EC8 soil class

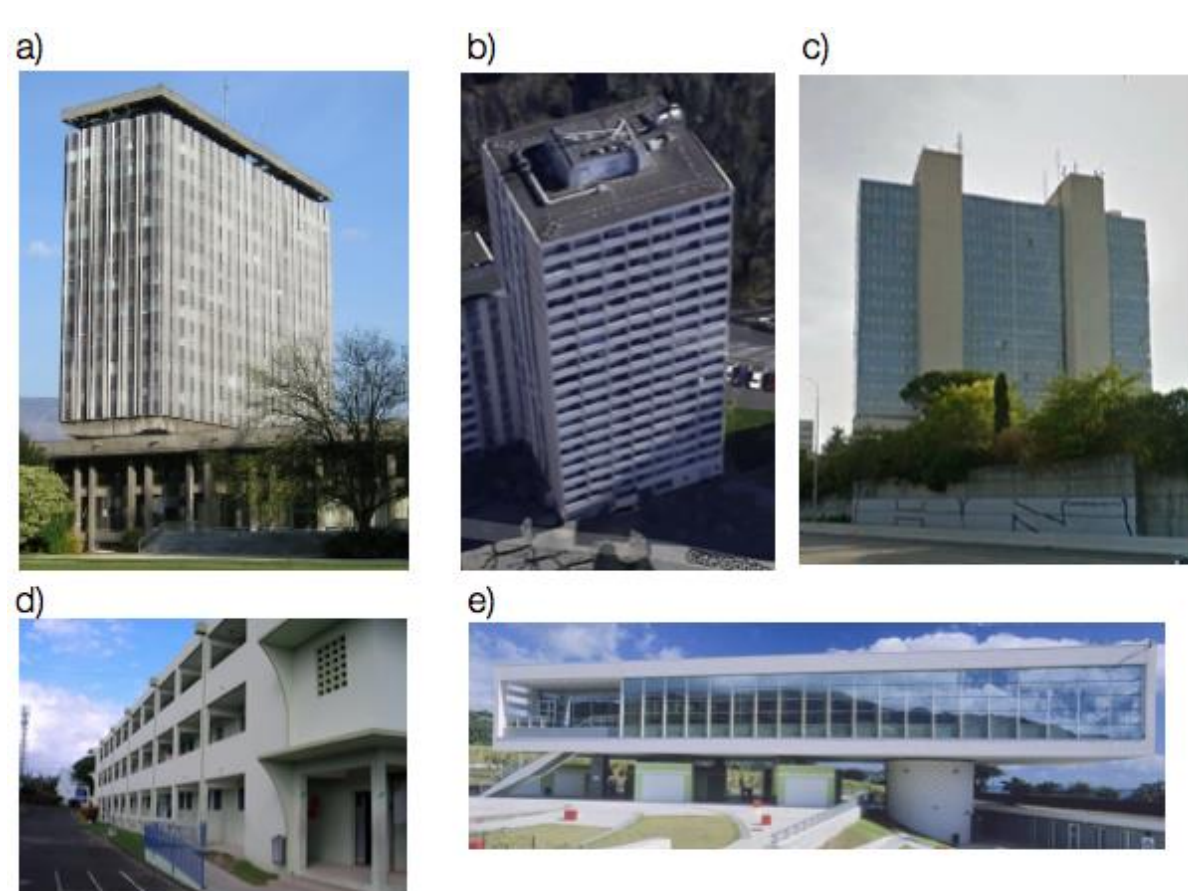
Done for 55 sites over 160.

Next to be done:
➢ French West Indies in 2020
➢ Availability on RESIF portal

Product of the RAP WG Site conditions.

Applications: amplifications of seismic waves by geology, microzonation, ground-motion prediction models, Shakemaps, magnitude estimations, etc.

SEISMIC STRUCTURAL HEALTH MONITORING IN FRANCE



5 reinforced concrete buildings equipped permanently with continuous real-time accelerometers

Towers ≥ 15 stories high

Elongated buildings

Limongelli *et al.* 2019

- a) Hôtel de Ville, **Grenoble** 21 channels (starting 2004)
- b) Tour Ophite, **Lourdes** 24 channels (starting 2008)
- c) Préfecture de **Nice** 24 channels (starting 2010)
- d) Collège de Basse-Pointe, **Martinique** 24 channels (starting 2011)
- e) Centre de Découverte de la Terre, **Martinique** 6 channels (starting 2005)

Applications: structural behavior to local seismicity, relation between ground motion and structural deformation, between structural dynamics and building conception modes, non-linear behavior inside buildings or inside soil/foundations, etc.

OUTREACH AND DISSEMINATION

- Several short and long-term RAP **working groups** on earthquake hazard and risk
- A **scientific call** every two years for projects to foster partnerships between members
- **Newsletter** published twice a year, in French and in English, presenting projects, recent results, new equipment and news intended for the earthquake engineering seismology community
- A scientific **national workshop** every two years (80 participants in Lourdes in November 2018), including dissemination of information towards local authorities, professional audiences and populations



REFERENCES

- RESIF; (1995): RESIF-RAP French Accelerometric Network; RESIF - Réseau Sismologique et géodésique Français. doi: [10.15778/RESIF.RA](https://doi.org/10.15778/RESIF.RA)
- RESIF; (1995): RESIF-RLBP French Broad-band Network, RESIF-RAP strong motion network and other seismic stations in metropolitan France; RESIF - Réseau Sismologique et géodésique Français. doi: [10.15778/RESIF.FR](https://doi.org/10.15778/RESIF.FR)
- Chevrot S., Sylvander M.; RESIF; (2017): Seismic network X7: PYROPE PYrenean Observational Portable Experiment (RESIF-SISMOB). RESIF - Réseau Sismologique et géodésique Français. Seismic Network. doi: [10.15778/RESIF.X72010](https://doi.org/10.15778/RESIF.X72010)
- Hollender F., Cornou C., Dechamp A., Oghalaei K., Rénalier F., Maufroy E., Burnouf C., Thomassin S., Wathélet M., Bard P.Y., Boutin V., Desbordes C., Douste-Bacqué I., Foundotos L., Guyonnet-Benaize C., Perron V., Régnier J., Roullé A., Langlais M., and Sicilia D. (2018). Characterization of site conditions (soil class, V_{530} , velocity profiles) for 33 stations from the French permanent accelerometric network (RAP) using surface-wave methods. Bulletin of Earthquake Engineering, 16(6), 2337-2365. doi: [10.1007/s10518-017-0135-5](https://doi.org/10.1007/s10518-017-0135-5)
- Limongelli M.P., Dolce M., Spina D., Guéguen P., Langlais M., Wolyniec D., Maufroy E., Karakostas C.Z., Lekidis V.A., Morfidis K., Salonikios T., Rovithis E., Makra K., Masciotta M.G., and Lourenço P.B. (2019). S²HM in some European countries. In: Limongelli M.P., Çelebi M. (eds), Seismic structural health monitoring, 303-343. Springer Tracts in Civil Engineering, Springer. doi: [10.1007/978-3-030-13976-6_13](https://doi.org/10.1007/978-3-030-13976-6_13)
- Mayor J., Traversa P., Calvet M., and Margerin L. (2018). Tomography of crustal seismic attenuation in Metropolitan France: implications for seismicity analysis. Bulletin of Earthquake Engineering, 16(6), 2195-2210. doi: [10.1007/s10518-017-0124-8](https://doi.org/10.1007/s10518-017-0124-8)
- Traversa P., Maufroy E., Hollender F., Perron V., Bremaud V., Shible H., Drouet S., Guéguen P., Langlais M., Wolyniec D., Péquegnat C., and Douste-Bacqué I. RESIF RAP and RLBP dataset of earthquake ground motion in mainland France. In preparation.
- Zhao L., Paul A., Solarino S.; RESIF; (2016): Seismic network YP: CICALPS temporary experiment (China-Italy-France Alps seismic transect). RESIF - Réseau Sismologique et géodésique Français. Seismic Network. doi: [10.15778/RESIF.YP2012](https://doi.org/10.15778/RESIF.YP2012)

Emeline MAUFROY



RESIF is a national Research Infrastructure, recognised as such by the French Ministry of Higher Education and Research. RESIF is managed by the RESIF Consortium, composed of 18 Research Institutions and Universities in France. RESIF is additionally supported by a public grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'Avenir" program (reference: ANR-11-EQPX-0040) and the French Ministry of Ecology, Sustainable Development and Energy.

