

Adrien P. M. Broquet

German Aerospace Center (DLR)
Berlin, Germany

adrien.broquet@dlr.de

<https://ab-ares.github.io/website/>

EMPLOYMENT

- 2024 – 2026 **Postdoctoral Research Associate – Humboldt Fellowship** – German Aerospace Center (DLR), Berlin, Germany.
- 2020 – 2024 **Postdoctoral Research Associate (advisor: Jeffrey Andrews–Hanna)** – Lunar and Planetary Laboratory, University of Arizona, Tucson, USA.
- 2018 – **NASA InSight collaborator.**
- 2017 – 2019 **Teaching assistant** – Department of Earth, Environment & Space, Université de Nice Côte d'Azur, Nice, France.

EDUCATION

- 2020 **P.h.D** – Planetary Geophysics, Observatoire de la Côte d'Azur, Nice, France
Grant: Doctoral School SFA, Nice.
Advisor: Mark A. Wieczorek, Subject: *The lithosphere of Mars*
- 2017 **Master 2** – Solid-Earth Geophysics, Institut de Physique du Globe de Paris, France
With honors
- 2016 **Master 1** – Geosciences, Université Pierre et Marie Curie, Paris, France
With honors
- 2015 **BSc** – Earth Sciences, Université Pierre et Marie Curie, Paris, France
Best student honors

RESEARCH INTEREST

My scientific interest encompasses various aspects of planetary geophysics and is fueled by data collected from space missions. More specifically, I enjoy studying and modeling large-scale physical processes with geologic implications, from lithospheric compensation mechanisms, tectonics, thermal evolution models, to the spatio-temporal variation of the magnetic field.

PHD THESIS PROJECT

Links: [Manuscript](#) – [Defense slides](#)

My thesis characterizes the strong and cold outermost portion of Mars, conventionally referred to as the lithosphere. When the lithosphere is loaded by volcanoes or ice caps, it deviates from its original state and bends. This compensation mechanism gives rise to two principal observables that are detectable from orbit: gravity anomalies, and topographic expressions.

As a first project, I conducted an analysis (Broquet & Wieczorek, 2019) of the gravitational signature of kilometer-sized Martian volcanoes. In this study, we model the deformation of the lithosphere under volcanic loads and compare the resulting theoretical gravitation signal to observations. The bulk density of the volcanic structures is found to have a mean value of $3200 \pm 200 \text{ kg m}^{-3}$, which is representative of iron-rich basalts as sampled by the Martian basaltic meteorites. The elastic part of the lithosphere, which maintains loads over geologic timescale, is constrained to have been weak when the oldest volcanoes ($>3.2 \text{ Ga}$) formed, which implies that the lithosphere was hot and thin ($<20 \text{ km}$) early in geologic history. Conversely, we obtain that younger volcanoes ($<3 \text{ Ga}$) were emplaced on colder and stronger elastic lithospheres ($30\text{--}100 \text{ km}$). This chronology of formation is consistent with a geodynamic history in which the lithosphere strengthens with time as the planet cools and controls the surface expression of magmatism.

In a second project, I investigated the composition and geodynamic state of the lithosphere beneath the Martian polar caps (Broquet et al., 2020, 2021). In these studies, we make use of radar and gravity data coupled with a lithospheric loading model to self-consistently estimate the composition of the polar cap, and the elastic thickness of the lithosphere underneath. We show that the lithosphere below the north polar cap is currently extremely rigid and cold ($>330 \text{ km}$). In the south polar region, the present-day lithosphere is potentially thinner ($>150 \text{ km}$), which helps satisfy global thermal evolution simulations that predict hemispheric differences in surface heat flow. Our inferred compositions suggest that for reasonable dust content, a minimum of 10% CO_2 are buried in the north polar deposits. This is the first time a large quantity of dry ice is found within the north polar regions of Mars. Like on Earth, where the composition of buried ices gives hints on the climatic evolution of our planet, having CO_2 at the north pole of Mars will help improve scenarios for the climate evolution of the planet.

MISSION INVOLVEMENT

NASA Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight), Collaborator (2018 –).

ESA BepiColombo Laser Altimeter (BELA), Collaborator (2024 –).

PROFESSIONAL ACTIVITIES

Reviewer and panelist for the *NASA Solar System Workings, Lunar Data Analysis, and Mars Data Analysis* programs (2020 –).

Reviewer for *UK Space Agency Exploration Science program* (2024 –).

Reviewer for the *Journal of Geophysical Research, Geophysical Research Letters, Icarus, Physics of the Earth and Planetary Interiors, Planetary and Space Science, Nature Geoscience*.

TEACHING

- 2 years, 160 hours, at the Department of Earth, Environment & Space, Université de Nice Côte d'Azur, Nice, France. Classes per level:
 - 1st year - Planetology, Stratigraphy & Paleontology ;
 - 2nd year - Sedimentology, Magmatism, Metamorphism, Mineralogy, Geophysics;
 - 3rd year - Mass wasting & risks (including field work), Geophysics.

- About 15 hours of teaching Planetology in middle schools with [EduCosmos](#) & MEDITES.

SUPERVISION

- **Internship supervision & co-supervision:** Felix Rolser (2024, DLR, Germany), Sabatino Santangelo (2024, DLR, Germany)
- **Master thesis co-supervision:** Sabatino Santangelo (2024, DLR, Germany)
- **PhD co-supervision:** Aymeric Fleury (2023–, DLR, Germany), Claudia Szczech (2023–, DLR, Germany).

OUTREACH

- 2024 Invited speaker – Centre International de Valbonne à Sophia-Antipolis
Lunar Odyssey: Tracing the Journey from Initial Sketches to Pioneering Steps
- 2022 Press coverage for [Broquet & Andrews-Hanna \(2022\)](#).
[University of Arizona press release](#). Interviews for journals including [New Scientist](#), [Le Monde](#), [EL PAÍS](#). More info [@Altimetric](#)
- 2021 Invited speaker — Société d’Astronomie de Cannes, Cannes, France – *Exploration of the terrestrial planets* ([video link](#), in French)
- 2020 [Namazu Contest](#) Scientific tutor — French International School (Ireland) IES Nueve Valles (Spain), Middle School Roy d’Espagne (France).
- 2020 Invited speaker — Externat St Joseph la Cordeille, Toulon, France – *Our solar system*
- 2020 Invited speaker — Insight@School, Sophia Antipolis, France – *The lithosphere of Mars*
- 2019 Invited speaker — Club Véga, Ollioules, France
The worlds around us: history and future of space exploration
- 2019 Interview [La science en chemin, avec Adrien Broquet](#) (Ciel & Espace, David Fossé)
- 2017-18 Science Festival, Nice, France

GRANTS – AWARDS

- 2023 [Best reviewer award](#), *Icarus*
- **Alexander von Humboldt Foundation Fellowship, 2 years**
- **Co-I Mercury’s tectonics** (PI: Jeff Andrews-Hanna – NASA SSW, 1 year)
- 2022 **Co-I Faulting on Pluto** (PI: Moruzzi – NASA FINESST, 2 years)
- [Best reviewer award](#), *Icarus*
- 2019 My thesis in 180 seconds, Final in Nice, 3rd place ([video link](#), in French)
- 2018 **Scholarship** Workshop in Geology and Geophysics of the Solar System, Serbia
- 2016 **Scholarship** 29th International School of Space Science, Italy

PEER-REVIEWED PUBLICATIONS

Students supervised/co-supervised by A.B.

1. Szczech, C., Broquet, A., et al.. Relaxation states of large impact basins on Mercury based on MESSENGER data. *Geophysical Research Letters* (2024). <https://doi.org/10.1029/2024GL110748>.
2. **Broquet, A.***, Rolser, F.*, Plesa, A. C., Breuer, D., & Hussmann, H. (2024). Mercury's crustal porosity as constrained by the planet's bombardment history. *Geophysical Research Letters* (2024). <https://doi.org/10.1029/2024GL110583>. (*) **both authors contributed equally to this work**
3. Liang, W.*, **Broquet, A.*** et al., Vestiges of a lunar ilmenite layer revealed by GRAIL gravity data. *Nature Geoscience* (2024). <https://doi.org/10.1038/s41561-024-01408-2>. (*) **both authors contributed equally to this work**.
4. **Broquet, A.**, & Andrews-Hanna, J. C., A volcanic inventory of the moon. *Icarus* (2024). <https://doi.org/10.1016/j.icarus.2024.115954>.
5. **Broquet, A.**, & Andrews-Hanna, J. C., The moon before mare. *Icarus* (2024). <https://doi.org/10.1016/j.icarus.2023.115846>.
6. Xu, Z., **Broquet, A.**, et al., Investigation of Martian regional crustal structure near the dichotomy using S1222a surface-wave group velocities, *Geophysical Research Letters* (2023). <https://doi.org/10.1029/2023GL103136>.
7. Andrews-Hanna, J. C., & **Broquet, A.**, The history of global strain and geodynamics on Mars. *Icarus* (2023). <https://doi.org/10.1016/j.icarus.2023.115476>.
8. **Broquet, A.** & Andrews-Hanna, J. C., Plume-induced flood basalts on Hesperian Mars: An investigation of Hesperia Planum, *Icarus* (2023). <https://doi.org/10.1016/j.icarus.2022.115338>.
9. **Broquet, A.** & Andrews-Hanna, J. C., Geophysical evidence for an active mantle plume underneath Elysium Planitia on Mars, *Nature Astronomy* (2022). <https://doi.org/10.1038/s41550-022-01836-3>.
10. Wicczorek, M. A., **Broquet, A.**, et al., InSight constraints on the global character of the Martian crust, *Journal of Geophysical Research: Planets* (2022). <https://doi.org/10.1029/2022JE007298>.
11. Khan, A., [...], **Broquet, A.**, et al., Upper mantle structure of Mars from InSight seismic data, *Science* (2021). <https://doi.org/10.1126/science.abf2966>.
12. Knapmeyer-Endrun, B., [...], **Broquet, A.**, et al., Thickness and structure of the martian crust from InSight seismic data, *Science* (2021). <https://doi.org/10.1126/science.abf8966>.
13. **Broquet, A.**, Wicczorek, M. A., & Fa W., The composition of the south polar cap of Mars derived from orbital data. *Journal of Geophysical Research: Planets* (2021). <https://doi.org/10.1029/2020JE006730>.
14. **Broquet, A.**, Wicczorek, M. A., & Fa W., Flexure of the lithosphere beneath the north polar cap of Mars: Implications for ice composition and heat flow. *Geophysical Research Letters* (2020). <https://doi.org/10.1029/2019GL086746>.
15. **Broquet, A.**, & Wicczorek, M. A., The Gravitational signature of Martian volcanoes. *Journal of Geophysical Research: Planets* (2019). <https://doi.org/10.1029/2019JE005959>.

FIRST AUTHOR ABSTRACTS

1. **Broquet, A., et al. (2024).** Viscoelastic relaxation of the lithosphere beneath the Martian polar caps: Implications for the polar caps' formation history and planetary thermal evolution. *European Geosciences Union 2024.*
2. **Broquet, A., & Andrews-Hanna, J. C., (2024).** A volcanic inventory of the Moon. *Lunar Planet. Sci. 55*, Abstract #[1626](#).
3. **Broquet, A., & Andrews-Hanna, J. C., (2024).** Coupling geophysical inversions and machine learning to unveil Mercury's tectonic and geodynamic history *Lunar Planet. Sci. 55*, Abstract #[2412](#).
4. **Broquet, A., & Andrews-Hanna, J. C., (2023).** The Moon without mare. *Lunar Planet. Sci. 54*, Abstract #[2404](#).
5. **Broquet, A., & Andrews-Hanna, J. C., (2022).** Is there an active mantle plume underneath Elysium Planitia? *Lunar Planet. Sci. 53*, Abstract #[2351](#).
6. **Broquet, A., & Andrews-Hanna, J. C., (2021).** Plume-induced flood basalts on Hesperian Mars: An investigation of Hesperia Planum. *Lunar Planet. Sci. 52*, Abstract #[1893](#).
7. **Broquet, A., Plesa, A.-C., Michaut, C., & Wieczorek, M. A. (2020).** Constraints on the thermal state of Mars from orbital data. *Lunar Planet. Sci. 51*, Abstract #[2064](#).
8. **Broquet, A., Wieczorek, M. A., & Fa, W. (2020).** Composition of the Martian polar caps and planetary heat flow. *Lunar Planet. Sci. 51*, Abstract #[1838](#).
9. **Broquet, A., Wieczorek M. A., & Fa, W. (2019).** Geodynamic state of the lithosphere beneath the northern polar cap of Mars. *Lunar Planet. Sci. 50*, Abstract #[1892](#).
10. **Broquet, A., & Wieczorek, M. A. (2018).** The gravitational signature of Martian volcanoes. *Lunar Planet. Sci. 49*, Abstract #[1859](#).

SELECTED LIST OF TALKS

- 2024 **ETH Zurich, Zürich, Switzerland (invited)**
Lunar volcanism: a Geophysical perspective.
55th Lunar and Planetary Science Conference, Houston TX, USA
A volcanic inventory of the Moon
General Assembly 2024 of the European Geosciences Union, Vienna, Austria (invited)
Viscoelastic relaxation of the lithosphere beneath the Martian polar caps: Implications for the polar caps' formation history and planetary thermal evolution
- 2023 **ETH Zurich, Zürich, Switzerland (invited)**
Geophysical evidence for an active mantle plume underneath Elysium Planitia on Mars.
- **International Plate Tectonics Group (invited)**
Geophysical evidence for an active mantle plume underneath Elysium Planitia on Mars.

- 2022 **IPGP, Planetary Science group, Paris, France (invited)**
Geophysical evidence for an active mantle plume underneath Elysium Planitia on Mars.
- **53th Lunar and Planetary Science Conference, Houston TX, USA**
Is there an active mantle plume underneath Elysium Planitia?
- 2021 **ETH Zurich, Zürich, Switzerland (invited)**
Loading the Martian lithosphere in space and time.
- **52th Lunar and Planetary Science Conference, Houston TX, USA**
Plume-induced flood basalts on Hesperian Mars: An investigation of Hesperia Planum.
- 2020 **DLR Institute, Berlin, Germany (invited)**
The lithosphere of Mars.
- **InSight Science Team meeting, Nice, France**
Flexure of the lithosphere beneath the polar caps of Mars.
- 2019 **50th Lunar and Planetary Science Conference, Houston TX, USA**
Geodynamic state of the lithosphere beneath the northern polar cap of Mars.
- 2018 **InSight French Team meeting, Paris, France**
Constraints on the Martian lithosphere from gravity and topography.
- **49th Lunar and Planetary Science Conference, Houston TX, USA**
The gravitational signature of Martian volcanoes.
- **Martian crust workshop, Ecole Normale Supérieure de Lyon, France**
The lithosphere of Mars as seen by gravity and topography.
- **DLR Institute, Berlin, Germany (invited)**
Composition, elastic and thermo-mechanical properties of the Martian lithosphere.
- 2017 **Geodesy & Rheology, Université Valrose, Nice, France**
The gravitational signature of Martian volcanoes.

OPEN SOURCE CODES AND CONTRIBUTIONS

- DSP (*Displacement Strain Planet*) — **Creator**
https://github.com/AB-Ares/Displacement_strain_planet — [documentation](#)
Displacement_strain_planet provides several Python functions and example scripts for generating gravity, crustal thickness, displacement, lateral density variations, stress, and strain maps on a planet given a set of input constraints such as from observed gravity and topography data.
- TeHF (*Te Heat Flow*) — **Creator**
https://github.com/AB-Ares/Te_HF_Conversion — [documentation](#)
Te_HF_Conversion provides several Python functions that allow 1) converting the elastic thickness of the lithosphere to planetary heat flow (and a yield strength envelope) given several input parameters including crustal thickness, strain rate, or radiogenic heating; 2) retrieving the elastic thickness (or mechanical thickness, and a yield strength envelope) of the lithosphere based on a temperature profile.
- Py_Admittance — **Creator**

https://github.com/AB-Ares/Py_Admittance – [documentation](#)

Py_Admittance is a code that allows computing the global observed and theoretical admittance functions and their spatio-spectrally localized versions.

- SHTOOLS (*Spherical Harmonic Tools*) — **Contributor**

<https://github.com/SHTOOLS/SHTOOLS>

SHTOOLS/pyshtools is a Fortran-95/Python library that can be used for spherical harmonic transforms, multitaper spectral analyses, expansions of gridded data into Slepian basis functions, standard operations on global gravitational and magnetic field data.