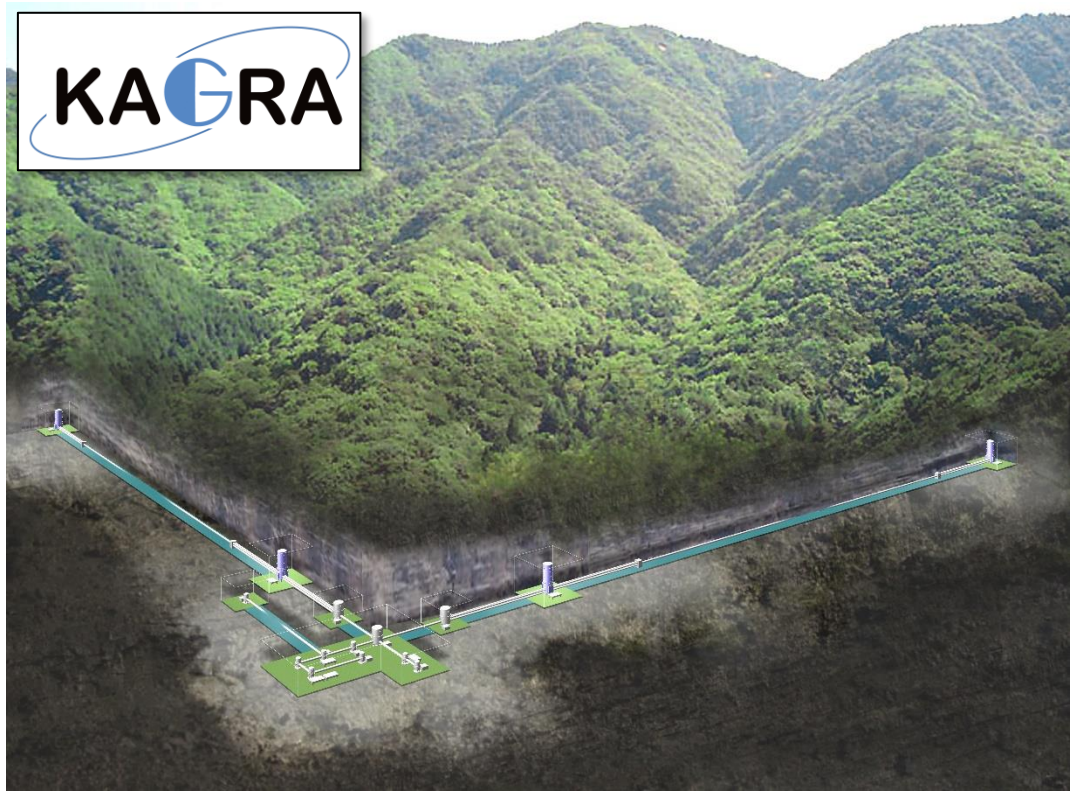
Workshop on the development of innovative tools for new collaborations within gravitational wave detection experiments, 2022-04-15
https://indico.in2p3.fr/event/26414/

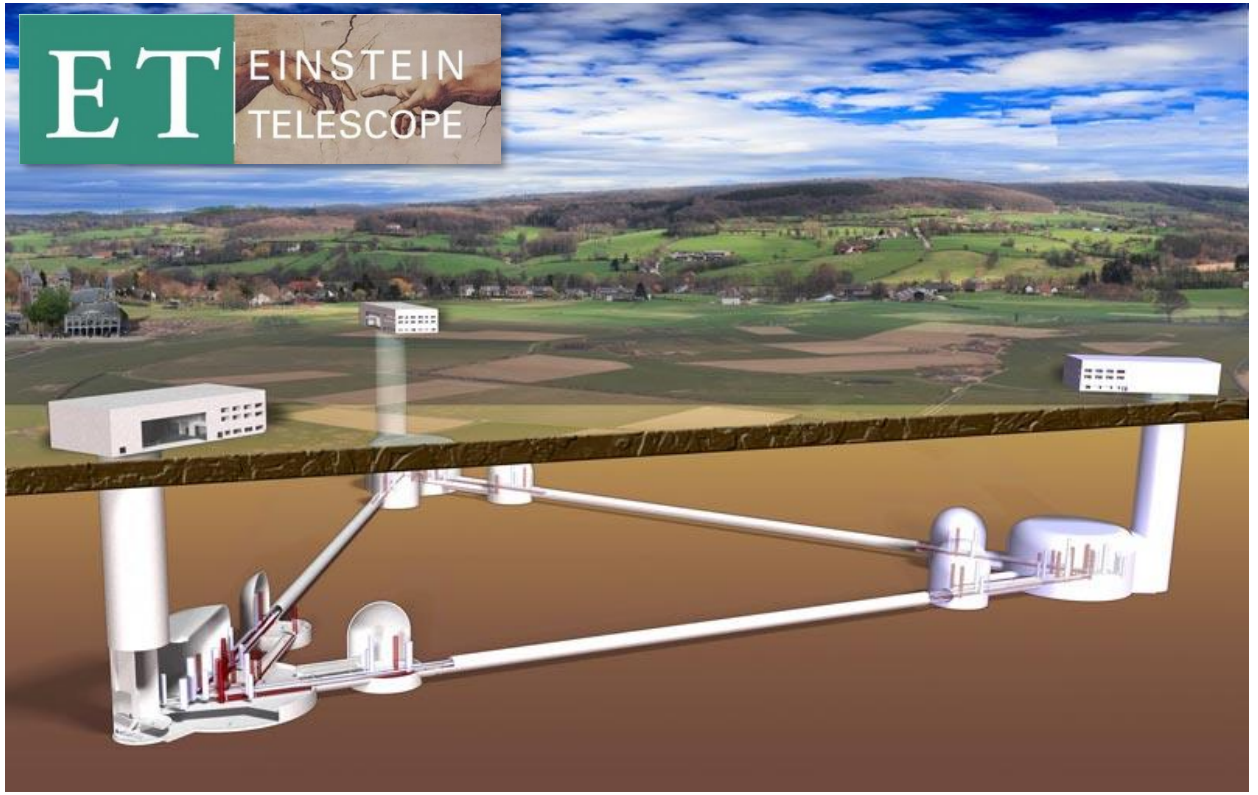
Underground Environment KAGRA

Tatsuki Washimi (NAOJ)

on behalf of the KAGRA collaboration

Underground site for GW detectors



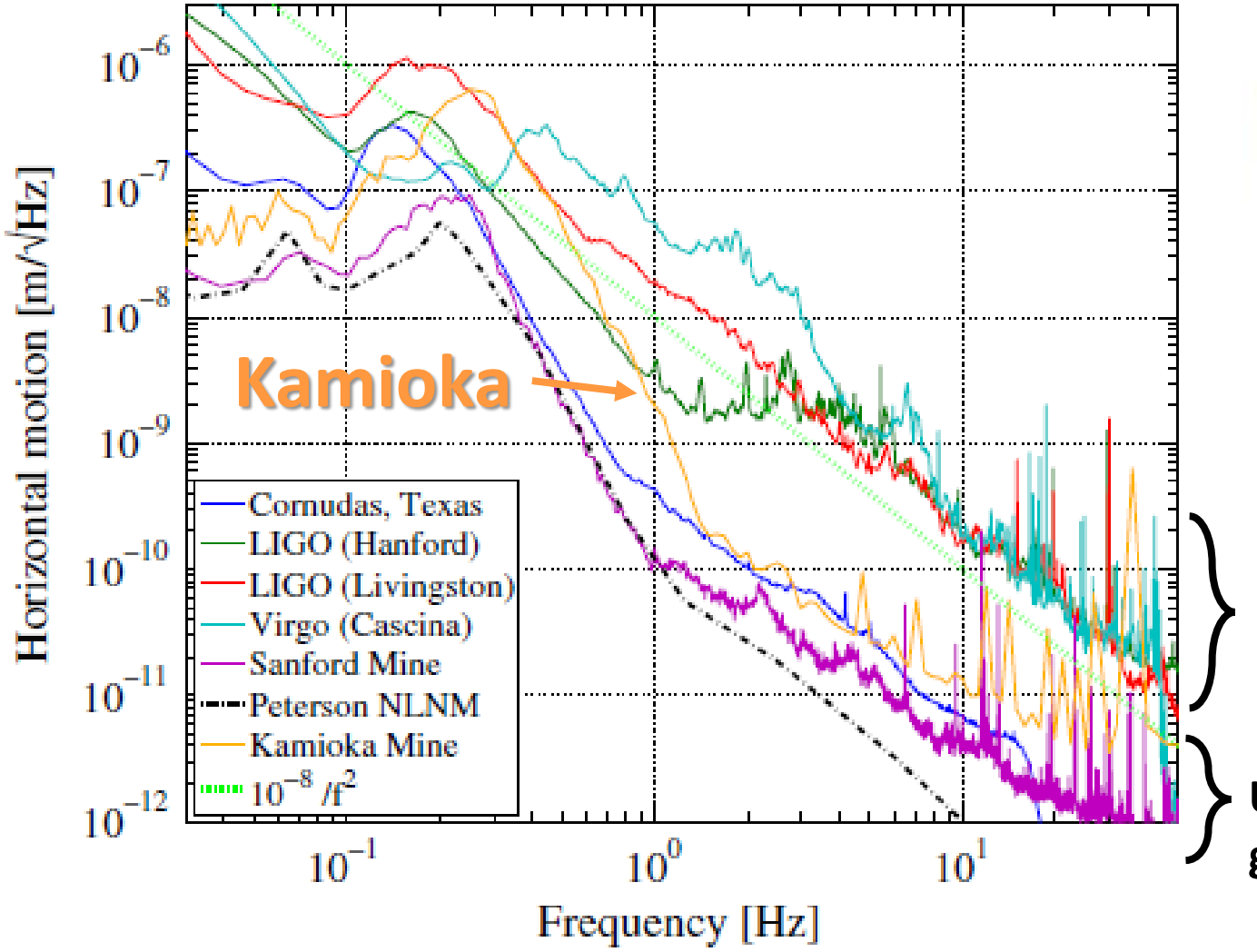


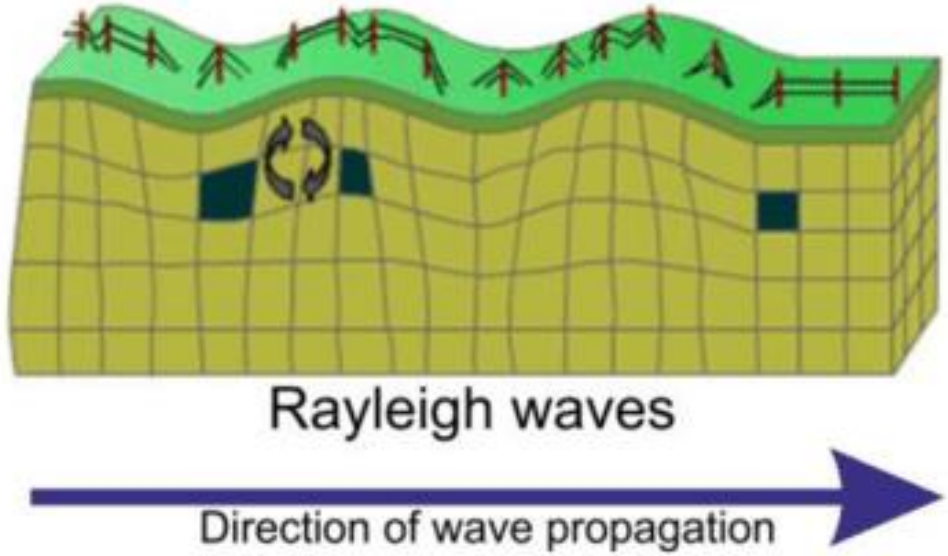
Generally speaking, an underground facility is low-noise and good for a GW detector.
In this talk, I report the evaluation of the underground environment in KAGRA for multi-aspects.

Seismic motion

Seismic wave (Rayleigh) propergate mainly on surface.

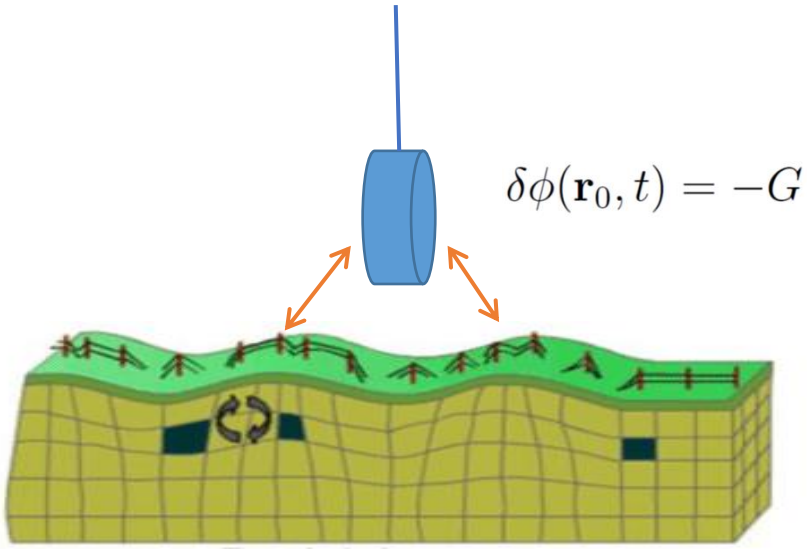
- Seismic level is reduced $O(100)$ for > 1Hz.





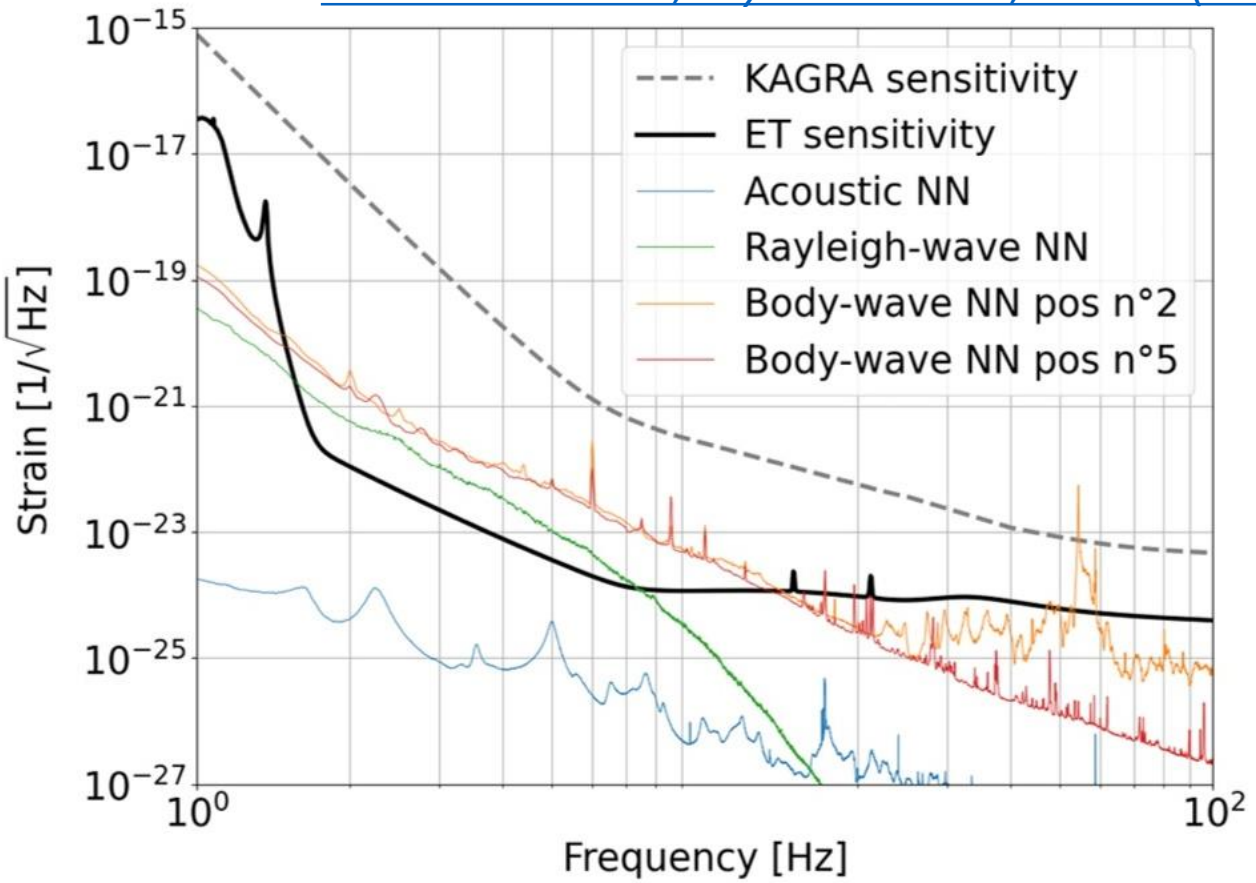
Seismic Newtonian noise (NN)

Perturbation of the gravity field due to a variation in the density (δρ) of the surrounding media.



$$\delta\phi(\mathbf{r}_0, t) = -G \int dV \frac{\delta\rho(\mathbf{r}, t)}{|\mathbf{r} - \mathbf{r}_0|}$$

F. Badaracco *et al.*, *Phys. Rev. D* **104**, 042006 (2021)



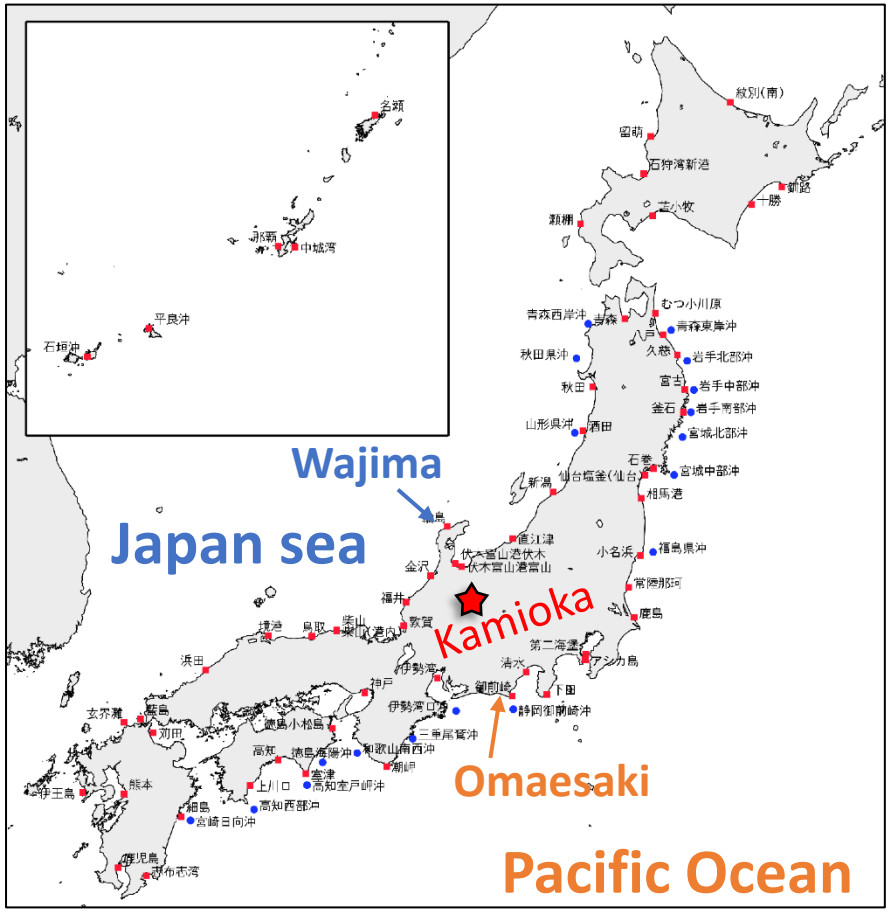
Estimated NNs are much below the design sensitivity of KAGRA, but larger than that of ET.

- Some new approaches (e.g. NN cancelation developing in Virgo) are necessary.

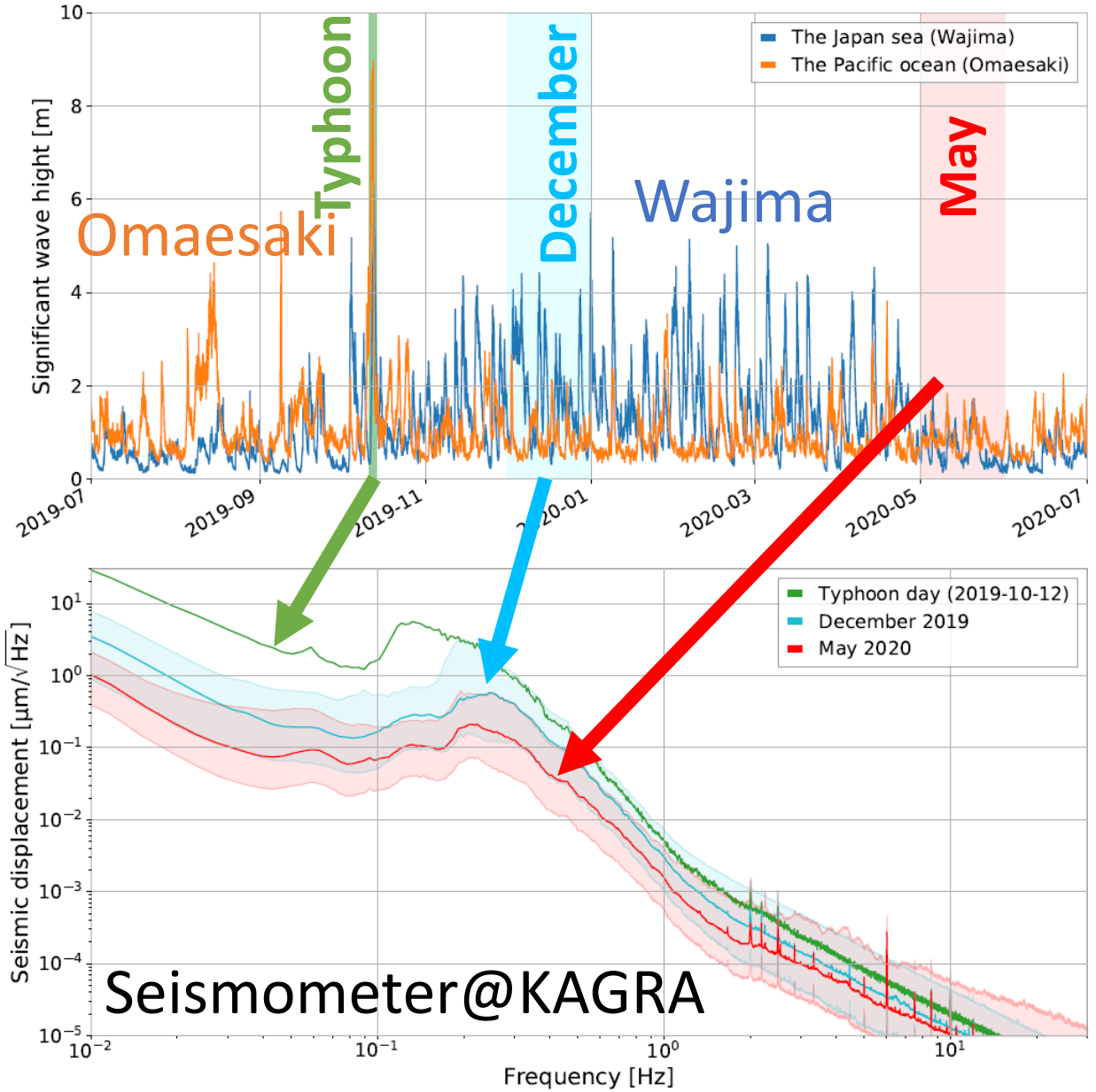
Seasonal character of the Microseismic motion

Microseismic motions (~0.2Hz) is

- caused by the sea wave
- not reduced at underground
- depending on season/weather condition

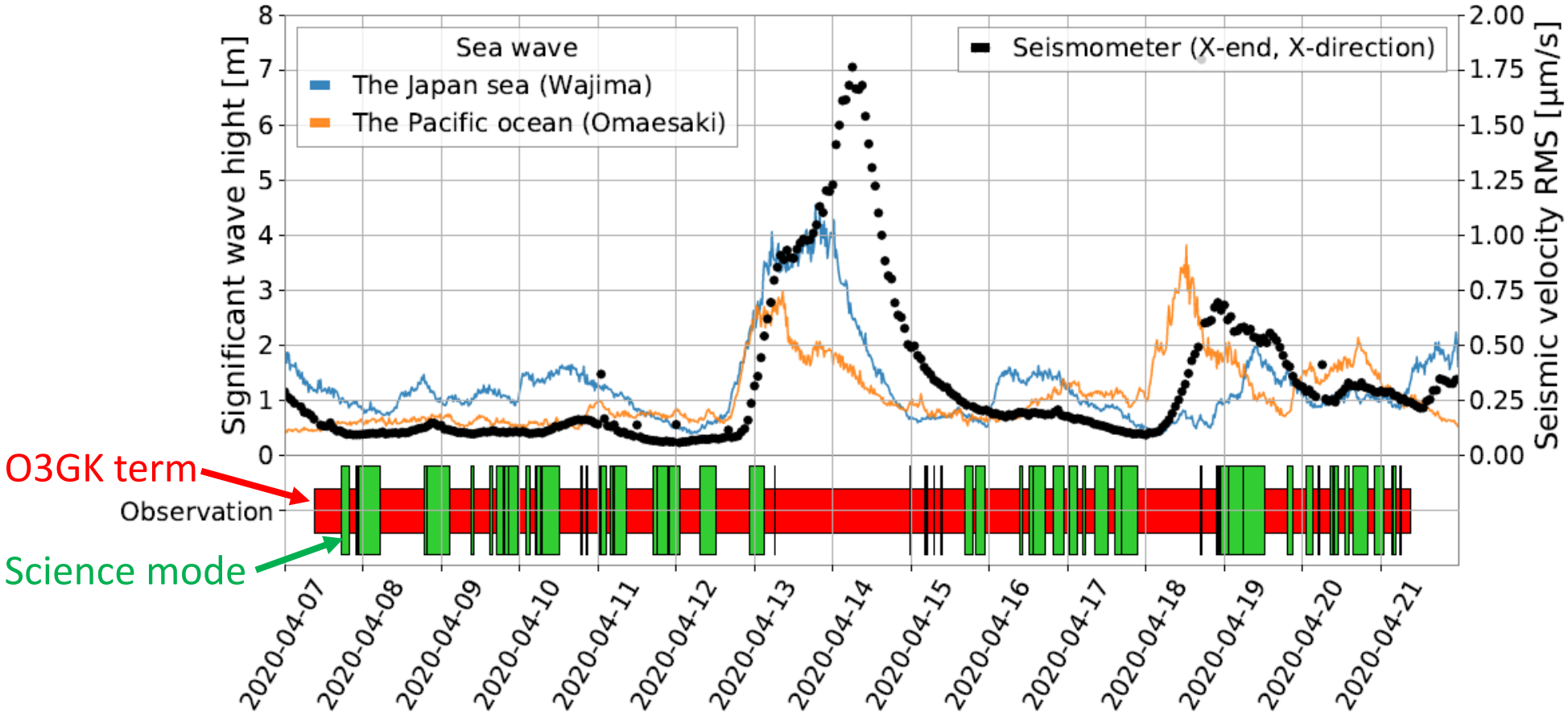


https://www.mlit.go.jp/kowan/nowphas/index_eng.html



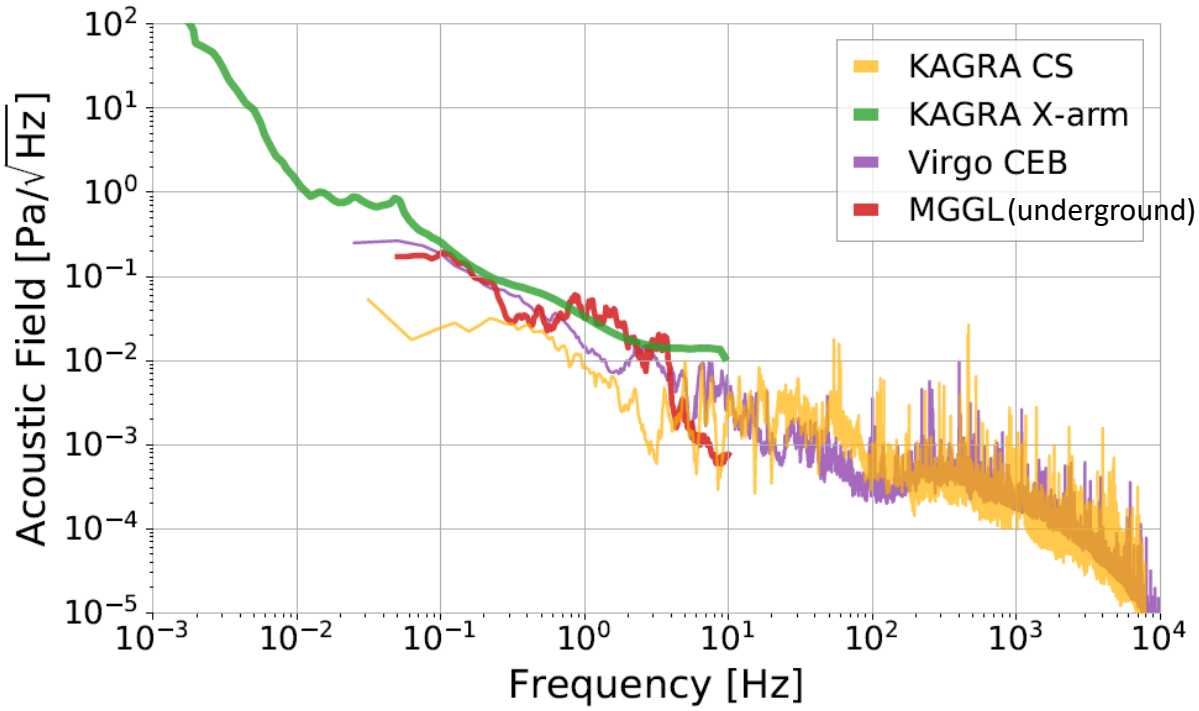
Microseismic motion and Interferometer's lock-loss

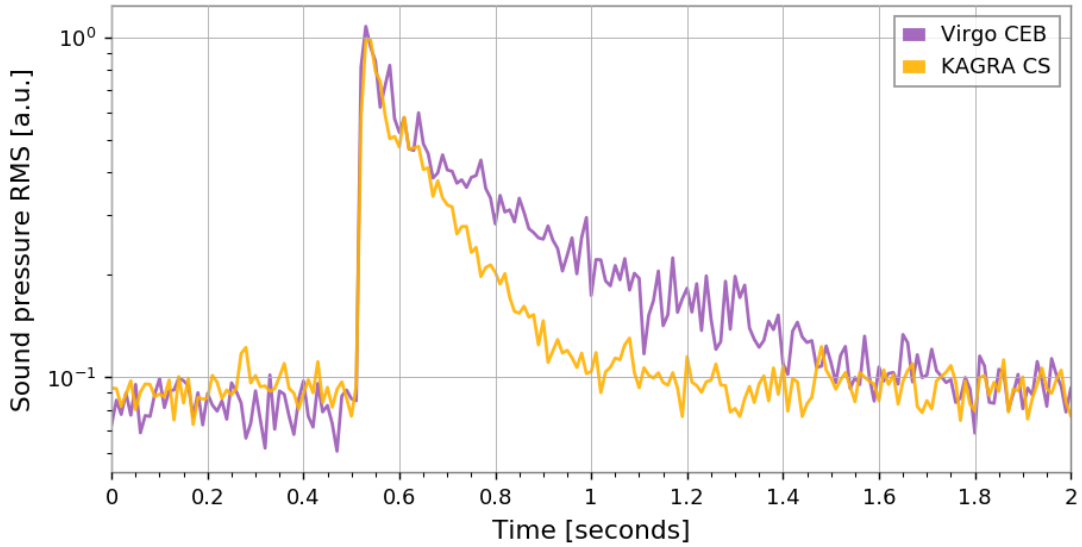
Correlations between sea waves, microseismic motion at KAGRA, and lock-loss of the interferometer are observed.



Detailed studies are ongoing (Y. Fujikawa, S. Hoshino @ Niigata U.)

Acoustic field (air-pressure) at KAGRA





- The acoustic levels are similar the underground and the on-surface environment, at quiet conditions.
- The underground is more stable with respect to transient external disturbances
  - *e.g.*, agricultural work, airplane

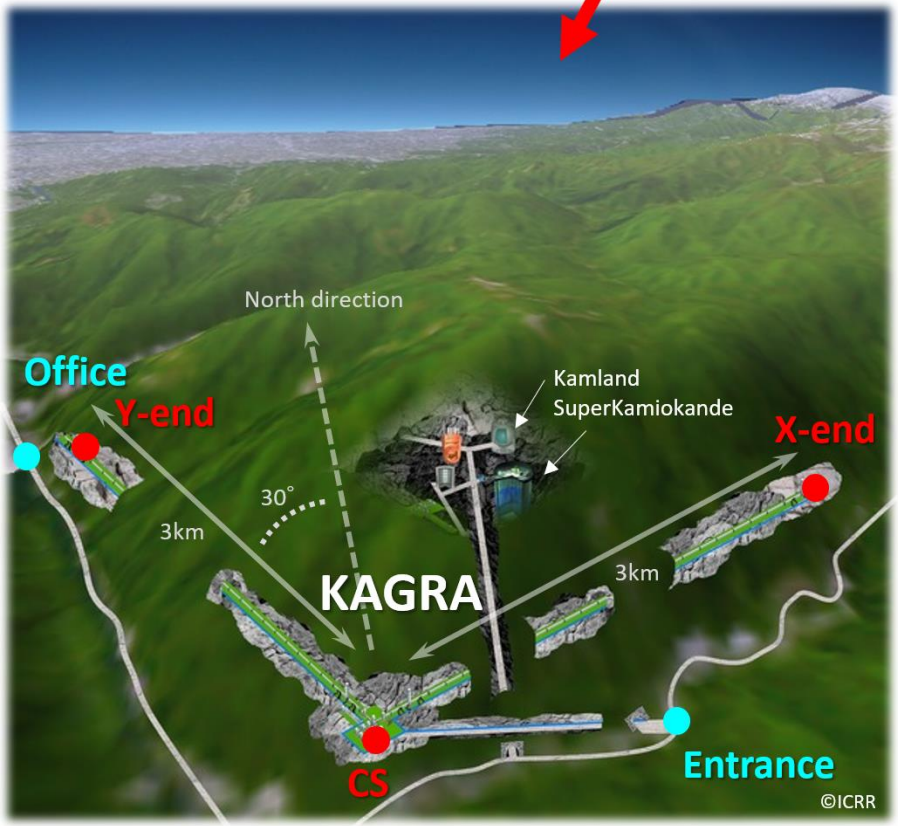
Reverberation time in the KAGRA site is much shorter than that of LIGO and Virgo.

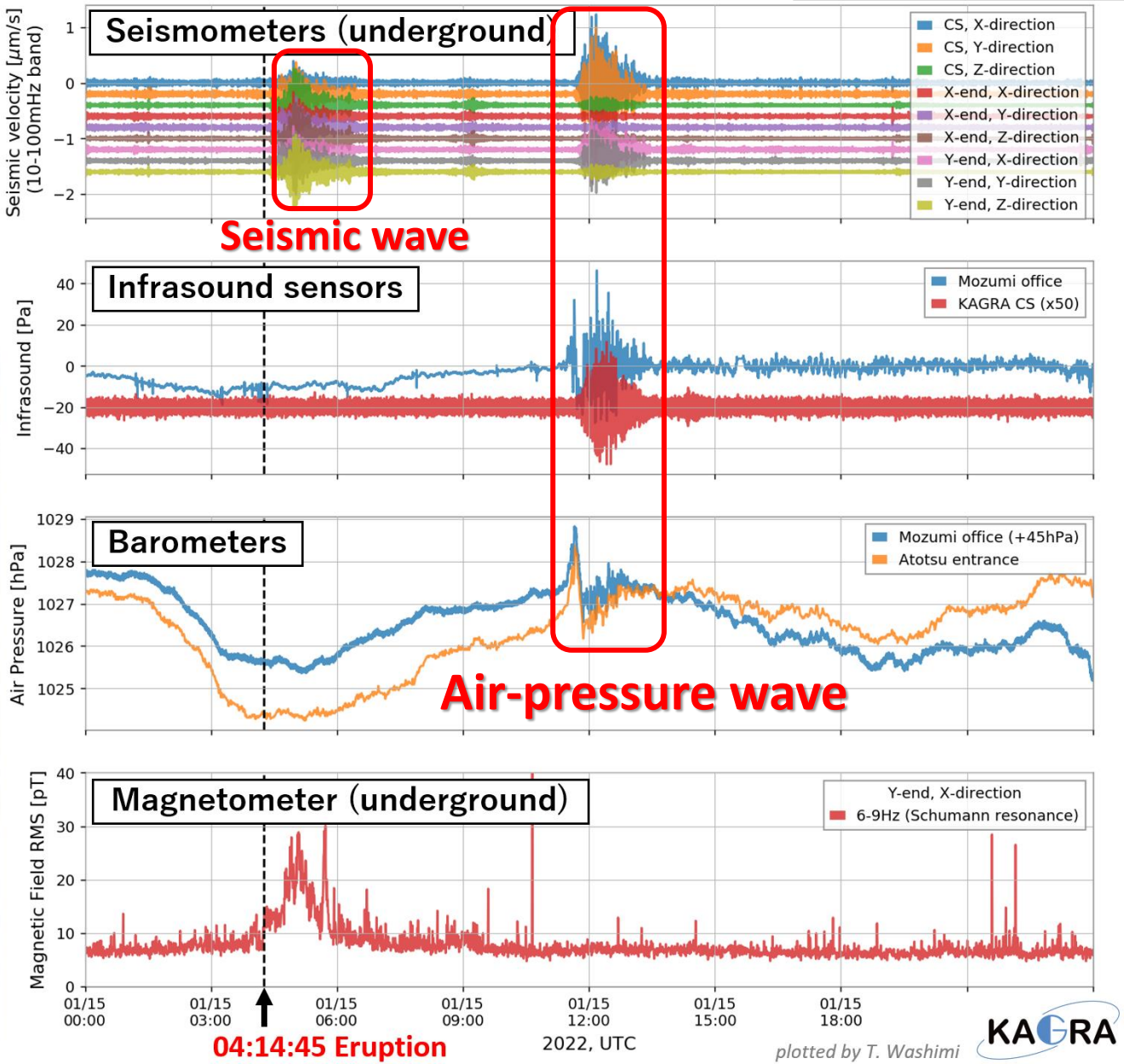
➢ This is because of the difference in the inner surface of the walls, rather than the location.

Tonga volcano eruption signal at KAGRA

https://gwcenter.icrr.u-tokyo.ac.jp/en/tonga-20220115

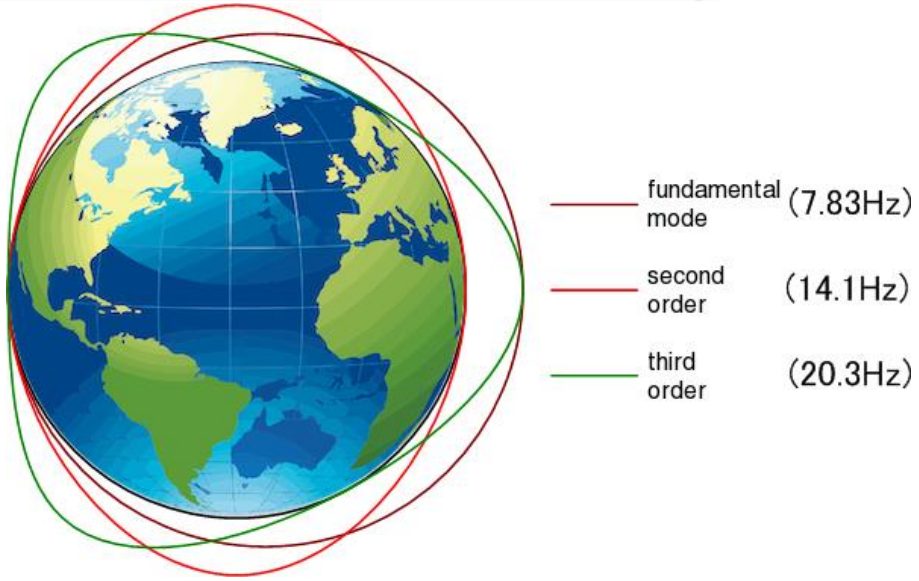
Analysis is ongoing

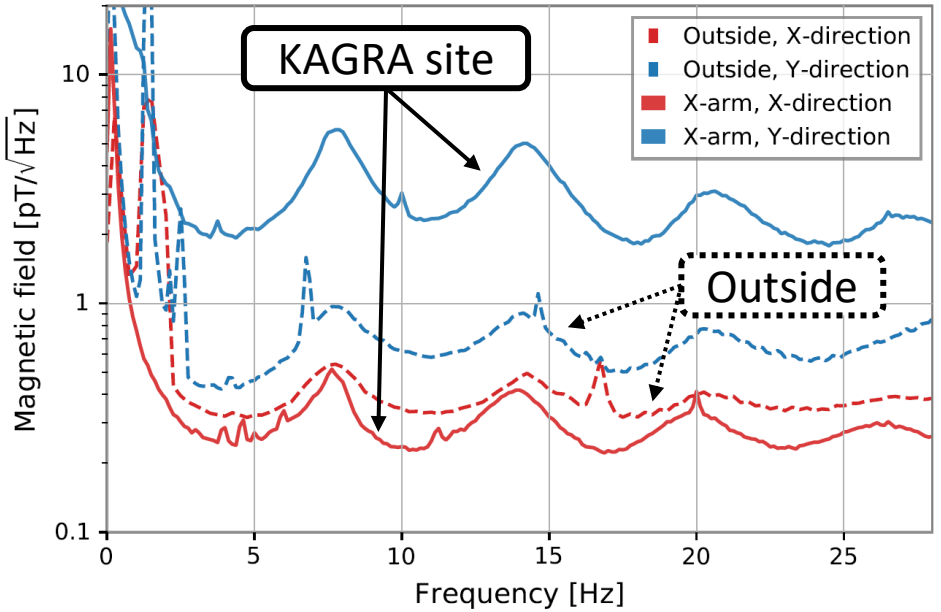




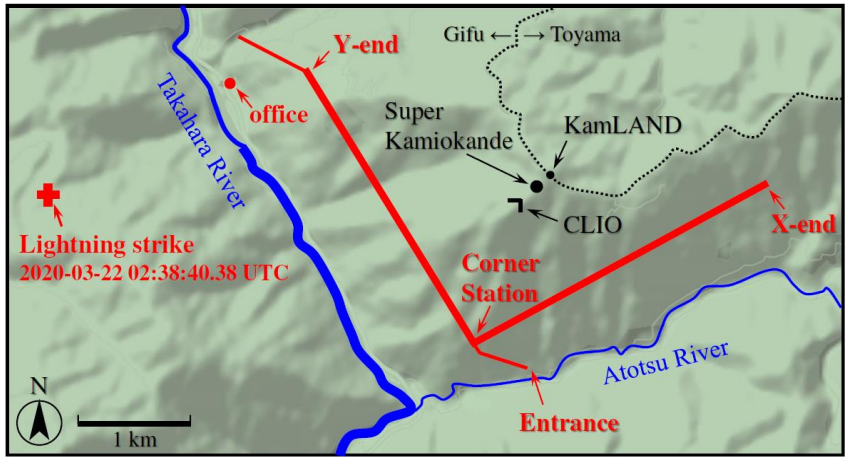
Stationary Magnetic field (Schumann resonance)

- Schumann resonance is a coherent magnetic field on the Earth.
  - It can affect the stochastic background GW search.
- LVK simultaneous measurement was performed in 2016.
  - M. W. Coughlin *et al. Phys. Rev. D* **97**, 102007 (2018)
- In the KAGRA site (underground), the amplitude looks larger than that of the outside.
  - Effect of the beam-duct metal? Sensor's problem?
  - Detailed studies are ongoing
  - Preparation for continuous monitoring is also ongoing.





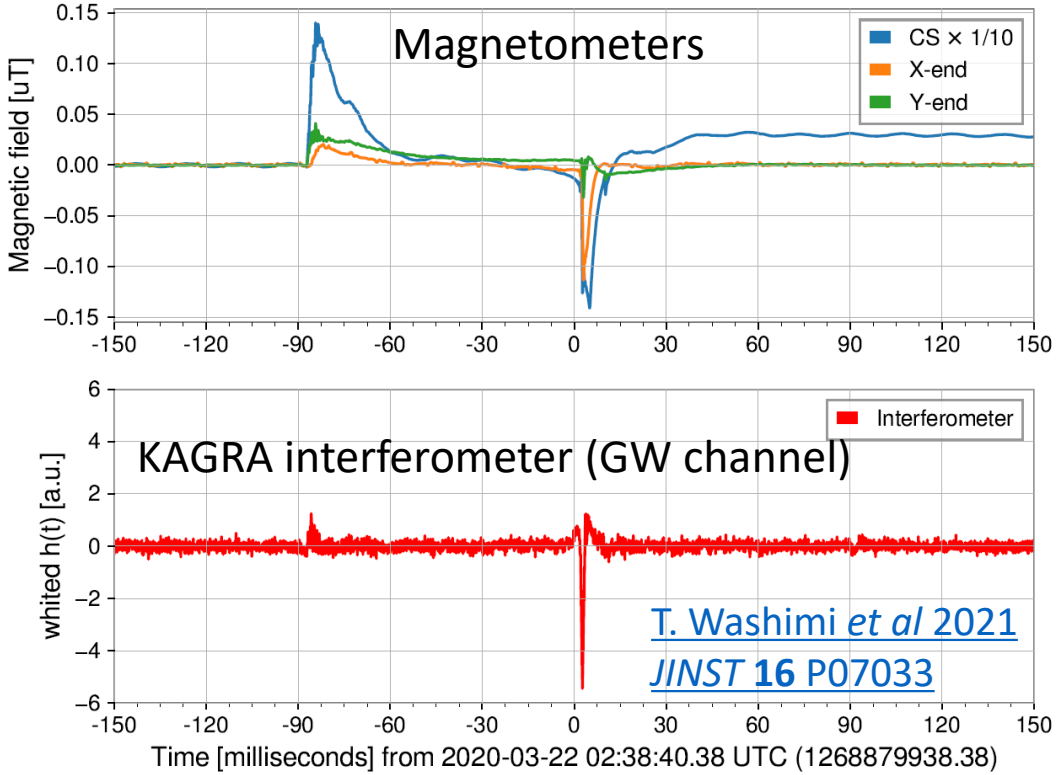
Transient Magnetic field from Lightning strokes

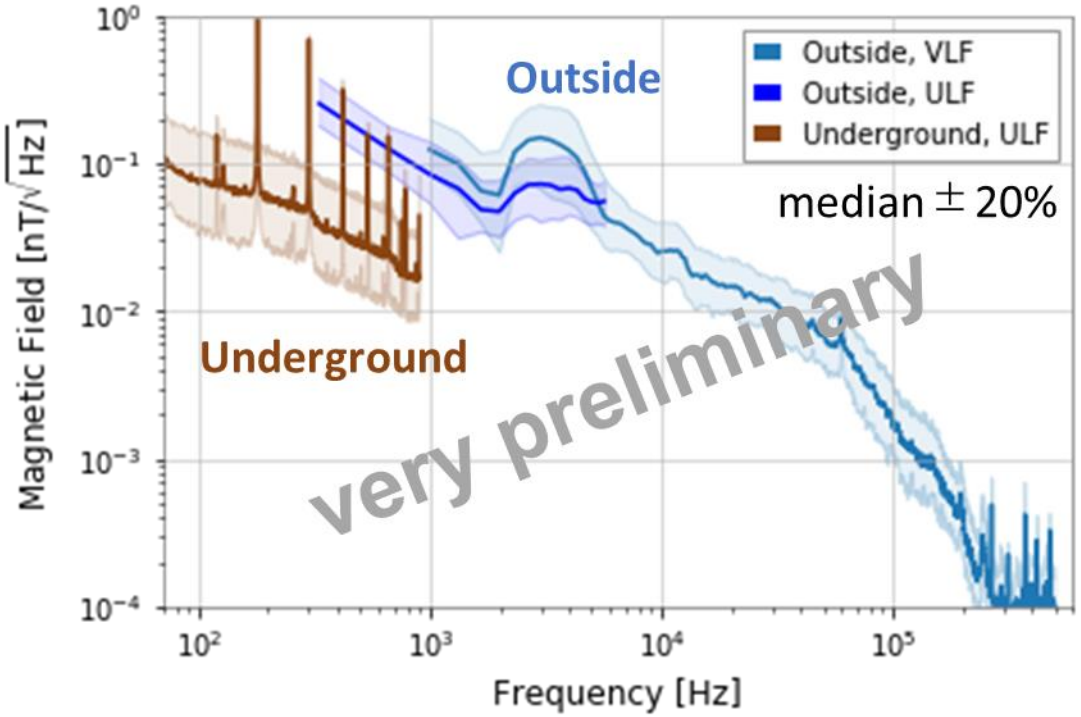


Lightning strokes cause glitch noise in the GW channel.
We have the monitoring system:

- Magnetometers @ underground/outside
- Lightning detector (VLF) @ outside

Measurement of the transfer function for the magnetic field (outside -> underground) is ongoing.



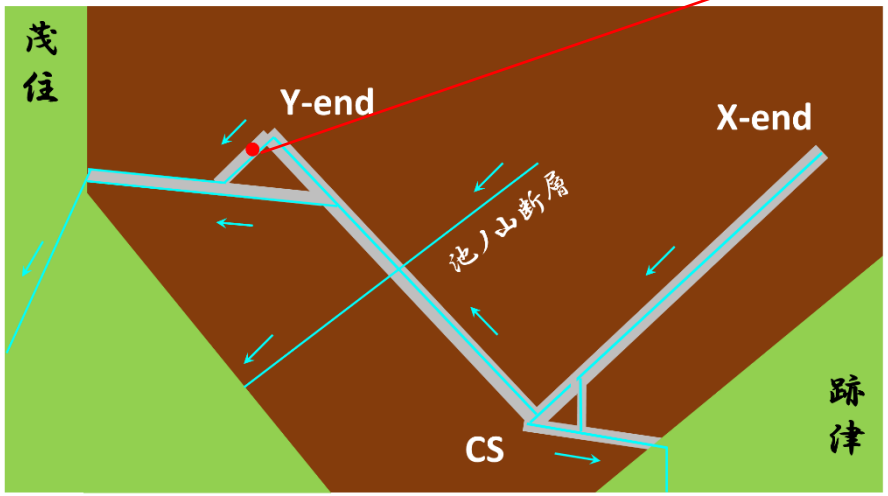


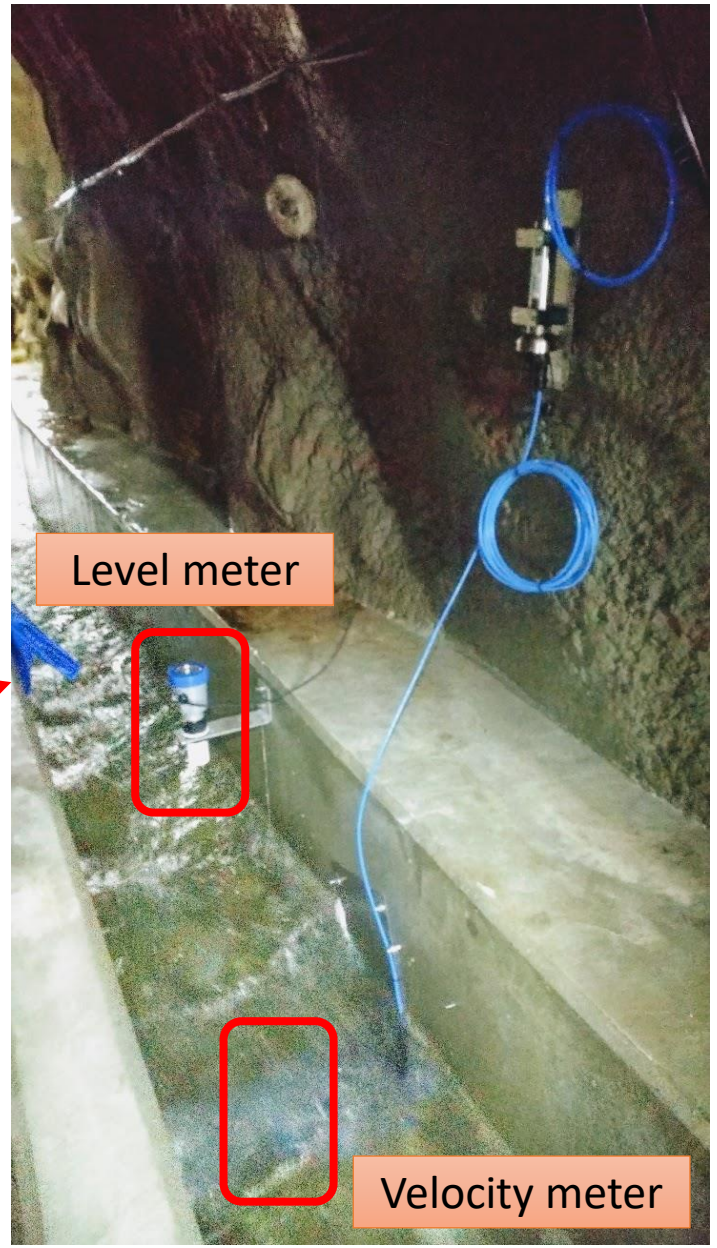
Underground water

Water fluid in the drainpipes can cause Newtonian noise. So we are working on

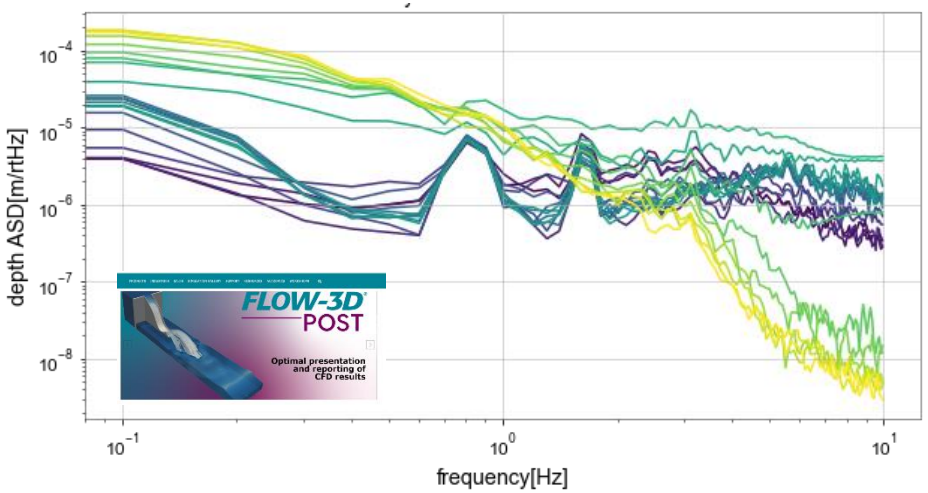
- Monitoring the water fluid @ Y-end
- NN estimation with water simulation

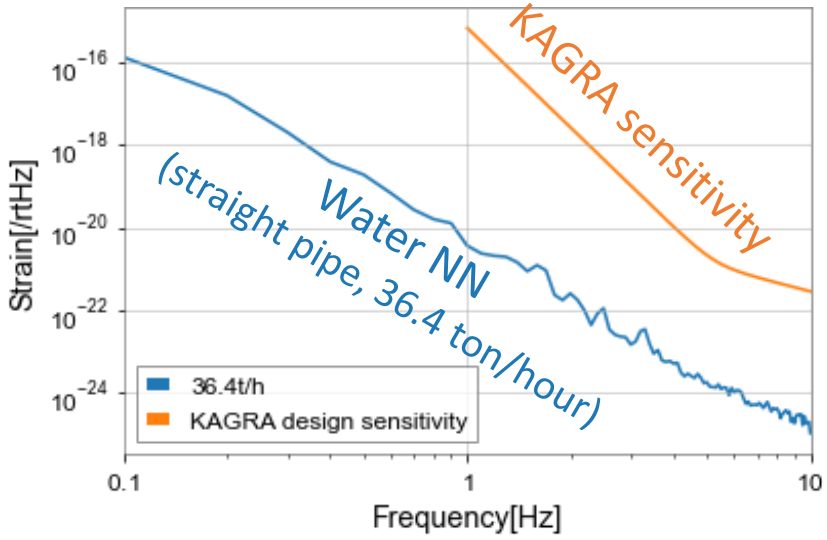
If we conclude this noise possibly affects the KAGRA design sensitivity and/or will be observed in O4 data, we need to mitigate this noise before O5 starts.





Simulation study is ongoing
(T. Suzuki @ TITECH)

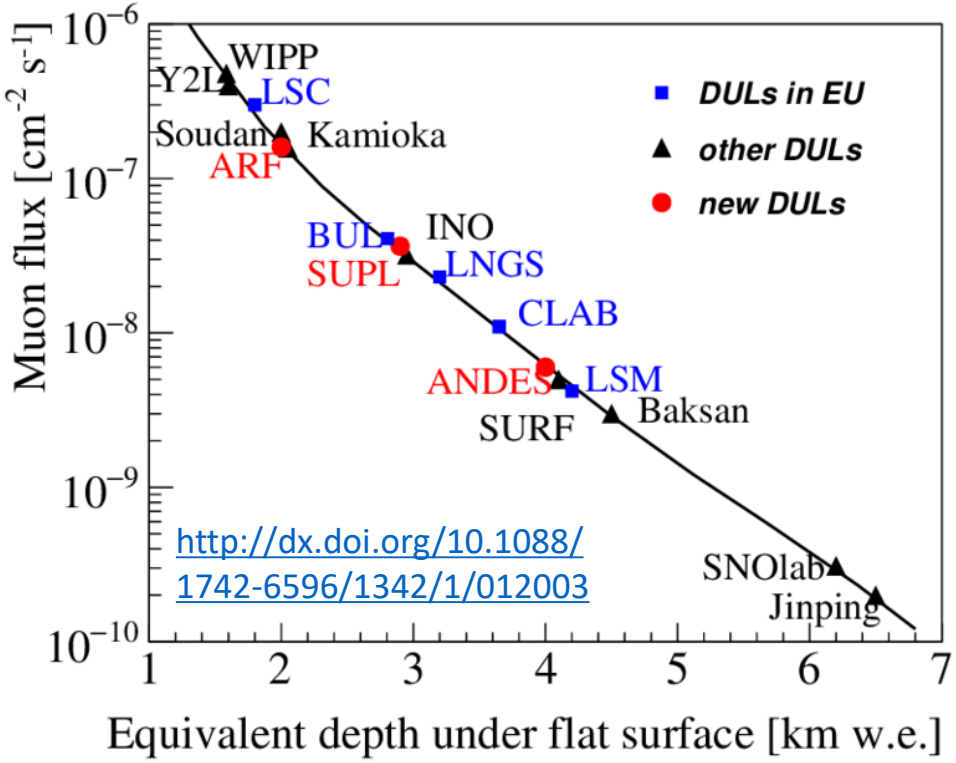


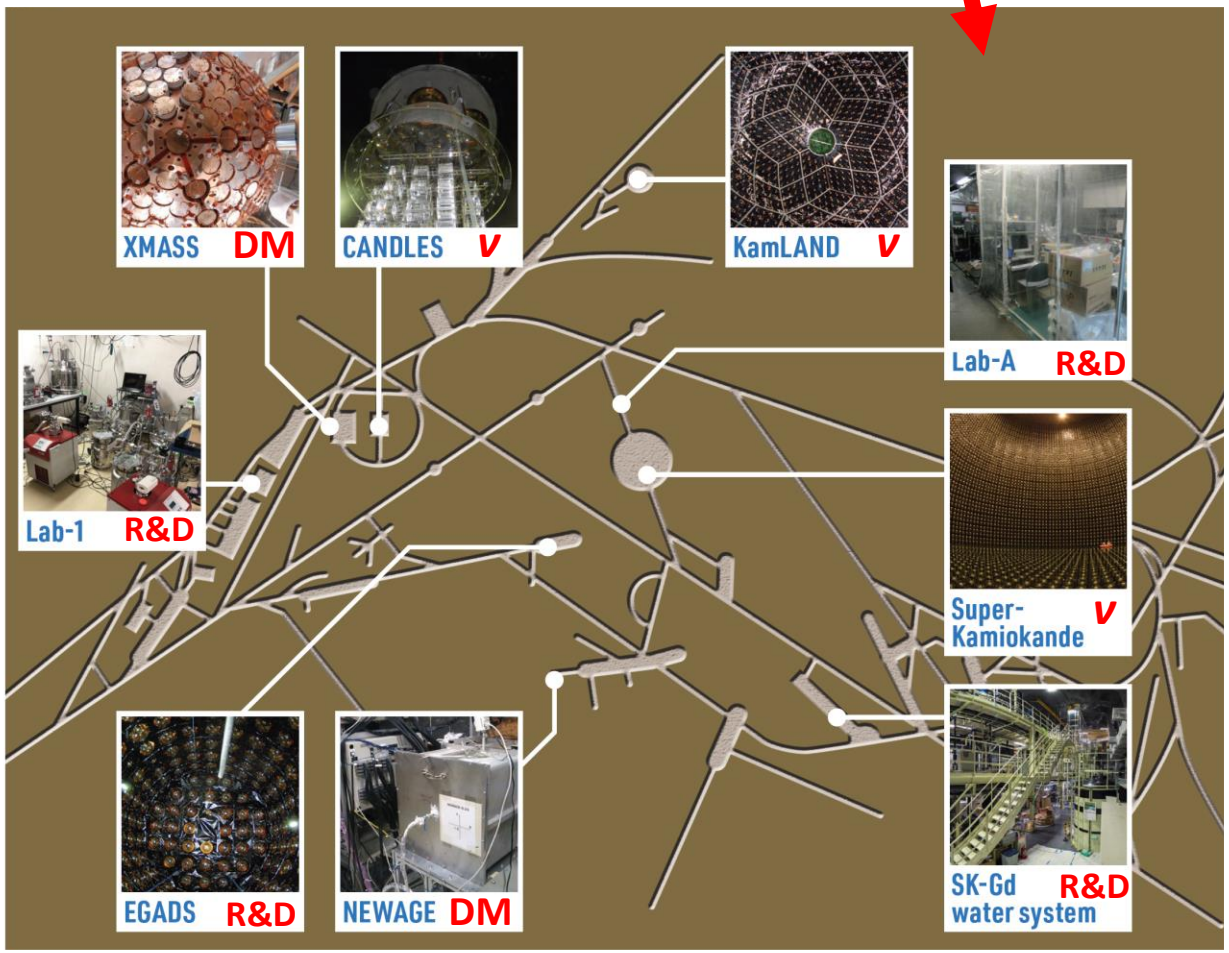


Cosmic ray background

OMAKE

- Cosmic ray (muon) flux is reduced in underground sites.
- At Kamioka, many low-background experiments are running.
  - Neutrino experiments
  - Darkmatter search experiments





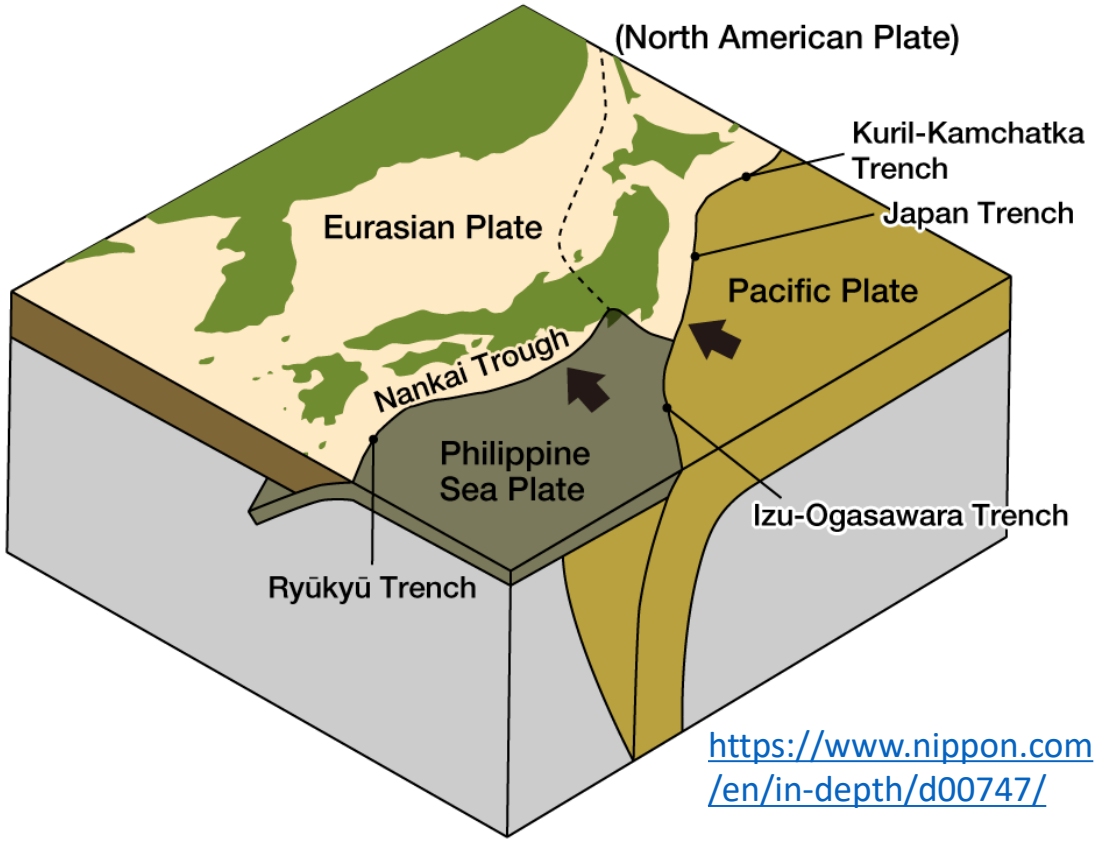
Summary

- Underground is low-noise and good for GW detectors.
- Underground environment is be studying at KAGRA.
  - Seismic motion: Well reduced at observation frequency, but not at a lower frequency.
  - Acoustic field: Stationary level is not so different from on-surface, but more stable.
  - Magnetic field: The situation is a little bit complicated and understudying.
  - Water: One difficulty of underground
- Understanding the underground environment is important for the next generation GW detectors.

Backup

Earthquake in Japan

Japan is famous for its frequent earthquakes.



https://www.nippon.com/en/in-depth/d00747/

The earthquakes' waves are weakened when they propagate across the Tateyama mountain range.
This is because the low-density ground is distributed at an altitude of approximately -5 km and it works as a cushion.