

SPATIAL EVALUATION OF PORE PRESSURE VARIATIONS RELATED TO RAINFALL FROM SEISMIC VELOCITY CHANGES

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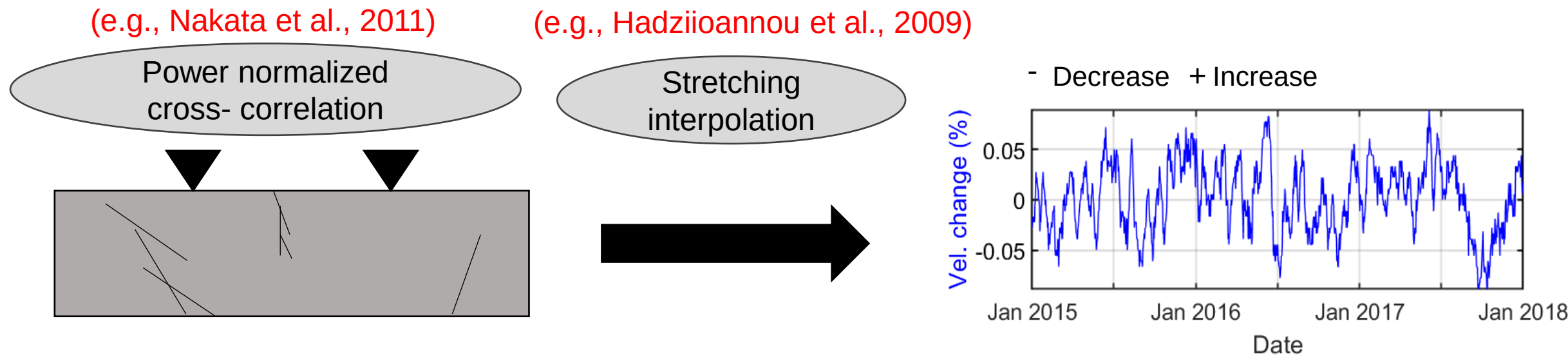


1. Background

- Passive seismic method provides **low cost** and **continuous monitoring system** using seismic ambient noise. This method can be used to evaluate pore pressure change.

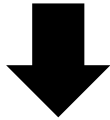
Why change of pore pressure is important?

- Industrial activities such as underground mining, water reservoir impoundment, oil and gas production, and natural gas storage can cause pore pressure change.
- Under critically stressed rocks, even small change of pore pressure generates cracks, triggering seismicity

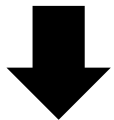


1. Background

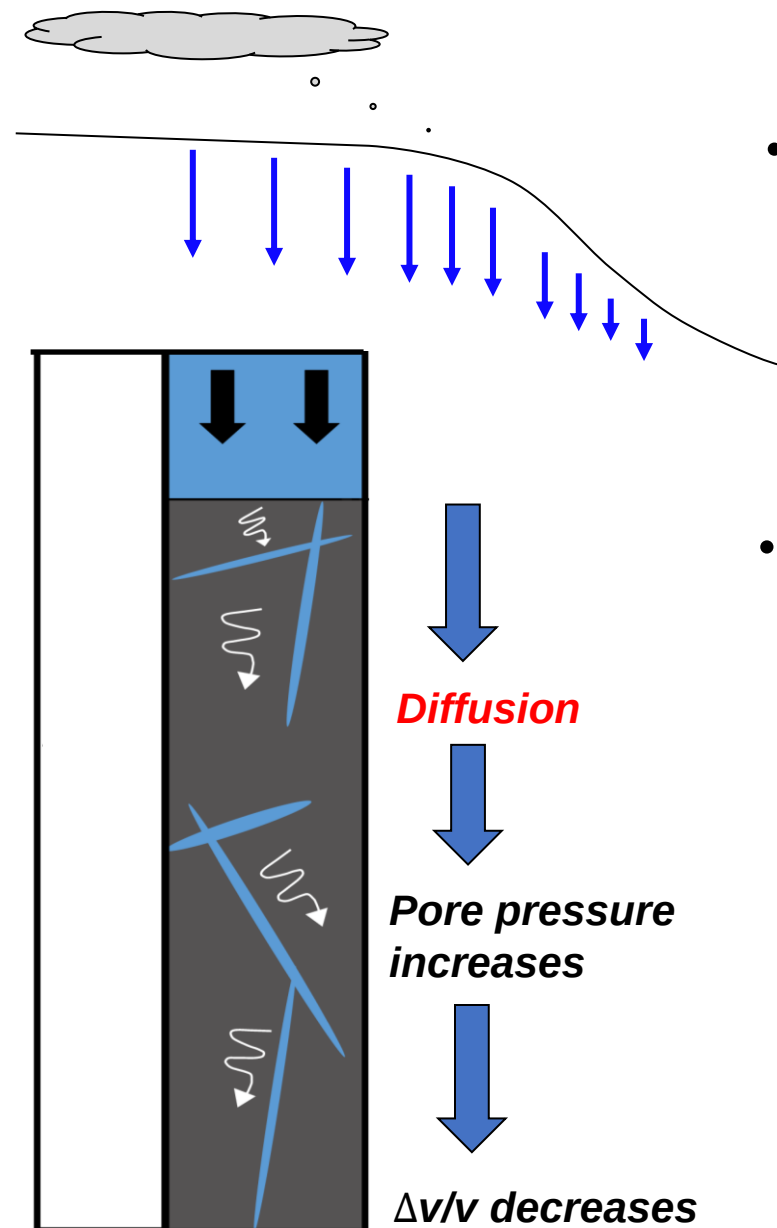
Infiltration of rainfall can cause seismic velocity change to vary temporally



Groundwater recharge due to rainfall can trigger pore pressure diffusion in deeper formation



Seismic vel. change from ambient noise monitoring can reflect the pore pressure change because of fluid diffusion



- The crust is neither homogeneous nor flat

- The impact of these disturbances is likely to differ in different locations

Q: What can we discover about deep formation condition?

1. Background

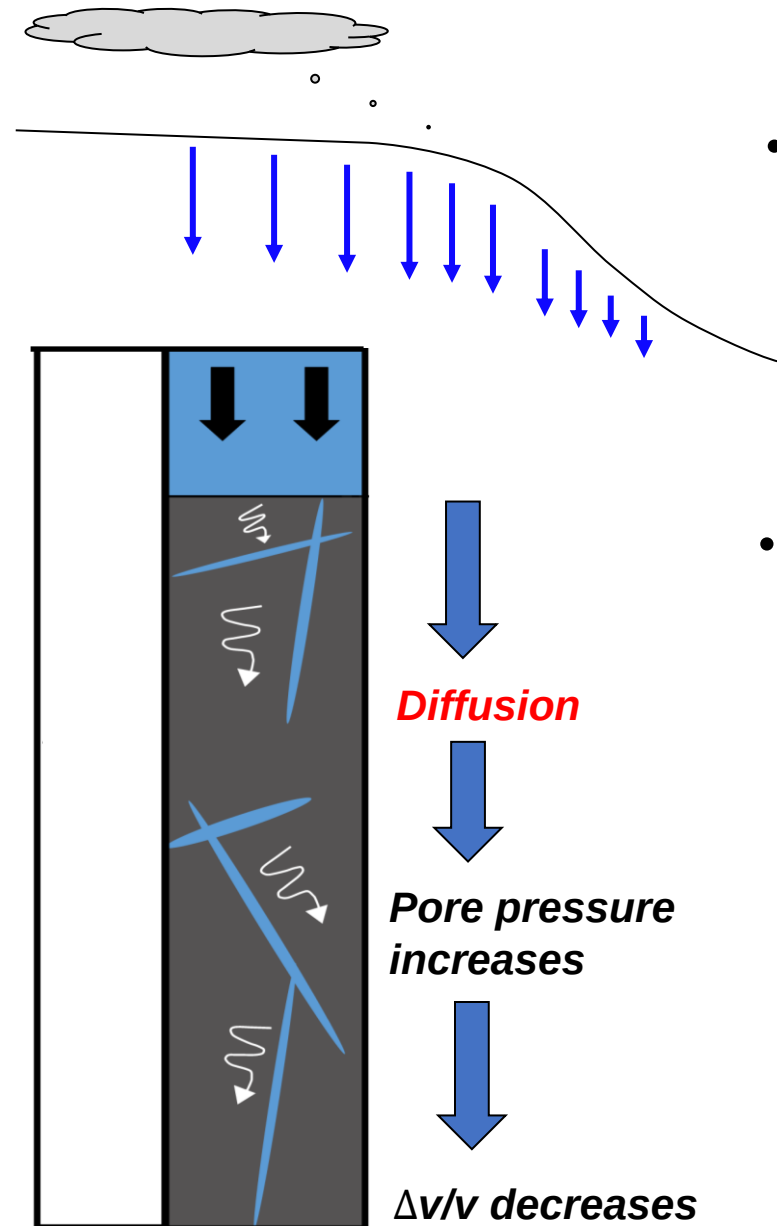
Gap

Effect of location has not been discussed widely



Objective

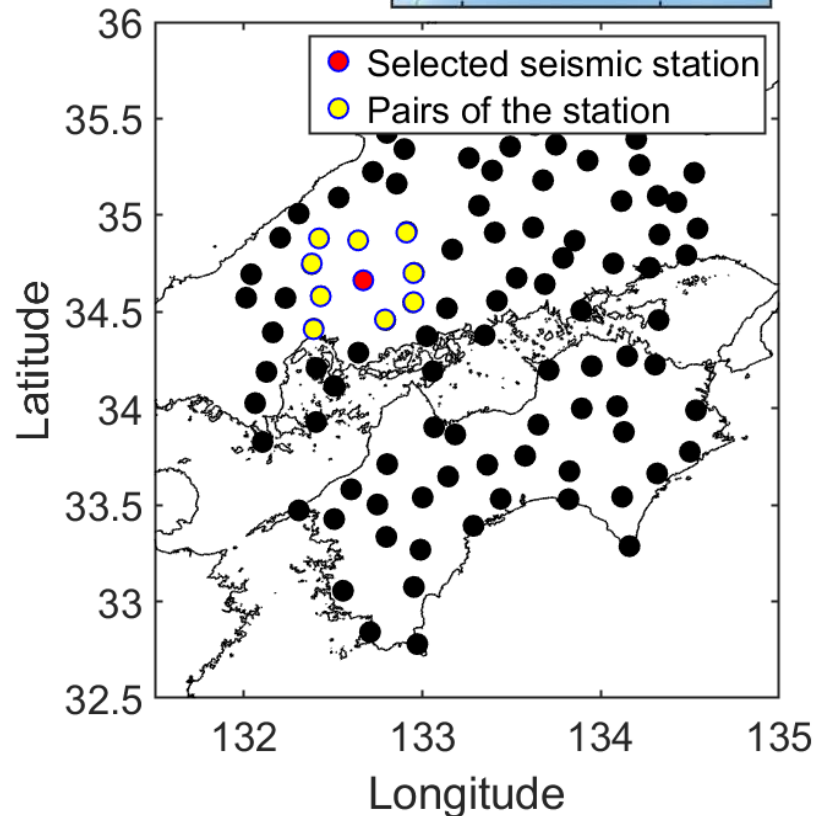
Investigate the impact of rainfall in deep pore pressure from seismic velocity change at various location



- The crust is neither homogeneous nor flat

- The impact of these disturbances is likely to differ in different locations

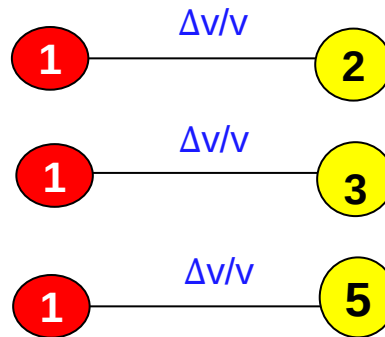
Q: What can we discover about deep formation condition?



- Period: 2015 - 2017

Average the seismic stations
(radius < 40 km)

Cross-correlation

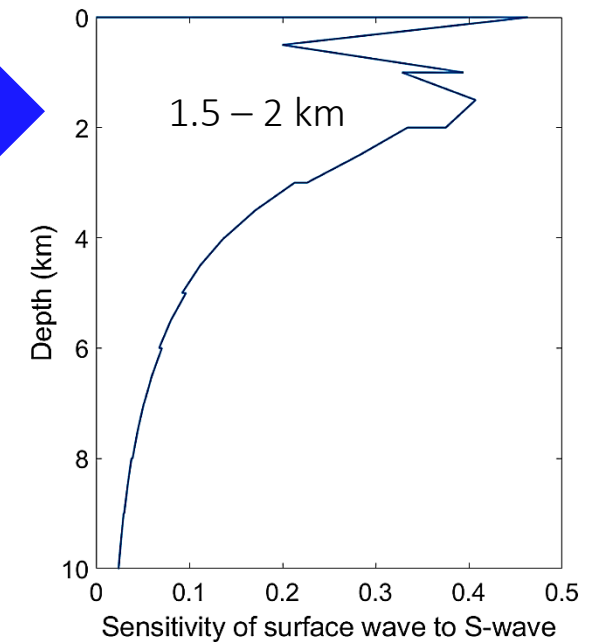


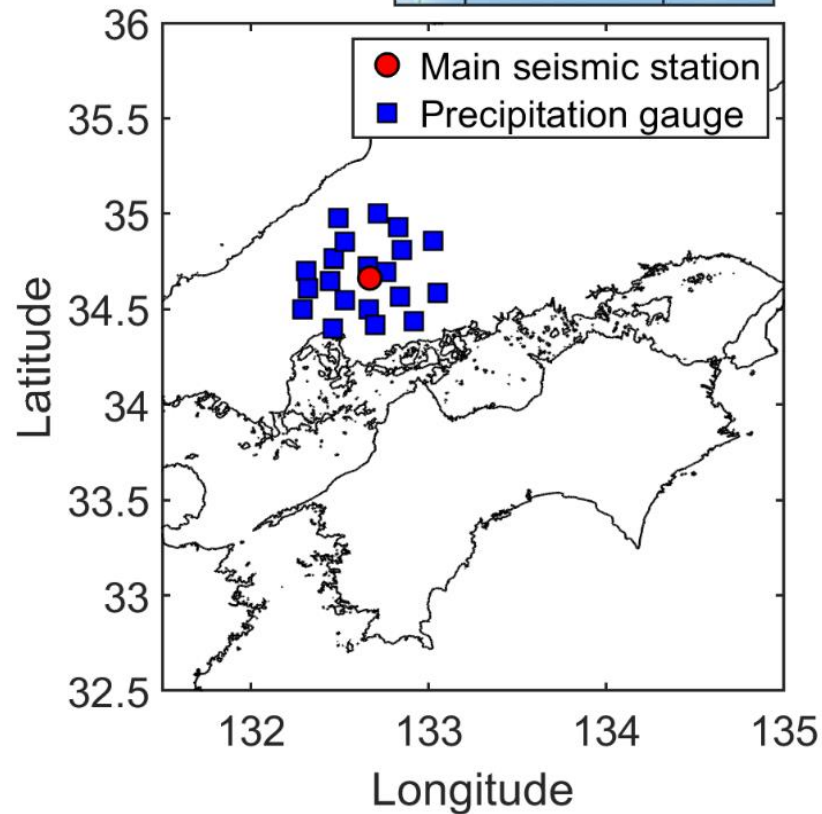
1 $\Delta v/v$

At the exact seismometer

Seismic velocity changes ($\Delta v/v$)

- Vel. change is assumed to be dominated by surface (Rayleigh) wave
- Sensitivity of surface wave to S-wave in this area





- Period: 2015 - 2017

Average the seismic stations
(radius < 40 km)

1
 $\Delta v/v$



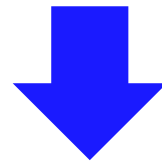
Rainfall averaged from precipitation
gauge within radius of 40 km around
seismic station

Pore pressure modeling

- While the infiltration of rainfall results in **immediate loading**, the effect of pore pressure diffusion **could manifest at a later time (Talwani, 1997)**

Modelling pore pressure diffusion from rainfall

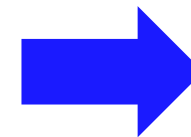
Talwani et al. 2007



n = 365 days

$$P_k = \sum_{k=1}^n \delta p_k \operatorname{erfc} \left[\frac{r}{(4c\delta t_k)^{1/2}} \right]$$

Pore pressure



$$\sum \Delta P = \sum P_{n+1} - P_n$$

**Pore pressure
change**

δp_i : water level change
 r : the depth from the surface
 c : hydraulic diffusion

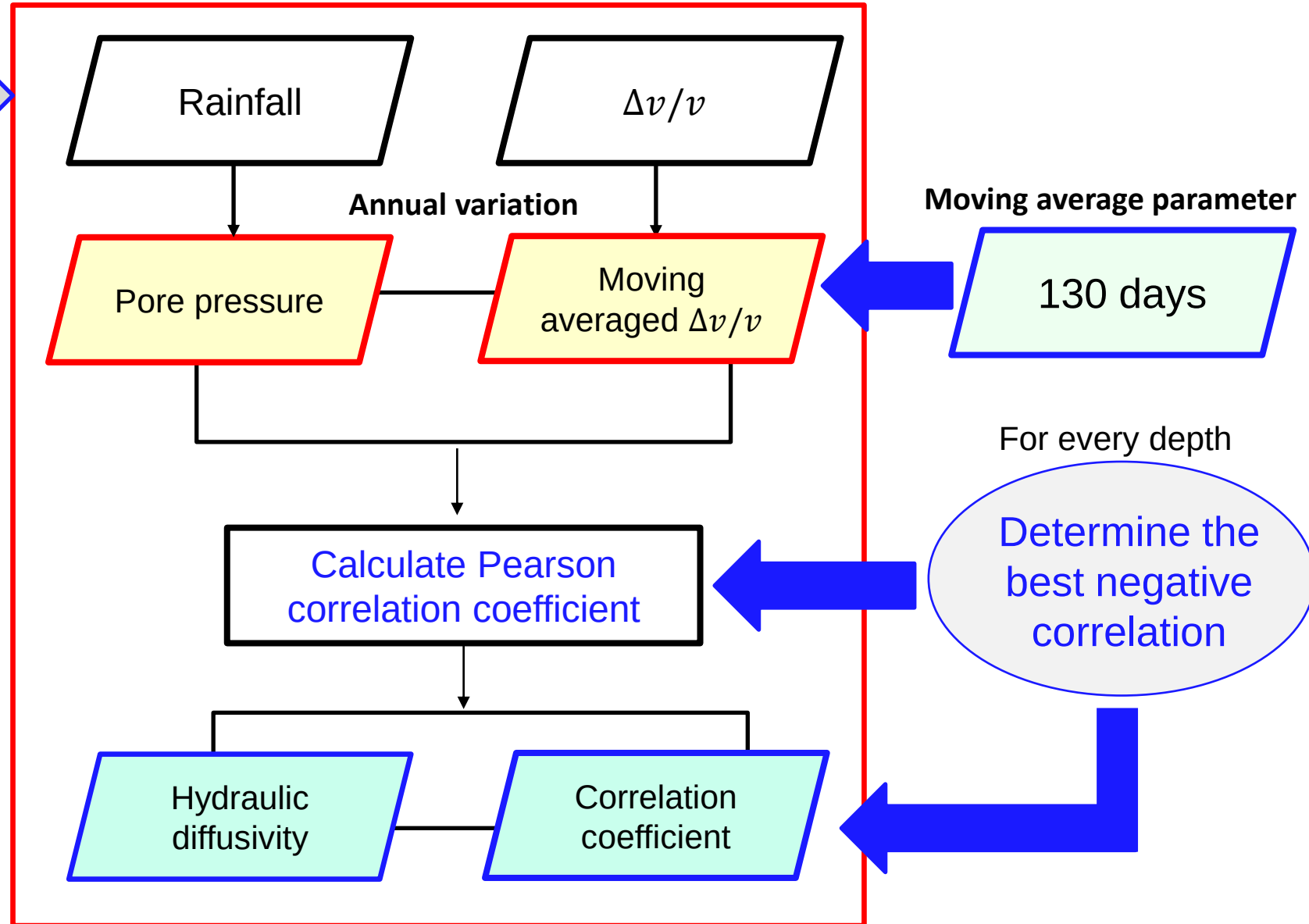
δt_k : time increment from the starting time k to n
 erfc : denotes error complementary function

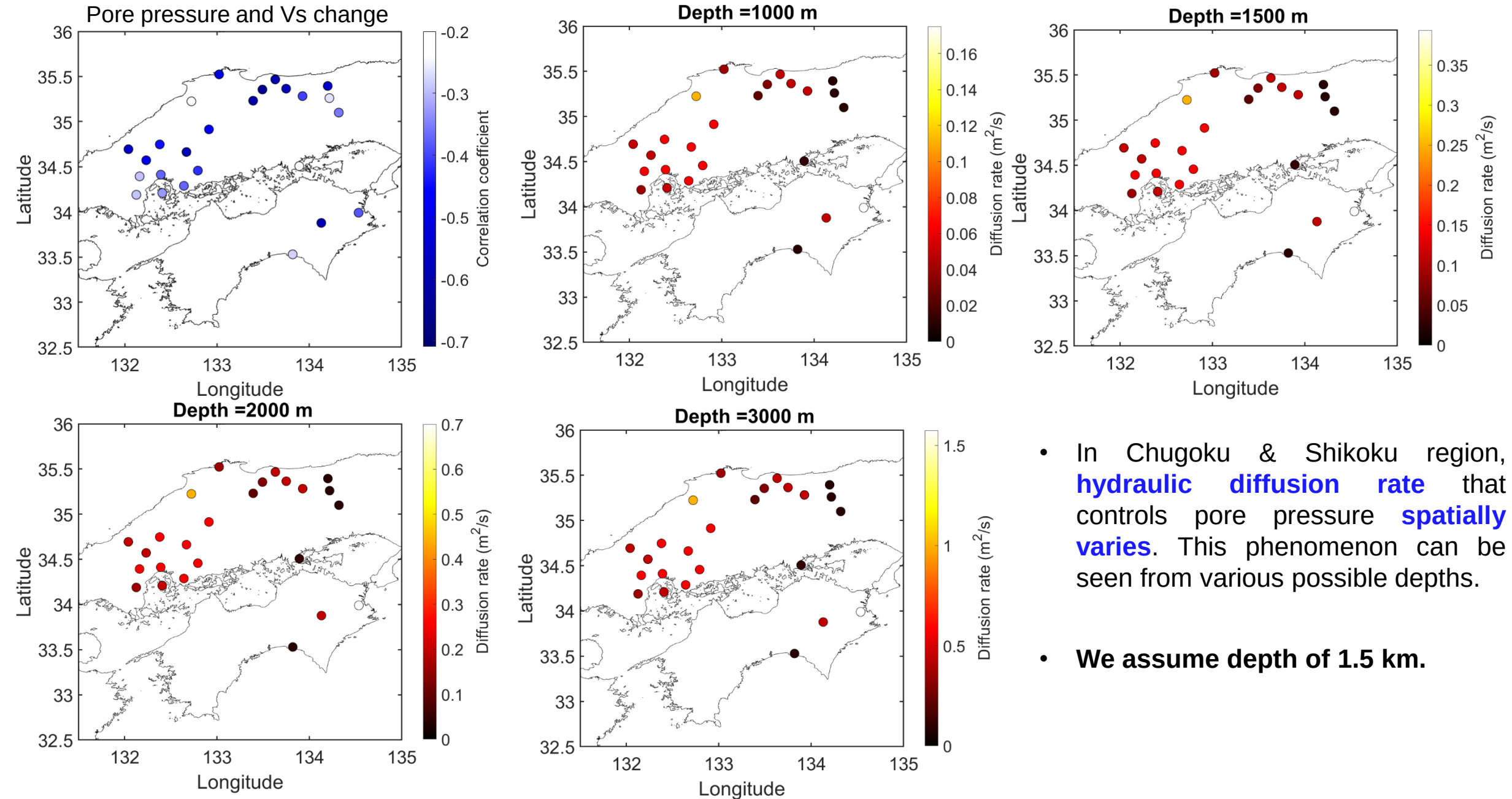
Shorter term

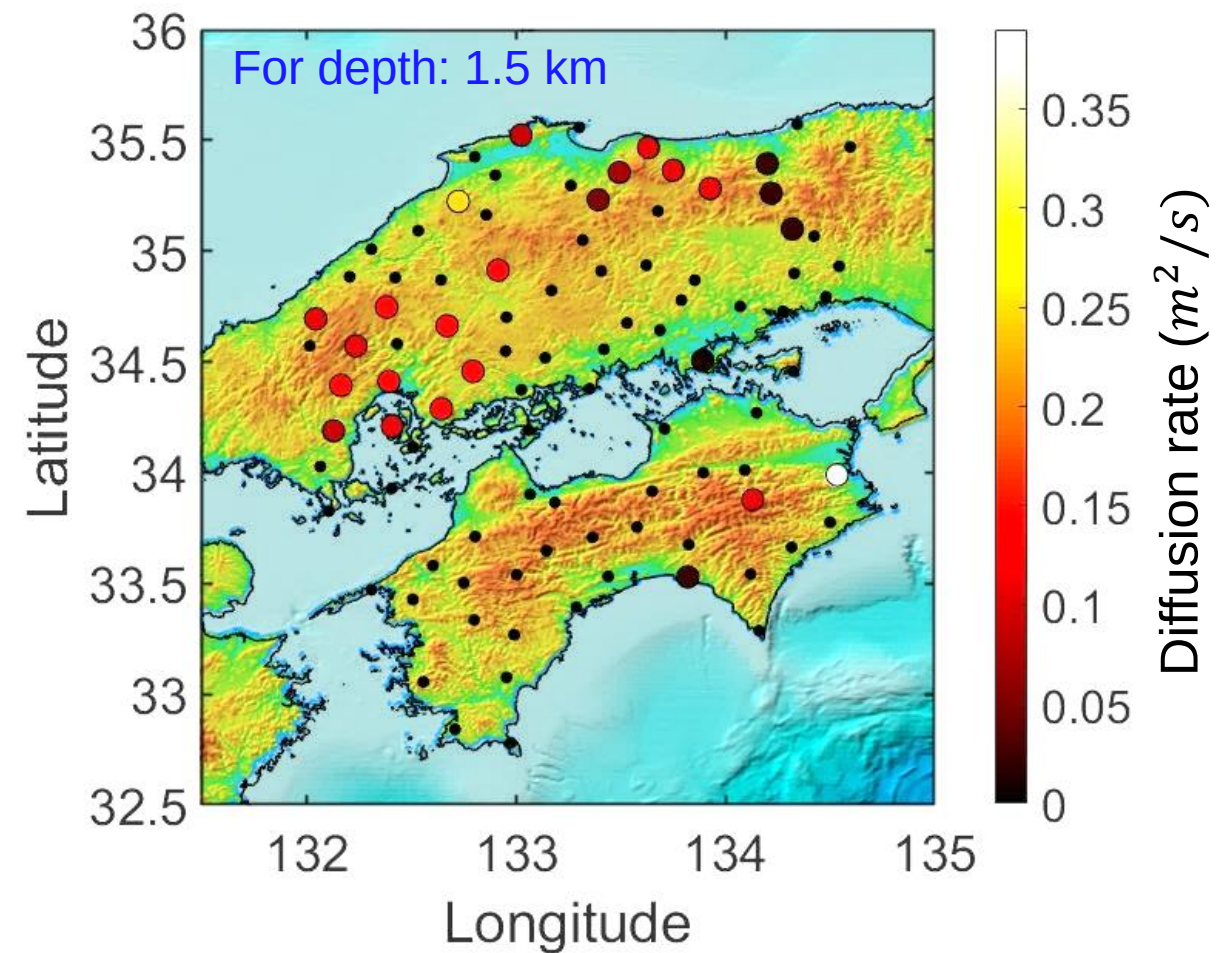
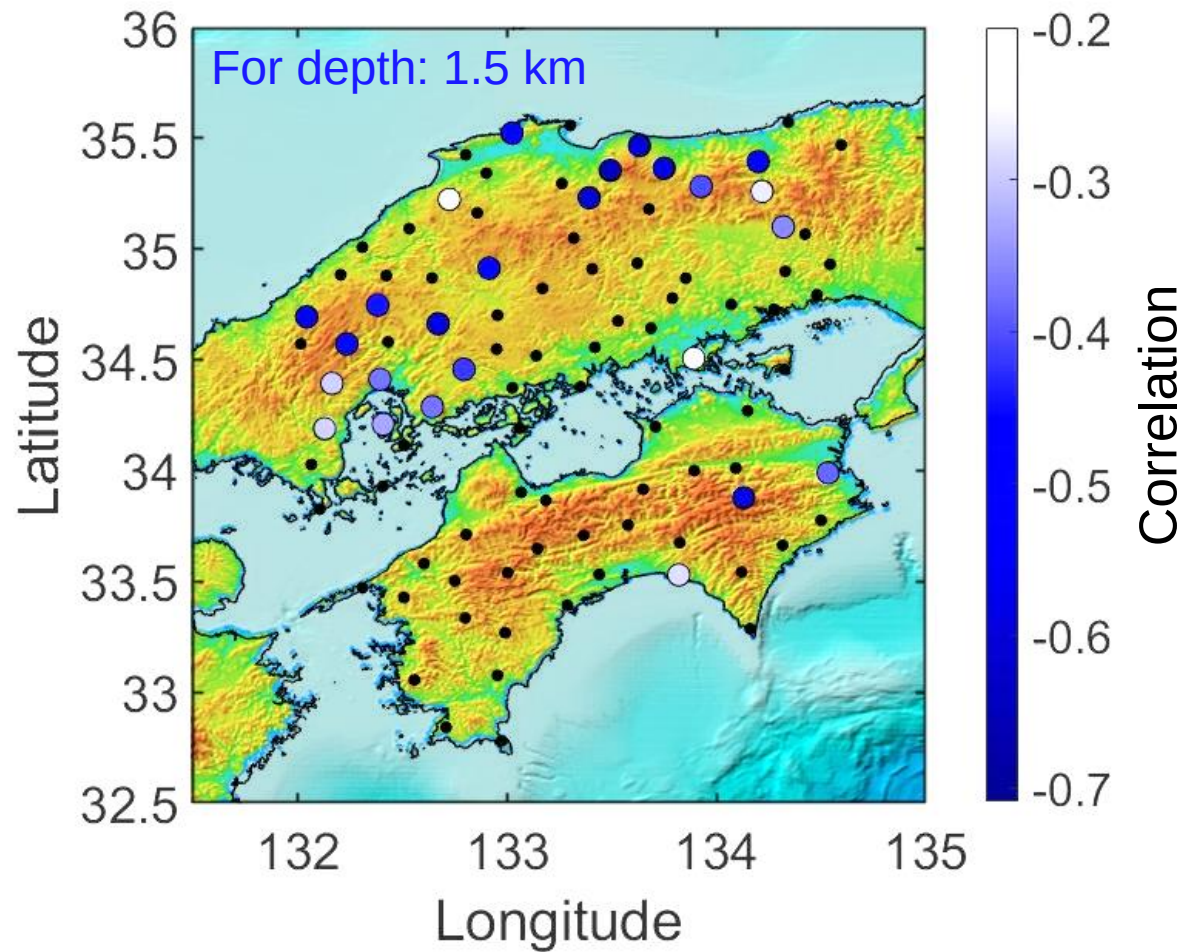
Longer term

Locations with
groundwater
replenish

[Click here - To identify the location
of groundwater replenish](#)







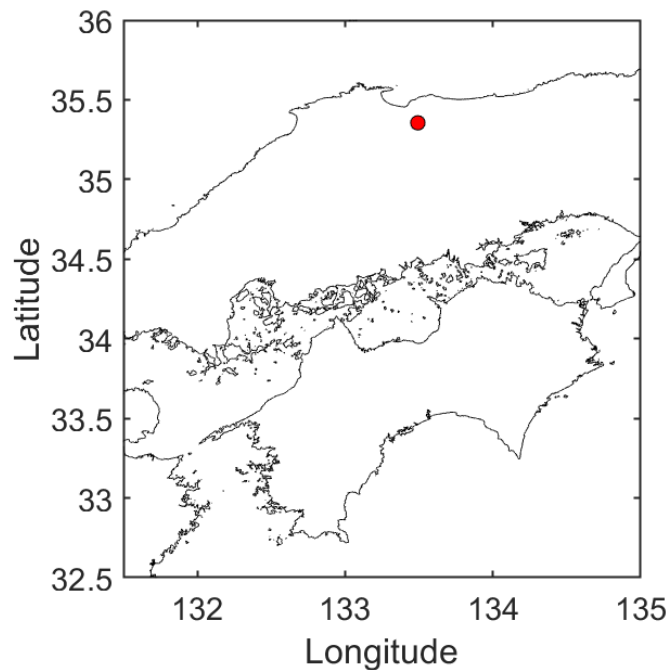
- Stations with indication of groundwater replenishment
- Stations without indication of groundwater replenishment

Hydraulic diffusion rate that controls
pore pressure diffusion spatially
varies

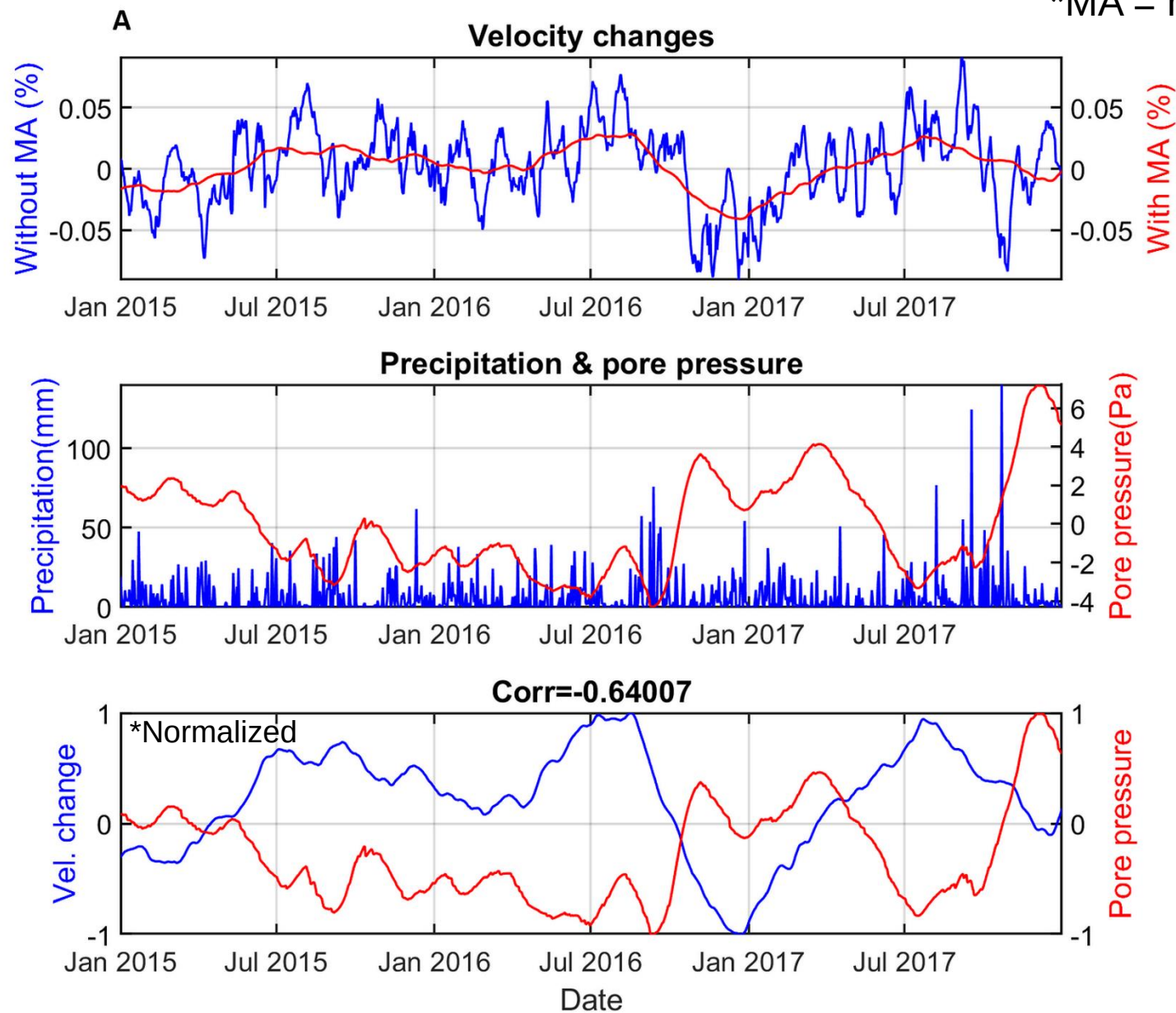
Best parameter for this location

For depth: 1.5 km

Diffusion rate: $0.07 \text{ m}^2/\text{s}$

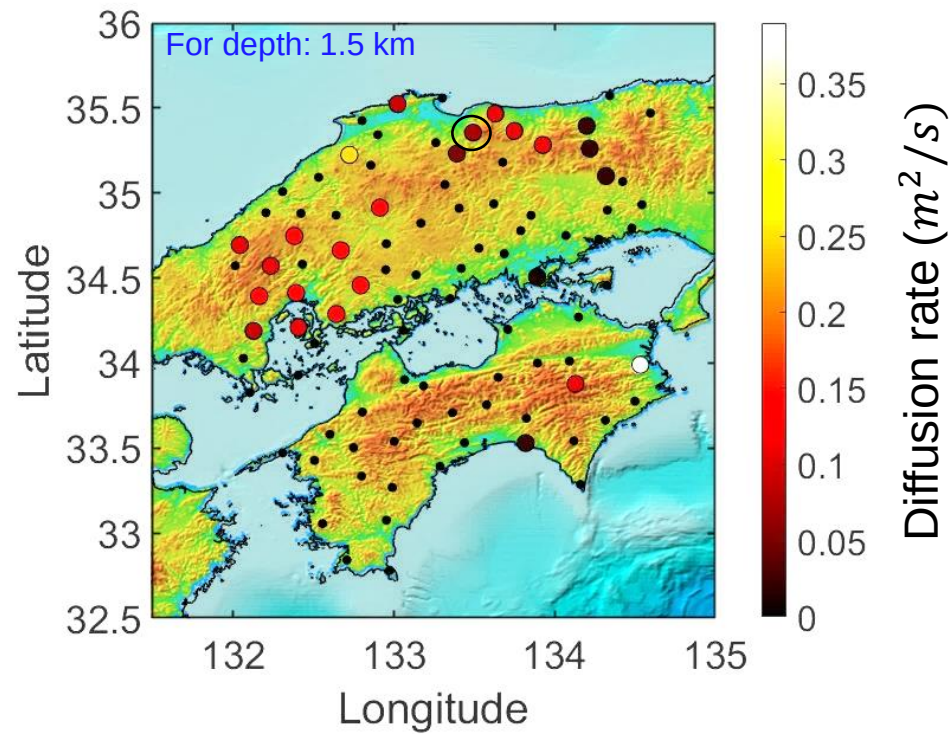


*MA = moving average

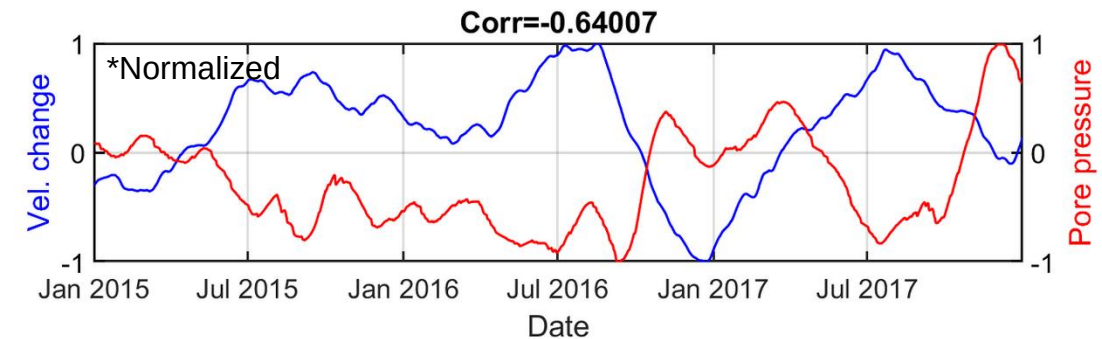
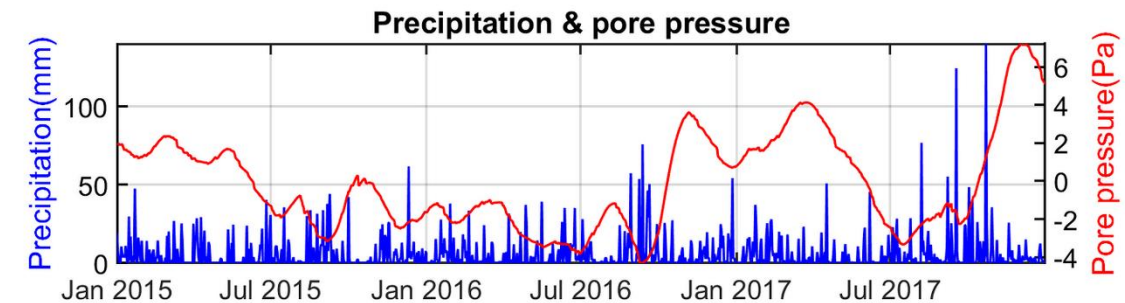
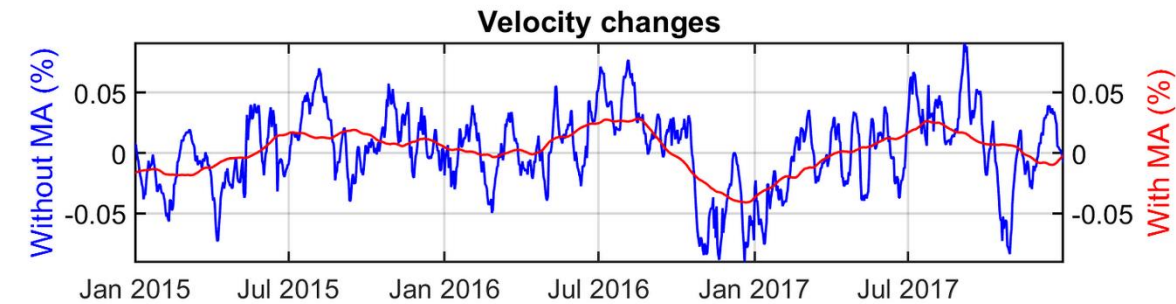


- Spatial variation of the hydraulic diffusivity infers the heterogeneity of the rocks in different locations.
- **The response of pore pressure** induced by rainfall percolation **depends on location**

Maximum precipitation usually happens in **July and September** (Aizen et al., 2001)



- At Chugoku region, seasonal seismicity in **July- September** (Ueda & Kato 2019).
- The velocity changes ($\Delta v/v$) decreases from **July - November** (Andajani et al., 2020)



- We show that seismic velocity monitoring can be used to evaluate pore pressure condition in deep formation.
- In the Chugoku and Shikoku region, hydraulic diffusion rate parameter that controls pore pressure diffusion spatially varies.
- Such hydraulic diffusion rate reflects the heterogeneity of the fractures developed in deep formation.

This work is a part of published paper:

Andajani, R. D., Tsuji, T., Snieder, R., & Ikeda, T. (2020). Spatial and temporal influence of rainfall on crustal pore pressure based on seismic velocity monitoring. *Earth, Planets and Space*, 72(1), 177.

<https://doi.org/10.1186/s40623-020-01311-1>

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- Hadziioannou, C., Larose, E., Coutant, O., Roux, P., & Campillo, M. (2009). Stability of monitoring weak changes in multiply scattering media with ambient noise correlation: Laboratory experiments. *The Journal of the Acoustical Society of America*, 125(6), 3688-3695. <https://doi.org/10.1121/1.3125345>
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- Talwani, P., Chen, L., & Gahalaut, K. (2007). Seismogenic permeability,ks. *Journal of Geophysical Research*, 112(B7). <https://doi.org/10.1029/2006jb004665>
- Ueda, T., & Kato, A. (2019). Seasonal variations in crustal seismicity in San-in district, Southwest Japan. *Geophysical Research Letters*, 46(6), 3172-3179. <https://doi.org/10.1029/2018gl081789>