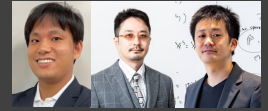# Introducing data-driven sparse sensor placement to determine rain gauge locations

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Background

Previous placement methods

MLIT: Rain gauges should be placed as many as possible to cover various precipitation patterns. (Qualitative)

Periago et al. (1998): Rain gauge locations are determined with geographical and geological data in Spain. (Quantitative, but non-generic)

Quantitative and generic placement method ➜ **Sparse Sensor Placement (SSP)**

Sparse Sensor Placement (SSP)

Precipitation data (training period) X

Time

Precipitation

Rain gauge locations

1. Dimensionality reduction
2. To extract important features for sensor placement
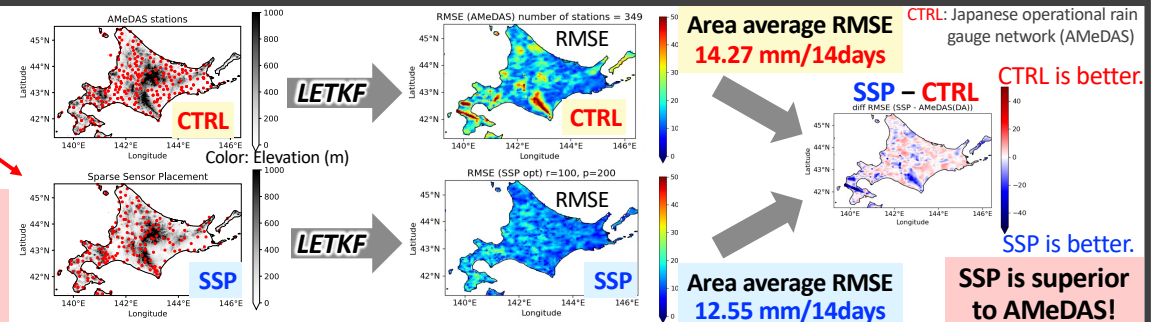
Data: radar/raingauge-analyzed precipitation (2006 – 2018)

Dimensionality reduction
- Singular value decomposition (SVD)
- Non-negative matrix factorization (NMF)

Which is better?

The number of grids: n X : input data Time step: T

Algorithm of SSP with SVD
- $X \approx U_r \Sigma_r V_r^T$ (SVD)
- $x = U_r a$ (a snapshot of X)
- $y = Hx = HU_r a = Ca$

For an overdetermined system, $\det(C^T C)$ is maximized.
Manohar et al. (2018), Saito et al. (2021)

y: observation H: observation locations
Obs.   Obs. operator
p = y H x H U_r a
p: number of sensors

Determining H (obs. Locations) that can accurately reconstruct x from a limited number of observation

Rain gauge placement with SSP-SVD
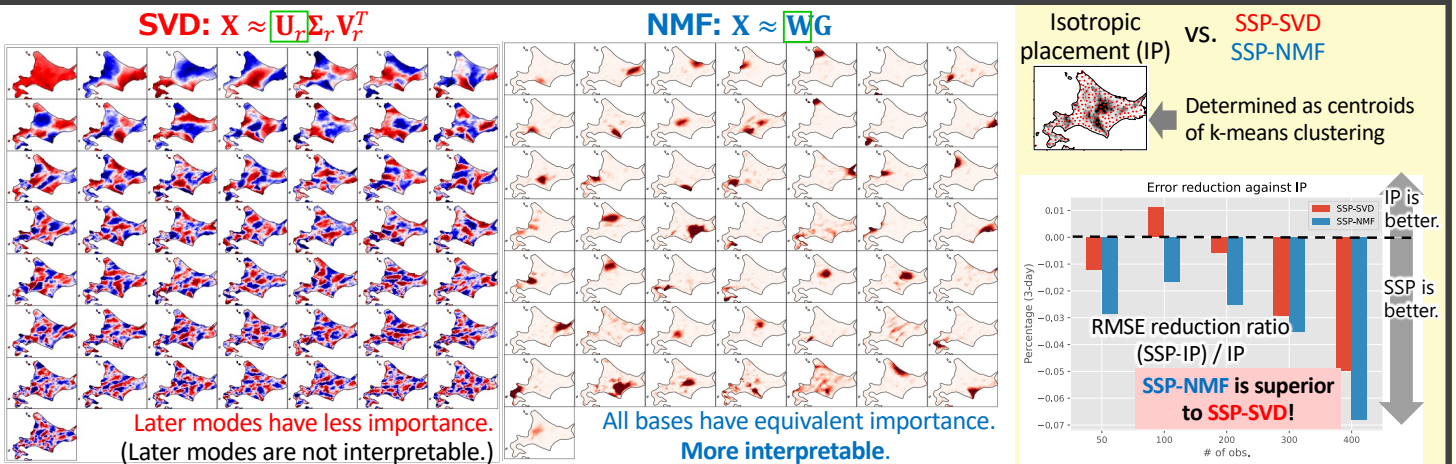
Based on 14-day accumulated precipitation

CTRL: Japanese operational rain gauge network (AMeDAS)

With SSP, many rain gauges are placed in mountainous areas.

SSP is a generic method! Requiring only X. (w/o geographical and geological data)

AMeDAS stations — Color: Elevation (m) — CTRL
Sparse Sensor Placement — SSP

LETKF

RMSE (AMeDAS) number of stations = 349 — RMSE — CTRL
RMSE (SSP opt) r=100, p=200 — RMSE — SSP

Area average RMSE 14.27 mm/14days
Area average RMSE 12.55 mm/14days

SSP – CTRL diff RMSE (SSP - AMeDAS(DA))
CTRL is better.
SSP is better.

SSP is superior to AMeDAS!

SSP-SVD vs. SSP-NMF

Based on 3-day accumulated precipitation

SVD: $X \approx U_r \Sigma_r V_r^T$

NMF: $X \approx WG$

Later modes have less importance. (Later modes are not interpretable.)

All bases have equivalent importance. **More interpretable.**

Isotropic placement (IP)   vs.   SSP-SVD SSP-NMF

Determined as centroids of k-means clustering

Error reduction against IP
IP is better.
SSP is better.
RMSE reduction ratio (SSP-IP) / IP
SSP-NMF is superior to SSP-SVD!
# of obs.

NMF works more effectively as a dimensionality reduction method for SSP than SVD!

Conclusion

- SSP is beneficial for rain gauge placement.
- Rain gauges are placed in mountainous areas by SSP.
- NMF decomposes to physically interpretable patterns.
- NMF is superior to SVD for SSP.