沖合観測網を活用した津波データ同化による津波予測

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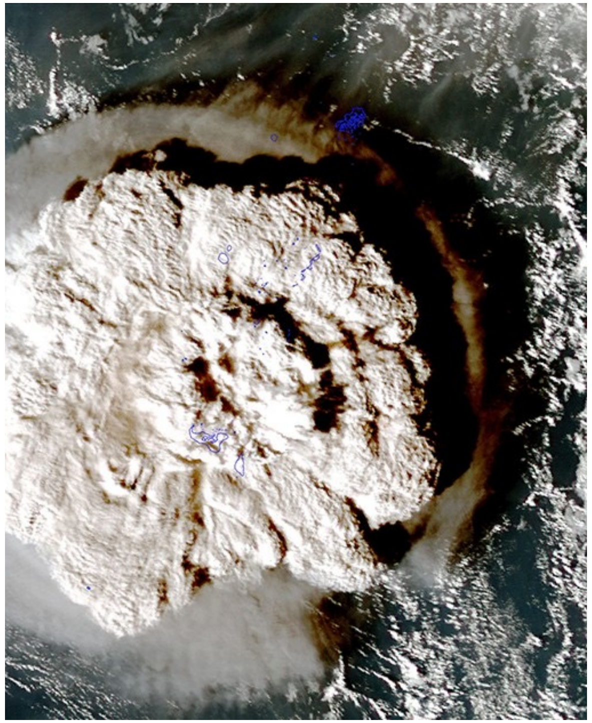
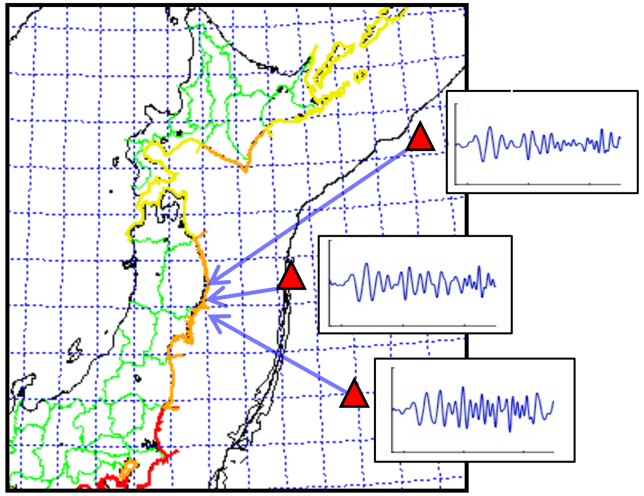
Introduction – Tsunami from 2022 Tonga Volcanic Eruption

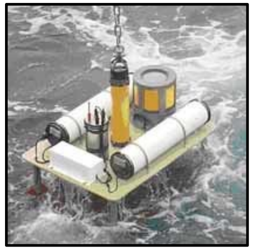
- Hunga Tonga-Hunga Ha'apai volcano
- Large eruption: 04:14:45 (UTC), January 15, 2022.
- The tsunami event had a complex generating mechanism, making it difficult to use traditional tsunami early warning method based on source inversion.



(Witze, 2022 *Nature*; SCMP, 2022)

Tsunami Data Assimilation Approach





$$x_n = (h(n\Delta t, x, y), M(n\Delta t, x, y), N(n\Delta t, x, y))^T$$

Height X-Velocity Y-Velocity

$$x_n^f = F x_{n-1}^a \qquad x_n^a = x_n^f + W(y_n - H x_n^f)$$

I. Forecasting Step II. Assimilating Step

Offshore Tsunami Observation

↓

Tsunami Forecasting

Do not need source information!

x_n^f: Forward Tsunami Wavefield

y_n: Observation

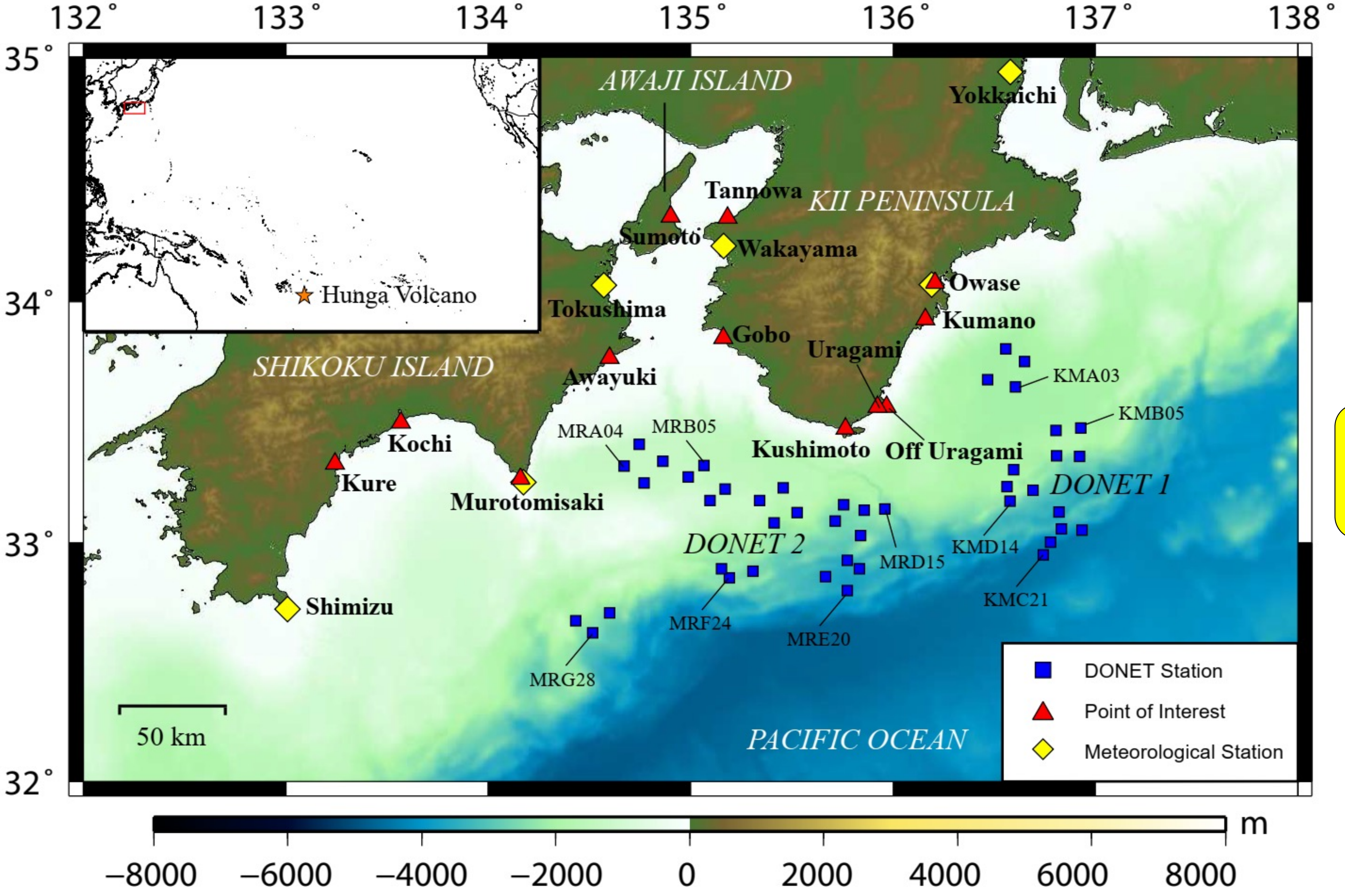
x_n^a: Assimilated Tsunami Wavefield

W: Weight Matrix

H: Sparse Linear Observation Matrix

F: Propagation Matrix

(Maeda et al., 2015 *GRL*; Gusman et al., 2016 *GRL*)



Observation at **44** DONET stations

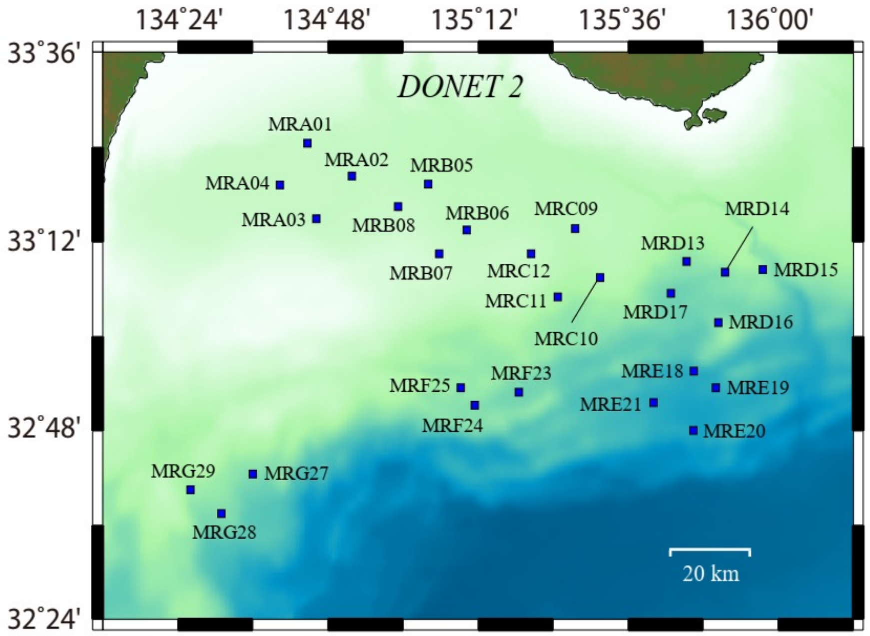
Data Assimilation

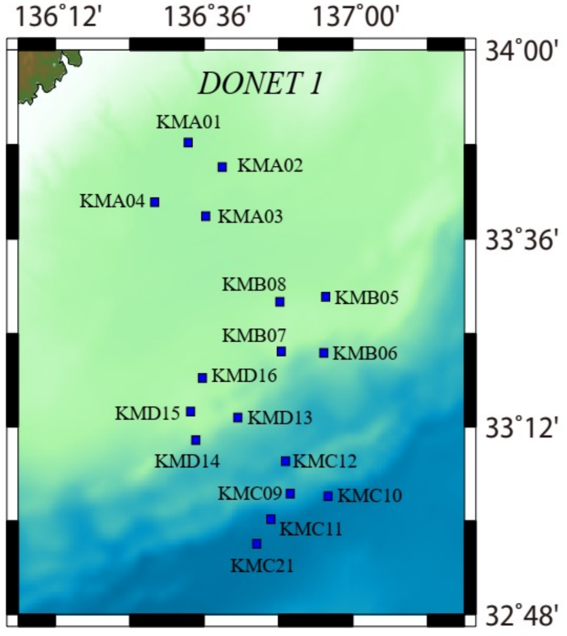
Tsunami forecasting at **12** points of interest

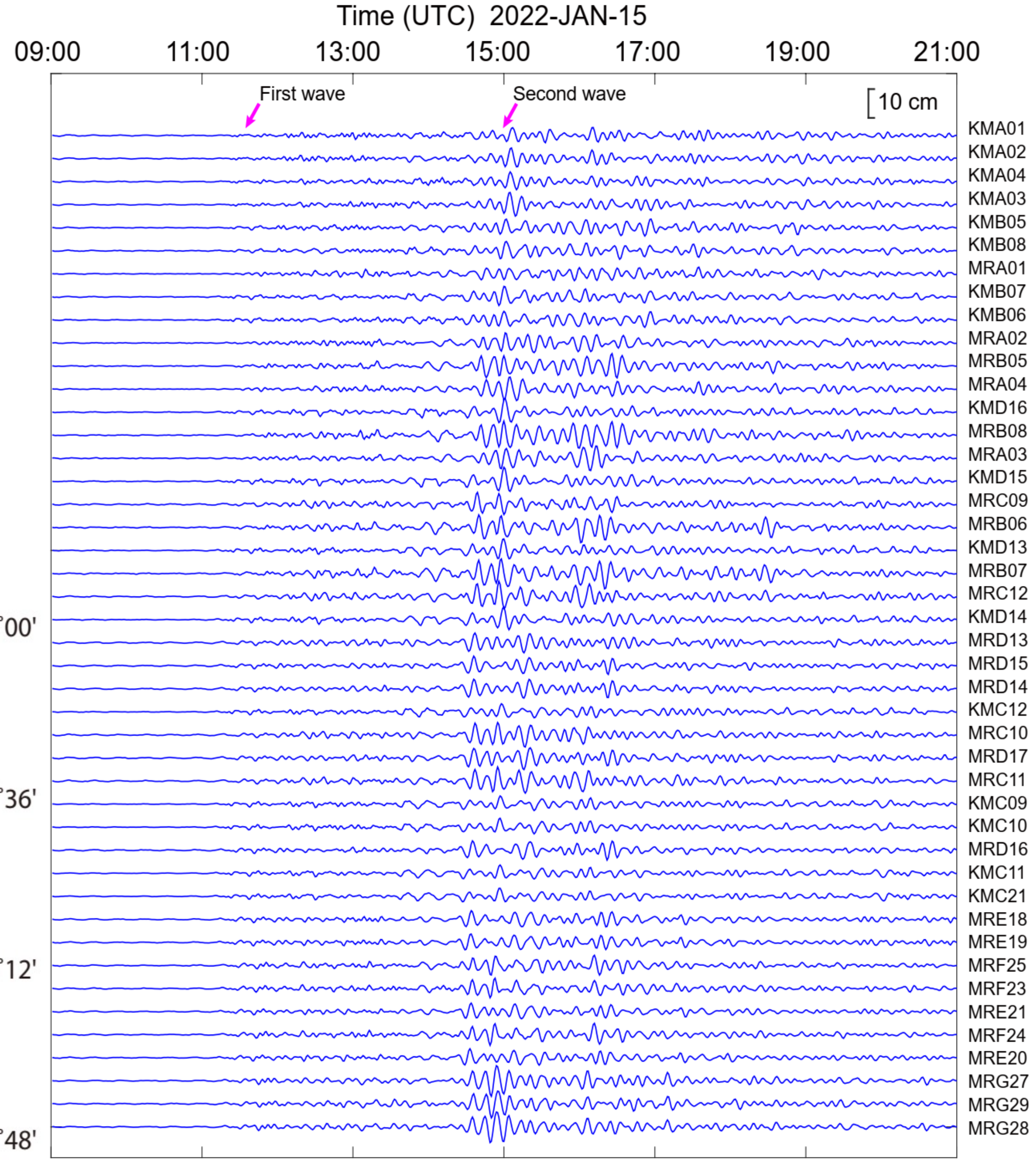
DONET data available at doi:10.17598/nied.0008

DONET Data Processing

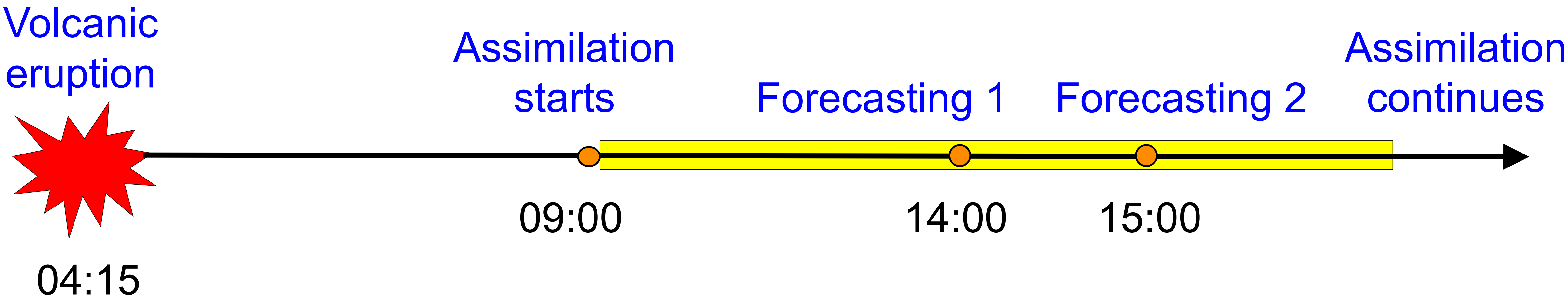
1. Basic quality control
2. Convert pressure to water height
3. Linear interpolation
4. Band-pass filtering (200–1200 s)





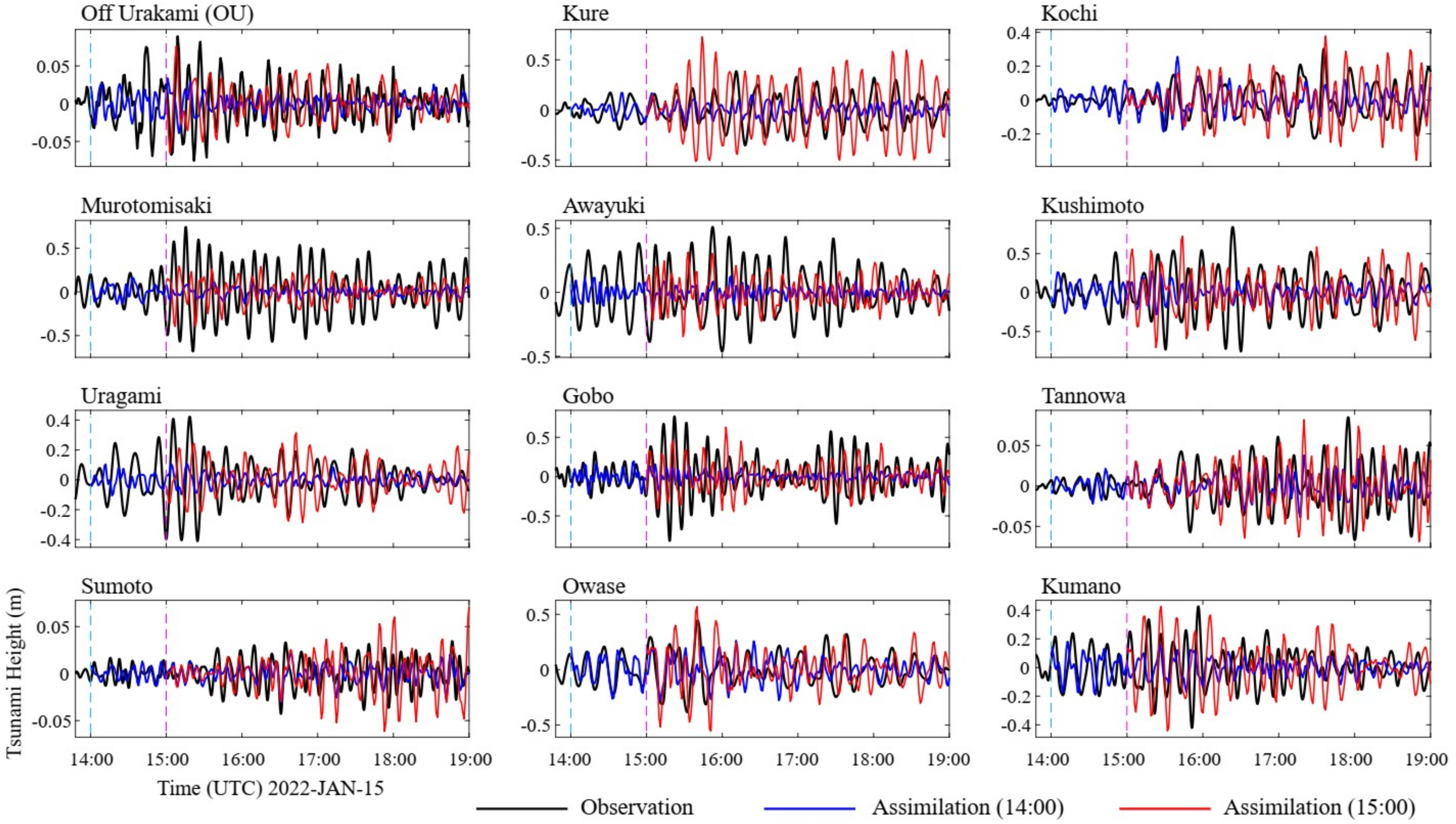


Assimilation Setting



Computational parameters

- Time step: 1 s
- Grid size: 0.3 arc min (~ 500 m)
- Grid range: 132–138° E and 32–35° N
- Propagation model: Linear dispersive model



Off Urakami (OU)
Kure
Kochi
Murotomisaki
Awayuki
Kushimoto
Uragami
Gobo
Tannowa
Sumoto
Owase
Kumano
Tsunami Height (m)
Time (UTC) 2022-JAN-15
14:00
15:00
16:00
17:00
18:00
19:00
Observation
Assimilation (14:00)
Assimilation (15:00)

Accuracy Analysis

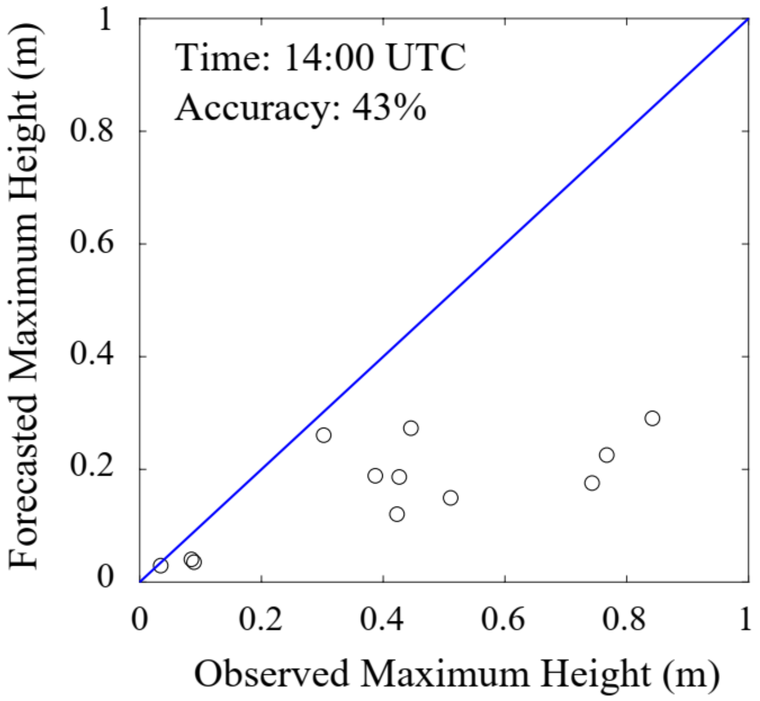
$$\log(K) = \frac{1}{N}\sum_{j=1}^{N}\log\left(\frac{A_j^{obs}}{A_j^{pred}}\right)$$

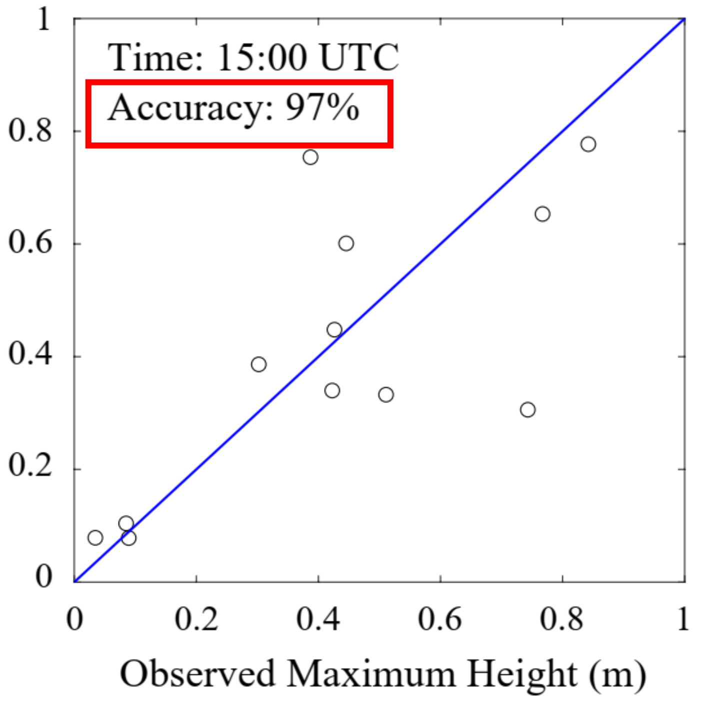
Accuracy = 1/K * 100% (K>=1)

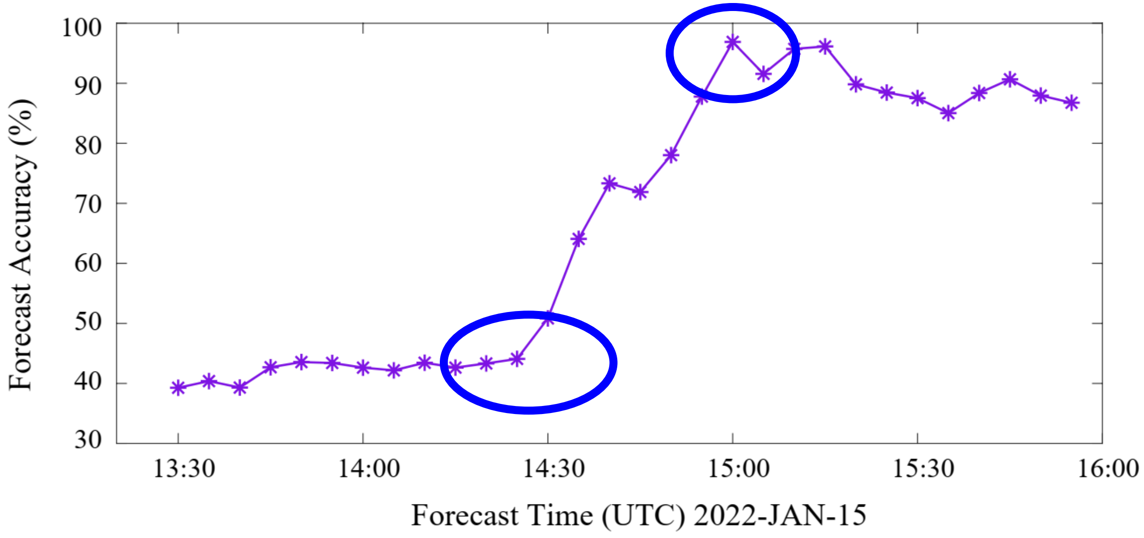
or K*100% (K<1)

A_j^{obs}: Observed maximum amplitude at *j*-th station

A_j^{pred}: Predicted maximum amplitude at *j*-th station





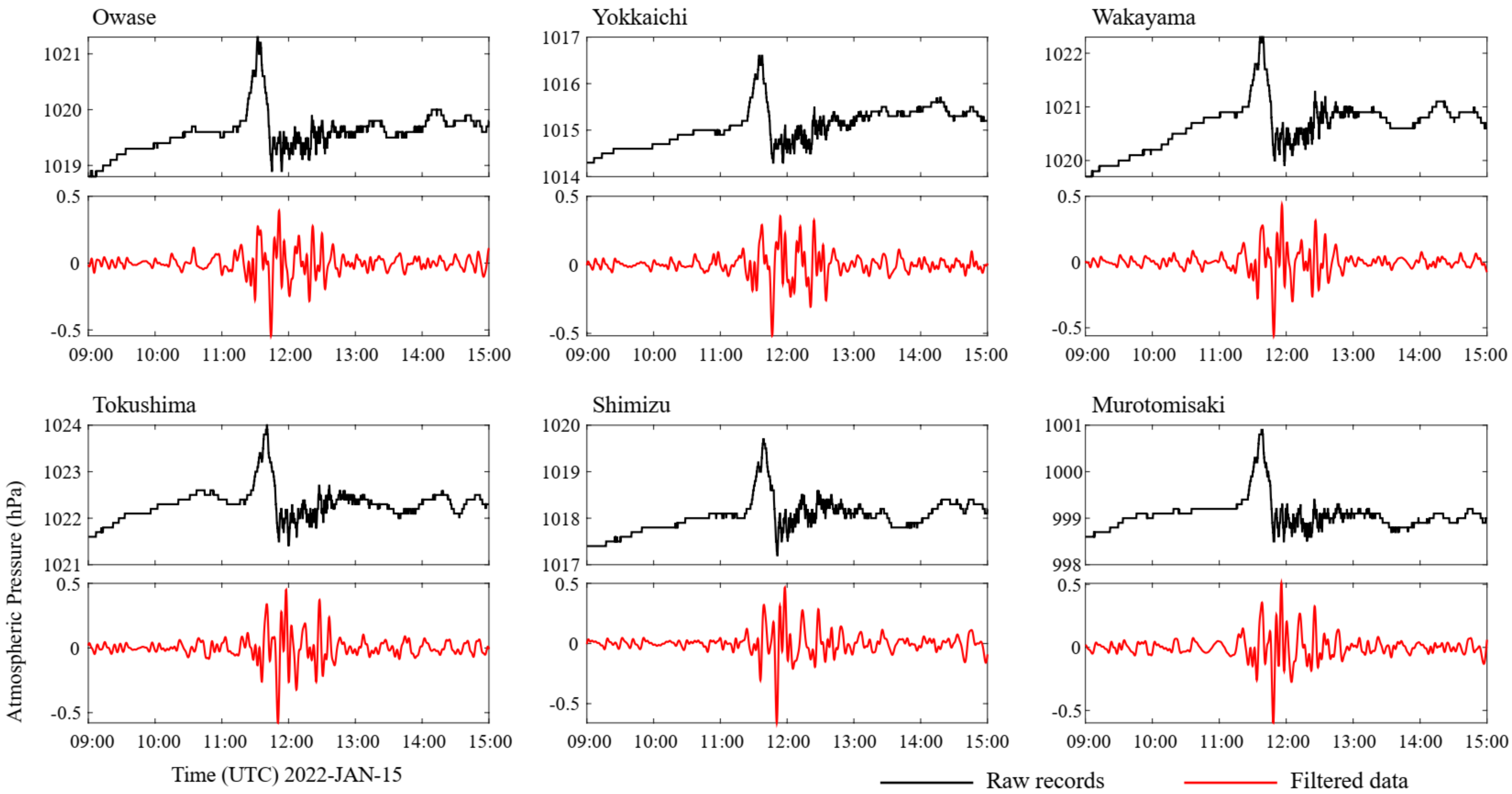


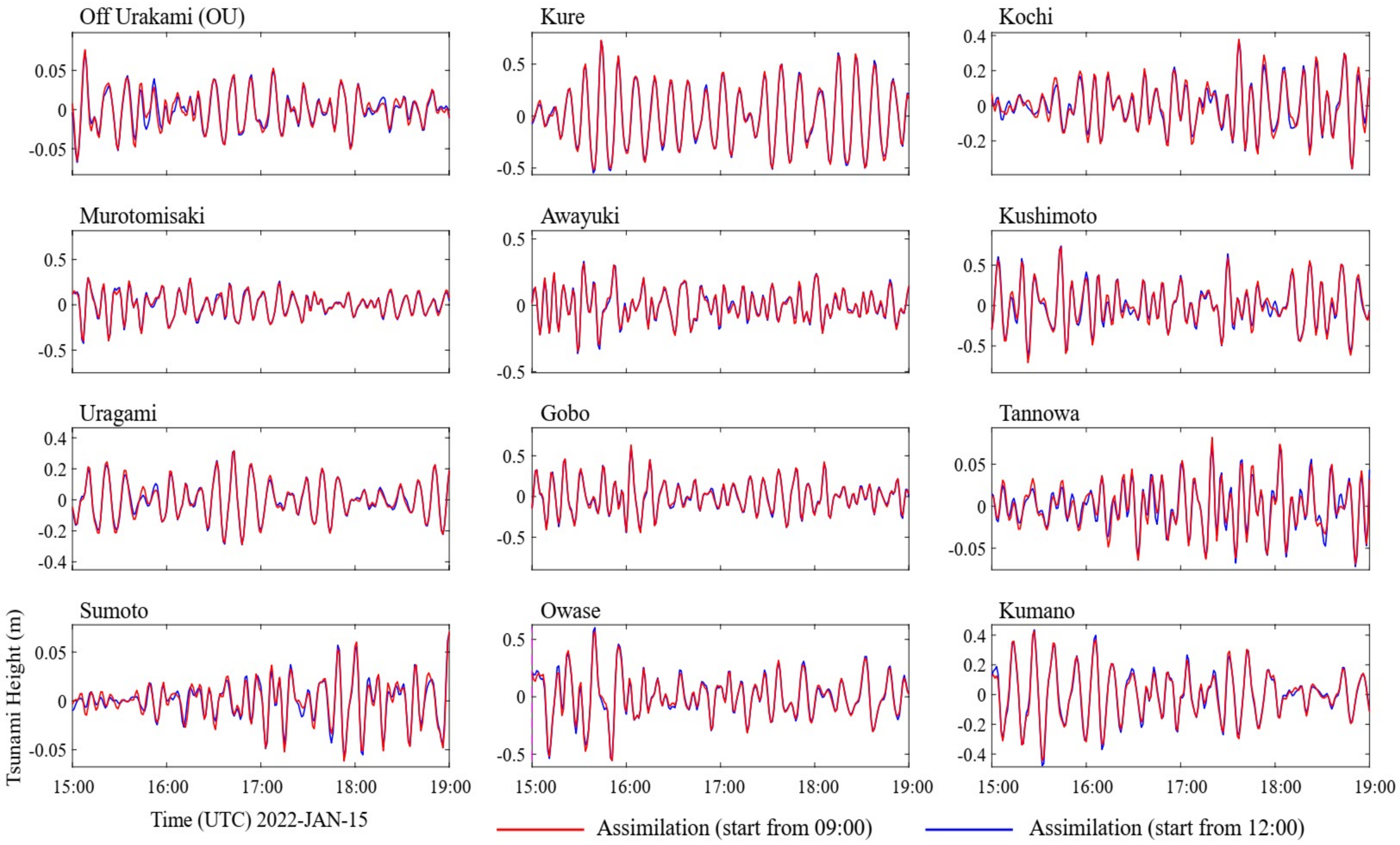
Low accuracy: Before 14:25

Accuracy increase: 14:30 – 14:55

High accuracy: After 15:00

Effects of Air-Pressure Change on Data Assimilation





Almost same results of different starting time (09:00 & 12:00).

Very limited effects from initial air-pressure change.

Reason: Data assimilation is a self-corrective process (Wang & Satake, 2021 *SRL*)

Conclusion

- First time to conduct data assimilation for a non-seismic tsunami
- Predicting coastal tsunami waveforms using DONET observations
- A forecast accuracy of 97% at 15:00 (UTC)
- Little effects on data assimilation from air-pressure variations

Next step:

Use radar observations (tsunami velocity) for data assimilation

Thank you for your attention!