The impact-based forecasting with a large-ensemble DA

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Why Impact-based forecasting?

Current: Forecast only weather. We verify the forecast with rainfall amount, temperature, wind, etc.
Future: Beyond traditional weather forecasts, we predict hazard itself for mitigating the people's damage. **The impact to people** is the target of the operation.

Impact-based forecasting should be probabilistic because the severe weather is chaotic.

WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services（2015、2021）

JMA has operated the impact-based forecasts and warnings **using nowcast technique since 2008.**

Increasing extreme natural hazards year by year!

Flood

Germany (July 2021)

Vatican news

Japan (4 July 2020)

MLIT Kyushu local office

New York (02 Sep 2021)

AFP

Japan (Aug 2021)

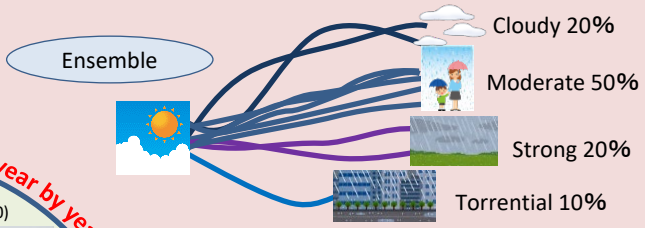
Nishi-nippon

Inundation

Landslide

Why Large-ensemble?

Probabilistic forecast with every 10% needs **more than 500 members** to neglect the sampling errors.

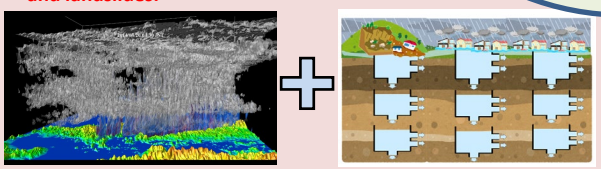


Deterministic forecast is invalid for long range due to chastity especially for severe weather. Instead, probabilistic forecast provide useful information for long time.

1000-ensemble on Fugaku

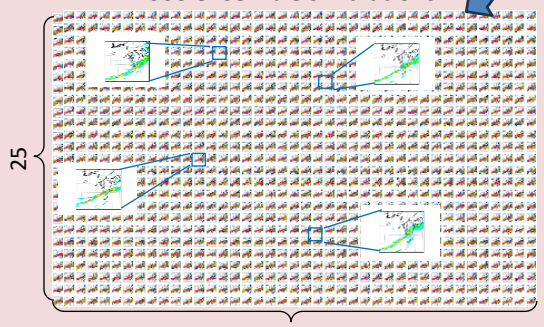
How realize?

Predict rain as well as inundation, floods, and landslides.



Large ensemble of meteorological model coupled with hydrological model **predicting probability** of hydrological disaster occurrence.

1000 ensemble simulations

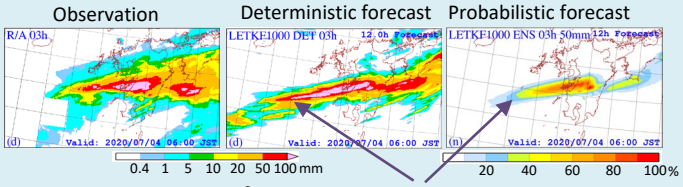


Case 1: Linear convective system (3-4 July 2020)

(Courtesy of Oizumi and Duc)

- Accurate deterministic forecasts for more than 100 mm and longer than 6-h.
- High probability of 80% to 50 mm/3-h was predicted.

Observation | Deterministic forecast | Probabilistic forecast



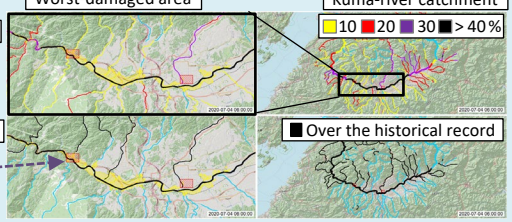
Overestimate in deterministic forecast, whereas low probability in probabilistic forecast

Meteorological ensemble simulation
Coupled!
Hydrological ensemble simulation

Just around the flooding (06 LST)

Worst-damaged area | Kuma-river catchment

Probabilistic forecast

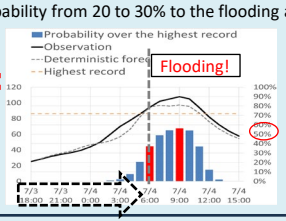


Observation

Over the historical record

* Predict tens of rivers in the Kuma-river catchment area with 1000-ensemble.
* The observation related to the Kuma river reaches mostly the highest record at 05 LST.
* Probability from 20 to 30% to the flooding appears in the worst-damaged area.

Sankei



Deterministic forecast exceeds the record

At the flooding time, the probability is 40%.

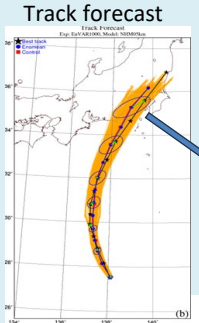
60% of probability for the flooding is predicted eventually.

A half day ahead!

Case 2: Typhoon Hagibis (2019) (5-14 Oct. 2019)

(Courtesy of Wu and Duc)

Track forecast



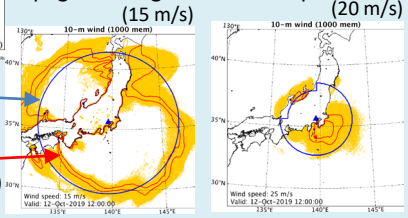
- Death: 91 people
- Total destruction: 3,273 houses
- Inundation: 29,556 houses

(Fire and Disaster Management Agency)

Ellipse-shape (Flow-dependent) probabilistic location forecast (>70%)

Spaghetti diagram of Wind speed

(15 m/s) (20 m/s)

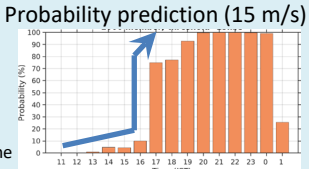


Best track (statistical)

90% of probability (dynamical, ensemble)

- Radiuses of the winds at 15 m/s are the same between the best track and 1000-ensemble.
- While those at 20 m/s in the best track is much larger than that in the large ensemble (Flow-dependent).

Probability prediction (15 m/s)



Rinkai station

Very quick change in time → Difficult to predict

1. Le Duc, T. Kawabata, K. Saito, T. Oizumi (2021), Forecasts of the July 2020 Kyushu Heavy Rain Using a 1000-Member Ensemble Kalman Filter, *SOLA*, **17**, 41-47.
2. Oizumi T.,T. Kawabata, L. Duc, K. Kobayashi, K. Saito, T. Ota (2023), Impact of a Number of Ensemble Members in Numerical Weather Prediction Models on Flood Prediction, AOGS 20th Annual Meeting.
3. Wu, P.-Y., T. Kawabata, and L. Duc, (2023), High-resolution 1000-member Ensemble Simulations of Typhoon Hagibis (2019). Japan Geoscience Union Meeting 2023, Chiba, Japan, 21-26 May 2023.