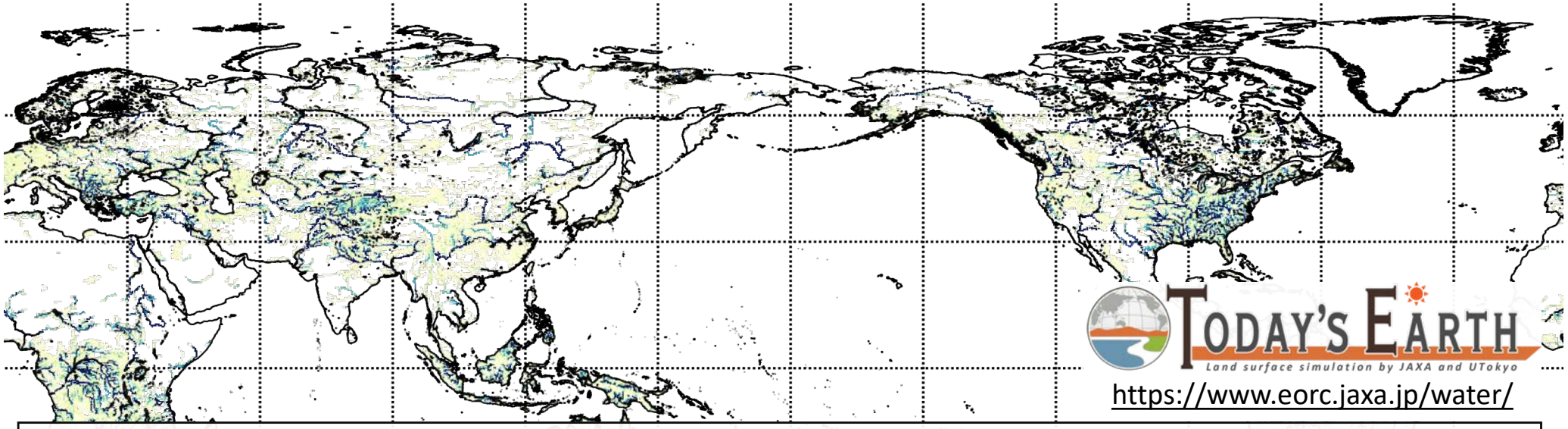


TODAY'S EARTH
Land surface simulation by JAXA and UTokyo

https://www.eorc.jaxa.jp/water/

Predictability of the floods caused by Typhoon Hagibis in 2019 using *Today's Earth*

Kei Yoshimura, Wenchao Ma, Yuta Ishitsuka, Akira Takeshima, Kenshi Hibino, Dai Yamazaki, Kosuke Yamamoto, Misako Kachi, Riko Oki, Taikan Oki

Institute of Industrial Science, The University of Tokyo
Earth Observation Research Center, JAXA

2020 Nov 11, Virtual GFP Conference Week 2

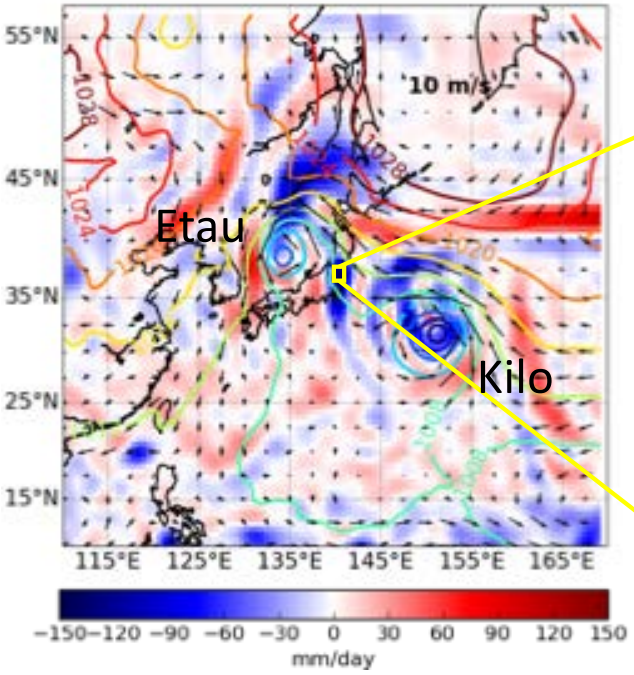
JAXA EORC 東京大学 生産技術研究所 Institute of Industrial Science, The University of Tokyo

Kanto/Tohoku Heavy Rain (Sep 2015)

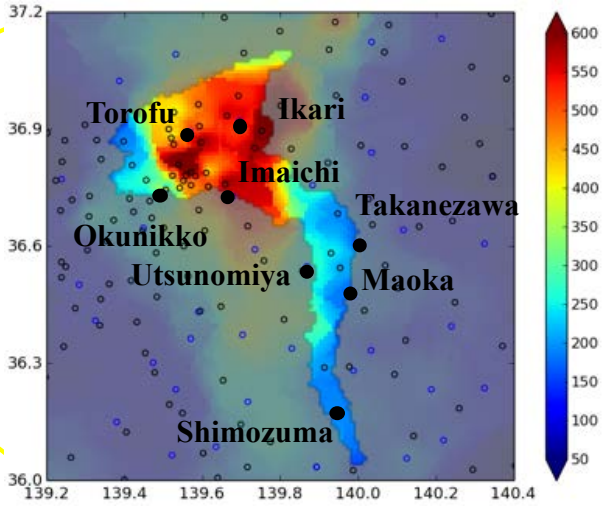
Heavy precipitation for 8 to 10 September 2015 over Tochigi and Ibaraki prefectures was caused by clustered linear rain bands influenced by Typhoon Etau (No 18) and Kilo (No 17).

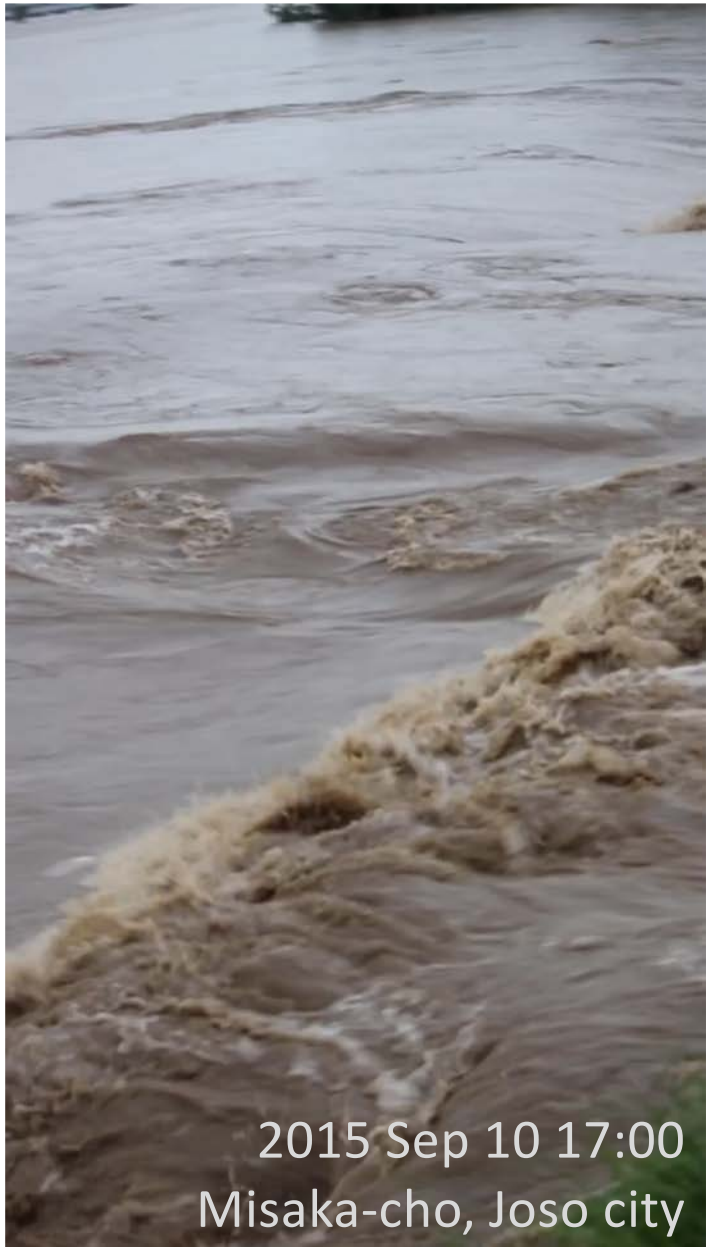
Over 40 km^2 in Joso-city including 11,000 houses were inundated, evacuation orders were issued for more than 10,000 citizens, and over 2,000 people were rescued by helicopters and boats.

Moisture conv. and wind speed
2015/9/10 3:00JST



Accumulated Rainfall for Sep 8-10 [mm]

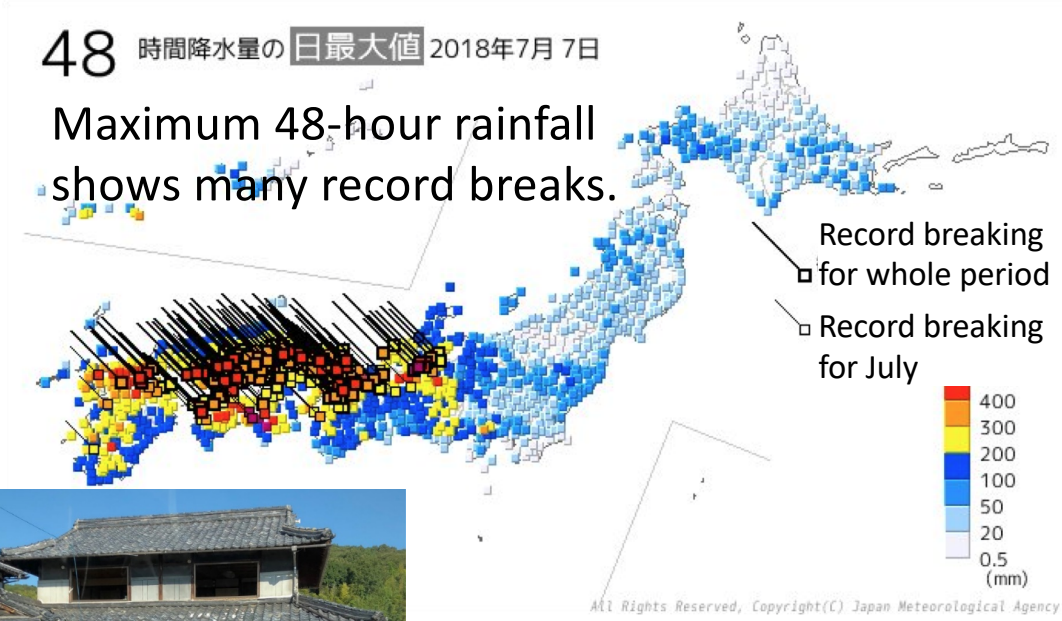




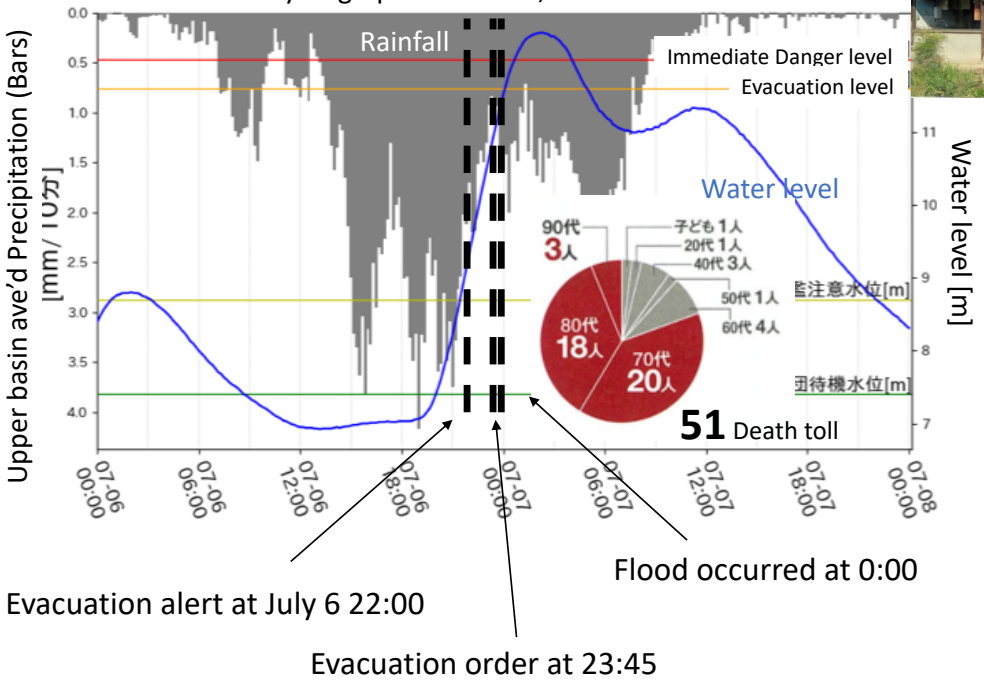
West Japan Heavy Rain (July 2018)

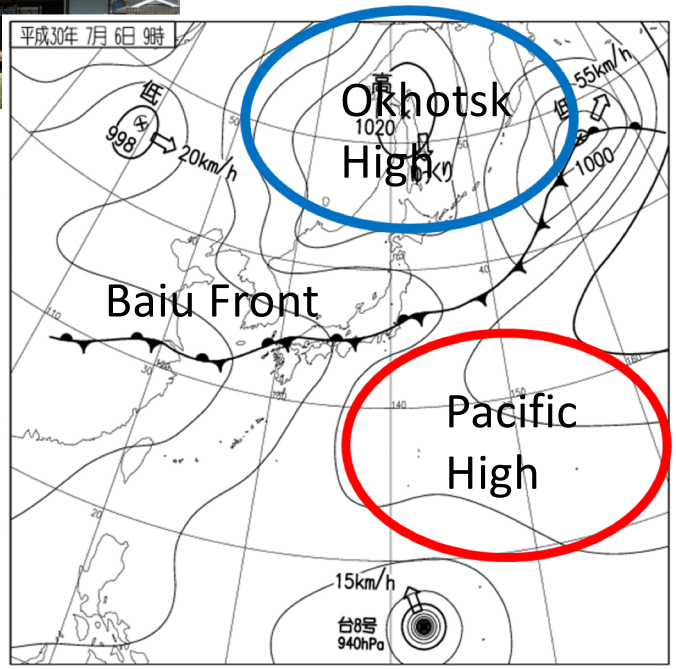
Because of long time halt of Baiu Front, which was influenced by powerful Pacific High and the Okhotsk High, it brought large amounts of precipitation across western Japan from July 5-8, 2018.

In terms of 24-hour accumulated rainfall, some watersheds experienced rainfall on a multi-100-year scale, resulting in flood inundation and mudslides in many areas of western Japan. It **killed 263 people** in total.



Hydrograph at Sakatsu, Takahashi River



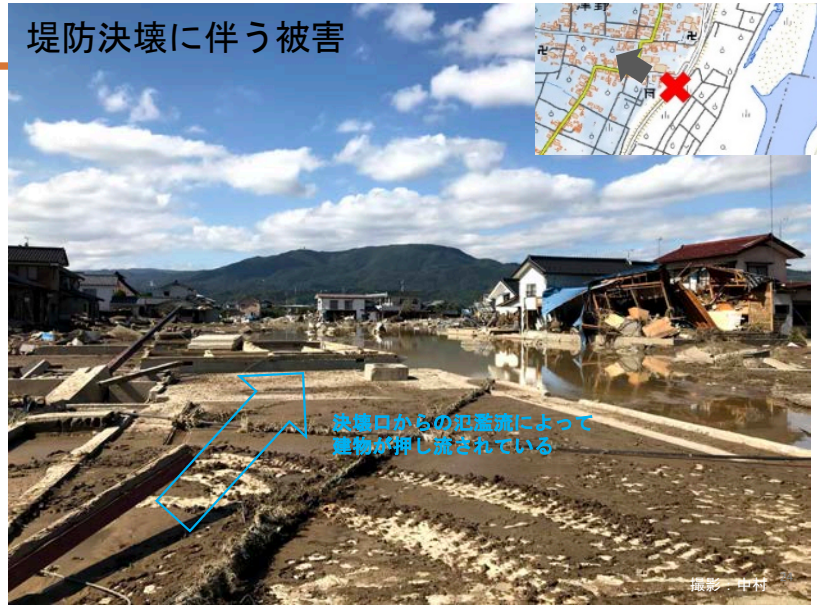


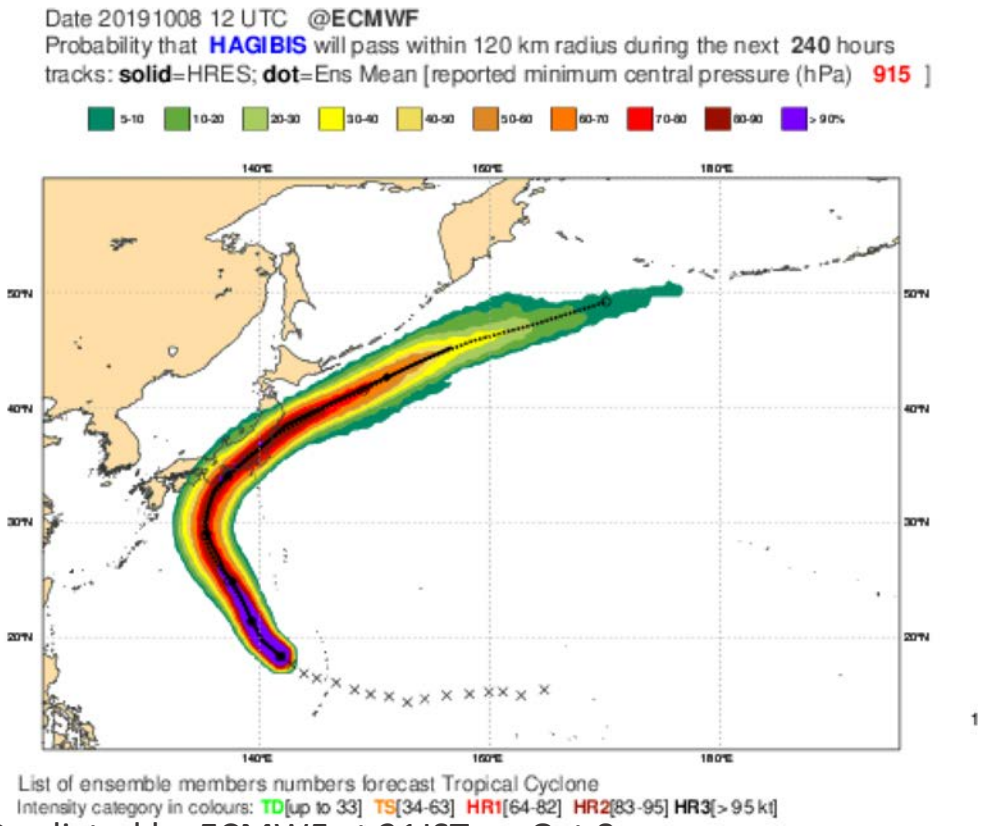
Sea level Pressure @2018/7/6 9JST by JMA

TODAY'S EARTH
Land surface simulation by JAXA and UTokyo

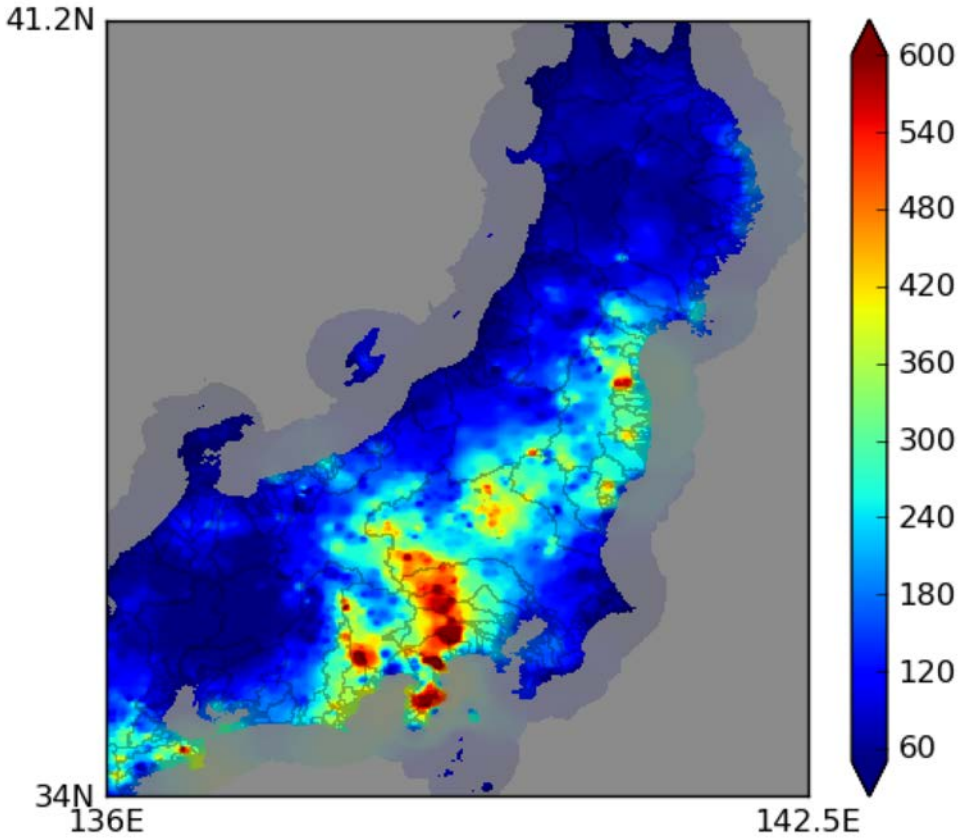
Typhoon Hagibis (Oct 2019)

Typhoon Hagibis (in Japan, No 19 in 2019) was emerged on Oct 6 and became category 5 on Oct 7. On 12 Oct 19:00JST, it made landfall on Izu peninsula, and it moved Kanto region to southern Tohoku region until early morning of 13 Oct. Hagibis caused extensive **damages at more than 70 river systems and killed more than 100 people** in the eastern part of Japan.





Predicted by ECMWF at 21JST on Oct 8.
https://www.ecmwf.int/en/forecasts/charts/tcyclone/tc_strike_probability?facets=undefined&time=2019100812,0,2019100812&unique_id=25W_HAGIBIS_2019



24-hour accumulated rainfall on Oct 12.

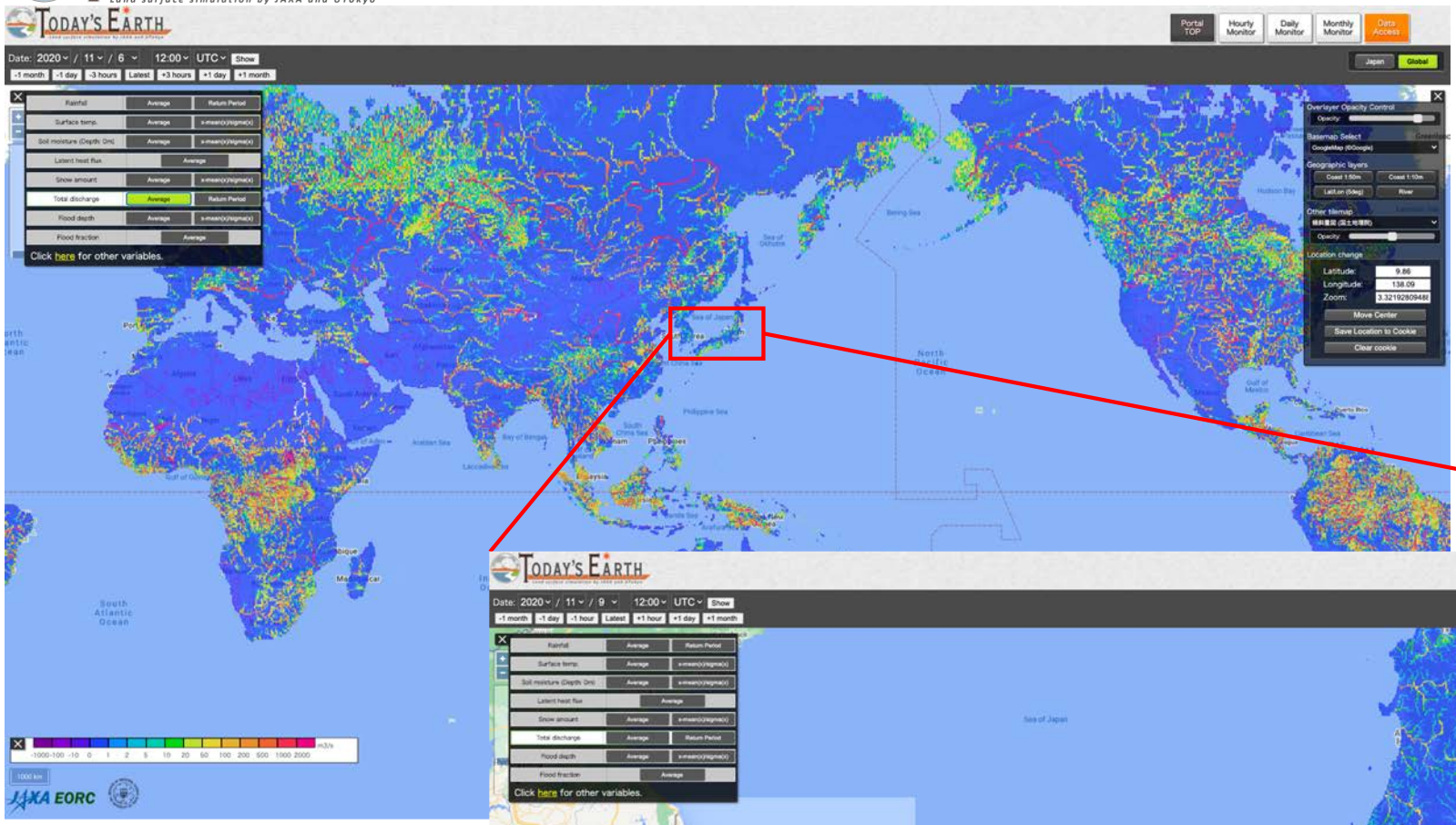
Today's Earth system

Yoshimura et al., 2008
Ma et al., in prep., etc.

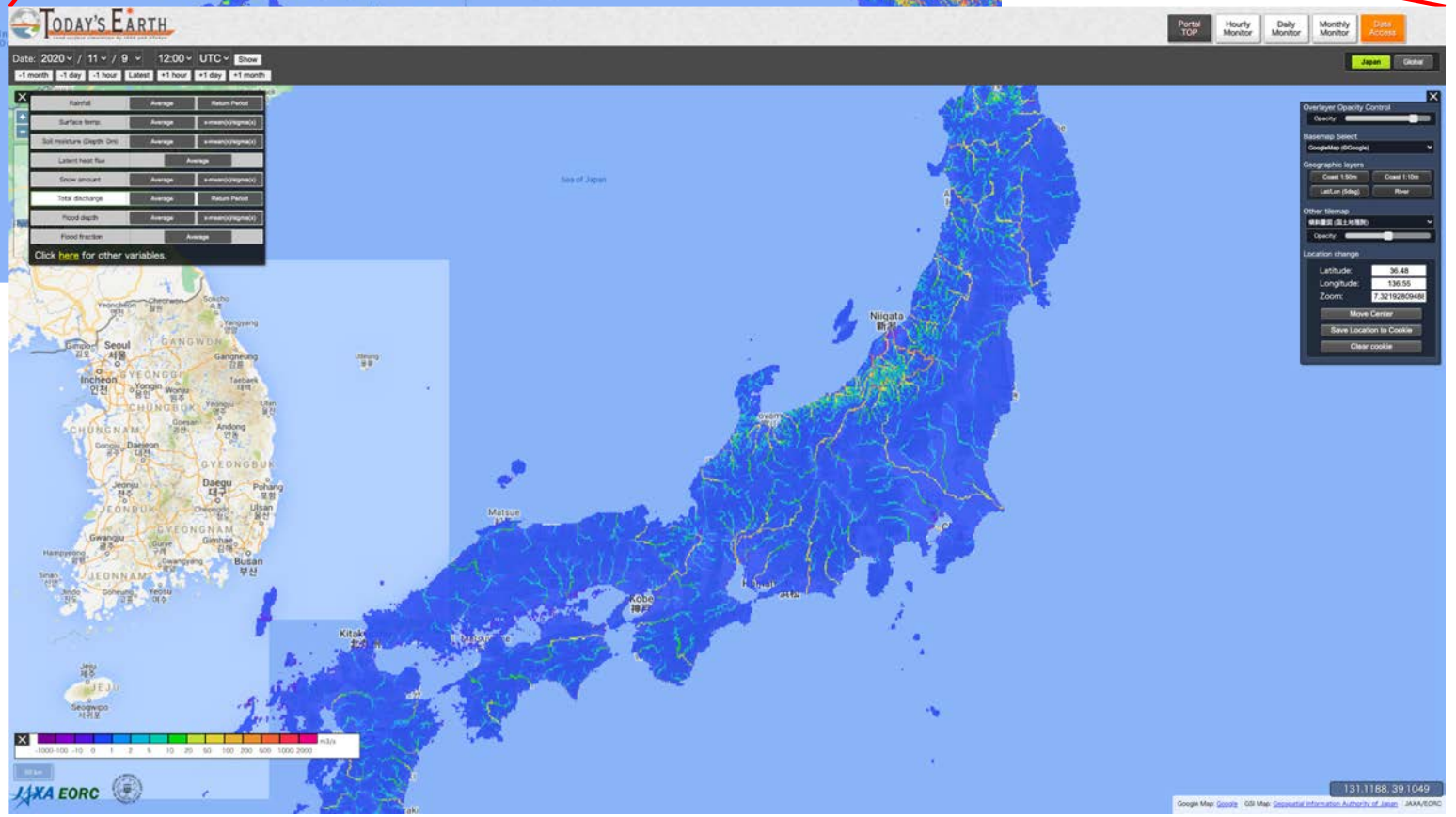
Go to www.eorc.jaxa.jp/water
Or search "today's earth"

- *Near real time* land surface simulation system for global (1/4° res.) and Japan (1/60° res.).
- Forced by multiple satellite based atmospheric variables including GSMaP precip, MODIS radiation.
- Data downloadable from 1958.
- Forecast versions are being tested.

TODAY'S EARTH
Land surface simulation by JAXA and UTokyo

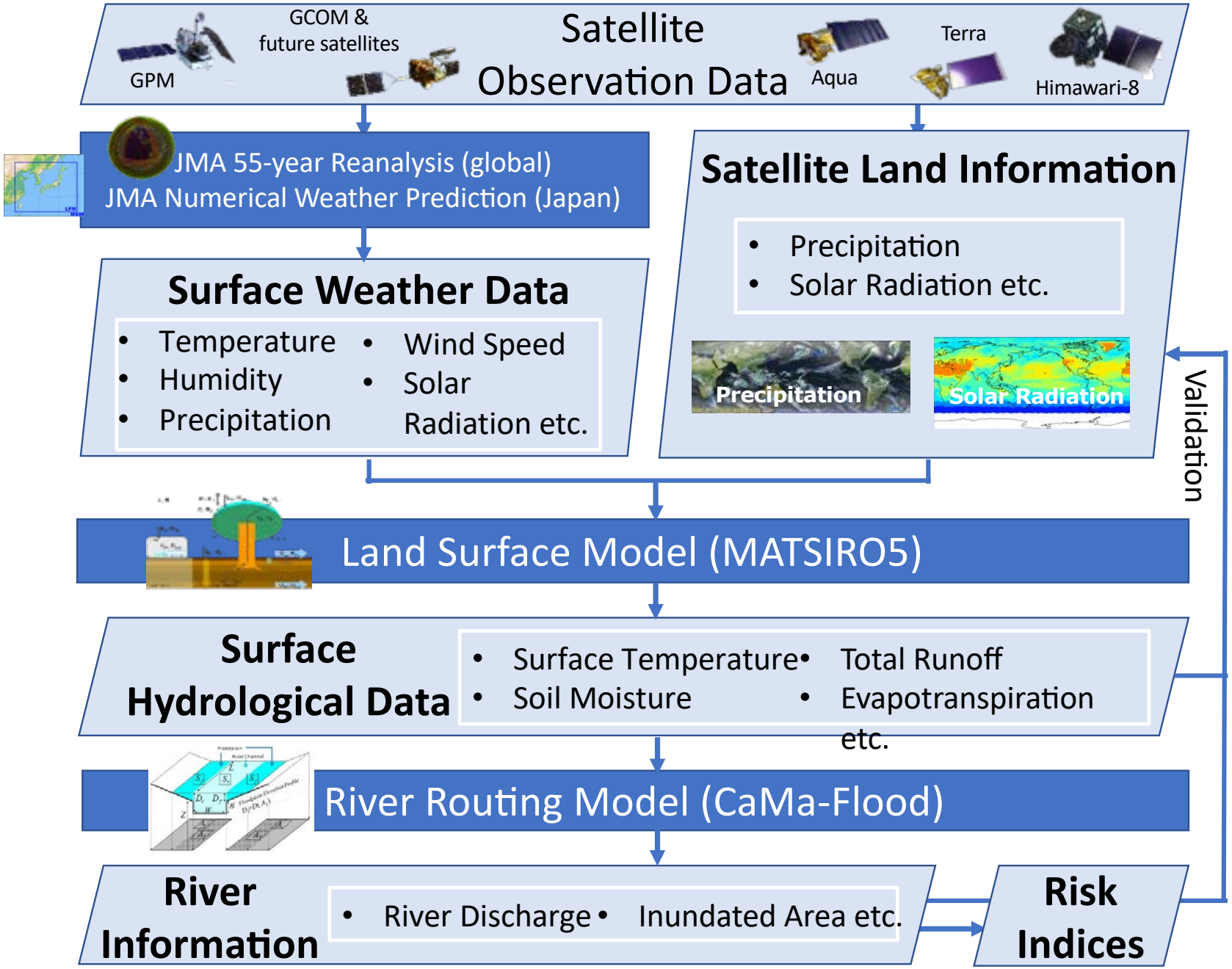


TE-Global
(1/4°)

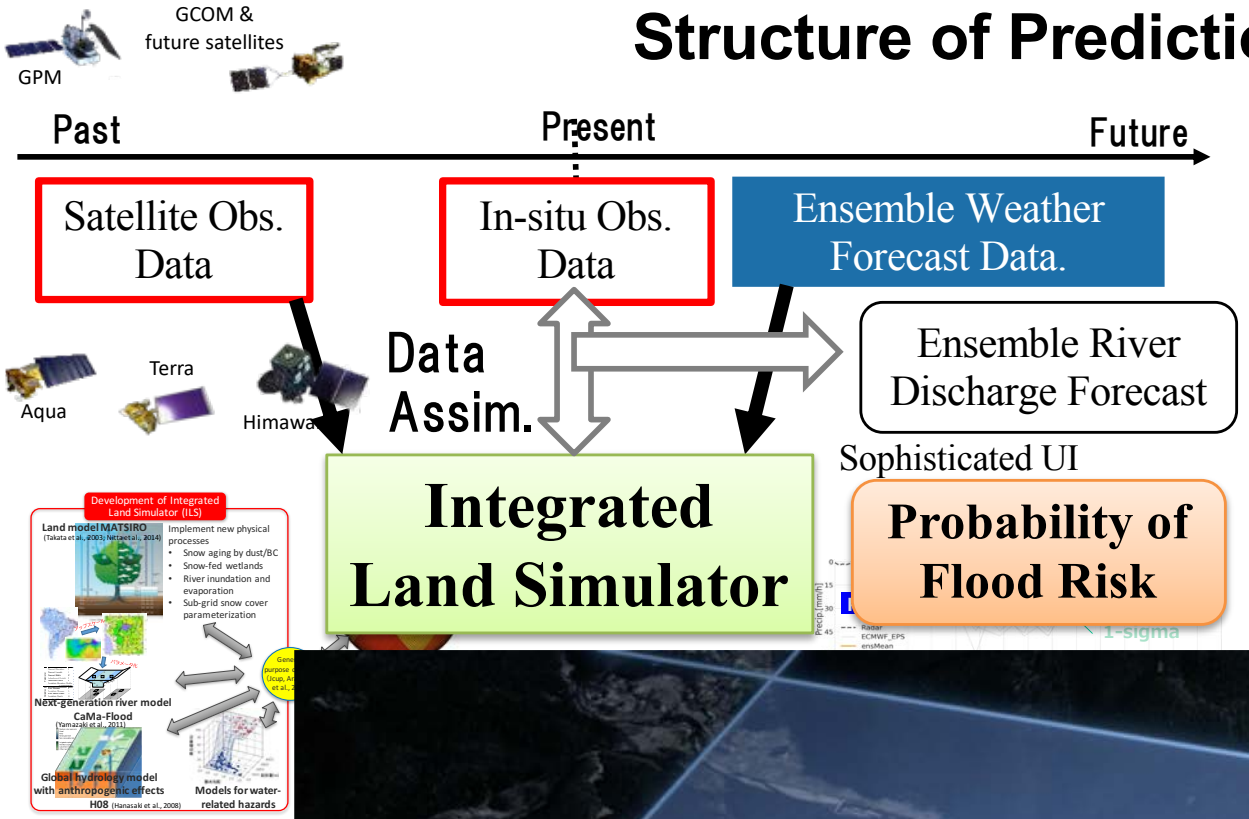


TE-Japan
(1/60°)

TE Data flow


GPM
GCOM &
future satellites
Satellite
Observation Data
Aqua
Terra
Himawari-8
JMA 55-year Reanalysis (global)
JMA Numerical Weather Prediction (Japan)
Satellite Land Information
• Precipitation
• Solar Radiation etc.
Precipitation
Solar Radiation
Surface Weather Data
• Temperature
• Humidity
• Precipitation
• Wind Speed
• Solar Radiation etc.
Validation
Land Surface Model (MATSIRO5)
Surface Hydrological Data
• Surface Temperature
• Soil Moisture
• Total Runoff
• Evapotranspiration
etc.
River Routing Model (CaMa-Flood)
River Information
• River Discharge
• Inundated Area etc.
Risk Indices

Structure of Prediction using Today's Earth



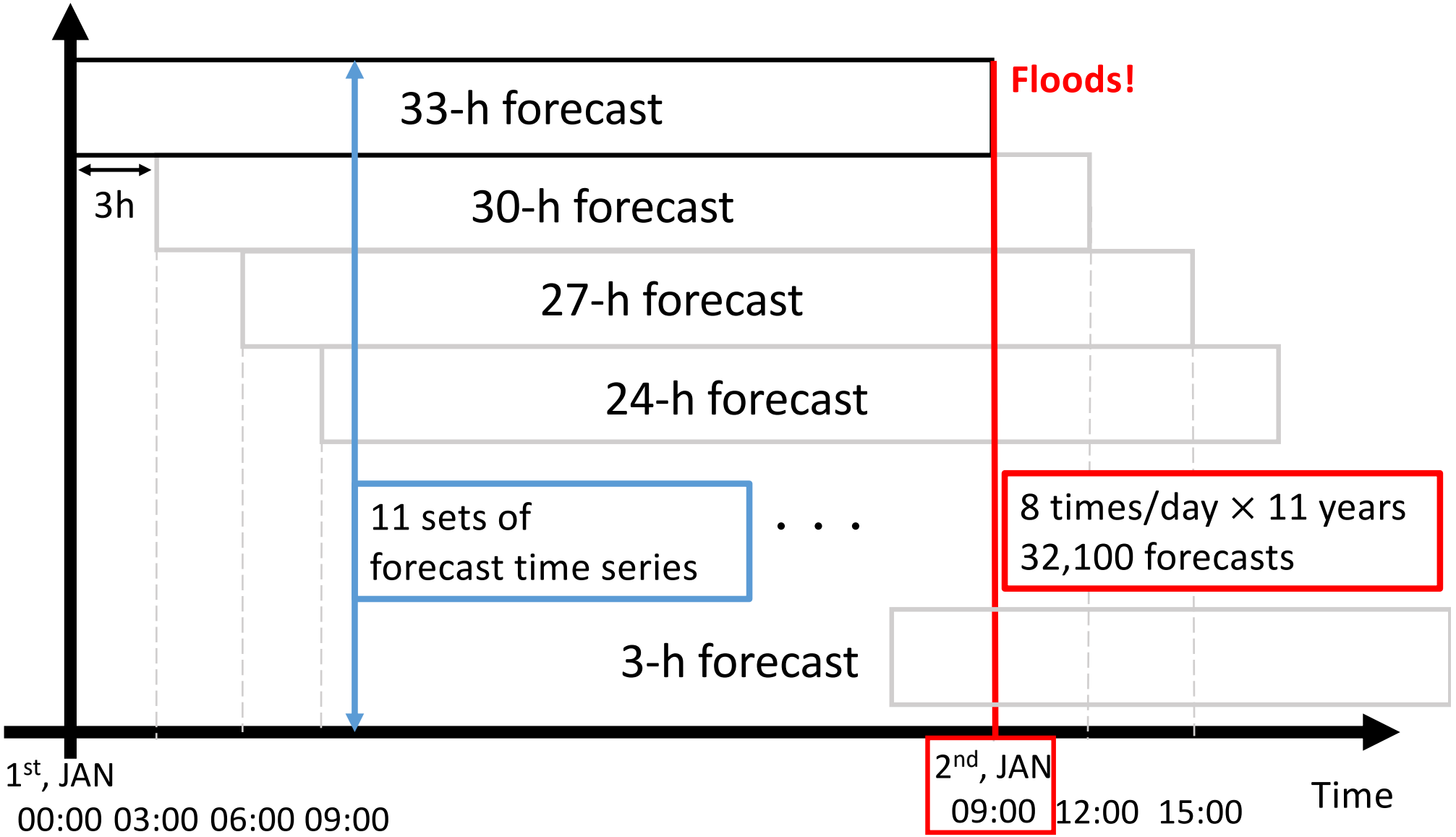
We developed a reliable *flood prediction system over all Japan*, aiming to provide those information well before hazard (1-2 days ahead) in horizontally 1km resolution.

©NHK

Validation for 11-year hindcasted runs

Forecasts: 33-h lead time, Issued every 3hours

Assessing the accuracy in each lead time from short to long



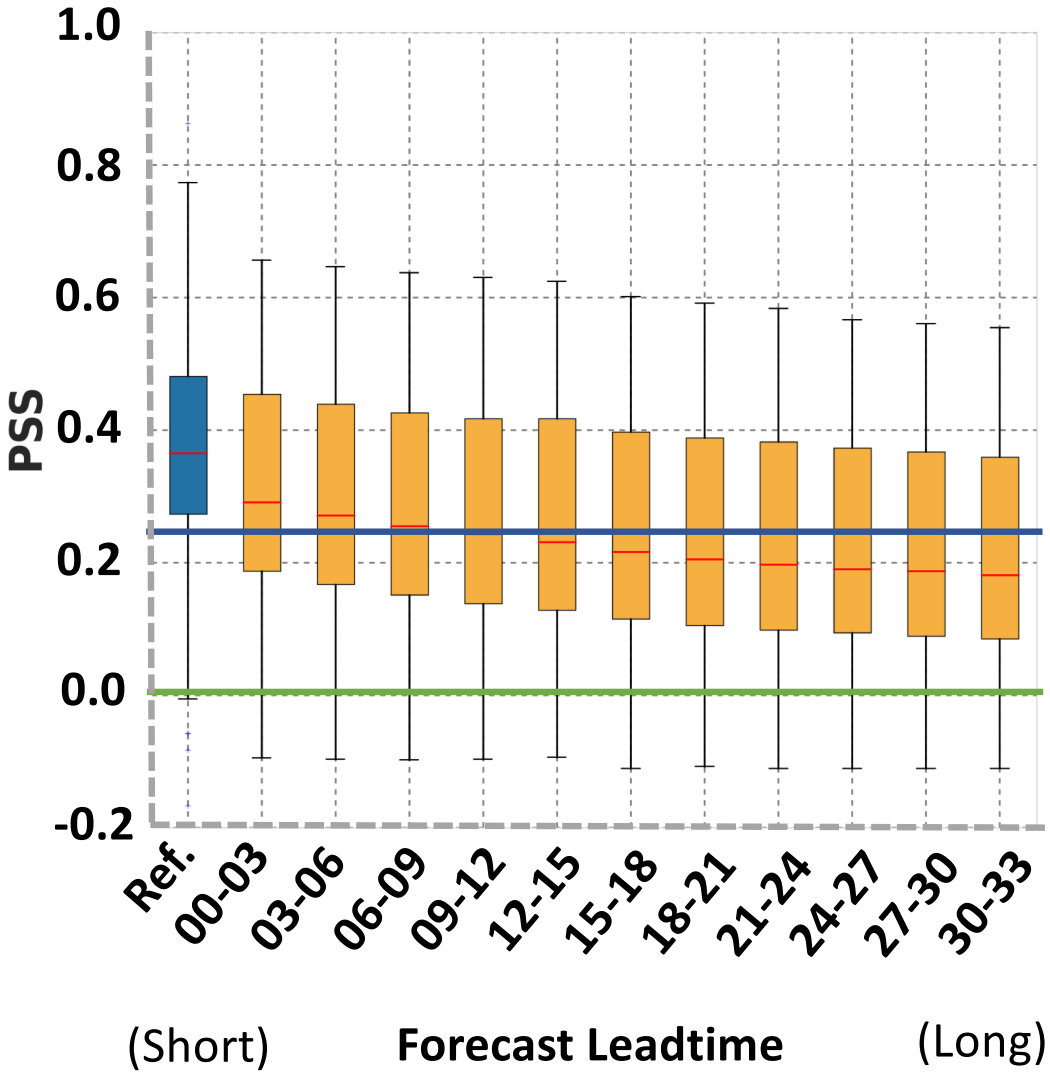
Forecast ability for high flows

[2007 - 2017]

N = 849 stations

$$PSS = \frac{Hit}{Hit+Miss} - \frac{FA}{FA+CN}$$

Hit Rate (1−Miss Rate) — **False Alarm Rate**



Reference Values

[e.g., Addor et al., 2011; Alfieri et al., 2013]

- PSS ≥ 0.00 : **Have a Predictability**

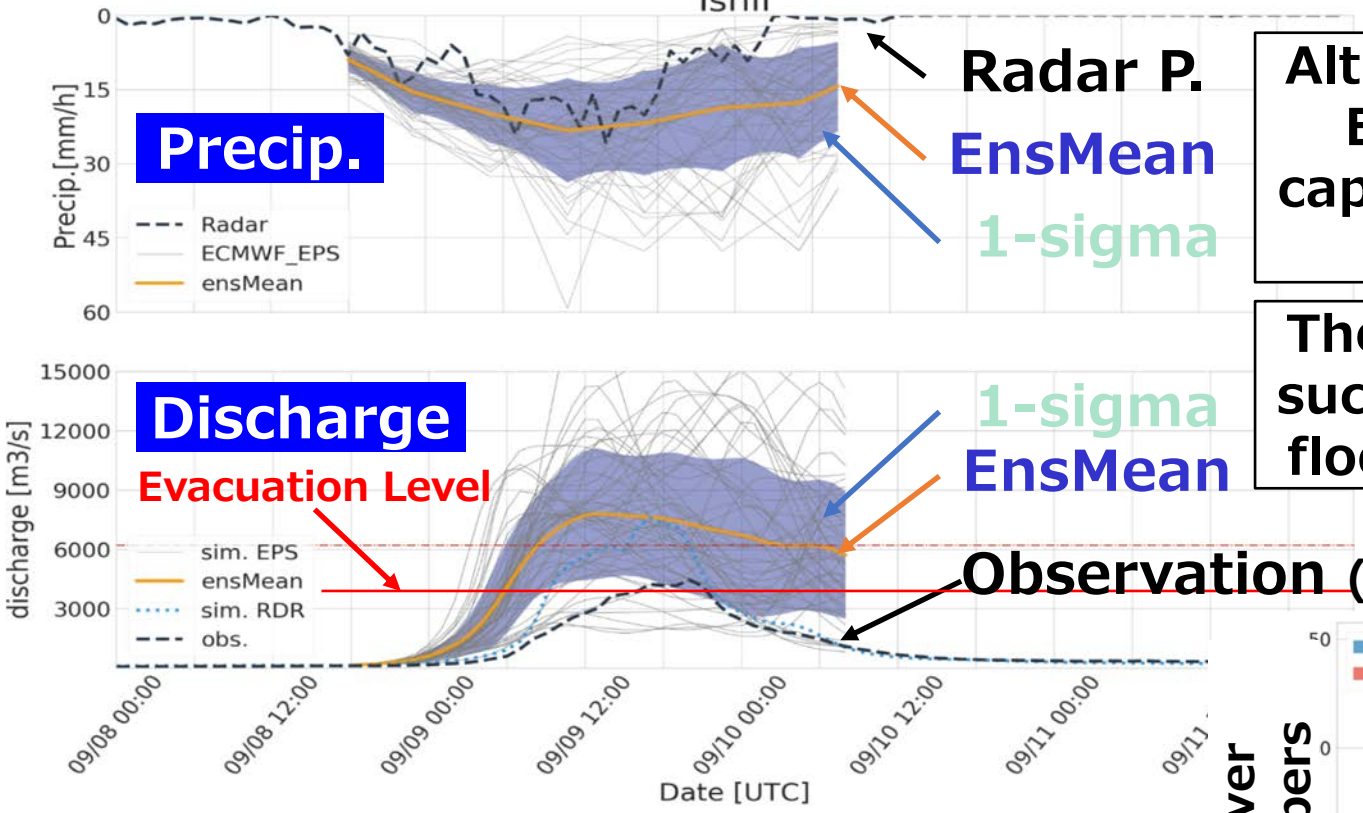
Forecasts 33-h before:
Having a positive PSS at more than ***90%*** out of 849 stations.

Forecasts 12-h before:
Having PSS > 0.25 at more than ***50%*** out of 849 stations.

Ishitsuka et al., in prep.

2015's case

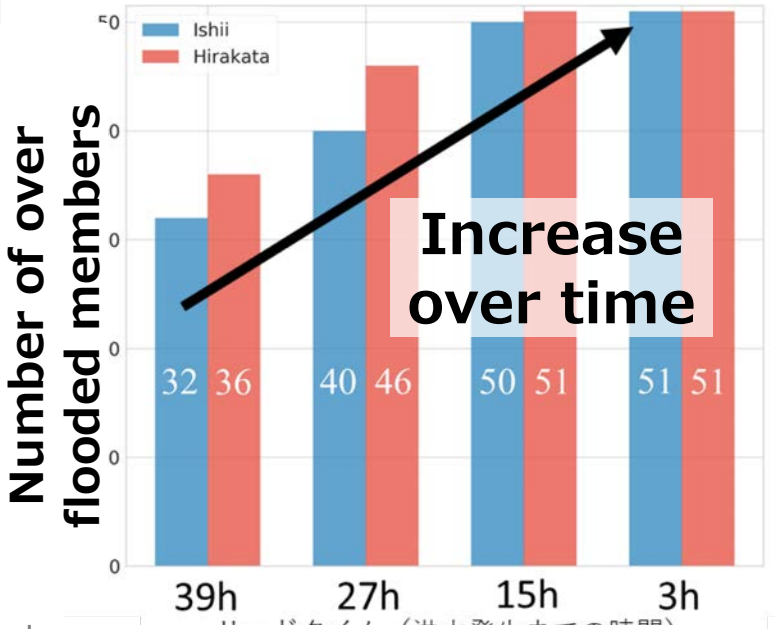
Ensemble forecasts of 39-hour ahead



Although overestimated, Ensemble prediction captures the actual radar rainfall

The ensemble prediction successfully captured the floods from 39-h before.

(with 4 dams in upstream)



- **Successfully forecasted even in the mid-small basin (1,761 km²)**
- **The framework is globally applicable**
- **Integration with satellite datasets is highly desired and ongoing.**

Ishitsuka, Y., D. Yamazaki, K. Yoshimura, Ensemble approach for flash flood forecasting: A case study of the Kinu River flood of 2015, submitted to JAMES, in revision.

Results from TE-Japan for 2018-Floods

2018's case

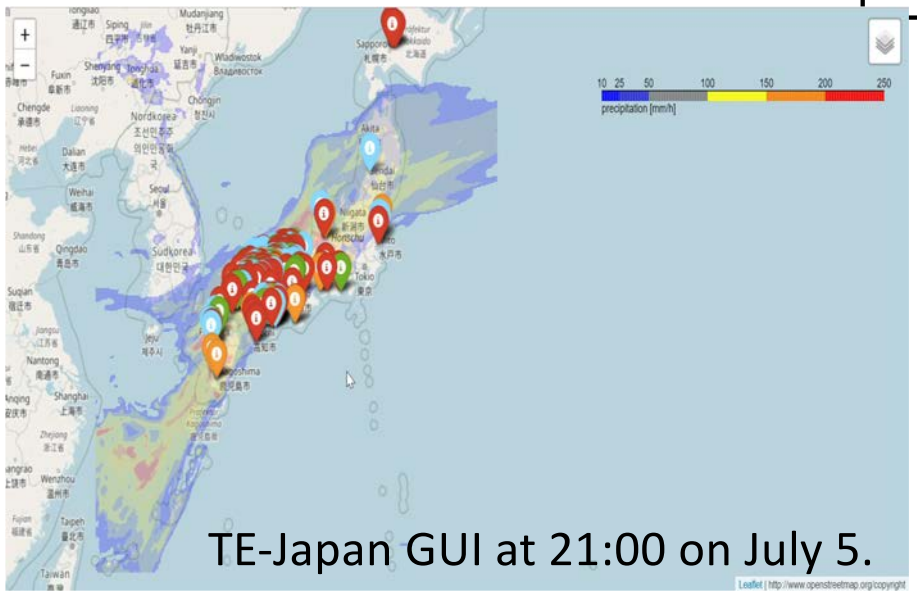
7/6/19:40 Heavy rain alert in Okayama

7/6/22:00 Evacuation alert
7/6/22:20 Reached an evacuation level
7/6/22:40 Heavy rain alert at Kurihashi

7/6/23:35 Evacuation order

7/7/00:30 Flood occurred

7/7/00:30 Evacuation order



TE-Japan GUI at 21:00 on July 5.

Initial date of the forecast

Note: Numbers in the cells represent recursive-years

1tile = 1hour

It could predict a high recursive-year water level from the forecasts 39 hours before

Recursive-year forecasts

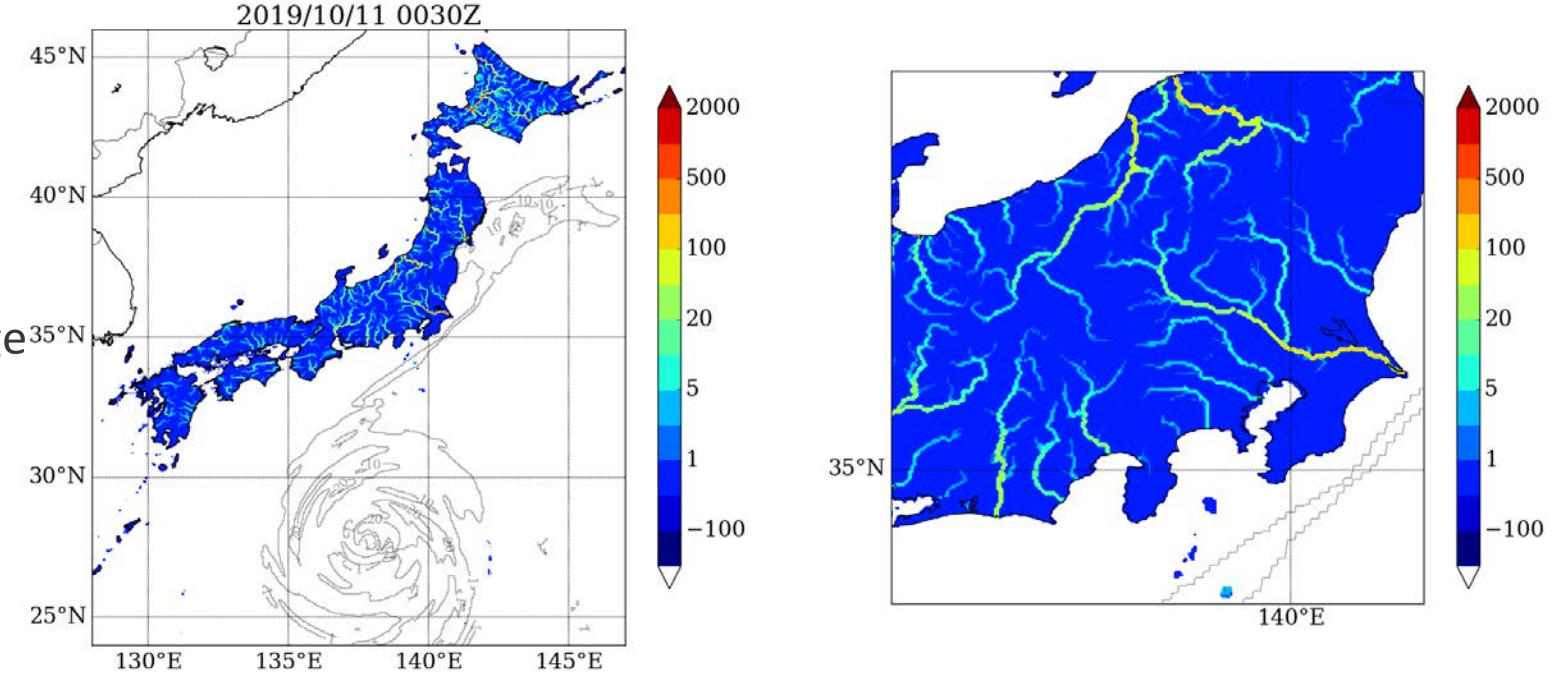
Return Periods: 1～9, 10～19, 20～99, 100～199, 200～

7/5/9:00 7/6/0:00 7/6/12:00 time

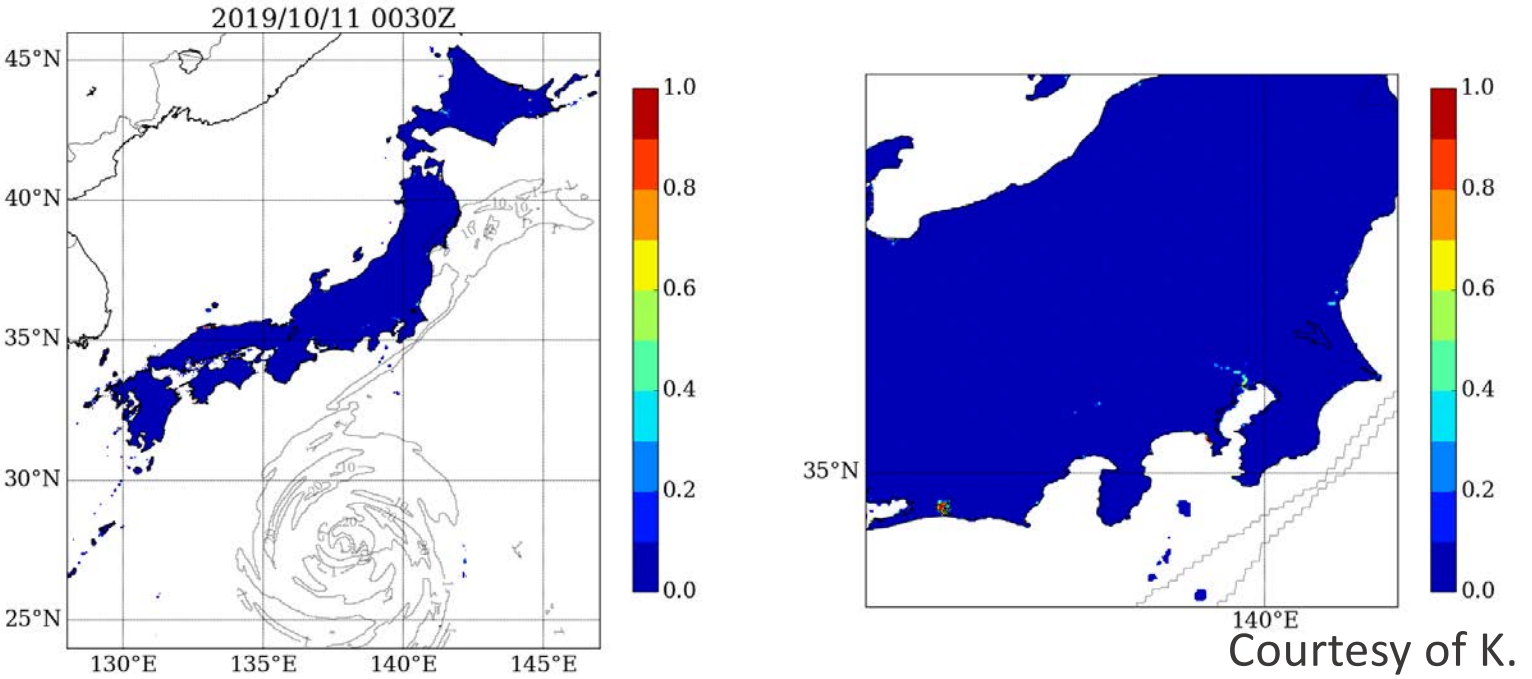
2019's case

Prediction from 11 Oct 9JST by TE-Japan (1km-ver.)

River Discharge [m^3/s]

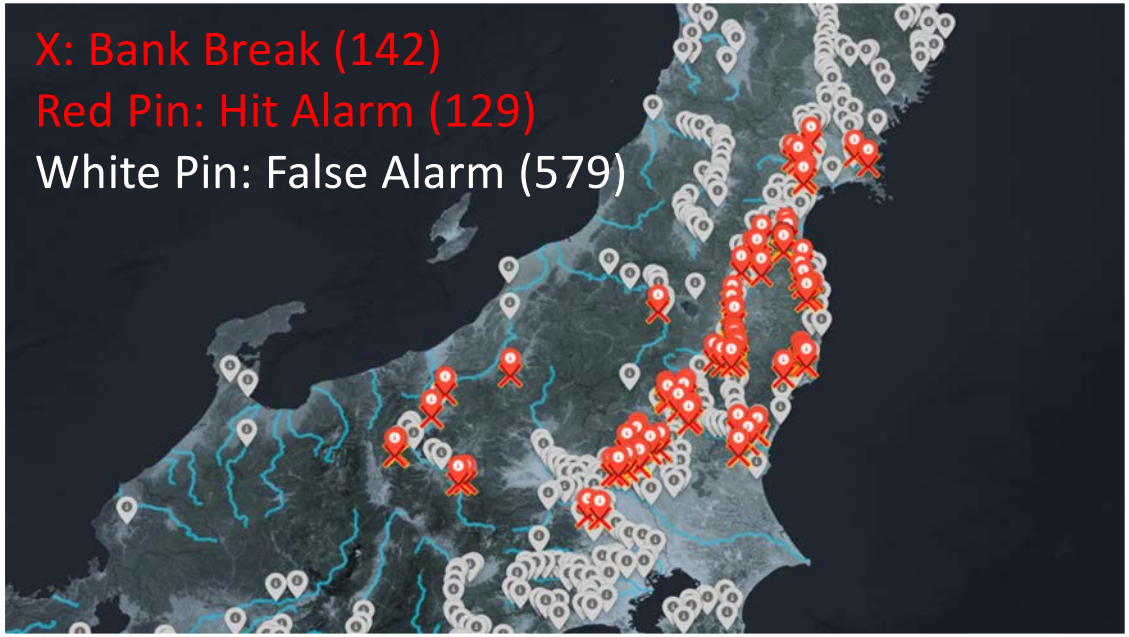


Inundated area [fraction]

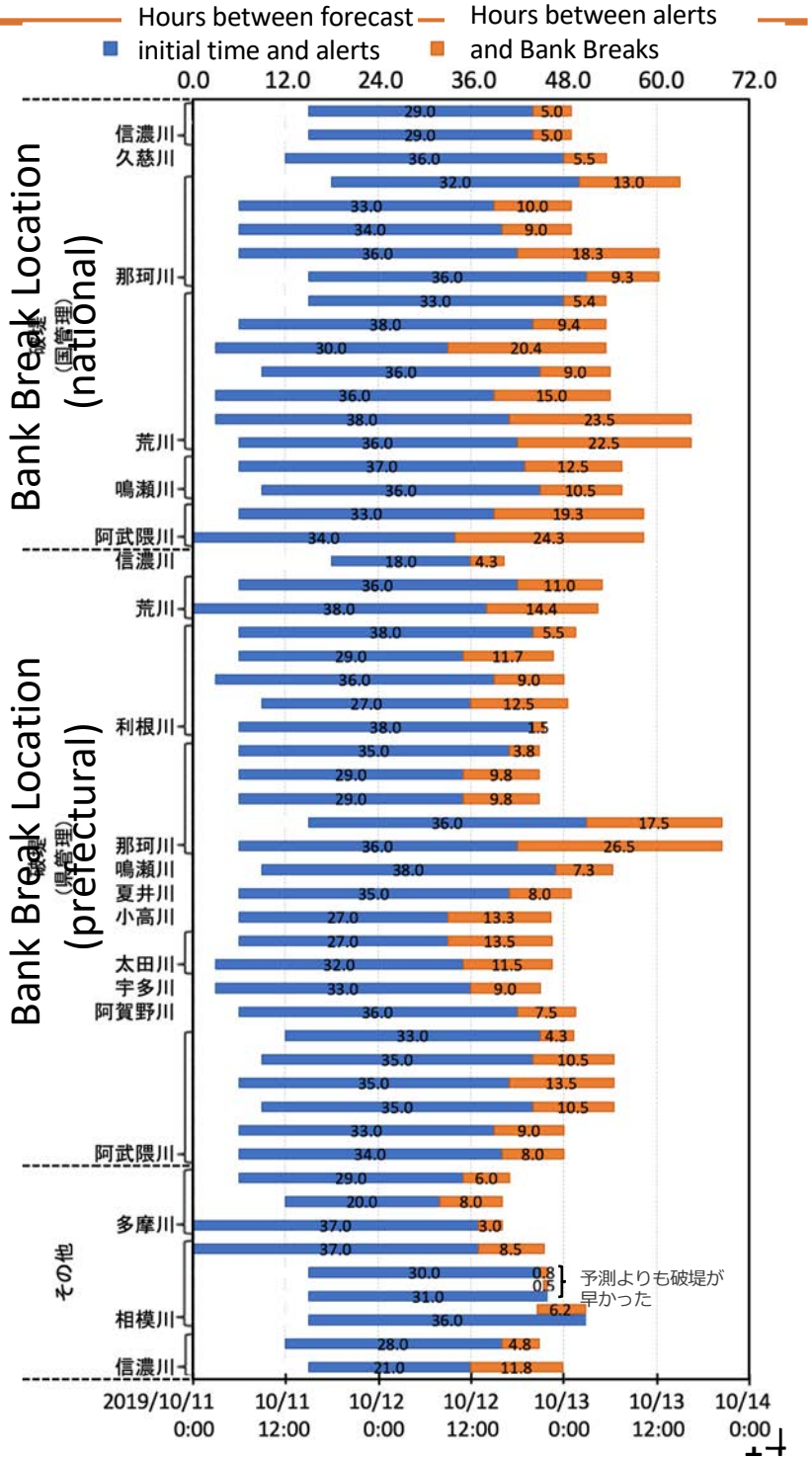


Courtesy of K. Hibino

Predictability for Floods by Hagibis



©NHK



According to authority, there were **142 levee-broken sites**. TE-Japan **successfully gave "alerts" at 129 sites** (i.e., 1/200yr water level) with sufficient lead time (in average 32.3 hours). Levees were destroyed 8.5 hours later than the "alerts".

False alarm rate is about **90% at 3am Oct 11**, but decreased to **70% since 9am Oct 11**, and reached 60% at 9pm Oct 12, when actual flooding started to occur.

Ma et al., in prep.

Municipals started using prediction by *TE-Japan*

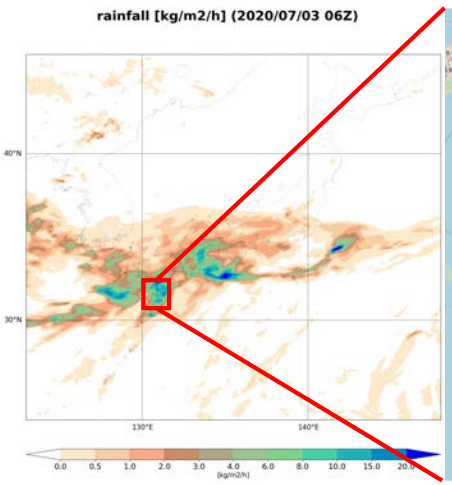
Because of Japanese law, it is NOT permitted to provide predicted results to public (Meteorological Service Act Article 17-1). Therefore, currently *TE-Japan*'s prediction is only used by municipals as a collaborative feasibility study. Member municipals of our collaborative feasibility study are as follows (as of Nov 2020):

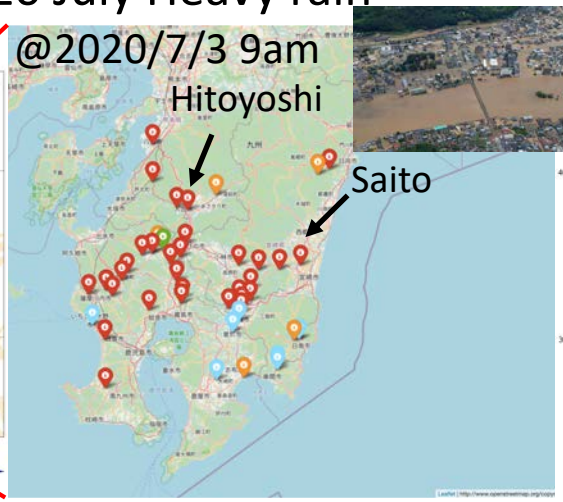
- Miyazaki city / Miyazaki
- Saito city / Miyazaki
- Takanabe city / Miyazaki
- Nagano city / Nagano
- Matsuyama city / Ehime
- Masaki town / Ehime
- Mito city / Ibaraki
- Joso city / Ibaraki
- Tsukuba city / Ibaraki
- TsukubaMirai city / Ibaraki
- Sakai town / Ibaraki
- Hitachiomiya city / Ibaraki
- Hitachiota city / Ibaraki
- Wakayama pref.
- Hitachinaka city / Ibaraki
- Jori town / Ibaraki
- Edogawa ward / Tokyo
- Daigo town / Ibaraki
- Ryugasaki city / Ibaraki
- Tokushima city / Tokushima
- Nagano Pref.
- Bando city / Ibaraki

Meeting with Mito city, 2020/9/5 NHK Special

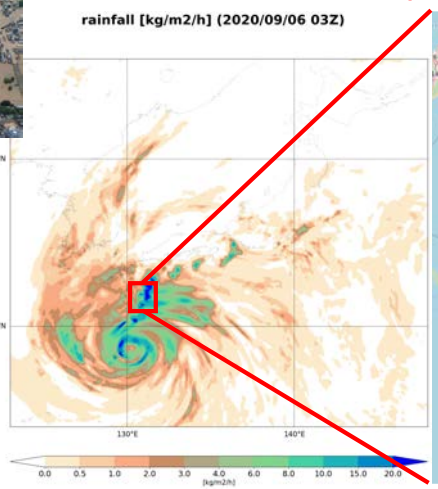
Kyushu floods in July 2020 and Typhoon Haishen in Sept. 2020

2020 July Heavy rain



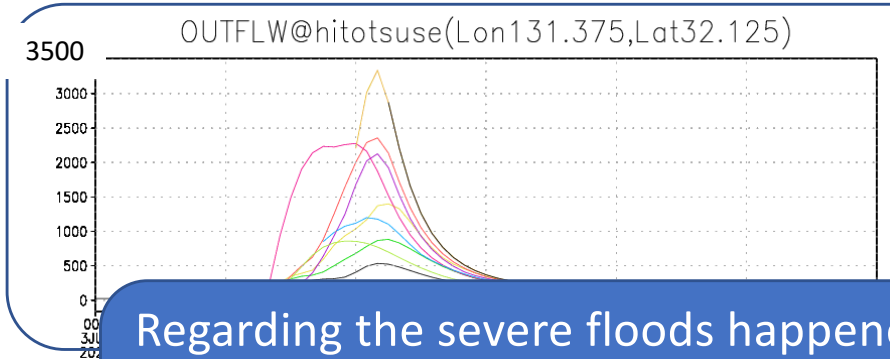


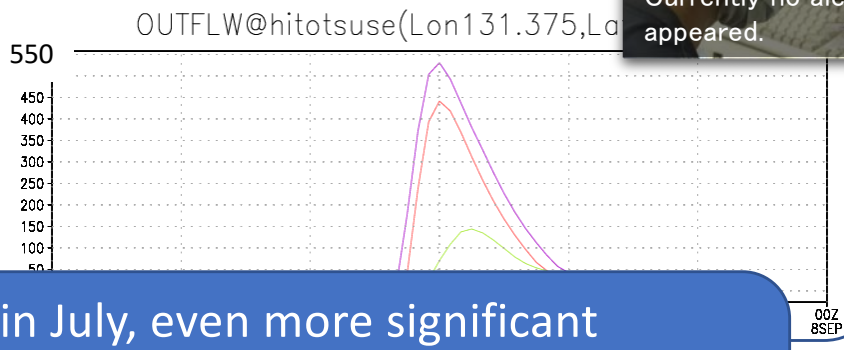
2020 Sept. Haishen



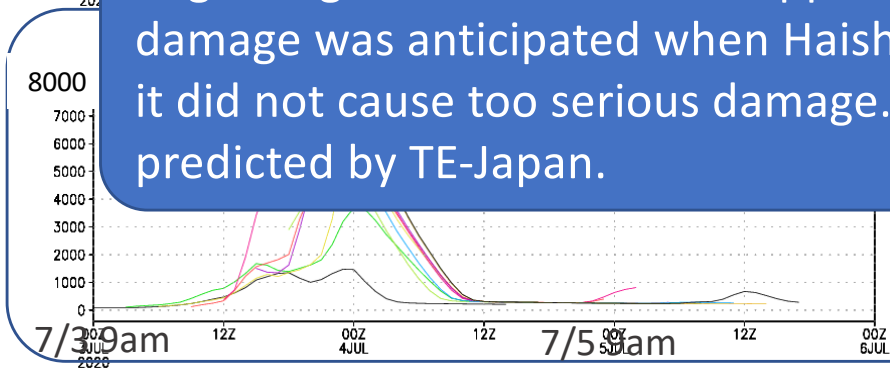
2020/9/5 NHK Special

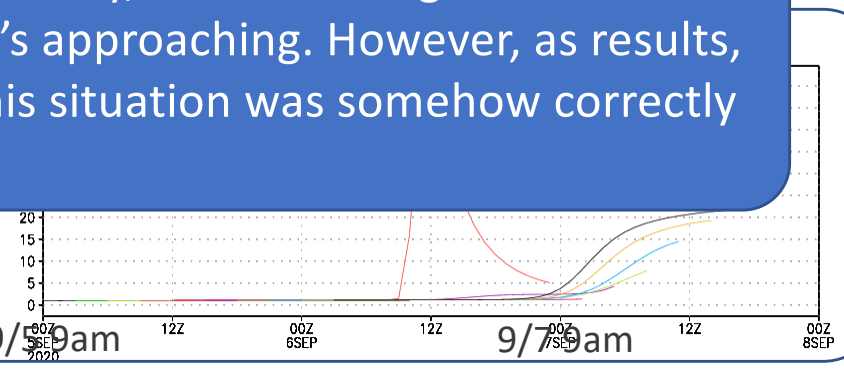
Saito





Hitoyoshi





Regarding the severe floods happened in July, even more significant damage was anticipated when Haishen's approaching. However, as results, it did not cause too serious damage. This situation was somehow correctly predicted by TE-Japan.

7/3 9am

7/5 9am

Hydrographs predicted from 9am July 3

9/5 9am

9/7 9am

Hydrographs predicted from 9am Sept. 6 Unit: m^3/s

Fusion with Satellite Observation (SAR)

Ohki et al. 2020

Probability of class i $P(F_i|\boldsymbol{x}) = \dfrac{P(F_i)P(\boldsymbol{x}|F_i)}{\sum_{j=0}^{3} P(F_j)P(\boldsymbol{x}|F_j)}$

SAR data $\boldsymbol{x} = \begin{pmatrix} \text{Co-event amplitude} \\ \text{Pre-event amplitude} \\ \text{Coherence difference}* \end{pmatrix}$

*co-event coherence − pre-event coherence

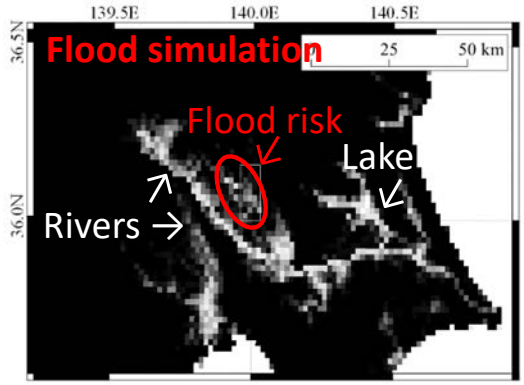
Prior probability

Probability density function of SAR data for each class

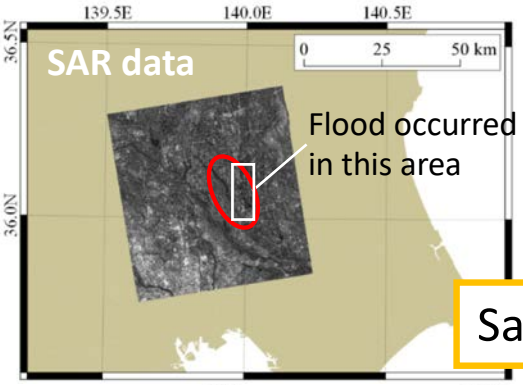
$P(\boldsymbol{x}|F_i) = \mathrm{N}(\boldsymbol{\mu}_i, \boldsymbol{\Sigma}_i)$

N：Gaussian Distribution
$\boldsymbol{\mu}, \boldsymbol{\Sigma}$：Parameters of N (should be set along the incidence angle)

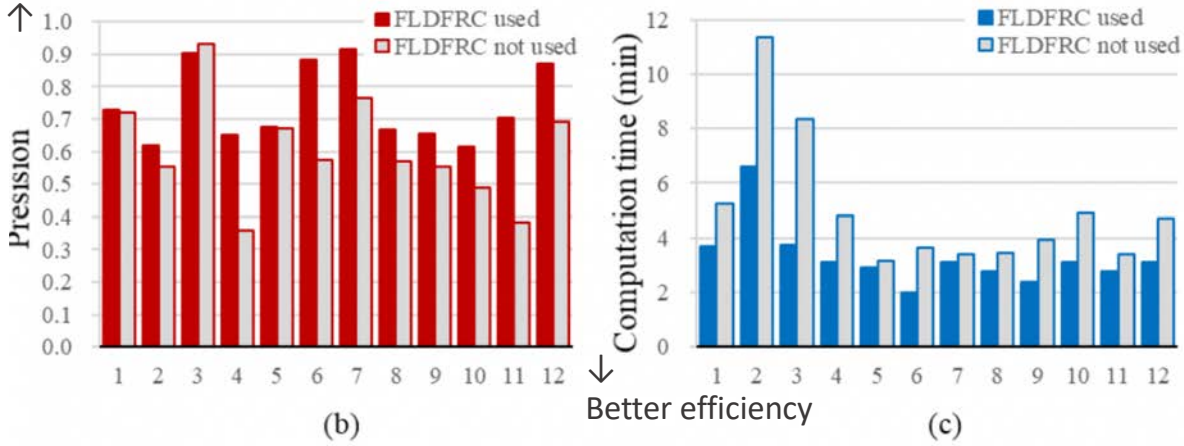
TE

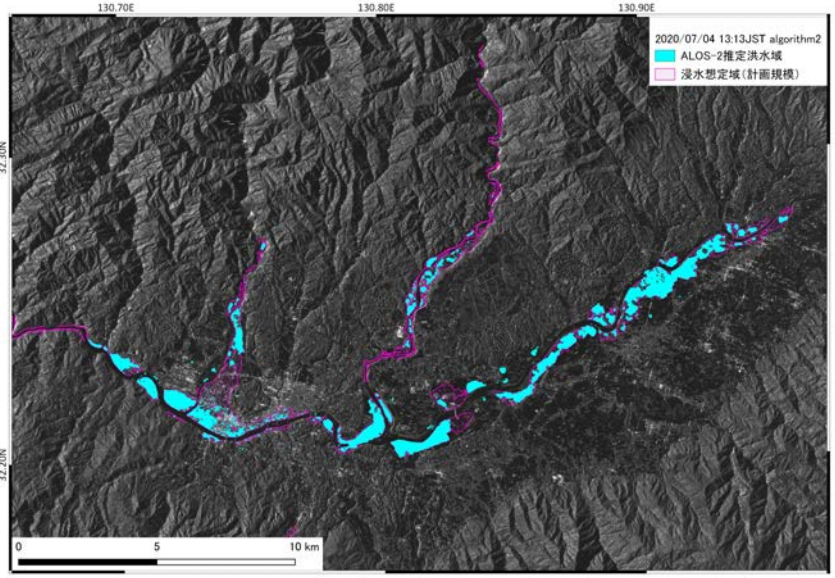


Satellite



Better accuracy



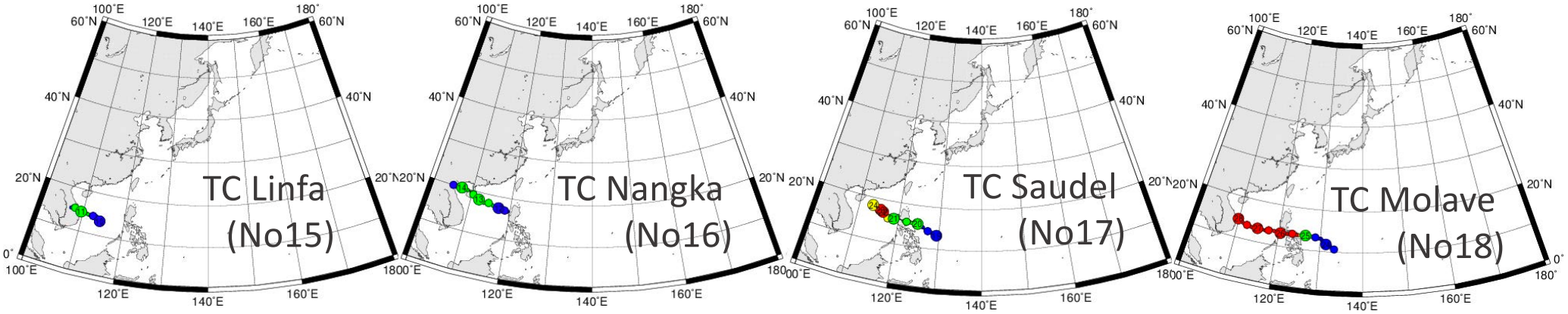


Even though TE-J's low resolution (i.e., 1km), using predicted flood fraction as prior helps to improve the SAR-based (3m) inundation estimates.

Estimate of inundation is promptly announced in case of July flood 2020.

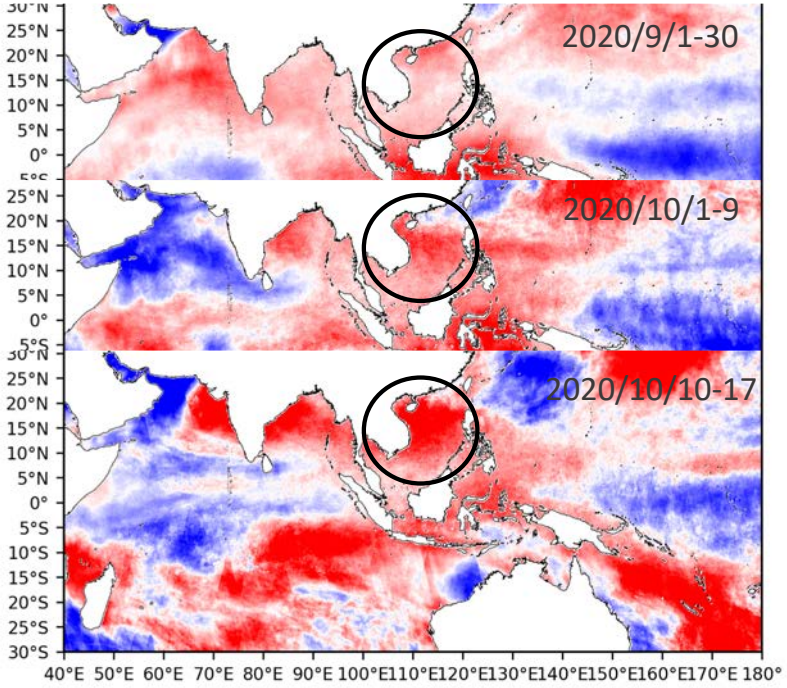
https://www.eorc.jaxa.jp/ALOS-2/img_up/jdis_pal2_heavyrain_kyushu_20200706.htm

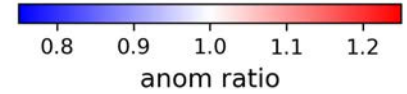
Example of global view: TCs Linfa, Nangka, Saudel, Molave…



http://agora.ex.nii.ac.jp/digital-typhoon/

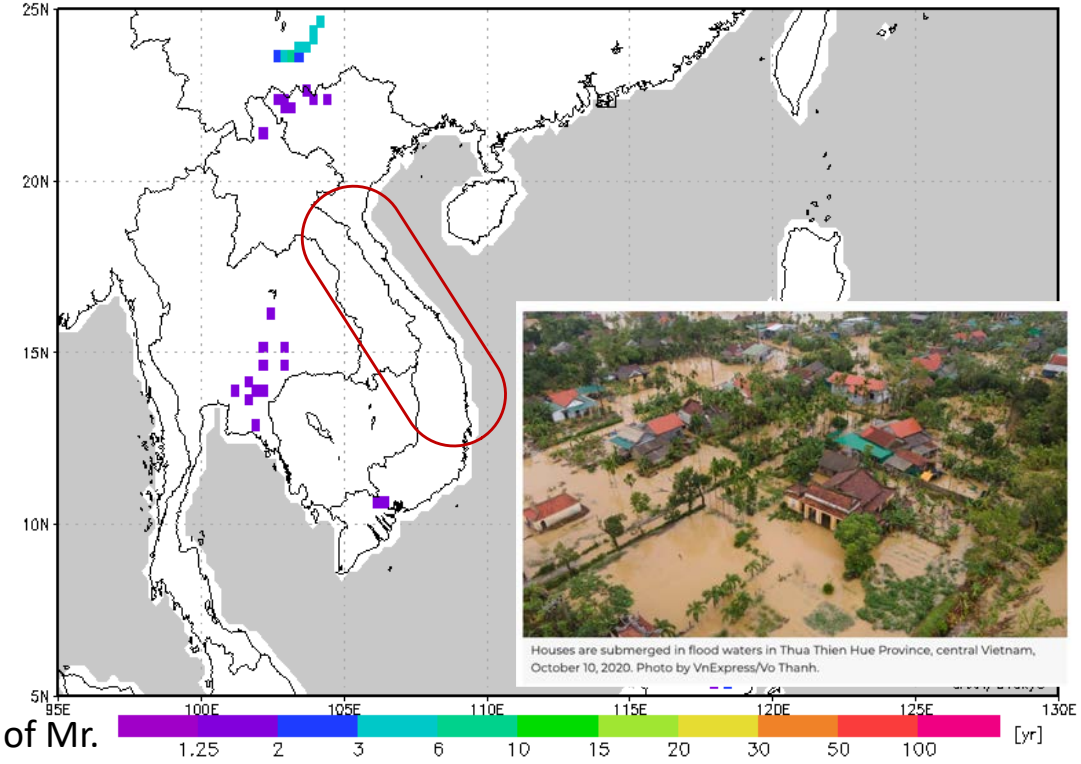
AMSR2/GCOM-W TWV anomaly ratio





Courtesy of Mr. Ohara (JAXA)

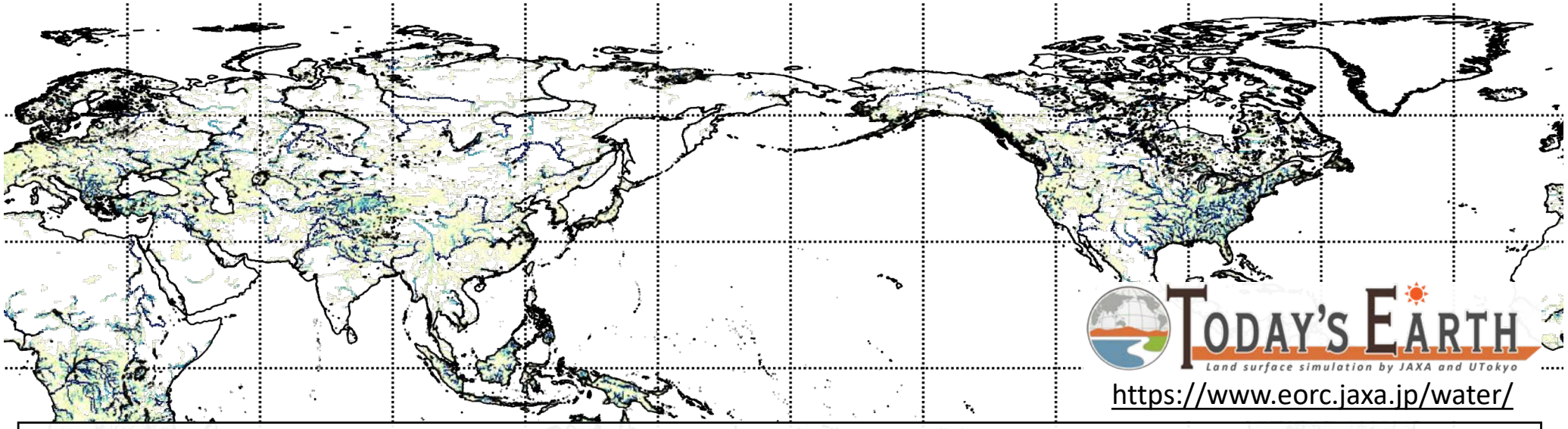
[JRA55] Return Period of River Discharge [yr] 2020/10/01Z



Courtesy of Mr. Yamamoto (JAXA)

Summary

- We developed *Today's Earth*, or *TE*, a simulation system that provides integrated estimates of physical quantities related to the water cycle on land (e.g., soil moisture content, river flows, evapotranspiration, and many others).
- *Today's Earth* utilizes the land surface simulation technology of the University of Tokyo and the satellite data analysis technology of JAXA/EORC, respectively, and enables us to continuously monitor global land conditions through the internet.
- In the Japanese region in particular, we have established a system to distribute real-time prediction with a resolution of 1/60° grid (about 1 km grid) to the public. It is called *TE-Japan*. Global version (*TE-Global*) has 1/4° grid (about 25km grid).
- We tested the performance of *TE-Japan* for some extreme events. In the case of Typhoon Hagibis in 2019, at 129 of the 142 sites where breaches were reported, the system predicted a once-in-200 years flood level (defined as an alert) for an average of 32.3 hours prior to the event.
- The false alarm rate was around 70% to 80 % throughout the period. This predictive information is being considered for use in a variety of fields, such as the distribution of disaster prevention information in the domestic media and public municipal offices.
- Fusion of *TE* and SAR makes the inundation area estimate better.



TODAY'S EARTH
Land surface simulation by JAXA and UTokyo

https://www.eorc.jaxa.jp/water/

Thank you!

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