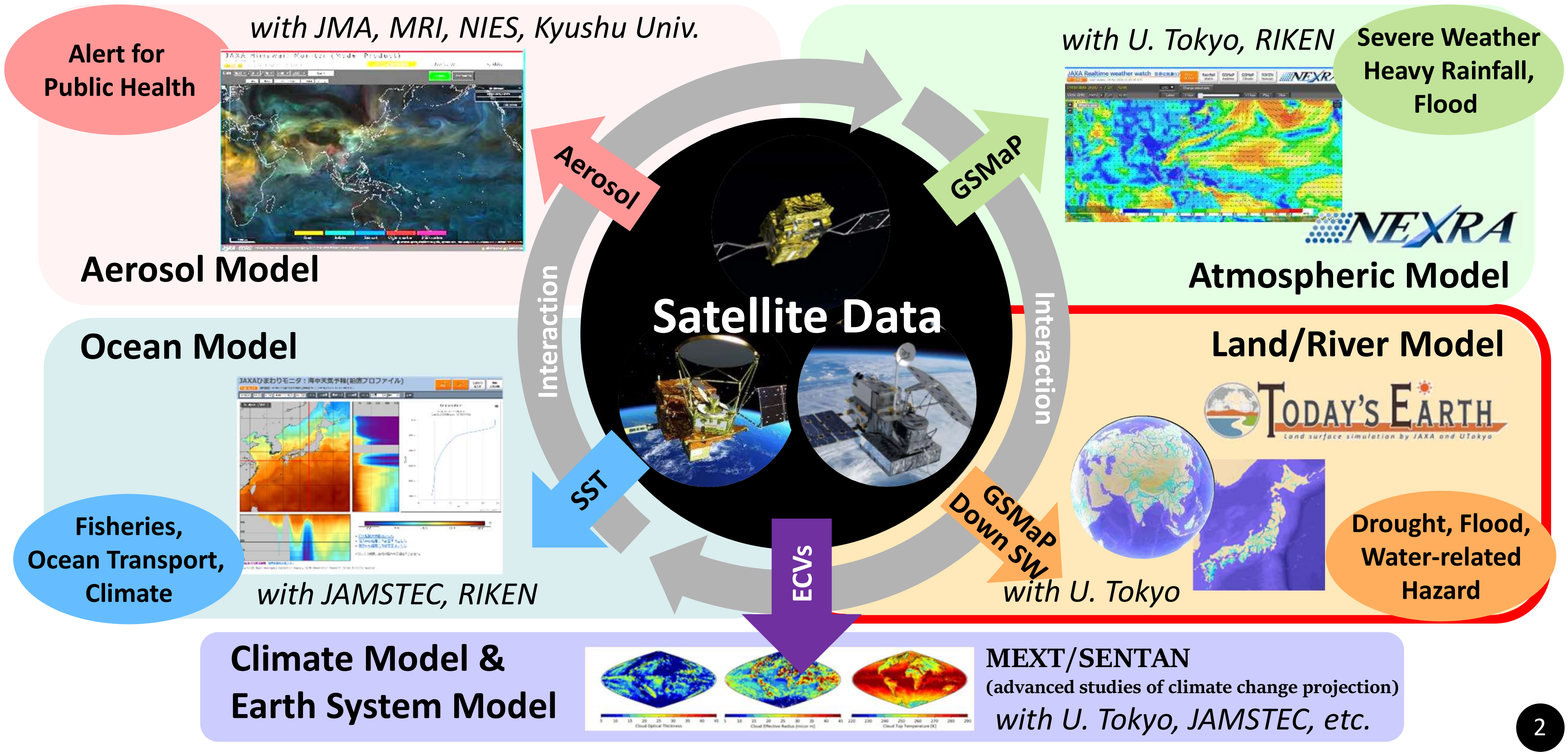
Today's Earth: Introduction of Global Hydrological Simulation System

K. Yamamoto (JAXA/EORC) & Today's Earth R&D Group

9th Joint Project Team Meeting for Sentinel Asia STEP-3 (JPTM2024)

November 5-7, 2024

Satellite and Model Collaborations toward Earth Environment Predictions



What is Today's Earth(TE)?

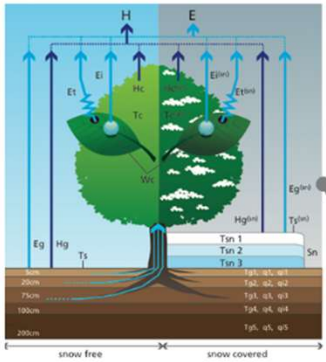
- **Global terrestrial hydrological simulation system integrating satellite observation data**

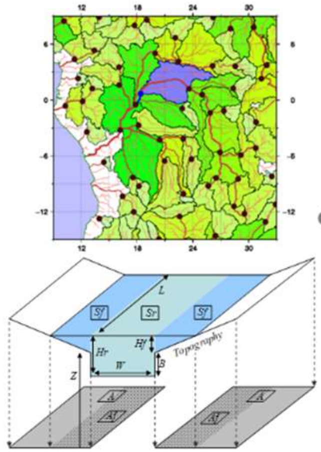
- Developed and operated under the collaborative research of JAXA and the University of Tokyo
  - https://www.eorc.jaxa.jp/water/

- Main goals:
  - To produce and evaluate **realistic global long-term land water cycle**
  - To **provide risk indices** for extremes or water-related disaster

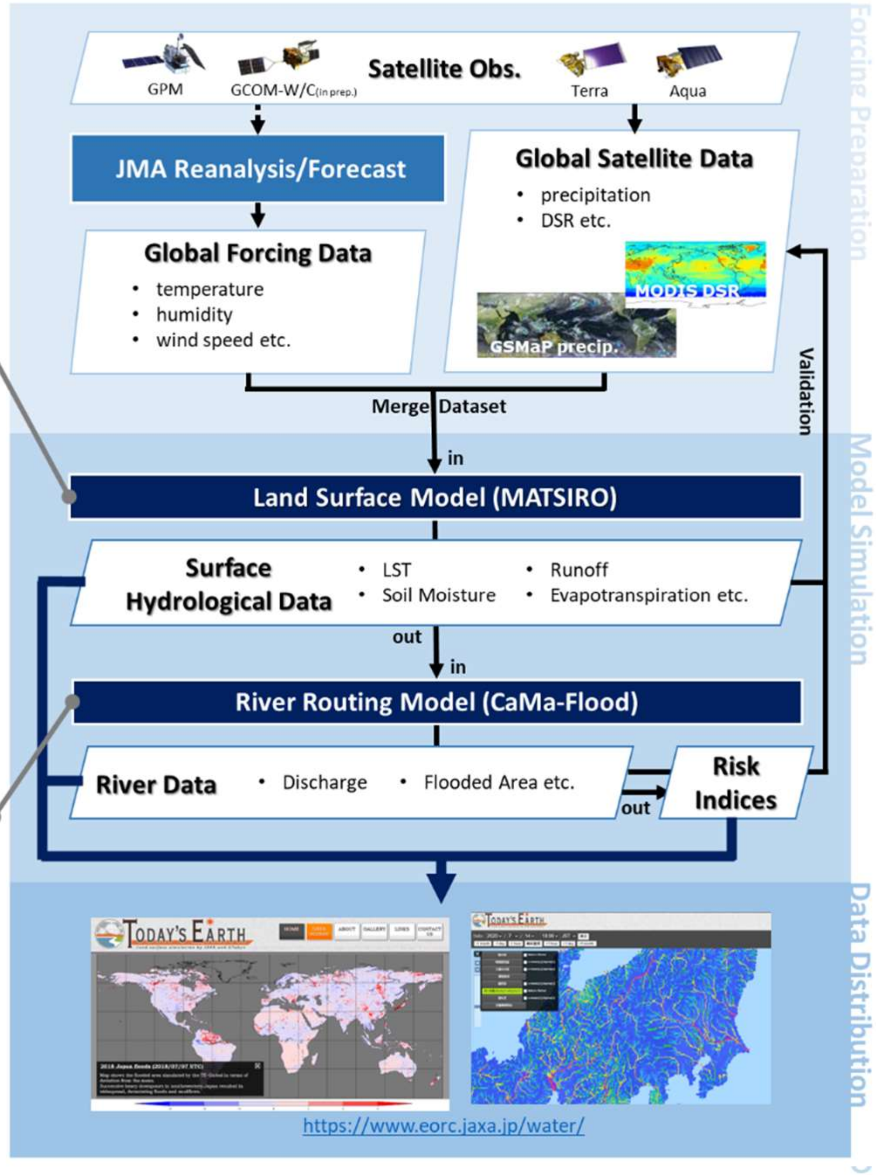
  - Contribute to disaster monitoring and prediction, and water resources management

Takata et al., 2003





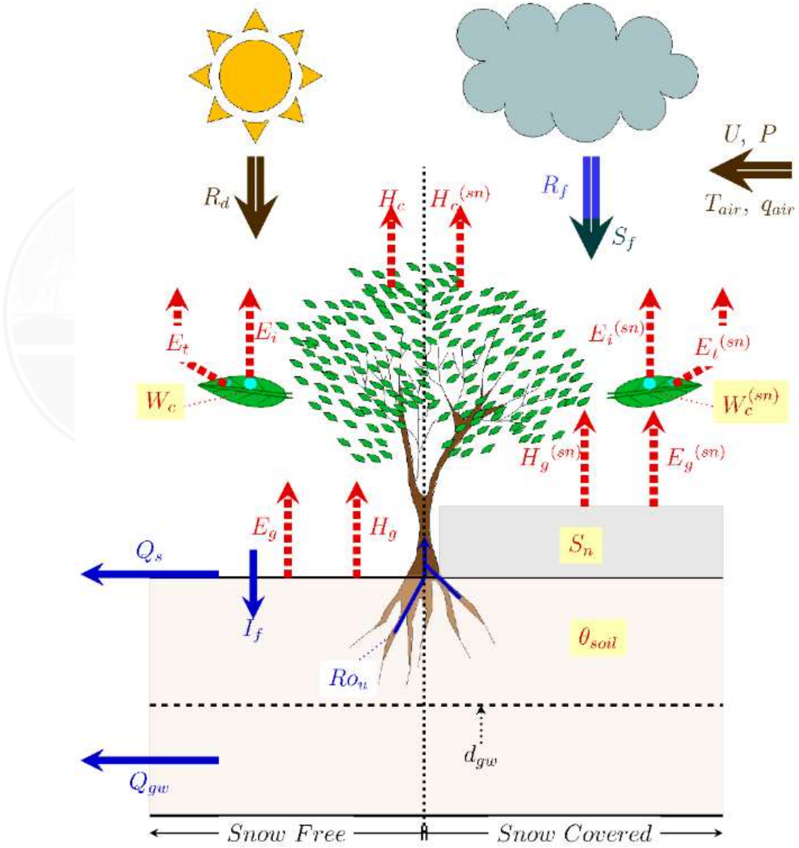
Yamazaki et al., 2011



Land Surface Model: MATSIRO5

Takata et al., 2003

- MATSIRO: Minimal Advanced Treatments of Surface Interaction and RunOff
    - Originally developed for climate studies(GCMs) at the global and regional scales.



- Temperature
- Wind speed
- Solar radiation
- Precipitation etc...

MATSIRO5

①LNTFLX
Flux Calculation

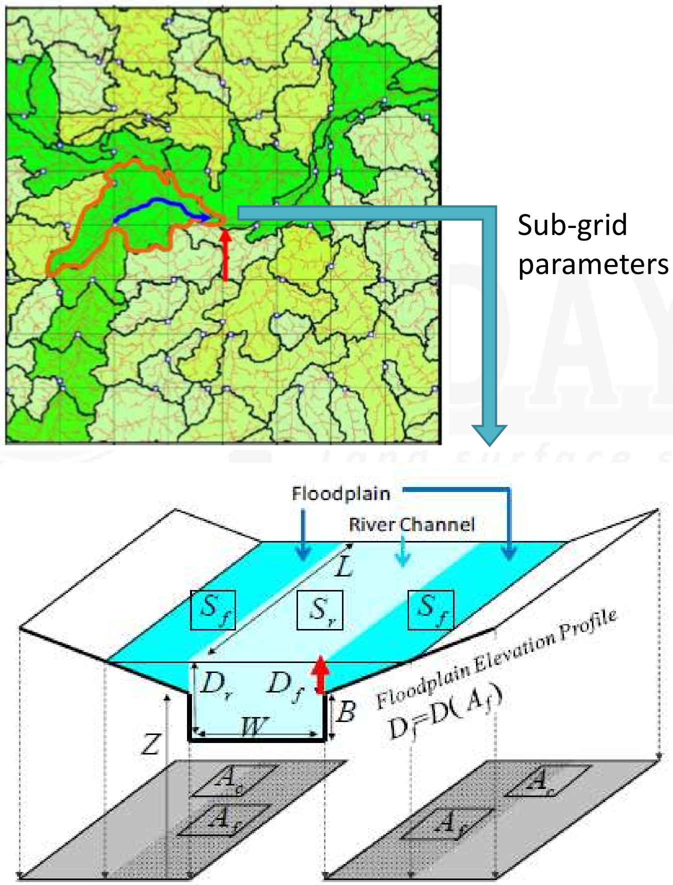
②LNDSTP
Treating Ground Processes

- Soil Moisture
- Evapotranspiration
- **Runoff** etc...

River Routing Model: CaMa-Flood

Yamazaki et al., 2011

- CaMa-Flood: Catchment-based Macro-scale Floodplain model
  - River routing model, which incorporate physically based representation of floodplain inundation dynamics



- Elevation (DEM)
- **Runoff** (from MATSIRO)

CaMa-Flood

①Calculate river discharge
Shallow water momentum equation

②Calculate water storage in next time step
mass-balance equation

- River discharge
- River water depth
- Flooded fraction (area) etc…

Various types of Today's Earth

	TE-Global (Global System)	TE-Global NEXRA (Global Ensemble System)	TE-Japan (Regional System)
Horizontal resol. (lat/lon)		er: 0.25 d	1/60 deg.
Temporal resol.		our	Every hour
Latency	About 3 days~ (Depends on experiment)	About 1~5 days, unstable (Depends on the operation status of JAXA supercomputing system (JSS))	**Real-time** *forecast data distribution is limited within research purpose due to the Japanese law
Satellite data used in the System	GSMaP, Terra/Aqua MODIS, NOAA AVHRR (AW3D, GCOM-C in prep.)	NEXRA (assimilate GSMaP, ATMS, AMSU-A, MHS etc.) with 128 ensemble members	Himawari-8, ALOS HRLULC, NOAA AVHRR (GSMaP in prep.)
Product	River discharge/depth, Flooded area, Soil moisture, Snow amount, Evapotranspiration, etc.		
Reference	Ma et al., 2024	Yamamoto et al. (in revision)	Yoshimura et al., 2008

Operation temporary stopped Will be updated within JFY2024!

Just released in last year!

- All products are distributed in netCDF format and freely available with simple registration via website.
  - Monitoring page can be used without any registration.

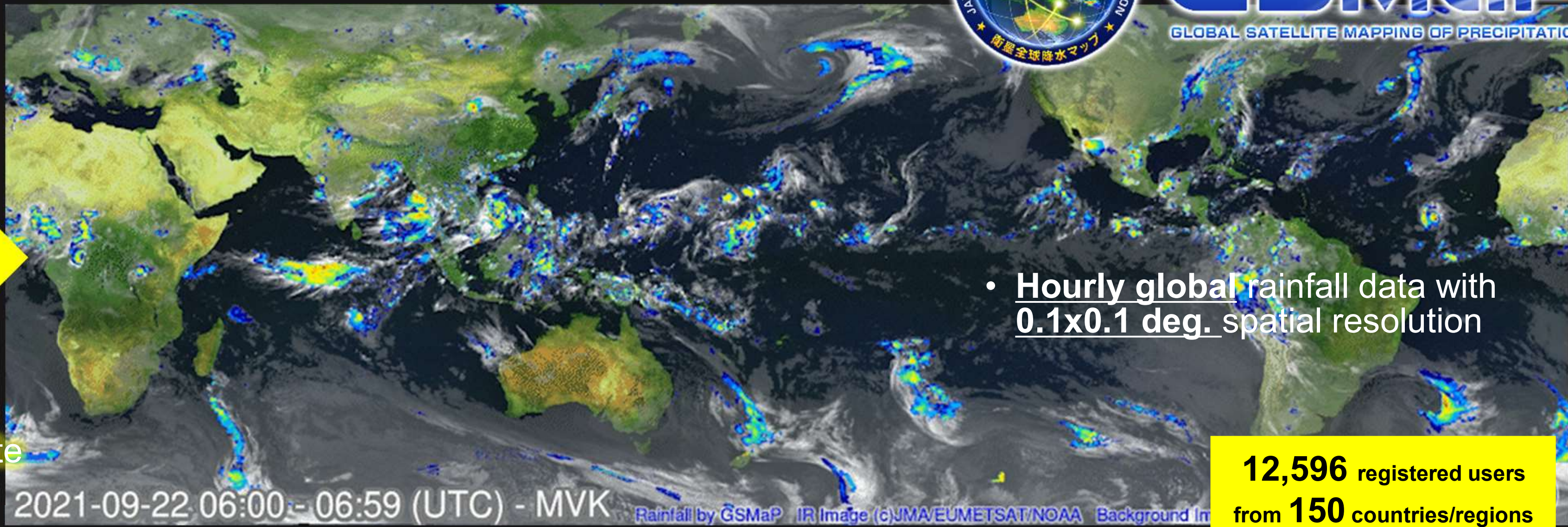
For more detail: https://www.eorc.jaxa.jp/water/documents.html

Satellite-based global rainfall map:

衛星全球降水マップ GSMaP GLOBAL SATELLITE MAPPING OF PRECIPITATION

GPM Constellation Satellites

GPM Core Satellite



- **Hourly global** rainfall data with **0.1x0.1 deg.** spatial resolution

12,596 registered users from **150** countries/regions (as of Dec. 2023)
+ website users (not registered)

Access real-time global precipitation easily!

https://sharaku.eorc.jaxa.jp/GSMaP_NOW/index.htm

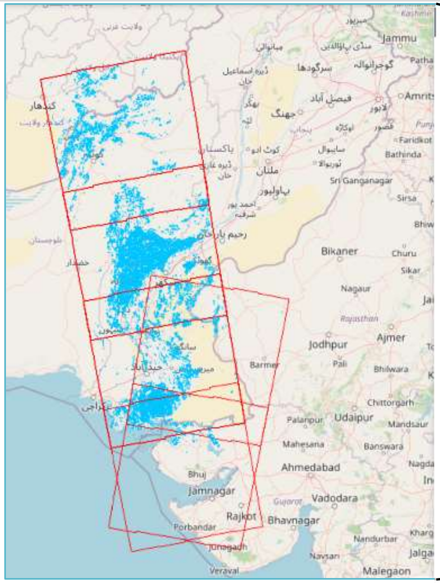
The unique advantage of GSMaP

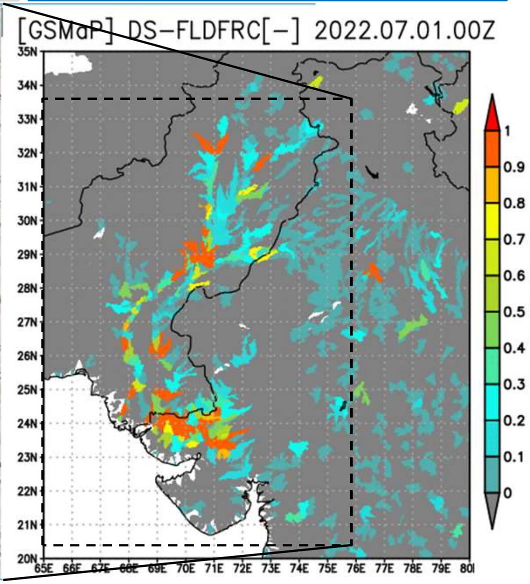
- Space-based rainfall observations allow us to capture the rainfall **even in the area lack of ground-based observations**.
- Rainfall can be measured **globally, continuous and same interval, and consistent accuracy**.
- **Open and freely available** via web-based GUI, FTP site and data analysis cloud platforms (ex. GEE)
- **Long-term archive data** for more than **25 years** (since 1998)

Example of TE-Global simulation

◆ Flood in Pakistan in 2022

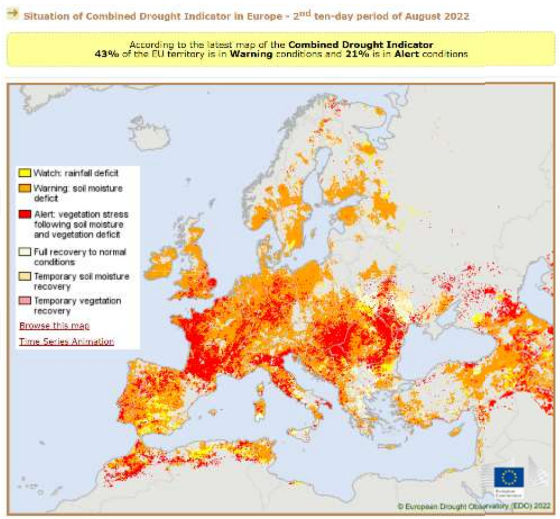
Flooded area detected by ALOS-2	**TE-Global estimation (Flooded area fraction)**

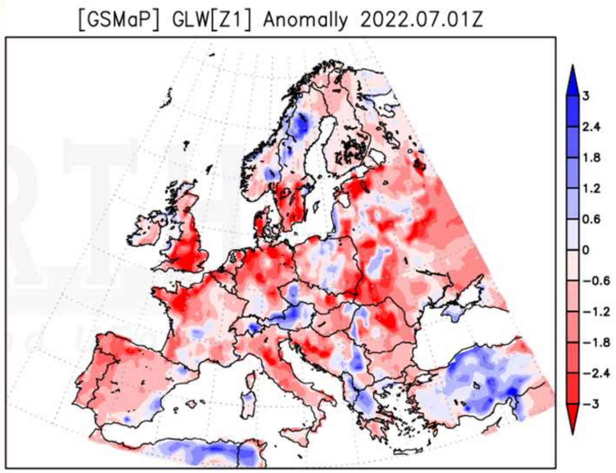




◆ European Heatwave 2022

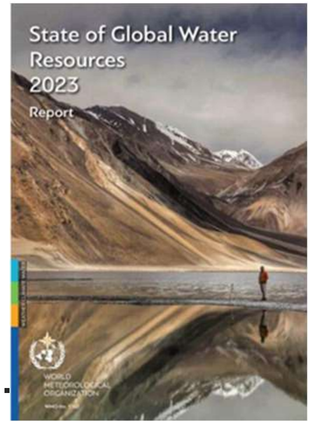
Drought severity estimated by EU	**TE-Global estimation (Soil Moisture Anomaly)**



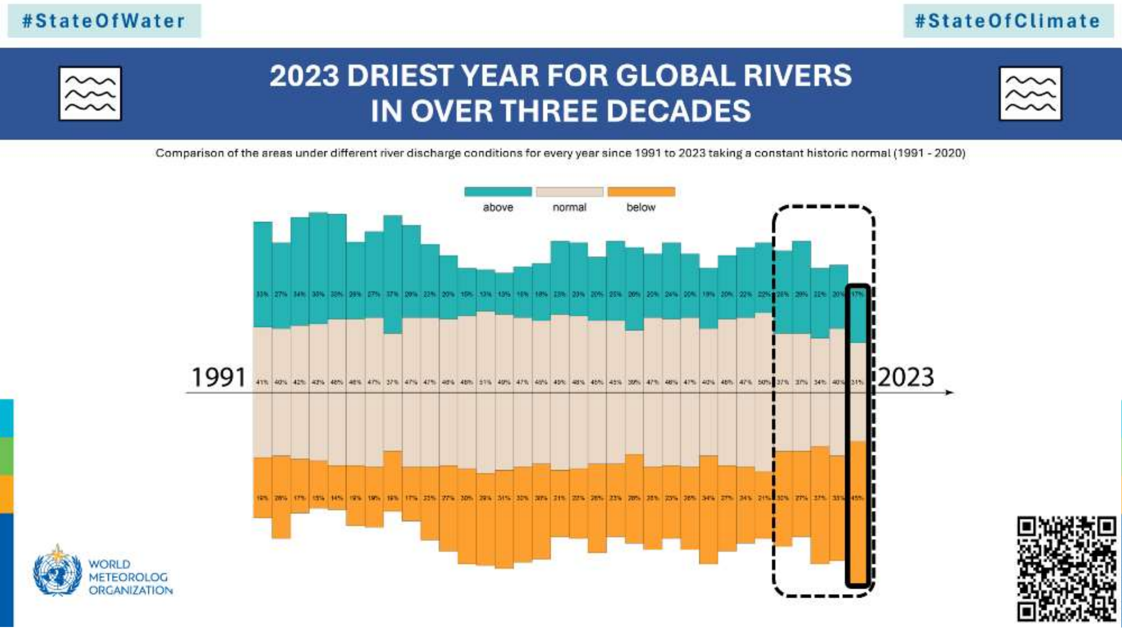


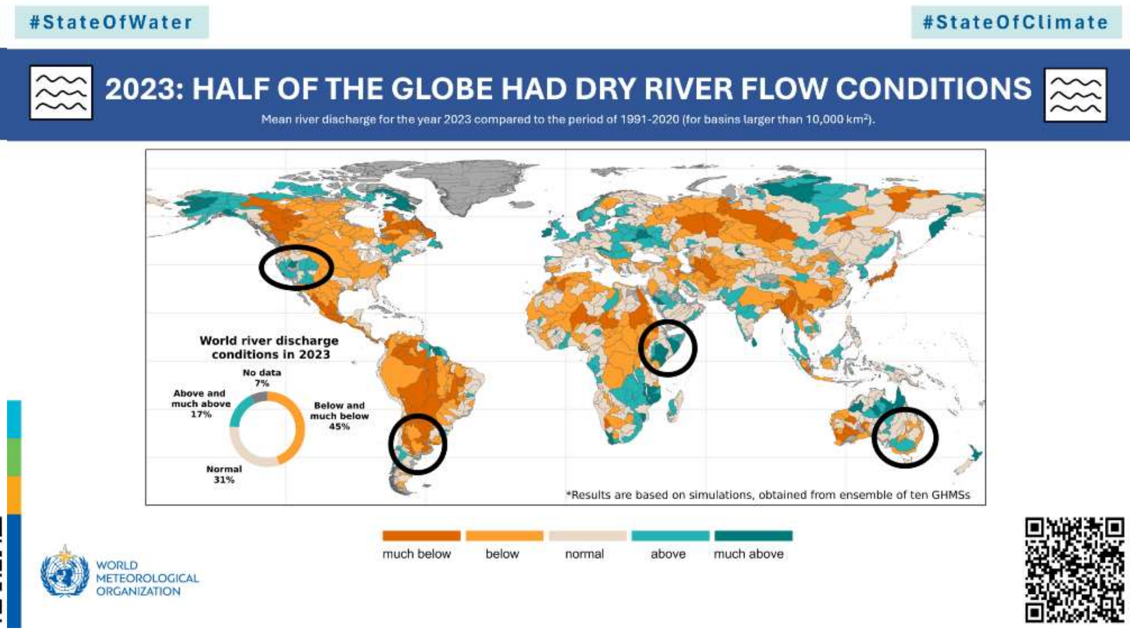
- TE-Global demonstrates its capability to reproduce such hydrological events by physically solving near-surface water and energy budgets globally.

WMO State of Global Water Resources Report



- Each year, the WMO evaluates the hydrological conditions of the previous year based on global water cycle simulation results from various countries, including TE, and publishes these findings in a report.
- The evaluation results for 2023 were released at a press event on October 7th, 2024, highlighting that **global rivers experienced the driest conditions in the past 30 years**.
    - This year, the report garnered coverage from over 2,500 media outlets, including major news agencies





The report and summary slides are available

https://wmo.int/publication-series/state-of-global-water-resources-2023
https://storymaps.arcgis.com/stories/c56d4a08c1ce4b05b900d3f5852a52af

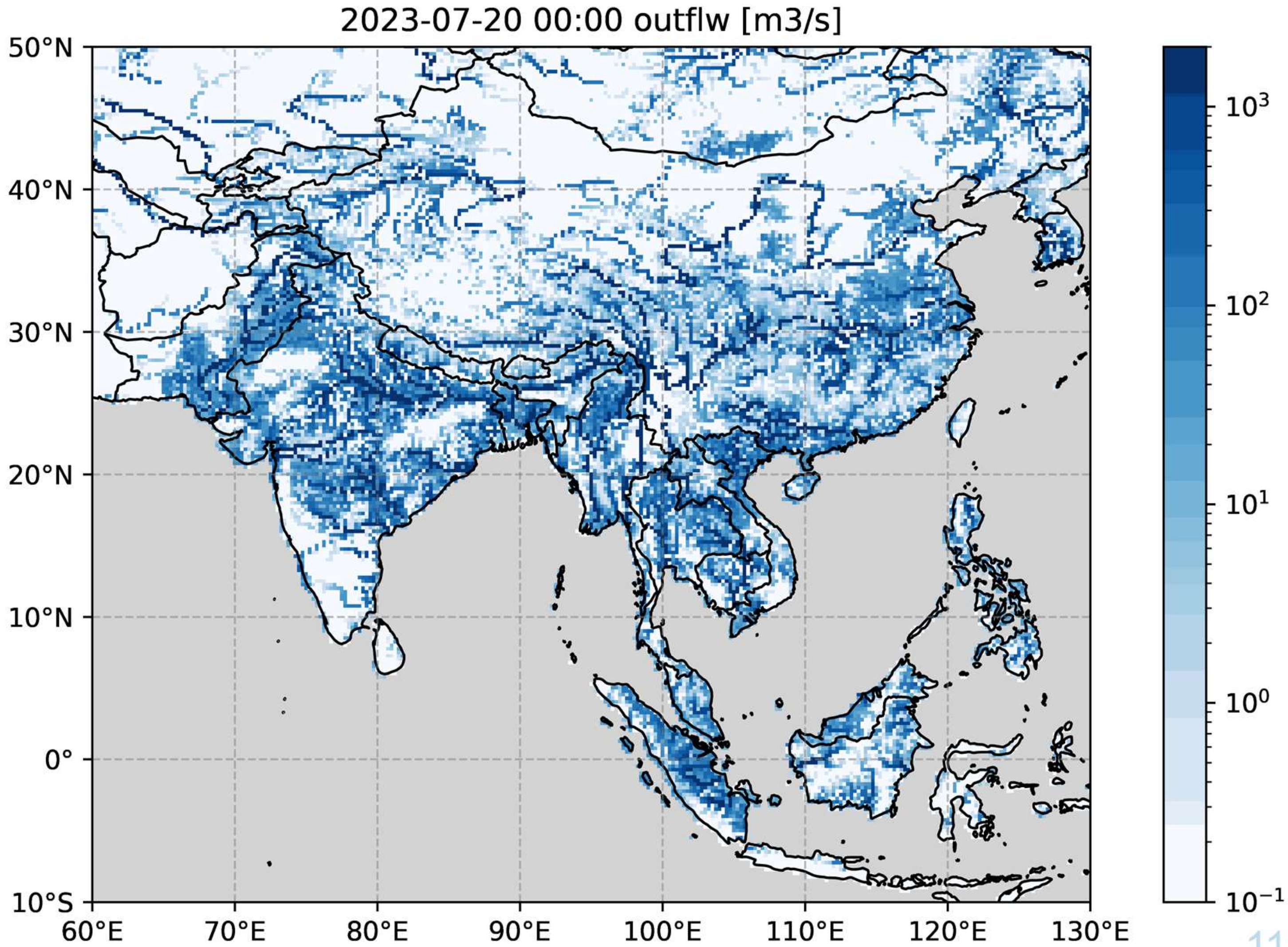
Update plan of TE-Global

- The current version of TE-Global stopped its operation on January 31, 2023, due to the cessation of updates to the Japan Meteorological Agency (JMA)'s JRA-55 data (atmospheric reanalysis), which had been used as atmospheric forcing.
- Alternatively, we are now developing a **high-resolution global system with about 5-day forecast,** utilizing JMA's global weather forecast (GSM).
- The new TE-Global is now planned to be released within JFY2024.

	TE-Global (~JFY2023)	TE-Global (JFY2024~)
Horizontal resol. (lat/lon)	Land : 0.5 deg., River : 0.25 deg.	**0.1deg**
Temporal resol.	Every 3 hour	Every 6 hour
Latency	About 3 days~ (Depends on experiment)	**~5-day forecast** (Depends on operation status)

River discharge simulation by TE-Global (old)

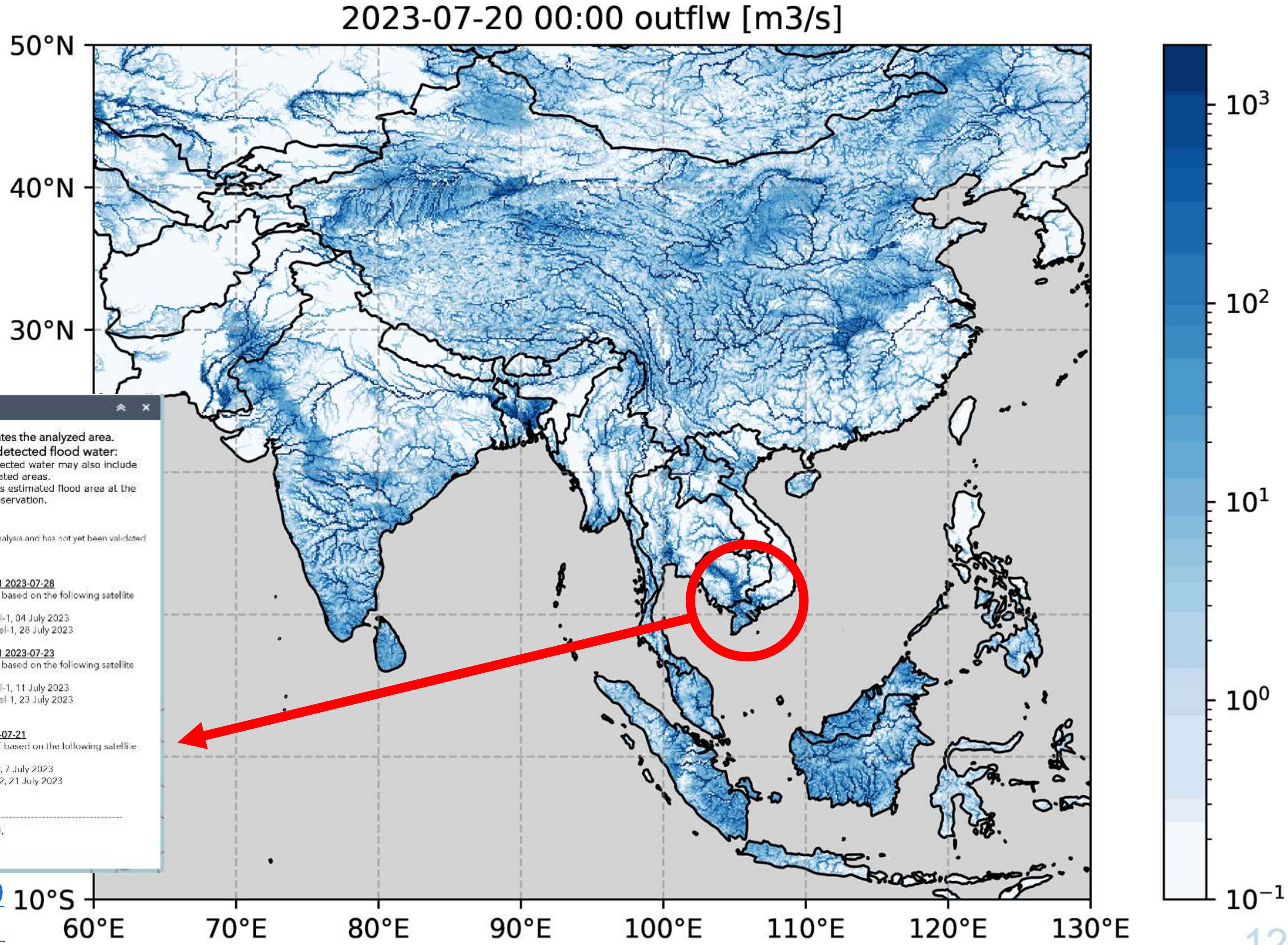
- 0.25deg
- With several days of latency

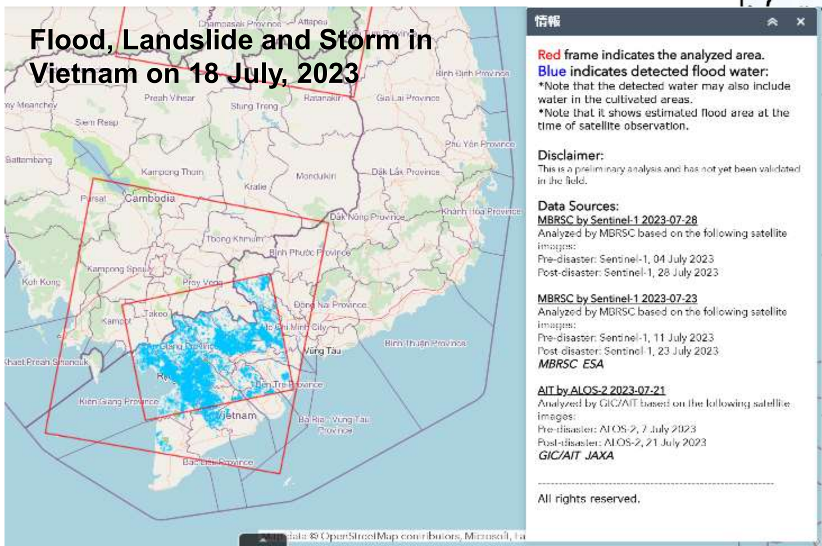


River discharge simulation by TE-Global (upcoming)

- **0.1deg**
- **~5-day forecast**

- forecast test result starting from 20th July 2023
  - (Under confirmation)



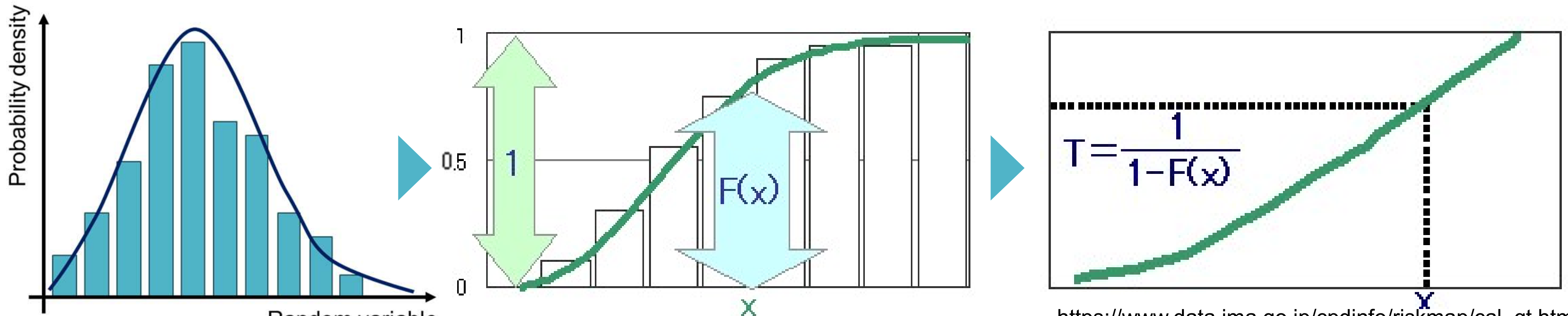


https://storymaps.arcgis.com/collections/179437e1cb484b97b495153228603a65?item=1

Risk estimation

- The physical quantities output such as river discharge contain biases, making direct use challenging

- Convert them into "**return periods**" (i.e., an estimated average time between events) based on past simulation statistics



https://www.data.jma.go.jp/cpdinfo/riskmap/cal_qt.html

- In TE, the Gumbel distribution, which shows a good fit for annual maximum water level, is used for calculating return periods

$$\Pi = (1 - F_{(D)})^{-1} = \left(1 - \exp\left(-\exp\left(-\frac{D-\mu}{\beta}\right)\right)\right)^{-1}.$$

Yoshimura et al., 2008

Risk estimation

- The **Flood Risk Level is a five-level alert level** based on return period of river water level forecast by TE-Japan
- Currently we define lev.5 as the “Alert” for the flood (Ma et al., 2021).

- Similar framework can be applied for the next version of TE-Global

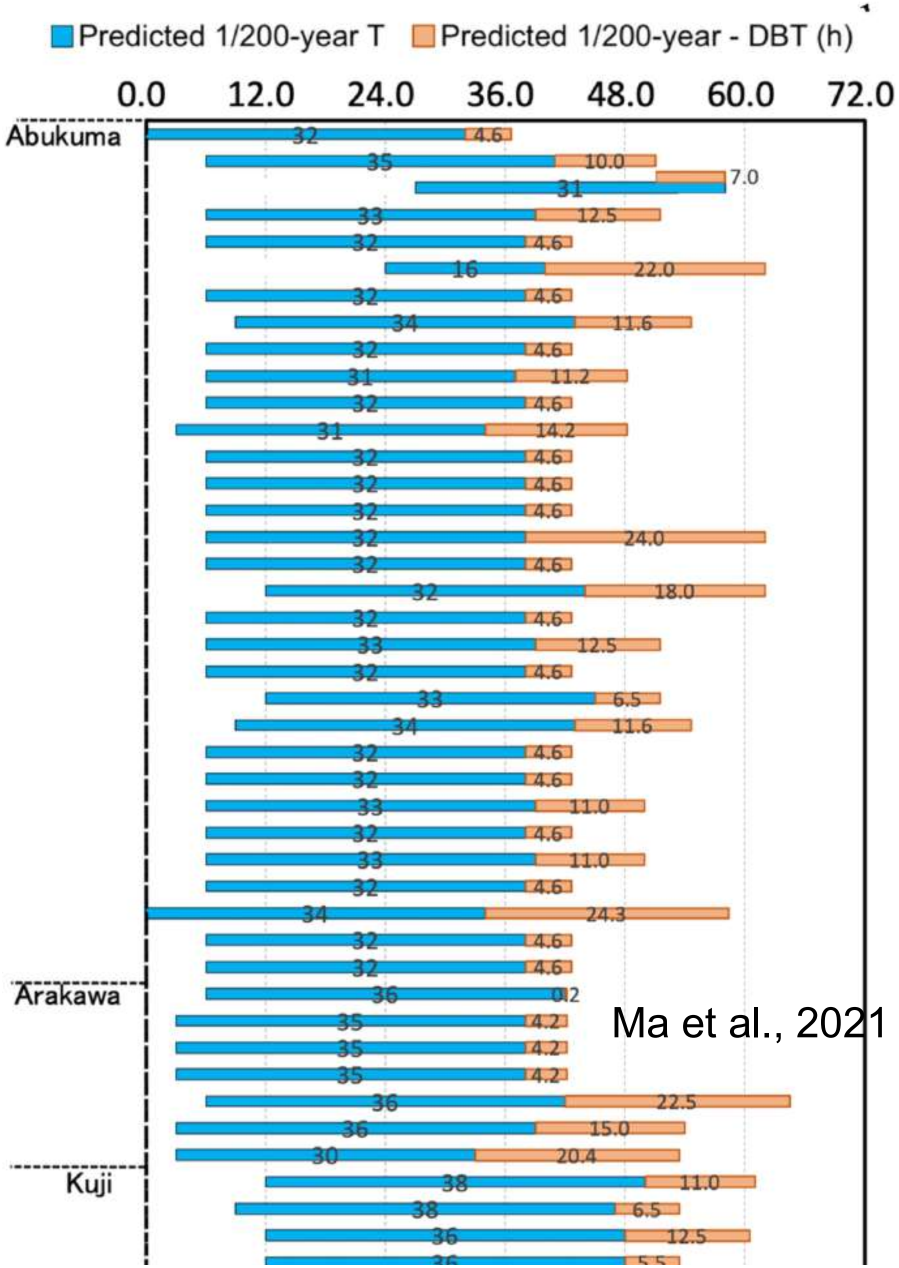
Flood Risk Level	Definition *N = Return period of estimated river water level
Lev.5	200≦N
Lev.4	150≦N＜200
Lev.3	100≦N＜150
Lev.2	50≦N＜100
Lev.1	10≦N＜50

Severe

Example of the Issued alert

Case study on typhoon Hagibis, 2019

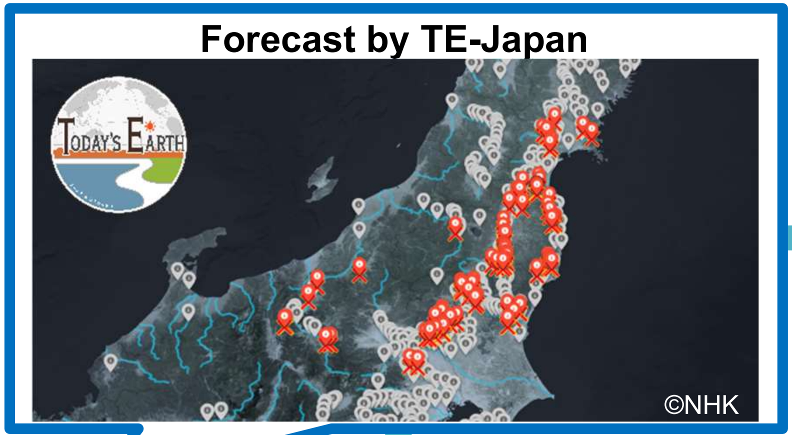
- Among the 142 locations reported to have experienced levee breaches, **TE-Japan successfully alerted at 129 of these sites**
  - **An average lead time was 32.3 hours** and actual breaches occurred 8.5 hours later than the predicted warnings.
- The false alarm rate was approximately 90% at the initial phase of the forecast, eventually rising to about 60%.
  - The false alarm rate for flood warnings issued by the Japan Meteorological Agency is around 70-90%; Tanaka et al., 2008.

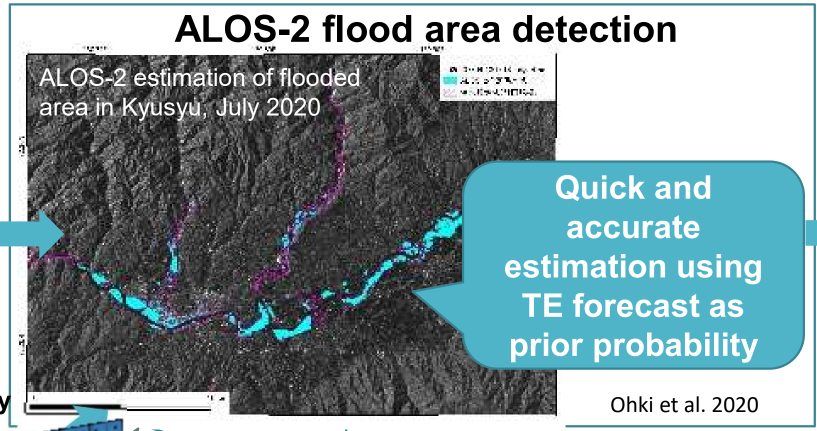


Ma et al., 2021

What can we do with the next TE-Global?

- Example of the use of TE-Japan forecast





Emergency obs.

~30hrs before | ~10 hrs before | Disaster | 10 hrs after~ | 30hrs after~ | Time

- This framework is effectively used for disaster response
- It is expected that, if TE-Global can provide high-resolution forecasts, collaboration with emergency satellite observations will be possible in a similar manner

Summary

- Today's Earth (TE) is the **global terrestrial hydrological simulation system that integrates satellite observation data**.

- Currently, TE-Japan is operated in real-time with some limitations in forecast provision due to Japanese law, while TE-Global only provides a past long-term reanalysis of the global water cycle (open & free).

- Within JFY2024, **we plan to update TE-Global system** as follows:
  - Spatial resol.: **0.1 deg.**
  - Temporal resol.: 6 hourly
  - Latency: **5 days forecast**

- With this update, we aim to contribute to the Sentinel Asia framework based on the experience gained from TE-Japan utilization in Japan.

TODAY'S EARTH

Land surface simulation by JAXA and UTokyo

Website

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

How to use

https://youtu.be/FaVpeZTq870?si=EjmWydqU0IsBaoVs

*Please turn on the automatic translation on YouTube

Thank you for your attention!