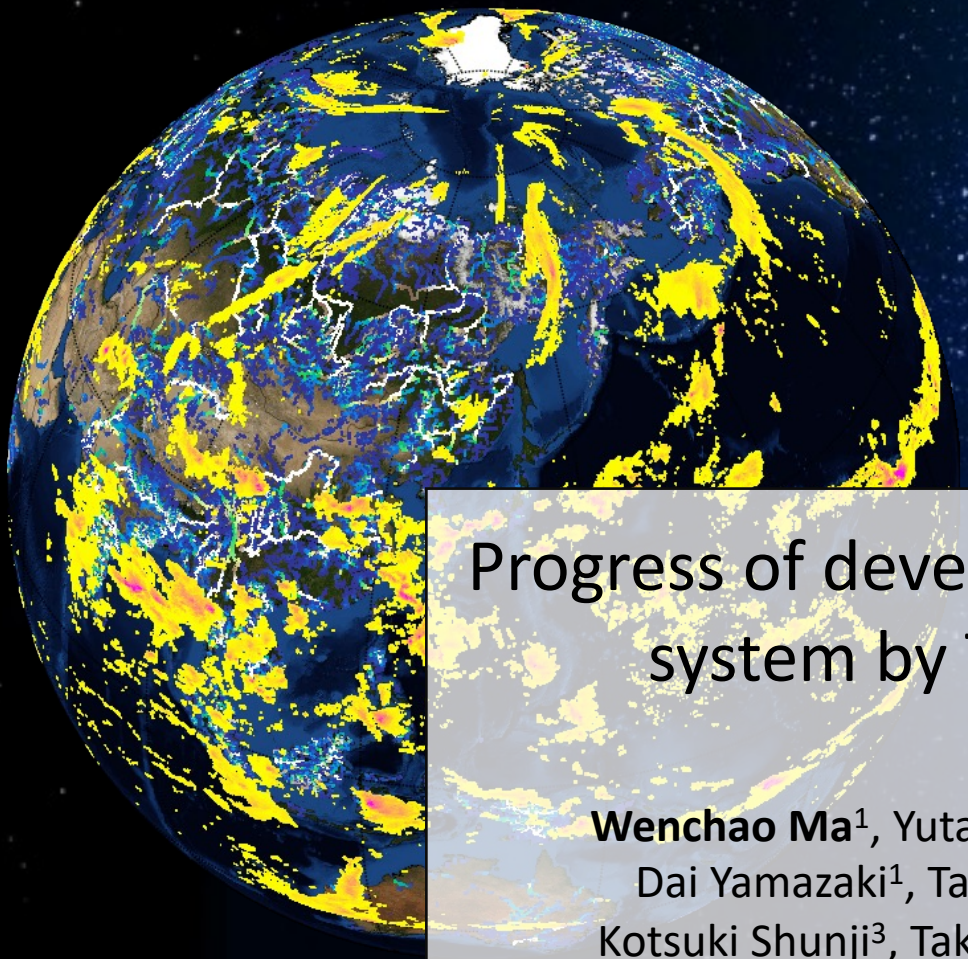
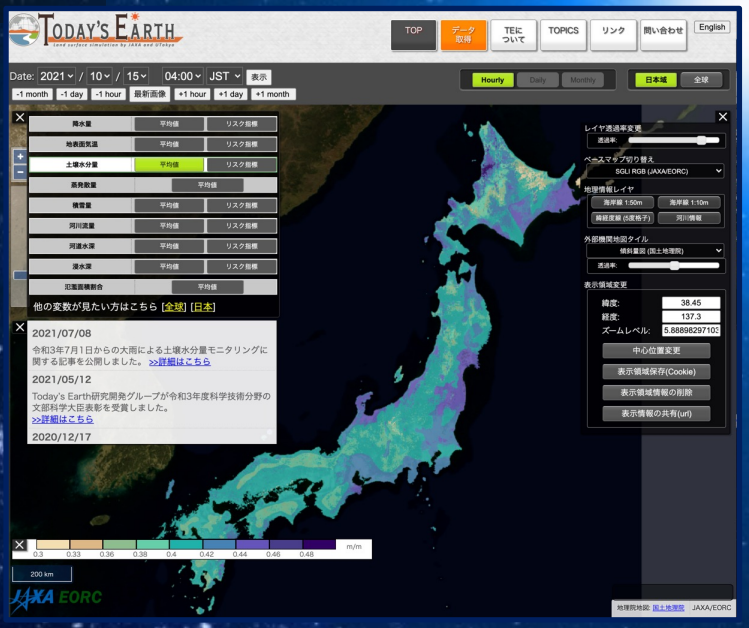


Progress of developing flood forecasting system by Today's Earth (TE)

Wenchao Ma[1], Yuta Ishitsuka[1], Akira Takeshima[1], Kenshi Hibino[1], Dai Yamazaki[1], Taikan Oki[1], Ying- Wen Chen[2], Masaki Satoh[2], Kotsuki Shunji[3], Takemasa Miyoshi[3], Kosuke Yamamoto[4], Misako Kachi[4], Takuji Kubota[4], Riko Oki[4], and Kei Yoshimura[1,4]

[1]The University of Tokyo, Institute of Industrial Science, Japan
[2]The University of Tokyo, Atmosphere and Ocean Research Institute, Japan
[3]RIKEN Center for Computational Science, Japan
[4]Japan Aerospace Exploration Agency (JAXA), Japan

Today's Earth: Global & Japan



Today's Earth versions:

	Experiment	Cov.	Spatial resolution	Temporal resolution	Period	Publication period	Latency	Forcing
TE-Global	JRA-55 ver. (baseline)	Global	0.5-deg. (land) 0.25-deg. (river)	3-hourly, daily, monthly	1958 - present	3-hourly: For the last 13 month daily: For the last 10 year monthly: All	About 3.5 days	Surface meteorological parameters by JRA-55
	GSMaP ver.				2001 - present		About 5 days	Same as JRA-55 ver. except rainfall from GSMaP
	MODIS ver.				2003 - present		About 20 days	Same as JRA-55 ver. except solar radiation from MODIS
	NEXRA_128ens			**fcst. In prep.**	**2019.01 - present**	--	--	**NICAM**
TE-Japan	**MSM/GPV ver.**	Japan	1/60-deg.	**39 hrs fcst.**	**2007 - present**	hourly: For the last 13 month daily: For the last 10 year monthly: All	Realtime	Surface meteorological parameters by MSM/GPV
	Satellite ver.			hourly, daily, monthly	2015 - present		About 9~33 hrs	Surface meteorological parameters by MSM/GPV except solar radiation from Himawar-8
	NEXRA_5^{+}ens			**7 days fcst.**	**2021.10 - present**	--	**About 1 day**	**NICAM**

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

Today's Earth Scheme

TE-Global

Explore Our Changing Planet.

GCOM-W/C(in prep.) GPM — Seattleite Obs. — Terra Aqua

JMA 55-year Reanalysis (JRA-55)

Global Forcing Data
- temperature
- humidity
- wind speed etc.

Global Satellite Data
- precipitation
- DSR etc..

GSMaP precip. — MODIS DSR

Merge Dataset → in

Land Surface Model (MATSIRO)

Surface Hydrological Data
- LST
- Soil Moisture
- Runoff
- Evapotranspiration etc.

out → in

River Routing Model (CaMa-Flood)

River Data
- Discharge
- Flooded Area etc.

out → **Risk Indices**

Validation

Data Distribution through Website

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

TE-Japan

See the Detailed Shape of Japan.

GCOM-W/C(in prep.) GPM — Seattleite Obs. — Himawari-8

JMA Weather Forecast (MSM/GPV)

Forcing Data
- temperature
- humidity
- wind speed etc.

Satellite Data
- precipitation
- DSR etc..

GSMaP precip. — Himawari DSR

Merge Dataset → in

Land Surface Model (MATSIRO)

Surface Hydrological Data
- LST
- Soil Moisture
- Runoff
- Evapotranspiration etc.

out → in

River Routing Model (CaMa-Flood)

River Data
- Discharge
- Flooded Area etc.

out → **Risk Indices**

Validation

Data Distribution through Website

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

Figure. Schematic figure of TE system.

MATSIRO (Takata et al., 2003), **ILS** (Nitta et al., 2014); **CaMa-Flood**: http://hydro.iis.u-tokyo.ac.jp/~yamadai/cama-flood/

Today's Earth Outputs

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

Model/Category		Variable Name	Item Name	Unit (netCDF)
Forcing		rainfall	GPRCT	kg/m^2/s
		snowfall	GSNWL	kg/m^2/s
		eastward wind	GDU	m/s
		northward wind	GDV	m/s
		surface air temperature	GDT	K
		specific humidity	GDQ	kg/kg
		surface shortwave radiation (downward)	SSRD	W/m^2
		surface longwave radiation (downward)	SLRD	W/m^2
		surface air pressure	GDPS	hPa
MATSIRO	Water balance (State)	soil moisture (at each level) [Z1-Z6][*1]	GLW	kg/m^2
		soil moisture (total volume)	GLWtot	kg/m^2
		canopy water	GLWC	kg/m^2
		snow amount	GLSNW	kg/m^2
	Water balance (Flux)	snow melt	SNMLT	kg/m^2/s
		snow freeze	SNFRZ	kg/m^2/s
		snow sublimation	SNSUB	kg/m^2/s
		ice melt	ICEMLT	kg/m^2/s
		ice sublimation	ICESUB	kg/m^2/s
		snow & ice sublimation	SSUB	kg/m^2/s
		transpiration	ETFLX	kg/m^2/s
		canopy evaporation	EIFLX	kg/m^2/s
		canopy sublimation	EISUB	kg/m^2/s
		soil evaporation	EBFLX	kg/m^2/s
		soil sublimation	EBSUB	kg/m^2/s
		total runoff (total) [W1-W2][*4]	RUNOFF	kg/m^2/s
		base runoff	RUNOFFB	kg/m^2/s
		surface runoff	SRUNOF	kg/m^2/s
		runoff (lake & land) [W1-W2][*4]	RUNOFFA	kg/m^2/s
	Heat balance (State)	soil temperature [Z1-Z6][*1]	GLG	K
		snow temperature [L1-L3][*2]	GLTSN	K
		land skin temperature [C1-C2][*3]	GLTS	K
		canopy temperature [C1-C2][*3]	GLTC	K
	Heat balance (Flux)	soil heat flux	GFLUXS	W/m^2
		snow surface heat flux	SNFLXS	W/m^2
		ground heat flux in total	GFLXTL	W/m^2
		surface shortwave radiation (upward)	SSRU	W/m^2
		surface longwave radiation (upward)	SLRU	W/m^2
		sensible heat flux	SENS	W/m^2
		latent heat flux	LTNT	W/m^2
		latent heat flux (evaporation)	EVAP	W/m^2
	River	river flow [W1-W2][*4]	RFLOW	m^3/s
		river water [W1-W2][*4]	GDRIV	kg/m^2
		river storage [W1-W2][*4]	GDRIVL	kg/m^2
	Others	snow covered fraction	SNRAT	-
		albedo	ALB	-
		snow albedo [A1-A3][*5]	GLASN	-
		soil potential [Z1-Z6][*1]	GPSI	Pa
		dust density in snow [L1-L3][*2]	CDSTM	ppmw
		water flux atmosphere to land	WA2L	m/s
		water flux land to river	WL2R	m/s
		soil ice (at each level) [Z1-Z6][*1]	GLFRS	m/m
		soil ice (total volume)	GLFRStot	kg/m^2
		land water	WLND	m
		inland water sinkbudget	BUDIND	kg/m^2/s
		distributed water sinkbudget	RBUDIND	kg/m^2/s
		ground water input	WINPT	kg/m^2/s
		lake sh	SHLK	cm
		lake surface temperature	TSIL	℃
CaMa-Flood		river discharge	RIVOUT	m^3/s
		river water storage	RIVSTO	m^3
		river water depth	RIVDPH	m
		river flow velocity	RIVVEL	m/s
		floodplain flow (discharge)	FLDOUT	m^3/s
		floodplain water storage	FLDSTO	m^3
		floodplain water depth	FLDDPH	m
		flood area	FLDARE	m^2
		flood fraction	FLDFRC	-
		water surface elevation	SFCELV	m
		total discharge (RIVOUT + FLDOUT)	OUTFLW	m^3/s
		total storage (RIVSTO + FLDSTO)	STORGE	m^3

1. Z1-Z6 represents the soil layers, the depth (m) of which is Z1: 0 - 0.05, Z2: 0.05 - 0.25, Z3: 0.2
   1, Z4: 1 - 2, Z5: 2 - 4, and Z6: 4 - 14.
2. L1-L3 represents the snow layers. The number of the effective layers and their depth are varia
   See Takata et al. (2003) for more details.
3. C1 and C2 represent the outputs for snow-free canopy and snow-covered canopy, respectivel
4. W1 and W2 represent the values regarding water and ice, respectively.
5. A1, A2 and A3 represent the snow albedo of visible, near-infrared and infrared area, respectiv

Figure. Hydrological variables of TE system (https://www.eorc.jaxa.jp/water/index.html).

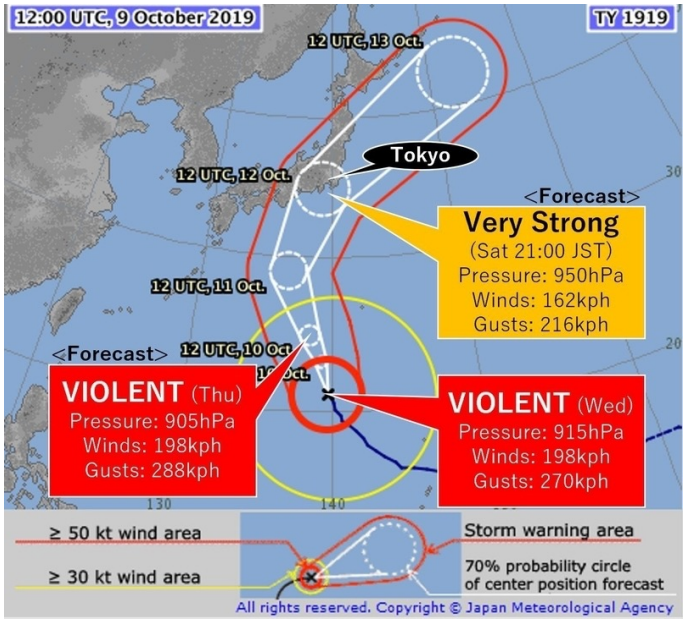
➢ Flood Forecasting, an application of TE

➢ Typhoon Hagibis, 2019

Source: Wikipedia

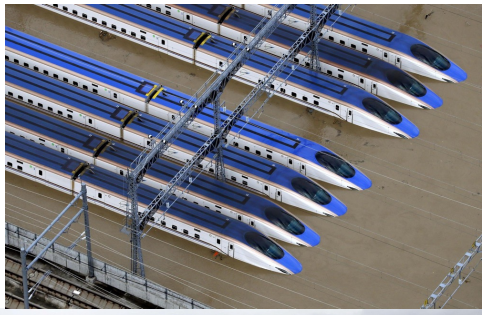
Fatalities	98 total, 7 missing
Damage	$15 billion USD (2019)
Areas Affected	Mariana Islands, Japan, Russia, Alaska

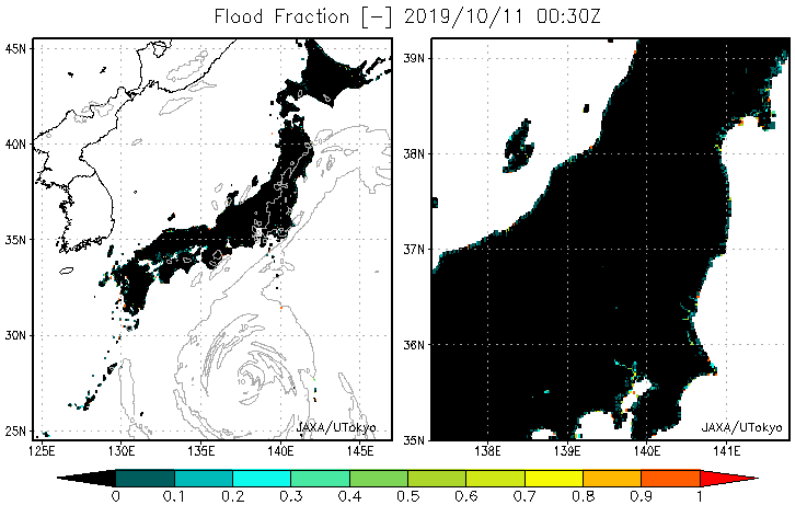
Source: JMA



Damage by flood

Source: Nikkei.com



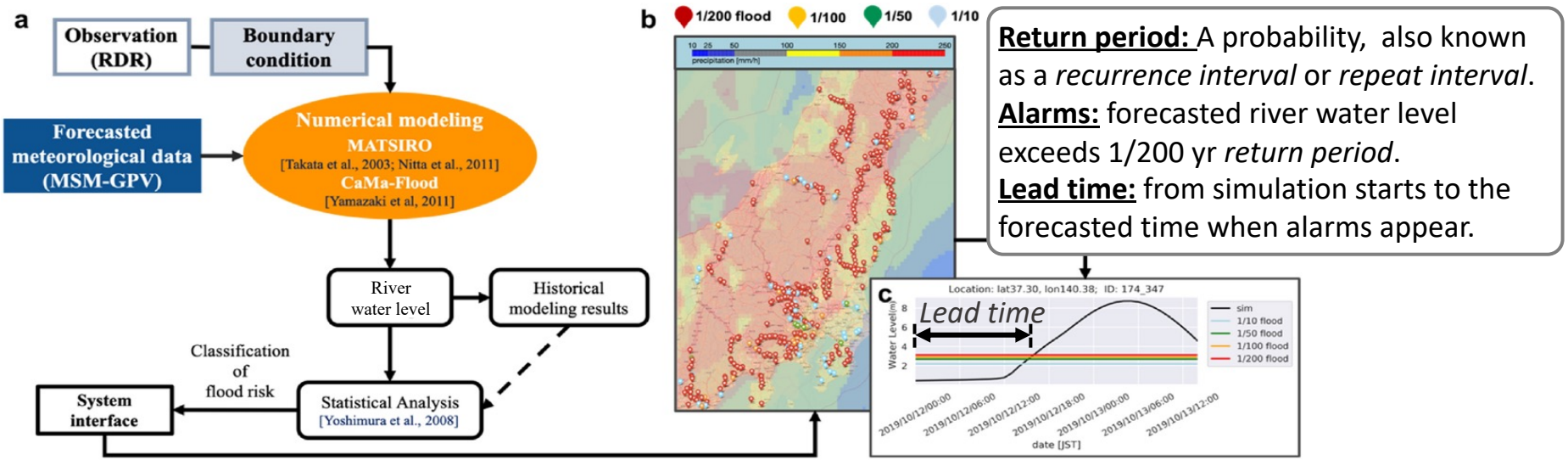


Courtesy of Hibino k. (Univ. Tokyo), *Today's Earth*

➢ Flood Forecasting, an application of TE

➢ Methods

http://apps.diasjp.net/tdjpn/training/latest/jpn.html



Return period: A probability, also known as a *recurrence interval* or *repeat interval*.
Alarms: forecasted river water level exceeds 1/200 yr *return period*.
Lead time: from simulation starts to the forecasted time when alarms appear.

Fig. Schematic of the flood forecasting system. (**a**) Flowchart of the flood forecasting system. (**b**) Snapshot of the system interface at 00:00 JST on Oct. 12, 2019 for Typhoon Hagibis.

➢ Data preparation: forecing + observation/calibration

Meteorological data (JMA)	MSM-GPV (Meso Scale Model – Grid Point Value) + RDR **Prediction length: 39 hour**
Model (UT)	MATSIRO (Land surface model) + CaMa-Flood (catchment-based macroscale floodplain model) **Resolution: 0.05°**
Validation data (MLIT)	Dike break list (April 10th 9:00 am.) (https://www.mlit.go.jp/common/001313204.pdf) **Geographic coordinates and timing of the dike break (DBT)**

Ma, W., Ishitsuka, Y., Yoshimura, K. *et al.*, Applicability of a nationwide flood forecasting system for Typhoon Hagibis, *Sci. Rep.* 2021.

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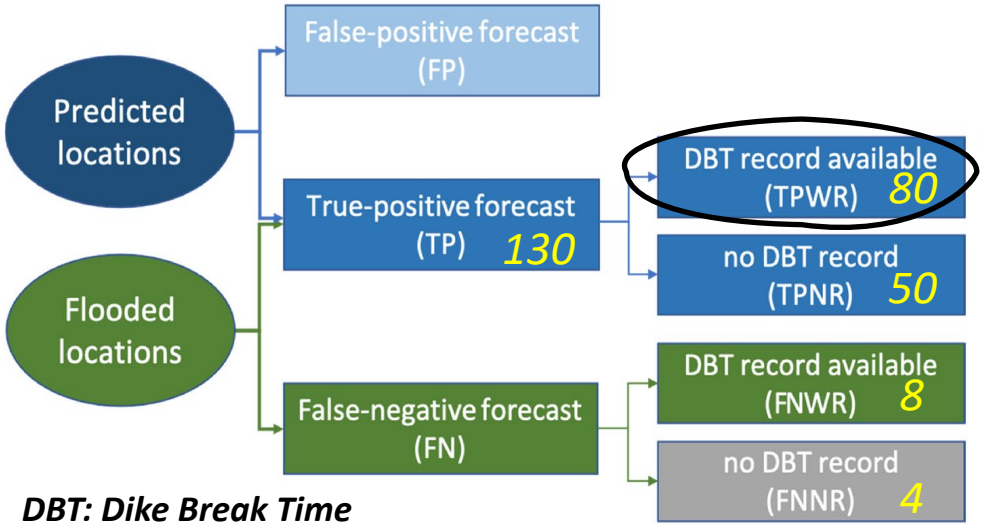
➢ Flood Forecasting, an application of TE

- Accurate predicted locations: 130, which is 91.6% of 142 real flooded locations (MLIT).
- TPWR, true-positive with DBT record (successfully predicted, 80 spots).
- TPNR, true-positive without DBT record (50 spots).
- FNNR indicates false-negative sites with no DBT records (blue diamonds, 8 spots).
- FNWR indicates false-negative locations with DBT records (blue crosses, 4 spots).



DBT: Dike Break Time

Fig. Classification of flood locations related to Typhoon Hagibis.

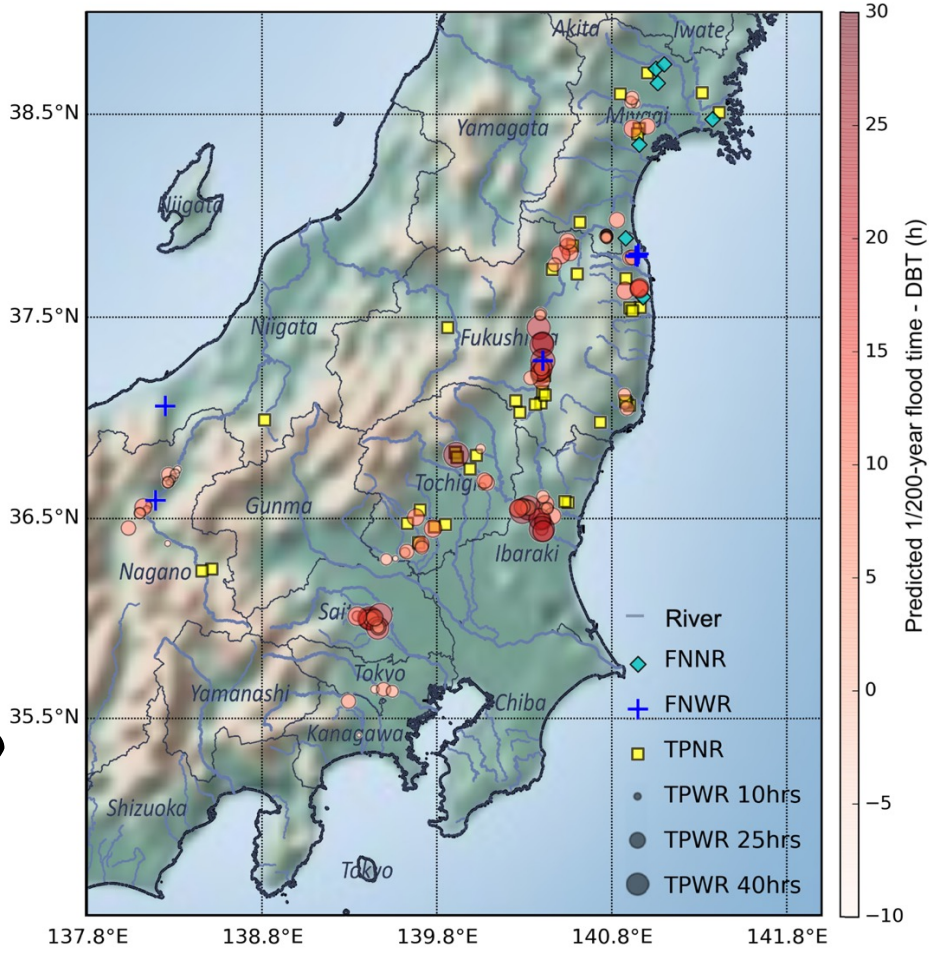
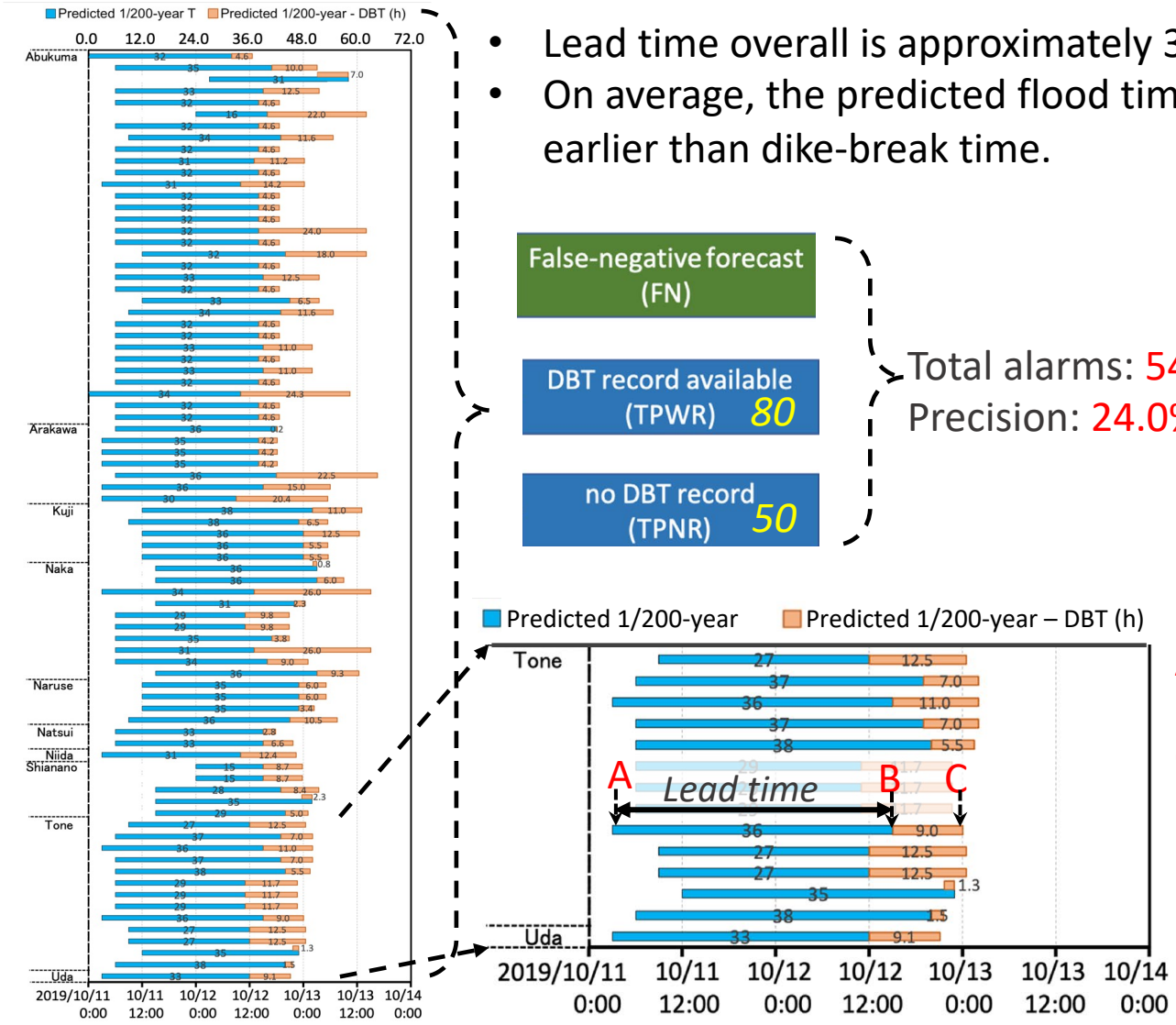


Fig. Lead time and distribution for the 142 locations. The color of the circle indicates how much the predicted 1/200-year flood time preceded the DBT at a given location. The size of the circle indicates the lead time.

➢ Flood Forecasting, an application of TE



- Lead time overall is approximately 32.75 h.
- On average, the predicted flood time was approximately 8.53 h earlier than dike-break time.

False-negative forecast (FN)

DBT record available (TPWR) 80

no DBT record (TPNR) 50

Total alarms: 542 locations
Precision: 24.0% (130/542)

A: simulation start (1st alarm)
B: predicted 1/200-year food time
C: dike break time

Fig. Comparison of predicted 1/200-year flood times and DBTs. The vertical axis shows the location of each flooded river. Each blue bar begins at the time when a 1/200-year flood was first predicted by the system.

Ma, W., Ishitsuka, Y., Yoshimura, K. *et al.* Scientific Reports. 2021. **Applicability of a nationwide flood forecasting system for Typhoon Hagibis**

➢ Flood Forecasting, an application of TE

➢ River in high risk

- The total alarms are 542 locations, distributed in 21 real flooded 1st level rivers (red), and 4 not flooded (blue).
- Observation shortages may lead to underestimating the accuracy of modeling and cause deviations in the validity of forecasted results.

➢ Q: How to improve FFS?

1. Meteological forcing data:
   resolution, accuracy
2. Model:
   resolution, accuracy
3. Lead time:
   data preparation, transfer, simulation
4. Ensemble method:
   MEPS-GPV (Sayama *et al.*, 2020)
   NICAM/TE-NEXRA
5. Observation/Validation:
   powerful in-situ device? Satellite image?

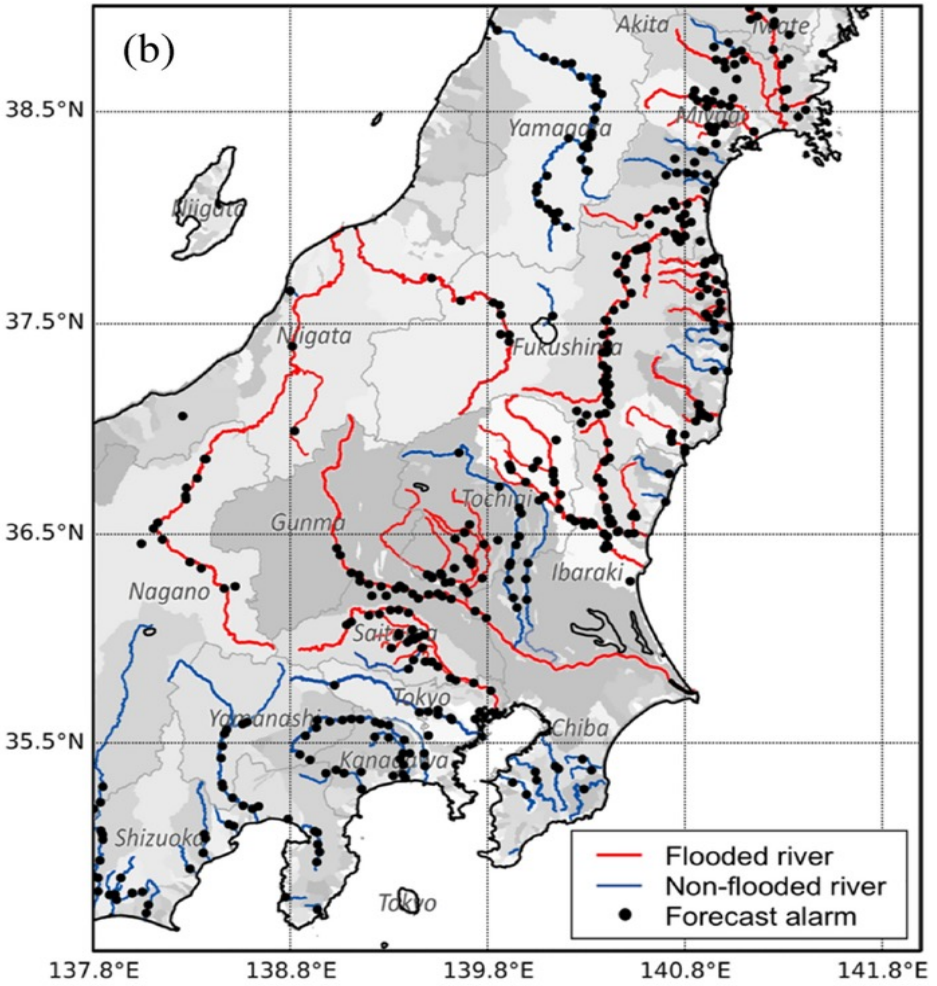
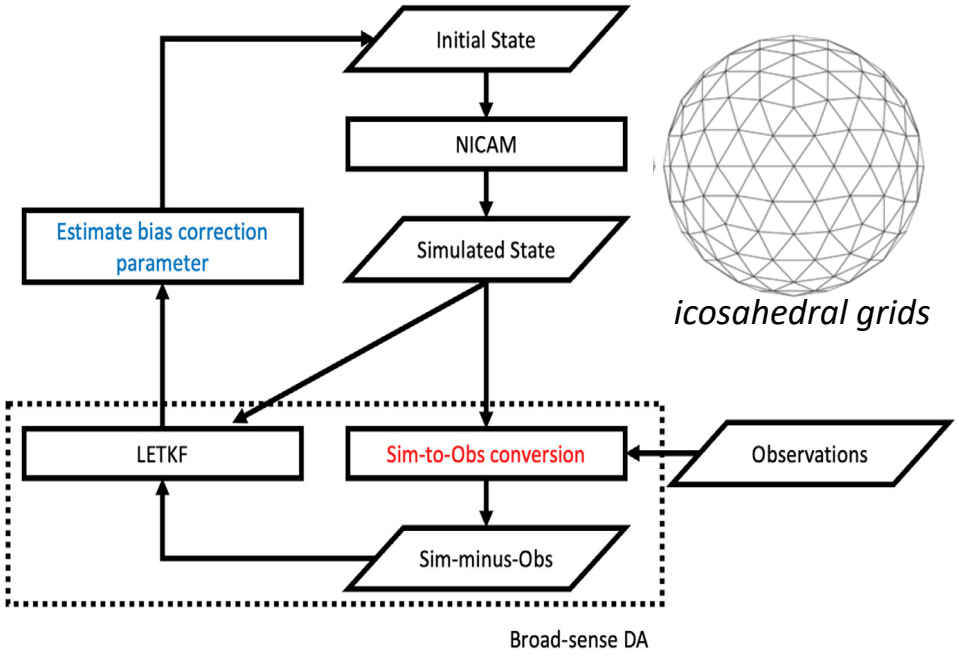


Fig. The spatial distribution of forecast alarms and flooded major rivers due to Typhoon 19.

➢ Development of Ensemble Flood Forecasting System: TE-NEXRA

NEXRA (NICAM-LETKF JAXA Research Analysis) which JAXA has jointly developed with the University of Tokyo and RIKEN, combining satellite data and numerical weather models.

NICAM: The Non-hydrostatic **Icosahedral** Atmospheric Model (Tomita and Satoh 2004; Satoh et al. 2008; Satoh 2013).



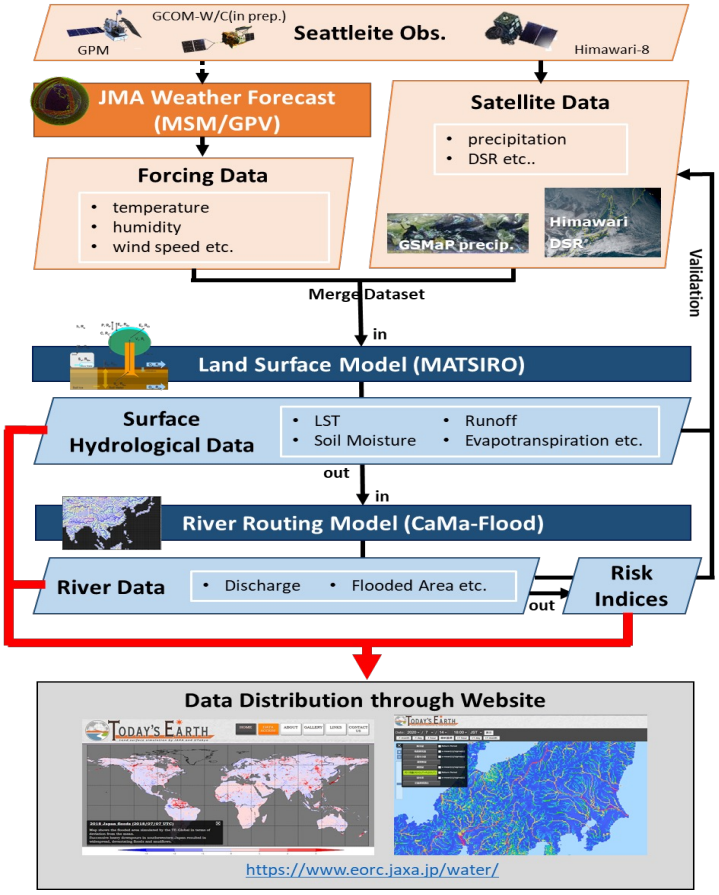
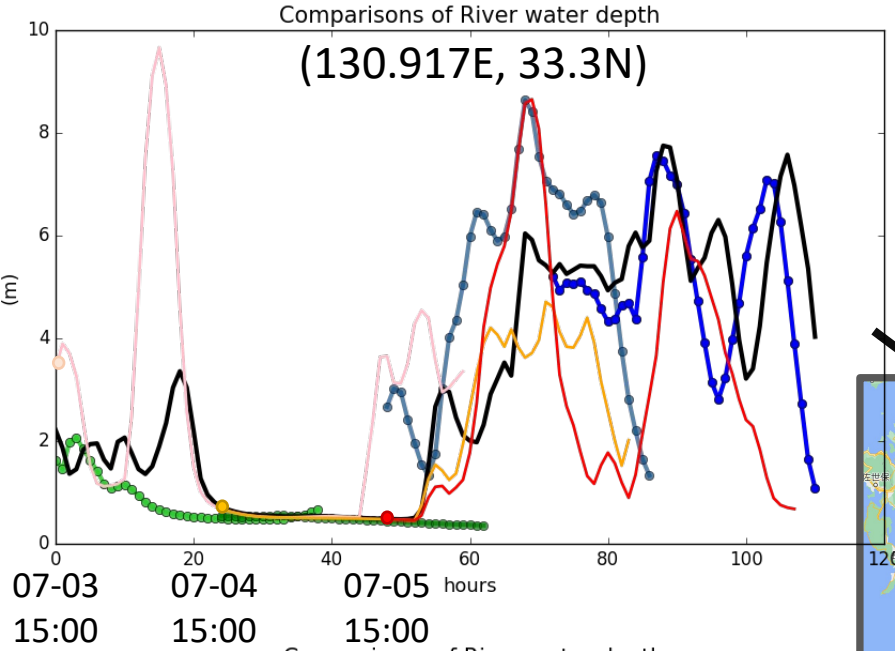
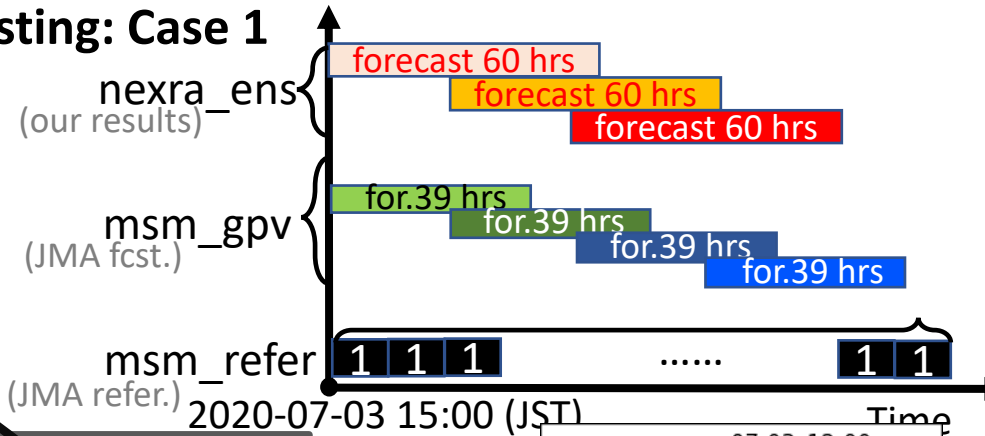
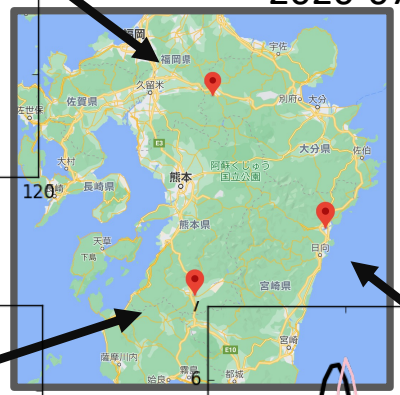


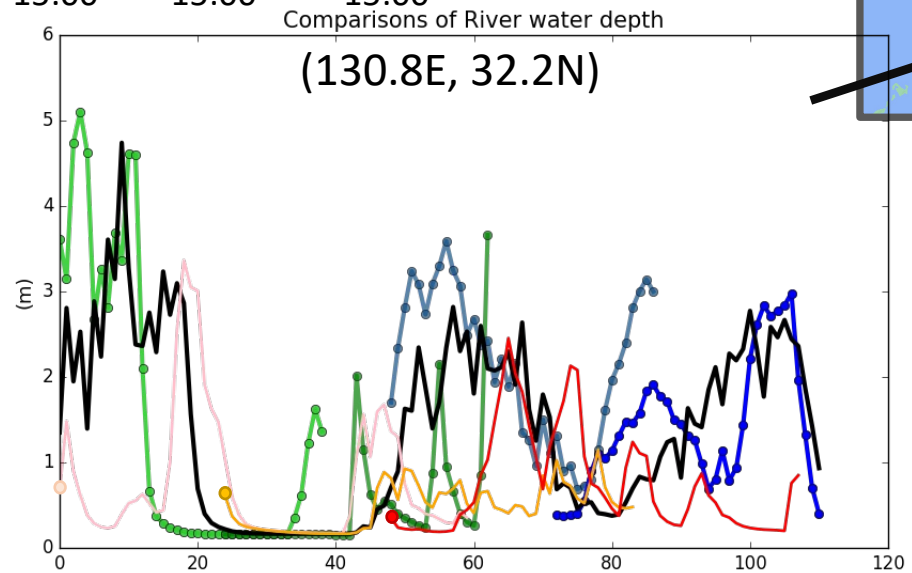
Fig. Flowchart of the NICAM-LETKF system (Terasaki et al., 2015). LETKF, Local Ensemble Transform Kalman Filter; NICAM, Nonhydrostatic ICosahedral Atmospheric Model (Miyoshi et al., Precipitation Science, p787-804, 2022).

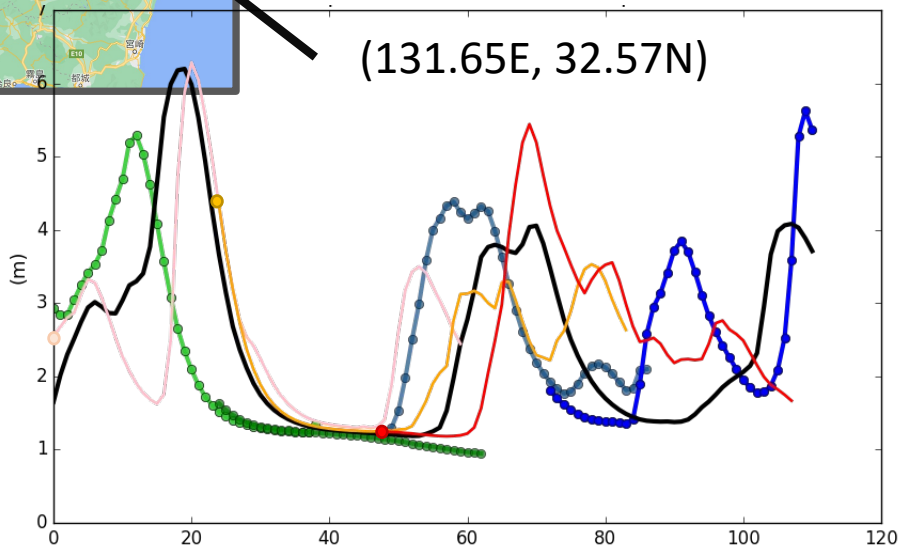
➢ River depth, 5ensemble, 7days forecasting: Case 1

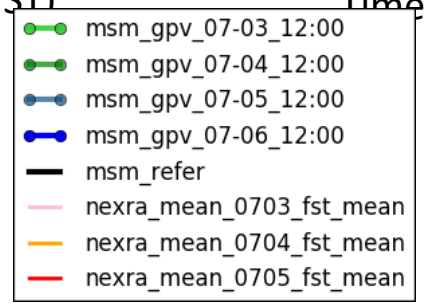










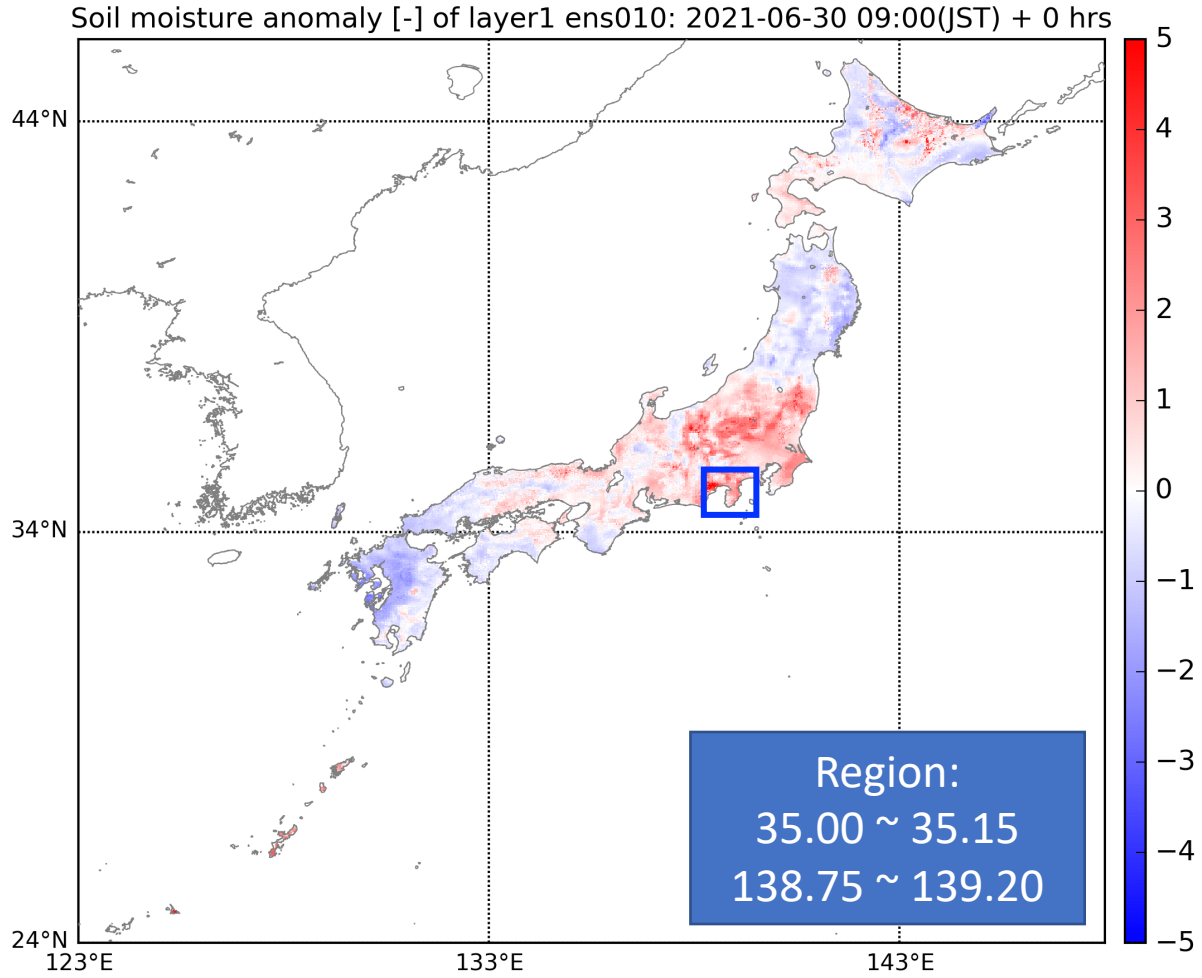


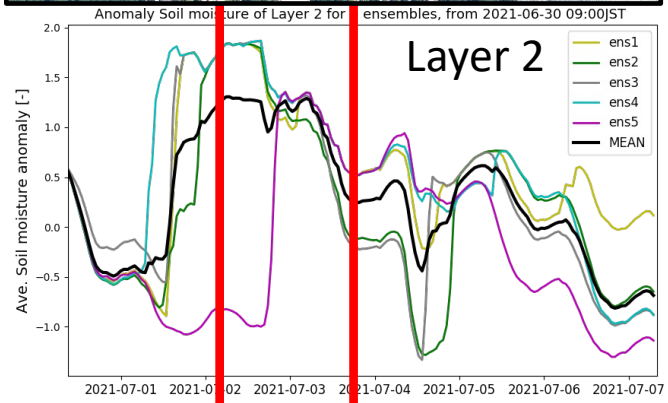
➢ Soil moisture, 5ensemble, 7days forecasting: Case 2

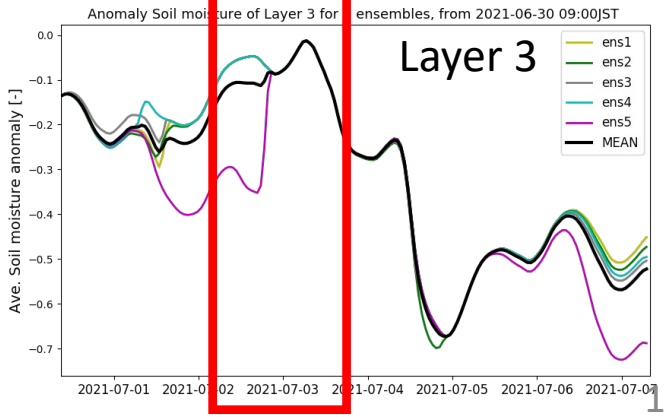
- ➢ Atami landslide: 2021-07-03 10:30 a.m.
- ➢ Results: 2021-06-30 → 2021-07-02

Soil moisture anomaly: (x - mean(x)) / sigma(x)

MSM-GPV







Thank you for listening!

TODAY'S EARTH
Land surface simulation by JAXA and UTokyo

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

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