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Advancing nearshore and onshore tsunami hazard approximation with machine learning surrogates

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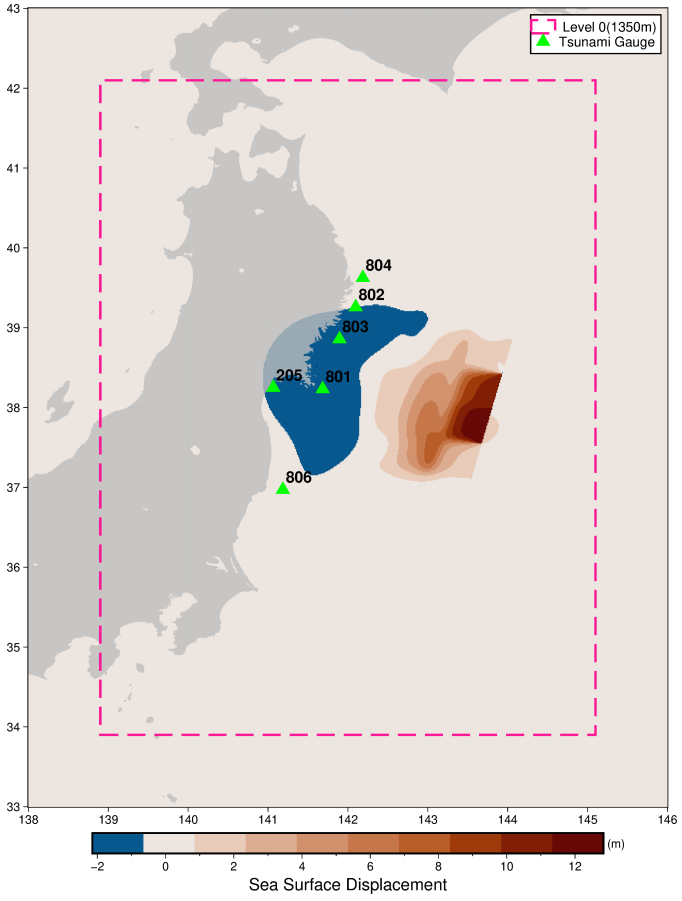
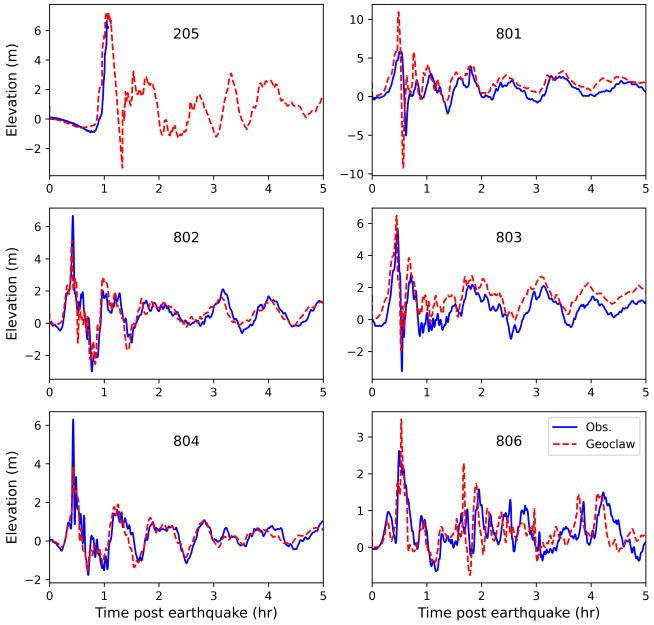
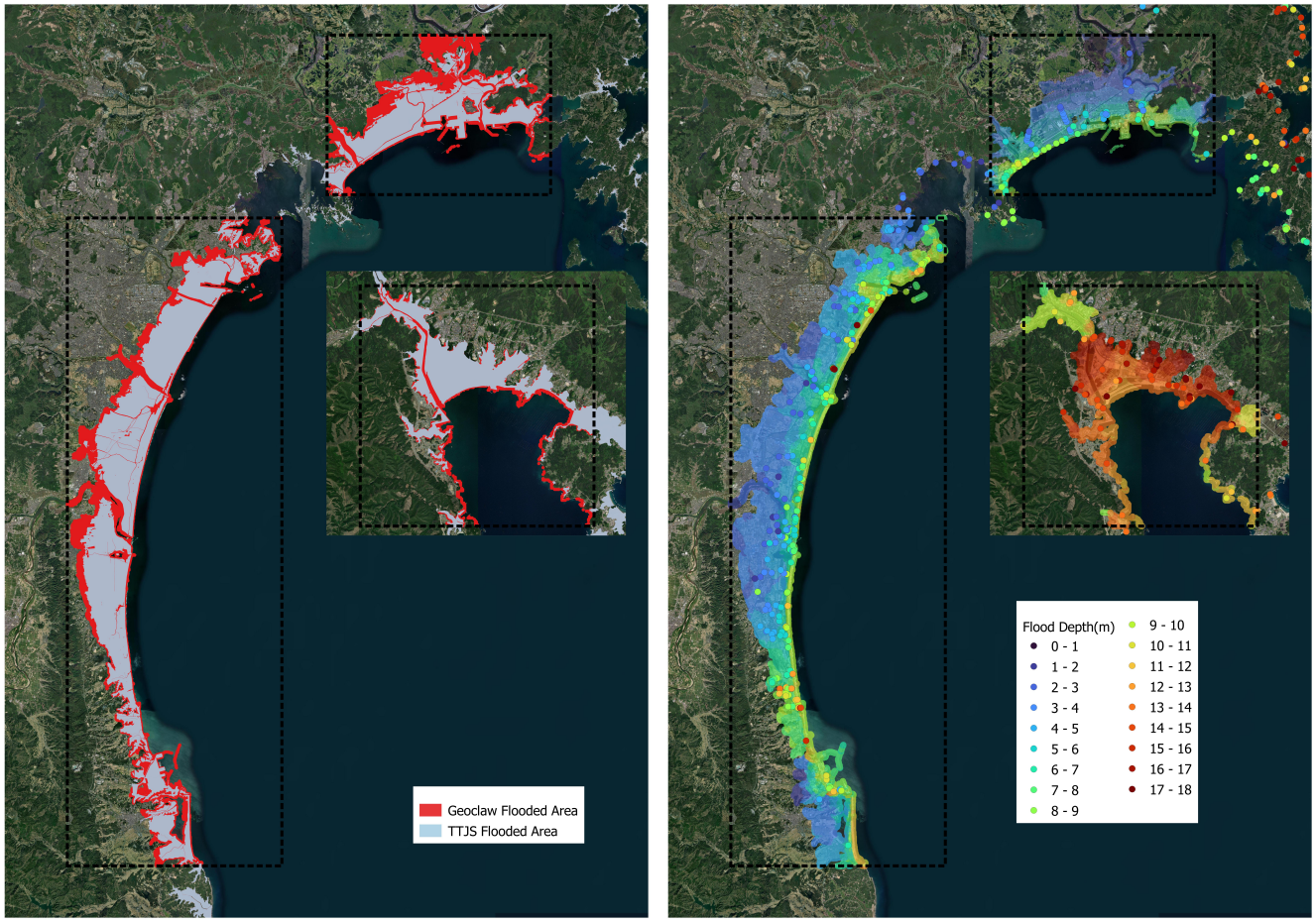


(a) Initial Displacement



(b) Waveforms at gauge site marked in figure 3a

Figure S1. Plots of simulated tsunami inundation using source (Fujii et al., 2011) compared to the actual observation for the 2011 Tohoku tsunami event



(a) Flooded Area

(b) Flooded Depth

Figure S2. Plots of simulated tsunami inundation using source (Fujii et al., 2011) compared to the actual observation for the 2011 Tohoku tsunami event.(Basemap from ESRI World Imagery)

Surrogate architecture and configuration

Table S1. Model Parameters of the VED network - Nearshore

Layer Number	Layer Type	Input Channels or Size	Output Channels or Size	Activation	Pooling Operation
Offshore Encoder					
1	Conv1d	input	64	Leaky ReLU (0.5)	MaxPool1d (2x2)
2	Conv1d	64	64	Leaky ReLU (0.5)	MaxPool1d (2x2)
3	Conv1d	64	128	Leaky ReLU (0.5)	MaxPool1d (2x2)
4	Conv1d	128	128	Leaky ReLU (0.5)	MaxPool1d (2x2)
5	Linear	[8192]	[2 x Zdim]		
Variational Encoding					
6	Reparametrise	[2 x Zdim]	[Zdim]		
Nearshore Decoder					
7	Linear	[Zdim]	[128 x 64]		
8	ConvTranspose1d	128	128	Leaky ReLU (0.5)	MaxPool1d (2x2)
9	ConvTranspose1d	128	64	Leaky ReLU (0.5)	MaxPool1d (2x2)
10	ConvTranspose1d	64	64	Leaky ReLU (0.5)	MaxPool1d (2x2)
11	ConvTranspose1d	64	output	Leaky ReLU (0.5)	MaxPool1d (2x2)

Table S2. Model Parameters of the VED network - Onshore

Layer Number	Layer Type	Input Channels [Size]	Output Channels [Size]	Activation	Pooling Operation	Other Operations
			Offshore Encoder			
1	Conv1d	input	64	Leaky ReLU (0.5)	MaxPool1d (4x4)	BatchNorm1d
2	Conv1d	64	64	Leaky ReLU (0.5)	MaxPool1d (4x4)	
3	Conv1d	64	128	Leaky ReLU (0.5)	MaxPool1d (4x4)	
4	Conv1d	128	128	Leaky ReLU (0.5)	MaxPool1d (4x4)	Dropout (0.1)
5	Linear	[512]	[2 x Zdim]			
			Variational Encoding			
6	Reparametrise	[2 x Zdim]	[Zdim]			
			Onshore Decoder			
7	Linear	[Zdim]	[64]			
8	Linear	[64]	output			

Performance metrics for the generalisation test using historic events

Table S3. Model performance statistics for different events at various sites using the mean prediction from the nearshore surrogate.

Site	Event	G	R^2	MSE	L2Norm
Rikuzentakata	FUJI2011_42	0.106	0.18	10.196	125.919
	SANRIKU1896	0.17	0.508	0.246	22.612
	SANRIKU1933	0.2	0.419	0.717	35.587
	TOKACHI1968	0.046	0.895	0.201	44.266
	YAMAZAKI2018	0.058	0.566	4.044	106.158
Ishinomaki	FUJI2011_42	0.099	0.562	1.727	83.648
	SANRIKU1896	0.433	0.378	0.012	4.404
	SANRIKU1933	0.145	0.777	0.037	13.236
	TOKACHI1968	0.173	0.672	0.012	6.189
	YAMAZAKI2018	0.066	0.836	0.533	60.553
Sendai	FUJI2011_42	0.068	0.759	1.395	80.902
	SANRIKU1896	0.506	0.251	0.02	5.292
	SANRIKU1933	0.325	0.431	0.1	13.566
	TOKACHI1968	0.312	0.441	0.022	6.322
	YAMAZAKI2018	0.144	0.507	1.724	61.162

Table S4. Model performance statistics for different events at various sites using the mean prediction from the onshore surrogate.

Site	Event	G	R^2	MSE	L2Norm
Rikuzentakata	FUJI2011_42	0.028	0.842	3.774	706.438
	SANRIKU1896	0.147	0.683	0.051	33.559
	SANRIKU1933	0.246	0.102	0.474	61.982
	TOKACHI1968	0.464	0.461	0.105	37.078
	YAMAZAKI2018	0.017	0.918	1.213	511.5
Ishinomaki	FUJI2011_42	0.285	0.262	3.712	747.957
	SANRIKU1896	0.275	-0.684	0.001	6.475
	SANRIKU1933	0.097	0.691	0.003	24.125
	TOKACHI1968	0.161	0.48	0.001	9.82
	YAMAZAKI2018	0.041	0.896	0.158	337.745
Sendai	FUJI2011_42	0.153	0.429	2.575	1233.79
	SANRIKU1896	0.178	0.688	0.004	39.573
	SANRIKU1933	0.06	0.879	0.004	61.973
	TOKACHI1968	0.105	0.679	0.001	14.827
	YAMAZAKI2018	0.166	0.528	2.256	1108.09

Predictions for Ishinomaki and Sendai

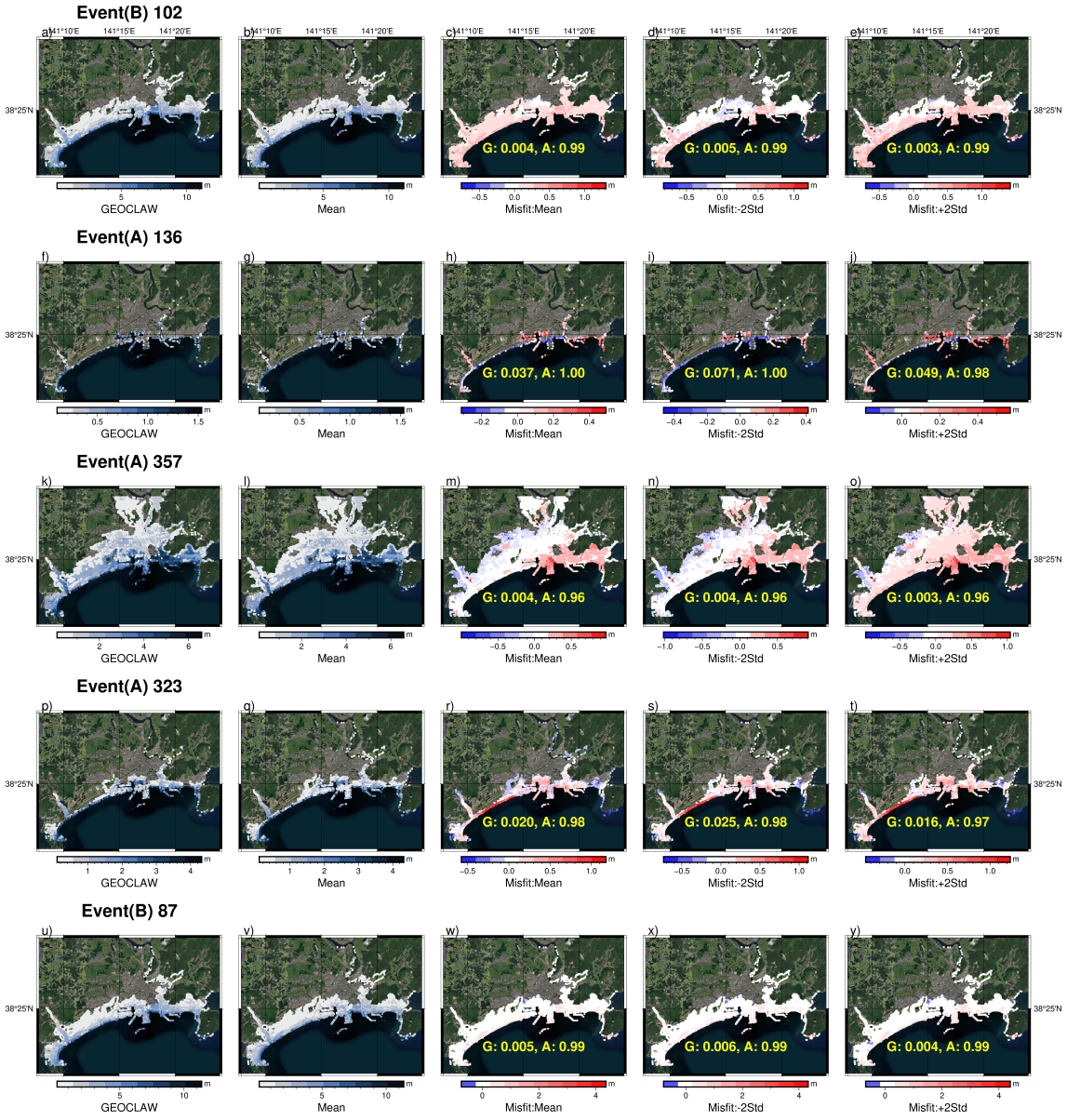


Figure S3. Prediction examples from the onshore surrogate at Ishinomaki for the test events.(Basemap from ESRI World Imagery)

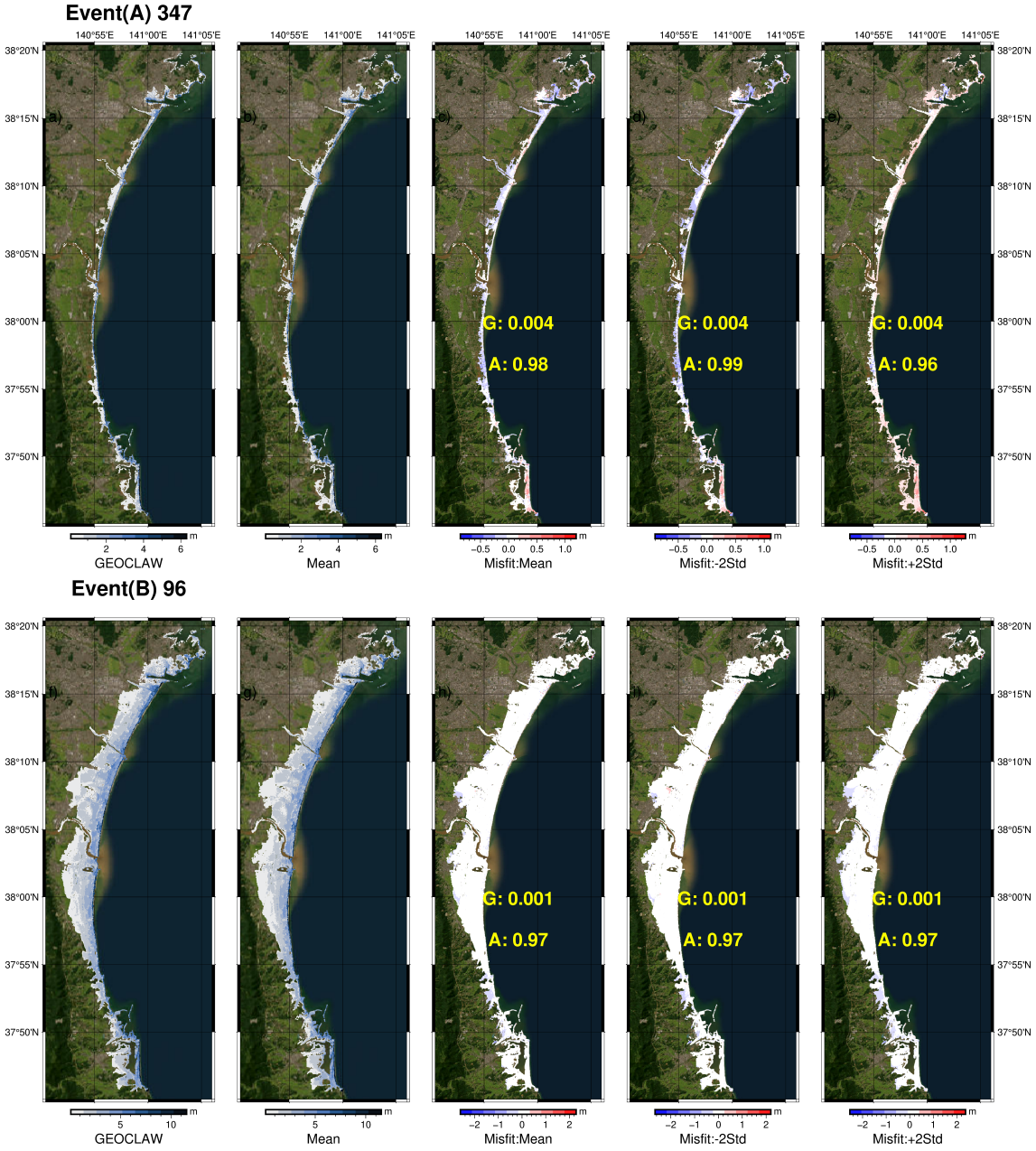


Figure S4. Prediction examples from the onshore surrogate at Sendai for the test events.(Basemap from ESRI World Imagery)

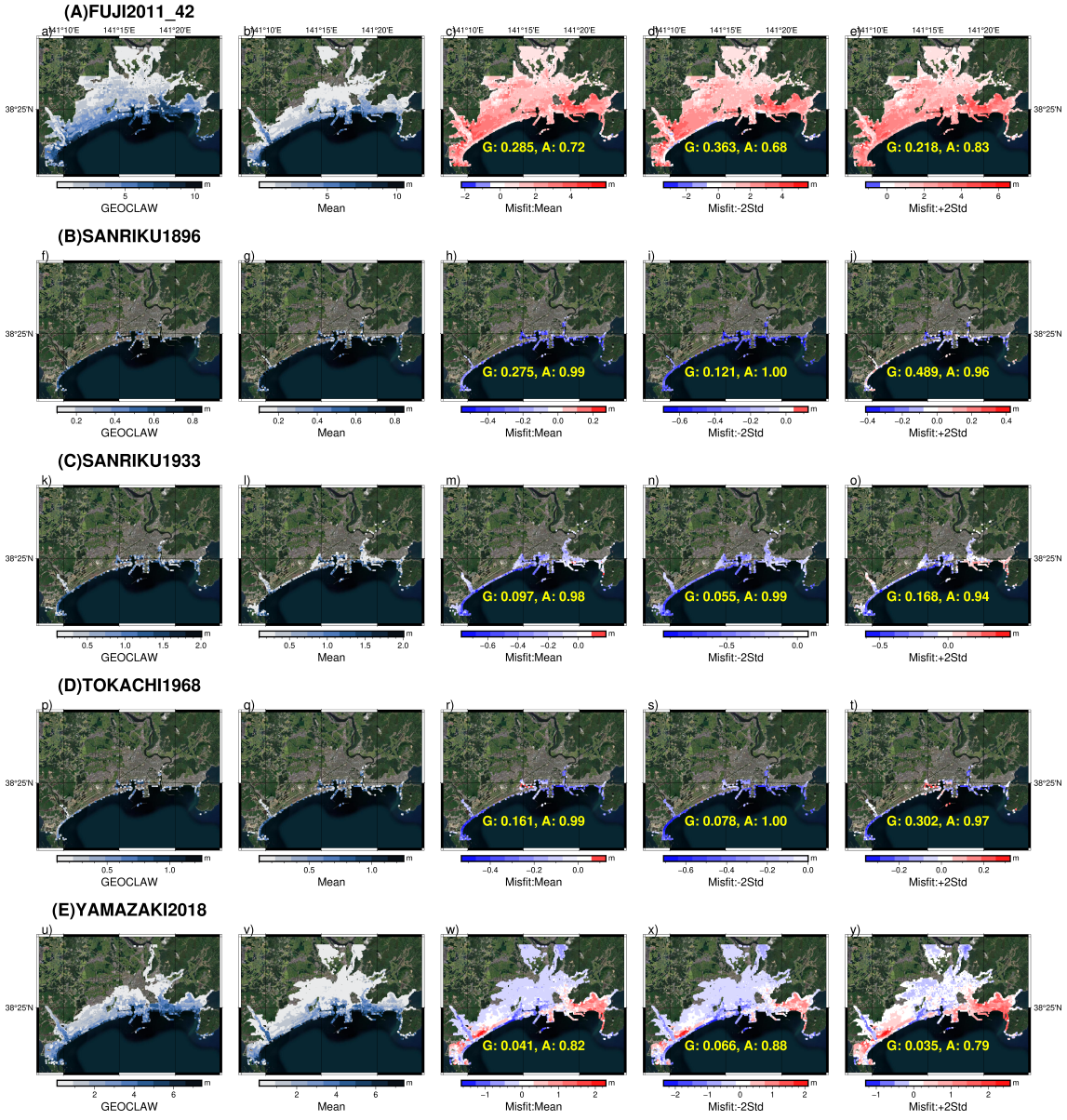


Figure S5. Historical prediction from the onshore surrogate at Ishinomaki.(Basemap from ESRI World Imagery)

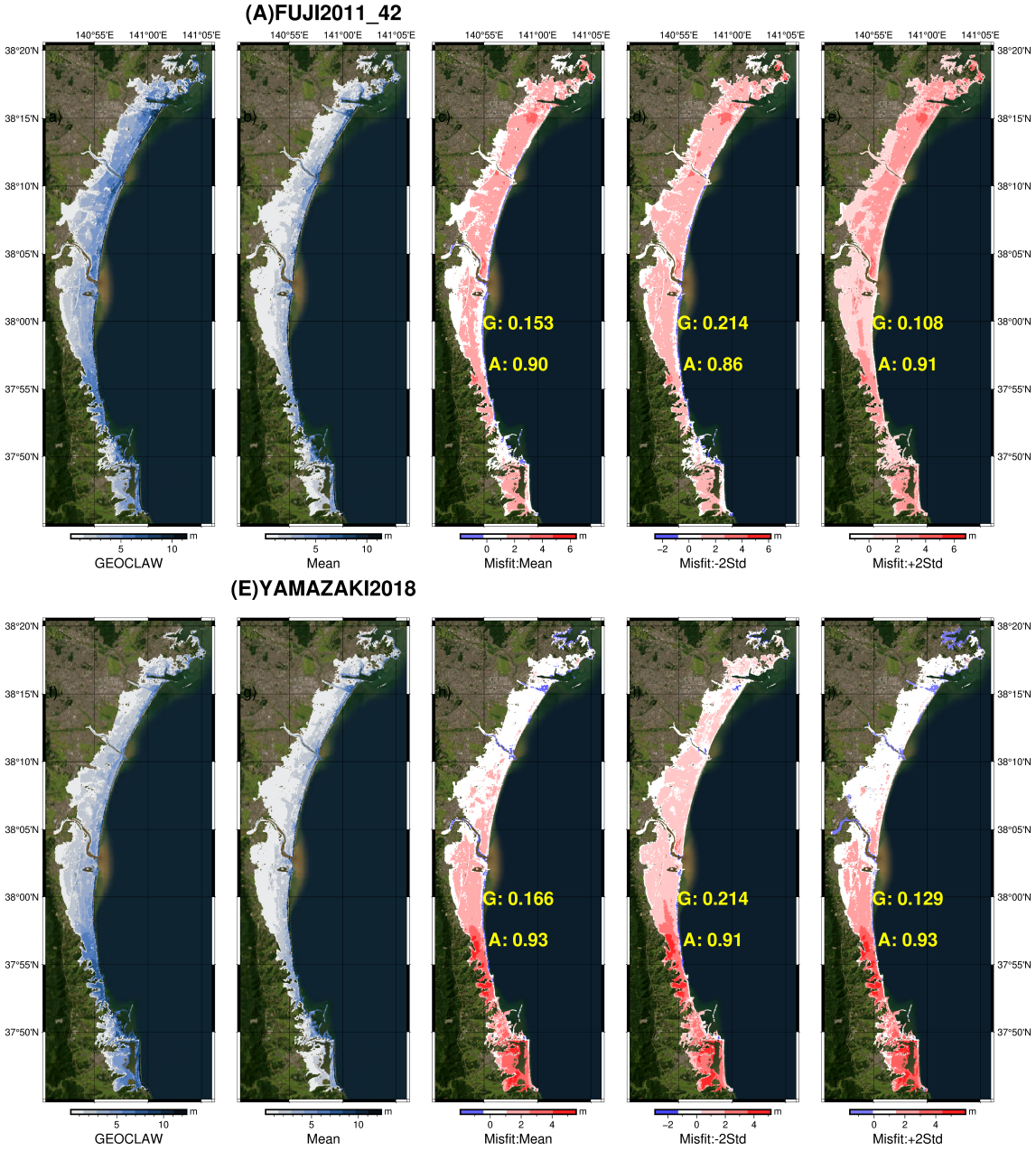


Figure S6. Historical prediction for 2011 Tohoku events from the onshore surrogate at Sendai.(Basemap from ESRI World Imagery)

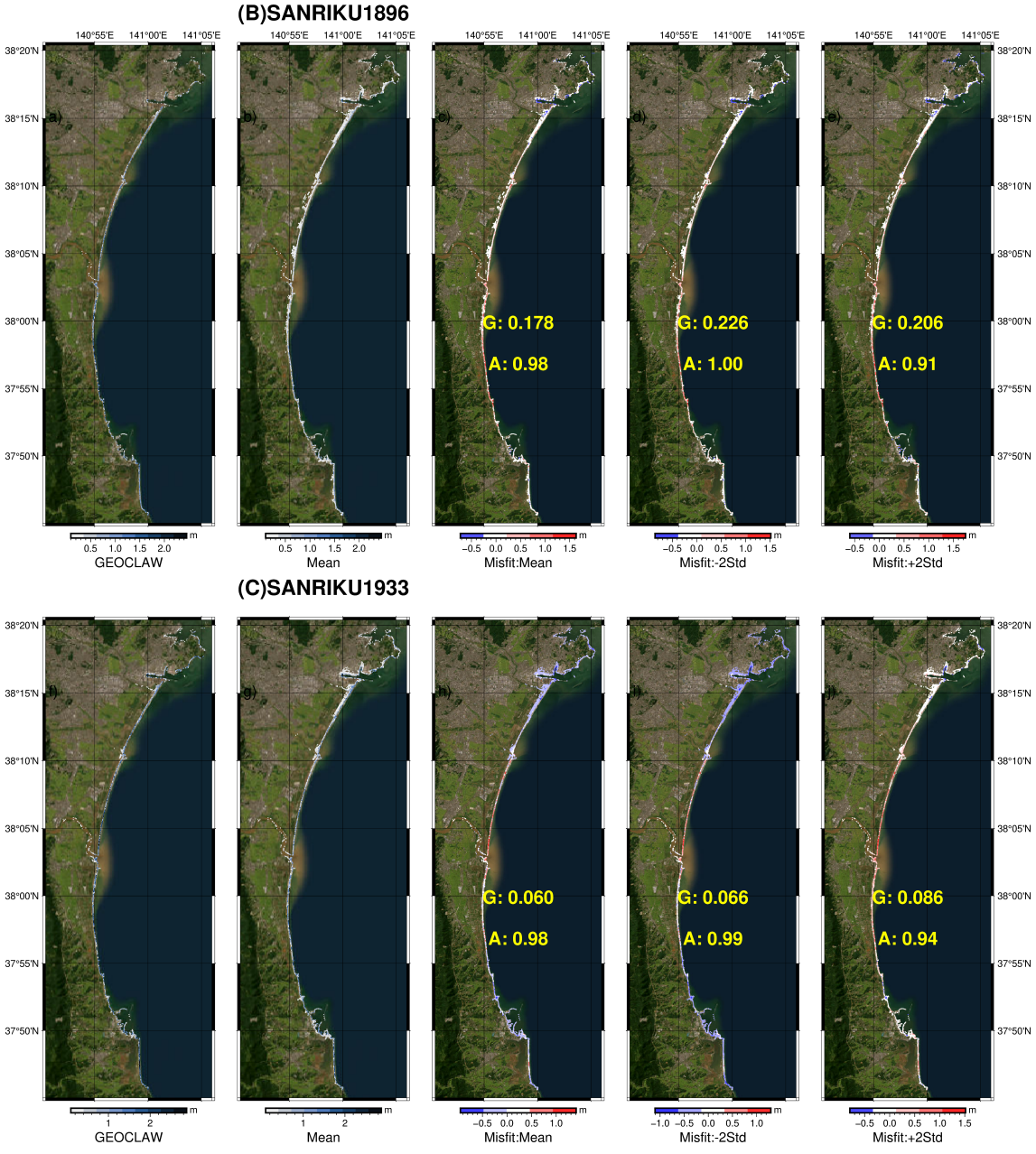


Figure S7. Historical prediction for the Sanriku events from the onshore surrogate at Sendai.(Basemap from ESRI World Imagery)

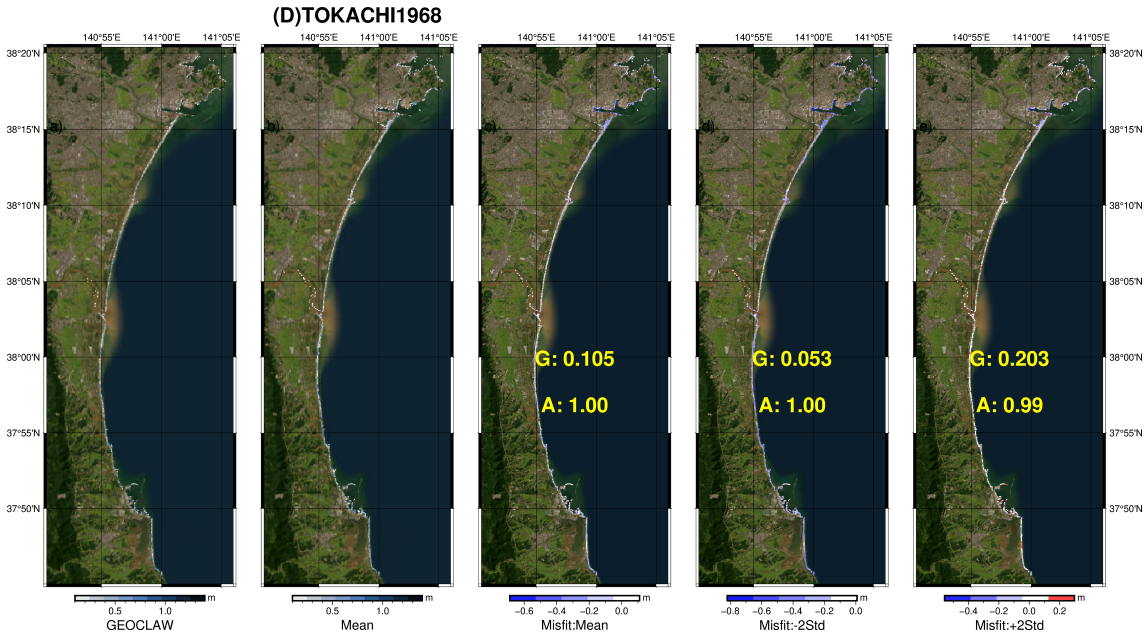
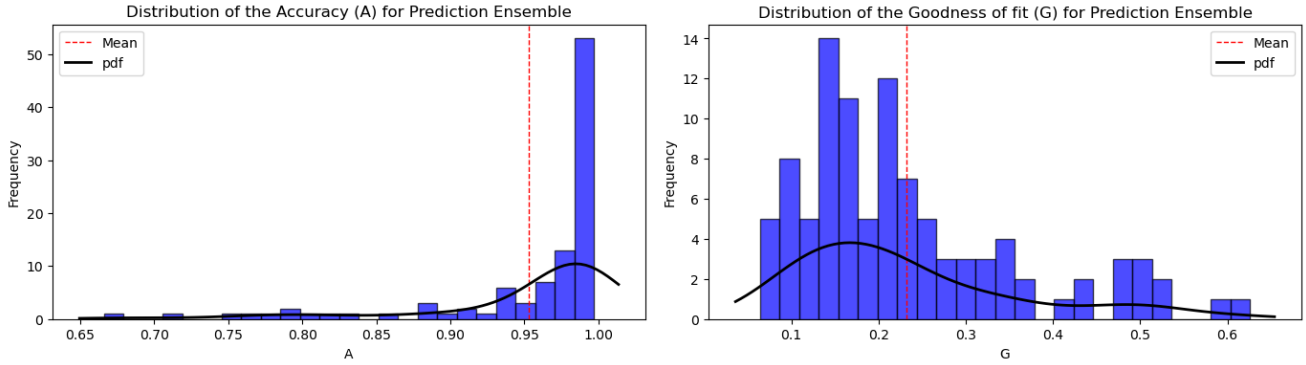


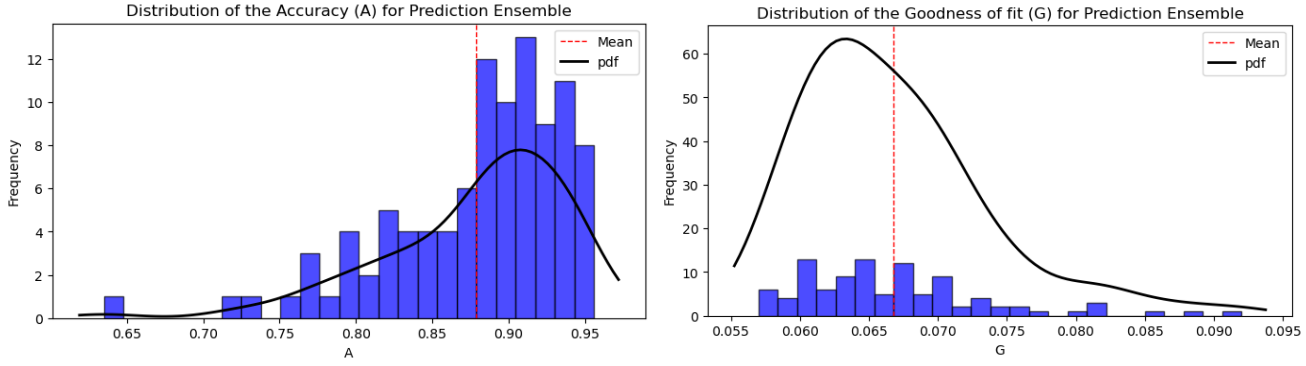
Figure S8. Historical prediction for the Tokachi-Oki event from the onshore surrogate at Sendai.(Basemap from ESRI World Imagery)

Benefit of ensemble predictions



(a) Accuracy(A) (b) Goodness of fit(G)

Figure S9. Assessing the variability of the performance for the prediction ensemble for the test event 158 of type A at Rikuzentakata



(a) Accuracy(A) (b) Goodness of fit(G)

Figure S10. Assessing the variability of the performance for the prediction ensemble for the test event 33 of type B at Rikuzentakata