Supplementary information - Forecasting people exposed to tropical cyclone flooding in South East Africa, lessons learnt from recent events.

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Validation data and results

Validation of flood extents and exposure estimates from the second landfall of tropical cyclone Freddy makes use of remotely sensed extent maps from UNOSAT and Copernicus. These are detailed below, along with population exposure estimates given WorldPop data aggregated to the district level.

The analysis begins on the 14th March 2023 with a RADARSAT image of the Sofala and Zambezi provinces in Mozambique. Exposure estimates are provided in Table S1. Flood extent maps are presented in Figures S1 to S4, showing the remotely sensed flood extents over the flood map return period (Hazard). At Quelimane, the remote sensing appears to have picked up significant amounts of surface water flooding. However, the timing of this imagery is potentially before the peak of fluvial flooding would have reached this far downstream and may underestimate maximum extents as a result. A good match is made at the inland towns of Nammacurra and Nicoadala. Both of these towns sit within smaller fluvial catchments that will have been amongst the first to react to rainfall. Note that there appears to be a consistent offset between the satellite extents and the modelled extents in these areas. A poorer match is shown in Licuare in Nicoadala district; Licuare is on a larger river that is unlikely to have responded at the time of this imagery. Similarly, the Rio Licungo in the east of the Nammacurra district doesn't appear to have responded fully, explaining the good match in town, and poor match elsewhere. The coastal regions around Macuse might show some coastal and pluvial flooding that, as expected, is not simulated by the fluvial flood model.

In Malawi, on the 14th March 2023 population exposure is presented in Table S2 and inundation extents in Figures S5 to S8. Flooding was observed further north than forecast in Malawi. For example, in Phalombe state (Figure S5), particularly downstream of Lake Chilwa, appears to have suffered significant flooding. It is unclear from our data alone if this is lake overflow, fluvial or pluvial flooding. GloFAS did not predict any significant event this far north, however the flood extents are most consistent with the 1 in 100 year Fathom flood hazard maps. Downstream of Phalombe in Milanje/Mulanje and Zomba (Figure S6) a fluvial event is observed along the Ruo River, a tributary of the Shire River). High exposure is picked up by the satellite extents (suggesting >1000yr event), however the satellite extents are much smaller than forecasted extents, and do not align well with the channel. Inspection of high-resolution satellite imagery (not presented) indicated the presence of tall

vegetation on the floodplain that potentially obscures much of the flooding in unpopulated areas. In Chikwawa and Nsanje (Figures S7&8) the edges of the modelled Shire River floodplain appear to match well with the edges of the satellite extents, although large swathes of what is shown as early activation flood plain in the model are not picked up in the satellite extents due to vegetation cover. Estimated populations from the satellite extents are correspondingly lower, although if the missing flooding from the remote sensing is filled, estimates from the model are likely good. Generally, we might expect floodplains of larger rivers to be easier to simulate in the inundation model.

Returning to Sofala and Zambezi districts in Mozambique, exposure to a later image from COSMO-SkyMed on 14th March 2023 is summarised in Table S3. This image appears to capture more fluvial flooding on larger rivers compared to the earlier UNOSAT (Figure S1-4; Table S1), with much less evidence of remnants of pluvial flooding. Limited flooding is seen in Quelimane (Figure S9), with a smaller extent than the earlier UNOSAT, likely due to the reduction of surface water flooding. A good match is still made in Nicoadala, Namacurra and an improved match is made in Licuare and on the Rio Licungo (Figures S10 and S11). It can be seen on the overview maps where the peak still appears not to have reached the farthest downstream locations, although tidal interactions cannot be ruled out here. Figure S12 indicates that Mahanjga da Costa and the east bank of the Rio Licungo have also now begun to react to the fluvial flooding, and a good match is seen with the forecast flood extents, with some missing downstream areas. Finally, due to being on the edge of the storm, an overestimate is observed towards the east.

Analysis of the COSMO-SkyMed flood extents on the 14th March 2023 shows an improvement on the earlier UNOSAT product for the Lower Chire river, with much better filling of low-lying floodplain areas (Figure S13). A good match between forecast and observed exposure (Table S4) is shown on Lower Chire, with satellite extents possibly extending beyond the largest modelled extents on the main river in some locations (Figure S13). There are interesting results in Caia and Mopeia (Figures S14 and S15), which give a better understanding of the interactions with the Zambezi river, a large river not in flood, and its tributaries that are in flood. The forecast model was particularly poor at capturing these river-river compounding effects due to the reliance on an offline return-period inundation mapping method, which assumes equal return periods at confluences. Specifically, GloFAS forecasts a substantial difference in return-period between the Zambezi and its tributaries, but the inundation model cannot capture the compound interaction (this issue is discussed in the main text). Flooding is seen around Mopeia (Figure S15), which indicates this tributary is reacting independently of the Zambezi. Updated data from this area is available on the 15th March from RADARSAT with exposure results summarised in Table S5. However, inundation maps are not provided as flood extents show little change.

A further UNOSAT extent map on the 17th March 2023 from Sentinel-1 covers the lower Shire river and confluence with the Zambezi. The focus of this UNOSAT output in Table S6 has moved further downstream on the Shire River from that in Table S2, with very good matches at Morrumbula and Nsanje, with the floodplain now filled. Delineation between Zambezi and tributary catchments in Mutarara is still poor in the forecast data, although it remains unclear if the full extent of flooding had reached downstream of Shire at the time of capture. Flooding is observed to have receded in southern Malawi above the Ruo/Shire Confluence (Figure S16). A very close match is seen along the Shire floodplain from Makhanga to Nsanje (Figure S17 and S18), with limited flooding observed along Shire tributaries, with any flooding on these is assumed to have passed. Very close exposure matches are found in Morrumbula district, although Nsanje appears very sensitive to small changes in

flood extents (Table S6). Extents in Mutarra (Figure S19) show the Shire floodplain, which is important to delineate from the Zambezi floodplain because this region has a relatively high population on the floodplain. The location of the flood edge between the Shire and Zambezi Rivers appears critical and has resulted in an overestimation in the forecast data because the compounding effect isn't considered. This is the first UNOSAT product that shows flooding on the Caia (southern) side of the Zambezi (Figure S20). This flood extent shows a close match to a smaller event in the Fathom hazard data (5-10yr), giving a large overestimation of exposure here from the forecast model. Peak flow is likely to have been reached in this location, so it appears that the forecast BE and RWC were an overestimate, with the storm track passing further north.

The UNOSAT update on the 17th March 2023 for the Sofala and Zambezia districts (Table S7) from the previous UNOSAT release (Table S1) appears to show more fluvial flooding, with fewer patch areas associated with pluvial flooding. Exposure matches in Nicoadala and Namacurra (Figures S21 and S22) remain good, although the observed extent is already beginning to shrink compared to previous estimates. However, in Quelimane (Figure S23), estimates of flooding and exposure are significantly less than forecast. Whilst it is possible that full extents have not developed here (peak flows were estimated to be around the time of the underlying imagery by GloFAS), the smaller extents on the river from Mopeia to Quelimane (Figure S24) suggest flooding flows on this river were not as extreme as predicted with a 5-10 year return period providing better exposure estimates compared to the remote sensing. Lack of consideration of coastal water levels may be an issue here and the complex interaction at the upstream of this watercourse with the Zambezi is not captured by GLOFAS or the Fathom inundation model. Results from COSMO SkyMed via Copernicus on the 17th March 2023 in the Quelimane area (Table S8) show that very similar conclusions can be made to the most recent UNOSAT of this area (Table S7), with receding flooding now clearly visible at upstream areas such as Nicoadala and Namacurra (Figure S25), and still a lack of extents at Quelimane (Figure S26), with smaller extents east of Mopeia (Figure S27).

The final scene analysed was obtained by RADARSAT on the 23rd March 2023. Primarily, this update shows recession, except on the lower Shire River, where flooding continues to grow, closer to the Zambezi confluence (Figure S28). Clear growth in floodplain extents can be seen on the lower Shire River since the last update on 17/03/2023 (Figure S19), with greater extents in this complex confluence area. This has a very significant impact on the exposed population of Mutarara district (Table S9), which primarily lies in this confluence region.

UNOSAT 3528 Sofala and Zambezia districts. Situation at 14/03/2023 at 03:10 UTC

Release Date: 2023-03-13
Post-event image: RADARSAT Constellation Mission Imagery © Government of Canada (2023) - RADARSAT is an official mark of the Canadian Space Agency (acquired on 13/03/2023 at 03:01 UTC).
Scope: Quelimane area - Region between the Zambezi River Mouth and Pebane Town

Table S1: Exposure by district for Mozambique as observed on 14/03/2023 by RADARSAT. From left to right columns indicate: administrative district; country; total population of district; the best estimate (BE) of return period in the district given the median return period forecast by GloFAS rounded to the nearest available fathom flood map return period; the reasonable worst case (RWC) given the highest return period forecast (capped at 1 in 100 year); population exposure to the remotely sensed data; and population exposure to fathom return period, where closest to the remote sensing is highlighted in bold and GloFAS best estimates and reasonable worst cases are highlighted in blue and red, respectively.

District	Country	Population	BE	RWC	Exposure from Satellite Extents	Fathom Global Flood Model Fluvial Exposure Estimates by Return Period							
						1in5	1in10	1in20	1in50	1in100	1in200	1in500	1in1000
Nicoadala	MOZ	181541	1in500	1in1000	8469	1317	2458	3655	5490	8060	11529	16253	19593
Inhassunge	MOZ	96032	1in500	1in1000	4922	27	103	147	226	458	776	918	1816
Cidade De Quelimane	MOZ	267158	1in500	1in1000	4243	9172	14544	17160	19555	23255	27151	33439	36871
Maquival	MOZ	111862	1in500	1in1000	3952	65	143	229	313	381	489	614	770
Namacurra - Namacurra	MOZ	167612	1in500	1in1000	3552	790	1472	2055	2957	3587	3933	4447	4994
Maganja Da Costa	MOZ	211994	1in200	1in500	2631	342	1025	1876	3388	4248	5185	6980	8103
Chinde	MOZ	83070			1950	6123	10651	12850	15665	17128	18745	20422	23324
Mopeia - Not Zambezi	MOZ	89117	1in500	1in1000	1522	2305	5763	9366	14332	18416	22304	26890	31573
Namacurra - Rio Lucungo	MOZ	60920	1in200	1in500	813	431	873	1393	1866	2589	3375	4484	5167
Mopeia - Zambezi Region	MOZ	377			280	76	175	287	334	341	358	366	370
Luabo	MOZ	31226			236	6246	10701	15461	19717	21921	23586	25218	26412
Marromeu - Zambezi Region	MOZ	109122			85	27764	47136	62084	76490	82967	88006	93237	96595
Muanza - Coastal Region	MOZ	873	1in20	1in50	35	0	0	0	0	0	56	116	184
Cheringoma - Coastal Re	MOZ	2813	1in20	1in50	17	6	6	6	10	34	105	169	255
Mocubela	MOZ	90933	1in200	1in500	3	117	223	459	676	974	1079	1171	1238
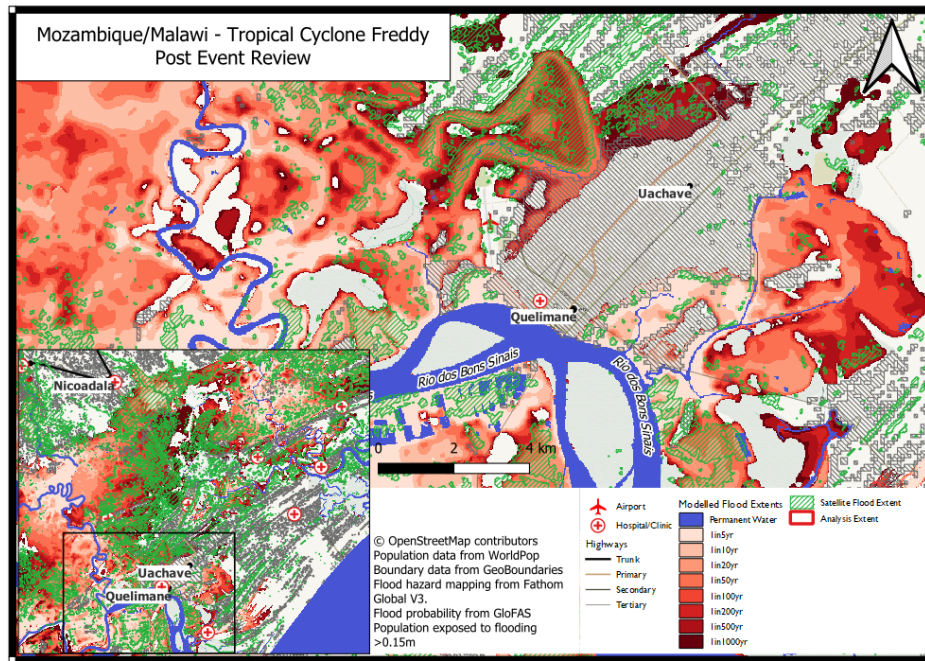
Figure S1: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Quelimane.
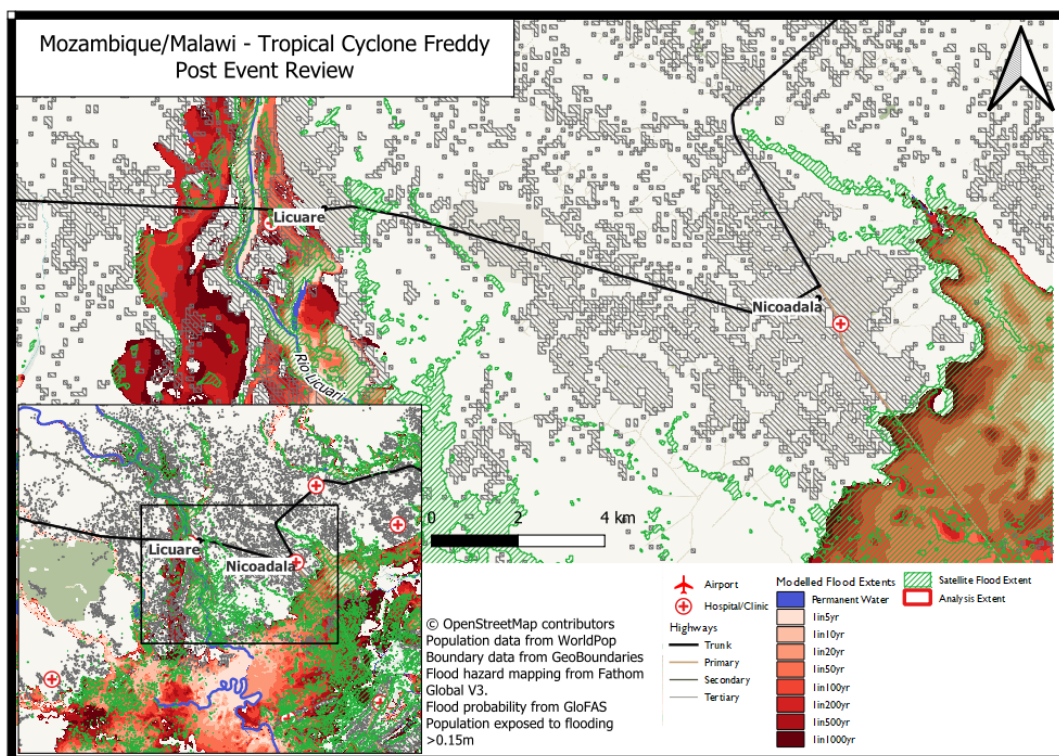
Figure S2: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Licuare and Nicodala.
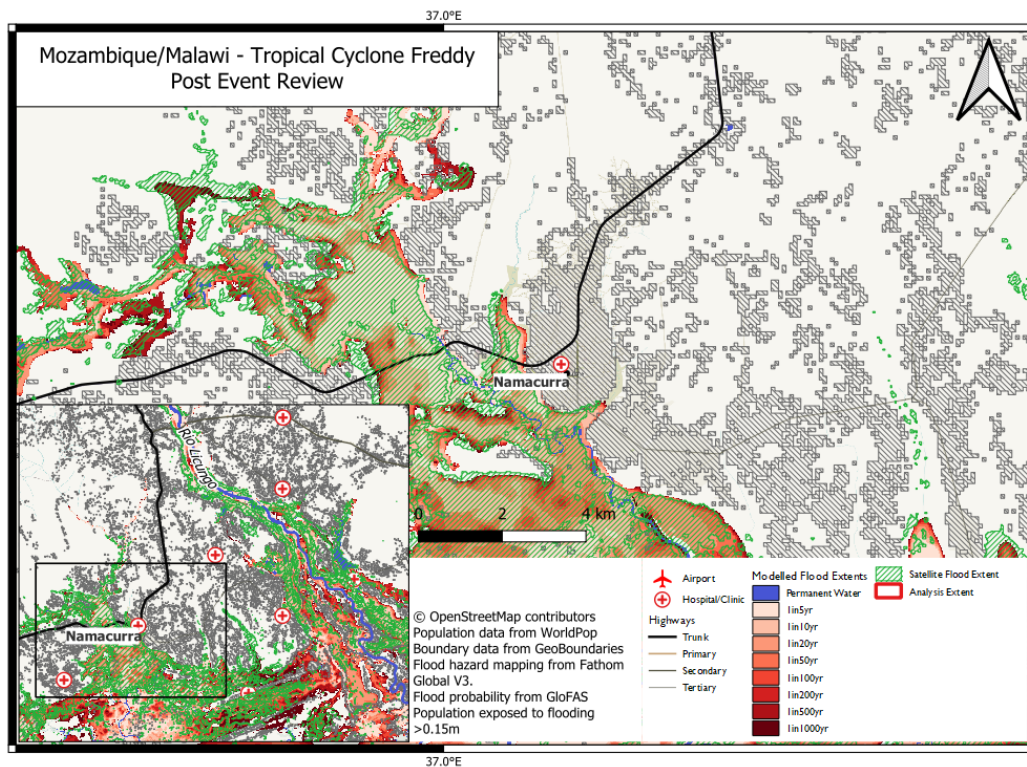
Figure S3: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Namacurra.
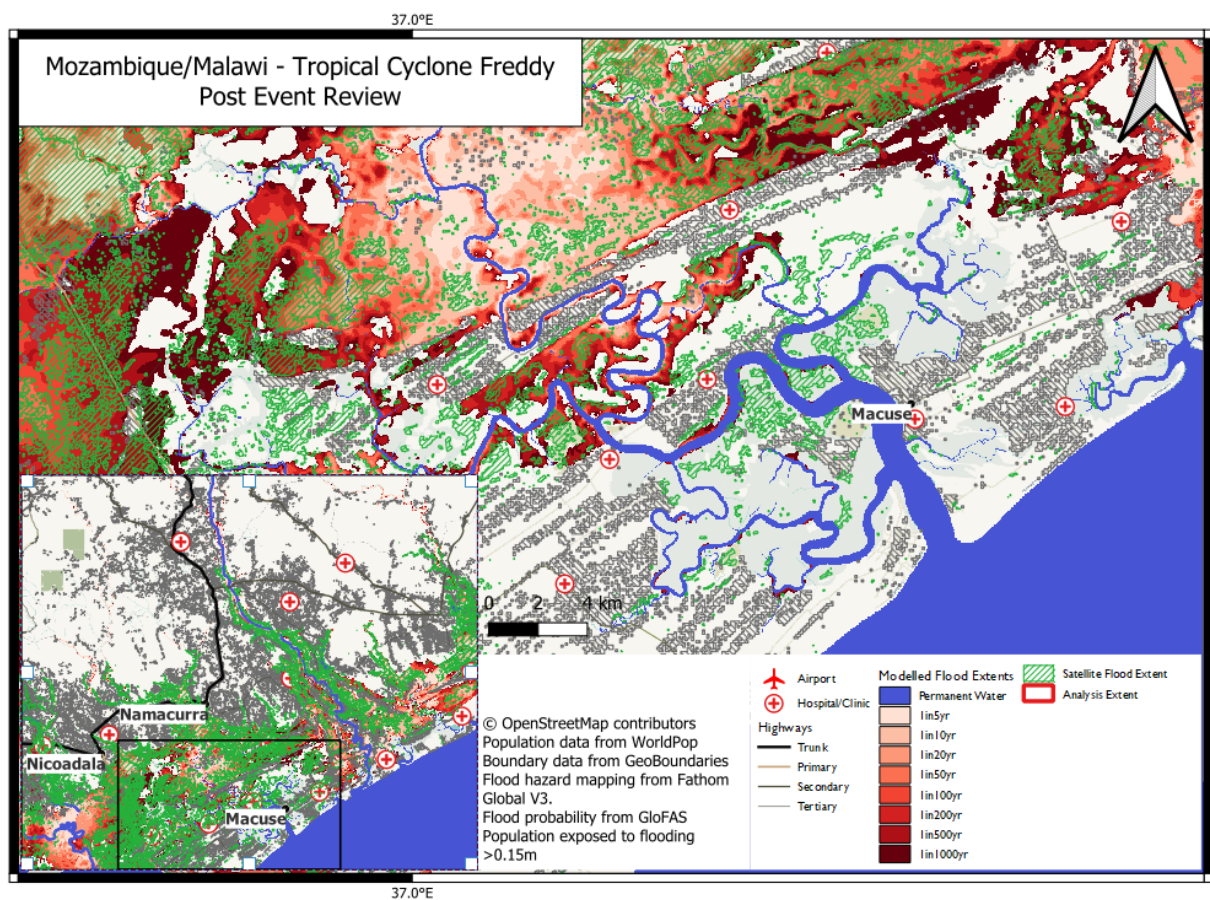
Figure S4: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Macuse.

UNOSAT 3529 Southern Region, Malawi. Situation at 14/03/2023 at 03:10 UTC

Release Date: 2023-03-14
Post-event image: RADARSAT Constellation Mission Imagery © Government of Canada (2023) - RADARSAT is an official mark of the Canadian Space Agency (acquired on 14/03/2023 at 03:10 UTC).
Scope: Southern Malawi

Table S2: Exposure by district for Mozambique as observed on 14/03/2023 by RADARSAT. From left to right columns indicate: administrative district; country; total population of district; the best estimate (BE) of return period in the district given the median return period forecast by GloFAS rounded to the nearest available fathom flood map return period; the reasonable worst case (RWC) given the highest return period forecast (capped at 1 in 100 year); population exposure to the remotely sensed data; and population exposure to fathom return period, where closest to the remote sensing is highlighted in bold and GloFAS best estimates and reasonable worst cases are highlighted in blue and red, respectively.

District	Country	Population	Final Estimate as of 2023-03-13 BE	RWC	Exposure from Satellite Extents	Fathom Global Flood Model Fluvial Exposure Estimates by Return Period 1in5	1in10	1in20	1in50	1in100	1in200	1in500	1in1000
Phalombe	MWI	419529			14938	1790	4295	5975	7829	9330	10762	12819	**14112**
Mulanje	MWI	672064	1in20	1in50	5599	447	690	919	1427	1992	2782	4100	**5271**
Milange - Rio Shire	MOZ	590774	1in20	1in50	4860	456	805	1117	1625	1998	2381	3122	**3890**
Chikwawa	MWI	459216	1in20	1in50	4144	**10942**	19536	25727	31613	35519	39817	45371	49385
Zomba	MWI	678840			3703	1934	3003	**3621**	**4573**	5406	6258	7281	8082
Nsanje	MWI	304132	1in200	1in500	3456	**8688**	10803	13278	15668	17062	18303	20075	21341
Morrumbala	MOZ	257569	1in200	1in500	2842	**1627**	3710	6265	10301	12712	14835	17606	19875
Molumbo - Zambezi Region	MOZ	35666			438	3	12	24	42	54	66	83	**98**
Molumbo - Zambezi Region	MOZ	53077			438	4	13	25	43	55	67	84	**99**
Chiradzulu	MWI	363845	1in20	1in50	400	69	87	104	122	146	164	186	**212**
Thyolo	MWI	806094	1in20	1in50	277	203	**238**	**313**	375	422	495	604	722
Blantyre	MWI	1290825			43	**1158**	1415	1556	1774	1916	2059	2202	2298
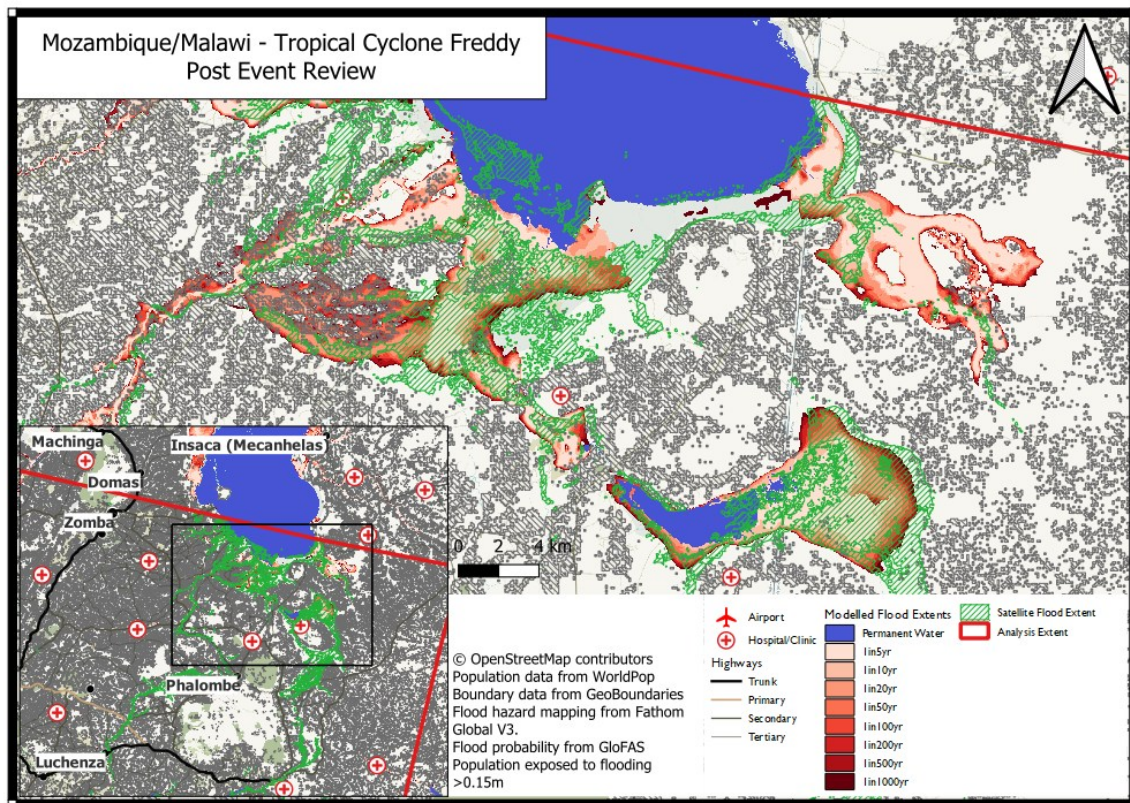
Figure S5: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Phalombe state.
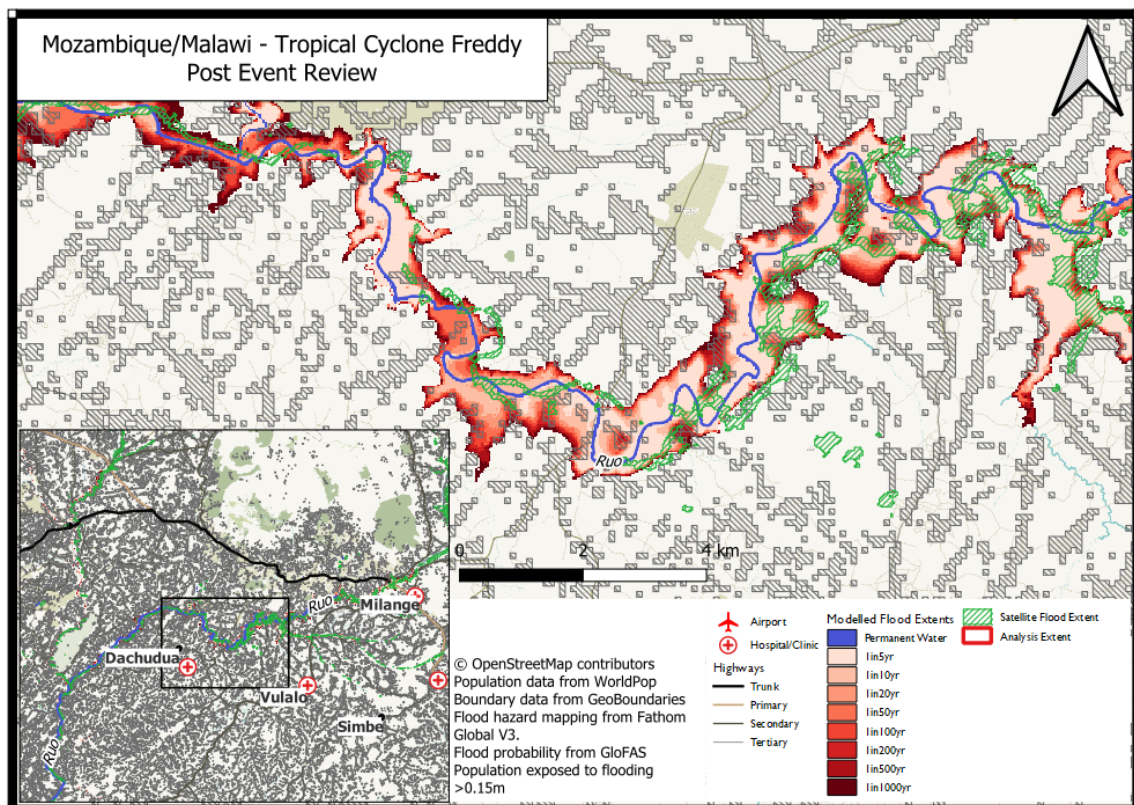
Figure S6: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure near Dachudua on the Malawi-Mozambique boarder.
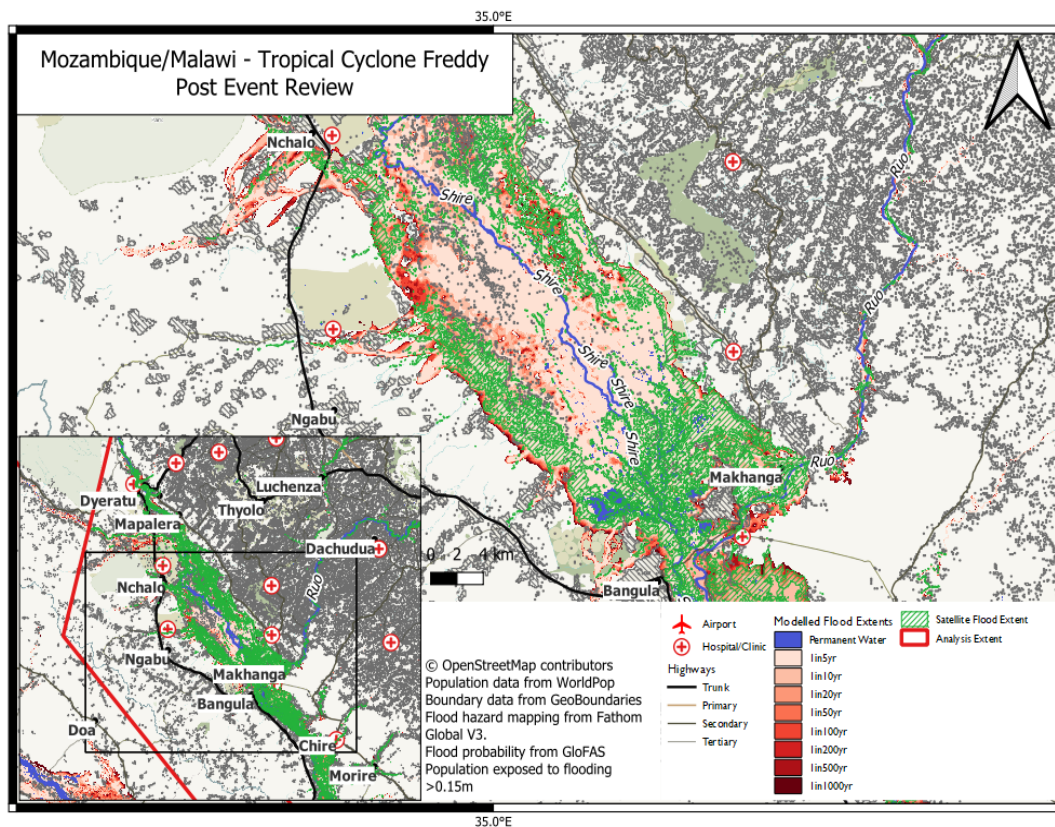
Figure S7: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Makhanga.
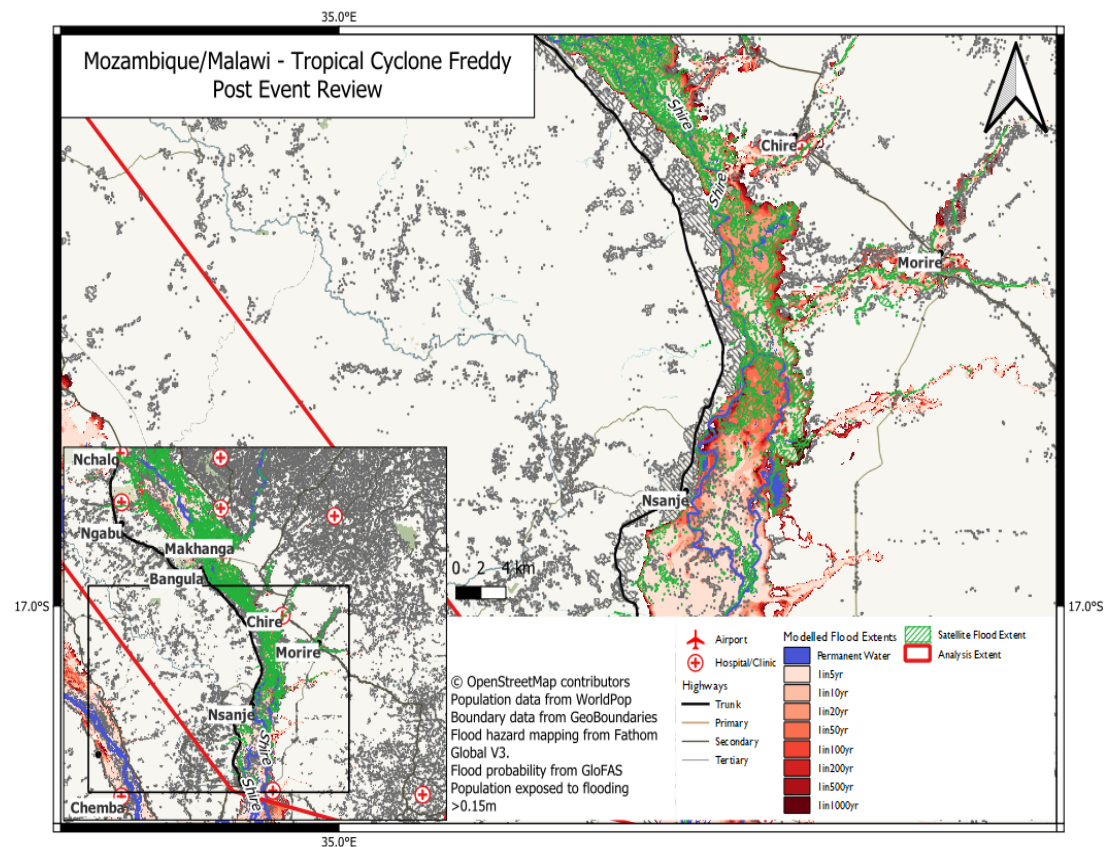
Figure S8: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Chire, Morire and Nsanje.

Copernicus EMSR654 Quelimane Release 1. Situation at 14/03/2023 at 14:47 UTC

Release Date: 2023-03-15 05:34
Post-event image: COSMO-SkyMed© ASI (2023), distributed by e-GEOS S.p.A. (acquired on 14/03/2023 at 14:47 UTC, GSD100.0m), provided under COPERNICUS by the European Union and ESA, all rights reserved.
Scope: Quelimane area - Region between the Zambezi River Mouth and Pebane Town

Table S3: Exposure by district for Mozambique as observed on 14/03/2023 by COSMO-SkyMed. From left to right columns indicate: administrative district; country; total population of district; the best estimate (BE) of return period in the district given the median return period forecast by GloFAS rounded to the nearest available fathom flood map return period; the reasonable worst (RWC) case given the highest return period forecast (capped at 1 in 100 year); population exposure to the remotely sensed data; and population exposure to fathom return period, where closest to the remote sensing is highlighted in bold and GloFAS best estimates and reasonable worst cases are highlighted in blue and red, respectively.

District	Country	Population	Final Estimate as of 2023-03-13		Exposure from Satellite Extents	Fathom Global Flood Model Fluvial Exposure Estimates by Return Period							
			BE	RWC		1in5	1in10	1in20	1in50	1in100	1in200	1in500	1in1000
Nicoadala	MOZ	152158	1in500	1in1000	13184	1076	2178	3323	5109	7606	**10961**	**15391**	18462
Namacurra - Namacurra	MOZ	156062	1in500	1in1000	5422	771	1452	2033	2931	3558	3899	4406	**4947**
Maganja Da Costa	MOZ	177295	1in200	1in500	2951	305	965	**1784**	**3264**	4086	4987	6698	7756
Inhassunge	MOZ	49175	1in500	1in1000	1848	27	103	147	196	381	655	733	**807**
Namacurra - Rio Lucungo	MOZ	60300	1in200	1in500	1714	431	873	**1393**	**1866**	2589	3375	4484	5167
Mopeia	MOZ	18853	1in500	1in1000	644	215	391	**622**	1134	1880	2544	3069	3304
Mocuba - Rio Licungo	MOZ	4821	1in200	1in500	23	**32**	40	48	52	54	54	54	55
Maquival	MOZ	111862	1in500	1in1000	5	**65**	143	229	313	381	489	614	770
Mocubela	MOZ	5618	1in200	1in500	3	**24**	103	319	507	777	859	903	934
Cidade De Quelimane	MOZ	267158	1in500	1in1000	0	9172	14544	17160	19555	23255	27151	33439	36871
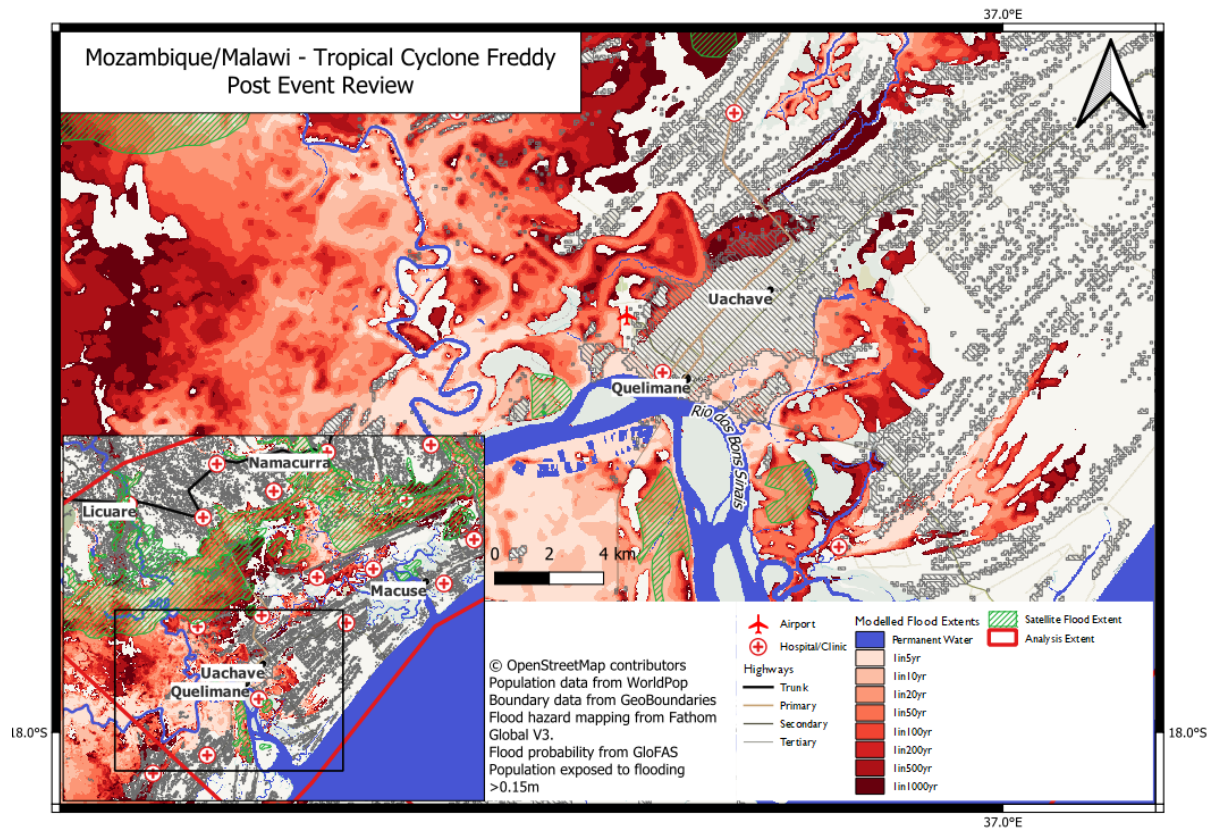
Figure S9: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Qualimane.
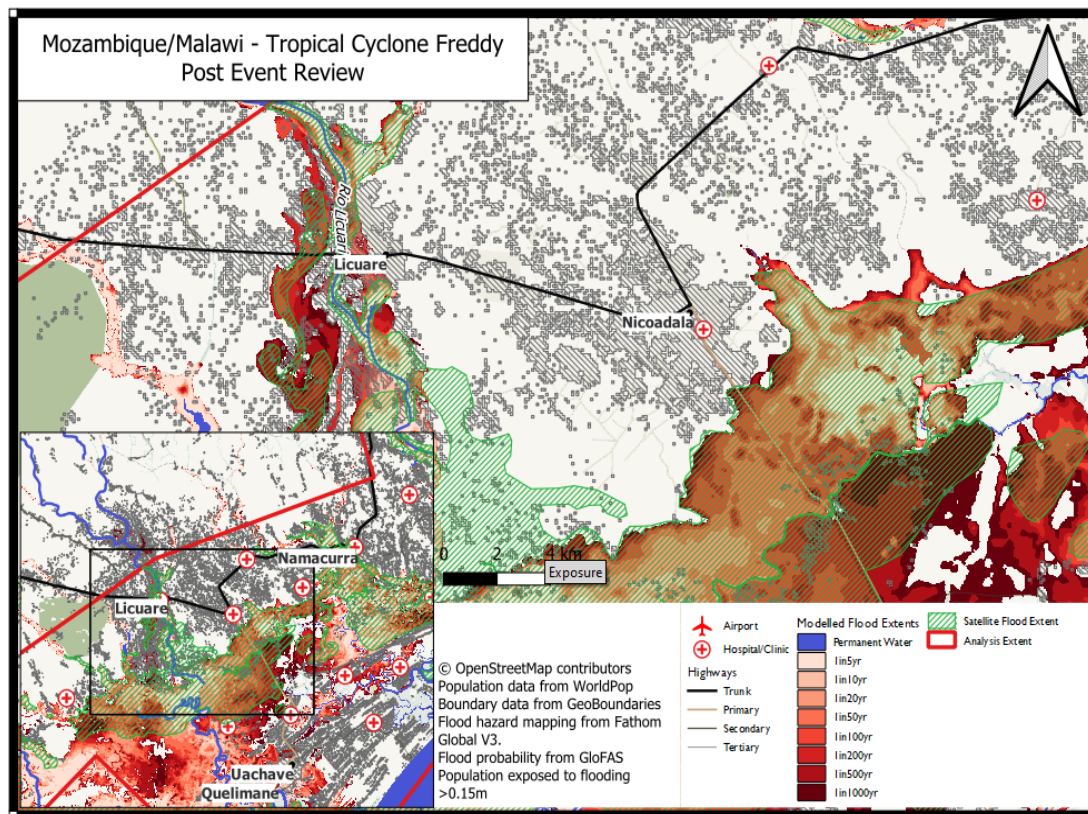
Figure S10: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Licuare and Nicodala.
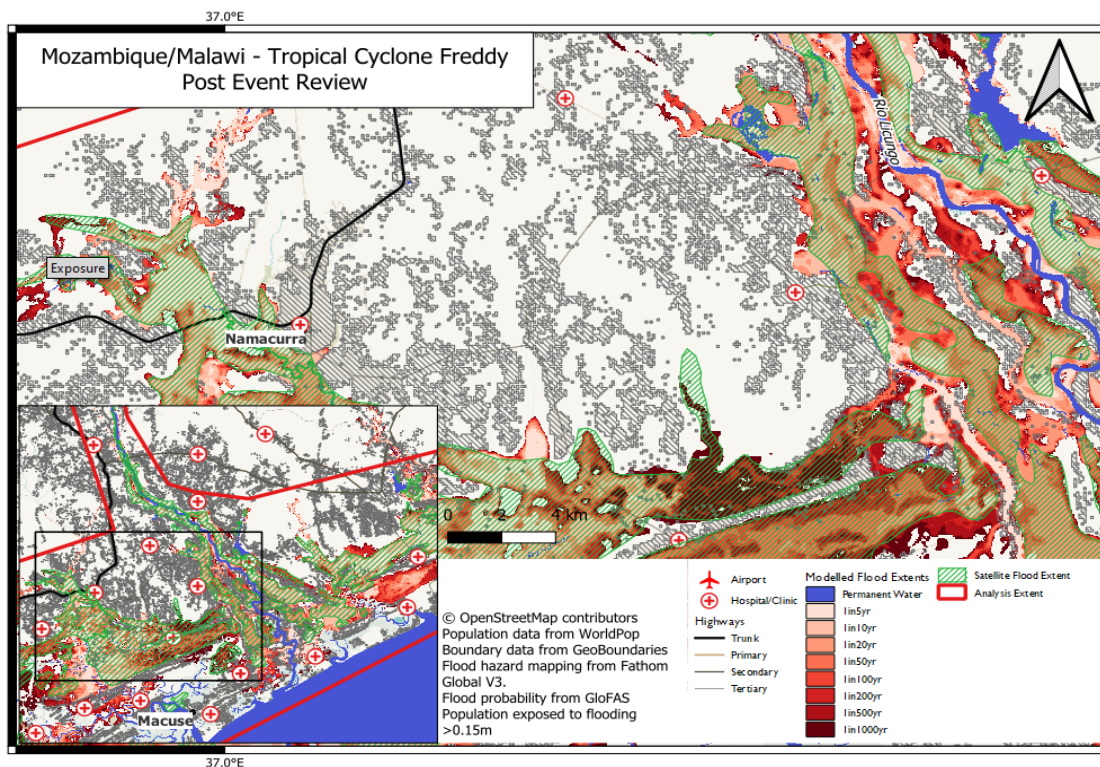
Figure S11: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Namacurra.
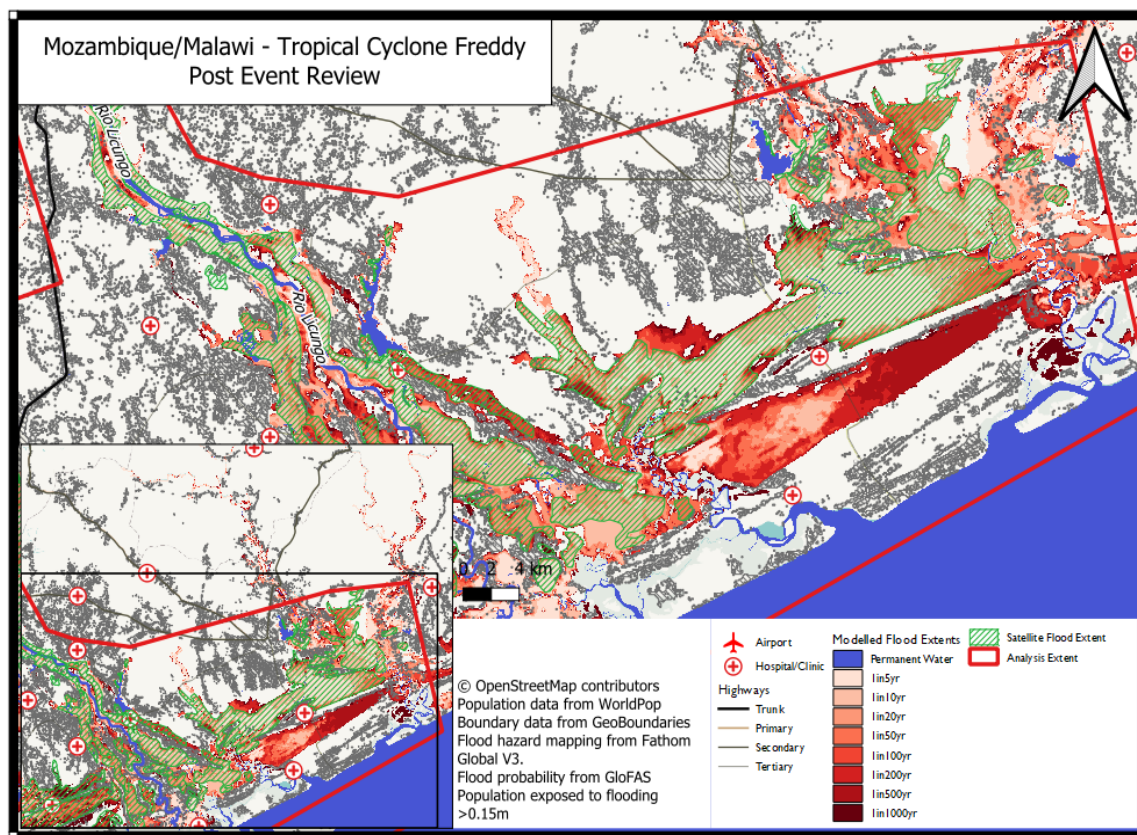
Figure S12: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Rio Licungo.

Copernicus EMSR654 Mutarara Release 1. Situation at 15/03/2023 at 03:53 UTC

Release Date: 2023-03-15 19:40
Post-event image: COSMO-SkyMed© ASI (2023), distributed by e-GEOS S.p.A. (acquired on 15/03/2023 at 03:53 UTC, GSD100.0m), provided under COPERNICUS by the European Union and ESA, all rights reserved.
Scope: Mopeia Town upstream along Zambezi and Chire Rivers

Table S4: Exposure by district for Mozambique as observed on 15/03/2023 by COSMO-SkyMed. From left to right columns indicate: administrative district; country; total population of district; the best estimate (BE) of return period in the district given the median return period forecast by GloFAS rounded to the nearest available fathom flood map return period; the reasonable worst (RWC) case given the highest return period forecast (capped at 1 in 100 year); population exposure to the remotely sensed data; and population exposure to fathom return period, where closest to the remote sensing is highlighted in bold and GloFAS best estimates and reasonable worst cases are highlighted in blue and red, respectively.

District	Country	Population	BE	RWC	Exposure from Satellite Extents	Fathom Global Flood Model Fluvial Exposure Estimates by Return Period							
			Final Estimate as of 2023-03-13			1in5	1in10	1in20	1in50	1in100	1in200	1in500	1in1000
Morrumbala	MOZ	79329	1in200	1in500	15021	1983	4021	6714	11016	**13574**	**15787**	18663	21044
Mopeia - Zambezi Region	MOZ	40347			825	**6536**	11185	14514	17026	18115	18928	19738	20368
Caia - Zambezi Region	MOZ	95644			807	**15130**	28007	36246	42268	45231	47253	50366	55635
Nsanje	MWI	679	1in200	1in500	526	59	178	316	451	**526**	556	578	594
Mutarara - Not Zambezi	MOZ	36369	1in200	1in500	443	**5574**	9392	13660	19023	22670	26773	28073	29178
Mopeia - Not Zambezi	MOZ	33646	1in500	1in1000	319	**623**	1605	2191	2643	2917	3226	3585	3857
Doa - Zambezi Region	MOZ	15196			202	**2377**	2868	3501	4749	5445	6046	6563	7159
Caia - Not Zambezi	MOZ	26229	1in500	1in1000	149	**1787**	6092	9812	13045	14064	14576	15058	15499
Mutarara - Zambezi Region	MOZ	50831			91	**4531**	9830	13396	16206	18142	19885	21967	24254
Doa - Not Zambezi	MOZ	20636	1in20	1in50	36	19	**30**	55	127	192	320	514	782
Cheringoma - Inland Region	MOZ	1791	1in500	1in1000	15	**90**	102	114	139	157	187	277	319
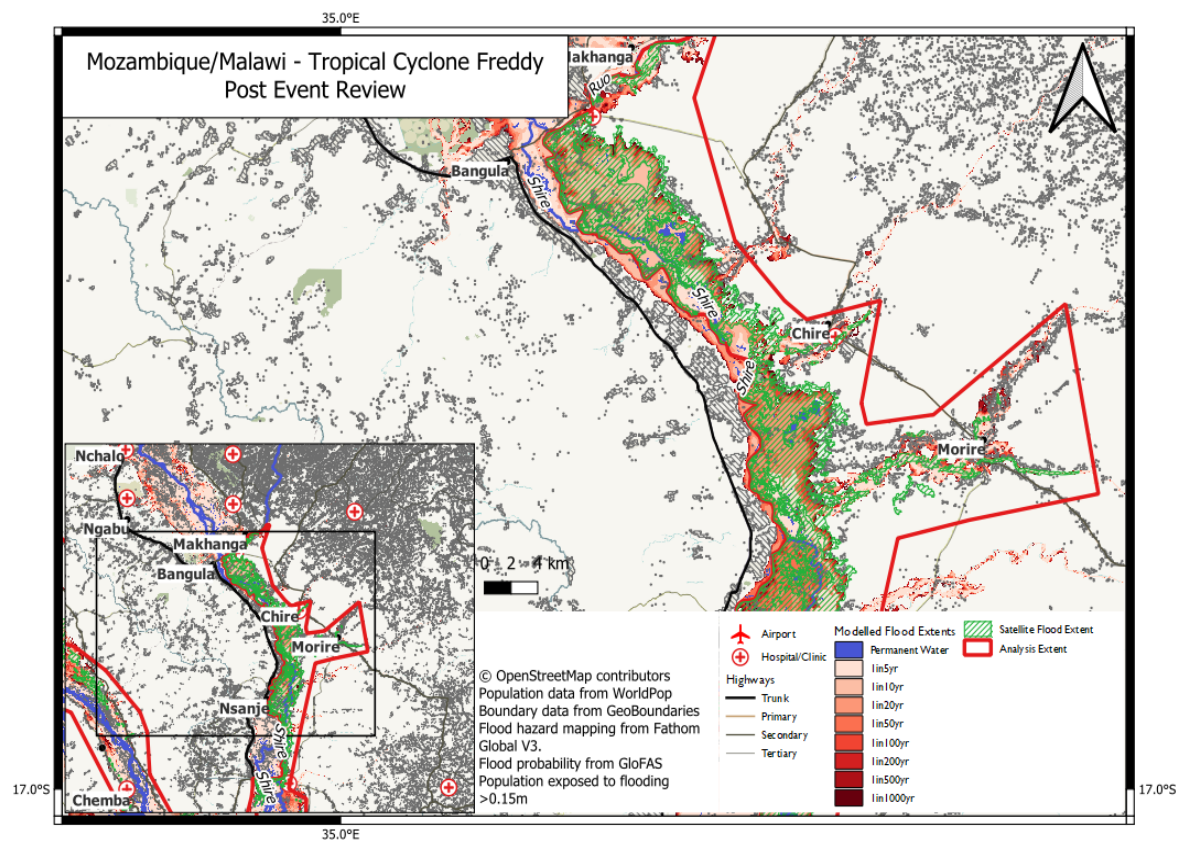
Figure S13: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around the Shire River, Southern Malawi.
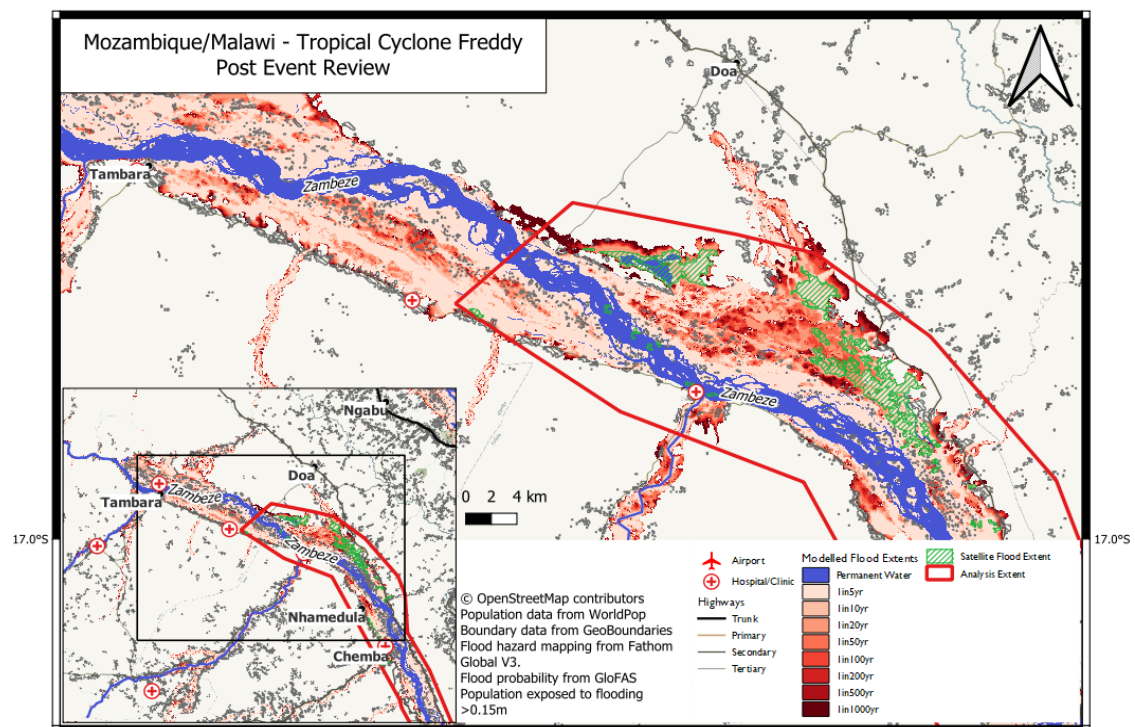
Figure S14: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around the Zambezi River, Mozambique.
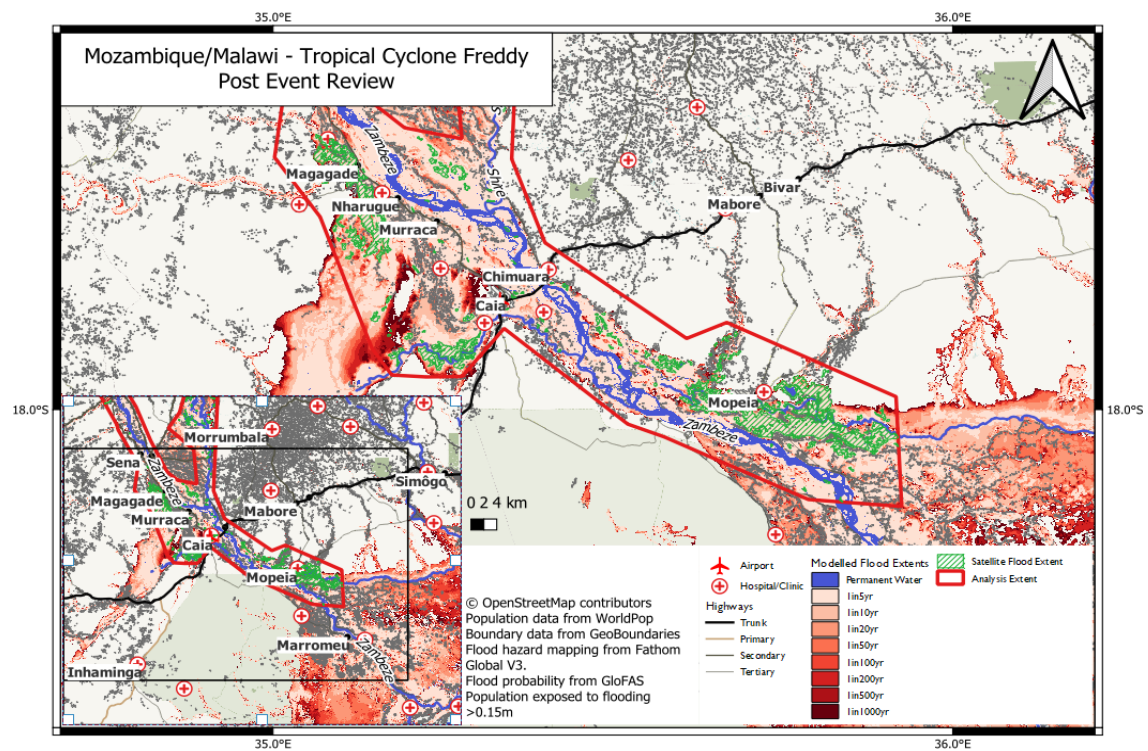
Figure S15: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around the Zambezi River near Mopeia, Mozambique.

Copernicus EMSR654 Mutarara Monitoring 1. Situation at 16/03/2023 at 03:09 UTC

Release Date: 2023-03-16 14:11
Post-event image: RADARSAT 2 Data and products © Mac Donald, Dettwiler and Associates Ltd. (2023). (acquired on 16/03/2023 at 03:09 UTC, GSD100.0m) - RADARSAT is an official mark of the Canadian Space Agency - provided under COPERNICUS by the European Union and ESA, all rights reserved.
Scope: Mopeia Town upstream along Zambezi and Chire Rivers

Table S5: Exposure by district for Mozambique as observed on 16/03/2023 by RADARSAT. From left to right columns indicate: administrative district; country; total population of district; the best estimate (BE) of return period in the district given the median return period forecast by GloFAS rounded to the nearest available fathom flood map return period; the reasonable worst case (RWC) given the highest return period forecast (capped at 1 in 100 year); population exposure to the remotely sensed data; and population exposure to fathom return period, where closest to the remote sensing is highlighted in bold and GloFAS best estimates and reasonable worst cases are highlighted in blue and red, respectively.

District	Country	Population	Final Estimate as of 2023-03-13		Exposure from Satellite Extents	Fathom Global Flood Model Fluvial Exposure Estimates by Return Period							
			BE	RWC		1in5	1in10	1in20	1in50	1in100	1in200	1in500	1in1000
Morrumbala	MOZ	79329	1in200	1in500	16380	1983	4021	6714	11016	13574	15787	18663	21044
Mutarara - Not Zambezi	MOZ	36369	1in200	1in500	4665	5574	9392	13660	19023	22670	26773	28073	29178
Mopeia - Zambezi Region	MOZ	40347			926	6536	11185	14514	17026	18115	18928	19738	20368
Caia - Zambezi Region	MOZ	95644			922	15130	28007	36246	42268	45231	47253	50366	55635
Nsanje	MWI	679	1in200	1in500	549	59	178	316	451	526	556	578	594
Mopeia - Not Zambezi	MOZ	33646	1in500	1in1000	370	623	1605	2191	2643	2917	3226	3585	3857
Caia - Not Zambezi	MOZ	26229	1in500	1in1000	246	1787	6092	9812	13045	14064	14576	15058	15499
Doa - Zambezi Region	MOZ	15196			216	2377	2868	3501	4749	5445	6046	6563	7159
Mutarara - Zambezi Region	MOZ	50831			91	4531	9830	13396	16206	18142	19885	21967	24254
Doa - Not Zambezi	MOZ	20636	1in20	1in50	41	19	30	55	127	192	320	514	782
Cheringoma - Inland Reg	MOZ	1791	1in500	1in1000	24	90	102	114	139	157	187	277	319

UNOSAT 3529 Southern Region, Malawi. Situation at 17/03/2023 at 03:03 UTC

Release Date: 2023-03-17
Post-event image: Sentinel 1 - Contains modified Copernicus Sentinel data [2023] - (acquired on 17/03/2023 at 03:03 UTC).
Scope: Southern Malawi

Table S6: Exposure by district for Mozambique as observed on 17/03/2023 by Sentinel-1. From left to right columns indicate: administrative district; country; total population of district; the best estimate (BE) of return period in the district given the median return period forecast by GloFAS rounded to the nearest available fathom flood map return period; the reasonable worst case (RWC) given the highest return period forecast (capped at 1 in 100 year); population exposure to the remotely sensed data; and population exposure to fathom return period, where closest to the remote sensing is highlighted in bold and GloFAS best estimates and reasonable worst cases are highlighted in blue and red, respectively.

District	Country	Population	BE	RWC	Exposure from Satellite Extents	Fathom Global Flood Model Fluvial Exposure Estimates by Return Period							
						1in5	1in10	1in20	1in50	1in100	1in200	1in500	1in1000
Mutarara - Not Zambezi	MOZ	124215	1in200	1in500	11589	**6189**	**14266**	27213	41403	49420	59080	67124	74093
Morrumbala	MOZ	264857	1in200	1in500	9983	2076	4232	**6982**	**11338**	13945	16226	19222	21677
Nsanje	MWI	317531	1in200	1in500	8625	**8688**	10803	13278	15668	17062	18303	20075	21341
Chikwawa	MWI	357159	1in20	1in50	1668	**9885**	17468	22984	28247	31756	35683	40749	44355
Caia - Not Zambezi	MOZ	60706	1in500	1in1000	254	**1889**	6263	10139	13561	14636	15201	15771	16300
Mutarara - Zambezi Region	MOZ	77743			232	**5285**	14445	24875	32669	36081	38440	40914	43424
Caia - Zambezi Region	MOZ	95644			159	**15130**	28007	36246	42268	45231	47253	50366	55635
Chemba - Zambezi Region	MOZ	23107			87	**1918**	2152	2424	2791	3140	3629	4552	5853
Doa - Zambezi Region	MOZ	8540			78	**1693**	2107	2650	3822	4467	5025	5459	5715
Mopeia - Zambezi Region	MOZ	9944			36	**109**	199	389	609	773	918	1170	1366
Mopeia - Not Zambezi	MOZ	18786	1in500	1in1000	25	**107**	147	176	210	242	276	315	349
Cheringoma - Inland Reg	MOZ	7292	1in500	1in1000	20	**142**	167	196	234	282	326	448	529
Thyolo	MWI	806094	1in20	1in50	16	**203**	238	313	375	422	495	604	722
Mulanje	MWI	613417	1in20	1in50	15	**394**	619	833	1301	1828	2564	3774	4807
Doa - Not Zambezi	MOZ	110883	1in20	1in50	12	**81**	146	187	283	350	494	701	988
Blantyre	MWI	1051856			2	**15**	15	15	15	15	18	19	19
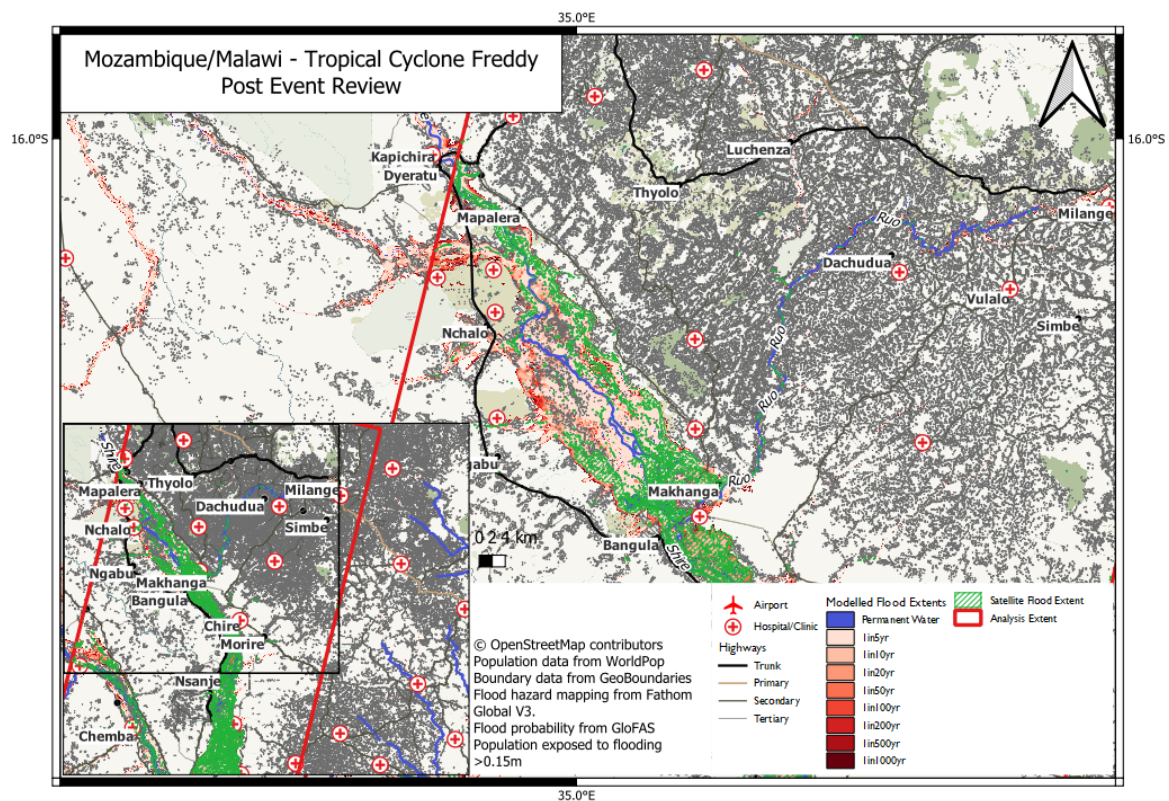
Figure S16: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure north of Makhanga and the Ruo River confluence with the Shire River.
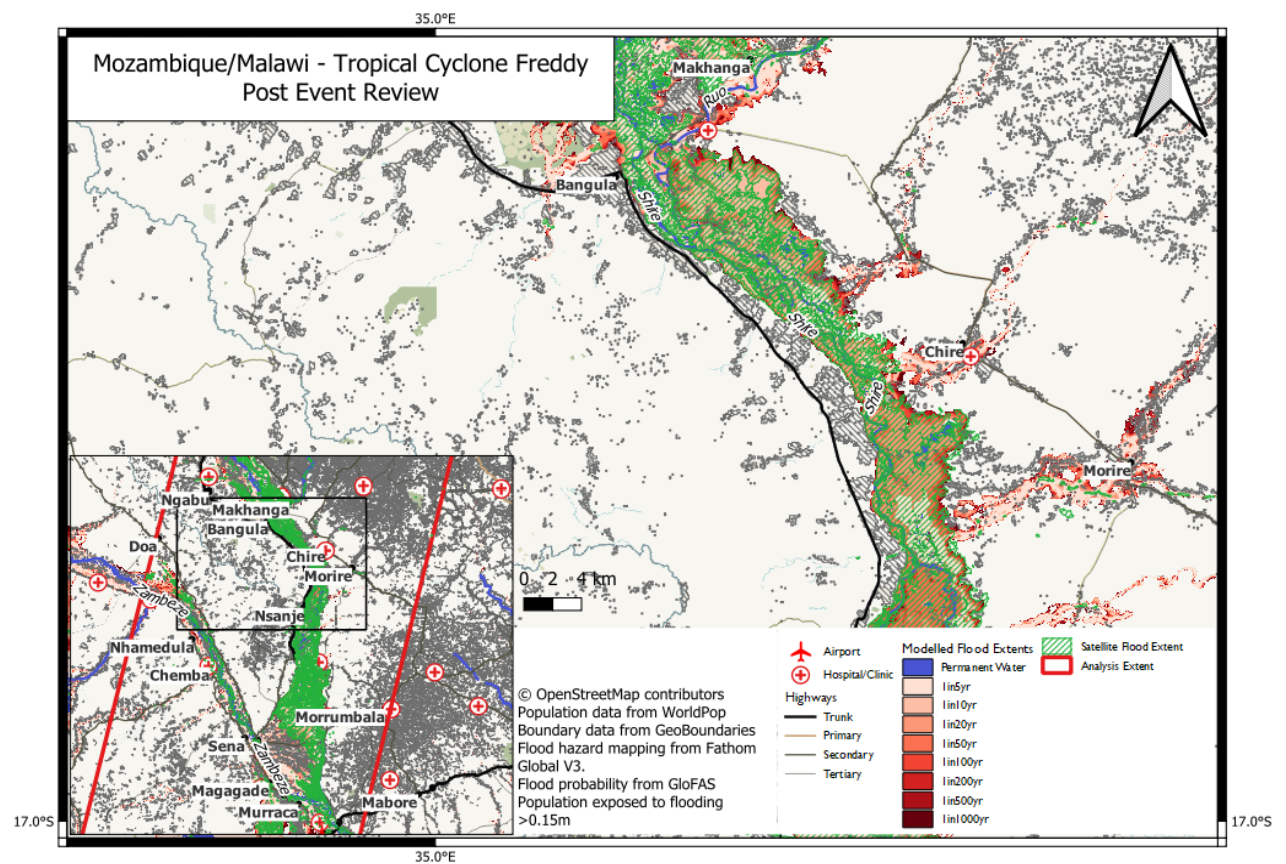
Figure S17: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure along the Shire River from Makhanga to Chire
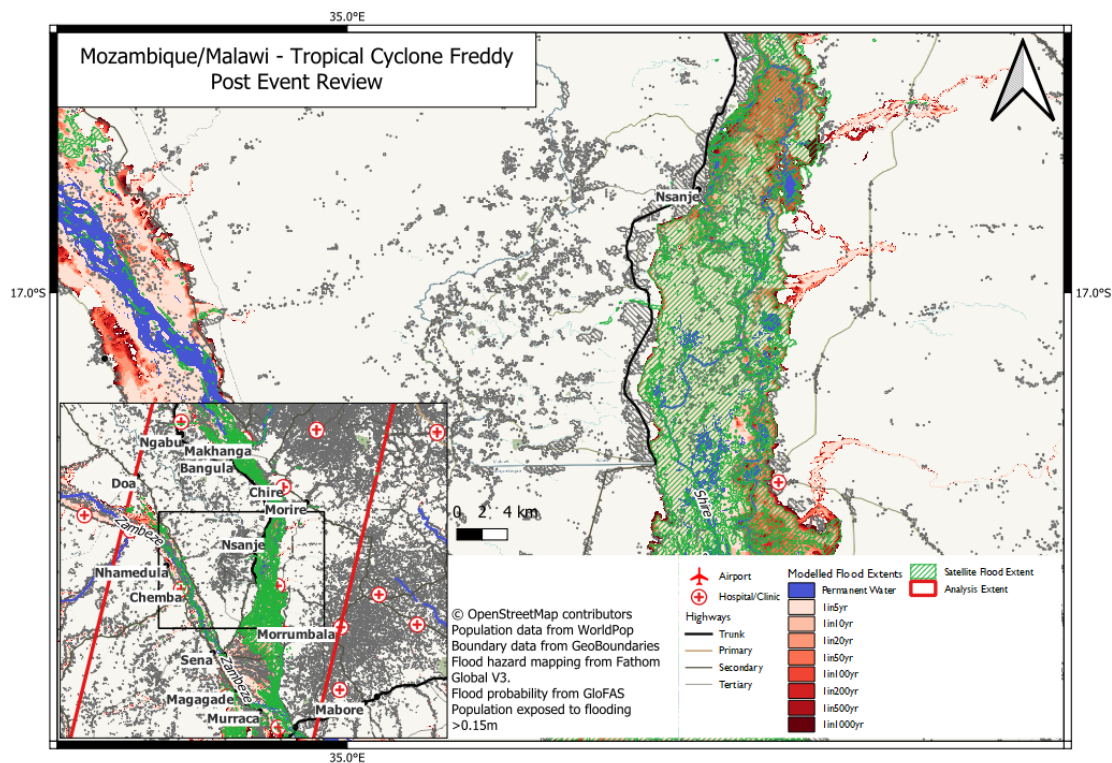
Figure S18: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure along the Shire River around Nsanje.
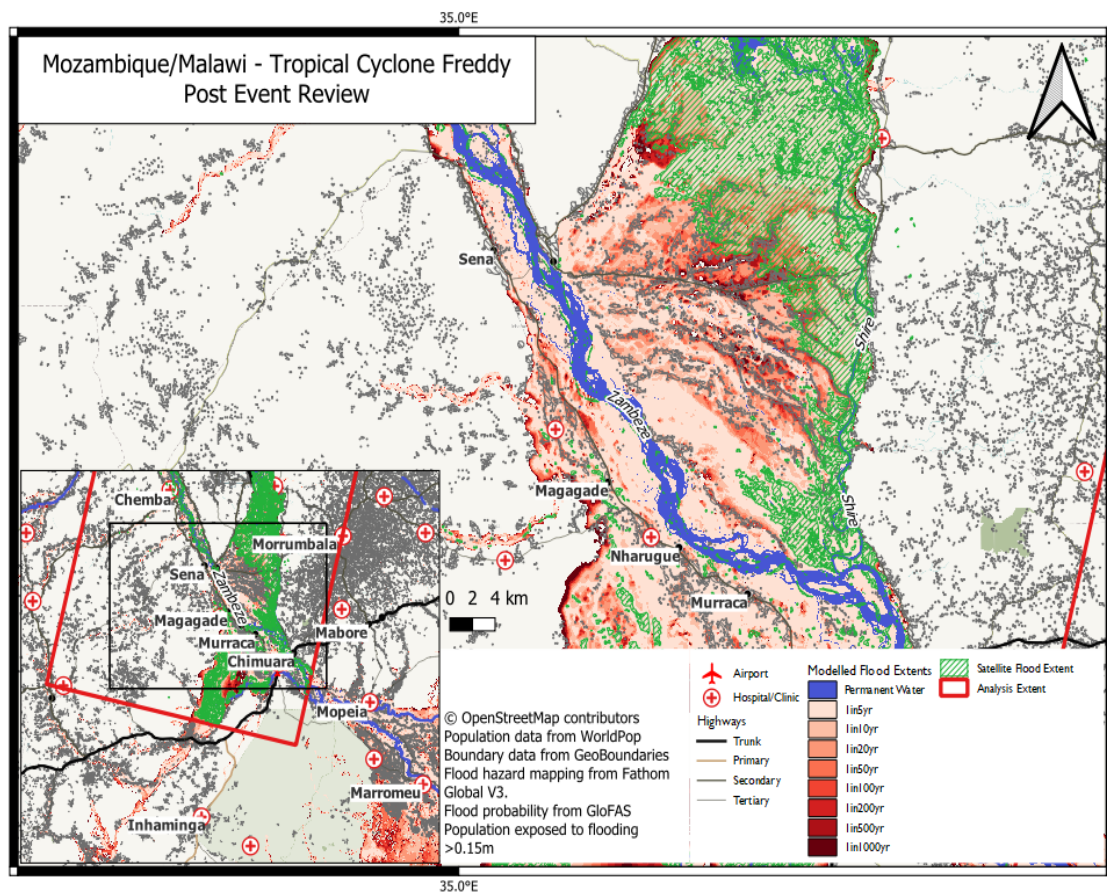
Figure S19: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure at the Shire River and Zambeze River confluence.
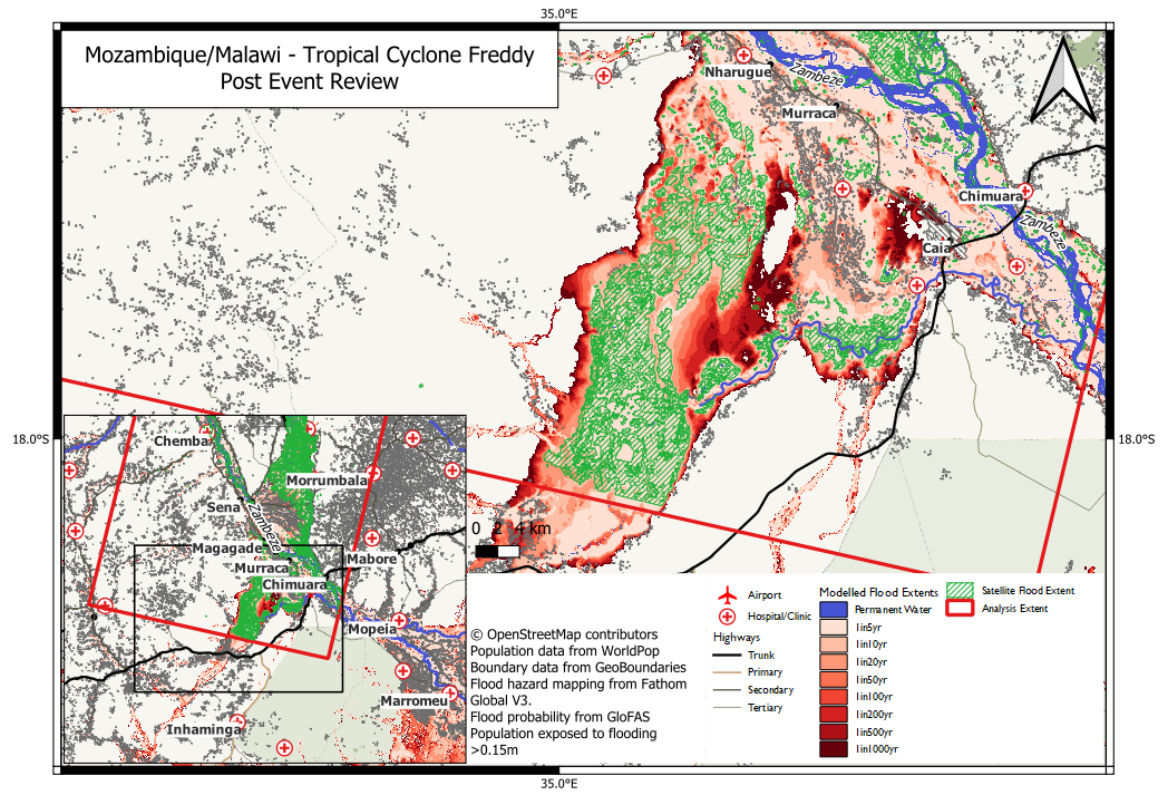
Figure S20: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure South of the Zambeze River near Caia.

UNOSAT 3528 Sofala and Zambezia districts. Situation at 17/03/2023 at 03:03 UTC

Release Date: 2023-03-17

Post-event image: Sentinel 1 - Contains modified Copernicus Sentinel data [2023] - (acquired on 17/03/2023 at 03:03 UTC).

Scope: Quelimane area - Region between Zambezi River Mouth and Pebane Town

Table S7: Exposure by district for Mozambique as observed on 17/03/2023 by Sentinel-1. From left to right columns indicate: administrative district; country; total population of district; the best estimate (BE) of return period in the district given the median return period forecast by GloFAS rounded to the nearest available fathom flood map return period; the reasonable worst case (RWC) given the highest return period forecast (capped at 1 in 100 year); population exposure to the remotely sensed data; and population exposure to fathom return period, where closest to the remote sensing is highlighted in bold and GloFAS best estimates and reasonable worst cases are highlighted in blue and red, respectively.

District	Country	Population	Final Estimate as of 2023-03-13		Exposure from Satellite Extents	Fathom Global Flood Model Fluvial Exposure Estimates by Return Period							
			BE	RWC		1in5	1in10	1in20	1in50	1in100	1in200	1in500	1in1000
Nicoadala	MOZ	181541	1in500	1in1000	8138	1317	2458	3655	5490	8060	11529	16253	19593
Namacurra - Namacurra	MOZ	167612	1in500	1in1000	3932	790	1472	2055	2957	3587	3933	4447	4994
Maganja Da Costa	MOZ	211994	1in200	1in500	1304	342	1025	1876	3388	4248	5185	6980	8103
Namacurra - Rio Lucungo	MOZ	60920	1in200	1in500	774	431	873	1393	1866	2589	3375	4484	5167
Mopeia - Not Zambezi	MOZ	89117	1in500	1in1000	652	2305	5763	9366	14332	18416	22304	26890	31573
Inhassunge	MOZ	96032	1in500	1in1000	324	27	103	147	226	458	776	918	1816
Maquival	MOZ	111862	1in500	1in1000	188	65	143	229	313	381	489	614	770
Mocubela	MOZ	90933	1in200	1in500	150	117	223	459	676	974	1079	1171	1238
Chinde	MOZ	83070			101	6123	10651	12850	15665	17128	18745	20422	23324
Pebane	MOZ	48797			35	11	13	13	15	20	25	29	33
Cidade De Quelimane	MOZ	267158	1in500	1in1000	25	9172	14544	17160	19555	23255	27151	33439	36871
Mocuba - Rio Licungo	MOZ	74092	1in200	1in500	12	182	222	249	281	311	336	360	405
Derre	MOZ	33445	1in500	1in1000	10	46	50	55	65	76	89	111	149
Luabo	MOZ	31226			7	6246	10701	15461	19717	21921	23586	25218	26412
Mopeia - Zambezi Region	MOZ	377			0	76	175	287	334	341	358	366	370
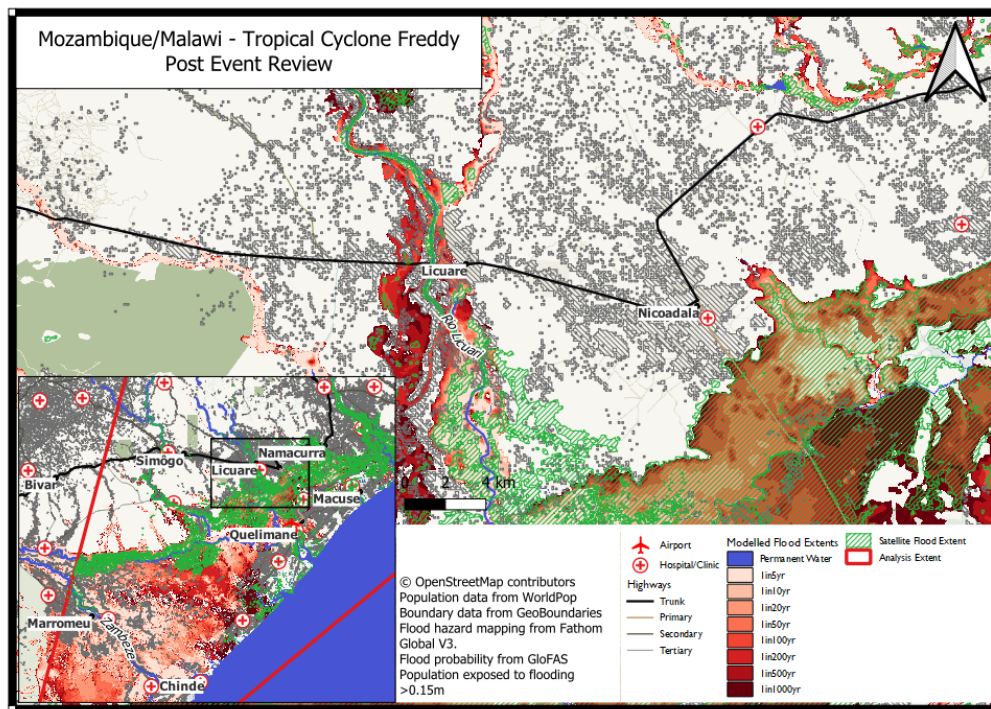
Figure S21: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Licuare and Nicodala.
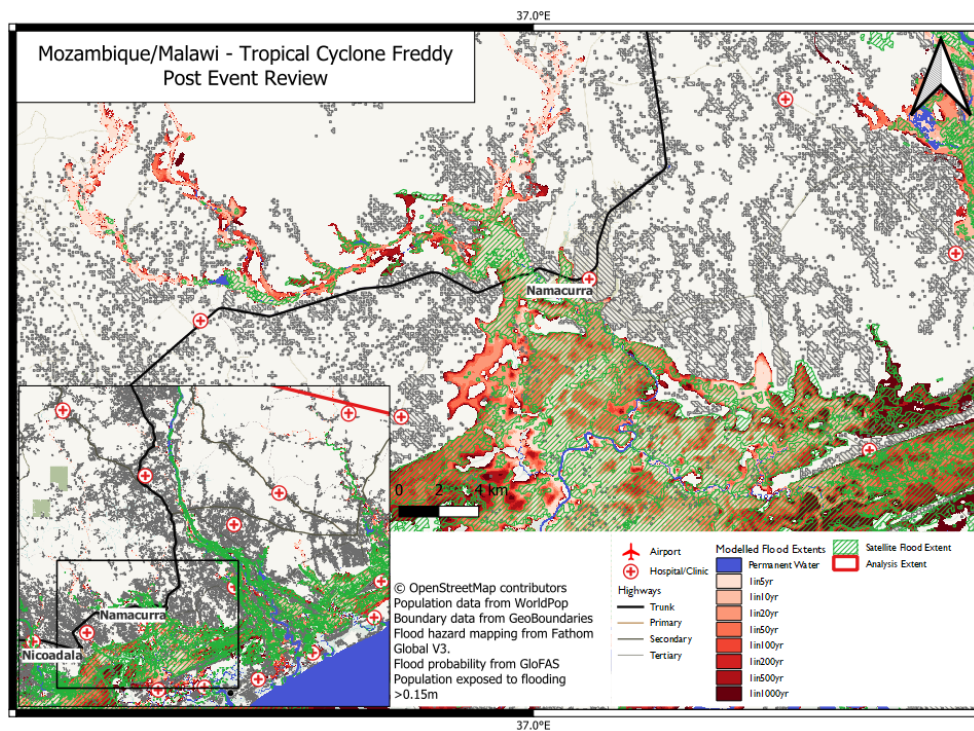
Figure S22: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Namacurra.
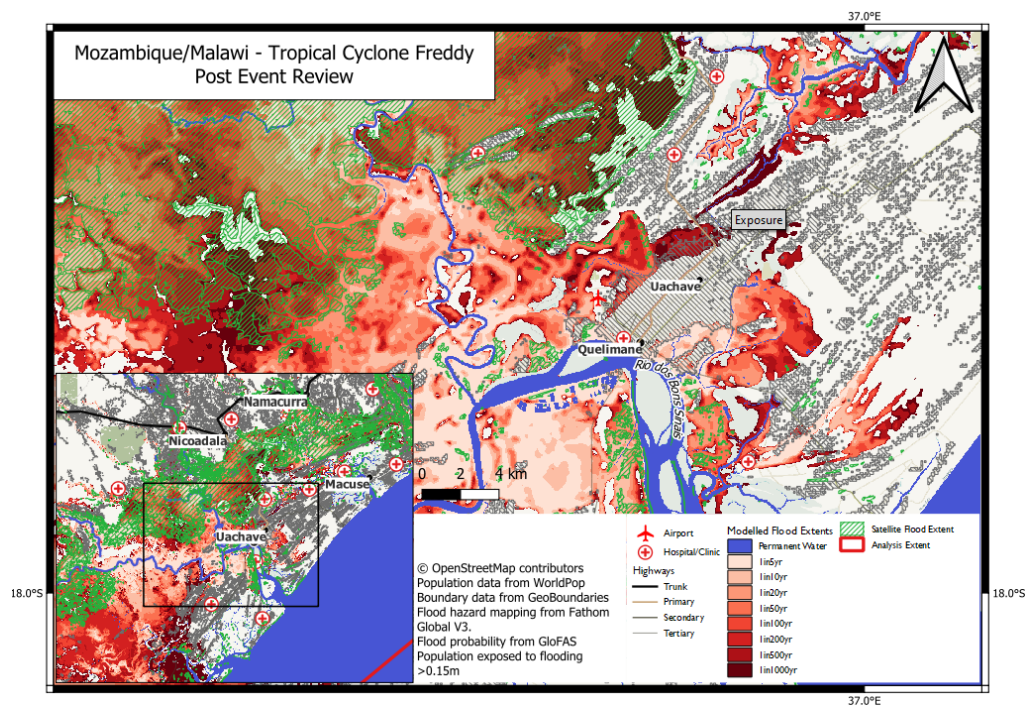
Figure S23: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Quelimane.
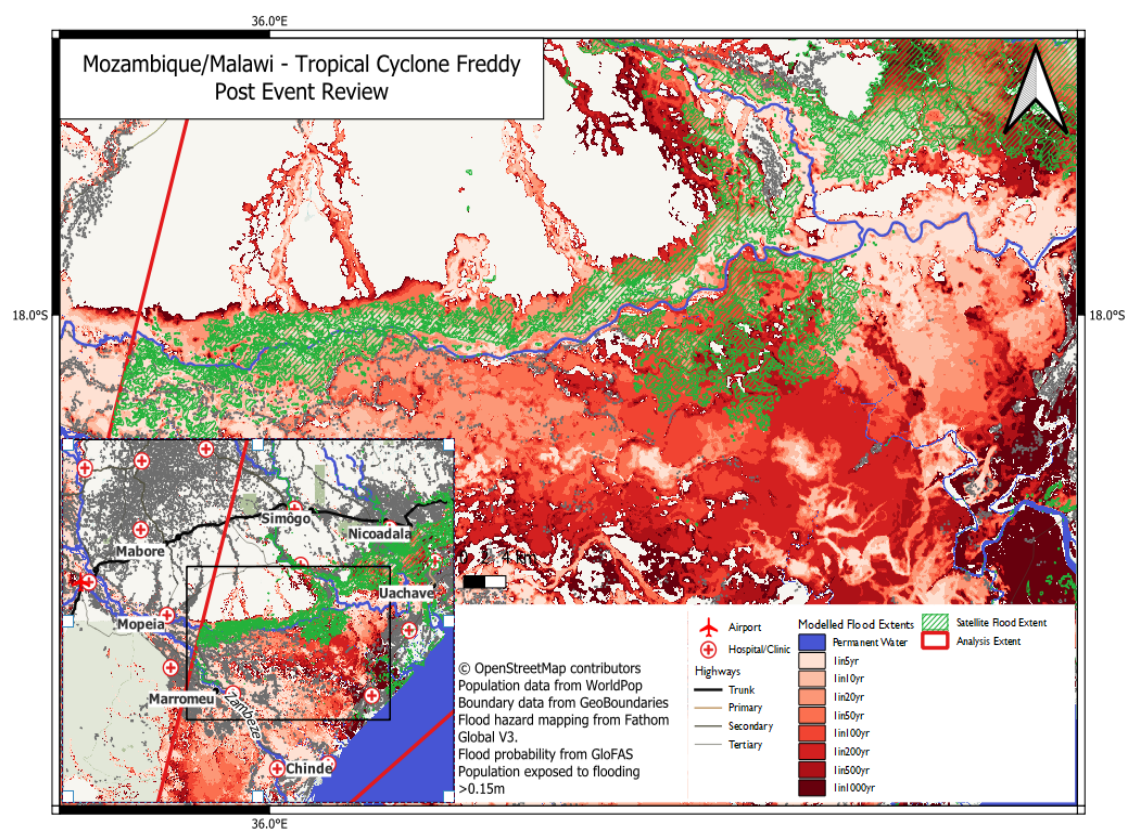
Figure S24: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure between Mopeia and Uacheve.

Copernicus EMSR654 Quelimane Monitoring 1. Situation at 17/03/2023 at 14:53 UTC

Release Date: 2023-03-18 01:32
Post-event image: COSMO-SkyMed© ASI (2023), distributed by e-GEOS S.p.A. (acquired on 17/03/2023 at 14:53 UTC, GSD100.0m), provided under COPERNICUS by the European Union and ESA, all rights reserved.
Scope: Quelimane area - Region between the Zambezi River Mouth and Pebane Town

Table S8: Exposure by district for Mozambique as observed on 17/03/2023 by COSMO-SkyMed. From left to right columns indicate: administrative district; country; total population of district; the best estimate (BE) of return period in the district given the median return period forecast by GloFAS rounded to the nearest available fathom flood map return period; the reasonable worst case (RWC) given the highest return period forecast (capped at 1 in 100 year); population exposure to the remotely sensed data; and population exposure to fathom return period, where closest to the remote sensing is highlighted in bold and GloFAS best estimates and reasonable worst cases are highlighted in blue and red, respectively.

District	Country	Overall Population	BE	RWC	Exposure from Satellite Extents	Fathom Global Flood Model Fluvial Exposure Estimates by Return Period							
						5	10	20	50	100	200	500	1000
Nicoadala	MOZ	152158	1in500	1in1000	15361	1076	2178	3323	5109	7606	**10961**	15391	18462
Namacurra - Namacurra	MOZ	156062	1in500	1in1000	6830	771	1452	2033	2931	3558	3899	4406	**4947**
Maganja Da Costa	MOZ	177351	1in200	1in500	3190	310	970	1789	**3268**	**4091**	4993	6705	7765
Inhassunge	MOZ	96032	1in500	1in1000	1848	27	103	147	226	458	776	918	**1816**
Namacurra - Rio Lucungo	MOZ	60300	1in200	1in500	1707	431	873	**1393**	**1866**	2589	3375	4484	5167
Mopeia - Not Zambezi	MOZ	22915	1in500	1in1000	920	448	**710**	**1082**	1740	2693	3673	4754	6564
Mocubela	MOZ	54276	1in200	1in500	224	26	**108**	**327**	523	805	899	970	1022
Maquival	MOZ	111862	1in500	1in1000	121	**65**	**143**	229	313	381	489	614	770
Mocuba - Rio Licungo	MOZ	4821	1in200	1in500	20	**32**	40	48	52	54	54	54	55
Chinde	MOZ	3224			0	**0**	5	14	115	181	412	612	1698
Cidade De Quelimane	MOZ	267158	1in500	1in1000	0	**9172**	14544	17160	19555	23255	27151	33439	36871
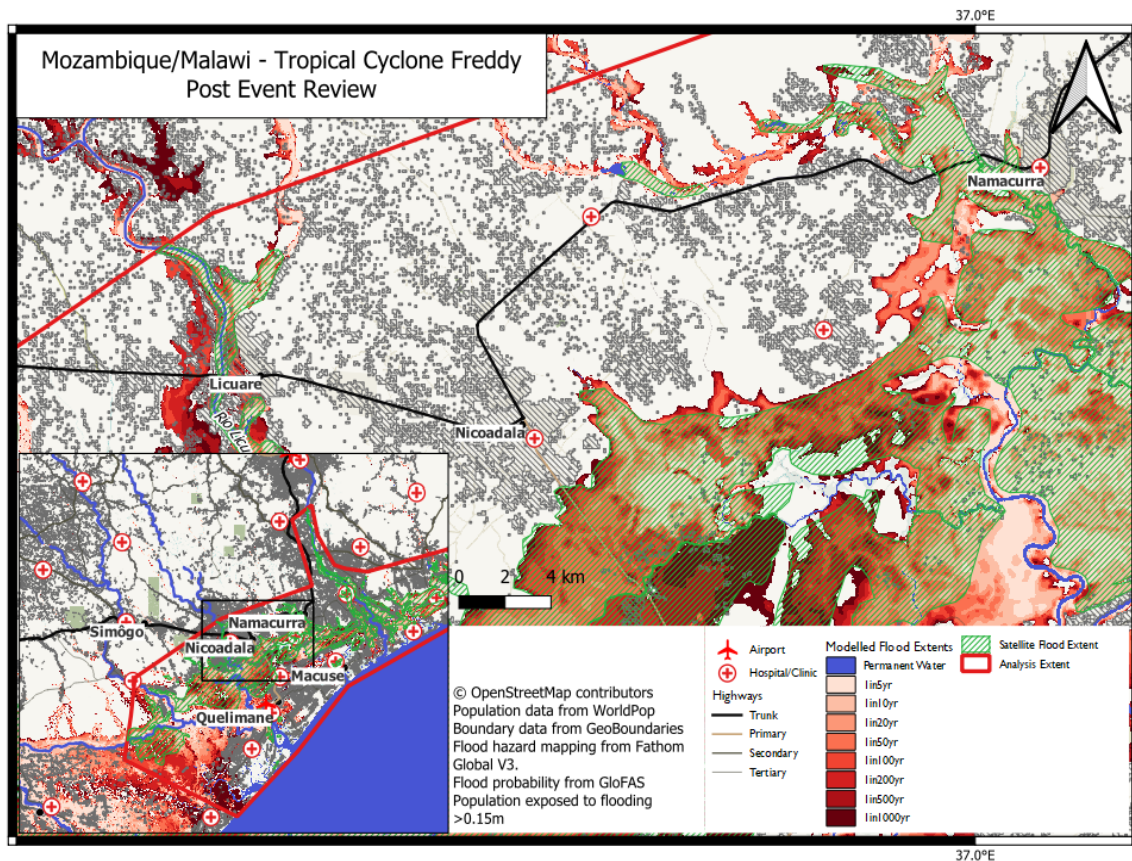
Figure S25: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Licuare and Nicodala.
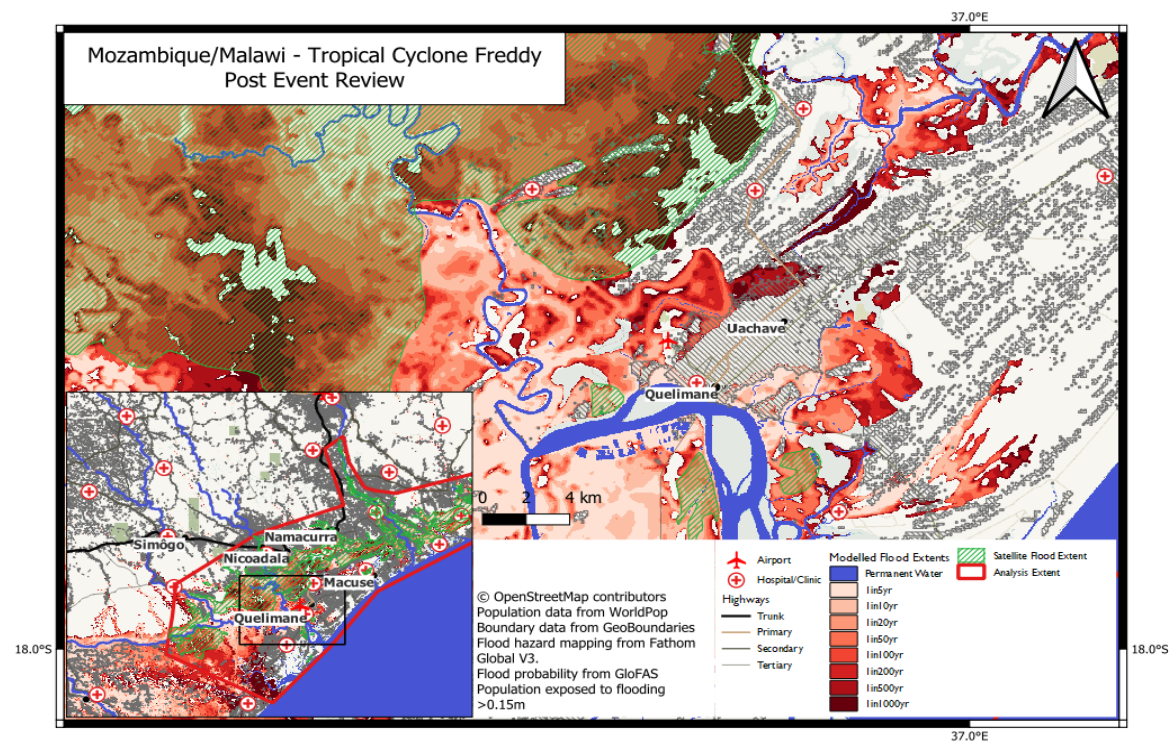
Figure S26: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure around Quelimane.
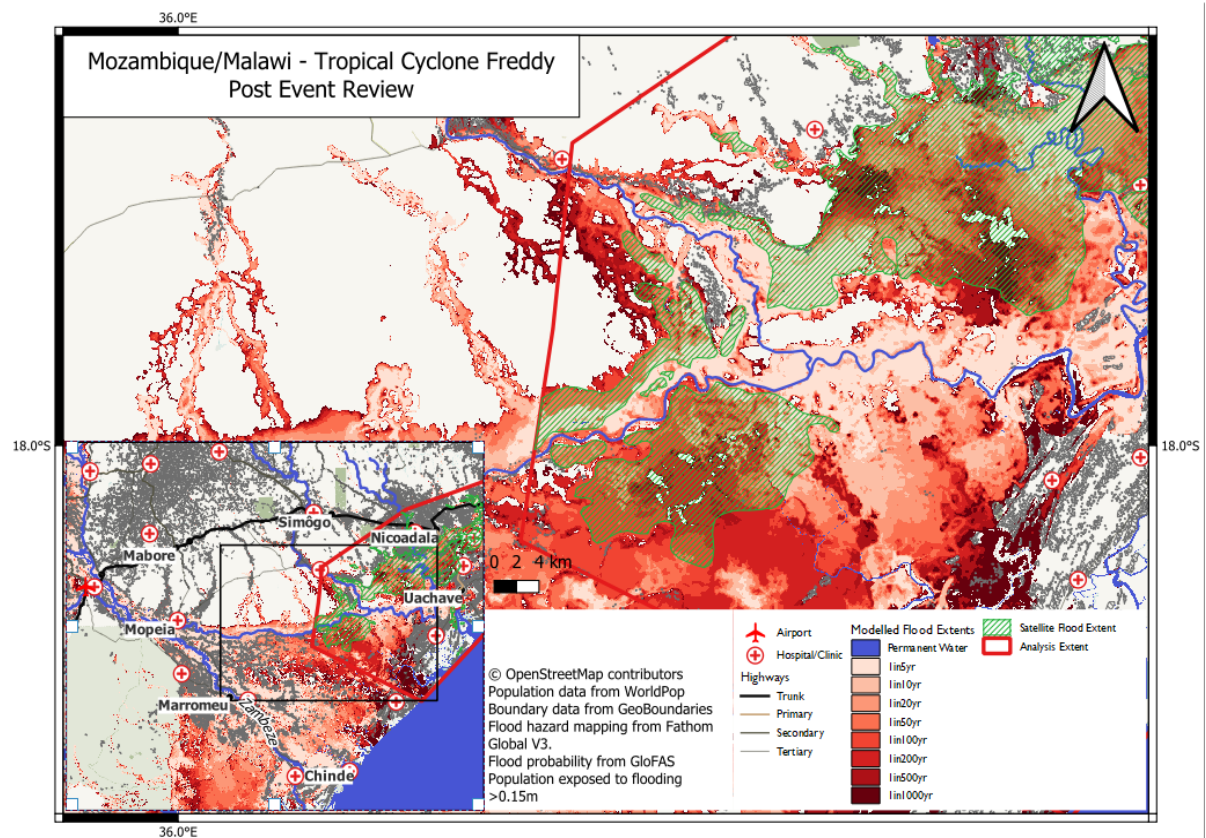
Figure S27: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure east of Mopeia to near Uacheve.

Copernicus EMSR654 Mutarara Monitoring 1. Situation at 23/03/2023 at 03:05 UTC

Release Date: 2023-03-23 15:01
Post-event image: RADARSAT 2 Data and products © Mac Donald, Dettwiler and Associates Ltd. (2023). (acquired on 23/03/2023 at 03:05 UTC, GSD50.0m) - RADARSAT is an official mark of the Canadian Space Agency - provided under COPERNICUS by the European Union and ESA, all rights reserved.
Scope: Mopeia Town upstream along the Zambezi and Chire Rivers

Table S9: Exposure by district for Mozambique as observed on 23/03/2023 by RADARSAT. From left to right columns indicate: administrative district; country; total population of district; the best estimate (BE) of return period in the district given the median return period forecast by GloFAS rounded to the nearest available fathom flood map return period; the reasonable worst case (RWC) given the highest return period forecast (capped at 1 in 100 year); population exposure to the remotely sensed data; and population exposure to fathom return period, where closest to the remote sensing is highlighted in bold and GloFAS best estimates and reasonable worst cases are highlighted in blue and red, respectively.

District	Country	Population	Final Estimate as of 2023-03-13 BE	RWC	Exposure from Satellite Extents	Fathom Global Flood Model Fluvial Exposure Estimates by Return Period 1in5	1in10	1in20	1in50	1in100	1in200	1in500	1in1000
Mutarara - Not Zambezi	MOZ	95536	1in200	1in500	19353	6185	**14262**	**27209**	41399	49416	59075	67118	74088
Morrumbala	MOZ	82355	1in200	1in500	4943	1983	**4021**	**6716**	11024	13583	15801	18687	21071
Mopeia - Zambezi Region	MOZ	40347			883	**6536**	11185	14514	17026	18115	18928	19738	20368
Caia - Zambezi Region	MOZ	95644			872	**15130**	28007	36246	42268	45231	47253	50366	55635
Caia - Not Zambezi	MOZ	31559	1in500	1in1000	623	**2031**	6496	10588	14637	16079	17052	18125	19073
Mopeia - Not Zambezi	MOZ	33646	1in500	1in1000	498	**623**	1605	2191	2643	2917	3226	3585	3857
Mutarara - Zambezi Region	MOZ	77743			133	**5285**	14445	24875	32669	36081	38440	40914	43424
Nsanje	MWI	679	1in200	1in500	132	**59**	**178**	316	451	526	556	578	594
Doa - Zambezi Region	MOZ	15196			70	**2377**	2868	3501	4749	5445	6046	6563	7159
Cheringoma - Inland Reg	MOZ	5675	1in500	1in1000	56	**136**	189	216	265	339	435	620	754
Marromeu - Zambezi Region	MOZ	50835			30	**538**	1997	6663	11350	12592	13087	13558	14154
Luabo	MOZ	4061			26	**647**	1391	2263	3073	3475	3692	3883	3949
Doa - Not Zambezi	MOZ	20636	1in20	1in50	10	**19**	30	55	127	192	320	514	782
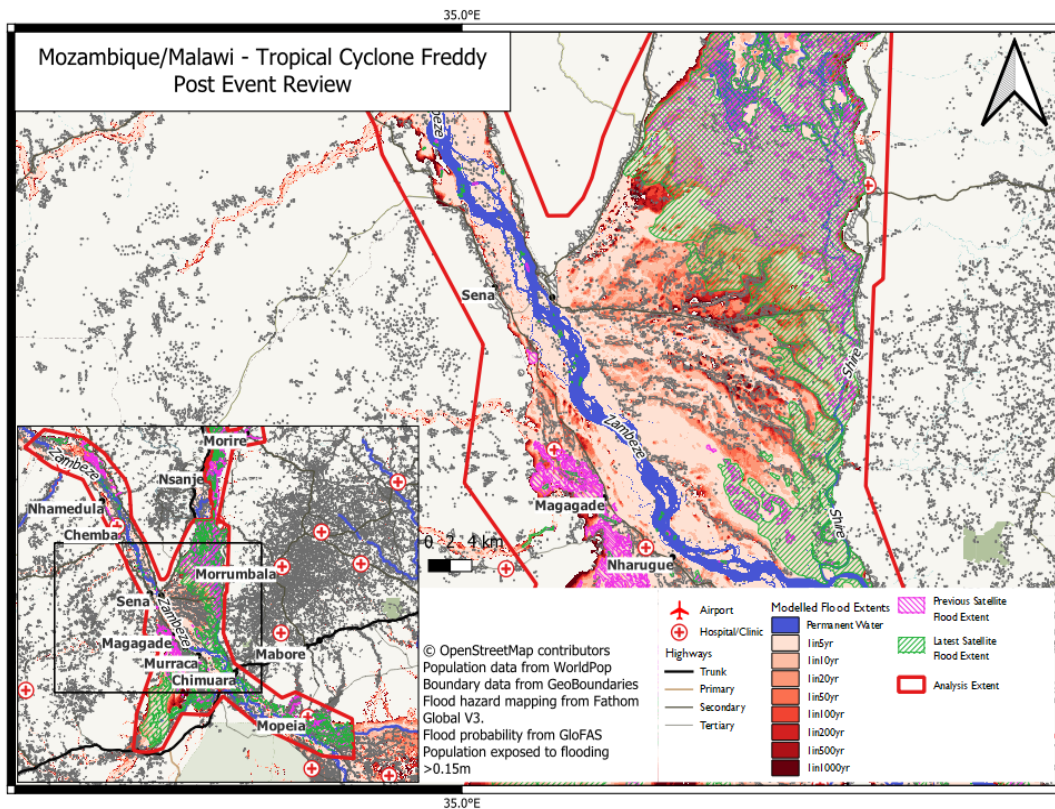
Figure S28: Return period flood extents (red), satellite derived inundation extent (Green) and major infrastructure at the Shire River and Zambezi River confluence.