

Supplementary Material

S.1 Dataset Geographic Distribution

To ensure robust geometric feature learning, the HiRes-FusedMIM dataset is curated from 56 distinct urban regions. While the volume is driven by high-resolution open data availability in Central Europe, we explicitly include anchor samples from diverse global morphologies (e.g., North American grids, South American density, Asian verticality) to prevent geographic overfitting.

Table S1: **Geographic distribution of the 1.2M pre-training tiles.** The dataset balances high-volume European regions (for training stability) with diverse global anchor points (for morphological generalization).

Region	Representative Cities	Samples	Dominant Morphology
Germany	Nurnberg, Ingolstadt, Bayreuth, Berlin, Munich	$\approx 890k$	Dense Historical & Modern European
France	Lyon, Toulouse, Bordeaux, Strasbourg, Nantes	$\approx 140k$	Dense Urban & Rural Transitions
Switzerland	Zurich, Geneva, Bern, Winterthur, Lausanne	$\approx 45k$	Complex Alpine Terrain & Mixed Use
Brazil	São Paulo	19,320	High-Density Megacity
Lebanon	Tripoli	16,146	Coastal / Arid Dense Urban
USA	Washington D.C.	2,793	Orthogonal Grid / Federal
Colombia	Medellin	1,539	Complex Topography / Valley
Vietnam	Ho Chi Minh City	143	Asian High-Rise / Mixed Density

S.2 Geographic Visualization of Training Data

Figure S1 visualizes the geographic distribution of the 1.2 million pre-training tiles. The dataset balances high-volume regions in Central Europe with strategic global anchor points to ensure morphological diversity.

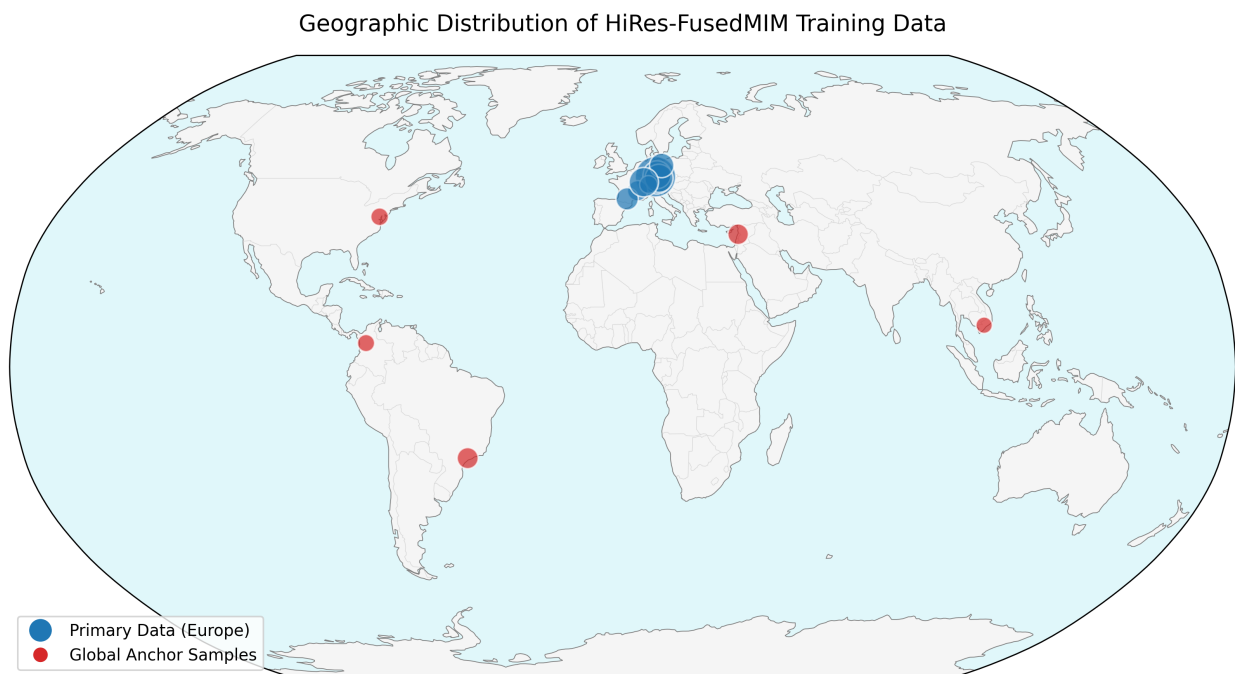


Figure S1: **Geographic distribution of the HiRes-FusedMIM dataset.** Bubble size represents the number of samples (log scale). The dataset includes 1.2M tiles spanning 56 urban regions, with major clusters in Germany, France, and Switzerland, and diversity anchors in the Americas, Asia, and the Middle East.

Table S2: Source-level provenance of the RGB–DSM pre-training corpus. For each source region, we report the native RGB and DSM product identities, the nominal native ground sample distance (Nominal GSD), the final targeted spatial resolution utilized during model training (Training GSD), the documented orthophoto type, the DSM production source specified by the provider, and the number of sampled training chips.

Country/Region	City/Region	RGB product	DSM product	Nominal GSD (m)	Training GSD (m)	Orthophoto type	DSM source	# chips
Brazil	São Paulo	Satellite (Pan-sharpened)	DSM	0.5	0.5	Satellite Ortho	Airborne LiDAR	19320
Colombia	Medellín	Satellite (Pan-sharpened)	DSM	0.3	0.3	Satellite Ortho	Airborne LiDAR	1539
France	Avignon	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	6958
France	Châtelleraut	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	2485
France	Lyon	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	14384
France	Nancy	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	7120
France	Nîmes	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	5680
France	Orléans	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	12412
France	Poitiers	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	7921
France	Rennes	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	9523
France	Toulouse	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	28480
France	Épinal	BD ORTHO HR	MNS High-Res	0.5	0.5	Orthophotomosaic	IGN Source	2485
Germany	Augsburg	DOP20 (BVV)	DOM20 (BVV)	0.2	0.5	Orthophotomosaic	Image Matching	26928
Germany	Bamberg	DOP20 (BVV)	DOM20 (BVV)	0.2	0.2	Orthophotomosaic	Image Matching	54635
Germany	Bayreuth	DOP20 (BVV)	DOM20 (BVV)	0.2	0.2	Orthophotomosaic	Image Matching	81830
Germany	Berlin	Satellite (Pan-sharpened)	DSM	0.3	0.3	Satellite Ortho	Airborne LiDAR	45350
Germany	Bielefeld	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	8560
Germany	Bochum	Satellite (Pan-sharpened)	DSM	0.5	0.5	Satellite Ortho	Airborne LiDAR	1936
Germany	Bonn	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	10568
Germany	Cologne	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	16472
Germany	Dortmund	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	16492
Germany	Dresden	Satellite (Pan-sharpened)	DSM	0.2	0.2	Satellite Ortho	Airborne LiDAR	47526
Germany	Düsseldorf	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	50730
Germany	Essen	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	36391
Germany	Hagen	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	5680
Germany	Hamburg	Satellite (Pan-sharpened)	DSM	0.5	0.5	Satellite Ortho	Airborne LiDAR	1734
Germany	Hann	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	9523
Germany	Herford	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	3286
Germany	Ingolstadt	DOP20 (BVV)	DOM20 (BVV)	0.2	0.2	Orthophotomosaic	Image Matching	94552
Germany	Krefeld	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	7921
Germany	Mannheim	DOP20 rgb	DOM1	0.2 / 1.0	1.0	Orthophotomosaic	Airborne LiDAR	1496
Germany	Minden	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	5680
Germany	Munich	Satellite (Pan-sharpened)	DSM	0.5	0.5	Satellite Ortho	Airborne LiDAR	8712
Germany	Münster	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	7120
Germany	Neubrandenburg	DOP20	DOM20	0.2	0.2	Orthophotomosaic	not specified	15842
Germany	North Rhine-Westphalia	Satellite (Pan-sharpened)	DSM	0.3, 0.5	0.3, 0.5	Satellite Ortho	Airborne LiDAR	46464
Germany	Nuremberg	DOP20	DOM20	0.2	0.2	Orthophotomosaic	not specified	274455
Germany	Paderborn	DOP10 rgbi	BDOM50	0.1 / 0.5	0.5	Orthophotomosaic	Geobasis NRW	6400
Germany	Regensburg	DOP20 (BVV)	DOM20 (BVV)	0.2	0.2	Orthophotomosaic	Image Matching	84100
Germany	Rosenheim	DOP20 (BVV)	DOM20 (BVV)	0.2	0.2	Orthophotomosaic	Image Matching	35600
Germany	Stuttgart	DOP rgb20	DOM1	0.2 / 1.0	1.0	Orthophotomosaic	Airborne LiDAR	3520
Libya	Tripoli	Satellite (Pan-sharpened)	DSM	0.5	0.5	Satellite Ortho	Airborne LiDAR	16146
Switzerland	Appenzell	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	289
Switzerland	Bern	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	13994
Switzerland	Buchs SG	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	2288
Switzerland	Geneva	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	8108
Switzerland	Herisau	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	884
Switzerland	Lausanne	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	5355
Switzerland	Schaffhausen	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	1225
Switzerland	St. Gallen	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	3111
Switzerland	Winterthur	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	1352
Switzerland	Zürich	SWISSIMAGE 10 cm	swissSURFACE3D	0.1	0.5	Orthophotomosaic	Airborne LiDAR	3172
United States	Washington, D.C.	Satellite (Pan-sharpened)	DSM	0.5	0.5	Satellite Ortho	Airborne LiDAR	2793
Vietnam	Ho Chi Minh City	Satellite (Pan-sharpened)	DSM	0.5	0.5	Satellite Ortho	Airborne LiDAR	143
Total	—	—	—	—	—	—	—	1186670