

Supplementary material

Vegetation dynamics in Alpine glacier forelands tackled from space

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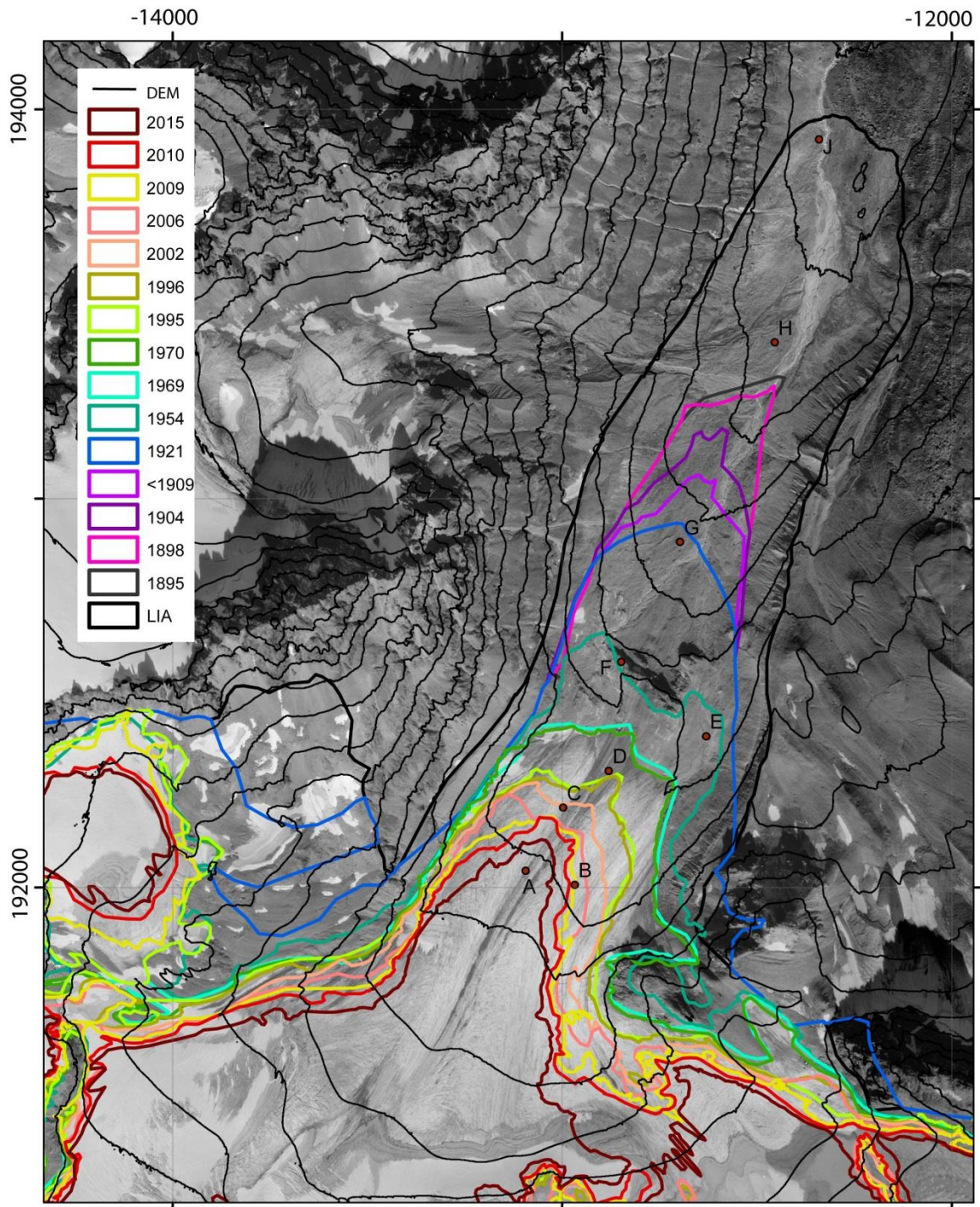


Fig. S1: Extent of Jamtalferner in various years between LIA maximum and 2015, as well as contour lines (DEM of 2006) superimposed on an orthophoto from 1970 (source: Land Tirol - data.tirol.gv.at CC BY 4.0).

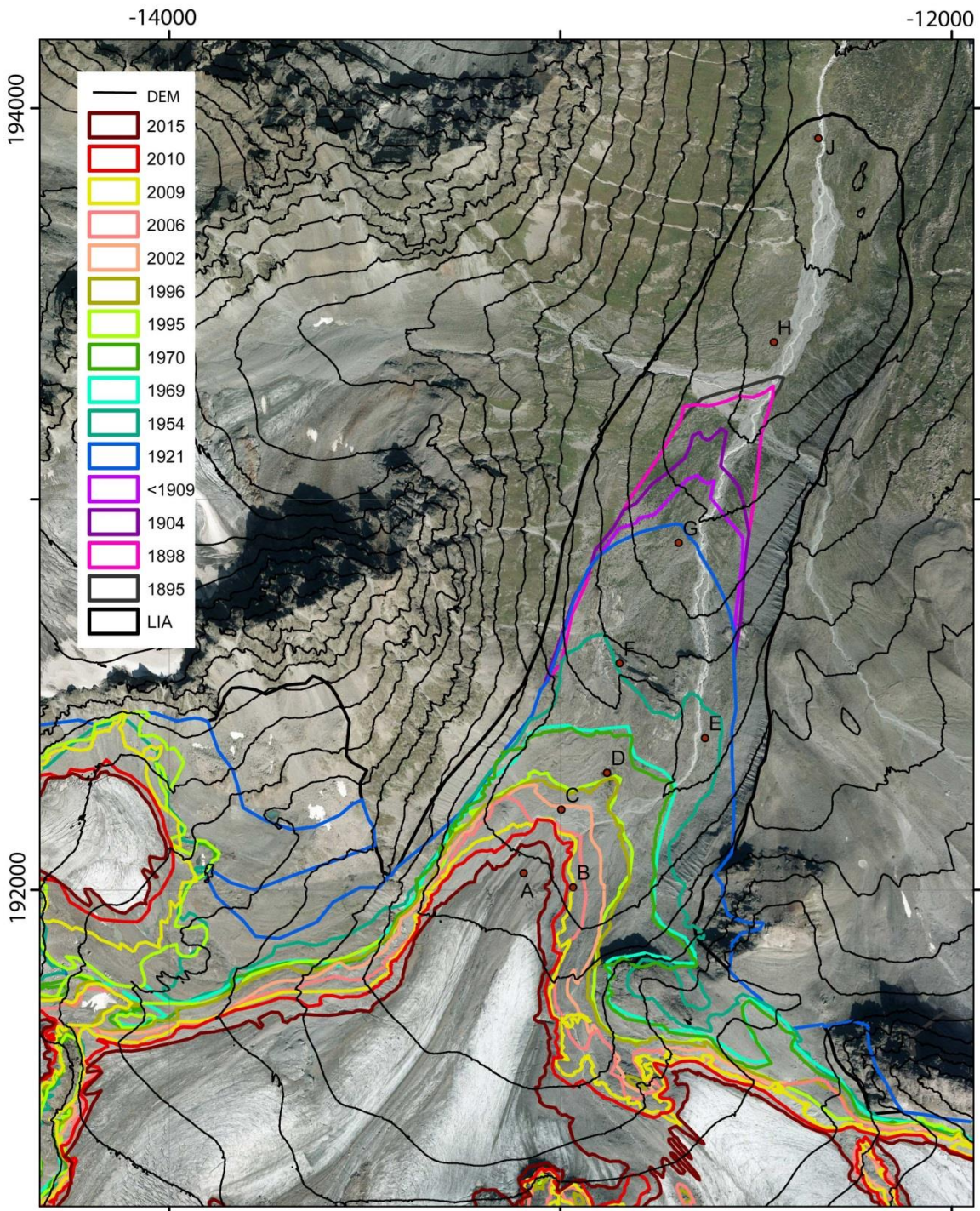


Fig. S2: Extent of Jamtalferner in various years between LIA maximum and 2015, as well as contour lines (DEM of 2006) superimposed on an orthophoto from 2015 (source: Land Tirol - data.tirol.gv.at CC BY 4.0).

Table S1: Monthly, seasonal and annual means of air temperature and precipitation sums at the Galtür station (1587 m, 1951-2000) and precipitation at the rain gauge at the tongue of Jamtalferner (2400 m, 1989-2017), provided by the Hydrographical Service of the Federal Government of Tyrol. % of Galtür: percentage of precipitation at the glacier tongue compared to precipitation measured in Galtür. See also the insert in Figure 1.

Galtür	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	May-Sep	Oct-Apr	year
Temperature in °C	3.9	-1.7	-5.0	-5.9	-5.0	-2.2	1.3	6.3	9.5	12	11.2	8.2	9.4	-2.1	2.7
Precipitation in mm	60	64	62	66	57	60	54	81	123	147	142	97	590	423	1013
Jamtalferner	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	May-Sep	Oct-Apr	year
Precipitation in mm	102	97	98	94	93	93	90	120	183	195	205	137	840	667	1507
% of Galtür	170	151	159	142	163	155	167	148	149	133	144	141	142	158	149

Table S2. Fossil trees (*Pinus cembra*) found close to the Jamtal hut with lab code and results.

sample ID	laboratory ID	altitude	¹⁴ C age BP	calibrated age BC (2σ)
FT-1	VRI-1990	2290	4630±60	3631-3116
FT-2	VRI-1991	2240	4550±60	3500-3020

Table S4: NDVI 2016, as well as means and changes for two periods (1985-1991, 2009) at the sample sites with altitude. * glacier area at that date.

Ice-free years	Sample	Altitude	NDVI mean 1985-1991	NDVI mean 2009	NDVI 85_91-2009	NDVI 2016
1	A	2464	*	*	0.09	-0.03
7	B	2430	*	*	0.12	0.00
15	C	2409	*	0.03	0.08	0.11
25	D	2405	0.01	0.13	0.11	0.21
55	E	2389	0.16	0.29	0.13	0.40
70	F	2384	0.16	0.29	0.13	0.40
90	G	2271	0.27	0.29	0.02	0.35
120	H	2177	0.32	0.40	0.08	0.46
150	J	2123	0.36	0.43	0.07	0.50
average			0.11	0.20	0.09	0.27

Table S5: Maps and DEMs of Jamtalferner with source and date. GI1,2,3: part of the glacier inventory. BW: Black and white images. * The LIA maximum state has been reported for 1864, based on a conversation of Greim with Gottlieb Lorenz (1844-1911), who was a shepherd in Jamtal in his 20s. This oral reported date is not consistent with other literature, for example, Richter's observation about the contact of Jamtalferner and Totenfeldferner and older maps. Therefore, this date must be considered uncertain. TIRIS: orthophotos of surveys of the federal government of Tyrol.

Year	Type	Source	Remarks
2015	orthophoto	TIRIS	
2010	orthophoto	TIRIS	
2006	LiDAR	TIRIS	GI3
2002	orthophoto	TIRIS	
2002	orthophoto		BW GI2
1996	orthophoto		GI2
2009	orthophoto	TIRIS	
1995	orthophoto	TIRIS	BW
1970	orthophoto	TIRIS	BW
1969	orthophoto		BW GI1
1954	orthophoto	TIRIS	BW
1921	map	[20]	1:15,000
not specified	map	[35]	1:25,000
1909	map	[20]	1:15,000
1904	map	[20]	1:15,000
1898	map	[20]	1:15,000
?	map	[40]	1:50,000
1895/1897	map	[25]	1:10,000
1888	point		
1870	point		
	map	[34]	1:50,000
~1864*	LIA moraine	[20]	GI LIA

Table S6: List of remote-sensing images used in the study.

Satellite sensor	Date	Path/Row
Landsat 5 TM	19850813	193/027
Landsat 5 TM	19900802	194/027
Landsat 5 TM	19900811	193/027
Landsat 5 TM	19910830	193/027
Landsat 5 TM	19980808	194/027
Landsat 5 TM	20040801	193/027
Landsat 5 TM	20060823	193/027
Landsat 5 TM	20070826	193/028
Landsat 5 TM	20090806	194/027
Landsat 5 TM	20090815	193/027
Landsat 5 TM	20090831	193/028
Landsat 8 OLI	20130801	194/027
Landsat 8 OLI	20150731	193/027
Landsat 8 OLI	20160825	194/027

Table S7: Spectral bands used for this study with wavelength range and spatial resolution for the sensors in Table 4.

	Red		NIR	
Satellite sensor	wavelength range (nm)	Resolution (m)	wavelength range (nm)	Resolution (m)
Landsat 5 TM	630-690	30	760-900	30
Landsat 8 OLI	636-673	30	851-879	30