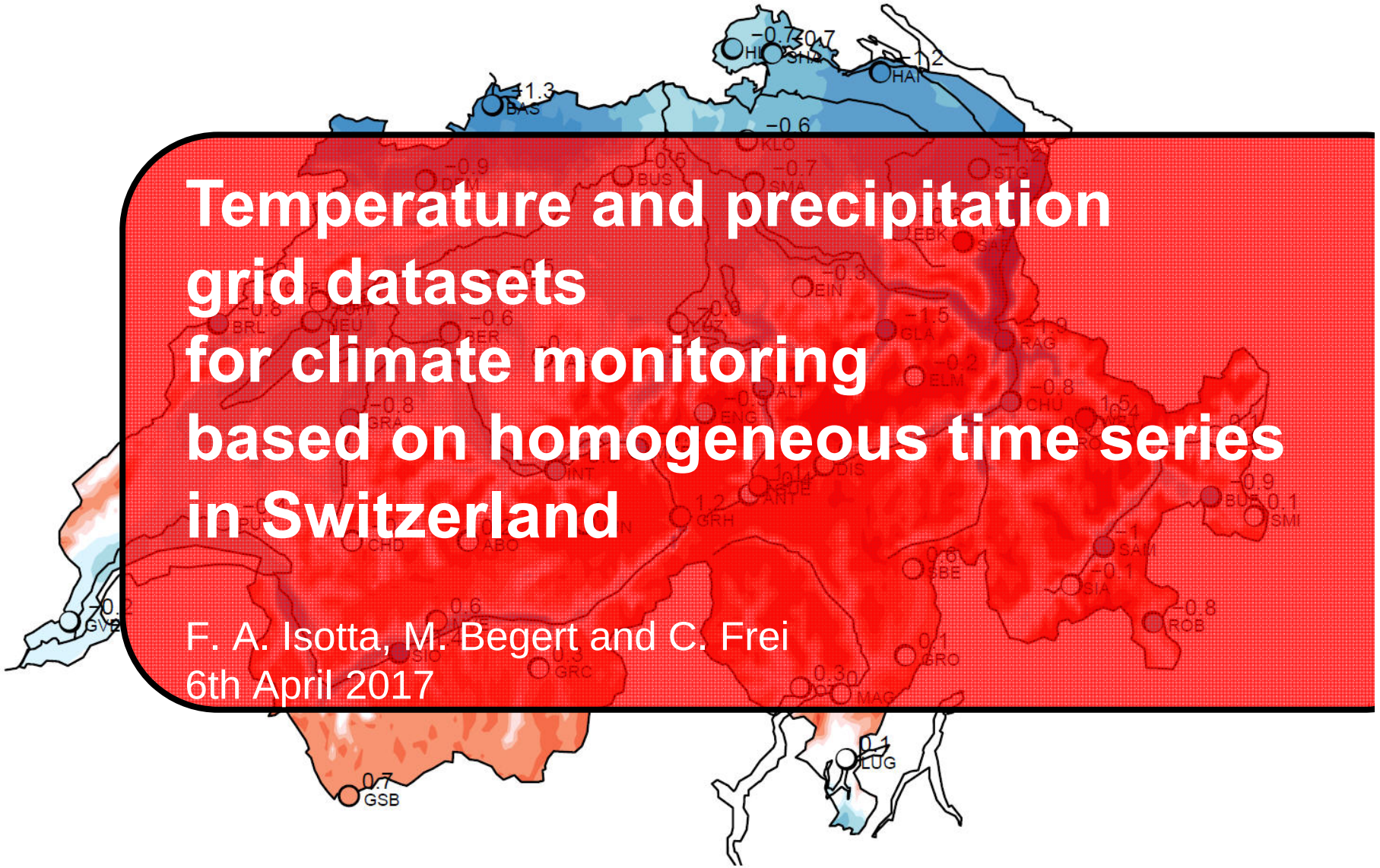
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

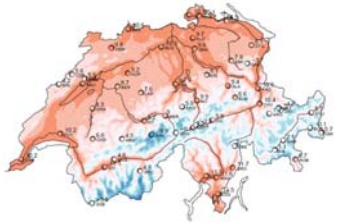


Temperature and precipitation grid datasets for climate monitoring based on homogeneous time series in Switzerland

F. A. Isotta, M. Begert and C. Frei
6th April 2017

Content

Introduction: motivation, method

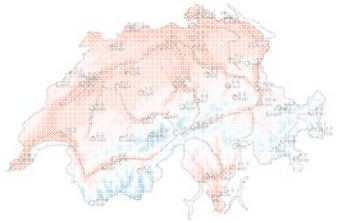


Results and evaluation

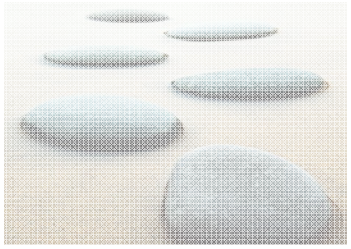
Conclusion and outlook

Content

Introduction: motivation, method



Results and evaluation



Conclusion and outlook

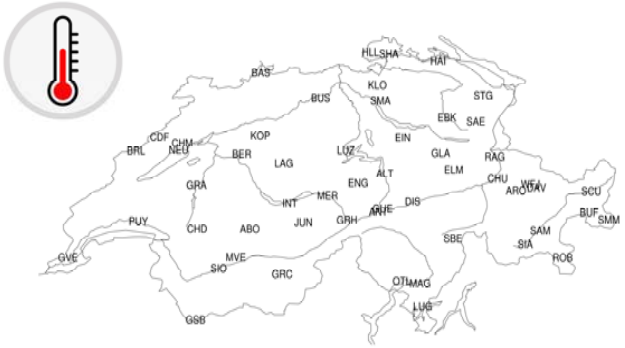
Introduction - Motivation

- Develop new datasets for monthly temperature and precipitation suitable for climate monitoring (regularly updated)
  - 1864-2016 (-now) , 1901-2016 (-now) and 1961-2016 (-now)
  - Only with homogenized station data
  - Continuous measurements (no gaps)
  - Constant station density and distribution (same stations every time step)

Introduction - Motivation

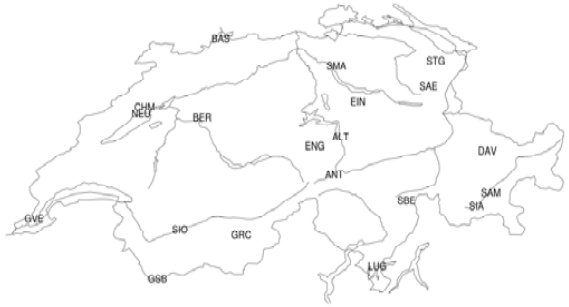
- The amount of stations fulfilling all requirements is low

	Temperature	Precipitation
1864-2016	20	17
1901-2016	28	69
1961-2016	54	292



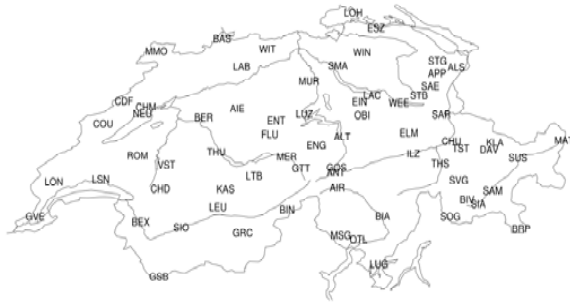
T, 1961-2016, 54 stations

T, 1901-2016, 28 stations

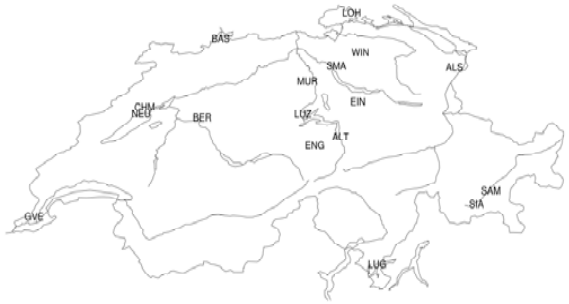


T, 1864-2016, 20 stations

P, 1961-2016, 292 stations

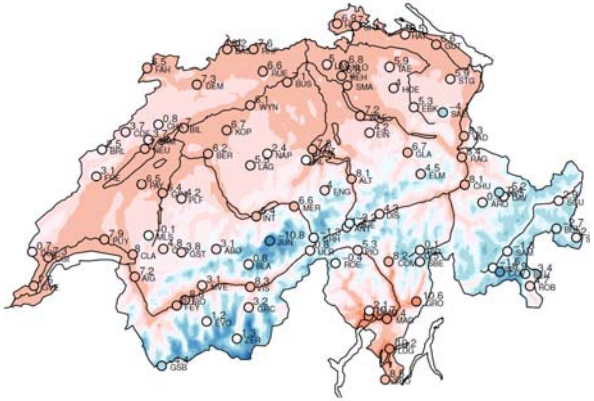


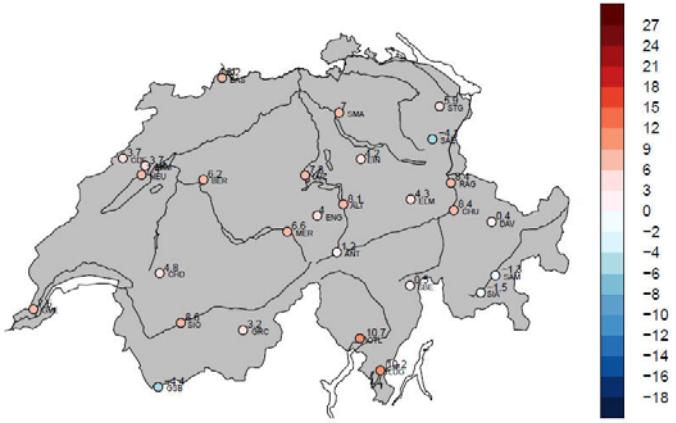
P, 1901-2016, 69 stations



P, 1864-2016, 17 stations

Introduction - Method

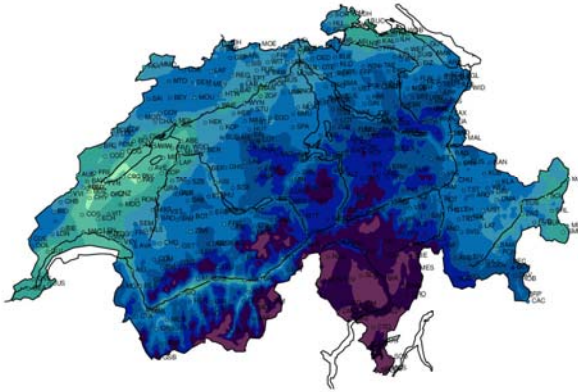




High-resolution component
1981-2010, 2-km grid dataset
~ 85 (T) / 670 (P) stations

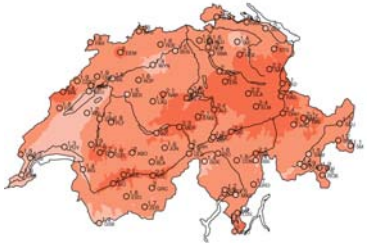
+

Long-term component
1901-2016
28 (T) / 69 (P) stations (continuous)



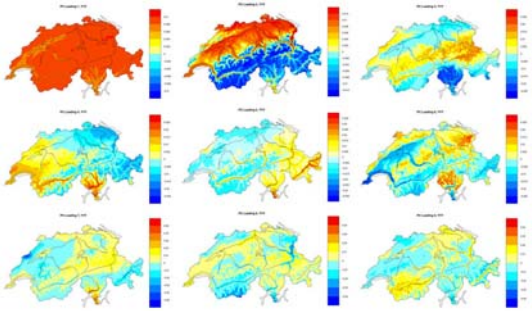
RSOI - Overview

- **R**educed **S**pace **O**ptimal **I**nterpolation (Kaplan et al., 1997; Schmidli et al. 2001, 2002; Schiemann et al., 2010; Masson et al., 2015)



High-resolution component
CALIBRATION PERIOD (1981-2010)
(anomalies for T, data transformation for P)

PCA →



PC loadings
Dimensionality reduction (truncation)

+

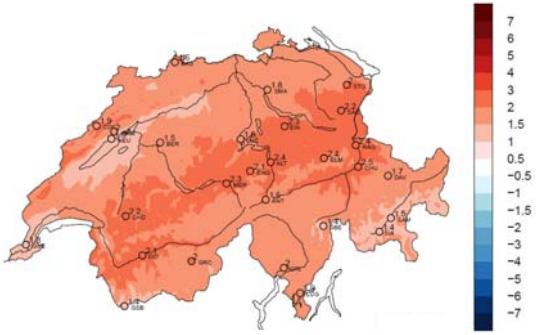
```
$data
   station         time    value
1      ALT 200203010000 2.43
2      ANT 200203010000 1.60
3      BAS 200203010000 1.59
4      BER 200203010000 1.52
5      CDF 200203010000 1.88
6      CHD 200203010000 2.18
7      CHM 200203010000 1.98
8      CHU 200203010000 2.46
9      DAV 200203010000 1.71
10     EIN 200203010000 2.28
11     ELM 200203010000 2.36
12     ENG 200203010000 2.07
13     GRC 200203010000 2.00
14     GSB 200203010000 1.41
15     GVE 200203010000 1.27
16     LUG 200203010000 1.85
17     LUZ 200203010000 1.85
```

Station data (sparse network)
CALIBRATION PERIOD
(1981-2010) (transformed for P)

Station data (sparse network)
RECONSTRUCTION PERIOD
(1864/1901/1961-2016)
(transformed for P)

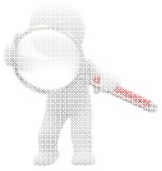
```
$data
   station         time    value
1      ALT 200203010000 2.43
2      ANT 200203010000 1.60
3      BAS 200203010000 1.59
4      BER 200203010000 1.52
5      CDF 200203010000 1.88
6      CHD 200203010000 2.18
7      CHM 200203010000 1.98
8      CHU 200203010000 2.46
9      DAV 200203010000 1.71
10     EIN 200203010000 2.28
11     ELM 200203010000 2.36
12     ENG 200203010000 2.07
13     GRC 200203010000 2.00
14     GSB 200203010000 1.41
15     GVE 200203010000 1.27
16     LUG 200203010000 1.85
17     LUZ 200203010000 1.85
```

→ OI

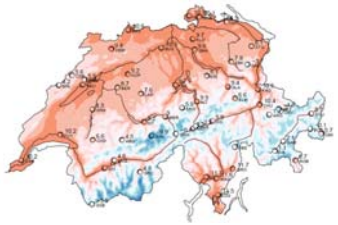


Reconstruction (sparse network)
RECONSTRUCTION PERIOD
(1864/1901/1961-2016)
(back-transformed for P)

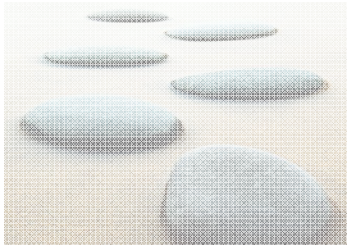
Content



Introduction: motivation, method



Results and evaluation



Conclusion and outlook

RSOI – Results and evaluation

- Calibration period: 1981-2010
- Reconstruction period: 1961-2016, 1901-2016, 1864-2016
- Dimensionality reduction (truncation): 12 🌡️, 30/22/14 🌧️
- Evaluation:
  - Tests with changing calibration (length and period), truncation, data quality, stations amount
  - Use of crossvalidation (leave-one-out): $x_{i,reconstr}, x_{i,obs}$
  - Mean absolute error (MAE)
  - Mean-Squared Error Skill Score (MSESS)

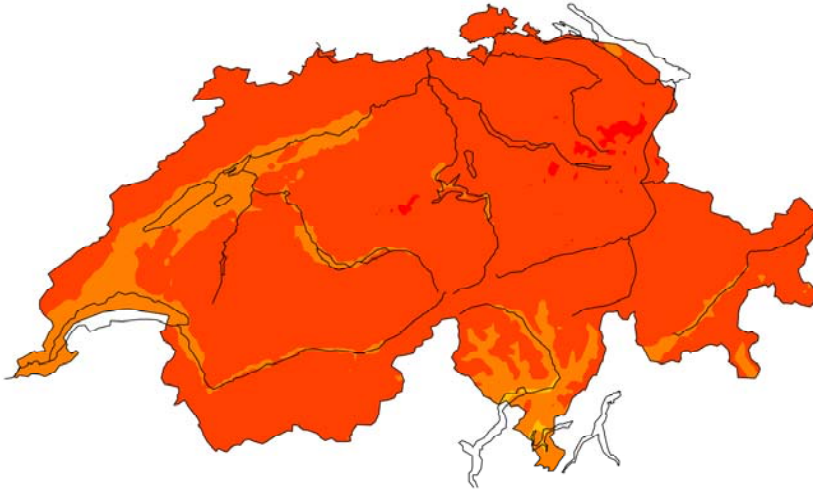
    1= perfect reconstruction, 0=no skill
  - Trend

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left(|x_{i,reconstr} - x_{i,obs}|\right)$$

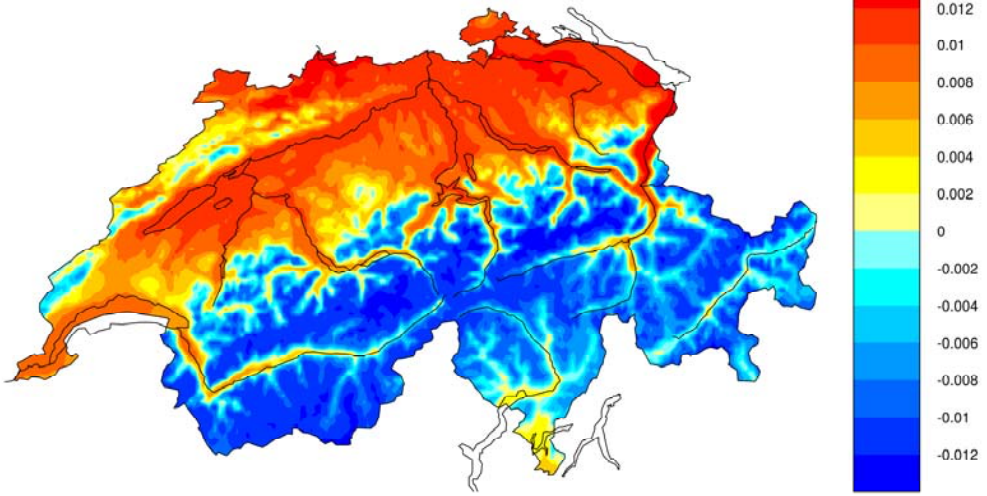
$$MSESS = 1 - \frac{\sum_{i=1}^{n}\left(x_{i,reconstr} - x_{i,obs}\right)^2}{\sum_{i=1}^{n}\left(x_{i,obs} - \overline{x_{i,obs}}\right)^2}$$

PCA (on anomalies)

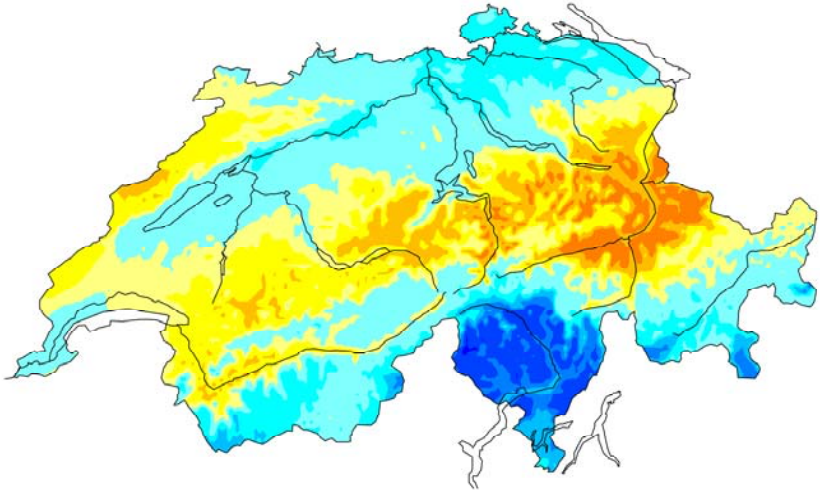
PC loading 1 – 91%



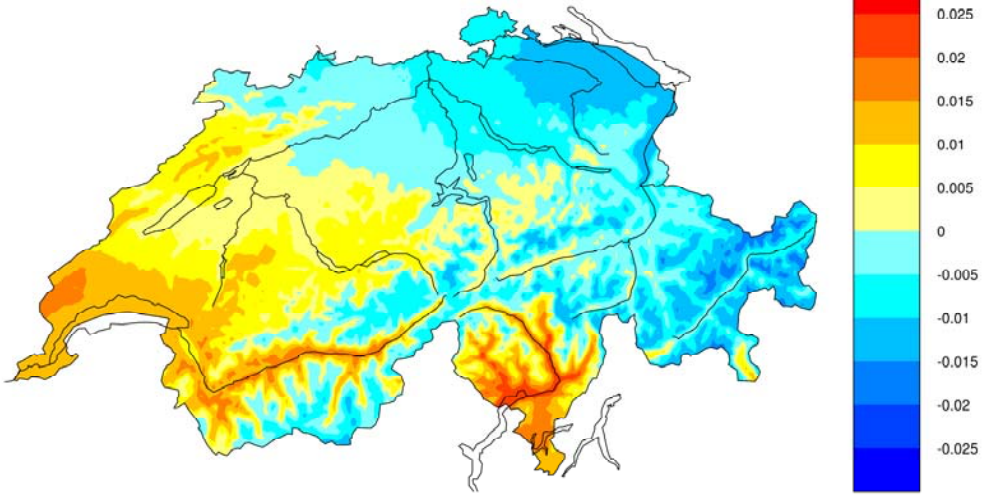
PC loading 2 – 5%



PC loading 3 – 1%



PC loading 4 – 1%

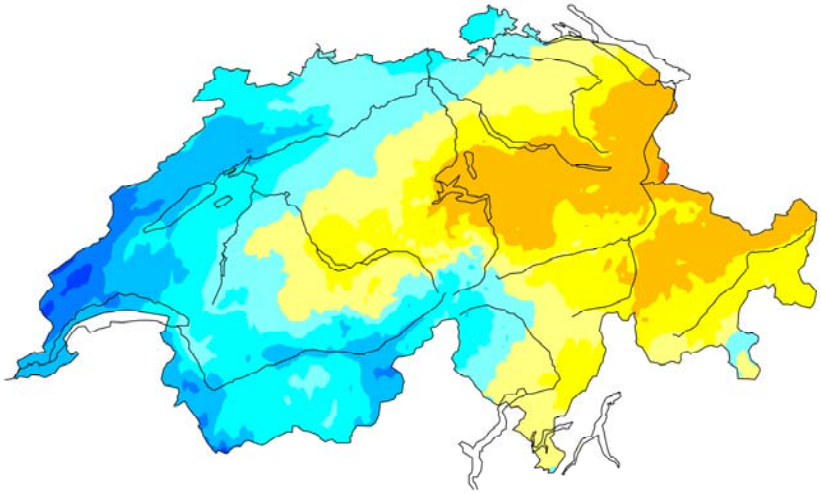


PCA (P)

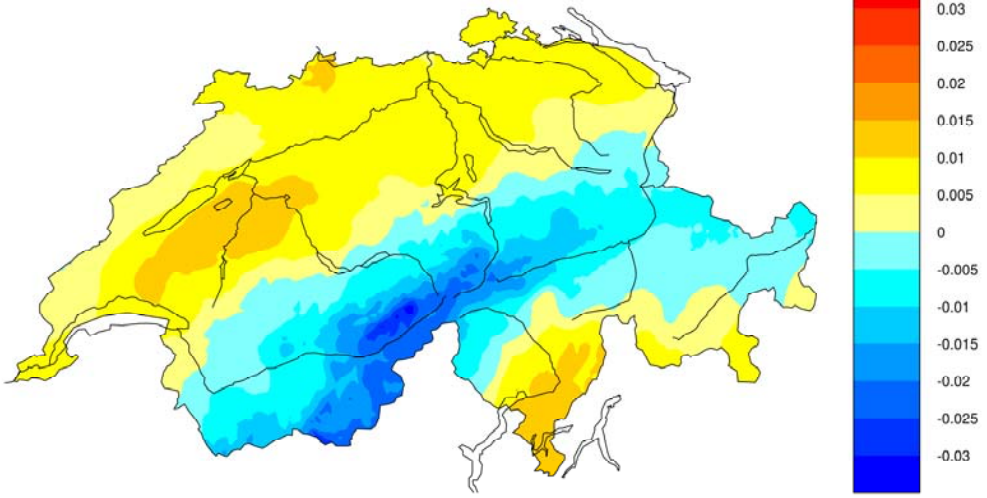
PC loading 1 – 65%

PC loading 2 – 15%

PC loading 3 – 5%

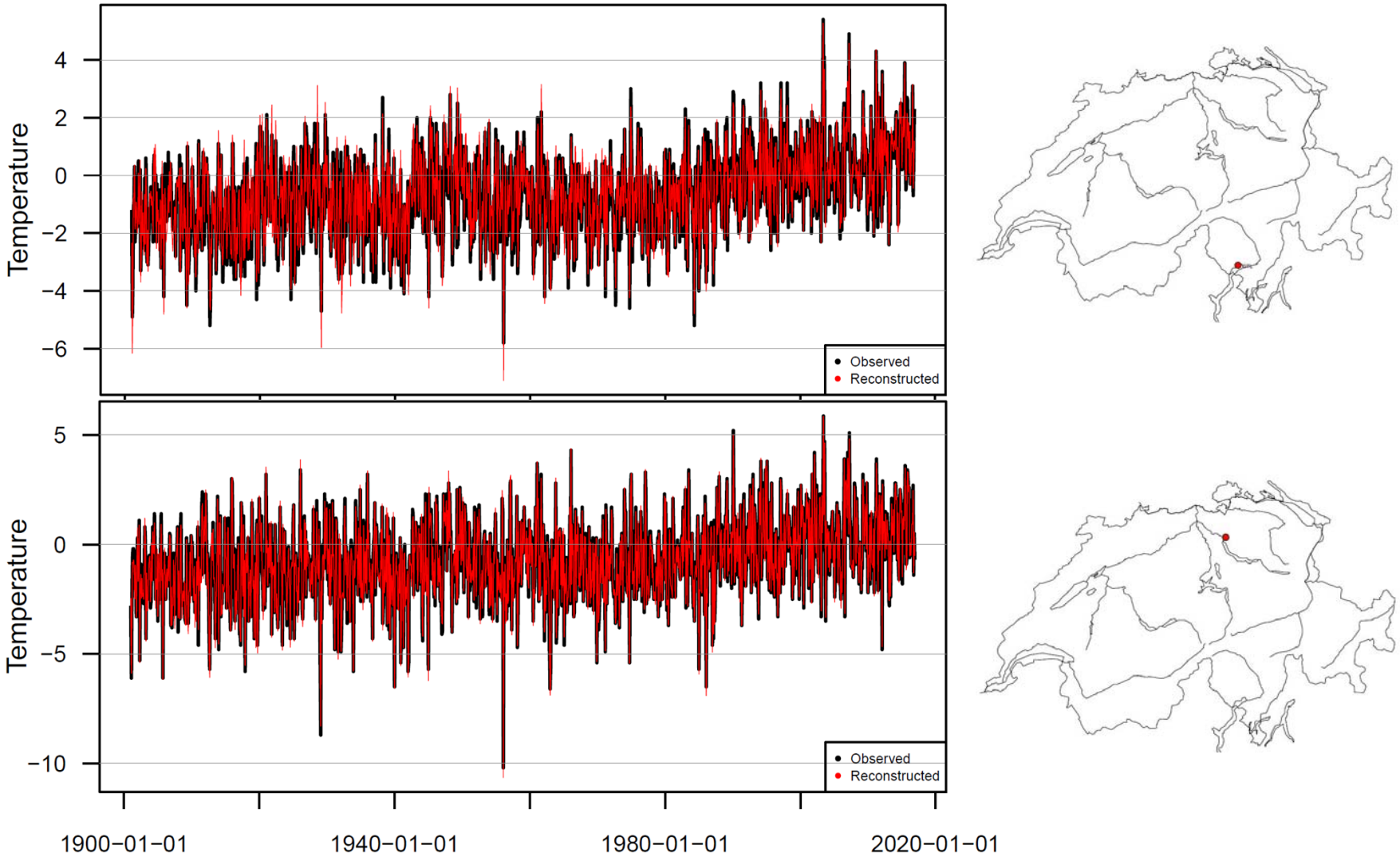


PC loading 4 – 4%



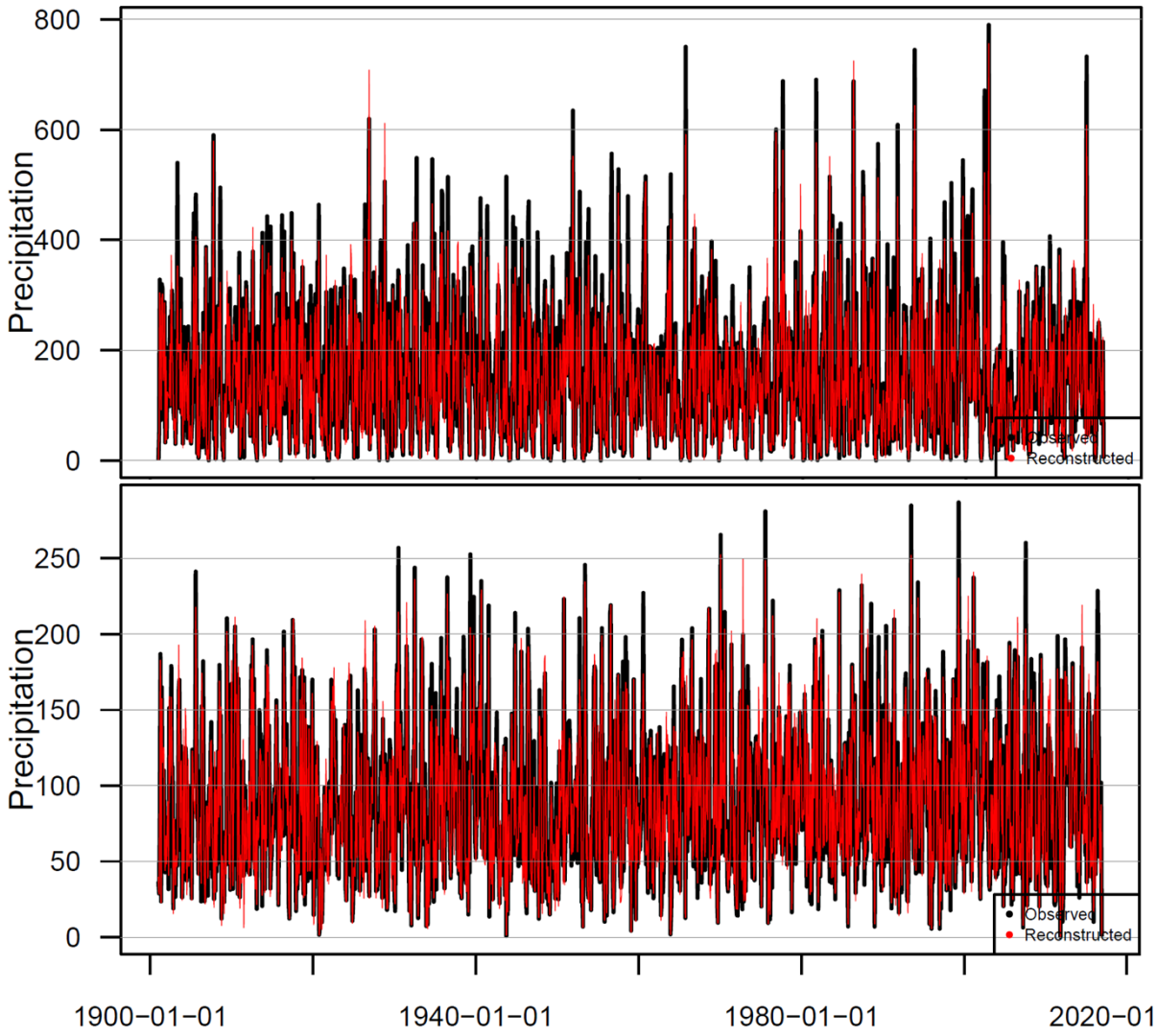
Reconstruction examples

(anomalies 1981-2010)



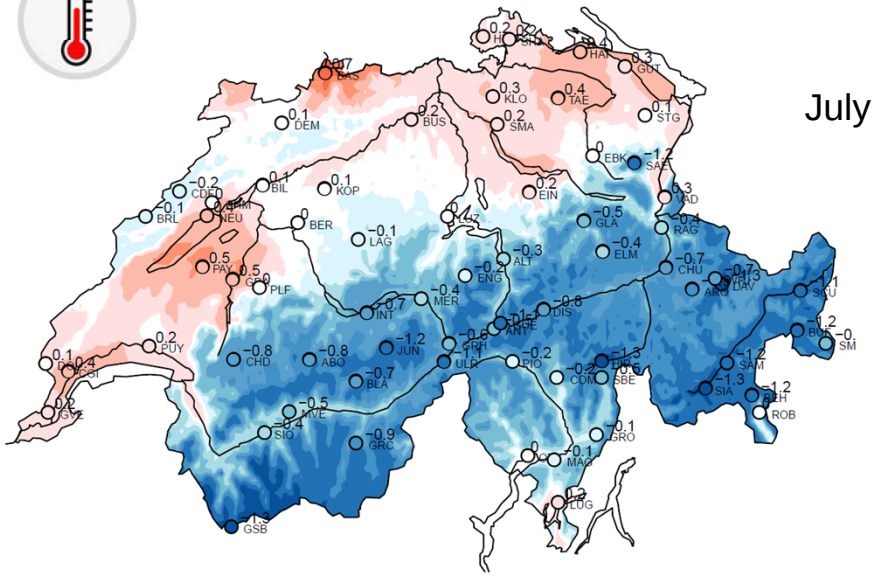
Reconstruction examples

[mm/month]



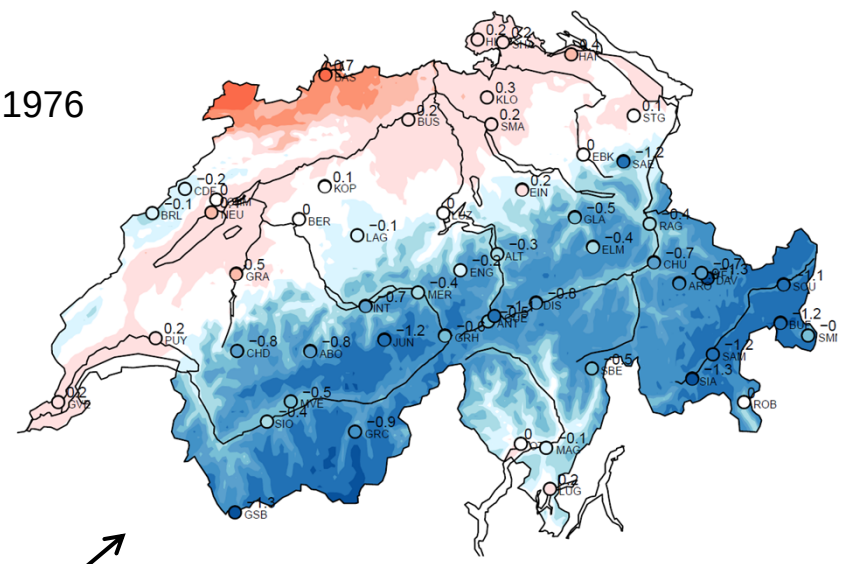
Reconstrucion examples (anomalies 1981-2010)

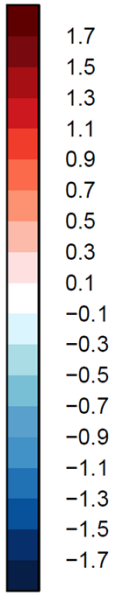
Direct interpolation



July 1976

Reconstruction

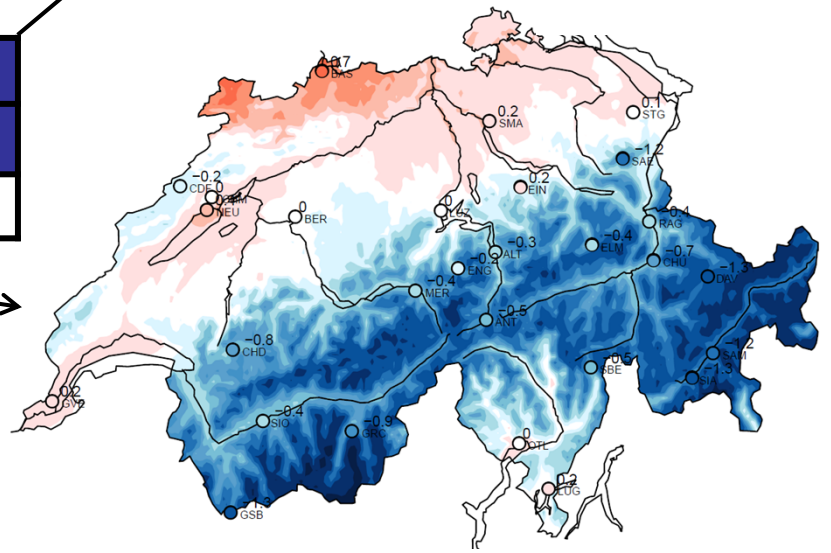




MSESS		
ALL	54 stations	28 stations
0.61	0.65	0.59

MSESS	
54 stations	28 stations
0.76	0.70

MSESS
28 stations
0.63

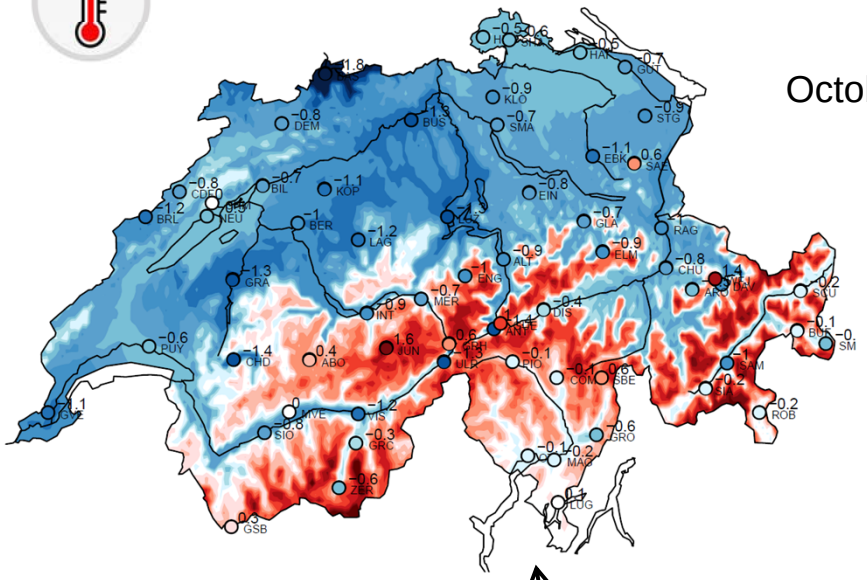


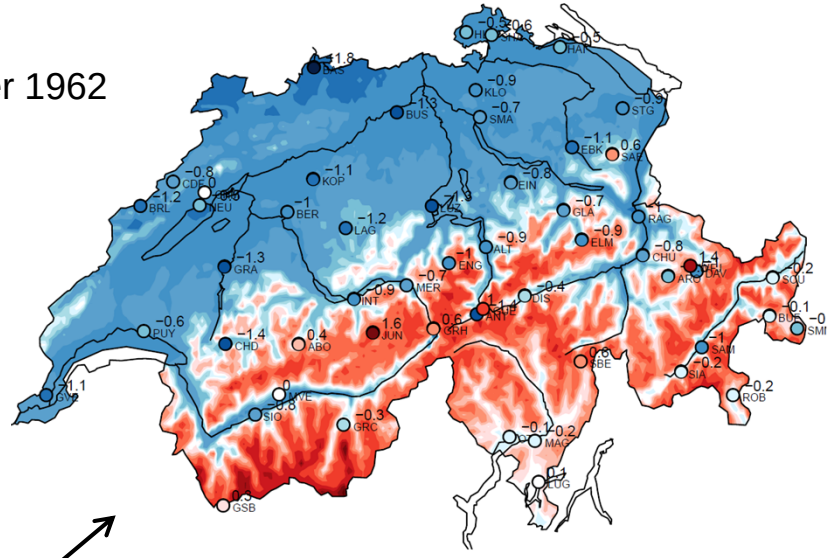
Reconstrucion examples (anomalies 1981-2010)

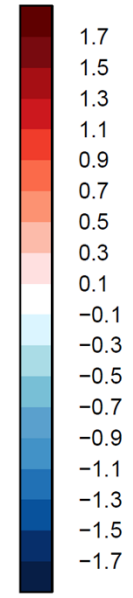
Direct interpolation

Reconstruction

October 1962



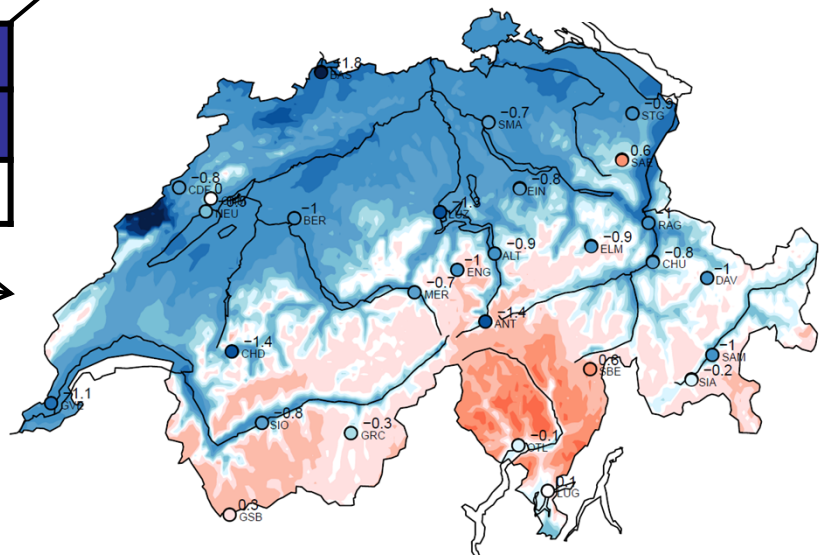




MSESS		
ALL	54 stations	28 stations
0.36	0.38	0.21

MSESS	
54 stations	28 stations
0.23	-0.33

MSESS
28 stations
0.02

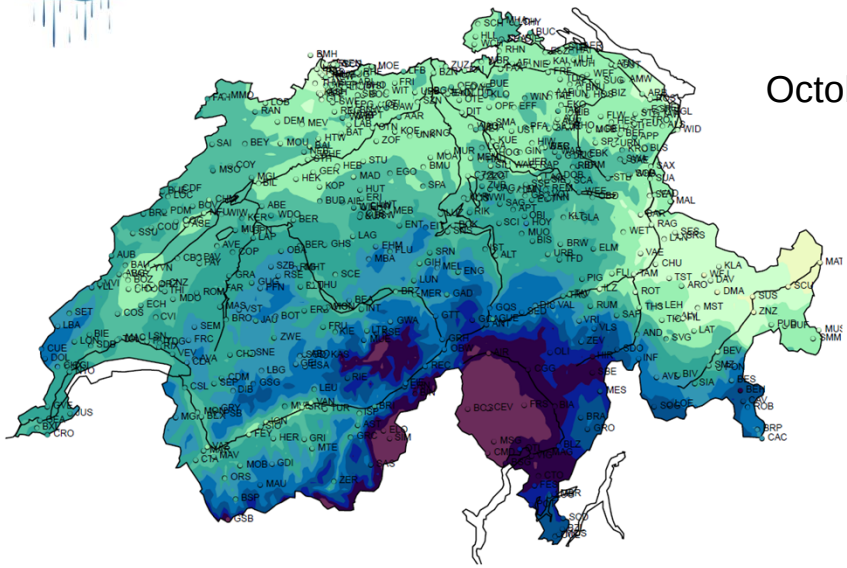


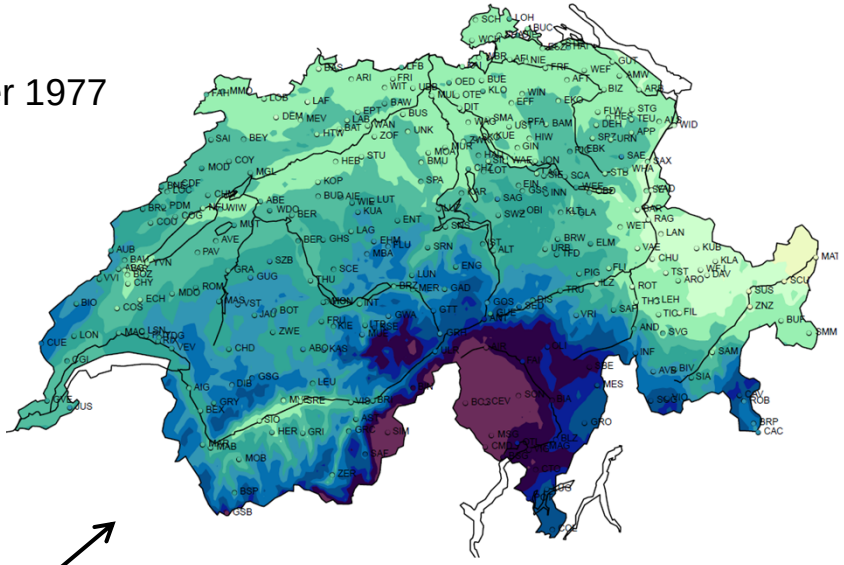
Reconstrucion examples

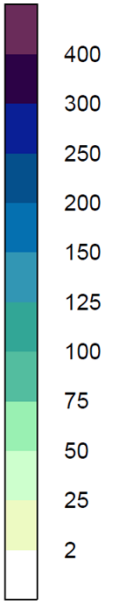
Direct interpolation

Reconstruction

October 1977



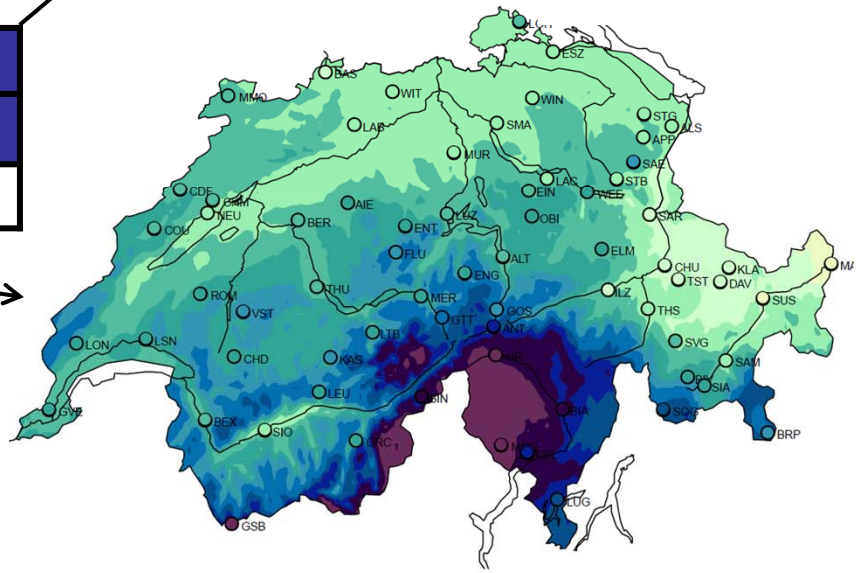




MSESS		
ALL	292 stations	69 stations
0.91	0.91	0.88

MSESS	
292 stations	69 stations
0.94	0.96

MSESS
69 stations
0.94

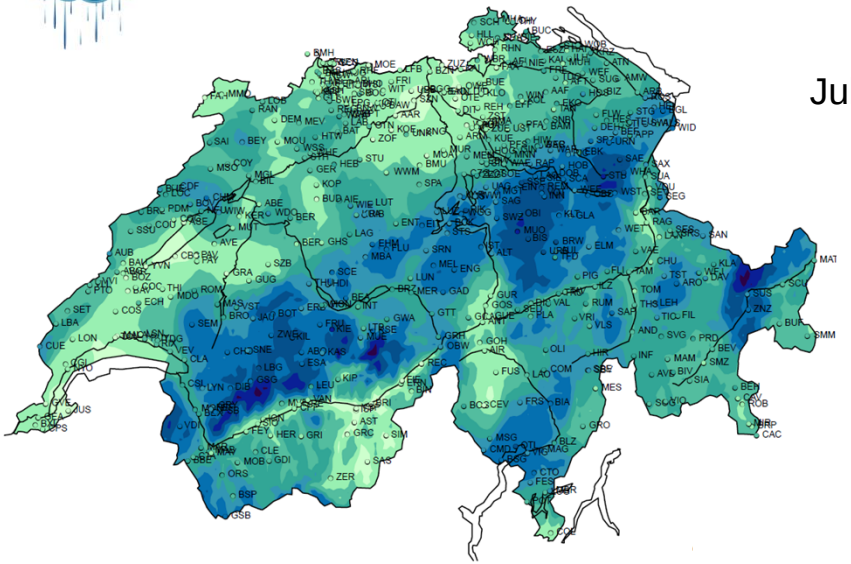


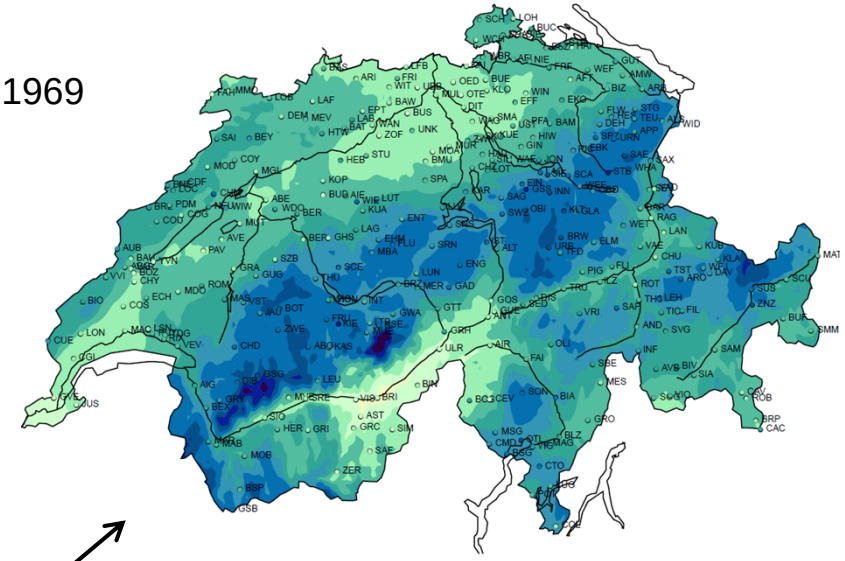
Reconstrucion examples

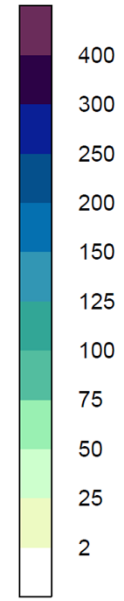
Direct interpolation

Reconstruction

July 1969



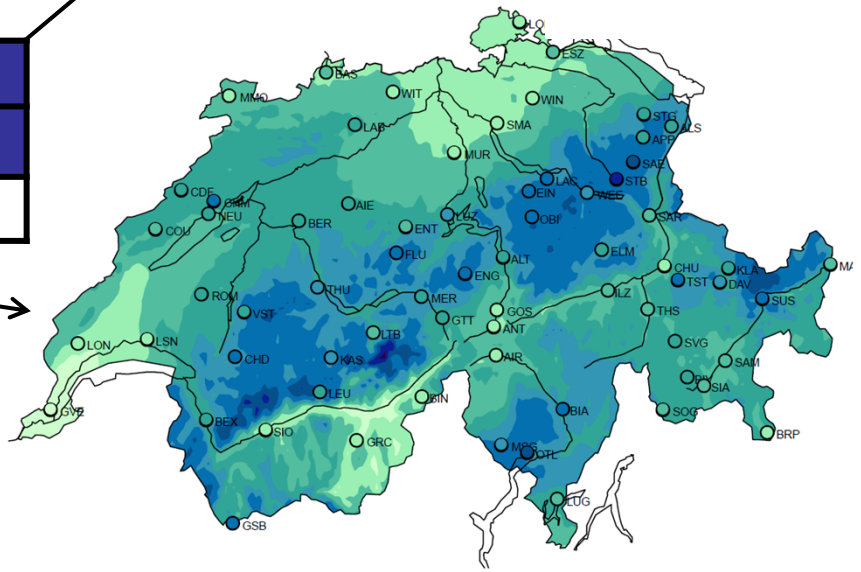




MSESS		
ALL	292 stations	69 stations
0.70	0.62	0.65

MSESS	
292 stations	69 stations
0.51	0.45

MSESS
69 stations
0.27



Mean absolute error (degC, mm/month)

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left(|x_{i,reconstr} - x_{i,obs}|\right)$$

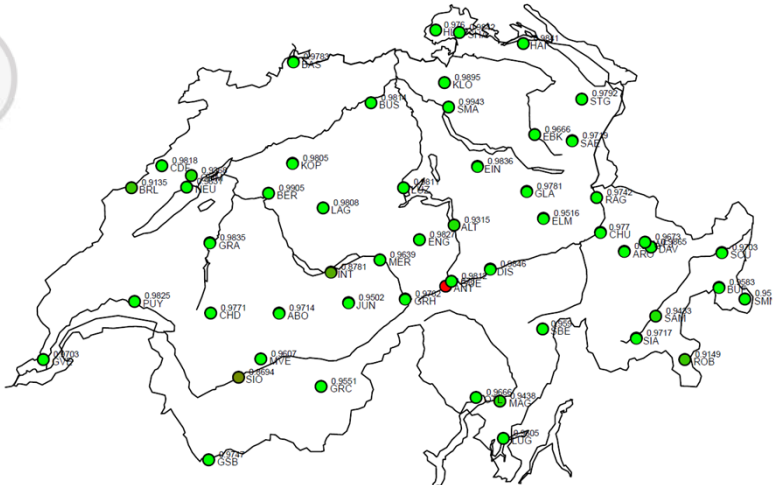
t	Grid	# stat	ALL	DJF	MAM	JJA	SON	# stat xval
1961-2016	Reconstr.	54	0.26	0.35	0.21	0.19	0.27	20
1901-2016	Reconstr.	28	0.33	0.42	0.28	0.26	0.33	
1864-2016	Reconstr.	20	0.37	0.47	0.32	0.30	0.37	

t	Grid	# stat	ALL	DJF	MAM	JJA	SON	# stat xval
1961-2016	Reconstr.	292	12.2	9.6	11.2	17.1	11.0	17
1901-2016	Reconstr.	69	14.2	10.8	13.3	19.9	13.1	
1864-2016	Reconstr.	17	16.9	13.1	15.7	22.7	16.1	

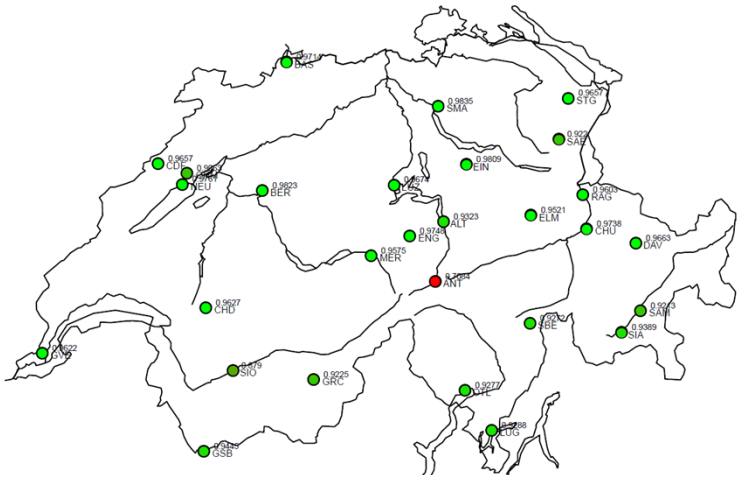
Skill: MSESS 1901/1961-2016

Explained **temporal** variance

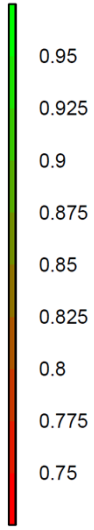
- Most of the stations have MSESS > 0.85

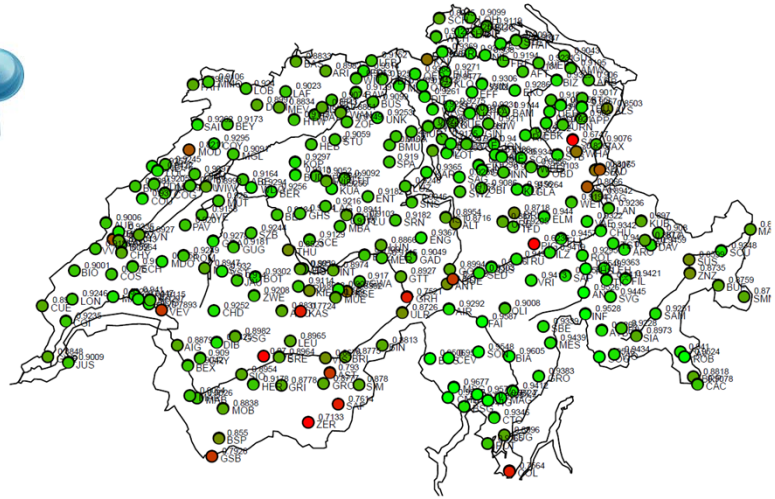


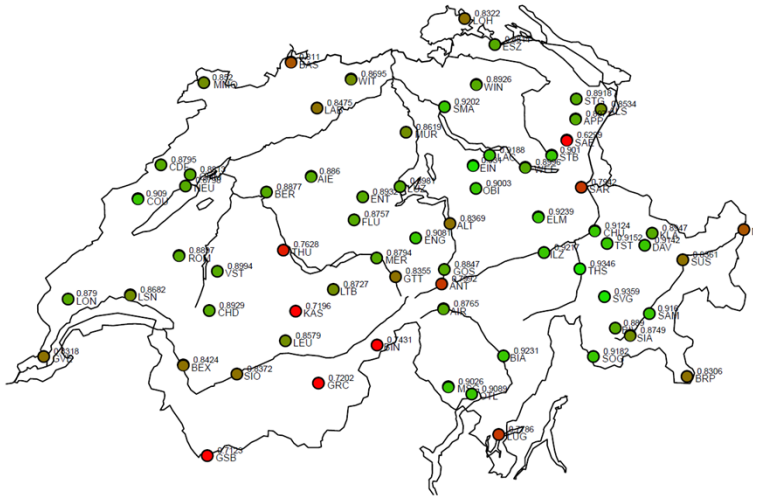
1961-2016



1901-2016

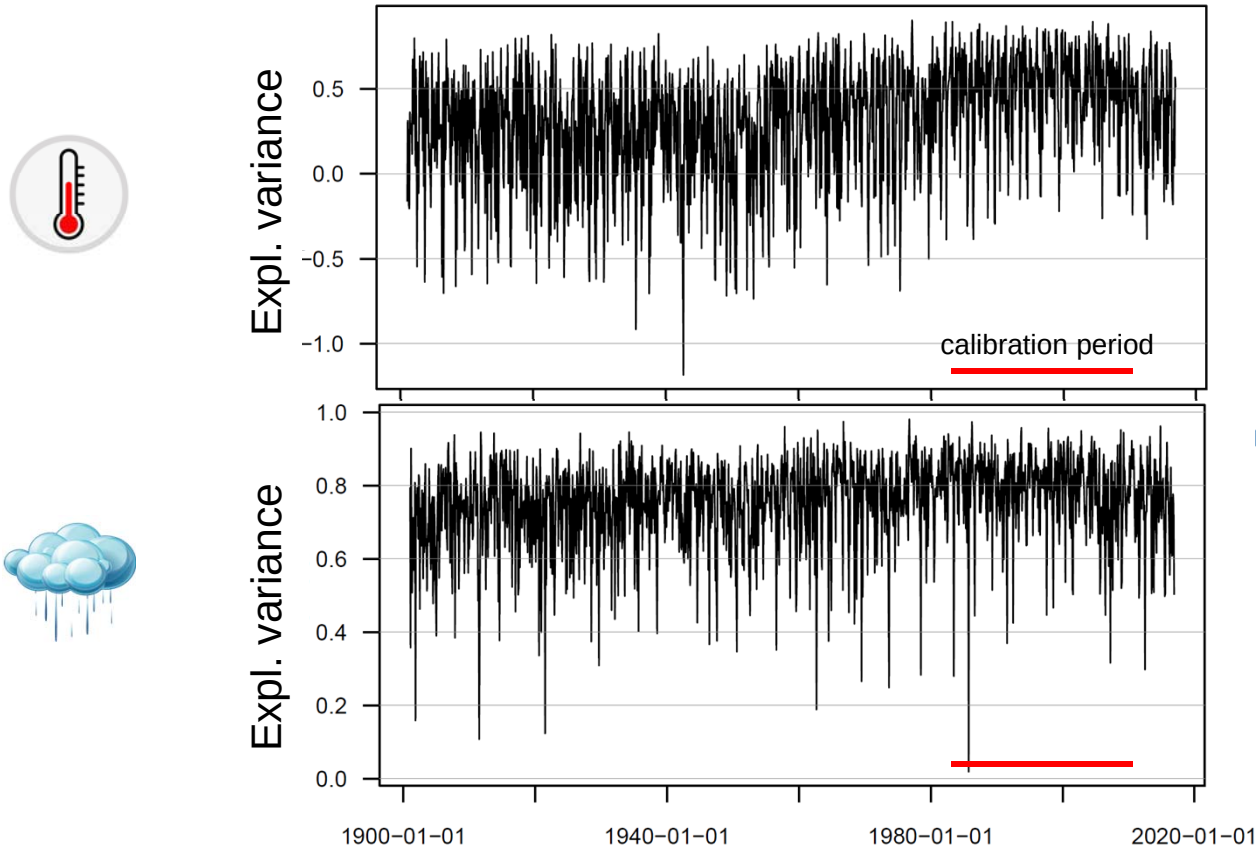






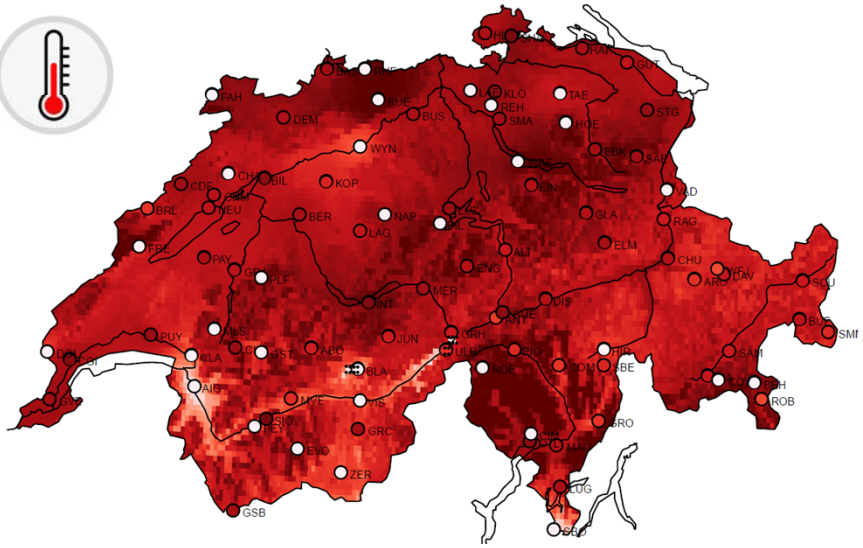
Skill: MSESS 1901-2016

Explained **spatial** variance

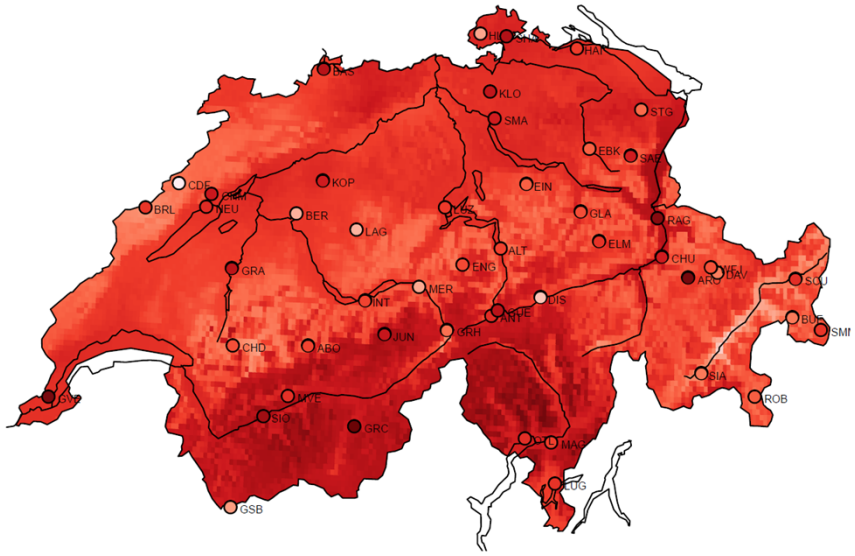


Trend 1961-2016

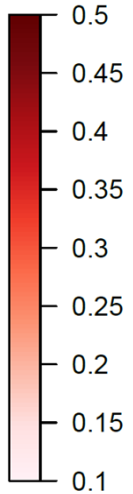
Theil-Sen trend estimate (degC/10y)
Stippling: statistically not significant (0.05)
(Mann-Kendall; multiple hypothesis testing: Benjamini, Y., and Hochberg, Y., 1995)

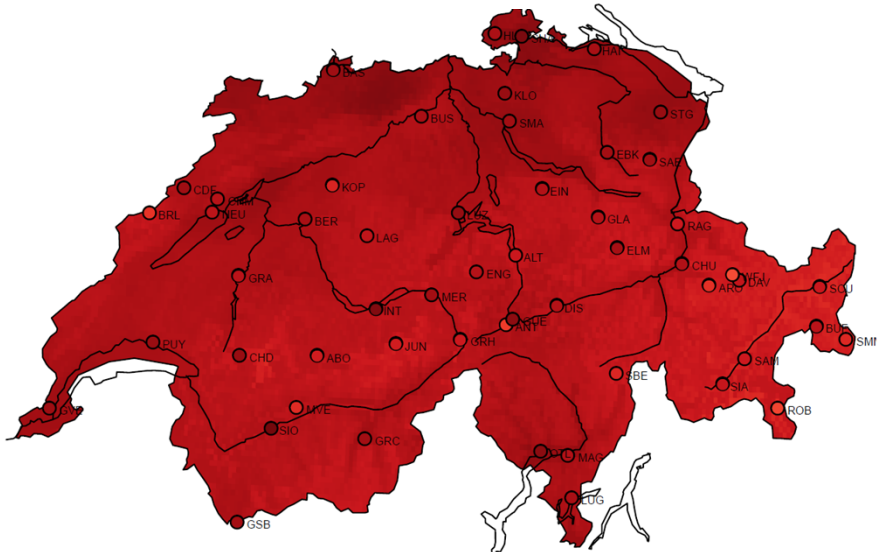


Direct interpolation (94 stations)

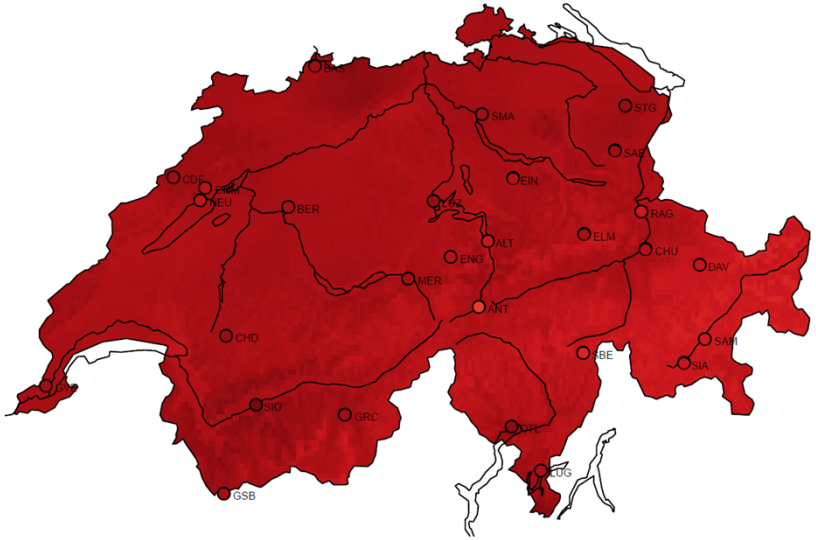


Non homogenized data (50 stations)





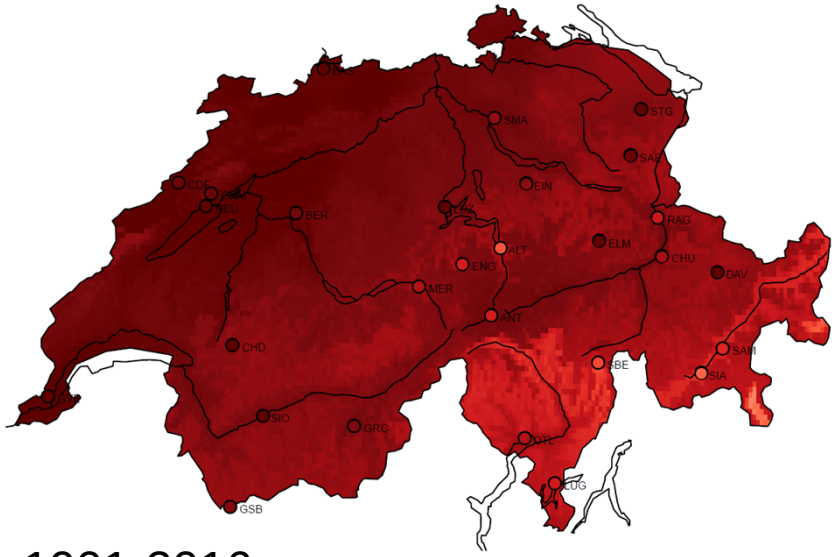
Homogeneous data (54 stations)



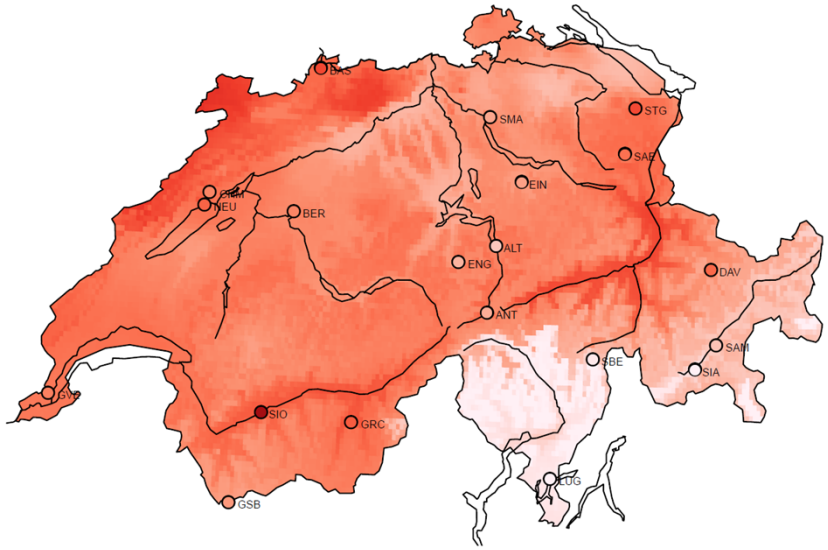
Homogeneous data (28 stations)

Trend 1864/1901-2016

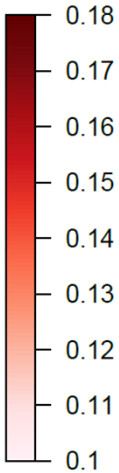
Theil-Sen trend estimate (degC/10y)
Stippling: statistically not significant (0.05)
(Mann-Kendall; multiple hypothesis testing: Benjamini, Y., and Hochberg, Y., 1995)



1901-2016

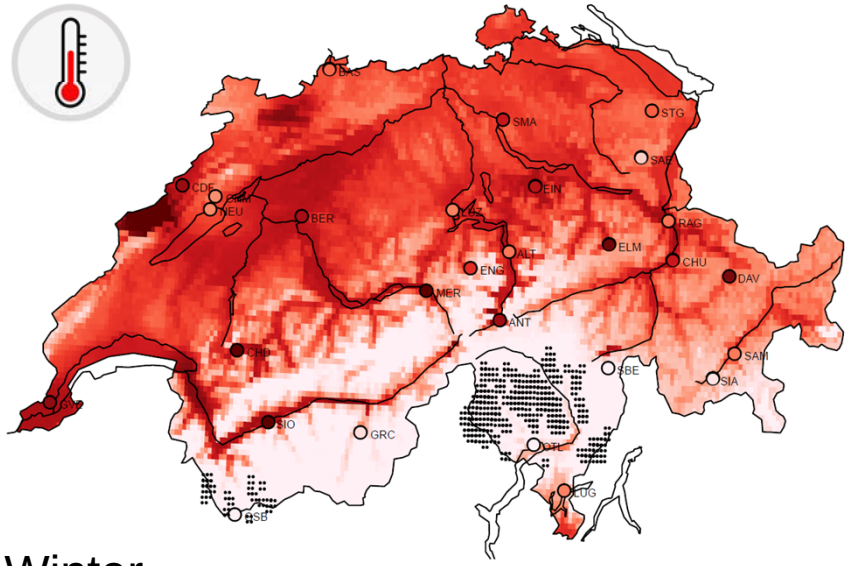


1864-2016

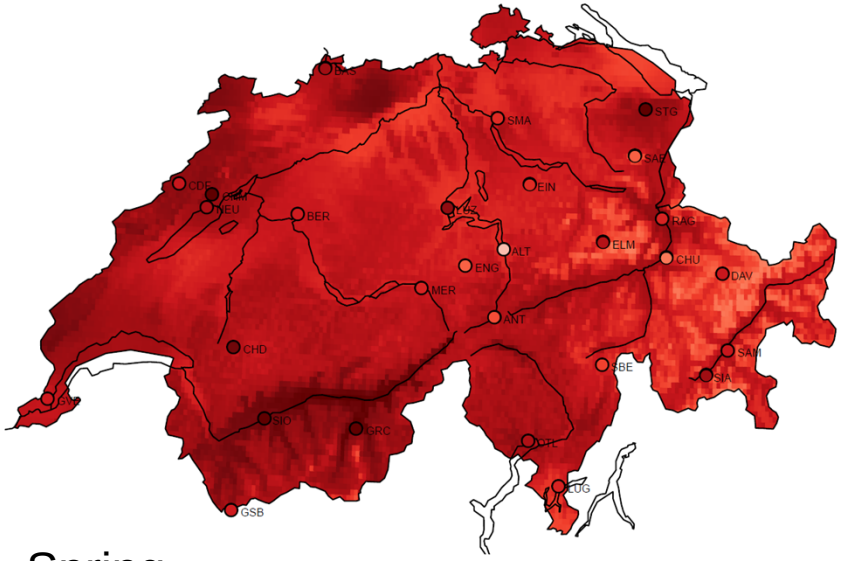


Trend 1901-2016

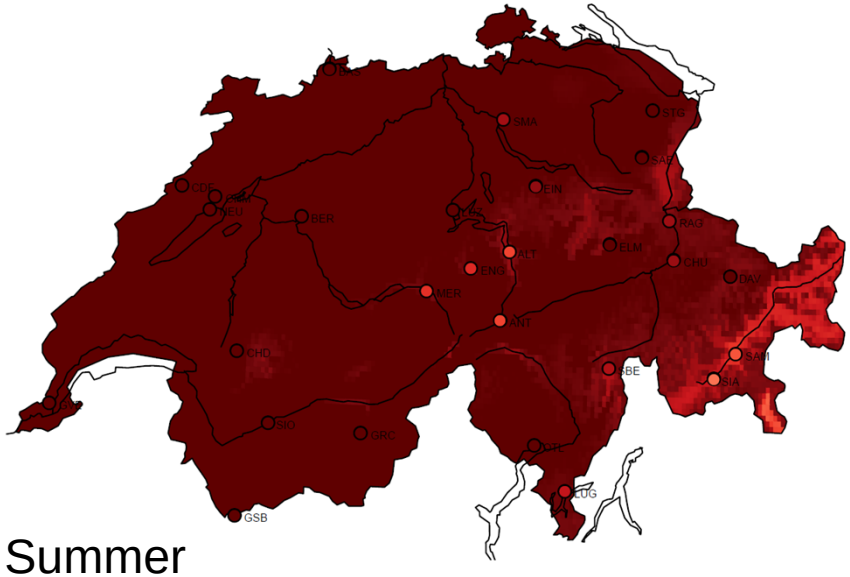
Theil-Sen trend estimate (degC/10y)
Stippling: statistically not significant (0.05)
(Mann-Kendall; multiple hypothesis testing: Benjamini, Y., and Hochberg, Y., 1995)



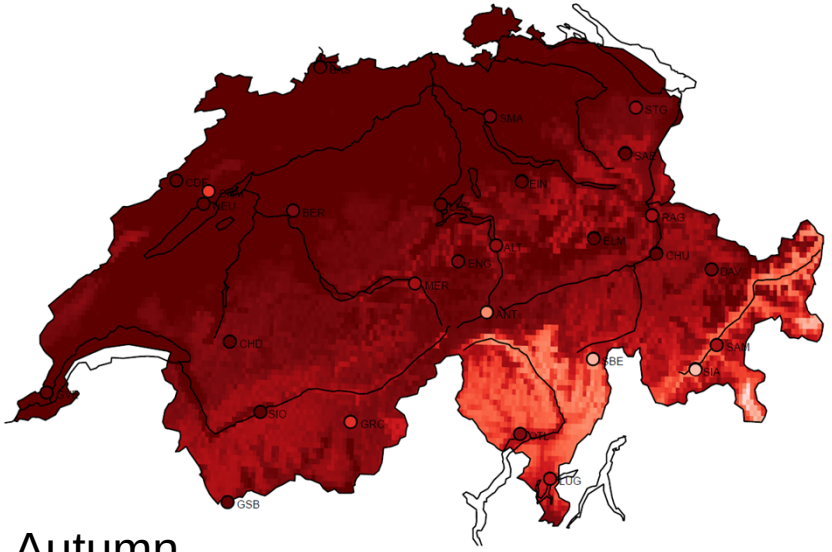
Winter



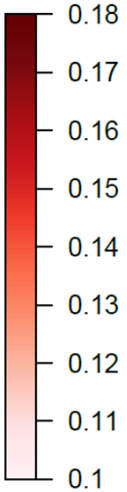
Spring



Summer

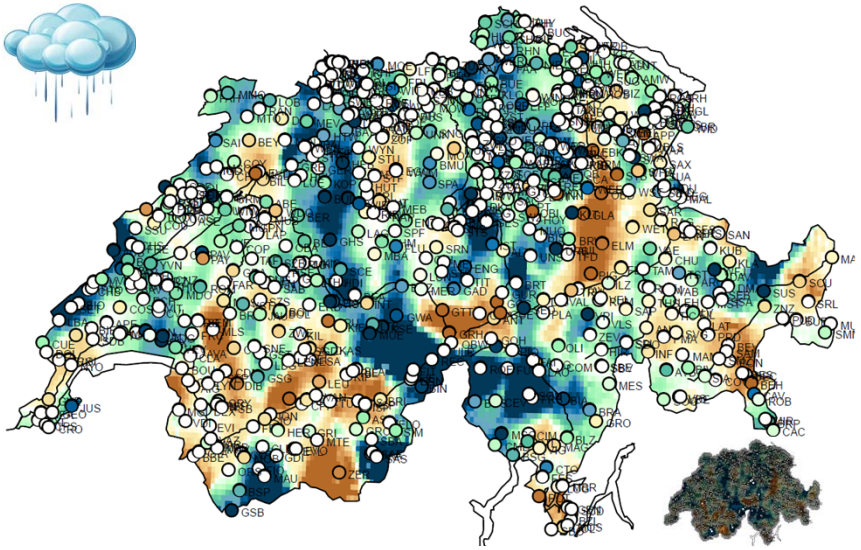


Autumn

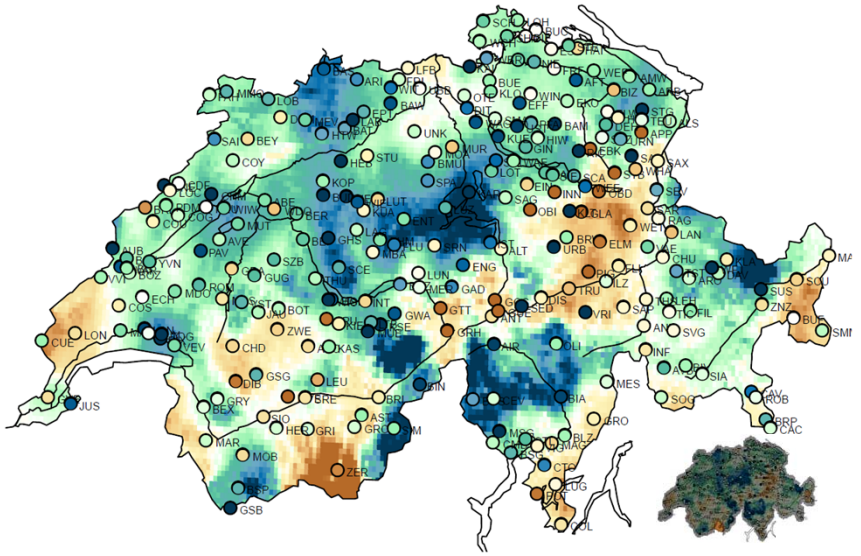


Trend 1961-2016

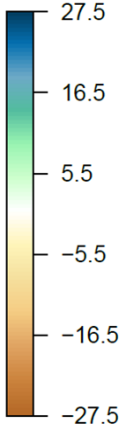
Theil-Sen trend estimate [mm/(y*10y)]
Stippling: statistically not significant (0.05)
(Mann-Kendall; multiple hypothesis testing: Benjamini, Y., and Hochberg, Y., 1995)

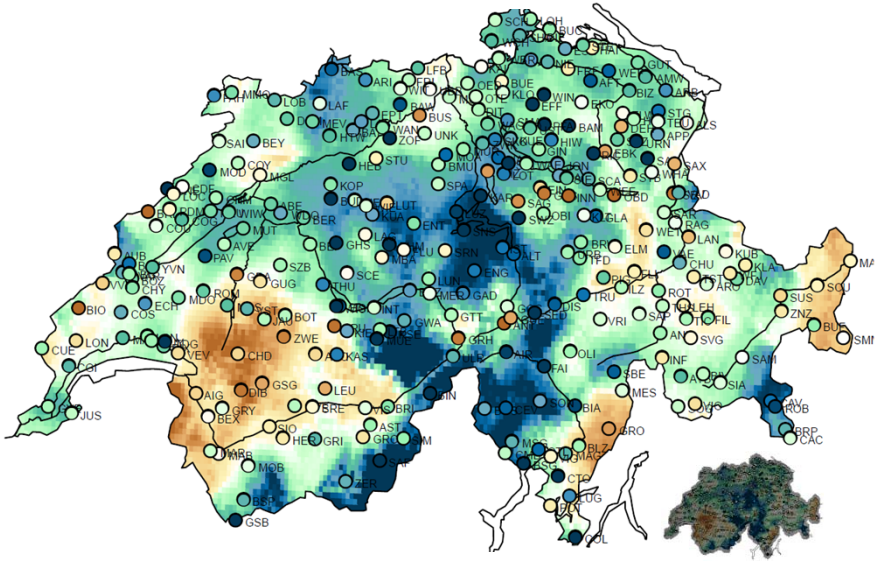


Direct interpolation (678 stations)

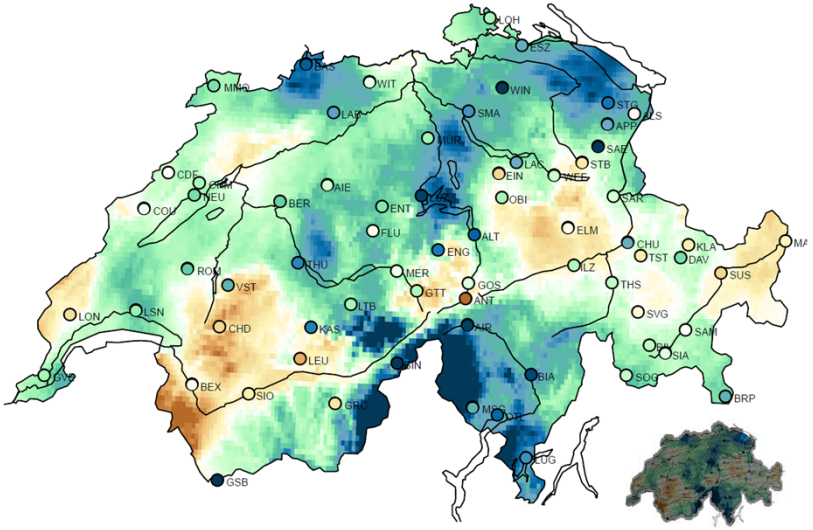


Non homogenized data (258 stations)





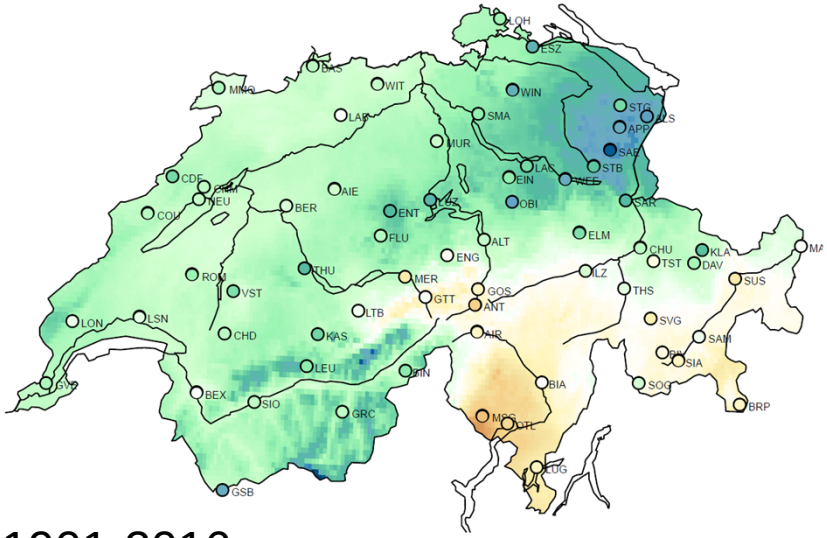
Homogeneous data (292 stations)



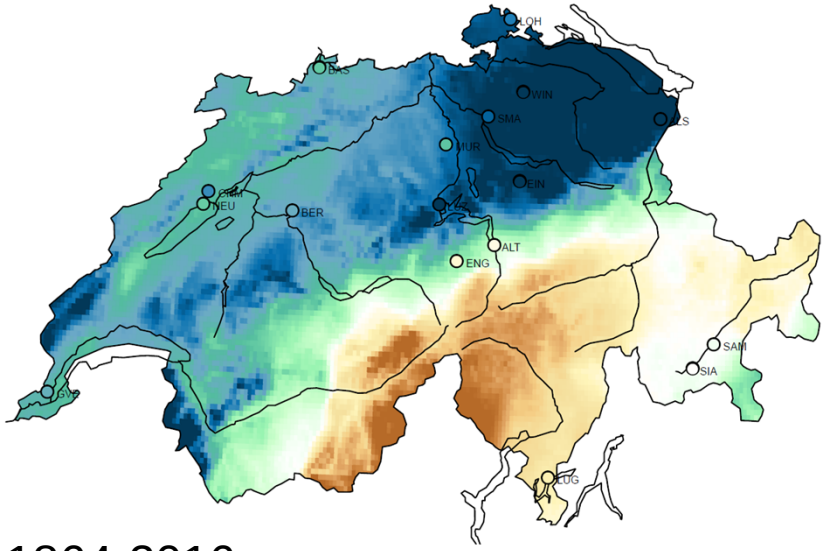
Homogeneous data (69 stations)

Trend 1864/1901-2016

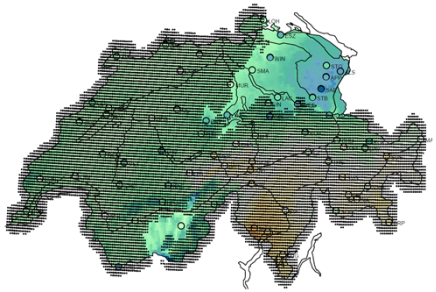
Theil-Sen trend estimate [mm/(y*10y)]
Stippling: statistically not significant (0.05)
(Mann-Kendall; multiple hypothesis testing: Benjamini, Y., and Hochberg, Y., 1995)

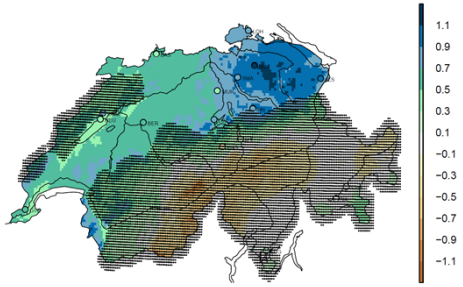


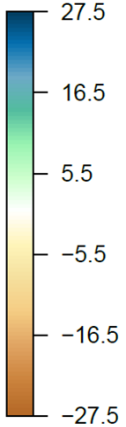
1901-2016



1864-2016

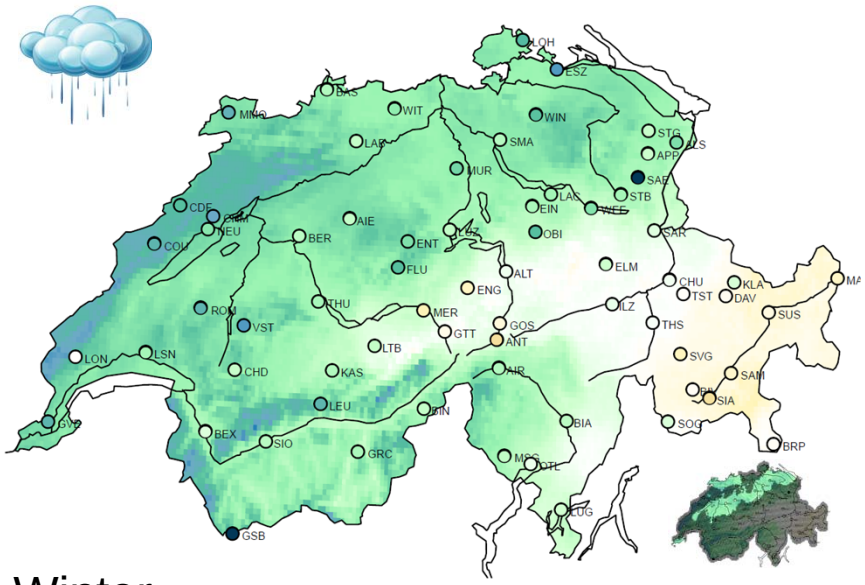




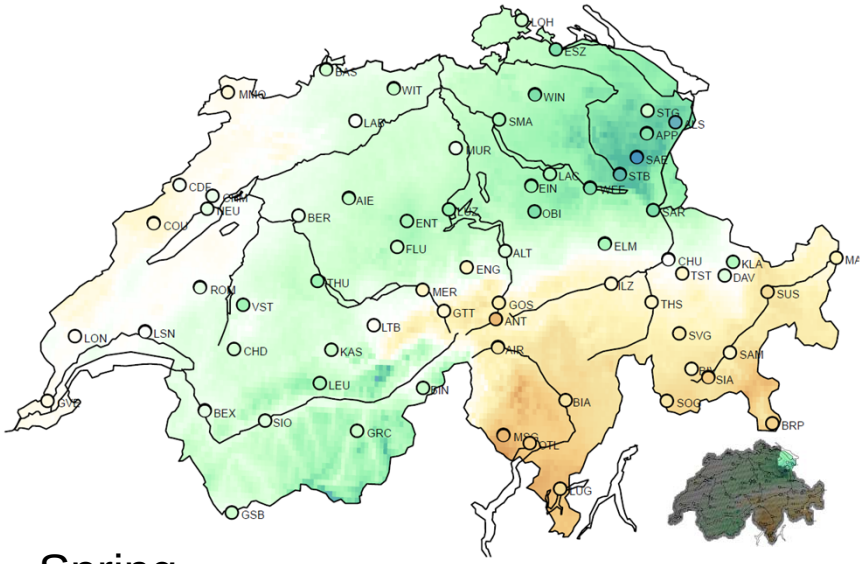


Trend 1901-2016

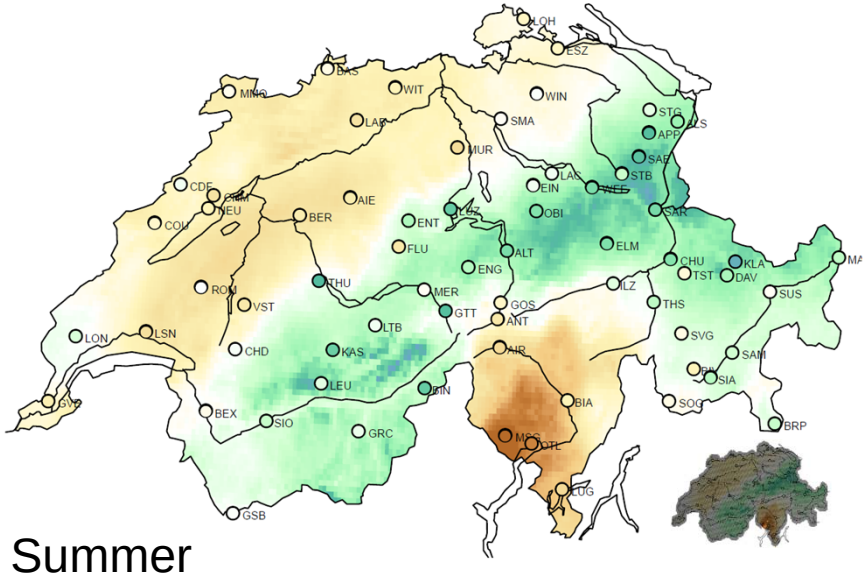
Theil-Sen trend estimate [mm/(season*10y)]
Stippling: statistically not significant (0.05)
(Mann-Kendall; multiple hypothesis testing: Benjamini, Y., and Hochberg, Y., 1995)



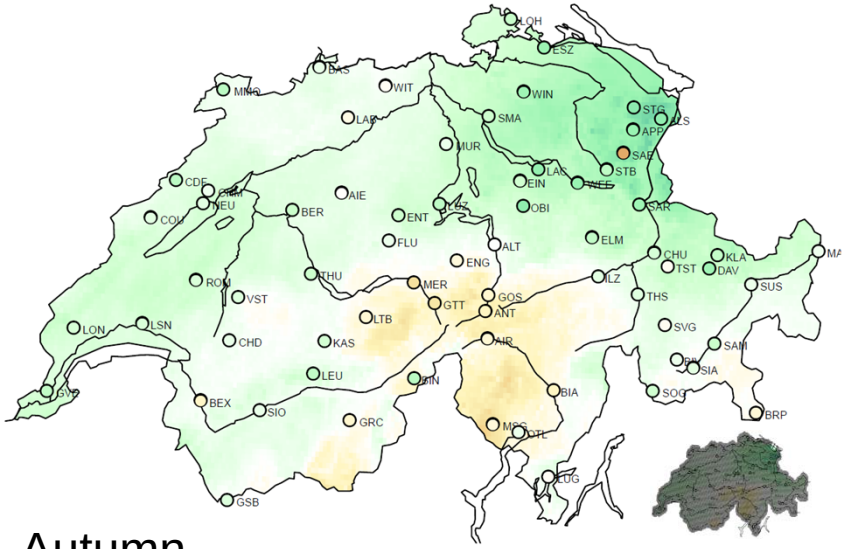
Winter



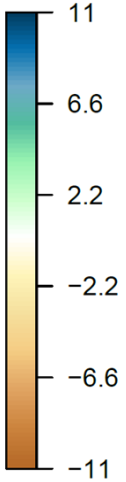
Spring



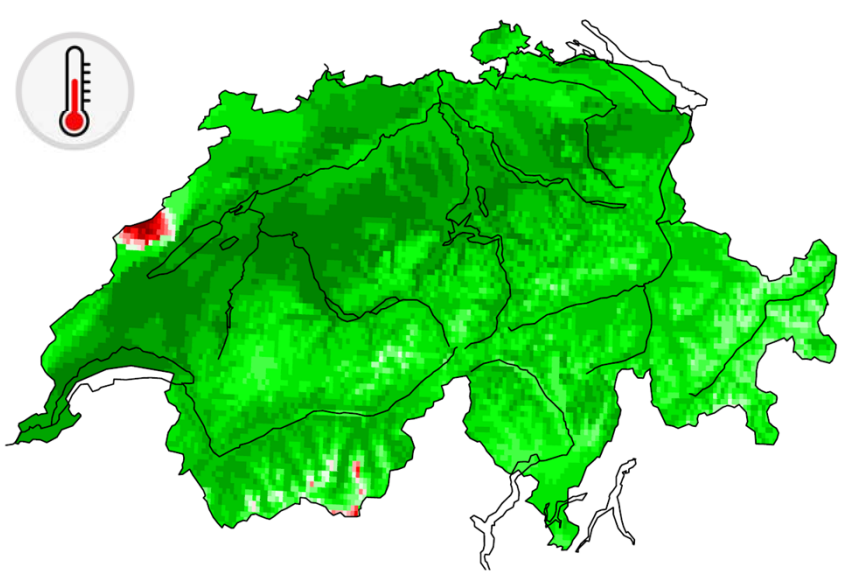
Summer



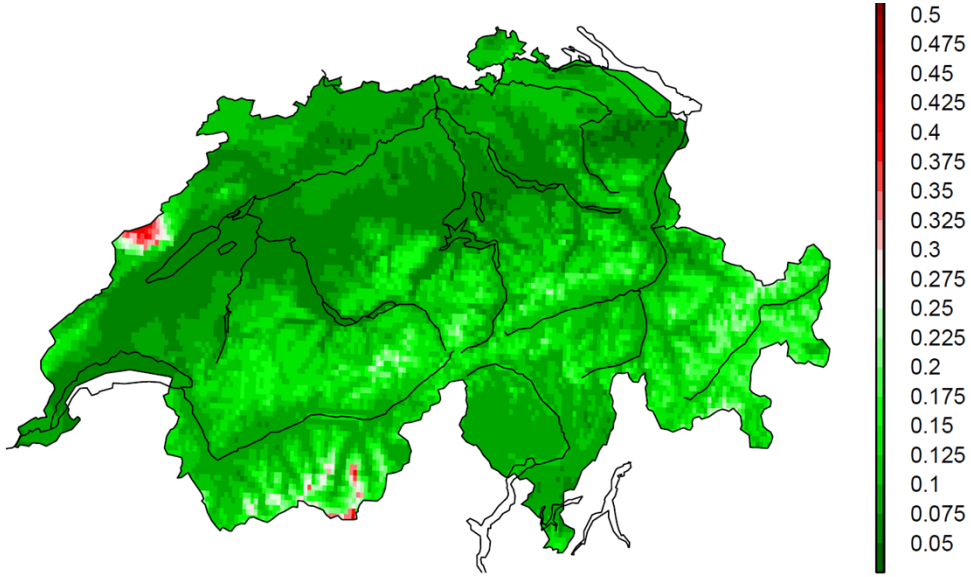
Autumn



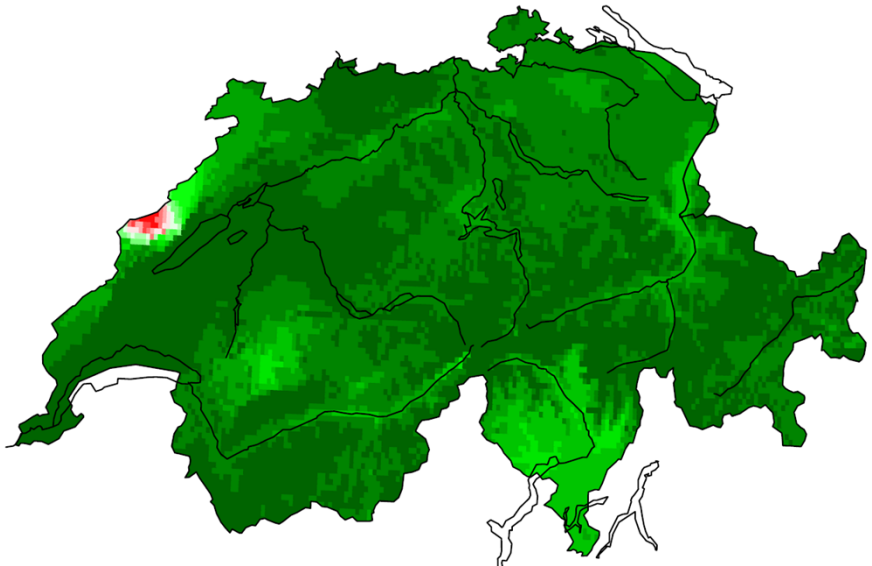
Datasets comparison, MAE (1961-1980)



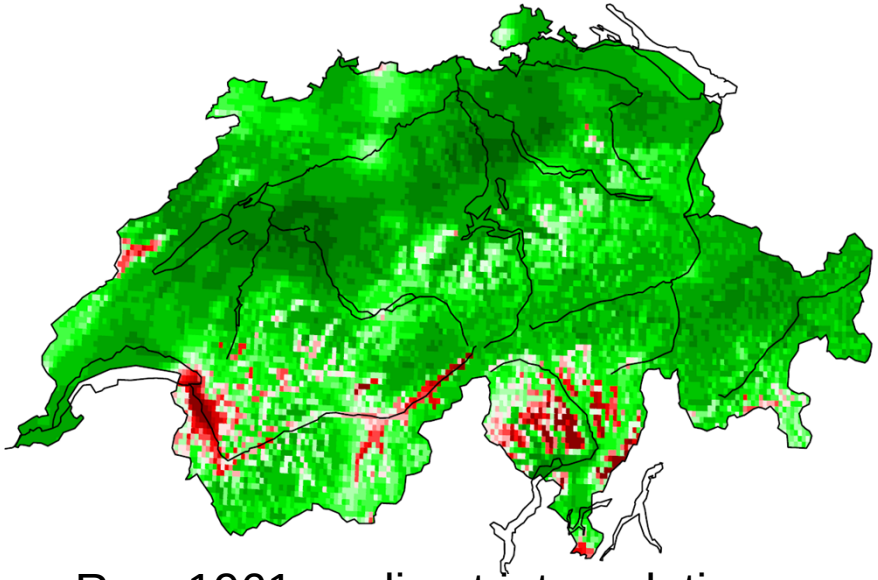
Rec. 1864 vs rec. 1961



Rec. 1901 vs rec. 1961



Rec. 1864 vs rec. 1901



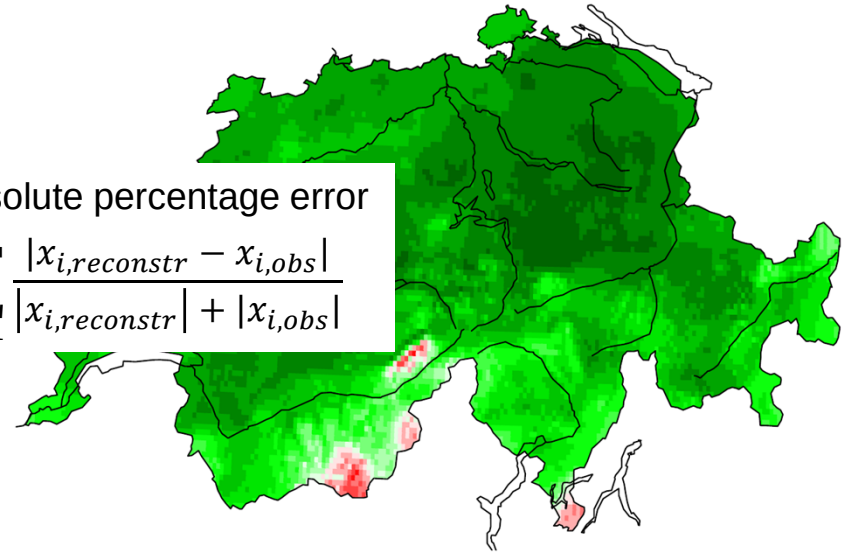
Rec. 1961 vs direct interpolation

Datasets comparison, sMAPE (1961-1980)

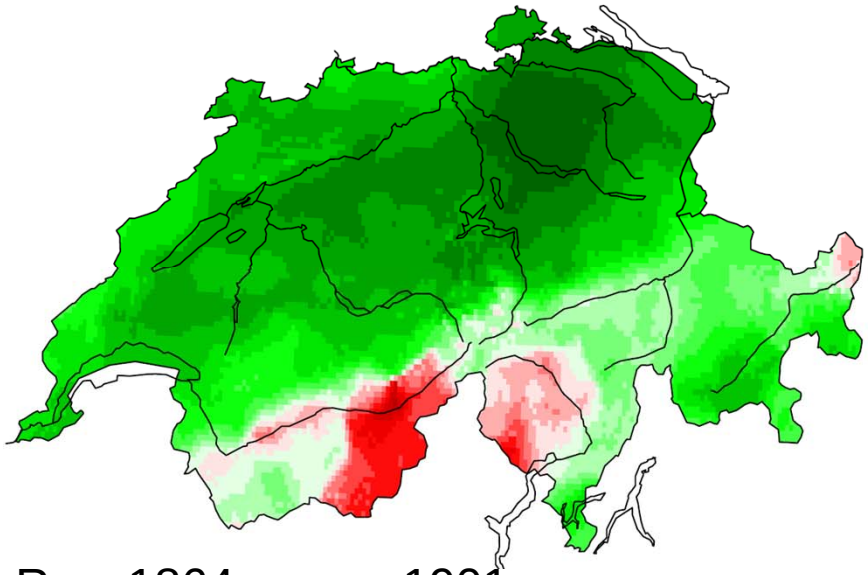
Symmetric mean absolute percentage error

$$sMAPE = \frac{100\%}{n}\sum_{i=1}^{n}\frac{|x_{i,reconstr} - x_{i,obs}|}{|x_{i,reconstr}| + |x_{i,obs}|}$$

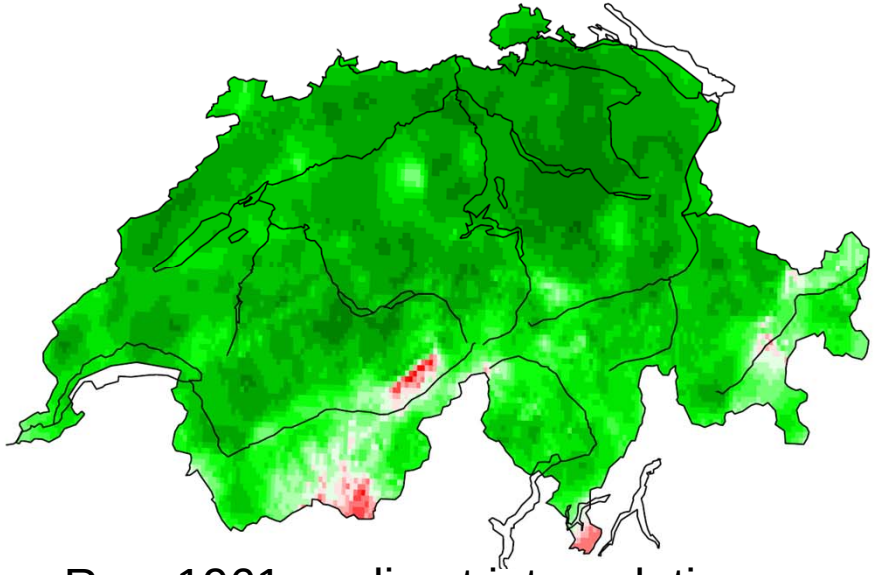
Rec. 1864 vs rec. 1961



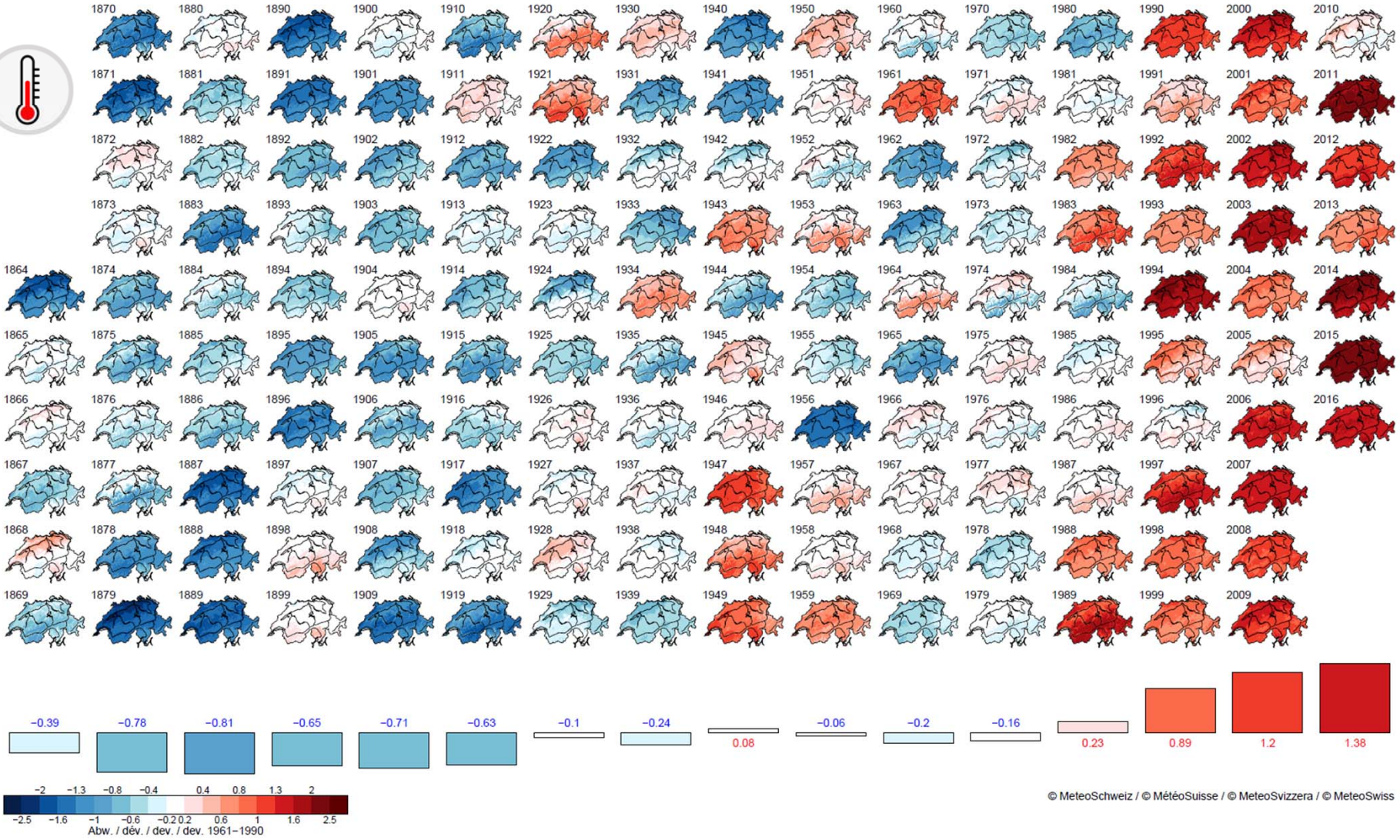
Rec. 1901 vs rec. 1961



Rec. 1864 vs rec. 1901



Rec. 1961 vs direct interpolation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1871 1881 1891 1901 1911 1921 1931 1941 1951 1961 1971 1981 1991 2001 2011
1872 1882 1892 1902 1912 1922 1932 1942 1952 1962 1972 1982 1992 2002 2012
1873 1883 1893 1903 1913 1923 1933 1943 1953 1963 1973 1983 1993 2003 2013
1864 1874 1884 1894 1904 1914 1924 1934 1944 1954 1964 1974 1984 1994 2004 2014
1865 1875 1885 1895 1905 1915 1925 1935 1945 1955 1965 1975 1985 1995 2005 2015
1866 1876 1886 1896 1906 1916 1926 1936 1946 1956 1966 1976 1986 1996 2006 2016
1867 1877 1887 1897 1907 1917 1927 1937 1947 1957 1967 1977 1987 1997 2007
1868 1878 1888 1898 1908 1918 1928 1938 1948 1958 1968 1978 1988 1998 2008
1869 1879 1889 1899 1909 1919 1929 1939 1949 1959 1969 1979 1989 1999 2009
−0.39 −0.78 −0.81 −0.65 −0.71 −0.63 −0.1 −0.24 0.08 −0.06 −0.2 −0.16 0.23 0.89 1.2 1.38
−2 −1.3 −0.8 −0.4 0.4 0.8 1.3 2
−2.5 −1.6 −1 −0.6 −0.2 0.2 0.6 1 1.6 2.5
Abw. / dév. / dev. 1961−1990
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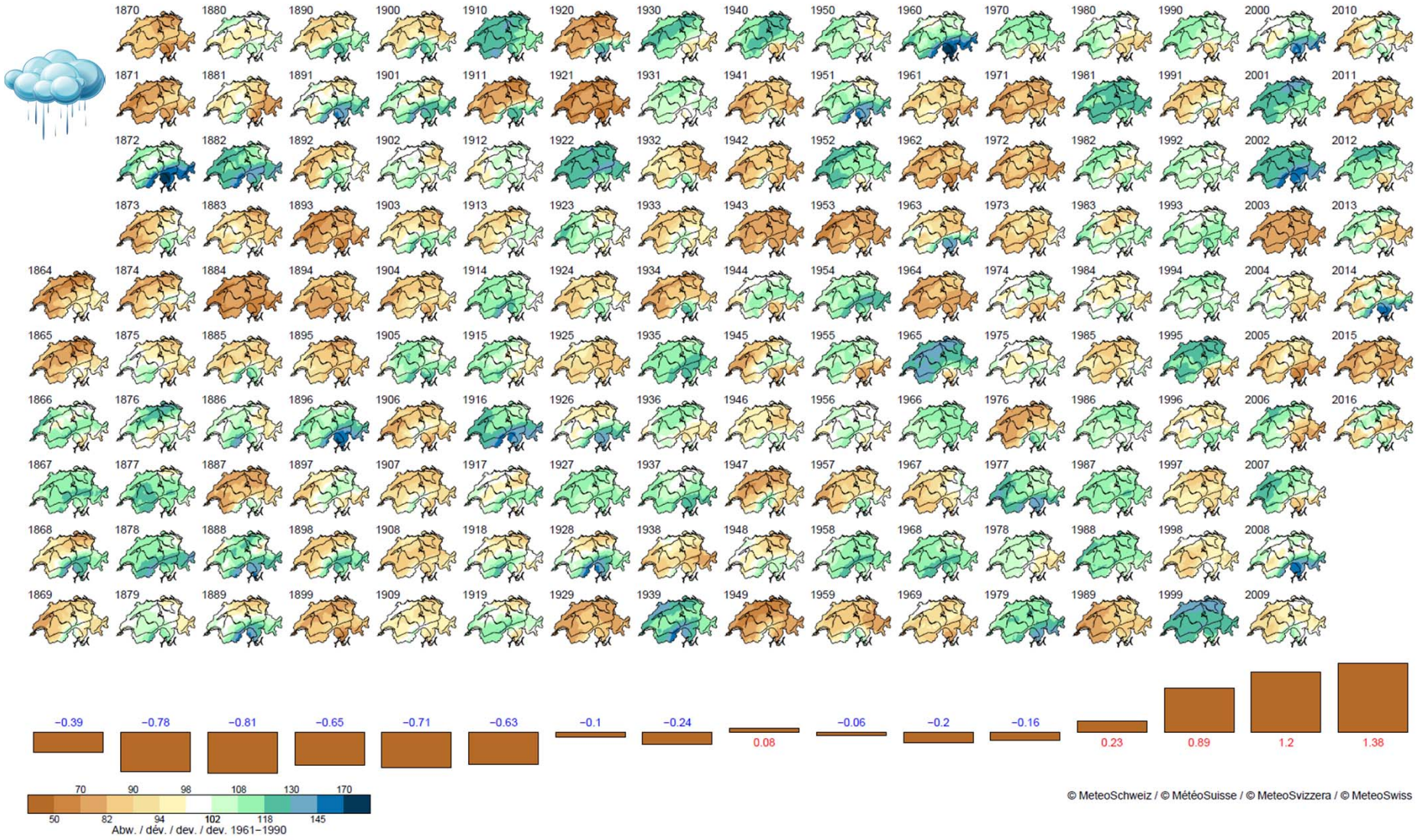
1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
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−0.39 −0.78 −0.81 −0.65 −0.71 −0.63 −0.1 −0.24 0.08 −0.06 −0.2 −0.16 0.23 0.89 1.2 1.38
70 90 98 108 130 170
50 82 94 102 118 145
Abw. / dév. / dev. / dev. 1961–1990
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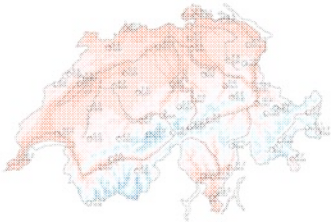
Content

Introduction: motivation, method



Results and evaluation

Conclusion and outlook

Conclusion and outlook

RSOI method

- **RSOI is an attractive method to benefit of short-term high-resolution information to reconstruct longer time scales with less observations available.**
- **Method suitable for complex terrain where variations are spatially anchored.**
- **Successful reconstruction of time series and spatial distribution of temperature and precipitation**
- **The discrepancies between observations and reconstruction are relatively moderate (MAE≈0.3 degC and 15 mm/month)**
- **Reconstruction improves long-term consistency**
- **Potential for application in the entire Alpine Region**