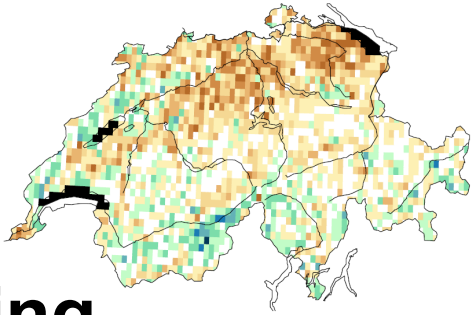
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

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

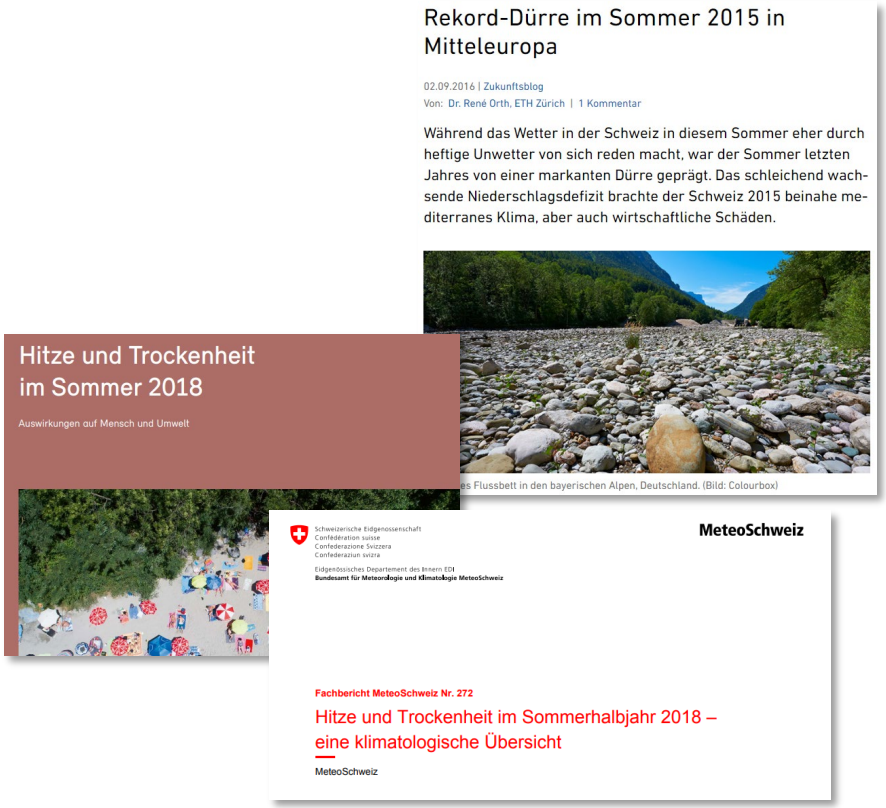


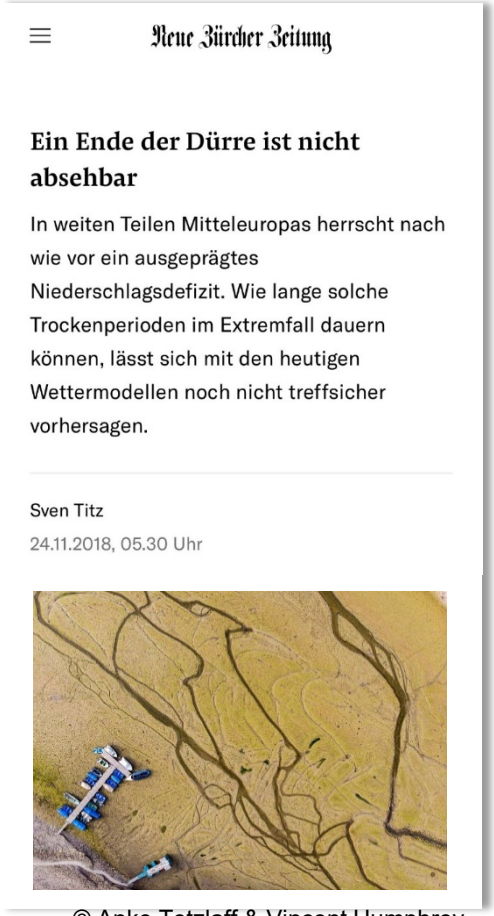
Climatological Drought Monitoring in Switzerland Using SAF Satellite Products

Anke Tetzlaff[1], Vincent Humphrey, **Annkatrin Burgstall**[1], Dominik Michel[2], Martin Hirschi[2], Sebastian Hahn[3], Jose Miguel Barrios[4], Alirio Arboleda[4], William Moutier[4], Françoise Gellens-Meulenberghs[4], Wolfgang Wagner[3], Sonia I. Seneviratne[2], Reto Stöckli[1]

[1]Federal Office of Meteorology and Climatology MeteoSwiss, Zurich, Switzerland
[2]Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland
[3]Department of Geodesy and Geoinformation, TU Wien, Vienna, Austria
[4]Department of Research and Development, Royal Meteorological Institute of Belgium, Brussels, Belgium

Motivation





Summer Droughts in Switzerland

TOP 5 since 1981

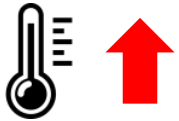
2018 **2003** **2020** **2015** **2011**

Changes 1981-2020

Precipitation

–66 mm
(–11 %)

Temperature



+2,2 °C

Evapotranspiration

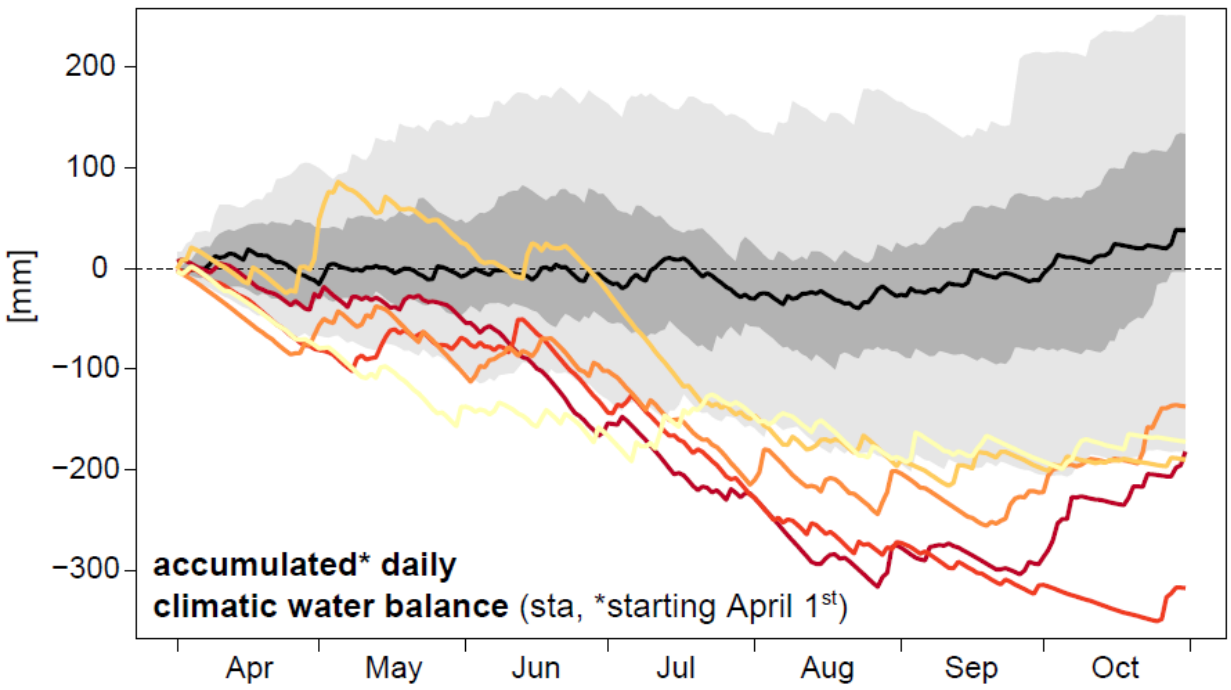
≈ +60 mm
(+11 %)

Soil Moisture

≈ –20 mm
(–5 %)

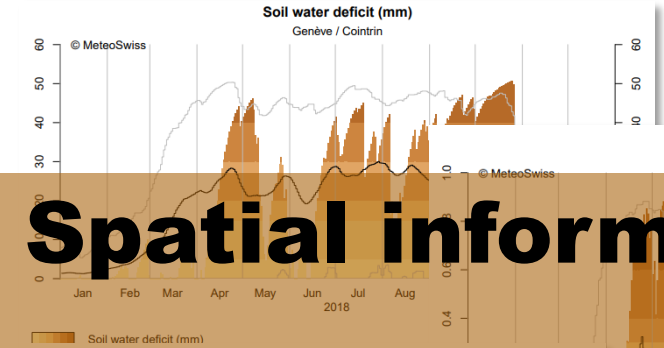
Scherrer et al. (2022)
https://doi.org/10.1088/2515-7620/ac4fb9

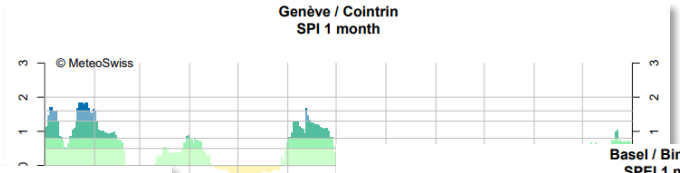
Summer Droughts in Switzerland since 1981

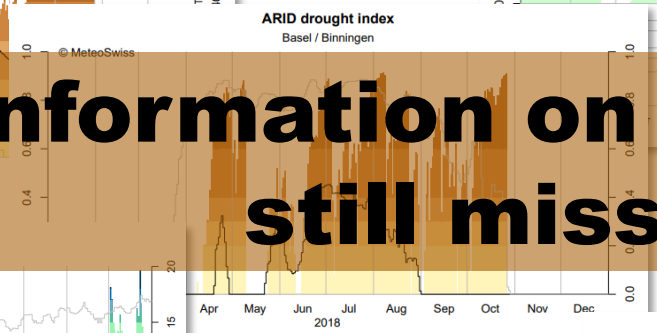


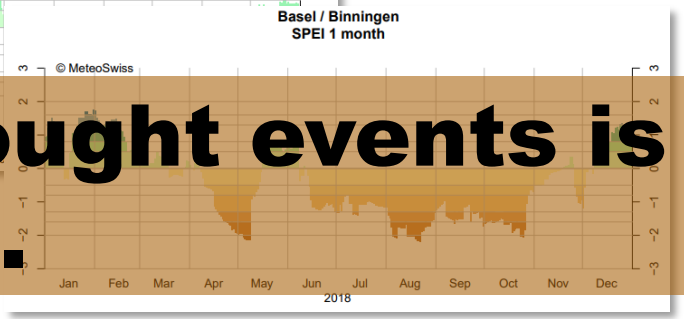
Current drought monitoring @MeteoSwiss

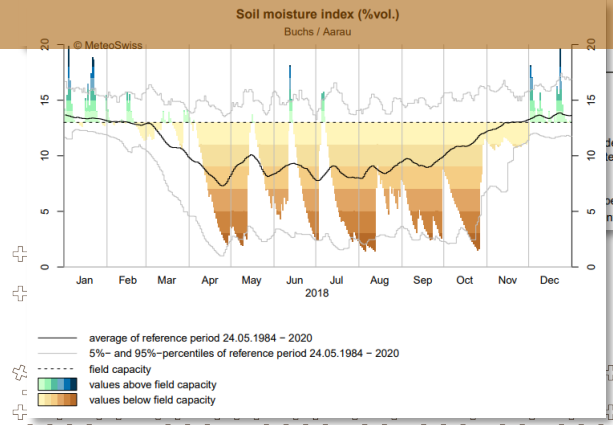
Spatial information on drought events is still missing.

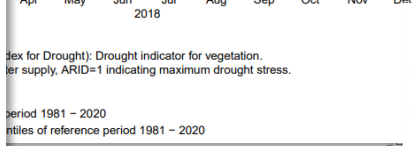


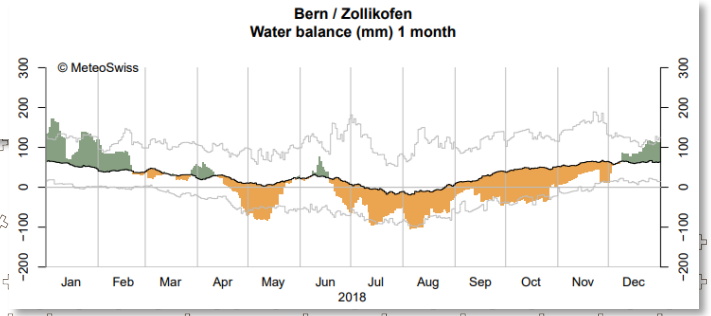






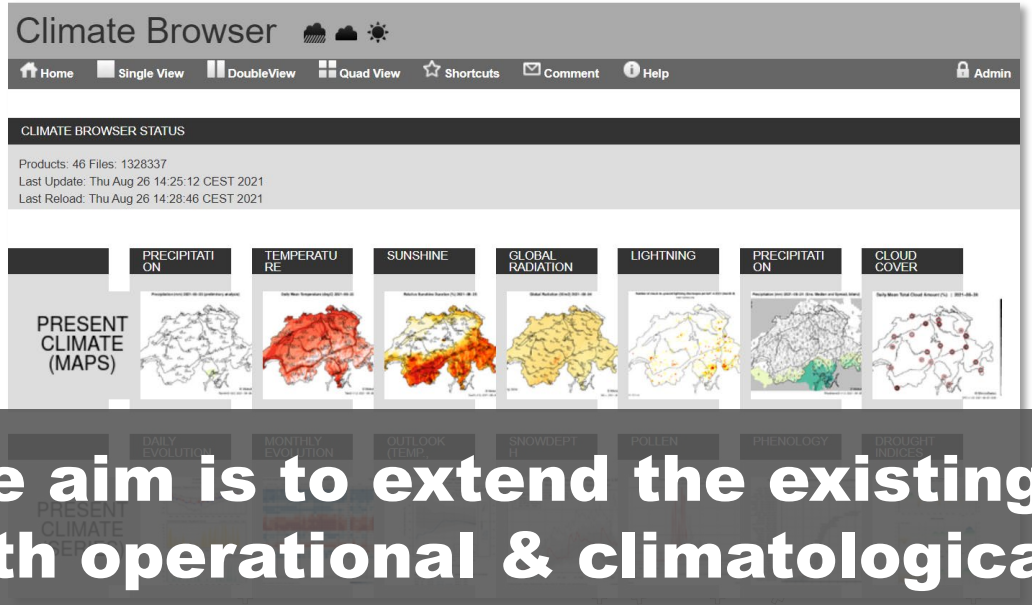






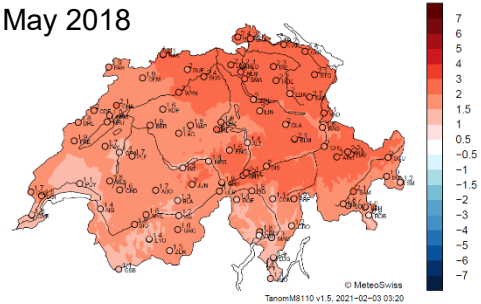
Climate Browser at MeteoSwiss

Internal web platform for visualizing automated climatological analyses.

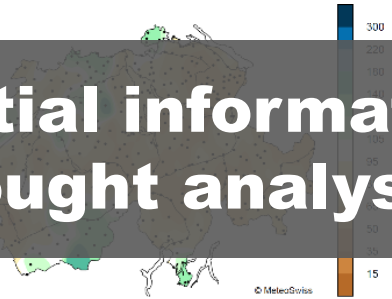


Monthly Temperature Anomaly (°C)

May 2018



Monthly Precipitation Anomaly (%)



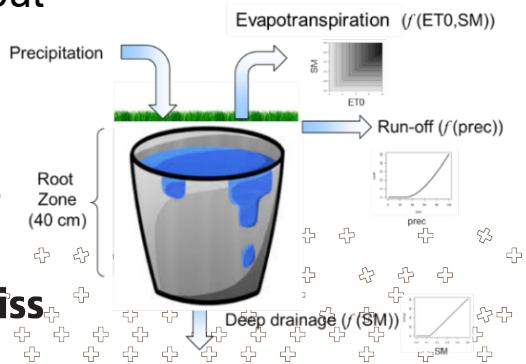
The aim is to extend the existing spatial information with operational & climatological drought analyses.

Station-based drought indicators

Station-Based Drought Indices

Soil Moisture Index (SMI)

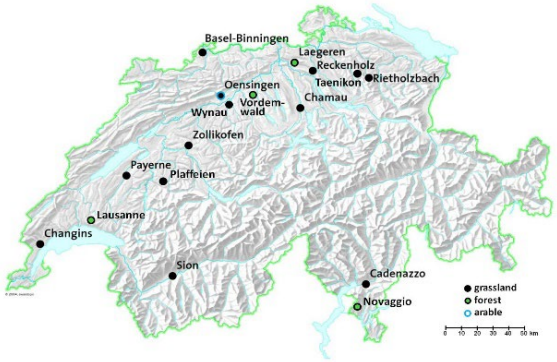
- **Modeled soil moisture** assuming a soil with **average properties** and a **dense grass surface**
- «**Bucket-model**» with daily balance of input and output



MeteoSwiss

Swiss Soil Moisture Experiment (SwissSMEX)

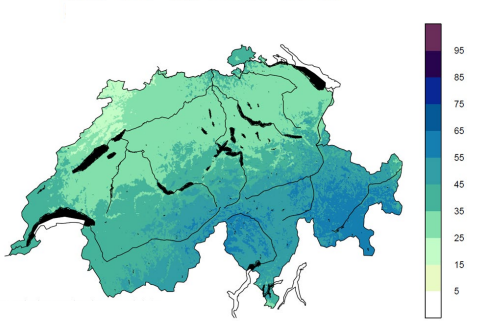
- Monitors **soil moisture** at 19 sites in Switzerland
- Some sites include lysimeteres to measure **evapotranspiration**



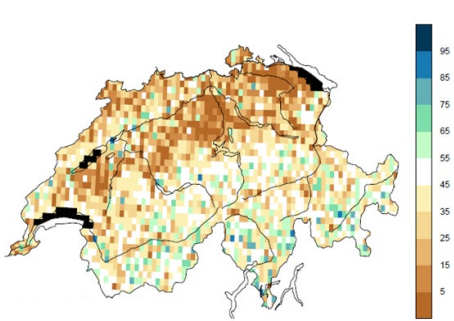
Source: https://iac.ethz.ch/group/land-climate-dynamics/research/swisssmex.html

Satellite-based drought indicators

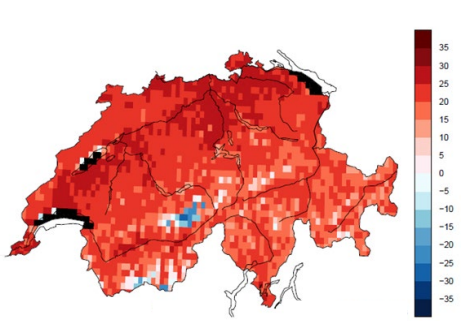
Satellite-Based Drought Indices



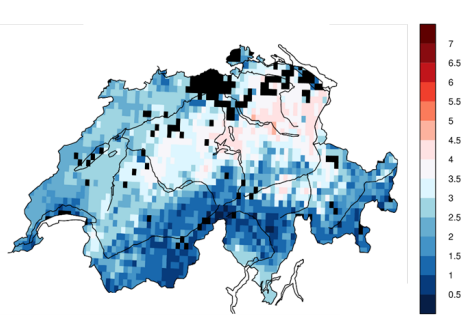
H SAF ASCAT surface **soil moisture** product



NOAA AVHRR **vegetation products**



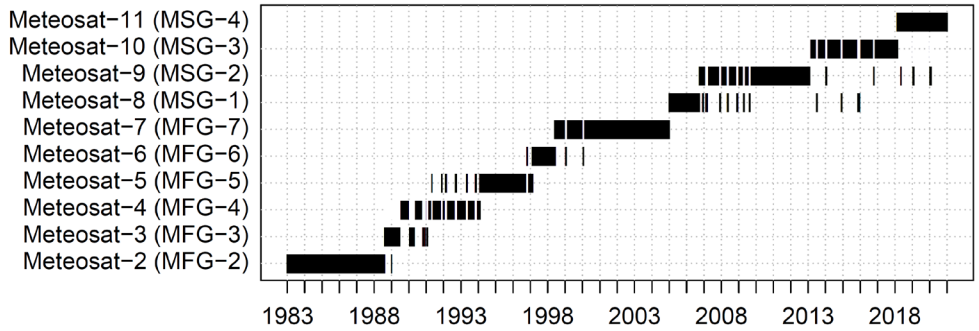
CM SAF **land surface temperature**



LSA SAF Meteosat **evapotranspiration** products

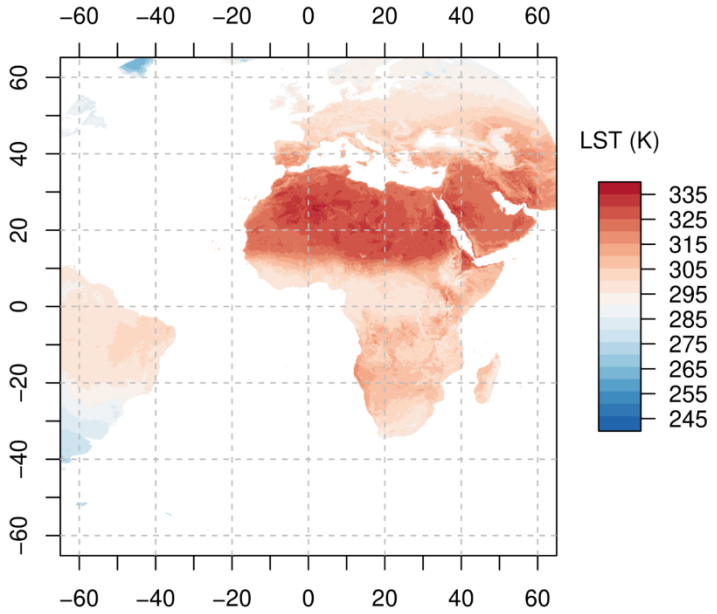
Meteosat CM SAF CDRs

Meteosat First and Second Generation (MFG & MSG) satellites:



- Different time resolutions: 30 & 15 min for MFG & MSG satellites
- Different spatial resolutions: 2.5 to 5 km (depending on the channels)
- Different spectral channels (e.g., 1 visible channel vs 2 visible channels)

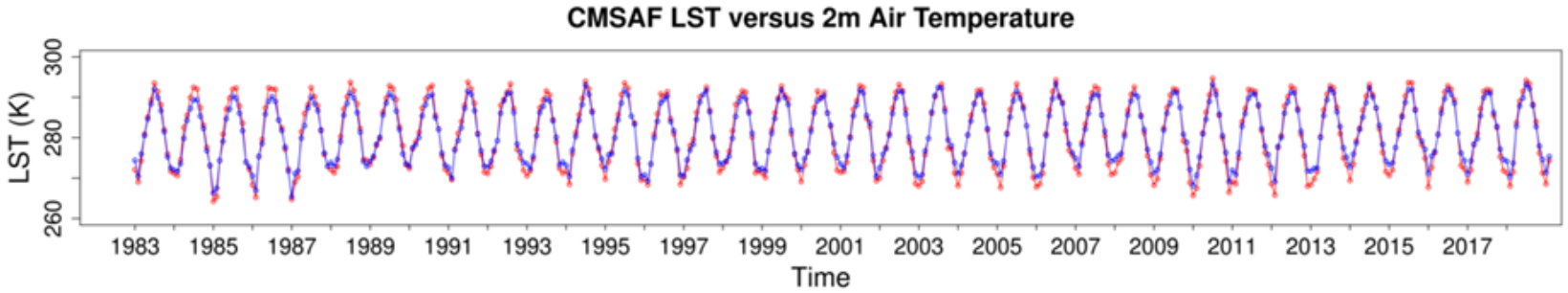
Land Surface Temperature CDR since 1983

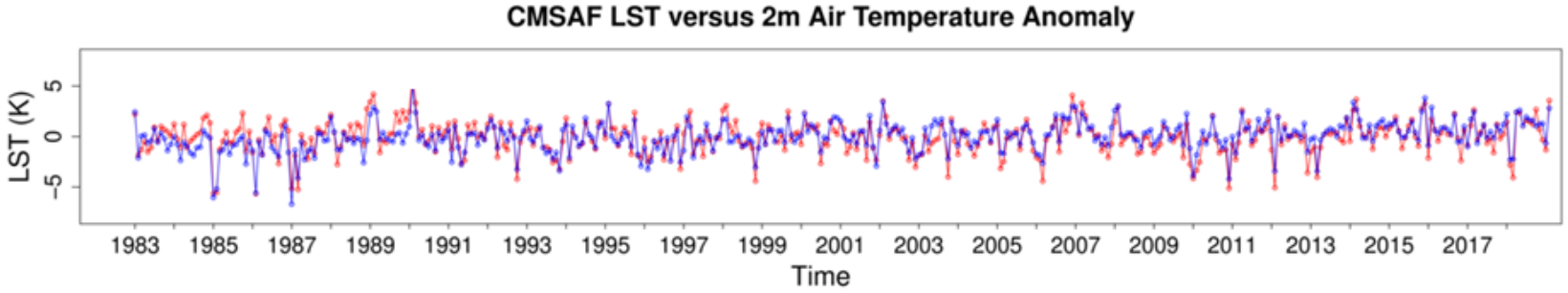


CM SAF LST CDR 1983 to 2020 June (12 am).

38 years **clear-sky** Land Surface Temperature for the period 1983-2020 with a spatial coverage 65°N/S-65°W/E.
Spatial resolution: 0.05°x0.05°.
Time scale: hourly sample, monthly diurnal cycle

CM SAF Land Surface Temperature since 1983





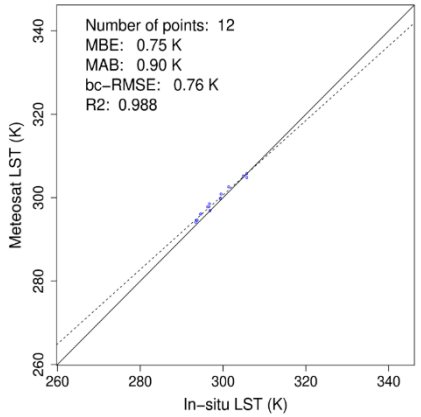
Stability against EUSTACE T 2m air

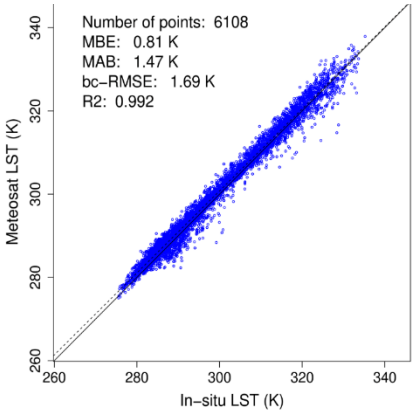
Region	1983-1998	1999-2019	1983-2020
Southern Europe			
bias $_{\text{CM SAF–T2m anom}}$ (K)			-0.03
bc-RMS $_{\text{CM SAF–T2m anom}}$ (K)			0.86
t $_{\text{CM SAF–T2m anom}}$ (K/dec)	-0.28	0.07	-0.26
t $_{\text{T2m}}$ (K/dec)	0.55 K*	0.33 *	0.31 *
t $_{\text{CMSAF}}$ (K/dec)	0.16 K*	0.44 *	0.03 *
Eastern Europe			
bias $_{\text{CM SAF–T2m anom}}$ (K)			-0.07
bc-RMS $_{\text{CM SAF–T2m anom}}$ (K)			1.26
t $_{\text{CM SAF–T2m anom}}$ (K/dec)	-0.39	0.13	-0.33 K
t $_{\text{T2m}}$ (K/dec)	0.22	0.48 *	0.49 *
t $_{\text{CMSAF}}$ (K/dec)	-0.27	0.59 *	0.16
Western Europe			
bias $_{\text{CM SAF–T2m anom}}$ (K)			-0.06 K
bc-RMS $_{\text{CM SAF–T2m anom}}$ (K)			0.99 K
t $_{\text{CM SAF–T2m anom}}$ (K/dec)	-0.31	0.13	-0.30
t $_{\text{T2m}}$ (K/dec)	0.53 *	0.36 *	0.40 K*
t $_{\text{CMSAF}}$ (K/dec)	0.16	0.48 *	0.08 K*
Central Europe			
bias $_{\text{CM SAF–T2m anom}}$ (K)			-0.07 K
bc-RMS $_{\text{CM SAF–T2m anom}}$ (K)			1.16 K
t $_{\text{CM SAF–T2m anom}}$ (K/dec)	-0.40 K	0.07	-0.30
t $_{\text{T2m}}$ (K/dec)	0.47 K	0.36	0.43 K*
t $_{\text{CMSAF}}$ (K/dec)	-0.05 K*	0.42	0.11 K
Europe (all stations)			
bias $_{\text{CM SAF–T2m anom}}$ (K)			-0.06 K
bc-RMS $_{\text{CM SAF–T2m anom}}$ (K)			0.85 K
t $_{\text{CM SAF–T2m anom}}$ (K/dec)	-0.51	-0.05	-0.34
t $_{\text{T2m}}$ (K/dec)	0.36	**0.37 ***	0.44 *
t $_{\text{CMSAF}}$ (K/dec)	-0.10 *	**0.34 ***	-0.06 *

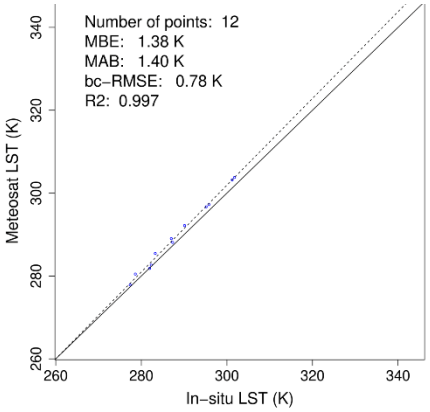
Threshold | Target | Optimal

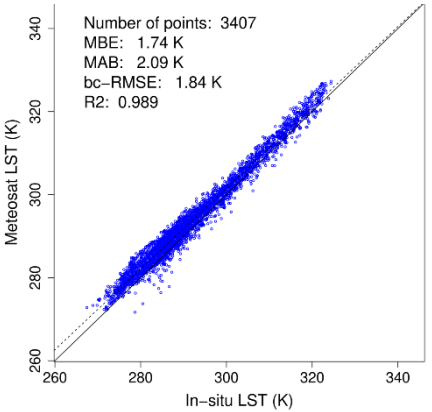
Temperature trends calculated from CM SAF LSTs for Europe for the period 1999-2019 are with 0.34 K/decade almost identical to trends obtained from homoginized air temperature data (0.37 K/decade).

CM SAF Land Surface Temperature since 1983

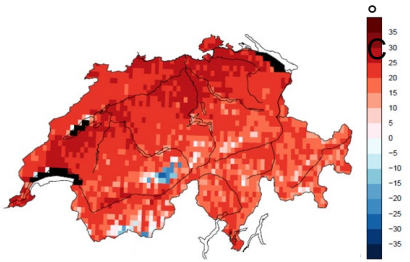




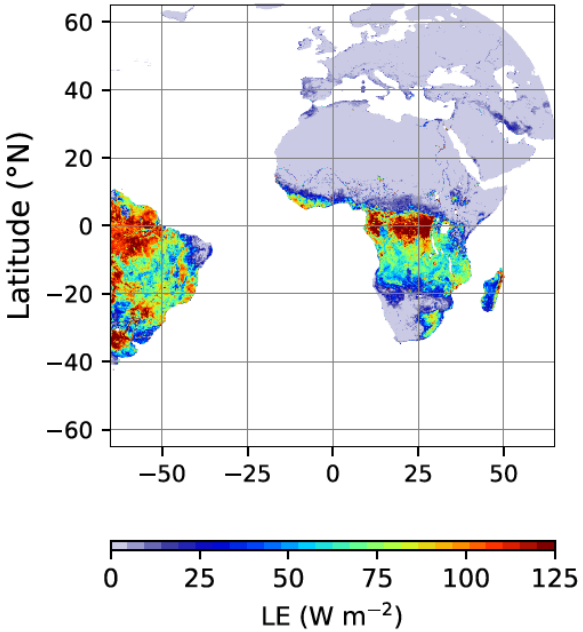




	Product Requirements CM SAF LST			Achieved Accuracy & Precision CM SAF LST	
	Threshold	Target	Optimal	Hourly	Monthly*
Bias	1.5 K	1.0 K	0.5 K	0.58	0.36
Bc-RMS	2.5 (1.5* K)	1.5 (1.0*) K	1.0 (0.5* K)	1.9	0.97



CM SAF & LSA SAF Latent Heat (ET) back to 1983



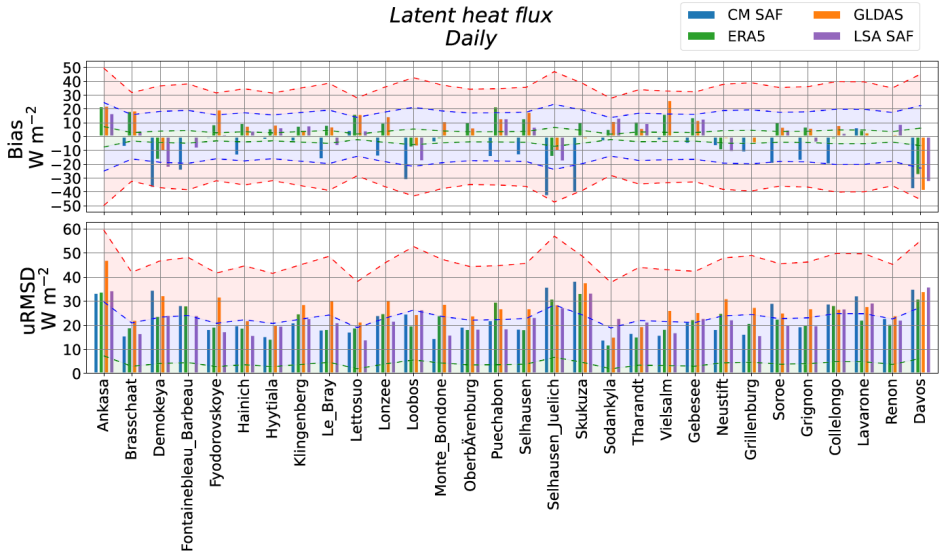
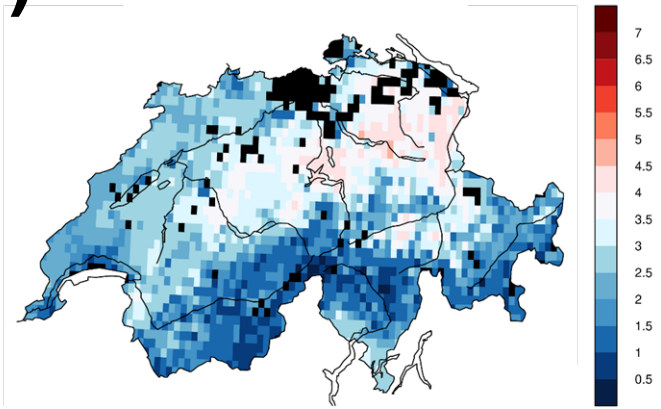


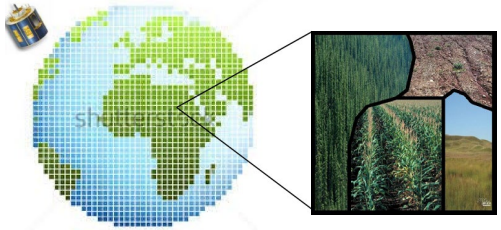
Figure 4: Bar plot showing the daily bias (W m^{-2}; top) and the daily unbiased root mean square error (W m^{-2}; bottom) of CM SAF (blue), ERA5 (green), GLDAS (orange) and LSA SAF (violet) datasets as compared to FLUXNET2015/ICOS dataset at stations for the latent heat flux. The shaded areas represent the optimal (green), target (blue) and threshold (red) accuracy requirements.

CM SAF & LSA SAF Meteosat Evapotranspiration (ET) back to 1983



Model simulation based on satellite data:

- Radiation (S)
- Albedo (α)
- Land surface temperature (T_{SKT})
- Longwave radiation (SDL)
- Soil moisture …

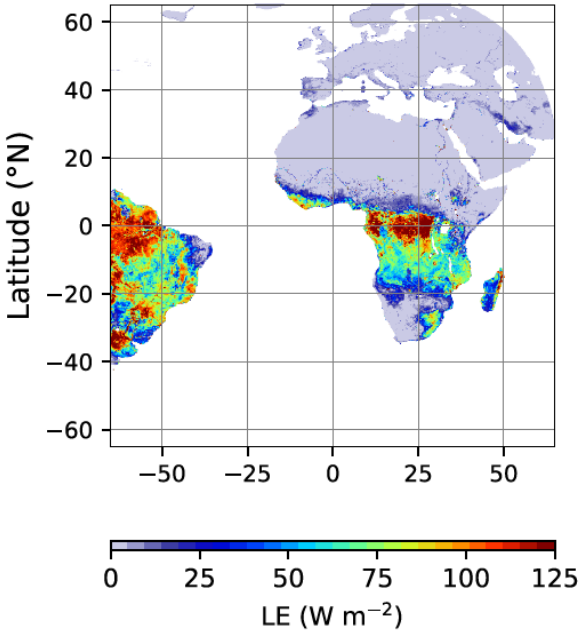


Energy balance model:

$$(1-\alpha)\,S + \varepsilon\,(SDL-\sigma T^4_{SKT}) + H + LE - G = 0$$

Evapotranspiration (ET)

CM SAF & LSA SAF Latent Heat (ET) back to 1983



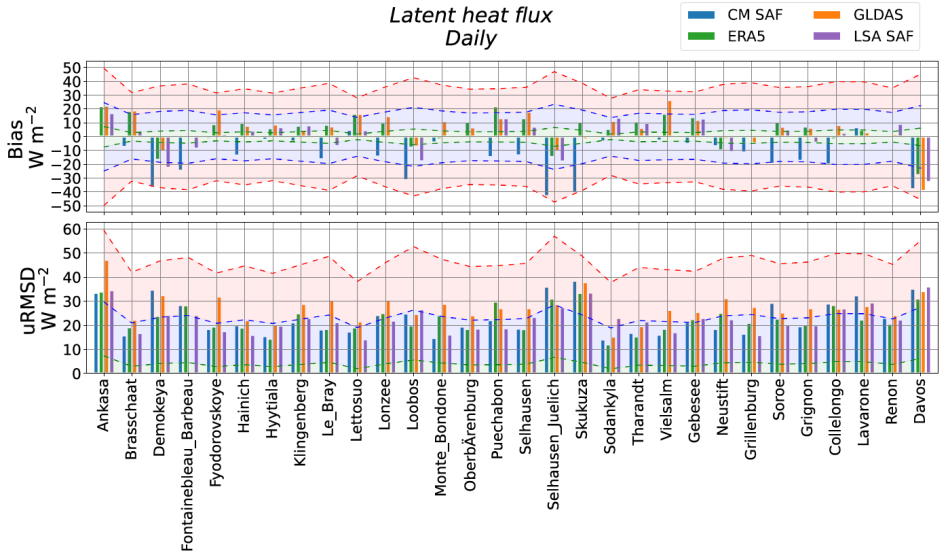
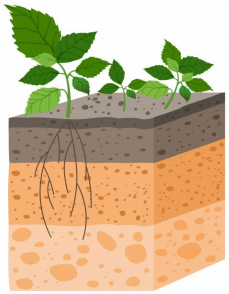
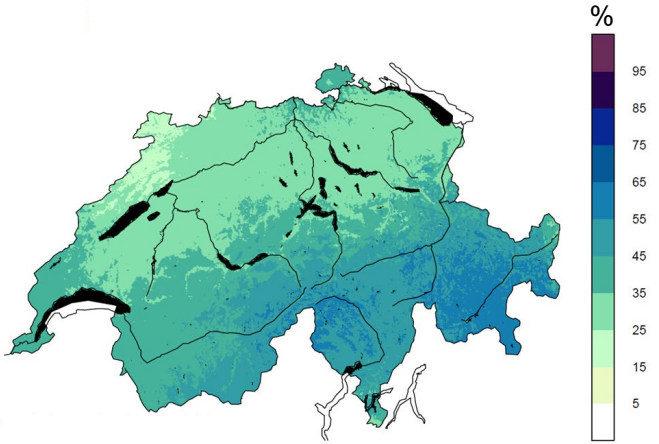


Figure 4: Bar plot showing the daily bias (W m^{-2}; top) and the daily unbiased root mean square error (W m^{-2}; bottom) of CM SAF (blue), ERA5 (green), GLDAS (orange) and LSA SAF (violet) datasets as compared to FLUXNET2015/ICOS dataset at stations for the latent heat flux. The shaded areas represent the optimal (green), target (blue) and threshold (red) accuracy requirements.

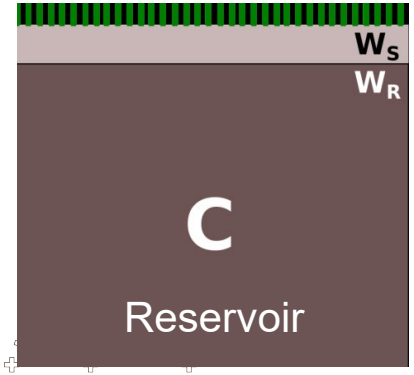
HSAF ASCAT Soil Water Index (SWI)



Radar measurements



25 km → 500 m



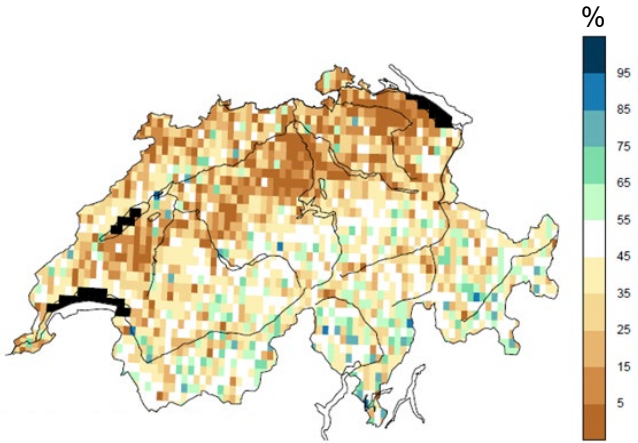
$$SWI(t_n) = \frac{\sum_{i}^{n} SSM(t_i) e^{-\frac{t_n - t_i}{T}}}{\sum_{i}^{n} e^{-\frac{t_n - t_i}{T}}} \quad for\, t_i \le t_n$$

$t_{n,\,i}$ = *observation times*
T = *scaling factor*

Vegetation Health Index (VHI)

NOAA satellite-based drought index:

- CM SAF Land surface temperature
- NOAA Vegetation (NDVI)



CM SAF Land Surface Temperature

$$\mathrm{TCI}_j = \frac{T_{\max} - Ts_j}{T_{\max} - T_{\min}} \times 100\,\%$$

NOAA Vegetation

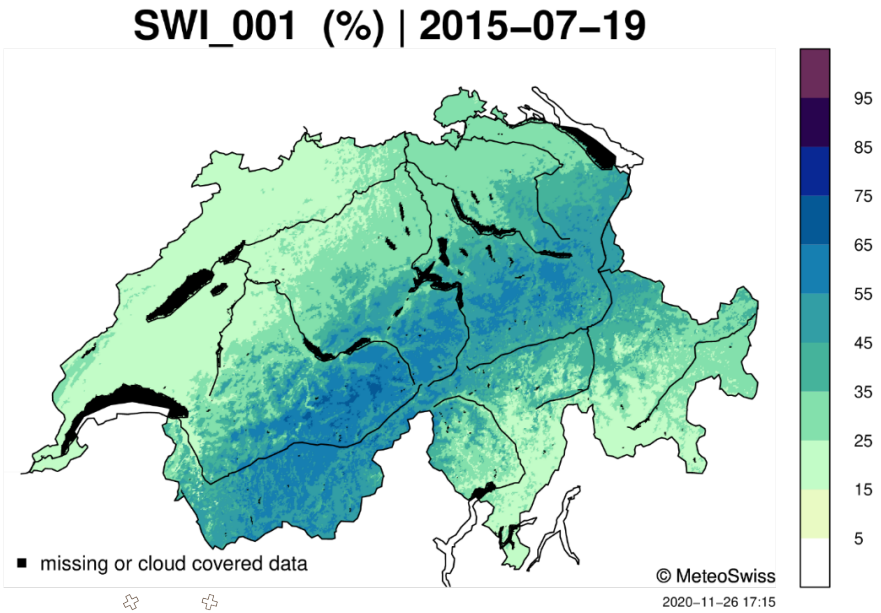
$$\mathrm{VCI}_j = \frac{\mathrm{NDVI}_j - \mathrm{NDVI}_{\min}}{\mathrm{NDVI}_{\max} - \mathrm{NDVI}_{\min}} \times 100\,\%$$

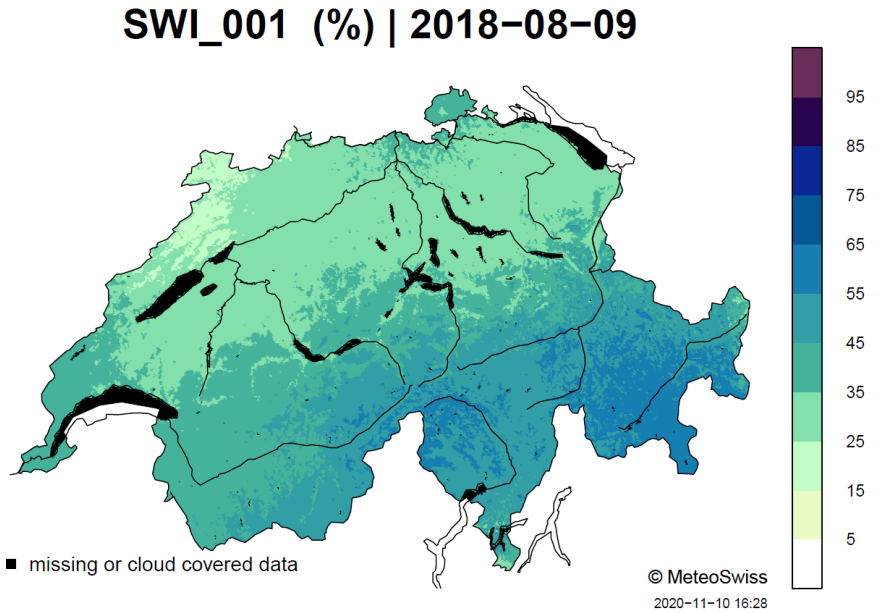
$$\mathrm{VHI} = a\mathrm{VCI} + (1 - a)\,\mathrm{TCI}$$

Met

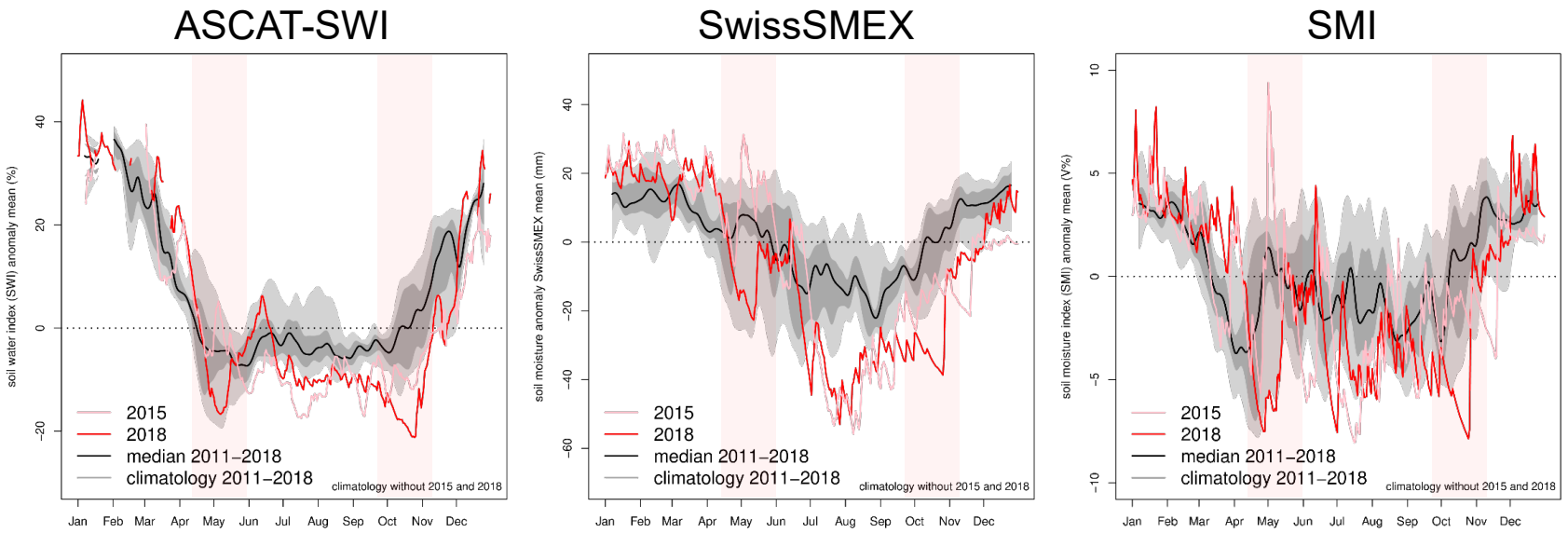
Results

HSAF ASCAT Soil Water Index (SWI)



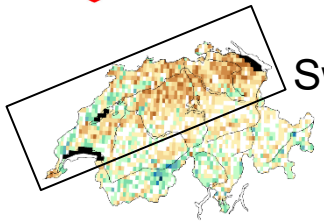


Soil Moisture Anomalies



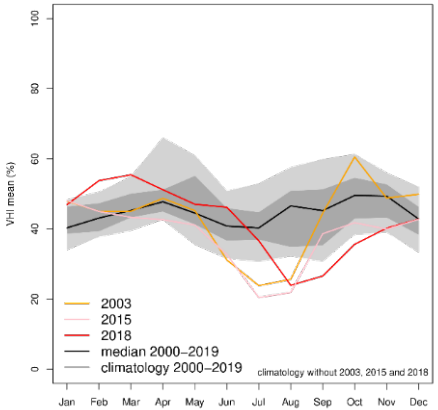
Soil moisture anomalies of 2015 and 2018 (with respect to the long-term mean) are **consistently represented** in the gridded ASCAT SWI, SwissSMEX measurements and SMI data by showing a similar temporal evolution with pronounced phases of dryness.

Vegetation and Surface Temperatures

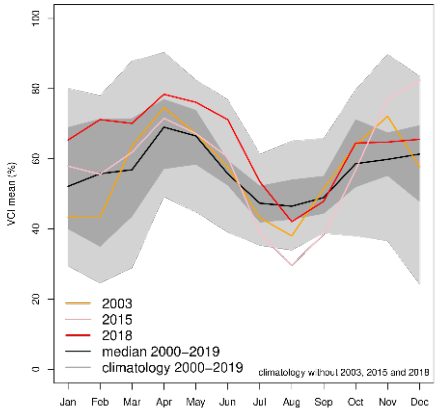


Swiss Plateau

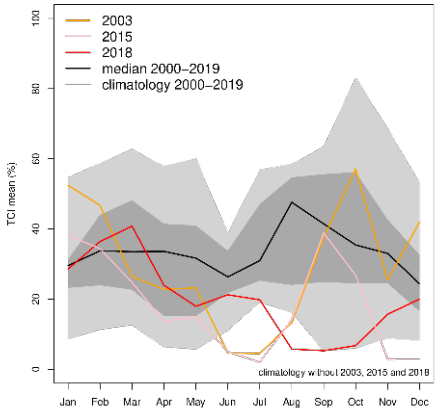
VHI



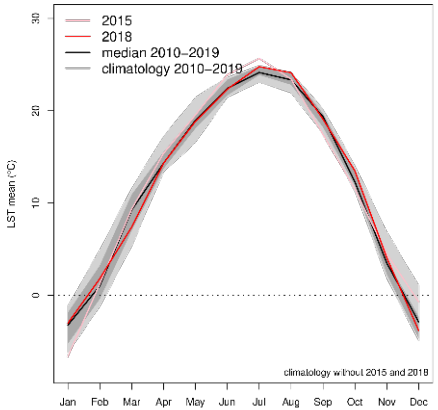
VCI



TCI



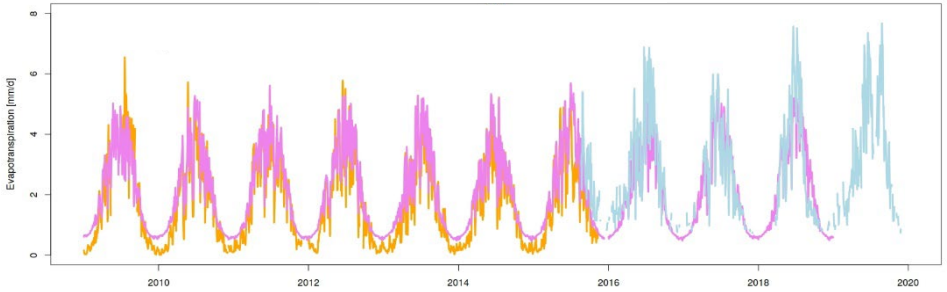
LST



VHI shows earlier onset and shorter duration of dry conditions **in 2003 and 2015 compared to 2018**. This can be **mainly explained by surface temperatures** (TCI, LST), while the VCI is rather similar during the dry years 2003, 2015 and 2018.

Evapotranspiration

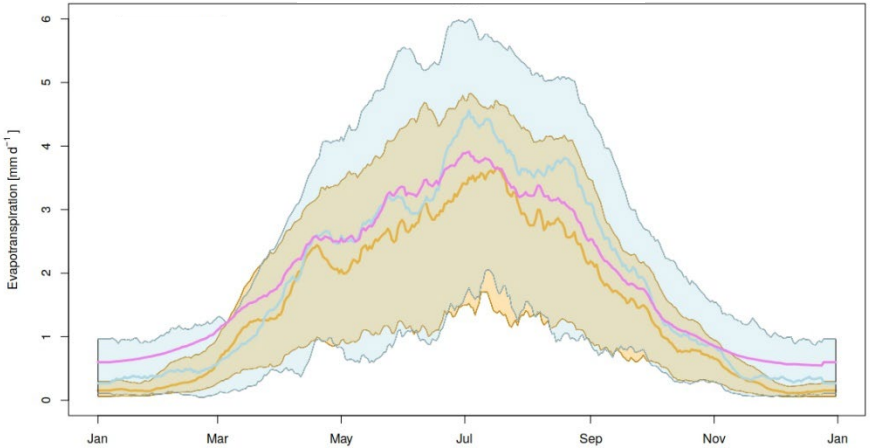
Payerne



ET LSA SAF ETP LSA SAF Mini Lysimeter

Daily absolute values (mm/d; 2009-2020)

Rietholzbach



ET LSA SAF ETP LSA SAF Lysimeter

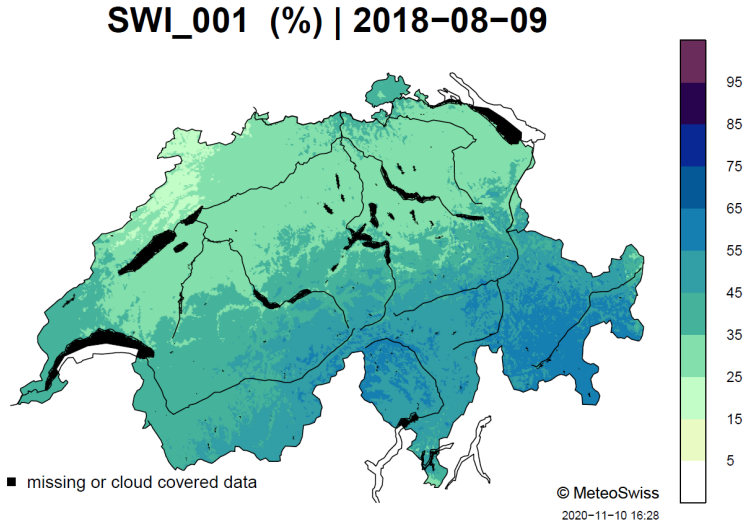
Daily absolute values (mm/d; 2009-2015)

ET and ETP are similar, as **evapotranspiration is hardly limited by soil moisture in Switzerland**. During dry and warm summers even higher ET can be seen at times, as more energy is available for evaporation.

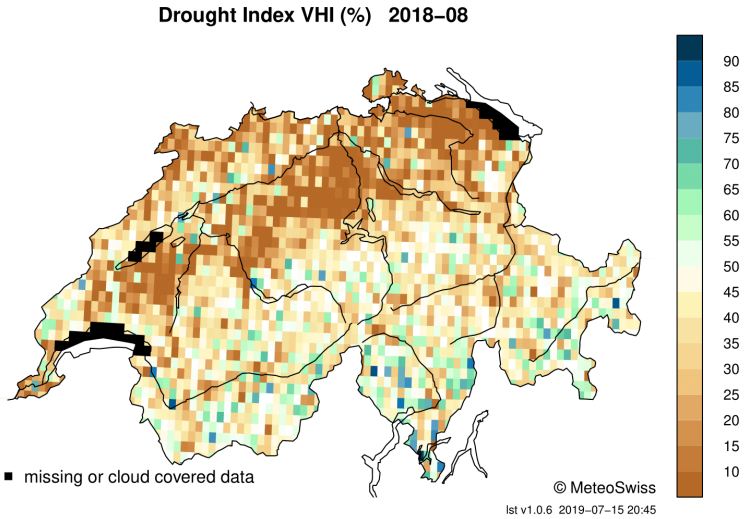
LSA SAF evapotranspiration **products agree well** with SwissSMEX **measurements**.

MeteoSwiss ETH zürich

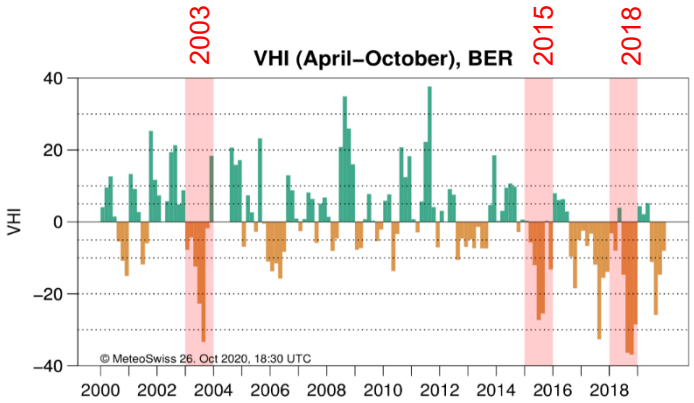
Soil Moisture

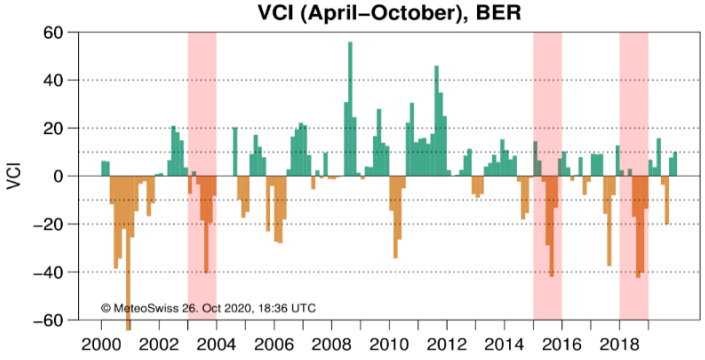


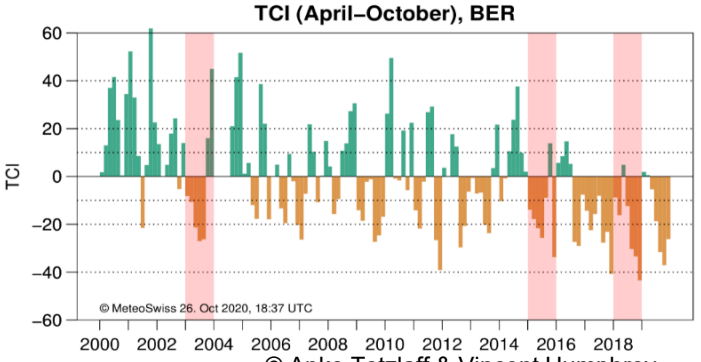
VHI



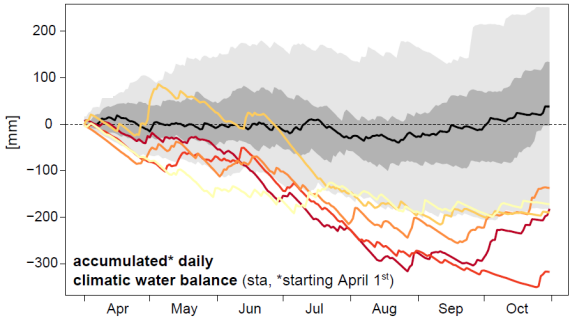
Vegetation Heat Indices (VHI)

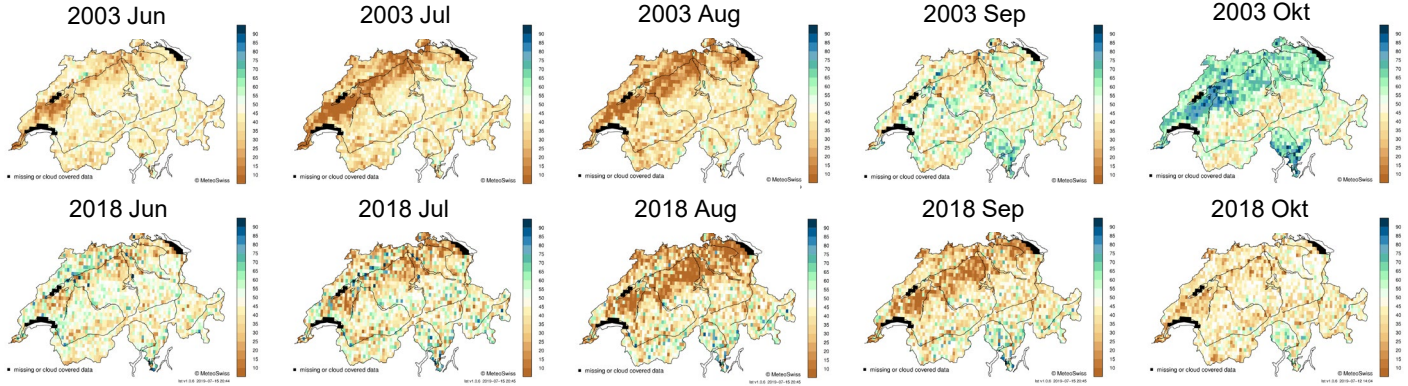




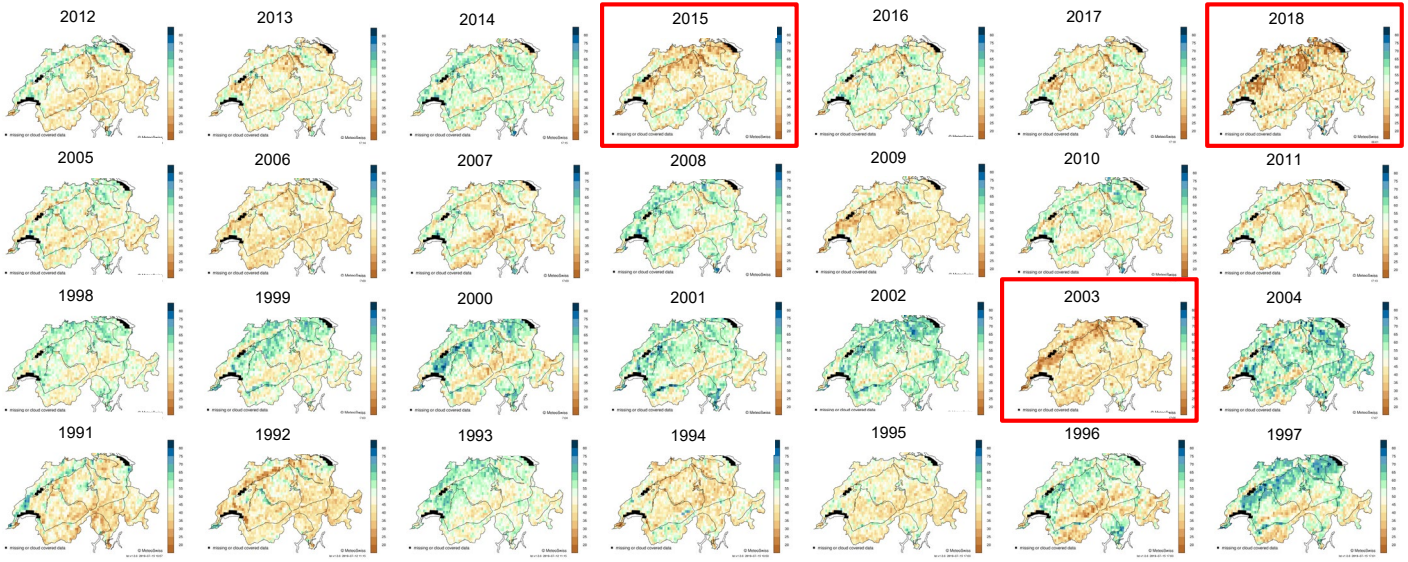


VHI 2003 + 2018





Drought Index VHI



Summary

- HSAF **soil moisture data** correlate high with modeled Soil Moisture Index (except in high altitudes) and with SwissSMEX measurements
- CM SAF **evapotranspiration data** agree well with SwissSMEX measurements
- Drought events are well depicted in combined **CM SAF land surface temperature** and NOAA **vegetation products**

SAF satellite products can well complement the station-based indicators for drought monitoring in Switzerland with spatial information.

Open Access Article

Climatological Drought Monitoring in Switzerland Using EUMETSAT SAF Satellite Data

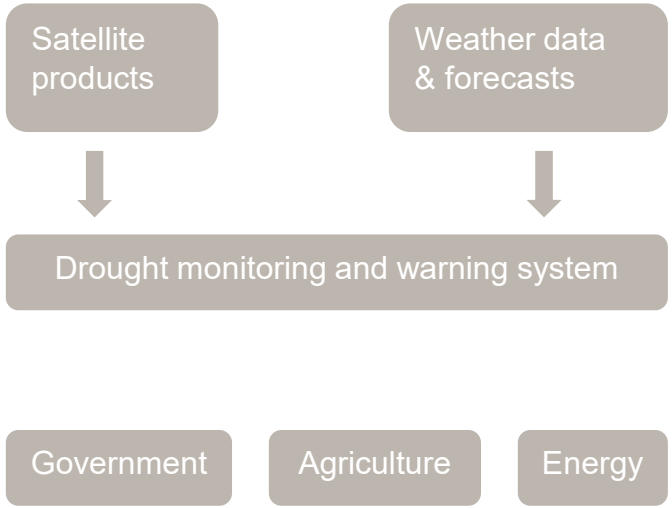
by Annkatrin Rassl [1], Dominik Michel [2], Martin Hirschi [2], Anke Duguay-Tetzlaff [1,*] and Sonia I. Seneviratne [2]

Integration of satellite products into drought early warning systems

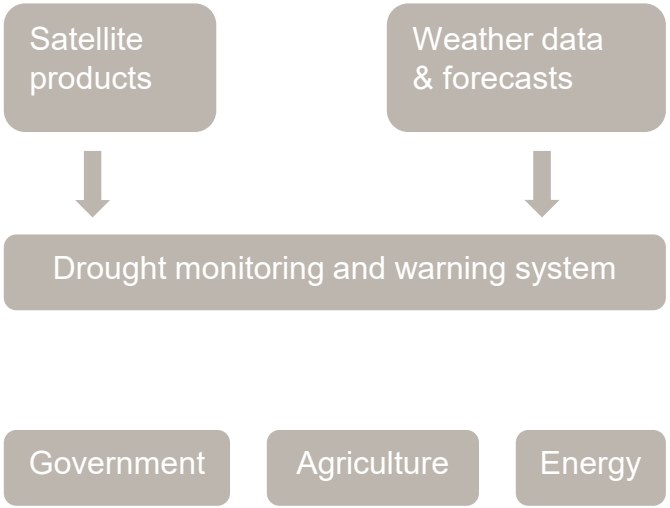
Contents

1. Synergies between satellite and weather products
2. Relating indices to impacts
3. Integration into warnings

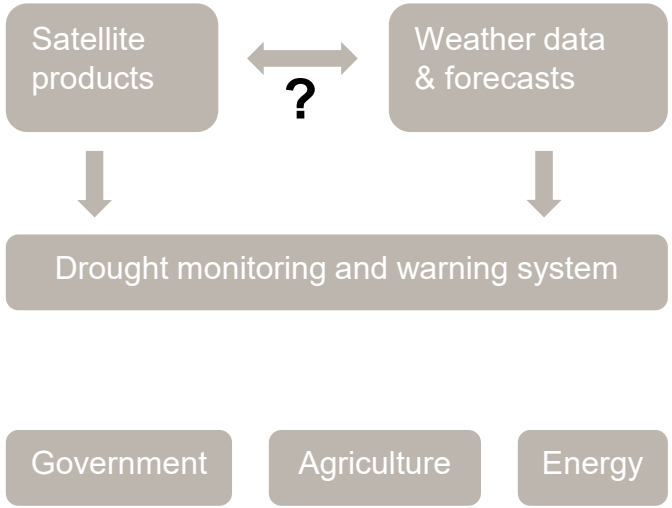
Integration of satellite products



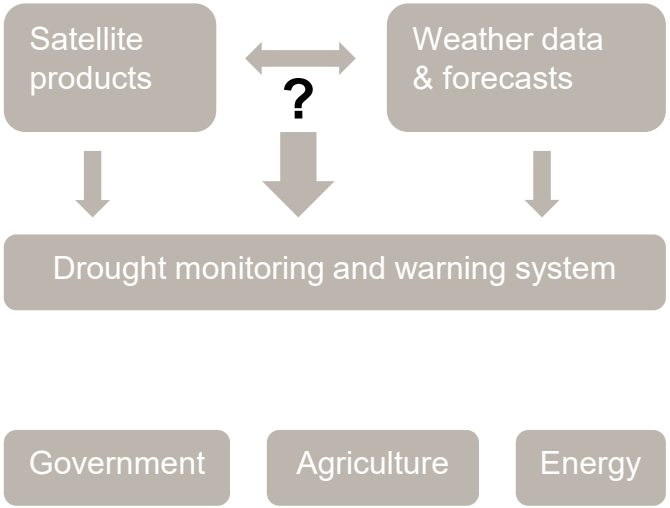
Integration of satellite products



Integration of satellite products

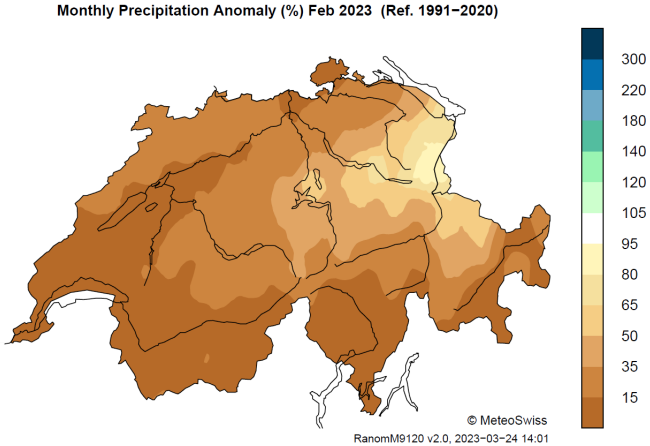


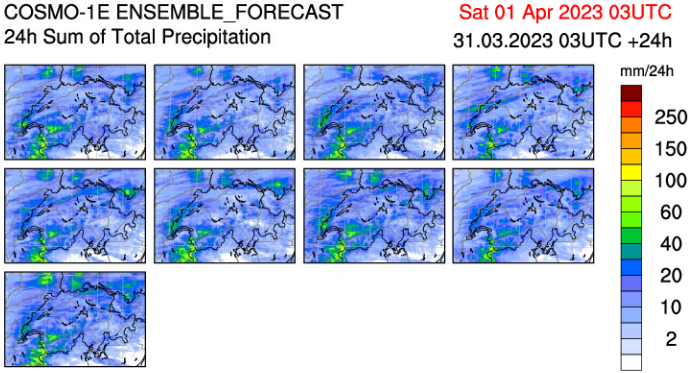
Integration of satellite products



Synergies

Historical weather data | Weather forecast





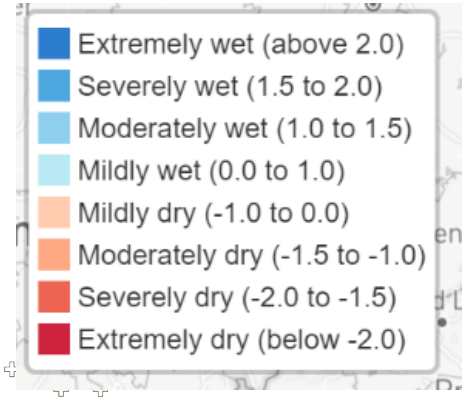
Synergies

Historical weather data

Weather forecast

Drought indices (e.g. SPI, SPEI, …)

Warning?



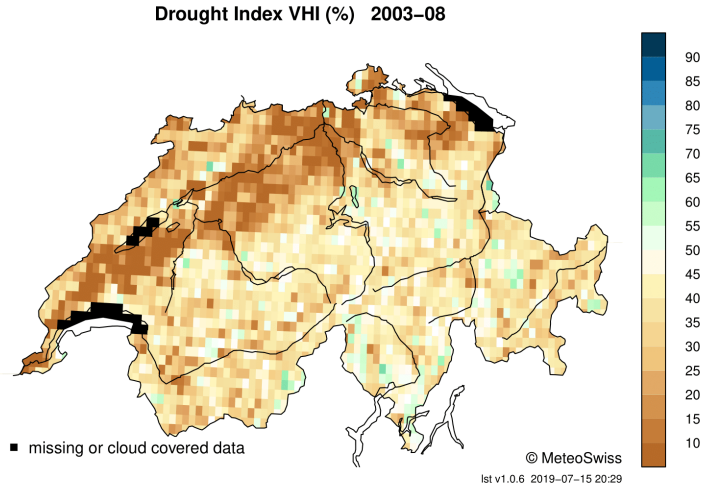
Synergies

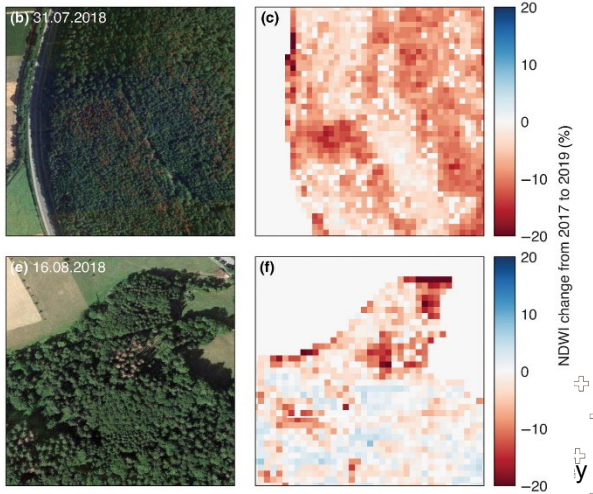
Historical weather data

Weather forecast

Drought indices (e.g. SPI, SPEI, …)

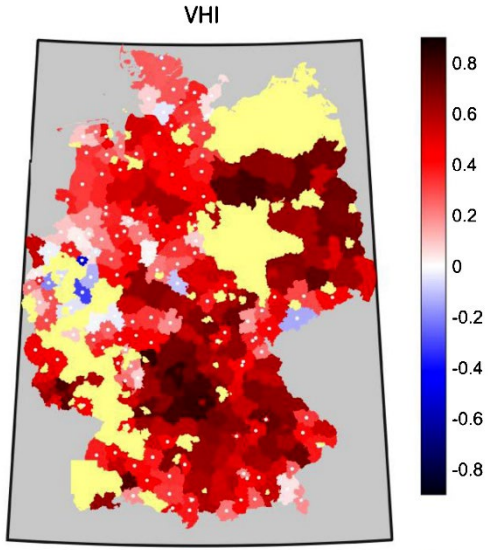
Historical drought impacts





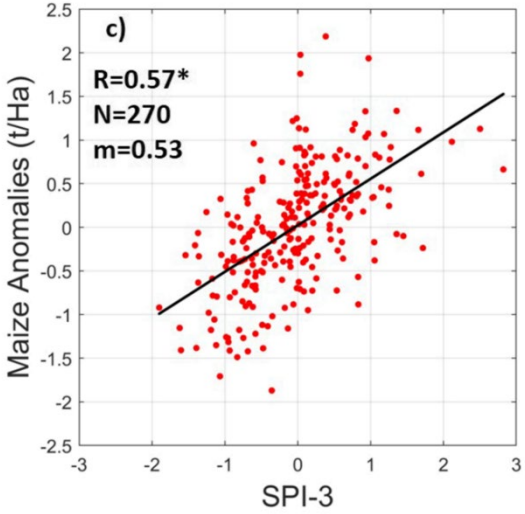
Sturm et al. 2023, Global change Biology

Synergies



Correlation of VHI and corn yield (Germany)

Bachmair et al. 2018, ERL



Deccan Plateau (India)

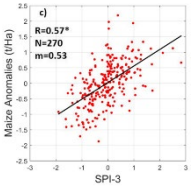
Modanesi et al. 2020, WRR

Synergies

Historical weather data

Weather forecast

Drought indices (e.g. SPI, SPEI, …)



Historical drought impacts

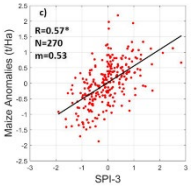
Impact forecast

Synergies

Historical weather data

Weather forecast

Drought indices (e.g. SPI, SPEI, …)



Historical drought impacts

Impact forecast

Warning

- no drought impact
- drought affected crops, yield loss up to 10%
- moderate drought damage, yield loss 10 - 30 %
- severe drought damage, yield loss 30 - 40 %
- extreme drought damage, yield loss above 40%

Conclusions

1. Drought has many dimensions
   - There is no universal index, but many indices/products
   - End-users are often confused about what is most relevant to them

2. Combining both worlds
   - Satellite observations: high-resolution monitoring & closer to the impacts
   - Weather models: generic & low-resolution but ability to make forecasts

3. User-tailored warnings are almost unavoidable for droughts

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

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

MeteoSwiss
Operation Center 1
CH-8058 Zurich-Airport
T +41 58 460 91 11
www.meteoswiss.ch

Thank you.

Contact: annkatrin.burgstall@meteoswiss.ch

MeteoSvizzera
Via ai Monti 146
CH-6605 Locarno-Monti
T +41 58 460 92 22
www.meteosvizzera.ch

MétéoSuisse
7bis, av. de la Paix
CH-1211 Genève 2
T +41 58 460 98 88
www.meteosuisse.ch

MétéoSuisse
Chemin de l'Aérologie
CH-1530 Payerne
T +41 58 460 94 44
www.meteosuisse.ch