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Drought in China September 2022

GDO Analytical Report

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GDO Analytical Report

Drought in China - September 2022

JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) - 26/09/2022

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Executive summary

- An intense and long-lasting heatwave in central-eastern China combined with a moderate precipitation deficit has been driving a severe hydrological drought over the Yangtze River basin, one of the major river basin in the world and home to one third of China's population.
- Yangtze River flow is about 50% below the average of the last 5 years in August-September. Severe impacts on energy production and inland shipping have been reported. Crops and vegetation start to be affected as well as drinking water supply, with further concerns for the coming months.
- Forest fires have been severely impacting the Sichuan province and other regions along the Yangtze River.
- Warmer and drier than usual conditions are likely to occur in eastern China in the coming months, impacting also the last part of the wet season.

Introduction

The Yangtze River basin (Fig. 1) is one of the major in the world, the third for length and the seventh for discharge. Its drainage area is about one-fifth of Chinese land and one-third of Chinese population live there[1]. The river is an extremely important source for water supply, energy production, transportation, and crop irrigation. Crops are mainly located in the lower basin (eastern regions). Most of the hydro-power plants are in the central region, including the Three Gorges Dam, the largest hydro-power plant in the world.

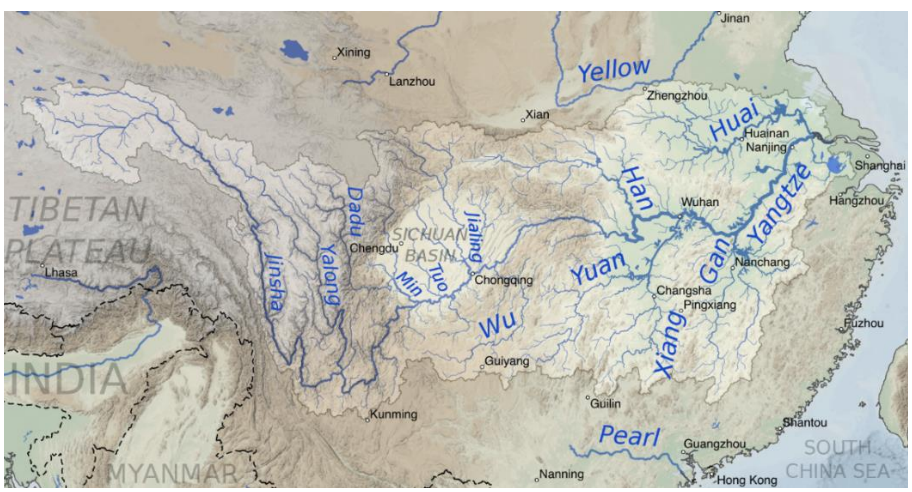


Figure 1: *Yangtze River basin. Source: Wikipedia (CC BY-SA 4.0).*

[1] https://geoscienceletters.springeropen.com/articles/10.1186/s40562-021-00187-7

Standardized Precipitation Index (SPI)

Most of the Yangtze River basin has been affected by negative precipitation anomalies in the three months ending at September 10th 2022. The greatest negative anomaly can be seen in the lower basin (eastern part) and even more in the central part. Extremely dry conditions are detected also in the south-western Chinese regions, just outside of the Yangtze River basin (SPI-3, Fig. 2). SPI-6 (not presented here) shows less severe anomalies confirming the recent onset of the event. In the SPI-1 analysis (not shown), the August data shows negative anomalies mainly in the lower Yangtze River basin, while in July the upper basin is more affected. The event is relatively recent and is rapidly expanding from the upper to the whole basin.

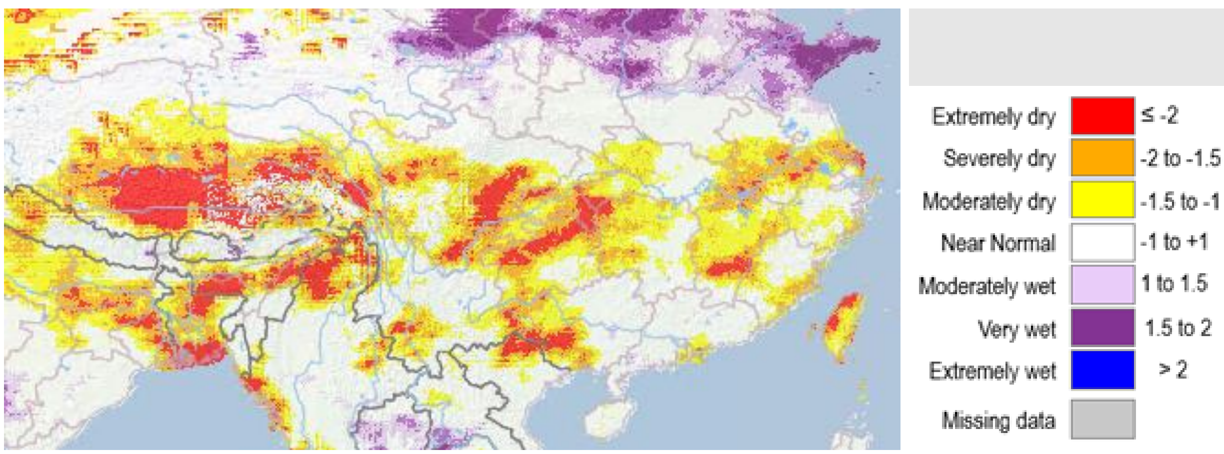


Figure 2: *Standardized Precipitation Index SPI-3, three months ending at September 10th 2022.*

Rainfall temporal profiles show cumulative values starting to depart from average conditions in early July in the west (Xizang Zizhiqu) and mid-end July in the centre and east (Sichuan and Anhui) to reach one of the lowest values in the last 20 years on the first *dekad*[2] of September (Fig. 3).

[2] With the term *dekad* we refer to a period of about ten days. Each month of the year is composed by three *dekads* and the year is composed by 36 *dekads*.

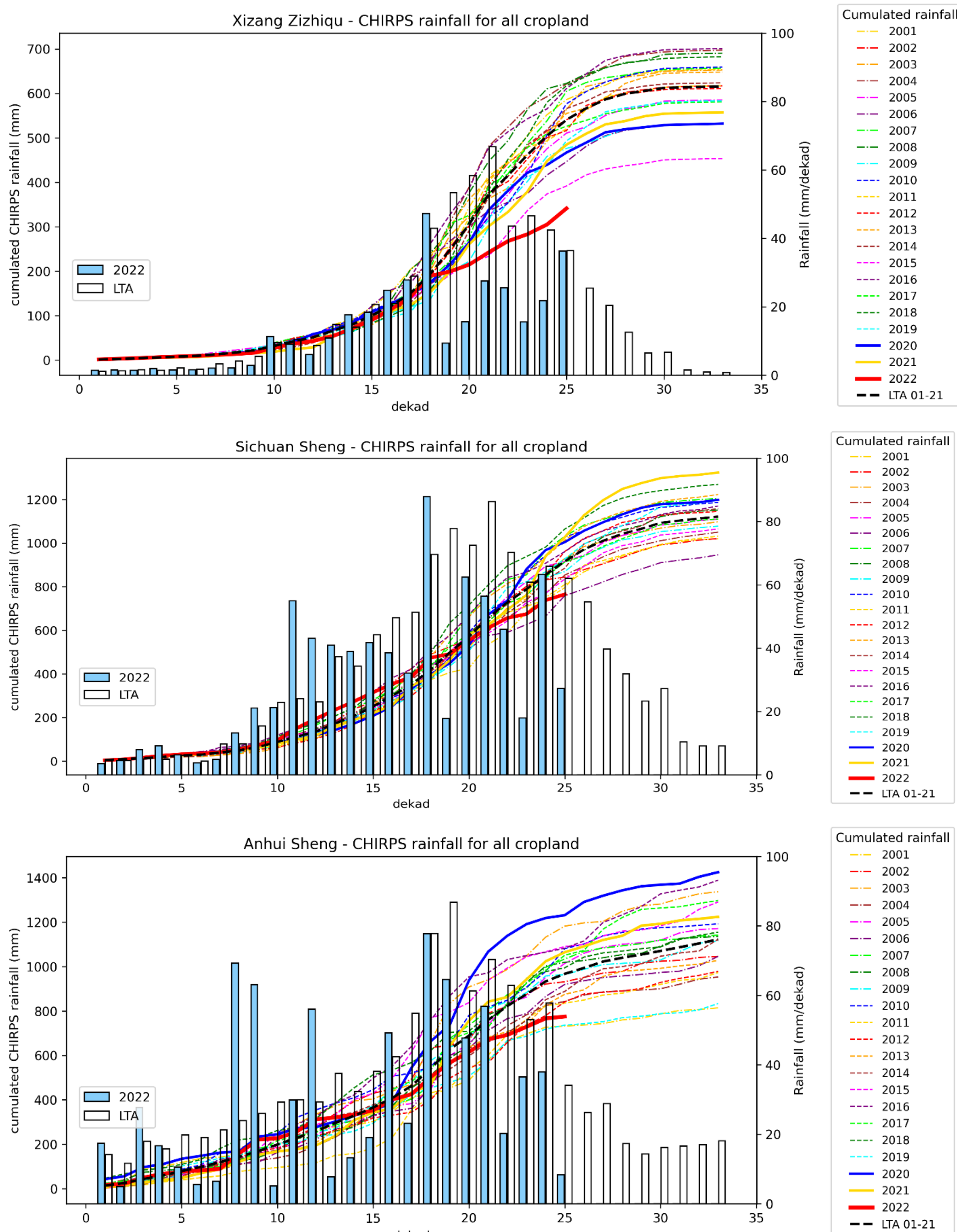


Figure 3: *CHIRPS rainfall for Xizang Zizhiqu (western part of the basin – upper panel) Sichuan (central part of the basin – central panel) and Anhui (eastern part of the basin – lower panel) provinces of the Yangtze River basin.*

Heatwaves

Hot temperatures increase evapotranspiration and trigger higher water demand, thus contribute substantially to enhance drought severity and water scarcity.

Central-eastern China has been experiencing a prolonged heatwave since mid-July 2022, with a peak in mid-August 2022 (Fig. 4). The persistence, intensity, and spatial extent of the heatwave are extremely severe and have worsened the effect of the drought on the soil and likely on crops (e.g. air temperature above 35 °C may reduce fertility and alter grain filling). The most severely hit region is the eastern part of the Yangtze River where the heatwave duration is longer than one month. The extent of the area under heatwave was slowly reducing at the end of August 2022.

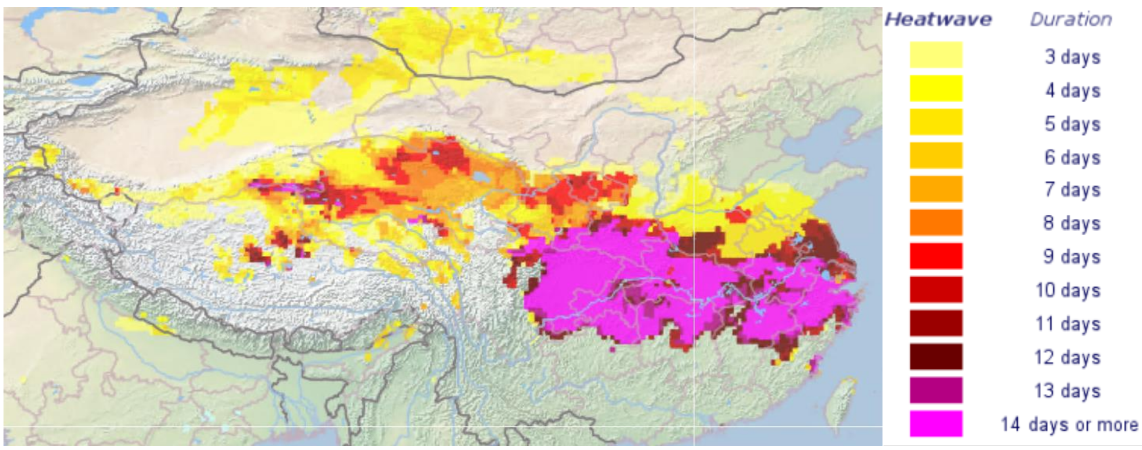


Figure 4: *Duration (days) of the identified heatwaves. Yellow to purple colours represent increasing duration (days). Map issued for 2022 August 12th.*

Maximum temperatures exceeded 35°C in the last part of June and then from mid-July to the end of August mostly in the eastern part of the Yangtze River basin. In the western part maximum temperatures have been generally lower (20-25°C) also thanks to higher altitudes, but in any case they have been anomalous for the region and the period (Fig. 5)

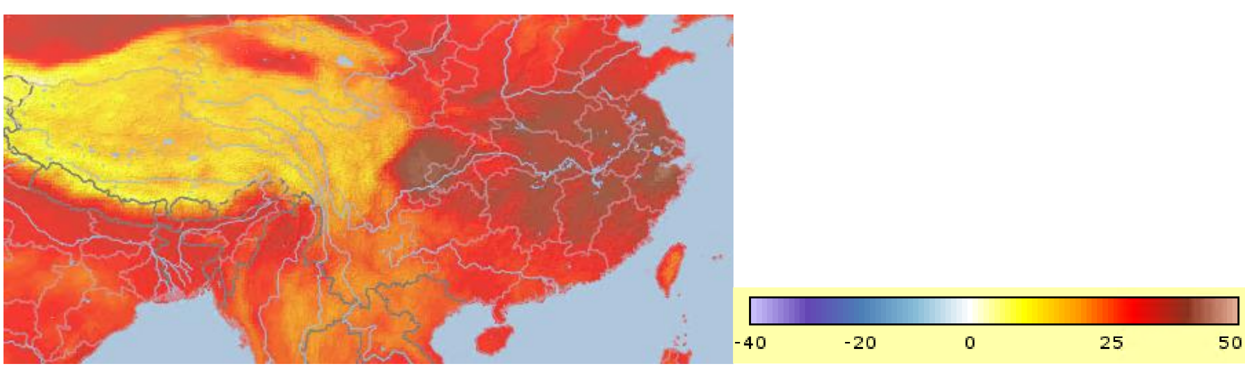


Figure 5: *Maximum daily temperature for 2022 August 12th.*

The average monthly temperature anomaly has been positive (+1 to +3 °C) for June and July mainly in the eastern regions (not shown here). In August, the warm anomalies were covering almost the whole Yangtze River basin with increasing values up to +6 °C (even more in a small central region), with record deviations from the mean in the east of Sichuan and the west of Chongqing provinces in the centre (Fig. 6).

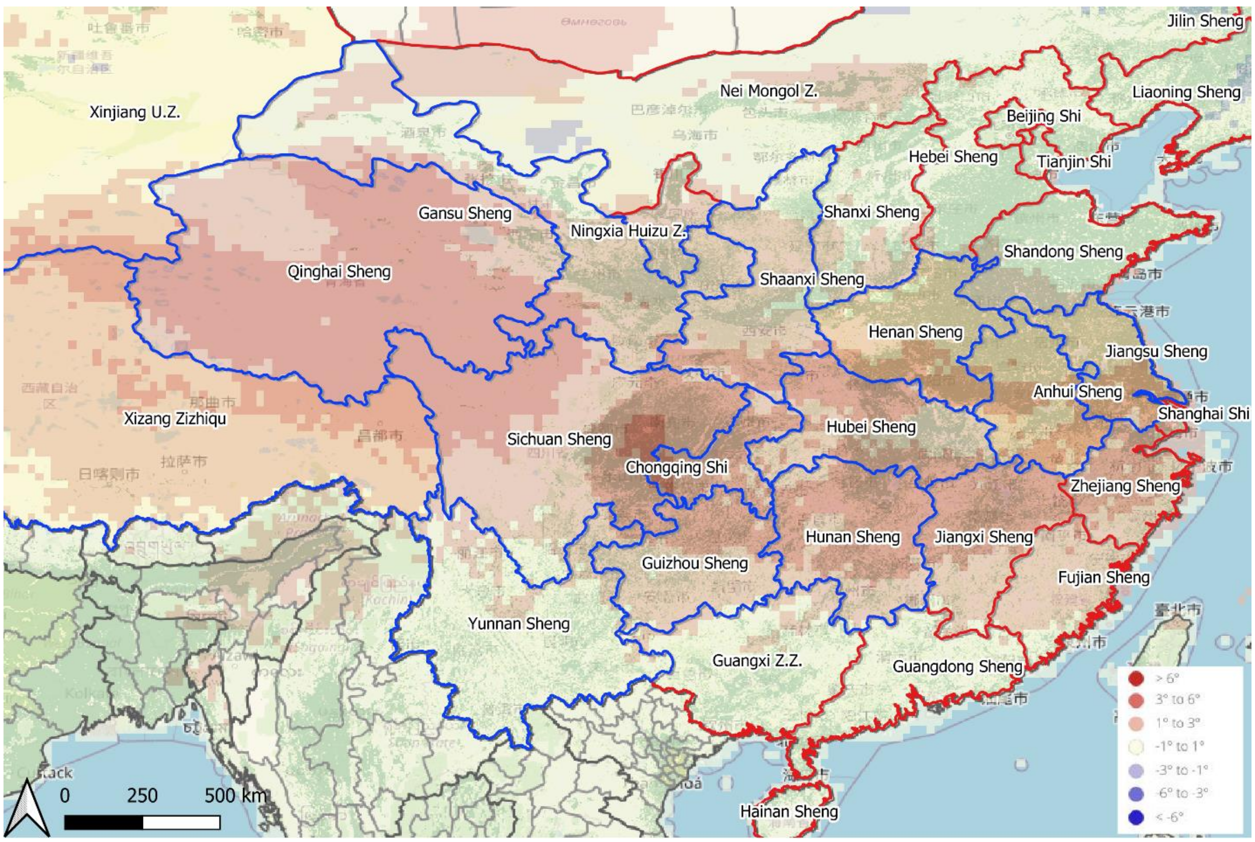


Figure 6: *Anomaly of average monthly temperature (ERA5) for August 2022.*

The temporal evolution of average air temperature over cropland areas for the centre (Sichuan) and the east (Anhui) of the Yangtze River basin shows above average temperatures from early June and the end of June in the east and the centre respectively, with record temperatures for the last 33 years reached in August in all provinces of the basin (Fig. 7).

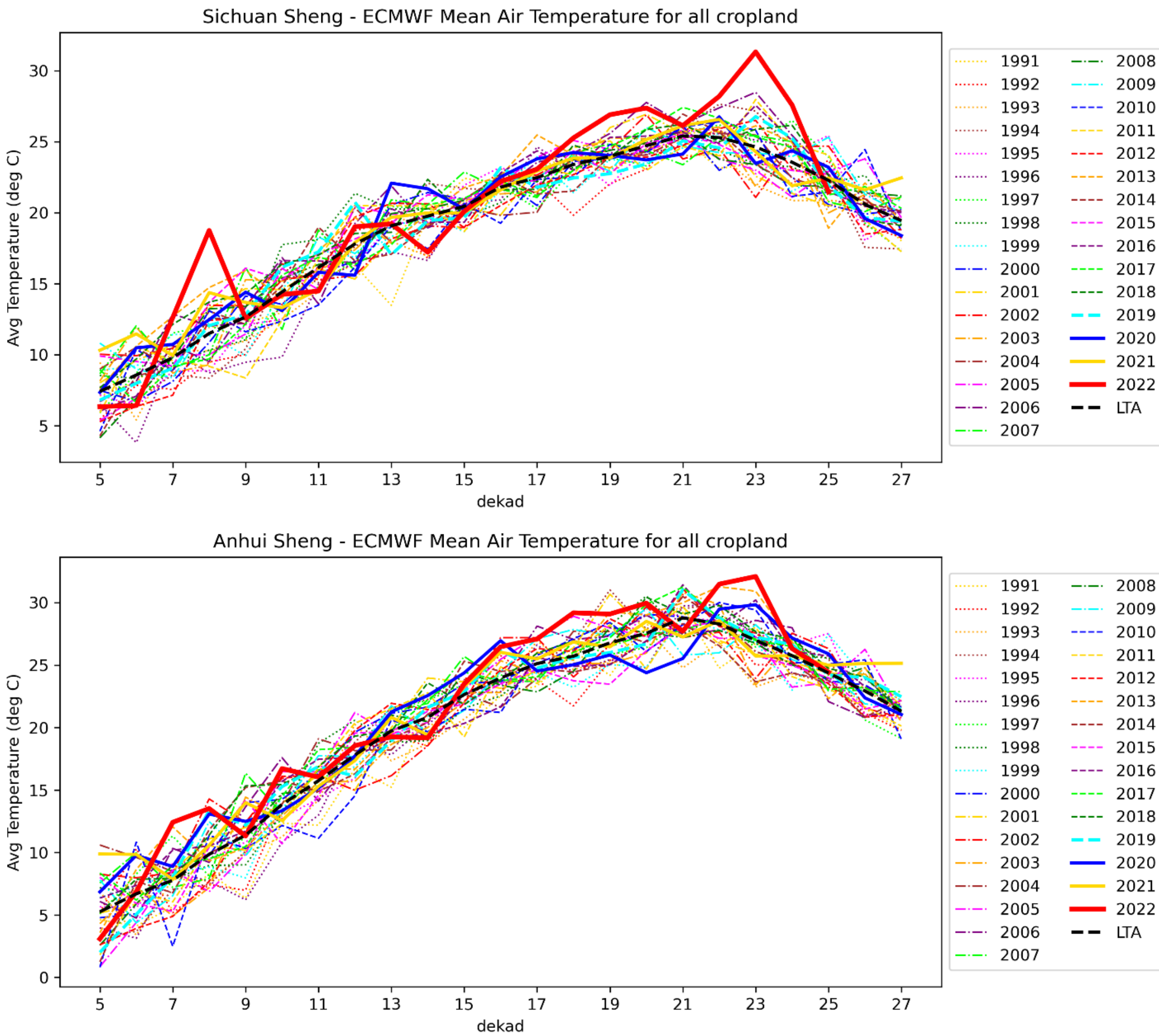


Figure 7: *Average temperature temporal profiles (ERA5) for Sichuan (central part of the basin – upper panel) and Anhui (eastern part of the basin – lower panel) provinces of the Yangtze River basin for the period 1991-2022.*

Soil Moisture Anomaly

The soil moisture anomaly is markedly negative in most of Yangtze River basin (Fig. 8) due to the lack of precipitation and the heatwaves that occurred in the last months. The most critically affected regions are in the central and eastern part of the Yangtze River basin and agree well with the negative SPI-3 patterns. The driest regions in the central-eastern part of the Yangtze River basin have been also affected by the severe heatwave which intensified the drying up of the soil. Large areas of the basin in the central and eastern regions have a Soil Moisture Anomaly indicator below -2 (corresponding to the driest conditions).

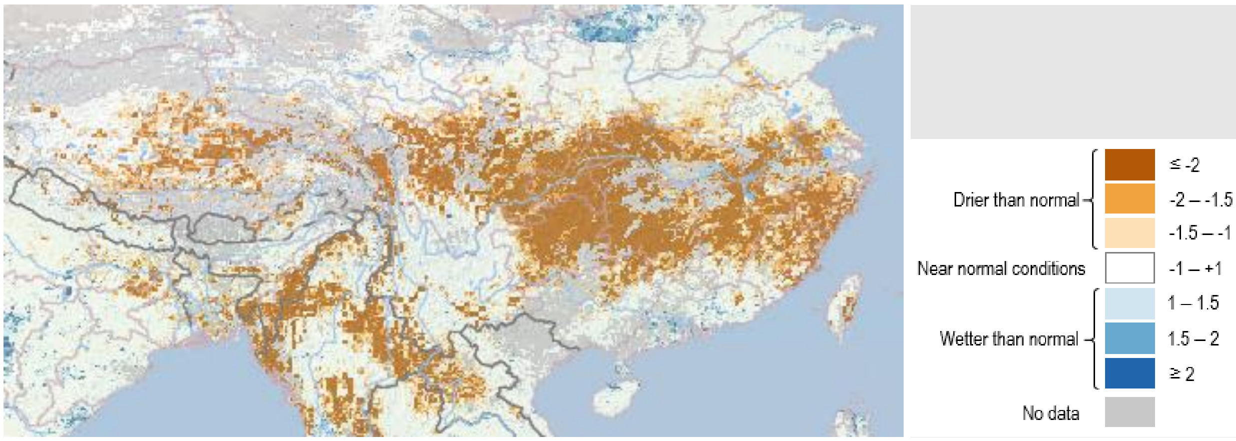


Figure 8: *Soil Moisture Anomaly – beginning of September 2022.*

Biomass anomaly

Vegetation conditions have being affected by this drought only since mid-August and some more relevant anomalies are detected at the beginning of September 2022 (Fig. 9). The precipitation deficit and the heatwave mostly occurred in August; thus further impacts on vegetation may emerge later. The worst conditions are observed in the eastern regions of the Yangtze River basin, and in the central part with a smaller extent. Western regions appear to be affected as well; however, due to large areas having missing data, there are some uncertainties.

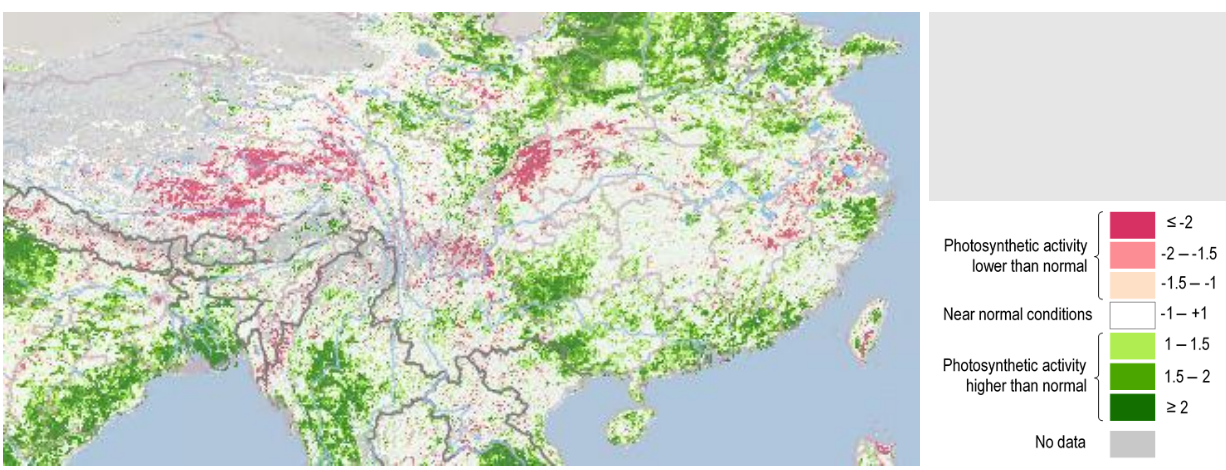
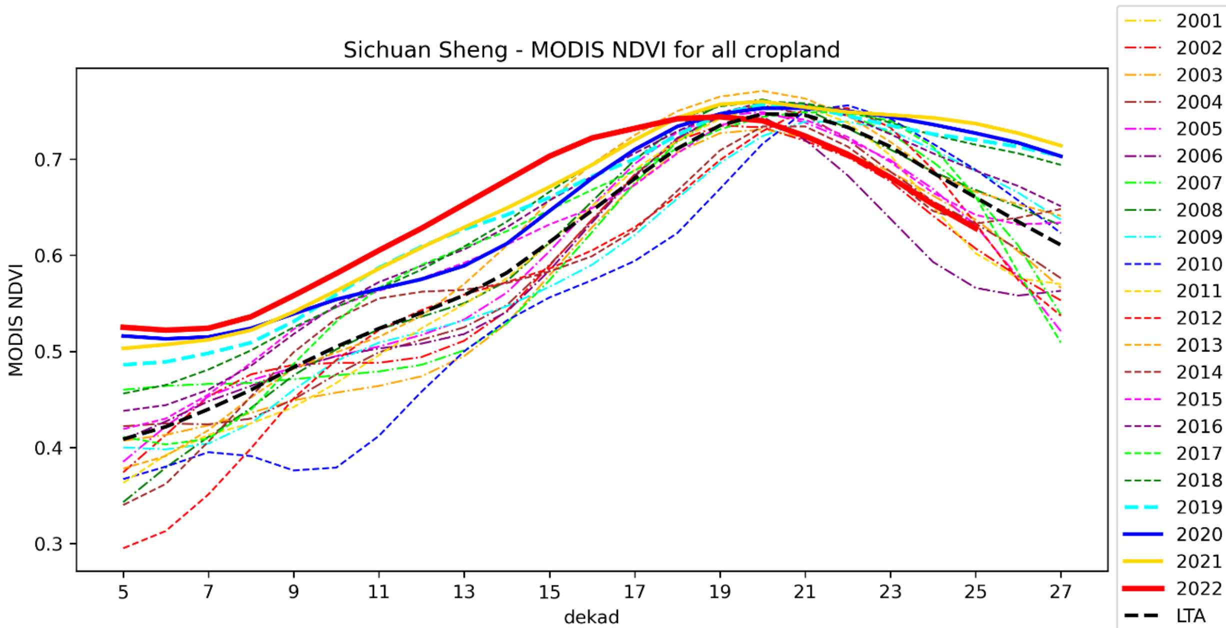


Figure 9: *fAPAR anomaly – beginning of September 2022.*

MODIS NDVI temporal profiles show an earlier than average start of (spring-summer) crop season in the centre (Sichuan, Chongqing) and close to average start of the season in the east of the basin (Anhui, where summer crops follow a winter crop). Up to end of June, crops benefitted from normal rainfall and average to above average temperatures (in the centre and the east respectively). As a result, crop biomass is mostly close to average in the Yangtze basin, However, in some areas of the centre (Sichuan and Chongqing) and west, summer crops have experienced a fast senescence (as shown by their NDVI profile, Fig. 10) likely caused by soil moisture deficit (where irrigation water has been lacking) combined with high temperatures. Actually, heat stress may have negatively impacted fertility and grain filling.



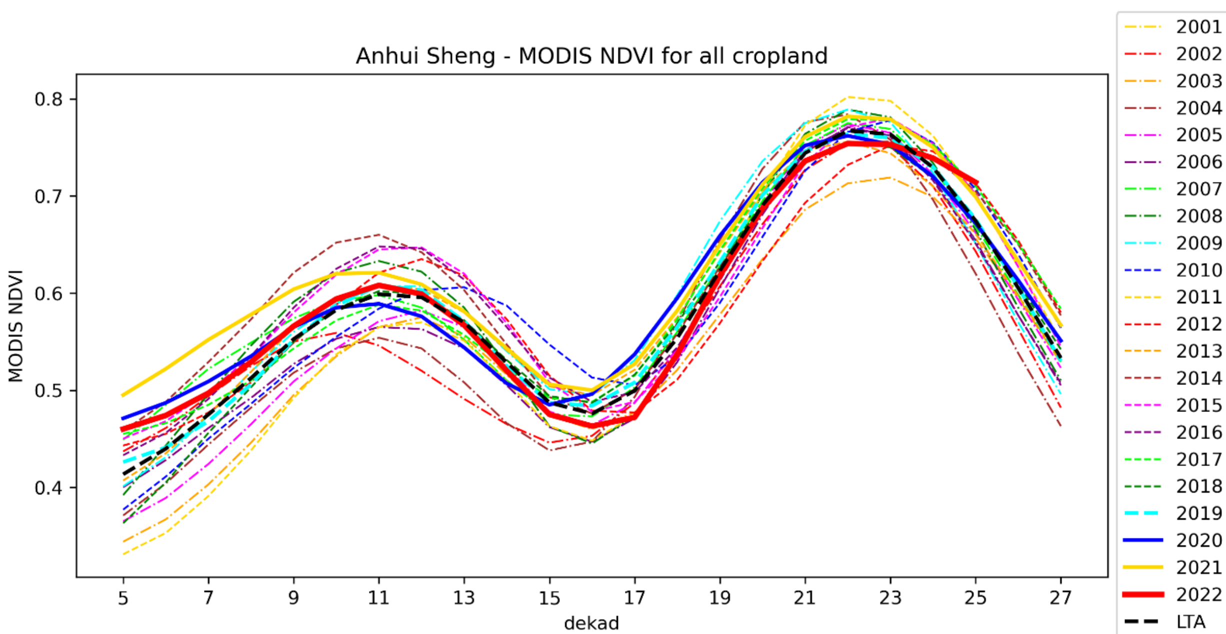
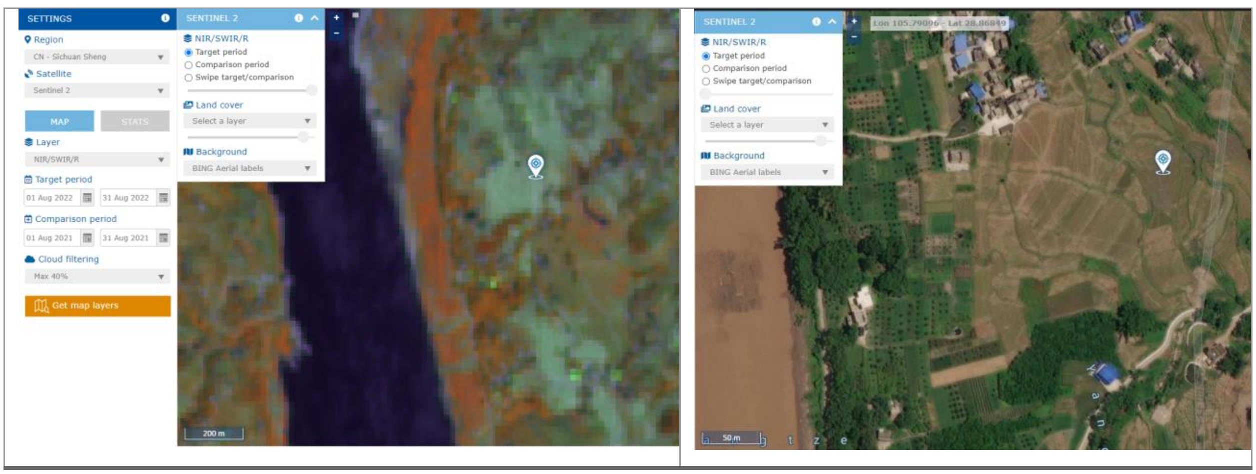
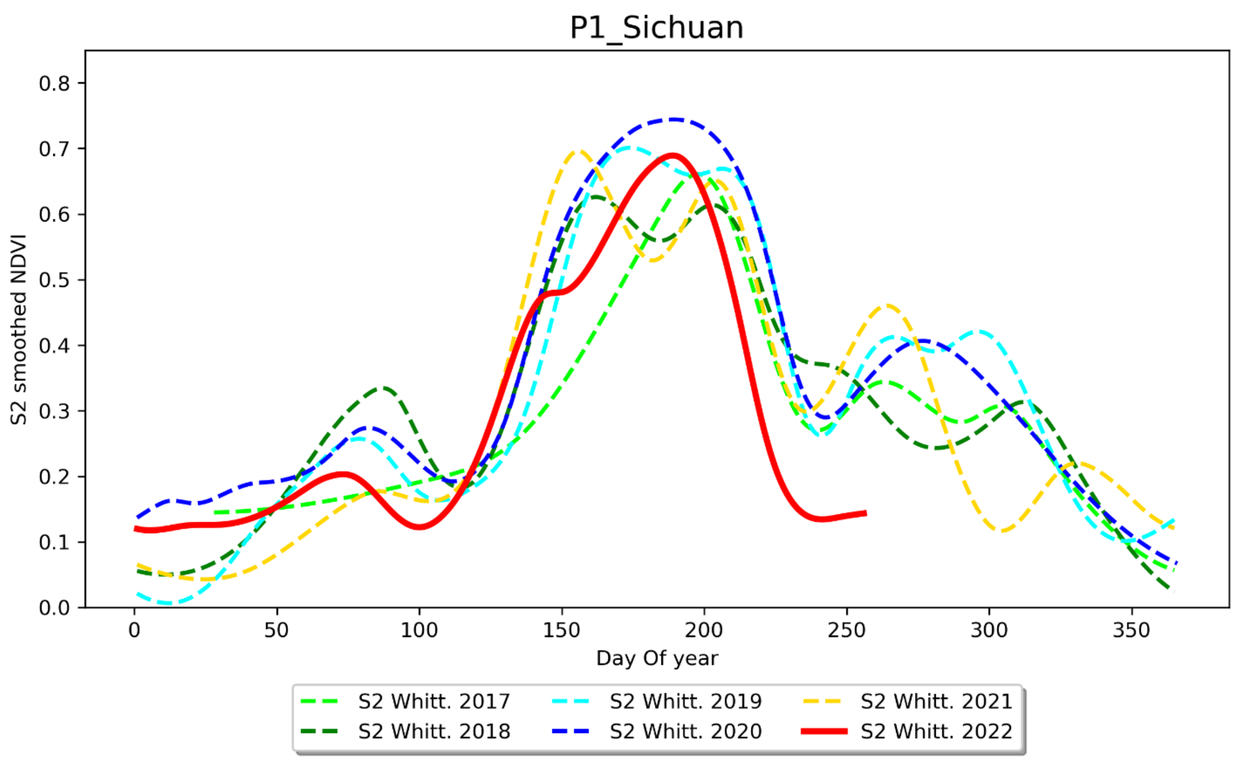
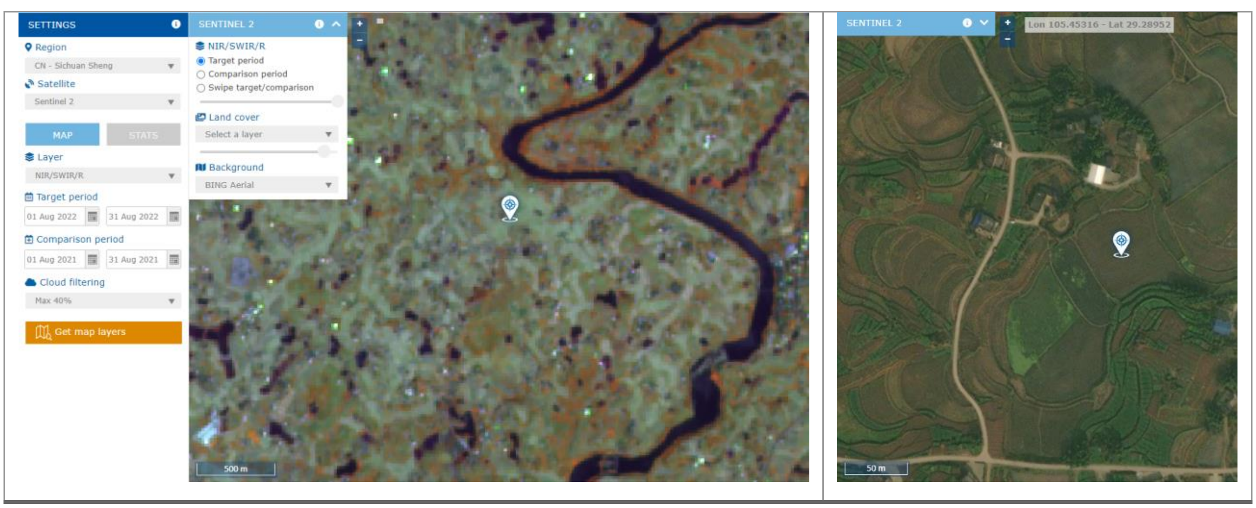


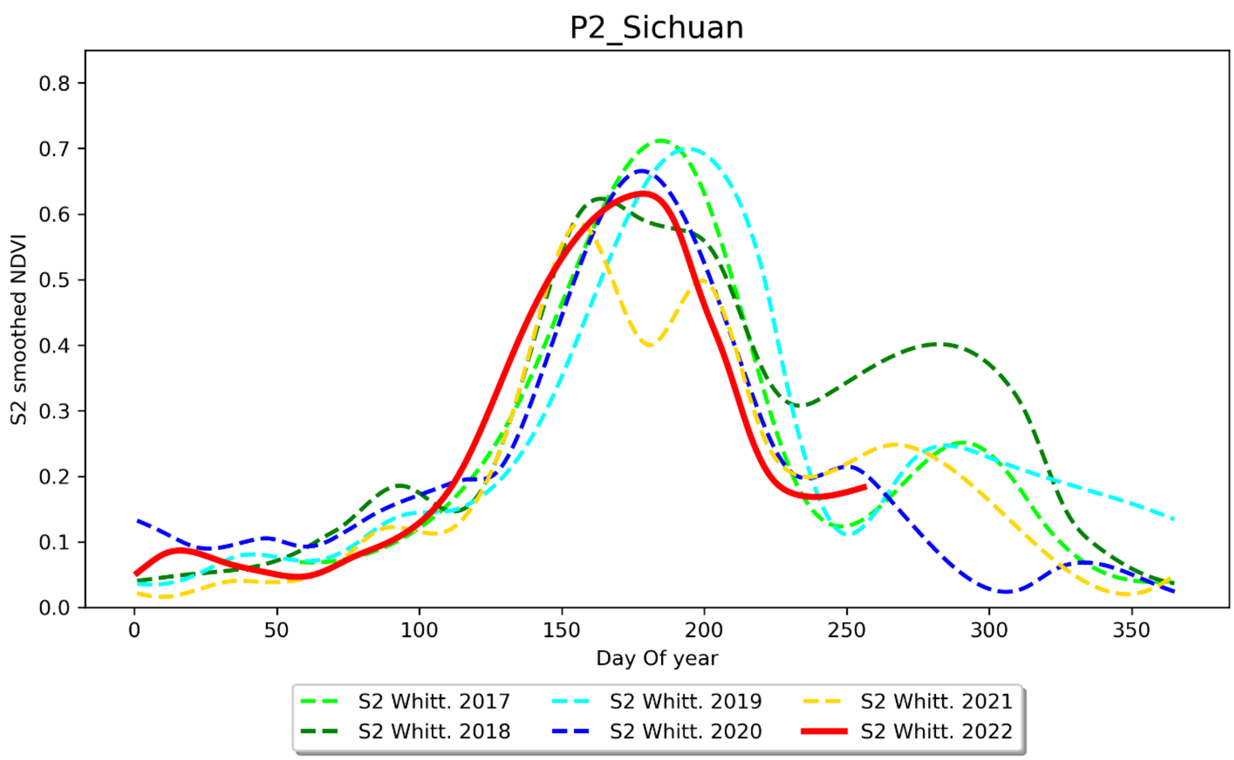
Figure 10: *MODIS NDVI temporal profiles for cropland in Sichuan (central part of the basin – upper panel) and Anhui (eastern part of the basin – lower panel) provinces for years 2001 to 2022. In recent years, crop cycle has been earlier than average in the centre of the Yangtze basin.*

Sentinel 2 NDVI temporal profiles extracted over a sample of points allow observing single crop fields for the last 6 years (2017 to 2022). These NDVI profiles do not show large biomass differences between 2022 and the 5 previous seasons, except for some fields (see P1 and P3 in Sichuan) in the centre of the Yangtze basin where crop cycle appears to be shortened due to a fast senescence and therefore reduced grain filling phase (Fig. 11).




P1_Sichuan
S2 smoothed NDVI
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
50
100
150
200
250
300
350
Day Of year
S2 Whitt. 2017
S2 Whitt. 2018
S2 Whitt. 2019
S2 Whitt. 2020
S2 Whitt. 2021
S2 Whitt. 2022


SETTINGS
Region
CN - Sichuan Sheng
Satellite
Sentinel 2
MAP
STATS
Layer
NIR/SWIR/R
Target period
01 Aug 2022
31 Aug 2022
Comparison period
01 Aug 2021
31 Aug 2021
Cloud filtering
Max 40%
Get map layers
SENTINEL 2
NIR/SWIR/R
Target period
Comparison period
Swipe target/comparison
Land cover
Select a layer
Background
BING Aerial
500 m
SENTINEL 2
50 m


P2_Sichuan
S2 smoothed NDVI
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
50
100
150
200
250
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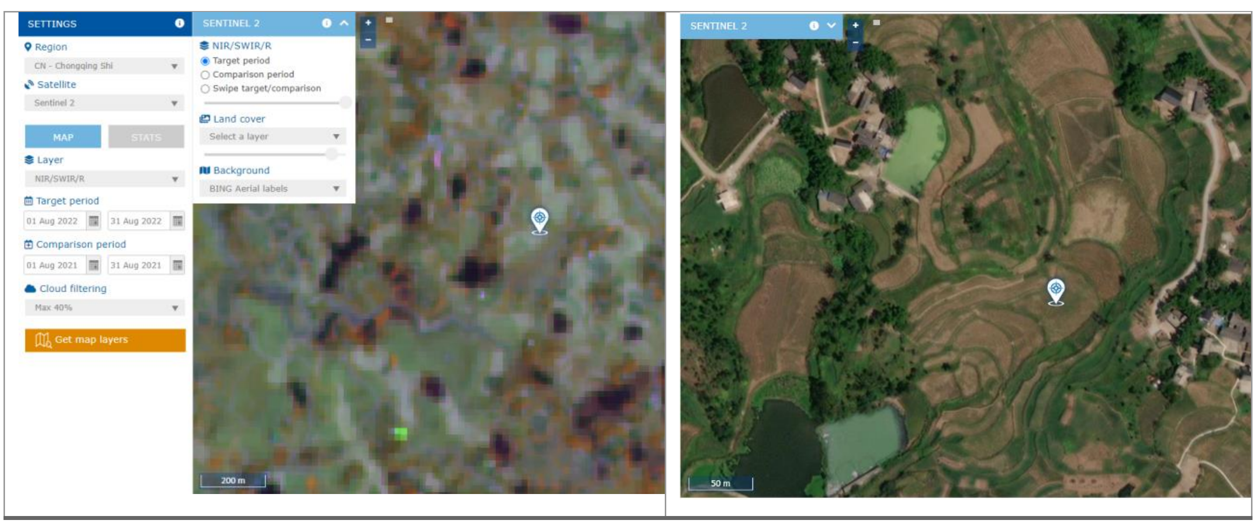
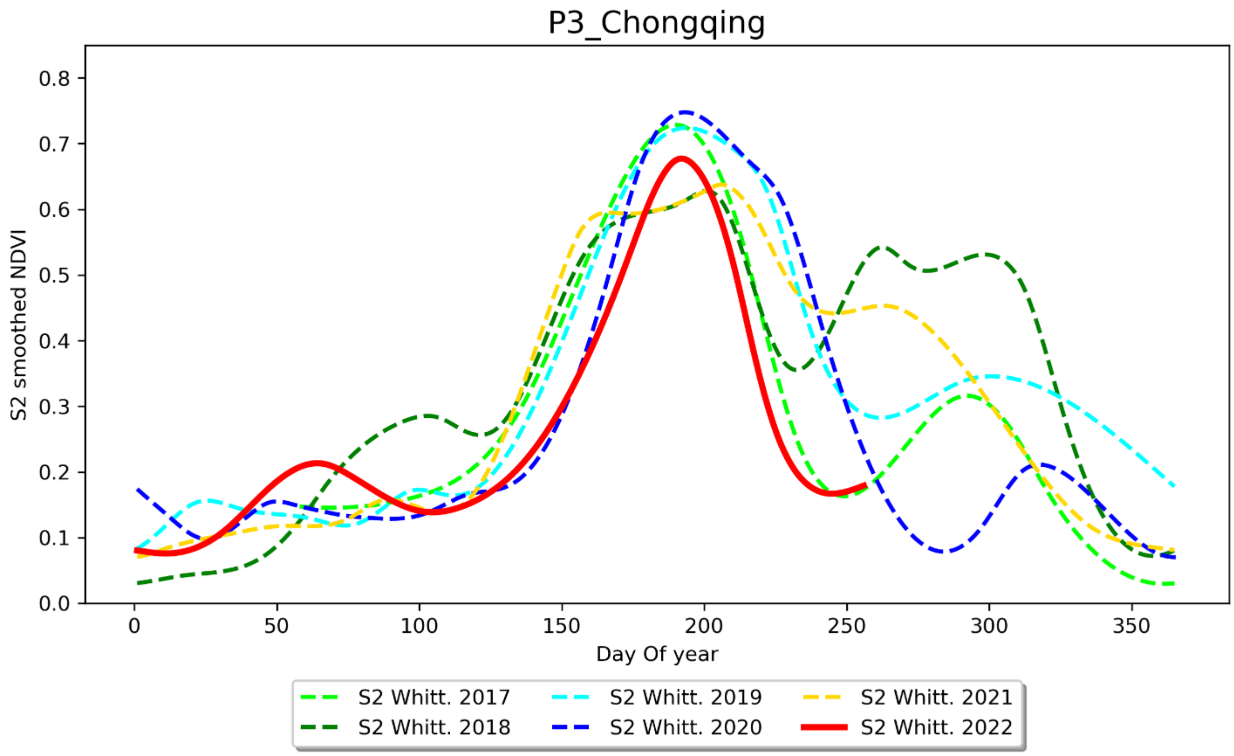
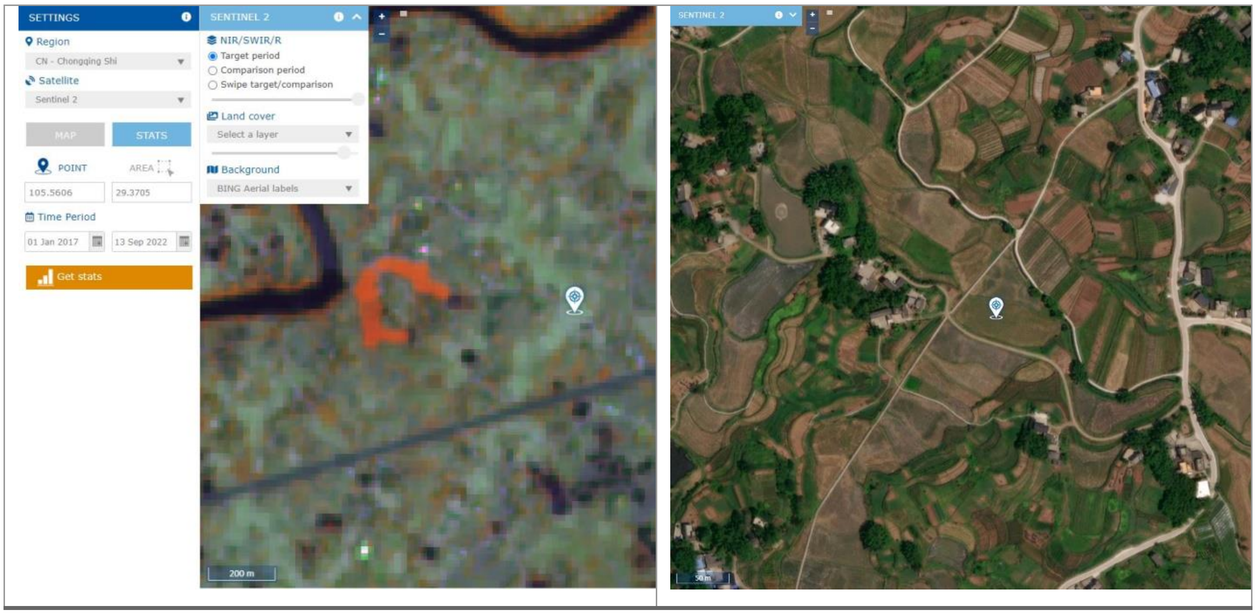
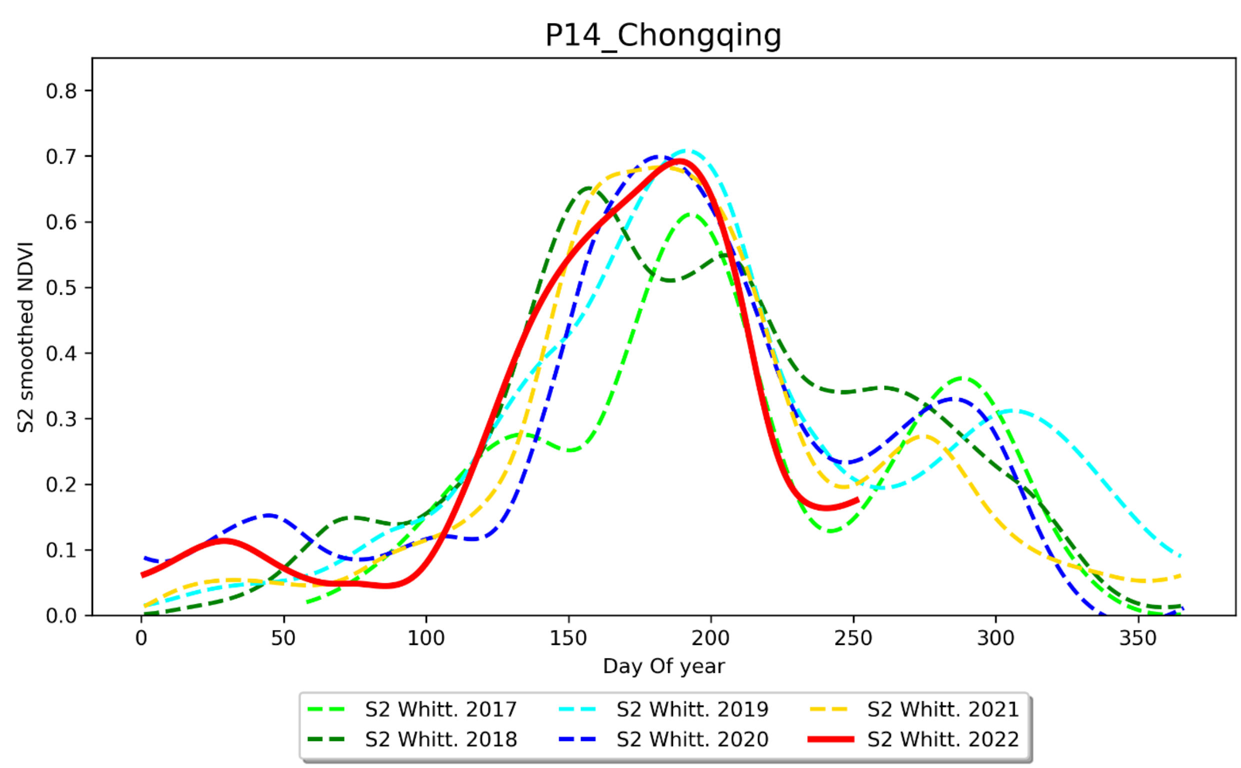
Day Of year
S2 Whitt. 2017
S2 Whitt. 2018
S2 Whitt. 2019
S2 Whitt. 2020
S2 Whitt. 2021
S2 Whitt. 2022


SETTINGS
Region
CN - Chongqing Shi
Satellite
Sentinel 2
MAP
STATS
Layer
NIR/SWIR/R
Target period
01 Aug 2022
31 Aug 2022
Comparison period
01 Aug 2021
31 Aug 2021
Cloud filtering
Max 40%
Get map layers
SENTINEL 2
NIR/SWIR/R
Target period
Comparison period
Swipe target/comparison
Land cover
Select a layer
Background
BING Aerial labels
200 m
SENTINEL 2
50 m


P3_Chongqing
S2 smoothed NDVI
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
50
100
150
200
250
300
350
Day Of year
S2 Whitt. 2017
S2 Whitt. 2018
S2 Whitt. 2019
S2 Whitt. 2020
S2 Whitt. 2021
S2 Whitt. 2022


SETTINGS
Region
CN - Chongqing Shi
Satellite
Sentinel 2
MAP
STATS
POINT
AREA
105.5606
29.3705
Time Period
01 Jan 2017
13 Sep 2022
Get stats
SENTINEL 2
NIR/SWIR/R
Target period
Comparison period
Swipe target/comparison
Land cover
Select a layer
Background
BING Aerial labels
200 m
SENTINEL 2


P14_Chongqing
S2 smoothed NDVI
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
50
100
150
200
250
300
350
Day Of year
S2 Whitt. 2017
S2 Whitt. 2018
S2 Whitt. 2019
S2 Whitt. 2020
S2 Whitt. 2021
S2 Whitt. 2022

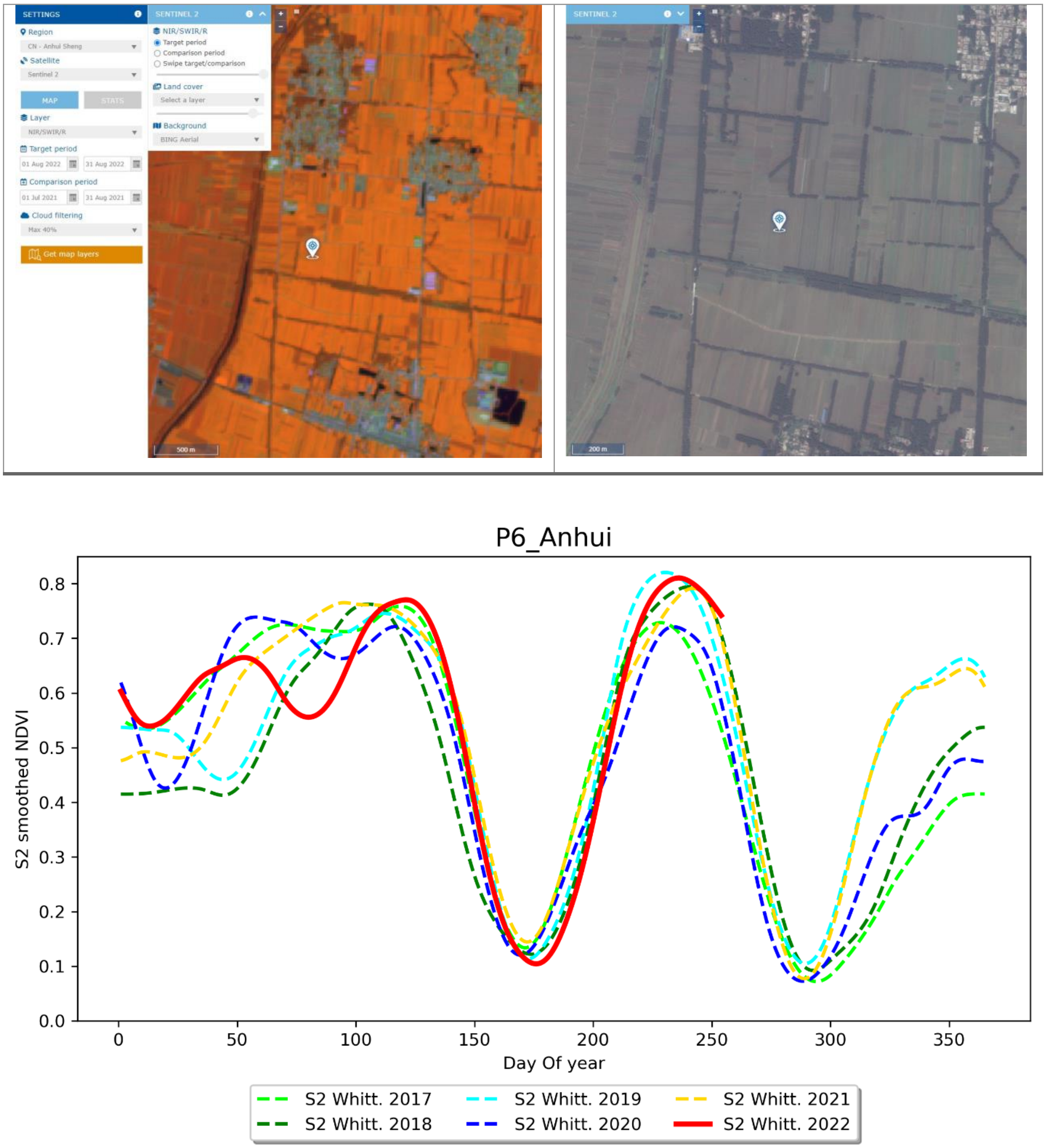


Figure 11: Sentinel 2 (S2) NDVI profiles smoothed with Whittaker filter for 2017 – 2022 on a sample of single crop fields (actually 3x3 10 m pixels windows) selected on Bing imagery. The field location on S2 most recent (cloud free) image as well as on Bing imagery is reported above the S2 NDVI profile. P1, P2, P3: summer crop NDVI profiles in Sichuan, P14 in Chongqing and P6 in Anhui (where double cropping is practised, i.e. a summer crop after a winter crop). Sources: Sichuan province, Dafangzi: https://mars.jrc.ec.europa.eu/asap/s/9482ce3e (P1); Sichuan province,

Huadong village, https://mars.jrc.ec.europa.eu/asap/s/3e5df5d9 *(P2) ; Chongqing, Yunlongsi :* https://mars.jrc.ec.europa.eu/asap/s/9b68fea3 *(P3); Anhui, Yaozhuang: https://mars.jrc.ec.europa.eu/asap/s/f6871d90 (P6); Chongqing, Tuduizi : https://mars.jrc.ec.europa.eu/asap/s/46fa1ea3 (14).*

River Flow

The analysis of the Copernicus Global Land Service River and Lake Water Level data[3] shows that water levels in August were below or far below the average for most measuring points in the eastern China river network compared to the previous 10 years. The same conditions appear also for the few available data in south-western and south-eastern China. Especially the Yangtze River basin appears to be severely affected (Fig. 12).

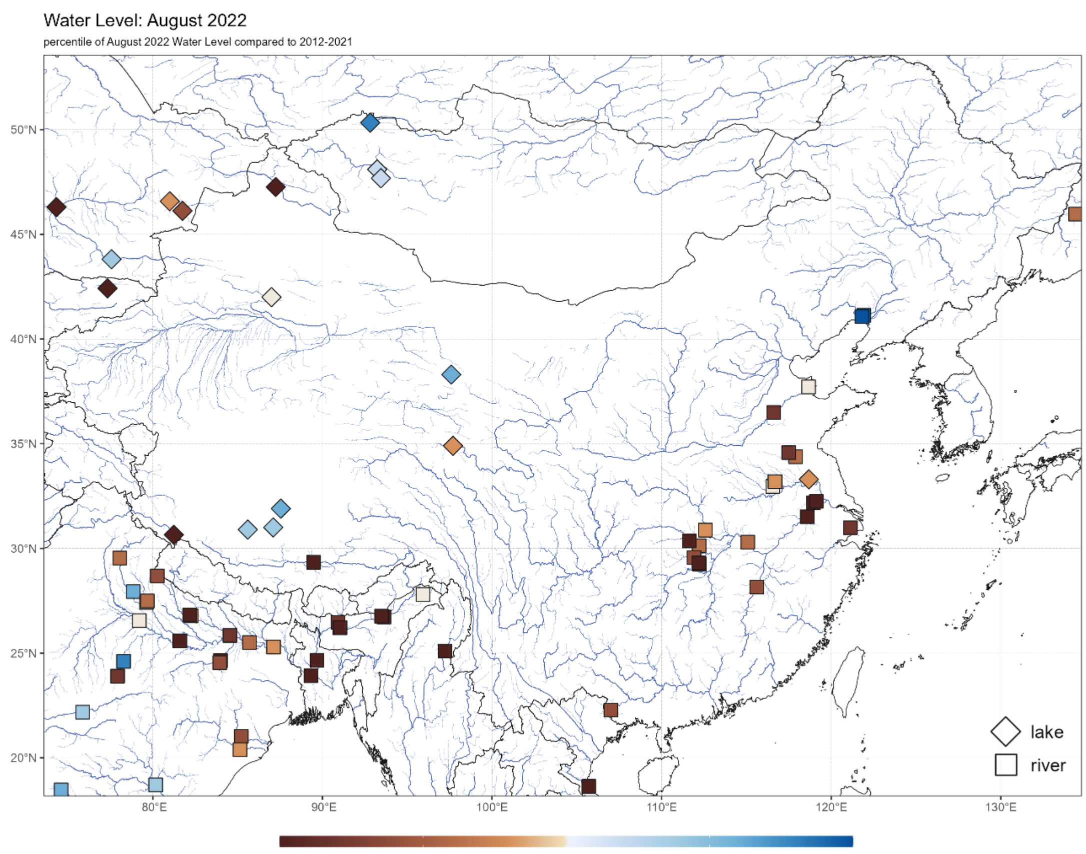


Figure 12: *River and Lake Water Level percentiles for August 2022 compared to the averages in the period 2012-2021. Data source: Copernicus Global Land Service.*

[3] https://land.copernicus.eu/global/products/wl

Comparing this year water level data time series with the percentiles computed over the last 10 years from the measurement points in the Yangtze and Yellow River closest to the mouth of the river, July and August appear unprecedented for the Yangtze river, while August water levels are not exceptional but still substantially lower than normal (in the 10-25% range) for the Yellow river. The Yellow river water level was very high in June but then it has decreased rapidly. (Fig. 13).

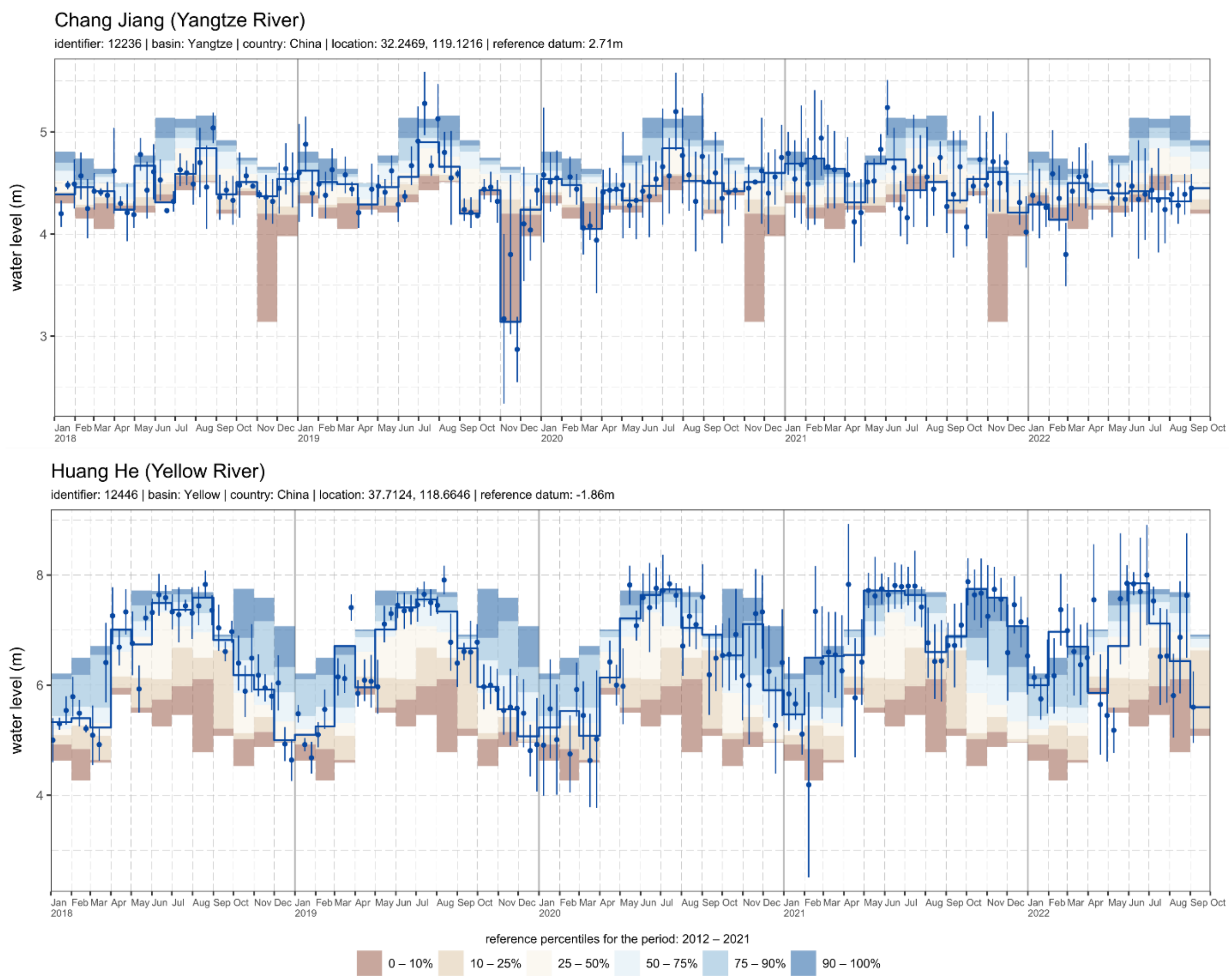


Figure 13: *River Water Level time series for Yangtze River (upper panel) and Yellow River (lower panel). Average values for the current month (horizontal blue line) and individual observations with their uncertainties (blue dots and vertical lines). References percentile for the period 2012-2021. Data source: Copernicus Global Land Service.*

As a consequence of lower water levels, some lakes reduced their extent with respect to the same period in 2021. A couple of samples are shown in Figures 14 and 15. The reduction could also depend on reservoir management for energy production and irrigation and a prudential approach should be considered for the proper interpretation of the satellite data when it is not possible to couple data with these information.

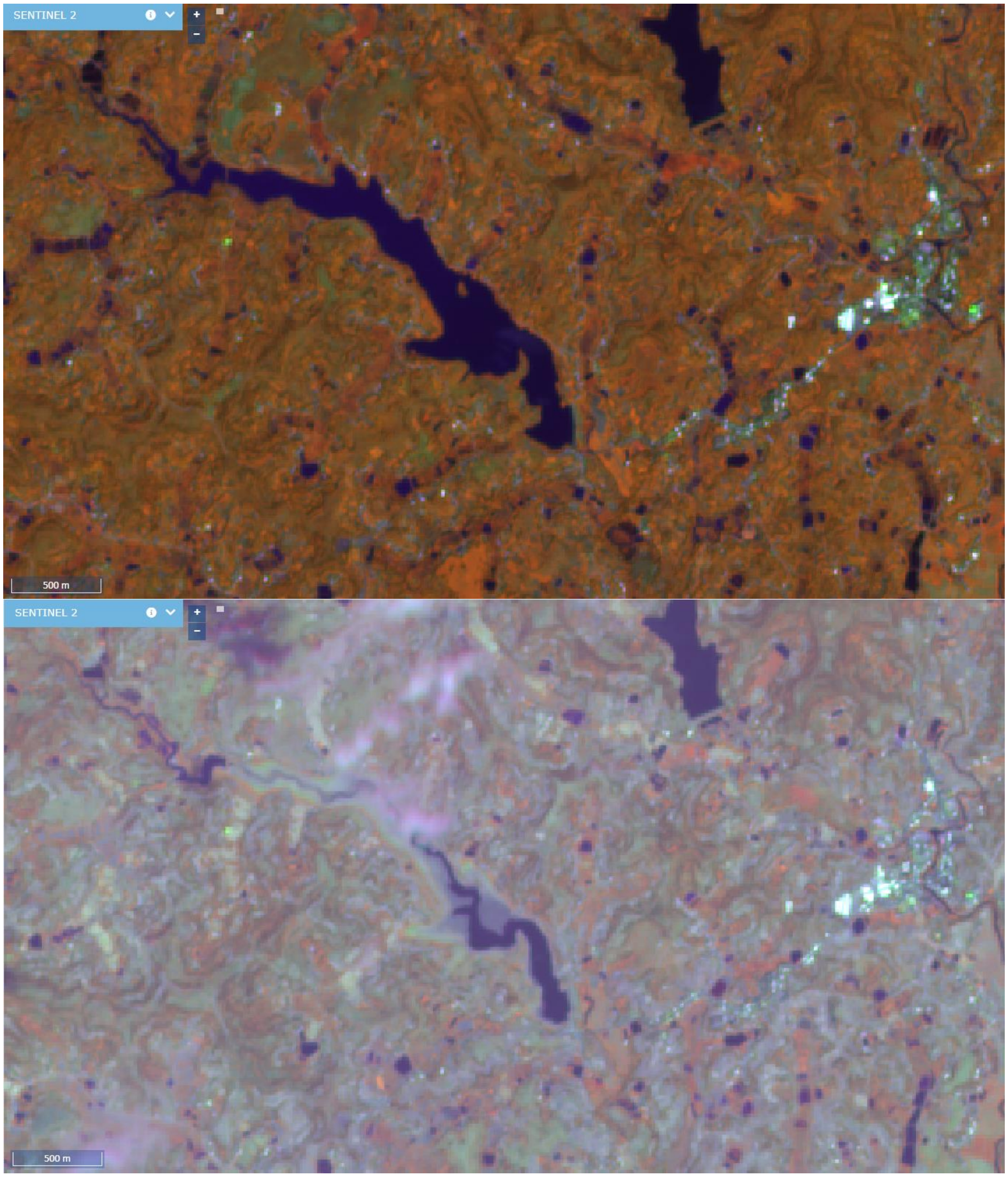


Figure 14: *Xinchang reservoir, Sichuan province, on Sentinel 2 data at end August 2021 (upper panel) and end August 2022 (lower panel). Link:* https://mars.jrc.ec.europa.eu/asap/s/5878b419.

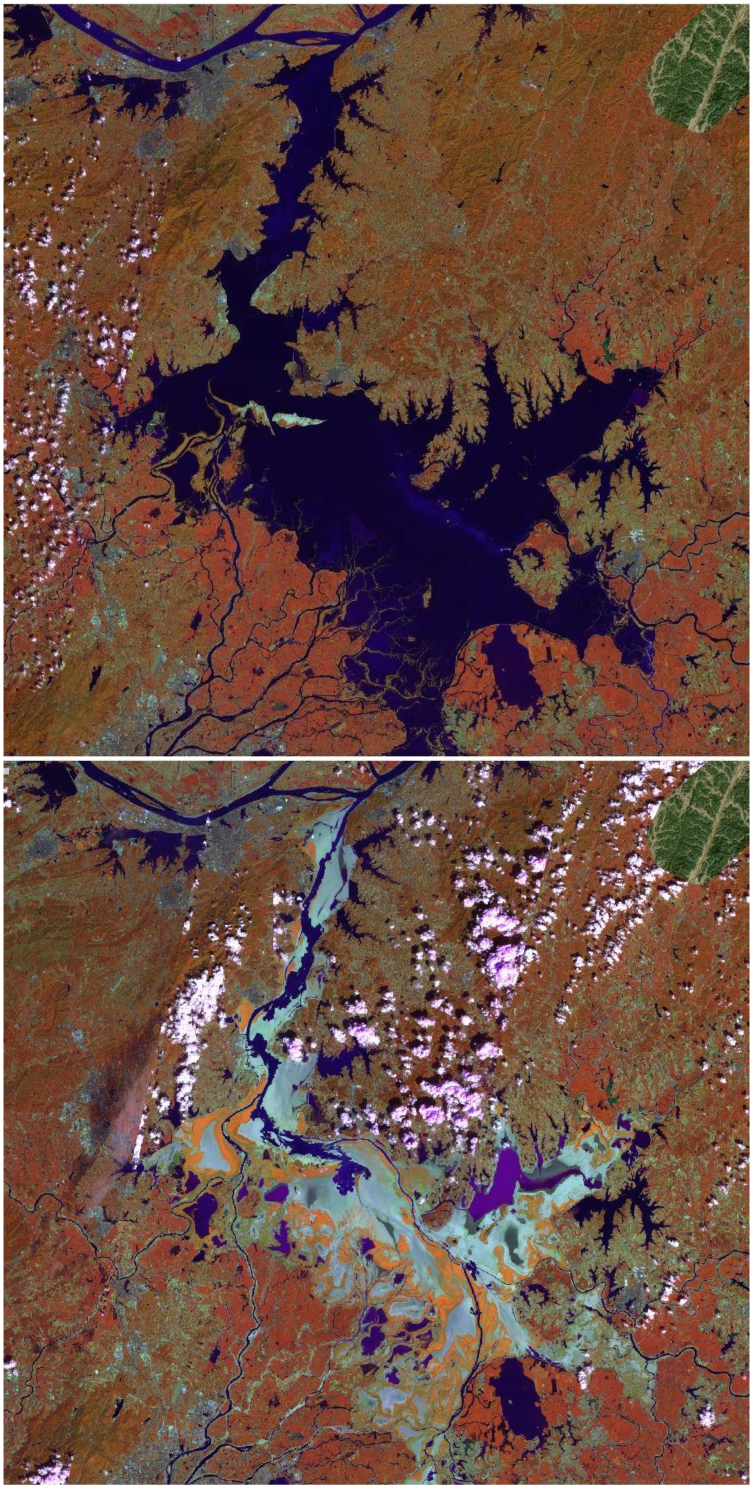


Figure 15: *Lake Poyang in Jiangxi province on Sentinel 2 data in September 2021 (upper panel) and September 2022 (lower panel). Link:* https://mars.jrc.ec.europa.eu/asap/s/688522a2.

Large-scale atmospheric conditions

The monsoon system known as the East Asian summer monsoon is the main responsible for most of the summer rainfall in most of East Asia. A system that gradually penetrates deeper into mainland China advecting moisture from the South China Sea and Indochina[4]. The Japan Meteorological Agency has reported East Asian Monsoon Index (SAMOI-N) values of -0.9, 0.8, -1.2 and –0.8 for the months of May, June, July and August 2022, respectively.[5] The negative values in May, July and August are not extreme, but indicate a lower-than-average monsoon activity. Figure 16 (top) displays the mean summer (June-August) vertical air velocity anomalies as a measure of convective activity in the mid-lower troposphere. Overall, there is a decrease in convection when compared to the typical conditions indicative of a less extended or weaker monsoon in south-eastern China (middle and low Yangtze River basin). There is a good agreement between negative SPI3 (Fig. 2), negative soil moisture anomalies (Fig. 3) and lower-than-average convective activity (Fig. 16, top) over the Yangtze River basin.

Large scale middle troposphere conditions also display anomalous anticyclonic circulation over central and eastern China during the summer months (Fig. 16, bottom). This persistent and widespread atmospheric feature is most likely responsible for the long-lasting heatwave in the region and the overall lower-than-average precipitation supporting the development of this drought.

[4] Yihui, D., & Chan, J. C. (2005). The East Asian summer monsoon: an overview. *Meteorology and Atmospheric Physics*, *89*(1), 117-142.

[5] https://ds.data.jma.go.jp/tcc/tcc/products/clisys/emi/samoi-n.txt

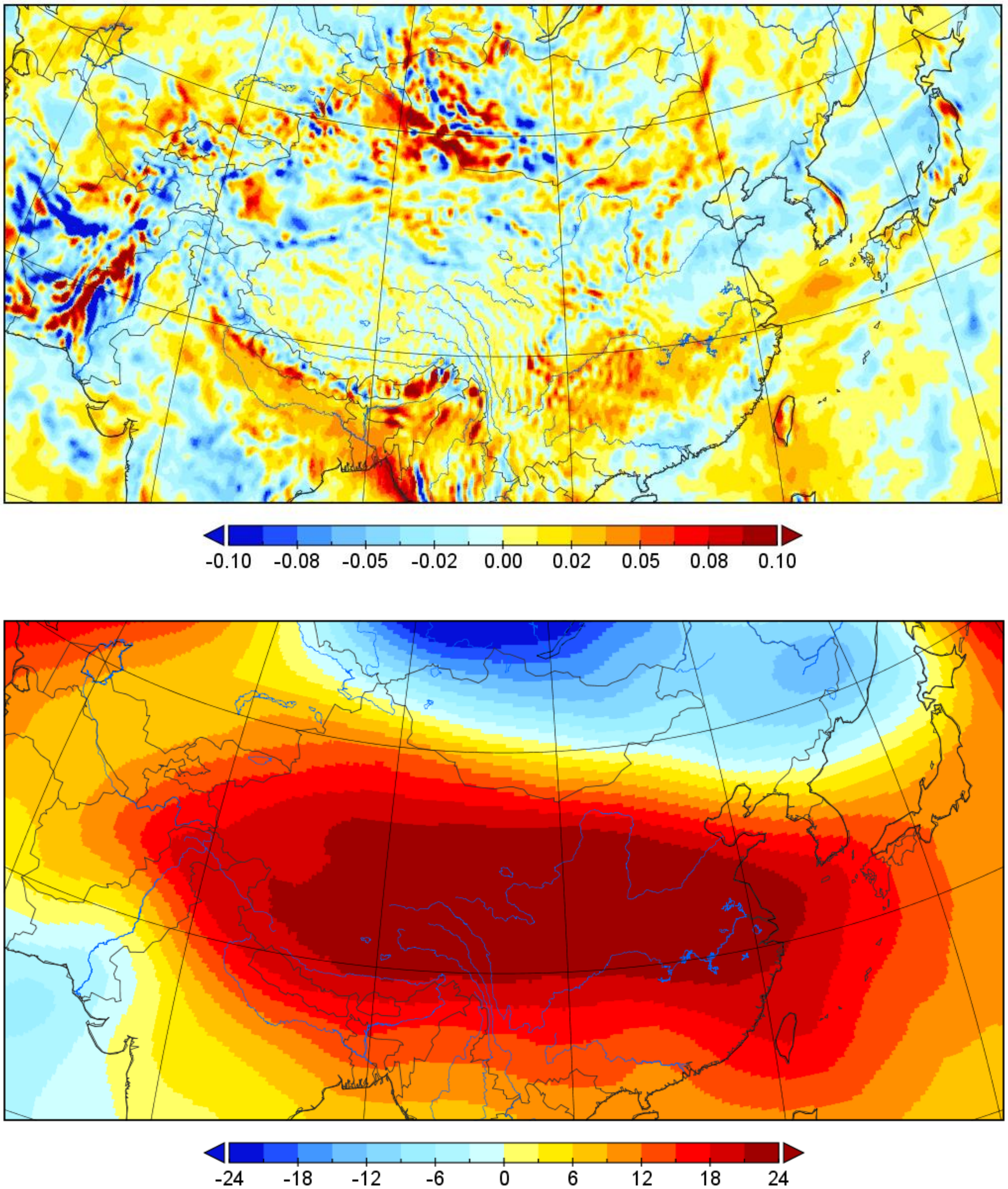


Figure 16: Top: June-August 2022 vertical air velocity anomaly at 700 hPa (Pa/s), as an indicator of convective activity (positive values indicate less convective activity). Bottom: June-August 2022 geopotential height anomaly at 500 hPa (gpm). Data from ERA5 reanalysis. Reference climatological period 1991-2020.

Seasonal forecast

For most of Yangtze River lower basin (eastern regions), unusually dry conditions are predicted from September to November 2022 (Fig. 17). This forecast suggests that the drought will continue and, if conditions evolve as forecasted, the dry conditions could exacerbate the already severe impacts, as the coming months correspond to the last part of the wet season (which already shows below average values in late July and August).

Seasonal forecasts of mean temperature and precipitation up to November 2022 from the ECMWF SEAS5 and other modelling centres[6] point to likely warmer- and drier-than usual conditions in most of China and particularly over the Yangtze River basin.

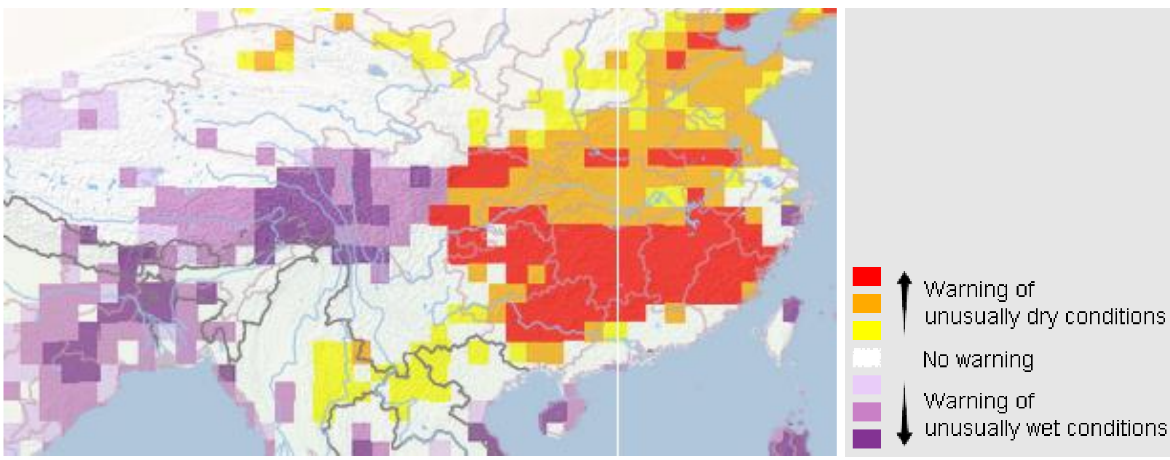


Figure 17: *Indicator for forecasting unusually wet and dry conditions from September to November 2022 (based on ECMWF SEAS5).*

ECMWF SEAS5 long-range meteorological data are used by the Global Flood Awareness System (GloFAS) to produce seasonal forecasts of river flow. GloFAS seasonal forecast for the coming 4 months (August-November 2022) predicts higher than average probability of low flows over the whole Yangtze River basin. In the lower basin (eastern part) the probability of low flow exceeds 75% (Fig. 18). This forecast is based on LISFLOOD-OS hydrological model[7] and GloFAS

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[6] https://climate.copernicus.eu/seasonal-forecasts

[7] De Roo, A., C. Wesseling, and W. van Deursen. 2000. Physically based river basin modelling within a GIS: the LISFLOOD model, Hydrological Processes, 14, 1981–1992. Doi: 10.1002/1099-1085(20000815/30)14:11/12<1981::AID-HYP49>3.0.CO;2-F; [ec-jrc/lisflood-code: Lisflood OS - LISFLOOD (github.com)]

operational version v3.2[8]. The model calibration made use of historical observations of discharge from 1226 gauge stations[9]. However, in the Yangtze River basin, the only gauge station available for calibration was in the western upstream area and covered 7.5% of the total basin area. Therefore, care must be taken when using GloFAS v3.2 forecasts for the Yangtze River basin.

Figure 18: *Maximum probability [%] of high (> 80th percentile) or low (< 20th percentile) river flow during the 4 month forecast horizon for basins overview and for river network. Source: Global Flood Awareness System (GLOFAS) https://www.globalfloods.eu.*

Reported impacts

The China Meteorological Administration activated level four emergency responses at the end of August to address the meteorological drought conditions, requiring that the meteorological departments provide timely and precise forecast for impact assessment.[10]

According to Beijing Climate Centre, the spatial coverage of extreme temperature and the duration of the heatwave has been the most severe observed in the data since 1961 (beginning of data records).[11]

[8] https://confluence.ecmwf.int/display/COPSRV/GloFAS+versioning+system

[9] Alfieri, L., Lorini, V., Hirpa, F. A., Harrigan, S., Zsoter, E., Prudhomme, C., and Salamon, P.: A global streamflow reanalysis for 1980–2018, J. Hydrol., 6, 100049, https://doi.org/10.1016/j.hydroa.2019.100049, 2020.

[10] http://www.cma.gov.cn/en2014/news/News/202208/t20220823_5049070.html

[11] http://www.cma.gov.cn/en2014/news/News/202208/t20220821_5045788.html

It has been reported [12] [13] [14] [15] [16] [17] that the Yangtze River flow has been reduced by more than 50% and has been affecting hydropower generation at several stations, including at the Three Gorges Dam, the biggest one in the world. The region depends on hydropower for more than 75% of its electricity generation. Some emergency measures have been imposed to save energy: power supply has been suspended or reduced for many factories, and public electricity usage has been rationed. The hydropower low production in Sichuan – where it contributes 80% of power supply – would probably lead to a fossil fuel-driven response in the short term, as efforts will be required for moving towards other renewable sources. Also, some shipping routes have been partially closed.

The same sources reported also that drinking water supply required truck distribution in some neighbourhoods where tap water dried up completely. Forest fires have broken out in the Sichuan province, with the Chongqing municipality being particularly badly affected. Other provinces along the Yangtze River basin are also on high alert for grassland and forest fires. Lakes fed by Yangtze River shrunk, limiting crop irrigation and locally affecting drinking water supply. The heat wave and drought are also indirectly starting to drive food prices higher in China, especially for fruit and vegetables. Due to the unreliable global supply chain China is now relying more heavily on its own corn production, 4% of which was grown in drought affected Sichuan and Anhui.

While water and heat stress can strongly affect crop production, the impact of the current drought appears so far to be limited probably thanks to its timing at the end of summer crops cycle in July-August (depending on the region) and possibly to some irrigation capacity. The evolution should be monitored to get more information and details.

[12] https://www.bbc.com/news/world-asia-china-62644870

[13] https://www.theguardian.com/world/2022/aug/30/its-getting-extremely-hard-climate-crisis-forces-china-to-ration-electricity

[14] https://www.theguardian.com/world/2022/aug/22/china-drought-causes-yangtze-river-to-dry-up-sparking-shortage-of-hydropower

[15] https://www.bloomberg.com/news/articles/2022-08-23/worst-drought-in-decades-threatens-china-s-economic-recovery

[16] https://www.nytimes.com/2022/08/26/business/economy/china-drought-economy-climate.html

[17] https://www.theguardian.com/world/2022/aug/24/china-issues-alert-drought-heatwave-put-crops-at-risk

Appendix

The Standardized Precipitation Index (SPI) provides information on the intensity and duration of the precipitation deficit (or surplus). SPI is used to monitor the occurrence of drought. The lower (i.e., more negative) the SPI, the more intense is the drought. SPI can be computed for different accumulation periods: the 3-month period is often used to evaluate agricultural drought and the 12-month period for hydrological drought, when rivers fall dry and groundwater tables lower.

The Heat and Cold Wave Index (HCWI) is used to detect and monitor periods of extreme-temperature anomalies (i.e. heat and cold waves) that can have strong impacts on human activities, health and ecosystem services such as sprouting of crops. The HCWI indicator is computed for each location (grid-cell). It is based on the persistence for at least three consecutive days of events with both daily minimum and maximum temperatures (T_{min} and T_{max}) above the 90th percentile daily threshold (for heat waves) or below the 10th percentile daily threshold (for cold waves). For each location, the daily threshold values for T_{min} and T_{max} are derived from a 30-year climatological baseline period (1991-2020), using the GloFAS/ERA5 derived temperature data.

Lack of precipitation induces a reduction of soil water content. The Soil Moisture Anomaly index provides an assessment of the deviations from normal conditions of root zone water content. It is a direct measure of drought associated with the difficulty of plants in extracting water from the soil.

The satellite-based fraction of Absorbed Photosynthetically Active Radiation (FAPAR) monitors the fraction of solar energy absorbed by leaves. It is a measure of vegetation health and growth. FAPAR anomalies, and specifically negative deviations from the long-term average, are associated with negative impacts on vegetation.

The Low-Flow Index (LFI) is based on the daily river water discharge simulated by the LISFLOOD hydrological model. It captures consecutive periods of unusually low streamflow. It compares the consequent water deficit during those periods with the historical climatological conditions.

The indicator for 'forecasting unusually wet and dry conditions' provides early risk information for Europe. The indicator is computed from forecasted SPI-1, SPI-3, and SPI-6 derived from the ECMWF seasonal forecast system SEAS5.

Glossary of terms and acronyms:

CEMS	Copernicus Emergency Management Service
EDO	European Drought Observatory
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
EFFIS	European Forest Fire Information System
ENTSO-E	European Network of Transmission System Operators for Electricity
ERA5	ECMWF Reanalysis v5
ERCC	European Emergency Response Coordination Centre
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
GDO	Global Drought Observatory
GLOFAS	Global Flood Awareness System
JRC	Joint Research Centre
LFI	Low-Flow Index
MARS	Monitoring Agricultural ResourceS
SMA	Soil Moisture Index (SMI) Anomaly
SMI	Soil Moisture Index
SPI	Standardized Precipitation Index
WMO	World Meteorological Organization

EDO indicators versioning:

The GDO/EDO indicators appear in this report with the following versions:

EDO FAPAR (fraction of Absorbed Photosynthetically Active Radiation) Anomaly, v.1.3.2
GDO Indicator for forecasting unusually wet and dry conditions, v .1.0.0
GDO Heat and Cold Wave Index, v. 1.0.0
GDO Ensemble Soil Moisture Anomaly (SMA), v. 2.3.0
Standardized Precipitation Index SPI ERA5 (1/4-dd resolution)

Check https://edo.jrc.ec.europa.eu/download for more details on indicator versions.

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JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) - 26/09/2022

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