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27 March 2023
Submitted by upload to:
https://infrastructure.planninginspectorate.gov.uk/projects/eastern/sunnica-energy-farm/?ipcsection=submission

Dear Sir

Ref: EN010106 Application by Sunnica Ltd for an Order Granting Development Consent for the Sunnica Energy Farm.

The Cambridgeshire and Peterborough Branch of the Campaign to Protect Rural England (CPRE) is an apolitical, independent charity which works to maintain the thriving and beautiful countryside of Cambridgeshire and Peterborough, to encourage strong rural communities and to prevent urban sprawl into and other damage to the countryside.

In our submission of 3rd March 2022, we re-summarised our objections to the above application as follows:

- Inconsistency with National Planning Policy
- Inconsistency with Local Planning Policy
- Threat to national food supply due to use of productive agricultural land at a time of increasing risk to food imports and flood risk to the Fens
- Threat to public and defence safety and the environment from battery storage accidents
- Potential impact on local public transport and highways improvements
- Damage to the historic and unspoiled landscape environs of Newmarket
- Poor information regarding any visual mitigation measures
- Damage to local communities particularly the farming community
- No consideration of alternatives such as brownfield sites or installation on large commercial buildings & warehouses
- Lack of sustainability due to no current means of end-of-life recycling of materials

CPRE continues to object strongly to this proposal and our purpose in writing today is to update, amplify, clarify and provide additional information relating to the issues previously raised. Please see our additional comments below.

Food Security
In our submission of 3rd March 2022, we provided detailed information relating to the issue of UK Food Security which is increasingly threatened and will be increasingly threatened by the effects of climate change.

These effects include, summer drought (East Anglia remains officially in drought due to the hot weather in summer 2022), threats to the Fens and other Grade 1 agricultural areas due to glacial melt causing sea level rise and increased flood risk arising from more intense rainfall events.

The UK imports a high proportion of its fresh food, vegetables and salad crops from Europe, much from Spain, Portugal and the Netherlands.

More recently, we have become aware of a study which has been using satellite data to assess the effect of climate change on groundwater levels across Europe. The results are quite alarming and, if the trends identified continue, this will increase the threat to UK food supply because the countries that supply our imports will no longer be able to maintain supply.

We are therefore submitting the documentation that we have found as further evidence of the national imperative to retain UK farm land in production.

Public Rights of Way and Safety
We have previously expressed our concerns with respect to the safety issues arising from the proposed use of large installations of lithium-ion battery storage.

We have expressed the view that the Health and Safety Executive, HSE should be taking this issue far more seriously and that these large installations pose a major fire and explosion hazard and should be at least registered as Control of Major Accident Hazard, COMAH, sites.

As an example of how dangerous these batteries are, albeit on a smaller scale, the British Metals Recycling Association is now urging the government to lead a new campaign as figures show that the number of fires caused by exploding lithium-ion batteries in e-scooters and e-bikes soared by almost 150% in 2021. Please see enclosed article.

It is our view that, just as increasing numbers of small LI-ion battery in use are resulting in increased fire occurrence, so the risk and occurrence of fires in large installations will increase as their numbers rise and the potential for accident or mis-management increases.

Conclusions
Our conclusions remain unchanged as follows.

1. This proposal is not compliant with national planning policy.
2. This proposal is not compliant with local planning policy.
3. This proposal will take out of production a large area of good agricultural land currently used for growing valuable food crops.
4. This proposal is inconsistent with required responses to the national and international issue of dwindling food supply due to climate change and conflict.
5. This proposal is in direct opposition to the advice of the Environmental Audit Committee and DEFRA concerning national food security.
6. This proposal takes no account of the increasing risk of flooding of the Fens due to sea level rise and the associated loss of agricultural production of around 24% of UK food crops.
7. There will be significant harm to local agricultural businesses, especially those which may be made the subject of compulsory purchase.
8. There will be significant adverse impact on residential and visual amenity.
9. This proposal will have a further cumulative effect on specific local roads which are already overloaded.
10. It will put at risk the Combined Authority's ability to reopen a rail service between Cambridge and Mildenhall.
11. There will be unacceptable levels of harm to local landscapes and to views across the countryside from the hills around Newmarket as well as significant harm to the historic landscape pattern.
12. The mitigation proposed is minimal and inadequate. It will not reduce the negative impacts on the most sensitive receptors.
13. There will be increased risks to the safety of walkers and riders using the existing Public Rights of Way.

14. The scale of installation and the known fire and explosion hazard arising from the proposed use of lithium-ion batteries in several locations indicates that the HSE should be involved at an early stage in assessing the consequent risks to the population and the countryside.
15. CPRE is advised that there could be a significant risk to installations and operations at RAF Mildenhall should a major battery fire or explosion occur.
16. There is no detailed, resilient plan for the safe decommissioning of the site and the recycling or re-use of the materials removed.
17. A decommissioning fund must be available, sufficient and placed in escrow in advance of any construction commencing.
18. A full carbon lifecycle analysis has not been carried out for this installation, without which it cannot be claimed to be sustainable.

CPRE Cambridgeshire and Peterborough would urge the Planning Inspectorate not to approve this application.

Please note that our submission is in respect of the proposed development. While we have taken every effort to present accurate information for your consideration, as we are not a decision maker or statutory consultee, we cannot accept any responsibility for unintentional errors or omissions and you should satisfy yourselves on any facts before making decisions arising from our submission.

Yours faithfully,

Alan James BScTech., PhD, MBCS, CITP, MIMMM, CEnv
Chairman - CPRE Cambridgeshire and Peterborough

cc:
Rt Hon. Matt Hancock MP
Rt Hon. Lucy Fraser MP

Enc.

Article	"Very precarious': Europe faces growing water crisis as winter drought worsens"	March 2023	Guardian
Article	"Satellite Data Shows Sustained Severe Drought in Europe"	Jan 2023	Graz University of Technology
Publication	"Quantifying the Central European Droughts in 2018 and 2019 With GRACE Follow-on"	Sept 2020	Geophysical Research Letters
Article	"Government action urged as new figures show surge in lithium-ion battery fires"	March 2023	IFSEC Global

Europe

‘Very precarious’: Europe faces growing water crisis as winter drought worsens

Multiple governments warn of critical water shortages as heatwaves and lack of rain leave river systems depleted

Jon Henley *in Paris,* **Sam Jones** *in Madrid,* **Angela Giuffrida** *in Rome, and* **Philip Oltermann** *in Berlin*

Sat 4 Mar 2023 06.00 GMT

The scenes are rare enough in mid-summer; in early March, they are unprecedented. Lac de Montbel in south-west France is more than 80% empty, the boats of the local sailing club stranded on its desiccated brown banks.

In northern Italy, tourists can walk to the small island of San Biagio, normally reached only by boat, from the shore of Lake Garda, where the water level is 70cm (27in) lower than average. The Alps have had 63% less snow than usual.

In Germany, shallow waters on the Rhine are already disrupting barge traffic, forcing boats heading up into central Europe to load at half capacity, and in Catalonia, now short of water for three years, Barcelona has stopped watering its parks.

After its driest summer in 500 years, much of Europe is in the grip of a winter drought driven by climate breakdown that is prompting growing concern among governments over the water security for homes, farmers and factories across the continent.

A study published in January by Graz University of Technology in Austria, whose scientists used satellite data to analyse groundwater reserves, concluded that Europe has been in drought since 2018 and its water situation was now "very precarious".

Torsten Mayer-Gürr, one of the researchers, said: "I would never have imagined that water would be a problem here in Europe, especially in Germany or Austria. We are actually getting problems with the water supply here. We have to think about this."

The World Weather Attribution service said last year northern hemisphere drought was at least 20 times more likely because of human-caused climate change, warning that such extreme periods would become increasingly common with global heating.

Andrea Toreti, a senior scientist at the European Drought Observatory, said: "What is unusual is the recurrence of these events, because we already experienced a severe to extreme drought a year ago, and another one in 2018.

"Clearly, in some parts of Europe, the lack of precipitation and the current deficit is such that it won't be easy for water levels to recover before the start of the summer," Toreti told Euronews. Experts have said the coming months will be crucial.

A map of current droughts in Europe from the EU's Copernicus programme shows alerts for low rainfall or soil moisture in areas of northern and southern Spain, northern Italy and southern Germany, with almost all of France affected.

France recently recorded 32 days without significant rainfall, the longest period since records began in 1959, and the state forecaster Météo-France has said little or no precipitation of note is expected until at least the end of the month.

Simon Mitelberger, a climatologist, said about 75% less rain had fallen across France last month than usual for February, continuing a year-long trend. Nine of the past 12 months had seen rainfall up to 85% below the norm, he told France Info news.

France's CNRS scientific research centre said that by comparing droughts before 1945 and since 1945 it had established that last summer's drought was caused by anthropogenic climate change and this winter's showed "the same characteristics".

Local authorities in all seven of the country's major river basins have been ordered to start enforcing water restrictions as the government works on a crisis plan to tackle a shortage that it has said will inevitable lead to "water scarcity problems" this year.

The minister for ecological transition, Christophe Béchu, warned that France would have to cope with up to 40% less water in coming years, adding that the country was already on a "state of alert" and restrictions in some areas were fully justified.

"The situation is more serious than this time last year," Béchu said. People in four southern *départements* have been barred from filling swimming pools or washing their cars, while farmers must cut their water consumption by up to half.

Echoing the terms he used to describe the energy crisis sparked by Russia's invasion of Ukraine, the French president, Emmanuel Macron, called this week for a "sobriety plan" to save water and warned the "time of abundance" had come to an end.

"All of us are going to have to be careful," he said. Among the government's plans are modernising agricultural irrigation, which represents up to 80% of consumption in summer, boosting wastewater recycling, and reducing loss due to leakage.

All of **Spain** has been in drought since January 2022, but water supplies in

Catalonia have fallen so low that authorities this week introduced laws including a 40% reduction in water used for agriculture, a 15% reduction for industrial uses, and a cut in the average daily supply per inhabitant from 250 litres to 230 litres.

Rubén del Campo, a spokesperson for the state meteorological agency Aemet, said the situation showed no sign of improving over the coming months. The worst affected areas were the northern third of the country and parts of Andalucía and the south of Castilla-La Mancha, he said.

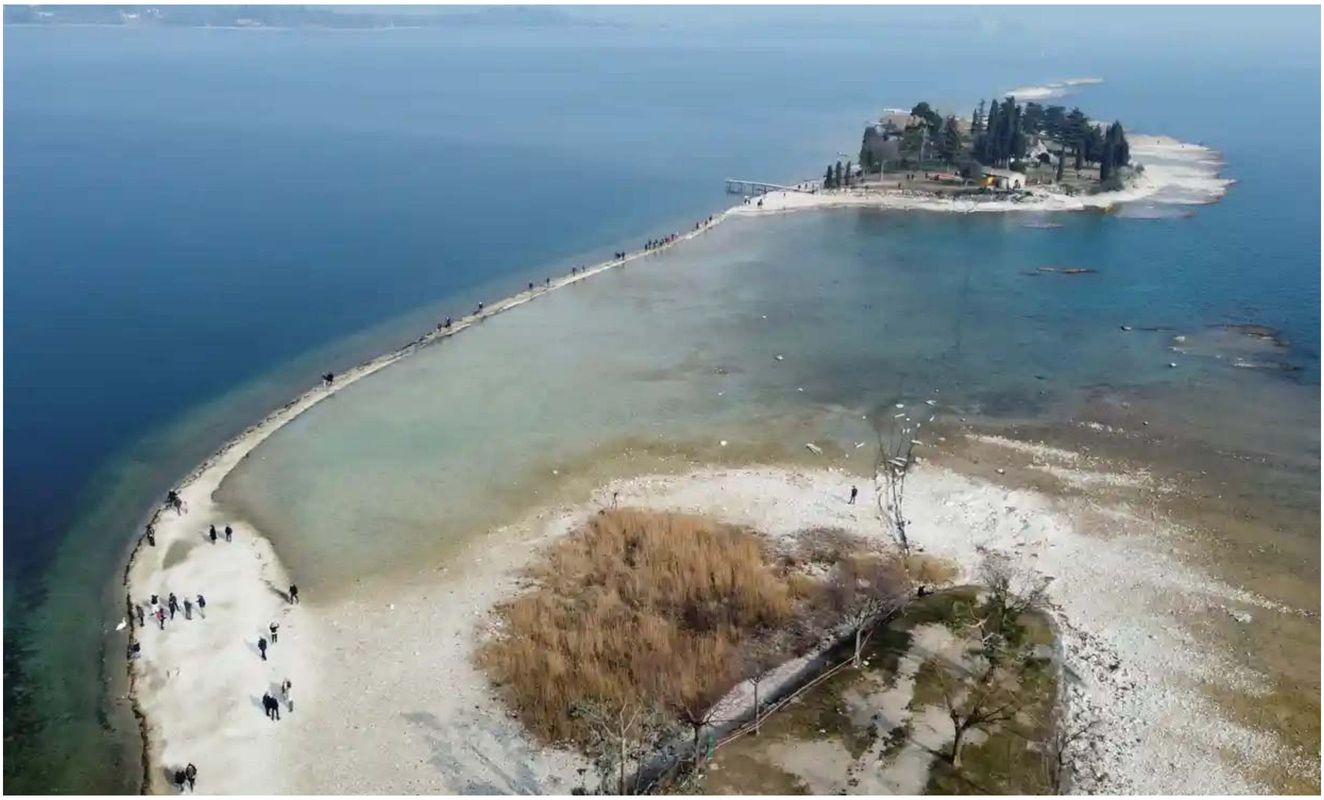
Asked about the role of global heating, Del Campo said that while drought had always been a natural phenomenon because of Spain's geographical location, a change had been seen over recent decades.

"We've noticed the droughts in the south of Spain are lasting longer and that, when the rains come, they're shorter but more intense," he said. "It's badly spaced out. When the rains are hard, they're less useful for refilling reservoirs and watering the fields, which need gentler rain."

In January, Spain's environment minister, Teresa Ribera, warned of the inescapable reality of the climate emergency, saying the country had to be prepared for "much longer cycles of extreme drought and periods of incredibly tough flooding".

The average amount of available water had fallen by 12% since 1980, Ribera noted, and projections suggested a further drop of between 14% and 40% by 2050. "We can't depend solely on rain when it comes to guaranteeing the supply of drinking water or water for economic uses," she said.

Spain's socialist-led government in January approved a €23bn (£20bn) plan to protect and improve water supplies by investing in areas including infrastructure, water treatment and purification, irrigation modernisation and flood-risk management.



The island of San Biagio in Lake Garda, Italy, now accessible by foot due to lake levels falling by 70cm. Photograph: Alex Fraser/Reuters

The government in **Italy** is reportedly preparing to create a taskforce including a "super-commissioner" and officials from several ministries to tackle the effects of severe drought, which is already starting to impact agriculture.

Water levels in the Po, the country's longest river that nourishes several northern and central regions, were 61% down on the February norm. While recent rainfall has alleviated some pressure, the environment and energy security minister, Gilberto Pichetto, warned last week water rationing may be required in some areas.

"The problem of drought is serious," he told Corriere della Sera. "We've only had half the average amount of snow. We found ourselves with waterways, lakes and reservoirs in a very critical state, and hydroelectric basins in extreme difficulty."

Italy's national research council (CNR) said last month that rainfall in the north was 40% lower than average in 2022, adding that the absence of precipitation since the beginning of 2023 had been "significant".

A leading meteorologist, Luca Mercalli, said Italy would only avoid a repeat of last summer's extreme drought if there was plentiful rainfall during spring. "It's the last hope," he said. "If we have no spring rain for two consecutive years, that would be the first time this has ever happened."

In central and northern Europe, lack of precipitation has so far mainly been seen

In central and northern Europe, lack of precipitation has so far mainly been seen in Alpine regions where winter tourists have faced snowless skiing pistes.

In the state of Tirol, **Austria**, for example, the towns of Landeck and Reutte have measured their driest winter on record, while in parts of **Switzerland** municipalities have again had to urge citizens to save water, after already doing so last summer.

But scientists warn the impact of the winter drought will most likely be felt in **Germany** and Austria's lower regions in the coming months: less snow over the winter means less meltwater to feed the rivers of central Europe in the warmer months.

"Today's snow deficit could potentially become tomorrow's summer drought," said Manuela Brunner, a professor in hydrology and climate impacts at Zurich's ETH university.

The meteorologist Josef Eitzinger, of Vienna's Institute of Meteorology and Climatology, told the dpa news agency: "If this spring's weather is similar to that of 2022, dryness will increase significantly." He pointed to historically low water levels at Lake Neusiedl, a key water source straddling the border between Austria and Hungary.

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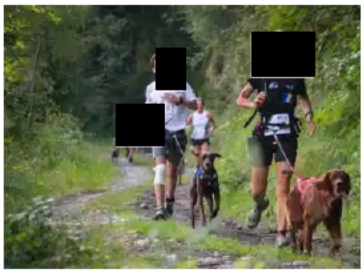

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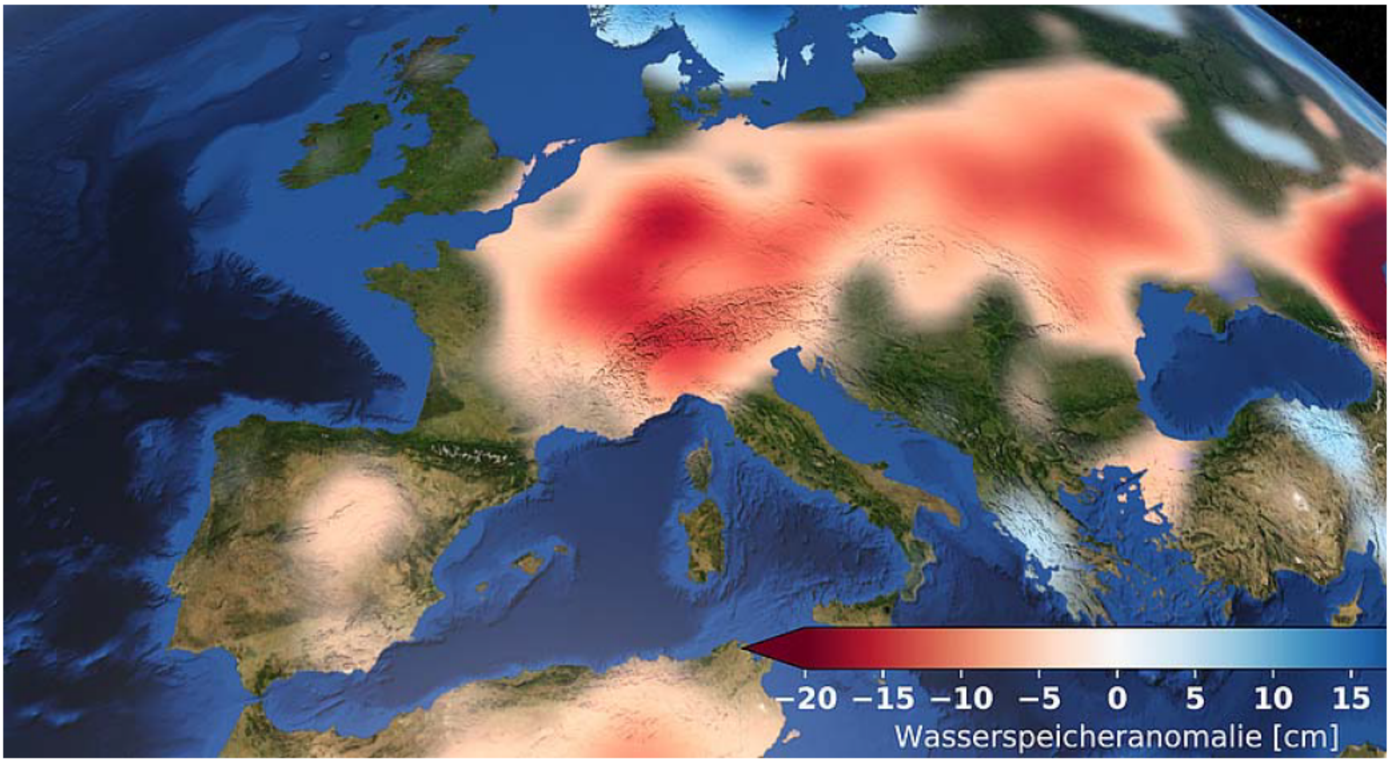
Media Service:

Satellite Data Shows Sustained Severe Drought in Europe

01/25/2023 | TU Graz news | Research
By Falko Schoklitsch

Europe lacks groundwater – a lot of groundwater. The continent has alre been suffering from a severe drought since 2018. This is confirmed by sat data analysed at the Institute of Geodesy at TU Graz.



Already in 2019 the amount of ground water in Central Europe was very low. Image Source: Kvas - TU G

Europe has been experiencing a severe drought for years. Across the continent, groundwater levels have bee consistently low since 2018, even if extreme weather events with flooding temporarily give a different picture.

The beginning of this tense situation is documented in a publication by Eva Boergens in Geophysical Researc from the year 2020. In it, she noted that there was a striking water shortage in Central Europe during the months of 2018 and 2019. Since then, there has been no significant rise in groundwater levels; the levels have remained constantly low. This is shown by data analyses by Torsten Mayer-Gürr and Andreas Kvas from the Ir Geodesy at Graz University of Technology (TU Graz). As part of the EU's Global Gravity-based Groundwater Pr (G3P) project, they used satellite gravimetry to observe the world's groundwater resources and documented changes in recent years.

Far-reaching consequences

The effects of this prolonged drought were evident in Europe in the summer of 2022. Dry riverbeds, stagnant that slowly disappeared and with them numerous impacts on nature and people. Not only did numerous aqu species lose their habitat and dry soils cause many problems for agriculture, but the energy shortage in Euro worsened as a result. Nuclear power plants in France lacked the cooling water to generate enough electricity hydroelectric power plants could not fulfil their function without sufficient water either.

Groundwater measurement from space

How can the geodesists at TU Graz use data from space to make accurate statements about groundwater res At the heart of the G3P project are twin satellites named Tom and Jerry, which orbit the Earth in a polar orbit altitude of just under 490 kilometres. The distance between the satellites of around 200 kilometres is importa one behind must not catch up with the one in front, which is why they have been given the name Tom and Je reference to the cartoon characters.

The distance between the satellites is being constantly and precisely measured. If they fly over a mountain, th satellite in front is initially faster than the one behind because of the increased mass under it. Once it has pas mountain, it slows down slightly again, but the rear satellite accelerates as soon as it reaches the mountain. (are over the mountain, their relative speed is established once more. These changes in distance over large m the main measurement variables for determining the Earth's gravitational field and are ascertained with micr precision. As a comparison, a hair is about 50 micrometres thick.

Monthly gravity map of the Earth

All of this happens at a flight speed of around 30,000 km/h. The two satellites thus manage 15 Earth orbits a c means that they achieve complete coverage of the Earth's surface after one month. This in turn means that T can provide a gravity map of the Earth every month. “The processing and the computational effort here are q We have a distance measurement every five seconds and thus about half a million measurements per month this we then determine gravity field maps,” says Torsten Mayer-Gürr.

Mass minus mass equals mass

However, the gravity map does not yet determine the amount of groundwater. This is because the satellites s mass changes and make no distinction between sea, lakes or groundwater. This requires cooperation with al partners in the EU G3P project. Torsten Mayer-Gürr and his team provide the total mass, from which the mass in the rivers and lakes are then subtracted, the soil moisture, snow and ice are also subtracted and finally onl groundwater remains.

Each of these other masses has its own experts who contribute their data here. These are located in Austria (University of Technology, Vienna University of Technology, Earth Observation Data Center EODC), Germany (GeoForschungsZentrum GFZ in Potsdam), Switzerland (University of Bern, University of Zurich), France (Coll Localisation Satellites CLS, Laboratoire d'Etudes en Géophysique et Océanographie Spatiales LEGOS, Magelli Spain (FutureWater), Finland (Finnish Meteorological Institute) and the Netherlands (International Groundwa Resources Assessment Centre IGRAC).

Europe has a water problem

The result of this cooperation shows that the water situation in Europe has now become very precarious. Tor Mayer-Gürr had not expected this on such a big scale. “A few years ago, I would never have imagined that wat be a problem here in Europe, especially in Germany or Austria. We are actually getting problems with the wat here – we have to think about this,” he explains. From his point of view, it is first of all necessary to be able to document the continuing drought using data and to have continuous satellite missions on this in space.

The European Space Agency ESA and its US counterpart NASA will continue this research with the MAGIC (Ma change And Geoscience International Constellation) project. TU Graz will again be on board for the data evalu

For more information on satellite geodesy, see the article “Cat chases mouse in space”

Information on the G3P project

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ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2020GL087285

Key Points:
- GRACE-FO quantifies continental water mass anomalies in continuation of the GRACE mission (2002–2017)
- GRACE-FO observes a water storage deficit of 112 and 145 Gt in 2018 and 2019 in Central Europe relative to the average conditions
- These deficits amount to 73% and 94% of the mean amplitude of seasonal water storage variations, respectively

Supporting Information:
- Supporting Information S1
- Figure S1
- Figure S2
- Figure S3
- Figure S4
- Figure S5
- Figure S6

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Citation:
Boergens, E., Güntner, A., Dobslaw, H., & Dahle, C. (2020). Quantifying the Central European droughts in 2018 and 2019 with GRACE Follow-On. *Geophysical Research Letters*, *47*, e2020GL087285. https://doi.org/10.1029/2020GL087285

Received 28 JAN 2020
Accepted 14 JUN 2020
Accepted article online 8 JUL 2020

[Correction added on 16 SEP 2020, after first online publication: Projekt DEAL funding statement has been added.]

Quantifying the Central European Droughts in 2018 and 2019 With GRACE Follow-On

Eva Boergens[1], Andreas Güntner[1,2], Henryk Dobslaw[1], and Christoph Dahle[1]

[1]GFZ German Research Centre for Geosciences, Potsdam, Germany, [2]Institute of Environmental Sciences and Geography, University of Potsdam, Potsdam, Germany

Abstract The GRACE-FO satellites launched in May 2018 are able to quantify the water mass deficit in Central Europe during the two consecutive summer droughts of 2018 and 2019. Relative to the long-term climatology, the water mass deficits were -112 ± 10.5 Gt in 2018 and -145 ± 12 Gt in 2019. These deficits are 73% and 94% of the mean amplitude of seasonal water storage variations, which is so severe that a recovery cannot be expected within 1 year. The water deficits in 2018 and 2019 are the largest in the whole GRACE and GRACE-FO time span. Globally, the data do not show an offset between the two missions, which proves the successful continuation of GRACE by GRACE-FO and thus the reliability of the observed extreme events in Central Europe. This allows for a joint assessment of the four Central European droughts in 2003, 2015, 2018, and 2019 in terms of total water storage deficits.

Plain Language Summary During the droughts of 2018 and 2019, Central Europe had a water deficit of about 112 and 145 Gt compared to an average year. As the water storage differences between winter and summer is about 150 Gt, the drought-related deficit amounts to 73% and 94% of these annual variations. These mass variations can be observed with the twin satellite missions GRACE (Gravity Recovery and Climate Experiment, 2002–2017) and its successor GRACE Follow-On (launched May 2018). With the satellite observations, the change in the total water storage can be estimated, including ground water, soil water content, and surface waters such as lakes and rivers. During the 21st century, Central Europe experienced four major droughts in 2003, 2015, 2018, and 2019, and we document the severity of the more recent droughts with respect to earlier events. We also find no systematic offset between the GRACE and GRACE-FO observations, so that the available satellite gravity record extends now over 18 years already.

1. Introduction

Satellite gravimetry is the only remote sensing technique available today that provides quantitative estimates of water storage changes at regional to global scales, independent of whether these are exposed at the Earth's surface or occurring in the deep subsurface. The Gravity Recovery and Climate Experiment (GRACE, 2002–2017) satellite mission measured tiny variations in the distance between two twin satellites trailing each other in a polar orbit at very low (500 km) altitudes (Tapley et al., 2019). GRACE applications in hydrology were manifold, such as quantifying the contributions of the continental ice sheets to sea level rise (Velicogna & Wahr, 2006), groundwater changes (Frappart & Ramillien, 2018), water storage capacity and flood potential (Reager & Famiglietti, 2009), or drought effects, for example, in California's Central Valley (Famiglietti et al., 2011). The monitoring of water mass anomalies from space initiated with GRACE is being continued by the GRACE-FO mission (Landerer et al., 2020) launched in May 2018.

Since the launch of GRACE-FO, Central Europe experienced two severe droughts in 2018 and 2019. In the summer months of 2018, Central and Northern Europe experienced exceptionally dry conditions (Toreti et al., 2019) with parts of Central Europe receiving less than 50% of the long-time mean precipitation (European Drought Observatory, 2018). Combined with a heat wave in July and August, this led to a severe drought in the region. In addition to the long-lasting effects of the 2018 drought event, parts of Central Europe again experienced below-average precipitation in 2019 and heat waves in June and July 2019, leading to the second drought in two consecutive years (European Drought Observatory, 2019). The water deficit had severe consequences for agricultural productivity, forest management, and industrial production, with the latter cut back by disrupted transport on inland water ways due to extremely low water levels. The associated heat waves also had severe impacts on the health conditions of the population. Comprehensive information on the extent, severity, and impact of the droughts is needed to guide future large-scale water management decisions. The recent conditions should also be set into the context of earlier drought events in the area such as the European heat wave of 2003 (Andersen et al., 2005; Seitz et al., 2008), which was exceptionally hot and dry all over Central Europe leading to widespread water scarcity at that time (Laaha et al., 2017).

There is no universal definition of drought, as it largely depends on the discipline and the area of application. Commonly, meteorological, hydrological, agricultural, and socioeconomic droughts are distinguished (Wilhite & Glantz, 1985). This study deals with hydrological droughts, which is the shortage of surface or subsurface water compared to a reference that is considered to represent "normal" conditions for a given time period of the past. Many drought investigations seek to characterize deviations from the "normal" via standardized drought indices (Heim, 2002). Many operational drought indices focus on meteorological quantities, as, for example, the Standardized Precipitation Index (SPI) (e.g., McKee et al., 1993; Pietzsch & Bissolli, 2011), the Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente Serrano, 2010), or a combination of those (Ziese et al., 2014). Hydrological droughts of the surface water scarcity are characterized by the Surface Water Supply Index (SWSI) (Shafer & Dezman, 1982) or the Streamflow Drought Index (SDI) (Nalbantis & Tsakiris, 2009). Indices indicating drying of soil moisture are usually based on precipitation and evapotranspiration observations and associated numerical modeling, like the series provided by the European Drought Observatory (EDO) (Horion et al., 2012).

GRACE gravity data have also been used before to define global drought indices. Houborg et al. (2012) introduced a percentile index for the North American Drought Monitor. Thomas et al. (2014) proposed a standardized index that incorporates not only the absolute value of the water mass deficit but also the duration of the drought. Zhao et al. (2017) proposes an index that explicitly considers both GRACE measurement and leakage errors. A comprehensive assessment of GRACE-based drought indices has been recently provided by Gerdener et al. (2020). Cammalleri et al. (2019) showed that a shortage of precipitation, as indicated by meteorological drought indices, can be used as a local proxy to hydrological droughts observed with GRACE.

In this work we investigate the capability of GRACE-FO to identify and quantify the water mass deficit of the two exceptionally dry summers 2018 and 2019 in Central Europe. We classify these events in the context of 18 years of GRACE and GRACE-FO observations and discuss the reliability of the newly available GRACE-FO estimates. We also compare a drought index based on satellite gravity data to independent soil moisture and lake level indices and discuss potential and limitations of a GRACE-based index with respect to more conventional hydrometeorologic indicators.

2. Processing of GRACE/GRACE-FO Data

We use 178 monthly GRACE and GRACE-FO gravity fields from the GFZ RL06 time series (Dahle et al., 2019), given in Stokes coefficients expanded up to degree and order 96 that cover the time frame April 2002 until November 2019. Coefficients of degree 2 and order 0 are replaced by estimates from Satellite Laser Ranging (König et al., 2019). We further subtract a model of glacial isostatic adjustment (Klemann et al., 2008), insert approximated degree 1 terms following Bergmann-Wolf et al. (2014), remove an aliased tidal signal at a period of 161 days, and apply time-variable decorrelation filters (Horvath et al., 2018) with different smoothing widths (i.e., the stronger VDK3 and the weaker VDK5).

The Stokes coefficients are subsequently synthesized on a global 1° latitude-longitude grid. To reduce the impact of spatial leakage, trends as well as annual and semiannual signals are filtered with VDK5, whereas residual month-to-month variability is filtered with the somewhat stronger VDK3 version of Horvath et al. (2018). In contrast to mascon solutions, no spatial leakage correction is applied. Coseismic gravity changes associated with three megathrust earthquakes are empirically estimated and removed. The resulting gridded terrestrial water storage (TWS) estimates are publicly available from the GravIS portal (gravis.gfz-potsdam.de, Zhang et al., 2019). From the gridded data, a mass anomaly time series is aggregated for Central Europe (CE), which is defined in this study as the region between 4° and 24° eastern longitude and between 45° and 55° northern latitude, thereby ranging from Netherlands to Poland and from the Alps to the coast of the Baltic Sea. The size of the land area is approximately 1.45 million square km. The mass anomaly time series are provided with an uncertainty estimation, which will be given for all mass anomaly values in this study.

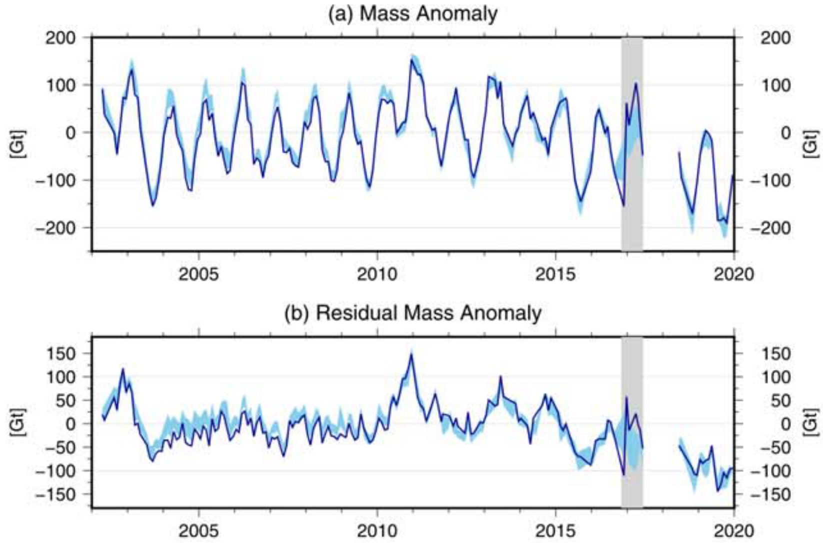

Figure 1. (a) Total water storage (TWS) anomaly time series observed over CE with GRACE and GRACE-FO; (b) the TWS anomaly reduced for annual signal component (dark blue: GFZ RL06 solution; light blue: range of six GRACE/GRACE-FO solutions; standard deviation around ensemble mean; gray: GRACE end-of-life period).

3. Water Mass Deficits From GRACE/GRACE-FO

Apart from a strong seasonal signal, the GRACE-based mass anomaly time series for CE shows distinct minimal values of TWS during the summer-to-autumn periods of 2003, 2015, 2018, and 2019 (Figure 1). In July 2019, GRACE-FO documents with -146 ± 12 Gt the largest deficit of water mass observed in CE so far of the past 18 years. The gap between maximum and minimum of the seasonal signal amounts to 154 Gt, meaning that the overall deficit in 2019 corresponds to 95% of this seasonal oscillation. Note that in the year 2018, GRACE-FO solutions are only available for June, July, October/November (mean epoch 31 October), and November (mean epoch 15 November), so that the seasonal minimum might have been missed. In November 2018 the deficit amounted to -113 ± 10.5 Gt, corresponding to 73% of the seasonal signal. From the whole GRACE and GRACE-FO data record, these two very recent years show the largest water mass deficit observed so far. We note that even the exceptionally high amount of snowfall in the Alps and a conventionally humid winter elsewhere in Europe were not able to restore the water storage to the pre-drought conditions, thereby providing important insights into the cumulative stress of repeated dry periods on the hydrological systems. In contrast, the extremely hot summer of the year 2003 just had a maximum deficit in September of -80 ± 10 Gt. Year 2015 exhibited another drought in the satellite record with a mass deficit of -83 ± 15 Gt peaking in December. Compared to the other events discussed above, the drought in 2015 persisted over the longest period of time until finally a recovery of the water storage deficit relative to the mean seasonality occurred which was only in middle of 2016.

To further assess the uncertainty of these results, we also use three additional recent (compatible with GFZ RL06) global spherical harmonics solutions from GRACE and GRACE-FO processed by Center for Space Research (Bettadpur, 2018; Save, 2019b), Jet Propulsion Laboratory (Yuan, 2018, 2019), and Technical University of Graz (Kvas et al., 2019). For completeness, we also consider the global mascon solutions published by CSR (Save, 2019a; Save et al., 2016) and JPL (Watkins et al., 2015; Wiese et al., 2016, 2018). The spread of these six different solutions is characterized for each month by the standard deviation of the mass anomalies around the ensemble mean, which is displayed as shaded area in Figure 1. We note that GFZ RL06 used in this paper typically fits well into this uncertainty range. Some exceptions are notable, in particular during the early years of the GRACE mission. During the GRACE end-of-life months from November 2016 to June 2017, the data quality degraded due to the loss of the accelerometer data on one spacecraft (Bandikova et al., 2019), which leads to an increased spread among the series. Those months are therefore ignored in the following analysis.

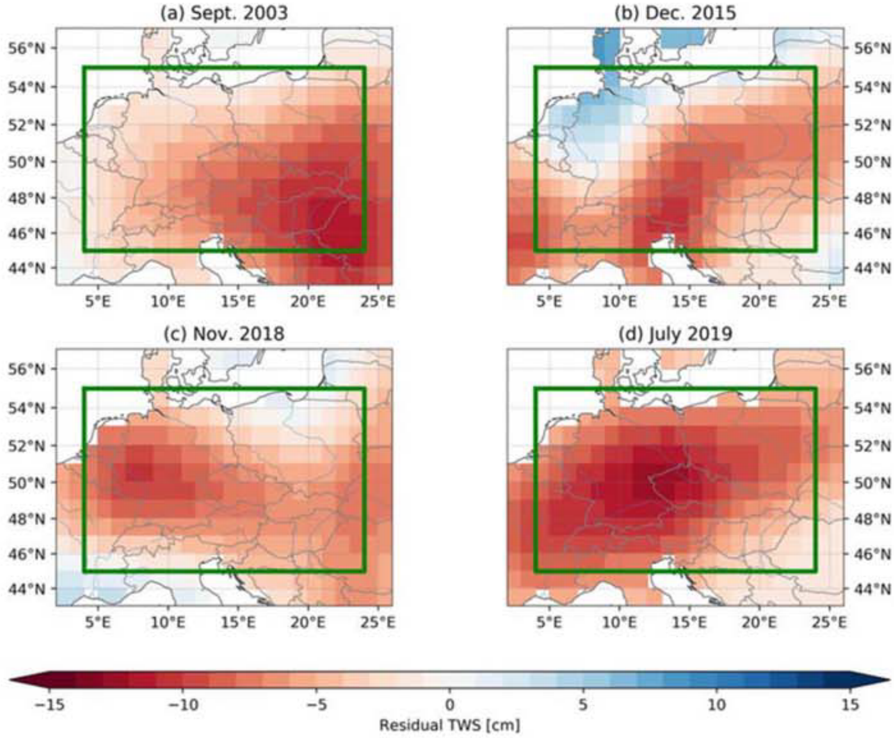

Figure 2. Residual TWS anomaly (annual signal reduced) for (a) September 2003, (b) December 2015, (c) November 2018, and (d) July 2019. The green box marks the area of CE.

Besides total water storage anomalies estimated over the whole region of Central Europe, satellite gravimetry also provides some information on the spatial distribution of the water deficits, here given for each drought year at the month of seasonal minimum in TWS (Figure 2). In November 2018, the drought conditions were most severe in the western part of Germany. The Baltic coast region in Poland even had slightly above-average water storage conditions. In July 2019, the drought was centered in eastern Germany and Poland. However, the drought was more widespread across CE in 2019, since many regions affected by the previous dry summer did not yet recovered to the full extent. In 2003, the biggest water deficit was detected in the southeast of Europe. The drought of 2015 instead was centered in Austria, while the coastal regions and northwest Germany experienced above-average water storage conditions.

While November 2018 was the overall driest month in 2018, the region of southwestern Germany and neighboring countries saw an even larger drought earlier that year (Figure S5). Similarly, the northwestern part of CE exhibited an even more severe water deficit in August 2019, or Austria and the Adriatic coast were drier in August than in September 2003. The spatiotemporal pattern of water storage evolution in 2003 compared to 2019 shows that conditions were much more severe in 2019, both in terms of maximum deficits and the duration of the drought. Unfortunately, the spatiotemporal evolution of the droughts in 2015 and 2018 cannot be fully tracked due to several missing GRACE/GRACE-FO monthly solutions in those years.

4. Comparison With Soil Moisture and Lake Level Indices

In order to relate the GRACE and GRACE-FO results to other hydrometeorological observations, we utilize both a publicly available drought index for soil moisture and a specifically calculated index based on lake level in situ observations. Compared to GRACE/GRACE-FO, soil moisture and surface water storage represent only a certain compartment of the terrestrial water storage. It should be noted, however, that the storage variations of large unregulated lakes can be considered as an integral representation of the overall water storage dynamics of the river basins that drain into the lakes and, thus, compare fairly well to the TWS variations measured by GRACE and GRACE-FO.

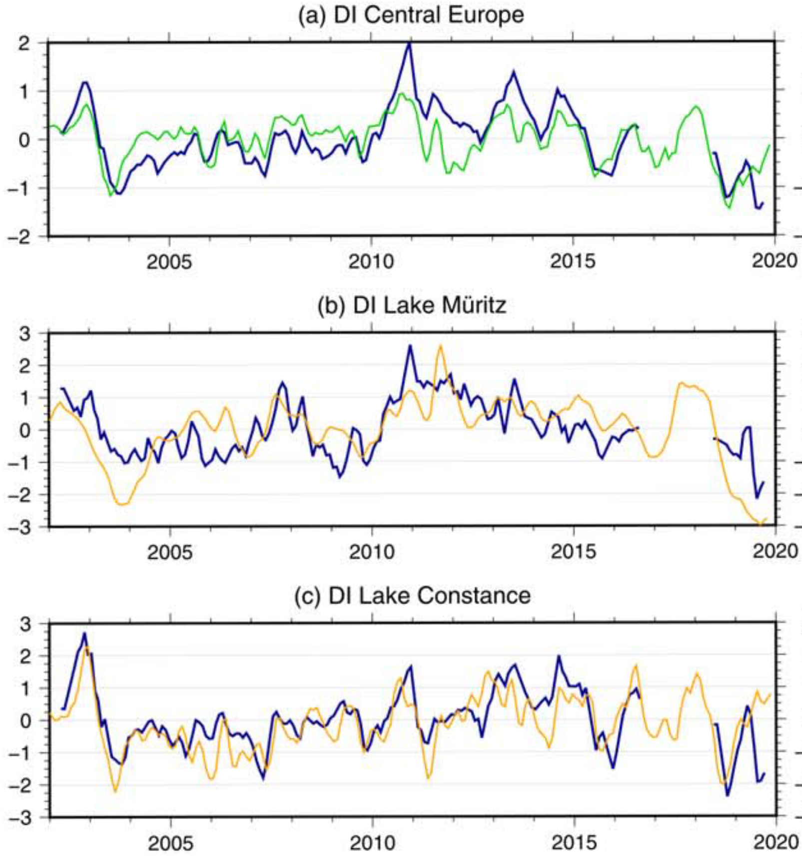

Figure 3. Comparison of DI-TWS (blue lines) to other drought indices: (a) DI-SM (green) and (b and c) DI-LL (orange) of Lake Müritz and Lake Constance.

We use the soil moisture index of the European Drought Observatory (EDO) (Horion et al., 2012), given for Europe on a $(5\ \text{km})^2$ equal-area grid with a temporal resolution of 10 days. The index is based on the plant available soil moisture between wilting point and field capacity as simulated with the hydrological model LISFLOOD (van der Knijff et al., 2010). The corresponding soil depth varies spatially with the rooting depth of the dominant land cover. Here, the index values (DI-SM) are standardized at each time step by subtracting the long-term mean of the time step μ_i (i.e., its climatology) and dividing by the standard deviation σ_i of the time step over the entire soil moisture time series:

$$\text{DI -SM}_{i,j}^{EDO} = \frac{\text{SM}_{i,j} - \mu_i}{\sigma_i}. \tag{1}$$

We adjust the original reference time period of the index (1995–2018) to the temporal mean of all GRACE and GRACE-FO months used in this study and calculate monthly means to aligned to the epochs of the satellite gravimetry solutions. Note that the index values after March 2019 are based on a new model version, which is not yet fully validated.

We also use lake water level observations of Lake Constance in the southwest and Lake Müritz in the northeast of Germany, which are the two largest lakes in the country. The lake water level time series are given between January 2000 and October 2019 with a daily resolution. We convert them to monthly-mean values and normalize each gauge time series to the lake level index (DI-LL) similarly as DI-SM. As before, only months with available GRACE/GRACE-FO data are used for the normalization.

For comparison, we transform the gridded TWS data to a standardized anomaly index for each grid cell similar to the soil moisture index introduced above. The epochs of the TWS data are the mean epochs of data

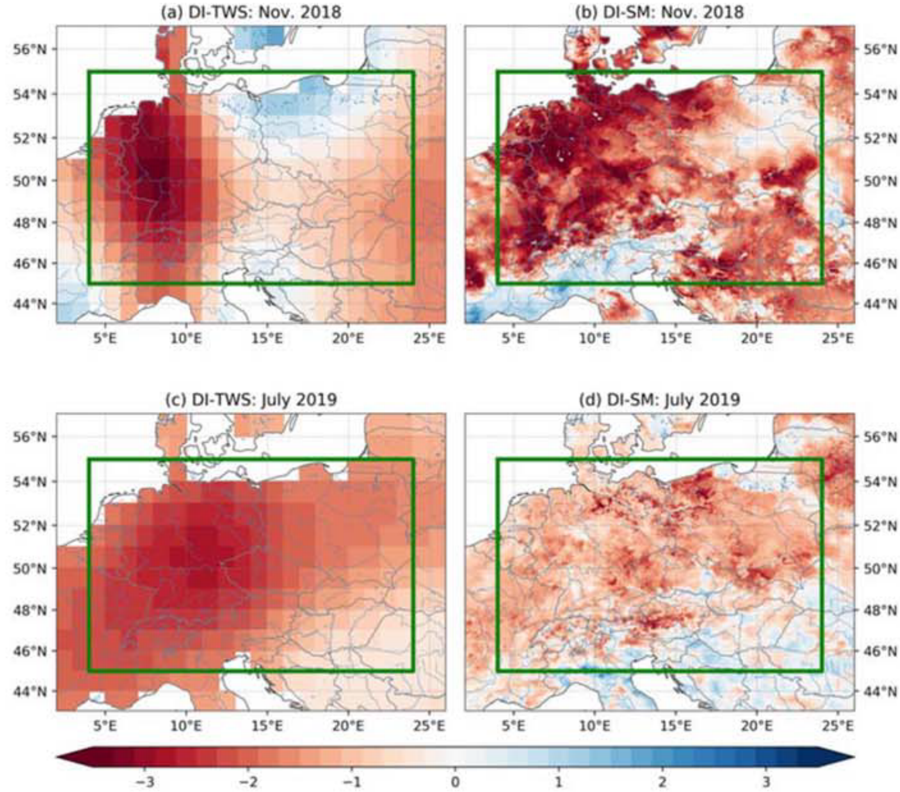

Figure 4. Spatial patterns of (a) DI-TWS and (b) DI-SM for November 2018 and for July 2019 (c and d).

acquisition that are not always aligned with calendar months. In these cases the data are assigned to the month of the mean epoch for the normalization. This index will further be referred to as DI-TWS.

Area-average time series for CE were calculated for DI-TWS and DI-SM and smoothed with a 3-month moving average filter to suppress high-frequency variations (Figure 3a). While both summer droughts of 2018 and 2019 are clearly indicated by minimum values of DI-TWS, the summer 2019 was not as dry as 2018 in terms of DI-SM soil moisture. The drought in the very hot summer of 2003 is captured by both indices but with a time lag and a longer persistence of DI-TWS compared to DI-SM, indicating a larger memory effect of TWS as compared to soil moisture.

DI-LL of Lake Müritz and Lake Constance is now compared to DI-TWS of the respective grid cells that encompass the lakes. Overall, the interannual variations of DI-TWS are similar to those of DI-LL for both cases (Figures 3b and 3c) with a slightly higher correlation for Lake Constance (0.69). For Lake Müritz (correlation 0.62), both indices show their overall minimum value in summer 2019. For Lake Constance, both DI-LL and DI-TWS similarly represent the 2018 drought but differ markedly in the case of the 2019 drought with a recovery of DI-LL but another minimum of DI-TWS. The high water level of Lake Constance during summer 2019 as represented by DI-LL is caused by the runoff of snow melt from the Alps feeding Lake Constance after an exceptionally snow-rich winter.

For November 2018 and July 2019, we compare the spatial distribution of the indices DI-TWS and DI-SM in Figure 4. It should be noted that DI-TWS captures large-scale effects only, while DI-SM has a significantly higher spatial resolution (Figure 4). In 2018, the general pattern of driest conditions in western Germany is reflected by both indices. However, a wet pattern along the coast of the Baltic Sea is more pronounced in DI-TWS. The correlation between DI-TWS and DI-SM on a 1° grid is 0.83 in 2018. In 2019, the two indices agree on the center of the dry region in eastern Germany/western Poland and a rather moist area in southeastern Europe. For July 2019, the spatial correlation between the grids is 0.88. A further comparison to precipitation-based drought indices is given in Supporting Information S1, which largely corroborates the results presented above.

5. Discussion

We showed that the residual water storage anomaly observed by GRACE and GRACE-FO over CE ranges between 151 and −145 Gt, with an typical error of 7 to 22 Gt associated to a single monthly-mean estimate as provided with the GFZ solutions. Even under consideration of those uncertainties, the most recent summers of 2018 and 2019 were the driest in the combined GRACE and GRACE-FO data record. The water storage deficit of the droughts in 2003 and 2015 are with -80 ± 16 Gt and -87 ± 16 Gt clearly less severe. It will be interesting to see how the storage situation will further evolve during the upcoming 2020 summer period.

To assess the data continuity between GRACE and GRACE-FO, we compare the GRACE/GRACE-FO TWS data with TWS data reconstructed from precipitation Humphrey and Gudmundsson (2019). We find that GRACE-FO TWS is very close to the reconstructed TWS and no offsets are detected (Figure S6). Thus, we conclude that GRACE-FO consistently continues the GRACE time series and that the extreme events observed in CE by GRACE-FO in 2018 and 2019 are not impacted by data biases or other spurious effects of the new satellite mission.

The spatial patterns of GRACE-based water storage deficits indicate that the summer droughts of 2003 and 2019 had a larger spatial extent throughout CE than the 2015 and 2018 events. Based on GRACE-FO, the latter was regionally more severe in southwestern Germany and neighboring countries. Also, southern Europe experienced above-average wet conditions in 2018 (Toreti et al., 2019). In 2015, the GRACE-based patterns with predominant water deficits in particular in the eastern parts of CE are similar to patterns of precipitation deficits given in Orth et al. (2016) and the focus area of the drought from a hydrological perspective reported by Laaha et al. (2017).

Due to the filtering necessary in GRACE/GRACE-FO data processing, water mass signals are spread out over larger areas, thereby reducing the spatial resolution. Signals can either leak into the region of interest from the outside or, vice versa, signals inside the area can leak to the outside, which is called leakage-in or leakage-out, respectively (Klees et al., 2007). We investigated the effect of leakage for our study area by comparing the mass anomaly and the residual mass anomaly time series for CE based on all VDK filtered fields between VDK2 to VDK6. Overall, no significant difference is visible between the filters, especially not during the summer drought periods. This indicates that spatial leakage does not dominate the uncertainties in the study region. This is also supported by the rather small spread of the ensemble that also includes two mascon solutions with sophisticated leakage corrections. In September 2003, for instance, the difference between the strongest (VDK2) and the weakest filter (VDK6) is 7 Gt only, in November 2018 4.5 Gt, and in July 2019 14 Gt. In the latter case, a positive water storage anomaly over southwestern France leaks into the CE study area when using the strong VDK2 filter and thereby spuriously reduces the drought severity.

The comparison between the three different indices shows both advantages and limitations of drought identification with satellite gravity data. All indices indicate droughts in different hydrological storages. Temporal lags of different extent can be observed between the water mass in surface water, soil moisture, and TWS. However, only TWS indicates possible shortages in the amount of water potentially available in a certain region and therefore shows a stronger memory effect than, for example, precipitation, soil moisture, or surface water (Creutzfeldt et al., 2012). This memory effect and the slight dampening of the signal might be caused by the deep groundwater included in TWS, which has an overall slower response compared to soil moisture or surface water. Because of this, the persistence of the 2018 drought well into 2019 is clearly observable with satellite gravity data, since the winter precipitation was obviously not sufficient to recharge the large total water deficit. Since soil moisture was already restored to the predrought level, this index misses this potentially important information for the long-term water availability. Local surface water observations can be influenced strongly by local effects not observed by TWS such as the aftermath of the heavy snowfall in winter 2018/2019 on Lake Constance. Nevertheless, the general correspondence among the different indices is very good, thereby further indicating the reliability of GRACE-FO.

6. Conclusions

In this work, we quantified the total water storage deficit over Central Europe during the droughts of 2018 and 2019 with GRACE-FO. Compared to the long-term mean climatology, the deficits are -112 ± 10.5 Gt and -145 ± 12 Gt, respectively. This amounts to over 73% and 95% of the mean seasonal storage change in this region. In terms of soil moisture the drought of 2019 was less severe than 2018 but, the winter 2018/2019 could not sufficiently recharge the deep storages, which led to the even higher deficit in 2019. With GRACE-FO we can also observe the regional intensity of droughts. While the 2018 event was centered in southwest Germany and neighboring countries, the drought in 2019 affected mostly parts of Poland, eastern Germany, and the Czech Republic until July before spreading westward in August. Overall, in 2019 the drought affected all of CE while the eastern part of CE was less affected in 2018.

The two earlier droughts of 2003 and 2015 are also put into perspective with more recent data. Unfortunately, no GRACE-FO data are available for several months during 2018, so that the peak deficit in that year might have been missed. The drought of 2015 lasted the longest but only with a maximum water deficit of 54% of the maximum 2019 deficit.

The comparison of three different drought indices, namely, a soil moisture index, an index derived from surface water level gauges, and the gravity-based TWS index gave evidence of all drought events in any of them, albeit with partly differing dynamics of the water cycle components represented by the respective indices. Furthermore, as the GRACE-FO TWS data for CE closely matches the expected TWS of a long-term reconstruction, we are confident that GRACE-FO provides a reliable, offset-free, and unique view on the impact of the two consecutive drought years on the water budget in Central Europe. GRACE-FO therefore successfully continues the time series of regional water mass anomalies secured by the GRACE satellite mission.

Data Availability Statement

GRACE and GRACE-FO gridded TWS data are freely available over the GFZ portal GravIS ([redacted] The EDO drought index, generated using Copernicus Emergency Management Service information (2019), can interactively be viewed online [redacted] Water level gauge data of Lake Müritz and Lake Constance were provided by the *Wasserstraßen- und Schifffahrtsverwaltung des Bundes* (WSV) via the *Bundesanstalt für Gewäcurren;sserkunde*(BfG, [redacted] on request.

Acknowledgments

We thank Carolina Arias Muñoz of the EC Joint Research Centre in Ispra, Italy, for providing the full EDO data set. We also want to thank Bridget Scanlon for her very valuable review. Open access funding enabled and organized by Projekt DEAL.

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LITHIUM-ION BATTERY FIRES

Government action urged as new figures show surge in lithium-ion battery fires

[redacted]

Ron Alalouff [redacted]

Trade and consumer bodies are warning that action is needed in the light of a sharp increase in e-bike and e-scooter lithium-ion battery fires.

The British Metals Recycling Association is urging the government to lead a new campaign (https://www.ifsecglobal.com/fire-news/concerns-raised-over-increase-in-unsafe-disposal-of-lithium-ion-batteries/) to highlight the dangers of fires from exploding lithium-ion batteries, saying the problem has been "ignored for too long".

The warning comes as new figures show that the number of fires caused by exploding lithium-ion batteries in e-scooters and e-bikes soared by almost 150% in 2021, according to data obtained in response to a Freedom of Information request by insurance company Zurich. The number of such fires to the end of September 2022 shows a further increase of 28% on 2021's monthly average figure.

In London alone, firefighters attended 88 fires caused by e-bikes in 2022 – an increase of 80% on the 49 responded to in 2021. Many of the fires have been attributed to e-bike conversion kits, which can be used to convert a standard push bike into an electric bike.

Safe use and disposal of lithium-ion batteries

"These figures underline the need, once again, for more education and communication about the dangers of lithium-ion batteries found in rechargeable items, including e-bikes and e-scooters," said James Kelly, the CEO of BMRA. "This is a growing problem, which is putting the safety of members of the public and those working right across the recycling sector at risk. For too long it has been ignored, which is why the BMRA is now calling for a government supported campaign to better inform the public of the hazards, both for safe use and disposal of lithium-ion batteries."

London Fire Brigade Assistant Commissioner for Fire Safety, Charlie Pugsley, said: "There is a significant risk posed by the e-bikes which have been converted, and we are predominantly seeing fires in ones which have been purchased from online marketplaces and batteries which have been sourced on the internet, which may not meet the correct safety standards.

Credit: Perry van Munster/AlamyStock

"When these batteries and chargers fail, they do so with ferocity and because the fires develop so rapidly, the situation can quickly become incredibly serious. These items are often stored in communal areas and corridors, and can block people's only means of escape."

E-bike and e-scooter warnings

The Chartered Trading Standards Institute has also recently warned retailers and the public to avoid non-compliant devices. It is urging the public to:

- Only purchase e-bikes, e-scooters, chargers and batteries from reputable retailers
- Never buy counterfeit batteries or chargers, and ensure that any device you use displays a valid UKCA or CE mark
- Check that separate components, such as batteries and chargers, are compatible with one another
- Register your product with the manufacturer to validate any warranties on components including batteries. Registering makes it easier for manufacturers to contact you in the event of safety or recall information
- Check any products you have bought are not subject to a product recall. You can do this by checking Electrical Safety First's website or the government website

"For importers and retailers, getting this wrong could cost you an absolute fortune," said Alonso Ercilla, Trading Standards Manager at the London Borough of Islington. "Trading Standards can seize non-compliant devices and gain a forfeiture order, so that we can safely dispose of them. We advise anyone selling these devices to get them tested to make sure they comply with product safety laws. When things go wrong, there are consequences. Businesses can be prosecuted and the public can be exposed to great risk of harm."

Evolving opportunities, same challenges - Learnings from FIREX International 2022

This eBook provides a summary of several key debates and presentations that took place at FIREX International 2022 in May, alongside some additional exclusive content for readers.

We cover topics ranging from the issue of single staircases in high risk and multi-occupied buildings, through to the role the Internet of Things (IoT) is playing in the fire safety industry at present. There are also chapters on how BIM can support fire safety standards, the role of the digital golden thread, smoke control in high-rise residential buildings an insight into a new guidance note for fire alarms from the FIA.