



European
Commission

JRC TECHNICAL REPORT

Annual Progress Report of the European and Global Drought Observatories, 2019

*From Monitoring
to Mitigation*

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Joint
Research
Centre

EUR 30004 EN

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EU Science Hub

<https://ec.europa.eu/jrc>

JRC118685

EUR 30004 EN

PDF ISBN 978-92-76-11266-2 ISSN 1831-9424 doi:10.2760/43976

Luxembourg: Publications Office of the European Union, 2019

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How to cite this report: de Jager A. ea. *Annual Report of the European and Global Drought Observatories 2019*, EUR 30004 EN, Publisher, Luxembourg, 2019, ISBN 978-92-76-11266-2, doi:10.2760/43976, JRC118685.

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Foreword

With this report, the reader finds an overview of the changes, upgrades and new features created in the European Drought Observatory (EDO) and the Global Drought Observatory (GDO) and made in 2019.

The year proved relatively quiet concerning drought events in Europe; the subcontinent was only affected in the Baltics, although fires broke out vigorously in the Balkans, Spain and Russia. Thanks to the recent juvenile concern with regard to the heating up of the climate, drought events and forest fires drew more public attention. Our reaction upon this concern in the Global Drought Observatory is the development of a new group of data, which we call Drought Mitigation. With more people genuinely concerned in the effect of our alternation of the properties of the lower atmosphere, we take up the task to provide guidelines for repair and adaptation. Higher temperatures imply that air depletes more vapour from vegetation and soil, leading to more intense droughts or floods. Conscious management of our freshwater resources and massive tree planting are measures that can have a significant impact on the effects of a Drought, Forest Fires or also Flood events. Therefore, we started with including the results of the often-cited research result regarding reforestation potential of the Crowther Lab as a layer in the Global Drought Observatory. We completed this work with enriching data describing dams with data regarding the location, name and quantitative characteristics of dams as an additional layer. We worked on the integration of the GRACE Dataset, which gives us an actualised satellite born, insight in the depletion of groundwater resources.

We created a new index, alerting drought impacts on protected wetlands. Droughts events in these areas might affect rare species living in these protected wetlands, thus creating a link to the biodiversity crisis. The drought alerting mechanism we developed thus far were human-centred. With this new index and with the Crowther Lab reforestation inventory we hope to correct this one species view of the past, learning to share our territory with all species, also during hard times of a drought disaster.

With these additions, we hope that EDO and GDO will give you a better overview of the impacts of drought events, not only for our economy but also for our shared ecosystems and their services to us. Finally, note that we engage in a project to export EDO and GDO knowledge and software to African regional partners. We are thus enabling them to set up drought observatories in Africa just as if we did for South- and Central America. Such a collaboration works both ways, we understand better the impacts of Drought events in their region, and we learn from their practical skills with regard to making things work in a challenging environment, while we can give them working drought observatory software, practical manners to, almost, fully automate the filling and updating of the systems combined with our specific expertise on droughts build up in the last 12 years.

Acknowledgements

The drought observatories profit from the provision of data from many sources and the dedication of many people. In particular, we thank Carlo Antoniotti (JRC Bio-Economy unit) for maintaining the database, Andrea Toreti (JRC Food Security unit) for providing MARS (Monitoring Agricultural ResourceS) meteorological data and Andreas Becker (German Weather Service) for providing GPCP monthly rainfall data. Several regional, national and local authorities collaborate efficiently by providing data and indicators for their area of competence. In particular, we acknowledge the Drought Management Centre for South Eastern Europe (Gregor Gregoric), the Confederación Hidrográfica del Segura (Jaime Fraile Jiménez), the Drought Monitor for the Czech Republic and Slovakia (Mirek Trnka) and the Slovenian Environmental Agency (Andreja Susnik). This year we are happy to add the Portuguese initiative to display SPI data integrated into EDO, with help from Ricardo Deus and Vanda Cabrinha both working for the Portuguese Institute for the Ocean and Atmosphere, IMPA.

Apart from data and people, an Early Warning System needs financial resources in order to be viable. DG JRC, DG ECHO and DG GROW, the latter under the Copernicus Programme, support EDO and GDO. DG ECHO is mainly interested in the alert mechanism of the GDO, their interest explains the rich reporting unit report that we generate for areas that are drought-stricken during the last ten days period.

The Drought Team is led by Paolo Barbosa and assisted by Jürgen Vogt. Alessandra Zampieri leads the Disaster Risk Management unit with Tom De Groeve, allowing us to benefit from a variety of skills available in our unit that also encompass other disastrous events, such as Forest Fires, Floods, Earth quakes and Human security issues. Collaborations with the Bioeconomy unit of Directorate D and the Knowledge Centre for Sustainable Development & Food Security are intensified in three activities, thanks to collaboration with Marco Clerici, Nadine Gobron, Mirko Marioni and Dario Simonetti. Whilst the contribution of Drought events to the Disaster Risk Data hub and the Global Disaster Alert System, both additional systems operational in our unit, was consolidated thanks to efforts of Tiberiu Antofie and Stefano Paris.

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Abstract

This report gives a comprehensive overview of the new functions in the European and Global Observatories (EDO and GDO) that were created in 2019. This report completes the user documentation of the systems and is to be used in conjunction with the previous reports presented since 2010.

In 2019, we added layers describing means to mitigate droughts and integrated total terrestrial water storage information; we reviewed the system technically in order to comply with new system vulnerability tests and the use of shared libraries that vigour the europa.eu domain. We created various sectorial drought indices, both in testing as well as in a production phase. The sectorial indices tested, concern droughts in wetlands, water security during drought events for big cities, water intake limitations for industrial activities during droughts and a low flow index at world level in addition to the low flow index for Europe. We analysed methods to produce a new SPI index every ten days instead of once a month, thus allowing our indices to be more up to date during a lasting drought event. In brief, drought is becoming, in reaction to society's hesitation to react on the Climate Heating drama, more and more a political tense topic, putting our work in the centre of attention together with the results of our colleagues of forest fire alerts.

A copy of the system is developed using Open Source technology, making it ready to be exploited by regional meteorological agencies in Africa, the Caribbean and the Pacific, this in addition to the version already functioning in Ecuador. The project making this possible we baptized Mukau, the name in some local Kenyan languages of *Melia volkensii*, a plant adapted to dry climates and native to East Africa. This project, financed by DG DEVCO, will allow us to match up more with our counterparts in Africa thus enabling us to give more accurate information during events in exchange of sharing our technologies with our counterparts in the more drought stroked parts of the planet.

1 General System Upgrade

In 2019 DG DIGIT organised a series of new procedures to which websites in the europa.eu domain have to adhere to. Apart from a series of documents that describe the system also specific security tests were put in place. In preparation of this effort templates describing the ‘business need’ of EDO and GDO were to be filled. This activity was assisted by JRC LISO of Directorate R.I, in particular by Enos D’Andrea and Roberto Soriano Doménech to whom we are grateful for their assistance.

The scans resulted in a series of activities in which especially the Web Mapping component of the website had to be reinforced with additional parameter checks. In addition to this purely technical harnessing, we also put the server into the encrypted HTTPS protocol, removed the last trace of personal information by hashing the so-called internet address (IP address) and we were recommended to place a cookie warning around the side, although EDO and GDO use no cookies since 2018.

The year 2019 came with various initiatives presented ‘Top Down’ in which services of the Commission presented additional rules on cyber security and website branding in order to address the various threads that exist in a public space such as the Internet. For example, a ‘Copernicus Emergency Look and Feel template’ was proposed, aiming to make the interface of the various Emergency websites more alike. On top of that also the Commission itself presented an update of the look and feel with accompanying templates. The latter is named Europa Component Library (ECL) and can be consulted at this website: <https://wikis.ec.europa.eu/display/WEBGUIDE/03.+EC+branded+harmonised+websites+design>.

Looking back on these unplanned activities, coordination is lacking as well as a technical perspective. Web Map Services are all look a likes and the underlying technology is mature. It would make sense that well harnessed central services in the Commission provide fast technical database utilities and related web map services to replace gradually the hundreds of systems now in place. The current approach to make different systems look alike, will anyhow fail due to the speed of development of tools being used by programmers. Managers should acquire a better understanding of how to decide on URLs, web systems and databases irrespective of relating these matters to physical control. On the other side, the Top-Down approach now often exercised on banal details, hinders the deployment of a powerful central service, local technical specialist are not listened to, in a working field in which radical changes follow up faster than the organisation of a next meeting.

1.1 Security Scans

Two security scans were performed on srv-dry-stg.ies.jrc.it (staging server, April 2019) and srv-dry-ext.jrc.ec.europa.eu (external DMZ server, August 2018) and some interventions to improve the code of all the websites hosted by those servers (hence not only EDO and GDO, but also the ADO, SCADO, CCM, and GHS were asked¹) to reduce vulnerabilities.

Only one of such interventions is still pending, the **upgrade of PHP** from version 5.4.45 to version 7, with the following upgrade of all dependencies and libraries. Moreover, exactly the update of the PHP MapScript library is blocking the process, in turn depending on the update of OsGeo MapServer from version 6.4.1 to version 7.4 still not put in place. In fact, since all the servers where EDO and GDO are hosted rely on a JRC-compiled version of MapServer and its upgraded distribution to version 7.4 is not completed yet, the cascading upgrade of PHP MapScript is pending and hence blocking the PHP upgrade too. We hope to be able to finalize every update in the first months of 2020.

However, we already successfully tested the new versions of PHP, MapServer and PHP MapScript in the frame of the Mukau project, verifying the modifications that will be necessary in the code of EDO and GDO to adapt to the new releases.

All the other interventions come up from the security scans were put in place from April to September 2019 and are listed in the following.

- **SQL injection from calls of MapServer WMS (Web Map Service):** MapServer validation functions do not work properly if URL parameters are passed through a WMS GetMap request, being partially vulnerable to malicious values. By consequence, an internal functional WMS server was implemented to deal with this issue: mswms.php. If a MapViewer layer of EDO, GDO, SCADO or ADO loads data with

¹ ADO: African Drought Observatory; SCADO: Desertification, Land Degradation and Drought (DLDD) Observatory for Latin America; CCM: Catchment Characterisation and Modelling; GHS: Restructuring GSHHG (Global Self-consistent, Hierarchical, High-resolution Geography Database) global coastline done with IHO (International Hydrographic Organization) definitions of Oceans and Seas.

time or other additional parameters, it is not served by the core mapserv WMS server, but by mswms.php, which has strict checks of values passed via URL parameters. mswms.php includes a configuration file, named mswms.config.php, and a collection of functions, named mswms.function.php. Each website has its own mswms.php. Another setting to avoid vulnerable calls of mapserv from outside the MapViewer was done including in each possible affected layer of any MapServer mapfile an ancillary mapfile fragment, named disable.wms.shared.map and disabling GetMap and GetFeatureInfo WMS requests.

- All inputs provided by users by means of **URL parameters are now strictly validated** to only allow expected values and to avoid insertion of possible dangerous SQL or JavaScript code fragments (SQL injection, cross-site scripting).
- Among URL parameters, a particular work was dedicated to those referencing a choice made by users to **highlight a geographical feature** in the MapViewer, after a zoom or a query (identify) function. Previously the user choice was referenced by the web session id, but that has been replaced by a **new identifier** with syntax `[DO]::ge::[TABLE]_[ID_VALUE]::[RN]`, where `[DO]` is the drought observatory, `[TABLE]` is the Oracle table containing the selected geographical feature, `[ID_VALUE]` is the value of its id column, and `[RN]` is a random number from 0 to 999. For example, the identifier `gdo::ge::COUNTRIES_AT::761` was generated after a zoom to Austria in GDO, with 761 as random number.
- The **webpage edit function** is not allowed anymore and has been removed from every webpage of all websites to avoid inserting/updating (and subsequently displaying) dangerous contents.
- To avoid **information leakage**, all error messages were removed from public webpages, leaving only a generic message of service unavailability or redirecting to the standard webpage -404, used for missing content. The latter solution was adopted in particular for errors triggered by MapServer.
- **External contents** (i.e. resources loaded from external websites, e.g. images), also those coming from European Commission domains, were avoided as much as possible, copying them inside EDO/GDO servers.
- **Upgrade of Python to version 3.6.8** on all the srv-dry servers, since Python 2 will be in end-of-life in 2020 and bug fixing support will be not available anymore.

1.2 No Cookies and the cookie warning

In October 2019 a library was made available to be used in all websites in the europa.eu domain, named Cookies Consent Kit (CCK): <https://wikis.ec.europa.eu/display/WEBGUIDE/04.+Cookies>. The library creates a cookie message using the Blue and White standard of the European Commission, allowing the user to accept to continue with or without cookies on the calling website. Subsequently the library sets a cookie, on behalf of the calling website, with the choice made by the user, also if the user chooses to not allow cookies. EDO and also CCM are functioning without cookies, but by using this library they now do set 1 cookie.

The inclusion of the library in EDO and CCM was straightforward (just a link to https://ec.europa.eu/info/cookies_en and a <SCRIPT> tag added at the top of each webpage² header). However after installing the tool submission of data using our contact form or downloading CCM river segment and catchment data it appeared that the tool adds a URL parameter with a JSON (JavaScript Object Notation) as a value to each post request. In order to allow for this specific object we had to intervene in the security part of the program and allow for the object provided by the cookie script. This intervention was a good test for the improved security checks put in place during year 2019 and described below.

The rule that the program is to be called from a central commission service, creates therefore an extra risk for the functioning of our sites, for example if updates are made to the central library which compromise our security rules. It is therefore imperative that we are informed on updates or that we copy the library to our website and call it from there.

² All publicly available websites were provided with the European Commission CCK: EDO, GDO, ADO, SCADO, CCM, GHS. To avoid dealing with such an additional message during development or staging, the CCK was disabled into internal web servers. Three PHP constants are available in the config.php of each website to switch the CCK on or off: CCK_DISABLE_EXT, CCK_DISABLE_INT, and CCK_DISABLE.

1.3 IP address hashing and privacy-related data

In order to avoid to store IP addresses in EDO/GDO servers, their display was removed from Apache httpd access and error logs and their save in WEBHITS, HITS and DNS_IP Oracle tables is not done with plain text anymore but applying an encryption. Encrypted values are saved in the new MASKED_REMOTE_ADDRESS column, while the column REMOTE_ADDRESS is left empty. When there are needs to monitor suspicious website accesses is still possible to enable the previous behaviour and save plain IP addresses in REMOTE_ADDRESS column. This is done by dedicated settings developed to switch between the plain and the encrypted solution.

Moreover, another column, named PARTIAL_NAME, was added to DNS_IP. This is used for privacy reasons to store partial names of detected accessing users instead of full names, stored in the NAME column. The value of PARTIAL_NAME is taken considering the last three elements of the full name after exploding it by dot. For example, if a user makes access from edo.jrc.ec.europa.eu (i.e. the value stored in NAME), the value saved in PARTIAL_NAME is 'ec.europa.eu'.

IP encryption and partial names work together: when IP encryption is enabled, accessing names are saved partially, while IPs are not encrypted, accessing names are saved completely.

1.4 HTTPS activation

In addition to the security scans the request was to have all systems in the JRC working within the HTTPS protocol before 31 October 2019. The EDO and GDO system were not put in this 'encrypted' protocol up to now since the systems do not process personal or banking data. With the progress of internet use and the increasing hacking phenomena it is more prudent to also place scientific sites such as EDO and GDO in an encrypted environment. The movement of a system to a different protocol does not require any specific adaptation of the server software. However, the whole system has to be tested in order to be sure that all links still work, since the addition of this 's', might break hyperlinks or calls to programs wherever they are coded without a relative path. A specific test site was set up and minor adaptations were implemented. In general it took up to 1 week of work to port the whole system to the HTTPS protocol.

Please remember to update 'bookmarks' or 'favourites' on your web browser using the new internet address of edo being <https://edo.jrc.ec.europa.eu>. At the moment the system will automatically forward if the **s** is missing in the request.

1.5 Metadata catalogue

The Drought Metadata Catalogue, implemented during the EuroGEOSS project (years 2009-2012) and hosted by EDO subsequently, was switched off in August 2019 and replaced by a lighter dynamic list of accessible metadata.

The reasons for the dismissal of the Drought Metadata Catalogue derive from security needs and from the impossibility to update the catalogue's core software. In fact, a new version of Apache Tomcat – the servlet container which the Drought Metadata Catalogue was running on – was required to be compliant with security constraints but did not allow the catalogue work anymore. An upgrade of the catalogue was not possible either, since only the compiled Java classes and not the source code were transferred when the product was delivered to EDO by the University of Zaragoza at the end of the EuroGEOSS project. Until summer 2019 the result of this situation was a product still working, but on a server - vap-xjeddo.jrc.it – with an outdated version of Tomcat.

The mandatory request to move also vap-xjeddo.jrc.it to the HTTPS protocol accelerated the decision to switch the whole server off and to close the Drought Metadata Catalogue consequently, since any other application was not running on vap-xjeddo.jrc.it and not enough resources were available to re-build the catalogue from scratch with up-to-date and secure software.

However, in order to keep the metadata and their accessibility available, a light alternative solution was implemented. It is hosted by <https://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1103>, the same webpage which the former Drought Metadata Catalogue was accessed from.

It is a **dynamic list of drought metadata**, developed in PHP and JavaScript directly in the EDO CMS. When the webpage 1103 is opened, the included PHP program mdcatscan.php looks into the directory /var/www/edo/site/documents/DroughtMetadataCatalogue/: if the JSON file mdcat_xml_list.json exists, it is taken and read by mdcatscan.php, otherwise a scan of the /repository/ subfolder is done. In the former case, mdcat_xml_list.json is already the list of metadata and mdcatscan.php has only to display it as HTML and create the filter tools. In the latter case the scan involves all the XML files of /repository/ and its subdirectories and

the list is generated and presented on-the-fly. Moreover, the results of such an on-the-fly scan are made permanent saving the mdcat_xml_list.json file seen before and then available to be read directly in the next access of webpage 1103.

When the list of metadata is generated, it is presented as a table in webpage 1103. Metadata entries are displayed with their name, data provider and abstract and are listed in alphabetical order by name. At the top of the table there are three text fields providing input argument to JavaScript filters: if a user writes a search text in the page, the list is automatically filtered and only entries containing the inserted text are listed in the table. These three filters work independently on each column (NAME, PROVIDER, ABSTRACT) and can be used together to define composite conditions.

At the end, it is possible to get the whole drought metadata entry from a table result by clicking the value of NAME: it contains a hyperlink allowing to download the XML file of the correspondent metadata entry.

Figure 1. The new dynamic list of drought metadata: the applied filter ‘NAME contains Anomaly’ produced only 5 of 3039 possible results.

Drought Metadata Catalogue

With the move of the EDO website to the HTTPS protocol we could not take along the Drought Metadata Catalogue that was previously accessible from this page. The system worked for more that 10 years but now the technology behind it is too old to keep the software running in a secure manner. The system was based on XML files, one for each metadata record. They are listed in the table below with information on item name, provider and abstract.

- **Filter the list** writing free text in the fields below.
- **Download an XML file** clicking on metadata name; then you can use standard metadata editors to access all the information.

NAME	PROVIDER	ABSTRACT
Daily Soil Moisture Index (SMI) Anomaly Forecast for Europe, EDO (5 km Grid)	JRC-IES-CRM	In the forecasting mode the European Flood Alert System produces information on the development of soil moisture in Europe for up to ten days ahead. T [...]
fAPAR Anomaly, EDO (10-daily)	EC JRC.E.1 Disaster Risk Management Unit	The Fraction of Absorbed Photosynthetically Active Radiation (fAPAR) Anomaly shows the deviation of the current absorption of solar energy from the av [...]
Precipitation Anomaly	National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences	Precipitation anomalies are calculated for periods with different duration (hours , days, months , etc.)in order to figure out eventual drought events [...]
Soil Moisture Index (SMI) Anomaly, EDO (5 km Grid)	EC JRC.E.1 Disaster Risk Management Unit	Ten-daily soil moisture information provides an image of the current situation of the water content in the top soil layer. Soil water content is conve [...]
Water balance anomaly	DMCSEE-Drought management center for Sotheastrn Europe on Environmental Agency of the Republic of Slovenia	Water balance anomaly is based on numerical weather prediction (NWP) model simulations for area, limited to SE Europe. Non-hydrostatcal Meso-scale M [...]

1.6 Making a responsive site with the Copernicus standard

Currently, the web-sites “European Drought Observatory” and “Global Drought Observatory” are developed using an *in-house* developed Content Management System (CMS). On the server, they are organised in different folders, they share the same Oracle database and other common libraries and procedures. The system was developed in 2008 targeting desktop computers.

Nowadays, websites focus to serve multiple devices such as tablets and smartphones, besides a desktop PC.

While we were planning to reorganise our web site to make it adaptive and responsive, we received directives to adapt our pages to a common “look & feel” for websites financed by the Copernicus Project. We can use the so-called Copernicus Component Library (CCL which is a tool developed by an unknown party) to achieve this target.

As far CCL is supposed to adhere to the adaptive/responsive requirements, we decided not to implement our own new look & feel, but try to apply the CCL standard to our web pages.

A few concerns aroused using this CCL adoption:

- Its complexity: several compulsory scripts and styles to include, highly impacting coexistence with ours;
- Instability: due to many existing bugs we found, we assume that additional releases will follow, making continuous adaptations likely.

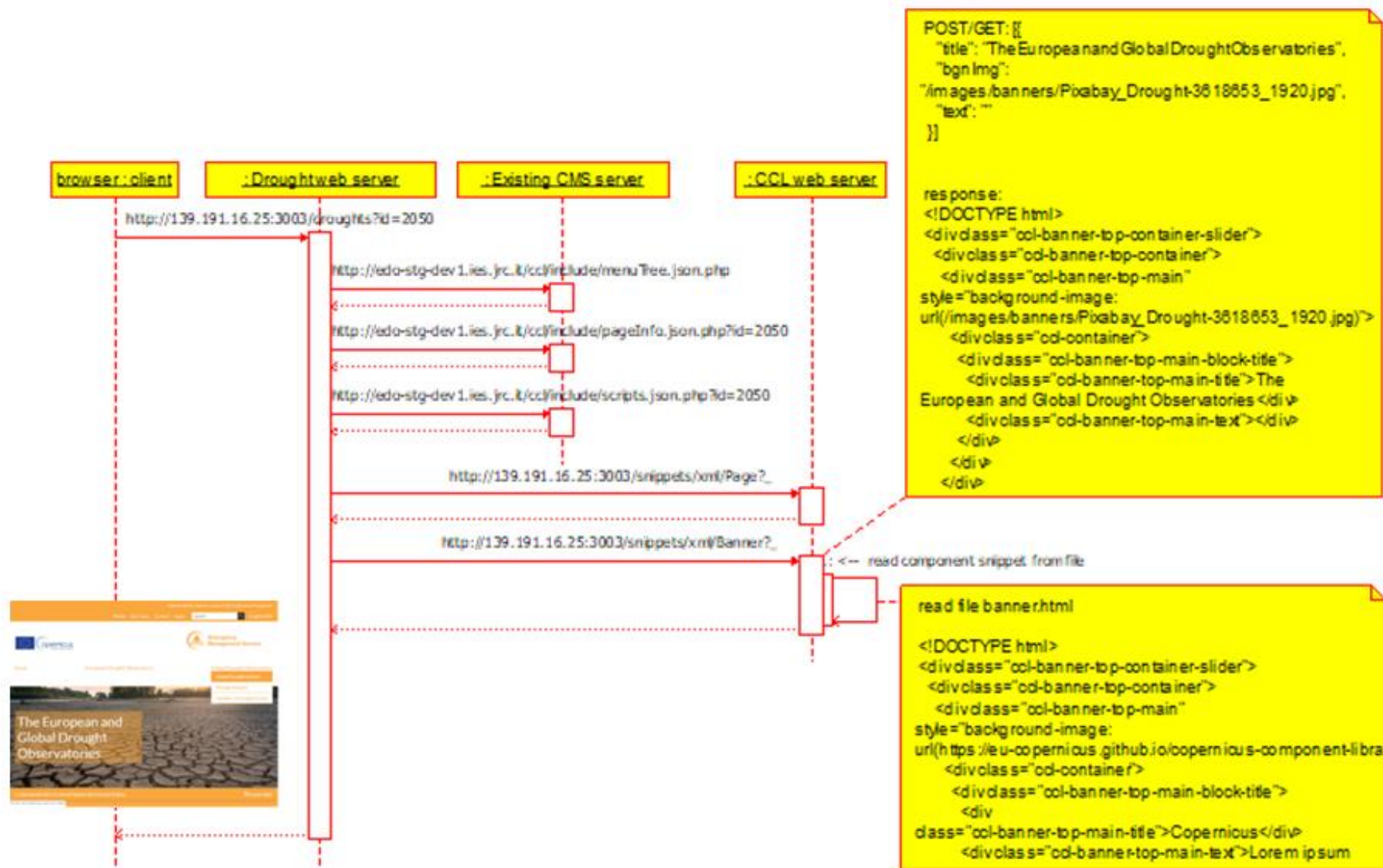
1.6.1 Proposed implementation strategy

A traditional CMS, like ours, delivers a complete HTML page assembled by backend CMS services. It is difficult to render such a page properly on different devices. “Templates” used in traditional CMS cannot be successfully used to display content on smartphones as well as desktop PCs. A feasible solution is the so-called “Headless CMS” or “Decoupled CMS” architecture, a new trend in CMS development, which separates presentation (HTML generation) from content. This is achieved by instructing the CMS back-end to generate, via API (Application Programming Interface) calls, a sort of “neutral” costumed set of HTML snippets to feed a “device best-suited page framework”, usually managed by independent processes.

Because we have full control of our CMS coding, we decided to extend it, adding APIs to make it work as a Headless CMS, instead of replacing it. Using such an approach, we can keep the current web site working, while implementing a new one; sharing the same page content stored in the database. Although, we need a complete new module to manage the presentation component that calls APIs on CMS rendering its responses into Copernicus Component Library (CCL) templates.

In Figure 2, the proposed architecture is presented. Starting from a web page user request, the schema shows the chain of calls and processes involved to serve the final web page to the user.

Figure 2. Schematic overview of the Web page creation



Three core services are displayed in Figure 2, theoretically described as hosted on a single ‘server’ each.

- **Drought Web Server**. It directly interacts with user requests and composes the page to display. It does this by requesting raw information from the “Existing (but extended) CMS server”, and sending it to the “CCL web server” to have the page properly styled using the corresponding components, before merging all of them in a final HTML page.
- **Existing CMS Server**. The one in production today. A new API interface, built on top of it, can deliver ‘beans’ of raw information, accessing the same database we use now.
- **CCL Web Server**. It takes care of returning properly formed snippets of HTML code (components of Copernicus templates); it’s conceived as a separate service, because it could be used by any other partner using CCL directives.

1.6.1.1 DOM Manipulation

As an alternative to direct streaming of a complete HTML page, by using DOM APIs (available with many programming languages) we can create new HTML- or XML documents, clone existing pages or parts of them from existing saved files, navigate among their ‘nodes’, create, insert, delete or alter ‘nodes’, before ‘streaming’ the final HTML document to the user. This technique is useful for the adaptation of our web site to the new Copernicus standard. Using DOM APIs we can “inject” information extracted from our database into predefined HTML components of the CCL library.

The architecture based on this technique can adapt dynamically to changes that might occur in the CCL library, during its bug-fixing and implementation.

Moreover, DOM manipulation can occur on either server-side or client-side; meaning that on his browser a user can receive a complete HTML page (built using this technique) from the server or have it built from scratch on his browser, having received a set of scripts that start requesting ‘to fill in’ information from the server and build the final HTML page on-the-fly.

This second option would make the system more performant and would release the server from recursive loads.

In the prototyping phase of the project, we have chosen to use DOM manipulation on the server, but having in mind to move it to the client. To ease this transition, we use JavaScript as developing language, because it is the language used by browsers but it can also be used server-side by using a tool called Node.js.

Summarising, the three services described above are implemented as described below.

- Drought Web Server hosts a service built on top Node.js and Express.js.
- Existing CMS Server, that uses PHP, is extended with new APIs using PHP.
- CCL Web Server hosts a service built on top Node.js and Express.js.

1.6.2 The Europa Component Library (ECL)

While the above-described implementation was in progress, we received additional directives on a new look & feel standard to adopt for all European Commission web pages.

These new directives are accompanied by a new Europa Component Library (ECL).

ECL structure looks like CCL. That means that the software architecture planned to manage CCL could be used by both of them. Namely: textual information extracted from our database could be adapted on-the-fly as CCL or ECL adding just a parameter to differentiate between them.

For the user this implies that switching between a Copernicus and Commission standard Look and Feel is just a switch of 1 parameter only.

1.6.3 Progress in the development server

Studying the new ECL architecture, we started adapting the code produced for CCL to work properly also with ECL. Beside this latest “reset”, progress of our CCL developing project is described below.

A test-site is running in the local network as <http://139.191.16.25:3003>, as a Node.js/Express instance.

1.6.3.1 Services on Node.js

Currently, Drought Web Server and CCL Web Server respond on the same web server instance as:

<http://139.191.16.25:3003/drougths/>

<http://139.191.16.25:3003/snippets/>

Invoking [http://139.191.16.25:3003/snippets/html/banner?items=\[.....\]](http://139.191.16.25:3003/snippets/html/banner?items=[.....]) (value of item being a specific chunk of json format data to be render) we get a costumed "banner" to insert into the main page.

Figure 3. The HTML code of the costumed banner

```
<!DOCTYPE html>
<div class="ccl-banner-top-container-slider slick-initialized slick-
slider">
  <div class="slick-list draggable">
    <div class="slick-track" style="opacity: 1; width: 909px; transform:
translate3d(0px, 0px, 0px);">
      <div class="ccl-banner-top-container slick-slide slick-current
slick-active" data-slick-index="0" aria-hidden="false" tabindex="0"
style="width: 909px;">
        <div class="ccl-banner-top-main" style="background-image:
url(/images/banners/Pixabay_Drought-3618653_1920.jpg)">
          <div class="ccl-container">
            <div class="ccl-banner-top-main-block-title">
              <div class="ccl-banner-top-main-title">The European and
Global Drought Observatories</div>
              <div class="ccl-banner-top-main-text"/>
            </div>
          </div>
        </div>
      </div>
    </div>
  </div>
```

Invoking <http://139.191.16.25:3003/drougths>, it displays the page in the **Error! Reference source not found.**

Figure 4. Drought landing-page



This page is rendered invoking many sub calls. One of them asks the “Existing CMS Server” for a hierarchical data structure of the whole web site. It uses this information to render the top menu

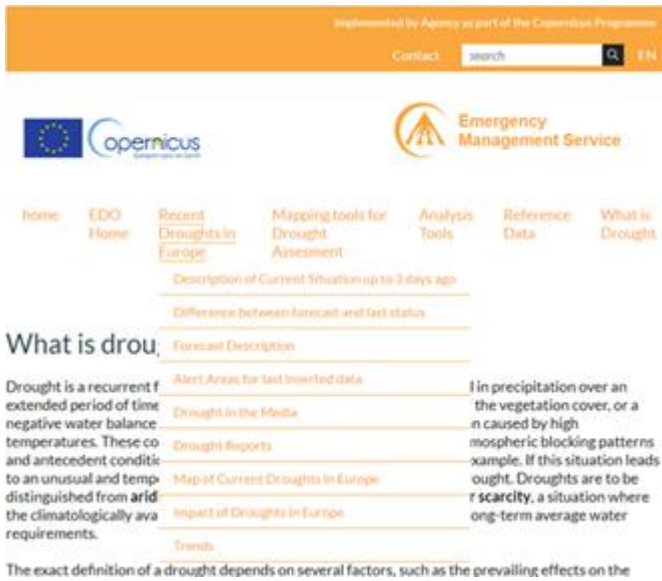
This first page is an access point to both the European and Global Drought Observatories, currently organised as independent web sites (EDO and GDO).

Figure 5. Main menu in landing-page



Any item in main menu invokes a new specific page appending an “id” to its address (e.g. <http://139.191.16.25:3003/droughts?id=1001>), that displays a new page with the main menu integrated into it.

Figure 6. Main menu in a sub-page



1.6.3.2 APIs extending the web server in use

All contents of previous page examples come from the same database actually used by the EDO and CCM web sites. Their extraction is deferred to the new APIs extending the CMS in use.

1.6.4 Concerns on further development

At present, extended APIs on Existing Web Server can generate simple HTML code or chunks of structured data (e.g.: the one used for menus).

The main part of EDO and GDO are however pages delivering Web Maps and Graphics. The current standard is not providing a reference for those functionalities making the work to be done on that aspect uncertain.

Other uncertainties derive from the unclear relationship with the third party in charge of CCL development. The current version of CCL has bugs to be fixed and functionalities to be changed. The main flaw being the colour choice of orange fonts colour over a white background, which is against Commission readability standards. Any change on the CCL cannot be decided without coordination between the Copernicus partners. Such coordination might take an additional investment in time before delivering a usable product that satisfies all needs. In addition to this also the new Commission standard arose, adding up to the uncertainty.

1.7 Virtual Machine upgrades and automation

Since 2019, a processing Virtual machine (address: e1-drought-pro.ies.jrc.it) is running, and it is used to execute the data processing. We are in a process to base all pre-processing of EDO and GDO data on Open Source software with Python 3.x as the main working force. With this strategy we aim to make the system portable to other institutions or third parties entrusted with executing operational tasks. In addition to this the platform allows to initiate and automate processes automatically, confirming the status of processing by sending emails to the operator. The virtual machine created for this purpose is based on the CentOS 7 operating system and uses 3 processors and 16 GB of RAM, with different system internal storages (281 GB). The system can be mounted from ies-ud02.ies.jrc.it. At the moment, the procedures running inside the virtual machine are:

Table 1. Running procedures on the processing virtual machine

Site	Procedure	Programming languages	Periodicity

EDO	Soil Moisture Index (SMI) and Soil Moisture Index Anomalies	Python, sql	Daily
EDO	Low flow Index	Python, sql	Daily
EDO		Python, R, sql	Monthly
GDO	Low flow Index	Python, IDL, sql	Daily
GDO	Precipitation data update Standardized Precipitation Index (SPI) SPI forecast	Python, R, sql	Monthly

The remaining EDO and GDO data procedures will be migrated gradually to be processed on the virtual machine, or they will be triggered automatically in the database (upon completion of a certain record in the database) in order to centralize, manage and automate the data processing needed to insert data into EDO and GDO.

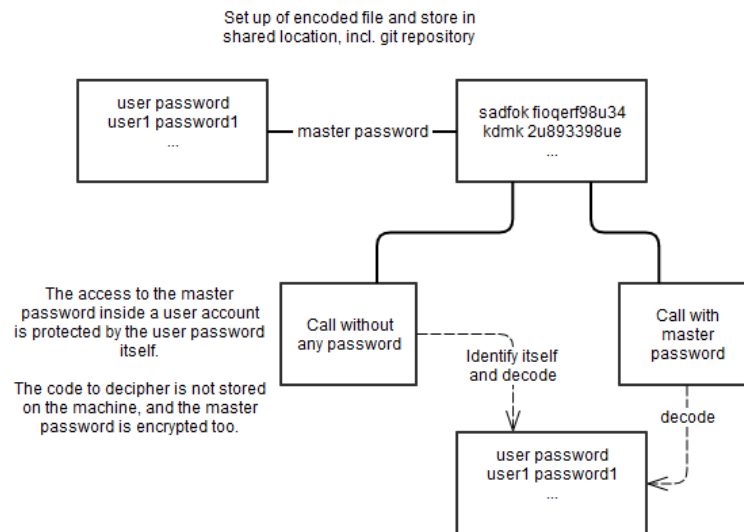
1.8 Python utilities

Occasionally, passwords are required to execute some procedures, thus preventing their full automation. Since hardcoding of passwords in code scripts is unsafe, a utility program was written to store and retrieve passwords protected by encryption, accessible to procedures. The methodology roughly consists in storing encrypted access IDs and passwords in a file and using one or more master keys to decipher them. The master key may be embedded inside a user account and specific machine, therefore allowing the automatic retrieval of passwords during programs execution on that specific machine and user account. This has some advantages:

- A user may include many id-password combos encrypted with different master passwords in a single file and each would be decoded only with the related master password (i.e. users can share such file, but only those passwords for the master key is known are accessible to a certain user).
- There is not a readable list of user id or schemas, which must be known in advance to access its password.
- It enables the use of programs that require password input without actually typing any at execution time (nor hard-coding it in programs).
- No need to interact forcefully with a database.
- Files with passwords can be tracked in version control.

As mentioned above, this approach allows to set up a master password only once inside a machine and user account and then decode the file containing the id-password information without submitting or hard-coding passwords any further, under the condition that execution is launched from the same user/machine (i.e. it is protected by password to access those). The program is written in Python. This is useful for procedures running on the virtual machine, or any program that needs passwords during execution. There, the account executing the procedure will recognize itself and decode correctly the master password to be used to access the id-password combos, stored in the encrypted file.

Figure 7. Password encrypting schema



1.9 Software and Documentation management

Collaborative development capabilities were extended by joining projects on GitHub and Gitlab platforms. Accessible (after permission) via <https://webgate.ec.europa.eu/CITnet/confluence/display/DROUGHT>. Bitbucket is the platform of choice for GDO and EDO development, currently operational, as already documented in 2018. Documentation about software developments, thematic information, tasks, etc. grew steadily during 2019, doubling the content on Confluence compared to 2018. In particular, most procedures are now described and supported with help pages. Part of this report is generated using components of the Confluence library.

1.10 Data provision to third parties

The provision of soil moisture data to **InterDrought** (InterSucho) continued in 2019 with the changes described in Section 4.4.3.

The data provision as legacy of the SCADO / EuroLima project via automatic upload to the partner's FTP server continued as well involving:

- quicklook maps of **fAPAR Anomaly** of Central and South America delivered every 10 days to **CIIFEN** (Centro Internacional para la Investigación del Fenómeno de El Niño);
- quicklook maps of **fAPAR Anomaly** of Central and South America delivered every 10 days to **EUMETSAT** (European Organisation for the Exploitation of Meteorological Satellites);
- GeoTIFF files and quicklook maps of **SPI** (all timescales) of Central and South America delivered every monthly to **EUMETSAT**.

As an output of the EDO User Meeting 2019 we started a collaboration with **CRC-SAS** (Centro Regional del Clima para el Sur de América del Sur / Centro Regional do Clima para o Sul da América do Sul) providing maps of SPI (all timescales), Soil Moisture Anomaly and fAPAR Anomaly for the southern part of South America from the begin of the time series (1950 for SPI, 2001 for the others) to 2019 (July for SPI, 1st dekad of August for the others).

Moreover, during the year, EDO and GDO offered occasional data provision to:

- Andreas Güntner, senior scientist from Potsdam University (Institute of Earth and Environmental Science), G3P (Global Gravity-based Groundwater Product) project: upon request of SMI Soil Moisture Index anomalies and monitoring data, from 2002 to 2019 of the new LISFLOOD extended window. Any further request did not followed, but the project will be active for four years.

- Rachel Green, PhD student at the Department of Geography, University of California, Santa Barbara (USA): upon request, we delivered GeoTIFF files with data from 2001 to September 2019 over the central part of Eastern Africa of Soil Moisture Anomaly, SPI (timescales 01, 03 and 12) and fAPAR Anomaly, together with a flowchart displaying the algorithm to calculate the hazard component of RDrl-Agri and .qml files to colorize data in Quantum GIS according to the classifications used in GDO.
- Mélanie Ludot, Euralis Semences, Lescar (France): upon request of drought maps of Europe, we suggested the use of the WMS service of EDO and webpages 1161 (OWS Delivery Wizard) and 1167 (Download CDI data by country in CSV format) for the CDI.
- Johannes Klein, Senior Researcher, Geological Survey of Finland, Espoo (Finland), project "Territorial impacts of natural disasters": upon request of drought maps of EDO, we suggested the use of EDO Web Map Services for your own GIS (EDO webpage 1165) and the Database of Drought Events (GDO webpage 2020).
- Hamideh Nouri, Senior Research Fellow, Water Engineering and Management, University of Göttingen (Germany): as part of the GlobeDrought project working on droughts and in the context of agricultural drought and the Global Crop Water Model, they built two indicators named aridity index (AI) and crop drought index (CDI) to distinguish between aridity and drought impacts and check for drought effects on different crops. On a global scale for the period 1986-2016 and as part of the comparison section, they intended to compare the RDrl-Agri indicator with their results, which we provided for the period from 2013 to 2019 in NetCDF format.
- Mapping Team of Unit E.1 of JRC: as agreed with them, for every analytical drought report produced they would make a daily map related to the event. This resulted in seven daily maps published on ECHO ERCC portal (out of 13 analytical reports), for which we provided all or some of the data.

2 Enhancing the content of the Global Observatory

In this chapter we present the work done in 2019 in which expanding and improving the content of the Global Observatory was the main objective. New data sources relevant for Drought Monitoring become available each year. But perhaps more important for a monitoring platform is that technologies evolve fast both in the pre-processing phase as well in the phase where we deploy products and present them on an Internet platform. In chapter 5 the more technical oriented changes are reported. With the gradual growing together of the European and Global Drought observatory, most content changes at Global Level are also represented in the European Interface. Main driver this year was to improve the understanding of additional drought-related issues, related to mitigation, total water storage availability and an alternative for the Vegetation monitoring product we now use, since the lifecycle of the MODIS Satellite it depends on, is overdue.

2.1 Drought Mitigation

In the Drought Monitoring field, we see a gradual convergence of methods to monitor drought. Standardized Precipitation Indices, fAPAR or NDVI (Normalized Difference Vegetation Index) anomalies are more or less measured and reported everywhere. This convergence of methods allows researchers to compare events and to exchange data. The comparability of methods leads to a similar demand about the mitigation. This are the methods to make society or a landscape less prone to drought impact. In this field however methods are still very divergent. In short, we can distinguish so-called grey and green solutions. The grey solutions involve engineering solutions such as dams and canals whilst the green solutions focus more on adapted tillage methods, restoration of micro relief, reforestation and restoration of river systems to their natural, often meandering, state.

2.1.1 Global Dam's database

Data available internally about dams were updated and extended. GRanD data were updated to version 1.3 (<http://globaldamwatch.org/grand>). The database was extended with several other datasets (Table 2), but data currently accessible on GDO are derived solely from GRanD database version 1.3. The datasets not included were left out for two possible reasons: some data have uncertain or restrictive copyrights, while other lack key information to be useful. Nevertheless, they are still useful for monitoring purposes and are being maintained with periodical checks to the sources, specifically: OpenStreetMap Dams, Japan Dam Foundation, United States National Anthropogenic Barrier Database and United States National Inventory of Dams, Volta Basin Dams - Google Earth, GLObal georeferenced Database of Dams (GOOD2), Future dams FHReD 2015 (beta version). It should be noted that the most extensive and complete global dataset of dams is ICOLD (<http://icold-cigb.org/>), but so far the data do not include any geospatial information. The raw data from various sources is uploaded or updated on the database through the program *rawdata_2_oracle_power_dam.R*.

The table DAMS in the GEOREF schema is the table of reference for dams data. The table contains the data from different datasets validated and integrated across a few relevant attributes: unique identifier (ORIGIN_ID), item name (DAM_NAME), latitude (LAT), longitude (LON), dam capacity (RESERV_CAP_MCM), main use (USE), river name (RIVER), size of upstream basin (BASIN_KM2), country (COUNTRY), source dataset (SOURCE) and specific record information (INFO). Underlined are those attributes that should be visible to the user in the final product. Missing values are allowed. The lookup table below (Table 2) provides the key to link the attributes to those from source datasets.

Table 2. Look-up table to link the attributes of the main DAMS table to attributes of source datasets, when applicable. Currently, only those in bold are used to populate the main table.

Final table view fields →	ORIGIN_ID	DAM_NAME	LAT	LON	RESERV_CAP_MCM	USE	RIVER	BASIN_KM2	COUNTRY	SOURCE	INFO
DAMS_GRAND_13	GRAND_ID	DAM_NAME	LAT_DD	LONG_DD	CAP_MCM	MAIN_USE	RIVER	CATCH_SKM	COUNTRY	[GRanD v1.3]	URL

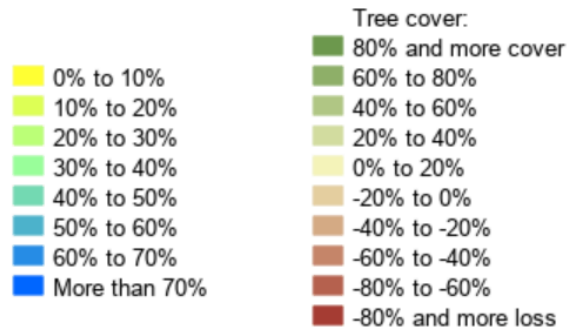
DAMS_ECRINS	NOEEA	DamName	Y_DD	X_DD	VolRet	use_sor ted	ic_River		CT		
DAMS_MARS		dam_na me	lat	lon	-		ic_river		cc		
DAMS_OSM	osm_id	name	lat	lon	-	-	-		-	OpenStreet Map Dams	-
DAMS_JAPAN	-	name	lat	lon	capacity_mcm	use	-	catchment_ km2	[all JAPAN]	Japan Dam Foundation	url
DAMS_USA	NIDID	Dam_na me	newY	newX	NID_stor	Purpose s	River	Drain_area	[all USA]	United States National Anthropoge nic Barrier Database and United States National Inventory of Dams	
DAMS_VOLTA_ BASIN	Name	-	Latdeg	Londeg	-	-	-		-	Volta Basin Dams - Google Earth	-
DAMS_GOOD2	DAM_ID	-	lat	lon	-	-	-		-	GlObal geOreferen ced Database of Dams (GOOD2)	-
DAMS_FUTURE	DAM_ID	Projectna me	LAT_Clea ned	Lon_Clea ned	-		Main_ri ver		Country	Future dams FHReD 2015 (bet a version)	Referen ce1

2.1.2 Potential Tree planting Location theme

In July the Crowther Lab published a much-cited article in Science (Bastin, et al. 2019) describing the potential locations for massive tree planting. Their objective was focussed on the carbon sequestration potential of trees. However it is clear that massive tree planting would alter local weather and ultimately impact the local climate with respect to both temperature as well as precipitation. We contacted the author who subsequently gave us access to the result data of his analysis. We converted this result to our system, allowing to include 3 new themes into the Global Drought Observatory. From a unique multi-theme layer named “**Potential tree cover analysis**”, placed in the new “Drought Mitigation” subgroup of “Global Drought Products”, these themes can be accessed: “**Potential tree cover**”, “**Tree restoration potential**” and “**Risk of future changes in tree cover**” (all in percentages per pixel).

The three themes load raster images at 1/10 decimal degree resolution from the directory /var/www/edo/gisdata/world/tree_cover/ (Total_potential_wgs84.tif, Restoration_potential_01dd.tif, and Future_risk_01dd.tif respectively), using OsGeo MapServer WMS and its base.map mapfile. Their classifications are displayed in the next figure.

Figure 8. Classification of the themes of “Potential tree cover analysis”: “Potential tree cover” and “Tree restoration potential” share the classification on the left while “Risk of future changes in tree cover” uses that in the right.



The “Tree restoration potential” is the default layer: it is the potential tree cover minus agricultural and urban land. The future changes in tree cover are related to climate heating scenarios and therefore very relevant to confront with the existing forest cover. The latter is available in the Land cover theme of EDO and the FAO (Food and Agriculture Organization of the United Nations) Land use themes in GDO.

Figure 9. Excerpt of GDO showing Europe with pixels displaying a potential percentage for reforestation (theme “Tree restoration potential”)

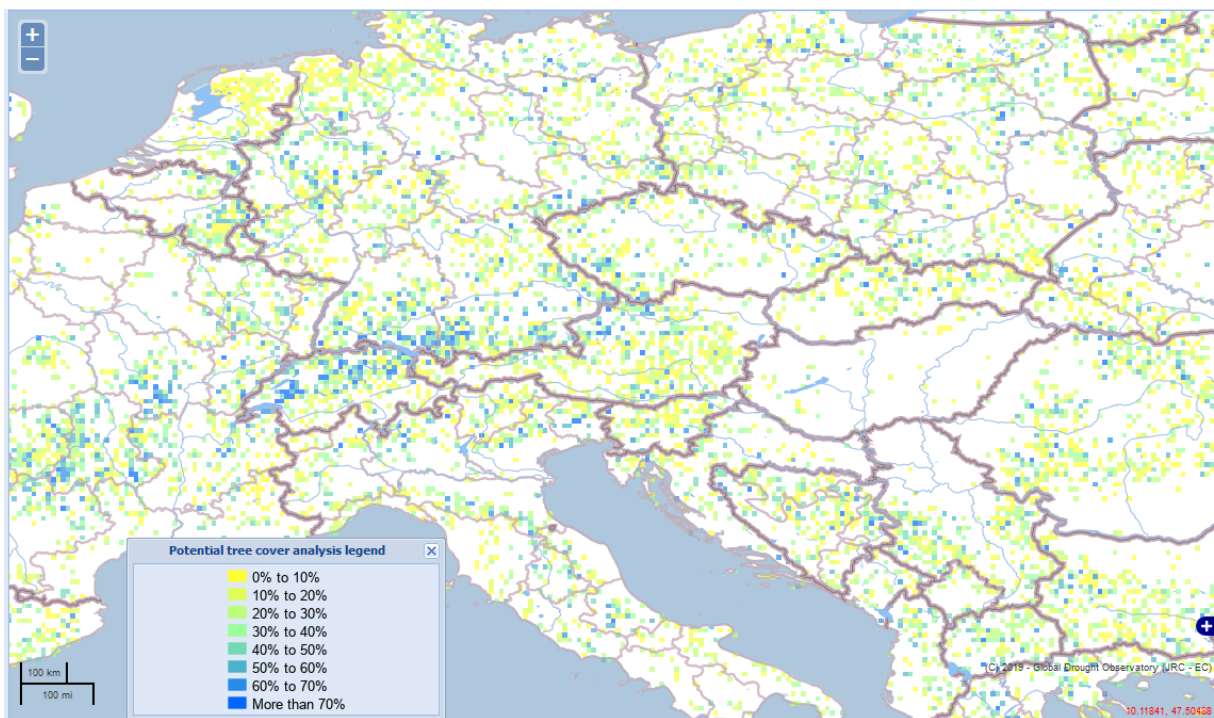
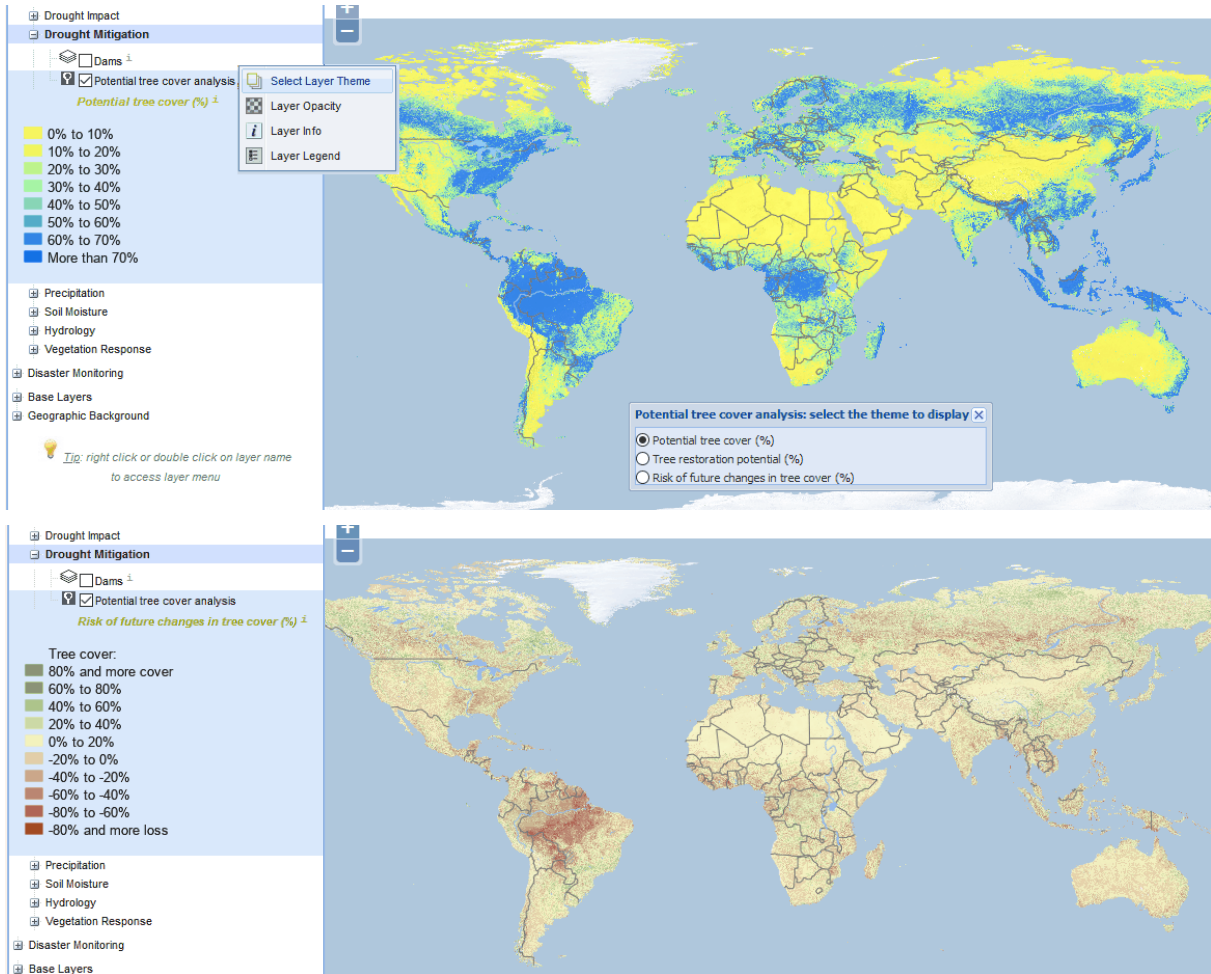


Figure 10. “Potential tree cover” (top) and “Risk of future changes in tree cover” (bottom) worldwide. They are accessible right-clicking the layer “Potential tree cover analysis” within the new “Drought Mitigation” subgroup, opening the “Select theme” tool and choosing the theme.



The maps give a comprehensive overview of the potential of Massive Tree planting in direct relation to the occurrence of Droughts in the past and now. Such a combination of data helps to understand the feasibility of ambitious projects as well as it clarifies the direct interest of combating drought through reforestation such as is done in the Green Wall project in the Sahel region.

2.2 PROBA-V experiment

The Copernicus Global Land Service (<https://land.copernicus.eu/>) has made available fAPAR maps since the launch of PROBA-V (Project for On-Board Autonomy - Vegetation) sensor in 2013 as a successor of the SPOT (Satellite Pour l'Observation de la Terre) series of vegetation instruments. The version 2 of the Copernicus 1-km fAPAR product (namely GEOV2) provides near-real time, continuous series of fAPAR maps starting in 1999 by combining data from both SPOT-VGT (SPOT Végétation) and PROBA-V.

Unfortunately, some systematic discrepancies in the transition from SPOT-VGT to PROBA-V, which affects the inter-annual precision, were observed by several authors (e.g., (Fuster, Sánchez-Zapero and Camacho 2018)). Effects of this temporal inconsistency has been investigated and corrected by (Cammalleri, et al. 2019) by comparing the data with MODIS (Moderate Resolution Imaging Spectroradiometer) product. Bias corrected fAPAR maps based on two separate lagged linear corrections are produced.

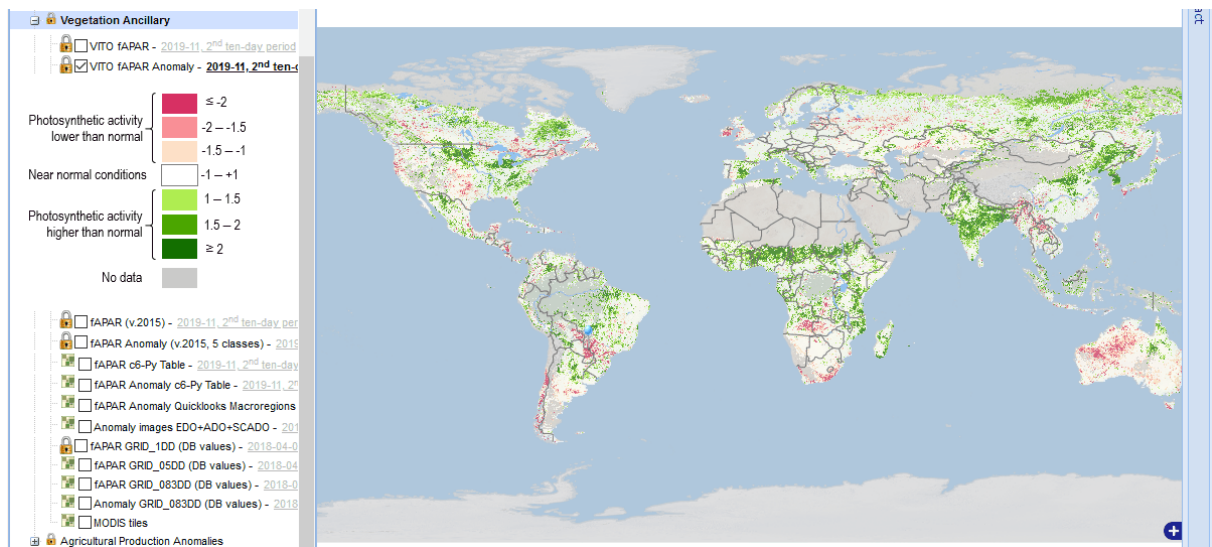
The data are processed in the ENVI+IDL environment. Dekad raw data (in NetCDF format) are analysed by the program `fapar_vito_oper.pro`, which resamples the data on a 0.01 degree lat/lon grid, applies the bias correction factors and masks areas with low quality estimates. Successively, the data are aggregated at 1/12 degree resolution with the program `fapar_aggregate_global_vito.pro` and anomalies are computed with the program `fapar_anomalies_global_aggregate_vito.pro`. For every dekad the final output of this procedure are two GeoTIFF

images saved into the /FAPAR/Global_NEW/ directory of the central repository: fAPAR_VIT_[YYYY]_[DK].tif (/fAPAR_VITO_oper_083/ subdirectory) with fAPAR data and fAPAR_anom_VIT_[YYYY]_[DK].tif (subdirectory /anomalies_VITO_oper_083/) with fAPAR Anomaly data, where [YYYY] and [DK] are the year and the dekad number (from 01 to 36).

Subsequently fAPAR_VIT_[YYYY]_[DK].tif and fAPAR_anom_VIT_[YYYY]_[DK].tif are processed by geotiff2ora.py to use data in GDO, at the moment only in its internal development and stage servers. Values are inserted into the Oracle table GRID_083DD_VITO_FAPAR (vegeprd user, ABSORBED_[MM][DD] and ANOMALY_[MM][DD] columns) and quicklooks named fAPAR_an_[YYYY]-[MM]-[DD].gif and fAPAR_VIT_an_[YYYY]-[MM]-[DD].gif ([MM] is the month, [DD] the 10-day period) are saved into the /fapar/[YYYY]/ and /fapar_anom/[YYYY]/ subdirectories /var/www/edo/gisdata/world/fapar/quicklook/083dd/. For example, from fAPAR_anom_VIT_2019_33.tif the quicklook fAPAR_VIT_an_2019-11-21.gif is generated and fAPAR Anomaly data of the last dekad of November are put into the table.

The PROBA-V quicklooks are visible within the GDO MapViewer through the locked layers “VITO fAPAR” and “VITO Anomaly fAPAR” of “Vegetation Ancillary” subgroup, as displayed in the next figure. They adopt the same classifications and colour schemes of the correspondent MODIS-based layers. Data are available since January 2019.

Figure 11. “VITO fAPAR Anomaly” of the second dekad of November 2019 for the whole world.



2.3 Soil Moisture 2M/3M and inclusion in RDrl-Agri

An important drought indicator was revised in GDO during 2019, “**Soil Moisture Anomaly**” (SMA). In GDO it is derived from anomalies of estimated soil moisture (or soil water) content, which are produced as an ensemble of three datasets: the JRC’s in-house LISFLOOD hydrological model, the MODIS-derived land surface temperature and ESA Climate Change Initiative (CCI) combined active/passive microwave skin soil moisture. Details on the use of these datasets for drought detection can be found in the 2018’s Annual Progress Report of the European and Global Drought Observatories and in the product factsheet at https://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_soilmoisture_gdo.pdf.

Theoretically, it would be computed 3 times a month (after the 10th, the 20th and the last day of the month) with a moving window covering the previous 30 days, for a total of 36 updates in a year.

However, since the ESA CCI component usually becomes available almost a week later than the other two datasets, a practical approach to compute a first guess and a complete version of the SMA for each moving window has been established. This allows producing a first guess update of SMA at the same day of the corresponding date’s fAPAR Anomaly and subsequently re-computing it with the missing component.

By consequence, there are 2 updates for each moving window, hence 6 computations of SMA for a month and 72 computations in total in a year.

SMA images are saved into the central repository: 2M ones as ENS_anm_[YYYY]_[MW].img (or .hdr) in /soilmoisture/dekad/, 3M ones as ENS3M_anm__[YYYY]_[MW].img (or .hdr) in /soilmoisture/3M_dekad/, where [YYYY] is the year and [MW] the number of the moving window, from 01 to 36.

In GDO we refer to the **First Guess SMA**, made with LISFLOOD and MODIS datasets, with the **2M** abbreviation (meaning two models) and to the **Complete SMA**, made with all the three components, with **3M**.

This approach does not affect the computation of RDrl-Agri, since the considered SMA moving window is not that corresponding to the RDrl-dating fAPAR Anomaly but the previous one, which is already available as complete (3M), except for longer than usual delays of ESA CCI data. For example, this is the chronological sequence of Soil Moisture Anomaly 2M/3M and RDrl-Agri for the second dekad of October:

Table 3. Chronological sequence of computations of SMA 2M/3M and RDrl-Agri for dekad 2019-10-01. Used abbreviations are: LIS = LISFLOOD, MOD = MODIS, CCI = ESA CCI, fPA = fAPAR Anomaly.

Date of source dataset availability and derived indicator processing	Source dataset	Source dataset processing date	Derived indicator	Indicator reference date	Used for RDrl-Agri 2019-10-01?
Oct. 7 th , 2019	GPCC SPI	Oct. 7 th , 2019	SPI	2019-09	Yes
Oct. 3 rd , 2019 (LIS); Oct. 10 th , 2019 (MOD)	LIS + MOD	Oct. 10 th , 2019	SMA 2M	2019-09-21	No
Oct. 3 rd , 2019 (LIS); Oct. 10 th , 2019 (MOD); Oct. 14 th , 2019 (CCI)	LIS + MOD + CCI	Oct. 14 th , 2019	SMA 3M	2019-09-21	Yes
Oct. 17 th , 2019	MODIS	Oct. 17 th , 2019	fAPAR Anomaly	2019-10-01	Yes
Oct. 7 th , 2019 (SPI); Oct. 14 th , 2019 (SMA 3M); Oct. 17 th , 2019 (fPA)	SPI + SMA 3M + fAPAR Anomaly	Oct. 17 th , 2019	RDrl-Agri	2019-10-01	-

The procedure to put data into Oracle and to generate quicklooks to be visualized in the MapViewer is that described in Section 6 of the 2018's Annual Progress Report of the European and Global Drought Observatories, with few modifications and the need to specify the type of data to be processed (2M or 3M). The updates done in 2019 are listed below, while a step-by-step description of the current procedure is reported in the CITnet Confluence workspace at <https://webgate.ec.europa.eu/CITnet/confluence/display/DROUGHT/GDO+10-daily+Soil+Moisture+Anomaly>.

- The Python program `1_converttogrism.py` requires now 4 arguments: year, month, dekad (01, 11, or 21) and type of SMA (2M) or (3M). For example:

```
python C:\dev\applications\python\soilmoist\1_converttogrism.py 2019 11 21 3M
```

The program saves the downloaded image in the correct directory depending on its type, 2M or 3M. Moreover, it automatically launches `check_sm_rowid.py [YYYY]`, to manage ROWIDs depending on the provided year and used to optimize the computation.

- Also `2_netcdf2grid.py` and the automatically called `sync_filedbturboid.py` require the additional argument of SMA type, for example:

```
python C:\dev\applications\python\soilmoist\2_netcdf2grid.py 2019 11 21 3M
```

The SMA type is included into the comment associated to the column ANOMALY_[MM][DD] of the target GRID_01DD_ENSEMBLE_SM Oracle table. Moreover, values over oceans are now excluded from processing, with a significant improvement in computation time.

- `sync_grid_01dd_ensemble_sm.py` requires the additional argument of SMA type as well, for example:

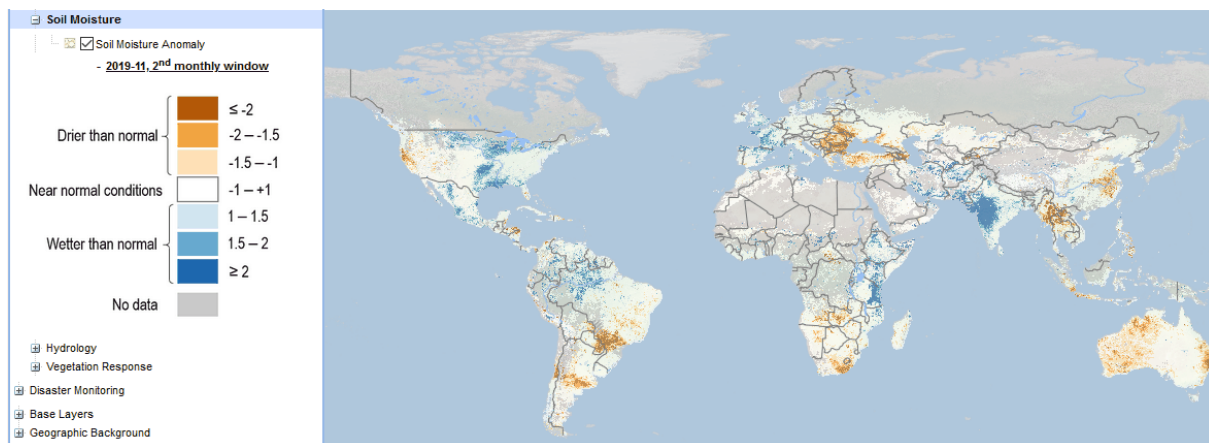
C:\dev\applications\python\soilmoist\sync_grid_01dd_ensemble_sm.py 2019 11 21 3M

It deals with writing logs about the processed SMA:

- o Like the previous, it writes comments for GRID_01DD_ENSEMBLE_SM.ANOMALY_[MM][DD] on Esposito;
- o inserts a log into the new GRID_01DD_ENSEMBLE_SM_LOGS Oracle table (solmprd schema), stating target year, month, dekad, SMA type and processing date;
- o updates DATA_LOGS Oracle table (drought schema), used to compute RDrl-Agri, to state if the SMA of a certain dekad is 2M or 3M.
- SMA type must be specified also in <http://edo-stg.ies.jrc.it/gdo/php/index.php?id=2065>, the web interface to generate the map of Soil Moisture Anomaly.
- Every time new Soil Moisture Anomaly data are available, the “history” to generate graphs of SMA in the Automatic Report webpage³ must be updated. To do that, the following two procedures must be executed in Oracle, drought schema:
 - o execute `gdo.UPD_ARU_HST('SoilMoisture', [YYYY][MM][DD], NULL)`; to actually compute the “history” in DEA DB;
 - o execute `gdo.SYNC_TABS_ARU_HST([YYYY][MM][DD])`; to synchronize Esposito DB.

Within the GDO MapViewer and the Compare 10day-period maps (webpage id=2076), the layer “Soil Moisture Anomaly” is now adopting the new classification and colour schema seen for the EDO-equivalent layer and shown in the figure below.

Figure 12. “Soil Moisture Anomaly” of the second monthly window of November 2019 for the whole world.



The value of soil moisture anomaly is displayed also in the output of Identify All Drought Indicators.

³ On every dekad we estimate drought impact on each administrative reporting unit (ARU, administrative region or country) through the distribution of risk classes over the whole reporting unit. This is done both for RDrl-Agri and for fAPAR and Soil Moisture anomalies. Since the last two are collected at higher resolution (1/12 degree and 1/10 degree, respectively), their time-consuming computation is done once and their results are stored in a dedicated database table (REPORTING_UNITS_STATS_2), later used in reports to draw bar-charts representing the evolution over time (“history”) of cited indicators for each reporting unit.

3 Sectorial Drought Indices

With the development of the Combined Index for Europe and the Risk of Drought Impact index for the Global Observatory we concentrated on Drought alerts related to potential agricultural losses. Drought impacts also other sectors of society and nature and we therefore promised to develop additional indices helping to create an alert when an ongoing drought impacts a specific sector. The sectors we addressed this year are all related to so-called Hydrological Droughts, it are droughts that last a long period and can even be interrupted by some rainfall. The main problem of the sectorial indices is that for the alert to be valuable, geographic context information is required. For agricultural indices we could accommodate this requirement up to a certain extent with the fAPAR component, which gives an indication of the growth of the vegetation. Whether a city such a Cape Town or Rio de Janeiro ran out water in reservoirs high up in the hills around the cities requires specific information on the manner such a city is provisioned with drinking water. Industry using water to cool down, for example (nuclear) power plants, also requires specific information on how the local water system is functioning. In order to address this issue of local relevance we developed an index for drought in wetlands accompanied by as much local information of the wetlands as we can find. Wetlands being protected under the Ramsar treaty are collected by a central organisation which collects site-specific information on the wetland, thus allowing a quick determination on whether the drought puts specific ecosystem services at risk.

Research and Development of Future sectorial indices are manifold. But most require specific local knowledge in order to be predictive. In order to be successful in this domain we will set up collaborations with more regional based institutions studying drought. Examples are:

- Drought Impacts on herds of free wandering cattle (Sahel region, droughts leading to conflicts)
- Long-lasting Droughts and increase of air pollution (Notably in Mega cities such as Beijing or Delhi)
- Droughts and fire risk for forests due to the ‘cleaning with fire practise’ (Indonesia, Angola, Brazil)
- World Heatwave monitoring

3.1 Cities with water supply shortages

Cape Town and Rio de Janeiro were hit by water supply deficits in 2018 and 2017 respectively. The drought that caused the deficit was not detected by the RDrl, which is based on 1 and 3 months anomalies. The drought in these specific cases could be detected with the 12-month SPI index, which is the index used for Hydrological Droughts. Specifically, the deficit accumulated during a long period, in which some rain fell, but largely below the normal quantity. Both cities are situated on the coast of an area with a relatively dry climate without nearby a river flowing out in the sea. The water supply for such cities is based on reservoirs in the hills. The reservoirs might be situated far away from the cities, thus creating even more difficulty for predicting the drought impact based on solely the location.

In order to asses an extreme hydrological drought we created a program that analyses how many times a 1 decimal degree cell falls, uninterrupted in a SPI 12-month deficit of less than -2. Subsequently we pick the cells which are more than 3 consecutive months in this extreme situation.

In order to limit the result we analyse only cells in known dry climates using cell with KOPPEN climate Classes Aw, BWh, BWk, BSh, Csa, Csb, Cwa, Cfa, Dsa, Dsb, Dsd, Dwa. We finally look for cities in these cells with more than 500.000 inhabitants.

The result yielded many cities in Brazil in 2017, confirming the problems reported from Rio de Janeiro. The Cape Town event was signalled as well with this analysis. The main issue is that other cities such as Phnom Penh, Jos (Nigeria) or Cartagena (Colombia) also appeared on the list. The list can therefore not ‘directly’ be transposed to the web service. A city as Phnom Penh lies on the Mekong River and is therefore less vulnerable for hydrological droughts. We will therefore have to enrich our city database with additional information on the water supply system of big cities in order to make sure that cities in dry climates might enter into a water supply emergency when a hydrological drought occurs. The result of an analysis start in 2016 is presented in Table 4.

Table 4. Mega Cities affected by Hydrological Drought from 2016 to 2019

City	Country	Population	Start date	End date	Months
------	---------	------------	------------	----------	--------

Valencia	Venezuela	119600	2016-01	2016-03	3
Puchon	South Korea	779412	2016-01	2016-04	4
Jos	Nigeria	510300	2016-01	2016-04	4
Cape Town	South Africa	1490935	2016-01	2018-04	15 (2 events)
Cartagena	Colombia	616231	2016-01	2016-06	6
Chongju	South Korea	531376	2016-01	2016-06	6
Inchon	South Korea	2230818	2016-01	2016-04	4
Seoul	South Korea	10231217	2016-01	2016-04	4
Koyang	South Korea	518282	2016-01	2016-04	4
Kaduna	Nigeria	869094	2016-01	2016-03	3
Songnam	South Korea	869094	2016-01	2016-04	4
Phnom Penh	Cambodia	1077853	2016-01	2016-09	9
Suwon	South Korea	755550	2016-01	2016-04	4
Anyang	South Korea	591106	2016-01	2016-04	4
Naypyidaw	Myanmar	924608	2016-01	2016-07	7
Taejon	South Korea	1272121	2016-01	2016-06	6
Ansan	South Korea	510314	2016-01	2016-04	4
Solapur	India	873037	2016-02	2016-05	4
Aleppo	Syria	1582930	2016-05	2016-11	7
Gaziantep	Turkey	853500	2016-06	2016-11	6
Brasilia	Brazil	2043169	2016-07	2016-10	3
Belo Horizonte	Brazil	4013562	2016-08	2018-01	13 (2 events)
Mysore	India	742261	2016-09	2017-08	12
Jaboatao	Brazil	567319	2016-10	2017-05	8
Rio de Janeiro	Brazil	11057136	2017-05	2018-01	9
Genova	Italy	610307	2017-05	2018-02	10
Homs	Syria	540133	2017-05	2017-10	6
Kayseri	Turkey	536400	2017-05	2018-01	9

Mogadishu	Somalia	696000	2017-08	2019-10	6 (2 events)
Yaoundé	Cameroon	650535	2017-11	2018-01	3
Varanasi	India	1100748	2017-12	2019-06	19
Santos	Brazil	1314314	2018-05	2019-01	9
Sao Paulo	Brazil	1707936	2018-05	2019-01	9
Patna	India	1377000	2018-11	2019-06	8

The program `finddrycities.sql` in the `DEA/DROUGHT/SPI12` directory generates the cities list for a given month. The affected cities are written in the table `URBAN_POPULATIONS_HYDRO` in the `DROUGHT` schema.

The program consults the table `grid_1dd_spi_hazards`, in particular the field `SPI_12_LESS2` which contains the count of moments a pixel is belong the value `-2` for the 12 Month SPI. The field `SPI_12_LESS2` is filled by the program `DEA/PRECPRD/SPIHAZARD/COMPUTE_SPI_HAZARD_MIN2.sql`. This program is run after the completion of the SPI 1 decimal degree cell computation.

After marking the potential vulnerable cities, for example on analysing distance to freshwater sources, to hydrological droughts we will create a layer in GDO to display the cities having stress and detected with this algorithm. For the moment we will run the program every month and escalate a city detected which we find suspected.

3.2 Ramsar protected Wetlands with long-lasting Droughts

In EDO and GDO we developed a new layer called “Wetlands” which is filled with the Ramsar wetlands and contains over 2342 protected wetlands in the whole world. The website ramsar.org distributes data about the location and various characteristics of the Ramsar protected sites to the public. The information contains, amongst others the site name and the coordinates of the site location. The protected planet website (www.protectedplanet.net) provides the delineations of all protected areas in the world. We used the name and location of the polygons provided by protected planet in order to enrich the official data provided by the RAMSAR dataset. Thus we could create a valid polygon for over 80 percent of the Ramsar wetlands. The resulting polygons of the Ramsar wetlands are used for analysis of Drought, with a focus on long term droughts. The polygons are intersected with the 1 decimal degree grid containing the SPI values for each month. In order to assess the impact of the drought on the wetland we developed a magnitude as previously developed by Spinoni, 2018. In the following table the decision matrix of the magnitude is displayed. By giving a weight to types of droughts, we expect to be able to give an alert that can be used for any wetland, after which the impact of the drought is to be assessed based on the descriptive data of the wetland concerned. The following table gives an overview of the weight we give to any occurrence of a pixel being affected by a negative SPI values of a certain period of months.

Table 5. Weights attributes to negative SPI values per duration period

SPI	value < -2	value < -1
1 Month	+ 0.22	
3 Months	+ 0.44	
6 Months	+ 0.66	+ 0.22
9 Months	+ 0.88	+ 0.44
1 Year	+ 1.1	+ 0.66

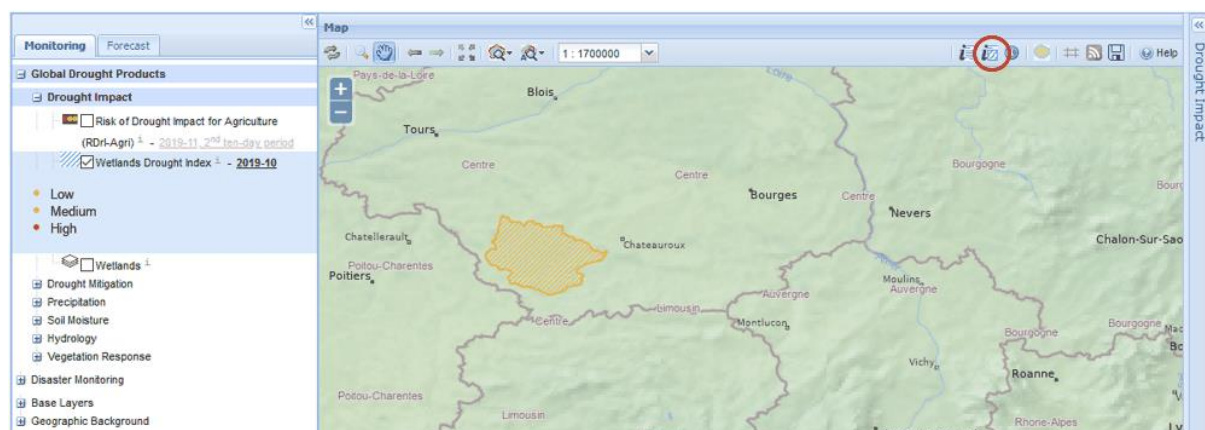
2 Years	+ 1.32	+ 0.88
4 Years	+ 1.54	+ 1.1

3.2.1 The Web Interface

In the MapViewer every month we can highlight wetlands at risk activating the new layer “**Wetland Drought Index**” within “Drought Impact” subgroup of “Global Drought Products” and selecting the month of interest. The last available situation is set by default, while the time series starts from June 2019. Data come from the Oracle table RAMSAR_INDICES are visualized by means of the GDO’s MapServer WMS used by the MapViewer (mapfile gdo_wms.map, layers “ramsar_drgt_ndx_pt” and “ramsar_drgt_ndx_poly”).

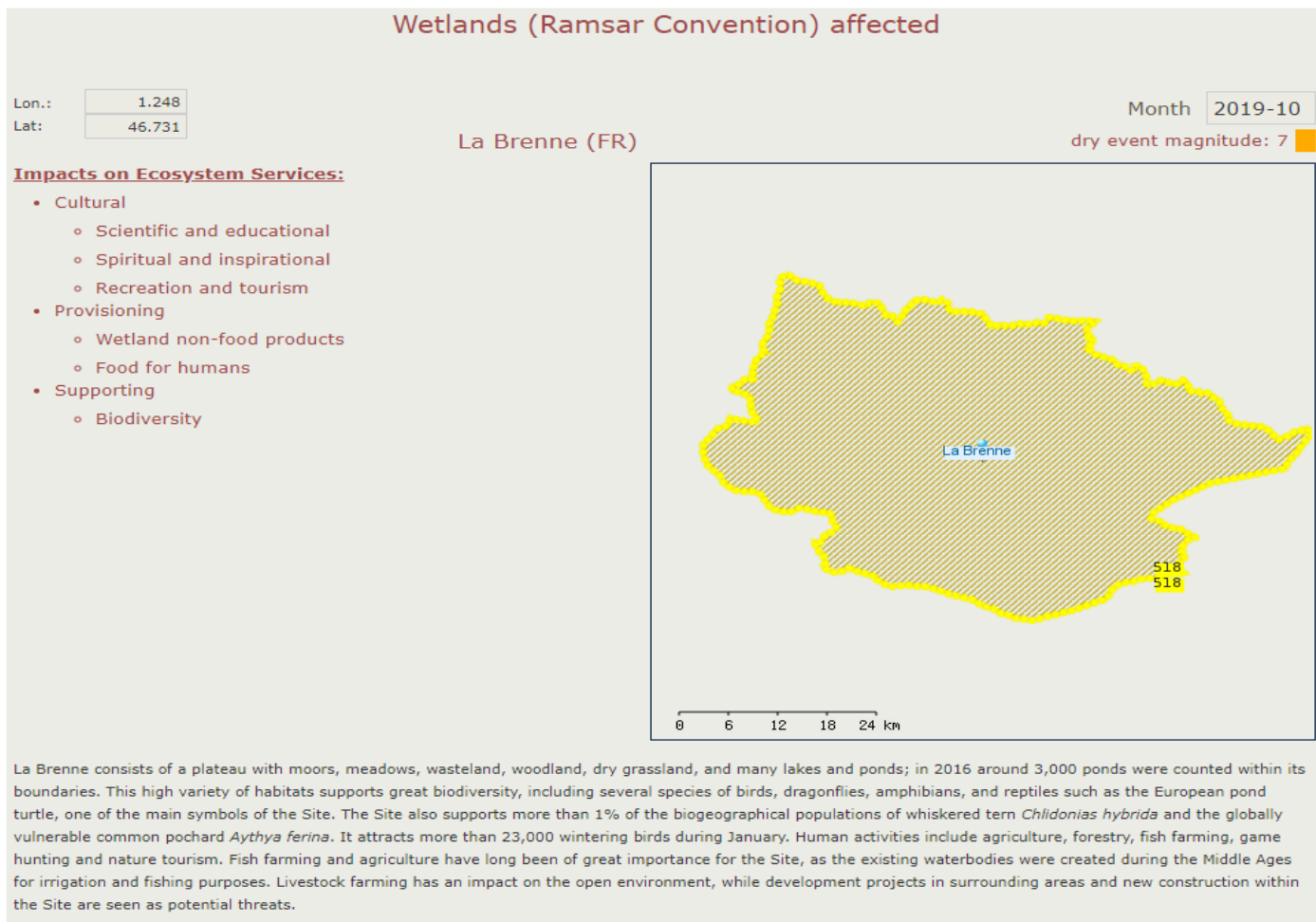
Also the generic “Wetlands” layer, containing all the wetlands despite its status in terms of drought (hence also displaying those not affected by drought), was moved here from the “Geographic Background” group.

Figure 13. The new “Wetlands Drought Index” in the GDO MapViewer: La Brenne, a Ramsar site in central France, results affected by a medium drought in October 2019.



A report page, accessible selecting the icon highlighted by the red circle in the previous figure and clicking the wetland on the map, can be opened. The report webpage (id=2025) contains a map of the wetland area, its roles in ecosystem and a brief description.

Figure 14. Automatic report on wetlands: drought information, impact on ecosystem services, description and map of La Brenne affected Ramsar site.



User can choose to display additional information about land use of the area: FAO Land Use Types are available worldwide, while CORINE Land Cover only for Europe.

Figure 15. Automatic report on wetlands: map of CORINE Land Cover for La Brenne affected Ramsar site.

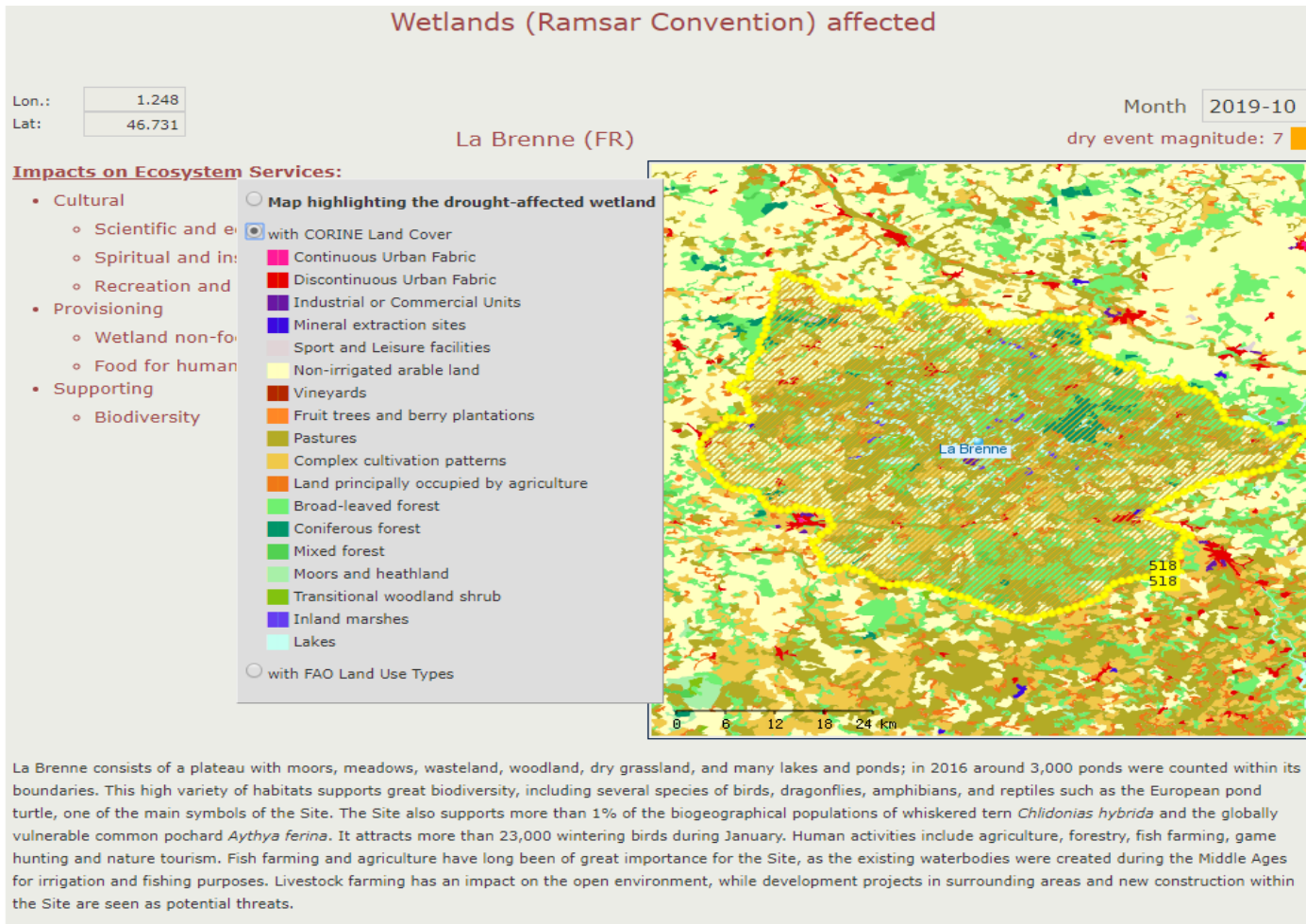
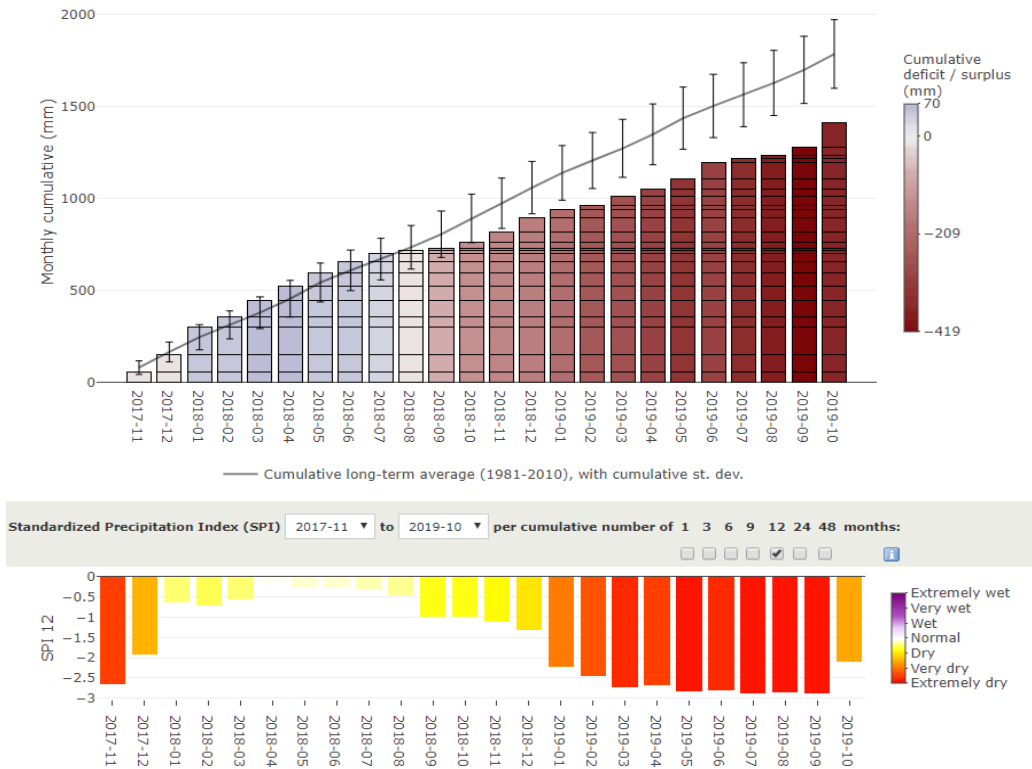


Figure 16. Automatic report on wetlands: graphs related to La Brenne affected Ramsar site.



In the report, precipitation data are displayed, along with information on wetland area.

As statistics on precipitation are collected according to a geographical grid with 1 decimal degree resolution, precipitation data refer to the most impacting cell area involved with the wetland area itself.

Cumulative rain deficit and long term SPI (12 months accumulation period) are shown to allow the user an impact evaluation, at a first glance.

3.2.2 Possible improvements

The current index is experimental and not crosschecked with comparable indexes due to the lack of availability of the latter. By using a Magnitude based on a series of underlying parameters, we created a flexible mechanism allowing to tune the index with altering interfaces. This might lead to small updates on the index with regard to the decision matrix.

The experimental Magnitude, calculate in this phase, will soon be accompanied other evaluation indicators like

- Distance to the sea (GISCO countries)
- Distance to a large river (CCM2 for Europe and Glofas for the whole world)
- Distance to a lake (CCM2 for Europe and FAO for the whole world)

3.3 Drought risk for power plants

In order to build an indicator of risk in the form of Hazard x Exposure x Vulnerability, we describe separately the three components. The overall risk is available for Europe, in accordance with the current available low-flow indicator window. The index is under development and expected to be available in EDO in January 2020.

Hazard: the likelihood of hydrological drought, which entails the probability of missing or reduced water flows in input. Based on expected or average water flows and recorded anomalies at plant location, for real time monitoring the use of the lowflow index from EDO is used. The information is available at ten days interval and stored in table LOWFLOW_PP_DAM_2.

Exposure: assets potentially affected by the reduction of energy production are hard to quantify locally, as electricity can be transported long distances from the source, often across national boundaries. However, power

plant gross capacity can be used as a proxy of exposure: the bigger the power plant, the higher the exposure, as presumably more electricity demand is relying on it. Exposure is recorded inside POWERPLANTS table.

Vulnerability: it is the measures in place to mitigate the lack of water for energy production and relates to the cooling system. Four classes are identified and assigned on a log scale of median water withdrawal (m³MWh⁻¹): “None”, “Low”, “Medium”, “High”. Vulnerability is recorded inside POWERPLANTS table.

Figure 17 shows the tables involved in the process. The technical steps for a drought risk for power production indicator, based on individual power plants information and hazard indicator, are briefly described. The table LOWFLOW_PP_DAM_2 stores all valid power plants and dams extracted from a number of other sources (see below). The important columns here are ID and GRID_ID, identifying respectively the identifier of the point of interest and the grid id of reference for low flow:

1) *select ID, GRID_ID from LOWFLOW_PP_DAM_2*

The GRID_ID column above refers to the cell id as stored by ID column of table GRID_5KM_LOWFLOW_XTND that is used to extract the low flow value, provided year, month and dekad of interest. The output of this query should always contain a valid low flow value, but only low flows greater than zero are of interest, so the result are also filtered accordingly:

2) *select ID, DEFICIT_[MONTH][DEKAD] from GRID_5KM_LOWFLOW_XTND where YEAR= [YEAR] and ID in [GRID_ID] and DEFICIT_[MONTH][DEKAD] > 0*

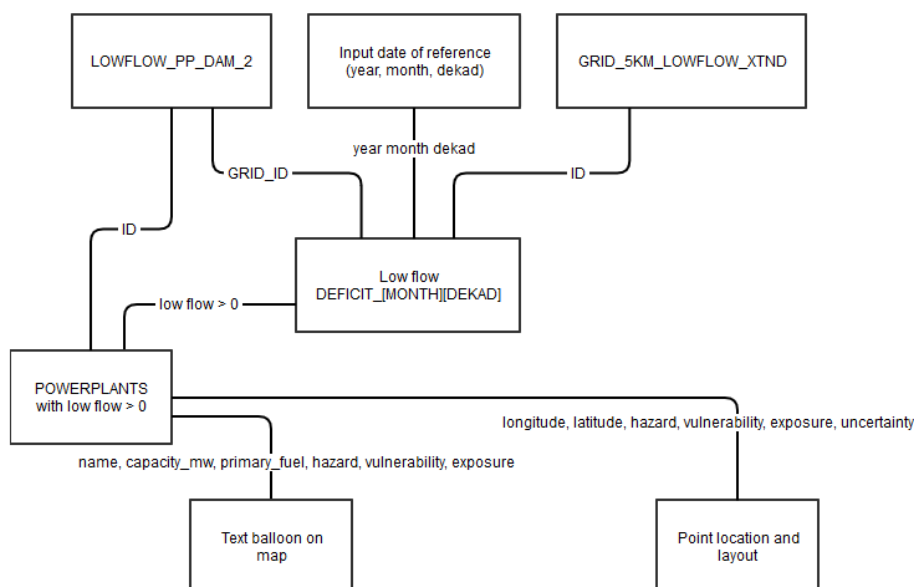
The query returns only those cells that have low flow value > 0 for the selected dekad. These cells are used to retain only the points of interest with corresponding low flow value > 0. So from 1) are further removed all those records whose GRID_ID is not returned by 2).

Now more information on the points of interest is required. These are all static info, stored in table POWERPLANTS under schema MASANDA. So using the previous filters and the identifier of point of interest (ID column in LOWFLOW_PP_DAM_2):

3) *select ORIGIN_ID, NAME, CAPACITY_MW, PRIMARY_FUEL, VULNERABILITY, EXPOSURE, LONGITUDE, LATITUDE from POWERPLANTS where ORIGIN_ID in [ID]*

This query will return relevant information for plotting the points on the map, making their layout and fill the balloon upon user click on points. To this selection it is necessary to append the low flow value extracted from 2).

Figure 17. Flowchart of Oracle table relations for the representation of the risk indicator.



GEOREF.POWERPLANTS is the table of reference for power plants data. The table contains the data from different datasets validated and integrated across a few relevant attributes: unique identifier (ORIGIN_ID), item name (NAME), latitude (LAT), longitude (LON), power gross capacity (CAPACITY_MW), type of power plant (TYPE), cooling system (COOLING), country (COUNTRY), source dataset (SOURCE) and specific record information (INFO). **Underlined** above are those attributes that should be visible to the user in the final product. Missing values are allowed. The lookup table below (Table 6) provides the key to link the attributes to those from source datasets. Currently, of the datasets incorporated, only those in bold in the table below are used to populate the main POWERPLANTS table. The raw data from various sources is uploaded or updated in the database through the program *rawdata_2_oracle_power_dam.R*. Then, to match attributes and make the main POWERPLANTS table, a program *powerplants_main_builder.R* is to be run.

Table 6. Look-up table to link the attributes of the main POWERPLANTS table to attributes of source datasets, when applicable. Currently, only those in bold are used to populate the main table.

Final table view fields →	ORIGIN_ID	NAME	LAT	LON	CAPACITY_MW	TYPE	COOLING	COUNTRY	SOURCE	INFO
Input tables ↓										
PP_WEPP_PLATTS	UNITID	PLANT	-	-	MW	FUEL	COOL	Country	World Electric Power Plants Database	-
PP_WORLD_NUCL_ASSOC	id	name	lat	lon	gross_capacity	[All nuclear]	match id and PP_PRIS_IAEA.Unit_name PP_PRIS_IAEA.Primary_means_of_condenser_clng	country	World Nuclear Association	url
PP_GLOBAL_DB_WRI	gppd_idnr	name	latitude	longitude	capacity_mw	primary_fuel	match wepp_id and PP_WEPP_PLATTS.UNITID PP_WEPP_PLATTS.COOL	country_lo ng	WRI Global Power Plant Database	source
PP_PRIS_IAEA	Unit_name	Site_Name	-	-	Latest_Gross_Electrical_Power	[All nuclear]	Primary_means_of_condenser_clng	Country	IAEA Power Reactor Information System	
PP_JRC_HYDROPOWER	id	name	lat	lon	installed_capacity_MW	[all hydro]	volume_Mm3 storage_capacity_MWh	country_code	JRC Hydro-power plants database	-

4 Other improvements in EDO

In 2018 we introduced a new Soil Moisture product in EDO based on the last operational version of the European LISFLOOD version. Already in 2018 we noticed that persistent droughts were more severe in the new product compared to the old product. We were suspicious on an error in the calibration of the model and escalated the issue after some additional research. The work concluded in a manner that we found the cause and that a solution was possible. Thus proving that dual use of data sources helps significantly to find errors and to improve the quality of the work. With our ambition to update EDO every ten days for the rainfall borne index, instead of once per month, we further embarked on the procedures applied to make the European LISFLOOD model work. We found that the procedure of interpolating rainfall data was not well-tuned for using the rainfall data as an input for a decadal high-resolution product. In 2020 we must make another attempt in which we will use better-interpolated rainfall data or we must interpolate the data ourselves.

Positive is that in 2019 we increased collaboration with partners to exchange EDO data and to include partner data in our platform. The yearly Copernicus conference in an essential facilitator for this collaboration. Especially the fact that technical personnel gets an opportunity to meet and exchange ideas at this platform.

4.1 Soil moisture anomalies exaggeration in LISFLOOD, reporting and solution through EDO

EDO's Soil Moisture Index (SMI) Anomaly Indicator and Low-Flow Index (LFI) inputs are computed with the In-house JRC LISFLOOD model. Last year the model was upgraded, and specific adaptation tasks had to be completed allowing EDO to use the outputs of the new model. As it was described in the report of 2018, before the SMI implementation on EDO, the agreements and possible inconsistencies between previous and current LISFLOOD model versions were verified, to ensure that the new version was providing correct Soil Moisture information for EDO. However, after LISFLOOD outputs started to be provided operationally on a daily basis, we noticed that for the last two years (2017 -2018) roughly 10% of anomaly values were particularly low (arid areas), in some cases with values that range from -4.7 to -3 and approximately 5% of the values are between 3 to 4.7. Such "extreme" values were also found in maps from the previous LISFLOOD model, but these values did not cover such broad geographical areas as in the new model. Some areas like the Northern France and the Southern Norway had a significant drop in values since September 2018. These unusual values made us suspicious about the correctness of the new LISFLOOD model outputs.

In order to identify the cause of the low values, several checks were made between December 2018 and February 2019:

Recalculation of pF values instead of SMI for the time window 1995 - 2018: The comparison between the old and the new model version was initially done for the year 1995 - 2016. To analyse the unusual SMI values from 2017 - 2018, we calculated pF and pF anomalies for the same years using as baseline 1995 - 2017. The pF calculation algorithm can be found in the central repository, at the directory `central_repo\procedures\python\sm_oldvsnew\`:

`soilmois_extended_longrun_pf.py`: algorithm

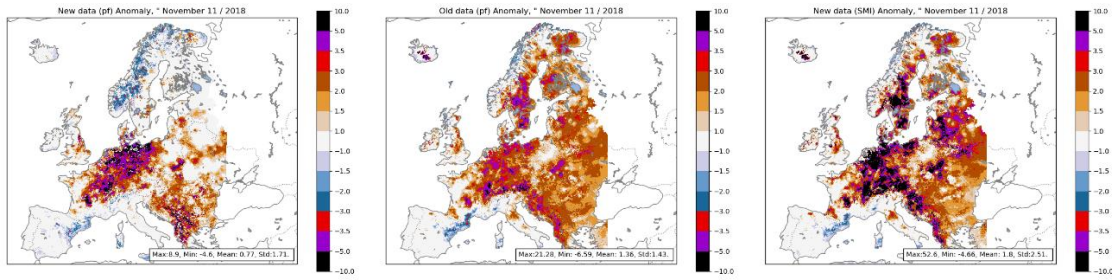
`soilmois_config_longrun.json`: the attached configuration file

`soilmoisture_data_analysis_logging_config.json` is the attached logging configuration file

In this case, the hypothesis was that the SMI calculation could have some errors, or that the SMI anomalies were not suitable to be compared with the pF anomalies from the old model version. After the calculation and verification of the data, we found that pF calculated values were as unusual as the SMI values, although, SMI seemed to be more sensitive than pF by showing drier anomalies; see Figure 18 as an example. This can be seen through all the *Old (pF) vs new (pF) vs new (SMI) anomalies* comparison maps created for 2015, 2016, 2017 and 2018 (these maps were calculated using the ipython notebook `central_repo\procedures\python\sm_oldvsnew\anomaly_oldvsnew.ipynb`, and they are published on confluence at:

<https://webgate.ec.europa.eu/CITnet/confluence/display/DROUGHT/1.2.3.+Unusual+Soil+Moisture+Values+2017+-+2018>).

Figure 18. Old (pF) vs new (pF) vs new (SMI) anomalies maps second dekad of November 2018



Calculation of pF for each individual soil layer: This was done adapting `soilmois_extended_longrun_pf.py` by setting a specific function to calculate pF for each layer. The script can be found at `central_repo\procedures\python\sm_oldvsnew\soilmois_extended_bylayers_pf.py`. The results of the calculations indicated that the top layer seems to be drier, as expected, but the results of the analysis were not conclusive.

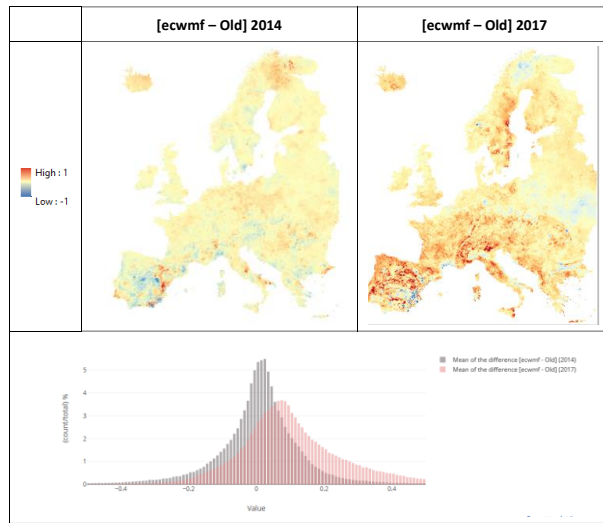
Calculation of the average map of the difference between the different runs (see Table 7) and old model pF data, as well as time series graphs. Another hypothesis was that the LISFLOOD outputs provided by The European Centre for Medium-Range Weather Forecasts (ECMWF) from 2017 onwards were produced with a different configuration of the model (in terms of parameters, for example) that made the data different from the previous years. To test this hypothesis, we did an Average Maps Comparison and time series plotting between the new and the old model versions and the different time windows of data provided (1990 – 2016 vs 2017 – 2018) by ECMWF and JRC. This was done using the ipython notebook `sm_data_analysis.ipynb` at the directory `central_repo\procedures\python\sm_oldvsnew\`.

Table 7. LISFLOOD new window provided data.

Time period	Source	Provider
1990 -2014	<code>H07_floods\efas\EfasXtendedDomain\LT_19902016_Full_Split Routing_Forcingstill2016\outNF</code>	JRC
2015-2016	<code>H07_floods\efas\EfasXtendedDomain\LT_19902016_Full_Split Routing_Forcingstill2016\outNF20152016</code>	JRC
2017 - 05/11/2018	<code>Sftp://ecmwf @139.191.1.8/ecmwf/</code>	ECMWF
Daily NetCDF files since 05/12/2018	<code>Sftp://ecmwf @139.191.1.8/ecmwf/ecmwf/extended/soilmoist</code>	ECMWF

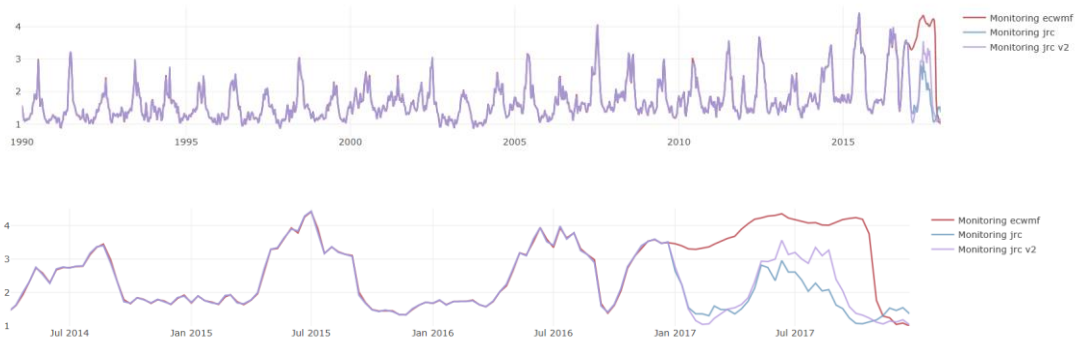
Several maps were created. If we take Figure 19 as an example, it was clear that ECMWF data from 2017 was considerably drier compared with the previous LISFLOOD model with respect to various years (2014 for example, on the figure), which is also confirmed by the maps histograms.

Figure 19. pF average maps and histogram of the difference between the ECWMF data and old model, 2017 vs. 2014



Further confirmation can be seen with a time-series graph, for example, a point in Iceland (Figure 20); where ECWMF data have an unexpected behaviour, better seen on the zoom in the lower part of the figure, corresponding to year 2007 and onwards.

Figure 20. pF Time series graph of the difference between the ECWMF data and JRC data in Iceland (1)



(1) Monitoring ECMWF: LISFLOOD run made at ECMWF; Monitoring jrc: LISFLOOD run made at JRC with forcings from JRC historical dataset and water abstraction maps of 2014; Monitoring jrc v2: LISFLOOD run made at JRC with ECMWF forcings.

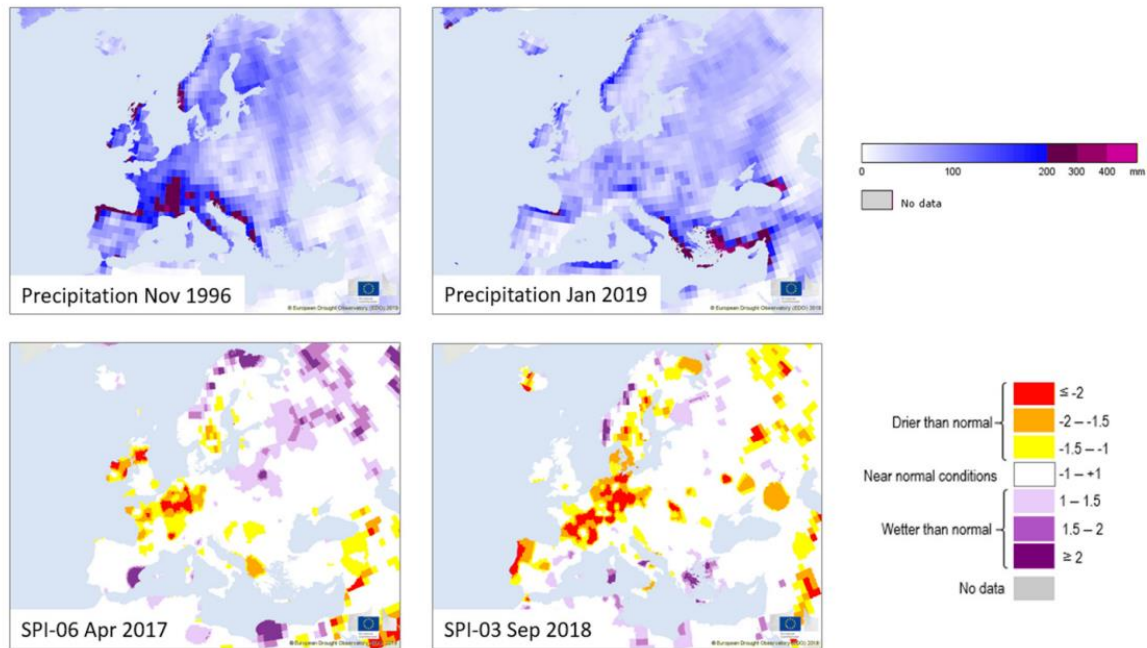
The results of the analysis were shared the EFAS (European Flood Awareness System) team, and after some investigation they understood that the extreme drier values were due to the use of wrong version of the LISVAP model⁴ by ECWMF to produce evapotranspiration maps as inputs to LISFLOOD model for the 2 anomalous years. Subsequently ECWMF reprocessed a corrected version of the LISFLOOD model that now gives accurate input for EDO and consequently correct maps in MapViewer and other data displaying tools. We continue to monitor the SMI values to detect any irregularities.

⁴ LISVAP is a pre-processor for the LISFLOOD water balance and flood simulation model that calculates estimates of potential evaporation and evapotranspiration. (<https://ec-jrc.github.io/lisflood-lisvap/>)

4.2 Standardized Precipitation Index SPI every ten days using LISFLOOD input

The current Standardized Precipitation Index SPI in EDO (see Figure 21) is a blended and interpolated product computed from daily rainfall observations from the Surface Synoptic Observations SYNOP stations of the Monitoring Agricultural ResourceS MARS⁵ database, interpolated to 0.25 degree resolution, and blended with SPI computed from Global Precipitation Climatology Centre GPCC⁶ monthly precipitation at 1.0 degree.

Figure 21. Examples of the monthly updated Precipitation and SPI indicators in EDO



The temporal resolution of the current SPI is monthly. For drought monitoring, it would be ideal to have an SPI calculated every ten days, consistent with EDO operational data publication, in other words, using a 30 days moving window with time steps every ten days.

In order to achieve that, precipitation data input for LISFLOOD model could be used. The hypothesis is that the SPI calculated in this way would be more consistent with the LISFLOOD outputs already being used for Low Flow and Soil Moisture Index in EDO; and the new SPI would be at a higher resolution, both in space and time.

LISFLOOD uses daily precipitation data from JRC-MARS and interpolates them using the SPHEREMAP algorithm (Willmott et al., 1985) is the spherical adaptation of the interpolation scheme developed by Shepard (1968). It is based on a combined distance and angular weighting plus a correction using the gradient of the observations. Several radiuses are defined within SPHEREMAP for the calculation of the distant weights.

First of all, an initial search radius for stations around the grid point is defined based on the number of available stations in the data set and the size of the gridding area. Based on the initial radius, a radius for switching the calculation rule of the distance weights is defined. Finally, a small radius "epsilon" around the grid point is defined. Between four and up to ten stations are utilized to interpolate the value at the grid point. If less than four stations were found within the initial search radius, then this radius is increased stepwise until at least 4 stations are detected. The angular weights are used to take the possible clustering of stations into account. Clustered station are less weighted than solitary stations. Distance and angular weights are combined and adjusted by the gradient to get the final applied interpolation weights. The resulting interpolated maps are then used as inputs for the LISFLOOD model.

We did a test of calculating SPI with this interpolated data, using as a baseline 1981 – 2010, and the results are shown on Figure 22.

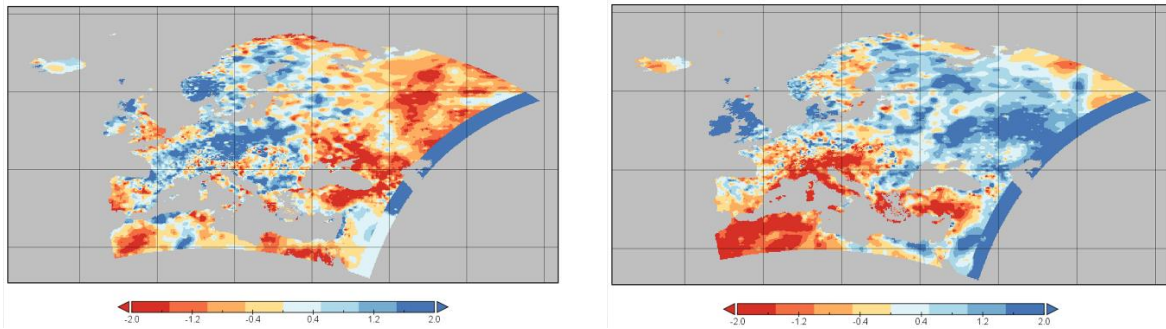
⁵ <http://mars.jrc.ec.europa.eu/>

⁶ <http://gpcp.dwd.de>

Figure 22. Results of the SPI test, using LISFLOOD model precipitation input

SPI 3 anomalies, June 2013

SPI 3 anomalies, January 2016



At a first glance, we see that the resulting maps are strongly “sphered” instead of what is expected to be a smoother surface, making the SPI calculation extremely dependent of the location of the stations. The following steps will be to try to achieve a more fitted interpolation for SPI maps creation. Another aspect to take into account is to determine if the temporal resolution of 10 days will considerably be an improvement with respect to the actual monthly temporal resolution, in other words, to understand if the decadal SPI changes considerably between dekads or if it is giving the same information as the current monthly SPI.

4.3 Integration of new Soil Moisture anomalies in the CDI

The new Soil Moisture Index (SMI) Anomaly is computed to have negative values for drier conditions and positive values for wetter conditions. This is in contrast with the former soil moisture version based on pF, which had positive dry anomalies and negative wet anomalies. By consequence the programs to compute the Combined Drought Indicator (CDI) and the Risk of Drought Impact for Agriculture (RDri-Agri) needed to be updated in order to take into account the new anomaly.

For the CDI, the former PL/SQL program drought_index_v7.sql was updated and saved as drought_index_v8.sql: the source table GRID_5KM_SOILMOIST_XTND replaced GRID_5KM_SOILMOIST and the conditions on anomaly were changed to consider negative values instead of positive ones.

For the RDri-Agri, the function GET_HAZARD (drought schema) was updated replacing positive conditions with negative conditions.

4.4 Updates in the Partner Layers

The situation of data provision to EDO by national, regional and local partners is stated in the following table, where BRGM (Bureau de Recherches Géologique et Minières) is not present anymore because its layers (“Groundwater bodies” and “Piezometers – ADES”) have been definitively dismissed. Dedicated subsections going more in detail follow.

Table 8. Situation of data provision for national, regional and local partners’ layers in EDO.

Provider partner	Group	Layer name	Frequency	Actual situation
DMCSEE (Drought Management Centre for Southeastern Europe)	Southeastern Europe	SPI	Monthly	Operational Usual delay of 2 months in data publication due to migration from DMCSEE (http://www.dmcsee.org/) to Drought Watch (https://droughtwatch.eu/) Last available date: 2019-08

CHE (Confederación Hidrográfica del Ebro)	Ebro River Basin	Temporary water scarcity, last situation	Monthly	Operational New layer provided by CHE from January 2019; see details below. Only the last available date is delivered via WMS Last available date: 2019-11
		Natural drought, last situation	Monthly	Operational New layer provided by CHE from January 2019; see details below. Only the last available date is delivered via WMS Last available date: 2019-11
CHS (Confederación Hidrográfica del Segura)	Segura River Basin	Basin System Status Index	Monthly	Index computation ended Past data still available in EDO database Last available date: 2018-12 Layer still visible on EDO
		Temporary water scarcity	Monthly	Operational New layer provided by CHS from January 2019; see details below. Last available date: 2019-12
		Natural drought	Monthly	Operational New layer provided by CHS from January 2019; see details below. Last available date: 2019-12
InterSucho (InterDrought)	InterDrought	Drought Intensity 0- 100 cm	Weekly	Operational Areas outside Czechia and Slovakia have been masked Last available date: 2019, week 49
		Drought Impact on Agriculture by District	Weekly	Operational Last available date: 2019, week 49
ARSO (Agencija Republike Slovenije za Okolje)	Integrated Drought Management Programme in Central and Eastern Europe (IDMP-CEE)	SPI Slovenia	Monthly	Data provision ended WMS service still available Last available date: 2016-09-15 Layers still visible on EDO
		Standardize d	Monthly	Under development; not public yet

IPMA (Instituto Português do Mar e da Atmosfera)	Continental Portugal	Precipitation Index (SPI) 3,6,9,12		Available from: 2011-08 Last available date: 2019-11
		Palmer Drought Severity Index (PDSI) Observed	Monthly	Under development; not public yet Available from: 2012-01 Last available date: 2019-11
		Palmer Drought Severity Index (PDSI) Preview 2 nd Decile	Monthly	Under development; not public yet Available from: 2019-01 Last available date: 2019-12
		Palmer Drought Severity Index (PDSI) Preview 5 th Decile	Monthly	Under development; not public yet Available from: 2019-01 Last available date: 2019-12
		Palmer Drought Severity Index (PDSI) Preview 8 th Decile	Monthly	Under development; not public yet Available from: 2019-01 Last available date: 2019-12

4.4.1 New layers from Ebro River Basin Authority

According to the Spanish national Ley 10/2001 del Plan Hidrológico Nacional y del Real Decreto 1/2016 and the subsequent definition of the Plan Especial de Sequía, the Confederación Hidrográfica del Ebro (CHE, Ebro River Basin Authority) implemented new indicators in 2019 concerning water scarcity (*Índices de Escasez*, see (Confederación Hidrográfica del Ebro 2018)) and prolonged drought (*Índices de Sequía Prolongada*, see (Confederación Hidrográfica del Ebro 2018)).

Following a long-lasting collaboration with CHE, the EDO MapViewer included two new layers in the dedicated “Ebro River Basin” subgroup of the “Regional, National, Local Products” group, named “Temporary Water Scarcity, last situation” and “Natural drought, last situation”. Both display a raster image from a WMS service, but since time support is not available, only the last month is shown. The date of such a month is written directly inside the images and any action to register the last available date is not necessary by consequence.

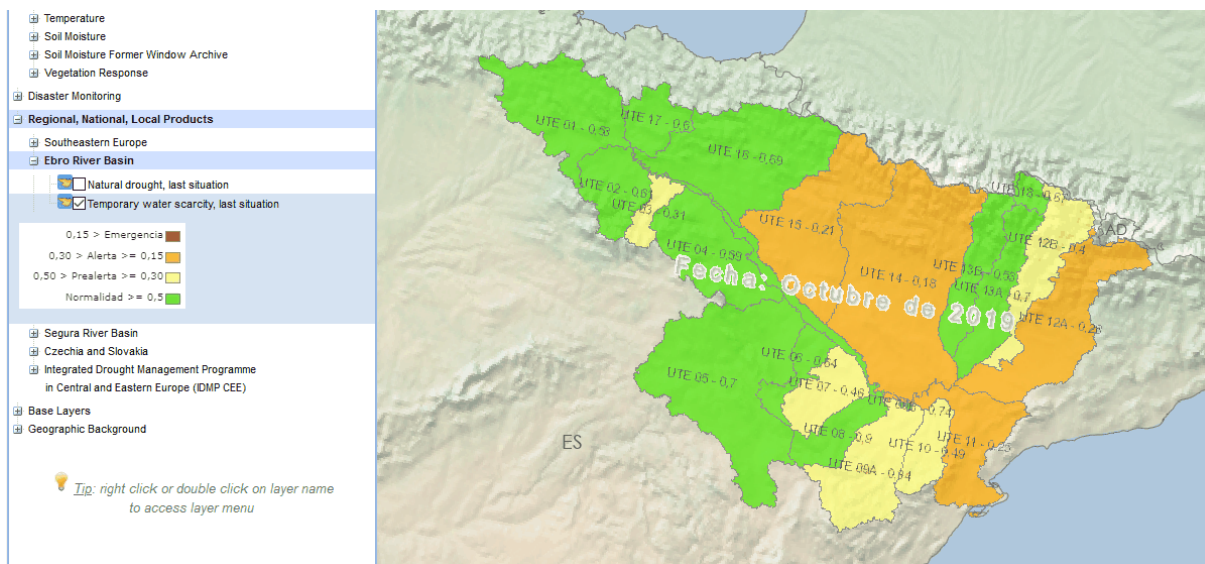
“**Temporary Water Scarcity, last situation**” loads from <http://iber.chebro.es/WMS/escasez> the situation of water scarcity of all the *Unidades Territoriales de Escasez (UTE)* present in the river basin. Index values vary from 0 to 1 and are classified as in the following table:

Table 9. Classification of CHE layer “Temporary Water Scarcity, last situation”.

Class	Index value	Colour
Normal conditions (Normalidad)	$v \geq 0.5$	Green (110 236 51)
Pre-alert (Prealerta)	$0.3 \leq v < 0.5$	Yellow (255 255 153)

Alert (Alerta)	$0.15 \leq v < 0.3$	Orange (255 151 0)
Emergency (Emergencia)	$v < 0.15$	Red (255 0 0)

Figure 23. Ebro river basin, “Temporary Water Scarcity, last situation”: October 2019

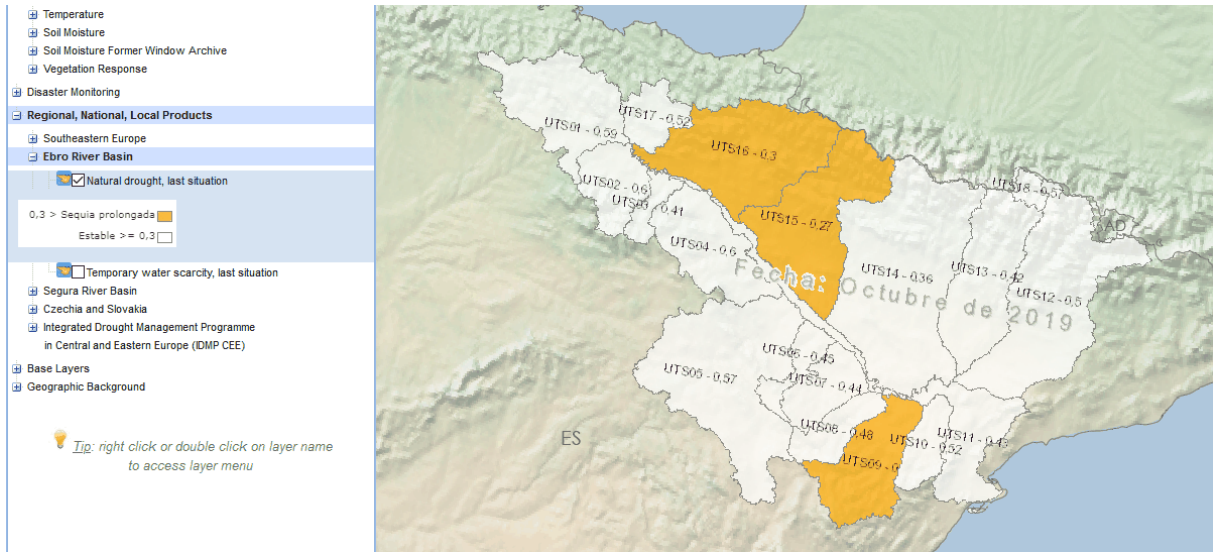


“Natural drought, last situation” loads from <http://iber.chebro.es/WMS/sequia> the situation of water scarcity of all the *Unidades Territoriales de Sequía* (UTS) present in the river basin. Index values vary from 0 to 1 and are classified as in the following table:

Table 10. Classification of CHE layer “Natural drought, last situation”.

Class	Index value	Colour
Stable situation (Estable)	$v \geq 0.3$	White (255 255 255)
Prolonged drought (Sequía prolongada)	$v < 0.3$	Orange (255 151 0)

Figure 24. Ebro river basin, “Natural drought, last situation”: October 2019



4.4.2 New layers from Segura River Basin Authority

According to the Spanish national *Ley 10/2001 del Plan Hidrológico Nacional y del Real Decreto 1/2016* and the subsequent revision of the *Plan Especial de Sequía*, the Confederación Hidrográfica del Segura (CHS, Segura River Basin Authority) implemented two new indicators in 2019, named Índice de Escasez Coyuntural (Cyclical Shortages or Temporary Water Scarcity, see (Confederación Hidrográfica del Segura, O.A. 2018)) and Índice de Sequía Prolongada (Prolonged Drought, see (Confederación Hidrográfica del Segura, O.A. 2018)) and available on <https://www.chsegura.es/chs/cuenca/sequias/indicesinformesPES/>, meanwhile abandoning the Índice de Estado del Sistema Cuenca (Basin System Status Index).

The EDO MapViewer adopted these changes adding the two new indicators in the dedicated “Segura River Basin” subgroup of the “Regional, National, Local Products” group. The new layers are named “**Temporary Water Scarcity**” and “**Natural drought**” and have monthly frequency. Differently from what happens with the correspondent Ebro River Basin layers, past situations can be visualized too, playing with the “Select time” tool.

“**Temporary Water Scarcity**” refers to the whole river basin; its values vary from 0 to 1 and are classified as in the following table. Data have a monthly frequency and are available usually before the 5th of each month.

Data acquisition and publication are done with the following steps, described in detail in <https://webgate.ec.europa.eu/CITnet/confluence/pages/viewpage.action?pageId=882439284>:

1. Take the last available value of water scarcity from <https://www.chsegura.es/chs/cuenca/sequias/indicesinformesPES/> (table: ÍNDICE DE ESCASEZ COYUNTURAL, column: ÍNDICE, row: GLOBAL);
2. Update the Oracle table `BASIN_DROUGHTS` (MIXPRD schema), setting the new value in the correspondent `STATUS_[MM]` column, where [MM] is the reference month. E.g. for November 2019:

```
UPDATE BASIN_DROUGHTS SET STATUS_11=0.245
```

```
WHERE MCY_ID=12 AND DROUGHT_INDEX='escasez' AND YEAR=2019;
```

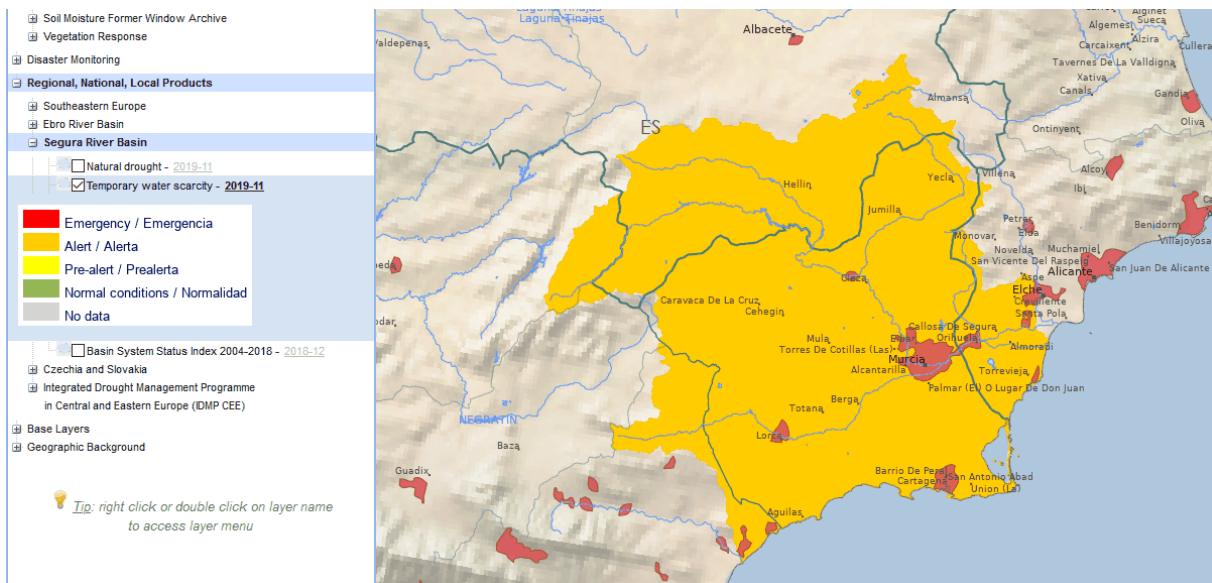
3. Update `layerDates.js` in all the servers, e.g., using the PowerShell program `updateEdoLayerDatesJs.ps1`, with layer id=86.

Table 11. Classification of CHS layer “Temporary Water Scarcity”.

Class	Index value	Colour

Normal conditions (Normalidad)	$v > 0.5$	Green (149 182 85)
Pre-alert (Prealerta)	$0.3 < v \leq 0.5$	Yellow (255 255 0)
Alert (Alerta)	$0.15 < v \leq 0.3$	Orange (255 204 0)
Emergency (Emergencia)	$v \leq 0.15$	Red (255 0 0)
No data	-	Grey (210 210 210)

Figure 25. Segura river basin, “Temporary Water Scarcity”: situation issued on November, the 1st, 2019



“**Natural drought**” refers to the whole river basin; its values vary from 0 to 1 and are classified as in the following table. Data have a monthly frequency and are available usually before the 5th of each month.

Data acquisition and publication are done with the following steps, described in detail in <https://webgate.ec.europa.eu/CITnet/confluence/pages/viewpage.action?pageId=882439284>:

1. Take the last available value of prolonged drought from <https://www.chsegura.es/chs/cuenca/sequias/indicesinformesPES/> (table: ÍNDICE DE SEQUÍA PROLONGADA, column: ÍNDICE, row: GLOBAL);
2. Update the Oracle table BASIN_DROUGHTS (MIXPRD schema), setting the new value in the correspondent STATUS_[MM] column, where [MM] is the reference month. E.g. for July 2019:

```
UPDATE BASIN_DROUGHTS SET STATUS_07=0.491
```

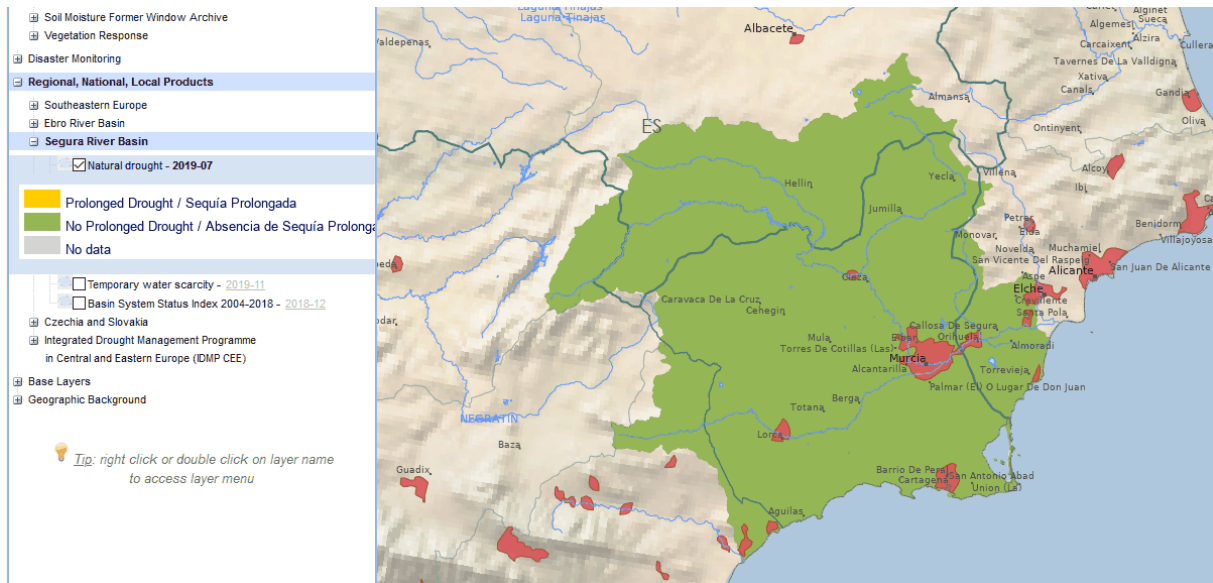
```
WHERE MCY_ID=12 AND DROUGHT_INDEX='sequia' AND YEAR=2019;
```

3. Update layerDates.js in all the servers, e.g., using the PowerShell program updateEdoLayerDatesJs.ps1, with layer id=86.

Table 12. Classification of CHS layer “Natural drought”.

Class	Index value	Colour
No Prolonged Drought (Absencia de Sequía Prolongada)	$v \geq 0.3$	Green (149 182 85)
Prolonged drought (Sequía Prolongada)	$v < 0.3$	Orange (255 151 0)
No data	-	Grey (210 210 210)

Figure 26. Ebro river basin, “Natural drought”: situation issued on July, the 1st, 2019



The former layer “**Segura Basin System Status Index**” is still present in the “Segura River Basin” subgroup, but with archive data only, since its update was interrupted on December 2018.

All the three layers are present also in Side-by-Side Maps, as described in Section 4.4.4.

4.4.3 Updates in data exchange with InterDrought

The new extended window of Soil Moisture Index (SMI) and its anomaly, described in Section 3 of the 2018’s Annual Progress Report of the European and Global Drought Observatories, entailed also an update in provision of EDO soil moisture data to InterDrought (see Section 2.4 of the same report). After a service interruption of some weeks due to the issues described in Section 4.1 of this report, data delivery became regular again in spring 2019, with the files in the following table uploaded to the FTP server of InterDrought:

Table 13. List of soil moisture images delivered to InterDrought, where [YYYY][MM][DD] and [YYYY][MM][TT] are respectively the day and the dekad the image refers to.

Data	File name	Date and time of delivery
Daily Soil Moisture Index (SMI) Forecast	lf[YYYY][MM][DD]smdF.tif	Every day at 15:00 CET

Daily Soil Moisture Index Anomaly Forecast	lf[YYYY][MM][DD]sadF.tif	Every day at 15:00 CET
Daily Soil Moisture Index Monitoring	lf[YYYY][MM][DD]smdA.tif	Every day at 15:00 CET
Ten-daily Soil Moisture Index (SMI) Monitoring	lf[YYYY][MM][TT]smtA.tif	Days 3 ([TT]=21), 13 ([TT]=01), and 23 ([TT]=11) of each month at 15:00 CET
Ten-daily Soil Moisture Index Anomaly Monitoring	lf[YYYY][MM][TT]satA.tif	Days 3 ([TT]=21), 13 ([TT]=01), and 23 ([TT]=11) of each month at 15:00 CET

Every day all available files are uploaded through a unique compressed file named `edo.soilmoist.[YYYY][MM][DD].zip`.

Regarding the data provided by InterDrought to EDO, only one change was done in 2019: upon a direct request by InterDrought, a mask layer was introduced in EDO's MapServer mapfile to limit the area covered by "**Drought Intensity 0-100 cm**" to Czechia and Slovakia only, hiding the neighbour areas of Austria.

4.4.4 New layers from and to IPMA, the Portuguese Institute for Sea and Atmosphere

Following the EDO User Meetings 2018 and 2019 a collaboration between Drought Team and Instituto Português do Mar e da Atmosfera (IPMA, Portuguese Institute for Sea and Atmosphere) has started. IPMA made some layers available via WMS (Web Map Service), while EDO created a WFS (Web Feature Service) to share data of its drought indicators.

WMS layers provided by IPMA were added to the EDO MapViewer in a new subgroup named "Portugal", under "Regional, National, Local Products" group. They are:

- **Standardized Precipitation Index (SPI)** for timescales 3, 6, 9, and 12, available from August 2011.
- Palmer Drought Severity Index (PDSI) Observed, available from January 2012.
- **Palmer Drought Severity Index (PDSI) Preview** for 2nd, 5th and 8th Decile, available from January 2019.

All the layers cover the territory of continental Portugal.

Since the WMS service and all its layers aren't publicly available on IPMA website yet, they aren't accessible from the public EDO ever, but visible only on the internal ones.

In the next figures examples of two IPMA layers and their legends are displayed. Please note that both "PDSI observed" and "PDSI preview" adopt the same classification; moreover, as you can see, the SPI classification adopted by IPMA is different from that used by EDO/GDO.

Figure 27. SPI-3 of October 2019 provided by IPMA and its legend.

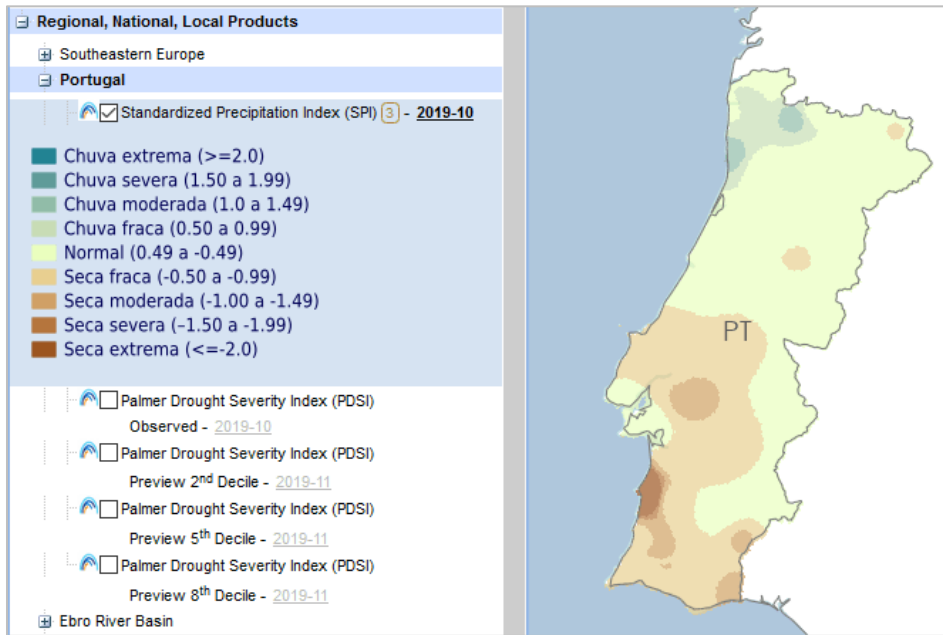
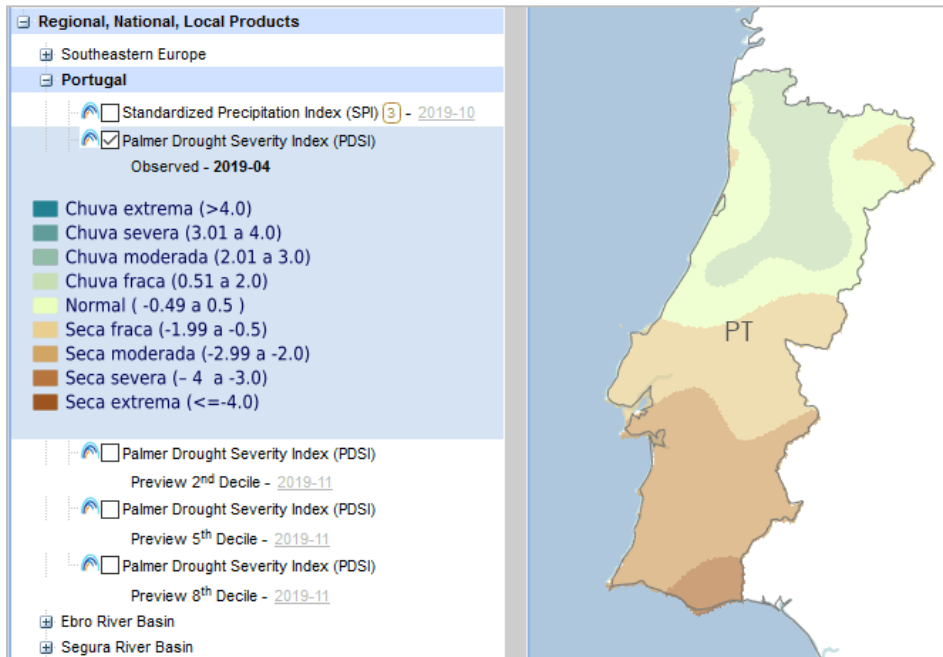


Figure 28. Observed PDSI of April 2019 provided by IPMA and its legend.



The **WFS service implemented by EDO** to share data with IPMA, made with OsGeo MapServer, PHP MapScript and ad hoc PHP programs is available at <https://edo.jrc.ec.europa.eu/edov2/php/gis/mswfs.php>.

With a GetFeature request and the proper TYPENAME parameter, data of the following layers can be downloaded:

- **fAPAR Anomaly** (TYPENAME=fapar_anom): frequency: 10-day period, spatial resolution: 1/24 decimal degree;
- **Soil Moisture Index Anomaly** (TYPENAME=smi_anom): frequency: 10-day period, spatial resolution: 5 km;

- **Former Soil Moisture Anomaly** (TYPENAME=pf_anom): frequency: 10-day period, spatial resolution: 5 km; available until the 2nd dekad of January 2019-01.
- **Combined Drought Indicator** (TYPENAME=cdi): frequency: 10-day period, spatial resolution: 1/24 decimal degree.

By default, the bounding box of Portugal is considered.

The following time parameters must be specified, since the standard TIME parameter is not supported: YEAR, MONTH, DEKAD.

Example of calls:

- GetCapabilities:

https://edo.jrc.ec.europa.eu/edov2/php/gis/mswfs.php?map=edo2ipma_wfs&SERVICE=WFS&VERSION=1.0.0&REQUEST=GetCapabilities

- fAPAR Anomaly of 2019-04-21:

https://edo.jrc.ec.europa.eu/edov2/php/gis/mswfs.php?map=edo2ipma_wfs&SERVICE=WFS&VERSION=1.0.0&REQUEST=GetFeature&TYPENAME=fapar_anom&YEAR=2019&MONTH=04&DEKAD=21

- CDI of 2018-11-01:

https://edo.jrc.ec.europa.eu/edov2/php/gis/mswfs.php?map=edo2ipma_wfs&SERVICE=WFS&VERSION=1.0.0&REQUEST=GetFeature&TYPENAME=cdi&YEAR=2018&MONTH=11&DEKAD=01

The format used by default for data output is GML (Geography Markup Language); the id values of the resulting grid cells are present as attribute together with the indicator value.

4.5 New layers in MapViewer, Side by Side Maps and other web GIS tools

As an outcome of the studies to introduce or revise drought indicators, new layers and indexes have been added to the EDO MapViewer, Side by Side Maps and Time-series webpages.

4.5.1 New layers in MapViewer

Significant changes and additions in layers involved the EDO MapViewer in 2019.

New EDO partners' layers included into the MapViewer were described in the previous section: the pair "Temporary Water Scarcity" and "Natural Drought" for both Ebro and Segura river basin authorities and the provisional layers of IPMA.

Other layers and subgroup of layers were revised or added, as presented in the next lines.

4.5.1.1 Soil Moisture

"Soil Moisture" (subgroup of "European Drought Indicators" within the *Monitoring* tab) and "Soil Moisture Forecasts" (group of *Forecast* tab) now contain the new Soil Moisture Index (SMI) layers, according to what described in Section 3 of the 2018's Annual Progress Report of the European and Global Drought Observatories. New data are processed and published by the procedure described in the 2018's Annual Progress Report and working between 9:00 and 11:00 CET every day.

In the *Monitoring* tab, the layers available in "**Soil Moisture**" subgroup are:

- "**Last Daily SMI**": the last picture of Soil Moisture Index (SMI), usually 2 days behind the current date;
- "**Soil Moisture Index (SMI)**": layer with 10-daily periodicity; new data are usually available 3 days after the end of the dekad they refer to (for example, the image of the 2nd dekad of a month arrives on the 23rd of that month); time series begins in January 1990;
- "**Soil Moisture Index Anomaly**": layer with 10-daily periodicity; as for the previous, new data are usually available 3 days after the end of the dekad; time series begins in January 1990.

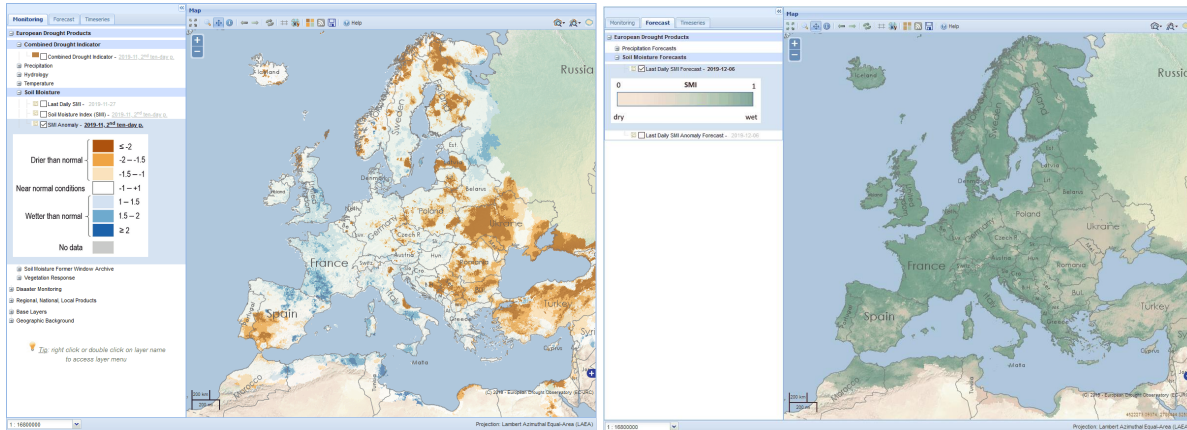
In the *Forecast* tab, the layers available in "**Soil Moisture Forecasts**" group are:

- "**Last Daily SMI Forecast**": the last available forecast of Soil Moisture Index (SMI), usually 7 days ahead the current date;

- **“Last Daily SMI Anomaly Forecast”**: the last available forecast of Soil Moisture Index (SMI) Anomaly, usually 7 days ahead the current date.

Two new classifications and colour schemes were adopted for these new layers, one for all the SMI layers and one for all the SMI Anomaly layers, as displayed in the next figure and table.

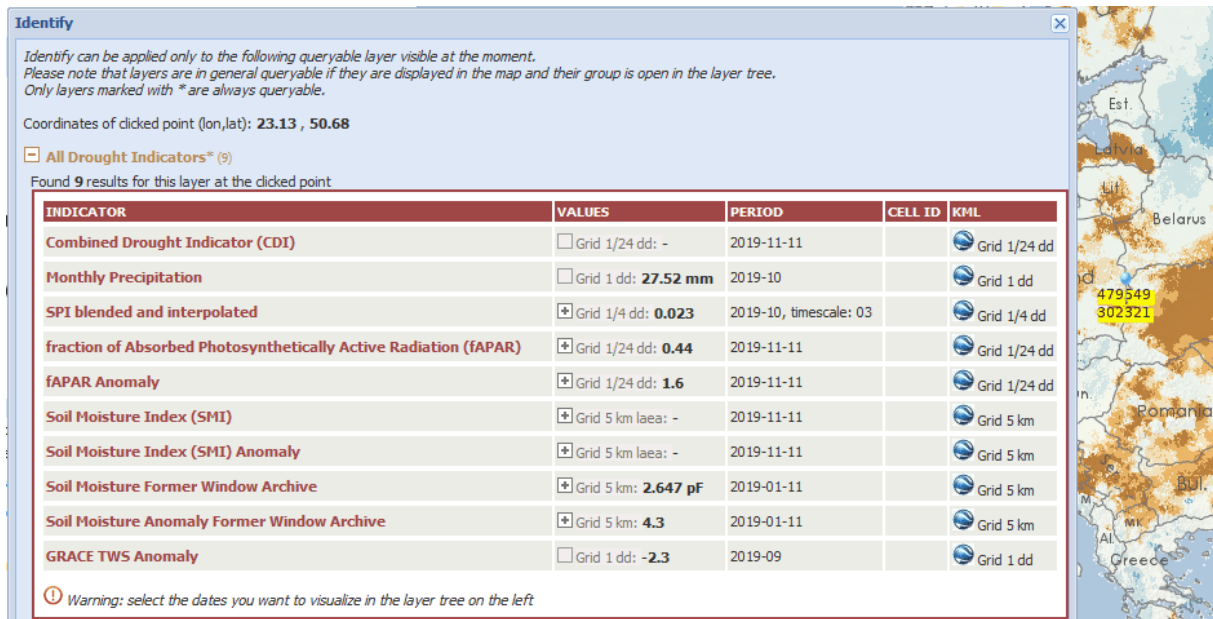
Figure 29. Maps of Soil Moisture Index (right; Daily Forecast SMI of 2019-12-06) and Soil Moisture Anomaly (right; 10-daily SMI Anomaly of the 2nd dekad of November 2019) and their classifications and colour schemes.



Former soil moisture information is still present in a dedicated subgroup named **“Soil Moisture Former Window Archive”** of the *Monitoring* tab, but limited to the 10-daily layers only, renamed **“Soil Moisture Archive”** and **“Soil Moisture Anomaly Archive”** and with data available until the second dekad of January 2019.

Both new and old soil moisture indices are present in the current version of **“Identify All Drought Indicators”**, as shown below.

Figure 30. Identify All Drought Indicators in a location on the boundary between Poland and Ukraine: both new SMI and Former Window 10-daily soil moisture indicators are present. The latter have their last available date of 2nd dekad of January 2019. The new GRACE TWS Anomaly is also present.



SMI Anomaly was also added to the options of the *Time series* tab to display graphs of that index.

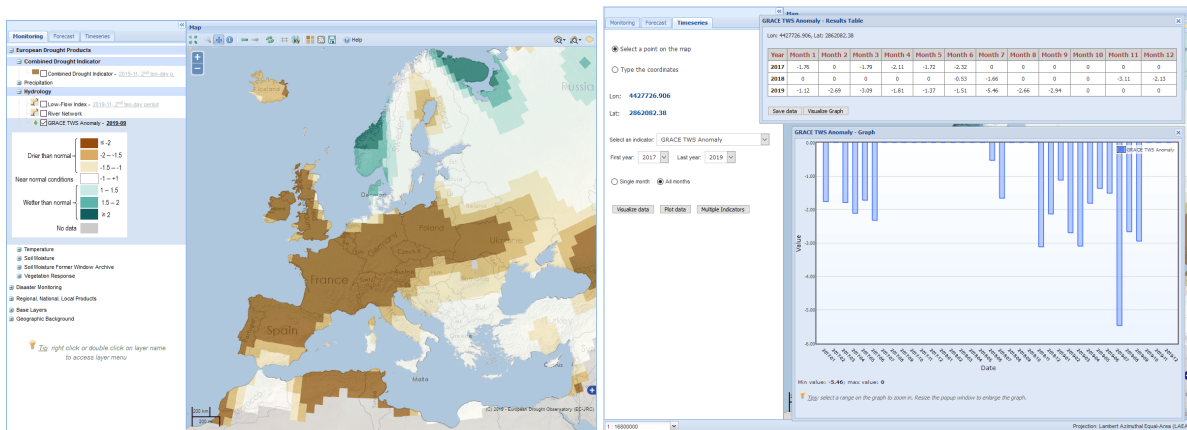
4.5.1.2 Hydrology subgroup with Low-Flow Index layers and the new GRACE TWS Anomaly

A new subgroup of “European Drought Indicators”, named “**Hydrology**”, have been added for layers of drought indicators dealing with water storage. It contains the two layers dealing with low flow and previously included in a dedicated subgroup, i.e. “Low-Flow Index” and “River Network”, and a new layer named “GRACE TWS Anomaly”.

“Low-Flow Index” loads now data of the new LISFLOOD extended window. Also its identify function has been updated accordingly.

“**GRACE TWS Anomaly**” is an EDO regionalization of the correspondent layer of GDO, described in Section 5.1. It loads maps directly from the MapServer-based WMS service of GDO and its data are available not only as a map in the *Monitoring* tab but also through tables and graphs in the *Time series* tab.

Figure 31. “GRACE TWS Anomaly” in the new “Hydrology” subgroup, visualized into the map (left) and by the graphs of Time series tab (right).



4.5.1.3 Other changes

The following other changes involved the EDO MapViewer during 2019:

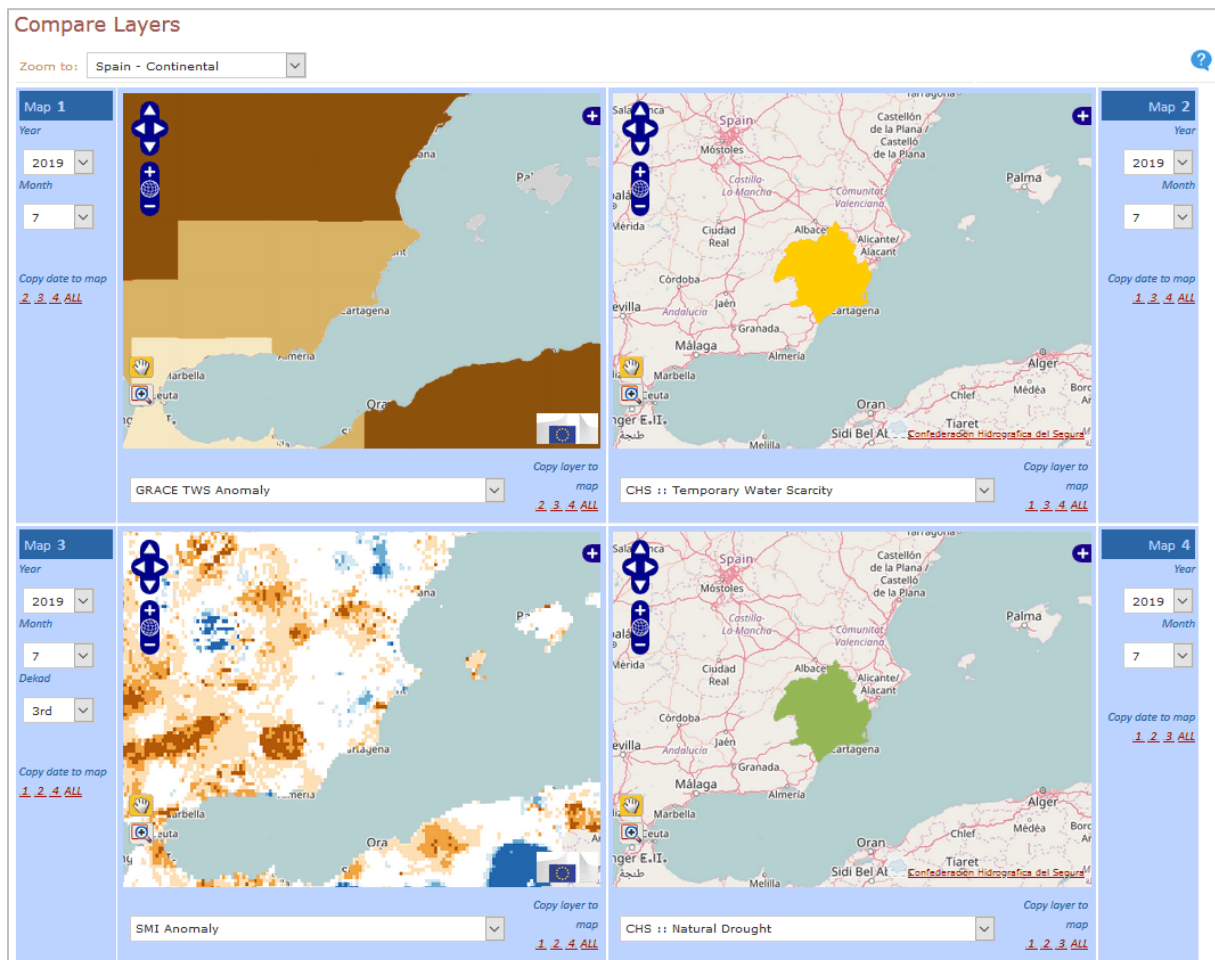
- “Continent” and “Natural Earth” base layers were re-organized optimizing the archive of source raster files, now stored into /var/www/edo/gisdata/world/natural_earth/ of the external server. Derived base layers are:
 - o “Natural Earth”: raster Natural Earth’s shaded relief without bathymetry; this is the default base layer;
 - o “Natural Earth with Bathymetry”: raster Natural Earth’s shaded relief with bathymetry;
 - o “Continent”: empty map with white land mass and light blue seas, based on vector sources (ESRI shapefiles) from Natural Earth, replacing the previous version loading a lesser resolution raster image.
- Layers displaying the Heatwave Magnitude Index (HWMI) were removed.
- The WMS layer loaded by “Fire Danger (FWI)” (FWI standing for Fire Weather Index) of GWIS (Global Wildfire Information System) was changed to ecmwf.fwi, while its service ies-ows.jrc.ec.europa.eu/gwis was moved from HTTP to HTTPS protocol by Forest Fires team.
- For security reasons some WMS layers provided by EDO are now served by a new PHP program named mswms.php instead of directly by OsGeo MapServer (mapserv).
- For security reasons the system layer used to highlight queried or zoomed geographical features does not use anymore the session id but a key based on a random number and on the id and table name of the selected object.

4.5.2 New layers in Side by Side Maps

Side by Side Maps (webpage 1138) reflects changes affecting the MapViewer: updates made in 2019 are listed below.

- New soil moisture layers based on SMI replaced the former ones; current layers are “Last Daily SMI”, “Last Daily SMI Forecast”, “Last Daily SMI Anomaly Forecast” (daily maps), “Soil Moisture Index (SMI)”, and “SMI Anomaly” (10-daily maps).
- The new monthly layer “GRACE TWS Anomaly” was added.
- “Low-Flow Index” was added with its new LISFLOOD extended window.
- The new “Natural Drought” and “Temporary Water Scarcity” provided by Confederación Hidrográfica del Segura (CHS) were added.
- “Piezometers-ADES” was removed since not provided anymore by BRGM.
- All colour schemes were revised according to the new classifications.

Figure 32. Side by Side Maps used to examine the two WMS layers provided by CHS for July 2019 (right) together with “GRACE TWS Anomaly” (top-left) and “Soil Moisture Index (SMI) Anomaly”.



4.5.3 Changes in other web GIS tools

Only one new entry in the public **Time series** webpage (id=1141) in 2019: the Total Water Storage (TWS) Anomaly, based on GRACE (Gravity Recovery And Climate Experiment) satellite data and described in section 5.1. Here below an example of its graph.

Indeed, internal versions of EDO Time series was provided also with Soil Moisture Index (SMI).

Figure 33. Graph of TWS Anomaly, together with CDI and Soil Moisture Anomaly, from 2017 to 2019 on the Öland Island (Sweden).



MapGenerator (webpage 1181) was updated with the new soil moisture SMI layers and in general with the new colour schemes.

The generic WMS service **ows.php** and the **desktop GIS project files** of webpage 1165 were updated as well with the new soil moisture SMI layers, colour schemes and security improvements.

New soil moisture SMI layers and GRACE TWS Anomaly were included in the data presence scan of **Availability of Maps in Archive** (webpage 1104)

4.6 New colour schemes

Several drought indicators of EDO and GDO were reviewed in order to check and update their classifications and colour schemes. In EDO “fAPAR (fraction of Absorbed Photosynthetically Active Radiation)”, the Combined Drought Indicator, the temperature layers and the Low-Flow Index in EDO did not change, while in GDO “fAPAR” and the Risk of Drought Impact for Agriculture have not been varied in their presentation. The main goal of this operation was homogenizing all anomaly layers in terms of number of classes, set to seven, and differentiating their colour schemas in order to clearly distinguish them. Changes in classifications of main drought indicators are described in detail in the following.

■ **Monthly Precipitation** (layer present in EDO, GDO, SCADO, ADO)

There are two classifications, one for EDO and one for the other drought observatories, with a continuous part from 0 to 200 (EDO) or 400 (others) mm of precipitation and three discrete extra classes for extreme rains.

Table 14. Classification of layer “Monthly Rainfall”.

Continuous classification						
Drought Observatory	Minimum		Number of classes	Class length (mm)	Maximum	
	Value (mm)	Colour			Value (mm)	Colour
EDO	0	White (255 255 255)	100	2	200	Blue (0 0 255)
GDO, SCADO, ADO				4	400	
Discrete extra-classes						
Extra class	Colour	Drought Observatory	Values interval (mm)			
1	Dark purple (102 0 76)	EDO	$200 < v \leq 300$			
		GDO, SCADO, ADO	$400 < v \leq 500$			
2	Purple (153 0 104)	EDO	$300 < v \leq 400$			
		GDO, SCADO, ADO	$500 < v \leq 600$			
3	Deep pink (204 0 153)	EDO	$v > 400$			
		GDO, SCADO, ADO	$v > 600$			
No Data	Grey (210 210 210)	all	-			

Figure 34. Legend of Monthly Precipitation for EDO (left) and GDO, SCADO and ADO (right).



■ Standardized Precipitation Index (SPI) (EDO, GDO, SCADO, ADO) and SPI at SYNOP stations (EDO only)

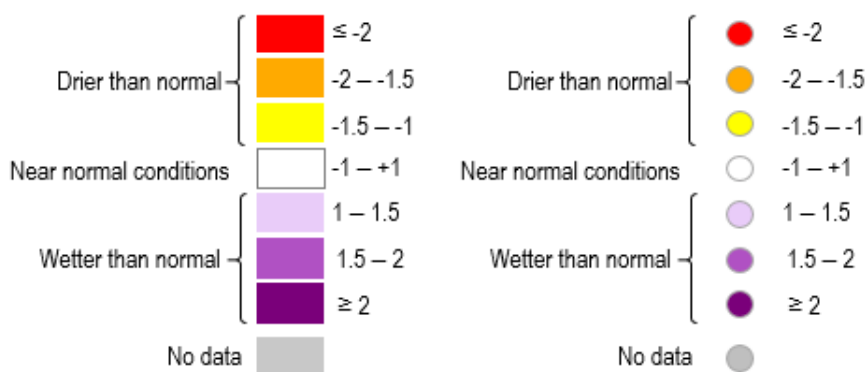
The classification of SPI for both gridded and station layers have been revised introducing a violet-based discrete gradient for wet classes instead of the previous blue-based one.

Table 15. Classification of SPI layers.

Class name	Index value	Colour
Drier than normal	$v \leq -2$	Red (255 0 0)
	$-2 < v \leq 1.5$	Orange (255 170 0)
	$-1.5 < v \leq 1$	Yellow (255 255 0)

Near normal conditions	$-1 < v \leq 1$	White (255 255 255)
Wetter than normal	$1 < v \leq 1.5$	Lilac (233 204 249)
	$1.5 < v \leq 2$	Medium violet (201 128 198)
	$v \geq 2$	Dark purple (131 51 147)
No data	-	Grey (210 210 210)

Figure 35. Legend of SPI layers: “Standardized Precipitation Index (SPI)” (left) and “SPI at SYNOP stations” (right).



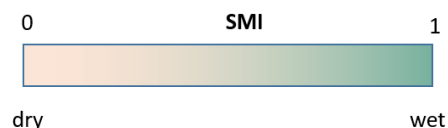
■ Soil Moisture Index (SMI) (EDO only)

The new Soil Moisture Index (SMI) layers present in EDO, i.e. “Last Daily SMI”, “Last Daily SMI Forecast” and “Soil Moisture Index (SMI)” (LISFLOOD new extended window; see Section 4.1) have a continuous classification with values going from 0 to 1 and colours ranging from pink to green.

Table 16. Classification of Soil Moisture Index (SMI) layers.

Minimum		Number of classes	Class length	Maximum	
Value	Colour			Value	Colour
0.0	Pink (247 190 175)	200	0.005	1.0	Green (74 130 111)

Figure 36. Legend of Soil Moisture Index (SMI) layers.



■ Soil Moisture Anomaly (EDO and GDO)

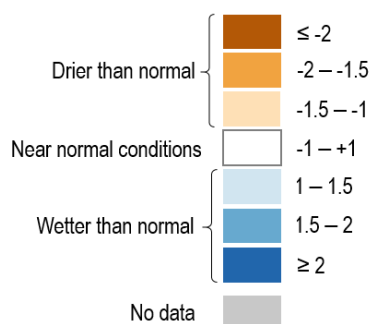
The Soil Moisture Index (SMI) Anomaly layers of EDO (i.e. “Last SMI Anomaly Forecast” and “SMI Anomaly”; LISFLOOD new extended window) and the “Soil Moisture Anomaly” layer of GDO from the ensemble approach

(weighted average of LISFLOOD root zone soil moisture, MODIS Land Surface Temperature, ESA CCI (Climate Change Initiative) remote sensing skin soil moisture; see Section 2.3) share the same classification, using a discrete gradient of blue for wet classes and a discrete gradient of brown for the drier ones.

Table 17. Classification of Soil Moisture Anomaly layers.

Class name	Index value	Colour
Drier than normal	$v \leq -2$	Dark brown (179 88 6)
	$-2 < v \leq 1.5$	Orange (241 163 64)
	$-1.5 < v \leq 1$	Bisque (254 224 182)
Near normal conditions	$-1 < v \leq 1$	White (255 255 255)
Wetter than normal	$1 < v \leq 1.5$	Light blue (209 229 240)
	$1.5 < v \leq 2$	Sky blue (103 169 207)
	$v \geq 2$	Blue (33 102 172)
No data	-	Grey (210 210 210)

Figure 37. Legend of Soil Moisture Anomaly layers.



■ **fAPAR Anomaly** (EDO, GDO, SCADO, ADO)

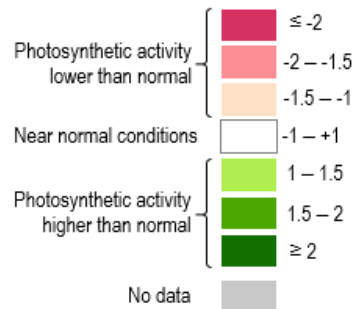
New 7-classes classification with green discrete gradient for positive anomalies and pink discrete gradient for negative ones.

Table 18. Classification of layer “fAPAR Anomaly”.

Class name	Index value	Colour
Photosynthetic activity lower than normal	$v \leq -2$	Deep pink (215 48 99)
	$-2 < v \leq 1.5$	Light coral (252 141 149)
	$-1.5 < v \leq 1$	Bisque (254 224 199)
Near normal conditions	$-1 < v \leq 1$	White (255 255 255)

Photosynthetic activity higher than normal	$1 < v \leq 1.5$	Light green (175 237 81)
	$1.5 < v \leq 2$	Green (75 166 0)
	$v \geq 2$	Dark green (19 111 0)
No data	-	Grey (200 200 200)

Figure 38. Legend of fAPAR Anomaly.



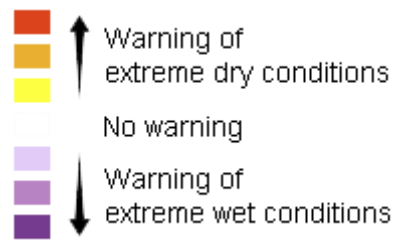
■ Extreme SPI Forecasts for 3 months (EDO and GDO)

Classification of SPI Forecast was changed not in colors but in actual class definition, moving value 2 in the orange class, value 3 in the red, 5 in the lilac and 6 in the violet.

Table 19. Classification of layer “Extreme SPI Forecasts for 3 months”.

Class name	Index value	Colour
Warning of extreme dry conditions	$v = 1$	Red (255 0 0)
	$v = 2$	Orange (255 170 0)
	$v = 3$ or $v = 4.25$	Yellow (254 255 0)
No warning	$v = 0$	White (255 255 255)
Warning of extreme wet conditions	$v = 4.75$ or $v = 5$	Lilac (233 204 249)
	$v = 6$	Violet (201 128 198)
	$v = 7$	Dark violet (131 51 147)

Figure 39. Legend of Extreme SPI Forecasts for 3 months.



5 Other improvements in GDO

For the Global Drought Observatory we were able to include the Groundwater evolution through time, and although this layer is still to be validated, the information therein is very important as it displays one of the main concerns in establishing drought plans and the often unsustainable use of irrigation. In addition we completed the integration of Glofas, the global LISFLOOD version at 0.1 decimal degrees and added layers describing low flow at world level. Important development described in the chapter is the attempt to map fAPAR trends using the Sentinel high resolution sensors. We expect that in the course of 2020 we can integrate a high resolution map with Sentinel born data for areas with reported drought warnings. We also describe the work done in the MUKAU project in which we prepare our systems to function fully on Open Source software, replacing the Oracle Spatial Database for a PostgreSQL POSTGIS version. With this project we can enable organisations in Africa, the Caribbean and the Pacific to use our platform and thus inform the public in their countries on drought alerts, fine-tuned to their specific reality.

5.1 Total water storage data inclusion through GRACE input

In 2002, the Gravity Recovery and Climate Experiment (GRACE) mission was launched (Tapley, et al. 2004), aiming at providing satellite observations of the gravity field of the Earth. In the framework of hydrological applications, this dataset represented an unprecedented stream of data to globally monitor the dynamic of the total terrestrial water storage (TWS; the sum of all above and below surface water storages, including canopy water, rivers and lakes, soil moisture, and groundwater) (Wahr, Swenson and Velicogna 2006). Following the decommissioning of the GRACE satellites in 2017, a follow-on mission, namely the GRACE-FO, was successfully launched in 2018 in order to ensure continuity to the Earth's gravity measurements collected by its predecessor.

Monthly TWS anomalies (TWSA) are derived from the GRACE-FO dataset, using the GRACE data for the period 2002-2017 for the computation of the baseline climatology monthly statistics. Data at the 1 degree resolution can be downloaded from

https://podaac-tools.jpl.nasa.gov/drive/files/allData/tellus/L3/gracefo/land_mass/RL06/JPL

Only months with at least 10 days covered are considered. Cells in desert areas are masked in the final product.

The data are processed in the ENVI+IDL environment. Monthly raw data (in NetCDF format) are analysed by the program `read_gracefo_nc.pro`, which checks data projection, masks the low-quality areas and tests the temporal overlap between available dates and the monthly window. Successively, the monthly data are converted in anomalies with the program `gracefo_anm.pro`. The output file is saved into the `/GRACE_anm/` directory of the central repository, with name `tw_s_anm_[YYYY]-[MM].img`, e.g. `tw_s_anm_2019-10.img` for October 2019.

Successively, such a file is read by `geotiff2ora.py` to copy the data into the Database. The target table is `GRID_1DD_GRACE` (owners are drought and gdopr in DEA and Esposito respectively) while the target column is `LWE_ANOM_[MM]`, e.g. `LWE_ANOM_06` for data of June.

When data insertion is completed, the last available date for GRACE TWS Anomaly is updated into `layerDates.js`, by means of the usual PowerShell tools `updateGdoLayerDatesJs.ps1` and `updateEdoLayerDatesJs.ps1` (layer id=45).

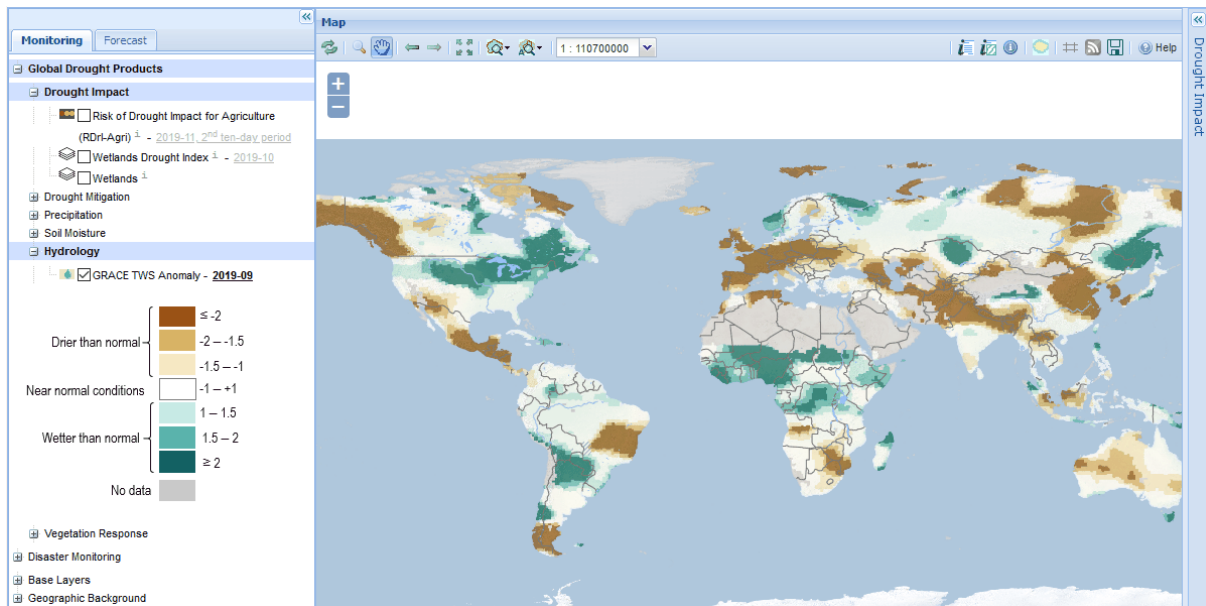
The GDO MapViewer presents the “**GRACE TWS Anomaly**” layer within a new subgroup of “Global Drought Products” named “**Hydrology**”, in analogy with EDO (see Section 5.1). Its classification and colour scheme follow.

Table 20. Classification of GRACE TWS Anomaly.

Class name	Index value	Colour
Drier than normal	$v \leq -2$	Brown (140 81 10)
	$-2 < v \leq 1.5$	Ochre (216 179 101)
	$-1.5 < v \leq 1$	Bisque (246 232 195)
Near normal conditions	$-1 < v \leq 1$	White (255 255 255)

Wetter than normal	$1 < v \leq 1.5$	Light cyan (199 234 229)
	$1.5 < v \leq 2$	Turquoise (90 180 172)
	$v \geq 2$	Teal green (1 102 94)
No data	-	Grey (210 210 210)

Figure 40. The new subgroup “Hydrology”, its “GRACE TWS Anomaly” layer with related legend.



“GRACE TWS Anomaly” is available also in MapViewer’s Identify All Drought Indicators and in Compare monthly maps (webpage id=2075), as illustrated in the next two figures.

Figure 41. “GRACE TWS Anomaly” and the revised “Soil Moisture Anomaly” in output of Identify All Drought Indicators.

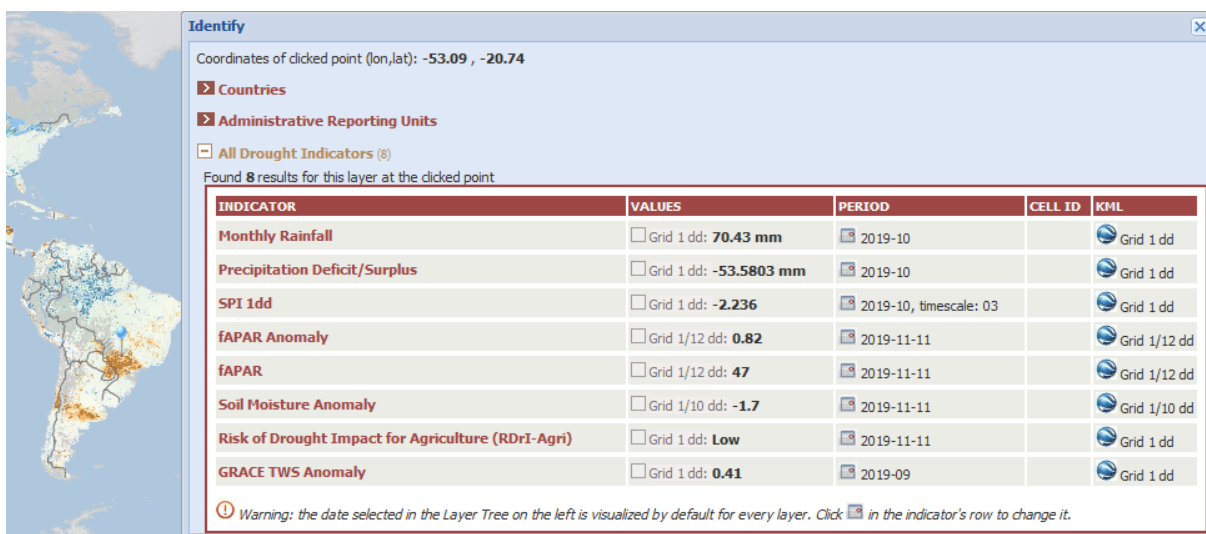
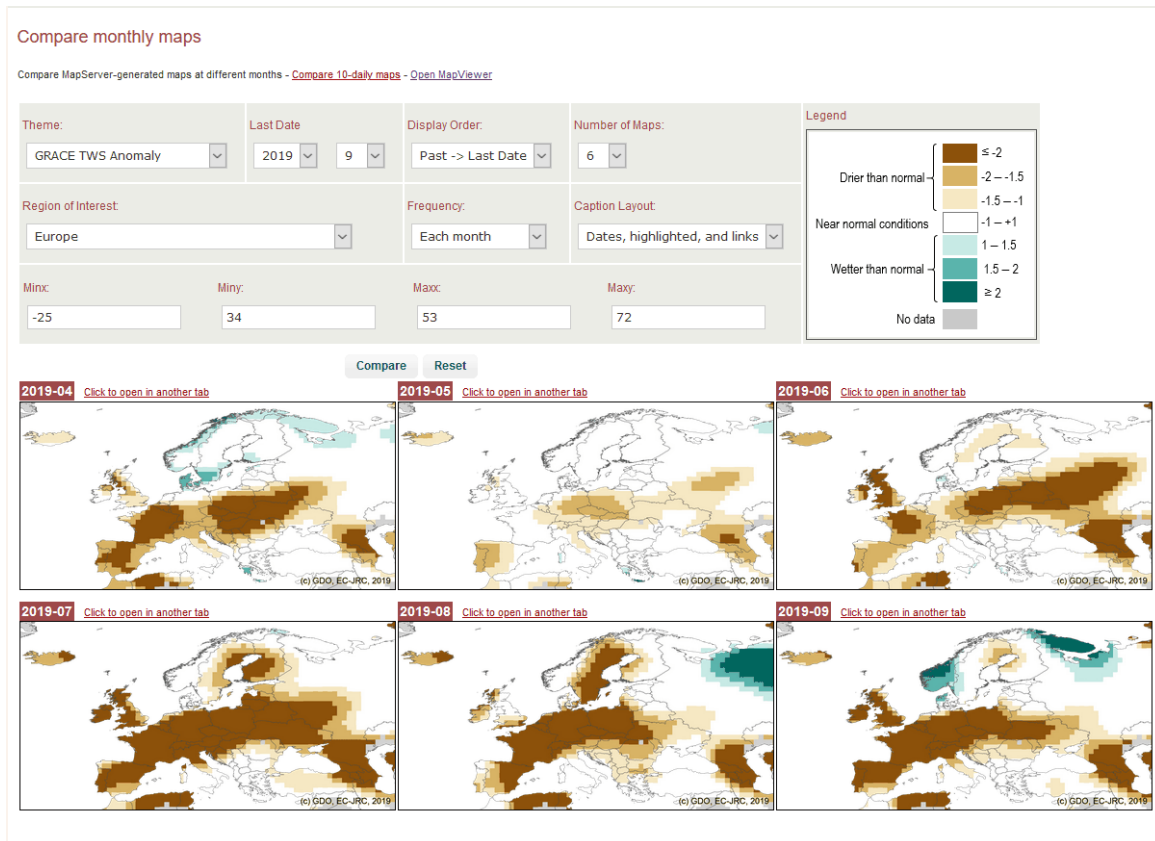


Figure 42. “GRACE TWS Anomaly” in Compare monthly maps: situation from April to September 2019 in Europe.



5.2 Low Flow Index LFI generation using Global LISFLOOD output

A Low Flow Index LFI was introduced in 2016, and all the details regarding its design are described in (Cammalleri, Vogt, & Salamon, Development of an operational low-flow index for hydrological drought monitoring over Europe, 2017), in Chapter 2. Method . Since 2018 Low Flow daily procedure for EDO was updated to work with the new LISFLOOD window, and written in Python programming language.

Subsequently, in 2019, the LFI for GDO was tested. The calculation procedures are the same as EDO’s LFI and are detailed in EDO and GDO Annual Progress Report of 2018 in Chapter 3. Unlike EDOs’ LFI, GDO’s LFI uses as input the Global LISFLOOD model discharge output.

Since this year, LISFLOOD has now been released as a fully open-source code and can be downloaded from the repository: <https://ec-jrc.github.io/lisflood/>. This version of LISFLOOD is available as a Docker image⁷ that now is running in our processing Virtual Machine (see 1.7. Virtual Machine upgrades and automation). All the steps followed to install Docker on the virtual machine are described in Confluence: <https://webgate.ec.europa.eu/CITnet/confluence/display/DROUGHT/LISFLOOD+Open+source>.

5.2.1.1 Description of the daily procedure

The new LFI daily procedure is available on the central repository, under the directory `central_repo\procedures\dea\gdolowflowprd`.

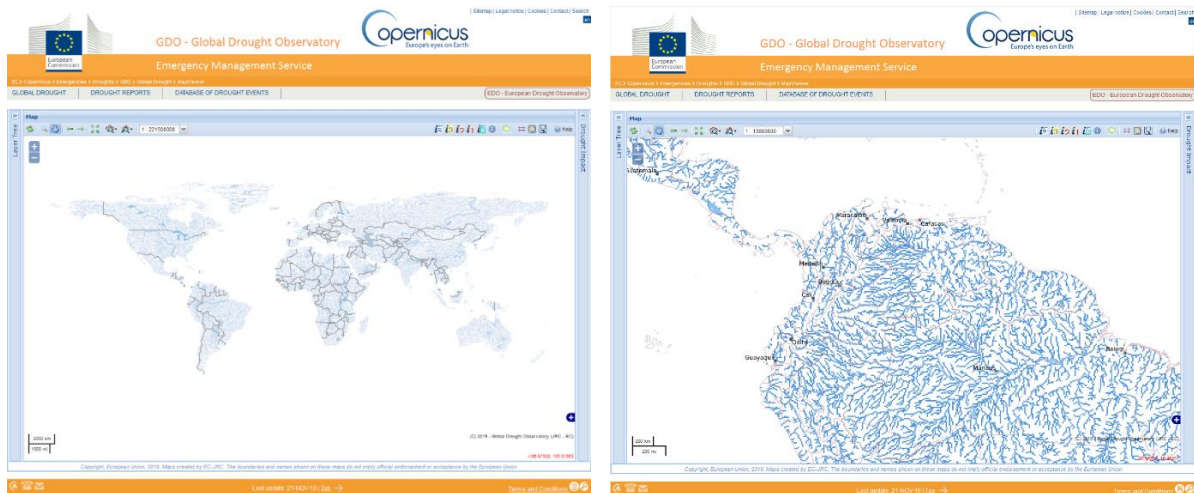
The LISFLOOD output NetCDF grid is stored as a vector layer on the database (Oracle Dea database, gridref schema) in the `GRID_01DD` table. It has 5400000 cells and dimensions [x: 3600, y: 1500, time], with origin on the upper left corner of the grid. `DEA.GRID_01DD` grid has 6480000 cells and dimensions [x: 3600, y: 1800] with a cell ID `G01D_ID`, resolution of 0.1 degrees in ESPG 4326. Some adjustments had to be made for seemly

⁷ <https://www.docker.com/>

GRID import/export between the vector model database and the Python array model due to the differences between the 2 grids.

On the grid, the drainage network cells (column `DRAINED_KM2`) correspond to river pixels above 1000 km², represented by the upstream area (in km²), as is shown in Figure 43.

Figure 43. World River Network, in raster format on GDO



The procedure is done through a series of scripts, described as it follows:

- `lowflow_calculations.py`: Python module containing a series of functions for LFI calculations that are common for `getgdolowflow_log.py`, `getlowflow_extended.py` and `lowflow_to_ora.py`.
- `getlowflow.py`: Python module containing a series of functions to execute the daily procedure for inserting daily data into `PRECPRD.GRID_01DD_LOWFLOW_DECADE`.
- `getgdolowflow_log.py`: Is the task manager of the procedure. This Python script controls the file's creation – process - export and launches daily and dekadal calculations and procedures of LFI. The script :
 - Updates table `PRECPRD.LOWFLOW_FILE_LOG` (daily file log), describing the state of the files (pending/created/processed),
 - Creates pending files according to the daily file log by running LISFLOOD, using the following process :
 - Updates LISFLOOD's meteorological forcing variables (potential evapotranspiration, soil evaporation, open water evaporation, precipitation and average temperature) files from MARS database,
 - Changes the procedure settings file to update the date for the run,
 - Creates an output folder with the run date,
 - Copies and deletes the .end files of the last run into init folder for the next run. It also makes a backup for past runs, maintaining the last week/month,
 - Runs LISFLOOD. LISFLOOD creates the discharge file as output.
 - Launches daily procedures (`getlowflow.py`) for each created file.
 - Launches dekadal procedures (`calclowflow_extended.py`) for LFI calculations every ten days.
- `calclowflow_extended.py`: Python module containing a series of functions to execute the dekadal procedure for the LFI calculation. Its main function `dekadal_procedure`:

- Gets last dekad values of deficit, gap and duration from `PRECPRD.LOWFLOW_FILE_LOG_DECADE`,
- For each day of the dekad, calculates daily deficit, gap, duration according to the proposed LFI implementation in (Cammalleri, Vogt and Salamon 2017),
- Calculates the dekadal LFI according to its proposed implementation in (Cammalleri, Vogt and Salamon 2017),
- Inserts new calculated deficit, gap, duration first in `PRECPRD.GRID_01DD_LOWFLOW_TMP` table to use the data then to update the `PRECPRD.GRID_01DD_LOWFLOW_DECADE` table,
- Inserts the LFI first in `PRECPRD.GRID_01DD_LOWFLOW_TMP` table to use the data then to update the `PRECPRD.GRID_01DD_LOWFLOW` table.
- Updates table `PRECPRD.LOWFLOW_PROCESSING_LOG` (dekadal log) once calculations have been made.

This procedure uses a configuration file `getlowflow_gdo_config.json` and the Drought Python Modules `oracle_mgt` and `netcdf_handling`.

For logging purposes, the procedure produces a log file `calclowflow.log`, that can be set up on the logging configuration file `getlowflow_logging_config.json`.

More technical details of the procedure are described on the *Drought wiki on Confluence*; section *Global LISFLOOD* <https://webgate.ec.europa.eu/CITnet/confluence/display/DROUGHT/Global+LISFLOOD>

5.2.1.2 Calculation of Low Flow Index historical data

A long run of LISFLOOD was made to calculate discharge data from 1989 to 2019, and with this data LFI was calculated.

Discharge data and LFI are now stored in the database (Oracle *DEA* database, *PRECPRD* schema) `PRECPRD.GRID_01DD_LOWFLOW` table by dekad from 1989 to the present. The recalculation and database insertion algorithm can be found in an *ipython notebook* available in the central repository, at the directory: `central_repo\procedures\python\ipython_notebooks\lowflow_to_ora.ipynb`. The script, for each dekad:

- Aggregates data and calculates the discharge average (by time) of each dekad,
- Calculates daily deficit, gap, duration and the LFI according to the proposed LFI implementation in (Cammalleri, Vogt and Salamon 2017),
- Inserts the discharge average is first in `PRECPRD.GRID_01DD_LOWFLOW_TMP` table to use the data then to update the `PRECPRD.GRID_01DD_LOWFLOW` table,
- Inserts the LFI first in `PRECPRD.GRID_01DD_LOWFLOW_TMP` table to use the data then to update the `PRECPRD.GRID_01DD_LOWFLOW` table.

As an extra feature, processed data can be exported in a NetCDF file compliant with the CF-1.6 NetCDF Convention⁸.

5.2.1.3 Next steps

The daily procedure will be operational at the beginning of next year. To get a vector visualization of the river network as it is on EDO, it is necessary to evaluate the topological relation of the existing world river networks⁹ that can be used, and correct them if necessary. Once the river network is corrected, and the major rivers identified, vector layer can be spatially related with the dekadal results of the LFI for GDO.

⁸ <http://cfconventions.org/Data/cf-conventions/cf-conventions-1.7/cf-conventions.pdf>

⁹ https://www.bafg.de/GRDC/EN/02_srvcs/22_gslrs/gislayers_node.html,
<https://www.hydrosheds.org/page/gloric>.

<https://geo.nyu.edu/catalog/stanford-fv375tj7951>,

5.3 Web mapping functions for the Global Drought Observatory

The GDO MapViewer was not subject to massive changes during 2019 but was updated with the layers presented in the previous sections - i.e. Soil Moisture Anomaly, GRACE TWS Anomaly, Potential tree cover analysis, and Wetland Drought Index - and with the following improvements:

- Like in EDO, “Continent” and “Natural Earth” base layers were re-organized optimizing the archive of source raster files, now stored into `/var/www/edo/gisdata/world/natural_earth/` of the external server. Derived base layers are:
 - o “**Natural Earth**”: raster Natural Earth’s shaded relief without bathymetry; this is the default base layer;
 - o “**Natural Earth with Bathymetry**”: raster Natural Earth’s shaded relief with bathymetry;
 - o “**Lands and Oceans**”: empty map with white land mass and light blue seas, based on vector sources (ESRI shape files) from Natural Earth.
- The **background layers active by default** changed after excluding “Capitals” and “Urban areas” and now they are: “Towns”, “Countries”, “Administrative Reporting Units” (ARUs), “Water surfaces” and “Rivers”. Their look and feel changed too, with the common goal of making them less impacting in the map: for example country or ARU borders were reduced in thickness and set with a less evident colour and the colour of seas was set to salty lakes.
- As a consequence of the change of the default background layers and of renaming¹⁰ of cities and countries, the **new *geoback_light* TileCache layer** was defined with such default layers and replaced the former *geoback_default*. In order to guarantee good performance in map generation at least at small scales, tiles of *geoback_light* were pre-generated and cached with `tilecache_seed.py` according to the following table. Levels from 1 to 6 are complete, since tiles over lands and oceans are all already available. Levels 7 and 8 are complete only on lands and parts of oceans falling in the bounding box of all the world countries. Levels 9 and 10 are incomplete: available are tiles over areas accessed by users during map navigation or when drought events are defined for GDACS or a new analytical report is published. In the first case, the program **`tilecache_seed_by_agri_event.py`** selects from `AGRI_EVENTS` Oracle table all the bounding boxes of every drought event marked as confirmed and delivered to GDACS; then it launches `tilecache_seed.py` for each of them. In the latter case, **`tilecache_seed_by_country.py`** takes as argument a CSV list of all the countries affected by the drought situation described into the report and then calls `tilecache_seed.py` for the bounding box of each country. By default, both `tilecache_seed_by_agri_event.py` and `tilecache_seed_by_country.py` are executed for levels from 7 to 10; usually very few new tiles are generated for levels 7 and 8, i.e. when the event’s bounding box covers an ocean area not included in any country’s bounding box.

Table 21. Available cached tiles of *geoback_light* TileCache layer.

Zoom level / TileCache level	Approximated value of map scale displayed by the MapViewer	Number of cached tiles
1	1 : 110 700 000	All tiles, oceans included
2	1 : 55 400 000	
3	1 : 27 700 000	
4	1 : 13 800 000	
5	1 : 6 900 000	
6	1 : 3 500 000	

¹⁰ Indeed, a local refresh of tiles was necessary to take into account the renaming of the Kazakhstan capital from Astana to Nursultan.

7	1 : 1 700 000	All tiles included in country bounding boxes
8	1 : 900 000	
9	1 : 400 000	Only tiles in areas affected by drought events since July 2019 or visualized by users
10	1 : 200 000	

- The WMS layer loaded by "**Fire Danger (FWI)**" (FWI standing for Fire Weather Index) of GWIS (Global Wildfire Information System) was changed to ecmwf.fwi, while its service ies-ows.jrc.ec.europa.eu/gwis was moved from HTTP to HTTPS protocol by Forest Fires team.
- The layer "**Dams**" was moved to the new "**Drought Mitigation**" group together with the multi-theme layer "Potential tree cover analysis".
- For security reasons some WMS layers provided by GDO are now served by a new PHP program named **mswms.php** instead of directly by OsGeo MapServer (mapserv).

For security reasons the system layer used to **highlight queried or zoomed geographical features** does not use anymore session id but a key based on a random number and on the id and table name of the selected object.

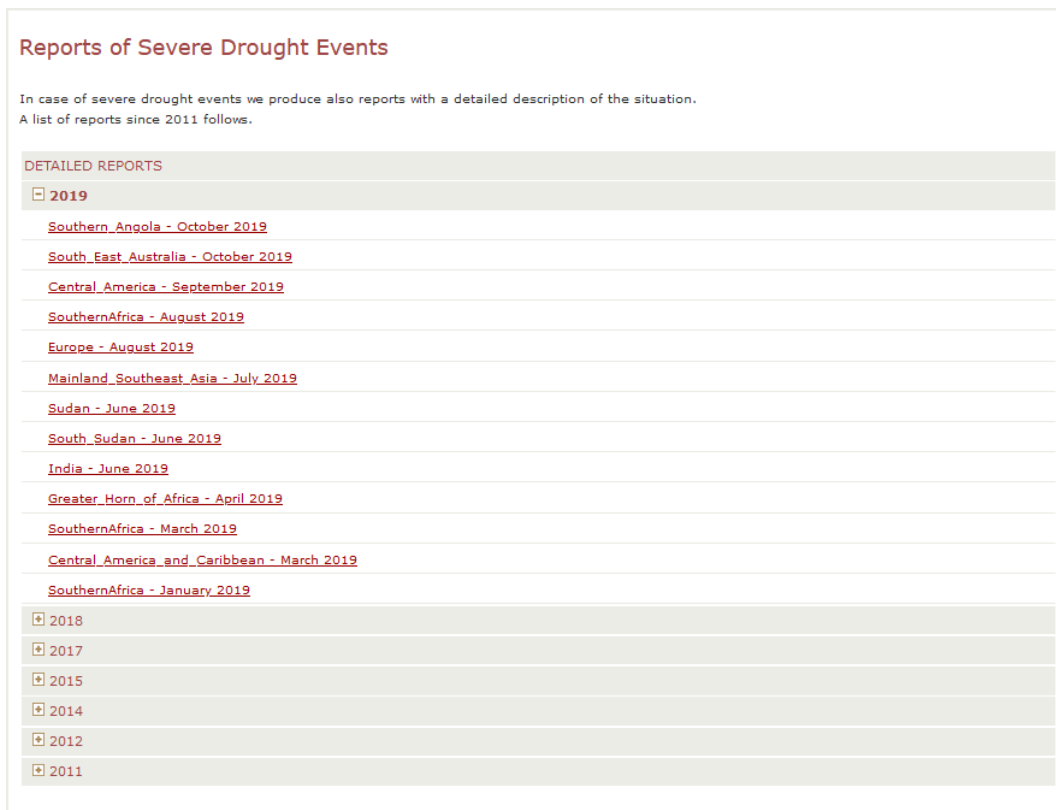
5.4 Other tools and informative webpages

The following changes affected other webpages of GDO, both in public and development/staging webservers.


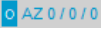
- **Analytical reports of GDO are grouped by year**, in order to limit the length of the containing webpage <https://edo.jrc.ec.europa.eu/gdo/php/index.php?id=2050>. Each year appears as a block that can be expanded/collapsed clicking the dedicated icon. This property is managed by the PHP constant GROUP_BY_YEAR in /var/www/edo/site/edov2/php/include/reports.class.php (please note that GDO utilized the function of EDO). By default the blocks of the last two years are expanded, the other are collapsed; this setting can be modified using the PHP constant YEAR_BACK_INIT_EXPANDED in the previously mentioned reports.classes.php.

This property is available in EDO too, but it is disabled at the moment because the list of reports concerning Europe is still enough short to be visualized entirely.

Figure 44. “Reports of Severe Drought Events” webpage updated with year-based expand/collapse blocks.



- The following improvements involved “Define Drought Events” (webpage id=2067), the web interface available only on development and staging servers to analyse and finalize **drought events for GDACS**.
 - o The new **IMPACT_SHORT** column has been added to AGRI_EVENTS, MANUAL_EVENTS, AGRI_EVENT_EVOLUTION and MANUAL_EVENT_EVOLUTION Oracle tables, with possible values “Minor”, “Medium”, and “Severe”. This value is used in GDACS event presentation, in the “Impact” field and in the “Episode Timeline” of “Impact” section.
 - o A new set of properties with pre-defined values, used to perform an “**Event Evaluation**” and organized in a table highlighted by an orange border (e.g. see in the next Figure 45), has been introduced in 2019. When an event is selected in the map or from the list, such a table is displayed below the blue-bordered block of “Edit Event”. All those properties can be set from the interface and saved into the GDACS_EVALUATION (drought user) Oracle table. Each property corresponds to a column and set of fix values have been associated to them by means of CHECK constraints. Every time at least one among GDACS_MAX, EVALUATOR and REFERENCE_DATE is changed, a new row is inserted into GDACS_EVALUATION. Instead, if any other property varies, it is updated within an existent evaluation row. Properties and allowed values are listed below. Each property and class are defined by specific references or definitions, to help the evaluator to select attributes more objectively.
 - AID: no, support, humanitarian
 - CHRONIC_WATER_ISSUES: yes, no
 - CONFLICTS: no, local, yes
 - CROP_DAMAGE: none, minor, major
 - DURATION_GT90D: short, long
 - EVALUATOR: list of Drought Team members
 - EXTENSION: local, medium, large

- FAMINE: yes, no
 - FOOD_SECURITY: no, local, wide
 - FORECAST_OUTLOOK: normal, bad
 - FREQUENT_EVENTS: yes, no
 - GDACS_MAX: number from 0 to 3, in quarters of units
 - GRAIN_PRICE: ok, increase
 - GROWING_SEASON: no, slight, core
 - HIGH_TEMP_ANOM: yes, no
 - INDICATORS_AGREEMENT: good, fair, bad
 - LIVESTOCK: ok, shortage, famine
 - MEDIA_NEWS: none, few, many
 - METSOURCES: confirm, no
 - MIGRATIONS_REFUGEES: no, local, mass
 - POLITICAL_INSTABILITY: yes, no
 - RAINFALL_SEASONALITY: weak, strong
 - RDRI: low, medium, high
 - REFERENCE_DATE: dekad as YYYY-MM-DD
 - RESERVOIRS_STATUS: ok, bad
 - RIVERS_STATUS: ok, poor, bad
 - SMALL_FARMING: yes, no
 - SOCIAL_INSTABILITY: no, protests, riots
 - WATER_SUPPLY: discomfort, dry, good
 - WIDER_ECONOMY_AFFECTED: yes, no
 - WILD_FIRE_HAZARD: yes, no
- New thematic layers added: “Monthly Precipitation”, “Soil Moisture Anomaly”, “fAPAR Anomaly”, “SPI Forecast”.
 - “**Below Threshold (BT) Events**”, having $class_2 < 3$ and $class_3 < 1$, are marked with the  BT icon followed by the number of cells for each class. For any reason the algorithm which finds drought events during the “Unsupervised phase” can propose also events with 0 affected cells for each class: such events are named “**Ghost events**” or “**All-zero (AZ) events**” marked with the  label. Persistence of BT, AZ, and closed events in the interface list and in the GeoJSON output delivered to GDACS are discussed in CITnet Confluence: <https://webgate.ec.europa.eu/CITnet/confluence/display/DROUGHT/Supervised+definition+notes>.
 - The new property (and table column) “**GDACS_ID**” is used when an event with ID=x must be passed to GDACS with another ID=y, in order to link it to an active Episode Timeline. For example, an event X, with ID=x, stays active for 10 dekads and an Episode Timeline is defined in GDACS accordingly. Then the event X is closed and another event Y appears in the same area of X, found by the unsupervised algorithm as an independent event, identified with a new ID=y. During GeoJSON publication, Y appears with its ID=y and a completely new event is defined in GDACS. This is correct if Y is not related to X in any way. But if Y can be considered as a continuation of the event X even if the unsupervised algorithm has found it as independent event, there is the need to link Y to the 10-dekad Episode Timeline of X seen before. During supervised definition with webpage 2067, the evaluator can set the value of GDACS_ID of the event Y with the ID of the event X. In this way, GDACS will take the value of

GDACS_ID as event ID, therefore considering Y as X and appending the current situation to the Episode Timeline of X. In fact, to set the ID of an event, GDACS considers first of all the value of GDACS_ID; if this is NULL, the value of ID is taken into account.

When an event has a reference to another event via GDACS_ID, there are consequences on the value of BEGIN_DATE to be exposed to GDACS. In fact, if an event A has disappeared and has been substituted by another event B and B has GDACS_ID=ID_of_A, the value of BEGIN_DATE should be the oldest between BEGIN_DATE of A and BEGIN_DATE of B. To take this into account, the view EVENTS_TO_GDACS has three columns dealing with BEGIN_DATE for an event B having a reference to another event A via GDACS_ID:

- BEGIN_DATE: is the value of BEGIN_DATE one can find in the record of event B;
- SEIZED_BEGIN_DATE: is the value of BEGIN_DATE one can find in the record of event A;
- MIN_BEGIN_DATE: is the oldest value between BEGIN_DATE and SEIZED_BEGIN_DATE or just BEGIN_DATE if GDACS_ID is null.

The GeoJSON file exposed to GDACS has an attribute named **begin_date**, whose value is the value of min_begin_date.

Figure 45. “Define Drought Events”: the new Event Evaluation block.

Define Drought Events

No.	Id	Name	Begin date	Persistence	Linked to	Last check	GDACS score	Status
1	1012686	2018 Mindanao (Philippines)	2018-10-21	open		2019-11-27, 13:33:08	0.6	✓
2	1012728	2018 Southern Africa	2018-10-21	open		2019-11-28, 10:57:32	1.75	✓
3	1013680	2019 Kariba Lake (Zambia-Zimbabwe)	2019-10-21	open	1012728	2019-11-27, 13:34:35	1.75	✓
4	1013707	2019 Central-Southern Zambia	2019-10-21	open	1012728	2019-11-27, 13:35:06	1.75	✓
5	1012806	2019 Mainland Southeast Asia	2018-11-21	open		2019-11-27, 13:35:29	1.6	✓
6	1012828	2019 Bolivia-Brazil-Paraguay	2018-12-21	open		2019-11-27, 13:37:37	1.6	✓
7	1013150	2019 Eastern Europe	2019-02-21	BT 6 / 0 / 0		2019-11-27, 13:43:55	0.75	BT

- Three important changes in geographical names happened in 2019:
 - o North Macedonia is now the name of the previous Former Yugoslav Republic of Macedonia (FYROM)
 - o The official name of Swaziland is now eSwatini
 - o Astana, the capital of Kazakhstan, was renamed to Nursultan

5.5 High resolution drought indicators using JRC Earth Observation Data and Processing Platform (JEODPP)

Typically for Drought Analysis, we focus on the so-called fraction of Absorbed Photosynthetically Active Radiation, fAPAR, analysis when it comes down to Satellite data processing. Plant water stress caused by drought affects the capacity of vegetation canopies (e.g., agricultural crops and natural vegetation) to intercept solar radiation, thereby reducing vegetation growth rate. fAPAR represents the fraction of incident solar radiation that is absorbed by land vegetation for photosynthesis, and has been shown to be effective for detecting and assessing drought impacts on vegetation canopies.

The idea of calculating fAPAR using the JRC Earth Observation Data and Processing Platform JEODPP capabilities came about to start exploiting High-Resolution data, as the one provided by Sentinel mission, to understand the advantages and possible setbacks of using these type o data for GDO and EDO drought monitoring.

The project is ongoing, and the details are explained in the following paragraphs.

5.5.1 JRC Earth Observation Data and Processing Platform (JEODPP)

The JRC Earth Observation Data and Processing Platform (JEODPP)¹¹ provides petabyte scale storage coupled to high throughput computing capacities to enable and facilitate the production of knowledge inside and outside the JRC.

Storage servers are automatically populated with data requested by the applications of the different Knowledge Production Units within the JRC. For example, the automatic download of Sentinel-2A data is achieved by using a time-based job scheduler launching OpenSearch and OpenData (ODat) scripts taking into account user requirements (geographical areas, cloud coverage, seasonality, etc.).

Processing on JEODPP can be performed at various levels:

- JEO-lab: high-level interactive processing and visualisation through web browser client
- JEO-desk: intermediate level access through remote desktop connection
- JEO-batch: low-level batch processing orchestrated by a dedicated workload manager.

Also, the JEODPP team has developed a series of Python libraries for data processing and access. Some of the most important ones are: JEODPP Interactive Library¹² for interactive map display and analysis based on Jupyter notebooks and PyJEO¹³, a python package for the analysis of geospatial data (EUPL license) to be release publicly next year (Kempeneers, et al. 2019).

5.5.2 Fraction of Absorbed Photosynthetically Active Radiation fAPAR calculation with Sentinel 2 data

GDO identifies areas prone to drought impact which are exchanged with the Global Disaster Alerting Coordination System GDACS¹⁴ system every 10 days. At the moment, GDO's fAPAR anomalies are based on MODIS data with a resolution of 500 meters (and then converted to 0.1 decimal degrees resolution) and a time series of 18 years from 2001 up-to-the last available full year.

High-resolution data from Sentinel 2 (10, 20 and 60 meters) can be used for calculating fAPAR to further characterize the identified areas. Also, the computed data could replace the current EDO's and GDO's fAPAR from MODIS¹⁵, as the end of the orbit mission is foreseen for spring 2020. Imagery can be resampled to a continental or global resolution. Therefore, we are developing a procedure to extract such data, for the moment limited to the GDACS drought prone areas, in order to include it in the GDO report tool, as an initial prototype.

The Directorate D – Sustainable Resources D6 unit, specifically Nadine Gobron's team have developed an algorithm for the calculation of fAPAR with several sensors, and have a lot of experience with this analysis¹⁶.

¹¹ <https://jeodpp.jrc.ec.europa.eu/home/>

¹² <https://jeodpp.jrc.ec.europa.eu/services/processing/interhelp/index.html>

¹³ <https://ec.europa.eu/jrc/en/publication/pyjeo-python-package-analysis-geospatial-data>

¹⁴ <https://www.gdacs.org>

¹⁵ Check the fAPAR factsheet for more information:
https://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_fapar.pdf

¹⁶ See : https://fapar.jrc.ec.europa.eu/WWW/Data/Pages/FAPAR_Algorithms/FAPAR_Algorithms_Fapar.php

More recently, they have developed a procedure for the calculation of fAPAR with Sentinel-2 L1C data, which corrects reflectance measures at the top of the atmosphere (TOA). This current procedure is a mix of IDL language, Sentinel Application Platform SNAP¹⁷, Sen2Cor processor¹⁸, GDAL geospatial library and a compiled C++ program. We are collaborating with them in order to migrate the application into Python using the JEODPP open source library Pyjeo, data storage infrastructure and multicore computing capabilities, taking into account that high resolution data is computational intensive and therefore we benefit from the JEODPP infrastructure to achieve an acceptable performance.

All the source code for this project is hosted by the JEODPP's Git-repository manager GitLab application: https://jeodpp.jrc.ec.europa.eu/apps/gitlab/use_cases/3reda/.

5.5.2.1 Initial exploration of the data

Initially we used the **JEO-lab** by developing a Jupyter notebook to prototype and exploring the JEODPP Interactive Library capabilities for extracting and managing Sentinel data using their python API's. The Notebook:

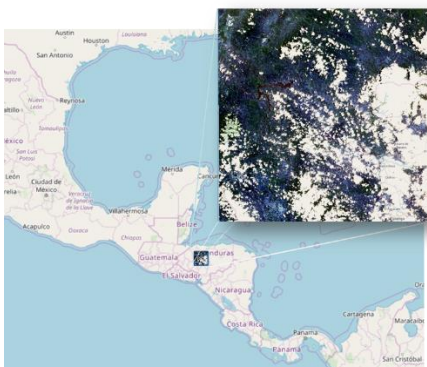
- Gets a geojson file (via url) containing the GDACS drought polygons, converts each polygon in a JEODPP VectorLayer object, import a collection (Sentinel 2A or NDVI time series) and filters the collection according to some criteria (cloud coverage, water, etc). giving a result similar to the one shown on Figure 46.

Figure 46. Example of Sentinel 2A data cropped using GDACS drought polygons



- Then, it makes a test calculation (selecting a band, making band algebra to calculate a value, calculate NDVI, etc.), masks the collection with the created VectorLayer object, exports the results as GeoTIFF, and finally puts the results on a map, as you can see in Figure 47. The map resolution changes dynamically, according to the map.

Figure 47. Example of a 10 day composite using JEO-lab



¹⁷ <https://step.esa.int/main/toolboxes/snap/>

¹⁸ <https://step.esa.int/main/third-party-plugins-2/sen2cor/>

In this case, because it was a prototype, no efforts were done to fill the black areas due to clouds and other type of masking.

5.5.2.2 fAPAR Procedure

For developing the procedure to calculate fAPAR from Sentinel 2 data, we are using the JEO-desk environment with PyCharm integrated development environment. The procedure workflow is the following:

The GDACS drought polygons are retrieved, and for each of them the extent is extracted as well, together with the IDs of all the tiles to be processed, within the polygon extent. Then, the procedure loops a single tile processor that transform data from L1C data to fAPAR, using JEODPP's PyJEO and OpenEO libraries and in a combination with its multi-core capabilities. For each tile and date:

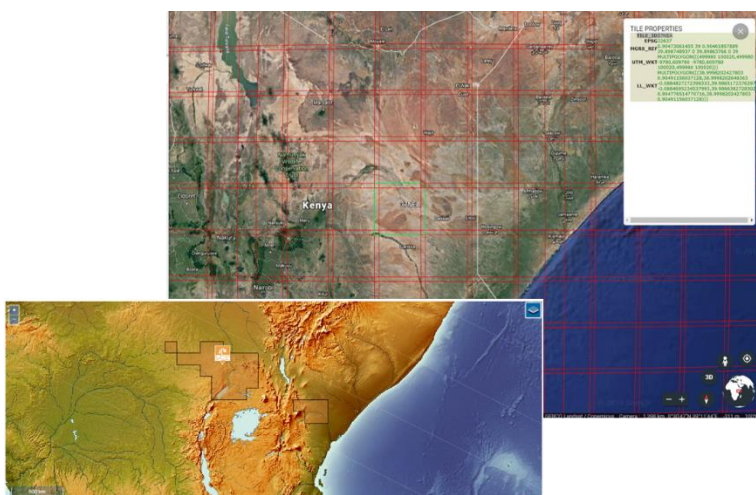
- Pre-processing: L1C data is read from the file system using JEODPP's API OpenGeo and all bands (Red, Nir Infrared, blue and angle data) are resampled according to the required resolution (For the prototype is 60 m which is the lowest resolution within the three needed bands for fAPAR calculation).
- Masking: Then cloud masking (and other type of masking) is applied to all required bands. This part of the procedure is currently under development.
- Rectification: Atmosphere Rectification and Anisotropic correction is made, in other words, the estimate of the so-called rectified reflectance at the red and near-infrared wavelengths in order to minimize atmospheric and angular perturbations.
- fAPAR calculation: with the rectified bands and using a polynomial between the bands and the coefficients, calculated in advance.

Once the tile fAPAR is calculated, a second processor calculates an anomaly map, meaning the difference between the current median of a dekad period -10 days- of the tile's climatology. In this specific case, the baseline is too short to be considered suitable for anomaly calculation, so this anomaly is only calculated for demonstration purposes.

Finally a merge and crop operation is made to create geographic composition within the GDACS polygon bounding box, and the result then is ready to be published on the GDO report.

A test run was made for a particular tile located in Kenya. On Figure 48, you can see the GDACS polygon at the bottom, and the test tile in the upper image.

Figure 48. Test tile for fAPAR calculation



Preliminary results, like the ones on Figure 49 show tile-detailed variation of fAPAR index during year 2019.

Figure 49. 2019 fAPAR anomalies calculated for the test tile



5.5.2.3 Next steps

The procedure needs to be finally deployed into the JEO-batch using parallelization and multiprocessing by tile, once the testing phase is over.

fAPAR anomalies are to be calculated by comparing the 10-day composite fAPAR maps with a consistent baseline of fAPAR statistics of a large number of years. The new Sentinel data is available since 2012, therefore a combination of Sentinel data with other existing satellite data is needed. The advantage of this procedure is that it can be escalated to be used with other Sensors, for example Sentinel 3.

5.6 The Mukau project, expanding GDO functions to Open Source

In 2017 the drought team completed a project in which our Content Management System and Web Mapping system was installed at CIIFEN (Centro Internacional para la Investigación del Fenómeno de El Niño) in Ecuador. The rolling out of the system allowed the organisation to invest more in Web Mapping technologies, also for not drought-related data. Currently, the main project member is project leader of a new project in which he transfers Web Mapping technology to a large number of meteorological organisations in South America. With the evolution of the GMES (Global Monitoring for Environment and Security) for Africa project relations with sister institutions in Africa are readily established. The opportunity to assist these institutions in professionalising their use of web and open source software for better informing their public on Disaster Risk Reduction arose with a new formulation of the successor of the GMES for Africa project, called ACP Climate (ACP standing for Africa, the Caribbean and the Pacific).

In 2019 we upgraded the system to function with the last stable software versions of PHP, MapServer and PostgreSQL, moreover we made software to install the platform 'automatically' using new tools such as Ansible and Vagrant. These tools allow for a scripting of all the steps to install the standard software our application depends on. In addition to this we deploy the installation of the application on GitHub in a private library with a wiki documentation on <https://github.com/ec-jrc/MUKAU-GEOCMS/wiki> allowing our partners in Nairobi to install the software on their platforms in real time.

The method was used to give a workshop at the premises of ICPAC, the Climate Prediction and Application Centre of IGAD the Intergovernmental Authority on Development of East Africa in Nairobi in October 2019. The Workshop created a start of the project in which we will next year install the system at ICPAC, create functionalities that serve their specific business purpose, such as a Pastoral Drought Index, and better automate

their work. This work will be done in the setting of the ACP Climate project, which is a successor of the GMES for Africa project facilitated by DG DEVCO.

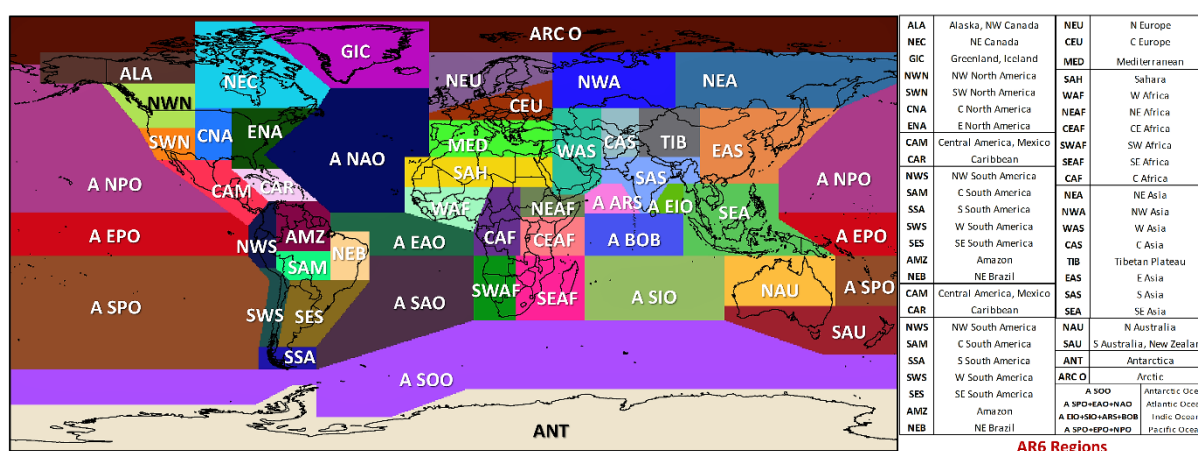
5.7 Update in the Database of Drought Events

Currently, the global meteorological database of drought events hosted in GDO spans from 1951 to 2016. It is organized per indicator, country or macro-region, and it also includes a list of most relevant droughts in per period (see Spinoni et al., 2019). During 2019, in particular after the publication of the mentioned scientific paper, we received requests by various users, trusted universities, research institutions, specific stakeholders and managers, to get access to the underlying data and also to the outputs organized per country. Up to now, we shared data only with trusted users who intended to apply the requested data for non-commercial use. For example; Georgetown University in Washington DC, Bocconi University in Milan and the University of Cambridge.

The current version of the database will be replaced by a new version in spring 2020. The most relevant improvements will be:

- Extended period (from 1951-2016 to 1950-2019);
- Higher spatial resolution (from 0.5° to 0.25°);
- New accumulation periods for the SPI and the SPEI (Standardised Precipitation-Evapotranspiration Index) indicators;
- More and smaller macro-regions (see figure below);
- A list with the (approximately) 200 most severe drought events in the encompassed period.

Figure 50. The new version of the database will be designed around new macro regions defined in the upcoming Sixth Assessment Report of the IPCC (Intergovernmental Panel on Climate Change)



Together with the new database, which will focus on events of the past seventy years, a new section about drought hazard (and exposure) projections will be created for GDO. The results are available and will be structured for use in a spatial relational database and the website. The data source for this study is the unique collection of more than 270 climate simulations in the framework of the CORDEX (Coordinate Regional Downscaling Experiment) Project. The CORDEX input dataset can be shared with users if requested and only the final outputs will be part of the GDO.

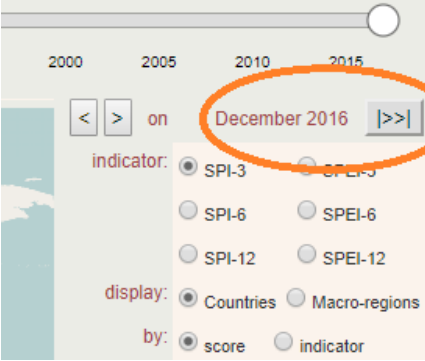
Finally, the analyses leading to past and future drought trends allowed us creating new aridity and climate classification maps for the periods 1981-2010 and corresponding to future warming levels (1.5°, 2°, 3°, and 4°). These maps will be included in GDO in 2020.

5.7.1 Database of Drought Events, web page improvements

The dedicated web page has been enriched with an “animation” tool. Users can choose to view the drought events evolution without having to manually change the month to examine. Once “animation” is started, the user can freely change the display mode indicator to show and even move to a different period, with no need to stop the animation.

When the new data (from 2017 to 2019) will be added, we plan to revisit the page operating mechanism. We have noticed unexpected behaviours when accessing the system through a slow network. This happens because the page initially loads all data. The expected increase of data will require a further tuning of the web page.

Figure 51. The new animation tool of the interface of Database of Drought Events.



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List of abbreviations and definitions

ACP Climate	Sub-Sahara African, Caribbean and some Pacific assistance in Climate Research
ADO	African Drought Observatory
API	Application Programming Interface
ARSO	Agencija Republike Slovenije za Okolje
ARU	Administrative Reporting Unit
BRGM	Bureau de Recherches Géologique et Minières
CCI	Climate Change Initiative
CCK	Cookies Consent Kit
CCL	Copernicus Component Library
CCM	Catchment Characterisation and Modelling
CDI	Combined Drought Indicator
CET	Central European Time
CHE	Confederación Hidrográfica del Ebro
CHS	Confederación Hidrográfica del Segura
CIIFEN	Centro Internacional para la Investigación del Fenómeno de El Niño
CMS	Content Management System
CORDEX	Coordinate Regional Downscaling Experiment
CRC-SAS	Centro Regional del Clima para el Sur de América del Sur / Centro Regional do Clima para o Sul da América do Sul
CSV	Comma Separated Value
DB	Database
DC	District of Columbia
DG	Directorate-General
DMCSEE	Drought Management Centre for South Eastern Europe
DMZ	De-Militarized Zone
DOM	Document Object Model
ECL	Europa Component Library
ECMWF	European Centre for Medium-Range Weather Forecasts
EDO	European Drought Observatory
EFAS	European Flood Awareness System
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAO	Food and Agriculture Organization of the United Nations
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FTP	File Transfer Protocol
FWI	Fire Weather Index
FYROM	Former Yugoslav Republic of Macedonia
GDACS	Global Disaster Alerting Coordination System

GDO	Global Drought Observatory
GHS	Restructuring GSHHG global coastline done with IHO definitions of Oceans and Seas
GIS	Geographical Information Systems
GMES	Global Monitoring for Environment and Security
GISCO	Geographic Information System for the Commission (Eurostat)
GML	Geography Markup Language
GRACE	Gravity Recovery And Climate Experiment
GRACE-FO	GRACE Follow-On
GSHHG	Global Self-consistent, Hierarchical, High-resolution Geography Database
GWIS	Global Wildfire Information System
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
HTTPS	HyperText Transfer Protocol over Secure Socket Layer
HWMI	Heatwave Magnitude Index
ICPAC	IGAD Climate Prediction and Application Centre
IGAD	InterGovernmental Authority on Development
IHO	International Hydrographic Organization
IP	Internet Protocol
IPCC	Intergovernmental Panel on Climate Change
IPMA	Instituto Português do Mar e da Atmosfera
JEODPP	JRC Earth Observation Data and Processing Platform
JSON	JavaScript Object Notation
LFI	Low-Flow Index
MARS	Monitoring Agricultural ResourceS
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
NetCDF	Network Common Data Form
PDSI	Palmer Drought Severity Index
PHP	PHP: Hypertext Preprocessor
PROBA	Project for On-Board Autonomy
PROBA-V	PROBA-Vegetation
RAM	Random Access Memory
RDII	Risk of Drought Impact Index
SCADO	Desertification, Land Degradation and Drought (DLDD) Observatory for Latin America
SMA	Soil Moisture Index (SMI) Anomaly
SMI	Soil Moisture Index
SPEI	Standardised Precipitation-Evapotranspiration Index
SPI	Standardized Precipitation Index
SPOT	Satellite Pour l'Observation de la Terre

SPOT-VGT	SPOT Végétation
SQL	Structured Query Language
TIFF	Tagged Image File Format
TOA	Top Of the Atmosphere
TWS	Total Terrestrial Water Storage
TWSA	TWS Anomaly
URL	Uniform Resource Locator
UTE	Unidades Territoriales de Escasez
UTS	Unidades Territoriales de Sequía
WFS	Web Feature Service
WMS	Web Map Service
XML	eXtensible Markup Language

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Annexes

Annex 1. Mukau Content Management System CMS Documentation

Available upon request via <https://github.com/ec-jrc/MUKAU-GEOCMS/wiki>

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doi:10.2760/43976

ISBN 978-92-76-11266-2