Project Topic A

Project Topic B x

Integrated Approach for the Development across Europe of user oriented climate indicators for GFCS high-priority sectors: agriculture, disaster risk reduction, energy, health, water and tourism ERA4CS Joint call 2016

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This document is to be filled out by the coordinator in collaboration with the project partners. It must be sent by the coordinator within the deadlines specified in the acts of award to the ERA4CS

Unless otherwise indicated, it reports on the activity of all the project partners.

A IDENTIFICATION

Project acronym	INDECIS
Project title	Integrated Approach for the Development across
	Europe of user oriented climate indicators for GFCS
	high-priority sectors: agriculture, disaster risk
	reduction, energy, health, water and tourism
Project start date	15/09/2017
Project end date	14/09/2020
Period covered by the report	15/09/2017-14/03/2019
Project website if applicable	www.indecis.eu
Date of submission of the report	26-04-2019
Version	1.0

B PROGRESS REPORT

B.1 OBJECTIVES OF THE PROJECT

Maximum 10 to 20 lines.

INDECIS, "Integrated Approach for the Development across Europe of user oriented climate indicators for GFCS high-priority sectors: agriculture, disaster risk reduction, energy, health, water and tourism" constitutes a pan-European effort focused on the development and production of climate indices, specifically targeting the priority sectors of the GFCS plus tourism and their conversion into climate services by engaging stakeholders in their definition and communication.

The main objective of the project is to develop historical high quality and dense climate networks across Europe based on long-perspective time series of different stations-based meteorological variables from which accurate and robust climate indices can be calculated to create user-oriented climate products and services.

In pursuing this main objective INDECIS, secondary objectives are:

- Improve the spatial and temporal availability of climate data, especially at the daily scale and in connection with the European Climate Assessment and Dataset (ECA&D).
- Create a quality controlled and homogenized version of the improved ECA&D dataset.
- Define and compute a set of sectorial-relevant climate indices and compared them to sectorial information.
- Study the temporal evolution of those indices and their relation to atmospheric circulation patterns.
- Compare station-based and gridded data based sets of indices.
- Engage users, define and communicate climate products and services based on the indices previously defined.

B.2 WORK PERFORMED AND RESULTS ACHIEVED IN THE PERIOD CONCERNED

Maximum 1 page. Work performed and results obtained during the period concerned, conformity of work progress with initial schedule. Clearly indicate who performed the work, and do not omit to mention the work performed by eventual foreign partners. Work forecast for the next period(s).

INDECIS' results through the first half of the project are detailed below, organized by Work Package and Deliverable. Appendix 1 shows a summary and identifies contributors.

Work Package 2, Identification and Catalogue of Climate Data Sets and Portal

D2.1, coordinated by MeteoRO, has identified data coverage discrepancies between ECA&D, and global repositories like GHCN and GSOD. WP2 expanded the ECA&D dataset by rescuing 610K meteorological station-based daily observations from the Balkans and Central Europe (D2.2) for the essential climate variables (https://doi.pangaea.de/10.1594/PANGAEA.896957). This work was coordinated by URV and external contribution by Dubravka Rasol (DHMZ). In addition, INDECIS rescued 339 Italian series (rainfall and temperature), coordinated by CNR-IRPI. A Global Dataset with 311 wind tall mast data has been compiled by BSC. A request to Europe's National Met Services to update records in ECA&D was successful and adds 577 series for global radiation.

Work Package 3, Data Quality and Homogeneity

D3.1 has been produced by Czech Globe, BSC and URV. Three QC software suites are available: INQC (http://github.com/INDECIS-Project/INQC), and MetQC (http://www.indecis.eu/software.php), to quality control ECA&D daily data; and QCSS4TT software built specifically for tall masts wind data (https://earth.bsc.es/gitlab/jramon/INDECIS-QCSS4TT/). In D3.2, two Homogenization Benchmarks are available (http://www.indecis.eu/benchmarking.php). Baboon Benchmark (created by AEMET, URV, Czech Globe, KNMI, with external contribution by Victor Venema, University of Bonn) is based on KNMI Climate Regional Model and a real-data based benchmark is created by combining close by stations to simulate real relocations.

Work Package 4, Indices Catalogue, Definition and Implementation.

D4.1 and D4.2 are available, led by IPE/CSIC, with contributions from all consortium members. They inventory and catalogue indices datasets according to GFCS high-priority sectors to be linked with sectorial data. INDECIS has produced, after consultation with the whole consortium and with some prospect users (e.g. INDECIS Workshop in Bajo Aragón by URV) a list of 136 sector-oriented climate indices (<u>http://www.indecis.eu/docs/Deliverables/INDICIS-list_4.2.pdf</u>). Regarding D4.3, the software suite to compute indices is ready (<u>https://gitlab.com/indecis-eu/indecis/</u>), created by IPE/CSIC, and 80% of climate indices are already computed across Europe and are available in a Portal (<u>http://www.indecis.eu/indices.php</u>).

Work Package 5, Indices Time Evolution and relations with the Atmosphere.

D5.1 has been completed by UREAD to catalogue a list of indicators related to circulation variability. D5.2 is under progress with the analysis of the evolution of indices, links with atmospheric circulation patterns and time emergence of climate change signals.

Work Package 6, Evaluation of gridded datasets, reanalyses and model output.

D6.1 has been completed, coordinated by MeteoRO, in which a software suite for datasets intercomparison was released (<u>https://github.com/alexdum/interdecis</u>) and the statistical measures to achieve it described. The report also presents the inventory and catalogue of selected hind-casts of climate simulations, reanalysis products, model-derived data and gridded observational datasets, as well as the set of five datasets selected to be used within the second part of the WP6 activity.

Work Package 7, Generation and communication of climate services.

D7.1 is ready and has been produced by URV by defining the communication strategy to deliver climate services. D7.2 is underway and 4 new workshops related to the tourism sector are planned to engage users and stakeholders in the delivery of climate services. D7.3 is underway working on the release of the software suite to be integrated into the Portal, coordinated by AEMET.

B.3 DIFFICULTIES ENCOUNTERED AND SOLUTIONS

Maximum 10 to 20 lines. Any difficulties encountered and the solutions envisaged.

- In case of delay, please write four lines for justifying the delay and estimate risks for the project.

- If you have encountered difficulties or made changes, please write four lines of explanation

INDECIS has had a normal development over its first half. Consequently, we do not need to report any difficulties threatening the project. It is necessary, though, to report some setbacks resulting in delays on different tasks/deliverables and the solutions adopted to ensure a smooth workflow and completion of INDECIS' objectives. These issues/solutions are listed in Table 1:

(45 61 6 1/2019)	
Problem	Solution
Difficulties in contracting in-cash fellows, mostly	Redistribution of tasks and increased dedicated
due to bureaucratic aspects	time for contract management
Difficulties to engage users/stakeholders and to	Some initial users/stakeholders abandoned after
obtain sectorial data from them	unfruitful discussions and focus moved to others
Data access restrictions preventing some series to	When critical, replaced by other data sources (e.g.
be rescued	Global Telecommunications System), to the price of
	lower quality
Data access restrictions preventing some series to	Series are used for the purposes of the project and
become fully public	in derived products (like a gridded dataset), but
	cannot be forwarded or made available to third
	parties
Software development delays in QC	Resolved by adding a new software suite
Delays in ERA5 Reanalysis release affecting the	Indices computed upon release, as machinery is
computation of INDECIS' indices	ready
Delays in the Deliverables	To ensure that those delays are not affecting the
	optimal development of the project.

Table 1. Issues encountered and solutions adopted to ensure the completion of INDECIS' objectives. (as of 04/2019)

Source: INDECIS Consortium

These problems have affected deliverables in WPs 2, 3 and 4, but they have been or will be resolved in time to provide data to WPs 5, 6 and 7.

C IMPACT SINCE BEGINNING

These section groups elements accrued since the beginning of the project, which will be monitored as its proceeds and taken up in the final project review.

C.1 INDICATORS

Work force statistics

Work force statistics provided by INDECIS Consortium are summarised in Table 2, as percentages of person/month for each partner by work package and totals during the first half of the project (from 14/09/2017 to 15/03/2019). In general terms, the efforts dedicated by each partner for each work package is well related with the work force committed in the Consortium Agreement. Partners which their major efforts are basically focused in WP1, WP2, WP3 and WP4 exceeded 50% of work force due to these work packages started at the beginning of the project. Partners with most of the work force committed in WP5, WP6 and WP7 present loads between 10% and 30%, as these work packages will progress through the second half of the project. Notice that the partner UCH-IHC consumed more efforts than expected (109%) in WP4. In this case, the implementation of some of the indices to be computed over the original climate dataset presented more difficulties than expected and required a larger effort to change the computational implementations. The verification of the implementations required the collection of additional relevant information from specific stakeholders, and the consultation process took more time than expected. Once the information was received from those stakeholders, the work for organizing and analysing this material has taken a supplementary effort due to the complexity and variety of the results. In general terms, INDECIS is managing well the efforts dedicated to the project and will make the necessary arrangements, if any, to ensure that all the committed tasks are finalized.

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	TOTAL
URV	56	75	65	75	-	-	27	55
UREAD	-	-	-	50	25	50	-	31
FMI	-	-	-	51	-	12	0	19
BRGMI	-	-	-	91	-	7	6	10
CNR	-	73	45	90	16	-	60	62
UCH-IHC	-	-	-	109	23	22	-	42
SMHI	-	95	56	-	-	-	-	67
Met Éireann	-	88	78	-	-	0	-	55
AEMET	-	33	75	50	-	-	22	37
BSC	-	100	83	81	44	4	-	50
Fciencias.ID	-	-	75	-	31	-	8	39
CVGZ-GCRI	-	-	75	42	-	20	-	50
KNMI	-	50	20	-	-	-	-	35
RMI	-	-	-	-	33	-	-	33
METEORO	-	100	-	100	100	25	100	50
CSIC	-	55	-	45	-	-	0	42

Table 2. Work Force Statistics expressed in percentage of expected persons/month. (as of 04/2019)

Source: INDECIS Consortium

- Gender Aspects

INDECIS takes in consideration gender balance. Two Work Package Leaders and members of the Executive Board are female as well as two members of the External Experts Advisory Board. One female and one male do project management. In-cash contracts attached to INDECIS have followed a strict equal-opportunity policy. Table 3 provides a detailed information about gender aspects in contracts attached directly to INDECIS for each partner. In total, 32 researchers are contracted directly by INDECIS, of which 51,6% are male and 48,4% are female.

INDECIS activities, such as stakeholders/users' workshops, demand the participation in the discussions of a gender balanced group.

,		
Partner	Male	Female
URV	2	3
UREAD	1	0
FMI	3	2
BRGMI	1.5	0.5
CNR	1	0
UCH/IHC	0	1
SMHI	1	0
Met Éireann	0	0
AEMET	0	1
BSC	3	2
Fciencias.ID	0	0
CVGZ-GCRI	0	0
KNMI	1	1
RMI	0	0
METEORO	3	5
CSIC	0	0
TOTAL	16.5	15.5

 Table 3. INDECIS' In-cash contracts. (as of 04/2019)

Source: INDECIS Consortium

- Engaging with Civil society and policy makers [exchange with impacts to society]

INDECIS is a "from data to service" project. Its ultimate goal is to provide service and, thus, produce a positive impact over society. Although the first half of the project is intensive on the data management part (WPs 2, 3, 4) societal engagement is considered since early stages. This includes the nomination of an External Experts Advisory Board (EEAB), integrated by six members from different fields of expertise and geographical origins. Their role includes to assist INDECIS in reaching out and engaging with society. The list of the EEAB members are:

- Phillip D. Jones; Chair of the EEAB and retired Director of Climatic Research Unit (CRU), UEA, UK.
- Carlo Buontempo; Manager of the Sectorial Information System of Copernicus Climate Change Service at ECMWF, UK.
- Jose Luis Camacho; Scientific Officer/Agricultural Meteorology at World Meteorological Organization (WMO).

- Tanja Cegnar; Meteorological and Hydrological Office, Slovenian Environmental Agency, Slovenia.
- Florence Habbets; Director of Hydrology Research at French National Centre for Scientific Research (CNRS), France.
- Salvador Samitier; Director of Climate Change Office in Catalonia, Spain.

INDECIS engagement with Civil Society splits in three different axis:

1. Digital Image: INDECIS' digital image is built using a traditional website and the social media. INDECIS' website (www.indecis.eu) provides access to the project description and objectives, consortium, deliverables, products and services and host the access portal to data and services. The digital presence completes with accounts in Facebook (https://www.facebook.com/Indecisproject/) and Twitter (@Indecisproject), which disseminate INDECIS' news and achievements. The content of INDECIS' Twitter has been integrated into the front page of the website (Figure 1) to enhance users' interaction. Social media allows to build an image of the project and, at the same time, the possibility to interact with potential users or stakeholders among others. Figure 2 shows statistics on the usage of INDECIS' social media. INDECIS' management has recently installed a web-monitoring tool. Although statistics are not yet available, it will provide, through the second half of the project insight on the usage of the website and its contents (e.g., data and services). The number of INDECIS' followers and retweets and shares of INDECIS' posts are continuously increasing. We expect to increase the frequency of new contributions through the second half of the project, when most products and results will be delivered.



Figure 1. Front page of INDECIS' website. Source: INDECIS Project.



*retweets/shares of our tweets/posts (by other users)

Figure 2. Statistics on the usage of INDECIS' social media. (as of 04/2019)

Source: INDECIS Consortium

2. Face-to-face Contact: the project dedicated through its first half substantial efforts to engage with different agents with potential interest in INDECIS's results. These on-going contacts helped to define some INDECIS' products (e.g. DARE activities developed in WP2, the listings of sectorial indicators selected, programmed and computed by WP4). Table 4 includes the actions and contacts established and the achieved/expected impact, such as the visibility of the project in different European countries, the establishment of new collaborations and the dissemination of knowledge in future workshops, where the participation of different stakeholders from various sectors are key factors.

ACTION	SECTORS	CONTACTED STAKEHOLDERS	ACHIEVED/EXPECTED IMPACT
Workshop: Pilot experience to involve tourism stakeholders on climate services co- creation in Bajo Aragón (Spain). Organized by C3/URV. 22nd - 23rd January 2018	- Tourism	 Municipality of Alcañiz Comarca del Bajo Aragón Bajo Aragón Tourist Office AEMET Aragón Rural Hotels (i.e. Casa de la Fuente) Outdoor activities (Geoventur experiences) BTT experts (Club Ciclista 5C) Birdwatching experts Natural Areas Association (Asociación de amigos del río y de los espacios naturales de Alcañiz) Environmental education (EANA Maestrazgo) Cultural Association (Oceano Atlántico) 	Presentation of the project and introduction to Climate Services. Potential interest in Climate Services for the Tourist Sector. Input of sectorial data. Media coverage before and during the event spread INDECIS project as well as the linkages between tourism and climate to the general audience, at regional, provincial and county media: 4 Newspapers (Heraldo de Aragón, Diario de Teruel, La Comarca, El territorio (not available online)) and 6 interviews to INDECIS' researchers in different radio stations (Aragon Radio, Radio Nacional de España - Delegación de Teruel, Radio La Comarca).

Table 4. INDECIS' Actions. (as of 04/2019)

Contact with National and regional Agencies/ Offices/Companies. Contacted by CNR-IRPI, Calabria (Italy) February-March 2018	 Agriculture Disaster risks reduction Water Tourism 	 The Regional Agency for Environment Protection of Calabria (ARPACAL) Centro Funzionale Multirischi della Calabria. The Regional Agency for Agriculture in Calabria (ARSAC). The private/public Company for Water Resources in Calabria (SORICAL). The Tourism Department of the Calabria Region. The Unity for Civil Protection in Calabria. 	The aim was to know the possibility to collect data (climatic data and sectorial data) to involve them as stakeholders and users of the Climate Service provided by the project.
Contact with Länsförsäkringar and Lantbrukarnas RiksFörbund (Sweden) Contacted by SMHI. February-March 2018	- Agriculture	 Länsförsäkringar (Swedish insurance company) Lantbrukarnas RiksFörbund (Swedish National organisation of farmers) 	SMHI explained the scope of INDECIS project and listened their needs about climate information
Seminar: all ERA4CS projects with Dutch contribution. Participation by KNMI (Netherlands). March 2018	 Agriculture Disaster risks reduction Water Energy 	 Dutch Ministry of Infrastructure and the Environment Dutch Science Foundation NW0 	All ERA4CS projects who had a Dutch contribution were presented in this seminar. These projects feed into information available for the Dutch programme for spatial adaptation planning.
Stakeholders meeting in AEMET, Madrid (Spain). Organized by AEMET and IPE/CSIC. April 2018	- Water - Agriculture	 Insurance companies Water Economy and Irrigation Spanish Department Agriculture, Fishing and Feeding Spanish Ministry 	INDECIS main objectives were detailed and a really valuable feedback was received.
Contact with Ferrocarrils de la Generalitat de Catalunya, managers of Public Ski Stations in Catalonia (Spain) Contacted by C3/URV. May 2018	- Tourism	 Ferrocarrils de la Generalitat de Catalunya 	Presentation of the project. Lack of interest in contributing as do not see benefits. Highlights the need to invest in demonstrating benefits.

Workshop: Jaca (Spain). Organized by C3/URV. 25th April 2019	- Tourism	 Observatorio Pirenaico de Cambio Climático (OPCC) Comarca de la Jacetania Aragon Government – tourism department Touristic business association Tourism office of Hecho Tourism office of Jaca 	The workshop will consist on a conference session on vulnerability of mountain destinations and strategies to adapt to climate change; and a collective work session for the design of climate indicators and services to adapt mountain destinations to climate change. Social agents from the Jacetania region and other destinations in the Pyrenees are expected to attend.
Workshop: Calvià, Balearic Islands (Spain). Organized by C3/URV 9th May 2019	- Tourism	 Municipality of Calvià Tourism Department of Mallorca Tourism agencies and companies (to be confirmed) 	The aim is to involve tourism stakeholders on climate services co- creation. Stakeholders will be divided in different discussion groups in order to discuss about the specialized tourism product of the destination (Seaside Tourism) taking into account regional climate conditions.
Workshop: Sila National Park, Calabria (Italy). Organized by CNR/IRPI. 30th May 2019	- Tourism - Agriculture	 Tourism Department of Regione Calabria Sila Park National Authority Tourism promotion associations Tourism agencies Tourist guides Hotel groups, C.A.I. Alps Italian club, A.R.S.A.C. Regional agency for Agriculture in Calabria (to be confirmed) 	Main objective is to examine one or more types of tourism (mountain/lake tourism) involving stakeholders of the Sila ecosystem. The stakeholders will be divided into groups of 6-7 people. Each group will focus on a specific tourism product/aspect.
Workshop: Barcelona (Spain). Organized by C3/URV 27th June 2019	- Tourism	 Municipality of Barcelona Tourism Department of Barcelona Tourism agencies and companies Barcelona DMOs (to be confirmed) 	The workshop will highlight the importance of Climate Services for tourism. Stakeholders will discuss about climate indicators and strategies to adapt to climate change.

Source: INDECIS Consortium

3. Service Delivery: although service delivery will be the focus of the second half of the project INDECIS is already delivering to society by providing access to its products (at this point, indices, data and software, as reported in other sections of this same document) through its website.

- Training and capacity building

INDECIS' proposal does not specifically include training and capacity building activities, although they are implicit in the contacts with stakeholders and policy makers. In fact, the workshops conducted and planed build (or develop) climate services usage capacities. INDECIS' software and products usage activities, in the form of workshops or summer schools, are under feasibility study and are expected to happen through the second half of INDECIS. In fact, the 2nd General Assembly already included a training activity on the different software developed by the project, i.e. The Software Suite for Indices Calculation (IPE/CSIC), CLIMATOL (AEMET) for data homogenization purposes, INQC (C3/URV), METQC (GCRI) and INDECIS-QCSS4TT (BSC) for quality control routines. This specific actions are complemented by training-on-the job, which routinely transfers the skills and knowledge of the INDECIS' senior scientist to the in-cash personnel. INDECIS Consortium is studying further involvement and development of education and training activities in the forms of workshops and courses.

- Sharing of research infrastructure

INDECIS, in consonance with the integration philosophy of the ERA4CS projects, is keen to integrate research infrastructure from the partners and other European institutions and build upon previous results. In particular, INDECIS is benefiting from the research infrastructures used to produce:

- ECA&D and E-OBS data (KNMI and contributing partners) are both used by INDECIS. While ECA&D fulfils the role as the backbone of the Climate Data node of the WMO Regional Climate Centre for RA VI (Europe and the Middle East), INDECIS contributes to this dataset by providing additional data (both rescued and modern data) and enhances the quality of the data by applying an advanced Quality Control and homogenization to this dataset. INDECIS uses this dataset as the core dataset for indices computation. Furthermore, the E-OBS is funded by the Copernicus Climate Change Service and INDECIS contributes to this project by gathering series for daily global radiation data which are developed in a new E-OBS member. Similarly, the INDECIS-funded QC'ed and homogenized station data in ECA&D are used to calculate future versions of the E-OBS (from v20.0e or v21.0e onward). These E-OBS data are made available to the C3S Copernicus Data Store. Likewise, the E-OBS is used by INDECIS for calculation of the INDECIS indices.
- ERA-5 Reanalysis (ECMWF) as input data for indices computation.
- UERRA Regional Reanalysis for Europe (Copernicus Climate Data Store) as dataset to be compared in WP6.
- Seasonal Predictions from C3S (Met Office, Météo-France, ECMWF, DWD and the Euro-Mediterranean Centre on Climate Change) to be used in WP6.
- INDECIS Indices Monitoring Tool (IPE/CSIC) designed specifically under INDECIS to visualize climate indices computed in WP4 and also used in WP7.
- In order to undertake the different tasks dealing with seasonal forecast data in the framework of INDECIS, UC and IHC will exploit the Santander Meteorology Group User Data Gateway (UDG) as the main entry point providing harmonized data access to state-of-the-art seasonal forecast datasets. Furthermore, data post-processing and analysis, including downscaling/bias correction and visualization will be done using the climate4R suite of tools, seamlessly integrated with the UDG infrastructure. This provides a comprehensive framework for end-to-end applications of

seasonal predictions in the context of impact studies, including those involving sector-specific indices.

- Research knowledge and infrastructure (Science and Technology Park for Tourism and Leisure of Catalonia) shared with INDECIS to generate valuable innovation and knowledge related to tourism sector in WP7.

INDECIS, at the time of writing this report, is sharing a set of Benchmark Data Sets for Quality Control and Homogenization and a series of software suites, as reported in previous sections.

- Project's impact on society: participation in other areas; elaboration of policy briefs

INDECIS is active in publishing results and contributing to scientific fora. The project is acknowledged in 36 contributions: 11 peer reviewed publications, 20 contributions to international workshops (e.g. EGU and EMS 2018) and 5 contributions to national conferences (e.g. AEC-Spain, AISAM-Italy). See Appendix 2 for a detailed list of contributions.

The Science and Technology Park for Tourism and Leisure of Catalonia (PCT) showed its interest, as intermediate user, in using INDECIS climate products and services when available. Moreover, PCT are willing to collaborate actively on the design of a workshop in Costa Daurada (sun and sand touristic sector) to reach stakeholders and users.

INDECIS contributed to JPI Climate activities by submitting an article about INDECIS results during the first half of the project to a magazine/e-book. This is related to the work package dedicated to valorisation of research results under the new project SINCERE. The magazine will be available on-line soon.

INDECIS also participated to ERA4CS Newsletter published at <u>http://www.jpi-climate.eu/media/default.aspx/emma/org/10895893/ERA4CSNL9.pdf</u> in September 2018. The report explains the progress of all ERA4CS on-going projects and INDECIS summarised the activities undertaken in the first year of life (e.g. the Kick-Off Meeting, software released, developed datasets and workshops to engage users, among others).

C.2 OTHER VALORISATION ACTIVITIES

The valorisation factors are spin-offs other than publications. The following shall be detailed in particular: - unexpected results

The lack of climate data for particular regions or for specific historical periods is still affecting negatively climate products in Europe increasing the associated uncertainties. In this line, a huge effort was focused on data rescue missions in WP2 to fill spatial-temporal data gaps. It allowed to rescue about 610.000 daily values of meteorological observations for maximum and minimum temperature, rainfall, sunshine duration, wind direction and speed and snow depth in Central Europe, the 19th and 20^{th} Sardinia, Ireland and the Balkans along century (https://doi.pangaea.de/10.1594/PANGAEA.896957). Data rescue activities were planned in the project proposal, but the amount of rescued values reached was not expected at the beginning of the project. It will have a positive impact over ECA&D dataset by improving climate data coverage over Europe and increasing the reliability and robustness of future climate products derived from the **INDECIS** project.

Even though the project agreed to work at the daily resolution, the Tall Wind Masts Data Set includes sub-daily data. Two of the quality control software designed and implemented in the INDECIS project are able to test sub-daily and daily observations for wind direction, wind speed (the INDECIS Quality Control Software Suite for Wind Data) and temperature, precipitation, relative humidity, sunshine duration and sea level pressure (the MetQC software).

- national and international patents, licences, and other elements of intellectual property resulting from the project.

The generation of patents or licenses are not in accordance with the typology of this project. Thus, this kind of elements of intellectual property has not been contemplated in the INDECIS proposal.

- software and any other prototype

The development, management and analysis of large climate datasets require the use of specific software to make it possible. In the INDECIS project, five stand-alone software (<u>http://www.indecis.eu/software.php</u>) were designed and released so far, and are described below.

- **INDECIS QC (INQC)** (https://github.com/INDECIS-Project/INQC): This is an R-coded and open-source software suite with capabilities to quality control large datasets in ECA&D format. 19 QC routines were developed and tested for daily data of maximum, minimum and average temperature, precipitation, sea level pressure, relative humidity, wind speed, snow depth, cloud coverage and sunshine duration. INQC works applying a series of tests to the data. The result of each test is either 0 (*pass*) or 1 (*does not pass*). At this point (beta version) no decision tool is provided, so users need to filter out those values which, according to the tests failed and their particular purpose, should not be considered for further climatological analyses. Additional functions and results interpreter with default decisions are also expected in next versions. INQC will be available in the INDECIS website and GitHub repository with sample data.

- INDECIS Quality Control Software Suite for Tall Tower Data

(https://earth.bsc.es/gitlab/jramon/INDECIS-QCSS4TT/): In order to ensure a minimum quality of tall tower wind data, a set of sequential Quality Control (QC) tests were coded to be performed over wind speed and wind direction measurements. These QC routines flag each observation according to their level of confidence. Hence, any observation is removed, modified or set to NA if it is deemed untrustworthy. Three different categories were defined depending on whether an observation passes the test successfully (*Pass*); passes the test but could need further check (*Suspect*); or fails the test (*Fail*). These classification has been done by setting different threshold values based on the World Meteorological Organization standards, manuals or scientific articles and after testing them over observations from more than 200 tall towers. A total of 18 QC tests were provided within the INDECIS WP3 and were applied over the previously compiled tall tower wind data (e.g. plausible values test, internal consistency checks, repeated sequences, out of range values...). The QC routines can be run independently. Hence, any user of this software can redefine the order and decide whether a test is applied or not. In addition, as different levels of confidence have been considered, the data user can decide their own level of restriction.

- **INDECIS MetQC** (http://www.indecis.eu/software.php): This software suite for quality control purposes is based on the ProClimDB software, but re-programmed into R language, for QC testing the variables included in the ECA&D Dataset (maximum, minimum and average temperature, precipitation, sea level pressure, relative humidity, wind speed, snow depth, cloud coverage and sunshine duration). The aim of this software is to process large datasets of daily (and sub-daily) values fully automatically without the intervention of the user. MetQC is able to analyse data at spatial and temporal scale to find potential errors by selecting neighbour stations following various criteria; the best correlated stations, less geographical distance and altitude together with to share a common period between test and reference station. The user is able to manually manage this automatic selection. Errors detection is based on 7 statistical tests, relying both on time and spatial aspects. MetQC is also able to replace wrong measurements or fill missing values proposing an expected value. MetQC also provides many kind of outputs such as tables with errors found, suspicious values, repeated values or duplicated stations and also plots showing the error detection, differences in test and reference series and various statistics used for evaluation of outliers. Suspicious values are flagged by using a code system depending on the percentage of probability of being an error.

- INDECIS Software Suite for Indices Calculation (<u>https://gitlab.com/indecis-eu/indecis/</u>):

Open-source software, stand-alone and designed in R with capabilities to compute the 136 indices defined in the INDECIS project. Each index corresponds to a single function with options to be calculated on different time scales: annual, monthly and seasonal. Some of the indices only show an annual functionality, but most of them can be calculated at the three different time scales. The functions can be adapted to any format of data inputs and they can be adapted to calculate iteratively the climate indices from large datasets (e.g. gridded netcdf files). The software has been tested by using gridded climate data from ECA&D and ERA5.

- INDECIS software for intercomparison of reanalysis datasets (INTERDECIS)

(<u>https://github.com/alexdum/interdecis</u>): This is an open-source software, stand-alone and designed in R with capabilities to analyse the various climatic datasets performance using as reference E-OBS gridded dataset and ERA5 reanalysis product. The functions can be applied to any NetCDF files, as long as they are regularly spaced in the lat/lon grid format. Accuracy measures can be computed from the values extracted from the cells (grids) of the reference (E-OBS/ERA5) and analysed datasets, in which a given coordinates (points) fall. The development version of the interdecis can be installed in R environment from the GitHub repository, with sample data available on interdecisdata R package (see: <u>https://github.com/alexdum/interdecis/wiki)</u>. The package is under development and currently provides common accuracy indicator for prediction models (i.e. mean error, mean absolute error, root mean squared error, correlation coefficients, index of agreement, among others). The indicators can be computed from daily data at annual, seasonal and monthly scale. The routines implemented in the package can be applied for the ECV selected in the project (2m air temperature, relative humidity, 10m wind speed, daily total of precipitation and global solar radiation).

- standardization actions

ECA&D and E-OBS, to which INDECIS is contributing strongly, are de-facto standard datasets to gain a high resolution observation-based pan-European view of climate variability and climate change. This adds to having a uniform source for climate information.

The Centre for Climate Change (C3/URV), as coordinating institution of the project, has joined the network of climate service provider in the Climate knowledge HUB (available at: <u>https://www.climate-knowledge-hub.org/</u>) and attempts to be involved in future standardization activities to transfer them to INDECIS.

- launching of product or service, new project, contract, etc.

By now, main climate products derived from the INDECIS project are related to the creation of different climate datasets to work with them. All datasets are described below.

The INDECIS Core Climate Datasets:

The INDECIS Core Climate Dataset is based on the existing ECA&D dataset (https://www.ecad.eu/dailydata/index.php), which contains series for the Essential Climate Variables sourced directly from the European National Meteorological Services, from over 15700 stations in Europe. INDECIS adds to this dataset through Data Rescue, homogenization of daily records and expansion of the dataset with updates of existing series, addition of new stations and addition of series for global radiation as a new element (complementing the existing sunshine duration records). These data remain in the ownership of the NMSs, but the part that ECA&D is allowed to share, some 80%, will be made available in this INDECIS Core Climate Dataset.

The form in which these data will be made available is through zipped files from the INDECIS data portal or through a tailored download made available by ECA&D (and accessible through INDECIS). These zipped files contain 'original' data, flagged where a data point does not pass the QC but unaltered compared to the original data provided by the NMS, and files will be made available which contain the homogenized data, where adjustments are made for e.g. relocations of stations or changes in the measurement procedure.

- Tall Towers Dataset:

The Tall Tower Database is a unique archive containing meteorological observations from instrumented tall towers measuring winds at heights above 10 meters. A total of 311 potential sites were identified (Figure 3). Almost 70% of these sites (214 tall towers) were already processed and formatted so far. It is expected to enlarge this database by adding new observations, especially in the European continent. The heights of these structures is quite diverse. On the one hand, masts placed in historical observatories (e.g. often having more than 20 years of data) tend to be shorter. They

usually range between 20 to 50 meters. On the other hand, modern towers often reach 100 to 200 meters of height and exceptionally, up to 400 meters. The record lengths of the 214 time series is also different. Although it ranges from 1 to 37 years, most of the time series do not cover more than 20 years. Nevertheless, several of these masts were recently installed and measurements are currently ongoing. Regarding the location of the towers, the 78% are found inland whilst the 22% of them are placed over oceanic regions. Finally, other meteorological variables were included to complete wind speed and wind direction observations: temperature, relative humidity and barometric pressure have been added to the database when available (in most of the cases).



Figure 3. Global distribution of the 311 identified tall towers. Source: Obtained from D2.2 and provided by BSC.

- INDECIS Benchmark Datasets:

INDECIS Benchmark Datasets are based on KNMI's Climate Regional Model and the series were sampled from the model grid points composing a network of 100 stations in South Sweden and 30 stations in Slovenia for maximum and minimum temperature, precipitation, sea level pressure, snow depth, wind speed, sunshine duration, relative humidity and cloud cover at daily scale. Two Homogenization Benchmarks are available at: <u>http://www.indecis.eu/benchmarking.php</u>. The main purpose of the benchmarking experiment is to identify the capabilities, strengths and weakness of the different quality control and homogenization approaches as well as the associated uncertainties. The initial dataset were corrupted by including an average of one breakpoint every 20 years. The most common quality control problems (QC layer) and missing value masks were also introduced into the corrupted dataset in order to evaluate different aspects of homogenization and its main procedures. The final goal is to homogenize a large dataset (ECA&D) by using a synthetic but realistic perturbed dataset to obtain a new dataset free of perturbations. Thus, a final comparison of the latest obtained dataset and the original non-perturbed dataset will characterize the present capabilities of the quality control and homogenization procedures.

- INDECIS Indices Datasets:

A set of sectorial relevant climate indices were defined and inventoried to determine the response and sensitivity of sectorial variables to the different climate indices. A list of 136 indices for temperature (42 indices), precipitation (22 indices), bioclimatic (21 indices), snow (13 indices), aridity/continentality (10 indices), drought (8 indices), cloud/radiation (6 indices), wind (5 indices), fires (5 indices), and 4 indices for tourism were identified (<u>http://www.indecis.eu/indices.php</u>). All climate indices are being computed by applying the INDECIS Software Suite for Indices Calculation to E-OBS and ERA5 Reanalysis datasets and also to the INDECIS-Quality-Controlled and Homogenised Dataset (when available) to obtain the newly INDECIS Indices Datasets (station-based

and gridded). In their calculations, some indices were computed by using climatic data at daily resolution, while other indices employed data at coarser temporal resolution (i.e. monthly, annual).

- development of a new partnership

The development of INDECIS Project is in consonance and requirement of new alliances and international work networks, the collaboration with Copernicus such as (https://www.copernicus.eu/en), ECA&D (https://www.ecad.eu/), PANGAEA (https://www.pangaea.de/) or PIRAGUA POCTEFA project (https://www.opcc-ctp.org/en/piragua). In addition, INDECIS is organizing different workshops focused on coastal and mountain destinations, the aim of which is to demonstrate that a participatory process for co-creation of climate services is crucial for the adequacy and endorsement of them at the scale of destinations. Thus, contacts and new relationships are required in order to engage local stakeholders of different sectors and government levels.

- creation of a platform available to a community

Climate products and services developed in INDECIS (all datasets, software, climate indices, climate services and reports) are being stored in the INDECIS Portal available at: <u>www.indecis.eu</u>. As the "portal" concept suggests, it is conceived to direct the user to our partners and other infrastructures which support and host INDECIS' products and to host or mirror other products. INDECIS' portal points to:

 Data Portal: It allocates daily station-based data across Europe and also the different versions of the dataset (QC'ed and homogenised) when available. From the INDECIS Data Portal (<u>http://www.indecis.eu/data.php</u>) (Figure 4), European daily data is accessible through ECA&D at: https://www.ecad.eu/dailydata/predefinedseries.php (Figure 5).



Figure 4. INDECIS Data Portal where daily station data across Europe is available through ECA&D. Source: INDECIS' website developed by URV in collaboration with KNMI.

European Climate Assessment & Dataset							
Home FAQ Daily data Indices of extremes Extreme e	vents Project info						
See also: KNMI Climate Explorer ICA&D Co	pernicus/C3S_311a_Lot4						
Daily data > Download predefined subsets in ASCII Download predefined subsets in ASCII Predefined subsets of ECA data are created on a regular basis for easy bulk download. These are ZIPped-files, containing separate ASCII files for each station. A list of stations is available for each subset as well as a list of sources that are used to produce the blended series for each station. No changes have been made to the source data from the participants. Only quality codes have been added More details on the source data are available upon request from ECABD Project Team							
Indecit Sectorial Climate Services Blended ECA dataset ?							
Daily maximum temperature TX (345Mb)	s Stations						
Daily minimum temperature TN (377Mb)	s E <u>Stations</u>						
Daily mean temperature TG (372Mb)	s E Stations						
Daily precipitation amount RR (952Mb)	s Stations						
Daily mean sea level pressure PP (107Mb)	s E <u>Stations</u>						
Daily cloud cover CC (117Mb)	s E <u>Stations</u>						
I Daily humidity HU (142Mb)	s 🗄 Stations						
M Daily snow depth SD (687Mb)	s Stations						
Daily sunshine duration SS (83Mb)	s E <u>Stations</u>						
Daily mean wind speed FG (70Mb)	s Estations						
Daily maximum wind gust FX (45Mb)	579						
	s 🖻 Stations						

Figure 5. ECA&D Portal where daily station-based data across Europe is allocated. Source: ECA&D website designed by KNMI.

- **INDECIS Climate index monitoring tool**: An interactive platform has been developed by IPE/CSIC in WP4 in order to store, visualize and download a set of gridded climate indices from INDECIS. Currently the indices based on temperature and precipitation data are already available based on the ECA&D data. The indices that need inputs of other variables are being calculated based on ERA5 data and they will be uploaded in the monitoring tool once they are available. The monitoring tool is available at: <u>http://www.indecis.eu/indices.php.</u> As example, Figure 6 shows the spatial distribution of summer days (month) over Europe for July 2003 based on the ECA&D station data.



Figure 6. Spatial distribution of summer days (July 2003) across Europe. Temporal evolution of annual count of summer days for the period 1950-2018 is also shown as example for a selected grid point.

Source: The Indices Monitoring Tool designed by IPE/CSIC.

- Web mapping application for Climate Services Delivery: AEMET is developing a new platform through a web mapping application (Figure 7). This platform, still in an initial stage, will be able to store, show and download climate services developed during the project. It will be available at: www.indecis.aemet.es/monitor.



Figure 7. Web mapping application for climate services delivery. Spatial distribution of dry days across Europe in 2017 as example.

Source: Provided by AEMET.

- company creation, spin-off companies, fund-raising

The initial INDECIS' proposal does not include company creation among its objectives and actions.

- international cooperation

INDECIS also contributes to the Copernicus Climate Change Service contract C3S_311a_Lot4 which develops the E-OBS, by adding data (rescued data and modern data), an alternative Quality Control and Homogenization. In addition, station records for global radiation data are collected within INDECIS which are used in C3S_311a_Lot4 to produce a new member of the E-OBS family. These E-OBS datasets are made available to the general public through the Copernicus Climate Data Store. INDECIS is also collaborating with the Project IMDROFLOOD (2014 JPI-Water Era-Net) (https://imdroflood.csic.es/), which planned different actions to improve the mitigation of the impact of droughts and floods at the catchment level for Europe and South Africa.

INDECIS will cooperate with the PIRAGUA POCTEFA project (<u>https://www.opcc-ctp.org/en/piragua</u>). It focuses on the evaluation and integrated management of the hydrological cycle in the Pyrenees, with the main goal of improving the adaptation capacity to the consequences of climatic change. PIRAGUA will support the already existing investments dedicated to adaptation to climate change with respect to water resources.

PIRAGUA is thus closely related to the trans-boundary strategy of the Pyrenean Observatory for Climate Change (OPCC), and will develop actions aiming at:

i) Improving the existing knowledge and building datasets on climate change impacts on the hydrological cycle and the water resources in the region.

ii) Defining and monitoring relevant indicators.

iii) Elaborating future water resources scenarios.

iv) Developing pilot experiences at the local level with focus on different water uses and economic sectors.

v) Estimating the costs associated to climate change in relation with the water resources.

vi) Elaborating recommendations for improving the sectorial adaptation to climate change.

vii) Transferring of the results to the relevant water agencies in the POCTEFA territories.

In this framework, the climate data base provided by the INDECIS project over the Pyrenean territory and, in particular, the climate indices resulting from WP4 and the model simulations that will be performed in WP6, will be compared with the results of the PIRAGUA project and shared with all the local stakeholders and water managers of the project.

In the 2nd General Assembly (November 2018), the INDECIS Consortium proposed to invite participants from other projects to attend to the next General Assembly (Lisbon, November 2019) to pursue potential synergies.

- others (international opening, etc.).

In this table, give details of the national and international patents, licences, and other valorisation factors resulting from the project, the know-how, any other spin-offs from the project, any partnerships, etc.

The initial INDECIS' proposal does not include patents and licences among its objectives and actions.

Table 5. List of factors. Indicat	Table 5. List of factors. Indicate the titles, years and comments			
International patents	1.			
obtained	2.			
International patents	1.			
pending	2.			
National patents obtained	1.			
	2.			
National patents pending	1.			
	2.			
Operating licences	1.			
(obtained / transferred)	2.			
New collaborative projects	1.			
	2.			
Scientific symposiums	1.			
	2.			
Others (specify)	1. Workshops in various tourism destinations: Alcañiz, Spain (January			
	2018); Jaca, Spain (April 25 th , 2019); Calvià, Spain (May 9 th , 2019),			
	Calabria region, Italy (May 30 th , 2019) and Barcelona (June 27 th , 2019).			
	2. Capacitation software activity. It was performed in Dublin, during the			
	INDECIS 2nd General Assembly (November 13 th -14 th , 2018).			

Source: WP7 participants (1) and all Consortium (2).

D FINANCIAL STATUS

Give an indicative account of the grant budgets spent by the partners. Indicate how this complies with the forecasts and explain any significant divergences.

Grant budgets spent provided by INDECIS Consortium is summarised in Table 6. It reports percentages of total budgets spent for each partner, divided into in kind and in cash, for the first half of the project (from 14/09/2017 to 15/03/2019). Overall, the efforts dedicated by each partner for each work package (shown in Table 2) fits well with the expected budgets spent justified in the Consortium Agreement. As occurred when describing work force statistics (in section C1), most of the partners which their major efforts are basically allocated in WP1, WP2, WP3 and WP4 spent around or more than 50% of budget due to these work packages started at the beginning of the project. Partners with most of the work force dedicated at WP5, WP6 and WP7 spent between 10% and 40% of budget due to these work packages set up later and most portion of the budget is expected to be spent due second half of the project. In general, most of budgets spent by the partners are in kind (72%) and the rest of 28% are in cash.

Name of partner	Grant budgets spent (TOTAL in %)	In kind (in %)	In cash (in %)
1. URV	49	74	26
2. UREAD	32	82	18
3. FMI	19	0	100
4. BRGMI	9	100	0
5. CNR	59	75	25
6. UCH-IHC	47	100	0
7. SMHI	61	60	40
8. Met Éireann	49	100	0
9. AEMET	31	66	34
10. BSC	50	70	30
11. Fciencias.ID	39	91	9
12. CVG-GCRI	48	70	30
13. KNMI	43	70	30
14. RMI	40	79	21
15. METEORO	45	23	77
16. CSIC	60	98	2

Table 6. Grant budgets spent by the partners (expressed in percentages) for the reporting period. (as of 04/2019)

Source: INDECIS Consortium

E APPENDICES (IF NECESSARY)

WPs	Deliverables		Deadline	Status	Contributors (deliverables due)
	D1.1	Kick-off Meeting Report http://www.indecis.eu/docs/Deliverables/Deliverable_1.1.pdf	14/03/2018	\checkmark	URV
WP1	D1.2	Dissemination and Exploitation Plan http://www.indecis.eu/docs/Deliverables/Deliverable_1.2.pdf	14/09/2018	\checkmark	URV
WEI	D1.3	Mid-term Report	14/03/2019	\checkmark	All Consortium
	D1.4	End of Project Report	14/09/2020	-	-
	D2.1	Inventory and Catalog of Climate Datasets <u>http://www.indecis.eu/docs/Deliverables/Deliverable_2.1.pdf</u>	14/03/2018	\checkmark	KNMI, MeteoRO, CNR, BSC
W/B2	D2.2	Report on Data Rescue Missions http://www.indecis.eu/docs/Deliverables/Deliverable_2.2.pdf	14/09/2018	\checkmark	KNMI, URV, CNR, BSC, Met Éireann
VVFZ	D2.3	INDECIS Raw-Data Set and IDISP Portal	14/03/2019	on-going, jointly with WP3, WP4 and WP7	KNMI, AEMET
	D2.4	Update of the INDECIS Raw Data-set, including rescued data	14/09/2019	-	
	D3.1	INDECIS Quality Control Software and Manual D3.1.a) INDECIS QC software: http://www.indecis.eu/docs/Deliverables/Deliverable_3.1.a.pdf D3.1.b) QC software for tall towers wind data: http://www.indecis.eu/docs/Deliverables/Deliverable_3.1.b.pdf D3.1.c) MetQC software: http://www.indecis.eu/docs/Deliverables/Deliverable_3.1.b.pdf	14/03/2018	provisional	CVG-GCRI, KNMI, URV, BSC
W/D2	D3.2	Report on Recommended Homogenization Techniques based on Benchmarking Results	14/09/2018	provisional	AEMET, URV, KNMI, SMHI, Met Éireann
WF3	D3.3	Release of INDECIS Homogenization Suite and Manual	14/12/2018	on-going	KNMI, AEMET, URV
	D3.4	Release of INDECIS-QHDS (Station data and gridded versions)	14/03/2019	on-going	KNMI, AEMET, URV
	D3.5	Report on the uncertainty of the homogenization process	14/09/2019	Х	
	D4.1	Report on the Inventory and Catalog of Indices Datasets http://www.indecis.eu/docs/Deliverables/Deliverable_4.1.pdf	14/03/2018	\checkmark	CSIC/IPE
	D4.2	Report on indices of INDECIS-ISD, including definitions, and accompanying sectorial data <u>http://www.indecis.eu/docs/Deliverables/Deliverable_4.2.pdf</u>	14/09/2018	\checkmark	CSIC/IPE with contributions from all consortium and prospect users
WP4	D4.3	Release of the Software Suite for indices Calculation	14/12/2018	on-going	CSIC/IPE
	D4.4	INDECIS-ISD released and integrated into the IDISP	14/03/2019	on-going	CISC/IPE, AEMET
	D4.5	Report on comparison of the ISD with sectorial data	14/09/2019	Х	
WP5	D5.1	Inventory and Catalog of Indicators of circulation variability for comparison with the INDECIS-ISD http://www.indecis.eu/docs/Deliverables/Deliverable 5.1.pdf	14/03/2019	\checkmark	UREAD with contributions from WP5 participants

Appendix 1. Status of Deliverables in INDECIS Project for each Work Package. (as of 04/2019)

	D5.2	Report on temporal evolution of the INDECIS-QCHDS and INDECIS-ISD, including the time-emergence of climate- change signals and relation with atmospheric patterns	14/09/2019	Х	
	D5.3	Report on the relation between INDECIS-QCHDS and INDECIS-ISD and atmospheric patterns	14/06/2020	х	
WP6	D6.1	Release of the datasets comparison software suite, including the description of statistical measures used for the datasets inter-comparison <u>http://www.indecis.eu/docs/Deliverables/Deliverable_6.1.pdf</u>	14/03/2019	\checkmark	MeteoRO with contributions from WP6 participants
	D6.2	Report on the datasets inter-comparisons with regard to selected ECVs and INDECIS-ISD	14/09/2019	х	
	D6.3	Report on the reliability and uncertainties associated with the (hindcast-type) seasonal forecasts of selected sectorial INDECIS indices	14/03/2020	Х	
	D6.4	Report on the assessment of sectorial climate change impact based on INDECIS-ISD in the context of climate change scenarios	14/06/2020	Х	
WP7	D7.1	Document Communication Strategy for Delivering Effective Climate Services http://www.indecis.eu/docs/Deliverables/Deliverable_7.1.pdf	14/03/2019	\checkmark	URV
	D7.2	Document Business Cases Study for the Delivery of Climate Services in the Tourism Sector	14/09/2019	on-going	URV
	D7.3	Release of the software suite and integration into IDSIP	14/03/2020	on-going	AEMET
	D7.4	Basic semi-automated Climate Services and protocol for requesting advanced climate services launched at IDISP	14/09/2020	X	

Source: INDECIS Consortium

Appendix 2. List of Scientific Contributions

List of publications in which the INDECIS Project is acknowledged:

Coll, J.R., van der Schrier, G., Aguilar E., Rasol D., Coscarelli R., and Bishop A. (2019). Data rescue of daily climate station-based observations across Europe. Earth System Science Data <u>https://doi.org/10.5194/essd-2019-6</u> (under discussion).

Coll, J.R., van der Schrier, G., Aguilar E., Rasol D., Coscarelli R., and Bishop A. (2019). Daily rescued meteorological observations across Europe (1917-1990). PANGAEA data repository, <u>https://doi.pangaea.de/10.1594/PANGAEA.896957</u> (dataset in review).

Diez-Sierra, J., del Jesus, M. (2019). Subdaily rainfall estimation through daily rainfall downscaling using random forests in Spain. Water (Switzerland), 11 (1), art. no. 125,. <u>https://www.mdpi.com/2073-4441/11/1/25</u>

Hans van de Vyver and J. van den Bergh, (2018). The Gaussian copula model for the joint deficit index for droughts. Journal of Hydrology 561, 987-999. https://www.sciencedirect.com/science/article/pii/S0022169418302361

Gazol, Antonio; Camarero, Jesus Julio; Vicente-Serrano, S M; Sanchez-Salguero, Raul; Gutierrez, Emilia; De Luis, Martin; Sangüesa-Barreda, Gabriel; Novak, Klemen; Rozas, Vicente; Tiscar, Pedro; Linares, Juan Carlos; Martín-Hernández, Natalia; Martínez del Castillo, Edurne; Ribas, Montserrat; Garcia-González, Ignacio; Silla, Fernando; Camisón, Alvaro; Génova, Mar; Olano, José; Longares, Luis; Hevia, Andrea; Tomás-Burguera, Miquel; Galván, Diego, (2018) Forest resilience to drought varies across biomes. Global Change Biology 24, 2143-2158. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14082

Khorchani, M., Vicente-Serrano, S.M., Cesar Azorin-Molina, Monica Garcia, Natalia Martin-Hernandez, Marina Peña-Gallardo, Ahmed El Kenawy, Fernando Domínguez-Castro. (2018) Trends in LST over the peninsular Spain as derived from the AVHRR imagery data. Global and Planetary Change. 166, 75-93.

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Vicente-Serrano, Sergio M., Diego G. Miralles, Fernando Domínguez-Castro, Cesar Azorin-Molina, Ahmed El Kenawy, Tim R. McVicar, Miquel Tomás-Burguera, Santiago Beguería, Marco Maneta, Marina Peña-Gallardo. (2018) Global assessment of the Standardized Evapotranspiration Deficit Index (SEDI) for drought analysis and monitoring. Journal of Climate, 31: 5372-5393. https://journals.ametsoc.org/doi/10.1175/JCLI-D-17-0775.1

Gonzalez-Hidalgo, J.C., Vicente-Serrano, S.M., Dhais Peña-Angulo, Celia Salinas, Miquel Tomas-Burguera, Santiago Beguería, (2018) High resolution spatio-temporal analyses of drought episodes in western Mediterranean basin (Iberian Peninsula). Acta Geophysica 66: 381–392. https://link.springer.com/article/10.1007/s11600-018-0138-x Vicente-Serrano, S.M., Nieto, R., Gimeno, L., Azorin-Molina, C., Drumond, S., El Kenawy, A., Dominguez-Castro, F., Tomas-Burguera, M., Peña-Gallardo. M., (2018): Recent changes of relative humidity: regional connection with land and ocean processes. Earth System Dynamics. 9, 915-937. https://www.earth-syst-dynam.net/9/915/2018/

Peña-Gallardo, M., Vicente-Serrano, S.M. Jesús J. Camarero, Antonio Gazol, Raúl Sánchez-Salguero, Fernando Domínguez-Castro, Ahmed El Kenawy, Santiago Beguería-Portugés, Emilia Gutiérrez, Martín de Luis, Gabriel Sangüesa-Barreda, Klemen Novak, Vicente Rozas, Pedro A. Tíscar, Juan C. Linares, Edurne Martínez del Castillo, Montserrat Ribas Matamoros, Ignacio García-González, Fernando Silla, Álvaro Camisón, Mar Génova, José M. Olano, Luis A. Longares, Andrea Hevia, J. Diego Galván. (2018) Drought sensitiveness on NDVI and forest growth in peninsular Spain and the Balearic Islands. Forests. 9, 524; doi: 10.3390/f9090524. <u>https://www.mdpi.com/1999-4907/9/9/524</u>

Vicente-Serrano, S.M., Miquel Tomas-Burguera, Santiago Beguería, Fergus Reig, Borja Latorre, Marina Peña-Gallardo, M. Yolanda Luna, Ana Morata, José C. González-Hidalgo (2017). A high resolution dataset of drought indices for Spain. Data. 2, 22; doi: 10.3390/data2030022. http://digital.csic.es/handle/10261/152350

List of INDECIS contributions to national/international conferences:

Erik Engström, Javier Sigró and Mary Curley (2019). Testing daily homogenisation methods in parallel series data base. EGU 2019, Vienna (Austria). Oral presentation. https://meetingorganizer.copernicus.org/EGU2019/EGU2019-1947.pdf

José A. Guijarro, Enric Aguilar, Peter Domonkos, Javier Sigró, Petr Štěpánek, Victor Venema, and Pavel Zahradníček (2019). Benchmarking results of the homogenization of daily Essential Climatic Variables within the INDECIS project. EGU 2019, Vienna (Austria). Oral presentation. https://meetingorganizer.copernicus.org/EGU2019/EGU2019-10896-1.pdf

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