Copernicus Climate Change Service (C3S) overview of scope, progress and plans: seasonal to multi-decadal timescales

Chiara Cagnazzo and C3S colleagues

European Centre for Medium-Range Weather Forecasts
Copernicus Climate Change Service

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The Copernicus services

C3S numbers: 97.000+ users

Typical download: 70 TB /day

Copernicus Europe's eyes on Earth

European Commission

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C3S: seasonal to multi-decadal timescales

Data Products and Tools

Lessons learnt from user perspective

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C3S seasonal, multi-annual to multi-decadal information – relevant products

Past:

Atmospheric & Oceanic Climate reanalyses, global and regional

Climate Evolution:

Seasonal forecasts

Projections: CMIP and CORDEX simulations

Sector Applications:

Operational Services including Impact model simulations

A prototype Service for decadal predictions (see Nick presentation later)

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Global Reanalyses: the most popular

ERA5: *A full-observing-system global reanalysis for the atmosphere, land and ocean waves*

ERA5 has replaced ERA-Interim (end date 31 August 2019).

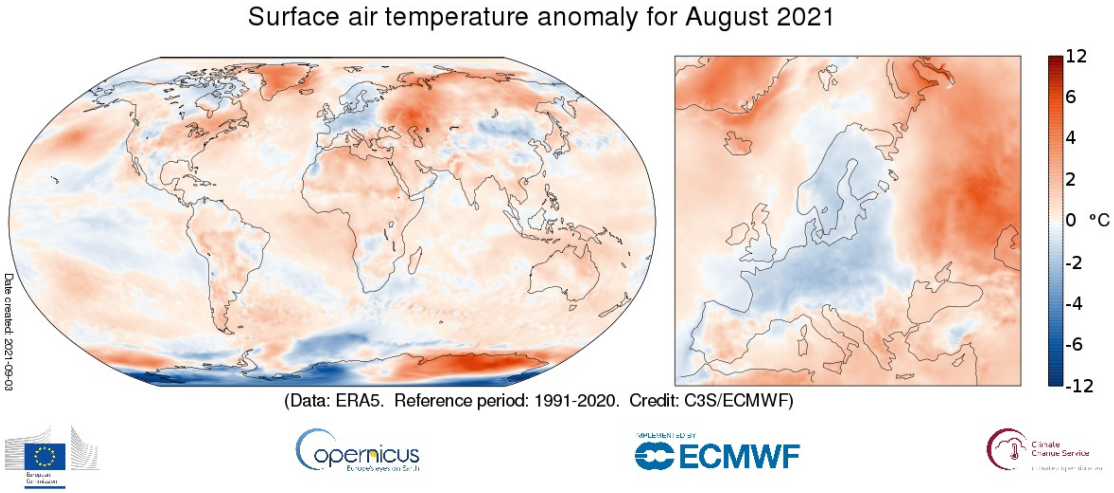
Better model, higher resolution, more and better input data

Most popular dataset in the CDS : 59,000 users; order of 400 Tb weekly downloads

available from 1950 onwards (ERA5 Back extension: 1950 - 1978)

daily updates 5 days behind real time

About 100 billion observations have been used so far



ERA5-Land: *a dynamical downscaling to 9km*

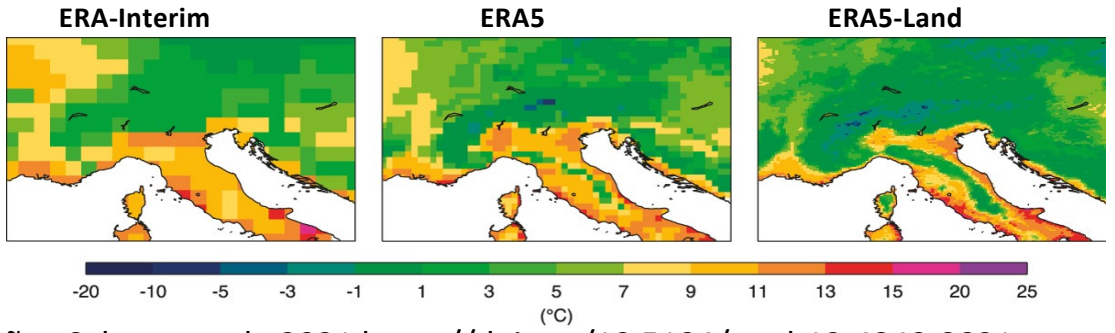
> 13,000 CDS users,

available from 1981

updates 2-3 months behind real time

1950 completed and published shortly

ERA5T-Land by 2022



Muñoz-Sabater et al., 2021 https://doi.org/10.5194/essd-13-4349-2021

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Preparations for ERA6

Start production of **ERA6** in 2024 and preparation for ERA6-Land

- Higher resolution (TBC), from 1950 or earlier

- Coupled with the ocean, based on the latest IFS cycle:
  additional 8 years of ECMWF R&D like improved stratosphere, new ozone model, etc.

- Improved observations from our C3S providers:
  - Reprocessed (EUMETSAT) and newly-rescued satellite data In-situ observations

ERA5 is to be maintained into the late 2020s

In addition we aim for **improvement of the following methodologies**:

- Self-updating static part of the background error covariance matrix
- Counteract on model error by using weak-constraint 4D-Var retrospectively
- Improve the uncertainty estimate, in particular for the mean state.

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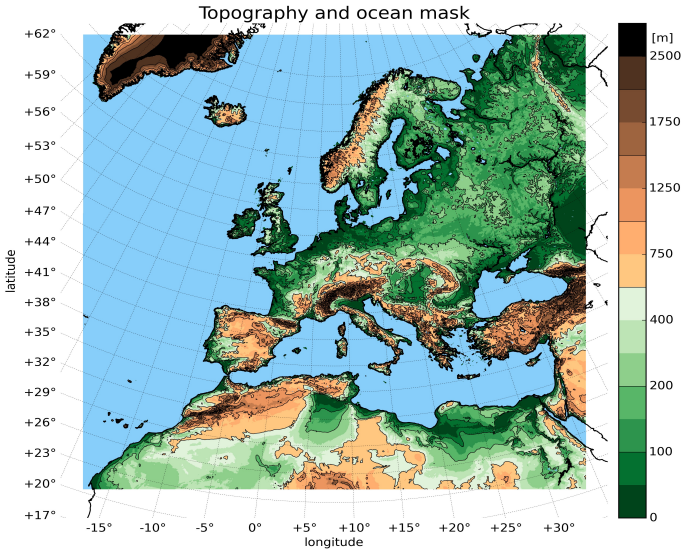
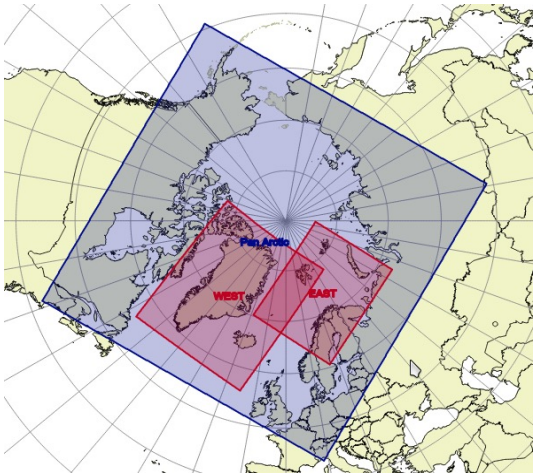
C3S Regional reanalysis, using boundary conditions from ERA-Interim/ERA5

European Domain



Arctic Domain



Available in the CDS (> 900 users):
UERRA, **1961 – mid 2019 @ 11/5.5km**
Based on system as developed in the EU FP7 UERRA project

Currently in production: CERRA, **early 1980 –May 2021 @5.5km**
Production started in Feb 2020

SMHI, Météo-France - MET Norway

Currently in production: (red sub domains)
CARRA, **July 1997 – June 2020 @ 2.5km**
Special emphasis on “cold surfaces”
68% complete (@20/05/2020)

Proof of concept: (grey domain)
1-year pan-Arctic reanalysis, **Sep 2017/18 @ 3.75km**

Met Norway, Nordic countries and Météo-France.

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Ocean reanalyses

ORAS5 global ocean reanalysis monthly data from 1958 to present

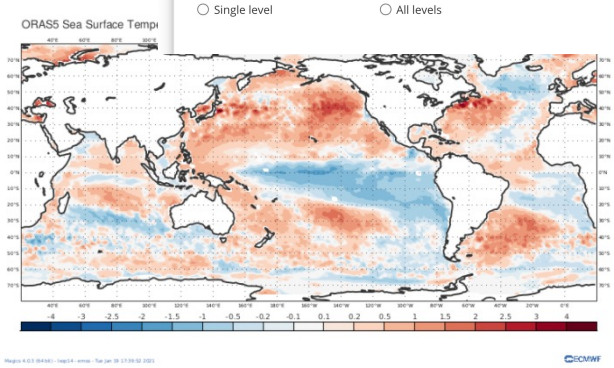
Overview | Download data | Documentation

This dataset provides global ocean and sea-ice reanalysis (ORAS5: Ocean Reanalysis System 5) monthly mean data prepared by the European Centre for Medium-Range Weather Forecasts (ECMWF) OCEAN5 ocean analysis-reanalysis system. This system comprises 5 ensemble members from which one member is published in this catalogue entry.

Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset taking into account the laws of physics. The reanalysis provides information without temporal and spatial gaps, i.e. the data are continuous in time, and the assimilation system provides information on every model grid point independently of whether observations are available nearby or not.

The OCEAN5 reanalysis system uses the Nucleus for European Modelling of the Ocean (NEMO) oce
assimilation system. NEMOVAR uses the so-called 3D-Var FGAT (First Guess at Appropriate Time) assin
sub-surface temperature, salinity, sea-ice concentration and sea-level anomalies.

The ORAS5 data is forced by either global atmospheric reanalysis (for the consolidated product) or
(for the operational product) and is also constrained by observational data of sea surface tempe
concentration, global-mean-sea-level trends and climatological variations of the ocean mass.



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Seasonal prediction

C3S multi-system

– world-leading contributors (*from Europe, US, Canada, Japan; Australia due soon*)

– large set of variables

– data service:

- download from forms and API
- detailed documentation
- guidance and user support
- monthly, daily, sub-daily frequency

Graphical illustrations

http://climate.copernicus.eu/charts/c3s_seasonal/

Operational schedule

Tools and computational environment

C3S seasonal prediction multi-system

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C3S seasonal predictions – tools and applications

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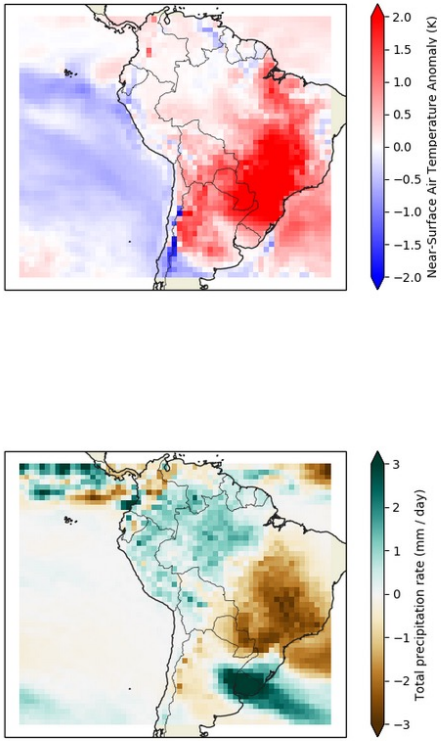
```python
import cdsapi

c = cdsapi.Client()

c.retrieve(
    'seasonal-monthly-single-levels',
    {   'format':'grib',
        'originating_centre':'meteo_france',
        'variable':'total_precipitation',
        'product_type':[
            'ensemble_mean','hindcast_climat
        ],
        'year':'2018',
        'month':'09',
        'leadtime_month':['1','2','3','4','5
    'cds_seasonal_output.grib')
```

example seasonal anomalies ... | Console | History | Your queue

Layout | Copy | Save | Run

```python
import cdstoolbox as ct

leadmonths=
['2019-05-01','2019-06-01','2019-07-01','2019-08-01','2019-09-01','2019-10-01']

@ct.application(title='Seasonal forecast monthly anomalies')
@ct.output.carousel()
@ct.output.carousel()
def application():
    """
    """

    t2m = ct.catalogue.retrieve(
    'seasonal-postprocessed-single-levels',
    {
        'originating_centre':'ecmwf',
        'variable':'2m_temperature_anomaly',
        'product_type':'ensemble_mean',
        'year':'2019',
#         'month':['10','11'],
        'month':['10'],
        'leadtime_month':['1','2','3','4','5','6'],
#         'leadtime_month':'1',
        'format':'grib'
    })

    print("##### T2M ######")
    print(t2m)


    rain = ct.catalogue.retrieve(
    'seasonal-postprocessed-single-levels',
    {
        'originating_centre':'ecmwf',
        'variable':'total_precipitation_anomalous_rate_of_accumulation',
        'product_type':'ensemble_mean',
        'year':'2019',
        'month':'10',
        'leadtime_month':['1','2','3','4','5','6'],
        'format':'grib'
    })

    print("##### RAIN ######")
    print(rain)

#     fig = ct.cdsplot.geomap(t2m)

#     figs={'t2m':[], 'rain':[]}
#     for mm in range(1,6):
#         fcmonth=leadmonths[mm]
#         fig = ct.cdsplot.geomap(
#             ct.cube.select(t2m, time=fcmonth, lat=(-40,10),
```

Seasonal forecast monthly anomalies



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Climate projections: international cooperations & C3S Role

- Global: CMIP (Climate Model Intercomparison Project), now CMIP5 and especially CMIP6 (5th and 6th phase)
- Regional: CORDEX (Coordinated Regional Climate Downscaling Experiment) project
- C3S supported to have additional RCM simulations for Europe (EURO-CORDEX, 12km resolution, more than 130 simulations altogether, being half of it funded by C3S) → significantly larger ensemble than usual for Europe
- C3S supported to curate and quality control simulations from all over the World (14 CORDEX domains covering the main land masses of the Globe)

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The 14 CORDEX domains (published in the CDS)

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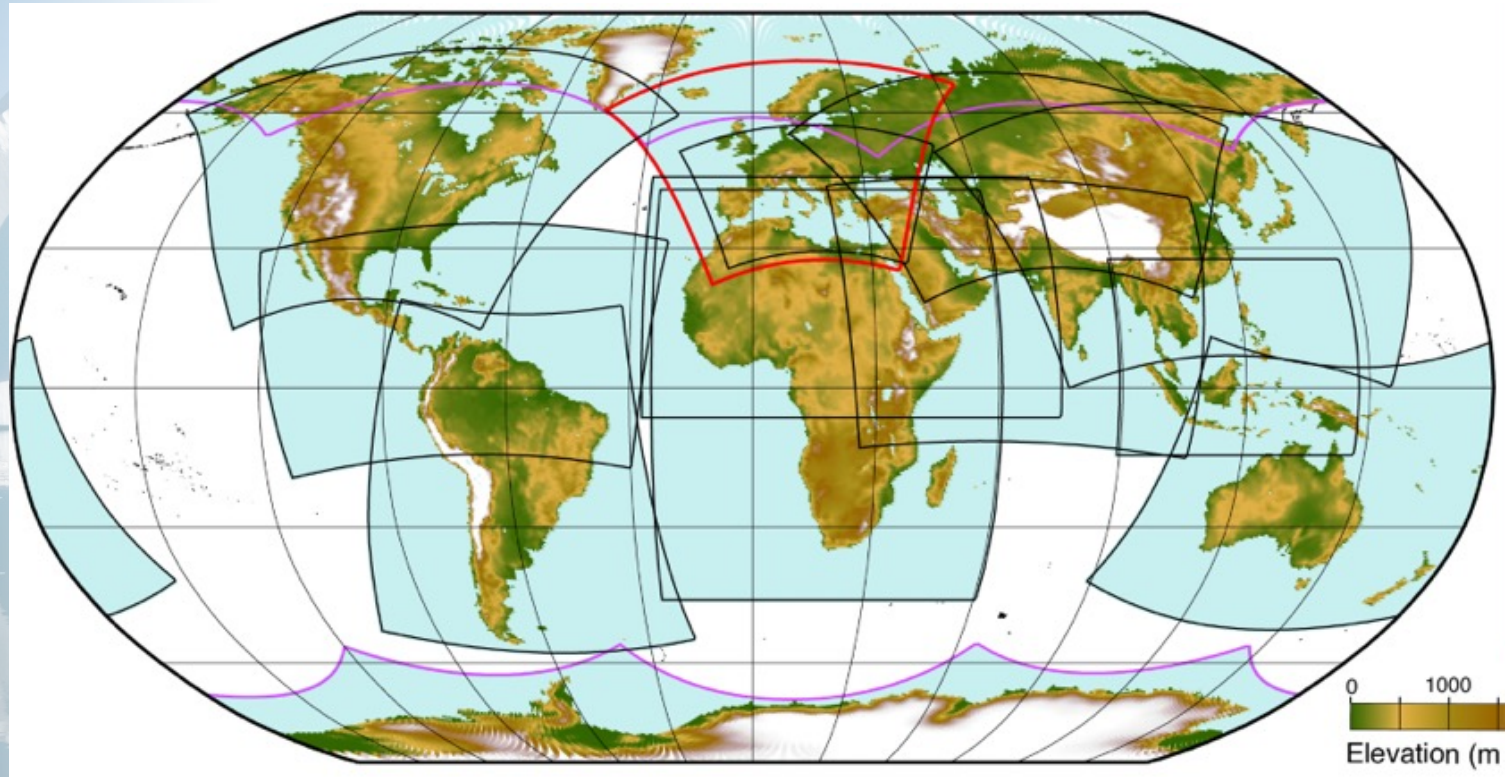

1: South America (SAM)
2: Central America (CAM)
3: North America (NAM)
4: Europe (EUR)
5: Africa (AFR)
6: South Asia (WAS)
7: East Asia (EAS)
8: Central Asia (CAS)
9: Australasia (AUS)
10: Antarctica (ANT)
11: Arctic (ARC)
12: Mediterranean (MED)
13: Middle East North Africa (MNA)
14: South-East Asia (SEA)

0 1000 2000 3000
Elevation (m a.s.l.)

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Climate information and knowledge

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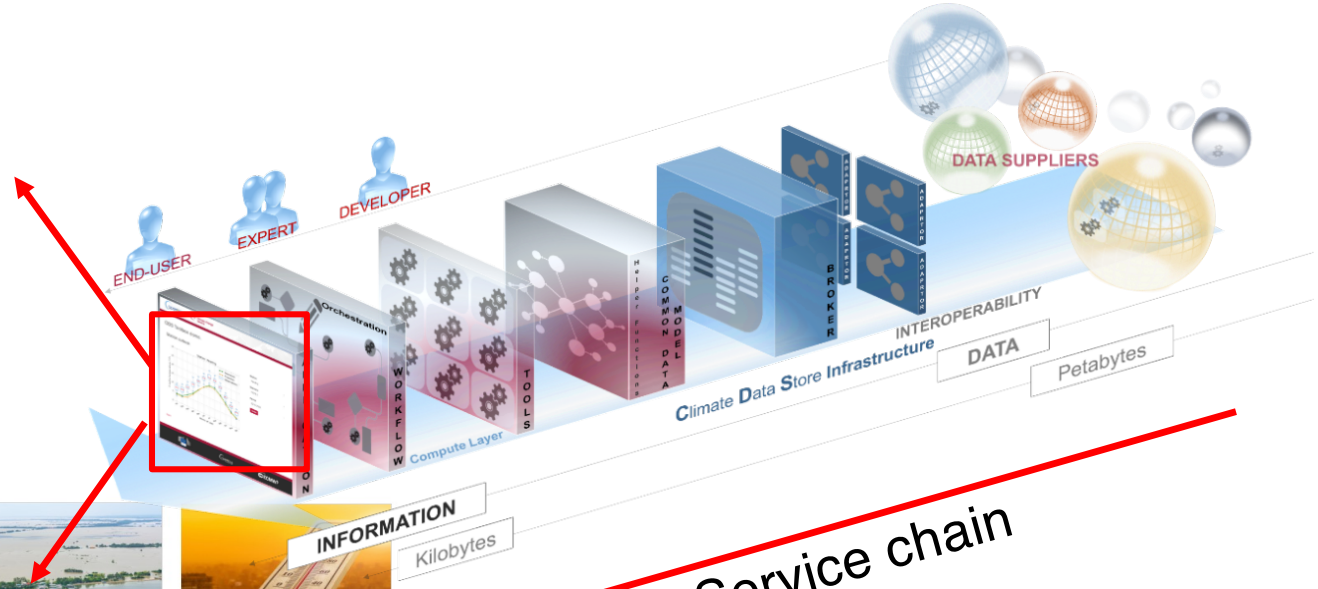
Monitoring



Service chain


Infrastructure, Transport and Associated Standards


Biodiversity


Energy


Disaster risk reduction


Health


Water management


Insurance


Coastal areas


Agriculture and forestry


Tourism

Quality assured information and tools for users ranging from scientists to practitioners and policy makers.

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The SIS next phase

OPERATIONAL SERVICES

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Operational service for the Water Sector

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Climate Data Store - European water and climate data explorer

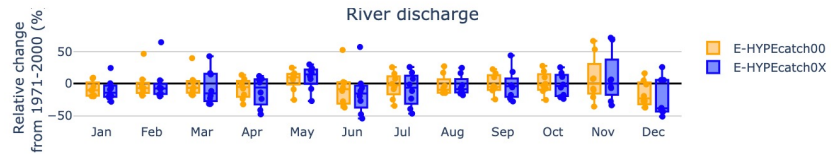
Indicator type: Water quantity

Impact indicator: River discharge

Climate Model: Climate Ensemble (median)

Hydrological Model: E-HYPEcatch Ensemble (median)

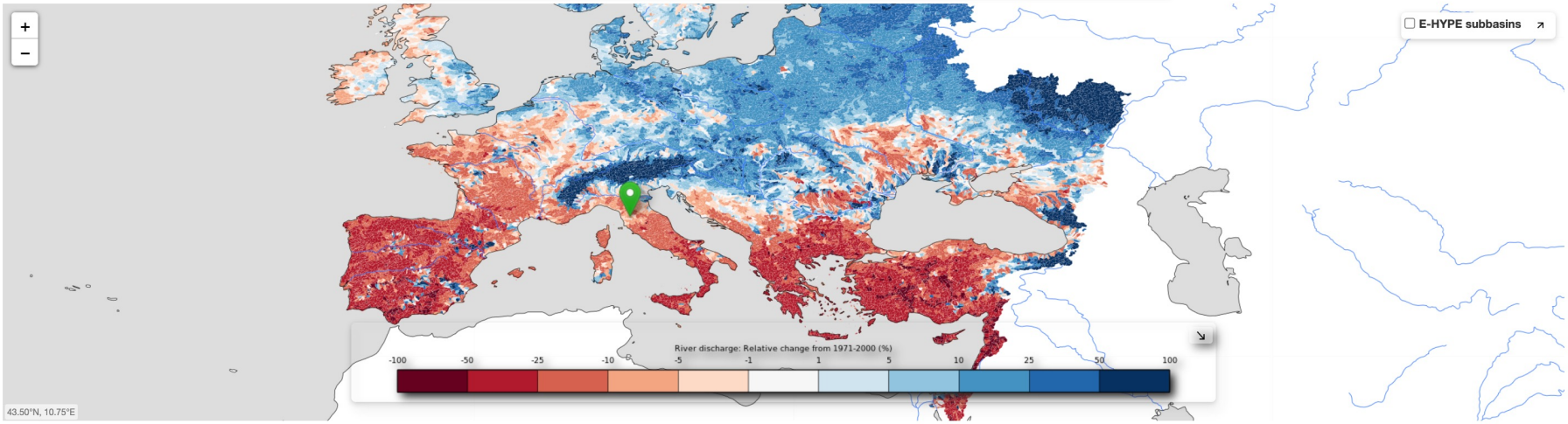
Position: 43.50°N, 10.75°E



Spatial aggregation: Catchments (mean 215 km²)

Time period: 2071-2100

Emission scenario: High (RCP 8.5)



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Operational service for the Water Sector

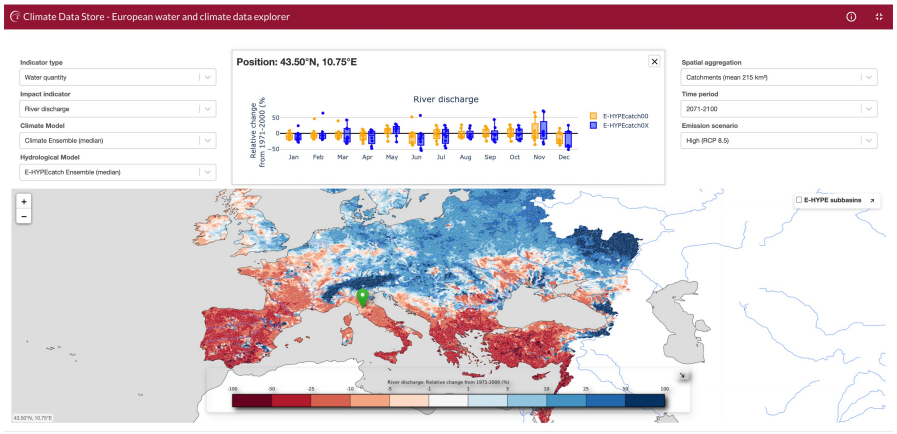
- To support the water sector in planning their operations at seasonal and climate scales

- developed through **co-design** workshops and user survey's : Climate Impact Indicators

- Information available for RCPs and **degree scenarios**

- ensembles of **bias adjusted high resolution** climate model simulations and hydrological models.

- **Uncertainty**: Multi-model GCMs- RCMs – hydrological models



Users: Public companies responsible for the design, construction, operation, management and supervision of hydraulic works and irrigation networks. Municipalities which provide the development organizations with local planning or municipal data on water needs and uses. Regional administrational units which are responsible for the development of adaptation plans…

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C3S prototype service for decadal climate predictions

https://climate.copernicus.eu/sectoral-applications-decadal-predictions

- Developing a prototype decadal climate service in partnership with a user in that sector
- Four European institutions involved in decadal climate predictions : Germany (DWD), Italy (CMCC), Spain (BSC) and the UK (Met Office)
- Four different sector: infrastructure, energy, agriculture and insurance
- Key points:
  - the use of large multi-model ensembles and large-scale circulation indicators to give skilful regional predictions of user relevant variables
  - the development of a standard format to present forecast information to users, including the current probabilistic forecast, retrospective forecast skill and reliability.

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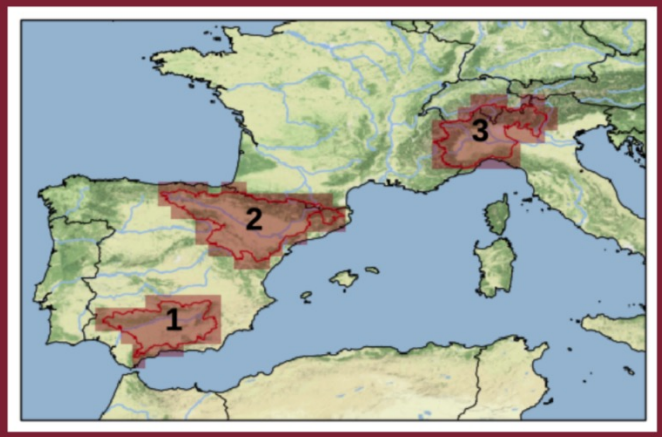
2020–2029 Precipitation Forecasts

Forecast based on predictions made in November 2019

This document provides decadal predictions for precipitation for the coming 10 years to address the needs of the hydropower industry. Forecasts correspond to the extended cold-season precipitation (November–March) in three drainage basins: Guadalquivir (1), Ebro (2) and Po (3), shown in the map on the right.



Outlook for 2020–2029 for each basin:

The predicted ensemble-mean precipitation for the period 2020–2029 is close to 10% above the 1981–2010 climatology, while the ensemble spread indicates that the upper tercile category is more likely to occur (low to high: 22.2%, 16.7%, 61.1%).

Decadal Predictions – Case Studies : The Energy Sector

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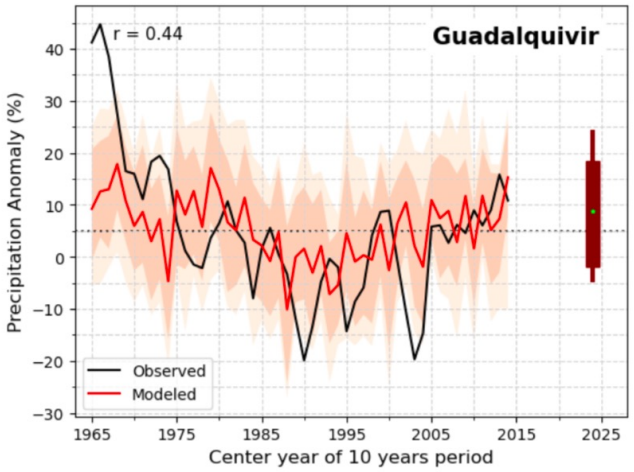
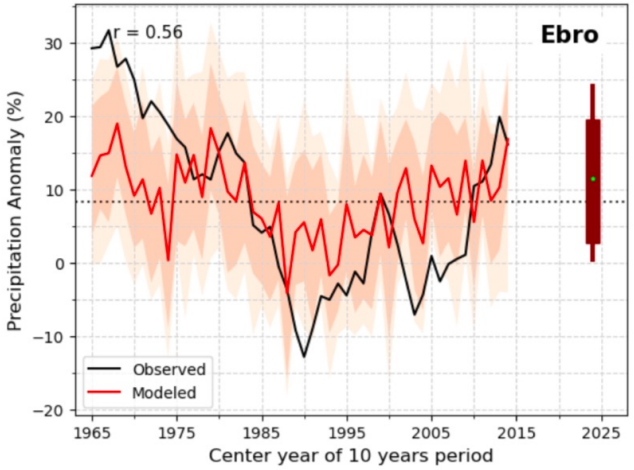
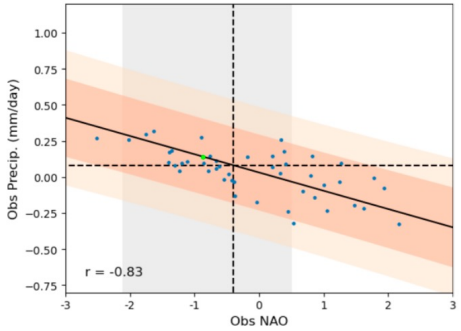
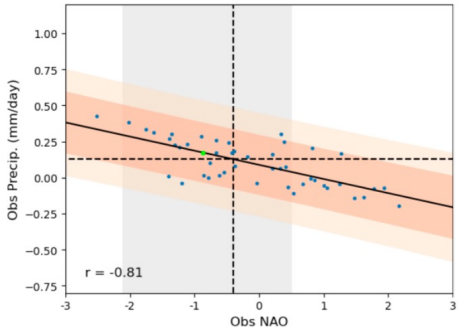




GUADALQUIVIR			
Above-average Precip		Observed: Yes	Observed: No
Predicted	Yes	19 Hits	9 False alarms
Predicted	No	6 Misses	16 Correct rejections
Hit Rate:		76%	
False Alarm Rate:		36%	



EBRO			
Above-average Precip		Observed: Yes	Observed: No
Predicted	Yes	22 Hits	6 False alarms
Predicted	No	3 Misses	19 Correct rejections
Hit Rate:		88%	
False Alarm Rate:		24%	



Climate Change Service climate.copernicus.eu · cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici · Copernicus Europe's eyes on Earth · European Commission · ECMWF

Opreational wind storm service: from wind extremes to Track->Footprint->Losses

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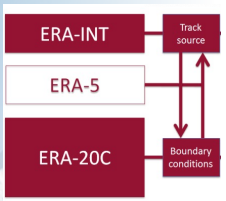
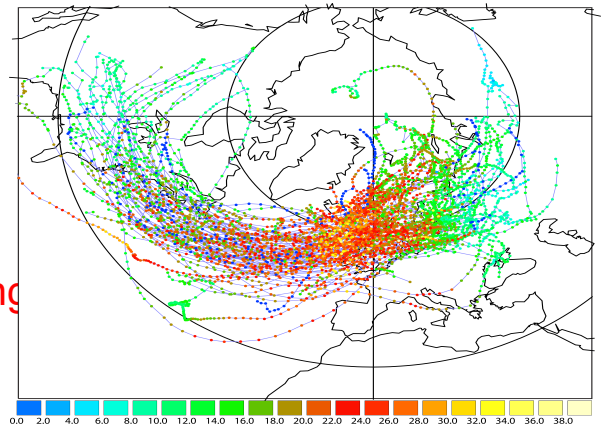


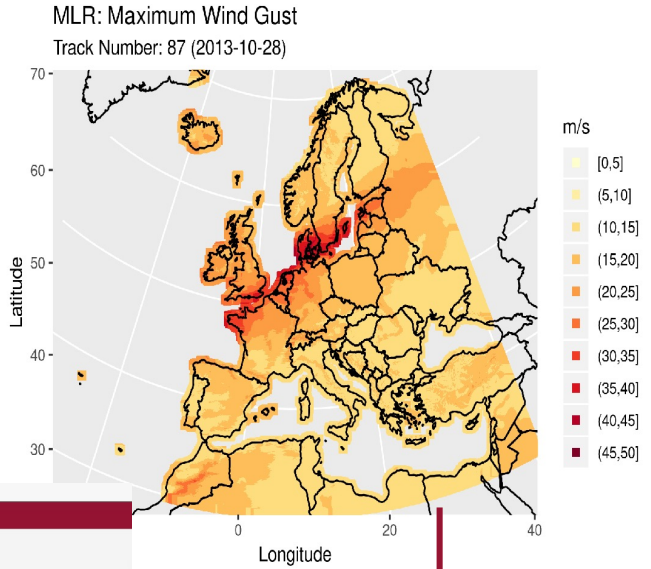
storm tracking

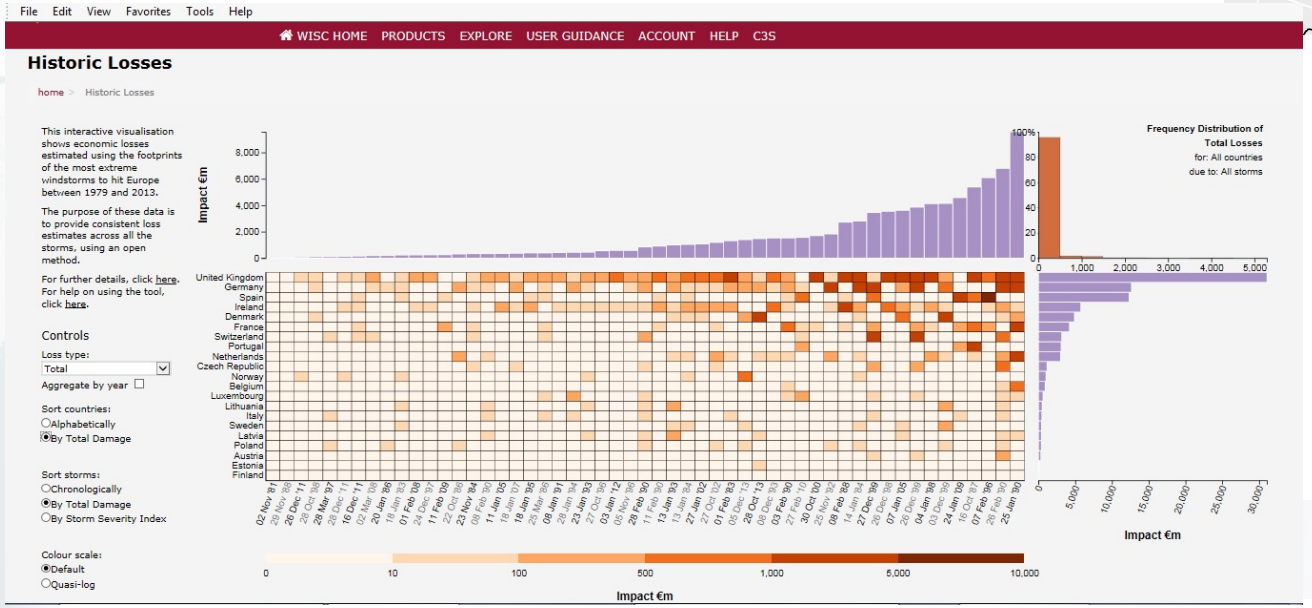
(Univ. Reading)



storm footprint

(UKMO/KNMI)





Economic loss calculations

(VU Amsterdam)

European Commission

ECMWF

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Expert Team on Climate Change Detection (ETCCDI) & Heat Stress Indices

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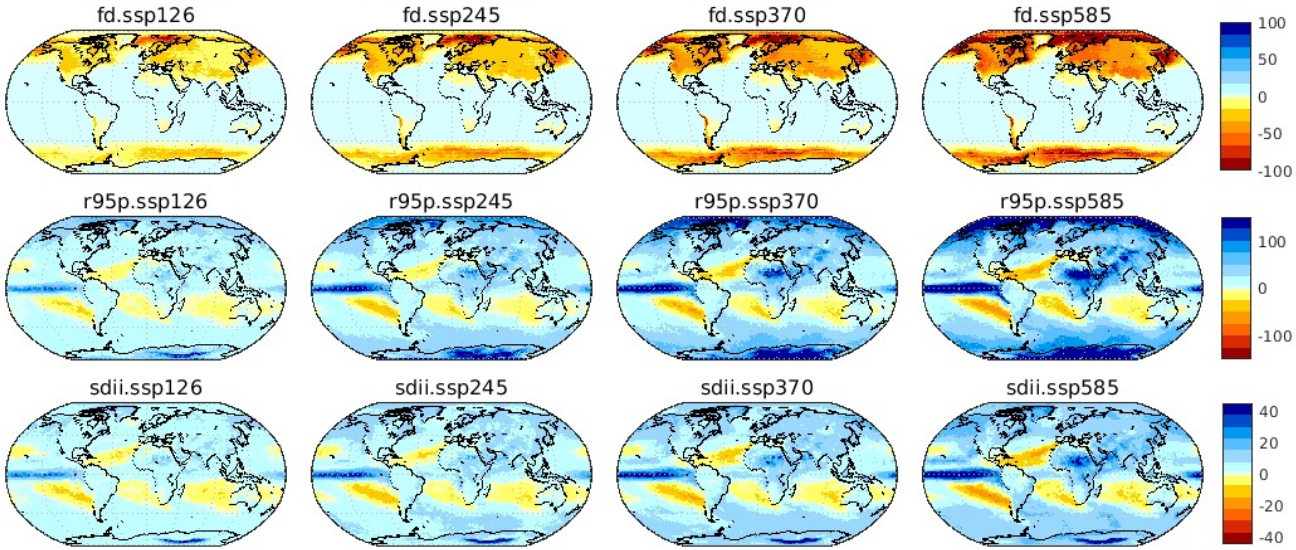
Climate extreme value indices and heat stress indicators derived from climate projections

Overview Download data Documentation

This dataset provides extreme temperature and precipitation indices (ETCCDI and selected heat indices) for historical and future projection (ssp126, ssp245, ssp370, ssp585) runs included in the AR6, CMIP6 datasets.



CICERO
Center for International Climate Research

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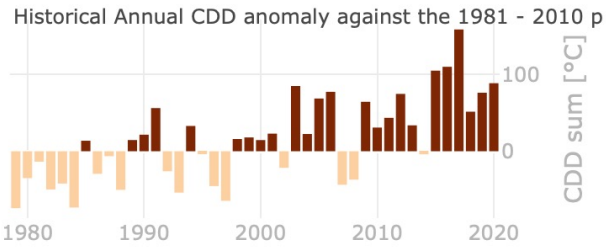
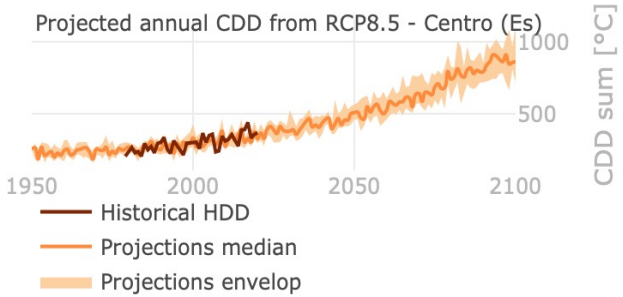
From data to Tools

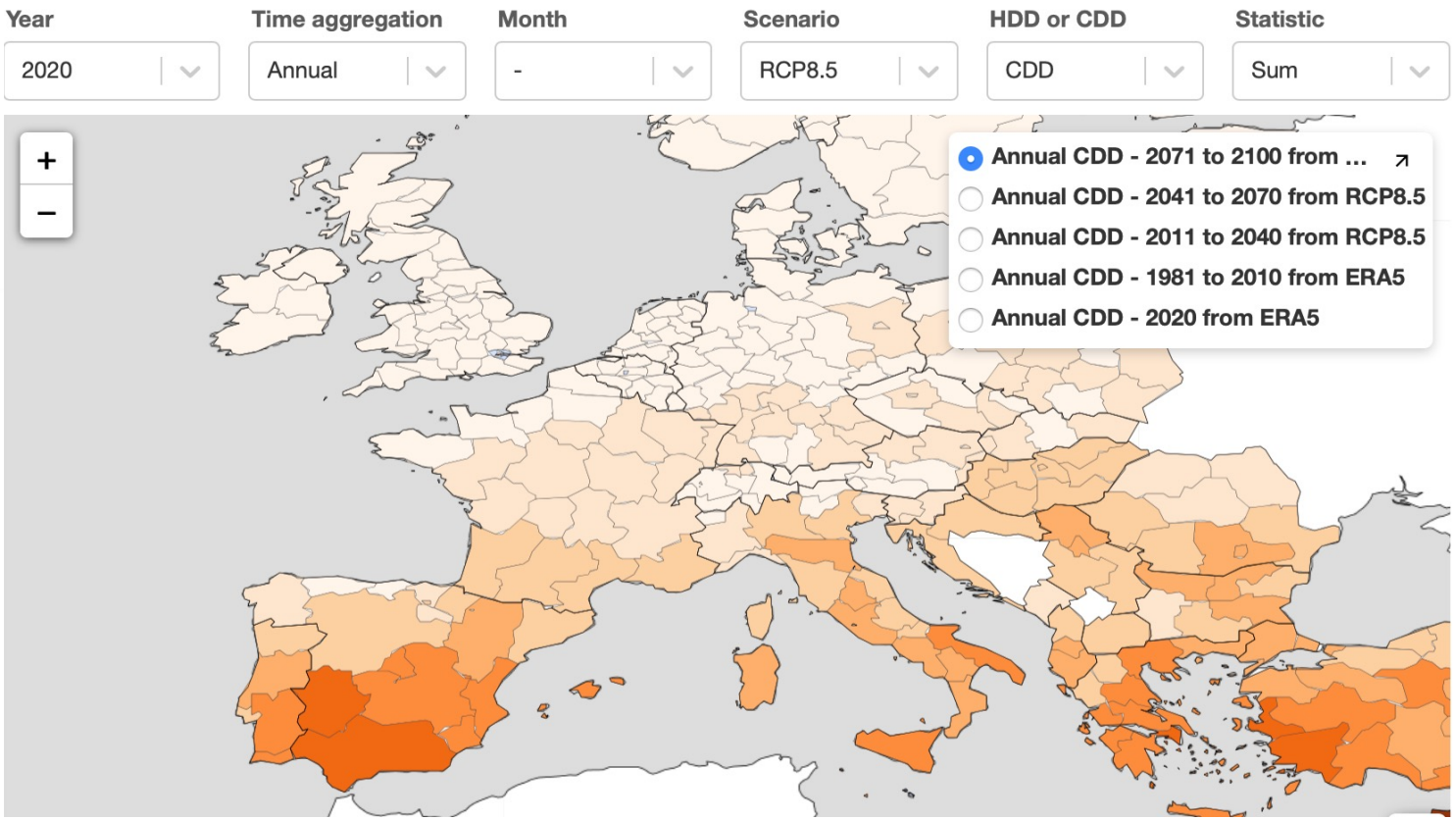
Heating and cooling degree days

Heating degree days (HDDs) and cooling degree days (CDDs) are proxies for the energy demand needed to heat or cool a building. Both variables are derived from measurements of outside air temperature. The heating and cooling requirements for a given structure at a specific location are considered, to some degree, proportional to the number of HDDs and CDDs at that location. They are quantified as number of degrees the daily average temperature is below or above a certain threshold.





Annual Cooling degree days (°C day) under current and future climate using a bias adjusted EURO-CORDEX model ensemble. The graph shows the median, 15 th and 85 th percentiles of the model spread from 1950 to 2100. The red line represents the past degree days from ERA5.



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Challenges (some thoughts…)

Different timescales= different typology of users (e.g. city planners 5-10 yrs info, building a wind-farm…)

Information at the multi-decadal timescale is available as collections of 'opportunity' – often not properly designed for the purpose of services (e.g. incomplete sampling of uncertainties)

Users need information on extremes – we need tailored products

Qualitative info often useless

May compose the info in many ways (analogues, optimally weighted ensembles…)

Use of uncertainty coming from ensemble of opportunities- tools are needed

Downscaling= tools and interpretation - risk of mis-interpretation of higher res information

skills in forecast do not automatically imply skill in the final Application

The lack of a standard adapted to operational purposes

Matter of opportunities

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Thank you for your attention

chiara.cagnazzo@ecmwf.int

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