Climate Change

Climate Change Service

Current status

Carlo Buontempo, Jean-Noël Thépaut

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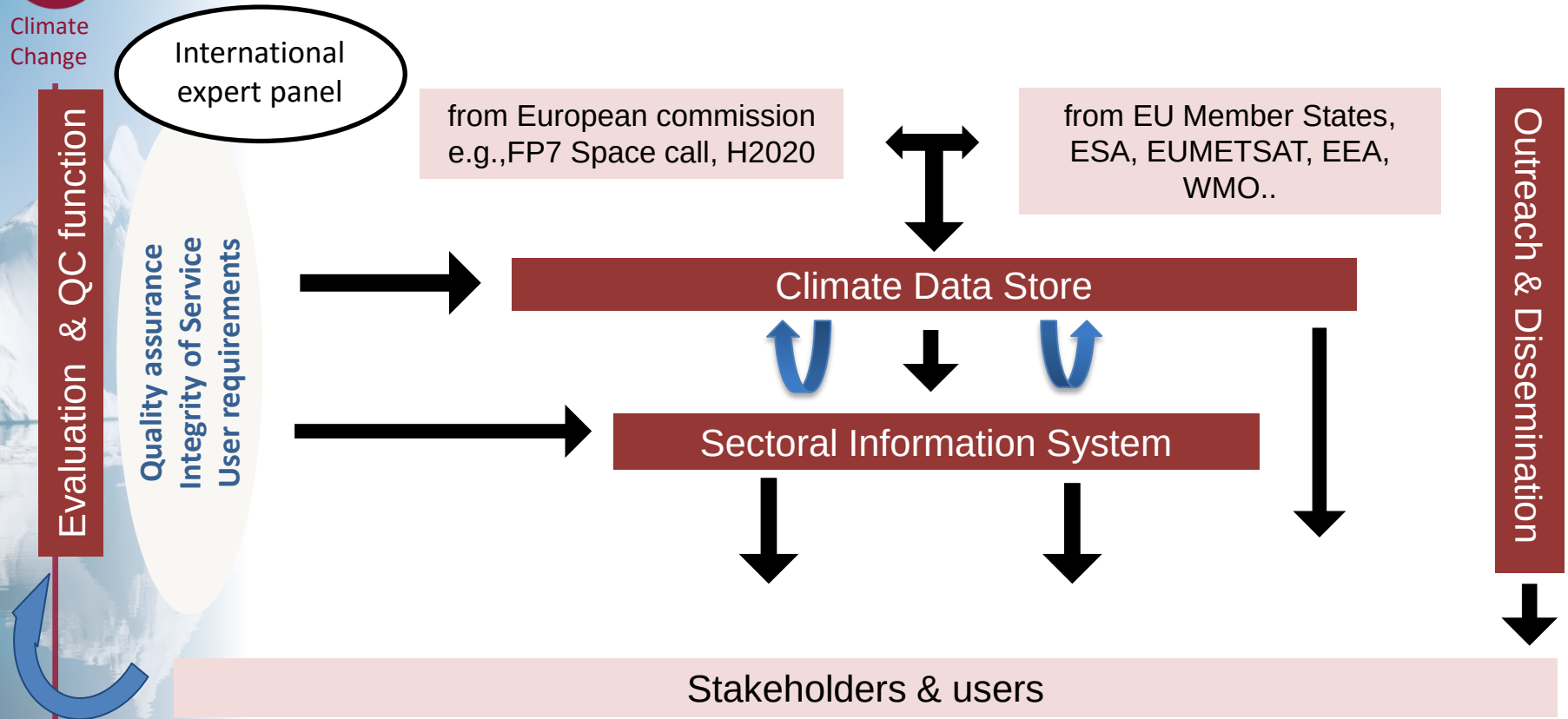
C3S in a nutshell

Climate Change



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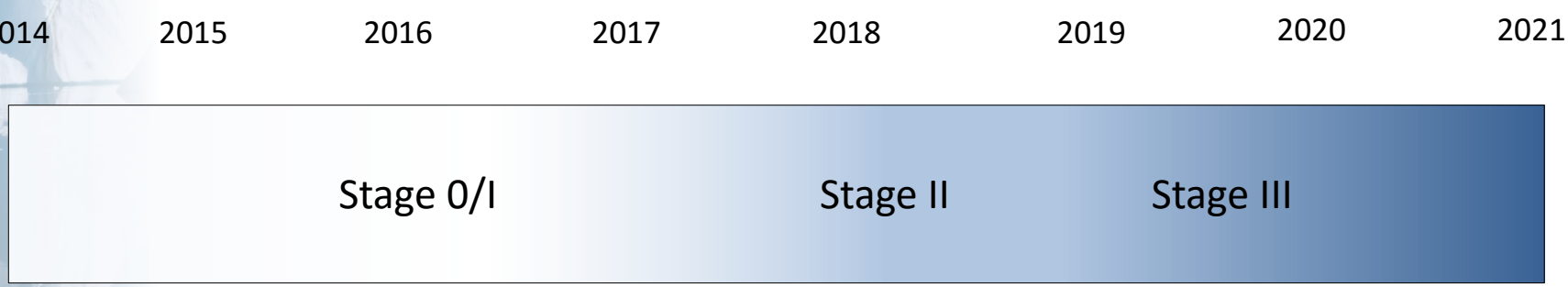
C3S - Development timeline

Climate Change

Stage 0/I - Proof of Concept/Pre-Operational
Stage II - Operational ~20 ECVs, ~5-6 Sectors
Stage III - Operational ~30 ECVs, ~10 Sectors



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Building Upon National and European Investments

National investments: Modeling capabilities, in-situ observations, seasonal forecasts, …

ERA5, ERA6
Data rescue
Satellite reprocessing

Regional reanalysis workshop
Upcoming regional reanalysis ITT

EQC on gridded observations
ECV datasets production

Best practices
Vocabularies, provenance, metadata
User engagement

Workshop on Attribution in October 2017 to decide what next

Significant uptake on ECV datasets production

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Climate Data Store content

Climate Change

Scientific basis:

- Essential Climate Variables as defined by GCOS
- GCOS Status Report and Implementation Plan
- IPCC, CMIP

Action engaged

In preparation (PIN or ITT out)

Not started

Observations	Global estimates of ECVs from satellite and in-situ observations	Reprocessed CDRs, reference observations	Support for data rescue, climate data collections	Climate Indicators
Climate reanalysis	Global atmosphere, ocean, land	Regional reanalysis for Europe	Coupled climate reanalysis for 100 years	
Model output	Multi-model seasonal forecast products	Access to CMIP data and products (global and regional)	Reference set of climate projections for Europe	

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ECV ROADMAP

- ~ 30 ECVs, described in the C3S Technical Annex, and planned for stages II and III, are either:
  - **engaged** (via ERA5/ORA5, 312a lots all awarded, and 311a in-situ)

  or
  - under **PIN / ITT** (2nd set ECVs in 312b).
- These ECVs will progressively become available through 2017/2018.
- Will be complemented by additional ECVs (as outcomes or reanalysis products)

- Liaison with other Copernicus services (e.g. CAMS, CMEMS ..) and ESA-CCI, SAFs, NOAA, etc. is being implemented (Coordination, ITTs spec, evaluation and follow-up, etc.) to ensure complementary and synergies

- ECVs are all traceable to GCOS status report

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Roadmap for Atmospheric ECVs

	GCOS Status Report	C3S Technical Annex	CDS	Reanalysis	Observations
Atmosphere (surface)					
Air temperature	4.3.1	Stage III	2017	ERA5	C3S_311a
Wind speed and direction	4.3.2	Stage II	2017	ERA5	C3S_311a
Water vapour	4.3.3	Stage II	2017	ERA5	C3S_311a
Pressure	4.3.4		2017	ERA5	C3S_311a
Precipitation	4.3.5	Stage II	2017	ERA5	C3S_311a
Surface radiation budget	4.3.6	Stage II	2017	ERA5	
Atmosphere (upper air)					
Temperature	4.5.1		2017	ERA5	
Wind speed and direction	4.5.2	Stage II	2017	ERA5	
Water vapour	4.5.3		2017	ERA5	
Cloud properties	4.5.4	Stage II	2017	ERA5	
Earth radiation budget	4.5.5	Stage II	2017	ERA5	
Atmosphere (composition)					
Carbon dioxide	4.7.1	Stage II	2017		C3S_312a
Methane	4.7.2	Stage II	2017		C3S_312a
Other long-lived greenhouse gases	4.7.3	Stage III	2018		C3S_312b
Ozone	4.7.4	Stage II	2017	ERA5	C3S_312a
Aerosol	4.7.5	Stage II	2017		C3S_312a

Action engaged

In preparation (PIN or ITT out)

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Roadmap for Oceanic ECVs

Climate Change

	GCOS Status Report	C3S Technical Annex	CDS	Reanalysis	Observations
Ocean (physics)					
Sea surface temperature	5.3.1	Stage II	2017	ORA5	C3S_312a
Subsurface temperature	5.4.1	Stage II	2017	ORA5	
Sea surface salinity	5.3.2		2018	ORA5	
Subsurface salinity	5.4.2	Stage III	2018	ORA5	
Sea surface currents	5.3.6		2018	ORA5	
Subsurface currents	5.4.3	Stage III	2018	ORA5	
Sea level	5.3.3	Stage II	2017	ORA5	C3S_312a
Sea state	5.3.4		2018	ERA5	
Sea ice	5.3.5	Stage II	2017	ORA5	C3S_312a
Ocean surface stress	NEW		2018	ORA5	
Ocean surface heat flux	NEW		2018	ORA5	
Ocean (biochemistry)					
Inorganic carbon	NEW		2018		C3S_312b
Ocean colour	5.3.7	Stage II	2018		C3S_312b

Action engaged

In preparation (PIN or ITT out)

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Roadmap for terrestrial ECVs

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	GCOS Status Report	C3S Technical Annex	CDS	Reanalysis	Observations
Land (hydrology)					
Lakes	6.3.4	Stage III	2018		C3S_312b
Soil moisture	6.3.16	Stage III	2017	ERA5	C3S_312a
Land (cryosphere)					
Snow	6.3.5	Stage II	2017	ERA5	
Glaciers	6.3.6	Stage II	2017		C3S_312a
Ice sheets and ice shelves	6.3.7	Stage II	2018		C3S_312b
Permafrost	6.3.8	Stage III	2018		C3S_312b
Land (biosphere)					
Albedo	6.3.9	Stage II	2017		C3S_312a
Land cover (including vegetation type)	6.3.10	Stage III	2018		C3S_312b
Fraction of absorbed photosynthetically	6.3.11	Stage II	2017		C3S_312a
Leaf area index	6.3.12	Stage III	2017		C3S_312a
Fire	6.3.15	Stage II	2018		C3S_312b

Action engaged

In preparation (PIN or ITT out)

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Climate Data Store: Reanalyses

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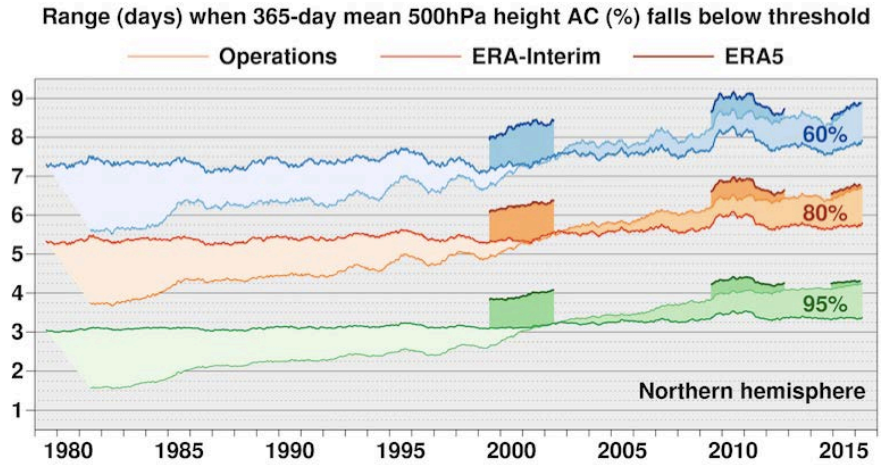
ERA5 global reanalysis:

- Atmosphere/land/wave parameters
- 31 km global resolution, 137 levels
- Hourly output from 1979 onward

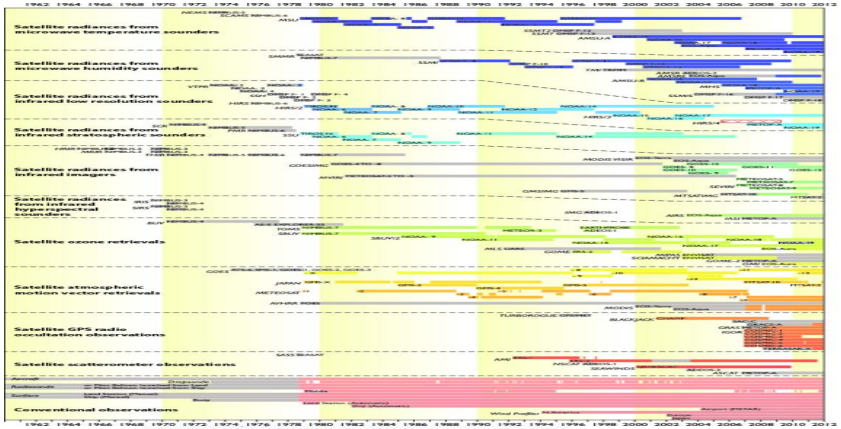
- Based on IFS Cy41r2 (March 2016)
- Using improved input observations
- Ensemble data assimilation
- Providing uncertainty estimates



Regional reanalysis:

- European + Arctic domains
- Higher spatial resolution
- Workshop organised 2016 Q2
- Competitive call issued 2016 Q4, bids under evaluation

EUMETSAT reprocessing activity



Seasonal forecasts- content

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Variables:

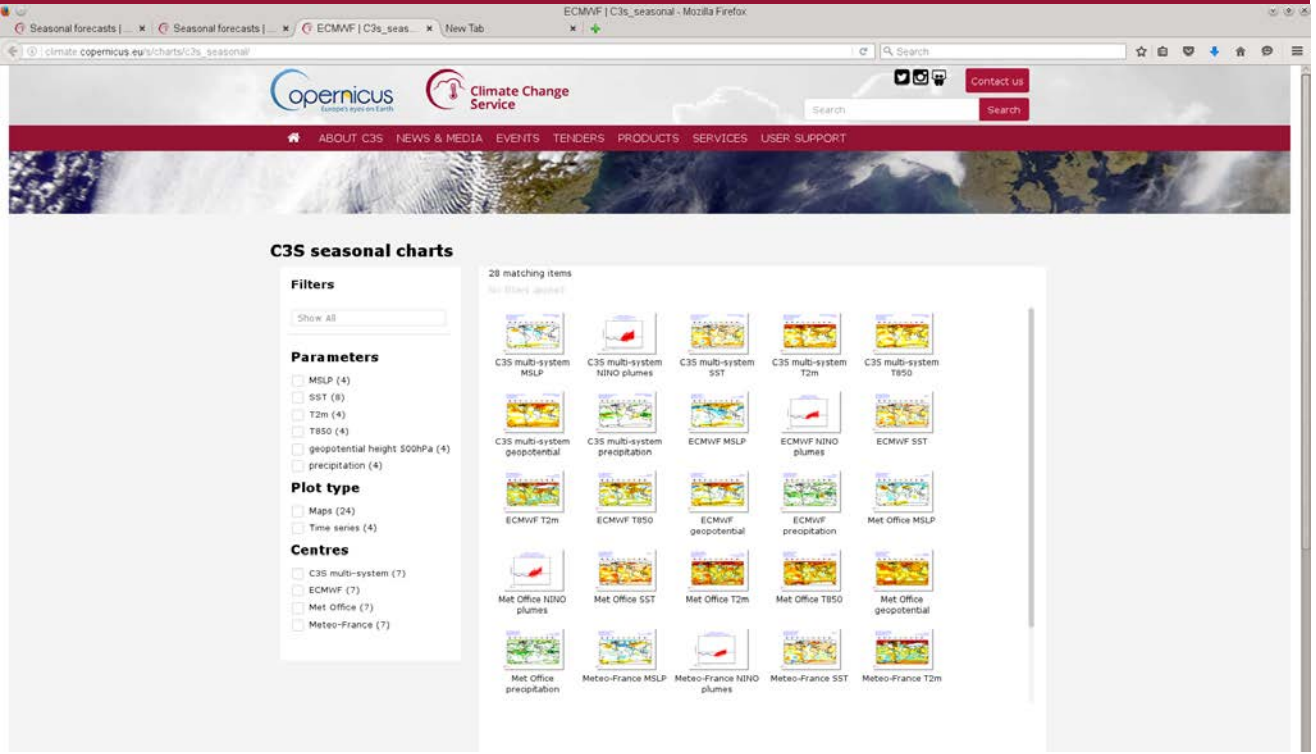
- sea-level pressure
- geopotential height
- precipitation
- air temperature

Type of plots:

- maps:
  - global
  - pre-defined regions
- time series

Publication schedule:

- monthly updates
- published on each 15th



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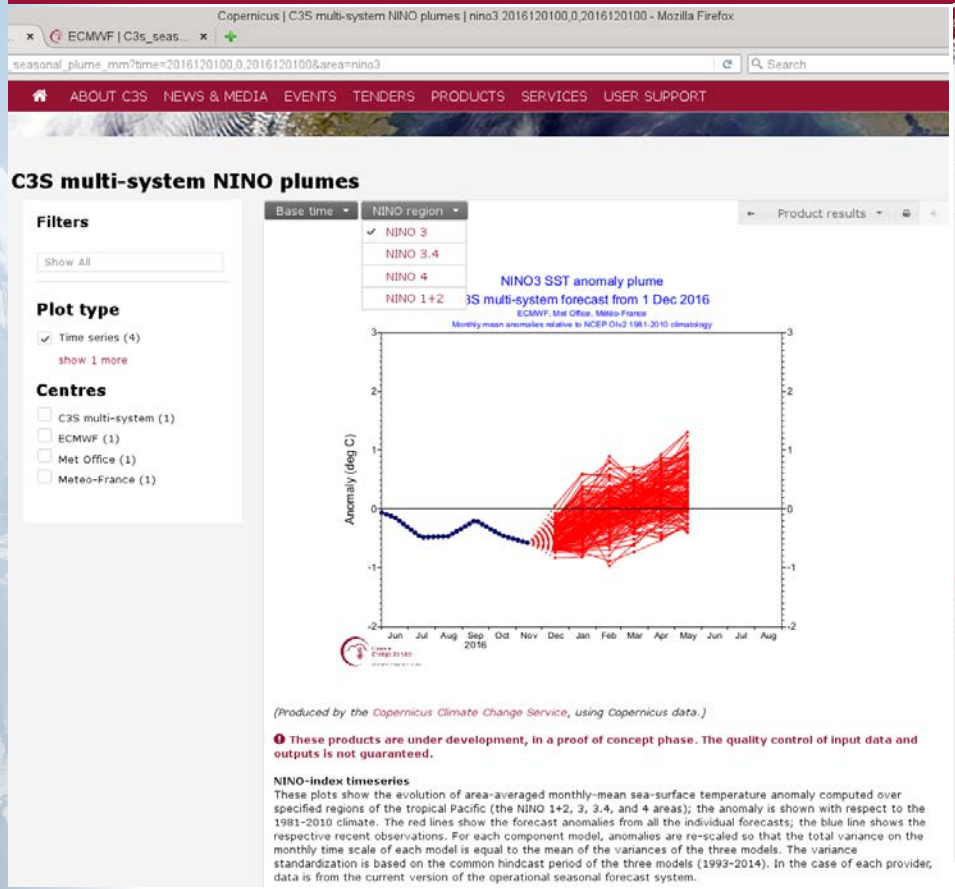
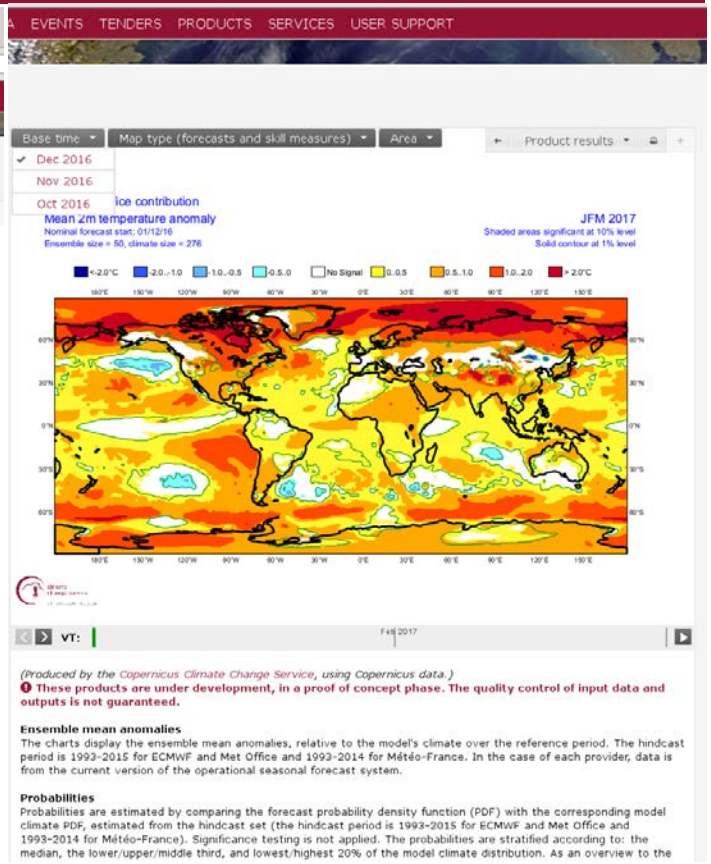
Seasonal forecasts- example





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Seasonal forecasts- variables

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From the ocean model:

every 24h:

- Sea-level (without tides)
- Depth of 28 deg isotherm
- Depth of 26 deg isotherm
- Depth of 20 deg isotherm
- Mixed layer depth
- Surface salinity
- Zonal surface current
- Meridional surface current

From the atmosphere model:

every 6 hours:

- 2 metre temperature (or nearest equivalent)
- 2 metre dewpoint temperature
- 10 metre u wind
- 10 metre v wind
- mean sea level pressure
- total cloud cover
- skin temperature

every 24 hours:

- sea-ice concentration
- sea surface temperature
- volumetric soil moisture level 1
- volumetric soil moisture level 2
- volumetric soil moisture level 3
- volumetric soil moisture level 4
- (*or* total soil moisture)
- surface temperature
- snow depth (water equivalent)
- snow density
- Tmax and Tmin at 2 metres
- Max 10m wind gust

every 24 hours, accumulated:

- large scale precipitation
- convective precipitation
- (or total precipitation)
- snow fall
- surface sensible heat flux
- surface latent heat flux
- surface solar radiation downwards
- surface thermal radiation downwards
- surface solar radiation
- surface thermal radiation
- top solar radiation
- top thermal radiation
- east-west surface stress
- north-south surface stress
- evaporation

every 12 hours:

- geopotential
- temperature
- specific humidity
- vorticity/divergence
- *or* u/v wind components

at 925, 850, 700, 500, 400, 300, 200, 100, 50, 30, 10 hPa

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Seasonal forecasts- the science

Why multi-system?

★ **Larger samples**: each system will provide at least 50 ensemble members for the real-time forecast and at least 25 ensemble members per year for re-forecasts.

★ **Diversity**

- ★ ECMWF (System 4): IFS atmosphere (~75 km and 91 levels), NEMO ocean (1 deg, 42 levels)
- ★ Met Office (GloSea 5): UM atmosphere (~60 km and 85 levels , NEMO ocean (¼ deg, 75 levels), CICE sea-ice
- ★ Météo France (System 5): IFS atmosphere (as ECMWF), NEMO ocean (as ECMWF), GELATO sea-ice
- ★ CMCC (SPS.v3): CSEM atmosphere (~100 km, 46 levels), NEMO ocean (¼ deg, 50 levels), CICE sea-ice
- ★ DWD (GCFS 1.0): ECHAM6 atmosphere (~200 km, 47 levels), MPIOM ocean (1.5 deg, 40 levels)

(all current configurations)

★ **Complementarity of strengths**

Technical and scientific issues

- **metadata standards** for data service
- **post-processing techniques**
- **multi-model combination**
- **verification of forecast products**

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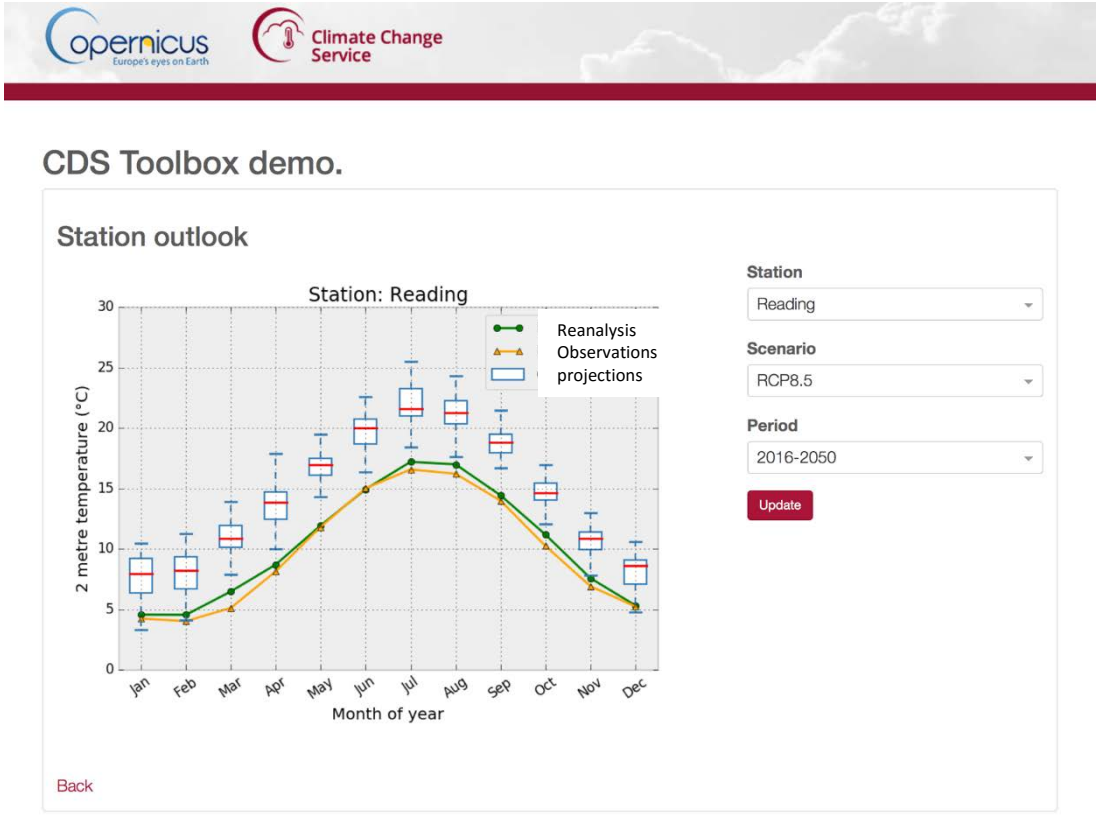
CDS infrastructure and tool box

CDS infrastructure (Telespazio UK): alpha version Jan 2017, beta version summer 2017
CDS toolbox (B-open, IT): incremental until 2019

Technical challenges:

- Diversity of users
- Diversity of data sets
- Very large data volumes
- Data residing at different locations
- Interoperability, efficiency
- User-defined workflows
- Variety of presentation methods
- Need for interactivity
- Access via API
- User management
- Performance monitoring



CDS infrastructure and toolbox

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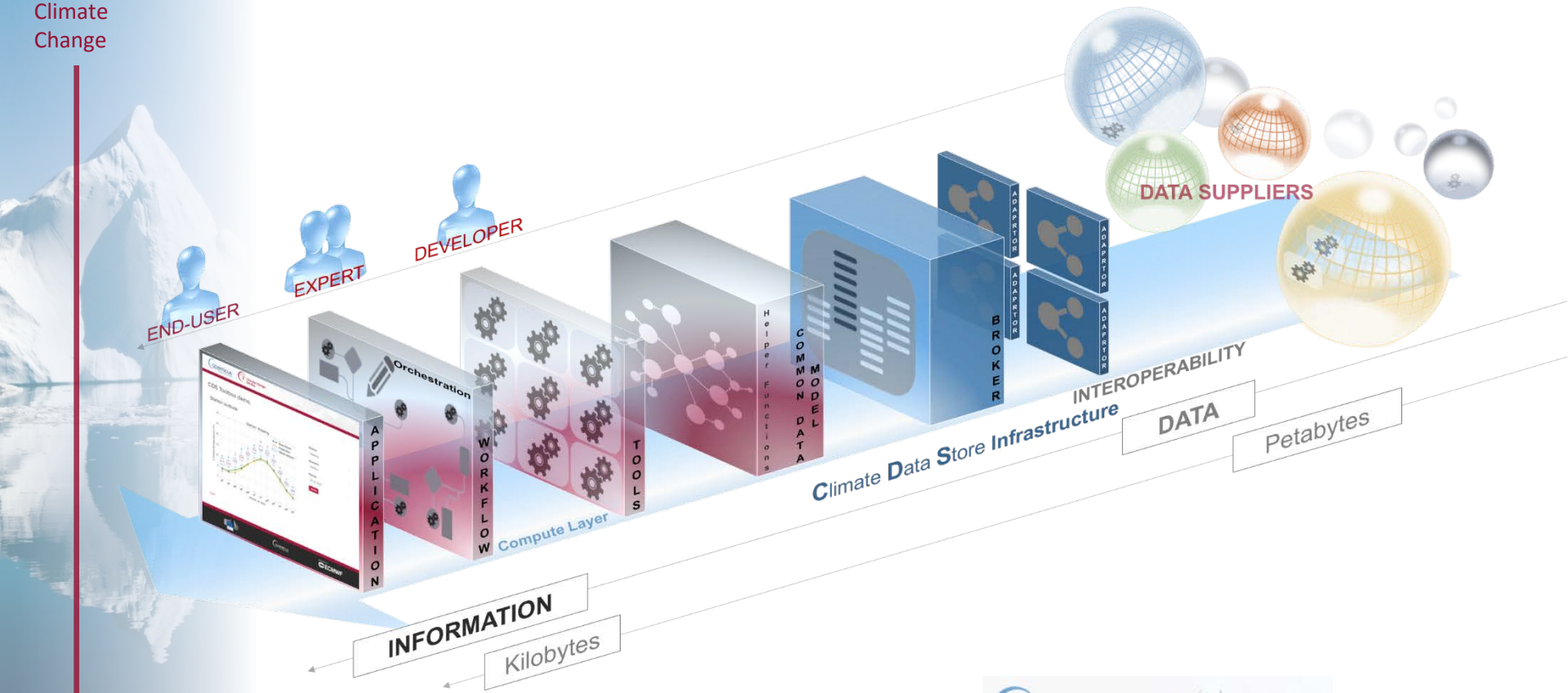

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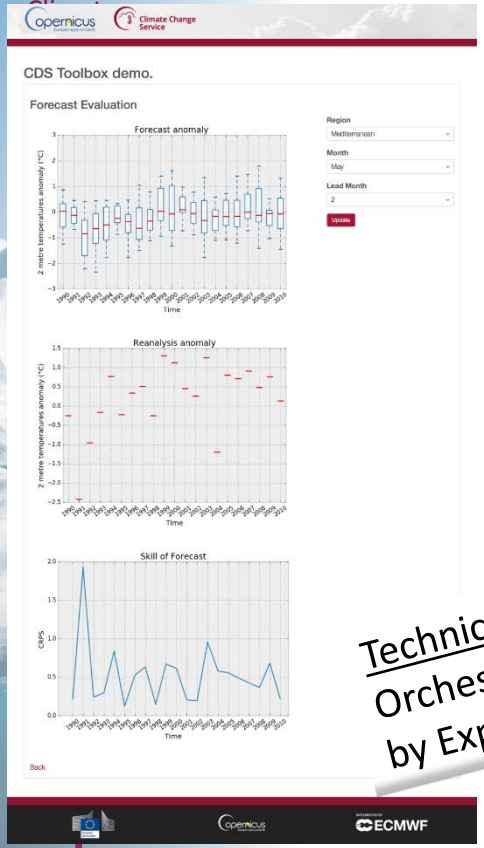
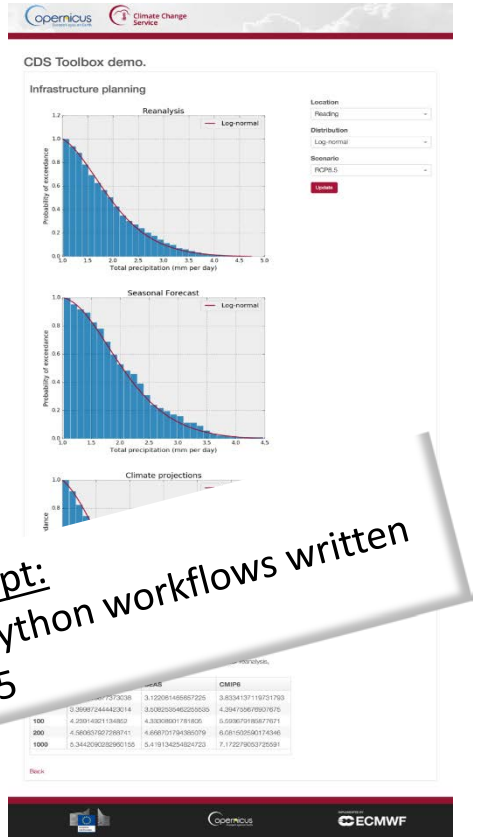
CDS toolbox: Application workflows



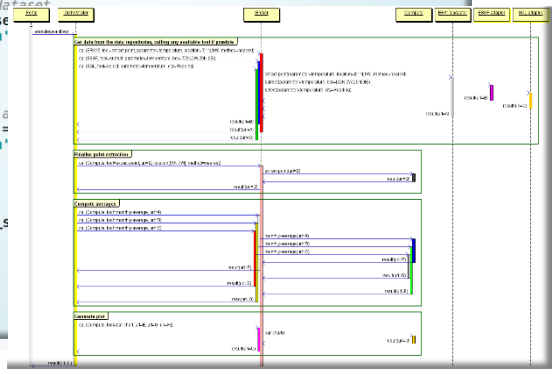


Technical Concept:
Orchestrated Python workflows written by Experts2225

Workflow code 1/2

```
def CRPS(month_neme, lead_time_month=2, variable_name='T2m'):
    month = month_names.index(month_neme)  # month index starting from 1

    #
    # CDS queries
    #

    observations = c3s.queryDataset(
        name='OBSERVATIONS'
    ).timeFilter(
        time_interval=('1990-01-01', '2010.12.31')
    ).spatialFilter(
        bbox=(9, 38, 17, 45)  # Italy
    )

    lead_month = (month - lead_time_month) % 12 + 1  # NOTE: month start form 1
    seasonal_forcasts = c3s.queryEnsemble(
        name='SEASONAL_FORCASTS'
    ).ensembleFilter(
        lead_month=lead_month,
        lead_year=['%d' % year for year in range(1990, 2011)]
    ).spatialFilter(
        same_as=observations,  # requests same bbox and same coordinate system and spacing
        how='average',         # assuming observations is lower resolution
    )

[...]
```

```
#
# Processing
#

# observations is one dataset
mean_observations = obse
    rule='M', how='mean'
).select(
    month=month,
)

# seasonal_forcasts is a
mean_seasonal_forcasts =
    rule='M', how='mean'
).select(
    month=month,
)

scores = c3s.CRPS(mean_s

#
# Return the raw data
#

return scores
```



CDS toolbox: Application framework

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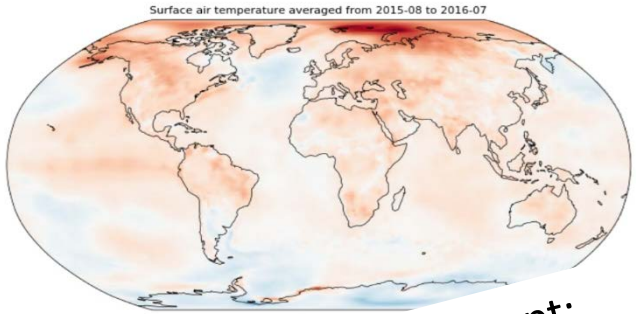
Surface air temperature



−6

2:26 / 2:26

JavaScript application code

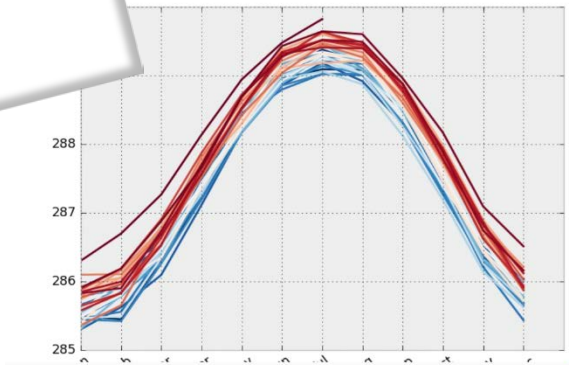
```
<!DOCTYPE html>
<html lang=""en">
    <head>
        <title>Evaluation of fitness for purpose of the Sectoral Information System</title>
        <script src="c3s.js"></script>
    </head>
    <body>
        <h1>Evaluation of fitness for purpose of the Sectoral Information System</h1>
        <p>Parameters: lead time month 2, variable: 2m temperature, time period 1990-2010</p>
        <h2>May</h2>
        <div id="may_plot"></div>
        <table id="may_table">
        </table>
        <script>
            var CRPSService = c3s.service({
                user: "alexamici",
                password: "secret",
                workflow: "CRPS"
            });

            var may_crps = CRPSService.query({month: "May"});

            c3s.table_component({
                renderTo: 'may_table',
                data: may_crps
            });

            c3s.plot_component({
                renderTo: 'may_plot',
                data: may_crps
            });
        </script>
    </body>
```

Technical Concept:
Easy JavaScript framework to implement customized applications



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Sectoral Information System

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WHAT WILL THE INFORMATION BE USED FOR?

The wealth of climate information will be the basis for generating a wide variety of climate indicators aimed at supporting adaptation and mitigation policies in Europe in a number of sectors. These include, but are not limited to, the following:

C3S WILL DELIVER SUBSTANTIAL ECONOMIC VALUE TO EUROPE BY:

1. **INFORMING**
   POLICY DEVELOPMENT TO PROTECT CITIZENS FROM CLIMATE-RELATED HAZARDS SUCH AS HIGH-IMPACT WEATHER EVENTS
2. **IMPROVING**
   PLANNING OF MITIGATION AND ADAPTATION PRACTICES FOR KEY HUMAN AND SOCIETAL ACTIVITIES
3. **PROMOTING**
   THE DEVELOPMENT OF NEW SERVICES FOR THE BENEFIT OF SOCIETY

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Contractors and sub-contractors contributing to C3S

Up to date, ***131 different entities*** *from* ***20 European countries*** *and* ***3 international organisations*** *are involved in 54 contracts as a contractor or subcontractor counting for 225 participations in contracts managed by ECMWF.*

+ International Organisations

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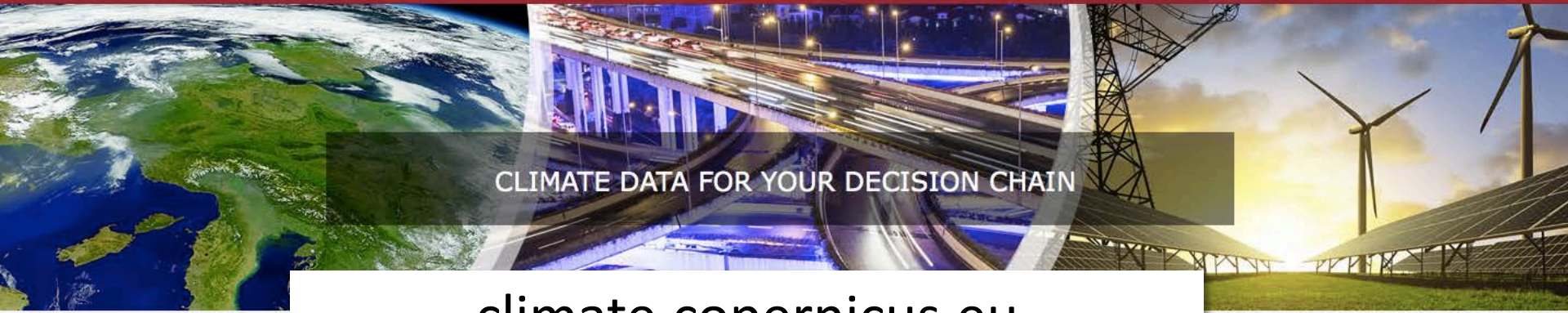

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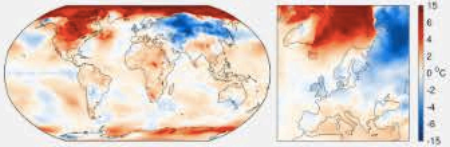
IN FOCUS

#OpenDataHack @ECMWF - explore creative uses of open data

13 Dec 2016

MONTHLY MAPS

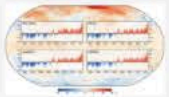


Average surface air temperatures for November 2016

November 2016

NEWS

13 Dec 2016
#OpenDataHack @ECMWF - explore creative uses of open data



06 Dec 2016
Report Reassesses Variations in Global Warming

28 Nov 2016
Copernicus at Wissenswerte

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Global projection-related service

- **Lot 1: Provision of support to one Earth System Grid Federation (ESGF) node in Europe –** solution for access to and manipulation of global climate projections from the CMIP archive, consistent with the requirements of climate services.
- **Lot 2: Multi-model product generation**
  - **metrics for fidelity** of models in simulating historical climate, to be **translated into quality** for specific applications
  - **interactive tools** for generic products (e.g. maps of intra-ensemble variability for different models and scenarios), and **tailored products** for several economic sectors
- **Lot 3: Roadmap towards a reference set of climate projections for Europe:** studies on how well climate projections address sectoral needs, to guide requirements for the operational phase of C3S. Areas of interest: the benefit of **ensemble size versus resolution** for global models, and the benefit of **initialised decadal predictions,** in relation to the specific needs of different economic sectors.

Regional climate projection service

The goal

- to facilitate access to and manipulation (via the CDS) of output of regional climate projections over Europe and boundary conditions from GCM simulations needed for future regional projections.
- to define, agree and complete a matrix of global/regional model combinations and scenarios, which allows robust assessment of the uncertainties arising from these factors in a multi-model set of regional projections.

Evaluation and quality control component for climate projection-based services

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SIS: Next steps

- Definition of an operational SIS:
  - Sectoral user guidance and support
    - on datasets, indicators
    - With an appropriate toolbox
    - promoting best practices
  - Use cases
    - Demonstrators
    - Success stories
- Development of a “global” SIS
    - Operational services providing global climate information of high impact and relevance to users operating on a global scale (e.g. insurance, food-security, transport, commodity market, tourism).
    - Clearly interfaced with the CDS
    - Beneficial to European businesses and the society at large
    - Clear demonstration of the business case for use of state-of-the-art climate information provided by C3S.
- SISs for the remaining Sectors

EQC: Engaged and future activities

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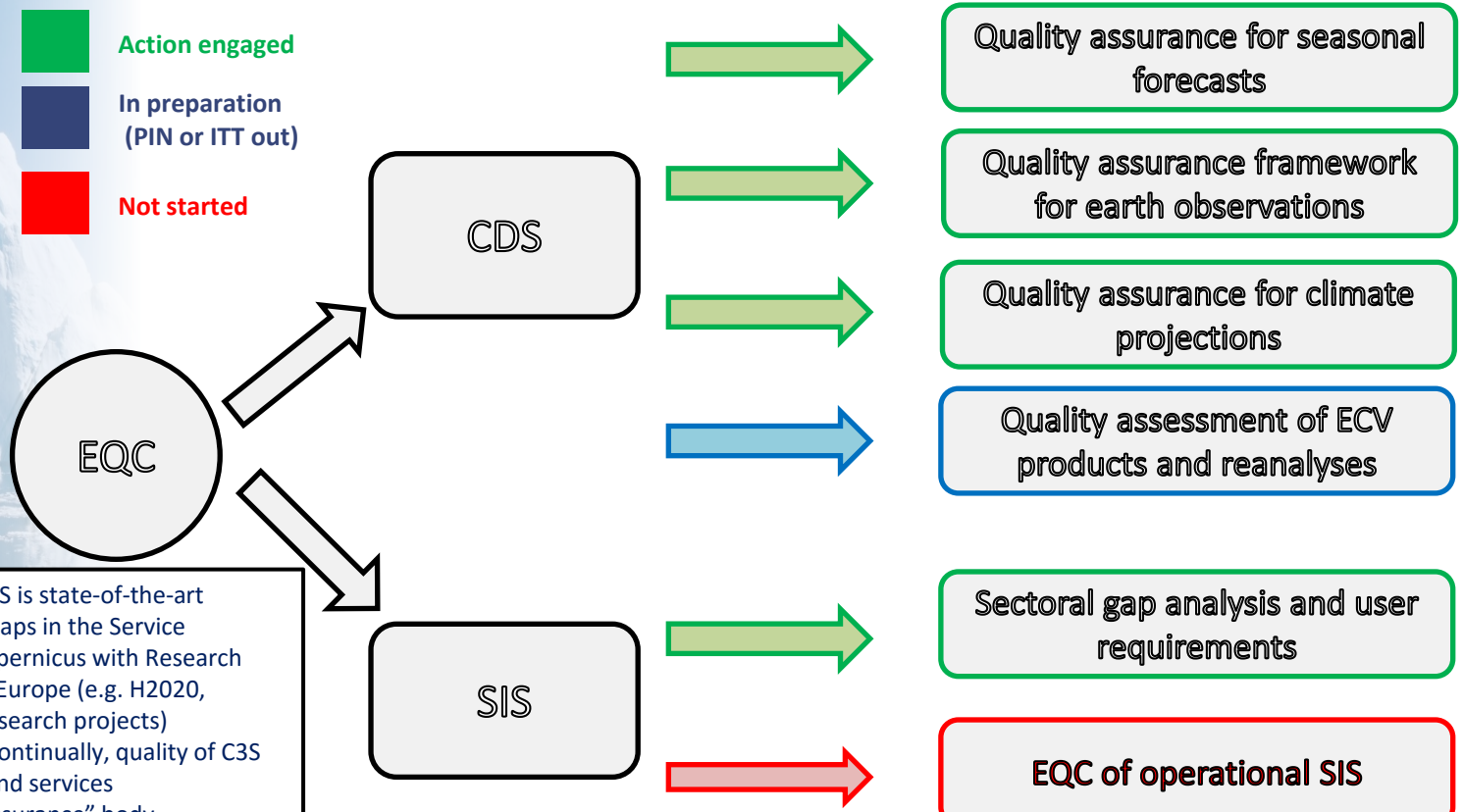
Action engaged

In preparation (PIN or ITT out)

Not started



Ensures C3S is state-of-the-art
Identifies gaps in the Service
Bridges Copernicus with Research Agenda in Europe (e.g. H2020, national research projects)
Monitors continually, quality of C3S products and services
"Quality Assurance" body
Contributes and develops URDB/SES/etc documents

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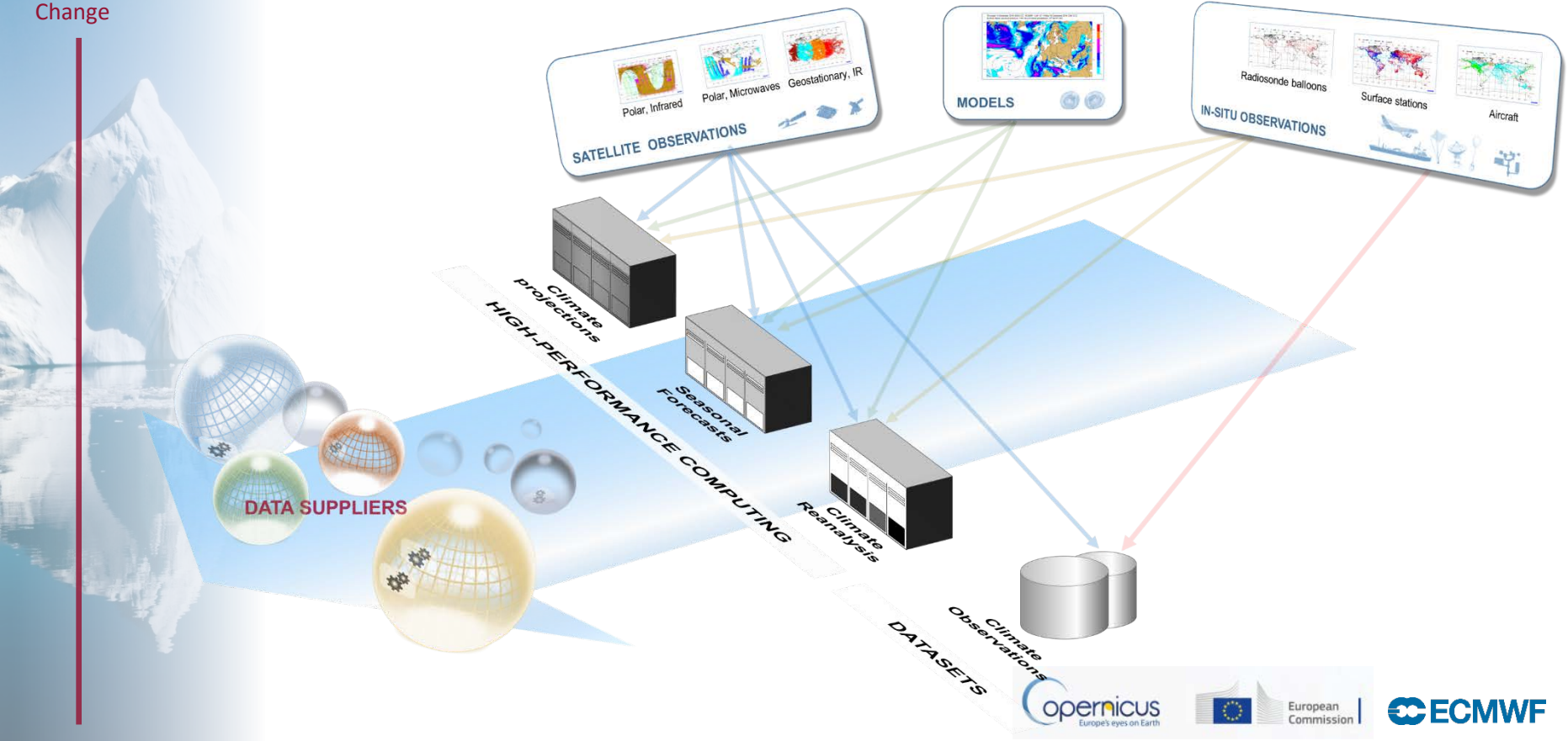
What do we mean by Data?



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