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SUNSET: Addressing key challenges for the successful provision of climate services

V. Agudetse, N. Pérez-Zanón, A. Batalla, C. Delgado-Torres, A. Bojaly, P.-A. Bretonnière, J. Corvillo, E. Duzenli, T. Kariyathan, A. Lacima-Nadolnik, A. Llabrés-Brustenga, B. de Paula Kinoshita, P. Trascasa-Castro, V. Torralba, A. Soret, and F.-J. Doblas-Reyes

Earth Sciences Department, BSC-CNS

EGU26 ESSI2.8
PICO spot 1b.4

SUNSET: Addressing key challenges for the successful provision of climate services

"Climate services are the provision and use of climate data, information and knowledge **to assist decision-making.**" (WMO, Global Framework for Climate Services).

CLIMATE SERVICE REQUIREMENTS

- **Tailoring to needs**
- **Scientific rigor**
- **Timely delivery**
- **Recurrent services**

SOFTWARE CHALLENGES

- **Flexibility**
- **Reproducibility**
- **Robustness**
- **Operationalization**

IMPETUS 4CHANGE

The Impetus4Change project (I4C, grant agreement 101081555) is funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Commission. Neither the European Union nor the granting authority can be held responsible for them.

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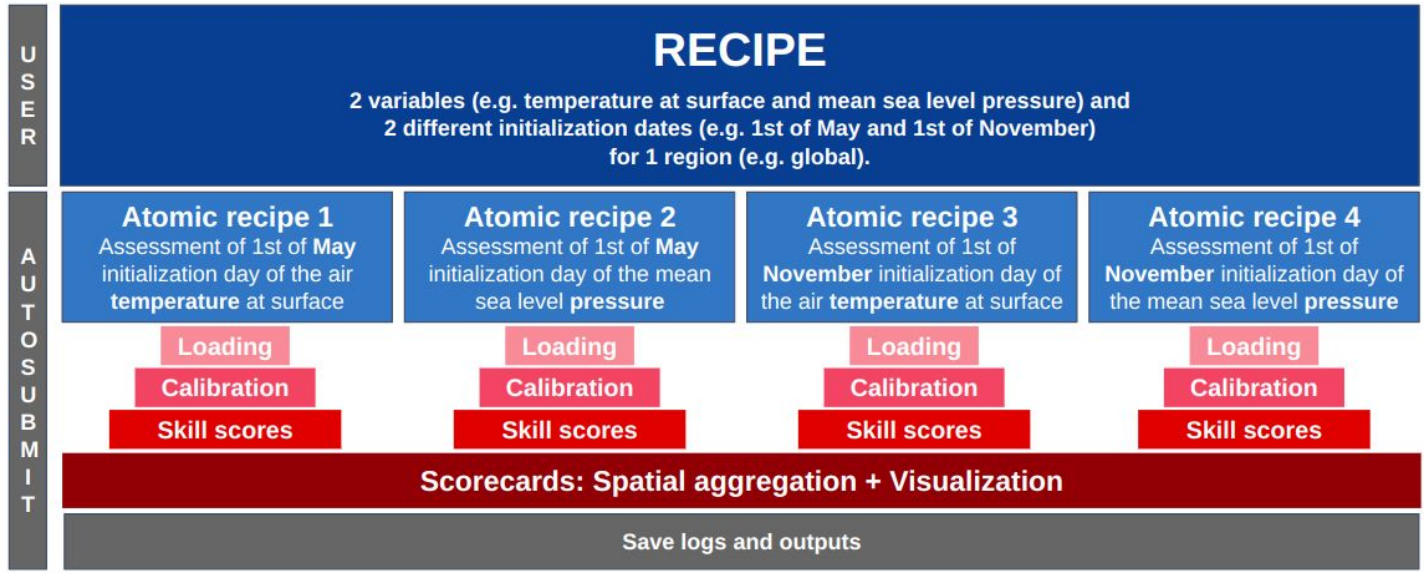
SUNSET is an R-based software suite developed collaboratively at the Barcelona Supercomputing Center, aiming to address these challenges in **post-processing climate forecast outputs to provide climate services** for sub-seasonal, seasonal and decadal time scales.

Its **modular design** allows flexibility in defining the required products and post-processing steps, which can then be **easily parallelized on HPC platforms** making use of the Autosubmit workflow manager.

The **SUNSET** repository:
https://gitlab.earth.bsc.es/es/sunset



Pérez-Zanón, N., et al.: SUNSET: SUbseasoNal to decadal climate forecast post-processIng and asSEssmenT suite, EMS Annual Meeting 2024, Barcelona, Spain, 1–6 Sep 2024, EMS2024-361, https://doi.org/10.5194/ems2024-361, 2024.

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1. Data post-processing for Climate Services

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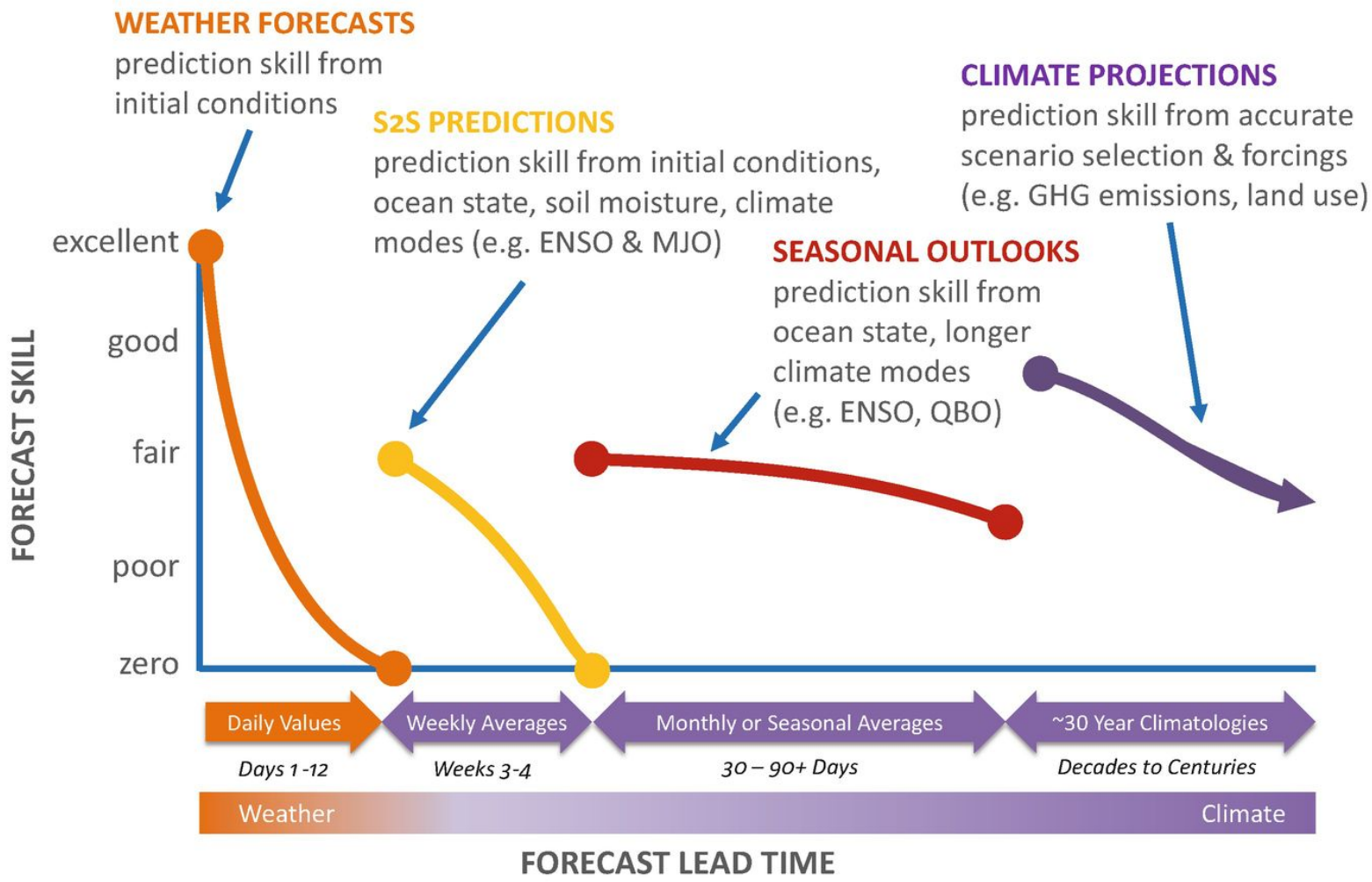
What is a “climate forecast”? Forecast horizons

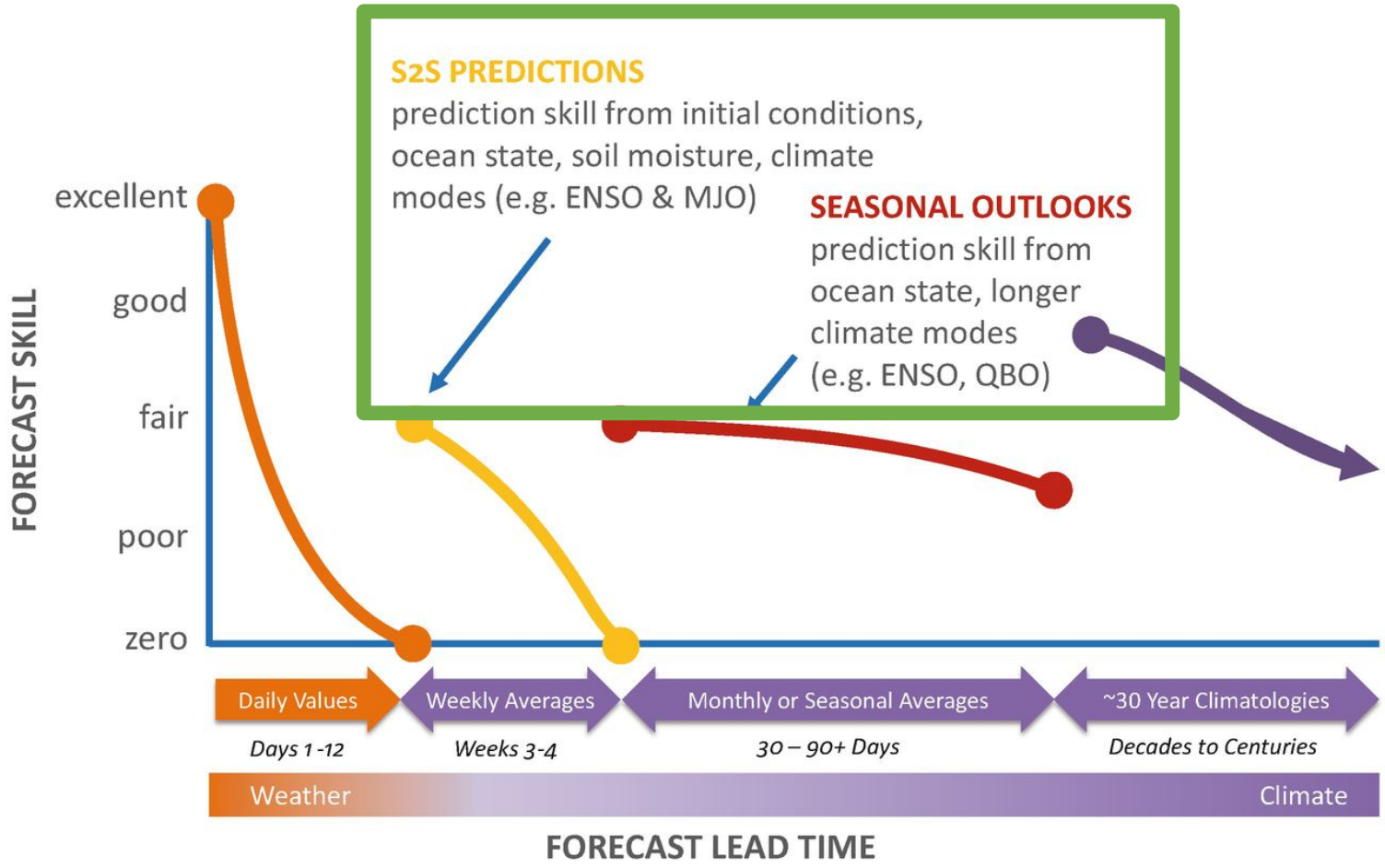
Weather and climate predictions can be classified according to the time horizon they cover.

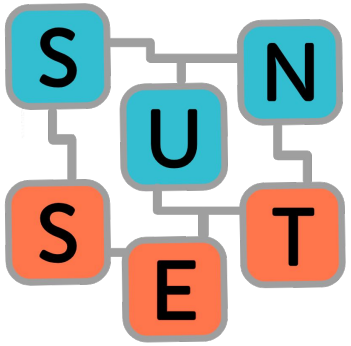


Adapted from iri.columbia.edu/news/qa-subseasonal-prediction-project

What is a “climate forecast”? Forecast horizons

SUNSET (**SUbseasoNal to decadal climate forecast post-processiNg and asSEssmenT suite**) is an R-based software suite that deals with subseasonal, seasonal and decadal predictions.

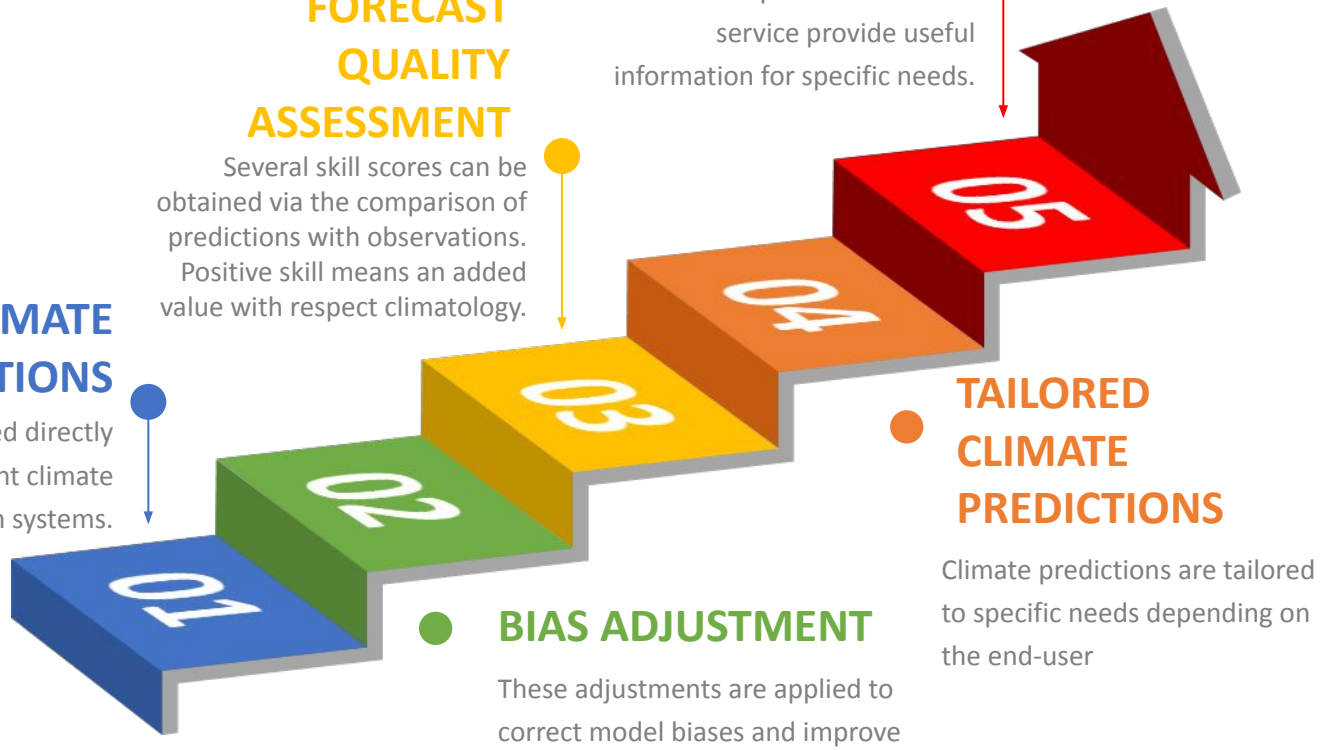




Adapted from iri.columbia.edu/news/qa-subseasonal-prediction-project

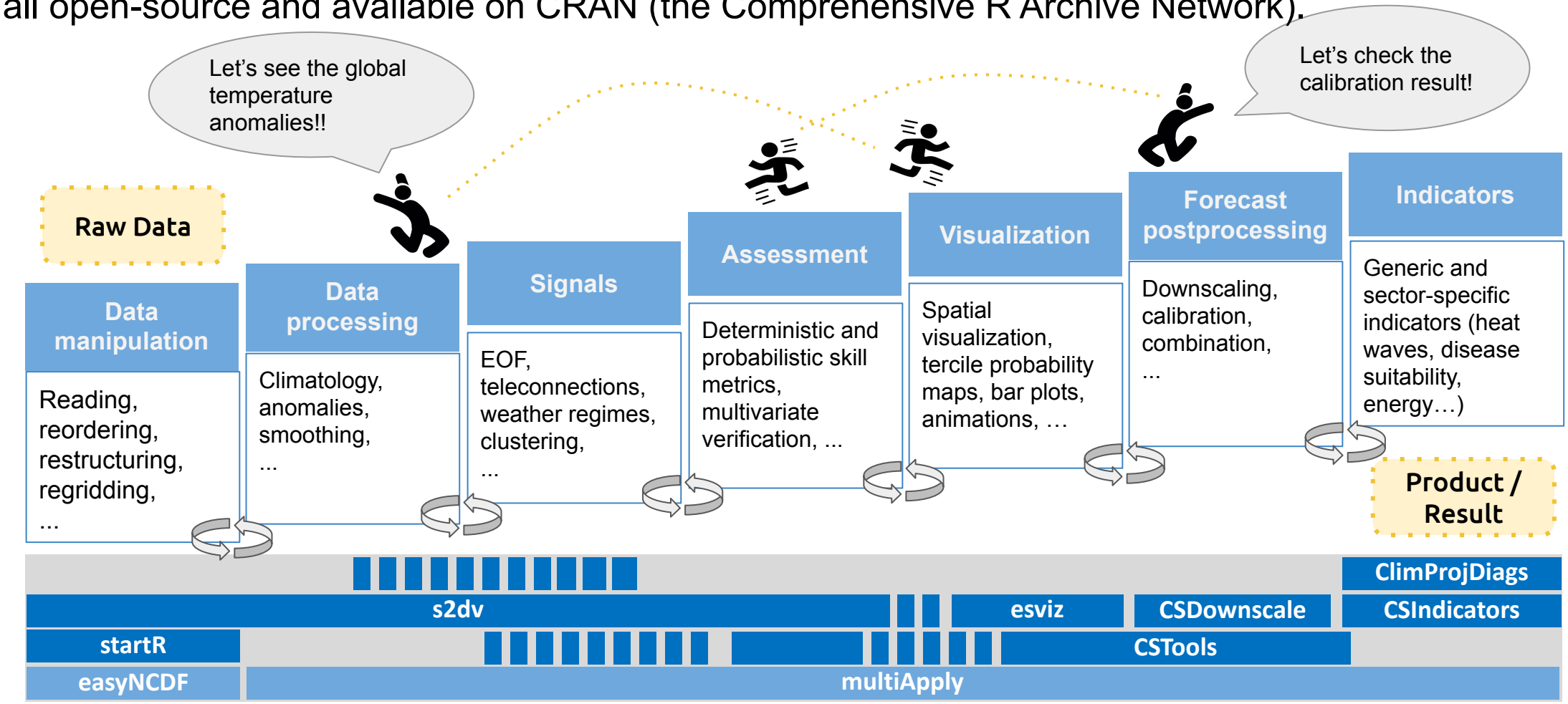
Climate Services: From climate data to climate products

Climate forecast data requires **multiple post-processing steps** to be transformed into an **informative result or product**, that is, a Climate Service:



BSC Earth Sciences R-Tools Ecosystem for Climate Forecast Analysis

SUNSET relies on an **ecosystem of R packages** developed in-house at BSC-ES. These packages are all open-source and available on CRAN (the Comprehensive R Archive Network).



Development strategy and user engagement

SUNSET is built through **a collaborative approach**, with a core developer team that maintains the code and organizes the strategy, and scientists who make contributions according to their needs.

The development and user engagement strategy includes:

- ➔ Weekly meetings with the core developer team
- ➔ Biweekly updates through a mailing list
- ➔ Monthly user meetings to maintain aligment with projects and user needs
- ➔ 3-month scheduled release cycle
- ➔ Ongoing documentation improvements and creation of hands-on use cases.

2. File configuration and Workflow definition

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File configuration

SUNSET is able to read data in the following formats:

- ➔ NetCDF
- ➔ GRIB (experimental)

In the tool, the **archive** is a YAML configuration file that defines the **paths**, time **horizons**, available **variables** and other information needed to access the datasets in a given filesystem.

This archive can be configured to work on any filesystem, provided the datasets follow a given structure.

archive.yml

```
<filesystem_name>
    src:  [general directory]

    System:          [Parameters for each system]
        <system_name>:
            src:             [dir path]
            monthly_mean:    [variable dictionary]
            daily_mean:      [variable dictionary]
            nmember:
              hcst:          [int]
              fcst:          [int]
            reference_grid:  [path to .nc]

    Reference:       [Parameters for each reference]
        <reference_name>:
            src:             [dir path]
            monthly_mean:    [variable dictionary]
            daily_mean:      [variable dictionary]
            reference_grid:  [path to .nc]
```

Workflow definition: the recipe

The **recipe** is a YAML configuration file that must be defined by the user for each distinct workflow. It contains the information about the data retrieval and the details of the post-processing steps.

What dataset?

```yaml
Analysis:
  Horizon: Seasonal
  Variables:
    - {name: tas, freq: monthly_mean}
    - {name: slp, freq: monthly_mean}
  Datasets:
    System:
      - {name: ECMWF, system: '5.1'}
    Multimodel: False
    Reference:
      - {name: ERA5}
```

What dates?

```yaml
  Time:
    sdate:
      - '0501'
      - '1101'
    fcst_year: '2020'
    hcst_start: '1993'
    hcst_end: '2016'
    ftime_min: 1
    ftime_max: 6
```

What region?

```yaml
Region:
  latmin: -10
  latmax: 10
  lonmin: 0
  lonmax: 20
Regrid:
  method: bilinear
  type: to_system
```

Workflow definition: the recipe

The **recipe** is a YAML configuration file that must be defined by the user for each distinct workflow. It contains the information about the data retrieval and the details of the post-processing steps.

What to do?

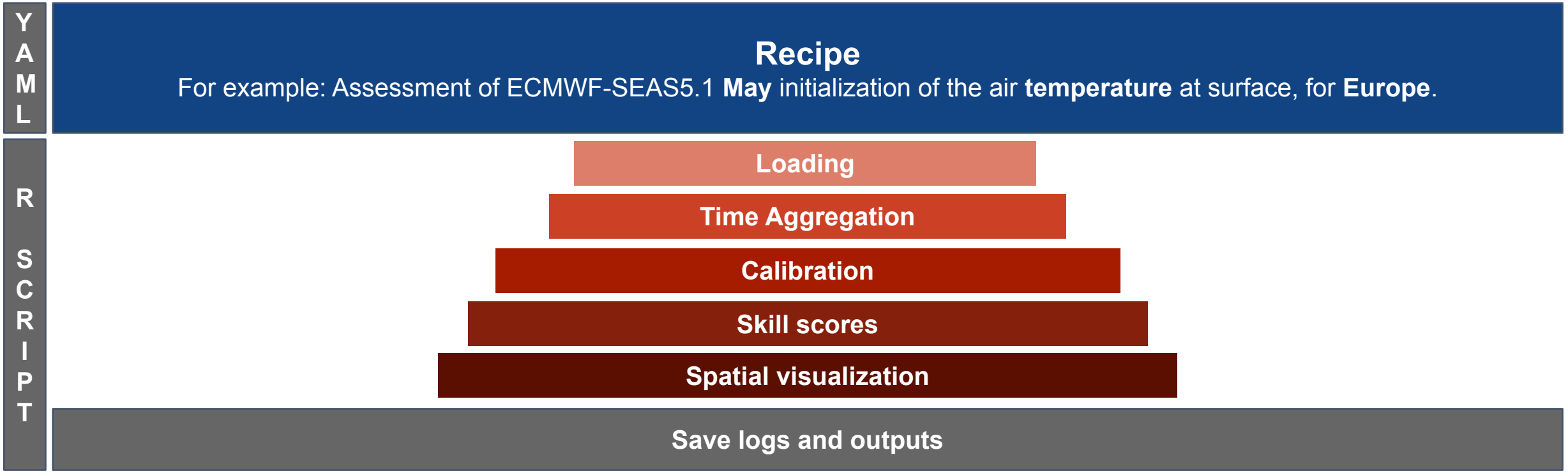
```yaml
Workflow:
  Anomalies:
    compute: no
    cross_validation: no
    save: none
  Calibration:
    method: bias
    cross_validation: yes
    save: none
  Skill:
    metric: rpss
    save: all
    cross_validation: yes
  Probabilities:
    percentiles: #[[1/3, 2/3]]
      Terciles: [1/3, 2/3]
      P10: [1/10]
      P90: [9/10]
    save:  all
```

Where to do it? And more…

```yaml
Run:
  Loglevel: INFO
  Terminal: yes
  filesystem: gpfs
  output_dir: /esarchive/scratch/vagudets/auto-s2s-outputs/
  code_dir: /home/Earth/vagudets/git/auto-s2s/
  autosubmit: yes
```

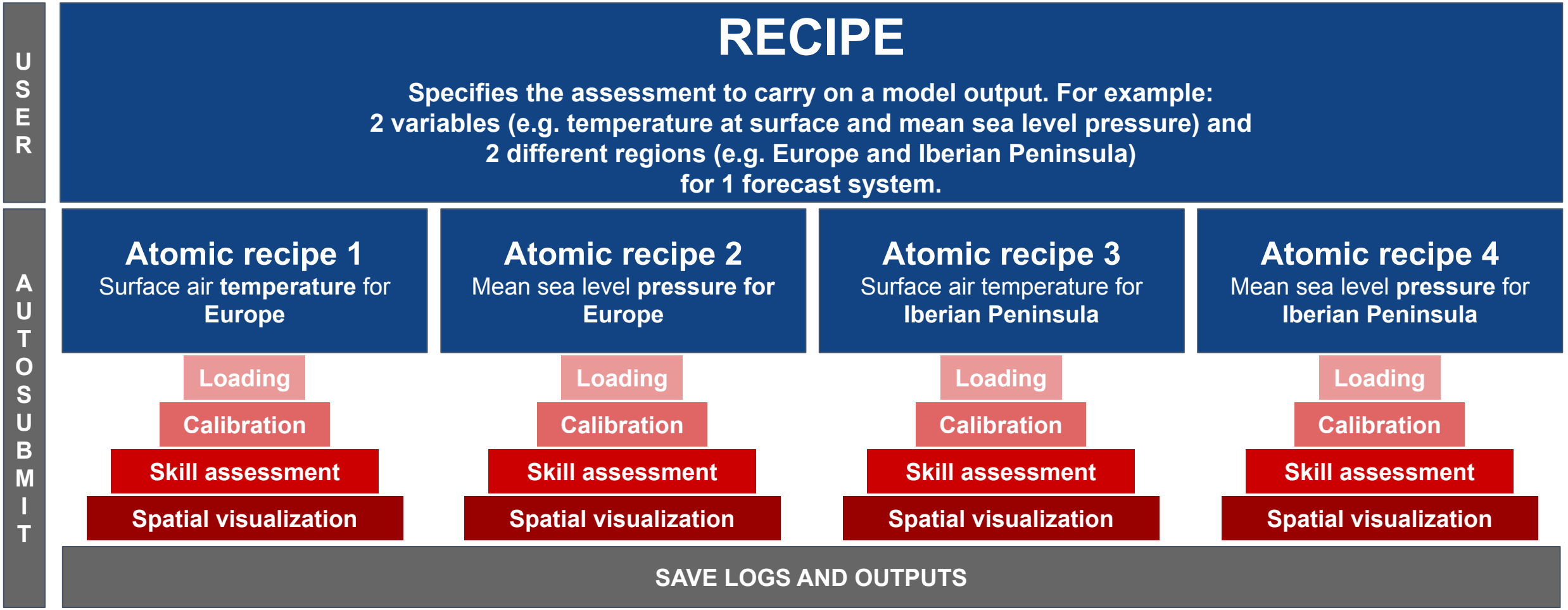
Workflow definition: the script

The main functions in SUNSET follow a **modular structure**, with each module performing a specific task. The user must create an **R script** using these functions to perform the desired tasks.



Parallel executions for independent workflows

A recipe can be divided into independent tasks to be submitted to an HPC cluster.



Provenance

To enhance traceability and reproducibility, we have explored the implementation of metadata encoding in SUNSET products through the **METACLIP Provenance Framework** (Bedia et al., 2019)

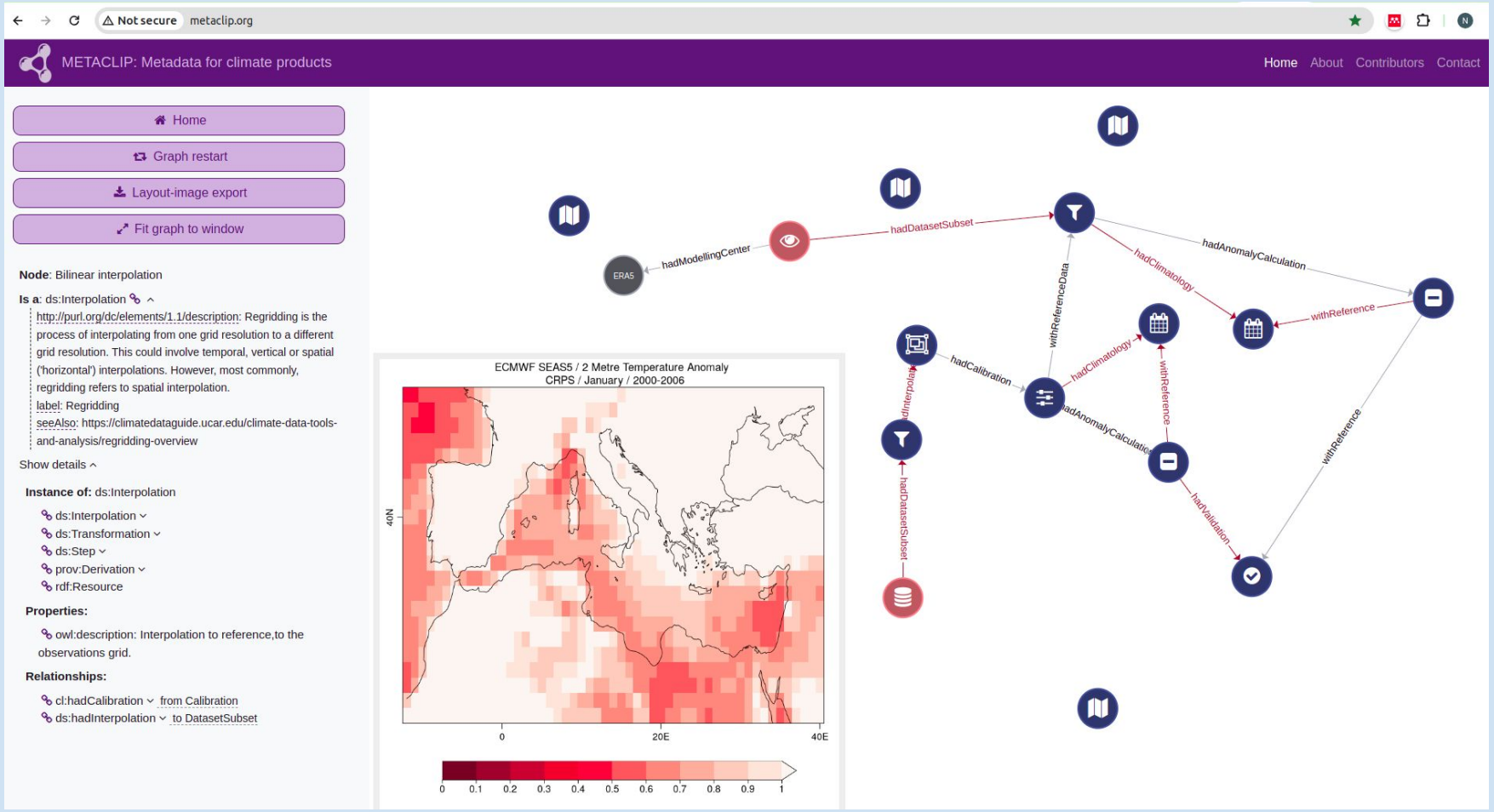
The embedded metadata can be viewed through the METACLIP online interpreter:

SEE EXAMPLE

J. Bedia, D. San-Martín, M. Iturbide, S. Herrera, R. Manzanas, J.M. Gutiérrez: The METACLIP semantic provenance framework for climate products, Environmental Modelling & Software, Volume 119, 2019, Pages 445-457, ISSN 1364-8152, https://doi.org/10.1016/j.envsoft.2019.07.005.

Provenance

To enhan ta
encodin , 2019)



MINIMIZE

3. User-friendly computation on HPCs with Autosubmit

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What is Autosubmit?

Autosubmit (Manubens-Gil et al., 2016) is an open-source Python **experiment and workflow manager** used to handle job submission and monitoring for complex workflows on Cloud and HPC platforms.

SUNSET can **automatically initiate and run an experiment with Autosubmit**.
It creates the experiment configuration files according to the specifications in the recipe:

- ★ User and platform info
- ★ HPC cluster resource requests
- ★ Job dependencies

```
auto_conf:
    script: my_script.R
    expid: a6wq
    platform: mn5
    hpc_user: bscXXXXX
    wallclock: 01:00
    processors_per_job: 16
    custom_directives: ['#SBATCH --exclusive']
    email_address: victoria.agudetse@bsc.es
    notify_completed: yes
    notify_failed: yes
```

Translating SUNSET workflows into Autosubmit

USER

RECIPE

Example: 2 variables x 2 regions x 1 forecast system x 1 initialization = 4 atomic recipes

SUNSET

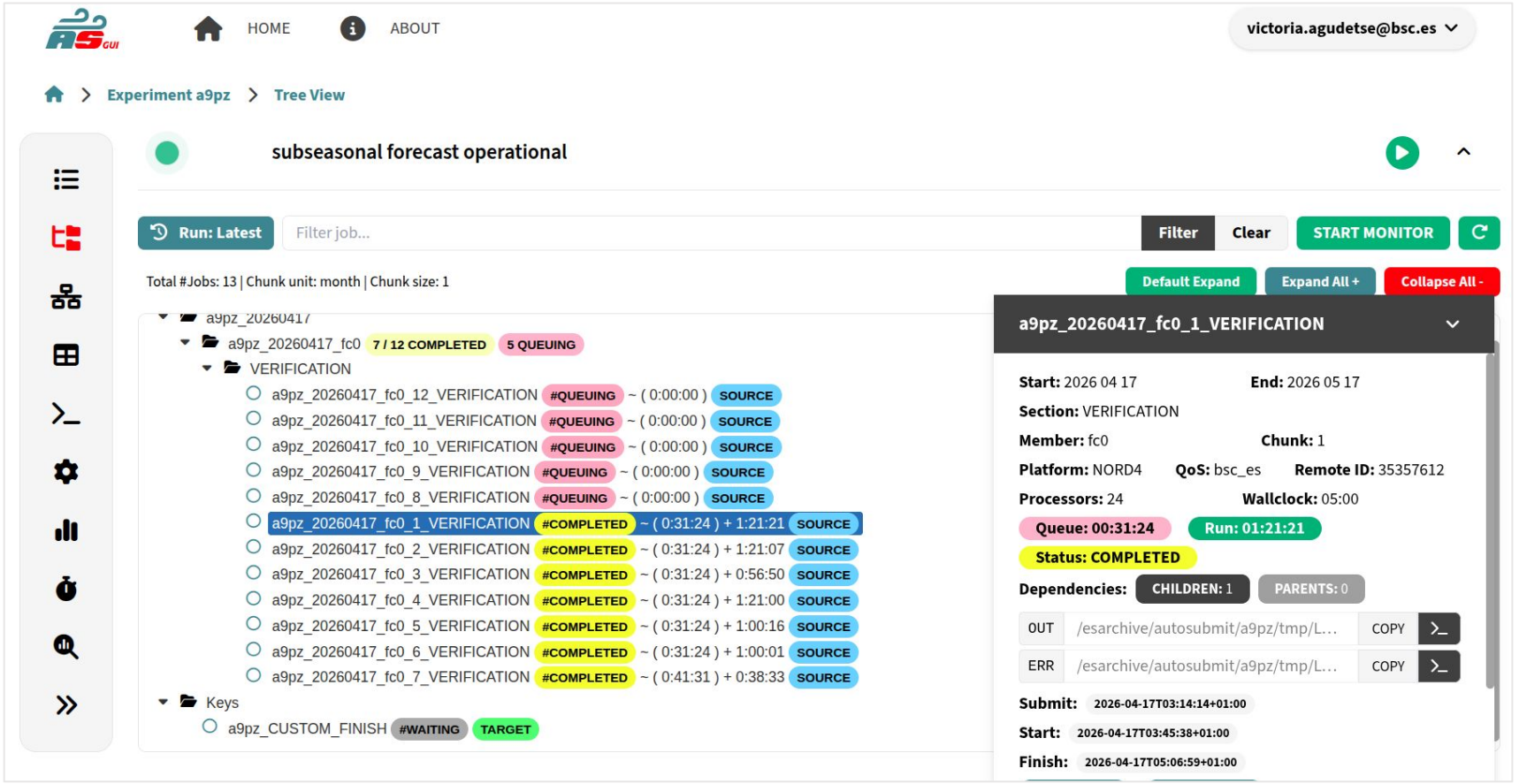
The “CHUNK” feature in Autosubmit can be used to divide an execution in different pieces. On the HPC cluster, Autosubmit will launch one job per chunk.
SUNSET splits the recipe and writes a file linking each atomic recipe to a CHUNK number.

AUTOSUBMIT

Atomic recipe 1 (tas, Europe)	Atomic recipe 2 (psl, Europe)	Atomic recipe 3 (tas, Iberian Peninsula)	Atomic recipe 4 (psl, Iberian Peninsula)
Run script auto-verification.sh %CHUNK% = 1	Run script auto-verification.sh %CHUNK% = 2	Run script auto-verification.sh %CHUNK% = 3	Run script auto-verification.sh %CHUNK% = 4

Autosubmit GUI: A user-friendly interface to monitor experiments

When the jobs are launched with Autosubmit, the **Autosubmit GUI** can be used to monitor their status in real time. Logs and performance statistics can also be consulted through the GUI.



4. Workflow operationalization with Jenkins

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Operationalization requirements

Projects such as **Impetus4Change** often require climate service products to be **delivered operationally** (e.g. on a weekly or monthly basis).

SUNSET has a command that can be launched to automate this process for subseasonal and seasonal forecasts, allowing easy operationalization.

As with other executions of the tool, this requires the user to define:

RECIPE
User-defined template with the data, post-processing workflow and HPC specifications.

SCRIPT
The R script to execute the workflow, calling SUNSET functions and/or custom code.

Operational execution script: Steps

```
>_ bash <dir_path>/SUNSET-oper.sh --expid=a000
--recipe=my_template.yml --horizon=seasonal
--code_dir=<dir_path>
```

STEP 1	STEP 2	STEP 3
The initialization date is calculated according to the forecast horizon.	A new recipe is created for that initialization date, from the provided template.	The autosubmit experiment is launched and the jobs are run on the HPC cluster.

Operational execution script: Scheduling

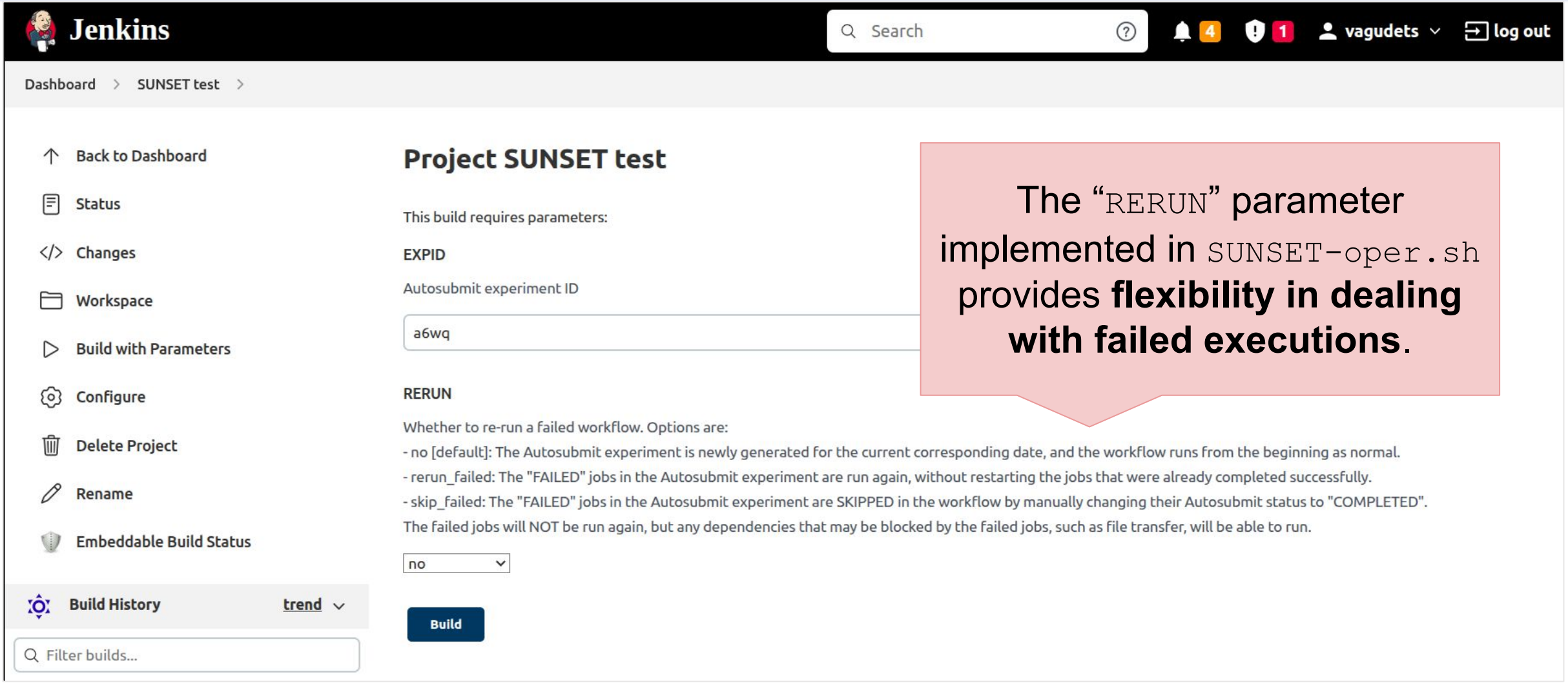
```
>_ bash <dir_path>/SUNSET-oper.sh --expid=a000
   --recipe=my_template.yml --horizon=seasonal
   --code_dir=<dir_path>
```

The **SUNSET-oper.sh** command could be launched manually, with a time-based job scheduler (e.g. cron) or with an automation-server such as The Jenkins Project (Jenkins Contributors).

We use Jenkins because it allows time-based scheduling, command parameterization and shared access between multiple individuals.

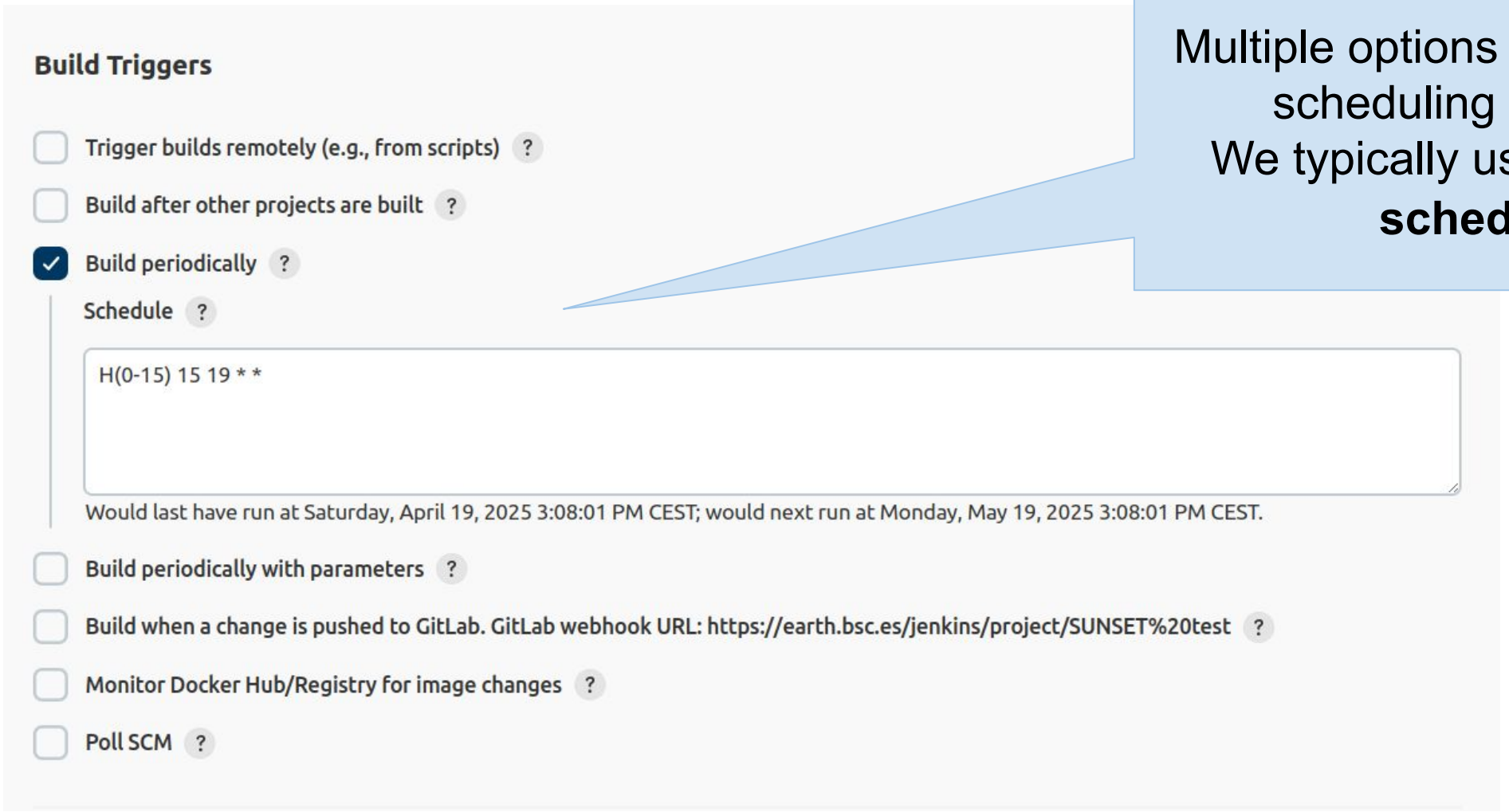
Jenkins

Operational workflow management with Jenkins



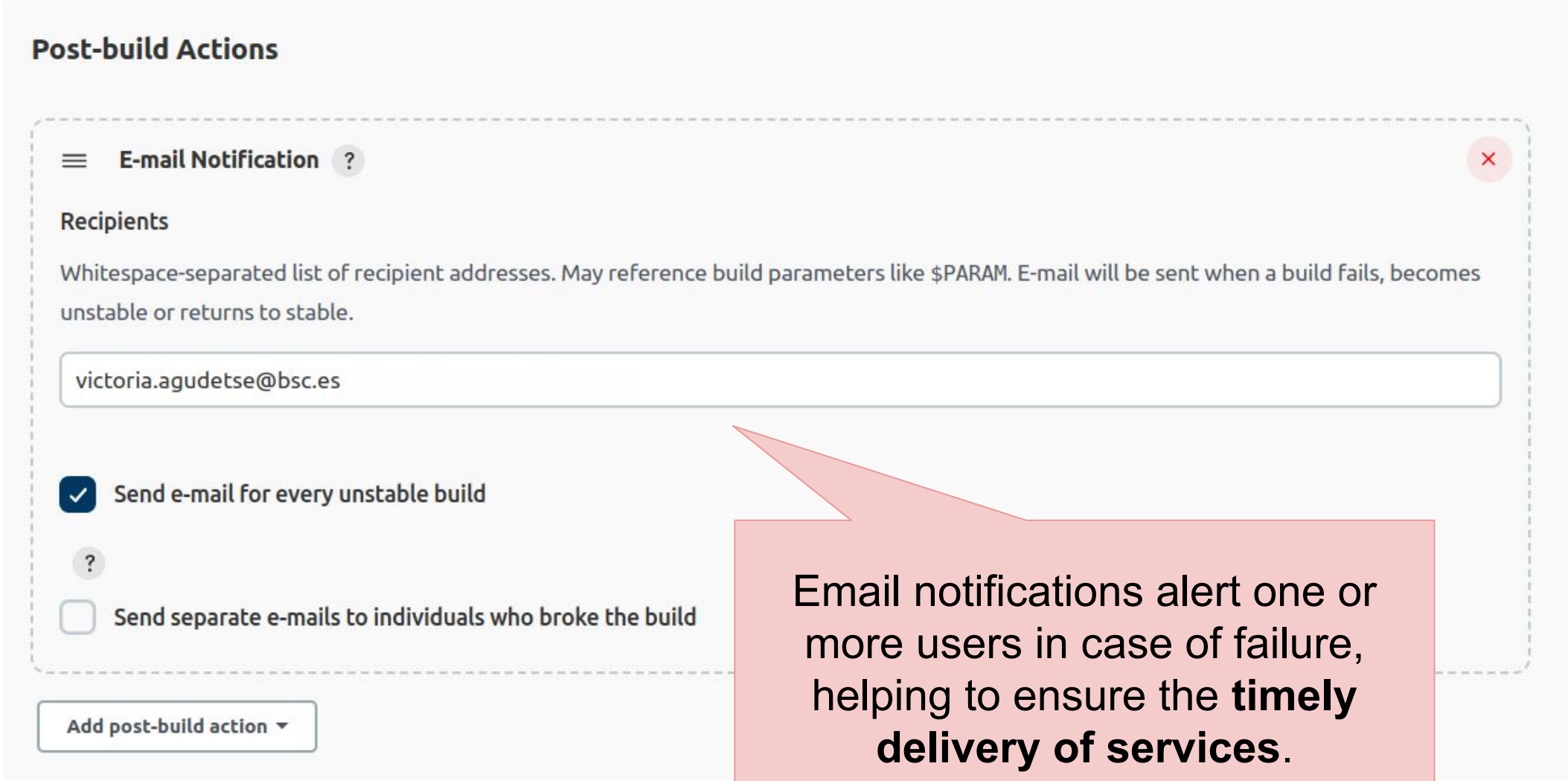
The "`RERUN`" parameter implemented in `SUNSET-oper.sh` provides **flexibility in dealing with failed executions**.

Operational workflow management with Jenkins



Multiple options are available for scheduling executions.
We typically use **time-based scheduling**.

Operational workflow management with Jenkins



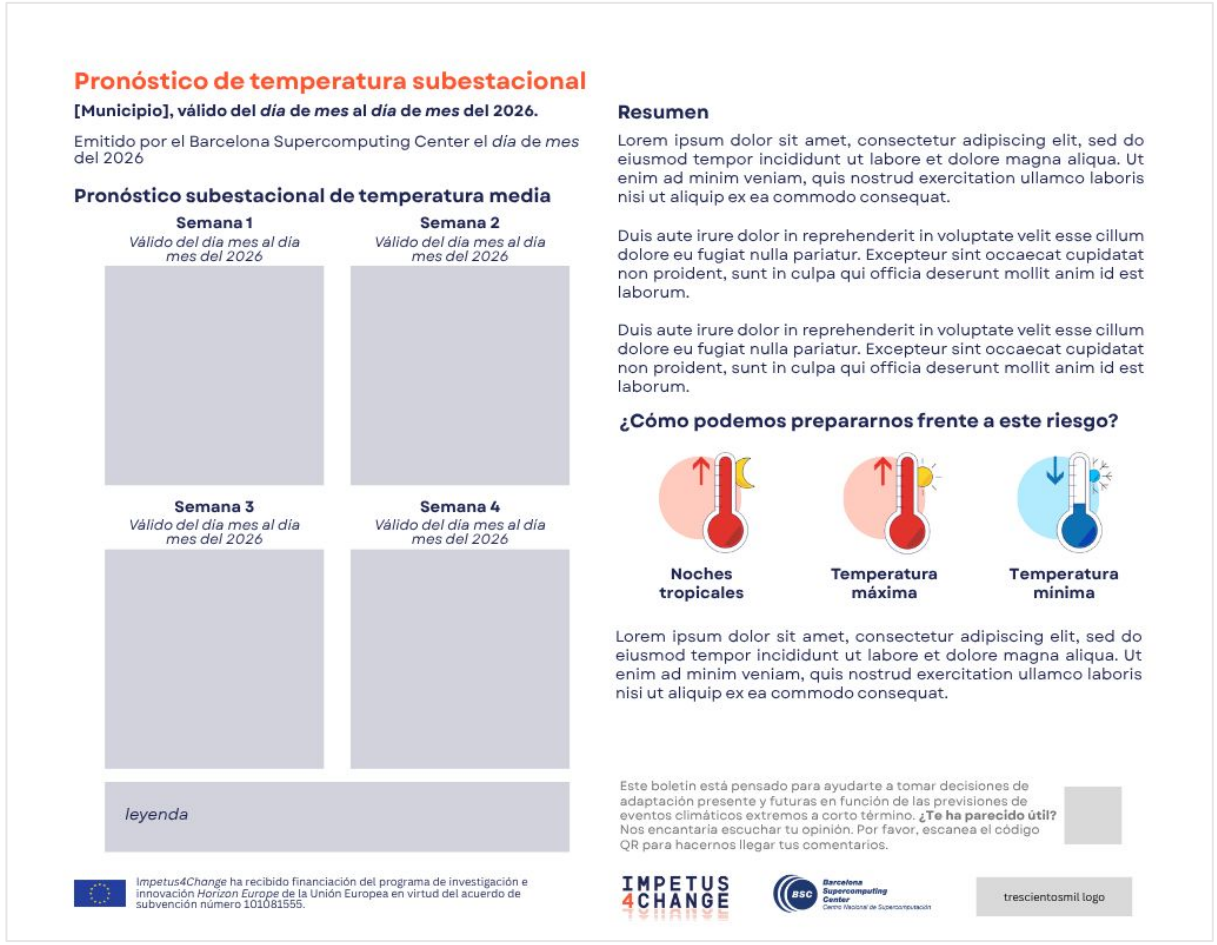
Email notifications alert one or more users in case of failure, helping to ensure the **timely delivery of services**.

5. Synergies with other projects

Synergies with other projects

➔ The work for the **Impetus4Change** project includes periodic delivery of bulletins with forecast outlooks and infographics.

These outlooks take advantage of many features that were developed for projects across many disciplines and sectors, such as **Energy** (S2S4E, BOREAS), **Agriculture** (VitiGEOSS, BigPrediData, ASPECT), **Risk Mitigation** (MedEWSa) and **Health** (HARMONIZE).



Sample design for an I4C Subseasonal Forecast Bulletin

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Synergies with other projects

➔ SUNSET can generate **Scorecards** showcasing different metrics for multiple initializations of a model.
In the CERISE project, these are used to support the **evaluation of the next generation of Copernicus Climate Change Service seasonal forecast systems**.

Near-Surface Air Temperature of ECMWF SEAS5 (Interpolation = to system, Aggregation level = score, Cross-validation = anomalies & terciles & crps_clim)

(Ref: ERA5 1993-2016)

Mean bias (K) — Start date

Region	Forecast Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	-0.42	-0.17	-0.10	-0.12	-0.10	-0.08	-0.09	-0.03	0.07	-0.07	-0.24	-0.45
	2	-0.45	-0.20	-0.23	-0.24	-0.18	-0.11	-0.11	0.10	0.22	0.05	-0.37	-0.55
	3	-0.32	-0.34	-0.38	-0.37	-0.25	-0.20	0.04	0.27	0.32	-0.09	-0.49	-0.43
	4	-0.39	-0.46	-0.51	-0.42	-0.34	-0.11	0.17	0.31	0.06	-0.36	-0.42	-0.35
	5	-0.50	-0.58	-0.54	-0.48	-0.23	-0.06	0.21	0.11	-0.20	-0.39	-0.36	-0.41
	6	-0.62	-0.62	-0.60	-0.35	-0.18	-0.01	0.00	-0.19	-0.26	-0.32	-0.43	-0.50
Tropics	1	-0.20	-0.21	-0.16	-0.15	-0.11	-0.16	-0.18	-0.18	-0.16	-0.16	-0.21	-0.23
	2	-0.24	-0.20	-0.16	-0.09	-0.10	-0.14	-0.14	-0.15	-0.17	-0.19	-0.24	-0.24
	3	-0.19	-0.18	-0.11	-0.07	-0.09	-0.12	-0.13	-0.18	-0.18	-0.22	-0.22	-0.25
	4	-0.20	-0.15	-0.08	-0.06	-0.08	-0.11	-0.16	-0.20	-0.22	-0.22	-0.23	-0.22
	5	-0.19	-0.13	-0.08	-0.06	-0.10	-0.15	-0.19	-0.25	-0.22	-0.24	-0.21	-0.22
	6	-0.16	-0.12	-0.08	-0.07	-0.14	-0.19	-0.24	-0.24	-0.24	-0.22	-0.22	-0.20
Extra-tropical SH	1	0.07	0.09	0.12	0.05	-0.05	-0.12	0.00	-0.07	-0.03	0.04	-0.07	0.01
	2	0.26	0.31	0.25	0.02	-0.15	0.02	-0.03	-0.01	0.02	-0.11	-0.06	0.10
	3	0.51	0.45	0.17	-0.12	-0.11	-0.09	-0.03	-0.02	-0.17	-0.14	0.03	0.31
	4	0.66	0.37	-0.02	-0.08	-0.19	-0.10	-0.07	-0.21	-0.20	-0.03	0.26	0.57
	5	0.56	0.16	0.00	-0.16	-0.16	-0.10	-0.25	-0.22	-0.06	0.23	0.55	0.76
	6	0.32	0.13	-0.12	-0.14	-0.14	-0.26	-0.25	-0.09	0.19	0.53	0.77	0.66

-0.56 -0.45 -0.34 -0.23 -0.11 0 0.11 0.23 0.34 0.45 0.56

Correlation — Start date

Region	Forecast Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	0.69	0.75	0.77	0.73	0.69	0.66	0.66	0.68	0.65	0.66	0.69	0.68
	2	0.29	0.40	0.38	0.34	0.31	0.38	0.40	0.40	0.30	0.25	0.26	0.36
	3	0.29	0.32	0.28	0.26	0.29	0.35	0.37	0.26	0.25	0.25	0.20	0.28
	4	0.25	0.25	0.24	0.26	0.30	0.32	0.30	0.20	0.22	0.23	0.26	0.23
	5	0.22	0.26	0.24	0.19	0.33	0.26	0.20	0.22	0.21	0.21	0.23	0.22
	6	0.25	0.29	0.21	0.26	0.25	0.25	0.21	0.22	0.23	0.22	0.22	0.20
Tropics	1	0.81	0.86	0.83	0.83	0.80	0.80	0.78	0.80	0.79	0.79	0.78	0.79
	2	0.66	0.67	0.68	0.63	0.62	0.63	0.65	0.63	0.65	0.59	0.62	0.63
	3	0.60	0.63	0.58	0.56	0.58	0.58	0.59	0.61	0.56	0.55	0.59	0.61
	4	0.59	0.55	0.53	0.56	0.54	0.54	0.59	0.54	0.54	0.53	0.59	0.57
	5	0.52	0.50	0.53	0.52	0.53	0.55	0.51	0.52	0.54	0.53	0.55	0.55
	6	0.46	0.51	0.50	0.50	0.53	0.49	0.49	0.52	0.55	0.51	0.55	0.48
Extra-tropical SH	1	0.72	0.74	0.68	0.69	0.68	0.64	0.64	0.68	0.67	0.69	0.72	0.71
	2	0.46	0.45	0.40	0.33	0.28	0.34	0.34	0.32	0.40	0.39	0.37	0.45
	3	0.38	0.37	0.29	0.23	0.27	0.24	0.26	0.31	0.33	0.31	0.38	0.39
	4	0.34	0.27	0.24	0.23	0.21	0.19	0.31	0.30	0.33	0.30	0.32	0.34
	5	0.23	0.24	0.22	0.22	0.23	0.27	0.28	0.28	0.29	0.26	0.31	0.28
	6	0.20	0.24	0.23	0.24	0.29	0.30	0.26	0.28	0.23	0.27	0.28	0.20

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

RPSS — Start date

Region	Forecast Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	0.28	0.38	0.40	0.34	0.30	0.28	0.26	0.29	0.25	0.27	0.29	0.28
	2	0.03	0.09	0.07	0.06	0.05	0.08	0.09	0.08	0.05	0.00	0.02	0.07
	3	0.03	0.05	0.03	0.02	0.03	0.06	0.07	0.02	0.02	0.01	0.01	0.04
	4	0.01	0.02	0.02	0.01	0.04	0.05	0.04	-0.01	0.00	0.01	0.03	0.01
	5	-0.01	0.02	0.00	-0.01	0.05	0.02	0.00	0.00	0.01	0.00	0.02	0.00
	6	0.01	0.03	-0.01	0.01	0.02	0.02	0.00	0.00	0.02	0.01	0.00	-0.01
Tropics	1	0.45	0.51	0.46	0.44	0.42	0.43	0.40	0.41	0.41	0.41	0.40	0.42
	2	0.27	0.28	0.28	0.25	0.25	0.24	0.27	0.24	0.27	0.23	0.26	0.27
	3	0.21	0.23	0.19	0.20	0.20	0.19	0.21	0.23	0.20	0.21	0.24	0.23
	4	0.20	0.18	0.16	0.18	0.15	0.16	0.20	0.19	0.19	0.19	0.22	0.18
	5	0.14	0.14	0.14	0.13	0.15	0.16	0.15	0.17	0.19	0.17	0.18	0.16
	6	0.11	0.13	0.11	0.13	0.15	0.14	0.15	0.17	0.18	0.14	0.16	0.12
Extra-tropical SH	1	0.32	0.36	0.29	0.30	0.29	0.24	0.24	0.27	0.30	0.29	0.34	0.30
	2	0.12	0.11	0.09	0.05	0.03	0.06	0.05	0.05	0.09	0.09	0.07	0.11
	3	0.07	0.07	0.03	0.00	0.03	0.00	0.02	0.04	0.06	0.05	0.08	0.08
	4	0.06	0.02	0.01	-0.01	-0.01	-0.03	0.04	0.03	0.05	0.04	0.04	0.05
	5	0.00	0.01	-0.01	-0.01	0.01	0.01	0.03	0.03	0.04	0.01	0.03	0.02
	6	0.00	0.00	0.00	0.01	0.03	0.03	0.02	0.02	0.00	0.02	0.02	-0.01

-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

CRPSS — Start date

Region	Forecast Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	0.27	0.36	0.39	0.34	0.29	0.27	0.28	0.29	0.26	0.27	0.29	0.29
	2	0.06	0.11	0.10	0.09	0.08	0.10	0.12	0.12	0.10	0.05	0.05	0.10
	3	0.07	0.07	0.07	0.06	0.07	0.10	0.11	0.08	0.06	0.06	0.05	0.07
	4	0.05	0.06	0.06	0.06	0.08	0.09	0.09	0.05	0.06	0.05	0.07	0.05
	5	0.05	0.07	0.05	0.04	0.09	0.08	0.05	0.06	0.06	0.05	0.06	0.05
	6	0.06	0.08	0.04	0.06	0.08	0.07	0.05	0.06	0.06	0.05	0.05	0.05
Tropics	1	0.43	0.50	0.45	0.42	0.41	0.40	0.39	0.42	0.41	0.42	0.40	0.42
	2	0.26	0.27	0.27	0.24	0.24	0.24	0.27	0.26	0.28	0.24	0.27	0.26
	3	0.21	0.22	0.19	0.20	0.20	0.21	0.22	0.24	0.21	0.23	0.23	0.23
	4	0.19	0.17	0.16	0.19	0.18	0.19	0.22	0.20	0.21	0.20	0.22	0.19
	5	0.14	0.15	0.16	0.16	0.17	0.19	0.17	0.20	0.20	0.18	0.18	0.16
	6	0.11	0.15	0.15	0.15	0.18	0.16	0.17	0.19	0.19	0.15	0.17	0.12
Extra-tropical SH	1	0.31	0.34	0.27	0.28	0.29	0.24	0.26	0.27	0.26	0.29	0.33	0.31
	2	0.13	0.13	0.10	0.07	0.06	0.07	0.07	0.06	0.10	0.11	0.10	0.12
	3	0.09	0.09	0.07	0.05	0.06	0.03	0.05	0.08	0.09	0.09	0.09	0.10
	4	0.08	0.06	0.05	0.03	0.03	0.02	0.07	0.08	0.10	0.07	0.07	0.08
	5	0.05	0.05	0.04	0.05	0.05	0.06	0.07	0.08	0.07	0.06	0.07	0.05
	6	0.05	0.04	0.04	0.05	0.07	0.08	0.07	0.06	0.05	0.06	0.05	0.03

-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

Spread-to-error ratio — Start date

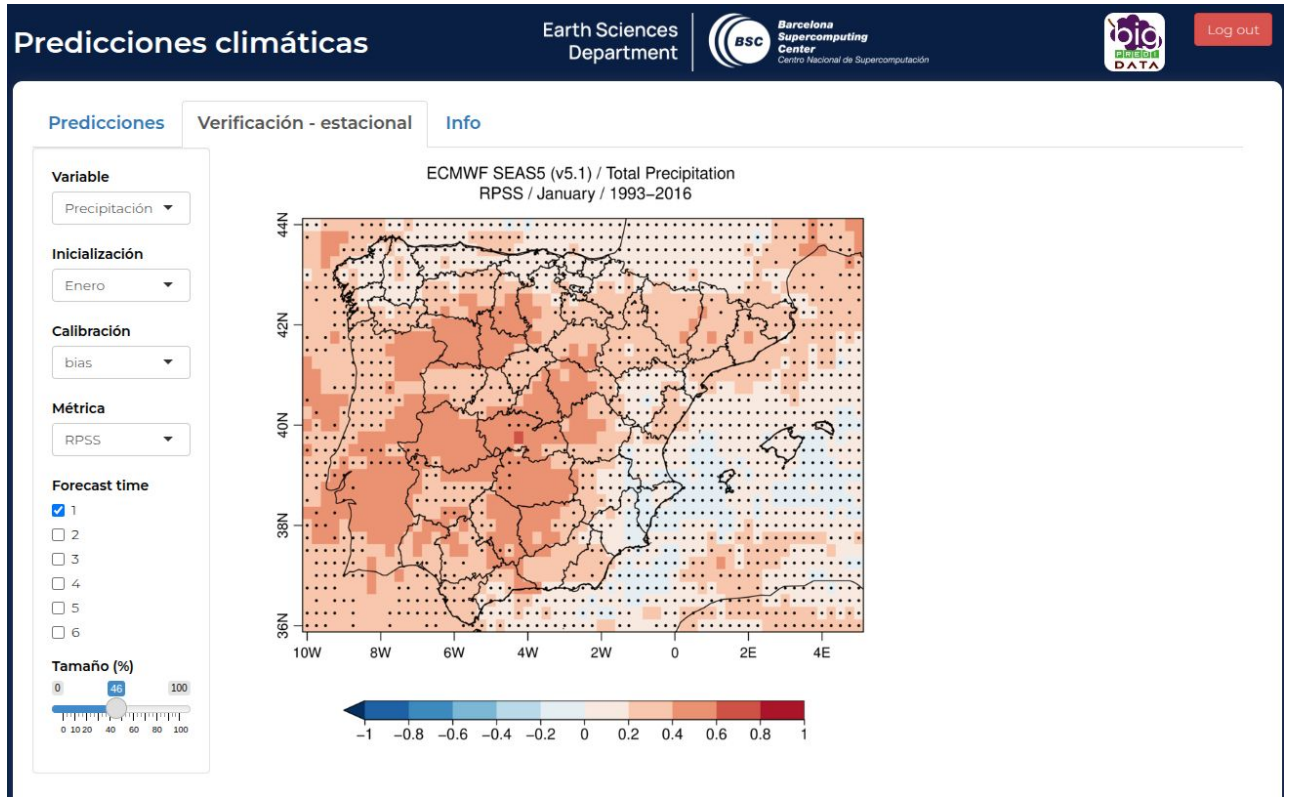
Region	Forecast Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extra-tropical NH	1	0.96	0.95	0.99	0.93	0.90	0.92	0.93	0.92	0.94	0.95	0.96	0.95
	2	0.98	0.98	0.95	0.94	0.98	1.01	1.00	1.03	0.98	0.96	1.01	1.09
	3	0.97	0.95	0.92	0.99	1.01	1.00	1.03	0.98	0.97	1.01	1.05	1.01
	4	0.94	0.93	0.99	1.02	0.99	1.05	1.02	0.95	1.00	1.08	1.03	0.97
	5	0.93	1.00	1.02	0.97	1.06	1.03	0.96	1.00	1.07	1.02	0.99	0.94
	6	1.01	1.05	0.98	1.04	1.03	1.01	1.01	1.07	1.01	0.98	0.96	0.94
Tropics	1	0.96	0.93	0.92	0.95	0.91	0.86	0.88	0.89	0.89	0.92	0.92	0.92
	2	0.98	0.99	1.04	0.98	0.97	0.95	0.97	0.94	0.99	0.99	1.02	1.02
	3	1.00	1.05	0.99	0.99	0.99	0.96	0.95	0.99	1.02	1.02	1.06	0.99
	4	1.06	1.01	0.99	1.02	0.97	0.96	1.01	1.03	1.03	1.03	1.02	1.00
	5	0.99	0.99	1.01	0.99	0.99	1.00	1.02	1.02	1.05	0.99	1.03	1.03
	6	0.98	1.02	0.98	1.00	1.02	1.03	1.02	1.04	1.01	1.00	1.06	0.99
Extra-tropical SH	1	0.96	0.99	0.95	1.01	1.05	1.01	0.94	0.98	0.96	1.02	0.98	0.86
	2	1.00	1.00	0.99	1.01	1.03	1.01	1.00	0.93	1.03	0.95	0.90	1.01
	3	1.00	0.98	1.00	1.03	0.99	0.96	0.93	0.99	0.92	0.91	1.05	0.99
	4	0.98	0.99	1.03	0.98	0.96	0.91	1.00	0.94	0.93	1.03	0.99	0.97
	5	0.96	1.02	0.97	0.98	0.96	0.98	0.93	0.92	1.04	0.97	0.99	0.95
	6	0.99	0.97	0.99	0.96	1.02	0.94	0.92	1.05	0.99	0.99	0.95	0.96

0 0.6 0.7 0.8 0.9 1 1.2 1.4 1.6 1.8 2

Several skill scores can be obtained via the comparison of predictions with observations. Positive skill means an added value with respect to the climatology.

Synergies with other projects

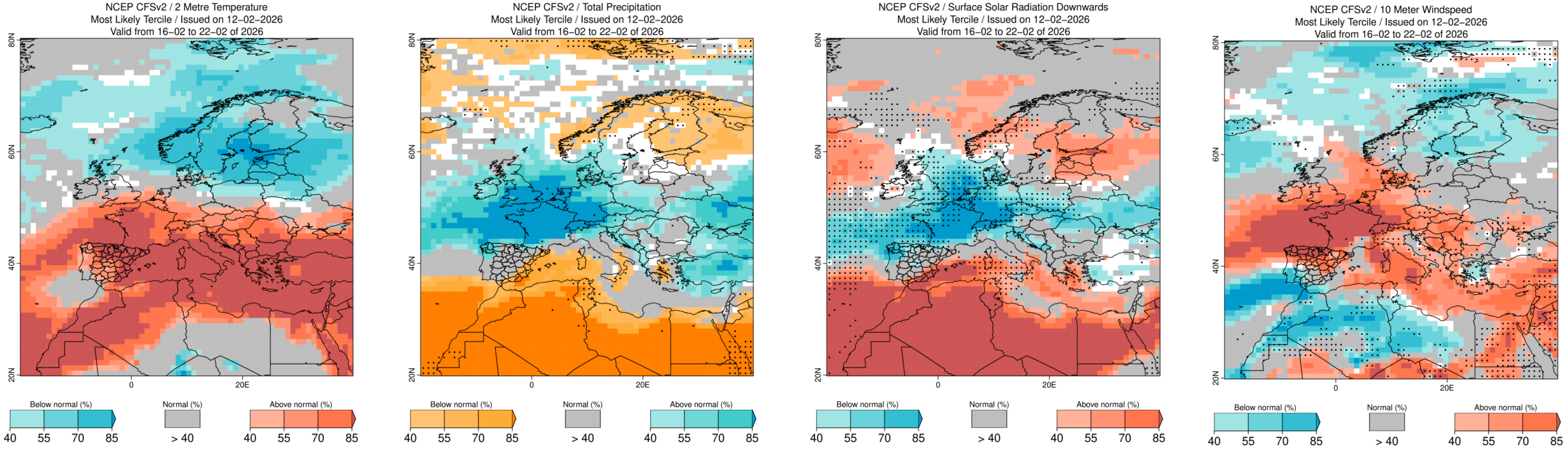
➔ The Visualization module in SUNSET can also produce **maps of the skill scores**, to provide information about the estimated quality of a forecast for a particular time and place.



Screenshot from the BigPrediData shiny app, hosted by BSC-CNS.

Synergies with other projects

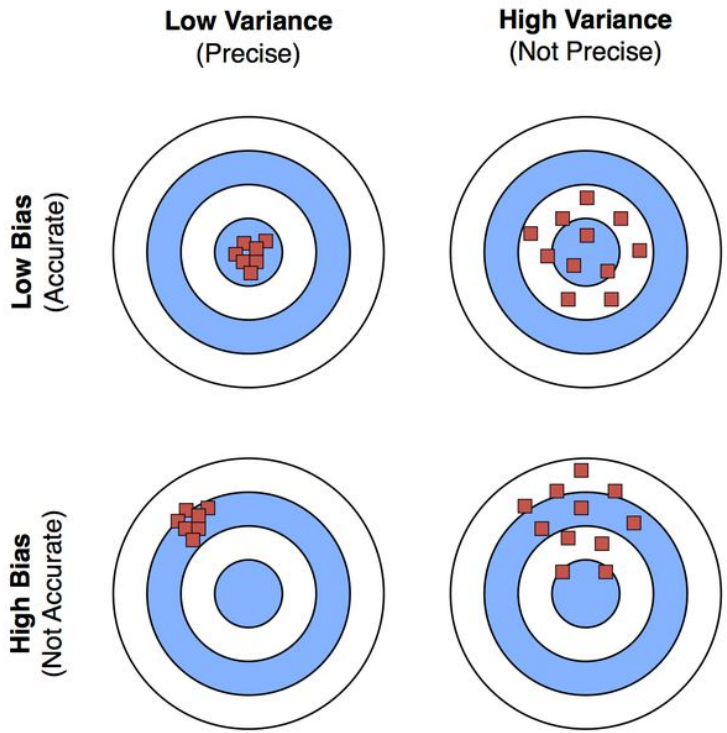
➔ **Most Likely Tercile maps** summarize probabilistic information to aid decision-making. This type of visualization was originally developed within the CSTools R package (Pérez-Zanón et al., 2022), as part of the MEDSCOPE project.



Most Likely Tercile maps for multiple essential climate variables, generated as part of the operational subseasonal forecast provided for the BOREAS project.

Synergies with other projects

➔ **Bias adjustment methods** are used to correct model biases and improve the reliability of climate predictions. In SUNSET, multiple bias adjustment and forecast calibration technique can be applied using the methods present in the CSTools package.



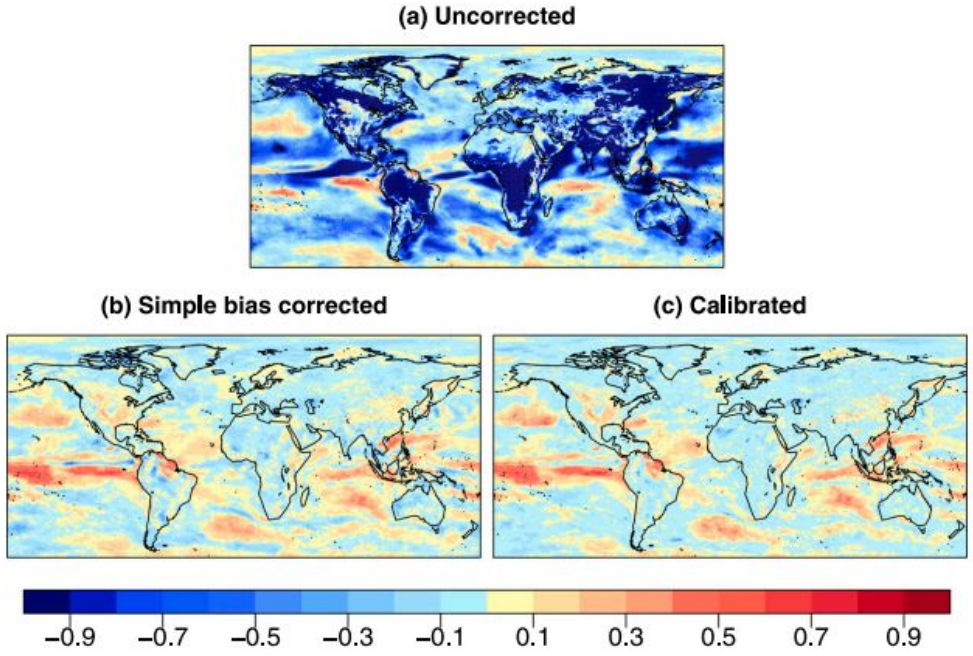


FIG. 4. Fair RPSS for tercile events of 10-m wind speed forecasts from ECMWF System 4 and ERA-Interim reanalysis in winter (DJF). These predictions have been initialized on 1 Nov for the period of 1981–2012.

Torralba, V., Doblas-Reyes, F. J., MacLeod, D., Christel, I., & Davis, M. (2017). Seasonal Climate Prediction: A New Source of Information for the Management of Wind Energy Resources, *Journal of Applied Meteorology and Climatology*, *56*(5), 1231-1247. Retrieved Apr 9, 2021, from https://journals.ametsoc.org/view/journals/apme/56/5/jamc-d-16-0204.1.xml

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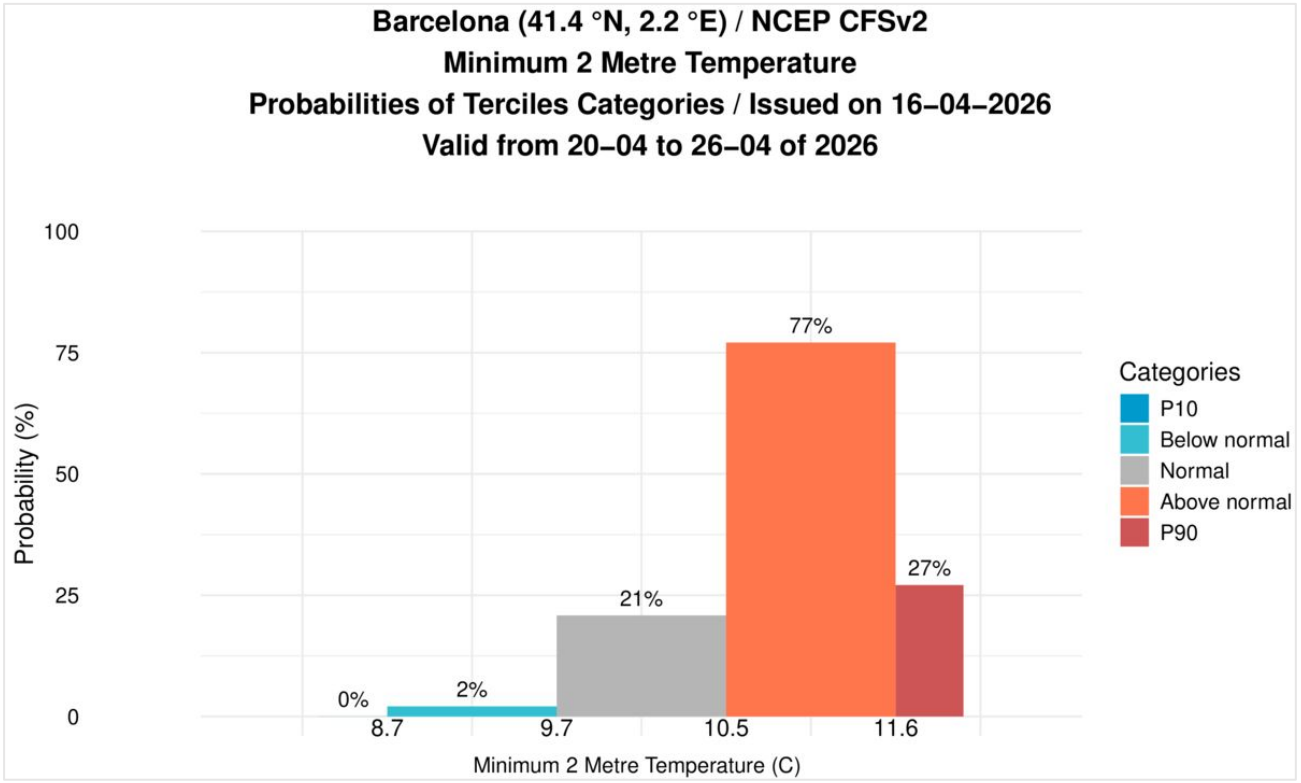
Synergies with other projects

➔ Bar plot type visualizations showing **probabilistic forecast outlooks for point locations** were originally developed for the VitiGEOSS project.



Bat plot showing the likelihood of minimum 2 metre temperatures falling within given probability thresholds.

6. Future developments

Future developments

SUNSET is under continuous development, and many new features and improvements are currently planned to meet project needs and enhance the usability of the tool:

- ➔ Lazy loading and domain decomposition for very large datasets
- ➔ Docker containerization and general portability improvements
- ➔ Climate Indicators for the Health and Energy sectors
- ➔ AI-based downscaling methods
- ➔ Clearer and more complete documentation

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Thank you for your interest!

The **SUNSET** repository:
https://gitlab.earth.bsc.es/es/sunset

V. Agudetse, N. Pérez-Zanón, A. Batalla, C. Delgado-Torres, A. Bojaly, P.-A. Bretonnière, J. Corvillo, E. Duzenli, T. Kariyathan, A. Lacima-Nadolnik, A. Llabrés-Brustenga, B. de Paula Kinoshita, P. Trascasa-Castro, V. Torralba, A. Soret, and F.-J. Doblas-Reyes

victoria.agudetse@bsc.es

Earth Sciences Department, BSC-CNS