WP5 - DATA INTEGRATION AND MANAGEMENT

iAOS, data integration, Results and impact

INTAROS Final Meeting - Synthesis

January 20th-21st 2022

Hervé Caumont, Terradue Srl

Agenda

1. Objective and Tasks
2. Main Achievements
3. Expected Impact
4. Challenges
5. Recommendations

↳ **INTAROS Synthesis Report**
4 pages for WP5

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1. WP5 Objective and Tasks

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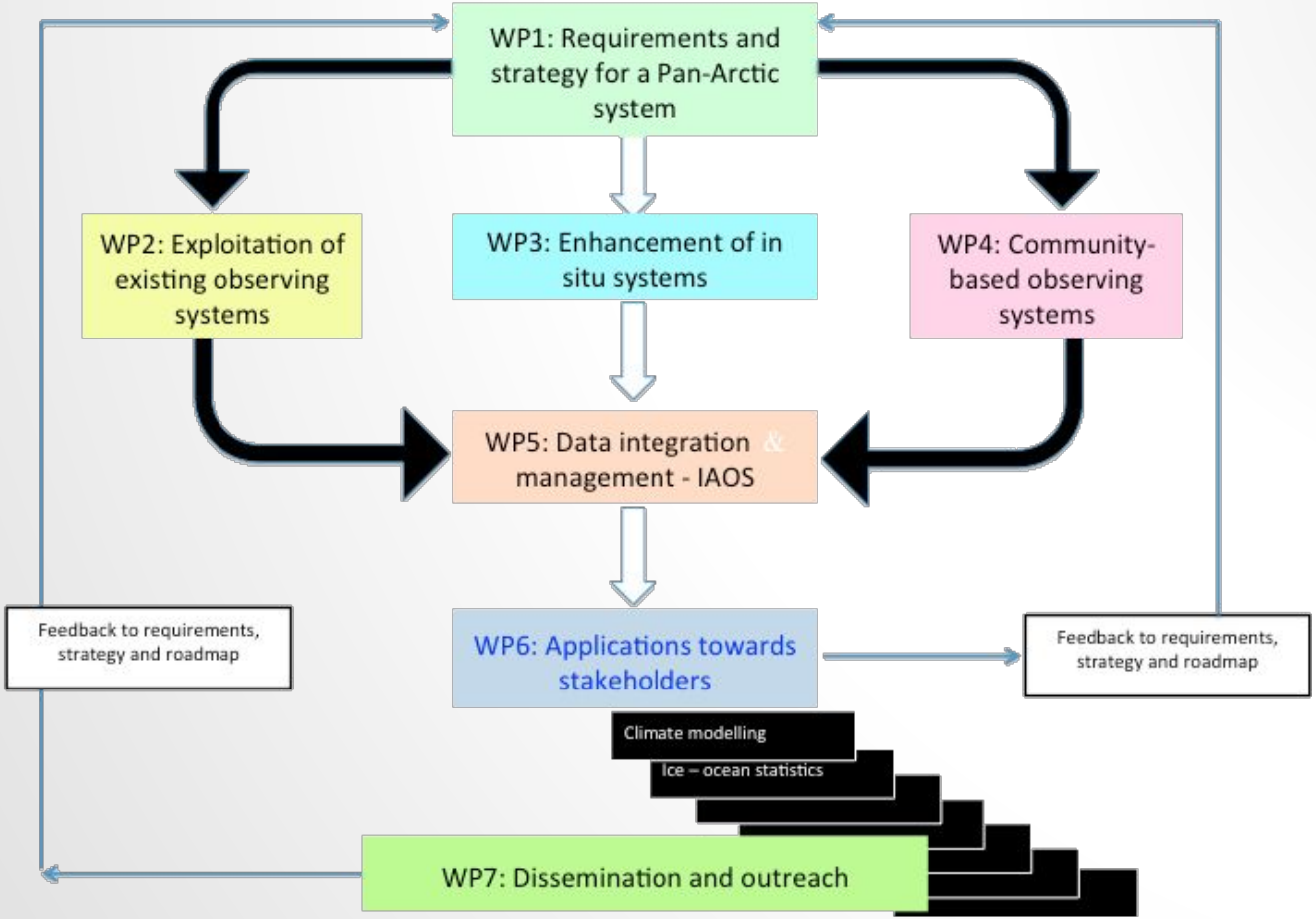
WP1: Requirements and strategy for a Pan-Arctic system
WP2: Exploitation of existing observing systems
WP3: Enhancement of in situ systems
WP4: Community-based observing systems
WP5: Data integration & management - IAOS
WP6: Applications towards stakeholders
Feedback to requirements, strategy and roadmap
Feedback to requirements, strategy and roadmap
Climate modelling
Ice – ocean statistics
WP7: Dissemination and outreach

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WP5 Objectives

- **Integrate multidisciplinary and distributed data repositories** into a scalable and resilient Pan-Arctic observing system (iAOS), which will offer seamless access to observations and derived parameters.
- iAOS will also provide a set of **tools for data analysis, transformation and visualization**.
- **Develop new geo-statistical methods** for interpolation of spatiotemporal datasets.
- **Process new observations** from WP2-4, and **store generated datasets** in an iAOS enabled repository.

WP5 Tasks

- **Task 5.0** Workpackage Coordination [**TERRADUE** & **NERSC**]
- **Task 5.1** System requirements and architecture [**TERRADUE**, NERSC, AWI]
- **Task 5.2** IAOS platform deployment and operation [**TERRADUE**]
- **Task 5.3** Integrate data from repositories [**AWI** & **TERRADUE**, NERSC, FMI, UIB, GEUS, IMR, IFREMER, NUIM, NORDECO, CNRS-LOCEAN]
- **Task 5.4** Geostatistical methods for data integration [**ARMINES**, NERSC, DTU]
- **Task 5.5** Integration of new processing services [**TERRADUE**, NERSC, ARMINES]
- **Task 5.6** iAOS portal development [**NERSC**, TERRADUE]
- **Task 5.7** Synthesis of IAOS infrastructure deployment and operation [**TERRADUE**, all partners]

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2. WP5 Main Achievements

Deliverables

All WP5 deliverables submitted to EC

- D5.1 iAOS requirements and architectural design V1
- D5.2 iAOS platform and tools V1
- D5.3 Data integration from existing repositories V1
- D5.4 iAOS Portal with user manual V1
- D5.5 iAOS requirements and architectural design **V2** - revision 1.3
- D5.6 Geostatistical library V1 - revision 1.8
- D5.7 Processing services integration V1 - revision 1.1

- D5.8 iAOS Platform and tools **V2** - revision 1.4
- D5.9 Data integration from existing repos **V2**
- D5.10 Geostatistical library **V2**
- D5.11 Processing services integration **V2**
- D5.12 iAOS Portal with user manual **V2**

- D5.13 Synthesis of the iAOS infrastructure

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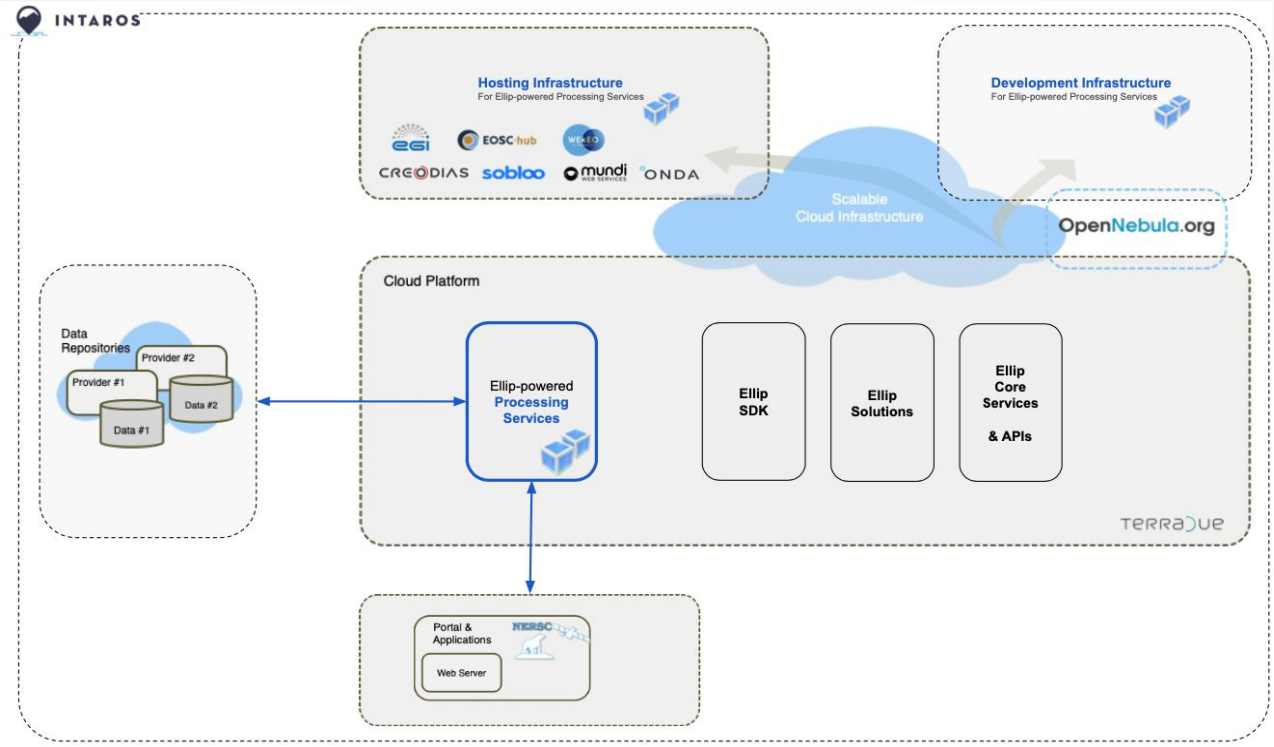
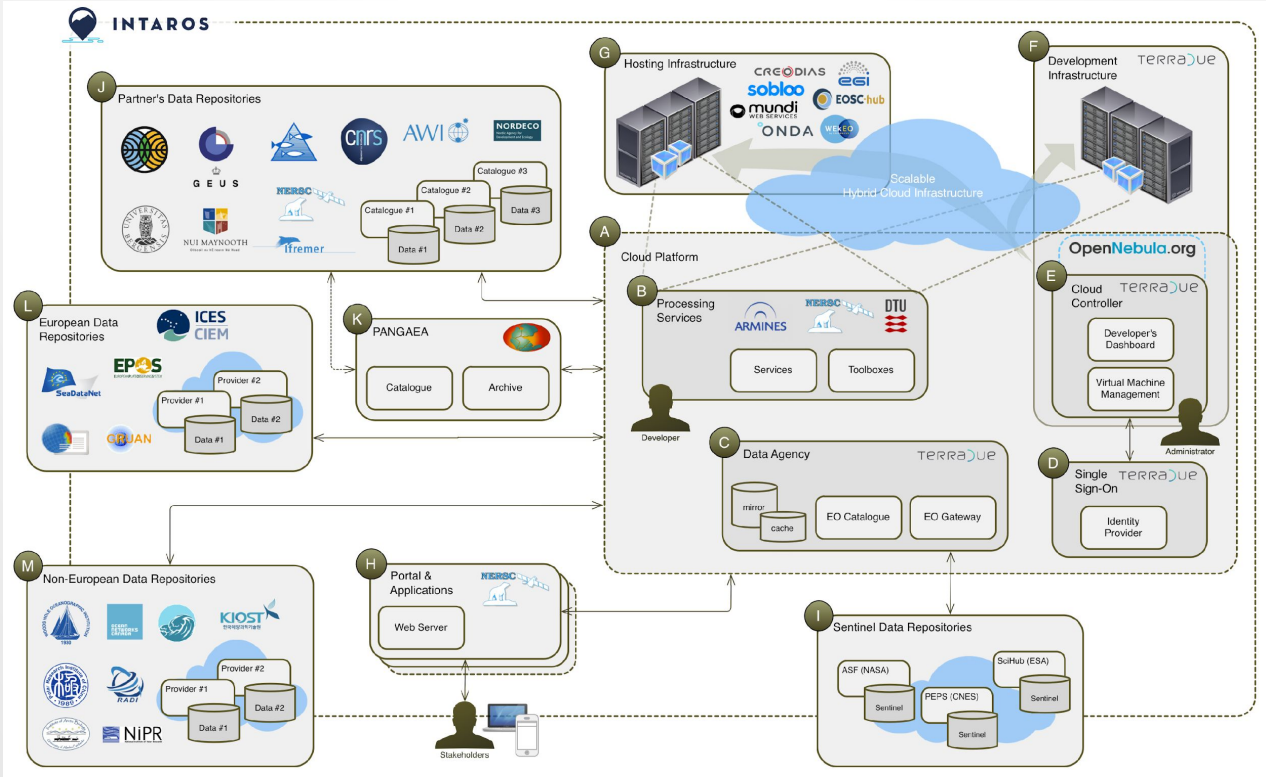
Synoptic view of the Cloud platform, linked to other components of the iAOS (e.g. data repositories, iAOS portal), and to development and deployment (hosting) infrastructures.

- As part of the INTAROS project, Terradue operates the **iAOS Cloud Platform**, a set of tools and services for online data access and data processing.



Architecture of the Information and Communication Technologies (ICT) components of the overall iAOS

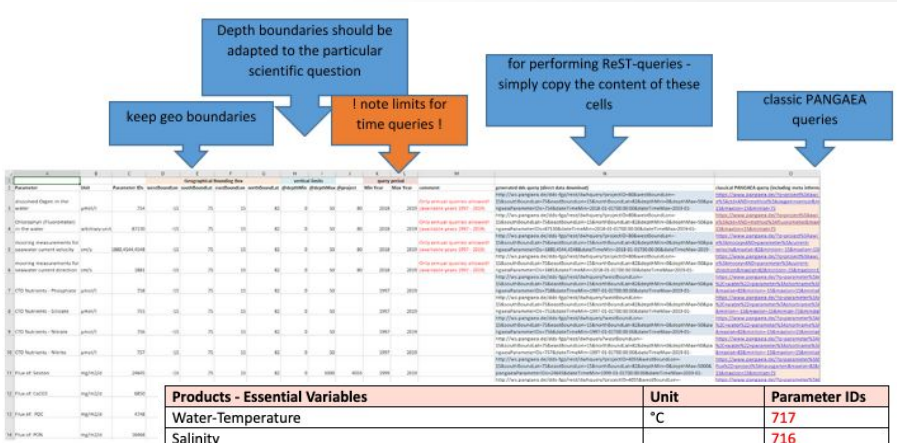
- One key achievement of INTAROS is to have extended, improved and unified existing observing systems in the different regions of the Arctic, as part of an integrated Arctic Observation System (iAOS)



Data Integration on PANGAEA

- Updates on AWI/PANGAEA/FRAM data-products
- Delivery of PANGAEA API for data-mining functionalities (data-warehouse), allowing to combine parameter records from different PANGAEA datasets in one file

cf. D5.9 Data integration from existing repos V2 (May 2021)



Products - Essential Variables	Unit	Parameter IDs
Water-Temperature	°C	717
Salinity		716
dissolved Oxgen in the water	µmol/l	754
Chlorophyll (Fluorometer) in the water	arbitrary units	87130
mooring measurements for seawater current velocity	cm/s	1880,4544,4548
mooring measurements for seawater current direction	cm/s	1881
CTD Nutrients - Phosphate	µmol/l	758
CTD Nutrients - Silicate	µmol/l	755
CTD Nutrients - Nitrate	µmol/l	756
CTD Nutrients - Nitrite	µmol/l	757
Flux of: Seston	mg/m2/d	24645
Flux of: CaCO3	mg/m2/d	6850
Flux of: POC	mg/m2/d	4748
Flux of: PON	mg/m2/d	16468
HAUSGARTEN biogeochemistry: Sediment porosity	% vol	26
HAUSGARTEN biogeochemistry: sediment bound Chlorophyll a	µg/cm3	14019
HAUSGARTEN biogeochemistry: sediment bound Phaeopigment	µg/cm3	14006
HAUSGARTEN biogeochemistry: Esterase activity per sediment volume	nmol/ml/h	4870
		14016
		15611
		754

Base URL for all ReST-queries is http://ws.pangaea.de/dds-fgp/rest/dwhquery? followed by mandatory and optional search parameters.

Service call example:
http://ws.pangaea.de/dds-fgp/rest/dwhquery?westBoundLon=-15&southBoundLat=75&eastBoundLon=15&northBoundLat=82&pangaeaParameterIDs=717&projectID=80&depthMin=0&depthMax=50&dateTimeMin=2018-01-01T00:00:00&dateTimeMax=2019-01-01T00:00:00

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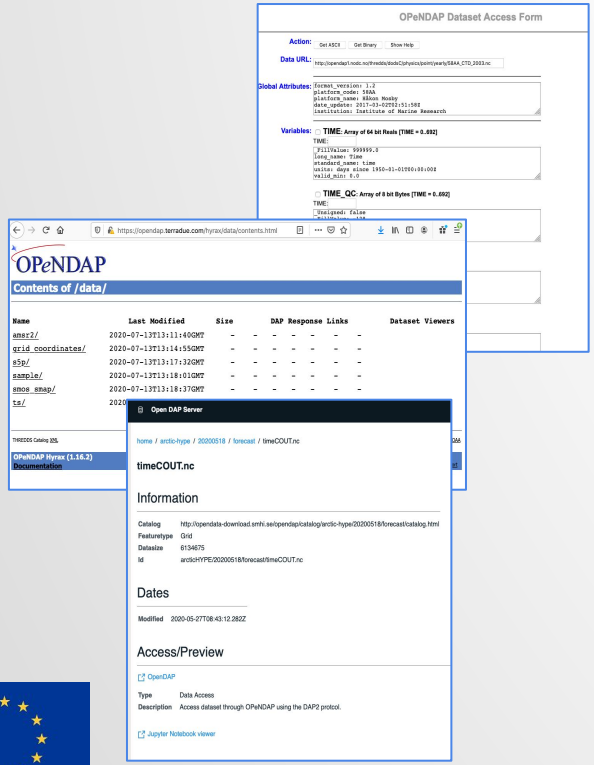
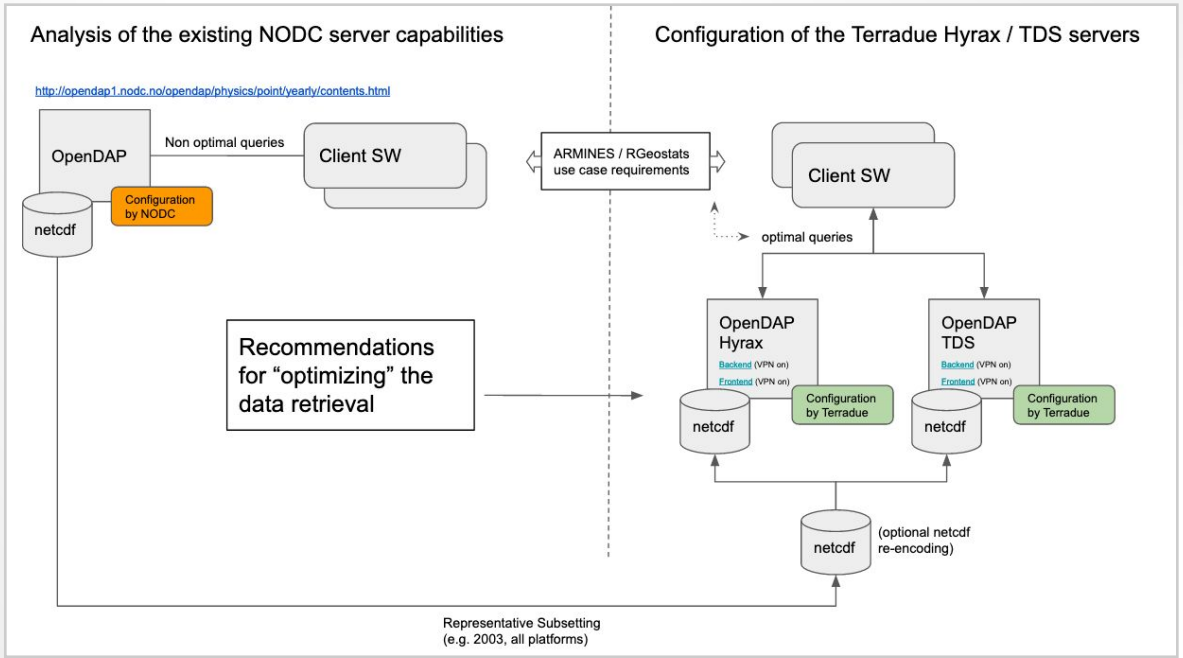
OPenDAP solutions for the iAOS

Integration of distributed data repositories





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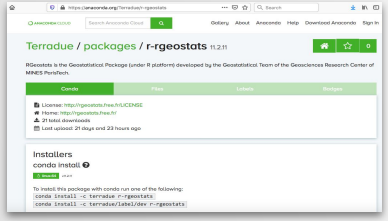
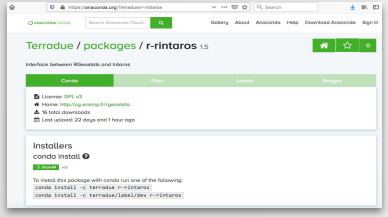
Geostatistics tools for the iAOS

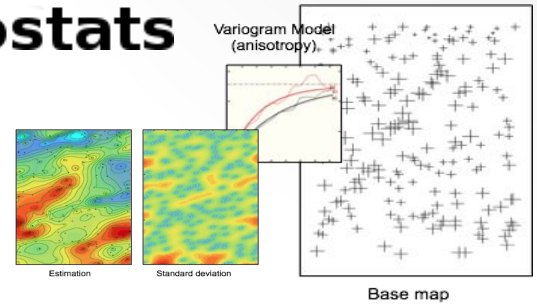
Tools for data analysis, transformation and visualization

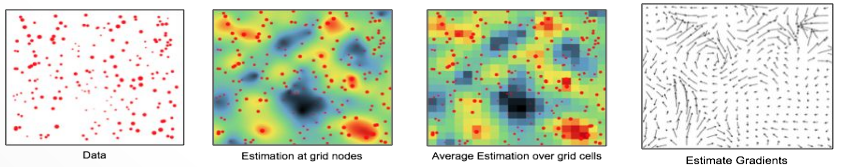


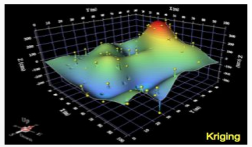


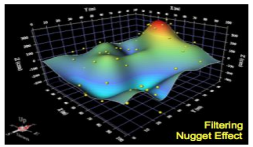
- Deployment of RGeostats package with anaconda for iAOS developers: https://anaconda.org/Terradue/r-rgeostats
- Creation and deployment of RIntaros Geostatistical package for iAOS developers: https://anaconda.org/Terradue/r-rintaros
- Dissemination material produced to outreach the iAOS users community (Bremen Workshop, Terradue Seminar at Fontainebleau XIVème Journées de Géostatistique)

RGeostats









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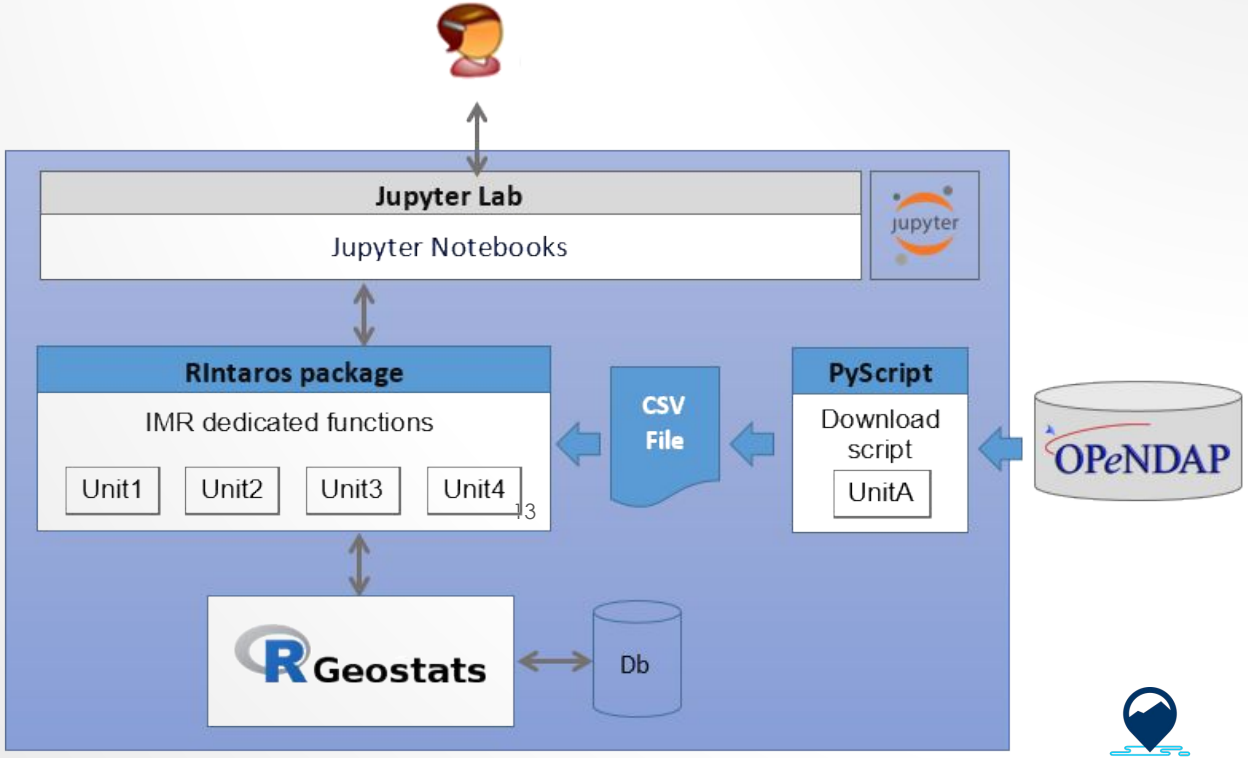
Geostatistics tools for the iAOS

Tools for data analysis, transformation and visualization

- Python scripts for downloading CTD data
- Unitary R scripts using RIntaros package for Geostatistical operations
- Jupyter Notebooks for download and ingestion of CTD data as part of Geostatistical models



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Processing Services

Tools for data analysis, transformation and visualization

Data processing services integrated and ran by NERSC from collaboration with the EC H2020 project NextGEOSS

Run of complex, compute-intensive EO data processing chains (processing of copernicus Sentinel-1 observations) in order to generate value-added products supporting the INTAROS tasks

- Sea ice classification service
- Sea ice drift service

The services made use of Cloud Computing resources funded by the EC NextGEOSS project on the **EGI.eu Federated Cloud**, delivering data products for exploitation as part of INTAROS tasks.

For the **sea ice classification service**, two processing campaigns covering:

- a three week period in July-August 2018, coinciding with the INTAROS 2018 field experiment in the Fram Strait and north of Svalbard.
- a three week period in August-Sept. 2019, coinciding with the CAATEX/INTAROS 2019 field experiment in the Fram Strait – Eurasian Basin.

In total, over 500 Sentinel-1 SAR scenes were classified during these two campaigns.

For the **sea ice drift service**, two processing campaigns have been ran, for the same time periods as for the sea ice classification service:

- for the first period (2018), over 1500 pairs of Sentinel-1 images were processed,
- for the second period (2019) over 2000 pairs were processed.

The estimated ice drift vectors are grouped into daily datasets for up to 1-day, up to 2-day and up to 3-day time difference between the images in the pair. The ice drift vectors have been published back to the data server at NERSC for exploitation as part of INTAROS.

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WP5 / WP6 coordination for the definition of iAOS Showcases

"WP6 will integrate **remote sensing data** and **in situ observations delivered through WP5**, from a variety of platforms and geographical scales and locations. *Incorporation of these data into analysis and modelling systems, including physical and* ***ecological process models***, ***climate models*** *and* ***forecast methods***, *will provide support for better products to key societal areas*."

-- from WP6 Description of work

Helsinki, 2018 - Joint WP5-6 Workshop (but WP6 starting later)

Bremen, 2019 - RGeostats Workshop

Sopot, 2020 - Interviews with WP6 task leaders for their work plan analysis, and identification of best 'showcase' opportunities to be supported by the iAOS (WP5)

- As return of experience (INTAROS internal) on how the WPs interact in order to illustrate the iAOS added value
- As a set of results-oriented data collections and services, which can support the INTAROS outreach activities in 2020-2021

Remote, 2020 - Intermediate results reviews and definition of final objectives for each Showcase

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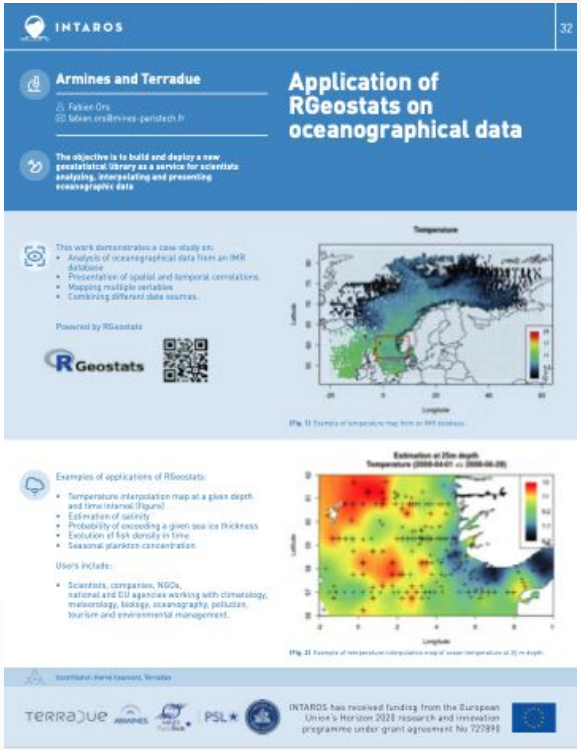
Contribution to the INTAROS Booklet

Geo-statistical methods

Application of RGeostats on oceanographical data

ARMINES and Terradue

- Analysis of oceanographical data (CTD)
- Presentation of spatial and temporal correlations
- Mapping multiple variables
- Combining different data sources



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Support to iAOS Showcase applications
Other collaborations

With SMHI
Climate Model initialisation

SMHI
David Gustafsson
David.Gustafsson@smhi.se

Pan-Arctic Hydrological Modelling

Objectives - Improve predictions of spring floods, river ice breakup and freshwater flow to the Arctic Ocean. Support the integration of river discharge into the ocean, providing data at user defined resolution

Climate model initialization

Data resources for checking the modelling initial conditions, the model analysis of current conditions and the model forecast

- Arctic-Hycos Observational data search and download from the iAOS Portal for daily pre-processing tasks:
  - Archive of quality controlled data with 4months/2years lag
  - Provisional datasets
- Arctic-HYPE model results published as open data:
  - Daily analyses of last 60 days
  - Medium range forecast of coming 10 days

Figure 1. iAOS OpenDAP server (SMHI) for Arctic-HYPE model outputs

With FMI
Modelisation of spatial and temporal behavior for snow thickness

FMI
Roberta Pirazzini
Roberta.Pirazzini@fmi.fi

Maps for Svalbard Avalanche Forecast Modelling

Objectives - Derive geostatistical relationships between in-situ measurements and model data of snow and weather conditions to improve the snow accumulation forecast

Modelisation of spatial and temporal behavior for snow thickness

Data resources for avalanche forecast modelling built from meteorological parameters and in-situ data recording

- Analysis of snow stations discontinuous data records, arome model outputs and terrain model data
- Modelisation of snow thickness through co-variables (temperature, wind speed by class of wind direction)
- Use the Geostatistical Library (RIntaros / RGeostats) and build the R software for interpolating snow depth maps

Powered by RGeostats

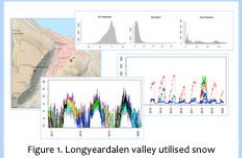

Figure 1. Longyeardalen valley utilised snow stations & automatic weather station. Temperature time series and Snow depth measurements over time.

With Aarhus Univ.
Climate Change & Fish resources

Aarhus University
Mikael Sejr
mse@bios.au.dk

Baffin Bay Sea Bottom Temperature Maps

Objectives - Exploit temperature fields at bottom of the ocean for:
- Analysis of long term global warming influence
- Analysis of the fish stock correlation to temperature

Climate Change & Fish resources

Data resources for

- Analysis of CTD, bottle and Trawl datasets (archives over 1960 to 2017)
- Modelisation of spatial and temporal behavior for ocean floor temperature through Bathymetry co-variable
- Use of the Geostatistical Library (RIntaros / RGeostats) to build the R software application for interpolating ocean floor temperature maps

Powered by RGeostats

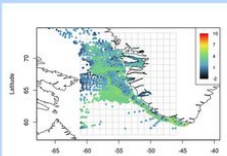

Figure 1. Maximum Depth Temperature (Overall)

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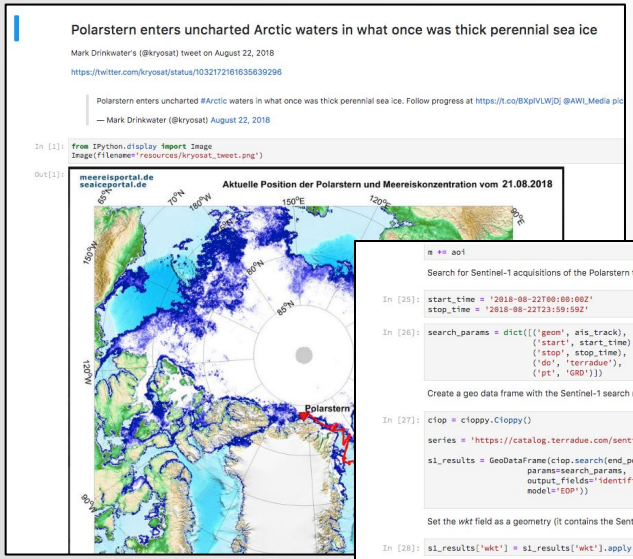
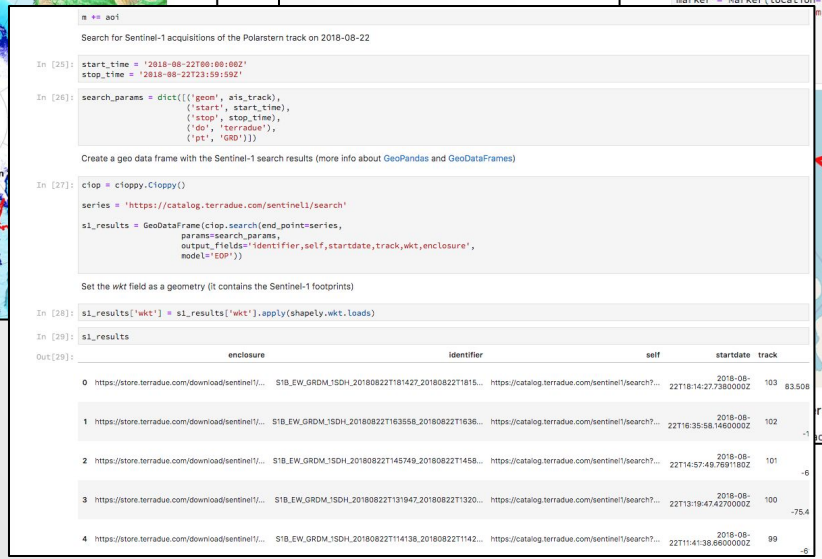
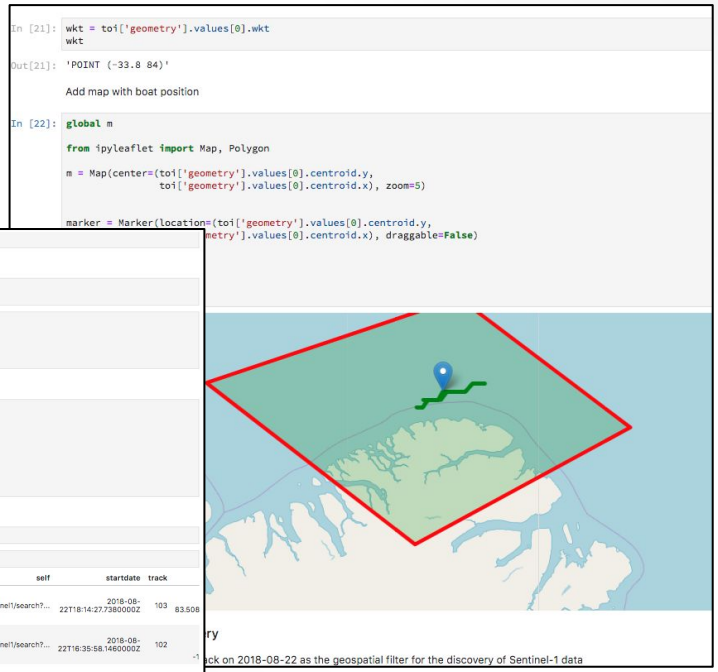
EO Data Discovery

Tools for data analysis, transformation and visualization







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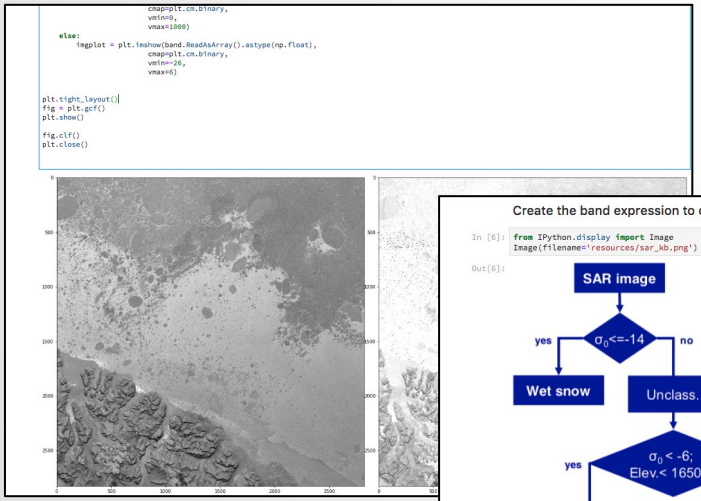
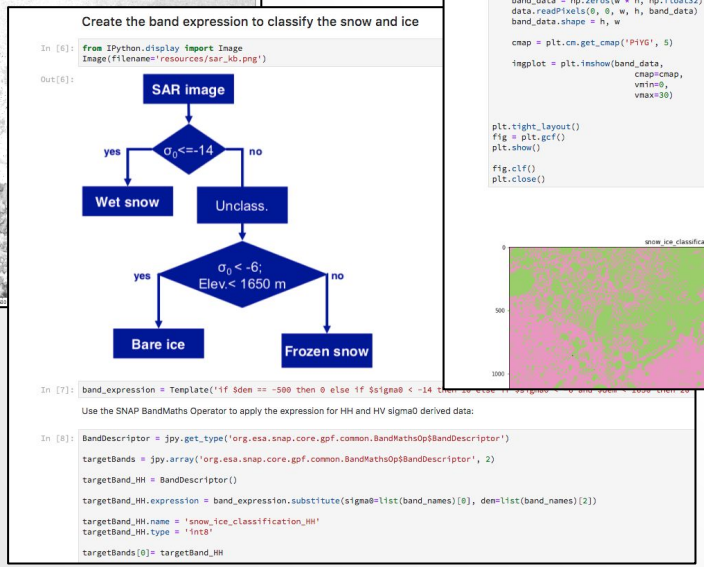
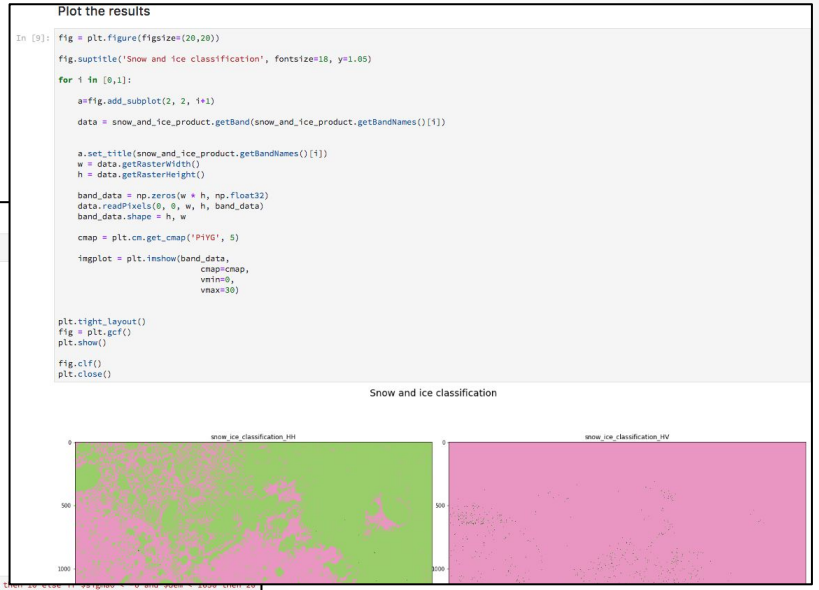
EO Data Access and Processing

Tools for data analysis, transformation and visualization







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Jupyter Notebooks for EO data processing

Tools for data analysis, transformation and visualization

Jupyter Notebook applications introducing EO data processing techniques for Arctic areas monitored using satellite earth observations:

- **01-polarstern.ipynb**: get and clean the Polarstern AIS data, use the Polarstern position at 2018-08-22 03:00 to discover Sentinel-1 data, stage-in the discovered Sentinel-1 data, and plot a quicklook of the staged-in Sentinel-1 product
- **02-snap-intro.ipynb**: introduce the Sentinel Application Platform (SNAP) and create a data processing graph to extract the Sigma0 measure out of a Sentinel-1 product
- **03-snow-ice-classification.ipynb**: apply a simple snow and ice classification derived from a knowledge-based approach.
- **04-glacier-velocity.ipynb**: apply the offset tracking technique to derive the glacier velocity maps with Sentinel-1 Level-1 Ground Range Detected (GRD) products. Offset Tracking is a technique that measures feature motion between two images using patch intensity cross-correlation optimization.
- **05-multitemporal-rgb-2018.ipynb**: use of multi-year SAR data to study the seasonal dynamic of the snow melt patterns.

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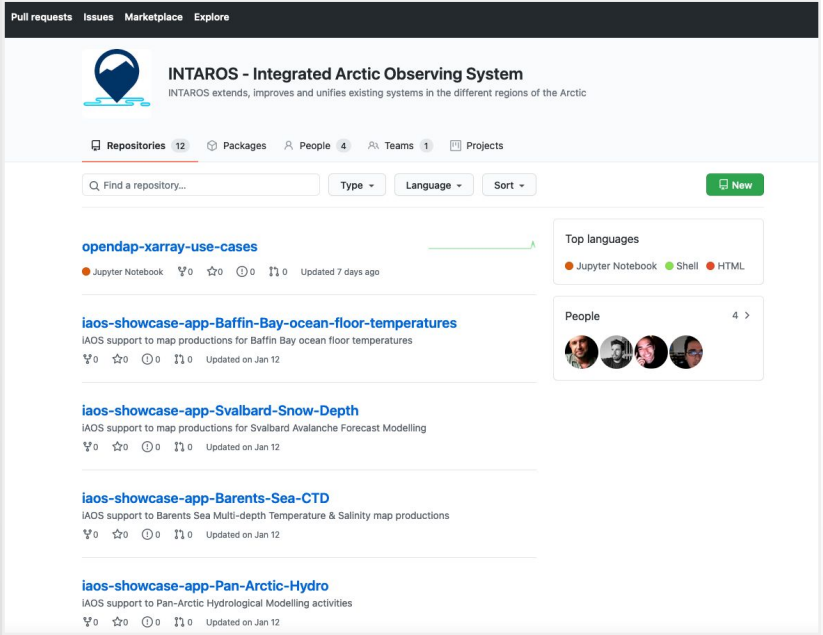
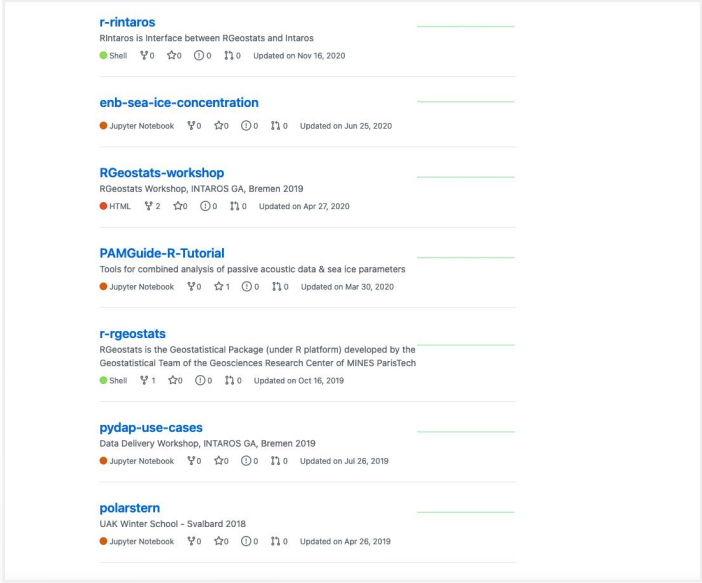
Software Repositories

Overview of the INTAROS GitHub community contents

https://github.com/ec-intaros





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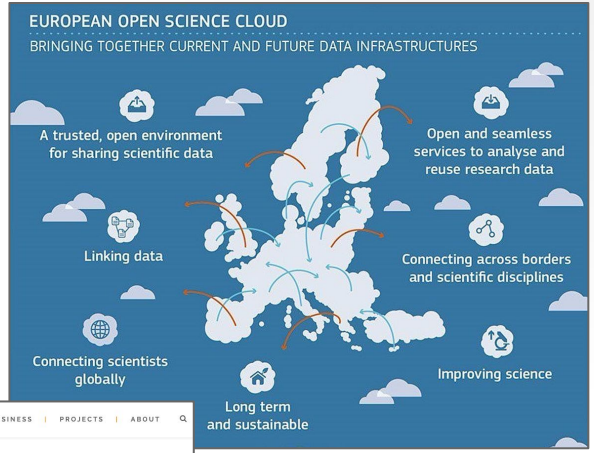
3. WP5 Expected Impact

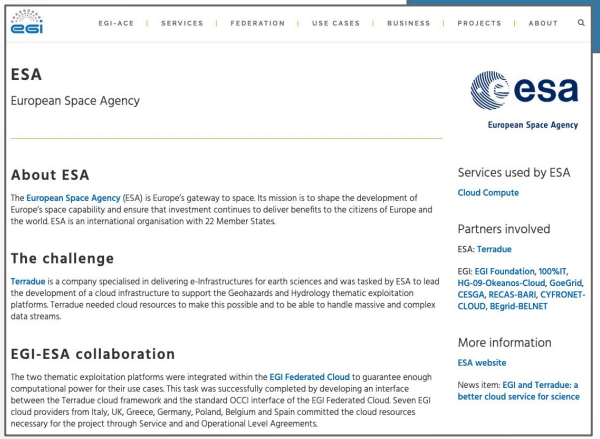
Key factors for iAOS to have an impact
Cost, legal, trust, privacy, security, usability

With the achieved maturity level of the iAOS cloud infrastructure, having a sustained impact after the completion of the project implies to consider **funding sources** (e.g. other projects), and stakeholder activities as part of a broad picture (e.g. **EOSC**), having in scope transformative changes and socio-economic impacts.

See also D5.13 - Synthesis of the iAOS infrastructure

Terradue is involved in EOSC-support actions with EGI.eu and ESA, building further Cloud Platform capacity of interest for the iAOS




EGI-ACE | SERVICES | FEDERATION | USE CASES | BUSINESS | PROJECTS | ABOUT

ESA

European Space Agency

About ESA

The European Space Agency (ESA) is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment continues to deliver benefits to the citizens of Europe and the world. ESA is an international organisation with 22 Member States.

The challenge

Terradue is a company specialised in delivering e-Infrastructures for earth sciences and was tasked by ESA to lead the development of a cloud infrastructure to support the Geohazards and Hydrology thematic exploitation platforms. Terradue needed cloud resources to make this possible and to be able to handle massive and complex data streams.

EGI-ESA collaboration

The two thematic exploitation platforms were integrated within the EGI Federated Cloud to guarantee enough computational power for their use cases. This task was successfully completed by developing an interface between the Terradue cloud framework and the standard OCCI interface of the EGI Federated Cloud. Seven EGI cloud providers from Italy, UK, Greece, Germany, Poland, Belgium and Spain committed the cloud resources necessary for the project through Service and and Operational Level Agreements.

Services used by ESA

Cloud Compute

Partners involved

ESA: Terradue

EGI: EGI Foundation, 100%IT, HG-09-Okeanos-Cloud, GoeGrid, CESGA, RECAS-BARI, CYFRONET-CLOUD, BEgrid-BELNET

More information

ESA website

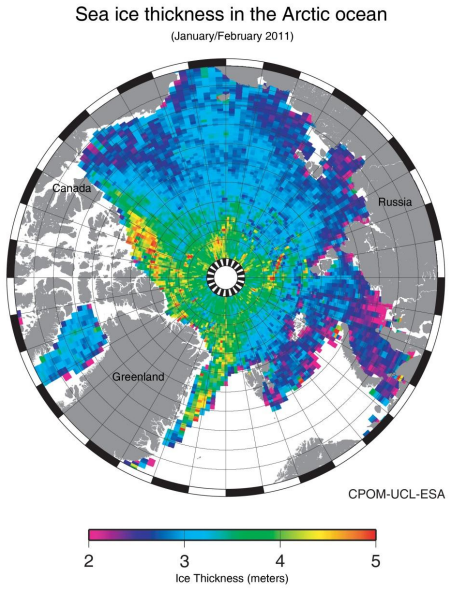
News item: EGI and Terradue: a better cloud service for science

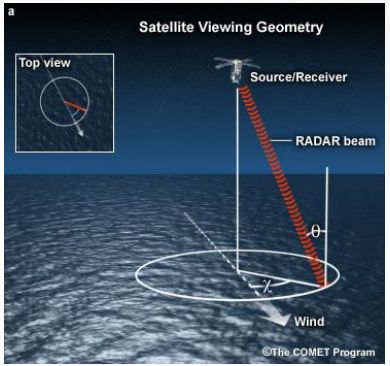
INTAROS

Exploitation plan - Terradue
Cloud processing services using EO data

- Earth observation data, in particular the Copernicus Sentinel products, have proven a good level of relevance and applicability in the iAOS cloud infrastructure context
- Tools and platform services successfully demonstrated with the iAOS applications:
  - UAK research school
  - INTAROS collaboration with the EC NextGEOSS project

This target impact was defined from the start of the WP5 activities in INTAROS, and a number of tutorials and training assets have been produced consequently. They are publicly shared on the INTAROS community on GitHub.





Exploitation plan - Terradue
Cloud processing services using EO data

Providing data services/processing services

Improved “Ellip Solutions” EO data processing services and documentation, which are used both to generate new EO products (level 3-4) and for enabling scientists to prototype new algorithms and validate services.

Portal:
https://www.terradue.com/portal/ellip

Documentation:
https://docs.terradue.com/ellip

Dashboard:
https://ellip.terradue.com
(private access, Ellip users)

Providing improved access to data from repositories

New capacity to test and validate Ellip-powered applications over OpenDAP standard endpoints (Hyrax/Thredds) configured over dataset samples, thus releasing operational servers from testing-only workloads.

TDS OpenDAP Server for Ellip users:
https://opendap.terradue.com/thredds/
(private access, Ellip users)

Hyrax OpenDAP server for Ellip users:
https://opendap.terradue.com/hyrax/
(private access, Ellip users)

Demonstrating useful applications towards stakeholders

Jupyter Notebook files executable on a Jupyter Lab software environment (https://jupyter.org/), with access to Open Science software repositories, stored by the EC-INTAROS GitHub organisation.

UAK Winter School - Svalbard 2018
https://github.com/ec-intaros/polarstern

RGeostats Workshop - Bremen 2019
https://github.com/ec-intaros/RGeostats-workshop

Barents Sea Multi-depth Temperature & Salinity Maps
https://github.com/ec-intaros/iaos-showcase-app-Barents-Sea-CTD

Data extraction from OPeNDAP server at NMDC
https://github.com/ec-intaros/iaos-CTD-extract-from-opendap

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4. WP5 Challenges

Deploying and operating the IAOS cloud infrastructure (1/3)

Specific challenges	Return of experience
Federate access to distributed data repositories from multiple stakeholders and with disparate technical maturity levels.	Only **Pangaea and OPeNDAP-based servers** provide structured support (software tools for developers, online documentation) but still the **maturity level** is low, estimated at TRL6 “prototype demonstration in a relevant environment”, compared to TRL8 “System complete and qualified” and TRL9 “Actual system proven in operational environment”.
Federate access to Cloud providers from major initiatives (DIAS, EGI.eu, EOSC).	The **capacity within iAOS** to tap into Cloud Computing resources was delivered to few use cases in INTAROS (**support to ARMINES and NERSC**). While Terradue Cloud Platform provides the capability to connect to the Cloud Providers from major initiatives in Europe (DIAS, EGI.eu, EOSC), the INTAROS partners with high compute load needs made use of their pre-established corporate access to HPC resources.

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Deploying and operating the IAOS cloud infrastructure (2/3)

Specific challenges	Return of experience
Validate and brand a Software Development Toolkit (SDK) encapsulating all the key developer functions for API-based functions	Cross-projects coordination was difficult to handle in this particular scope. The Ellip Software Development Kit (SDK) was presented in the INTAROS deliverable D5.8 iAOS Platform and Tools V2 (revised 10 June 2020). The goal to repackage the Ellip SDK tools as presented was **partially attained within INTAROS**, since a technical trend emerging from the ESA and OGC communities (EOEPCA), while anticipated and contributed to by Terradue, is going to change some of the orientations initially described in D5.8. **Terradue is still actively contributing to EOEPCA** (**ESA/OGC press release upcoming end January 2022**)
Build a data catalogue federating Arctic-related data sources	This objective was successfully attained by NERSC as part of the task T5.6. Cf. updates on the **iAOS Portal and the INTAROS catalogue** in D5.12 “iAOS Portal with user manual V2”.

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Deploying and operating the IAOS cloud infrastructure (3/3)

Specific challenges	Return of experience
On-board and support a developer user community	Due to technical efforts allocated by WP5 on building and consolidating the iAOS cloud service features, it was not possible to put much extra efforts on developing the user community of the iAOS beyond the **WP5 partners and the WP6 partners in charge of a selected iAOS showcase application**. A notable success in this matter was the **"polarstern" Earth Observation module and training delivered during the UAK Winter School** held on 02-07 December 2018 at UNIS, Longyearbyen, Svalbard, that brought together leading researchers, educators and young scientists from Norway, USA and Canada, and working on Arctic science topics.
Deliver data processing **applications as online services accessed from a user Portal**	It was not possible to address this objective, simply due to the fact that **no specific INTAROS-specific web processing service has reached a maturity level allowing this type of system integration**. The orientation was put halfway through the INTAROS project to focus on delivering Jupyter Notebooks instead. Latest developments (December 2021) on CTD extraction tool might address further this challenge (under evaluation between Terradue and NERSC).

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Integrating data from existing data repositories

Specific challenges	Return of experience
Find and assess datasets accessible online, based on their potential relevance for a given use case or a set of initial requirements	It remains difficult for persons that were not previously exposed (meetings, telcos, reports) to a specific dataset to rely on current search engine technologies (web search engine or portal search engine) in order to get a clear overview of the initiatives, data producers and online repositories able to deliver on the use case expectations. The **data discovery processes involved in support of the definition of the iAOS showcases were largely dependent on human expertise and advice**, and therefore not straightforward from the start.

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5. Recommendations from WP5

Establishing a sustainable pan-Arctic iAOS cloud infrastructure

Address long-term infrastructure properties from the start, along the lines of the technical work performed during the INTAROS project timeframe:

- infrastructure cost assessment,
- legal dimensions,
- trust building,
- privacy policies,
- security policies
- and usability criteria.

See D5.13 - Synthesis of the iAOS infrastructure

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Focused work to be pushed forward

Implementation of **Data standards**, while being well established in the software systems involved within iAOS, are still lacking support to software application developers, and it is still needed to:

- Assess the l**earning curve** and improve **user experience** related to all the aspects of an infrastructure such as iAOS cloud platform, for an application integrator.
- Improve **online support resources related to interoperability protocols** (e.g. DAP2, DAP4), for software application developers.

This challenge appeared quite from the start of the WP5 activities in INTAROS, and a number of tutorials and training assets have been produced consequently.

These Data standards related resources are publicly shared on the INTAROS community on GitHub, and shall be pushed forward.

Tooling support for the **volume, variety and variability of data sources**. The set of iAOS showcase applications demonstrated this remains a challenge, and it is still needed to:

- Optimise tools for **data preparation** effort, in particular to assess the data quality, as platform-based automations to support this effort-consuming step.
- Optimise tools for **data analysis** effort of poly-structured data sources, in order to perform exploratory analysis and come up with work plan hypotheses.

The WP5-WP6 collaboration on the iAOS showcases helped to pinpoint the high interest of scientific users for improved, platform-based, data science capabilities.

The overall data value that is represented here is very important for research and development and shall be pushed forward.

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WP5 - DATA INTEGRATION AND MANAGEMENT

Results and impact

INTAROS Final Meeting - Synthesis

Looking forward
hearing from you !

January 20th-21st 2022

Hervé Caumont, Terradue Srl

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