The Next Generation Earth System Grid Federation

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ESIP Discovery Cluster

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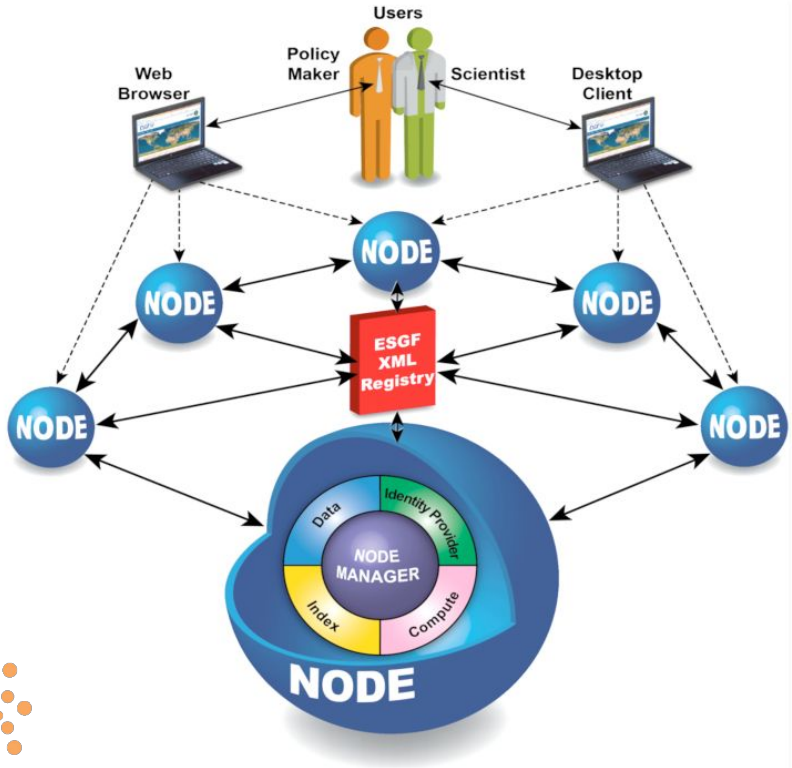
U.S. DEPARTMENT OF ENERGY | Office of Science

- Overview of ESGF
- Architecture of the next generation ESGF
  - Data index/search technology
  - Data search/discovery -- Web UI; Python library and CLI;
  - Data citations/DOI

What is the Earth System Grid Federation?

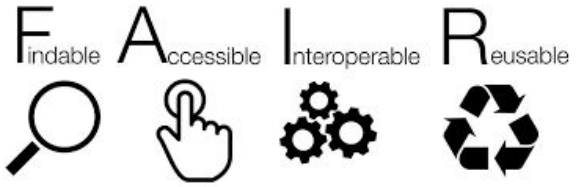
- **Earth System Grid Federation (ESGF)** is an *international consortium* and a *globally distributed peer-to-peer network of data servers* using a common set of protocols & interfaces to archive and distribute Earth system model output and related input, observational, and reanalysis data
- **Open Science data** are used by scientists all over the world to investigate Earth system variability and feedbacks and to inform research and assessments

ESGF Conceptual Diagram



ESGF2 US ESGF Holdings are Open and Large

- CMIP5 totals >1.5 PB (>5 PB including replicas)
- CMIP6 totals >16.1 PB (>27 PB including replicas)
- CMIP7 is expected to have more experiments, high resolution output, and ensembles, totaling ~100 PB



CMIP6 14,893,892 total datasets 27,983.73 TB	CMIP6 7,670,309 distinct datasets 16,120.41 TB	CMIP6 7,223,583 replica datasets 11,863.32 TB
CORDEX 187,785 total datasets 1,473.33 TB	CORDEX 187,513 distinct datasets 1,472.77 TB	CORDEX 272 replica datasets 0.56 TB
CMIP5 201,130 total datasets 5,293.61 TB	CMIP5 52,163 distinct datasets 1,525.07 TB	CMIP5 148,967 replica datasets 3,768.55 TB
INPUT4MIPS 5,871 total datasets 10.84 TB	INPUT4MIPS 21 distinct datasets 0.9 TB	INPUT4MIPS 5,850 replica datasets 9.95 TB
OBS4MIPS 126 total datasets 0.2 TB	OBS4MIPS 108 distinct datasets 0.2 TB	OBS4MIPS 18 replica datasets 0.01 TB

As of August 21, 2025

Planned ESGF-NG Architecture

Data Access via https & Globus Transfer (US)
Zarr/aggregation data supported

via Kerchunk (limited nodes)
Direct Data Access via User Computing (limited nodes)

Identity & Access Management
Globus Auth (US)
EGI Check-in (EU)

Metagrid –
Data Discovery
User Interface

intake-ESGF –
Programmatic Search
& Access

esgpull –
Data Search & Bulk
Data Transfer

ESGF
Earth System Grid Federation

Cloud-based Global Synchronized Catalogs (Can be expanded)

DOE (US)

West Catalog
STAC on
Globus Search

Data Search and Query

Catalog Update & Synchronization

East Catalog
STAC on
ElasticSearch

CEDA (UK)

Publisher –
Data Publication,
Retraction, Replication

Message Queue

Services
Data Movement, Value-Added Products, Rapid Evaluation Framework, Community Projects

High Capacity Storage

User Computing / JupyterHub

Server-side Computing / WPS & Globus Compute

Tier 1 Data Node

Tier 1 Data Node

Tier 1 Data Node

Tier 2 Data Node

Version 1.0, 5 August 2025

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ESGF Data Catalog/Index

- In past, ESGF has used Apache Solr for storing and searching metadata for all datasets.
- Apache Solr Index nodes were operated and maintained by individual ESGF nodes [5+2 Solr nodes currently in operation].
- These index nodes were federated and Web UI conducted distributed search across these federated index nodes.

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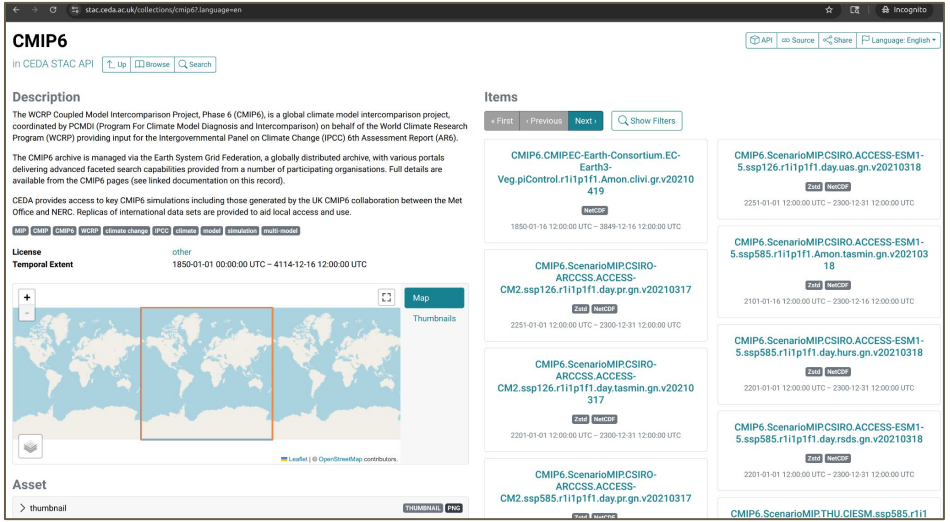
- Apache Solr Index nodes were operated and maintained by individual ESGF nodes.
- These index nodes were federated and Web UI conducted distributed search across these federated index nodes.
- **Challenges/Limitations**:
  - However, maintaining these Solr indices have been difficult and resource consuming
  - Security vulnerabilities
  - Resulted in varying search experiences depending on whether nodes were online/offline

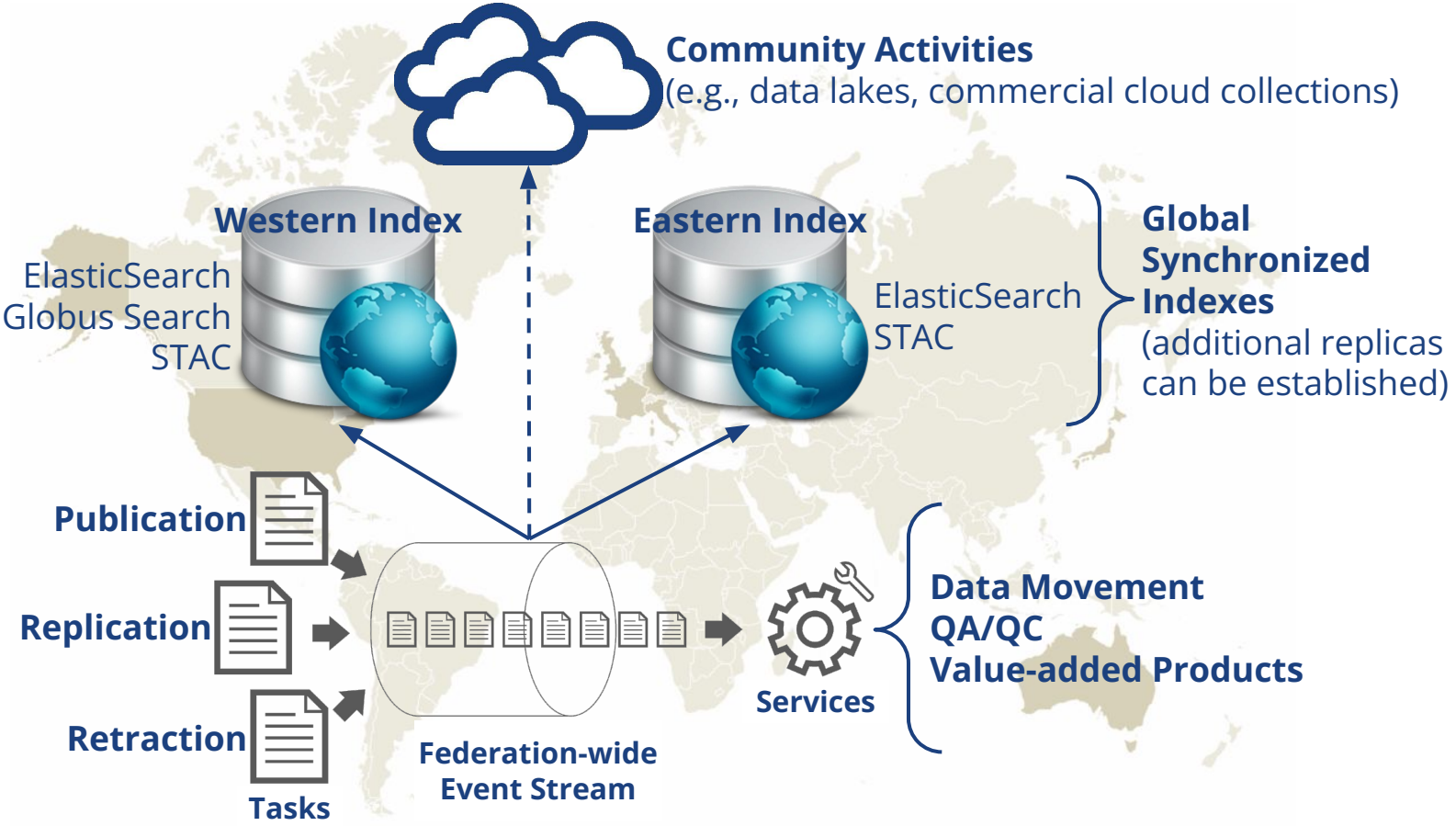
ESGF Data Catalog/Index

- The next generation of ESGF, currently in development, will use Spatio Temporal Asset Catalog (STAC) for storing and searching ESGF metadata
  - Benefits from range of community developed tools to interact with STAC
  - Enables integration with earth observation data from other providers
- Two cloud based index nodes to enable a seamless and consistent search experience for the users
- Solr nodes will be retired and technology no longer supported



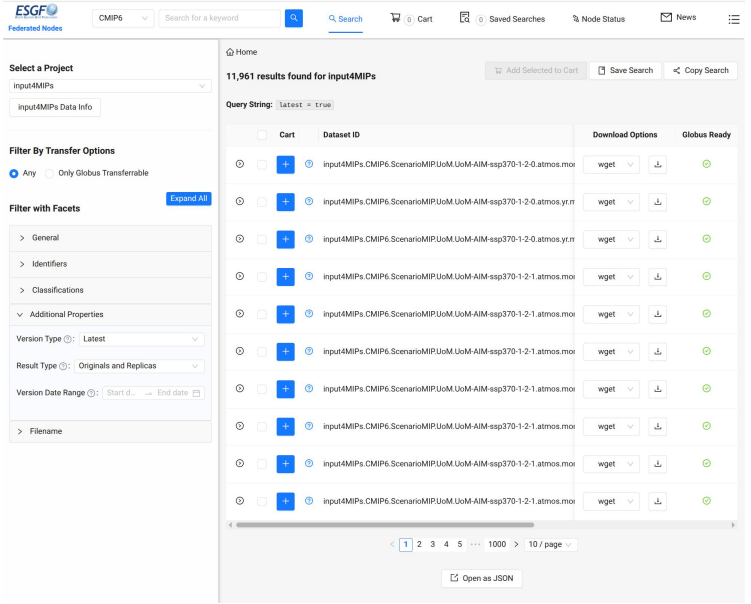
STAC catalog in operation @CEDA

New Redundant Index Strategy



Metagrid Enhances ESGF Search

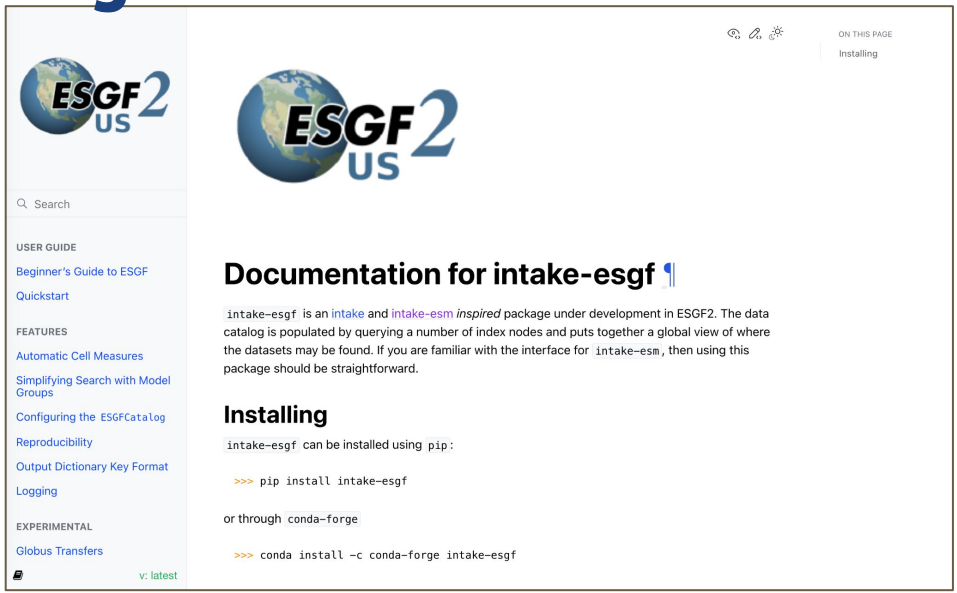
- New **Metagrid faceted search user interface**, developed at LLNL on popular React Javascript framework, deployed at ORNL, LLNL and ANL
- Offers new features, including a **shopping cart**, ability to **save and share searches**, integration with **Globus authentication & transfer** and a search page **tour & support dialog**
- User experience enhancements make it **faster and easier** to discover published data
- **Globus integration** offers faster and more reliable data access



The Metagrid Web Interface for ESGF search is a completely redesigned interface from CoG. It features a familiar faceted search and a new capability to save searches.

Integrating with intake-esgf

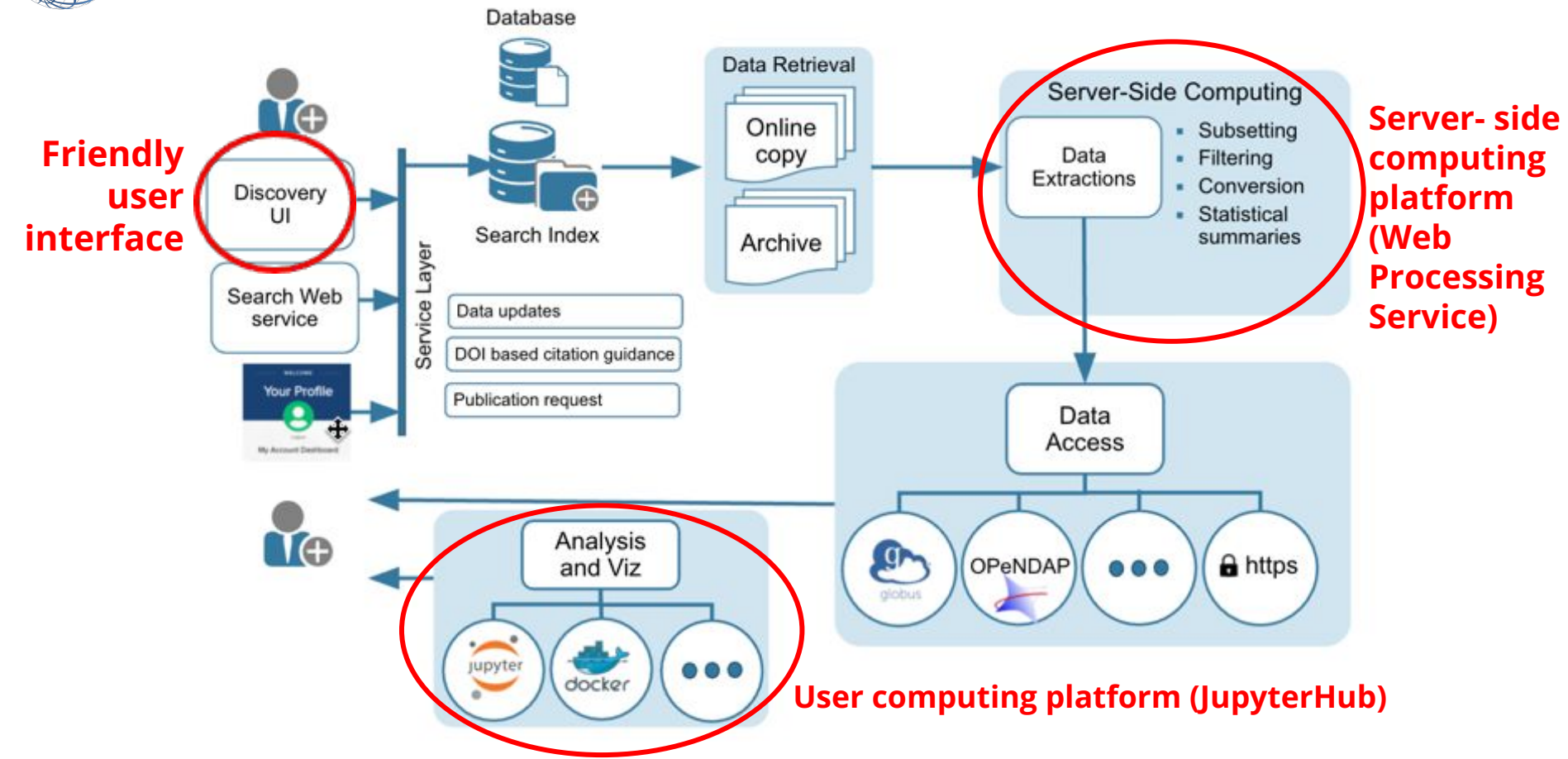
- Improve the APIs to access data; simplify searching for data programmatically across the federation
- Provide STAC-based index query in addition to the existing Solr and Globus indices [backwards compatibility]
- Extend the interface to provide capability for data streaming (OPeN-DAP, Kerchunk, Virtual Zarr) as available
- Integrate the errata service provided by es-doc into intake-esgf catalogs



- Intelligently determines the quickest way to access data (download, Globus Transfer, stream, load locally)
- **Provides method to package compute + flows**

Repository: https://github.com/esgf2-us/intake-esgf
Documentation: https://intake-esgf.readthedocs.io/
Installation: PyPI and Conda-forge

Data Discovery, Access & Analysis Platform



Proposed DOI Workflow

ESGF
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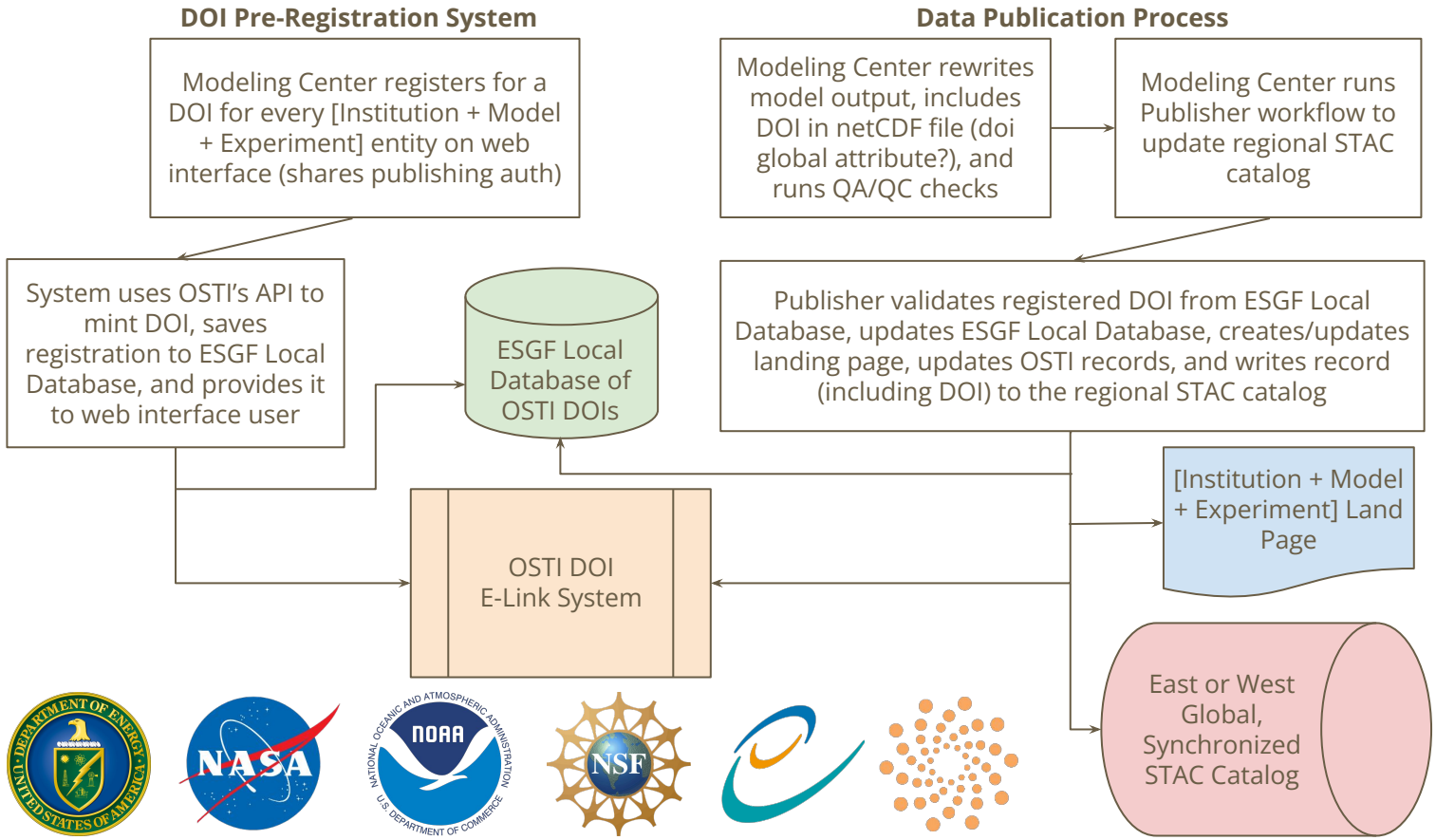

- Modeling center pre-registers for DOI through web interface
- They encode the DOI within every netCDF file
- The Publisher extracts and validates the DOI, and updates the local database, landing page, and OSTI registration
- DOI is included in STAC catalog along with metadata

- Data Granularity:
  - DOIs will be issued for unique combination of *mip_era* + *institution_id* + *source_id* + *experiment_id*
  - Issued DOIs will follow the format:
    10.25981/ESGF.{**mip_era**}.{**institution_id**}.{**source_id**}.{**experiment_id**}/XXXXXX
    10.25981/ESGF.**CMIP7**.**MIROC**.**MIROC-ES2L**.**ssp245**/9999999
- DOIs will be included in the global header of the NetCDF files
- ESGF-Publisher will perform QA/QC before data publication and DOI release
- DOI registration:
  - We are leveraging DOE OSTI ELINK service to register data DOIs with DataCite
  - ESGF DOI Service will auto-generate landing pages for DOIs
  - Follow landing page best practices from DataCite (https://support.datacite.org/docs/landing-pages)

Thank you for your attention!

Comments/feedback/suggestions are welcome on our ongoing developments.

Email: kumarj@ornl.gov