COVERAGE
CEOS Ocean Variables Enabling Research & Applications for GEO

An Initiative & Platform to Simplify and Expand the Accessibility and Usage of Inter-agency Satellite & in-situ Oceanographic Data

V. Tsontos, J. Vazquez, T. Huang, M. Chin , J. Jacob , J. Roberts , F. Platt
Jet Propulsion Laboratory, California Institute of Technology
vtsontos@jpl.nasa.gov

NASA · CEOS — The Committee on Earth Observation Satellites

Motivation & Vision

- Imperative to better marshal available observations of different types for societal benefit.
- Address key constraints to access and synergistic use of multi-sensor/variate Earth Observations and ocean observing system data, particularly amongst currently underserved user communities with a need for such environmental information.
- Enable more widespread, integrated use of ocean satellite, in-situ and model data products in support of interdisciplinary open science & applications to more fully realize their potential.
- Reusable data platform and software toolkit leveraging Hybrid-Cloud infrastructures
- Support UN Decade of Oceans and UN Sustainability Goals 13 (Climate Action) & 14 (Life Below Water) to help catalyze the data-driven Blue Economy of the future.
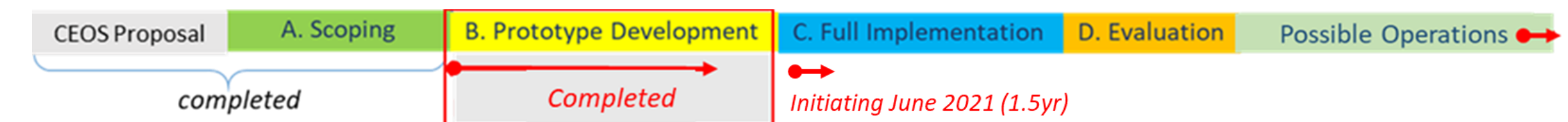
Initiative & Project

- Cross-cutting, collaborative initiative within CEOS and NASA project
- Build upon an advanced technology platform being implemented providing access to complementary satellite & in-situ datasets via value-added data services
- Improves access to a coherent, curated set of global, interagency data products from the 4 Ocean Virtual Constellations (SST, Ocean Color, Ocean Winds, Ocean Surface Topography), including near real-time datasets, at common resolution as a baseline dataset.
- Exercises emerging cloud technologies for Earth Observation applications across heterogeneous cloud environments (NASA-AWS, EUMETSAT WEkEO)
- Demonstrates utility of the technical capability and approach in the context of an example thematic Ecosystem application relating to: "Pelagic fisheries & Biodiversity in relation to the environment"

Approach

NASA · NOAA · EUMETSAT · cnes · IMOS · Australian Government · Copernicus Marine Service · SARGASSO SEA COMMISSION

- User community driven, Stakeholder focused, Open Source, data FAIR
- Emphasis on data interoperability standards and thematically-based data access via distributed data architecture
- Phased Development: currently Phase C (18 months)

CEOS Proposal	A. Scoping	B. Prototype Development	C. Full Implementation	D. Evaluation	Possible Operations

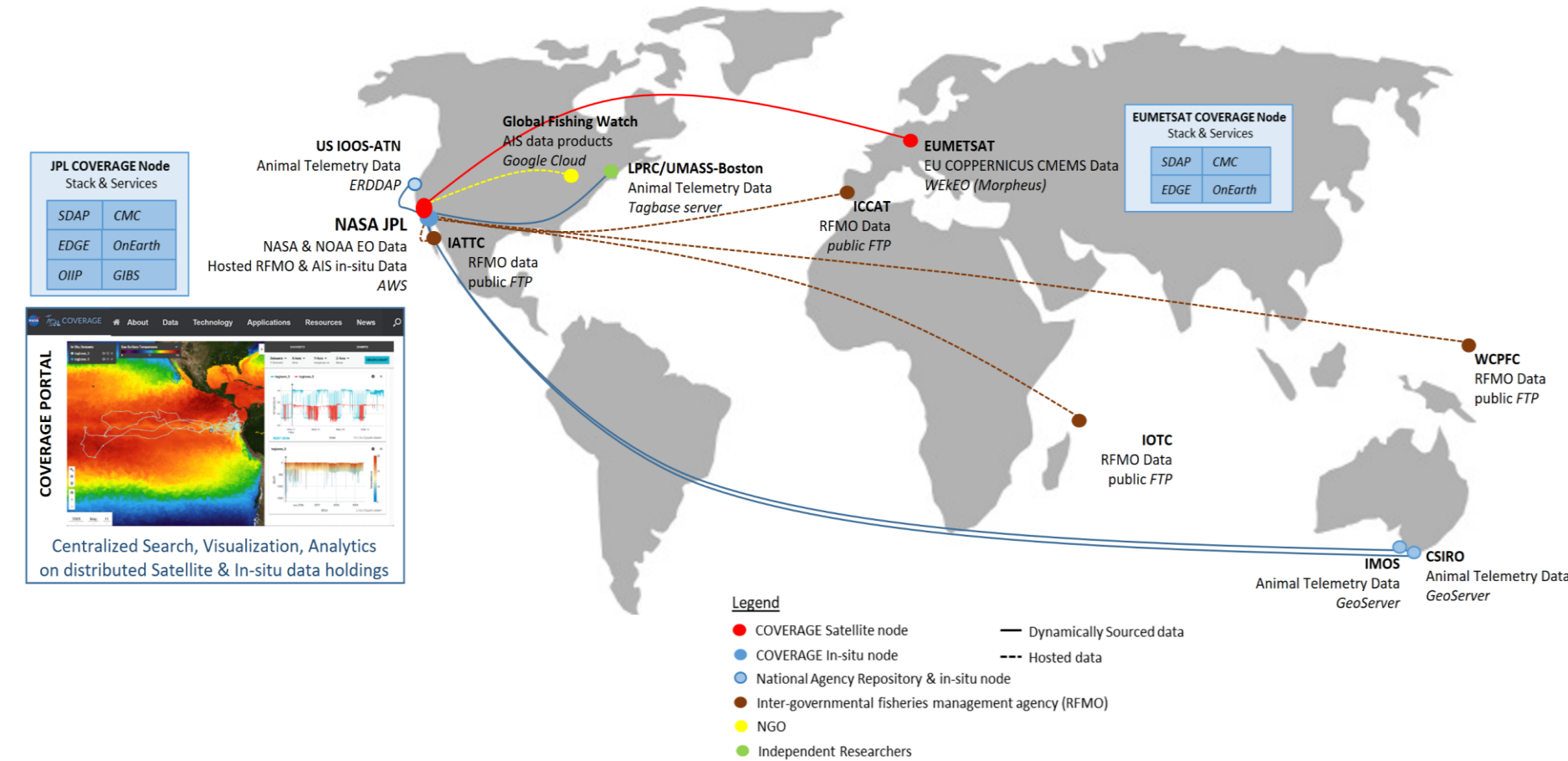*completed* — *Completed* — *Initiating June 2021 (1.5yr)*

- Governance: Advisory Board (stakeholder agencies)
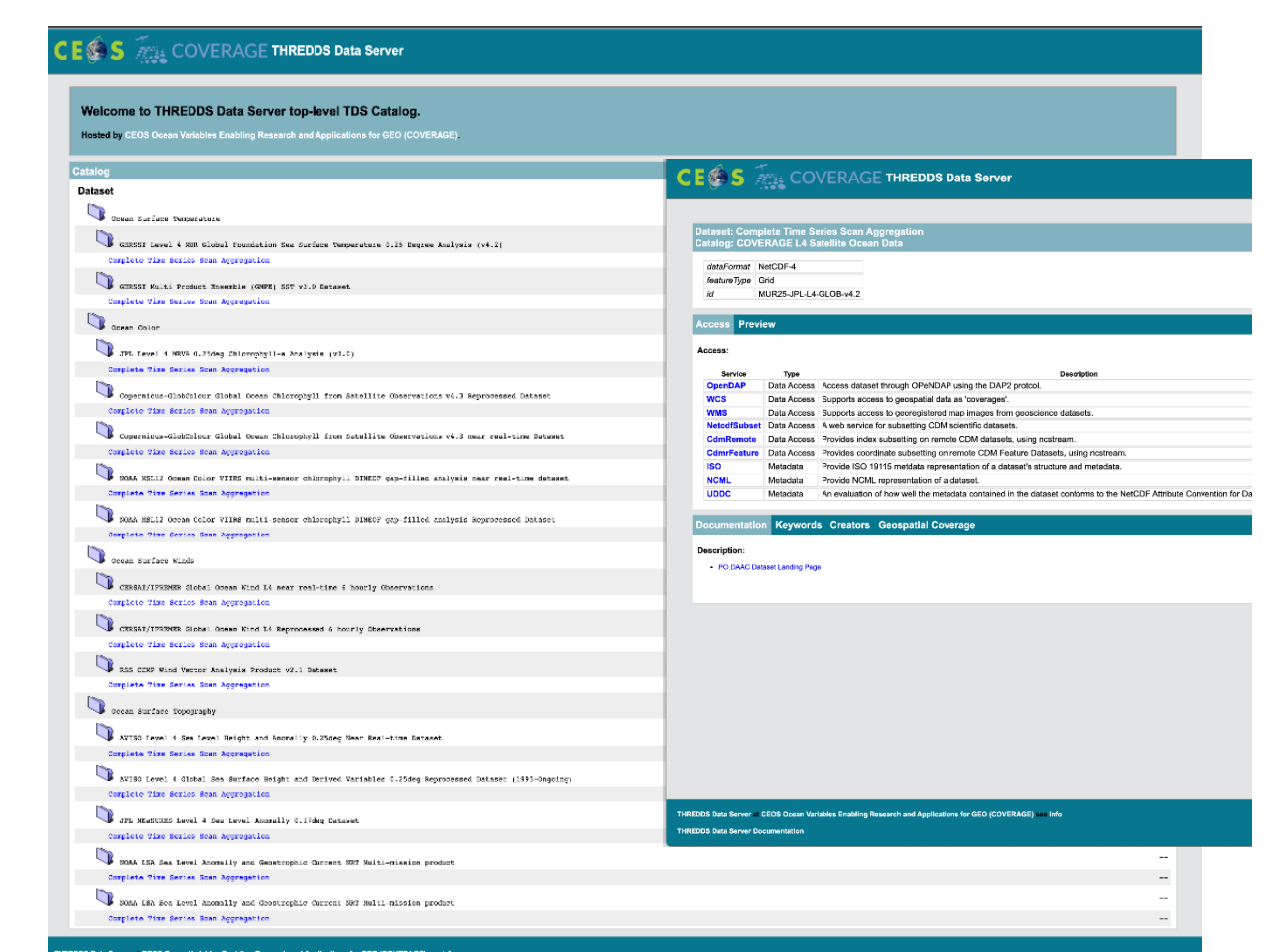- Operationalization concept and Sustainability strategy development

Results

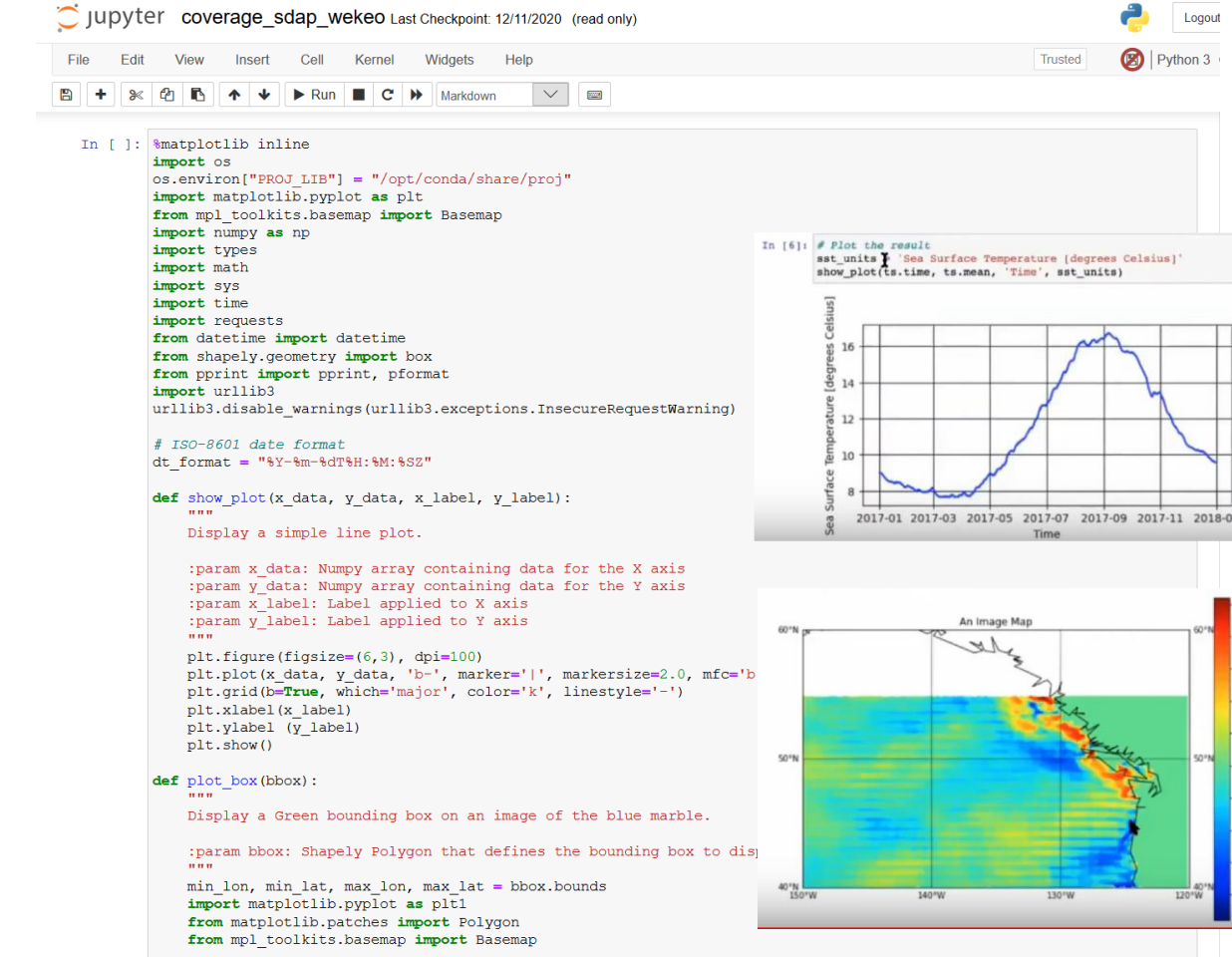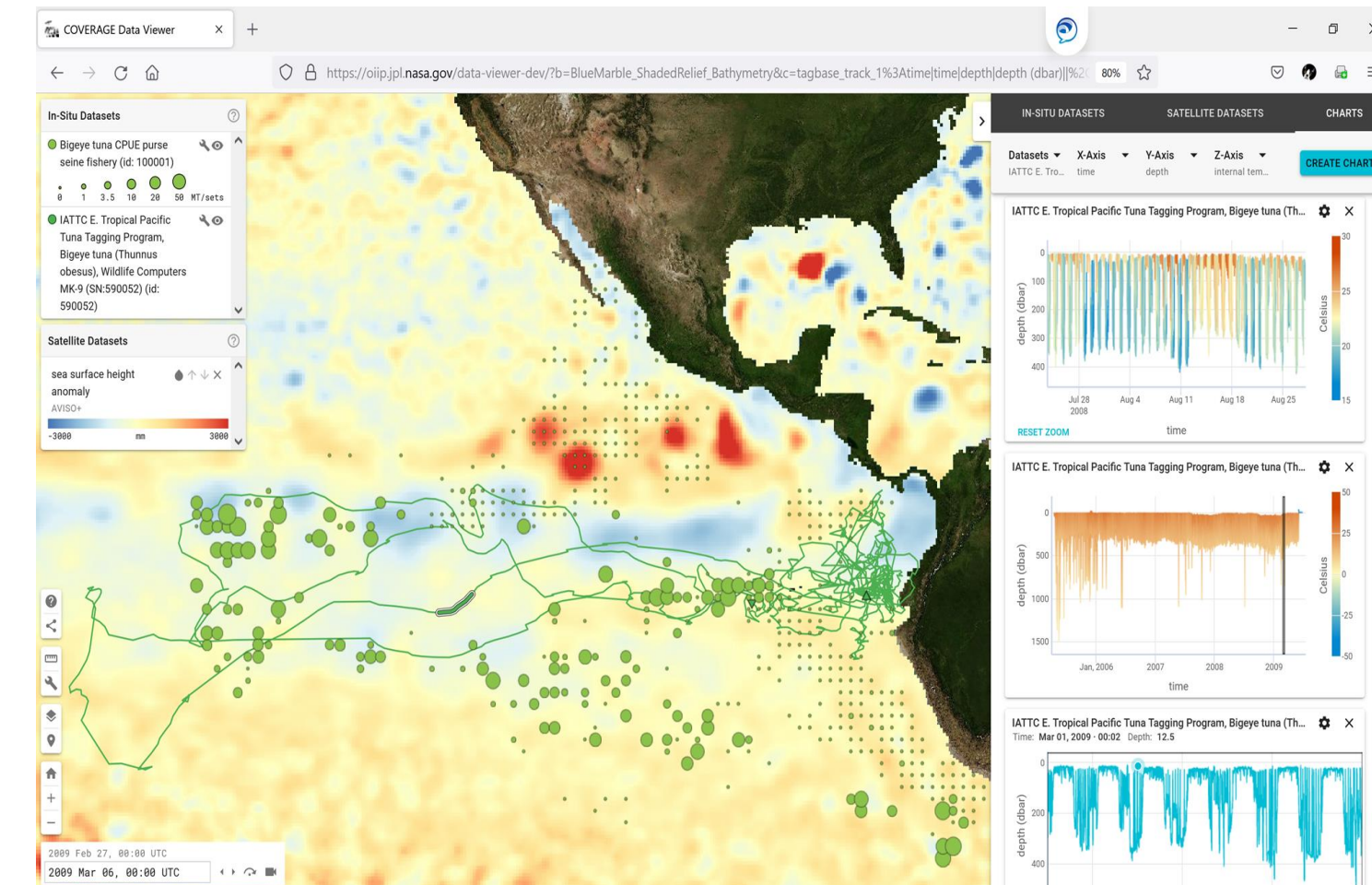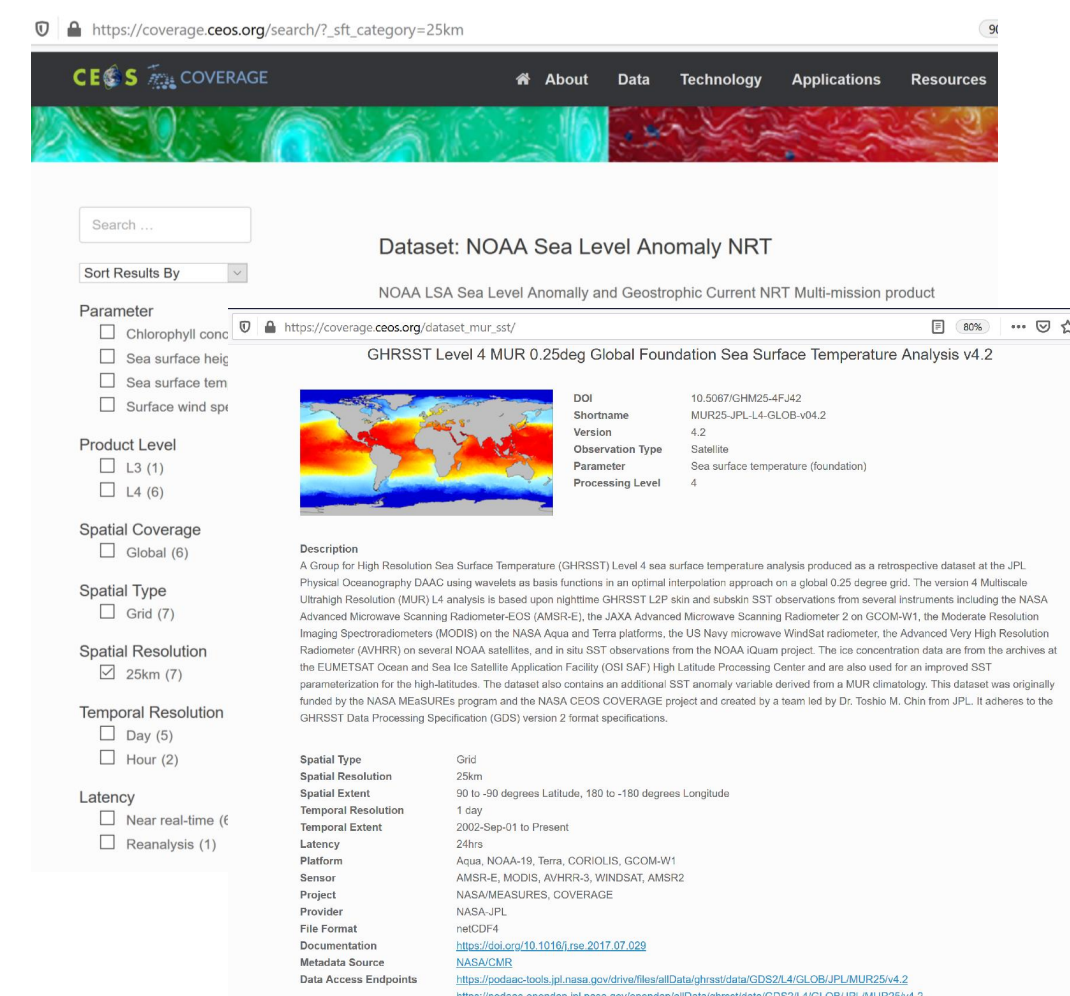Outcomes from the Phase-B (prototype implementation) project

Click figures below to enlarge

Distributed Data Architecture

Centralized Search, Visualization, Analytics on distributed Satellite & In-situ data holdings

Legend
- COVERAGE Satellite node
- COVERAGE in-situ node
- Inter governmental fisheries management agency (RFMO)
- NGO
- Independent Researchers
- Dynamically sourced data
- Hosted data

Cloud-enabled Data Services

Integrated Search

Web-based Data Visualization

Analytics Services

TDS OGC Services
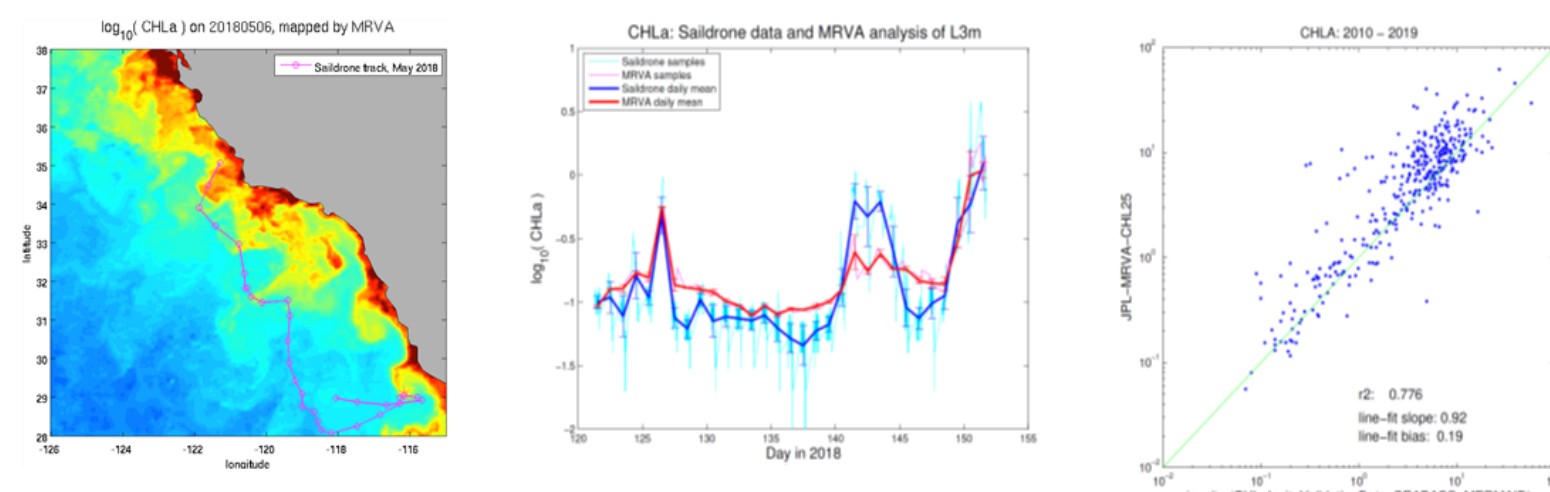
Web Portal   https://coverage.ceos.org

L4 Ocean Color Product Development

L4CHLA MRVA - *in situ* Comparisons

Saildrone Baja Campaign

*SEABASS/NOMAD/MERMAIDS Matchup Database Comparisons*

L4 CHLA Product Inter-comparisons

MRVA , Globcolour, NOAA-MSL12

Datasets - Season	Correlation	Bias (mg/m**3)	RMSD (mg/m**3)
MRVA/CMEMS - Winter	0.94	-0.0575	0.144
MRVA/CMEMS - Spring	0.94	-0.0484	0.147
MRVA/CMEMS - Summer	0.95	-0.0215	0.135
MRVA/CMEMS - Fall	0.94	-0.0485	0.149
MRVA/MSL12 - Winter	0.97	-0.0189	0.094
MRVA/MSL12 - Spring	0.97	-0.0191	0.112
MRVA/MSL12 - Summer	0.93	-0.0439	0.167
MRVA/MSL12 - Fall	0.95	-0.0210	0.132

Regional Ecosystem Applications involving Inter-governmental Agency Partners

Sargasso Sea Commission (SSC)
- Promote stewardship of the Sargasso ecosystem via work program & action plan development for this high seas area
- Global Environmental Facility (GEF) & FFEM funded projects
  - Ecosystem Diagnostic Analysis (EDA), identifying trends and impacts from available environmental, biological and socio-economic data
  - Development and adoption of ecosystem-based stewardship approach for the Sargasso Sea
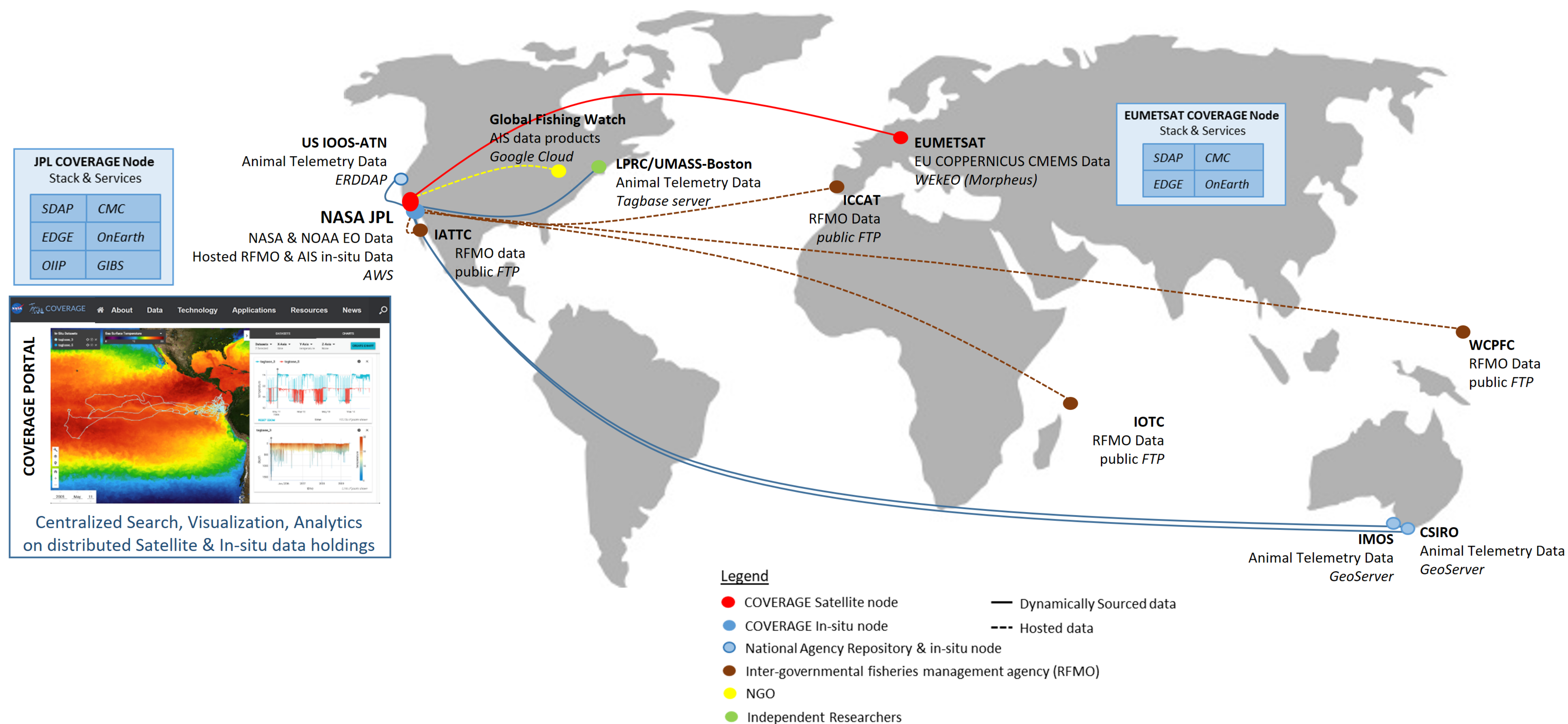 - COVERAGE providing integrative data system
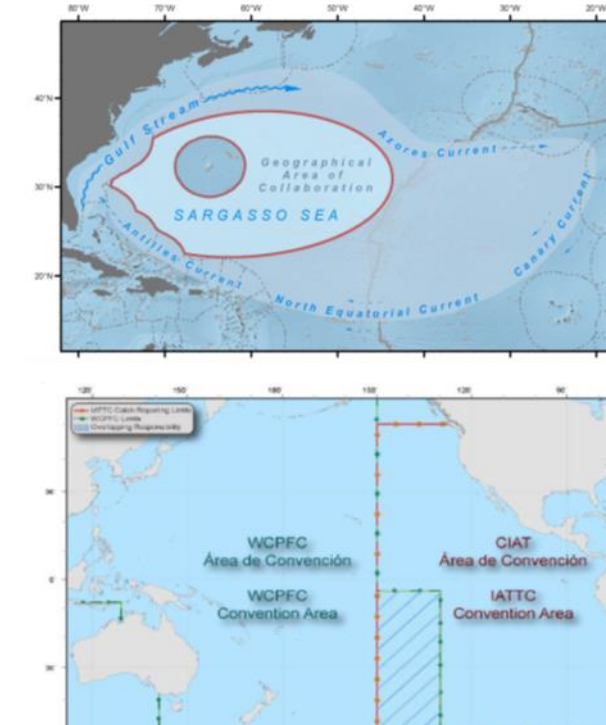
Inter-American Tropical Tuna Commission (IATTC)
- 21 Nation Intergovernmental Regional Fisheries Management Organization (RFMO)
- Responsible for the scientific assessment and management of Tuna and large pelagic fisheries in the E. Tropical Pacific (ETP)
- Potential applications of remote sensing data to support fisheries *Dynamic Ocean Management*, habitat analyses, MPA designation, Spatial catch forecast, By-catch mitigation
- IATTC-COVERAGE regional spin-off application

Distributed Data Architecture
Supporting the Fisheries/Ecosystem Demonstration Application

COVERAGE
CEOS Ocean Variables Enabling
Research & Applications for GEO

JPL COVERAGE Node
Stack & Services

SDAP	CMC
EDGE	OnEarth
OIIP	GIBS

US IOOS-ATN
Animal Telemetry Data
ERDDAP

Global Fishing Watch
AIS data products
Google Cloud

LPRC/UMASS-Boston
Animal Telemetry Data
Tagbase server

EUMETSAT
EU COPPERNICUS CMEMS Data
WEkEO (Morpheus)

EUMETSAT COVERAGE Node
Stack & Services

SDAP	CMC
EDGE	OnEarth

NASA JPL
NASA & NOAA EO Data
Hosted RFMO & AIS in-situ Data
AWS

IATTC
RFMO data
public *FTP*

ICCAT
RFMO Data
public FTP

WCPFC
RFMO Data
public *FTP*

IOTC
RFMO Data
public *FTP*

IMOS
Animal Telemetry Data
GeoServer

CSIRO
Animal Telemetry Data
GeoServer

COVERAGE PORTAL

Centralized Search, Visualization, Analytics
on distributed Satellite & In-situ data holdings

Legend

- 🔴 COVERAGE Satellite node
- 🔵 COVERAGE In-situ node
- 🔵 National Agency Repository & in-situ node
- 🟤 Inter-governmental fisheries management agency (RFMO)
- 🟡 NGO
- 🟢 Independent Researchers
- —— Dynamically Sourced data
- - - - Hosted data

High Seas Fisheries Applications involving integration of ocean remote sensing, physical model and in-situ datasets enabling decision support:

- Habitat analysis for Highly Migratory Species (HMS)
- Tuna Spatial catch forecasting
- By-catch mitigation
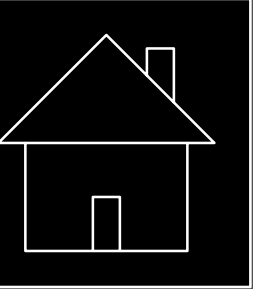- MPAs/fishery closed areas
- Ecosystem-based management

Supporting Data used in Phase-B *(publicly available)*
- RFMO monthly spatial catch/effort time series by species, aggregated spatially at 1 & 5 deg., 1952-2018
- Electronic tagging datasets: high resolution trajectory-profile series
- AIS fishing vessel movement data products by category (daily, since 2012 from *Global Fishing Watch*)
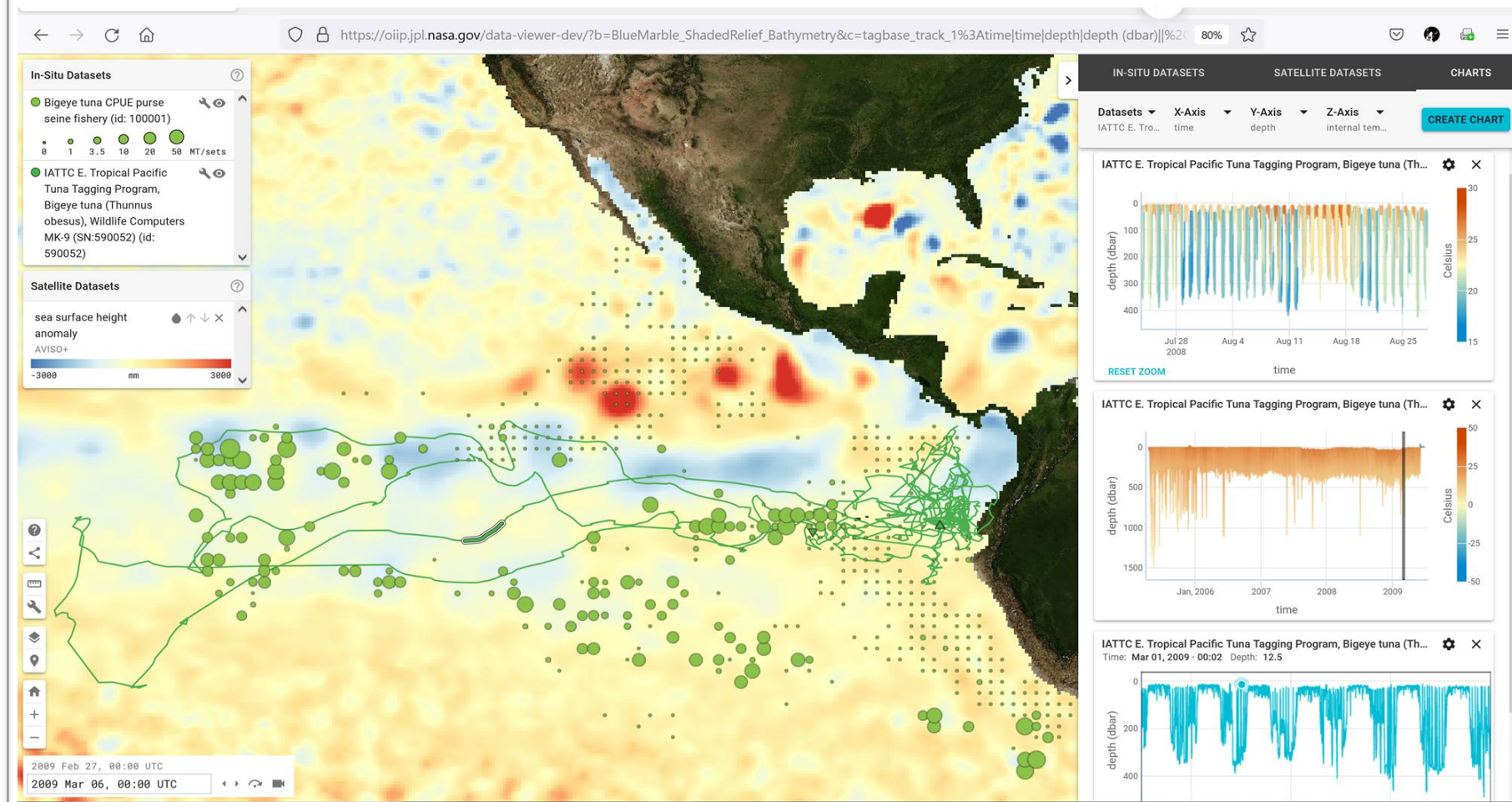
Stakeholder Agencies eg.
- RFMOs
- NOAA/NMFS
- GEO-MBON
- GEO-Blue Planet

COVERAGE
CEOS Ocean Variables Enabling
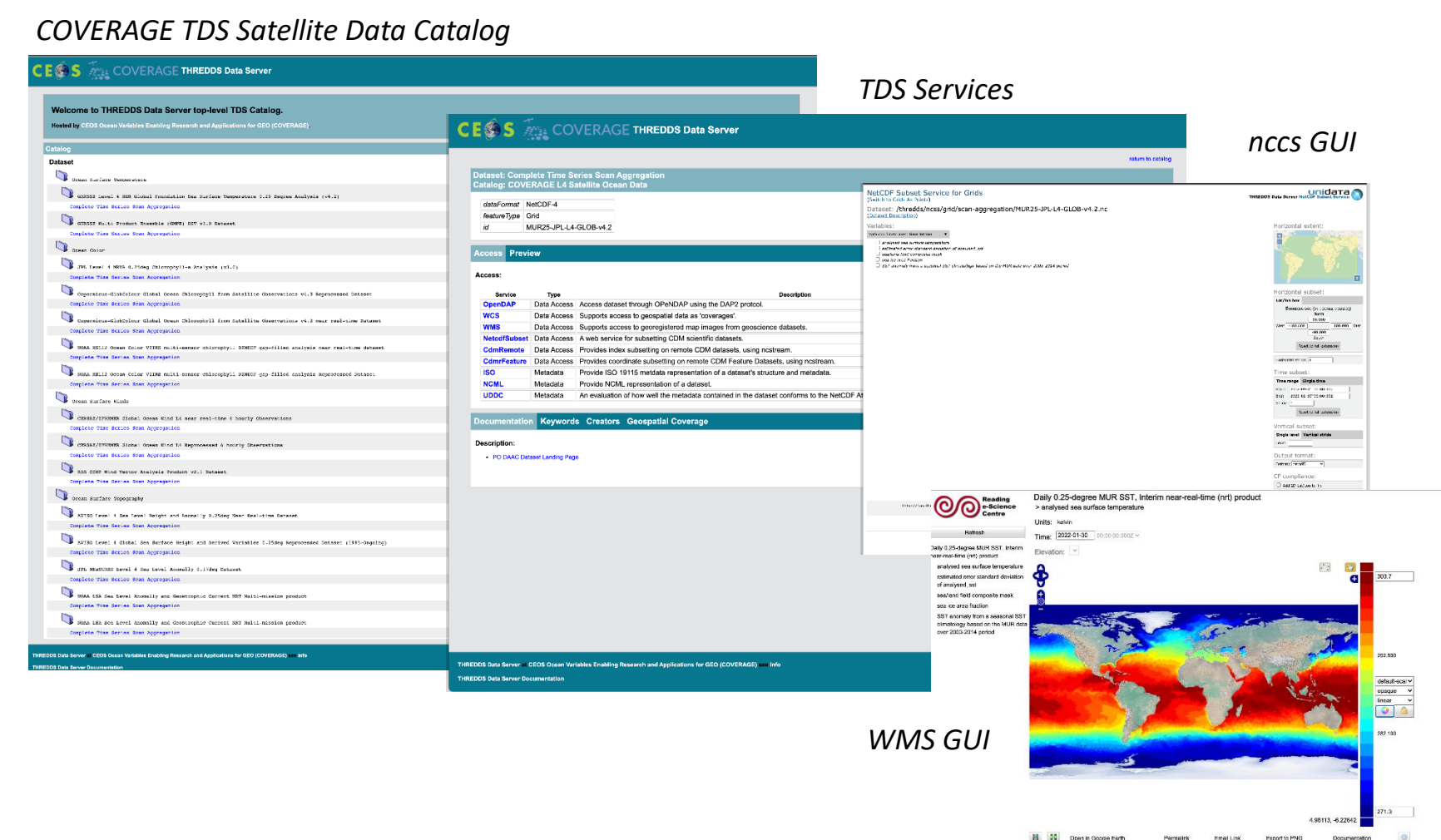Research & Applications for GEO

Web-based Data Visualization

- Integrated visualization of satellite & in-situ data
- Synchronized horizontal and vertical views of data and their evolution over time
- Integrated dataset Search
- "One-stop" Data Subsetting capability (both satellite & in-situ)
- Open Source: JPL Common Mapping Client
- What's Next: Analytics API integration

IATTC Bigeye Tuna archival tag & spatial catch distribution data relative to AVISO-SSHA and animal telemetry environmental measurements
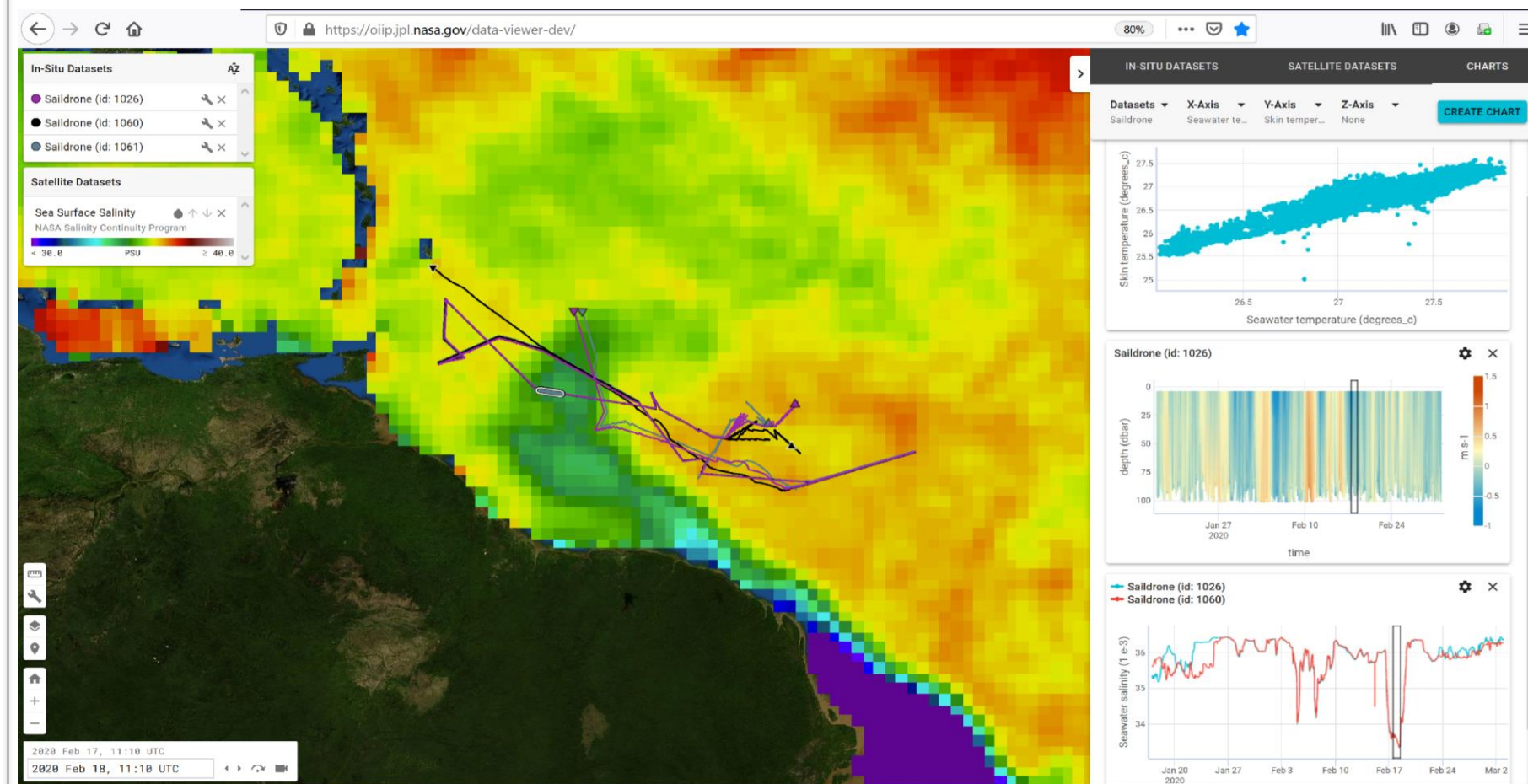
Saildrone ATOMIC cruise ADCP and CTD data overlaid on Sea Surface Salinity data from SMAP
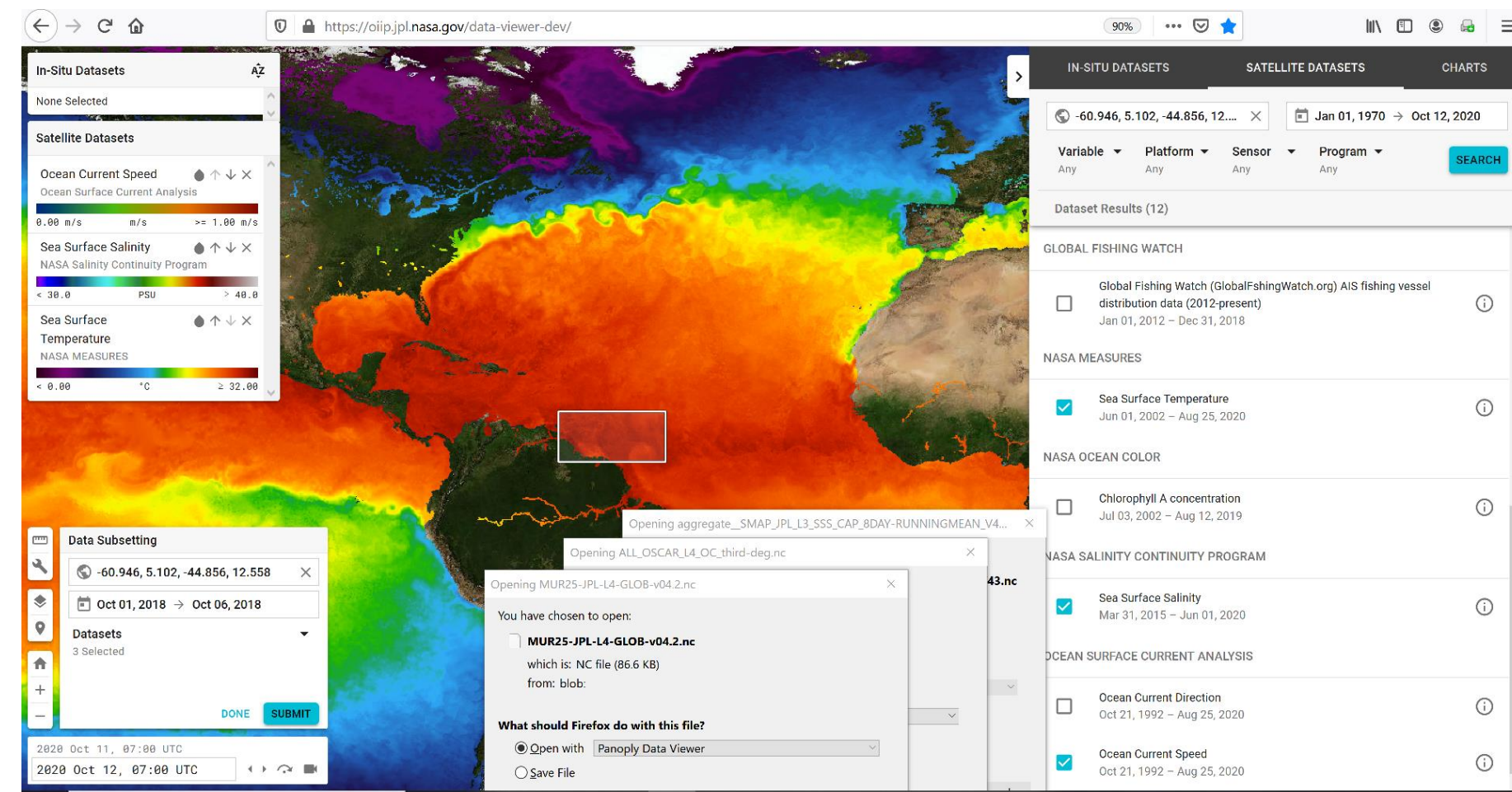
Integrated Data Search & Subsetting

Data Search

- Integrates Dataset Metadata from multiple repositories: e.g.
  - NASA/CMR
  - FedEO (CMEMS)
  - IMOS
  - CSIRO "Marlin"

- Features
  - Keyword search
  - Facetted search filters

- Returns dataset descriptive & access point information

Analytics Cloud Services

SDAP WEkEO Deployment Instance

- 3 Worker Nodes
  - Parallel computations
  - Tiled data store
  - Rapid geospatial search and tiled data retrieval
- 1 Master Node
  - Web tier
  - Job request handler / orchestrator

Client Host at JPL
- Jupyter Notebook
- Issue web service requests to SDAP

- Science Data Analytics Platform (SDAP)
- Open Source : http://sdap.apache.org
- "Enabling Big Data Science Without Download"

- Cloud Deployments:
  AWS (JPL) & WEkEO (EUMETSAT)
- Interfaces:
  Jupyter notebooks & APIs

TDS OGC Services

- Powered by THREDDS v5 in the Cloud
- Deployed on both COVERAGE AWS and WEkEO nodes
- TDS catalogs accessing COVERAGE dataset granule repositories natively in S3 object stores
- Integration of forward data file stream on ongoing basis via COVERAGE "Harvester software"
- Supported TDS services/APIs: nccs subsetting, opendap, WMS, WCS, ISO metadata, and CDM-remote
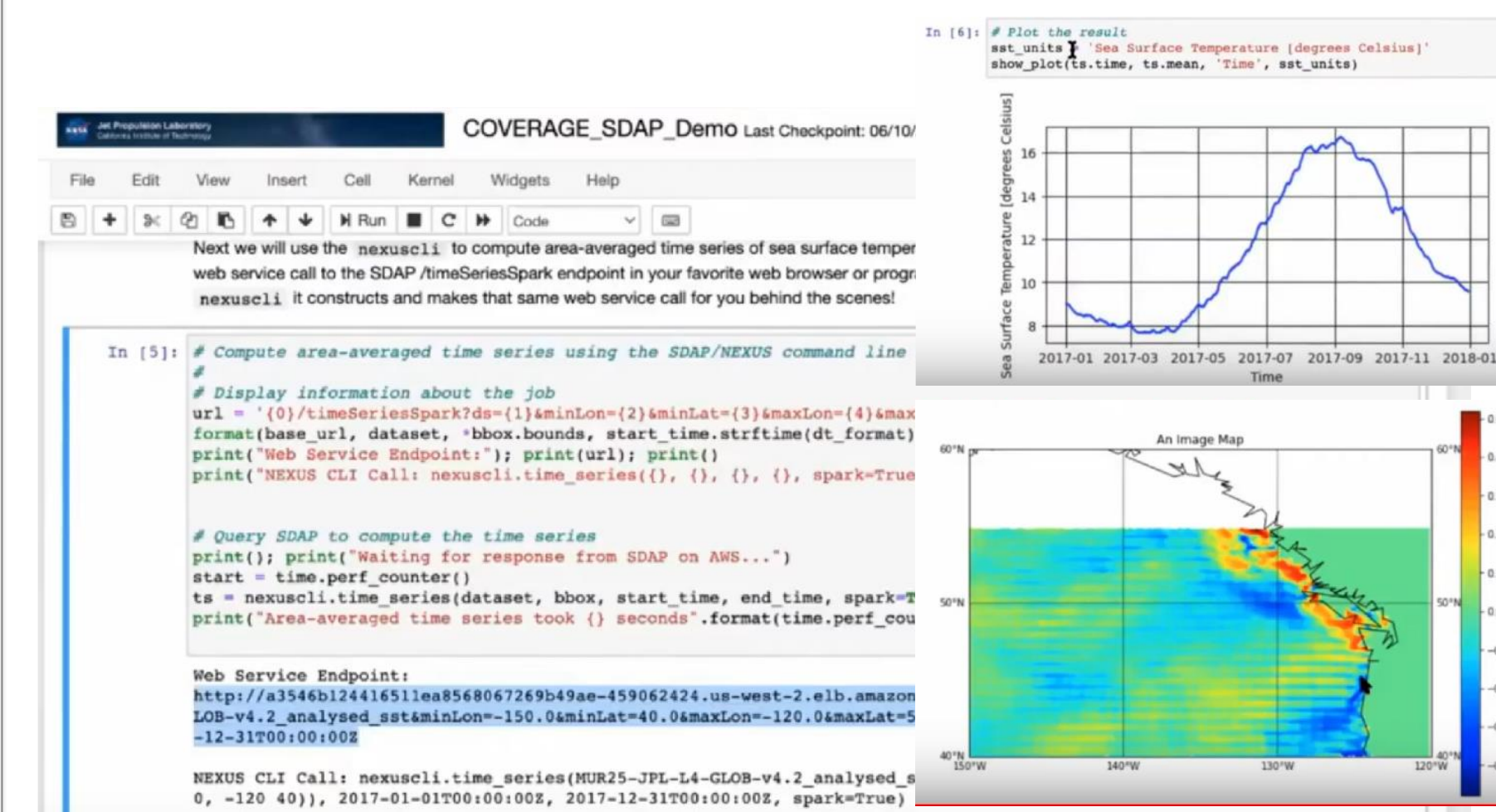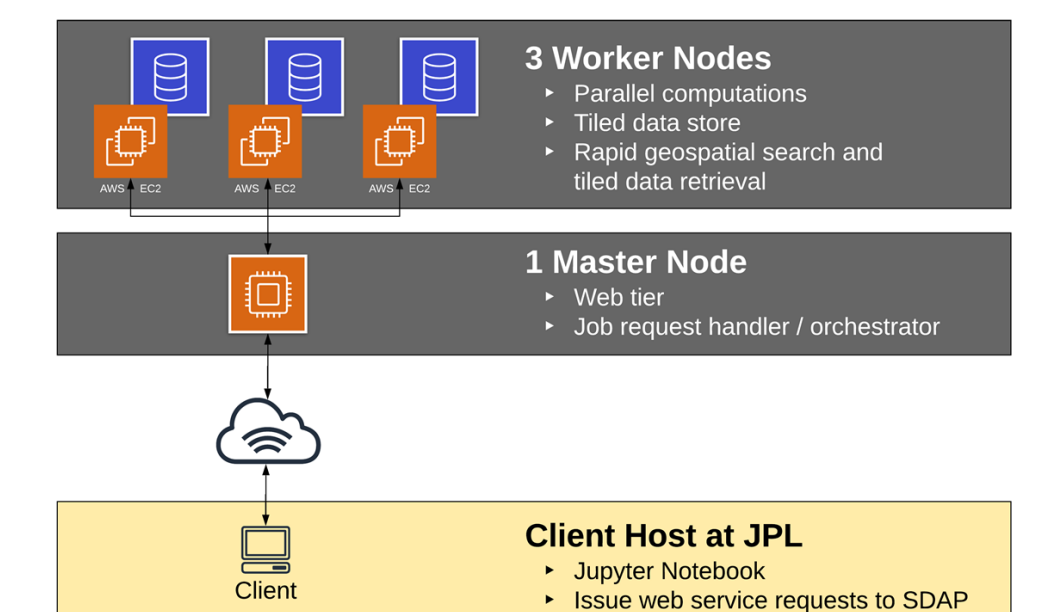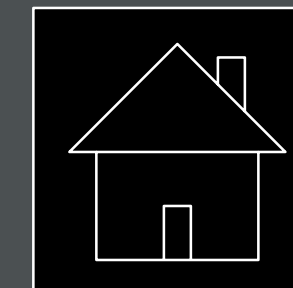- TDS-5 also provides support for in-situ discrete spatial geometry type data in addition to gridded data

COVERAGE TDS Satellite Data Catalog

TDS Services

nccs GUI

WMS GUI

COVERAGE — CEOS Ocean Variables Enabling Research & Applications for GEO

Development of the NASA/JPL L4 CHLA-MRVA Product

- L4 multi-mission CHLA MRVA product implemented: daily, NRT, gap-free CHLA and uncertainty fields
- "Sibling" product to popular JPL GHRSST MUR-SST 1km product (Mike Chin, JPL)
- MUR/MRVA wavelet-based algorithm allows accurate preservation of input data geolocations
- Useful dT flag: data integration time window (when set to zero product is L3)
- Currently based on L3 MODIS and VIIRS inputs (4km)
- Complete 0.25 degree series processed and integrated into COVERAGE services
- Technical Report (ATBD, Validation, Product specification)   https://coverage.ceos.org/l4chla25/
- Hi-resolution (1km) product development effort during Phase-C using L2 MODIS, VIIRS inputs - initial results very promising based on regional testbeds

For Phase C
- Update the above baseline dataset
- Include select additional datasets in support of regional Sargasso and ETP spinoffs

L4CHLA MRVA – *in situ* Comparisons

Saildrone Baja Campaign

SEABASS/NOMAD/MERMAIDS Matchup Database Comparisons

L4 CHLA Product Inter-comparisons

MRVA , Globcolour, NOAA-MSL12

Hi-resolution 1km prototype

Baja MRVA-CHL1km

Log CHLA (mg/m3)

Datasets - Season	Correlation	Bias (mg/m**3)	RMSD (mg/m**3)
MRVA/CMEMS - Winter	0.94	-0.0575	0.144
MRVA/CMEMS - Spring	0.94	-0.0484	0.147
MRVA/CMEMS - Summer	0.95	-0.0215	0.135
MRVA/CMEMS - Fall	0.94	-0.0485	0.149
MRVA/MSL12 - Winter	0.97	-0.0189	0.094
MRVA/MSL12 - Spring	0.97	-0.0191	0.112
MRVA/MSL12 - Summer	0.93	-0.0439	0.167
MRVA/MSL12 - Fall	0.95	-0.0210	0.132

COVERAGE Generalized *in-situ* Support Capability

- COVERAGE services can support full suite of in-situ spatial geometry data types (point, profile, trajectory series)
- Demonstrated support for Saildrone, IOOS-glider, USGS estuarine station series, and range of NASA SPURS field campaign datasets

Thematic Application Data Integrated During Phase B (publicly available)
- High seas monthly spatial catch/effort time series by species, aggregated spatially at 1 & 5 deg. spatial resolution, 1952-2018 from the 4 Tuna RFMOs
- Electronic tagging datasets: high resolution trajectory-profile series
- AIS fishing vessel movement data products by category (daily, since 2012 from *Global Fishing Watch*)

Baseline L4 Inter-agency Satellite Data for the Key Ocean Parameters Included
(NRT & delayed mode/historical series)

SST
- METOFFICE-GLO-SST-L4-NRT-OBS-GMPE-V3   (GHRSST-CMEMS/UK Met.Office)
- MUR25-JPL-L4-GLOB-v4.2   (GHRSST- NASA/Measures)

Winds
- WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_006   (CERSAT/IFREMER - CMEMS)
- WIND_GLO_WIND_L4_NRT_OBSERVATIONS_012_004   (CERSAT/IFREMER - CMEMS)
- RSS_CCMP_WINDS_V2.1   (NASA/Measures – RSS)

Ocean Surface Topography
- SEALEVEL_GLO_PHY_L4_NRT_OBSERVATIONS_008_046   (AVISO/CLS - CMEMS)
- SEALEVEL_GLO_PHY_L4_MY_008_047   (AVISO/CLS - CMEMS)
- SEA_SURFACE_HEIGHT_ALT_GRIDS_L4_..._JPL1812   (NASA/Measures - JPL)
- NOAA_LSA_SLA_GLOB_L4_NRT and DT   (NOAA/LSA)
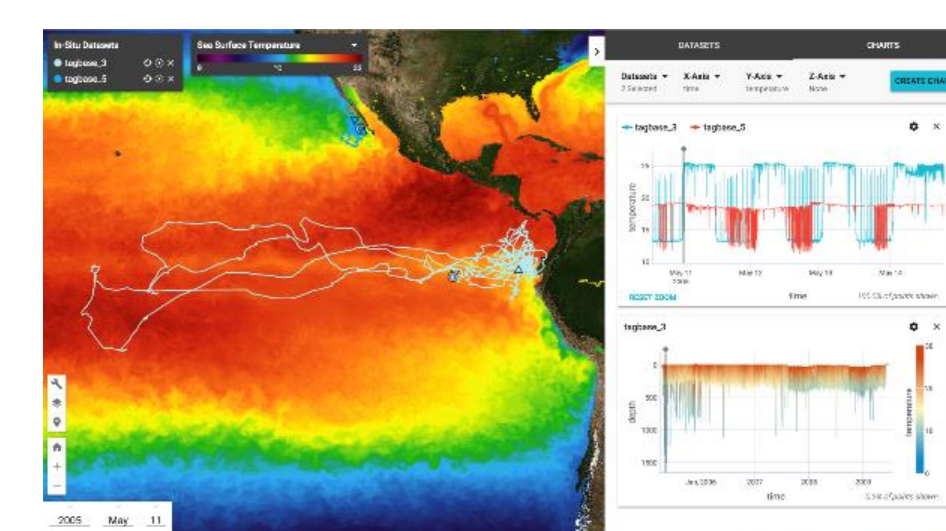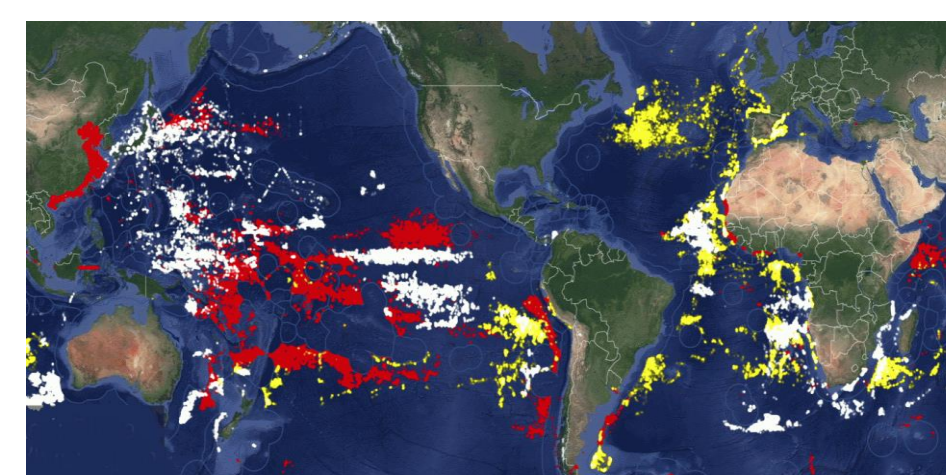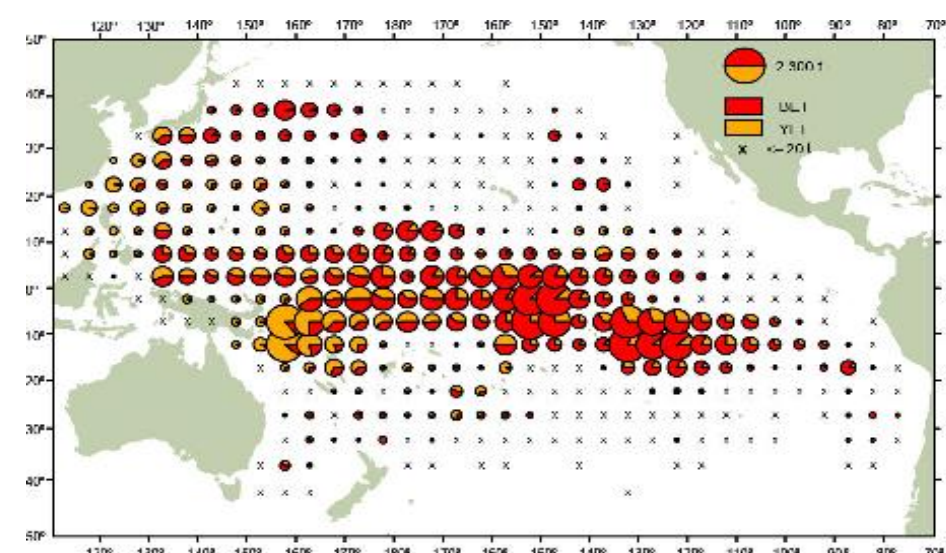
Ocean Color
- JPL-MRVA25-CHL-L4-GLOB-v3.0   (NASA/COVERAGE -JPL)
- OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_082 (Globcolour – CMEMS)
- OCEANCOLOUR_GLO_CHL_L4_NRT_OBSERVATIONS_009_033 (Globcolour – CMEMS)
- NOAA_MSL12-NRT-CHL-Daily-L4 and DT   (NOAA/Coastwatch)

Satellite-derived Ecological Products included in COVERAGE

GEO-MBON "SeaScapes" marine habitat classification monthly product integrated in COVERAGE Viewer

USF Sargassum Floating Algal Index Product
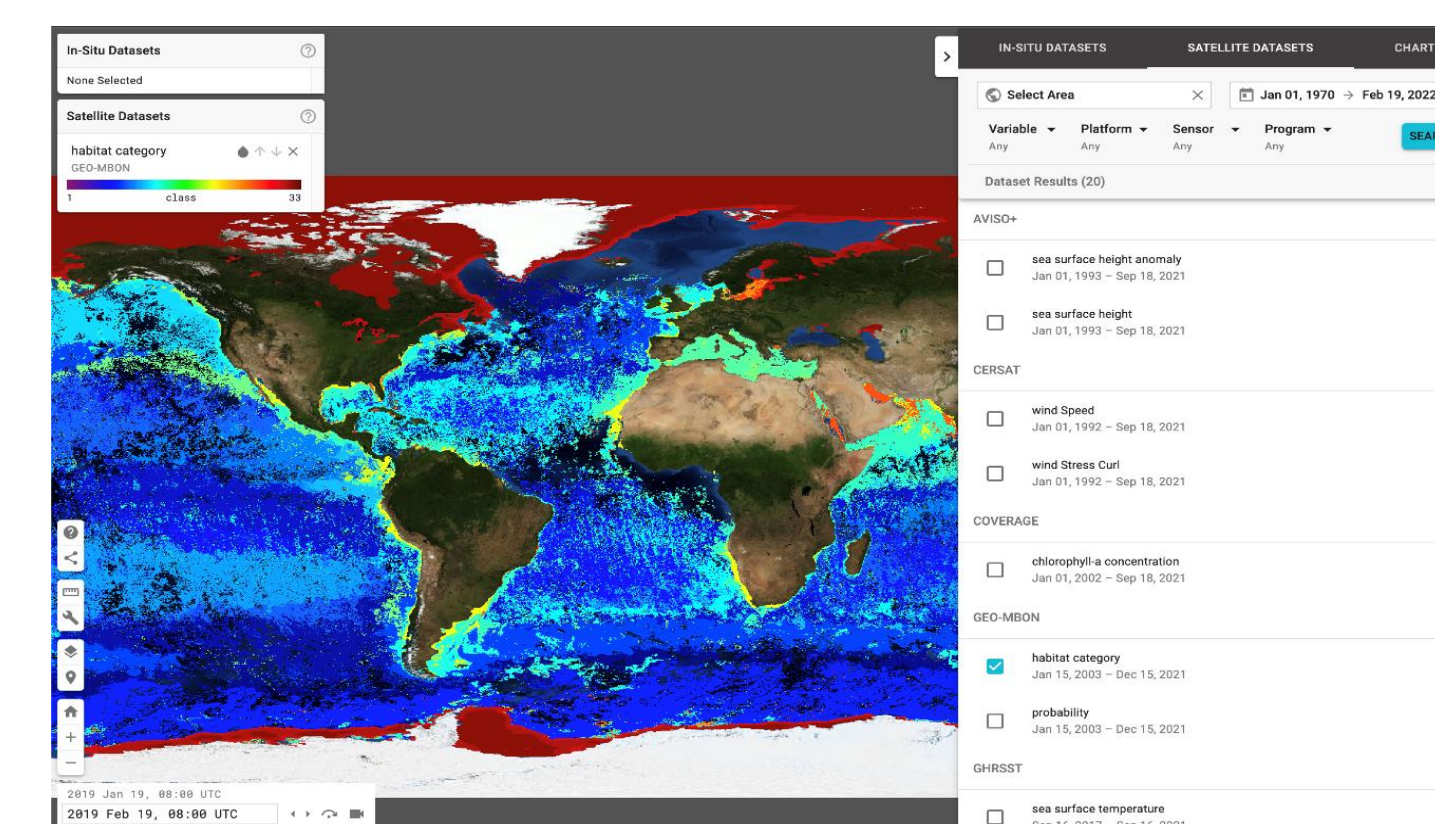
- *Served via NOAA-Coastwatch THREDDS*
- *Developed by M. Kavanaugh (OSE)*
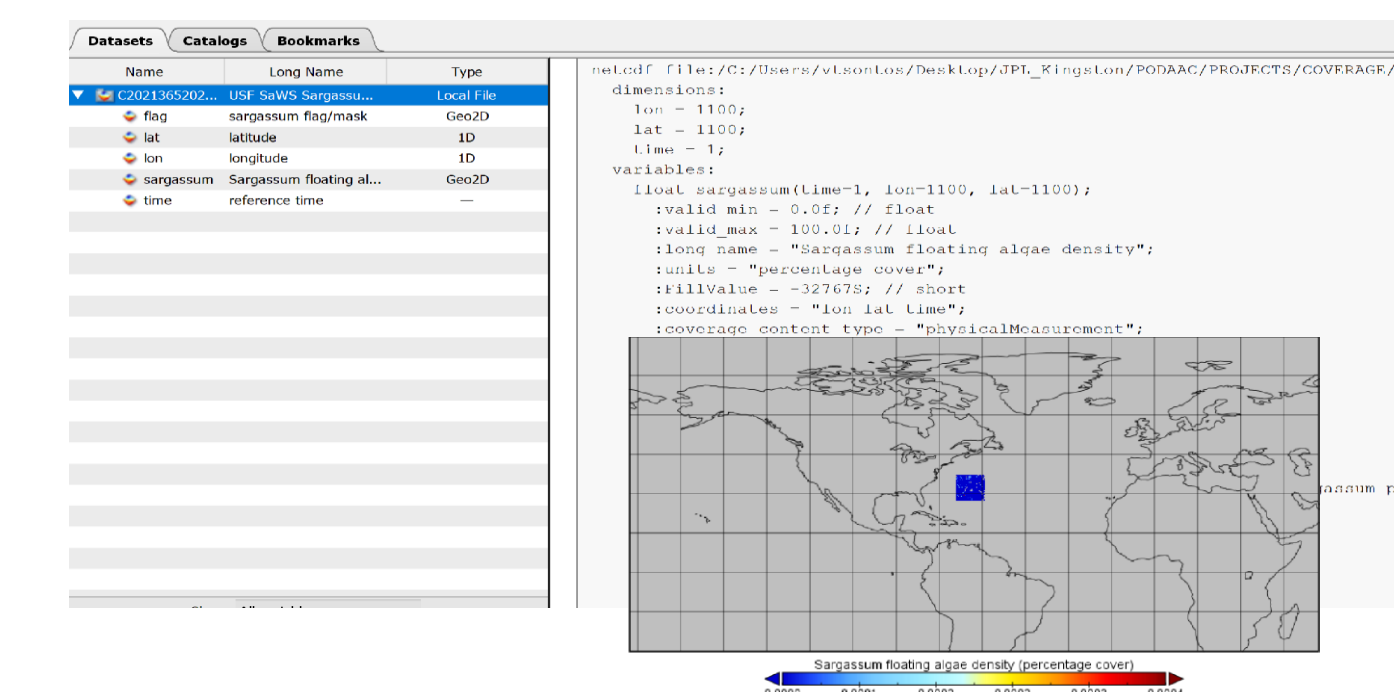
- *Developed by Chuanmin Hu- USF Optical Oceanography Lab*
- Available via USF Satellite-based Sargassum Watch System (SaWS) as PNG imagery for several regions
- *COVERAGE-USF collaborated to develop a netCDF-CF compliant dataset integrated into COVERAGE*

COVERAGE
CEOS Ocean Variables Enabling
Research & Applications for GEO

Sargasso Sea Commission

- Established by the 2014 *Hamilton Declaration* for conservation of the Sargasso Sea area of collaboration by 10 signatory nations
- Promote stewardship of the Sargasso ecosystem via work program and action plan development for this high seas area
- Multiple institutional partners, including NASA via COVERAGE since 2016

SSC multi-year, Global Environmental Facility (GEF) & FFEM funded projects
"Strengthening the Stewardship of an Economically and Biologically High Seas Area – The Sargasso Sea"

- Part of an overall global GEF Programmatic Approach entitled Common Oceans – Sustainable utilization and conservation of biodiversity in areas beyond national jurisdiction (ABNJ) involving 4 child projects under UN agency oversight (FAO, UNEP, UNDP) and linked to UN BBNJ treaty
- UNDP and IOC-UNESCO oversight roles (implementing and executing UN agencies)
- Future instrument supporting UN BBNJ Treaty (under negotiation) and High Seas Governance
- Complex, multi-faceted project involving:
  - Ecosystem Diagnostic Analysis (EDA), identifying trends and impacts from available environmental, biological and socio-economic data
  - Development and adoption ecosystem-based stewardship approach for the Sargasso Sea
- COVERAGE collaboration on SSC project
  - Regional spin-off application focusing on the Sargasso during Phase-C
  - Integrative data system enabling the production and communication of ecosystem indicators for scientific and policy assessments

SARGASSO SEA COMMISSION

Signatories:
Azores, Bermuda, Monaco, United Kingdom, United States, British Virgin Islands, Bahamas, Canada, Cayman Islands, Dominican Republic
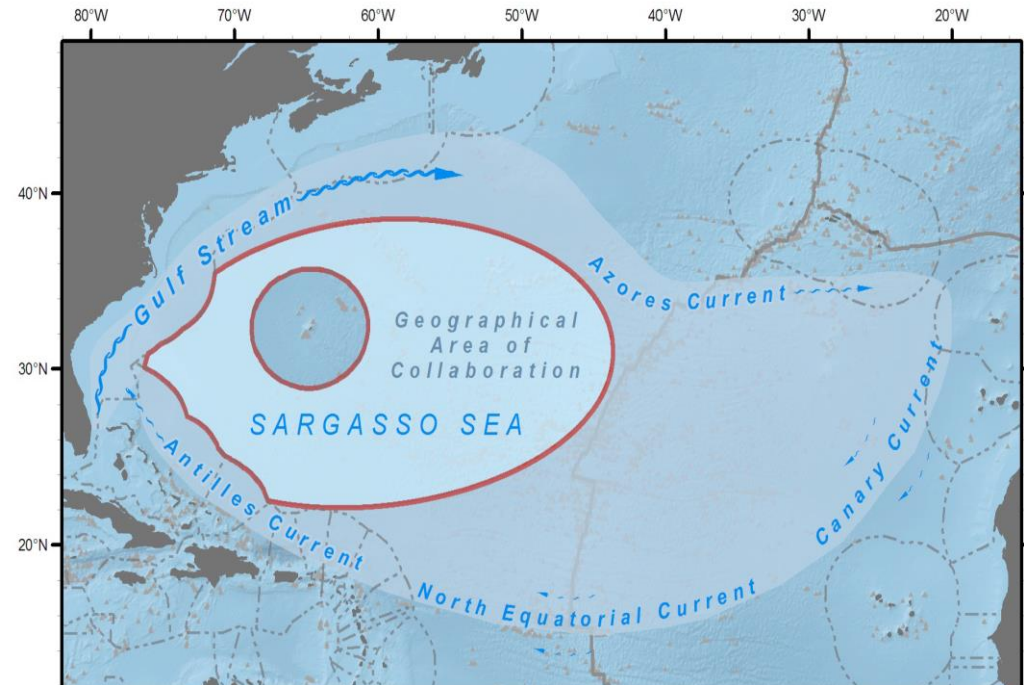
Inter-American Tropical Tuna Commission (IATTC)

- 21 Nation Intergovernmental Regional Fisheries Management Organization (RFMO)
- Responsible for the scientific assessment and management of Tuna and large pelagic fisheries in the Eastern Tropical Pacific (ETP)
- Potential applications of remote sensing data in fisheries investigations in support of *Dynamic Ocean Management*
  - Habitat analyses and changes in resource distributions under environmental regime shifts
  - Spatial catch forecasting
  - Fishery closed areas & Marine Protected Areas (MPAs)
  - By-catch mitigation (protected/vulnerable species)

COVERAGE collaboration with IATTC during Phase-C
- MOU signed between IATTC and NASA/JPL for a collaborative activity under COVERAGE
- Spin-off application for the Eastern Tropical Pacific to be developed during Phase-C
- Build upon prototype (Phase B) demonstration application based on publicly accessible RFMO data:
  - Augment with detailed Fisheries observer datasets and higher resolution remote sensing datasets
  - Support IATTC quantitative statistical analysis workflows via COVERAGE analytics capabilities
  - Recreate a published analysis use case to demonstrate end-to-end utility of COVERAGE
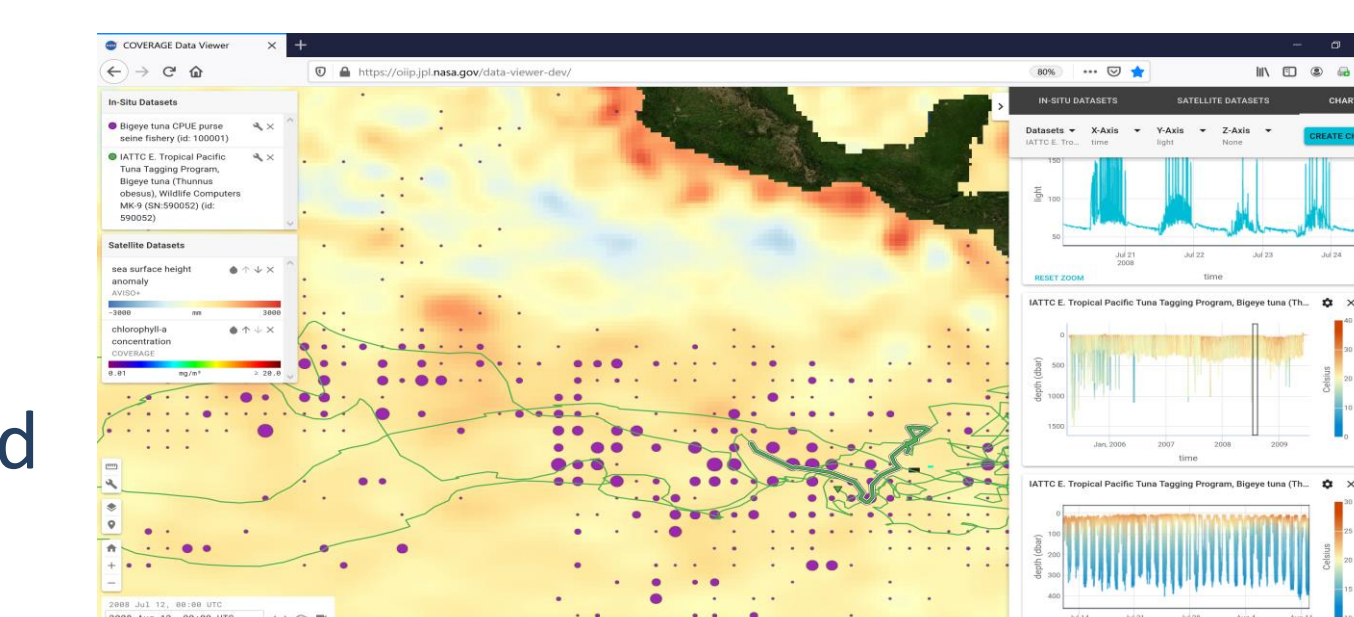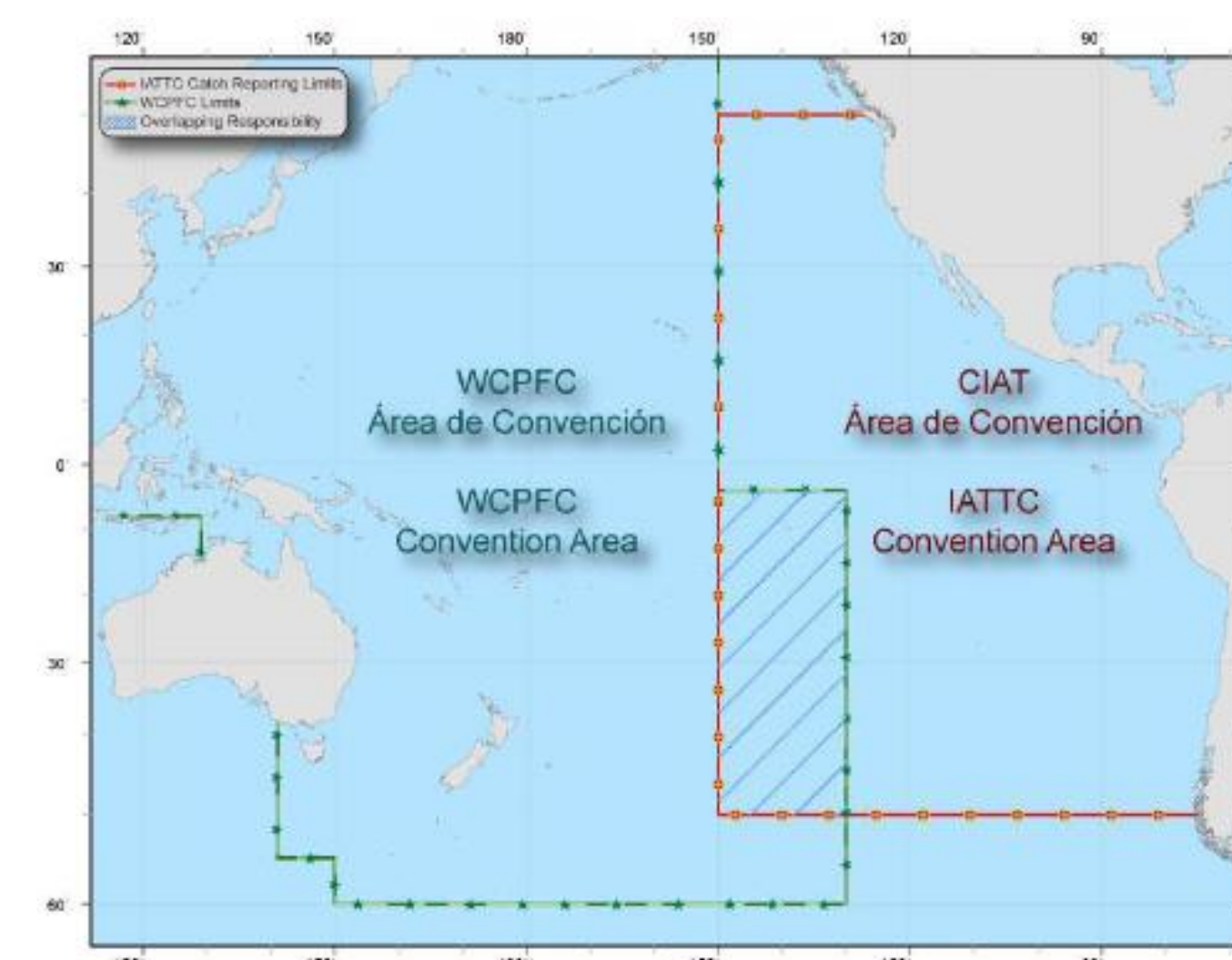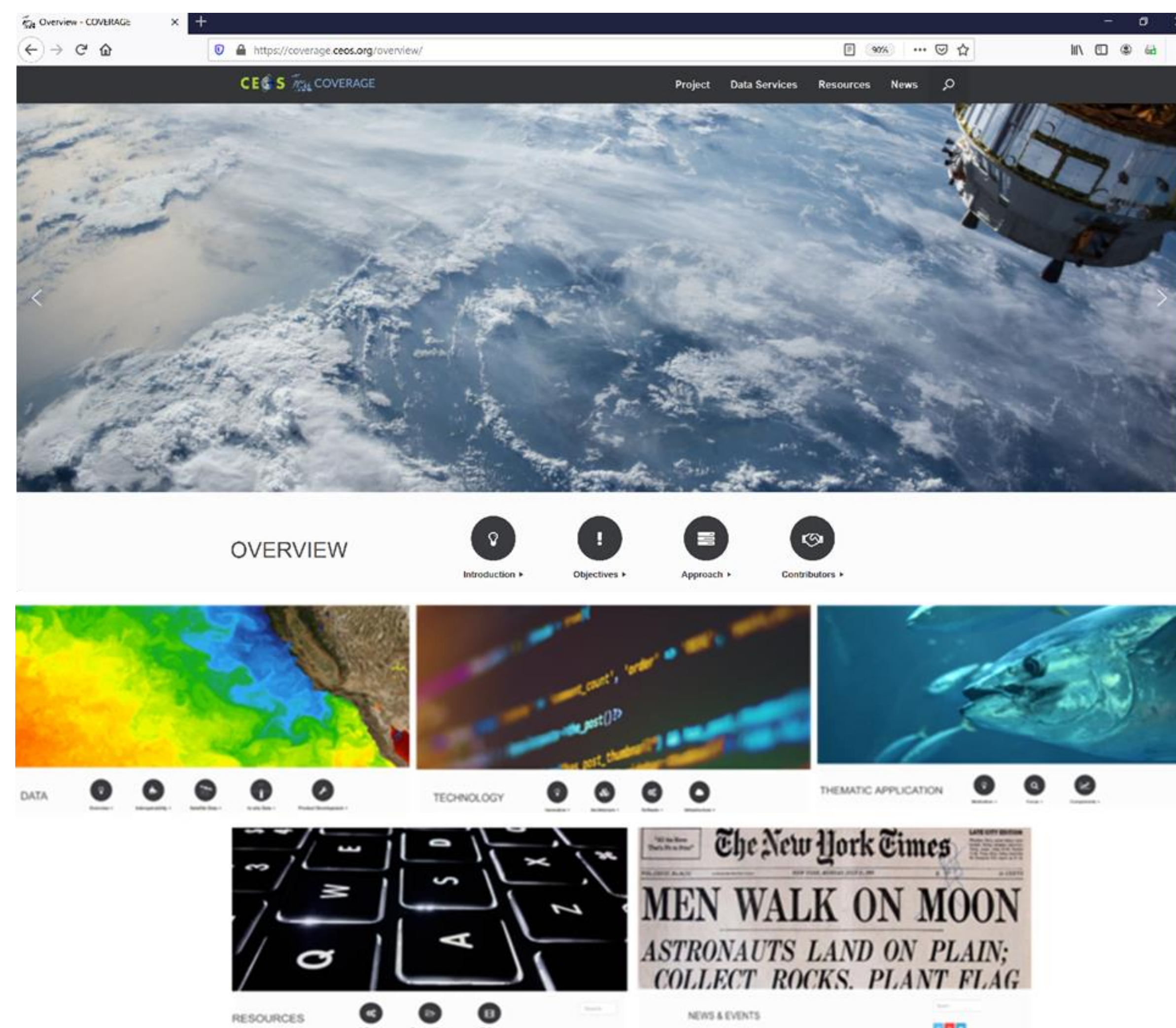

IATTC Bigeye Tuna archival tag & spatial catch distribution data relative to AVISO-SSHA and animal telemetry environmental measurements
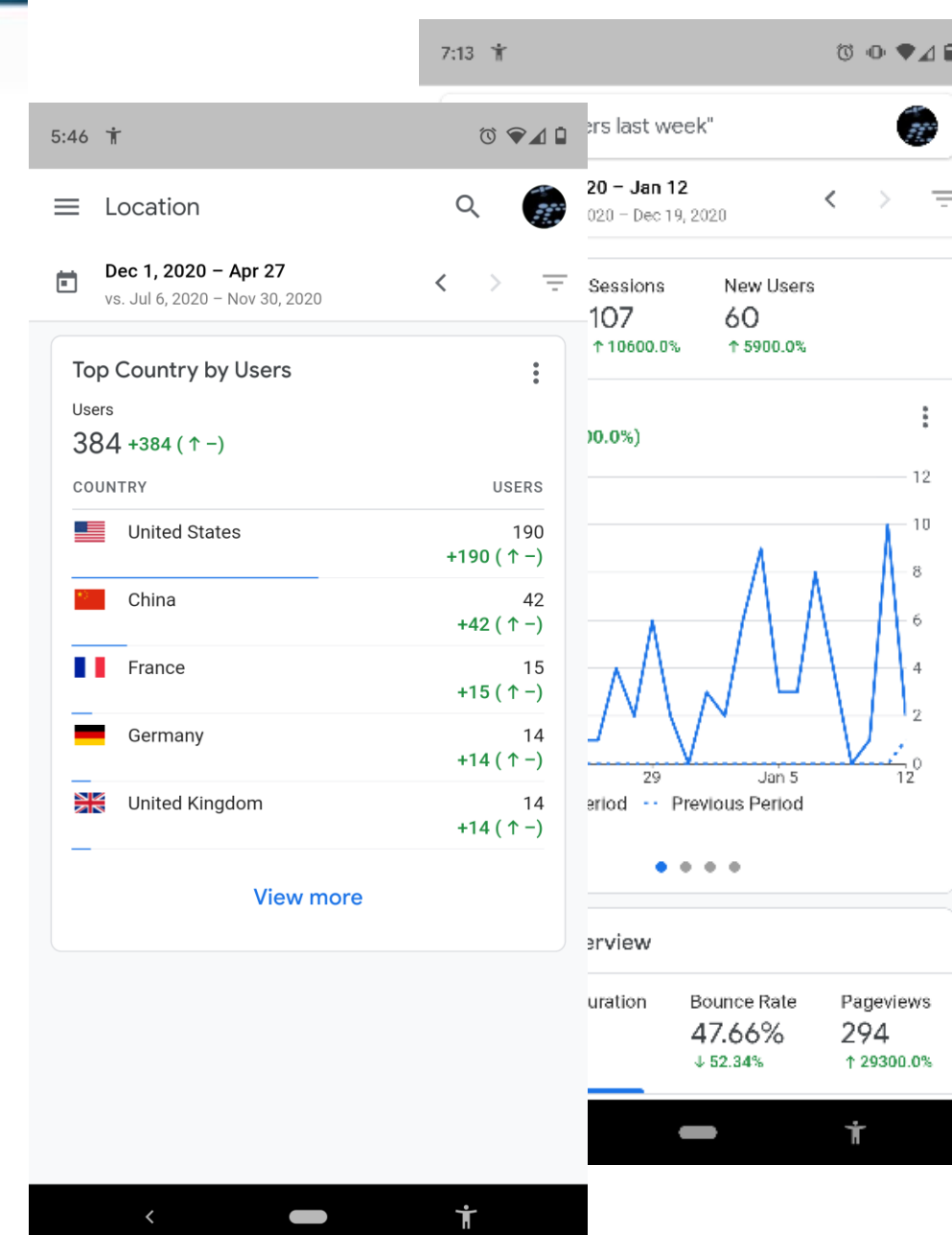
COVERAGE — CEOS Ocean Variables Enabling Research & Applications for GEO

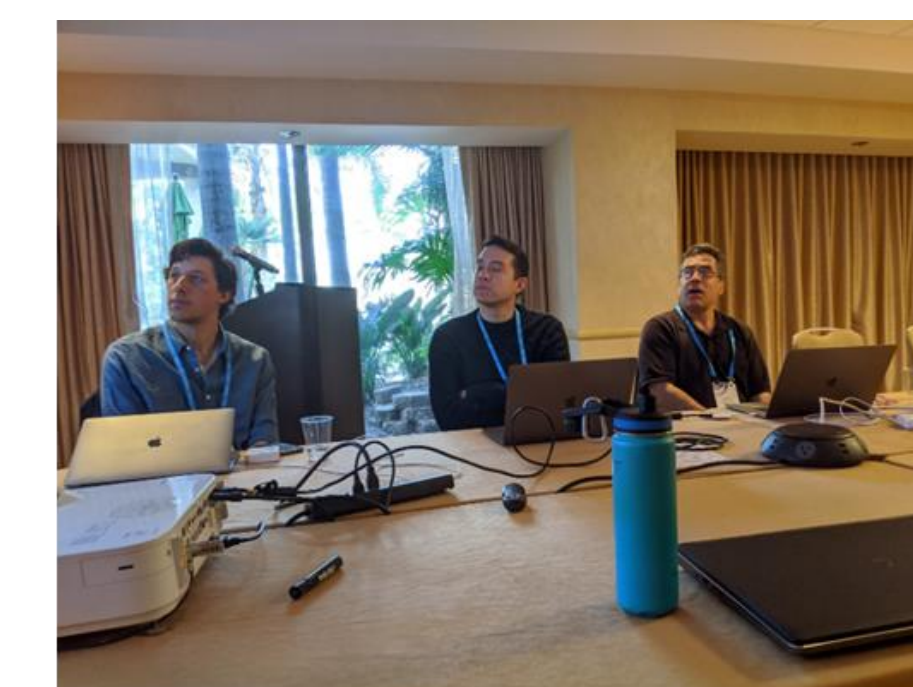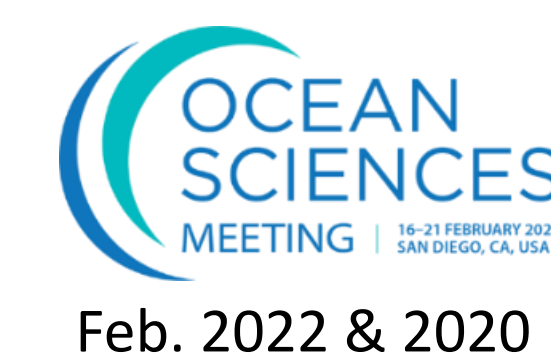## Web-Portal https://coverage.ceos.org

- Descriptive information on COVERAGE Initiative & Project
- Integrates Data services/tools
- Resources Area: project technical documentation, tutorial videos
- News Area: events & announcements
- Integrated COVERAGE you-tube channel & Twitter feed
- Detailed site usage metrics via Google Analytics integration

Community & Stakeholder Engagement

Workshop Events:

OCEAN SCIENCES MEETING 18–21 FEBRUARY 2020 | SAN DIEGO, CA, USA
Feb. 2022 & 2020

ESIP MAKING DATA MATTER
Jul. 2020

EUMETSAT
Aug. 2020

Conference presentations & Workshops
ESIP-Summer 2020, GEO-BON2020, Ocean Sciences 2020 & 2022, Fall AGU2019, WEkEO/CMEMS webinars

Stakeholder consultations: Advisory Board Meetings, CEOS, Agency partners: EUMETSAT, Sargasso Sea Commission (SSC), Inter-American Tropical Tuna Commission (IATTC), CSIRO, IMOS, US IOOS-ATN

Publications:
- Marine Technology Society Journal https://doi.org/10.4031/MTSJ.55.3.45
- Limnology and Oceanography Bulletin *(in press)*

https://twitter.com/coverage_ceos
Project announcements

https://tinyurl.com/coverage-channel
Demonstration/tutorial Materials