CEOS COAST

(Coastal Observations, Applications, Services &Tools Ad Hoc Team)

Phase 2 Implementation Plan

(February 9, 2021)

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GLOSSARY/ACRONYMS

4DAtlantic Regional Initiatives Science EBUS – Theme 1 of the ESA's 4D Atlantic Regional Initiatives Science
AHT- Ad Hoc Team
AltiKa GDR-F - Level-2 (L2) altimeter products of SARAL/AltiKa taking into account:a new orbit solution : POE-F instead of POE-E, a new range solution including Look Up Table correction, a new wet troposphere correction based on 3D ECMWF fields, a new 3D-SSB correction taking into account swell period in addition to SWH and wind.
ARD – Analysis Ready Data
ASCAT - Advanced Scatterometer (ASCAT) instrument aboard the EUMETSAT Metop satellites
AWS – Amazon Web Services
cal/val – Calibration and Validation activities
CARD4L – CEOS Analysis Ready Data for Land
CDOM – colored dissolved organic matter
CEOS – Committee on Earth Observation Satellites
CNES - Centre National d'Etudes Spatiales
COAST Coastal Observations, Applications, Services, and Tools
CONAI - Consorzio Nazionale Imballaggi.

COVERAGE - CEOS Ocean Variables Enabling Research and Applications for GEO
CSIRO - Commonwealth Scientific and Industrial Research Organisation (Australia)
Data Cube - multi-dimensional array of values
DE Africa – Digital Earth Africa
EAIL – Earth Analytics Interoperability Laboratory
EO – Earth Observations
EO4CZM - Earth Observation services for the Black Sea Coastal Zone Management
EPS - European Politics and Society
eReef – Great Barrier Reef data portal
ESA – European Space Agency
EUMETSAT - European Organisation for the Exploitation of Meteorological Satellites
FAIR – Findable, Accessible, Interoperable, and Reusable
FDA - Future Data Access
GA – Geoscience Australia
GEF – Global Environment Facility
GEO – Group on Earth Observation
GEO Blue Planet – GEO Initiative linking coastal and ocean information and society
GEO/LEO/SAR - Geosynchronous Earth Orbit/Low Earth Orbit/Synthetic Aperture Radar
GEOAquaWatch – GEO's Water Quality Initiative
GHRSST - Group for High Resolution Sea Surface Temperature.
GMES - Global Monitoring for Environment and Security
GOES - Geostationary Operational Environmental Satellite
HYDROCOASTAL – ESA's Coastal ocean and inland water altimetry program
INSAT - Indian National Satellite System
ISRO - Indian Space Research Organisation
JAXA - Japan Aerospace Exploration Agency
JPSS – Joint Polar Satellite System (United States)
L2 – Level 2, products derived from Level 1 B data
LEGOS - Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (CNES)
LSI-VC – Land Surface Imaging Virtual Constellation (CEOS)
NASA - National Aeronautics and Space Administration (United States)
NOAA – National Oceanic and Atmospheric Administration (United States)
VIIRS - Visible Infrared Imaging Radiometer Suite Instrument
OLCI – Ocean and Land Colour Instrument (Sentinel)
OM – organic matter
SAR Synthetic Aperture Radar
SDG – Sustainable Development Goal
SEO Systems Engineering Office (CEOS)
SL – Sea Level
SLSTR - Sentinel-3 instrument that provides a reference Land Surface Temperature and Sea Surface Temperature dataset for climate data records
SME – Subject Matter Expert
SRAL/MWR instruments
SST Sea Surface Temperature

SWH – Significant Wave Height
SWOT – Surface Water and Ocean Topography altimetry mission .
TSI products - Trophic State Index
UNEP - United Nations Environmental Programme
USGS – United States Geological Survey
VC – Virtual Constellation (CEOS)
WaveFoRCE - Wave-driven Flood-forecasting on Reef-lined Coasts Early warning system
WG – Working Group
WGCapD – Working Group on Capacity Building and Data Democracy (CEOS)
WGCV – Working Group on Calibration & Validation (CEOS)
WGDisasters – Working Group on Disasters (CEOS)
WGISS – Working Group on Information Systems and Services

Introduction

Background of COAST Ad Hoc Team and Phase 1 Effort

Timely, accurate and sustained observations for coastal zones are essential to address existing and emerging societal issues, needs and concerns, from coastal resiliency, flood forecasting, and disaster recovery to habitat monitoring, eutrophication, water quality and assessment of climate change impacts. With robust calibration/validation and fit for purpose application of data and derived products, satellite remote sensing is an effective tool to help understand, monitor and forecast changing conditions in coastal zones globally, particularly across the land-sea interface.

To this end, CEOS COAST Phase 1 Study Team efforts identified and prioritized user-driven observing needs, issues, information gaps, and the observational trade space for COAST Pilot Projects that could be implemented in a timely, efficient and cost-effective/resource-leveraging manner; see COAST whitepapers available at https://ceos.org/ourwork/ad-hoc-teams/ceos-coast/.

This was accomplished by engaging CEOS members about agency priorities and attendant stakeholder needs, likewise partnering with relevant GEO initiatives and other international organizations (e.g. Custodian Agencies for the U.N. Sustainable Development Goals - SDGs) as part of extensive COAST team led co-design and co-development activities.

These efforts helped to identify priority user-driven observing and information requirements, with scoping of essential coastal observation types and identification of representative coastal supersites and systems wherein the technical details, data gaps, and coordination complexities can be identified and fully addressed and resolved prior to subsequent global-scale implementation across all coastal zones.

The COAST Phase 1 White Papers as above detailed specific challenges and opportunities that CEOS will address in this context, working to facilitate technology transfer from developed to developing nations, identifying high priority, at-risk (natural and/or anthropogenic impacts and

hazards) coastal sites at both continental scales as well as small island developing states that collectively can be used as pathfinder systems to scale up to full global implementation.

The diverse COAST membership will leverage observing systems and broader technological capacity that already exist within CEOS, as well as support planning for future space-based platforms and new and improved measurement capabilities. Engaging other observing system partners to ensure user needs are successfully met by the COAST Pilot Projects will be crucial, particularly other data and information providers such as IOC/GOOS and WMO. These partners will provide essential field measurements et al. to complement the multi-sensor satellite data.

Likewise, these observations will need to be complemented by modeling, data assimilation and the forecasting/prediction capabilities afforded by key partners such as OceanPredict, including the CoastPredict Initiative that has recently emerged from OceanPredict. CoastPredict and CEOS-COAST have both been submitted for consideration as Programmes for the UN Decade for Ocean Science for Sustainable Development (2021-2030), and CEOS COVERAGE has submitted as an "Ocean Shot." Extensive collaboration with these, and other, coastal-related Decade Programmes and activities is anticipated.

Tapping into the wealth of existing and planned Earth observations (likewise complementary socio-economic observations) held by diverse international partners, assembling the supporting technical infrastructure to incorporate diverse data types into development and operations, and adopting GEO Data Sharing Principles and FAIR data principles, will all be crucial for the success of the COAST Phase 2 activities. This document outlines the team work plans for the next two years (2021-2022).

Criteria for selection of Pilots and locations

The COAST members assembled and reviewed the list of criteria (available upon request) to be used to arrive at the final pilot focus areas as well as the geographic locations for the two pilot projects. Emphasis will be placed on choosing pilot areas where sufficient data exists or can be easily acquired to execute the pilot project during the 12-month Phase 2 period and where there is interest in space agencies to contribute to or lead the project. Areas of mutual interest to other CEOS entities would facilitate both cross-collaboration and leverage resources and expertise.

Master Communication/Change Management Plan

At a minimum, COAST Pilots will follow the Master COAST Communication and Change Management Plan to be completed by Spring/Summer 2021 and appended with the outcomes of the proposed GEO/CEOS Virtual Workshop. The Plan will identify responsible points of contact for each pilot for communications and change management. At a minimum, each pilot will each create and maintain 1.) a master stakeholder list with names, affiliations, contact and the preferred method and frequency of contact for updates and outcomes, 2) a comprehensive list of user needs and specific, measurable requirements; and which lists the top 5 priority requirements to be met by COAST in a Phase 2 product developed, 3) a change log to document any changes

made that result in the top 5 priority requirements not being met in Phase 2, and 4) a formal acknowledgement process where the COAST leadership is made aware of any changes that result in the top 5 priority requirements not being met during Phase 2.

COAST - Sea Impacts to Land Pilot

The Sea Impacts to Land Pilot has four focus areas: physical oceanographic forcing (sea level, waves, tides et al.) in the coastal zone, nearshore bathymetry, coastal characterization (mapping shorelines and intertidal and inland coastal elevations), and coastal flood maps. Accurate satellite-derived physical oceanographic parameters, as well as bathymetry, shoreline mapping products and flood maps are now readily available through a variety of remote sensing satellites and sensors (e.g., Sentinel series, GOES, JPSS, Landsat) and ample validation data sets are also available in some pilot areas. The need for high accuracy, lower latency products (although perhaps not daily) is integral to evaluating ecological response to sea-level rise and more human-centric concerns such as shoreline erosion, sediment transport, resource extraction, navigation safety, spill responses, and legal claims for native/indigenous people.

A. Implementation Planning
   i. Introduction - Planning in Phase 2 will initially be open to any volunteer stakeholders on the team who wish to participate and represent their space agency or CEOS WG/VC/AHT and will include relevant external stakeholders identified in the selected pilot area (including but not limited to: identified product and data information users in the pilot area, other public or private data or product providers, academic researchers, social scientists and economists to the extent possible on a volunteer basis).

      Phase 2 stakeholder engagement planning will be enabled through a GEO/CEOS Virtual Workshop to be held in the first half of Phase 2. One key outcome of the Workshop will be a documented list of requirements for any products, tools, and services developed by COAST. This list will guide product development. Stakeholder engagement should also document the frequency and best method to inform each stakeholder about ongoing progress and training users to access the products and services developed by COAST.

   ii. Purpose - Goal: The primary stakeholder requirement is development and application/use of the pilot project product(s) tools and services in pilot region(s) to measurably improve remotely sensed physical ocean properties and coastal mapping including bathymetry and shoreline characterization.

iii. Implementation goals -

Physical Ocean Parameters - Coastal Sea Level, Sea State, Sea Surface Temperature

Goals: To implement a prototype fully validated data product system of physical oceanographic parameters (Coastal Sea Level (SL), Sea Surface Temperature (SST) and Sea State, primarily Significant Wave Height (SWH)) for a few selected pilot sites.

Towards these goals ISRO will work with AltiKa GDR-F product for sea level and SWH for the coastal sites in Bay of Bengal. These data (generated by CNES) will be validated against the available in situ observations and finally accuracy statistics will be made available to the researchers so that they can have confidence in these newly generated products for coastal applications. Apart from this, we can make available fully validated data-assimilative wave model outputs for the Indian coastal regions to the researchers. ISRO generates SST products at 4 km spatial resolution from INSAT (geostationary) series of satellites. This product at the moment is not a part of GHRSST. As a standalone product, we can provide this information. If SWOT comes up during this timeframe, will work on SWOT sea level and currents near coastal regions, and assess its validity.

ESA will perform similar activities in the frame of existing or planned Research and Development contracts such as HYDROCOASTAL (coastal ocean and inland water altimetry and other sensors for interaction between river discharge and coastal dynamics), Coastal Erosion 1 and 2, Sentinel Coastal Charting Worldwide, Sentinel-2 for Land and Water (Coastal and Inland Waters Theme), SL_cci+ (Coastal Sea Level), SS_cci+, SST_cci+, World Ocean Circulation (Mediterranean Sea), Earth Observation services for the Black Sea Coastal Zone Management (EO4CZM), 4DAtlantic Regional Initiatives Science EBUS (Eastern Boundary Upwelling Systems) and Coastal Hazard. The access to the Coastal Thematic Exploitation Platform can support these goals.

CNES will also contribute to these goals with its existing or planned Research and Development contracts.

EUMETSAT provides Copernicus marine L2 products from the Sentinel-3 dual constellation and Sentinel-6 satellites. Sentinel-3 missions provide accurate products in coastal areas from SRAL/MWR instruments (sea level anomaly, significant wave height and wind speed), from SLSTR instrument (sea surface temperature), and from OLCI instrument (ocean color). Sentinel-6 Michael Freilich satellite was successfully launched on 21 November 2020. The early performance from the Poseidon-4 altimeter is excellent and, after an 11-month commissioning phase, the mission should be declared operational, taking over from Jason-3 as the new reference altimetry mission. In the coastal zone, the new capacity of the Sentinel-6 mission radar altimetry will be particularly useful for understanding storm surges and will allow a better estimation of global and regional sea level rise, wave height and wind speed. EUMETSAT's EPS Programme also provides accurate wind vectors from ASCAT A, B and C C-band scatterometers.

NOAA provides a wide range of direct and derived measurements of coastal sea level data, including contributions to the Argo array, tide gauges in the GLOSS network, and satellite data. NOAA is also a partner in the reference radar altimetry missions, Jason-3 and Sentinel-6, and collaborates with EUMETSAT on developing and maintaining the Radar Altimeter Database System (RADS) as a source of data from all altimeter missions. At a higher level, NOAA provides coastal sea level information for stakeholder planning including a sea level rise viewer (https://coast.noaa.gov/slr/). To develop better stakeholder information, a team that includes representatives from several NOAA line offices has started a collaboration (RISE) with a team from the NASA Jet Propulsion Laboratory with a goal of co-developing coastal sea level predictions and projections.. The collaboration has defined a five-year work plan for regional projections of future relative sea level change from present to 2100, regional predictions of future sea level change on seasonal to decadal timescales, and contemporary rates of vertical land motion at each location across the globe.

Assumption: Retrieval/model accuracy for the above products is as per the standards.

Risks: Availability of the in situ data for validating the above products. If the in situ data set is not fully available over the study regions, in that case inter-satellite comparison would be a fall back option.

Bathymetry - 2 goals: 1) Publish a whitepaper of CEOS-wide coastal bathymetry describing the State of the science. 2) Identify prototype data

products and evaluate the optimal pathway to open-source product development/improvement. 3) Establish and build relationships with end users and partners in the pilot areas to sustain any products developed into the transition to operational phase. It is assumed that existing prototype bathymetry data products and available cal/val data will be of sufficient value to select one to improve as part of the effort to reach the Phase 2 goals. It is also assumed that available CEOS - GEO outreach and capacity building partnerships, and those that arise from a planned joint Stakeholders Engagement workshop will be sufficient to reach Phase 2 goals. The risks for this approach are: no CEOS member agency is willing to assume a leadership role in development of this product for Phase 2 tasks, the available cal/val datasets are insufficient to produce a quality data product that meets identified end users' needs in Phase 2.

Coastal and Intertidal Mapping - Phase2 goals: 1) Produce shoreline mapping and Intertidal elevation examples for pilot areas. 2) Establish/build relationships with end users and partners in the pilot areas to sustain products into the transition to operational phase. It is assumed that existing demonstration products and available cal/val data will be of sufficient value to users in the pilot areas to reach the Phase 2 goal. It is also assumed that available CEOS - GEO outreach and CEOS-level or agency-level capacity building partnerships, and those that arise from a planned joint Stakeholders Engagement workshop, will be sufficient to reach Phase 2 goals. The risks for this approach are minimal since it has been successfully demonstrated in Australia by Geoscience Australia and the same core team has interest in shepherding the transfer of that successful product to the W Africa coastline pilot areas for Phase 2 tasks and have established an early network of users and partners for sustainment in Africa. A remaining risk is if the available cal/val datasets are insufficient to produce a quality data product that meets identified end users' needs in Phase 2.

Flood/inundation maps - Phase2 goals: 1) Build an application for new or improved coastal flood maps for *continental* pilot areas. 2) Acquire ground truthed flood contours dataset for *island* pilot areas. 3) Establish and build relationships with end users and partners in the pilot areas to sustain products into the transition to operational phase. It is assumed that existing flood map data products exist for some pilot areas or can be successfully transferred to pilot areas if they do not exist; and that available cal/val data will be of sufficient value to improve and reach the Phase 2 goal. It is also assumed that available CEOS - GEO outreach and capacity building partnerships, and those that arise from a planned joint

Stakeholders Engagement workshop will be sufficient to reach Phase 2 goals. The risks for this approach to Phase 2 tasks for some potential pilot project areas is minimal due to ongoing coordination with CEOS WG Disasters and the leadership of several United States space agencies on key tasks, however, there is some risk if leadership is not found for the task to acquire a ground truth dataset for pilot project islands, or the available cal/val datasets are insufficient to produce a quality data product that meets identified end users' needs in Phase 2.

iv. Implementation recommendation -

The Sea Impacts to Land Pilot team comprises those COAST members representing agencies or WG/VC/AHT with identified projects supporting the products/tools/services being created and/or the geographic locations for the demonstration of the pilot(s) and user engagement. Nominally, these would include WGDisasters, WGCapD, WGCV, WGISS, COVERAGE, LSI-VC, USGS, GA, NOAA, NASA, ESA, ISRO, EUMETSAT, JAXA, and CNES/LEGOS, with specified leads to be determined for the implementation activities.

All the above have verbally committed active participation and/or resources to COAST to complete a successful Phase 2 product in the form of: team leadership, supplying expertise, data, computational capabilities, models, assembled user requirements, technology infrastructure, training expertise, and contacts to relevant stakeholders and user groups.

B. Implementation activities

i. Implementation activities listing

- Identify Data gaps in potential pilot areas
- Physical Oceanographic Products: Coastal Sea Level, Sea State, Sea Surface Temperature.
    - Description

      Implement a prototype fully validated data product system of physical oceanographic parameters (Coastal Sea Level (SL), Sea Surface Temperature (SST) and Sea State, primarily Significant Wave Height (SWH)) for a few selected pilot sites.

    - Tasks

      Compile a dataset inventory for each pilot site.

Generate a list of target data needed to support the products for the pilot sites, with all the needed metadata.

Sourcing of validation and supporting data from the pilot study locations.

Collaboration with local stakeholders to evaluate pilot study products.

- Bathymetry
  - Description

    Develop a satellite-derived product of the depth and contours of the area below the Mean High Water. Validate this product with available datasets referenced to a known fixed elevation. Also provide synoptic coastal bathymetry maps with greater spatial coverage but potentially of reduced accuracy and resolution.

  - Tasks

    Compile a dataset inventory for a given pilot location. This would include a list of target data needed to support the pilot, with information on volumes, source, format/metadata, interfaces, etc.

- Coastal Interface Characterization
  - Description

    The accurate characterization of the interface between land and sea is a crucial component of flood and inundation modelling studies, as well as providing important information for the management of issues such as coastal erosion and habitat conservation. However, coastal environments are constantly changing, and monitoring and mapping these dynamic regions with traditional surveying techniques or airborne surveys is challenging from both cost and logistical perspective.

    This activity aims to leverage publicly available satellite data from the Landsat and Sentinel 2 platforms to develop models which characterize ***a) the elevation of intertidal zone (the land exposed between high and low tide)*** and ***b) historical coastline and coastal change analysis***. This activity will be led by Geoscience Australia, in

collaboration with Digital Earth Africa (DE Africa), in-partner countries and other CEOS COAST members.

- Tasks

  Initial stakeholder engagement to determine suitable African pilot study locations, leveraging DE Africa and European Commission in-country activities and relationships (e.g., GMES and Africa).

  Sourcing of validation and supporting data from the pilot study locations.

  Porting of existing algorithm workflows from Digital Earth Australia to the DE Africa AWS infrastructure.

  Collaboration with in-country participants to generate and evaluate pilot study products.

- Flood/Inundation Maps -
  - Description

    A new WGDisasters GEO/LEO/SAR Flood Pilot was endorsed at CEOS Plenary 2020, which will explore and demonstrate good practices related to optical, SAR and geosynchronous data fusion and integrated methodologies for flood/inundation mapping at regional and local scales. The Flood Pilot Team will collaborate with COAST to identify several coastal case study locations, demonstrating improved methodologies that leverage and integrate optical (LEO and GEO) and SAR data sources, tailored to the unique challenges present in mapping coastal flooding/inundation.

  - Tasks

    Identification of several coastal focus areas (Odisha Coastal Plain, India and Mid-Atlantic coastal region, United States already identified).

    Document and improve access to and use of existing imagery, data access and processing technologies, and

community expertise for the mapping of coastal flood water extent from optical and SAR approaches.

Develop good practice documents that capture improvements of existing flood mapping methodologies and/or algorithms through the GEO/LEO/SAR integration approach.

Examine existing operational flood mapping capabilities (NOAA/VIIRS) in terms of specific coastal flood applications and share any lessons learned/recommendations in terms of improvement potential.

Improved estimation of flood vulnerability and risk using inputs from flood hazard maps, and additional available data sources.

Explore the use of the CEOS Earth Analytics Interoperability Lab (EAIL) and CEOS CARD 4L-compliant data sources, and document benefits of these developments in terms of coastal flood applications.

ii. High-level milestone/timeline chart

		2021				2022		
TASK	Dec	Apr	July	Sept	Dec	Apr	July	Sept
Sea2Land								
Select Pilot Geographic Boundaries								
Gather EO data sets								
Gather corrections, masks, algorithms								
Determine Quality Metrics and Use Case(s)								
Develop prototype product(s)								
Test Prototype product								
Demonstrate Prototype with users & implement feedback								
Product Release and Training								
Capacity Building for product								
CEOS Partner Co-led Community Coastal Projects								

iii. Implementation Team -

- Members - The entire COAST will be members, with specified leads to be determined for the implementation activities. Participation is expected especially by those representatives with expressed interest in the pilot product or pilot locations and who have committed resources (data, expertise, information, etc.) on behalf of their agency or WG/VC/AHT.
- Structure - Pilot activity leaders and interested team members will meet as needed to accomplish a Phase 2 deliverable testable by users within 12 months. Pilot activity leaders will meet with

COAST co-Leads about schedule adherence and key milestone progress quarterly, with high-level report-outs expected in written or oral form during monthly COAST meetings. To the extent practical, the collaborative workspaces and the cloud will be utilized to house the latest public version of Phase 2 deliverables. Products will be freely and openly available at the CEOS Agency level and incorporated in the WGISS EAIL. Products should be tested by an external independent quality review team or by the Activity Leadership for quality and meeting user requirements prior to initial product release; and also with identified users and other relevant stakeholders and partners at least upon the initial release of a Phase 2 satellite derived product(s), or at the end of the 2021 calendar year.

- Roles and responsibilities - Pilot activity leaders are responsible for day-to-day activity management, reporting, and execution of tasks as well as preparing calls for AHT assistance: contribution of data, subject matter expertise, testing or capacity building, and assistance with file transfer and document preparation as needed. COAST members are responsible for contributing timely and responsively to all Pilot Activity Leader calls for AHT assistance through interactions with your WG, VC, agency, or SME network.

iv. Implementation resources requirements Phase 2

- Dedicated Activity Leadership time
- User Requirements from available sources and GEO/CEOS Workshop (Summer 2021)
- Identification of partnerships for sustainment and users for capacity building
- Acquire relevant satellite and validation datasets for each pilot area
- Dedicated SME, hardware and software, data storage, and computational expertise to create, test and improve data products
- Testing and Quality Improvement Process
- Training and Capacity Development with users
- Transition to operations with users and/or receive user feedback and continue into Phase 3 tasks

v. Potential implementation locations - Flagships: Bay of Bengal, west coast of Africa, coastal Virginia/Chesapeake Bay (United States), Caribbean, and Pacific.

<u>Waveforce Flooding:</u>
Bahamas – NOAA plus WaveForce partners
Tahiti/Kiribati/New Caledonia – WaveForce partners

Continental Flooding:
Virginia/Chesapeake Bay - USGS, NOAA, NASA (includes models)
Bay of Bengal - ISRO

Other Ancillary/Underpinning Data Products (Bathymetry/Intertidal Elevations)
Bay of Bengal - ISRO (Bathymetry)
west coast of Africa - GA, DE Africa (Coastal Erosion and intertidal elevation)
La Plata (Backup Location) – GEF, World Bank, UNEP, CONAI recently has declined overtures by WGDisasters-Flood Pilot, but Paraguay and Chile have expressed interest

vi. Immediate action plan
- Identify Agency responsibilities for activities
- Determine activities and milestone deliverables
- Formalize Agency contribution of resources to tasks and activities

vii. Barriers and obstacles to implementation
- Risk and Dependencies - the risks of this pilot are low because products/tools and technology exist in one-to-several examples for bathymetry, shoreline mapping and coastal elevation (intertidal to supratidal). Effective engagement with user groups and investment in training and transitioning into sustained use by identified local stakeholder partners in the selected pilot locations will be crucial to successful outcome. The biggest risk is developing a product for a region that is not used by national-to-local stakeholders for planning and problem solving (i.e., becoming a one-use application).

COAST - Land Impacts to Sea Pilot

As the interface between the terrestrial environment and open oceans, coastal waters encompass many unique habitats and serve important human needs. Coastal habitats include estuaries, coastal wetlands, seagrass meadows, coral reefs, mangrove forests, kelp forests, and upwelling areas. Coastal waters support many fish species and are important areas for the fisheries and shellfish industry. They also provide habitat for many other organisms such as marine mammals, corals, sea turtles, and submerged aquatic vegetation. This interface between the land and water is also important because most of

the world's population inhabit coastal areas. Healthy coastal ecosystems are also critical for food security. These regions support dynamic interactions between the land, ocean, and atmosphere and account for about 15% of global ocean productivity, 90% of sediment-based mineralization, and 80% of organic matter (OM) burial.

A. Implementation planning

Sediments: Coastal sediments result from the redistribution of the material supplied by rivers and/or eroded from rocks in the coastal area and/or from the production of particles in the sea due to waves, tides, and currents. Coastal sediments are well recognized for their importance in biogeochemical cycling of critical elements such as carbon, nitrogen, and phosphorus. Increased sediment loading is severely impacting our coastal regions, including fisheries spawning grounds, shellfish beds and primary productivity (light attenuation). Humans are having profound effects on the amount of sediment carried by rivers to coastal areas, with consequences for marine life and pollution control. Increasing sediment loads, now estimated at 15 billion tons of sediment around the world every year impact coastal management such as dredging operations, preventing or planning for coastal erosion, impacts of anthropogenic alterations on coastal ecosystems, restoration of coastal habitats, and planning for climate change.

Eutrophication: In 2015, the 2030 Agenda for Sustainable Development was adopted by the United Nations Member States. At its core were 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries. SDG 14 focuses on "Life Below Water," aims to conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

SDG 14 has 14 targets, each with indicators for reporting on progress. GEO Blue Planet contributed to the drafting of the methodology for the eutrophication indicator of SDG target 14.1 - *index of coastal eutrophication* (indicator 14.1.1a). The indicator uses a progressive monitoring approach where countries can use globally and nationally derived data. Eutrophication is a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to increased growth, primary production and biomass of algae, changes in the balance of organisms, and water quality degradation.

Eutrophication can lead to:

- harmful algal blooms
- hypoxia
- fish kills
- seagrass die off
- loss of coral reef and nearshore hard bottom habitats

- health hazards to swimmers and fishers.

In coastal waters, excessive nutrient inputs primarily come from anthropogenic sources including agricultural fertilizers, livestock waste and outlets from wastewater treatment plants. Eutrophication is undesirable if ecosystem health and/or the sustainable provision of goods and services are appreciably degraded. Assessing chlorophyll-a concentration is a way to measure algal biomass in surface waters, a primary symptom of eutrophication, and is among the most common Earth Observations made by satellites.

Satellite Indicators for parameters of interest:

Optical properties - Coastal waters are affected by the presence of colored dissolved organic matter (CDOM), phytoplankton and sediments. These complex waters generally exhibit high reflectance values with increasing turbidity with the relationship between the concentrations of aquatic constituents and ocean color being non-linear. Sensors with high signal-to-noise ratios and high dynamic ranges are needed to carry out measurements effectively in these highly reflective waters. Consequently, requirements for remote sensing of these waters are important in terms of sensors and complex in terms of retrieval algorithms.

i. Introduction - Planning in Phase 2 will initially be open to any volunteer stakeholders on the study team who wish to participant and represent their space agency or CEOS WG/VC/AHT and will include relevant external stakeholders identified in the selected pilot area (including but not limited to: identified product and data information users in the pilot area, other public or private data or product providers, academic researchers, social scientists and economists to the extent possible on a volunteer basis).

   Goal: The primary stakeholder requirement is development and application/use of the pilot project product(s) tools and services in pilot region(s) to measurably improve remotely sensed turbidity and coastal eutrophication.

ii. Purpose - Phase 2 stakeholder engagement planning will be enabled through a GEO/CEOS Virtual Workshop to be held in the first half of Phase 2. A key outcome of the Workshop will be a documented list of requirements for any products, tools, and services developed by COAST. This list will guide product development. Stakeholder engagement should also document the frequency and best method to inform each stakeholder about ongoing progress and training users to access the products and services developed by COAST.

iii. Implementation goals -

Sediment - Phase 2 goal: Develop a blended product representing coastal water column sediment distribution (maps) of pilot areas. Utilize available experimental products that leverage available satellite imagery but need calibration and validation to optimize for pilot areas. Improve processing efficiency and ensure end user needs are met with temporal/spatial resolution and data product quality. Establish and build relationships with end users and partners in the pilot areas to sustain products into the transition to operational phase. It is assumed that existing sediment data products and available cal/val data will be of sufficient value to improve and reach the Phase 2 goal. It is also assumed that available CEOS - GEO outreach and capacity building partnerships, and those that arise from a planned joint Stakeholders Engagement workshop will be sufficient to reach Phase 2 goals. The risks for this approach are: no CEOS member agency is willing to assume a leadership role in development of this product for Phase 2 tasks, the available cal/val datasets are insufficient to produce a quality data product that meets identified end users' needs in Phase 2.

Coastal Eutrophication - Phase 2 deliverable: Work with the Regional Seas Programmes to develop capacity for higher resolution national/regional chlorophyll-a analysis based on the approach taken by the Northwest Pacific Region.

Coastal Eutrophication - Phase 2 deliverable: Assemble Artificial Intelligence datasets needed to utilize Machine Learning to improve this coastal eutrophication indicator product, such as: training datasets, inventory of available products and details. Phase 2 goal: Develop an improved indicator data product and conduct capacity building with end users in the pilot areas. Establish and/or build relationships with end users and partners in the pilot areas to sustain the product into the transition to operational phase. It is assumed that existing available cal/val data will be of sufficient value to improve and reach the Phase 2 goal. It is also assumed that available CEOS - GEO outreach and capacity building partnerships, and those that arise from a planned joint Stakeholders Engagement workshop will be sufficient to reach Phase 2 goals. The risks for this approach are: the available AI datasets or Machine Learning technology are insufficient to improve the Coastal Eutrophication Indicator data product in Phase 2; and identified stakeholders/end users feel the data product does not meet identified user needs, adversely affecting capacity building efforts.

iv. Implementation recommendation -

- Membership - The Land Impacts to Sea Pilot team comprises those COAST members representing agencies or WG/VC/AHT with identified projects supporting the products/tools/services being created and/or the geographic locations for the demonstration of the pilot(s) and user engagement. Nominally these would at least include WGDisasters, WGCapD, WGCV, WGISS, COVERAGE, LSI-VC, USGS, GA, NOAA, NASA, ESA, ISRO, EUMETSAT, JAXA, and CNES/LEGOS. GEO AquaWatch and GEO BluePlanet lead this effort with contributions from all CEOS Study Team members.
- Contributions and resources – GEO AquaWatch will leverage an existing award to create a global blended turbidity data product. GEO BluePlanet will extensively leverage an existing Coastal Eutrophication Product developed for UN Environment and will also leverage the WAVEFORCE project (led by NOAA with multi-agency partners). In addition, all the above agencies have verbally committed resources to COAST to complete a successful Phase 1 product: team leadership, supplying expertise, data, computational capabilities, models, assembled user requirements, technology infrastructure training expertise, and contacts to relevant stakeholders and user groups.

B. Implementation activities

i. Implementation activities listing - Eutrophication and Sediment Loading/Turbidity

- Project workflows and categories
  - Data set compilation (AKA global inventory)
  - Data Product Development
  - Data gaps in pilot areas
- Project tasks (years 1 and 2, any specific tasks and deliverables)
  - Sediment loading has been identified as a critical issue to be addressed in the Land-to-Sea component of the COAST project. This effort is being led by GEO AquaWatch and involves three interrelated strategies for determining coastal sediment in the proposed pilot projects

(a) Cataloging a global inventory suspended sediment data and putting it into a common database and portal. Our specific aim is to create an open, accessible visualization tool embedded in the GEOAquaWatch.org website with capabilities that will include map displays of satellite-derived sediment information, in situ data sources, graphs,

and charts. Our goal is to assemble disparate and hard-to-find information in one, easy-to-use web portal for comparison and evaluation.

(b) As part of a new initiative with Google Earth Engine, GEO AquaWatch will provide new global-scale, open access, freely available fit-for-purpose total suspended solids information for inland and coastal waters to be used by multiple end users including the science community, water resource managers, industry, and the public. This project is a collaborative effort between the GEO AquaWatch community, the World Bank, Conservation International and Google Earth Engine, leveraging their respective strengths. This project will also leverage and consult with ongoing work by NASA, ESA and JAXA.

ii. High-level milestone/timeline chart -

		2021				2022		
TASK	Dec	Apr	July	Sept	Dec	Apr	July	Sept
Land2Sea								
Select Pilot Geographic Boundaries								
Gather EO data sets								
Gather corrections, masks, algorithms								
Determine Quality Metrics and Use Case(s)								
Develop prototype product(s)								
Test Prototype product								
Demonstrate Prototype with users & implement feedback								
Product Release and Training								
Capacity Building for product								
CEOS Partner Co-led Community Coastal Projects								

iii. Implementation team

- Members - The entire COAST will be members, with leadership provided by Steve Greb (GEO AquaWatch) and Emily Smail (GEO Blue Planet), with participation expected especially by those representatives with expressed interest in the pilot product or pilot locations and who have committed resources (data, expertise, information, etc.) on behalf of their agency or WG/VC/AHT.
- Structure - Pilot activity leaders and interested team members will meet as needed to accomplish a Phase 2 deliverable testable by users within 12 months. Pilot activity leaders will meet with COAST co-Leads about schedule adherence and key milestone progress quarterly, with high-level report-outs expected in written

or oral form during monthly COAST meetings. To the extent practical, the collaborative workspaces and the cloud will be utilized to house the latest public version of Phase 2 deliverables. Products will be freely and openly available at the CEOS Agency level and incorporated in the WGISS EAIL. Products should be tested by an external independent quality review team or by the Activity Leadership for quality and meeting user requirements prior to initial product release; and also with identified users and other relevant stakeholders and partners at least upon the initial release of a Phase 2 satellite derived product(s), or at the end of the 2021 calendar year.

- Roles and responsibilities - Pilot activity leaders are responsible for day-to-day activity management, reporting, and execution of tasks as well as preparing calls for AHT assistance: contribution of data, subject matter expertise, testing or capacity building, and assistance with file transfer and document preparation as needed. COAST members are responsible for contributing timely and responsively to all Pilot Activity Leader calls for AHT assistance through interactions with your WG, VC, agency, or SME network.

c. Implementation resources requirements

- Dedicated Activity Leadership time
- User Requirements from available sources and GEO workshop (Summer 2021)
- Identification of partnerships for sustainment and users for capacity building
- Acquire relevant satellite and validation datasets for each pilot area
- Dedicated SME, hardware and software, data storage, and computational expertise to create, test and improve data products
- Testing and Quality Improvement Process
- Training and Capacity Development with users
- Transition to operations with users and/or receive user feedback and continue into Phase 3 tasks

ii. Potential implementation locations and contributing agencies/collaborators

<u>Eutrophication</u>:
Regional Seas Programme pilots: JAXA, NOAA, NASA, ESA
Virginia/Chesapeake AI pilot - USGS, NOAA, NASA, Maryland Department of Natural Resources (data provider)
West Coast of Africa
Kenya-UN

Sediments:
Virginia/Chesapeake - USGS, NOAA, NASA, Maryland Department of Natural Resources (data provider)
Bay of Bengal - ISRO
West Coast of Africa - West Africa Coastal Areas (WACA) management program PML-CCI, NOAA, ESA
La Plata - CONAE, INPE,SABIA-Mar 2 mission
NOAA, ESA, Particles in the Americas

iii. Immediate action plan -
- Agency commitment of responsibilities for activities
- Determine activities and milestone deliverables
- Agency commitment of resources for tasks and activities

iv. Barriers and obstacles to implementation
- Risk and dependencies - the risks of this pilot are low because products/tools and technology exist in one-to-several examples for turbidity/TSI products and one coastal eutrophication product. Effective engagement with user groups and investment in training and transitioning into sustained use by identified local stakeholder partners in the selected pilot locations will be crucial to successful outcome - for eutrophication, the United Nations has an extensive network that will help sustain this product, however interest in other areas of coastal eutrophication will be challenging. It is hoped that eReef and other GEO Partners will assist. The biggest risk is developing a product for a region that is not used by national-to-local stakeholders for planning and problem solving (i.e., becoming a one-use application).

COAST - Underlying Tools Products and Services

The Underlying Tools Products and Services component seeks to identify common COAST Tools, Products and Services needs across the Pilots and where possible make interoperable services available so these can be reused. This includes Data Discovery, Access, Analysis and Product publication. CEOS COAST is collaborating with WGISS and the CEOS Systems Engineering Office (SEO) to achieve this goal by connecting through to CEOS Agency services and influencing how CEOS Agencies make data and analytics available. This approach aligns with the CEOS Analysis Ready Data (ARD) and Future Data Access and Analytics Architectures Strategies.

A. Implementation Planning: led by Woodcock (CSIRO), Killough (NASA), Tsontos (NASA), Armstrong (NOAA), and DiGiacomo (NOAA)

i. Introduction - The CEOS Earth Analytics Interoperability Lab (EAIL) can be used to support COAST data analysis and product testing. The RAIL provides a suitable platform for both ARD data preparation, access and analytics capability using CEOS Agency services including both production and prototype services (e.g., not yet endorsed ARD data). The primary objective for this stage of COAST will be to use the EAIL to support the COAST Pilot needs, using prototype services if necessary, and build out the desired CEOS interoperable services. In demonstrating this use WGISS and SEO will then take the results and use them to develop CEOS Best Practices thus advancing the CEOS ARD and FDA strategic objectives.

ii. Purpose - Deliverables and Stakeholder Engagement

The EAIL will be built by the CEOS Systems Engineering Office (SEO) and CSIRO. SEO and CSIRO have committed to funding the EAIL through the end of 2021 within bounded Cloud compute and storage capacity. Any commitments to operate the EAIL beyond this date or operational cost boundaries will require additional resources from CEOS Agencies and entities. In addition to the SEO and CSIRO, there will be support from other CEOS groups (e.g., WGISS, LSI-VC, WGCV) and CEOS Agencies to supply satellite data in proper formats (e.g., ARD). WGISS is also seeking the establishment of additional EAIL nodes supported by other CEOS Agencies. This would allow for alternate technology stacks and improve interoperability considerations for services.

iii. Implementation goals

- Infrastructure enabling ARD Discovery for common data which results in reusable data services across COAST Pilots
- CEOS COAST Pilot analytics enabled by the ARD and the Cloud computing infrastructure in the EAIL
- CEOS COAST Pilot participants able to share and collaborate on analytics and data needs using the EAIL Jupyter Notebooks environment
- WGISS and SEO develop Best Practices for ARD data access and interoperable Data Cube analytics

iv. Implementation recommendation -

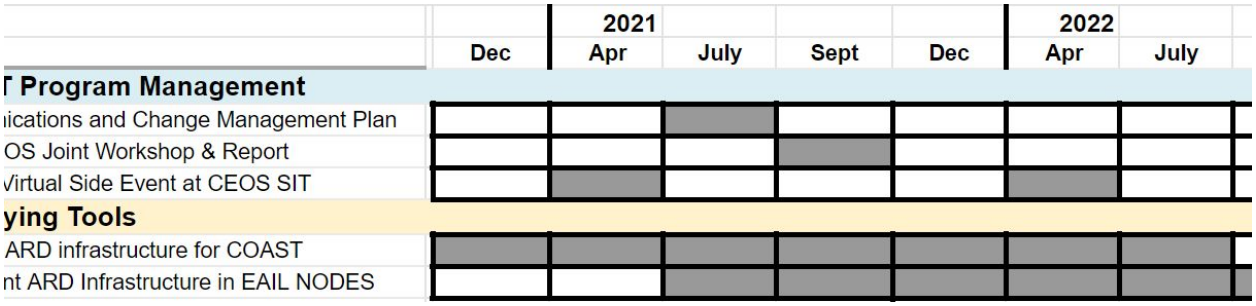
- Membership - The EAIL team within WGISS in collaboration with the Underlying tools team on COAST
- Phase 2 - Agency level contributions to support the EAIL and associated Nodes, other resources as available.

B. Implementation activities - Woodcock and others

i. Implementation activities listing

- Deploy EAIL baseline infrastructure and make available to Pilot participants
- Develop EAIL training materials and establish support mechanisms for Pilot participants.
- Identify Pilot Project data product workflows and data categories and anticipated storage capacity and processing subroutines
- Determine current ARD status of data products (EO and in situ) in conjunction with CEOS Agencies. Identify those that Agencies can/will supply and those that the EAIL and COAST team may need to prototype ARD pipelines for.
- Identify new capabilities that EVIL needs to develop to support any given pilot, based on pilot requirements and dataset inventory
- Establish data pipeline workflow automation and begin population of EAIL archive
- Develop Pilot analytics requirements inventory and create suitable analytics containers for use in the EAIL Jupyter Notebooks environment
- Support Pilot activities in the use of the RAIL ecosystem
- Liaise with WGISS, LSI-VC and other CEOS WG/VC to develop Best Practices for common interoperable services.

ii. High-level milestone/timeline chart



iii. Implementation Team

- EAIL Team (CSIRO and SEO), WGISS leaders
- Pilot project team representatives

C. Implementation resources requirements -

i. Immediate action plan - Once the EAIL is ready for operation, projects such as COAST can use the system to store satellite data and generated products and use the system for analyses with Jupyter notebooks and Python programming. It may be possible for users to bring their own tools

and algorithms to the system, but such details will need to be evaluated by the EAIL team to understand how, and if, they can be integrated.

It assumed that users of the EAIL system will have Python programming experience and can navigate Jupyter notebooks. In some cases, training may be required to allow users to operate the system and perform analyses. To date, there is no formal training available for EAIL as it is a new system. Therefore, training in Python and Jupyter Notebooks will need to be found using other sources (e.g., DE-Africa, WGCapD, online). In many cases, the RAIL developers (e.g., SEO and CSIRO) will be able to support basic user requests and troubleshooting.

- Agency commitment of responsibilities for activities
- Determine activities and milestone deliverables
- Agency commitment of resources for tasks and activities

ii. Barriers and obstacles to implementation -

- Risk and Dependencies - There are many possible risks to successful implementation of COAST using the EAIL system. Users will need to have some Python and Jupyter notebook proficiency. Data will need to be readily available with limited pre-processing requirements. Sub-projects and tasks will need to be clearly defined such that it is possible to achieve reasonable results within the one-year prototype period. Finally, there is a risk that the resources from SEO and CSIRO will be limited due to a high demand for the EAIL from numerous (over 5) other CEOS groups

- Phase 2 Deliverables List (6-24 month):
  A. 6 months
     i. Prototype regional satellite-derived data products covered in the two pilot areas (bathymetry, mapping and intertidal elevations, sediment/turbidity, coastal eutrophication) in the selected geographical regions.
     ii. Pilot-specific User requirements List
     iii. EAIL Support Needs List
     iv. Stakeholder List
     v. Communications Plan
     vi. Lessons Learned inventory of interoperable services need for WGISS Best Practice development
  B. 12-24 months
     i. User-tested data products for the above that are publicly available
     ii. Integration of the Phase 2 pilot data products into the EAIL to the extent practicable.
     iii. WGISS Best Practices published

iv. Phase 3 Implementation Plan