**ss US CLIVAR Working Group Prospectus**

# Climate Data and Predictions for Coastal Solutions

*Co-Developing equitable, trusted, and actionable climate information for coastal communities*

## 1. Motivation & Scope

Along the U.S. coastlines, climate-related pressures such as sea-level rise, flooding, marine heatwaves, storms, and, more generally, the compounded effects of ocean-atmosphere weather extremes, are rising and leading to more vulnerable natural and human coastal systems [e.g., *Colburn et al. 2016; Pershing et al. 2019, Sweet et al., 2022*]. While a few communities are in the process of developing solutions strategies for climate resilience, a significant disconnect still exists between the climate science community, their ability to co-produce and deliver actionable information and predictions, and the coastal stakeholders who are in need of incorporating this information into their decision-making processes [*Porter and Dessai, 2017*]. This gap is even more significant for under-served communities, which are disproportionately impacted by climate and have limited to no access to climate information, expertise, and resilience-planning tools.

Recent scientific advances show that seasonal to interannual to decadal forecasts can provide critical information for coastal adaptation [e.g. *Kirezci et al. 2020*] and the management of ecosystem services [*Tommasi et al. 2017; Jacox et al. 2020*]. New coastal and marine ecosystems observing strategies focused from global to coastal are also being co-designed by interdisciplinary groups of scientists to provide the data requirements to support the development of climate forecasts [*Capotondi et al. 2019; Stammer et al. 2019*]. With the launch of the U.N. Ocean Decade for Sustainable Development, new global programs and projects such as CoastPredict and their endorsed project Future Coastal Ocean Climates (FLAME) are coming online to beckon the next generation of coastal predictions on seasonal to interannual timescales reaching the urban scales, as well as high-resolution, downscaled decadal to centennial projections of future coastal ocean climates necessary to inform decision-making. However, ensuring that these efforts and programs can generate actionable information for managing risks and developing coastal resilience strategies poses several challenges [see *Kopp et al. 2019*]. One such challenge for this wicked problem [*Rittel & Webber, 1973*] - a challenge that all convergent science faces [see *Finn et al. 2022*] - is breaking down the silos between climate science, social science, and decision-makers and accounting for the highly disparate needs of coastal communities for coastal climate knowledge and predictions. To this end, it is essential to put in place efforts and processes that enable climate experts to co-produce the critical information and forecast targets with coastal stakeholders, resilience practitioners, and scientists from other fields [e.g., *Di Lorenzo et al. 2019; Finn et al. 2022*], and inform climate research by the relevant social contexts (see WCRP recommendation at COP27, https://youtu.be/04SfPccUAI0).

US CLIVAR recently released a report outlining a strategic plan for addressing the next generation of research on climate at the coast [*Nielsen-Gammon et al. 2021*], which highlights a unique opportunity for US CLIVAR to bring its integrated approach, from observations to modeling to prediction to applications, to inform and support the development of coastal climate solutions. To advance the US CLIVAR Coastal Initiative, this proposed working group aims to establish essential research building blocks for developing a U.S. coastal climate prediction and impact information system, trusted and

vetted by the climate and coastal science community, that can inform equitable coastal solution strategies. These building blocks can be divided into two main categories:

**(Building Block 1) Co-designing and Communicating Climate Information for Equitable Coastal Solutions: *Towards incorporating stakeholder needs into the science of coastal climate predictions, thereby delivering actionable climate information for coastal solutions.***

- *What are the most needed climate forecasts and estimates of uncertainty for community-scale coastal resilience planning, and what tools are available or missing to best access the information?*
- *What are key user-driven social-ecological metrics to evaluate the coastal impacts of climate, and what data source needed to quantify them? How do we translate physical climate information into the social-ecological dimensions and services that matter most to people (e.g.. impact metrics)?*
- *How and what type of climate-projected scenarios can enable communities to develop and proactively adapt to a vision for their future?*
- *What are best practices for co-designing the climate forecast target products with coastal decision-makers and communities?*

**(Building Block 2) Downscaling Coastal Climate Information, Predictions, & Uncertainty: *Advancing user-inspired research to bridge the gap between large-scale climate forecasts and relatively small-scale coastal climate information needs.***

- *What are the dynamics and limits of coastal climate predictability at the scale of decision-makers?*
- *How do we down-scale large ensembles of climate predictions and projections, and their uncertainties to inform coastal resilience planning?*
- *Do we improve coastal predictions by increasing overall model resolution or are there other approaches (e.g., variable grid, dynamical downscaling, empirical dynamics, machine learning approaches) that might be more fruitful?*
- *How do we best link physical and biological climate forecasts and projections to the marine resources and economic factors that are most salient for decision-making processes of coastal stakeholders?*
- *What are the key model errors that degrade coastal climate and climate impact forecasts? How are they related to climate model simulation and process errors, and how might we reduce them?*
- *What are the observing gaps in coastal physics, biogeochemistry, and living marine resources? How do we integrate observations into coastal-scale reanalyses that are useful for both model assessment and forecast initialization and verification?*

Although the questions above will serve as initial guidance for the working group, **it is important to recognize that this effort is transdisciplinary, and as such, the key questions and the objective/tasks outlined below cannot be fully prescribed ahead of the work but must be co-developed as part of this work (e.g., through interactions across experts from the different domains, stakeholder, etc.).** To this end, this working group, in collaboration with other boundary organizations (see Appendix B), will contribute to establishing the foundations for a U.S. national trusted interdisciplinary **community of**

**practice (CoP)** to allow interested climate scientists to take a more permanent stand in the co-production of scientific information and tools for coastal solutions and resilience.

## 2. Objectives, Tasks, and Timeline

Following the motivation presented above, the WG builds around the recognition that (1) the climate research community needs to understand the stakeholder needs and use those to inform critically essential gaps in research, and (2) the stakeholder community also needs to understand how to access and use existing climate information and predictions. The WG efforts are organized around three main objectives and corresponding tasks to establish a research framework for co-developing equitable, trusted, and actionable climate information for coastal communities. The timeline and framework for objectives are provided in Appendices C and D.

### Objective/Task #1: Co-designing actionable climate information & forecast targets for coastal solutions

Goals: (1) Understand the climate information and forecasts needs of coastal communities, including the type of impact variables and their spatial and temporal scales. (2) Inform coastal communities of current availability and advances in the delivery of climate information and uncertainties.
Outcome: A synthesis white paper that discusses the climate information and forecast needs of coastal communities, documents specific case studies and early examples, and articulates research & innovation gaps that limit us from bridging climate science to its application for coastal resilience. A web-based repository of the information collected to be determined with the WG at a later date (see outreach section for more information on the website).

Task 1a: The WG will convene boundary organizations (e.g., IOOS Regional Associations, Climate Mayors, Resilient City Catalyst, Center for Sea-Level Rise Solutions, Ocean Visions, see list and description in Appendix B) that work with coastal decision-makers and planners to co-develop with climate and coastal modelers an initial set of climate downscaling information and forecast targets (i.e., impact variables in the physical, biological, societal dimensions) that are both (1) important for addressing the stakeholders necessary to advance adaptation solutions for coastal climate resilience, and (2) reflective of the current capabilities within the climate research community. To advance this task, we will leverage the 50 case studies collected through the Ocean Visions Coastal Solutions Task Force and Workshops held between 2020-2021, which document concrete examples where research universities are directly working with coastal communities to advance coastal solutions to flooding. Although the focus of this series was on flooding, some of the best practices, gaps, and needs identified are more general (see presentation https://youtu.be/Z-X0ZGIAKEI). This effort engaged over 400 coastal climate scientists. We anticipate advancing this task through a workshop where participants will be asked to engage in work sessions together.

***Addendum**: We will leverage a discrete set of existing coastal pilot projects and communities (e.g. 4-6), which are already engaged with the boundary organizations we have listed, to identify what the user needs are in terms of climate downscaling information and forecast targets (i.e., impact variables in the physical, biological, societal dimensions) (Task 1a),*

*As a premise, we want to make sure it is understood that community-driven science needs to be inspired by the stakeholder and local decision-makers' needs when it comes to selecting the range of phenomena of interest. Having said that, we do recognize that is useful to anticipate a set of variables and dynamics that are going to be addressed by this group. After consultation, we have identified the following variables/processes as being likely the initial target by the WG:*

- ***Coastal inundation** caused by sea-level rise, storms and hurricanes, tides, low-frequency climate variability, and extreme precipitation including atmospheric rivers.*
- ***Heatwaves** both over land and marine linked to atmospheric blocking and large-scale climate.*

*We are likely going to consider also one process that focuses more on biogeochemical and ecosystem impacts such as hypoxia or acidification. This will be part of the initial discussion of the WG. However, given that US CLIVAR has primary expertise in physical variables, we think that coastal inundation and heatwaves is an important foundation.*

Task 1b: Expand the scope of Task 1a by including social scientists to explore the current ability and challenges of co-developing coastal climate projection scenarios and communicating this information with adequate narratives and impact indicators that will enable communities to develop a vision for their future. Social scientists from a selected number of pilot communities will be engaged to set a foundation for linking climate to community-driven social-ecological impact indicators. We anticipate that going forward, the relationship between these indicators and climate data can be modeled with innovative approaches (see Objective 2). We anticipate advancing this task with a series of virtual roundtable discussions and direct interview with social scientists and domain experts.

***Addendum:** We will also greatly reduce the scope of Task 1b by avoiding the co-development of user-informed climate scenarios. We will mostly focus on the science of downscaling the variables of primary interest to the communities.*

**Objective/Task #2: Innovations for downscaling coastal climate information, forecasts, and uncertainties at the decision-making scales**

Goals: (1) Assess the current capability and science gaps for downscaling climate onto the forecast targets identified in Objective 1 at the spatial and temporal timescales identified by decision-makers. (2) Draft a set of best practices and modeling approaches for downscaling large ensemble simulations at the coastal decision-making scales and for quantifying the regional uncertainties originating from both internal natural variability and intermodal spread. (3) Identify available observational, reanalysis, and modeling products necessary for downscaling coastal climate information and producing forecasts.

Outcome: We anticipate several outcomes for this objective. The WG will curate a special collection in Frontiers of Marine Science Ocean Solutions on *Downscaling climate information for coastal solutions* (goal 1) that will also include a white paper on best practices (goal 2) and a summary of the existing and missing data products for coastal climate downscaling and prediction.

Task 2a: In coordination with IOOS, the WG will convene experts from the climate and coastal modeling, and from the social, biological, chemical, and computer science communities to (1) better define and quantify the forecast target products, which we anticipate will span several social-ecological-environmental dimensions, and link them to the downscaling of climate predictions, and (2) **draft a series of promising approaches to execute the downscaling of predictions and uncertainties. We plan to advance this task with a workshop.**

Task 2b: In coordination with U.N. Ocean Decade Programme CoastPredict, the WG will review the output of Task 2a with a more global community to refine the modeling approaches for downscaling and discuss the observational needs for model assessment, forecast initialization, and verification. We plan to advance this task with WG members joining existing events (virtually or remotely) organized by these program or their working groups.

Task 2c: The WG will engage communication experts, social scientists, and some of the boundary organizations to design a strategy and narratives for delivering the findings from Objectives 1 and 2 in a format that will allow decision-makers to incorporate in community engagement and planning processes. We anticipate advancing this task with a series of roundtable discussion.

***Addendum:*** *While we hope to maintain the same scope for Task 2a and b, we will reduce the scope of Task 2c, which aims at designing a strategy and narratives for delivering climate information. We will provide the boundary organizations collaborating with the WG with the information for them to carry forward this task.*

*For this objective, the SSC (in a comment below) suggests that the WG also focus on improving the understanding and modeling of coastal (and shelf) processes for improving prediction. We would like to be careful with this specific aim because there are many groups and programs working on this already. Our suggestion is that we collaborate with these groups such as the UN Ocean Decade Program CoastPredict and NOAA UFS rather than initiating a thread of our own.*

**Objective/Task #3: Recommendations for a U.S. coastal climate prediction and impacts information system**

***Addendum:*** *We agree that it is wise to remove the third objective at this time and let that evolve naturally as a follow-up. We will still plan on providing some recommendations at the end of the WG lifespan.*

Goals: Summarize the findings of Tasks 1 and 2 with the boundary organizations and draft a set of recommendations for a coastal solutions-inspired research agenda identifying critical gaps in knowledge and approaches that are necessary for delivering climate predictions for decision-makers.

Outcome: We anticipate the publication of one or two high-level perspectives and organizing sessions at international meetings that summarize and introduce to the broader community the main findings of the WG.

Task 3a: Through a series of virtual roundtables followed by an in-person workshop, the WG will re-convene boundary organizations to report on the findings of Task 2 and provide recommendation for

the use of climate information at the coast that outlines current capabilities, knowledge, and methodological gaps for establishing a coastal climate predictions.

Task 3b: As a final step for the WG, we plan to host one or more sessions at a major international or national meeting to introduce to the broader community the findings of this work. This may include also one of the US CLIVAR summits.

## 3. Publications and Outreach

We anticipate publishing a peer-reviewed white paper for each of the objectives listed in the previous section and a special topic collection in Frontiers of Marine Science Ocean Solutions (Dr. Di Lorenzo, WG co-chair, is Special Chief Editor of the journal's section). Also, as part of our co-design work with coastal communities outlined in the scope of work under objective 1, the WG will interact with a series of boundary organizations (see Appendix B) that have direct connections to local stakeholders and national and international coastal resilience efforts. This will extend the reach of the US CLIVAR climate community to coastal communities and efforts beyond climate science. Finally, the WG will likely develop a simple web portal on Wix.com to post updates of their work that will serve as a reference point for the WG and the broader community. At the end of the WG term, in accordance with US CLIVAR preferences, we will explore migrating selected content under the US CLIVAR website.

## 4. Reporting Plan

The activities of this proposed WG are highly relevant to the goals of US CLIVAR Coastal Initiative, and particularly to the priority identified by the PPAI Panel. WG activities will be communicated to the PPAI Panel through members serving on the Panel (Newman). We will also communicate with and seek feedback from the other US CLIVAR Panels, and will report annually at the US CLIVAR Summit or individual panel meetings. We also plan to use management platforms of US CLIVAR to maintain a live status update on the activity of this WG. The website described in the previous section will also serve as an open-access report on the WG activities.

## 5. Leadership and suggested membership

Given the scope of this effort, the working group will be led by four co-chairs, serving as a small executive team:

- Emanuele Di Lorenzo (Brown University, Ocean Visions)
- Samantha Siedlecki (University of Connecticut)
- Clarissa Anderson (Southern California Coastal Ocean Observing System at Scripps)
- Malin Pinsky (UC Santa Cruz)

The suggested membership are provided below arranged by the expertise and the type of connectivity they bring:

**Connection to national agencies and international efforts**

1. Climate model projections (**Ben Hamlington, Caltech/NASA JPL**)
2. Coastal stakeholder connection (**open**)
3. Coastal flood modeling (**Shuyi Chen, UW, DOE ICOM** team)
4. Coastal observing systems (**Clarissa Anderson, UC San Diego/SIO/SCCOOS, Co-Lead**)

5. Climate prediction at NOAA (**Matt Newman, NOAA PSL**)
6. U.N. Ocean Decade connections and synergies (**Emanuele Di Lorenzo, Brown U., Co-Lead**)

**<u>Connection to the Coastal Climate Science Community</u>**

7. Ecology, fisheries, and marine spatial planning (**Malin Pinsky, Rutgers, Co-Lead**)
8. Coastal ocean modeling, dynamical downscaling (**Mercedes Pozo Buil*, UC Santa Cruz/ NOAA SWFSC)**
9. Ecological prediction (**Desiree Tommassi*, NOAA SFSC**)
10. Climate services, social-dimension, communication (open)
11. Chemical (e.g., hypoxia, acidification) and coastal pollution (**Samantha Siedlecki**, **UCONN, Co-Lead**)
12. Atmospheric synoptic (e.g., hurricanes and extreme precip) (**Andra Garner*, Rowan U.**)
13. Data science (**Marybeth Arcodia*, CSU**)
14. Emulators for downscaling multisector information (**Baylor Fox-Kemper, Brown U.**)
15. Physical circulation, sea level and flooding, global modeling (**Ben Kirtman, U. Miami**)
16. Regional ocean modeling/dynamical downscaling (**Elizabeth Drenkard*, NOAA GFDL**)
17. Social/cultural interactions with coastal/marine ecosystems (open)
18. Climate risk planning (**Bob Kopp, Rutgers**, Megalopolitan Coastal Transformation Hub)

The proposed membership is designed to have a multidisciplinary and diverse WG with 50% gender balance (including 2 lead women scientists) and 5 early career scientists (denoted by *).

## 6. Resource Requirements

- Annual subscription for a Wix.com website dedicated for posting the advances of the WG
- Publication charges for 3 high-impact publications linked to the three main objectives
- Organizational & travel support for 3 workshops of about ~40 participants, including members from the WG and boundary organizations.

## Appendix A: References


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## Appendix B: Boundary Organizations

**List of Boundary Organizations** that will interact with the WG to help bridge climate science into actionable coastal solutions for resilience:

- **Ocean Visions** is a nonprofit organization that brings an international consortium of research universities together to catalyze solutions for ocean and climate health. In June of 2022, Ocean Visions established a U.N. Decade Collaborative Center for Ocean-Climate Solutions in Atlanta, GA, USA to serve as a major hub for advancing solutions to climate under the Ocean Decade. (**Contact**: *Emanuele Di Lorenzo, Chairman of Ocean Visions*)

- **Climate Mayors** is a bipartisan network of more than 470 U.S. mayors demonstrating climate leadership through meaningful actions in their communities. Representing 48 states and 74 million Americans, the Climate Mayors coalition reflects U.S. cities' commitment to climate progress. (**Contact**: *Kate Wright, Executive Director, CM*)

- **Center for Sea Rise Solutions (CSRS)** is a global nonprofit that empowers local decision-makers to take action around sea level rise and coastal resilience. Through their initiatives, they are developing a shared and equitable roadmap for addressing sea level rise. (**Contact**: *Janelle Kellman, CEO of CSRS, Mayor of the City of Sausalito*)

- **Resilient City Catalyst (RCC)** is an independent nonprofit organization formed by members of the 100 Resilient Cities (100RC) team, created to empower change in the way cities plan and act. (**Contact**: *Anna Friedman, Director, Policy & Programs, RCC*)

- **CoastPredict** is a U.N. Ocean Decade endorsed Programme aiming to transform the science of observing and predicting the Global Coastal Ocean, from river catchments, including urban scales, to the oceanic slope waters. It integrates observations with numerical models to produce predictions with uncertainties from extreme events to climate, for the coastal marine ecosystems (their services), biodiversity, co-designing transformative responses to science and societal needs (**Contact**: *Nadia Pinardi, Lead for CoastPredict and Director of the U.N. Decade Center for Coastal Resilience*).

- **The IOOS Regional Associations** are extramurally funded ocean observing systems that comprise the U.S. Integrated Ocean Observing System (U.S. IOOS) and provide quality and timely information about our oceans, coasts, and Great Lakes to deliver sustained information, support decision-making, and bring outstanding value to society. (**Contact**: *Clarissa Anderson, Director of SCCOOS; alternative Jake Kritzer, NERACOOS*)

- **Ocean Acidification Research for Sustainability (OARS)** is a U.N. Ocean Decade endorsed Programme that aims to foster the development of ocean acidification science, including the impacts on marine life and sustainability of marine ecosystems in estuarine, coastal, and open ocean environments. One of the Outcomes from this activity - Outcome 5 - seeks to provide accessible, actionable, societally relevant projections, employing new technologies, such as digital twins, for all ocean 'users' of the impacts of ocean acidification to implement adaptation and mitigation by 2030. (**Contact**: *Jan Newton, co-lead of OARS*).

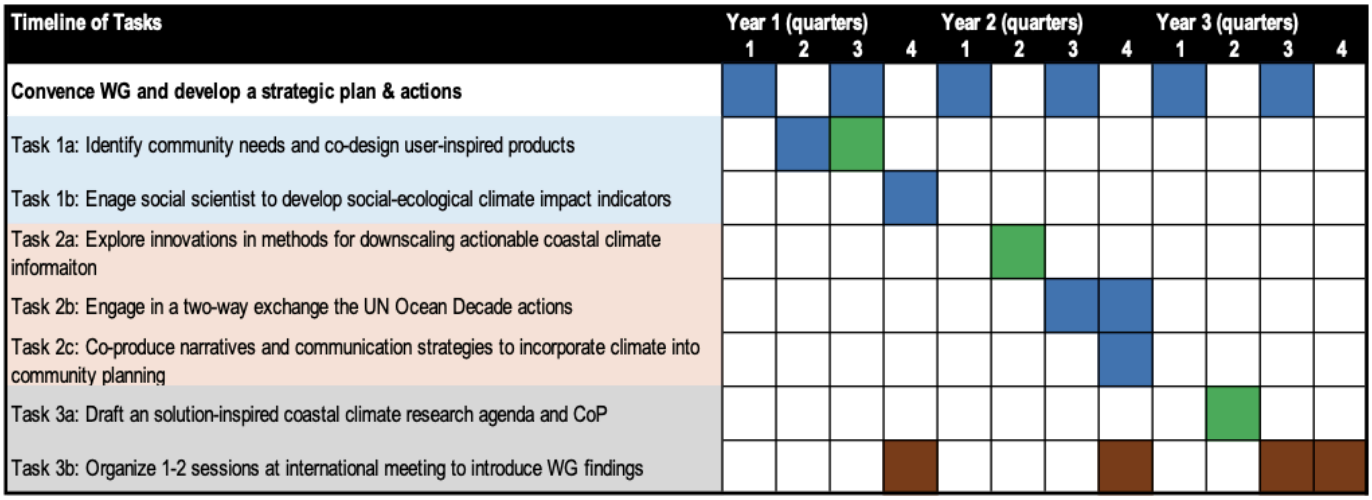
- **NOAA's Office of National Marine Sanctuaries (ONMS)** serves as the trustee for a network of marine protected areas encompassing more than 600,000 square miles of US marine and Great Lakes waters. In 2021, ONMS published its first Climate Resilience Plan, representing a commitment to integrating a climate-informed approach to management across the national marine sanctuary system. The Sanctuaries engage local stakeholders as part of developing management plans, including climate adaptation. (**Contact**: *Zac Cannizzo, ONMS Climate Coordinator)*

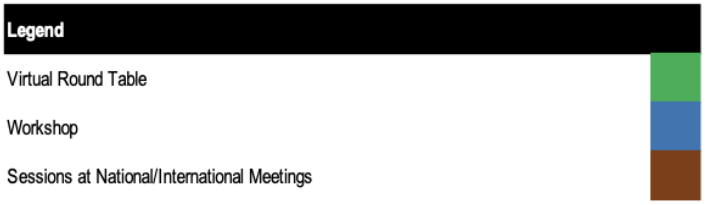
- **Mid-Atlantic Regional Council on the Ocean (MARCO)** is a partnership between the Governors of New York, New Jersey, Delaware, Maryland, and Virginia to address shared regional priorities and provide a collective voice for a healthy ocean. Climate Adaptation is one of their four main priorities. The Council serves as a regional focus for government, business, and community ocean planning activities. (**Contact:** *Laura McCay, MARCO Board Member and Program Manager, Virginia Coastal Zone Management Program)*

- **Sea Grant** mission is to enhance the practical use and conservation of coastal, marine and Great Lakes resources in order to create a sustainable economy and environment. They host a network of coastal resilience practitioners nationwide. (**Contact**: Jill Gambill, Sea Grant Office UGA)

## Appendix C: Table of Timeline

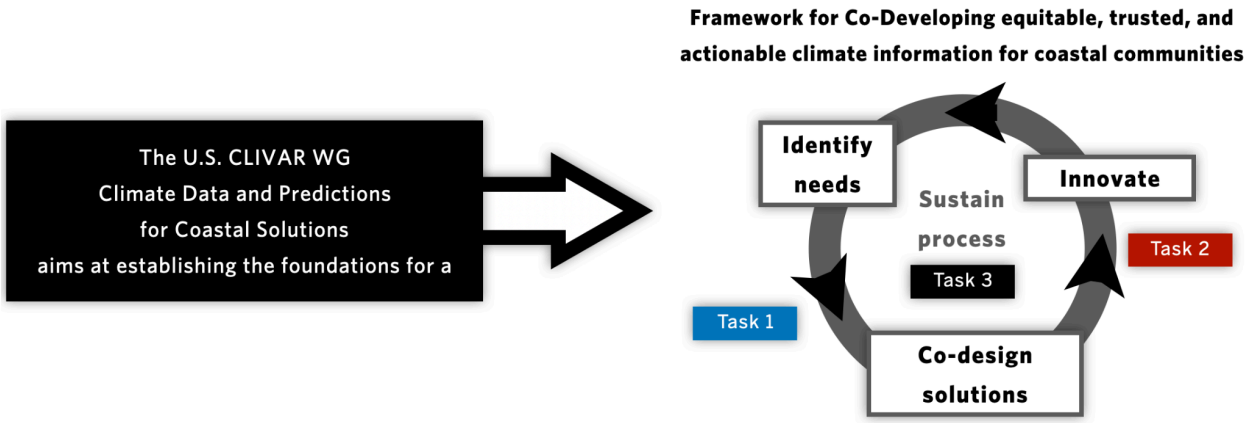
The overall duration of the WG is estimated at **3-years**. The table below provide an estimate of the timelines associated with each task and the type of activities for advancing the tasks. As already described in the text above, the three objectives will be pursued through a series of virtual roundtables followed by an in-person workshop (we anticipate 3 in total) over three years.



## Appendix D: Summary of Objectives

The research framework outlined by the objectives above involves a feedback loop (see schematic below) that begins with identifying the needs and co-designing solutions with coastal communities (or community proxies such as boundary organizations). In our WG-specific case, the focus is on an initial set of climate products and social-ecological impact indicators that are important for decision-making and resilience planning (**Building Block 1 & Task 1**). Next, the output of the co-design will highlight critical gaps in knowledge that will inform a call for research and innovation for downscaling the climate predictions and uncertainties for the use of coastal communities while also leading to new solution-inspired basic research (**Building Block 2 & Task 2**). To close the feedback loop, the output of the innovation process needs to be shared back with communities to start a new iterative cycle that, over time, will converge into real solutions and impact. For this approach to work, new mechanisms such as a national CoP are required to sustain this iterative process; the WG will set the foundations to activate such mechanisms (**CoP & Task 3**).




**Schematic: A research framework to co-develop equitable, trusted, and actionable climate information and predictions for coastal communities.**