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# ABSTRACT BOOK

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**Climate Change and Security Threats in the Arctic Ocean: Assessing theFunctioning of the Arctic Council**

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The purpose of this study is to scrutiny the policy decisions and implementations of the Arctic Council against the climate change-related security threats in theArctic Ocean environment. Climate and ocean as focal points require to engage with the adaptation and resilience strategies, which can be traced through political, legal and scientificpolicy decisions and implementations of the Arctic Council. With this purpose and requirementin mind, the focus will be directed to the Arctic Ocean environmental protection as essential for the ontological underpinnings of the Arctic Council. However, the structural constraints and divisions in the Arctic Council and the impacts of the international conflicts and controversial issues jeopardize the relevance and value of the Arctic Council as an inter-governmental forum. Such remarks give critical and sceptic insights regarding the functioningof the Arctic Council against internal and external challenges. For this reason, it is important to address these challenges while looking into the accompanied responses as linked to the efficiency of the Arctic Council and to the priorities and concerns regarding the Arctic Oceanenvironment in the context of the climate change.

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# Improving Copernicus Forecasts of Arctic Sea Ice and Iceberg with the ACCIBERG Project

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Sea ice and icebergs are a major security risk for navigation and fisheries in Arctic waters. Both will remain a significant threat even in a warmer Arctic, where traffic is expected to increase. Sea Ice Services are needed more and more to support less experienced captains with automated high quality forecasts and new information about icebergs that are not availabletoday. To monitor and forecast sea ice types and icebergs ahead of time, adequate forecasts of sea ice, ocean, wind, and wave conditions for the whole Arctic are crucial. The Copernicus Marine and Climate Change Services provide such information products. However, their uncertainties are not provided in a consistent and user-friendly manner. Reliable uncertainty estimates can however be based on forecast ensembles across the two Copernicus Services. ACCIBERG will improve the quality of sea ice, and ocean products and their uncertainty estimates in both Copernicus Services. It will also extend the coverage of the satellite detection of icebergs and develop a completely new iceberg forecast service. ACCIBERG will build uponstate of the art sea ice and ocean models, remote sensing algorithms, data assimilation and cloud computing to offer probabilistic sea ice and iceberg forecasts based on Copernicus data consistently. National or commercial sea ice services are limited to smaller regions and will benefit from the increased accuracy and consistency across the Copernicus products. The new forecasts will be demonstrated in ACCIBERG by European Ice Services and ships of opportunity. The new iceberg forecasts will be automated and validated, and benefit a wide range of user groups navigating in the Arctic, from fisheries to cruise tourism, including Marine Surveillance under the Copernicus Security Service. We will provide prototype products ready to be implemented in the Copernicus services and accessible from a single entry point: its inherentcloud computing solution.

# Future Changes in Wave Climate in the Mediterranean and High North Seas under Naval Operations Perspective

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While past studies have relied on Global Climate Models (GCM) with low spatial resolution toanalyze future wave climate changes, high-resolution Regional Climate Models (RCMs) projections can improve the characterization of wave climate. This is especially important for conducting coastal impact assessments and adaptation studies, but the same can be done fornaval operations. For example, a sea state above 3 (i.e., significant wave height above 1.25 meters) might make difficult Search and Rescue and further naval operations. This study focuses on analyzing the changes in the frequency of occurrence of sea states above 3 comparing historical and future periods in two areas of NATO interest: the Mediterranean Seaand the High North (including Northeast Atlantic Ocean and Nordic Seas). For the Mediterranean, we employ hindcast and projections developed by the MeteOcean research group of the University of Genoa with the numerical wave model Wavewatch III. The hindcast was forced by surface wind fields from the Climate Forecast System. The wave projections consist of a regional ensemble, forced by surface wind field from three EURO- CORDEX RCMs that dynamically downscale the EC-EARTH GCM. For the High North, the ERA-5 reanalysis was used as historical wave conditions and the projections of the Norwegian Meteorological Institute and the Arctic Data Centre for the CMIP5 EC-EARTH GCM were considered. In order to improve consistency between historical and future period, future wave projections have been bias-corrected. Distributions of seasonal and monthly changes of wave events in the Mediterranean and HighNorth regions are presented.

## Geo-Hazard of Cyclone-Induced Turbidity Currents on Critical Underwater Infrastructures

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Tropical cyclones cause catastrophic impacts on coastal regions, unleashing extreme waves and surges that have led to some of history's most devastating coastal floods (NOAA, 2021). What is less commonlyrecognized is that when cyclones make landfall on narrow continental shelves, they can also initiate sediment gravity flows in deeper waters, challenging the paradigm that such highly destructive flows typically result from infrequent submarine landslides. Recent research has unveiled the plunging of typhoon-induced turbid shelf currents directed towards the head of submarine canyons as a novel triggering mechanism for turbidity currents that can displace and damage submarine pipelines and cables (Porcile et al., 2020). These flows, once initiated, can traverse considerable distances, spanning hundreds to thousands of kilometers into the Deep Ocean, and reach velocities as high as 20 m/s (Piper et al., 1999). The potential consequences for infrastructure along their path are severe, as demonstrated by the impact on the submarine cable sector dating back to the installation of the first transatlantic cables, notably during the1929 Grand Banks earthquake and other subsequent events. Repeated turbidity current events over a period of 10 years offshore the Philippines were the cause of significant displacement of a subsea gas pipeline in several locations. An integrated modelling approachenabled us to assess the specific metocean conditions required for flow initiation, enabling a forecast- based risk approach to specific sites. In this presentation, we will show how learnings from forensic analysis and numerical modelling techniques used in the pipeline industry can be used for optimized routing of infrastructure on theseabed and help mitigate against the impact of potentially destructive underwater flows.

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# Using Climate Ensembles to Detect Present Signs of Future Climate: the Case of the 2022 Drought on the Po Valley

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Climate Change can impact a number of strategic assets, from the integrity and operability of infrastructures, to the functionality of risk-prone productive districts and ecosystem services. The severe drought that affected large areas of Europe in Spring and Summer 2022 hit the Po river system with particular intensity, with heavy impacts on productive activities and extensive saltwater intrusion in the coastal areas. Based on the use of observed discharge records and precipitation data from reanalysis and climate models, in this contribution we analyse this event in the framework of the recent past climate and of possible end-of-century scenarios. Our results show that persistent negative rainfall anomalies like the one that characterised the 2022 event, though unlikely to become typical features of the future climate, could remarkably increase their frequency. Furthermore, the impacts of events with similar intensity will be magnified by rising temperatures, enhancing evapotranspiration rates in agriculture and water demand from the mainland, and by rising sea level, leading to a longer and more persistent intrusion of salt water in the river branches and in the neighbouring surface aquifers. Besides framing in a climate perspective a recent severe event that struck an important economic and ecological region, and stimulating the adoption of an integrated source-to-sea approach to climate adaptation in coastal regions, this work shows how available climate ensembles provide a rich, and still only partially exploited, capital of information for strategic applications.

**Abstract for the Application to the Workshop "Climate Change and Security"**

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While the reality of climate change is widely accepted within the scientific community and supported by overwhelming amounts of data and research, it is still rejected by a significant portion of the general population. Traditionally, belief is thought to be governed by descriptive facts – as following the truth as an individual finds it when looking out into the world. However, belief has a significant normative component, as well. The answer to the question "What should I believe?" is not simply given just by appealing to the facts. It requires addressing further issues, such as proper justification of belief, trustworthiness of sources and conflict with antecedently held beliefs and values. Changing a person's beliefs is not as easy as just giving them the correct facts. We want to argue that climate change denialism is a problem that needs to be partially explained in normative terms, and therefor strategies for dealing with this problem need to include normative responses. To this end, we want to analyze the issue through the lens of the virtue epistemology. We argue that the insights from this philosophical sub-discipline have value both in addressing climate change denialism on the level of the individual (by providing people with the epistemic tools in the form of epistemic virtues which allow them to find and incorporate truths into their framework of beliefs even in domains with high levels of disinformation), as well as the organizational level (by providing language and concepts that help organizations avoid epistemic vices which make them more untrustworthy as sources of information).

**Climate Securitization or Arctic Militarization - The best Way to Preserve NATO's Strategic Dominance in the Arctic**

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The Arctic Circle, encompassing a vast landmass in Northern Canada and Eurasia is a region with vast ice fields and permafrost. The region is rich in mineral and oil and gas deposits. On top of its economic importance, the region also has immense geopolitical importance for NATO and its adversaries. The Arctic is one of the most impacted regions by climate change because climate change exacerbates current geopolitical issues shaping global security policies. Rising sea levels, ill-defined Exclusive Economic Zones (EEZ) and increased commercial shipping through the Arctic could lead to heightened aggressive confrontation between NATO and its adversaries namely Russia and China. In this paper, I intend to conduct an analysis NATO and Sino-Russian Arctic policies through the securitization lens first introduced by BarryBuzan[1]. I argue that the Arctic states[2] are militarizing Arctic instead to securitizing the climate change i.e. considering climate change as a threat to national security, which limits their ability to effectively address the issue. To increase awareness of such looming issue I believe that NATO should create an office of climate resiliency and along with NATO's Public Diplomacy division should conduct broad outreach targeting the local public and NATO member states. NATO's 2030 policy would need to adapt to the race for resource extraction in the Arctic and prepare NATO member states especially Arctic states to maintain effective situational awareness of theirsovereign territories in the High North. To exert effective control over their sovereign territories, NATO member states will need to update their naval and aerial infrastructure as they will be threatened by rising sea levels and could limit NATO's reach if not mitigated earlier.[3]

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## Copernicus Climate Change Service (C3S): from Data to Actionable Climate Information

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The operational Copernicus Climate Change Service (C3S) delivers climate data and information designed to address the evolving needs of different community of users within diverse decision contexts. The service offers open and free access to data and information based on current and past climate data, on climate predictions and multi-decadal climate projections in a standardized way, through the Climate and Atmosphere Data Store infrastructure (CADS). The CADS development platform allows the creation of web-based applications operating on the datasets and products available in the C3S catalogue. Sector-specific, user-tailored & co-designed applications are developed as a concatenation of operations performed on the underpinning data within the cloud-based CADS Infrastructure. All computations are executed within the infrastructure in a distributed, service-oriented architecture. These workflows include user guidance and full documentation. Working at the data-to-user and science-to-service interface, C3S offers numerous examples where the generation of customizable climate information is the added value for different applications in diverse contexts and sectors. This presentation focuses on examples for the energy, the finance and security sector at the global and European level and it shows how climate-based applications become benchmarks to support regional and transnational climate adaptation strategies.

## Canada's National and International Programme on Climate Change and Security

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This workshop presentation will provide: (1) an overview of NATO Collaborative Programme of Work (CPOW) on Climate Change and Security (CC&S), and a summary arising from three workshops regardingClimate Change and Security hosted by Defence Research and Development Canada (DRDC), and supported by NATO partners from Denmark, Norway, the Netherlands and the NATO Centre for Maritime Research and Experimentation (CMRE); (2) next steps for the CPOW (3) an overview of the Canadian defence research program in Environment, Energy and Climate & Security (EECS) including some specific examples in the arctic maritime environment; and (4) an overview of the Canadian Department of National Defence Climate Resilience and Environmental Sustainability Science and Technology Strategy (CRESST).

**Interdisciplinary Talent Generation for Climate Governance and Security: A Program Overviewfrom Canada**

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In an era of complex global challenges such as climate change and its implications for security, there is a growing need for military and civilian leaders who can effectively navigate the intersection of climate science, policy, and governance. This presentation introduces a ground-breaking program aimed at developing a new generation of talent equipped with a diverse range of skills and knowledge, including climate science, big data analytics, machine learning, and transdisciplinary training in climate-related security and defence issues. This undergraduate program is being developed at the *Royal Military College Saint-Jean*, in Canada, and will educate the future officers of the Canadian Armed Forces. It is based on the premise that there is a need to bridge the gap between climate scientists and security and defence operators and policymakers. It emphasizes the importance of integrating scientific expertise with geopolitical perspectives to inform evidence-based decision-making. By breaking downdisciplinary boundaries, emerging scientists and officers are exposed to the benefits of collaborative research development and learning across diverse fields and areas of expertise. Graduates of this hybrid education program will be uniquely positioned to become future leaders in Earth sciences and climate security.

**Scenario-building, AI, and Decision-making in the Arctic under Climate Change Conditions**

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The security implications of climate change in the Arctic are attracting more research and policy attentionby the day. The changing Arctic climate, biosphere and weather patterns come and interact with new developments in the geopolitical, military and security domains, exposing new security dilemmas. The question as to whether climate change can be a catalyst for armed conflict in the Arctic has been at the forefront but might not be the most pressing concern. Arctic climate security scenarios have a long historyand usually reflect the assumptions of the scenario makers who have varying degrees of understanding ofthe security implications of climate change. In this context, this paper seeks to analyse the interaction between the rapidly transforming Arcticenvironment and the rapidly evolving setting of risk assessment and decision-making. We seek to emphasize how climate change and the evolution of AI-assisted scenario-building transform risk assessments, the (political/policy) framing of such risks, and thus the decision-making tools, processes, and options for managing these risks. It is not enough to assess the impact of climate change to security.We must also assess how it is or should be changing of policy and decision-making tools and processes.

# Path-loss analysis in Anomalous Electromagnetic Propagation Conditions over Oceans induced by Climate Change: Preliminary results

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Climate change (CC) is leading to unprecedented changes to the whole Earth ecosystem, including the oceanic and atmospheric domains. In the last decade, some studies have analysed the impact of CC on underwater acoustic communication systems, e.g., [1]. Conversely, very little work on the effects of CC on the performance of microwave-based technologies, such as radar and wireless telecommunication systems, has been carried out, mainly devoted to rainfall impact [2]. Consequently, the potential effects of CC on such technologies remain rather unexplored. Indeed, it is expected that CC will lead to significant changes in the atmospheric structure and parameters, including the intensity and rate of anomalous conditions, such as atmospheric ducts. This work aims at trying to fill this gap and address the potential impact of expected changes in atmosphericducts on electromagnetic (EM) propagation at microwaves. To this end, we made use of both reliable EM propagation numerical solvers [3] and simplified closed-form path-loss models able to account for duct height and strength [4]. The EM propagation numerical solvers use in input climate atmospheric data for historical and future periods provided by ERA5 [5] and the Coupled Model Intercomparison Project 6 (CMIP6) outputs [6]. Preliminary investigations have revealed that such parameters might have a major impact on EM propagation. First results of our analysis will be included in the extended abstract.

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## Climate Change, Arctic Security and Future Operations (CLIMARCSEC): a Multinational CapabilitiesDevelopment Campaign (MCDC) Project

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CLIMARCSEC is a new Project within the 2023-24 project cycle of the Multinational Capabilities Development Campaign (MCDC), forming a US-led partnership of 23 nations/IGOs, to create non-materiel capabilities to support multinational force operations and exercise by resolving or at least diminishing common military problems. With Norway as project lead, 19 states and IOs participate inCLIMARCSEC as contributors or observers. Climate-change occurs at some of the highest rates in the Arctic regions resulting in both emergingrisks and new opportunities. The opening of the Arctic provides non-Arctic states/actors with easieraccess to the Arctic Ocean. In combination with changing geopolitical-/strategic conditions and growing political and military tensions, climate change makes the Arctic strategically important for Multinational Forces (MNF) but also exacerbates an already challenging field for operations. These factors increase the need for stronger MNF situational awareness, operational capability, coordination and policy changes. So far, various capability and coordination gaps (e.g. insufficiency in resources and modern equipment, missing joint command structures) restrict MNF abilities to address the current and future challenges adequately. Enhancing MNF's Arctic capabilities requires a robust policy framework and better coordination of policies and activities in order to maintain a strong and effective security presence in the region andto ensure an operational advantage towards competitors in a rapidly changing - climate and threat- based – environment. All domains are relevant to the operational environment for this problem set: land, maritime, air and(cyber)space with a focus on the first two. CLIMARCSEC will contribute to the analysis and to making suggestions as to how existing andpotential coordination and capability gaps could be closed and how future coordination and capability requirements could be met. To support this main goal, CLIMARCSEC will analyse how theimplications and consequences of climate change will impact policy, strategy, arrangement for deterrence and defence, military assistance, planning, preparedness, exercises and operations in theArctic. It will also inform military and political decision makers of the current and projected state of security operations. The poster will present an overview of the major contents, the motives and objectives of CLIMARCSEC with a view on possible findings and recommendations.

## On the Triggering of the Atlantic Niño: Southern versus Western Forcing

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The Atlantic Niño (AN) is the strongest source of interannual climate variability of the Tropical Atlantic.It appears recurrently as a warm Sea Surface Temperature Anomaly (SSTA) in the region 20ºW-0º; 3ºS-3ºN (Atlantic Region 3-Atl3) and peaks in the boreal summer. The generation of the AN is often explained using the Bjerknes feedback, which involves the propagation of equatorial Kelvin wave (KWs). Another mechanism, named Benguela Niño, concurs in the initiation of the AN. Specifically, equatorial KW impinging the eastern Atlantic boundary, are partially reflected and partially transmittedalong the African coast as coastally trapped waves propagating southward. When these waves reach the Angola-Benguela front at 15ºS, cause pronounced SSTA variability (the Benguela Niño) and provide a source of heat to the Benguela current. By comparing changes in the SSTA and KW activity deduced from altimeter data, we show that, over the period 1993-2022, two sub-periods can be identified: one between May 2013 and Dec 2021, in which the correlation between KW activity and SSTA in the Atl3 is higher than 0.85, showing that ANs occurred in this period can be ascribed to equatorial KW; and another period, spanning Jan 1993-May 2013, in which the correlation between KW activity and SSTA over the Atl3 drops, while the correlation between the average SSTA over the Atl3 and a region over the Benguela current located at 15ºS increases, indicating that between Jan 1993 and May 2013 the SSTA variability in the eastern tropical Atlantic is driven by the Benguela current heat transport.

## Nature-based Infrastructure for Coastal Erosion: A Dual-impact Technology?

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Nature-based solutions (NbS) for coastal flood and erosion risk reduction capitalize on the inherent capabilities of natural features (such as beaches, wetlands, barrier islands, reefs, and headlands) to preventor mitigate flooding and erosion [1]. NbS tend to require lower costs, offer greater flexibility, and capableto adjust to a changing environment than conventional solutions such as concrete seawalls [2]. NbS are receiving growing international acceptance and uptake, with an explosion of research in past few decades:the United States Army Core of Engineers (USACE) led the development of the International Guidelines on Natural and Nature-Based Features for Flood Risk Management (NNBF) which included contributions from two-hundred practitioners in ten countries. [3] The National Research Council of Canada's Ocean, Coastal, and River Engineering Centre (NRC-OCRE) and Defence R&D Canada's Centre for Security Science (DRDC-CSS) led a collaborative applied research project on the performance of NbS for managing coastal flood and erosion risk in Canada. It contributed greatly to the body of technical knowledge surrounding the performance of nature-based solutions for managing flood and erosion risk on Canada's coasts and culminated in the production of aCanadian design guide for coastal nature-based infrastructure. The purpose of this paper will be to describe the methodology of NbS in the context of the NRC- OCRE/DRDC-CSS project which includes: (1) community workshops and engagement; (2) field monitoring; (3) numerical modelling; and (4) laboratory experiments (physical modelling). The results ofthis "living laboratory" approach into design guidelines for NbS will also be discussed. Finally, this paper aims to explore the possibilities surrounding the "dual-impact" (civilian/military) useof this technology for protecting NATO maritime infrastructure against coastal erosion brought about by climate change.

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## Impact of global warming on the earth's hydrologic cycle

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One of the most robust responses of the climate system to global warming is the so-called "intensification of the hydrologic cycle". This phenomenon can be summarized with the following sentence: in a warmer climate, rain events tend to be more intense but less frequent. The first part of this sentence is rather intuitive, and stems from the fact that warmer air has more energy and can contain higher amounts of water, the second part of the sentence, i.e. the decrease in precipitation frequency, is less obvious, and it can be explained from an energetic and a hydrologic viewpoint. The main consequence of the intensification of the hydrologic cycle is that global warming is expected to lead to an increase in the risk of flood-prone (due to the higher precipitation intensities) and drought-prone (due to longer and warmer dry periods). Many studies have clearly identified this response to global warming in future climate projections carried out with global and regional climate models, using different precipitation indices and statistics, although this signal can be highly variable in space due to the heterogeneous response of precipitation patterns to global warming (e.g. wetter conditions at mid to high latitudes and drier conditions in sub-tropical regions). On the other hand, the identification of this signal in observational data for the last decades has been more elusive, both because of the relatively small signal to noise ratio for the recent past and the insufficient quality of precipitation observations, especially in terms of density and spatial cover of observing stations and length of observation periods. Despite these uncertainties, the last report of the Intergovernmental Panel on Climate Change (IPCC) has identified a large number of land regions with statistically significant increases in the intensity of precipitation and agricultural drought conditions during the last decades. This contribution reviews the issue of the intensification of the hydrologic cycle in response to global warming, focusing in particular on the issue of the increase in extreme precipitation events using a range of methodologies. Attention will also be given to the Mediterranean region, for which different global and regional climate model projections suggest a trend towards increasingly dry conditions, but with the occurrence of intense localized events.

**The connection of Atlantic and Arctic Oceans in the 21st Century: Challenges of Maritime and Human Securities. Portugal in the Arctic. Scenario thinking (2023-2035)**

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This research intends to evaluate how the Arctic region can be an opportunity for Portugal to add to its foreign policy as well as defence and maritime strategies, using the prospective analysis by presenting scenarios in the 2023-2035 timeline. Portugal finds itself at the crossroad between climate change, oceans and the closeness of the Arctic due to the possible expansion of the continental shelf and the melting of the Arctic Ocean that opens new maritime routes connecting Atlantic and Arctic regions. A trinity of topics represented by the theoretical and conceptual framework that includes Green Theory, maritime security and human security. The two oceans already meet through the Atlantification process that is accelerating the melting ice and placing challenges to non-traditional security: maritime security and human security by confirming the crossroad of securities and oceans, Portugal needs to reposition at a geopolitical level as a global co-producer of maritime security by preventing human security. Thus, challenges transform in opportunities for Portugal by being in the Arctic in the 21st century, or at least looking closely at this region.

## Alternative Future Visions for NATO Maritime Operational Energy & Power

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There has been much discussion regarding the global maritime energy transition and what this will mean for NATO maritime forces. Whilst there is potential for it to present major challenges in sustainment and freedom of action and manoeuvre, there are also opportunities which could deliver enhanced operational capability – throughidentifying ways to operate differently with new technology. To mitigate risks and exploitopportunities, NATO maritime forces will need a joint vision of this future maritime operational energy system. This concept study proposes a selection of alternative future visions for NATO Maritime power and energy, building on previous studies in this area to present future visions (in the 2045/ 55 timescale) in the form of six 'Operational View (OV-1)' diagrams (example at Figure 1). The aim is to bring these to life to assist in stimulating structured discussion and debate, drawing out national perspectives. Examples of alternative futures could include:

- F-76 transition to a bio-diesel fuel pathway
- Methanol and synthetic diesel mixed fuel fleets and tankers
- Solar/ wind/ nuclear power sources with synthetic fuel energy vectors
- Electrical power by default with energy storage and off board systems
- Distributed sustained uncrewed platforms (solar/ wind powered).

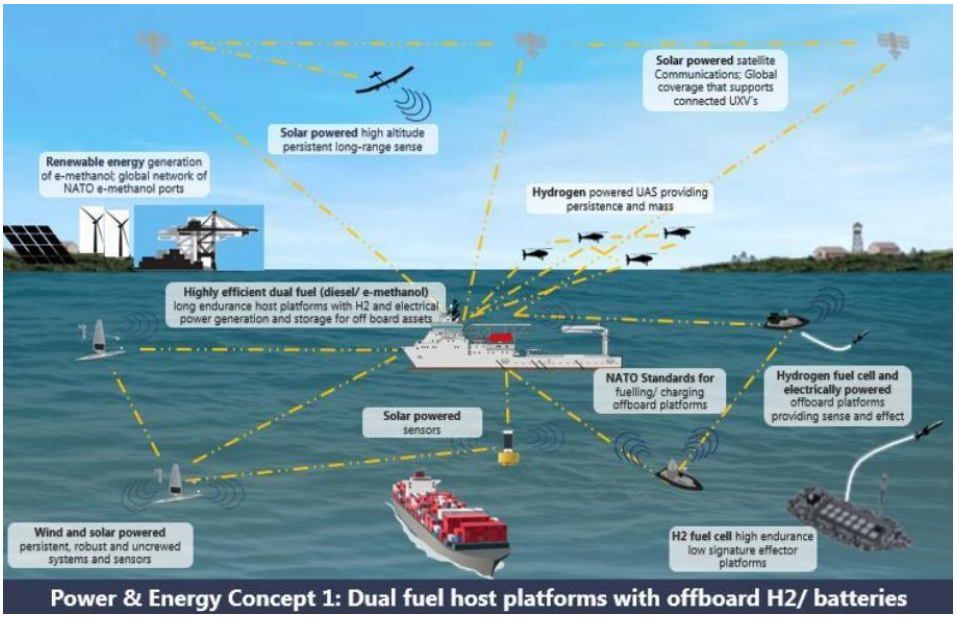


Figure 1: Example Operational View diagram for Power & Energy Concepts

## Climate Predictions in the Mediterranean basin

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Capability to predict climate fluctuations from seasonal–to–decadal timescales would have large and significant socio–economic benefits. On the other hand, our limited comprehension of the mechanisms and processes responsible for predictability and model systematic errors hampers our capability to simulate and forecast climate variability, and thus, the current forecast quality is still relatively unsatisfactory, particularly in the mid–latitudes and in the Mediterranean basin. In recent years, several research studies and collaborative projects have been conducted in order to improve the skill of the forecasting systems and the quality of the data and climatic information that they produce. This effort has produced some substantial advancements in understanding the Mediterranean climate variability and its drivers, and improved the capability to provide climate predictions for this region. This talk will illustrate and discuss some of the main aspects of our understanding of the sources of climate predictability in the Mediterranean basin, the current capability of climate prediction systems(e.g., the C3S operational seasonal forecasting multisystem) to provide skilful predictions in this region,and examples of applications of climate prediction–based services in relevant socio–economic sectors.

**Security Threats Posed by Climate Change Misinformation and Disinformation Campaigns: Implications for Military Security and the Extended Maritime Ecosystem**

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Climate change is a complex, multifaceted global challenge extending beyond its environmental implications. This presentation examines the security threats posed by climate change misinformation and disinformation campaigns, focusing on implications for defence and security and the extended maritime ecosystem. By exploring the intersection of climate change, misinformation, and maritime concerns, we aim to raise awareness of these threats, the urgency with which they must be addressed, and systems that can mitigate them. Climate change misinformation and disinformation campaigns employed by industry-funded think tanks, political groups, and online influencers are increasingly prevalent and sophisticated. They exploit societal vulnerabilities like political polarization and economic interests, disseminate false narratives, and sow doubt regarding scientific consensus. Rising sea levels, changing weather patterns, and increasingly frequent extreme weather directly affect naval operations, coastal defence infrastructure, and safety of maritime personnel. Misinformation can hinder effective planning, preparedness, and response measures, jeopardizing military capabilities and mission success. Disinformation campaigns influence public opinion and policy decisions, potentially hindering key investments in sustainable maritime infrastructure, resource management, and ecosystem protection. This poses risks to critical maritime assets, supply chains, and communities reliant on maritime industries, exacerbating existing vulnerabilities. Potential strategies for raising awareness and mitigating these threats would help to enable timely and accurate assessment of climate-related risks. Education and training programs promoting climate change literacy and critical thinking within military and maritime communities can foster an informed understanding of the interconnectedness of climate change, security, and maritime operations to better anticipate and respond to evolving challenges. The integration of climate change considerations in the maritime context into military doctrines, policies, and planning is crucial for building resilience and adaptability in the face of changing environmental conditions.

**Environmental Research Towards Climate Change and Security in South America**

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As Latin America is impacted by climate change, governments and researchers have pushed scientific funding for basic and applied research in new directions to study these changes and better prepare for the energy transition. Countries currently look to both buildtheir ability to obtain renewable energy and leverage their own renewable resources to improve the economic health of the country. Basic research funding often tracks similar areas of technical focus for renewable energy as other parts of the world, but with individual projects often using approaches that would result in lower cost end products oradapt technology for local climatic patterns. This includes projects that replace expansive elements with lower cost materials while looking for similar or improved performance. Further, local climate related studies provide information that may translate to other regions of the world. Notable examples include (1) the central Chilean mega drought and (2)coastal ecosystem response to melting glaciers and (3) Similarities in the Pacific-facing coast of both North and South America.

## A Systems Thinking Approach addressing the Impact of Climate Change on Naval Defence Operations

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Dynamics resulting from climate change that significantly affect planning and operations of the Alliance can be better understood by applying a systems thinking approach. A systems thinking approach allows us to gain insight into complex systems like climate change and its first and second order effects on naval operations. We will present the application of this systems thinking method to naval operations securing the High North region, as well as maritime facilities. We first identified trends in different domains (demographic, ecological, sociological, technological, economical and (geo)political) and subsequently captured these trends and their interdependencies in a causal loop diagram. The diagram provides a basis for exploring different scenarios and interventions for naval defence operations, and supports to map the first and second order effects. An example could be effects of rising seawater temperature on underwater acoustics and sonar performance. The temperature changes directly influence acoustic propagation characteristics; also, the soundscape is changed through increased shipping activities caused by ice-free shipping lanes. During the CC&SW, we will present a method that enables the investigation of the wide impact of climate change. We do hope to inspire the audience to explore this impact of climate change on the defence naval operations, since it is expected to have a significant impact, which we are only beginning to understand.

## Climate-change induced Sea Level Rise and Coastal Floods in Northern Adriatic - Past Observations, Future Projections and Deep Learning Coastal Flood Modeling

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Coastal flooding due to climate-change induced mean sea level rise will exacerbate problems related to civil safety and global security. We present a multidecadal sea level time series (1961- 2022) from a tide gauge in Koper (Slovenia) and use threshold based detection to count the number of mild, severe and extreme floods over this time window. We then raise past observed sea levels byamounts from climate projections and estimate the extent of coastal flooding for each of the climatescenarios, raising the sea level in steps of 10 cm. We show that exposure to flooding rises non- linearly with mean sea level rise, specifically as a cumulative error function of the normal distribution of sea levels. For Slovenian coast, these analyses implicate that even the sea level rise of 30 cm, corresponding to perfect fulfilment of Paris Agreement, increases the likelihood of extreme flooding by 20-30 times, while 1 meter sea level rise leads to daily flooding (by today's standards at current coast configuration). This implies extreme flooding twice a day due to tidal cycle alone and with no meteorological contribution. Cyclonic events and related Adriatic basin’s seiches and storm surges would of course further worsen the conditions. We then present a deep learning sea level model HIDRA, developed for ensemble modelling of coastal floods at very high accuracy and very low numerical cost.

**Security implications of Climate Change in the Arctic Maritime Domain and Priorities for NATO's Climate Change and Security Action Plan**

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[2] Center for Climate and Security, Arctic360 and Université du Québec à Montréal, Canada

Climate Change (CC) has been described in the last NATO Strategic Concept (SC) as "[…] a crisis and a threat multiplier". The same document, released in June 2022, mentions the High North for the first time as an area of prioritization where Russia poses a strategic challenge. Indeed, no other region in the world is more affected by CC than the Arctic, which is estimated to be warming four times as fast as the rest of the globe. In addition to posing significant threats to human security, ice sheet melting, permafrost thaw, and other physical phenomena challenge NATO's artificial installations, all subject to logistical stress and extreme-weather events, and influence the strategic decision-making of Arctic nations, thus ultimately altering NATO operating environment. As NATO released its Climate Change and Security Action Plan (CCSAP) in June 2021, this paper aims to explore the key strategic and operational implications of CC in the Arctic maritime domain, as well as the priorities to consider for the regional implementation of the CCSAP. Building on three of the Plan's main pillars, we will attempt to address three main sets of research questions: (1) Increasing Allied awareness of the strategic impacts of CC in the Arctic: what are the main drivers of competition in the Arctic, and what is their relationship with CC in the maritime domain? How can allies improve their awareness of the way CC will affect strategic decision-making in the region, (2) Adapting to CC: what are the main challenges for NATO to adapt its planning and maritime capabilities to the changing Arctic environment? (3) Mitigating CC: how can Allies minimize their carbon and environmental footprint when operating in a changing Arctic maritime domain? This work intends to be an introduction for a more comprehensive research on the topic, aiming at formulating policy recommendations for the application of NATO's CCSAP in the Arctic maritime domain.

## How Climate Change Can Worsen Security Dilemmas in the Norwegian High North

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Climate change related security and security scenarios for relevant areas (e.g., High North) are topics of interest to the workshop. Our paper will examine the impact of climate change on security dilemmas in the Norwegian High North. Security dilemmas are well known in international relations, whereby one state's efforts to enhance its security might provoke reactions from other states, potentially leading to less security for all states involved. Norway's security and defence policy aims in the Norwegian High North (the Norwegian Sea, Barents Sea, and Spitzbergen) are still to maintain low tensionsby cooperating with Russia in areas of common interests, like fisheries and the incidents-at-seaarrangement. This aim remains valid after the second Russian attack on Ukraine in February 2022. In an era of growing great power competition and confrontation, climate change might function as a threat-multiplier. Climate sensitivity is higher in the High North because the initialwarming yields events that amplify further warming, mainly due to the albedo effect that makesArctic warming 3 times faster than the global average. This article contributes to our understanding of High North security dynamics by analysing how climate change affects NATO's patterns of operations and exercises in the Norwegian High North. It specifically askshow climate change affects how actors like NATO members and Russia interact in this area, and how a potential war might play out. Furthermore, we ask how Norway's approach to security and defence changes due to the continuing warming of the High North. The article contributes to the growing debate within NATO on how climate change functions as a threat multiplier and adds to our understanding of how NATO addresses climate change as seen in the2021 "NATO Climate Change and Security Action Plan".

## On the Impact of Climate Change on Sonar Performance

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Climate change is already affecting the security and defence capability of nations. For what concern sonar systems, we know that climate change is altering, and will alter, the oceanographic conditions that affect sonar performance. Changes in oceanography, including layering of the water column and modifications of sound ducts, evidently influence the propagation of sound. Furthermore, indirect impacts must be considered as well. The latter ones include modifications of environmental noise (generated by wind, rain, waves, and sea ice), biological noise (generated by marine mammals and other marine species), and anthropogenic noise (generated by human activities). In general, the most significant one appears to be the impact of climate change on human behaviour. New marine areas are becoming of interest, and the corresponding economic activities such as shipping impact the soundscape, and consequently the background noise levels in sonar performance. Knowing whether climate change impacts sonar performance in areas of interest to NATO is important for the planning and execution of anti-submarine warfare operations, and can be used as an indicator whether the environmental knowledge needs to be strengthened to realize an effective capability. This paper introduces a systemic approach to investigate the complex relationship between climate change and sonar performance.

**Assessing Climate Change Impacts on Underwater Acoustic Signal Transmission Loss: A Simulation Analysis**

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NATO STO Centre for Maritime Research and Experimentation, La Spezia, Italy

The Arctic Ocean and its numerous shallow passages are experiencing rapid transformations due to global warming. Satellite data indicates that Arctic sea ice has been on a declining trajectory since 1979, and some researchers anticipate an ice-free Arctic summer by 2040. Thecontinuous summer ice decline creates conditions for new navigation routes changing the naval theatre of operations. Ad-hoc Underwater Acoustic Networks, composed of a mix of mobile andstatic nodes, are anticipated to be instrumental in future surveillance operations within Polar Regions. Nevertheless, this paradigm relies entirely on the ability to transmit digital information acoustically underwater over extended ranges - a capability not currently available. In this work, we study the effect of sound speed in the transmission power loss of underwater signals. The latter depends on refraction effects caused by the sound speed variation, frequency-dependent absorption and scattering effects due to sound interaction with the seabedand the sea surface. Climate change-induced events exert a significant impact on sea temperature and salinity, which, in turn, influence the sound speed. An exploratory study fundedby the NATO Office of the Chief Scientist and executed by CMRE researchers has generated future sound speed profiles (SSPs), for distinct months and years, relying on temperature and salinity fields from a Coupled Model Intercomparison Projects 6 (CMIP6) climate model. Utilizing these SSPs, we conduct an acoustic propagation simulation using the Bellhop ray tracing software, aiming to predict transmission loss across different transmitter/receiver depths, ranges, and frequencies. Our analysis identifies particular link geometries that are advantageous for underwater acoustic communications, thus laying the foundation towards effective naval operations in Polar Regions.

## Are we approaching a tipping point of the Atlantic Ocean circulation?

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The Atlantic Meridional Overturning Circulation (AMOC) is a large-scale overturning motion of the entire Atlantic, from the Southern Ocean to the high north. It moves around 15 million cubic meters of water per second (i.e. 15 Sverdrup), passing through the Gulf Stream as part of its much longer journey. Since the AMOC moves the bulk of the heat into the northern Atlantic, triggering also the southward cold and deep return flow, it is highly relevant for climate. Several new studies suggest that it may already be approaching a "tipping point" this century, possibly even in the next few decades, leading to completely new climatic configurations. The AMOC has repeatedly shown major instabilities in recent Earth history and it has weakened over the past hundred years, being now likely weaker than any time in the past millennium. Several groups of paleoclimatologists have used a variety of methods to reconstruct the AMOC over longer time spans, and it is clear that the long-term weakening trend is anthropogenic, confirmed also by climate models as a response to global warming. In addition, there appear to be decadal oscillations particularly after the mid-20th century. The AMOC "tipping point", first described by Stommel in a highly simple model that captures a fundamental feedback, was later confirmed by sophisticated 3-dimensional ocean circulation models, as well as fully fledged coupled climate models. The big uncertainty, however, is in how far the present climate is from this tipping point. Models greatly differ in this regard, as this appears to be sensitively dependent on the finer details of the density distribution of the Atlantic waters, but increasingly the evidence points to the risk being greater than 10% already during this century. The keynote will prevent evidence that unequivocally supports unprecedented, urgent and ambitious climate action to tackle the risks of this and other climate system "tipping points".

## Studying Future Changes in Sonar Performance in Areas of NATO Interest

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Sonar is a fundamental sensing tool in Anti-Submarine Warfare. Sonar performance depends on severalfactors, the sound speed profile being a significant one. Underwater sound speed varies with temperature, salinity and depth; consequently, it is influenced by climate change. Modifications of the vertical physical structure of the water column due to changes in the heat and salt fluxes, as well as in the ocean circulation and vertical mixing, induce changes of the sound speed profiles, which in turn modify acoustic propagation. Generation or disappearance of sound ducts as well as changes in the sound speed vertical gradients have significant impacts on sonar detection ranges. In the present study,we analyse future changes of sound speed and sonar performance in the High North and the Mediterranean regions. Sound speed profiles are computed from public available outputs provided by the Coupled Model Intercomparison Project 6 (CMIP6) [1] – HighResMIP experiment [2]. The latter one covers the period from 1950 to 2050, with historical period until 2014 and future period from 2015under the SSP5-8.5 scenario with nominal horizontal resolutions varying from 10 to 100 km. The computed historical and future sound speed profiles are provided in input to the CMRE's Rapid Acoustic Prediction Service (RAPS), which computes sonar detection ranges and other parameters forevaluating sonar performance. Preliminary results show significant changes of sound speed profiles and sonar detection ranges in theinvestigated areas.

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**Security of Mediterranean Coastal Areas under Future Inundation Scenarios**

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Sea level rise, together with human activities, may induce significant coastlinemodifications that need to be assessed and analysed, to evaluate the future risks of inundation in coastal areas, and the impacts on the infrastructures there residing. In this work, we present an integrated, GIS based approach to this problem that relies on state-of- the-art numerical projections of future sea level in the Mediterranean area, for specific emission scenarios, and on the extrapolation of present trends of vertical ground motion obtained from the European Ground Motion Service (EGMS). The approach is applied to five coastal areas hosting important Italian harbours, namely Brindisi, Napoli, La Spezia, Taranto, and Cagliari. Main outcomes of this study are coastal flooding maps at different time horizons. In creating these maps, sea level rise information from the numerical simulations has been transported to the coast using the "bathtub" approach, without considering the effects of thelocal morphology on the inundation process. This is something to be refined in future implementations. The main assets exposed to flooding risk are low elevation wetlands, and backshoreareas, together with coastal infrastructures. The high degree of subsidence of infrastructuresduring the first years after construction may significantly contribute to the risk of flooding. Inthese cases, however, predictions based on present EGMS data, with a limited time span, should be considered with caution. Further investigation of the geotechnical interactions involved, together with the constant update of the Copernicus database, will be of help in making the related projections more reliable.

# NATO Capability Development in a Changing Climate: Climate Intelligence

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Abstract: climate change is the defining challenge of our time. It is vital that modern militaries integrate climate change considerations into Force and Capability Development. This requires review and refresh of military doctrine and standards as well as innovation and upgrade of fixed and deployed assets. This paper will discuss how Climate Intelligence is a NATO necessity in terms of Capability Development.

Keywords: climate change, capability development, causation, climate intelligence, DOTMLPFI, compound cascade risks, predictive analysis, climate change hazards, risk management, futures, anticipation, readiness, resilience

**On the Vulnerability of NATO Installations to Climate Variability and Change: A System-Level Perspective**

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This work focuses on the understanding of the spatial connections among NATO installations worldwide in light of hydroclimatological extremes, including extreme precipitation and temperature. It will allow a system-level view of the vulnerabilities of NATO bases to climate change and the associated extremes. These analyses will be performed under current and future climate conditions based on model outputs from the Sixth Phase of the Coupled Model Intercomparison Project (CMIP6).

# Enhancing Port Security: A ComprehensiveApproach for Dynamic Threat and Performance Monitoring

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Ports play a crucial role in sustaining the economy and society, making them vital piecesof critical infrastructure. Ensuring the security of ports significant for modern interconnected societies is of utmost importance for national security due to their particular role as major logistic hubs for the alliance in times of crisis and war. However,ports face vulnerabilities from sea and land, including threats such as hybrid attacks, sabotage, trafficking, terrorist attacks, accidents as well as natural hazards. To safeguard ports and to make them resilient, a comprehensive approach is necessary to identify and address risks, threats and vulnerabilities. This research paper introduces a project that aims to develop a holistic method for real-time evaluation of the current resilience and securitystatus of seaports, with a special focus on the impact of climate change. The Projects investigates the influence of various parameters on the recovery capability asa main component of a port's resilience and aims to identify correlations between them. For this purpose, in addition to machine learning approaches, digital models of the port are being developed, with the seaport of Bremerhaven serving as the model infrastructure.Using the digital port model, the research endeavours to identify measures which are improving the recovery capability after climate change related disturbances of operation as well as operational interruptions caused by acts of sabotage and similar attacks. The findings of this project will significantly enhance the security and resilience of seaports. The development of a resilience assessment tool will optimize decision-makingprocesses to allocate resources more efficiently to measures that improve both climate change adaptation and hardening against attacks. The project aims to establish a framework for identifying potential mitigation measures to reduce the impact and minimize damages resulting from safety and security threat scenarios. Ultimately, this research contributes to the foundational aspects of critical infrastructure protection and resilience by supporting decision-making during disasters and preparedness efforts.

## Safeguarding Maritime Critical Infrastructure: A Model-Driven Approachfor Safety and Security of Offshore Wind Farms in the German North and Baltic Seas

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Offshore wind farms are essential for transitioning to renewable energy sources, especiallyin densely populated areas with limited onshore expansion potential. They are projected to contribute significantly to European and global energy targets, becoming a crucial partof the energy supply. However, these offshore wind farms (OWFs) are also vulnerable tovarious threats, including both human-induced as well as natural hazards due to their exposed locations and their spatial extent as well as associated infrastructure such as submarine cables. A study by Gabriel et al. (2022) highlighted the particular relevance of OWFs as maritimecritical infrastructure (MCI) and identified vulnerable components, especially on major high-voltage transformer platforms. Given the increased hybrid threat as a result of the ongoing Russo-Ukrainian war and increased vulnerabilities caused by climate change to the energy sector, security and safety requirements have become even more critical. To address these multidimensional challenges, the paper introduces an indicator-based approach to assess the risks and threats faced by OWFs from accidental events and intentional physical and hybrid attacks. The paper briefly outlines OWF infrastructure design and relevant threat scenarios, discusses existing risk assessment approaches, and introduces the proposed indicator- based assessment framework with its underlying probabilistic and machine-learning models. It concludes with an exemplary application of the framework on two OWFs in the German North Sea and Baltic Sea, highlighting findings and future research opportunitiesto expand the approach to other maritime critical infrastructures such as pipelines and subsea data cables where a similar climate change induced vulnerability appears to become highly relevant.

## Quantifying the Impact of Climate Non-stationarity on Military Infrastructure Resilience

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Future climate change poses a severe threat to the ability of critical alliance infrastructure systems. In order to evaluate potential solutions, current systemic resilience to inundation from both sunny day flooding and abrupt weather impacts is quantified using novel network analysis techniques. This methodology of quantifying resilience, which is typically evaluated qualitatively, is then applied to projected future flooding threats. In this study,resilience is defined as the system's ability to prepare for, absorb, recover from, and adapt to future threats. Traditional design and planning techniques rely on risk management principles and definedthreat recurrence intervals. This approach is fundamentally flawed when applied to non-stationary threats such as future coastal flooding impacted by sea level rise and changing riverine inflows. This analysis applies a combined ego-net based network science with hydrologic modelling of predicted climate change impacts to evaluate coastal military infrastructure on the eastern seaboard of NorthCarolina, USA to identify the ability of existing infrastructure to fulfil mission requirements. This analysis is also capable of identifying areas of weakness within the network, aiding future planning for mitigation strategies. The methodology is scalable and has been applied to installation scale and regional problems. The methodology is also infrastructure system and stressor agnostic and can intake threat or stressor information from any geospatially based modelling system or observational data and apply that to any infrastructure system that can be represented as a network.