

Attachment A. SCAR affiliated research relevant to the climate change related science needs identified in the CEP 5-Year Work Plan, CEP Climate Change Response Work Programme, CEP Final Reports and other CEP Manuals

Colours indicate science needs identified within the relevant issues of the Climate Change Response Work Programme (CCRWP): Issue 1: Non-native species (yellow); Issue 2: Terrestrial and freshwater environments (green); Issue 3: Marine near-shore environments (blue); Issue 4: Species at risk (grey); Issue 5: Built environment (purple); and Issue 6: Emerging issues (red).

CEP Work Plan priority	Science needs identified by the CEP in relation to climate change	Source	SCAR group ¹	Details / objectives	Upcoming developments / outputs	Timeframe for outputs
1. Introduction of non-native species	Identify terrestrial and marine regions and habitats at risk of non-native species introductions	5-YWP, NNS Manual (Annex), CCRWP (Issue 1), CEP IX (para. 129)	ANTOS	ANTOS aims to coordinate long-term biologically focused data collection that is necessary to assess environmental and biological variability and change in terrestrial and near-shore habitats across the Antarctic continent.	ANTOS will recommend technical guidelines for an internationally-coordinated installation of sensor networks, and standards for long-term data collection, storage, and sharing among national programmes.	Ongoing (long term environmental data)
			Ant-TAG	Ant-TAG harnesses the range of expertise in SC-HASS and related Standing Committees on tourism topics, serving as a platform for researchers from different disciplinary perspectives to work together collaboratively and make evidence-based recommendations. A key Ant-TAG activity is to develop a Report on the future of Antarctic tourism. This document will include discussion on how climate change affects the spatial and temporal patterns of future tourism in Antarctica and how such changes will have implications on introduction of non-native species.	Information Paper for ATCM XLIV, and papers for future ATCMs; Collaborative research outputs (peer-reviewed article and conference presentations; Operations Workshop on Antarctic Tourism and science connections; Antarctic Environments Portal submission on current issues in Antarctic tourism.	2022-2026
	Identify pathways for the introduction of marine and terrestrial non-native species	5-YWP, NNS Manual (Annex), CCRWP (Issue 1)	Ant-ICON	Clarifying non-native species pathways and associated impacts (SCAR Horizon Scan)		
			Ant-TAG	(see above)		

¹ See Table 1 for the full names of SCAR subsidiary and affiliated groups listed here.

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	Generate a list, with suitable descriptions, of potential non-native species based on the experience of the sub-Antarctic Islands (or other relevant environments) and the biological characteristics and adaptability of the “effective” colonisers	CCRWP (Issue 1)	SC-ATS	SC-ATS will work with other SCAR experts to compile a list of available biodiversity information sources and databases to help Parties establish which native species are present at Antarctic sites and thereby assist with identifying the scale and scope of current and future introductions (CEP 5-Year Work Plan)	Report to CEP	2022-2024
	Identify native marine and terrestrial species at risk of relocation and vectors and pathways for intra-continental transfer	5-YWP, NNS Manual (Annex), CCRWP (Issue 1)	Ant-ICON	Clarifying non-native species pathways and associated impacts (SCAR Horizon Scan)		
	Synthesise knowledge of Antarctic biodiversity, biogeography and bioregionalisation and undertake baseline studies to establish which native species are present	5-YWP, NNS Manual (Annex), CEP XIII (para. 331), CEP XII (para. 232), CEP IX (para. 129)	SOOS	SOOS Key Science Challenge 4.2: Understand biodiversity of Southern Ocean benthic and pelagic ecosystems at regional and circumpolar scales by investigating the potential changes accruing from influences of climate change and human activities. This work will be undertaken by SOOS's Regional Working Groups.	Scientific publications, reports and workshops	Ongoing
	Improve understanding of the effects of climate change on the distribution and impacts of disease organisms on native plants and animals	CCRWP (Issue 1)	Ant-ICON	Understanding of how diseases and pathogens will impact and adapt to the extreme Antarctic environment (SCAR Horizon Scan)		
			ANTOS	(see above)	ANTOS observation systems are gathering data on variations and changes in environmental conditions and biological systems around Antarctica. This data will help to understand the mechanisms behind changing distributions of native plants and animals. Analysis of data collected to date (terrestrial) and establishing observation systems at new locations.	Ongoing (long term environmental data)

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			Ant-TAG	(see above) Report on the future of Antarctic tourism will include discussion on how climate change affect the spatial and temporal patterns of future tourism in Antarctica and how such changes will have implications on introduction of disease organisms on native plants and animals.	(see above) Papers for future ATCMs.	
			SC-HASS	Projects on Greening the Poles (GRETPOL), and Dynamic Territory (DynamiTe) – studying how existing frameworks for invasive species management are consistent (or not) with climate change expanding the range of potential habitats for non-native species. Exploration of how the expansion of such potential habitats may force re-evaluation of what is considered ‘natural’ presence of species in Antarctica.		
1. Climate change implications for the environment	Physical environment					
	Develop future spatial climate change predictions on the timescale of decades. Identify and prioritise Antarctic biogeographic regions most vulnerable to climate change	CCRWP (Issue 2)	AntClim ^{now}	AntClim ^{now} aims to answer fundamental science questions (as identified by the SCAR Horizon Scan) relating to Antarctic climate variability. It will investigate prediction of near-term conditions in the Antarctic climate system on timescales of years to decades, and improve Antarctic climate prediction capacity.	Scientific publications, reports and workshops.	
			INSTANT	INSTANT aims to quantify the Antarctic ice sheet contribution to past and future global sea-level change, from improved understanding of climate, ocean and solid Earth interactions and feedbacks with the ice.	Scientific publications, reports and workshops.	
			Ant-ICON	Identification of vulnerable ecosystems and food webs (SCAR Horizon Scan)		
			Bedmap	Providing data to support ice sheet models which will in turn identify future climate change risks and areas of potential ice loss from terrestrial environments.		

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	Improve understanding of the effects of climate change (e.g. changing sea ice extent and duration, snow cover, ground moisture, microclimate, changing melt flows and consequences to lake systems) on habitat status, trends, vulnerability and distribution.	5-YWP, CCRWP (Issue 2)	BEPSII	The BEPSII EG is one aspect of the bi-polar international BEPSII community and closely aligned with SCOR WG 152: Measuring Essential Climate Variables in Sea Ice (ECV-ICE). BEPSII also received endorsement or support from SOLAS, CLiC, and IASC. BEPSII undertakes a broad range of activities related to improving our understanding of sea ice biogeochemical processes. These include intercalibration experiments and methods development, data synthesis activities, and overview-perspective activities (BEPSII 5-year science plan).	Products, including contributions to the Australian Antarctic Data Center, can be found here	Ongoing
			AntClim ^{now}	(see above)		
			INSTANT	(see above)		
			EOAG	The EOAG will make recommendations about the type and accuracy of satellite observations required in order to measure Essential Climate Variables (ECVs) relevant to the Polar Regions.		
			SOOS	SOOS Science Theme 1: Understanding and quantifying the state and variability of the Southern Ocean cryosphere. This theme includes a number of key challenges understanding ocean properties and processes affecting ice shelves, sea ice, and melting with a focus on ocean-ice/ocean-ice-atmosphere interfaces. SOOS will be working with connected SCAR programs including ASPeCt, INSTANT and AntClim ^{now} .		

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			IPICS	IPICS research outputs provide information on natural variability and change in a range of climate variables, proxies and environmental tracers. Some of these are important in the context of this CEP priority: in particular, records from the priority project 'IPICS 2k array' which provide high resolution records through the late Holocene and anthropogenic era. These can provide baseline natural variability and recent change in relevant environmental parameters such as sea ice, snowfall accumulation, dust and pollutant loadings (e.g. lead).	Scientific publications and reports	Ongoing
			ANTOS	(see above)	(see above) – analysis of data collected to date (terrestrial and marine) and establishing observation systems at new locations	Ongoing (long term environmental data)
			ASPeCt	ASPeCt aims to understand and model the role of Antarctic sea ice in the coupled atmosphere-ice-ocean system. This requires an understanding of key processes, and the determination of physical, chemical, and biological properties of the sea ice zone.	Data archives, workshops and conference sessions, data exchanges and collaboration with other SCAR groups.	
			AGIVA	AGIVA considers how the intrinsic value of Antarctic environments should be determined and how such values determine the level of management intervention. AGIVA and DynamiTe projects exploring how physical features such as ice sheets may be regarded as possessing value or rights that warrant action to prevent their being altered by climate change.		
			Terrestrial environment			
	Improve understanding of current and future change to the terrestrial (including aquatic) biotic and abiotic environment due to climate change	5-YWP, CCRWP (Issue 2)	ANTOS	(see above) The data being collected by ANTOS observation systems across the continent and sub-Antarctic will underpin our understanding of terrestrial habitat community composition, activity and diversity to allow impact predictions under current climate change projections.	(see above) - analysis of data collected to date (terrestrial) and establishing observation systems at new locations.	Ongoing (long term environmental data)

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			Ant-ICON	Understand the impact of future environmental conditions on ecosystem functioning (SCAR Horizon Scan)		
			EOAG	(see above)		
	Continue to develop biogeographic tools to provide a sound basis for informing Antarctic area protection and management at regional and continental scales in light of climate change, including identifying the need to set aside reference areas for future research and identifying areas resilient to climate change. Identify and prioritise Antarctic biogeographic regions most vulnerable to climate change	5-YWP, CCRWP (Issue 2), CEP XVII (para. 61)	SC-ATS	Follow up to SCAR/CEP protected areas workshop in collaboration with Ant-ICON.		
			Ant-ICON	Identification of vulnerable ecosystems and food webs (SCAR Horizon Scan)		
	Marine and nearshore environment					
	Understand and predict changes to the near-shore marine environment, and the impacts on species and habitats of that change	5-YWP, CCRWP (Issue 3)	ANTOS	(see above) The data being collected by ANTOS observation systems, on variations in environmental conditions around nearshore Antarctic and sub-Antarctic areas will underpin our understanding of benthic habitat, community composition and diversity investigations being carried out in aligned projects.	(see above) – analysis of data collected to date (coastal marine) and establishing observation systems at new locations.	Ongoing (long term environmental data)

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			ICED	Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) is an international multidisciplinary programme examining the response of Southern Ocean ecosystems to natural and anthropogenic change and feedbacks to the Earth System. ICED's coordinated circumpolar aim to understand interactions between climate and ecosystem dynamics, and generate scenarios and projections of the impacts of future change to support sustainable governance. ICED has 3 Research Challenges; 1) Understanding and quantifying the state and variability of Southern Ocean ecosystem, 2) Improving scenarios and projections of future Southern Ocean ecosystems at multiple scales, and 3) Improving and achieving sustainable Southern Ocean governance.	Scientific publications, workshops and outreach focussing on priority tasks identified under each Research Challenge.	
	Determine marine areas vulnerable to increasing human activities (excluding fishing activities) where impacts may be exacerbated as a consequence of climate change	CCRWP (Issue 3)	Ant-ICON	Identification of vulnerable ecosystems and food webs; Clarifying the synergistic effects of multiple stressors and environmental change drivers on Antarctic and Southern Ocean biota (SCAR Horizon Scan)		
			SOOS	SOOS Key Challenge 4.2: Understand biodiversity of Southern Ocean benthic and pelagic ecosystems at regional and circumpolar by investigating the potential changes accruing from influences of climate change and human activities. This work will be conducted across SOOS's working groups and in collaboration with other connected international initiatives.	Scientific publications, reports and workshops	Ongoing
	Assessment on impact of ocean acidification to marine biota and ecosystems	5-YWP, CCRWP (Issue 3), CEP XIV (para. 37)	SKAG	SKAG aims to use a combination of long-term data sets and process-orientated field studies to understand the resilience of Antarctic krill, a Southern Ocean key species, to climate change.	Results will be communicated through scientific publications, workshops and communication with stakeholders such as CCAMLR.	Ongoing

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			SOOS	SOOS in collaboration with the Global Ocean Acidification Observing Network (GOA-ON) is in the early stages of establishing an ocean acidification collaborative hub for the Southern Ocean.	New network	Late 2022 onwards
	Southern Ocean observations and modelling to understand climate change	5-YWP, CEP XVIII (para. 95)	ANTOS	ANTOS observation systems will collect data in nearshore areas that can contribute to models to understand climate change.	Analysis of data as it is collected.	Ongoing (long term environmental data)
			EOAG	(see above)		
			SOOS	(see above)		
	<i>Effects on species</i>					
	Enhance understanding of Antarctic biogeography and how species distribution is likely to change with climate change	CCRWP (Issue 4)	SOOS	SOOS Science Theme 4: Understanding and quantifying the state and variability of the Southern Ocean ecosystems and biodiversity. This theme includes key challenges address key drivers of change in Southern Ocean ecosystems, understanding Southern Ocean biodiversity and changes in this biodiversity due to climate change and human activities, as well as evaluation of the distribution of species in relation to CCAMLR MPAs. This work will be conducted across SOOS's working groups, in particular SOOS's Task Team on ecosystem Essential Ocean Variables (eEOV) and in collaboration with other connected international initiatives.	Scientific publications, reports and workshops	Ongoing
			AGIVA	AGIVA and DynamiTe projects exploring how biogeographic changes caused by climate change may be regarded as changing a natural state and thus warranting human intervention.		
		SKAG	(see above)	(see above)	Ongoing	

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	Assess the conservation status of key Antarctic species. Understand population status, trends, vulnerability and distribution.	5-YWP, CCRWP (Issue 4)	SOOS	SOOS Key Challenge 4.1: Assess the key drivers of change and their impacts on Southern Ocean ecosystems (food webs and biogeochemical cycling) at circumpolar and regional scales, with emphasis on the effects of changing sea ice conditions on key species that are central to Southern Ocean food webs (e.g., Antarctic krill, upper trophic level species). This work will be conducted across SOOS's working groups, in particular SOOS's Task Team on ecosystem Essential Ocean Variables (eEOV) and in collaboration with other connected international initiatives.	Scientific publications and reports	Ongoing
			EG-BAMM	EG-BAMM aims to collate and provide information on the status and trends of populations of species in the SCAR area of interest, and to contribute to the conservation and management of Antarctic birds and mammals through the appropriate utilisation and interpretation of currently available scientific data. The EG-BAMM emperor penguins working group is tasked with providing information to the CEP on to the conservation status and of this species.	Advice to ATS bodies as requested and in collaboration with these bodies, including the exchange of data.	
	Understand the effect of climate change on species potentially at risk, including critical thresholds yielding irreversible impacts	5-YWP, CCRWP (Issue 4)	EG-BAMM	Emperor penguins working group assessing the impacts of projected sea ice loss on emperor penguin populations.	Scientific publications.	
			SKAG	(see above)	(see above)	Ongoing
	Develop remote sensing methodologies to determine the status of key Antarctic species	5-YWP, CCRWP (Issue 4)	EOAG	The EOAG merged in 2021 with the Remote Sensing Action Group, which focuses on satellite-based remote sensing for monitoring animal populations.		

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			SOOS	The SOOS Capability Working Group on Censusing Animal Populations from Space (CAPS) is working to coordinate efforts to study and monitor larger animal populations using satellite remote sensing. Projects include highlighting hotspots for predator populations, and work on crabeater seal distribution and emperor penguin monitoring.	Scientific publications, machine learning algorithms and reports.	2015-2025
			SKAG	(see above)	(see above)	Ongoing
	Determine the relationships and interactions between species (food webs, habitat transformation, etc.) to determine the impacts of climate change on communities and ecosystems	5-YWP, CCRWP (Issue 4)	Ant-ICON	Understand the impact of future environmental conditions on ecosystem functioning (SCAR Horizon Scan)		
			SOOS	SOOS Science Theme 4: Understanding and quantifying the state and variability of the Southern Ocean ecosystems and biodiversity. This work will be conducted across SOOS's working groups, in particular SOOS's Task Team on ecosystem Essential Ocean Variables (eEOV) and in collaboration with other connected international initiatives.	Scientific publications, reports and workshops	Ongoing
			ICED	(see above)		
	Develop future spatial climate change predictions on the timescale of decades	CCRWP (Issue 5)	AntClim ^{now}	(see above)	Scientific publications, reports and workshops	
	Monitor emperor penguin colonies, including using remote sensing and complementary techniques, to identify trends in populations and potential climate change refugia	5-YWP, CEP XX (para. 222), CEP XVI (para. 176)	EG-BAMM	The EG-BAMM emperor penguin working group will provide information on emperor penguin conservation status, population assessment studies, research and monitoring activities, and research gaps relevant to the protection and management of the species.	Reports to the CEP on the conservation status of the emperor penguin.	
			EOAG	(see above)		
			SOOS	SOOS Capability Working Group on Censusing Animal Populations from Space (CAPS) emperor penguin monitoring.		
	Infrastructure					
Identify risk presented to Antarctic infrastructure by storms, sea level change, melting of permanent ice/flooding, permafrost melt, etc.	CCRWP (Issue 5)					

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	Research practical solutions to address climate change-related impacts on infrastructure	CCRWP (Issue 5)				
	Pollution Assess the impact of plastic pollution on natural systems in light of climate change	CCRWP (Issue 6)	Plastic-AG	An objective of the Polar Plastics AG is to improve the understanding of potential cumulative effect of plastic (micro and nano) with climatic stressors (i.e. global warming and ocean acidification)	Scientific publications and reports. Submission to CEP 2022.	Ongoing
2. Repair or remediation of environmental damage	How will climate change affect mobilization and exposure of species/ecosystems to contaminants?	CCRWP (Issue 5)	Ant-ICON	Improve understanding of the impact of contaminants and pollutants (SCAR Horizon Scan)		
	What is the susceptibility of microbial and macroscopic species in the Antarctic terrestrial environment to contaminants, including under warmer and wetter environmental conditions?	CCRWP (Issue 5)				
2. Monitoring and state of the environment reporting	Undertake long-term monitoring of change to the terrestrial (including aquatic) biotic and abiotic environment due to climate change	5-YWP, CCRWP (Issue 2)	ANTOS	ANTOS aims to foster and facilitate long-term collection of automated climate and associated environmental observations across Antarctica and national programmes.	Data will be added to the ANTOS database as it is collected and processed	Ongoing (long term environmental data)
	Identify areas vulnerable to increasing human footprint as a consequence of climate change	CCRWP (Issue 6)	Ant-TAG	Key Ant-TAG activities include development of a report on the future of Antarctic tourism and an Information Paper on key tourism challenges. These documents would include a discussion on how climate change affect tourism operations, tourist activities and subsequent human footprint in the future. Ant-TAG also includes consideration of how Antarctic tourism may disproportionately affect certain sites.	Information Paper for ATCM XLIV, and papers for future ATCMs	
	Long-term monitoring of change to the near-shore marine biotic and abiotic environment due to climate change	5-YWP, CCRWP (Issue 3)	ANTOS	ANTOS aims to foster and facilitate long-term collection of automated climate and associated environmental observations across Antarctica and national programmes.	Data will be added to the ANTOS database as it is collected and processed	Ongoing (long term environmental data)

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	Support and undertake collaborative long-term monitoring of change (e.g. SOOS, ANTOS) and seek regular state of knowledge reports from such programmes	CCRWP (Issues 2 and 3)	ANTOS	ANTOS will recommend technical guidelines for an internationally-coordinated installation of sensor networks, and standards for long-term data collection, storage, and sharing among national programmes.	Data will be added to the ANTOS database as it is collected and processed. These data will be made available to the community as an open-access asset.	Ongoing (long term environmental data)
			SOOS	(see above)		
	Develop remote sensing methodologies to determine the status of key Antarctic species	CCRWP (Issue 4)	ANTOS	ANTOS aims to foster and facilitate long-term collection of automated climate and associated environmental observations across Antarctica and national programmes.	Current designs of the ANTOS installations include a variety of near-field remote sensing capabilities that will be integrated and telemetered to a database in real time.	Ongoing (long term environmental data)
2. Overview of the protected areas system	Continue to develop biogeographic tools to provide a sound basis for informing Antarctic area protection and management at regional and continental scales in light of climate change, including identifying the need to set aside reference areas for future research and identifying areas resilient to climate change	5-YWP, CCRWP (Issue 2)	SC-ATS	Follow up to SCAR/CEP protected areas workshop in collaboration with Ant-ICON.		
			Ant-ICON	Explore the extent to which the concept of biogeographic regions might benefit from being expanding to encompass the notion of biocultural ethics and how we can most effectively reconsider the history of human-environment interactions in Antarctic socio-ecological systems for conservation management.	A workshop in Cambridge, UK, in early September 2022 will address this challenge (with a focus on the McMurdo Dry Valleys), and further online workshops will explore practical recommendations. Peer-reviewed articles discussing this topic are also planned.	2022-2025
			IBCSO	The goal of IBCSO is to provide the authoritative map of the Southern Ocean. It is aimed to serve as the base map and key data set for geospatial interpretations.	IBCSO Version 2 (IBCSO v2) will be accepted for publication in 'scientific reports'. Accompanying Digital Bathymetric Models and a printable version of the IBCSO v2 map will be available for download at https://doi.pangaea.de/10.1594/PANGAEA.937574	

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2. Designation and management of Historic Sites and Monuments	Assess the risk of climate change to HSMs and ASPAs designated to protect heritage values	CCRWP (Issue 5)	Ant-TAG	Ant-TAG members will explore how climate change affects a range of Antarctic values (and perceptions of these values), including wilderness, aesthetic, heritage and science values. These are all relevant to tourism and the tourist experience. This work will also inform a submission on current issues in Antarctic Tourism to the Antarctic Environments Portal.	Collaborative research outputs (peer-reviewed article and conference presentations; Antarctic Environments Portal submission on current issues in Antarctic tourism)	
			SC-HASS	"Decay Without Mourning" project considers how the material changes to Antarctic heritage from climate change may be addressed and where necessary accommodated.	Collaborative research outputs (peer-reviewed papers)	
	Assess climate change impacts on rates of degradation of historic infrastructure (e.g. microbial degradation of timber and organic artefacts)	CCRWP (Issue 5)				
	Characterise how implemented solutions to climate change impacts at historic sites may alter perceptions of their historic value	CCRWP (Issue 5)				
	Determine how climate change will affect artefacts left in situ, or those still to be unearthed (i.e. in a warmer and wetter environment)	CCRWP (Issue 5)	SC-HASS	(see above)		