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SCAR Science Lecture

Exploring the Future of Scientific Research in Antarctica

Jerónimo López-Martínez

Universidad Autónoma de Madrid, Spain

President of SCAR

Acknowledgements

- Chuck Kennicutt, past President of SCAR and major driver behind the success of the Horizon Scan and ARC initiatives
- COMNAP, especially Michelle Rogan-Finnemore, Kazuyuki Shiraishi and Yeadong Kim
- The SCAR and COMNAP secretariat staffs
- The sponsors
- The contribution of hundreds of scientists, managers and policy-makers from over 40 countries

Outline

- SCAR Antarctic and Southern Ocean Science Horizon Scan

Highest priority scientific questions

- COMNAP Antarctic Roadmap Challenges Project
Technology, Infrastructure, Access, Cost
- International cooperation
- Integrating Science, Conservation and Policy
- SCAR adaptation and new Strategic Plan

1st SCAR Antarctic and Southern Ocean Science Horizon Scan



“A roadmap for Antarctic and Southern Ocean Science for the next two decades and beyond”

Horizon Scan Sponsors



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What is a Horizon Scan?

The systematic search for opportunities, which are then articulated as a vision for future directions



The 1st SCAR Antarctic and Southern Ocean Science Horizon Scan

The international Antarctic community came together to “scan the horizon” to identify the highest priority scientific questions that researchers should aspire to answer in the next two decades and beyond

An inclusive process

- Community-wide solicitations
 - Round 1: 751 questions
 - Round 2: 115 questions
- Retreat invitations
 - 789 nominations of 510 individuals
 - 75 Retreat attendees from 22 countries
 - Scientists, Program Directors/Managers, policy makers, decision makers and early career scientists.
 - Observers (eg. Nature, Antarctica NZ, NZARI, Media, Tinker Foundation)



Horizon Scan Outcomes

From nearly 1000 ideas, the 80 most important scientific questions were identified through structured debate, discussion, revision and voting



The 1st SCAR Antarctic and Southern Ocean Science Horizon Scan

Antarctic Atmosphere and Global Connections

1. How is climate change and variability in the high southern latitudes connected to lower latitudes including the Tropical Ocean and monsoon systems?
2. How do Antarctic processes affect mid-latitude weather and extreme events?
3. How have teleconnections, feedbacks, and thresholds in decadal and longer term climate variability affected ice sheet response since the Last Glacial Maximum, and how can this inform future climate projections?
4. What drives change in the strength and position of Westerly winds, and what are their effects on ocean circulation, carbon uptake and global teleconnection?
5. How did the climate and atmospheric composition vary prior to the oldest ice records?
6. What controls regional patterns of atmospheric and oceanic warming and cooling in the Antarctic and Southern Ocean? (*Cross-cut: "Southern Ocean"*)
7. How can coupling and feedbacks between the atmosphere and the surface (land ice, sea ice and ocean) be better represented in weather and climate models? (*Cross-cut: "Southern Ocean" and "Antarctic Ice Sheet"*)
8. Does past amplified warming of Antarctica provide insight into the effects of future warming on climate and ice sheets? (*Cross-cut: "Antarctic Ice Sheet"*)
9. Are there CO₂ equivalent thresholds that forestall collapse of all or part of the Antarctic Ice Sheet? (*Cross-cut: "Antarctic Ice Sheet"*)
10. Will there be release of greenhouse gases stored in Antarctic and Southern Ocean clathrates, sediments, soils, and permafrost as climate changes? (*Cross-cut: "Dynamic Earth"*)
11. Is the recovery of the ozone hole proceeding as expected and how will its recovery affect regional and global atmospheric circulation, climate and ecosystems? (*Cross-cut: "Antarctic Life" and "Human"*)

Southern Ocean and Sea Ice in a Warming World

12. Will changes in the Southern Ocean result in feedbacks that accelerate or slow the pace of climate change?
13. Why are the properties and volume of Antarctic Bottom Water changing, and what are the consequences for global ocean circulation and climate?
14. How does Southern Ocean circulation, including exchange with lower latitudes, respond to climate forcing?
15. What processes and feedbacks drive changes in the mass, properties and distribution of Antarctic sea ice?
16. How do changes in iceberg numbers and size distribution affect Antarctica and the Southern Ocean?
17. How has Antarctic sea ice extent and volume varied over decadal to millennial time scales?
18. How will changes in ocean surface waves influence Antarctic sea ice and floating glacial ice?
19. How do changes in sea ice extent, seasonality and properties affect Antarctic atmospheric and oceanic circulation? (*Cross-cut: "Antarctic Atmosphere"*)
20. How do extreme events affect the Antarctic cryosphere and Southern Ocean? (*Cross-cut: "Antarctic Ice Sheet"*)
21. How did the Antarctic cryosphere and the Southern Ocean contribute to glacial-interglacial cycles? (*Cross-cut: "Antarctic Ice Sheet"*)
22. How will climate change affect the physical and biological uptake of CO₂ by the Southern Ocean? (*Cross-cut: "Antarctic Life"*)
23. How will changes in freshwater inputs affect ocean circulation and ecosystem processes? (*Cross-cut: "Antarctic Life"*)

Antarctic Ice Sheet and Sea Level

24. How does small-scale morphology in subglacial and continental shelf bathymetry affect Antarctic Ice Sheet response to changing environmental conditions? (*Cross-cut: "Dynamic Earth"*)
25. What are the processes and properties that control the form and flow of the Antarctic Ice Sheet?

26. How does subglacial hydrology affect ice sheet dynamics, and how important is it? (*Cross-cut: "Dynamic Earth"*)
27. How do the characteristics of the ice sheet bed, such as geothermal heat flux and sediment distribution, affect ice flow and ice sheet stability? (*Cross-cut: "Dynamic Earth"*)
28. What are the thresholds that lead to inevitable loss of all or part of the Antarctic ice sheet?
29. How will changes in surface melt over the ice shelves and ice sheet evolve, and what will be the impact of these changes?
30. How do oceanic processes beneath ice shelves vary in space and time, how are they modified by sea ice, and do they affect ice loss and ice sheet mass balance? (*Cross-cut: "Southern Ocean"*)
31. How will large-scale processes in the Southern Ocean and atmosphere affect the Antarctic Ice Sheet, particularly the rapid disintegration of ice shelves and ice sheet margins? (*Cross-cut: "Antarctic Atmosphere" and "Southern Ocean"*)
32. How fast has the Antarctic Ice Sheet changed in the past and what does that tell us about the future?
33. How did marine-based Antarctic ice sheets change during previous interglacial periods?
34. How will the sedimentary record beneath the ice sheet inform our knowledge of the presence or absence of continental ice? (*Cross-cut: "Dynamic Earth"*)

Dynamic Earth - Probing beneath Antarctic Ice

35. How does the bedrock geology and/or the Antarctic Ice Sheet inform our understanding of supercontinent assembly and breakup through Earth history?
36. Do variations in geothermal heat flux in Antarctica provide a diagnostic signature of sub-ice geology?
37. What is the crust and mantle structure of Antarctica and the Southern Ocean, and how do they affect surface motions due to glacial isostatic adjustment?
38. How does volcanism affect the evolution of the Antarctic lithosphere, ice sheet dynamics, and global climate? (*Cross-cut: "Antarctic Atmosphere" and "Antarctic Ice Sheet"*)
39. What are and have been the rates of geomorphic change in different Antarctic regions, and what are the ages of preserved landscapes?
40. How do tectonics, dynamic topography, ice loading and isostatic adjustment affect the spatial pattern of sea level change on all time scales? (*Cross-cut: "Antarctic Ice Sheet"*)
41. Will increased deformation and volcanism characterize Antarctica when ice mass is reduced in a warmer world, and if so, how will glacial- and ecosystem be affected? (*Cross-cut: "Antarctic Life"*)
42. How will permafrost, the active layer and water availability in Antarctic soils and marine sediments change in a warming climate, and what are the effects on ecosystems and biogeochemical cycles? (*Cross-cut: "Antarctic Life"*)

Antarctic Life on the Precipice

43. What is the genomic basis of adaptation in Antarctic and Southern Ocean organisms and communities?
44. How fast are mutation rates and how extensive is gene flow in the Antarctic and the Southern Ocean?
45. How have ecosystems in the Antarctic and the Southern Ocean responded to warmer climate conditions in the past? (*Cross-cut: "Antarctic Atmosphere" and "Oceans"*)
46. How has life evolved in the Antarctic in response to dramatic events in the Earth's history? (*Cross-cut: "Dynamic Earth"*)
47. How do subglacial systems in form models for the development of life on Earth and elsewhere? (*Cross-cut: "Eyes on the Sky"*)
48. Which ecosystems and food webs are most vulnerable in the Antarctic and Southern Ocean, and which organisms are most likely to go extinct?
49. How will threshold transitions vary over different spatial and temporal scales, and how will they impact ecosystem functioning and/or future environmental conditions?
50. What are the synergistic effects of multiple stresses and environmental change drivers on Antarctic and Southern Ocean biota?
51. How will organisms and ecosystems respond to a changing sealandage in the Southern Ocean? (*Cross-cut: "Human"*)
52. How will non-generation contaminants affect Antarctic and Southern Ocean biota and ecosystems?

53. What is the exposure and response of Antarctic organisms and ecosystems to atmospheric contaminants (e.g. black carbon, mercury, sulphur, etc.), and are the sources and distributions of these contaminants changing? (*Cross-cut: "Antarctic Atmosphere" and "Human"*)
54. How will the sources and mechanisms of dispersal of propagules into and around the Antarctic and Southern Ocean change in the future?
55. How will invasive species and range shifts of indigenous species change Antarctic and Southern Ocean ecosystems? (*Cross-cut: "Human"*)
56. How will climate change affect the risk of spreading emerging infectious diseases in Antarctica? (*Cross-cut: "Human"*)
57. How will increases in the ice-free Antarctic intertidal zone impact biodiversity and the likelihood of biological invasions?
58. How will climate change affect existing and future Southern Ocean fisheries, especially kill stocks? (*Cross-cut: "Human"*)
59. How will linkages between marine and terrestrial systems change in the future?
60. What are the impacts of changing seasonality and transitional events on Antarctic and Southern Ocean marine ecology, biogeochemistry, and energy flow?
61. How will increased marine resource harvesting impact Southern Ocean biogeochemical cycles? (*Cross-cut: "Human"*)
62. How will deep sea ecosystems respond to modifications of deep water formation, and how will deep sea species interact with shallow water ecosystems as the environment changes?
63. How can changes in the form and frequency of extreme events be used to improve biological understanding and forecasting? (*Cross-cut: "Antarctic Atmosphere"*)
64. How can temporal and spatial "omic-level" analyses of Antarctic and Southern Ocean biodiversity inform ecological forecasting?
65. What will key marine species tell us about trophic interactions and their oceanographic drivers such as future shifts in frontal dynamics and stratification?
66. How successful will Southern Ocean Marine Protected Areas be in meeting their protection objectives, and how will they affect ecosystem processes and resource extraction? (*Cross-cut: "Human"*)
67. What ex situ conservation measures, such as genetic repositories, are required for the Antarctic and Southern Ocean? (*Cross-cut: "Human"*)
68. How effective are Antarctic and Southern Ocean conservation measures for preserving evolutionary potential? (*Cross-cut: "Human"*)
69. What happened in the first second after the universe began?
70. What is the nature of the dark universe and how is it affecting us?
71. What are the differences in the inter-hemispheric coupling between the ionosphere and that in the lower, middle and upper atmosphere, and what causes these differences?
72. How does space weather influence the polar ionosphere and what are the wider implications for the global atmosphere? (*Cross-cut: "Antarctic Atmosphere"*)
73. How do the generation, propagation, variability and climatology of atmospheric waves affect atmospheric processes over Antarctica and the Southern Ocean? (*Cross-cut: "Antarctic Atmosphere"*)

Human Presence in Antarctica

74. How can natural and human-induced environmental changes be distinguished, and how will this knowledge affect Antarctic governance? (*Cross-cut: all other Chapters*)
75. What will be the impacts of large-scale, direct human modification of the Antarctic environment? (*Cross-cut: "Antarctic Life"*)
76. How will external pressures and changes in the geopolitical configurations of power affect Antarctic governance and science?
77. How will the use of Antarctica for peaceful purposes and science be maintained as barriers to access change?
78. How will regulatory mechanisms evolve to keep pace with Antarctic tourism?
79. What is the current and potential value of Antarctic ecosystem services?
80. How will humans, diseases and pathogens change, impact and adapt to the extreme Antarctic environment? (*Cross-cut: "Antarctic Life"*)

Available at: <http://www.scar.org/horizonscanning>

Publications

7 August 2014



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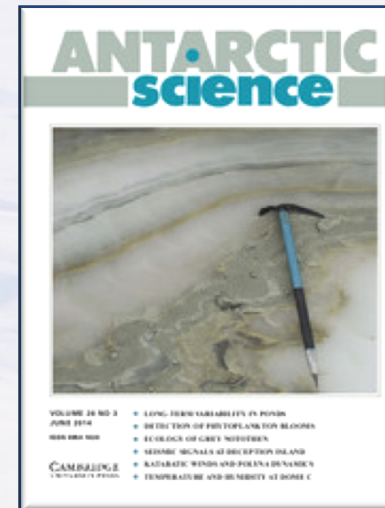
A roadmap for Antarctic and Southern Ocean science for the next two decades and beyond

M.C. KENNICUTT II, S.L. CHOWN, J.J. CASSANO, D. LIGGETT, L.S. PECK, R. MASSOM, S.R. RINTOUL, J. STOREY, D.G. VAUGHAN, T.J. WILSON, I. ALLISON, J. AYTON, R. BADHE, J. BAESEMAN, P.J. BARRETT, R.E. BELL, N. BERTLER, S. BO, A. BRANDT, D. BROMWICH, S.C. CARY, M.S. CLARK, P. CONVEY, E.S. COSTA, D. COWAN, R. DECONTO, R. DUNBAR, C. ELFRING, C. ESCUTIA, J. FRANCIS, H.A. FRICKER, M. FUKUCHI, N. GILBERT, J. GUTT, C. HAVERMANS, D. HIK, G. HOSIE, C. JONES, Y.D. KIM, Y. LE MAHO, S.H. LEE, M. LEPPE, G. LEITCHENKOV, X. LI, V. LIPENKOV, K. LOCHTE, J. LÓPEZ-MARTÍNEZ, C. LÜDECKE, W. LYONS, S. MARENSSI, H. MILLER, P. MOROZOVA, T. NAISH, S. NAYAK, R. RAVINDRA, J. RETAMALES, C.A. RICCI, M. ROGAN-FINEMORE, Y. ROPERT-COUDERT, A.A. SAMAH, L. SANSON, T. SCAMBOS, I.R. SCHLOSS, K. SHIRASHI, M.J. SIEGERT, J.C. SIMÕES, B. STOREY, M.D. SPARROW, D.H. WALL, J.C. WALSH, G. WILSON, J.G. WINTHER, J.C. XAVIER, H. YANG and W.J. SUTHERLAND

mckennicutt@gmail.com

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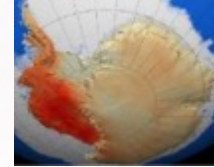


Science Priorities for...

DEFINE

*the global reach of the
Antarctic atmosphere and Southern Ocean*

**RECOGNIZE
AND MITIGATE**
human influences



UNDERSTAND
*how, where and
why ice sheets lose mass*



Antarctic and Southern Ocean Science

OBSERVE
space and the Universe

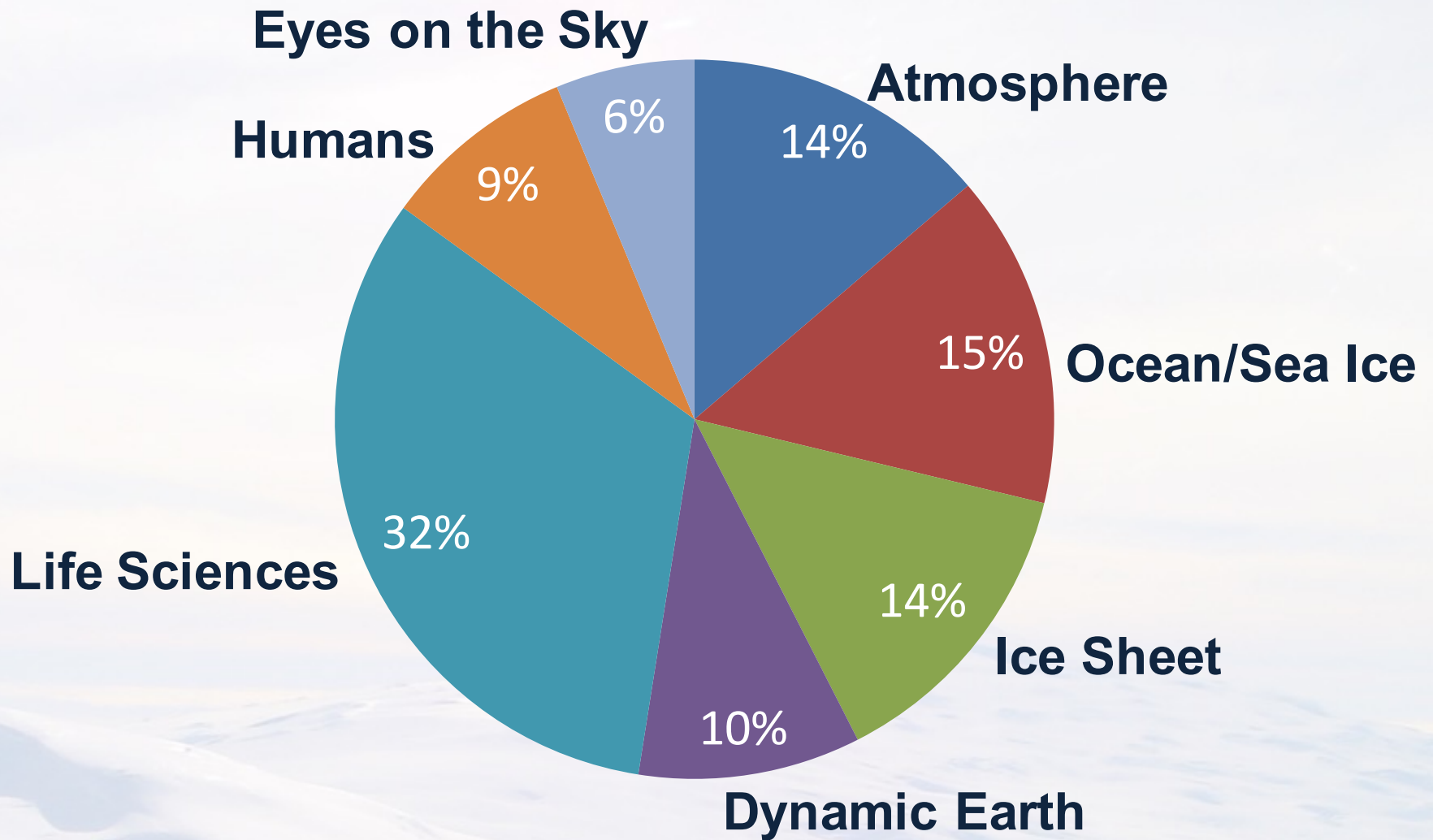


REVEAL
*Antarctica's
history*



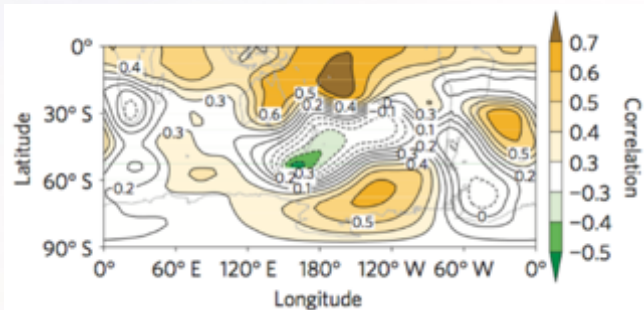
LEARN
*how Antarctic life
evolved and survived*





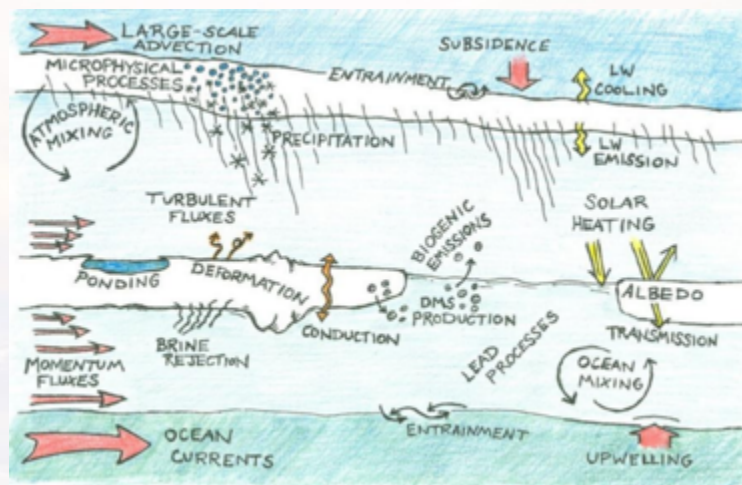
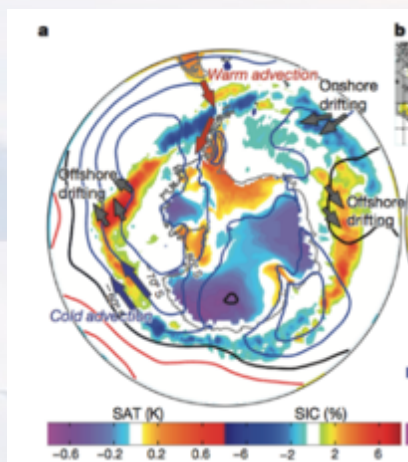
50% of the questions cross-cut other topical clusters

Antarctic Atmosphere and Global Connections

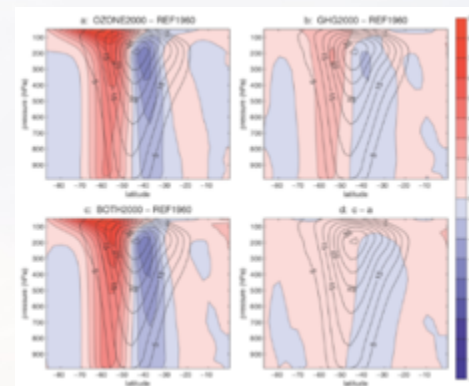


Tele-connections

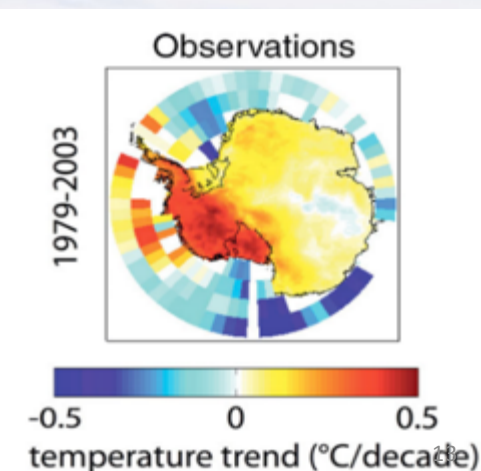
Processes and interfaces



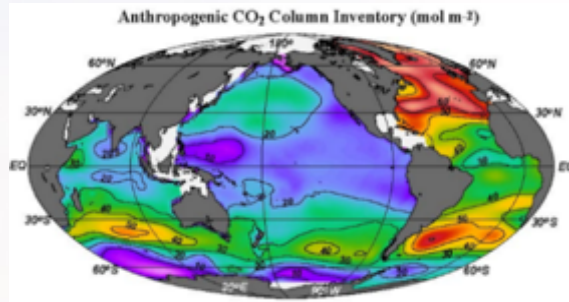
Regional variations



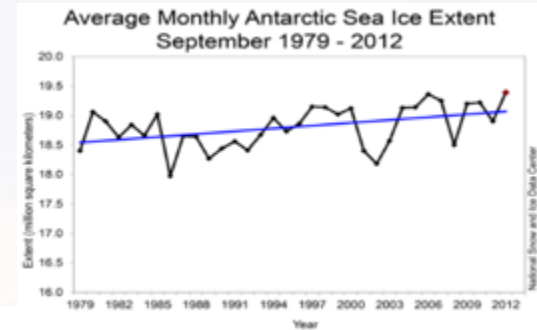
Greenhouse gases/Ozone recovery



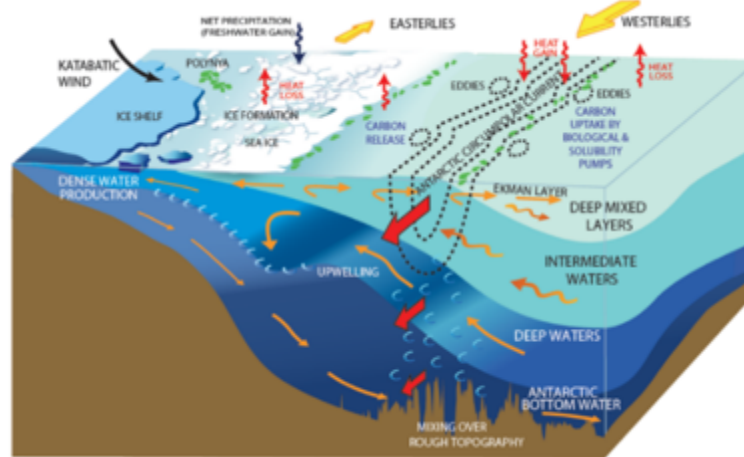
The Southern Ocean and Sea Ice in a Warming World



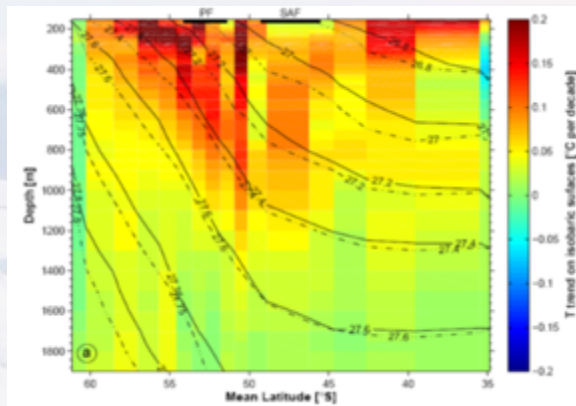
Human role
in ocean change



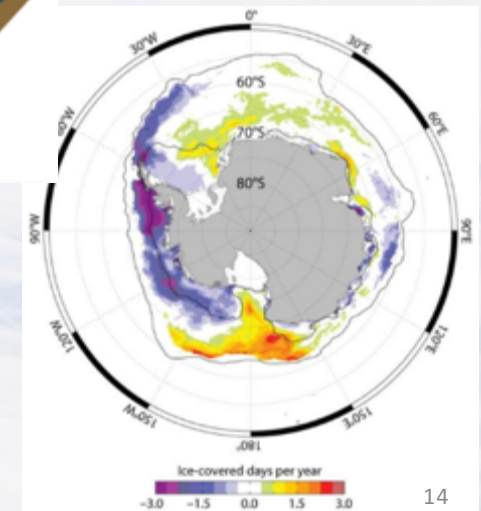
Heat, energy, carbon
dioxide, carbon,
oxygen and nutrient
cycles and budgets



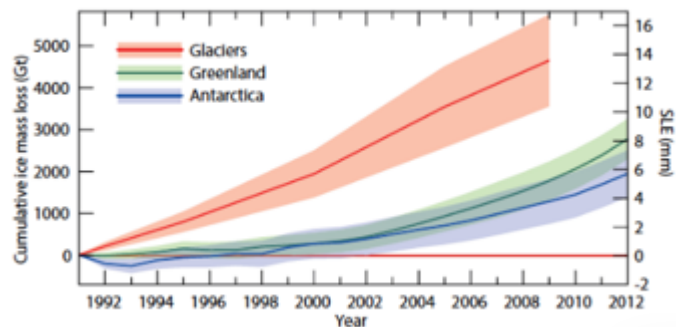
Sea ice
variability



Improved climate
forecasts



Antarctic ice sheet and sea level

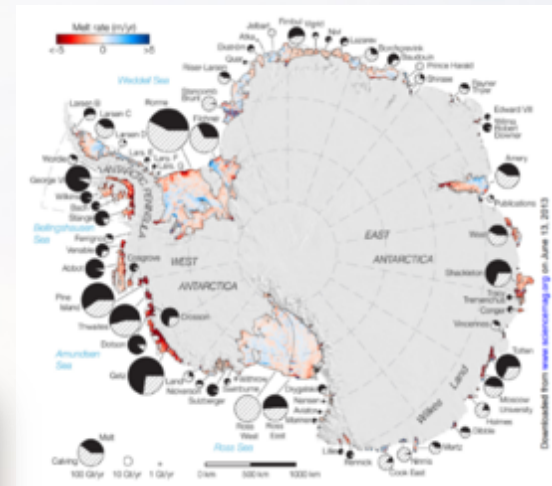
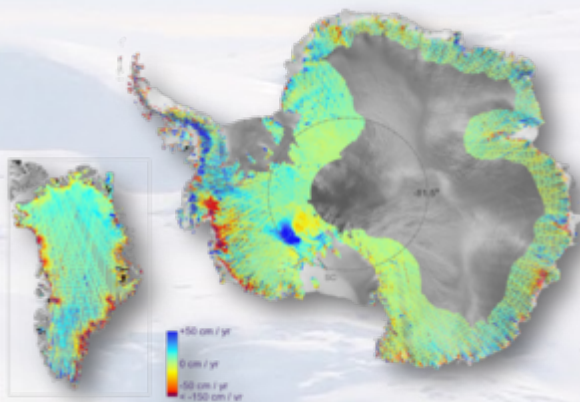


Controls and processes

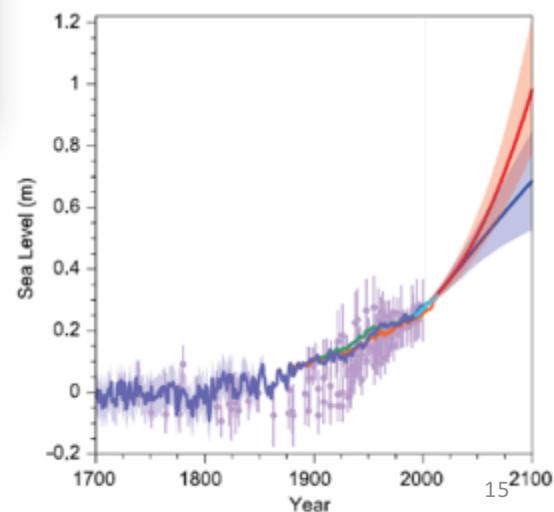
Ice sheet thinning, retreat, and melt



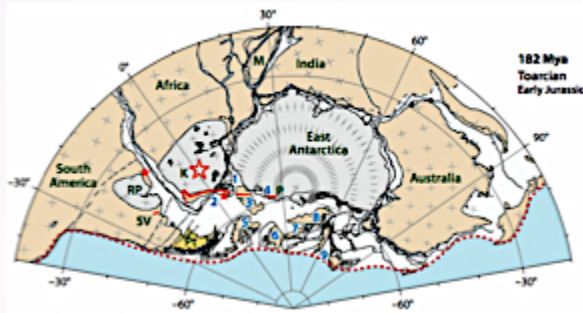
Improved climate and sea level forecasts



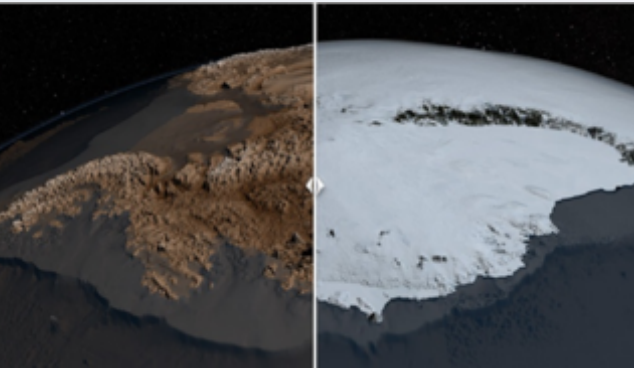
Sea level



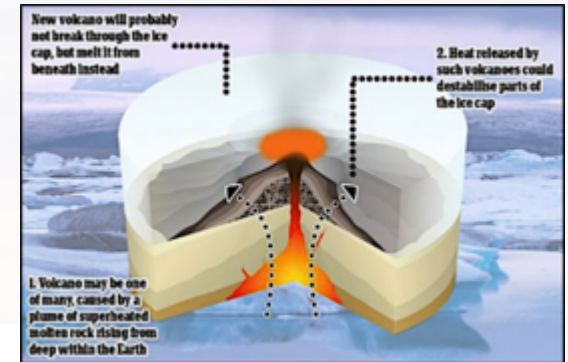
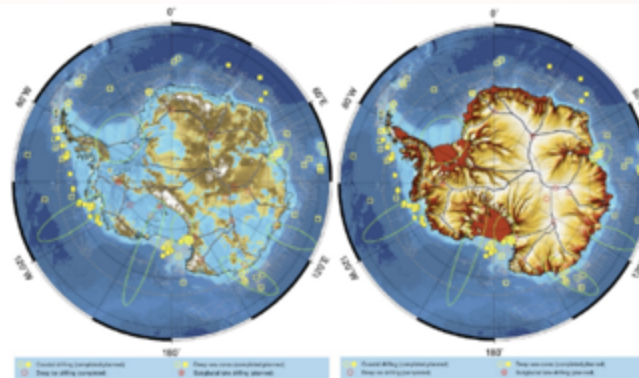
Dynamic earth – probing beneath Antarctic ice



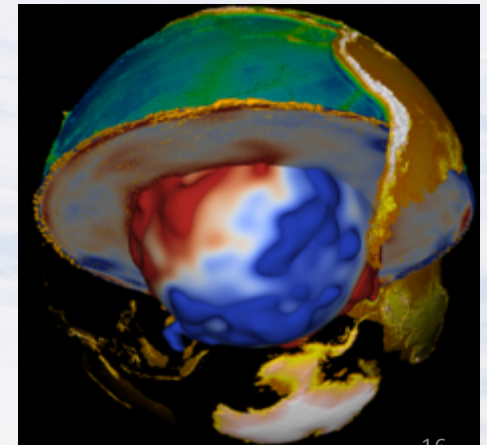
Super continent assembly



Heat flux and volcanism



Deep Earth structure



Cryospheric feedbacks

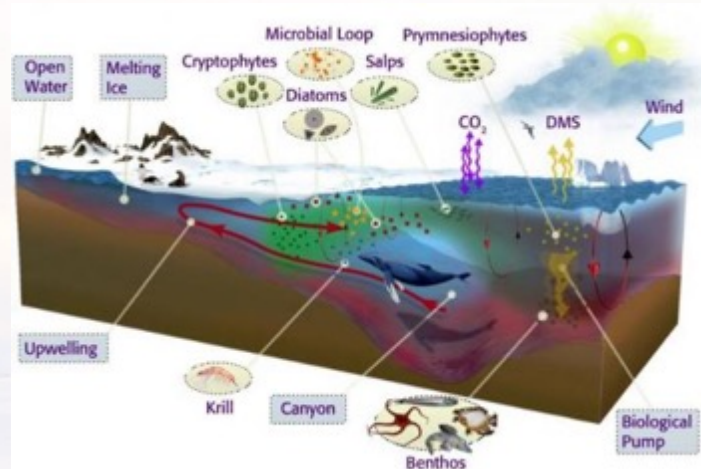
Antarctic life on the precipice



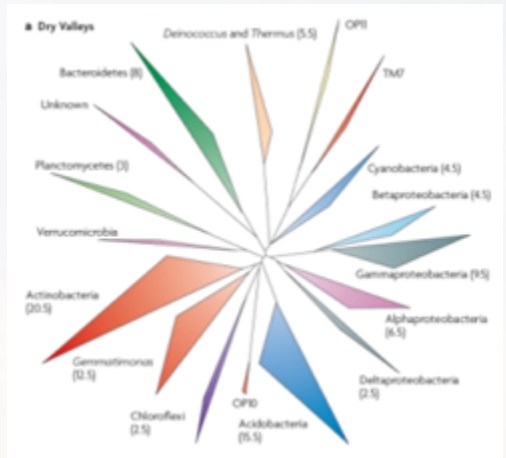
Adaptation and biodiversity



Ecosystem structure and function



Conservation science



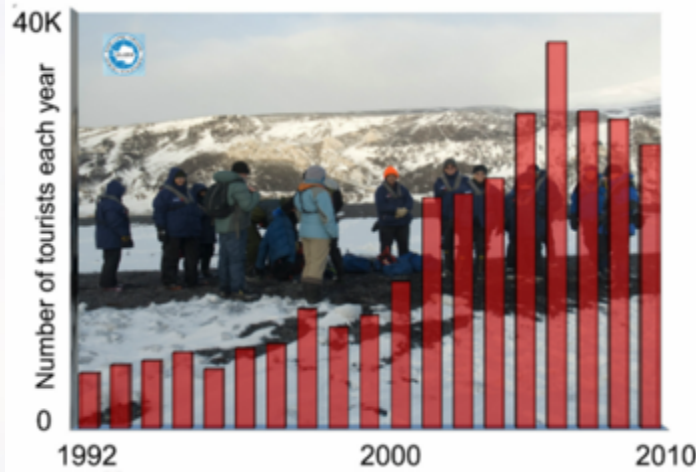
Environmental drivers



Human presence in Antarctica

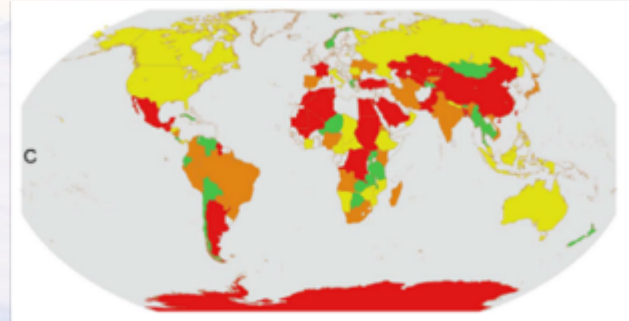
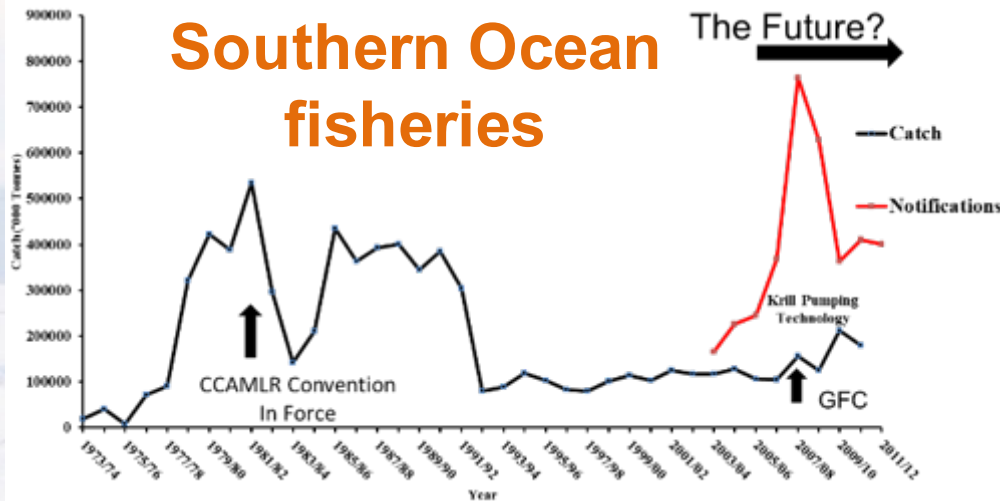
Scientific footprint

Tourism



Southern Ocean fisheries

The Future?

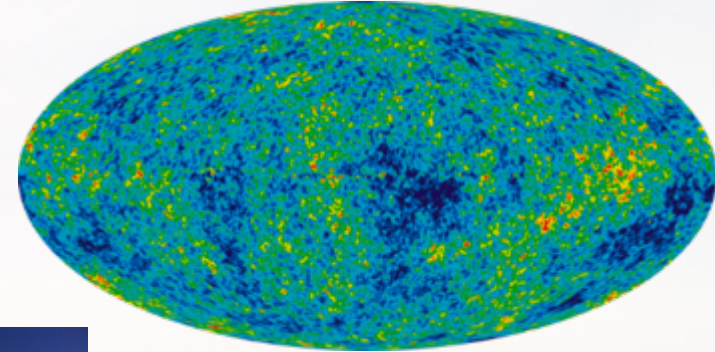


Conservation, protection, ecosystem services, and governance

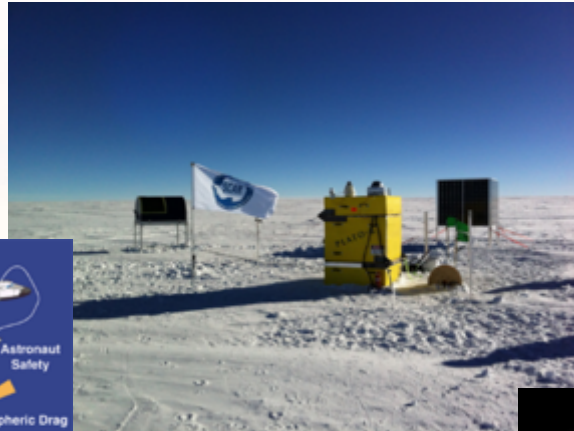
Near-Earth space and beyond – eyes on the sky



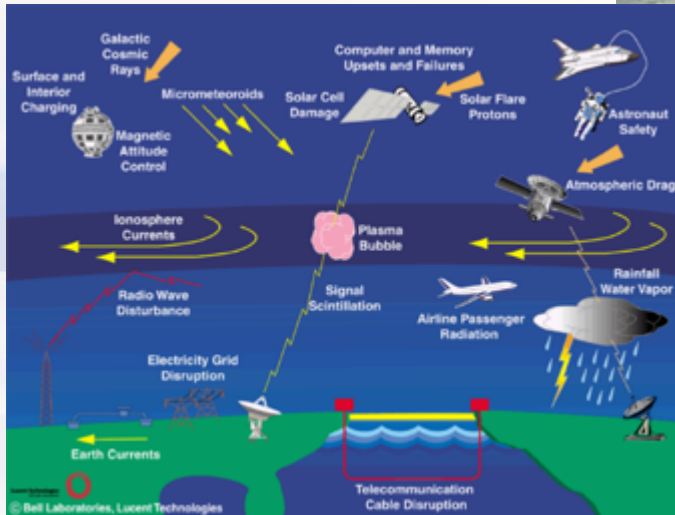
The origins of the Universe



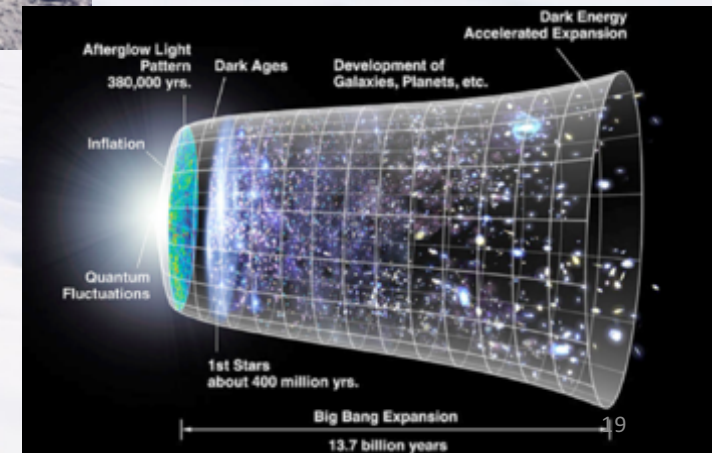
Life beyond Earth



The nature of the dark Universe



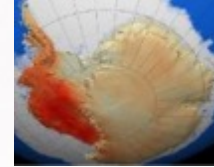
Space weather



The Challenges to...

**SUSTAIN
STABLE FUNDING**

COMMUNICATE
with all stakeholders



PROVIDE ACCESS
*Region wide
Year round*



**ENHANCE
INTERNATIONAL
COLLABORATION**



**APPLY
EMERGING TECHNOLOGIES**



**STRENGTHEN
ENVIRONMENTAL PROTECTION**

***...realizing
the promise
of Antarctic
science***

Antarctic Roadmap Challenges Project

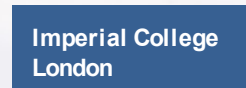


Welcome to the “Antarctic Roadmap Challenges” (ARC) website

JOIN US to define the next steps in delivering Antarctic research into the coming decades.

The Antarctic Roadmap Challenges (ARC) Project

Sponsors





COMNAP



The Council of
Managers of National
Antarctic Programs
www.comnap.aq
info@comnap.aq

Reaching for the Horizon: Enabling 21st Century Antarctic and Southern Ocean Science

The Antarctic Roadmap Challenges Project

Identify the challenges

1. Technologies
2. Extraordinary logistics requirements
3. Infrastructure/Access
4. Collaboration
5. Energy
6. Human resources
7. Long term, sustainable funding

Delivering the “Roadmap for Antarctic and
Southern Ocean science for the next two
decades and beyond”

ARC Project Methodology

- Formed a Steering Committee (11 members)
- Two on-line open surveys
 - Survey 1: 453 responses (38 countries)
 - Survey 2: 257 responses (29 countries)
- Workshop (60 participants)
- Workshop Writing Reports (7 reports and 14 external reviewers)
- White papers (12 communities)
- Outcomes
 - Publications
 - Presentations

COMNAP Antarctic Roadmap Challenges (ARC) project



Technology

Infrastructure

Access

Cost

International
Collaboration

TECHNOLOGY



- Automated observing technologies, capable of sustained, remote/isolated, long-term deployment (years) with attendant energy, interoperability & calibration requirements
- High performance computing technologies with data storage/transfer capabilities
- Expanded satellite remote sensing with integrated, synoptic, region-wide measurement technologies
- Improved coupled Earth System Models
- Improved sample retrieval technologies

INFRASTRUCTURE

- Existing infrastructure important-Antarctic science will always be field-based
- “Super-sites” - a concentration of interdisciplinary science activity
- Increased ship-time (research capable ice breakers)
- Reliable computing, information and communications (ICTS) infrastructure and support

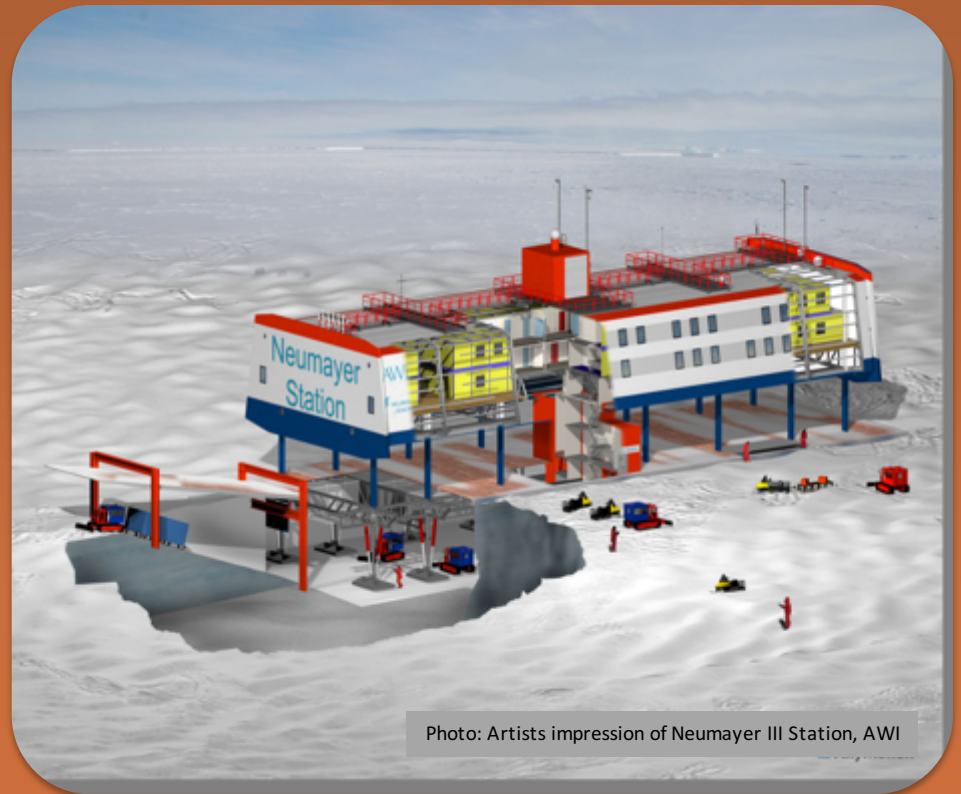


Photo: Artists impression of Neumayer III Station, AWI

ACCESS

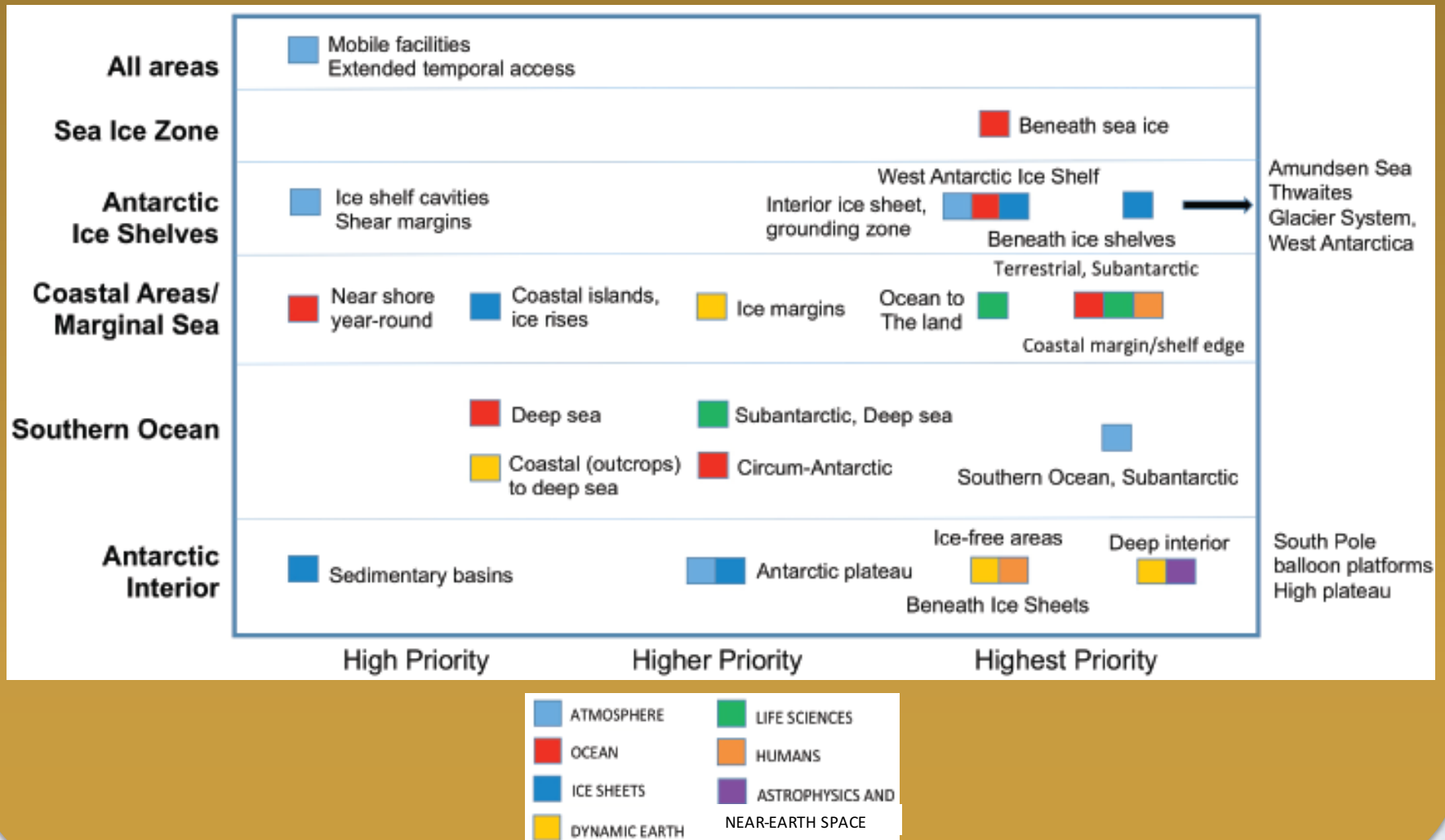
“Continent-wide and ocean-wide access year-round”

- **Coastal areas** (including beneath floating ice)
- **Interior** (by way of deep field camps)
- Southern Ocean (especially **deep ocean** sampling and emplacement of observatories)
- Social sciences/humanities research community requires **greater access to data and information**



Photos: SA Agulhas II, SANAP

Priority Areas for Access to the Antarctic Region

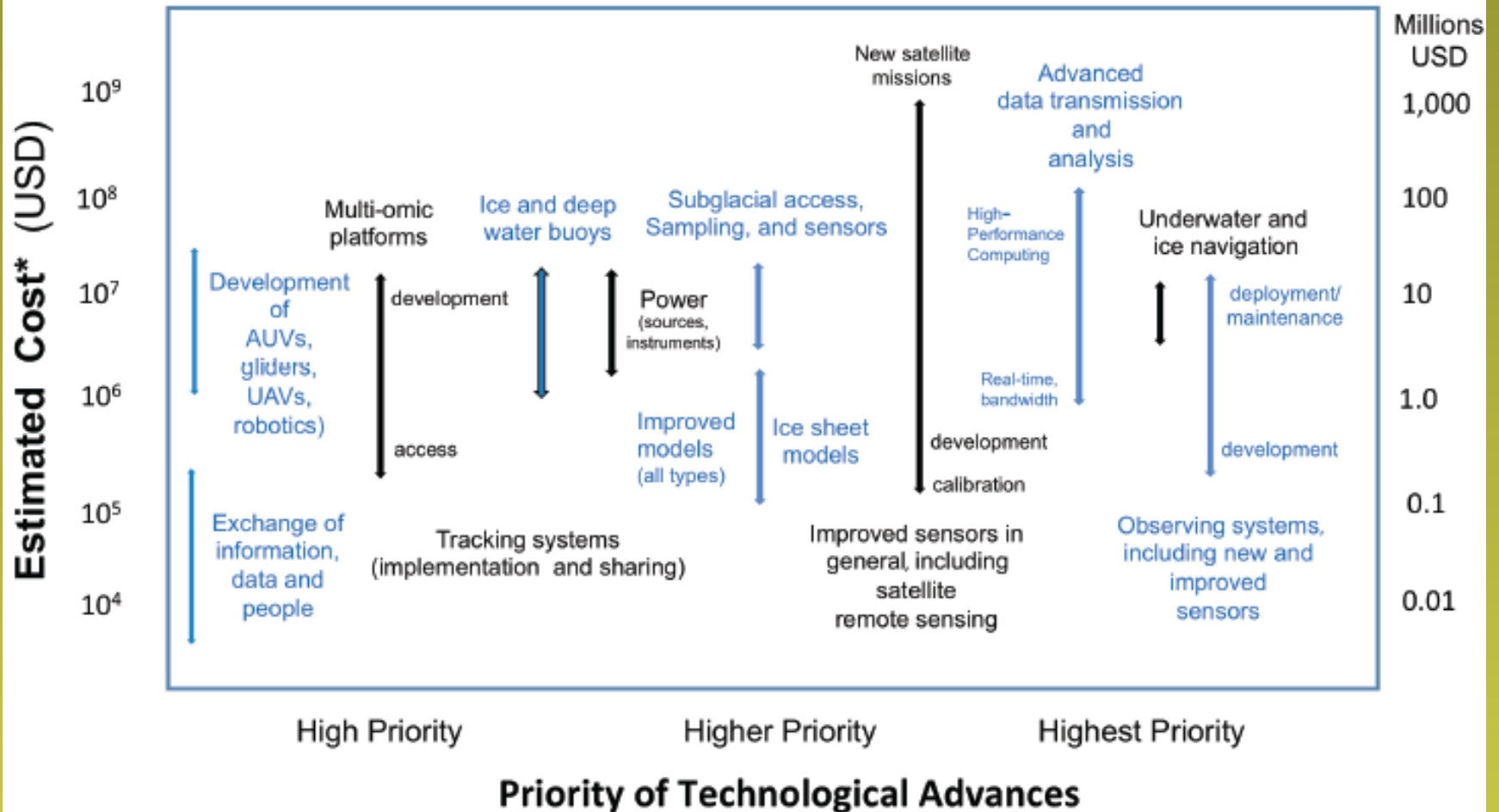


Antarctic science is expensive. The top five critical technologies and infrastructure requirements are also the most expensive



Photo: Polar Geospatial Center

COST



*Cost estimates are order of magnitude over wide ranges, highly variable and dependent on the scope of the activity.

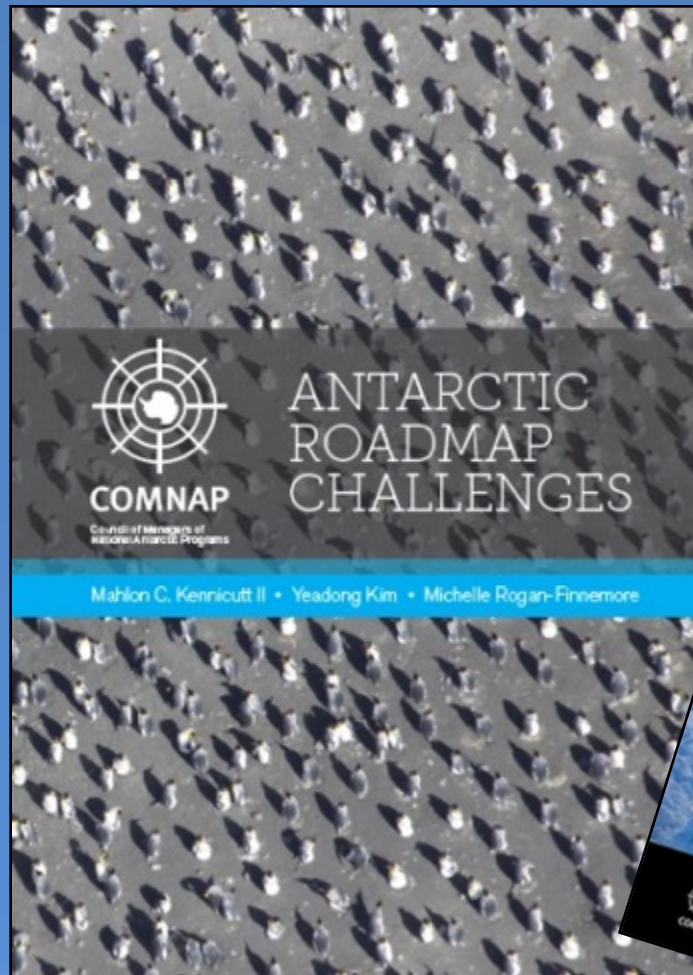
COST

INTERNATIONAL COLLABORATION



Photo: US National Science Foundation

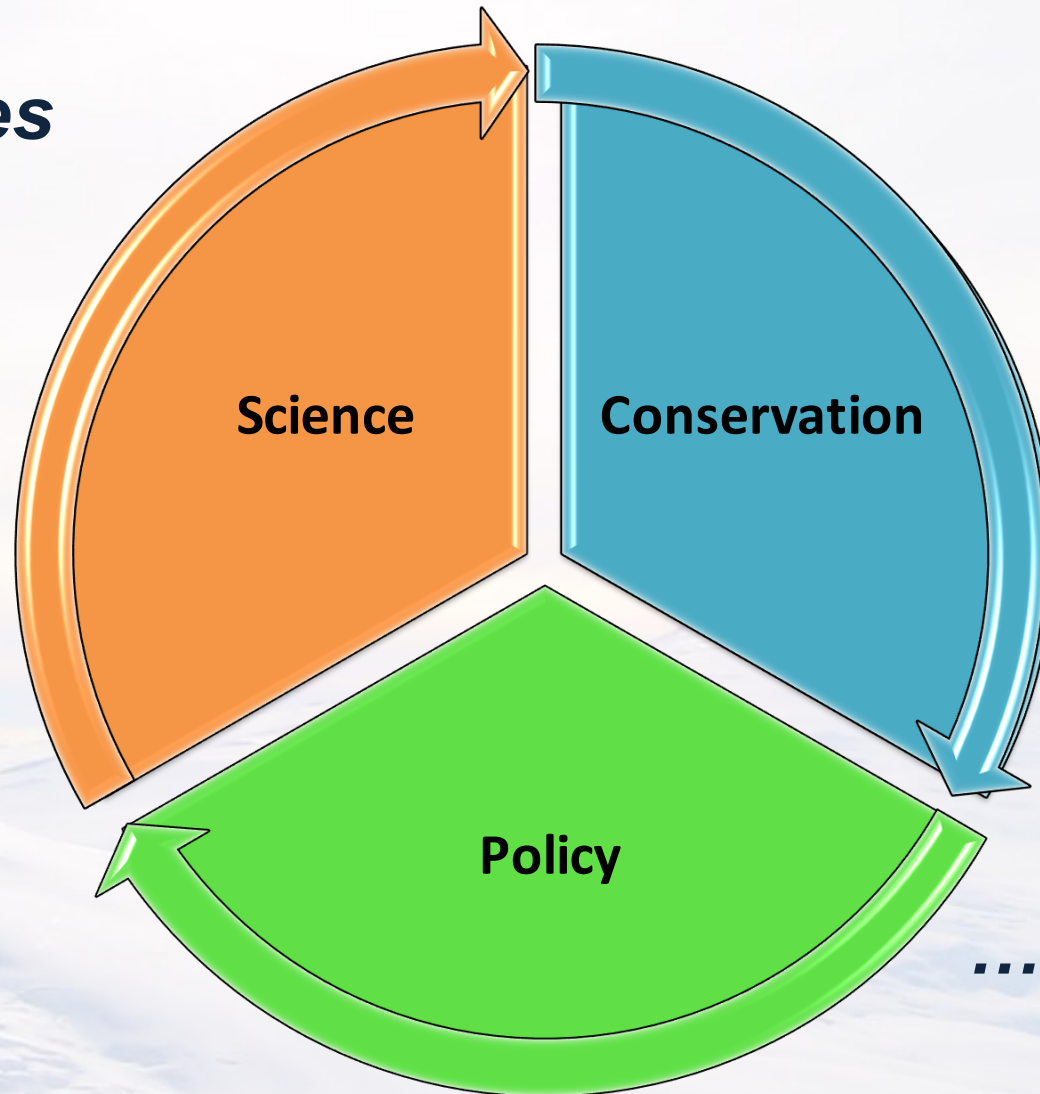
- Status of critical technologies: 1/3 scientists said they did not have access to critical technologies which already existed
- More-effective use of existing facilities amongst community
- Greater ability to rapidly deploy science teams to rapidly changing areas of the Antarctic region to collect benchmark observations (West Antarctica)
- No one country can do Antarctic research alone
- Antarctic community must engage with “external” science & technology communities



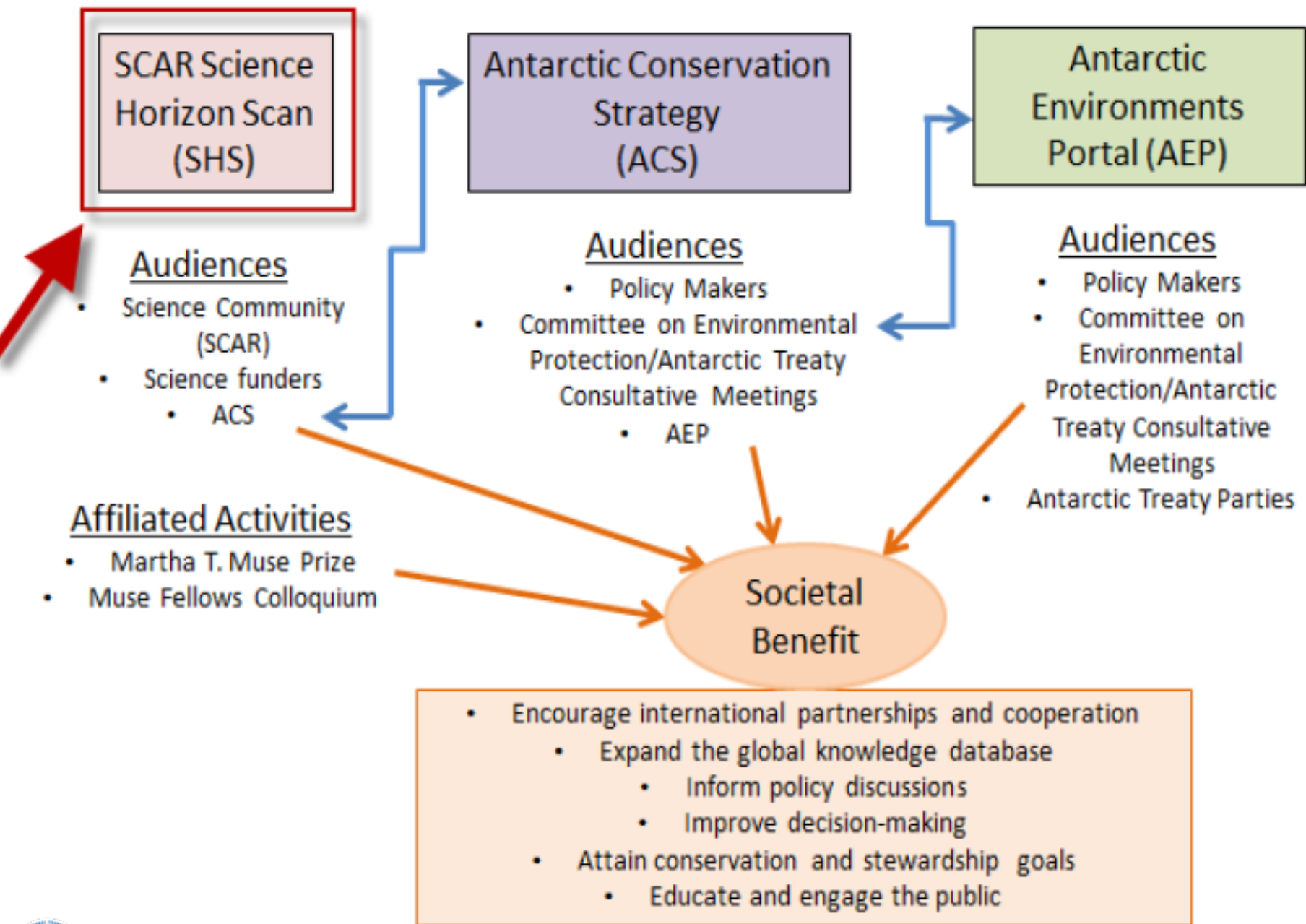
Available at : <https://www.comnap.org/Projects/SitePages/ARC.aspx>

Integrating Science, Conservation and Policy in Polar Science in the 21st Century

*Interfaces
and...*



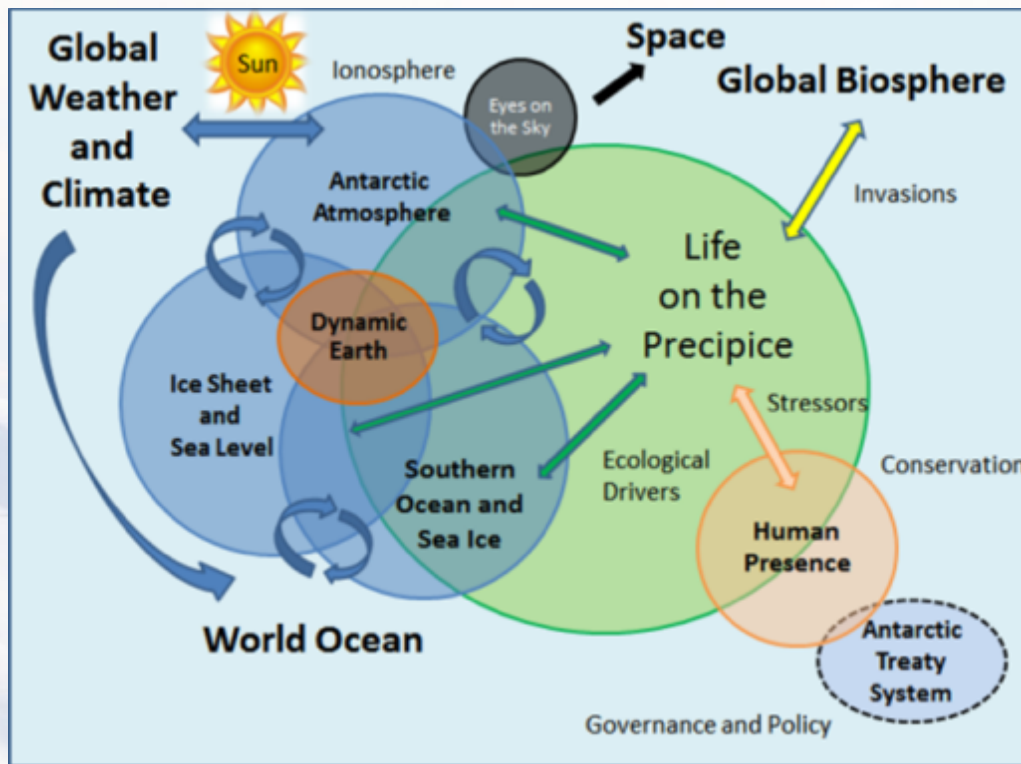
...Challenges



To reach for the horizon:

A coordinated, portfolio of interdisciplinary science, based on enhanced international cooperation is essential

Future Antarctic science will continue to address multi-disciplinary issues, will be complex and will require international collaborative efforts...



No one scientist, program or nation can realize these aspirations alone

SCAR adaptation

- Interaction with the Community, National Committees and Partner Organizations
- New Member Countries
- Strategic Plan 2017-2022



SCAR flag flying over the Ridge A international observatory

(Photo C. Kulesa, Feb. 2013)



New SCAR Strategic Plan 2017-2022

- SCAR will use the key questions arising from the **1st Antarctic and Southern Ocean Science Horizon Scan** to **guide research priorities and research direction** over the next five years and beyond.
- SCAR's vision is **to be an engaged, active, forward-looking organization that promotes, facilitates, and delivers scientific excellence and evidence-based policy advice on globally significant issues that are relevant to Antarctica.**



ATCM XXXIX- CEP XIX, Santiago, Chile, 2016

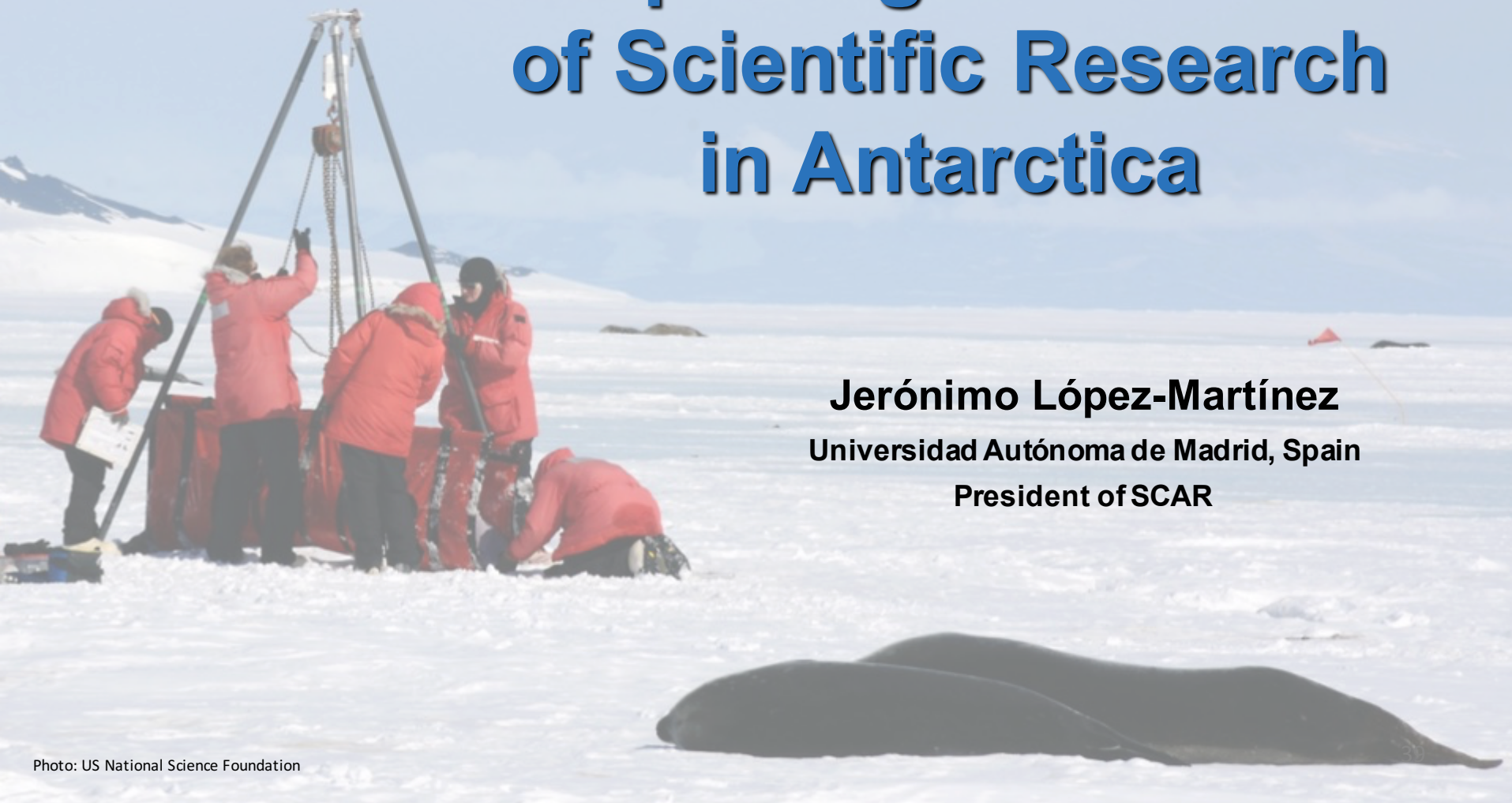
SCAR Science Lecture

Exploring the Future of Scientific Research in Antarctica

Jerónimo López-Martínez

Universidad Autónoma de Madrid, Spain

President of SCAR





ATCM XXXIX- CEP XIX, Santiago, Chile, 2016

SCAR Science Lecture

Exploring the Future of Scientific Research in Antarctica

Prof. Jerónimo López-Martínez

Wednesday 25 May 2016

12.00 – 13.00 Room 1 (CEP Room)

Photo: US National Science Foundation