# ID35- EUROPEAN POLAR RESEARCH: STATUS AND CHALLENGES OF EUROPEAN POLAR FLEET FOR ENHANCING STRATEGIC COLLABORATION

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*Abstract –Polar Regions are the most vulnerable world areas to any climate change, and therefore can be considered drivers of global climate change, so small and systematic changes in the Polar Regions affect critically the global environment. This is particularly worrying for Europe and the Arctic due to ocean circulation interaction between the North Atlantic and the Arctic Oceans whose outcome is already producing significant climate anomalies in the Northern Hemisphere. Many European countries support polar research, not only in the Arctic but also in Antarctica, and in fact many European polar research programs have a two-pole perspective. However Europe lacks sufficient marine technological platforms to meet the challenges posed today in marine polar research.*

*Keywords – Polar Research Infrastructures, Artic, Antarctic, Global change.*

**I. INTRODUCTION**

During the 70s, the opinion of scientists was increasingly in favor of the views of global warming. In the early 90s, the improvements and reliability of computer models, together with an extensive observational work confirming the Milankovitch theory of ice ages, allowed for a broad consensus in the scientific community on the role of the greenhouse effect on most climate change and that anthropogenic emissions favored global warming. Since then the polar scientific community has persistently warned about the urgent need to investigate the Polar Regions in order to respond adequately to the growing societal concerns about how to respond to these significant global changes. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was set up by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP). The IPCC is the international body for assessing the science related to climate change with regular reviews of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation.

Polar-related issues have been growing in the political agenda across Europe over the past last decade. The increasing level of investment now being made by governments is a clear demonstration of how critical polar research outcomes are for informing policy objectives, including those relating to climate change, energy security, global food security, innovation and economic growth. This situation can be substantially improved by an overall integrated scientific approach, increasing the level of coordination of polar research and promoting cooperation with all relevant European and international actors.

**II. THE POLAR FLEET STATUS.**

In recent years the European Commission has promoted through different coordinated actions and/or funded projects (including Eurofleets2, EU-PolarNet, ARICE), an analysis of the European status of the large scale infrastructures (i.e., Polar Research Vessels (PRVs), Polar Stations, etc.) which is a fundamental step to organize a pan-European polar approach.

Here we summarize the studies on the large scale facilities after assembling information on PRVs operating at both poles (Arctic and Antarctica).

In a first approach, we have distributed the PRV´s in accordance with the new International Maritime Organization (IMO) Polar Code (PC) classification (Fig 1): Category A, B and C. Most of the information has been assimilated from the EU-project Eurofleets2 and information by EurOcean, Council of Managers National Arctic Program (COMNAP), International Research Ship Operators (IRSO), European Research Vessel Operators (ERVO), etc.

| POLAR RESEARCH VESSELS | | IACS | |
|---|---|---|---|
| World | Europe | | |
| Healy, Polar Sea, L. S. St. Laurent, Amundsen, Shirase II | Polarstern, Oden, | PC1 PC2 PC3 | Year-Round navigation in Polar Waters |
| N. B.Palmer, Araon, Agulhas II, Al. Irizar, Sikuliaq | Akademik Tryoshnikov | PC4 PC5 | |
| Winter navigation in Sub-Polar waters | IA Super | PC6 PC7 | Summer Navigation in Polar waters |
| | IA | | |
| | IB | | |
| | **FSICR** Ice Class Rules | | |

***Fig 1. Equivalence between new IMO Polar Code (PC) and the previous ice classification for PRVs***

*a) Heavy Icebreakers*

We have identified worldwide 13 operational Category A vessels (Fig 2) potentially empowered to accomplish research in the Polar Oceans, operating at least in first-year sea-ice (according to the new Polar Code classification, between PC1-PC5). The heavy Icebreakers are generally long vessels (95-167 m) with large draft and well prepared for long endurance voyages. The crew ranges mostly from 25-45 members, except for the Swedish PRV "Oden" which reports only 23 crew members. However, these ships show great variability with reference to capacities, equipment, schedules, access, etc. All of these Research Vessels also have capacities to support polar stations within the Antarctic or Arctic areas, and a few of them are fully equipped for multidisciplinary science. Regarding vessels with full capacity of year-round operations, Europe is currently limited to two PRVs, the German "Polarstern", and the Swedish "Oden". Worldwide only a few more are available, such as the USA "Healy" and USA "Polar Sea" ("Polar Sea" has been out of service since 2010 due to engine failure and a decision is pending as to whether it will be scrapped or repaired) the Canadian "Louis S. St. Laurent" and "Amundsen" and the Japanese "Shirase II".

Among these PRVs, only the "Polarstern" is exclusively dedicated to research.

When restricted to European PRV´s, the list includes the Russian "Akademik Tryoshnikov" in addition to "Polarstern" and "Oden". Worldwide the list is extended with "Sikuliaq" and "Nathaniel B. Palmer" (both USA), "Agulhs II" (South Africa), "Araon" (Republic of Korea), and "Almirante Irizar" (Argentina). This justifies that, to provide a response to societal demands it is necessary to increase the international cooperation for the use of these expensive platforms. Most of these PRVs are operated by National Science Agencies; exceptions' being those operated by the USA and Canada Coast Guards. The heavy icebreakers are generally old ships and only three of the ships (Fig. 2), are less than 5 years old. The remainder each have more than twenty years of service. We have identified only the "Araon", "Amundsen" and the "Polarstern" as capable of working with deep sea Remotely Operated Vehicles (ROVs). The PRVs "Polarstern", "Healy", "Louis S. St Laurent" also have Automated Underwater Vehicles (AUV) capacities. The worldwide scenario for heavy icebreakers is a little bit more optimistic due to recent constructions. The continuation of operations at least in Antarctic waters is almost guaranteed by the three PRVs recently built; "Araon" (2009), "Akademik Tryoshnikov" (2011) and "Agulhas II" (2012), although these vessels – with the exception of the "Araon" - are more specifically commissioned to logistical support to polar stations than to perform marine research. In addition, USA extended its PRV fleet in 2014 with "Sikuliaq" - the first vessel built for the US National Science Foundation in more than three decades. "Sikuliaq" is an almost 80m length, well equipped research platform operated by the University of Alaska Fairbanks School of Fisheries and Ocean Sciences. Furthermore, the Australian Government has signed a

| Region | Polar Code Category | IACS Class | Ship Name | Picture | Country | Length (m) | Built year | Operator | Ice Class NEW POLAR CODE | Research Equipment | Operating area | Major Refit | Supply Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EUROPE | A | PC1 to PC3 | Polarstern | | Germany | 118 | 1982 | AWI | PC2/PC3 | 100/100 | Antarctic Arctic | 2002 | Yes |
| | | | Oden | | Sweden | 108 | 1988 | SMA | PC2/PC3 | 60/100 | Antarctic Arctic | | Yes |
| WORLDWIDE | A | PC1 to PC3 | Healy | | USA | 128 | 1997 | USACGC | PC2 | 60/100 | Antarctic Arctic | | Yes |
| | | | Polar Sea | | USA | 122 | 1978 | USACGC | PC2 | 25/100 | Antarctic Arctic | | Yes |
| | | | L. S. St-Laurent | | Canada | 120 | 1969 | CCG | PC2 | 60/100 | Arctic | decom m. 2017 | No |
| | | | Amundsen | | Canada | 98 | 1979 | CCG | PC3 | 50/100 | Arctic | 2003 | No |
| | | | Shirase II | | Japan | 138 | 2008 | Ministry of Defence & JARE | PC3 | 50/100 | Antarctic Arctic | | Yes |
| EUROPE | A | PC4 to PC5 | Ak. Tryoshnikov | | Russia | 134 | 2011 | AARI | PC4-PC5 | 50/100 | Antarctic Arctic | | Yes |
| WORLDWIDE | A | PC4 to PC5 | N.I B. Palmer | | USA | 94 | 1992 | USAP | PC4/PC5 | 100/100 | Antarctic | | Yes |
| | | | Almirante Irizar | | Argentina | 121 | 1978 | Argentina Navy | PC5 | 60/100 | Antarctic | ongoing | Yes |
| | | | Agulhas II, | | Souht Africa | 134 | 2012 | SANAP | PC5 | 60/100 | Antarctic | | Yes |
| | | | Araon | | South Korea | 110 | 2009 | KOPRI | PC5 | 100/100 | Antarctic Arctic | | Yes |
| | | | Sikuliaq | | USA | 80 | 2014 | U. of Alaska UNOLS | PC5 | 100/100 | Arctic | | No |

***Fig 2. Summary of Heavy PRV Ice-Classes for year-round polar operations modified from EUROFLEETS2***

contract for a new icebreaker with the Australian company DMS Maritime Pty Ltd. They will be responsible for both the overall design and build of the ship, and the operation and maintenance of the ship over its expected 30 year life, starting in 2020. China has recently (April 2016) published a public tender for a new PRV icebreaker which is expected to be in service around 2019. In the beginning of 2016, Chile announced a contract for the design of a new icebreaker for the Chilean Navy as replacement for the "Oscar Viel" in 2021. The contract, with Chile's ASMAR Shipbuilding & Ship Repair Company, will be for a 400- foot icebreaker of 13,000 tons displacement, rated for one meter of ice. She will carry a complement of 150 and will serve throughout the Southern Ocean for purposes including research, Search and Rescue (SAR), logistics support and resupply for Chile's bases in Antarctica. In Peru, the PRV "BAP Carrasco" of 97m length, polar class PC7, was launched in May 2016 at "Construcciones Navales P. Freire" shipyard in Vigo, Spain. The PRV belongs to the Peruvian Navy Hydrographic Service to carry out research and support to the Peruvian Antarctic stations and perform research in Peru's exclusive economic zone. The vessel is equipped with the latest technology and will be the platform for Peruvian Navy to conduct investigations in hydrography, oceanography, geology, biology and geophysics.

*b) Ice classified Icebreakers*

The Ice Class B and C (PC 6-8) PRVs in Fig 3 are mostly designed for science purposes, except the PRV "Oscar Viel" which is principally a station logistical support vessel.

Most of the ships have underwater vehicle capacity for both AUVs and ROVs. Most vessels (with the exception of some naval ships) have ample space for scientists and technicians due to a reduced crew. There is also a reasonably good balance between vessels operating at either pole.

| Region | Polar Code Category | IACS Class | Ship Name | Picture | Country | Length (m) | Built year | Operator | Ice Class New POLAR CODE | Research Equipment | Operating area | Major Refit | Supply Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EUROPE | B | PC6 to PC7 | Aranda | | Finland | 59,2 | 1989 | Finnish Env. Insti. | PC-6 | 100/100 | Artic | | No |
| | | | Astrolabe | | France | 65 | 1986 | IPEV/P&O Maritime | PC 6 | 40/100 | Antarctic | | Yes |
| | | | Akad.Federov | | Russia | 141 | 1987 | AARI | PC 6 | 50/100 | Antarctic Arctic | | Yes |
| | | | James C. Ross | | UK | 99 | 1990 | BAS | PC 6 | 100/100 | Antarctic Arctic | | No |
| | | | Maria S Merian | | Germany | 95 | 2005 | IOW_Warnemunde | PC 7 | 100/100 | Artic | | No |
| | | | Sanna | | Greenland | 32,3 | 2012 | GINR | PC 7 | 100/100 | Artic | | No |
| | | | Italica | | Italy | 130 | 1981 | DIAMAR | PC 7 | /100 | Antarctic | | Yes |
| | | | Helmer Hanssen | | Norway | 64 | 1988 | University of Tromso | PC 7 | 100/100 | Artic | 1992 | No |
| | | | Lance | | Norway | 61 | 1978 | Norwegin Polar Ins. | PC 7 | 100/100 | Antarctic Artic | | No |
| WORLDWIDE | B | PC 6 to PC 7 | Aurora Australis | | Australia | 95 | 1989 | P & O / ADD | PC6 | 60/100 | Antarctic | 2013 | Yes |
| | | | L. M. Gould | | USA | 70,2 | 1997 | USAP | PC 6 | 50/100 | Antarctic | | Yes |
| | | | Xue Long | | China | 167 | 1993 | CAA | PC6-PC7 | 50/100 | Antarctic Artic | 2013 | Yes |
| EUROPE | C | PC7 to PC8 | G.O. Sars | | Norway | 77,5 | 2003 | UiB | PC 7 | 100/100 | Antarctic Artic | | No |
| | | | Hesperides | | Spain | 82,5 | 1991 | Spanish Navy CSIC-UTM | PC 7 | 100/100 | Antarctic Artic | | Yes |
| | | | E. Shackleton | | UK | 80 | 1995 | BAS | PC 7 | 25/100 | Antarctic | 2001 | Yes |
| | | | Dana | | Denmark | 78 | 1981 | DTU Aqua | PC 8 | 100/100 | Artic | 1992 | No |
| | | | A. Fridriksson | | Iceland | 69,9 | 2000 | MRI | PC 8 | 100/100 | Artic | | No |
| | | | OGS-Explora | | Italy | 73 | 1973 | OGS -Trieste | PC 8 | 100/100 | Antarctic Artic | | No |
| WORLDWIDE | C | PC7 to PC8 | BAP Carrasco | | Peru | 95 | 2016 | Peru Navy | PC 7 | 100/100 | Antarctic | | Yes |
| | | | Al. Maximiniano | | Brasil | 93,4 | 1974 | Brasil Navy | PC 8 | 100/100 | Antarctic | | Yes |
| | | | Oscar Viel | | Chile | 90 | 1969 | Chile Navy | PC 8 | 25/100 | Antarctic | | Yes |
| | | | Tangaroa | | New Zealand | 70 | 1991 | NIWA | PC 8 | 100/100 | Antarctic | | |
| | | | Sagar Kanya | | India | 100 | 1983 | NACAOR | | 100/100 | Antarctic Artic | | |

***Fig 3. Summary of Ice-Class PRVs for winter navigation in subpolar operations, modified from EUROFLEETS2***

## III. SCIENCE REQUIREMENTS REGARDING EQUIPMENT AND PRV CAPABILITIES

*a) Future equipment needs*

Due to the constant increase in costs for the deployment of these ships, and increasing needs for transdisciplinary research, the next generation of PRVs must be multifunctional, and comprise modular components that are easily interchanged, mobilized and demobilized depending on the type of research scheduled for an upcoming cruise. The ship should have the capacity to operate in winter ice with pressure ridges and multi-year ice. The ship should be equipped with a centreline moon pool to facilitate sampling of the water column under extreme conditions and to enable also e.g. the deployment of AUVs and ROVs through this access point. As the Antarctic Research Vessel Oversight Committee (ARVOC, USA) suggests, new technological capabilities are expected to support the investigation of atmospheric sciences using remote sensing instruments based on laser and microwave technologies. This also includes unmanned aerial drones for research in the atmosphere and studies of sea ice and glacier ice in areas where polar research vessels will be required to serve as the main base, and also in SAR operations. Acoustic instruments are crucial to both physical and biological marine research. This includes multibeam echosounders, subbottom profilers, acoustic current meters, fisheries acoustics, and acoustic underwater positioning and navigation systems. An optimized hull design is therefore required to achieve a certain acoustic noise reduction level (ringing, reverberation, background noise, acoustic blocking, etc.) as well as for transit in open water (benign in heavy seas, resistance, energy efficiency etc.). Powerful and versatile winch and crane arrangements are key elements.

*b) Predictable evolution of the Polar Research fleet*

We consider here the perspective of the European Polar Research fleet (Fig. 2) based on the forecast at the beginning of 2014. From the point of view of the heavy icebreakers, Europe has two operative vessels, the "Oden" which is dedicated exclusively for Arctic research since 2011, and the "Polarstern" which mostly spends her time in Antarctic waters. "Polarstern" is reaching the end of its life time, after 30 years of continuous operation, while "Oden" has an estimated 15 years to go without a major refit.

There are some progressing projects such as the Norwegian 100 m length PRV "Kronprins Haakon", polar class PC 3, under construction and to be operational in early 2018. With deep sea ROV and AUV operations capacity, together with a moonpool and a hangar for sampling at low temperatures, this vessel is carrying state of the art equipment to support the highest standards in Polar science, targeting areas mostly in the Arctic region, but also on a regular basis in the Antarctic.

Another ongoing project is the "Polarstern" replacement by "Polarstern II". This is a 140m length PRV with polar classification PC2-PC3 and designed with an optimized hull to reduce noise and vibration, high level energy efficiency- and environmental standards, a moonpool, and a hangar for sampling at low temperatures. "Polarstern II" is planned to be arranged and equipped with state of the art scientific technology that will support high class research standards and with a significant cargo capacity to supply the German Antarctic station Neumayer III. It is estimated to be operational in 2019.

In the UK, "James Clark Ross" will be replaced by the new 125m length "Sir David Attenborough" which will enter in to service in 2019. It will be used for both marine research and logistics support to British Antarctic research stations. The vessel will have a number of marine research instruments and systems on board, including multiple hydro acoustics systems for bathymetry, oceanography and biology and a moonpool for launch and recovery of underwater vehicles.The Swedish government has given the Polar Research Secretariat the task to do a pre-study on how Sweden should plan long-term for a polar research vessel after that Oden has been decommissioned.

*c) Status of the Polar Research fleet front of H-2020*

When estimating an average vessel lifespan of 30 yearsand correcting where midlife refit is reported, the life-time termination of the fleet will be about year 2025. This scenario predicts that few of the current European heavy icebreakers will be operating beyond the 2020 horizon (Fig. 4), and as well predicts higher global reduction when considering vessels fully equipped for high standard quality science. The current heavy icebreaker fleet analysed here show signs of aging as a whole (Figure 4), hopefully the Norwegian and German ongoing projects improves the outlook, but requires thorough reflection by funding agencies and research agencies.

The other ice classified PRV´s, the UK "James Clark Ross" (to be replaced by the new "Sir David Attenborough") and the Spanish "Hespérides" will continue in op-

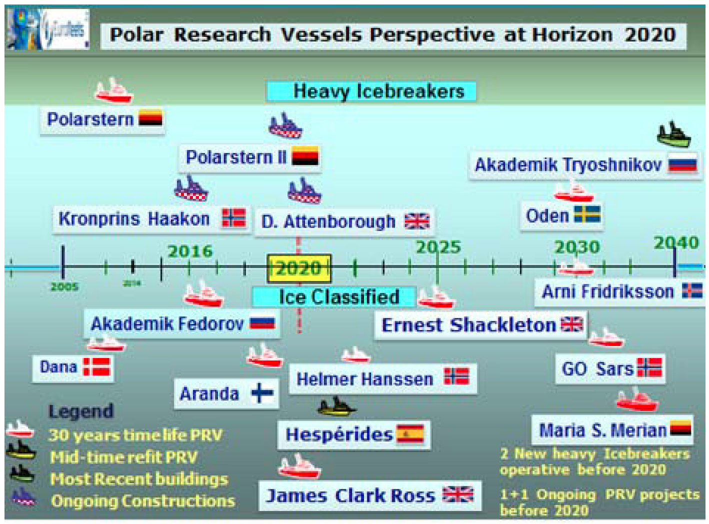


***Fig 4. H-2020 perspectives of EUROPEAN PRV´s***

eration until 2020, while the "Ernest Shackleton" will reach 30 years of polar service by 2025. A few of the ice strengthened PRV´s, i.e. "Arni Fridriksson" "Aranda" (is currently going through a midlife update), and the "Maria S. Merian", mostly operating in Arctic waters, will remain in operation well beyond year 2020. This scenario points to where efforts should be made to maintain the competitiveness of European polar research, through more and better cooperation within the European Union. A line of action already initiated by Norway and Germany is the planned construction of highly interoperable medium-size ships with research and cargo capacities, and finding mechanisms to share them. In this respect, the lesson learned from the grounded "Aurora Borealis" project, possibly as consequence of the enormous building costs and essentially the huge operating cost, has to be taken into account. Furthermore, due the low possibility of new PRV's constructions, strategies for sharing existing European PRV capacities, as intended by the Arctic Research Icebreaker Consortium for Europe (ARICE) initiative, should be supported by the European Union, since in the horizon 2020 only three heavy icebreakers will be available and most PRV's will be at the tail end of their lifetime.

## IV. SEA-ICE VARIABILITY IN THE POLAR REGIONS

*a) Arctic*

After a study over 32 years (1979-2010) of Arctic sea ice using microwave radiometers satellite data(Parkinson & Cavalieri , 2012), concluded that the sea-ice extent (the outer edge of the area covered with ice) and area trends vary widely by month depending on the region and season. The results of these three decades of observations show a remarkable decrease in the sea-ice area and the amount of multiyear ice (perennial) as illustrated in Figure 5.

In terms of areas for year-round research, the thicker/older sea ice is located north-north east of Greenland and Canada as shown in this recent ice extension image from NSDC (Figure 6).

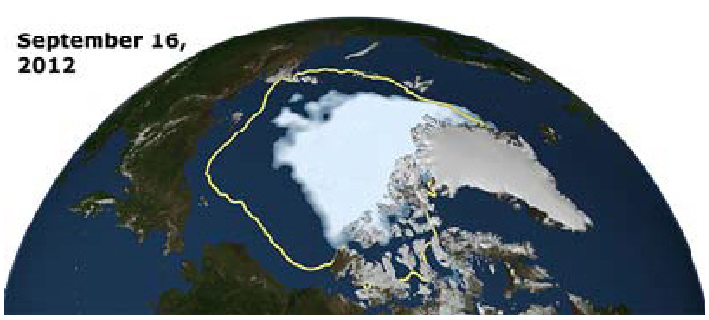


***Fig 5. Minimum sea-ice extent, the yellow line indicates the average of the minimum sea-ice extent over last 30 years compared with the minimum sea-ice extent on September 16th 2012***

*b) Antarctic*
In contrast with the dramatic decreasing sea-ice extent in the Arctic area, something more complex is happening in Antarctica (Fig. 7). A NASA study shows that from 1978 to 2010 (Parkinson, C. L. and Cavalieri, D. J, 2012) the total extent of sea ice in the Southern Ocean surrounding Antarctica grew at an average rate by roughly 17.000 km² ± 15% every year, with some indications that this rate of increase has recently accelerated.

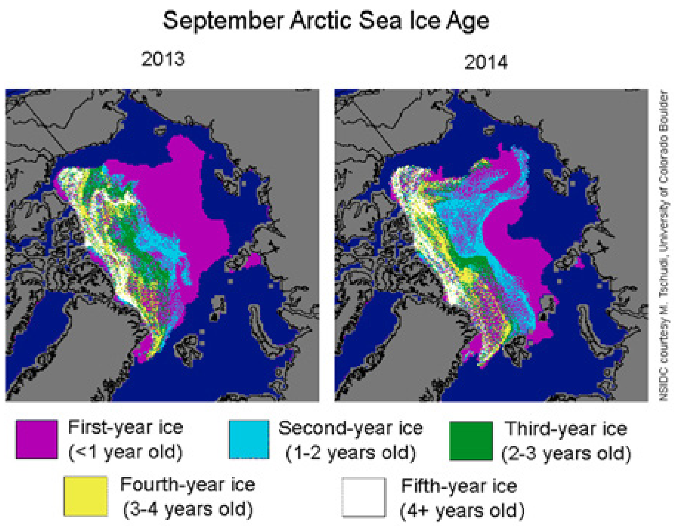


***Fig 6. Variability of sea-ice ages between September 2013 and 2014 (after NSDC, 2015)***

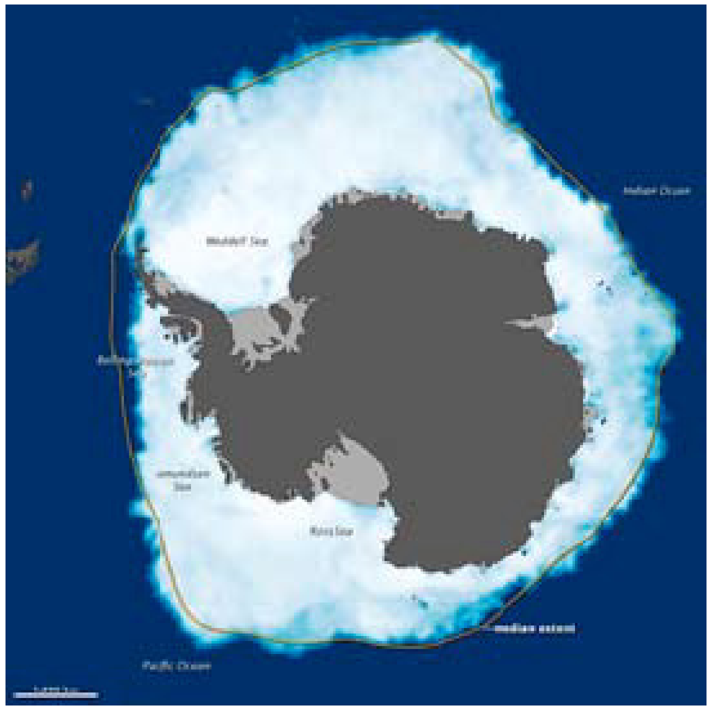


***Fig 7. The average sea-ice extent in September from 1979 to 2000 is marked by the yellow line (after NASA/Goddard Space Flight Centre Scientific Visualization Studio)***

The European polar research fleet with ice classification able to work in thin to medium ice sheet shows a good coverage, mostly in autumn and summer time, at both poles in terms of both research and cargo capacities. These are vessels within the new polar categories B and C. Research has mostly been limited to the marginal sea ice zone areas that are accessible with the current icebreaking/icegoing capabilities.
However, the situation is quite different in terms of yearround European polar operations capacity, with only two PRV´s ("Polarstern" and "Oden"); an analogue scenario applies for worldwide PRVs, even though it is more extensive in the Arctic because of the greater ice breaking capability of the Polar Class icebreakers such as USCG "Healy". Therefore, under these conditions, little research can be done during the polar winter or in areas with thick ice cover year-round, especially in Antarctica.

**V. CONCLUSIONS**
The capacity and infrastructure of the European Polar fleet does not reach the level that is needed by the European Polar Research Community, even when considering the ongoing construction projects of "Kronprins Haakon" and "Polarstern II", to support the societal demands and needs for multifaceted polar research targeting critical thematic issues such as climate change impacts at large, e.g. ocean circulation patterns, and sustainability in exploitation of natural resources addressing e.g. environmental issues, biodiversity, and systems ecology. There is, beyond doubt, an increased interest within the European society for Polar Research involving both an Arctic and an Antarctic dimension in support of a number of research and policy issues.
EU-PolarNet intends to establish an ongoing dialogue between policymakers, business and industry leaders, local communities and scientists to increase mutual understanding and identify new ways of working that will deliver economic and societal benefits. This consortium brings together science, business and policy teams with recognised expertise in the field of stakeholder and public engagement.
The Antarctic scenario is somewhat different, as a natural reserve, devoted to peace and science, due to the Antarctic Treaty System and the number of countries that have greed to be bound by that system. However, in both regions the stuy of recent and past climate processes, ocean circulation and other topics, require a complex and expensive scientific infrastructure, as well as significant continuing international cooperation. his paper benefited from EUROFLEETS2 Grant Agreement No. 312762 FP7-INFRA-0098, and EUPolarNet funded network Horizon 2020 Programme Grant Agreement No. 652641.

***VI. REFERENCES***
*M. A New U.S. Polar Research Vessel (PRV): Science Drivers and Vessel Requirements, Final Report of the UNOLS PRV SMR Refresh Committee, pp 38, 2012).*
*Arctic Marine Transport Workshop, Edits. Lawson Brigham United States Artic Research Commission and Ben Ellis, Institute of the North, 56 pp, 2004. IASC in Transition, Facing New Challenges in Artic Science, Open Forum discussion, 12 pp, 2012International Cooperation in the Arctic, Russian International Affairs Council, 46 pp, 2013*
*O'Rourke, R., Coast Guard Polar Icebreaker Modernization: Background and Issues for Congress, May 2016, Congressional Research Service7-5700, www.crs.gov, RL3439, pp 50.*
*Parkinson, C. L. and Cavalieri, D. J.: Antarctic sea ice variability and trends, 1979–2010, The Cryosphere, 6, 871-880, Doi: 10.5194/tc-6-871-2012, 2012.*
*Perovich, D., Meier, W., Tschudi, M., S. Gerland, S., and J. Richter-Menge, Artic Report-Sea Ice, December 2012. (http://www.arctic.noaa.gov/report12/sea_ice.html*
*Polar Class Rules - Sea Ice Engineering / C. Daley / Memorial Univ*
*Scientific Research in Polar Seas- ERICON, Science Perspective 2015-2030, 107 pp, 2012*
*Saenz, B.L., 2011, Spatial and Temporal Dynamics of Primary Production in Antarctic*
*Sea Ice, Ph.D. Dissertation, Stanford University, Stanford, CA, USA*
*Worby, A.P., Geiger, C.A., Paget, M.J., Van Woert, M.L., Ackley, S.F., and T.L. DeLiberty, 2008, Thickness distribution of Antarctic sea ice, Journal of Geophysical Research, 113, C05S92, doi: 10.1029/2007JC004254.*
*EUROFLEETS2, http://www.eurofleets.eu/np4/ EU-PolarNet, http://www.eu-polarnet.eu/ https://ourchangingclimate.files.worldpress.com/2013/03/arctic*