Report on the first SOOS Censusing Animal Populations from Space (CAPS) workshop

August 20, 2016, Kuala Lumpur

The inaugural meeting on the SOOS Censusing Animal Populations from Space (CAPS) working group was held before the SCAR Open Science Conference in Kuala Lumpar, Malaysia. Working group members that were present were M. Hindell and P. Fretwell (co-chairs), D. Costa, H. Lynch, C. McMahon, M. La Rue, A. Lowther, H-U. Peter and H. Bornemann. The meeting was well attended by interested observers from the SCAR Remote Sensing Action group.

The meeting opened with D.Costa (SOOS Scientific Committee member) describing the structure of SOOS, the intended role of the working groups and the vision for the CAPS group in particular. In summary, CAPS is intended to facilitate and develop the use of high-resolution satellite imagery to provide population status data for Antarctic animals. This technique has been used successfully to estimate the number and size of Emperor and Adelie Penguin colonies, and is showing promise for several species of flying birds. The on-going development of analytical techniques and the launch of new, higher resolution satellites ensure that the potential for satellite imagery to make important contributions to our understanding of Southern Ocean ecosystems will only increase.

CAPS has a broad remit, but has agreed that its initial focus will be the design and implementation of a circumpolar census of Antarctic Pack-ice seals. The last attempt to do this was in 1990, when a major internal program coordinated by SCAR used ship-based survey techniques. This resulted in baseline estimates of abundance for large sections of the Southern Ocean, but left some regions without an estimate. CAPS aims to repeat this work in order to provide the first indication of trends relating to this key component of the Southern Ocean ecosystem. The project will also provide the first fully global census.

There are many obstacles to overcome if we are to meet this aim, and the inaugural CAPS workshop in Malaysia was intended to take the first steps in addressing these issues. The meeting began with presentations from existing programs working in this space, to establish the current state of experimental design, validation and analytical techniques. These were followed by discussions on how best to progress towards a global census in 2019-2020.

BAS pack-ice seal project (PF)

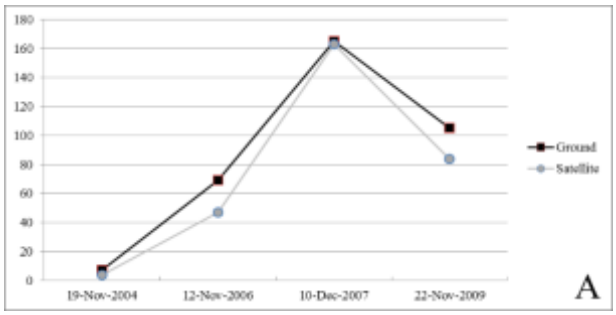
BAS conducted ground-truthing studies on the West Antarctic Peninsula in 2015-16, by conducting simultaneous aerial surveys and comparing these with high-resolution images of the same region from DigitalGlobe. The analysis of the results is ongoing, but preliminary results have shown that the same seals could be detected in both types of images. The biggest challenge was that it was impossible to obtain the satelite images at precisely the same time as the aerial surveys (these were typically several hours apart). This means the seals have time to move in out of the water between the two sets of images so there is no longer an expectation of

Figure 3: Two images taken 4 hours apart. (a) is the high resolution satellite image and (b) is from the aerial survey. The same seal is visible in both images (indicated by the arrows). The circles indicate the breathing hole used by the seal

a 1:1 concordance between the two types of images. The solution is to compare estimates of seal density between the two types of images, which is simply done by dividing the images into a number of sub-units of known area. It is likely that a correction factor for time of day will need to be applied as there is diurnal pattern in the number of seals hauled out throughout the day. This question of time-of-day corrections is another important parameter that will need to be quantified with independent studies, most likely from dive recorders.

NSF pack-ice seal project (ML)

The use of high-resolution images to count Weddell seals in Ross Sea is currently being investigated as part of a project that was recently funded by the US National Science Foundation, and is headed by ML. The study has several components. One is to compare estimates of seal numbers with ground counts; figure 2 shows very good agreement between the two methods at one site (Turtle Rock) in the McMurdo Sound. ML has also compared census data from 2006-2010 (satellite) with census taken in the late 1960s, and found evidence for a decline in numbers over that time.



Another important component of this project is the use of citizen science to process the many images generated. This is challenge common to all studies using satellite images, and one that is particular concern for the pack-ice seal project, which will produce hundreds of images covering many thousands of square kilometers of ocean, all of which need to be processed. Project leaders established a collaboration with Tomnod, a citizen science coordination group, and this allowed the images to be processed quickly and accurately. Citizen science is likely to become an important component of CAPS.

Automated analysis of seals in pack-ice (HL)

A method for automatically identifying seals in high-resolution images of Antarctic pack –ice is another key challenged for CAPS. HL presented an overview of on-going work in her lab that uses modern machine learning (deep learning) techniques to perform this task. They are using Squeezenet Model architecture implemented in a Caffe frame work. Squeezenet is a convolutional neural network (CNN) trained to identify different classes of particular objects, and is particularly well suited to the challenge of distinguishing seal from ice. This development is progressing well and has considerable promise for CAPS. BAS is also developing automated detection algorithms with collaborators at Oxford, and it was agreed that it would be important to compare approaches and progress.

Prydz Bay pack-ice seal project (MH)

The first year of tasked images of the Prydz Bay pack ice occurred between December 2015 and February 2016. This is the first of 4 years where 5 x 60 km^2 images are tasked each year. The distribution of images is based on a stratified sampling design with more images collected

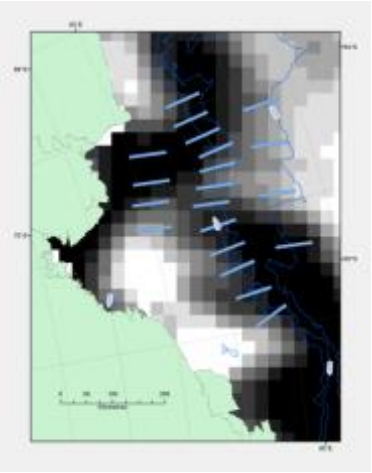


Figure 3: The stratified survey design for CAPS in Prydz Bay, The dark shading represents ice concentration, the thin blue line bathymetry and the light blue bars are the 5x60 km transect lines

along the shelf break (known preferred habitat for seals) than further inshore or off-shore (figure 3).

Only one of the five images tasked was obtained due to extensive and continuous cloud cover in the region last summer. That image was from the outer band of transects (in the less preffered habitat) and a visual search of the image revealed no seals, although there was overall a relatively high cover of loose pack-ice.

Although a disappointing start, there are several lessons here. Cloud cover can be a bigger problem than anticipated, although it also seems that 2015/16 was an unusually cloudy year in Prydz Bay. Future tasking will use a wider temporal window (October to February) to improve the likelihood of images being collected. It may also be that lack of seals was a genuine reflection of their use of the outer pack ice in this region. Both the BAS and NSF studies detected many seals, but these were images taken in region with higher ice densities. We will also modify some of the image parameters to improve the contrast and potential detectability of the seals. Nine images have now been tasked for 2016/17 taking these recommendations into account.

Towards a global pack-ice seal census in 2019-2020

Three primary challenges remain before an internationally coordinated pack-ice seal census can be conducted, but it was thought likely that CAPS members would be in a position to try in 2019-2020 or soon after. The challenges are:

a. Ground truthing. The work done by BAS on WAP was a great start to this. However, it would be desirable to conduct similar studies in other regions of the Antarctic, particularly the East Antarctic. MH has applied for funding from the Australian Research Council which could be used for this. The work could be done at Davis Station in Prydz Bay. Preliminary discussions were held with Barbara Breen from Auckland University of Technology about the use of long range drones to do this.

   The question of correction factors for the number seals underwater when the images are taken was also recognized. This is compounded by a strong diurnal pattern to crabeater seal haulouts, requiring time specific correction factors. DC has a NSF proposal under consideration that will enable the deployment of time depth recorders to provide these data.

b. Future funding. There is currently little demand for tasked images in the Antarctic, with the exception for coastal region, which means that acquiring images of regions of interest to CAPS would relatively straightforward. Further, images are free to NSF funded projects. It was decided that (i) ML would enquire about getting some off-shore images taken in the 2016-17 summer under her existing NSF project, (ii) the HL, ML and DC would lead a new NSF proposal for CAPS (iii) Other nations (UK, Australia, Norway and Germany) would also develop national CAPS proposals. These could focus on other issues such as ground-truthing, correction factors and habitat models if the US proposal is successful and can provide the necessary images. Subsequent to our workshop at SCAR, ML and HL spoke with Dr. Christian Fritsen of NSF to assess NSF's interest in funding CAPS or, alternatively, some of the technical developments required for CAPS. One of the key issues discussed was the need to focus on scientific questions rather the management questions, the latter of which would fall outside of NSF's remit. ML and HL discussed next steps, which include (i) demonstrating the technique for identifying seals in high-resolution satellite imagery,

and (ii) developing a set of key scientific hypotheses to be address by CAPS. HL has identified collaborators within the computer vision community and will fund a pilot study in summer 2017, with the hope to address the issue of technical feasibility for future funding.

c. Image analysis. Enumerating the number of seals in hundreds of high-resolution images is a substantial challenge, and the need to develop a fast but accurate methodology is paramount. The two approaches presented at this meeting (citizen science and machine learning) will both undoubtedly play a key role, with the former playing a critical role for developing a training dataset on which to train the latter. One model is that we can use citizen science in combination with machine learning in the early algorithm development phase, but move to a great reliance on the later as the methods are developed and validated.

Future meetings

It was agreed that CAPS should continue to have annual meetings in conjunction with SCAR Biology and SCAR Open Science symposia. MH will request a side meeting for the 2017 SCAR Biology meeting in Belgium. However, it was also recognized that there will be a need for longer workshop meetings in the near future. DC suggested we could apply for a SCOR workshop in the lead-up to the first global census.