SCAR-COMNAP Fellowship Report 2013-14

Title: Niche modelling as a tool for invasive risk assessment of vascular plants in terrestrial Antarctica

Candidate: Luis R. Pertierra, Autonomous University of Madrid, Spain

Host: Aleks Terauds, Justine D. Shaw & Dana M. Bergstrom (Terrestrial and Nearshore Ecosystem Lab – Australian Antarctic Division)

Other Participants: Miguel A. Olalla-Tarraga, University Rey Juan Carlo, Span. Pedro Aragon, National Museum of Natural History, Spain

INTRODUCTION. Predictions of species distributions based on correlative models can help to understand the spatial patterns of biological diversity (Jimenez-Valverde et al. 2008). Models exploring the relationships between species' occurrences and sets of predictor variables produce two kinds of useful outputs. The first are estimates of the probability that species might occur at given unrecorded locations. The second are estimates of an area's suitability for species (Segurado & Araujo 2004). Risk maps summarizing landscape suitability of novel areas for invading species can be valuable tools for preventing species' invasions or controlling their spread (Jimenez-Valverde et al. 2011). This study aims to provide a niche analysis for the two native vascular plants (*Deschampsia antarctica, colobanthus quitensis*) and from the *Poa* genus two non-native species (*Poa pratensis, Poa annua*) in the Maritime and Continental Antarctica.

Invasive species are an increasing threat to Antarctic ecosystems (Hughes and Convey 2010, Chown et al 2012). The use of biogeographic modelling approaches have recently been identified as effective tools to inform future conservation activities in Antarctica (Gutt et al. 2012). In conjunction with their colleagues, researchers at the Australian Antarctic Division (AAD) have delivered major Antarctic biogeographic works on native and non-native species in recent years (see Terauds et al. 2012, Chown et al. 2012). The AAD also hosts an important Antarctic Data Centre, which holds considerable original data and derived GIS products generated by AAD scientists and their collaborators. As such, it is the ideal location to facilitate new collaborations using the emerging approaches proposed for data analysis.

Previous works have provided general invasive risk assessments (Chown et al. 2012). This study aims to follow this approach, but provide more detailed insights into the potential niche of these plant species in Antarctica as well as clarifying specific biotic elements that can further inform the conservation and/or management of these taxa.

EXECUTION. The research secondment of Luis R. Pertierra, hosted in the Australian Antarctic Division (AAD), has come to a satisfactory end. The 4-month period was covered between April 1st – July 31st 2014. In addition to this period the researcher spent November and December 2013 as an AAD guest through an invitation to participate in the Australian Antarctic science program. While the main purpose of these initial extra months was preparing field research, it allowed activities to be set in motion beforehand regarding the modelling work.

WORK CONDUCTED. The methodogical framework proposed consisted of five consecutive steps scheduled for the length of the stage: 1) Collection of species presence records, 2) Identification of key environmental variables, 3) Model construction, 4) Performance analysis, and 5) Results interpretations / expert discussion. However in the particular case of Antarctica, step 2 is not automatically done, first the variables need to be created in an standardized way to be comparative to the rest of the world (see preliminary results).

At the first step, species available records were retrieved and depurated. A preliminary survey in GBIF repository contains large datasets for all four studied species, with more than enough data to build and run the models. The final database was completed at the invasive range from additional literature revision.

ID	Presence	Longitude	Latitude	HEIGHT	BIO1	BIO2	BIO3	BIO11	BIO4	BIO5	BIO6	BIO7	BIO10
11816569	1	-58.972300	-62.233500	36	-9	39	15	-72	2016	30	-129	162	13
11816593	1	-58.398600	-62.172300	51	-14	43	15	-86	2236	29	-148	178	10
11816630	1	-60.480600	-62.941900	121	-13	40	18	-75	2071	30	-127	158	11
11816744	1	-62.388400	-64.498000	140	-53	72	11	-154	3409	15	-228	243	-18
11816763	1	-57.901800	-63.364200	34	-39	67	12	-142	3529	23	-211	234	-3
11816869	1	-62.833800	-64.893300	455	-59	79	9	-167	3565	12	-251	263	-21
11816747	0	-60.964900	-64.165200	126	-51	75	13	-152	3553	18	-219	237	-15
11816518	0	-60.872400	-62.443700	17	-7	33	19	-61	1808	34	-109	140	14
11816519	0	-62.620800	-62.974000	580	-8	33	17	-67	1795	34	-133	167	11
11816520	0	-62.450900	-62.933800	850	-8	33	17	-67	1795	34	-133	167	11
11816521	0	-62.281500	-62.893400	112	-8	34	18	-66	1793	34	-123	157	12
11816522	0	-61.609200	-62.729400	16	-7	33	20	-63	1795	34	-109	143	13
11816523	0	-61.442500	-62.687900	17	-8	34	20	-63	1804	33	-108	141	13
11816524	0	-61.276300	-62.646200	17	-7	33	20	-62	1795	34	-109	141	14
11816525	0	-61.110600	-62.604200	17	-8	33	20	-62	1801	33	-107	138	14
11816526	0	-60.945400	-62.562000	23	-8	34	20	-64	1839	33	-110	141	14

Fig 1. Worldwide dataset including spatial Antarctic background data (ice free grounds) and presence data (*Poa annua* records) linked to the environmental variables.

The second step was addition of environmental layers, from 3 bioclimatic variables proposed to be included in the analysis of the species (type of monthly temperatures and annual precipitation). Using the WorldClim data repository and/or the AAD data centre, up to 9 were eventually created. All related to temperature features. Extra features are expected be added to these in the near future, and could include the ice-free area distribution, or the human accessibility factor (in terms of travelling distance), in this regard the available information previously built by AAD will be essential.

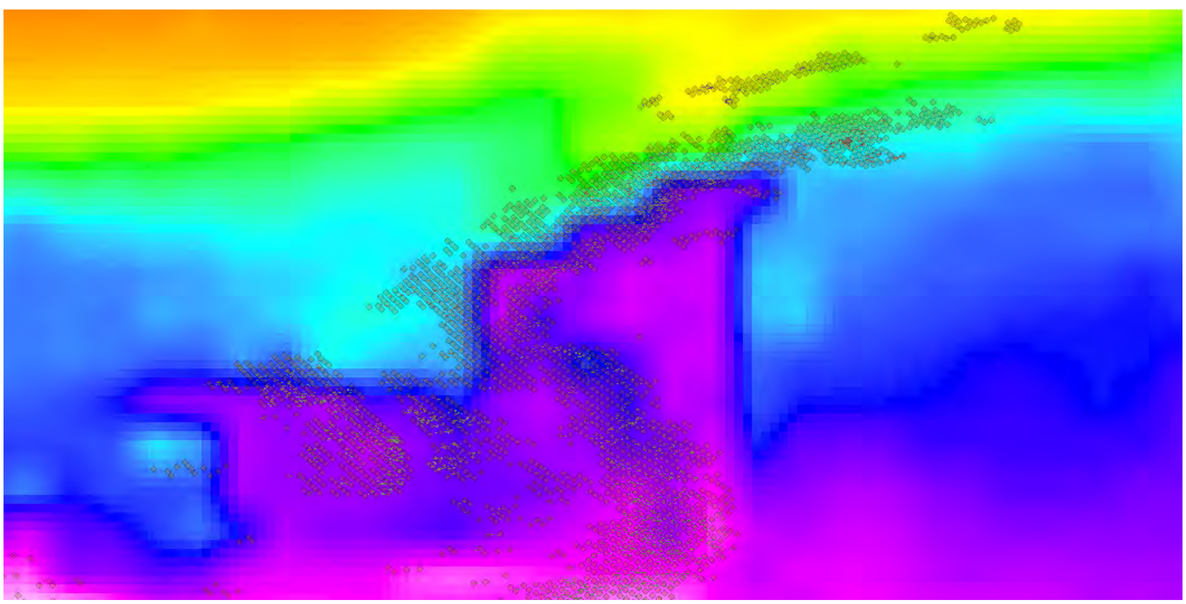


Fig 2. Bio6 (minimal temperature of the coldest month). New layers were created for the Maritime Antarctica region for up to 9 bioclimatic features, then overlaid to ice free grounds (light grey squares)

Step three (currently in process…) is be the selection of model/s appropriate to the available data (from the simpler ones such BIOCLIM (Thuiller et al. 2009), to the most complex ones (eg Maxent's) with participation of experts from both institutions. Performance and comparisons between selected models would be assessed in a later stage through 'ensemble forecasting' techniques. Lastly, results would be interpreted and the relevant outputs published, here the expertise of AAD members were (and will be) most valuable.

During the 4-month visit, most of the planned tasks were successfully achieved (although the latter are still in process), with learning and consecution of several steps on the modelling process along with host Drs. Terauds, Shaw and Bergstrom of the Terrestrial and Nearshore Ecosystem Lab (AAD) and remote participation of home Drs. Olalla-Tarraga and Aragon. First, a dataset for Antarctic bioclimatic range of variables (9) was built from available climatic information provided by the AAD, this new information will be valuable for future works. Second, worldwide recorded presences of the 2 studied species were compiled (c. of 200k records) and filtered (30k records). Global bioclimatic information was extracted and associated to these presences. Third, modelling on the information is now being explored under several techniques. Fourth, a refined model of the outputs based in local variables is currently being developed, with creation of new regional ones for the Antarctic Peninsula (such topographic or human footprint). Results of these anlayses are currently being collated and written up for publication.

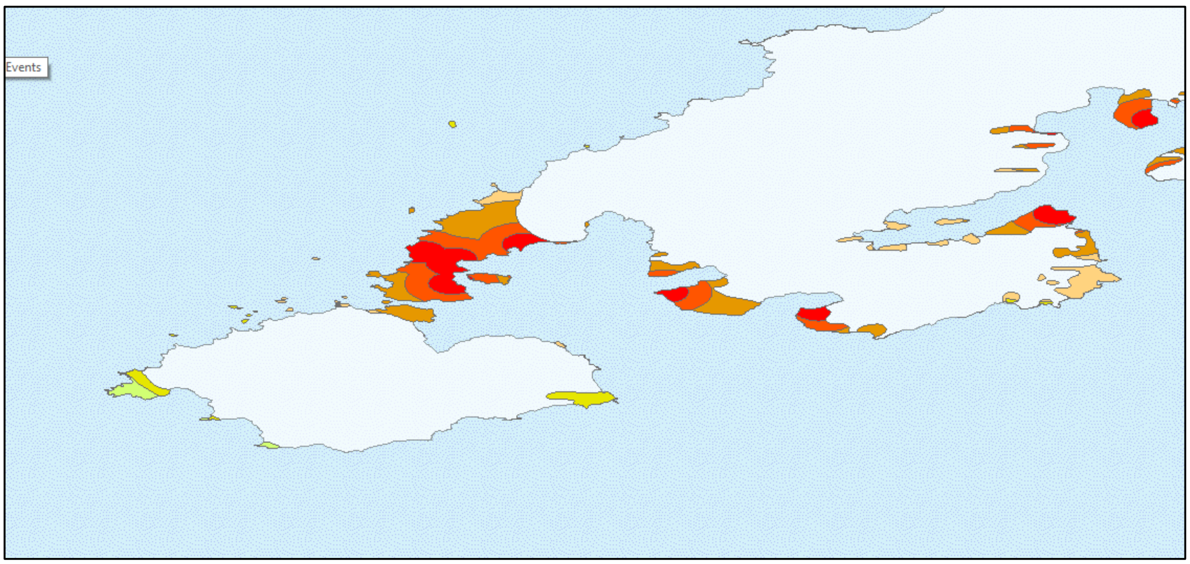


Fig 3. Local human footprint layer created as a buffer scaling system from human activity sites.

PRELIMINARY RESULTS.

A major output of the visit and ongoing research is the inclusion of the Antarctic Peninsula in datasets matching the temperature bioclimatic variables worldwide. As far as I know this is the first attempt ever to incorporate Antarctica to global bioclimatic modelling. Including Antarctica in the global context biogeographic analyses is fundamental to understand its relationship with other continents. Once this step was finished, a whole range of new possibilities to explore became possible. In this regard presence data for the selected species were next attached to the bioclimatic data and analyzed.

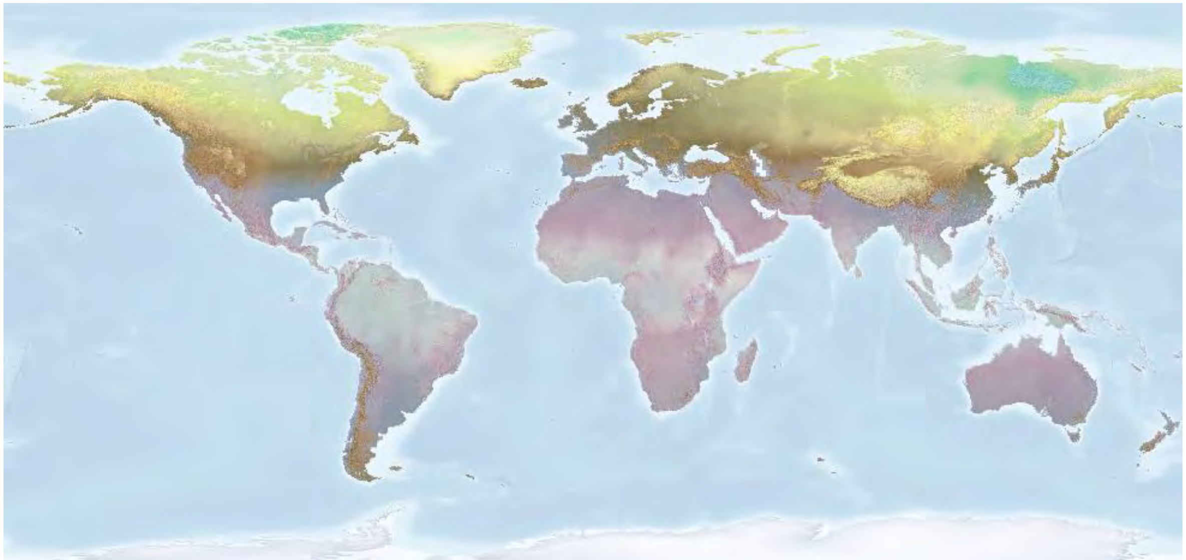


Fig 4. Bio11 (Mean temp of coldest quarter). Bioclimatic info available online. There is no Antarctic data (traditionally excluded).

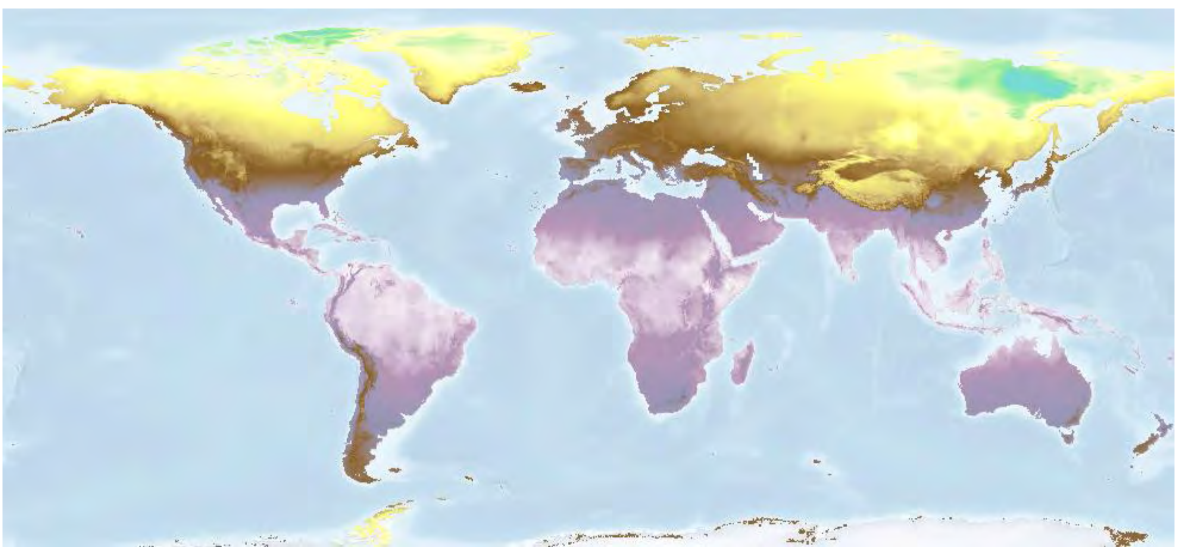


Fig 5. Bio11 (Mean temp of coldest quarter). New layer manually created worldwide, now incorporating Antarctic data after local temp calculations from satellite information.

First results obtained with the BIOCLIM Climatic Envelope Model* follow the observational suggestion made in Pertierra et al. (2013) pointing out the comparatively low summer temperatures of Maritime Antarctica as a strong restricting factor for the two Poaceae non-native invasion. In the latest results from all 9 bioclimatic features incorporated in the analyses, the most distinctive in the Antarctic continent were Bio5 (mean temperature of the warmest month) and Bio10 (mean temperature of the warmest quarter), whereas other variables were more important in the natural range at the arctic locations (where the bioclimatic limits found were often even more extreme).

Fig 6. Bio2 (mean diurnal range) offered no restrictions to the species range in Maritime Antarctica according to BIOCLIM.

Fig 7. Bio10 (mean temp of the warmest month) was found to be the most restrictive variable assigning the species range according to BIOCLIM.

The most restricting factors were identified as one of the strengths of this model. But also the spatial distribution of the natural ranges were tentatively plotted, obtaining a first indication of those areas with potentially higher habitat suitability (however the info obtained is very limited with this model, see below).

It is worth highlighting that BIOCLIM analysis provides valuable range information for making suitable range predictions with accuracy; even with limited data and many internal sampling biases (it does not account for all the quantitative data compiled of the realized niche, but rather the extremes) while it lacks the strength to inform on other predictor aspects of value to explore (potential suitability niches built based on all available data processing). Therefore other models, such for instance those based on Mahalanovis distances, offer complementary information. By combining multiple models we minimize the commission/omission errors to obtain the best picture of the species realized + potential niches. This is work in progress…

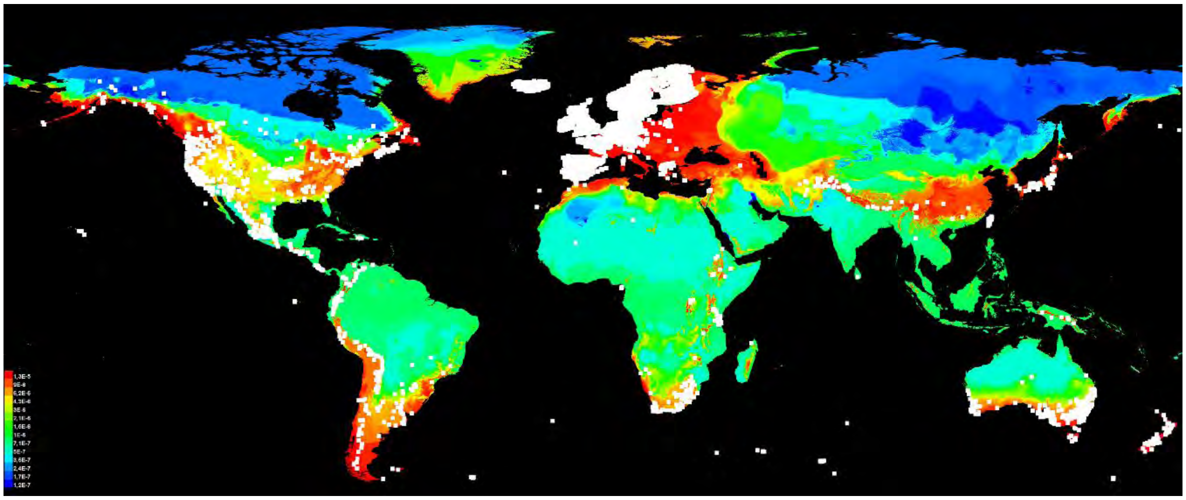


Fig 8. A MAXENT model was early created just from Non-Antarctic data (variables+presences. White: presence data. Potential niche: Reddish (high suitability) to blueish (lesser suitability). A new MAXENT is now in process to be created including Antarctic data thanks to the new layer creation.

*The idea of BIOCLIM is to find a single rule that identifies all areas with a similar climate to the locations of the species. To do this, the basic BIOCLIM algorithm finds the climatic range of the points for each climatic variable.

RESEARCH OUTREACH. The conducted research is strongly aligned with the objectives SCAR's AnT-ERA and Ant-ECO research programs. Firstly it is intended to 'explain what biodiversity is there, how it got there, what it does there, and what threatens it' and secondly 'to determine the resistance, resilience and vulnerability to change of Antarctic biological systems'. These combined goals are approached by developing and validating emerging modelling tools and applying these to Antarctic terrestrial ecosystems. This research also matches the SCAR's strategic plan 2011-2016 by contributing to the formulation of objective and independent scientific advice on the conservation and management of Antarctica and the Southern Ocean, particularly including the human element, in this case for the development of invasive risk assessments. This results from this study will be useful in horizon scanning exercises to identify evolving issues and emerging frontiers in Antarctic science. This was carried out while developing the capacity of an early career scientist under an interdisciplinary philosophy through cross-fertilization of ideas and access to new Antarctic scientific data.

Perhaps the two most relevant questions are: 1) Under a scenario of changing abiotic factors, how likely is the introduced *Poa* genus to become a major threat to the Antarctic ecosystems? 2) Given the human factor (facilitated dispersion) and the potential for these species to access to previously unconnected niches, where, and to what extent is this likely to occur?

As a result, two high outreach JCR papers are envisaged, one being in an advanced stage about *the macro environmental envelope of the species and the regional variation of niches* (Pertierra et al. in preparation) and another in gestation about *the prediction of suitable areas for colonization in Antarctica applied to biosecurity* (Pertierra et al. in preparation). The preliminary results from works conducted under the fellowship scheme were presented in an oral communication at SCAR OSC Auckland NZ 2014.

Potential abiotic niche modelling for terrestrial non-native species in Antarctica **Date:** 25/08/2014, **Session Name:** Session I (a) S19 AntEco: Diversity and Distribution of life in Antarctica **The Session Starts at:** 1130 in SCCC - New Zealand 1 **presentation starts at:** 1210hrs

OPPORTUNISTIC EXTRAS The grant has also allowed the possibility to participate last season 2013-14 with the Australian Antarctic Program in the sub-Antarctic Macquarie Island (4 months). This was consistent with the objectives of the fellowship scheme and brought new valuable insights. Some additional lead publications are expected in the future (for instance; Pertierra et al. *Altitudinal effects on alien flowering* & Pertierra et al. *Assessment of Agrostis invasors in the subantarctic*, In preparation) and participations (for instance; Shaw et al. *Faunal Facilitation of Poa annua*, In preparation). , Some outputs from this opportunistic work were also presented in the upcoming SCAR OSC 2014:

Monitoring the floral development of two alien vascular plants (Poa annua and Cerastium fontanum) along an altitudinal gradient on sub-Antarctic Macquarie Island
Poster session: Poster Session B on 26/08/2014

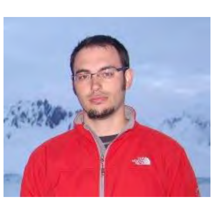
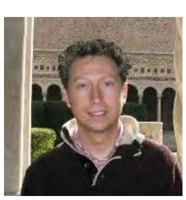
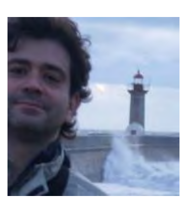
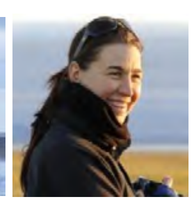
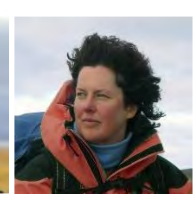
BUDGET EXPENSES. Expenses provided by the fellowship effectively covered the cost of the 4-month research stay in Kingston, Tasmania. No remaining money was left at the end of this period but the budget provided was reasonable, and mainly expended in accommodation and subsistence. The cost for the initial extra time living and working in Tasmania were covered by the researcher invited project AAS4158. Registration to SCAR OSC NZ was made also from fellowship the budget; and AntEco also provided some funding support for the travel costs associated with this conference. All expenses related to the field campaign were funded by the research project AAS4158 without any extra cost to the fellowship scheme.

Financial statement

- **Transport…………………………………………..…. 3000 $**
- **Accommodation (Hobart) ……………………….... 4000 $**
- **Local expenses (subsistence)…………………… 3000 $**
- **Computer Software/Hardware……………………. 1000 $**
- **Registration to SCAR OSC 2014 Auckland…….. 500 $**
- **Total…………………………………………………… 11500 $**

FUTURE PROSPECTS. A new 3-year project (ALINANT CTM2013-47381-P) has been granted now to the home research team of Spain with joint participation of the host team, thus consolidating further collaboration in the future. This project allocation has largely benefited from the SCAR fellowship scheme pilot works. Therefore, the studies initiated in the fellowship scheme will have a continuity.

CONCLUSION/ACKNOWLEDGEMENTS The SCAR research fellowship awarded here should be regarded as a great success. I want to thank SCAR for providing the means for this excellent framework opportunity. Thanks also to the AAD members that hosted me with their magnificent scientific and personal advice and support.

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