

Opinion: Status, Plans and Needs of Southern Ocean Modelling

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Abstract. In preparation for the *SOOS/OCEAN:ICE Workshop on ice-ocean observation harmonization and future priorities agenda*, a survey targeting the modelling community was conducted to assess research priorities for the Southern Ocean and Antarctica. While this initiative was tailored mostly towards physical ocean and ice modelling, its outcome specifically supports the design of field activities from the open Southern Ocean to the Antarctic shelf for the forthcoming *Antarctica InSync* campaign and is aligned with broader strategic planning efforts ahead of the next *International Polar Year*. The survey results are a useful basis to further communication between modeling and observing science communities. We believe this is crucial for optimizing campaign planning, achieving enhanced data usage and improving numerical experiments.

1 Background

The Southern Ocean is responsible for 83% of the global ocean heat content increase over the historical period and more than 40% of global ocean anthropogenic carbon uptake (Frölicher et al., 2015; Huguenin et al., 2022; Williams et al., 2024). Ocean heat is a major driver of the current Antarctic ice sheet mass imbalance (Adusumilli et al., 2020; Bell & Seroussi, 2020; Noble et al., 2020). Nevertheless, this part of the world ocean features some of the most severe and long-standing biases present in state-of-the-art climate models with far reaching implications for climate projections (Stouffer et al., 2017; Beadling et al., 2020; Moreno-Chamarro et al., 2022; Zhang et al., 2023).

Recently, two major programs have been launched, *Antarctica InSync* (<https://www.antarctica-insync.org/>) and the *5th International Polar Year* (<https://ipy5.info/>)(IPY5), to advance understanding of polar climate change and synchronize research across nations and disciplines. For both, coordinated observational campaigns with broad international participation are planned to take place in Antarctica and the Southern Ocean 2027–2030 and 2032/33, respectively. Research activities will expand beyond in-situ observations to, amongst others, Earth observations and numerical modelling. Especially for

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51 [Antarctica InSync an effort has been made to include modelling groups from the beginning,](#)
52 [which lead to the survey presented here.](#)

53
54 Full understanding of the processes and feedbacks of climate change in the Southern Ocean
55 and Antarctica can only be gained by combining in-situ observations, satellite reconnaissance
56 and numerical modelling. The region is difficult to access, especially where ice covered, and
57 direct observations thus remain sparse. Remote sensing is limited to the surface, at least for
58 the ocean. And models are valuable tools but never perfect. The upcoming Antarctica InSync
59 and the IPY5 programs are centered around field campaigns, which is [logical](#), considering the
60 need for strategically planning ship schedules and equipment acquisition years in advance.
61 Satellite missions and model development follow again different cycles and routines, partly
62 on even longer schedules. Dedicated numerical experiments can be accomplished on a much
63 shorter time scale, though. Nevertheless, coordinating efforts across these science
64 communities and intensifying exchange between them from early on in these major programs
65 will be crucial for turning advanced process understanding into improved projections of the
66 future climate in and beyond the southern high latitudes. Therefore, the survey initiative
67 documented here supports a push for early integration of and engagement by the modeling
68 community in these observation-driven efforts.

69
70 As a rather spontaneous effort, the survey was of ad hoc design. Despite being launched just
71 before the northern hemisphere summer break, it received a relatively large number of
72 completed responses (98), representing a broad cross-section of the ocean and climate
73 modeling community. This great turnout is also owed to the endorsement by [SOOS](#)
74 (<https://www.soos.aq/>), the Southern Ocean Observing System and [CLIVAR](#)
75 (<https://www.clivar.org/>), Climate and Ocean Variability, Predictability, and Change offices
76 and Scientific Steering Groups, who spread the call in the SOOS Update (Issue 31) and the
77 CLIVAR Bulletin, respectively, in August 2025 as well as the sharing of the call across
78 mailing lists of [Antarctica InSync](#) (<https://www.antarctica-insync.org/>), [APECS](#)
79 (<https://www.apecs.is/>), [ASPeCt](#) (<https://aspectsouth.org/>), [BEPSII](#)
80 (<https://sites.google.com/site/bepsiiwg140/home>), [BioEcoOcean](#) (<https://bioecocean.org/>),
81 [Polar-CORDEX](#) (<https://climate-cryosphere.org/polar-cordex/about/>), [Cryolist](#)
82 (<https://lists.cryolist.org/mailman/listinfo/cryolist>), the [EU Polar Cluster](#)
83 (<https://polarcluster.eu/>), [ICED](#) (<https://www.iced.ac.uk/>), [IMBeR](#) (<https://imber.info/>),
84 [IMECaN](#) (<http://imecan/>), [MISOMIP2](#) (<https://misomip.github.io/misomip2/>), [ObsSea4Clim](#)
85 (<https://obssea4clim.eu/>), [Ocean & Carbon Biogeochemistry](#) (<https://www.us-ocb.org/>),
86 [OCEAN:ICE](#) (<https://ocean-ice.eu/>), CLIVAR's [Ocean Modeling Development Panel](#)
87 (<https://www.clivar.org/clivar-panels/omdp>) and [Southern Ocean Region Panel](#)
88 (<https://www.clivar.org/clivar-panels/southern>), [POGO](#) (<https://pogo-ocean.org/>), [SCAR](#)
89 (<https://scar.org/>), [SCOR](#) (<https://scor-int.org/>), [SOCCOM](#) (<https://socom.org/>), the
90 CLIVAR task team and Community-MIP [SOFIA](#) (<https://sofiamip.github.io/>), and [TipESM](#)
91 (<https://tipesm.eu/>). This positive engagement yielded a valuable and unprecedented dataset
92 that offers quantitative insights into current priorities and gaps in Southern Ocean research
93 and modeling. It provides a robust foundation for ongoing and future strategic discussions
94 regarding the alignment of modeling and observational efforts.

95
96 The survey was designed with primarily the physical ocean modeling community in mind and
97 thus pre-defined answers often highlight physical oceanographic processes (see Appendix).
98 Although leaning towards such processes, coupled interactions with other components of the
99 climate system, such as sea ice, ice shelves, and the atmosphere were considered as well.
100 Contributions related to biogeochemical processes and ecosystem modeling were also

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102 encouraged though not covered comprehensively. It turns out that a more careful selection of
103 the pre-defined answers would have been advantageous and likely beneficial for a broader
104 coverage of these coupled processes. Relatively little use was made of the “Other” free text
105 option by the respondents. Similarly, the survey started out with an emphasis on probing
106 modelling groups using realistic regional Southern Ocean configurations and CMIP-class
107 global climate and Earth system models to study the historical period and maybe 21st century
108 projections. But it evolved into covering a much broader range of spatial and temporal scales,
109 and model complexities, for which the respondents did make use of the free text comment
110 fields. For pragmatic reasons, we limited the geographical region and defined the Southern
111 Ocean as the area south of approximately 50°S in the survey context.

112
113 The following summary presents key findings of the survey. While the [dataset](https://doi.org/10.5281/zenodo.17289776)
114 (<https://doi.org/10.5281/zenodo.17289776>) (Martin et al., 2025) can be further explored, a
115 first look already holds significant potential for informing cross-disciplinary planning and
116 collaborative program development in the Southern Ocean and Antarctic research landscape.

117 **2 Who participated?**

118
119 About half of the 98 survey participants [48%] identified as oceanographers, others see
120 themselves as experts in coupled climate [13%], sea ice [12%], ice shelf cavity [10%] and
121 land ice [8.2%] modelling. Colleagues studying processes at basin to global scales and from
122 annual to centennial scales contributed two-thirds of the replies; less than a quarter indicated
123 a research focus on mesoscale (10-100 km) processes with periods of months to seasons.

124 **3 Survey results and discussion**

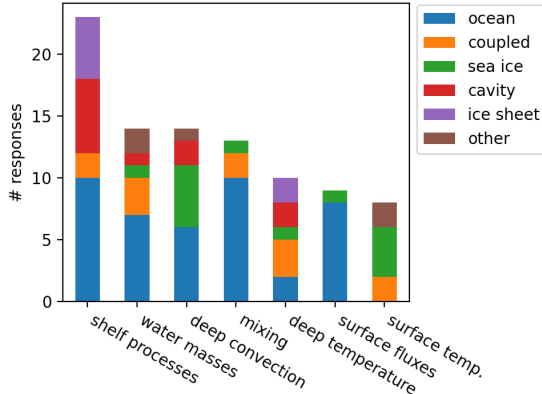
125 **3.1 Model status and evolution**

126
127 We asked the participants for the most problematic ocean model bias allowing a single choice
128 only aiming for a clear emergence of the most pressing issue from the survey. About a
129 quarter identified processes of the Antarctic continental margin (shelf seas, slope current, ice
130 shelf cavities) as requiring most attention (Figure 1). Further, open ocean deep convection
131 and water mass transformation [both 14.3%] and mixing were highlighted. Individual free
132 text answers mentioned deep ocean circulation, modeling of biogeochemical cycles and the
133 carbon pump, planetary boundary layer of ice-covered seas, and impacts on benthic
134 ecosystems as other major model biases, which are not displayed in Figure 1. The
135 respondents related such biases in particular to global coupled climate [38%] and ocean
136 models [28%] in general such as those used for the Climate Modelling Intercomparison
137 Project (CMIP); this may, [however](#), reflect the dominant area of expertise of the participants,
138 Moreover, the respondents identified a dozen specific ocean models and state estimates as
139 well as specifically high-resolution model versions that include some of these major biases
140 (see published survey data for details; Martin et al., 2025). We emphasize that moving
141 towards finer grid resolution alone may yield individual improvements but will not solve all
142 the biases—as is documented in Moreno-Chamarro et al. (2022).

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ocean model biases by expert group



149
 150 Figure 1: “What is the most problematic ocean model bias?” Eight well-known issues were listed as pre-
 151 defined, single-choice answers to ensure emergence of the most pressing problems. In this distribution of the
 152 responses we merged seasonality of surface fluxes and air-sea CO₂ flux into surface fluxes. The 91 responses (of
 153 98 in total) are color-coded with respect to the area of expertise provided by the respective respondents. Here,
 154 “other” refers to all areas of expertise not explicitly listed, e.g. atmosphere and ecosystem.
 155

156 It is important to understand that open ocean deep convection—while physically not
 157 unrealistic (Gordon, 1978)—is dramatically overestimated in many climate models,
 158 specifically those of coarse resolution, with consequences for ocean to atmosphere heat
 159 redistribution, sea ice coverage, bottom water characteristics, and eventually also internal
 160 climate variability (Reintges et al., 2017; Heuzé et al., 2021). In reality, most Antarctic
 161 Bottom Water (AABW) is formed on the continental shelf where sea ice formation and ice
 162 shelf melt play key roles in the transformation of upwelled deep water (Silvano et al., 2023)
 163 and so does mixing for its transformation into Antarctic Intermediate Water (AAIW) further
 164 equatorward (Li et al., 2022). To this end, nearly three-quarters of all participating experts
 165 pointed out biases that are inter-connected and play an imminent role in the formation of
 166 water masses, such as AABW and AAIW, crucial for the global overturning circulation and
 167 for the natural sequestration of heat and anthropogenic carbon.
 168

169 Hence, it is no surprise that implementation of ice shelf cavities [20%], convection
 170 parameterization [18%], scale aware (mixing) parameterizations [15%] and overflow
 171 parameterization [13%] were listed as most urgent model development targets. There has
 172 been remarkable advancement in these directions over the past two decades (e.g., De Rydt et
 173 al., 2024; Legg et al., 2009; Bruciaferri et al., 2024). It has been demonstrated that these new
 174 developments can mitigate model biases in the Southern Ocean even at relatively coarse
 175 resolution despite remaining issues (e.g. for ice shelf cavities see Hutchinson et al., 2023).
 176 However, we believe there is often significant delay or inaction in implementing such
 177 advancements, as model development is rarely funded directly by dedicated research projects.
 178 The push for rapid research outcomes tends to favor easily implemented targets — the 'low-
 179 hanging fruit' — over more complex, long-term efforts.
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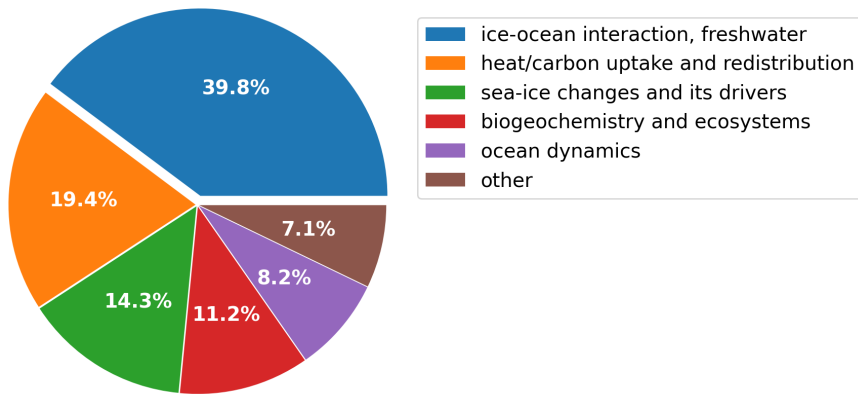


Figure 2: “What is in your view the singular key science topic in the Southern Ocean?” The five most frequent answers were provided as part of seven examples and could be simply ticked. Pre-defined answers less picked were air-sea exchange and extreme events. Additional topics were given by the respondents as free text input. These include, amongst others, cloud-radiation processes, extreme events, nutrient redistribution and cross-disciplinary topics, and are collated as ‘other’.

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This behavior is evident in the responses on near-term model evolution. Among those, increasing model complexity [27%] and spatial resolution [24%] stand out. Other goals such as improving or developing novel parameterizations and including artificial intelligence based modules are only considered by 11-13% of the participants. In this case multiple answers were possible and participants ticked or listed 2-3 responses on average. It appears that preference is given to model complexity—evolving climate models into Earth system models by coupling more components, for example, ice sheets or biogeochemistry modules—over improving model physics. However, we think this could also be a sign of a more diversified, cross-disciplinary science landscape. As computing power keeps growing, resolving model issues by enhancing grid resolution appears to be a possible avenue to reduce biases (e.g., Rackow et al., 2022). But this is a costly option and impractical for applications on centennial time scales since proper representation of mesoscale dynamics in the high latitudes of the Southern Ocean requires grid spacing of $1/8^{\circ}$ - $1/20^{\circ}$ (and finer on the continental shelf), to properly resolve the Rossby radius (Hallberg, 2013, their Fig. 1). We suggest that new observations supporting model development could thus lead to improved and yet affordable simulations on a large range of spatial and temporal scales.

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3.2 Scientific focus

Reducing the major model biases and advancing ocean and climate models as laid out above will be essential to address the key research topics identified in the survey responses. Freshwater, heat and carbon budgets are high on the scientific agenda of the modelling community (Figure 2). Questions on process understanding and future evolution of the Antarctic ice sheet, its ice shelves and their interaction with the ocean through heat and meltwater dominate the results [40%]. While this is research at the continental margin, heat and carbon uptake where the low latitude Southern Ocean plays a major role was named second [19%], followed by interest in the recent and future sea ice trends [14%]. On the one hand, these results are somewhat biased by the research areas of the participants. On the other hand, scientific interest has migrated poleward in the Southern Ocean, where major challenges have been identified, such as knowledge gaps in ice-ocean interaction affecting

226 global sea level rise projections, and where new observational techniques for under-ice
227 sampling and mesoscale ocean simulations have become available.
228
229 The results suggest that oceanic processes themselves, such as dynamics from mesoscale
230 eddies to large-scale circulation, tides, waves and mixing are not “big questions” by
231 themselves anymore despite remaining issues and their important role in current “grand
232 challenges” like ice-ocean interaction, warm water intrusion onto the continental shelf and
233 biogeochemical modeling. Further, we assume that the underrepresentation of
234 biogeochemical and ecosystem research as well as atmospheric process understanding, most
235 prominently clouds and aerosols, is likely a consequence of questionnaire design and the
236 focus group addressed.
237

238 3.3 Observations used and needed

239
240 Before diving into a discussion on the observational needs of the modelling community, we
241 would like to call attention to the data sources actually used. There is an unbroken preference
242 by modellers to use gridded data products [28%], i.e. statistically interpolated fusions of
243 observations from various sources, and reanalysis or state estimates [21%], which are based
244 on a numerical model and incorporate observations through, e.g. assimilation techniques.
245 Likely also due to their extensive spatial coverage, satellite-borne remote sensing products
246 are favored as well [15%]. Data from ship-borne instruments, moorings, and floats appear to
247 be used less often directly [10-13%]. We acknowledge that observational data of all kinds, in
248 particular including in-situ data, feed into the gridded products. Nevertheless, it is important
249 to note that modelers tend to validate their simulations against these kind of “observations”,
250 which in fact are advanced data products and rather not viewed as actual observations by the
251 observing, sea-going science community. Further, any in-situ data that ~~are~~ not included in
252 such gridded products is likely less used or even overlooked by modelers and thus does not
253 contribute as much to the improvement of models.
254

255 Based on our personal experience, modelers tend to lean on derived products, such as
256 reanalyses and state estimates, because (1) observations are typically sparse and direct
257 comparisons require complex subsampling of model output, (2) formats and platforms used
258 to share observational data are still not unified and easily accessible to users despite ongoing
259 efforts, and (3) original measurements require advanced background knowledge and
260 interpretation for use in model validation. These issues can be mitigated by, for instance,
261 providing open-source validation packages along with the measurements and the
262 development of virtual instruments, i.e. tool boxes allowing for the subsampling of model
263 output in ways emulating specific observational instruments. Further, we suggest that
264 communication between the science communities should be strengthened. ~~Additionally,~~
265 educational programs, such as summer schools, could introduce instruments, proper data
266 handling and aforementioned tool boxes to the next generation of modelers.
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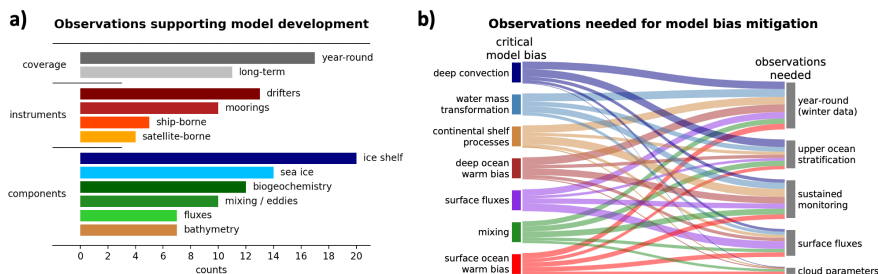


Figure 3: (a) “Which kind of observations would further this [model] development?” (without pre-defined answers). Free text responses were grouped by key words (right hand side bar labels) and sorted into groups of temporal coverage, instrumentation/sensors/platform and Earth system components (left hand side labels). In total 130 responses were identified. (b) Linking the two questions “What is the most problematic ocean model bias?” and “Which observations could help understanding biases or further the process understanding?” by the same respondent. In both cases pre-defined answers were provided but free text replies were also possible; multiple choice was allowed. Overall 200 responses were cross-linked. The number of responses on the left side are normalized, see Fig. 1 for specific numbers.

For reducing observational gaps, especially with mitigating model biases in mind, modelers should be given and [should](#) take the opportunity to provide input to evolving observational programs early in the planning phase. [In the end](#), this would ensure multiple use of the data collected. Figure 3a shows observations desired for bias mitigation with in-situ observations clearly dominating over remote sensing data. This preference can be interpreted as a need for better process understanding in which in-situ data are considered actual “ground truth” and often provide higher resolution in space and time, which is useful in several aspects, such as model validation, identifying of processes resolved at a given grid spacing, improving model parameterizations, etc. Another interpretation is that modellers are well aware of in-situ measurements being crucial for better quality gridded products. And while such products are preferred in the actual validation process, the dire need for more ground truth data in a changing climate is acknowledged and its collection valued.

The scientific goals and observational plans of Antarctica InSync appear to be very much in line with the needs of the modelling community wishing for year-round data, especially in ice-covered seas and combining physical and biogeochemical measurements (Figure 3a). The strong desire for winter observations and year-round monitoring in the Southern Ocean [29%] is linked nearly equally to all major biases identified (Figure 3b). As is already discussed by the Antarctica InSync community, building capacity for sustained monitoring in preparation for the International Polar Year in 2032/33 and beyond would also strongly support model improvement and advancement [25%]. Observations of the upper ocean stratification and surface fluxes would enable a better process understanding of the mixed layer and help to constrain vertical/diapycnal mixing parameterizations in models. Interestingly, the role of other climate system components causing biases in the ocean, for example, sea ice and snow, clouds and radiative processes, was not highly considered. This is likely owed to the limited choice of pre-defined answers we provided and the behavioral bias of the respondents preferring to tick one of those rather than entering individual answers. Nevertheless, we take this as an opportunity to point out the need for improved fundamental understanding and acknowledgement of coupled mechanisms and feedbacks within and beyond the focus group. Having better records of magnitude and variability of Southern Ocean surface fluxes of both physical and chemical quantities will help significantly. Similarly, any observations in

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β18 support of heat and freshwater budgets, especially with a focus on ice-ocean interaction, will
319 be instrumental in advancing models and improving climate projections. And last but not
320 least, high-resolution bathymetry data of the Southern Ocean from the Antarctic Circumpolar
β21 Current to the continental margin and into the ice shelf cavities are urgently needed.
322 Topography is a key ingredient for realistic simulations of the ocean circulation, specifically
β23 the import of Warm Deep Water and the export of dense bottom waters, and therefore crucial
324 for reliable projections of ice shelf melting.

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326 4 Conclusions and Outlook

327 In conclusion, surveys like this provide a valuable overview of the current status, plans, and
328 data needs not only for the Southern Ocean but also for the global modeling community.
329 There are also some experiences to take away from this exercise, in particular how the pool
330 of respondents shapes the usefulness of the survey, how to ask targeted questions without
331 being exclusive, how pre-defined multiple-choice answers simplify the analysis but reduce
332 the variety of responses, and which meta-information really is instrumental for interpreting
β33 the responses. All of this is well known and demonstrates the importance to involve experts
334 on questionnaire design rather than constructing an ad hoc survey. Nevertheless, the feedback
335 by the community to our survey has been very positive indicating that such surveys can be a
336 valuable tool for future international program planning.

338 With the Antarctica InSync program in active planning and IPY5 approaching, we hope the
339 results presented—with additional data available (Martin et al., 2025)—will inform both the
340 scientific community and stakeholders to advance observations and models. The findings
341 already contributed to the *SOOS/OCEAN:ICE Workshop* discussions and conclusions.
342 Research priorities include ice-ocean interactions, Southern Ocean heat and carbon uptake,
343 and the recent major changes in sea ice. Addressing these challenges requires model
β45 developments such as ice-shelf-ocean coupling, implementing biogeochemical processes,
β46 and applying higher resolution grids, alongside improved understanding of continental shelf
347 processes and upper-ocean stratification. This, in turn, requires new observations in key
348 regions with ice shelves most vulnerable to warm water intrusions and ocean circulation
349 choke points. Further, the survey results call for stronger communication between the
350 modeling and observing communities and dedicated data-use training for modelers.
351 Antarctica InSync offers a major opportunity to advance such efforts.

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354 Data availability

355 The survey results are available through Zenodo (Martin et al., 2025),
356 <https://doi.org/10.5281/zenodo.17289777>.

358 Author Contributions

359 TM conceived the original idea of conducting the survey, led the analysis and produced all
360 figures. All authors contributed to the survey design, its content and writing of this
361 manuscript. AMH explored different survey platforms and distributed the survey call.

363 Competing Interests

364 The authors declare to have no competing interests.

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474

475 **Appendix**

476 Here we repeat for convenience the survey introduction and questions along with the
477 response options. A screenshot of the original questionnaire website is available at
478 <https://doi.org/10.5281/zenodo.17289777>.

479

480 **Southern Ocean modelling: status, plans and needs**

481 In preparation of the *SOOS/OCEAN:ICE/Antarctica InSync workshop* on ice-ocean
482 observation harmonisation and future priorities agenda, which will be held in Copenhagen in
483 September this year and also serves for the planning of [Antarctica InSync](#) activities, we
484 kindly ask for your input.

485 All of the 12 questions below focus on the Southern Ocean region (south of ~50°S), physical
486 ocean processes are prioritised but immediate interaction with other system components can
487 be addressed (atmosphere, sea ice, ice shelves, biogeochemistry, ecosystem etc.), and the
488 applications we have in mind range from realistic regional models in the Southern Ocean to
489 CMIP-type global climate models (with or without further coupled components like ice
490 shelves or biogeochemistry).

491 **Please select from the multiple choice items or add an alternative item as "other".**
492 **This should not take more than 10 minutes.**

493 Note, the first three questions on expertise and scales may help to "set the stage" for the
494 answers of the other questions. If you work on very different scales, you may consider
495 answering the questionnaire twice for different cases. A link for another response is provided
496 after submitting the first one.

497 **Please respond until September 15. (deadline extended)**

498 Thank you for your time and effort.

499 Torge Martin (OMDP), Carolina Dufour (SORP), Andrew Meijers (SOOS), Alyce Hancock
500 (SOOS)

501 This questionnaire is supported by SOOS and CLIVAR panels SORP and OMDP. The
502 anonymous(!) data may be used by these panels for planning of further activities beyond the
503 above mentioned workshop.

504 <https://www.soos.ag>, <https://www.clivar.org/clivar-panels/southern>,
505 <https://www.clivar.org/clivar-panels/omdp>

506

507 **1) What is your primary area of expertise?**

508 This is independent of a focus on physical, biological or other processes.

- 509 Ocean
510 Sea ice
511 Ice-shelf cavity
512 Ice sheet/ice shelf/icebergs
513 Atmosphere
514 Coupled climate modelling
515 Other: _____

516

517 **2) What spatial scales do you work on?**

- 518 Submesoscale (<10 km)
519 Mesoscale (10-100 km)
520 Basin-scale (>100 km)
521 Global impacts

522

523 **3) What temporal scales do you work on?**

- 524 Days to weeks
525 Months to seasons
526 Years to decades
527 Decades to centuries
528 Beyond centuries

529

530 **4) What is in your view the singular key science topic in the SO?**

- 531 Ocean dynamics (sub-/mesoscale eddies to large-scale circulation)
532 Ice sheet/shelf–ocean interaction, fresh water
533 Heat and/or carbon uptake and redistribution
534 Sea-ice change and drivers/consequences thereof
535 Air-sea exchange, incl. carbon/trace gasses
536 Marine biogeochemistry and ecosystems
537 Extreme events
538 Other: _____

539

540 **5) What kind of observational data do you preferably use?**

541 *[multiple answers allowed]*

- 542 Campaign based data (e.g. ship transects, gliders, ...)
543 Stationary, year-round data (e.g. moorings)
544 Varied spatial and temporal coverage (e.g. Argo-Floats)
545 Gridded data products integrating various data sources
546 Reanalysis/ocean state estimate products
547 Remote sensing data (please specify below)

548 ○ Other: _____

549

550 **If you selected “Remote sensing data” above, please specify the variable and**
551 **product here:**

552

553

554 **6) What is the most problematic ocean model bias?**

555

○ Surface warm bias, too small sea ice extent

556

○ Deep warm bias

557

○ Mixing

558

○ Seasonality of surface fluxes

559

○ Air-sea CO₂ flux

560

○ Water mass formation and characteristics (AABW, AAIW, ...)

561

○ Open-ocean convection (polynyas)

562

○ Shelf processes (e.g. slope current, ice shelf cavities, overflows, ...)

563

○ Other: _____

564

565 **7) Which type of model did you have in mind when answering the last question**
566 **on biases?**

567

For example, list model complexity, grid resolution, application case, or anything
568 else.

569

570

571 **8) Which observations could help understanding biases or further the process**
572 **understanding? [multiple answers allowed]**

573

○ Winter data (year-round observations)

574

○ Upper ocean stratification

575

○ Surface fluxes

576

○ Cloud observations

577

○ Sustained monitoring

578

○ Other: _____

579

580 **9) Where do mismatches exist between traditionally observed quantities and**
581 **model diagnostics (e.g. mixed layer depth)?**

582

583

584 **10) What is the most pressing ocean model development?**

585

[multiple answers allowed]

586

○ Implementation of ice shelf cavities

587

○ Overflow parameterization, vertical coordinates

588

○ Convection parameterization, vertical mixing

589

○ Scale-aware parameterization, e.g. for eddies

590

○ Biogeochemistry module

591

○ Coupled ecosystem module

592

○ Surface waves and/or tides

593

○ Sea ice dynamics

594

○ Other: _____

595

596 **11) Where will you or your collaborators evolve ocean models towards over the**
597 **next decade?**

598 *[multiple answers allowed]*

- 599 ○ Coupling more Earth system components (ice sheets, biogeochemistry, ...)
- 600 ○ Including more processes (tides, waves...)
- 601 ○ Novel parameterizations (submesoscale, scale-aware...)
- 602 ○ Higher resolution (horizontal and/or vertical)
- 603 ○ Unstructured grids, variable topography (wetting/drying, ice shelf cavity
- 604 shape)
- 605 ○ AI-based model components (parameterizations, emulators, ...)
- 606 ○ Other: _____

607 **12) Which kind of observations would further this development?**
608 _____

609 _____

610 **Voluntary option:** provide your contact details for further discussion regarding Antarctica
611 InSync modeling activities: **name, affiliation, e-mail** (comma delimited please).
612 _____

613 _____

614

615

616