

Reply to: 'The role of ocean dynamics in king penguin range estimation'

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REPLYING TO A.J.S. Meijers et al. *Nature Climate Change* <https://doi.org/10.1038/s41558-018-0388-2> (2019)

In their Comment, Meijers et al. argue that the 5 °C sea surface isotherm, one of the parameters used in the model of Cristofari et al. to map, hindcast and forecast king penguin range, is not a good proxy to locate the species' foraging area. Using a different approach and the average of two 30-year windows (1976–2005 and 2071–2100), they suggest that the Antarctic circumpolar current core (ACCC) will make only regional shifts of ~100 km, but with significant uncertainty across an ensemble of 11 Coupled Model Intercomparison Project Phase 5 (CMIP5) models.

Our scope, however, was not to predict the position of the ACCc, but king penguins' breeding and foraging behaviour. Several studies^{1–3} demonstrated that sea surface temperature (SST) is an accurate predictor of the species' foraging range, and short-term poleward shifts in the 5 °C isotherm have clearly been linked to decreased breeding success in past decades⁴. King penguins forage where their prey (myctophid fish stock) can be predictably found within average diving depth (200 m). King penguins are thought to use SST as a proximal cue⁵. Thus, in the context of our study, the strong behavioural association between SST and the species' foraging range is clearly more relevant than actual water mass representation.

We note that Meijers et al. present the displacement of the ACCc as defined by Sen Gupta et al.⁶, and not of the polar front (PF) itself. To the best of our knowledge, there is no evidence that the ACCc is a valid indicator of the king penguins' foraging range that is as good as or better than SST. In addition, the data presented by Meijers et al. show that, within nearly all the king penguin's range (between 50° W and 130° E), the ACCc is displaced polewards by ~100 km. As the relationship between ACCc and king penguin foraging efficiency is currently unknown, we cannot conclude if it will be a negligible or a critical displacement for some of the colonies.

The link between the ACCc and king penguins' behaviour is probably more complex than argued by Meijers et al., and we claim that empirical data remain a strong and reliable source of information for understanding animal ecology^{2,4}. In addition, the biological features of the systems, such as the critical time for foraging during the breeding season (February in our model), must always be integrated into the model. Other indicators of the frontal position^{7,8}, as well as higher resolution climate models (CM2.6⁹), may also fit king penguins' foraging behaviour, and they must be tested in real-case biological scenarios.

As multidisciplinary collaborations are probably the only way to understand complex processes like global climate change, we

warmly concur with Meijers et al. that developing models integrating physical oceanographic and biological features should provide better predictions of both physical and biological systems, an approach we also advocated¹⁰.

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Competing interests

The authors declare no competing interests.

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