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Elephant seals reveal Southern Ocean frontal structure and sea ice formation rates

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Polar oceans are sensitive to climate change, with the potential for significant feedbacks between ocean circulation, sea ice and the ocean carbon cycle. However, the difficulty in obtaining *in situ* data limits our ability to detect and interpret change, especially in the Southern Ocean, where the ocean beneath the sea ice remains almost entirely unobserved and the rate of sea ice formation is unknown.

As part of the Southern Elephant Seals as Oceanographic Sensors project, 59 elephant seal (*Mirounga leonina*) were tagged with Conductivity-Temperature-Depth Satellite-Relayed Data Loggers at four sub-Antarctic locations to study their foraging ecology in relation to oceanographic conditions. Here we demonstrate how, beside biological information, these seals equipped with oceanographic sensors can help fill the gap in the Southern Ocean observing system. Southern elephant seals regularly spend the winter feeding within the sea ice pack and high latitude waters of the Southern Ocean, covering a number of areas not sampled by conventional techniques. The seals

dived regularly and transmitted 2 CTD profiles per day (average depth 500 m, maximum 1998 m). They provided a 30-fold increase in hydrographic profiles from the sea ice zone when compared to concurrent data obtained with conventional means (ship, XBTs and Argo floats). When added to conventional data, the seal profiles resulted in a large increase in the fraction of the circumpolar path of the high latitude fronts of the Antarctic Circumpolar Current that can be determined. In addition, the temporal and spatial resolution of the frontal maps derived from the combined data set is much greater than those obtained from traditional hydrographic climatologies.

A number of seals stayed several weeks in the same area in the pack ice (sea-ice concentrations ranging 64-85 %) thereby providing temperature and salinity time-series in the upper water column. Sea-ice formation rates at four locations of the Antarctic shelf were estimated from changes in salinity in the upper 100 m of the water column obtained from such seal time-series. They agreed well to sea-ice freezing rates derived from a Finite Element Sea-ice Ocean Model obtained at the same locations. While past estimates of sea ice formation rates have been restricted to coastal polynyas and landfast ice, our sea ice formation rates are representative of the type of sea ice found over most of the Antarctic continental shelf. Such data will help to determine the contribution of sea ice to the freshwater budget that is still very uncertain because ice thickness and formation rate remain difficult to observe with traditional methods.