IMPACTS OF THE ROSS SEA ANOMALOUS SEA ICE CONDITIONS ON THE SOUTHERN HEMISPHERE ATMOSPHERE

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Abstract: This work examines the impact, on the Southern Hemisphere atmosphere, of anomalous sea ice extension in the Ross Sea, from the standpoint of two opposite conditions: with reduced and increased sea ice cover. To achieve this goal we have designed an experiment with the Atmospheric General Circulation Model of the Center for Weather Forecast and Climate Studies (AGCM-CPTEC/INPE). The whole experiment was composed of three large ensembles, sized with 60 members each, in order to achieve a significant recognition of signal. One of them, the control experiment, was forced with climatological sea surface temperatures and sea ice cover. In the other two ensembles the sea ice cover distribution in the Ross Sea was synthesized, from actual observed anomalies, using the least and the most observed sea ice cover in the 1979-2005 time series of measurements. Those experiments were named RO- and RO+, respectively. As expected, the sea ice cover primarily affects the heat fluxes from the ocean. When the sea ice layer is reduced (increased), the fluxes increase (reduce), and this effect is more evident in sensible than latent heat fluxes. The permanence for several weeks of those abnormal conditions is able to alter locally the pattern of low-level temperature. The results show positive (negative) temperature anomalies driven by the abnormal positive (negative) fluxes of heat due to the imposed sea ice perturbation. Thought the vertical penetration of the temperature anomalies is shallow, not exceeding the 700 hPa level, the sea ice cover anomaly imprints a discernible and permanent anomaly in the near-surface temperature field, as can be seen evaluating every member in the perturbed ensembles. A Principal Component Analysis of the hemispherical patterns of low-level temperature (925 hPa) identifies the local impact due to the sea ice cover in the first and second eigenvectors, for the RO- and RO+ respectively. The flux-driven anomalous patterns appeared merged with hemispherical patterns due to the internal variability of the model (CTRL). The difference between the CTRL and perturbed pattern depicts that part of the anomalous pattern not due to the internal variability. Among the most important results are the indications of a relationship between the state of sea ice cover in the Ross Sea and the low-level temperatures in subtropical and extratropical South America. The present results indicate that the relationship is such that the anomalies of temperature in South America are of reverse sign regarding the polarity of the sea ice anomaly in the Ross Sea.

Introduction

The Southern Hemisphere large scale circulation is throughout populated by fluctuations comprising a broad range of temporal and spatial scales. Zonally asymmetric modes of the circulation comprise planetary wave numbers 1 to 3-4. The genesis of those quasi-stationary waves is related to inhomogenities in the Earth's surface, like for instance, topography or land-sea contrasts. In this context the sea ice edge around Antarctic is a potential source for waves, due to the marked discontinuity in the surface radiation budget, surface fluxes of latent and sensible heat, and surface roughness associated to it. The objective of this work is to examine the impact, on the Southern Hemisphere atmosphere, of anomalous sea ice extension in the Ross Sea, from the standpoint of two opposite conditions: with reduced and increased sea ice cover

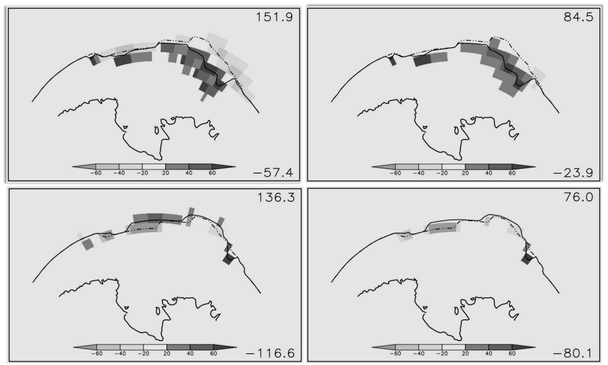

Figure 1 – Anomalous Surface (a) Sensible and (b) Latent Heat Fluxes for the RO- experiment; Anomalous Surface (c) Sensible and (d) Latent Heat Fluxes for the RO+ experiment. The dotted-dashed (continuous) curve indicates the LTM (perturbed) sea ice edge. The upper (lower) number on the right indicates the maximum (minimum) in the domain.

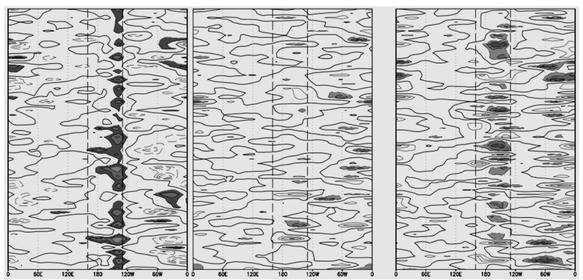

Figure 2 – Diagram longitude versus responses. Comparison between 60 individual standardized ATMT925 responses for RO- experiment (left), CTRL (center) and RO+ experiment (right). The y-axis presents the meridional average between 67 S and 57□S of each of the 60 members. The x-axis represens the longitudes. Contours are each 1 standard deviation unit. Negative (positive) values below (above) -1 (1) are grey shaded in the RO+ (RO-) picture. Two dashed vertical parallels indicate the limits of the Ross Sea

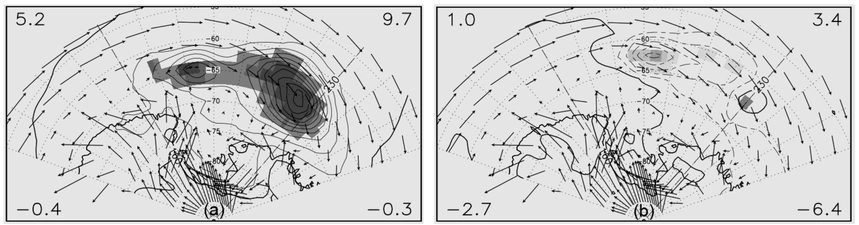

Figure 3 – a) Anomalous TP2M and ATMT925 for (a) RO- and (b) RO+ experiments. Dark (light) shades indicate positive (negative) anomalies of the TP2M. Continuous (dashed) contours indicate positive (negative) anomalies for ATMT925. Contours are each 0.5 degrees. The arrows show the climatological (CTRL) flow at 925 hPa. The two straight lines indicate the approximated limits of the Ross Sea. The upper (lower) number on the right indicates the maximum (minimum) for TP2M. The numbers on the left are analogous for ATMT925.

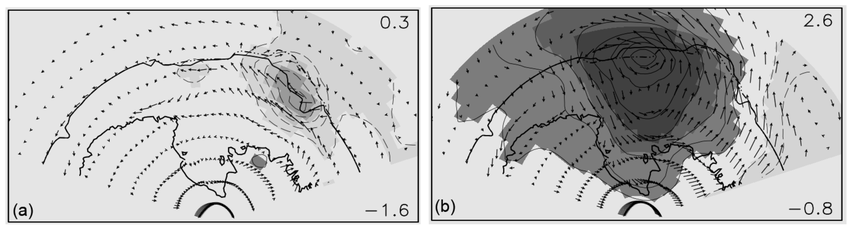

Figure 4 – Anomalous asymmetric (zonal mean removed) surface pressure for (a) RO- and (b) RO+ experiments. Dark (light) shades and continuous (dashed) contours indicate positive (negative) anomalies. The levels for shading are -1.2, -0.9, -0.3, 0.3, 0.9 and 1.2. The contour levels are each 0.3 hPa. The arrows indicate the anomalous flow at 925 hPa at scale 2 m.s^{-1} per inch. The continuous (dashed-dotted) thick line around Antarctica indicates the altered (LTM) SIE. The top (bottom) right number on the frame is the maximum (minimum) value found inside the subdomain. The two straight lines indicate the limits of the Ross Sea

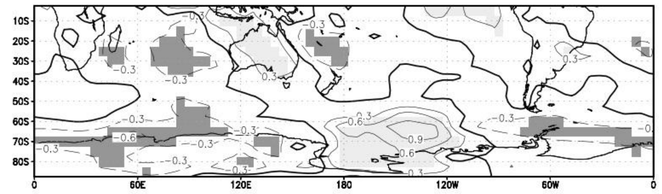

Figure 5 – Correlations between the first rotated expansion coefficient and the standardized ATMT925, for the RO- experiment. Shading indicates the correlations statistically significant at 95% level

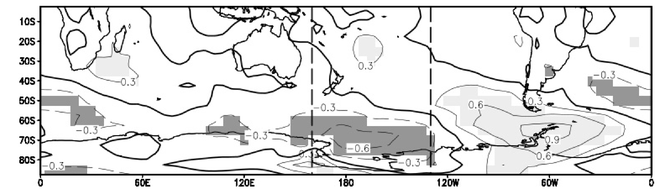

Figure 6 – Correlations between the first rotated expansion coefficient and the standardized ATMT925, for the RO- experiment. Shading indicates the correlations statistically significant at 95% level

Concluding remarks:

▹ The present results show that the location of the MIZ in the Ross Sea, Antarctic can impacts substantially on the surface heat fluxes. The results are consistent with previous studies, and show that whenever the sea ice layer is in excess (deficiency) the surface fluxes of latent and sensible heat by the underneath ocean are attenuated (enhanced), leading to large negative (positive) anomalies of net upward surface fluxes. The magnitude of the anomalies was substantial, reaching values of the order of 100 W.m^{-2} in a seasonal average. In general, the sensible heat flux anomalies presented values larger than the latent heat flux anomalies.

▹ The altered fluxes force on it turns changes in the near surface temperature. When the sea ice is retreated (advanced) the associated temperature anomalies are positive (negative), presenting substantial anomalies as high (low) as +9.7 (-6.4).

▹ The persistent modification in the sea ice condition is able to perturb the surface pressure. Associated to the SIE retreat (advance) there is a pressure fall (rise) over the exposed (covered) sea. This anomalous low (high) pressure center presents a corresponding clockwise (counterclockwise) anomalous circulation, which encircles locally the center of low (high) pressure.

▹ An interest characteristic is that despite the substantially larger perturbed area in the RO- case, the extension of the anomalous response in surface pressure is much larger in the RO+ case, and the circulating anomalous winds appear better configured and more intense in the RO+ case as well.

▹ The results from temperature analysis point to an out-of-phase behavior between the Ross Sea and the oceans to east, the Bellingshausen/Amundsen Seas and the Weddell Sea. This imbalance in the temperature field is present in both experiments, although appears clearer defined in the RO+ results.

1,42 x 0,9m