論文内容の要旨

A Study on Ningaloo Niño

(ニンガルー・ニーニョに関する研究)

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Sea surface temperature (SST) along the west coast of Australia undergoes large interannual variations. After unprecedented SST warming in austral summer of 2010/11, the phenomenon was named "Ningaloo Niño". Although this phenomenon has devastating impacts on the regional marine ecosystem, studies on Ningaloo Niño have just begun and there is no systematic understanding of its mechanism. This thesis is devoted to quantitative understanding of generation and decay mechanisms of Ningaloo Niño.

From observational analysis, it is found that Ningaloo Niño (Niña), which is associated with positive (negative) SST anomalies and atmospheric anomalies off Western Australia, reaches its peak during austral summer. Ningaloo Niño (Niña) events are classified into locally amplified and non-locally amplified cases. The former develops through an intrinsic unstable ocean-atmosphere interaction off Western Australia. Anomalously warm (cool) SSTs generate negative (positive) sea level pressure (SLP) anomalies that accompany northerly (southerly) alongshore wind anomalies. These cause anomalous coastal downwelling (upwelling) and stronger (weaker) southward warm advection, further enhancing the initial SST anomalies. This positive feedback loop is named as the coastal Bjerknes feedback. For the latter case, positive (negative) SST anomalies are induced by coastally-trapped downwelling (upwelling) waves, which are generated by wind anomalies in the western Pacific associated with La Niña, or alongshore wind anomalies in the northern coast of Australia.

Warmer (cooler) SSTs in both cases are associated with negative (positive) SLP anomalies off Western Australia. The SLP anomalies in the locally amplified case show a cell-like pattern and have a sharp cross-shore pressure gradient along the west coast of Australia. On the other hand, those in the non-locally amplified case tend to show a zonally elongated pattern. The difference is related to the continental SLP modulated by the Australian summer monsoon. It is also suggested that the Ningaloo Niño/Niña has significant impacts on the precipitation over Australia.

The calculation of mixed-layer temperature (MLT) balance using outputs from an ocean general circulation model reveals that positive meridional advection anomalies associated with stronger Leeuwin Current and enhanced warming by climatological shortwave radiation owing to anomalously shallow mixed layer contribute to the growth of positive SST anomalies in the near-shore region of both cases for Ningaloo Niño. On the other hand, larger sensible heat flux loss plays an important role in the decay. Since the strengthened meridional current during the developing season weaken meridional temperature gradient, meridional advection anomalies eventually change their sign and contribute to the decay as well.

Positive (Negative) MLT tendency anomalies in the offshore region, for both cases are generated by enhanced (suppressed) warming by the climatological shortwave radiation owing to negative (positive) mixed layer depth anomalies during the development (decay) phase.

The generation and decay mechanisms for both cases of Ningaloo Niña are generally close to a mirror image of those for Ningaloo Niño. In particular, negative meridional advection anomalies associated with the weaker Leeuwin Current, and reduced warming by the climatological shortwave radiation play an important role in the near-shoe and offshore region, respectively.

Since negative (positive) SLP anomalies off Western Australia are crucial for Ningaloo Niño (Niña) development, a series of an atmospheric general circulation model experiments are conducted to investigate the generation mechanisms of atmospheric circulation anomalies accompanied by Ningaloo Niño/Niña. Even when interannual SST anomalies are imposed only in the eastern South Indian Ocean, negative (positive) SLP anomalies are formed off Western Australia in Ningaloo Niño (Niña) years, supporting the existence of the local ocean-atmosphere interaction. Negative (positive) SLP anomalies are also generated in Ningaloo Niño (Niña) years owing to a Matsuno-Gill type response to diabatic heating anomalies in the western tropical Pacific when the model is forced with SST anomalies outside of the southeastern Indian Ocean. Regarding climatic impacts, it is found that even when SST anomalies outside of the eastern South Indian Ocean are removed, wet (dry) conditions are induced over the northwestern part of Australia associated with Ningaloo Niño (Niña).

Finally, to check whether Ningaloo Niño/Niña can develop independent of ENSO, a coupled model experiment in which SSTs in the tropical Pacific and maritime continent are strongly relaxed to their daily climatology to suppress ENSO is conducted. It is shown that Ningaloo Niño/Niña develops with the similar magnitude without ENSO through an intrinsic ocean-atmosphere interaction off Western Australia.