論文の内容の要旨

論文題目：Generation and decay mechanisms of subtropical dipole modes influencing the southern African climate (アフリカ南部の気候に影響を及ぼす亜熱帯ダイポールモードの形成と減衰のメカニズム)

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Southern Africa experiences most of the annual rainfall in austral summer and its interannual variation has a significant socio-economic impact on the regional society. The rainfall variation during austral summer is greatly influenced by the interannual sea surface temperature (SST) variations in the southern Indian and South Atlantic Oceans. These variations are associated with a dipole pattern of SST anomalies in the northeastern and southwestern parts of each basin, called subtropical dipole mode. Several studies discussed its generation mechanism by examining the upper-ocean heat budget of a constant thickness, and reported the importance of latent heat flux anomalies associated with variations in the subtropical high. However, no studies paid attention to a role of time-varying ocean surface mixed layer in the SST variations. Since the mixed layer in the subtopics undergoes significant seasonal variations, taking into account these variations are of great importance for comprehensively understanding the mechanism of the subtropical dipole mode and its impact on the summer rainfall over southern Africa.

This thesis proposes a new mechanism on the growth and decay of the subtropical dipole modes in the southern Indian and South Atlantic Oceans. Since the mechanism of the South Atlantic subtropical dipole (SASD) is almost similar to that of the Indian Ocean subtropical dipole (IOSD) and the mechanism of the negative event shows a mirror image to that of the positive event, only the mechanism of the positive IOSD is shown in the schematic diagram (Fig. 1). The positive (negative) SST anomaly pole associated with the positive IOSD starts to grow in late austral spring and reaches its peak in February. The mixed-layer heat balance calculated from outputs of an ocean general circulation model (OGCM) reveals that the warming of mixed layer by the climatological shortwave radiation is enhanced (reduced) by the thinner (thicker) than normal mixed layer. This thinner (thicker) mixed layer is induced by the suppressed (enhanced) latent heat loss associated with the southward shift and strengthening of the subtropical high in late austral spring.

The positive (negative) SST anomaly pole gradually decays in austral fall, because the cooling of mixed layer by the entrainment is enhanced (reduced) owing to a larger (smaller) temperature difference between the mixed layer and the entrained water as a result of the warmer (colder) mixed layer. In addition, the cooling of mixed layer by the climatological latent heat loss is enhanced (reduced) by the same thinner (thicker) mixed layer and the latent heat loss anomalously increases (decreases) due to the warmer (colder) SST. Both of these contribute to the decay of the positive (negative) SST anomaly pole.

These results are based on the outputs from an OGCM, where the surface heat fluxes were calculated by the bulk formula using the atmospheric reanalysis data and the simulated SST. To reveal air-sea interaction processes involving the IOSD in more detail, outputs from a coupled general circulation model (CGCM) are analyzed. The growth and decay mechanisms proposed based on the OGCM are successfully demonstrated in the model. Moreover, the present CGCM suggests that although both SASD and IOSD have impacts on the summer rainfall over southern Africa, the SASD may have more influence on the rainfall variations in the southern part of southern Africa than the IOSD. However, the observational data with a longer period is required to verify the relative contribution from the SASD and IOSD.

Since the variations in the subtropical high are crucial for the rainfall variations over southern Africa as well as the growth and decay of the IOSD, experiments using a CGCM are conducted to investigate causes of the variations in the subtropical high. In an experiment, where the SST outside the southern Indian Ocean is nudged toward the monthly climatology of the simulated SST, two types of the IOSDs occur owing to the anomalous Mascarene High. One type is associated with the zonal wavenumber four pattern of equivalently barotropic geopotential height anomalies in the midlatitudes. The pattern correlation analysis with the

EOF modes of the geopotential height anomalies suggests that this geopotential height anomaly may be linked with the Antarctic Circumpolar Wave. On the other hand, another type of the IOSDs occurs when the geopotential height anomalies have opposite signs in the midlatitudes and the Antarctica. This suggests a possible relation with the Antarctic Oscillation. These results indicate that even without atmospheric teleconnections from air-sea coupled modes outside the southern Indian Ocean, the IOSD may develop owing to the variations in the Mascarene High. However, the IOSD occurs less frequently in this case. This indicates that atmospheric teleconnections from air-sea coupled modes such as El Niño/Southern Oscillation and Indian Ocean Dipole may also play a role in generating the IOSD.

Figure

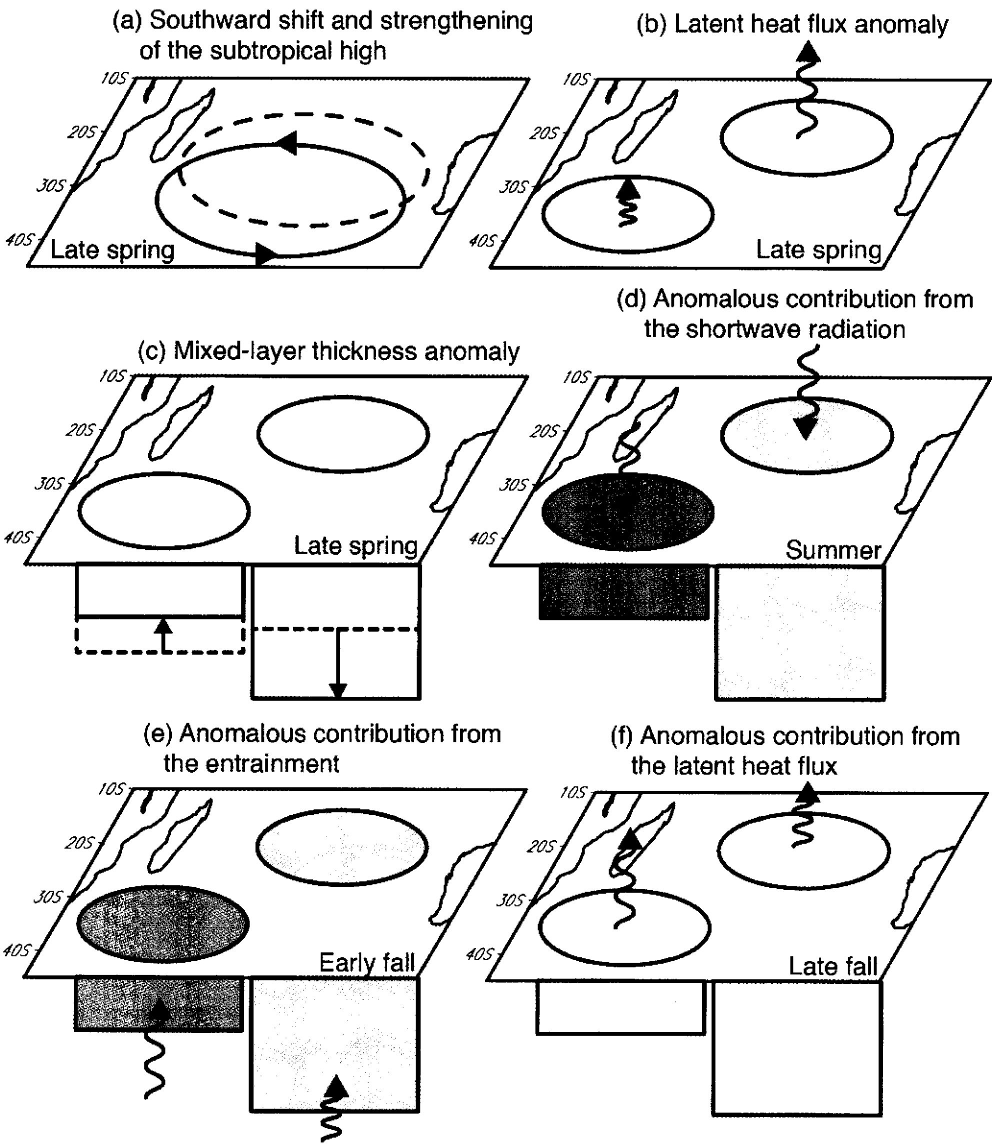

Figure 1: Schematic of (a-d) the growth and (e-f) decay mechanisms of the IOSD.