博士（理　学）　前　坂　　剛

学 位 論 文 題 名

Study on the Formation Process of Precipitation Systems in the Meiyu Front on the China Continent.

(中国大陸上の梅雨前線における降水システムの形成過程に関する研究)

学位論文内容の要旨

In early summer, a rainy season begins in East Asia and continues for several weeks. The event is called "Meiyu" in Chinese, and the rainfall is determined to be a part of a stationary rain belt that ranges from the southeastern edge of the Tibetan Plateau to the east of the Japan Islands. Therefore, this rain belt is called the "Meiyu front". To clarify the formation process of the precipitation systems in the Meiyu front on the China Continent, GEWEX (Global Energy and Water Cycle Experiment) Asian Monsoon Experiment / Huaihe River Basin Experiment 1998 (GAME/HUBEX 1998) was carried out during the Meiyu season in 1998. In this thesis, the characteristics and detailed structures of the precipitation system in the Huaihe River Basin during the Intensive Observation Period (IOP) of the GAME/HUBEX are investigated with dual Doppler radar, heat and moisture budget analysis, and numerical simulation to clarify the formation processes.

During the IOP, severe precipitation associated with the Meiyu front was brought on 29 June and 2 July 1998. The precipitation event on 29 June 1998 was associated with the Meiyu front moving northward in the subtropical air mass (ISA type), while the precipitation event on 2 July 1998 was associated with the Meiyu front which located on the polar front (OPF type) and moved southward.

The ISA-type Meiyu front moved northward, and two types of precipitation systems formed in this front. One was the organized pair of the convective precipitation system on the convergence line near the ground and the stratiform precipitation system formed to the north of the convective precipitation system. The other was the linear convective precipitation system to the south of the convergence line near the ground. In the former precipitation area, the stratiform precipitation system generated a cold pool near the ground. This cold pool intensified the local temperature gradient to maintain the Meiyu front, although there were only weak or reversed thermal gradient in the subtropical air mass. In the latter precipitation area, because the air near the ground was very moist (95 % in relative humidity), weak cold pool was enough to cause the condensation to create

a successive linear convective precipitation system in the leading side. Moreover, these precipitation system contributed to the significant heating of the upper tropospheric air, and this heating apparently contributed to the development of the meso-α low, because it generated the pressure trough at 300 hPa.

In the OPF-type Meiyu front moving southward, the convective precipitation system and stratiform precipitation system to the north of the convective precipitation system were observed to the north of the convergence line on the ground. In the stratiform region, a cold pool was also formed to intensify the temperature gradient. However, there was no precipitation systems to the south of the convergence line, since the lifting condensation level (LCL) was higher than that in the ISA type; therefore, a new convective precipitation system was generated with the synoptic convergence.

The numerical simulation indicated that the cold pool was formed along the line of moisture discontinuity in both types of Meiyu fronts. This cold pool maintained the mesoscale precipitation system in the Meiyu front, and the mesoscale precipitation system created the cold pool. This feedback means that the rainfall in the Meiyu front was caused and maintained by the mesoscale precipitation system, which released convective instability due to the latitudinal moisture gradient.

The heat and moisture budget analysis in the basin scale revealed that the maximum level of diabatic heating (releasing of latent heat, mostly) in the case of the OPF type (about 400 hPa) was higher than in the case of the ISA type (800 hPa). As to the formation of precipitation in the meso-γ scale convective precipitation system, Doppler radar analysis revealed that the level at which the precipitation formation was predominant was at 4.5 km in the case of the OPF type and 2.0 km in the case of the ISA type.

The differences in the processes of precipitation formation of the ISA- and OPF-type Meiyu fronts are due to the variance in the LCLs of the air parcel that flows into the Meiyu front. The southerly inflow into the Meiyu front moving northward in the subtropical air mass moves over wet ground. Therefore, the LCL of the inflow is decreased, because the mixing ratio of water vapor of the inflow is increased but a rise in temperature is inhibited. On the other hand, the southerly inflow to the Meiyu front moving southward with the polar front moves over the dryer ground than that in the ISA type. Therefore, the LCL of the inflow is increased because the water vapor that the air parcel can obtain is decreased, and the temperature is increased.

The rain belt recognized as the Meiyu front on the China Continent corresponds to the discontinuity line of the moisture, and which is separated from the discontinuity line of the temperature (the polar front). This means that the Meiyu front is located in the subtropical air mass, and the mesoscale precipitation system in the Meiyu front generates the local temperature gradient to maintain itself. On the other hand, when the polar air mass sometimes spreads to 30 °N in latitude, the Meiyu front has the temperature and moisture gradient and moves southward. At this time, the synoptic convergence supports

the mesoscale precipitation system to generate the rainfall in the Meiyu front. At last, the results of this study remark that the mesoscale precipitation process, such as the organization of the convective and stratiform precipitation systems, is necessary for the generation of the rainfall in the Meiyu front.

学位論文審査の要旨

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Study on the Formation Process of Precipitation Systems in the Meiyu Front on the China Continent.

（中国大陸上の梅雨前線における降水システムの形成過程に関する研究）

申請者は，中国大陸における梅雨前線の構造を，その降水システムに着目して，ドップラーレーダー等の観測データの数値解析と非静力学大気シミュレーションモデルによる数値実験とを駆使することにより明らかにした．

中国大陸上の梅雨前線は，通常亜熱帯気団内に存在するが，寒帯気団の南下時には寒帯前線上に存在する．本研究ではこの二つの梅雨前線について内部のメソスケール降水システムの構造を調べ，降水形成の高度の違いに着目した．研究の結果，亜熱帯気団内の梅雨前線では，地上の収束線の北側だけでなく，南側にも線状対流性降水システムが形成されることが明らかになった．この降水システムの形成・維持には，下層に持ち上げ凝結高度の低い気塊が流入することが重要であることが示された．一方，寒帯前線上の梅雨前線では，地上の収束線の北側にのみ降水が形成されており，対流降水域における降水の形成高度が亜熱帯気団内の梅雨前線に比べ高いことが明らかになった．降水システムの違いは，梅雨前線の南側下層に流入する気塊の持ち上げ凝結高度の違いによりもたらされ，その値は前線の南側における地表面からの顕熱・潜熱フラックスの違いによるという仮説が提案・検証された．

内部のメソスケール降水システムの維持に関してはどちらの梅雨前線においても共通した傾向が見られ，降水システム自身が形成した 500～1000km 程度の空間スケールを持つ東西方向に長い冷気塊によって維持されていること，降水の集中は冷気塊の形成に有利となる水蒸気傾度の大きな領域に見られることなどが明らかにされた．

モンスーン地域における初夏の非断熱加熱は地球大気大循環に大きな影響を与えているが，本研究はその非断熱加熱の一部を担う中国大陸上の梅雨前線の形成・維持機構を明らかにしたものであり，地球惑星科学分野に大きな貢献をしたものと高く評価できる．よって，申請者は、北海道大学博士（理学）の学位を授与される資格あるものと認める．