Negative entropy flow and its effect on the organization of tropical cyclones

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1. Introduction

Entropy is, to some extent, a measure of the disorderedness of a thermodynamic system and the equilibrium of an isolated system is the most disordered state with the maximum entropy. There exist irreversible processes producing positive entropy in any many-body system and the orderedness of the system will be continuously weakened due to the spontaneous entropy-increasing processes within it when no negative entropy enters into the system from its environment. In this paper, the dependence of the organization of an orderly structure which occurs frequently in the unstable non-equilibrium atmosphere, such as the typhoons (or hurricanes) and cyclones, on negative entropy flow will be analysed in terms of the theory of dissipative structures, so as to reveal the dissipativity of such atmospheric orderly structures far from equilibria

2. Entropy balance equation

Starting from the Gibbs-relation for specific entropy, omitting the contributions of both the chemical reactions and inertial energy change in the atmosphere (notice that C_vT can be simply used to describe the inertial energy within the range of the atmospheric temperature), and assuming that there exist no diffusive flows, for the traveling synoptic systems, such as typhoons, cyclones etc., the entropy balance equation for the mixed ideal gases in the quasi-Lagrangian coordinates can be finally derived as:

$$\frac{D\rho s}{Dt} = -div\,[\rho s(\vec{V} - \vec{C}) - \rho R\vec{V}] - \vec{V}\cdot\nabla\rho R$$
$$= EF + EP\,, \qquad (3)$$

where *D/Dt* is the quasi-Lagrangian change rate following the traveling system, *EF* and *EP* entropy flow and production, respectively.

3. Computational results

Using the entropy balance equation (4), we have calculated the entropy flow and production for two traveling atmospheric eddy systems: one is a Bay of Bengal cyclone, and the other a West Pacific typhoon. The results are shown in Table 1 where there is a common characteristic for the total entropy flows of these two atmospheric systems, that is, the entropy flow in the formation phase is larger than that of the mature phase. It is suggested that the evolution of the negative entropy flow is a significant indicator of the life cycle of an atmospheric system.

Table 1. The Entropy Budget for the Atmospheric Systems (unit: cal K^{-1} s^{-1} m^{-2})

	MONEX cyclone		Typhoon 7507	
	Formation (July 6)	Maturity (July 7)	Formation (Aug.18)	Maturity (Aug.22)
TEF	-0.6008×10^2	-0.3239×10^2	-0.1060×10^3	-0.2534×10^2
(TEF)'	id.	id.	-0.1057×10^3	-0.2170×10^2
TEP	0.5997×10^2	0.4097×10^2	0.9052×10^2	0.2031×10^2