Dependence of static stability on the water abundance in the troposphere of Jupiter's atmosphere

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Achterberg and Ingersoll (1989) estimates static stability of Jupiter's atmosphere from the difference between the moist pseudoadiabatic lapse rate and the dry adiabatic lapse rate, and concludes that the value of static stability is linearly proportional to the water abundance of the atmosphere. Ingersoll and Kanamori (1995) assumes this linear relationship, and argues that if the water abundance increases approximately ten times that of the solar abundance, the phase velocity of the SL9 impact wave could be explained as that of an internal gravity wave trapped in the stable layer generated by the cloud convection.

However, the calculation by Achterberg and Ingersoll (1989) is implicitly an approximation assuming that the water abundance is small enough, and actually the water abundance considered ranges from 0.06 to 3.5 times that of the solar abundance. It is a question whether static stability is linearly proportional to the water abundance even when the water abundance reaches 10 times that of the solar abundance. In our study, the water abundance is changed in the wider range than that of the previous study, and the relation between static stability and the water abundance of Jupiter's atmosphere is examined. The results are applied to the argument of Ingersoll and Kanamori (1995) and their conclusion is reconsidered.

The value of static stability is estimated from the difference between the moist pseudoadiabatic lapse rate and the dry adiabatic lapse rate as well as Achterberg and Ingersoll (1989). The moist pseudoadiabatic lapse rate is calculated by the method of minimizing Gibbs free energy. This is an advantageous method to a parameter study where the constituent abundance is changed. According to our calculation results, the linearly proportional relation between static stability and the water abundance is broken when the water abundance increases more than that of the solar abundance. Moreover, the value of static stability approaches a certain constant value when the water abundance is exceedingly large. The reason is that the moist adiabatic lapse rate has an upper limit which is obtained by approximating that the major component of the atmosphere is water, and as the increase of the water vapor amount, the moist adiabatic lapse rate approaches this limit.

The value of static stability obtained when the water abundance is 10 times that of the solar abundance is less than half of the value obtained by assuming the linear relation. By using this value of static stability, it is difficult to explain the phase velocity of the SL9 impact wave as that of an internal gravity wave. This result is held even if the water abundance increases up to 100 times that of the solar abundance.