Stratospheric Climate Modeling - especially QBO modeling -

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1. Background

A climate model or general circulation model (GCM) has been developed in the Center for Climate System Research (CCSR) in cooperated with the National Institute for Environmental Studies(NIES). The first author is seeking the role of stratosphere to the climate system. A possible role of the stratosphere is, for example ozone depression to the tropospheric climate. However, in the present situation, the CCSR/NIES GCM result is preliminary. It means that it is difficult to see the chemical problem. So we emphasize the dynamical properties of the stratospheric GCM.

2. Objective

As mentioned in the background, the dynamical properties in the CCSR/NIES stratospheric GCM is investigated. Until now, we see the dynamics of the stratosphere in the T21L30 (horizontal resolution triangular maximum wave number 21, 30 vertical layers) stratospheric GCM. The horizontal resolution is low, so dynamical properties, for example mean zonal wind in the stratosphere, is not good. We emphasized on the interesting time change in the equatorial stratosphere, namely equatorial quasi-biennial oscillation (QBO).

The basic mechanism of the QBO is Holton and Lindzen's[1] mechanism. Two equatorial waves, Kelvin and Rossby-gravity waves, are believed to produce the QBO by the wave-mean flow interaction. However, the GCM could not produce the QBO. Further, above two waves seem to be not enough to produce the QBO(cf. Takahashi and Boville[2], 1992; Takahashi[3], 1993). Gravity waves seem to be important to the QBO. So we test the possible role of the gravity waves to the QBO using the CCSR/NIES GCM.

3. Method

We use the CCSR/NIES general circulation model. The first is a standard low horizontal resolution GCM T21L30. The GCM is standard, so every process in the GCM is included.

Second is to test the role of gravity wave in the low horizontal, however higher vertical resolution T21L45. In this experiment, we change the sea surface temperature and rotation of the earth.

Final is the QBO generation using a higher horizontal resolution T106, however 1/5 sector GCM. A simple aqua-planet GCM is used for second and third tests. Because, the QBO is believed to be produced by waves in the atmosphere, and the simple situation is understandable.

4. Results

4-1 A standard experiment

Figure 1 shows the mean zonal wind at January. Basic feature has a good agreement to the observed mean zonal wind. Note that the basic agreement is due to the inclusion of strong Rayleigh friction in the model. If the Rayleigh friction is not included, the result is too bad. There are basic agreements, but there are several disagreements to the observed wind. One is the summer hemisphere. Usually, there is easterly in the summer hemisphere in the stratosphere. But in this experiment, there is westerly in the summer hemisphere.

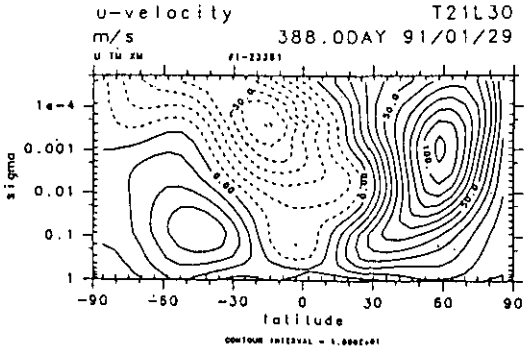

Fig. 1: Mean zonal wind in the stratosphere at January in a standard experiment.

There is another discrepancy in the winter hemisphere lower stratospheric wind. There are seperate jets (so called, sub-tropical jet and polar night jet) in the observed mean zonal wind. However, in the experiment, the jets does

not seperate each other. Correspondingly, the mean zonal temperature is cooler in the polar lower stratosphere in comparison with the observed temperature (not show).

At the present simulation, the stratospheric climate is not so good. Now we change the GCM experiment to higher horizontal resolution T42L30 GCM. The experiment is now starting. More impotant improvement (the new radiation code) is now proceeding. Better results will be obtained in the near future.

4-2 Low resolution QBO experiment

As mentioned in the above subsection, the results of stratospheric climate model are preliminary. Next test is the QBO experiment. Figure 2 shows the time-height section of the mean zonal wind over the equator, in the case of high equatorial SST 320 K over the equator. We can see a QBO like oscillation in the height around 5mb. The height seems to be higher, but the height of tropopause is about 20mb. So the oscillation is the QBO like oscillation in the equatorial lower stratosphere. However, there is no rotation of the earth in this experiment.

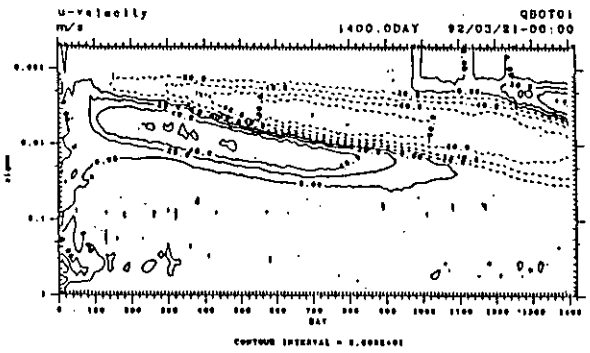

Fig. 2: Time-height section of mean zonal wind over the equator, *in the case of high SST and no-ratation in the low horizontal* resolution.

Figure 3 shows the time-height section of the mean zonal wind over the equator, in the case of usual earth rotaion and high SST experiment. In this experiment, there is no signal of the QBO like oscillation. In the case of rotation of the earth, the wave response to convection in the troposphere is different from the case of no-ratation. Now detailed analysis is performed and wil be reported in the next time. This result suggests that gravity waves are important.

4-3 high resolution QBO experiment

In this subsection, we will report the QBO experiment using high horizontal resolution case. Figure 4 shows the time-height section of mean zonal wind over the equator. The result is preliminary. It takes much time for computaion. However, there is a signal of a QBO like oscillation, even though the figure just shows the westerly downward propagation and the easterly is in the higher

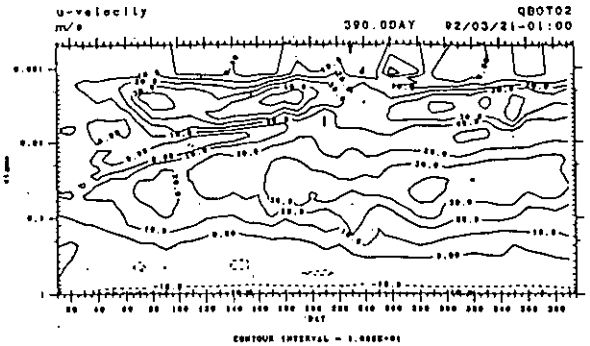

Fig. 3: Same as Fig. 2 but for ratation of the earth.

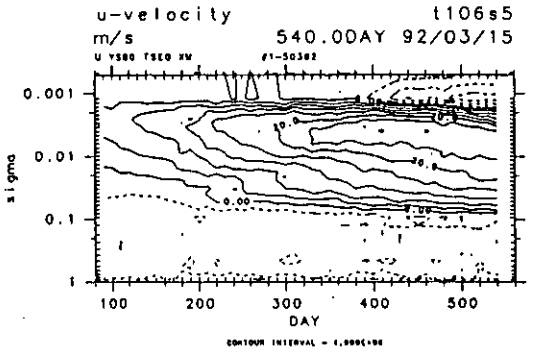

Fig. 4 Time-height section of the mean zonal wind in the case of high horizotal resolution.

altitude. Now the calculation is proceeding. If the QBO is obtained, it is the first experiment of the QBO using the GCM.

5. Conclusion

The main results are as follows:

1. The stratospheric climate modeling is preliminary.
2. The QBO like oscillation is obtained in the case of high SST and no-rotation using low horizontal resolution.
3. The QBO like oscillation may be obtained in the case of high horizontal resolution.

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References

1. Holton, J. R. and R. S. Lindzen, *J. Atmos. Sci.* **29**, 1076 (1972)
2. Takahashi, M and B. A. Boville, *J. Atmos. Sci.* **49**, 1020 (1992)
3. Takahashi, M, *J Metor. Soc. Japan* **71**, to appear (1993)