ASPECTS OF THE STRATOSPHERIC FINAL WARMING IN THE SOUTHERN HEMISPHERE SIMULATED BY A GENERAL CIRCULATION MODEL

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1. INTRODUCTION

The simulation of the breakdown of the Southern hemisphere winter stratospheric circulation is know to be a challenge for global models (Boville, 1995; Hamilton, 1995, Manzini and Bengtsson, 1996). A major improvement is reported for a simulation made with the MA / ECHAM4 general circulation model that employs parameterizations of the momentum deposition due to a continuous spectrum of gravity waves (Hines, 1996a,b) and of the orographic gravity wave drag (McFarlane, 1987). The general circulation model used in this study is the middle atmosphere version (vertical domain: surface to 0.01 hPa) of the ECHAM4 model described in (Roeckner et al. 1996). Previous applications of the Hines parameterization in general circulation models include (Manzini et al. 1996a,b; McFarlane and Manzini, 1996, McFarlane et al. 1996). Presently, gravity waves are supposed to be launched at ~100 hPa and the background gravity wave rms wind is enhanced over regions of high precipitation, in order to represent gravity wave activity generated by convective and frontal systems.

The simulation with the Hines and McFarlane parameterizations (hereafter ECH4F1) is compared to NMCCAC analyses (15 years) and to a previous simulation with Rayleigh friction instead (hereafter ECH4RFD). Both simulations used climatological sea surface temperature (AMIP average), the seasonal and diurnal cycles, and were integrated for 10 years with T30 horizontal truncation and 39 vertical levels.

2. RESULTS FOR OCTOBER

The stratospheric final warming for the 10 seasons available from the two MA/ECHAM4 versions are examined focusing on the southern hemisphere circulation in October. Figure 1 presents the October zonal mean zonal wind and interannual variability from the NMCCAC analyses and from the ECH4F1 and ECH4RFD simulations. In the Southern stratosphere, the ECH4F1 polar jet is considerably weaker (of ~20-30 ms^{-1}) than that simulated by the model with Rayleigh friction, the ECH4RFD simulation (compare upper right with bottom left). Consistently, also the cold bias in the spring polar middle stratosphere is also alleviated in the ECH4F1 simulation (Manzini et al. 1996a). This improvement is presumably associated with the dependence on vertical variations of the background large scale zonal wind in the parameterization of the momentum deposition due to a spectrum of gravity waves. However, the ECH4F1 polar jet is still 10-20 ms^{-1} stronger than observed (compare upper panels). Note also that the ECH4F1 Southern upper tropospheric jet is weaker (wrt the ECH4RFD one), suggesting a deep downward impact of the mesospheric drag, and that easterlies appear in the upper mesosphere in the ECH4F1

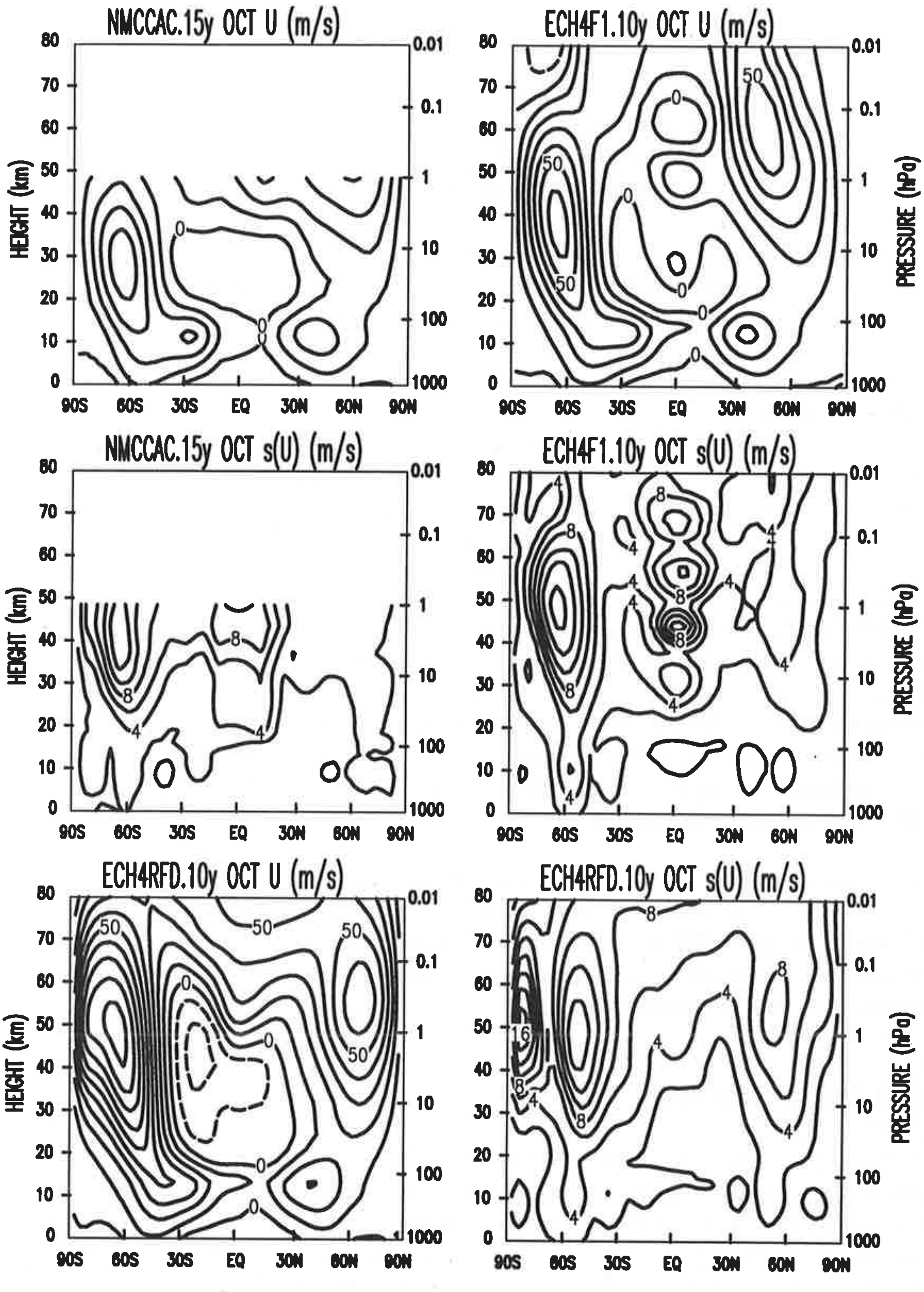

FIGURE 1: October zonal mean zonal wind from the NMCCAC analyses (15 year average, upper left), the ECH4F1 simulation (10 year average, upper right) and the ECH4RFD simulation (10 year bottom left), contour: 10 ms^{-1}; October zonal mean zonal wind interannual variability from NMCCAC analyses (middle left), the ECH4F1 simulation (middle right), and the ECH4RFD simulation (10 year bottom right), contour: 2 ms^{-1}.

simulation only.

A realistic structure and amount of interannual variability in zonal mean zonal wind is found for ECH4F1 only (compare middle panels and bottom right). The two variability maxima found for ECH4RFD at the polar and equatorward side of the stronger westerlies suggest that the polar stratospheric jet in this simulation decays in situ (i.e., radiatively).

Further analysis has shown that the westward tilt of the quasi stationary wave vertical structure is captured by the ECH4F1 simulation in the stratosphere, while the ECH4RFD stationary waves present a more equivalent barotropic vertical structure and planetary wave-2 dominates in the ECH4RFD lower stratosphere. This latter feature is absent from both the NMCCAC and ECH4F1 data. Note also that in the ECH4RFD simulation the planetary wave-2 is not present in the troposphere, suggesting that this is not an upward propagating wave generated in the troposphere. The tropospheric stationary waves appears instead to be similar in the two simulations.

The realistic representation of the stationary waves and of the monthly interannual variability in the ECH4F1 simulation motivates the inspection of the daily evolution of the stratospheric circulation. Two Octobers characterized by a particularly disturbed monthly mean circulation have been selected from the ECH4F1 simulation. The selected simulated Octobers present periods of transients in the geopotential height anomaly that are manly associated with eastward planetary wave-2 and cold conditions over the South Pole. As the transient height anomaly approaches the Pacific sector (120E-180E), planetary wave-2 decays while planetary wave-1 amplifies and a polar warming occurs in the model. A similar influence of dynamical processes on the Southern stratosphere vortex breakdown has been documented in observations by Mechoso et al. (1988) and Hirota et al. (1990).

3. CONCLUSIONS

The comparison of two simulations made with the MA / ECHAM4 model and the NMC-CAC analyses have shown that a realistic representation of the dynamical processes characterizing the Southern hemisphere polar vortex breakdown is obtained only for the simulation that included the Hines and McFarlane parameterizations (the ECH4F1 simulation).

The Southern hemisphere polar vortex breakdown in the ECH4F1 simulation is associated with a quasi-stationary anticyclone that develops in the 90E-180E region in the middle stratosphere and that is presumably forced by vertically propagating tropospheric planetary waves. When a disturbed circulation characterizes the simulated October circulation, the model results suggest that the final warming involves the interaction of quasi-stationary wave-1 and eastward travelling planetary wave-2, in agreement with previous observational studies. Statistics of the stationary and transient wave amplitude and the momentum and heat fluxes however suggest that during the simulated final warming transient waves plays a larger role than that indicated by the NMCCAC data. This model feature is consistent with the still present spring polar stratospheric cold bias and stronger westerlies, typically of more winter-like meteorological conditions.

The stratospheric polar jet in the simulation with Rayleigh friction (i.e., ECH4RFD) appears instead to decay in situ (i.e., radiatively) and not to be favoured by upward propagating quasi stationary planetary waves.

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