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SPATIAL AND TIME DOMAIN SPECTRAL ENERGETICS IN THE GLAS GENERAL CIRCULATION MODEL

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ABSTRACT

Zonally averaged eddy kinetic energies and time domain energetics spectra have been calculated for the new GLAS general circulation model. The spatial results show significant improvements in the magnitude and distribution of the eddy kinetic energy. The spectral results provide a technique for tracing when and where the model predictions diverge from observations.

Introduction

Three major approaches are used to check agreements between general circulation models and the real atmosphere: synoptic comparisons, climate mean statistics, and time domain analyses. All three attempt to quantify the model's success and identify the details of its failure. Time domain analyses also permit one to study how to extract the maximum possible information at times approaching the predictability limit. The usual example here is one's intuitive belief that some skill should remain in the low wave number spectral coefficients even after grid point values have approached the noise level. Since only limited success has been obtained in this regard, a related question is where, in detail, is the model going wrong.

Method

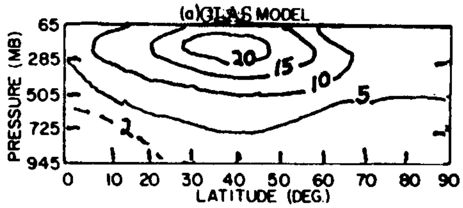
Energetics calculations involve subdividing atmospheric energy into four components: zonal kinetic energy (KO), eddy kinetic energy (KE), zonal potential energy (PE). The eddy energies may be further subdivided by calculating the one-dimensional Fourier transforms around each latitude circle, P(n) and K(n). Further details of the calculations are given in Tenenbaum, 1976. In this report, we use the formulas given there to evaluate new model and observational runs for January 1975 and 1977 (Halem et al., 1978). The domain of comparison is the northern hemisphere troposphere.

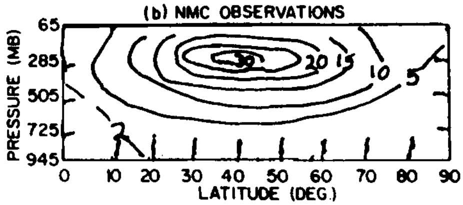
Spatial Results

The primary improvement in the new model occurs in the magnitude and distribution of KE. Fig. 1 shows the zonally averaged KE for the model, the corresponding observations, and a climatic mean. The model distribution is significantly less diffuse than previous results (Tenenbaum, 1976, Fig. 15). The qualitatively incorrect behavior of the conversion from KE to KO has also been eliminated and one now obtains the characteristic dipole structure (Tenenbaum, 1976, Fig. 17).

Time Domain Spectra

An excellent example of the model following the behavior of





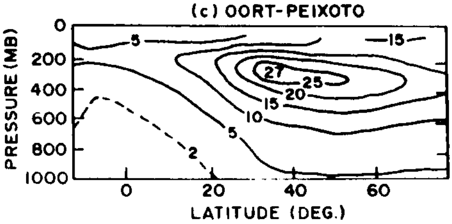


Fig. 1. (a) Spatial distributions of the eddy kinetic energy, KE. Data are for the northern hemisphere troposphere, January 1975, for the GLAS model. (b) NMC observations. (c) Climatic means from Peioxto and Oort (1974). Units: 10^5 J/(m^2 bar).

the atmosphere for almost two weeks is given in Fig. 2a (January 1977). Significant skill is maintained for a highly averaged quantity, KE, right out to the predictability limit. Fig. 3a (January 1975) shows another example where a discrepancy occurs after only 5 days. An important value of time dependent spectral techniques is to let us pursue the cause of the discrepancy in Fig. 3a. Most KE is contained in the lowest few wave numbers, and on comparing model and observation wave number by wave number we find that the primary difference is in wave number 3. This quantity is shown in Fig. 3b for the first 15 days of the model run. Note that the major portion of the KE discrepancy for days 5 through 10 is explained by the elevated values of K(3) during this period. Just previous to this period the fall of K(3) was compensated for by small contributions from many other wave numbers.

Time domain spectral techniques permit us to analyze the disagreements further by examining all of the conversions to and from K(3). These are: conversions from PE and all other K(n) and conversions to KO and sub-grid scales (dissipation). For this case only the conversion from P(3) to K(3) has major disagreements between model and observations (Fig. 3c). Note that the positive and negatives excursions of the model's K(3) seem causally linked to this conversion.

A spectral analysis also permits us to verify whether the model is accurately predicting the time dependence of each K(n) even when it is properly calculating the sum. Although the KE predictions in Fig. 2a are quite good, Fig. 2b and 2c show that the sum masks an erroneous distribution between K(1) and K(3).

Conclusions

Time domain spectral energetics provides a tool which deals with quantities displaying significant skill over periods comparable to the predictability limit. More importantly, we can (1) pinpoint the specific times and conversions which appear causally correlated with departures between model and observations; and (2) isolate cases where apparently correct predictions of KE mask major errors in its spectral components. By examining the spatial dependence of both the spectral components and conversions, we may seek linkages with erroneous physical processes in the model.

References

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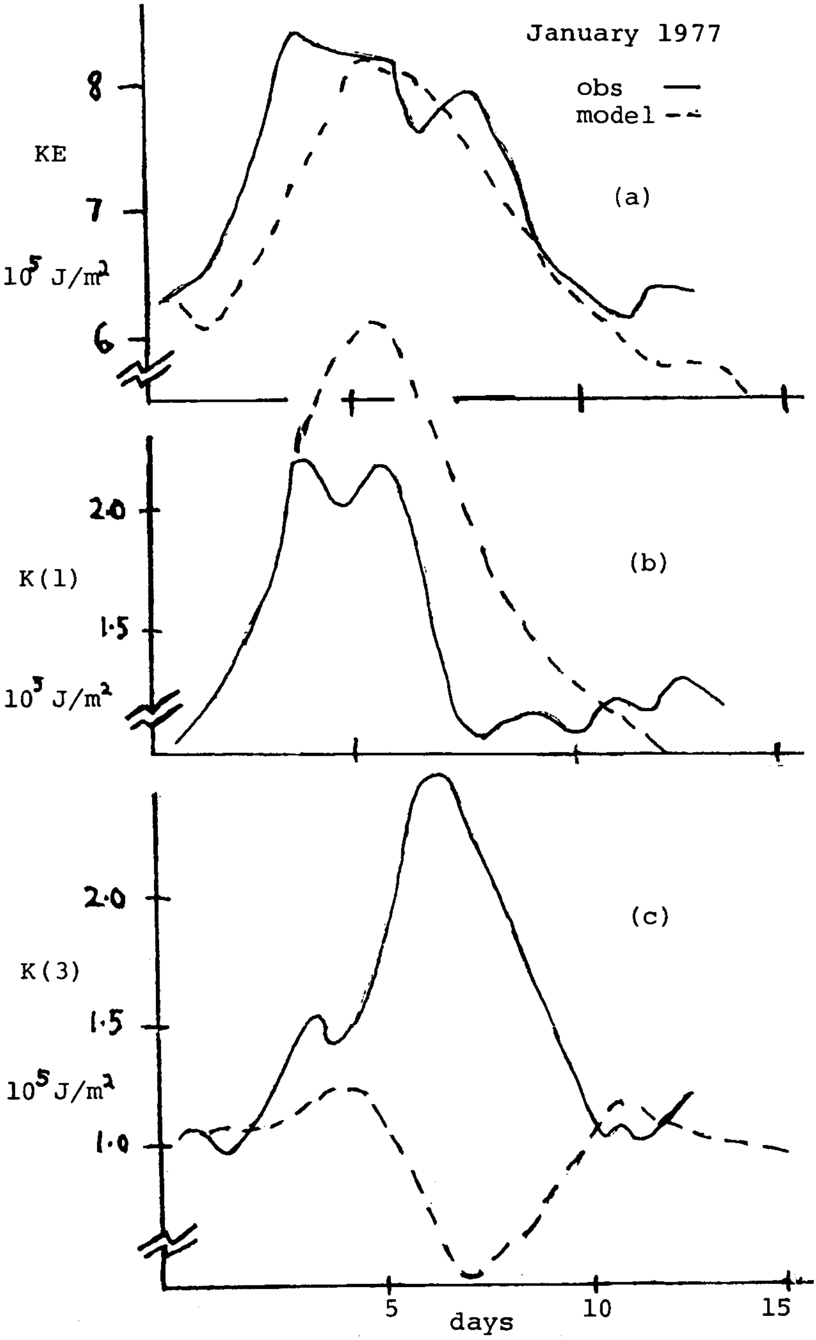

Fig. 2. (a) KE, (b) K(1), and (c) K(3) for January 1977 over the northern hemisphere troposphere.

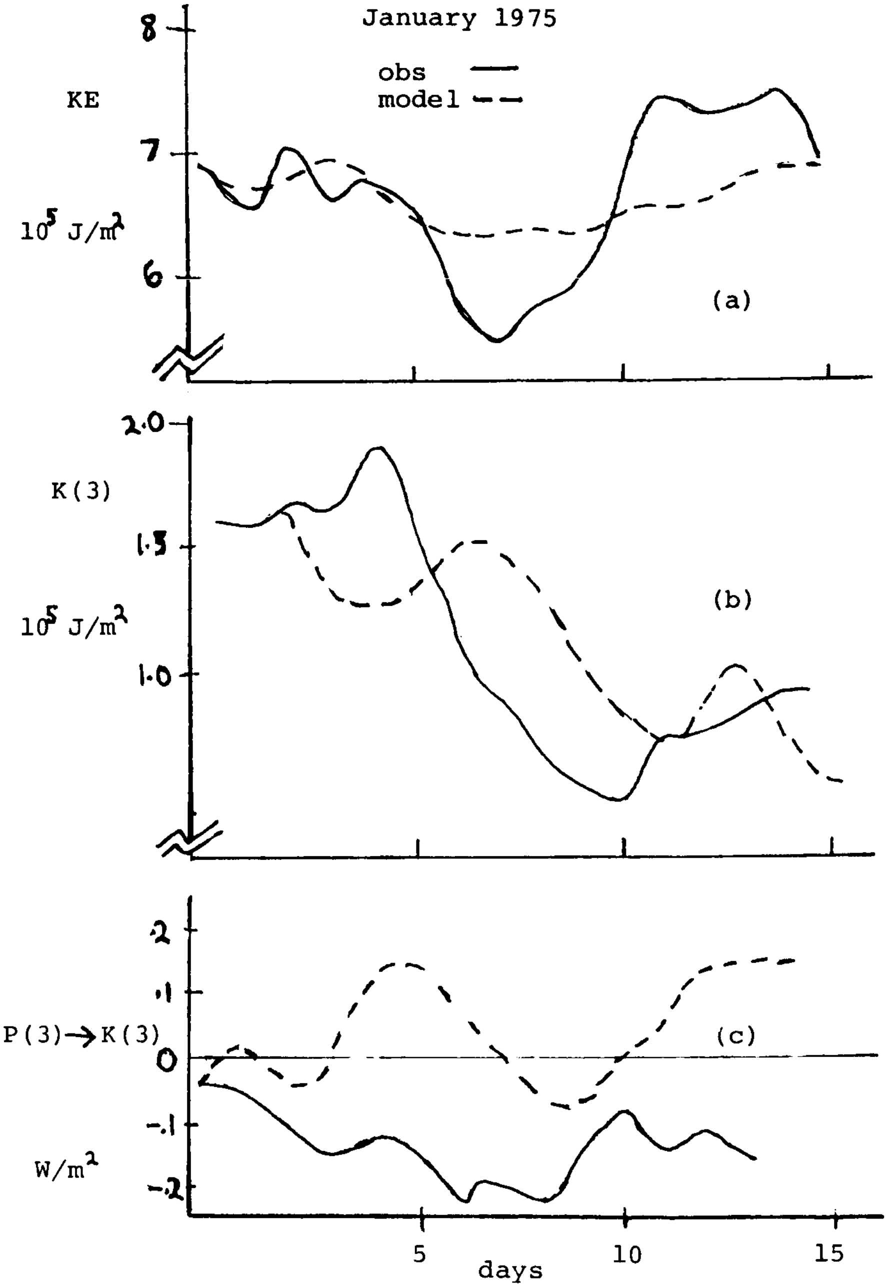

Fig. 3. (a) KE, (b) K(3), and (c) P(3) K(3) for January 1975 over the northern hemisphere troposphere.