Comparison of zonal large scale ozone variability derived from ECHAM4.L39/CHEM and TOMS total ozone data

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Abstract

Total ozone fields of the coupled chemistry-climate model ECHAM4.L39(DLR)/CHEM (hereafter: E39/C) and corresponding Total Ozone Mapping Spectrometer (TOMS) data are analyzed in order to compare zonal large scale ozone variations.

Emphasis is on monthly and inter-annual variability of the zonal wave numbers one and two, which are interpreted as the manifestation of the quasi stationary planetary waves number one and two.

To compare the ozone variability of the CCM and the satellite observations, the horizontal zonal amplitudes and phases are derived by means of a spectral statistical analysis. These results are also used to derive two hemispheric Ozone Variability Indices.

We present a comparison of total ozone, wave amplitudes and phases, their zonal and hemispheric means, to address the differences of the total ozone variability.

Data and Method

We present first results of a multi-year model simulation representing "2000" conditions with an updated version of E39/C (Hein et al. 2001, Austin et al. 2003), a coupled chemistry-climate model with a horizontal resolution of T30 and 39 layers in the vertical (surface to ~10 hPa).

The total ozone results from this time slice experiment, covering 16 years, are compared to TOMS observations (Version 7) from August 1996 to July 2003.

Total ozone can be considered as a tracer to illuminate the dynamics of the lower stratosphere, since the variability of the ozone column is mainly controlled by the dominating dynamical processes in the lower stratosphere that are planetary waves.

In order to determine the wave parameters from the ozone distribution the spectral statistical technique Harmonic Analysis (Bittner et al 1997) is applied to each latitude (the TOMS data is remapped to the E39/C grid). Generally, the technique corresponds to an approximate deconvolution of the power spectrum by successively subtracting the dominating spectral feature.

Total Ozone – Zonal Means

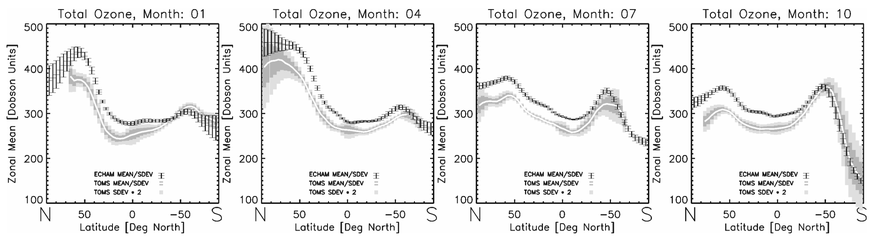


Fig 1: Zonal means of total ozone for Jan, Apr, Jul and Oct. 16 years of the E39/C time slice experiment „2000“ are compared to TOMS data from Aug 1996 to Jul 2003. E39/C is represented by error bars in black (mean ± strd dev), TOMS in gray shaded bars (dark gray: ± strd dev; light gray: ± 2 * strd dev; white line: mean). Note the latitudinal coincidence with a maximum bias of E39/C >40°N of about 60 DU (~15%).

Total Ozone – Hemispheric Means

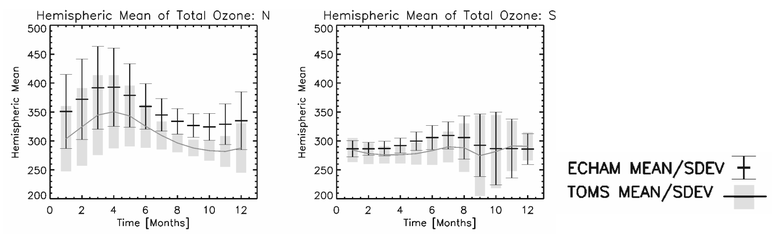
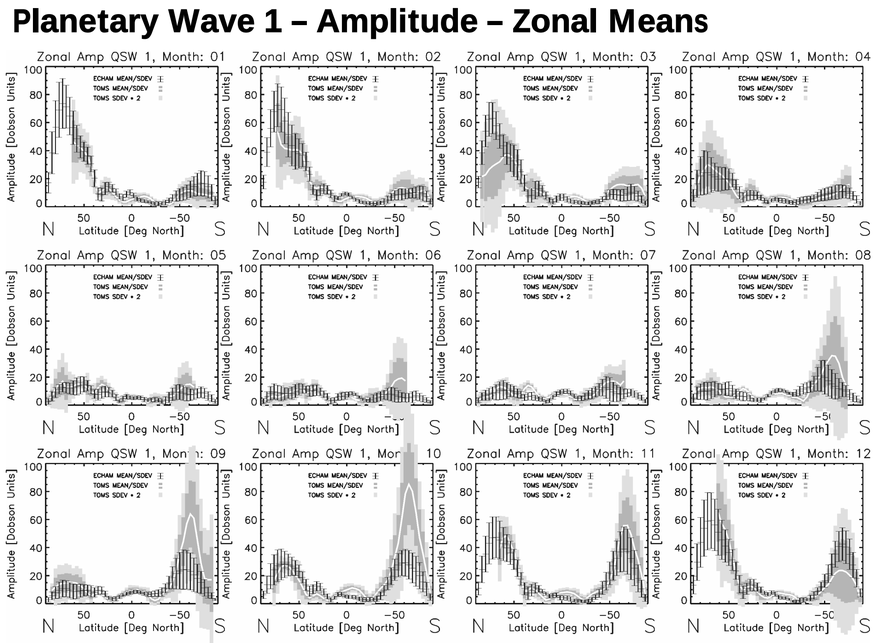


Fig 2 shows the hemispheric total ozone means for each month covering 16 years of the E39/C time slice „2000“ and TOMS data from Aug 1996 to Jul 2003. The left plot shows the northern hemisphere, where a positive bias of E39/C (10-15%) is evident. E39/C values are depicted by error bars in black (mean ± strd dev), TOMS means by a gray line with gray bars indicating ± strd dev.

Planetary Wave 1 – Amplitude – Zonal Means



Planetary Wave 1 – Amplitude – Hemispheric Means

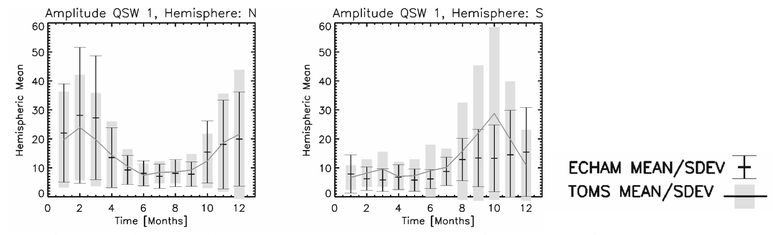


Fig 4: Variability Index 1 for both hemispheres and each month covering the years as defined in Fig 2. The Variability Index 1 is defined as the hemispheric mean of the quasi stationary wave number 1. The left plot shows the northern hemisphere, where the annual cycle is reproduced well by the model. The Variability Index 1 of the southern hemisphere deviates significantly in Sep and Oct.

Fig 3: Zonal means of the amplitude of the quasi stationary planetary wave number 1 for each month covering the years as defined in Fig 1. E39/C tends to overestimate the amplitude in Feb and Mar >60°N and to underestimate the amplitude and its variability from Aug to Nov between 50°S and 80°S.

Planetary Wave 2 - Amplitude – Zonal Means

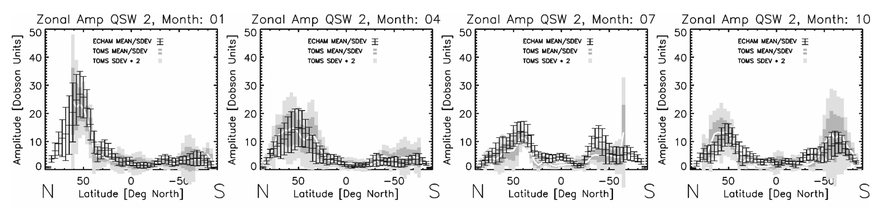


Fig 5: Zonal means of the amplitude of the quasi stationary planetary wave number 2 for Jan, Apr, Jul and Oct. Depicted is the comparison for the years defined in Fig 1. The values coincide well except for Nov between 40°S and 80°S (final warming)

Planetary Wave 2– Amplitude - Hemispheric Means

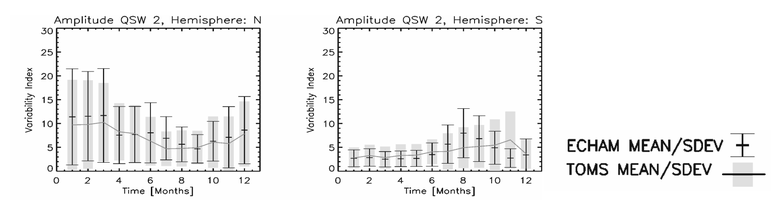


Fig 6: Variability Index 2 for both hemispheres and each month covering the years as defined in Fig 2. The Variability Index 2 is defined as the hemispheric mean of the quasi stationary wave number 2. The left plot shows the northern hemisphere.

Planetary Wave 1 – Phase – Zonal Means

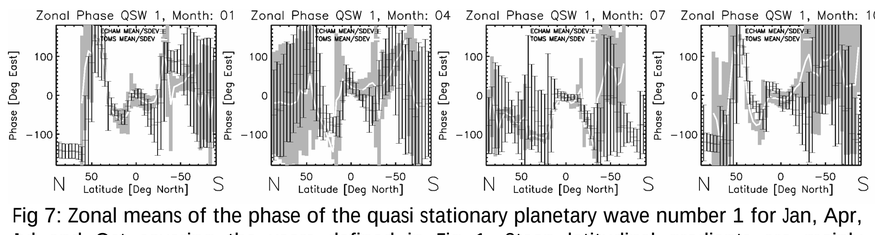


Fig 7: Zonal means of the phase of the quasi stationary planetary wave number 1 for Jan, Apr, Jul and Oct covering the years defined in Fig 1. Steep latitudinal gradients are mainly reproduced by the model. Details and deviations need further investigation.

Summary

ECHAM4.L39(DLR)/CHEM total ozone results from the time slice experiment 2000 and corresponding TOMS data are compared focusing on zonal large scale ozone variability. A Harmonic Analysis is applied to derive amplitudes and phases of the quasi stationary planetary waves number one and two.

- Generally, the zonal and hemispheric means of total ozone, amplitudes and phases of model and observations agree well.
- Yearly cycles and latitudinal distributions are reproduced, too.
- E39/C shows a positive bias of total ozone up to 10-15% (>40°N) (Fig 1,2).
- E39/C overestimates the amplitude of wave 1 in Feb and Mar >60°N (Fig 3).
- It underestimates the amplitude and its variability from Aug to Nov between 50°S and 80°S (Fig 3,4).
- Amplitudes of wave 2 coincide well except for Nov from 40°S to 80°S (Fig 5).
- Strong latitudinal gradients of phases of wave 1 are mainly captured by E39/C (7)
- The comparison results of the 1980 time slice experiment (not presented here) show similar results.

Outlook

The intercomparison will be extended to ERS-2/GOME total ozone data and the E39/C time slice experiments 1980 and 2000.

Acknowledgement

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