On the effect of planetary Rossby waves on total ozone from GOME

M. L. R. Liberato[1,2], C. Gouveia[2,3], J. M. Castanheira[4], C. Da Camara[2], M. Weber[5] and J. P. Burrows[5]

1 – Physics Department, University of Trás-os-Montes e Alto Douro, 5001-801 Vila Real, Portugal (mlr@utad.pt)
2 – CGUL, IDL,University of Lisbon, 1749-016 Lisbon, Portugal
3 – Escola Superior de Tecnologia de Setúbal (EST), Instituto Politécnico de Setúbal, Setúbal, Portugal
4 – CESAM, Physics Department, University of Aveiro, 3810-193 Aveiro, Portugal
5 – Institute of Environmental Physics, University of Bremen, Bremen, Germany

1. Introduction

Traditionally, the analysis of the wave forcing of stratospheric polar vortex is performed within the framework of Eliassen-Palm (EP) flux. In this study we consider the wave forcing of the stratospheric polar vortex from the point of view of the energy associated with the forcing waves. The main goal of this work is to perform a diagnostic study of the total energy associated with planetary waves which force the vortex dynamics and its relation to total Ozone.

2. Method and Data

The analysis is based on a 3-Dimensional normal mode expansion of the atmospheric general circulation (Castanheira 2000). This scheme allows partitioning the total (i.e. Kinetic + Available Potential) atmospheric energy into the energy associated with planetary (Rossby) and inertio-gravity modes with barotropic and baroclinic vertical structures. The use of the 3-D normal mode decomposition also allows the study of the effects of both zonal and meridional scales.

This analysis scheme is applied to the global NCEP/NCAR reanalysis data set, using November to April daily means of the horizontal wind components (u, v) and of the geopotential height, at the 17 standard pressure levels, with the spatial horizontal resolution available (2.5° regular grid) and spanning the period 1958-2005. Each period from November to April is identified by the year to which January belongs. The data were projected onto the normal modes of an atmosphere at rest (see details in Liberato et al. 2007).

$$\begin{bmatrix} u \\ v \\ \phi \end{bmatrix} = \sum_{m=0}^{\infty}\sum_{s=-\infty}^{\infty}\sum_{l=0}^{\infty}\sum_{\alpha=1}^{3} w_{msl}^{\alpha}(t) G_m(p) \exp(is\lambda) C_m \cdot \begin{bmatrix} U(\theta) \\ iV(\theta) \\ Z(\theta) \end{bmatrix}$$

where, $G_m(p)$ are the vertical structure functions and $(U, iV, Z)^T$ are the Hough vectors. The energy associated with each wave is given by

$$E_{msl}^{\alpha}(t) = \frac{p_s h}{c_s} \left| w_{msl}^{\alpha}(t) \right|^2$$

where w is the complex wave amplitude, p_s is a constant near surface pressure and h is the equivalent height.

Stratospheric sudden warming (SSW) event dates used in this work were identified in the NCEP/NCAR reanalysis dataset. SSW events were identified by means of the algorithm developed by Charlton and Polvani (2006).

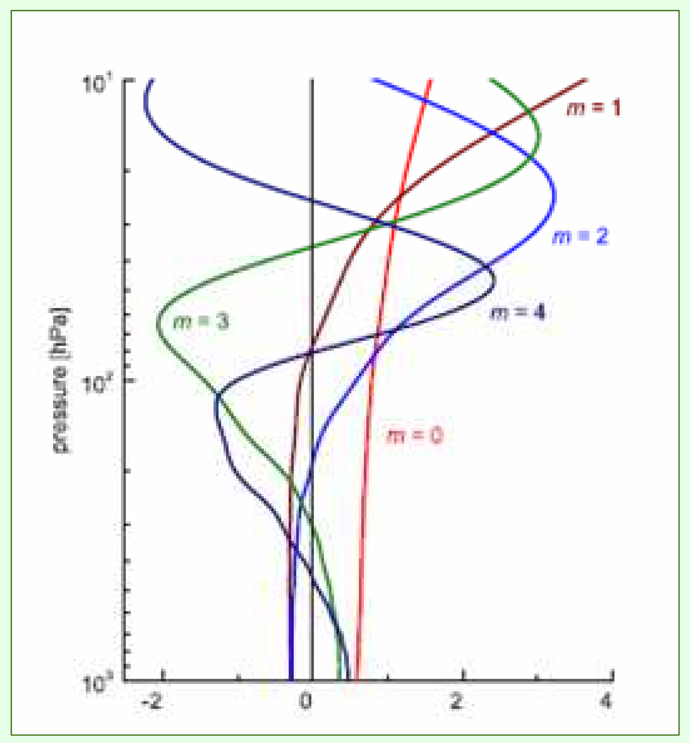
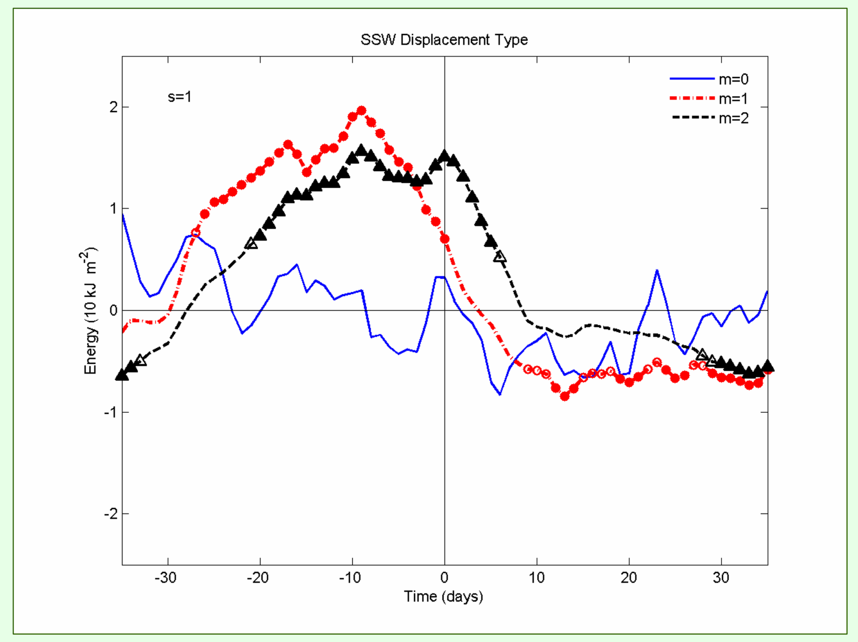


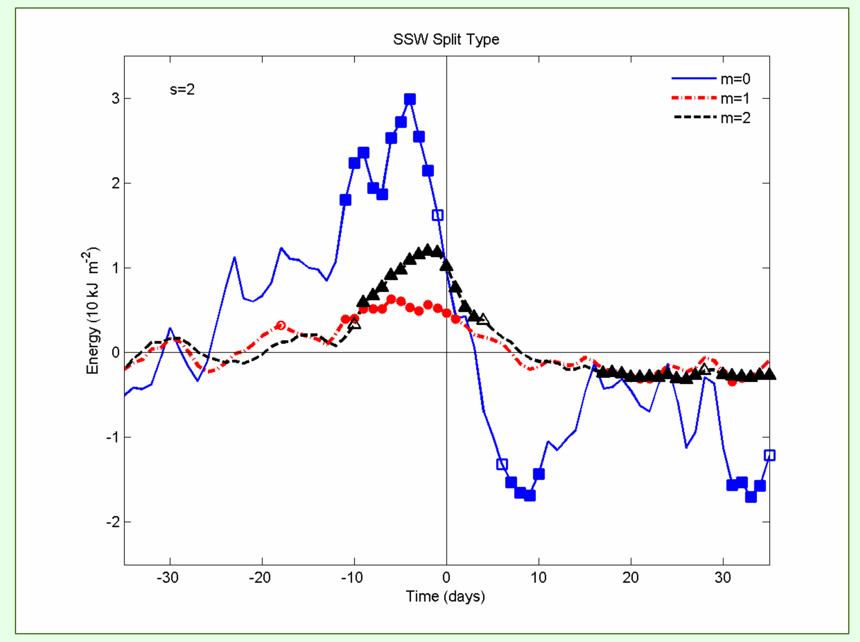
Figure 1: The first five vertical structures of the normal modes of the NCEP atmosphere.

3. SSW events

Separated analysis was made on stratospheric sudden warming (SSW) events of the displacement and split types. Two composite analyses of SSW events of the displacement and split types have revealed different dynamics (Figure 2).



SSWs of displacement type are forced by positive anomalies of the energy associated with the first two baroclinic modes of planetary Rossby waves with zonal wavenumber 1.



SSWs of the split type are in turn forced by positive anomalies of the energy associated with the planetary Rossby wave with zonal wavenumber 2 and the barotropic mode appears as the most important component.

Figure 2: Daily composites of intraseasonal anomalies of wave energy for SSW events of the displacement type (left) and of the split type (right). Day 0 refers to the central date of the event. Solid (open) symbols identify mean values of intraseasonal anomalies that statistically differ from zero at the 5% (10%) significance level.

4. Total Ozone

Total ozone columns used in this study have been retrieved from nadir observations of the Global Ozone Monitor Experiment (GOME) on the ERS-2 satellite using WFDOAS algorithm approach (Coldewey-Egbers et al. 2005). This algorithm has been extensively validated by comparison with measurements from the World Ozone and UV Radiation Data Centre (Weber et al. 2005). Total ozone data products have been derived at the Institute of Environmental Physics of the University of Bremen.

Distributions within the stratospheric polar vortex of total ozone during SSW events have been analyzed, and figure 3 describes the 25th February 1999 event, a SSW event of the split type.

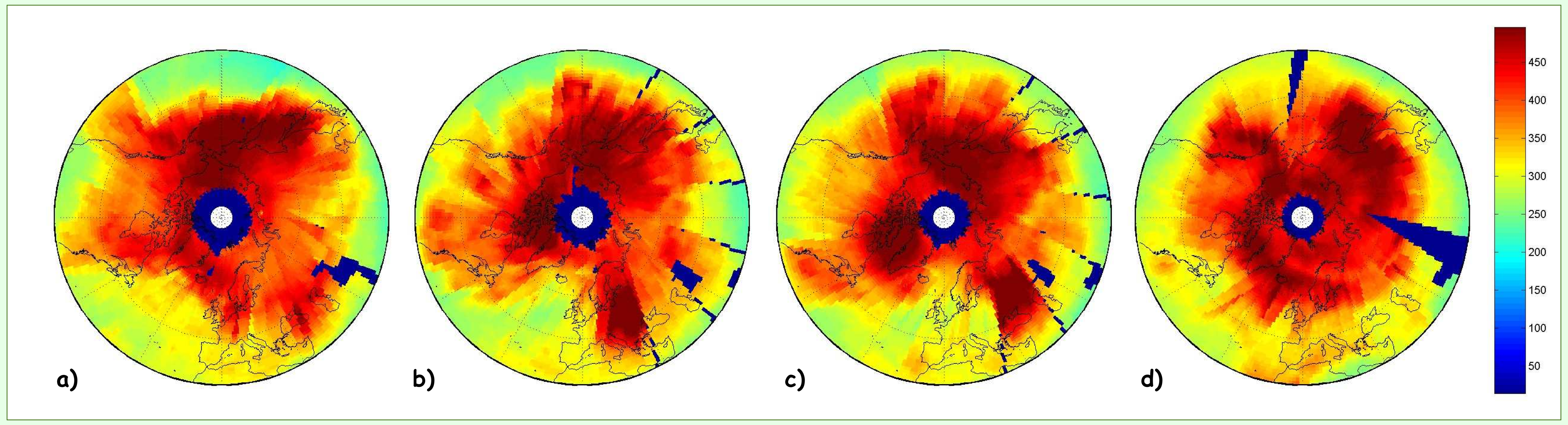


Figure 3: Distributions within the stratospheric polar vortex of total ozone (Dobson units, DU) during the previous and disturbed periods of a stratospheric sudden warming event of the split type: (a) on 20-22 February 1999; (b) on 23-25 February 1999; (c) on 25-27 February 1999 and (d) on 1-3 March 1999. Day 25 refers to the central date of the event.

5. References

Castanheira, J. M. (2000): "Climatic Variability of the Atmospheric Circulation at the Global Scale". Ph. D. Thesis, University of Aveiro, Portugal, 186 pp.

Charlton, A. J., and L. M. Polvani (2007): "A new look at stratospheric sudden warmings. Part I. Climatology and modelling benchmarks". J. Climate 20, 449-469.

Coldewey-Egbers M., M. Weber, L. N. Lamsal, R. de Beek, M. Buchwitz, J. P. Burrows (2005): "Total ozone retrieval from GOME UV spectral data using the weighting function DOAS approach", Atmos. Chem. Phys. 5, 1015-1025.

Liberato, M. L. R., J. M. Castanheira, L. da la Torre, C. C. DaCamara and L. Gimeno (2007): "Wave energy associated with the variability of the stratospheric polar vortex". J. Atmospheric Sciences 64, 2683-2694.

Weber M., L. N. Lamsal, M. Coldewey-Egbers, K. Bramstedt, J. P. Burrows (2005): "Pole-to-pole validation of GOME WFDOAS total ozone with groundbased data", Atmos. Chem. Phys. 5, 1341-1355.