Analyzing the preconditioning of major SSWs in ECMWF assimilations

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Motivation

Major Sudden Stratospheric Warnings (SSWs) can develop differently. By analyzing ERA-40 reanalysis data Bancală et al. [2012] showed that, although most of the major SSWs follow increased activity of the zonal wavenumber-1, a quarter of these events are caused by an amplified zonal wavenumber-2. Major SSWs are classified as wavenumber-1 (W1) or wavenumber-2 (W2) based on the preconditioning of the polar vortex, in contrast to the criteria of Charlton and Polvani [2007], which distinguish between vortex splitting (S) and vortex displacement (D) events according to the post-warming phase. In this study, the preconditioning criterion is applied to the ERA-Interim data in order to determine how the W1/W2 ratio changes if a different data assimilation is considered. Also we investigate if the inclusion of 10 additional reanalysis years significantly changes this relationship.

1 Data

ERA-40:
- Horizontal resolution T159 (2.5°x2.5° grid)
- Vertical resolution L60, model top at 0.1 hPa
- 45 NH winters are analyzed between 1957-2002

ERA-Interim:
- Horizontal resolution T255 (1.5°x1.5° grid)
- Vertical resolution L60, model top at 0.1 hPa
- 32 NH winters are analyzed between 1979-2011

2 SSW Criteria

- Major warmings are identified during the NH stratospheric winter circulation season (ONDJFMAM) by the reversal of the zonal mean zonal wind (U) at 10 hPa and 60°N, with the first day of easterlies defined as the central date of the warming.
- To distinguish different events at least 20 days of westerlies are needed (modified Bancală et al. [2012] criterion).
- The warmings are characterized depending on which zonal wave number is responsible for the poleward eddy heat transport (νT).
- W1, major SSW:
  - Z1 > Z2 ≥ 10 hPa, 60°N
  - ΔZ = Z1 − Z2 > 100 m (at 50 hPa, 60°N)
  - If only condition 1) is met, the major SSW is classified as a W1 event. If instead condition 2) is satisfied at least for one day, the event is classified as a W2 event.
- Final warmings are cases where the δ becomes easterly but does not return to westerly for at least 10 consecutive days. In addition, no day of this reference period must have wind speeds exceeding 5 m/s.

3 Case Studies

W1 major SSW of 22 February 2008

W2 major SSW of 25 January 2009

4 Major SSWs Climatology

Long-term Climatology

The two data assimilations have similar occurrence of major SSWs, with ERA-40 having slightly lower relative frequency compared to ERA-Interim (0.60 versus 0.63) (Fig. 2). This is due to the increased number of major SSWs observed since the late 1990s [Manney et al., 2005, 2009]. The comparison between the two data assimilations reveals the occurrence of one major SSW in February 1995 in ERA-Interim (see Fig. 4), which is not detected in ERA-40 (Fig. 2, top) and FUB data [Labitzke et al., 2002].

Seasonal Climatology

The W1/W2 major SSW distributions reveal different W1/W2 ratios: 0.29 for ERA-40 and 0.11 for ERA-Interim (Fig. 3, top). Less W1 events were observed during the ERA-Interim reanalysis period. Both for the ERA-40 and the combined dataset, the distribution peaks in January. In ERA-Interim, however, January and February have the same number of major SSWs. This shows a tendency towards later major SSWs in more recent years, consistent with the occurrence of more late final warmings (in May) since 2002 (Fig. 3, bottom).

The comparison of the W1/W2 and splitting/displacement distributions shows that not all W1 events resulted into vortex displacements.

5 Conclusions

The analysis of the different data assimilations shows that:
- More than 70% of all detected major SSWs are W1 events, although this may vary for different periods.
- Different W1/W2 and splitting/displacement ratios exist. Not all W1 major SSWs led to vortex displacements (about 1/3 caused splitting events), whereas all W2 events resulted into vortex splittings.
- This diagnostic is a useful tool to compare stratospheric winter variability in assimilation and model data.

References

Labitzke, K. et al. (2006), The Berlin Stratospheric Data Base (BSDB), Meteorol. Z., 15, 626-637.

Fig. 1 (left) 10 hPa GPH field one week prior to the major SSW. (right) Time series of the central dates (Z) of the SSW (red), the amplitude (ΔZ) and the heat flux (H) of Z2 and Z1 at 10 hPa for the indicated pressure levels. The vertical black lines indicate the central date of the warming while the green dots delimit the 10-day window period around the day ΔZ (= 60°N).

Fig. 2 Long-term climatology of major SSWs using ERA-40 and ERA-Interim data assimilations.

Fig. 3 Seasonal distribution of major SSWs and final warmings in ERA-40 and ERA-Interim data. The splitting-displacement distribution is obtained from Charlton and Polvani [2007] and Cohen and Jones [2011]. In ERA-Interim and in the combined dataset, the total number of W1 and W2 events in January and February differs from that of the splitting-displacement distribution obtained using ERA-40 and NCEP-NCAR data [Charlton and Polvani, 2007; Cohen and Jones, 2011]. This is referable to the 2009/10 major SSW that is detected in January in ERA-Interim and in February in the NCEP-NCAR reanalyses (see Fig. 4).

Fig. 4 Time series of the ERA-40 and ERA-Interim zonal mean zonal wind (u bar) at 10 hPa and 60°N, for the winters 1957/58 and 2010/10. The continuous vertical black line indicates the central date of the warming in ERA-Interim data, while the dashed one indicates the central date in the NCEP-NCAR reanalyzes (Cohen and Jones, 2011).

Fig. 5 Case Studies