Analyzing the preconditioning of major SSWs in ECMWF assimilations

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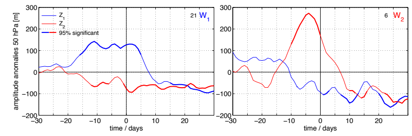
Motivation

Major Sudden Stratospheric Warmings (SSWs) can develop differently. By analyzing ERA-40 reanalysis data Bancalà et al. [2012] showed that, although most of the major SSWs follows 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 (W_1) or wavenumber-2 (W_2) 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 W_2/W_1 ratio changes if a different data assimilation is considered. Also we investigate if the inclusion of 10 additional reanalysis years significantly changes this relationship.

W_1/W_2 Major SSWs Composites



1 Data

ERA-40:

- Horizontal resolution T159 (used on a 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 ($\bar{u}$) 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 Bancalà et al. [2012] criterion).
- The warmings are characterized depending on which zonal wavenumber is responsible for the poleward eddy heat transport *(v'T')*. Following conditions are verified in a 10 day window period centered around the day with maximum wind deceleration *(D)*:

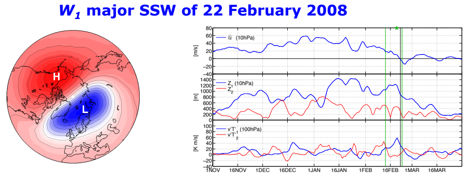
  1) ***W_1* major SSW**:
  - $Z_1 > Z_2$ (at 10 hPa, 60°N)
    (Z_n : amplitude of GPH wave of zonal wavenumber n)

  2) ***W_2* major SSW**:
  - $\Delta Z = Z_2 - Z_1 > 100$ m (at 50 hPa, 60°N)
  - $\Delta v'T' = v'T'_2 - v'T'_1 > 15$ K m/s (at 100 hPa, 60°N).

  If only condition 1) is met, the major SSW is classified as a W_1 event. If instead condition 2) is satisfied at least for one day, the warming is classified as a W_2 event.
- **Final warmings** are cases where the $\bar{u}$ 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

W_1 major SSW of 22 February 2008



W_2 major SSW of 25 January 2009

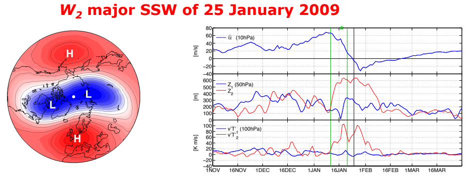


Fig. 1 (left) 10 hPa GPH field one week prior to the major SSW. **(right)** Time series of the zonal mean zonal wind $\bar{u}$ (m/s), the amplitude (m) and the heat flux (K m/s) of $Z_{1,2}$ at 60°N for the indicated pressure levels. The vertical black line indicates the central date of the warming while the green lines delimit the 10-day window period around the day D (*).

4 Major SSWs Climatology

Long-term Climatology

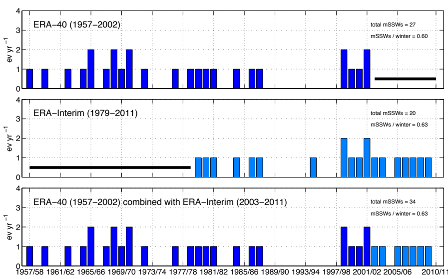


Fig. 2 Long-term climatology of major SSWs using ERA-40 and ERA-Interim data assimilations.

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 assimilatons 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

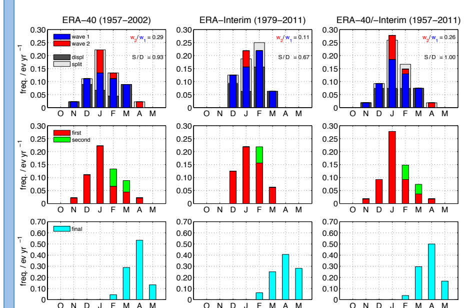


Fig. 3 Seasonal distribution of major SSWs and final warmings in ERA-40 and ERA-Interim data. The splitting-displacement distribution is obtained from Charlton and Polvani [2007] and Cohen and Jones [2011].

The W_1-W_2 major SSW distributions reveal different W_2/W_1 ratios: 0.29 for ERA-40 and 0.11 for ERA-Interim (Fig. 3, top). Less W_2 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 W_1-W_2 and splitting-displacement distributions shows that not all W_1 events resulted into vortex displacements.

In ERA-Interim and in the combined dataset, the total number of W_1 and W_2 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).

Case Studies

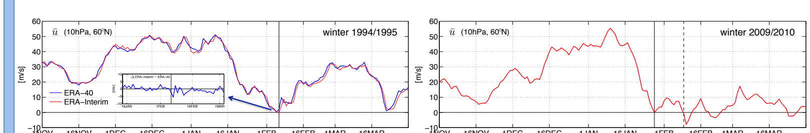


Fig. 4 Time series of the ERA-40 and ERA-Interim zonal mean zonal wind $\bar{u}$ (m/s) at 10 hPa and 60°N, for the winters 1994/95 and 2009/10. The continuous vertical black line indicates the central date of the warming in ERA-Interim data, while the dashed one indicates the central date in the NCEP-NCAR reanalysis [Cohen and Jones, 2011].

5 Conclusions

The analysis of the different data assimilations shows that:

- More than 70% of all detected major SSWs are W_1 events, although this may vary for different periods
- Different W_2/W_1 and splitting/displacement ratios exist. Not all W_1 major SSWs led to vortex displacements (about 1/3 caused splitting events), whereas all W_2 events resulted into vortex splittings.
- This diagnostic is a useful tool to compare stratospheric winter variability in assimilation and model data.

References

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