Quality of Reanalysis Data during Stratospheric Vortex Weakening and Intensification Events

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Introduction

Stratospheric Vortex Weakening (SVW) and Intensification (SVI) events in the Northern-Hemisphere winter have been shown to produce anomalous weather regime in the lower troposphere. The majority of the studies leading to this conclusion have used reanalysis datasets but the quality of the data has not been assessed during those events. This work evaluates the quality of reanalysis data for SVW and SVI events in two steps:

- Intercomparison of various reanalysis projects (ERA-40 ERA-Interim JRA-25 NASA-MERRA NCEP/DOE NCEP/NCAR) from 1979 to 2009.
- Comparison between reanalysis data and COSMIC/FORMOSAT-3 GPS radio occultation soundings for the record-breaking SVW event of 2009 (Manney et al. 2009).

Event Detection

The normalized polar cap geopotential height anomalies averaged over the area north of 65°N is used as an estimation of the Northern Annular Mode (NAM) index (Cohen et al. 2002). Extreme events of both signs are detected as follows:

- SVW events : $NAM_{10hPa} \leq -2.5\sigma$
- SVI events : $NAM_{10hPa} \geq 1.5\sigma$

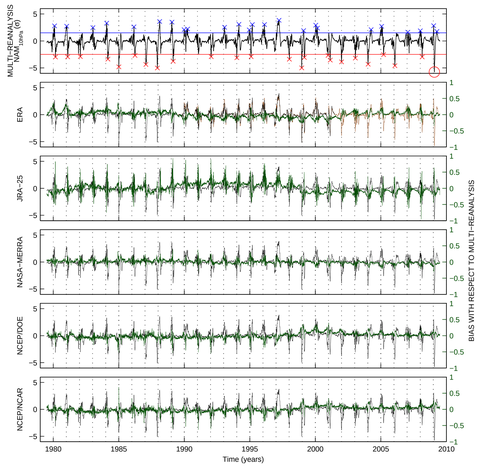

Figure 1 : Event Detection

- The *MULTI-REANALYSIS panel* presents the NAM index at 10 hPa averaged amongst all available reanalyses. Red and blue lines indicate the threshold for detecting SVW and SVI events respectively. SVW and SVI events are identified by red and blue marks while the record-breaking 2009 event used for comparison with COSMIC soundings is indicated by a red circle. 24 SVW and 24 SVI are detected from 1979 to 2009.
- *Bottom panels* present the NAM index (black) for individual reanalyses and their residual (green) with respect to the multi-reanalysis ensemble. Most reanalyses are consistent with one another and present a small residual except JRA-25 which shows the greatest residual with some decadal variability.

Reanalysis Data Intercomparison

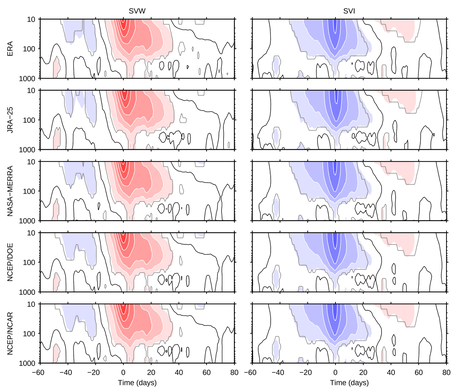

Figure 2 : Reanalysis Intercomparison

- Composites of SVW and SVI events for all reanalyses used in this study. The value presented is the NAM index in function of pressure and time, using red for low NAM index values and blue for high NAM index values. Reanalyses show strikingly similar representation of SVW and SVI composites to one another.
- SVW and SVI composites show the typical stratospheric onset of NAM anomalies and their downward propagation to the troposphere as observed by Baldwin and Dunkerton (2001).
- A t-test for the composite anomalies not being equal to 0 reveals statistically significant propagation of anomalies to the surface (gray line).

COSMIC vs Reanalyses : 2009 Stratospheric Vortex Weakening Event

The COSMIC mission was launched in 2006 jointly by the National Aeronautics and Space Administration (NASA) and Taiwan's National Space Organization (NSPO) and has provided about 2000 temperature profiles per day over the globe since June, 2006 [Anthes et al., 2008]. He et al. [2009] showed that the temperature profile derived from the COSMIC GPS radio occultation measurements is remarkably accurate in the upper troposphere and stratosphere with a typical difference to radiosonde measurements within 1 K.

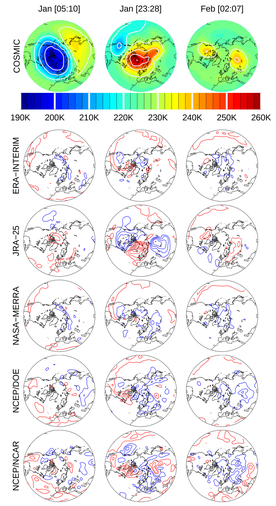

Figure 3 : Cosmic vs Reanalyses : 10hPa temperature bias

- The top panel shows the evolution of temperature as observed by COSMIC for different representative time periods of the 2009 SVW event. There is an observed warming of ≈ 60 K over the north pole between the cold and undisturbed vortex phase (left column) and the maximum warming phase (middle column). The vortex then cools again in the recovery phase (right column).
- The bias of all reanalyses (lower panels) is maximized during the maximum warming phase while it is smaller in the cold vortex phase and the recovering vortex phase.
- Reanalyses have an overall acceptable performance with the smallest biases displayed by ERA-Interim and NASA/MERRA (≈ 4 K) while the greatest bias is observed in JRA-25 (up to ≈ 12 K)

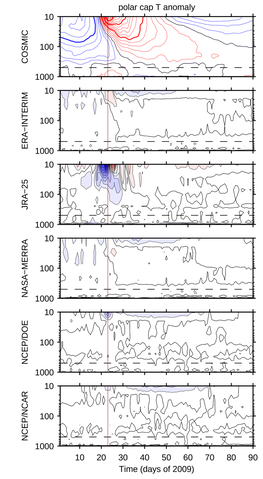

Figure 4 : Cosmic vs Reanalyses : Downward propagation of polar cap temperature bias

- The top panel shows onset and downward propagation of temperature anomalies as observed by COSMIC. There is an observed warming of ≈ 50 K in 10 days of the polar cap. The warming at 10 hPa is followed by subsequent warmings of smaller amplitudes at higher pressure levels, indicating downward propagation.
- The bias of reanalyses (lower panels) appears to be somewhat limited to the 10 hPa level.
- Greatest bias is observed in JRA-25 but is found to be due to a delay in the onset of the event rather than a difference in the warming amplitude.
- Most reanalyses present too cold temperatures during the vortex recovering (cooling) period.

Conclusion

The current generation of reanalysis data reproduce SVW and SVI events and their downward propagation reasonably well :

- Inter-comparison between reanalysis data shows that composites of NAM index during SVW and SVI events are almost identical in all datasets.
- Most reanalysis data captured well the record-breaking 2009 SVW event.

References

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