Karlsruhe Institute of Technology

Institute of Meteorology and Climate Research
Atmospheric Trace Gases and Remote Sensing
IMK-ASF

QBO-composite mean meridional circulation: ERA5 and MIPAS tracer-derived residual velocities

How to get useful dynamical information from satellite derived trace gases.

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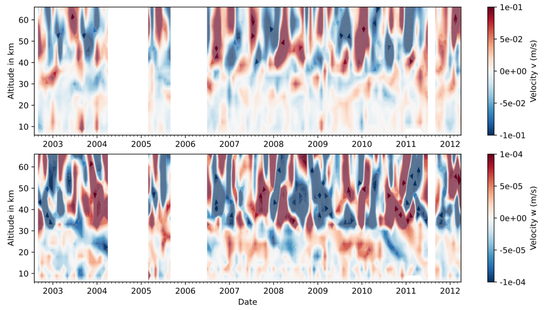
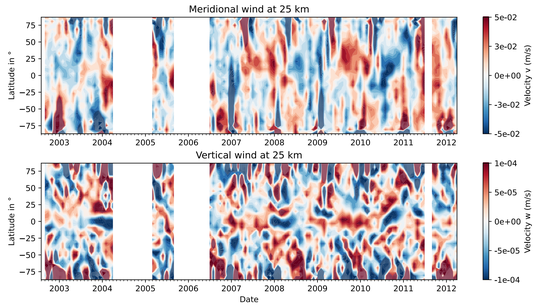
Monthly mean zonal mean meridional and vertical transport vectors of the residual circulation in the stratosphere have been derived from MIPAS trace gas distributions by inversion of the continuity equation (von Clarmann and Grabowski, 2016). The figure columns on the very right show the climatology of transport velocities for the 2002 to 2012 period derived from MIPAS (von Clarmann et al., 2021). The advantage of the method is that it does not involve a dynamic model; instead it provides independent observation-based information on the mean meridional circulation.



Time series of meridional (top) and vertical (bottom) velocity anomalies at the equator (±5° latitude) as cross-sections of altitude over time. Note the separation of the QBO vs. SAO regime at about 35 km.



Same as above but as cross-sections of latitude over time at 25 km altitude

This study focuses on analyzing the Quasi-Biennial Oscillation (QBO)-composite mean meridional circulation during the MIPAS measurement period 2002 to 2012, using ERA-Interim and ERA5 reanalyses and MIPAS tracer-derived velocities. The investigation employs the approach described in the S-RIP report: We constructed a composite of deseasonalized QBO-W onsets at 20 hPa (4 events) and compared zonal-mean vertical and meridional velocity anomalies extracted from MIPAS tracer measurements with reanalysis data from ERA-Interim and ERA5.

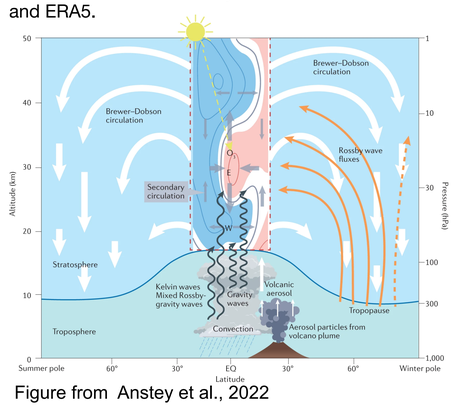
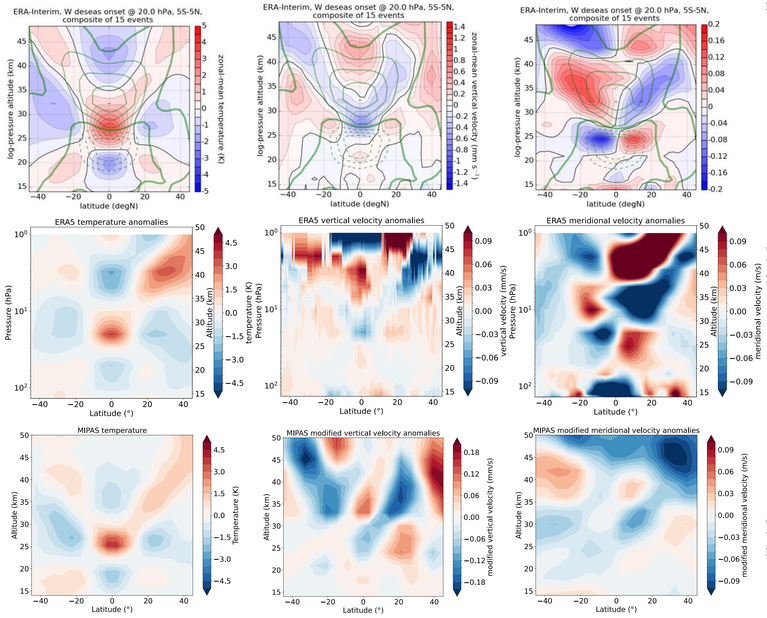


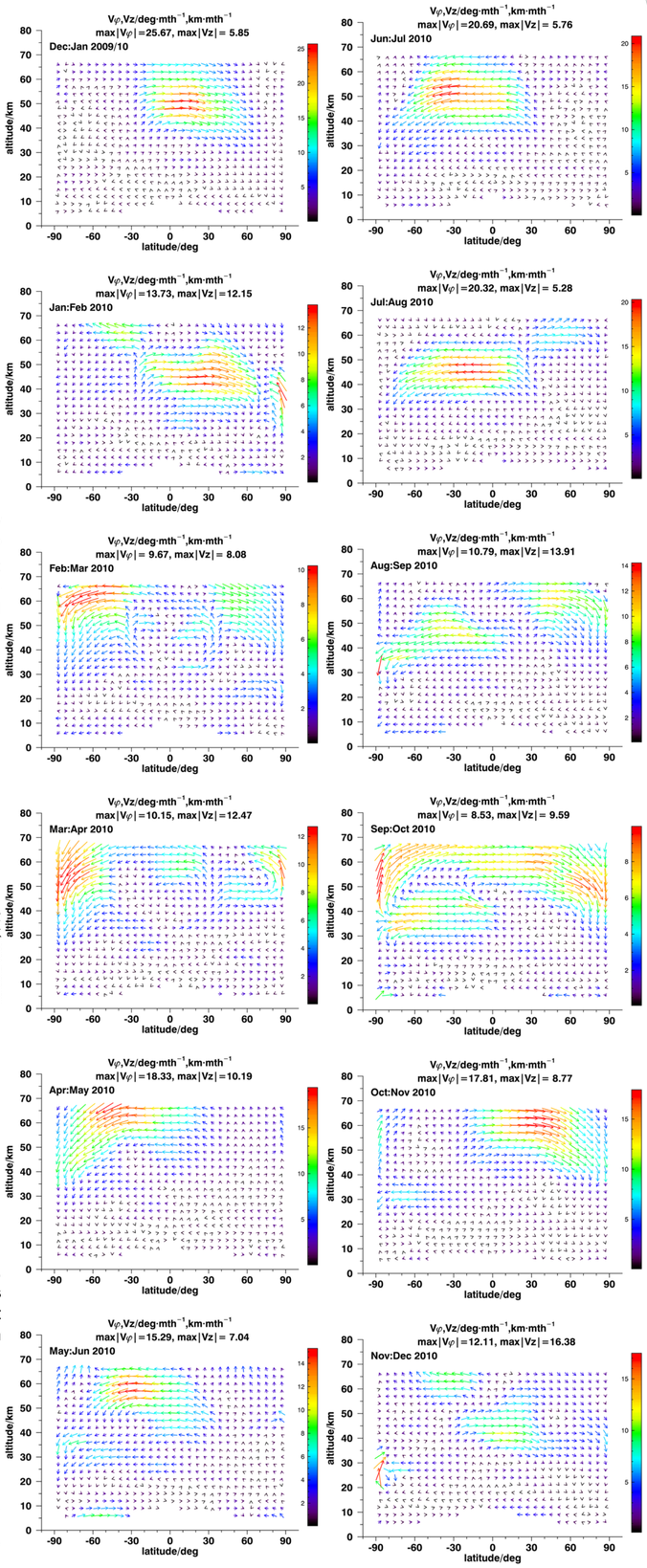
Figure from Anstey et al., 2022

We are interested in the quantification of the so-called secondary circulation (grey arrows in the figure above) that is superimposed on the Brewer-Dobson circulation by the QBO. In the figure above, the QBO phase is transitioning from westward to eastward at 30 hPa, while we focus on the onset of the western phase at 20 hPa, similar to analyses in the S-RIP report (Chapter 9).

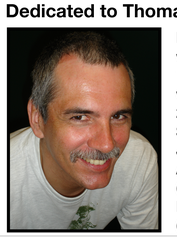
QBO-composited temperature and mean-meridional circulation, based on QBO-W deseasonalized onsets at 20 hPa, for the 1980 to 2016 period of ERA-Interim (from S-RIP report, Chapter 9) and the MIPAS period (2002 to 2012) for ERA5 and MIPAS. Left column: zonal-mean temperature, middle column: zonal-mean vertical velocity, right column: zonal-mean meridional velocity. Green lines show the corresponding zonal-mean zonal wind composites, 5 m/s contours (solid: positive, dashed: negative, thick solid: zero). All fields shown are deseasonalized (for ERA-Interim).



This study reveals QBO patterns in tracer-retrieved velocities within the mean circulation. Observed structures compare favourably with ERA5 and S-RIP ERA-Interim reanalysis results. Quantitative comparisons reveal differences that have the potential to pinpoint certain processes that might not be adequately represented in the models or deficiencies in the tracer-based inversion of the continuity equation.



Dedicated to Thomas von Clarmann



References

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