Stratospheric ozone intrusion events and their impacts on tropospheric ozone in the Southern Hemisphere

Jesse W. Greenslade[1], Simon P. Alexander[2,3], Robyn Schofield[4,5], Jenny A. Fisher[1,6], and Andrew K. Klekociuk[2,3]

[1]Centre for Atmospheric Chemistry, School of Chemistry, University of Wollongong, Australia
[2]Australian Antarctic Division, Hobart, Australia
[3]Antarctic Climate and Ecosystems Co-operative Research Centre, Hobart, Australia
[4]School of Earth Sciences, University of Melbourne, Australia
[5]ARC Centre of Excellence for Climate System Science, University of New South Wales, Australia
[6]School of Earth & Environmental Sciences, University of Wollongong, Australia

Correspondence to: Jesse Greenslade (jwg366@uowmail.edu.au)

Abstract. Stratosphere-to-troposphere transport (STT) provides an important natural source of ozone to the upper troposphere, but the characteristics of STT events in the southern hemisphere extra-tropics and their contribution to the regional tropospheric ozone budget remain poorly constrained. Here, we develop a quantitative method to identify STT events from ozonesonde profiles. Using this method we estimate the seasonality of STT events and quantify the ozone transported across the tropopause over Davis (69° S, 2006-2013), Macquarie Island (54° S, 2004-2013), and Melbourne (38° S, 2004-2013). STT seasonality is determined by two distinct methods: a Fourier bandpass filter of the vertical ozone profile, and an analysis of the Brunt-Väisälä frequency. Using a bandpass filter on 7–9 years of ozone profiles from each site provides clear detection of STT events, with maximum occurrences during summer and minimum during winter above all three sites. The majority of tropospheric ozone enhancements from STT events occur within 2.5 km and 3 km of the tropopause at Davis, and Macquarie Island. Events are more spread out at Melbourne, occurring frequently up to 6 km from the tropopause. The mean fraction of total tropospheric ozone attributed to STT during STT events is ~ 1.0–3.5% at each site; however, during individual events over 10% of tropospheric ozone may be directly transported from the stratosphere. The cause of STTs is determined to be largely due to synoptic low pressure frontal systems, determined using coincident ERA-Interim reanalysis meteorological data. Ozone enhancements can also be caused by biomass burning plumes transported from Africa and South America, which are apparent during austral winter and spring, and are determined using satellite measurements of CO.

To provide regional context for the ozonesonde observations, we use the GEOS-Chem chemical transport model, which is too coarsely resolved to distinguish STT events but is able to accurately simulate the seasonal cycle of tropospheric ozone columns over the three southern hemisphere sites. Combining the ozonesonde-derived STT event characteristics with the simulated tropospheric ozone columns from GEOS-Chem, we estimate STT ozone flux near the three sites and see austral summer dominated yearly amounts of between 5.7 and 8.7×10^{17} molecules cm^{-2} a^{-1}.