Stratospheric ozone intrusion events and their impacts on tropospheric ozone

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

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 extratropics 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 and quantify the ozone transported across the tropopause over Davis (69° S), Macquarie Island (54° S), and Melbourne (38° S). STT seasonality is determined by two distinct methods: a Fourier bandpass filter of the vertical ozone profile, and an analysis of the Brunt-Viäsälä 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, 3 km of the tropopause at Davis, and Macquarie Island. Events are more spread out at Melbourne, occurring frequently up to 7.5 km from the tropopause. The mean fraction of total tropospheric ozone attributed to STT during STT events is 2–4% 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, these 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 conservatively estimate that the annual tropospheric ozone flux over the Southern Ocean due to STT events is $\sim 3.2 \times 10^{16}$ molecules cm^{-2} yr^{-1}. This value is significantly lower than expected from previous global estimates due to the conservative nature of several components of our calculation, in particular the contribution of STT to total tropospheric ozone during an event (STT impact). Using an assumed STT impact of 35%

based on prior modelling studies rather than our observational estimate of 2–4% increases the estimated Southern Ocean flux by an order of magnitude.Despite lingering uncertainties in scaling ozonesonde measurements to regional values, ozonesonde datasets provide a useful tool for STT detection, and the analysis methods described in this paper could be applied to many existing long-term records.