Stratosphere Troposphere Exchange in the Southern Hemisphere

Kathleen P Monahan(1); Adrian J McDonald(1); Greg E Bodeker(2);
(1) Department of Physics and Astronomy, University of Canterbury, Christchurch, New Zealand
(2) National Institute of Water and Atmospheric Research (NIWA), Lauder, New Zealand
(kpm29@student.canterbury.ac.nz)

Introduction

Stratosphere troposphere exchange (STE) is the movement of air parcels between the stratosphere and the troposphere in either direction. Some possible methods of exchange are shown in Figure 1. Using the ozonesonde records from Lauder, New Zealand, a climatology of the atmosphere over Lauder has been developed. The main type of STE studied to date has been the tropopause fold (TPF), which is a region of stratospheric air that has been pulled down into the troposphere. An automated algorithm has been used to identify TPFs, with validation of the identification via back trajectory modelling.

Possible Methods of Exchange

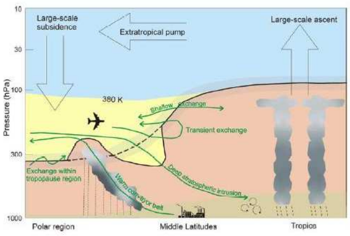
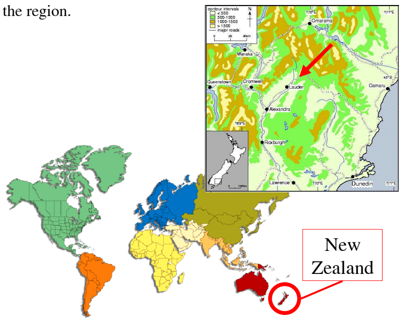


Figure 1 Stohl et al (2003)

Location of Study

Ozonesondes are released from Lauder (169.7°E 45.0°S) in the South Island of New Zealand. The terrain of the South Island is dominated by a range of mountains running down the centre of the island, this effects the weather patterns of the region.



Variations in Tropopause Height

Figure 2 shows the variations in tropopause height from the Lauder Ozonesesondes over 19 years. Tropopause heights were separated into months then binned vertically and normalised. This essentially gives the normalised frequency of different tropopause heights by month. Note that the lowest tropopause heights are in the Southern Hemisphere winter months, and the highest tropopause heights are in the Southern Hemisphere summer months. This is consistent with theory. When this process is repeated with the NCEP/NCAR reanalysis data, the same repeatable pattern is observed (Figure not shown).

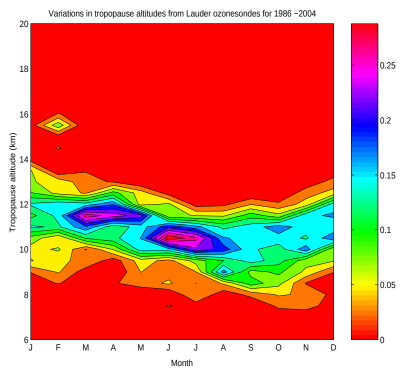


Figure 2. Variations in the tropopause height over Lauder, NZ. Values are shown as the percentage of time that a particular tropopause altitude occurs in a particular month.

Seasonal Variation in Ozone

Figure 3 shows the seasonal variations of ozone over Lauder for the length of the data set. The highest levels of ozone in the stratosphere are coincident with the lowest tropopause level. The ozone in the troposphere is also highest at this time of year.

Figures 2 and 3 give an overview of the state of the atmosphere above Lauder. This gives a measure of the normal state of the atmosphere above Lauder, which is important when looking for regions of tropopause folds.

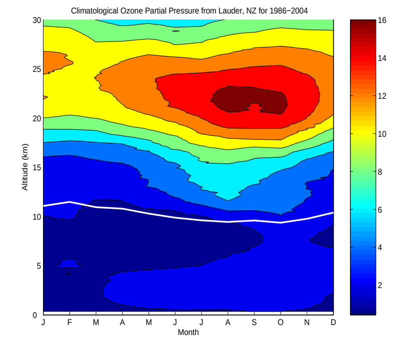


Figure 3. Variations in ozone partial pressure (in mPa) from Lauder ozonesondes for 1986-2004. The white line shows the average tropopause height from the ozonesondes.

Tropopause Fold Identification Algorithm

An algorithm using ozone content, humidity and stability to identify Tropopause folds in ozonesonde data has been developed, Stratospheric air has a distinct signature, therefore by looking for this signature in the troposphere, regions of air parcel exchange can be detected. The algorithm has the following conditions to identify tropopause folds, which are based on Van Haver et al (1996).

- Ozone peaks between 3km up to 1km below tropopause
- Pronounced ozone peak with respect to climatological mean and surrounding profile
- Relative humidity at peak of less than 25%
- A stable layer, determined by comparison of the Brunt Väisälä between 20-25km ie. a stable stratospheric layer
- Vertical wind gradient must be greater than or equal to 5 m/s/km in the adjacent region.

An example of a tropopause fold as identified by the algorithm is shown in Figure 4.

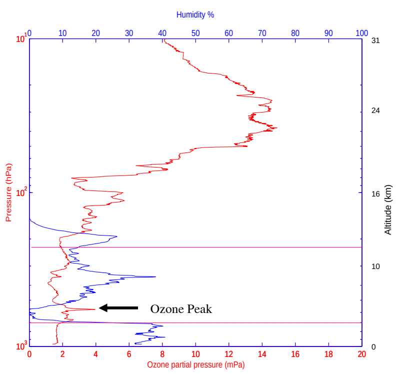


Figure 4. An example of a tropopause fold in an ozonesonde record from 19th December 1997. The red line shows the ozone partial pressure and the blue dotted line shows the humidity. The pink dotted lines show the region for finding tropopause folds, the upper line is the tropopause and the lower line is 300hPa.

Distribution of Tropopause Folds

Some initial results which display the yearly distribution of tropopause folds over Lauder are listed in Table 1. There are instrument variations over the data set which affect the resolution of the data. Prior to 1990, the data is extremely coarse and this data has not be used with the algorithm. A higher resolution sonde was used from 1999 onwards in comparison to those used from 1990-1998, however by adjusting the resolution to that of the older measurements, comparable results have been obtained.

There is seasonal variation in the occurrence of tropopause folds, with 12.0% of sondes showing tropopause fold events. In comparison to the results in Van Haver et al (1996), they found no seasonal variation and less than 5% of sondes showing fold events. There are several different reasons for this discrepancy - the current algorithm is picking up non fold events or is picking up smaller scale events. Or tropopause folds are highly location dependent.

Note that these events are still requiring validation from trajectory modelling to confirm whether they are tropopause fold events. There are many variables in the identification algorithm, so validation is key to correctly identifying the folds.

DJF	MAM	JJA	SON
18.5%	14.9%	2.7%	11.8%

Table 1. Proportion of ozonesondes recording a tropopause fold event in a season from 1990 to 2004

Back Trajectory Model

To confirm the origin of the parcels of air identified using the tropopause fold identification algorithm, a back trajectory model was used. The model details are as follows:

- Semi-Lagrangian model
- 4th order Runge Kutta advection scheme
- Isentropic approximation as time scales less than 15 days
- Spherical Grid – valid as long as sufficiently far from poles
- NCEP/NCAR reanalysis data on constant theta levels
- Linear Interpolation between grid points
- Time step 15 mins

This model is currently in development.

Conclusions & Further Work

As a speculative conclusion, there appears to be a link between the highest occurrence of tropopause folds, reduced ozone in the stratopshere and high tropopause level. However, as the tropopause algorithm is currently unvalidated, this is an extremely loose conclusion. Is this a valid link to make? What are the physical reasons behind this apparent connection of circumstances?

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The method outlined above will be applied to other Southern Hemisphere Ozonesonde records. This information, in conjunction with additional data from satellites, will be used to produce a distribution and climatology of tropopause fold events in the Southern Hemisphere.

This method can also be extended to finding ozone laminae, which are the opposite event to TPFs, that is tropospheric air in the stratosphere (Krizan and Lastovicka, 2005).

It is also hoped to be able to study how active and efficient these events are at transporting pollutants. This will ideally lead to determining how much STE affects New Zealand, and how big an impact New Zealand has on the quantity of pollutants in the stratosphere.

References

Krizan, P.; Lastovicka, J.; 2005, Trends in positive and negative ozone laminae in the Northern Hemisphere, *Journal of Geophysical Research – Atmospheres* 110(D10)

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