Google[x] Project Loon Measurements of Stratospheric Temperature, Pressure and Wind as a Data Source for Reanalyses over Southern High Latitudes

Jared Lewis[1], G.E. Bodeker[1], A. McDonald[2], K. Cooper[3], A. Schwertheim[1], L. Friedrich[2]

1. Bodeker Scientific, Alexandra, New Zealand. 2. University of Canterbury, Christchurch, New Zealand. 3. Google[x], Mountain View, CA, United States of America.

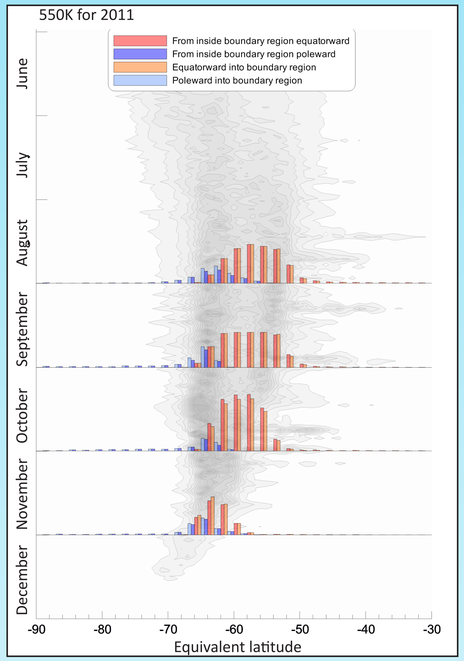

Figure 1: Plots showing the likelihood of vortex crossing events in each month (coloured histograms) overlaid on contour plots of meridional impermeability – darker regions show where the vortex edge is less permeable to meridional transport and/or mixing.

Motivation

- Google[x] Project Loon is flying hundreds of long duration super-pressure balloons to provide global internet connectivity. Many of these balloons fly over southern middle and high latitudes.
- Location data from Loon flights to date provide an order of magnitude more data than all previous scientific balloon campaigns combined.
- Wind, pressure and temperature measurements obtained from Loon balloons provide information about sub-grid scale processes occurring in the stratosphere and, once available in real-time, data for assimilation into NWP analysis.
- This poster presents analysis of the scientific utility of the wind, pressure and temperature measurements from the Project Loon flights.

Wind fields

- Meridional and zonal wind velocities were calculated from the GPS location of the balloon and compared to the MERRA, MERRA2 and ERA-Interim reanalyses.
- Reanalyses showed excellent agreement with the reanalyses with errors smaller than those identified in Podglajen et al. (2014).
- MERRA2 had smaller biases compared to MERRA.
- Measurements from latitudes equatorward of 15°S had larger mean biases than the region poleward of 15°S.
- The current data set does not have high enough temporal resolution to be useful for gravity wave analysis.

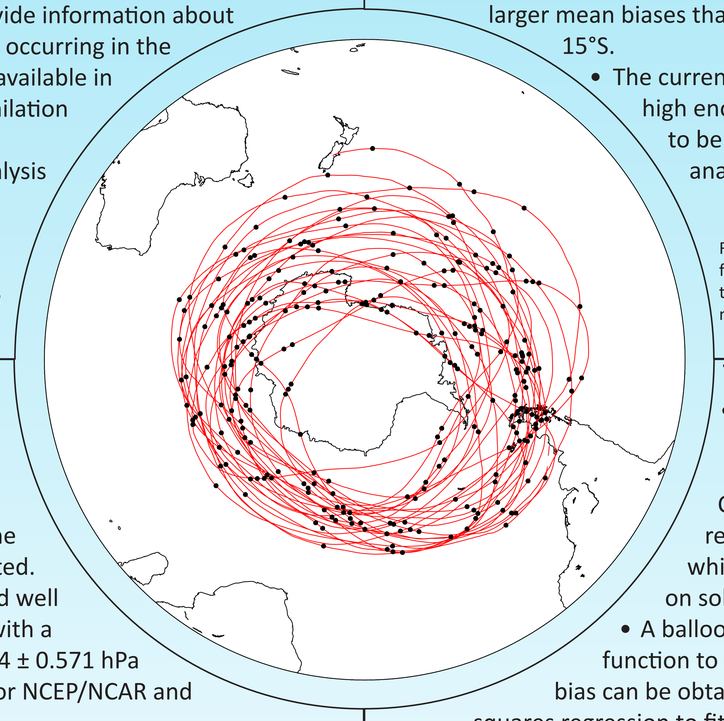

Figure 2: Trajectory of Project Loon flight I-283. Black dots represent the location of the balloon at local midnight.

Pressure

- Differences between the onboard pressure measurements from Loon flights and the values extracted from the reanalyses were calculated.
- These differences agreed well for all but a few flights with a mean difference of 0.174 ± 0.571 hPa and 0.535 ± 0.537 hPa for NCEP/NCAR and NCEP/CFSR respectively.
- Some flights showed a larger than usual difference in pressure values which was likely due to faulty sensors.

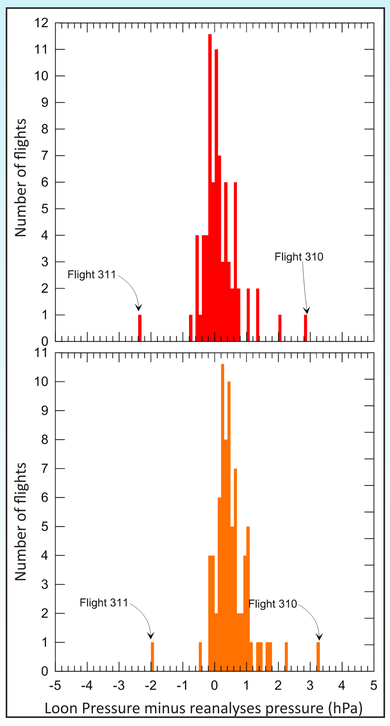

Figure4: Histograms of the mean pressure differences between Loon measurements and NCEP/NCAR (top) and NCEP/CFSR (bottom) reanalyses.

Temperature

- Onboard temperature measurements, when compared to NCEP/CFSR and NCEP/NCAR reanalyses, exhibit a bias which is strongly dependent on solar zenith angle.
- A balloon specific correction function to remove the temperature bias can be obtained using linear least squares regression to fit the following equation to derived differences:

$$T_{corr} = \alpha + \beta(1 - e^{(\theta-95)/\lambda_0}) + \gamma(e^{-(\theta-90)^2/\lambda_1}|_{\theta<90^\circ}; e^{-(\theta-90)^2/\lambda_2}|_{\theta\geq 90^\circ}) \quad (1)$$

- Corrected temperatures agree with reanalyses to within 1K, significantly improving the scientific utility of the Loon temperature data.

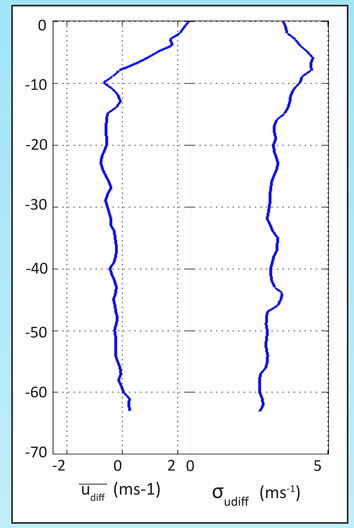

Figure 3: Mean (left) and standard deviation (right) of the differences between the zonal velocity calculated from Loon observations and the ERA-Interim reanalyses for a range of latitudes.

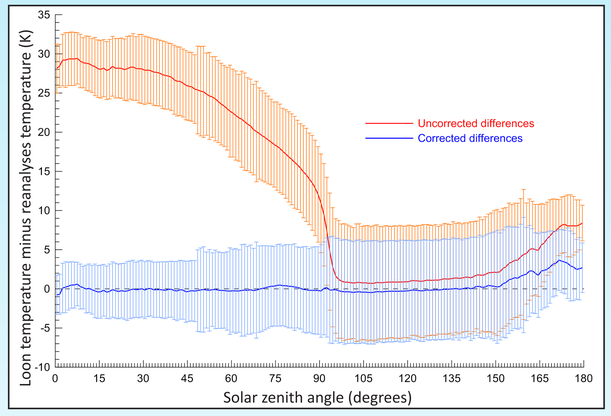

Figure 5: An example of the differences between Loon measured temperatures and those extracted from NCEP/CFSR reanalysis at the time and location of the Loon measurements. The temperature differences have been disaggregated by solar zenith angle (SZA). The solid red line shows the mean difference in each SZA bin. The blue line shows the modelled differences obtained by fitting equation 1 to the differences. Error bars show the 1σ variance on the differences in each bin.

Outlook

- Use trajectory models and Project Loon location information to determine how the polar vortex permeability changes seasonally and inter-annually
- Identify sub-grid scale processes which are not captured in the reanalyses

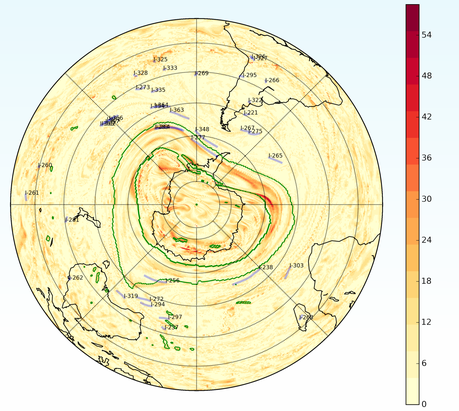

Figure 6: The differences between potential vorticity obtained from reverse domain filling and NCEP/CFSR for 1 September 2014 at the 550 K potential temperature surface. Also shown is the location of Loon balloons within 3 hours (purple) and the contour of the equatorial and poleward edge of the polar vortex (green).

Acknowledgements:
We would like to thank the New Zealand Antarctic Research Institute and the Royal Society of New Zealand for supporting this project.

References:
Podglajen, A., Hertzog, A., Plougonven, R., and Zagar, N.: Assessment of the accuracy of (re)analyses in the equatorial lower stratosphere, Journal of Geophysical Research-Atmospheres, 119, 11,166–11,188, doi:10.1002/2014jd021849, 2014.