STAG Low-Altitude Measurement Campaign Development, Testing, Data Analysis

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Abstract

Atmospheric measurements are the basis for weather prediction. The "Stratosphere Troposphere Atmospheric measurement Glider" (STAG) has been designed to make measurements with a re-usable instrument, which could make low-level soundings more accurately and cost effectively. Final steps in the development of the current prototype are presented. Analysis of data from initial low-altitude flights and surface weather-station data have been used to confirm that accurate measurements of atmospheric phenomena are made. In particular, a period associated with a sea breeze is observed in both STAG and surface weather-station data. The vertical profiles obtained by STAG display a temperature inversion between 250 and 300m associated with the depth of the sea breeze.

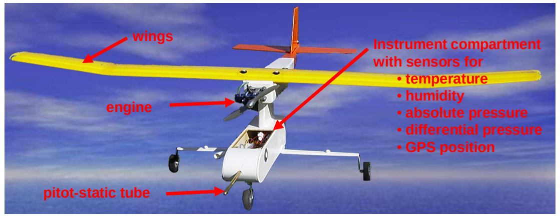

Figure 1: *STAG prototype III.*

Introduction

STAG is a small powered glider (≈2.0m wingspan) equipped with a set of meteorological measurement sensors which currently measure pressure, temperature, and relative humidity. Work on developing a wind speed and direction capability is also progressing. A pitot-static tube is used to make air speed measurements (see Figure 1). The wind vector is the vector difference of the flight vector and the ground path vector. The flight vector is obtained from the heading (taken from an onboard digital compass) of the aircraft and the air speed. The ground path vector is calculated by subtracting two GPS locations. The system consisting of the pitot-static tube and the differential pressure sensor was calibrated in a wind tunnel (Figure 2). For angles up to 25° between the wind tunnel flow and the pitot head-on direction no angle dependency was found and the calibration coefficients were obtained.

The standard deviation was 0.5ms^{-1} at typical air speeds of 15ms^{-1}. However, once in realistic winds, the measurement degraded, the standard deviations reached up to 3ms^{-1}. A microprocessor on board averages data over a period of 1ms and transmits the obtained value every 5 seconds. Further investigations suggest that averaging over longer periods will decrease the standard deviation of the air velocity measurement.

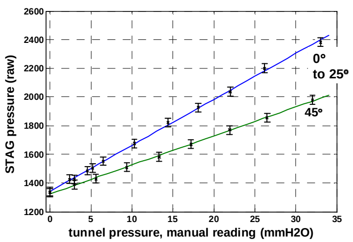

Figure 2: *(LEFT) Comparison of differential pressure measurements made by STAG in a wind tunnel and the pressure measurements made by the wind tunnel instrumentation.*

Statistical sea breeze analysis

On the Canterbury Plains, New Zealand, sea breezes are thought to be an important weather phenomenon and should be observable by STAG. In order to define periods for field campaigns, a statistical study was performed. It aimed to determine the frequency and characteristics of the local sea breeze. Analysis of long-term data from Rangiora weather station suggested that if a sea breeze is present in summer it occurs between 11am and 7pm and has a strength of 3ms^{-1} to 5ms^{-1}. In winter, the onset is two hours later and the strength varies between 1ms^{-1} and 5ms^{-1}. Figure 3 shows a set of wind roses showing the statistical characteristics of the sea breeze flow observed by the Rangiora weather-station.

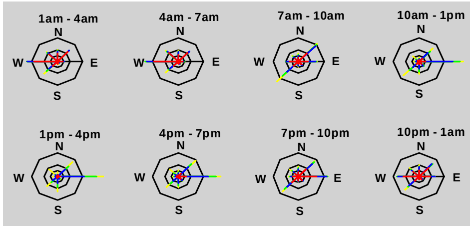

Figure 3: *Statistical wind roses derived from weather-station data in the summers of 2000 to 2003. Colours indicate wind strength (red: 1-3m/s blue: 3-5m/s green: 5-6m/s yellow: >6m/s) and the length of the vector indicates relative frequency.*

An algorithm to extract data associated with sea breezes was developed and suggested sea breezes on 29% of all days. Figure 4 shows typical variations of the temperature, specific humidity and wind speed and direction during a day where a sea breeze was identified. The absolute humidity shows a sudden rise after 3pm. At the same time the temperature drops from 21.2°C to 20.0°C within minutes. The wind changes from a southerly wind to a north-easterly with a strength of 3ms^{-1}. This clearly confirms that a sea breeze front passed through Rangiora at about 3pm. The characteristics were shown to be typical for the sea breeze in summer.

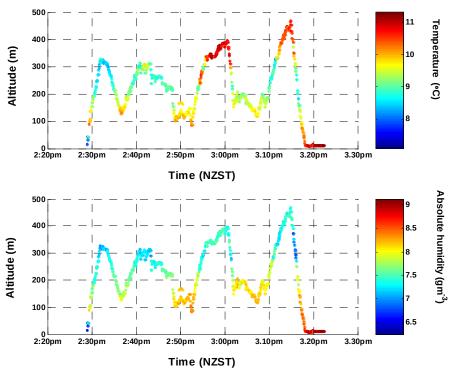

Figure 5: *Temperature and humidity as a function of flight altitude and time observed by STAG.*

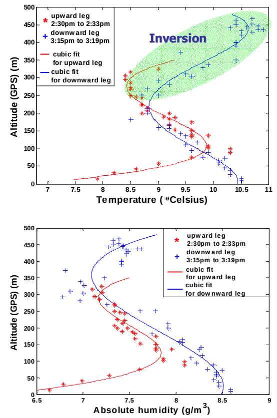

Figure 6: *Vertical profiles of temperature and absolute humidity before (upward leg) and after (downward leg) the onset of the sea breeze.*

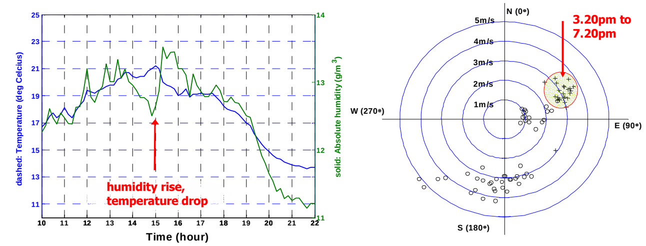

Figure 4: *Surface weather-station data during a sea breeze.*

Sea breeze observation with STAG

On August 6, 2003 a sea breeze was observed by STAG and the Rangiora weather-station. With several up- and down-legs, as well as horizontal flights, STAG gathered both vertical and horizontal profiles before and after the onset of the sea breeze (Figure 5 and 6). As the STAG flight was further inland compared to the weather-station, the sea breeze arrived later, at about 2:50pm. From this and the weather-station data a speed of 1.1ms^{-1} was suggested for the advance of the sea breeze front. Figure 7 shows a decrease in temperature by 1°C and an increase in absolute humidity by 0.75gm^{-3} between 2pm and 2:30pm. A wind with a speed up to 3ms^{-1} coming from the north east (between 45° and 90°) was already present before 2pm, when the sea breeze arrived after 2pm this wind increases in strength by about 1ms^{-1} and stabilised at 67° (Figure 7). These findings are indicators of a sea breeze passing through Rangiora. Similar results are observed in the STAG data (Figure 8).

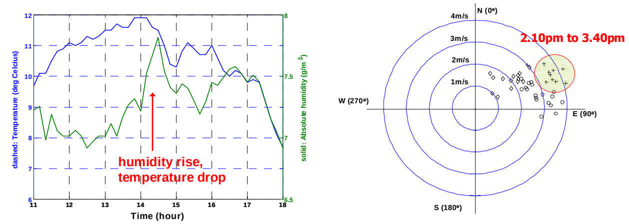

Figure 7: *Surface weather station data during 6th August 2003.*

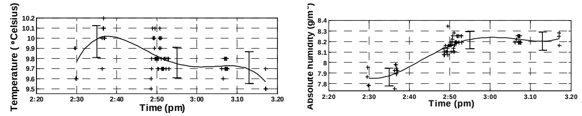

Figure 8: *STAG data obtained between 100 and 140m during the flight period on 6th August 2003.*

Conclusions and Future work

On initial instrumented flights atmospheric measurements showed patterns similar to data from a nearby surface weather-station. A statistical study of sea breezes in Rangiora revealed its frequency and characteristics. These findings allowed the identification of a sea breeze from weather-station data on a day a STAG flight was performed. Work will continue on the wind measurement system which with the addition of a new digital compass will be more accurate than thus far possible.

Acknowledgements

We would like to thank Dr Tony Bowen and Graeme Harris who made the wind tunnel experiment possible. We would also like to acknowledge the use of receiving equipment provided by Prof. Andy Sturman. Dr. McDonald would like to acknowledge grant U6331 awarded by the University of Canterbury.