**7.2** THE PERLAN PROJECT: New Zealand Flights, Meteorological Support & Modeling

Elizabeth J. Carter*, Firnspiegel LLC, Kings Beach, California
Edward H. Teets, Jr., NASA Dryden Flight Research Center, Edwards, California
Stephen N. Goates, Firnspiegel LLC, Kings Beach, California

## 1. INTRODUCTION

The Perlan project is an international scientific endeavor to soar a manned sailplane into the stratosphere using stratospheric mountain waves. The word *Perlan* is an Icelandic word meaning pearl. Perlan is the name given to this project and is inspired by mother-of-pearl or nacreous clouds occasionally seen at high altitudes and high latitudes. The mother-of-pearl or Polar Stratospheric Clouds (PSC's) are present in the northern hemisphere when wave outbreaks are ongoing.

There are two phases of the Perlan Project. Phase one uses a certified production DG505M sailplane to reach 62,000 feet to demonstrate the feasibility of the project. This phase requires the use of pressure suits in an unpressurized cabin. Phase 2 of the project is to soar to 100,000 feet (30 km) in a manned sailplane with atmospheric instrumentation. This phase will require a special pressurized sailplane to be built.

Phase I of the project to soar to 62,000 feet began with flight tests in the Sierra Nevada mountains of California, U.S.A., during April of 2002. High altitude attempts took place in Omarama, New Zealand, from July 11-August 14, 2002. Some of the initial results from the New Zealand campaign flights, meteorology and atmospheric modeling will be presented in this paper.

## 2. WHY NEW ZEALAND?

A unique combination of meteorological conditions are required to get mountain waves to penetrate into the stratosphere to altitudes of more than 100,000 feet (30 km). These requirements include: (1) atmosphere must be influenced by the Polar vortex edge, (2) prefrontal conditions, (3) close to perpendicular winds hitting a mountain range, and (4) increasing wind speeds with height and fairly constant wind directions at all levels. These conditions are detailed in Carter and Teets, 2001, and Teets and Carter, 2002. Strong stratospheric mountain waves have been identified during the winter months over New Zealand. The New Zealand flights take place at the south island of New Zealand between 43°S to 46°S latitude which provides comparatively longer days and warmer temperatures, than in northern hemisphere locations such as Sweden.

* *Corresponding author address*: Elizabeth J. Carter, Firnspiegel LLC, 8130 North Lake Blvd., P.O. Box 2720, Kings Beach, California 96143-2720 U.S.A.; email: ecarter@weatherextreme.com

## 3. THE 2002 NEW ZEALAND FIELD CAMPAIGN

The 2002 Perlan Project field campaign took place from July 11 – August 14, 2002, in Omarama, New Zealand. Figure 1 shows the location of Omarama on the eastern side of the southern Alps on the south island of New Zealand. The actual high altitude flight attempts took place between July 23 – August 11, 2002.

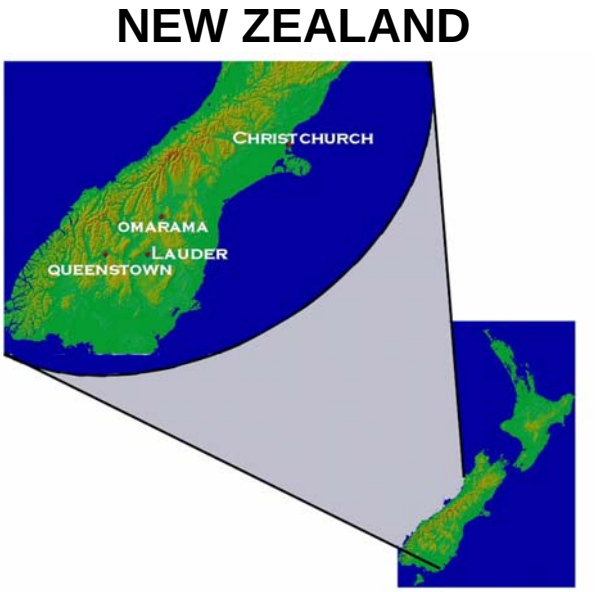


**Figure 1**. New Zealand topography showing the staging location of the Perlan Project in Omarama. The town of Lauder is also noted. Lauder is location where the GPS sondes were launched during the field campaign.

Fifteen total flights were made during the New Zealand campaign. Some of these flights were test flights of equipment and consequently not all of the flights were made with the pilots wearing pressure suits. Figure 2 is a photograph of the two pilots, Steve Fossett and Einar Enevoldson, in pressure suits getting ready for tow.

There were one or two weather briefings per day provided during the campaign. This was necessary due to the timing of the weather events. The pilots can fly for a maximum of 9-12 hours so the timing of the prefrontal event is critical especially if it requires a night landing. Throughout the campaign more equipment including atmospheric instrumentation was being added to the sailplane. This included UV-A sensors, a relative humidity sensor and an ozone sensor.

**Figure 2**. Pilots in pressure suits awaiting tow. The sailplane is a certified production DG505M.

During the actual three-week period for high-altitude flights (July 23-August 11) the weather conditions were not conducive for soaring into the stratosphere. A high pressure formed over the Tasman Sea region for a two week period which kept the storm door shut for a time. Once the high pressure migrated out of the region and some weak storms were allowed through the Polar Vortex was not in a position to enable the mountain waves to penetrate into the stratosphere. This first campaign was very successful however as there were flights made to 30,000 feet during the campaign, the pilots and crew became familiar with the terrain and weather of New Zealand, and all systems (air and ground) worked very well.

## 4. PERLAN FLIGHT ON JULY 20, 2002

On July 20, 2002, the DG505 Perlan sailplane flew to 30,000 feet. The July 20 Perlan glider flight path from Omarama is shown over the topography in Figure 3. On this day prefrontal conditions were occurring over the south island of New Zealand (Figure 4).

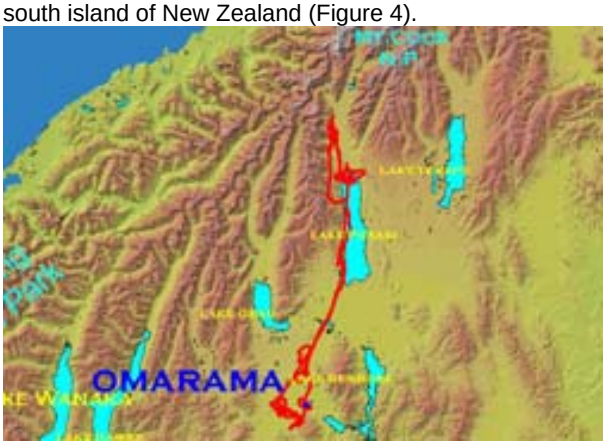


**Figure 3**. Flight of Perlan DG505 sailplane from Omarama north to the Mt. Cook region of New Zealand (shown in red). The sailplane made it to 30,000 feet over the Mt. Cook region.

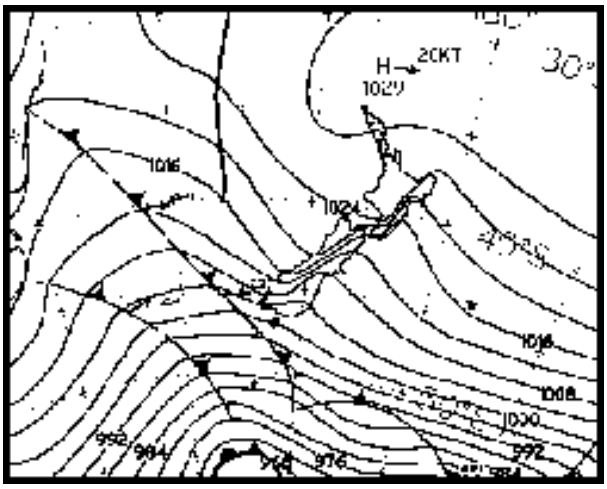


**Figure 4**. Surface analysis chart for 12Z July 20, 2002, over New Zealand showing the prefrontal conditions affecting the region. (Image Courtesy of Met Service New Zealand).

The winds were strong and west to northwesterly at all levels (Figure 5). Figure 5 shows a comparison of wind speeds and wind directions measured from the DG505 glider versus those measured from the GPS sonde launched from Lauder, New Zealand. The sondes were launched by the National Institute of Water and Atmospheric Research. Ltd. (NIWA). Differences in these data arise from the fact that the sonde was launched much earlier in the day than the flight occurred and the sonde was launched from a different location than from where the flight originated by approximately 50 miles. The temperatures measured from the Perlan glider compared well to those measure by the NIWA GPS sonde (Figure 6).

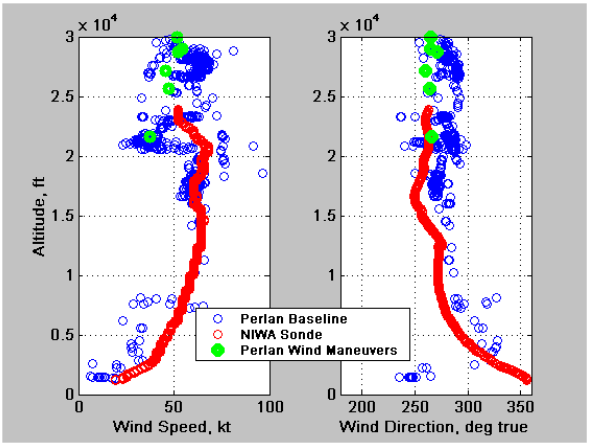


**Figure 5**. Wind speeds and directions from July 20, 2002, as measured by the Perlan glider and the NIWA GPS sonde.

The tropopause was very high on this day (approximately 46,000 feet). The edge of the Polar Vortex was affecting New Zealand (Figure 7). Only one

pilot was in a pressure suit on this day and the choice to go only to 30,000 feet was made as it was still very early in the campaign and only one of the two official pilots was on site.

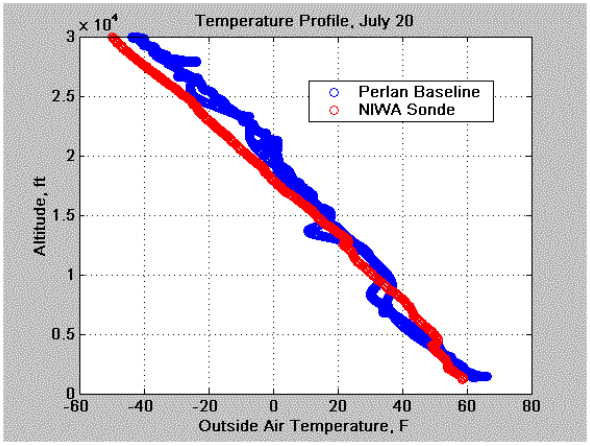


**Figure 6**. Temperatures measured by the Perlan glider compared to those measured by the NIWA sonde.

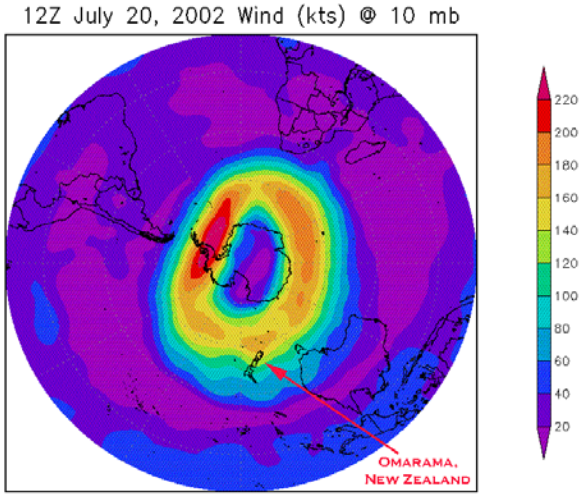


**Figure 7**. Wind speeds at the 10mb level (approximately 100,000 feet) looking down on the South Pole.

The large "Canterbury Arch" wave coming off of the east coast of the south island is easily visible in the infrared satellite image in Figure 8. This image was taken at 1626Z on July 20, 2002, or 4:00 a.m. New Zealand Local Time on July 21, at least 12 hours after the Perlan glider landed from its 30,000 foot flight. All flight and atmospheric systems worked well during this wave flight on July 20, 2002.

## 5. MODELING THE ATMOSPHERIC CONDITIONS

Many of the New Zealand wave cases are being modeled using the Penn State/NCAR (National Center for Atmospheric Research) MM5 Mesoscale Modeling system 5 model. Some of the results from the July 20, 2002, wave day will be presented. The MM5 model was chosen because it has multiple-nest capabilities, nonhydrostatic dynamics, four-dimensional data assimilation, uses terrain-following coordinates, multiple physics options, and is portable to a wide range of platforms.

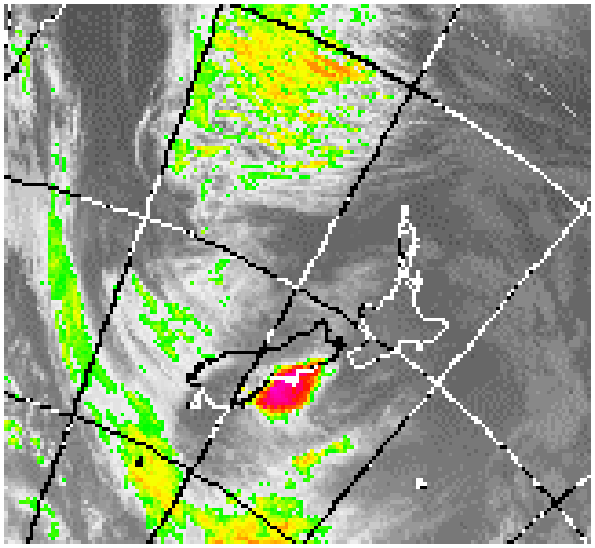

**Figure 8**. Infrared satellite image over New Zealand for 1626Z July 20, 2002. (Image courtesy of NIWA).

The modeled temperatures compared well with those measured both by the NIWA sonde and the Perlan glider. Figure 9 is a cross section of temperature from a 3 km x 3 km horizontal resolution MM5 model run. The location and the temperature where the glider reached the 30,000 foot level is indicated on this figure. The modeled data show the temperature to be approximately –46.0°C at this level and the sonde measured –45.6°C at this level earlier in the day. The Perlan glider measured approximately –43.5°C at 30,000 feet.

The location of the Perlan glider in the wave at 30,000 feet is shown in Figure 10. This figure is a cross section showing potential temperature, circulation vectors, and potential vorticity. The glider at this point was in the lee of the Ben Ohau mountain range over the Mt. Cook township. The vertical velocities (in centimeters per second) for the same cross-section are shown in Figure 11. For reference, 200 cm/s is approximately 2,500 feet per minute and 550 cm/s is abut 7,000 feet per minute.

## 6. FUTURE PLANS

During March and April of 2003 the Perlan Team will fly in the Sierra wave in California prior to the New Zealand 2003 field campaign. The purpose of these Sierra wave flights will be to: (1) perform additional cold testing of equipment, (2) to fly at night to evaluate the effect of loss of solar heating and to assess the decreased situational awareness, and (3) to install and test additional atmospheric data systems on the

sailplane. The next high-altitude field campaign will take place for 4-6 weeks sometime between June and September 2003 in Omarama New Zealand. It is anticipated that during the 2003 New Zealand campaign such ground-based instruments as Lidar, wind profilers, and live cameras will be added to the project as well as additional instrumentation on the sailplane such as cloud particle sampling probes, SiC detectors, newly developed and modified UV-A sensors, and a BAT (Best Aircraft Turbulence) probe.

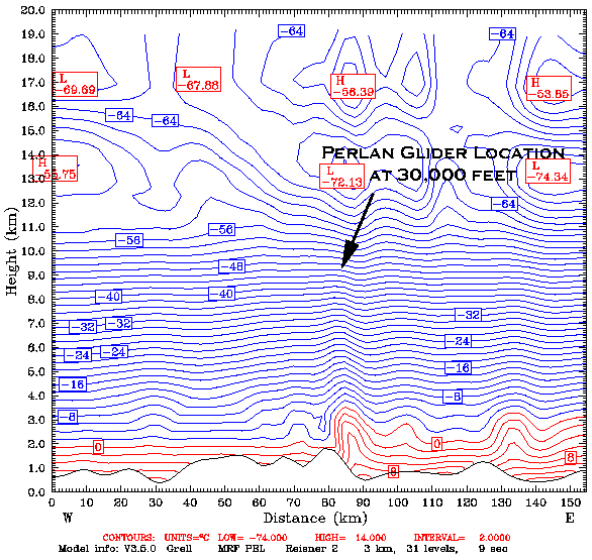


**Figure 9**. MM5 output of temperature (°C) with altitude (km) at 12Z July 20, 2002. The location of the Perlan glider at 30,000 feet is indicated.

The MM5 model along with meteorological analysis software will be used in near-real time in the field to forecast the weather conditions and the stratospheric mountain wave conditions. As with the previous year's campaign, the meteorologist will be in constant contact with the pilots during their attempts to reach high altitudes.

## 7. CONCLUSIONS

The Perlan New Zealand 2002 campaign was very successful in terms of flights, testing of equipment, instrumentation, and teamwork. Lessons learned from the 2002 campaign will be implemented in the 2003 New Zealand campaign. The project will be extended in terms of the time in the field and the use off ground-based instruments will be very helpful for both the meteorologists and the pilots in terms of identifying when and where to go. The Perlan project represents a balanced collaborative effort between model, observation and theory and is expected to have high scientific return.

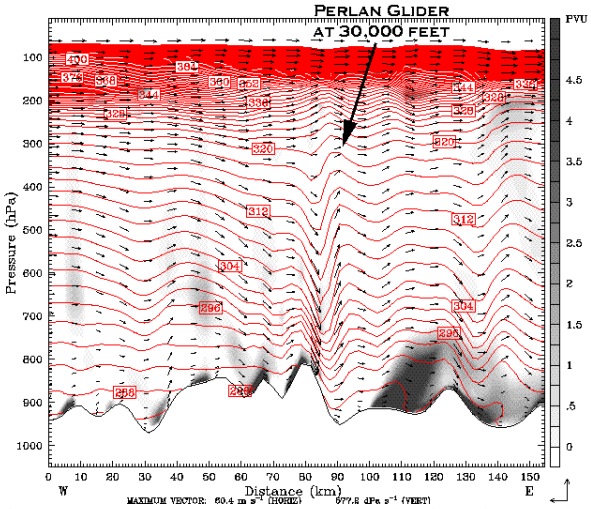


**Figure 10**. Cross-section showing the location of the Perlan glider in the wave. This MM5 model output is for 12Z July 20, 2002. Plotted are potential temperatures, circulation vectors, and potential vorticity.

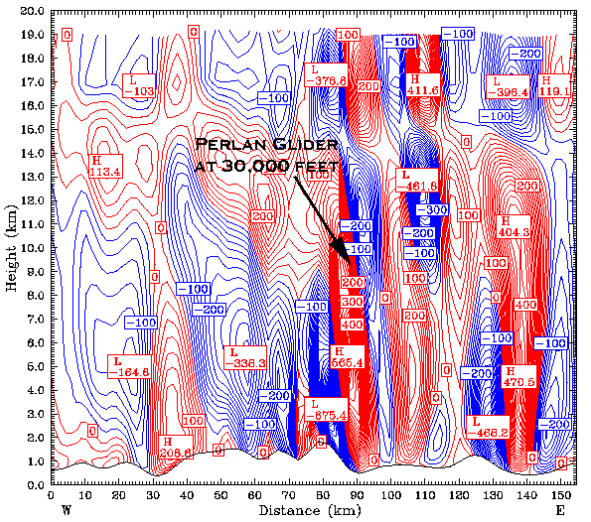


**Figure 11**. Vertical velocities for 12Z July 20, 2002 form the MM5 model run. Red are upward and blue are downward. The velocities are in centimeters per second. The location of the Perlan glider at 30,000 feet is shown.

## 8. ACKNOWLEDGEMENTS

The authors wish to acknowledge one of our partners on this project, the National Institute of Water and Atmospheric Research. Ltd. (NIWA) in New Zealand. NIWA provided sounding data and real-time access to satellite data over New Zealand and the Tasman Sea region of the Southern Hemisphere. NIWA also provided UV-A sensors, a relative humidity sensor and an ozone sensor. We would also like to acknowledge the Australian Bureau of Meteorology supplied on-line meteorological charts over Australia and New Zealand and hemispheric satellite images

during the campaign. Some of the weather charts are courtesy of the New Zealand Met Service. This research is supported in part by NASA under contract number E04917D.

## 9. REFERENCES

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