# CONCORDIASI

## SHORT REPORT

## SUBJECT

The Concordiasi balloon campaign, a French-US cooperation effort for earth atmospheric science with major contributions from CNES and NSF, took place from McMurdo, Antarctica from late August to early November 2010. Concordiasi is an international project, supported by the following agencies: Météo-France, CNES, CNRS/INSU, NSF, NCAR, University of Wyoming, Purdue University, University of Colorado, the Alfred Wegener Institute, the Met Office and ECMWF. Concordiasi also benefits from logistic or financial support of the operational polar agencies IPEV, PNRA, USAP and BAS, and from BSRN measurements at Concordia. Concordiasi is part of the THORPEX-IPY cluster within the International Polar Year effort.

Nineteen long duration balloons were launched during that period and drifted over the Antarctic region at constant level in the lower stratosphere. The flight of the last balloon was terminated late January 2011. The balloon flotilla formed a regional observatory of the atmosphere, which provided in-situ measurements inside the winter stratospheric polar vortex and allowed the performance, on command, of hundreds of soundings of the troposphere.

Concordiasi was for CNES and CNRS/INSU the second long-duration balloons campaign in Antarctica, after the very fruitful Stratéole-Vorcore conducted in 2005 with NSF from McMurdo. After Vorcore, Concordiasi was aimed at much wider scientific goals, taking benefit of new balloon systems offering more capability, and of new scientific instrumentation developed accordingly with a wider scope.

This report gives a short description of the ballooning operations and a preliminary overview of the flight results.

## LAUNCH CAMPAIGN FROM MCMURDO

### INSTALLATION

The twenty-people Concordiasi field team, including technical staff from CNES and technical staff and scientists from four of the involved research institutes, arrived at McMurdo Station on August $20^{th}$. The main bulk of the hardware was already at the station, shipped previously aboard surface vessel. Very convenient laboratory space and offices at the second floor of the Crary lab were put at our disposal, and there we could start very early the assembly and control of the flight systems and the installation of the Flight Control Center. Efficient help was provided by the Crary staff whenever needed.

The launch pad, located on the ice close to the “transition,” had been leveled before our arrival. The station teams started immediately the assembly of two “Ractent” temporary buildings, about one hundred feet long, and the setting up of the power generators (a picture of the launch pad fully set is in appendix 1). We were particularly impressed by the efficiency of these teams, who almost met the delivery date despite many interruptions due to stormy conditions.

Final coordination with the station’s Air Traffic Control and the Meteorological Office for surface weather forecasts was quickly concluded. Finally, readiness of the various control centers in McMurdo, Toulouse (in CNES and in Météo-France) and Boulder (in NCAR) was checked (a synoptic of these centers is in app. 1) and on September $4^{th}$ , everything but the weather, was ready for the start of the launch operations phase, just two days beyond our target date.

## LAUNCH OPERATIONS

We launched twenty balloons from September 8th to October 26th, for actually nineteen flights. We stopped a flight very early after take-off because of a launch operation mishap that would have probably impaired the mission of this flight. The payload was nevertheless launched again after refurbishment.

The launches were possible only if several conditions were met, in particular: that the stratospheric polar vortex extended over the McMurdo region, and that surface wind were weak enough. Despite a rather stormy season as compared to 2005, launch windows meeting these criteria and long enough for the balloon operations were found, enabling us to achieve a regular launch rate of two-three launches per week over seven weeks. Therefore, in addition to placing the balloons at the right time for science, it was also possible to obtain a smooth distribution of the balloons in time and space inside the vortex.

The availability on the launch pad of two launch-preparation “Ractent” buildings, a special effort agreed on by NSF, was a key factor for making possible this sustained launch rate. This was possible also thanks to the quality and reliability of the support provided by the station teams and management, kept at a high level especially during this whole critical phase.

## FLIGHTS OVERVIEW

The mean flight duration has been 69 days, the longest flights lasted 95 days, the number of days for the flotilla summed up to 1316 days. Fig.1 depicts the trajectories of the balloons, very well centered over the Antarctic region. The size of the flotilla peaked at 17 balloons, its evolution with time is presented in fig. 2.

Three payloads were recovered after landing: two at McMurdo and one in Tasmania. Twelve flights were terminated above the ocean (Pacific Ocean 7, Atlantic 3, Indian 2) and four above Continental Antarctica or Ice Shelves. The landing positions of these last four payloads, unrecovered, are reported in app. 1.

Correlative measurements, consisting mainly of vertical soundings of the ozone concentration, were performed during the campaign from different bases on the Antarctic Continent, when Concordiasi balloons were passing over these locations. It included Dumont D’Urville (F), Syowa (J), Neumayer (G), Davis (A), Belgramo (Arg-Sp) and of course McMurdo. Intense observation activity was also conducted for Concordiasi from Rothera (UK), Dumont D’Urville (F) and Concordia (It-F).

## SCIENTIFIC DATA

The “Driftsonde” measurement program, actually the primary objective of Concordiasi, was achieved beyond expectations. 639 atmospheric soundings could be done successfully from the balloons, through the release of “dropsondes” from the NCAR Driftsonde systems, under command by Météo-France. This was well in line with the 600 soundings we were expecting.

A map of the soundings is drawn in fig.3, one can see the distribution almost exclusively over the Continent, and over the Sea-Ice, thanks to the Winter Polar Vortex which forced the trajectories of the balloons to stay over the Antarctic region.

Most of these soundings were performed during overpasses by the “IASI” space-borne atmospheric sounder onboard METOP, some of them also by the A-Train, a series of satellites including AQUA with “AIRS”, a similar instrument to IASI, and other instruments documenting cloud profiles. These soundings will be analyzed in particular to help design and validate methods and algorithms to process observations provided by these space-borne sounders over icy surfaces, and thus increase their contribution to numerical weather prediction models.

These soundings will also be used for other goals related to atmosphere modeling such as for instance to study the impact of targeted observations on these models.

A second range of measurements, “in situ”, were aimed at documenting the depletion of the stratospheric ozone layer, the ozone layer seasonal evolution, and stratospheric dynamics; three highly interrelated topics. Super-pressure balloons tend to continuously drift in the same air parcel, which makes them a very unique device to monitor the evolution with time of the sampled air parcels. The instruments for in situ measurements had been designed and produced by: U. of Wyoming in Laramie, U. of Colorado in Boulder and Laboratoire de Météorologie Dynamique in Palaiseau. Although anomalies, involving CNES systems, occurred on several flights which reduced by about 30% the amount of measurements that the flight extents would have allowed, the scientific goals were met. This was possible thanks to a high level of redundancy between the flights, combined with a very good reliability of the scientific instruments.

Simultaneous measurements of Polar Stratospheric Clouds, of ozone concentration and of air pressure and temperature were obtained over a total duration of 8 weeks. Fig. 4 depicts the trajectory segments with such measurements. This measurement duration is less than expected, that part of the mission being the most affected one by the anomalies of the onboard systems. However this brings very valuable and unprecedented data for the study of ozone destruction process parameters.

Fig. 5 depicts the trajectory segments with simultaneous measurements of ozone concentration and of high precision air pressure and temperature, over a total duration of 35 weeks. This will help in the study of Spring depletion and Summer recovery of the ozone layer in relation with the atmosphere dynamics.

High precision and high temporal and spatial resolution measurements of balloons position, air pressure and temperature have been performed over a total duration of 128 weeks over the various flights. This type of measurements had already been performed during Stratéole-Vorcore, they are recognized today as unique information on the stratospheric dynamics. The new set of data with higher precision and a gain of an order of magnitude in spatial and temporal resolution will allow a new step forward in this area.

It was essential to start these flights early in September, to document the most active season, when polar atmosphere is lit again by the sun, inducing ozone hole formation. As already said above, that objective was achieved, adding much to the value of the measurements.

Finally we flew the two instruments from Purdue U. as a first experiment of atmospheric sounding through GPS radio-occultation. Measurements over 15 weeks were achieved, well in line with the expectation, trajectories with these instruments active are presented in fig. 6.

A wide part of the Concordiasi data was disseminated by Météo-France in near real time on the Global Telecommunication System of the World Meteorological Organization to be made available for the numerical weather prediction models. The impact of these data sets on the quality of the predictions is currently being studied. These data are also used to document model performance in general, and several numerical weather predictions centers have provided their outputs at the sonde locations to perform an intercomparison study.

## CONCLUSION

Super-Pressure balloons offer unique observation capabilities of the atmosphere. When associated with the Driftsondes, the scientific scope of these systems gains one more dimension. Motivated by Science groups clearly ready to invest on research with such observation systems, CNES and NCAR have devoted a long-standing effort to bring them to a high level of capabilities. Concordiasi is the first program using this observation system at its full maturity.

As a program to be conducted in Antarctica, with induced high logistics costs, preparation of Concordiasi has been specially defined so as to maximize the chances of success. This approach consisted first in a conservative validation phase, including a long and comprehensive ground test program and flight campaigns. The campaign was finally decided after completion of this cumbersome validation phase. Secondly a high level of redundancy was applied, to cope with several feared events. Unfortunately, such an anomaly that was not one of those feared a priori but that impacted the onboard communications, did occur on some of the flights, and contributed to reduce the quantity of in-situ measurements. This problem is being analyzed at CNES, and has remained so far unexplained. Despite this anomaly, the results obtained, thanks to the flights redundancy level and the very good reliability of the scientific instruments and Driftsonde systems, are for most parts of the mission clearly sufficient to meet the scientific goals. Concordiasi has brought an unprecedented batch of data sets performed at the right time in the situations that were looked for, and while the analysis of the results is still in a very preliminary phase, there is no doubt that the scientific outcome will be of great value.

Concordiasi is the result of a close cooperation between French and US scientific and technical teams. Lot of work in common and close collaboration was required at many levels to form a consistent and efficient system from design to operations. Concordiasi is in particular a result of the excellent cooperation between NCAR and CNES initiated about seven years ago.

The cooperation with NSF, obviously a key factor for this success, has been very efficient; all actions were conducted according to the plans, despite the many difficulties inherent to Antarctica. We would like to gratefully acknowledge the NSF and the USAP staff for their contributions to the Concordiasi project. We fully appreciate the value of the effort that has been devoted to meet the objectives, and we have been very sensitive to the warm spirit that has prevailed all along this activity.

The French Polar Institute IPEV, in addition to support and bring direct contributions to the project at Concordia and Dumont D'Urville has been very helpful in setting up the cooperation with NSF, we fully appreciate the value of these commitments.

Currently the data are being processed for a final check and analysis has started. A second Concordiasi scientific workshop, organized by Météo-France, and kindly hosted by NCAR will take place in Boulder, Co. late October 2011.

May 6th 2011,

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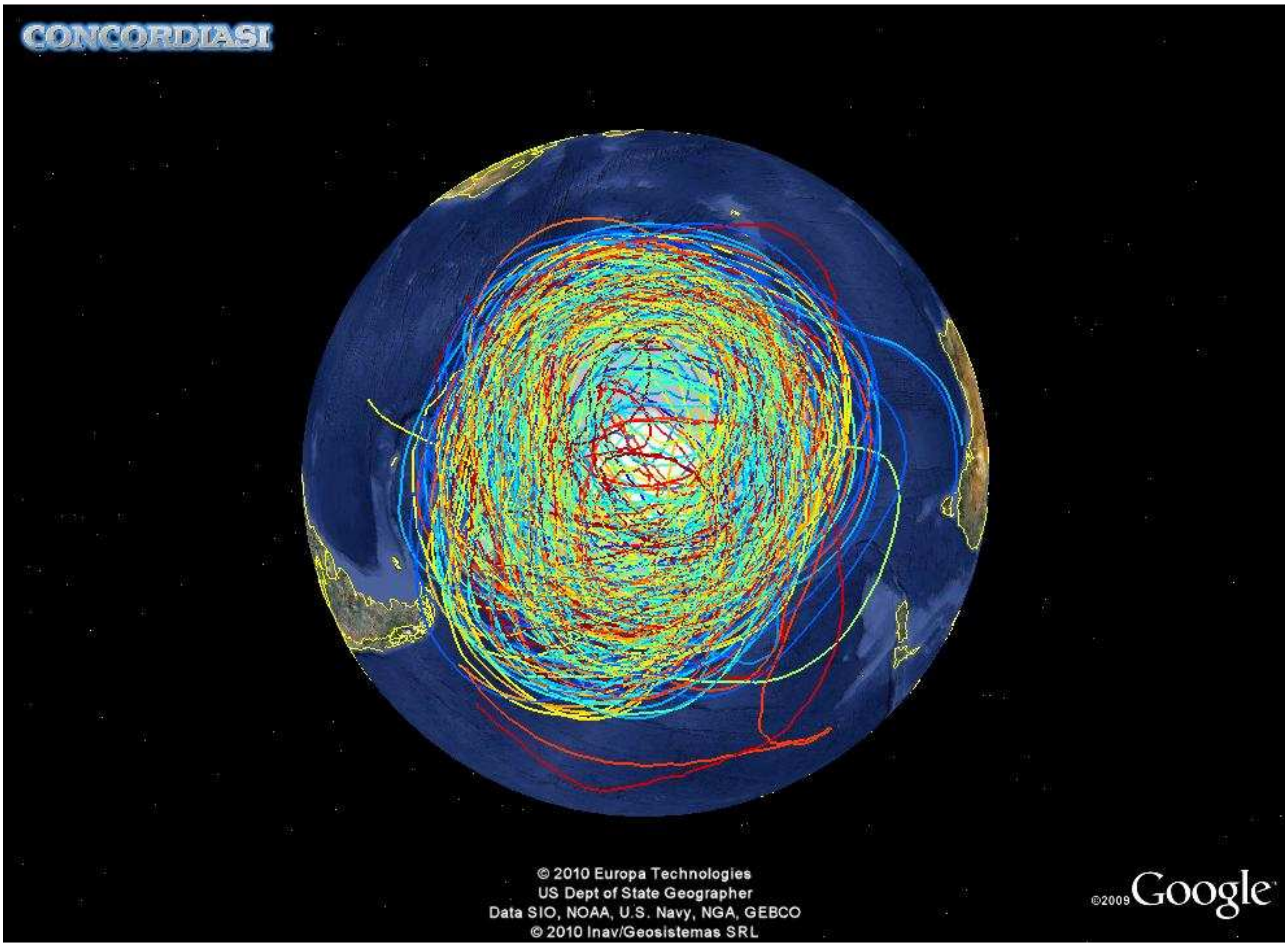



**Fig. 1 Flight Trajectories**

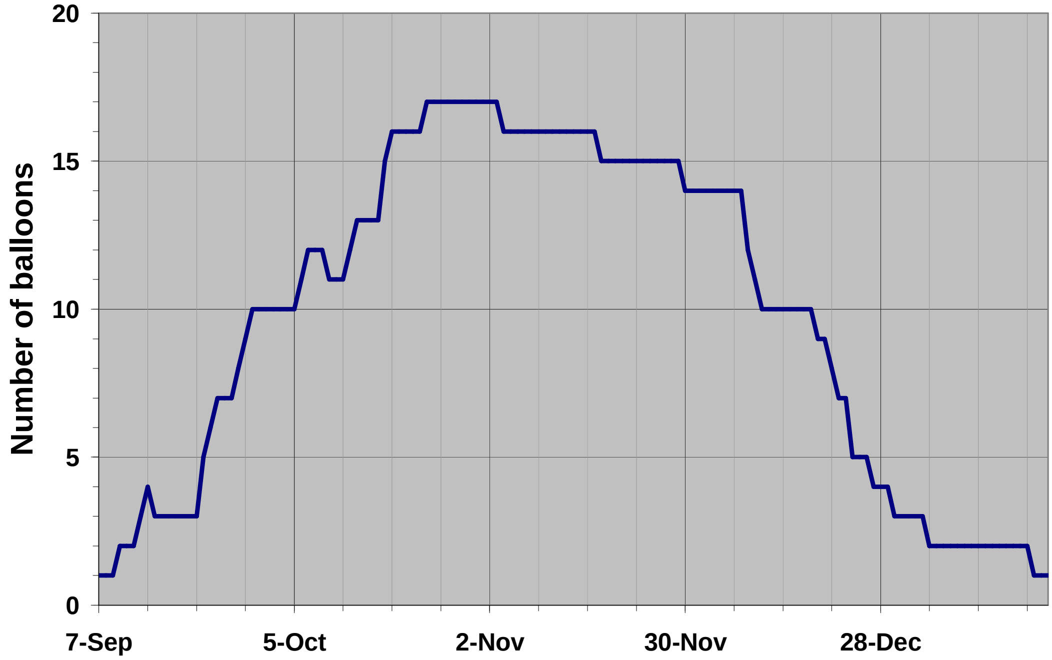



**Fig. 2 Flotilla size versus time**

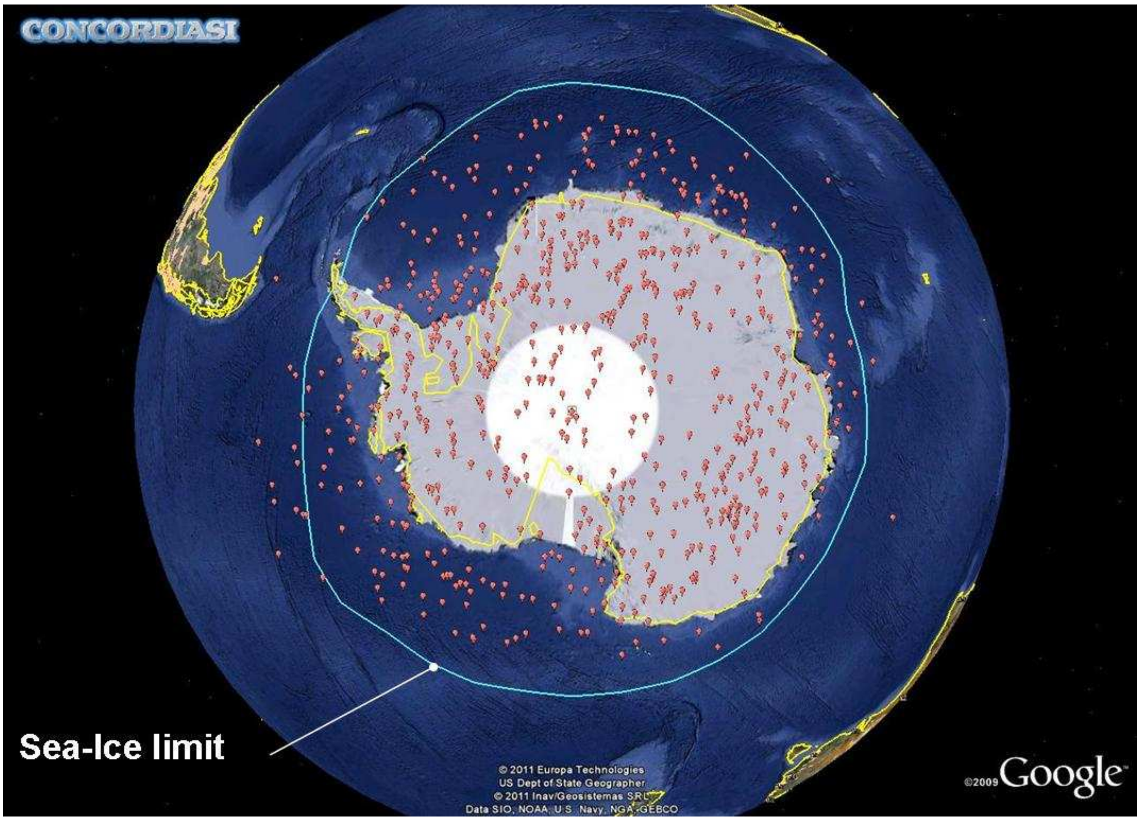



**Fig. 3 Map of the 620 Driftsonde soundings, Sept. 25th to Nov.15th**

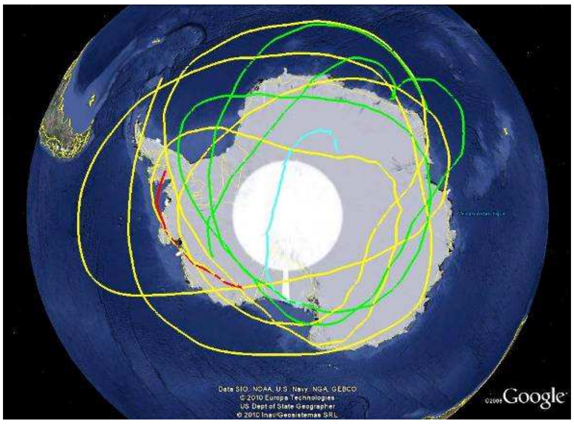



**Fig. 4 Trajectories with measurements for study of ozone destruction process**

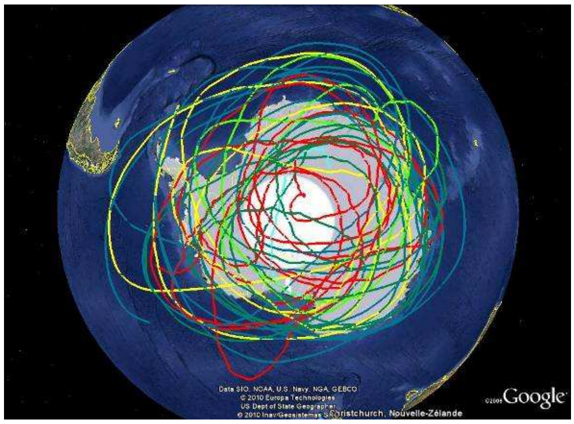



**Fig. 5 Trajectories with measurements for the the study of ozone seasonal evolution**

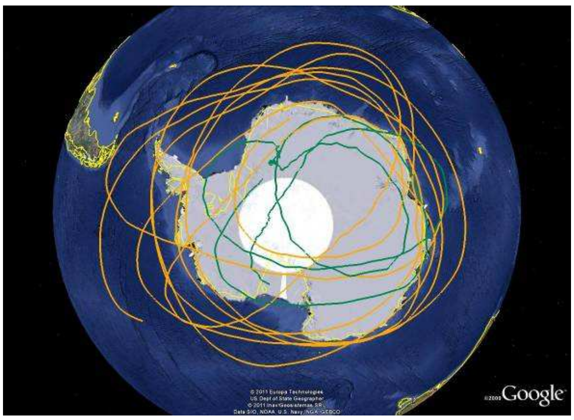
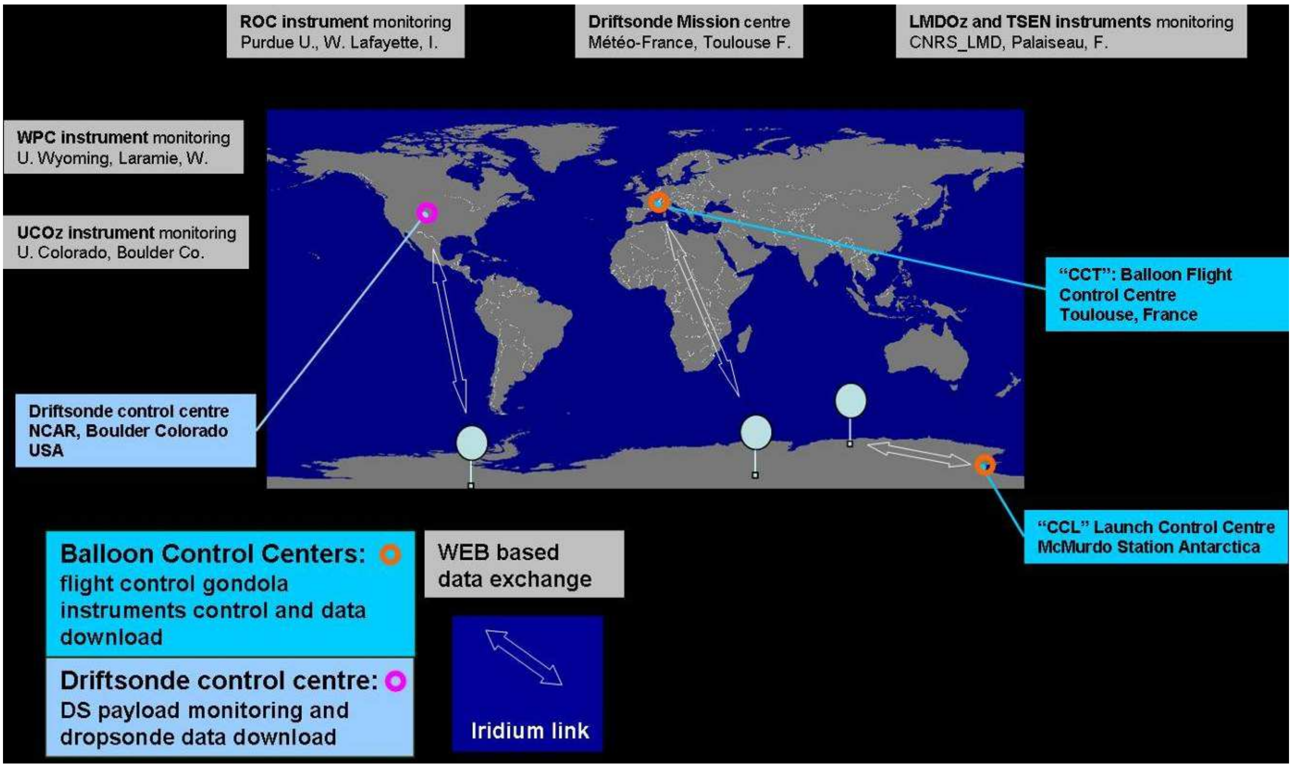



**Fig. 6 Trajectories with measurements for the GPS radio-occultation experiments**

# APPENDIX 1

**Launch pad, with the 2 "Ractents"**




**Organization for flight and science control**

**Flight # 9, Sept. 28th**

**Recovery of a payload in Tasmania**

| Flight | Launch | Landing | | | |
|---|---|---|---|---|---|
| **MSD05** | 25-sept | 22-déc | 84.815 °S | 91.715 °W | **Marie Byrd Land** |
| **MSD06** | 28-sept | 09-déc | 79.388 °S | 172.709 °E | **Ross Ice Shelf** |
| **MSD07** | 30-sept | 09-déc | 76.209 °S | 7.342 °W | **Queen Maud Land** |
| **MSD13** | 19-oct | 30-nov | 75.799 °S | 56.686 °W | **Ronne Ice Shelf** |

**Location of the landing points of the four unrecovered payloads over Antarctica**