CONCORDIASI
Antarctica
Overview of the measurement campaign

Atmospheric Science
Long duration stratospheric balloon experiment
Sept 2010 – January 2011
A French-US initiative for climate / meteorology over Antarctica and at global scale

- Improve the use of space-borne atmospheric sounders over polar regions, in particular "IASI" on board MetOp
- Benefit from the continental French-Italian station "CONCORDIA"
Main goals:

■ To improve the assimilation of satellite data over the southern polar region, and more generally over ice regions
  ♦ In particular for the new IASI sounder
  ♦ And thus to improve weather predictions.

■ To improve understanding of stratospheric ozone
  ♦ Through examination of the interaction of ozone at flight level and stratospheric clouds
  ♦ Together with the improved characterization of the polar vortex.
Main goals:

- To provide recommendations on the design of the global observing system over the southern polar region
  - By determining the extent to which additional observations over Antarctica can improve the prediction of high impact weather over lower latitudes.

- To advance understanding of the Earth system
  - By examining the two-way interactions between the climates of Antarctica and lower latitudes.

_Labeled « Thorpex » by the World Meteorological Organization_
Super Pressure Balloon

Concept

Mission

Technical challenges
- Balloon
- Infrastructure and launch process
- On board systems
- Flight monitoring and control
- Rapid distribution of scientific data

CONCORDIASI

Scientific investigators
Measurement plan
Launch campaign
Flight overview
Driftsondes

In situ measurement
1 – Ozone destruction
2 – Ozone depletion/replenishment
3 – Stratospheric Dynamics - waves

Experiment
- Atmospheric sounding through GPS occultation
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Zero Pressure Balloon
- Open balloon (venting ducts)
- Can fly high with heavy loads
- Short duration (except special conditions…)

Super-Pressure balloon
- Sealed balloon
- Lowermost stratosphere, light loads
- Long duration flights
Super Pressure Balloon

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Super-Pressure Balloons Mission

Flights of several months in the lowermost stratosphere, quasi-lagrangian observations of the local air parcel

- 16 500 / 20 000 m
- Air Pressure 70 / 60 hPa, Air Temperature -50 / -90°C

Any season and latitude

Balloon constellation (~20) forming a regional observatory

Light instrumentation (overall suspended weight ~45/50 kg)
Super Pressure Balloon

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SPB Technical Challenges

**Balloon design and operations**

### Envelope

- Strength and endurance
- Gas-tightness

### Operations

- **Launch technique compatible with a constellation deployment, must withstand:**
  - Moderate surface level winds (8-10 kts)
  - A wide range of ground conditions, from dry and cold winter polar to warm and moist tropical
  - A sustained launch rate, 2/3 per week launch rate over several months

- **Must not require heavy specific infrastructure**
SPB Technical Challenges

Light mobile means

Launch pad fully set

Inside a “Ractent”

Inflatable launch table
SPB Technical Challenges

Manual launch technique
Reliability
Fail safe design
Thermal control under extremely variable stratospheric environment
Stringent mass limitation
A standard versatile payload module providing instruments with energy, thermal control, command and data management.

It carries up to 3 instruments that must comply with the following overall capabilities:
- Weight ~8 kg
- Mean power ~10 w
- Daily Mean data rate ~1MByte

Photo J N Valdivia
Flight control of the flotilla over several months
- For safety
- For mission success
  - 6 people on duty 7/7
  - 3 of them on 24/24 alert through pagers

Scientific Instrument control
- Hourly data transfer Balloon > Control centers > Internet
- Daily requests from scientists > Control centers

Global Telecommunication System (WMO)
- Most of the data is to be transferred promptly to the GTS for access by the NWP centers.
SPB Technical Challenges

**Flight control / data transfer**

- **CCL**: Launch Control Center McMurdo Station Antarctica
- **CCT**: Balloon Flight Control Center Toulouse, France
- Driftsonde Mission center Météo-France, Toulouse F.
- Driftsonde control center NCAR, Boulder Colorado USA
- UCOz instrument monitoring U. Colorado, Boulder Co.
- ROC instrument monitoring Purdue U., W. Lafayette, In.
- LMDOz and TSEN instruments monitoring CNRS_LMD, Palaiseau, F.

Balloon Control Centers:
- flight control of the gondola, instrument control and data download
- Driftsonde control center: DS payload monitoring and dropsonde data download

WEB based data exchange

Iridium link

“CCL” Launch Control Center McMurdo Station Antarctica

“CCT”: Balloon Flight Control Center Toulouse, France
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Scientific Investigators

♦ Principal Investigator:
  – Météo-France, (CNRM-GAME Toulouse, F), Florence Rabier

♦ Investigator / Experimenter (on board SPB)
  – CNRS / LMD (Palaiseau, F)
  – National Center for Atmospheric Research (Colorado, USA)
  – University of Wyoming (Laramie, USA)
  – University of Colorado in Boulder (USA)
  – Purdue University (West Lafayette, Indiana, USA)

♦ Investigator / Experimenter (Concordia and Dumont d’Urville)
  – CNRS / LGGE (Grenoble, F)
  – Météo-france

♦ Investigators
  – ECMWF
  – Met Office UK
National Science Foundation (USA)
- US instrument development and production
- US scientists for field experiment
- Logistics, infrastructure and life support at McMurdo Station.

CNES
- French scientific experiments
- Development and production of all flight and ground hardware
- Field experiment and flight control operations
- Overall technical management of the experiment

Institut Polaire Français IPEV
- Support to promote Concordiasi as an international program in Antarctica
- Measurements from Concordia and Dumont d'Urville
CONCORDIASI Presentation outline

Super Pressure Balloon

- Concept
- Mission

Technical challenges
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CONCORDIASI

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- Measurement plan
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- Driftsondes

In situ measurement
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Experiment
  - Atmospheric sounding through GPS occultation
### CONCORDIASI Measurement plan

#### 19 SPB flights

<table>
<thead>
<tr>
<th>SPB Flight #</th>
<th>Driftsonde fitted with ~50 dropsondes</th>
<th>Meteo sensors</th>
<th>Ozone Concentration</th>
<th>PSC aerosols</th>
<th>GPS Radio Occultation</th>
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Driftsonde payload (13 “MSD” flights)

Perform 600 soundings of the atmosphere beneath the balloon over the Antarctic region, at times / situations chosen by météo-France

- ~70% during overpasses by IASI and/or AIRS space borne instruments
- ~30% “Targeting” over sensitive areas

« Driftsonde » gondola developed by NCAR

A driftsonde releases on command up to 50 “Dropsondes” which measure from balloon to ground:

- Pressure
- Temperature
- Moisture
- Wind
CONCORDIASI Measurement plan

In situ Measurements

1 – Ozone destruction (4 PSC flights),
   Links among stratospheric chemistry, dynamics and cloud microphysics
   Key period: early Sept. to mid-Oct.
   - Detection and quantification of PSC related aerosols: « WPC », U. Wyoming
   - Ozone concentration: « LMDOz », CNRS-LMD or « UCOz », UC Boulder
   - Air temperature: « TSEN », CNRS-LMD

2 – Ozone depletion / replenishment (6 PSC flights)
   Key period: early September to late December
   - Ozone concentration: LMDOz or UCOz
   - Air temperature and pressure, trajectory: TSEN

3 – Meso-scale stratospheric dynamics-waves (13 MSD and 6 PSC flights)
   Key period: as long as possible
   Space and time high resolution measurements of pressure and position
   - Pressure variations: TSEN
   - Balloon position: GPS on board CNES systems

GPS occultation experiment (2 PSC flights)
   - Dual band GPS receivers « ROC », U. Purdue
Ozone soundings at overpass of the SPB PSC flights
For calibration of the ozone photometers

From the following stations:
- Amundsen–Scott, USA
- Belgrano, Sp.-Arg.
- Davis, Aus.
- Dumont d’Urville, Fr.
- McMurdo, USA
- Neumayer, Ger.
- Siowa, Jap.

Augmented atmosphere observation plan at
- Concordia, LGGE / IPEV-PNRA
- Rothera, UK
CONCORDIASI Presentation outline

Super Pressure Balloon

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Driftsondes

In situ measurement
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Experiment
- Atmospheric sounding through GPS occultation
McMurdo unique combination

- Accessible during late Winter
- Protected from katabatic winds
- Well South (~1300 km from Pole)
CONCORDIASI Launch Campaign

August 20th transfer NZ - McMurdo
## CONCORDIASI Launch Campaign

### Actual launch schedule

<table>
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<th>Date</th>
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**Launch phases:**
- **Unpacking Preparation**
- **Launch phase**
- **Dismantling Packing**

### Points of Note:
- 20 launches over 7 weeks, averaging 3 per week
Super Pressure Balloon

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Experiment
- Atmospheric sounding through GPS occultation
Flight overview

Flight duration:
- overall 1316 days
- Average 69 days per flight

Significant loss of measurements (~30% of the potential amount) due to on board loss of communication with the CNES systems (yellow phases)
2010, a stable Austral Winter Polar Vortex
3 payloads recovered:

PSC15 et PSC16 near McMurdo
PSC17 in Tasmania
CONCORDIASI Presentation outline

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**Experiment**
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**Driftsonde**

Releases dropsondes that measure from balloon to ground:
- Pressure
- Temperature
- Moisture
- Wind

50 dropsondes per Driftsonde gondola, dropped on command

Appropriate management of the balloon helium gas
Driftsonde operations

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Intensive dropsonde releases ~12 per day for 7 weeks

> 600 dropsondes
CONCORDIASI Driftsondes

Dropsonde map

Sea-ice limit mid-November
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Experiment
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4 Flights with 3 instruments on board

- Particle Counter « WPC »
- Ozone photometer « LMDOz »
- Ozone photometer « UCOz »
- Thermodynamic Sensors « TSEN »
On board 4 flights

Results

Simultaneous measurements from the 3 instruments in the winter vortex at return of daylight over a cumulated duration of 8 weeks

PSC15 and PSC17 flights: Loss of communication with the Payload Supervisory Board (CNES) after 1 week and 1 month respectively in flight

PSC16 flight: WPC end of life after 3 weeks of intensive use (~ nominal)

PSC14 flight: WPC early failure after 2 days in flight
RESULTS

- Cumulated measurement duration 35 weeks
- 3 instruments measuring simultaneously during 8 weeks
- Good agreement with ozone soundings and data from space borne instruments

- High level of reliability of the photometers
- Measurements were interrupted after loss of contact with CNES PSB or Power Management Unit
TSEN on board each flight

- Position (GPS), every minute
- Air Pressure (TSEN), every 30 sec (high accuracy Paroscientific)
- Air Temperature (TSEN), every 30 sec (micro-thermistor)

Results
Data collected over ~900 days

Measurements were interrupted after loss of contact with CNES PSB or Power Management Unit
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Experiment
- Atmospheric sounding through GPS occultation
2 “PSC” flights partly dedicated to experimental atmospheric sounding through GPS occultation from stratospheric balloons.

“ROC” instrument includes:

- One or two dual band GPS receivers
- On board data processing for minimization of downlink data flow

ROC onboard together with Ozone photometer and TSEN
Results

Measurements over 15 weeks

Measurements have been interrupted after loss of contact with CNES PSB or Power Management Unit
**Excellent reliability of the scientific instruments**
- All 13 Driftsonde gondolas performed very well with a 95% success rate
- Out of 29 other instruments on board just one unit failed prematurely

**Overall very good performance of the flight systems, control centers and flight operations**
- Mature Iridium based flight control and data transfer system
- Efficient renewable power system
- Anomaly on on-board CNES systems reduced the potential amount of in-situ data collection by 30%, investigation in progress at CNES, so far “no direction home”

- Impact on scientific mission achievement limited, thanks to an overall high redundancy level

**Anomaly on the balloons. 3 balloons did burst unexpectedly after months in flight while drifting well inside their design limits**
- Investigation in progress, what could cause an apparently progressive damage?
- Did not impact significantly the scientific mission
Collection of huge amounts of data at the right time and the right place, often unprecedented, will produce very valuable scientific outcomes.

Scientific exploitation in progress
- Data validation
- Post flight calibration on several instruments after recovery
- Analysis/modeling

Second scientific workshop at NCAR in Boulder October 2011
CONCORDIASI
Step back to the future

Pre - CONCORDIASI took place early 2010, 3 flights, 3 months each

α As a successful preparation for CONCORDIASI

Ω As an anticipation of STRATEOLE II, scheduled over 2016-2018
Study of the Tropical Upper Troposphere Lower Stratosphere
CONCORDIASI Acknowledgements

Excellent international cooperation
- With the scientific teams for the long validation phase
- Support at McMurdo station
- Flight Operations by CNES and Météo-France teams in Toulouse, and NCAR in Boulder

The result of a long standing effort to expand the scientific capabilities of long duration flights by
- CNES balloon, flight systems and operations teams
- Industry teams Zodiac, ELTA, Sogeti, R-Tech, Atelier Image, and others
- Science teams bringing unswerving motivation and meteorology expertise

The outcome of a long standing effort to develop a consistent and efficient Balloon-Driftsonde system between CNES and NCAR

http://www.cnrm.meteo.fr/concordiasi/
http://www.lmd.polytechnique.fr/VORCORE/McMurdo.htm

Author: Philippe Cocquerez, CNES Toulouse Space Center, DCT/BL/PR