The Concordiasi field experiment over Antarctica:
first results from innovative atmospheric measurements

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Concordiasi field campaign

Concordiasi is a multi-disciplinary effort studying the lower stratosphere, troposphere, and land surface of Antarctica. In 2010 an innovative constellation of balloons provided a unique set of measurements covering both volume and time. The balloons drifted for several months on isopycnic surfaces in the lowermost stratosphere around 18km, circling over Antarctica in the winter vortex. In situ measurements included position, temperature, pressure, ozone, and particles, and profiles below the gondolas included temperature, pressure, humidity, and winds. Nineteen balloons were launched, between September 8th and October 26th. The mean flight duration was 69 days.

Stratospheric balloons, gravity-waves and GPS/Radio Occultation measurements

In-situ balloon-borne meteorological observations are first useful to study the activity of mesoscale gravity waves above Antarctica and the surrounding oceans. Due to the quasi-Lagrangian behavior of long-duration balloons, the gravity-wave intrinsic frequencies and momentum fluxes can be directly inferred from these observations. During Concordiasi, these observations were made every 30s, so as to resolve the whole spectrum of gravity waves. First analyses indicate the signature of mountain waves above the Antarctic Peninsula, and significant activity above the ocean. A proof-of-concept balloon-borne GPS radio occultation system was furthermore deployed on two of the Concordiasi campaign balloon flights to provide refractivity and derived temperature profiles for validation and improving satellite data assimilation. 711 occultations were recorded, comparable to the total number of dropsonde profiles.

Ozone and Particle observations

The in-situ observations of temperature, ozone, and particle size from the Concordiasi balloons provided new observations, along near Lagrangian trajectories, of the evolution of ozone and particle size as the sun returned to the Antarctic stratosphere. The instruments were designed to take advantage of this unique opportunity to observe, along air parcel paths, changes in ozone due to photochemical destruction, and changes in particle size due to temperature changes. The ozone measurements were made on six balloons, four of which were launched in early September. The Concordiasi payloads provided unique observations of ozone from which near-instantaneous ozone loss rates can be determined. Initial calculations suggest that ozone is being lost at rates up to 10 ppb per sunlit hour, which is slightly larger than published values.

Driftsonde data

The needs of Concordiasi spurred technological advances of the NCAR Driftsonde system, which provided unprecedented high-quality, high vertical resolution upper air observations from float level to the surface. Overall, the 13 Driftsonde gondolas returned 644 high quality profiles. Consistent cold biases are found in all satellite data except in the upper troposphere in Microwave Integrated Retrieval System (MIRS) and in the lower troposphere in the Infrared Atmospheric Sounding Interferometer (IASI). The cold bias is larger relative to dropsondes than radiosondes as a result of a larger cold bias over the Antarctic continent than the coast and ocean. All radiosonde stations but a couple are located along the coast. The satellite data can reproduce observed temperature profiles reasonably well in spite of the biases.

Impact of the data in NWP models in the Southern polar area

Concordiasi meteorological observations, both at the gondola level and from the dropsondes were used in real-time at Numerical Weather Prediction Centres. The comparison between short-range forecasts and the data was investigated for 7 centres in the US, France, Canada, ECMWF, Japan, Germany and the United-Kingdom. Results show that models suffer from deficiencies in representing near-surface temperature over the Antarctic high terrain. The very strong thermal inversion observed in the data is a challenge in numerical modelling, because models need both a very good representation of turbulent exchanges in the atmosphere and of snow processes to be able to simulate this extreme atmospheric behaviour. Dropsondes were shown to have a positive impact on the forecast performance in four different models, with an impact of the same order of magnitude as the one brought by radiosondes. The total short-range forecast error-reduction produced by assimilation of dropsonde observations from Concordiasi is smaller than that provided by satellite radiance and wind observations, although the average error reduction per-observation is much larger for dropsondes compared to satellite data. For the dropsonde observations, both temperature and wind data have more impact when they are closer to the pole, with temperature information contributing most at low levels while wind information dominates at high levels (<400 hPa). On a per-observation basis, however, both wind and temperature have larger impact closer to the surface (lower troposphere). This corresponds to areas where there are very few other competing observations, mainly because of the difficulty of using satellite radiance information close to the surface, especially over high terrain.
The development of a Lagrangian approach to assimilating the driftsonde positions into the GEOS5 assimilation system at NASA's Global Modeling and Assimilation office has been developed. Lagrangian assimilation utilizes position observations by producing a forecast of the balloon positions through a forward model of the balloon trajectory. The correction to the wind fields is done through the tangent linear and adjoint of this model. Initial testing of the Lagrangian assimilation in 3DVAR mode showed that it is essentially equivalent to assimilating derived winds from the balloons.

Interactions of the lower atmosphere with the snow over Antarctica

At the surface, particular attention has been paid to the observation and the modeling of the interaction between snow and the atmosphere, which controls surface and near-surface temperatures and strongly influences the radiances as measured by the IASI satellite-borne sensor. The Dome-C Concordia station has been the focal point of this activity, thanks to its exceptional instrumentation, including observations of atmospheric profiles with a 45 m tower, turbulence, radiation, and snow-profile, among others. Both NWP operational and research models have been evaluated. This research has led to an improvement of snow representation over Antarctica in the IFS model at ECMWF. Coupled snow-atmosphere simulations performed at Météo-France with the Crocus/AROME models have been shown to realistically reproduce the snow internal and surface temperatures and boundary layer characteristics.

Website: http://www.cnrm.meteo.fr/concordiasi/
Data can be accessed at the following address http://www.cnrm.meteo.fr/concordiasi-dataset/