

1. General Information

Project title:

Signatures of Evaporation of Artificial Snow in Alpine Lower Troposphere

Project acronym:

SEASALT

Main scientific field / specific discipline:

Earth Sciences & Environment / FP6 - Ecosystems & Biodiversity

Scientific theme:

Impact of artificial snow production on the atmospheric-context of the water budget of Alpine ski-resort surroundings.

Participants undertaking research:

Name	Institution	Department	Position
ARABAS Sylwester (lead scientist)	Institute of Geophysics, Warsaw University	Atmospheric Physics Division	student

Lead scientists background:

(scientific background and experience, English level, etc)

Student of atmospheric physics (2nd year of specialized studies, 5th year of 5-year programme MSc studies on faculty of physics). Specialized courses undertaken include thermodynamics and cloud physics, hydrodynamics, dynamic and synoptic meteorology, numerical modelling; preceded by 3-year pure and applied physics base course. Fields of interest concentrated around scientific computing. Fluent English knowledge.

Lead scientist considers himself / herself as:

Inexperienced in the use of research aircraft: Yes

Requiring access to an aircraft he / she has not used before: Yes

Number of participants on campaign site:

1

Total number of participants:

1

Scientific problems being addressed by the experiments and brief summary of experiments:

The topic of the experiment is the alteration of natural environment caused by the process of large-scale production of man-made snow. Campaign is focused on the modification of the local hydro-budget by atmospheric processes involving the artificial snow.

The issue was the key-subject of the Great Debate of the EGU General Assembly in 2007 entitled "We must curtail the use of artificial snow". The debate triggered a significant press response quoting the warning tone of the talk: "The use of artificial snow [...] is seriously damaging the environment and putting pressure on water reserves, scientists said this week. Artificial snow is used on 30 per cent of slopes in the Alps, covering 23,800 hectares [...] The water used for the snow is typically taken from surface streams, artificial reservoirs and ground reserves. Up to a third of water used evaporates and drifts to other regions. [...] Dr de Jong told the European Geosciences Union in Vienna [...] ("Artificial snow causes real problems", Telegraph.co.uk/21/04/2007); "by keeping water in surface reservoirs instead of in the ground and by spraying it through the air to create the snow, around one third of the water evaporated, forming clouds that often travelled to other regions [...] "This could also have an enormous impact on the Mediterranean Sea if river discharges continue to fall," ("Artificial snow harms Alpine water system", Reuters/18/04/2007).

The experiment, conducted by a group of students to be completed by means of EUFAR

"Join an existing campaign" opportunity, aims at measuring the signatures of evaporation of the water vapour during artificial snow production.

Aircraft:

FUB - C 207

Why this aircraft best suits for this experiments?

The FUB-C207 aircraft is the only Alpine-country-based small tropospheric aircraft of the EUFAR fleet equipped with both ground-looking LIDAR and in-situ hygrometer. Such equipment combination enables to search for the signatures in water vapour and aerosol distribution both by means of in-situ data and active remote-sensing based profiling.

Usage of the ground-looking LIDAR (with the vertical resolution of 7.5m) helps to overcome the minimum-flight-altitude limit affecting the in-situ measurements.

Alternative aircraft choice, in contrary to in-situ+LIDAR strategy, is based on the aim to maximize the in-situ measured water vapour and ice-related parameters favouring the smaller aircrafts capable of flying at low speeds and low relative altitudes in order to allow for measurement of relatively small spatial scale phenomena as water vapour distribution variability between alpine valleys. The two alternative choices are: Enviscope-Partenavia with FSSP, ice-water-content measurements and standard hygro-sensor and FZK ENDURO capable of flying at 50 ft above ground and being equipped with snowboards.

Alternative aircraft:

Enviscope-Partenavia
FZK - ENDURO

2. Description of the experiment

Scientific objectives / proposed work / anticipated output:

The key sources of water for production of the artificial snow in the ski-resorts of Europe are mountain lakes, streams and springs. Evaporation of the water vapour is a vital process for efficient snow production - the release of latent heat cools the liquid streak enhancing the crystallization activity. The evaporation and further transport of the water vapour alters the water budget of the Alpine regions yet drained by the climate-change.

The topic of the environmental impact of artificial snow is widely covered in the literature in context of soil and vegetation interactions and particularly the influence of the crystallization-nuclei additives (e.g. review articles by Rixen et al, 2002; Wipf et al, 2005). There is lack of experimental depiction of the atmospheric context of the issue. Measurements of the signatures of alteration of tropospheric water vapour distribution over the Alpine skiing valleys would give a good background for further quantitative studies.

The objective of the experiment is to obtain a proof and scale-estimation of the process of advection of the water vapour introduced into the atmosphere during man-made snow production which may have a significant impact on the Alpine water-budget. Proposed measurements include in-situ water vapour sensing and LIDAR profiling of the air below aircraft. The campaign data-set, besides aircraft measurements, have to include DEM of the flight path surroundings, ski-resort concentration, snow-production intensity as well as accompanying meteorological parameters defining the state of the atmosphere during flight.

Analysis of the LIDAR profiles may yield as well a valuable results concerning the vertical distribution of the crystallization-nuclei spread by the snow-cans. Due to usage of a bacteria-sourced (*Pseudomonas syringae*) proteins for the ICN additives, there is a significant ecological concern acknowledged by legislative limitations in selected Alpine countries - what confirms the need for further research in the field. Whereas the successful measurements of artificial-snow are dependant on numerous conditions including both short- an long-term weather situation in Alps, both the scientific and educational value of the flights will be kept regardless of final conditions. In case of artificial-snow measurements failure, the emphasis of the proposed methodology of data-analysis will be shifted to the general air-quality comparison between the highly-urbanised ski-resorts and tourist-free valleys - closely related subject within the same EC scientific discipline.

The data analysis is aimed at separation and identification of the phenomena signatures with limited expectations for quantitative results. The flight planning is adequately focused on wide area coverage in order to create a data-set with wide spectrum of cases for comparison. The approach aims at enlarging the probability of successful qualitative phenomena reflectance in the data while simplifying the experiment planning within the framework of "Education & Training".

Weather conditions:

(e.g. clouds, atmospheric stability, wind speed and direction, weather...)

Snow-making requires (dependant on technique and usage of water additives including ICN) specific weather conditions of low snow cover and generally negative temperatures (theoretically negative wet bulb temperatures).

Time constraints:

(night time, under-pass(es) of satellites, weekends...)

There is no strict time constraint, however normally man-made snow production is intensified during piste-grooming taking place mostly in the afternoon and night. Afternoon or night measurements would also reduce the background from LIDAR sensor which may be important due to high albedo of snow. Additionally cross-valley circulations may have influence on the vertical range of the artificial snow sourced signatures - particularly the afternoon anabatic currents.

Highest probability of artificial-snowing is assumed to occur in December--February period due to lower temperatures and high tourist-traffic.

Location(s) and reason for that choice:

The research topic of the experiment is strictly related to the Alpine environment. Together with the need of locating the experiment in the region characterised by extensive ski-resort coverage, the choice of locations can be narrowed down to: France, Germany, Spain,

Austria, Switzerland or Italy. Furthermore, taking into account legislative issues concerning the usage of crystallization-nuclei-rich water additives for artificial-snowing (notably Snomax), excluding Germany and Italy from the choice allows expecting the man-made snow production at higher temperatures. The final location of the experiment should depend on the current weather conditions and artificial snowing activity reported by the ski-resort - it may be chosen from a wide choice of options and can therefore bypass the problems of local weather conditions for flight. In order to enhance the quality of the comparison of the measured properties to the assumed modified state of atmosphere, a location in the vicinity of aerological sounding station or weather observatory should be selected. An example of suitable flight-path goes along the French-Swiss and French-Italian borderlines starting southward from the Lemman lake. Such route would

give the opportunity to probe the air over such resorts as: 3 Valleys - 1920 snow cannons (Wikipedia), Alpe d'Huez - 785 snow cannons (ski-france.com), Paradiski - 559 snow cannons (resort website), Chamonix - 403 snow cannons (ski-france.com), Espace Killy - 331 snow cannons (ski-france.com) and compare the results with non-ski-cultivated valleys as well as smaller resorts. Such option would imply refuelling before come-back to Berlin (in case of C207), therefore a similar set of ski-resorts can be selected from the Austrian Alps if needed.

Number of flights and flight patterns:

Following the proposed approach of measuring various valley-cases during single flight, a single-flight data-set would create the possibility to carry out planned data analysis and further research. Given the opportunity for two or three flights attempt to repeat the same flight path is suggested. Flight patterns should present a compromise between constant-level LIDAR scanning along the valleys/ski-areas and in-situ dives. The LIDAR leg flight-level should be set up as close to the local boundary layer capping as possible while agreeing with the terrain characteristics and ATC allowance. The shorter in-situ legs should preferably be performed at the lowest possible flying altitude with descent and ascent in the vicinity of snow-production locations. One flight would consist of 5 to 15 valley-cases depending on the region-choice and relative ski-resort location.

Other constraints or requirements:

none

3. Parameters to be measured / Instrumentation

Description of parameter / measurement required for the experiment:

The key measurement for the experiment are the water vapour distribution in the lower troposphere. In case of the FUB-C207 aircraft, in-situ measurement is carried out using the DLR hygrometer ensemble consisting of a dew-point mirror, capacitive sensor and a Lyman-Alpha instrument. Remote sensing is performed by the downward-looking POLIS LIDAR providing vertical profiles based on reflectance-based signal. Other measured meteorological parameters as temperature and radiative fluxes may be used in data analysis to reinforce the identification of man-made snow signatures from other phenomena. The alternative Partenavia aircraft, while not providing remote sensing measurements, enhances the in-situ measurement spectra with the Nevzorov Liquid Water and Total Condensate Probe and various cloud-water and aerosol radii spectrum equipment.

Instruments to be provided by hosting Aircraft Operator:

(basic instrumentation described on EUFAR website only)

DLR-Falcon hygrometer (basic instrumentation)
Temperature sensor
POLIS downward looking LIDAR (optional instrumentation)
GPS via aircraft avionics (if possible)

Own instruments to be added:

(have they already been flown? Do they have their own data acquisition system?)

none (or GPS if needed)

Number of instrument operators needed onboard:

(in addition to those provided by the Aircraft Operator)

2

If applicable, plans for simultaneous field work / ground equipment to be used:

Snow-production intensity and reported weather conditions is to be acquired by means of contact with ski-resort maintenance entities and archiving of the web-published ski-conditions reports.

4. Data processing and analysis

Methodology for handling the data and analysis of output:

(airborne data acquisition, ground-truthing / observations, data processing and interpretation)

The methodology of data analysis places emphasis on elimination of any background phenomena which may lead to false interpretation of a weak signal of the man-made snow production. This implies good spacial recognition of the artificial snow production sites. In order to ease the understanding of terrain and geography influences and correlations with the measurement results, usage of GIS (Open Source Grass package e.g.) software is proposed for data storage and manipulation. GIS package would allow to merge the data-sets of different types as in-situ data, profile-derived values, satellite and geographical data (location of ski-resorts, and snow-cannons concentrations) and create an effective tool for selecting high-resolution samples for case-studies. Additionally a complete data-set in form of netCDF files will be compiled for publishing on the experiment website.

Both case-study analysis and the overall GIS-based approach are proposed in order to extract the correlation coefficients between snow-production intensity and deviations of water vapour concentration in the air.

Noting of the significant features on the ground during in-situ legs: valley classification, snow-production activity etc. should be carried out onboard the aircraft.

What resources are available to support the project beyond flying / data acquisition:

(funding, cooperation with other projects, manpower for analysis of results and preparation of user report, availability of laboratory facilities, etc)

Data analysis and further experiment planning will be supervised by the staff of the Atmospheric Physics Division, Institute of Geophysics, University of Warsaw.

5. Planning

Primary / preferred dates:

Starting date: 11-02-2008

Ending date: 16-02-2008

Acceptable dates:

(season / time windows)

all Alpine winter months: November -- April with emphasis on colder months.

Agree to share aircraft time:

Yes

6. Other useful comments

Training benefit of the project:

(e.g. spread potential of airborne research to a wide scientific community; training of research students in experimental planning, methodology, data analysis and applications, etc)

The campaign aims at creating an academic experiment carried out by students. The campaign

planning would preferably be continued with other co-operating students invited to join the campaign through the "Join an existing campaign" EUFAR opportunity.

Further campaign planning and data analysis will be reinforced by the knowledge gathered during the EUFAR Summer School On Boundary Layer Research With Instrumented Aircraft.

Scientific reviewers suggested by applicant:

Carmen de Jong, The Mountain Institute University of Savoy (co-chairman of the EGU 2007 artificial-snow debate) (carmen.dejong@institut-montagne.org)

Mathias Wiegner, Meteorologisches Institut, Universitat Munchen (POLIS Lidar) (m.wiegner@meteo.physik.uni-muenchen.de)

Martin Streibel, Centre for Atmospheric Science, Cambridge University (airborne campaign logistics / scientific coordination, supervisor of Sylwester Arabas activities during participation in the Geophysica-AMMA campaign through the EUFAR "Education & Training" programme) (Martin.Streibel@atm.ch.cam.ac.uk)

Other European funding:

not known

Is the applicant agreeing to host a student during campaign and data analysis:

(in the frame of Education & Training "Join an existing campaign" activity)

Yes

Number of students: 3

Number of days recommended for students: 5

Where does the applicant know EUFAR Transnational Access and Education&Training opportunities from?

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