SEASALT

Signatures of Evaporation of Artificial Snow in Alpine Lower Troposphere

Academic Airborne Research Campaign Proposal

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EUFAR Application form for Transnational Access Project Education and Training proposal

Project title *(Max 255 characters):

Signatures of Evaporation of Artificial Snow in Alpine Lower Troposphere

Project acronym *(Max 20 characters):

SEASALT

Main scientific field:

Earth Sciences & Environment

Figure 1: Artificial snow production in the Valdezcaray resort, Spain. November 2005. (photo released into the public domain)

Specific discipline: * Note: This is a complete list of Scientific Fields from the European Commission and only some will be applicable to EUFAR

FP6 – Ecosystems & Biodiversity

Scientific theme:*(one sentence)

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

Participants undertaking research:

Sylwester Arabas

Other scientists (mandatory to get Travel&Subsistence expenses reimbursed)

A students group to be completed by means of EUFAR *Join an existing campaign* opportunity.

List up to 5 relevant publications by applicant group in last 5 years (not mandatory). (can be added even after having submitted this form)

none

Describe the scientific problems being addressed by the experiments you would like to perform. Give a brief summary of your experiments. * (max 250 words)

The key 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 atmospheric context of the issue - modification of the local hydro-budget by atmospheric processes involving the artificial snow: advection of the evaporated water vapour. 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 i 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 issue was the key-subject of one of the Great Debates of the European Geosciences Union General Assembly in 2007 entitled *We must curtail the use of artificial snow.* The debate (leaded by Carmen de Jong, Christian Rixen, Christan Baumgartner and Nicholas Arndt) 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); *"To make artificial snow all day long and during the whole* *season is just completely irresponsible for our climate, especially on such a large scale," said Carmen de Jong, professor and research manager at the Mountain Institute at the University of Savoie in France [...] during the annual meeting this week of the European Geosciences Union in Vienna. [...] 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," she said [...]* (*Artificial snow harms Alpine water system*, Reuters 18/04/2007).

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.

Aircraft: (leave blank if unknown,the evaluation panel will propose you the most suitable aircraft) Details of the aircraft

FUB - C 207 (Cessna T207A) operated by Freie Universität Berlin, Institut für Weltraumwissenschaften

Figure 2: A satellite view over the Alps. source: earthobservatory.nasa.gov

Briefly indicate why you believe this aircraft best suits your experiments: * (mandatory if you select an aircraft)

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: (leave blank if unknown. You can select several aircraft that could be used for your experiments)

Enviscope-Partenavia (Frankfurt, Germany) and FZK - ENDURO (Garmisch-Partenkirchen, Germany)

Scientific objectives / proposed work / anticipated output: *(1 page max)

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-canons. 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: (time of the day, under-pass(es) of satellites, weekends, season...)

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: (if location is mandatory, provide justifications)

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

Figure 3: Alpine ski-resort map. source: www.all-mountain.com

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 Leman 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 refualling before come-back to Berlin (in case of C207), therefore a similiar 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.

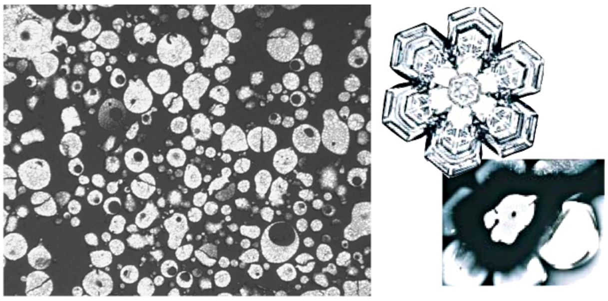

Figure 4: left: Artificial snow grains (thin section $0.03mm$, $2mm$ x $2mm$), liquid water in some grains, some grains broken from pressure during freezing process. source: Fauve et al. 2002; right: A schematic snowflake drawing compared to a micrograph of (4200x magnified) ice crystal crystallized on a Snomax nucleus (The dark speck at the flake's center). source: Scientific American Jan 07 / SNOMAX Technologies

Other constraints or requirements:

none

Description of parameter/measurement required for experiment:

The key measurement for the experiment are the water vapour distribution in the lower troposphere. In case of the FUB-C207 aircraft, insitu 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.

If you know, please indicate instruments to be provided by hosting Aircraft Operator: (basic instrumentation owned by the aircraft operator described on EUFAR website only: http://www.eufar.net/ instruments)

DLR-Falcon hygrometer (basic)
POLIS downward looking LIDAR (optional)

Own instruments to be added:

none

Do you need instrument operators onboard (in addition to those provided by the Aircraft Operator)?: If so, how many?

yes – at least one person in charge of noting the significant features on the ground during in-situ legs: valley classification, snow-production activity etc.

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.

What is your 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.

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...)

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

Primary/Preferred dates: (DD-MM-YYYY)

11-02-2008 – 15-02-2008

Acceptable dates:

01-12-2007 – 31-02-2008

(season / time windows): note: greater flexibility improves ability of operator to accommodate request

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

Would you agree to share aircraft time?: (cost sharing)

yes

Training benefit: (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.

If possible, suggest up to 3 scientific reviewers for your application that EUFAR may contact:

Carmen de Jong, The Mountain Institute University of Savoy (co-chairman of the EGU 2007 artificial-snow debate) (carmen.dejong@institut-montagne.org)
Mathhias Wiegner, Meteorologisches Institut, Universität München (POLIS Lidar) (m.wiegner@meteo.physik.uni-muenchen.de)
Martin Streibel, Centre for Atmospheric Science, Cambridge University (airborne campaign logistics / scientific coordiation, 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)

List all sources of "European Commission" funding (mandatory): (as far as you are aware, please list any current EU funded projects that your proposed work may be related to)

Can your institute provide scientific training to EUFAR sponsored scientists within the fields of your proposed experiments and analysis? (in other words, can you host students (supported by EUFAR) during the campaign and the data analysis (in the frame of EUFAR Education & Training "Join an existing campaign" activity?)

yes

If yes: Number of students:

3

Number of days recommended for students:

5

Where do you know EUFAR Transnational Access and Education & Training opportunities from?

Advertisement from your University/Institute