Wednesday, 25/May/2016 12:00pm - 12:20pm
ID: 102 / 25-AM3-SA6: 5
oral presentation
Topics: SA - Science applications

An update on the ERASMUS (Evaluation of Routine Atmospheric Sounding Measurements using Unmanned Systems) Campaign

Gijs de Boer[1,2], Dale Lawrence[1], Scott Palo[1], Brian Argrow[1], Gabriel LoDolce[1], James Mack[1], Nathan Curry[1], William Finamore[1], Joshua Fromm[1], Cameron Trussel[1], Phillip D'Amore[1], Douglas Weibel[1], Chuck Long[1,2], Ru-Shan Gao[2], Hagen Telg[1,2], Beat Schmid[3], Mark Ivey[4], Albert Bendure[4], Geoff Bland[5]

[1]University of Colorado - Boulder, United States of America; [2]NOAA Earth System Research Laboratory; [3]Pacific Northwest National Laboratory; [4]Sandia National Laboratories; [5]NASA Wallops

The US Department of Energy has funded a campaign to make atmospheric measurements at Oliktok Point, Alaska. This campaign, Evaluation of Routine Atmospheric Sounding Measurements using Unmanned Systems (ERASMUS) deploys two different unmanned aircraft systems, the 1-meter CU DataHawk2 and the 3.2-meter, 55 lb. CU Pilatus. As of April 2016, these platforms will have completed two deployments to Oliktok Point, with the first being during August, 2015, and the second during April, 2016. Primary measurement targets for these aircraft include thermodynamic quantities and surface temperatures (DataHawk2) as well as aerosol size distribution, broadband net radiation, and atmospheric thermodynamics (Pilatus).

In this presentation, we will provide an overview of all aspects of these platforms and their deployment as part of ERASMUS. This will include information on systems and sensors, details on scientific goals, flight patterns, available airspace, and preliminary scientific results. Additionally, we will provide insight into upcoming activities at Oliktok Point, including information on new capabilities being developed by the US Department of Energy Atmospheric Radiation Measurement (ARM) program, related to use of unmanned aircraft.

Wednesday, 25/May/2016 10:40am - 11:00am
ID: 103 / 25-AM3-SA6: 1
oral presentation
Topics: SA - Science applications

Observations of Air-Sea Interactions in an Antarctic Coastal Polynya Using Small Unmanned Aerial Systems

John Joseph Cassano
University of Colorado, United States of America

Since 2009 our research group has used modest (~15 kg) sized Aerosonde UAS to make observations of the polar atmospheric boundary layer and air-sea interactions. Long distance and duration Aerosonde flights in 2009 and 2012 were used to study the atmospheric state and air-sea interactions over the Terra Nova Bay polynya. The UAS observations documented the downwind evolution of the cold, dry, continental atmospheric boundary layer as it passed over the polynya and were used to estimate turbulent heat, moisture, and momentum fluxes and diagnose thermodynamic and dynamic processes acting over the polynya. This presentation will focus on our analysis of the terms in the horizontal momentum equation diagnosed from the UAS observations.

ID: 104
poster
Topics: SA - Science applications

Methane source and sink localization with a hexacopter in the lowest planetary boundary layer: Proof of concept and first results

Caroline Brosy, Karina Krampf, Benjamin Wolf, Wolfgang Junkermann, Stefan Emeis, Klaus Schäfer, Harald Kunstmann
KIT/IMK-IFU, Germany

Investigation of the planetary boundary layer (PBL) is important to understand the interactions between the global climate system and the earth's surface. The global budget of greenhouse gases is well known, but small-scale information is still missing to improve the knowledge about processes and dynamics in this layer. During our ScaleX intensive measurement campaign in June and July 2015, vertical profiles of the highly effective greenhouse gas methane were measured with a hexacopter over the Fendt field site, located in the foothills of the Bavarian Alps in southern Germany. The prevailing land use here is grassland with sporadic cropland. The dominating methane sources at this measurement site are probably nearby dairy farms, while wet grassland sites may play a further important role.

Due to the fact, that the methane sensor was too heavy to fly on board the unmanned aerial vehicle (UAV), a Teflon tube was mounted on it and raised up in the air for the measurements. The possible payload of the small UAV restricted the flight height to 50 m above ground level (agl). Additionally, the hexacopter measurement results were compared with in situ methane measurements at a 10 m tower. Investigations of the dispersion of methane are dependent on information about the atmospheric conditions. Therefore, air temperature, humidity and air pressure were measured on board the hexacopter, while wind direction and speed were calculated from the autopilot's attitude control data with pitch, roll and yaw angles.

During night-time with stable atmospheric stratification, accumulation of methane near the ground was found with concentrations of about 500 ppb higher compared to the background concentration of 1.85 ppm, also measured during this campaign. Wind speed was slow during that time and wind direction often matched with the location of the dairy farms.

Our future research focuses on a small and lightweight methane sensor for installation on board to be able to investigate horizontal methane distributions, too. This would allow for an even better localization of sources and sinks, possibly also the determination of their strength and the mixing of the lower PBL.

ID: 105
poster
Topics: IPI - Instrumentation and payload integration

VOLTIGE program educational aspect : active teaching and learning of the use of RPA in meteorology.

Grégoire Cayez[1], Greg Roberts[2]
[1]National School for Meteorology, Météo-France, France; [2]National Center for Meteorological Research, Météo-France, France

The VOLTIGE (Vecteurs d'Observation de La Troposphere pour l'Investigation et la Gestion de l'Environnement) program developed an observing system to study the life cycle of fog with multiple ultra-light RPAs (Remotely Piloted Aircraft). The National School for Meteorology (ENM) contributed to the project as a partner to develop active teaching and learning of the use of RPA in meteorology.

Four engineering classes have been conducted to address general topics related to atmospheric measurements performed by RPAs :

- brainstorming on the research topics particularly suited for RPA in atmospheric measurements,

- participating and analyzing data from VOLTIGE field campaigns,

- preparing the RPA, the ground station and the sensors for the BAC+ (Basse Couche Campagne); a follow-up project from VOLTIGE to conduct regular measurements towards an operational program.

These topics, based on real cases of scientific and technological challenges, have helped the students to choose their advanced study projects within the ENM curriculum. It was also an opportunity to encourage them to develop careers in atmospheric sciences.

Students' reflections about integrating RPA into an operational network has initiated discussions of the operational programs using RPA as reusable sondes within METEO FRANCE. ENM students have developed the platform and sensors for the BAC+ program, which serves as a pilot study towards an operational program. The next phase of the study will analyse the data of the recurrents flights performed in the Landes region of southwestern France.

The implication of students provided an opportunity for VOLTIGE to add educational component by engaging the next generation of engineers and scientists. Outreach has been conducted via university newsletters to highlight the student involvement in the project. VOLTIGE has also provided a link to the world of research and operational meteorology – even providing incentive for choosing career paths in the field. For ENM, this type of experience develops active learning experience and creates motivation and a strong will for team efforts among the students.

ID: 106
poster
Topics: SA - Science applications

Vertical profile measurements of aerosol and cloud properties using Remotely Piloted Aircraft System during Pallas Cloud Experiment 2015

Priit Tisler, David Brus
Finnish Meteorological Institute, Finland

Remotely Piloted Aircraft Systems (RPAS) are increasingly being used for scientific studies. On the one hand it is due to the miniaturization of scientific instrumentation and versatility of unmanned platforms, on the other hand due to cost-effectiveness and safety compared to manned flights. Modern RPAS are rather easy to operate, that make the utilization of them for scientists very attractive, particularly in remote (polar) environments.

The 6th Pallas cloud experiment was carried out between September 25th and December 5th 2015, at Finnish Meteorological Institute's (FMI) Pallas-Sodankylä Global Atmosphere Watch (GAW) station in Finnish sub-Arctic region. Clouds, and their interaction with the environment, are in general investigated through two types of measurements: a) in-situ, airborne or ground-based campaigns or b) ground-based remote-sensing techniques (i.e. lidar, ceilometer and radar) and satellite. During the campaign we utilized both above mentioned approaches to investigate aerosol-cloud interactions.

Vertical profiling of aerosol and cloud properties up to 150 m (aviation authorities restricted height) was performed by using a FMI-owned RPAS platform (rotary-wing quadcopter). Measurements were carried out in the vicinity of the Sammaltunturi fjeld at three locations with different above sea level altitudes: next to Pallasjarvi (300 m.a.s.l.), Sammaltunturi foothills (440 m.a.s.l.) and Kenttärova station (345 m.a.s.l.). The RPAS platform carried on following set instruments: a CPC model 3007 (TSI Inc., USA), an OPS model 3330 (TSI Inc., USA), a micro-Aethalometer model AE51 (AethLabs, USA). Observed particle number concentration show generally decreasing trend with height, except in case of presence of cloud at foothills. The vertical profiles were mutually compared to ground-based measurements conducted at the Sammaltunturi station which resides on the top of Sammaltunturi fjeld (565 m.a.s.l.) and also data obtained from Kenttärova station, where the remote-sensing instruments were located. Comparison of the airborne measurements with station data show reasonably good agreement.

ID: 107
poster
Topics: IPI - Instrumentation and payload integration

Implementation of a 5-hole Probe on Remotely Piloted Aircraft for Aerosol-Cloud Interaction Measurements

Radiance Calmer[1], Greg Roberts[1,2], Kevin Sanchez[1,2], Keri Nicoll[3], Jana Preissler[4], Jurgita Ovadnevaite[4], Jean Sciare[5], Murat Bronz[6]

[1]CNRS-Météo France, France; [2]Scripps Institution of Oceanography, CA, United States; [3]University of Reading, UK; [4]National University of Ireland Galway, Ireland; [5]The Cyprus Institue, Cyprus; [6]Ecole Nationale de l'Aviation Civile, France

Enhancements in Remotely Piloted Aircraft Systems (RPAS) have increased their possible uses in many fields for the past two decades. For atmospheric research, ultra-light RPAS (< 2.5kg) are now able to fly at altitudes greater than 3 km and even in cloud, which opens new opportunities to understand aerosol-cloud interactions. The European project BACCHUS (Impact of Biogenic versus Anthropogenic Emissions on Clouds and Climate: towards a Holistic Understanding) focuses on these specific interactions.

Field experiments in Cyprus and Ireland have already been conducted as part of the BACCHUS project to study aerosol-cloud interactions in climatically different environments. The RPAS are being utilized in this study with the purpose of complementing ground-based observations of cloud condensation nuclei (CCN) to conduct aerosol-cloud closure studies by characterizing the vertical distribution of aerosol, radiative fluxes, 3D wind vectors and meteorological state parameters. Cloud microphysical properties such as cloud drop number concentration and size can be predicted directly from the measured CCN spectrum and the observed updraft, the vertical component of the wind vector. On the RPAS, updraft measurements are obtained from a 5-hole probe synchronized with an Inertial Measurement Unit (IMU). The RPA (Remotely Piloted Aircraft) are programmed to fly at a level leg just below cloud base to measure updraft measurements while a scanning CCN counter is stationed at ground level. Vertical profiles confirm that CCN measurements on the ground are representative to those at cloud base. The 5-hole probe to measure 3D wind vectors has been calibrated in wind tunnel and comparison of flight results has been done with sonic anemometer located on meteo mast. Vertical wind velocity obtained from the 5-hole probe has also been compared with vertical wind measured from cloud radar and Doppler Lidar installed at Mace Head station, Ireland. Whatever the weather conditions were, weak or strong wind, updraft range at cloud base from the 5-hole probe and ground instruments are very similar.

ID: 108
oral presentation
Topics: SA - Science applications

Observing shallow convective cumulus with an UAV

Hongbin Chen, Hongrong Shi, Jun Li, Jinqiang Zhang, Chao Ling, Wenying He
Institute of Atmospheric Physics, Chinese Academy of Sciences, China, People's Republic of

Shallow convection may play an important role in the vertical transports of heat, moisture and momentum and in the albedo enhancement both over ocean and land. In summer season, there is cluster of shallow cumulus over Inner Mongolian Plateau. Due to their relatively small size, short lifetime, and random occurrence, observational studies are difficult to conduct on them with satellite and ground-based remote sensing.

During 2 to 9 August 2015, an intensive observation campaign in Baiqi over the Inner Mongolian Plateau was carried out mainly for investigating the environmental conditions of shallow convection formation. About 9 GPS radiosondes were launched from 8:30 to 20:30 in the daytime. A RGP 14-channel microwave radiometer, a boundary layer wind profiler, a Cimel-318 sunphotometer, an AWS, and a Licor7500 flux measurement system were deployed. In particular, an UAV equipped with a modified GPS radiosonde, a pair of pyranometers and a camera was used to make flight observations at 5 height levels in a 10 km by 10 km area. Some preliminary measurement results are given in this presentation.

(This work is supported by the National Science Foundation of China under the grant 41305011.)

Tuesday, 24/May/2016 1:20pm - 1:40pm
ID: 109 / 24-PM2-SA4: 1
oral presentation
Topics: SA - Science applications

Electrical charge measurements in clear and cloudy conditions from fixed wing UAVs

Keri Nicoll[1], Giles Harrison[1], Greg Roberts[2]
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Charge is a fundamental property of the atmosphere and is continually generated in the form of atmospheric cluster ions by ionisation from galactic cosmic rays from outside the solar system, and, near the ground, radioactivity from the soil. Attachment of cluster ions to atmospheric aerosol particles and cloud droplets transfers charge, potentially influencing the growth and transport of particles and droplets. Such effects may play a role in long range transport of dust and volcanic ash layers, as well as influencing cloud microphysical properties such as cloud droplet growth. Few quantitative measurements of the typical magnitude of charge in the fair weather and semi-fair weather atmosphere exist above the surface, therefore quantifying the effect of charge on such processes is difficult. This work presents new measurements of charge from fixed wing UAV platforms in both clear air and cloudy conditions. Charge is measured using a small spherical electrode connected to a sensitive electrometer, which primarily responds to induced displacement currents generated by electric field changes as the sensor moves through the charge layer. In cloud measurements are augmented by a specially developed disposable optical cloud droplet sensor which uses a backscatter technique to sense cloud droplets. The combination of optical and charge measurements not only provides a very accurate measurement of the location of the upper and lower cloud edges, but enables a measurement of cloud droplet charge to be made. Charge measurements in clear sky conditions show the close correlation between charge and boundary layer stability, with elevated charge levels almost always being capped by the boundary layer top inversion.

Monday, 23/May/2016 4:00pm - 4:20pm
ID: 110 / 23-PM6-ACS2: 1
oral presentation
Topics: ACS - Aircraft and control systems

Modelling of sub-cumulus thermal updrafts for autonomous soaring UAVs

Martin Tobias Stolle, Yoko Watanabe, Carsten Döll
ONERA, France

This work focuses on the vision-based remote sensing of thermal updrafts under cumulus clouds for glider UAVs. These clouds can indicate the position of thermal updrafts, which are required in autonomous soaring. To this date, methods have been presented for the on-board estimation of cumulus cloud positions, based on vision. The presented methods presume the unlimited lifespan of cumulus-related thermal updrafts. Naturally occuring thermals are however of limited duration. This increases the risk of an outlanding when utilizing these methods. By observing the evolution of the cloud's diameter, human glider pilots draw conclusions on both the remaining lifetime and the strength of the related updraft. To bring this capacity to autonomous soaring UAVs, a simple but realistic model describing the relation between cloud size evolution and updraft parameters is presented. The model lays the foundation for future on-board updraft lifespan and strength estimation, thus contributing to the applycability of autonomous soaring.

Monday, 23/May/2016 10:00am - 10:20am
ID: 111 / 23-AM3-SA1: 3
no preference
Topics: SA - Science applications

Evaluation of UAS for Infrared Bridge Inspection Using Historic and Predictive Weather Data

Suzanne Weaver Smith, Gregorio Robles-Vega
University of Kentucky, United States of America

Motivation for this study is the potential of using an unmanned aerial system (UAS) with an infrared camera to scan bridges for material delamination forming beneath the pavement or structure surface. Effective inspection is known to be possible on days when the temperature increase exceeds a required minimum for infrared imaging of delamination. Investigations across the U.S., including in Kentucky, with fixed and ground-vehicle-based moving infrared systems previously demonstrated the potential and scanning motion limits of infrared delamination detection. However, when sensors are UAS-mounted, weather conditions may also limit the ability to fly when precipitation, sustained wind speeds or gusts are too high. The first phase of the study quantified the expected daily opportunity to employ UAS-based infrared inspection based on the National Oceanic and Atmospheric Administrations (NOAA) historical weather database. Metrics obtained from the NOAA database included hourly temperature and hourly average wind speed in order to determine when historically sufficient temperature differences and necessary low-wind conditions existed simultaneously. In order to have acceptable conditions the temperature gradient for the day needed to be at least 14°F (10°C) with a maximum permissible wind speed of 10mph (16kph). For the state of Kentucky, acceptable conditions occur historically in months from May to October with optimum time periods between 11:00 a.m. and 5:00 p.m. The results indicate that UAS equipped with infrared can be used to conduct bridge inspections in the state for six months of the year. Further, the process applied for the evaluation can be applied to evaluate viability for locations across the U.S.

In addition, a tool for short-term (weekly) advance planning is desirable. For this reason, an evaluation was conducted of using the hourly NOAA weather forecast available to the public for UAS-based infrared inspection planning. NOAA's hourly weather forecast provides forward predictions as far out as five days for heat index, dew point, temperature, surface wind speed, gusts, precipitation potential, sky cover, relative humidity, rain, and thunder. The city of Lexington in the state of Kentucky was used as a location for evaluating NOAA's hourly weather forecast tool for planning infrared UAS bridge inspection. The first evaluation focused on the accuracy of the temperature gradient, average wind speed, and precipitation predictions for the target inspection day compared to the actual. A comparison was made for each progressive day for which there was a prediction made (i.e. second day out prediction, third day out prediction) to see if there when the prediction-based planning breaks down. The evaluation also looked specifically at the hourly results to see if a satisfactory accuracy resulted for planned scheduling on a certain day would be possible. Through these evaluations it was shown that the forward prediction tool is sufficiently reliable for UAS-based infrared bridge inspection planning.

Wednesday, 25/May/2016 10:00am - 10:20am
ID: 112 / 25-AM1-SA5: 4
no preference
Topics: SA - Science applications

Atmospheric research with drones in Ny-Ålesund, Svalbard

Stian Solbø, Rune Storvold, Agnar Sivertsen
Norut Northern Research Institute, Norway

Ny-Ålesund is a hotspot for climate and environmental studies in the Arctic, with the presence of permanent research stations from ten countries and scientific activities from numerous more. Starting with IPY, there has been conducted several scientific measurement campaigns using drones each year, with objectives within different disciplines, including, atmosphere, climate, meteorology, biology and glaciology. Recently, the Arctic Centre for Unmanned Aircraft (ASUF) opened a new facility next to the airport, which enhances the use of drones from Ny-Ålesund even further. It is possible to conduct science flights BVLOS of several hundred KMs, well into the Fram Strait and Barents sea as well as altitudes up to 12000'.

In this talk we will highlight the comprehensive capacity of the existing facilities in Ny-Ålesund to provide supporting data in connection to drone based research on atmospheric research including trace gases, aerosols, clouds and boundary layer meteorology just to mention some applications. Further, we will provide an overview of previous flight campaigns from Ny-Ålesund, and describe how to get access to the ASUF facilities and the airspace.

Tuesday, 24/May/2016 2:20pm - 2:40pm
ID: 113 / 24-PM3-IPI1: 1
oral presentation
Topics: IPI - Instrumentation and payload integration

Boundary-layer radiosonde and UAV sensors

Anders Petersson
Sparv Embedded AB, Sweden

Sparv Embedded will present how the company supplies novel measurement equipment to atmospheric researchers.

Windsond is a new, miniature radiosonde specialized for low altitudes, where it only needs 30 liters of helium and a 8 gram balloon. This enables a new level of portability such as releasing a radiosonde through a rolled down car window. The sondes are easily recovered and reused. Windsond is becoming popular for meteorological reseach.

Researchers have also started using Windsond for different special projects which we will present. Stripping down the sonde and attaching it to fixed-wing and rotary-wing UAVs is becoming quite popular. We took inspiration from this to start development of a "sensor kit".

The sensor kit is specialised for making it trivial to integrate a range of sensors on UAVs, balloons and other mobile platforms. Weight, size and power consumption are designed to fit even the smallest RPAS. A large number of sensors of the same or different kinds can be connected at the same time. The kit hides the electrical and programming details of sensors, making them plug-and-play. Data is synchronized with GPS, logged and optionally transmitted as real-time, long-range telemetry. For telemetry, Android and Windows devices can receive the data on the ground, with option to add support for Mac, Linux and iOS. The kit is very adaptable to new sensors, radio modems, etc.

We will show the possibilities of our solutions and ask for suggestions for the continued development. For example, we want to know what sensors the community would find useful.

Tuesday, 24/May/2016 10:00am - 10:20am
ID: 114 / 24-AM2-SA3: 4
oral presentation
Topics: ACS - Aircraft and control systems

EUFAR: a portal for airborne research in Europe

Elisabeth GERARD[1], Phil BROWN[2], Francesco CAIRO[3]
[1]Météo-France, France; [2]Met Office, UK; [3]Consiglio Nazionale delle Ricerche, Italy

Created in 2000 and supported by the EU Framework Programmes since then, EUFAR was born out of the necessity to create a central network and access point for the airborne research community in Europe. With the aim to support researchers by granting them access to research infrastructures, not accessible in their home countries, EUFAR also provides technical support and training in the field of airborne research for the environmental and geo-sciences.

Today, EUFAR2 (2014-2018) coordinates and facilitates transnational access to 18 instrumented aircraft and 3 remote-sensing instruments through the 13 operators who are part of EUFAR's current 24-partner European consortium. In addition, the current project supports networking and research activities focused on providing an enabling environment for and promoting airborne research.

The EUFAR2 activities cover three objectives, supported by the internet website www.eufar.net: (i – Institutional) improvement of the access to the research infrastructures and development of the future fleet according to the strategic advisory committee (SAC) recommendations; (ii – Innovation) improvement of the scientific knowledge and promotion of innovating instruments, processes and services for the emergence of new industrial technologies, with an identification of industrial needs by the SAC; (iii – Service) optimisation and harmonisation of the use of the research infrastructures through the development of the community of young researches in airborne science, of the standards and protocols and of the airborne central database.

With the launch of a brand new website (www.eufar.net) in mid-November 2015, EUFAR aims to improve user experience on the website, which serves as a source of information and a hub where users are able to collaborate, learn, share expertise and best practices, and apply for transnational access, and education and training funded opportunities within the network. With its newly designed eye-catching interface, the website offers easy navigation, and user friendly functionalities. New features also include a section on news and airborne research stories to keep users up-to-date on EUFAR's activities, a career section, photo galleries, and much more. By elaborating new solutions for the web portal, EUFAR continues to serve as an interactive and dynamic platform bringing together experts, early-stage researchers, operators, data users, industry and other stakeholders in the airborne research community.

A main focus of the current project is the establishment of a sustainable legal structure for EUFAR. This is critical to ensuring the continuity of EUFAR and securing, at the least, partial financial independence from the European Commission who has been funding the project since its start. After carefully examining different legal forms relevant for EUFAR, the arguments are strongly in favour of establishing an International non-profit Association under the Belgian law (AISBL). Together with the implementation of an Open Access scheme by means of resource-sharing to support the mobility of personnel across countries envisaged in 2016, such a sustainable structure would contribute substantially toward broadening the user base of existing airborne research facilities in Europe and mobilising additional resources for this end. In essence, this would cement EUFAR's position as the key portal for airborne research in Europe.

Part of the strategy for the AISBL will be to consider how manned aircraft and unmanned aerial systems can be used together in the future and how developments in one area interact with the other.

ID: 115
poster
Topics: IPI - Instrumentation and payload integration

Recent measurement instrumentation for the research UAV MASC

Alexander Rautenberg, **Andreas Platis, Norman Wildmann, Jens Bange**
Eberhard Karls Universität Tübingen, Germany

For atmospheric research, boundary-layer meteorology and wind-energy studies, the environmental physics group ('umphy') at the Centre for Applied Geo-Science (ZAG), University of Tübingen, Germany, designed and built a research UAV named MASC (Multi-purpose Airborne Sensor Carrier). MASC is an electrically propelled single engine (pusher) aircraft of 2.7 to 3.5 m wing span. The total weight of the aircraft is 5 to 8 kg, including up to 1.5 kg scientific payload. This UAV is typically operated at an airspeed of 25 m/s, as a trade-off between high spatial resolution of the measured data and gathering a snap-shot of the atmosphere in short time. MASC operates fully automatically (except landing and take-off). Height, flight path and all other parameters of flight guidance are controlled by the autopilot system ROCS (Research Onboard Computer System) developed at at the Institute of Flight Mechanics and Control (iFR) at the University of Stuttgart. The overall endurance of MASC is up to 90 minutes or 135 km. The standard scientific payload carried by MASC consists of several subsystems in order to measure the 3D wind vector, air temperature, water vapour and further parameters. This includes several fast thermometers, a capacitive humidity sensor, a five-hole flow probe, an inertial measurement unit (IMU) and GNSS for position and velocity above ground. The air sensors allow for a real resolution of about 30 Hz (except for air humidity (3 Hz)). Additionally a Fast Response Probe (FRP) will be mounted to resolve turbulence one order of magnitude faster. Preliminary results of wind tunnel measurements and the concept of integration will be presented. Furthermore the optical particle counter CLASP (Compact Lightweight Aerosol Spectrometer Probe), developed at the Institute for Climate and Atmospheric Science, University of Leeds, UK, will be presented. The integration and first measurements with MASC will be shown.

ID: 116
no preference
Topics: ACS - Aircraft and control systems

Monitoring the Evolution of Cumulus Clouds with UAVs

Christophe Reymann, Alessandro Renzaglia, Simon Lacroix
LAAS-CNRS, France

In this work, developed in the framework of the SkyScanner project, we study the problem of monitoring the evolution of atmospheric variables within low-altitude cumulus clouds with a fleet of Unmanned Aerial Vehicles (UAVs). This challenging objective presents two main issues that need to be overcome: i) building on-line maps of highly dynamic phenomena based on sparse, local and noisy measurements and ii) designing planning algorithms which exploit the obtained map to generate trajectories that optimize the adaptive data sampling process, minimizing the uncertainty in the map, while steering the vehicles within the air flows to perform energy-efficient flights.

To deal with the on-line mapping, Gaussian Process Regression (GPR) methods have been adopted. Due to the sparsity of the sampling process in a dynamic 3D environment, the GPR probabilistic framework is indeed particularly suited for this problem. Furthermore, a particular care has been devoted to the on-line optimization of the hyper-parameters defining the Gaussian Processes, as the mapped phenomena may significantly vary in time, and depending on the area within which the UAVs are flying.

The proposed regression model is then the basis on which the energy-efficient data gathering strategies are developed. The local map built with the GPR can indeed be used to generate local feasible trajectories and at the same time provide a prediction on two fundamental quantities: the energy needed to perform such trajectories and the information gain their execution will bring to the cloud map. With all these information in hand, the initial goal can be translated in a multi-criteria optimization problem as follows: finding the optimal control inputs to design safe and feasible trajectories which minimize the UAVs energy consumption, taking into account the wind field, while maximizing the total information collected along the paths. The different criteria are combined in a weighted sum, whose weights can be changed during the mission to define the impact of each criterion. For the trajectory generation and evaluation, we consider short-time planning horizons, typically in the order of 20 seconds. This choice is motivated by two main reasons: firstly, the reliability of the local maps significantly decreases (especially in time), making unrealistic any long-term prediction; secondly, the computational constraints would be harder to respect with larger optimization spaces. Each planning horizon is then further divided in sub-intervals of fixed duration in which the controls (optimization variables) are kept constant. To solve this constrained multi-criteria problem, we propose an optimization scheme composed of two successive phases: a good initialization for the set of trajectories is initially obtained thanks to a blind random search algorithm, and then optimized by using a constrained version of the Simultaneous Perturbation Stochastic Approximation (SPSA) algorithm. This algorithm is based on a simultaneous stochastic perturbation of the entire set of optimization variables to obtain a fast gradient approximation, thanks to which a convergence to a local optimum of the problem is ensured.

The final objective of this work, that is experiment the flight of a fleet of drones within actual cumulus clouds, is yet to achieve. Beforehand, intensive simulations are required to assess the validity of the proposed solutions. With this intent, we present a first integrated simulation architecture, which aims at validating both the mapping and planning algorithms. Some exploration tasks have been depicted, where a fixed area of interest in which the UAVs were tasked to map the 3D wind field has been defined. The obtained results are based on a cumulus cloud model produced by realistic Meso-NH simulations and a realistic motor glider flight dynamics model. Extensive analysis varying the weights on the criteria to optimize and a thorough study of the evolution of the GP hyper-parameters are provided.

Monday, 23/May/2016 2:40pm - 3:00pm
ID: 117 / 23-PM4-ACS1: 1
oral presentation
Topics: ACS - Aircraft and control systems

Fleets of enduring drones to probe atmospheric phenomena with clouds

Simon Lacroix[1], Greg Roberts[2], Emmanuel Bénard[3], Murat Bronz[4], Fédéric Burnet[2], Elkhedim Bouhoubeiny[3], Jean-Philippe Condomines[4], Carsten Doll[5], Gautier Hattenberger[4], Faycal Lamraoui[2], Alessandro Renzaglia[1], Christophe Reymann[1]

[1]LAAS/CNRS, France; [2]CNRM/GAME, France; [3]ISAE, France; [4]ENAC, France; [5]ONERA, France

A full spatio-temporal four-dimensional characterization of the microphysics and dynamics of cloud formation including the onset of precipitation has never been reached. Such a characterization would yield a better understanding of clouds, e.g. to assess the dominant mixing mechanism and the main source of cloudy updraft dilution.

It is the sampling strategy that matters: fully characterizing the evolution over time of the various parameters (P, T, 3D wind, liquid water content, aerosols...) within a cloud volume requires dense spatial sampling for durations of the order of one hour. A fleet of autonomous lightweight UAVs that coordinate themselves in real-time as an intelligent network can fulfill this purpose.

The SkyScanner project targets the development of a fleet of autonomous UAVs to adaptively sample cumuli, so as to provide relevant data to address long standing questions in atmospheric science. It mixes basic researches and experimental developments, and gathers scientists in UAV conception, in optimal flight control, in intelligent cooperative behaviors, and of course atmospheric scientists. Two directions of researches are explored: optimal UAV conception and control, and optimal control of a fleet of UAVs.

The design of UAVs for atmospheric science involves the satisfaction of trade-offs between payload, endurance, ease of deployment... A rational conception scheme that integrates the constraints to optimize a series of criteria, in particular energy consumption, would yield the definition of efficient UAVs. This requires a fine modeling of each involved sub-system and phenomenon, from the motor/propeller efficiency to the aerodynamics at small scale, including the flight control algorithms. The definition of mission profiles is also essential, considering the aerodynamics of clouds, to allow energy harvesting schemes that exploit thermals or gusts. The conception also integrates specific sensors, in particular wind sensor, for which classic technologies are challenged at the low speeds of lightweight UAVs.

The overall control of the fleet so as to gather series of synchronized data in the cloud volume is a poorly informed and highly constrained adaptive sampling problem, in which the UAV motions must be defined to maximize the amount of gathered information and the mission duration. The overall approach casts the problem in a hierarchy of two modeling and decision stages. A macroscopic parametrized model of the cloud is built from the gathered data and exploited at the higher level by an operator, who sets information gathering goals. A subset of the UAV fleet is allocated to each goal, considering the current fleet state. These high level goals are handled by the lower level, which autonomously optimizes the selected UAVs trajectories using an on-line updated dense model of the variables of interest. Building the models involves Gaussian processes techniques (kriging) to fuse the gathered data with a generic cumulus conceptual model, the latter being defined from thorough statistics on realistic MesoNH cloud simulations. The model is exploited by a planner to generate trajectories that minimize the uncertainty in the map, while steering the vehicles within the air flows to save energy.

Wednesday, 25/May/2016 9:20am - 9:40am
ID: 118 / 25-AM1-SA5: 2
oral presentation
Topics: SA - Science applications

Investigation of the flow in complex terrain with regard to wind-energy research using the small remotely piloted aircraft MASC

Alexander Rautenberg[1], Norman Wildmann[1], Christoph Schulz[2], Jan Anger[2], Jens Bange[1]
[1]Eberhard Karls Universität Tübingen, Germany; [2]Universität Stuttgart, Germany

Wind energy is of primary importance for renewable electricity generation and large investments are being made in the field. In southern Germany the best potential sites for wind energy are in complex terrain, where inhomogeneities in the boundary layer, such as thermals and transient structures are induced.

In a joint effort by several research groups of the WindForS (www.windfors.de) competence cluster, the flow over an escarpment on the Swabian Alb is currently investigated in detail. For the prevailing wind direction at our test site, upstream of the potential site for turbines, the flow passes an escarpment, causing acceleration, shear and inclination. A variety of instruments is installed, including several wind LiDAR and a 100 m meteorological tower equipped with IEC-Standard analogue instruments and sonic anemometers. The Environmental Physics working group of the University of Tübingen is collecting airborne in-situ measurements with multiple remotely piloted aircraft on several days of intensive measurements. The instrumentation includes several fast thermometers (≈ 30Hz), a capacitive humidity sensor (≈3Hz), a five-hole flow probe (≈30Hz), an inertial measurement unit (IMU) and GNSS for position and velocity above ground. The goal is to study the airflow in different regimes of thermal stability, different wind speeds and wind directions, as well as different seasons with varying land-use and thus surface roughness, in this complex terrain. Flight patterns with MASC (Multipurpose Airborne Sensor Carrier) are horizontal straight parallel level flights (so-called legs) stacked in 25 m steps between 75-300 m AGL. These flight legs are used to calculate turbulence statistics and turbulent transport, spectra, mean values but also the influence of surface heterogeneity and orography (complex terrain) on the atmosphere. Results of several days of measurements will be presented and compared to the other measurement systems on site and the CFD simulation.

Tuesday, 24/May/2016 3:00pm - 3:20pm
ID: 119 / 24-PM3-IPI1: 3
oral presentation
Topics: IPI - Instrumentation and payload integration

Status Update on iMet-XQ and XF UAV Sensors

Fred Clowney, Joe Barnes
InterMet Systems, United States of America

InterMet has been developing atmospheric sensors for UAVs since 2011 when it helped a customer install a modified radiosonde into a fixed-wing Coyote. This modified sonde has since been transformed into the multi-sensor iMet-XF system that can be configured for a wide range of mission profiles. In 2015 the self-contained iMet-XQ was introduced for making vertical profiles using low-cost rotary-wing airframes. The XQ was distributed to several ISARRA members for beta testing with their feedback incorporated into the recently released production model. This presentation will discuss modifications made to the beta version to improve sensor performance while enhancing the overall usability of the device. We will also discuss our progress in integrating gas sensors into the XF and XQ platforms.

Wednesday, 25/May/2016 9:40am - 10:00am
ID: 120 / 25-AM1-SA5: 3
no preference
Topics: SA - Science applications

3D in-situ measurements of entrainment-related cumulus clouds properties using a swarm of unmanned aerial vehicles

Fayçal Lamraoui[1], Greg Roberts[1,2], Frédéric Brunet[1], Simon Lacroix[3]
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Entrainment-related shallow cumulus clouds properties have largely been studied using large-eddy simulation. These previous studies have led to various cumulus clouds parameterizations. On the other hand, simultaneous in-situ 3D sampling of individual cloud at spatial and temporal resolutions comparable to Large Eddy Simulation (LES) is still lacking. The need to fill in this 3D observational data insufficiency and to validate previous LES findings has propelled the Skyscanner project; using the concept of a multi-UAV-based adaptive sampling strategy. This project is a joint collaboration with institutes specializing in aviation, robotics, and atmospheric science. In order to capture 3D cloud properties simultaneously, the multi-UAVs path planning relies on a cumulus cloud conceptual model. This model that relates the evolution of geometrical and microphysical properties of individual clouds has been derived from LES numerical experiments using MesoNH-LES and potentially WRF-LES models. In addition to the interaction with individual cloud properties, the multi-UAVs path planning is sensitive to the evolution of the convective boundary layer and the cloud spatial extent. The synchronized swarm of unmanned aerial vehicles (UAVs) focuses mainly on locating and quantifying the evolution of the entrainment-related cloud properties including the subsiding shell around individual shallow cumulus clouds.

Monday, 23/May/2016 11:40am - 12:00pm
ID: 121 / 23-AM6-SA2: 3
oral presentation
Topics: SA - Science applications

Weser15 campaign

Burkhard Wrenger[1], Joan Cuxart[2]
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RPAS allow to undertake measurement strategies and address scientific questions that were unthinkable just very recently. In August 2015, the Weser15 campaign was dedicated to the investigation of the small scale thermal signal of the German river Weser, approx. 60 km from Hannover, Paderborn and Kassel, using a multicopter. The region of interest, near Höxter, is characterised by a low mountain range of hills 150-400 m above river level on both sides of the river and the flat river valley created mainly during the last glacial period.

Measurements of temperature of the air and of the surface were made across the river and above the fields at the two shores, both agricultural fields just plowed, therefore essentially bare soil. Rain on the previous days had left the ground saturated and the Weser back to normal height after high tide. The multicopter made 14 flights between 11 UTC of August 15th to 02 UTC of August 16th, 2015, flying approximately once per hour at several heights up to 100 m above the ground in a vertical plane normal to the river stream. Daytime was hot and with clear skies, dominated by dry convection, and stable thermal stratification developed before sunset. Measurements lasted until a nocturnal valley fog arrived on the area.

Preliminary results show that in the daytime both the land and the river are warmer than the air above them, but the vertical temperature gradients above land are much more intense and there is a horizontal gradient of heat flux across the river; however convection seems to redistribute this difference very efficiently and no sign of thermal heterogeneity is seen in the temperature above 20 m. At night, instead, the land surface is colder than the air, but the water surface is warmer, the river generating a warm plume that can be sensed for several tens of meters above the surface. These data can be used to estimate the surface variability of the heat fluxes when water bodies are present and be used for validation and improvement of parameterizations.

Multicopter RPAS are used for ABL investigations since 2011 by HSOWL and it has been demonstrated that they are capable of sampling meteorological and air chemical parameters from close to the ground up to several hundred meters above ground level if operated in a suitable way. The HSOWL multicopters use four propellers driven by electrically powered motors. The total power consumption is about 150-250 W for normal flight patterns and moderate wind conditions. Depending on the capacity of the battery and the system setup, flight times up to 45 min are possible. In the Weser15 campaign, we were flying vertical survey patterns with a horizontal speed of 5 m/s and vertical speed of 2 m/s resulting in flight times of less than 10 minutes per flight. Night time operation of the RPAS is made possible due to suitable illumination which allows the identification of the multicopter's orientation, if required. All flights were supervised by a safety pilot.

Tuesday, 24/May/2016 9:20am - 9:40am
ID: 122 / 24-AM2-SA3: 2
oral presentation
Topics: SA - Science applications

Scientific missions of INTA from unmanned research aerial platforms

Neves Seoane-Vieira[1], Ana Corrales-Sierra[1], Susana Osuna-Esteban[2], Elena González-Toril[2], Ángeles Aguilera[2], Jose Cano-Hernández[1], Bartolomé Marqués-Balaguer[1]

[1]INTA (Instituto Nacional de Técnica Aeroespacial), Spain; [2]CAB (Astrobiology Center, CSIC-INTA), Spain

INTA (National Institute for Aerospace Technology) presents MICRAS (MICRAS (MIsiones Científicas desde platafoRmas Aéreas tripuladas y no tripuladaS, or, in english, Scientific missions in manned and unmaned aircrafts) as an interdisciplinary project for the study of atmospheric aerosols and airborne microorganisms using aerial research platforms manned and unmanned.

The confluence of disciplines such as chemistry, physics and microbiology, with the clear support of engineering and information technology, will enable us to cover the complete study and innovative way of aerosols. INTA is a public research institution which develops new airborne platforms for research and has a needed infrastructure for RPAS (Remotely Piloted Aerial Systems) R&D. In this study, infrastructure used was the Rozas Airborne Research Center (in the north of Spain).

Airborne microorganisms may play an important role in the global climate system by absorbing or reflecting incoming sunlight, acting as cloud condensation nuclei or serving as ice nucleating particles. However, little is known about it and very few studieshave been performed directly from aircraft.INTA is developing sophisticated unmanned flying platforms with high potential in the study of the atmosphere. Between them, the Lightweight Observation Air Vehicle (ALO, according to its initials in Spanish) operates in automatic flight, and its gets more than five hours endurance and 100 Km range. ALO is a flexible system, provides close range, real time reconaissance and target acquisition information by means of Light Air Vehicles equipped with small, or both, stereable sensors (TV or FLIR (Forward Looking InfraRed) Systems). Furthermore, ALO have been selected to improveaerobiology studies and a specific mechanisms for collecting microorganisms from atmosphere have been performed and placed at ALO. MICRAS represents a huge advantage in the study of atmospheric microbial ecology and its relationship with the atmospheric physicochemical parameters and the different microbial environments wich could found.Different experiments were performed on land and in fligth and a total of 15 bioaresol samples were collected. DNA extraction from samples were done and the use of molecular ecology tools will allow identification and quantification of the presence of microorganisms from atmosphere.

Another interesting aspect is the study of the physical and chemical composition of the atmosphere. We study the formation of Secondary Organic Aerosols (SOA), by photochemistry of atmospheric gases of humans (such as hydrocarbons, combustion products, etc.) and natural origins (plant emissions, marine organic materials, etc.) found in water droplets of the sea aerosol. The result is the formation of glyoxylic and oxalic acids, among others. Atmospheric aerosols are therefore essentials to carry both, biological and chemical agents. There is also a correlation between all the foregoing and altitude where exist aerosols pollutants (NOx, SO2, CO, etc.).

The study of the SOAs is the basic methodology of organic material removal filters and analysis using chromatographic analytical techniques (GC-MS). These techniques will allow to identify and quantify the chemistry composition of the atmosphere in the differents campaign with aircrafts.

Also we'll study, the content of inorganic aerosols. The composition of atmospheric aerosols is essential in the formation of clouds and already and those already mentioned above, SOAs.The inorganic composition RAMAN and other techniques of mass spectrometry with inductively coupled plasma (ICP-MS, Inductively Coupled Plasma Mass Spectrometry) will be studied. It is a variant of the technical analysis by mass spectrometry. The main advantages of this technique lie in high precision, low detection limits and low cost, analyzing most elements and isotopes in the periodic table simultaneously in no more than a couple of minutes.

Tuesday, 24/May/2016 4:20pm - 4:40pm
ID: 123 / 24-PM5-IPI2: 2
oral presentation
Topics: IPI - Instrumentation and payload integration

INSTRUMENTATION AND PAYLOAD INTEGRATION IN UAS FOR THE STUDY OF ATMOSPHERIC AEROSOLS AND AIRBORNE MICROORGANISMS

Ana Corrales-Sierra[1], Neves Seoane-Vieira[1], Jose Cano-Hernandez[1], María Jesus Morales de la Rica[1], Francisco Javier Angel-Martínez[1], Fernando Lahoz-Pequerul[1], Juan Tardaguila-Dueso[1], Elena González-Toril[2], Susana Osuna-Esteban[2], Angeles Aguilera[2], Bartolomé Marqués-Balaguer[1]

[1]INTA (National Institute for Aerospace Technology), Spain; [2]CAB (Astrobiology Center), Spain

Aircraft for research, in particular UAS (Unmanned Aircraft Systems), should be modified and instrumented before each research campaign, according to its needs and characteristics. All this work should be realized in order to guarantee the safety of the flight.

MICRAS (MIsiones Científicas desde platafoRmas Aéreas tripuladas y no tripuladaS, or, in English, Scientific missions in manned and unmaned aircrafts) is presented as a multidisciplinary project for the study of atmospheric aerosols with the objective of conducting a study of the presence of aerosols and microorganisms in different layers of the atmosphere. The CAB (Centro de Astrobiología, or, in English, Astrobiology Center) wants to use the ALO PT09 (Avión Ligero de Observación, or, in English, Light Weight Observation Air Vehicle) aerial platform to carry a payload capable of collecting samples of said elements at different elevations of flight.

ALO is an unmanned aircraft system with short-medium range, low maintenance cost and easily operable, capable of autonomous missions with a short time-to- flight. The system performs flight missions entirely automatically providing real-time images. The aircraft has 3,48m of wingspan, 60kg of Maximum Take-Off Weight, 6kg of payload and more of 5 hours of endurance.The Ground Control Station is divided into two operation monitoring and control of the aircraft and Payload.

The needed payload consists of the following elements:

• Sample collection Capsules: Small cylinders of transparent plastic material, which put up a sheet filter and collect the samples. For this campaign, ALO fly with six capsules, three of them in each half-wing.

This installation must interfere as little as possible on the lift distribution along the span of each wing, as well as in its structural loads.

• Suction pump: To facilitate the entry of outside air into the capsule in flight, suction is performed in each capsule through a small vacuum pump located inside the fuselage. The size and weight of the vacuum pump (300 gr) is almost negligible compared to the size and weight of the ALO, but must have a correct mechanical grip.

• Pipes and fittings: To perform the air suction, a system of pipes and fittings obtained for the pneumatic applications industry, are mounted from each capsule to the vacuum pump through the interior of each wing.

• Additional elements: the placement of a small video camera on the underside of the fuselage was decided for safety reasons for the operation of the ALO and faces the nose of the aircraft. In addition, a small monopole video transmitter with corresponding omnidirectional antenna type, was installed for GCS (Ground Control Station) to have an image ALO Pilot View in real-time during flights. These additional payload facilitate the detection of possible failure or loss of control on the aircraft.

Apart of the mechanical integration, an electrical integration should be realized in order to guarantee the correct power supply of the payload. The only electrical interface with this payload is the power of the suction pump, plus camera and video transmitter. The power supply to the three elements is obtained from the supply line to the nominal transmitter ALO. Using this switching power supply from the external pilot console also allows us to connect or disconnect the vacuum pump in a flight emergency, or if an operation of the payload would put at risk the proper functioning of the aircraft

An Electromagnetic Compatibility analysis should be done in order to analyse the interference with aircraft equipment essential for flight.

Before the flight with this new payload, all functional ground tests necessary will be made after the integration of all new equipment on the plane to validate the integration of new payload and to verify correct operation of all aircraft systems.

Monday, 23/May/2016 4:20pm - 4:40pm
ID: 124 / 23-PM6-ACS2: 2
no preference
Topics: ACS - Aircraft and control systems

Fixedwing UAS soundings of the boundary layer during the ScaleX campaign 2015 in southern Germany

Andreas Philipp, Alexander Groos, Erik Petersen
University of Augsburg, Germany

In order to retrieve information on the stratification (and later also aerosol load) of the planetary boundary layer for applications in urban climatology and air quality studies, several UAS based on the PPRZ APOGEE system have been build and tested, in the style of the SUMO prototype of Reuder et al. (2009) but using flying wings of 1,6 to 2 m wing span. Three summer test campaigns took place in June to August together with the KIT IMK-IFU (Karlsruhe Institute of technology, institute for meteorology and climatology/institute for envirnonmental research) in order to compare UAS in situ measurements of temperature, humidity and wind to remote sensing instruments in a shallow valley.

The ScaleX site (Fendt) is located in southern Germany in a rural, hilly landscape and equipped with several ground based remote sensing instruments. In order to complement these instruments by in situ measurements of the boundary layer, three intensive observation periods (IOPs) for taking temperature and humidity and wind profiles took place, each with a different set up in order to evaluate optimal operation modes:

A first IOP (30.06.-01.07.2015) covered a small site of 500 by 500 meters (well-apointed with hydrological instruments) in a 24 hours period. Three simultaneous helical profile flights (radius 70 m) have been run at each full hour around three different centres with heights ranging up to 1000 m above ground level (with special permissions).

During a second IOP (15.07.2015) it has been tried to increase the frequence of profile flights up to 2 flights per hours between 7:30 and 14:00 CEST. These soundings have been accompanied by flyovers of a manned ultra light aircraft of the IMK-IFU.

Finally a third experiment (06.08.2015) tried to evaluate longer flights (up to 55 minutes) of two UAVs at constant levels of 300 and 500 m above ground level between 6:00 and 14:00 CEST in order to cover the early diurnal cycle even more constantly by the in situ measurements.

Data analysis using a newly developed 3D software showed that these flight experiments are able to reveal several distinct meteorological processes developing during the diurnal cycle. Even though data examination is still ongoing, some results of these experiments are described in this field report.

Tuesday, 24/May/2016 2:00pm - 2:20pm
ID: 125 / 24-PM2-SA4: 3
oral presentation
Topics: IPI - Instrumentation and payload integration

Measuring carbon dioxide mole fractions in the atmosphere with RPAS

Martin Kunz[1], Jošt Valentin Lavrič[1], Wieland Jeschag[1,2], Maksym Bryzgalov[3], Bertil Hök[4], Burkhard Wrenger[5], Pieter Tans[6], Martin Heimann[1]

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The Paris Agreement, adopted last year at COP21 by 195 countries, aims at limiting the global warming to less than 2 °C by reducing the net anthropogenic greenhouse gas emissions to zero by the second half of the century. In order to meet this ambitious goal, better tools for the quantification of greenhouse gas sources and sinks are needed. Small remotely piloted aircraft systems are flexible, cheap and easily operated platforms that could be used for this purpose, e.g. to study gas exchange between ecosystems and the atmosphere, to quantify emissions from small-scale sources and to observe trace gas transport in the planetary boundary layer. However, this potential has not been exploited so far because currently available greenhouse gas sensors are either too large and heavy or too inaccurate for this application.

Here we present a compact carbon dioxide analyzer for airborne platforms (COCAP), designed to deliver accurate measurements on board remotely piloted aircraft with a maximum takeoff weight of 5 kg or less. We carried out extensive tests in an environmental chamber under changing temperature, pressure and carbon dioxide dry air mole fraction to establish a calibration function for the analyzer. Moreover, an uncertainty of less than 2 ppm is achieved by performing two-point calibrations before and after each mission in the field, allowing to correct for residual drift effects. In tests outside the lab, COCAP has shown good agreement with a high-accuracy greenhouse gas analyzer. However, fast changes in ambient temperature had a considerable effect on the measurement result, which is why we developed a lightweight thermal stabilisation that counterbalances variations in heat flow within seconds.

Being equipped with a GPS receiver, a data logger and wireless real-time data transfer capabilities, COCAP is a self-contained package weighing only 1 kg that can be deployed on a variety of platforms including fixed-wing aircraft, multicopters and balloons.

Monday, 23/May/2016 11:20am - 11:40am
ID: 126 / 23-AM6-SA2: 2
oral presentation
Topics: SA - Science applications

Probing the atmospheric boundary layer morning transition with two airborne systems Helipod and MASC

Jens Bange, Gerrit Rau, Norman Wildmann
University of Tübingen / Germany, Germany

Small unmanned resarch aircraft (UAV or RPA) are well suited for the probing of the atmospheric boundary layer (ABL) and other turbulent atmospheric flows. We show that especially during the morning transition (MT) of the ABL, UAV have large potential, also compared to multi-million Euro systems like the helicopter-borne turbulence probe Helipod. Research UAV like MASC (Multi-purpose Airborne Sensor Carrier) are small enough to avoid any disturbance of the studied turbulent scales (just sub-meter). Small UAV are very inexpensive both in purchase and especially during a field campaign. Required logistics are very basic, no ground facilities are necessary, and the systems are small and light enough to be carried to the experiment site by car (or even bicycle). Thus many repeated flights for higher statistical certainty can be done by small research groups even without project funding. And MT studies can be carried out almost everywhere, e.g. 'next door' to the research groups location.

In the framework of such a 'at home' field campain the MT in somewhat complex terrain was studied in the Neckar valley near Tübingen, SW Germany, in 2015. In addition to usual 'momentary' vertical profiles of the ABL, a special flight strategy named CAP (constant-altitude profiling) was applied. CAP allows for (in contrast to usual vertical profiles) horizontal averaging. Thus turbulent fluxes and other second-order statistics (co-variances and variances) can be calculated. The results are compared to a larger field campaign with the Helipod system in 2002. The overall goal of both field campaigns was the application of a scaling strategy for the MT, similar to e.g. Deardorff's scaling. The results and the limitations of such scaling approaches are shown and discussed.

Tuesday, 24/May/2016 9:00am - 9:20am
ID: 127 / 24-AM2-SA3: 1
oral presentation
Topics: SA - Science applications

Airborne Measurement of a New Particle Formation Event in the Atmospheric Boundary Layer

Andreas Platis[1], Jens Bange[1], Barbara Altstädter[2], Birgit Wehner[3], Astrid Lampert[3], Markus Hermann[2]
[1]Universität Tübingen, ZAG, Germany; [2]Leibniz Institute for Tropospheric Research (TROPOS); [3]Airborne Meteorology Institute of Flight Guidance TU Braunschweig

We studied the influence of atmospheric boundary-layer (ABL) development on new particle formation (NPF) during the morning transition. Continuous in-situ measurements of vertical profiles of the ABL were measured near Melpitz, Germany by unmanned aerial systems to understand the potential connection between NPF and boundary-layer development in the context of turbulence, temperature and humidity fluctuations. On April 3, 2014 high number concentrations of nucleation mode particles up to 6.0x10^4 cm^-3 in the diameter range 5-10 nm) were observed in an inversion layer located about 450 m above ground level. Importantly, the inversion layer exhibited a spatial temperature structure parameter CT2 10 times higher and a spatial humidity structure parameter CQ2 5 times higher than in the remaining part of the vertical profile. We assume that the inversion layer is responsible for creating favorable thermodynamic conditions for a NPF event. In addition, this layer showed a strong anti-correlation of humidity and temperature fluctuations. Using estimates of the turbulent mixing and dissipation rates, we conclude that the downward transport of particles by convective eddies was also the cause of the sudden increase of nucleation mode particles in the surface observations. This work supports the hypothesis that many of the NPF events that are frequently observed near the ground may, in fact, originate at elevated altitude, with newly formed particles subsequently being mixed down to the ground.

Tuesday, 24/May/2016 9:40am - 10:00am
ID: 128 / 24-AM2-SA3: 3
oral presentation
Topics: SA - Science applications

Investigation of the Southern Methane Anomaly using Unmanned Octocopters

Rick M. Thomas[1], Colin Greatwood[2], Tom Richardson[2], Jim Freer[2], Rob MacKenzie[1], Rebecca Brownlow[3], David Lowry[3], Rebecca E. Fisher[3], James France[4], Euan G. Nisbet[3]

[1]The University of Birminngham, UK; [2]University of Bristol, Bristol, UK; [3]Royal Holloway, University of London, Egham, UK; [4]Univ. of East Anglia, Norwich, UK

Here we provide details of the recently completed Southern Tropical Methane Anomaly project. Bespoke octocopter platforms were used to collect whole air samples up to 2.5km above ground level on Ascension Island in the mid-Atlantic. Sampling is targeted above, within and below the Trade Wind Inversion (TWI). On-board Temperature and humidity sensors profiled the TWI characteristics in real time on ascent and helped guide the altitudes at which samples were taken on descent.

Our operations at Ascension Island were arranged with both the UK Royal Air Force and US Air Force. We present our mission planning, platform control, onboard sensors and logistics required to deploying such technologies for beyond-line-of-sight applications. We show how such a platform can be deployed safely and successfully, resulting in some 60 sampling flights within a 10 day period. A number of technical challenges are discussed, including an unpredicted variability in windspeed above the TWI requiring us to develop real-time estimates of wind speed to adjust the flight plan accordingly.

The science driver for this research is investigation of the Southern Methane Anomaly and, more broadly, the hemispheric-scale transport of long-lived atmospheric tracers in the remote troposphere. The methane concentration and isotopic ratios are presented along with analysis of the meteorological soundings. Challenges remain regarding the deployment of such platforms routinely and cost-effectively, particularly regarding training and support.

Acknowledgement

This work is supported by the Natural Environment Research Council Grant NE/K005979/1.

Wednesday, 25/May/2016 9:00am - 9:20am
ID: 129 / 25-AM1-SA5: 1
oral presentation
Topics: SA - Science applications

An Evaluation of Wind Measurements From SUMO Collected During the BLLAST Campaign

Phillip Chilson[1], Jennifer Handsley[1], Brandon Centeneo[1], Timothy Bonin[2], Line Baserud[3], Marius Jonassen[3,4], Joachim Reuder[3]

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The Boundary Layer Late Afternoon and Sunset Turbulence (BLLAST) was a multinational collaborative research experiment conducted in Lannemezan, France during the summer of 2011 (http://bllast.sedoo.fr/). Numerous institutions fielded a variety of instruments during the experiment with the intention of gaining better understanding of boundary layer transitions. The resulting dataset has provided a unique opportunity to cross-compare vertical profiles of the thermodynamic and kinematic state of the boundary layer under a variety of meteorological conditions. In this presentation we focus our attention on data obtained using the University of Bergen SUMO platform in conjunction with wind estimates provided by complementary measurements from radiosondes, tethersondes, and radar wind profilers. SUMO conducted 168 profile flights up to 1500 m AGL during June and July. The primary meteorological measurements consisted of pressure, temperature, humidity, and wind. We begin by reviewing wind retrieval techniques suitable for small UAS platforms such as SUMO and address their respective strengths and weakness. Then we provide examples of wind profiles retrieved using SUMO in relation to the general structure and evolution of the boundary layer during the time of the observations. Visual and statistical comparisons of the wind retrievals from different techniques and instruments will be presented, again considering their respective strengths and limitations.

Wednesday, 25/May/2016 11:20am - 11:40am
ID: 130 / 25-AM3-SA6: 3
oral presentation
Topics: SA - Science applications

The ISOBAR project (2016--2018) -- Observations on the stable polar Atmospheric Boundary Layer from Remotely Piloted Aircraft Systems

Stephan T. Kral[1,3,4], Joachim Reuder[1], Stephanie Mayer[2], Marius O. Jonassen[3,1], Timo Vihma[4,3], Jens Bange[5], Burkhard Wrenger[6], Siegfried Raasch[7], Zbigniew Sorbjan[8], Line Båserud[1], Anak Bhandari[1]

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The purpose of the research project ISOBAR (Innovative Strategies for Observations in the Arctic Atmospheric Boundary Layer) is to increase our understanding of the Atmospheric Boundary Layer (ABL) in the Arctic. In particular, we aim to study the physical processes governing the turbulent exchange under stable conditions, which are not well represented in current Numerical Weather Prediction (NWP) and climate models, due to insufficient parameterization schemes for the Stable Boundary Layer (SBL). Applying new innovative observation strategies, which include meteorological Remotely Piloted Aircraft Systems (RPAS) in addition to well-established ground based and profiling systems, we will provide data sets on the turbulent structure of the SBL, with unique spatial and temporal resolution. The project includes the test and characterization of the RPAS based turbulence sensors through laboratory experiments and a validation campaign at DWD observatory in Lindenberg. Three different RPAS systems, the Multipurpose Atmospheric Sensor Carrier (MASC, for long-range horizontal turbulence measurements), the Small Unmanned Meteorological Observer (SUMO, for turbulence measurements and vertical profiles) and the Advanced Mission and Operation Research (AMOR) multicopter system (for vertical profiles of the Surface Layer and fixed-location turbulence measurements) will be applied during two four-week long campaigns. These campaigns will focus on the SBL over homogeneous sea-ice (Arctic Ocean around Svalbard, winter/spring 2017) and surface heterogeneities due to partially open water (western fjords of Svalbard, winter/spring 2018). Collocated and coordinated measurements by a large number of RPAS (2 MASC, 7 SUMO, 2-4 AMOR) will provide a unique opportunity to sample the relevant data with so far unreached resolution. Supported by Single Column Model and Large-Eddy Simulation experiments we will use the collected data sets to develop new SBL parameterization schemes and implement them in the state-of-the-art Weather and Research Forecasting model (WRF).

Wednesday, 25/May/2016 11:40am - 12:00pm

ID: 131 / 25-AM3-SA6: 4

oral presentation

Topics: SA - Science applications

Observations on the Arctic Boundary Layer using the Small Unmanned Meteorological Observer (SUMO) during polar night

Marius O. Jonassen[1,2], Stephan T. Kral[2,1], Siiri Wickström[1,2], John J. Cassano[3], Daniel Martinez[4], Martin Müller[5], Christian Lindenberg[5], Line Båserud[2]

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During the field course "The Arctic Atmospheric Boundary Layer and Local Climate Processes" (AGF-350/850) at the University Centre in Svalbard (UNIS) in February 2016 numerous different measurement systems were used for detailed atmospheric observation in the area around Adventdalen and Adventfjorden, Svalbard. Besides a dense network of ground based automatic weather stations, stand-alone temperature sensors and eddy-covariance systems, three different atmospheric profiling systems were operated, i.e. a tethered balloon for in-situ observations of atmospheric variables, a SodarRASS remote-sensing system providing permanent data on the vertical profiles of wind speed, direction and virtual temperature and the RPAS Small Unmanned Meteorological Observer (SUMO) for vertical profiles at different locations. The measurements were accompanied by ground based transects from skidoos and a small boat using mobile weather stations.

The structure of the ABL was mainly stably stratified, but showed significant spatial variability in terms of boundary layer height, which could be observed in SUMO profiles from different locations. Under off-shore flow cases the height of the ABL over land decreased toward the fjord before it increased over the fjord and continued increasing further out. Furthermore the temporal evolution of the ABL could be monitored from consecutive SUMO profiles, indicating events with large scale-subsidence leading to a decrease in ABL height over time. Combining time series of consecutive SUMO profiles with co-located ground based measurements will enable us to estimate profiles of the turbulent fluxes of sensible and latent heat and study the vertical structure of the ABL and its temporal and spatial variability in more detail. In addition the SUMO profiles taken close to the main measurement site will be used for a comparison and validation of the three different profiling systems.

Tuesday, 24/May/2016 3:20pm - 3:40pm
ID: 132 / 24-PM3-IPI1: 4
no preference
Topics: IPI - Instrumentation and payload integration

Placement of Sensors for Local Wind Measurement by a Hexacopter

Matthew Walker
University of Oklahoma, United States of America

While most of the research in recent years has focused on fixed wing aircraft, rotorcraft allow for many unique opportunities of meteorological measurement. However, with these opportunities comes several challenges, especially with wind measurement. For the past few years, the University of Oklahoma has been developing a hexacopter testbed, SAMRAMP (Semi-Autonomous Multi-Rotor Aerial Meteorological Platform) in order to test sensor locations for temperature, humidity, and wind speed/direction. This talk will provide an overview of our recent progress, which includes tests to determine optimal location for a cup anemometer above SAMRAMP and tests to determine the feasibility of measuring wind speed and direction using the internal accelerometers.

Wednesday, 25/May/2016 11:00am - 11:20am
ID: 133 / 25-AM3-SA6: 2
oral presentation
Topics: SA - Science applications

RPA-borne measurements of stable and convective offshore boundary-layers over the North Sea

David James Tupman, Andreas Platis, Alexander Rautenberg, Norman Wildmann, Jens Bange
University of Tubingen, Germany

There are many operating and planned offshore wind energy installations within the North Sea region. Direct measurements of the vertical profiles of wind and turbulence are naturally essential to these operations, but are limited to the height of meteorological towers. With the objective of providing direct measurements up to altitudes of 500 m, we deployed our Multiprobe Airborne Sensor Carrier (MASC), for 80 autumn and winter flights based from the

offshore island of Helgoland, near the Alpha Ventus wind park. MASC is a small remotely piloted aircraft (RPA), with measurement systems capable of resolving the wind vector, temperature, and humidity, down to turbulent scales.

The conditions encountered were generally strong winds (8-15 m/s), and relatively small air-sea heat fluxes (5-20 W/m^2). There was typically a diurnal cycle in the heat fluxes when the wind came from mainland Germany (approx. 50 km fetch), caused by cold air outbreaks in the morning, and warm air outbreaks in the afternoon. Under such conditions, the boundary-layer would be classified as near-neutral by most studies. However, our measurements showed very clear convective and stable boundary-layers, that had depths, wind speed profiles, and turbulence profiles, similar to those observed in other studies during much stronger heat fluxes.

Preliminary attempts to normalise the turbulent statistics using the boundary layer height, and the air-sea fluxes as computed by a bulk algorithm (COARE 3.5; Edson et al., 2014), are proving successful. Plots of normalised turbulent statistics against altitude show reasonable convergence, given the very small mean air-sea heat fluxes. We plan to investigate the modelling of turbulent statistics during very weak thermal boundary layers, using the turbulence profile models of well established 'textbook' studies (cited in e.g. Stull, 1988) as a starting point. Early indications are that our data match the textbook studies well, but in some cases require modification of the parameterisations: for example, our entrainment fluxes during the weak convective boundary layers are more significant than for the overland studies.

We also will present some interesting and fortunate measurements made during single case studies: the passing of a warm front, and upwind of the downdraft from a convective shower.

Tuesday, 24/May/2016 1:40pm - 2:00pm
ID: 134 / 24-PM2-SA4: 2
oral presentation
Topics: SA - Science applications

Bottom-up and top-down closure of aerosol-cloud interactions using RPAS

Greg Roberts[1,2], Radiance Calmer[1], Kevin Sanchez[1,2], Gregoire Cayez[1,3], Keri Nicoll[4], Jurgita Ovadnevaite[5], Murat Bronz[6], Gautier Hattenberger[6], Jana Preissler[5], Danny Rosenfeld[7]

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Clouds are omnipresent in earth's atmosphere and constitute an important role in regulating the radiative budget of the planet. However, the response of clouds to climate change remains uncertain, in particular, with respect to aerosol-cloud interactions and feedback mechanisms between the biosphere and atmosphere. Aerosol-cloud interactions and their feedbacks are the main themes of the European project FP7 BACCHUS (Impact of Biogenic versus Anthropogenic Emissions on Clouds and Climate: towards a Holistic Understanding).

The National Center for Meteorological Research (CNRM-GAME, Toulouse, France) conducted airborne experiments in Cyprus and Ireland in March and August 2015 respectively to link ground-based and satellite observations. Multiple RPAS (remotely piloted aircraft systems) were instrumented for a specific scientific focus to characterize the vertical distribution of aerosol, cloud microphysical properties, radiative fluxes, 3D wind vectors and meteorological state parameters. Flights below and within clouds were coordinated with satellite overpasses to perform 'top-down' closure of cloud micro-physical properties. Measurements of cloud condensation nuclei spectra at the ground-based site have been used to determine cloud microphyical properties using wind vectors and meteorological parameters mesured by the RPAS at cloud base. These derived cloud properties have been validated by in-situ RPAS measurements in the cloud and compared to those derived by the Suomi-NPP satellite. In addition, RPAS profiles in Cyprus observed the layers of dust originating from the Arabian Peninsula and the Sahara Desert. These profiles generally show a well-mixed boundary layer and compare well with ground-based LIDAR observations.

Monday, 23/May/2016 3:20pm - 3:40pm
ID: 135 / 23-PM4-ACS1: 3
no preference
Topics: ACS - Aircraft and control systems

Experimental Wind-Field Estimation

Murat Bronz, Jean-Philippe Condomines, Gautier Hattenberger
ENAC, France

The use of small RPAS (Remotely Piloted Aircraft System) in atmospheric research has increased mainly because of their compact size and ease of operation.The presented work focus on the wind estimation based on real flight experiments as part of the SkyScanner project. The overall objective of the project is to estimate the local wind field in order to study the formation of cumulus-type clouds with a fleet of autonomous mini-RPAs. Generally, wind field measurements have been done by using a commercial 5-hole probe, such as the one from AEROPROBE. This is an expensive and heavier solution.With the help of algorithmic estimation of the wind field, multiple smaller and cheaper RPAs can be used for atmospheric measurements.

On this study, a small UAV has been equipped with a classical pitot-static tube for airspeed, a hall effect rotary encoder for angle of attack, and the AEROPROBE for reference values. Location of the on-board sensors has been carefully selected in order to reduce the flow effects coming from the vehicle geometry. Nevertheless these unavoidable effects has been corrected beforehand through a wind tunnel calibration. Autonomous flights have been performed using the Paparazzi Autopilot System and flight data are recorded on-board the autopilot (APOGEE v1.0) at high speed for post-analyses. An approach based on Unscented Kalman Filter (UKF) is proposed for nonlinear wind estimation by fusing the on-board GPS, pitot-static tube and the angle of attack sensor. Wind field estimation during both wind tunnel and real flight is compared with AEROPROBE measurements. As a first result, wind updraft estimation is highlighted by exploiting recorded flight test data.

Tuesday, 24/May/2016 4:40pm - 5:00pm
ID: 136 / 24-PM5-IPI2: 3
oral presentation
Topics: IPI - Instrumentation and payload integration

CLOUD MAP: Atmospheric Sampling with UAS

Alyssa Avery, Nicholas Foster, Jamey Jacob
Oklahoma State Universtiy, United States of America

CLOUD MAP – Collaboration Leading Operational UAS Development for Meteorology and Atmospheric Physics – is a 4 year, 4 university collaboration to develop capabilities that will allow meteorologists and atmospheric scientists to use unmanned aircraft as a common, useful everyday tool. Currently, we know that systems can be used for meteorological measurements, but they are far from being practical or robust for everyday field diagnostics by the average meteorologist or scientist. In particular, UAS are well suited for the lower atmosphere, namely the lower boundary layer that has a large impact on the atmosphere and where much of the weather phenomena begin. Due to the boundary layer's proximity to the ground and its transient nature, current technologies have severe limitations in providing detailed measurements: manned aircraft are too dangerous or expensive to fly near the ground; radar cannot see over the horizon and do not measure all of the important thermodynamic parameters forecasters need; and weather balloons have too short of a duration at low altitudes to provide useful information, particular during transient events such as severe storms or fronts. This data will be used to improve our understanding and develop more accurate forecasting models in the near future. Partners include Oklahoma State University, the Univ. of Oklahoma, the Univ. of Kentucky, and the Univ. of Nebraska.

Numerous platforms and sensors combinations are being examined, including both fixed wing and rotary wing systems. One of the systems developed and built at Oklahoma State University is a fixed wing UAS designed specifically to gather meteorological data for improving severe storm and tornado prediction. The Meteorological Analysis Research and Investigation Aircraft (MARIA) is focused on gathering comprehensive, accurate, and relevant atmospheric data. The sensors have been integrated into the design so that they collect the best quality data. The airframe is capable of flight in conditions that off-the-shelf airframes are not able to withstand, with an endurance of 6-8 hours. This expanded envelope will allow that necessary data may be collected to improve severe storm models. The 30lb system is able to carry a variety of sensors and can sample atmospheric data at a larger scale than current unmanned systems. The platform is capable of simultaneously collecting data from a five-hole probe, hot wire sensor, an onboard meteorological sensor suite (pressure, temperate, density) as well as small inexpensive meteorological packages to be dropped from the aircraft. The presentation will discuss results from various sensor packages and flight-testing of CLOUD MAP UAS.

Tuesday, 24/May/2016 10:40am - 11:00am
ID: 137 / 24-AM4-RPA: 1
oral presentation
Topics: SA - Science applications

Public Perception of UAS for Atmospheric Science

Lisa PytlikZillig[2], Adam Houston[1], Carrick Detweiler[1]
[1]University of Nebraska-Lincoln, United States of America; [2]Nebraska Public Policy Center

The routine application of UAS for studying and surveilling the atmosphere will require careful consideration of the public response to such proposed use in the US national airspace system. It is necessary to understand likely public reactions to large-scale implementation of UASs over the US and how these attitudes might be affected by different forms of technological and policy responses, and by different forms of public engagement. Prior work indicates that privacy and personal safety concerns remain at the forefront of resistance to adoption of UAS technology; while hopes for improving pilot safety during war or rescue missions and use of drones for security purposes lead as areas of public enthusiasm for UASs—but overall public attitudes appear to be not fully formed. Understanding potential facilitators and resistance to UAS adoption and how to best respond to public values and concerns is vital for ensuring that UAS technology is developed responsibly and results in useful and usable technologies.

In this presentation we will discuss preliminary results from national focus groups and surveys aimed at gauging attitudes toward UAS systems and UAS policies, preferences and willingness to pay for UAS operation, attitudes toward intended uses for UAS technology, and hurdles to implementation of UAS technology—especially in the area of use of UAS technology for monitoring and measuring weather and atmospheric events. Preliminary results indicate that trust is an important factor in predicting public support for new technologies, but not the only factor, and that perceptions of distrustworthiness vary in importance when predicting support across contexts.

Tuesday, 24/May/2016 4:00pm - 4:20pm
ID: 138 / 24-PM5-IPI2: 1
oral presentation
Topics: IPI - Instrumentation and payload integration

Proof of concept for turbulence measurements with the RPAS SUMO during the BLLAST campaign

Joachim Reuder[1], Line Båserud[1], Stephan T. Kral[1], Marius O. Jonassen[1,2], Mostafa Bakhoday Paskyabi[1], Marie Lothon[3]
[1]Geophysical Institute, University of Bergen, Norway; [2]The University Centre in Svalbard, Longyearbyen, Norway; [3]Laboratoire d'Aérologie, University of Toulouse, CNRS, France

The micro-RPAS SUMO (Small Unmanned Meteorological Observer) equipped with a five hole probe (5HP) system for turbulent flow measurements has been operated in 49 flight missions during the BLLAST (Boundary-Layer Late Afternoon and Sunset Turbulence) field campaign in 2011. Based on data sets from these flights we investigate the potential and limitations of airborne velocity variance and TKE (Turbulent Kinetic Energy) estimations by an RPAS system with a take-off weight below 1 kg.

The integration of the turbulence probe in the SUMO system was still in an early prototype stage during this campaign. The main shortcomings were the use of two different, unsynchronized data loggers for the 5HP flow measurements and the aircraft's attitude data required for the motion correction, and the different sampling rate for both data sets. Therefore, extensive post-processing of the data was required in order to calculate the turbulence parameters. In addition, the fine-tuning of the autopilot was not fully optimized, leading to oscillations in the vertical velocity that the motion correction routine was not able to remove. A simple block-filter has been used for the removal of these oscillations. For a filter constant of 0.61 s, the SUMO data show a good agreement to sonic anemometer data for the integral parameter of the vertical velocity variance, but there is still a distinct difference in the underlying energy spectrum of the data sets. Resulting estimates of TKE profiles, obtained from consecutive flight legs at different altitudes, show reasonable results, both with respect to the overall TKE level, as well as the temporal variation. A thorough discussion of the methods used and the identified uncertainties and limitations of the system for turbulence measurements is included and should help the developers and users of other systems with similar problems.

Monday, 23/May/2016 4:40pm - 5:00pm
ID: 139 / 23-PM6-ACS2: 3
oral presentation
Topics: ACS - Aircraft and control systems

The Unmanned Systems Research Laboratory (USRL) of the Cyprus Institute: Current Status and Perspectives

Christos Keleshis[1], Marios Argyrides[1], Apostolos Apostolou[1], Gregoris Demetriades[1], Panayiota Antoniou[1], Panos Vouterakos[1], Michalis Pikridas[1], Iasonas Stavroulas[1], Mihalis Vrekoussis[1,2,3], Jean Sciare[1]

[1]The Cyprus Institute, Nicosia, Cyprus; [2]Institute of Environmental Physics, Bremen, Germany; [3]Center of Marine Environmental Sciences - MARUM, U of Bremen

The Autonomous Flying Platforms for Atmospheric and Earth Surface Observations (APAESO) infrastructure project (2009-2013) has been co-financed by the European Development Fund and the Republic of Cyprus through the Cyprus Research Promotion Foundation and has led into the establishment of a new facility titled: Unmanned Systems Research Laboratory (USRL). The general objective of the USRL is to become a sustainable facility under the Cyprus Institute (CyI) in order to provide high quality services to relevant research projects while maintaining efforts to improve, to develop and to enhance current Unmanned Aerial Systems (UAS) capacities. The USRL, located at CyI premises (Nicosia, Cyprus) resides in a 100m² laboratory equipped with advanced techniques for unmanned systems research and development. Its current fleet consists of 4 small and 4 medium fixed-wing UAVs and 2 rotary-wing UAVs with a total flying time of more than 200 hours. A mobile Ground Control Station (GCS) has been recently upgraded in order to monitor, control and transport all the above UAVs and their payload to the deployment field. The recent construction of a permanent runway suitable for UAV test and operational flights represents the last important development of the USRL. The new runway which lies on a flat terrain remote area is 25 km west of Nicosia, in the center of a permanent airspace committed for the CyI UAVs. Furthermore, it is located nearby the CyI ground-based Atmospheric Observatory (Agia Marina Xyliatou) allowing comparison of atmospheric in-situ observations at the surface and in the atmospheric column (up to 3km above sea level) using the UAVs. Currently the USRL is providing services for two European funded projects (FP7-BACHUS and H2020-ACTRIS II) by participating in UAV campaigns and regular (weekly) flights providing vertical measurements of key atmospheric components (gases and aerosols). In conclusion, it is expected that the USRL will continue to expand its UAS capacities while fulfilling the operational goals of ongoing and future atmospheric projects. In this context, the novel CyI runway and exclusive overhead airspace may serve as an international facility for UAV test and training purposes.

ID: 140
oral presentation
Topics: SA - Science applications

Vertical Profiles of Black Carbon in an urban area using a multi-copter.

Christos Keleshis[1], Michalis Pikridas[1], Spyros Bezantakos[1], Gregoris Demetriades[1], Mihalis Vrekoussis[1,2,3], Grisa Mocnik[4,7], Fred Brechtel[5], Eleni Liakakou[6], Nikos Mihalopoulos[6], Jean Sciare[1]

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Black Carbon (BC) vertical measurements up to 1 km above sea level were performed in the centre of Athens, Greece from the 14th to the 21st of January 2016. These aerosol absorption vertical profiles were part of an intensive field campaign organized by the National Observatory of Athens as part of the ACTRIS II Horizon 2020 Project. The campaign aimed at inter-comparing a suite of commercial and prototype miniaturized BC sensors against standardized absorption instruments, as well as evaluating their performance when airborne and their potential to constrain remote sensing (LIDAR) observations. Due to strong constrains related to the urban environment, an octocopter (DJi S1000+) with 10 kg take-off weight was selected as the platform to carry various miniaturized absorption instruments in order to ensure safe and accurate position hold in a very narrow vertical column. A miniaturized dual-wavelength prototype (DWP) Aethalometer was mounted on the vibration-isolated mount of the UAV along with a temperature and relative humidity sensor, a GPS sensor and a small Data Acquisition (DAQ) system. A total of 18 flights have been performed carrying the above configuration. A second payload configuration with the Brechtel Manufacturing Inc. STAP instrument and an Aethlabs Microaeth instrument, has been also installed on the same UAV. Another 8 flights have been performed using this configuration. Additionally to the scientific goals of this project, this campaign allowed testing the performance of the selected octocopter in terms of endurance, payload capacity and reliability for intensive vertical flights up to 1 km a.s.l. The flight operations for the aerosol-absorption vertical profiles along with the overall performance of the sensors and the UAV will be presented in this paper.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 654109.

Monday, 23/May/2016 11:00am - 11:20am
ID: 141 / 23-AM6-SA2: 1
oral presentation
Topics: SA - Science applications

Heat fluxes estimated from SUMO profiles during the BLLAST field campaign

Line Båserud[1], Joachim Reuder[1], Marius O. Jonassen[2,1], Timothy Bonin[3,4], Phillip Chilson[3], Maria A. Jiménez[5], Eric Bazile[6]

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The Small Unmanned Meteorological Observer (SUMO) was operated for 299 flight missions during the Boundary Layer Late Afternoon and Sunset Turbulence (BLLAST) field campaign in France in 2011. Included are 168 profile flights up to about 1500 m above ground level. Intensive observation periods with more than 10 flights per day enable the investigation of convective boundary layer (CBL) structure as the layer evolves from daytime to evening conditions.

Sensible and latent heat fluxes are estimated from a simplified version of the prognostic equation for temperature or humidity that relates the change of the mean quantity with time to the corresponding flux divergence. The result is average profiles of the fluxes for the time periods between successive flights.

Profiles of the sensible heat flux follow the expected shape in the convective boundary layer with a linear decrease with height and slightly negative values on top of the boundary layer due to entrainment processes. The retrieved ground values fit well with observations from a network of eddy covariance surface stations for the corresponding time periods.

In many cases the resulting profiles depend strongly on the contribution from advection. We investigate how the flux profiles respond when this is taken into account either by using a simple method where advection is treated as a constant throughout the boundary layer, or by using advection output from the mesoscale models MesoNH and AROME.

Monday, 23/May/2016 9:40am - 10:00am
ID: 142 / 23-AM3-SA1: 2
oral presentation
Topics: SA - Science applications

Ensemble Sensitivity Analysis for Targeted Observations of Supercell Thunderstorms

George Limpert, Adam Houston
University of Nebraska-Lincoln, United States of America

The potential value of targeted observations collected by mobile platforms such as UAS for numerical weather prediction of storm-scale phenomena is explored using ensemble sensitivity analysis (ESA). ESA has been demonstrated for use in guiding targeted observations of synoptic scale and mesoscale phenomena but this is the first time that it has been applied on the storm-scale. An idealized supercell is used in this examination with a horizontally homogeneous initial state. The strongest correlations at 20, 40, and 60 minute lead times were found outside the core of the supercell, though most of the domain showed a statistically significant relationship between the perturbations and forecast responses. The results show that, for this case, greater value would likely be obtained at those lead times by targeting observations that are representative of the storm environment rather than within the actual storm. The storm environment and the impacts of the storm on the far field appear to be the most important predictors of future storm strength for this supercell case.

ID: 143
oral presentation
Topics: SA - Science applications

Small Fixed Wing UAV for Characterizing Marine Surface Layer Environment

Qing Wang, Kevin D. Jones, Ryan Yamaguchi, Richard J. Lind
Naval Postgraduate School, United States of America

One of the unique applications of research in the marine atmospheric surface layer (MASL) is to characterize the near surface refractivity and its vertical variation. The vertical gradient of the index of refraction in the MASL determines the effects of the atmosphere on the propagation of radar and communication signals from surface vessels by forming a layer where the electromagnetic waves tend to be trapped. This layer is often referred to as the evaporation duct. While most of the previous research on the marine atmospheric surface layers has focused on surface flux parameterization, the mean vertical profiles of wind, temperature, and humidity near the sea surface have not been thoroughly characterized, although they are generally considered to follow the same flux-profile relationship as those in the surface layers over land. This raised a general concern of the applicability of the currently used surface layer models in applications where characterizing the surface layer profiles becomes crucial. The lack of in situ measurements in the lowest 30 meters of the atmosphere with sufficient vertical resolution and statistical representation thus becomes a serious predicament in developing new and improved evaporative ducting models.

We are developing a capability to use small Unmanned Aerial Systems (sUAS) deployable from ships to sample the near surface vertical variations of wind, temperature, and humidity in undisturbed air. The fixed wing sUAS are considered ideal, especially compared to rotorcraft, due to their longer endurance and they introduce minimum disturbances to the ambient air flow. The targeted system should be sea-worthy, capable of flying at altitudes on the order of meters above the sea surface, low-cost, and hopefully recoverable/reusable. The design will rely heavily on COTS products, open-source components and rapid prototyping techniques such as 3D printing and desk-top CNC machining. The airframes selection process took into account the weight and volume of the sensor components, clean access to the air for sensing, and a size and wing-loading that is able to support the desired speed range and endurance. In this presentation, we will discuss some of the modifications made to the airframe in preparation for water landings. Results from recent test flights will be shown to demonstrate the sampling capability of the instrumented sUAS system.

Tuesday, 24/May/2016 2:40pm - 3:00pm
ID: 144 / 24-PM3-IPI1: 2
no preference
Topics: IPI - Instrumentation and payload integration

Measuring the urban atmosphere with a UAV and Waggle

Robert Jacob, Rajesh Sankaran, Pete Beckman
Argonne National Laboratory, United States of America

The urban atmosphere is one of the most poorly studied regions of the atmospheric boundary layer. Since a majority of the world's population now lives in urban areas, it is becoming a more important region to measure and model. We have mounted a new sensor and compute platform called Waggle on an off-the-shelf XR8 octo-copter from 3DRobotics. Waggle consists of multiple sensors for measuring pressure, temperature and humidity as well as trace gases such as carbon monoxide, nitrogen dioxide, sulfur dioxide and ozone. A single board computer running Linux included in Waggle on the UAV allows in-situ processing and data storage. Communication of the data is through WiFi or 3G and the Waggle software can save the data incase communication is lost during flight. The flight pattern is a deliberately simple vertical ascent and descent over a fixed location to provide vertical profiles and so flights can be confined to urban parks, industrial areas or the footprint of a single rooftop. We will show how Waggle on the XR8 performs in flights in and around Chicago.

ID: 145
poster
Topics: ACS - Aircraft and control systems

Basse Couche Campaign (BAC+) to study evolution of boundary layer and fog events

Stéphan Defoy, Gregoire Cayez, Greg Roberts, Sebastien Paslin, Jean-François Robert
Météo-France, France

Vertical profiles from the VOLTIGE project (Vecteurs d'Observation de La Troposphere pour l'Investigation et la Gestion de l'Environnement) have been compared to Météo France forecast models, and the results suggest that forecast models may be improved using high resolution and frequent in-situ measurements. Based on these results, The Basse Couche Campaign (BAC+) was initiated as a collaborative agreement with the military's flight school (French Army Light Aviation; EALAT) to conduct regular UAS flights in the Landes – a region known for its fog. BAC+ provides a first-step towards deploying small RPAS in an operational network at Météo France. A collaborative agreement has been signed between Météo France and the military flight school (EALAT) in Dax, France to allow the use of remotely piloted vehicles (RPAs) in the military airspace. The goal of the project is to achieve one year of regular vertical profiles (every 2 weeks) of meteorological state parameters (pressure, temperature, humidity) via completely autonomous flights (from 0 to 500m above ground level) with mini-RPAs. The BAC+ project will sustain the collaboration between Météo France and EALAT initiated during the VOLTIGE project and assess the capacity of autonomous RPA observations in an operational environment.

Monday, 23/May/2016 9:20am - 9:40am
ID: 146 / 23-AM3-SA1: 1
oral presentation
Topics: SA - Science applications

Meteodrones – Towards the perfect 24-hour forecast

Martin Fengler, Christian Schluchter
Meteomatics GmbH, Switzerland

The Planetary Boundary Layer (PBL), which is the lowest part of the atmosphere, is the main trigger for phenomena like fog, low stratus, freezing rain and thunderstorms. For lack of measurements in this layer, however, forecasts of existing weather models often are not as accurate as desired.

In 2012, Meteomatics started developing a drone capable of flights up to altitudes of 1.5 km above ground and was the first organisation to get the approval of the Swiss Federal Office of Civil Aviation (FOCA) to fly their Meteodrones Beyond Visual Line of Sight (BVLOS).

Roughly 450 sounding flights were conducted in a measurement campaign during two weeks in July 2015: In five locations in Switzerland (Altenrhein, Amlikon, Bad Ragaz, Oberriet and Schänis) highly accurate measurements of weather parameters in the boundary layer up to 1.5 km above ground were performed and analysed.

The Meteodrones revealed fascinating weather phenomena, as for example temperature inversion and alpine pumping, which have not been measured that explicitly before. Data collected within the boundary layer during the campaign, was then used to initialise a local weather model. Forecasts based on this model were compared to forecasts based on models initialized with data from weather stations, balloons and satellites only, showing that the Meteodrones significantly improve short-term forecasts and help in reaching the self-imposed target of creating the perfect 24-hour forecast.

Apart from the meteorological insight, several tough challenges during the development and operation of the drone led to technological advancements that can be applied to drones in all business segments. Meteomatics, therefore, besides being an established provider of accurate weather forecasts, evolved into one of the leading experts in BVLOS-approved drones.

ID: 147
poster
Topics: IPI - Instrumentation and payload integration

Sensors and infrastructure for UAVs

Anders Petersson
Sparv Embedded AB, Sweden

Sparv Embedded will present how the company supplies novel measurement equipment to atmospheric researchers.

Windsond is a new, miniature radiosonde specialized for low altitudes, where it only needs 30 liters of helium and a 8 gram balloon. This enables a new level of portability such as releasing a radiosonde through a rolled down car window. The sondes are easily recovered and reused. Windsond is becoming popular for meteorological reseach.

The sensor kit is specialised for making it trivial to integrate a range of sensors on UAVs, balloons and other mobile platforms. Weight, size and power consumption are designed to fit even the smallest RPAS. A large number of sensors of the same or different kinds can be connected at the same time. The kit hides the electrical and programming details of sensors, making them plug-and-play. Data is synchronized with GPS, logged and optionally transmitted as real-time, long-range telemetry. For telemetry, Android and Windows devices can receive the data on the ground, with option to add support for Mac, Linux and iOS. The kit is very adaptable to new sensors, radio modems, etc.

ID: 148
poster
Topics: IPI - Instrumentation and payload integration

INSTRUMENTATION AND PAYLOAD INTEGRATION IN UAS FOR THE STUDY OF ATMOSPHERIC AEROSOLS AND AIRBORNE MICROORGANISMS

Ana Corrales-Sierra[1], Neves Seoane-Vieira[1], Jose Cano-Hernandez[1], F. Lahoz-Pequerul[1], J. J. Angel-Martínez[1], Mª.J. Morales de la Rica[1], J. Tardáguila-Dueso[3], Elena Gonzalez-Toril[2], Susana Osuna-Esteban[2], A. Aguilera[2], Bartolomé Marqués-Balaguer[1]

[1]INTA, Spain; [2]CAB, Spain; [3]ISDEFE, Spain

Aircraft for research, in particular UAS (Unmanned Aircraft Systems), should be modified and instrumented before each research campaign, according to its needs and characteristics. All this work should be realized in order to guarantee the safety of the flight.

MICRAS (MIsiones Científicas desde platafoRmas Aéreas tripuladas y no tripuladaS, or, in English, Scientific missions in manned and unmaned aircrafts) is presented as a multidisciplinary project for the study of atmospheric aerosols with the objective of conducting a study of the presence of aerosols and microorganisms in different layers of the atmosphere. The CAB (Centro de Astrobiología, or, in English, Astrobiology Center) wants to use the ALO PT09 (Avión Ligero de Observación, or, in English, Light Weight Observation Air Vehicle) aerial platform to carry a payload capable of collecting samples of said elements at different elevations of flight.

ALO is an unmanned aircraft system with short-medium range, low maintenance cost and easily operable, capable of autonomous missions with a short time-to- flight. The system performs flight missions entirely automatically providing real-time images. The aircraft has 3,48m of wingspan, 60kg of Maximum Take-Off Weight, 6kg of payload and more of 5 hours of endurance.The Ground Control Station is divided into two operation monitoring and control of the aircraft and Payload.

The needed payload consists of the following elements:

• Sample collection Capsules: Small cylinders of transparent plastic material, which put up a sheet filter and collect the samples. For this campaign, ALO fly with six capsules, three of them in each half-wing.

This installation must interfere as little as possible on the lift distribution along the span of each wing, as well as in its structural loads.

• Suction pump: To facilitate the entry of outside air into the capsule in flight, suction is performed in each capsule through a small vacuum pump located inside the fuselage. The size and weight of the vacuum pump (300 gr) is almost negligible compared to the size and weight of the ALO, but must have a correct mechanical grip.

• Pipes and fittings: To perform the air suction, a system of pipes and fittings obtained for the pneumatic applications industry, are mounted from each capsule to the vacuum pump through the interior of each wing.

• Additional elements: the placement of a small video camera on the underside of the fuselage was decided for safety reasons for the operation of the ALO and faces the nose of the aircraft. In addition, a small monopole video transmitter with corresponding omnidirectional antenna type, was installed for GCS (Ground Control Station) to have an image ALO Pilot View in real-time during flights. These additional payload facilitate the detection of possible failure or loss of control on the aircraft.

Apart of the mechanical integration, an electrical integration should be realized in order to guarantee the correct power supply of the payload. The only electrical interface with this payload is the power of the suction pump, plus camera and video transmitter. The power supply to the three elements is obtained from the supply line to the nominal transmitter ALO. Using this switching power supply from the external pilot console also allows us to connect or disconnect the vacuum pump in a flight emergency, or if an operation of the payload would put at risk the proper functioning of the aircraft

An Electromagnetic Compatibility analysis should be done in order to analyse the interference with aircraft equipment essential for flight.

Before the flight with this new payload, all functional ground tests necessary will be made after the integration of all new equipment on the plane to validate the integration of new payload and to verify correct operation of all aircraft systems

ID: 149
poster
Topics: SA - Science applications

Scientific missions of INTA from unmanned research aerial platforms

Neves Seoane-Vieira[1], Ana Corrales-Sierra[1], Susana Osuna-Esteban[2], Elena González-Toril[2], Ángeles Aguilera[2], José Cano-Hernández[1], Bartolomé Marqués-Balaguer[1]

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INTA (National Institute for Aerospace Technology) presents MICRAS (MICRAS (MIsiones Científicas desde platafoRmas Aéreas tripuladas y no tripuladaS, or, in english, Scientific missions in manned and unmaned aircrafts) as an interdisciplinary project for the study of atmospheric aerosols and airborne microorganisms using aerial research platforms manned and unmanned.

The confluence of disciplines such as chemistry, physics and microbiology, with the clear support of engineering and information technology, will enable us to cover the complete study and innovative way of aerosols. INTA is a public research institution which develops new airborne platforms for research and has a needed infrastructure for RPAS (Remotely Piloted Aerial Systems) R&D. In this study, infrastructure used was the Rozas Airborne Research Center (in the north of Spain).

Airborne microorganisms may play an important role in the global climate system by absorbing or reflecting incoming sunlight, acting as cloud condensation nuclei or serving as ice nucleating particles. However, little is known about it and very few studieshave been performed directly from aircraft.INTA is developing sophisticated unmanned flying platforms with high potential in the study of the atmosphere. Between them, the Lightweight Observation Air Vehicle (ALO, according to its initials in Spanish) operates in automatic flight, and its gets more than five hours endurance and 100 Km range. ALO is a flexible system, provides close range, real time reconaissance and target acquisition information by means of Light Air Vehicles equipped with small, or both, stereable sensors (TV or FLIR (Forward Looking InfraRed) Systems). Furthermore, ALO have been selected to improveaerobiology studies and a specific mechanisms for collecting microorganisms from atmosphere have been performed and placed at ALO. MICRAS represents a huge advantage in the study of atmospheric microbial ecology and its relationship with the atmospheric physicochemical parameters and the different microbial environments wich could found.Different experiments were performed on land and in fligth and a total of 15 bioaresol samples were collected. DNA extraction from samples were done and the use of molecular ecology tools will allow identification and quantification of the presence of microorganisms from atmosphere.

Another interesting aspect is the study of the physical and chemical composition of the atmosphere. We study the formation of Secondary Organic Aerosols (SOA), by photochemistry of atmospheric gases of humans (such as hydrocarbons, combustion products, etc.) and natural origins (plant emissions, marine organic materials, etc.) found in water droplets of the sea aerosol. The result is the formation of glyoxylic and oxalic acids, among others. Atmospheric aerosols are therefore essentials to carry both, biological and chemical agents. There is also a correlation between all the foregoing and altitude where exist aerosols pollutants (NOx, SO2, CO, etc.).

The study of the SOAs is the basic methodology of organic material removal filters and analysis using chromatographic analytical techniques (GC-MS). These techniques will allow to identify and quantify the chemistry composition of the atmosphere in the differents campaign with aircrafts.

Also we'll study, the content of inorganic aerosols. The composition of atmospheric aerosols is essential in the formation of clouds and already and those already mentioned above, SOAs.The inorganic composition RAMAN and other techniques of mass spectrometry with inductively coupled plasma (ICP-MS, Inductively Coupled Plasma Mass Spectrometry) will be studied. It is a variant of the technical analysis by mass spectrometry. The main advantages of this technique lie in high precision, low detection limits and low cost, analyzing most elements and isotopes in the periodic table simultaneously in no more than a couple of minutes.

Monday, 23/May/2016 2:20pm - 2:40pm
ID: 150 / 23-PM3-RPA: 1
oral presentation
Topics: SA - Science applications

Teaching the New Cohort what they don't know they don't know about RPA

Philip Stuart Anderson
Scottish Association for Marine Science, United Kingdom

Many national research councils foresee a major role for robotic platforms in the future of monitoring, survey and explorative science. A natural response is to fund studentships to use such platforms, such as AUVs, sea-gliders, ASV and of course RPA. The relative novelty of the technology means many PIs and indeed review panels, are relatively naive regarding the capability and limitation of these platforms, and students often start off thrown into deep water of an unknown depth. Many projects favour the RPA as an apparently cheap and hands on technology, compared to e.g. a multi €deca-k submarine.

A UK 'response to the response' since 2013 has been run Short Advanced Training Courses at postgrad level which focuses on the less familiar science, sensor and legal constraints, rather than platform programming and flying. More recently we have started the NEXUSS call "Next Generation Unmanned Systems Science", focusing on teams of studentships operating diverse robotics with quarterly focused training and an annual Grand Challenge for heterogeneous fleets.

Are these courses still valid and relevant? What can we as 'teachers' learn from our students, as they take on the tasks of using RPA for science? An invitation to open the discussion on how best to teach RPA-based science.

Monday, 23/May/2016 3:00pm - 3:20pm
ID: 152 / 23-PM4-ACS1: 2
oral presentation
Topics: ACS - Aircraft and control systems

A guiding vector field algorithm for path following control of drones

Hector Garcia de Marina[1], Yuri Kapitanyuk[2], Anton Proskurnikov[2], Ming Cao[2]
[1]ENAC, France; [2]University of Groningen, Netherlands

In this presentation we propose an algorithm for path-following control of a fixed-wing drone based on the idea of the guiding vector field. The desired path may be an arbitrary 3D smooth curve in its implicit form, that is, a level set of some known smooth function. Using this function and by controlling the course heading and climbing rate of the drone, we design a guiding vector field, whose integral curves converge to the desired trajectory. From a practical point of view, the proposed algorithm has several interesting features: it can be made robust against unknown constant disturbances, such as wind; and the desired trajectory can be made time-variant, for example, we can make a 3D closed orbit surrounding a cloud to travel following such a cloud.

ID: 153 / 23-AM5-INV: 1
oral presentation
Topics: IPI - Instrumentation and payload integration

GHOST - Green House gas Observations of the Stratosphere and Troposphere

Andy Vick
STFC, United Kingdom

GHOST is a SWIR spectrometer designed and built by the UK Astronomy Technology Centre for the Universities of Leicester and Edinburgh. GHOST uses a novel multi-order dispersive optical system and very low noise detectors to measure CO2, CH4, CO and H2O at resolutions that allow sinks, as well as sources, of GHGs to be identified. GHOST flew on a NASA Global Hawk during the Spring of 2015 and later on the NERC ARSF. This talk will concentrate on the GHOST instrument development and Global Hawk installation and operations from California.