ID: 101

Heat flux estimates from SUMO profiles during the BLLAST campaign

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Abstract

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. More than 10 profile 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 θ or q 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.

Many of the heat flux profiles 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.

Several of the flux profiles depend strongly on advection. We investigate how the flux profiles respond when this is taken into account either by using a method where advection is treated as a constant throughout the boundary layer, or by using horizontal advection output from the mesoscale model MesoNH.

The fluxes are compared to measurements from a network of eddy covariance surface stations. The sensible heat flux fits in general better than the latent heat flux to the surface station flux values.

ID:102

Development of an Integrated Gas Monitoring and Source Identification Unmanned Aircraft System

David Bridges, Richard Coffin, and Ahmed Mahdy

Texas A&M University – Corpus Christi

Abstract

Texas A&M University – Corpus Christ (TAMU-CC) has operated a modified Arcturus T-16XL for ground survey measurements for over three years, conducting eight week-long exercises and amassing over 81 hours of flight time in capturing visible wavelength, infrared, and ultraviolet images of the south Texas coastline. These images have been used for research topics ranging from coastal erosion to mapping of bird habitats to mapping sea grass. In 2016, TAMU-CC received funding from the US National Science Foundation under their Major Research Instrumentation (MRI) program to develop an integrated gas monitoring and source identification unmanned aircraft system (UAS) for exploration, environmental compliance and assessment. The project objective is to enable a wide range of interdisciplinary and multidisciplinary research activities around national and regional oil and gas industry needs with emerging developments in UAS and sensor technologies. The aircraft will be an existing airframe currently in production, and the primary sensor to be installed on the aircraft will be a microportable gas analyzer that can detect methane with ppb sensitivity as well as carbon dioxide and water vapor. This instrument will be used to survey regions with high methane and carbon dioxide flux to the atmosphere to identify regions in the ocean water column and sediment where there is an active source of methane and high levels of methane cycling. The presentation will give a brief overview of the prior UAS experience at TAMU-CC and then will discuss the proposed UAS and its uses.

ID:103 (Poster)

Enhanced UAV-sensor systems with capacities for monitoring air pollutants from mobile (shipborne) platform and in the upper troposphere (with radiosonde)evelopment of an Integrated Gas Monitoring and Source Identification Unmanned Aircraft System

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Abstract

The Eastern Mediterranean and Middle East (EMME) region has exceptional environmental specificities, with extensive deserts, and is the most water-scarce region on Earth. In addition, heat extremes, dryness, atmospheric dust and air pollution combine into a major public health hazard. The AQABA project will address these issues; it will provide the first-ever comprehensive in-situ characterization of the photochemical and aerosol processes in the EMME and organize for that purpose a 2-month oceanographic cruise (during summer 2017) with pioneering atmospheric measurements across the Mediterranean and Arabian Basin (Malta-Kuwait-Malta). Unmanned Aerial Vehicles (UAVs) will be operating on-board and extend vertically shipborne gas/aerosol measurements through the entire marine boundary layer and above.

In the framework of AQABA, ENAC (Ecole Nationale de l'Aviation Civile) in collaboration with the Unmanned Systems Research Laboratory (USRL) of the Cyprus Institute (CyI) will develop a cost-effective UAV- sensor system with the capability of providing autonomously gas/aerosol measurements in the atmospheric column up to an altitude of 2.5km above sea level while the research vessel is sailing. The UAV will be equipped with the novel Chimera autopilot system developed by ENAC; it will be equipped with an Optical Particle Counter (OPC), Ozone, NO_2, and basic meteorological parameters (Temperature, Relative-Humidity, and Pressure).

This particular UAV-sensor system will be developed in such a way that it could be easily utilized later on as “Return Glider Radiosonde” (RGR), being lifted to the upper troposphere (10km) using upper-air balloon soundings. Upon reaching the desired altitude the RGR will automatically get released from the balloon and glide back to the launch site or to another landing location for recovering the measurements as well as the sensors.

The methodology that has been implemented for the development, optimization and operation of this UAV is presented. It is also envisioned that such a new UAV-sensor system will offer the atmospheric community with an easy-to-use and cost-effective solution to perform flights within new atmospheric environments (Open Ocean / Upper Troposphere) and with the capability of providing dense vertical profiles of key climate forcers in the troposphere.

ID: 104

Validation of 3D Wind Vector Measurements using a 5-hole Probe with Remotely Piloted Aircraft

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4 Laboratoire d'Aerologie, University of Toulouse, CNRS, France

Abstract

Enhancements in Remotely Piloted Aircraft Systems (RPAS) have demonstrated their potential in atmospheric research as ultra-light RPAS (< 2.5 kg) which are able to fly through the boundary layer, in clouds and different weather conditions. The European project BACCHUS (Impact of Biogenic versus Anthropogenic Emissions on Clouds and Climate: towards a Holistic Understanding) focuses on aerosol-cloud interactions.

Vertical wind velocity at cloud base is an important parameter for understanding aerosol-cloud interactions, in particular to estimate the supersaturation that aerosol particles grow into cloud droplets. 3D wind measurements are obtained from a 5-hole probe synchronized with an Inertial Measurement Unit (IMU). The 5-hole probe has been first calibrated in a wind tunnel, then comparison of flight results has been done with sonic anemometer located on a 60 m meteorological mast (Lannemezan, France). Error analysis has been conducted to estimate the accuracy of 3D wind measurements.

Comparison of Power Spectral Density function (PSD), vertical wind distribution and Turbulent Kinetic Energy values (TKE) between RPAS measurements and static sonic anemometer in calm wind, but different turbulent conditions, validate the RPAS measurements. During BACCHUS field experiments (Mace Head, Ireland), the RPAS were programmed to fly at a level leg just below cloud base to measure updraft. Cloud radar data were also available to compare with RPAS updraft. Three case studies present distinct meteorological conditions to analyse within measurements. The cloud types include a stratocumulus deck, small convective clouds and a broken cloud field. RPAS flight comparisons with anemometer and cloud radar validate 5-hole probe measurements. The 3D wind measurements, particularly the updraft, have been used in an air parcel model to obtain cloud microphysical properties for aerosol-cloud interactions.

ID:105

The 3D Mesonet Concept: Extending Networked Surface Meteorological Tower Observations Through Unmanned Aircraft Systems

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Abstract

Fixed monitoring sites, such as those in the US National Weather Service Automated Surface Observing System (ASOS) and the Oklahoma Mesonet provide valuable, high temporal resolution information about the atmosphere to forecasters and the general public. The Oklahoma Mesonet is comprised of a network of 120 surface sites providing a wide array of atmospheric measurements up to 10 m height with an update time of five minutes. The deployment of small unmanned aircraft to collect in-situ vertical measurements of the atmospheric state in conjunction with surface conditions has potential to significantly expand weather observation capabilities. This concept can enhance the safety of individuals and support commerce through improved observations and short-term forecasts of the weather and other environmental variables in the lower atmosphere. We report on a concept of adding the capability of collecting vertical atmospheric measurements (profiles) through the use of unmanned aerial systems (UAS) at remote Oklahoma sites deemed suitable for this application. While there are a number of other technologies currently available that can provide measurements of one or a few variables, the proposed UAS concept will be expandable and modular to accommodate several different sensor packages and provide accurate in-situ measurements in virtually all weather conditions. Such a system would facilitate off-site maintenance and calibration and would provide the ability to add new sensors as they are developed or new requirements are identified. The small UAS must be capable of accomodating the weight of all sensor packages and have lighting, communication, and aircraft avoidance systems necessary to meet existing or future FAA regulations. The system must be able to operate unattended, which necessitates the inclusion of risk mitigation measures such as detect and avoid radar and the ability to transmit and receive transponder signals. Moreover, the system should be able to asses local weather conditions (visibility, surface winds, cloud height) and the integrity of the vehicle (system diagnostics, fuel level) before takeoff. We provide a notional concept of operations for a 3D Mesonet being considered, describe the technical configuration for one station in the network, and discuss plans for future development.

ID:106

First experiments and results with a new developed airborne aerosol sampling unit carried by a multirotor UAV.

Claudio Crazzolara, Andreas Platis, Jens Bange, Annett Junginger, Martin Ebner and Tatjana Miranda

Abstract

In-situ measurements of the spatial distribution and transportation of atmospheric particles such as pollen, spores and particulate matter (PM) are of great interdisciplinary interest. The few known state of the art in-situ measurement systems employ passive sampling units carried by fixed wing UAVs, thus providing only limited spatial resolution of aerosol concentration. Also the passively sampled air volume is determined with low accuracy as it is only estimated by the air speed and the length of the flight path. We will present a new approach, which is based on the use of a multirotor UAV providing a versatile platform. Due to its automated position stabilisation system, the aerosol concentration can be measured with a very high spatial resolution. First, experiments with artificial smoke were conducted to examine the airflow created by the UAVs rotors downwash in flight and to determine where on the multirotor UAV the aerosol sample air intake can be placed, ensuring a minimum effect on the aerosol concentration. Second, a particle collecting unit, e.g. a conventional filter or an inertial mass separator (impactor) were installed. Post flight, the collected aerosols can be classified on ground by type, size and number using light or scanning electron microscopy (SEM). A particle concentration can be calculated by the sampled air volume, measured by a mass flow sensor. The feasibility of placing an optical particle counter (OPC) on the multirotor UAV will be evaluated in future experiments. The combination of comprehensive determination of type, size and number of aerosol particles by sampling or in-situ measurement in combination with the very high spatial resolution provides not only valuable progress in agriculture, paleoclimatology and meteorology, but also opens up the application of multirotor UAVs in new fields, for example for precise determination of the mechanisms of generation and distribution of fine particulate matter.

ID:107

Use of Unmanned Aerial Systems to Study Atmospheric Processes During Sea Ice Freeze Up

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3 Sandia National Laboratories;
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Abstract

In October 2016, a team of scientists deployed to Oliktok Point, Alaska to make atmospheric measurements as part of the Evaluation of Routine Atmospheric Sounding measurements using Unmanned Systems (ERASMUS) and Inaugural Campaigns for ARM Research using Unmanned Systems (ICARUS) campaigns. The deployment included operations using the University of Colorado DataHawk UAS and the US Department of Energy's Atmospheric Radiation Measurement (ARM) program's tethered balloon system. The DataHawk was configured to make measurements of atmospheric thermodynamics, wind and surface temperature. The tethered balloon was operated with a variety of instruments, including devices to measure thermodynamic structure, turbulence, aerosol properties and ice crystal microphysics.

During this time, the team experienced a variety of weather regimes and witnessed the development of near shore sea ice. In this presentation, we will give an overview of the measurements obtained during this time and how they were used to better understand freeze up processes in this coastal environment. Additionally, we will provide insight into how these platforms are being used for evaluation of a fully-coupled sea ice forecast model operated by NOAA's Physical Sciences Division. Finally, we will provide details on planned 2017 Arctic unmanned aircraft operations by the US DOE, NOAA and others.

ID:108

3D Atmospheric Temperature and Wind Profiles using UAV-Based Acoustic Tomography

Anthony Finn, Kevin Rogers, Feng Rice & Joshua Meade

University of South Australia, Adelaide, Australia

Abstract

The natural sound generated by an Aerosonde unmanned aerial vehicle is used in conjunction with tomography to remotely sense atmospheric temperature and wind profiles up to altitudes of 1,200m and over baselines of 600m. Sound fields recorded onboard the unmanned aircraft and by an array of microphones on the ground are compared and converted to sound speed estimates for the ray paths intersecting the intervening medium. Tomographic inversion is then used to transform these sound speed values into vertical cross-sections and 3D profiles of virtual temperature and wind vector, which enables the atmosphere to be visualised and monitored over time. This paper reports on the results of a two-day trial during which tomographically-derived wind vector and temperature estimates were compared to measurements taken by a co-located mid-range Doppler SODAR and sensors onboard the aircraft. Large eddy simulation of daytime atmospheric boundary layers were used to assess the anticipated threshold of performance and nature of errors.

ID:109

Calibration and Validation of Weather Sensors for Rotary-Wing UAS

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Abstract

The capabilities of small unmanned aircraft systems (sUAS) to make atmospheric observations is rapidly being realized as a means to collect previously unobtainable observations in the lowest part of Earth's atmosphere. However, in order for these systems to provide meaningful kinematic and thermodynamic data, it is imperative to establish an understanding of the strengths and limitations of the sensors and retrieval algorithms implemented, as well as how they perform under various configurations and flight conditions. This presentation will address sensor packages produced by International Met Systems (InterMet) and Sparv Embedded AB (Windsond), which provide temperature, humidity, pressure, and GPS data. We focus on two primary stages of experimentation. The first step is the calibration of the sensors against reference measurements from the Oklahoma Mesonet, which yields confirmation that the instruments themselves are reliable in quasi-ideal environments. The second step is the validation of these measurements by mounting the sensors onto a rotary-wing platform and comparing in-flight measurements to those from a 10-meter meteorological tower operated by the Oklahoma Mesonet, a 60-meter instrumented tower operated by the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility in Northern Oklahoma, radiosondes, and other UAS. It appears that these measurements are robust provided the instrument packages are properly mounted in locations that provide adequate air flow and proper solar shielding. Experiments to locate this ideal location are underway, and are conducted in an isolated chamber using wind probes along with the sensors themselves all mounted onto a linear actuator arm which moves laterally underneath the propeller wash. Furthermore, efforts have been made to calculate horizontal wind fields using Euler angles derived from the rotary-wing's autopilot. While these wind calculations have shown promise, results exhibit appreciable uncertainties and variance. Further studies are underway to derive wind estimations in a more robust manner using rotary-wing UAS, and show optimistic theoretical possibilities. This presentation will provide a general evaluation of the sensors along with their performance characteristics, suggestions for sensor placements based on experience and isolated chamber experimental results, and an overview of the current wind retrieval algorithms used as well as their uncertainties and an outlook for improved versions.

ID:110

Diversity and Ice Nucleation Activity of Microorganisms collected with a Small Unmanned Aircraft System (sUAS) in France and the United States

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Abstract

Many microbes relevant to crops, domestic animals, and humans are transported over long distances through the atmosphere. Some of these atmospheric microbes catalyze the freezing of water at higher temperatures and facilitate the onset of precipitation. We collected microbes from the lower atmosphere in France and the United States with a small unmanned aircraft system (sUAS). Fifty-five sampling missions were conducted at two locations in France in 2014 (an airfield in Pujaut, and the top of Puy de Dome), and three locations in the U.S. in 2015 (a farm in Blacksburg, Virginia, and a farm and a lake in Baton Rouge, Louisiana). The sUAS was a fixed-wing electric pusher platform equipped with a remote-operated sampling device that was opened once the aircraft reached the desired sampling altitude (40 to 50 meters above ground level). Samples were collected on agar media (TSA, CLA, R4A, R2A, and CA) with and without the fungicide cycloheximide. Over 4,000 colonies were recovered across the 55 sUAS sampling missions. A droplet freezing assay was used to screen nearly 2,000 colonies for ice nucleation activity, and 15 colonies were ice nucleation active at temperatures warmer than -8 degrees Celsius. Colonies are being identified based on DNA sequences of portions of the 16S rDNA gene. Future work aims to understand the potential origin of the atmospheric microbial assemblages collected with sUAS, and their association with mesoscale atmospheric processes.

ID:111

Aerosol measurements in Antarctica using "Kite Plane" in January 2017

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Abstract

We focused on the performance of Unmanned Aerial Vehicles (UAV) for meteorological research and using UAVs from 2000. At the first, the observations of Aeolian dust (KOSA, Yellow Sand) were performed from 2000 to 2002 at Dunhuang, China and Karatsu, west Japan. Development of automated navigation systems were also continued and a new idea of UAS, Balloon borne Gliding Platform (BalGliP) have been tested.

Meteorological observations using a UAV in the Antarctica also have been carried out at S17 Air Base (69o 02' S, 40o 06' E, 606m a.s.l.), near Syowa Base by the 48th, 54th, and 56th Japanese Antarctic Research Expedition, called JARE). The JARE 58th also planned to perform meteorological observations including snow, water vapor and aerosols budgets at S17 air base during December 22th, 2016 and February 4th, 2017. Main mission of the observation focused on aerosol processes using automated Kite Planes, UAVs with Rogallo wings.

S17 locates on the slope of Antarctic continent at 17km from the edge of continent. It was constructed as an airport for international manned airplane network, called DROMLAN. We used two types of Rogallo wing UAV, called KitePlane, for two different observation missions. First mission was horizontal two ways flight from S17 to Tottsuki cape (TTK), 18km far from S17, using Engine powered Kite plane. Another mission was arranged for a high altitude observation. Electric motor KitePlane was launched by an 800g rubber balloon and separated from the balloon at preset level (5 km in altitude in this campaign). After separation, the KitePlane return to home base, automatically. XENO manufactured by Xenocross Co. Ltd., was employed for an autonomous navigation system. Flight course was controlled by a guidance control referring flight direction or magnetic heading. Level of flight was controlled referring altitudes with assumption of iso temperature lapse rate.

Horizontal two ways flight Automated flights were performed 24 times during the campaign, including 5 flights for checking system, 11 flights for observations to Totsuki cape (TTK), 8 flights for observation to on the way to TTK . Observation flight was planned with two different level flight of 700 m for outgoing and 1200m for return. Vertical flight by BalGliP Three flight were performed during campaign, including one test flight with balloon separation at 1300 m a.s.l. and two observation flight with 5,000 m a.s.l. separation. Kite Planes return to S17 by gliding flight, successfully.

Acknowledgement: this campaign was supported by teams of JARE57 and JARE58. It also supported by crews of Japanese Ice Breaker "Shirase"

ID:112

The impact of sensor response on the representation of atmospheric boundary layer phenomena by airborne instruments

Adam L. Houston and Jason M. Keeler

University of Nebraska-Lincoln

Abstract

Large-eddy simulations are used to evaluate the impacts of sensor response on the representation of meso-γ-scale and micro-α-scale phenomena by aircraft-borne meteorological instruments. Synthetic thermodynamic state variables are developed using large eddy simulations. Offline models for simple/generic fixed-wing and rotary-wing aircraft are used to evaluate the representativeness of mixed-layer vertical profiles, convective boundary layer structures (e.g., open-celled convection), and storm-generated outflow boundaries. The experiment parameter space also includes air speed (ascent/descent rates) for fixed-wing (rotary-wing) aircraft since the large gradients that characterize these phenomena might be better represented at lower air speed (ascent/descent rates). However, when instantaneous representation of a rapidly evolving phenomenon is required, slower air speeds may ultimately degrade the accuracy of in-situ observations. This tradeoff is quantified in this research.

ID:113

Results from the 2016 CLOUD-MAP Flight Campaign

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3 Earth and Atmospheric Sciences, University of Nebraska-Lincoln;
4 Donald and Gertrude Lester Professor of Mechanical Engineering and Director, UK Unmanned Systems Research Consortium, University of Kentucky;

Abstract

CLOUD-MAP – the Collaboration Leading Operational UAS Development for Meteorology and Atmospheric Physics – is a 4 year, 4 university partnership funded by the National Science Foundation to develop capabilities that will allow meteorologists and atmospheric scientists to use unmanned aircraft as a common, useful everyday tool following recognized needs as outlined in a 2009 US National Research Council Report:

The vertical component of … mesoscale observations is inadequate. Assets required to profile the lower troposphere above the near-surface layer … are too limited in what they measure, too sparsely or unevenly distributed, sometimes too coarse in vertical resolution, sometimes limited to regional areal coverage, and clearly do not qualify as a mesoscale network of national dimensions. Likewise, vertical profiles above the Earth's surface are inadequately measured in both space and time…

Unmanned Aircraft Systems (UAS) are a potential solution to this problem as they 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.

The CLOUD-MAP team is examining numerous systems including both fixed wing and rotary wing solutions. In June 2016 over 60 team members from the 4 partner institutions (Oklahoma State University, the University of Oklahoma, the University of Kentucky, and the University of Nebraska at Lincoln) met in Oklahoma to evaluate platforms and sensor suites. The exercise was also designed to evaluate operational considerations of a large, multi-institutional team. Selected sites included the Oklahoma State University Unmanned Aircraft Flight Station, the Marena Mesonet, and the US Department of Energy Atmospheric Radiation Monitoring Climate Research Facility Southern Great Plains site. Over a 3½ day period, the team conducted approximately 250 individual flights with 25 total flight hours focused on gathering comprehensive, accurate, and relevant atmospheric data. Sensors included standard meteorological sensors for pressure, temperature, and relative humidity, various wind sensors such as five-hole probes, hot wire sensors, and IMUs, gas concentration sensors including CO2 and CH4, and small inexpensive meteorological packages designed for aerial deployment. The presentation will discuss results from selected platform and sensor suite flight-testing of various CLOUD-MAP UAS as well as operational and logistical considerations for such a large exercise. Plans for the next CLOUD-MAP Flight Campaign will also be presented, scheduled to take place at the same location in June, 2017.

This work is supported in part by the National Science Foundation under Grant No. 1539070.

ID:114

Sensitivity of Supercells to UAS Data Assimilation in an OSSE Framework

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Abstract

UAS have the potential to characterize the thermodynamic and kinematic state in the vicinity of supercell thunderstorms. The impact of UAS observations on simulated supercells is being assessed through Observing System Simulation Experiments (OSSEs), wherein synthetic observations are "collected" by a simulated UAS within a high-resolution idealized simulation (termed the nature run) that represents the true atmospheric state. The nature run was developed using the First-Generation Pennsylvania State University/National Center for Atmospheric Research Cloud Model (CM1), and was initialized in an environment consisting of open-cell boundary layer convection and deep-layer vertical wind shear sufficient to support a supercell. Realistic boundary layer structures were seeded using random thermal perturbations in the lowest 1 km in the nature run initial conditions and were maintained through inclusion of radiative parameterization, thermal and moisture surface fluxes, and a semi-slip surface. An aircraft model was developed to sample synthetic data from the storm environment in a manner consistent with a fixed-wing UAS. The impact on forecasts achieved through assimilation of these synthetic data into coarse-resolution idealized Weather Research and Forecasting model (WRF) simulations will be discussed. This comparison of the nature run predictions (truth) to the coarse-run predictions allow for evaluation of the impact UAS data could have on real time convection allowing models (CAMs).

ID:115

Long-Term Monitoring of Aerosols and Cloud Properties using Unmanned Aerial Vehicles (UAVs)

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Abstract

The central location of Cyprus in the Eastern Mediterranean and Middle-East region provides a unique site for studying the characteristics of a wide range of aerosol types originating from natural (e.g. dust, sea salts) and anthropogenic (e.g. human-made) sources transported from three continents: Europe, Africa, Asia. The field deployment of a large range of new UAV-sensor systems operated by the Unmanned Systems Research Laboratory (USRL) of the Cyprus Institute (CyI) will bridge ground- and satellite-based observations. These UAV-sensor systems aim to document the in-situ properties of aerosols and their interactions with clouds in the first 3-4 km of the atmosphere. Several UAVs have been designed, built, and equipped for this purpose with a set of miniaturized prototype and commercial aerosol instruments in collaboration with EU and US colleagues. The onboard payload consists of a miniature Scanning Aerosol SunPhotometer (miniSASP), a Printed Optical Particle Spectrometer (POPS), an Ice-Nuclei (IN) sampler, a Dual Wavelength Prototype (DWP) to monitor aerosol absorption, as well as pressure, temperature, relative humidity sensors and video. The fleet of UAVs has been adjusted and optimized for flying efficiently and providing reliably high quality atmospheric observations on a weekly basis for the duration of the entire year 2017. The flight plan is arranged accordingly to ensure sampling in a wide range of contrasted atmospheric conditions. In addition, the flight strategy is based on real-time LIDAR observations of the boundary layer height and the dust layers and, when possible, synchronized with satellite overpasses. All flights are performed in the private CyI airfield and the overhead UAV airspace strategically located nearby the CyI "Cyprus Atmospheric Observatory" (CAO) for boundary layer observations and the Troodos station for lower troposphere observations. As a result, the unmanned airborne routine measurements should provide a unique and comprehensive dataset of key atmospheric species and properties over the Eastern Mediterranean, a strategic region where long-term atmospheric observations are still lagging behind.

ID:116

The Aerosonde meterological platform

Jack Kormas

Abstract

The Aerosonde Unmanned Air Vehicle (UAS) has been in operation since 1995 with its primary purpose of providing meteorological soundings to the worldwide scientific community with the ability to undertake long range and long endurance missions exceeding 18 hours and over 500km away. Many research papers have been written describing the use and value of utilising the Aerosonde UAS and how this data is still being utilised today to enable researchers to better understand the environment. This paper will describe the power of the Aerosonde UAS describing the past, present, and future missions and the deployed uses surrounding the types of payloads that have been carried to collect the multitude of metereological data. The presentation will describe the use of the Aerosonde UAS in missions for Hurricane/Typhoon monitoring in USA and Taiwan, data collection in austere environments such as Arctic/Antarctic in the collection of data associated with Katabatic winds and how the Aerosonde UAS has been deployed for environmental monitoring for both air sampling and wildlife monitoring. The Aerosonde Team has been able to undertake these missions in commercial airspace navigating regulations ranging from Australia's Civil Aviation Safety Authority through to USA's FAA utilising a risk assessment approach and will share lessons learnt.

ID:117

RPAS based observation on the Arctic Boundary Layer during the ISOBAR campaigns on Andøya and Hailuoto

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Abstract

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. During the winter 2016/17 we carried out the first two measurement campaigns related to this project. The first two-week campaign was held on Andøya, Norway at the facilities of the Andøya Space Centre during December 2016 and served as a test and validation campaign for our RPAS systems and the corresponding sensor packages. In February 2017 we carried out our second campaign on the Finnish island Hailuoto in the northern Baltic Sea. During the three week-long field period we studied processes within the Atmospheric Boundary Layer over the sea-ice of the Bothnian Bay, based on observations from several different RPAS as well as ground based flux and automatic weather stations and remote sensing systems (Lidar and Sodar). Turbulence measurements from different altitudes were provided by the fixed-wing Multipurpose Atmospheric Sensor Carrier (MASC, University of Tübingen) and a new fixed-wing aircraft developed by Lindenberg und Müller GmbH & Co. KG, based on the miniTalon model airframe. The Small Unmanned Meteorological Observer (SUMO, University of Bergen) was used for atmospheric profiles from about 30 m to 1800 m, the maximum allowed flight level within our designated danger area. In addition, different multicopter systems were applied to take profiles from the ground to an altitude of up to 400 m. In total more than 150 scientific flights have been conducted during the three weeks with five intensive observational periods. Together with the ground based and remote sensing data this results in an extensive high resolution data set of observations on the stable ABL which will be used for detailed investigations of the processes within the stable ABL. Further we aim to implement these processes in new ABL parametrization schemes for numerical models.

ID:118

sUAS Detect and Avoid: Forecasting errors associated with the position of an aircraft on a radar displays.

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University of North Dakota

Abstract

Given the increased volume of small Unmanned Aircraft System (sUAS) traffic in recent years, the mitigation of hazards within the airspace is critical. Therefore, research concerning the ray-tracing of Electromagnetic (EM) propagation and forecasting those conditions using atmospheric models to quantify the errors associated with the position of an aircraft on a radar display is also very crucial. This research will assist an sUAS pilot in remaining well-clear of an intruder aircraft. Well-clear for an sUAS has been defined, through work with the Science and Research Panel (SARP), as ±250 feet vertically and ±2000 feet horizontally. Because of the relationship between atmospheric conditions and EM propagation, this research will benefit many areas of aviation.

Atmospheric conditions affect the propagation of radar beams, causing them to bend up or down. When this happens, it can cause an aircraft's apparent position on the radar display to be significantly altered from reality. In order to mitigate the hazards to sUAS and other aircraft that arise from such positional uncertainties, aviators would benefit from forecasts of EM propagation conditions. Although this analysis will be applied to the use of sUAS, the nature of the results and conclusions can be applied to other airframes and supporting systems. A major type of supporting system that is heavily affected by anomalous EM propagation is a Detect And Avoid (DAA) system. If EM propagation properties are not handled properly, intruder targets may be misplaced. If a maneuver is made using a misplaced target, it is possible that the aircraft could maneuver incorrectly and cause a safety issue like a Near Mid Air Collision (NMAC) or worse.

A forecast product must be developed to inform a pilot of the scope of positional errors. To explore this, forecasted atmospheric soundings are being used in a ray-tracing algorithm. Bufkit soundings will be pulled from the North American Mesoscale (NAM) model and the Rapid Refresh (RAP) model at two locations in the Continental United States (CONUS): Bismarck, North Dakota and Oklahoma City, Oklahoma. A forecast 12 hours into the future from the model run time, incremented every 3 hours, will provide the end-user the EM propagation type and degree of positional uncertainty that will affect their sUAS operations. After this analysis is complete, the ray-tracing output from the NAM and RAP will be verified using atmospheric sounding data at the two locations listed above. This will provide information on the accuracy of these forecasts and whether they can be used for situational awareness or integrated into DAA algorithms.

ID:119

Initial TTwistor Results from EPIC Phase 1

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Abstract

A team from the University of Colorado Boulder joined the University of Oklahoma (OU) and the National Severe Storms Laboratory (NSSL) at the Southern Great Plains (SGP) Department of Energy ARM site 29-30 October 2016 for the initial deployment for the pre-storm Environment Leading to initiation of Convection (EPIC) project. The objective was to demonstrate the ability of the TTwistor UAS to collect pressure, temperature, humidity (PTH) and wind data between two towers in the Oklahoma Mesonet while OU and Meteomatics Gmbh simultaneously operated instrumented unmanned rotorcraft in the vicinity of the towers located at the SGP ARM site near Lamont, OK and Medford, OK.

The TTwistor utilizes an RS-92 sonde for pressure, temperature, and humidity measurements, while a five-hole probe from Aeroprobe Corporation measures the 3D relative wind. Flights on the first day demonstrated good agreement between the TTwistor and ground based measurements in wind, temperature, and relative humidity. Data obtained on the second day indicated a potential error with the multi-hole probe on the TTwistor, leading to discrepancies of roughly 2-4 m/s in measured winds between the UAS and towers. A novel approach was used to correct the erroneous wind components, yielding improved agreement with ground based sensors. Results indicate that the current temperature and humidity sensors are of sufficient accuracy while issues related to consistency of the wind measurements are currently being resolved.

Special thanks to Steve Borenstein, Dr. Eric Frew, Daniel Hesselius, and Dr. Doug Weibel from CU for their flight operations support.

ID:120

The Impact of UAS Observations on Model Forecasts of the 28 June 2016 PRECIP Event

George Limpert and Adam L. Houston

University of Nebraska-Lincoln

Abstract

UAS observations of the planetary boundary layer were collected in western Nebraska on 28 June 2016 as part of the field phase of the Program for Research on Elevated Convection with Intense Precipitation (PRECIP). Two Tempest (fixed-wing) UAS flights of approximately 40 minutes in duration were conducted in the southern Nebraska Panhandle during the early afternoon, prior to thunderstorms developing over southeast Wyoming. Later in the evening, a severe bow echo that initiated over South Dakota moved southeast through the region sampled by the flights. Low-level observations of temperature, humidity, and pressure were recorded by the aircraft. Additionally, near-surface observations were recorded in approximately the same location as the aircraft by the integrated mesonet and tracker (IMeT). A computer model prediction created by downscaling high-resolution rapid refresh (HRRR) initial and lateral boundary conditions had too little areal coverage of thunderstorms compared to radar observations and, although the model predicted the track of the bow echo well, initiation and progression of the storms were too slow by approximately 1.5 hours. Simulations will be conducted that systematically examine the sensitivity of model predictions to assimilated aircraft and IMeT observations, conventional surface and upper air observations, and radar observations. Results of these data-denial experiments will be presented.

ID:121

Current UAV-assisted Wind Energy Research Projects at the University of Tuebingen with the in-house built MASC Aircraft

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University of Tuebingen, Germany

Abstract

In wind energy site assessment, numerical modeling has become widely accepted and even further, has become an indispensable tool especially for assessments in complex terrain. Each numerical study should be backed by in-situ measurements of the simulated flow. Thereby advancing model tasks and resolution requirements for in-situ data evaluations are increasing which poses a common issue in in-situ turbulence measurement research.

From the Environmental Physics group at the department of Geoscience two current projects are presented where high resolution in-situ data is vital for a scientific evaluation: HeliOW and WINSENT. These projects are motivated by the results of the previous projects Lidar Complex and KonTest, were the remotely controlled aircraft system MASC (Multipurpose Airborne Sensor Carrier) was applied to. The MASC system allows measurements of thermodynamic parameters (e.g. temperature, humidity, pressure etc.) as well as the wind velocity components up to 30 Hz resolution. This makes it perfectly suitable for turbulence measurement.

In HeliOW the wake of off-shore wind energy converter systems (WECS) are studied. The goal is to connect in-situ measurements - obtained in four campaigns throughout a year - and modeled data also to statistically evaluate weather data and pilot weather reports (PiReps) to increase helicopter crew safety when approaching WECS for servicing or hoisting, since more and more helicopter approaches have to be aborted for safety reasons in the wake of a WECS. At the end, reasonable safety regulations and recommendations for maritime helicopter operations shall be concluded.

The WINSENT project comprises a wind energy test site in complex terrain in Baden-Wuerttemberg, not far from the University of Tuebingen. The goals in this project are the installation of two research wind energy converter systems for test purposes, validations of simulated data of the overall flow field as well as of the micro scale around a rotor blade. To study the local wind field and the influence of the installation of the WECSs weekly measurements are planned.

This presentation will give an overview of the previous results in this field and an introduction into future objectives relating to the application of UAVs in wind energy research in the Environmental Physics group of the University of Tuebingen.

ID:122

The Small Whiskbroom Imager for atmospheric compositioN monitorinG (SWING)

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5 Free University of Berlin, Germany

Abstract

(SWING) is a compact payload developed for trace gas mapping from an Unmanned Aerial Vehicle (UAV). The payload is based on a compact UV-Visible spectrometer and a scanning mirror to collect scattered sunlight under the aircraft and in zenith. The spectra recorded on flight are analysed with the Differential Optical Absorption Spectroscopy (DOAS) method. The weight, size, and power consumption of SWING are respectively 1100 g, 33x12x8 cm3, and 15 W.

We present NO2 and SO2 measurements performed with SWING during three campaigns above different geophysical targets. During the AROMAT campaign in September 2014, SWING was operated from a UAV in the vicinity of a power plant in Romania. We flew the UAV in visual range and thus covered a limited area, but downwind of the plant, and the NO2 exhaust plume was clearly detected. Moreover, the SWING measurements can be compared with simultaneous mobile DOAS measurements from the ground and from another aircraft (the FUB Cessna) flying at 3 km altitude, carrying the AirMAP instrument. During the AROMAT-2 campaign held in August 2015, SWING was installed in the Cessna alongside AirMAP and measured a larger area around the same Romanian power plant, both NO_2 and SO_2, and the NO2 field above Bucharest. Finally, during the AROMAPEX campaign in Berlin in April 2016, SWING and AirMAP were still in the Cessna and another airborne DOAS instruments was operated from another aircraft at a higher altitude (6 km), namely the APEX onboard the DLR Dornier. The dataset collected during these three campaigns enable to characterize the SWING instrument which could be used in the future for different applications such as air quality satellite validation or ship emissions monitoring.

ID:123

Two new RPAS for atmospheric boundary layer research based on an off-the-shelf model aircraft and the Paparazzi autopilot

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Abstract

Motivated by our experiences with the Small Unmanned Meteorological Observer (SUMO) and its capabilties and limitations we developed two new RPAS for atmospheric boundary layer (ABL) research and operated them during a first scientific campaign on Hailuoto, Finland, under harsh Arctic conditions (ISOBAR project). The SUMO system was originally designed as a recoverable radiosonde and is very efficient for taking atmospheric profiles of temperature, humidity, pressure, wind speed and direction from about 40m to up to 5000m. During the past years it has also been equipped with turbulence sensors for measurements of turbulent quantities along straight flight legs. However, the limited payload of the SUMO and its flight capabilities are not ideal for these kind of operations. Furthermore, safety considerations require a minimum flight level of about 30m agl., resulting in an observational gap in the important lowermost part of the ABL. The two new aircraft systems, a quadcopter system based on the commercially available Bebop2 by Parrot and a fixedwing aircraft based on the mini Talon by X-UAV are designed to overcome the limitations of the SUMO system, but are inspired by the concept of combining affordable off-the-shelf model aircraft with the Paparazzi autopilot and meteorological sensors.
The Bebop2 is a commercial available off-the-shelf quadcopter that was equipped with additional electronics for sensing temperature and humidity. The wifi data link was replaced with an XBee modem to increase reliability and range. The additional parts consist of ready available electronic boards and 3D printed parts for housing, which can be easily self-built. The sensor is positioned above one of the motors to allow for good ventilation. After flashing the Paparazzi autopilot software on the Bebop2's CPU it can be operated in the same way as the SUMO and the mini Talon. This allows to program the flight path and gives full access to all raw flight sensors (accelerometer, gyro, magnetometer) and estimated attitude. The idea is to use the Bebop2 as a high-resolution profiling system from the ground level up to an altitude of about 400m and further to use the entire vehicle as a sensor to estimate wind speed, direction and turbulence. First results from almost 100 test and scientific flights during the campaign on Hailuoto look promising.
The mini-Talon is a further development of the SUMO. The main differences are the significantly increased payload and longer flight times and the ability to fly at a higher air speed. The main focus is on carrying a 5-hole probe for turbulence measurements. This sensor war previously installed on the SUMO, but created problems due to its weight and the high data sampling rate. During the campaign on Hailuoto we carried out seven successful test flights with the system. During three of these flights we equipped the mini Talon with the five-hole probe and operated it simultaneously to the MASC system of the University of Tübingen. Future enhancements will include the integration of dual antenna GPS to measure the aircrafts yaw angle in flight with higher accuracy as required for good direct turbulence measurements.

ID:124 (poster)

VolcLab: An instrument package for UAVs and balloons to measure ash, gas, electrical, and turbulence properties of volcanic plumes

Keri A. Nicoll[1,2], Martin W. Airey[1], R. Giles Harrison[1], Paul D. Williams[1], Graeme J. Marlton[1]

[1] Department of Meteorology, University of Reading, U.K.;
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Abstract

Release of volcanic ash into the atmosphere poses a significant hazard to air traffic. Disruption of flights due to potential risks of engine damage caused by ingestion of appreciable ash concentrations can have major societal and economic consequences, such as that experienced during the 2010 eruption of Eyjafjallajökull. Accurate and effective measurement of the mass of ash in a volcanic plume along with in situ characterisation of other plume properties such as charge, turbulence, and SO_2 concentration can be used in combination with plume dispersion modelling, remote sensing, and more sophisticated flight ban thresholds to mitigate the impact of future events.

VolcLab is a low cost, disposable instrument package that can be attached to a small UAV or standard commercial radiosonde, for rapid emergency deployment. The total weight of the payload is ~500g. The payload includes a newly developed gravimetric sensor using the oscillating microbalance principle to measure mass directly without assumptions about particles' optical properties. The package also includes an SO_2 gas detector, an optical sensor to detect ash and cloud backscatter from an LED source, a charge sensor to characterise electrical properties of the plume, and an accelerometer to measure in-plume turbulence. This work describes the development of the sensor package, which consists of multiple stackable sensor boards. In particular the oscillating microbalance will be described, which utilises a wire vibrating at its natural frequency which is subjected to increased loading of ash. The increase in mass modifies the wire properties such that its natural frequency of oscillation changes. By measuring this frequency, the increase in mass can be inferred. The ultimate goal of the VolcLab sensor package is to provide in situ ash plume characteristics for airspace risk management planning as well as providing valuable scientific information on plume dynamics.

ID:125

UAV sensors and miniature radiosondes

Anders Petersson

Sparv Embedded, Sweden

Abstract

Sparv Embedded serves the scientific community with in-situ atmospheric sensor solutions. We will present our latest developments for UAV-based measurements with “Sparv Sensors” and the miniature radiosonde “Windsond”.

Sparv Sensors is an easy-to-use tool for a range of measurements for scientific use. Some highlights are: a response time for T and RH around 0.5 seconds, logging and telemetry, up to 100 Hz logging of suitable parameters, plug-and-play operation, support for arrays of sensors, etc.
Windsond is the radiosonde specialized for low altitudes, where low gas consumption, reusable sondes and portability make it suitable for both education and research requiring frequent boundary-layer soundings in a portable package.

We will also introduce our ongoing project with Uppsala University, where Sparv Sensors will be used for high-accuracy, UAV-based measurements of CO_2 during inversion conditions for research of the carbon cycle. The CO_2 sensor is a new model, with the potential for sub-ppm measurement resolution.

Through our ISARRA participation, we strive to find technical synergies between diverse research groups and to inspire ideas about new measurement possibilities. We are also open to cooperating with research groups that develop their own sensors to integrate, promote and sell the sensors.

ID:126

First results of a 2017 winter flight campaign in Berlin for the "Urban Climate Under Change" project

Andreas Philipp[1], Erik Petersen[1], Pia Ferenci[1], Stefan Engerer[1], Jucundus Jacobeit[1], Achim Holtmann[2], Fred Meier[2], Ute Fehrenbach[2], Dieter Scherer[2]

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Abstract

In order to develop, validate and apply a new urban climate model the project "Urban Climate Under Change" includes a module for three dimensional measurements in the urban boundary layer (called 3DO) within the cities of Stuttgart, Hamburg and Berlin. For the campaign in Berlin (17.-20. January 2017) hourly ascents of PPRZ-based fixed wing UAS were planned simultaneously during three consecutive days and nights at two locations, one directly in the center of Berlin (Moabit/Charlottenburg) and a rural one at Grunewald west of the city (Dahlemer Feld). Due to air traffic, icing and fog not all ascents could be realized, however most of the flights, operated in shifts of 8 hours duration, provided useful data for estimating temperature, humidity and wind profiles. Even though raw data are still in the stage of postprocessing first preliminary results are presented together with the UAS setup and a discussion of administrative and technical questions, which are also relevant for three future project campaigns in Berlin in July 2017 and 2018 as well as in January 2018.

ID:127

Investigating New Particle Formation in the Arctic Boundary Layer

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Abstract

In the framework of the new project "Investigating the Small-Scale Vertical and Horizontal Variability of the Atmospheric Boundary Layer Aerosol using Unmanned Aerial Vehicles" founded by the German Research Foundation, new particle formation (NPF) in the arctic boundary layer will be investigated by unmanned air vehicles.

A brief overview of the project is given, highlighting the challenges of UAV measurements in arctic regions. The project is motivated by results of earlier flight campaigns conducted by the University of Tübingen related to arctic conditions as well as NPF will be presented.

One part is a field report showing experiences of a recent field campaign (called ISOBAR) of UAV flights under cold conditions in Finland in February 2017.

The other part describes the results of a case study showing the importance of atmospheric boundary-layer (ABL) dynamics on NPF during the morning transition. Continuous in-situ measurements of vertical profiles of the ABL were measured near Melpitz, Germany by UAV to understand the potential connection between NPF and boundary-layer development in the context of turbulence, temperature and humidity fluctuations.

This earlier study shows further the importance of airborne measurements for the understanding of NPF. In fact, many of the NPF events that are frequently observed near the ground may, originate at elevated altitude, with newly formed particles subsequently being mixed down to the ground. These findings appeared only due to the use of UAV.

ID:128

Comparing Common Wind Measurement Algorithms of Remotely Piloted Fixed-wing Aircraft

Alexander Rautenberg, Martin Graf, Jens Bange

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Abstract

Research of phenomena in the lower atmospheric boundary layer (ABL) is more and more often complemented by in-situ measurements with unmanned aircraft systems (UAS). The payloads of UAS for meteorological sampling ranges from a more accurate and diverse, but larger sensor payload, to small aircraft allowing to be operated from almost anywhere and with minimal logistical overhead. Atmospheric sampling from UAS nowadays includes atmospheric physics, boundary layer meteorology and increasingly wind-power meteorology. The in-situ wind measurement is often crucial for the scientific findings or eligible for a deeper understanding of the phenomena of interest.

The common method to measure the 3D wind vector from aircraft is using multi hole probes in combination with the measured attitude, position and velocity of the aircraft. The wind vector is defined in geodetic coordinate system and equals the vector difference between inertial velocity of the aircraft and the true airspeed onto the aircraft. This method (LMHP for Lenshow multi-hole-probe) is used in manned aircraft and was adapted for the use in remotely piloted fixed-wing aircraft. The achievable high resolution and accuracy of this method demands a precise and fast measurement of the inertial navigation system (INS) as well as of the pressure measurement with multi hole probes.

This presentation will compare the LMHP-method with the no-flow-sensor (NFS) algorithm and with the Chor-algorithm by Rianne de Jong and Tomas Chor using data from different flights performed by the environmental physics group (’umphy’) at the Centre for Applied Geo-science (University of Tübingen). All three algorithms are post-processable with this fully equipped sensor system which includes a five-hole probe and the inertial navigation system (INS) IG500-N from SBG Systems. To evaluate the Chor algorithm, only a pitot tube for dynamic pressure measurement and the INS data is used. This method is already applicable only using commercial flight control systems, like e.g. the Pixhawk. For this comparison, only the front whole of the five-whole probe and the INS data is used to calculate the wind speed. The NFS algorithm uses only ground speed and flight path azimuth information from the INS and is the least complex and expensive method in this comparison.

A representative selection with wind speeds between 2 and 15 m/s as well as various flight pattern are used to argue this comparison.

ID:129

Meteodrones – pioneers in autonomous UAV based meteorological data collection

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Meteomatics AG, Switzerland

Abstract

In order to fill the measurement data gap within the Planetary Boundary Layer, 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). Early in 2017, an additional Extended-VLOS permission for BVLOS flights during the day could be received, enabling flights on an operational daily basis.

In total, roughly 2500 soundings have been conducted both in numerous measurement campaigns as well as on a daily operational basis. With applications ranging from air pollution measurements (in collaboration with Canton Uri and Canton of Grisons) to capturing pre-convective conditions for optimized severe storm forecasts (in cooperation with NOAA), the Meteodrones proved to be a reliable and highly precise measurement system. The goal of assimilating collected data from all over Switzerland into regional numerical weather models comes along with the necessity of highly autonomous drone flights. Therefore, the research on autonomous landing as well as anti-icing systems is developing at a high pace, showing promising results.

These challenges during the development and operation of the Meteodrone led to technological advancements that can be applied to drones in all business segments. Just recently, Meteomatics received a US-patent for a new drone safety system, representing an alternative for parachute systems. Meteomatics, therefore, besides being an established provider of accurate weather forecasts, evolved into one of the leading experts in BVLOS-approved drones.

ID:130

Improving the performance of the Multi-Purpose Airborne Sensor Carrier using a Pixhawk flight controller

Martin Schön, Alexander Rautenberg, Jens Bange

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Abstract

The MASC (Multipurpose Airborne Sensor Carrier) system of the environmental physics group ('umphy') at the Centre for Applied GeoScience (University of Tübingen) is a 3 m wingspan fixed- wing UAV with 1.5 kg sensor payload. It is used for atmospheric research, boundary layer meteorology and wind energy studies. For this purpose, it logs pressure, temperature and humidity with a frequency of 100 Hz and calculates a 3D wind vector using an Inertial measurement unit and a five-hole probe.
In an ongoing effort to refine this method, a Pixhawk autopilot is tested for use in the MASC. This system provides several improvements over the previous autopilot.

To measure the airflow directly over an escarpment at a wind energy test site, very low-altitude flights are necessary. Carrying out these measurements was impossible until now, because the previous autopilot did not possess the capability to hold an altitude relative to the underlying topography. By using elevation data stored in its internal memory, the new autopilot is able to follow terrain features and avoid collisions.

By optimizing the airspeed control and the integration of a differential GPS for cm- accurate positioning the accuracy of the collected data is improved.

In upcoming projects, measurements in the direct vicinity of wind turbines will be needed.
The improved attitude and position control and the capability to fly the airframe at lower speeds helps to avoid collisions with the wind turbines.

This study will evaluate the performance of a commercially available flight control system when following a predefined flight pattern in very low altitudes and complex terrain as well as in close proximity to wind turbines.

ID:131

Measurement of atmospheric surface layer turbulence using unmanned aerial vehicles

Brandon M. Witte, Suzanne Weaver Smith and Sean C.C. Bailey

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Abstract

We describe measurements of the turbulence within the atmospheric surface layer using highly instrumented and autonomous unmanned aerial vehicles (UAVs). Results from the CLOUDMAP measurement campaign in Stillwater Oklahoma are presented including turbulence statistics measured during the transition from stably stratified to convective conditions. The measurements were made using pre-fabricated fixed-wing remote-control aircraft adapted to fly autonomously and carry multi-hole pressure probes, pressure, temperature and humidity sensors. Two aircraft were flown simultaneously, with one flying a flight path intended to profile the boundary layer up to 100 m and the other flying at a constant fixed altitude of 50 m. The evolution of various turbulent statistics was determined from these flights, including Reynolds stresses, correlations, spectra and structure functions. These results were compared to those measured by a sonic anemometer located on a 7.5 m tower.

This work was supported by the National Science Foundation through grant #CBET-1351411 and by National Science Foundation award #1539070, Collaboration Leading Operational UAS Development for Meteorology and Atmospheric Physics (CLOUDMAP).