

**AGENDA**

**EUFAR AISBL**

**Expert Working Group Meeting 02**

**Atmospheric temperature measurement from**

**research and operational aircraft**

**11/12 November 2020**

Day 1: Wednesday 11 November 2020

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| Item no. | Time  (GMT) | **EUFAR AISBL EWG02 meeting** | Speaker |
| 1.1 | 13:00 | Introduction: EUFAR and meeting objectives | Phil Brown  *(EUFAR / Met Office)* |
| 1.2 | 13:15 | Historical sensors and their capabilities | Bob Sable  *(Collins Aerospace)* |
| 1.3 | 13:45 | Use of airborne data in operational meteorological forecasting | Bruce Ingleby)  *(ECMWF)* |
| 1.4 | 14:15 | E-AMDAR data monitoring | Jitze van der Meulen  *(KNMI)* |
|  | 14:45 | break |  |
| 1.5 | 15:00 | AMDAR temperature bias correction | Siebren de Haan  *(KNMI)* |
| 1.6 | 15:30 | Mode-S – (observation-background) statistics | Ed Stone  *(Met Office)* |
|  | 16:00 | General discussion |  |
|  | 17:00 | End of Day 1 |  |

Day 2: Thursday 12 November 2020

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| Item no. | Time  (GMT) | **EUFAR AISBL EWG02 meeting** | Speaker |
| 2.1 | 13:00 | Development and use of thermistor sensors in a Rosemount 102 housing | Hannah Price  *(FAAM)* |
| 2.22 | 13:30 | Calibration of static pressure defects using flight manoeuvres | Anna Katharina Lehmann  *(Free Univ of Berlin)* |
| 2.3 | 14:00 | Developments of fast-response temperature sensors | Szymon Malinowski  *(Univ of Warsaw)* |
|  | 14:30 | break |  |
| 2.4 | 14:45 | Contrail and Enroute Wake Turbulence Air Temperature Field Flight Data | Anthony Brown  *(NRC, Canada)* |
| 2.5 | 15:15 | Development of Appendix D Capable TAT, XDTAT™ | Andy Gilb  *(Collins Aerospace)* |
|  | 15:45 | break |  |
|  | 16:00 | General discussion and meeting summary |  |
|  | 17:00 | End of Day 2 |  |

# Summary

All presentation materials are available from the EUFAR website, <https://www.eufar.net/event/event/atmospheric-temperature-measurement-from-research-and-operational-aircraft-an-online-workshop-324457/>

* 1. Introduction to EUFAR and meeting objectives

Phil Brown described the current objectives and activities of EUFAR in its current form as an international non-profit association (AISBL).

This workshop is intended to bring together the research aircraft community with those using aircraft-reported temperatures for operational meteorological purposes. It was prompted by discussion at the ECMWF/EUMETNET workshop on Aircraft Based Observations held in February 2020 (<https://www.ecmwf.int/en/learning/workshops/workshop-aircraft-weather-observations-and-their-use>) noting that both research and operational aircraft commonly use the same types of sensor. The is the potential to share information on calibrations, bias detection and removal etc.

* 1. Historical sensors and their capabilities

Bob Sable introduced the principles of air temperature measurement and a survey of the evolution of Rosemount total air temperature sensors. Recent developments have seen the introduction of housings that are more resistant to icing in supercooled clouds and ice buildup in high ice water content (HIWC) cloud regions. A new generation of sensors (105 series) capable of operation in conditions prescribed by the new Appendix D regulations that cover HIWC operations – these will be covered further by Andy Gilb on Day 2.

It was noted that the time response of newer-generation sensors is generally slower. This may have significance for both operational and research use (where sensors are used for turbulent heat flux measurement).

Bob also described the Collins icing wind tunnel facility used for testing purposes. Headline capabilities include Mach 0.9 airspeed, -60C temperature and 47,000ft equivalent altitude and the ability to cover Appendix C and D icing conditions.

* 1. Use of airborne data in operational meteorological forecasting

Bruce Ingleby described the operational use of airborne data, including temperature, at ECMWF. Biases are currently identified by comparing observations with the model itself. He noted the identification of biases that can be linked to aircraft type and/or airline. It would be desirable to reduce the observation bias as much as possible at source in order to be able to use the data as “anchor” observations to assess model performance and climatology.

* 1. E-AMDAR data monitoring

Jitze van der Meulen the quality evaluation of temperature observations from AMDAR. Again, the primary comparison of the observations is against meteorological models which is recognized to be imperfect. He showed various sets of statistics that illustrate the variation of biases with aircraft type (and sub-type) and airline. These likely result from unidentified differences in the processing of data within onboard avionics systems as well as actual sensor differences.

* 1. AMDAR temperature bias correction

Siebren de Haan described a model for reducing AMDAR temperature biases. This assumes that a component of the bias is due to unaccounted errors in static pressure measurement, which can be sensitive to various aspect of the flight conditions eg. TAS, ascent/descent, lateral manouevring. Some of the parameters required for the correction scheme are obtained from Mode-S data reports. In comparisons with radiosonde data, the scheme reduces both the mean and standard deviation of differences.

* 1. Mode-S temperature introduction

Ed Stone described some of the characteristics of Mode-S EHS (EnHanced Surveillance) and ADS-B (Automatic Dependent Surveillance-Broadcast data which relay Mach number (M), True Airspeed (TAS) and navigational data. True air temperature is derived using TAS and M. Data are gathered automatically using a distributed network of receivers. He then presented a statistical assessment of data quality, comparing observations with atmospheric model background fields and also an in-flight comparison between a BA aircraft and the FAAM aircraft flying closely behind. Some improvement in data quality can be obtained by recalculating M from received TAS and Indicated airspeed (IAS) since the received M values are limited by the reporting precision. Large volumes of data are potentially available.

* 1. Discussion
  2. Development and use of thermistor sensors in a Rosemount 102 housing

Hannah Price described work on the use of thermistor sensors within a 102-series housing on the FAAM research aircraft in the UK. This work is prompted by the availability/cost of replacement PRT sensors plus their susceptibility to in-flight damage which can impact calibration. Commercially available miniature thermistors provide an equivalent fast response but are susceptible to both electronic noise an greater self-heating effects. The former is being addressed via improved circuit design. The self-heating impact is being calibrated with a combination of laboratory and in-flight testing. The sensor is still subject to wetting when in (liquid) cloud but this can be easily identified.

* 1. Calibration of static pressure defects using flight manoeuvres

Katharina Lehmann described the process of using sets of flight manoeuvres in the process of determining the static pressure defect. This is an offset applied to the measured static pressure, dependent on flight conditions which can have an impact on subsequent measurements that utilize static pressure such as temperature. The process assumes that the pressure and wind field in which the aircraft flies is stationary in time. Runs at varying speeds change both the dynamic pressure and angle of attack whilst yawing oscillation change the angle of sideslip. From measurements a model fit is obtained in which the static pressure defect is a linear function of the dynamic pressure and quadratic functions of both attack and sideslip. The measurements were obtained with a Rosemount 858 5-hole airspeed/flow-angle sensor on a slow-flying ASK-16 motor-glider. However, the principle is applicable to any aircraft flying at about M=0.7 or below where the attack/sideslip differential pressures are insensitive to M.

* 1. Developments of fast-response temperature sensors

Szymon Malinowski described recent developments of a series of ultra-fast airborne temperature sensors that have been developed over many years. These employ ultra-fine open-wire sensors with shielding to reduce damage from aerosol/cloud particles. The sensors have been used on a variety of airborne platforms from motor-gliders up to a LearJet. They are of particular interest for studies of turbulent entrainment processes in the atmosphere. Recent installations have exploited existing mounting infrastructure from Dantec that may enable the use of such ultra-fast sensors more widely. Applications may include the mounting of a ultra-fast sensor within an existing Rosemount sensor housing in order to further study the internal flow field.

* 1. Contrail and En-route Wake Turbulence Air Temperature Field Flight Data

Anthony Brown described measurements using an instrumented Lockheed T-33 aircraft in wake turbulence and contrails behind commercial airliners. Such measurements are of interest in the air transport sector, for example through the use of biofuels and their impact on contrail formation. Data are sampled at 600Hz in order to provide the required spatial resolution. The real response of the Rosemount temperature sensor is lower than this. A number of measurement examples were presented showing the temperature structure of wake vortex and contrail regions. In this application, the dependence of static temperature measurements on static pressure defects that may be highly variable in the complex flow field is important.

* 1. Development of Appendix D Capable TAT, XDTAT™

Andy Gilb described a new generation of Rosemount temperature sensor, the 105-series, that is being developed in compliance with Appendix D standards for high ice water content (HIWC) cloud regions. Such regions are associated with engine rollback incidents and others where temperature and airspeed sensors become blocked with ice accretion. The new sensor housing is similar to previous generations but with further internal modification to prevent ice particles from reaching the sensor itself and to pass more easily out of the rear of the housing. It exploits additive manufacturing techniques in order to achieve the required internal structure. Some early performance data were shown. This will be expanded when a new revision of the Rosemount documentation (Revision D?) is issued within a few months. The new probe is expected to have its first use certification within about a year.